PHOBOS ~~RHIC~~ results on cluster production in pp and heavy ion

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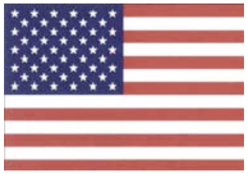
Collaboration



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Talk Roadmap

- Introduction to correlations in PHOBOS
- In the spirit of this workshop, I will concentrate on the more technical aspects of the correlations
  - Correlations using a "trigger" track with p_T>2.5 GeV/c
  - Correlations between inclusive particles (no high p_T cut)
  - Effects of limited pseudorapidity acceptance
- Summary

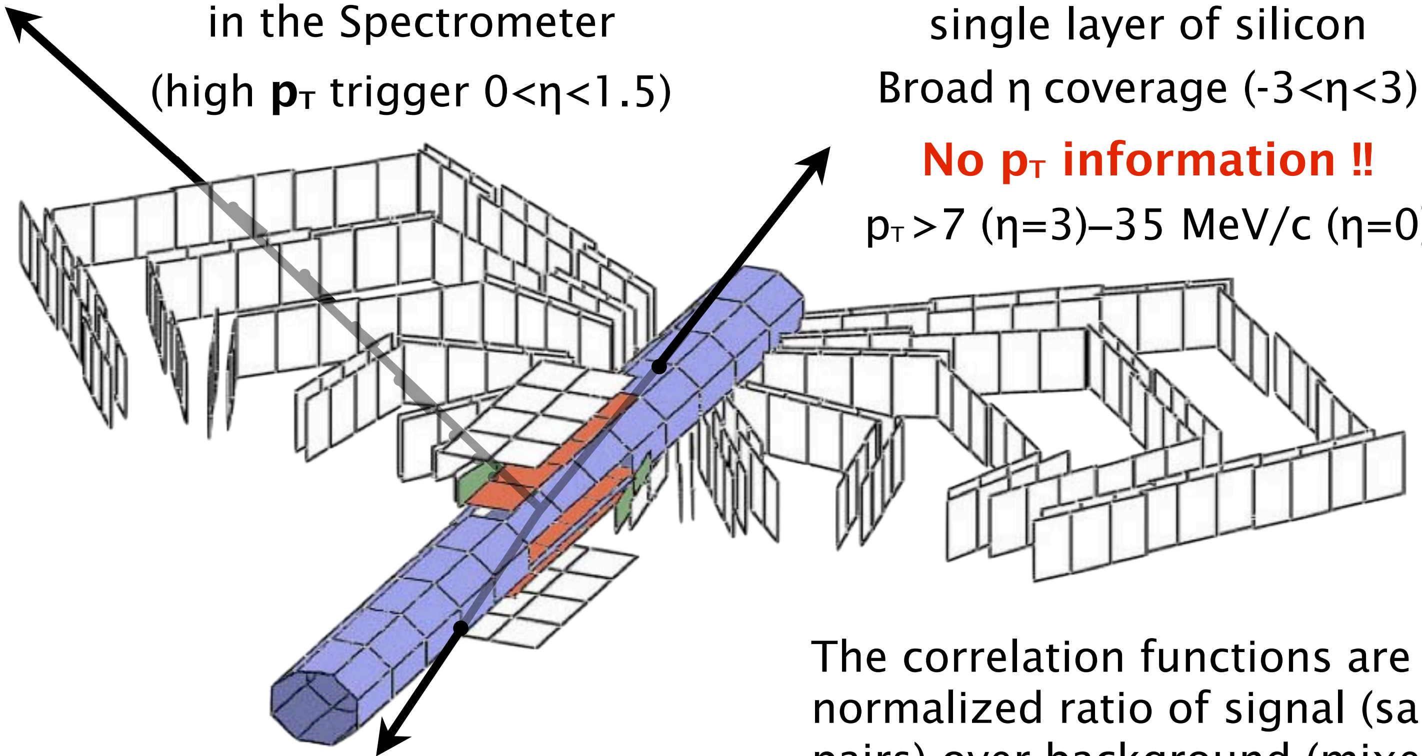
Correlation Measurements

Triggered Correlations:
"Trigger" particles detected
in the Spectrometer
(high $\mathbf{p_T}$ trigger $0<\eta<1.5$)

In **both** cases:
Associated particles detected in a
single layer of silicon
Broad η coverage ($-3<\eta<3$)

No $\mathbf{p_T}$ information !!

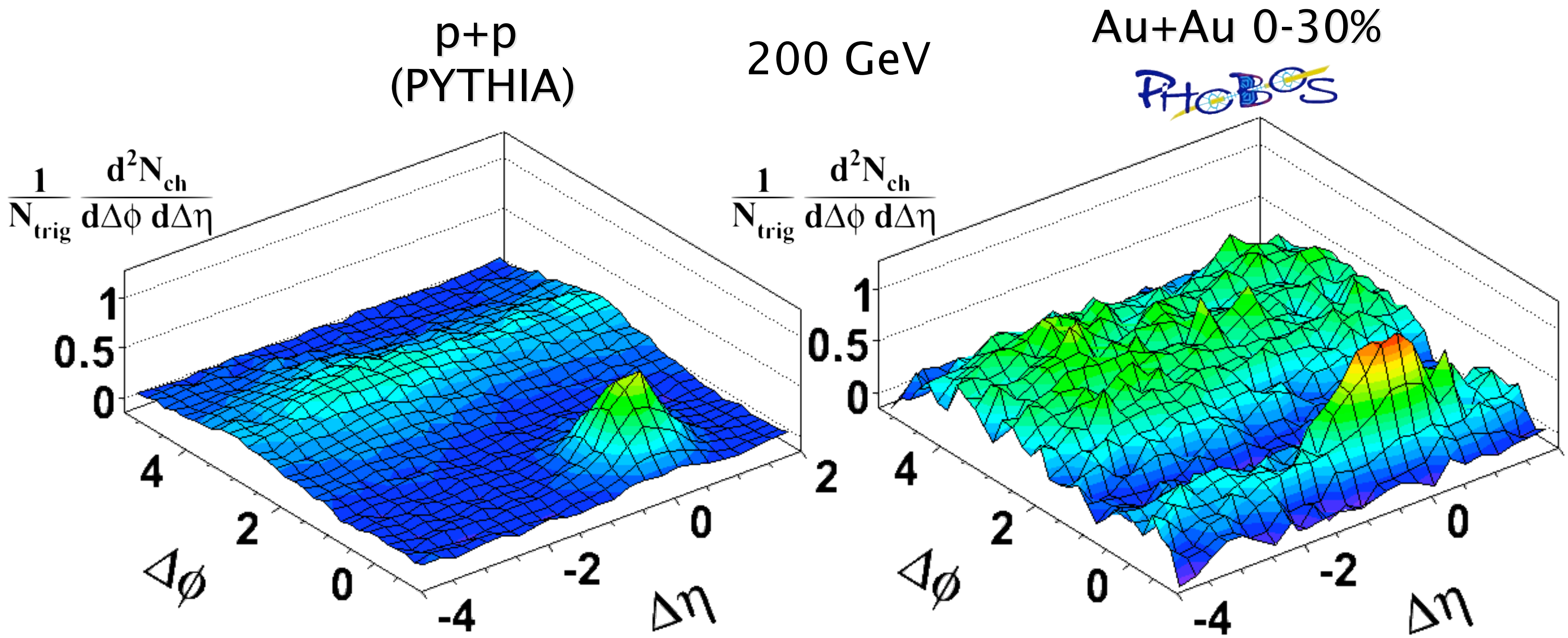
$p_T > 7$ ($\eta=3$)–35 MeV/c ($\eta=0$)



Inclusive Correlations:
Pairs start with an inclusive
particle detected in a single
layer of silicon ($-3<\eta<3$)

The correlation functions are the suitably normalized ratio of signal (same-event pairs) over background (mixed-event pairs). The effect of elliptic flow is removed either by subtraction (triggered correlations) or by integrating over $\Delta\phi$ (inclusive correlations).

Correlations with p_T>2.5 GeV/c Trigger



arXiv:0903.2811

p_T^{trig} >2.5 GeV/c

p_T^{assoc} > 4 - 35 MeV/c

NB: PYTHIA closely matches STAR data at mid-rapidity for a similar set of p_T cuts

Construction of Correlated Yield

$$\frac{1}{N_{trig}}\frac{d^2N_{ch}}{d\Delta\phi d\Delta\eta} = B(\Delta\eta)\left\{\frac{s(\Delta\phi,\Delta\eta)}{b(\Delta\phi,\Delta\eta)} - a(\Delta\eta)\left[1+2V(\Delta\eta)\cos(2\Delta\phi)\right]\right\}$$

$\frac{s(\Delta\phi,\Delta\eta)}{b(\Delta\phi,\Delta\eta)}$ **Raw correlation**: ratio of per-trigger same event pairs to mixed event pairs

$1+2V(\Delta\eta)\cos(2\Delta\phi)$ **Elliptic flow**: $V(\Delta\eta) = \langle v_2^{trig}\rangle\langle v_2^{assoc}\rangle$

PHOBOS Phys. Rev. C **72**, 051901(R) (2005)

$a(\Delta\eta)$ **Scale factor**: accounts for small multiplicity difference between signal and mixed events

