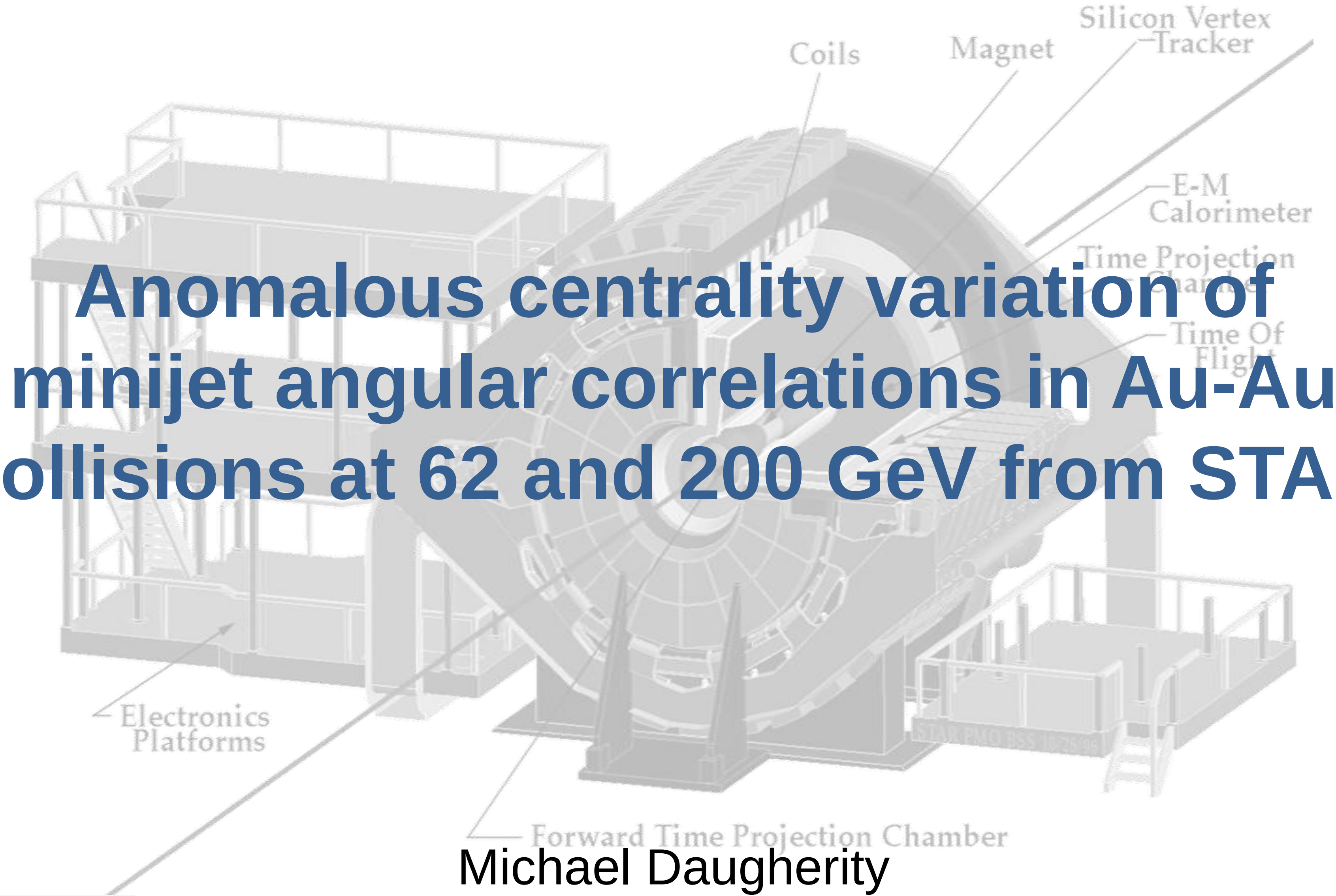
Anomalous centrality variation of minijet angular correlations in Au-Au collisions at 62 and 200 GeV from STAR



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Overview

- We report a survey of **minimum-bias** two-particle correlations in Au+Au collisions

- These are sensitive to ***minijets***, elliptic flow, resonances, HBT, etc. allowing a novel comparison of correlation amplitudes and ranges

minijet: Same-side jet-like correlations with *no trigger particle*

- Each correlation source has a **unique distribution** on relative (η,φ) making decomposition possible

- We observe a surprising trend in ***minijet correlations***

Correlation Measure

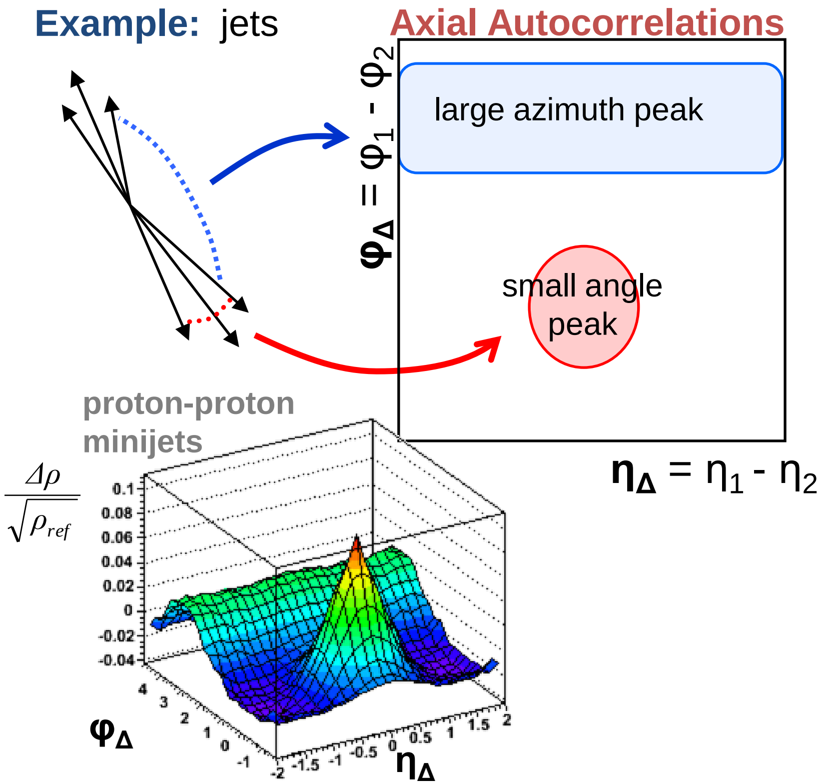
We use the correlation definition
and measure pair density ρ

$$Corr(x,y) = \frac{Cov(x,y)}{\sqrt{\sigma_x \sigma_y}}$$

Covariance = object - uncorrelated reference *(mixed-event pairs)*

The denominator provides ***per-particle*** normalization:

- Correlations are directly comparable ***regardless of event multiplicity***
- This is done with ***all possible pairs***
- ***No trigger particle*** is specified.



