

## Background Material for Non-Accelerator Research at Argonne National Laboratory

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## **1.A. Budget and Tables**

This documentation will be provided in a separate document.

## 2.A. Introduction and Overview

In this introduction we will give a short historical development of the non-accelerator research program at Argonne, describe how we arrived at the current situation and briefly outline future plans, which are described in more detail in the remainder of the document. In that sense this is the introduction and the summary, without all the details. A brief overview of the complete Argonne HEP program can be found at the following link under “Overview” and more details in the other talks presented on that page. <https://twindico.hep.anl.gov/indico/conferenceDisplay.py?confId=202>

The Argonne non-accelerator research program funded by B&R code KA-13 consists of two components: 1) an astrophysics part and 2) work on the Double Chooz (DC) reactor neutrino experiment. The involvement in the neutrino DC experiment is part of the larger neutrino program, which also includes very active involvement in MINOS and Nova and a growing involvement in LBNE. We have been part of the DC experiment for many years and remain committed to its science. This program has been funded by DOE HEP for many years and its funding was moved in to KA-13 in FY07.

Funding for the astrophysics part of the program from KA-13 was first established in FY07 with initial support for participation in the ground based gamma-ray experiment VERITAS. In 2007 we also submitted a proposal for an Astrophysics Initiative at Argonne to be funded by LDRD funds. The initiative was approved for funding for three years (FY08-FY10) and Karen Byrum became the initiative leader. The total funding was about \$4.5M, with \$1.5M coming to the HEP division, \$2.5M for development of threshold edge sensors (TES) sensors able to measure polarized CMB signal, and \$0.5M for nuclear astrophysics. With the funding coming to HEP division we have strengthened our efforts in ground-based gamma-rays by participating in VERITAS, developing a prototype upgrade L2 trigger for VERITAS with Iowa State, established a role in the analysis of the data, and joined CTA with work on design of their new telescopes; thereby establishing expertise in mechanical telescope design and building large structures for particle physics detectors. We also used these funds to join the Dark Energy Survey (DES) project and establish roles for Argonne scientists and engineers, resulting in a very active program of CCD testing and leading the calibration efforts in DES through Pre-cam. The LDRD funds allowed for us to establish clear roles in both VERITAS and DES and an initial involvement in CTA, which is now becoming part of a CTA-US effort.

The majority of the LDRD funds were used to establish a sensor development capability at Argonne to develop new, more sensitive TES sensors for the South Pole Telescope (SPT) experiment, enabling them to measure CMB polarization. This effort was part of a move to bring materials science expertise, available at Argonne to the area of sensor development, starting from selecting the best superconducting films for such sensors and then developing the sensors with the micro-fabrication facilities at Argonne. The sensors were indeed developed and are planned to be employed by SPT next year. This was a first step for Argonne in the direction of developing new sensors and we intend to continue in this direction with sensors for future experiments and other directions. The uniqueness of this direction is the Argonne expertise and facilities, such as the Center for Nanoscale Materials, to develop sensors that can be tailored to the need of the research that will be done with them. These developments have involved a strong collaboration with John Carlstrom’s SPT group at the University of Chicago, who were intimately involved in specifying and testing the sensors. This has led to a rather unique opportunity for

Argonne to become part of the SPT program, with a unique and enabling contribution, which can be further exploited in the future when needs for other sensors for upgrades or new directions arrive. To take advantage of the CMB science that SPT will do, the SPT PI, Carlstrom now has a joint appointment with Argonne as well as Clarence Chang, who has played a leading role in the development of the sensors and developing the science for SPTpol. For all these reasons as well as the overlap in science between DES and SPT we are proposing participation in the CMB program, and request funding for it, starting in FY11 from KA-13.

The table below gives an overview of past and current funding from KA-13 for the Argonne program up to and including FY10. The requests for future years are described and justified in the remainder of the document. A table in the summary chapter of this document lists funding requests for FY11-FY13 and the same numbers are also provided in the accompanying spreadsheet.

	<b>FY08 (k\$)</b>	<b>FY09(k\$)</b>	<b>FY10(k\$)</b>
<b>Double Chooz</b>	259	250	345
<b>VERITAS</b>	728*	432	373
<b>DES</b>	0	475	534
<b>CMB-SPTpol</b>	-	-	-

**Table 2A-1: Funding status for Detector R&D. \*This includes \$73.5k to SAO to operate VERITAS.**

## Progress Report for FY08-FY10

### 3.A. Cosmology and Dark Energy Group at Argonne

The cosmology and dark energy group at Argonne includes 1.2 FTE staff (S. Kuhlmann, H. Spinka, R. Talaga), one computational post-doctoral fellow (J.P. Bernstein, former DES post-doc at Argonne), and two post-docs (K. Kuehn, R. Biswas). In addition, a visiting scientist from Loyola (J. Cunningham) and his students are working closely with us, as well as students and a high school teacher from the DOE SULI, PST, and ACTS programs respectively. The hardware-related efforts such as DECam mechanical engineering, CCD X-Ray studies, and PreCam calibration camera benefit greatly from the strong technical infrastructure in ANL/HEP.

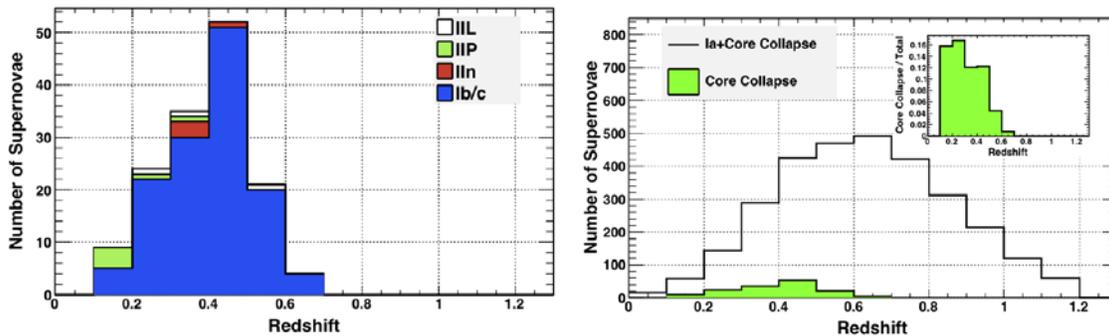
#### 3.A.1. Major Accomplishments 2008-2010

##### Supernova Science

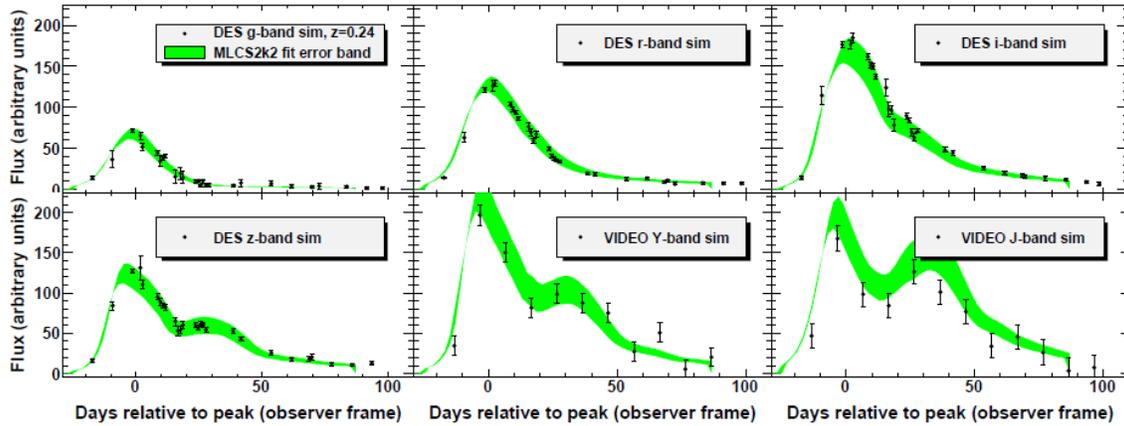
Argonne scientists have become a very strong group in supernova science. We are leading the simulation of supernova in DES, and are one of only 3 groups world-wide to be members of SDSS, DES, and LSST SN collaborations. The synergy between these three projects is extremely useful and unique: the SDSS data provide a crucial cross-check of our DES simulations, and the DES tools we develop are perfect to apply to LSST.

##### DES Supernova Strategy Studies

Argonne is a core developer of the SNANA analysis package [1], currently the most complete and sophisticated analysis/simulation package for SN cosmology. Argonne simulations using SNANA are ground-breaking studies [2-4] in core collapse contamination (Figure 3A-1) of a type-Ia supernova sample, photo-z resolution, and joint optical-IR measurements of SN (Figure 3A-2). Bernstein has presented this work in an invited talk at the Moriond cosmology conference, and in several talks at the American Astrophysical Society meetings.



**Figure 3A-1 (left):** Background contributions of the four principle types of core collapse supernovae to a five-year DES supernova survey with cuts optimized to perform cosmology with type Ia supernovae. The contribution of type Ib and Ic core collapse supernovae dominate the background, since they most closely resemble the light curves of type Ia supernovae. **Figure 3A.1 (right):** Projected redshift distributions of the DES supernova survey using a simple type Ia supernova identification method (SNR cuts plus a Ia fit-probability cut).



**Figure 3A-2:** A simulated light curve of a single supernova at  $z=0.24$  including overlapping infrared data from the VIDEO survey.

### Supernova Photometric Classification Challenge

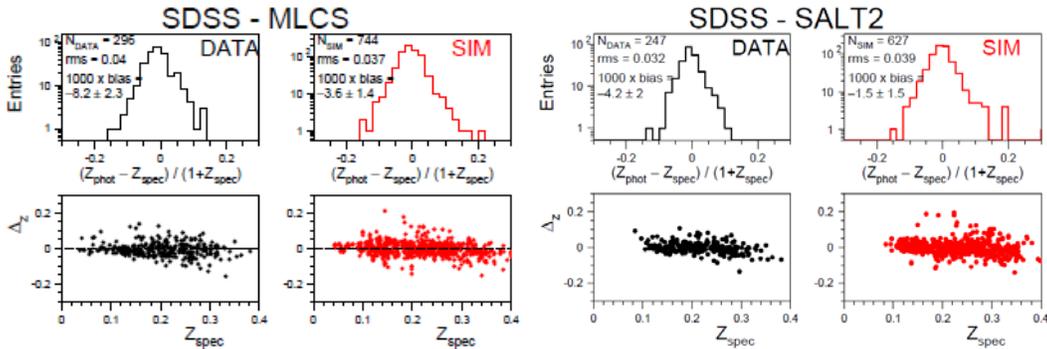
Using the SNANA core collapse simulation technology developed at Argonne in early 2009, and the results of many DES core collapse studies, Rick Kessler and S. Kuhlmann initiated an open challenge to classify supernovae types photometrically [5]. We created a blind sample of supernovae of all types, available at an Argonne web page, and posted an arXiv article advertising it. The SDSS, SNLS, and CSP collaborations provided 41 new supernova templates for the blind sample, many of them previously unpublished. Ten groups world-wide participated in the challenge, and became co-authors in a paper recently submitted to PASP detailing the results [6]. There was a wide dispersion of results, many of them extremely redshift dependent. The participants now have access to the blind sample, and discussions continue about optimizing both the algorithms and the best templates/input parameters to create the blind sample.

Name(s)	abbreviation <sup>a</sup>	classified +Z <sup>b</sup> /noZ <sup>c</sup>	SN $z_{ph}$ <sup>d</sup>	CPU <sup>e</sup>	description
P. Belov & S. Glazov	Belov+Glazov	yes/no	no	90	light curve $\chi^2$ test against Nugent templates
S. Gonzalez	Gonzalez	yes/yes	no	120	SiFTO $\chi^2$ with floated redshift
J. Richards, D. Homrighausen, C. Schafer, P. Freeman	INCA <sup>f</sup>	no/yes	no	1	spline fit & nonlinear dimensionality reduction
J. Newling, M. Varuguese, B. Bassett, R. Hlozek,	JEDI KDE	yes/yes	no	10	Kernel Density Evaluation with 21 params
D. Parkinson, M. Smith,	JEDI Boost	yes/yes	no	10	Boosted decision trees
H. Campbell, M. Hilton,	JEDI Hub	yes/no	no	10	Hubble diagram KDE
H. Lampeitl, M. Kunz, P. Patel (JEDI group <sup>g</sup> )	JEDI Combo	yes/no	no	10	Boosted decision trees + Hubble KDE
S. Philip, V. Bhatnagar, A. Singhai, A. Rai,	MGU+DU-1 <sup>h</sup>	no/yes	no	< 1	light curve slopes & Difference Boosting Neural Network
A. Mahabel, K. Indulekha	MGU+DU-2	no/yes	no	30	light curve slopes & Random Forests
H. Campbell, B. Nichol, H. Lampeitl, M. Smith	Portsmouth $\chi^2$	yes/no	no	1	SALT2- $\chi^2$ & False Discovery Rate Statistic
D. Poznanski	Portsmouth Hub	yes/no	no	1	Deviation from parametrized Hubble diagram
	Poz2007 RAW	yes/no	yes	2	SN Automated Bayesian Classifier (SN-ABC)
	Poz2007 OPT	yes/no	yes	2	SN-ABC with cuts to optimize $C_{FOM-Ia}$ .
S. Rodney	Rodney	yes/yes	yes	230	SN Ontology with Fuzzy Templates
M. Sako	Sako	yes/yes	yes	120	$\chi^2$ test against grid of templates & Bayesian prob(Ia,Ibc,II)
S. Kuhlmann, R. Kessler	SNANA cuts	yes/yes	yes	2	Cut on SN Ia (MLCS) fit probability, S/N & sampling

**Figure 3A-3:** Groups participating in the supernova photometric classification challenge, as well as a description of the algorithm they used.

### Photometric redshift tests using SDSS data

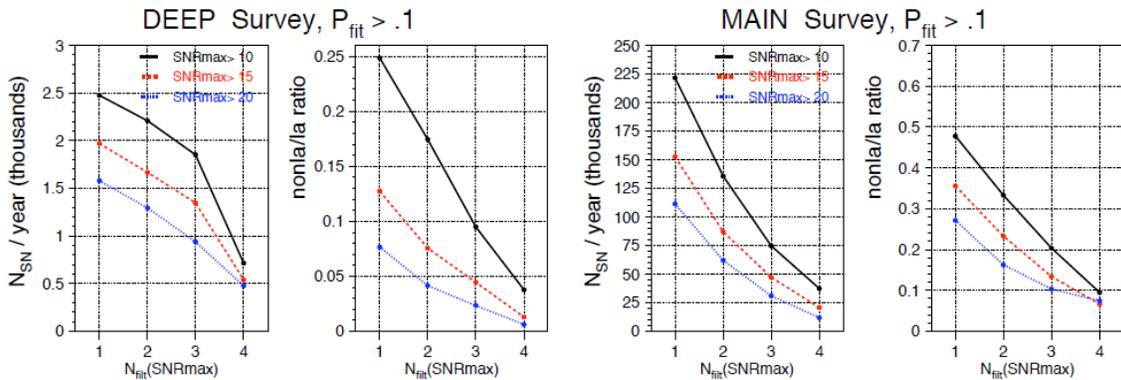
Modern supernova surveys like DES and LSST will detect too many supernovae and at such large redshift that only a small fraction of these supernovae will have a spectroscopic follow-up. It is possible a large fraction of the redshifts can be derived from spectra of the host galaxy, but this might only be available years after the supernovae are recorded. Therefore, the role of photometric redshift measurements is becoming a crucial component of supernova cosmology. The SNANA software package includes a photo-z measurement as an extra parameter in the light-curve fit. We have used this to fit SDSS data plus photo-z, for both MLCS and SALT2 light-curve fitters, and compare with the result from the measured spectra [7]. We find 3-4% resolution in the photo-z's, and negligible bias as a function of redshift.



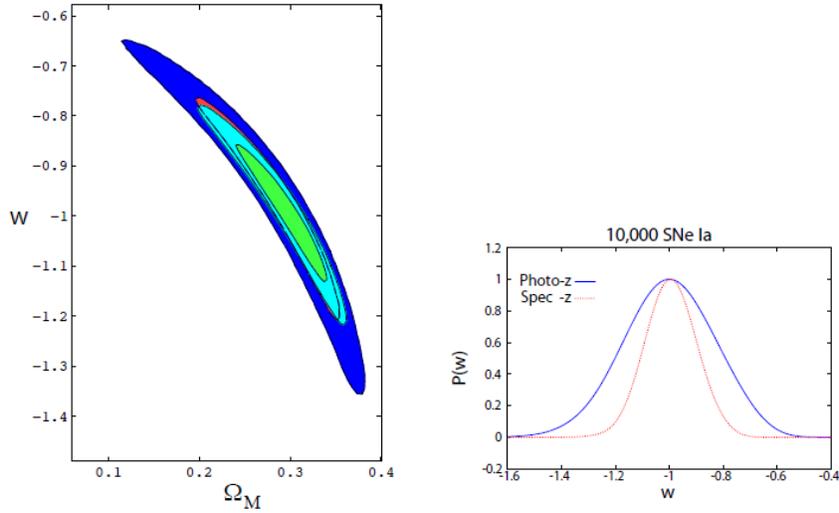
**Figure 3A-4:** Tests of photometric redshifts using SDSS data and the MLCS and SALT2 light curve fitters implemented in the SNANA package.

### LSST Supernovae

The tools developed for DES naturally apply to LSST, and we joined the LSST supernova collaboration in January of 2009. Argonne members were lead authors on two sections of the LSST Science Book, and a major contributor to a third section [8-10]. The most complete and precise survey estimates, for both type Ia supernovae and core collapse, were simulated at Argonne and are illustrated in Figure 3A-5 for both the main survey and the deep survey components of LSST. Figure 3A-6 shows cosmology constraints that new Argonne post-doc R. Biswas contributed to the Science Book.



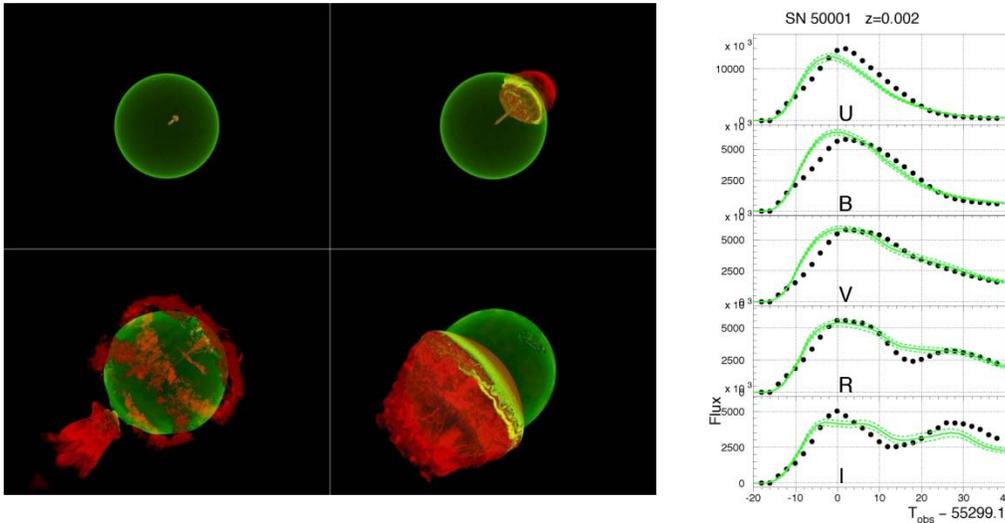
**Figure 3A-5:** LSST estimates for the number of type Ia supernova as a function of signal-to-noise, as well as the fraction of the sample that is core collapse supernovae that pass the Ia cuts.



**Figure 3A-6:** Forecast constraints for LSST supernovae from the LSST Science Book version 2.0, with a constant equation of state  $w$  in a flat cosmology from about 10,000 supernovae. The green and cyan contours show the 68% and 95% constraints when photometric redshifts are used, while the red and blue contours show the same with spectroscopic redshifts.

### Connecting Supernova Explosion Simulations and Data

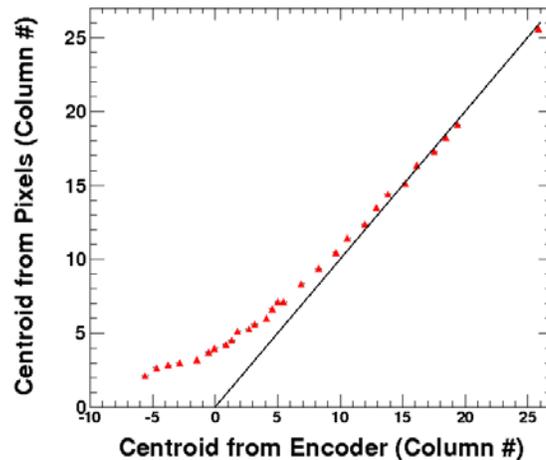
The age of precision cosmology has arrived, and dark energy constraints on the order of 1% are demanded. While SNe Ia continue to be a leading probe of dark energy, an improvement in the detailed understanding of their origins is necessary if 1% precision is to be reached. In order to help facilitate this improved understanding, Kuhlmann was co-PI and Bernstein the lead author of a successful joint UChicago/FNAL/ANL proposal to fund a UC graduate student, Benedikt Diemer. He is working with Chicagoland scientists on comparisons of ANL Blue Gene/FLASH supercomputer simulations of SN explosions with SDSS data-driven models (Figure 3A-7). In addition, Bernstein's position as ANL computational fellow has placed him in a key role in the generation of the Blue Gene explosion + radiative transfer simulated data.



**Figure 3A-7: (left):** Simulation of the gravitationally confined detonation (GCD) model of a Type Ia (thermonuclear-powered) supernova. Ignition occurs at a point offset 100 km from the center of the star. Hot material is shown in color and the stellar surface in green. **Figure 3A-7: (right):** MCLS data-driven model (green solid curves) fit to light curves in five wavelength bands predicted by a numerical simulation of the GCD model of SNe Ia that produced 0.75 solar masses of radioactive nickel (black dots).

### DES CCD X-Ray Studies

Argonne scientists commissioned a new portable CCD testing laboratory, and completed a series of four CCD diffusion data runs at the Advanced Photon Source X-Ray Lab. These data were submitted for publication to the Experimental Astronomy Journal, and we are replying to referee suggestions at this time. Literature searches have revealed no previous CCD diffusion studies with a <1-pixel beam of X-rays. Our studies show a diffusion effect on the edge of front-illuminated CCDs that was not expected by experts at LBNL and FNAL. The studies also highlight the centroid shifts in the DES science region in back-illuminated CCDs (Figure 3A-8). These centroid shifts have been confirmed with astronomical measurements of globular clusters at telescopes on CTIO.



**Figure 3A-8:** Study of CCD edge response at the Advanced Photon Source at Argonne. The deviation from the straight line is due to distorted electric fields at the edge of the CCD (seen in CCD engineering simulations at LBNL), and have been confirmed by astronomical measurements.

## PreCam Calibration and System Tests

Our work on CCDs naturally led us into a leadership position for the PreCam calibration project, since the dewars that were previously designed and built at Argonne were almost exactly the same size and shape needed for PreCam. Without PreCam, less than 1% of the DES fields will have any standard stars; with PreCam each field will have about 1000 standard stars. PreCam is a project to put a 2-DECam-CCD camera on the Curtis-Schmidt telescope at CTIO, using DECam electronics and software, and survey the entire DES area. It has already become an excellent system test for DECam. A new post-doc, Kyler Kuehn, was hired in 2010 to lead this project. The PreCam system is currently being commissioned at CTIO, as shown in Figure 3A-9.



**Figure 3A-9 (left):** Argonne post-doc Kyler Kuehn supervises the arrival of the first shipment of the PreCam system in La Serena, Chile. **Figure 3A-9 (middle):** The PreCam camera is shown installed on the Curtis-Schmidt telescope at CTIO, and Kuehn is working with CTIO staff on the Monsoon electronics crate installation. **Figure 3A-9 (right):** First light! First night image of globular cluster 47 Tucanae centered in the left CCD. Both CCDs are shown in this figure and are working well.

## DECam Mechanical Engineering

Argonne has made a tremendous and crucial contribution to DES mechanical engineering, design, and construction. The DECam project has funded more than \$1.3M of work at Argonne. This is more than 20% of the entire mechanical construction part of DECam. Argonne engineers have been the lead in many projects: f/8 mirror installation platform, electronics cooling system, filter changer installation hardware, the inner ring of the telescope simulator, the DECam instrument control system, original focal plane FEA for deflections, C5 lens cell.

### f/8 Mirror Installation Platform

We will highlight the design and complete construction of the 6-ton, 15' tall f/8 secondary mirror platform. This platform must align and install a 1-ton precision mirror to within 300 microns, yet be strong enough to withstand earthquakes which are common in Chile. This shows our strength at Argonne, our ability to perform a challenging project from conceptual design to complete assembly and testing on-site. The platform is the first piece of DECam to finish acceptance testing, with three CTIO engineers coming to ANL and FNAL to complete commissioning and sign off on its performance. The platform is being readied for shipment to Chile at this time.



**Figure 3A-10: (left):** Argonne engineer Allen Zhao standing next to the partially assembled f/8 platform in the ANL/HEP assembly building. The platform was fully assembled and tested at Argonne before shipping to FNAL. **Figure 3A-10 (right):** The fully assembled f/8 platform is shown next to the FNAL telescope simulator. The fake f/8 mirror is on top and the 1-ton counterweight is in front. The DECam imager cage is shown in the upper right corner as it is in position to mate with the fake f/8 mirror.

### 3.B. High-energy Cosmic Particles

Very High Energy (VHE) Gamma-ray astronomy, spanning the photon energy range of 100 GeV to 100 TeV, is one of the youngest branches of astrophysics. The first observation of a TeV gamma ray source (the Crab Nebula) only occurred in 1989 by the ground-based Whipple telescope. With the latest generation of instruments coming on line, HESS (2003), MAGIC (2004) and VERITAS (2007), the number of sources and source classes has grown to 100 [1].

Historically, the emergence of a new wavelength band in astrophysics has both answered existing questions and brought new discoveries and questions. VHE Gamma ray Astronomy has followed the same scenario. For example, recent imaging of gamma rays from a very distant quasar at a distance roughly half the radius of the Universe has modified our view of the transparency of the universe. This transparency is an important piece in cosmological structure formation. Recently, a number of VHE gamma ray sources have been identified that have no counterpart known at other wavelengths and represent one of the new questions brought forward by study of this new energy regime and new energy wavelength band.