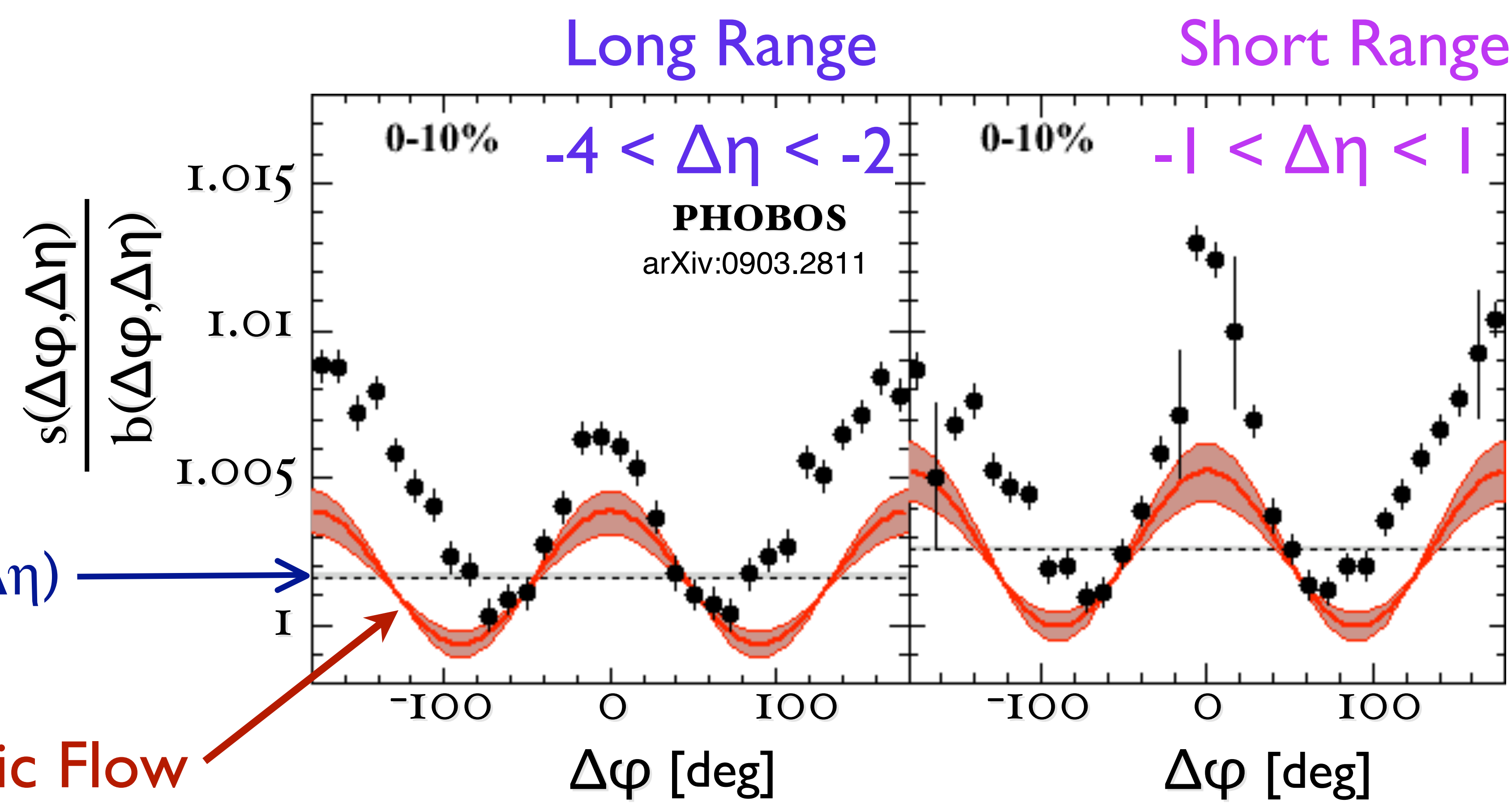
$B(\Delta\eta)$ **Normalization term:** relates flow-subtracted correlation to correlated yield

Comments on Correlation Function

$$\frac{1}{N_{trig}}\frac{d^2N_{ch}}{d\Delta\phi d\Delta\eta} = B(\Delta\eta)\left\{\frac{s(\Delta\phi,\Delta\eta)}{b(\Delta\phi,\Delta\eta)} - a(\Delta\eta)\left[1+2V(\Delta\eta)\cos(2\Delta\phi)\right]\right\}$$

- The normalization (s and b normalized by the number of triggers) is designed to measure the "correlated yield" aspects of the data, i.e. the number of associated particles per unit phase space.
- By definition and construction, the correlation function must be positive everywhere.
- The effect of elliptic flow must be removed using a scale factor ($a(\Delta\eta)$, very close to unity) which results from well-understood features of the data.

Subtraction of elliptic flow



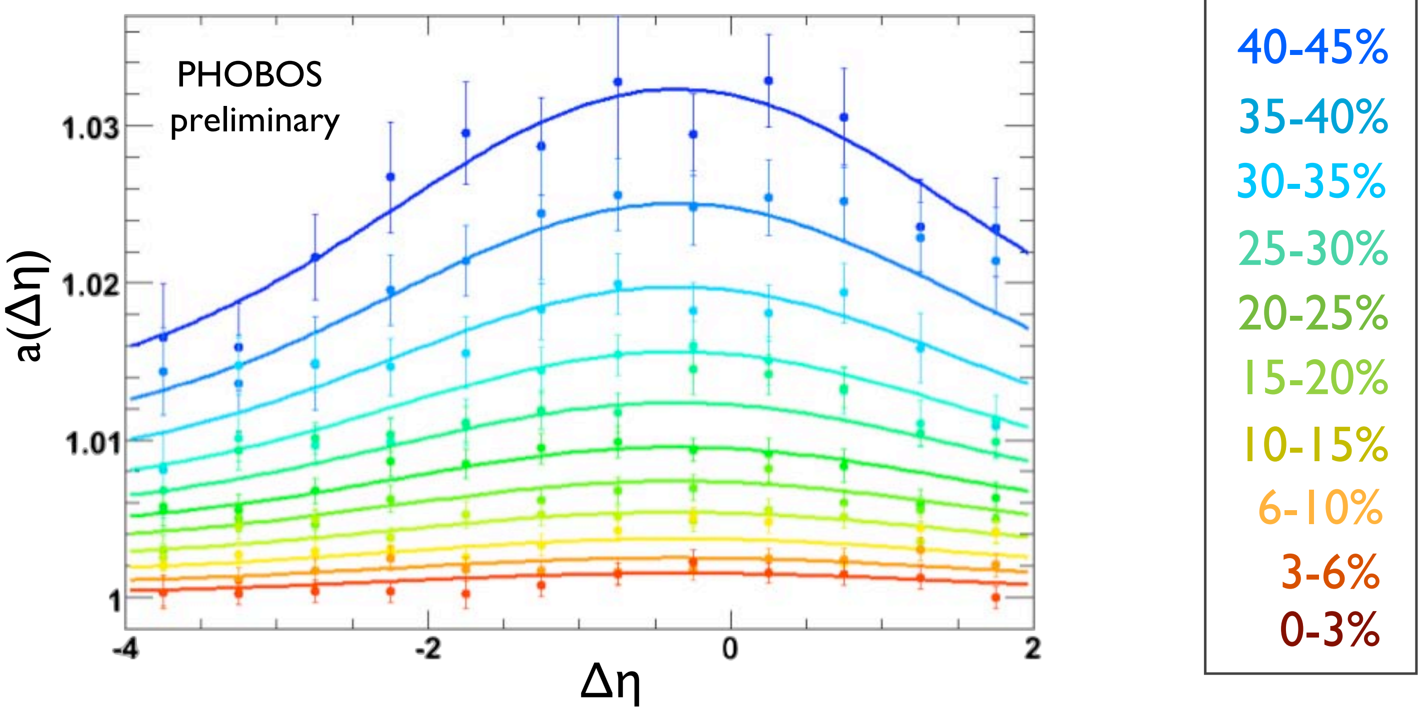
a(Δη)

Elliptic Flow

$$a(\Delta\eta)\left[1+2V(\Delta\eta)\cos(2\Delta\phi)\right]$$

Elliptic Flow Scale Factor ($a(\Delta\eta)$=ZYAM)

