Latest Results from RHIC

Multiparticle Production from Au+Au, Cu+Cu, d+Au and p+p Collisions

"Interplay between Collision Energy and Collision Geometry"

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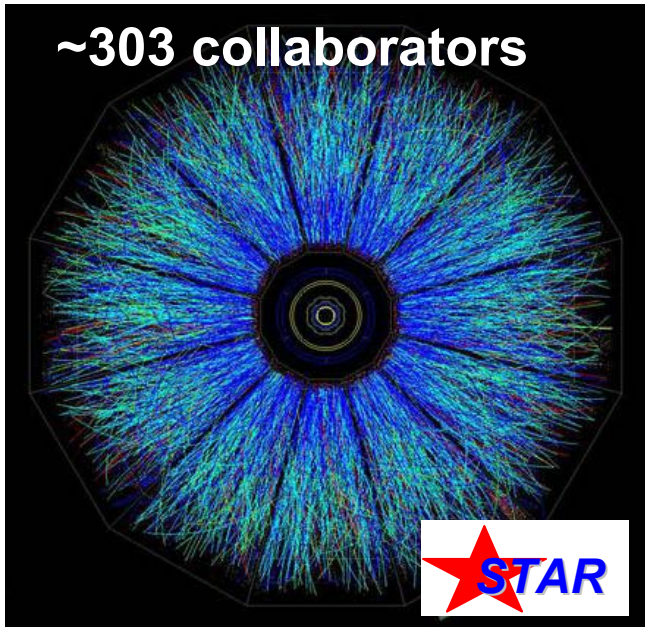
Brookhaven National Laboratory (BNL)

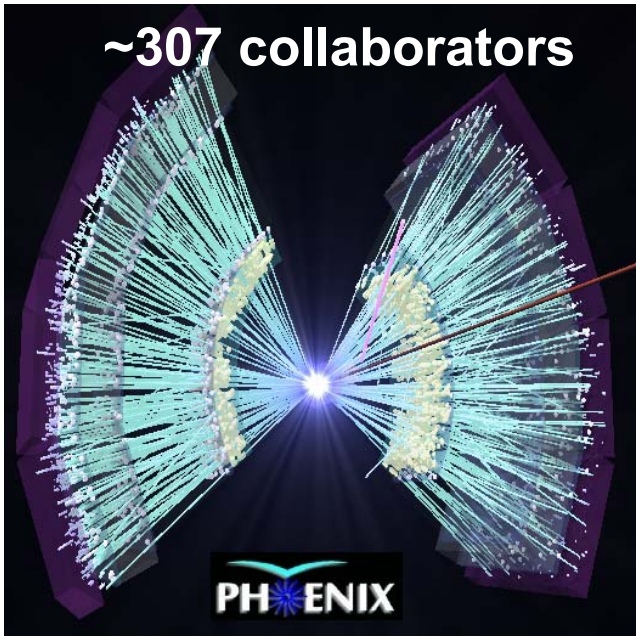
XXXV International Symposium on Multiparticle Dynamics
Kromeriz, Czech Republic, August 9-15, 2005

Four Complementary Experiments

Large solid angle tracking

~ Complete events

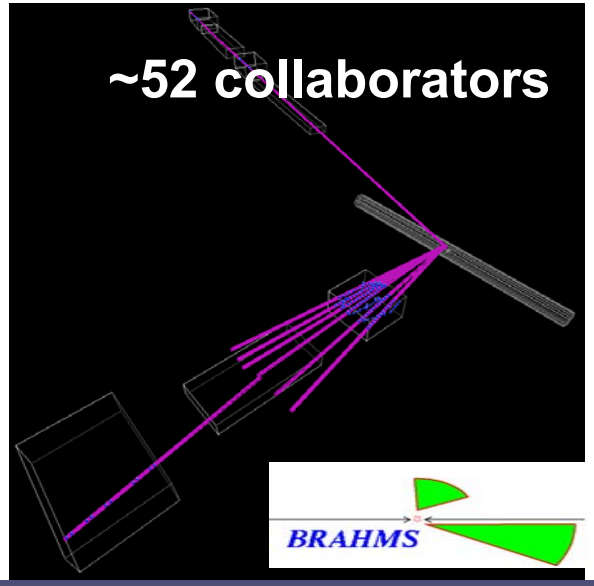


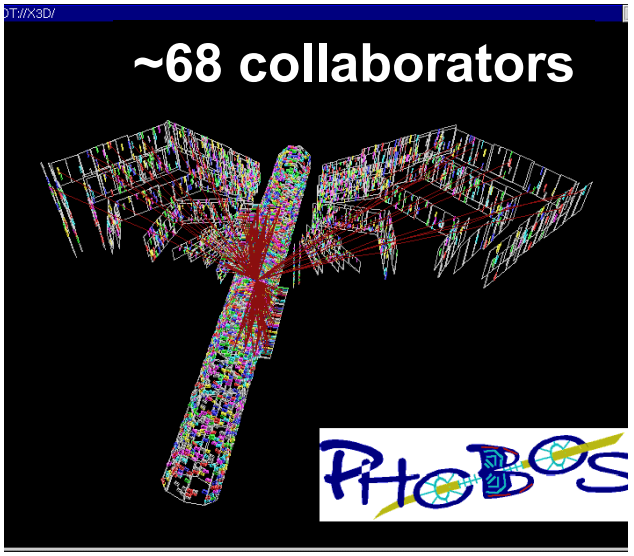


Leptons, (+h's, γ's)

High rate, Sophisticated triggering

Tracking & PID at high y





4π accept.

Good vtx. resolution (All Si det.)

Outline

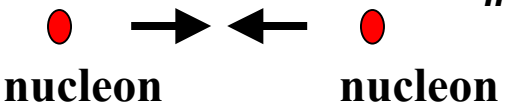
- Introduction:
  - Nucleon Participants and Constituent Quark Participants
- Global Properties:
  - New Results on Charged Particle Multiplicity in AuAu/CuCu/pp
  - Confrontation Models vs DATA for d+Au at 200 GeV
  - Hard Process vs Interacting Constituent Quarks
  - Factorization of Energy and Centrality Dependence at $|\eta| < 1$
  - Overall Factorization of the Pseudorapidity Distributions in AuAu/CuCu Collisions
  - Density per Nucleon and Density per Constituent Quark in AuAu/CuCu/PbPb/pp Collisions vs Colliding Energies
  - Extended Longitudinal Scaling "Limiting Fragmentation" Scenario
- Collective effect: Flow at RHIC
- Summary

Introduction: Number of Nucleon Participants " $N_{n\text{-}part}$ "

p + p Collisions

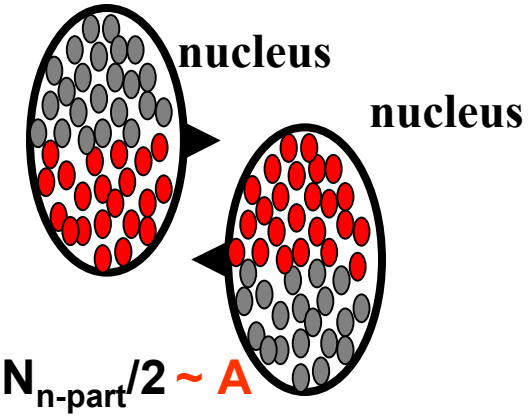
"Number of Participants"

Au+Au Collisions



# of participating pairs of nucleons

$\equiv N_{n\text{-}part}/2$



$N_{n\text{-}part}/2 = 1$

$N_{n\text{-}part}/2 \sim A$

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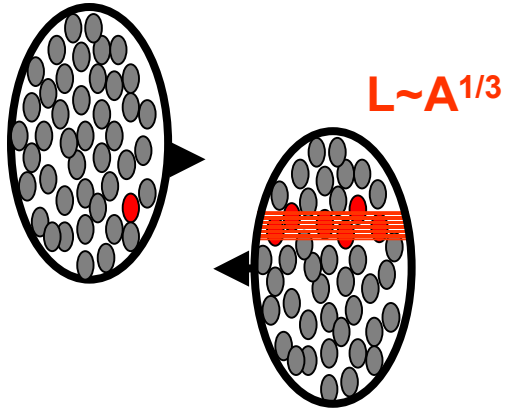
p + p Collisions

Number of Binary "Collision"

