ALICE in Discovery

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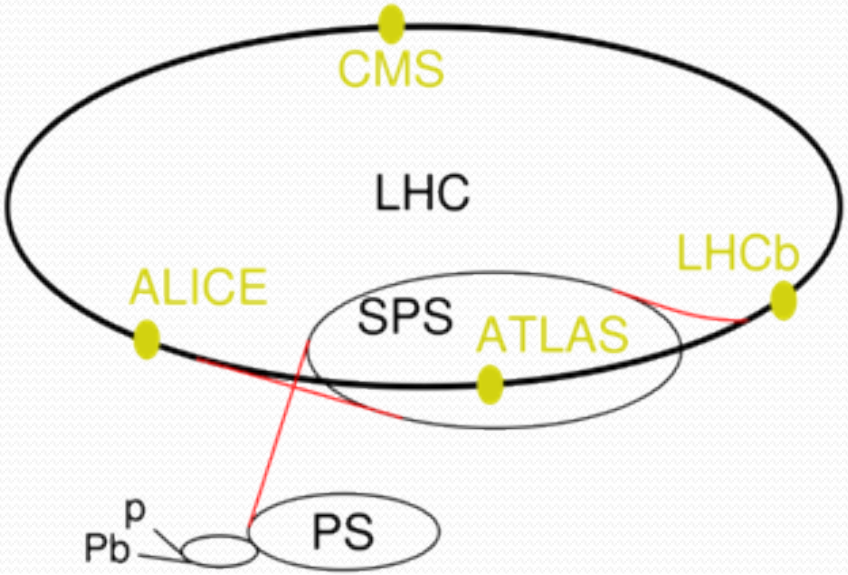
NBI – ALICE/Discovery group

The Large Hadron Collider

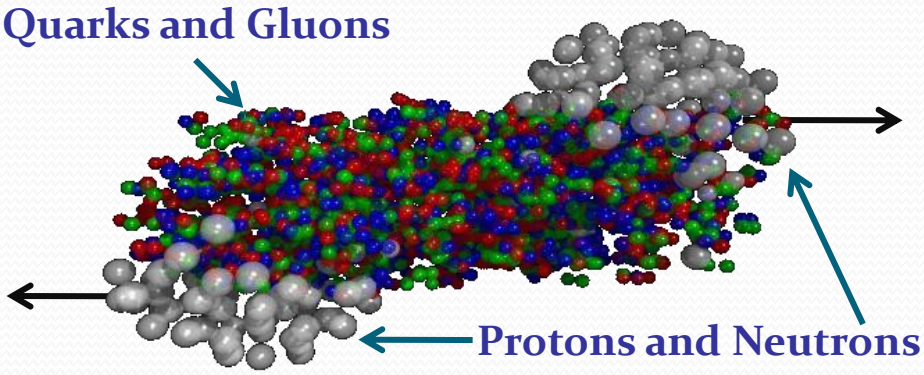


The Large Hadron Collider Accelerator Chain

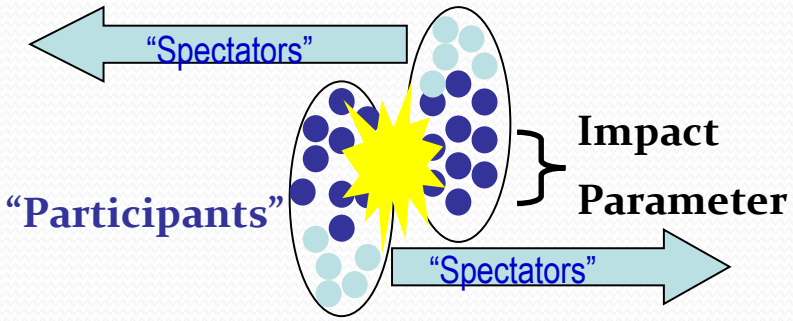
- Protons (since late 2009) and lead ions accelerated
- Delivered to 4 experiments
- ALICE is interested (mainly) in lead collisions
  - Proton collisions are important to the program though

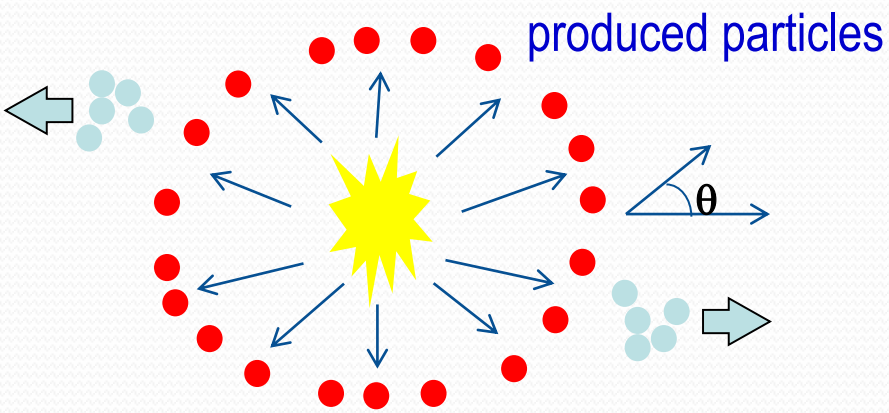
Heavy Ion Collisions

- Quarks and gluons normally confined with hadrons
- High energy nuclei are collided
  - State of nuclei believed to be a Colored Glass Condensate
- Ion collision creates region of strongly interacting particles – Quark Gluon Plasma
- QGP believed to be state of matter 1 μs after the big bang
- QGP expands and makes hadrons
- Analysis of these hadrons reveal properties of QGP and CGC



