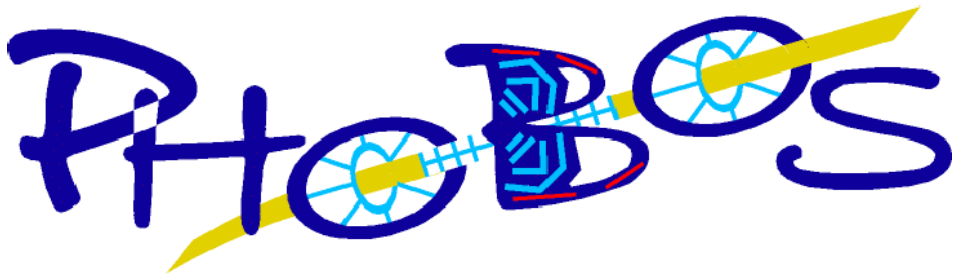
DoE Review of RHIC Program

9 July 2003



Wit Busza

PHOBOS Collaboration



Birger Back, Mark Baker, Maarten Ballintijn, Donald Barton, Bruce Becker, Russell Betts, Abigail Bickley, Richard Bindel, Andrzej Budzanowski, Wit Busza (Spokesperson), Alan Carroll, Patrick Decowski, Edmundo Garcia, Tomasz Gburek, Nigel George, Kristjan Gulbrandsen, Stephen Gushue, Clive Halliwell, Joshua Hamblen, Adam Harrington, Conor Henderson, David Hofman, Richard Hollis, Roman Holynski, Burt Holzman, Aneta Iordanova, Erik Johnson, Jay Kane, Nazim Khan, Piotr Kulinich, Chia Ming Kuo, Jang Woo Lee, Willis Lin, Steven Manly, Alice Mignerey, Gerrit van Nieuwenhuizen, Aaron Noell, Rachid Nouicer, Andrzej Olszewski, Robert Pak, Inkyu Park, Heinz Pernegger, Corey Reed, Louis Remsberg, Christof Roland, Gunther Roland, Joe Sagerer, Pradeep Sarin, Pawel Sawicki, Iouri Sedykh, Wojtek Skulski, Chadd Smith, Peter Steinberg, George Stephans, Andrei Sukhanov, Ray Teng, Marguerite Belt Tonjes, Adam Trzupek, Carla Vale, Robin Verdier, Gábor Veres, Bernard Wadsworth, Frank Wolfs, Barbara Wosiek, Krzysztof Wozniak, Alan Wuosmaa, Bolek Wyslouch, Jinlong Zhang

ARGONNE NATIONAL LABORATORY
BROOKHAVEN NATIONAL LABORATORY
INSTITUTE OF NUCLEAR PHYSICS KRAKOW
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
NATIONAL CENTRAL UNIVERSITY, TAIWAN
UNIVERSITY OF ILLINOIS AT CHICAGO
UNIVERSITY OF MARYLAND
UNIVERSITY OF ROCHESTER

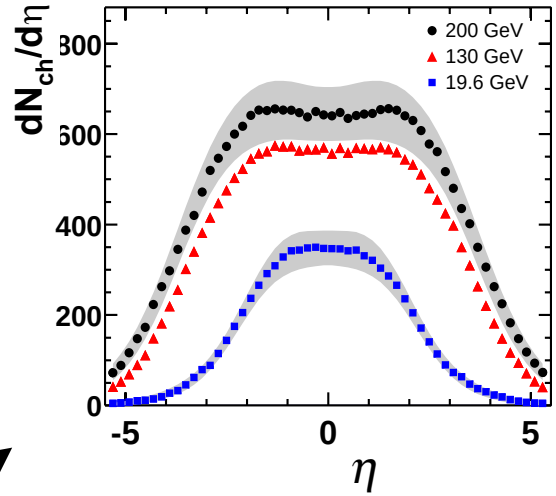
To date: 3 PhDs

Currently:16 PhD students

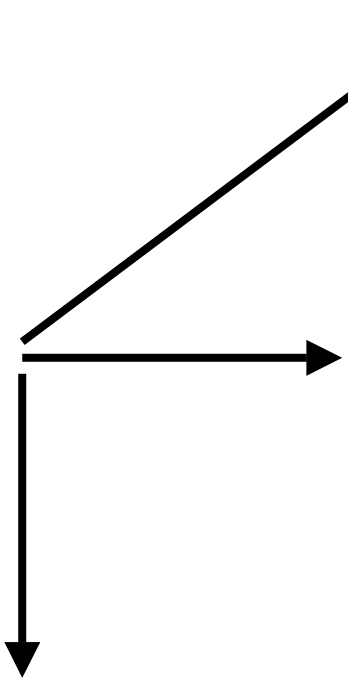
Early "Big Picture"

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

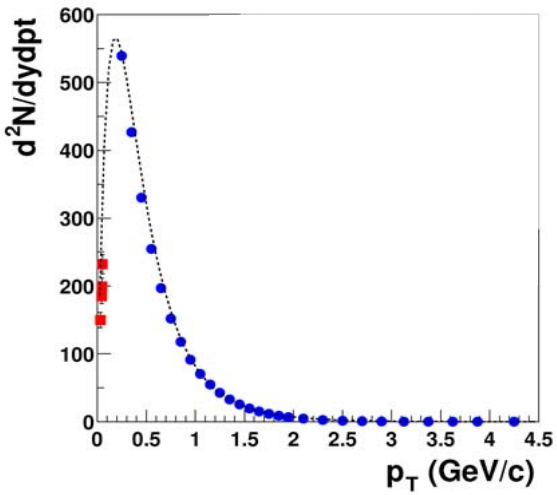
- Adequate overlap
  - Impressive agreement between all experiments
- Complementary



PHOBOS Mission



Low P_t Phenomena



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)

>400 citations

>150 citations first paper

>36 citations/paper

*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)

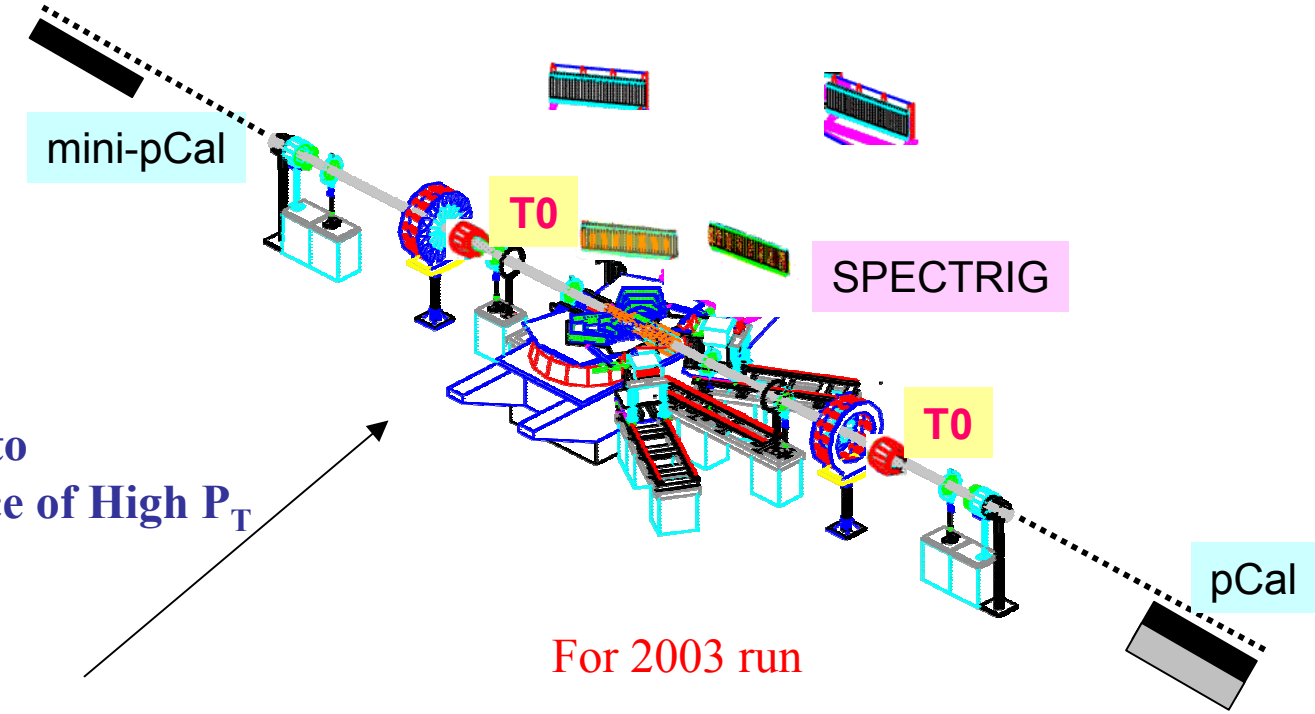
*The significance of the fragmentation region in ultrarelativistic heavy ion collisions
Phys. Rev. Lett (In press).