Au+Au Collisions

# of binary NN collisions

$\equiv N_{coll}$



$N_{coll} = 1$

$N_{coll} \sim A^{4/3}$

Introduction: Number of Constituent Quark Participants: $N_{q\text{-part}}$

Nucleus

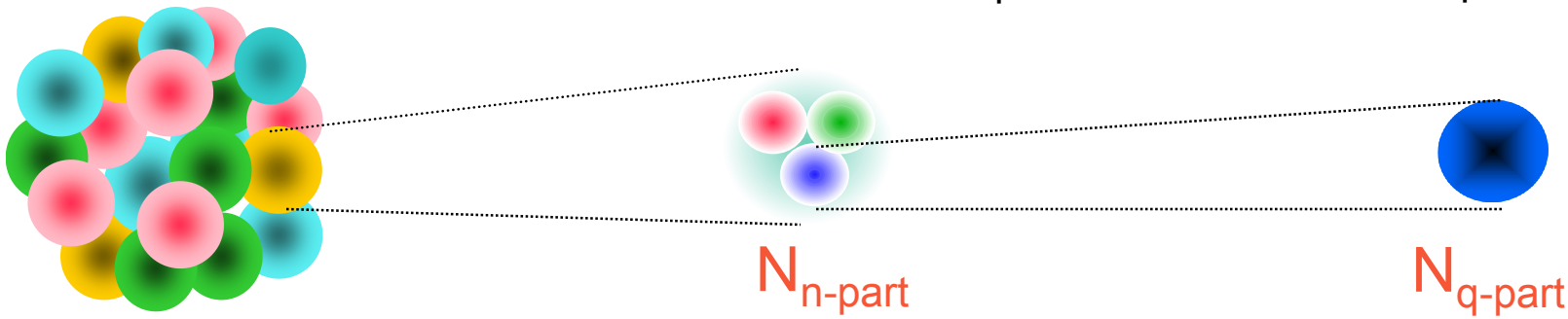
Made from nucleons

Nucleon

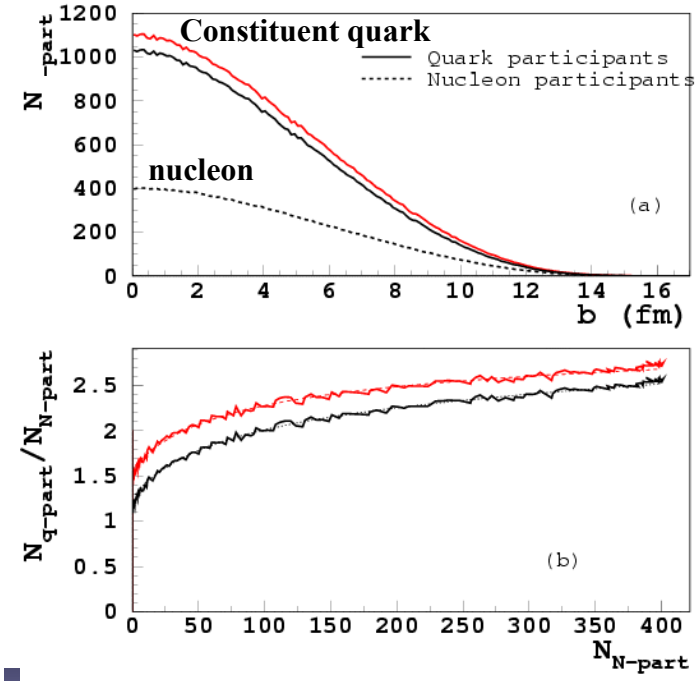
Made from 3 constituent quarks

Constituent Quarks

Made from quarks, gluons and $q\bar{q}$

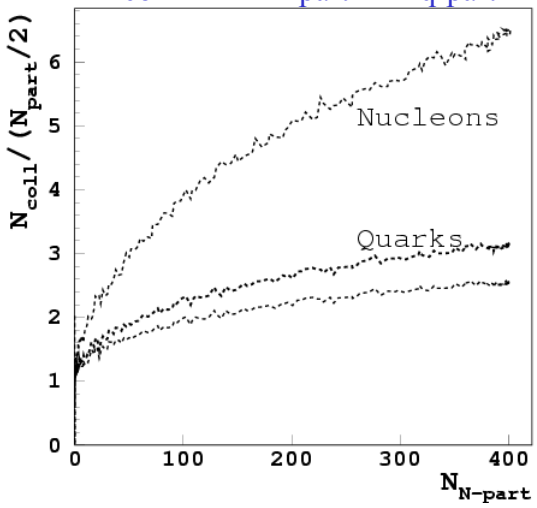


Impact parameter dependence

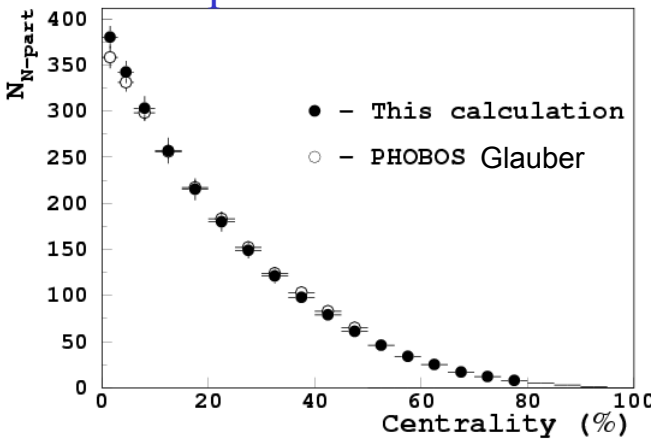


S. Eremin and S. Voloshin, PRC 67, 064905 (2003)

N_{coll} vs $N_{n\text{-part}}$, $N_{q\text{-part}}$



Comparison to PHOBOS

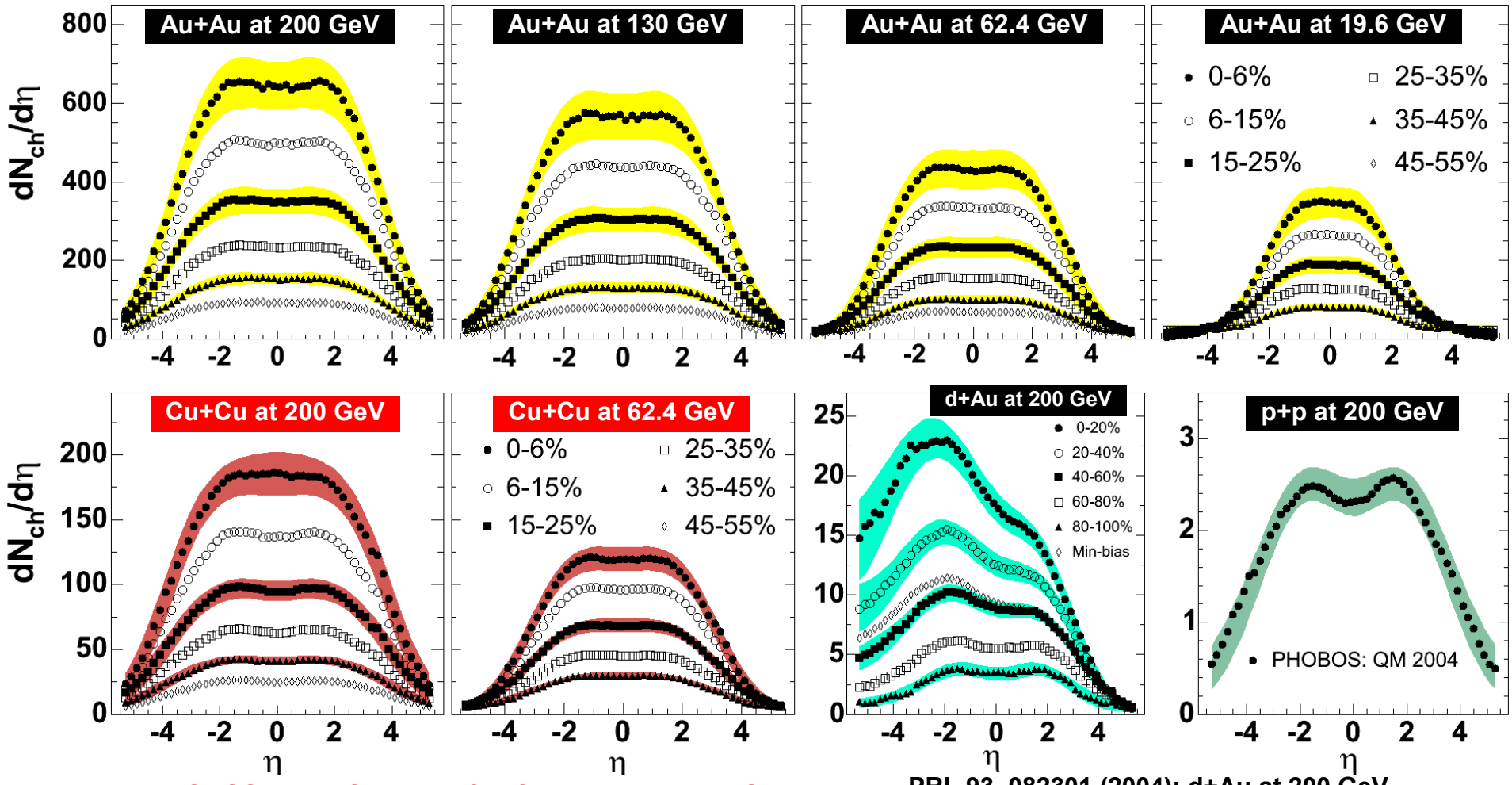


Pseudorapidity Distributions of Charged Particles

New Results from RHIC Cu+Cu at 62.4 and 200 GeV

Using data: PRL 93, 082302 (2004) for AuAu

Cu+Cu at 62.4 GeV: PHOBOS (Prel.) QM 2005



Using PHOBOS (Prel.) QM2005: Cu+Cu at 200 and 62.4 GeV

PRL 93, 082301 (2004): d+Au at 200 GeV

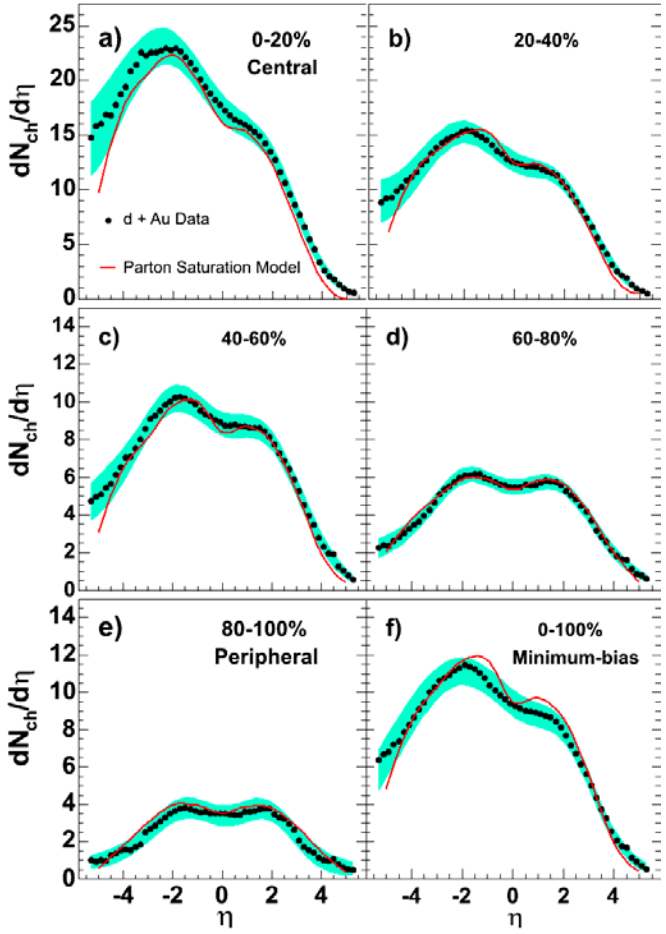
PHOBOS (Prel.) QM 2004: p+p at 200GeV

Pseudorapidity Distributions of Charged Particles

Confrontation Models vs Data d+Au at 200 GeV

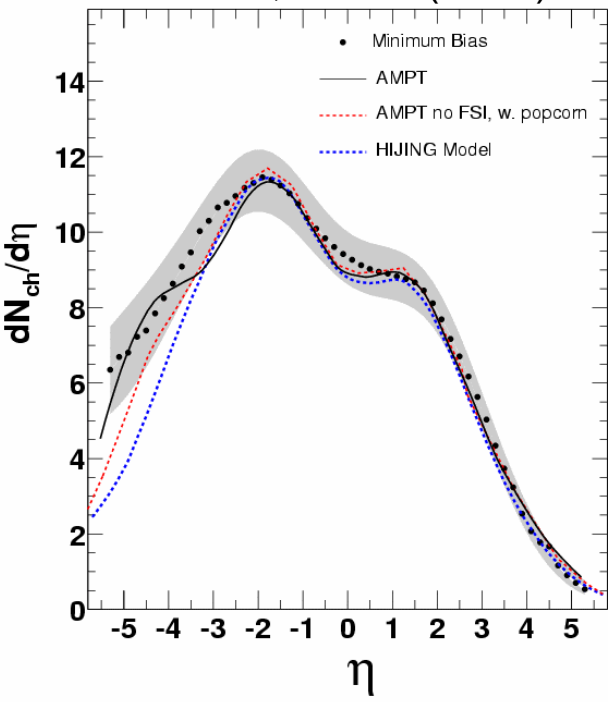
Parton Saturation Model

Using PHOBOS data accepted in PRC (2005)



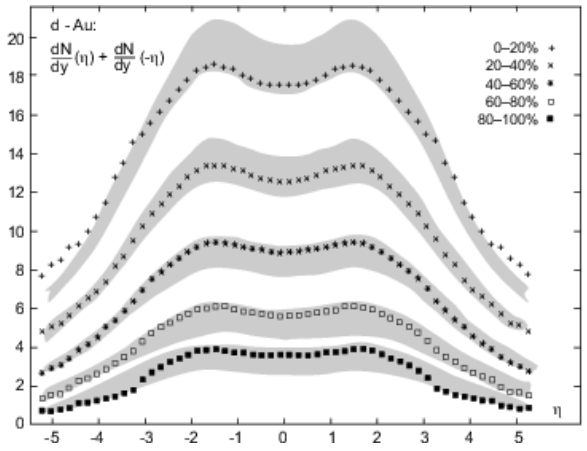
AMPT/HIJING Model

PRL 93, 08230 (2004)