Potentially, the most fundamental discovery from VHE Gamma-ray astronomy could come from the search for indirect evidence of particle dark matter if the hypothesis is correct that the particle of dark matter is a weakly interacting massive particle (WIMP) that produces the VHE gamma rays as a result of pair self-annihilation. Understanding the mysterious dark matter that holds together the cosmic entities in which we live, galaxies and galaxy clusters is one of DOE's key missions. Till now, ground based instruments with their small angular field of view had to target specific dark matter candidates such as sources with large mass-to-light ratios. With the recent launch of the Fermi Gamma-ray Space Telescope (FGST) all sky survey gamma-ray observatory, we expect the emergence of a new class of targets such as dark matter halo clusters that could be much less massive than dwarf galaxies; for example  $10^3 - 10^6$  solar masses. Ground based instruments like VERITAS are able to study these regions with finer angular resolution and higher energy thresholds than FGST. The VHE observatory also effectively complements the FGST which operates in the 300 MeV to 300 GeV range.

#### 3.B.1. Major Accomplishments 2008 – 2010

In FY10, the High-energy Cosmic Particle group at Argonne included 1.2 FTE of staff (K. Byrum and R.G. Wagner), and one post-doctoral fellow (pd supported out of LDRD, A. Smith). We have hosted several visiting scientists; Razmick Mirzoyan from the Max Planck Institute in Munich spent about 6 weeks at Argonne during the summer of 2008 working with us on SiPM R&D for future focal plane instrumentation in CTA. Prof. Frank Krennrich from Iowa State spent from September 2008 – January 2009 on sabbatical at Argonne working on R&D for a topological trigger. We have maintained a series of Student Undergraduate Laboratory Interns (SULI) who have worked with us on trigger R&D. Our previous post-doctoral candidate, Deirdre Horan, left in August 2008 to take a permanent position at Ecole Polytechnique in Paris, France. She received a prestigious ANL Named Fellowship, the “David Schramm” Named fellowship and was the first Astrophysics Named Fellow at Argonne.

Argonne is the only US laboratory pursuing ground based gamma-ray astronomy with the current generation of ground based instruments. We have been a member of VERITAS since Apr 2004; first as

an associate member with limited physics involvement and eventually (starting in Nov 2007) as a full collaborative member. We have received LDRD funding to fund engineering efforts (EE) to develop a topological trigger system. In addition, some R&D support using KA-15 funds were used for generic trigger R&D. Trigger development has been in collaboration with Iowa State University who received an ADR grant for their contribution. The engineering effort and M&S to build an upgraded VERITAS Level-2 trigger has been funded through a NSF MRI awarded to Dave Kieda at the University of Utah. Both Argonne and SLAC have played leading roles in development of technology for the next generation of ground based gamma-ray instruments. Argonne funding for AGIS and CTA mechanical design has been through multiple sources, LDRD has supported about 2 FTEs of mech. engineering, but we have also received funding from DESY as well as funds from the University of Chicago.

### **Dark Matter and Cosmology with VERITAS and AGIS/CTA: Overview**

Since 2007, we have been a key contributor to both the science and the hardware infrastructure of the rapidly evolving field of very high energy (VHE,  $> 50$  GeV) gamma-ray astrophysics. Our contributions to this field have been ultimately symbiotic; contributing to the fundamental science surrounding this field as well as the design and fabrication of the hardware improvements which will, in turn, improve the science impact of the tools at hand.

Our science contributions have centered around using data from VERITAS to study signatures of neutralino dark matter annihilation, and to study the gamma-ray spectra of distant AGN in order to constrain cosmological models of early star formation and evolution. Both of these science topics are still in their early days; while important observations have already been made with TeV telescopes, the truly telling Dark Matter measurements appear to lie just beyond the reach in sensitivity of current instruments.

Argonne and ISU are providing the design and fabrication of a new Level-2 trigger and advanced trigger upgrade for VERITAS. When installed, these systems will allow VERITAS to lower the energy threshold and allow the study of much more distant AGN, and consequently more expansive cosmological constraints. The dark matter science is both more fundamental and difficult; current measurements indicate that available instruments are several orders of magnitude in sensitivity away from strongly constraining phenomenological models. In order to truly connect the theory to observation, a next generation instrument such as AGIS/CTA is necessary and Argonne has been a strong contributor to the mechanical design of the proposed AGIS/CTA telescopes. Once this observatory is operational, more precise constraints will be forthcoming on the most conservative particle physics models of dark matter.

### **VERITAS Science**

VERITAS (Very Energetic Radiation Imaging Telescope Array System) is a ground based gamma-ray instrument operating at the Fred Lawrence Whipple Observatory (FLWO) in southern Arizona, USA. It is a mostly US collaboration and was a high-priority experiment in DOE/NSF SAGENAP reports and in the 2000 Astronomy & Astrophysics Decadal Survey, and is currently the most sensitive VHE ( $E > 100$  GeV) gamma-ray observatory in the world. The two European competitors to VERITAS are HESS, which is located in Namibia and MAGIC, which is located in the Canary Islands. Both MAGIC and HESS have planned upgrades to increase sensitivity. The three experiments work together to cover both

the northern and southern hemisphere and span multiple time zones for broader coverage of the night sky. VERITAS is an array of four 12meter imaging Cherenkov telescopes deployed such that they have the optimal sensitivity in the 100 GeV-50 TeV energy range. Figure 3B-1 shows a view of the FLWO basecamp where the VERITAS array is located.



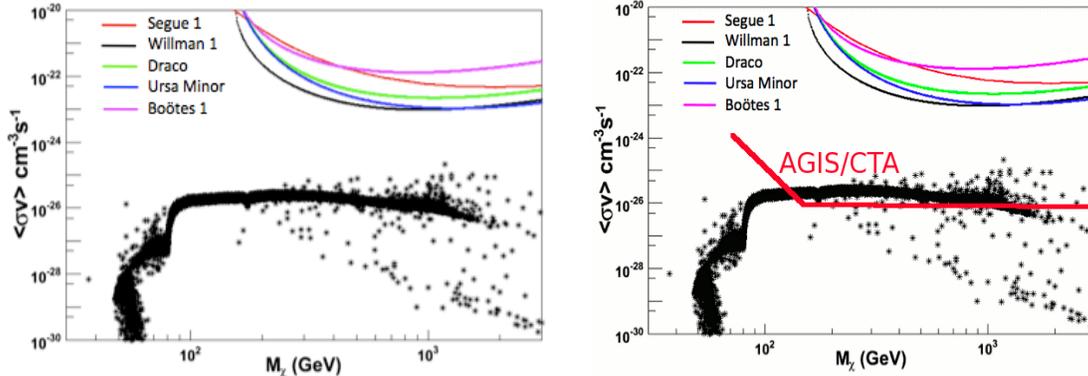
**Figure 3B-1:** View of the FLWO basecamp where the VERITAS array is located.

VERITAS has been in an operations phase since first light on April 27-28, 2007. The experiment recently submitted an NSF MRI upgrade proposal. The proposal, which received funding in April 2010, will replace the current PMTs with more efficient photon detectors, will develop and employ a more sophisticated telescope trigger system (Argonne and Iowa State are building this) and will add a new fast optical monitoring and intensity interferometer system.

### **Dark Matter Studies**

From the beginning, we have been involved with the VERITAS Dark Matter science program supported out of KA-13. Both Byrum (2007-2008) and Wagner (2009-2010) have been co-convenor of this science working group. Recently, the Dark Matter group within VERITAS has merged with the Astroparticle Physics working group with Smith being elected co-chair of the merged group. This has and will continue to provide an Argonne leadership presence within VERITAS Dark Matter science. Recently, Wagner and Smith led a VERITAS search for indirect dark matter using dwarf spheroidal (dSph) galaxies. These results were recently published in *The Astrophysical Journal*.

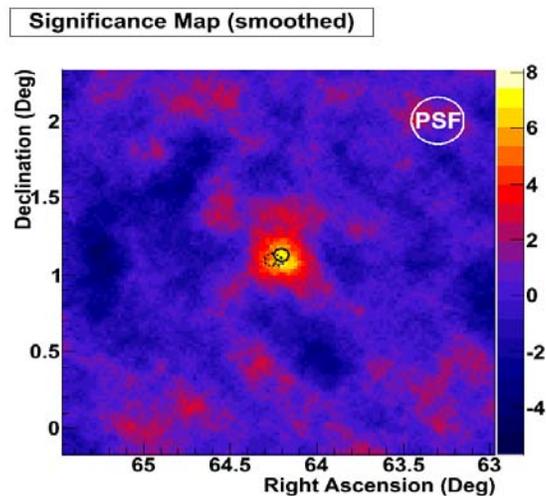
During the past two years, VERITAS has observed the local spiral galaxy, M33, and five low-surface brightness dwarf dSph galaxies: Ursa Minor, Draco, Boötes 1, Willman I and SEGUE 1. Wagner and Smith have performed the primary analysis of the dSph galaxy data and have also analyzed the M33 data. No significant gamma-ray signal was observed from the five dSphs. **Error! Reference source not found.** (left) shows the obtained upper limits on the product of the cross section and neutralino velocity,  $(\sigma v)$  as a function of the mass of the neutralino. The derived upper limits on the gamma-ray flux constrain  $(\sigma v)$  for neutralino pair annihilation as a function of neutralino mass are less than  $10^{-23} \text{ cm}^{-3} \text{ s}^{-1}$  for  $\text{mass}(\text{neutralino}) > 300 \text{ GeV}/c^2$ . The obtained limits are three orders of magnitude above generic predictions for MSSM models (black stars) assuming an NFW DM density profile, no boost factor and no additional particle-related gamma-ray flux enhancement factors. Should the neglected effects be included, the constraints on  $(\sigma v)$  in the most optimistic regime could be pushed to  $< 10^{-25} \text{ cm}^{-3} \text{ s}^{-1}$ . The improved sensitivity from a next generation instrument is shown in **Error! Reference source not found.** (right).



**Figure 3B-2:** (left) The obtained upper limits on the product of the cross section and neutralino velocity,  $\langle\sigma v\rangle$  as a function of the mass of the neutralino. (right) same figure with expectations from AGIS/CTA.

### Cosmological Constraints with High-Z AGN

There has also been significant activity with VERITAS in the study of TeV emission from high redshift active galactic nuclei (AGN) in order to provide constraints on cosmological parameters. Smith has been the primary analyst and author of a paper detailing the VERITAS observations of the high redshift ( $z=0.29$ ) active galactic nuclei (AGN) 1ES 0414+009. Since TeV gamma-rays are heavily attenuated by the extragalactic background light (EBL) and the character of the EBL is dictated by the history of star formation in the universe, the study of distant TeV sources yields crucial indirect constraints on cosmological parameters which are extremely difficult to measure directly. Due to its high redshift, 1ES 0414 +009 is an ideal target for such a study, and initial results from this analysis indicate that VERITAS observations will be able to heavily disfavor several popular models of the EBL. This publication is currently in preparation and will be submitted to the Astrophysical Journal in Fall 2010. Figure 3B-3 shows a two dimensional map of 1ES 0414 \_009.



**Figure 3B-3:** Here is shown the two dimensional map of the VERITAS TeV signal accrued from the high z AGN 1ES 0414 +009, along with the optical position of the AGN (circle), and location of the FGST GeV source (dotted circle).

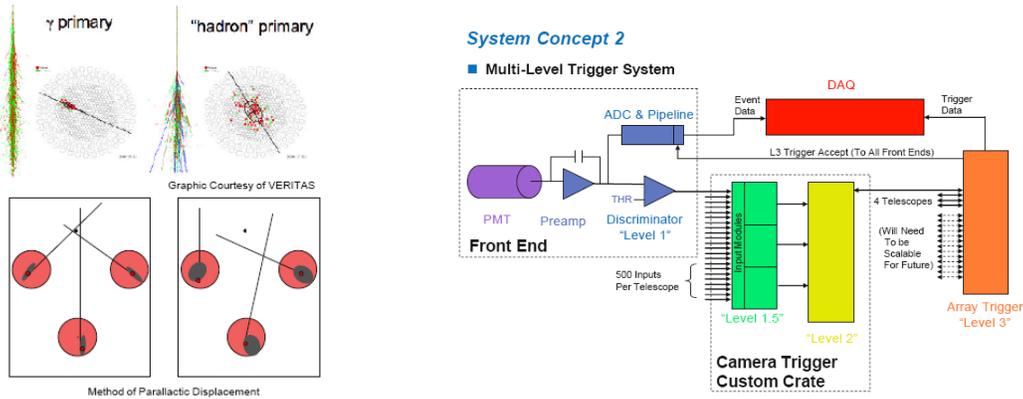
The effect of EBL attenuation on TeV gamma-rays is a function of both distance and energy; more distant AGN are only visible in the lower TeV regime (<100 GeV). Thus, by lowering the energy threshold of VERITAS, a new higher redshift window on the universe is opened. The upgraded Level-2 trigger should allow more expansive constraints to be made on the EBL and other cosmological parameters.

### **VERITAS Level 2 Trigger Upgrade (2008 – 2010) and Future Topological (2008 – 2010)**

Byrum, Smith, Drake, Anderson and Kreps have designed and are currently in the production phase of a Level-2 trigger upgrade for VERITAS. This new Level-2 trigger development has been in collaboration with Krennrich and Weinstein at Iowa State University and should give VERITAS enhanced capabilities compared to the current Level-2 trigger. These include coincidence window improvement down to (3-4ns) and improved diagnostic capabilities. The new trigger system will be delivered to VERITAS later this fall and winter.

The VERITAS level-2 trigger upgrade is based upon R&D for a topological trigger designed for a next generation (such as AGIS/CTA) ground based gamma-ray experiment. The topological trigger R&D has focused on applying particle-physics detection techniques to develop a fast pattern trigger for real time analysis of nanosecond time scale phenomena to particle astrophysics experiments and has been in collaboration with Frank Krennrich at Iowa State University. Our prototype topological trigger employed a new Level-2 which was designed to be a drop in replacement for aging VERITAS Level-2 trigger, but with enhanced capabilities compared to the current trigger and with all the hooks in place to eventually add a Level-4 topological trigger.

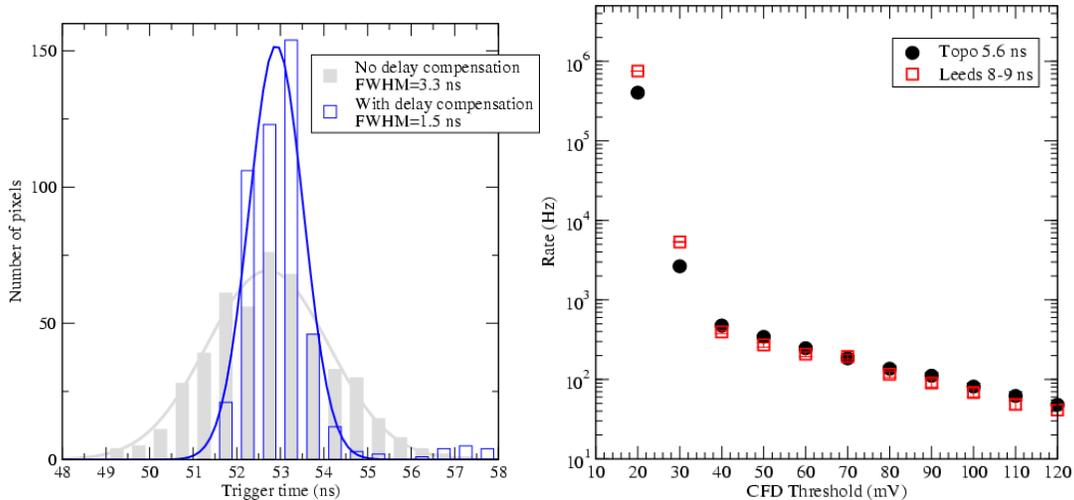
Our Level-4 concept uses parallactic displacement of Cherenkov light images to develop a trigger that exploits the imaging differences between gamma-ray and hadron-induced air showers by utilizing the different viewpoints in an IACT array. This is shown in Figure 3B-4. These fluctuations translate into a large spread of shower core reconstruction in the telescope plane. The key to our approach is to incorporate pattern recognition into a Level 2 Trigger by using the simple discriminated hits from Level 1 as input. When the Level 3 Trigger accepts an event, a signal is sent back to the front-end electronics of all cameras participating in the trigger, and the event is read out by the data acquisition system.



**Figure 3B-4:** (left) illustrates the use of parallax displacement for hadronic background suppression. The shapes of the electromagnetic component of a gamma-ray and a proton induced shower are shown and the effect on the shape and orientation of Cherenkov light images in the camera. **Figure 3B-4: (right)** is a block diagram of a proof-of-principle topological trigger demonstrator system.

We have designed a proof-of-principle topological trigger system that operates at an order of magnitude higher clock frequency than previous accelerator based pattern triggers. A Xilinx field programmable gate array (Virtex-5) with a clock frequency of more than 400 MHz provides the basis for the design of a nanosecond time scale trigger. To demonstrate the power and capability of our approach, we chose to incorporate our Level 2 trigger demonstrator system parasitically into one telescope of the VERITAS multi-telescope imaging array experiment. We have developed a methodology where we form cells composed of 7 pixels – a central pixel plus 6 neighbors, over the entire face of a VERITAS camera and form a sliding window of programmable length, and require 3-fold coincidence of hit pixels. Figure 3B-4 (right) shows the conceptual design of the demonstrator trigger which includes I/O boards to receive the signals onto a 10 layer circuit board custom layout backplane, a Level 1.5 processor to look for 3-fold coincidence of neighboring pixels within a programmable time window, a Level 2 processor that sorts data based on timestamps, counts the number of pixels and calculates the first and second moments of the hit pixels. This information is passed to a central Level 3 process which calculates the parallax width parameters.

We are presently in the middle of a production run for producing a new Level-2 trigger system. We have a MOU in place with University of Utah to deliver this hardware to the VERITAS experiment during this fall/winter observing season. Iowa State who will be delivering the Level-2 trigger software. We have performed many test measurements both in the laboratory and in the field. Figure 3B-5 shows several test measurements performed in March 2009 at the VERITAS experiment. In this test, the Level 2 moment analysis and the Level 3 topological analysis were not included.



**Figure 3B-5:** The left figure is the distribution of the signal arrival time for all pixels on one telescope of the VERITAS telescope. The improvement in narrowing the pixel signal arrival time due to programmable adjustment capability of our Level 1.5 Module is shown. The right figure is the VERITAS Level 2 cosmic ray rate as a function of the VERITAS Level 1 signal threshold. The flat part of the spectrum (above 40mV) is due to signals (cosmic rays); the exponential rising edge is background (mostly due to night sky random starlight). In our initial test, we were able to narrow the trigger gate to 5.6ns which is about 3ns below the current VERITAS trigger gate of 8-9ns. This resulted in a reduction of about 20% random night sky background, but was greater than 100% efficient at retaining the cosmic ray signal.

### **Theoretical and Computational Studies at ANL Impacting the VERITAS program.**

Argonne has an active theoretical dark matter program with 2 staff and up to 3 postdoctoral candidates pursuing Dark Matter theory, both from a particle physics perspective and an astrophysical/cosmological perspective. Within the last year, the ANL theory group has published 7 papers pertaining to dark matter models and interpretation of astrophysical results. Dark matter is at the heart of any study regarding the interface between particle physics, astrophysics and cosmology. The experimental VHE gamma-ray program benefits from this theoretical guidance, both for understanding the current VERITAS data and for determining where to look astrophysically for a signature of dark matter.

### **Towards the Future: AGIS/CTA (R&D, design, fabrication)**

The international community of gamma-ray scientists is currently planning the next generation very high energy gamma ray ground based observatories. Planning has centered around two large groups: the Cherenkov Telescope Array (CTA) mainly composed of Europeans, many from the H.E.S.S. and MAGIC gamma ray telescope collaborations; and the Advanced Gamma-Ray Imaging System (AGIS) mainly composed of Americans, mostly from the VERITAS, FGST and HAWC collaborations. Research and development work is in progress by both groups. CTA is emphasizing creation of a time allocated user facility with an array of 50-100 telescopes of three sizes using existing technology, e.g. single anode photomultipliers, single dish Davies-Cotton mirror structure, and state-of-the-art data acquisition electronics. The AGIS group has emphasized improved technology with the focus on cost reduction and increased sensitivity using larger field of view cameras, signal digitization and processing located on the camera, innovative photosensors such as multianode photomultipliers or Geiger-mode avalanche photodiodes (silicon photomultipliers), and improved telescope optics with novel telescope designs.

**AGIS/CTA Telescope Mechanical Designs Overview (FY08 – FY10)**

This work has been in collaboration with the University of California, Los Angeles (SC designs), and DESY Laboratory in Germany (DC designs).

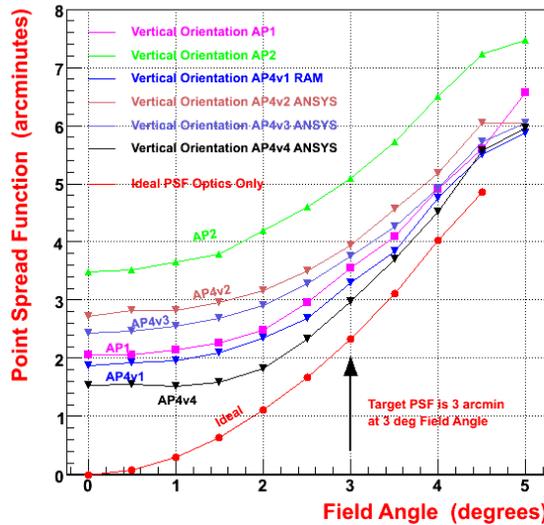
We have undertaken extensive mechanical design and analysis work for future ground based imaging Cherenkov telescopes including a novel 9-meter Schwarzschild-Couder (SC) telescope design and a more conventional 12-meter Davies-Cotton (DC) telescope design as well as designs of the motion systems required for the SC telescope. This effort includes studies of basic telescope structure deformations under rotation including thermal expansion and contraction.

**SC Designs**

In FY08, we completed a conceptual SC design of an optical support structure (OSS) which minimized deflections while also minimizing the weight of the structure and which should be easy to construct. This is shown in Figure 3Ba-6 [1]. This work involved:

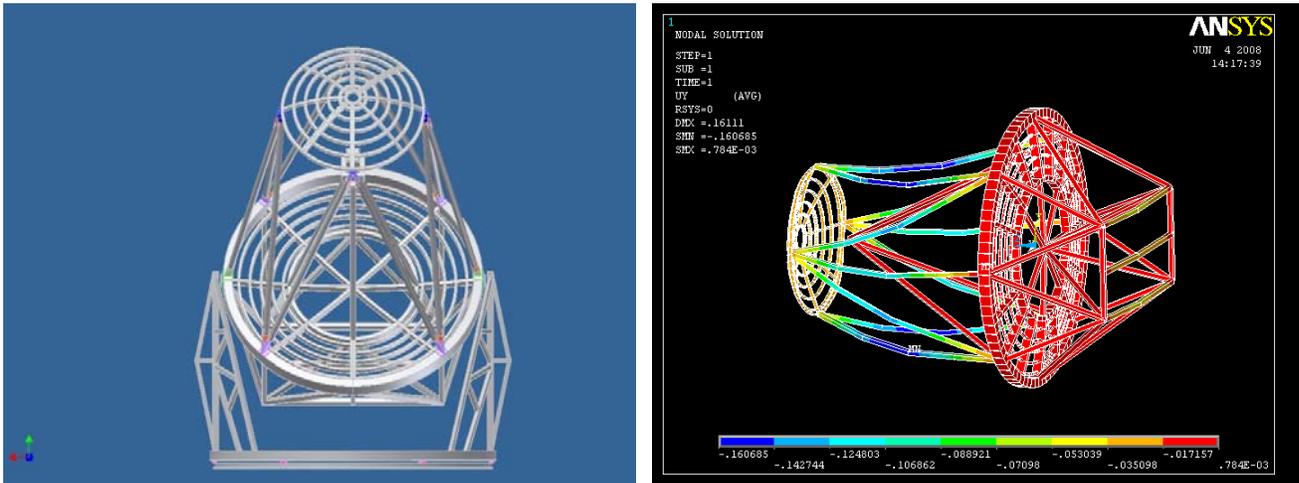
- the layout of the geometry needed to support the mirrors
- structural analysis of the structure at different elevations and under wind/ice loading
- Evaluation of the deformations and how they affected the telescope performance.
- Evaluation of the structure’s natural frequencies.
- The development of a conceptual design of the drive system.

Multiple iterations of the telescope structure were developed and a complete cost estimate was obtained. UCLA provided guidance on the design parameters and evaluation of the deformations that were found from the structural analysis. Figure 3B-6 shows the PSF calculated by UCLA and ANL from deformations for the various design iterations that were examined



**Figure 3B-6:** PSF calculated by UCLA and ANL from deformations for the various design iterations that were examined.

The current design is shown in Figure 3B-7 (left) below. The structure consists of a main support structure for the primary mirrors. The primary mirror structure supports through trusses the secondary mirror and the camera. The primary mirror structure has a truss structure on the back side that provides the required stiffness to minimize the deformations of the mirrors. Structural analysis was performed to examine the deformations of the structure in different elevations. Figure 3B-7 (right) shows a plot of the deformations when the telescope is pointing horizontally



**Figure 3B-7:** (left) is the mechanical design for a SC 9-meter telescope. The right top colored figure shows the deformation in the horizontal orientation from finite element analysis.

