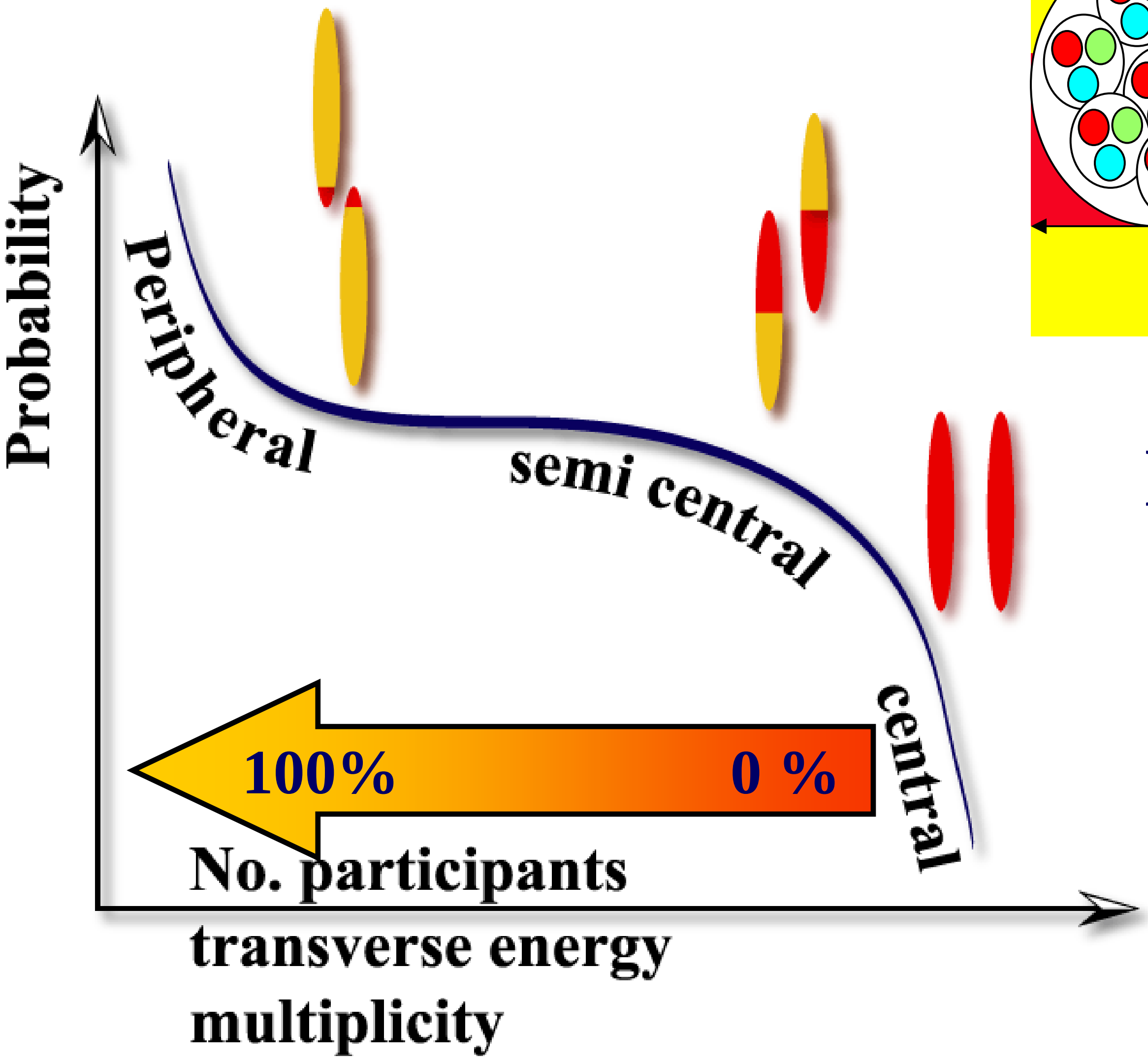
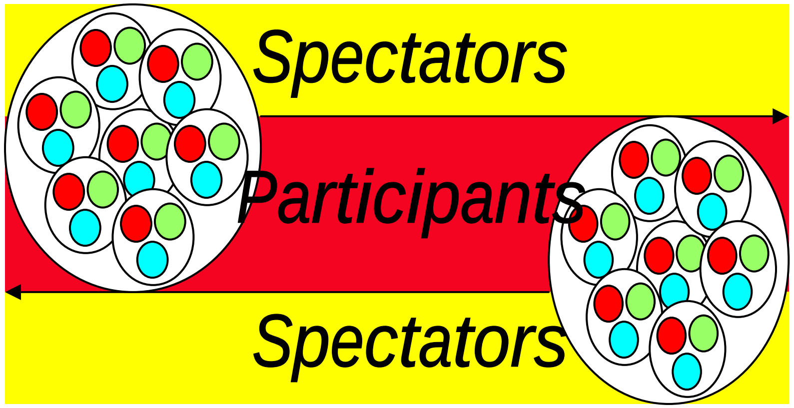
Lecture 07: particle production in AA collisions

- **Last lecture: soft particle production in pp collisions**
  - **Linear QCD potential at large distances and classical string theory reproduce the main features of the data:**
    - **Hadron masses and spins are related through the string constant**
    - **Rapidity distribution**
    - **M_T scaling for particle spectra for low m_T**
- **Today: AA collisions**
  - **Multiplicity: number of particles produced per event (i.e. for one pp or AA collision)**
  - **Differential multiplicity: $dN/d\eta$ or dN/dy : # of particles produced per event in a certain kinematic region**
  - **Centrality (see next page)**