ZYAM factors from 2d-fit in $\Delta\eta$ and N_{part}

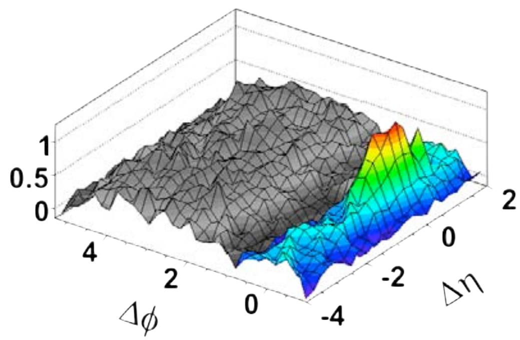


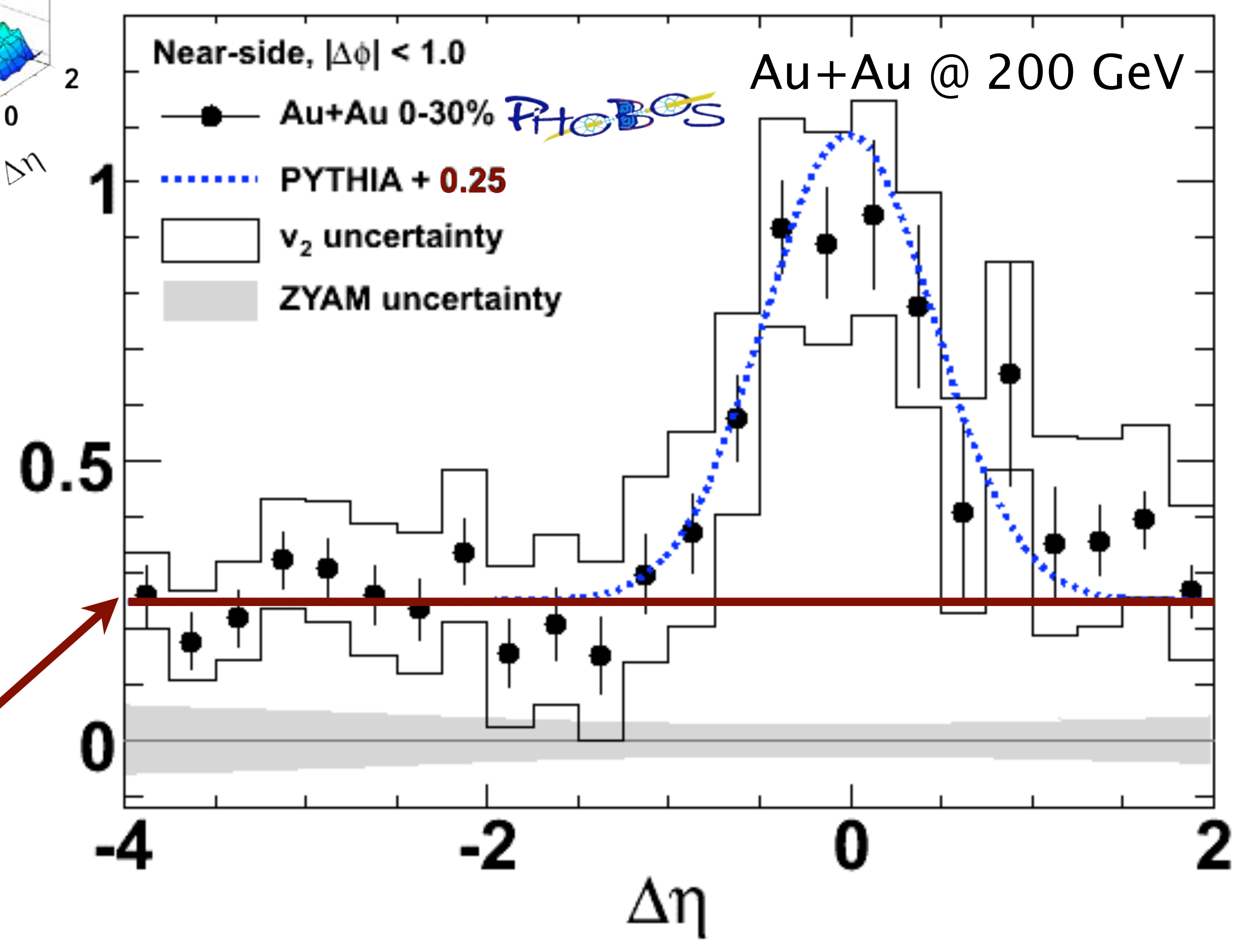
Constant term: bias of the p_T-triggered signal distribution to higher multiplicity

Gaussian term: $\Delta\eta$ correlation structure underneath v_2-subtracted $\Delta\varphi$ correlations. Width/amplitude/N_{part}-dependence same as inclusive correlations (to be discussed in 2nd part of this talk)

arXiv:0812.1172 (2008)

