Argonne National Laboratory HEP Division

Theoretical Physics

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Argonne HEP Theory Group

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Description of the Group

The Argonne HEP Theory Group is composed of seven staff members, three of them holding joint positions with nearby Universities. There are two base-funding supported postdocs and an additional number of postdocs holding part-time positions at nearby Universities. Subsequently to the last DOE Theory Review, the group saw the departure of Tim Tait, who has now an Associate Professor position at UC, Irvine. Following Tim's departure, the group hired Frank Petriello and a new Assistant Physicist, Radja Boughezal. Petriello is also an Associate Professor at Northwestern University. Both Boughezal and Petriello bring to the group expertise on perturbative QCD, Higgs physics and collider physics. Their addition has significantly strengthened the Argonne HEP phenomenology effort.

The group is unique in that it brings together a very diverse spectrum of research, from precise computations of cross section and the elucidations of the intricacies of QCD and its effects on hadron collider observables, to formal theory, model building and identification of collider, direct and indirect dark matter detection signatures in beyond the Standard Model scenarios.

Five years ago, the group decided to follow the strategy of adding group members who hold joint positions with local Universities. This includes not only staff members, but also postdocs. These positions have served to integrate the theory efforts at Argonne with those at the University of Chicago, Northwestern University, University of Illinois at Chicago and IIT. This strategy has served to strengthen the activities of our university partners and the midwest region in general (historically a phenomenology center). It also serves to provide the group access to students-and providing the students access to the rich research program of a national laboratory. It has also served to make the group highly cost effective in comparison to other laboratory theory groups of a similar size.

Broader Impact of the ANL HEP Theory Group

The Argonne HEP Theory Group is helpful in establishing the experimental program of the High Energy Physics Division at ANL and maintains close contacts with colleagues in the various ANL HEP experimental groups. Members of the group were strongly involved in the HEP division retreat in November 2010, when the near-future activities of the Division were discussed and planned. Petriello and Wagner were part of the retreat committee, Wagner being in charge of the writing of the Theory and Experimental Astrophysics sections, while Berger and Boughezal were in the Theory Panel that discussed the group's future direction and fielded audience questions. The Division asked theorists to come up with new ideas that could define future research directions, a summary of which was presented by Petriello in a division seminar at the Retreat's conclusion.

Members of the group maintain a close connection with theorists and experimentalists in the High Energy Physics community and are regularly invited to give plenary talks at international conferences. They have also organized several international meetings, which have fostered collaboration between theorists and experimentalists.

Berger enjoys frequent research interactions with LHC and Tevatron experimenters and directly influenced the recent CMS search for same sign top quark pairs. He has served as a conscientious mentor for theory postdocs. He has organized "Physics Jamborees" at Argonne with the ATLAS experimenters in 2009 and 2010 and the four-week Aspen 2010 Summer Workshop "Forefront QCD and LHC Discoveries". Chairmanship of the Committee on Constitution and Bylaws of the American Physical Society is another of his current external community service activities. Within Argonne, Berger is a member of the Lab-wide Search Committee for Senior Computational Scientists that identified and recruited Salman Habib and Katrin Heitmann to LDRD supported positions in the HEP division.

Bodwin is co-inventor of the nonrelativistic QCD (NRQCD) factorization approach for computing quarkonium decay and production rates. Bodwin serves as a consultant on theoretical issues for experimenters who are measuring quarkonium production cross sections at the LHC, the Tevatron and HERA. As a convener of the Quarkonium Working Group (QWG), Bodwin has helped to organize numerous international workshops on quarkonium physics. Bodwin has been a key author and convener for a recent QWG review of quarkonium physics, which lists specific new opportunities for collider experiments in quarkonium physics.

Boughezal and Petriello organized the 2011 LoopFest conference, which took place at Northwestern Univ. May 12–14, 2011, and which attracted numerous experts on precision QCD calculations to the Chicago area. Boughezal also organized the International Conference on Radiative Corrections (RADCOR) in October 2009 in Zurich, Switzerland. RADCOR is the premier international forum for the discussion of higher order corrections in quantum field theory.

Ian Low organized the 2011 Chicagoland meeting, which took place at Northwestern University at the end of May, 2011. This meeting was instrumental in bringing together the Theory Communities from the different institutions in the Chicago area. Low has been the convener of the "extra dimension" session at the SUSY 2009 conference and is a member of the SUSY 2011 Conference Local Organizing Committee, which will take place at Fermilab, on August 28–September 2, 2011.

Petriello is co-convener of the ATLAS-CMS-Theory Higgs working group, with mandates from ATLAS and CMS to produce agreements on theoretical predictions needed in Higgs analyses. The results of this work are being used by the LHC collaborations in their search for Higgs bosons. Petriello is also author of the analysis codes used by the Tevatron and LHC collaborations in

their studies of W and Z production, and interacts regularly with experimentalists working on these topics. He has co-organized workshops on QCD phenomenology at Aspen and CERN, and regularly lectures at summer schools on QCD and Higgs physics.

Wagner has mentored postdocs and supervised students, four of which have graduated in the last three years. He has been a member of the Particle Physics Project Prioritization Panel, with a charge of evaluating future directions of the National HEP program, and was active in the production of a Report on the Physics Opportunities at an extended run of the Tevatron Collider, submitted to the Fermilab management. Wagner has given public and outreach talks and is currently the Chair of the Organizing Committe of the PreSUSY 2011 school, which will take place at Chicago in August 24–26, 2011.

Zachos has been having regular interactions with the neutrino group this year, giving the first of several successful presentations at their monthly Thursday meeting. In these meetings, trends and ideas for measurements are discussed informally, and younger theorists have followed Zachos, with the expectation that these presentations continue until all theorists have participated.

Argonne National Laboratory HEP Division

Theoretical Particle Physics : Phenomenology

Report of Activities. Argonne HEP Theory Group : Phenomenology

Particle phenomenology is the main focus of the Argonne HEP Theory group and is carried out by E.L. Berger, G.T. Bodwin, R. Boughezal, I.Low, F.J. Petriello and C.E.M. Wagner.

Research Highlights:

As a whole the most noteworthy recent contributions are on Higgs physics. The cross sections and uncertainty estimates for Higgs production used by both the Tevatron and LHC collaborations in their searches were derived by Argonne personnel. We examined the discovery and exclusion reach of the Tevatron and LHC colliders in different production and decay channels in the SM and beyond. We also studied new methods for looking for the Higgs in beyond the SM scenarios as well as for the determination of the Higgs boson properties and the possible differentiation of Higgs from other look-alike particles.

The group contributed significantly to our understanding of the intricacies of QCD and its effects on hadron collider observables. We devised novel methods for the calculation of cross sections to high orders in perturbation theory, and closed long-standing loop-holes in the factorization proofs that provide the foundation for all hadron-collider predictions. We investigated "double parton scattering" in which two hard scatterings occur in a given pp collision at the LHC, and developed new parton distribution functions that incorporate the possibility of a light gluino as a hadronic constituent. We have resolved a significant discrepancy between theory and experiment in the exclusive production of two quarkonia at the B factories. We provided theoretical predictions and simulation codes used by all Tevatron and LHC experiments in their study of the electroweak gauge bosons, and contributed numerical codes to LHC experiments in their search for same sign top pairs.

The group also made nontrivial progress in model-building motivated either by new theoretical ideas or by attempts to provide interpretations of unexpected experimental results. These include CP-violation in the B_s meson system, the forward-backward asymmetry of the top quark, and the recently reported dijet excess in the production of a W plus two jets. We analyzed the possibility of explaining anomalies in direct and indirect dark matter detection, and studied ways to identify the properties of a dark matter particle. Finally, the group analyzed models that could lead to understanding baryogenesis, the origin of the matter-antimatter asymmetry in the Universe.

Specific Research Achievements in Higgs Physics:

• Working with postdoctoral fellows Cao, Jackson, and Shaughnessy at Argonne, Berger was among the first to compute expectations for Higgs boson discovery and exclusion at the reduced 7 TeV energy of the Large Hadron Collider (LHC) [9] [1]. They did a full simulation of the signal and principal backgrounds for Higgs boson production and decay, and computed signal sensitivities of about 2 standard deviations (σ) at $m_H = 160$ GeV (ATLAS), and about 3.6 σ (CMS) for 1 fb^{-1} of integrated luminosity. Recast as exclusion limits, their results show that with the cuts used and 1 fb^{-1} at 7 TeV, the LHC may be able to exclude $m_H \sim 160$ to 180 GeV provided no signal is seen.

• Boughezal and Petriello derived an estimate of the three-loop mixed QCD-electroweak corrections to Higgs production in gluon fusion using an effective-theory approach [37]. Previous work had

[1] Citations refer to publications listed in the Appendix for this thrust area.

assumed the enhancements over the two-loop corrections ranging between factors of one and three. They showed how to combine the various contributions to Higgs cross sections in a consistent fashion, leading to a re-evaluation and improvement of the Tevatron exclusion limit on the SM Higgs boson. These results are currently being used by the CDF and D0 collaborations in their searches.

• In several recent works, Boughezal has investigated what can be learned about physics beyond the SM from the Higgs exclusion limit set by the Tevatron collaborations. She quantified the effect of a fourth generation of fermions on the Higgs-boson cross section [31]. This result has been implemented by the Tevatron collaborations in setting their fourth-generation exclusion limits. Boughezal also realized that color-octet scalars, which appear in several extensions of the SM, can shift the Higgs production cross section by a factor of two in allowed regions of parameter space [32, 26]. She constrained the parameter space of these new states based on recent Tevatron data [26].

• Low has been pursuing projects which could unveil the infrared properties of the Higgs, such as spin, CP and electroweak quantum numbers. He proposed studying final states with two Z bosons to determine the precise coupling structure of a putative resonance with the two vector bosons [47, 44], which contains a wealth of information including the spin and CP property. He also considered how determination of the decay branching fraction into all four pairs of electroweak gauge bosons could uncover the electroweak quantum number of a new scalar particle [42]. On the other hand, the ultraviolet identity of the Higgs can be probed by a precise measurement of the gluon fusion production rate of the Higgs. In Ref. [46] he studied the implication of such a measurement in the MSSM, which could help understand the degree of fine-tuning in supersymmetry. For non-supersymmetric models, the works of Refs. [45, 40] suggest that models with a composite Higgs boson have a production in the gluon fusion channel that is reduced from the SM expectation. Therefore, an increase in the measured production rate would immediately disfavor a composite Higgs.

• Petriello is the theory co-convenor of the joint ATLAS-CMS-theory working group on Higgs cross sections, the mandate of which is to produce agreement on theoretical predictions and errors on quantities relevant to the search for Higgs bosons within and beyond the SM. He was the co-editor of the gluon-fusion chapter of the first CERN Yellow Report on Higgs cross sections at the LHC [27]. The methodology and numerical results established in this work are now being used by the LHC collaborations in their search for the Higgs boson.

• Wagner's work on Higgs searches at the Tevatron and the LHC concentrated on general benchmark models within the Minimal Supersymmetric SM. He demonstrated that the Tevatron collider can probe the existence of the SM-like Higgs in all scenarios in which the resulting Higgs mass is smaller than about 120 GeV, while it falls short of this goal for scenarios in which the Higgs mass can be as large as 130 GeV [67] [61]. They also showed that searches at an early LHC become more challenging for a lighter Higgs in certain parameter regions. Due to their complementary strength they advocated a combination of the final results of the Tevatron with those of the first LHC years [69]. Recently, Wagner studied the possibility of detecting Higgs from supersymmetric particle decays at the LHC [60], finding excellent prospects for its detection at a center of mass energy of 14 TeV.

Specific Research Achievements in Precision QCD:

• Berger has a long history of significant work on hadron production dynamices. His recent

publications in QCD include investigations of *double parton* scattering with Jackson and Shaughnessy [13], SM sources of isolated leptons with Sullivan [18, 10], next-to-leading-order production cross sections for fourth generation fermions with Cao [15], the parity-violating asymmetry in hadronic decays of W bosons in polarized proton collisions at Brookhaven's RHIC collider with former Argonne postdoc Nadolsky [17], and parton distribution functions with Nadolsky [6]. In the work on double parton scattering, they devised signature observables and regions of phase space that should allow double parton events to be distinguished from those from conventional single parton scattering.

• Bodwin and collaborators discovered a loophole in existing all-orders proofs of factorization, including traditional diagrammatic proofs and proofs in soft-collinear effective theory. The existing proofs are incomplete because they ignore the fact that, diagram-by-diagram, collinear gluons with vanishingly small energy can give contributions to hard-scattering amplitudes that are leading in the hard-scattering energy scale. Bodwin and collaborators developed new iterative methods to organize the low-energy collinear contributions and found that, after considerable re-arrangement, one recovers the traditional factorization theorem [23]. They used these methods to give detailed proofs of factorization theorems for exclusive decays of a B-meson into a charmonium and a light meson and for the exclusive double-charmonium production in e^+e^- annihilation [22].

• Bodwin and collaborators developed a novel and very efficient method for computing NRQCD short-distance coefficients to all orders in v, the heavy-quark velocity. The method has been applied to the order-α_s corrections to the quarkonium electromagnetic current [24], and it leads to a very compact expression for a class of short-distance coefficients to all orders in v.

• Members of the Quarkonium Working Group recently authored a review of the current status of theory and experiment in quarkonium physics [21]. The review covers spectroscopy, decays, production, and quarkonia in media and experimental prospects. Bodwin was a convener and author of the production chapter.

• Boughezal addressed a long standing discrepancy between the experimental result and the SM prediction for the muon magnetic anomaly [25]. A lingering issue regarding this discrepancy is the prediction for the hadronic light-by-light contribution. In this work she hprovided an important justification for the current central value and error in the theory prediction.

• Boughezal has addressed the problem of extracting infrared singularities (IR) from real radiation matrix elements at next-to-next-to-leading order [29]. This outstanding theoretical issue has prevented the development of precision phenomenology at the LHC. She has taken a first step in extending the antenna subtraction technique to deal with processes with two hadronic initial states. These subtraction terms are process independent and are needed to provide cross sections for LHC processes to NNLO accuracy.

• Petriello has recently begun developing an alternate approach to the resummation of transverse-momentum logarithms using soft-collinear effective theory [52]–[50]. This method can potentially improve the description of W, Z, and Higgs transverse momentum spectra at colliders, as it avoids several problems that plague other approaches. A smooth matching between low and high transverse momentum regions is naturally achieved without requiring any additional parameters in the perturbative region. The initial results agree well with Tevatron data.

• Petriello, students, and postdoctoral fellow Quackenbush developed a significantly improved new version of his analysis code FEWZ (Fully Exclusive W and Z production) which simulates electroweak gauge boson production through next-to-next-to-leading order in QCD [49]. It incorporates several technical advances and represents a significant step toward a more detailed and

precise comparison of theory with experiment. FEWZ is widely used by experimentalists at Tevatron and the LHC.

Specific Research Achievements in BSM Collider Physics:

• Among interpretations of the large forward-backward asymmetry for top quarks at the Tevatron, the exchange of a non-universal Z' naturally predicts a top quark in the forward region of large rapidity and requires large couplings of the Z' to SM quarks. Berger and postdoctoral fellow Cao were quick to realize that this explanation inevitably leads to copious production of *same-sign tt* pairs at the Tevatron and at the LHC. In Ref. [3], they evaluate the constraints on this model from three Tevatron measurements: (a) the $t\bar{t}$ cross section, (b) the $t\bar{t}$ invariant mass distribution, and (c) the same sign top pair cross section limits. If *no tt* signal is observed with 1 fb^{-1} of integrated luminosity at 7 TeV at the LHC, they conclude that a non-universal Z' alone cannot explain the Tevatron asymmetry. A CMS study and publication was directly motivated by this prediction [arXiv:1106.2142]. They also considered same sign *tt* production at the LHC in the context of exotic color sextet mesons [8, 7]. The papers emphasize top quark polarization to probe new physics contributions and describe methods to make the polarization measurements [3, 8, 7, 2].

• Petriello has developed new strategies to search for and interpret new physics at the LHC and in other experiments. Recent results include analysis techniques to infer details of high-scale physics from observations of new gauge bosons at the LHC and in low-energy experiments [53].

• Wagner demonstrated the existence of fourteen Renormalization Group Invariant quantities (RGIs) involving the gauge couplings and the soft supersymmetry breaking parameters within the MSSM. Determination of the values of these invariants at colliders allow the extraction of the same quantities at high scales. Considering the most general flavor independent model at the messenger scale, there is a one to one correspondence between the free parameters of the Theory and the RGIs [64], while in minimal models the RGIs allow not only the extraction of parameters, but also sum rules that should be fulfilled at low energies [62].

• Wagner and postdoctoral fellows Cao and Shaughnessy studied several new physics scenarios that could lead to an explanation of the top-quark forward backward asymmetry [65]. They additionally considered the production cross section as well as the invariant mass distribution and provided a χ^2 fit to these observables within these models. They showed that a heavy axigluon as well as a t-channel charged resonance led to the best new-physics explanations of these observables.

Specific Research Achievements in Dark Matter Theory:

• In dark matter phenomenology, Low has been studying implications of recent anomalies in various direct and indirect detection experiments of dark matter. In Ref. [43] he studied a connection between the direct detection experiment such as the CDMS and the anti-proton measurement made by the PAMELA collaboration. He continued to study such a connection between another direct detection experiment, the CoGeNT collaboration, and the anti-proton measurements [41]. Then in Ref. [39] he considered a new class of supersymmetric decaying dark matter without invoking R-parity violation, which could potentially explain the positron excess measured by the PAMELA collaboration.

• Wagner and collaborators analyzed the NMSSM and demonstrated that Higgs bosons and neutralinos may be naturally light [63], leading to compatibility with the CoGent direct dark matter detection cross section. They provided specific realizations of these ideas and discussed constraints from collider and flavor experiments on this scenario.

Argonne HEP Theory Group. Future Research Plans

We list below the research plans of the group staff members. In addition to the specific projects that are outlined in these plans, the group intends to continue to build on the strong coherence of staff research interests in Higgs physics and physics beyond the standard model and to explore new synergies and joint research projects that could result from the strong overlaps in staff research interests in precision QCD. The group also plans to hold regular meetings with the experimental groups in the ANL HEP Division so as to enhance the benefits of the theory group to the experimental program.

Ed Berger's Research Plan.

Collider Physics and QCD: Results from the Fermilab Tevatron and the CERN Large Hadron Collider will influence Berger's theoretical studies for the coming years: whether a state similar to the expected Higgs boson is discovered, whether one or more of the current beyond-the-standard model (BSM) formulations is favored, or whether some yet unexpected phenomena revolutionize our approach, as took place in 1974. Berger expects to work on Higgs boson and BSM phenomenology and on topics in perturbative quantum chromodynamics (QCD), computing in detail both new physics signals and their SM look-alikes. Standard model processes produce jets, leptons, missing energy, and heavy flavor final states (along with important correlations among them) that can mimic the signatures of new physics. Berger plans to compute matrix elements for SM and BSM production processes, followed by full partonic showering and detector simulations, in order to refine tests of QCD at higher transverse momenta and smaller parton x, and to propose search strategies for new phenomena. Berger enjoys mutually productive working relationships with members of the Argonne LHC ATLAS group, and he expects to continue to assist with the scientific efforts of the ATLAS Analysis Center.

Top Quark Physics: The large mass of the top quark, or more generally of both quarks of the third generation, makes them good candidates to appear in the decays of heavy states in models of new physics. In the past year, Berger and collaborators proposed and studied new physics signals in which pairs of top quarks play a key role [3, 7, 8] [2]. Their matrix elements retain full spin correlations among the final state partons, and their papers emphasize top quark polarization to probe new physics contributions. Berger intends to continue along these lines and to refine methods for making the polarization measurements efficiently.

Extra Gauge Bosons: Berger has had a long interest in the dynamics of massive gauge bosons. He has recently been working on the production and decay of new charged W' and neutral Z' gauge bosons that appear in some models of new physics [2]. He will continue these investigations, with particular interest in extra gauge bosons that have an affinity for fermions of the third (t, b) and possibly higher generations.

Double Parton Interactions: Production processes are expected at LHC energies in which two hard scatterings occur in a given pp collision, and two partons are active from each incident hadron ("double parton scattering"). Berger and collaborators published a study recently of

[2] Citations refer to publications listed in the Appendix for this thrust area.

$pp \to b\bar{b}j_1j_2$ in which two jets j_1j_2 are produced from one of the hard scatters, while the other hard scatter produces the $b\bar{b}$ pair [13]. They computed this double parton contribution, as well as the conventional process in which $b\bar{b}j_1j_2$ is produced from the scattering of only two partons in the initial state. They identified distinguishing variables and regions of phase space for the two competing physical processes, with the aim to establish whether double parton scattering can be demonstrated to occur and at what rate. In the coming years, they will improve their predictions by including higher-order contributions, follow the experimental analyses by the ATLAS and CMS collaborations, compute double parton contributions to other final states, and investigate the theoretical basis for the expression used to compute the double parton differential cross section. The double parton contribution to the $Wb\bar{b}$ final state is under active investigation. This process in an important background for single top quark final states and in the search for Higgs bosons.

Geoff Bodwin's Research Plan

v^4 Corrections to Gluon Fragmentation to J/ψ : Gluon fragmentation to a color-octet heavy-quark-antiquark state is believed to be the dominant mechanism for J/ψ production at large p_T. However, it is known that the color-octet fragmentation rate is connected to the color-singlet fragmentation rate in order v^4 by a logarithm of the factorization scale. (v is the heavy-quark velocity in the quarkonium rest frame.) Hence, only the sum of the color-singlet and color-octet contributions is physically meaningful. G. Bodwin, U-Rae Kim (Korea U.), and Jungil Lee (Korea U.) are carrying out the calculation of the v^4 correction to the color-octet fragmentation function. The calculation is difficult technically because of the appearance of both single and double logarithmic infrared singularities. These are controlled by making infrared subtractions, which are computed analytically, while the remaining finite part is computed numerically. This is the first explicit calculation in NRQCD in which there is a cancellation of infrared singularities at the two-loop level.

New Hard-Cutoff Infrared Regulator for QCD: G. Bodwin and X. Garcia have constructed a new hard-cutoff infrared regulator for QCD. The regulator prescription involves the systematic subtraction of renormalon singularities from dimensionally regulated amplitudes. Because the method is based on dimensional regularization, there is hope that it can be extended beyond one-loop order in a way that preserves the gauge invariance in non-Abelian theories, such as QCD. One motivation for the use of the new regulator is that it improves the convergence of the perturbation expansion.

Resummation of Endpoint and Superleading Logs : It has been pointed out recently [3] that the NLO amplitude for the production of $J/\psi + \eta_c$ in e^+e^- annihilation contains double logarithms of Q^2/m_c^2. Unlike single logarithms, these double logarithms are not contained in the Q^2 evolution of the meson light-cone distributions amplitudes. G. Bodwin proposes to investigate the origins of these amplitudes with the aim of using factorization methods to organize and resum them. This investigation might ultimately allow one to attack the more general and long-standing problem of endpoint singularities in light-cone amplitudes. Factorization methods might also allow one to organize and resum the so-called "super-leading" logarithms [4], which arise in high-energy processes

[3] Jia, Wang, and Yang [arXiv:1012.6007 [hep-ph]]

[4] Forshaw, Kyrieleis, and Seymour [JHEP 0608, 059 (2006)]

when one considers non-inclusive high-energy cross sections, such as the "gaps between jets" cross section.

Resummation in Quarkonium Two-Gluon Decay Rates : Several years ago, G. Bodwin and Y. Chen (ITP, Beijing) developed a new technique to resum the large logarithms of the factorization scale that appear in QCD corrections to the decay of η_c to two gluons. The technique makes use of the fact that the large logarithms arise from vacuum-polarization corrections and resums those corrections to all orders, absorbing non-perturbative, renormalon-like contributions into an NRQCD matrix element. The process $\eta_b \to gg$ has received experimental scrutiny at the B factories, and a more reliable theoretical prediction would be valuable. G. Bodwin, J. Lee (Korea University), and Y. Chen propose to apply this resummation technique to that process. They also propose to extend the method to the two-gluon decays of P-wave quarkonium states and to make numerical predictions for the P-wave two-gluon widths that can be compared with experiment.

Factorization Theorems for Inclusive Quarkonium Production : In recent years, there has been a good deal of theoretical and experimental effort aimed at understanding rates of inclusive quarkonium production in collider and fixed-target experiments. Much of the theoretical work on quarkonium production has been carried out in the framework of the NRQCD factorization conjecture. However, a proof of this conjecture has been lacking. Nayak, Qiu, and Sterman have made progress in this regard by giving convincing arguments that NRQCD factorization holds at least through two-loop order. G. Bodwin proposes to investigate whether the factorization argument for inclusive production can be extended to all orders.

Radja Boughezal's Research Plan

In order to successfully discover physics beyond the SM more complicated than a simple resonance bump, it is mandatory to have a very solid and precise understanding of the expected Standard Model backgrounds. This includes having precise theoretical predictions for those processes. It is not clear how to achieve this high precision in all required cases. While the existing formalism of perturbative QCD provides a guide to the expected result, new insights into the higher-order structure of quantum field theory are needed to facilitate the calculation of scattering processes to NNLO. The major purpose of Boughezal's proposed research is the theoretical development of techniques to enable the computation of differential $2 \to 2$ hadron collider observables to NNLO precision in QCD. One area she is currently investigating is the extension of the antenna subtraction method for canceling infrared singularities to processes with two hadrons in the initial state. The applications will be to benchmark processes that influence the precision of theoretical predictions for many other observables. She is also studying the application of the sector decomposition technique to enable calculations to NNLO precision. Her second goal will be to study the precision phenomenology of the Higgs boson within and beyond the Standard Model. Each project will lead to numerous applications, with content ranging from complex field theory calculations to the interpretation of experimental data.

