Multiplicity Fluctuations in Au+Au Collisions at RHIC

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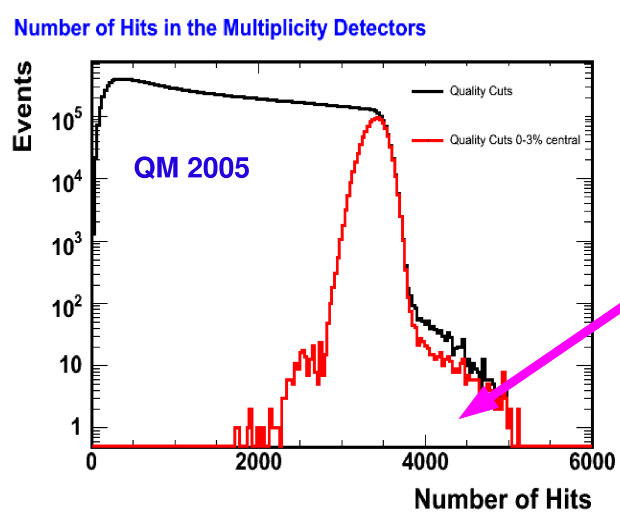
Search For Enhanced dN/dη Fluctuations



Central Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

Tail of large multiplicities consistent with fraction of pileup events
G.Stephans et al., PHOBOS Collaboration QM 2005

Motivation:

Identify unusual events in the most central Au+Au collisions by large deviations of dN/dη distribution with respect to normal events

Determination of dN/dη for each event:

- silicon pad sensors in the range |η|<5.3 used
- number of hits counted in η bins 0.2 wide
- corrections for acceptance and secondary particle production are neglected

<N(η)> is calculated in 60x5 bins of Z and Y vertex position

Event by event fluctuations of dN/dη are measured by:

$$X^2_{NDF} = \frac{1}{N_{bins}-1}\sum\frac{(N(\eta)-S<N(\eta)>)^2}{\sigma^2(N(\eta))}$$

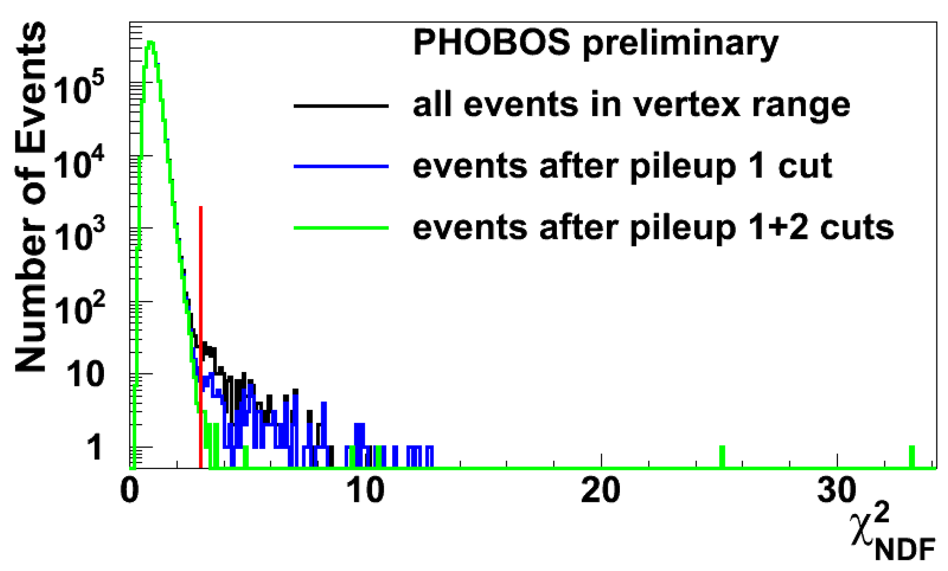
where:

- N_{bins} is the number of eta bins
- $N(\eta)$ is the number of hits in each η bin
- S is the fitted normalization scaling factor, accounting for varying total multiplicity

Events with χ^2_{NDF} > 3 are counted as unusual.

