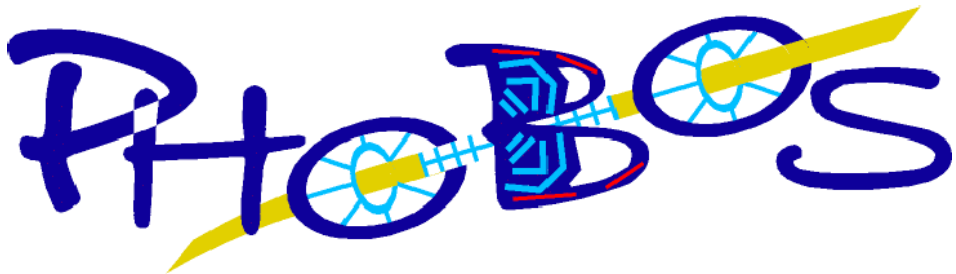
DoE Review of RHIC Program

9 July 2003



Wit Busza

PHOBOS Collaboration

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NATIONAL CENTRAL UNIVERSITY, TAIWAN
UNIVERSITY OF ILLINOIS AT CHICAGO
UNIVERSITY OF MARYLAND
UNIVERSITY OF ROCHESTER

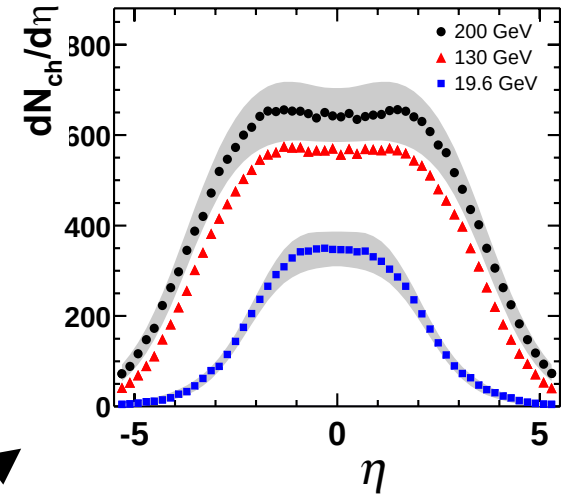
To date: 3 PhDs

Currently:16 PhD students

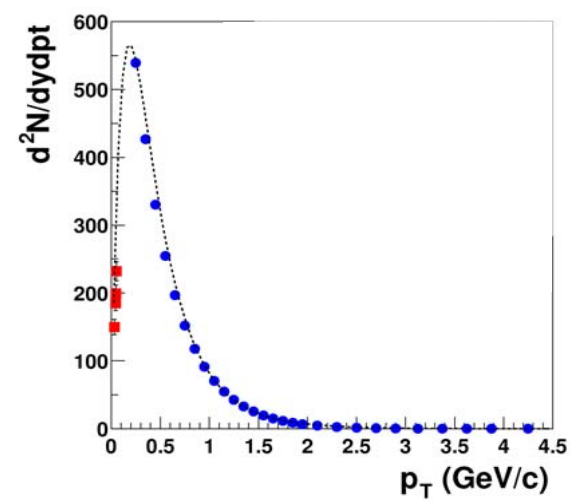
4-detector strategy for the initial RHIC program has turned out to be excellent:

- Adequate overlap
  - Impressive agreement between all experiments
- Complementary

Early "Big Picture"



Low P_t Phenomena



PHOBOS Mission

Flexibility to Respond to First Results

We would have liked

- More data
- Energy scan
- Species scan
- A larger BNL Group

BUT

Bottom line:

RHIC environment has been good for PHOBOS

- Strong support
  - -from management
    - ~for BNL Group
    - ~for 20 GeV Run
  - -from CAD

Result:

- PHOBOS has achieved to date more than we could have hoped for
- >50% of our mission complete

*Charged particle multiplicity near mid-rapidity in central Au+Au collisions at $\sqrt{s_{NN}}$ = 56 and 130 AGeV
Phys. Rev. Lett. 85, 3100 (2000) {first published results from RHIC data}

* Ratios of charged particles to antiparticles near mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV
Phys. Rev. Lett. 87, 102301 (2001)

*Charged-particle pseudorapidity density distributions from Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV
Phys. Rev. Lett. 87, 102303 (2001)

*Centrality Dependence of Charged Particle Multiplicity at Midrapidity in Au+Au Collisions at $\sqrt{s_{NN}}$ =130 GeV
Phys. Rev. C65, 31901R (2002).

*Energy dependence of particle multiplicities near mid-rapidity in central Au+Au collisions
Phys. Rev. Lett. 88, 22302 (2002) {first published results from data at maximum energy}

*Centrality Dependence of the Charged Particle Multiplicity near Mid-Rapidity in Au+Au Collisions at $\sqrt{s_{NN}}$ =130 and 200 GeV
Phys. Rev. C65, 061901R (2002).

*Pseudorapidity and centrality dependence of the collective flow of charged particles in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV
Phys. Rev. Lett. 89, 222301 (2002)

*Ratios of charged antiparticles to particles near mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV
Phys. Rev. C 67, 021901R (2003)

*The significance of the fragmentation region in ultrarelativistic heavy ion collisions
Phys. Rev. Lett (In press).

*Comparison of the Total Charged-Particle Multiplicity in High-Energy Heavy Ion Collisions with e+e- and pp/pbar-p Data
Submitted to Phys. Rev. Lett.

*Charged hadron transverse momentum distributions in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
Submitted to Phys. Lett.B

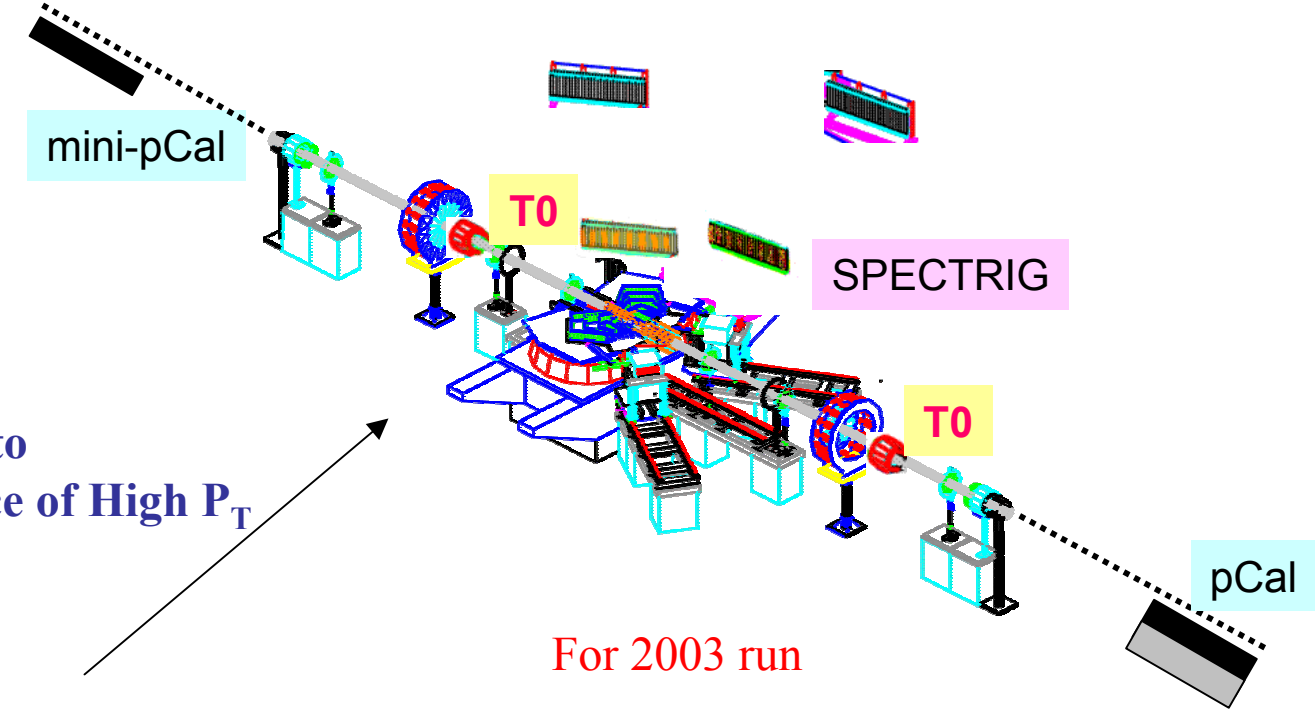
*Centrality Dependence of the Charged Hadron Transverse Momentum Spectra in d+Au Collisions at $\sqrt{s_{NN}}$ =200 GeV
Submitted to Phys. Rev. Lett. {jointly with STAR and PHENIX, first results from dAu run}

>400 citations

>150 citations first paper

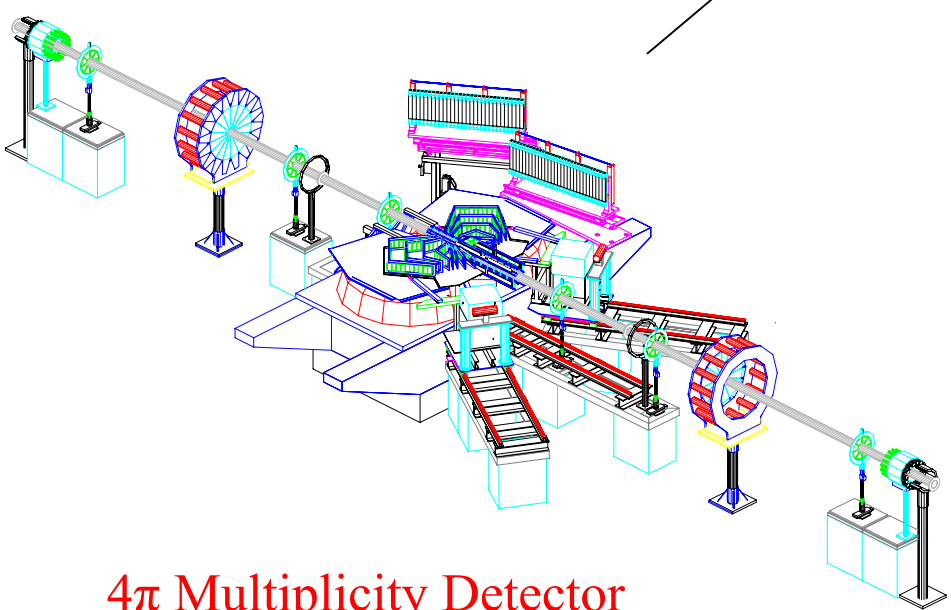
>36 citations/paper

Flexibility to respond to results:



For 2003 run

Response to Importance of High P_T Studies



4π Multiplicity Detector

2 Arm Multiparticle Spectrometer

i. **Moved TOF walls back**
   - **5 m from interaction point**

ii. **New on-line high p_T Spectrometer Trigger**

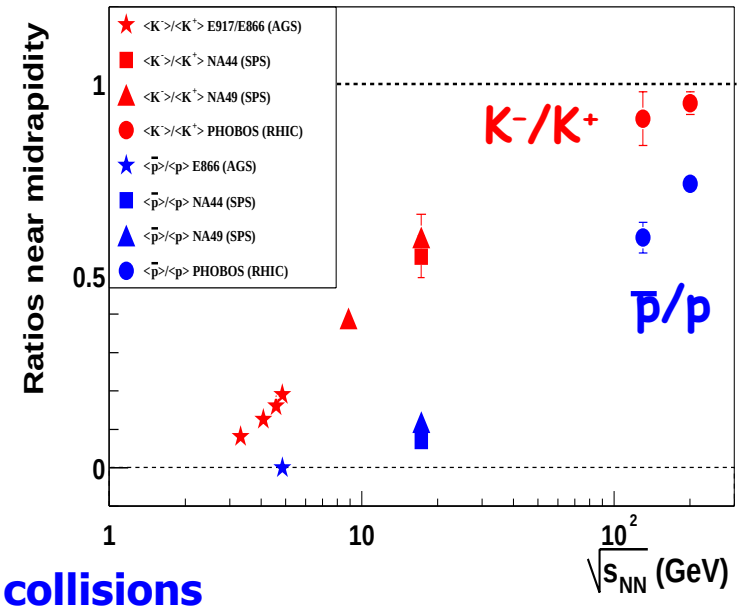
iii. **New "time-zero" (T0) Cerenkov detectors**
   - **On-line vertexing and ToF start time**

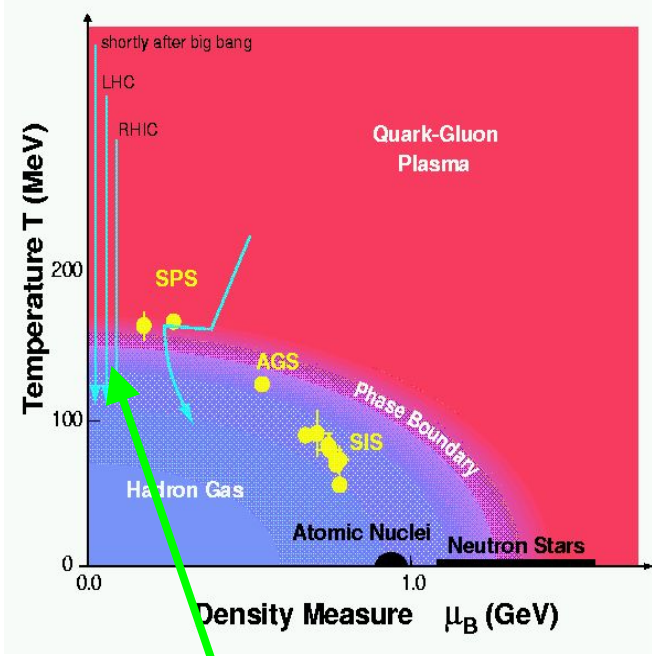
iv. **Forward proton calorimeters on Gold and Deuteron sides**

v. **DAQ upgrade (x10)**

What is the “Big Picture” as seen by PHOBOS?

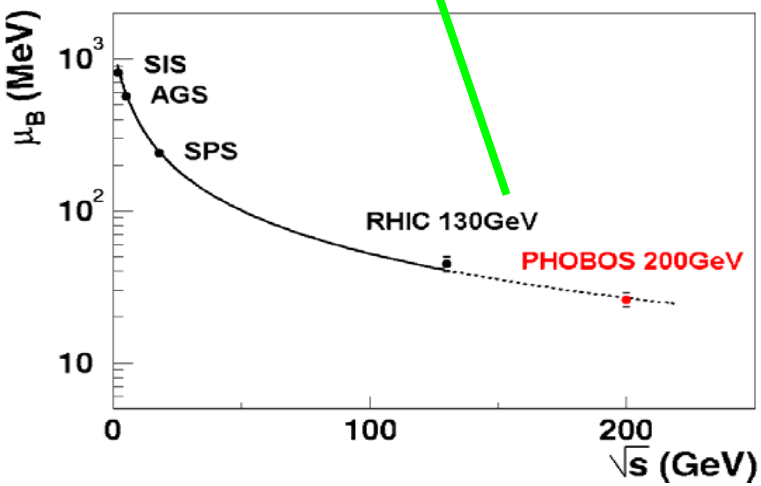
Baryon density at mid-rapidity rapidly decreases with energy



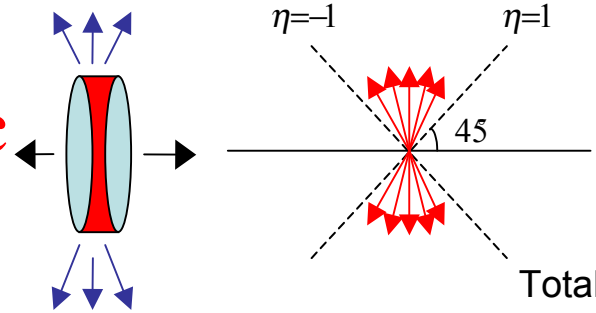


A+A central collisions

- PHOBOS 130 GeV
  PRL 87,102301,2001
- PHOBOS 200 GeV
  PRC 67, 021901(R), 2003



Energy density high; system must be partonic



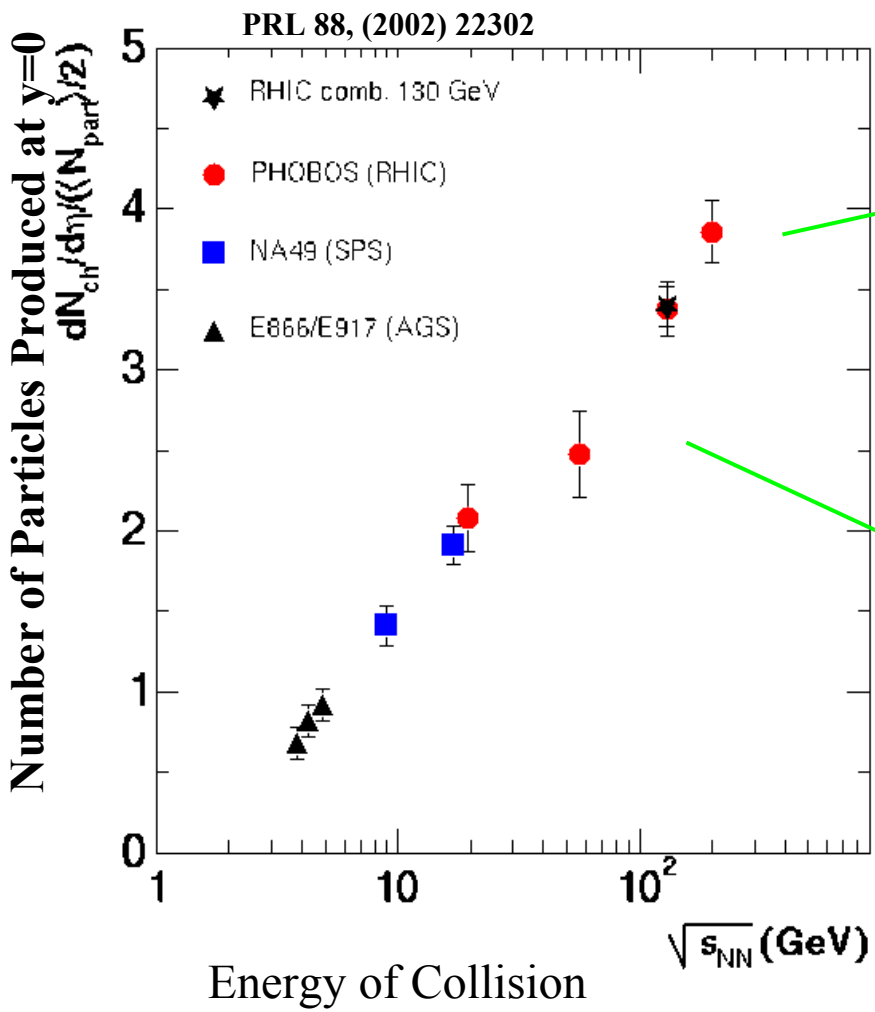
$$\left(\frac{dN}{d\eta}\right)_{all} \sim 1000$$

$$\langle E \rangle \sim 1GeV$$

Total energy released ~2000GeV

Max. initial overlap volume

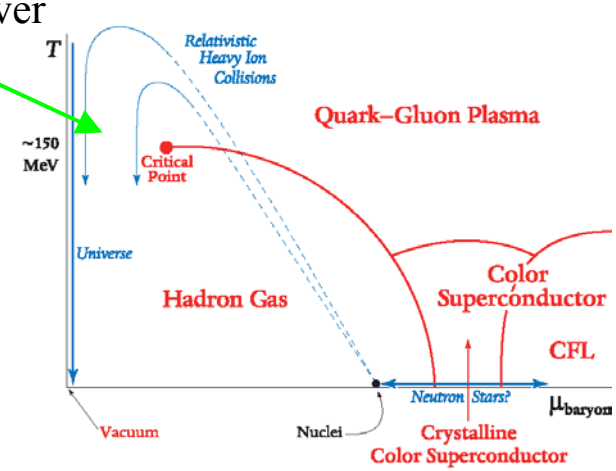
$$\sim \pi R^2 (1fm) \sim 200 fm^3$$



Initially released energy density >5GeV/fm^3

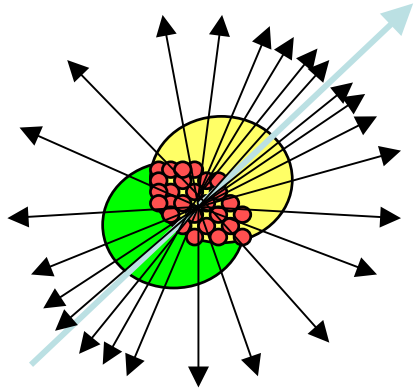
Note: energy density inside proton ≈ 0. 5GeV/fm^3