Subtraction methods and their applications at hadron colliders through NNLO: All NNLO predictions require both virtual and real emission corrections. While infrared singularities from purely virtual contributions are obtained immediately after integration over the loop momenta, their extraction is more involved for real emission contributions. The infrared singularities of real radiation matrix elements are extracted using infrared subtraction terms. One explicitly adds and subtracts divergent terms, the *subtraction terms*, which have the same infrared behavior

as the real matrix elements. While the construction of subtraction terms at the NLO level has been understood for some time, only two methods have been extended to extract singularities in a process-independent way at the NNLO level: antenna subtraction and sector decomposition. Boughezal is currently extending antenna subtraction to allow for the extraction of IR singularities from LHC processes. She is also investigating in collaboration with Petriello a proposed process-independent extension of the sector decomposition technique for the numerical cancellation of infrared singularities. Planned applications of these methods are to vector boson $+jet$, where the vector boson can be a photon, a W or a Z; Higgs $+jet$; $pp \to 2\,jets$; heavy-particle decays. All the calculations envisioned in these projects will be implemented in the form of parton-level event generators, which can be easily adapted to changing experimental requirements.

Higgs Physics: The search for the Higgs boson is one of the main goals of the LHC. The main production mechanism for the Higgs at hadron colliders, the gluon fusion process, is loop-induced and is therefore very sensitive to new physics that might change the production cross section. It is also famously subject to large QCD corrections, and calculations to NNLO accuracy and beyond are required to properly interpret experimental results. The properties of the Higgs boson can be modified in theories with additional particles, and measurement of these properties consequently serves as a window into physics beyond the SM. Boughezal has devised an effective theory approach to quantify the impact of mixed QCD-electroweak corrections which were previously highly uncertain and showed how to extend this approach to study new physics effects in the gluon fusion process. She plans on extending these investigations in several ways. The Tevatron exclusion limit implies bounds on the parameters of new colored states. She plans to first study the effect of such new heavy states on the Higgs production cross section in the gluon fusion mode. She then will use the Tevatron data to derive bounds on the parameter space of these new physics models. Examples are the study of the effects of possible heavy squarks and Majorana fermions on the inclusive gluon fusion cross section. Other interesting ideas include the calculation of the gluon fusion production rate of a composite Higgs boson.

Ian Low's Resarch Plan

Higgs Physics : Ian Low intends to pursue the following future directions related to understanding the UV identity of the Higgs. In the course of computing the gluon fusion production for a number of composite Higgs models in Ref. [40], we discovered that the corrections to the SM prediction only depends on the decay constant f of the non-linear sigma model, and not on the mass of the new particles participating in the cancellation of the Higgs quadratic divergence. Moreover, the correction also does not depend on the specific representation one chooses for the top sector. For example, in the $SO(5)/SO(4)$ minimal composite Higgs model, there are several choices to embed SM the top quark in the representation of the $SO(5)$ group, such as the **4** (spinor representation), the **5** (fundamental representation), and the **10**. In different representations the number of top-like fermions differs, implying the SM top contribution to the Higgs quadratic divergence is cancelled by different numbers of "top partners" whose masses could all be different. Naively one would expect all these top partners to contribute to the gluon fusion production of the Higgs and, as such, give rise to varying corrections depending on the number and the mass of top partners involved. This turns out to be *not* the case! I would like to understand why there is such universal corrections from different embedding of the top sector in the global symmetry group G. Furthermore, other considerations also indicate that there might even be a universal description of

the composite Higgs model, regardless of whether the collective breaking mechanism is employed or not, that are independent of the underlying global symmetry breaking pattern G/H. If this is the case, it might be possible to test the idea of a composite Higgs boson unambiguously at the LHC.

He also would like to consider the following future directions for better determining the IR identity of the Higgs. 1) Matrix element method in the Higgs discovery: at the LHC the discovery modes of the Higgs rely tremendously on its decay into di-bosons: WW, ZZ, and $\gamma\gamma$. The traditional method of selecting the Higgs signal is "bump hunting," by searching for a bump in the invariant mass spectrum of the di-boson system, which requires a certain number of events in order to achieve meaningful statistical significance. One possibility of boosting the discovery potential, and hence reduce the number of events required, is to include full angular correlations of the di-boson background and signal in the experimental analysis, as the signal and background have different angular dependence. The information on the angular correlations could be incorporated using the matrix element method in a straightforward fashion. I plan to apply the method to Higgs decays into all four possible di-boson pairs: WW, ZZ, $Z\gamma$, and $\gamma\gamma$, and study to what extent the discovery potential could be enhanced in each di-boson channel. This requires computing the angular correlations of the dominant SM background production of all di-boson pairs. 2) Electroweak properties of multiple scalar resonances: J. Lykken and I demonstrated how to understand the electroweak properties of a single scalar resonance in Ref. [42], by looking into the decay branching fractions into all four possible pairs of electroweak gauge bosons. However, in many theories beyond the SM, there is more than one scalar at the electroweak scale. Thus a possible follow-up is to study what information could be obtained by making the same measurements when there are multiple scalars. For example, one scenario of great interests is an electroweak singlet which mixes with an electroweak doublet. This case is currently under investigation.

Dark Matter: In addition, Ian Low plans to continue investigate phenomenology of dark matter from the particle physics point of view. In particular, he would like to construct the most general tree-level lagrangian giving rise to elastic, spin-independent scatterings of dark matter off the nuclei for a scalar and a vector dark matter, respectively. Once the lagranigan is in hand, he intends to study the interplay between (in)direct detection experiments and LHC collider phenomenology.

Frank Petriello's Research Plan

Petriello's future research will focus primarily on devising new theoretical ideas and tools to improve our understanding and modeling of perturbative QCD effects on hadron-collider observables. Although this will be influenced by the ever-changing requirements of the high energy experimental program, the following major directions are foreseen.

Differential distributions from effective field theory : Petriello has recently introduced a new technique based on soft-collinear effective theory (SCET) to describe the low transverse momentum region of Higgs and electroweak gauge boson production, a phase-space region where resummation of large logarithms is required. The SCET formulation has several advantages over the standard approach. Landau poles that appear for any p_T in the standard approach are avoided, and because the formulation is entirely in momentum space, instabilities that can occur in the matching of the resummed exponent to the fixed-order result do not occur. Initial results are in good agreement with Tevatron data. Petriello plans to extend his work on differential distributions within SCET. In the factorization theorem previously derived, several new operator structures

needed for the effective field theory analysis of the p_T distribution were uncovered. Petriello, LHC Theory-Initiative fellow Sonny Mantry, and Petriello's student Ye Li are calculating these objects to next-to-next-to-leading order in perturbation theory. This will allow for resummation of large logarithms to the next-to-next-to-leading logarithmic order of accuracy. They plan on releasing a program containing these results to the experimental community for use in hadron-collider studies. Petriello also plans to study the extension of the factorization theorem to observables where final-state hadronic information is constrained.

Standard candles at hadron colliders : The fully differential W and Z production cross sections are needed for numerous benchmark measurements. Petriello has previously calculated the next-to-next-to-leading order (NNLO) QCD corrections to the fully differential cross section for electroweak gauge bosons and has released the numerical program FEWZ for use in experimental simulation, as described in the summary section of this report. Several additional physics effects are being added to FEWZ. Together with student Ye Li, Petriello is calculating and incorporating the NLO electroweak corrections into the FEWZ framework. This will serve two important purposes. First, it will allow the impact of different electroweak renormalization schemes on precision W and Z measurements, such as the extraction of $\sin^2\theta_W$ or the W mass, to be assessed. Second, it will allow study of the combined effect of QCD corrections and final-state photon radiation (FSR). Comparison of experimental results with FEWZ or other QCD predictions currently necessitates the unfolding of this effect, potentially introducing errors into the analysis. Including FSR in FEWZ will remove the need for this unfolding when comparing theory with experiment. Other studies related to enabling FEWZ to produce exclusive events with weights, rather than just pre-defined histograms as currently, are being pursued.

A subtraction scheme for NNLO calculations : In previous work Petriello developed a new approach to the problem of extracting infrared singularities from real-emission corrections [5]. The technique relies upon sector-decomposing so-called 'entangled' singularities that appear at NNLO. The integration region is divided into sectors, and a different phase-space parameterization which allows the $1/\epsilon$ poles to be obtained via a plus-distribution expansion is used in each sector. The drawback of this approach is that a new parameterization must be chosen for each distinct process. For processes with multiple final-state particles, finding a global parameterization that permits an extraction of all $1/\epsilon$ poles becomes prohibitively difficult. Recently, an alternative approach was suggested that partitions phase space to separate different collinear limits [6]. In principle, this division of phase space implies that adding more final state particles does not require new parameterization choices; only an additional partitioning is needed. The sector decomposition required to extract $1/\epsilon$ poles need only be understood once. It then applies to all processes. Petriello, in collaboration with Boughezal, is currently studying this method and its application to hadron-collider observables. Initial phenomenological results are expected to be NNLO distributions for heavy particle decays, such as for the top quark. A next goal is the extension to $2 \to 2$ scattering processes at the LHC, such as di-jet and prompt-photon production, which are needed to understand parton distributions functions and the jet energy scale.

Preparation for the LHC Higgs program : Many open issues remain that must be addressed to assure that discovery of the Higgs boson and interpretation of its properties are possible. For example, are the QCD effects on the acceptances known? Petriello is currently convening the

[5] For example, see C. Anastasiou, K. Melnikov, F. Petriello, Phys. Rev. **D69**, 076010 (2004).

[6] M. Czakon, Phys. Lett. **B693**, 259-268 (2010).

gluon-fusion subgroup of the joint ATLAS-CMS-Theory working group on Higgs boson cross sections [7]. This aim of this group is to produce consensus on cross sections and error estimates for signal and background processes required for searches at the LHC. Within the context of this effort, Petriello is attempting to quantify the theoretical uncertainty induced by the division of events into bins of different jet multiplicity. This division is required experimentally in order to minimize the effect of the large top-quark background. The results of this study will be incorporated into a recommendation of the LHC Higgs cross section working group to ATLAS and CMS, and documented in a future working group report.

Carlos Wagner's Research Plan

Higgs Physics : Wagner is well known for his important contributions to the subject of electroweak symmetry breaking. In previous works, Wagner investigated the discovery reach of Higgs bosons at a 14 TeV LHC collider, in different MSSM benchmark scenarios [69],[67]. Wagner, with M. Carena, P. Draper and T. Liu, is extending his analysis of the MSSM Higgs benchmark scenarios to the 7 TeV LHC collider. The complementarity of SM-like Higgs searches at the Tevatron and at a 7 TeV collider is being emphasized, as well as the relevance of searches for non-standard Higgs bosons.

Wagner is continuing his work with Stefania Gori and Pedro Schwaller on the possibility of observing boosted Higgs bosons from cascade decays of supersymmetric particles [60]. Moreover, with Lian Tao Wang, Arjun Menon and Marcela Carena, Wagner is studying the possibility of applying similar boosted Higgs techniques for the observation of a non-standard Higgs produced in association with bottom quarks, decaying into a pair of bottom quarks at the LHC. This is being done in collaboration with CMS experimentalist Aurelio Juste, and motivated by an apparent excess at the Tevatron on similar channels. With collaborators Pedro Schwller, Ian Low and Gabe Shaughnessy, Wagner is also investigating the power of a Higgs line-shape measurement in the determination of Higgs couplings at the LHC.

Beyond the Standard Model and Collider Physics : Carlos Wagner is continuing working on Renormalization Group Invariants [72],[64], putting special emphasis on the information that may be extracted by measurements of the supersymmetry spectrum at the LHC. With collaborators Carena, Draper and Shah he is now working on the obtention of particular invariants that can be efficiently put in correspondence with specific search channels at the LHC. They have already identify invariants that depend on the gluino and squark mass difference, as well as on the overall weak eigenstate masses. Together with the well known gaugino mass invariants, and sum rules that measure the flavor dependence of the model, they provide excellent variables to represent supersymmetric particle searches at the LHC and establishing a direct infrared-ultraviolet connection, in a model independent way.

Wagner plans to continue working on the possible explanation of observed experimental signatures at the Tevatron and the LHC. This activity will become more relevant as the LHC starts to unveil high luminosity data. For instance, he has been working on an explanation of the excess in W plus 2 jets at the CDF experiment, updating his previous analysis [59], considering a detailed comparison of the kinematic distributions provided by the CDF updated analysis with the theoretical predictions within the two Higgs doublet and the Z' models proposed as a possible explanation of

[7] https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections

this anomaly. One should stress that the significance of this excess has grown at CDF, reaching more than 4 σ level. However, the D0 experiment has not seen a similar excess.

Neutrino Physics and Unification : Motivated by the reactor neutrino anomaly, as well as by the LSND and MiniBoone signatures, Wagner, with collaborators Arun Thallapillil and Bubanjyoti Battacharya, is studying the impact of sterile neutrinos on MINOS and SNO experiment results. Moreover, in colaboration with Jamie Gainer and Ran Huo, Wagner is analyzing the interrelation between lepton mixing in the charged sector and the unification of Yukawa couplings within the MSSM. Preliminary results suggest that, in order to explain the difference between the bottom and tau couplings, maximal mixing is required in the lepton sector, in apparent agreement with observations.

Baryogenesis and Dark Matter : Wagner has made significant contributions to the subject of electroweak baryogenesis in supersymmetric theories. With Marcela Carena and Nausheen Shah, he is working on the possibility of electroweak baryogenesis in the Dark Light Higgs scenario which he previously proposed to explain the large direct Dark Matter cross section observed at COGENT [63]. Preliminary results shows that in this region of parameters the electroweak phase transition tends to be first order, what is a condition for the realization of this scenario.

Appendix A

[1] E. L. Berger, "Investigations of Double Parton Scattering: Example of $pp \to b\bar{b}$jet jetX," arXiv:1106.0078 [hep-ph].

[2] E. L. Berger, Q. H. Cao, C. R. Chen and H. Zhang, "Top Quark Polarization As A Probe of Models with Extra Gauge Bosons," arXiv:1103.3274 [hep-ph], Phys. Rev. D, in press

[3] E. L. Berger, Q. H. Cao, C. R. Chen, C. S. Li and H. Zhang, "Top Quark Forward-Backward Asymmetry and Same-Sign Top Quark Pairs," Phys. Rev. Lett. **106**, 201801 (2011) [arXiv:1101.5625 [hep-ph]].

[4] E. L. Berger, "Dynamical Characteristics Double Parton Scattering," Proceedings of the Workshop on Multi Parton Interactions, DESY, Hamburg, Germany, September 13 - 15, 2010.

[5] M. Guzzi, P. Nadolsky, E. Berger, H. L. Lai, F. Olness and C. P. Yuan, "CT10 parton distributions and other developments in the global QCD Proceedings of 18th International Workshop on Deep Inelastic Scattering and Related Subjects (DIS 2010), Florence, Italy, April 2010 arXiv:1101.0561 [hep-ph].

[6] E. L. Berger, M. Guzzi, H. L. Lai, P. M. Nadolsky and F. I. Olness, "Constraints on color-octet fermions from a global parton distribution analysis," Phys. Rev. D **82**, 114023 (2010) [arXiv:1010.4315 [hep-ph]].

[7] H. Zhang, E. L. Berger, Q. H. Cao, C. R. Chen and G. Shaughnessy, "Color Sextet Vector Bosons and Same-Sign Top Quark Pairs at the LHC," Phys. Lett. B **696**, 68 (2011) [arXiv:1009.5379 [hep-ph]].

[8] E. L. Berger, Q. H. Cao, C. R. Chen, G. Shaughnessy and H. Zhang, "Color Sextet Scalars in Early LHC Experiments," Phys. Rev. Lett. **105**, 181802 (2010) [arXiv:1005.2622 [hep-ph]].

[9] E. L. Berger, Q. H. Cao, C. B. Jackson, T. Liu and G. Shaughnessy, "Higgs Boson Search Sensitivity in the $H \to WW$ Dilepton Decay Mode at $\sqrt{s} = 7$ and 10 TeV," Phys. Rev. D **82**, 053003 (2010) [arXiv:1003.3875 [hep-ph]].

[10] Z. Sullivan and E. L. Berger, "Isolated leptons from heavy flavor decays - theory and data," Phys. Rev. D **82**, 014001 (2010) [arXiv:1003.4997 [hep-ph]].

[11] E. L. Berger, "Search for Color Sextet Mesons in Early LHC Experiments", Proceedings of the 35th International Conference of High Energy Physics, July 22-28, 2010, Paris, France, PoS **ICHEP2010**, 382 (2010).

[12] E. L. Berger, "Characteristics and estimates of double parton scattering at the Large Hadron Collider," Proceedings of the 35th International Conference of High Energy Physics, July 22-28, 2010, Paris, France, PoS **ICHEP2010**, 097 (2010).

[13] E. L. Berger, C. B. Jackson and G. Shaughnessy, "Characteristics and Estimates of Double Parton Scattering at the Large Hadron Collider," Phys. Rev. D **81**, 014014 (2010) [arXiv:0911.5348 [hep-ph]].

[14] E. L. Berger and Z. Sullivan, "Trilepton production at the CERN LHC: SUSY Signals and Standard Model Backgrounds," PoS E **PS-HEP2009**, 226 (2009) [arXiv:0909.2131 [hep-ph]].

[15] E. L. Berger and Q. H. Cao, "Next-to-Leading Order Cross Sections for New Heavy Fermion Production at Hadron Colliders," Phys. Rev. D **81**, 035006 (2010) [arXiv:0909.3555 [hep-ph]].

[16] E. L. Berger, Q. H. Cao and I. Low, "Model Independent Constraints Among the Wtb, Zb anti-b, and Zt anti-t Couplings," Phys. Rev. D **80**, 074020 (2009) [arXiv:0907.2191 [hep-ph]].

[17] E. L. Berger and P. N. Nadolsky, "Longitudinal parity-violating asymmetry in hadronic decays of weak bosons in polarized proton collisions," Phys. Rev. D **78**, 114010 (2008) [arXiv:0810.0020 [hep-ph]].

[18] Z. Sullivan and E. L. Berger, "Trilepton production at the CERN LHC: Standard model sources and beyond," Phys. Rev. D **78**, 034030 (2008) [arXiv:0805.3720 [hep-ph]].

[19] G. T. Bodwin, "NRQCD Factorization and Quarkonium Production at Hadron-Hadron and ep Colliders," [arXiv:1012.4215 [hep-ph]].

[20] G. T. Bodwin, X. Garcia i Tormo, J. Lee, "Closing a Loophole in Factorization Proofs," [arXiv:1011.5899 [hep-ph]].

[21] N. Brambilla, S. Eidelman, B. K. Heltsley, R. Vogt, G. T. Bodwin, E. Eichten, A. D. Frawley, A. B. Meyer *et al.*, "Heavy quarkonium: progress, puzzles, and opportunities," Eur. Phys. J. **C71**, 1534 (2011). [arXiv:1010.5827 [hep-ph]].

[22] G. T. Bodwin, X. Garcia i Tormo, J. Lee, "Factorization in exclusive quarkonium production," Phys. Rev. **D81**, 114014 (2010). [arXiv:1003.0061 [hep-ph]].

[23] G. T. Bodwin, X. Garcia i Tormo, J. Lee, "Factorization of low-energy gluons in exclusive processes," Phys. Rev. **D81**, 114005 (2010). [arXiv:0903.0569 [hep-ph]].

[24] G. T. Bodwin, H. S. Chung, J. Lee, C. Yu, "Order-alpha(s) corrections to the quarkonium electromagnetic current at all orders in the heavy-quark velocity," Phys. Rev. **D79**, 014007 (2009). [arXiv:0807.2634 [hep-ph]].

[25] R. Boughezal and K. Melnikov, "Hadronic light-by-light scattering contribution to the muon magnetic anomaly: constituent quark loops and QCD effects," arXiv:1104.4510 [hep-ph].

[26] R. Boughezal, "Constraints on heavy colored scalars from Tevatron's Higgs exclusion limit," Phys. Rev. D **83**, 093003 (2011) [arXiv:1101.3769 [hep-ph]].

[27] S. Dittmaier *et al.* [LHC Higgs Cross Section Working Group], "Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables," arXiv:1101.0593 [hep-ph], published as a CERN Yellow Report.

[28] R. Boughezal, A. Gehrmann-De Ridder and M. Ritzmann, "Antenna subtraction for two hadronic initial states at NNLO," PoS D **IS2010**, 101 (2010).

[29] R. Boughezal, A. Gehrmann-De Ridder and M. Ritzmann, "Antenna subtraction at NNLO with hadronic initial states: double real radiation for initial-initial configurations with two quark flavours," JHEP **1102**, 098 (2011) [arXiv:1011.6631 [hep-ph]].

[30] R. Boughezal and F. Petriello, "Precise predictions for Higgs production in models with color-octet scalars," Nucl. Phys. Proc. Suppl. **205-206**, 289 (2010) [arXiv:1006.5773 [hep-ph]].

[31] C. Anastasiou, R. Boughezal and E. Furlan, "The NNLO gluon fusion Higgs production cross-section with many heavy quarks," JHEP **1006**, 101 (2010) [arXiv:1003.4677 [hep-ph]].

[32] R. Boughezal and F. Petriello, "Color-octet scalar effects on Higgs boson production in gluon fusion," Phys. Rev. D **81**, 114033 (2010) [arXiv:1003.2046 [hep-ph]].

[33] J. R. Andersen *et al.* [SM and NLO Multileg Working Group], "The SM and NLO Multileg Working Group: Summary report," arXiv:1003.1241 [hep-ph].

[34] R. Boughezal, A. Gehrmann-De Ridder and M. Ritzmann, "NNLO antenna subtraction with two hadronic initial states," PoS **RADCOR2009**, 052 (2010) [arXiv:1001.2396 [hep-ph]].

[35] R. Boughezal, "QCD-electroweak effects and a new prediction for Higgs production in gluon fusion process," PoS E **PS-HEP2009**, 233 (2009) [arXiv:0908.3969 [hep-ph]].

[36] R. Boughezal, "Theoretical Status of Higgs Production at Hadron Colliders in the Standard Model," arXiv:0908.3641 [hep-ph].

[37] C. Anastasiou, R. Boughezal and F. Petriello, "Mixed QCD-electroweak corrections to Higgs boson production in gluon fusion," JHEP **0904**, 003 (2009) [arXiv:0811.3458 [hep-ph]].

[38] I. Low, J. Lykken and G. Shaughnessy, "Singlet scalars as Higgs imposters at the Large Hadron Collider," arXiv:1105.4587 [hep-ph].

[39] H. C. Cheng, W. C. Huang, I. Low and A. Menon, "Goldstini as the decaying dark matter," JHEP **1103**, 019 (2011) [arXiv:1012.5300 [hep-ph]].

[40] I. Low and A. Vichi, "On the production of a composite Higgs boson," arXiv:1010.2753 [hep-ph].

[41] W. Y. Keung, I. Low and G. Shaughnessy, "When CoGeNT met PAMELA," Phys. Rev. D **82**, 115019 (2010) [arXiv:1010.1774 [hep-ph]].

[42] I. Low and J. Lykken, "Revealing the electroweak properties of a new scalar resonance," JHEP **1010**, 053 (2010) [arXiv:1005.0872 [hep-ph]].

[43] Q. H. Cao, I. Low and G. Shaughnessy, "From Pamela to CDMS and Back," Phys. Lett. B **691**, 73 (2010) [arXiv:0912.4510 [hep-ph]].

[44] Q. H. Cao, C. B. Jackson, W. Y. Keung, I. Low and J. Shu, "The Higgs Mechanism and Loop-induced Decays of a Scalar into Two Z Bosons," Phys. Rev. D **81**, 015010 (2010) [arXiv:0911.3398 [hep-ph]].

[45] I. Low, R. Rattazzi and A. Vichi, "Theoretical Constraints on the Higgs Effective Couplings," JHEP **1004**, 126 (2010) [arXiv:0907.5413 [hep-ph]].

[46] I. Low and S. Shalgar, "Implications of the Higgs Discovery in the MSSM Golden Region," JHEP **0904**, 091 (2009) [arXiv:0901.0266 [hep-ph]].

[47] W. Y. Keung, I. Low and J. Shu, "Landau-Yang Theorem and Decays of a Z' Boson into Two Z Bosons," Phys. Rev. Lett. **101**, 091802 (2008) [arXiv:0806.2864 [hep-ph]].

[48] Y. Li, S. Mantry and F. Petriello, "An Exclusive Soft Function for Drell-Yan at Next-to-Next-to-Leading Order," arXiv:1105.5171 [hep-ph].

[49] R. Gavin, Y. Li, F. Petriello and S. Quackenbush, "FEWZ 2.0: A code for hadronic Z production at next-to-next-to-leading order," arXiv:1011.3540 [hep-ph], accepted for publication in Computer Physics Communications.

[50] S. Mantry and F. Petriello, "Transverse Momentum Distributions in the Non-Perturbative Region," arXiv:1011.0757 [hep-ph].

[51] S. Mantry and F. Petriello, "Transverse Momentum Distributions from Effective Field Theory with Numerical Results," Phys. Rev. D **83**, 053007 (2011) [arXiv:1007.3773 [hep-ph]].

[52] S. Mantry and F. Petriello, "Factorization and Resummation of Higgs Boson Differential Distributions in Soft-Collinear Effective Theory," Phys. Rev. D **81**, 093007 (2010) [arXiv:0911.4135 [hep-ph]].

[53] Y. Li, F. Petriello and S. Quackenbush, "Reconstructing a Z-prime Lagrangian using the LHC and low-energy data," Phys. Rev. D **80**, 055018 (2009) [arXiv:0906.4132 [hep-ph]].

[54] W. Y. Keung and F. J. Petriello, "Electroweak and finite quark-mass effects on the Higgs boson transverse momentum distribution," Phys. Rev. D **80**, 013007 (2009) [arXiv:0905.2775 [hep-ph]].

