Angular correlations at PHOBOS

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PHOBOS collaboration (July 2006)

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UNIVERSITY OF MARYLAND
BROOKHAVEN NATIONAL LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
UNIVERSITY OF ILLINOIS AT CHICAGO
UNIVERSITY OF ROCHESTER

Overview

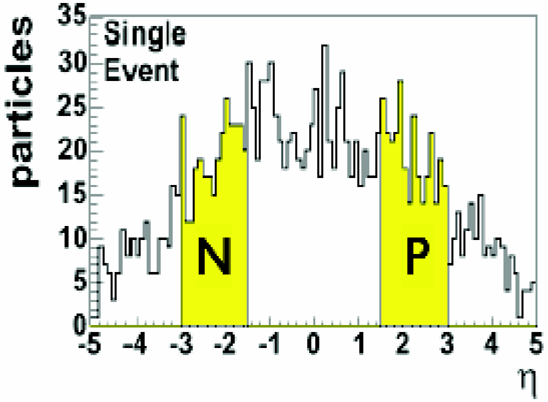
- Motivation: Clusters from F&B multiplicity correlations at PHOBOS;
- Two-particle angular correlation as another point of view to study in detail the multiplicity and shape of the clusters;
  - Definitions;
  - MC studies;
  - Cluster model and rapidity correlation function;
  - Other studies in HI collision;
- **In this talk, mainly the analysis technique will be discussed since results of PHOBOS data are not ready for publication yet.**

Clusters in F&B Multiplicity Correlations

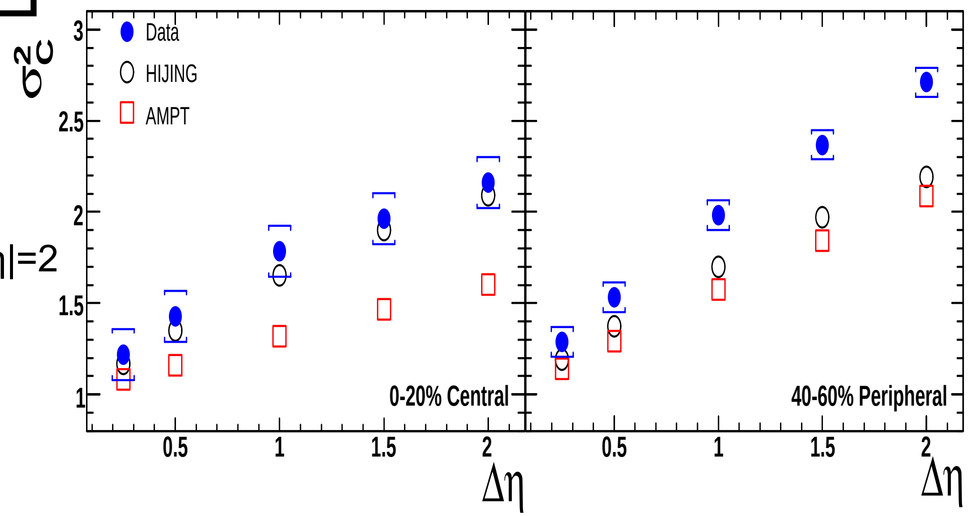
$$C = \frac{P - N}{\sqrt{P + N}}$$

$\sigma_C^2 \sim \langle K \rangle$

Cluster Multiplicity K



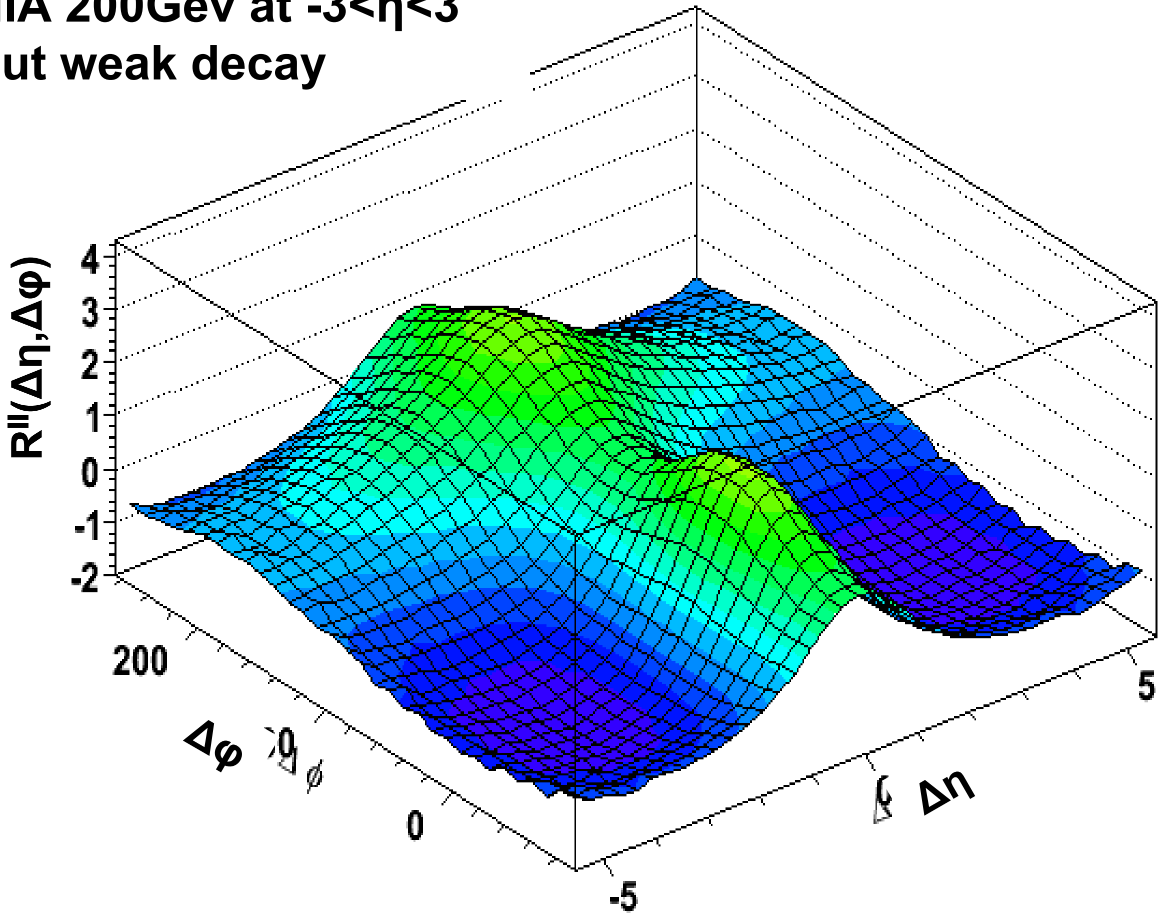
σ_C^2 as a function of $\Delta\eta$ at fixed $|\eta|=2$



This topic will be discussed in more details in Constantin Loizides' talk

Two-particle angular correlations

PYTHIA 200Gev at $-3<\eta<3$
without weak decay



Two-particle correlation function (C.F.)

Inclusive two-particle correlation function:

$$R^{II}(\Delta\eta,\Delta\phi) = <(n-1)\left(\frac{F_n(\Delta\eta,\Delta\phi)}{B_n(\Delta\eta,\Delta\phi)}-1\right)>$$

Foreground: $F_n(\Delta\eta,\Delta\phi) \sim \rho_n^{II}(\eta_1,\eta_2,\phi_1,\phi_2) = \frac{1}{n(n-1)\sigma_n}\frac{d^4\sigma_n}{d\eta_1 d\eta_2 d\phi_1 d\phi_2}$

Background: $B_n(\Delta\eta,\Delta\phi) \sim \rho_n^{I}(\eta_1,\phi_1)\rho_n^{I}(\eta_2,\phi_2) = \frac{1}{n\sigma_n}\frac{d^2\sigma_n}{d\eta_1 d\phi_1}\cdot\frac{1}{n\sigma_n}\frac{d^2\sigma_n}{d\eta_2 d\phi_2}$

Normalization relation:

$$\int F_n(\Delta\eta,\Delta\phi)d\Delta\eta d\Delta\phi = 1 \qquad \int \rho_n^{II}(\eta_1,\eta_2,\phi_1,\phi_2)d\eta_1 d\eta_2 d\phi_1 d\phi_2 = 1$$

$$\int B_n(\Delta\eta,\Delta\phi)d\Delta\eta d\Delta\phi = 1 \qquad \int \rho_n^{I}(\eta,\phi)d\eta d\phi = 1$$

Two-particle correlation function

$F_n(\Delta\eta, \Delta\phi)$
- Represents two particle density distribution;
- Obtained by taking particle pairs from the same events;
- Integral is normalized to be 1.

