Jet Quenching Proposal

Alexandre Vaniachine

HEP Division Retreat

December 14-15, 2010

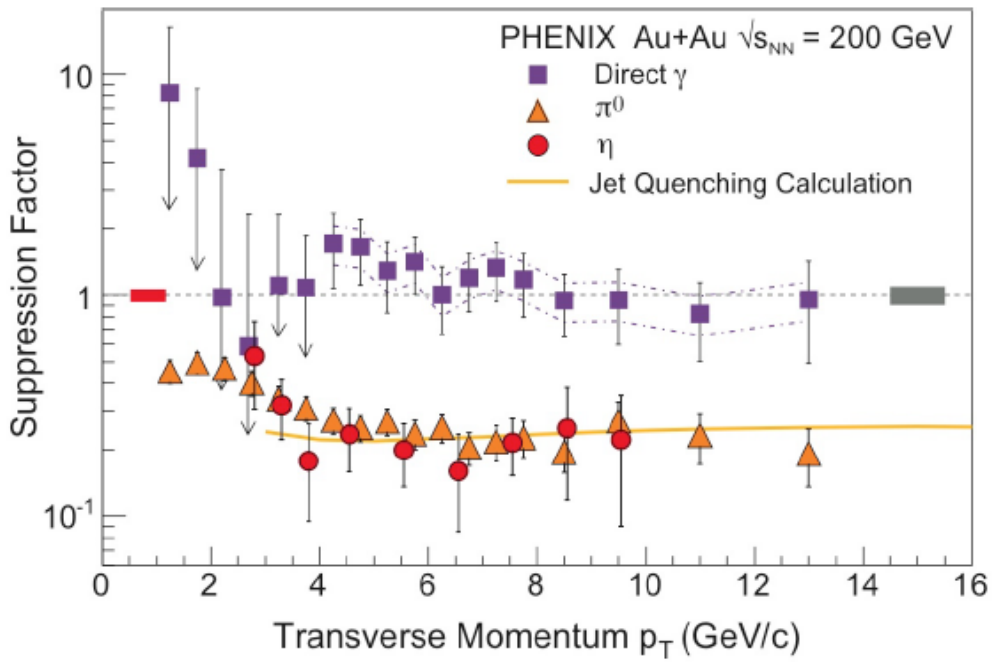
Argonne, IL

Elevator Pitch

- If the QGP medium at LHC is weakly coupled, then we should study it
  - Measurements of QCD asymptotic freedom is in the realm of HEP physics
- Such borderline project is aligned with the ASC strategy for expansion beyond HEP
- Longitudinal segmentation of ATLAS calorimetry provides us with a competitive advantage (vs. CMS) in jet quenching studies, where the background subtraction of the underlying event is done per each calorimeter cell
  - Most of the (low-energy) underlying event background is deposited in the first compartment
- Argonne ATLAS group expertise in calorimetry and jet shape analysis provide competitive advantage in jet quenching studies
- Potential for computational physics project at ALCF
- High outreach value of the studies that "will bring important insights into the evolution of the early Universe, and into the nature of the strong force that binds quarks and gluons together into protons, neutrons, and ultimately all the nuclei of the periodic table of elements"

QGP Medium at RHIC is Strongly Coupled

- How to measure $\hat{q}$? Compare AA collisions at RHIC to pp !



$$R_{AA}(p_\perp) \equiv \frac{Yield(A+A)}{Yield(p+p) \times A^2}$$

- RHIC data seem to prefer a rather large value for $\hat{q}$:

$\hat{q}_{\rm RHIC} \simeq 5 \div 15$ vs. $\hat{q}_{\rm pQCD} \simeq 0.5 \div 1\,{\rm GeV}^2/{\rm fm}$

$\Longrightarrow$ 5 to 10 times larger than the pQCD estimate !