Wounded Nucleon Model

Hep-ph/0410265



Models describe a reasonably well the pseudorapidity distributions

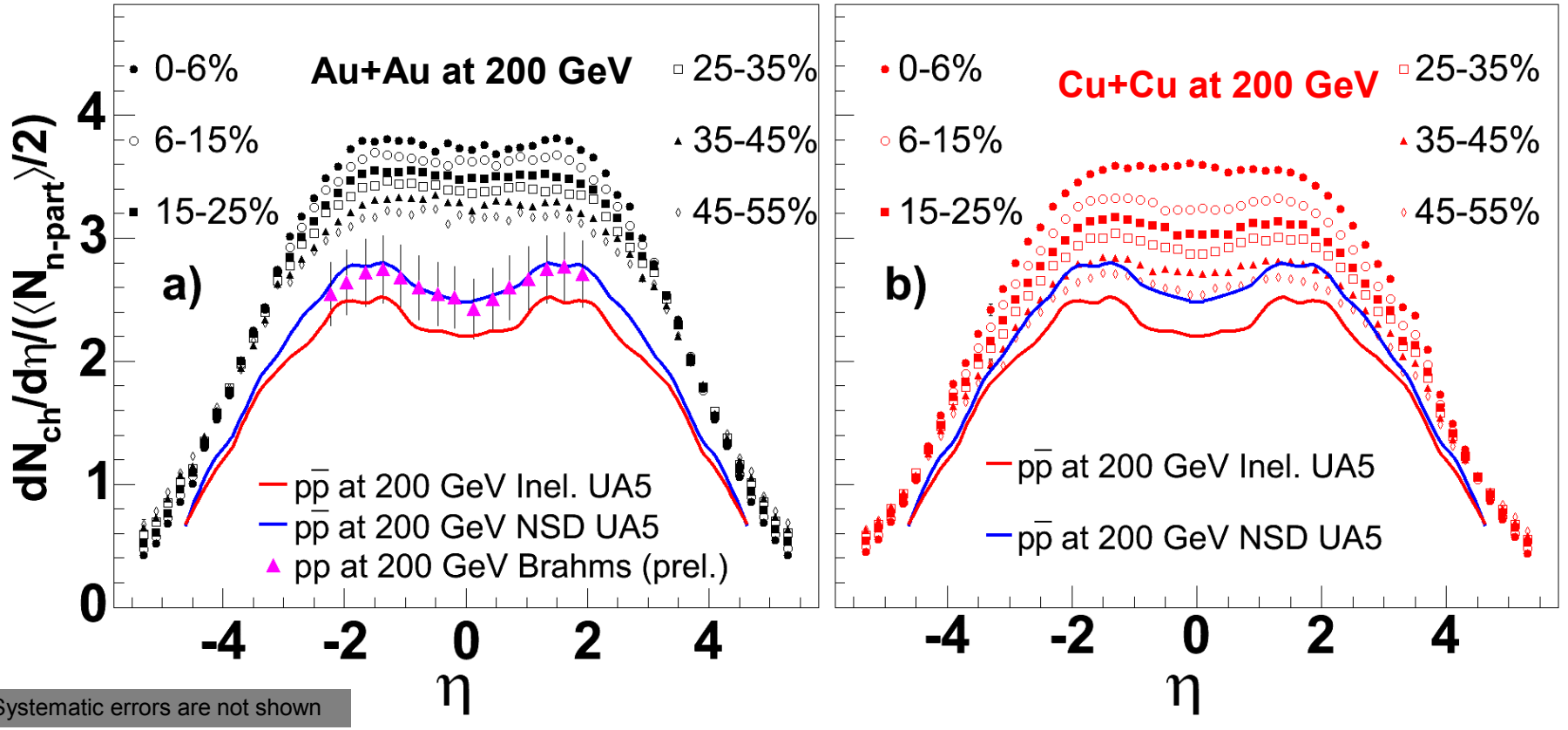
Pseudorapidity Distributions of Charged Particles

Overview of the Distributions in Au+Au and Cu+Cu vs p+p Collisions

Distributions Scaled to $N_{n\text{-}part}$

Au+Au vs p+p at 200 GeV

Cu+Cu vs p+p at 200 GeV



Systematic errors are not shown

Using data: PRL 93, 082302 (2004) for AuAu

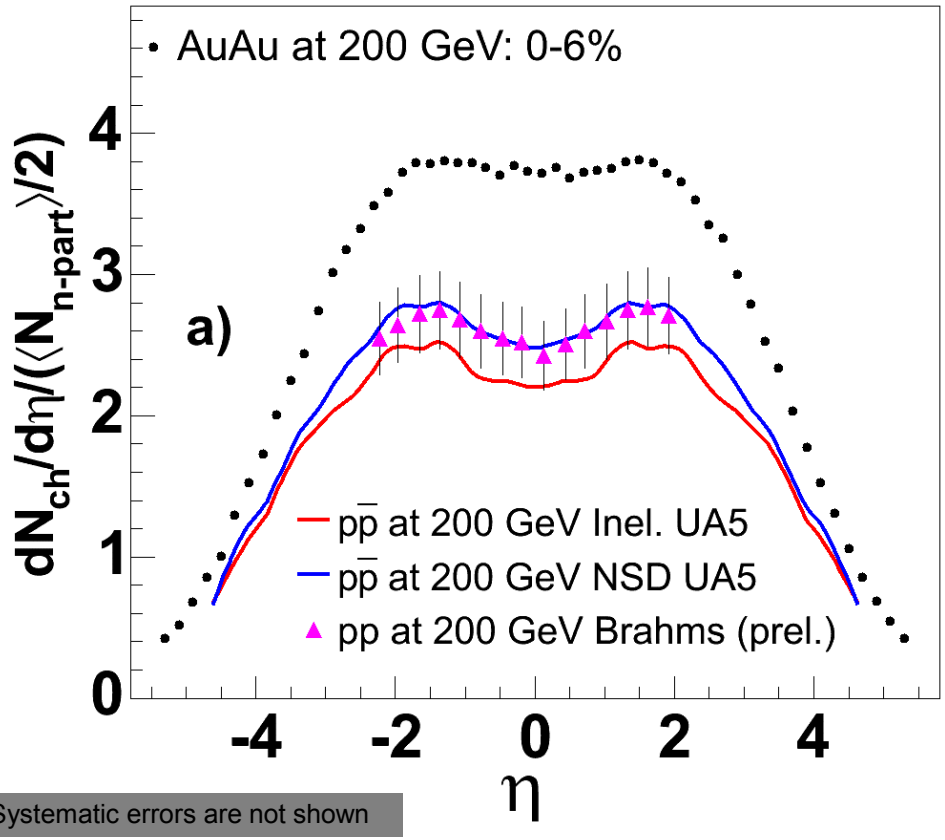
Using PHOBOS (Prel.) QM2005: Cu+Cu at 200 and 62.4 GeV

Pseudorapidity Distributions of Charged Particles

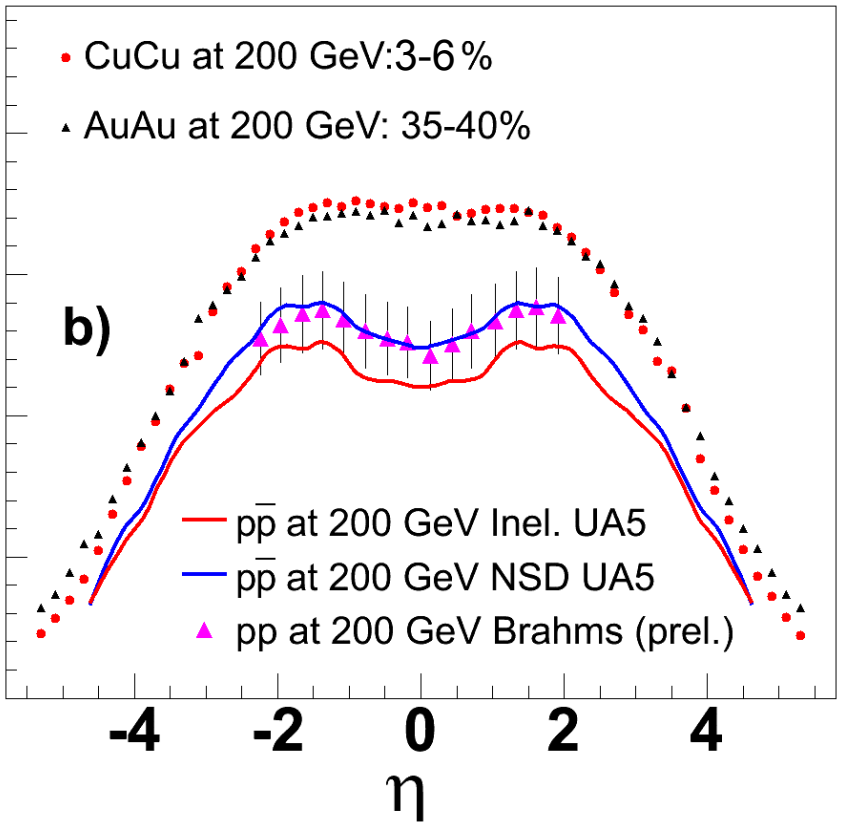
Overview of the Distributions in Au+Au and Cu+Cu vs p+p Collisions

Distributions Scaled to $N_{n\text{-}part}$

Au+Au vs p+p at 200 GeV



Cu+Cu vs p+p at 200 GeV



Systematic errors are not shown

Using data: PRL 93, 082302 (2004) for AuAu

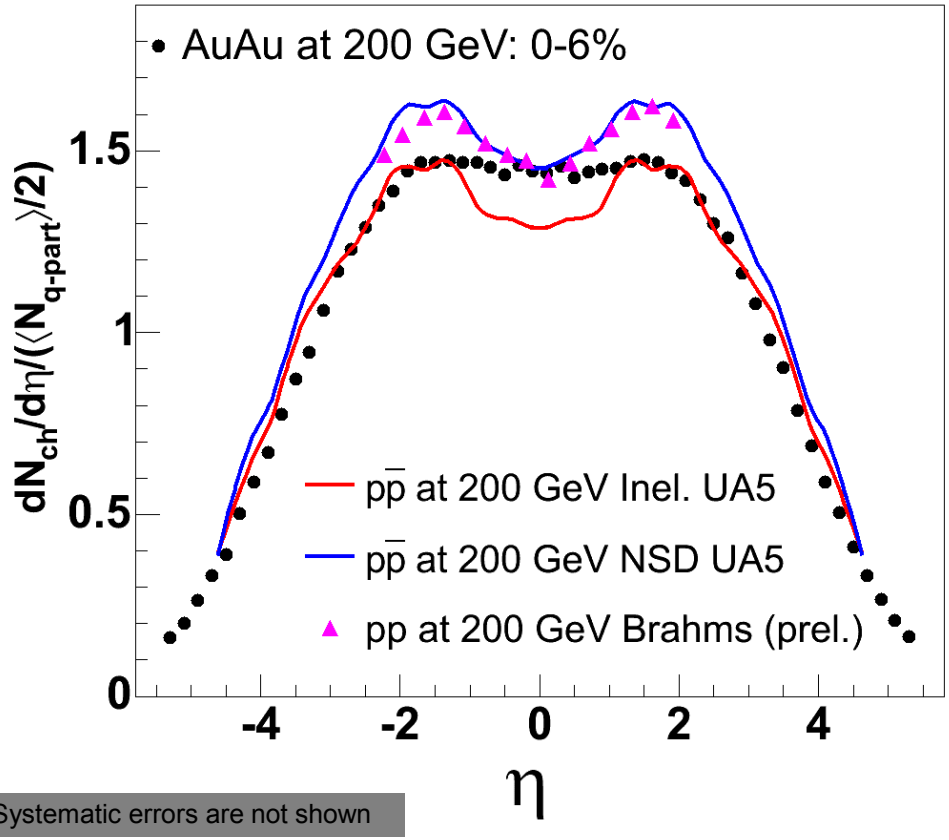
Using PHOBOS (Prel.) QM2005: Cu+Cu at 200 and 62.4 GeV