$B_n(\Delta\eta, \Delta\phi)$
- A product of two single particle densities;
- Constructed by event-mixing which randomly selects particles from different but similar events. (vertex position, centrality etc.)
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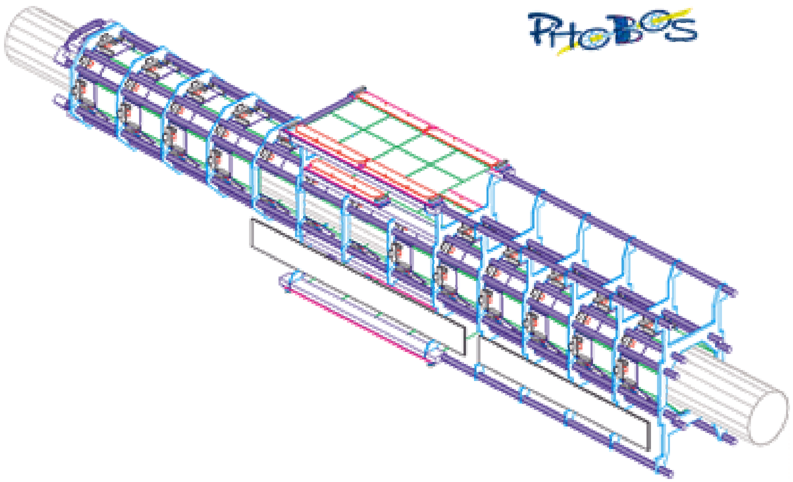
In $R^{II}(\Delta\eta, \Delta\phi) = < (n-1)(\frac{F_n(\Delta\eta, \Delta\phi)}{B_n(\Delta\eta, \Delta\phi)} - 1) >$ **:**

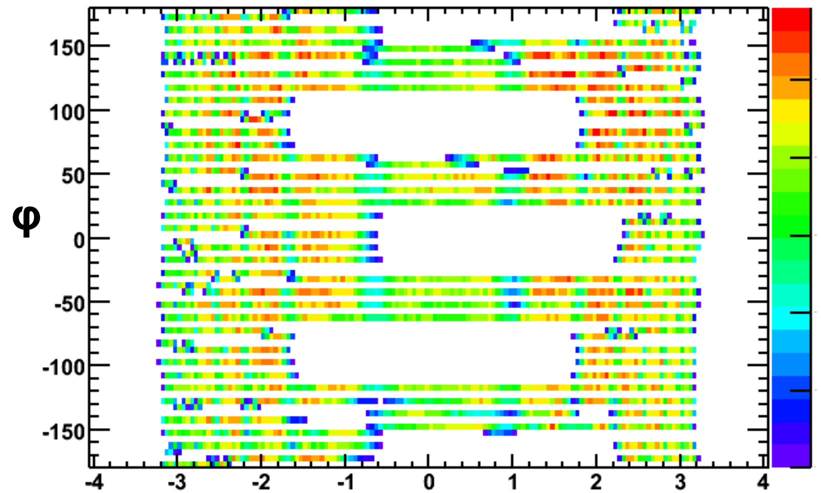
- $F_n(\Delta\eta,\Delta\phi)$is weighed by (n-1) event-by-event and then averaged over all the events to avoid dilution of the correlations trivially due to high multiplicity;
- A division of background distribution will help cancel the inefficiency of the detector in the foreground distribution such as acceptance.

Background construction



Octagon detector:
η from -3 to 3 and almost full azimuthal angle

η-φ distribution of hits on the Octagon detector



-1cm<vz<1cm

Have to appropriately build mixed-event background to correct the acceptance:

- Particles from different events;
- Event vertices within 0.5cm (vertex resolution) are mixed.;
- Events within same centrality bin are mixed (not necessary for pp);
- In practice, a pool of 30000 events is used for event-mixing and many pools are combined in the end.

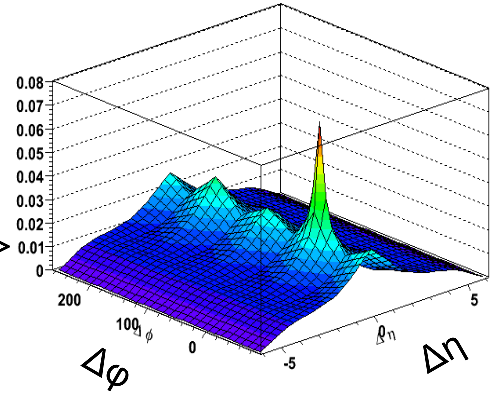
Turning on the detector

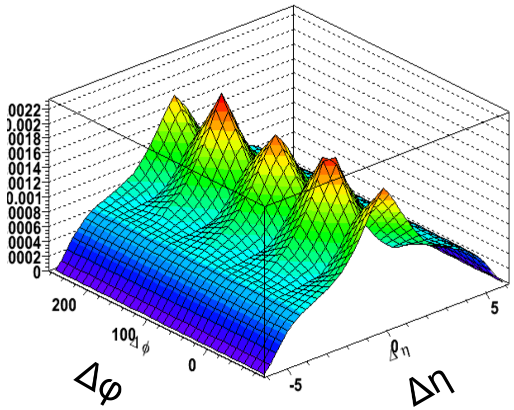
Things don't seem to be very encouraging for a first look…

After incorporating the PHOBOS detector simulation to the raw generator:

Foreground:

$$<(n-1)F_n(\Delta\eta,\Delta\phi)>$$





Background:

$$B(\Delta\eta,\Delta\phi)$$

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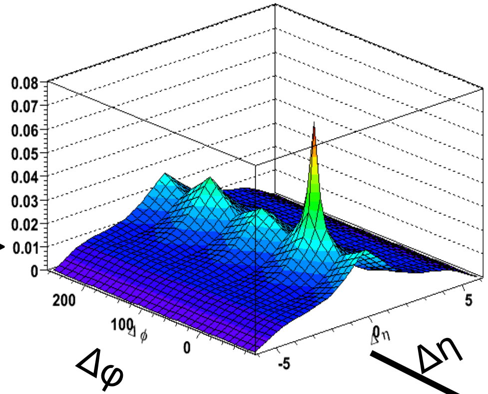
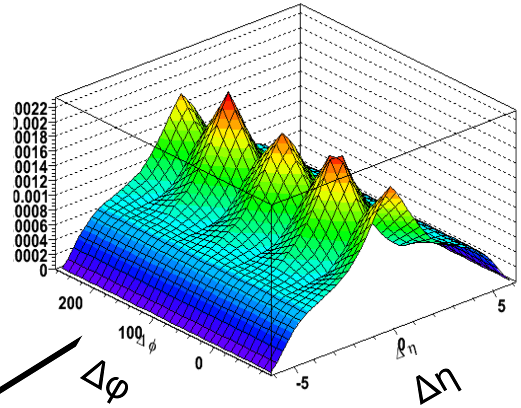
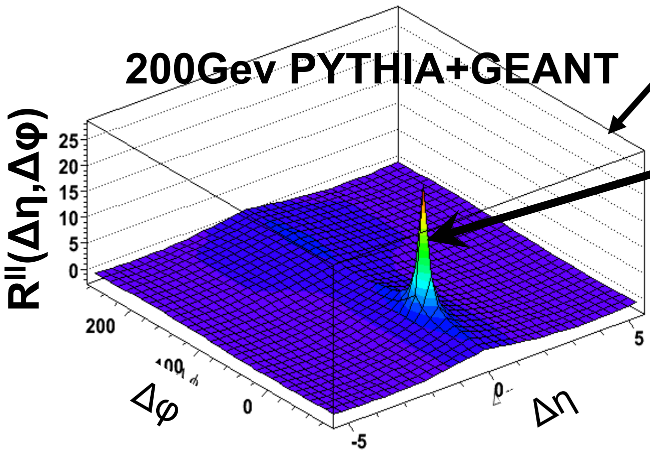




Background:

$B(\Delta\eta,\Delta\phi)$

200Gev PYTHIA+GEANT



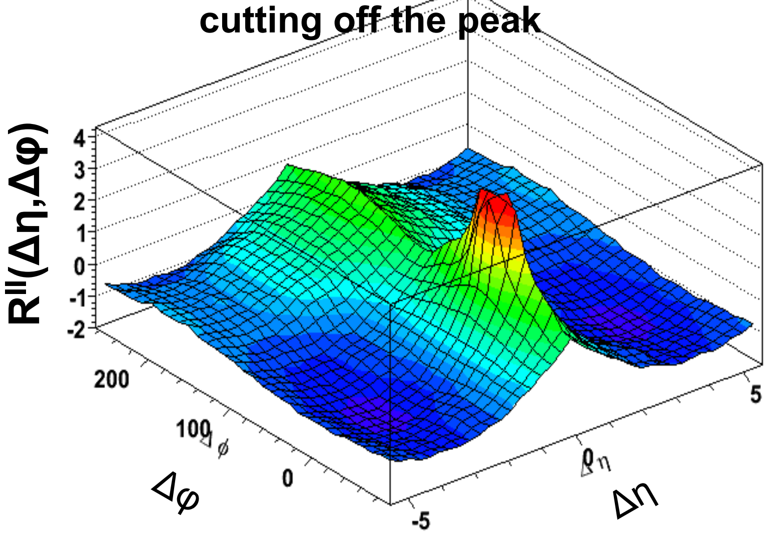
Peak at (0,0) suffering from secondary effects: Δ-electron(50%), γ conversion(40%) etc.

Since we have little information of the particles (only one hit), the secondary effects have to be corrected by MC simulation

