Centrality Dependence of Charged Particle Multiplicity in Au+Au Collisions at $\sqrt{s_{nn}}$ = 130 GeV

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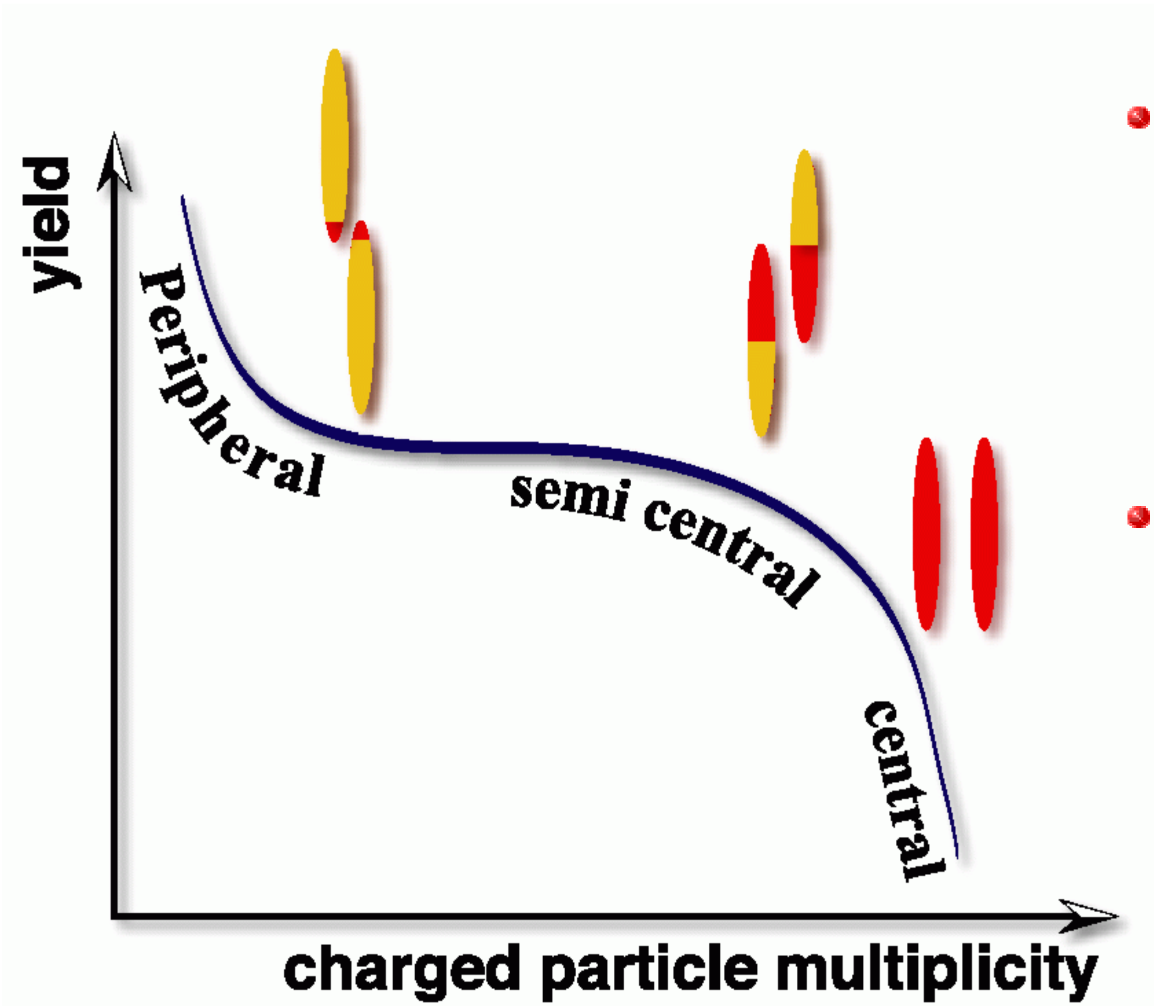
Geometrical Aspects of A+A collisions



- Clear separation between nucleons participating in the A+A reaction and 'spectator' nucleons
- Shape of multiplicity distribution of produced particles is governed by reaction geometry

Participating Nucleons

- Participants ('*Wounded Nucleons*'): All nucleons that suffer at least one inelastic nucleon−nucleon collision in a nucleus−nucleus collision

- *Soft* processes (small momentum transfer)
  - Big cross section
  - Particle production proportional to N_{part}

- *Hard* processes (high momentum transfer)
  - Small cross section
  - Particle production proportional to N_{coll}

Centrality Dependence of Particle Production

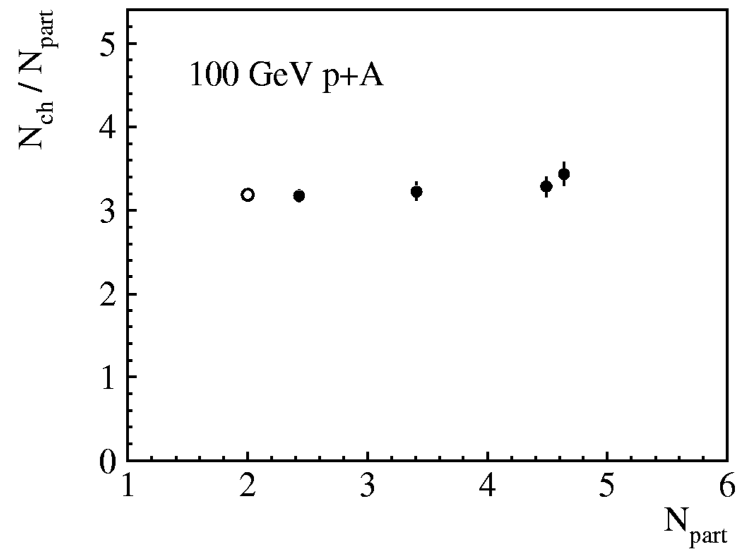
- Fundamental information about reaction mechanism: Scaling of particle production with N_{part} or N_{coll} ?
- Relative contribution of soft and hard processes to particle production

$$dN_{ch}/d\eta = A \times N_{part} + B \times N_{coll}$$

- Test of models of particle production
- Different behavior compared to $\sqrt{s_{nn}}$ = 17.2 GeV Pb+Pb collisions at CERN SPS ?

N_{ch}–Scaling at Lower Energies

- p+A at 100 GeV:
  (PRL 41, (1985) 94)
  Scaling with N_{part}
  $\rightarrow$ 'Wounded Nucleon Model'

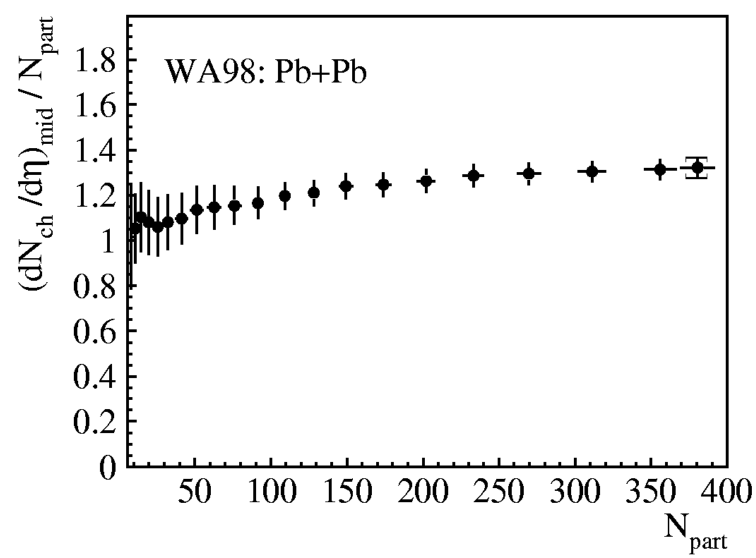


- Pb+Pb at $\sqrt{s_{nn}}$ = 17.2 GeV
  - WA98 (nucl−ex/0008004):

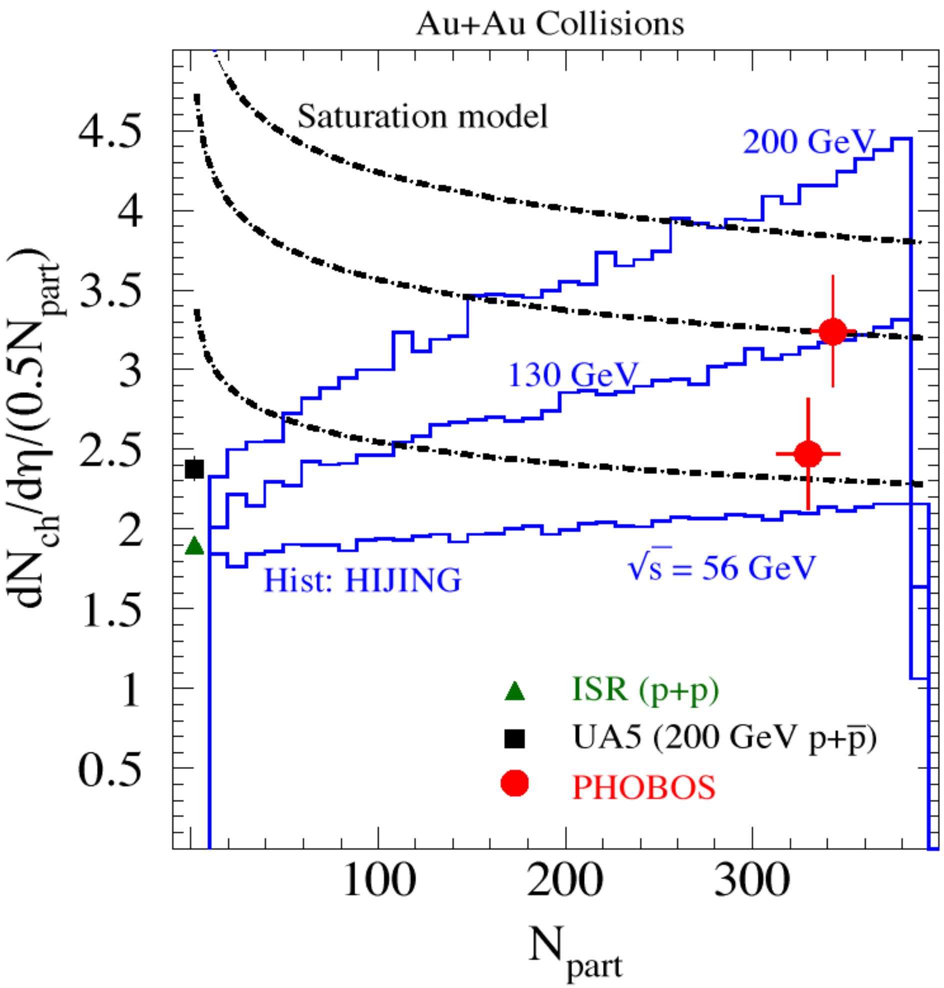
$$(dN_{ch}/d\eta)_{mid} \propto N_{part}^{1.07\pm0.04}$$