*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

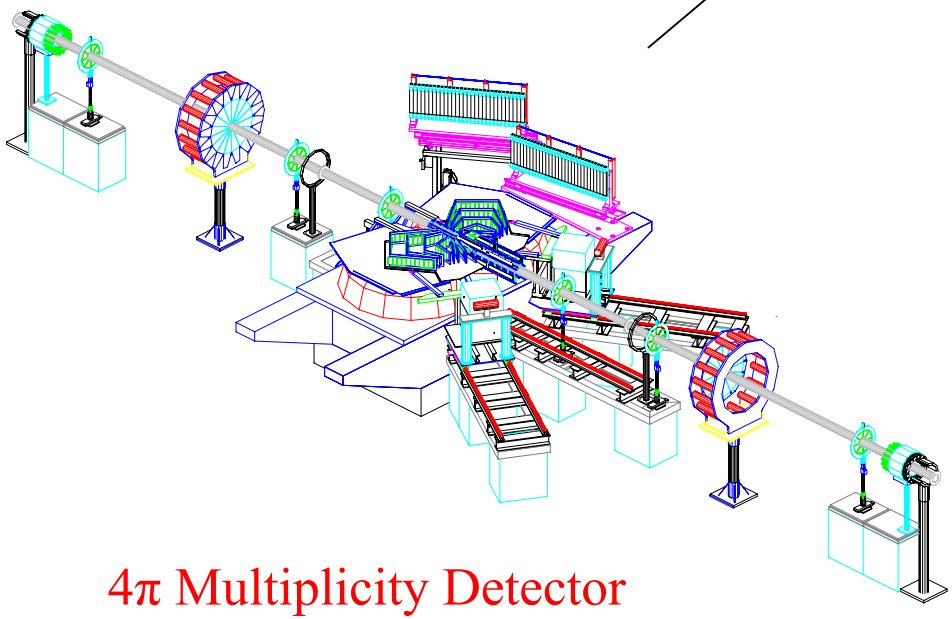
*Centrality Dependence of the Charged Hadron Transverse Momentum Spectra in d+Au Collisions at $\sqrt{s_{NN}}$ =200 GeV
Submitted to Phys. Rev. Lett. {jointly with STAR and PHENIX, first results from dAu run}

Flexibility to respond to results:



Response to Importance of High P_T Studies

For 2003 run



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**

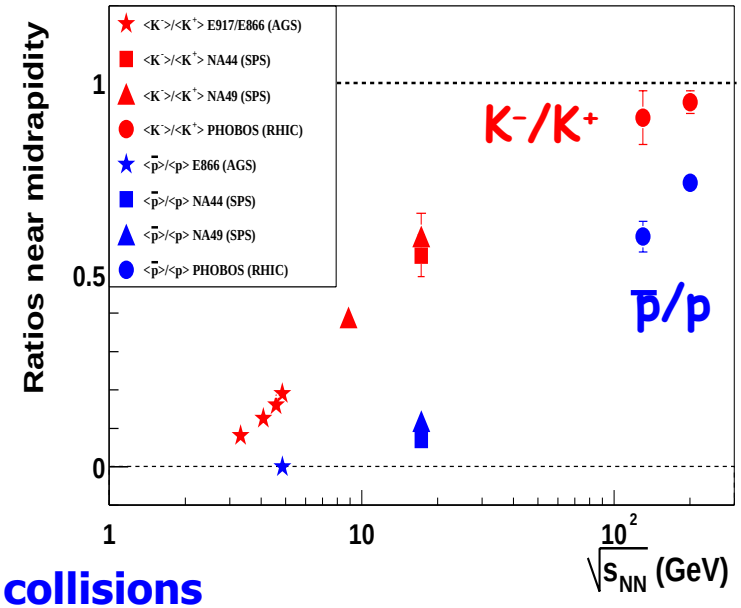
iii. **New "time-zero" (T0) Cerenkov detectors**
   - **On-line vertexing and ToF start time**

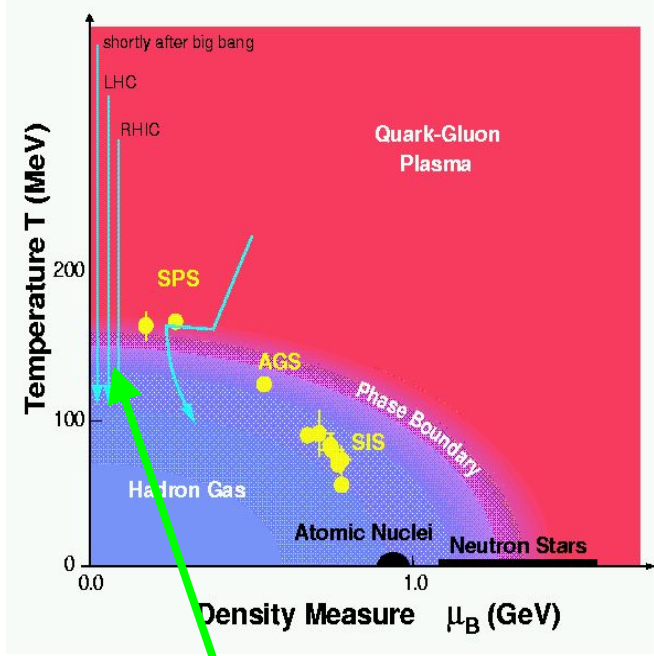
iv. **Forward proton calorimeters on Gold and Deuteron sides**

v. **DAQ upgrade (x10)**

What is the "Big Picture" as seen by PHOBOS?

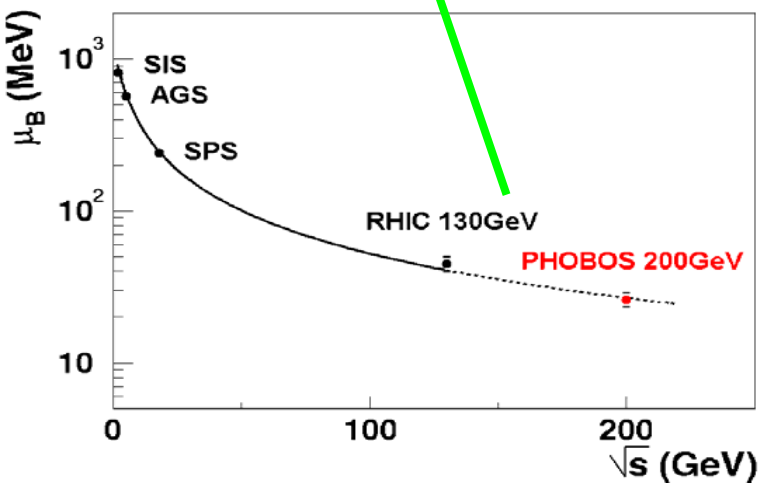
Baryon density at mid-rapidity rapidly decreases with energy



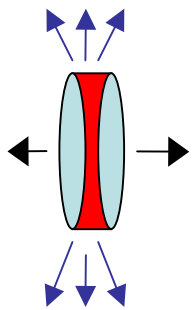


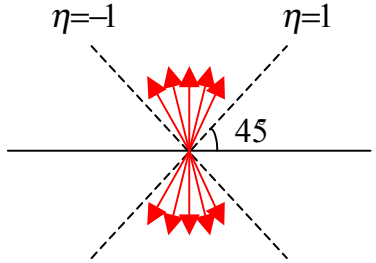
A+A central collisions

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



Energy density high; system must be partonic





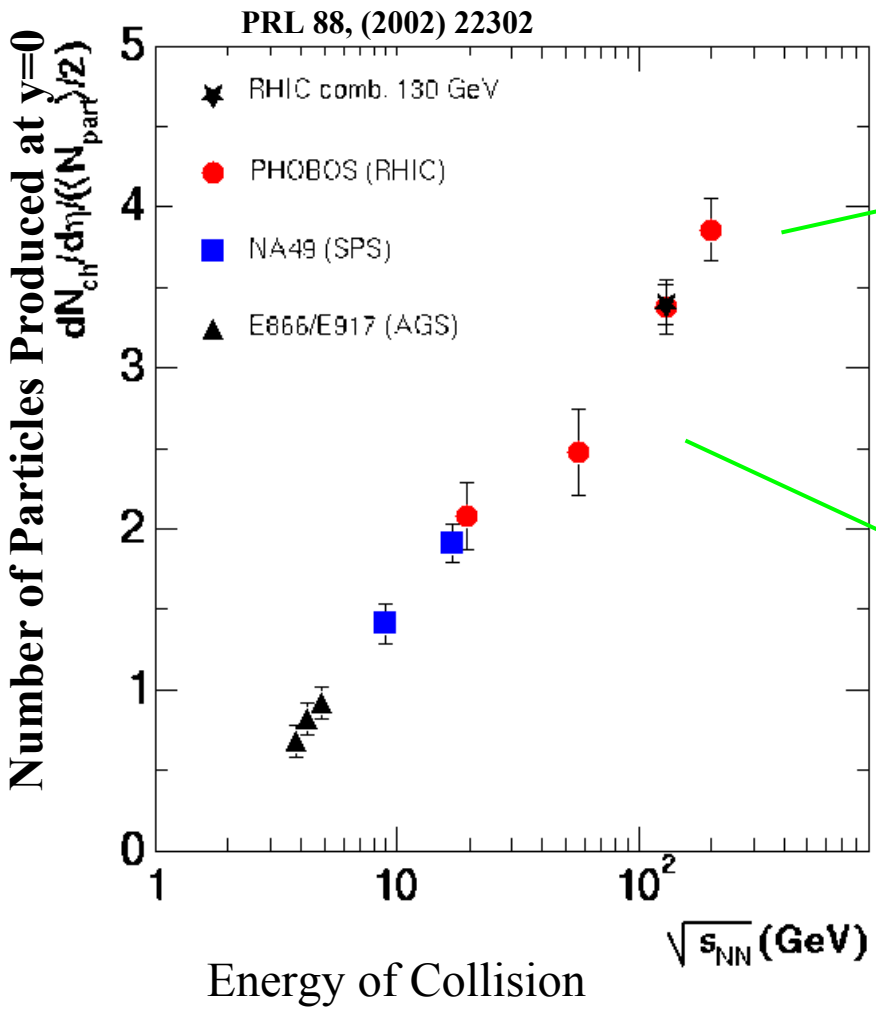
$$\left(\frac{dN}{d\eta}\right)_{all} \sim 1000$$