Pseudorapidity Distributions of Charged Particles

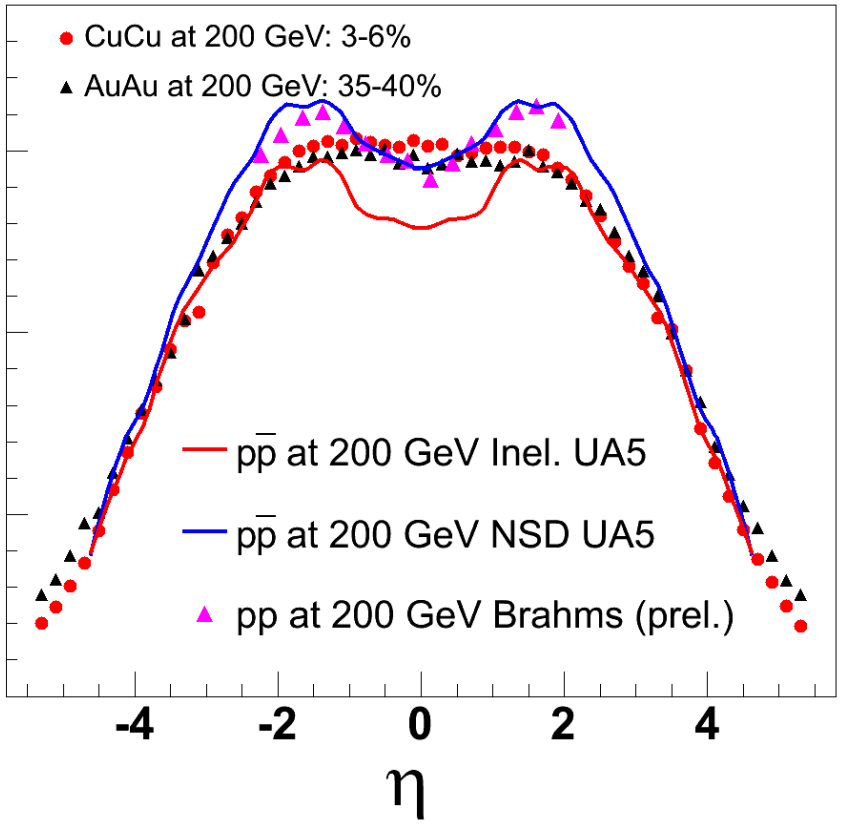
Overview of the Distributions in Au+Au and Cu+Cu vs p+p Collisions

Distributions Scaled to $N_{q\text{-part}}$

Au+Au vs p+p at 200 GeV



Cu+Cu vs p+p at 200 GeV



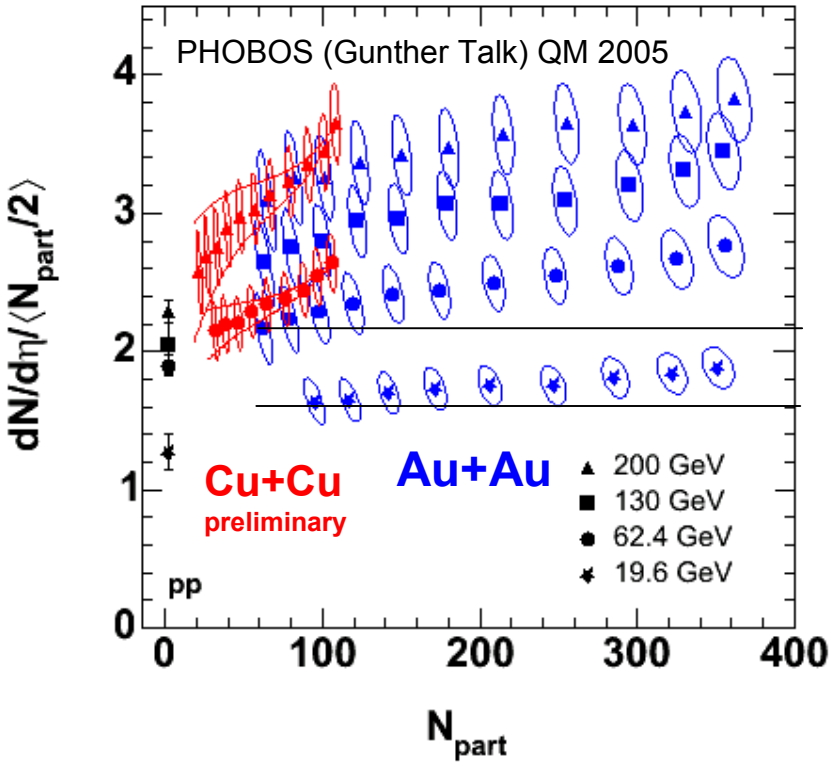
Systematic errors are not shown

Using data: PRL 93, 082302 (2004) for AuAu

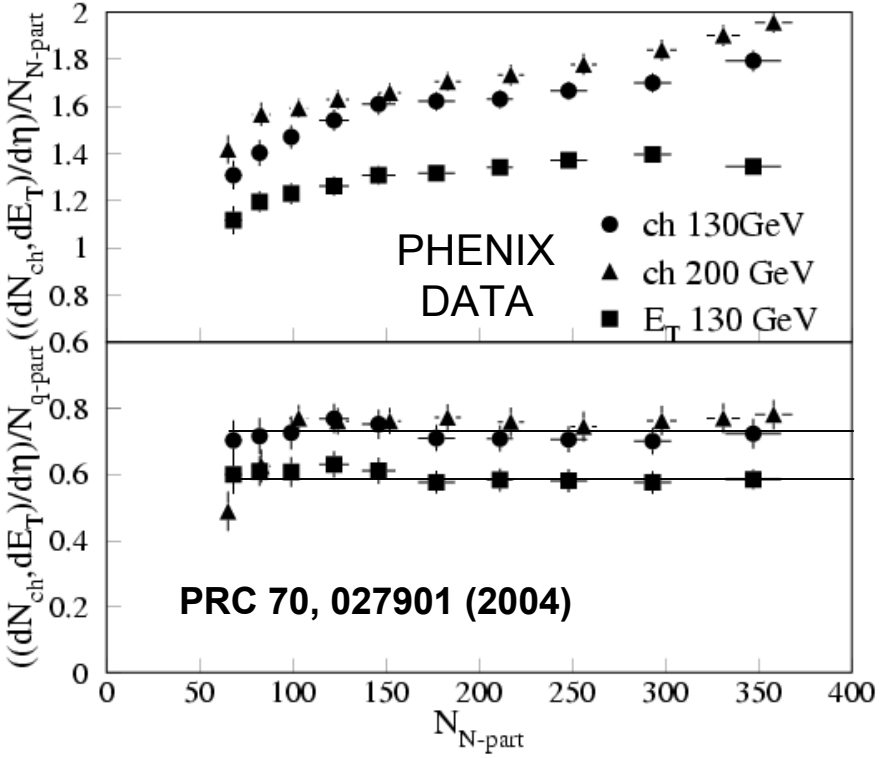
Using PHOBOS (Prel.) QM2005: Cu+Cu at 200 and 62.4 GeV

Multiparticle Production at Midrapidity $|\eta| < 1$
Hard Process vs Interacting Constituent Quarks

Scaled to Nucleon "$N_{n\text{-}part}$"



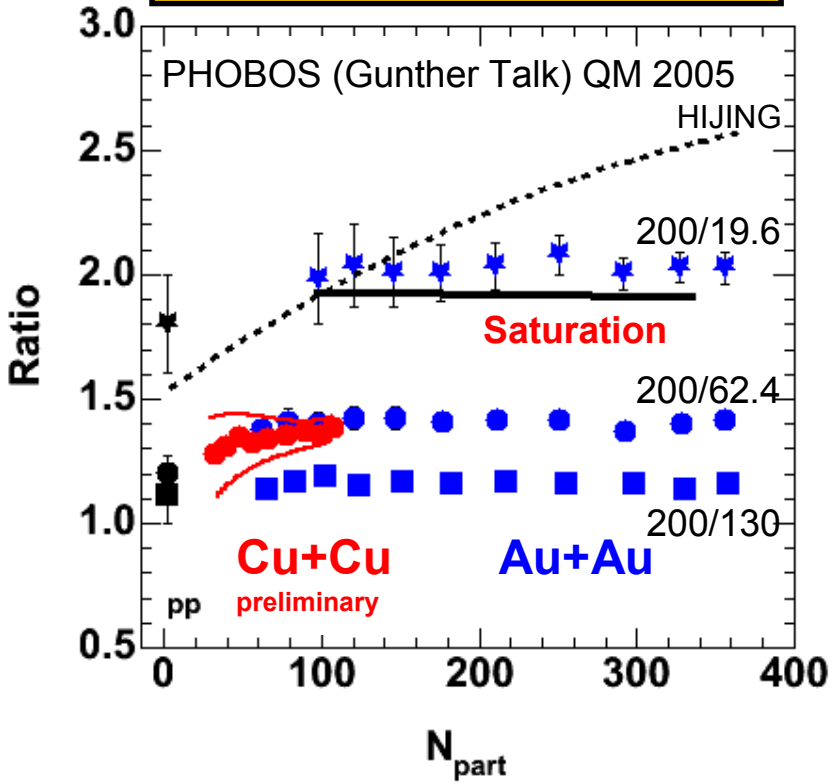
Scaled to Quark "$N_{q\text{-}part}$"



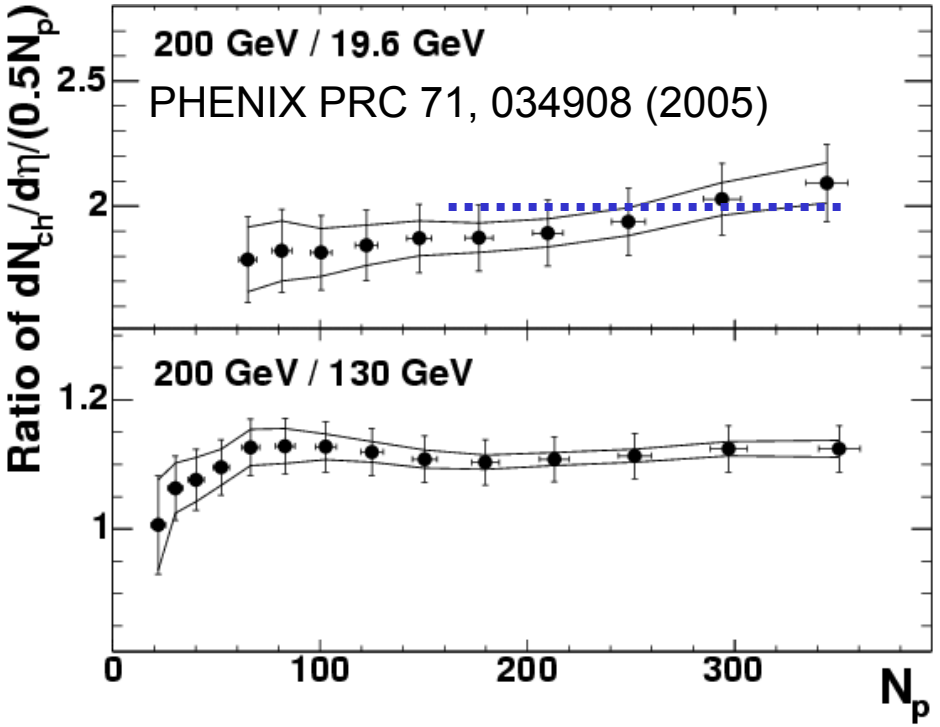
Increase of dN/dη per nucleon participant pair with centrality can be explained by the relative increase in the number of interacting constituent quarks in more central collisions

Multiparticle Production at Midrapidity $|\eta| < 1$
Factorization of Energy and Centrality Dependence