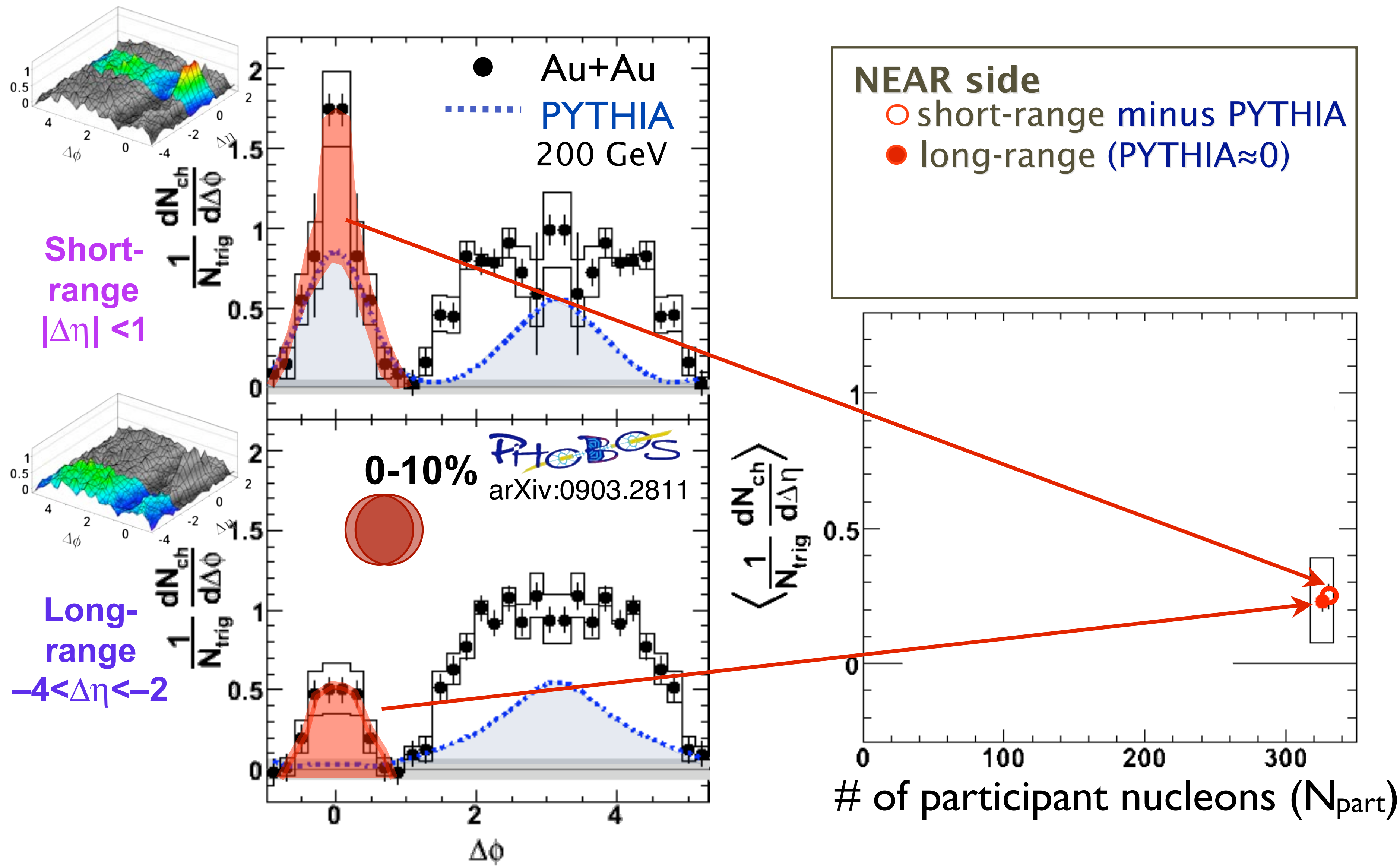
“Ridge” at small Δϕ: Extent in Δη



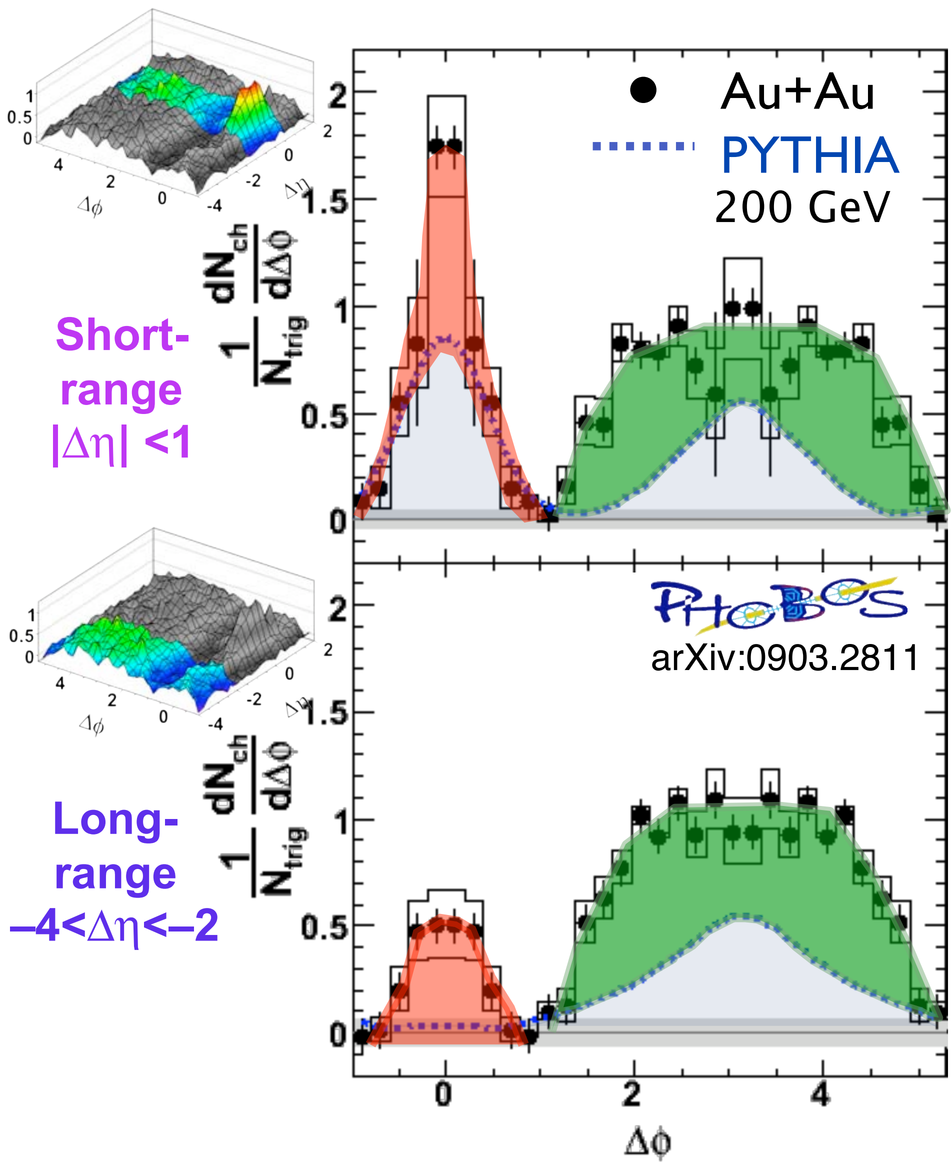


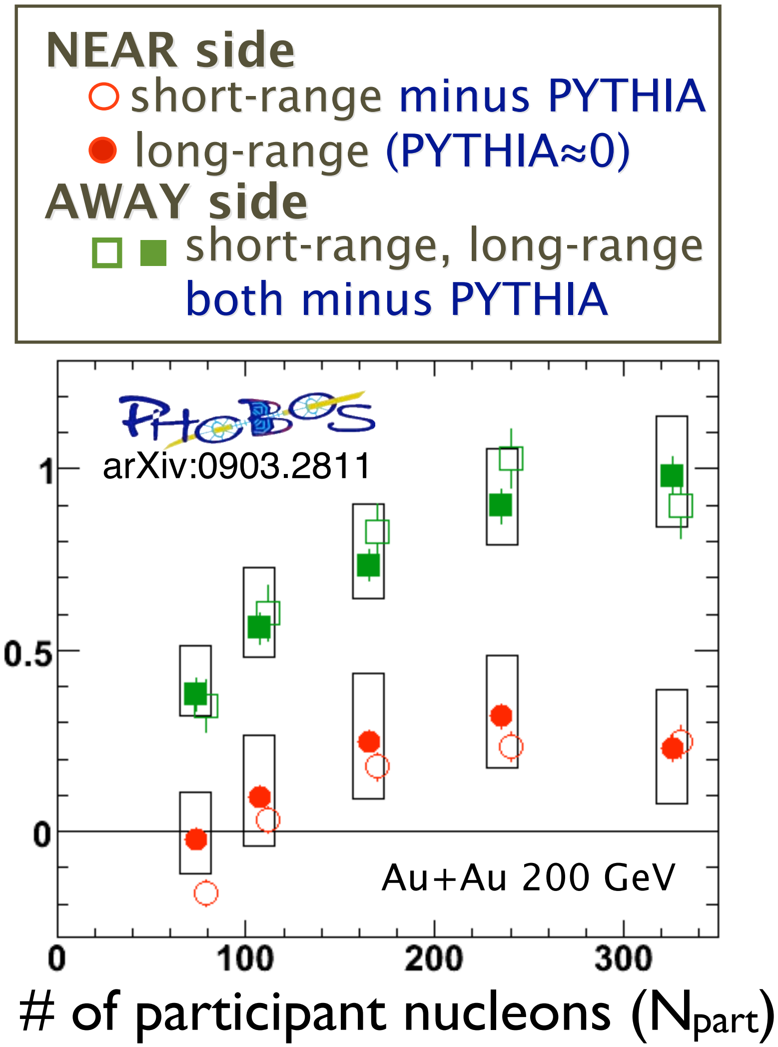
Long-range ridge yield

Integrated Ridge Yield: |Δη|<1 vs –4<Δη<–2

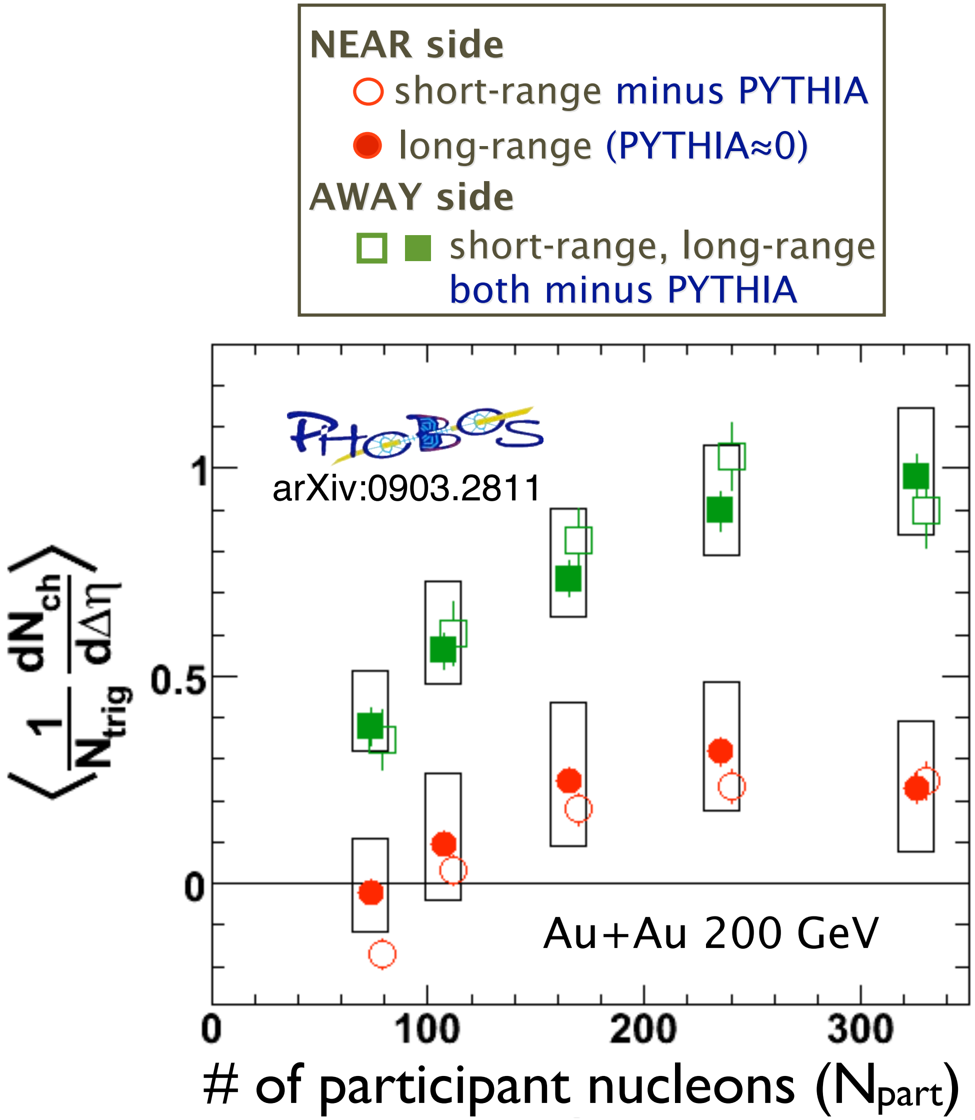


Integrated Ridge Yield: $|\Delta\eta|<1$ vs $-4<\Delta\eta<-2$





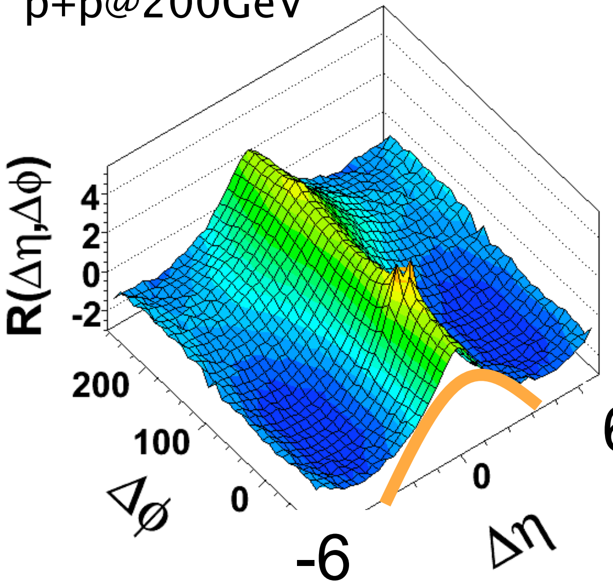
Triggered Correlation Observations



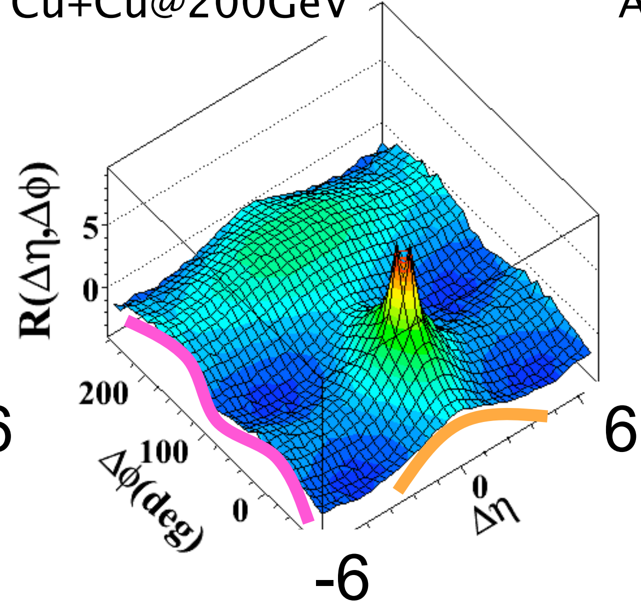
- Near side (small $\Delta\phi$) ridge yield extends to at least $|\Delta\eta|\sim 4$
- Short-range ($|\Delta\eta|<1$) and long-range ($-4<\Delta\eta<-2$) ridge yields are very similar in size at all centralities
- Ridge disappears for N_{part} below about 80
- Excess yield on the away side ($\Delta\phi\sim\pi$) is also uniform in $\Delta\eta$ and decreases for more peripheral collisions