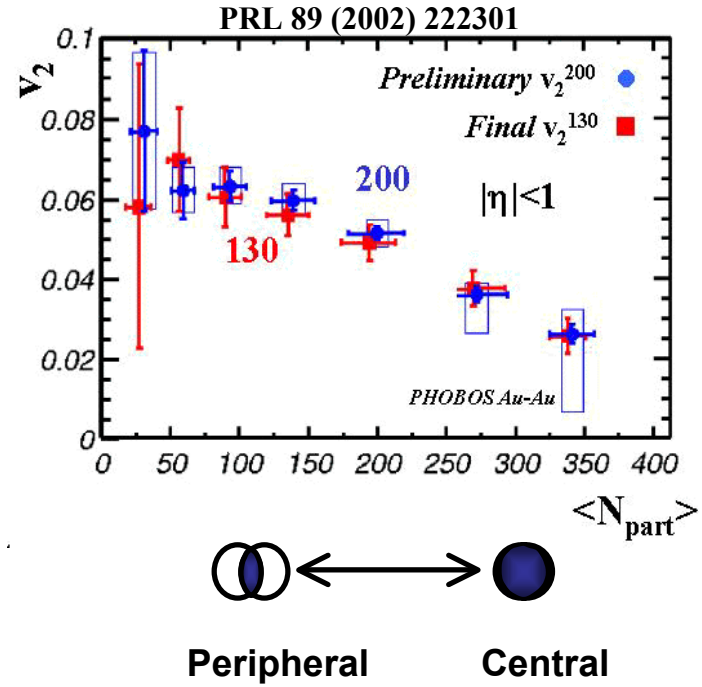
crossover

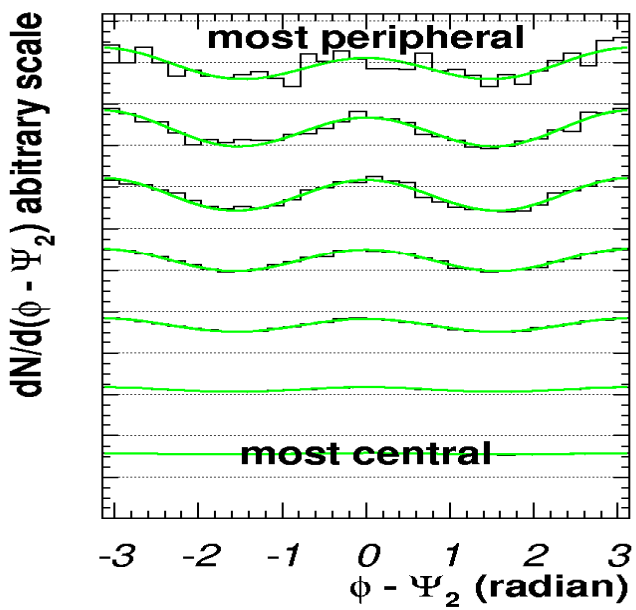


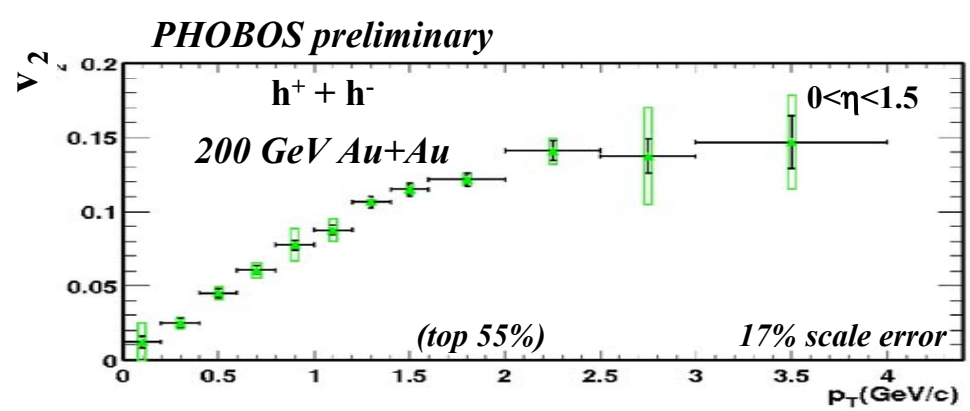
Medium is highly interactive

Elliptic flow:

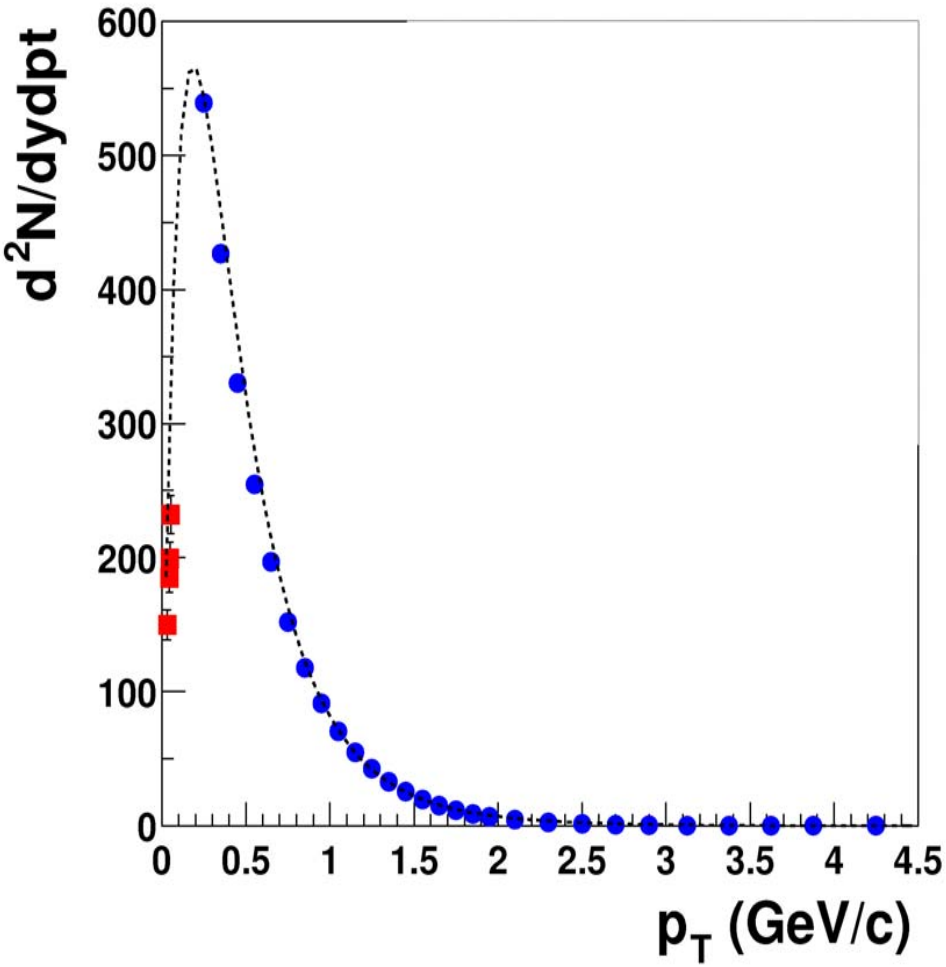


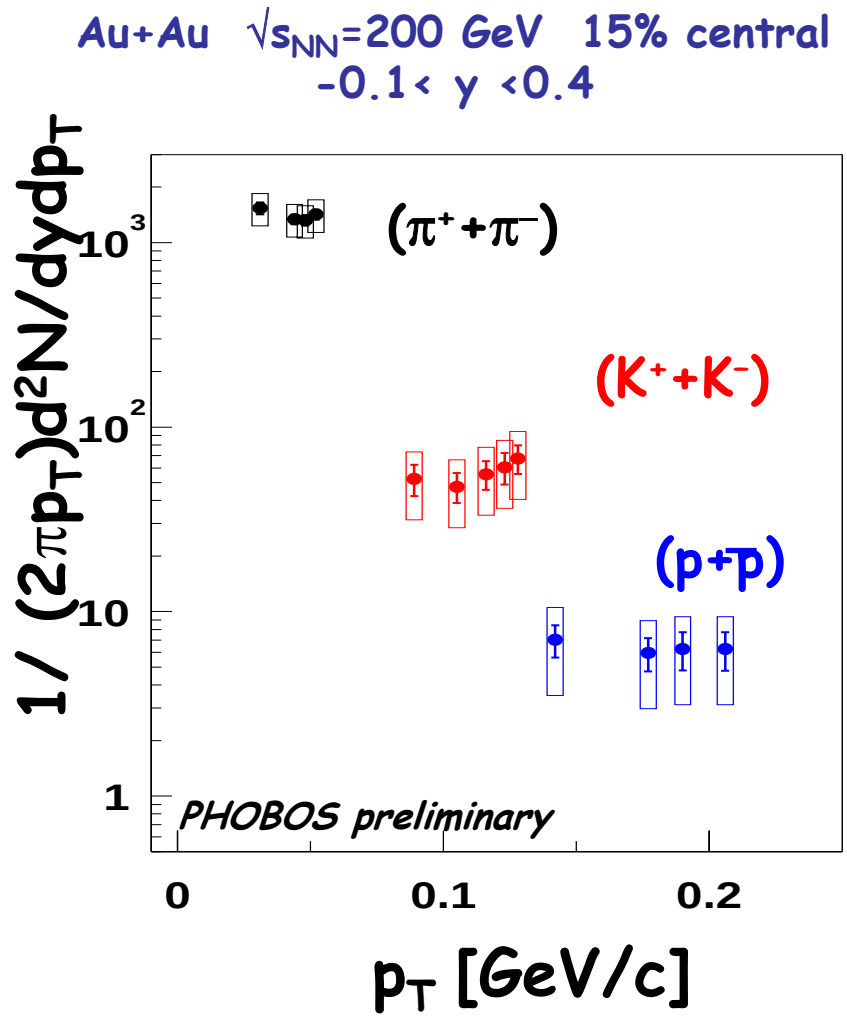




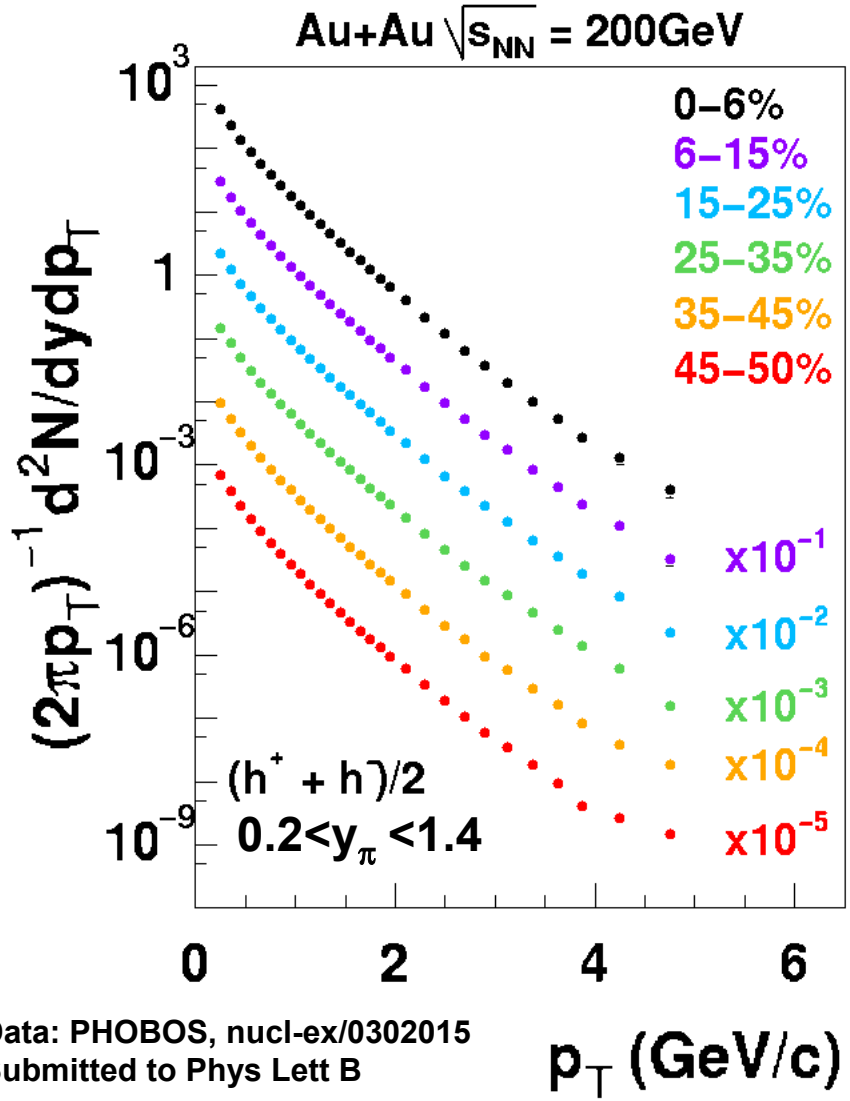


Very few low momentum particles because of flow

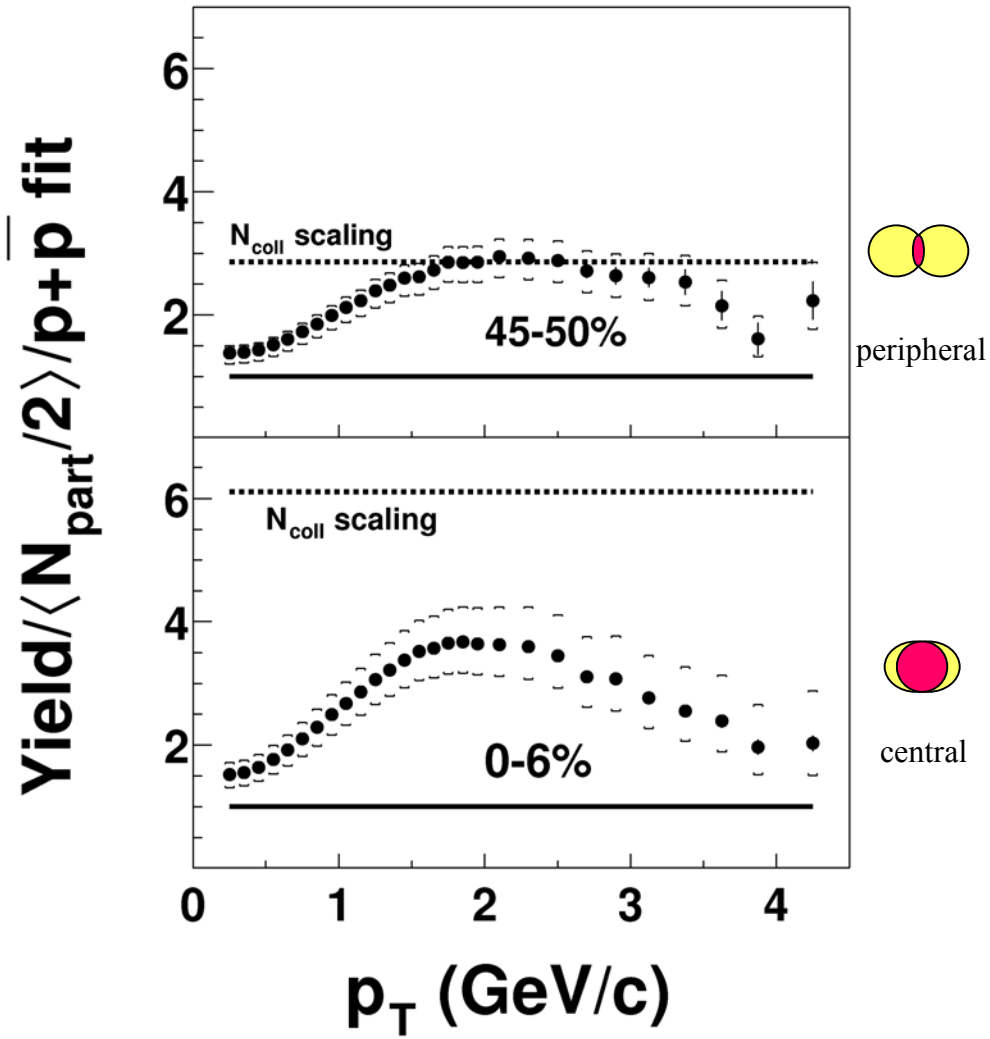




Jet-quenching: further evidence that medium interacts strongly and that parton density is very high.

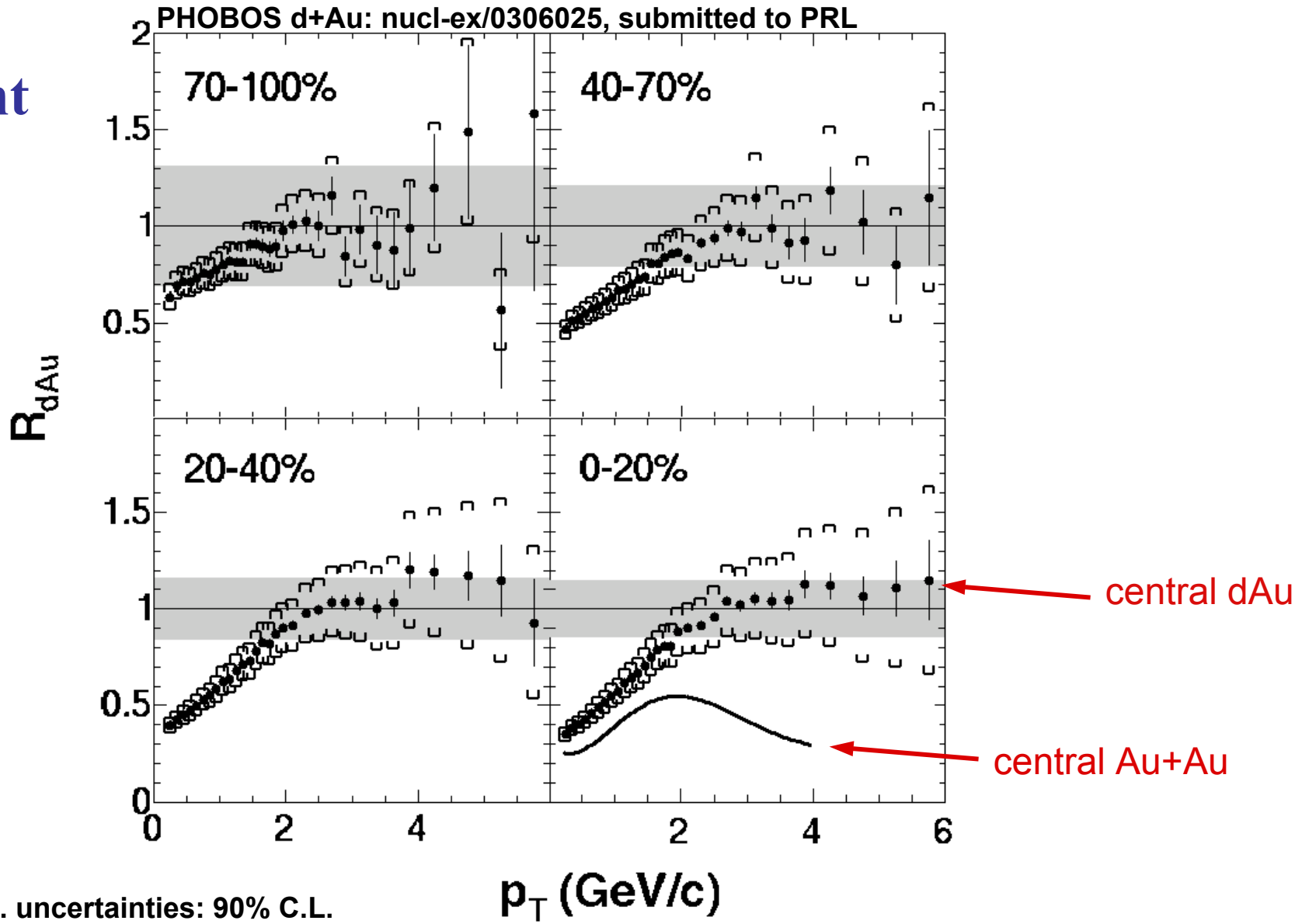


Data: PHOBOS, nucl-ex/0302015
Submitted to Phys Lett B



Jet-quenching is not an initial state effect!