PHOBOS in AuAu and CuCu



PHENIX Au+Au

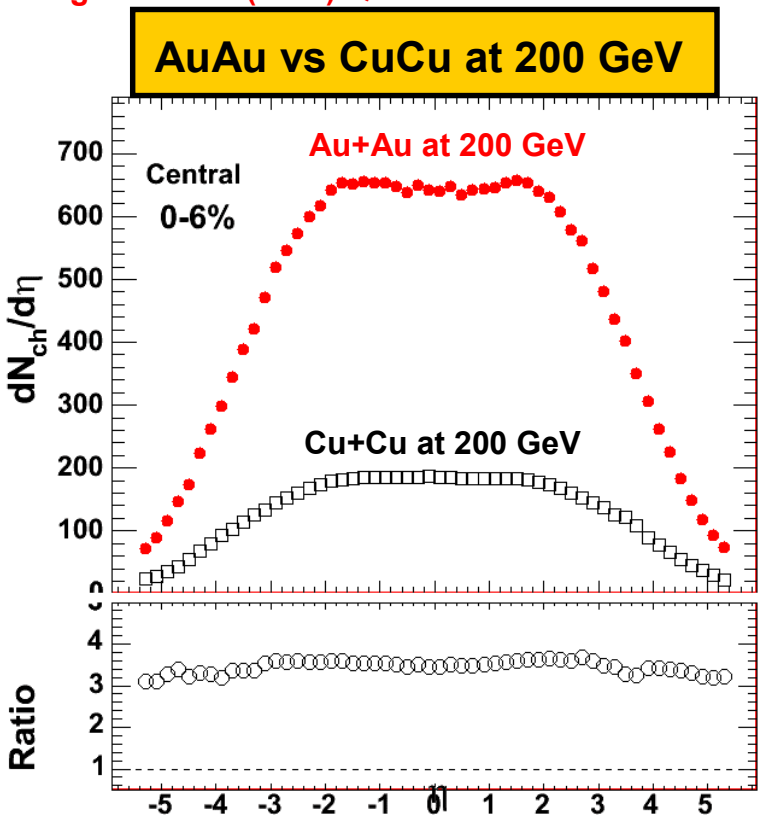


Is the factorization of energy and centrality dependence initial state effect?

Overall Factorization of the Pseudorapidity Distributions Au+Au vs Cu+Cu at 200 GeV

Using data: PRL 93, 082302 (2004) for AuAu

Using PHOBOS (Prel.) QM2005: Cu+Cu at 200 GeV



Systematic errors are not shown

An idea at high altitude over the Atlantic Ocean (expensive idea)!

$$\frac{dN/d\eta\ (Au+Au:\ 0\text{-}6\%)}{dN/d\eta\ (Cu+Cu:\ 0\text{-}6\%)} = R_{Cu}^{Au}(0\text{-}6\%)$$

$$\frac{dN^{Fact.}}{d\eta}(CuCu:\ x\ \%) = R_{Cu}^{Au}(0\text{-}6\%)\ \frac{dN^{Meas.}}{d\eta}(AuAu:\ x\ \%)$$

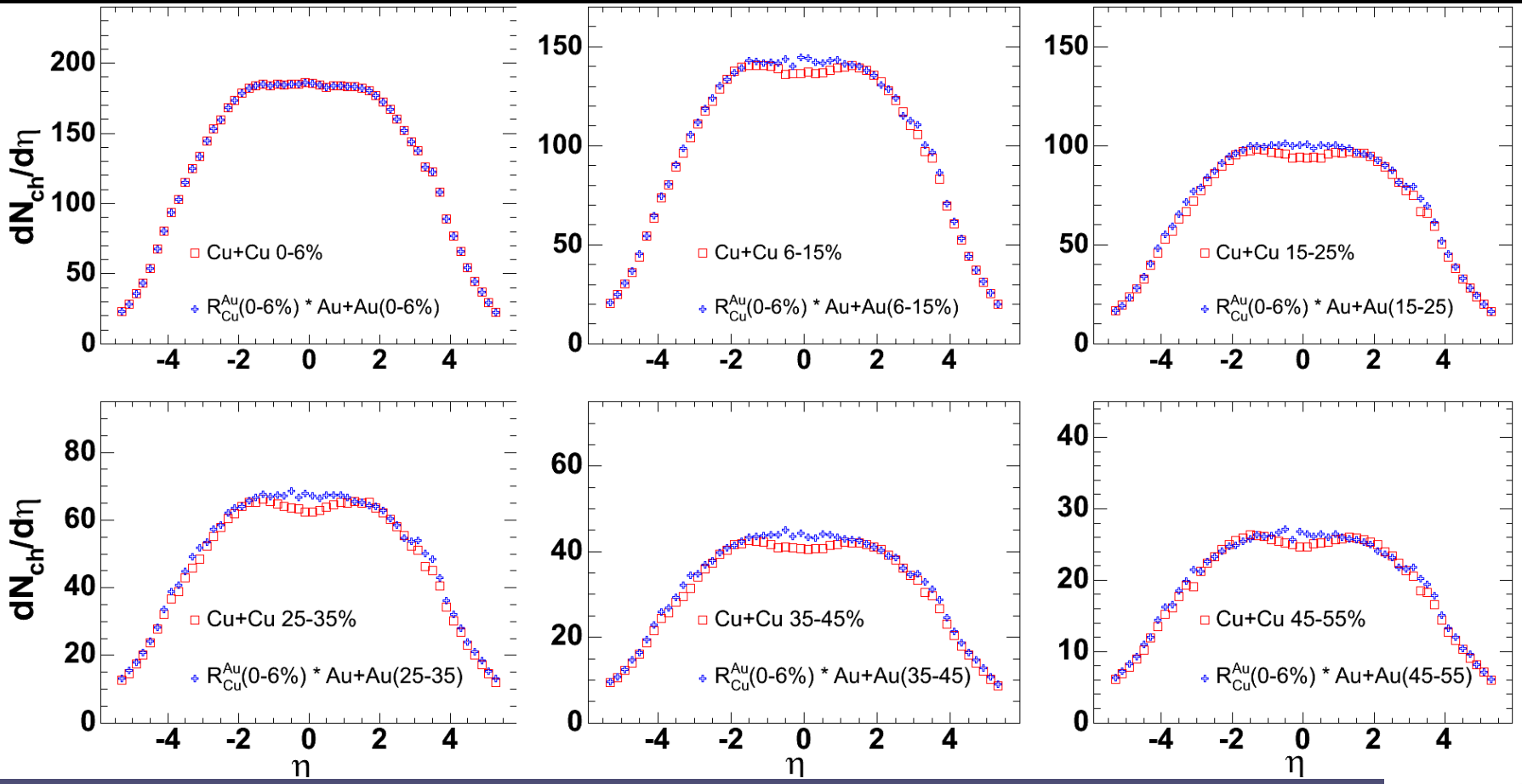
$$\frac{dN^{Fact.}}{d\eta}(Cu+Cu:\ x\%) \stackrel{?}{=} \frac{dN^{Meas.}}{d\eta}(Cu+Cu:\ x\%)$$

Does this factorization work and can we predict the dN/dη distributions of Cu+Cu based on Au+Au?

Overall Factorization of the Pseudorapidity Distributions Au+Au vs Cu+Cu at 200 GeV

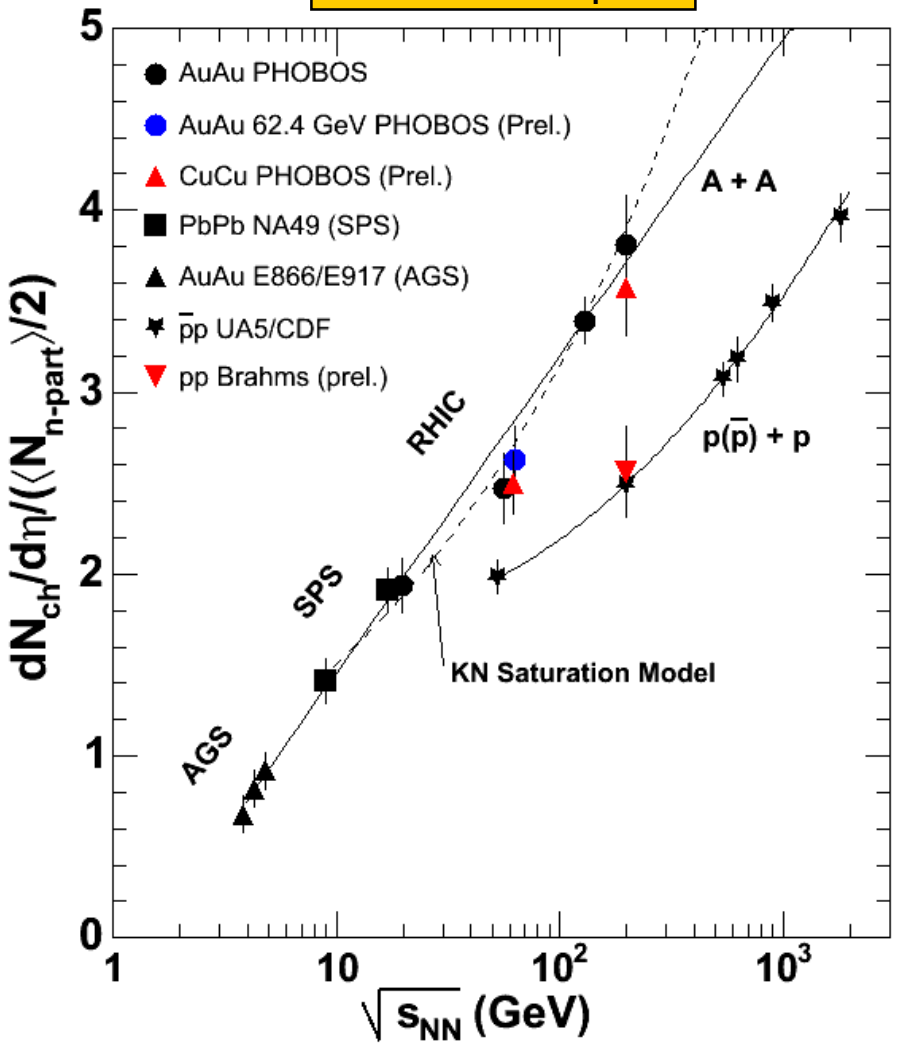
Using data: PRL 93, 082302 (2004) for AuAu **Using PHOBOS (Prel.) QM2005: Cu+Cu at 200 GeV**

YES, the overall factorization of the pseudorapidity distributions is working between Au+Au and Cu+Cu at 200 GeV



Multiparticle Production at Midrapidity $|\eta| < 1$
Interplay between Collision Energy and Collision Geometry
Particle Density per Nucleon in AuAu/CuCu

Scaled to $N_{n\text{-}part}$



Question:
What is the particle density per nucleon in Au+Au/Cu+Cu at the same Energy?