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

Total energy released ~2000GeV

Max. initial overlap volume

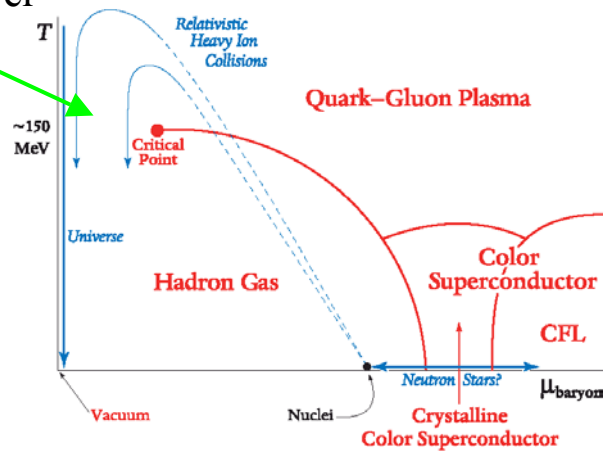
$$\sim \pi R^2 (1\,fm) \sim 200\,fm^3$$



Initially released energy density >5GeV/fm^3

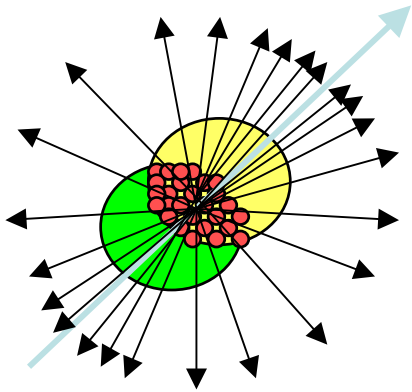
Note: energy density inside proton ≈ 0. 5GeV/fm^3

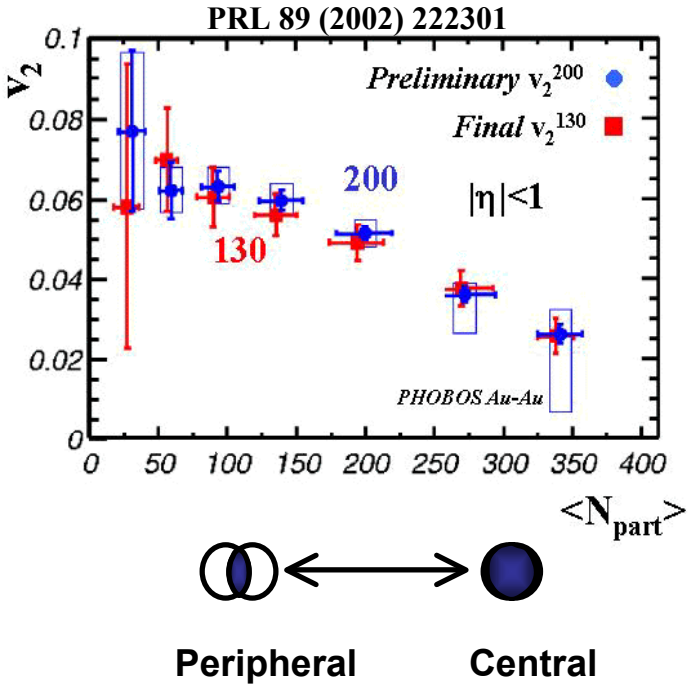
crossover

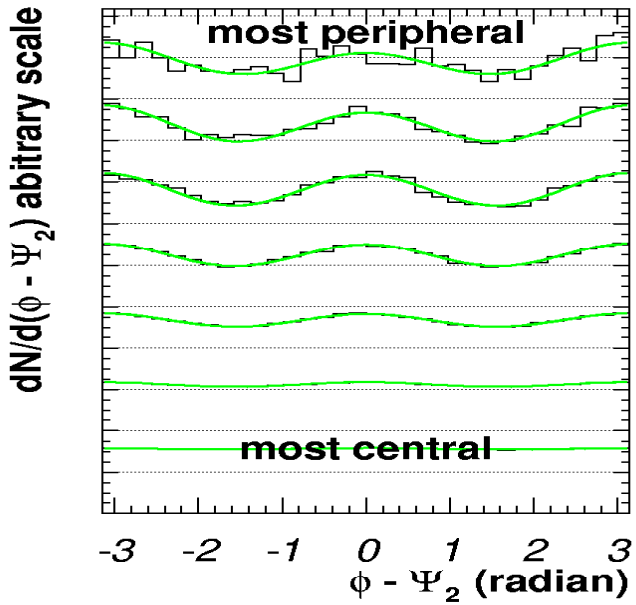


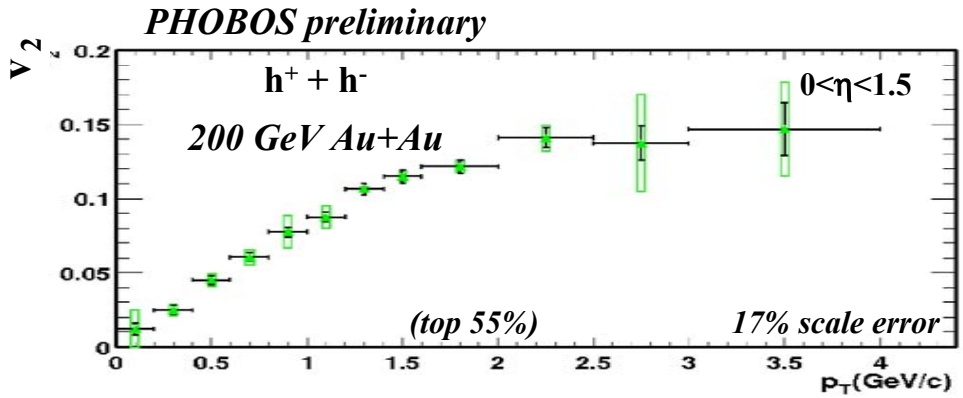
Medium is highly interactive

Elliptic flow:

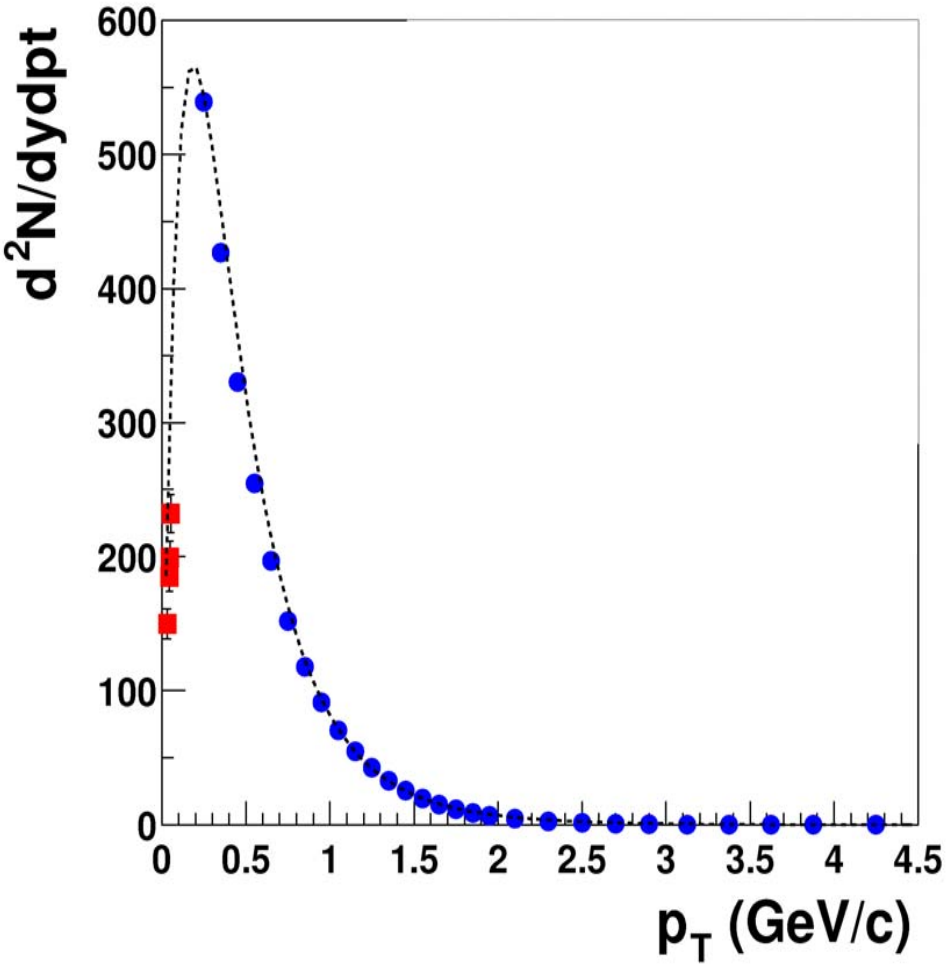


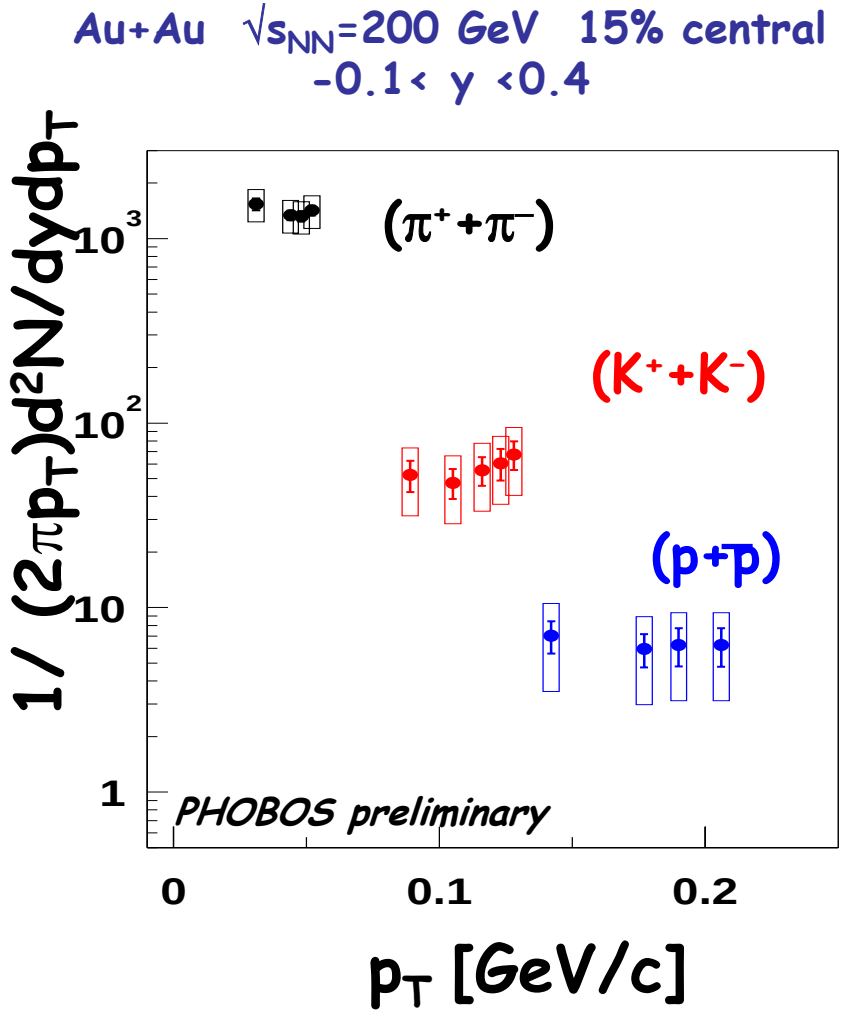




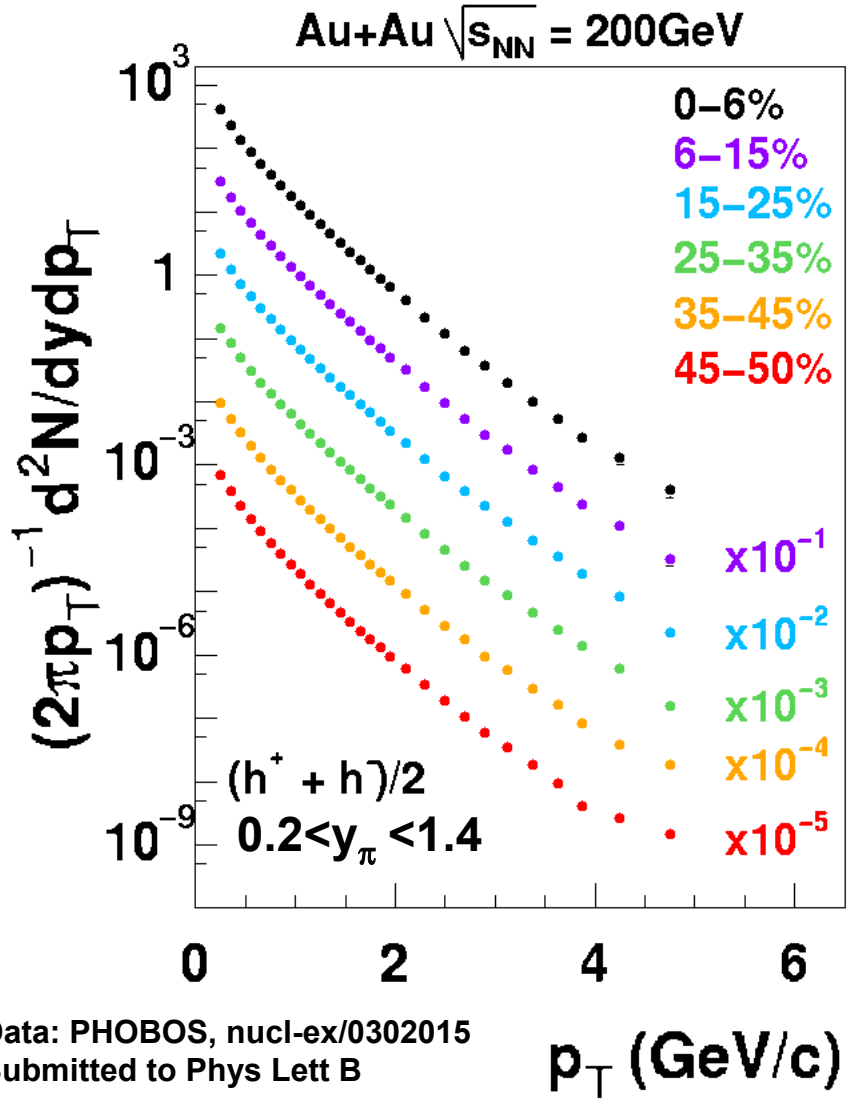


Very few low momentum particles because of flow

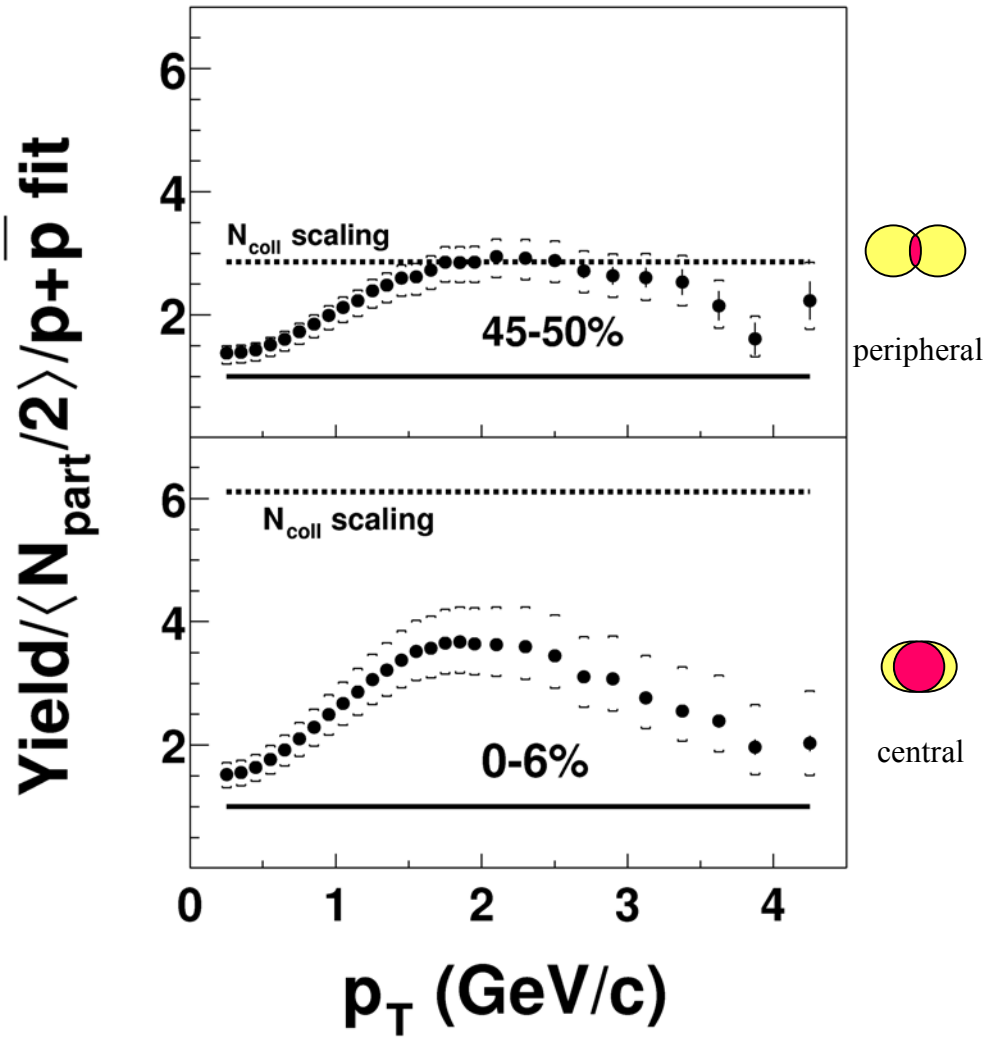




Jet-quenching: further evidence that medium interacts strongly and that parton density is very high.