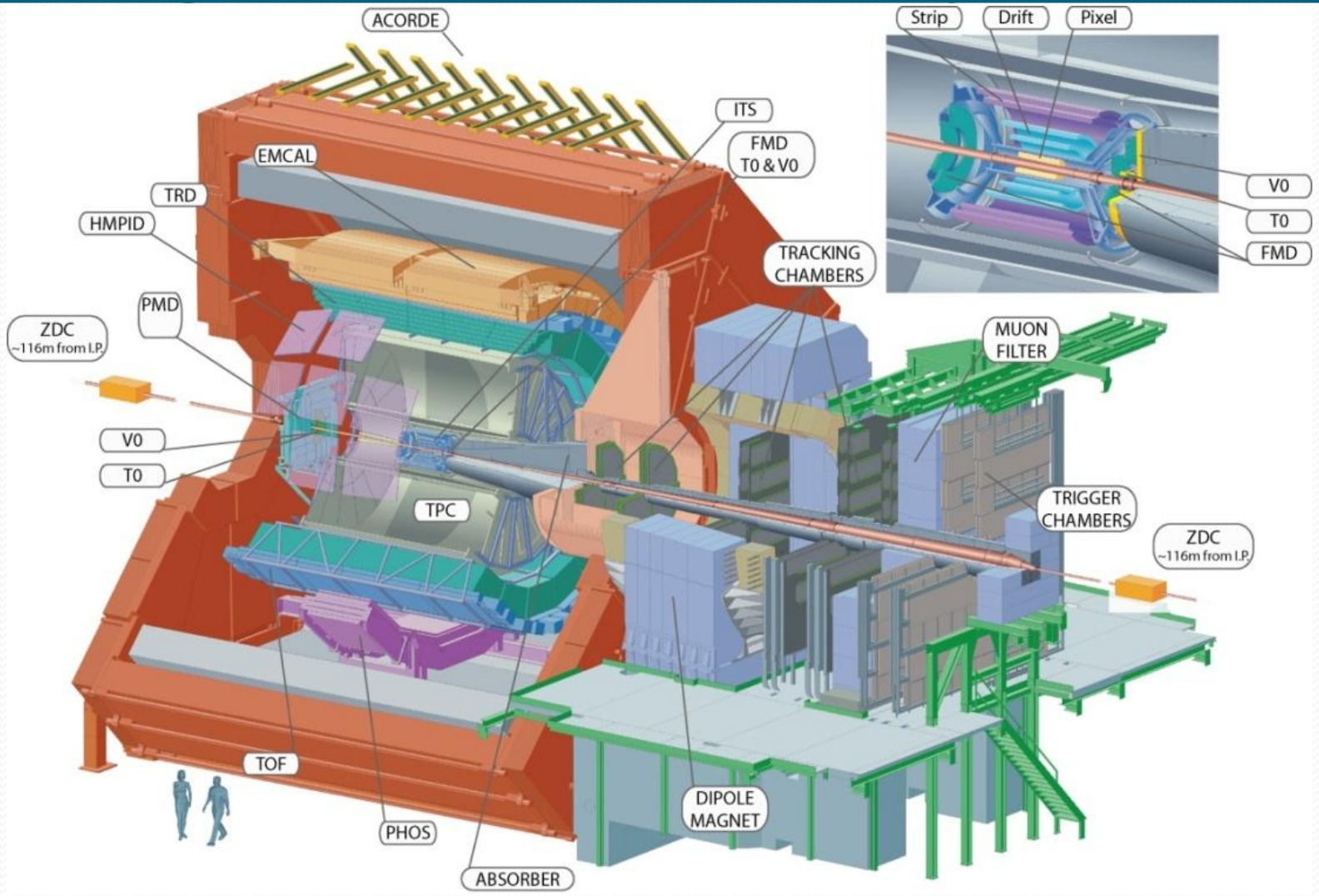
Ions after colliding at high energy





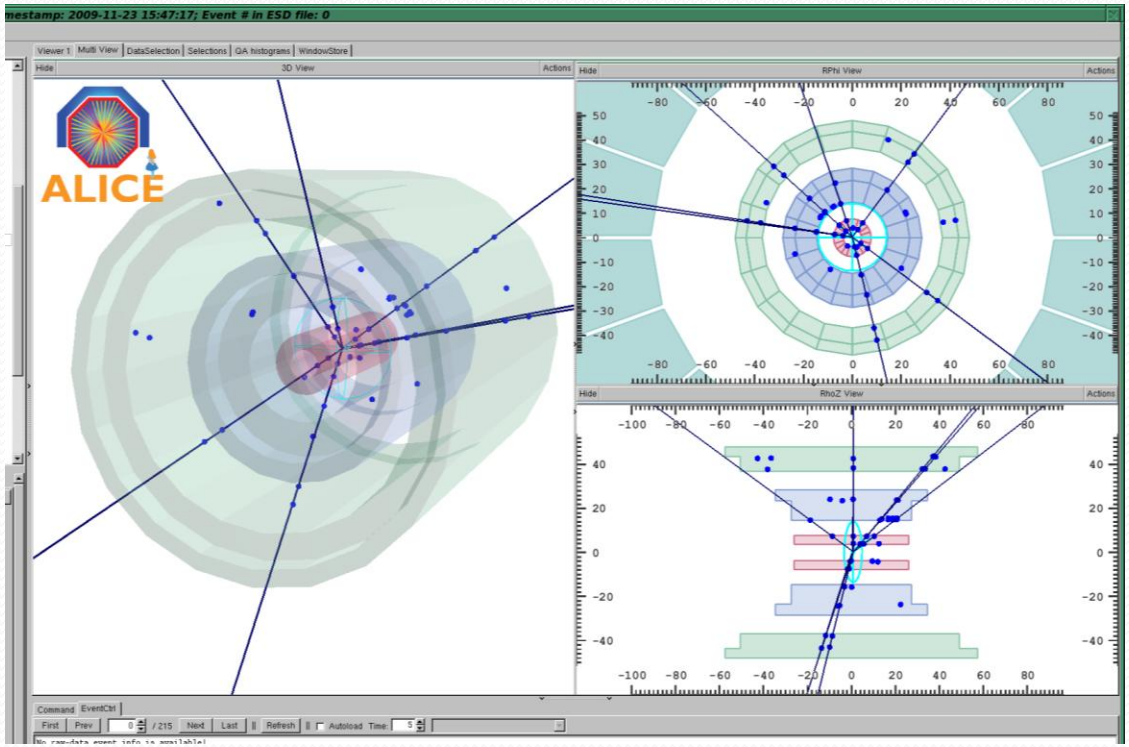
$$\eta = -\ln(\tan(\theta/2))$$

A Large Ion Collider Experiment



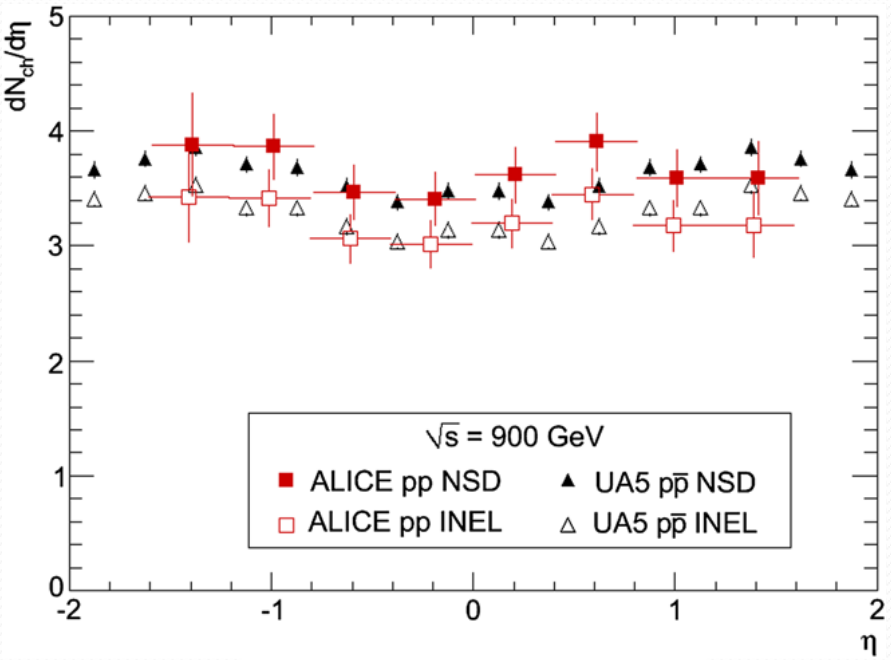
Data Taken

- The LHC provided p+p collisions initially at 900 GeV
- Small amounts of p+p data were provided at 2.36 TeV
- Much data with 7 TeV p+p collisions



900 p+p GeV Results

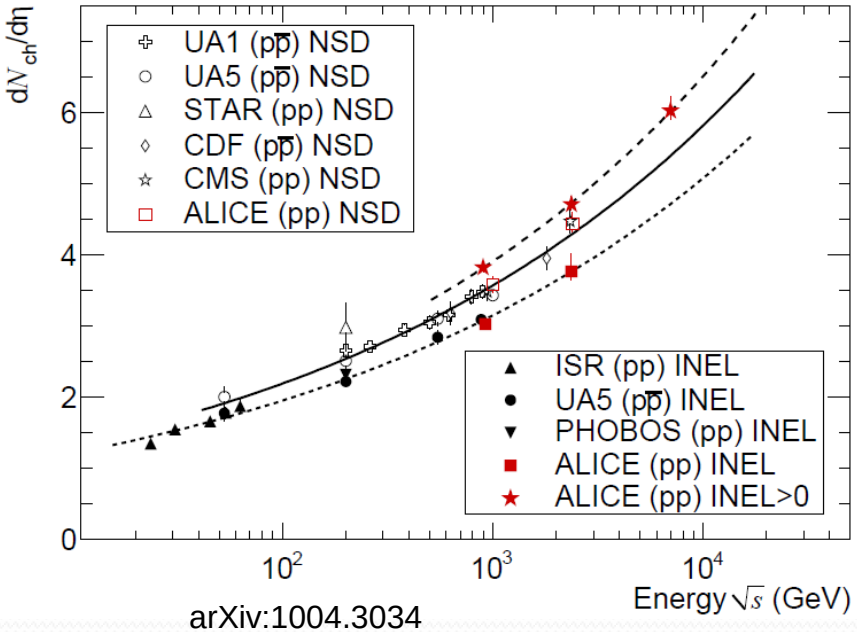
- Based on 284 events
- Uses tracklets in ITS to estimate multiplicity