Answer:
they are the same (within systematic errors)

In symmetric collisions Nucleus-Nucleus: it seems the density per nucleon doesn't depend on the size of the two colliding nuclei but it depends on the colliding energy

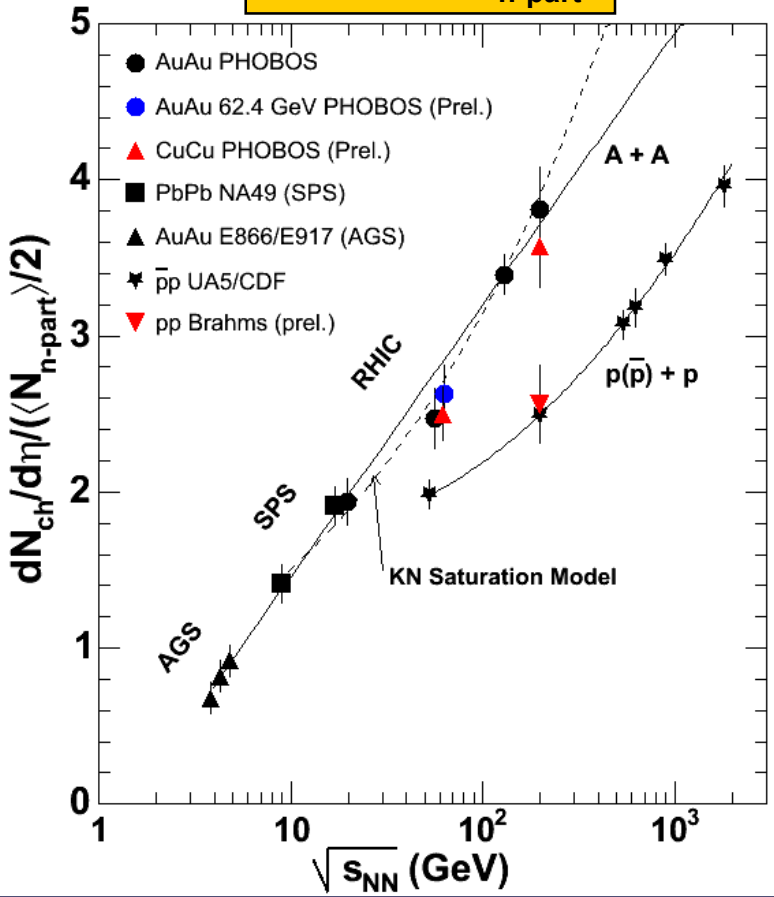
Multiparticle Production at Midrapidity $|\eta| < 1$
Density per Nucleon and Density per Constituent Quarks

Density per Nucleon: $dN/d\eta/0.5*N_{n\text{-}part}$

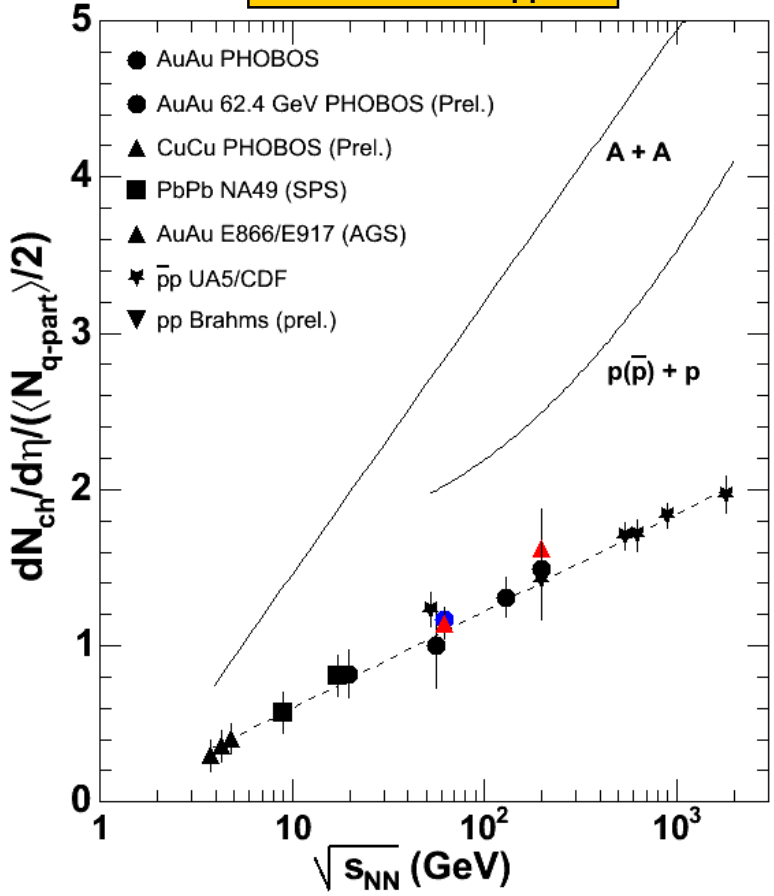
Density per constituent Quark: $dN/d\eta/0.5*N_{q\text{-}part}$

Thanks to Bhaskar De for providing me with the $N_{q\text{-}part}$.

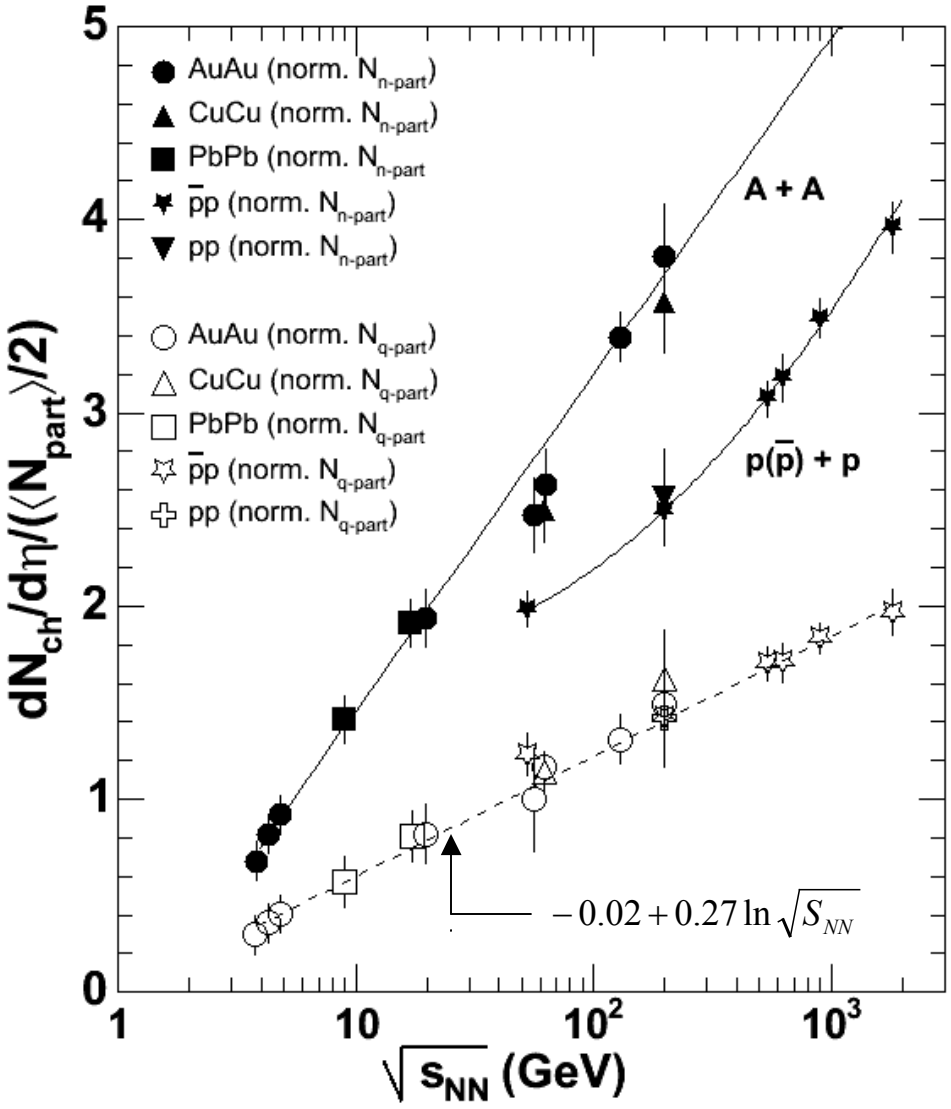
Scaled to $N_{n\text{-}part}$



Scaled to $N_{q\text{-}part}$



Multiparticle Production at Midrapidity $|\eta| < 1$
Density per Nucleon and Density per Constituent Quarks



Definitions:

Density per Nucleon: $dN/d\eta/0.5*N_{n\text{-}part}$

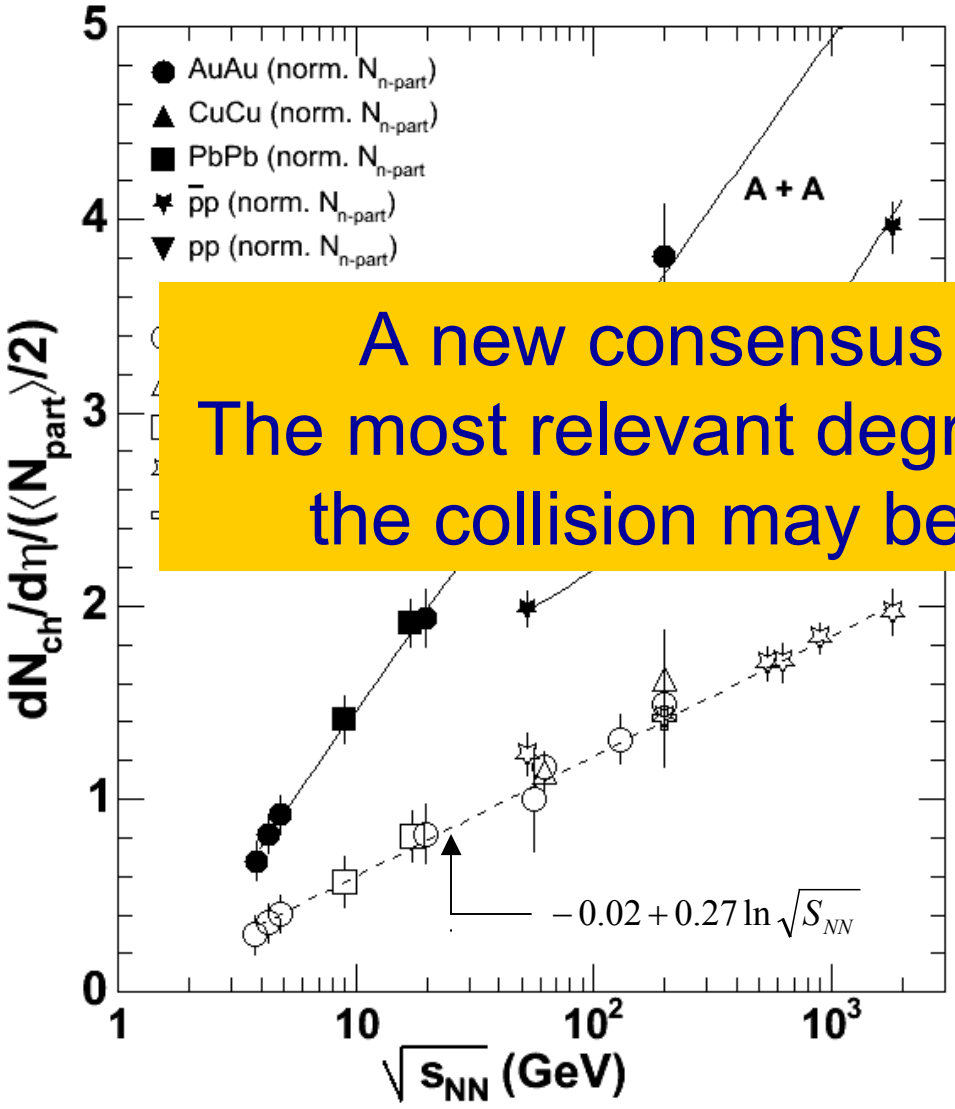
Density per Constituent Quark: $dN/d\eta/0.5*N_{q\text{-}part}$

At the same energy in C.M.