  - **Rapidity, energy, system size dependence of particle multiplicity**

Some definitions of terms



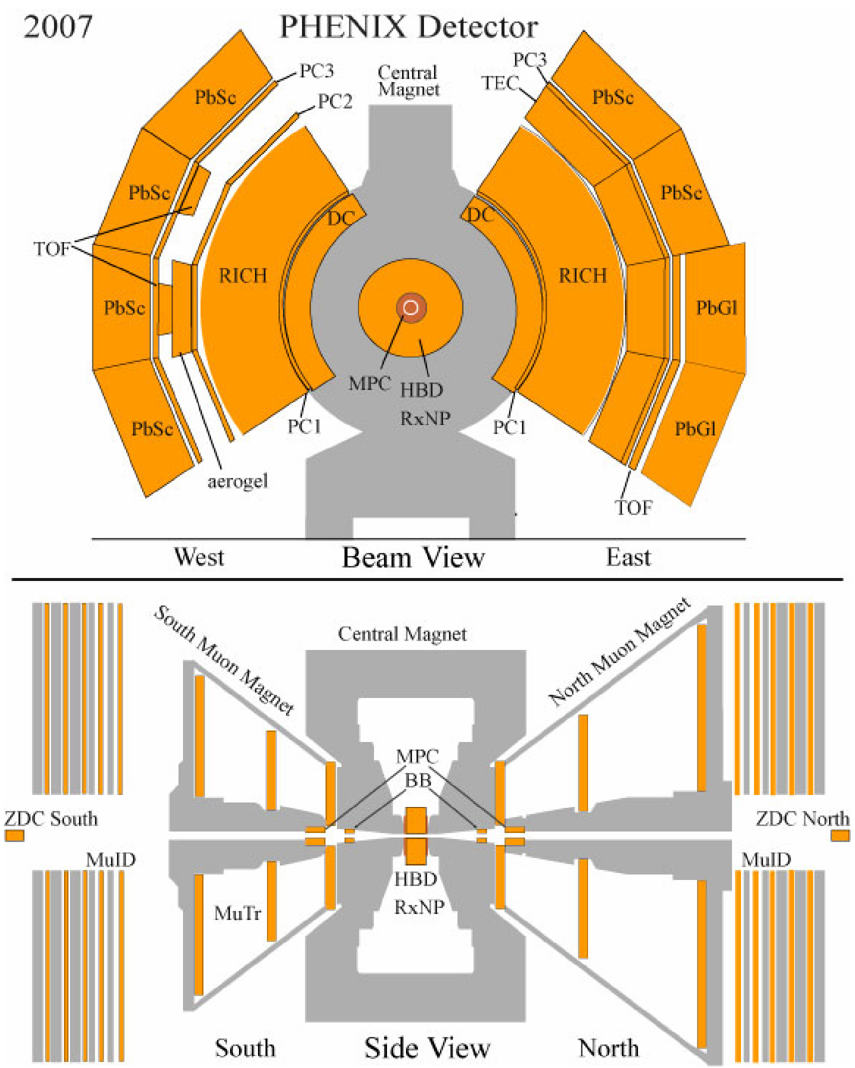


Nuclei are extended objects

- **Impact parameter**
- **Number of participants**
- **Centrality**

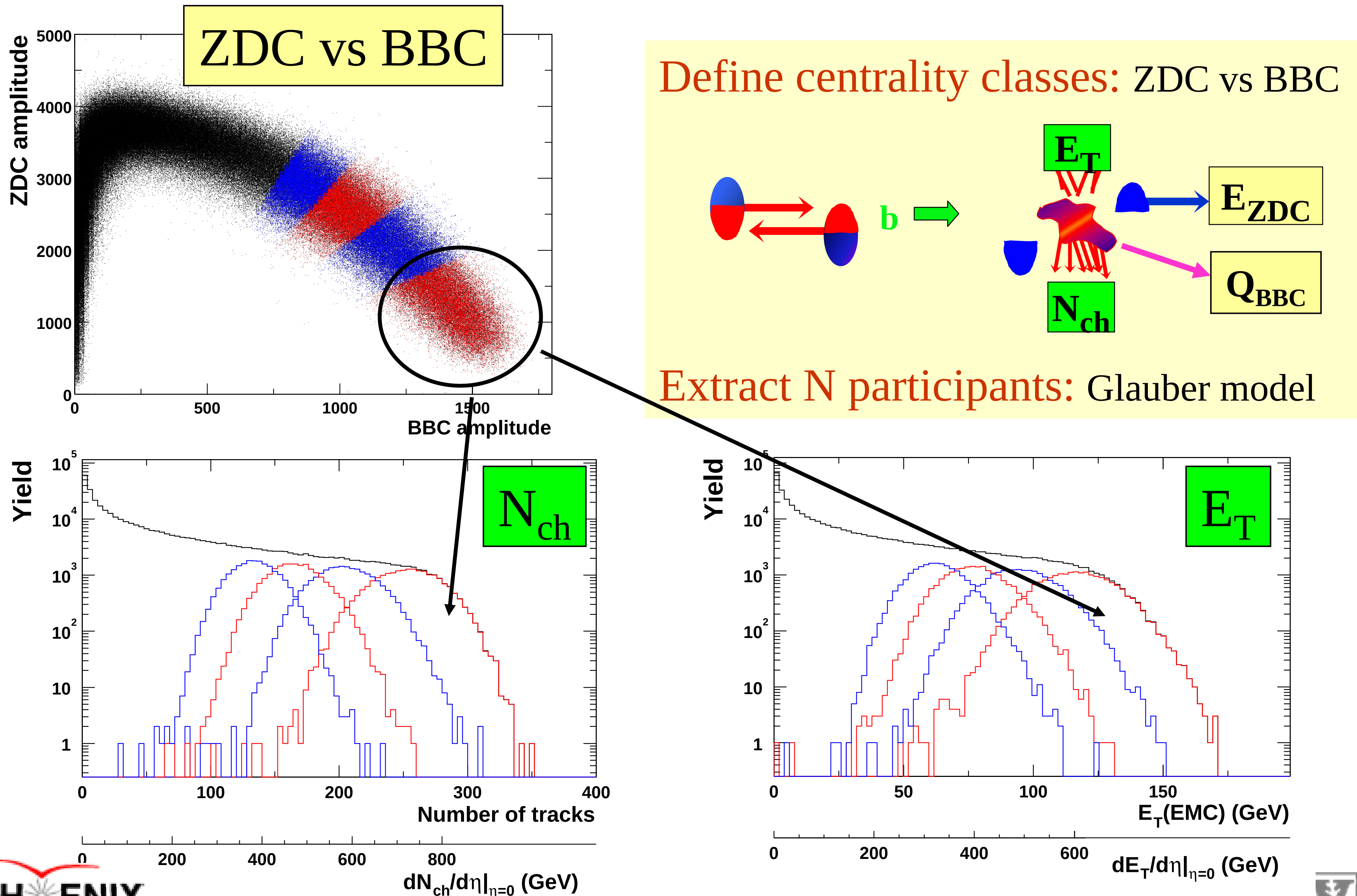
(% from total inelastic cross-section)

How to measure centrality (with PHENIX)



- **Beam-Beam Counters:**
- $3.0<|\eta|<3.9$, $\Delta\varphi = 2\pi$
- **Zero-Degree Calorimeters:**
- $|\eta| > 6$, $|Z|=18.25$ m