[55] Y. Gershtein, F. Petriello, S. Quackenbush and K. M. Zurek, "Discovering hidden sectors with mono-photon Z' searches," Phys. Rev. D **78**, 095002 (2008) [arXiv:0809.2849 [hep-ph]].

[56] P. Fileviez Perez, R. Gavin, T. McElmurry and F. Petriello, "Grand Unification and Light Color-Octet Scalars at the LHC," Phys. Rev. D **78**, 115017 (2008) [arXiv:0809.2106 [hep-ph]].

[57] D. Hooper, F. Petriello, K. M. Zurek and M. Kamionkowski, "The New DAMA Dark-Matter Window and Energetic-Neutrino Searches," Phys. Rev. D **79**, 015010 (2009) [arXiv:0808.2464 [hep-ph]].

[58] F. Petriello and K. M. Zurek, "DAMA and WIMP dark matter," JHEP **0809**, 047 (2008) [arXiv:0806.3989 [hep-ph]].

[59] Q. H. Cao, M. Carena, S. Gori, A. Menon, P. Schwaller, C. E. M. Wagner and L. T. M. Wang, arXiv:1104.4776 [hep-ph].

[60] S. Gori, P. Schwaller and C. E. M. Wagner, arXiv:1103.4138 [hep-ph], Phys. Rev. **D**, in press.

[61] M. Carena, P. Draper, S. Heinemeyer, T. Liu, C. E. M. Wagner and G. Weiglein, "Probing the Higgs Sector of High-Scale SUSY-Breaking Models at the Tevatron," Phys. Rev. D **83**, 055007 (2011) [arXiv:1011.5304 [hep-ph]].

[62] M. Carena, P. Draper, N. R. Shah and C. E. M. Wagner, Phys. Rev. D **83**, 035014 (2011) [arXiv:1011.4958 [hep-ph]].

[63] P. Draper, T. Liu, C. E. M. Wagner, L. T. M. Wang and H. Zhang, "Dark Light Higgs," Phys. Rev. Lett. **106**, 121805 (2011) [arXiv:1009.3963 [hep-ph]].

[64] M. Carena, P. Draper, N. R. Shah and C. E. M. Wagner, "Determining the Structure of Supersymmetry-Breaking with Renormalization Group Invariants," Phys. Rev. D **82**, 075005 (2010) [arXiv:1006.4363 [hep-ph]].

[65] Q. H. Cao, D. McKeen, J. L. Rosner, G. Shaughnessy and C. E. M. Wagner, "Forward-Backward Asymmetry of Top Quark Pair Production," Phys. Rev. D **81**, 114004 (2010) [arXiv:1003.3461 [hep-ph]].

[66] P. Nath *et al.*, "The Hunt for New Physics at the Large Hadron Collider," Nucl. Phys. Proc. Suppl. **200-202**, 185 (2010) [arXiv:1001.2693 [hep-ph]].

[67] P. Draper, T. Liu and C. E. M. Wagner, "Prospects for Higgs Searches at the Tevatron and LHC in the MSSM with Explicit CP-violation," Phys. Rev. D **81**, 015014 (2010) [arXiv:0911.0034 [hep-ph]].

[68] V. Barger, L. L. Everett, J. Jiang, P. Langacker, T. Liu and C. E. M. Wagner, "b $\to$ s Transitions in Family-dependent U(1)-prime Models," JHEP **0912**, 048 (2009) [arXiv:0906.3745 [hep-ph]].

[69] P. Draper, T. Liu and C. E. M. Wagner, "Prospects for MSSM Higgs Searches at the Tevatron," Phys. Rev. D **80**, 035025 (2009) [arXiv:0905.4721 [hep-ph]].

[70] A. D. Medina, N. R. Shah and C. E. M. Wagner, "A Heavy Higgs and a Light Sneutrino NLSP in the MSSM with Enhanced SU(2) D-terms," Phys. Rev. D **80**, 015001 (2009) [arXiv:0904.1625 [hep-ph]].

[71] V. Barger, L. Everett, J. Jiang, P. Langacker, T. Liu and C. Wagner, "Family Non-universal U(1)-prime Gauge Symmetries and b $\to$ s Transitions," Phys. Rev. D **80**, 055008 (2009) [arXiv:0902.4507 [hep-ph]].

[72] M. Carena, A. D. Medina, N. R. Shah and C. E. M. Wagner, "Gauge-Higgs Unification, Neutrino Masses and Dark Matter in Warped Extra Dimensions," Phys. Rev. D **79**, 096010 (2009) [arXiv:0901.0609 [hep-ph]].

[73] M. Carena, A. Menon and C. E. M. Wagner, "Minimal Flavor Violation and the Scale of Supersymmetry Breaking," Phys. Rev. D **79**, 075025 (2009) [arXiv:0812.3594 [hep-ph]].

[74] M. Carena, G. Nardini, M. Quiros and C. E. M. Wagner, "The Baryogenesis Window in the MSSM," Nucl. Phys. B **812**, 243 (2009) [arXiv:0809.3760 [hep-ph]].

[75] M. Carena, A. Freitas and C. E. M. Wagner, "Light Stop Searches at the LHC in Events with One Hard Photon or Jet and Missing Energy," JHEP **0810**, 109 (2008) [arXiv:0808.2298 [hep-ph]].

[76] M. Carena, G. Nardini, M. Quiros and C. E. M. Wagner, "The Effective Theory of the Light Stop Scenario," JHEP **0810**, 062 (2008) [arXiv:0806.4297 [hep-ph]].

[77] Q. H. Cao, A. Damanik, E. Ma and D. Wegman, "Probing Lepton Flavor Triality with Higgs Boson Decay," Phys. Rev. D **83**, 093012 (2011) [arXiv:1103.0008 [hep-ph]].

[78] R. Schwienhorst, C. P. Yuan, C. Mueller and Q. H. Cao, "Single top quark production and decay in the t-channel at next-to-leading order at the LHC," Phys. Rev. D **83**, 034019 (2011) [arXiv:1012.5132 [hep-ph]].

[79] Q. H. Cao, S. Khalil, E. Ma and H. Okada, "Observable T_7 Lepton Flavor Symmetry at the Large Hadron Collider," Phys. Rev. Lett. **106**, 131801 (2011) [arXiv:1009.5415 [hep-ph]].

[80] Q. H. Cao, C. R. Chen, C. S. Li and H. Zhang, arXiv:0912.4511 [hep-ph].

[81] S. Heim, Q. H. Cao, R. Schwienhorst and C. P. Yuan, "Next-to-leading order QCD corrections to s-channel single top quark production and decay at the LHC," Phys. Rev. D **81**, 034005 (2010) [arXiv:0911.0620 [hep-ph]].

[82] H. Zhang, C. S. Li, Q. H. Cao and Z. Li, "A Dark Matter Model with Non-Abelian Gauge Symmetry," Phys. Rev. D **82**, 075003 (2010) [arXiv:0910.2831 [hep-ph]].

[83] Q. H. Cao, C. R. Chen, C. Schmidt and C. P. Yuan, "Improved Predictions for Higgs Q(T) at the Tevatron and the LHC," arXiv:0909.2305 [hep-ph].

[84] Q. H. Cao, E. Ma and G. Shaughnessy, "Dark Matter: The Leptonic Connection," Phys. Lett. B **673**, 152 (2009) [arXiv:0901.1334 [hep-ph]].

[85] J. A. Conley, J. S. Gainer, J. L. Hewett, M. P. Le and T. G. Rizzo, "Supersymmetry Without Prejudice at the 7 TeV LHC," arXiv:1103.1697 [hep-ph].

[86] J. A. Conley, J. S. Gainer, J. L. Hewett, M. P. Le and T. G. Rizzo, "Supersymmetry Without Prejudice at the LHC," arXiv:1009.2539 [hep-ph].

[87] R. C. Cotta, J. A. Conley, J. S. Gainer, J. L. Hewett and T. G. Rizzo, "Cosmic Ray Anomalies from the MSSM?," JHEP **1101**, 064 (2011) [arXiv:1007.5520 [hep-ph]].

[88] D. Alves *et al.*, "Simplified Models for LHC New Physics Searches," arXiv:1105.2838 [hep-ph].

[89] M. Gillioz, A. von Manteuffel, P. Schwaller and D. Wyler, "The Little Skyrmion: New Dark Matter for Little Higgs Models," JHEP **1103**, 048 (2011) [arXiv:1012.5288 [hep-ph]].

[90] A. Freitas and P. Schwaller, "Multi-Photon Signals from Composite Models at LHC," JHEP **1101**, 022 (2011) [arXiv:1010.2528 [hep-ph]].

[91] V. Barger, G. Shaughnessy and B. Yencho, "Many Leptons at the LHC from the NMSSM," Phys. Rev. D **83**, 055006 (2011) [arXiv:1011.3526 [hep-ph]].

[92] G. Bertone, C. B. Jackson, G. Shaughnessy, T. M. P. Tait and A. Vallinotto, "Gamma Ray Lines from a Universal Extra Dimension," arXiv:1009.5107 [astro-ph.HE].

[93] V. Barger, Y. Gao, M. McCaskey and G. Shaughnessy, "Light Higgs Boson, Light Dark Matter and Gamma Rays," Phys. Rev. D **82**, 095011 (2010) [arXiv:1008.1796 [hep-ph]].

[94] V. Barger, M. McCaskey and G. Shaughnessy, "Complex Scalar Dark Matter vis-à-vis CoGeNT, DAMA/LIBRA and XENON100," Phys. Rev. D **82**, 035019 (2010) [arXiv:1005.3328 [hep-ph]].

[95] C. B. Jackson, G. Servant, G. Shaughnessy, T. M. P. Tait and M. Taoso, "Higgs in Space!," JCAP **1004**, 004 (2010) [arXiv:0912.0004 [hep-ph]].

[96] V. Barger, M. McCaskey and G. Shaughnessy, "Single top and Higgs associated production at the LHC," Phys. Rev. D **81**, 034020 (2010) [arXiv:0911.1556 [hep-ph]].

[97] V. Barger, Y. Gao, W. Y. Keung, D. Marfatia and G. Shaughnessy, "Dark matter and pulsar signals for Fermi LAT, PAMELA, ATIC, HESS and WMAP data," Phys. Lett. B **678**, 283 (2009) [arXiv:0904.2001 [hep-ph]].

[98] G. Bertone, C. B. Jackson, G. Shaughnessy, T. M. P. Tait and A. Vallinotto, "The WIMP Forest: Indirect Detection of a Chiral Square," Phys. Rev. D **80**, 023512 (2009) [arXiv:0904.1442 [astro-ph.HE]].

[99] V. Barger, H. E. Logan and G. Shaughnessy, "Identifying extended Higgs models at the LHC," Phys. Rev. D **79**, 115018 (2009) [arXiv:0902.0170 [hep-ph]].

[100] V. Barger, P. Langacker, M. McCaskey, M. Ramsey-Musolf and G. Shaughnessy, "Complex Singlet Extension of the Standard Model," Phys. Rev. D **79**, 015018 (2009) [arXiv:0811.0393 [hep-ph]].

[101] D. Hooper and T. M. P. Tait, "Neutralinos in an extension of the minimal supersymmetric standard model as the source of the PAMELA positron excess," Phys. Rev. D **80**, 055028 (2009) [arXiv:0906.0362 [hep-ph]].

[102] T. Adams *et al.*, "Renaissance of the 1-TeV Fixed-Target Program," Int. J. Mod. Phys. A **25**, 777 (2010) [arXiv:0905.3004 [hep-ex]].

[103] K. Kumar, T. M. P. Tait and R. Vega-Morales, "Manifestations of Top Compositeness at Colliders," JHEP **0905**, 022 (2009) [arXiv:0901.3808 [hep-ph]].

[104] W. Shepherd, T. M. P. Tait and G. Zaharijas, "Bound states of weakly interacting dark matter," Phys. Rev. D **79**, 055022 (2009) [arXiv:0901.2125 [hep-ph]].

[105] J. Buckley *et al.*, "Section on Prospects for Dark Matter Detection of the White Paper on the Status and Future of Ground-Based TeV Gamma-Ray Astronomy," arXiv:0812.0795 [astro-ph].

[106] T. Plehn and T. M. P. Tait, "Seeking Sgluons," J. Phys. G **36**, 075001 (2009) [arXiv:0810.3919 [hep-ph]].

[107] S. Dawson and C. B. Jackson, "One-loop Corrections to the S Parameter in the Four-site Model," Phys. Rev. D **79**, 013006 (2009) [arXiv:0810.5068 [hep-ph]].

[108] M. C. Chen, S. Dawson and C. B. Jackson, "Higgs Triplets, Decoupling, and Precision Measurements," Phys. Rev. D **78**, 093001 (2008) [arXiv:0809.4185 [hep-ph]].

[109] X. Garcia i Tormo, J. Soto and C. Yuan, "Radiative decays," Int. J. Mod. Phys. A **24S1**, 379 (2009).

[110] N. Brambilla, A. Vairo, X. Garcia i Tormo and J. Soto, "The QCD static energy at NNNLL," Phys. Rev. D **80**, 034016 (2009) [arXiv:0906.1390 [hep-ph]].

[111] D. M. Asner *et al.*, "Physics at BES-III," arXiv:0809.1869 [hep-ex].

Argonne HEP Division, Theoretical Particle Physics
June 2008—June 2011

Colloquia and Conference Talks

Edmond L. Berger

Top Quark Forward-Backward Asymmetry and Same-Sign Top Quark Pairs
Particle and Astro-Particle Physics Seminar, CERN, Geneva, April 8, 2011

Investigations of Double Parton Scattering
46th Rencontres de Moriond on QCD and High Energy Interactions, La Thuile, Italy, March 25, 2011

Double Parton Scattering at the LHC -- Dynamic and Kinematic Characteristics
LHC PhenoNet Meeting, Valencia, Spain, February 1, 2011

Double Parton Scattering at the LHC -- Dynamic and Kinematic Characteristics
Academia Sinica, Taiwan, November 5, 2010

Phenomenology of Color Sextet Scalar and Vector Mesons
LHC Topical Program on W, Z, and Beyond, National Center for Theoretical Physics (NCTS), Hsinchu, Taiwan, October 29, 2010

Dynamical Characteristics of Double Parton Scattering
DESY Workshop on Multi-Parton Interactions at the LHC, DESY, Hamburg, September 13-15, 2010

Search for Color Sextet Scalars in Early LHC Experiments
ATLAS LHC Exotics Group Meeting, Video Presentation from Argonne to the ATLAS Audience at CERN, August 30, 2010

High Energy Physics Division Theory Activities
DOE Office of High Energy Physics site visit to the Argonne High Energy Physics Division, August 25, 2010

Double Parton Scattering at the LHC--Characteristics and Estimates
International Conference on High Energy Physics (ICHEP 2010), Paris, July 22–28, 2010

Search for Color Sextet Scalars in Early LHC Experiments
International Conference on High Energy Physics (ICHEP 2010), Paris, July 22–28, 2010

Estimates of Standard Model Backgrounds in Searches for New Physics--the Case of Isolated Leptons
Workshop on Searching for New Physics at the LHC – Galileo Galilei Institute, Florence, Italy, September 8, 2009

Trilepton Production at the CERN LHC: SUSY Signals and Standard Model Backgrounds
2009 Europhysics Conference on High Energy Physics, Krakow, Poland, July 16-22, 2009

Longitudinal Single Spin Asymmetry in W Boson Production at RHIC
2009 RHIC-AGS Annual Users' Meeting, Brookhaven National Laboratory, NY, June 1, 2009

Dilepton and Trilepton Production--Standard Model and Beyond the Standard Model
Invited plenary talk, Workshop on Higgs Boson Phenomenology, ETH and University of Zürich, Switzerland, January 8, 2009

Dilepton and Trilepton Production--Standard Model Sources and Beyond the Standard Model Signals
High Energy Physics Seminar, Tsinghua University, Beijing, China, October 30, 2008

Dilepton and Trilepton Production--Standard Model Sources and Beyond the Standard Model Signals
High Energy Physics Seminar, Shandong University, Jinan, China. October 27, 2008

Trilepton Production at the LHC--SUSY Signal and Standard Model Backgrounds
Invited plenary talk, Conference on Going beyond the Standard Model, Marching into the LHC Era, Kavli Institute for Theoretical Physics, Chinese Academy of Sciences, Beijing, China, October 22, 2008

Dilepton and Trilepton Production--Standard Model Sources and Beyond the Standard Model Signals
High Energy Physics Seminar, Kavli Institute for Theoretical Physics, Chinese Academy of Sciences, Beijing, China, October 14, 2008

Dilepton and Trilepton Production--Standard Model and Beyond the Standard Model
High Energy Physics Seminar, Institute of High Energy Physics, Beijing, China, October 9, 2008

Geoffrey Bodwin

Quarkonium Production in *ep* and e^+e^- Collisions
Invited plenary talk, Workshop on Quarkonium Production in Elementary and Heavy Ion Collisions, Brookhaven National Laboratory, NY, June 6-18, 2011

Quarkonium Production in Hadron-Hadron Collisions
Invited plenary talk, Workshop on Quarkonium Production in Elementary and Heavy Ion Collisions, Brookhaven National Laboratory, NY, June 6-18, 2011

Closing a Loophole in Factorization Proofs
Invited seminar, IHEP, Beijing, China, October 23, 2010

NRQCD Factorization and Quarkonium Production at Hadron-Hadron and *ep* Colliders
Invited plenary talk, Charm 2010 Conference, Beijing, China, October 21-24, 2010

Quarkonium Decay and Production: NRQCD Confronts Experiment
Seminar, Department of Physics, University of Barcelona, Spain, September 7, 2010

Closing a Loophole in Factorization Proofs
Invited parallel talk, Conference on Quark Confinement and the Hadron Spectrum IX, Madrid, Spain, August 30--September 3, 2009

Closing Remarks
Invited plenary talk, Effective Field Theories in Particle and Nuclear Physics, KITPC, Beijing, China, September 11, 2009

Quarkonium Production and Decay: NRQCD Confronts Experiment
Seminar, Institute of High Energy Physics (IHEP), Beijing, China, September 9, 2009

J_psi and Upsilon Production Physics
Invited plenary talk, Workshop on Physics Opportunities with the First LHC Data, LBNL, CA, May 6-8, 2009

Issues in Quarkonium Production
Talk for a plenary round-table discussion, International Workshop on Heavy Quarkonia 2008, Nara, Japan, December 2-5, 2008

Decays of eta_b and eta_c
Invited talk for a plenary round-table discussion, International Workshop on Heavy Quarkonia 2008, Nara, Japan, December 2-5, 2008

Factorization in Exclusive Quarkonium Production
Invited plenary talk, International Workshop on Heavy Quarkonia 2008, Nara, Japan, December 2-5, 2008

Quarkonium Production and Decay: NRQCD Confronts Experiment
Invited plenary talk, International Conference on Quark Confinement and the Hadron Spectrum, Mainz, Germany, September 1-6, 2008

Quarkonium Production and Decay: NRQCD Confronts Experiment
Invited seminar, Physics Department, University of Illinois, Chicago, May 5, 2008

Radja Boughezal

Invited Plenary Talks:

Review of Higher Order QCD and EW Effects for LHC Processes
Physics at the LHC Conference, Perugia, Italy, June 2011

Color Octet Scalars and the Higgs
Implications of Electroweak Symmetry Breaking Workshop, University of Madison, WI, May 2011

Computing Hadronic Cross Sections through NNLO
XIX International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2011), Newport News, VA, April 2011

Constraining New Physics Using Tevatron's Higgs Exclusion Limits
XIX international workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2011), Newport News, VA, April 2011

Antenna Subtraction Terms for Initial-Initial Hadronic States at NNLO
LoopFest IX: Radiative Corrections for the LHC and Lepton Colliders, Stony Brook, NY, June 2010

Precise Predictions for $gg \to H$ Beyond the SM
Planck 2010: From the Planck Scale to the Electroweak Scale, CERN, Switzerland, May 2010

Antenna Subtraction Terms for Initial-Initial Hadronic States at NNLO
XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects, Florence, Italy, April 2010

Precise Predictions for Higgs Production at Hadron Colliders within the SM and Beyond
The Annual German Physical Society Meeting, Bonn, Germany, March 2010

Antenna Subtraction Terms for Initial-Initial Hadronic States at NNLO
9th International Symposium on Radiative Corrections (RADCOR 2009): Applications of Quantum Field Theory to Phenomenology, Ascona, Switzerland, October 2009

Theoretical Status of Higgs Production at Hadron Colliders within the SM
The 2009 Meeting of the Division of Particles and Fields of the American Physical Society (DPF 2009), Detroit, MI, July 2009

Electroweak Effects and a New Prediction for $gg \to H$ in the SM
The 2009 Europhysics Conference on High Energy Physics, Cracow, Poland, July 2009

Electroweak Effects and a New Prediction for $gg \to H$ in the SM
PASCOS 2009, 15th International Symposium on Particles, Strings and Cosmology, Hamburg, Germany, July 2009

Mixed QCD-Electroweak Corrections and a New Prediction for $gg \to H$ in SM
Les Houches 2009, Physics at TeV Colliders, Les Houches, France, June 2009

Mixed QCD-Electroweak Corrections and a New Prediction for $gg \to H$ in SM
Workshop on Higgs Boson Phenomenology, Zurich, Switzerland, January 2009

Numerical Evaluation of Multiloop Massive Integrals for NNLO Calculations
High Precision for Hard Processes at the LHC (HP2.2) Workshop, Buenos Aires, Argentina, October 2008

Towards a Complete NNLO Prediction for (bar)B → X_s gamma
Annual Workshop and Mid-Term Review Meeting of the European Flavour Physics Network FLAVIAnet, Durham, UK, September 2008

Seminars:

Confronting Theory Space with the Tevatron Higgs Exclusion Limit
Johns Hopkins University, Baltimore, MD, May 2011

Bounding New Physics using the Tevatron's Higgs Exclusion Limit
SLAC, Menlo Park, CA, April 2011

Bounding New Physics using the Tevatron's Higgs Exclusion Limit
Fermilab, Batavia, IL, March 2011

Precise Predictions for Higgs Production at Hadron Colliders within the SM and Beyond
Northwestern University, Evanston, IL, November 2010

Precise Predictions for Higgs Production at Hadron Colliders Beyond the SM
Durham University, UK, May 2010

Constructing Higher-Order Effective Higgs Theories
Argonne National Laboratory, Argonne, IL, May 2010

Searching for the Higgs at Hadron Colliders
University of Wisconsin, Madison, April 2010

Searching for the Higgs at Hadron Colliders
Johannes Gutenberg University, Mainz, Germany, July 2009

NNLO QCD Calculations for the Radiative B Decay
Paul Scherer Institute, Switzerland, October 2008

Qinghong Cao

Higgs Boson, Top Quark and New Physics
Department of Physics, Peking University, April 16, 2011

Top Quark and New Physics at the LHC
Seminar, Shanghai Jiaotong University, June 14, 2010

Sextet Scalar Phenomenology at the Tevatron and LHC
PHENO 2010, University of Wisconsin, Madison, May 10, 2010

Color Sextet Scalar and its Phenomenology at early LHC
Seminar, Department of Physics and Astronomy, Northwestern University, April 26, 2010

Top Quark and New Physics at the Tevatron and Early LHC
Seminar, Department of Physics and Astronomy, Michigan State University, East Lansing, March 16, 2010

Top Quark and New Physics
Seminar, Theory Group for Quarks, Hadrons, and Nuclei (TQHN), University of Maryland, College Park, November 23, 2009

Searching for Dark Scalars at the Colliders
Seminar, Institute of Theoretical Physics, Chinese Academy of Sciences, January 4, 2008

Search for Dark Scalars at the Large Hadron Colliders
Seminar, High Energy Group, Peking University, December 18, 2008

Search for Dark Scalars at the Colliders
Seminar, High Energy Group, University of Chicago, IL, October 16, 2008

Jamie Gainer

SUSY at the ILC
Muon Collider Physics Workshop, Fermilab, Batavia, IL, November 11, 2009

Supersymmetry without Prejudice
Argonne National Laboratory, Argonne, IL, January 19, 2010

Supersymmetry without Prejudice
Northwestern University, Evanston, IL, February 15, 2010

Supersymmetry without Prejudice
Brookhaven National Laboratory, Upton, NY, March 3, 2010

Supersymmetry without Prejudice
Massachusetts Institute of Technology, Cambridge, MA, April 29, 2010

Supersymmetry without Prejudice at the LHC
PHENO 2010, Madison, WI, May 10, 2010

New Topologies and Simplified Models from the pMSSM
Workshop on Topologies for Early LHC Searches, SLAC National Accelerator Laboratory, Menlo Park, CA, September 22, 2010

Supersymmetry without Prejudice at the LHC

Michigan State University, East Lansing, September 28, 2010

Supersymmetry without Prejudice at the LHC
University of Illinois at Chicago, October 11, 2010

Supersymmetry without Prejudice at 7 TeV
University of California, Davis, February 25, 2011

Matrix Element Method for Higgs Discovery and Analysis at 7 TeV
University of California, Irvine, March 2, 2011

Matrix Element Method for Higgs Discovery and Analysis at 7 TeV
SLAC National Accelerator Laboratory, Menlo Park, CA, March 4, 2011

Matrix Element Method for Higgs Discovery and Analysis at 7 TeV
University of Michigan, Ann Arbor, March 30, 2011

Matrix Element Method for Higgs Discovery and Analysis at 7 TeV
Argonne National Laboratory, Argonne, IL, May 3, 2011

Matrix Element Approach to Resonance Spin Measurement with the Z gamma Final State
PHENO 2011, Madison, WI, May 10, 2011

Xavier Garcia i Tormo

Factorization in Exclusive Quarkonium Production
SCET Workshop 2009, Massachusetts Institute of Technology, Cambridge, MA, March 24-26, 2009