- Provides base line for higher energy systems
- Agrees with earlier results (UA5)



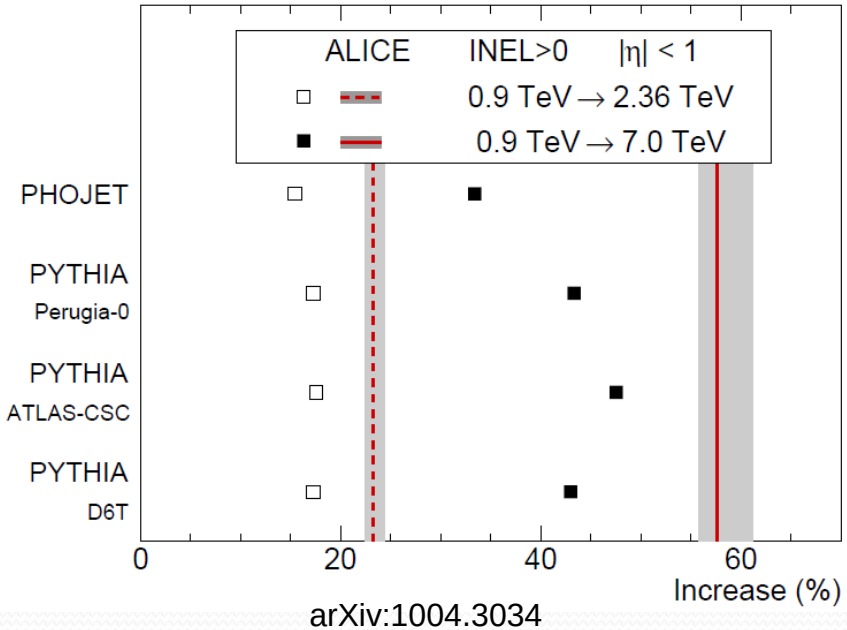
Eur. Phys. J. C. 65 (2010) 111 - 125

Energy dependence of $dN_{ch}/d\eta$

- 7 TeV p+p collisions analyzed
- Power-law increase in multiplicity
- Ratios of multiplicities compared to models
  - PHOJET and tunes of PYTHIA
  - Models do not describe increase

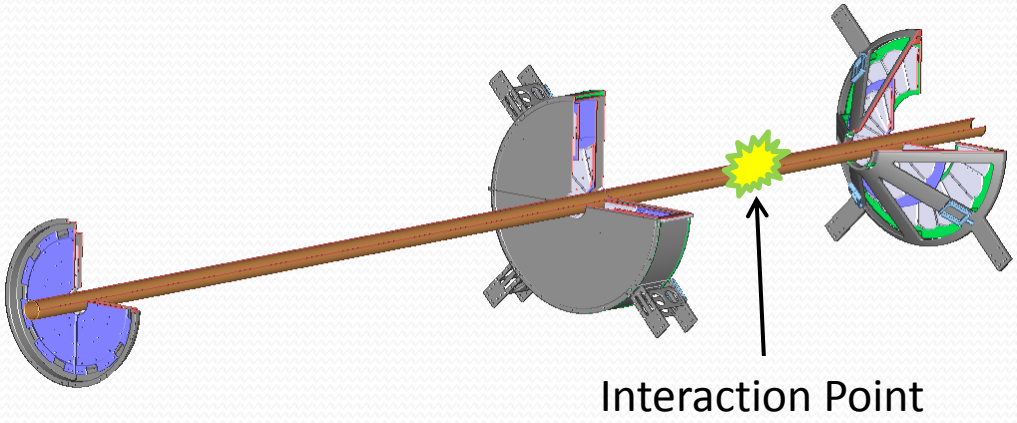


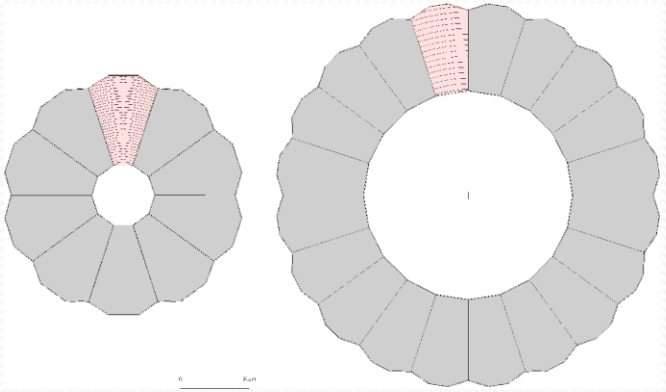
arXiv:1004.3034



arXiv:1004.3034

Forward Multiplicity Detector (NBI)