Inclusive 2-Particle Correlations

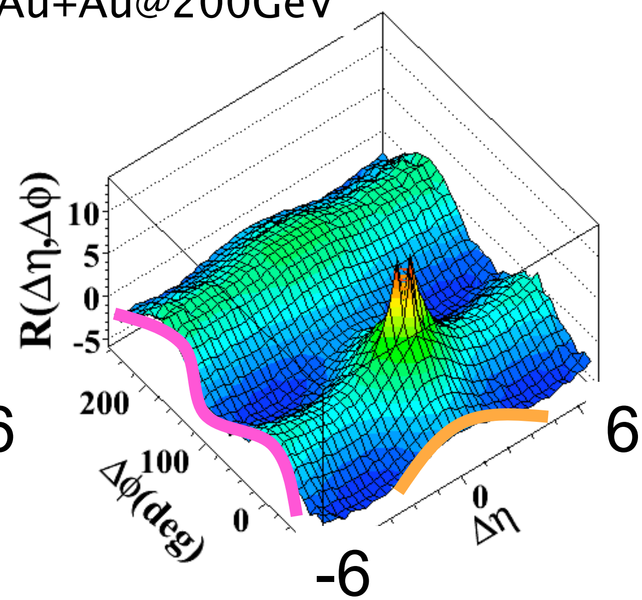
p+p@200GeV



Cu+Cu@200GeV

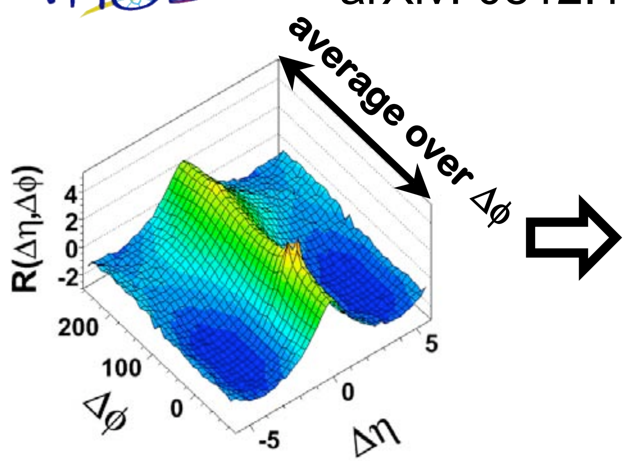


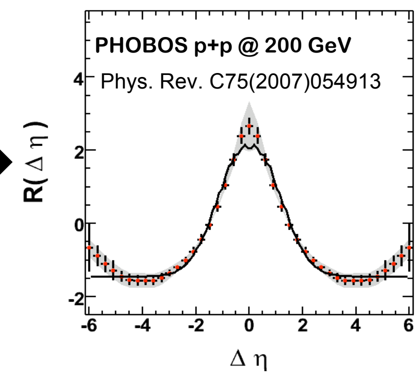
Au+Au@200GeV



Phys. Rev. C75(2007)054913 arXiv: 0812.1172

Project onto Δη axis and fit with a simple parameterization of a cluster model



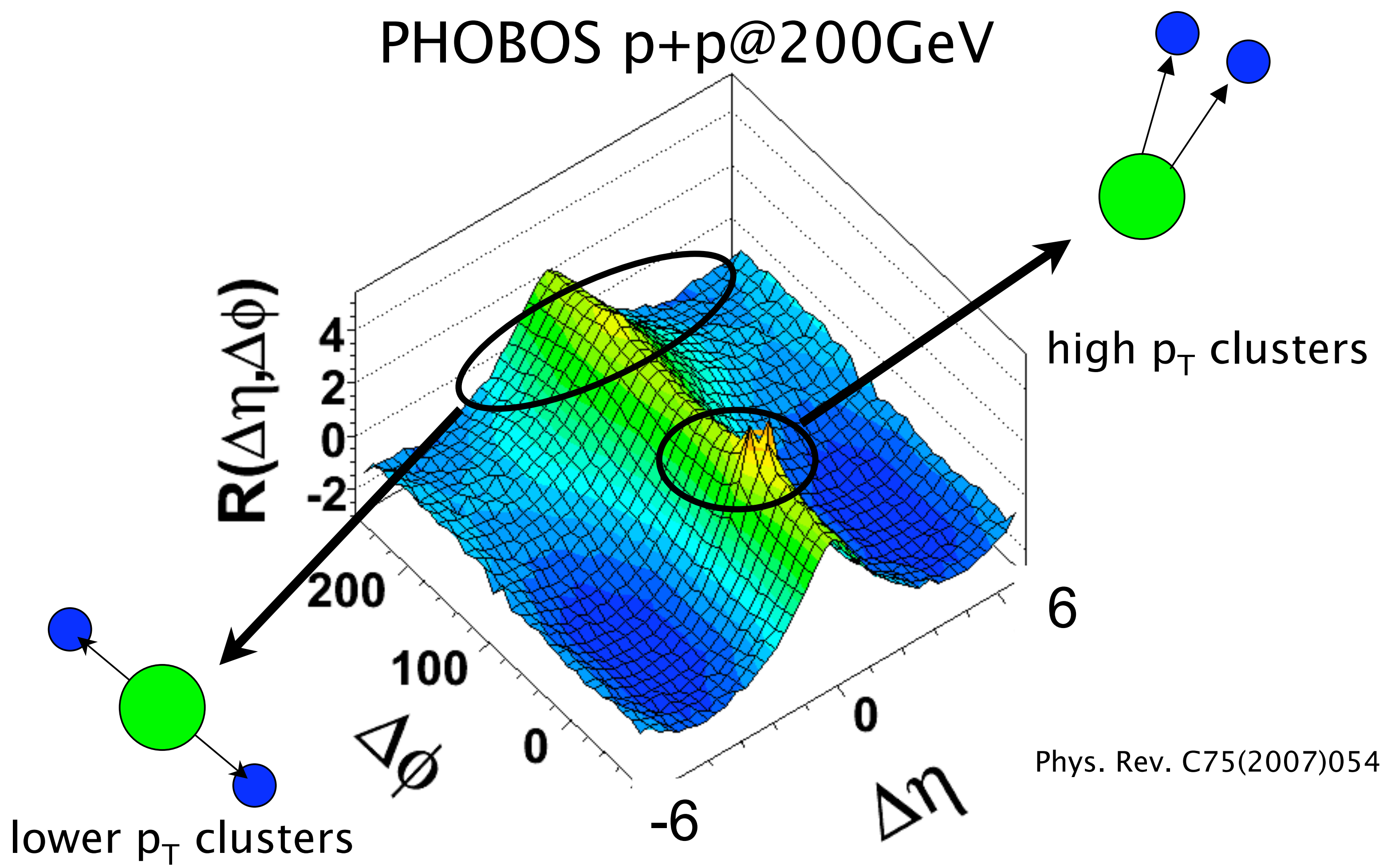


Comments on Correlation Function

$$R(\Delta\eta,\Delta\phi) = \left\langle (n-1)\left(\frac{F_n(\Delta\eta,\Delta\phi)}{B_n(\Delta\eta,\Delta\phi)} - 1\right)\right\rangle$$