## DC Designs

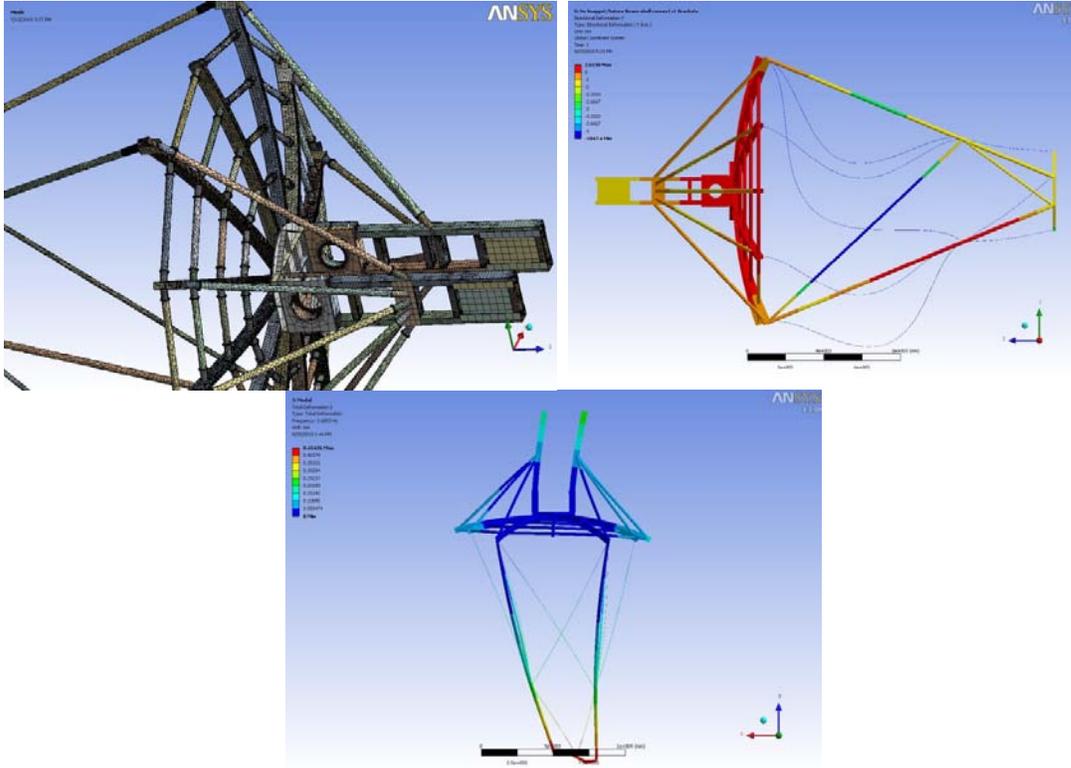
In FY09 and FY10, we also completed a DC design which is shown in Figure 3B-8. This work has been done in close cooperation with DESY for the CTA collaboration. The design effort initially focused on the development of a conceptual design of the main structure and motion system. In the past year ANL has developed a collaboration with DESY for the development of the medium sized telescope for the CTA collaboration. DESY is responsible for the motion system and ANL is responsible for the design of the main structure.

Figure 3B-8 shows the basic design and some results of the analysis.

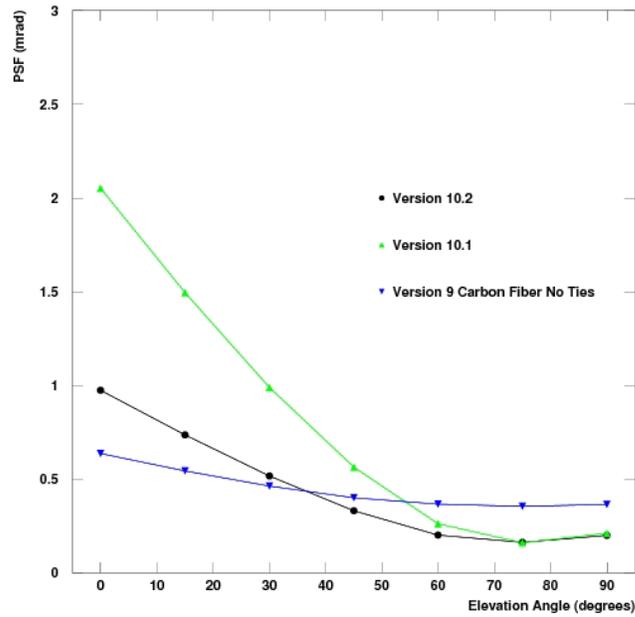
ANL has performed extensive structural analysis of the structure including:

- the layout of the geometry needed to support the mirrors
- structural analysis of the structure at different elevations and under wind/ice loading
- Evaluation of the deformations for different design concepts and how they affected the telescope performance, see Figure 3B-9
- Evaluation of the structures natural frequencies.
- The development of a conceptual design of the drive system

ANL is currently creating fabrication drawings for the prototype telescope that DESY and ANL will be constructing in Berlin next summer. ANL will supervise the construction of the prototype structure in Germany which is being funded by DESY.



**Figure 3B-8:** Top left is the FEA model. Top right is a plot of deformations in the horizontal orientation. Bottom is the model shape of the 2<sup>nd</sup> frequency of 3.6Hz.



**Figure 3B-9:** Evaluation of DC Telescope PSF for different design concepts.

**References:**

- [1] <http://www.hep.anl.gov/vjg/SC-OSS-Structure1.doc>
- [2] <http://www.hep.anl.gov/vjg/DC-OSS-Structure1.doc>

### 3.C. Neutrino Group at Non-Accelerator Physics

#### 3.C.1. Accomplishments (2007-2010)

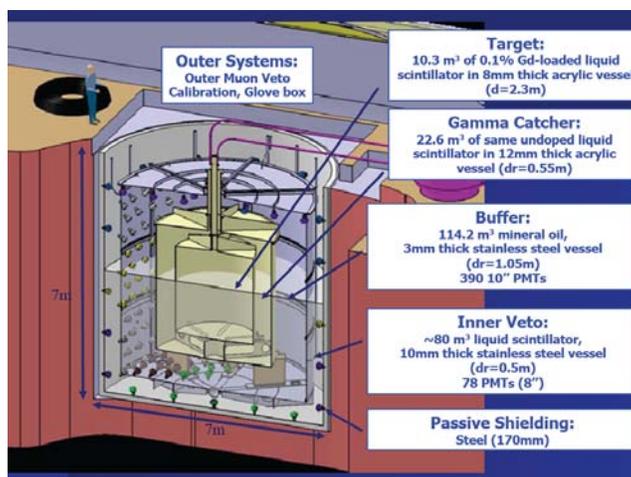
##### Overview

The Neutrino group has been actively involved in the study of neutrino oscillations as an outgrowth of the study of atmospheric neutrino oscillations on Soudan 2, and is deeply involved in accelerator (proton based) experiments MINOS, NOvA and LBNE. It was recognized in the early years of the 21<sup>st</sup> century that the one unmeasured neutrino mixing angle,  $\theta_{13}$ , could be much more highly constrained by a new reactor based experiment with at least two detectors. Argonne Physicists led the International Reactor  $\theta_{13}$  working group, which held a series of international meetings and considered a number of reactor sites around the world. A Reactor Neutrino White Paper was written and presented to the community in 2004, and is available in arXiv:hep-ex/0402041. The three current reactor neutrino experiments worldwide all use detector designs based on work in that report. Three members of the ANL neutrino group are currently working on the Double Chooz reactor experiment, Physicist Maury Goodman, Assistant Physicist Zelimir Djurcic, and postdoc Michelangelo D'Agostino.

##### The Double Chooz reactor neutrino experiment

The ANL  $\nu$  group helped form the US Double Chooz collaboration. The collaboration-wide proposal document was edited at ANL, and ANL personnel helped provide management throughout, serving as US co-spokesperson through 2009, on the executive committee continuously, and establishing a collaboration document database in 2008. Two proposals for equipment funding were submitted to the DOE in 2004 and 2006, which were not funded. We have hosted a variety of analysis meetings for the US collaboration.

The experiment consists of two detectors, one being finished in 2010, and the other to be built in late 2011. The design for both detectors is four volumes of liquids as shown in Figure 3C-1. The target is Gd-loaded liquid scintillator, the gamma-catcher is liquid scintillator without Gd, and the buffer is mineral oil. Outside the steel vessel is an inner veto with liquid scintillator.



**Figure 3C-1:** The Double Chooz Detector concept.

## Calibration devices

The ANL group has been an active part of the calibration group, and has taken primary responsibility for the z-axis calibration system, and secondary responsibility for an articulated arm calibration system, together with collaborators at Drexel. The calibration systems will be housed in a glovebox which sits on top of a chimney, built by our UC-Davis colleagues. We have worked closely with them on the design, testing and integration of the calibration devices. The system was originally designed and built by a former ANL neutrino group postdoc, Jurgen Reichenbacher, who is now on the Double Chooz experiment with the University of Alabama. Software to run the system was written by Michelangelo D'Agostino, who has performed reliability testing. In early 2010, we organized a design review at ANL for the z-axis and articulated arm systems. This included a risk analysis involving both the safety of personnel and protection of the detectors which will be required at the time of the readiness review at the nuclear reactor. As a result of this successful review, a z-axis system was built for each detector as well as a spare. Also, the articulated arm has been assembled in late 2010 and is ready for testing.

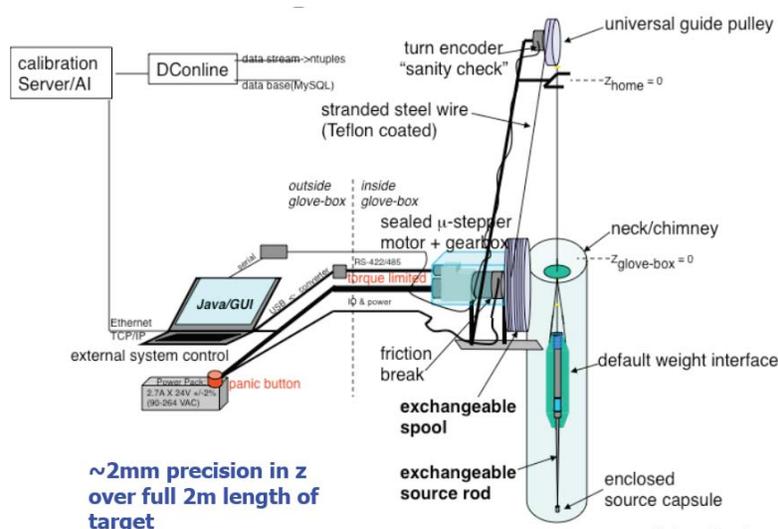
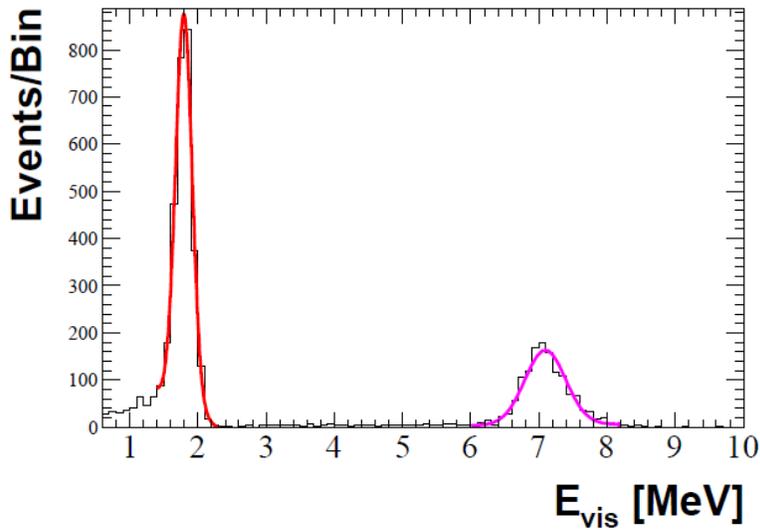


Figure 3C-2: The z-axis calibration system, which is housed in the glovebox and deployed through the chimney.

## Calibration simulations

As a logical extension of our work on calibration hardware, ANL has started simulations of cosmic calibrations and backgrounds. These include the most advanced studies to date of spallation neutrons. Spallation neutrons will be measured in both the gamma-catcher and the target, so that they will provide a calibration source for both the Hydrogen capture and Gd peaks. This is seen in Figure 3C-3 where the full detector was simulated with an unknown energy scale, and simultaneous fit was performed to spallation neutrons, associated with throughgoing muons (not shown), to the 2.2 MeV Hydrogen and 8.0 MeV Gadolinium peaks. This will be a useful cross check of the artificial calibration sources. Other cosmic calibrations such as Boron 12 and stopping muons have been studied in a similar way. A variety of codes have been developed such as a neutron generator, a faster muon simulation and a muon map of the overburden at Chooz. These codes will be used throughout the US analysis cluster, one of three that will calibrate and analyze neutrino data when it starts coming in late 2010.



**Figure 3C-3:** Full simulation of spallation neutrons with simultaneous H/Gd calibration

### Other Analysis

ANL physicist Zelimir Djurcic is also a member of the collaboration-wide reactor working group, which is modeling the reactor cores to accurately predict the anti-neutrino flux. He is an author of a short author list paper concerning uncertainties in anti-neutrino production at reactors. (arXiv:0808.0747). All three group members are developing a sensitivity analysis, focusing on the effects of backgrounds and uncertainties after calibration. One of the major backgrounds is muon spallation induced Lithium 9, unmeasured at these depths, which we are studying. We have worked with the Livermore and Sandia groups to consider antineutrino detection as a part of a nuclear non-proliferation regime, and a white paper on that subject was produced and disseminated in 2009.

### 3.D. Cosmic Microwave Background (CMB) Thrust

#### 3.D.1. Overview

The cosmic microwave background (CMB) has played a pivotal role in cosmology and particle physics. Its discovery in 1965 validated the hot big bang, its homogeneity led to the theory of inflation, and its anisotropy showed the geometry of the universe is flat and gave a complete census of the matter-energy content of the universe illuminating physics beyond the Standard Model. CMB measurements remain critical to answering questions in cosmology, indeed in physics, today. What is dark energy? What are the masses of the neutrinos? Did the universe in its first instants undergo a burst of inflation? And, if so, at what energy scale? CMB measurements are unique in their ability to constrain inflation. For example, measuring the CMB polarization signal at levels of  $\sim 0.1 \mu\text{K}$  investigates directly inflation-era physics at GUT energy scales.

These questions and recommendations for research programs to provide insights to their answers have been the focus of numerous national reports over the last decade. Most recently, the PASAG report and the 2010 Astronomy and Astrophysics decadal report further stressed the importance of CMB research and in particular emphasized the need to exploit the unique ability of CMB polarization measurements to probe inflation. This is well aligned with the focus of Argonne's CMB research thrust activities.

Argonne HEP scientists are key members of the SPT-SZE dark energy program and the SPT-POL inflation science program. Both programs bring unique and valuable resources to bear on the questions above. The nearly complete SZ-galaxy cluster survey of the SPT-SZE dark energy program will be unrivaled in resolution and deep sky coverage, and through its promised cluster catalog has already catalyzed a comprehensive and synergistic optical dark energy program, i.e., the Dark Energy Survey (DES). The SPT-POL inflation science program will conduct a sensitive search for the signature of Inflationary gravitational waves through their impact on the B-mode<sup>1</sup> polarization of the CMB. The SPT's small beam provides unique and complementary features to other planned CMB polarization experiments. It will provide the highest resolution CMB polarization observations, which will detect the lensing B-modes from which we can constrain the neutrino masses. This data can also be used to "clean" the lensing B-modes from the inflationary signal should that prove necessary. Lastly, its high resolution will allow SPT-POL to uniquely characterize the astronomical foregrounds.

The Argonne activities in this thrust area focus on the SPT-POL inflation science program to constrain inflation and the masses of the neutrinos. As described in detail below, Argonne's unique contribution to this program is the development and micro-fabrication of the sensitive bolometric polarization-sensitive detectors. This specialized capability has been enabled by the collaboration of HEP with the Materials Science Division and the Center for Nanoscale Materials (CNM) at Argonne, and with university groups at the University of Chicago, U.C. Berkeley, Case Western, McGill University, University of Colorado at Boulder, and the University of Michigan. Over the last three years using LDRD funding, Argonne has successfully developed cryogenic bolometric detectors suitable for the first generation SPT-POL focal plane array, and has established a solid foundation on which to build the next generation focal plane arrays for SPT-POL and future CMB telescopes.

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<sup>1</sup> The CMB polarization field is uniquely decomposed into even parity (E-modes) and odd parity (B-modes) fields.

### 3.D.2. Progress over FY08-FY10

#### **The South Pole Telescope (SPT)**

The SPT is a dedicated 10-meter telescope optimized for the observation of low surface brightness phenomena such as CMB anisotropy. The primary mirror is an off-axis, classical Gregorian design which gives a wide diffraction-limited field of view, low scattering, and high efficiency with no blockage of the primary aperture. It is located at the Amundsen-Scott South Pole station to take advantage of the transparent and exceedingly stable atmosphere found there [1]. The telescope provides a 12 FWHM beamwidth at  $\lambda = 2$  mm with a conservative illumination of the inner 8 meters of the telescope, enabling CMB anisotropy measurements to multipoles of 10,000. With a  $< 1$  deg<sup>2</sup> diffraction-limited field of view at  $\lambda = 2$  mm, the SPT is capable of supporting cameras with several thousand detectors. The current camera is a 960 element (non-polarization-sensitive) TES bolometer array built at U.C. Berkeley. It is currently being used to measure fine-angular scale CMB anisotropy and to conduct a 2500 square degree SZ survey for the SPT-SZE dark energy program. The (thermal) SZ effect is a small spectral distortion of the CMB caused by the inverse Compton scattering of the background photons off the hot (10 keV) intracluster gas of clusters of galaxies, the largest gravitationally bound objects in the universe. The beauty of the SZ effect is that its observed brightness is independent of distance. To first order, the SZ-survey therefore produces a distance independent, mass-limited cluster catalog, which can be used to place constraints on dark energy through its impact on the growth of structure.

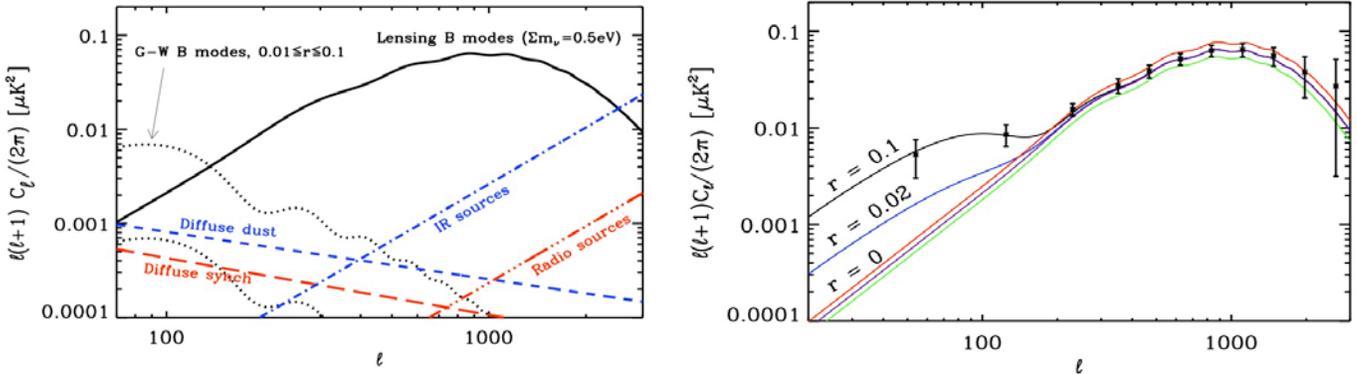
Over the FY08-FY10 time period the SPT has been carrying out the SZ-cluster survey of the SPT-SZE dark energy program. Over 2500 square degrees to full survey depth will be completed by November 2011, at which time the SPT-POL receiver will be deployed on the telescope. The first publications from the SPT-SZE program present results from 5 - 10% of the full survey, and are already having substantial impact. The analysis of the full survey promises strong constraints on the nature of dark energy, especially when jointly analyzed with DES data. The SPT-SZE results to date include the first detection of galaxy clusters via the SZ effect [2], the first SZ-cluster catalog and cosmological constraints [3], and the first detection of secondary CMB anisotropy from the integrated thermal SZ effect and its constraint on the normalization of the matter spectrum,  $\sigma_8$  [4]. The full list of SPT science and technical papers is given at the end of this section.



**Figure 3D-1:** Left panel: the 10 meter South Pole Telescope and laboratory building located 1 km from the geographic south pole. The cone emerging from the roof of the laboratory building houses the BICEP degree-scale CMB polarization experiment. The complementary SPT and BICEP experiments will target the same patch of sky 24/7/52. Right panel: The SPT-SZE receiver being fitted on the SPT optics cryostat that houses the 1-m cooled (10K) secondary mirror. Here the telescope is positioned so that the receiver cabin is docked against a portion of the laboratory roof that opens to provide warm access to the telescope and a high-bay work area.

The goal of the SPT-POL program is to detect and characterize the CMB B-mode polarization to probe inflationary physics and to determine the masses of the neutrinos. There are two sources of B-mode polarization in the CMB. The first source is gravitational waves produced at the end of the inflationary epoch. These metric perturbations produce an angular B-mode power spectrum that peaks near multipoles  $\sim 100$ . The amplitude of this signal is a measure of the tensor-to-scalar ratio,  $r$ , which is directly related to the energy scale of inflation. As such, the measurement of the inflationary B-mode signal would not only validate the inflationary paradigm, but also constrains the physics of inflationary processes. At higher angular scales, B-modes are also sourced by the gravitational lensing of the intrinsic CMB E-mode spectrum. This signal peaks near multipoles  $\sim 1000$ . Since it is a measure of structure growth it can be used to constrain the sum of the neutrino masses. Both of these signals have yet to be detected.

The B-mode measurements require a leap in sensitivity over current CMB polarization measurements, and a corresponding increase in control of systematic effects. To date, several experiments have reported detections of the predicted E-mode polarization with properties consistent with the concordant  $\Lambda$ CDM model [5] [6] [7] [8] [9] [10] [11] [12]. Although no B-mode polarization has been detected, there has been rapid progress in sensitivity and the South Pole instruments QUAD and BICEP have obtained the best limits [11] [12], respectively; BICEP reports the most significant constraints on the inflationary gravity wave B-modes and set an upper limit of  $r < 0.7$  [12].



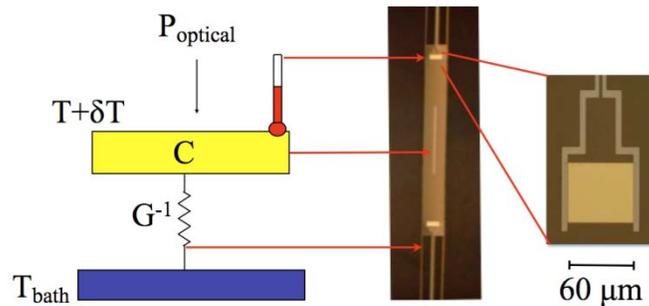
**Figure 3D-2: Left:** Projections for B-mode angular power spectra of polarized CMB, polarized diffuse foregrounds, and polarized point-source foregrounds. **Right:** B-mode power spectra (mean and scatter) from Monte-Carlo simulations of a  $625 \text{ deg}^2$  field with three seasons observations with the initial SPT-POL focal plane array. The simulations include  $1/f$  noise, foregrounds and foreground removal, and E/B separation. The errors, even in the lowest multipole bin, do not increase significantly even upon doubling the assumed  $1/f$  frequency to 0.1 Hz. Theory spectra shown are as follows:  $r = 0.1, \Sigma m_\nu = 0.5\text{eV}$  (black line);  $r = 0.02, \Sigma m_\nu = 0.5\text{eV}$  (blue line);  $r = 0, \Sigma m_\nu = 0\text{eV}$  (red line);  $r = 0, \Sigma m_\nu = 0.5\text{eV}$  (purple line);  $r = 0, \Sigma m_\nu = 1.0\text{eV}$  (green line); The SPT-POL 3-year sensitivity in the foreground-removed maps is such that a simultaneous fit to a gravitational-wave spectrum and a lensing spectrum produces a constraint of  $\sigma(\Sigma m_\nu) = 0.17\text{eV}$  and a  $2\sigma$  detection limit of  $r = 0.028$  (for a fiducial model with  $r = 0$  and  $\Sigma m_\nu = 0.5\text{eV}$ ). Note that precision on  $r$  will increase linearly with integration time.

There are a variety of other ground-based and balloon-borne instruments under construction that target measurements of B-mode polarization; these are discussed in the CMBpol Mission Concept Study [13], a community science white paper written to provide input to the 2010 Astronomy & Astrophysics Decadal Survey. That white paper and the previous CMB Task Force Report stressed the importance of using multiple technologies and techniques to search for the B-mode signals. SPT has several unique features that make it a valuable platform to use for this program: the large 10-meter diameter aperture provides a high resolution  $\sim 1'$  which reduces polarization systematics and aids E/B separation. Furthermore, the South Pole site offers 24 hour availability, 365 days a year, of an extremely low foreground region of the sky through a highly transparent and stable atmosphere.

Several bolometer-based polarimeter technologies are being pursued by other teams. These include the lenslet coupled antenna of POLARBEAR [14] and the phased-array antenna of BICEP2/KECK [15] [16]. The first focal plane for SPT-POL uses proven feedhorns to ensure clean, symmetric beams and standard single-moded waveguide coupling to ensure high optical efficiency. This approach is a viable and valuable member of the suite of technologies being explored for the current generation of CMB polarization measurements, and is first step toward meeting the challenge of future focal plane arrays with  $10^4$  to  $10^5$  or more detectors.

The BICEP2/KECK project is especially complementary to SPT-POL. They also will observe from the South Pole, but with an angular resolution of  $< 1$  degree. SPT, BICEP2/KECK (and in the future POLAR) are targeting the same low-foreground patch of sky. The datasets will provide valuable crosschecks, and the joint analysis of the data sets will allow much tighter constraints. For example, with its much higher angular resolution, SPT-POL will measure the lensing B-modes that, in addition to constraining the neutrino masses, will provide higher sensitivity to the inflationary B-modes by enabling the “delensing” of the angular power spectrum. The highest multipoles measured by SPT-POL will provide a detailed understanding of potential point source contamination for this patch of sky.

The projected constraints for SPT-POL after three years are shown in Figure 3D-2. While achieving these constraints will be a major step forward, our goal is to upgrade the focal plane considerably by developing the next generation polarization-sensitive bolometric focal planes at Argonne to increase the pixel count and incorporate multi-frequency band pixels.