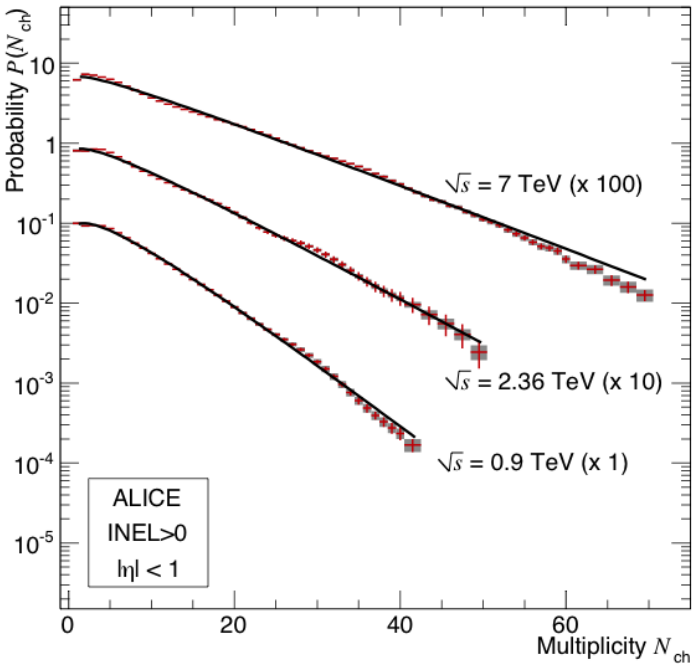


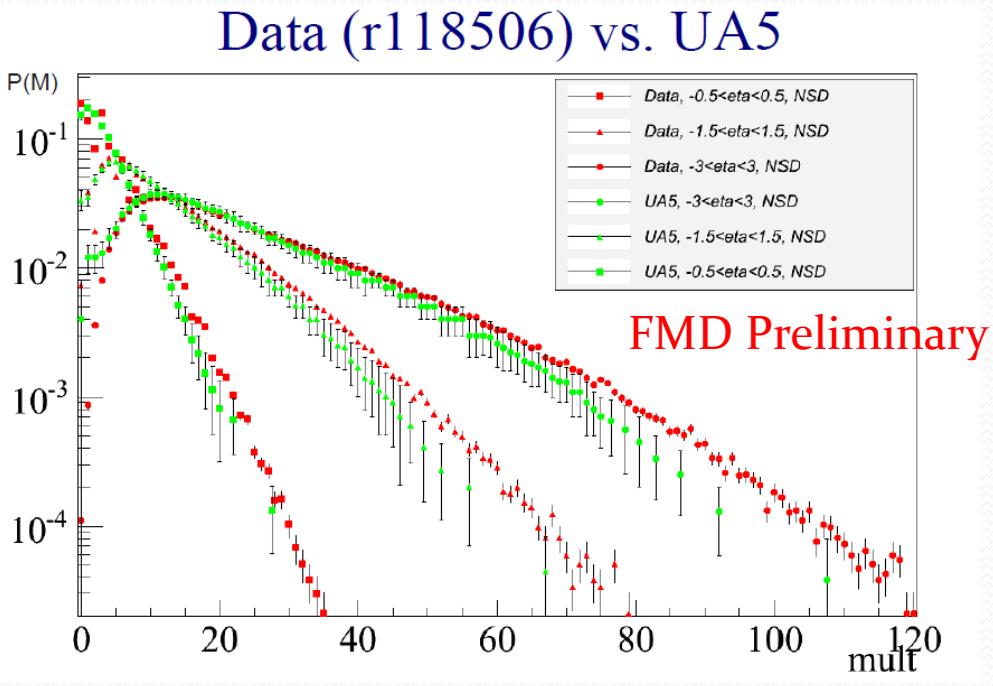


- Only detector in ALICE with high segmentation at high |η|
- 51200 silicon strips - radial and azimuthal segmentation
- position and energy information
- Hit information can be used in p+p for particles detection
- Energy information used in Pb+Pb (high occupancy)