  - WA97 (EPJC 18, (2000) 1, 57):

$$(dN_{ch}/d\eta)_{mid} \propto N_{part}^{1.05\pm0.05}$$



Theoretical Predictions



Wang, Gyulassy, nucl−th/0008014

- Various models predict different trends for N_{ch}/N_{part} for increasing N_{part}
  - Event generator Hijing: increase of N_{ch}/N_{part}
  - Calculation of Eskola, Kajantie, Ruuskanen, and Tuominen '*EKRT−Saturation model*': decrease of N_{ch}/N_{part}

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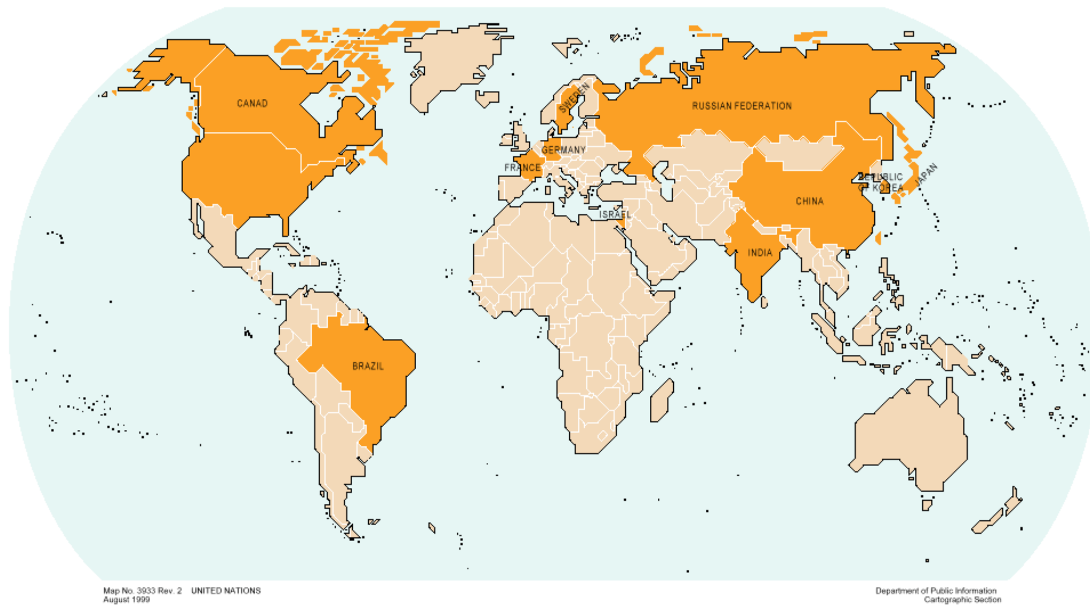

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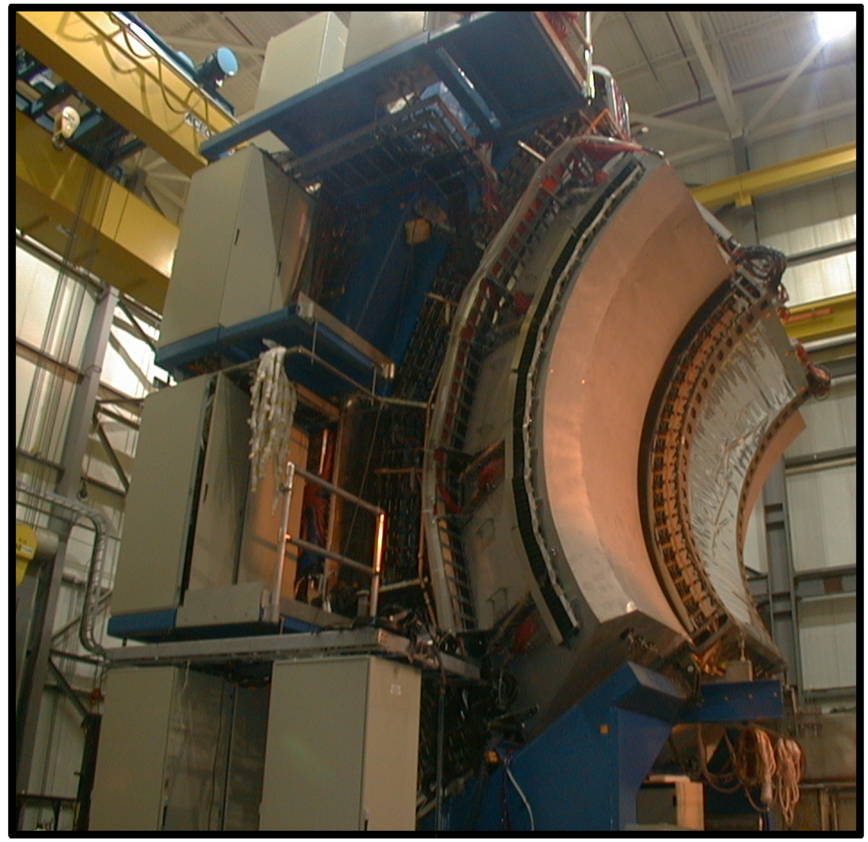
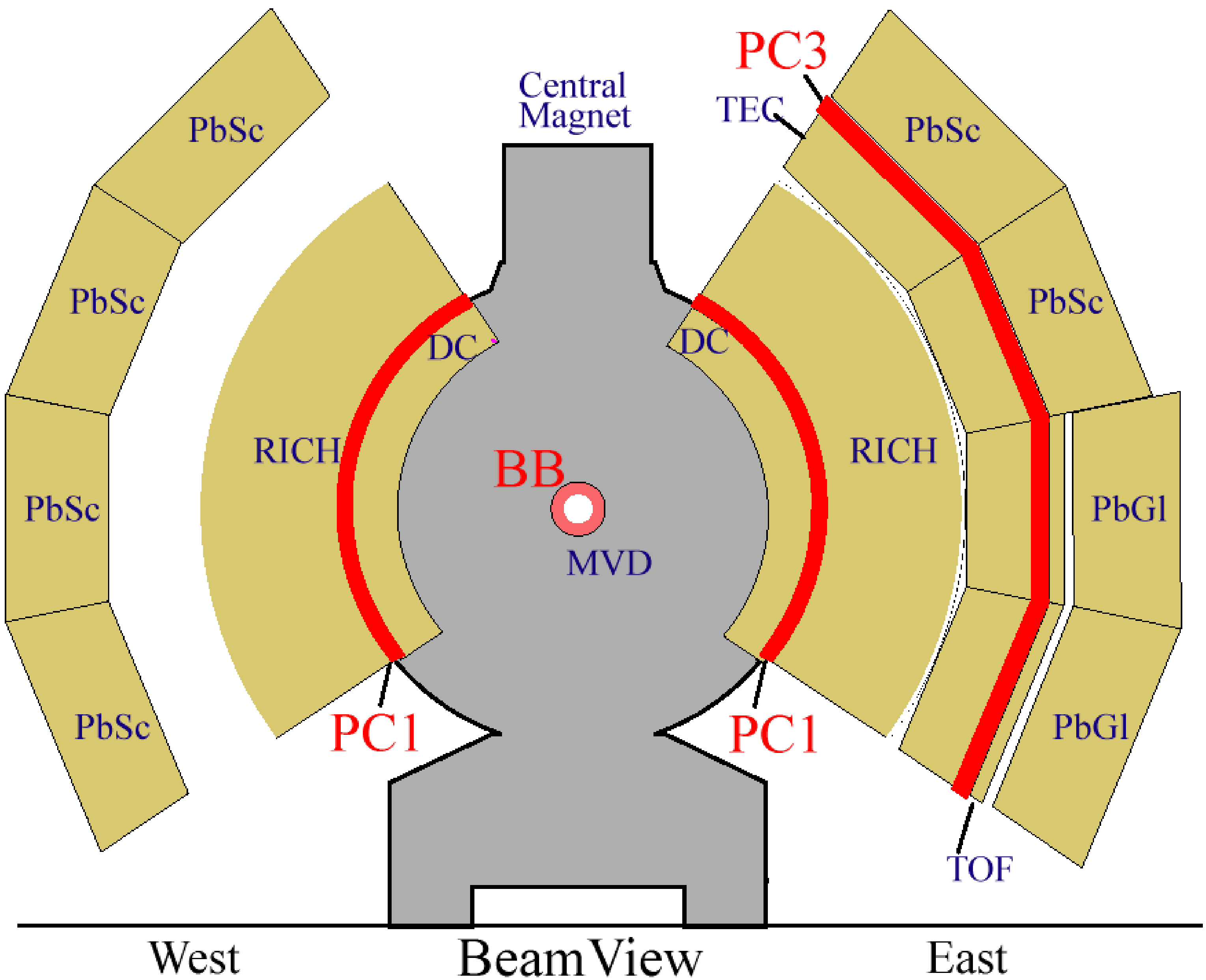
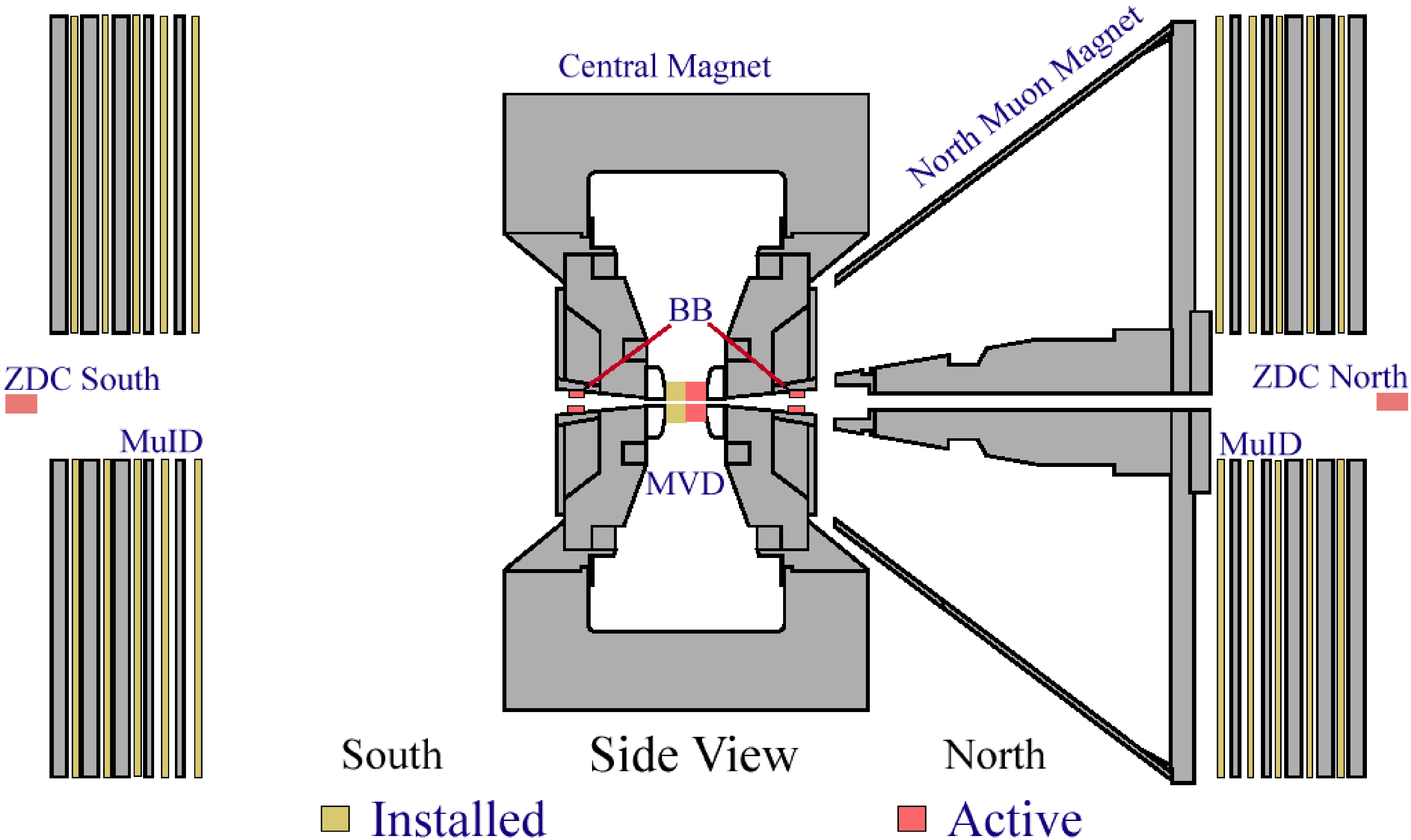