- <u>DENSITY PER NUCLEON</u> is similar between Au+Au and Cu+Cu but it's higher than p+p

- <u>DENSITY PER CONSTITUENT QUARKS</u> same in all systems Au+Au, Cu+Cu and pp

Multiparticle Production at Midrapidity $|\eta| < 1$
Density per Nucleon and Density per Constituent Quarks



Definitions:

Density per Nucleon: dN/dh/0.5*$N_{n\text{-}part}$

Density per Constituent Quark: dN/dh/0.5*$N_{q\text{-}part}$

A new consensus may be emerging.
The most relevant degrees of freedom early in the collision may be constituent quarks.

and Cu+Cu but it's higher than p+p

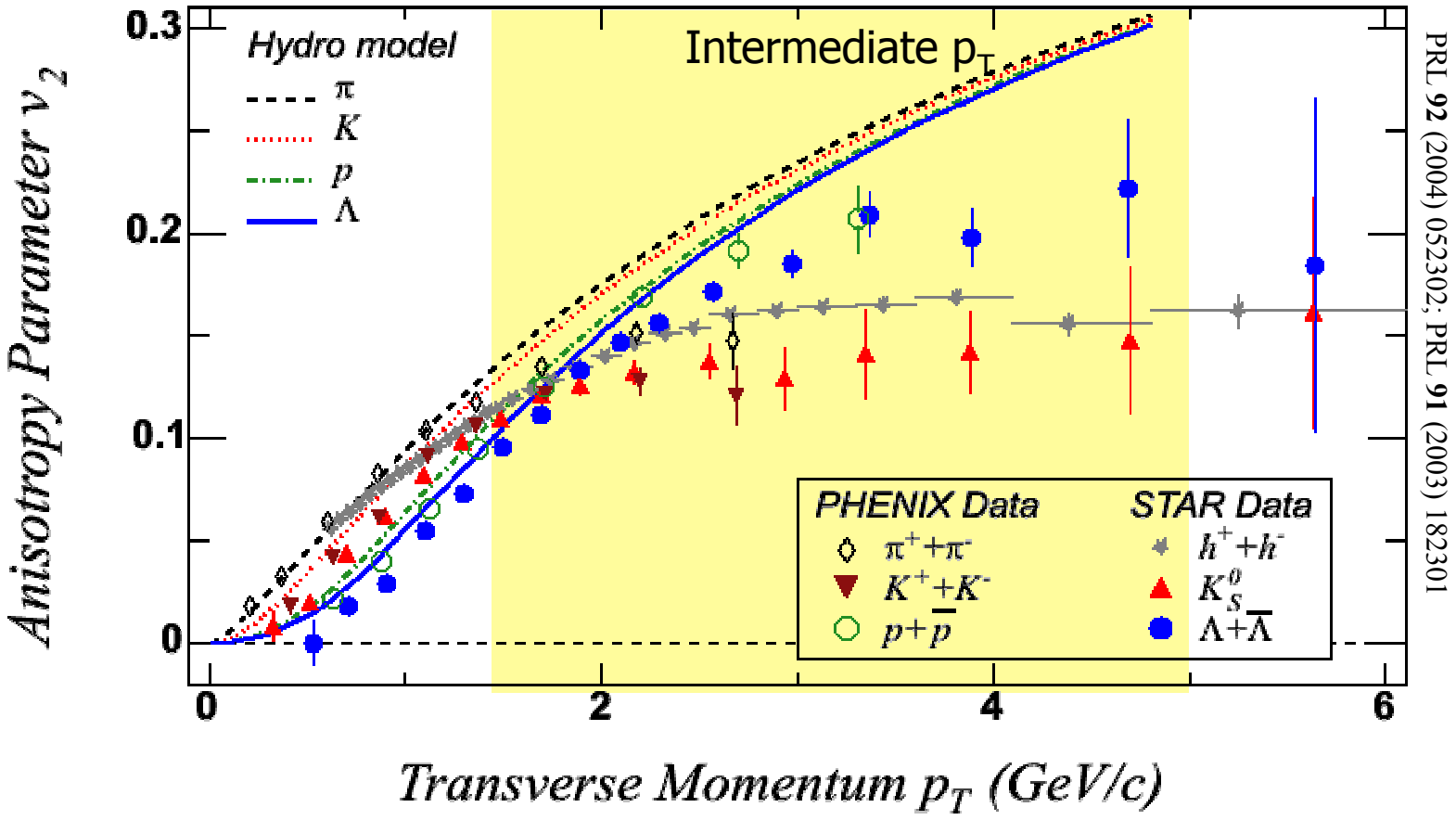
- <u>DENSITY PER CONSTITUENT QUARKS</u>

same in all systems Au+Au, Cu+Cu and pp

v_2 vs. p_T

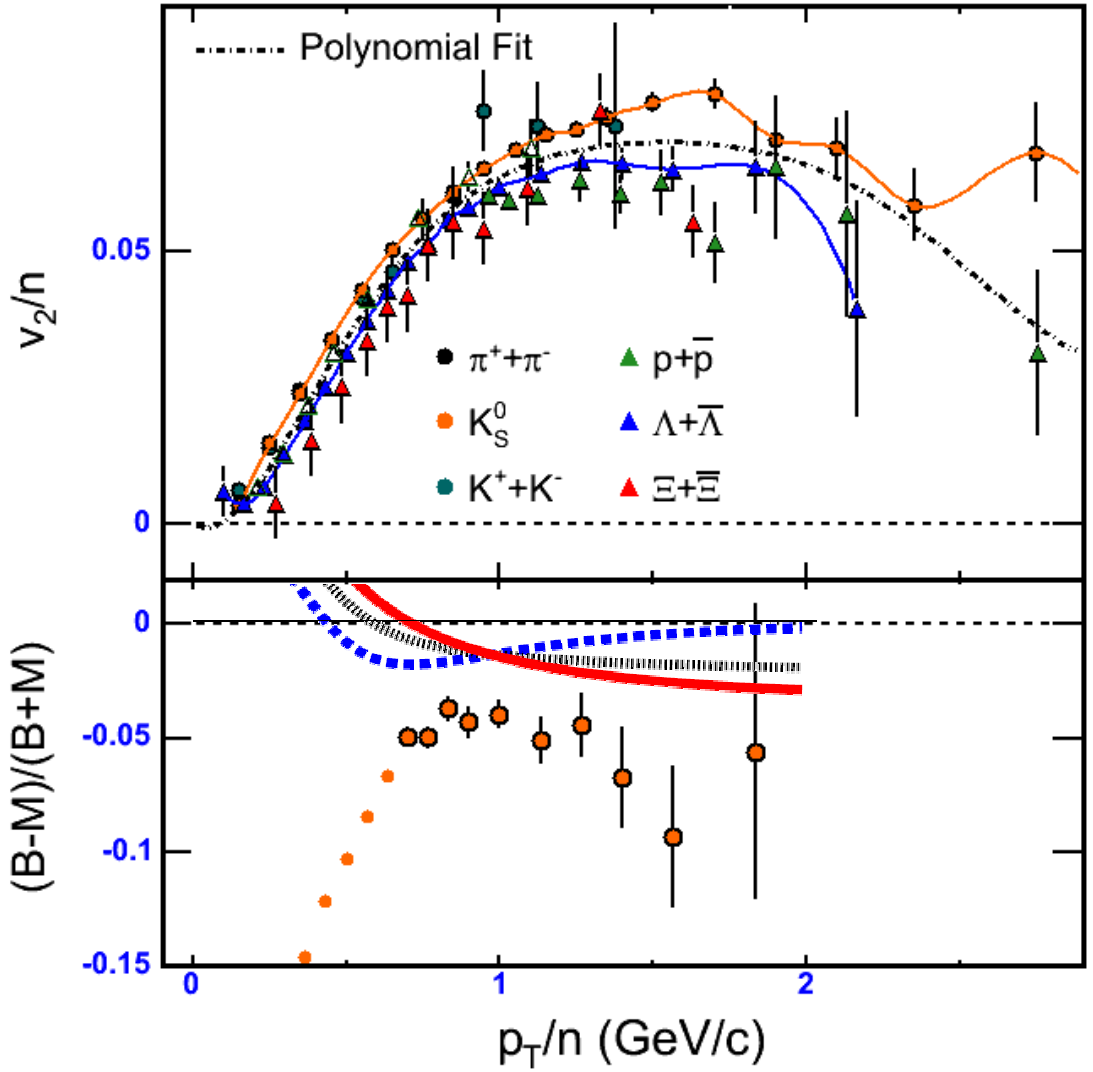
Large values indicate strong sensitivity to the system geometry for production at all measured p_T

v_2 at intermediate p_T is grouped by quark number

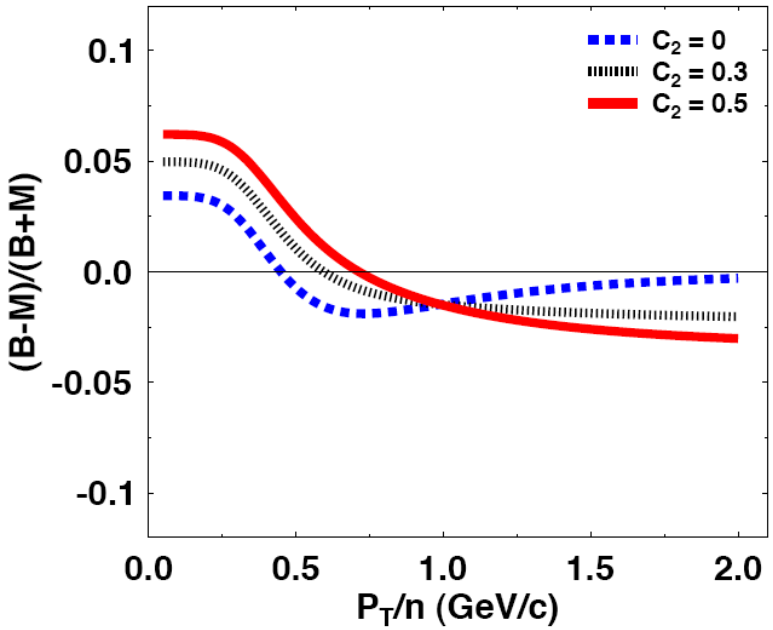


PRL **92** (2004) 052302; PRL **91** (2003) 182301

Comparison to Predictions



Inclusion of gluons in recombination was predicted to lead to a larger meson v_2/n than baryon v_2/n:
B.Müller, et al. nucl-th/0503003

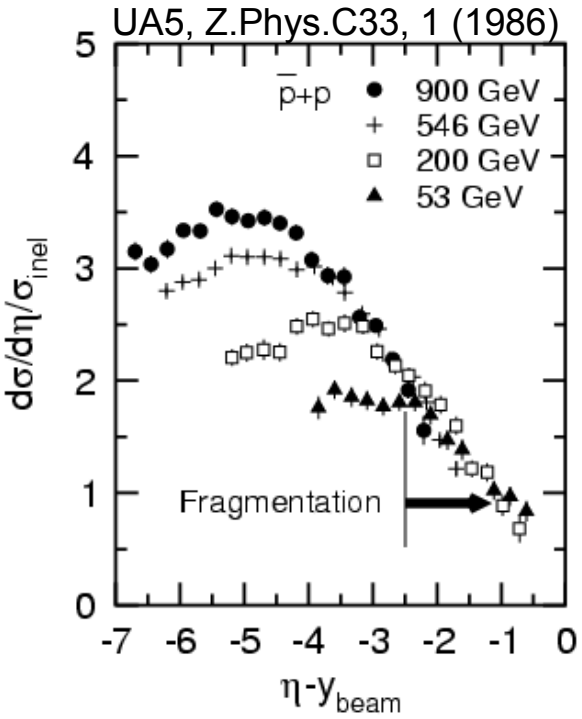


Tantalizing indication for the fate of gluons and the nature of the constituents
Systematic errors on the data and calculations need to be carefully addressed