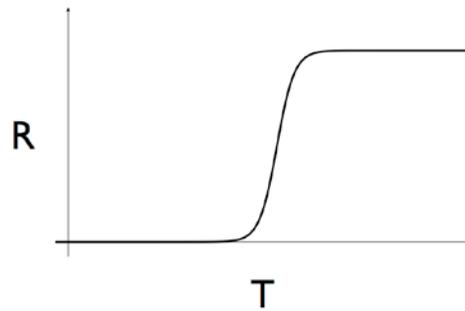
**Figure 3D-3:** Left: Schematic of a bolometer illustrating the thermalization of optical power by a weakly heat sunk thermal mass. The resulting temperature change is measured by a TES. Center and right: images of an Argonne-KICP polarization sensitive TES bolometer. The entire bolometer (center) is fabricated on a micro-machined silicon nitride microbridge. The sensitivity of the detector is determined by careful tuning of the thermal conductance along the legs of the bridge. The bolometer couples to and thermalizes radiation of a single polarization through a dipole absorber in the center of the bridge. The change in temperature arising from changes in the absorbed radiative power are measured by a Transition Edge Sensor thermometer (right) consisting of a Mo (23 nm-thick) and Au (30 nm-thick) bilayer.

### Argonne CMB Detector Development

In addition to the deployment and analysis of SPT-SZE, the Argonne CMB group has utilized an LDRD funded detector development effort to cultivate the expertise and partnerships needed for fabricating the next generation of detector arrays required for CMB polarization studies. This effort has resulted in a novel TES bolometer architecture that we have fabricated at Argonne [17] [18] [19] [20]. The initial prototype detectors demonstrate excellent performance for CMB polarization measurements. We plan to provide the 90 GHz detectors for the upcoming SPT-POL experiment to be deployed in November 2011.

As current CMB bolometric detectors are background limited, further improvements in sensitivity are achievable only through substantial increases in the number of detectors and frequency-bands. For the spectral ranges of interest, Transition Edge Sensor (TES) bolometers [21] are the favored technology due to their excellent noise performance and potential for integration into large arrays.

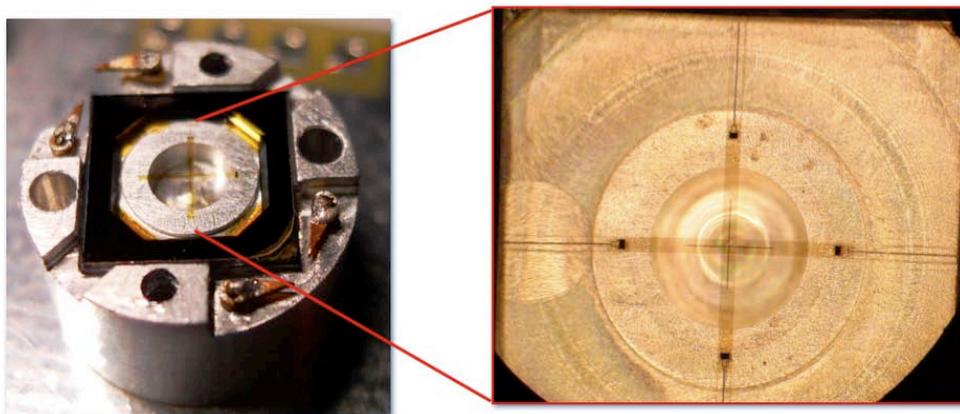
A bolometer is a miniature device composed of sub-structures performing three key functions as illustrated in the left panel of Figure 3D-3, 1) thermalization of the input energy, 2) measurement of the temperature change due to the input energy, and 3) thermal isolation and mechanical support of the measurement structures. The sensor can be efficiently coupled to the incoming radiation through one of four main schemes: an absorber with a broadband match to the impedance of free space, quarter-wave resonant cavities, feedhorns, and planar antennas [22].



**Figure 3D-4:** Illustration of a TES resistance vs. temperature curve. Near the critical temperature,  $T_c$ , a small increase (decrease) in the detector temperature results in a large increase (decrease) in the detector resistance. When operated under a voltage bias, this resulting change in Joule heating opposes the initial temperature perturbation establishing a strong negative electro-thermal feedback.

In a TES bolometer, the coupled radiation heats a thermal mass and the change in temperature is measured by a TES operating under strong electro-thermal feedback [23]. A TES sensor consists of a superconducting film weakly heat sunk to a thermal bath. The film is biased such that the Joule heating from the bias maintains the film in its normal-to-superconducting transition. In this state, a small change in the film temperature leads to a large change in the film resistance (Figure 3D-4). By operating the TES under a voltage bias, a negative (electro-thermal) feedback loop is established where the gain depends on the parameter  $\alpha = d\text{Log}R/d\text{Log}T$ , a dimensionless measure of the steepness of the film's transition. For typical TES detectors,  $\alpha$  is around 1000 making the feedback strong. As with all negative feedback loops, this strong electro-thermal feedback increases the detector bandwidth and linearizes the bolometer response when compared to semiconductor bolometers of similar sensitivity.

The TES is a low impedance ( $\leq 1$  ohm) device and is typically readout using low noise DC SQUID amplifiers. SQUIDs have a large noise margin over that of the background limited TES bolometer enabling the use of multiplexing where multiple TES devices are readout by a single SQUID amplifier [24]. Multiplexed pixel readout is critical for realizing large format focal planes.



**Figure 3D-5:** Images of an Argonne-KICP polarization sensitive TES bolometer. The bolometer consists of two crossed dipole absorbers suspended across circular waveguide above a quarter wave backshort. Left: a photo of a single pixel pair. Right: close-up showing the crossed absorbers, silicon nitride microbridges, and TES detectors.

For our prototype devices (see Figure 3D-5), light is coupled from the telescope into a single-moded circular waveguide using a profiled feedhorn. A single linear polarization is absorbed on a lossy gold resonator mounted in the waveguide a quarter-wave in front of the backshort. A pair of two resonators oriented at 90 degrees relative to each other provides simultaneous measurements of both linear polarization states. These resonators are suspended on individual silicon nitride membranes separated by 20  $\mu\text{m}$  and spanning the waveguide. A waveguide choke consisting of a quarter wave-length wide circular boss reduces leakage through the break in the guide to less than 1%. The thermal sensor is a TES consisting of a bilayer of Mo (23 nm-thick) and Au (30 nm-thick), where the thickness of the two layers is tuned to achieve an optimal transition temperature (480 mK). The optical performance of this architecture has been measured to be excellent with greater than 90% coupling and less than 1% cross-polar contamination.



**Figure 3D-6:** Left: Argonne Center for Nanoscale Materials. Right: Dedicated Magneton sputtering system for cryogenic detectors at Argonne's Materials Science Division.

The successful development of the Argonne detector is the result of two strategic partnerships. The first partnership is between HEP and the Argonne Material Sciences Division (MSD). Our collaborators at MSD possess the exact set of skills required for fabricating TES bolometers, including expertise and experience with thin-film deposition, bi-layers and micro-machining. Moreover, Argonne-MSD has a dedicated deposition system for cryogenic detectors and access to the required fabrication tools and facilities through the Argonne Center for Nanoscale Materials (CNM) shown in Figure 3D-6. Our detector development efforts over FY08 - FY10 have established a healthy working relationship with MSD together with the in-house knowledge base and tooling needed for detector fabrication. Of equal importance to the success of the detector effort are the university partnerships that have grown out of this strategic initiative. Specifically, Argonne is actively collaborating with university partners at the University of Chicago, U.C. Berkeley, Case Western Reserve, University of Colorado at Boulder, McGill University, and the University of Michigan. The university collaborators provide computer modeling of the detectors, cryogenic testing and characterization of fabricated devices, and digital multiplexing readout electronics.

In summary, we have established a fertile collaboration bringing together the expertise in micro-fabrication and thin-film growth technologies at the Materials Science Division at Argonne, and the expertise in the physics of low-noise and low-temperature detectors at our partner universities. This collaboration has developed a new TES bolometer capability with excellent demonstrated performance that will be integrated into the upcoming SPT-POL experiment. Our future development efforts will be focused on increasing sensitivity through larger, multi-chroic focal plane arrays and new multiplexing readout technologies.

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## **Proposed Research for FY11 – FY13**

### **4.A. Overview of ANL proposed research**

The Argonne non-accelerator proposed research program funded by B&R code KA-13 consists of two components: 1) an astrophysics part and 2) work on the Double Chooz (DC) reactor neutrino experiment.

The proposed astrophysics program includes the programs in High Energy Cosmic Particles and Dark Energy and Cosmology which we were already involved with. We also propose a new program in CMB science which includes a new unique sensor development capability at Argonne aimed at developing new, more sensitive sensors for future CMB polarization science. In the remainder of this section, we describe our proposed program for FY11-FY13 and beyond.

## 4.B. Dark Energy and Cosmology

### 4.B.1. Supernova Science and New Junior Staff Position

At the current level of precision in supernova science, there are nagging questions that need to be addressed before progressing to the next level can be considered. These include dust effects and SN color fluctuations, SN evolution including galaxy correlations, differences between the MLCS and SALT light-curve fitter results, uncertainties in the measured UV end of the SN spectrum, and the lack of a detailed understanding of how the explosion proceeds and the correlation with SN brightness and fluctuations.

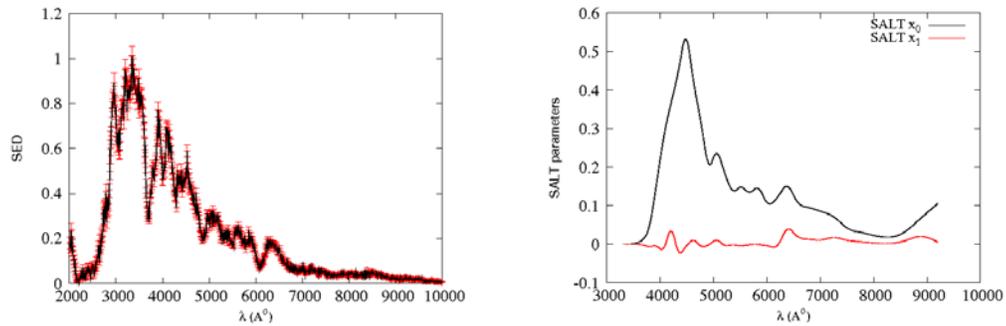
Argonne's cosmology group has positioned itself to play a major role in addressing these questions in the next three years, as detailed below, but will need additional manpower to fully take advantage of this position. With only 1.2 FTE senior staff and 1 post-doc devoted to supernova science, plus the departure of Bernstein in FY12 when his computational fellowship ends, we propose to start a new junior staff position in FY12 devoted to supernova science. This position would include supercomputer modeling of SN and their connections to data, and would keep Argonne's supernova group in a very strong position into the LSST era. In addition, we request 0.3FTE of a senior staff member currently working in Nuclear Physics (H. Spinka, current DES member).

Argonne's position in supernova science related to the major questions listed above:

- ❖ Leading role in SALT light-curve fitter retraining.
  - ANL post-doc Rahul Biswas and UPenn post-doc Jennifer Mosher are the majority of the manpower in this project.
  - Joint SDSS-SNLS/SALT international project.
  - Will address the MLCS and SALT discrepancies.
  - Will also provide new and critical information about the UV end of the spectrum.
  - Comparing SDSS and SNLS is already providing new information about dust and SN color fluctuations.
- ❖ SDSS and DES SN leading members.
  - Large and precise data sets for studying SN evolution and galaxy correlations, as well as dust effects and color fluctuations.
  - Comparing SDSS low redshift data with DES medium redshift provides information about the UV end of the spectrum.
- ❖ Connections to supercomputer modeling groups and resources.
  - First comparisons between simulated explosions and data the result of joint ANL/FNAL/UC proposal of which ANL was the lead author.
  - Scaling tests of radiative transfer code using up to 130K processors performed at ANL by Bernstein.
  - LDRD proposal to ANL for development of non-local thermal equilibrium software to take the radiative transfer code to the next level.

### SALT light-curve fitter retraining

The SDSS and SNLS/SALT groups have agreed to work together to retrain the SALT light-curve fitting using their final data sets. As mentioned above, this initiative will play a critical role in supernova science for many years to come. Argonne committed to play a major role in this project, and when Rahul Biswas joined ANL in August as a post-doc this immediately became his highest priority. Biswas and Jennifer Mosher, a post-doc at UPenn, form the majority of the manpower available for this retraining. Figure 4B-1 shows examples of a spectrum that could be used for training, as well as the results of training on that spectrum. The retraining program should be complete before the DES supernova survey begins.



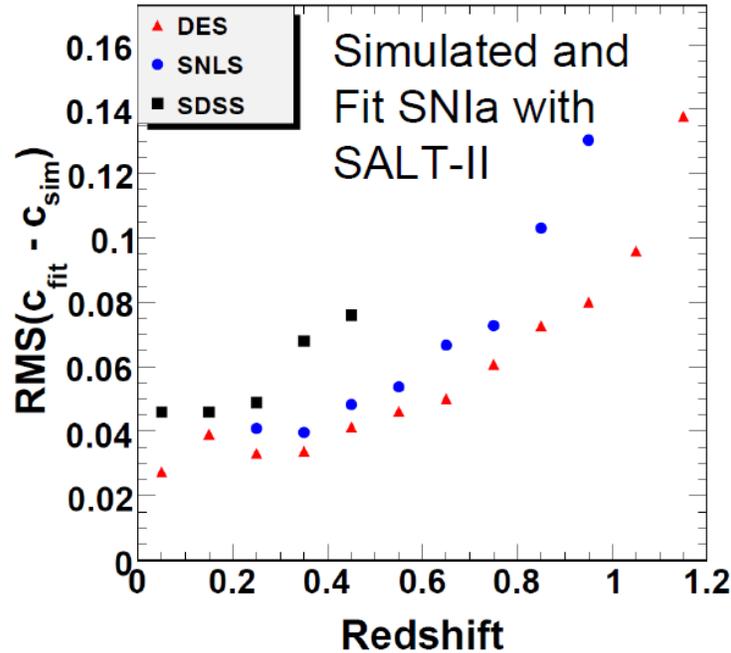
**Figure 4B-1: (left)** Example SN Ia spectrum being used to test the SALT training software. This spectra is the result of a simulated Ia explosion, not data. SDSS measured spectra are currently being implemented in the training program.

**Figure 4B-1: (right):** SALT luminosity and stretch parameters as a function of wavelength after training on example spectra.

### DES Supernova Survey Optimization and First Results

Argonne has led the planning for the DES supernova survey for more than two years, but this optimization and planning will continue through the first full year of data in 2012. Recent work on measuring supernova colors has indicated some changes in the survey cadence may be desirable. Figure 4B-2 shows a comparison of the precision in measuring the SALT SN color parameter “c” for the SDSS, SNLS, and DES surveys. DES, with its x4 more red-sensitive CCDs in the z band and deep exposures, can measure SN colors better than the previous surveys. This color determination would be improved with consistent measurements on the same day of the r and z filters, which is not currently part of our cadence requirement. Another example of continued optimization is the area of the “shallow” part of the DES hybrid survey. Increasing that area gives a lower redshift supernova that can be followed up with spectra. These kinds of studies are continuing.

In addition to continued refinement of basic survey parameters, there are many other tasks to complete for an effective supernova survey. The data processing in the DES supernova pipeline needs considerable testing and debugging as transients begin to be recorded in DES data. Proposals for the use of community time and spectral use follow-up need to be written for an effective survey. These kinds of activities will dominate our group’s activities in 2011/2012.



**Figure 4B-2:** Comparison of the RMS of the SALT color parameter “c” for 3 different simulated surveys, SDSS, SNLS, DES. The DES with its x4 more sensitive CCDs in the z band, as well as deep exposures, can improve the determination of supernova colors, a key component in constraining dust effects.

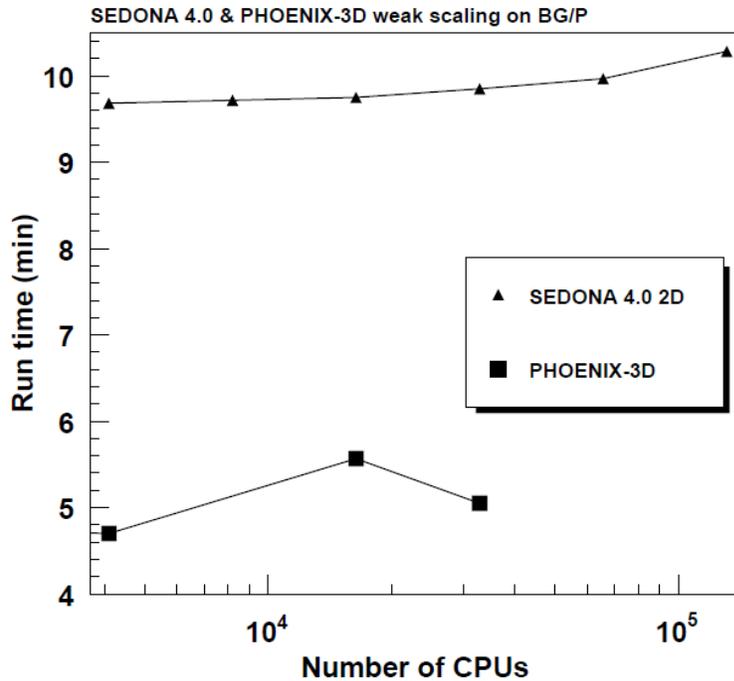
### **Supernova Explosion Simulations and Data: The Next Level**

The theoretical approach to interpreting observational SN Ia data involves two main stages: the explosion phase (hydrodynamics + nuclear synthesis), and the free expansion phase involving radiative transfer (*RT*). In the past decade, much effort has been put into the development of highly sophisticated hydrodynamical models, with which the Argonne – University of Chicago collaboration has successfully reached a world leading position. *RT* modeling has also been pursued. Work has been performed with two *RT* codes, PHOENIX-3D and SEDONA, which are both capable of processing SN remnants in detail.

PHOENIX-3D and SEDONA have both been successfully tested on the Argonne Blue Gene/P (*BG/P*) up to 32K and 131K CPUs, respectively (Figure 4B-3). External collaborators Daan van Rossum and Eddie Baron, who provided key input for this proposal, are PHOENIX-3D developers. Progressing the understanding of SN Ia systematics calls for large scale simulations requiring an increase in realism via a multi-Dimensional (multi-D) *RT* treatment that moves away from the assumption of local thermal equilibrium (*LTE*). The computational resources required, e.g., on the order of a few terabytes of memory, necessitate the utilization of high performance machines. With upcoming computer architectures, the limits discussed above could be removed. However, multi-D *RT* simulations are not easily pursued on machines that are compute-optimized. In the non-*LTE* *RT* treatment, the physical states at different spatial points depend on each other, which significantly complicates parallelization. Regardless, non-*LTE* calculations are a major source of computational expense. Thus, the creation of an efficient, parallel non-*LTE* solver is a necessary first step to produce a multi-D *RT* code that is optimized for the *BG/P* and can be scaled to future leadership architectures. Therefore, a primary goal of the proposed work is the creation of a highly parallelized,

non-LTE library, which will have wide application in the physical and material sciences. Argonne is an ideal site for the proposed research given the presence of SN Ia astrophysics (explosion hydrodynamics, nuclear synthesis, RT) experts, computer professionals, and the BG/P.

To the best of our knowledge, the proposed research represents a unique United States effort. related work outside of the U.S. includes that of Markus Kromer and collaborators at the Max Planck Institut and Keiichi Maeda and collaborators at the University of Tokyo and National Astronomical Observatory of Japan.



**Figure 4B-3:** PHOENIX-3D & SEDONA weak scaling on ANL Blue Gene/P. The PHOENIX-3D calculations were performed by D. van Rossum. The parallelization was done over characteristic rays used to sample the radiation field in the atmosphere. The number of rays increases quadratically with angular resolution. The SEDONA calculation was of the spectrum for a 2D FLASH model produced by G. Jordan. D. Kasen calculated the spectrum for a spatial resolution of 128x64 in cylindrical coordinates, velocity resolution of 390 km/s, and wavelength resolution of 40 angstroms. For the scaling test, the load was such that each CPU was assigned a self contained calculation. Bernstein selected a load of 4000 photons per CPU and performed the scaling runs.

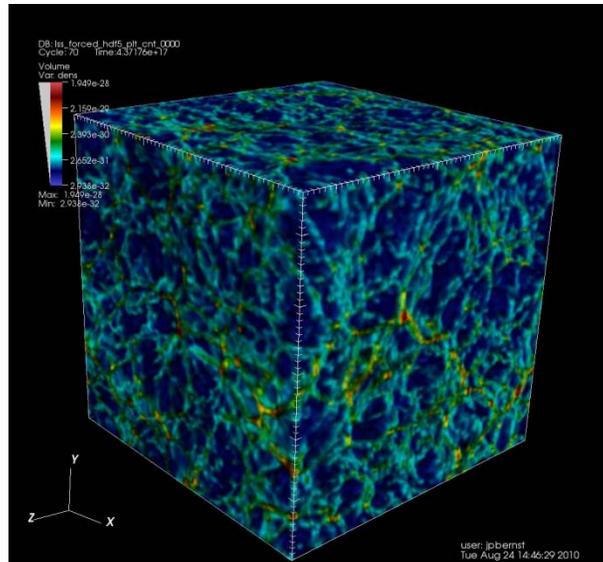
#### 4.B.2. Computational Cosmology

Current and future precision predictions and analyses from cosmological probes must rely on numerical simulations and the systematic error budget will very soon be dominated by theoretical uncertainties. Reducing these uncertainties depends critically on producing more realistic and detailed numerical simulations. To address the need for high-accuracy theoretical predictions demanded by future observations, we are engaged in efforts to create a new suite of high-resolution simulations following the growth of cosmic structures through gravitational instability in different cosmological models. These simulations will have a dynamical range sufficient to replicate the statistics of the forthcoming surveys while simultaneously capturing the internal structure of galaxy clusters. These simulations are extremely taxing on computational power and memory and will require resources at a level appropriate to a DOE

INCITE award. The near term goal of J. Bernstein's research as ANL computational fellow is the production of a competitive computational cosmology INCITE proposal.

In addition, Argonne is pursuing the hiring of two prominent computational cosmologists as part of a three-year seed program to enhance the scientific use and output of Argonne Leadership Computing facilities. If these hires are successful, Argonne will instantly become a significant center for computational cosmology.

Our computational cosmology studies will require hydrodynamic+N-body simulations with a minimum of a 1 Gpc ( $1 \text{ pc} = 3.09 \times 10^{16} \text{ m}$ ) box size,  $2048^3$  hydrodynamic cells, and  $10^{11}$  dark matter particles. These requirements push the limits of existing codes. We are participating in and facilitating science runs with the FLASH code cosmology module in order to produce the required simulations. Prof. Paul Ricker (University of Illinois) is involved with the DES Simulations Working Group and, along with Boyana Norris of the ANL MCS Division, is pursuing improved performance of the FLASH cosmology module on the ANL Blue Gene/P. We are collaborating with Prof. Ricker on enabling production FLASH cosmology BG/P runs. To date, we have successfully produced hydrodynamics-enabled test simulations with  $512^3$  dark matter particles and 6 levels of spatial refinement (see Figure 4B-4).

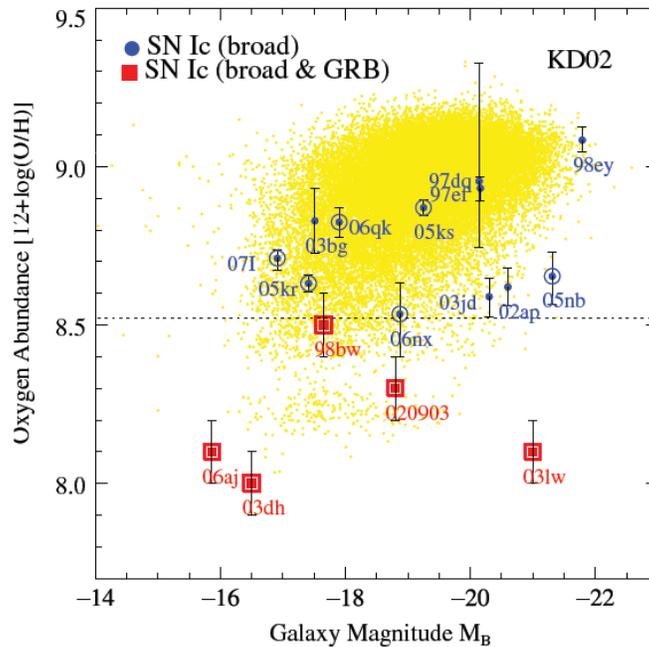


**Figure 4B-4:** A logarithmic visualization of the mass density at redshift zero for a FLASH N-body + hydrodynamics simulation with  $512^3$  dark matter particles and 6 levels of spatial refinement run on the ANL Blue Gene/P supercomputer.

### DES study of Gamma Ray Bursts & Supernova connection

DES can contribute to our knowledge of Gamma Ray Bursts (GRBs), as well as the connection with core collapse supernovae. Figure 4B-5 shows the metallicity and luminosity differences between galaxy hosts of Type Ic Supernovae with and without associated GRBs. The yellow points are the metallicity vs. luminosity of nearby galaxies observed by SDSS. The observed connection between some core-collapse SNe and GRBs (along with their clear differences) provides information on the possible progenitor environments and energy generation mechanisms of these explosive transient events.

Argonne post-doc Kyler Kuehn has considerable GRB experience and is interested in using DES capabilities to further our understanding of GRBs and the SN connection. DES will have “pre-discovery” images of 1/8 of the entire sky within its first year of operation. When any GRB is detected within the DES footprint, we will be able to publish information of that region in near-real-time, including potential host galaxy morphology, metallicity and other characteristics. In addition, DES is positioned to contribute useful information to the GRB community via host galaxy “follow-up” observations, even after the initial GRB transient has faded.



**Figure 4B-5:** Plot from Modjaz et al. (AJ 135:1136-1150 2008), comparing SN Ic galaxy properties with and without a GRB detection. (see text)

#### **4.C. High-energy Cosmic Particles (Very High Energy Gamma-rays)**

##### **VERITAS (2011-2013)**

Argonne will continue as a collaborating member of the VERITAS experiment. Our main science interest will continue to be focused on the indirect dark matter search. In addition to analysis of observations of dwarf spheroidal galaxies, VERITAS plans a continuing program of observation near the Milky Way Galactic Center. While the Galactic Center would be expected to provide the largest dark matter annihilation signal, it also contains many “conventional” VHE background sources. The Argonne group will contribute to the development of analysis techniques for the Galactic Center as well as help to refine the observation program, for example, by including observations slightly off the Galactic plane where the background may fall much faster than a potential dark matter signal. VERITAS observations of flaring blazars also represent an opportunity to address an aspect of quantum gravity: possible Lorentz Invariance violation (LIV). The sensitivity to gamma-rays over several orders of magnitude in energy allows us to search for possible dependence of the speed of propagation of gamma-rays on their energy. Such dependence is a feature of some models of quantum gravity. The default explanation of any difference in arrival time of gamma rays versus energy from a given blazar would simply be due to details of production. However, since AGN flux changes during flaring occur on the order of minutes, these observations permit some constraint on differences due to production as opposed to propagation. Observation of many AGN flares at a range of redshifts would be required to disentangle LIV from production should the former phenomenon actually exist.