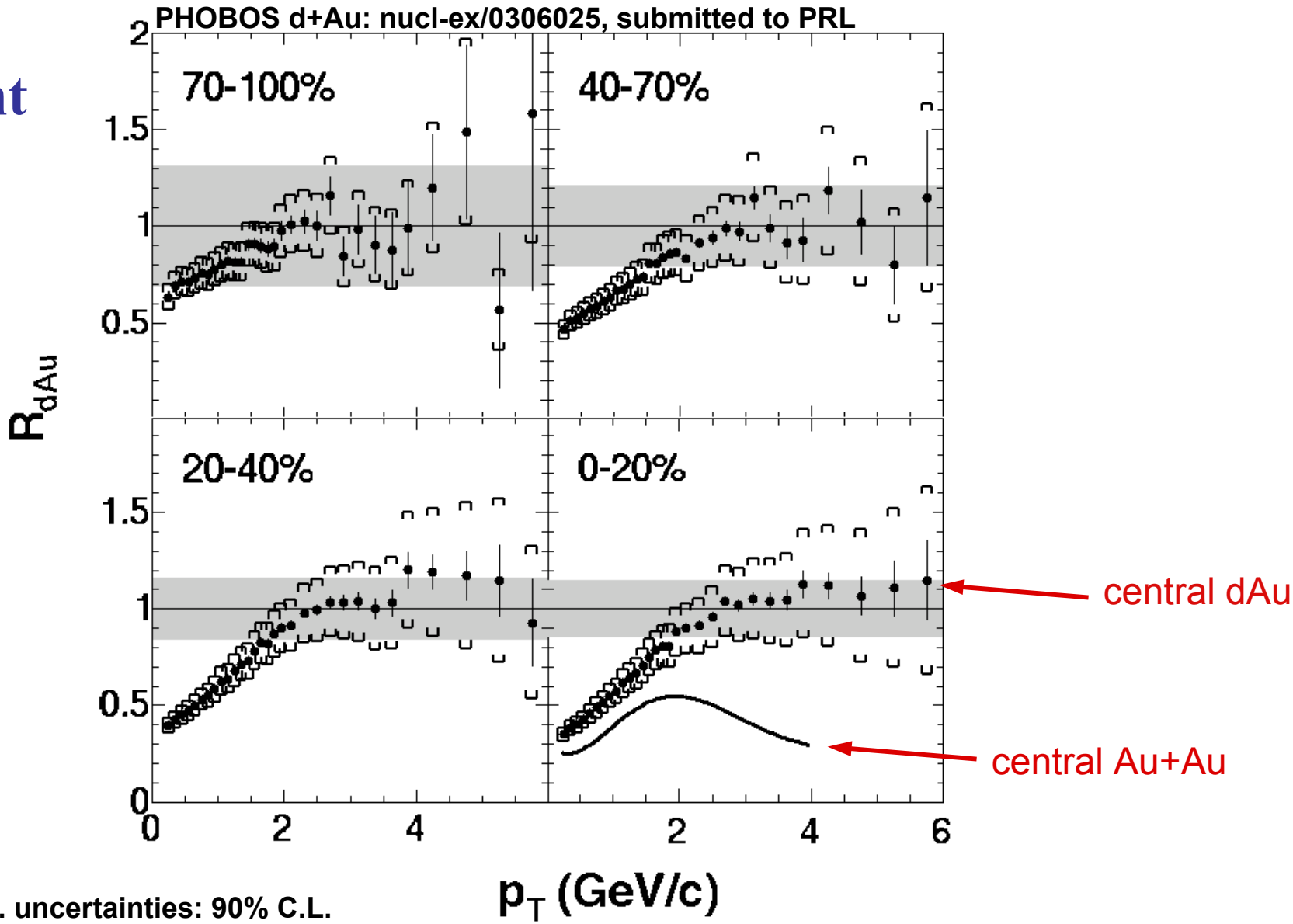


Data: PHOBOS, nucl-ex/0302015
Submitted to Phys Lett B



Jet-quenching is not an initial state effect!

recent dAu data

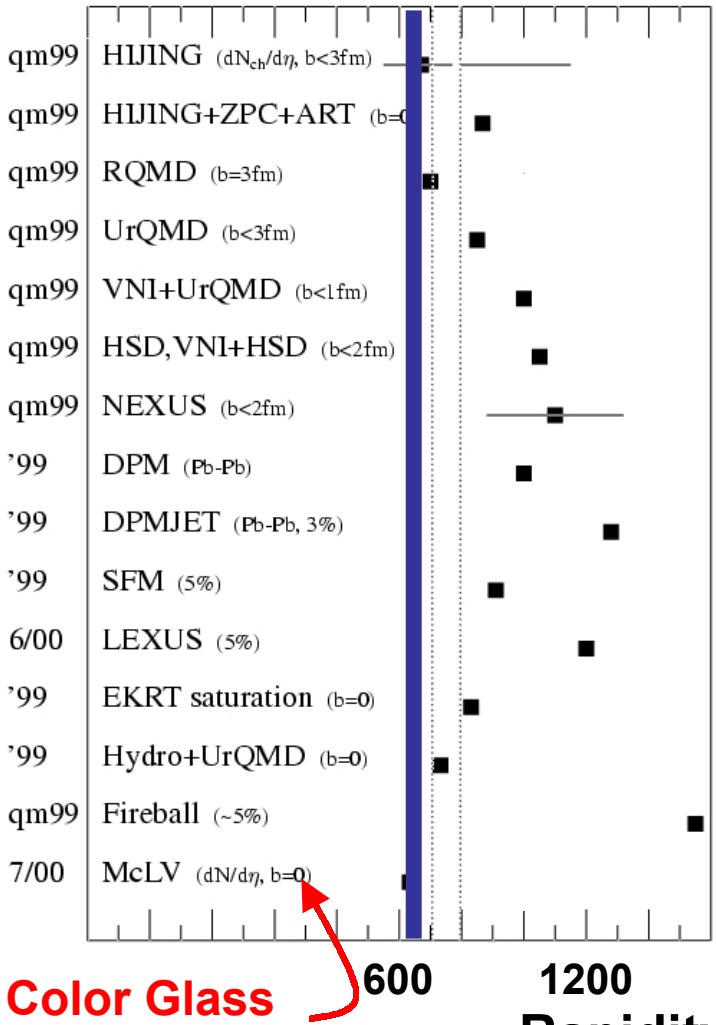


All syst. uncertainties: 90% C.L.

Comparisons with models

Particle Multiplicity

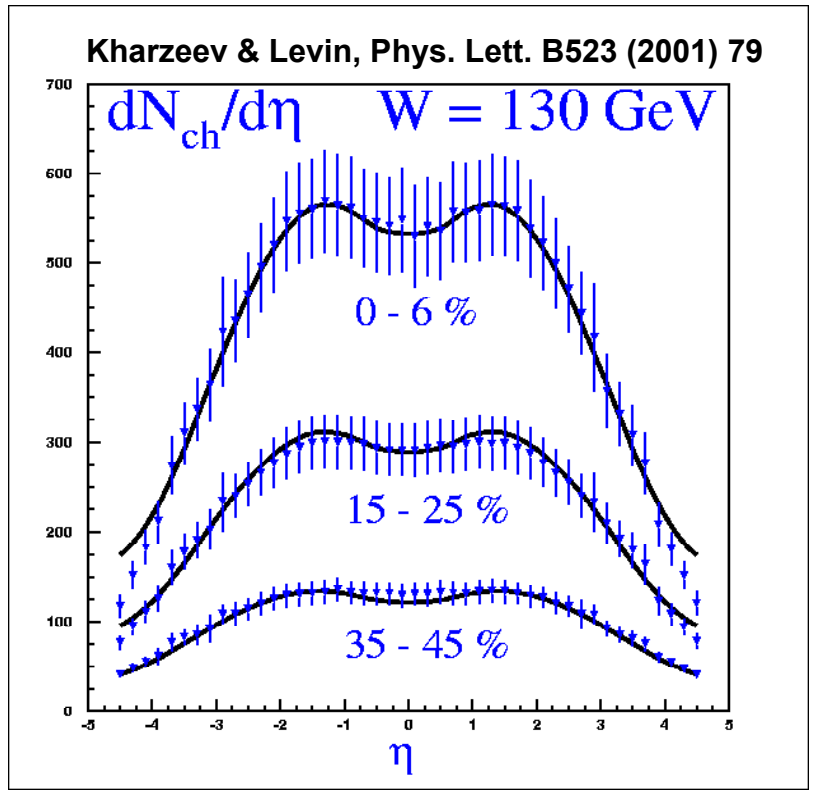
PHOBOS Central Au+Au (200 GeV)