The QCD Static Potential: Perturbative Calculations
8th Christmas Meeting, University of Barcelona, Spain, December 17-18, 2008

The QCD Static Potential: Perturbative Calculations
International Workshop on Heavy Quarkonia 2008, Nara Women's University, Nara, Japan, December 2-5, 2008

Christopher Jackson

Renormalization and BSM Physics: A Cautionary Tale
Michigan State University, East Lansing, September 23, 2008

The S Parameter at One-loop in Extra-dimensional and Deconstructed Models
Northwestern University, Evanston, IL, October 27, 2008

Higgs Triplets, Decoupling and Precision Measurements

International Linear Collider Workshop, Chicago, IL, November 18, 2008

The WIMP Forest
PHENO 2009 Symposium, Madison, WI, May 12, 2009

The WIMP Forest: Indirect Detection of Extra Dimensions
ANL-IIT Collider Physics Workshop, Argonne, IL, and Chicago, IL, May 19, 2009

The WIMP Forest and Higgs in Space!
Brookhaven National Laboratory, Upton, NY, July 10, 2009

Higgs Production in the MSSM
Meeting of the DPF of the APS, Detroit, MI, July 28, 2009

Double Parton Scattering at the LHC
USDOE Review, HEP Division, Argonne, IL, September 24, 2009

Higgs in Space!
Fermi National Accelerator Laboratory, Batavia, IL, October 1, 2009

Adventures in Dark Matter Spectroscopy
University of Minnesota, Minneapolis, January 19, 2010

Higgs in Space!
Florida State University, Tallahassee, March 2, 2010

Searching for a Higgs Boson... Here, There or Anywhere!
University of Texas at Arlington, April 12, 2010

Double Parton Scattering at the LHC
PHENO 2010 Symposium, Madison, WI, May 10, 2010

Ian Low

Landau-Yang Theorem and Final States with Two Z Bosons at the LHC
A Topical Conference on Elementary Particles, Astrophysics, and Cosmology, Ft. Lauderdale, FL, 2008

Warped KK-Parity
Argonne National Laboratory, Argonne, IL, May 2008

Warped KK-Parity
Fermilab, Batavia, IL, September 2008

Warped KK-Parity
University of Minnesota, Minneapolis, April 2009

Constraints on Higgs Effective Couplings
Stony Brook University/Brookhaven National Laboratory, Stony Brook, NY, May 2009

Constraints on Higgs Effective Couplings
IPMU, University of Tokyo, Japan, August 2009

Landau-Yang Theorem and Final States with Two Z Bosons at the LHC
Workshop on Higgs Boson Phenomenology, ETH, Zurich, Switzerland, 2009

Constraints on Higgs Effective Couplings
KEK, Tsukuba, Japan, August 2009

Constraints on Higgs Effective Couplings
National Taiwan University, Taipei, August 2009

Constraints on Higgs Effective Couplings
National Tsing-Hua University, Hsin-Chu, Taiwan, September 2009

Constraints on Higgs Effective Couplings
University of Wisconsin, Madison, October 2009

Constraints on Higgs Effective Couplings
Perimeter Institute, Waterloo, Canada, November 2009

The Identity of the Higgs Boson at the LHC, Parts I & II
LHC Physics Center "Theorist of the Week", Fermilab, Batavia, IL, March 2010

The Identity of the Higgs Boson at the LHC
PHENO 2010, Madison, WI, May 2010

The Identity of the Higgs Boson at the LHC
MCTP Spring Symposium on Higgs Boson Physics, Ann Arbor, MI, 2010

The Identity of the Higgs Boson at the LHC
Brookhaven Forum 2010, BNL, Upton, NY, 2010

A New Scenario for (Supersymmetric) Decaying Dark Matter
University of California, San Diego, February 2011

Frank Petriello

Invited and plenary conference talks:

Production of the Higgs Boson and Other Electroweak Objects at the LHC
Physics at the LHC 2011, Perugia, Italy, June 8, 2011

The Gluon-Fusion Cross Section with a Jet Veto
Higgs Cross Sections for the LHC, BNL, Upton, NY, May 5, 2011

The Strong Coupling Constant at the LHC
Workshop on Precision Measurements of the Strong Coupling Constant, MPI Munich, Germany, February 11, 2011

Standard Model Predictions for Gluon-Fusion Higgs Production
Invited talk, 2nd LHC Higgs Cross Section Workshop, CERN, Geneva, SZ, July 5, 2010

The Status of NNLO Tools for W and Z Production at Hadron Colliders
The Physics of W and Z Bosons, Brookhaven National Laboratory, Upton, NY, June 25, 2010

Resummation of Low Differential Distributions in Soft-Collinear Effective Theory
LoopFest IX: Radiative Corrections for the LHC and Lepton Colliders, Stony Brook, NY, June 22, 2010

Theory Systematics for Gluon-Fusion Higgs Production
Invited talk, Joint CDF/DO/Theory Meeting on Higgs Systematics, Fermilab, Batavia, IL, May 17, 2010

Higgs Boson Production in Proton-Proton Collisions
10th DESY Workshop on Elementary Particle Theory: Loops and Legs in Quantum Field Theory 2010, Worlitz, Germany, April 26, 2010

Gluon-Fusion Higgs Production in the Standard Model and Beyond
Emerging Problems in Particle Physics Phenomenology, Initiative for Theoretical Sciences, City University of New York, April 9, 2010

Recent Results in Perturbative QCD
APS April Meeting 2010, Washington, DC, February 14, 2010

Determining Z' couplings using LHC data and low energy measurements
Perimeter Institute ATLAS-LHC Day, Waterloo, Canada, October 30, 2009

Higher-Order Corrections and BSM Physics
LHC Theory Initiative Fellows Meeting, Fermilab, Batavia, IL, October 29, 2009

Z' Bosons from Low to High Energies
CIPANP 2009: Tenth Conference on the Intersections of Particle and Nuclear Physics, San Diego, CA, May 29, 2009

Recent Progress on QCD and Electroweak Corrections to Higgs Production

Collider Physics 2009: Joint Argonne & IIT Theory Institute, Argonne, IL, and Chicago, IL, May 20, 2009

Precision Higgs Physics
Workshop on Physics at the LHC: The 1st Year, TRIUMF National Laboratory, Canada, April 27, 2009

Getting Ready for the LHC: a QCD Status Report
Brookhaven Forum 2008, Terra Incognita: From LHC to Cosmology. Brookhaven National Laboratory, November 7, 2008

Z' Bosons from Q^2=0 to the LHC
Collider Physics Symposium: Preparing for the LHC, Institute for Nuclear Theory, Seattle, WA, September 20, 2008

QCD at the LHC
Quark Confinement and the Hadron Spectrum, Johannes Gutenberg University of Mainz, Germany, September 2, 2008

Colloquia:

The Hunt for the Higgs Boson
University at Buffalo, NY, March 18, 2010

The Hunt for the Higgs Boson
Northwestern University, Evanston, IL, January 18, 2010

The Hunt for the Higgs Boson
Florida State University, Tallahassee, FL, April 9, 2009

QCD Predictions for LHC Processes
Lawrence Berkeley National Laboratory, CA, December 4, 2008

Transverse Momentum Distributions from Effective Field Theory
BNL, Upton, NY, May 6, 2011

Theoretical Issues in Higgs Searches
Joint Johns Hopkins/University of Maryland particle theory seminar, Baltimore, MD, April 11, 2011

Transverse Momentum Distributions from Effective Field Theory
University of Chicago, IL, December 1, 2010

Transverse Momentum Distributions from Effective Field Theory

University of Michigan, Ann Arbor, October 29, 2010

Factorization and Resummation of Low Differential Distributions in SCET
University of Heidelberg, Germany, July 12, 2010

Factorization and Resummation of Low Differential Distributions in SCET
Fermilab, Batavia, IL, April 15, 2010

Precision Higgs Physics at Hadron Colliders
University of Indiana, Bloomington, February 8, 2010

Precision Higgs Physics at Colliders
SLAC, Menlo Park, CA, January 29, 2010

How to Analyze a Z' Discovery using the LHC and Low Energy Data
University of Zurich, Switzerland, November 10, 2009

Precision Higgs Physics at Colliders
Rutgers University, New Brunswick, NJ, October 20, 2009

Electroweak Effects in Higgs Physics
Florida State University, Tallahassee, April 10, 2009

Electroweak Effects in Higgs Physics
Fermilab, Batavia, IL, March 19, 2009

Electroweak Effects in Higgs Production
Yale University, New Haven, CT, February 17, 2009

Electroweak Effects in Higgs Production
University of Minnesota, Minneapolis, February 5, 2009

Electroweak Effects in Higgs Production
Argonne National Laboratory, Argonne, IL, January 27, 2009

DAMA and WIMP Dark Matter
University of Zurich, Switzerland, August 29, 2008

Summer School Lectures:

Techniques for Perturbative QCD
Paul Scherrer Institute Summer School on Particle Physics: Gearing up for LHC Physics, Zuoz, Switzerland, August 1-7, 2010

Perturbative QCD
2009 SLAC Summer Institute: Revolutions on the Horizon, Stanford Linear Accelerator Center, CA, August 7, 2009

Higgs Physics
IV Torino School in Physics at Colliders, Torino, Italy, June 29-July 3, 2009

Higgs and Electroweak Gauge Bosons
2009 CTEQ Summer School, Madison, WI, June 24-25, 2009

Seth Quackenbush

Z' Bosons On-peak, Off-peak, and Way Off-peak
Northwestern University, Evanston, IL, October 13, 2008

Z' Bosons On-peak, Off-peak, and Way Off-peak
Argonne National Laboratory, Argonne, IL, October 14, 2008

Z' Bosons On-peak, Off-peak, and Way Off-peak
Brookhaven Forum 2008, BNL, Upton, NY, November 7, 2008

Z' Bosons On-peak, Off-peak, and Way Off-peak
2008 Linear Collider Workshop, University of Illinois at Chicago, November 17, 2008

Z' Bosons On-peak, Off-peak, and Way Off-peak
Johns Hopkins University, Baltimore, MD, November 25, 2008

Z' Bosons On-peak, Off-peak, and Way Off-peak
University of Maryland, College Park, MD, December 1, 2008

Z' Bosons at Present and Future Colliders
Muon Collider Physics Workshop, Fermilab, Batavia, IL, November 12, 2009

Early Z' Searches at the LHC
PHENO 2010, University of Wisconsin, Madison, May 11, 2010

Early Z' Searches at the LHC
Brookhaven Forum 2010, BNL, Upton, NY, May 27, 2010

Z Gauge Boson Production at NNLO with FEWZ
Michigan State University, East Lansing, MI, November 16, 2010

W and Z Production at NNLO using FEWZ 2.0
Loopfest X, Evanston, IL, May 12, 2011

Gabe Shaughnessy

LHC Higgs Boson Search at 7 TeV
PHENO 2010, University of Wisconsin, Madison, May 10-12, 2010

New Physics Spectroscopy with Dark Matter
HEP Seminar, Michigan State University, East Lansing, February 23, 2010

New Physics Spectroscopy with Dark Matter
Aspen Winter Conference 2010, CO, January 17-23, 2010

The Higgs Boson as a Portal to Dark Matter
Meeting of the Division of Particles and Fields of the American Physical Society, Wayne State University, Detroit, MI, July 26-31, 2009

Identifying Extended Higgs Models at the LHC Collider Physics
Joint Argonne & IIT Theory Institute on Collider Physics, Argonne, IL, and Chicago, IL, May 18-22, 2009

Higgs ID at the LHC
PHENO 2009, University of Wisconsin, Madison, May 11-13, 2009

The Nature of Dark Matter
Physics Colloquium, University of Wisconsin-Milwaukee, May 8, 2009

Phenomenology of Singlet Models
HEP Theory Seminar, University of Kansas, March 27, 2009

Search for Dark Matter
HEP Seminar, University of Kansas, March 23, 2009

Search for Dark Matter
PHENO seminar, University of Wisconsin, Madison, December 16, 2008

Search for Dark Matter
ANL-HEP Lunch Seminar, November 25, 2008

Search for Dark Matter
HEP theory seminar, Fermilab, November 6, 2008

Search for Dark Matter
HEP seminar, Northwestern University, November 3, 2008

PAMELA and Dark Matter
LCWS08 - Cosmological Connections, November 17, 2008

Timothy Tait

Pictographs for Higgs Physics
Higgs Workshop, University of Seattle, WA, January 16, 2009

Fun with Top Compositeness
HEP Seminar, UC Irvine, CA, January 28, 2009

Unraveling the Nature of Dark Matter
Colloquium, UC Irvine, CA, January 29, 2009
Colloquium, University of Chicago, IL, April 23, 2009

Lectures on Top Physics
Fermilab, Batavia, IL, April 27-30, 2009 (3 hours total)
ATLAS Jamboree, Brookhaven National Lab, Upton, NY, June 17-19, 2009 (3 hours total)

Top as a Window to New Physics
APS Conference, Denver, CO, May 3, 2009

A Fourth Generation...REALLY?!
PHENO Conference, Madison, WI, May 12, 2009

Top Compositeness
Top Physics Workshop at CERN, Geneva, SZ, May 25, 2009

Carlos Wagner

Interplay between B Physics, Higgs Physics and Dark Matter Searches
Invited talk, CDF Collaboration Meeting, Fermilab, Batavia, IL, June 17, 2008

Gauge Higgs Unification and Radiative EW Symmetry Breaking in Warped Extra Dimensions
Plenary talk, Weihai Forum on Frontiers of HEP-LHC Physics, Weihai, China, July 11, 2008

The Supersymmetric Origin of Matter
KITPC Workshop, Beijing, China, July 14, 2008

Theoretical Aspects of Supersymmetry and SUSY Higgs

Plenary talk, ICHEP08, Philadelphia, PA, August 3, 2008

Cosmology and the LHC
Plenary talk, SEWM08 Conference, Amsterdam, Netherlands, August 28, 2008

Light Stop Searches at the Tevatron and the LHC
Workshop on Hadron Collider Physics, Fermilab, Batavia, IL September 18, 2008

CPT Violation and Neutrino Physics
Invited plenary talk, Ayres Fest, HEP Division, Argonne, IL, September 3, 2008

Phenomenological Constraints on Warped Extra Dimensions
Invited talk, NIT Workshop on Collider Physics, Seattle, WA, September 30, 2008

Electroweak Baryogenesis in the nMSSM and ILC Physics
American Linear Collider Group Workshop, UIC, Chicago, IL, November 19, 2009

Cosmology and Physics at Hadron Colliders
KICP Lunch Seminar, Univ. of Chicago, January 30, 2009
Invited Talk, Physics Department, Univ. of Wisconsin, Madison, Feb. 5, 2009
Invited Talk, Physics Department, Purdue University, West Lafayette, March 10, 2009
Physics Colloquium, Argonne National Laboratory, March 27, 2009

Interplay between B Physics, Higgs Physics and Dark Matter Searches
Invited Plenary Talk, Aspen Winter Workshop, Aspen, CO, February 10, 2009

Phenomenological Properties of Extra Dimensions
Plenary Talk, CIPANP Conference, San Diego, CA, May 30, 2009

Propects for MSSM Higgs Physis at the Tevatron
GGI Workshop, Florence, Italy, September 10, 2009
DOE Review, Univ. of Chicago, September 11, 2009
HDays09, Santander, Spain, September 15, 2009

New Physics at the Weak Scale
Aspen Physics Colloquium, Aspen, CO, August 6, 2009

Lectures on Supersymmetry
Parma School on Theoretical Physics, Parma, Italy, September 1--5, 2009

Weak Scale Baryogenesis in the MSSM and in an SU(2) extended Model
Workshop on Baryon and Lepton Number Violation, Madison, WI, September 22, 2009

Argonne HEP Theory Group Activities
Argonne DOE Review, September 23, 2009

Flavor Physics in the LHC Era
Invited Plenary Talk, Workshop on the Interplay of Flavor and Collider Physics, CERN, December 14, 2009

Is the Revolution in Particle Physics Here?
Summary Talk, Aspen Winter Conference Summary Talk, Aspen, CO, January 22, 2010

New Physics at the Weak Scale: From Collider Physics to Cosmology
Physics Colloquium, Notre Dame University, February 24, 2010

Theoretical High Energy Physics Physics
Talk given to prospective students, University of Chicago, April 9, 2010

Open Question in Particle Physics
Kennedy Junior High School, Outreach Talk, April 22, 2010

Prospects for MSSM Higgs Searches at the Tevatron Collider
MCTP Higgs Symposium, Ann Arbor, MI, May 15, 2010

Physics at the Energy Frontier
Plenary Talk, FNAL Users Meeting, Fermilab, Batavia, IL, June 3, 2010

New Physics at the Weak Scale: Supersymmetry and Extra Dimensions
Plenary Talk, Rencontres de Blois, Blois, France, July 15-20, 2010

Lectures on Electroweak Baryogenesis
Pre-SUSY 2010 School, University of Bonn, Germany, August 19-20, 2010

High Energy Physics in the LHC Era
Invited Plenary Talk, Meeting of the Argentine Physics Association, Malargue, Argentina, October 1, 2010

Beyond the Standard Model, Mass Generation, Cosmology and the LHC
Strings@ar meeting, University of Buenos Aires, October 7, 2010

Dark Light Higgs
PCTS Meeting on Dark Matter, Princeton University, November 16, 2010

Searches for WIMPS at Colliders
Public Lecture, Wimps of the Underground, Chicago, December 9, 2010

Dark Matter
Public Lecture, Ranelagh Public School, Buenos Aires, December 27, 2010

MSSM Higgs Physics at the End of the Tevatron and the Beginning of the LHC Era
Invited Plenary Talk, Aspen Winter Workshop, Aspen, CO, February 28, 2011

High Energy Physics at the Beginning of the LHC Era
Colloquium, University of Chicago, April 7, 2011
Colloquium, University of Washington, Seattle, April 25, 2011
Physics Division Colloquium, Argonne, May 13, 2011

New results on MSSM Higgs Physics
Workshop on Electroweak Symmetry Breaking, University of Wisconsin, Madison, May 8, 2011

The Quest for New Physics at the Weak Scale
Invited Plenary Talk, Perugia Conference on LHC, Perugia, Italy, June 10, 2011

High Energy Physics Community Activities

Edmond L. Berger

Major Responsibility:

Contact person and Organizer, Aspen Summer Workshop *Forefront QCD and LHC Discoveries* http://www.aspenphys.org/documents/program/summer2010.html, May 23 – June 20, 2010

Chair, Committee on Constitution & Bylaws, American Physical Society, 2011; Member, 2009 – present

Search Committee, Senior Computational Scientists, Argonne National Laboratory, 2009 – present

Co-Organizer, ATLAS Physics Jamboree, Argonne, November 17, 2010

Member, Search Committee, Joint Theory Position Between Argonne and Northwestern, 2009 – 2010

Scientific Program Organizing Committee, Rencontres de Moriond, *QCD and High Energy Hadronic Interactions*, La Thuile, Italy, March, 2008, 2009, 2010, 2011

Argonne Laboratory-wide Named and Director's Postdoctoral Appointments Committee, 2008--2009

Organizing Committee, *Collider Physics 2009*, Joint Argonne and Illinois Institute of Technology Theory Workshop, May18--22, 2009, High Energy Physics Division, Argonne

Member, Andrew Gemant Award Committee, American Institute of Physics, 2002 – 2008.

Director's Review Committee for 2008 LDRD Competitive Grants. 2007 - 2008

Other Committees and External Activities:

Member, Coordinated Theoretical-Experimental Project on QCD (CTEQ) Collaboration

Adjunct Professor of Physics, Michigan State University, 1997 - present. Reappointed for another three-year term effective July 1, 2010

Organizing Committee, CTEQ Summer School, July 11–19, 2011

International Advisory Committee, XIV International Conference on Hadron Spectroscopy (HADRON 2011), Munich, June 13–17, 2011

Organizing Committee, Symposium in Honor of Jon Rosner, University of Chicago, April 1, 2011

International Advisory Committee, Dual Colima-Puebla Workshop on High Energy Physics, Flavor Symmetries, Colima**,** Mexico, January 4–14, 2011

Host and Local Organizer, CTEQ Collaboration Fall Meeting, Argonne National Laboratory, IL, November 18, 2010

Technical Reviewer for University of Chicago – Argonne Strategic Collaboration Seed Grants, 2010

International Advisory Committee, XIII International Conference on Hadron Spectroscopy (HADRON 2009), Florida State University, Tallahassee, November 2009

International Advisory Committee, 5th International Conference on Flavor Physics, Hanoi, Vietnam, September 24-30, 2009

Organizing Committee, Sixteenth CTEQ Summer School on QCD Analysis and Phenomenology, Madison, WI, June 24--July 2, 2009

Scientific Program Committee, 10th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2009), San Diego, CA, May 2009

Host and Local Organizer, CTEQ Collaboration Fall meeting December 5-7, 2008, Argonne National Laboratory, IL

Chair, Postdoctoral Research Symposium, Argonne National Laboratory, IL, September 11, 2008

QCD Convener, CERN-Fermilab Hadron Collider Physics Summer School, Fermilab, IL, August 12-22, 2008

Geoffrey Bodwin

Co-convener, Production chapter, Quarkonium Working Group Document "Heavy Quarkonium, Progress, Puzzles, and Opportunities," August 2009—January 2010

Member, International Advisory Committee and Convener for Heavy Quarks and Gluonia, Quark Confinement and the Hadron Spectrum IX, Madrid, August 30—September 3, 2010

Co-chair, Local Organizing Committee, VIIth International Workshop on Heavy Quarkonium, Fermilab, May 18-21, 2010

Co-Proposer and Co-organizer, Kavli Institute "Effective Field Theories", KITPC, Beijing, August 3—September 11, 2009

Convener, Heavy Quarks and Gluonia, and

Member, International Advisory Committee, Quark Confinement and the Hadron Spectrum VIII, Mainz (Germany), September 1-6, 2008

Member, Argonne Physical Sciences Advisory Group, July 2006--June 2008

Convener, Quarkonium Working Group, April 2005--present

Convener, Production Section, Quarkonium Working Group, September 2004--present

Member, Quarkonium Working Group, March 2002--present

Radja Boughezal

Organizer, LoopFest X: Radiative Corrections for the LHC and Future Colliders, Evanston, IL, 12-14 May 2011.

Co-organizer, 9th International Symposium on Radiative Corrections (RADCOR 2009): Applications of Quantum Field Theory to Phenomenology, Ascona, Switzerland, 25-30 October 2009.

Panelist, Argonne High Energy Physics Division Retreat: led a discussion on the Future of the Theory Group, December 2010.

Referee, Physics Letters B, 2007—present

Qinghong Cao

Member, Argonne HEP Division Lunch Seminar Committee, September 2008--present

Jamie Gainer

'Theorist', in "Ask a Theorist" Booth at Argonne Open House, August 29, 2009

Xavier Garcia i Tormo

Member, Argonne HEP Division Lunch Seminar Committee, June 2008--August 2009

Member, Catalan Physical Society, June 2008--August 2009

Christopher Jackson

Co-organizer, ANL-IIT Workshop on Collider Physics 2009, Argonne National Laboratory, Argonne, IL and Illinois Institute of Technology, Chicago, IL, May 2009

‘Theorist’, in HEP’s "Ask a Theorist" Booth at Argonne Open House, August 29, 2009

Member, Argonne HEP Division Theoretical Physics Seminar Committee, September 2008—July 2010

Ian Low

Colloquium Committee, Northwestern University, 2008-2009

Graduate Qualifying Exam Committee, 2008-2009

HEP Division Seminar Committee, Argonne, 2008-2009

Graduate Curriculum and Advising Committee, Northwestern, 2009-2010

Graduate Qualifying Exam Committee, Northwestern, 2009-2010

Goldwater Scholarship Nominating Committee, Northwestern, 2009--present

2008 Hadron Collider Physics Summer School}, Fermilab, Batavia, Illinois, August 2008: Discussion Leader for the session "Extra Dimensions and Strong Dynamics."