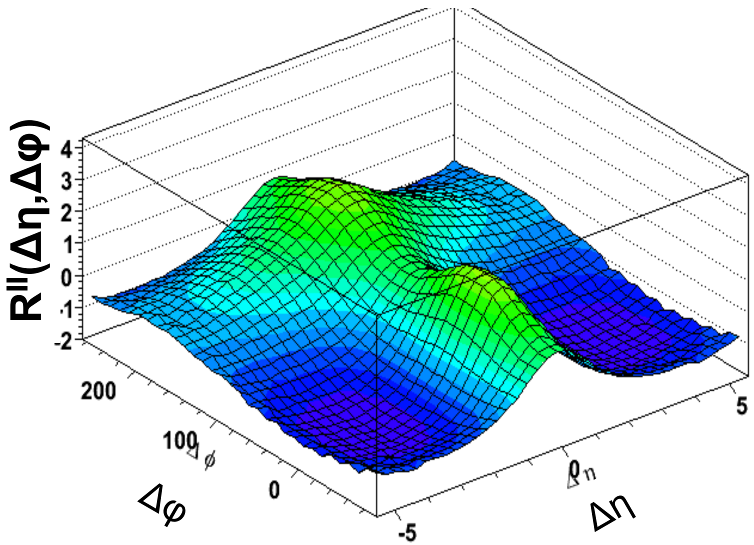
Turning on the detector

However, things are not actually too bad…

200Gev PYTHIA+GEANT,
cutting off the peak



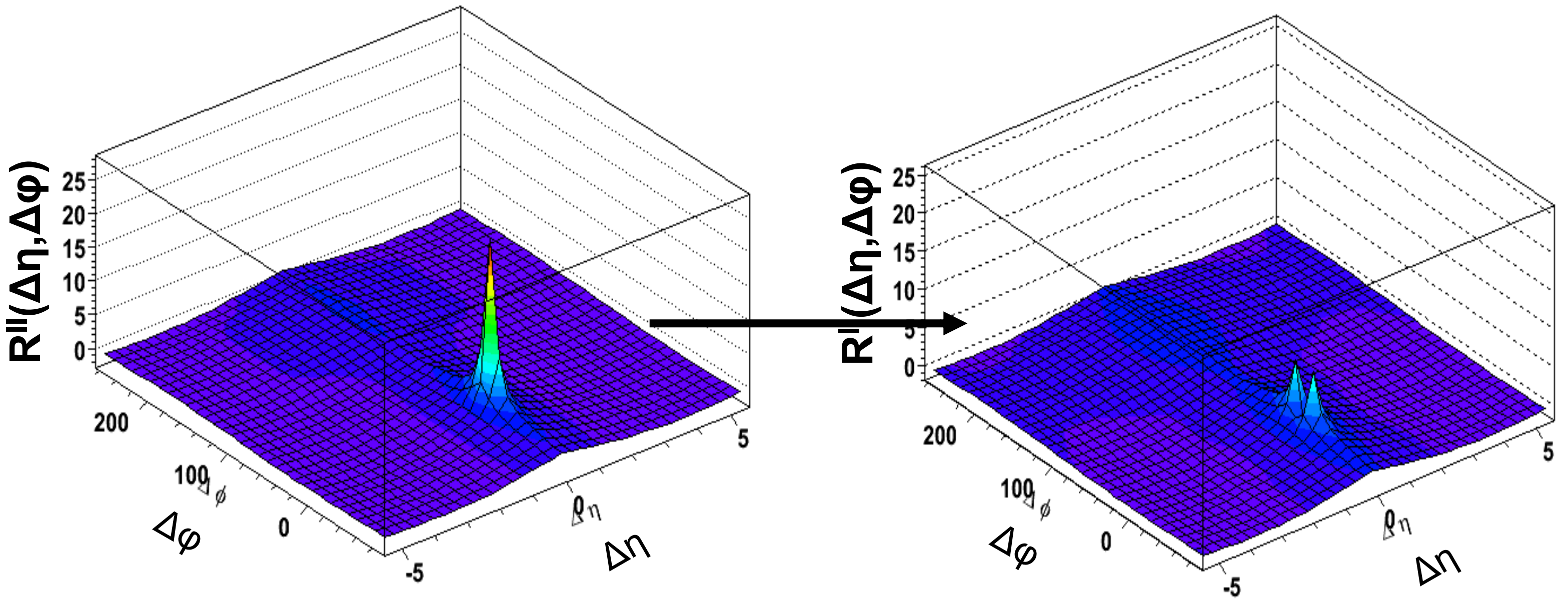
200Gev Raw PYTHIA



- **Fortunately, the overall structure except the high spike doesn't get distorted very much.**
- **Secondary effects sitting on top of the actual correlations at (0,0) need to be corrected.**

How to handle the high peak

First of all, we reject a small region of |Δφ|<5.625,|Δη|<0.3 from both foreground and background which cause the biggest uncertainties based on MC simulation.

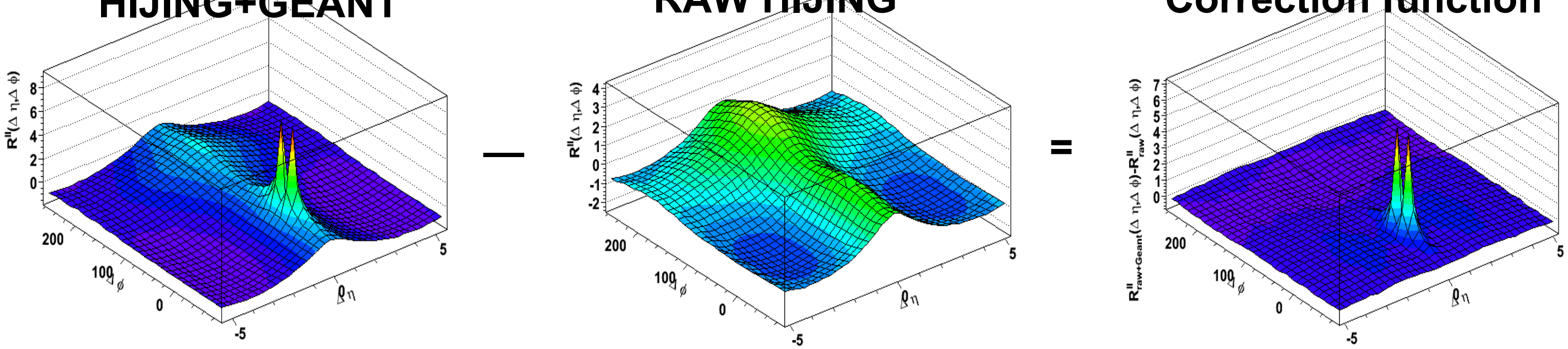


The physics we are going to study has a range of about 1 unit in Δη. Cutting off a small region won't cause too much loss of information.

Correcting the secondary effects

Then, we build correction function from HIJING

HIJING+GEANT — **RAW HIJING** = **Correction function**



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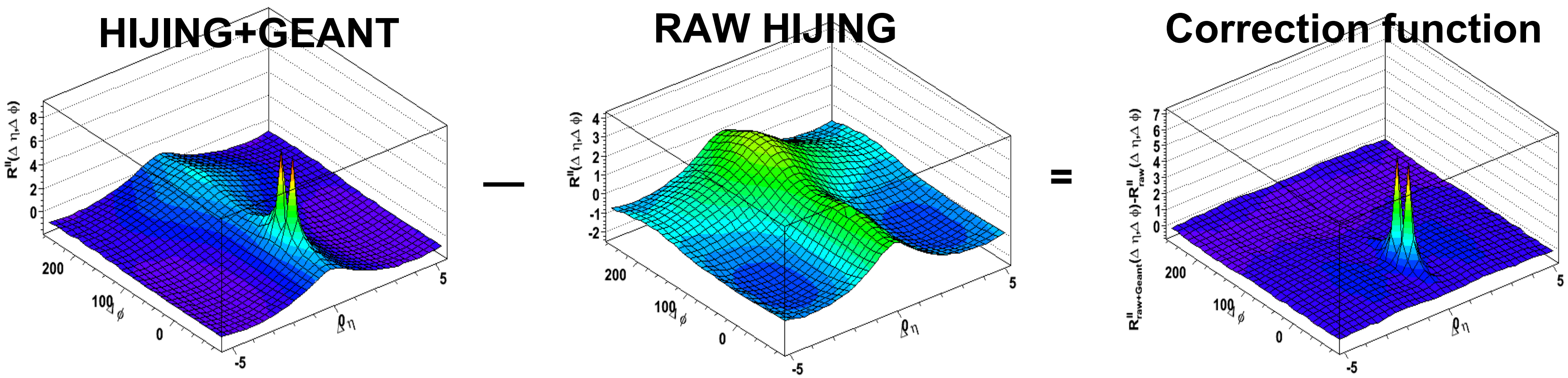

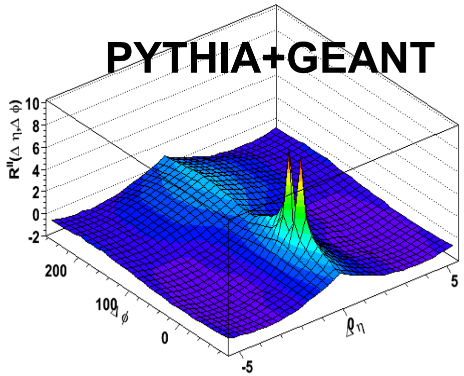

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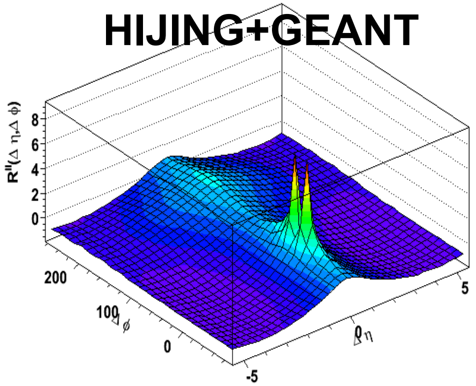
HIJING+GEANT



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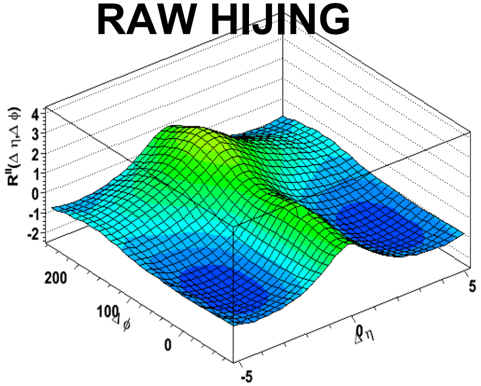
RAW HIJING



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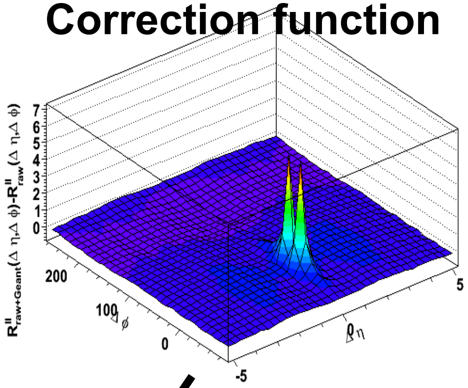
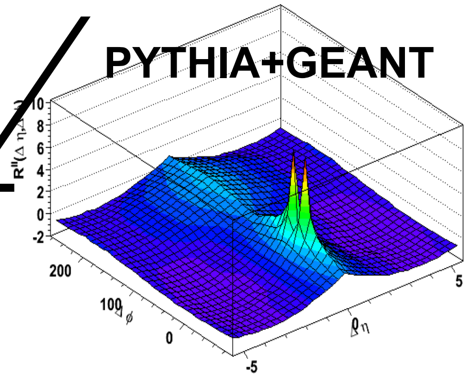
Correction function



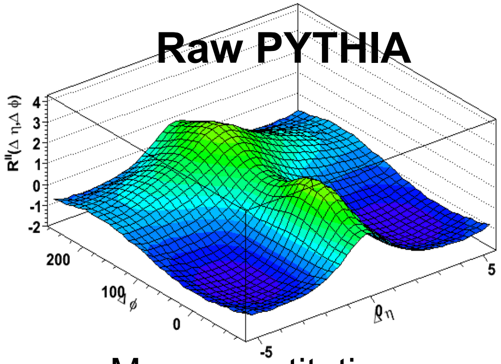
subtracted

PYTHIA+GEANT



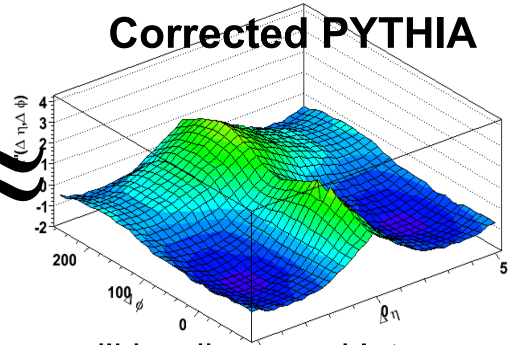
Correction almost recovers the original correlations!