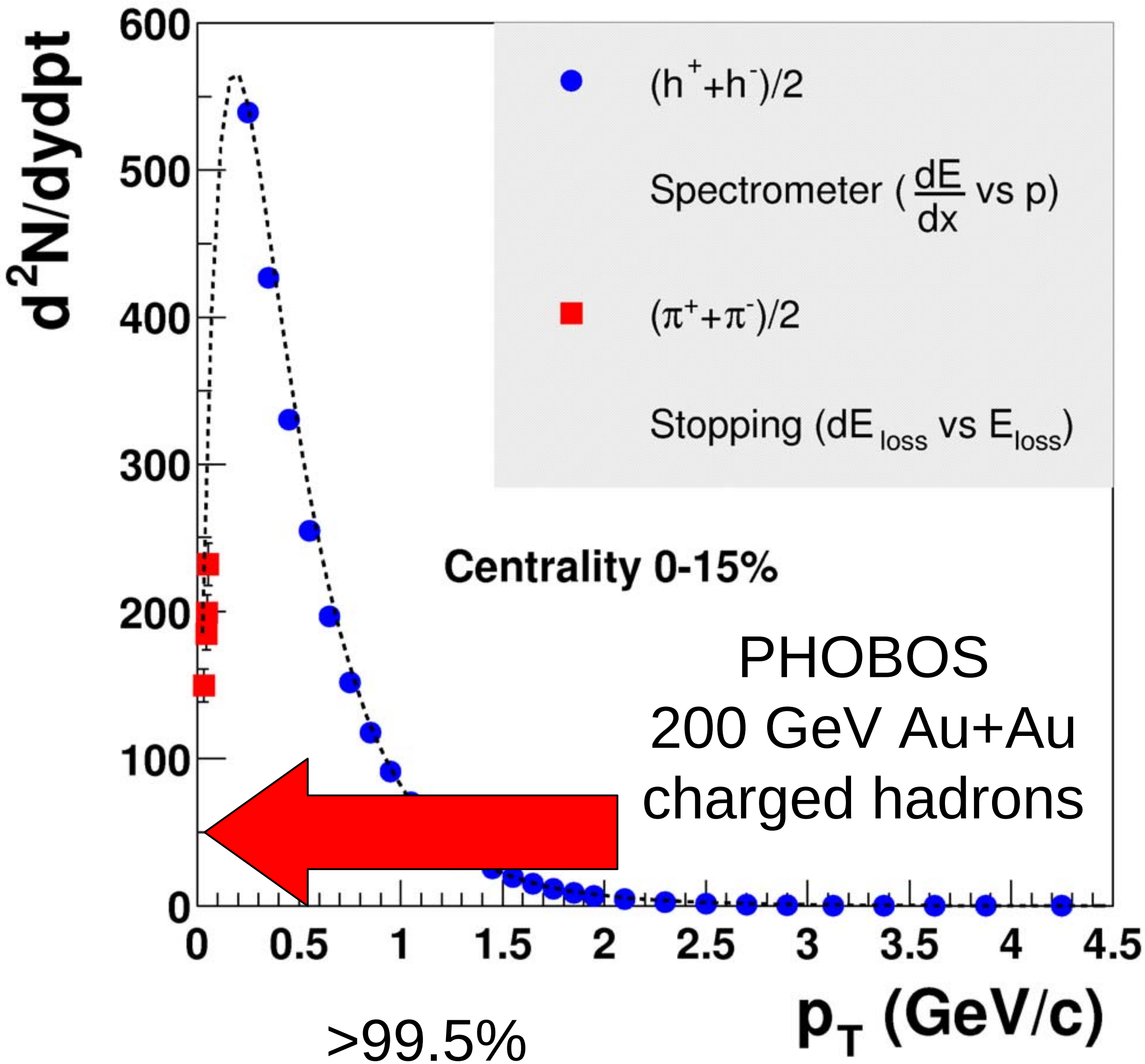
Centrality Selection in PHENIX



PHENIX

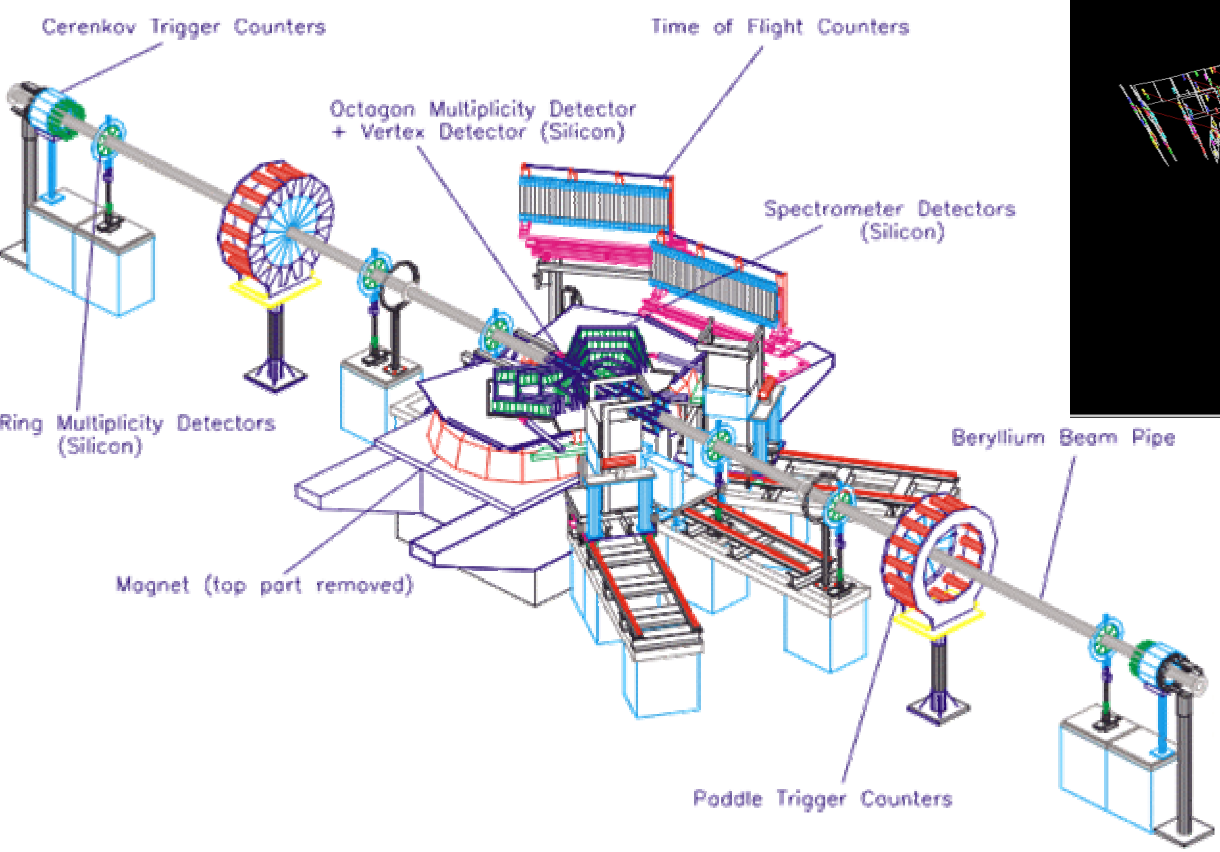
An almost central collision

The bulk of the particles are produced with low momentum: turn off the magnet and count!