Co-organizer, ANL-IIT Workshop on Collider Physics 2009, Argonne National Laboratory, Argonne, IL, and Illinois Institute of Technology, Chicago, IL, May 2009

Co-convener, SUSY 2009: Extra Dimensions (parallel session), Northeastern University, Boston, MA, June 2009

Lead organizer, Chicagoland Theory Meeting, Northwestern University, Evanston, IL, May 2011

Local Organizing Committee, SUSY 2011, Fermilab, Batavia, IL, August 2008

Frank Petriello

Joint ATLAS-CMS-Theory Working Group on Higgs Cross Sections, Theory Convenor for Gluon-Fusion Mode, February 2010—present

Organizer, LoopFest X: Radiative Corrections for the LHC and Future Linear Colliders, Evanston, IL, May 12-14, 2011

Reviewer, DOE Intensity Frontier Panel, Washington, DC, August 10-12, 2010

Organizer, Perturbative Higher-Order Effects at Work at the LHC, CERN Theory Institute, Geneva, SZ, June 21--July 9, 2010

Organizer, Forefront QCD and LHC Discoveries, Aspen Center for Physics Summer Workshop, Aspen, CO, May 23--June 20, 2010

Convenor, Jet and Photon Energy Measurements Working Group, 2009 Linear Collider Workshop of the Americas, Albuquerque, NM, September 29--October 3, 2009

Organizer, CTEQ Summer School on QCD Analysis and Phenomenology, Madison, WI, June 24--July 2, 2009

Organizer, LoopFest VIII: Radiative corrections for the LHC and the ILC, Madison, WI, May 7-9, 2009

Organizer, Workshop on Higgs Boson Phenomenology, ETH and University of Zurich, Switzerland, January 7-9, 2009

Seth Quackenbush

Member, Argonne HEP Division Theoretical Physics Seminar Committee, September 2010--present

Carlos Wagner

Recent Community Service:

Head, Argonne HEP Theory Group, June 2005--June 2011

Leader, Astrophysics Initiative, Argonne, April 2007--Dececember 2008

Head, Search Committee for a Joint Fermilab/University of Chicago position in Theoretical Particle Physics, March 2008--December 2008

Member, Search Committee for a Leader in Astrophysics at Argonne National Laboratory, November 2007--July 2008

Member, Particle Physics Project Prioritization Panel (P5) National Committee, January 2008--December 2008

Convener, American Linear Collider Group Conference, November 2008

Co-organizer, Argonne JTI Workshop, Argonne, IL, April 2009

Co-organizer, Argonne/IIT Workshop on Collider Physics, Argonne, IL, and Chicago, IL, May 2009

Member, Search Committee for an Associate Physicist position at Argonne National Laboratory, jointly with Northwestern University, September 2009--June 2010
(Led to the Appointment of F. Petriello and R. Boughezal)

Head, Search Committee for an Assistant Professor position at the University of Chicago, September 2009--July 2010 (Led to the Appointment of Lian-Tao Wang)

Particle Physics Project Prioritization Panel (P5) National Committee, October 2010

Member, Report Writing Committee, Retreat Argonne HEP Division, December 2010--April 2011

Member, Scientific Committee, Workshop on Muon Colliders, Telluride, CO, June 27--July 1, 2011

Chair, PreSUSY 2010 School Organizing Committee, University of Chicago, August 24-26, 2011

Co-organizer, Proposed Aspen Summer Workshop on Baryogenesis, Aspen, July 2012

Teaching Activities:

Lecturer, University of Chicago, Graduate course on Introduction to Cosmology, March 2008--June 2008

Lecturer, University of Chicago, Graduate course on Particle Physics, March 2009--June 2009

Lecturer, Parma School for Theoretical Physics, Graduate course on Supersymmetry. September 2009

Lecturer, University of Chicago, Graduate course on Physics at the LHC, March 2010--June 2010

Lecturer, Pre-SUSY 2010 School on Electroweak Baryogenesis, September 2010--October 2010

Lecturer, University of Buenos Aires, Graduate course on Physics Beyond the Standard Model, August 2010

Lecturer, University of Chicago, Graduate course on Advanced Quantum Field Theory, March 2011--June 2011

Argonne National Laboratory HEP Division

Theoretical Physics : Formal Field Theory

ANL Theory Progress Report: Field Theory
The Global Structure of the Renormalization Group

Over the past two years, in collaboration with T Curtright (Univ of Miami), C Zachos has been focusing on an extensive project centered on the remarkable global structure of the Renormalization Group, as revealed by the functional equations it obeys, explored through novel methods introduced.[8]

Specifically, the original, finite, renormalization group equation is $\Psi\left(g\left(t\right)\right)=\lambda^{t}\ \Psi\left(g\right)$, discovered in QED by Gell-Mann and Low[9], where t is the logarithm of the distance or energy reference point, λ sets its scale, $g\equiv g(0)$, and Ψ is essentially what is now known as the RG "scaling function" which "rectifies" complicated group flow to linear flow. It had not been appreciated that this global equation, which *preceded any local RG relation*, also introduced shortly by these same authors, is, in fact, Schröder's eponymous functional equation invented in 1870; and admits solutions by the methods introduced[1], *in the absence of local, differential, relations.* (Gell-Mann and Low, instead, proceeded to solve it by parameterizing the algebra (infinitesimal action) of the group, $\frac{dg}{dt}=\beta\left(g\right)\equiv\left(\ln\lambda\right)\Psi\left(g\right)/\Psi'\left(g\right)$; and then integrating a perturbative approximant to this algebra in g, to obtain the RG trajectory $g(t)=\Psi^{-1}(\lambda^{t}\Psi(g))$.)

In this conjugacy form, the global self-similar functional structure of the RG trajectory is more apparent, and illuminates the interplay between continuous and discrete rescaling (step-scaling in lattice gauge theory), often inaccessible to conventional local relations.

For example, periodic Ψ^{-1}s yield limit cycles even for just one real coupling, cf. the "Russian Doll" model.[10] Constancy of Ψ^{-1}, instead, yields fixed points. However, solutions thus[1] found may have novel, exotic physical features, including multiple branches: zeroes of β do *not* necessarily signal fixed points of the flow, but instead (if the acceleration or higher derivatives do not vanish), may only indicate turning points of the RG trajectories, analyzed by the novel functional conjugacy methods, and revealing intriguing multivalued behaviors[1], including chaotic (spin-glass) flows.[11]

The holographic functional methods introduced provide smooth, analytic interpolates of given discrete initial/boundary conditions, in a broad range of physics problems, such as chaotic systems[1], in the *absence of any prior local propagation dynamical equations*, somewhat analogous to inverse scattering. One of the new outputs of the method is the specification of differential equations, β-functions, and effective potentials, as *emergent phenomena*, when such were simply *unavailable at the start*, but only after the entire orbit was found. It was confirmed that the entire bulk information of the systems involved, (as in AdS/CFT), already *resides completely on the boundary*, hence the metaphorical term "holography" applied, and is then recoverable by analyticity through Schröder equation methods.

The functional methods produce continuous RG flows from step-scaling σ-functions originating on a discrete lattice in lattice gauge theory,[12] and yield exact functional relations for the local flow

[8] T Curtright & C Zachos, Phys Rev **D83** (2011) 065019; J Phys **A43** (2010) 445101, J Phys **A42** (2009) 485208, and arXiv:1105.3664

[9] M Gell-Mann and F E Low, Phys Rev **95** (1954) 1300-1312

[10] A LeClair, J M Román, and G Sierra, Phys Rev **B69** (2004) 20505

[11] e.g. the Ising model for imaginary magnetic field flows chaotically through the logistic map so analyzed: B Dolan, Phys Rev **E52** (1995) 4512-4516; cf. Dyson's hierarchical model in Y Meurice & S Nierman, Phys Rev **E60** (1999) 2612-2615

[12] T Appelquist, G Fleming, and E Neil, Phys Rev **D79** (2009) 076010

β-functions, exploited to provide the features outlined.

Distributary Projects

Progress has also been made in three areas only loosely connected to the above project.

The first has been elaboration of C Zachos' project with C T Hill (Fermilab) on Chern-Simons topological interactions across dimensions.[13] These holographically encode physical (safe, flavor-chiral) anomalies of our familiar world: the 4d Standard Model and its effective gauged chiral models. Elucidation of the gauge anomaly structure of new dimensional-deconstruction-based particles or phenomena, if such were discovered at the LHC, would be at the top of its priorities' list. The pedagogical simplest possible model constructed mimics the chiral structure of QCD, and was derived by integrating out the chiral brane-boundary fermion inflows present, both a) in 4d, directly, but also b) from the Chern-Simons functional of a compactified 5d pure gauge theory, which cancels the anomalies of these brane fermions. The respective boundary a) and the bulk b) topological terms are revealed to be *equivalent bosonic representations of the very same boundary fermion anomalies*, and may be effectively regarded as holographic AdS/CFT duals to each other. For $U(1)_L \times U(1)_R$ quark-flavor, even though the pure-meson term collapses, the full (gauge-coupling) interaction terms survive and determine the 4D WZW functional.

As circumscribed by by older systematic work of the same authors, in the end, the surviving players are both bosonic, CS in the bulk and full (gauged) WZW on the boundary, each generating the same anomaly, up to their sign, on the brane boundary. Conversely, this bulk-boundary system with the fermions eliminated manifestly evinces anomaly cancellations between CS and WZW terms, in a thus over-all gauge-invariant bosonic system. One is then justified to ask whether fermions *incompletely localized* on boundary branes developing chiral zero modes on the boundary, would *also* be amenable to analogous treatment.

The second project has resulted in several results[14] on novel infinite-dimensional ternary algebras (antisymmetrizations of *three* operators) discovered here. These algebras, unlike generic associative Quantum Nambu Algebras[15] further obey an all-but-impossibly-stringent condition (FI), for a special value of their parameter $s = \pm 2i$. (The FI condition is *not* an identity and is normally at odds with associativity—unlike Bremner identities[7] , the true analogs of Jacobi identities, easily satisfied in the ternary Virasoro-Witt algebra discovered. It serves to enforce supersymmetry in the superconformal lagrangian model of Bagger and Lambert[16] with a *finite* number of fields, which provides the holographic dual to two M2 branes superposed on an orbifold R^8/Z_2 in M-theory. The crucial Chern-Simons anomaly interaction in that model relies on ternary algebras.)

While finite-dimensional exemplars of such algebras satisfying the FI are provably few (essentially only Nambu's A_4), the V-W algebra found[7] had no trouble achieving compliance. The reason for this was revealed in the second paper[7]: a counter-intuitive algebra isomorphism was discovered to Nambu's Classical Brackets (for which the FI *is* a bona-fide identity, and thus the identical structure constants ensured compliance).

[13] C Hill and C Zachos, Ann Phys **323** (2008) 3065-3073

[14] T Curtright, D Fairlie, and C Zachos, Phys Lett **B666** (2008) 386-390;
T Curtright, X Jin, L Mezincescu, D Fairlie, and C Zachos, Phys Lett **B675** (2009) 387-392

[15] Y Nambu, Phys Rev **D7** (1973) 2405-2412, which introduces A_4;
T Curtright, C Zachos, Phys Rev **D68** (2003) 085001

[16] J Bagger and N Lambert, Phys Rev **D77** (2008) 065008

These results were further extended, heuristically, to cover several other concrete ternary algebras,[17], inspired by ref[7]; in fact, by now, *all known* FI-compliant ones. They are expected to hold in general: loosely speaking, all FI-compliant associative algebras are 3CNBs in disguise (isomorphs).

The third project is on the discrete spacetime umbral transforms of solitons introduced[18] by C Zachos. It was proven that the discretized solitons found there are actually dispersive, ie, they do not maintain their profiles faithfully as they propagate, in contrast to their continuum correspondents. This lack of persistence motivates searching for discretizations that avoid dispersiveness.

[17] S Chakrabortty, A Kumar, and S Jain, JHEP **0809** (2008) 091

[18] C Zachos, Int J Mod Phys **A23** (2008) 2005-2014

Argonne HEP Research Plan: Field Theory (C Zachos)
The Global Structure of the Renormalization Group

In collaboration with T Curtright (Univ of Miami), with whom this extensive project was initiated two years ago (cf. section on Recent Progress[19]), and possibly Y Meurice and associates at the Univ of Iowa, C Zachos is proposing extending and applying the novel functional methods already devised to analyze the RG in more specific physical quantum-field-theoretic systems; moreover, exploring for novel models, starting from their global RG structure.

The methods include:
a) Recursive series solution of Schröder's functional equation,[20] identified with the *finite* RG equation of Gell-Mann and Low, around *each* fixed point (they are all globally related), in turn, as already initiated;
b) Calculation of continuous (interpolated) β-functions and flows out of discrete step-scaling β-functions in selected lattice systems, where possible, as illustrated;
c) A *self-correcting*, astoundingly fast-converging, conjugation interpolation algorithm introduced, yielding the full RG orbit given a discrete step-function[21].

These methods effectively "rectify" RG flow to linear group flow, i.e., notionally refer to a system of coordinates (redefined couplings) where the RG flow with scale changes is equivalent to an apparent, hypothetical, 1-loop flow!

In contrast to integrating local β-function differential equations, though, the global methods utilized here lead to succinct appreciation of the self-similar structures at different scales, inasmuch as Schröder's equation amounts to a functional similarity (equivalence) transformation. Thus, functional conjugacy brings out non-local associations in renormalization flows, and links among widely separated fixed points of exemplary RG trajectories—thereby allowing for novel features, including multivalued β-functions.

It was already appreciated and illustrated how periodicity of the inverse of the scaling function leads to RG limit cycles even for *one* real coupling, a logical possibility only introduced by Wilson relatively recently,[22]. Limit cycles, however, are commonplace in settings involving complex or numerous couplings, where it has been verified that the functional methods in question also work, and afford the possibility of a unified treatment of limit cycles in both one and more than one couplings.[23]

Spin-glass states can also largely be characterized by chaotic RG orbits[24] and the functional methods introduced predicated on Schröder's conjugacy provide a handle for a more systematic treatment of them in field theory, when access to discrete rescalings is at hand, but not to conventional local relations.

The multivalued RG flows already observed resemble "trembling cutoff" higher-order RG evo-

[19] T Curtright & C Zachos, "Renormalization Group Functional Equations", Phys Rev **D83** (2011) 065019; "Chaotic Maps, Hamiltonian Flows, and Holographic Methods", J Phys **A43** (2010) 445101; and "Evolution Profiles and Functional Equations", J Phys **A42** (2009) 485208

[20] E Schröder, "Über iterirte Funktionen", Math Ann **3** (1870) 296-322

[21] T Curtright, X Jin, and C Zachos, ANL-HEP-PR-11-34, arXiv:1105.3664

[22] S D Głazek and K G Wilson, "Limit Cycles in Quantum Theories", Phys Rev Lett **89** (2002) 230401; Erratum, **92** (2004) 139901

[23] Limit cycles have already been employed in the strong interactions, e.g., E Braaten and H Hammer, "An Infrared renormalization group limit cycle in QCD", Phys Rev Lett **91** (2003) 102002

[24] B Derrida et al, "Renormalisation groups with periodic and aperiodic orbits", J Phys **A16** (1983) 893; P Damgaard and G Thorleifsson, "Chaotic renormalization-group trajectories", Phys Rev **A44** (1991) 27382,1

lution equations, encountered in models coupled to quantum gravity in two dimensions,[25] and the multivalued orbits studied so far promise extensive generalizations of these phenomena. This is the principal focus of this proposal: a systematic search for models starting from their posited global RG structure.

C Zachos has already been invited by World Scientific Publishers to write a review article on the subject; but perhaps this should wait to cover the best results of the method, and exploration of their potential significance on model-building, yet to come.

Modalities

A postdoctoral research associate expert in and focusing principally on Quantum Field Theory would be very salutary to the exceptionally labor- and computation-intensive project.

[25] S R Das, S Naik, and S Wadia, "Quantization of the Liouville Mode and String Theory", Mod Phys Lett **A4** (1989) 1033-1041; S R Das, A Dhar, and S R Wadia, "Critical Behavior in Two-Dimensional Quantum Gravity and Equations of Motion of the String", Mod Phys Lett bf A5 (1990) 799-813; A M Polyakov, "Singular States in 2D Quantum Gravity", pp 175-189 in *Two Dimensional Quantum Gravity and Random Surfaces,* proceedings of the Jerusalem Winter School for Theoretical Physics, 27 Dec 1990-4 Jan 1991, D J Gross, T Piran, and S Weinberg (ed), World Scientific (1992)

Appendix - Recent publications of C Zachos

1. Umbral Deformations on Discrete Spacetime
   IntJModPhys **A23** (2008) 2005-2014.

2. Chern-Simons and WZW Anomaly Cancelations Across Dimensions
   with C. Hill, AnnPhys **323** (2008) 3065-3073.

3. Ternary Virasoro - Witt Algebra
   with T. Curtright and D. Fairlie, PhysLett **B666** (2008) 386-390.

4. Classical and Quantal Ternary Algebras
   with T Curtright, X Jin, L Mezincescu, and D Fairlie, PhysLett **B675** (2009) 387-392.

5. Evolution Profiles and Functional Equations
   with T Curtright, JPhys **A42** (2009) 485208.

6. Chaotic Maps, Hamiltonian Flows, and Holographic Methods
   with T Curtright, JPhys **A43** (2010) 445101.

7. Renormalization Group Functional Equations
   with T Curtright, PhysRev **D83** (2011) 065019.

8. Quantum Mechanics in P$\hbar$ase Space
   with T Curtright, ANL-HEP-PR-11-31, arXiv:1104.5269 .

9. Approximate Solutions of Functional Equations
   with T Curtright and X Jin, ANL-HEP-PR-11-34, arXiv:1105.3664 .

Appendix - Recent Talks of C Zachos

1. Quantum Topology Seminar (Mathematics Dept), University of Illinois at Chicago, IL, April 15, 2008:
   "Deformation Quantization Structures"

2. Theory seminar at Argonne HEP, Argonne, IL, May 20, 2008:
   "Umbral Deformations on Discrete Spacetime"

3. ANL DEP Undergraduate seminar series inaugural talk, Argonne, IL, June 4, 2008:
   "High Energy Physics"

4. Physics Department Colloquium (joint with CMU) at the University of Pittsburgh, PA, October 20, 2008:
   "Quantum Mechanics Lives and Works in Phase Space"

5. Talk at the Miami 2008 Conference, Ft Lauderdale, December 16, 2008:
   "Umbral Deformations on Discrete Spacetime"

6. Seminar at the Enrico Fermi Institute, Univ of Chicago, January 14, 2009:
   "Basics of Ternary Algebras and their Underlying Nambu Brackets"

7. Physics Department Colloquium at the University of Syracuse, NY, January 29, 2009:
   "Deformation Quantization"

8. Invited talk at the IX "Quantum Mechanics in the Complex Domain" Symposium (Bender-Fest), St Louis, MO, March 20, 2009:
   "Ternary Algebras and their Underlying Nambu Brackets"

9. Talk at Caltech Physics Department, Pasadena, CA, March 31, 2009:
   "Basics of Ternary Algebras and their Underlying Nambu Brackets"

10. Talk at Argonne JTI workshop, PHY Division, April 14, 2009:
    "Basics of Ternary Algebras and their Underlying Nambu Brackets"

11. ANL DEP Undergraduate seminar series Argonne, IL, June 10, 2009:
    "Overview of High Energy Physics"

12. Invited talk at the VI International Symposium on Quantum Theory and Symmetries, Lexington, KY, July 21, 2009:
    "Basics of Ternary Algebras and their Underlying Nambu Brackets"

13. Talk at the Physics Department, Univ of Illinois, Chicago, April 26, 2010:
    "Evolution Profiles and Functional Equations: Holographic Interpolation"

14. Talk at the Theory Division of the Los Alamos National Laboratory, NM, May 27, 2010:
    "Deformation Quantization"

15. ANL-DEP Undergraduate seminar series, Argonne, June 24, 2010:
    "Overview of High Energy Physics"

16. Physics Department, Koç Univ, Istanbul, Turkey, July 19, 2010:
    "Deformation Quantization Overview"

17. Physics Department, Koç Univ, Istanbul, Turkey, July 20, 2010:
    "The Wigner Function and the Uncertainty Principle"

18. Physics Department, Koç Univ, Istanbul, Turkey, July 21, 2010:
    "The Harmonic Oscillator, Classical Limits, and Time Evolution"

19. Physics Department, Koç Univ, Istanbul, Turkey, July 22, 2010:
    "The Weyl Correspondence and Alternate Prescriptions"

20. Physics Department, Koç Univ, Istanbul, Turkey, July 23, 2010:
    "The Groenewold-van Hove Theorem and Miscellany; Brief Historical Overview"

21. Invited talk at the IMBM institute (Istanbul Matematiksel Bilimler Merkezi), Istanbul, Turkey, July 22, 2010:
    "Holographic Interpolation and Schröder's functional equation"

22. Talk at Physics Department, Univ of Kentucky, Lexington, October 25, 2010: "Holographic Interpolation and Functional Equations"

23. Talk at the Miami 2010 Physics Conference, Fort Lauderdale, December 16, 2010: "Holographic Interpolation, the Renormalization Group, and Chaos"

24. Seminar at the Enrico Fermi Institute, University of Chicago, Chicago, January 12, 2011: "Holographic Interpolation, Chaos, and the Renormalization Group"

25. Talk at the Physics Dept of Vanderbilt Univ, Nashville, TN, February 11, 2011: "Quantum Mechanics Lives and Works in Phase Space"

26. Physics Dept Seminar, University of Iowa, Iowa City, IA, April 18, 2011: "Holographic Interpolation, Chaos, and the Renormalization Group"

27. Physics Dept Colloquium, University of Iowa, Iowa City, IA, April 18, 2011: "Holographic Interpolation: Smooth Dynamics from Boundary Conditions"

28. Talk to the Neutino Group, HEP Division, ANL, April 21, 2011; " The MNS Matrix and Tribimaximal Mixing"

Appendix - Community Service of C Zachos

1. Elected Fellow of the American Physical Society, 2010, "For significant theoretical contributions to supersymmetry, and for pioneering investigations of fundamental mathematical structures underlying a broad range of physical systems."

2. Member of the APS Heineman Prize selection committee, 2011-2012.

3. Session organizer & chair (New Ideas & Developments) for the *Miami 2010 Conference*, 14-19 December, Ft Lauderdale, FL: http://cgc.physics.miami.edu/Miami2010.html Chair of Dec 15 & 16 afternoon sessions.

4. Co-organized JTI workshop 13-17 April 2009, ANL PHY, "Dynamics of Symmetry Breaking". Chair of April 16 morning session.

5. Session organizer & chair (New Ideas/Developments) for the *Miami 2008 Conference*, 16-21 December, Ft Lauderdale, FL: http://cgc.physics.miami.edu/Miami2008.html Chair of Dec 16 afternoon session.

6. Laboratory correspondent contact for the CERN Courier.

7. Member of the Advisory Panel (in lieu of Editors) of J Phys A: Mathematical and Theoretical (IOP).

8. Member of the Editorial Board of ISRN Algebra.

9. Refereed numerous proposals for GNSF (Georgia); for PSC-CUNY Research Awards; DOE; NSF; NSERC (Canada)

Brief Curriculum Vitae -- Edmond L. Berger June, 2011

Positions Held

Senior Physicist Argonne National Laboratory, High Energy Physics Division, 1976 - present

Argonne Distinguished Fellow, 1995– present

Adjunct Professor of Physics Michigan State University, 1997 - present

Visiting Scientist Theory Group, SLAC, Stanford, California, 1978–1979

Visiting Staff Member Theory Division, CERN, Geneva, Switzerland, 1972 – 1974; 1983 – 1984; and 1992 – 1993.

Education

Ph.D., Princeton University, Princeton, N.J., 1965

Bachelor of Science, Massachusetts Institute of Technology (MIT), Cambridge, Mass., 1961

Selected Honors

1987: University of Chicago Award for Distinguished Performance at Argonne

1975: Fellow, American Physical Society

Selected Professional Activities

2010: Organizer, Aspen Summer Workshop *Forefront QCD and LHC Discoveries*, 5/23 – 6/20

American Physical Society: 2009–present and Chair in 2011, Committee on Constitution and Bylaws; 2003–2007, Committee on International Scientific Affairs (CISA); 1991–1997 and Chair 1994–95, Committee on Meetings

Member, Coordinated Theoretical-Experimental Project on QCD (CTEQ Collaboration)

2005: Co-Chair, Organizing Committee, International Linear Collider Workshop, Snowmass, CO, August 14 – 27

2004: Co-Chair, Aspen Winter Conference on Particle Physics, "Where We Are and Where We Are Going", Aspen Center for Physics, February1 – 7

1995–2001: High Energy and Nuclear Physics Advisory Committee, Brookhaven National Laboratory

1991–94: U. S. Department of Energy High Energy Physics Advisory Panel (HEPAP)

1990: Chairman, Executive Committee, Division of Particles and Fields, American Physical Society

1990: Chairman, Organizing Committee, 1990 Summer Study on High Energy Physics, "Research Directions for the Decade", Snowmass, Colorado, June 25 – July 13

1980–1983: Physics Advisory Committee, Fermi National Accelerator Laboratory

Department of Energy Review Committees: Brookhaven National Laboratory, 1985 and 1992; Stanford Linear Accelerator Center, 1985, 1997, 2000, and 2001; Lawrence Berkeley Laboratory, 1986 and 1989

Scientific Program Organizing Committees for the series of Moriond Rencontres on QCD and High Energy Hadronic Interactions, and for numerous other national and international workshops and conferences

Mentoring

Howard Baer (Professor, Oklahoma), Jianwei Qiu (Staff Scientist, Brookhaven), Chien-Peng Yuan (Professor, Michigan State U), JoAnne Hewett (Professor, SLAC), Stephen Mrenna (Staff, Fermilab), Michael Klasen (Professor, Muenster University, Germany), Tim Tait (Assistant Professor, University of California, Irvine), John Campbell (Staff, Fermilab), Pavel Nadolsky (Assistant Professor, Southern Methodist), Zack Sullivan (Assistant Professor, Illinois Institute of Technology), Chris Jackson (Assistant Professor, U Texas, Arlington), and Qing-Hong Cao (faculty, Peking University, Beijing) are among Argonne postdoctoral fellows mentored by Ed Berger who have since continued to make significant contributions to the national and international high energy physics program.

A few Recent Significant Publications on Higgs Boson, perturbative QCD, and BSM.

"Top Quark Forward-Backward Asymmetry and Same-Sign Top Quark Pairs", with Q.-H. Cao, C.-R. Chen, C.-S. Li, and H. Zhang, Phys. Rev. Lett. **106**, 201801 (2011) arXiv:1101.5625 [hep-ph].

"Characteristics and Estimates of Double Parton Scattering at the Large Hadron Collider", with C. B. Jackson and G. Shaughnessy, Phys. Rev. D**81**, 014014 (2010) arXiv:0911.5348 [hep-ph].

"Trilepton production at the CERN LHC: Standard model sources and beyond", with Z. Sullivan, Phys. Rev. D**78**, 034030 (2008) arXiv:0805.3720 [hep-ph].

"Transverse momentum dependence of the angular distribution of the Drell-Yan process", with J.-W. Qiu and R. Rodriguez-Pedraza, Phys. Rev. D**76**, 074006 (2007) arXiv:0708.0578 [hep-ph], and Phys. Lett. **B656**, 74 (2007) arXiv:0707.3150 [hep-ph].