Pushing VERITAS sensitivity to lower energy will greatly aid either of the two above science studies. In the case of dark matter, the expected astrophysical flux continues to rise markedly with lower energy even for TeV range WIMP masses. For AGN observations, a lower energy threshold translates into the ability to observe to larger redshifts where any LIV signal would be correspondingly more pronounced. The ability of VERITAS to collect data at low energy will be greatly aided by the new Level-2 trigger system Argonne will deliver in FY2011. The system will be installed in VERITAS and commissioned into FY12. We will provide the long-term maintenance of this system for the duration of the experiment. Within VERITAS, the DOE institutions plan to submit a supplemental upgrade proposal to DOE (Washington University is PI) later this fall. Within this proposal, ANL and Iowa State University will apply for funds to add a Level-4 topological trigger. All the hooks are in place in the upgraded Level-2 trigger to add such a topological trigger capable of making fast intelligent real time decisions. This will allow not only lower energy threshold but permit a much cleaner sample of gamma-ray data to be recorded by VERITAS.

##### **Scientific Leadership in data calibration, analysis and interpretation**

ANL is continuing to establish scientific leadership in the field of very high-energy gamma-ray astroparticle physics focusing on fundamental physics topics like Dark Matter. We have been active in leading the Dark Matter Science Working Group within VERITAS. To take advantage of the VERITAS data and for a continued scientific program, one postdoctoral research FTE/year is requested starting in FY11. This pd would spend half of their time leading the upgraded Level-2 trigger which we are responsible for delivering to the experiment in FY11.

*Year-2011-2013:*

Continued science program in High Energy Cosmic Particles

### **Topological Trigger R&D -Funded by Detector R&D Funds & KA-13**

This R&D has focused on applying particle-physics detection techniques to develop a fast pattern trigger for real time analysis of nanosecond time scale phenomena to particle astrophysics experiments. This research is partially funded through the Detector R&D program. In FY11, Argonne will deliver a new Level-2 trigger system, which will be installed and commissioned into FY12.

*Year-2011:*

Completion of a proof-of-principle topological trigger demonstrator that operated at an order of magnitude higher clock frequency than previous accelerator based pattern trigger.

*Year 2012-2013:*

Design, build and deliver a new Level-4 topological trigger system that both connects to the upgraded VERITAS Level-2 trigger and is a path towards building an ultra fast real time trigger for CTA.

### **CTA(2011-2013)**

Continued VHE gamma ray studies and discoveries will require a new generation of ground-based observatories to be constructed during the next decade. The next generation of telescopes will need to achieve an order of magnitude better sensitivity than today's instruments so as to push the energy threshold lower, extend the redshift (distance) of observations, and provide a more complete survey of the sky. This level of sensitivity can already be achieved by a much larger deployment (of order 100 telescopes) using the current instruments. However R&D in key technologies could have a large impact on cost effectiveness as well as improved sensitivity. Extending the imaging atmospheric Cherenkov technique into the sub-100 GeV energy regime and/or the development of a wide field of view instrument could broaden its scientific purpose tremendously.

Recent National Research Council (NRC) and Federal Advisory Committee Reports have provided guidance to the Office of Science DOE HEP and to NSF Physics and Astronomy programs. In October 2009, the Particle Astrophysics Science Assessment Group (PASAG), a HEPAP subpanel, recommended an optimum program that addresses the highest priority science in particle astrophysics within different funding envelopes, as well as provided prioritization criteria for HEP involvement. The NRCs Decadal Survey of Astronomy and Astrophysics (ASTRO2010) report, released in September 2010, recommended priorities for the next decade. Both of these reports have given high priority to a next-generation ground based gamma-ray observatory such as CTA based on the scientific opportunities and the discovery potential. Both reports strongly endorsed funding in the US for a future ground based gamma-ray program (in the case of Astro2010, at the \$100M level over the next decade) assuming that NSF physics, NSF astronomy and DOE-HEP participate at roughly equal levels in the CTA project. In all funding scenarios, the PASAG strongly recommended timely upgrades to the existing VERITAS instrument.

As already described in the progress report section, the AGIS US group has recently joined the CTA (ANL was already member of CTA). The US group is currently defining a CTA-US role based on developing a mid-sized, wide-field-of-view Schwarzschild-Couder telescope, which would provide

enhanced performance capabilities over the traditional Davies-Cotton telescopes. There are currently about 20 research groups including two national laboratories which comprise CTA-US.

Argonne's interest in a next generation ground based gamma ray instrument like CTA is a natural extension to our current involvement with VERITAS. Two national labs, Argonne and SLAC are actively pursuing the design and R&D work for CTA. Both Argonne and SLAC have played complementary leading roles in the technology development. At ANL, we are leading international efforts devoted to the mechanical design of telescopes (both novel and traditional) while SLAC is leading the development of a very low-cost, analog pipeline electronics that offer the potential advantage of larger-scale integration and deeper memory than the electronics designs currently under study by the European CTA groups.

The ANL group has been collaborating with DESY Zeuthen for about 2 years and during the past year, with Saclay on the mechanical design of a 12 m Davies-Cotton telescope for CTA. Our design is now the baseline CTA mid-size telescope. Within the US, we have been collaborating with UCLA, completing a conceptual design of a novel 2-mirror telescope. The ANL group is also contributing on technology R&D in other areas as well. As we discussed previously, we are leading the design and development of a fast intelligent trigger in collaboration with Iowa State. Argonne HEP scientists are also leading the development of new large area micro-channel plate photodetectors. This R&D is ARRA funded; Washington University collaborates with us on the photocathode R&D. We have also been involved with focal plane R&D using photo-detectors like SiPMs (in collaboration with Santa Cruz).

The CTA is currently in a preparatory phase from 2010 – 2013. This is supported by an FP7 grant for over 5.2M euros from the European community. The main goals of this phase are i) to perform a cost optimization of the telescope components, ii) improvement of the reliability of telescope components requiring extensive prototyping, iii) to establish the formal framework to build and operate the instrument, and iv) funding of the infrastructure. The construction of the array is intended to be from 2014-2018. CTA will start to construct a first mid-sized telescope prototype in 2011 with Argonne playing a leading role in this construction.

The CTA-US group is in the process of negotiating with the CTA management a US role in light of the Astro2010 recommendations. The US group will submit an R&D proposal jointly to NSF and DOE. In this proposal, CTA-US would perform R&D work and begin prototype construction of a SC telescope within 3-4 year timescale which would put the US on a trajectory to significantly contribute to the construction and eventual science of the CTA observatory. A branch point in the US ground based gamma-ray program would be on the timescale of 2013-2014 once the US group has built and tested a novel mid-sized telescope employing secondary optics. At this point, a final decision on US contributions and future roles to the CTA array would be made.

### **Telescope Design - Funded by CTA-US R&D proposal and other external sources**

At ANL, we are already leading international efforts devoted to the mechanical design of both traditional and novel telescopes. This is evidenced by our collaborative work with DESY Zeuthen and Saclay on a 12m Davies-Cotton telescope for CTA and by our work with UCLA on a SC 9m novel design. For the DC design, Argonne is contributing the design of the optical support structure, DESY

Zeuthen contributing the drive system, DESY Hamburg contributing the telescope pedestal and Saclay contributing the octapod to the camera. ANL is currently creating fabrication drawings for the prototype telescope that DESY and ANL will be constructing in Berlin next summer. ANL will supervise the construction of the prototype structure in Germany which is also being funded by DESY.

*Year-2011 Goals:*

- a. Complete the design a 9 meter SC telescope optical support system based on our previous conceptual design.
- b. Complete the design for a 12 meter DC telescope optical support system.
- c. Construct a quarter dish of a 12 meter DC telescope at Argonne

*Year-2012 Goals:*

- d. Construct a prototype a 12 meter DC telescope
- e. Construct a 9 meter SC prototype

**Summary**

In conclusion, the current FY10 VERITAS/CTA effort funded out of KA-13 is 1.2 FTE staff. To maintain a scientific program in VERITAS and take advantage of the data now coming out, we request the addition of 1 FTE postdoctoral candidate per year starting in FY11. This postdoctoral candidate would also lead the installation and commissioning of the VERITAS upgraded Level-2 trigger which we are responsible for delivering. If DOE commits to CTA, we request 1 FTE of mechanical engineering per year starting in FY11 (and ending once CTA gets CD0). This request will be included in the joint R&D proposal that the CTA-US is submitting to the agencies. SLAC will be the PI for the DOE proposal.). Starting in FY12, we would request 1 new staff and 1 new postdoctoral candidate to work on CTA and position us to have a lead role. This request would start half way through FY12. This would bring the ANL VERITAS/CTA effort to a level of 4 FTEs total by 2013 plus 1FTE of engineering supported out of the R&D proposal.

**References**

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## 4.D. Neutrino Masses and Mixing

### Future plans

The next three years will be the most fruitful ones for the Double Chooz experiment, as the first results are obtained, first with just the far detector, and then with both detectors. New world's best sensitivity on  $\theta_{13}$  will be possible in just a few months. With the far detector only, we expect to reach a sensitivity  $\sin^2 2\theta_{13} < 0.06$  in 15 months. When the near detector is added, we will reach 0.03 in just over three years.

In the six weeks starting September 2010, ANL collaborators will help with the detector filling. As the neutrino data-taking starts at the end of this calendar year, the ANL Double Chooz collaborators will be deeply involved in calibration, operations and analysis. The calibration devices that have been constructed, the z-axis calibration system and the articulated arm, will be installed and used for the crucial understanding of the uniformity and energy scale. The relationship between the artificial calibrations and the cosmic calibrations has been considered in detail and is presented in a document, "The Calibration Plan" which was written by the Double Chooz calibration group [internal documents 684 and 811]. The key short term issue for calibration will be the extent to which the spatial variation of the calibration matches simulations which have already been performed. If the spatial variation is adequately close to the simulations, additional calibrations at more locations will be less important. The other important calibration decision that will have to be made is how frequently the various calibrations will be performed, and whether any time variations in calibration constants can be adequately monitored through cosmic calibrations.

ANL-HEP Double Chooz collaborators are part of a "United Cluster" team for analysis of Double Chooz neutrino data. There is a Common Trunk (CT) of analysis hardware, which will provide neutrino data to each of three analysis clusters. The "United Cluster" consists of the U.S. Double Chooz collaborators, currently Alabama, Argonne, Chicago, Columbia, Davis, Drexel, IIT, Kansas State, Livermore, MIT, Sandia, and Tennessee, together with Sussex in the UK. A copy of the CT data will be kept at ANL for cluster analysis, and the mechanisms for transferring that data will soon be worked out. While one ANL collaborator is a member of the reactor group, the integrated reactor power will be blinded until the first Far Detector only data is accumulated and analyzed. The  $\theta_{13}$  sensitivity will depend on a comparison of the Double Chooz neutrino event rate with the number predicted for a given reactor power by the reactor group.

Midway through the next three year period, Double Chooz' analysis strategy will switch between making an absolute flux prediction to one with a relative flux between the two detectors. Efficiencies and calibration priorities will evolve based on a greater need to understand relative efficiencies and a lower reliance on knowledge of the reactor flux. The analysis strategy, including expected efficiencies, backgrounds, and event rates is given in the proposal [<http://arxiv.org/abs/hep-ex/0606025>].

It would be valuable to have additional manpower in FY11 and 12 while important new data analysis is taking place. A key question for the future of the reactor neutrino community is whether an additional reactor-based experiment more sensitive than Daya Bay makes sense. The planning of the future accelerator-based neutrino program in the U.S. would be impacted by such an experiment, if it were

possible. It would not be prohibitively expensive, but its sensitivity depends on the currently unknown size of cosmogenic and other backgrounds. Daya Bay will have smaller backgrounds, but as a consequence of the reactor configuration, Double Chooz will be able to measure them better. With additional manpower, the ANL-HEP neutrino group is in an excellent position to contribute to this understanding, by combining our cosmic ray simulations and the data from the Double Chooz near and far detectors. The longer term future of Double Chooz depends on the timing and content of its results along with those from Daya Bay, RENO, T2K and NOvA. We are excited to part of this endeavor!

## 4.E. Cosmic Microwave Background

### 4.E.1. Planned activities for FY11 - FY13

There are two objectives for the Argonne CMB thrust in FY11-13. The first objective is the deployment of SPT-POL for which Argonne is responsible for the 90 GHz channel of the focal plane. SPT-POL targets  $r \sim 0.02$  after three years of observations. The second objective is detector research and development for improving focal plane sensitivity by another order of magnitude.

#### SPT-POL

The first objective of the Argonne CMB group is the deployment of SPT-POL and analysis of its initial data. The target SPT-POL deployment is November, 2011 with CMB polarization observations commencing in early 2012. Two copies of the SPT-POL receiver cryostat (similar to the SPT-SZE receiver seen in Figure 3D-1) have been built and are being commissioned at UC-Berkeley and the University of Chicago. A new set of digital multiplexing electronics is being manufactured at McGill University. SPT-POL university collaborators (including UChicago, UC-Berkeley, UC-Boulder, McGill University, Case Western Reserve, and UMichigan) are also responsible for high throughput detector testing and characterization. Argonne is responsible for delivering the detectors for the 90-GHz channel of the SPT-POL focal plane. Analysis of the initial three years of SPT-POL data will place Argonne HEP at the forefront of CMB polarization research. As shown in Figure 3D-2, this first stage of SPT-POL will be sensitive to  $r \sim 0.02$ , more than an order of magnitude better than the current limits. SPT-POL will also clearly detect the lensing of the CMB by large scale structure from which we can improve cosmological constraints on the neutrino masses. Success of SPT-POL will be a significant milestone for the Argonne CMB group demonstrating that the unique skills and resources of the Argonne detector development effort is capable of driving the frontier of CMB polarization measurement.

#### Detector R&D for Increased Sensitivity

Our second objective is technology research and development aimed at developing the next generation of bolometric focal planes for CMB polarization measurements including an upgrade of the SPT-POL detector array. Since current detectors are background limited, the push is for focal planes with increased pixel counts and multichroic pixels (single pixels observing multiple passbands simultaneously). So, while acquiring and analyzing SPT-POL data, we will continue to advance bolometric CMB detector technology, with an emphasis on scalable architectures. As a first step, we will migrate to fabricating monolithic bolometer arrays and extend our technology to other frequency bands. We will also begin integrating Argonne TES bolometers with low-loss superconducting microstrip coupling to the sky signal. Microstrip coupling is a promising technology because of its potential for multichroic pixels [1]. The combination of these developments will lead to a 10x increase in focal plane sensitivity.

Such a large increase in the number of detectors in a CMB polarization focal plane will require commensurate developments in multiplexing electronics. Towards that end, we plan on both extending the limits of current multiplexers while also exploring new readout technologies utilizing microwave

resonators [2] in collaboration with our existing university partners. This new technology has the potential to readout out 10-100 times the number of channels over current multiplexers.

The goal of the FY11- FY13 detector R&D is the strategic development of critical technology for future CMB polarization missions. This development will enable the Argonne CMB group to deliver a second, more sensitive, SPT-POL focal plane in 2014 while also positioning Argonne HEP to make unique contributions to next generation CMB polarization instruments using ground-, balloon-, and satellite-based platforms.

### **FY11 – FY13 Request**

We request DOE support for the above CMB science program, including support for the unique Argonne contribution of the CMB TES detector technology that until now has been supported by strategic LDRD funding. To continue this program, we request starting in FY11 1.5 FTE new junior staff positions, specifically, an FTE for a cryogenic detector expert with CMB experience and a 0.5 FTE Argonne-UChicago joint appointment with an emphasis on CMB science. We further request support for a 1.0 FTE engineer with micro-fabrication expertise to carry out this program. This specialized engineering is critical for the delivery of the Argonne detectors for the initial SPT-POL deployment, and for the continued success of our CMB detector development program. Lastly, we request 2 postdoctoral appointments.

### **References:**

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## 5. Summary and Strategic Planning

In conclusion, the Argonne non-accelerator research program funded by B&R code KA-13 consists of two components: 1) an astrophysics part and 2) work on the Double Chooz (DC) reactor neutrino experiment. The involvement in the neutrino DC experiment is part of the larger neutrino program, which also includes very active involvement in MINOS and Nova and a growing involvement in LBNE. We have been part of the DC experiment for many years and remain committed to its science. The next three years will be the most fruitful ones for the DC experiment and we propose to add 1 FTE to focus on science and to take advantage of this new data. The longer term future of DC depends on the timing and content of its results along with those from Daya Bay, RENO, T2K and NOvA.

The astrophysics program was established in FY07 with initial support for participation in the ground based gamma-ray experiment VERITAS. The laboratory has supported us with supplemental LDRD funds and a focused lab-wide strategic initiative dedicated to astrophysics and cosmology. The LDRD funding allowed us to establish clear roles in both VERITAS and DES and an initial involvement in CTA, which is now becoming part of a CTA-US effort. The initiative also allowed us to pursue CMB science and has allowed us to establish a sensor development capability at Argonne to develop new, more sensitive TES sensors for future CMB polarization science. We believe this is a uniqueness that the laboratory can provide to HEP DOE. Argonne has the materials science expertise, available to the area of sensor development, starting from selecting the best superconducting films for such sensors and then developing the sensors with the micro-fabrication facilities at Argonne. For all these reasons as well as the overlap in science between DES and SPT we are proposing participation in the CMB program, and request funding for it, starting in FY11 from KA-13.

In summary, the Table below gives an overview of our proposed program and the funding requested for the period FY11 – FY13.

	<b>FY010(k\$)</b>	<b>FY11(k\$)</b>	<b>FY12(k\$)</b>	<b>FY13(k\$)</b>
<b>Double Chooz</b>	345	475	485	494
<b>VERITAS</b>	373	457	568	752
<b>DES</b>	534	642	794	959
<b>CMB-SPTpol</b>	-	848	887	929
<b>Total astro</b>	907	1947	2249	2640
<b>Total</b>	1252	2422	2734	3134

Notes:

VERITAS funding request does not include CTA-US R&D funding if it becomes approved, but does include since contribution to CTA-US.

## **Strategy and Prioritization**

The proposed program at Argonne for the next few years is based on the current existing program and new expertise and collaborations we have established over the last few years. We realize it is a substantial increase over the current budget. At the same time we have been asked to present plans and a strategy for a flat-flat budget for the next few years. We have started working on this strategy, branch points and (re)prioritization of the program. Given the investment that has been made this is not an easy process. Given this and the recent prioritizations set by the decadal survey we would prefer not to commit to a strategy and prioritization in this document, but present our approach at the non-accelerator review at the end of September 2010. This gives us some more time to consider this in more depth. We want to avoid writing something down now, which we will revise in the next few weeks and which we have not been able to give the consideration it deserves.

## **6. Curriculum Vitas**

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### Education:

BSECE, 1981, University of Wisconsin-Madison

### Professional Employment:

2006-present : Argonne National Laboratory  
1989-2006 : Fermi National Laboratory  
1985-1989 : LeCroy Corporation  
1983-1985 : University of Wisconsin Physical Sciences Laboratory  
1982 : Wisconsin School of Electronics  
1981 : Lunar Radiation Corporation

### Awards, Memberships, and Professional Service:

Member of NIM committee 1993-1994  
Member, VME International Trade Association, 1992

### Selected Publications:

1. J.T. Anderson, K. Byrum, G. Drake, Member, IEEE, A. Kreps, F. Krennrich, M. Schroedter, A. W. Smith, "Field Tests of a New High-Speed Pattern Recognition Trigger for Ground-Based Gamma-Ray Telescope Arrays". IEEE Conference Record, NSS 2009, N10-2, October, 2009.
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### Education:

2008 Ph.D. (2002 M.S.) Astronomy & Astrophysics University of Michigan  
*NASA Graduate Student Researchers Program Fellow 2003 – 2006*  
*Rackham Graduate School Regents' Fellow 2000 – 2003*

1998 M.S. Physics University of Kentucky  
*U.S. Dept. of Education Areas of National Need Fellow 1996 – 1997*

1996 B.A. Physics University of Chicago  
*General & Physics Department Honors 06/1996, Dean's List 1993 – 1996*

### Professional Employment:

02/2010 – Present	Computational Postdoctoral Fellow	Argonne National Lab
03/2008 – 02/2010	Postdoctoral Appointee	Argonne National Lab
09/2007 – 02/2008	Engineering Assistant	Argonne National Lab
08/1999 – 04/2000	Adjunct Faculty	Bluegrass Com/Tech College
<i>Concurrent Appointments</i>		
07/2010 – Present	Adjunct Faculty	American Public University
07/2009 – 05/2010	Astronomy Mentor	Thomas Edison State College
01/2009 – 05/2009	Adjunct Faculty	College of DuPage

### Awards, Memberships, and Professional Service:

11/2008 – Present	Board Member, Postdoc Society	Argonne National Lab
01/2008 – Present	Full Member	American Astronomical Soc.
09/2009	Pacesetter Award	Argonne National Lab

### Selected Publications:

1. **J. P. Bernstein**, R. Kessler, S. Kuhlmann et al., *Supernovae Simulations and Strategies: Application to the Dark Energy Survey*, in prep., *Astrop. J.* (2010)
2. S. Kuhlmann, H. Spinka, **J. P. Bernstein** et al., *Narrow-Beam X-Ray Tests of CCD Edge Response*, submitted, *Exp. Astron.* (2010)
3. R. Kessler, **J. P. Bernstein**, D. Cinabro et al., *SNANA: a Public Software Package for Supernova Analysis*, *Pub. Astronomical Soc. Pac.*, Vol. 121, pp. 1028-1035 (2009)  
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### **Education:**

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University of Illinois, Urbana-Champaign,	M.S. 2004
Indian Institute of Technology, Kanpur	M.Sc.2001
Presidency College, University of Calcutta	B.Sc. 1999

### **Professional Employment:**

Postdoctoral appointee at HEP, ANL 2010

### **Selected Publications:**

1. **“Voids as a Precision Probe of Dark Energy”**, Rahul Biswas, Esfandiar Alizadeh and Benjamin D. Wandelt. Phys.Rev.D82:023002,2010,.
2. **“LSST Science Book, Version 2.0”** Contributing author to the **“Supernovae”** Chapter, 2009
3. **“Parameters and pitfalls in dark energy models with time varying equation of state.”** Rahul Biswas, Benjamin D. Wandelt (Submitted to Astrophysical Journal, arXiv:0903.2532 )
4. **“Constraining a spatially dependent rotation of the Cosmic Microwave Background Polarization”** Amit P.S. Yadav, Rahul Biswas, Meng Su, Matias Zaldarriaga. Phys.Rev.D79:123009,2009
5. **“The Taming of closed time-like curves”**. Rahul Biswas, Esko Keski-Vakkuri, Robert G. Leigh, Sean Nowling, Eric Sharpe, JHEP 0401:064,2004

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B.S. Physics/Minor Dance, Old Dominion University 1983  
M.S. Physics, University of Maryland, College Park 1985  
Ph.D. Physics, University of Wisconsin, Madison 1991

### **Professional Employment:**

Physicist, ANL (2000 - present)  
Assistant Physicist, ANL (1995-2000)  
Postdoctoral Fellow, ANL (1992-1995)

### **Awards, Memberships, and Professional Service:**

Conference organization (15+)  
Publications including conference proceedings (608)  
Unpublished technical reports (43)  
ANL service committee work (LDRD, Strategic Planning, ESE Advisory Group)  
Elected Member Fermilab Users Committee (1997-1999)  
CDF Service work (convenerships, detector reviews, Shift Leader)  
VERITAS Service work (Science Board, convenerships, observing shifts)  
Chicago Grad. School of Business - Strategic Lab. Leadership Program (2007-2008)

### **Selected Publications:**

1. **VERITAS Search for VHE Gamma-ray Emission from Dwarf Spheroidal Galaxies**, Accepted Astrophysical Journal, <http://arxiv.org/abs/1006.5955> (2010)
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5. **The TRICE Prototype MAMPT Imaging Camera**, <http://arxiv.org/abs/0710.0659> (2007).
6. **Measurement of b Quark Fragmentation Fractions in the Production of Strange and Light B Mesons in ppbar Collisions at sqrt(s)=1.8TeV**, Phys. Rev. D60 (1999) 092005.
7. **Shower Maximum Trigger For Electrons and Photons at CDF**, Nuclear Instrument Methods, A364 (1995) PP.144-149.