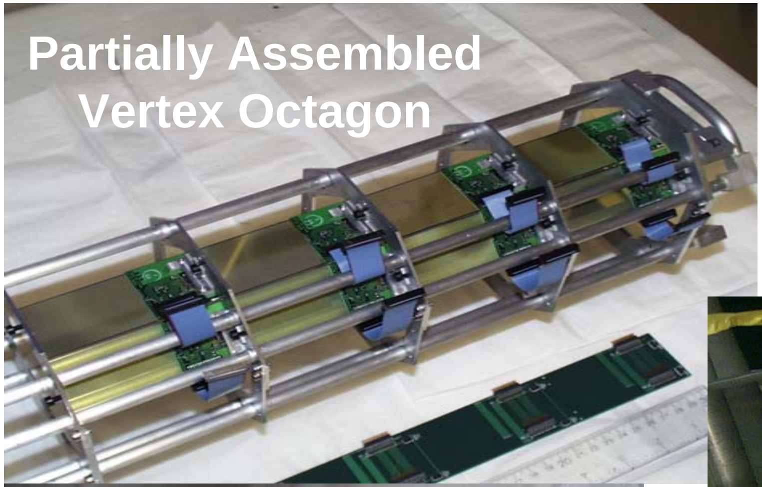
>99.5%

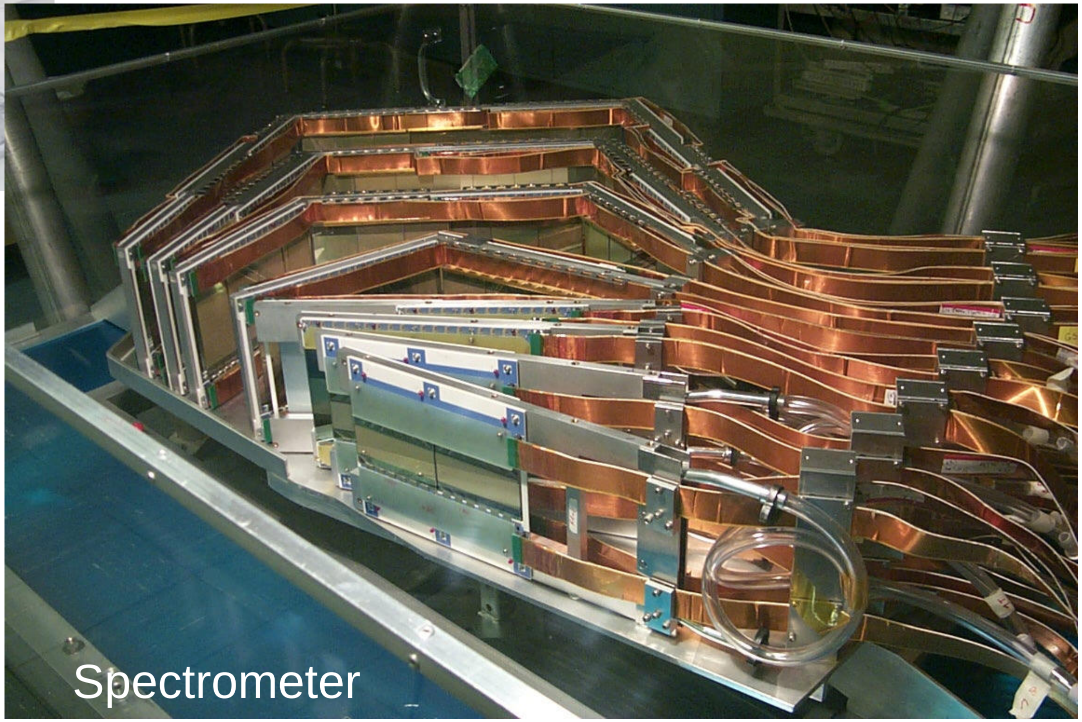
The Phobos experiment



- **Phobos: Si based spectrometer, PID by TOF and dE/dx in Si, large rapidity coverage**
- **I'll discuss pseudo-rapidity measurements of particle multiplicity**