Analyzed sample of central events (about 1,900,000):

- **centrality 0-3%, restricted vertex range -10 to 10 cm**
- **runs or events with hardware problems removed**
- **two types of pileup removal cuts applied (see below)**

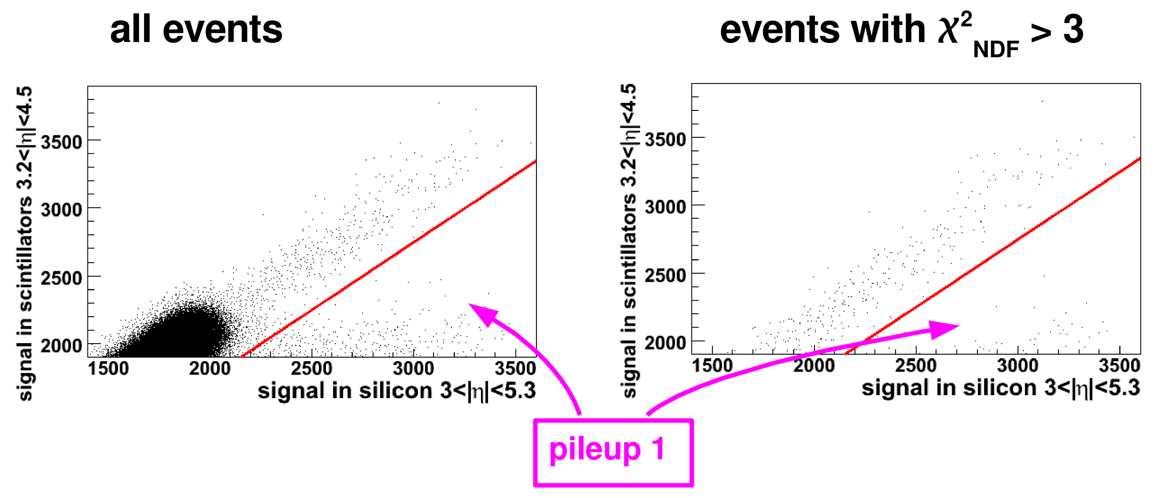


Final result:
The fraction of events with large deviations in dN/dη distribution is smaller than 10^{-5}

Identification and removal of pileup events (1)

two or more events from different bunch crossings:
- registered as one in silicon sensors due to long integration time
- registered separately in scintillator counters

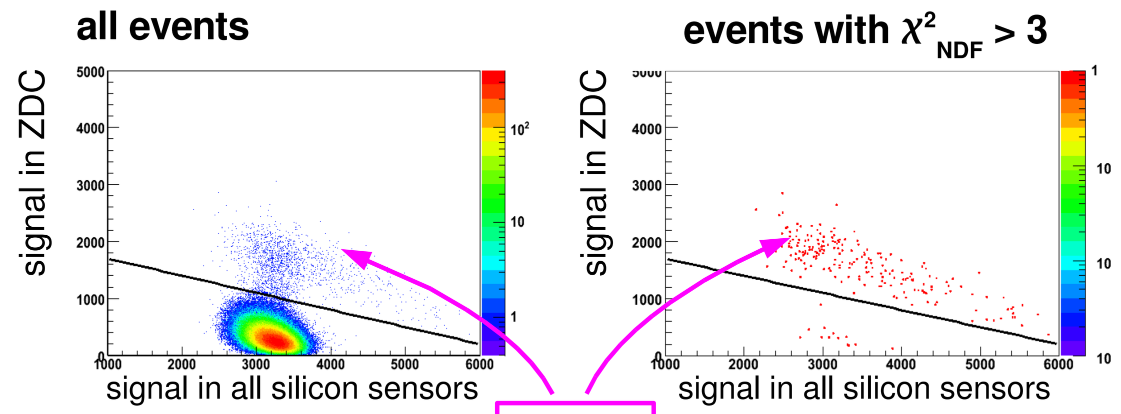
exclude: large signal in silicon detectors and smaller signal in scintillator detector (removes ~50% of events with χ^2_{NDF} > 3)