We use the notation

$$\frac{\Delta\rho}{\sqrt{\rho_{ref}}}$$

← same - mixed

← mixed

measured as a function of *relative* η and φ

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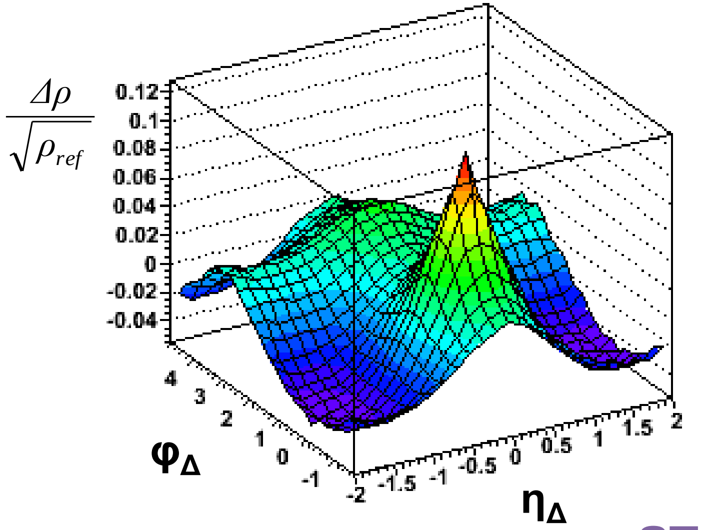
27 (2005) 98

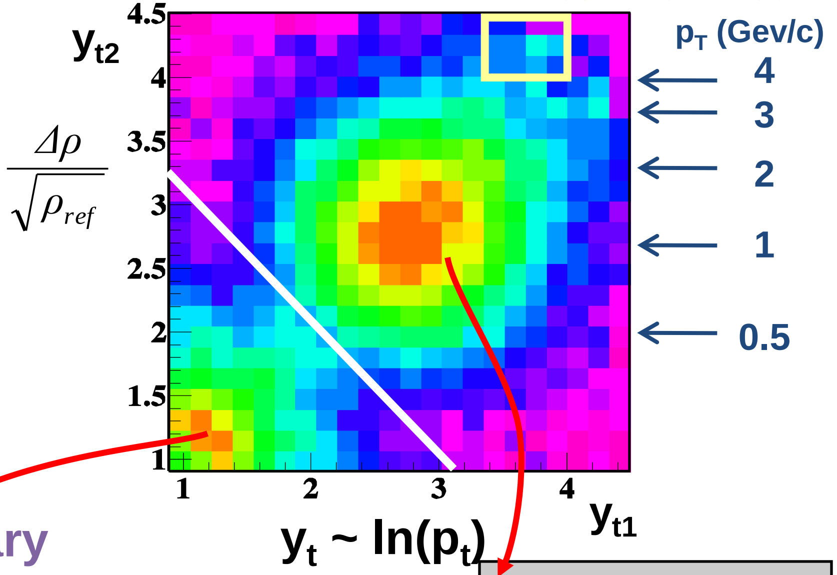
Proton+Proton Components

axial correlations



transverse correlations

typical jet trigger



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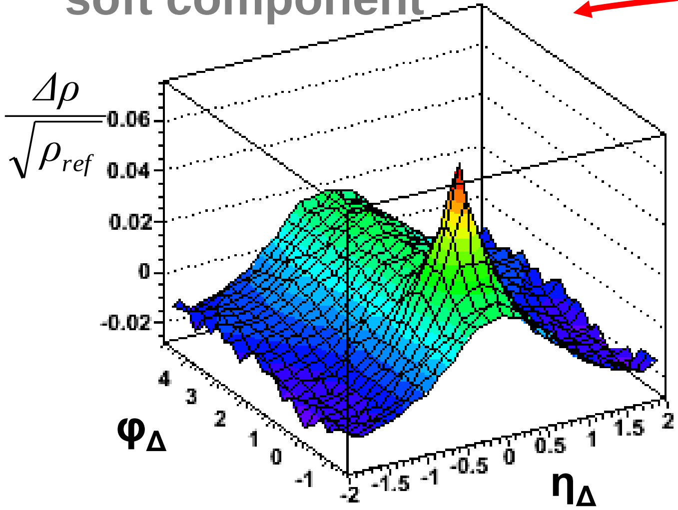
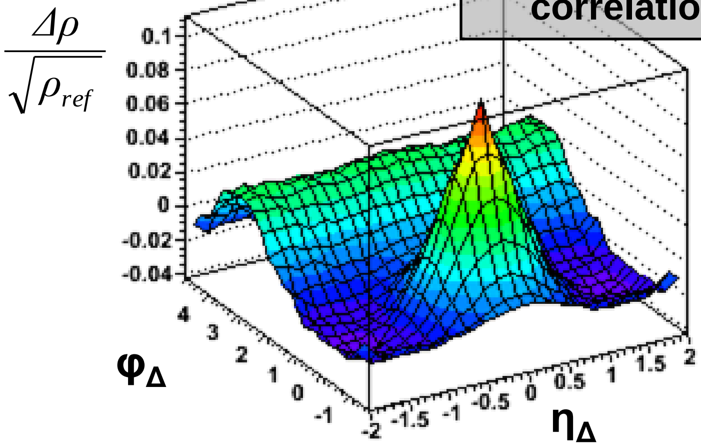
These structures *define* minijet correlations

soft component



hard component



Longitudinal Fragmentation ("strings") 1D Gaussian, US pairs
HBT peak at origin, LS pairs

Minijets 2D Gaussian at origin,
away-side peak actually cos(φ_Δ)

Fit Function (in 5 Easy Pieces)