Raw PYTHIA



≈

Corrected PYTHIA



More quantitative comparison will be discussed later

What can we learn?

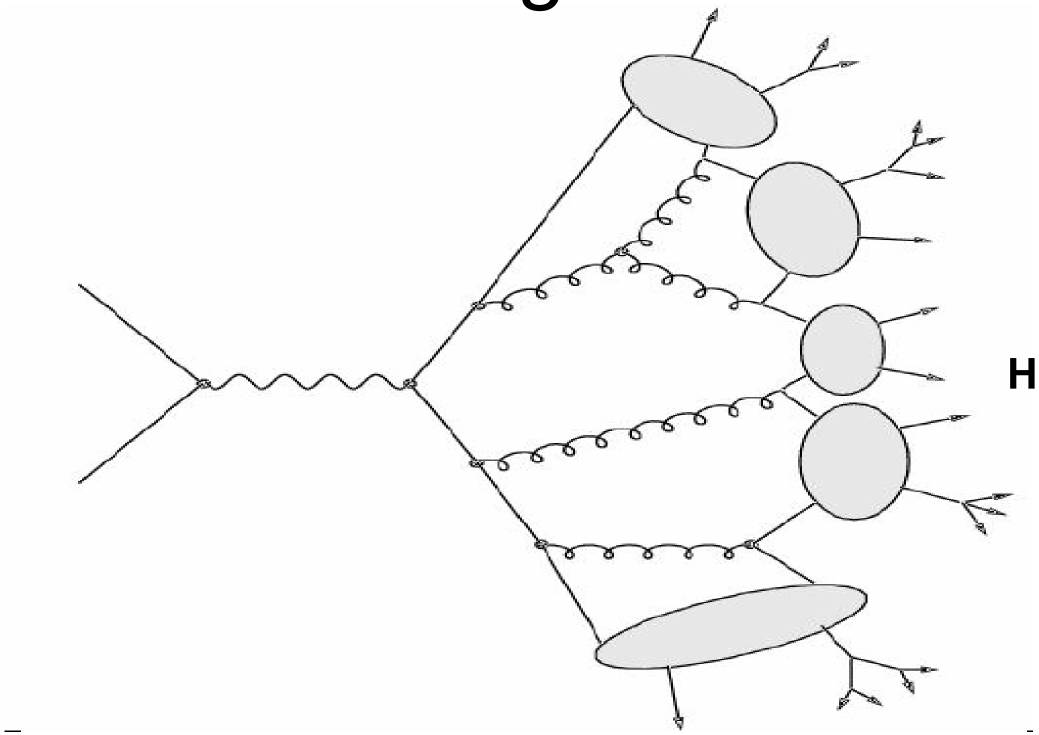
- Phenomenological model: Clusters;
- To quantitatively compare with the models by looking at 1D pseudo rapidity correlation function:

$$R^{II}(\Delta\eta) = <(n-1)\left(\frac{F_n(\Delta\eta)}{B_n(\Delta\eta)} - 1\right)>$$

$$F_n(\Delta\eta) = \int F_n(\Delta\eta, \Delta\phi) d\Delta\phi$$

$$B_n(\Delta\eta) = \int B_n(\Delta\eta, \Delta\phi) d\Delta\phi$$

Phenomenological model - Clustering



Hadronization via clusters

QCD and Collider Physics, p190, Ellis, Stirling and Webber, 1996

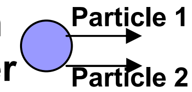
- **A phenomenological model of particle production in high energy collisions:**
  - **Non-perturbative gluons split into qqbar pairs;**
  - **Neighboring qqbar combine into color singlet cluster;**
  - **Clusters decay into final-state hadrons;**
- **Assumption of independent cluster emission**

Cluster model and Two-particle rapidity C.F.

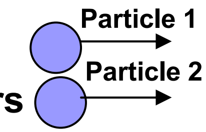
If there are c clusters in an event and k_i particles in a cluster, the two particle density:

$$\rho_n^{(II)}(\eta_1,\eta_2)=\frac{1}{n(n-1)}\sum_{c=1}^{n}P(c)\{\sum_{i=1}^{c}k_i(k_i-1)\Gamma^{(2)}_{\eta_1,\eta_2}+\sum_{i\neq j=1}^{c}k_ik_j\rho_n^{(I)}(\eta_1)\rho_n^{(I)}(\eta_2)\}$$

Pairs from one cluster



Pairs from different clusters



where $\Gamma^{(2)}_{\eta_1,\eta_2}$ is characterized by a Gaussian distribution: $\exp(-\frac{(\eta_1-\eta_2)^2}{4\delta^2})$ (Nucl.Phys.B, 78:541, 1974)

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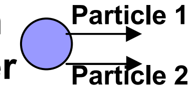

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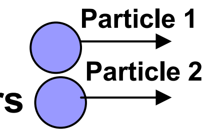

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Two-particle rapidity correlation function:

$$R^{II}(\eta_1,\eta_2) = \left\langle (n-1)\left(\frac{\rho_n^{(II)}(\eta_1,\eta_2)}{\rho_n^{(I)}(\eta_1)\rho_n^{(I)}(\eta_2)} - 1\right)\right\rangle = \alpha\left[\frac{\Gamma^{(2)}_{\eta_1,\eta_2}(\eta_1,\eta_2)}{\rho_n^{(I)}(\eta_1)\rho_n^{(I)}(\eta_2)} - 1\right]$$

where: $\alpha = \frac{\langle K(K-1)\rangle}{\langle K\rangle}$

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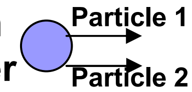

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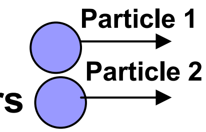

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$$R^{II}(\eta_1,\eta_2) = <(n-1)(\frac{\rho_n^{(II)}(\eta_1,\eta_2)}{\rho_n^{(I)}(\eta_1)\rho_n^{(I)}(\eta_2)}-1)> = \alpha[\frac{\Gamma^{(2)}_{\eta_1,\eta_2}(\eta_1,\eta_2)}{\rho_n^{(I)}(\eta_1)\rho_n^{(I)}(\eta_2)}-1]$$

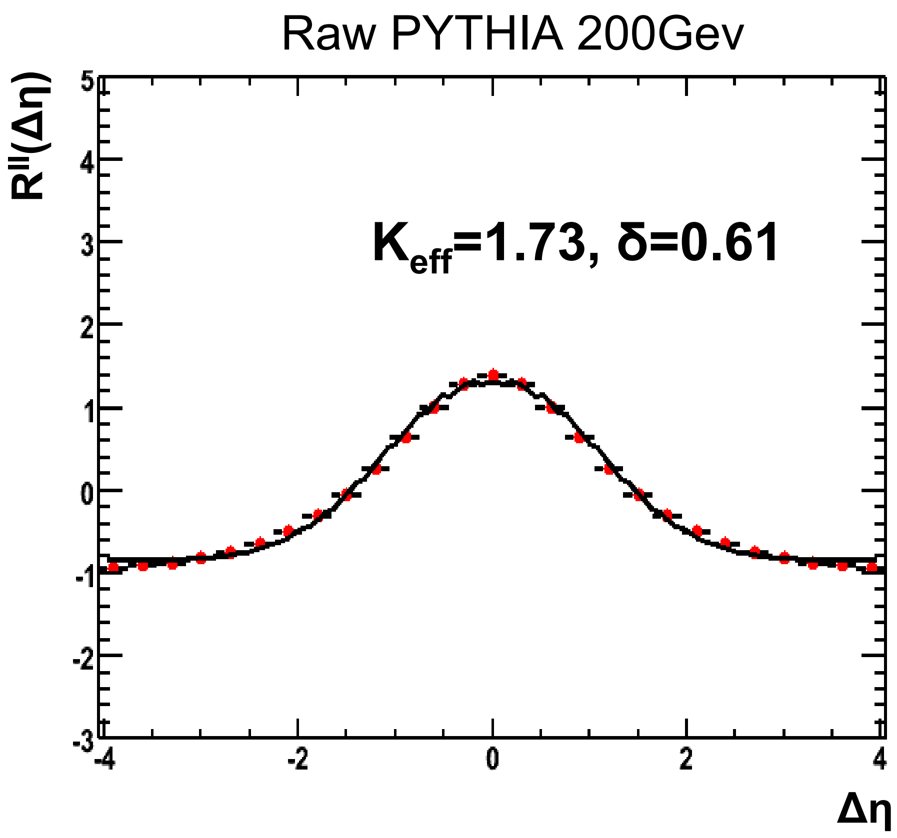
where: $\alpha = \frac{<K(K-1)>}{<K>}$

An effective cluster size can be defined as: $K_{eff} = \alpha + 1 = <K> + \frac{\sigma_K^2}{<K>}$

(Nucl. Phys. B 86:201, 1975)

Cluster model and Two-particle rapidity C.F.