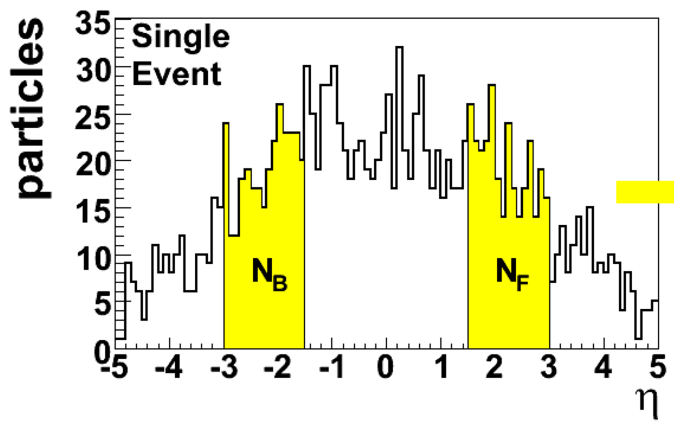
Identification and removal of pileup events (2)

two events in the same bunch crossing:
- central event without spectator neutrons (small ZDC signal)
- less central event with several spectators (larger signal in ZDC)

exclude: large signal both in all silicon sensors (|η|<5.3) and in ZDC (removes ~90% of events with χ^2_{NDF} > 3)



Forward-Backward Multiplicity Fluctuations and Cluster Models



Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

$$C = \frac{N_F - N_B}{\sqrt{N_F + N_B}}$$

For statistical fluctuations $\sigma^2(C) = 1$ independent of multiplicity

In Au+Au collisions at highest RHIC energy: $\sigma^2(C) > 1$
Phys. Rev. C74, 011901(R) (2006)
also: K.Woźniak, QM2004, P.Steinberg, QM2005

In the presence of short range correlations caused by production of particles in clusters with multiplicity (size) k, the value of $\sigma^2(C)$ increases:

$\sigma^2(C) \rightarrow k\ \sigma^2(C)$

(for a distribution of k we should use k_{eff} = <k> + σ^2(k)/<k>)

Possible explanation:
production of particles in clusters

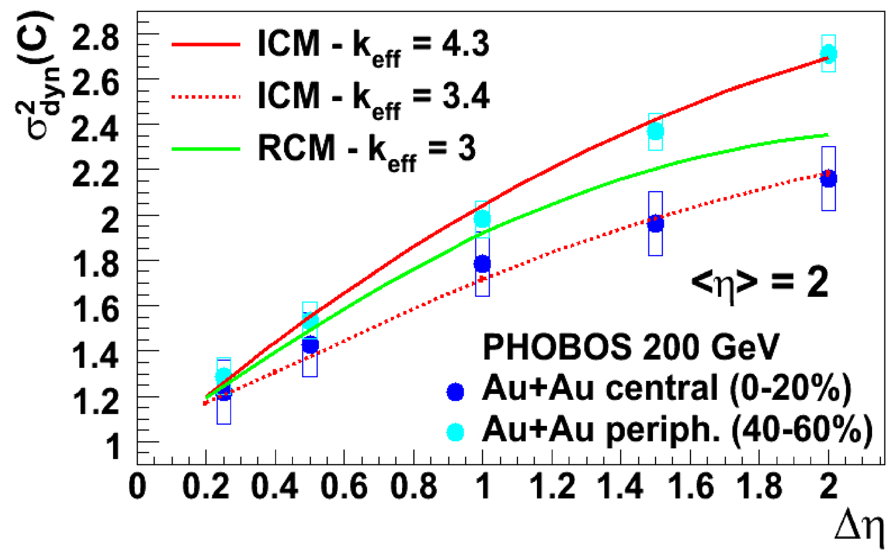
Two models of cluster production are studied:

Isotropic Cluster Model has one parameter, effective cluster size k_{eff}, which can be fitted to the data:

- k_{eff} = 3.4 for most central (0-20%) Au+Au collisions
- k_{eff} = 4.3 for peripheral (40-60%) Au+Au collisions