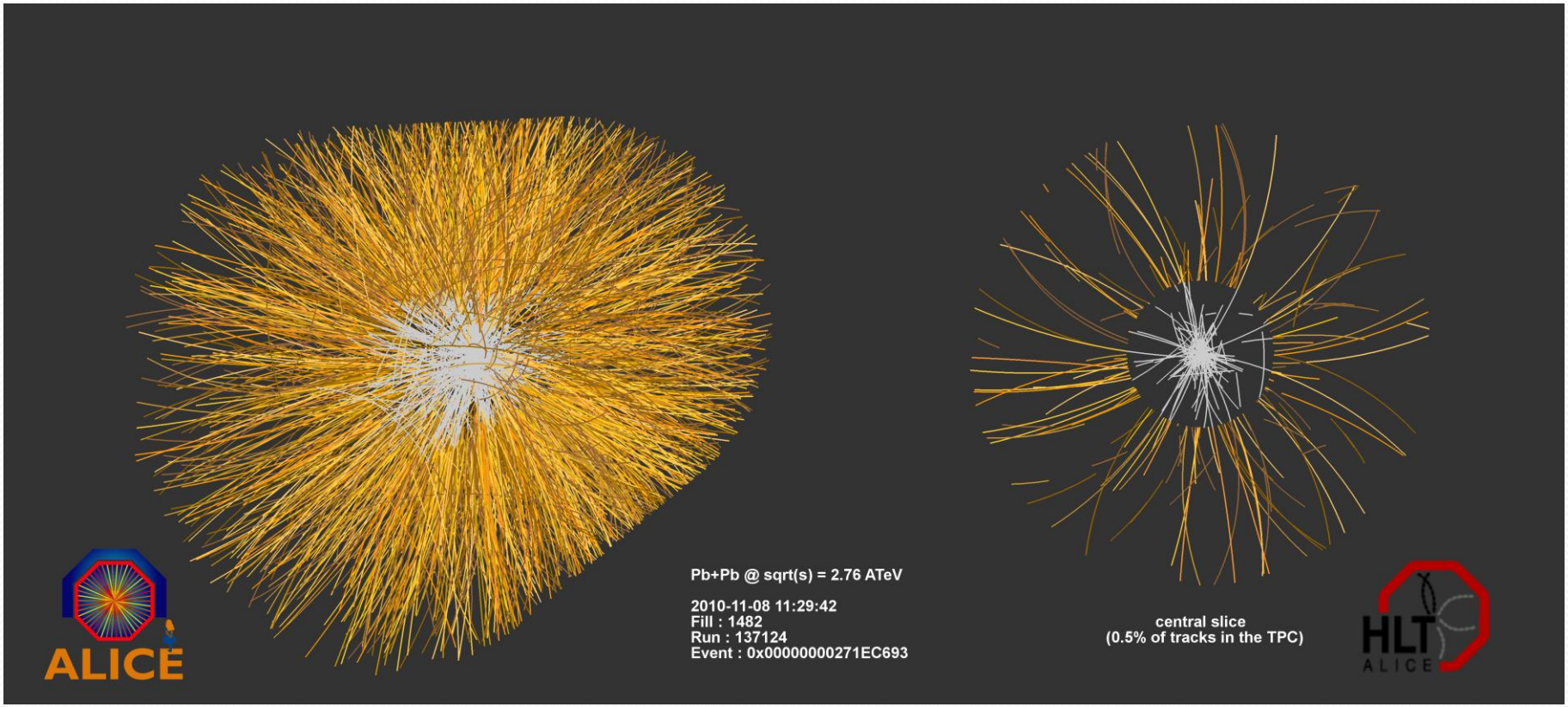
Multiplicity Distributions

- Negative binomial fits done to distributions at all energies
  - Tests of KNO scaling
- FMD allows for study of multiplicity distribution vs η



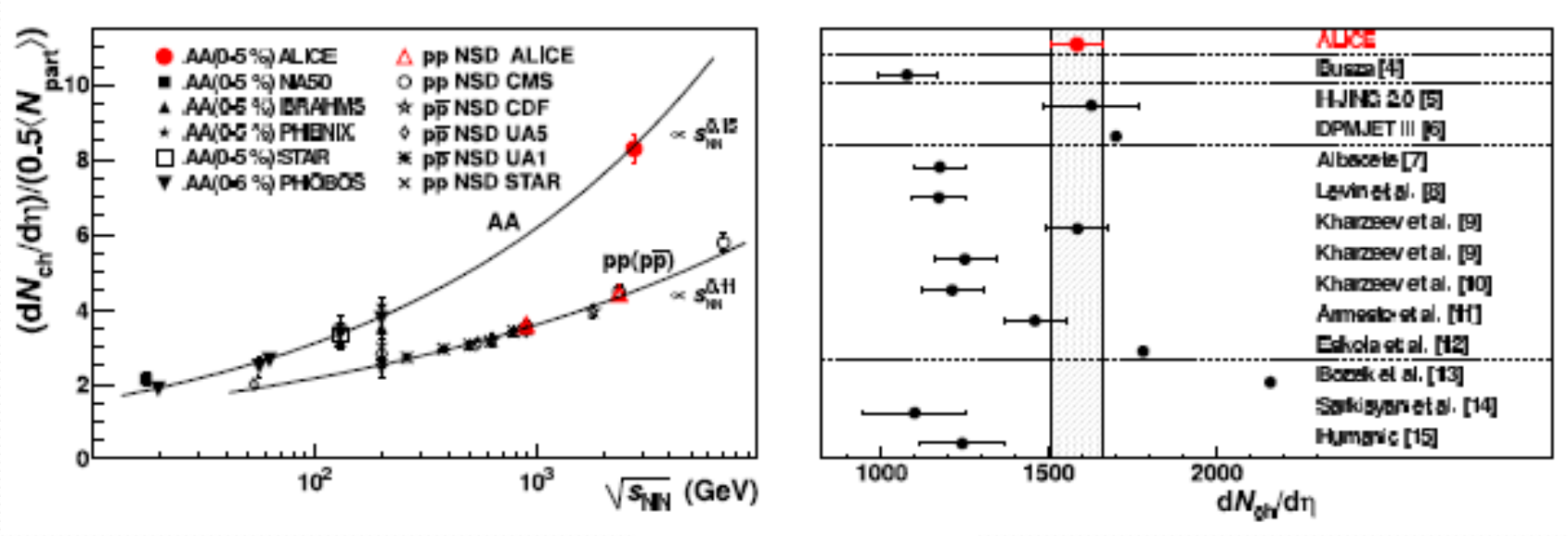


First Pb+Pb Collisions



2.76 TeV Pb+Pb Results

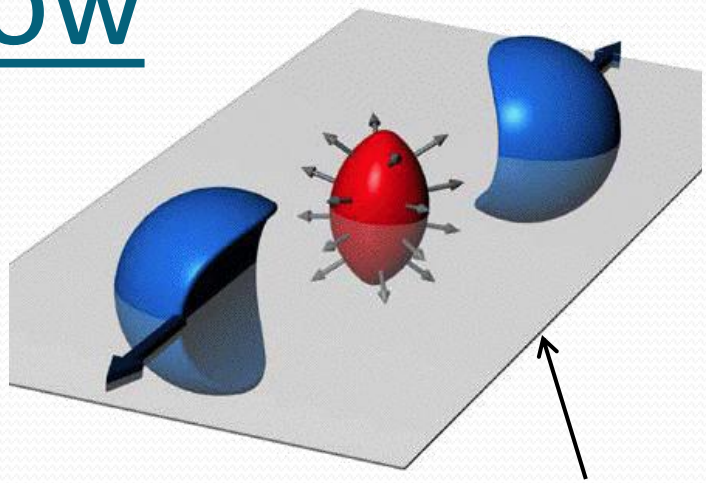
- Uses (again) tracklets in ITS to estimate multiplicity
- Significant increase from lower energies
- Some models predicted the right multiplicity
  - Provides some constraints on gluon saturation models