Proton-Proton fit function

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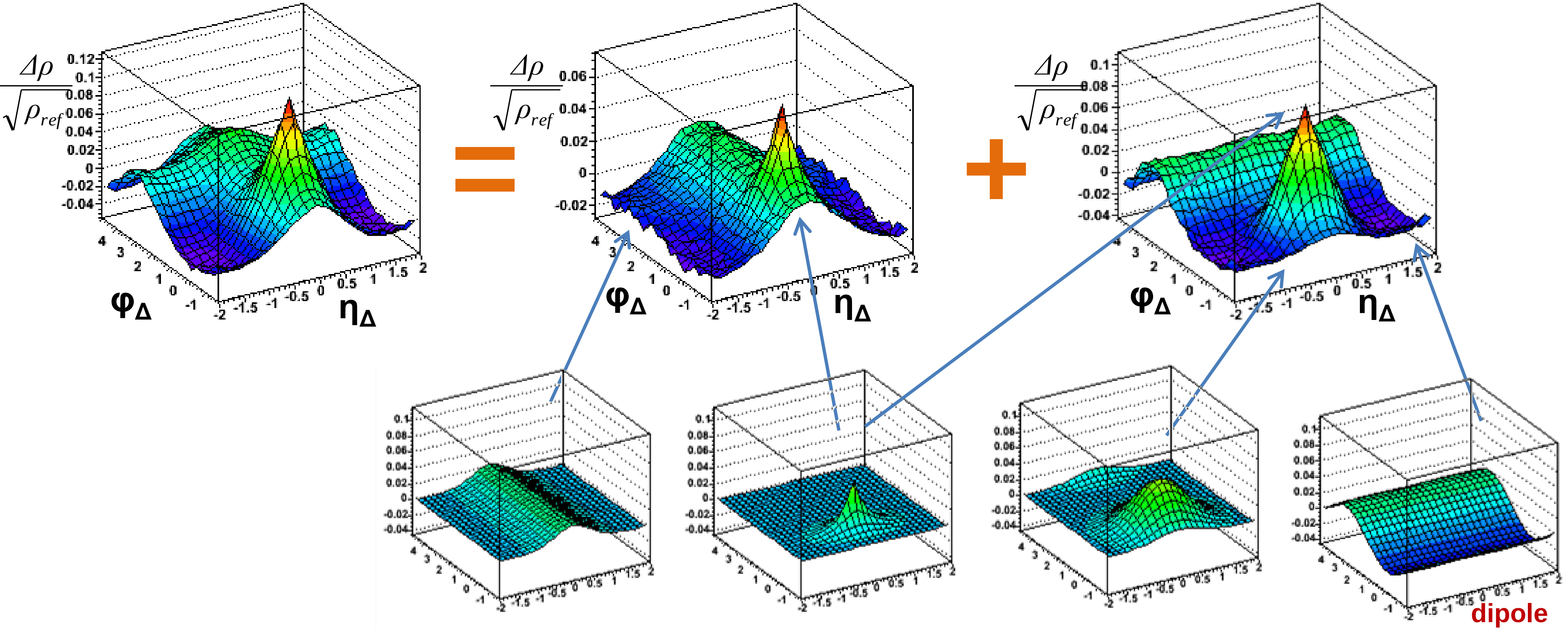


longitudinal fragmentation
1D gaussian

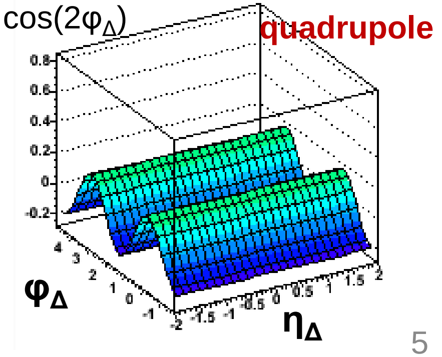
HBT, res., e+e-
2D exponential

Minijet Peak
2D gaussian

Away-side
-cos(φ)

Au-Au fit function

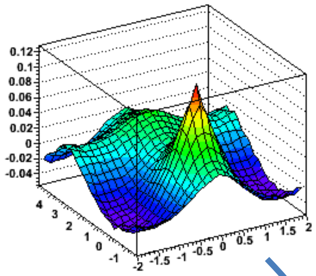
Use proton-proton fit function + cos($2\varphi_\Delta$) quadrupole term (“flow”).
This gives the ***simplest possible*** way to describe Au+Au data.



Note: from this point on we’ll include entire momentum range instead of using soft/hard cuts

200 GeV Data

proton-proton

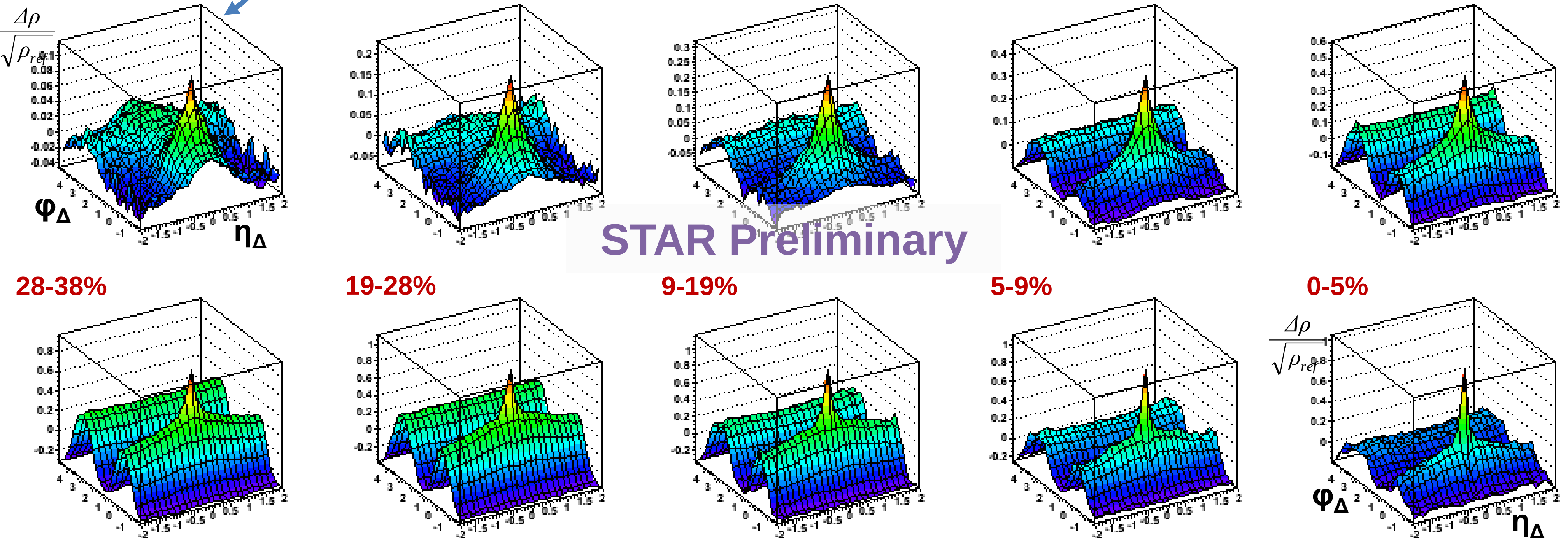


Analyzed 1.2M minbias 200 GeV Au+Au events, and 13M 62 GeV minbias events (not shown) Included all tracks with $p_T > 0.15$ GeV/c, $|\eta| < 1$, full φ