PHENIX–Setup: Beam View



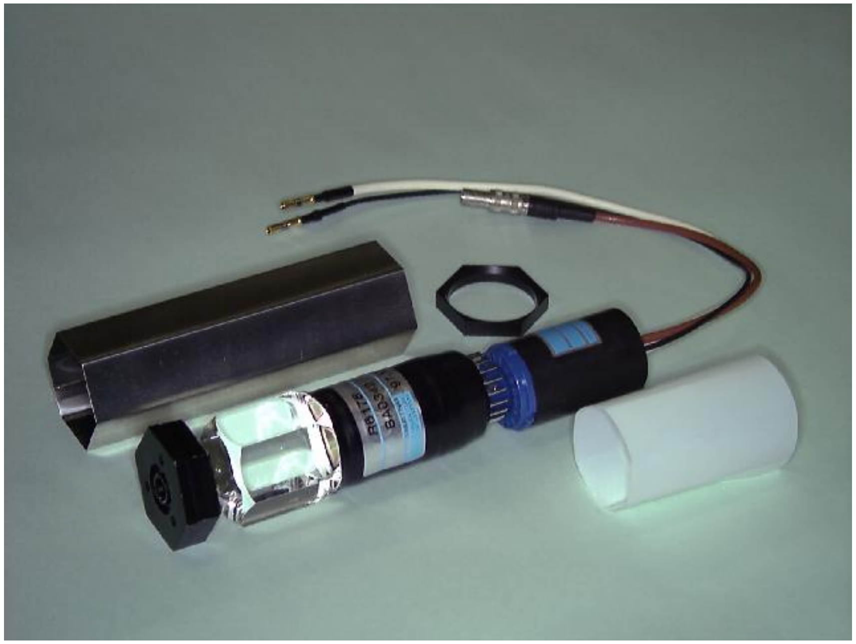
PHENIX–Setup: Side View



Detectors used in the Analysis

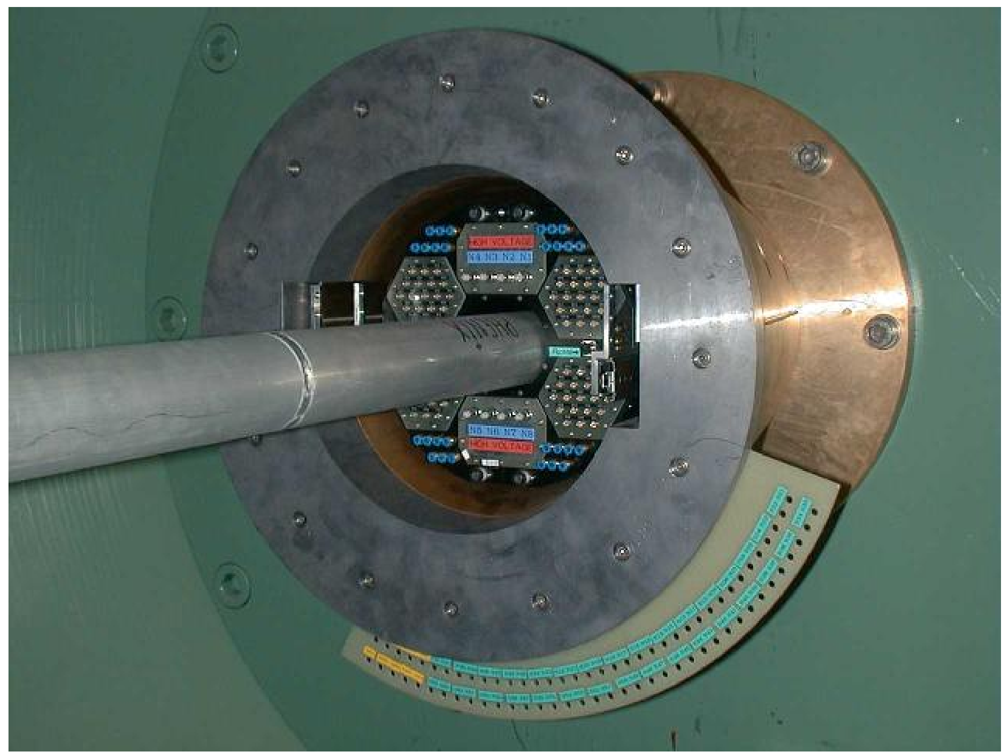
- Zero Degree Calorimeters
  - Measurement of (unbound) neutrons with $|\eta| > 6$
  - Located at ±18.25 m from interaction region
- Beam Beam Counters
  - Two arrays of 64 photomultipliers, each with quartz Cherenkov radiator
  - Full azimuthal coverage, η−acceptance: ± (3.0−3.9)
- Pad Chambers
  - Two layers (PC1, PC3) with radial distance of 2.49 m and 4.98 m to interaction region
  - η−acceptance: $|\eta| < 0.35$
  - Each layer consists of 8 wire chambers with cathode pad readout
  - Intrinsic efficiency for charged particles > 99%