These values can be treated as the upper limits for k_{eff}

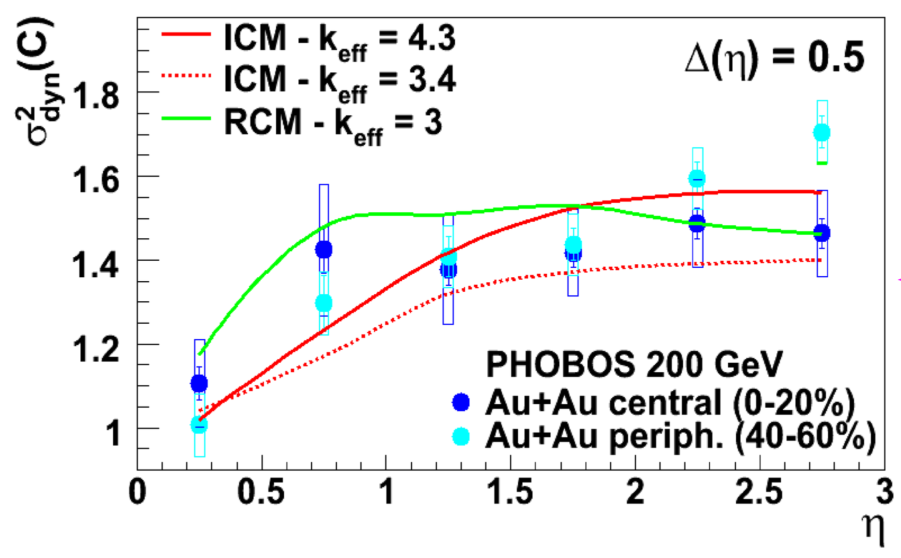
In **Resonance Cascade Model** for *Δ(1900)* we can change the number of charged final particles, but we show results only for k_{eff} = 3. For central collisions k_{eff} should be slightly smaller, for peripheral collisions – slightly larger



Using Forward-Backward fluctuations, the simultaneously determination of cluster width and size is difficult.

More direct measurement is possible in the studies of two-particle correlations.

Wei Li, "Two-particle angular correlations in pp, dA and AA collisions at PHOBOS", QM2006, Parallel Session 3.2



Assumptions for simple cluster models:

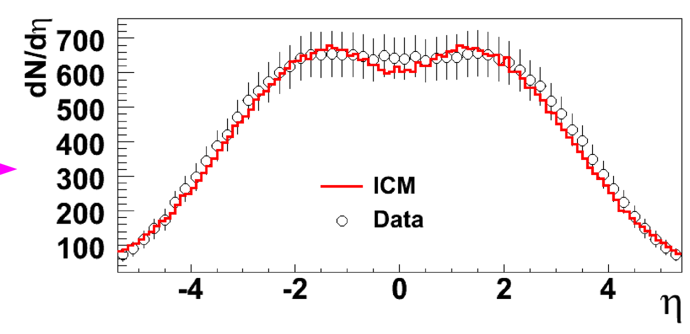
in Au+Au collisions intermediate objects (clusters) are produced and then decay into final particles
neutral particles (not measured in the experimental data compared) are neglected

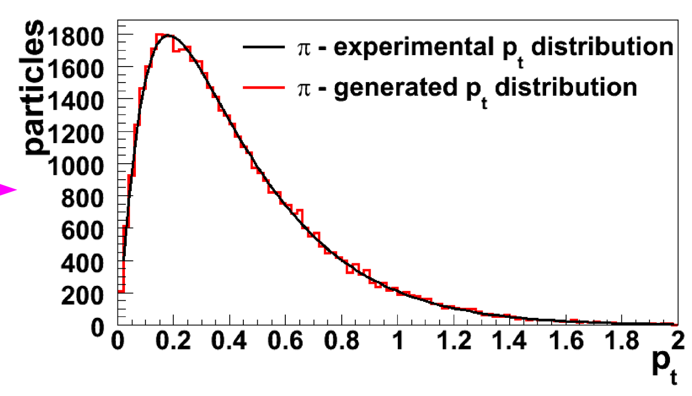
Requirements:

- the transverse momentum distribution of produced particles is reproduced
- the pseudorapidity distribution of produced particles is reproduced

Isotropic Cluster Model:

- clusters have negligibly small p_t
- clusters decay isotropically into pions
- p_t distribution of pions follows that from experiment
- p_z of initial cluster divided equally between decay products