note: 38-46% not shown

84-93% **75-84%** **65-75%** **55-65%** **46-55%**

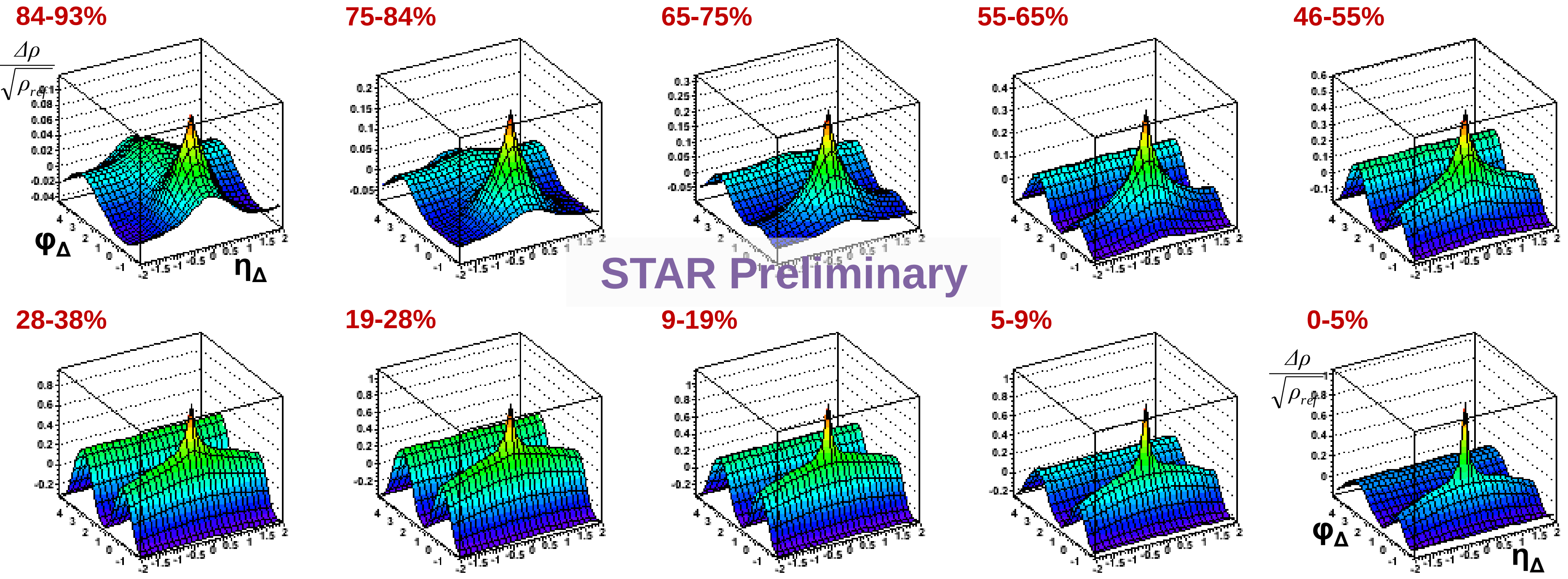
28-38% **19-28%** **9-19%** **5-9%** **0-5%**