Beam Beam Counter



BBC timing resolution: $\sigma_t \approx 40$ ps

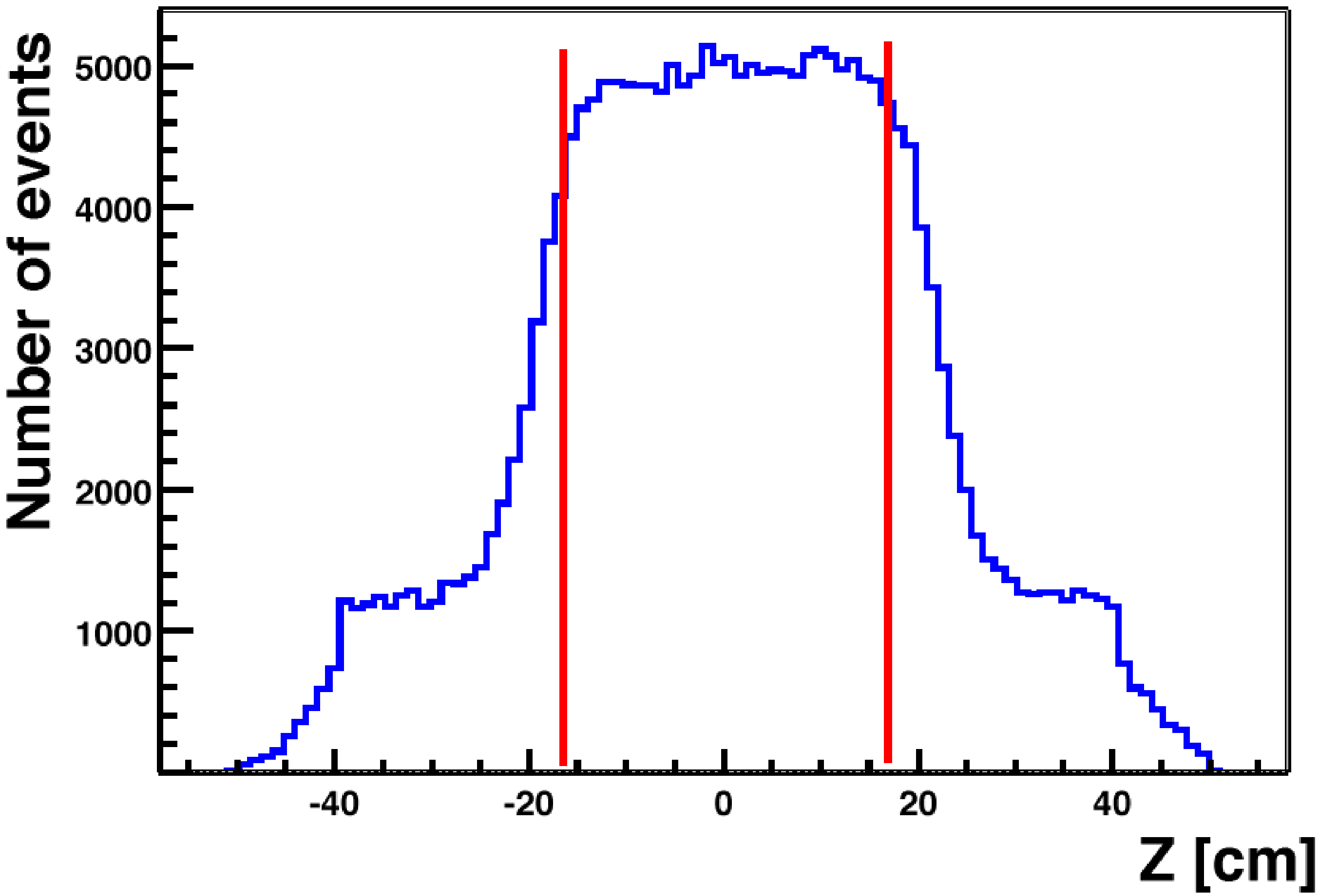
Vertex position resolution: $\sigma_z \approx 1$ cm



Trigger

- PHENIX−Trigger:
  - ZDC coincidence
    (E > 10 GeV in both ZDCs)
  - BBC coincidence
    (at least two photomultipliers fired in each BBC)
- ZDC−Trigger condition includes mutual Coulomb dissociation processes
- In this analysis:
  BBC trigger required
- BBC−trigger corresponds to (92 ± 2)% of the inelastic Au+Au cross section ($\sigma_{inel.} = 7.2$ b).
- 97.8% of the analyzed events also satisfy ZDC trigger condition

Vertex Distribution

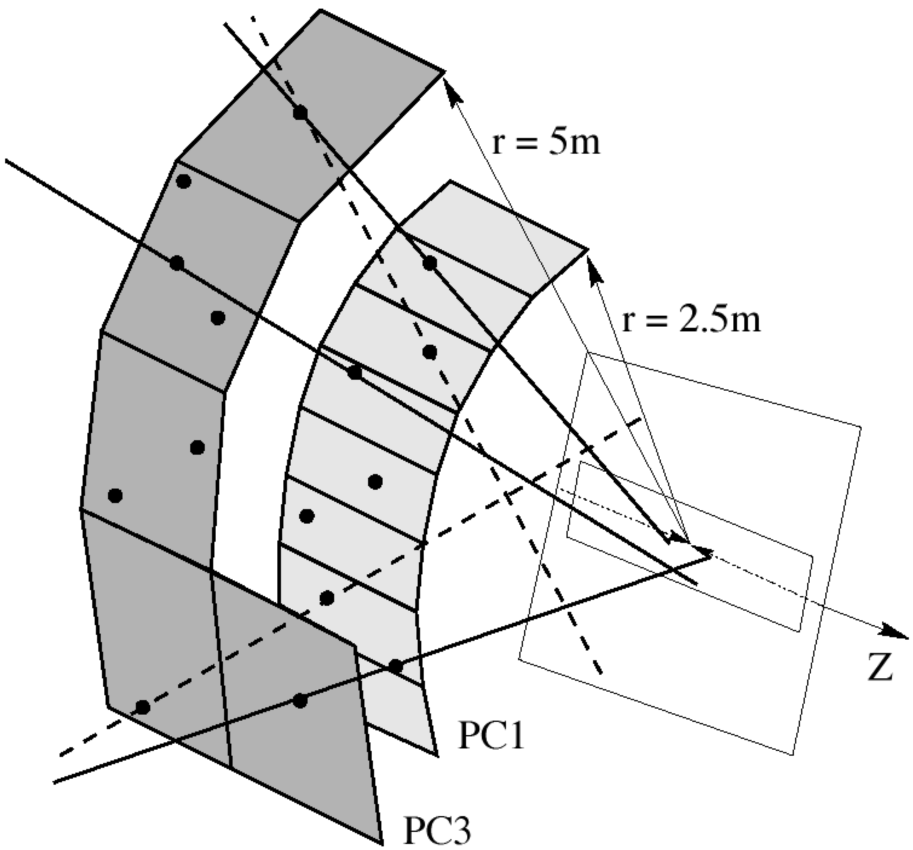


Events with |*z*|<17 cm accepted for further analysis

Charged Multiplicity Determination

- Strategy:
  count tracks in PC1/PC3 on statistical basis, no explicit track reconstruction

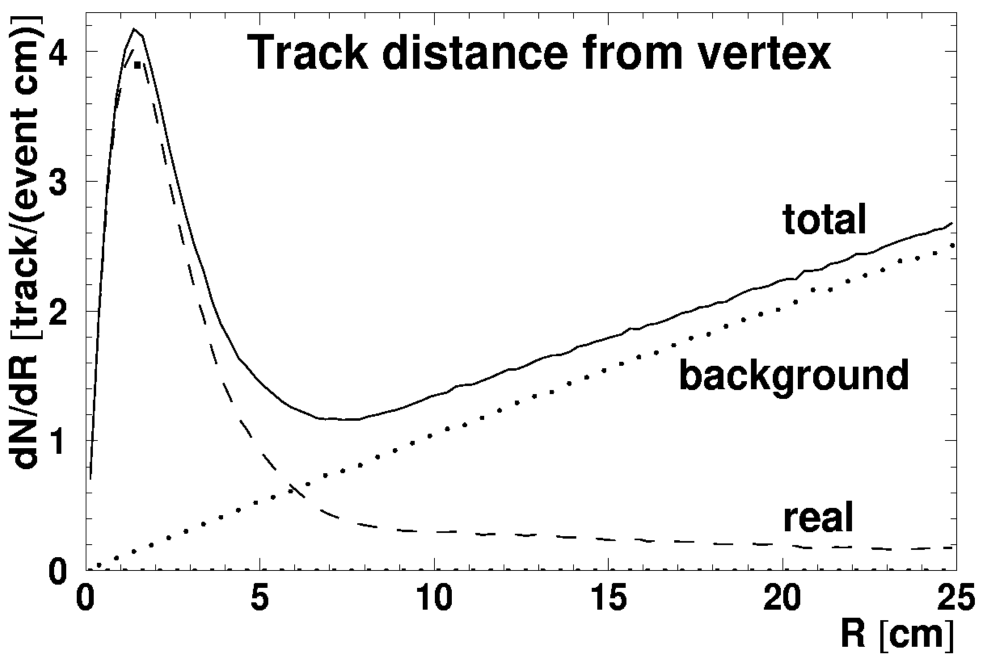
- Analysis steps:
  - Reconstruct vertex (with lines formed by all possible PC1/PC3 hit combinations)
  - Count lines that fall in a window around the reconstructed vertex
  - Determine combinatorial background lines by event mixing