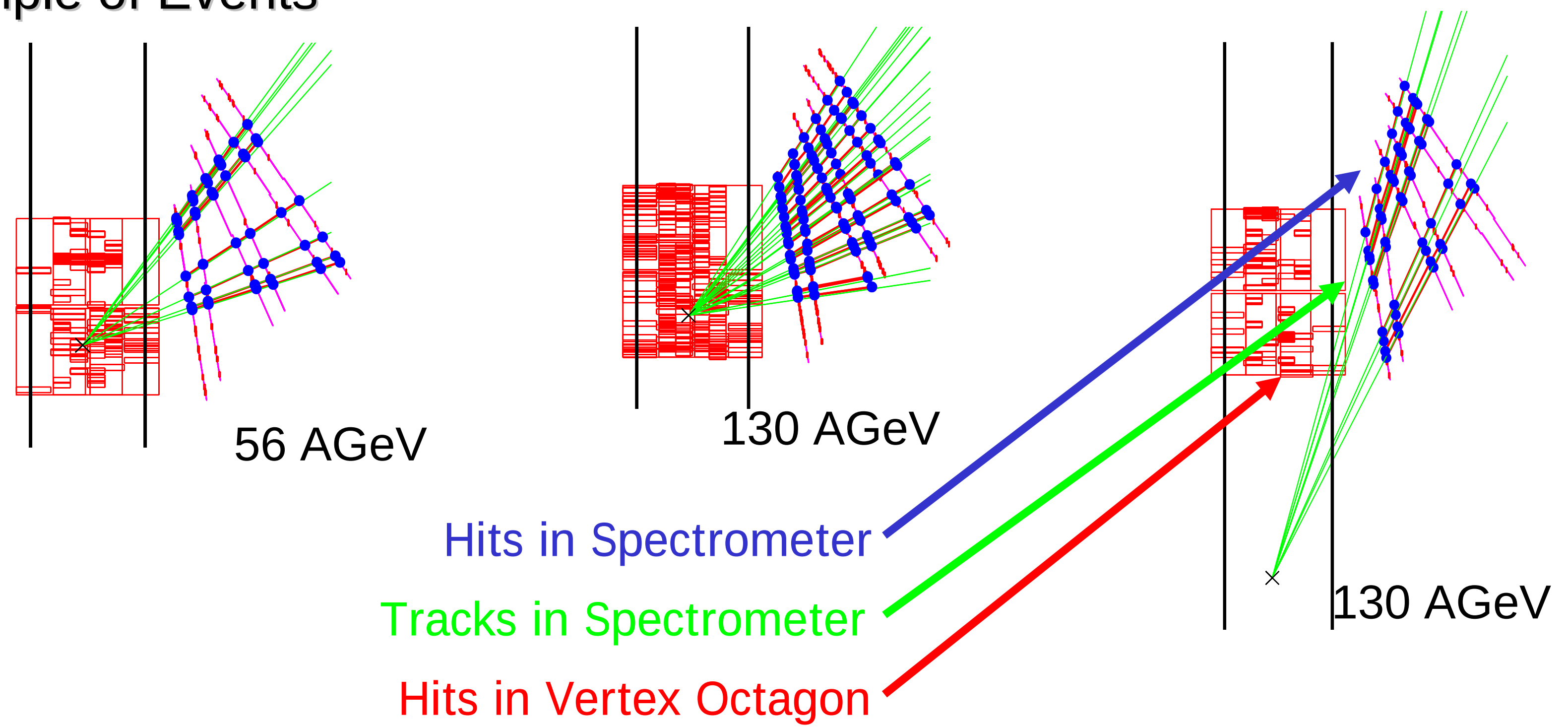
PHOBOS Silicon Detector Arrays





Example of multiplicity measurement from PHOBOS

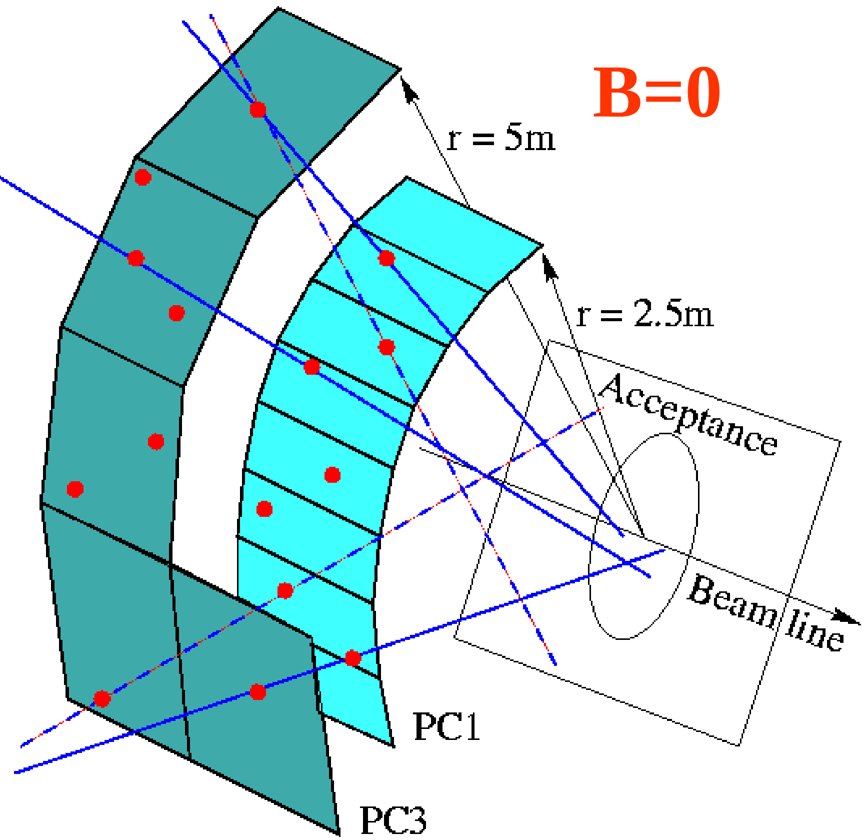
Sample of Events

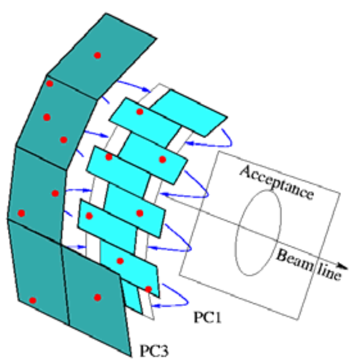


Charged Multiplicity Measurements

Count tracks on a statistical basis (no explicit track reconstruction)

- Combine all hits in PC3 with all hits in PC1.
- Project resulting lines onto a plane through the beam line.
- Count tracks within a given radius.
- Determine combinatorial background by event mixing technique





- MC corrections for acceptance, detector effects, decays, background

N_{part} and N_{coll} from Glauber MC simulations

Woods-Saxon nuclear density distributions.

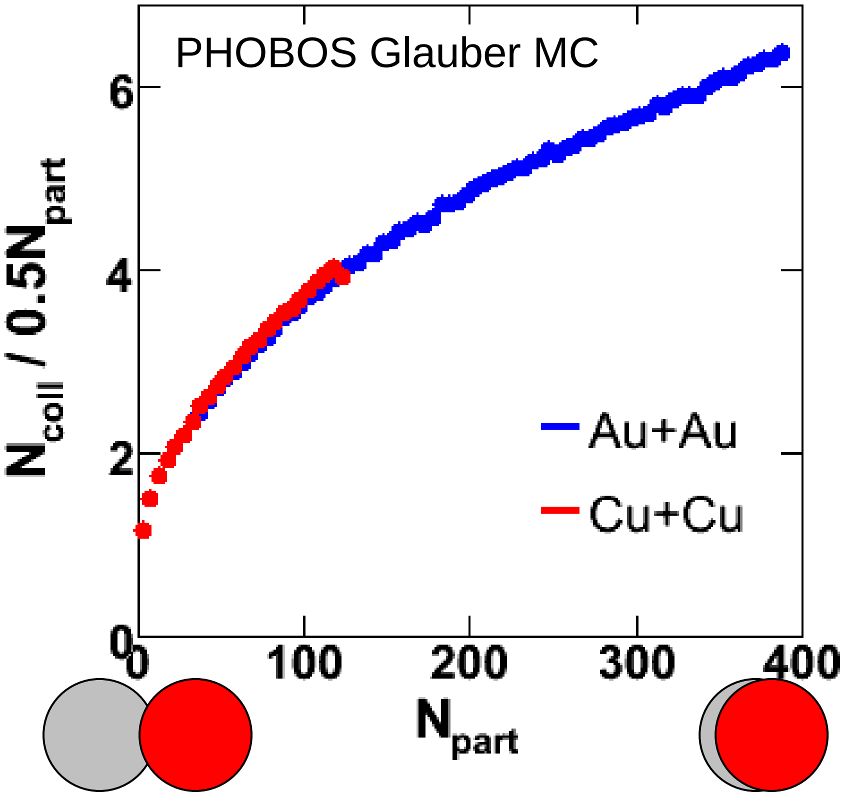
Put in the Lorentz boost

Put in the NN inelastic cross section (as parameterized from data)

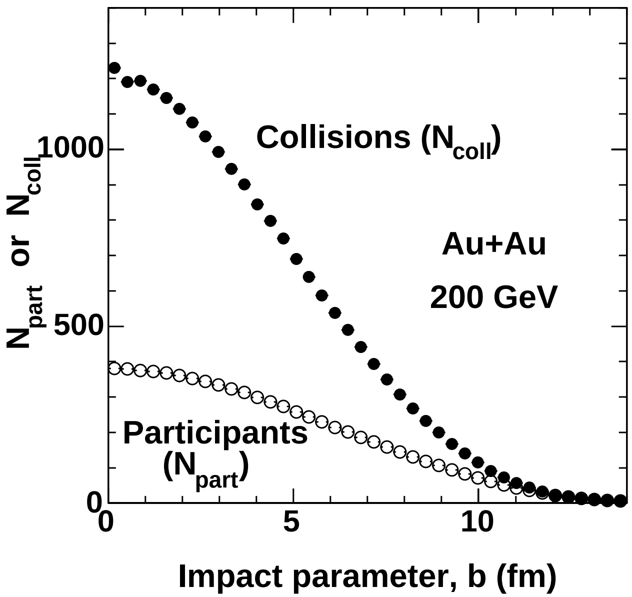
Straight line nucleon trajectories

Throw the dice:
•see if the nucleon is a participant
•See if the nucleon will collide with another nucleon more than once

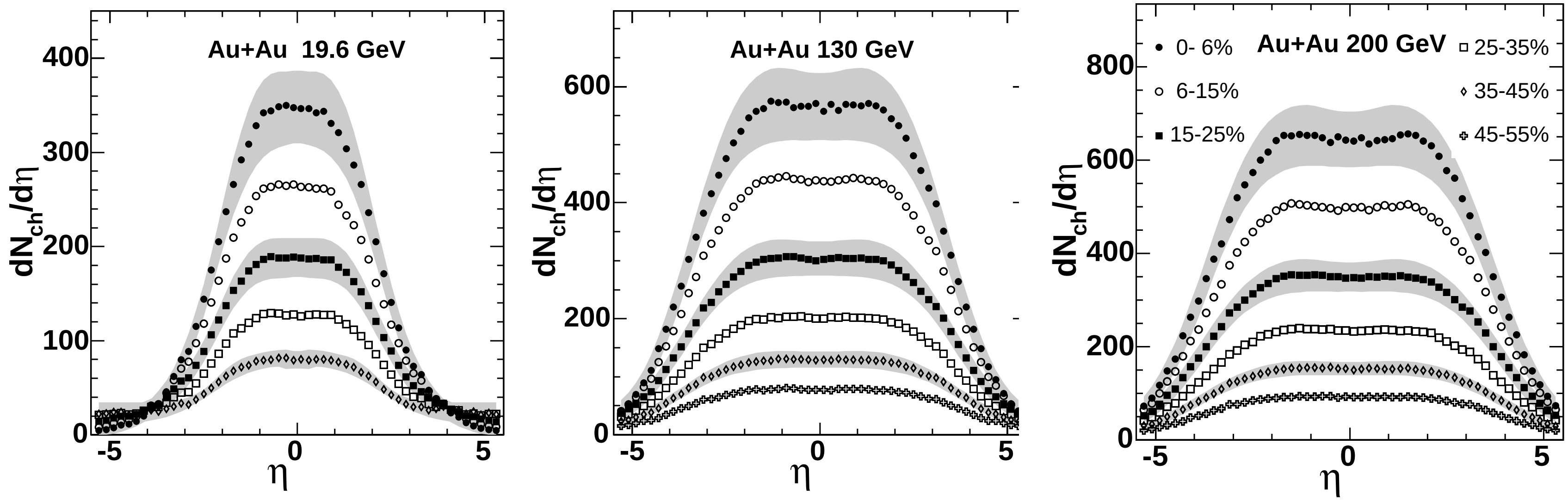
Variety of ways to make correspondence with exp't