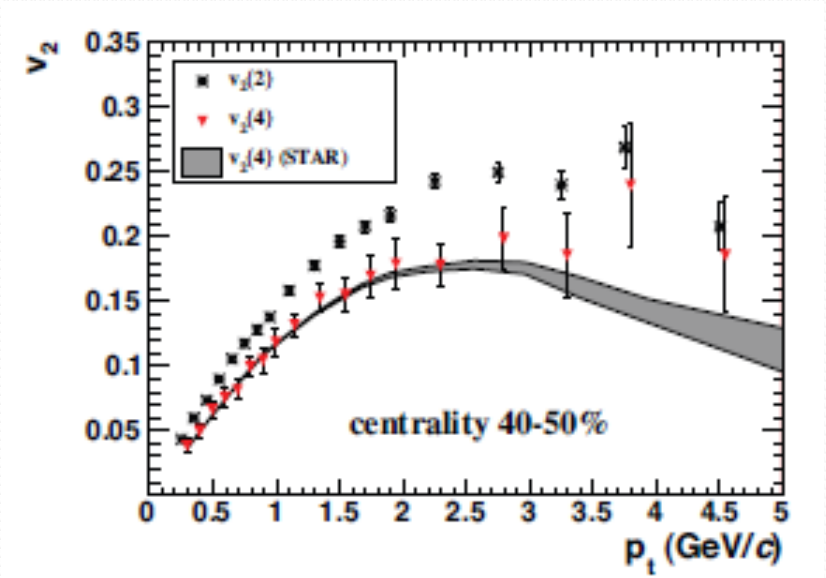
arXiv:1011.3916v2 [nucl-ex]

Elliptic Flow

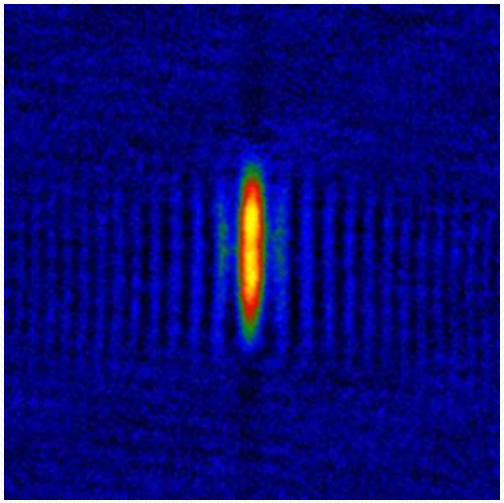
- Spatial anisotropy leads to momentum anisotropy
  - Requires interactions
- $v_2 = \langle \cos 2(\phi - \Psi_R) \rangle$ measure of anisotropy
- Large flow at high transverse momentum



Ψ_R - Reaction plane



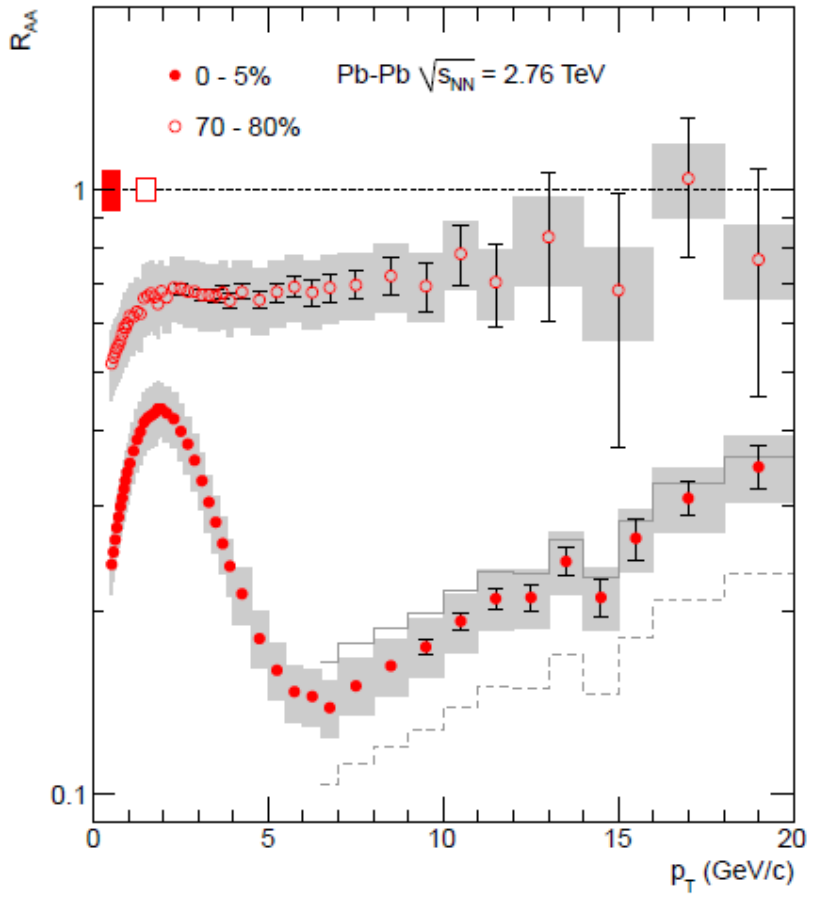
arXiv:1011.3914v1 [nucl-ex]



Duke – Jetlab – Cold Atoms
http://www.phy.duke.edu/research/photon/qoptics/news/stronginter/index.html

High P_T Particle Suppression

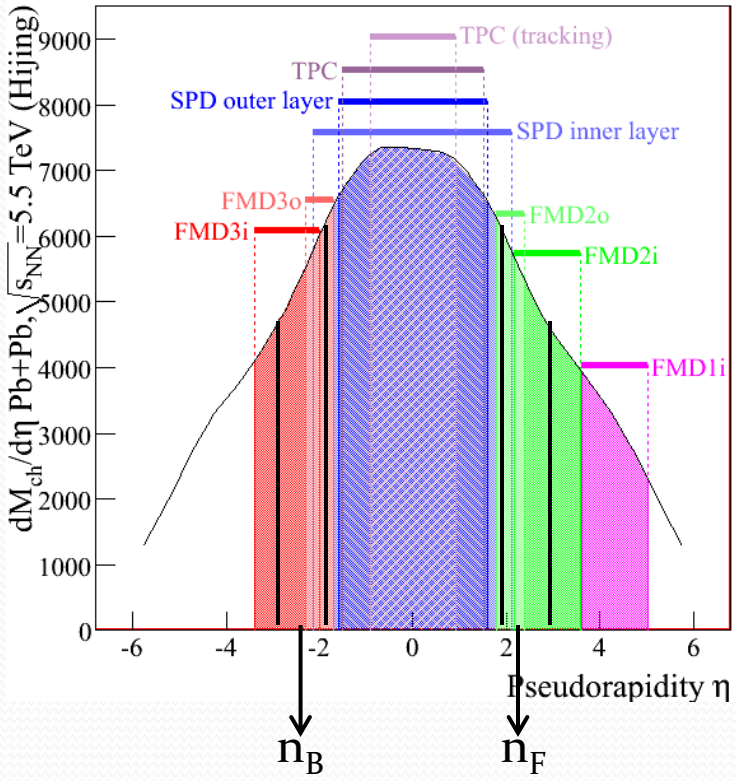
- R_{AA} – ratio of transverse momentum spectra in PbPb and pp (scaled by number of nucleons)
- Suppression of high p_T particles in central collision while not seen in peripheral collisions
  - Interpreted as energy loss of particles traversing dense medium



arXiv:1011.3916v2 [nucl-ex]