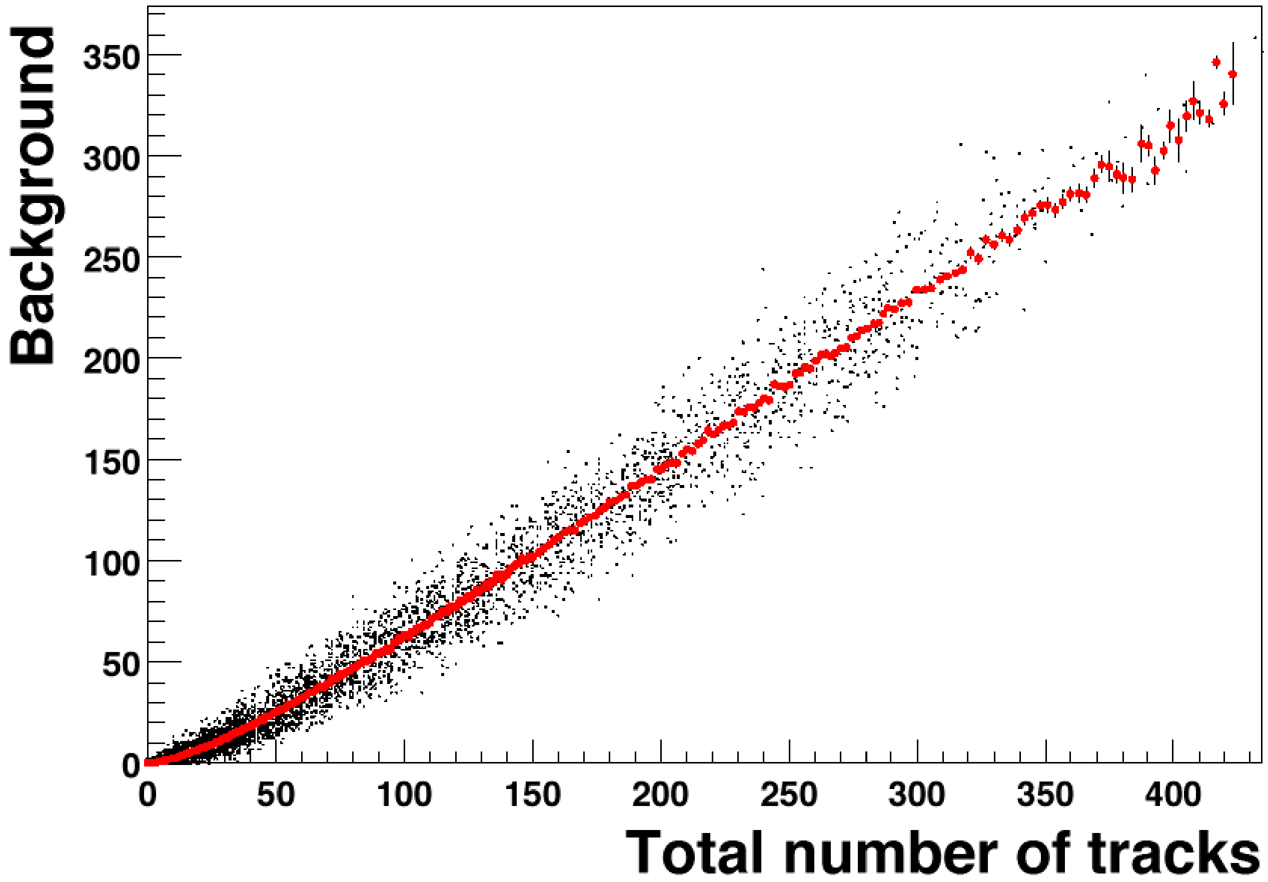
Measurement without magnetic field!

Vertex Distance Distribution

- Long Tail due to particle decays
- Tracks are counted up to *R* = 25 cm
- 96% of all tracks lie within the *R* = 25 cm window



Background Subtraction



Background subtracted on a statistical basis, not event−by−event

$dN_{ch}/d\eta$ in central Au+Au Collisions

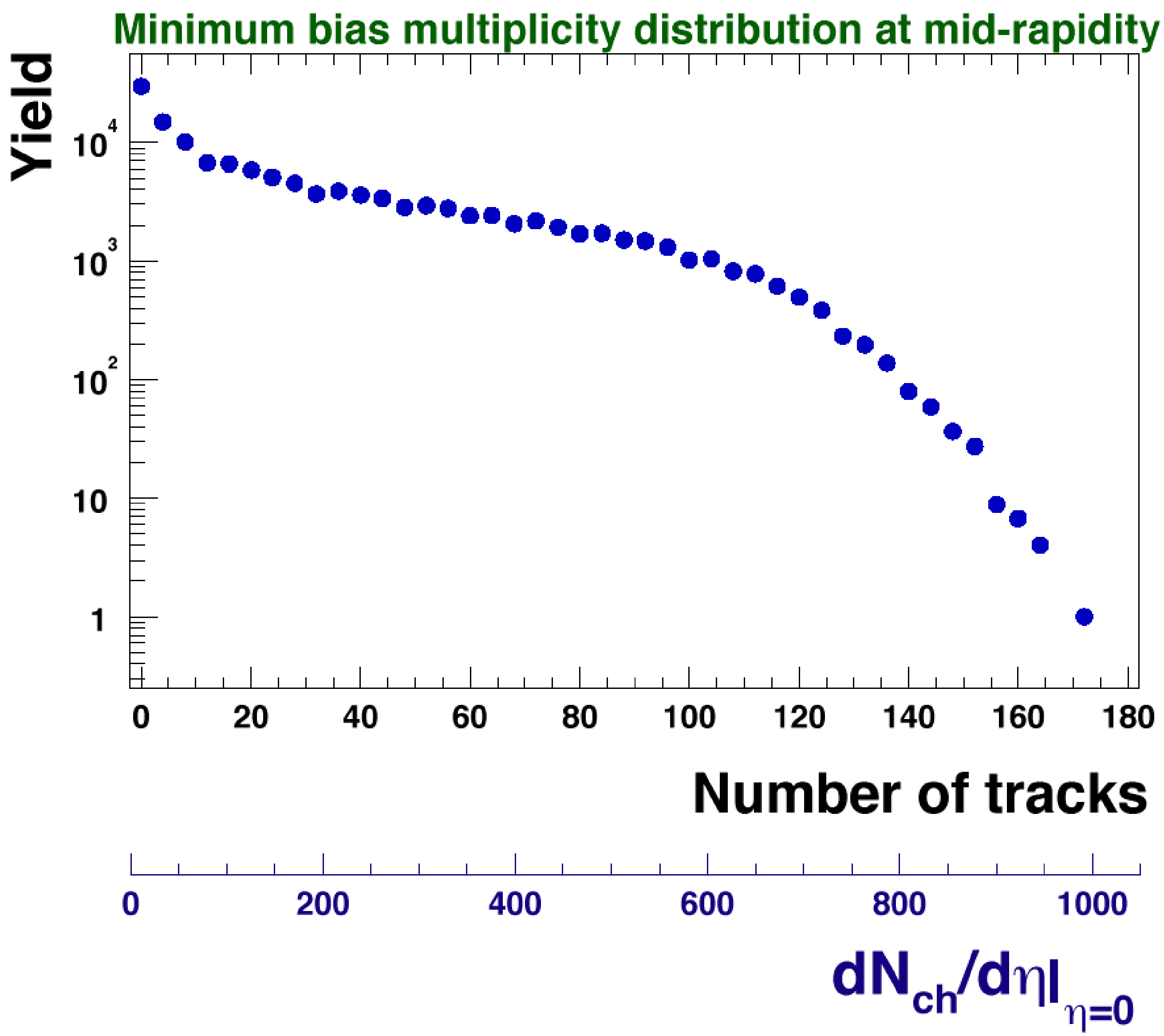
- Corrections for N_{ch} −measurement:
  A) Pad Chamber inactive regions: 15.3%
  B) Track losses due to finite double hit resolution: 13.3% in central collisions
  C) Charged Particles decaying in flight (mainly $\pi^{\pm}$)
  D) Decays of neutral particles (K_S^0, π^0)
- Corr. C) and D) rely on Hijing, net correction is 2.8%

- PHENIX result for 6% most central events:
  $dN_{ch}/d\eta = 609 \pm 1$(stat.)$\pm 37$(sys.)

- Slightly higher than PHOBOS result:
  $dN_{ch}/d\eta = 555 \pm 12$(stat.)$\pm 35$(sys.)

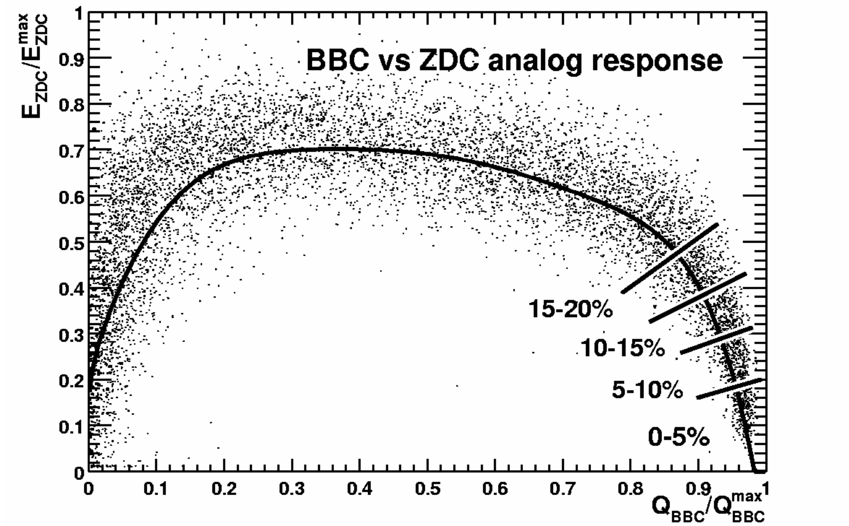
(PRL 85, 3100 (2000))

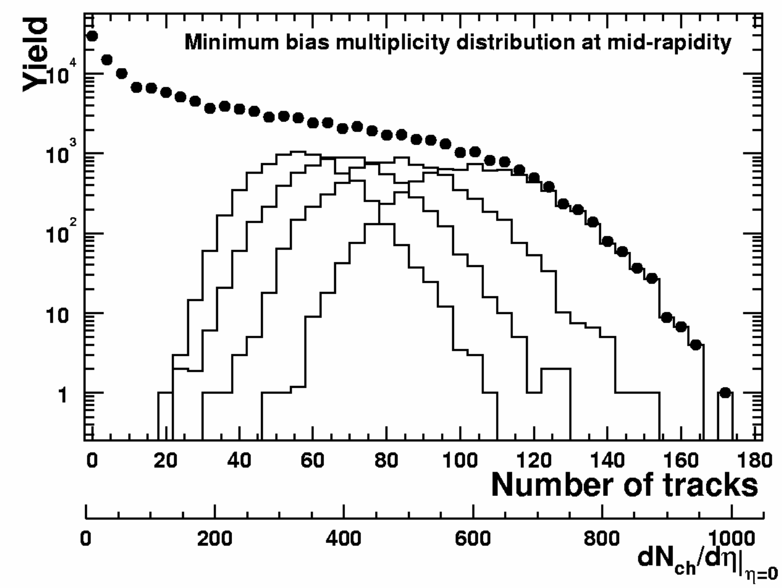
Multiplicity Distribution



Centrality Selection with ZDC and BBC

- Solid line indicates (Q_{BBC},E_{ZDC}) centroid positions for fixed Pad Chamber multiplicity
- Centrality classes were defined with cuts perpendicular to centroid−position curve