A fit to the C.F. to extract cluster: $R^{II}(\Delta\eta) = \alpha[\frac{\Gamma(\Delta\eta)}{B(\Delta\eta)} - 1]$ $\quad \Gamma(\Delta\eta) \propto \exp(-\frac{(\Delta\eta)^2}{4\delta^2})$



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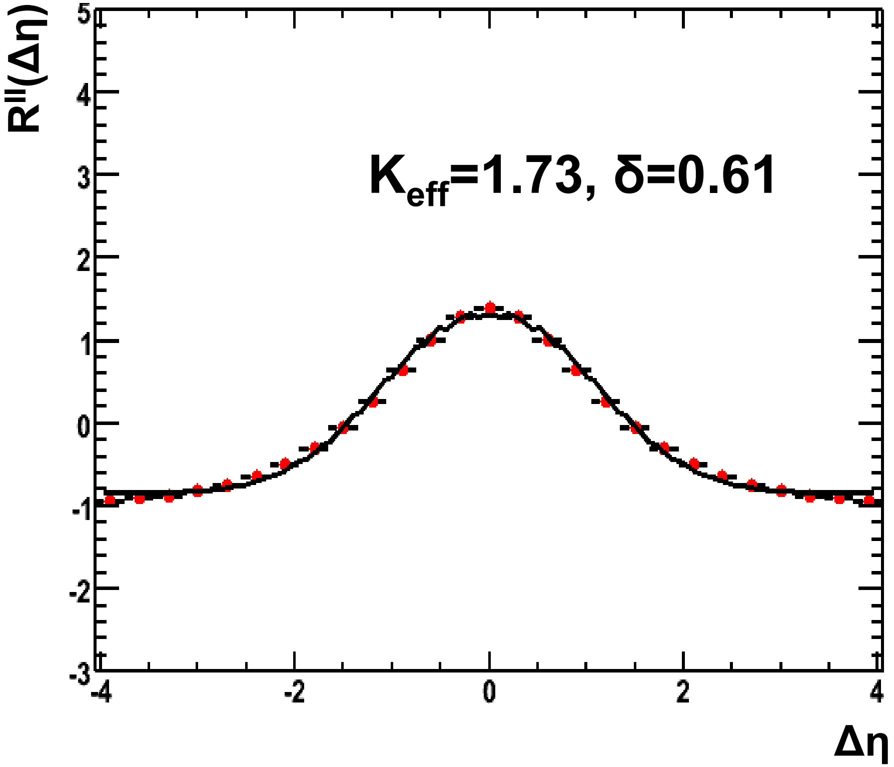
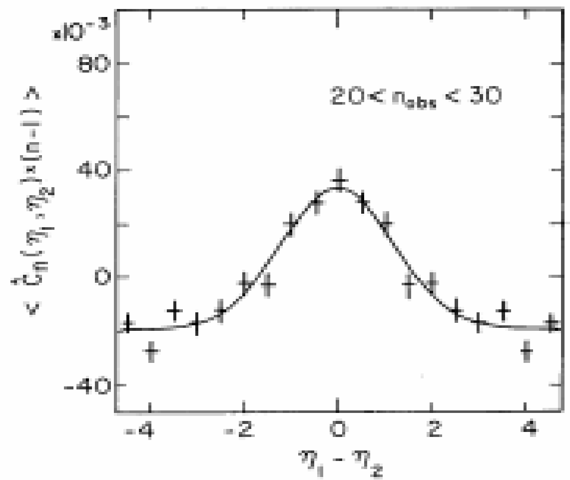
Raw PYTHIA 200Gev



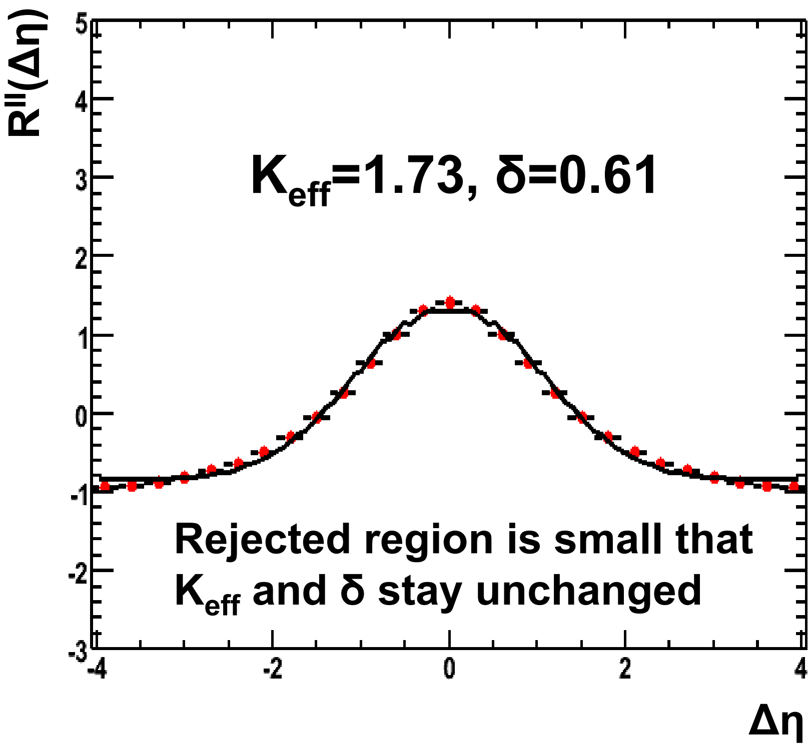
UA5 ppbar 540Gev



UA5: Phys.Lett.B123:361,1983

Cluster model and Two-particle rapidity C.F.

Raw PYTHIA after cutting off the region:
$|\Delta\varphi|<5.625, |\Delta\eta|<0.3$



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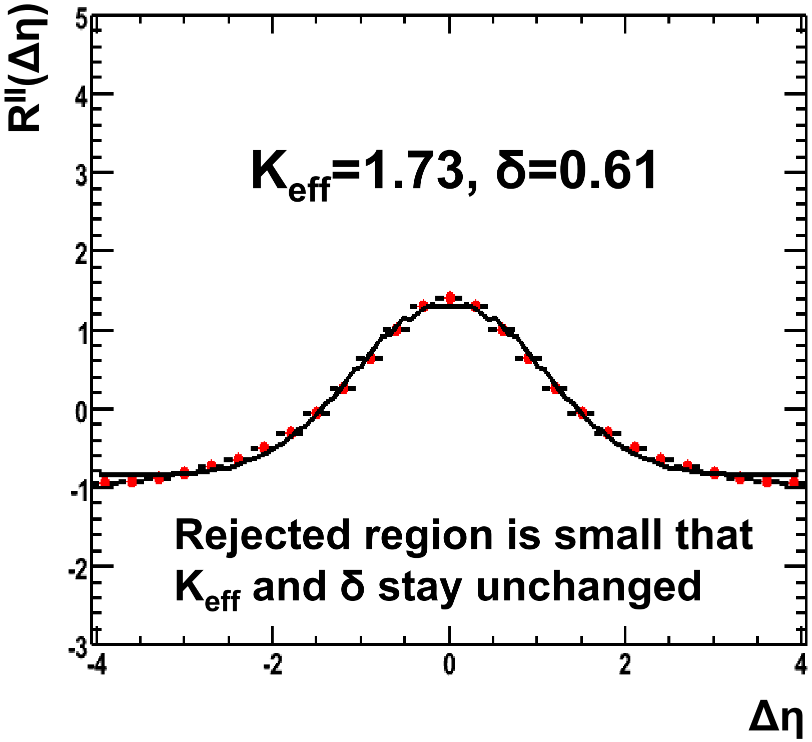
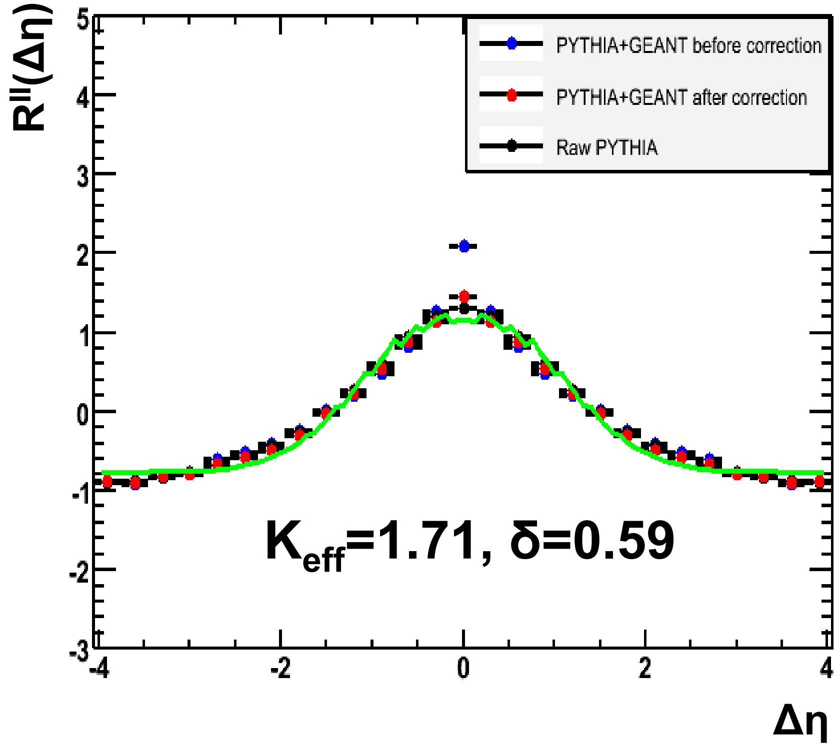
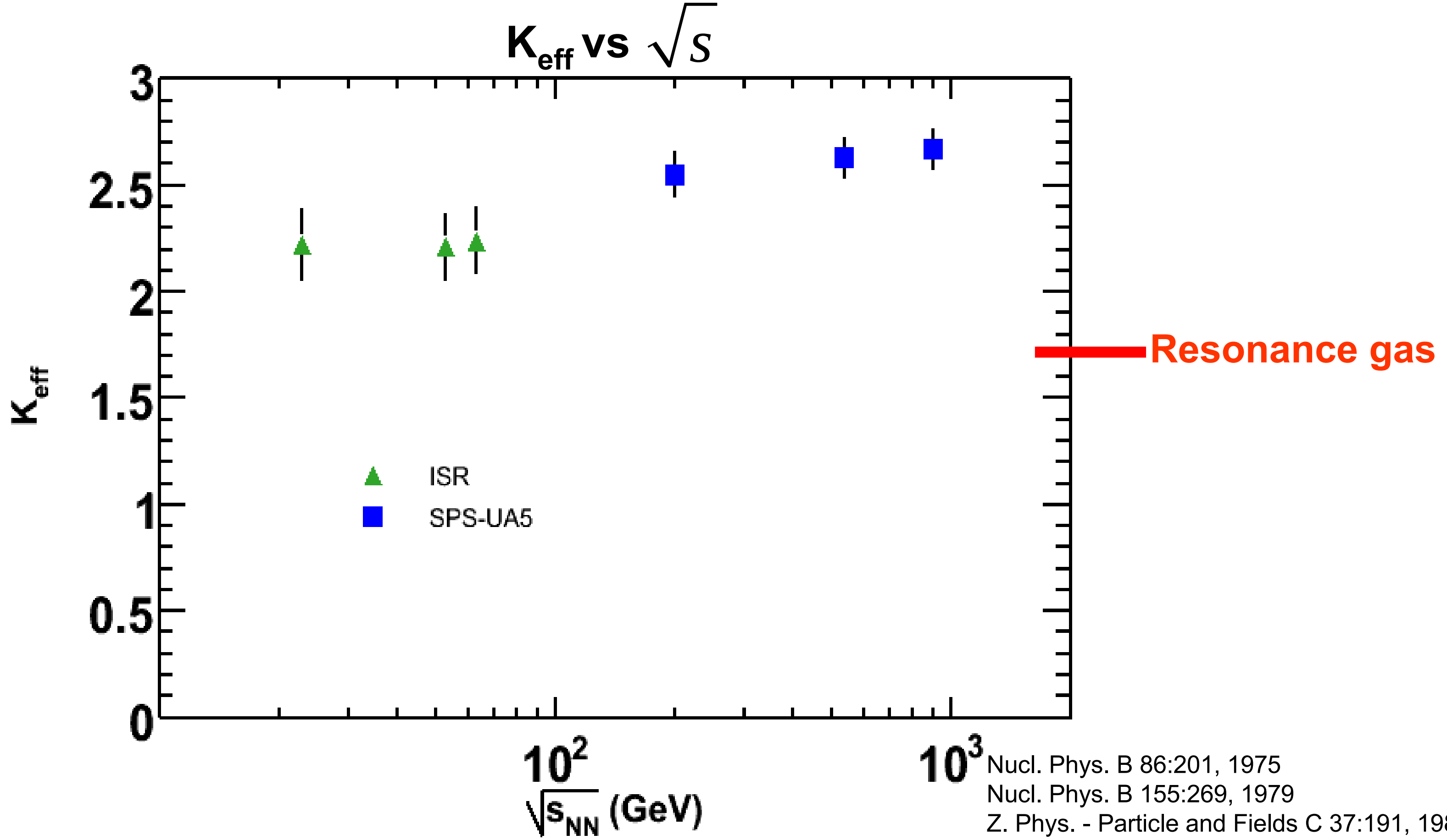