Color Glass

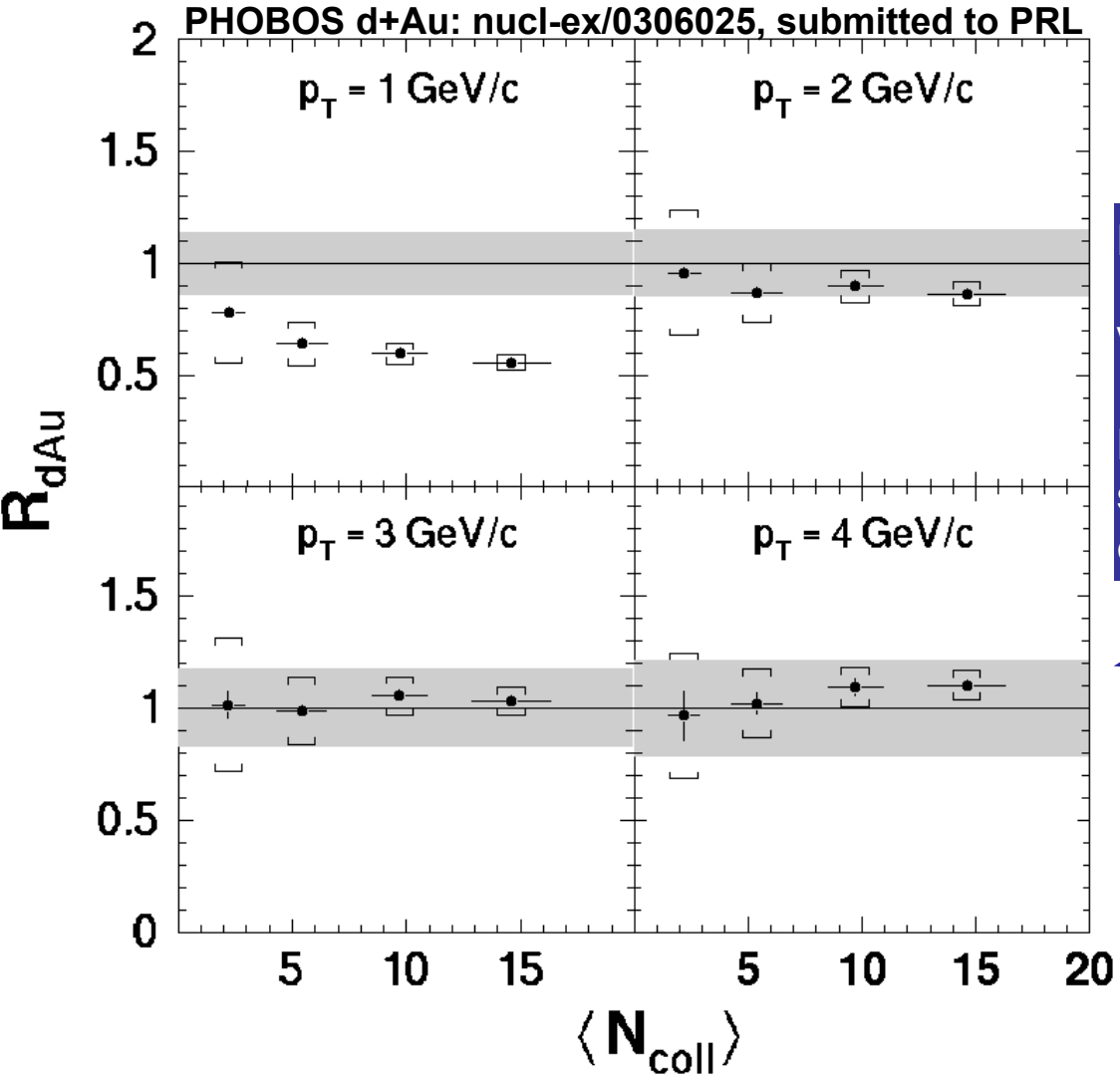
From Eskola, QM 2000

Hadron multiplicities at RHIC well described by Parton Saturation



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

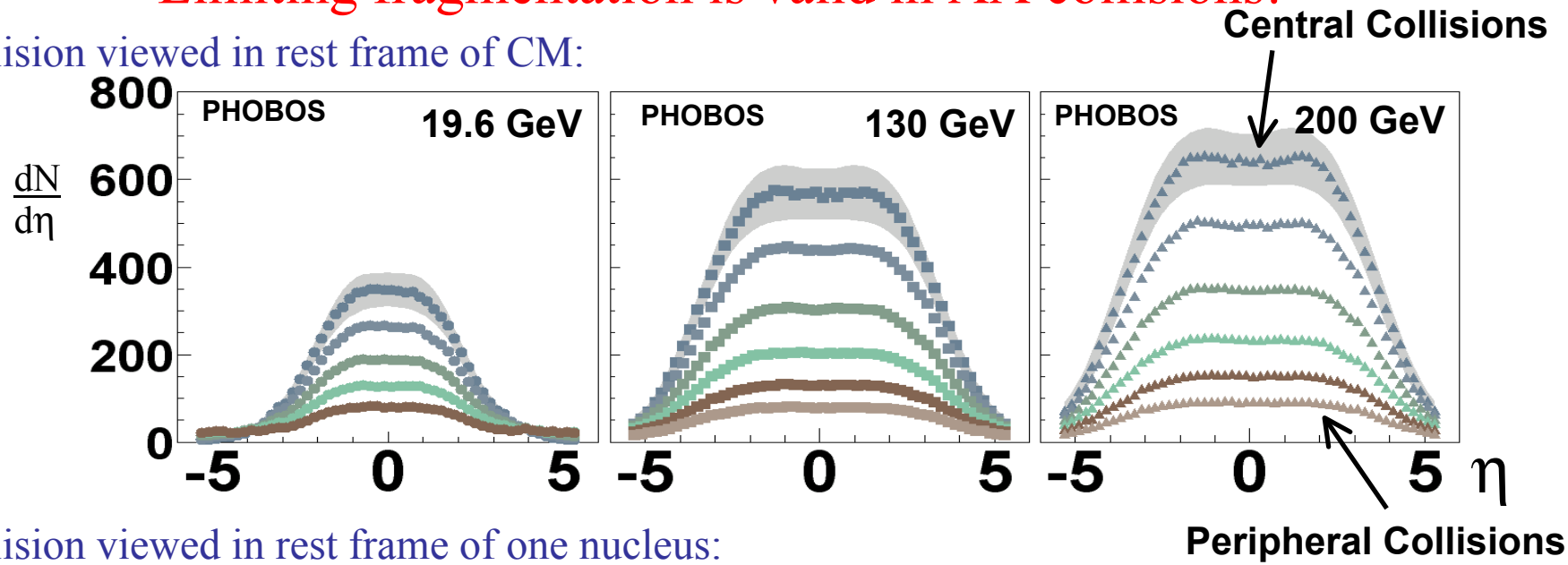
All syst. uncertainties: 90% C.L.

Some surprises

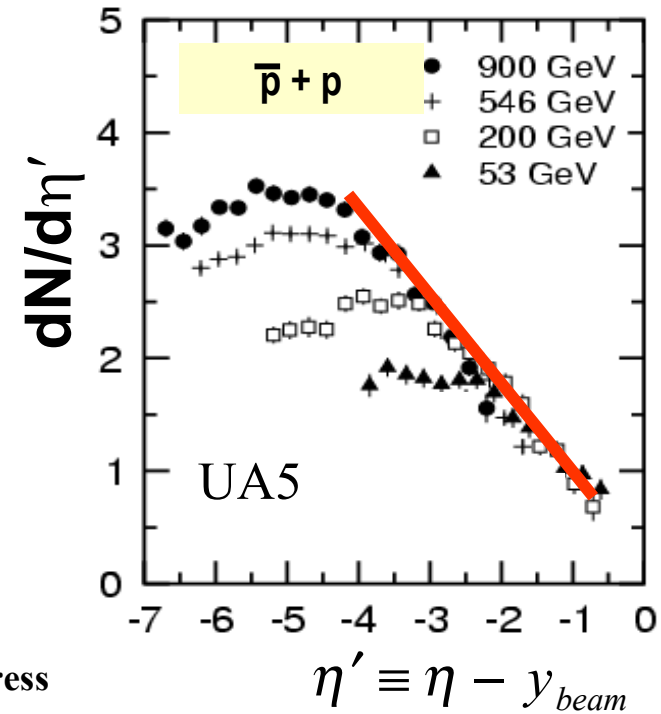
Accidental, trivial or profound?

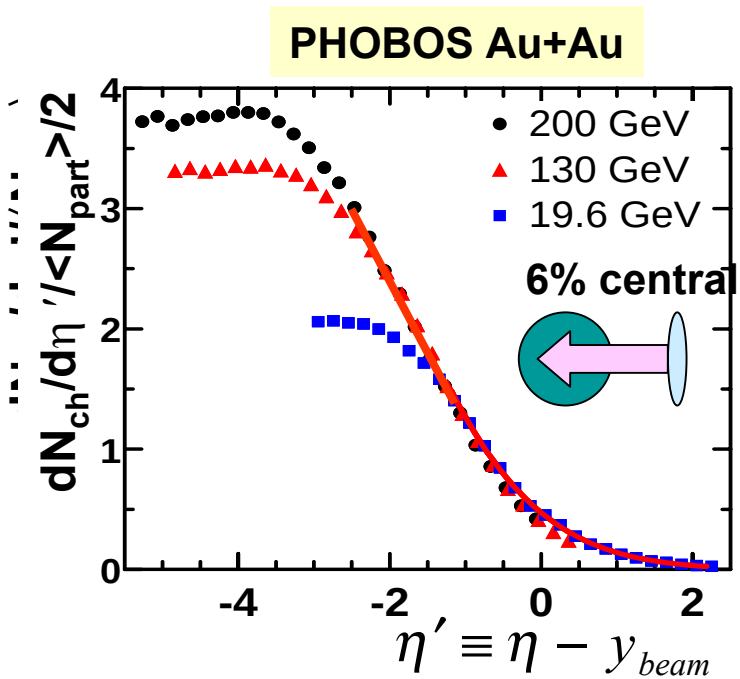
Limiting fragmentation is valid in AA collisions!