recent dAu data

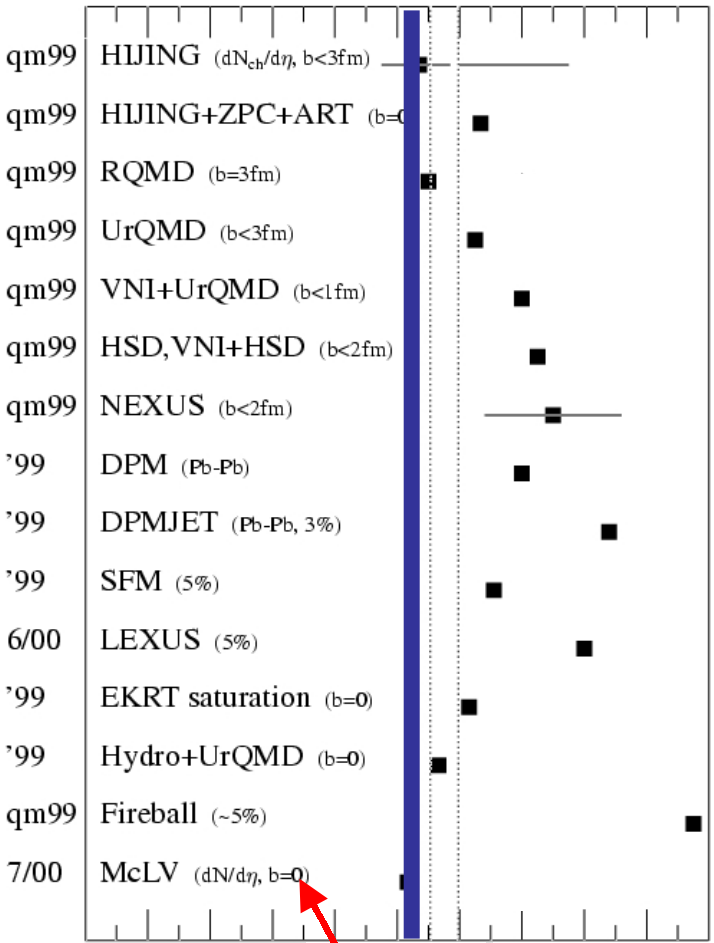


All syst. uncertainties: 90% C.L.

Comparisons with models

Particle Multiplicity

PHOBOS Central Au+Au (200 GeV)



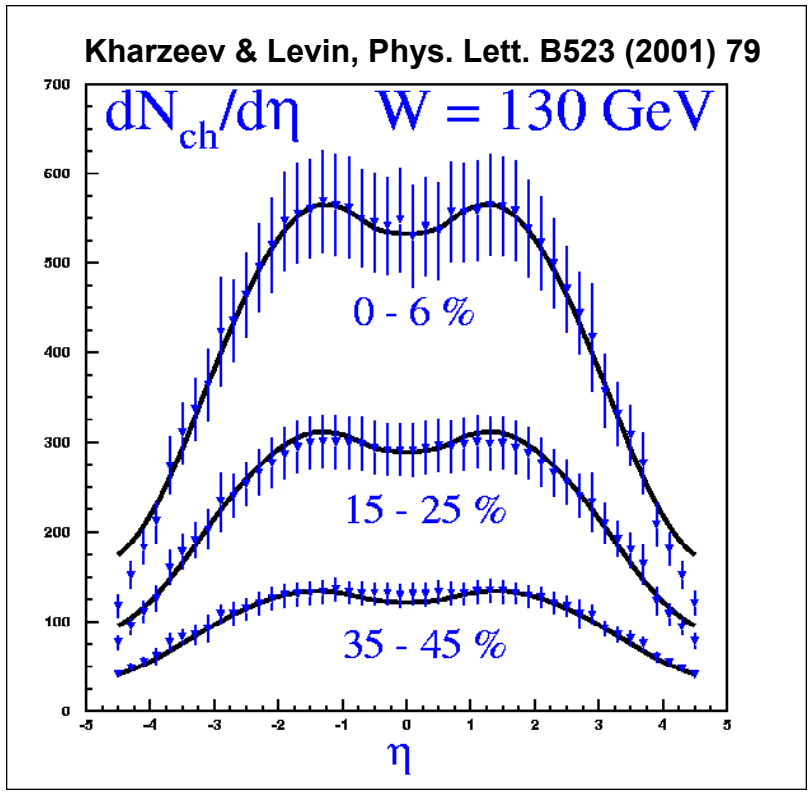
Color Glass

Rapidity Density

From Eskola, QM 2000

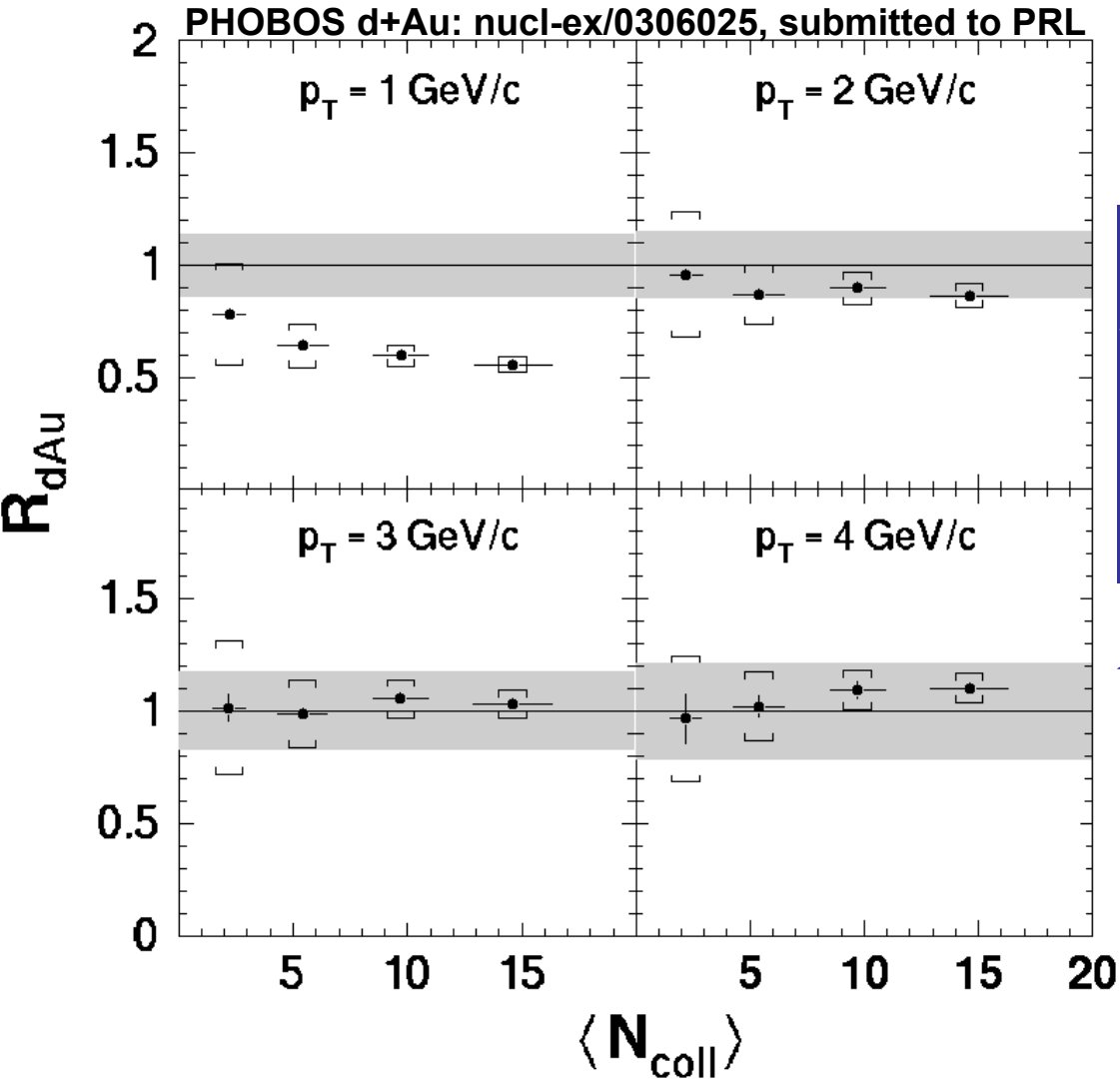
Hadron multiplicities at RHIC well described by Parton Saturation

Kharzeev & Levin, Phys. Lett. B523 (2001) 79



Data: PHOBOS, Phys. Rev. Lett. 87, 102303 (2001)

dAu data disfavor initial state interpretation of Au+Au high-p_T suppression



For example,

Vitev(pQCD) predicts 15% increase

Kharzeev, Levin, McLerran (parton saturation) predict 25-30% decrease over this range of centrality