More on N_{part} and N_{coll}

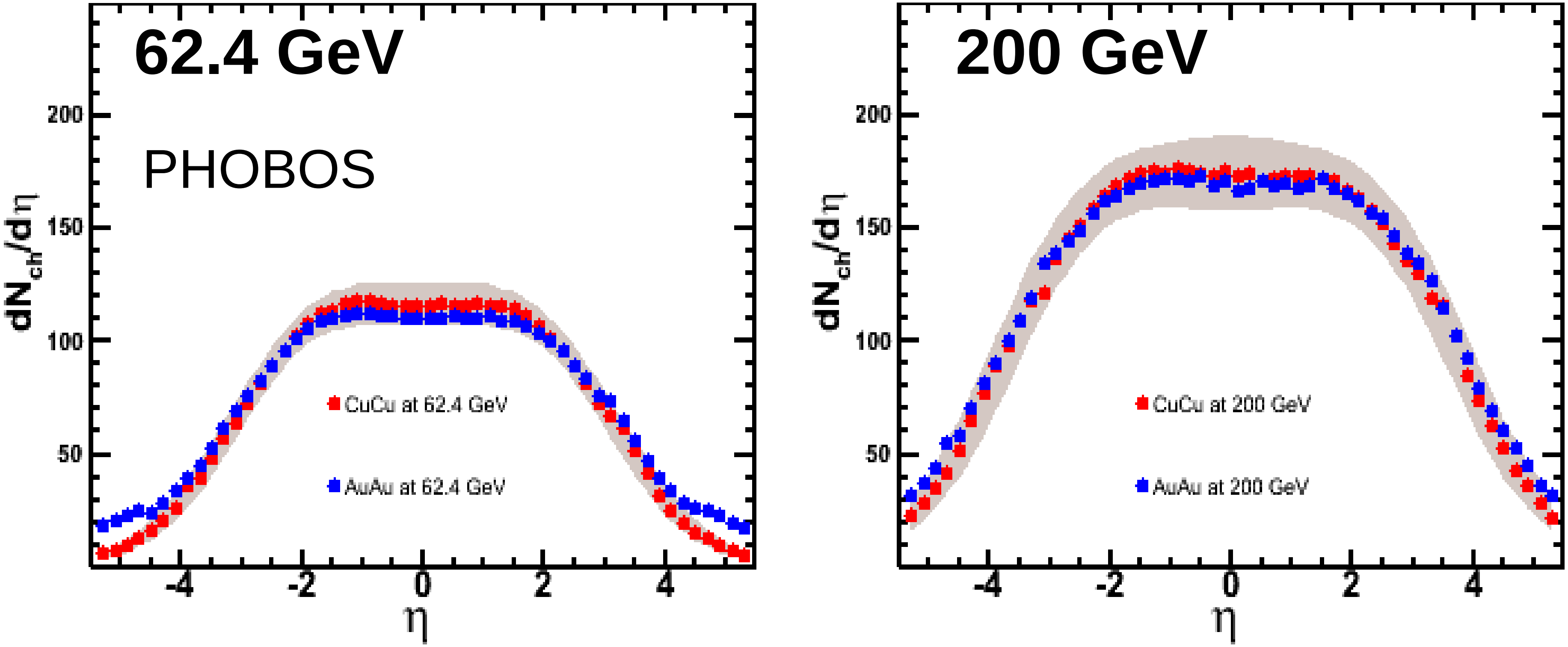


N_{ch} pseudo-rapidity dependence



- **Integrate the distribution to get total multiplicity – study the production as a function of energy**
- **Explore scaling behavior**
- **Is there longitudinal boost invariance ? Plateau around $\eta = 0$ increasing with energy. BUT, pseudo-rapidity maybe misleading…we'll find out …**