- **Correction is mainly located in the most central bin;**
- **Detector effects are eliminated reasonable well.**



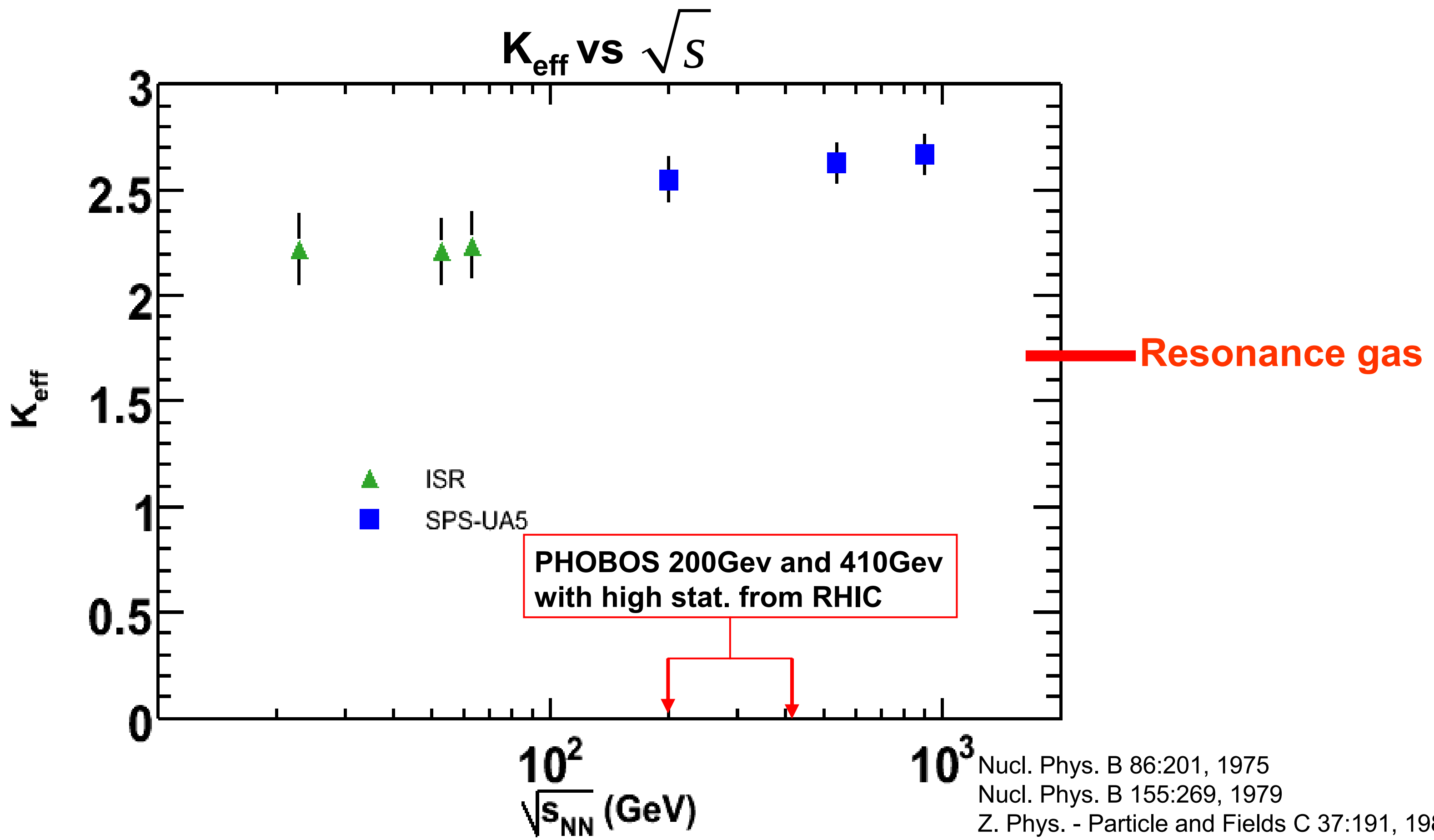
Clusters in pp collisions



Nucl. Phys. B 86:201, 1975
Nucl. Phys. B 155:269, 1979
Z. Phys. - Particle and Fields C 37:191, 1988

Resonance gas is not enough to explain the observed cluster multiplicity

Clusters in pp collisions



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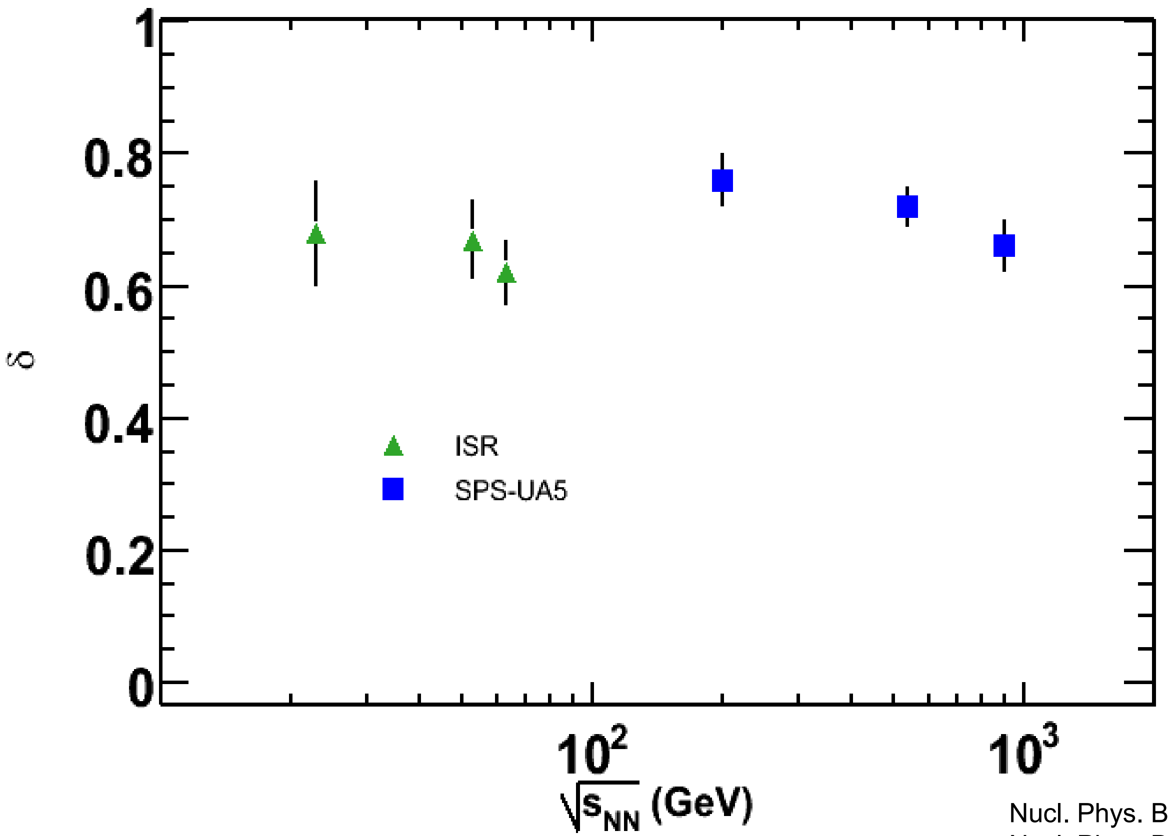
Clusters in pp collisions