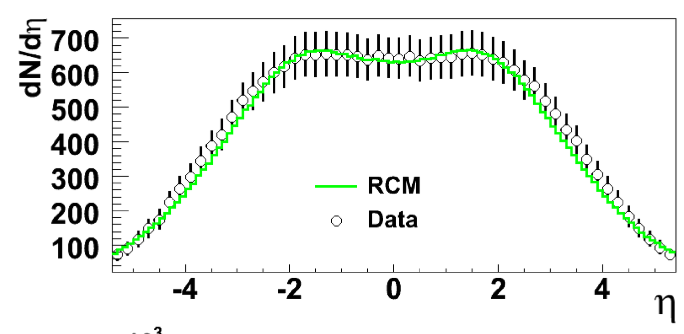


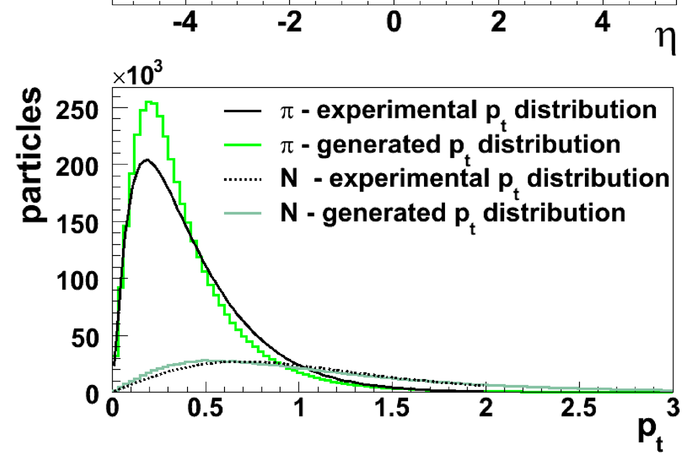
Resonances Cascade Model:

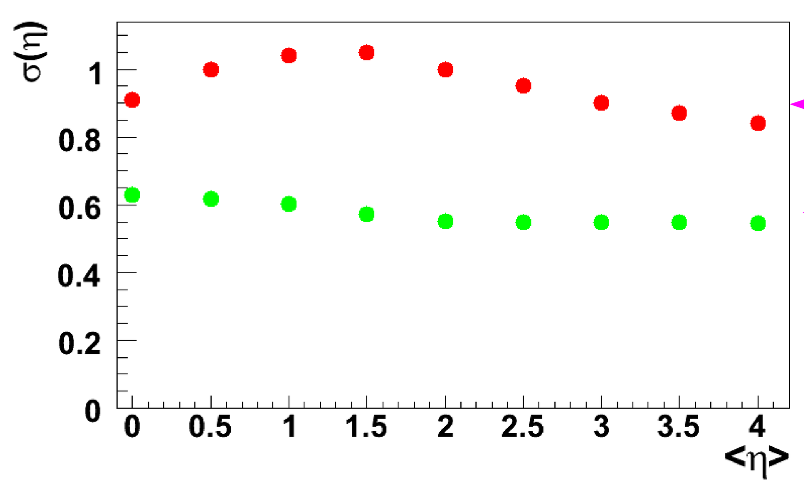
- resonances may be a suitable source of clusters if they decay in several steps
- in decays R(M_1) → R(M_2) + π, p_t of pion is determined by mass difference (⟨p_t⟩≈0.2 GeV/c for ΔM≈0.3 GeV)
- non zero initial p_t is necessary for reproduction of experimental p_t distribution

Δ(1900) with ⟨p_t⟩=2 GeV/c is used as an example:

Δ(1900) → Δ(1600) + π → Δ(1232) + 2π → N + 3π







Comparison of clusters width

Two cluster models present the extreme cases:

- in **Isotropic Cluster Model** the cluster width in pseudorapidity is the largest
- in **Resonance Cascade Model** for *Δ(1900)* the center of mass decay momenta of particles are small, initial p_t is large and thus cluster width is small

Studies of two-particle correlations give cluster width much smaller than 1, in favor of models with non-zero p_t of the clusters