Total charged particle production

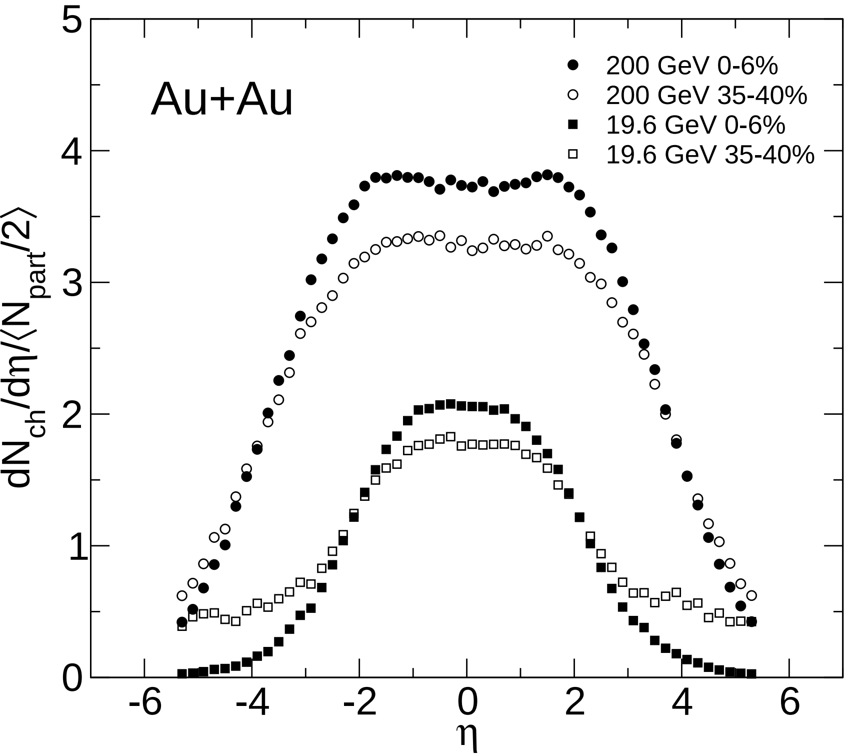


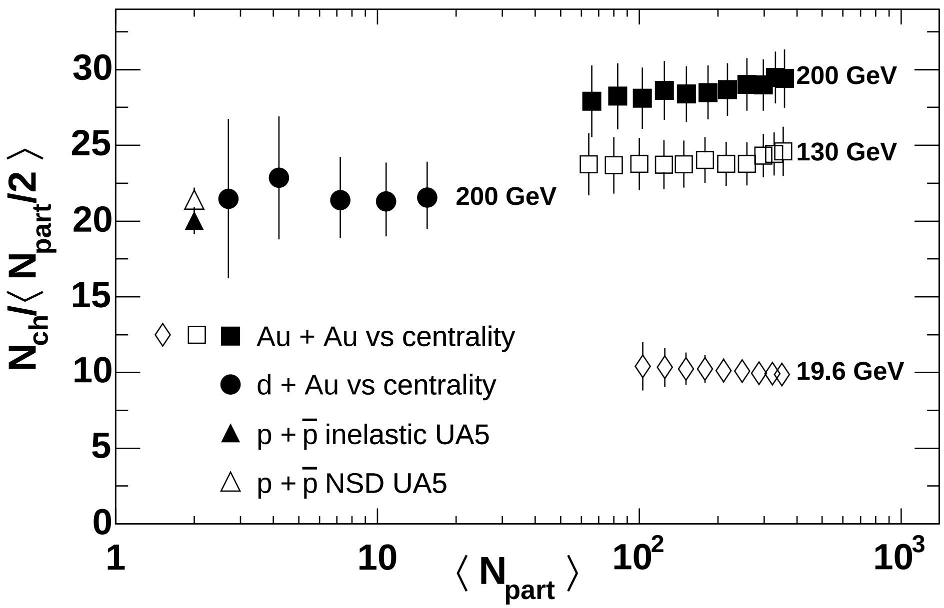
Here: number of participants ≈ 100

Same multiplicity for same N_{part}

G. Roland (QM'05)

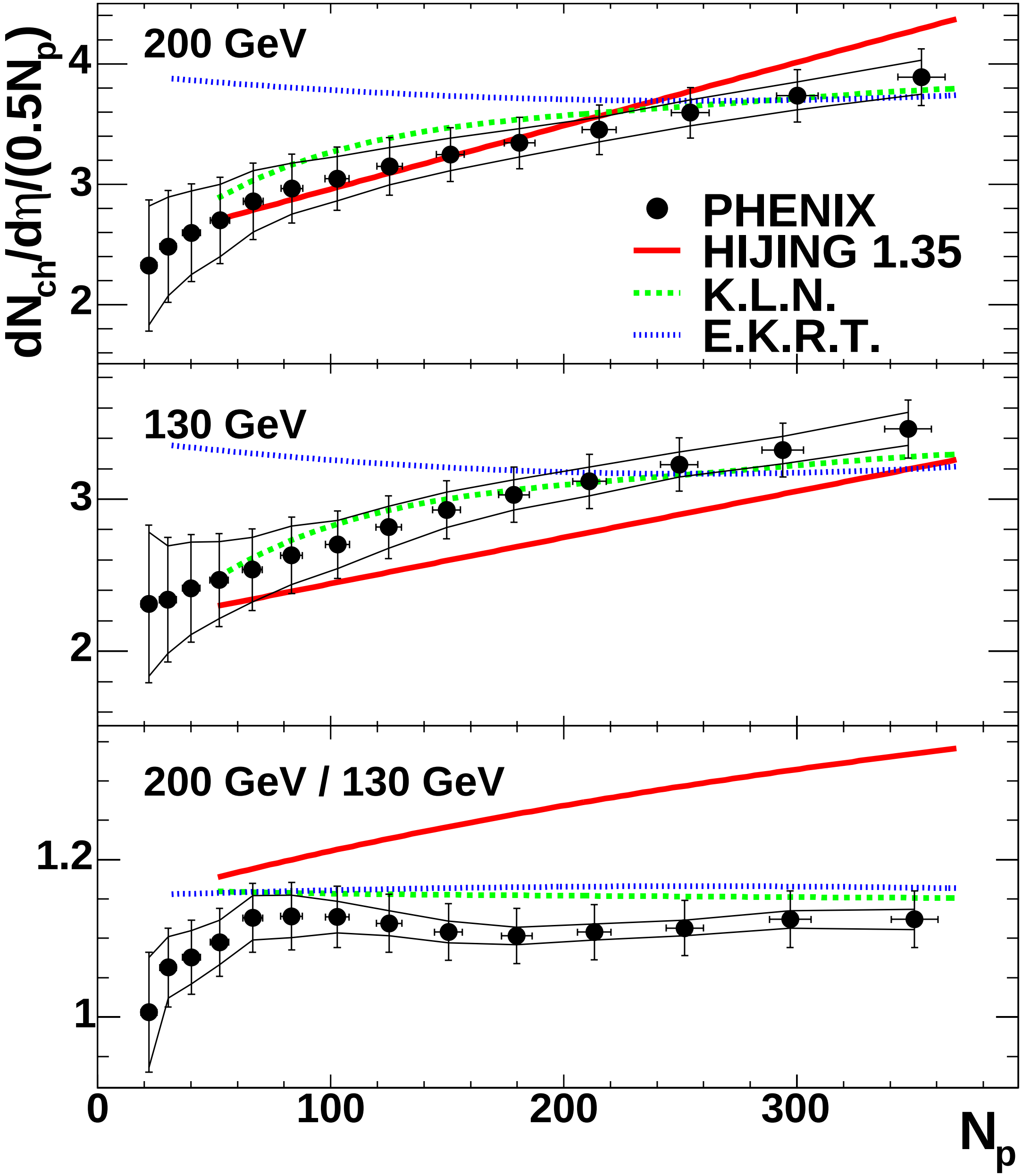
Total multiplicity per participant pair





- Total multiplicity (fixed energy/system) scales with Npart . With the change in centrality – change the system size and Ncoll , Npart
- Au+Au : increase in particle production with the available energy
- d+Au : not all “participants” are equal

N_{ch} as a function of centrality:comparison to models



- **NOTE: this is at central rapidity**
- **HIJING – pQCD based model with soft and hard component of particle production**

X.N.Wang and M.Gyulassy, PRL 86, 3498 (2001)

- **KLN – gluon saturation in the initial state**

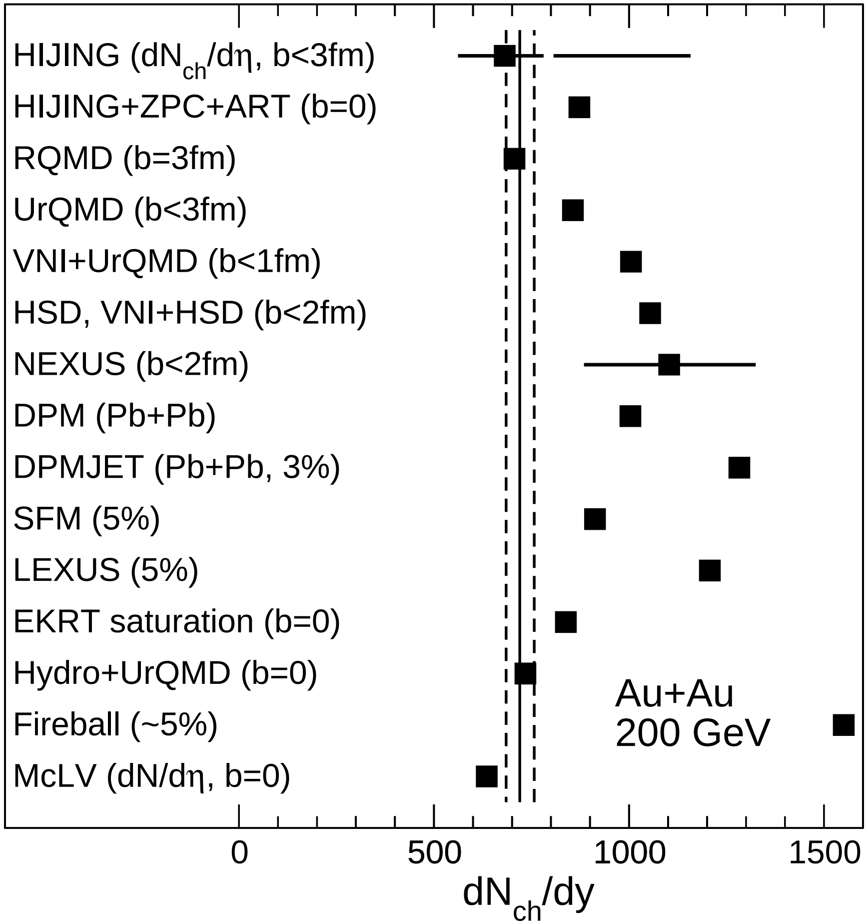
D.Kharzeev and M. Nardi, Phys.Lett. B503, 121 (2001)