Cluster decay width δ vs $\sqrt{s}$



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Almost remains constant with energy

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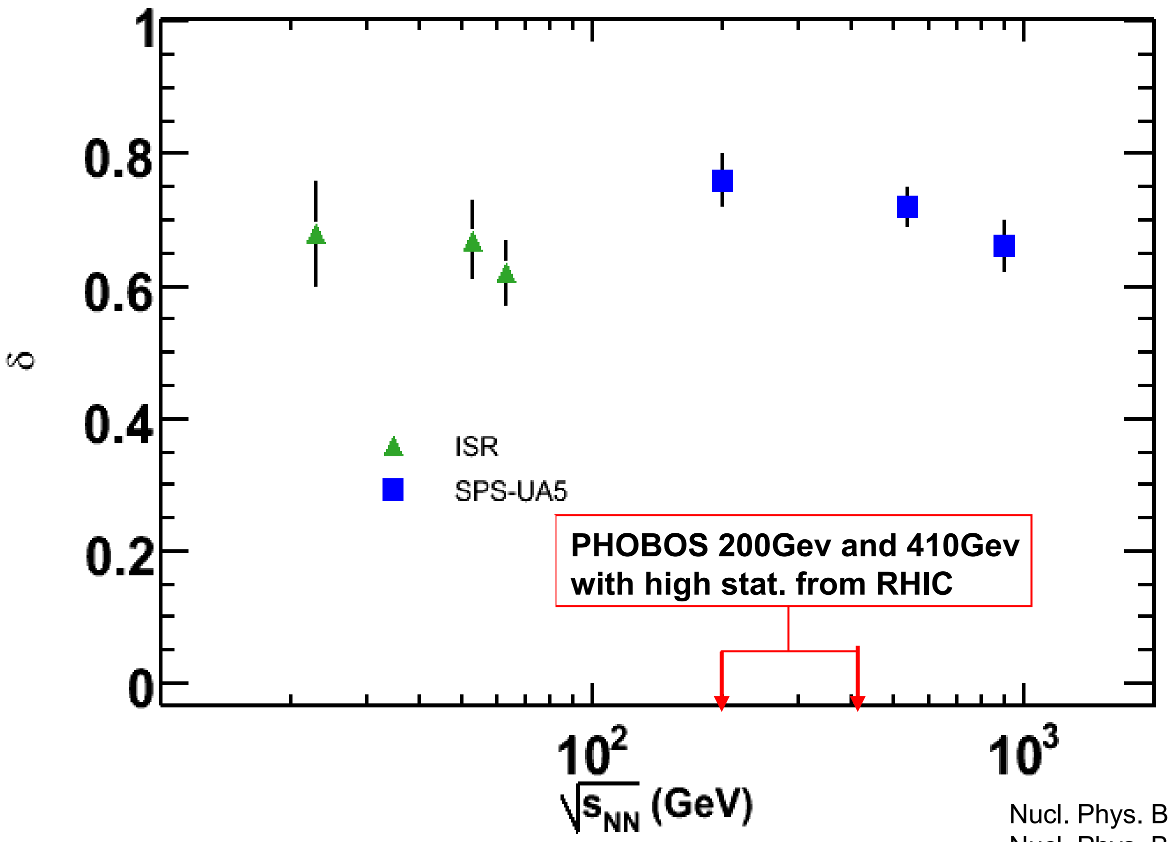

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Almost remains constant with energy

Summary

- Overall correlation structure from two particle angular correlation at a broad range in phase space.
- Two particle rapidity correlation function is interpreted in the context of cluster model. The information of cluster multiplicity and decay width can be extracted;
- Review of the previous cluster measurements in pp collisions and perspectives of PHOBOS;

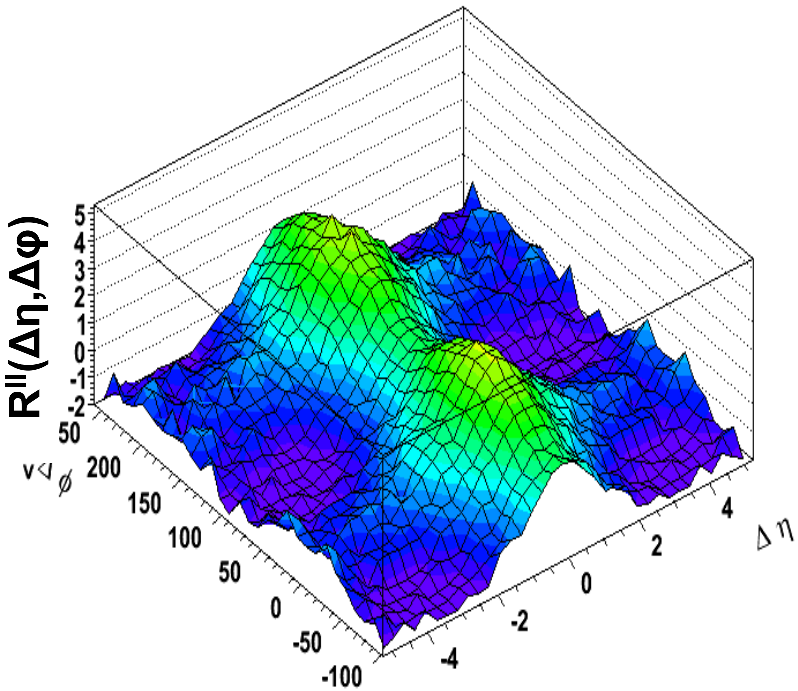
Results for pp at PHOBOS will be ready soon!

Outlook:

Two-particle angular correlation in Heavy Ion

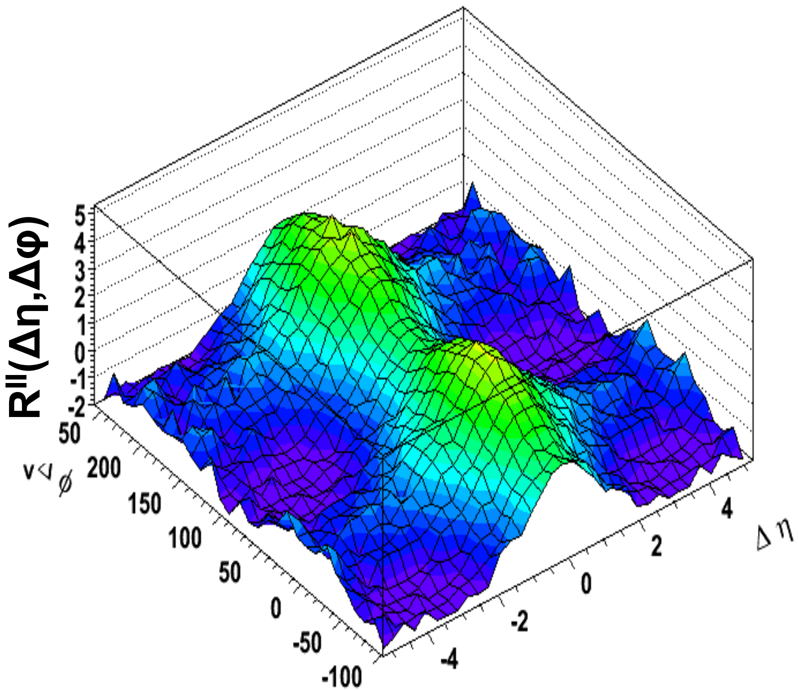
Two-particle correlations in AA

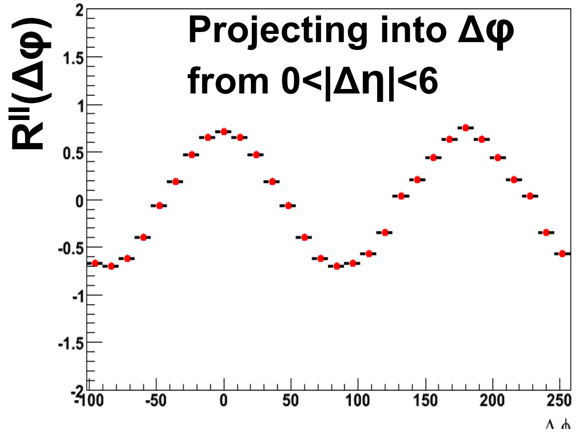
Mod. HIJING CuCu 200Gev
with triangular-shaped v2



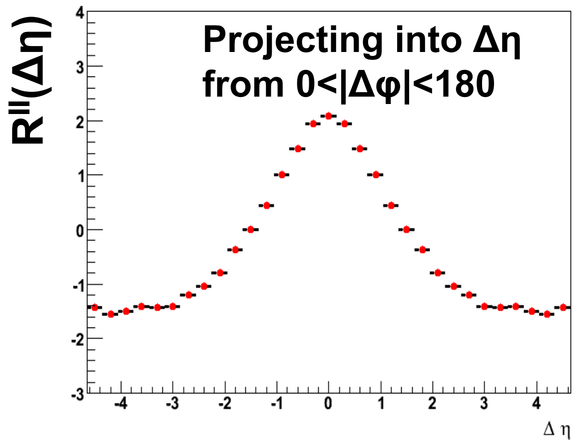
Two-particle correlations in AA

Mod. HIJING CuCu 200Gev with triangular-shaped v2





Flow effects $\langle v_2^2 \rangle$



Clusters in AA

Comprehensive study of two-particle correlation structure in pp, dA and AA will help disentangle different effects in complex heavy ion collision system!