## John Carlstrom

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### **Education:**

University of California, Berkeley, Ph.D. 1988, (Physics)  
Vassar College, A.B. cum laude, 1981 (Physics)

### **Professional Employment:**

2010 - Joint Appointment, Argonne National Laboratory  
2005 - 2010 Director, Kavli Institute for Cosmological Physics  
2002 - Director/PI, South Pole Telescope Project  
2000 - S. Chandrasekhar Distinguished Service Professor, U. Chicago  
2000 - Professor of Physics U. Chicago  
1998 - Professor of Astronomy and Astrophysics, Enrico Fermi  
Institute, U. Chicago  
1999 - 2003 Director, Center for Astrophysical Research in Antarctica  
1997 - 1998 Associate Professor, Astronomy and Astrophysics, Enrico Fermi  
Institute, U. Chicago  
1996 - 1997 Assistant Professor, Astronomy and Astrophysics, Enrico Fermi  
Institute, U. Chicago  
1994 - 1995 Associate Professor of Astronomy, Caltech  
1991 - 1994 Assistant Professor of Astronomy, Caltech  
1989 - 1991 Millikan Research Fellow in Astrophysics, Caltech  
1988--1989 Assistant Astronomer, University of California, Berkeley

### **Awards, Memberships, and Professional Service:**

#### *Selected Awards and Honors:*

2010 Elected Fellow of the American Physical Society  
2006 Beatrice M. Tinsley Prize of the American Astronomical Society  
2005 Robertson Memorial Lecturer of the National Academy of Sciences  
2005 Magellanic Premium Medal of the American Philosophical Society  
2002 Elected to the National Academy of Sciences  
2000 Fellow of the American Academy of Arts and Sciences  
1999 James S. McDonnell Centennial Fellowship  
1998 John D. and Catherine T. MacArthur Fellowship  
1997 NASA Medal for Exceptional Scientific Achievement  
1994 David and Lucile Packard Fellowship  
1992 National Science Foundation Young Investigator

*Memberships:*

National Academy of Science, American Academy of Arts and Sciences,  
American Physical Society (Fellow), American Astronomical Society,  
International Union of Radio Scientists (URSI)

*Recent Professional Service:*

NSF Senior Review, Astro2010 Decadal Survey, Fermilab PAC, Adler Board of  
Trustees

**Selected Publications:**

1. **“DASI First Results: A Measurement of the Cosmic Microwave Background Angular Power Spectrum,”** N. W. Halverson, E. M. Leitch, C. Pryke, J. Kovac, J. E. Carlstrom, W. L. Holzapfel, M. Dragovan, J. K. Cartwright, B. S. Mason, S. Padin, T. J. Pearson, M. C. Shepherd, A. C. S. Readhead, March 2002, ApJ, 568, 11. (astro-ph/0104489)
2. **“Cosmological Parameter Extraction from the First Season of Observations with DASI,”** C. Pryke, N. W. Halverson, E. M. Leitch, J. Kovac, J. E. Carlstrom, W. L. Holzapfel, M. Dragovan, March 2002, ApJ, 568, 1. (astro-ph/0104490)
3. **“Detection of the Polarization in the Cosmic Microwave Background with DASI,”** J. Kovac, E. Leitch, C. Pryke, J. E. Carlstrom, N. W. Halverson, W. L. Holzapfel, 2002, *Nature*, Dec 19, 2002, 420, 772-787. (astro-ph/0209478)
4. **“DASI Three-Year Cosmic Microwave Background Polarization Results,”** Leitch, E.M., Kovac, J.M., Halverson, N.W., Carlstrom, J.E., Pryke, C. and Smith, M. W. E., 2005, ApJ., 624, 10-20. (astro-ph/0409357).
5. **“Cosmology with the Sunyaev-Zel'dovich Effect,”** Carlstrom, J.E., Holder, G.P., Reese, E.D., *Annual Reviews of Astronomy and Astrophysics*, 2002, V40, 643.
6. **“Galaxy clusters discovered with a Sunyaev-Zel'dovich effect survey,”** Z. Staniszewski, et al., 2009, ApJ, 701, 32-41, arXiv:0810.1578
7. **“Measurements of Secondary Cosmic Microwave Background Anisotropies with the South Pole Telescope,”** Lueker et al., 2010, ApJ, 719, 1045, arXiv:0912.4317
8. **“Galaxy Clusters Selected with the Sunyaev-Zel'dovich Effect from 2008 South Pole Telescope Observations”,** Vanderlinde et al., 2010, ApJ in press, arXiv:1003.0003

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### Education:

Ph.D., Stanford University, 2005  
B.A., University of Chicago, 1997

### Professional Employment:

Staff, ANL (2010-present)  
Research Scientist, University of Chicago (2008-present)  
KICP Fellow, University of Chicago (2005-2008)  
Postdoctoral Scholar, Stanford University (2004-2005)

### Awards, Memberships, and Professional Service:

KICP Fellow (2005)

### Selected Publications:

1. **“Galaxy Clusters Selected with the Sunyaev-Zel'dovich Effect from 2008 South Pole Telescope Observations”**, Vanderlinde et al., 2010, ApJ in press, arXiv:1003.0003
2. **“Measurements of Secondary Cosmic Microwave Background Anisotropies with the South Pole Telescope,”** Lueker et al., 2010, ApJ, 719, 1045, arXiv:0912.4317
3. **“Galaxy clusters discovered with a Sunyaev-Zel'dovich effect survey,”** Z. Staniszewski, et al., 2009, ApJ, 701, 32-41, arXiv:0810.1578
4. **“Development of Absorber Coupled TES Polarimeter at Millimeter Wavelengths,”** G. Wang et al., IEEE Transactions on Applied Superconductivity, 19(3), 544-547 (2009)
5. **“Thermal Design and Characterization of Transition Edge Sensor (TES) Bolometers for Frequency-Domain Multiplexing,”** M. Lueker et al., IEEE Transactions on Applied Superconductivity, 19(3), 496-500 (2009)
6. **“Limits on Spin-Independent Interactions of Weakly Interacting Massive Particles with Nucleons from the Two-Tower Run of the Cryogenic Dark Matter Search,”** D. S. Akerib et al., Physical Review Letters 96(1), 011302 (2006)
7. **“Limits on spin-dependent WIMP-nucleon interactions from the Cryogenic Dark Matter Search,”** D. S. Akerib et al., Physical Review D (Particles and Fields) 73(1), 011102 (2006)
8. **“First Results from the Cryogenic Dark Matter Search in the Soudan Underground Laboratory,”** D. S. Akerib et al., Phys. Rev. L93, 211301 (2004)

## Michelangelo D'Agostino

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### **Education:**

Ph.D. (2009)	University of California, Berkeley
M.A. (2005) Physics	U of California, Berkeley, Berkeley
A.B. (2002) <i>Magna cum laude</i> in Physics.	Harvard University, Cambridge, MA

### **Professional Employment:**

Argonne National Laboratory, Chicago, IL Postdoctoral research associate	2009-Present
The Economist, London, UK Science and Technology Contributing Writer	2005-Present
Millfield School, Scientist-in-Residence, Street, Somerset, UK	2002-2003

### **Awards, Memberships, and Professional Service:**

National Association of Science Writers and American Physical Society

### **Selected Publications:**

1. J. Kiryluk and M.V. D'Agostino for the IceCube Collaboration. **"First search for atmospheric and extraterrestrial neutrino-induced cascades with the IceCube detector."** In preparation for submission to Physical Review D.
2. E. Middell and M. V. D'Agostino. **"Improved reconstruction of cascade-like events in IceCube."** Proceedings of the 31st International Cosmic Ray Conference (ICRC 2009), July 2009.
3. J. Kiryluk, M.V. D'Agostino, S.R. Klein, C. Song, D. R. Williams for the IceCube Collaboration. **"IceCube performance with artificial light sources: the road to cascade analyses."** Proceedings of the 30th International Cosmic Ray Conference (ICRC 2007), August 2007.
4. Ignacio Taboada and Michelangelo V. D'Agostino. **"Correlating prompt GRB photons with neutrinos."** arXiv:astro-ph/0711.2277 (2007)
5. **"Ye Cannae Change the Laws of Physics."** *The Economist* 31 August 2010. Lead article of science section. Topped list of week's most-recommended and most-read articles.
6. **"Techs and the City."** *The Economist* 27 July 2009. Five-part *Correspondent's Diary* on science in the San Francisco Bay Area. Number two on list of week's most-recommended articles.
7. **"Of Ice and Men."** *The Economist* 18 February 2008. Five-part *Correspondent's Diary* from Antarctica and the South Pole.
8. **"To Coldly Go."** *The Economist* 31 March 2007. Three page special report on science in Antarctica.

## Zelimir Djurcic

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### **Education:**

- Ph.D. Physics, The University of Alabama, Tuscaloosa, 2004.  
Thesis Title: ``Measurement of Reactor Anti-neutrinos at KamLAND: Preparation And Analysis".
- M.S. Physics, The University of Alabama, Tuscaloosa, 2002.  
Thesis Title: ``Measurement of Extremely Low Radioactivity Levels in KamLAND Liquid Scintillator".
- B.S. Physics, University of Novi Sad, 1996.  
Thesis Title: ``New gamma transition in the decay of  $^{137}\text{Cs}$ ".

### **Professional Employment:**

- Assistant Physicist, High Energy Physics Division, Argonne National Laboratory (2009 – present).
- Postdoctoral Fellow, Physics Department, Columbia University (2004 – 2009 ).
- Research Assistant, Physics Department, University of Alabama (1999 -2004).
- Research and Teaching Assistant, Nuclear Physics Laboratory, University of Novi Sad (1996 – 1999).

### **Awards, Memberships, and Professional Service:**

- American Physical Society, Member (1999 – present).
- Sigma Xi, honorary scientific research society, Full Member (2010 – present).

### **Selected Publications:**

1. **“Observed Event Excess in the MiniBooNE Search for anti- $\nu_\mu \rightarrow$  anti- $\nu_e$  Oscillations,”** A Aguilar-Arevalo *et al.*, submitted to Phys. Rev. Lett. (2010).
2. **“Unexplained Excess of Electron-Like Events From a 1-GeV Neutrino Beam,”** A. Aguilar-Arevalo *et al.*, Phys. Rev. Lett. 102, 101802 (2009).
3. **“Measurement of  $\nu_\mu$  and  $\nu_e$  Events in an Off-Axis Horn-Focused Neutrino Beam,”** P. Adamson *et al.*, Phys. Rev. Lett. 102, 211801 (2009).
4. **“Uncertainties in the Anti-neutrino Production at Nuclear Reactors,”** Z. Djurcic *et al.*, J. Phys. G: Nucl. Part. Phys. 36, 045002 (2009).
5. **“A Search for electron neutrino appearance at the  $\Delta m^2 \sim 1\text{eV}^2$  scale,”** A. A. Aguilar-Arevalo *et al.*, Phys. Rev. Lett. 98, 231801 (2007).
6. **“Measurement of neutrino oscillation with KamLAND: Evidence of spectral distortion,”** T. Araki *et al.*, Phys. Rev. Lett. 94, 081801 (2005).
7. **“First results from KamLAND: Evidence for reactor anti-neutrino disappearance,”** K. Eguchi *et al.*, Phys. Rev. Lett. 90, 021802 (2003).
8. **“Novel technique for ultra-sensitive determination of trace elements in organic materials,”** Z. Djurcic *et al.*, Nucl. Instrum. Meth. A 507, 680 (2003).

## Gary Drake

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### **Education:**

B.S.E.E., University of Wisconsin – Madison, 1982  
M.S.E.E., University of Wisconsin – Madison, 1983

### **Professional Employment:**

Senior Engineer, ANL (2008- )  
Engineer, ANL (1997-2008)  
Engineer, Fermilab (1983-1997)

### **Awards, Memberships, and Professional Service:**

Member, IEEE (1994)  
Publications (18)  
Additional published conference proceedings (25)  
Unpublished technical reports (46)

### **Selected Research Accomplishments:**

Design Engineer, development of electronics for the calorimeters of the CDF detector, Run I at Fermilab (1983-1989).  
Design of custom integrated circuits (1994-1996).  
Lead Project Engineer, design and production of front-end electronics for the Shower Maximum Detector for the CDF, Run II Upgrade at Fermilab (1995-1999).  
Lead Project Engineer and Level 3 Manager, development of electronics for the MINOS Near Detector at Fermilab (1999-2005).  
Lead System Engineer, design and production of readout instrumentation for Digital Hadron Detector R&D for CALICE (Detector R&D for the International Linear Collider) (2003-present).  
R&D on detector development using silicon photomultipliers (2006-2008).  
Lead engineer, development of switching power supplies for the Barrel Calorimeter of the ATLAS Experiment at the LHC at CERN in Switzerland (2006-present).  
Lead engineer, design of high-speed topological trigger for telescope arrays for gamma-ray astronomy (2007-present).  
Development of new switching power supplies for the upgrade of the Barrel Calorimeter of the ATLAS Experiment at the LHC at CERN in Switzerland (2008-present).  
Development of new readout instrumentation for the upgrade of the Barrel Calorimeter of the ATLAS Experiment at the LHC at CERN in Switzerland (2008-present).

### **Selected Publications:**

1. “A New High-Speed Pattern Recognition Trigger for Ground-Based Telescope Arrays Used in Gamma-Ray Astronomy”, *IEEE 2008 NSS Conf. Rec.*, 2008, 8 pages.
2. “The MINOS Near Detector Front End Electronics”, *IEEE Trans. Nucl. Sci.*, vol. 53, 2006, pp. 1347-1355.
3. “A Digital Hadron Calorimeter with Resistive Plate Chambers for the Linear Collider”, *Int. J. Mod. Phys.*, Vol. A20, 2005, pp. 3830-3833.

4. **"DCAL: A Custom Integrated Circuit for Calorimetry at the International Linear Collider"**, *IEEE 2005 NSS Conf. Rec.*, 2005, 8 pages.
5. **"The Shower Maximum Front-End Electronics for the CDF Upgrade"**, *IEEE Trans. Nucl. Sci.*, vol. 49, 2002, pp. 2567-2573.
6. **"The Upgraded CDF Front End Electronics for Calorimetry"**, *IEEE Trans. Nucl. Sci.*, vol. 39, 1992, pp. 1281-1285.
7. **"CDF Front End Electronics: The RABBIT System"**, *Nucl. Instrum. Meth.*, vol. A269, 1988, pp. 68-81.

## Maury Goodman

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### **Education:**

B.S., MIT 1972  
MS., The University of Illinois, 1976  
Ph.D., The University of Illinois, 1979

### **Professional Employment:**

Physicist, ANL (1985- present)  
Postdoctoral Staff, MIT (1979-1984)  
2<sup>nd</sup> Lt., 1<sup>st</sup> Lt. Captain, US Army (1972-1973); US Army Reserve (1974-1986)

### **Awards, Memberships, and Professional Service:**

Deputy Spokesman for LBNE collaboration (2010-2012)  
Fellow of the American Physical Society (2009)  
Society of Sigma Xi (1972)  
Co-spokesperson for US Double Chooz Collaboration (2006-2009)  
ANL service committee work (POC-HP, planning group, seminars committee,...)  
MINOS Service Work (Executive Committee, Chairman of Institutional Board) 1995-2010  
NOvA (Chairman of Speakers Committee) 2009-2010  
Spokesperson for THESEUS proposal (FNAL P822, neutrinos to Soudan 2) 1992-1996  
Chairman of Organizing Committee Long-Baseline Neutrino Workshop, 1991  
International Advisory Committee for Neutrino 2002, 2004, 2006, 2008, 2010  
International Advisory Committee for Lepton/Photon 2011

### **Selected Research Accomplishments**

Leader of the ANL-HEP neutrino group. 2007-present  
Led a MINOS analysis group on cosmic ray muon studies; first rise in charge ratio seen & explained, 2008  
Invited summary speaker on neutrino experiments at 2007 Weak Interactions and Neutrinos Workshop  
Detected neutrino oscillations using Rock Muons in MINOS, 2007.  
Active Participant & Writer for APS neutrino study, 2004.  
Observation of Atmospheric Neutrino Oscillations in Soudan 2, 2003.  
Search and limit on neutrinos from Active Galactic Nuclei in Soudan 2, 1999.  
Supervised 4 Ph.D. students and 5 postdoctoral appointees, 1996-present.  
Member of the Particle Data Group since 1996, spearheaded 2006 neutrino revision  
Significant contributions to MINOS (FNAL P875) Proposal, 1995  
Issues monthly newsletter on neutrinos with a subscription list over 1500 since 1992  
Led efforts to create a long-baseline neutrino oscillation program at Fermilab in the 1990s  
Initiated Soudan 2 neutrino oscillation analysis, 1988  
Led Soudan 2 data analysis for several nucleon decay modes, 1987-1998  
Organized use of Fermilab Experiment E594 for Cosmic Ray Studies, 1982-1984  
Mentored numerous undergraduate and High School students (Ill. Math/Science Academy) continuous

**Selected Publications**

1. **Measurement of Neutrino Oscillations with the MINOS Detectors**, Phys. Rev. Lett. 101, 2008.
2. **Reviews of Particle Properties**, Physics Letters, B167, 2008. (Also, 1998, 2000, 2002, 2004 & 2006)
3. **Search for the proton decay mode neutrino  $K^+$  in Soudan 2**, Physics Letters B427, 1998.
4. **Other Atmospheric Neutrino Experiments**, Nucl Physics B (Proc Suppl.) 118, 2003.
5. **A New Nuclear Reactor Neutrino Experiment to Measure  $\theta_{13}$** , [arXiv:hep-ex/0402041](https://arxiv.org/abs/hep-ex/0402041).
6. **Double Chooz, A search for the Neutrino Mixing Angle  $\theta_{13}$** , arXiv:hep-ex/0606025.
7. **Horizontal Muons and a search for AGN neutrinos in Soudan 2**, Astroparticle Physics 20, 2004.
8. **Interpretation of the Underground Muon Charge Ratio**, Astropart.Phys.32:61-71,2009

## Victor Guarino

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### **Education:**

B.S., Illinois Institute of Technology 1987  
M.S., Illinois Institute of Technology 1988  
Ph.D., University of Illinois at Chicago 1999  
MS, Civil Engineer, Illinois Institute of Technology, 2009

### **Professional Employment:**

Engineer, ANL (1993- )  
Assistant Engineer, ANL (1989-1993)

### **Awards, Memberships, and Professional Service:**

- Licensed Illinois Professional Engineer
- U.S. ATLAS Tile calorimeter Project Engineer – responsible for all US structural design, fabrication, and assembly on the ATLAS Tile calorimeter at the LHC
- NOvA Project Engineer – responsible for the analysis of the NOvA structure and the design and fabrication of all construction equipment for the detector
- MINOS Project Engineer – responsible for the design and fabrication of machinery for constructing MINOS modules.

### **Selected Publications:**

1. **“Stability of the EB When Cryostat Load is Applied”** Argonne National Laboratory Technical Report ANL-HEP-TR-04-65; June 23, 2004
2. **“Analysis of the Connections Between Modules in the EB”** Argonne National Laboratory Technical Report ANL-HEP-TR-02-056; May 16, 2002
3. **“Stress Analysis Of The Welds In The Girder”** Argonne National Laboratory Technical Report ANL-HEP-TR-98-06; December 1, 1997
4. **“Extended Barrel Support Saddle Design and Analysis”** presented at the Atlas engineering meeting at The European Center for Nuclear Research (CERN), Geneva, Switzerland; August, 2001
5. **“Proposal for the Completion of the Outstanding Work, Scheduling and Alignment of the SDC Central Calorimeter”** Argonne National Laboratory Technical Report ANL-HEP-TR-93-101; November 1993

## Andrew Scott Kreps

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### **Education:**

Bachelor of Science in Computer Engineering  
University of Illinois, Champaign-Urbana, IL

### **Professional Employment:**

Argonne National Laboratory, Argonne, IL 60439  
High Energy Physics Division - Engineering Specialist (2004 - Present)  
Electronics & Computing Technologies Division - Engineering Specialist (2000 - 2004)

### **Awards, Memberships, and Professional Service:**

None

### **Selected Publications:**

1. **Field tests of a new high-speed pattern recognition trigger for ground-based gamma-ray telescope arrays**, Anderson, J.T. *et al.* Digital Object Identifier: 10.1109/NSSMIC.2009.5401804  
Nuclear Science Symposium Conference Record (NSS/MIC), 2009 IEEE  
Publication Year: 2009 , Page(s): 199 - 204
2. **A Topological Trigger System for Imaging Atmospheric-Cherenkov Telescopes.**  
[M. Schroedter \*et al.\*](#) Aug 2009. 4pp.  
e-Print: [arXiv:0908.0179](#) [astro-ph.IM]
3. **A topological array trigger for AGIS, the Advanced Gamma-ray Imaging System.**  
[F. Krennrich \*et al.\*](#) 2009. 4pp.  
Published in AIP Conf.Proc.1085:894-897, 2009.
4. **A new high-speed pattern recognition trigger for ground-based telescope arrays used in gamma ray astronomy**, Anderson, John *et al.*  
[Nuclear Science Symposium Conference Record, 2008. NSS '08. IEEE](#)  
19-25 Oct. 2008 Page(s):2773 - 2780
5. **Calibration of a digital hadron calorimeter with muons.**  
[Burak Bilki \*et al.\*](#) FERMILAB-PUB-08-066-E, Feb 2008. 17pp.  
Published in JINST 3:P05001, 2008.
6. **A new readout system for “Digital Hadron Calorimetry” for the International Linear Collider**  
Butler, J. *et al.*  
[Nuclear Science Symposium Conference Record, 2007. NSS '07. IEEE](#)  
Volume 3, Oct. 26 2007-Nov. 3 2007 Page(s):2145 - 2153
7. **2-D scintillation position-sensitive neutron detector**  
De Lurgio, P.M. *et al.*  
[Nuclear Science Symposium Conference Record, 2005 IEEE](#)  
Volume 2, 23-29 Oct. 2005 Page(s):648 - 653
8. **A new detector for time-resolved small angle X-ray scattering studies**  
De Lurgio, P.M. *et al.*  
[Nuclear Science Symposium Conference Record, 2005 IEEE](#)  
Volume 2, 23-29 Oct. 2005 Page(s):1215 - 1222

## Stephen Kuhlmann

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### Education:

- Purdue University (1988, Ph.D. Physics)
- Wichita State University (1984, B.S. Physics)

### Professional Employment:

- Argonne National Laboratory – High Energy Physics Division
  - Physicist (October 1997 until Present)
  - Assistant Physicist (October 1992 – October 1997)
  - Enrico Fermi Fellow (October 1990 – October 1992)
  - Postdoctoral Appointee (July 1988 – October 1990)

### Awards, Memberships, and Professional Service:

- Dark Energy Survey ANL group leader
- Member SDSS Supernova group
- Member LSST Supernova group
- Member American Astronomical Society
- Airfly/Auger Collaboration member (April 2004 – December 2007)
- Former DOE Level 2 Manager CDF Calorimeter Upgrade
- Former Project Leader CDF Preshower Detector Upgrade
- Former CTEQ Co-Spokesperson
- Former Physics Coordinator CDF QCD Group
- SSC Fellowship

### Selected Publications:

1. **“SNANA: a Public Software Package for Supernova Analysis”**, R. Kessler *et al.*, submitted to Publications of the Astronomical Society of the Pacific
2. **“Dark Energy Survey Supernovae Simulations and Survey Strategy”**, J. P. Bernstein, R. Kessler, S. Kuhlmann, H. Spinka, Dark Energy Survey Collaboration, in “Cosmology. Proceedings of the 43rd Rencontres de Moriond”, Eds. J. Dumarchez, Y. Giraud Heraud, and J. Tran Thanh Van, World Publishing Company, Hanoi, Vietnam, 2009
3. **“Simulations of Core-Collapse Supernova Light Curves and Event Rates,”** J.P. Bernstein, D. Cinabro, R. Kessler, and S. Kuhlmann: *LSST Science Book Version 2.0*.
4. **“Photometric Estimates of Redshifts and Distance Moduli for Type Ia Supernovae,”** R. Kessler *et al.*, *The Astrophysical Journal, Volume 717, Issue 1, pp 40-57 (2010)*.
5. **“Results from the Supernova Photometric Classification Challenge,”** R. Kessler *et al.*, <http://adsabs.harvard.edu/abs/2010arXiv1008.1024K>, submitted to PASP.

## Val Novosad

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### Education:

- Postdoctoral Fellow, Materials Science Department, Tohoku University, Japan (1998-2001).
- Ph.D. in Physics, Verkin Institute for Low Temperature Physics and Engineering, National Academy of Sciences, Kharkov / Ukraine (1998).
- State Diploma in Mechanical Engineering (with Honors), Zhukovsky National Aerospace University of Ukraine (1993).

### Professional Employment:

2005 - Present: Materials Scientist, Mat. Sc. Div., Argonne Nat. Laboratory (MSD/ANL)  
2001 - 2004: Assistant Scientist, MSD/ANL.

### Awards, Memberships, and Professional Service:

- Post-doctoral Fellowship of Japanese Ministry of Education, 1998.
- Best PhD Student Award, International Science Soros Foundation (USA-Ukraine), 1996.
- Member of American Physical Society (2001 – present).
- Referee, Referee, Journal for Chemistry and Physics of Solids, Journal of Magnetism and Magnetic Materials, Journal of Applied Physics, Applied Physics Letters, Nature Physics, Nature Communications, Physical Review B, Physical Review Letters, Journal of Nanotechnology and Nanoletters.
- Reviewer for U. S. Department of Energy's SBIRR/ STTR programs (2007-08).

### Selected Publications:

1. G. Wang, V. Yefremenko, V. Novosad, A. Datesman, J. Pearson, G. Shustakova, R. Divan, C. L. Chang, J. McMahon, L. Bleem, A. T. Crites, T. Downes, J. Mehl, S. S. Meyer, and J. E. Carlstrom, **“Thermal Properties of Silicon Nitride Beams Below 1 Kelvin”**, AIP Conf. Proc., 1219, 75-82, 334-337 (2010).
2. J. J. McMahon, K. A. Aird, B. A. Benson, L. E. Bleem, J. Britton, J. E. Carlstrom, C. L. Chang, H. S. Cho, T. de Haan, T. M. Crawford, A. T. Crites, A. Datesman, M. A. Dobbs, W. Everett, N. W. Halverson, G. P. Holder, W. L. Holzapfel, D. Hrubes, K. D. Irwin, M. Joy, R. Keisler, T. M. Lanting, A. T. Lee, E. M. Leitch, A. Loehr, M. Lueker, J. Mehl, S. S. Meyer, J. J. Mohr, T. E. Montroy, M. D. Niemack, C. C. Ngeow, V. Novosad, S. Padin, T. Plagge, C. Pryke, C. Reichardt, J. E. Ruhl, K. K. Schaffer, L. Shaw, E. Shirokoff, H. G. Spieler, B. Stadler, A. A. Stark, Z. Staniszewski, K. Vanderlinde, J. D. Vieira, G. Wang, R. Williamson, V. Yefremenko, K. W. Yoon, O. Zhan, and A. Zenteno, **“SPTpol: an instrument for CMB polarization”**, AIP Conf. Proc., 1185, 511-514 (2009).
3. G. Karapetrov, M. Milosevic, M. Iavarone, J. Fedor, A. Belkin, V. Novosad, and F. Peeters, **“Transverse instabilities of multiple vortex chains in superconductor-ferromagnet bilayers”**, Phys. Rev. B, (Rapids), 80, 180506 (2009).
4. V. Yefremenko, A. Datesman, G. Wang, J. Pearson, V. Novosad, R. Divan, L. E. Bleem, C. L. Chang, A. T. Crites, W. Everett, J. McMahon, J. Mehl, S. S. Meyer, J. Ruhl, J. Sayre, and J. E. Carlstrom, **“Design and Fabrication of Argonne/KICP Detectors for CMB Polarization”**, AIP Conf. Proc., 1185, 359-362 (2009).