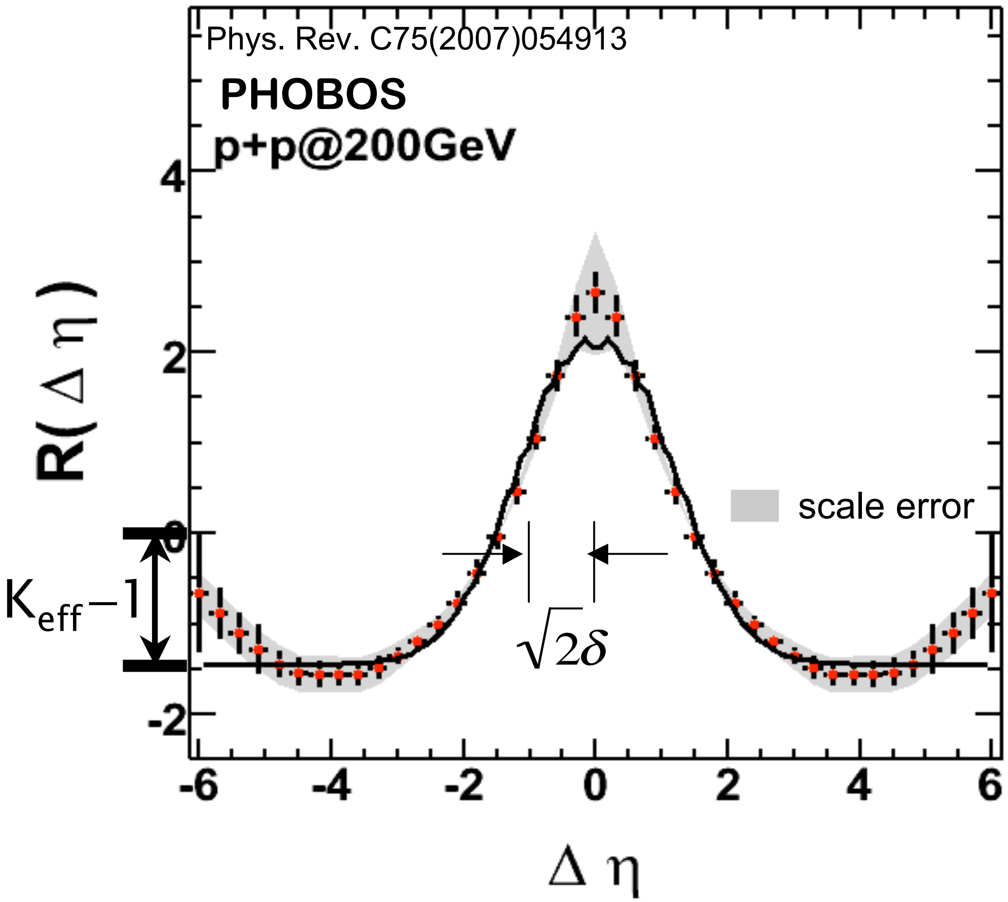
- The (n-1) normalization is included to specifically bring out the "cluster-like" aspects of the data.
- The foreground and background distributions are independently normalized to unity so the correlation function will be positive or negative in regions where the former or the latter is larger.
- Small regions where the foreground and background are comparable give R equal to zero. R would be zero everywhere if there were no correlations.
- Elliptic flow is removed (for now) by averaging over $\Delta\phi$ and only studying the correlation function versus $\Delta\eta$.

Cluster-like Correlation Structure



Phys. Rev. C75(2007)054913

Cluster-Model Fit to Correlation Function



$$R(\Delta\eta) = \alpha\left[\frac{\Gamma(\Delta\eta)}{B(\Delta\eta)} - 1\right]$$

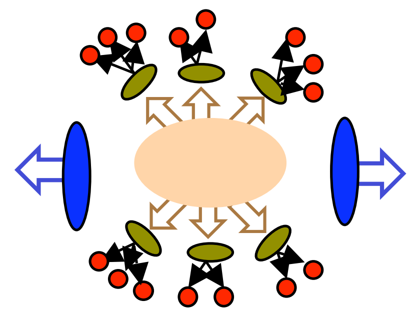
$$\Gamma(\Delta\eta) = \frac{1}{\delta\sqrt{4\pi}} e^{-(\Delta\eta)^2 / 4\delta^2}$$

$$K_{eff} = \alpha + 1 = \langle K \rangle + \frac{\sigma_K^2}{\langle K \rangle}$$

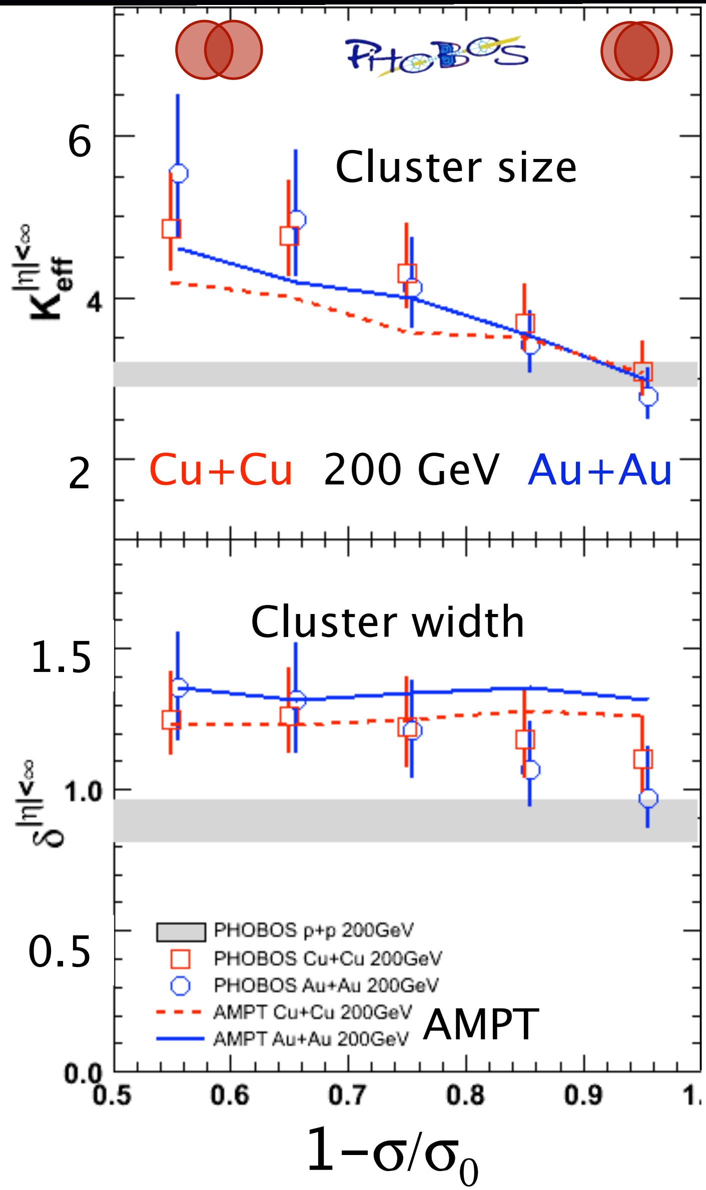
$$\delta = \left(\sqrt{K(K-1)}\right)\sigma_{\eta-\eta cluster}$$

K_{eff} : effective cluster size

δ: cluster decay width



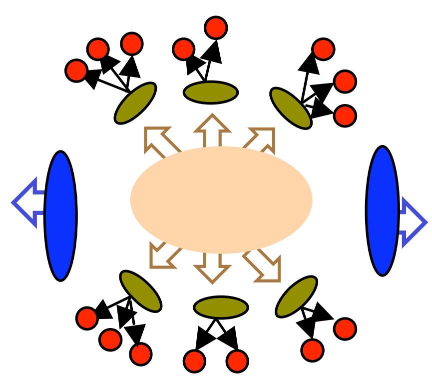
Inclusive Correlation Results



Cluster sizes are large: Up to ~5 charged particles (after correction for η acceptance, see later discussion). and scale with the fraction of inelastic cross-section, rather than N_{part}.

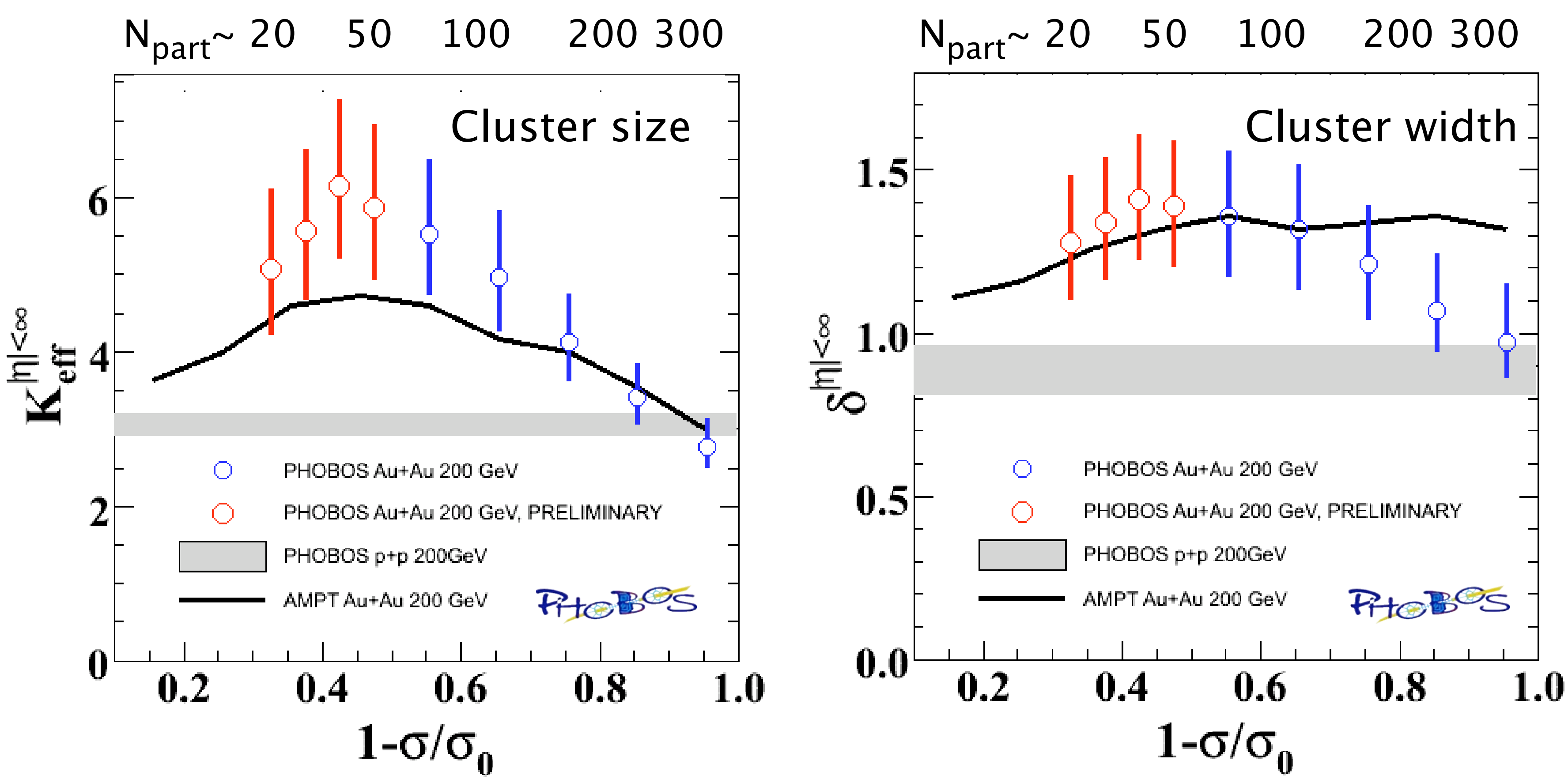
Model studies suggest that centrality dependence is due to the hadronic cascade phase and that cluster size is strongly dependent on string fragmentation parameters observed sizes are too large to be reproduced by simple decay kinematics).