Calculation of N_{part} and N_{coll}

- Glauber model approach: geometrical picture of a A+A collision
  - Straight−line nucleon trajectories
  - NN−cross−section independent of the number of collisions the nucleons have undergone before

- Parameters
  - Nuclear density profile (Woods−Saxon distribution)

$$\rho(r) = \rho_0 \cdot \frac{1}{1 + \exp(\frac{r - R}{d})}$$

$$R = 1.19\, A^{1/3} - 1.61\, A^{-1/3} = 6.65\ fm$$
$$d = 0.54\ fm$$

  - Nucleon−nucleon inelastic cross−section:

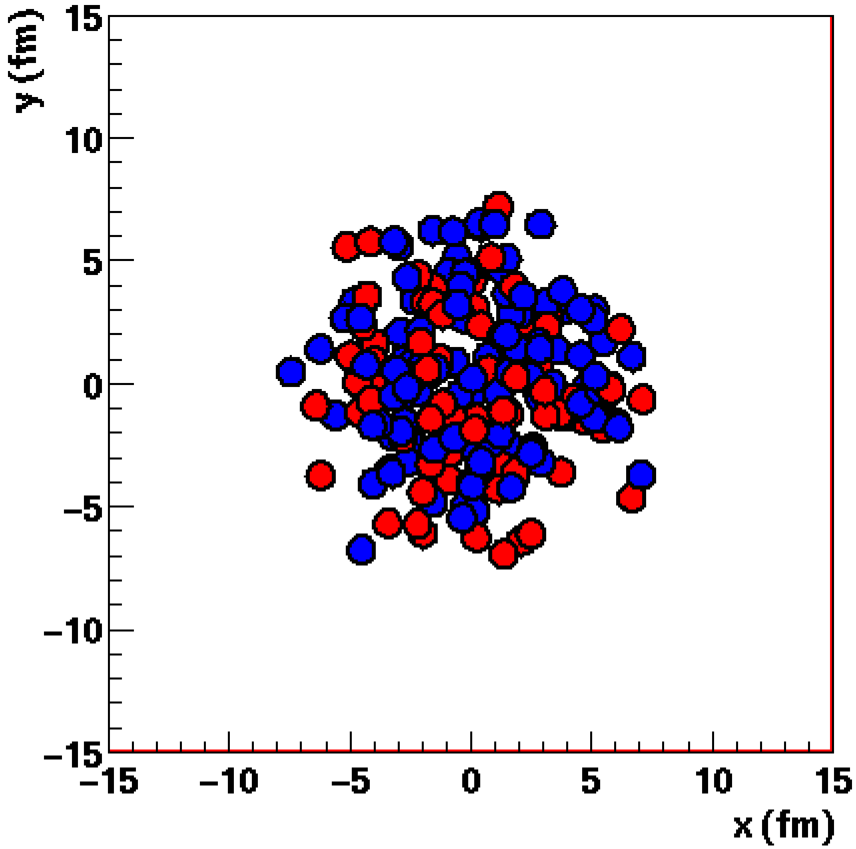
$$\sigma_{nn} = 40\, mb$$

Projectile's view of the Target Nucleus

- Monte−Carlo method was used for N_{part} and N_{coll} determination
  - Distribute nucleons randomly according to Woods−Saxon distribution
  - Collision between two nucleons takes place if

$$d < \sqrt{\sigma_{nn}/\pi} = 1.13\ fm$$

d: distance of the nucleons in the transverse plane

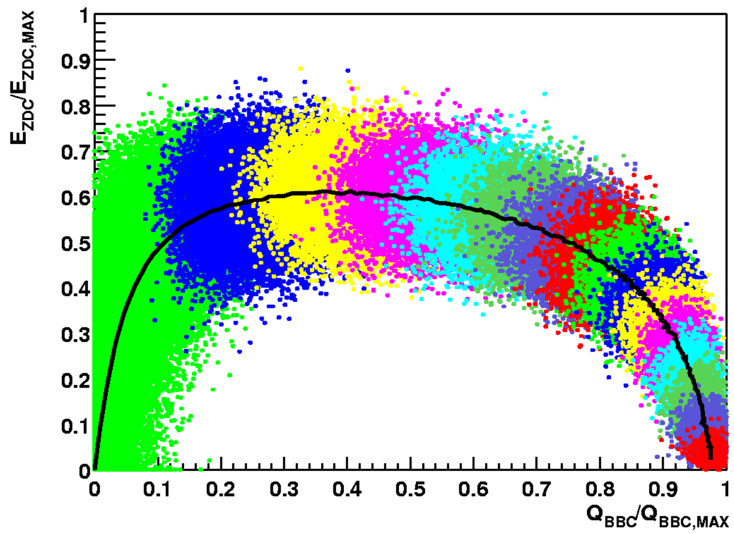


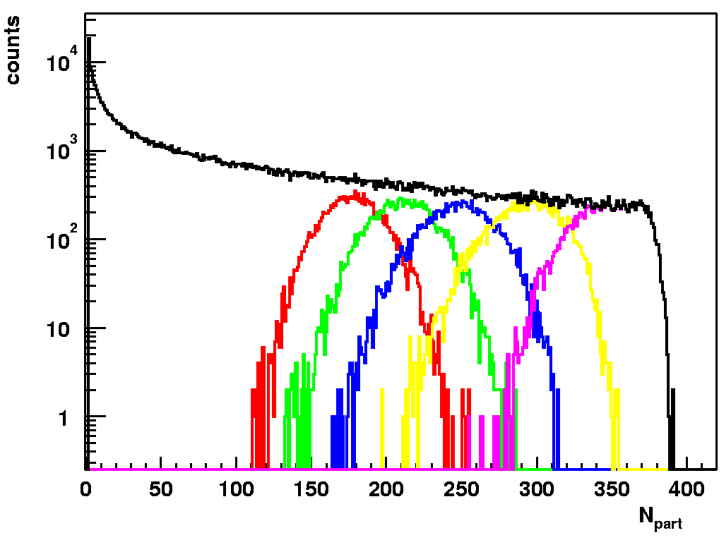
Extracting N_{part} and N_{coll}

- Define centrality classes as in analysis of real data
- Extract mean of N_{part} and N_{coll} distribution for each class
- Estimate errors by varying model assumptions:

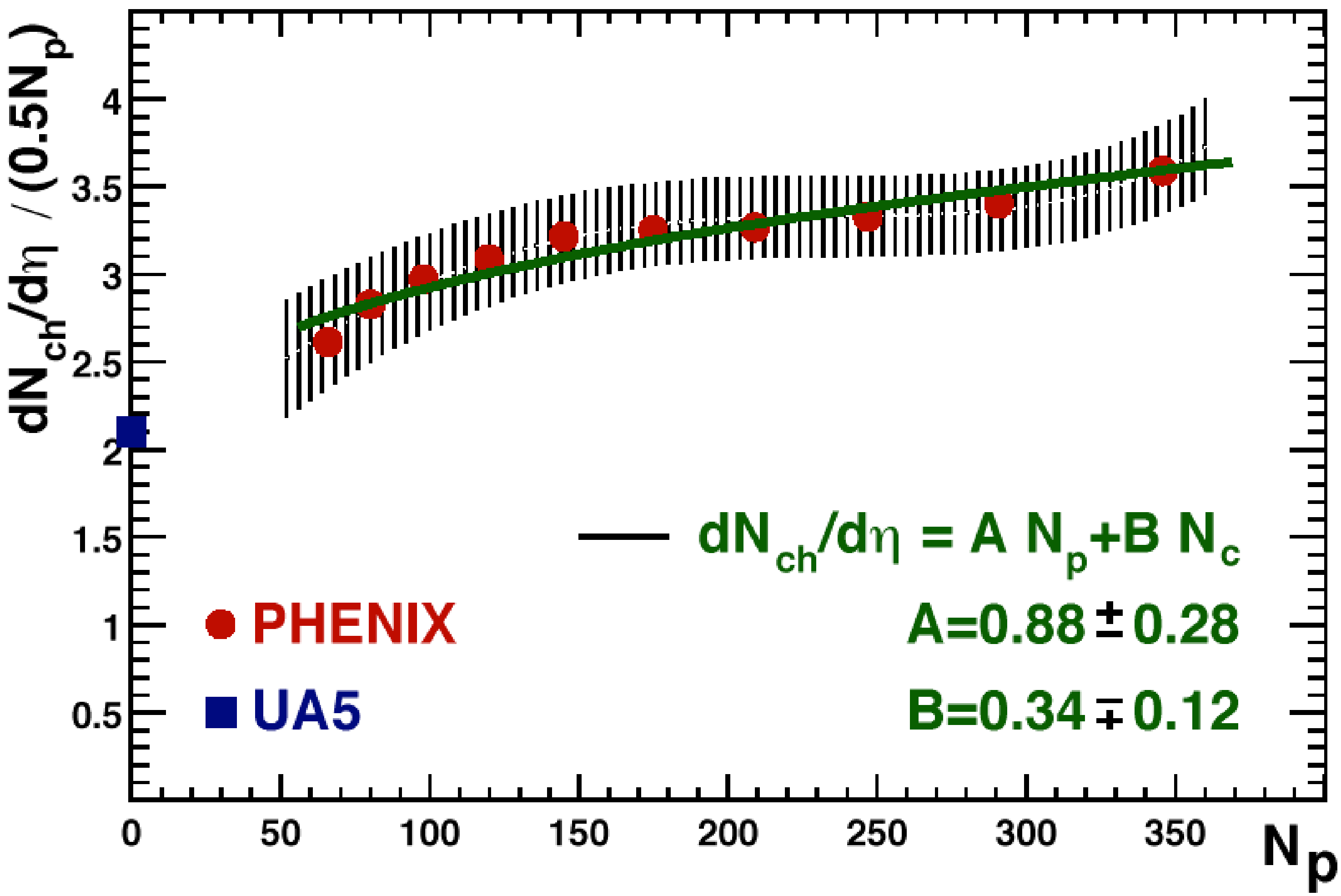
$$rel.error(N_{part})[\%] = 2 + 300/N_{part}$$