D.Kharzeev and E.Levin, Phys.Lett. B523, 79 (2001)

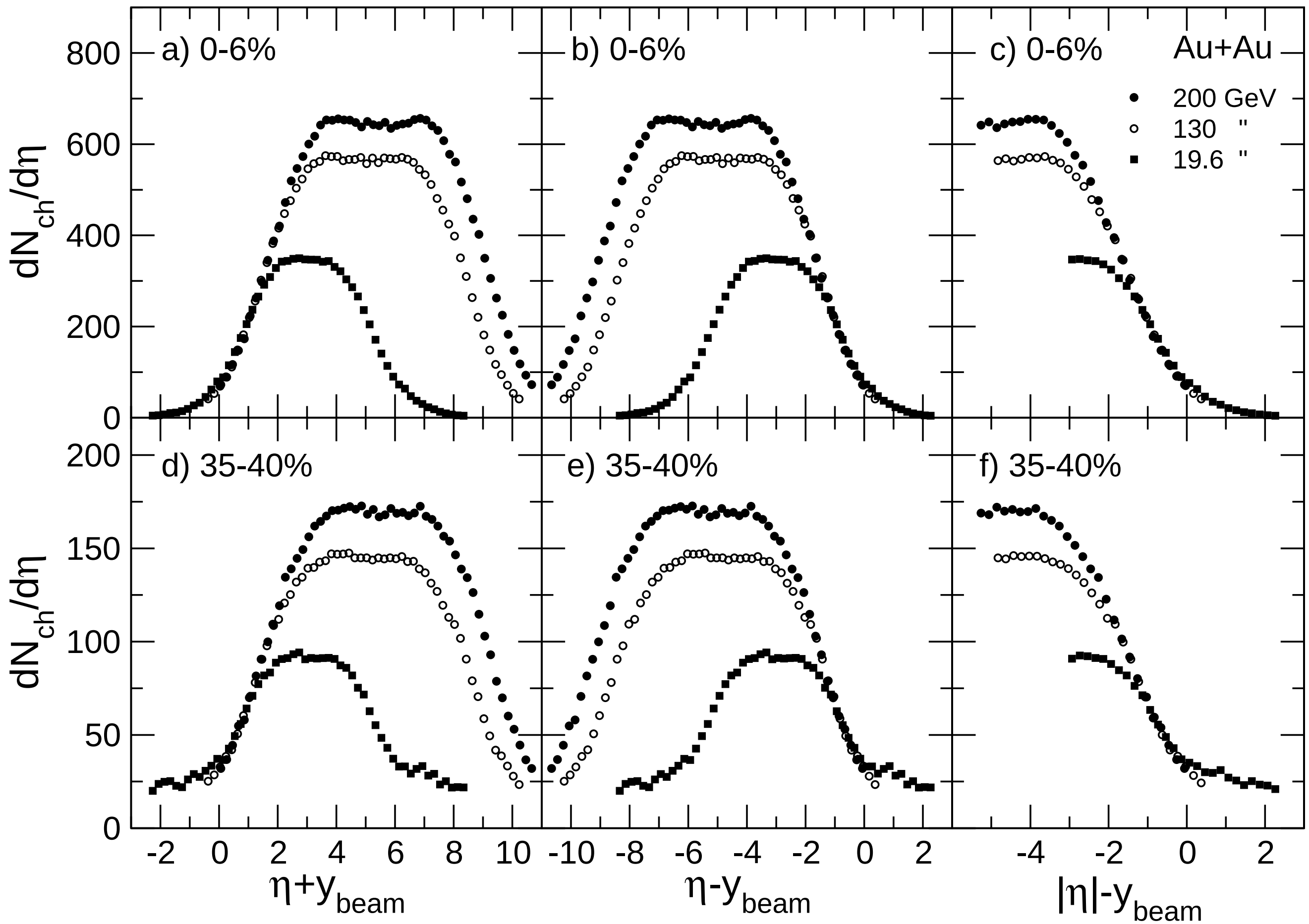
- **EKRT – saturation in the final state**

K.J.Eskola et al, Nucl Phys. B570, 379 and Phys.Lett. B 497, 39 (2001)

And a full pallet of N_{ch} to theory comparison from PHOBOS

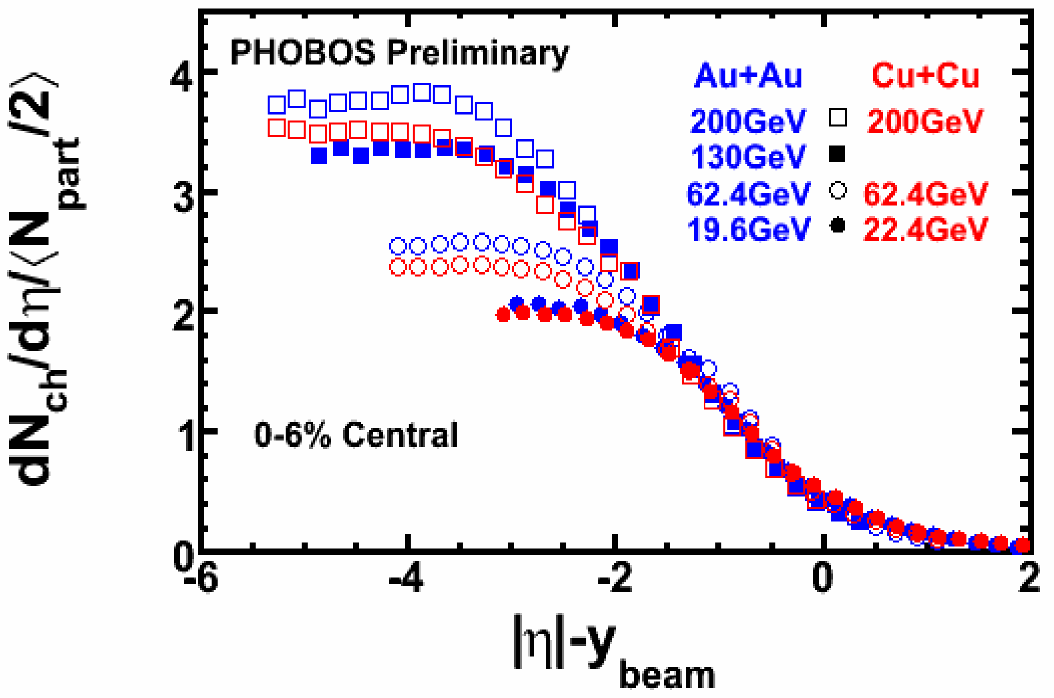


Julia Velkovska



- **Pa**
- **Projectile hadron viewed in the rest frame of the target is highly Lorenz contracted. It passes through the target leaving it in an excited state which is independent of energy. It then fragments to produce hadrons**

Longitudinal scaling: Adding Cu+Cu into the picture



- **Longitudinal scaling is independent even of the identity of the projectile!**

Summary

- **Particle production grows logarithmically with cm energy**
- **Total multiplicity is ~ N_{part}**
- **At mid-rapidity: multiplicity per participant grows slowly – consistent with gluon saturation in the initial state**
- **Near beam and target rapidity: universal scaling of multiplicity**
  - **Limiting fragmentation**