"Calculation of prompt diphoton production cross-sections at Tevatron and LHC energies", with C. Balazs, P. Nadolsky, C.-P. Yuan, Phys. Rev. D76, 013009 (2007) arXiv:0704.0001 [hep-ph], and Phys. Rev. D**76**, 013008 (2007) hep-ph/0702003.

"Higgs boson production in weak boson fusion at next-to-leading order", with J. Campbell, Phys. Rev. D**70**, 073011 (2004) hep-ph/0403194.

"Associated production of a top quark and a charged Higgs boson", with T. Han, J. Jiang, and T. Plehn, Phys. Rev. D**71**, 115012 (2005) hep-ph/0312286.

"Differential cross-section for Higgs boson production including all orders soft gluon resummation", with J.-W. Qiu, Phys. Rev. D67, 034026 (2003) hep-ph/0210135 and Phys. Rev. Lett. **91**, 222003 (2003) hep-ph/0304267.

A complete list of 280 or more publications along with citations may be found with a SPIRES HEP search under "FIND EA BERGER, Edmond L".

Geoffrey Thomas Bodwin

High Energy Physics Division
Argonne National Laboratory
Argonne, Illinois 60439

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Education

- Ph.D. in Physics, January 1978, Cornell University
  (Thesis Adviser: Donald R. Yennie)
- M.S. in Physics, January 1975, Cornell University
- B.A. (with high distinction) in Physics, May 1972, University of Michigan, Flint

Professional Employment

- Senior Physicist, HEP Division, Argonne National Laboratory, March 2002–present
- Physicist, HEP Division, Argonne National Laboratory, November 1985–February 2002
- Assistant Physicist, HEP Division, Argonne National Laboratory, May 1983–October 1985
- Postdoctoral Research Associate, Stanford Linear Accelerator Center, September 1980–April 1983
- Postdoctoral Research Associate, University of Illinois (Urbana), August 1978–August 1980
- Teaching Assistant, Physics Dept., University of Illinois (Urbana), September 1979–December 1979
- Postdoctoral Research Associate, Cornell University, November 1977–July 1978
- Teaching Assistant in Physics, Cornell University, January 1978–May 1978
- Graduate Research Assistant, Cornell University, Summer 1975, June 1976–November 1977
- Graduate Research Assistant, Cornell University, Summer 1975, June 1976–November 1977

Selected Awards

- Recipient, Argonne National Laboratory Distinguished Performance Award, 2010
- Recipient, Outstanding Referee Award for the journals of the American Physical Society, 2008

- Fellow, American Physical Society (elected 2000)
- Cornell Graduate Fellow, 1975–76
- National Science Foundation Graduate Fellow, 1972–75

Selected Publications

- **Factorization in Exclusive Quarkonium Production**
  G. T. Bodwin, X. Garcia i Tormo and J. Lee, Phys. Rev. D **81**, 114014 (2010)
- **Order-α_s Corrections to the Quarkonium Electromagnetic Current at All Orders in the Heavy-Quark Velocity**
  G. T. Bodwin, H. S. Chung, J. Lee and C. Yu, Phys. Rev. D **79**, 014007 (2009).
- **Resummation of Relativistic Corrections to $e^+e^- \to J/\psi + \eta_c$**
  G. T. Bodwin, J. Lee, and C. Yu, Phys. Rev. D **77**, 094018 (2008).
- **Bottomonium Decay Matrix Elements from Lattice QCD with Two Light Quarks**
  G. T. Bodwin, D. K. Sinclair, and S. Kim, Phys. Rev. D **65** 054504 (2002).
- **Quarkonium Decay Matrix Elements from Quenched Lattice QCD**
  G. T. Bodwin, D. K. Sinclair, and S. Kim, Phys. Rev. Lett. **77**, 2376 (1996).
- **A Lattice Formulation of Chiral Gauge Theories**
  G. T. Bodwin, Phys. Rev. D**54** 6497 (1996).
- **Rigorous QCD Analysis of Inclusive Annihilation and Production of Heavy Quarkonium**
  G. T. Bodwin , E. Braaten, G. P. Lepage, Phys. Rev. D**51**, 1125 (1995), [Erratum-ibid. D **55**, 5853 (1997)].
- ***P*-Wave Charmonium Production in B-Meson Decays**
  G. T. Bodwin, E. Braaten, T. C. Yuan, G. P. Lepage, Phys. Rev. D**46**, R3703 (1992).
- **Rigorous QCD Predictions for Decays of *P*-Wave Quarkonia**
  G. T. Bodwin, E. Braaten, G. P. Lepage, Phys. Rev. D**46**, (1992).
- **The Gluonic Contribution to g_1 and its Relationship to the Spin-Dependent Parton Distributions**
  G. T. Bodwin, J.-W. Qiu, Phys. Rev. D**41**, 2755 (1990).
- **Factorization of the Drell-Yan Cross-section in Perturbation Theory**
  G. T. Bodwin, Phys. Rev. D**31**, 2616 (1985). [Erratum-ibid. D**34**, 3932 (1986)].
- **Initial State Interactions and the Drell-Yan Process**
  G. T. Bodwin, S. J. Brodsky. G. P. Lepage, Phys. Rev. Lett. **47**, 1799 (1981).

Curriculum Vitæ

Radja Boughezal

Professional preparation

2002-2005	PhD studies in Physics, Albert Ludwigs University of Freiburg, Germany
2000-2001	Master's degree at the International Center for Theoretical Physics (ICTP), Trieste, Italy
1999-2000	Advanced studies in theoretical physics (Diplome d'Etudes Approfondis), Constantine, Algeria
1995-1999	General studies in theoretical physics (Diplome d'Etudes Superieures), Constantine, Algeria

Appointments

2010-present	Assistant Physicist at Argonne National Laboratory Adjunct Assistant Professor at Northwestern University
2008-2010	Post-doctoral research associate at the University of Zürich, Switzerland
2005-2008	Post-doctoral research associate at the University of Würzburg, Germany

Awards

Research stipend within the Sofja Kovalevskaja award of the Alexander von Humboldt Foundation sponsored by the German Federal Ministry of Education and Research for the years $2005 - 2008$

Fellowship from UNESCO and IAEA for the full academic year $2000 - 2001$ for the diploma course at ICTP, Trieste, Italy

Selected publications

R. Boughezal, K. Melnikov,
Hadronic light-by-light scattering contribution to the muon magnetic anomaly: constituent quark loops and QCD effects
arXiv:1104.4510 [hep-ph], submitted to PLB

R. Boughezal,
Constraints on heavy colored scalars from Tevatron's Higgs exclusion limit
Phys.Rev.D83:093003,2011

S. Dittmaier et al.
CERN Yellow Report, Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables
co-authored the gluon fusion chapter
arXiv:1101.0593 [hep-ph]

R. Boughezal, A. Gehrmann-De Ridder, M. Ritzmann,
Antenna subtraction at NNLO with hadronic initial states: double real radiation for initial-initial configurations with two quark flavours
JHEP **1102:098** (2011)

C. Anastasiou, **R. Boughezal**, E. Furlan,
The NNLO gluon fusion Higgs production cross-section with many heavy quarks
JHEP **1006:101** (2010)

R. Boughezal, F. Petriello,
Color-octet scalar effects on Higgs boson production in gluon fusion
Phys.Rev.D81:114033,2010

R. Boughezal,
Review of Theoretical Status of Higgs Production at Hadron Colliders in the Standard Model
eConf C090726

C. Anastasiou, **R. Boughezal**, F. Petriello,
Mixed QCD-electroweak corrections to Higgs boson production in gluon fusion
JHEP **0904:003** (2009)

R. Boughezal, M. Czakon, T. Schutzmeier,
NNLO fermionic corrections to the charm quark mass dependent matrix elements in $\bar{B} \to X_s\gamma$
JHEP **0709:072** (2007)

R. Boughezal, M. Czakon, T. Schutzmeier,
Charm and bottom quark masses from perturbative QCD
Phys.Rev.D74:074006,2006

Selected recent community activities

Organized conferences	*LoopFest X: Radiative Corrections for the LHC and future colliders,* Evanston, IL USA *http://groups.physics.northwestern.edu/loopfest/*
	RADCOR 2009 - 9th International Symposium on Radiative Corrections (Applications of Quantum Field Theory to Phenomenology), 25 - 30 October 2009, Ascona, Switzerland *http://www.itp.uzh.ch/radcor2009*
Editor for	RADCOR 2009 proceedings which are published in the online journal "Proceedings of Science" -PoS- organized by SISSA, the International School for Advanced Studies based in Trieste.
Panelist	Argonne High Energy Physics Division Retreat: led a discussion on the future of the theory group.
Research Funding	Successfully nominated an Argonne Director Postdoctoral Fellowship candidate, Markus Schulze, in a lab wide competition in 2010. The awarded money amounts to $156,000.

Teaching Experience

2002-2005	Teaching Assistant at the physics department of the University of Freiburg for the courses:
	Mathematical Methods for Physicists
	Theoretical Physics I: Classical Mechanics
	Theoretical Physics V: Quantum Mechanics II

Curriculum Vitae

Ian Low

High Energy Physics Division
Argonne National Laboratory
Argonne, IL 60439
Tel: (630) 252 8560
Email: iow@anl.gov

Department of Physics & Astronomy
Northwestern University
Evanston, IL 60208
Tel: (847) 467 2618
Email: ilow@northwestern.edu

Present Position

2007 – Present	Joint appointment:
	Assistant Physicist, High Energy Physics Division Argonne National Laboratory
	Assistant Professor, Department of Physics & Astronomy Northwestern University

Research Experience

2006 – 2007	Research Scientist, Department of Physics & Astronomy University of California at Irvine
2004 – 2006	Member, School of Natural Sciences Institute for Advanced Study, Princeton
2001 – 2004	Postdoctoral Fellow, Department of Physics Harvard University

Education

1996 – 2001	Ph. D. in Physics, Carnegie Mellon University, Pittsburgh
1990 – 1994	B. S. in Physics, National Tsing Hua University, Taiwan

Selected Publications

1. H. C. Cheng and I. Low, "*TeV symmetry and the little hierarchy problem*," JHEP 0309, 051 (2003).

2. H. C. Cheng and I. Low, "*Little hierarchy, little Higgses, and a little symmetry*," JHEP 0408, 061 (2004).

3. I. Low, "*T-parity and the Littlest Higgs*," JHEP 0410, 067 (2004).

4. R. Dermisek and I. Low, "*Probing the stop sector and the sanity of the MSSM with the Higgs boson at the LHC*," Phys. Rev. D 77, 035012 (2008).

5. W. Y. Keung, I. Low and J. Shu, "*On Decays of Z' into Two Z Bosons and the Landau-Yang Theorem*," Phys. Rev. Lett. 101, 091802 (2008).

6. I. Low and S. Shalgar, "*Implications of the Higgs Discovery in the MSSM Golden Region*," JHEP 0904, 091 (2009).

7. I. Low, R. Rattazzi, and A. Vichi, "*Theoretical Constraints on the Higgs Effective Couplings*," JHEP 1004, 126 (2010).

8. Q. H. Cao, C. B. Jackson, W. Y. Keung, I. Low and J. Shu, "*The Higgs Mechanism and Loop-induced Decays of a Scalar into Two Z Bosons*," Phys. Rev. D **81**, 015010 (2010).

9. I. Low and J. Lykken, "*Revealing the electroweak properties of a scalar resonance*" JHEP 1010, 053 (2010).

10. I. Low and A. Vichi, "*On the production of a composite Higgs boson*" arXiv:1010.2753 [hep-ph].

Biographical Sketch: Frank Petriello

Professional preparation:

Stanford University	Physics	Ph.D, 2003
University of Florida	Mathematics & Physics	B.A. & B.S., 1999

Appointments:

Associate Professor	Northwestern University	Sep. 2010 - current
Physicist	Argonne National Laboratory	Sep. 2010 - current
Visiting Scientist	Argonne National Laboratory	Jan. 2010 - May 2010
Associate Professor	University of Wisconsin	Jul. 2009 - Sep. 2010
Assistant Professor	University of Wisconsin	Aug. 2005 - Jul. 2009
Visiting Scientist	Fermilab	Jan. 2006 - May 2006
Research Associate	Johns Hopkins University	Sep. 2003 - Aug. 2005

Awards:

DOE Outstanding Junior Investigator	2006	Alfred P. Sloan Fellow	2006

Selected recent publications:

- **"Transverse Momentum Distributions from Effective Field Theory with Numerical Results,"** S. Mantry and F. Petriello, Phys. Rev. **D83**, 053007 (2011).
- **"Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables,"**: editor, gluon-fusion chapter, CERN-2011-002, [arXiv:1101.0593 [hep-ph]].
- **"FEWZ 2.0: A code for hadronic Z production at next-to-next-to-leading order,"** R. Gavin, Y. Li, F. Petriello, S. Quackenbush, [arXiv:1011.3540 [hep-ph]], accepted for publication in Computer Physics Communications.
- **"Color-octet scalar effects on Higgs boson production in gluon fusion,"** R. Boughezal and F. Petriello, Phys. Rev. D **81**, 114033 (2010)
- **"Factorization and Resummation of Higgs Boson Differential Distributions in Soft-Collinear Effective Theory,"** S. Mantry and F. Petriello, Phys. Rev. D **81**, 093007 (2010)
- **"Reconstructing a Z' Lagrangian using the LHC and low-energy data,"** Y. Li, F. Petriello and S. Quackenbush, Phys. Rev. D **80**, 055018 (2009)

- **"Electroweak and finite quark-mass effects on the Higgs boson transverse momentum distribution,"** W. Y. Keung and F. J. Petriello, Phys. Rev. D **80**, 013007 (2009)
- **"Mixed QCD-electroweak corrections to Higgs boson production in gluon fusion,"** C. Anastasiou, R. Boughezal and F. Petriello, JHEP **0904**, 003 (2009)
- **"The New DAMA Dark-Matter Window and Energetic-Neutrino Searches,"** D. Hooper, F. Petriello, K. M. Zurek and M. Kamionkowski, Phys. Rev. D **79**, 015010 (2009)
- **"Next-to-leading order QCD corrections to $t\bar{t}Z$ production at the LHC,"** A. Lazopoulos, T. McElmurry, K. Melnikov and F. Petriello, Phys. Lett. B **666**, 62 (2008)

Selected recent community activities:

- Theory convenor for gluon-fusion mode, joint ATLAS-CMS-theory working group on Higgs cross sections, Feb. 2010-current.
- Co-organizer, LoopFest X: Radiative Corrections for the LHC and a Future Linear collider, May 12-14 2011, Evanston, IL.
- Co-organizer, Forefront QCD and LHC Discoveries, Summer 2010, Aspen, CO.
- Reviewer, DOE Intensity frontier panel, August 2010.
- Lecturer, on Higgs physics and QCD, at the following schools: 2011 CTEQ summer school, Madison, WI; 2009 Graduate School on Physics at colliders, Torino, Italy; 2010 PSI summer school on particle physics, Zuoz, Switzerland; 2009 SLAC Summer Institute.

Supervision of students and postdoctoral scholars:

Graduate students: Seth Quackenbush (2006-2009), now postdoc at Argonne National Lab; Ryan Gavin (2007-2011), starting postdoc at the Paul Scherrer Institute, Switzerland; Ye Li (2008-present)
Postdoctoral scholars: Kathryn Zurek (2006-2009), now assistant professor at the University of Michigan; Tom McElmurry (2006-2009), starting postdoc at the University of Rochester; Sonny Mantry (2008-2010), now an LHC theory initiative fellow; Maike Trenkel (2009-2010)

Carlos E. M. Wagner
Curriculum Vitae

June 15, 2011

Current Position:
Head of the Theory Group, HEP Division, Argonne National Laboratory.
Professor, Physics Department, EFI and KICP, University of Chicago.

Research Activities :
Ph. D.: July 1989, University of Hamburg, Germany.
Sep. 1989 - Aug. 1991: Research Associate, Physics Department, Purdue University
Sep. 1991 - Sep. 1993: Research Associate, Max Planck Institute, Munich, Germany.
Oct. 1993 - Mar. 1996: Research Associate at CERN, Geneva, Switzerland.
Mar. 1996 - May 1999: Staff Member at CERN, Geneva, Switzerland.
May 1999-March 2005 : Part time Professor at the Physics Department and the Enrico Fermi Institute, University of Chicago
May 1999 - Present: Physicist at Argonne National Laboratory, Argonne, IL, U.S.A
March 2005-Present : Professor of Physics at the Physics Department, the Enrico Fermi Institute, and the Kavli Insitute for Cosmological Physics, University of Chicago

Publications, Honors and Awards:
Scientific publications: 131, cited 11300 times; in refereed journals: 107, cited 9770 times.
1982 - 1985: Undergraduate Scholarship - Centro Atomico Bariloche, Argentina.
1986 - 1987: Graduate Scholarship - Consejo Nacional de Investigacion, Argentina. 1987 - 1989 : Graduate Scholarship - DESY, Hamburg, Fed. Rep. of Germany.
1993 -1995: John Stewart Bell Fellowship - CERN, Geneva, Switzerland.
1995-1996: European Community Fellowship - CERN, Geneva, Switzerland.
2001: Argonne Performance Award Argonne, IL
2005: Named Head of the Theory Group, Argonne
2008 : Fellow of the American Physical Society

Recent Professional Duties: Member, Elementary Particle and Astrophysics NSF Review Panel, Arlington, VA, February 2006
Member, Lawrence Berkeley National Laboratory DOE Review Panel, Berkeley, CA, March 2006
Member, Lawrence Berkeley National Laboratory DOE Review Panel, Berkeley, CA, March 2007.
Member, Lawrence Berkeley National Laboratory DOE Review Panel, Berkeley, CA, March 2009.
Member, P5 National Committee, January 2008–December 2008, and October 2010.
Head, search committee for an Assistant Professor in Physics at the University of Chicago
Member, Scientific Program Committee, Muon Collider Workshop, Teluride, CO, June 27–July1, 2011.
Chair, PreSUSY 2011 School Organizing Committee, University of Chicago, August 2426, 2011.

Supervision of Graduate Students :
David Morrissey (graduated in 2005, permanent staff member, TRIUMF) , Arjun Menon (graduated in 2007, postdoc at IIT, IL), Anibal Medina (graduated in 2008, postdoc at UC Davis), Jing Shu (graduated in 2008, postdoc at IPMU, Japan), Nausheen Shah (graduated in 2009, postdoc at Fermilab), Patrick Draper (graduated in 2011, moving as a postdoc to UC Santa Cruz).

Teaching Activities :
In the last few years, C. Wagner taught courses on Advanced Electrodynamics, Introduction to Cosmology, Advanced Quantum Field Theory, Particle Physics, Supersymmetry, and Physics of the LHC at the University of Chicago. He also taught courses on Supersymmetry, Beyond the Standard Model Physics and Baryogenesis at a diversity of schools.

Relevant Recent Publications
1. S. Gori, P. Schwaller and C.E.M. Wagner, "Search for Higgs Bosons in SUSY Cascade Decays and Neutralino Dark Matter", [arXiv:1103.4138], Phys. Rev. D, in press.
2. M. Carena, P. Draper, N. Shah and C.E.M. Wagner, "SUSY Breaking Parameters from RG Invariants and the LHC", Phys.Rev.D83:035014,2011; [arXiv:1011.4958] .
3. P. Draper, D. McKeen, L.T. Wang, C.E.M. Wagner and H. Zhang, "Dark Light Higgs", Phys. Rev. Lett. 106.121805, 2011; [arXiv:1009.3963].
4. Q.H. Cao, D. McKeen, J. Rosner, G. Shaughnessy and C.E.M. Wagner, "Forward Backward Asymmetry of Top Quark Pair Production at the Tevatron Collider", Phys. Rev. D81:114004, 20010; [arXiv:1003. 3461].
5. P. Draper, T. Liu and C.E.M. Wagner, "Prospects for MSSM Higgs Searches at the Tevatron and LHC with Explicit CP-violation", Phys. Rev. D81:015014, 2010 ; [arXiv:0911.0034].
6. M. Carena, A. Menon and C.E.M. Wagner, "Minimal Flavor Violation and the Scale of Supersymmetry Breaking", Phys. Rev. D79:075025, 2009; [arXiv:0812.3594].
7. M. Carena, G. Naridini, M. Quiros and C.E.M. Wagner, "The Baryogenesis Window in the MSSM", Nucl. Phys. B812 (2009) 243; [arXiv:0809.3760].
8. M. Carena, A.D. Medina, B. Panes, N.R. Shah and C.E.M. Wagner, "Collider Phenomenology of Gauge-Higgs Unification Scenarios in Warped Extra Dimensions", Phys. Rev. **D77** 076003, 2008; [arXiv:0712.0095].
9. M. Carena, E. Ponton, J. Santiago and C.E.M. Wagner, "Electroweak Constraints on Warped Models with Custodial Symmetry", Phys. Rev. D76:035006, 2007; [hep-ph/0701055].
10. J.S. Lee, M. Carena, J. Ellis, A. Pilaftsis and C.E.M. Wagner, "CPsuperH2.0: an Improved Computational Tool for Higgs Phenomenology in theMSSM with Explicit CP Violation", Comput. Phys. Commun. 180:312-331, 2009; [arXiv:0712.2360 [hep-ph]].
11. M. Carena, T. Han, G.Y. Huang and C.E.M. Wagner, "Higgs signals in $H \to AA$ at Hadron Colliders", JHEP 0804:092, 2008; [arXiv:0712.2466].
12. M. Carena, S. Heinemeyer, G. Weiglein and C.E.M. Wagner, "MSSM Higgs Boson Searches at the Tevatron and the LHC", Eur. Phys. J C45:797-814, 2006; [hep-ph/0511023].

Curriculum Vitæ

Cosmas K Zachos

June 2011

Address: High Energy Physics 362, Argonne National Laboratory, Argonne, IL 60439-4815.
zachos@anl.gov Phone: (630)252 6207

Personal: Born 1951

Education: A.B., *Magna Cum Laude*, *Princeton University*, 1974;
Undergraduate thesis topic: "Landau-Ginsburg Formalism for Anisotropic Superfluids".

Ph. D. in Physics, *California Institute of Technology*, 1979;
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Research Associate in theoretical physics, *Fermilab*, September 1981-1983.
Research Associate in theoretical physics, *University of Wisconsin-Madison*, September 1979-1981.

Honors, Societies, and Professional Activities: Fellow of the American Physical Society (DPF), 2010, *"For significant theoretical contributions to supersymmetry, and for pioneering investigations of fundamental mathematical structures underlying a broad range of physical systems."*
Fellow of the Institute of Physics (UK), 2004.
Suichi Kusaka Physics Prize, 1973; ΦBK 1974; ΣΞ 1974, 1979; American Physical Society, 1984; Mathematical Association of America, 1988;
Principal Organizer of Workshops, 1984, 1986, 1990, 1996, 2003, and Co-editor of their Proceedings;
Member of the Editorial Board of Journal of Physics A (IOP), 1994-1998; presently, member of the Advisory Panel (in lieu of Editors).
Editorial Board of ISRN Algebra.
Member of the APS Heineman Prize selection committee, 2011-2012.
ANL correspondent for the CERN Courier.
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Referee of Research Proposals for numerous US Universities, NSF, DOE, NSERC, PSC-CUNY, and GNSF.

Teaching Experience: Teaching Assistant at Caltech for Particle Physics (Ph231 - R. P. Feynman); Lecture series on Supersymmetry and Supergravity at UW-Madison, 1980; and Fermilab, 1983; Lecture series on σ-models and superstrings at CINVESTAV, Mexico City, 1985; Lecture series on CFT and Quantum Groups, OSU, 1989, 1990; Lectures on particle physics to Argonne Science and Engineering Students, 1984 to date.

Visiting Appointments: IAS (Princeton) 1983; CINVESTAV (Mexico) 1985; Durham Univ (UK) 1987; OSU 1990; Yukawa Institute (Kyoto) 1994.

Selected Publications of C K Zachos

1. **"Renormalization Group Functional Equations"**
   T. L. Curtright and C. K. Zachos,
   Phys. Rev. **D83**, 065019 (2011) [arXiv:1010.5174 [hep-th]]

2. **"Features of time-independent Wigner functions"**
   T. Curtright, D. Fairlie and C. K. Zachos
   Phys. Rev. D **58**, 025002 (1998) [arXiv:hep-th/9711183]

3. **"Infinite Dimensional Algebras & a Trigonometric Basis for the Classical Lie Algebras"**
   D. B. Fairlie, P. Fletcher and C. K. Zachos
   J. Math. Phys. **31**, 1088 (1990)

4. **"Infinite Dimensional Algebras, Sine Brackets and SU(∞)"**
   D. B. Fairlie and C. K. Zachos
   Phys. Lett. B **224**, 101 (1989)

5. **"Trigonometric Structure Constants for New Infinite Algebras"**
   D. B. Fairlie, P. Fletcher and C. K. Zachos
   Phys. Lett. B **218**, 203 (1989)

6. **"Classical Dynamics of Strings with Rigidity"**
   T. Curtright, G. Ghandour and C. K. Zachos
   Phys. Rev. D **34**, 3811 (1986)

7. **"Torsion And Geometrostasis In Nonlinear Sigma Models"**
   E. Braaten, T. L. Curtright and C. K. Zachos
   Nucl. Phys. B **260**, 630 (1985)

8. **"Geometry, Topology And Supersymmetry In Nonlinear Models"**
   T. L. Curtright and C. K. Zachos
   Phys. Rev. Lett. **53**, 1799 (1984)

9. **"Phase Structure And Renormalization Trajectories Of Lattice SU(2) Gauge Theory"**
   K. M. Bitar, S. A. Gottlieb and C. K. Zachos
   Phys. Rev. D **26**, 2853 (1982)

10. **"N=2 Supergravity Theory With A Gauged Central Charge"**
    C. K. Zachos
    Phys. Lett. B **76**, 329 (1978)

Argonne National Laboratory HEP Division

Cosmology and Theoretical Particle Astrophysics

Argonne HEP Theory Group: Cosmology and Particle Astrophysics

Recently, HEP division has started a new effort in Theoretical and Computational Cosmology. This new effort is supported for three years by Argonne's LDRD (Laboratory Directed Research & Development) program and receives funding for a postdoctoral researcher from NSF and NASA. The effort includes currently two staff members (Salman Habib and Katrin Heitmann) and 5 postdocs (Adrian Pope, Named Postdoctoral Fellow, Amol Upadhye, Director's Fellow, Sanghamitra Deb, joining in June, Suman Bhattacharya, joining in August, partially supported by the University of Chicago, and Juliana Kwan, joining in September). The team has strong ties to the Argonne Leadership Computing Facility (ALCF) and the Mathematics and Computer Science Division, which supports another postdoc (Hal Finkel) and a student (Brittney Bullis). Argonne's leadership position in high-performance computing and the arrival of Mira, the new 10 PFlops BlueGene/Q system, in 2012, provide the exciting opportunity to push computational cosmology to the next level. In particular, such an effort is needed to tackle the formidable challenges posed by the exquisite statistical accuracy expected from ongoing and next-generation large scale surveys, such as the Dark Energy Survey (DES) and the Large Synoptic Survey Telescope (LSST).