We see the evolution of correlation structures from peripheral to central Au+Au

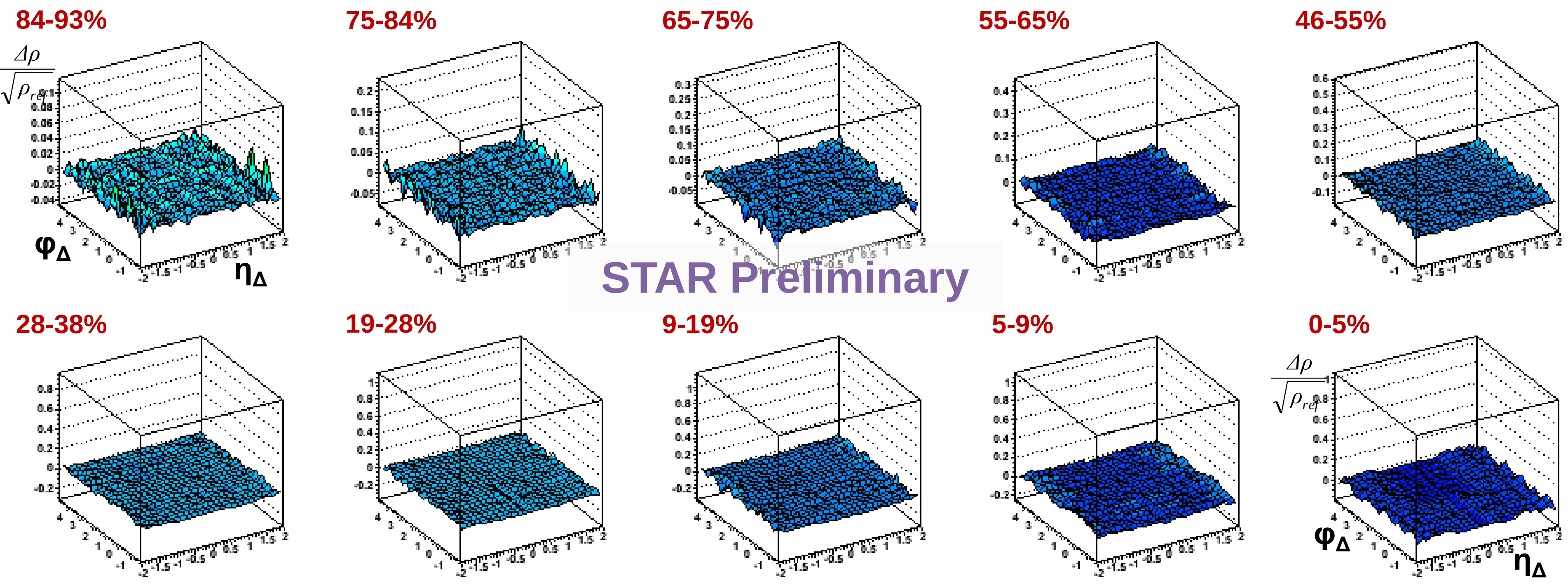
200 GeV Model

Fit model



200 GeV Residual

Fit residual = data - model



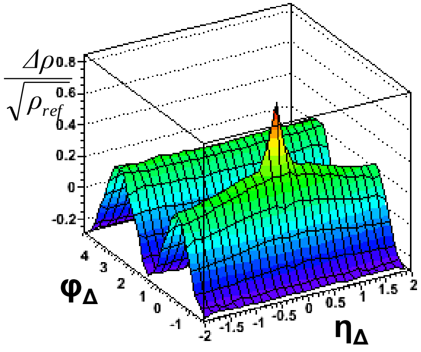
We have a good fit with the ***simplest possible*** fit function. Other than adding the cos(2ϕ_Δ) quadrupole term, no other modification was necessary.

Residuals at 62 GeV are comparable.