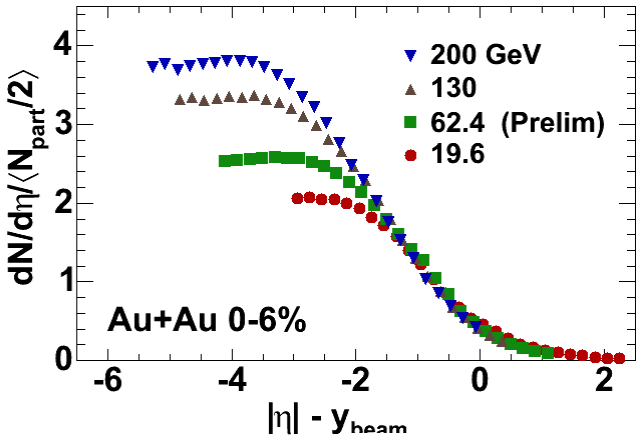
Charged Particle Production in forward Regions

Extended Longitudinal Scaling "Limiting Fragmentation" Scenario

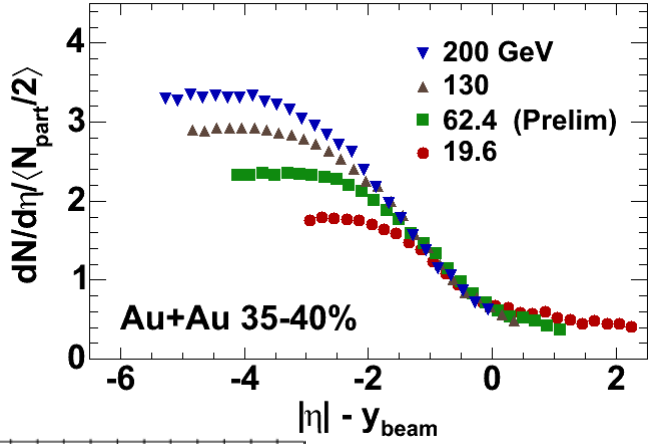
$\bar{p}$+p Collisions

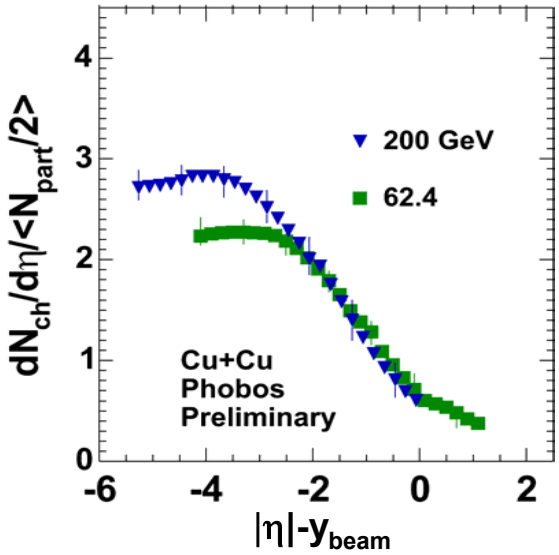


Au+Au Central Collisions



Au+Au peripheral Collisions





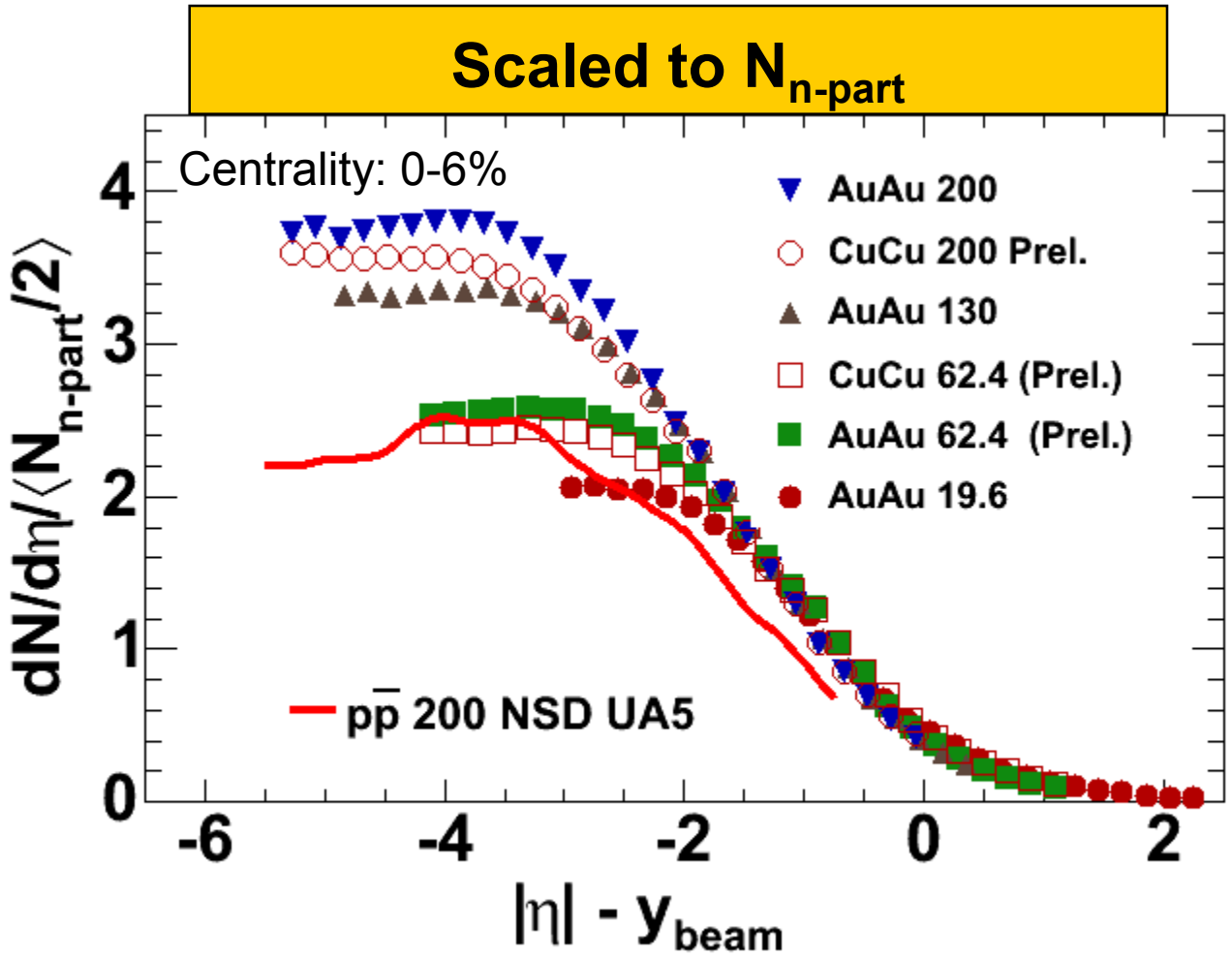
Cu+Cu Central Collisions

The extended longitudinal scaling is independent of the system size and it's grows as function of energy

Using data: PRL 93, 082302 (2004) for AuAu **Using PHOBOS (Prel.) QM2005: Cu+Cu at 200 and 62.4 GeV**

Charged Particle Production in forward Regions

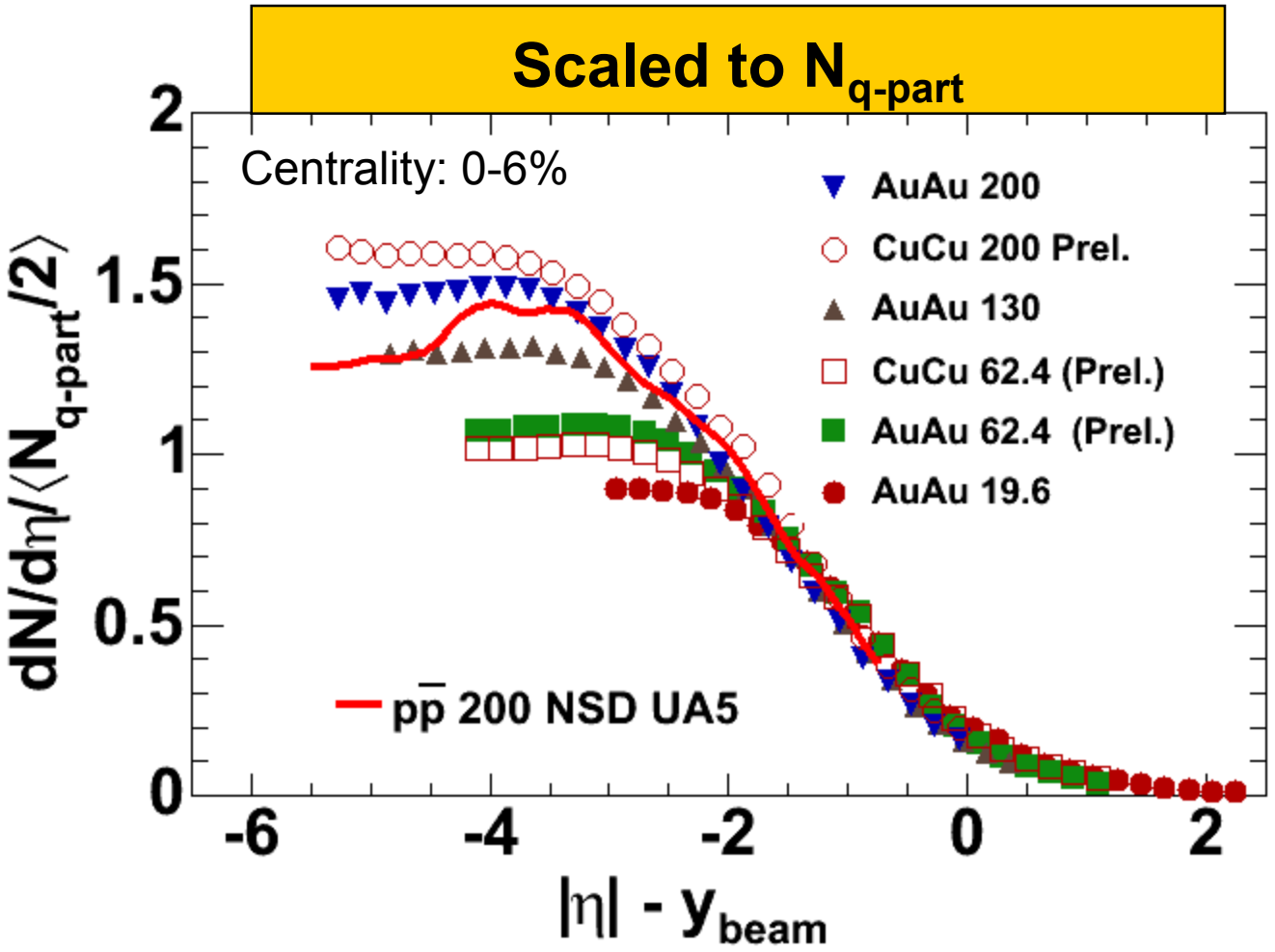
Extended Longitudinal Scaling "Limiting Fragmentation" Scenario



Until today, there is no clean description of how AA and pp differ
In the limiting fragmentation region

Charged Particle Production in forward Regions

Extended Longitudinal Scaling "Limiting Fragmentation" Scenario



If we Scale by the Constituent Quark Participants, AA and pp Collisions are the SAME.

Summary

- THE RHIC program is an incredible success
- At QM 2005, very impressive amount of experimental results from all over the word have been presented and are very interesting.
- The data are often simpler than the interpretations
- My main points in this talk are very simple:
  - In the Constituent Quarks Framework (CQF):

    the initial states in AA and pp collisions are SIMILAR
  - A lot of physics results which are not understood in the nucleon framework can be well explain in the constituent quarks framework.