Introduction

The rapid progress of observational cosmology has led to convincing evidence that the Standard Model of particle physics must be extended, primarily in a "dark sector" comprising dark matter, dark energy, and neutrinos. Parameters of the currently favored "concordance" cosmology are known to better than 10%, and future observations aim to bring this level of uncertainty down to $\sim 1\%$ or better. At this level of statistical control, subtle signatures of new physics can be searched for, not only in places beyond the reach of present capabilities, but also hiding below the current noise and systematics floor. Searches for these signatures require the development of sharp theoretical tools suited to the particular purpose.

Our broad aim is to develop precision theoretical approaches based on exploiting structure formation probes of cosmology; aside from the supernova evidence, all of current-day precision cosmology is based on our knowledge of the mass distribution in the Universe, whether probed by the cosmic microwave background or by the distribution of galaxies. Future observations will focus increasingly on the nonlinear domain of structure formation, where cosmic variance is small, but theoretical uncertainties can be significant.

This effort forms part of a wider thrust at Argonne covering theoretical and computational methods to study such questions as the nature of dark energy and dark matter, the generation and characteristics of primordial density fluctuations, constraints on the neutrino sector, and modifications of gravity on large length scales. The boost in computational power derived from petascale computing and data analysis is a central aspect of the proposed work, exploiting the new 10 PFlops Mira supercomputer at Argonne National Laboratory, and closely tied to DOE HEP-supported cosmological surveys such as BOSS, DES, and, most significantly, LSST.

A major supercomputer time allocation for this work has been made available via an Early Science Project (ESP) award at ANL (one of 15 nationwide) on the the IBM BG/Q Mira system due to arrive in 2012 and on the current BG/P system, Intrepid. In addition, we have major allocations on supercomputers at Los Alamos National Laboratory, NASA Ames, and Oak Ridge

National Laboratory. In support of this effort at ANL, we will host a high-bandwidth data server to make the project data and software products publicly available to the scientific community.

The supercomputers listed above have very diverse architectures, from hardware-accelerated machines at Los Alamos to many-core systems at Argonne. In order to enable the efficient use of these machines, we have recently developed the first petascale cosmology code framework HACC (Hardware Accelerated Cosmology Code) [1, 2]. The code is organized in two levels. At the first level, the medium/long range force is handled by an FFT-based method that operates at the CPU layer and is the same for each architecture. At the second level, the short range forces are solved with optimized solvers for the different architectures (tree algorithms for the BG systems and CPU clusters, particle-particle algorithms for cell and GPU systems). All the node-level parallelism of the code lives on the first medium/longe-range layer (which is never changed) – this makes it very easy to plug-in the different short range modules. This powerful new code enables the theory program outlined below.

Results from Previous Support

Previous work in this area has been partially supported under DOE HEP's Dark Energy R&D and Theory programs [Going Nonlinear with Dark Energy, S. Habib (PI) and Cosmological Signatures of Physics Beyond the Standard Model, S. Habib (PI)]. In this work, a team from three National Laboratories (ANL, LANL, LBNL) came together to address theoretical and computational challenges posed by baryon acoustic oscillations and weak gravitational lensing, widely considered to be the two most powerful future probes of dark energy. However, the systematic error budget for these probes will very soon be dominated by theoretical uncertainties. These uncertainties are due to limitations in our current ability to predict the mass power spectrum over a range of cosmological parameters, keeping enough spatial dynamic range, and taking into account baryonic effects. By melding a suite of large-scale N-body simulations with an advanced statistical framework, this project eliminated the first two shortcomings, thereby achieving better than 1% accurate predictions for mass fluctuations at spatial scales with wavenumbers $k < 1\ h\mathrm{Mpc}^{-1}$ [3, 4]. Significant results include (i) fast emulation of the nonlinear power spectrum [5], (ii) the halo mass function measured with excellent statistics (including a new fitting formula), showing a clear and systematic violation of universality, the best such result obtained to date [6], and (iii) successful development of a new nonparametric method for determining the history of the dark energy EOS parameter, $w(z)$ [7, 8, 9].

The set of simulations analyzed under this project have resulted in producing one of the largest current cosmology databases ($\sim$ 60 TB), based on which a large number of new science projects are possible. Some of these are already being carried out by other researchers to whom the data has been made available [10, 11, 12]. We are in the process of making this dataset fully public, including the associated analysis software. Hardware and leveraged support provided by Argonne National Laboratory will be essential in making this possible. This experience will be extremely valuable in making the results from the very large Mira ESP runs publicly available.

Proposed Research

- **Dark Energy:** A fundamental difficulty in dark energy investigations is the absence of a compelling theory to test against observations. Future surveys therefore focus on characterizing the dark energy EOS parameter w ($w = p/\rho$, p =pressure, and ρ =density) and

its time-dependence. A cosmological constant Λ ($w = -1$) is consistent with present data at the 10% level, the time variation of w being much less constrained (see, e.g., Ref. [7]). Future measurements aim to constrain w at one percent accuracy and its time variation to several percent. Closely related is the hunt for deviations from general relativity using measurements of the geometry of the Universe and the growth of structure. With these efforts in mind, we will focus on (i) dynamical explanations for cosmic acceleration and (ii) tests of modified gravity (new dynamics of space-time). The basic task is to produce high accuracy predictions for observational quantities of interest to be able to distinguish between different classes of dynamical explanations.

The classical dynamics of mean fields can induce cosmic acceleration, defining the class of quintessence models. Additionally, infrared quantum fluctuations can be amplified by inflation leading to a dark energy [15]. Currently $w(z)$ is modeled by fitting forms that ignore dark energy clustering. Field-theoretic models, however, generically produce inhomogeneities on large scales and these will be probed by next-generation sky surveys [16]. The fluctuations can be used to search for early influence of dark energy ($z > 2$); early dark energy fluctuations can have a significant effect on the abundance of massive objects as a function of redshift [17]. Therefore, these fluctuations must be treated self-consistently by (i) using initial conditions with the correct fluctuation transfer functions and (ii) by simultaneously solving for the inhomogeneous evolution of the fields along with that of matter. We will implement both in a staged manner.

To obtain model-independent constraints on w, we have developed a new nonparametric approach based on Gaussian process (GP) modeling (for an overview, see, e.g. Ref. [18]). Relying on the initial success of our program [7, 8, 9], our research plan is (i) to include weak lensing and cluster abundance constraints as measurements of the growth of structure and (ii) to carry out consistency checks between the geometry of the Universe and the growth of structure, a "smoking gun" for modified gravity.

- **Modified Gravity:** The possibility that dark energy can be interpreted in terms of modified gravity at large distances is beginning to be explored. It is widely recognized that rigorous tests of modified gravity theories will require accurate numerical simulations, on the same scale as for standard dark energy investigations. Therefore, we will initiate a program of research in this direction, investigating classes of metric theories of gravity, motivated by the success of general relativity on small scales.

  Modifications of gravity can be treated in two ways, either by fully specifying a particular model, or by asking how the data can constrain various classes of metric theories of gravity. The success of general relativity on small scales provides good motivation to stay with metric theories, the basic question being what sort of deviations to consider. Infrared finiteness and the weak equivalence principle are sufficient to build a parameterized post-Newtonian (PPN) formalism which generalizes general relativity at the level of the equations of motion. This leads to two types of modified theories – scale independent or scale dependent up to the Jeans scale ($\sim$ 1 Mpc, at the current epoch). The first can be characterized by one PPN parameter, but the second is more complicated, with extra field degrees of freedom – $f(R)$ models belong to this class, where R is the Ricci scalar [19].

Within linear theory, it is very difficult to distinguish dark energy from modified gravity [19]. To robustly study the nonlinear regime, we will build a new modeling capability for both classes of modifications to general relativity; in the first, a modified Poisson equation appears, while in the second, a nonlinear elliptical equation also exists which must be solved, e.g., by a relaxation method. Connecting the results to observations provides very interesting consistency tests, e.g., expectations of the fluctuation power spectra as measured by weak lensing can differ in the presence of modified gravity, as can results inferred from lensing and galaxy clustering. Our work will be very significant for enhancing the capabilities of cosmological surveys in this area [20].

- **Dark Matter Physics:** The Large Hadron Collider – with a reach into the few hundred GeV mass range – and direct dark matter searches can find new particle species that could be dark matter candidates. While such a discovery would be very exciting, it will not be by itself an unequivocal detection of dark matter [13]. Observations of dark matter annihilation and cosmic structure will provide complementary evidence to prove whether the new particle is indeed the dark matter. Structure formation holds information about dark matter via the matter fluctuation power spectrum $P(k)$, the density profile and substructure of galactic dark matter halos, and observations of interacting clusters. These observations are important in constraining dark matter properties and interactions, and provide sensitivity limits for current and planned direct detection experiments.

  We will focus on predictions for $P(k)$ on scales accessible by weak lensing surveys. $P(k)$ probes the effective temperature of the dark matter particles ("cold" to "hot") and is also sensitive to nonstandard (e.g., nonthermal) perturbations. Although CDM remains the primary candidate, there are hints suggesting a warm component (WDM). Theoretically, the fact that neutrinos have mass suggests the existence of massive sterile neutrinos as WDM candidates. The relevant signals can be extracted from precision measurements of $P(k)$ with LSST and by space missions. The accuracy of simulations must be $\leq 1\%$ at wavenumbers $k \sim 0.1 - 10\ h\mathrm{Mpc}^{-1}$ to make predictions for nonlinear neutrino clustering, given the size of expected deviations [14], with similar considerations operating for WDM. Gravity-only simulations will meet these requirements, as shown by us recently [3]. (However, baryonic effects become important at these scales and will be modeled by the hydro-enhanced version of HACC as dicussed below.)

- **Weak Lensing:** Weak lensing is the single most direct method of detecting the distribution of mass in the Universe and can be applied across a wide range of scales, from galaxies and clusters, to large-scale structure. The cosmology program of LSST relies heavily on weak lensing (see, e.g., Ch. 14 of the LSST Science Book [21]). Although there are many ways to exploit weak lensing (e.g., galaxy-galaxy lensing, cluster weak lensing, shear peak statistics, cosmic shear), in future the statistical limitations for all of these techniques will essentially disappear. Aside from the systematics of measuring weak lensing shear, the three remaining difficulties are (i) controlling errors in the determination of photometric redshifts, (ii) understanding intrinsic alignments, and (iii) overcoming theoretical shortcomings. Here we will focus primarily on reducing the theoretical uncertainty.

  Primarily, the theoretical uncertainties result from three causes: (i) insufficient exploration

of the degrees of freedom in cosmological models and parameters, (ii) realism/error control in the simulations, and (iii) missing physics (gasdynamics, feedback). These aspects are discussed in more detail in Ch. 15.5 of the LSST Science Book [21]. We have already indicated above our initial program for exploration of a more comprehensive model space, which can be finely sampled using our GP methodology [22]. In order to explore mitigation strategies for the second problem, we will incorporate the semi-analytic galaxy formation code Galacticus [23] within our framework (Galacticus can already input merger trees from N-body simulations), in addition to using more conventional approaches to galaxy formation that rely on resolved substructure or halo occupancy distribution modeling. Finally, inclusion of baryonic physics on Mpc and sub-Mpc scales will be an essential ingredient. We will follow both numerical and semi-analytic modeling strategies, the former, by implementing a new hydrodynamical scheme in HACC, the latter, by implementing a flexible halo-based method following ideas similar to those of Ref. [24].

We will implement particle-based hydro-solvers based on the Particle-In-Cell (PIC) approach in our framework. Particle-based methods are generally faster and easier to implement compared to grid-based schemes, such as adaptive mesh refinement (AMR). However, the more traditional such scheme, smoothed particle hydrodynamics (SPH) is known to have difficulties with treating instabilities such as Kelvin-Helmholtz or Rayleigh-Taylor [25]. Modern PIC methods, such as FLIP [26] do not suffer from these difficulties but are more computationally expensive. The evolution of supercomputer architectures, however, is driving a trend towards compute-heavy, but communication-local algorithms, precisely suited to exploiting the PIC method.

In modern PIC methods, all information is carried by the particles, and the grid is used only as an intermediate construct (also, just as for gravity, the Lagrangian PIC method can be integrated with an Eulerian grid-based solver at a different resolution level). This has the advantage (shared with SPH) that, in our application, there is no intrinsic resolution limit as there is with conventional grid codes. Unlike gravity, which is long-range and requires a global grid, PIC methods only require small, local grids. Thus once a computation is performed, memory is freed up for the next block of calculation, and so on. Additionally, all the software primitives needed for such a code already exist within the HACC framework, making us well-positioned to initiate this work.

In terms of direct computation of weak lensing shear, we have already demonstrated a 1% calibration of the mass power spectrum to $k \sim 1h\mathrm{Mpc}^{-1}$, a major leap forward in our ability to interpret arcminute-scale weak lensing. While these results are the current state of the art, we are now in a position to begin the very large task of pushing below this level. By dumping "density planes" which move through the computational volume at the speed of light as the simulation runs we can build up light-cones which correctly encapsulate the cosmological evolution. These can be passed as input to the ray-tracing code developed in [27] to incorporate the higher-order lensing terms. A prototype of the "density plane" algorithm has been tested on small simulations, and we plan to incorporate that into the HACC framework.

- **Simulation Suite:** The simulation database associated with this work will be very large – larger than all the data from the entire set of current observational databases in cosmology

– and will allow for many possible research projects, as well as the direct applicability to optimizing survey science. Fully exploiting such a database is clearly well beyond our own capabilities, and the appropriate solution is to make the dataset publicly available.

A major result of our work will be the reduced data products from the simulations (e.g., halo catalogs, merger trees, lensing planes, statistical analyses). Serving (or even storing) raw data at these data volumes is completely impractical, and we have developed fast analysis methods to extract processed data from the simulations while the code is running. These results and the results from post-run analysis will be made publicly available. A new aspect of the data server would be the introduction of active data streaming to a remote client: If someone wishes to do their own analysis on data subsets (especially subsets that exploit data locality, e.g., spatial cubes, or extended line-of-sight skewers), the system would allow for it via interfaces to programs written in standard languages such as C or Fortran.

Funding Request

We have recently submitted an FWP "Beyond the Standard Model with Cosmological Surveys" to the HEP Theory Program for support for one postdoctoral researcher for FY12 and FY13. The focus of this research will be the weak lensing work outlined above. This work will benefit strongly from the simulation suite carried out as part as this effort and will also tie closely into the developments and results from the hydrodynamics capabilities for the HACC framework. The results from the research on weak lensing will naturally feed back into the work on dark energy, dark matter, and modified gravity since weak lensing is one of the most powerful probes of the dark Universe.

The ANL LDRD seed support for this effort will end in May 2014. We therefore request support for 0.5FTE and 2 postdocs for FY14 from the HEP theory program. The effort that would be funded would focus more on the fundamental science questions asked (how can large scale structure probes help to distinguish between dark energy and modified gravity, how can modified gravity be investigated in a general framework, how can cosmology help to distinguish different types of dark matter) rather than on the computational aspects of our research program itself.

Appendix A

[1] S. Habib, A. Pope, Z. Lukic, D. Daniel, P. Fasel, N. Desai, K. Heitmann, C.-H. Hsu, L. Ankeny, G. Mark, S. Bhattacharya, and J. Ahrens, J. Phys. Conf. Ser. **180**, 012019 (2009)

[2] A. Pope, S. Habib, Z. Lukic, D. Daniel, P. Fasel, N. Desai, and K. Heitmann, Comp. Sci. & Eng. **12**, 17 (2010)

[3] K. Heitmann, M. White, C. Wagner, S. Habib, and D. Higdon, Astrophys. J. **715**, 104 (2010)

[4] K. Heitmann, D. Higdon, M. White, S. Habib, B.J. Williams, and C. Wagner, Astrophys. J. **705**, 156 (2009)

[5] E. Lawrence, K. Heitmann, M. White, D. Higdon, C. Wagner, S. Habib, and B. Williams, Astrophys. J. **713**, 1322 (2010)

[6] S. Bhattacharya, K. Heitmann, M. White, Z. Lukic, C. Wagner, and S. Habib, Astrophys. J. (in press); arXiv:1005.2239 [astro-ph.CO]

[7] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, and D. Higdon, Phys. Rev. Lett. **105**, 241302 (2010)

[8] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, and D. Higdon, Phys. Rev. D **82**, 103502 (2010)

[9] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, and D. Higdon, Phys. Rev. D (submitted); arXiv:1104.20141H [astro-ph.CO]

[10] T. Eifler, arXiv:1012.2978 [astro-ph.CO]

[11] M.C. Neyrinck, arXiv:1103.5476N [astro-ph.CO]

[12] X. Wang, M. Neyrinck, I. Szapudi, A. Szalay, X. Chen, J. Lesgourgues, A. Riotto, and M. Sloth, arXiv:1103.2166W [astro-ph.CO]

[13] J. Feng, Ann. Rev. Astron. Astrophys. **48**, 495 (2010)

[14] K. Abazajian, E.R. Switzer, S. Dodelson, K. Heitmann, and S. Habib, Phys. Rev. D **71**, 043507 (2005).

[15] V. Sahni and S. Habib, Phys. Rev. Lett. **81**, 1766 (1998).

[16] H. Zhan, $\cdots$, S. Habib, $\cdots$, K. Heitmann, $\cdots$, et al. "Exploring Dark Energy with Next-Generation Photometric Redshift Surveys", arXiv:0902.2599, white paper for the Astro2010 Decadal Survey.

[17] U. Alam, Z. Lukić, and S. Bhattacharya, Astrophys. J. **727**, 87 (2011)

[18] C.E. Rasmussen and K.I. Williams, Gaussian Processes for Machine Learning, MIT Press, www.GaussianProcess.org/gpml (2006)

[19] E. Bertschinger and P. Zukin, Phys. Rev. D **78**, 024015 (2008).

[20] R. Scranton, $\cdots$, S. Habib, $\cdots$, K. Heitmann, $\cdots$, et al., The Case for Deep, Wide-Field Cosmology, arXiv:0902.2590, white paper for the Astro2010 Decadal Survey.

[21] Abell et al. (LSST Science Collaborations), arXiv:0912.0201; http://www.lsst.org/lsst

[22] S. Habib, K. Heitmann, D. Higdon, C. Nakhleh, and B. Williams, Phys. Rev. D **76**, 083503 (2007).

[23] A.J. Benson, arXiv:1008.1786 [astro-ph.CO]

[24] A.R. Zentner, D.H. Rudd, and W. Hu, Phys. Rev. D, **77**, 043507 (2008).

[25] O. Agertz, et al., MNRAS **380**, 963 (2007)

[26] J. Brackbill, Int. J. Num. Meth. Fluids **47**, 693 (2005)

[27] C. Vale and M. White, Astrophys. J. **592**, 699 (2003)

Publications 2009 – 2011

[1] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, D. Higdon, "Nonparametric Reconstruction of the Dark Energy Equation of State from Diverse Data Sets," Phys. Rev. **D**, submitted, [arXiv:1104.20141 [astro-ph.CO]]

[2] J. Woodring, K. Heitmann, J. Ahrens, P. Fasel, C. -H. Hsu, S. Habib, A. Pope, "Analyzing and Visualizing Cosmological Simulations with ParaView," Astrophys. J. Supp., in press [arXiv:1010.6128 [astro-ph.CO]].

[3] J. Woodring, J. Ahrens, and K. Heitmann, "Semi-Random Sampling of Large Prticle Data with Resolution Change Cogerence for Multi-Scale Visualization" EuroVis 2011, accepted for publication.

[4] U. Alam, Z. Lukić, and S. Bhattacharya, Astrophys. J. **727**, 87 (2011)

[5] S. Bhattacharya, K. Heitmann, M. White, Z. Lukic, C. Wagner, S. Habib, "Mass Function Predictions Beyond LCDM," Astrophys. J. **732**, 122 (2011).

[6] D. Higdon, K. Heitmann, E. Lawrence, S. Habib, "Large-scale Inverse Problems and Quantification of Uncertainty" Book chapter, Publisher: Wiley, Editors: L. Bieger et al., p. 87 (2010)

[7] J. Ahrens, K. Heitmann, M. Petersen, J. Woodring, S. Williams, P. Fasel, C. Ahrens, C.-H. Hsu, B. Geveci, "Verification of Scientific Simulations via Hypothesis-Driven Comparative and Quantitative Visualization", invited paper to IEEE Computer Graphics and Applications, Volume 30, Issue:6, p. 16 (2010).

[8] C.-H. Hsu, J. Ahrens, and K. Heitmann, "Verification of the Time Evolution of Cosmological Simulations via Hypothesis-Driven Comparative and Quantitative Visualization" Pacific Visualization 2010 IEEE, 81 (2010)

[9] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, D. Higdon, "Nonparametric Dark Energy Reconstruction from Supernova Data," Phys. Rev. Lett. **105**, 241302 (2010).

[10] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, D. Higdon, "Nonparametric Reconstruction of the Dark Energy Equation of State," Phys. Rev. **D82**, 103502 (2010)

[11] E. Lawrence, K. Heitmann, M. White, D. Higdon, C. Wagner, S. Habib, B. Williams, "The Coyote Universe III: Simulation Suite and Precision Emulator for the Nonlinear Matter Power Spectrum," Astrophys. J. **713**, 1322-1331 (2010).

[12] S. Shandarin, S. Habib, K. Heitmann, "Origin of the Cosmic Network: Nature vs Nurture," Phys. Rev. **D81**, 103006 (2010).

[13] M. White, A. Pope, J. Carlson, K. Heitmann, S. Habib, P. Fasel, D. Daniel, Z. Lukic, "Particle mesh simulations of the Lyman-alpha forest and the signature of Baryon Acoustic Oscillations in the intergalactic medium," Astrophys. J. **713**, 383-393 (2010).

[14] A. Voevodkin, K. Borozdin, K. Heitmann, S. Habib, A. Vikhlinin, A. Mescheryakov, A. Hornstrup, "Fossil Systems in the 400d Cluster Catalog," Astrophys. J. **708**, 1376-1387 (2010).

[15] K. Heitmann, M. White, C. Wagner, S. Habib, D. Higdon, "The Coyote Universe I: Precision Determination of the Nonlinear Matter Power Spectrum," Astrophys. J. **715**, 104-121 (2010).

[16] A. Pope, S. Habib, Z. Lukic, D. Daniel, P. Fasel, N. Desai, and K. Heitmann, Comp. Sci. & Eng. **12**, 17 (2010)

[17] K. Heitmann, D. Higdon, M. White, S. Habib, B. J. Williams, C. Wagner, "The Coyote Universe

II: Cosmological Models and Precision Emulation of the Nonlinear Matter Power Spectrum," Astrophys. J. **705**, 156-174 (2009).

[18] Z. Lukic, D. Reed, S. Habib, K. Heitmann, "The Structure of Halos: Implications for Group and Cluster Cosmology," Astrophys. J. **692**, 217-228 (2009)

[19] S. Habib, A. Pope, Z. Lukic, D. Daniel, P. Fasel, N. Desai, K. Heitmann, C.-H. Hsu, L. Ankeny, G. Mark, S. Bhattacharya, and J. Ahrens, J. Phys. Conf. Ser. **180**, 012019 (2009)

[20] S. T. Myers, C. Pfrommer, J. Aguirre, J. R. Bond, J. O. Burns, T. Clarke, M. Devlin, A. Evrard *et al.*, "Galaxy Cluster Astrophysics and Cosmology: Questions and Opportunities for the Coming Decade," [arXiv:0903.0401 [astro-ph.CO]].

[21] H. Zhan, A. Albrecht, A. Cooray, S. Habib, A. Heavens, K. Heitmann, B. Jain, M. J. Jee *et al.*, "Exploring Dark Energy with Next-Generation Photometric Redshift Surveys," [arXiv:0902.2599 [astro-ph.CO]].

[22] R. Scranton, A. Albrecht, R. Caldwell, A. Cooray, O. Dore, S. Habib, A. Heavens, K. Heitmann *et al.*, "The Case for Deep, Wide-Field Cosmology," [arXiv:0902.2590 [astro-ph.CO]].

Presentations October 2009 – 2011

[1] S. Habib, March 2011, “The Universe as a Data Engine: Modeling and Obervsations”, The First Data-Intensive Science Workshop, Tokyo, Japan, invited

[2] S. Habib, March 2011, “Moore’s Law and the Universe", The Center for Computational Sciences, University of Tsukuba, Japan, invited

[3] S. Bhattacharya, March 2011, “Galaxy Clusters: laboratory for astrophysics and comology”, Stanford, KIPAC, cosmology seminar, invited.