Backups

Various definition of correlation function

1) $C(\eta_1,\eta_2) = \langle (N-1)(F(\eta_1,\eta_2)-B(\eta_1,\eta_2))\rangle$ ------UA5 Collaboration

2) $C(\eta_1,\eta_2) = \langle (N-1)(\frac{F(\eta_1,\eta_2)}{B(\eta_1,\eta_2)}-1)\rangle$

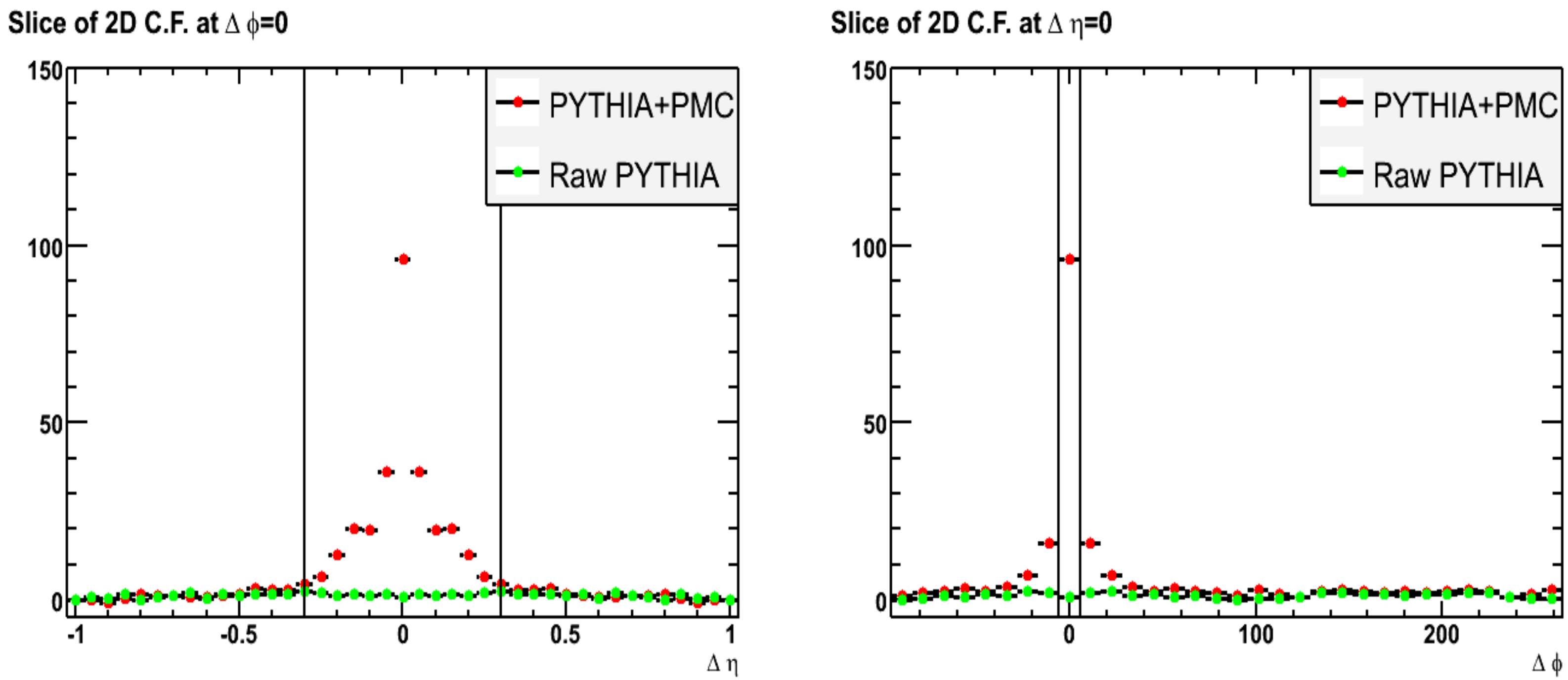
3) $C(\eta_1,\eta_2) = \langle N\rangle\langle \frac{F(\eta_1,\eta_2)}{B(\eta_1,\eta_2)}-1\rangle$ ------STAR Collaboration

4) $C(\eta_1,\eta_2) = \langle N\rangle\langle F(\eta_1,\eta_2)-B(\eta_1,\eta_2)\rangle$

$$F(\eta_1,\eta_2) = \frac{1}{N(N-1)}\frac{d^2N}{d\eta_1 d\eta_2},\quad B(\eta_1,\eta_2) = \frac{1}{N^2}\frac{dN\,dN}{d\eta_1 d\eta_2}$$

The range of secondary effects

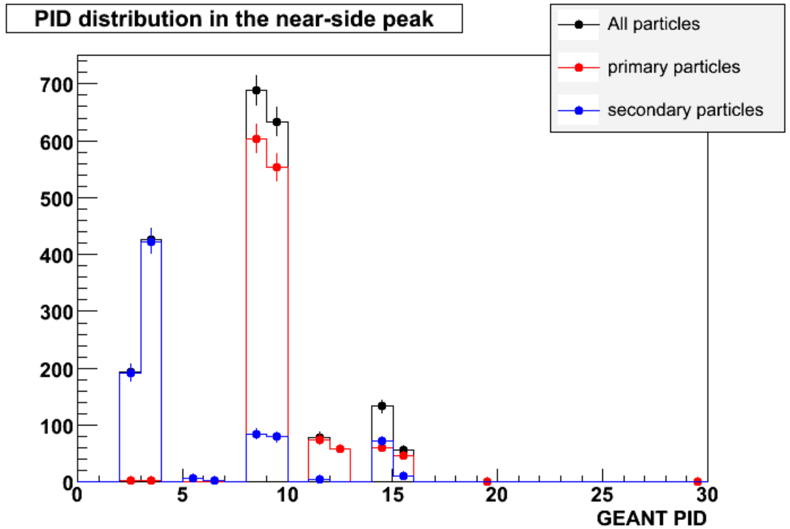
Pick out one slice of 2D C.F. at Δφ=0 and Δη=0 respectively and compare Raw PYTHIA and PYTHIA+GEANT



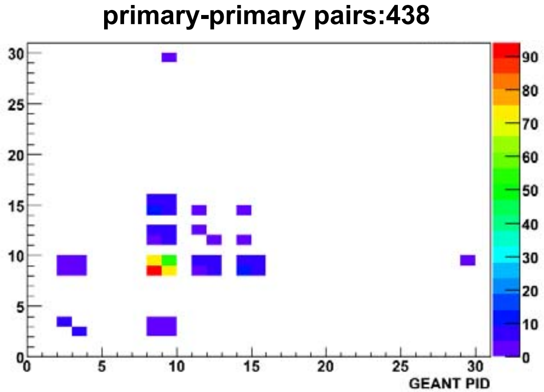
Rejected region: |Δφ|<5.625,|Δη|<0.3

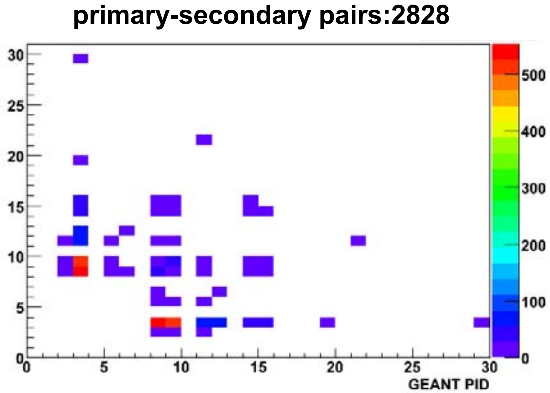
Secondary effects to the high peak

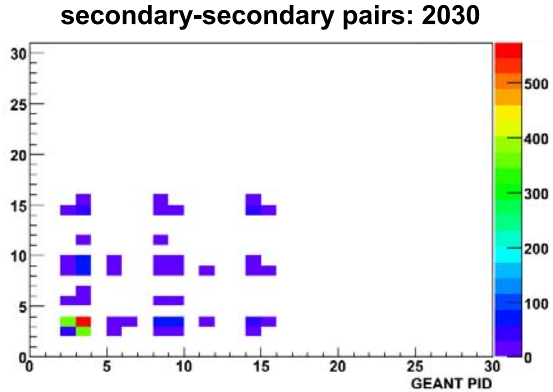
At the region of |Δφ|<5.625,|Δη|<0.3:



PID distribution:

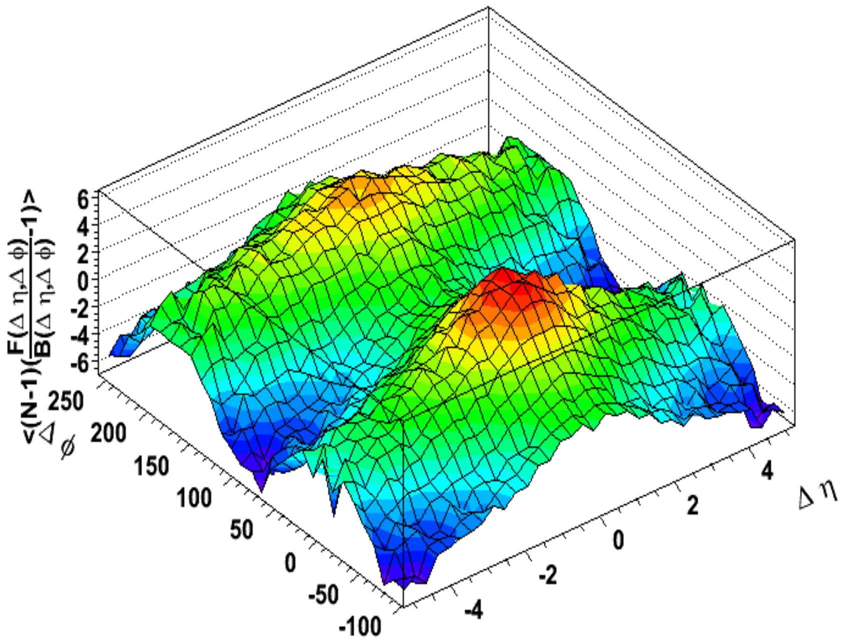






V1 contribution to two-particle C.F.

HIJING CuCu 200Gev with flat v1 and v2



V1 enhances near-side and decreases away-side for small Δη, vice versa for large Δη.