Forward-Backward Correlations

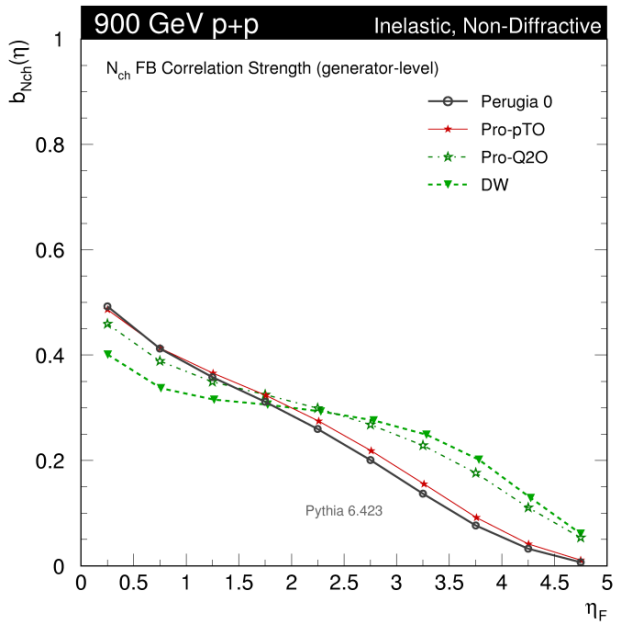
- Event by event correlation in number of particles created at different angles
- Provides constraints on underlying physics/models describing production of low-momentum particles over a broad range
- Not calculable from first principles

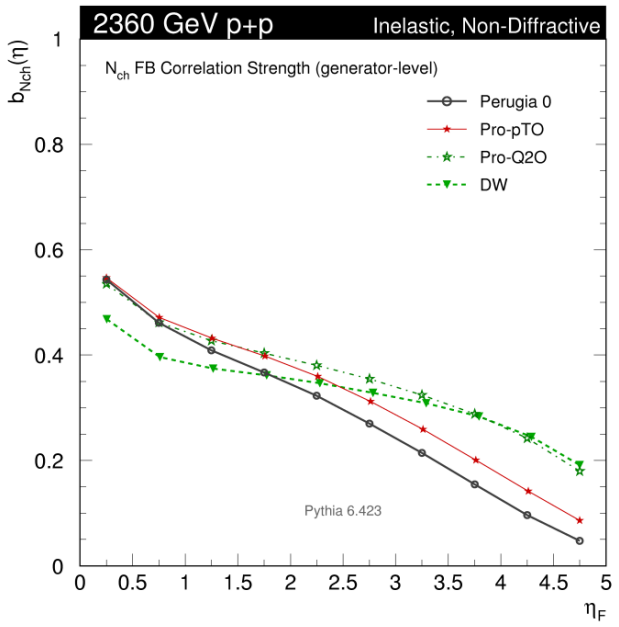


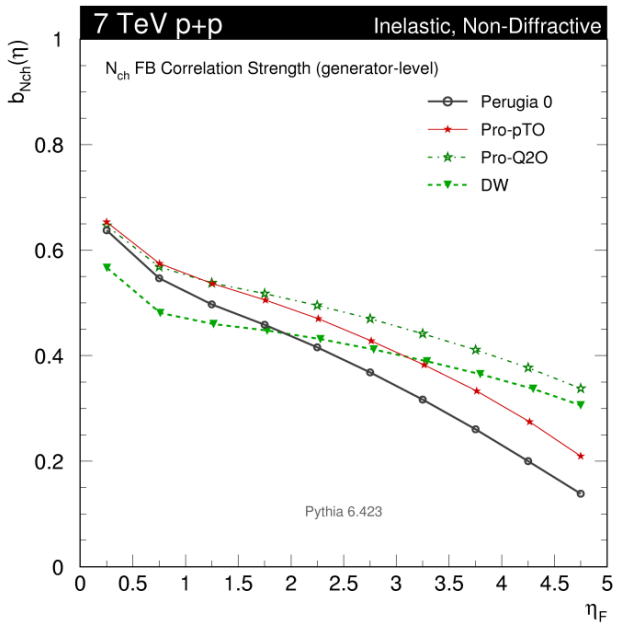
$$b = \frac{\langle n_F n_B \rangle - \langle n_F \rangle \langle n_B \rangle}{\sqrt{(\langle n_F{}^2 \rangle - \langle n_F \rangle^2)(\langle n_B{}^2 \rangle - \langle n_B \rangle^2)}}$$

FB Correlations - Models

- Peter Skands (Discovery associate) has produced b plots for Pythia tunes
- Disagreement at higher $\Delta\eta$
- FMD covers some of the range of disagreement