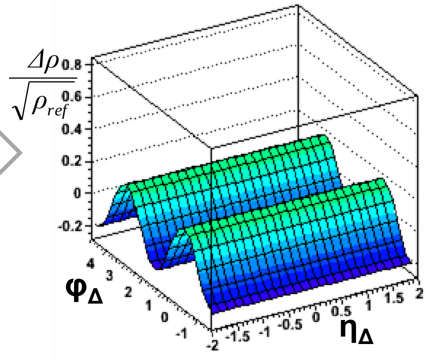
Quadrupole Component

Instead of removing a *background*, we can **make a measurement**

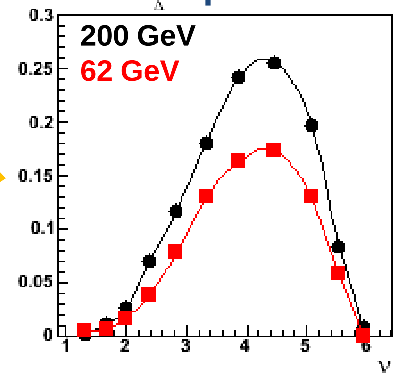
Data



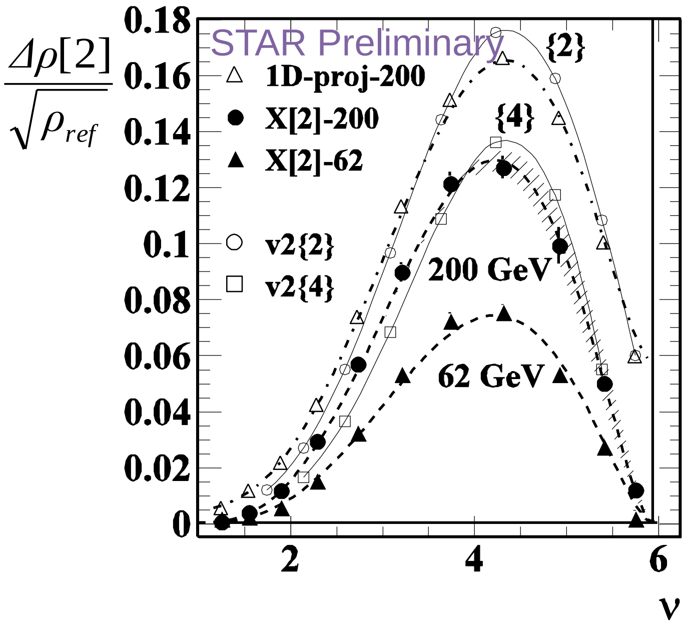
cos(2φ_Δ) component



Amplitudes

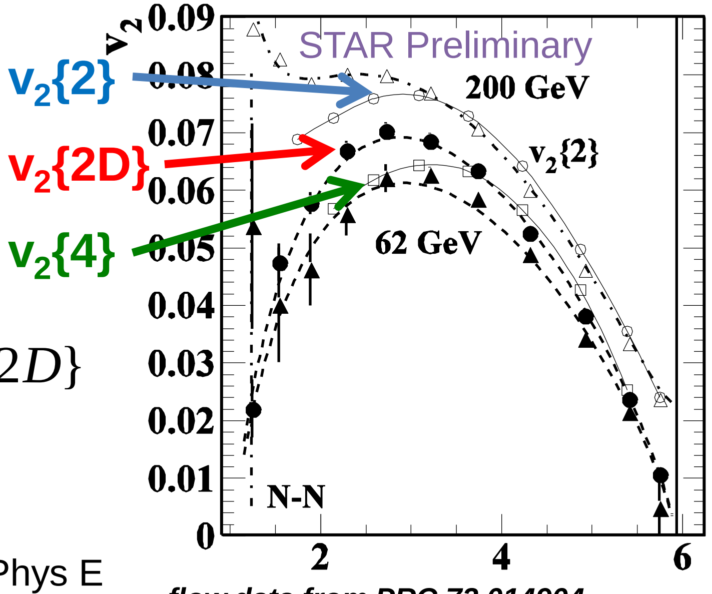


- 62 and 200 have the **same shape**
- *Substantial* amp. change with energy



$$\frac{\Delta\rho_A[2]}{\sqrt{\rho_{ref}}} = \frac{\bar{n}}{2\pi} v_2^2\{2D\}$$

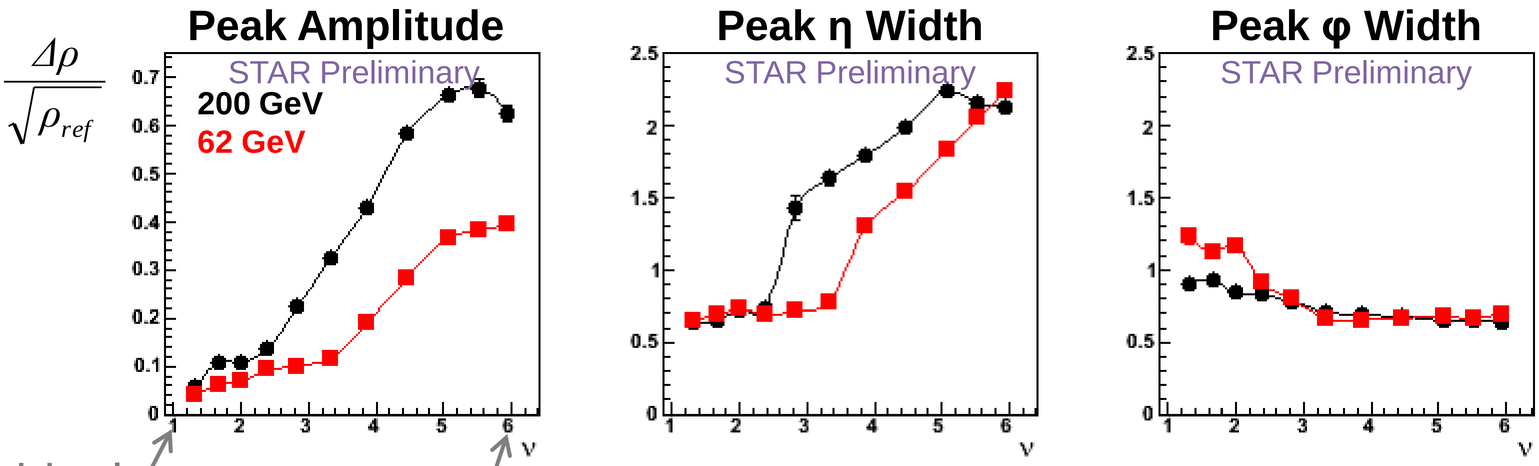
D. Kettler, T. Trainor
arXiv:0704.1674
accepted to J Mod Phys E



flow data from PRC 72 014904

The η-dependence of correlations separates quadrupole from other components

Minijet Same-Side Peak

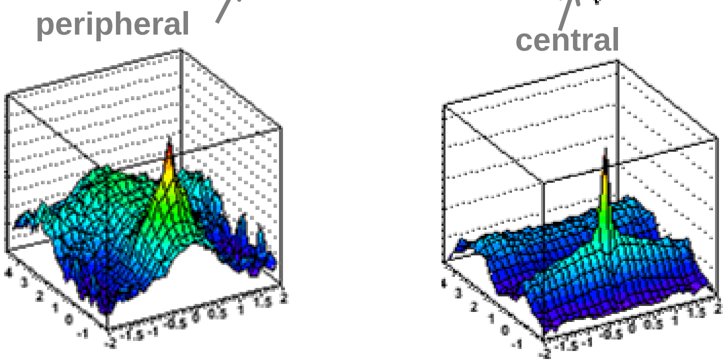

Peak Amplitude

Peak η Width

Peak φ Width

Statistical and fitting errors shown

Systematic error is 9% of correlation amplitude



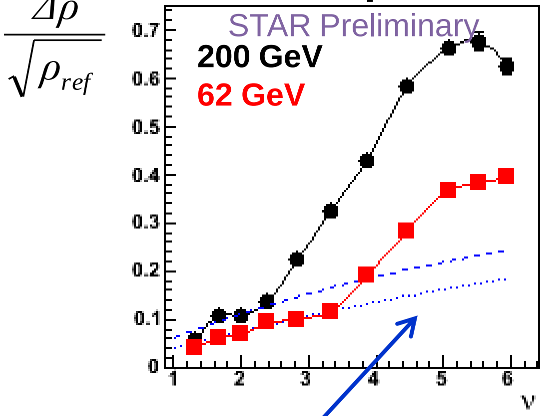
X-axis shows mean participant path-length

$$\nu \equiv \frac{\langle N_{bin} \rangle}{\langle N_{part} / 2 \rangle}$$

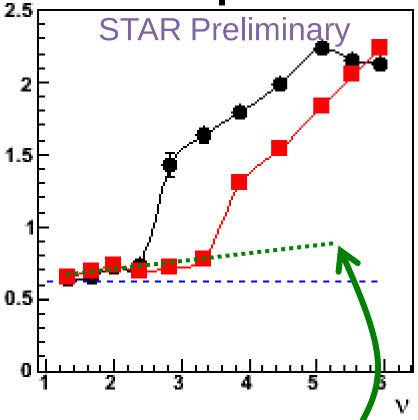
Observations

- Amplitude and η widths start small and experience a ***sharp transition***
- Transition occurs at ~55% centrality at 200 GeV, is more central (~40%) for 62
- φ width has a *very different centrality dependence*

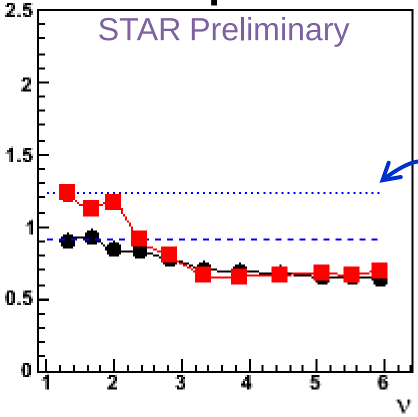
Binary Scaling



Peak Amplitude



Peak η Width



Peak φ Width

constant widths

small increase before transition

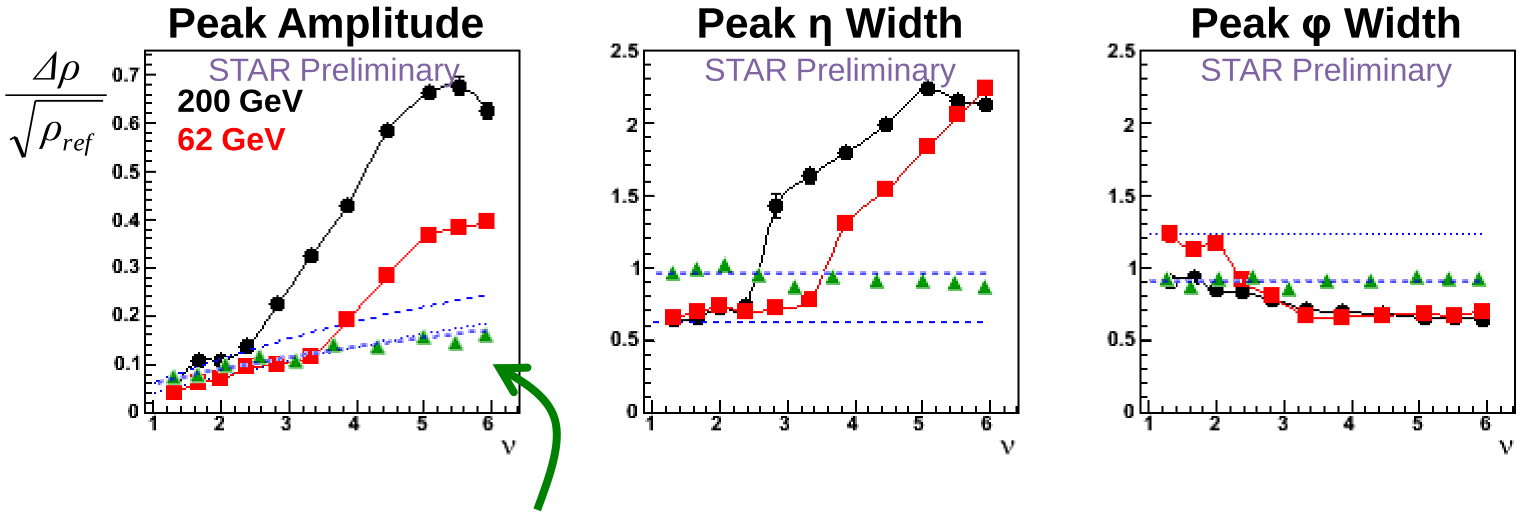
$$A_{AA}(\nu) = A_{pp}\frac{\nu}{1+x(\nu-1)}$$