E. Iancu arXiv:0812.0500

Expected

lanl.arXiv.org > nucl-ex > arXiv:1011.3916v2

Nuclear Experiment

Charged-particle multiplicity density at mid-rapidity in central Pb-Pb collisions at sqrt(sNN) = 2.76 TeV

The ALICE Collaboration

(Submitted on 17 Nov 2010 (v1), last revised 19 Nov 2010 (this version, v2))

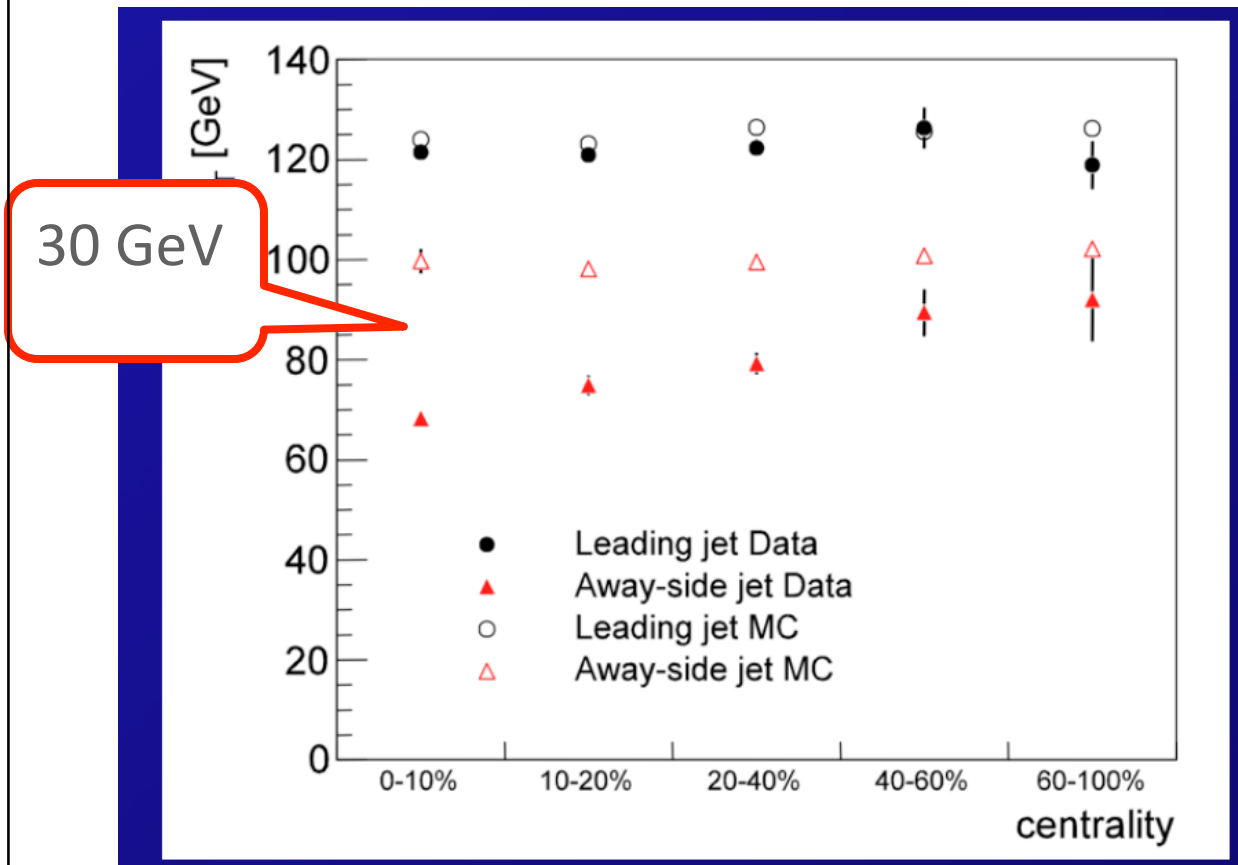
The first measurement of the charged-particle multiplicity density at mid-rapidity in Pb-Pb collisions at a centre-of-mass energy per nucleon pair sqrt(sNN) = 2.76 TeV is presented. For an event sample corresponding to the most central 5% of the hadronic cross section the pseudo-rapidity density of primary charged particles at mid-rapidity is 1584 +- 4 (stat) +- 76 (sys.), which corresponds to 8.3 +- 0.4 (sys.) per participating nucleon pair. This represents an increase of about a factor 1.9 relative to pp collisions at similar collision energies, and about a factor 2.2 to central Au-Au collisions at sqrt(sNN) = 0.2 TeV. This measurement provides the first experimental constraint for models of nucleus-nucleus collisions at LHC energies.