5. G. Wang, V. Yefremenko, A. Datesman, V. Novosad, J. Pearson, G. Shustakova, R. Divan, J. Lee, C. L. Chang, J. McMahon, L. Bleem, A. T. Crites, T. Downes, J. Mehl, W. Everett, S. S. Meyer, J. E. Carlstrom, J. Sayer, and J. Ruhl, **“Thermal Modeling of Absorber-Coupled TES Polarimeter”**, AIP Conf. Proc., 1185, 334-337 (2009).
6. T. Crites, L. E. Bleem, J. E. Carlstrom, C. L. Chang, A. Datesman, R. Divan, W. Everett, J. McMahon, J. Mehl, S. S. Meyer, V. Novosad, J. Pearson, J. Ruhl, J. Sayre, G. Wang, and V. Yefremenko, **“Optical Properties of Argonne/KICP TES Bolometers for CMB Polarimetry”**, AIP Conf. Proc., 1185, 203-206 (2009).
7. V. Yefremenko, A. Datesman, G. Wang, J. Pearson, V. Novosad, R. Divan, C. Chang, T. Downes, L. Bleem, A. Crites, S.S. Meyer, and J.E. Carlstrom, **“Control of Membrane Thermal Transport Supporting Superconducting Detector Development”**, IEEE Trans. of Applied Superconductivity, accepted.
8. V. Yefremenko , E. Gordiyenko , G. Shustakova , Yu. Fomenko , A. Datesman , G. Wang, J. Pearson, E.E. W. Cohen, and V. Novosad, **“A broadband imaging system for research applications”**, Review of Scientific Instruments, 80, 056104 ,2009.
9. Datesman, J. Pearson, G. Wang, V. Yefremenko, R. Divan, T. Downes, C. Chang, J. McMahon, S. Meyer, J. Carlstrom, D. Logan, T. Perera, G. Wilson, and V. Novosad, **”Frequency selective bolometer development at Argonne National Laboratory”**, Millimeter and Submillimeter Detectors and Instrumentation for Astronomy IV, Book Series: Proc. of SPIE, Vol. 7020, pp 2029-2029, 2008.

## Andrew W. Smith

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### Education:

2007 Ph.D. High Energy Astrophysics  
University of Leeds/Smithsonian Astrophysical Observatory  
Leeds, UK/Tucson, AZ  
Thesis Title: "Multiwavelength Observations of The TeV Binary LS I +61 303 with VERITAS, Swift, and RXTE"

2002 M.Sc. Particle Physics  
University of Durham  
Durham, UK  
Dissertation Title: "Braneworld Scenarios"

2001 B.A. Astrophysics  
University of California at Berkeley  
Berkeley, CA

### Professional Employment:

Postdoctoral Researcher	Argonne National Laboratory	2008-current
Lecturer	Northwestern University	2010-Current

### Awards, Memberships, and Professional Service:

2010- Current	Co-Chair of VERITAS Dark Matter and Astroparticle Physics Working Group
2009-Current	Member of the American Physical Society
2005-2008	Harvard-Smithsonian Center for Astrophysics Predoctoral Fellow

### Selected Publications:

1. Acciari, V., Smith, A. "VERITAS Search for VHE Emission From Dwarf Spheroidal Galaxies", 2010, ApJ, 720, 1174
2. Acciari, V. ....Smith, A. "Multiwavelength Observations of LS I +61 303 with VERITAS, Swift, and RXTE" 2009, ApJ, 700, 2
3. Smith, A. et al. "Long Term X-ray Monitoring Of The TeV Binary LS I +61 303 with RXTE" ApJ, 693, 1621
4. Smith, A. et al. , "Whipple 10m Observations of LS I +61 303: 2004-2006" Journal of Astrophysics and Space Sciences, 309, 299-303
5. 4. Acciari, V. et al. "VERITAS Observations of the Gamma-Ray Binary LS I +61 303", Astrophysical Journal, 629, 457

## Harold Spinka

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### Education:

<i>Year</i>	<i>Degree</i>	<i>Institution and Location</i>	<i>Field of Study</i>
1966	B.A.	Northwestern University, Evanston, IL	Physics
1971	Ph.D.	California Inst. of Tech., Pasadena, CA	Physics (Nuclear Astrophysics)

### Professional Employment:

- Aug. 1987 – Present: Senior Physicist, HEP, Argonne National Laboratory, Lemont, IL
- Oct. 1976 – Aug. 1987; Physicist, HEP, Argonne National Laboratory, Lemont, IL
- Mar. 1973 – Oct. 1976: Adjunct Assistant Professor, University of California at Los Angeles, Los Angeles, CA
- Dec. 1970 – Feb. 1973: Postdoctoral Fellow, Argonne National Laboratory, Lemont, IL

### Awards, Memberships, and Professional Service:

Member Sigma Xi and Phi Beta Kappa  
Fellow of the American Physical Society  
LAMPF Program Advisory Committee (1983 – 1986)  
LAMPF Board of Directors (1989 – 1991)  
STAR Spin Working Group co-convenor (2003 – 2005)  
Spokesperson/Co-spokesperson various experiments

### Selected Publications:

1. “**Experimental Determination of the Total Reaction Cross Section of the Stellar Nuclear Reaction  $^{16}\text{O} + ^{16}\text{O}$ ,**” H. Spinka and H. Winkler, Nucl. Phys. A233, 456 (1974).
2. “**Measurement of Spin Parameters for a Decisive Clarification of the Structure Observed in the p-p System,**” I.P. Auer et al., Phys. Rev. Lett. 51, 1411 and 1814 (1983).
3. “**Analyzing Power in Inclusive  $\pi^+$  and  $\pi^-$  Production at High  $x_F$  with a 200 GeV/c Polarized Proton Beam,**” D.L. Adams et al. (FNAL E704 collaboration), Phys. Lett. 264B, 462 (1991).
4. “**Measurement of the Differences in the Total Cross Section for Anti-parallel and Parallel Longitudinal Spins and a Measurement of Parity Non-conservation with Incident Protons and Antiprotons at 200 GeV/c,**” D.P. Grosnick et al. (FNAL E704 collaboration), Phys. Rev. D55, 1159 (1997).
5. “**Centrality Dependence of High  $p_T$  Hadron Suppression in Au+Au Collisions at  $\sqrt{s} = 130$  GeV,**” C. Adler et al. (RHIC STAR Collaboration), Phys. Rev. Lett. 89, 202301 (2002).
6. “**Evidence from d + Au Measurements for Final State Suppression of High  $p_T$  Hadrons in Au + Au Collisions at RHIC,**” J. Adams et al. (RHIC STAR collaboration), Phys. Rev. Lett. 91, 072304 (2003).
7. “**Correlation of the Highest Energy Cosmic Rays with Nearby Extragalactic Objects,**” J. Abraham et al. (Pierre Auger Observatory collaboration), Nature 318, 938 (2007).
8. “**Observation of the Suppression of the Flux of Cosmic Rays Above  $4 \times 10^{19}$  eV,**” J. Abraham et al., Phys. Rev. Lett. 101, 061101 (2008).

## Richard Talaga

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### **Education:**

B.S., University of San Francisco 1971  
MS., The University of Chicago 1973  
Ph.D., The University of Chicago 1977

### **Professional Employment:**

Physicist, ANL (1989- present)  
Assistant Professor, University of Maryland (1982-1988)  
Postdoctoral Staff, LANL (1979-1981)  
Postdoctoral Staff, LBNL (1978-1979)  
Postdoctoral Staff, UCLA (1977-1978)

### **Awards, Memberships, and Professional Service:**

Co-spokesperson for Parity Violation experiment at LAMPF (1980-81)  
ZEUS Service work (Run Coordinator, 1992)  
University of Maryland Summer Grant (1983)  
ANL service committee work (LMS R&D Process, Pacesetter Awards, Astrophysics Initiative)  
MINOS Service Work (WBS Level 3 manager)  
NOvA Service work (WBS Level 2 manager, EVMS certification, Exec. Board)

### **Selected Research Accomplishments**

Built low noise ion chambers & electronics to detect parity violation with proton beams (1973-80)  
Designed and built highly efficient veto wall and electronics for LAMPF neutrino experiment (1979-81)  
Detected electron-neutrino scattering interaction with electrons LAMPF (1986)  
Detected electron-neutrino transmutation of carbon nucleus to nitrogen at LAMPF (1987)  
Designed CYGNUS cosmic ray experiment muon detection electronics at LAMPF (1985-6)  
Designed & built ZEUS First Level Calorimeter Trigger (1989-1992)  
Designed and built ZEUS small rear tracking detector Trigger (1993-1995)  
Led ANL prototype beam tests for MINOS detector (1996-7)  
Developed extruded scintillator for MINOS (1998-2001)  
Led MINOS Near Detector Scintillator Assembly Factory (2000-2001)  
Led OMNIS and ADONIS supernova neutrino detector design group (2002-2005)  
Developed highly reflective PVC extrusions for NOvA (2006-2007)

### **Selected Publications:**

1. "Measurement of Neutrino Oscillations with the MINOS Detectors in the NuMI Beam", Phys. Rev. Lett. 101, 131802 (2008).
2. "The magnetized steel and scintillator calorimeters of the MINOS experiment", NIMA 596, 190 (2008).

3. **“OMNIS, The Observatory of Multiflavor Neutrinos from Supernovae”**, Nucl. Phys. A718,222 (2003)
4. **“Search for Lepton Flavor Violation in e-p collisions at 300 GeV cm energy”**, Z. Phys C73, 613 (1997)
5. **“Measurement of the Exclusive Cross Section  $^{12}\text{C}(\nu_e, e^-)^{12}\text{N}(\text{g.s.})$ ”**, Phys. Rev. Lett. 64, (1990).
6. **“First Observation and Cross Section Measurement of  $\nu_e + e^- \rightarrow \nu_e + e^-$ ”** Phys. Rev. Lett. 55, 2401 (1985).
7. **“Central Collisions with a Projectile of 1.8 GeV/Nucleon  $^{40}\text{Ar}$ ”**, Phys. Lett. 79B, 325 (1978).
8. **“Limit on Parity Violation in p-Nucleus Scattering at 6 GeV/c”**, Phys. Rev. Lett. 34, 1184 (1975).

## Robert G. Wagner

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### **Education:**

Undergraduate: University of Illinois-Urbana Physics B.S. 1972  
Graduate: University of Illinois-Urbana Physics M.S. 1973  
University of Illinois-Urbana Physics Ph.D. 1978  
Postdoctoral: Argonne National Laboratory Particle Physics 1977-80

### **Professional Employment:**

Argonne National Laboratory Physicist 1984-Present  
Argonne National Laboratory Assistant Physicist 1981-84

### **Awards, Memberships, and Professional Service:**

None

### **Selected Publications:**

1. **VERITAS Search for VHE Gamma-ray Emission from Dwarf Spheroidal Galaxies**, V.A. Acciari *et al.* (VERITAS Collaboration), *ApJ*, **720**, 1174-1180 (2010).
2. **The Track Imaging Cerenkov Experiment**, S. Wissel *et al.* (TrICE Collaboration), submitted to *Nucl. Instr. and Meth. A*.
3. **A Connection between Star Formation Activity and Cosmic Rays in the Starburst Galaxy M82**, V.A. Acciari *et al.* (VERITAS Collaboration), *Nature*, **462**, 770-772 (2009)
4. **VERITAS Observations of a Very High Energy Gamma-ray Flare from the Blazar 3C-66A**, V.A. Acciari *et al.* (VERITAS Collaboration), *ApJL* **693**, L104-L108 (2009).
5. **A Search for Dark Matter Annihilation with the Whipple 10 m Telescope**, M. Wood *et al.* (VERITAS Collaboration), *ApJ* **678**, 594-605 (2008).
6. **Observation of Top Quark Production in pbar-p Collisions with the Collider Detector at Fermilab**, F. Abe *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **74**, 2626 (1995).

## Gensheng Wang

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### Education:

Ph.D. 1999 – 2005 Experimental Particle Physics, Case Western Reserve University  
M.S. 1986 – 1989 Condensed Matter Physics, Lanzhou University, China  
B.S. 1982 – 1986 Condensed Matter Physics, Lanzhou University, China

### Professional Employment:

08/2007 – present Senior Postdoctoral Appointee, Argonne National Laboratory  
09/2004 – 08/2007 Postdoctoral Scholar, California Institute of Technology  
09/1999 – 06/2001 Teaching Assistant, Case Western Reserve University  
06/1998 – 06/1999 Visiting Scholar, Cavendish Laboratory, Cambridge University  
07/1991 – 05/1998 Engineer, Low Temperature Division, Lanzhou Institute of Physics  
07/1989 – 06/1991 Assistant Engineer, Lanzhou Institute of Physics

### Awards, Memberships, and Professional Service:

Outstanding researcher of the year at Lanzhou Institute of Physics (1995)  
Chinese Space Technology Achievement Award for a space radiant cooler development (1997)  
Chinese National Education Scholarship (1998)  
Member, the American Physical Society, 2001– present  
Member, the American Association for the Advancement of Science, 2006 – present  
Member, the American Astronomical Society, 2006 – present  
Chair, session of IEPA - Transition Edge Sensors II – Physics, ASC 2008

### Selected Publications:

- 1. Phonon Emission in Germanium and Silicon by Electrons and Holes in Applied Electric Field at Low Temperature**, G. Wang, *Journal of Applied Physics*, **107** 094504 (2010);
- 2. Thermal modeling of absorber-coupled TES polarimeter using finite element method**, G. Wang, *et al.*, LTD 13 conference proceedings (2009), pp. 334;
- 3. Optical Properties of Argonne/KICP TES Bolometers for CMB Polarimetry**, A. T. Crites, *et al.*, LTD 13 conference proceedings (2009), pp. 203;
- 4. Thermal properties of narrow silicon nitride beams below 1K**, G. Wang, *et al.*, *Advances in Cryogenic Engineering, Materials*, Vol. 56, pp. 75;
- 5. Search for Weakly Interacting Massive Particles with the First Five-Tower Data from the Cryogenic Dark Matter Search at the Soudan Underground Laboratory**, Z. Ahmed *et al.*, *PRL* **102**, 011301 (2009);
- 6. Surface Event Rejection Using Phonon Information in CDMS**, G. Wang (corresponding author), *Nuclear Physics B - Proceedings Supplements*, Volume 173, pp.137-140 (2007);
- 7. Antenna-Coupled TES Bolometers for the SPIDER Experiment**, C. L. Kuo *et al.*, *Nuclear Instruments and Methods in Physics Research Section A* **559** 608 (2006);
- 8. Limits on spin-independent WIMP-nucleon interactions from the two-tower run of the Cryogenic Dark Matter Search**, D. S. Akerib *et al.*, *PRL* **96**, 011302 (2006).

## Hendrik Weerts

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### **Education:**

1971 B.Sc. Physics (Vordiplom), *RWTH Aachen, Germany*  
1975 M.A. Physics (Diplom), *RWTH Aachen, Germany*  
1975 Diplom-Thesis: "Neutral Pion Production by the Neutral Current Interaction"  
1981 Ph.D. Physics, *RWTH Aachen, Germany*

### **Professional Employment:**

1972-1975 Teaching/Research Assistant, *III Phys. Institut, RWTH Aachen*  
1975-1981 Research Associate, *III Phys. Institut, RWTH Aachen*  
1981-1983 Research Associate, *Physics Division, Fermilab*  
1983-1988 Assistant Professor, *Dept. of Physics & Astronomy, Michigan State University.*  
1988-1993 Associate Professor, *Dept. of Physics & Astronomy, Michigan State University.*  
1993-2008 Professor, *Dept. of Physics & Astronomy, Michigan State University.*  
2008-present Professor Emeritus, *Michigan State University*  
1990-1992 Visiting Scientist, *DØ experiment, Fermilab.*  
1998-2002 Joint Appointment *Fermilab/Michigan State University*  
2004-2005 Sabbatical at Fermilab to work on International Linear Collider (ILC)  
2005-present Director of HEP Division, Argonne National Lab

### **Awards, Memberships, and Professional Service:**

- Coordinator of DØ detector commissioning, 1990-1992, Fermilab.
- Convener of QCD analysis group in DØ, 1990-1994.
- Founding member of the CTEQ collaboration, 1990.
- Member of Organizing committee and lecturer at CTEQ summer schools on QCD., 1993,1995 and 1997
- Overall Physics Convener of Physics Groups in DØ, 1994-1996
- Member of the Program Advisory Committee: Fermilab, 1995,1996 (resigned when became DØ spokesman in 1996).
- Organized many workshops in 1990's at MSU as well as outside MSU.
- APS Fellow 1997
- Int. Advisory Committee for "Hadron Collider Physics", 1995,1997,1999, 2002.
- Organizing it at MSU in 2004.
- Co-spokesman of DØ 1996-1999 and 1999-2002
- Distinguished Faculty Award ( College of Natural Science MSU) 2000
- Chair of APS Panofsky Prize Committee. (member1999, chair 2001)
- Co-project manager of DØ upgrade 1999-2001.
- Member of High Energy Physics Advisory Panel to DOE and NSF (HEPAP) 1999-2002.
- Vice-Chair/Chair of DPF nominating committee for DPF Executive Comm. ( 2002,2003)
- Editor of Physics Letters B 2003-present

- Organized HCP2004 conference at MSU in June 2004. See: [HCP2004](#)
- Leading one of the three worldwide ILC detector design studies with J.Jaros from SLAC.
- Member of two HEPAP subpanels: Particle Physics Project Prioritization Panel (P5) and Advanced Accelerator R&D Panel.
- Member of American Linear Collider Physics Group (ALCPG) and Linear Collider Steering Group of the Americas (LCSGA)
- US representative on International Linear Collider Steering Committee (ILCSC)
- 2009 High Energy and Particle Physics Prize of European Physical Society for discovery of Neutral Currents in 1972 with Gargamelle neutrino experiment.

## Volodymyr Yefremenko

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### **Education:**

- Ph.D. in Electrical Engineering, Kharkov Aviation Institute / Ukraine, 1987.
- M.S. State diploma in mechanical engineering, Kharkov Aviation Institute / Ukraine, 1975.

### **Professional Employment:**

- 06/2010 – present, R&D Engineer (Special Term Appointee), Materials Science Division (MSD), Argonne National Laboratory (ANL).
- 06/2007 – 06/2010, R&D Engineer (Term Appointee), MSD, ANL.
- 2003-2007, Visiting Scientist, MSD, ANL.
- 1997-2003, Group Leader, Infrared (IR) Devices Group, B. Verkin Institute for Low Temperature Physics and Engineering, National Academy of Sciences of Ukraine (ILTPE), Kharkov, Ukraine
- 1989-1997, Senior researcher, Department of Superconducting Electronics, ILTPE, Ukraine.
- 1975-1989, Engineer, Department of Infrared Devices, Special Research and Development Bureau for Cryogenic Technologies, ILTPE, Ukraine.

### **Awards, Memberships, and Professional Service:**

- Grant of International Science Soros Foundation (1992).
- Member of Scientific Technical Advisory Council of National Academy of Sciences of Ukraine on HTSC Electronics (1991-1994).
- Referee: Low Temperature Physics (Journal -"Fizika Nizkih Temperatur"- in Russian), IEEE Transactions on Applied Superconductivity.

### **Selected Publications:**

1. V. Yefremenko et al., **"Design and Fabrication of Argonne/KICP detectors for CMB polarization"**, Proceedings of 13<sup>th</sup> Int. Workshop on Low Temperature Detectors LTD13, vol. 1185, Stanford, CA, July 20-24, 2009.
2. V. Yefremenko et al., **"Low Temperature Thermal Transport in Partially Perforated Silicon Nitride Membranes"**, Appl. Phys. Letter, **94**, 183504 (2009).
3. V. Yefremenko et al., **"Control of Membrane Thermal Transport Supporting Superconducting Detector Development"**, IEEE Trans. of Applied Superconductivity, Vol.19, No3, pp. 489-492, June 2009.
4. V. Yefremenko et al., **"A broadband imaging system for research applications"**, Review of Scientific Instruments, **80**, 056104, 2009.
5. V. Yefremenko, E. Gordiyenko, V. Pishko, and V. Novosad, **"METHOD FOR DETECTION AND IMAGING OVER A BROAD SPECTRAL RANGE"**, US Patent # 7,274,019 B2, Sept. 25, 2007.
6. V. Yefremenko et al., **"Optically activated high Tc superconducting microbolometer"**, Journal of Physics: Conference Series vol. **43**, no.1: 1342-5, 2006.
7. V. Yefremenko et al., **"Superconducting microbolometer with controllable coordinate sensitivity: an alternative approach to FPA design"**, Infrared Technology and Applications XXXI, 28 March 2005, Orlando, FL, USA. Proceedings of the SPIE - The International Society for Optical Engineering vol. **5783**, no.1: 967-73, 2005.

## Huyue (Allen) Zhao

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### Education:

Ph.D.	Northwestern University	Mechanical Engineering	2008
M.S.	University of Maine	Mechanical Engineering	2002
B.S.	Huazhong Univ of Sci Tech, China	Mechanical Engineering	1996

### Professional Employment:

Mechanical Engineer High Energy Physics Argonne National Laboratory July 2007 – Present  
Lecture Mechanical Engineering Northwestern University Jan 2009 – Mar 2009

### Awards, Memberships, and Professional Service:

Argonne Pacesetter Award, 2010

Member, American Society of Mechanical Engineer, 2006-present

Level 3 Manager, International Collaboration of NOvA, 2008-2009

Level 3 Manager, International Collaboration of Dark Energy Survey (DES), 2008-present

### Selected Publications:

1. PH. Hu, H. Zhao, KF. Ehmann, “**Third-octave-mode chatter in rolling, Part 1, chatter model,**” Proc. IMechE, Part B: J. Engineering Manufacturing, Vol. 220, No. 8, 2006, p 1267-1277.
2. PH. Hu, H. Zhao, KF. Ehmann, “**Third-octave-mode chatter in rolling, Part 2, stability of a single-stand mill,**” Proc. IMechE, Part B: J. Engineering Manufacturing, Vol. 220, No. 8, 2006, p 1279-1292.
3. PH. Hu, H. Zhao, KF. Ehmann, “**Third-octave-mode chatter in rolling, Part 3, stability of a multi-stand mill,**” Proc. IMechE, Part B: J. Engineering Manufacturing, Vol. 220, No. 8, 2006, p 1293-1303.
4. S. Vel, V. Caccese, H. Zhao, “**Elastic coupling effects in tapered sandwich panels with laminated anisotropic composite facings,**” Journal of Composite Materials, Vol. 39, No. 24, 2005, p 2161-2183.
5. J. Zhao, Y. Hu, Y. Zhong, H. Zhao, “**Robust quality triangulation algorithm of arbitrary shaped planar domains,**” Journal of Huazhong University of Science and Technology, Vol. 28, No. 7, 2000, p 47-50.

## 7. Support and Infrastructure

In all experiments the Division has participated in or is participating in, members of the Division have played major roles in the design and construction of the hardware and detector sensors. Typically these are large mechanical structures that are assembled at Argonne or subsystems of trigger or readout electronics. In almost all cases, we provide electronics, installation systems and maintenance during the operation of the experiment. We also have access to the materials science expertise and micro and nano fabrication facilities within our materials science division and our center for nano-scale materials division which are both used in development of new detector sensors.

- We have Bldg. 366, a 23,000 sq ft high bay, 35 ton crane equipped, unique assembly area for large construction projects. ZEUS, MINOS and ATLAS modules as well as moving systems for ATLAS were built here. Currently the first prototype of a 56x56ft NOvA module is being assembled here. The Argonne lab provides and maintains this space.
- There is a mechanical design group within the Division, with two mechanical engineers, typically supported by project funds. Its size varies from a minimum of two FTEs up to three or four FTEs. We also have access to a lab wide engineering group in case more effort is needed. The division mechanical group currently also has four technical people (including one machinist) and typically this group is partially supported by project funds.
- The Division is the home of the electronics group with a total staff of ~ 9 engineers, designers and technicians who support ~10 Argonne divisions. This group designs, builds and maintains electronics associated with detectors provided by the Division for experiments. Typically at least 2-3 members of that group work on HEP activities.
- The Division has one major machine shop (plus machinist) in the large assembly building, plus two smaller machine shops in the electronics area and in one other lab.
- Within the main building for HEP, Bldg. 362, we have about 10 large lab spaces available, which are used for detector and electronics development, electronics repair, a cosmic ray test stand and several other testing and R&D activities.
- Through the competitive Laboratory Directed R&D (LDRD) program, we compete for these lab wide LDRD funds, which are typically used to develop a new idea for a detector or computing project, start a new activity and/or build a proof of principle for a new device. Typically LDRD funding is about \$1M/year in the division for several projects.
- Recently the division expanded substantially in office space, as a building became available connected to our main HEP building. The ATLAS group moved into this new space, providing more coherence to the group, better communications, more office space for visitors and workshops and the possibility to expand in the future. The Detector R&D group is in the process of moving into this new building including lab space for small scale production of large area micro-channel plate photodetectors. The group also plans to acquire an adjoining lab for a new photo-cathode growth and characterization facility connected to our large area photo-detector R&D program.