HIJING does a poor job of reproducing the cluster properties of both p+p and A+A. Cluster sizes in p+p are low in HIJING (about 30% fewer associated particles). In A+A, cluster sizes in HIJING are comparable to those for semi-central but have little or no centrality dependence.



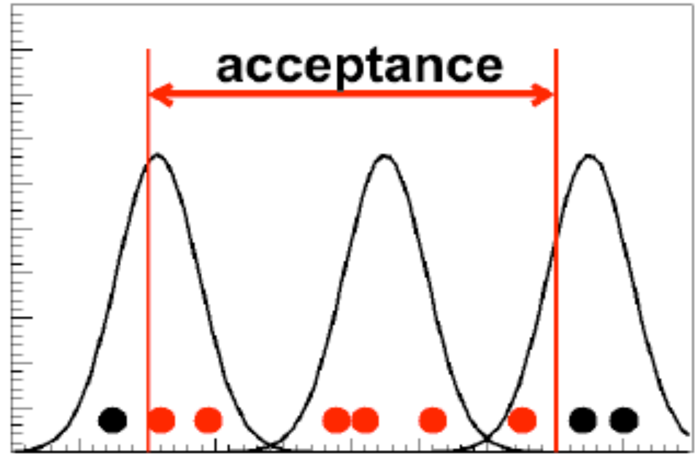
Expanded 2-Particle Correlation Result

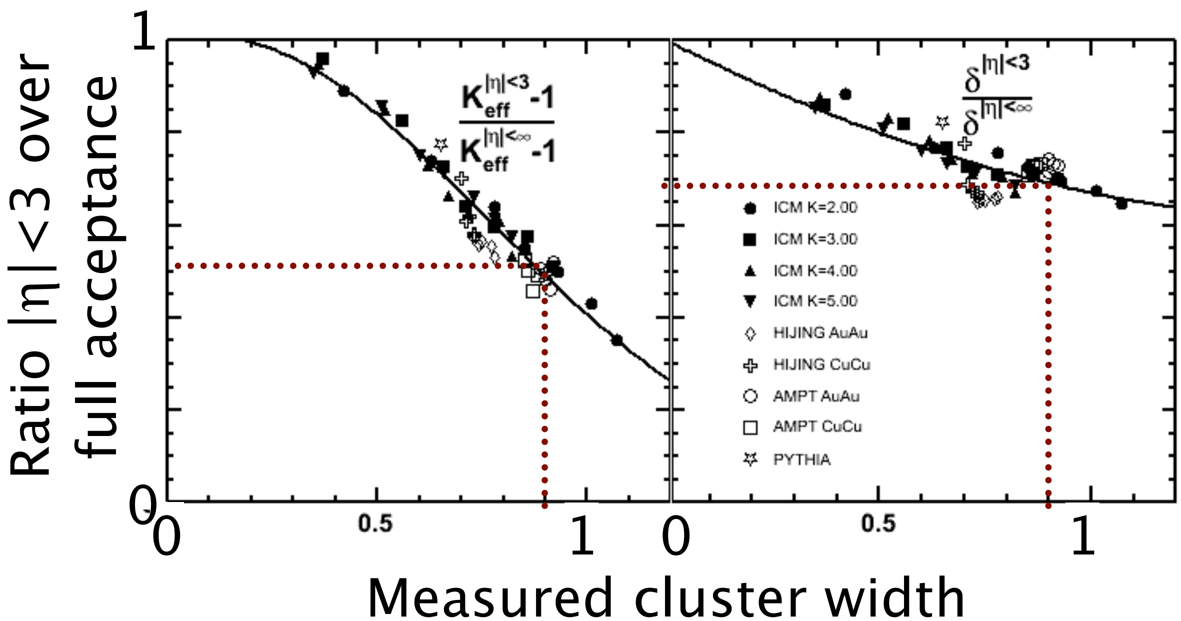
Au+Au @ 200 GeV



Acceptance Effect on Correlations

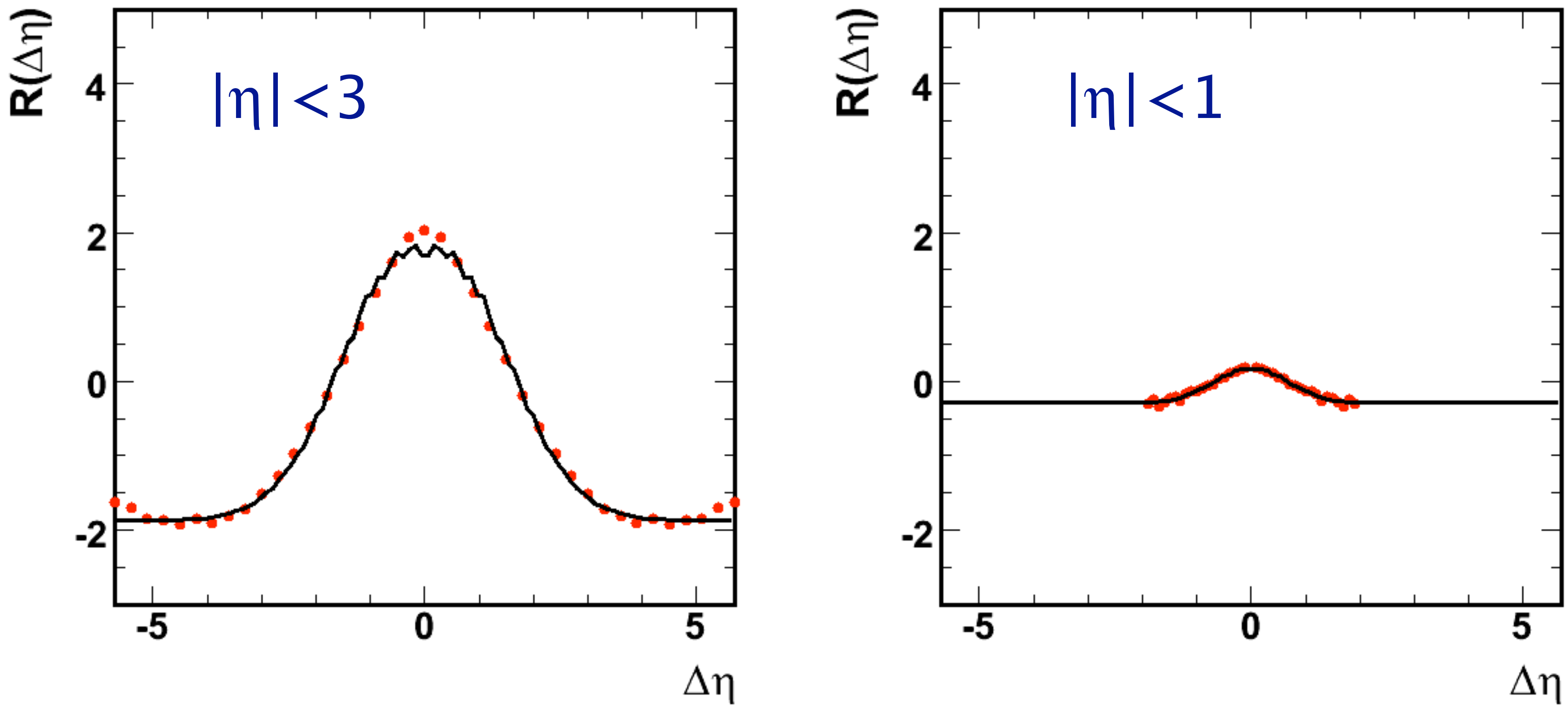
Limited η range causes loss of correlated particles leading to ***smaller*** measured sizes and widths for the clusters.





For A+A data in the range |η|<3, the correction is roughly a factor of 2 for the cluster size and 40% for the cluster width.