From "Jet Quenching in Heavy Ion Collisions", U. Wiedemann, arXiv:0908.2306

$$\hat{q}_{\rm LHC} = \sqrt{\frac{dN_{\rm ch}^{\rm LHC}/d\eta}{dN_{\rm ch}^{\rm RHIC}/d\eta}}\,\hat{q}_{\rm RHIC} \quad = 7 \ldots 22\ \mathrm{GeV}^2/\mathrm{fm}$$

- Expecting QGP medium, which is 1.5 times more strongly coupled than at RHIC

Observed



Simply calculate <ET> for leading, second jets in skimmed events

No, leading, second correlation

Compare to HIJING + PYTHIA MC

- $\hat{q}_{LHC}$ ~ 30 GeV / L^2 , using <L> = 4.2 fm, 1 fm^{-1} = 0.197 GeV, $C_R * \alpha_s = 1$

  $\hat{q}_{LHC}$ ~ 0.3 GeV^2 / fm

- If the QGP medium at LHC is weakly coupled, then we should study it

Backup

Related DOE Nuclear Physics R&D on "Strongly Coupled Quark-Gluon Plasma" (sQGP)

Proposal for a Topical Collaboration on

Quantitative Jet and Electromagnetic Tomography (JET) of Extreme Phases of Matter in Heavy-ion Collisions

for the period of
May 1, 2010 – April 30, 2015

(in alphabetical order of institutions)
Miklos Gyulassy (Columbia University)
Steffen Bass and Berndt Mueller (Duke University)
Volker Koch, Xin-Nian Wang and Feng Yuan (Lawrence Berkeley National Laboratory)
Ramona Vogt (Lawrence Livermore National Laboratory)
Ivan Vitev (Los Alamos National Laboratory)
Charles Gale and Sangyong Jeon (McGill University)
Ulrich Heinz and Abhijit Majumder (Ohio State University)
Denes Molnar (Purdue University)
Rainer Fries and Che-Ming Ko (Texas A & M University)

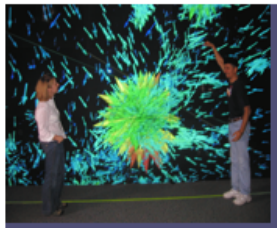
Co-Spokespersons: Berndt Mueller (Duke University) and Xin-Nian Wang (LBNL)

Argonne Expertise in QFT Computations

Salman Habib

My research focuses mainly on the dynamics of classical and quantum field theories with applications in particle physics, condensed matter systems, atomic and quantum optics, accelerator physics, and cosmology. Other areas include quantum dynamics of open systems, astrophysics, nonlinear dynamics, and stochastic PDEs. I am interested in the intelligent application of supercomputers to solving physics problems.

Katrin Heitmann



About Me

Cosmology

Rocks

QFT and Gauge Fields

Publications

Supercomputing

About Myself

I am a Technical Staff Member in ISR-1 in ISR Division at Los Alamos National Laboratory. I came to Los Alamos as a postdoc of the Elementary Particles and Field Theory Group (T-8), in the Theoretical Division. I received my Dr. rer. nat. from the University of Dortmund in 2000 with Prof. J. Baacke. A pdf- or ps-file of my thesis on **Non-equilibrium dynamics of symmetry breaking and gauge fields in quantum field theory** is available here. If you would like to read a summary of my scientific live so far you can download my CV. While my earlier research was mainly focused on quantum field theories out of equilibrium during my time in Los Alamos I have become more and more interested in cosmology and now I am spending most of my time thinking about our Universe. In order to work also on something more down to earth I recently started to study the nonlinear behavior of rocks with collaborators from EES- and T-division.