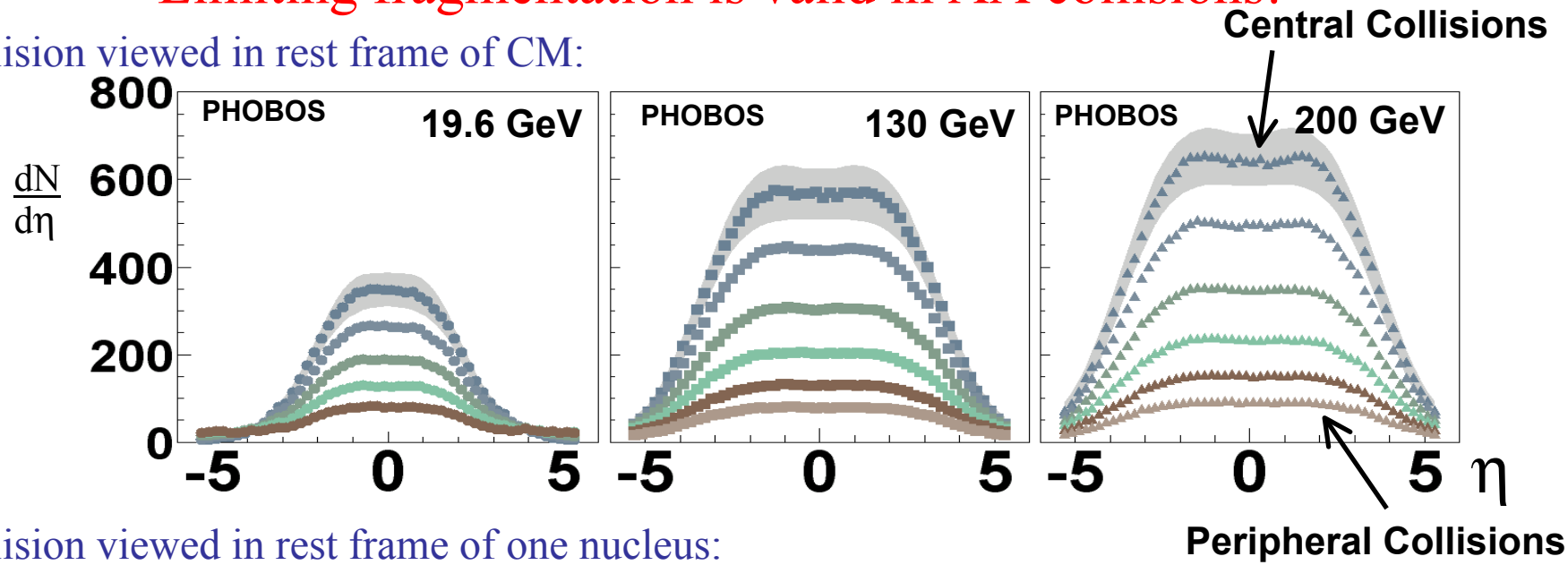
All syst. uncertainties: 90% C.L.

Some surprises

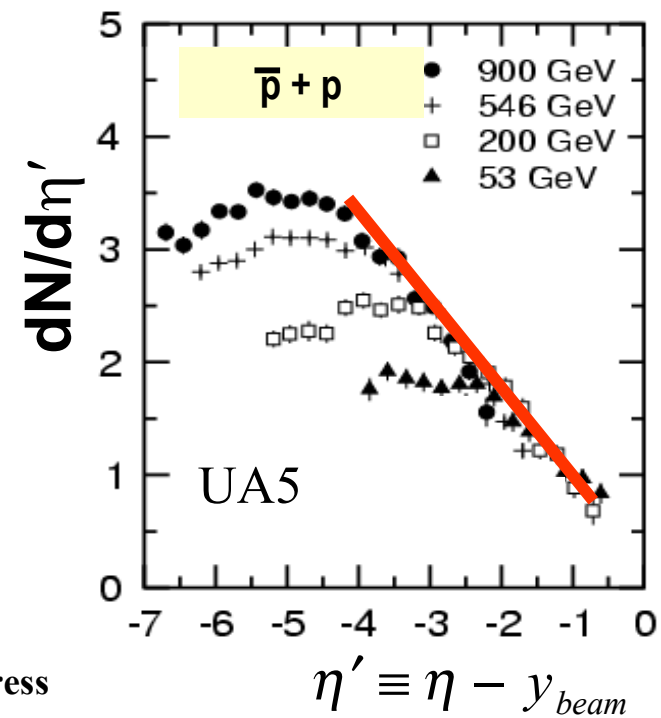
Accidental, trivial or profound?

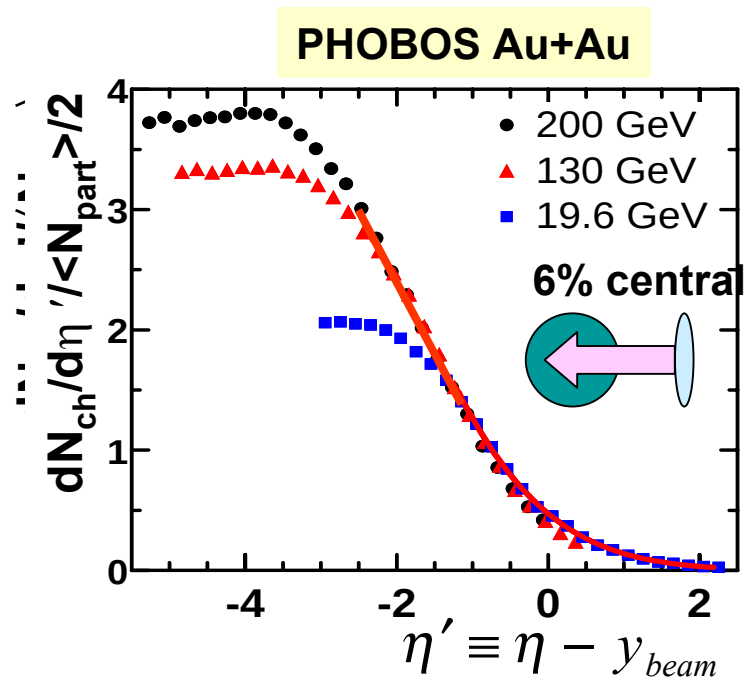
Limiting fragmentation is valid in AA collisions!

Collision viewed in rest frame of CM:



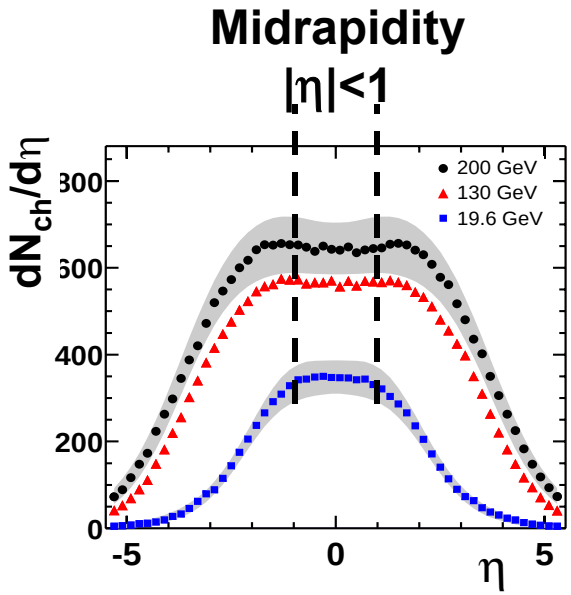
Collision viewed in rest frame of one nucleus:



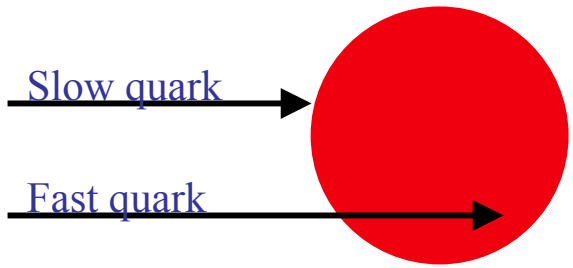


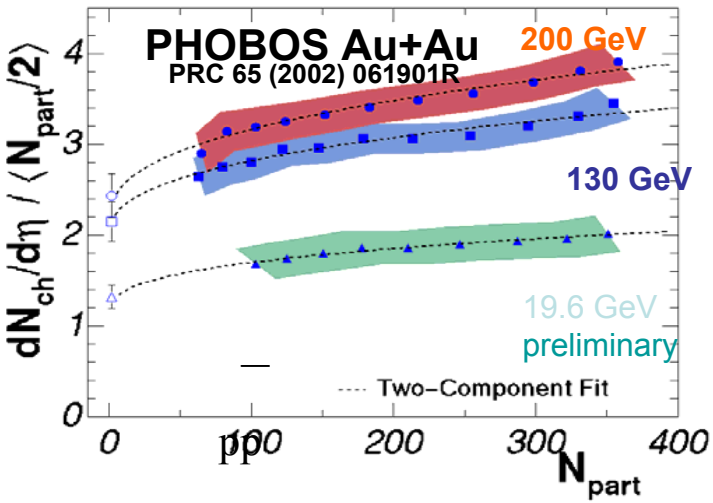
PRL in press

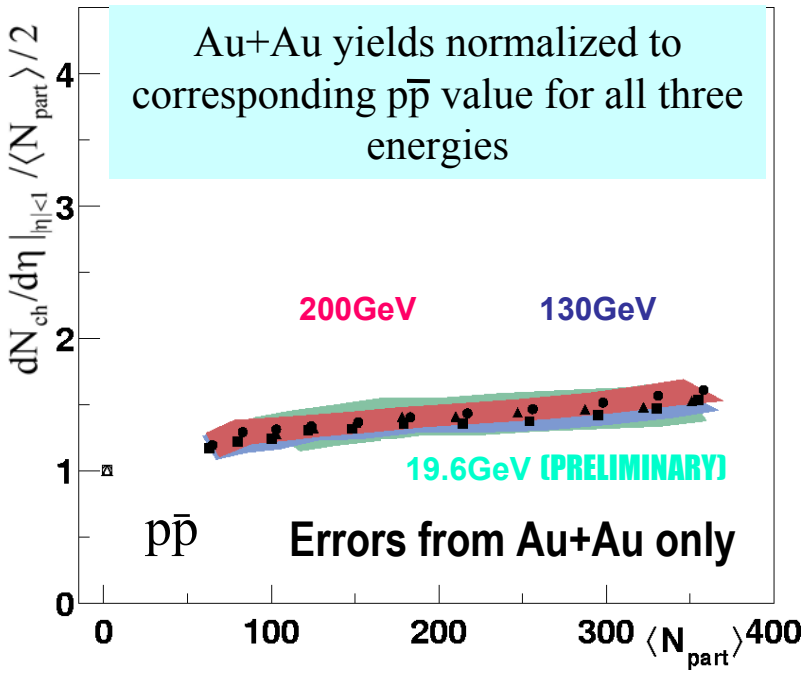
Scaling with N_{part} of midrapidity multiplicity inconsistent with naïve expectations:



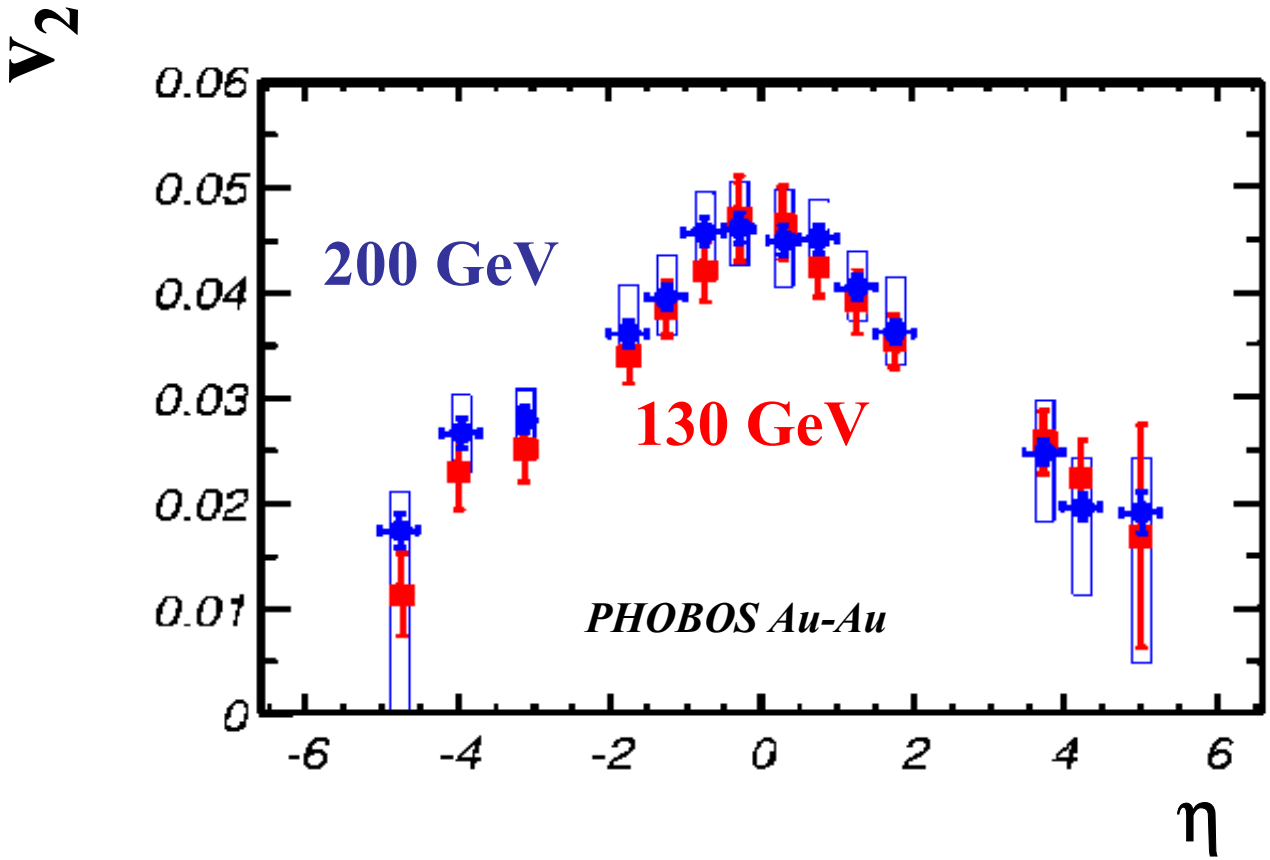
Data inconsistent with the following picture:







Flow is anything but boost invariant!



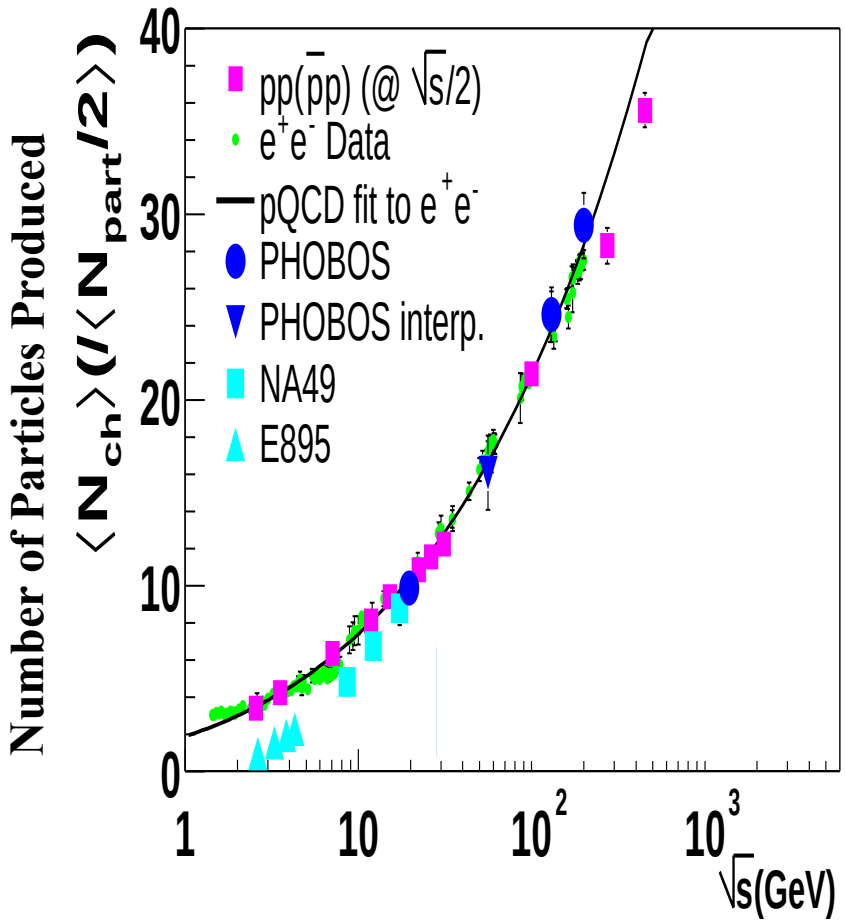
Preliminary v_2^{200}

Final v_2^{130}

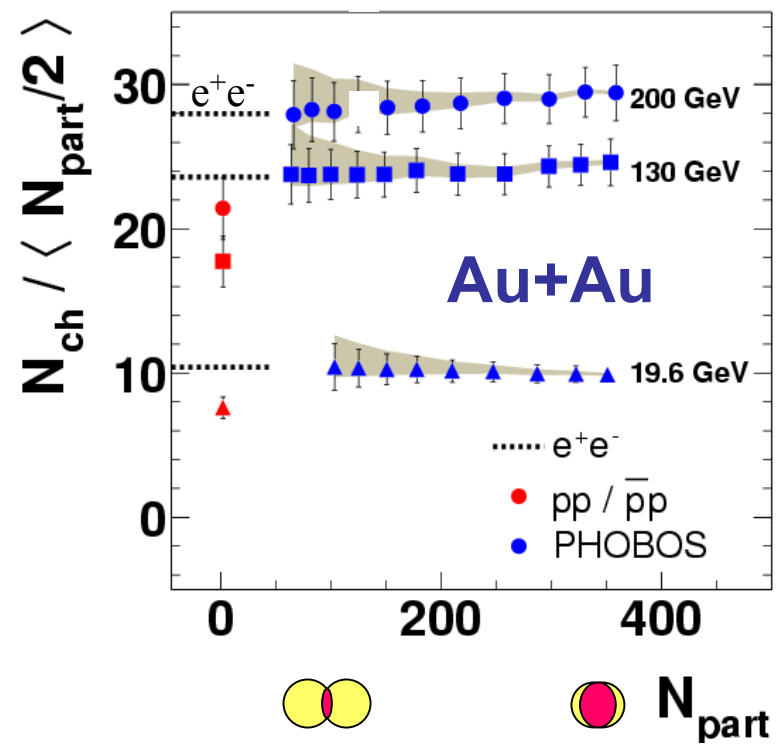
PRL **89**, 222301

$\langle N_{part} \rangle \sim 190$

Amazing similarity of multiplicity in e^+e^- and AA collisions



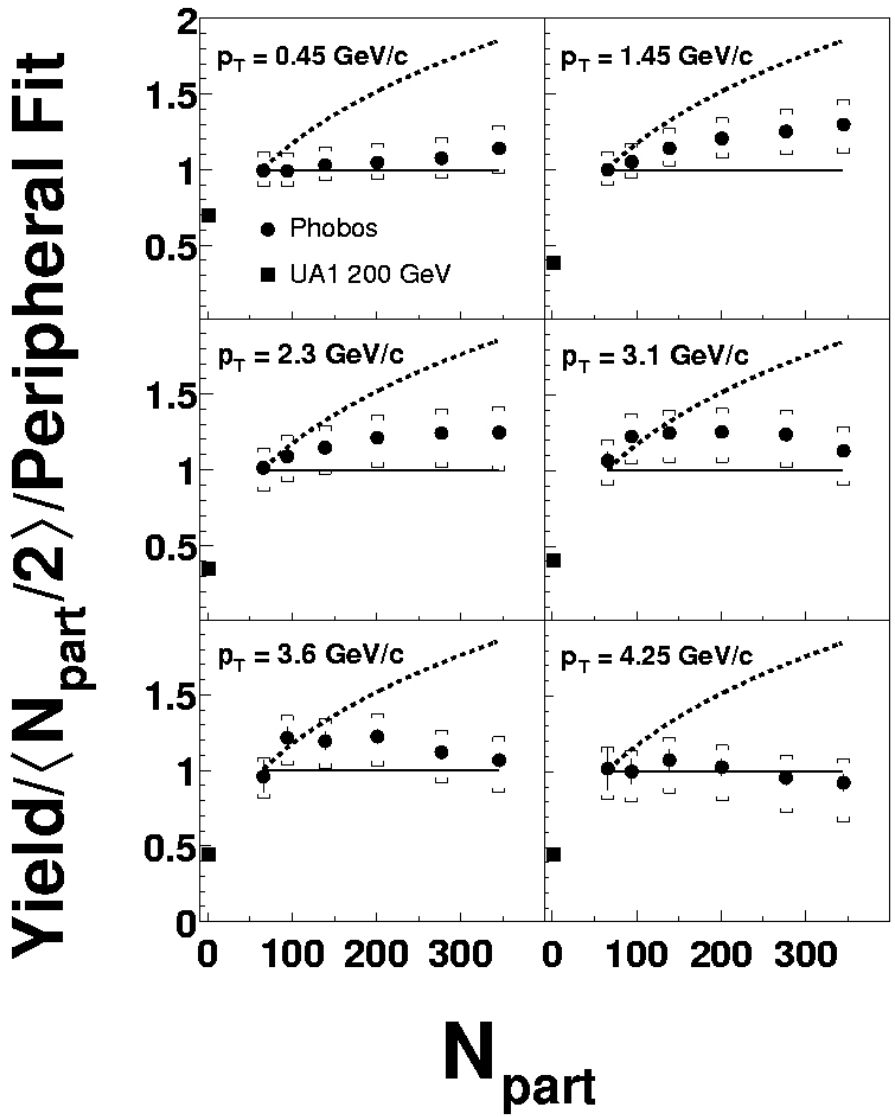
Energy of Collision



Submitted to PRL

Why high P_T particle yield scales approximately with N_{part}?