minijet amplitude assuming binary scaling in Kharzeev and Nardi model

Large increase in amplitude and η width are unexpected

Deviations from binary scaling represent new physics unique to heavy ion collisions

HIJING Minijets



HIJING 1.382 default parameters, 200 GeV, quench off

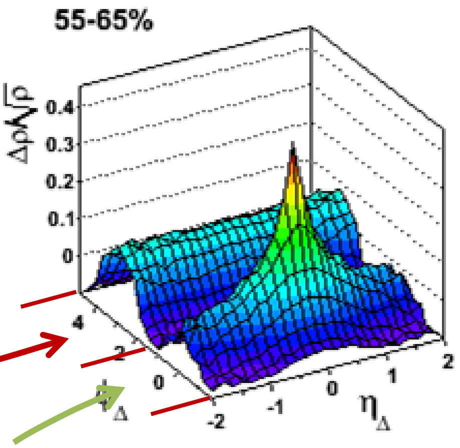
Quench on causes slight amplitude *decrease*

The observed minijets correlation is actually ***far greater*** than predicted by HIJING (factor of 4)

Consistency Check

Does interaction between same-side peak and cos(φ_Δ) terms cause the transition?

Two-stage fit:



fix cos(φ_Δ) and cos($2\varphi_\Delta$) on away-side

then fit remaining terms

Result

200 GeV: **standard, two-stage fit**

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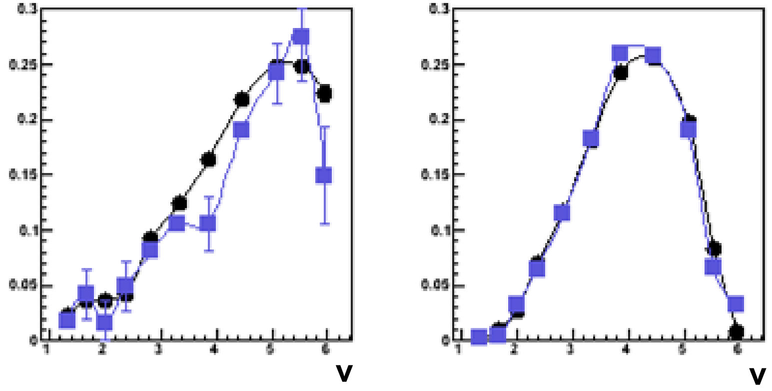
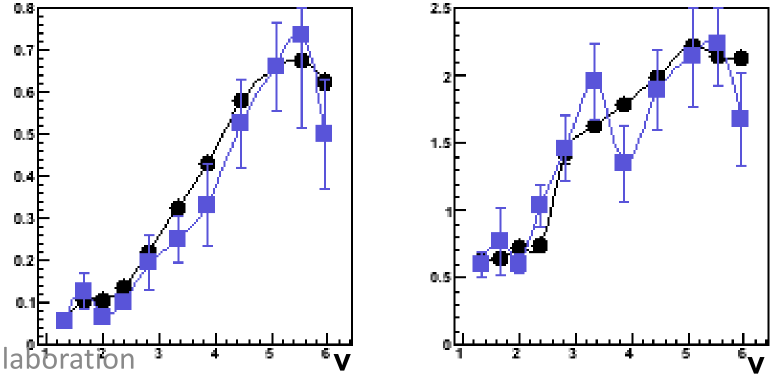
cos(φ_Δ) cos($2\varphi_\Delta$)



minijet peak minijet η width



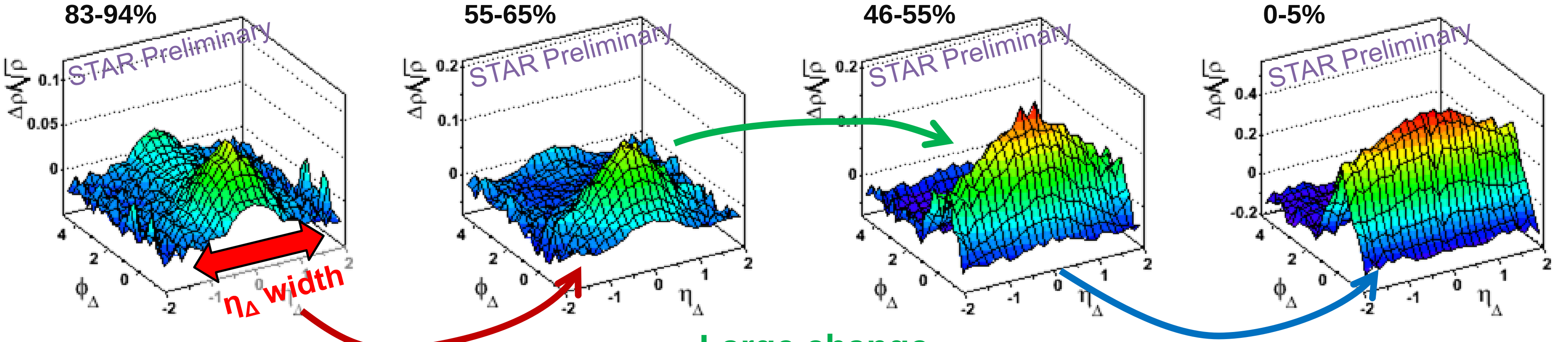
The results are consistent

Cancellation in fit terms does not cause the amplitude increases.