Argonne Expertise in Lattice QCD Computations

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arXiv.org > hep-ph > arXiv:0906.3175

High Energy Physics – Phenomenology

A lattice test of strong coupling behaviour in QCD at finite temperature

E. Iancu, A.H. Mueller

(Submitted on 17 Jun 2009)

We propose a set of lattice measurements which could test whether the deconfined, quark-gluon plasma, phase of QCD shows strong coupling aspects at temperatures a few times the critical temperature for deconfinement, in the region where the conformal anomaly becomes unimportant. The measurements refer to twist-two operators which are not protected by symmetries and which in a strong-coupling scenario would develop large, negative, anomalous dimensions, resulting in a strong suppression of the respective lattice expectation values in the continuum limit. Special emphasis is put on the respective operator with lowest spin (the spin-2 operator orthogonal to the energy-momentum tensor within the renormalization flow) and on the case of quenched QCD, where this operator is known for arbitrary values of the coupling: this is the quark energy-momentum tensor. The proposed lattice measurements could also test whether the plasma constituents are pointlike (as expected at weak coupling), or not.

Secondary Interactions in pp-collisions at LHC

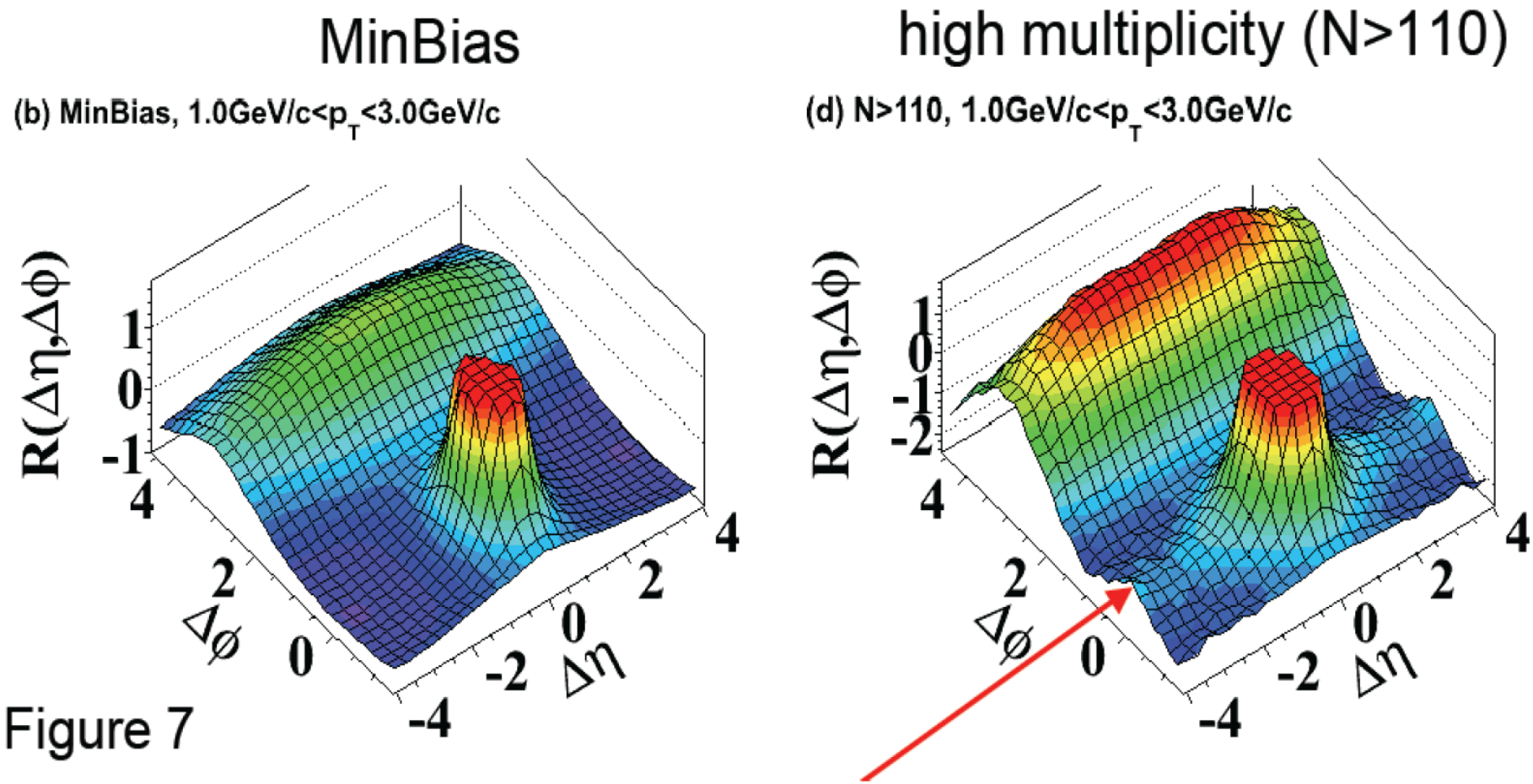


Figure 7

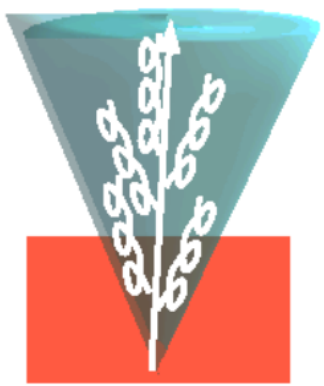
- CMS "ridge" effect shows that secondary interactions in pp are observable at LHC
  - There could be an observable jet quenching effect in pp
    - Perhaps ~20 times less than in PbPb, since jet quenching is an L^2 effect

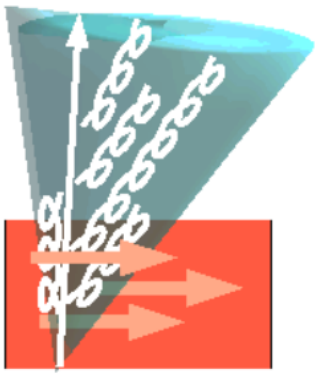
Relevance of Expertise in Jet Shapes Measurement

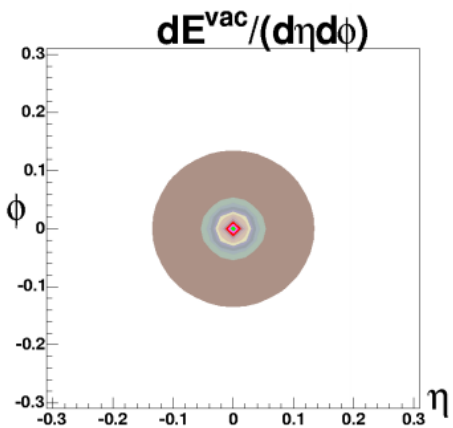
Vacuum
(reference)