PHOBOS, nucl-ex/0302015,submitted to Phys. Lett. B



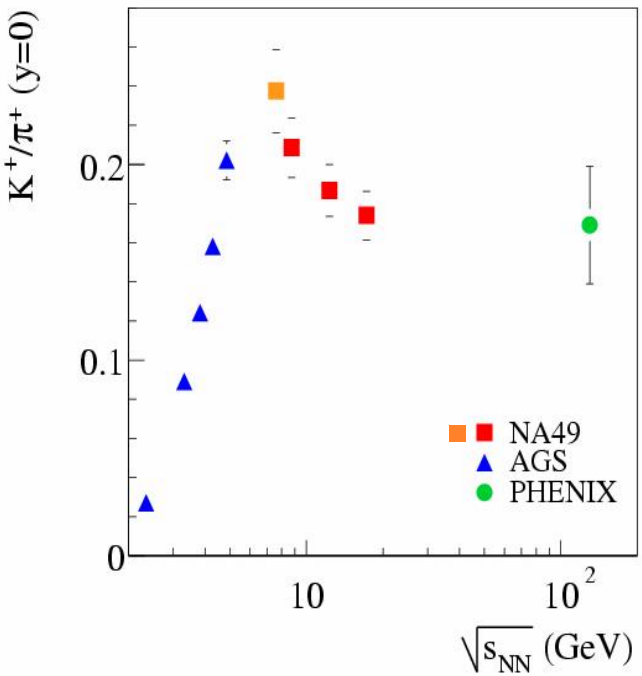
Is medium completely opaque?

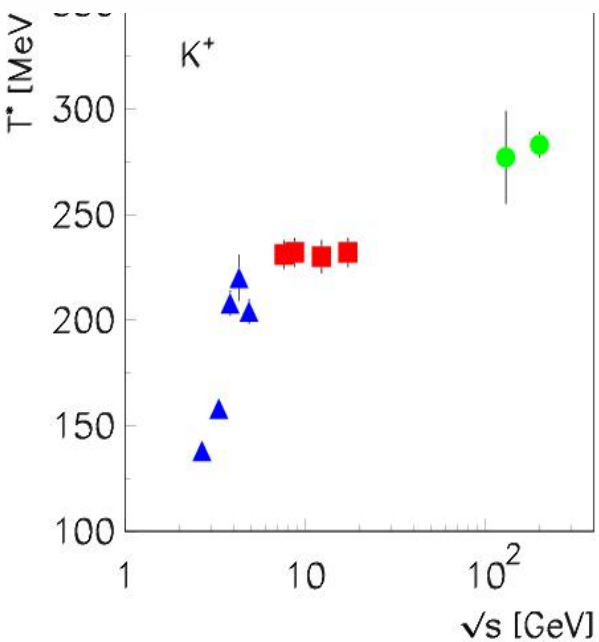
Are high P_T particles emitted only from surface?

PHOBOS Research program is >50% completed

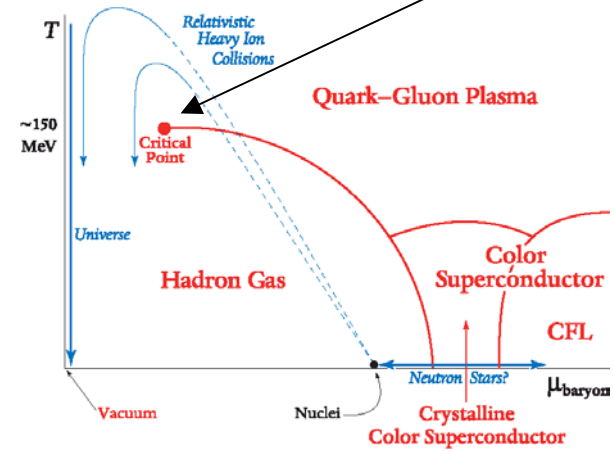
What are the needs to complete PHOBOS mission?

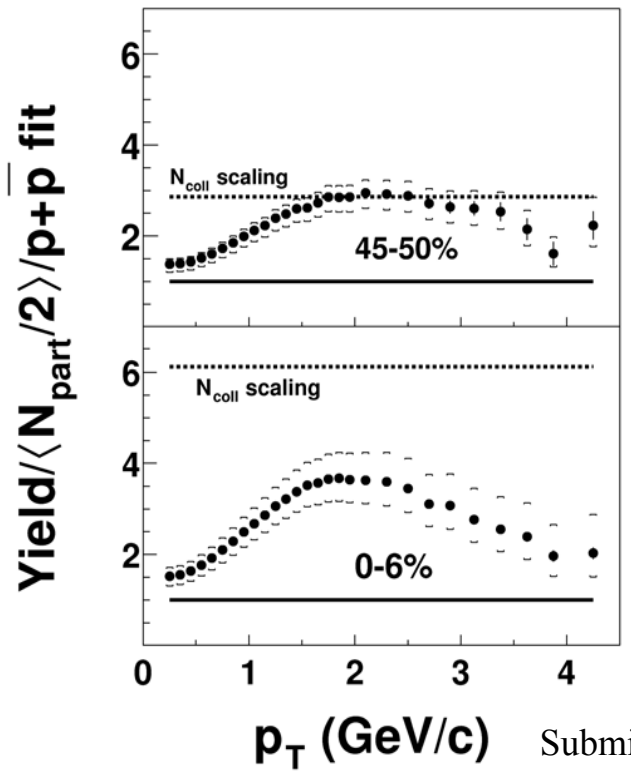
1. Energy scan





Where located?

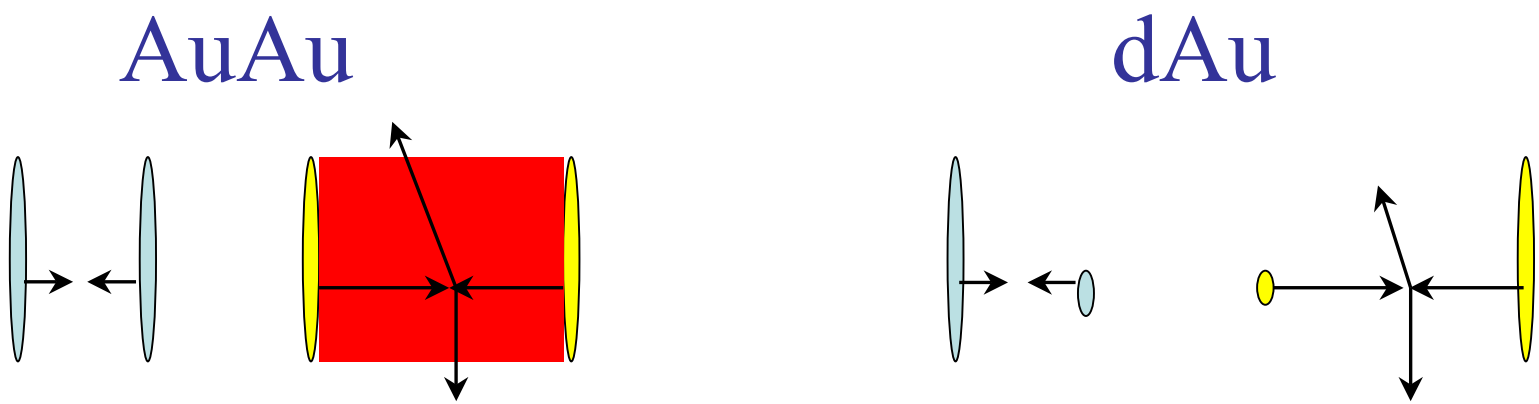




At what energy does jet-quenching switch off?

Submitted to Phys. Lett. B

2. Species scan



Also needed for better understanding of the geometry of the collision, in particular for peripheral collisions

3. More AuAu data at maximum energy for fluctuation studies, $\phi \rightarrow K^+K^-$, etc.

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4. More pp at 200 GeV and pp at 400-500 GeV
-baseline for comparisons with AuAu

Summary

- 4 detector strategy is working well
  - Where there is overlap, impressive agreement between all detectors
- RHIC environment has given PHOBOS the opportunity to complete >50% of its planned research program
- PHOBOS collaboration served well by the BNL PHOBOS Group
  - In operations
  - In data handling
  - In physics analysis
- The contribution of PHOBOS to the RHIC mission
  - Major contribution in obtaining early on in the program the "Big Picture"
  - Observation of several unexpected results
    - Scaling properties
    - Similarities with e^+e^- collisions
  - Pioneered the use of ROOT, (and more recently PROOF) in HI community

Summary continued

- Unfinished parts of PHOBOS mission
  - –High statistics AuAu and pp runs @ 200 GeV
  - –Species scan
  - –Energy scan
  - –pp at 400 or 500 GeV
- Phobos has some unique capabilities
  - -we would like to finish the program in a timely fashion