Transition

Does the transition from narrow to broad η_Δ occur quickly or slowly?

data - fit (except same-side peak)



Shape changes little from peripheral to the transition

Large change within ~10% centrality

Smaller change from transition to most central

Low-p_T manifestation of the “ridge”

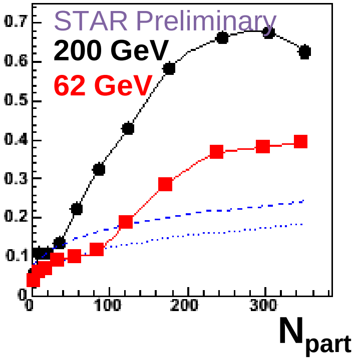
The transition occurs quickly

Scaling

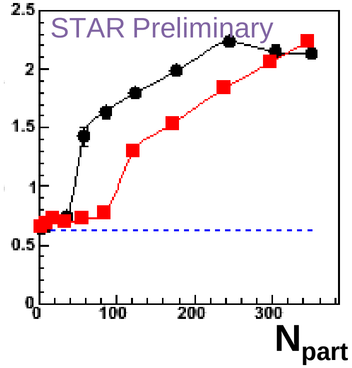
What is the best way to compare different energies? Does the transition scale?

N_{part}

Peak Amplitude



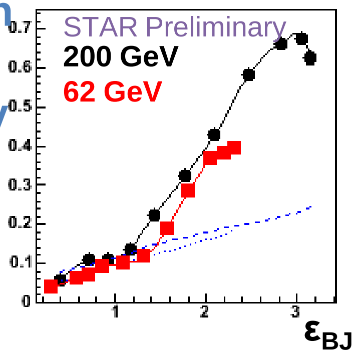
Peak η Width



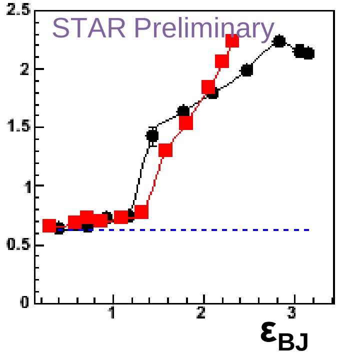
Peripheral bins are compressed.

Bjorken Energy Density

Peak Amplitude



Peak η Width



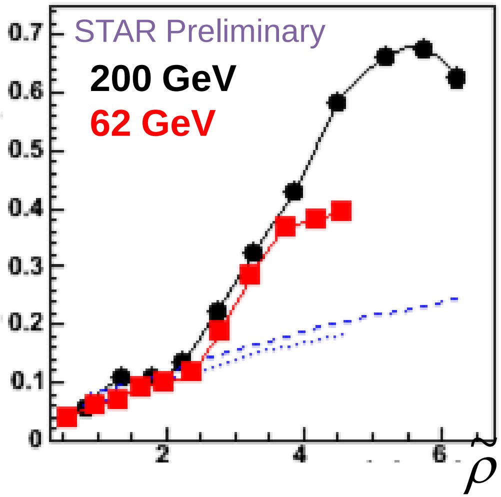
Depends *strongly* on formation time (used 1 fm/c), difficult to compare energies.

Transverse Particle Density

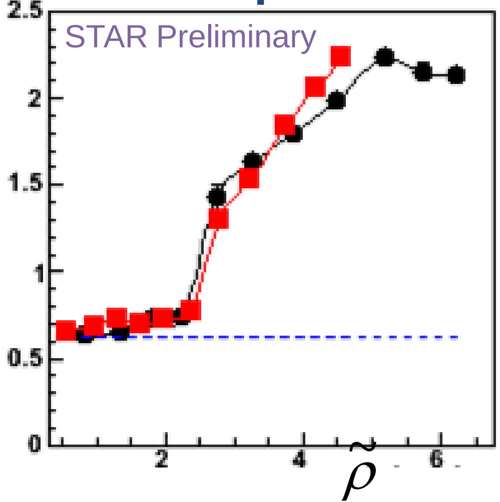
$$\tilde{\rho} = \frac{3}{2}\frac{dN_{ch}}{d\eta}/S$$

S = overlap area

Peak Amplitude



Peak η Width



Minijet parameters seem to scale with system density

Yield Estimates

Kharzeev and Nardi two-component model (PLB 507 (2001) 121)

"Hard" scattering fraction = (hard) / (soft + hard) = $\dfrac{x\nu}{1 + x(\nu - 1)}$

In 200 GeV central Au+Au, x ~ 0.1 and v ~ 6.

Estimate of total yield fraction = 0.6 / 1.5 ~ 1/3

Correlations from this analysis

Units: *# correlated pairs per particle*

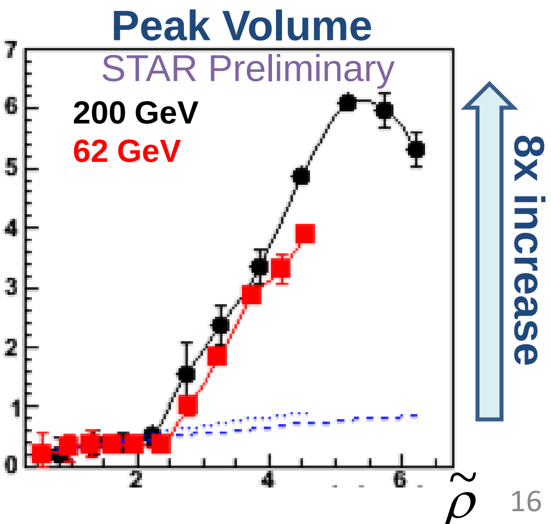
 # pairs = (N_{ch}) * (Peak Volume)

> 7,000 pairs in central collisions

Pair combinatorics require estimate of average number of structures per event to extract yield with *more structures giving greater yield.*

- Assuming number of structures follows binary collision scaling gives ***yield fraction of 32%***
- 1/2 binary scaling gives 23%, 1/10 gives 10%

This correlation represents a significant fraction of the total yield.



See also T. Trainor, arXiv:0710.4504, accepted to J Mod Phys E

Summary

We measure 2D angular autocorrelations on (η,φ) to study minijets in Au+Au collisions and make two primary observations:

Transition

- Minijet correlations follow binary scaling in peripheral Au+Au collisions and deviate at a ***sharp transition point***

- The transition points for 62 and 200 GeV occur at about the ***same value of transverse particle density***

Yield

- Beyond the transition point the peak amplitude and η width ***increase dramatically***

- The same-side correlations include a ***large number*** of hadrons, estimated at ***up to ~1/3 of the particle yield*** in central Au+Au collisions