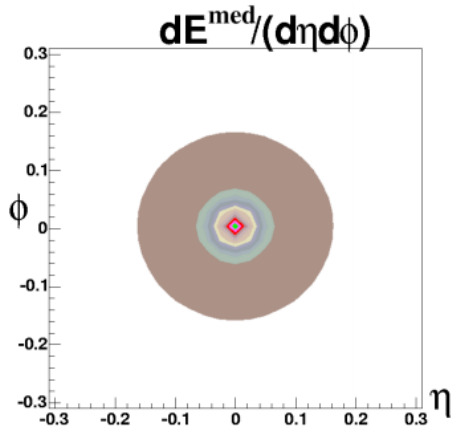
Medium:
broadening

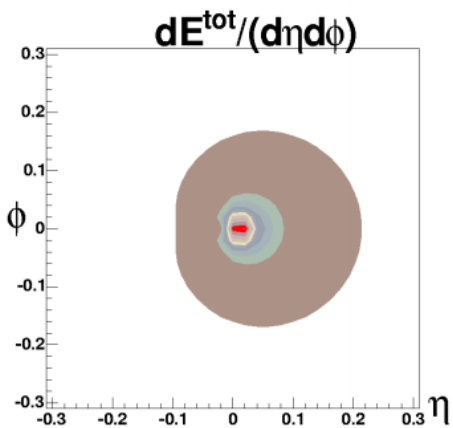
Flowing medium:
anisotropic shape











C. Salgado

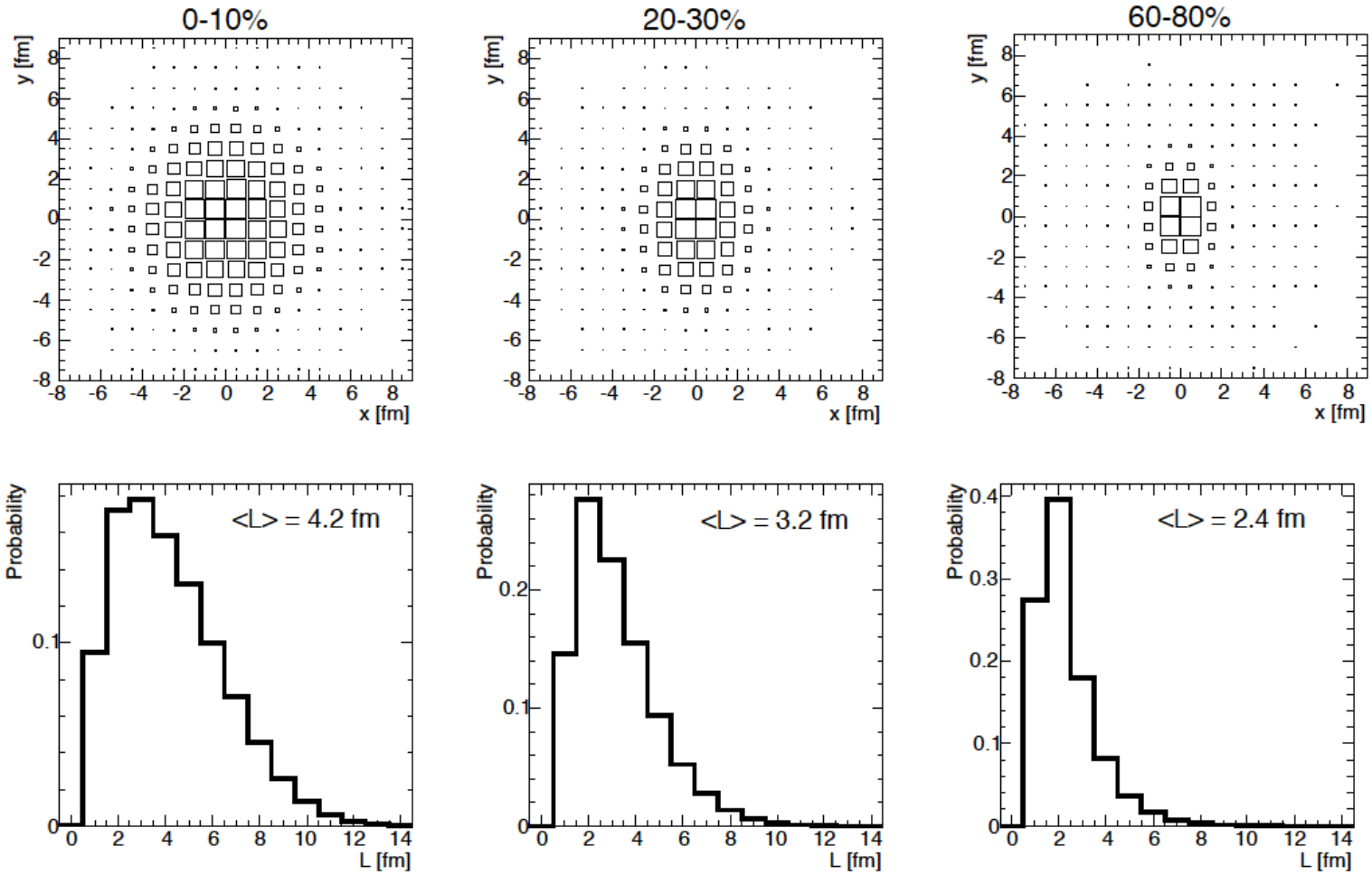


Figure 1: Distributions of parton production points in the transverse plane (upper row) and in-medium path length (lower row) in central, semi-central and peripheral Au–Au collisions. The quantity $\langle L \rangle$ is the average of the path length distribution.

arXiv:0406201v3