Cluster Fits to MC in $|\eta|<3$ and $|\eta| <1$

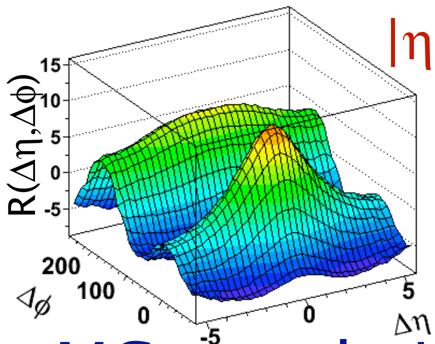


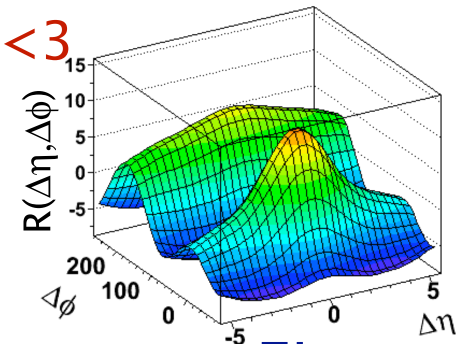
Identical MC independent cluster model events thrown into different detector acceptances and then fit with the simple cluster parameterization.

MC Study of Acceptance Effect

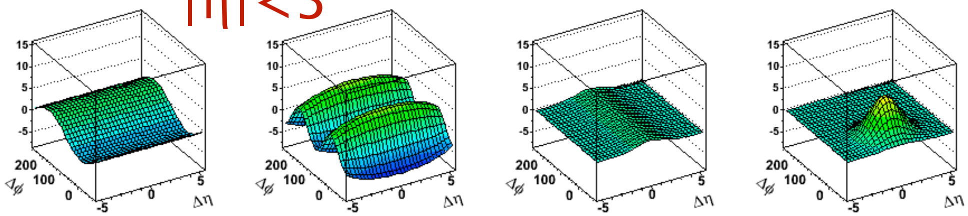
Events from cluster model plus flow are fit with a multi-component parameterization (similar to arxiv:0806.2121v2)

$|\eta|<3$





$|\eta|<3$

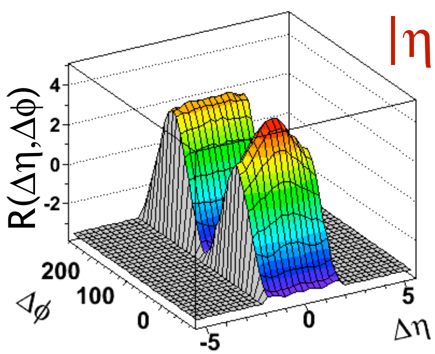


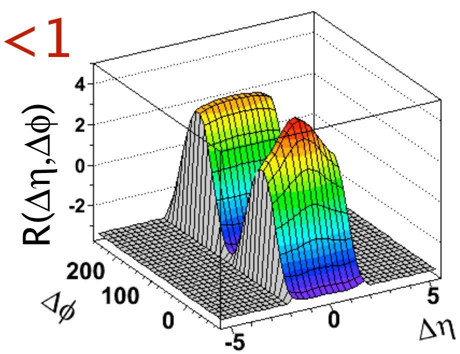
MC correlation

Fit

Individual components

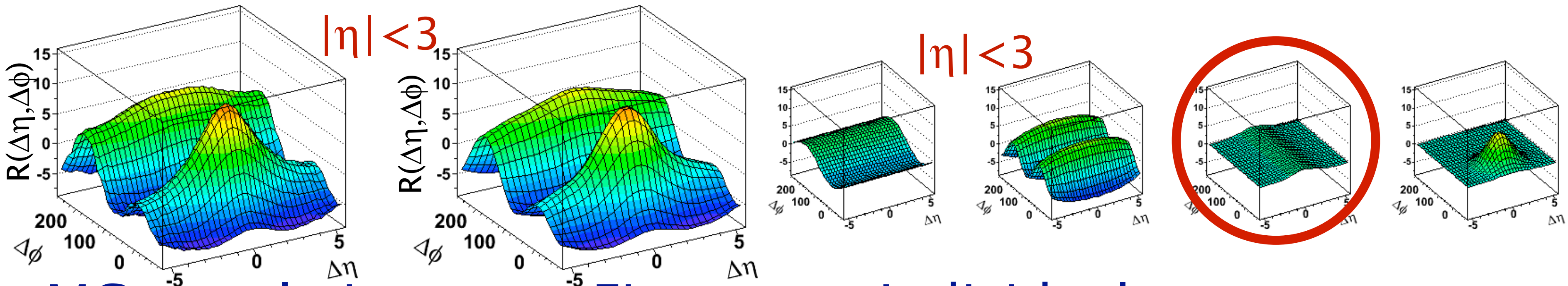
$|\eta|<1$



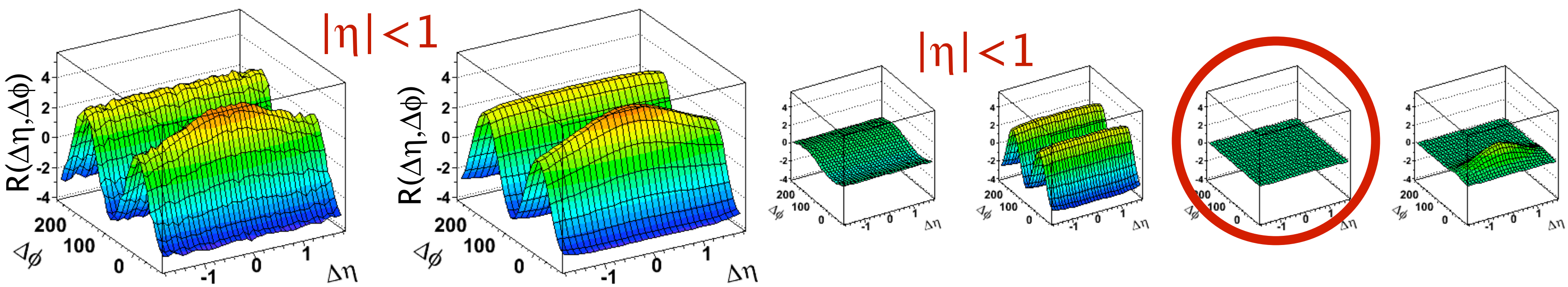


MC Study of Acceptance Effect

Events from cluster model plus flow are fit with a multi-component parameterization (similar to arxiv:0806.2121v2)



MC correlation   Fit   Individual components

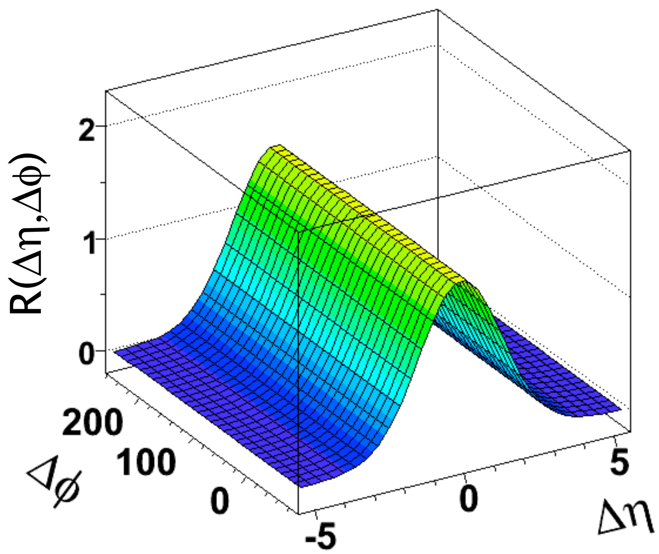


Note the almost complete disappearance of the 1D $\Delta\eta$ component in the reduced acceptance case

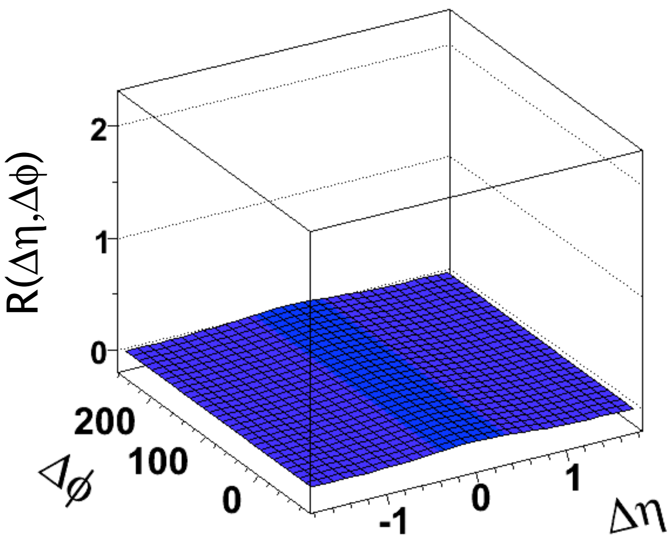
MC Study of Acceptance Effect

Events from cluster model plus flow are fit with a multi-component parameterization (similar to arxiv:0806.2121v2)

$|\eta|<3$



$|\eta|<1$



Note the almost complete disappearance of the 1D $\Delta\eta$ component in the reduced acceptance case

Summary

- Correlations in Au+Au @ 200 GeV using a trigger particle with p_T>2.5 GeV/c show a "ridge" of enhanced yield at small $\Delta\phi$ which extends to at least $|\Delta\eta|$=4
  - Appears to be a constant "ridge" under Pythia-like fragmentation
  - Effect seems to disappear for N_{part} below about 80
- Inclusive 2-particle correlations suggest that particles are emitted in very large "clusters" whose size scales with the geometry of the collision as opposed to N_{part}
- Quantitative interpretation of any correlation result needs to take into account the effect of η acceptance
  - For example comparing to models or comparing STAR & PHOBOS