[4] A. Pope, January 2011, “Cosmological Simulations on Large, Accelerated Supercomputers”, Workshop on Manycore and Accelerator-based High-performance Scientific Computing, UC Berkeley/LBNL, Berkeley, invited.

[5] A. Pope, January 2011, “Cosmological Simulations on Large, Heterogeneous Supercomputers”, talk , Cosmology on the Beach Conference, Mexico, invited .

[6] S. Bhattacharya, January 2011, "Galaxy clusters: what can we learn?", IUCAA, India , cosmology seminar, invited.

[7] A. Pope, December 2010, “Cosmological simulations on large, heterogeneous supercomputers”, The Future of AstroComputing Conference, San Diego Supercomputer Center (SDSC), San Diego, invited.

[8] S. Habib, November 2010, “Computing the Universe", Masterworks talk at SC10, New Orleans, invited.

[9] S. Habib, September 2010, “The Dark Universe Challenge: Is Theory up to the Task? ", Physics Colloquium, University of Michigan, invited.

[10] K. Heitmann, September 2010, “Is Dark Energy Dynamical?", High Energy-Astrophysics Seminar, University of Michigan, invited.

[11] S. Bhattacharya, September 2010, “Measuring peculiar velocities from LSST supernovae survey”, Cosmic Co-Motion Workshop, Australia, invited.

[12] S. Habib, August 2010, “Precision Cosmology with Gaussian Processes", Modern Cosmology: Early Universe, CMB, and LSS, Workshop in Benasque, Spain, invited.

[13] K. Heitmann, August 2010, “The Coyote Universe", Modern Cosmology: Early Universe, CMB, and LSS, Workshop in Benasque, Spain, invited.

[14] Z. Lukić, July 2010, “Cluster cosmology: theory challenges & applications", Seminar at ITP University of Zurich, inivited.

[15] Z. Lukić, July 2010, “Probing Early Dark Energy with Galaxy Clusters", Poster Presentation, Galaxy Clusters: Observations, Physics, and Cosmology, Garching (Munich)

[16] A. Pope, July 2010, “The Roadrunner Universe”, Santa Fe Cosmology Summer Workshop, Santa Fe, invited

[17] Z. Lukić, June 2010, “Mass function, structure and bias of galaxy clusters in simulations", Seminar at the University of Barcelona, invited

[18] S. Bhattacharya, June 2010, “Galaxy Clusters as a probe of Early Dark Energy”, Poster Presentation, Great Lakes Cosmology Conference, Chicago.

[19] K. Heitmann, May 2010, “The Coyote Universe", Advances in Theoretical and Observational Cosmology Workshop, U. of Maryland, inivited

[20] S. Habib, May 2010, “The Mass Function", Advances in Theoretical and Observational Cosmology Workshop, U. of Maryland, inivited

[21] Z. Lukić, May 2010, “LANL Halo Finder", talk at workshop "Haloes Going MAD, La Cristalera, Miraflores de la Sierra, Madrid, Spain, invited.

[22] A. Pope, April 2010, “Roadrunner Universe Project”, talk, Path to Petascale: Adapting GEO/CHEM/ASTRO Applications for Accelerators and Accelerator Clusters Workshop, NCSA, University of Illinois, Urbana, invited.

[23] K. Heitmann, April 2010, “Cosmic Clues on Dark Energy", KU Astronomy Seminar, KS, invited

[24] S. Bhattacharya, March 2010, “Theoretical Uncertainties in SZ power spectrum”, Snowcluster Meeting, Utah.

[25] K. Heitmann, March 2010, “Cosmic Clues on Dark Energy", San Diego Physics and Astronomy Colloquium, UCSD, inivited

[26] Z. Lukić, March 2010, “Cosmology with Galaxy Clusters: Early Dark Energy", SNOWCLUSTER Meeting, University of Utah

[27] A. Pope, March 2010, “Cosmology from Galaxy Clustering Statistics: Theory and Practice", SNOWPAC Meeting, University of Utah, invited

[28] K. Heitmann, March 2005, “The Coyote Universe", Argonne National Laboratory, HEP Seminar, invited

[29] K. Heitmann, January 2010, “Gaussian Process Modeling in Cosmology", AAS 215th Meeting, Washington DC, inivited

[30] S. Habib, December 2009, “The Dark Universe Challenge: Is Theory up to the Task?", Argonne National Laboratory, Physics Colloquium, inivited

[31] S. Bhattacharya, December 2009, “Sunyaev-Zeldovich Effect”, University of Illinois at Urbana-Champaign, invited.

[32] S. Bhattacharya, November 2009, “Cosmology Using Galaxy Clusters”, Yale University, invited.

[33] S. Habib, October 2009, “The Dark Universe Challenge: Is Theory up to the Task?", Brown University Physics Colloquium, invited

Salman Habib

a. Education and Training

University of Maryland, Physics, Ph.D., 1988
University of Maryland, Physics, M.S., 1985
Indian Institute of Technology, Delhi, M.S., 1981

b. Research and Professional Experience

2011 – present, Senior Scientist, Argonne National Laboratory
1994 – 2011, Technical Staff Member, Los Alamos National Laboratory
2000 – 2008, Visiting Faculty at California Institute of Technology
1991 – 1994, Postdoctoral Fellow, Los Alamos National Laboratory
1988 – 1991, Canadian Institute for Theoretical Astrophysics National Fellow, University of British Columbia

c. Publications (Selected)

[1] S. Bhattacharya, K. Heitmann, M. White, Z. Lukić, C. Wagner, S. Habib, "Mass Function Predictions Beyond ΛCDM", Astrophys. J. **732**, 122 (2011) (http://arxiv.org/abs/1005.2239)
[2] A. Pope, S. Habib, Z. Lukić, D. Daniel, P. Fasel, N. Desai, K. Heitmann, "The Accelerated Universe: A Hybrid Cosmology Code for Roadrunner", Comput. Sci. Eng. **12**, 4, 17 (2010)
[3] M. White, A. Pope, J. Carlson, K. Heitmann, S. Habib, P. Fasel, D. Daniel, Z. Lukić, "Particle Mesh Simulations of the Lyα Forest and the Signature of Baryon Acoustic Oscillations in the Intergalactic Medium", Astrophys. J. **713**, 1, 383 (2010) (http://arxiv.org/abs/0911.5341)
[4] S. Habib, A. Pope, Z. Lukić, D. Daniel, P. Fasel, N. Desai, K. Heitmann, C. H. Hsu, L. Ankeney, G. Mark, S. Bhattacharya, J. Ahrens, "Hybrid Petacomputing Meets Cosmology: The Roadrunner Universe Project", J. Phys.: Conf. Ser. **180**, 1, 012019 (2009)
[5] S. Habib, K. Heitmann, D. Higdon, C. Nakhleh, B. Williams, "Cosmic Calibration: Constraints from the Matter Power Spectrum and the Cosmic Microwave Background", Physical Review **D76**: 083503 (2007) (http://arxiv.org/abs/astro-ph/0702348)
[6] S. Habib, A. Heinen, K. Heitmann, G. Jungman, "Inflationary Perturbations and Precision Cosmology", Physical Review **D72**, 043518 (2005) (http://arxiv.org/abs/astro-ph/0501130)
[7] S. Habib, K. Heitmann, G. Jungman, C. Molina-París, "The Inflationary Perturbation Spectrum: Uniform Approximation" Phys. Rev. Lett. **89**, 281301 (2002) (http://arxiv.org/abs/astro-ph/0208443)
[8] K. Heitmann, Z. Lukić, P. Fasel, S. Habib, M.S. Warren, M. White, J. Ahrens, L. Ankeny, R. Armstrong, B. O'Shea, P.M. Ricker, V. Springel, J. Stadel, H. Trac,"The Cosmological Code Comparison Project", invited paper for Computational Science and Discovery **1**: 015003 (2008) (http://arxiv.org/abs/0706.1270)
[9] K. Heitmann, D. Higdon, M. White, S. Habib, B. Williams, C. Wagner, "The Coyote Universe II: Cosmological Models and Precision Emulation of the Nonlinear Matter Power Spectrum", The Astrophysical Journal **705**, 156 (2009) (http://arxiv.org/abs/0902.0429)
[10] K. Heitmann, M. White, C. Wagner, S. Habib, D. Higdon, "The Coyote Universe I: Precision Determination of the Nonlinear Matter Power Spectrum", The Astrophysical Journal

715, 104 (2010) (http://arxiv.org/abs/0812.1052)

d. Synergistic Activities

[1] Center Leader, Astrophysics and Cosmology Center (ACCent), Institute for Advanced Studies, Los Alamos National Laboratory.
[2] Reviews and panel member for DOE/ASCR, DOE/HEP, DOE/NP, NSF.
[3] Organizer, Santa Fe Cosmology Summer workshops and Quantum Enabled Science and Technology (QUEST) workshops.
[4] Los Alamos National Laboratory representative to the Large Synoptic Survey Telescope (LSST) Board.
[5] Outreach: Public lectures on cosmology.

e. Collaborators & Co-Editors

Abazajian, K. (U. Maryland), Ahrens, J. (LANL), Alam, U. (LANL), Ankeny, L. (LANL), Borozdin, K. (LANL), Fasel, P. (LANL), Habib, S. (LANL), Higdon, D. (LANL), Hornstrup, A. (TU Denmark), Jungman, G. (LANL), Knox, L. (UC Davis), Kronberg, P. (LANL/U. Toronto), Lee, H. (UC Santa Cruz), Lukić, Z. (LANL), Nakhleh, C. (SNL), Ma, K. (UC Davis), Mescheryakov, A. (IKI Moscow), Miller, C. (NOAO), Nichol, R. (U. of Portsmouth), O'Shea, B. (MSU), Pang, A. (UC Santa Cruz), Pope, A. (LANL) Reed, D. (U. Zürich), Ricker, P.M. (UIUC), Sansó, B. (UC Santa Cruz), Schneider, M. (Durham), Shandarin, S. (Kansas U.), Sundaram, B. (UMass Boston), Vikhlinin, A. (CfA), Voevodkin, A. (IKI Moscow), Warren, M.S. (LANL), White, M. (UC Berkeley), Wagner, C. (ICC Barcelona), Williams, B. (LANL)

f. Graduate and Postdoctoral Advisors and Advisees

[1] Graduate and Postdoctoral Advisors
Prof. Bei-Lok Hu (University of Maryland), Prof. W. Unruh (University of British Columbia), Dr. Wojciech Zurek (LANL)
[2] Postdoctoral Advisees
Current postdocs: Hal Finkel, Adrian Pope (Named Fellow), Amol Upadhye (Director's Fellow) **Former postdocs:** Kevork Abazajian (Assistant Professor, U. of Maryland), Suman Bhattacharya (Postdoc at LANL) Sergei Bashinsky, Kurt Jacobs (Assistant Professor, University of Massachusetts Boston), Leanne Duffy (Scientist at LANL), Savvas Koushiappas (Assistant Professor of Physics, Brown University), Zarija Lukić (Postdoc at LANL), Daniel Steck (Assistant Professor of Physics, U. of Oregon), Luis Teodoro (Researcher at Glasgow University), Yongzhong Xu.

Katrin Heitmann

a. Education and Training

University of Dortmund, Germany; Physics; Doctor of Science (Summa cum laude); 2000
University of Dortmund, Germany; Physics; Diploma; 1996

b. Research and Professional Experience

2011-present Scientist at Argonne National Laboratory
2009-2011 Scientist 4 and Team Leader, Space Science and Applications, LANL
06/2008-03/2009 Scientist 3, Space Science and Applications, LANL
01/2004-06/2008 Technical Staff Member, Space Science and Applications at LANL
09/02-01/04 Postdoctoral Research Associate, Elementary Particles and Field Theory Group and Theoretical Astrophysics at LANL Director's Postdoctoral Fellow, Elementary Particles and Field Theory Group at LANL
01/97-09/00 Teaching and Research Assistant at the University of Dortmund
06/95-12/96 Research Student at the University of Dortmund

c. Publications (Selected)

[1] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, D. Higdon, "Nonparametric Reconstruction of the Dark Energy Equation of State", Physical Review **D82**, 103502, (2010) (http://arxiv.org/abs/1009.5443)
[2] T. Holsclaw, U. Alam, B. Sanso, H. Lee, K. Heitmann, S. Habib, D. Higdon, "Nonparametric Dark Energy Reconstruction from Supernova Data", Physical Review Letters 105:241302 (2010) (http://arxiv.org/abs/1011.3079)
[3] K. Heitmann, D. Higdon, M. White, S. Habib, B. Williams, C. Wagner, "The Coyote Universe II: Cosmological Models and Precision Emulation of the Nonlinear Matter Power Spectrum", The Astrophysical Journal **705**, 156 (2009) (http://arxiv.org/abs/0902.0429)
[4] K. Heitmann, M. White, C. Wagner, S. Habib, D. Higdon, "The Coyote Universe I: Precision Determination of the Nonlinear Matter Power Spectrum", The Astrophysical Journal **715**, 104 (2010) (http://arxiv.org/abs/0812.1052)
[5] K. Heitmann, Z. Lukić, P. Fasel, S. Habib, M/S. Warren, M. White, J. Ahrens, L. Ankeny, R. Armstrong, B. O'Shea, P.M. Ricker, V. Springel, J. Stadel, H. Trac,"The Cosmological Code Comparison Project", invited paper for Computational Science and Discovery **1**: 015003 (2008) (http://arxiv.org/abs/0706.1270)
[6] S. Habib, K. Heitmann, D. Higdon, C. Nakhleh, B. Williams, "Cosmic Calibration: Constraints from the Matter Power Spectrum and the Cosmic Microwave Background", Physical Review **D76**: 083503 (2007) (http://arxiv.org/abs/astro-ph/0702348)
[7] K. Heitmann, D. Higdon, C. Nakhleh, S. Habib, "Cosmic Calibration", Astrophysical Journal **642**, L85 (2006) (http://arxiv.org/abs/astro-ph/0606154)
[8] Z. Lukić, K. Heitmann, S. Habib, S. Bashinsky, P.M. Ricker, "The Halos Mass Function: High Redshift Evolution and Universality", Astrophysical Journal **671**, 1160 (2007) (http://arxiv.org/abs/astro-ph/0702360)
[9] K. Heitmann, Z. Lukić, S. Habib, P.M. Ricker, "Capturing Halos at High Redshifts", Astrophysical Journal **642**, L85 (2006) (http://arxiv.org/abs/astro-ph/0601233)

[10] K. Heitmann, P.M. Ricker, M.S. Warren, S. Habib, "Robustness of Cosmological Simulations I: Large Scale Structure", Astrophysical Journal Supp. **160**, 28 (2005) (http://arxiv.org/abs/astro-ph/0411795)

d. Synergistic Activities

[1] Review Committees and Panels: Member of NSF Extragalactic Astronomy Panel (twice); co-chair of Science Advisory Panel for LANL Directed Research on Nuclear and Particle Physics, Astrophysics and Cosmology; member of LANL Early Career Grant committee, subsection physics; member of LANL postdoctoral fellowship committee, member of External Advisory Committee to the Institute for Geophysics and Planetary Physics (IGPP) at LANL.
[2] Organizational Committees: Co-organizer of the annual Santa Fe Cosmology Workshop; organizer of three "Cosmology Days" at Los Alamos; responsible for ISR Division Colloquium; co-organizer of SDSS spring collaboration meeting 2006 in Santa Fe.
[3] Outreach: Regular presenter at LAESSA Workshop for New Mexico High School Teachers; invited presenter for two day Hands-on Problem Solving session at SAMSI Summer School on Statistics at SFU; public lecture at the Bradbury Science Museum, Los Alamos.
[4] Thesis Committee Member: Zarija Lukić (PhD in Astrophysics, UIUC, August 2008), Eddy Chandra (Masters in Computer Science, UC Santa Cruz, August 2009), Tracy Holsclaw (Advancement in Statistics, UC Santa Cruz, October 2009, defense in May 2011).
[5] Student Mentor: Ryan Armstrong, Steve Haroz (UC Davis), Eddy Chandra, Tracy Holsclaw (UC Santa Cruz), Andreas Heinen (Dortmund), Christian Wagner (AI Potsdam).

e. Collaborators & Co-Editors

Abazajian, K. (U. Maryland), Ahrens, J. (LANL), Alam, U. (LANL), Ankeny, L. (LANL), Borozdin, K. (LANL), Fasel, P. (LANL), Habib, S. (LANL), Higdon, D. (LANL), Haroz, S. (UC Davis), Hornstrup, A. (TU Denmark), Jungman, G. (LANL), Knox, L. (UC Davis), Lee, H. (UC Santa Cruz), Lukić, Z. (LANL), Nakhleh, C. (SNL), Ma, K. (UC Davis), Mescheryakov, A. (IKI Moscow), Miller, C. (NOAO), Nichol, R. (U. of Portsmouth), O'Shea, B. (MSU), Pang, A. (UC Santa Cruz), Pope, A. (LANL) Reed, D. (U. Zürich), Ricker, P.M. (UIUC), Sansó, B. (UC Santa Cruz), Schneider, M. (Durham), Shandarin, S. (Kansas U.), Vikhlinin, A. (CfA), Voevodkin, A. (IKI Moscow), Warren, M.S. (LANL), White, M. (UC Berkeley), Wagner, C. (ICC Barcelona), Williams, B. (LANL), Woodring, Jon (LANL)

f. Graduate and Postdoctoral Advisors and Advisees

[1] Graduate and Postdoctoral Advisors
Prof. em. Jürgen Baacke (Technical University Dortmund, retired), Dr. Fred Cooper (NSF Program Director for Theoretical Physics, retired)
[2] Postdoctoral Advisees
Current postdocs: Adrian Pope (Named Fellow)
Former postdocs: Ujjaini Alam (Oppenheimer Fellow at LANL), Savvas Koushiappas (Assistant Professor of Physics, Brown University), Darren Reed (Postdoctoral Researcher at University of Zürich with Prof. B. Moore), Alexey Voevodkin (Researcher at IKI Moscow)

Support for HEP Theory efforts by Argonne

This is a list of bullet points describing the support for the Theory activities in the HEP division for FY10 and FY11.

1. In FY10 and FY11 the Office of the Associate Laboratory Director (ALD) for Physical Sciences has/is supporting theory group new hires with $290K/yr or a total of 580K. This was essentially support for new hires that arrived in Fall of 2010.
2. The ALD office supports two graduate student research appointments as part of startup for Ian Low and Frank Petriello. Total : $52.2K
3. In FY12 the Argonne share of a joint theory postdoc with Zack Sullivan from the Illinois Institute of Technology is supported by ALD funds. The total is $34K
4. Markus Schulze, will join the theory group as a Director's Postdoctoral fellow in October 2011, is supported for two years from lab funds. Radja Boughezal sponsored his candidacy and was able to win one of these highly competitive Argonne sponsored positions. Amount: $113K/year.
5. The laboratory wide Scientific Computing Science Initiative has enabled us to bring Salman Habib and Katrin Heitmann to Argonne HEP to start a Computational Cosmology/ Cosmic Frontier effort. This includes these two staff members plus one fellow, one director's postdoc and two additional postdocs. It strengthens both the theory as well as astrophysics efforts. This is supported on the order of $1,000K/year by internal Argonne funds for 3 years . This establishes another strong link between HEP (even DOE HEP) and leadership or petascale/exascale computing. Habib and Heitmann just arrived at the beginning of May. It is another sign of lab's investment in particle physics and establishing a link to exascale computing.
6. Joint appointments have strengthened the connection to other institutions in the Chicago land area. In theory there is one joint appointment with Chicago and two joint appointments with Northwestern. Currently there are two joint postdoc positions with Northwestern, one joint postdoc position with UIC and we will have another one with IIT in theory. So connections to local universities are very good. This is very much encouraged by the laboratory.
7. Computing resources at Argonne are available within the division and even more plentiful outside the division, because of the very strong computer science divisions at Argonne. In addition to leadership computing class machines like Blue Gene/P and in the future Q, there are many intermediate systems available to Argonne researchers. Examples of such systems are Magellan and FUSION. These systems are available to laboratory staff without charge.

DOE Support in FY 2010 (Actually Spent)

Personnel Support from DOE
(in FTEs)

Activity:	Phenomenology and Model Building	Lattice Gauge Theories	Formal Field Theory and String/Gravity Theory	Particle Astrophysics and Cosmology	Other (specify)	TOTAL
Permanent PhD	2.9	0.0	0.9	0.0	0.0	**3.8**
Temporary PhD	4.1	0.0	0.0	0.0	0.0	**4.1**
Graduate Students	1.0	0.0	0.0	0.0	0.0	**1.0**
Engineer / Computing Professional	0.0	0.0	0.0	0.0	0.0	**0.0**
Administrative / Technician	0.3	0.0	0.0	0.0	0.0	**0.3**
Other	0.0	0.0	0.0	0.0	0.0	**0.0**
DOE/HEP Funding (per activity):						
SWF (**in k$, include overhead**)	1,263	0	212	0	0	**1,475**
M&S (**in k$, include overhead**)	82	0	0	0	0	**82**
Travel (**in k$, include overhead**)	53	0	1	0	0	**53**
TOTAL	**1,398**	**0**	**212**	**0**	**0**	**1,610**

There was additional, internal ANL support for Theory group in FY10
Actual DOE funding received in FY10 was $ 2,030k$
These will be described/explained in detail in the presentations at the review

DOE Support FY 2011 (Proposed)

Personnel Support from DOE
(in FTEs)

Activity:	Phenomenology and Model Building	Lattice Gauge Theories	Formal Field Theory and String/Gravity Theory	Particle Astrophysics and Cosmology	Other (specify)	TOTAL
Permanent PhD	3.5	0.0	1.0	0.0	0.0	**4.5**
Temporary PhD	2.5	0.0	0.0	1.0	0.0	**3.5**
Graduate Students	1.0	0.0	0.0	0.0	0.0	**1.0**
Engineer / Computing Professional	0.0	0.0	0.0	0.0	0.0	**0.0**
Administrative / Technician	0.6	0.0	0.2	0.0	0.0	**0.8**
Other	0.0	0.0	0.0	0.0	0.0	**0.0**
DOE/HEP Funding (per activity):						
SWF (**in k$, include overhead**)	1,551	0	291	105	0	1,947
M&S (**in k$, include overhead**)	12	0	0	23	0	36
Travel (**in k$, include overhead**)	100	0	1	11	0	112
TOTAL	**1,663**	**0**	**292**	**140**	**0**	**2,095**

There is additional, internal ANL support plus carry-over from FY10 for Theory group in FY11
These will be described in detail in the presentations at the review

DOE Support FY 2012 (proposed)

Personnel Support from DOE
(in FTEs)

Activity:	Phenomenology and Model Building	Lattice Gauge Theories	Formal Field Theory and String/Gravity Theory	Particle Astrophysics and Cosmology	Other (specify)	**TOTAL**
Permanent PhD	4.5	0.0	1.0	0.0	0.0	**5.5**
Temporary PhD	3.0	0.0	0.0	1.0	0.0	**4.0**
Graduate Students	0.0	0.0	0.0	0.0	0.0	**0.0**
Engineer / Computing Professional	0.0	0.0	0.0	0.0	0.0	**0.0**
Administrative / Technician	0.6	0.0	0.2	0.0	0.0	**0.8**
Other	0.0	0.0	0.0	0.0	0.0	**0.0**
DOE/HEP Funding (per activity):						
SWF (**in k$, include overhead**)	1,974	0	304	125	0	2,403
M&S (**in k$, include overhead**)	2	0	0	12	0	14
Travel (**in k$, include overhead**)	100	0	1	22	0	124
TOTAL	**2,076**	**0**	**305**	**160**	**0**	**2,541**

DOE Support FY 2013 (Proposed)

Personnel Support from DOE
(in FTEs)

Activity:	Phenomenology and Model Building	Lattice Gauge Theories	Formal Field Theory and String/Gravity Theory	Particle Astrophysics and Cosmology	Other (specify)	**TOTAL**
Permanent PhD	4.5	0.0	1.0	0.0	0.0	**5.5**
Temporary PhD	3.0	0.0	0.0	1.0	0.0	**4.0**
Graduate Students	0.0	0.0	0.0	0.0	0.0	**0.0**
Engineer / Computing Professional	0.0	0.0	0.0	0.0	0.0	**0.0**
Administrative / Technician	0.6	0.0	0.2	0.0	0.0	**0.8**
Other	0.0	0.0	0.0	0.0	0.0	**0.0**
DOE/HEP Funding (per activity):						
SWF (**in k$, include overhead**)	2,069	0	319	132	0	2,519
M&S (**in k$, include overhead**)	2	0	0	12	0	14
Travel (**in k$, include overhead**)	100	0	1	22	0	124
TOTAL	**2,171**	**0**	**320**	**166**	**0**	**2,657**

DOE Support FY 2014 (Proposed)

Personnel Support from DOE
(in FTEs)

Activity:	Phenomenology and Model Building	Lattice Gauge Theories	Formal Field Theory and String/Gravity Theory	Particle Astrophysics and Cosmology	Other (specify)	**TOTAL**
Permanent PhD	4.5	0.0	1.0	0.7	0.0	**6.2**
Temporary PhD	3.0	0.0	0.0	1.3	0.0	**4.3**
Graduate Students	0.0	0.0	0.0	0.0	0.0	**0.0**
Engineer / Computing Professional	0.0	0.0	0.0	0.0	0.0	**0.0**
Administrative / Technician	0.6	0.0	0.2	0.0	0.0	**0.8**
Other	0.0	0.0	0.0	0.0	0.0	**0.0**
DOE/HEP Funding (per activity):						
SWF (**in k$, include overhead**)	2,279	0	332	521	0	3,132
M&S (**in k$, include overhead**)	2	0	0	11	0	13
Travel (**in k$, include overhead**)	100	0	1	22	0	124
TOTAL	**2,381**	**0**	**333**	**555**	**0**	**3,269**