$$rel.error(N_{coll})[\%] = 15 + 400/N_{coll}$$

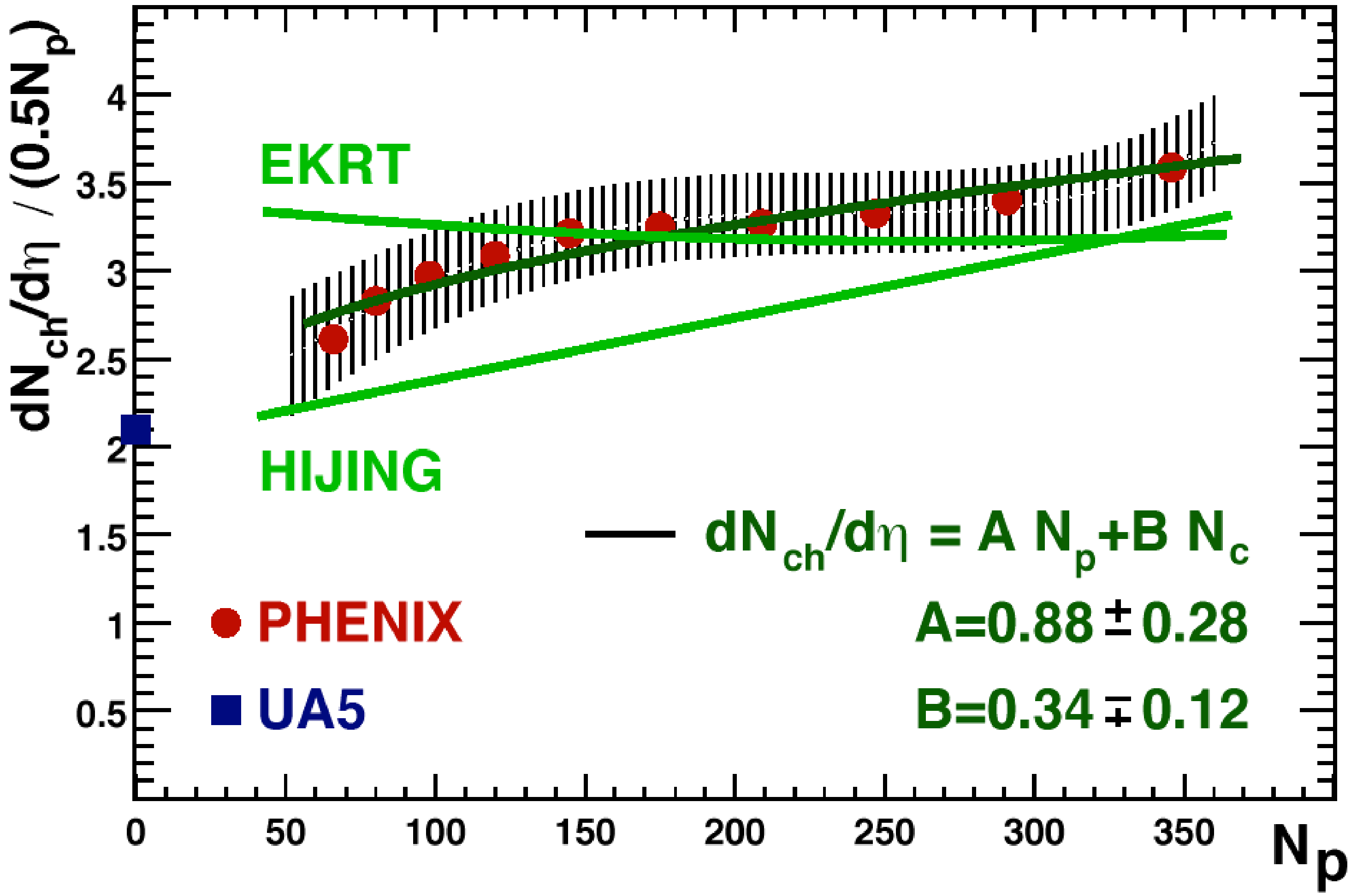




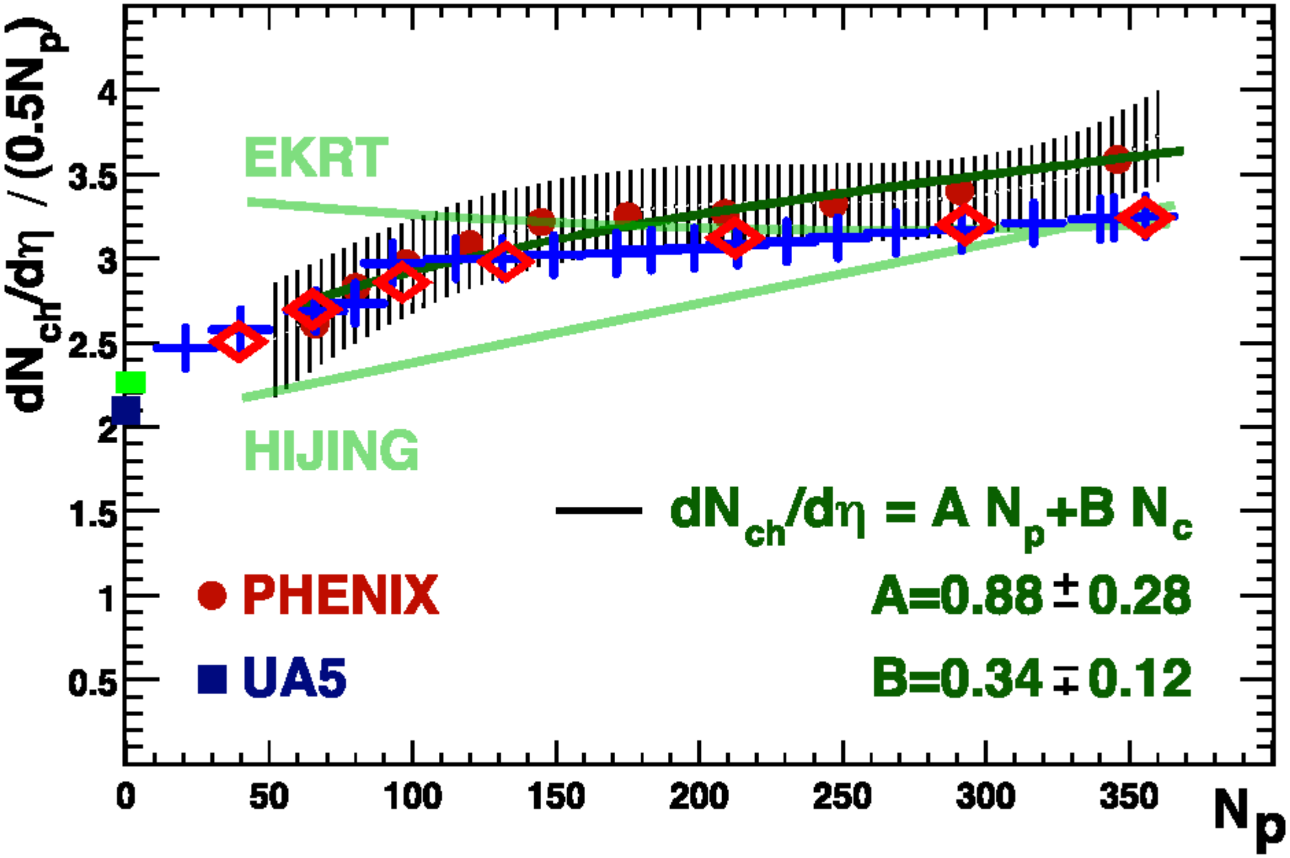
Centrality Dependence of dN_{ch}/dη



Model Comparison I



Model Comparison II



Kharzeev's and Nardi's calculations (nucl−th/0012025, Dec. 8)