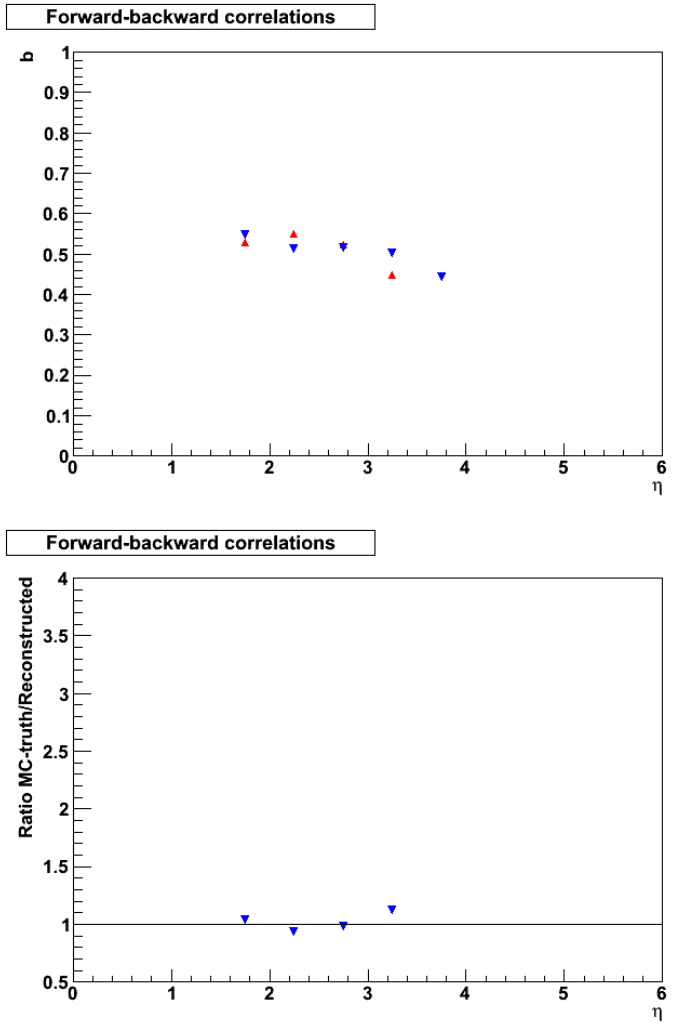






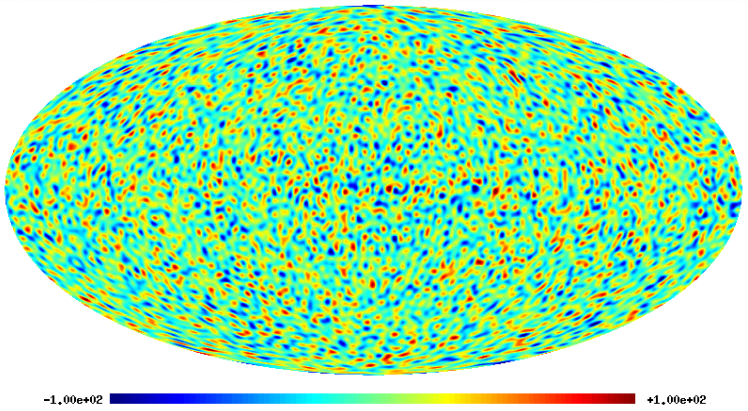
FB Correlations: Pythia with FMD

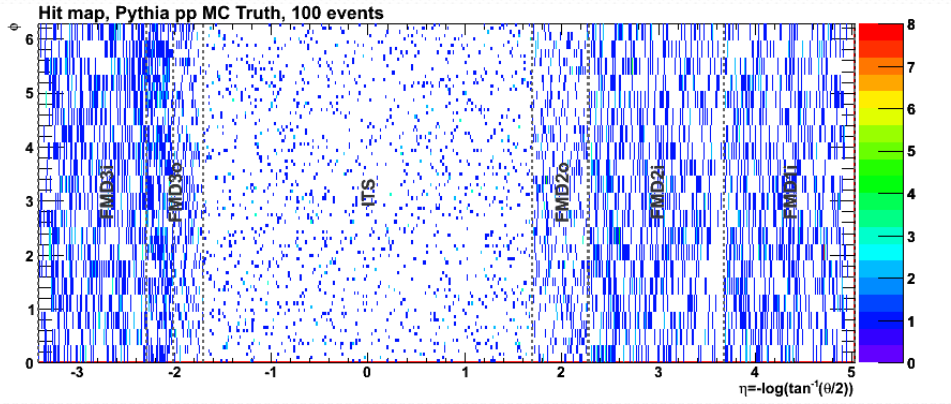
- For realistic values of b, the FMD can measure the correlation
- Systematic simulations versus many values of b must be done to determine error and bias



Fluctuations

- Planck group has data for CMB analysis
  - Very detailed framework
  - Deals with noise sources
- HEHI group would like to look at nonstatistical fluctuations in the multiplicity distribution (event to event)
  - Idea is to try to use their framework to analyze our data



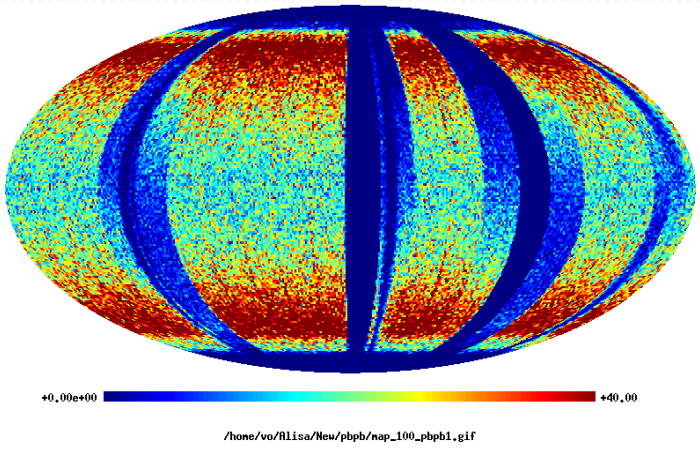


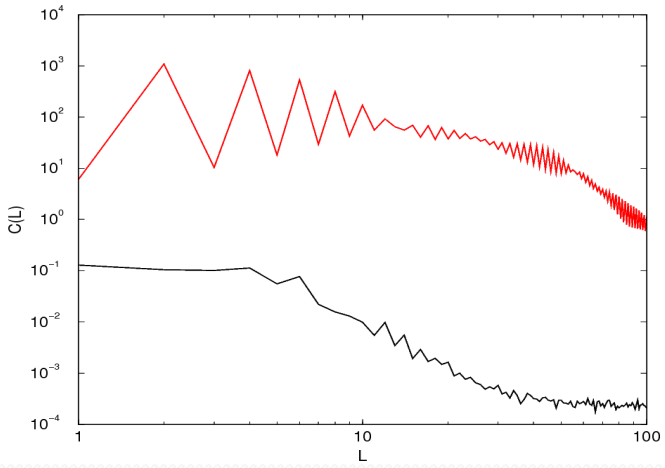
Fluctuations Analysis

$$S(\theta,\varphi) = \sum_{l=0}^{\infty} \sum_{m=-l}^{l} |a_{lm}| e^{i\phi_{lm}} Y_{lm}(\theta,\varphi)$$

$$C(l) = \frac{1}{2l+1} \left\langle \sum_{m=-l}^{l} |a_{lm}|^2 \right\rangle$$

- Decompose universe into spherical harmonics
- Construct power spectrum
- Look at power spectrum over many events for fluctuations
  - Discovery visitor – Oleg Verkhodanov has done initial analysis





Summary

- ALICE Detector is running taking pp and PbPb data
  - Many results have been published
  - Created medium has many interactions and QGP signs
- NBI has unique position for some analyses using FMD
- Discovery projects are in the works
  - Correlations – feed back into models
  - Fluctuations – use CMB analysis framework for detailed study