- The Division has access to expertise and capabilities within our Energy Systems and Materials Science Divisions which include facilities for Atomic Layer Deposition, Electron Microscopy Center, and a variety of surface analysis tools such as Low Energy Electron Diffraction, X-ray Photoelectron Spectroscopy, and Ultra-Violet Photoelectron Spectroscopy.
- The Division has access to the Blue Gene supercomputing capabilities within the Argonne Leadership Computing Facility
- The Division has access to the Center for Nanoscale Materials (CNM) which provides expertise, instruments and infrastructure for sensor development. This includes materials synthesis expertise, electron-beam lithography capabilities, an array of scanning probe tunneling and atomic force microscopy capabilities, scanning optical microscopy, and a dedicated hard X-ray beamline at our Advanced Photon Source for fluorescence, diffraction and transmission imaging.
- **Thin film synthesis tools**, including two 5-targets sputtering systems (AJA, direct and con-focal gun configurations) to synthesize superconducting and thin films and heterostructures. The confocal deposition system is dedicated for synthesis of superconducting films only, and provides film thickness uniformity ~2% across the 6” wafer.
- Clean Rooms (Class 1000) equipped with **microfabrication tools**, including 100-kV electron-beam lithography (JEOL 9300 FS), 30-kV electron-beam lithography (Raith 150), focused ion beam/scanning electron microscopy (FEI Nova 600 NanoLab Dual Beam, Step-and-repeat nanoimprint (Nanonex NX-3000), and Optical mask aligner (Karl Suss MA6), Reactive-ion etch (RIE) station for high resolution anisotropic etching of silicon, silicon dioxide, silicon nitride with a high degree of selectivity, anisotropic etching of refractory metals and removal of organic residue (uses CHF<sub>3</sub>, SF<sub>6</sub>, CF<sub>4</sub> gas chemistry), Inductive coupled plasma reactive ion etching chlorine chamber (Cl<sub>2</sub>, SF<sub>6</sub>, BCl<sub>3</sub>, HBr, CHF<sub>3</sub>, CO, O<sub>2</sub>, Ar) (Oxford Instruments Plasmalab 100); Reactive ion etching fluorine chamber (SF<sub>6</sub>, CF<sub>4</sub>, CH<sub>4</sub>, CHF<sub>3</sub>, HCFC-124, H<sub>2</sub>, O<sub>2</sub>, Ar) (Oxford Instruments Plasmalab 100); Table-top reactive ion etching chlorine chamber (Cl<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>, O<sub>2</sub>, Ar) (March Plasma); Table-top reactive ion etching fluorine chamber (SF<sub>6</sub>, CF<sub>4</sub>, H<sub>2</sub>, O<sub>2</sub>, Ar) (March Plasma); Table-top reactive ion etcher (CF, SF<sub>6</sub>, Ar, O<sub>2</sub>) (Plasma Sciences 600); Barrel asher system (Ar, N<sub>2</sub>, O<sub>2</sub>) (PlasmaTherm), Wet Wafer Processing tools, including, Wafer rinse dryer tool (2-, 4-, and 6-inch), Electroforming (Au, Cu, Ni, Pt), Silicon anisotropic etching, membrane fabrication and wet etching.
- **Metrological tools**, including Optical microscopes (Olympus MX-61), Three-dimensional surface profilometer (Veeco Dektak 8), Profilometer (Tencor Alpha Step 500), and Reflectometer (Filmetrics); X-ray diffractometers and Atomic Force Microscopes for structural of the films and devices. The AFM system is equipped with Q-control module for enhanced sensitivity and has a vibration isolation enclosure, which helps to ensure that the system has a vertical noise resolution of less than 0.5 Angstrom.
- **Conventional transport and magnetic characterization tools**, including Physical Properties Measurements System (PPMS, Quantum Design) for measurements of magnetization, magnetic anisotropy, susceptibility and I-V four-probe transport

measurements in temperatures 1.7K-400K, and magnetic fields up to 7 T, and Superconducting Quantum Interference Device (SQUID, Quantum Design) for high-sensitivity magnetization measurements at temperature range 1.7K - 350K, and magnetic fields up to 6 T.

- **Sub-Kelvin transport characterization tools**, (i) an insert-type liquid helium cryostat (CIA) with an open-cycled He3 refrigerator (280mK base temperature), (ii) liquid helium cryostat (Chase cryogenics) with a closed-cycled He3 refrigerator (230mK base temperature), (iii) four series DQUIDs arrays with home-built readout electronics, (iv) NIST time domain SQUIDs multiplexing read-out system, current one column first stage SQUIDs for 32 sensors readout, expandable to 32 x 8, (v) Lakeshore temperature controllers and temperature monitors; (vi) lock-in amplifiers (Stanford Research, SR830) and one AC resistance bridges (Stanford Research, SIM921).

## APPENDIX A: Dark Energy and Cosmology

### Publications

- [1] R. Kessler, **J.P. Bernstein**, D. Cinabro, B. Dilday, J.A. Frieman, S. Jha, **S. Kuhlmann**, G. Miknaitis, M. Sako, M. Taylor, and J. Vanderplas, “SNANA: A Public Software Package for Supernova Analysis,” *Publ. Astron. Soc. Pac.* *121* (2009), 1028–1035, <http://adsabs.harvard.edu/abs/2009PASP..121.1028K>.
- [2] **J.P. Bernstein**, R. Kessler, **S. Kuhlmann**, and **H. Spinka**, “Dark Energy Survey Supernovae: Simulations and Survey Strategy,” in *Cosmology. Proceedings of the 43rd Rencontres de Moriond*, edited by J. Dumarchez, Y. Giraud Heraud, and J. Tran Thanh Van, World Publishing Company, Vietnam (2009), 71–74, <http://adsabs.harvard.edu/abs/2009arXiv0906.2955B>.
- [3] **J.P. Bernstein**, R. Kessler, **S. Kuhlmann**, and **H. Spinka**, “Supernovae Simulations and Strategies: Application to the Dark Energy Survey,” *Bulletin of the American Astronomical Soc.*, prepared for the Dark Energy Survey Collaboration, **41** (2009), 754, <http://adsabs.harvard.edu/abs/2009AAS...21431302B>.
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- [6] R. Kessler et. al, “Results from the Supernova Photometric Classification Challenge,” <http://adsabs.harvard.edu/abs/2010arXiv1008.1024K>, submitted to PASP.
- [7] R. Kessler, D. Cinabro, B. Bassett, B. Dilday, J.A. Frieman, P.M. Garnavich, S. Jha, J. Marriner, R.C. Nichol, M. Sako, M. Smith, **J.P. Bernstein**, D. Bizyaev, A. Goobar, **S. Kuhlmann**, D.P. Schneider, and M. Stritzinger, “Photometric Estimates of Redshifts and Distance Moduli for Type Ia Supernovae,” *The Astrophysical Journal*, Volume 717, Issue 1, pp 40-57 (2010). <http://iopscience.iop.org/0004-637X/717/1/40/>
- [8] S. Bailey, **J.P. Bernstein**, D. Cinabro, R. Kessler, and **S. Kuhlmann**: section 11.2, “Simulations of SN Ia Light Curves and Event Rates,” *LSST Science Book Version 2.0*.
- [9] **J.P. Bernstein**, D. Cinabro, R. Kessler, and **S. Kuhlmann**: section 11.3, “Simulations of Core-Collapse Supernova Light Curves and Event Rates,” *LSST Science Book Version 2.0*.
- [10] P. Pinto, P. Garnavich, W.M. Wood-Vasey, **R. Biswas**, B.D. Wandelt, “Constraining the Dark Energy Equation of State,” *LSST Science Book Version 2.0*.

## APPENDIX B: High Energy Cosmic Particles (VHE-Gamma-Rays)

### Publications, and Technical Notes

- [1] V. Acciari...**R.G.Wagner**.. et.al., “VERITAS Search for VHE Gamma-ray Emission from Dwarf Spheroidal Galaxies,” Submitted to **Astrophysical Journal** July 2010, <http://arxiv.org/abs/1006.5955>
- [2] **A.Smith**, P. Kaaret, J. Holder, A. Falcone, G. Maier, D. Pandel and M. Stroh, “Long-Term X-ray Monitoring of the TeV Binary LSI +61 303 with the Rossi X-ray Timing Explorer”,**Astrophysical Journal** 693, Num 2, 1621 (2010)
- [3] **R.G. Wagner, K. Byrum, M. Sanchez, A.V. Vaniachine**, O. Siegmund, N.A. Otte, E. Ramberg, J. Hall, J. Buckley, “The Next Generation of Photo-Detectors for Particle Astrophysics”, white paper for Astro2010: The Astronomy and Astrophysics Decadal Survey, <http://arxiv.org/abs/0904.3565>
- [4] V.A. Acciari..**A. Smith**.. et.al., “Multiwavelength Observations of LSI +61 303 with VERITAS, Swift and RXTE,” **Astrophysical Journal Letters**, 700,1034-1041 (2009), <http://arxiv.org/abs/0904.4422>
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<http://www.hep.anl.gov/vjg/AzimuthDrives1.pdf>
- [6] **D. Horan** for the VERITAS collaboration, “VERITAS Observations of the TeV Blazar, 1es 3444+514,” Bulletin of the AAS (BAAS), vol. 40, no. 1, 2008 (20.05)
- [7] J. Buckley, E.A. Baltz, G. Bertone, **K. Byrum**, S. Fegan, F. Ferrer, P. Gondolo, J. Hall, D. Hooper, **D. Horan**, S. Koushiappas, H. Krawczynski, S. LeBohec, S. Profumo, J. Silk, **T. Tait**, V.V assiliev, **R. Wagner**, S. Wakely, M. Wood, **G. Zaharijas**, “Section on Prospects for Dark Matter Detection of the White Paper on the Status and Future of Ground-Based TeV Gamma-Ray Astronomy,” <http://arxiv.org/abs/0812.0795>
- [8] **Gary Drake, J. Anderson, Karen Byrum, John Dawson, Bill Haberichter, Deirdre Horan**, Frank Krennrich, **Andrew Kreps**, A. Madhavan, Martin Schroedter, **Andy Smith**, “A New High-Speed Pattern Recognition Trigger for Ground-Based Telescope Arrays Used in Gamma Ray Astronomy”, NSSC/MIC IEEE, Dresden Germany, October 2008
- [9] **K. Byrum**, J. Buckley, S. Bugayov, B. Dingus, S. Fegan, S. Funk, E. Hays, J. Holder, **D. Horan**, A. Konopelko, H. Krawczynski, F. Krennrich, S Lebohec, G. Sinnis, **A. Smith**, V. Vassiliev, S. Wakely, “Technology Section of the White Paper on the Status and Future of Ground-based TeV Gamma-ray Astronomy,” (2008), <http://arxiv.org/abs/0810.0367>

- [10] J. Buckley, **K. Byrum**, B. Dingus, A. Falcone, P. Kaaret, H. Krawczynski, M. Pohl, V. Vassiliev, D.A. Williams, “The Status and future of ground-based TeV gamma-ray astronomy. A White Paper prepared for the Division of Astrophysics of the American Physical Society (2008) <http://arxiv.org/abs/0810:0444>
- [11] **K. Byrum**, J. Cunningham, **G. Drake**, **E. Hays**, D. Kieda, **E. Kovacs**, **S. Magill**, **L. Nodulmann**, R. Norhtrop, S. Swordy, **R.G. Wagner**, S.P. Wakely, S.A. Wissel “The TrICE Prototype MAMPT Imaging Camera,” Oct 2007, <http://arxiv.org/abs/0710.0659>
- [12] **D. Horan** et. al., “Multiwavelength Observations of Markarian 421 in 2005-2006,” **Astrophysical Journal**, 695:Issue 1,596-618 (2009), <http://arxiv.org/abs/0901.1225>
- [13] M. Wood et. al. “A Search for Dark Matter Annihilation with the Whipple 10m Telescope,” **Astrophysical Journal**, 678:594-605, <http://arxiv.org/abs/0801.1708>
- [14] V.A. Acciari et al. “VERITAS Observations of the gamma-Ray Binary LSI +61 303,” **Astrophysical Journal**, 679:1427-1432, 2008 June, <http://arxiv.org/abs/0802.2363>
- [15] H.Krawczynski, et el. “Section on Extragalactic Science Topics of the White Paper on the Status and Future of Ground-Based TeV Gamma-Ray Astronomy,” Dec 2008, <http://arxiv.org/abs/0812:0793>
- [16] D.Horan et al. “Very High Energy Observations of Gamma-Ray Bursts with the Whipple/VERITAS Telescopes,” **Astrophysical Journal**, 655:396-405, 2007
- [17] V.A. Acciari et.al., “Discovery of Very High Energy Gamma-ray Emission from the SNR G54.1+.3,” **Astrophysical Journal**, 719,L69-L73 (2010)
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- [19] V.A. Acciari et.al., “The Discovery of Gamma-Ray Emission from the Blazar RGB J0710+591,” **Astrophysical Journal Letters**, 715,L49-L55 (2010)
- [20] V.A. Acciari et.al., “Observations of the Shell-type Supernova Remnant Cassiopeia A at TeV Energies with VERITAS,” **Astrophysical Journal**, 714,163-169 (2010)
- [21] V.A. Acciari et.al., “Discovery of Variability in the Very High Energy Gamma-Ray Emission of 1ES 1218+304 with VERITAS,” **Astrophysical Journal Letters**, 709,L163-L167(2010)
- [22] V.A. Acciari et.al., “A connection between star formation activity and cosmic rays in the starburst galaxy M82,” **Nature**, 462,770-772 (2009)
- [23] V.A. Acciari et.al., “Discovery of Very High Energy Gamma Rays from PKS 1424+240 and Multiwavelength Constraints on Its z,” **Astrophysical Journal Letters**, 708,100-106 (2010)

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- [25] V.A. Acciari et. al., “VERITAS Upper Limit on the VHE Emission from the Radio Galaxy NGC 1275,” **Astrophysical Journal Letters**, 706, L275-L280 (2009), <http://arxiv.org/abs/0911.0740>
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- [27] The VERITAS Collaboration, the VLBA 43 GHz M87 Monitoring Team, the HESS Collaboration, the MAGIC Collaboration, “Radio Imaging of the Very-High-Energy {gamma}-Ray Emission Region in the Central Engine of a Radio Galaxy,” **Science Magazine**, Vol. 325, pg 444-448 (2009), <http://arxiv.org/abs/0908.0511>
- [28] V.A. Acciari et. al., “Observation of Extended Very High Energy Emission from the Supernova Remnant IC 443 with VERITAS,” **Astrophysical Journal Letters**, 698, Issue 2, L133-L137 (2009), <http://arxiv.org/abs/0905.3291>
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- [32] A.D. Falcone et.al, “Gamma Ray Burst Section of the White Paper on the Status and Future of Ground-based TeV Gamma-ray Astronomy,” (2008) <http://arxiv.org/abs/0810.05620>
- [33] I. Donnarumma et.al, “The June 2008 flare of Markarian 421 from optical to TeV energies,” **Astrophysical Journal Letters**, 691: Issue 1,L13-L19 (2009), <http://arxiv.org/abs/0812.1500>
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- [34] M. Schroedter, F. Krennrich, S. LeBohec, A. Falcone, S. Fegan, D.Horan, J.Kildea, **A.W. Smith**, J. Toner, T.C. Weekes, “Search for Primordial Black Holes with SGARFACE,” **Astroparticle Physics**, Vol. 31, Issue 2, p. 102-115 (2009)

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- [36] A. Smith, “VERITAS Observations of Galactic Binaries”, Presentation, HEPRO 2010, Buenos Aires, Argentina (2010)
- [37] R.G.Wagner, “VERITAS Indirect Search for Dark Matter Program”, Presentation, IDM 2010: 8<sup>th</sup> International Workshop on Identification of Dark Matter, Montpellier, France (2010)
- [38] A. Smith, “Recent Results from VERITAS”, Invited Presentation, SnowPac 2010, Snowbird, UT Mar 2010
- [39] K.Byrum, “Large Area Fast Cameras for Gamma-Ray Astronomy and Cosmic Ray Physics”, Presentation, Workshop on Large-Area Picosecond-Photodetectors Electronics for Particle Physics and Medical Imaging, Jan 2010
- [40] K.Byrum, “Photon Detector R&D Program at Argonne National Laboratory,” General CTA Meeting, Zurich, Germany Oct, 2009
- [41] Wagner, R.G., "Technology Overview of the Advanced Gamma-ray Imaging System (AGIS), Presentation at 1st Technology and Instrumentation in Particle Physics Conference, Tsukuba, Japan, March, 2009.
- [42] V. Guarino, et. el; “The Advanced Gamma-ray Imaging System (AGIS) – Telescope Mechanical and Optical System Design”, Poster at APS, Denver Colorado, May 2-5, 2009 <http://www.hep.anl.gov/veritas/posters/AGIS-OSS-APS09-v2.ppt>
- [43] K. Byrum, J.Dawson, G. Drake, C. Duke, W. Haberichter, D. Horan, A. Imran, F. Krennrich, A. Madvahan, M. Schroedter, A. Smith, Design Report “A Fast Topological Array Trigger For Real Time Analysis of Nanosecond Time Scale Phenomena”, Internal Note (June 2008) for External Review
- [44] F.Krennrich, et el, “Topological Array Trigger”, Poster at APS, St. Louis, MO, Apr 2008 [http://www.hep.anl.gov/veritas/posters/APS08-AGIS\\_mechanics\\_v2.ppt](http://www.hep.anl.gov/veritas/posters/APS08-AGIS_mechanics_v2.ppt)
- [45] V. Guarino, E. Davis, “Schwarzschild-Couder Telescope Mechanical Design”, Aug 20, 2008; ANL Technical Note. <http://www.hep.anl.gov/vjg/SC-OSS-Structure1.doc>
- [46] V. Guarino, “ANL Mechanical Engineering Capabilities,” Presentation, Heidelberg, Germany Sept 2008 <http://www.hep.anl.gov/byrum/egis/Heidelberg2.ppt>
- [47] V. Guarino, “ANL Mechanical Engineering Capabilities and DC and SC Designs,” Presentation, CTA Collaboration Meeting, Italy Nov 2008 <http://www.hep.anl.gov/vjg/Transfer/Padova1.ppt>

[48] V.Guarino, K. Byrum, R.G.Wagner, et el, "AGIS Optical Mechanical Structure", Poster at APS, St. Louis, MO, Apr 2008 [http://www.hep.anl.gov/veritas/posters/APS08-AGIS\\_mechanics\\_v2.ppt](http://www.hep.anl.gov/veritas/posters/APS08-AGIS_mechanics_v2.ppt)

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[http://www.hep.anl.gov/veritas/posters/agis\\_mechanics\\_v5.pdf](http://www.hep.anl.gov/veritas/posters/agis_mechanics_v5.pdf)

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## APPENDIX C: Neutrino Masses and Mixing

### Selected Publications:

- [1] P. Adamson et al.(152 authors), "Neutrino and antineutrino inclusive charged-current cross section measurements with the MINOS near detector," *Phy.Rev.D*81:072002(2010).
- [2] E.W. Grashorn, J.K. de Jong, M.C. Goodman, A. Habig, M.L. Marshak, S. Mufson, S. Osprey, P.Schreiner, "The atmospheric charged kaon/pion ratio using seasonal variation methods," *Astroparticle Physics* 33,140-145. Mar 2010.
- [3] P. Adamson et al.(149 authors), "Search for sterile neutrino mixing in the MINOS long-baseline experiment," *Phy.Rev.D*81:052004 Mar 2010.
- [4] P. Adamson et al. (163 authors), "Search for muon-neutrino to electron-neutrino transitions in MINOS," *Phys.Rev.Lett.* 103, 261802 (2009).
- [5] P. Adamson et al. (154 authors), "Observation of muon intensity variations by season with the MINOS far detector," *Phys.Rev.D*81:012001, Jan 2010.
- [6] P. Schreiner et al. (3 authors) "Interpretation of the Underground Muon Charge Ratio", submitted *Astroparticle Physics* 32, pp. 61-71 May 2009.
- [7] M. Sanchez & M. Marengo, "A k-NN Method to Classify Rare Astronomical Sources: Photometric Search of Brown Dwarfs with Spitzer IRAC", Accepted for publication in the *Astronomical Journal*, arXiv:0904.3749
- [8] S. Osprey et al., (170 authors) "Sudden Stratospheric Warmings seen in MINOS deep underground muon data", *Geophys. Res. Lett.* 36, L05809 (2009).
- [9] C. Amsler et al., (192 authors) "Review of Particle Physics", *Physics Letters B*667, 1 (2008).
- [10] P. Adamson et al. (163 authors), "Search for active neutrino disappearance using neutral-current interactions in the MINOS long-baseline experiment," *Phys.Rev.Lett.* 101, 221804 (2008), Issue 22, 28 November 2008.
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- [12] P. Adamson et al. (152 authors), "Testing Lorentz invariance and CPT conservation with NuMI neutrinos in the MINOS near detector," *Phys.Rev.Lett.* 101, 151601 (2008), Issue 15, 10 October 2008.
- [13] P. Adamson et al. (170 authors), "Measurement of neutrino oscillations with the MINOS detectors in the NuMI beam," *Phys.Rev.Lett.* 101, 131802 (2008), Issue 13, 26 September 2008.
- [14] P. Adamson et al. (198 authors), "Study of muon neutrino disappearance using the Fermilab Main Injector neutrino beam," *Phys.Rev.D*77:072002 (2008), Vol. 77, No. 7, 1 April 2008.
- [15] P. Adamson et al. (203 authors), "Measurement of neutrino velocity with the MINOS detectors and NuMI neutrino beam," *Phys.Rev.D*76:072005 (2007), Vol. 76, No. 7, 1 October 2007.

- [16] P. Adamson et al. (200 authors), "Measurement of the atmospheric muon charge ratio at TeV energies with the MINOS detector," *Phys.Rev.D*76:052003 (2007), Vol. 76, No. 5, 1 September 2007.
- [17] P. Adamson et al. (199 authors), "Charge-separated atmospheric neutrino-induced muons in the MINOS far detector," *Phys.Rev.D*75:092003 (2007), Vol. 75, No. 9, 1 May 2007.
- [18] R. Zwaska et al. (17 authors), "Beam-based alignment of the NuMI target station components at FNAL," *Nucl.Instrum.Meth.A*568:548-560(2006), No. 2, 1 December 2006.

## APPENDIX D: Cosmic Microwave Background (CMB)

### Publications, and Technical Notes

#### *Science Publications:*

- [1] Brodwin et al., “SPT-CL J0546-5345: A Massive  $z > 1$  Galaxy Cluster Selected Via the Sunyaev-Zel'dovich Effect with the South Pole Telescope”, ApJL, in press, arXiv:1006.5639
- [2] Andersson et al., “X-ray Properties of the First SZE-selected Galaxy Cluster Sample from the South Pole Telescope”, ApJ, submitted, arXiv:1006.3068
- [3] Vanderlinde et al., “Galaxy Clusters Selected with the Sunyaev-Zel'dovich Effect from 2008 South Pole Telescope Observations”, ApJ in press, arXiv:1003.0003
- [4] High et al., “Optical Redshift and Richness Estimates for Galaxy Clusters Selected with the Sunyaev-Zel'dovich Effect from 2008 South Pole Telescope Observations”, ApJ, in press, arXiv:1003.0005
- [5] Lueker et al., “Measurements of Secondary Cosmic Microwave Background Anisotropies with the South Pole Telescope”, 2010, ApJ, 719, 1045, arXiv:0912.4317
- [6] Hall et al., “Angular Power Spectra of the Millimeter Wavelength Background Light from Dusty Star-forming Galaxies with the South Pole Telescope”, 2010, ApJ, 718, 632, arXiv:0912.4315
- [7] Vieira et al., “Extragalactic point sources in South Pole Telescope survey data: source counts, catalog, and statistics for an 87 square-degree field”, 2010, ApJ, 719, 763, arXiv:0912.2338
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- [9] Plagge et al., “Sunyaev-Zel'dovich Cluster Profiles Measured with the South Pole Telescope.”, 2010, ApJ 716, 1118, arXiv:0911.2444
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#### *Technical Publications:*

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- [16] Crites et al., “Optical Properties of Argonne/KICP TES Bolometers for CMB Polarimetry,” AIP volume 1185, pages 203-206, 2009. doi: 10.1063/1.3292315.
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- [18] Lueker et al., “A Frequency Domain Multiplexed Receiver for the South Pole Telescope,” AIP volume 1185, pages 241-244, 2009. doi: 10.1063/1.3292323.
- [19] Leuker et al., “Thermal Design and Characterization of Transition-Edge Sensor (TES) Bolometers for Frequency-Domain Multiplexing,” IEEE Transactions on Applied Superconductivity, 19:496-500, June 2009. doi: 10.1109/TASC.2009.2018036.
- [20] McMahon et al., “Planar Orthomode Transducers for Feedhorn-Coupled TES Polarimeters,” AIP, volume 1185, pages 490-493, 2009a. doi: 10.1063/1.3292386.
- [21] McMahon et al., “Optical design of Argonne/KICP Detectors for CMB Polarization,” AIP, volume 1185, pages 487-489, 2009b. doi: 10.1063/1.3292384.
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[31] “Observations of the Sunyaev-Zel'dovich Effect: Current Status and Future Plans,” 2008 Crafoord Prize symposium, Stockholm, Sweden, April 22, 2008, John Carlstrom

[32] “First results from the South Pole Telescope (SPT),” Dark Energy Conference, Munich, Germany, Oct 11, 2009, John Carlstrom

[33] “The Cosmic Microwave Background: Progress and Prospects,” in AAAS session: Origins and Endings: From the Beginning to the End of the Universe, Chicago, Feb 16, 2009, John Carlstrom

[34] “The South Pole Telescope,” at Submillimeter Astrophysics and Technology, A Symposium in Honoring of Thomas G. Phillips, Caltech, February 23-24, 2009, John Carlstrom

[35] “Update on the South Pole Telescope SZ Cluster Survey,” at *{\it Dark Energy, lighting up the darkness}*, Institute for the Physics and Mathematics of the Universe, University of Tokyo, Kashiwa, Japan, June 25, 2009, John Carlstrom

[36] “The 10 Meter South Pole Telescope,” at the IAU General Assembly, Special Session 3, Astronomy in Antarctica, Rio de Janeiro, August 6, 2009, John Carlstrom

[37] “New Cosmic Microwave Background Results from the South Pole Telescope,” KICC Opening Science Symposium, Cambridge, England, Nov 17, 2009, John Carlstrom

[38] “Cosmology with the Cosmic Microwave Background,” Plenary presentation at APS April Meeting, Washington, DC, Feb 16, 2010, John Carlstrom

[39] “Cosmic Microwave Background Results and Future Prospects,” Plenary presentation at the 216th meeting of the American Astronomical Society, Miami, Florida in May 2010, John Carlstrom

[40] “New Results from the South Pole Telescope,” Galaxy Clusters: Observations, Physics and Cosmology, Garching, Germany, July 2010, John Carlstrom

- [41] “Astrophysics and Antarctica,” Weyprecht Lecture at the Plenary Meeting of the 4th SCAR Open Science Conference, Buenos Aires, Argentina, August 2010, John Carlstrom
- [42] “Key Projects of the SPT,” SNOWPAC Workshop, 2010, Clarence Chang
- [43] “SPT-SZ: a SZ survey for galaxy clusters,” LTD-13 Conference, 2009, Clarence Chang