+ : Glauber Model

◊ : high density QCD

Comparison to CERN SPS Results

- Au+Au at $\sqrt{s_{nn}}$ = 130 GeV:
  - N_{part}^{α} −parameterization

    $$(dN_{ch}/d\eta)_{mid} \propto N_{part}^{1.16 \pm 0.04}$$

  - Param. with N_{part} and N_{coll}

    $$dN_{ch}/d\eta = A \times N_{part} + B \times N_{coll}$$

    $$B/A = 0.38 \pm 0.19$$

- Pb+Pb at $\sqrt{s_{nn}}$ = 17.2 GeV
  - N_{part}^{α} −parameterization

    WA98: $(dN_{ch}/d\eta)_{mid} \propto N_{part}^{1.07 \pm 0.04}$

    WA97: $(dN_{ch}/d\eta)_{mid} \propto N_{part}^{1.05 \pm 0.05}$

  - Param. with N_{part} and N_{coll}

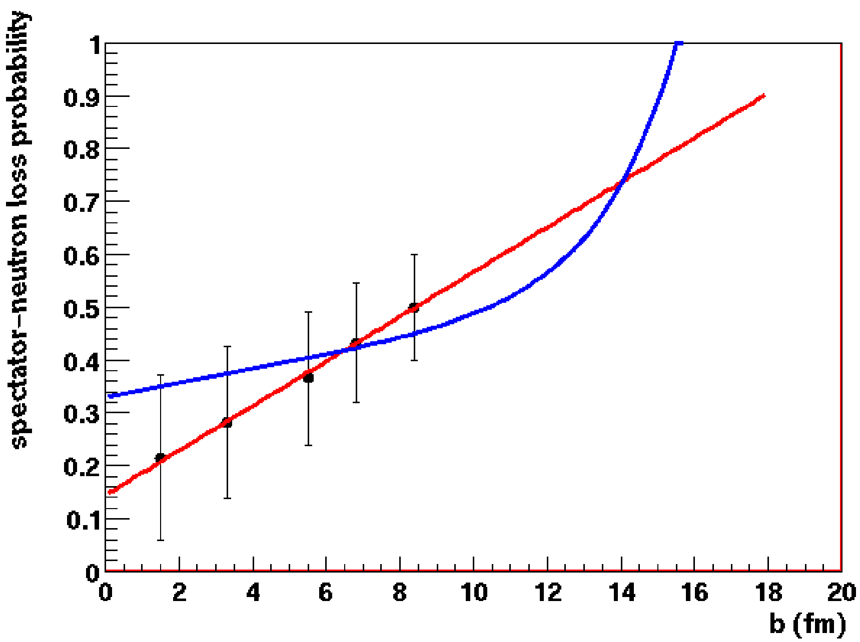
    WA98: $B/A = 0.20 \pm 0.10$

Summary

- Centrality dependence of particle production has been measured in $\sqrt{s_{nn}}$ = 130 GeV Au+Au collisions
- Yield/participant increases with centrality, in contrast to EKRT saturation model predictions
- Indication of stronger increase of yield/participant than observed at CERN SPS for Pb+Pb

Simple ZDC and BBC Simulation

- ZDC
  - coalescence of spectator neutrons has to be simulated: use NA49 data (Pb+Pb)

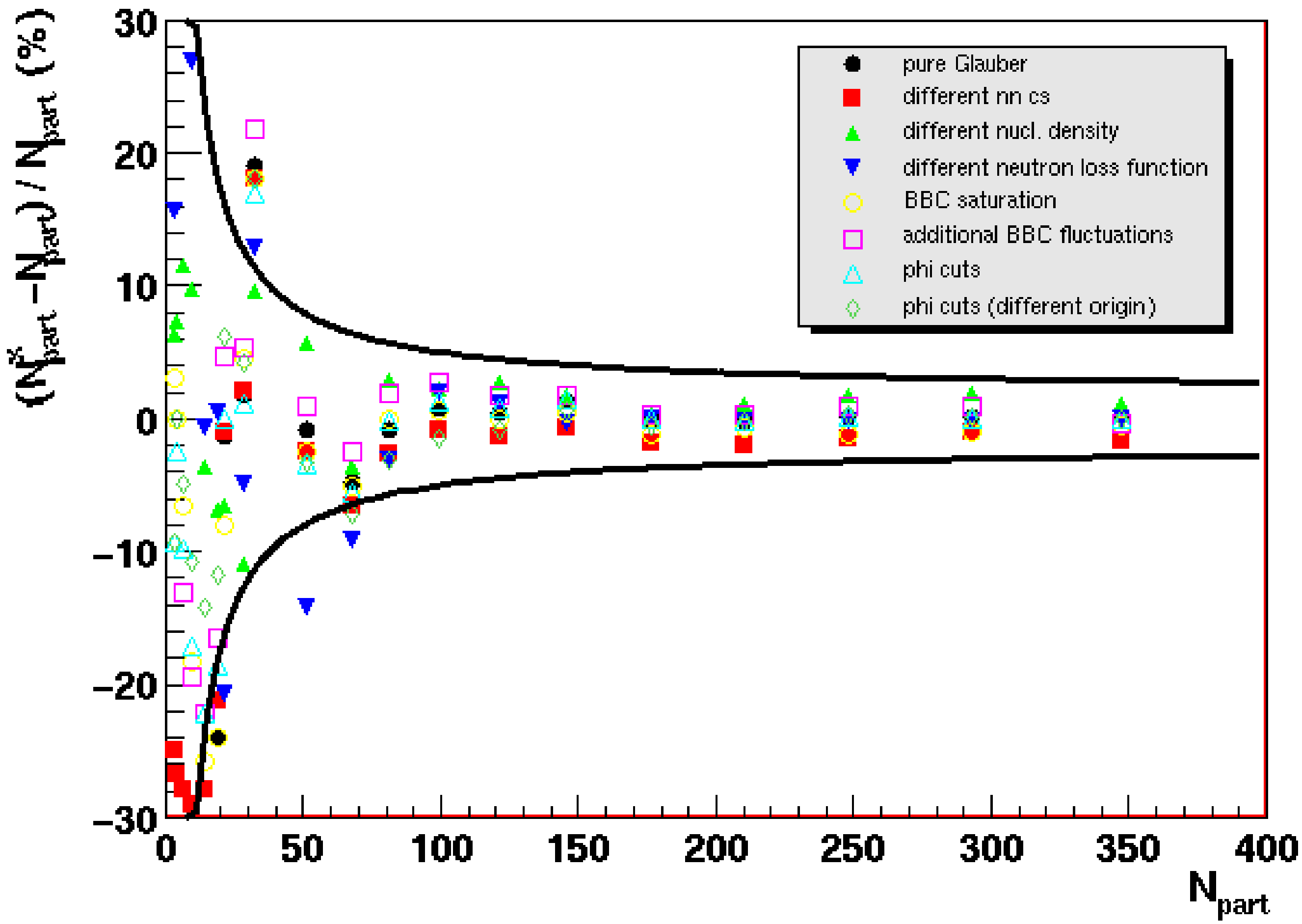


  - energy smearing

$$\sigma_E / E = 218\% / \sqrt{E/GeV}$$

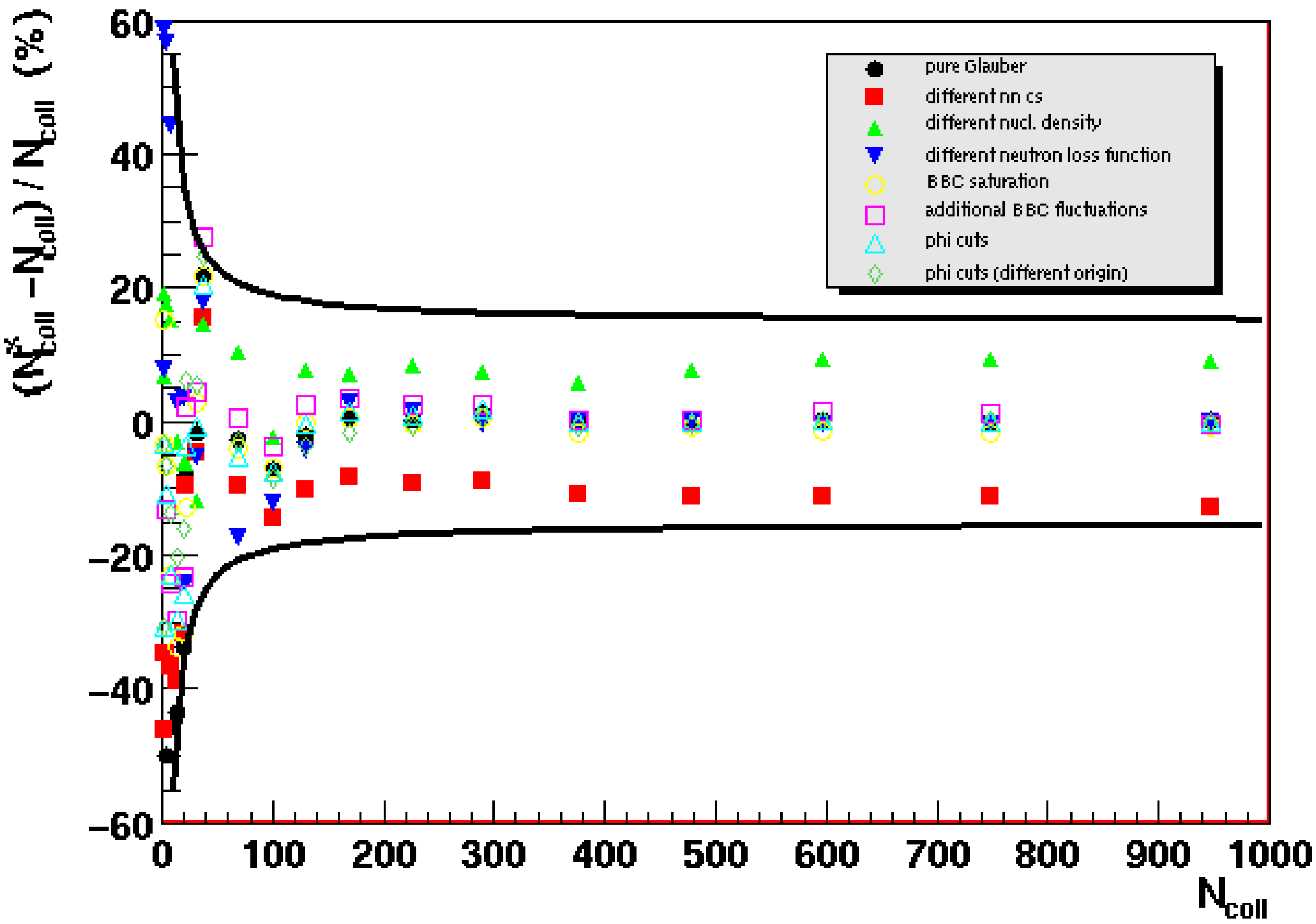
- BBC
  - assume relation between N_{part} and N_{ch}^{BBC} (default: linear scaling)
  - fluctuations in N_{ch}^{BBC} for given N_{part} by sampling Poisson−distribution for each participant
  - Sample Landau−distribution to simulate BBC response

Error estimation: N_{part}



$$rel.error(N_{part})[\%] = 2 + 300 / N_{part}$$

Error estimation: N_{coll}



$$rel.\,error\,(N_{coll})[\%] = 15 + 400 / N_{coll}$$