Collision viewed in rest frame of CM:



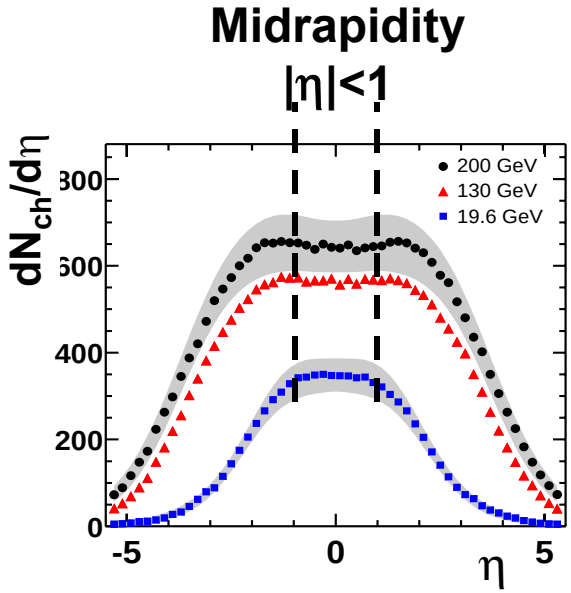
Collision viewed in rest frame of one nucleus:



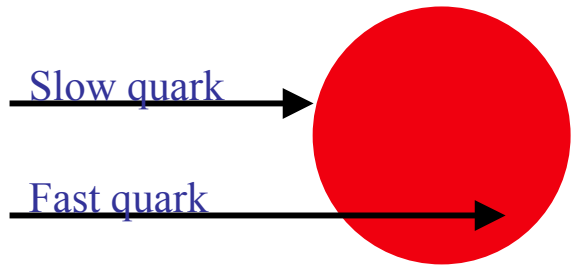


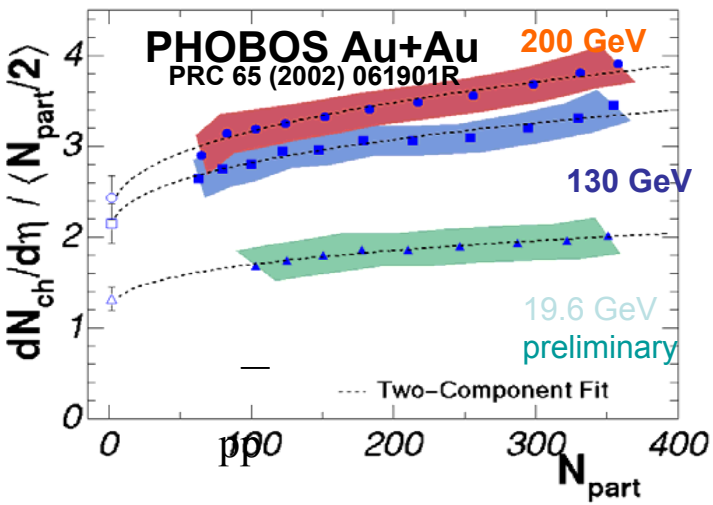
PRL in press

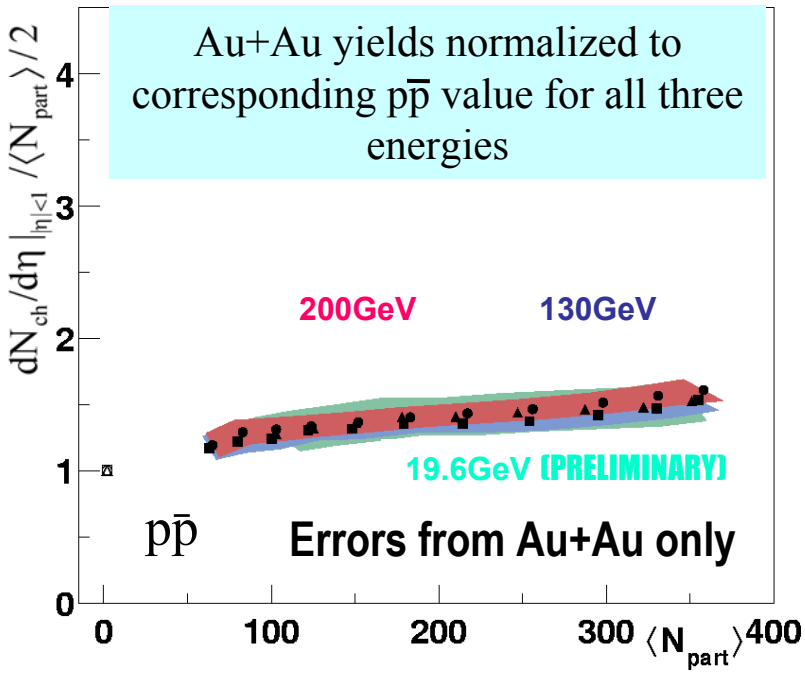
Scaling with N_{part} of midrapidity multiplicity inconsistent with naïve expectations:



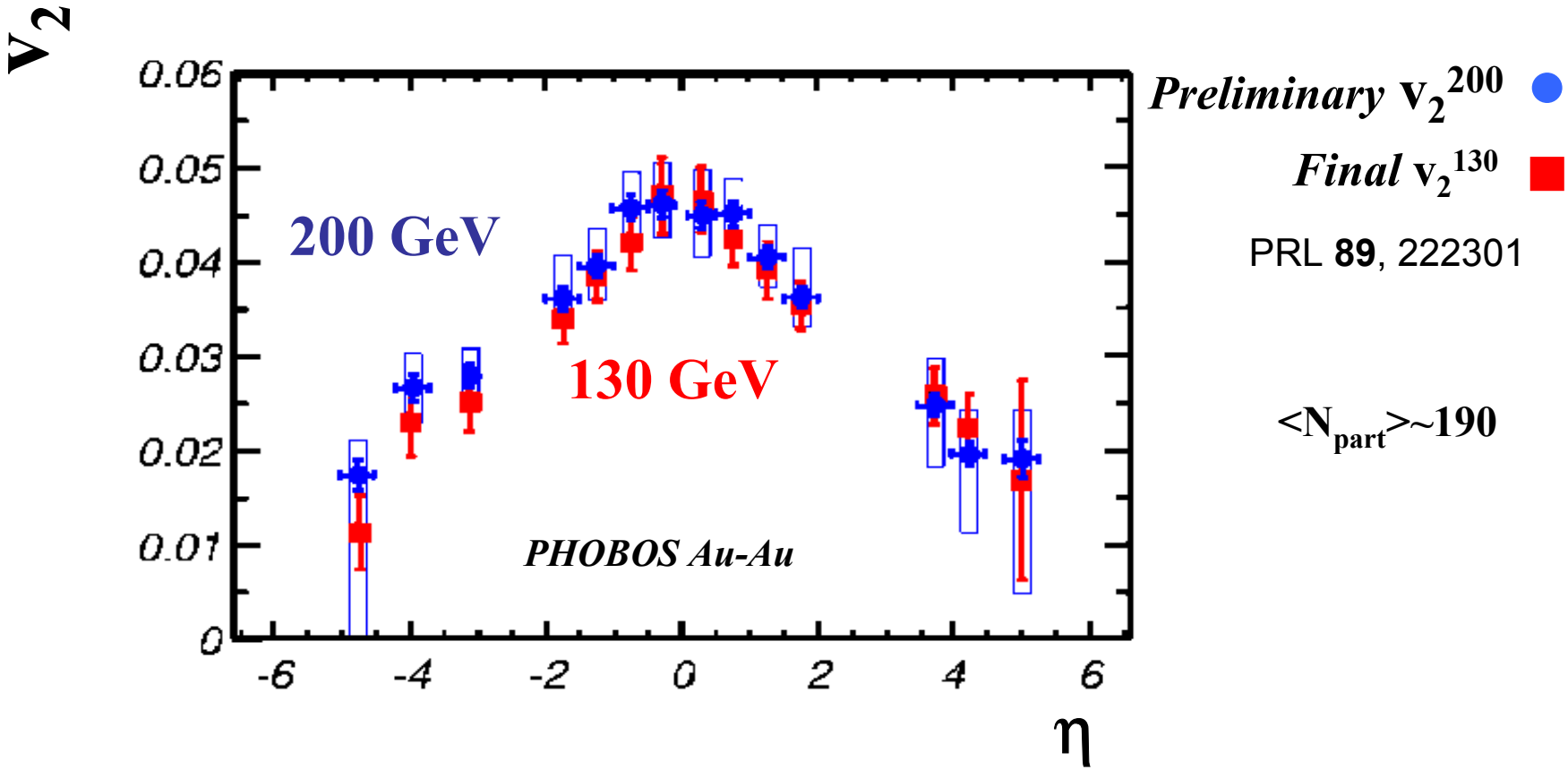
Data inconsistent with the following picture:



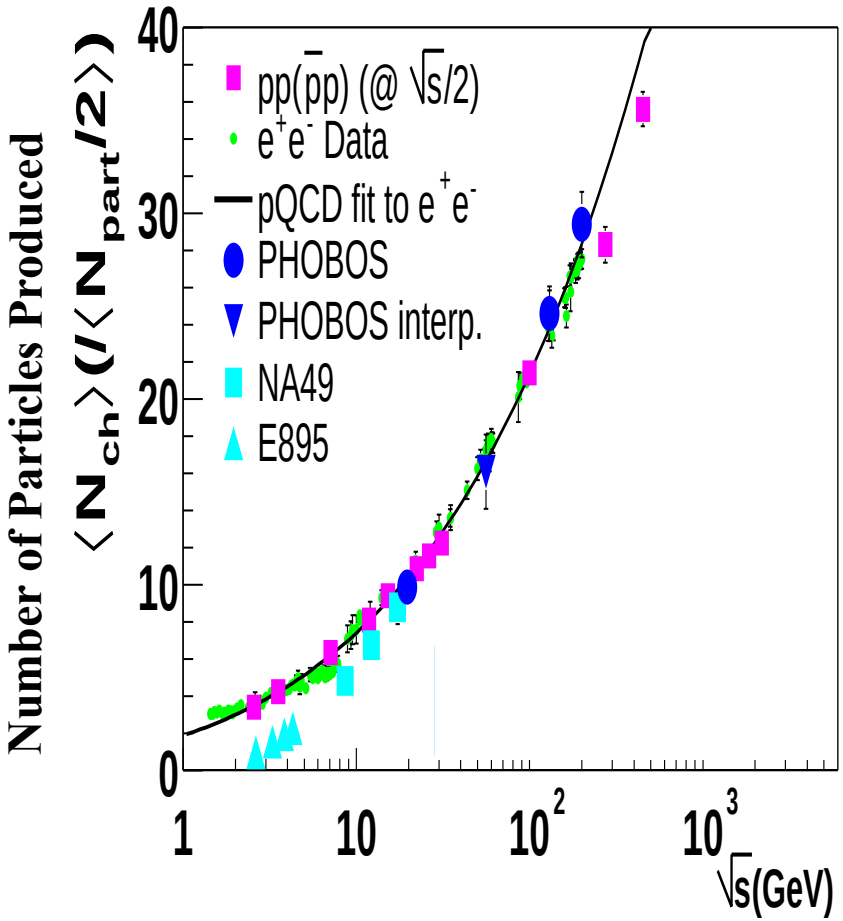


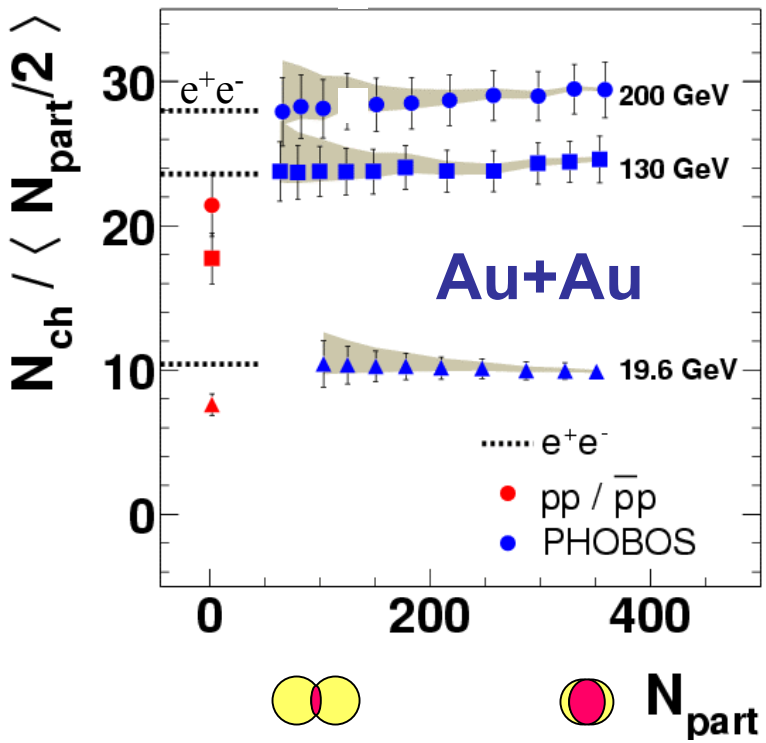


Flow is anything but boost invariant!



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

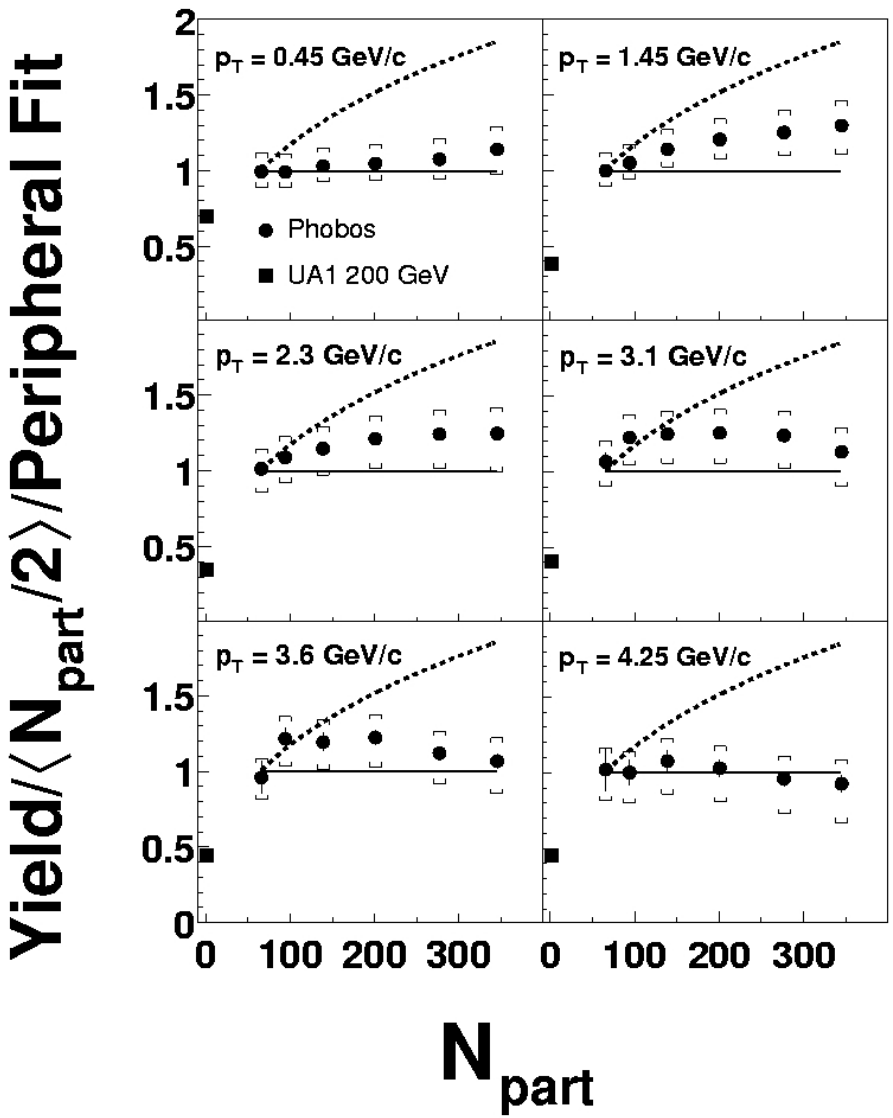




Submitted to PRL

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

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



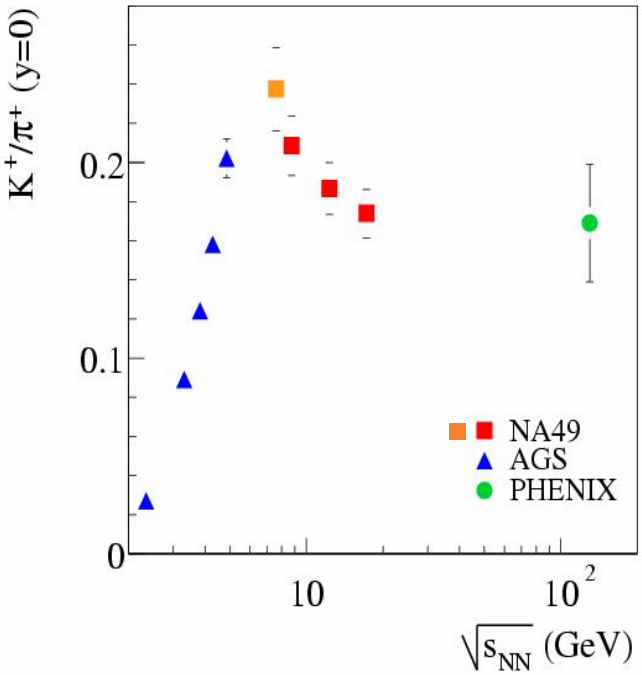
Is medium completely opaque?

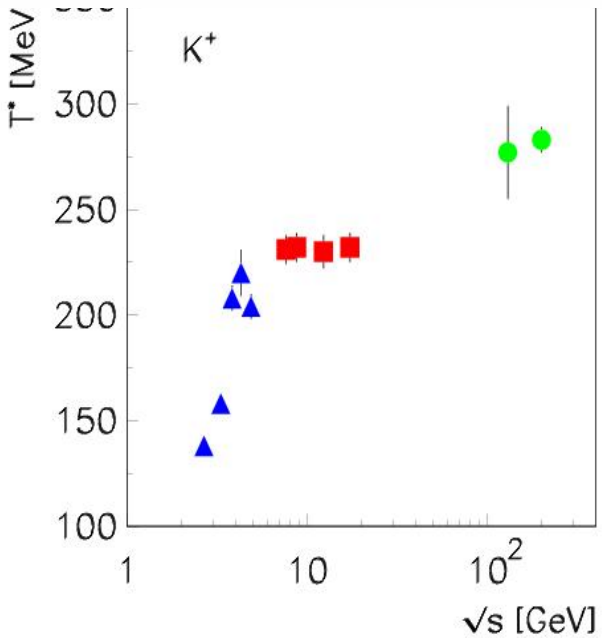
Are high P_T particles emitted only from surface?

PHOBOS Research program is >50% completed

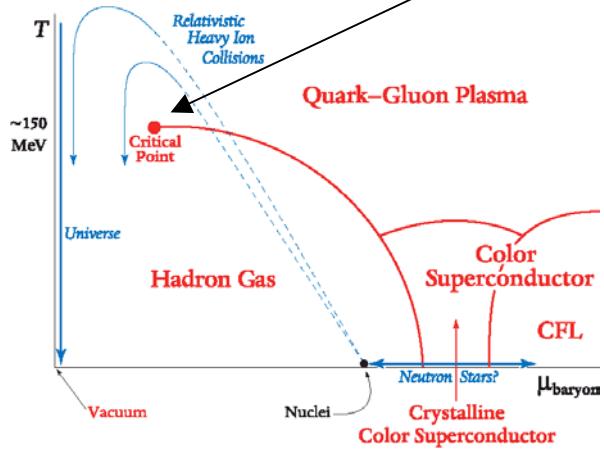
What are the needs to complete PHOBOS mission?

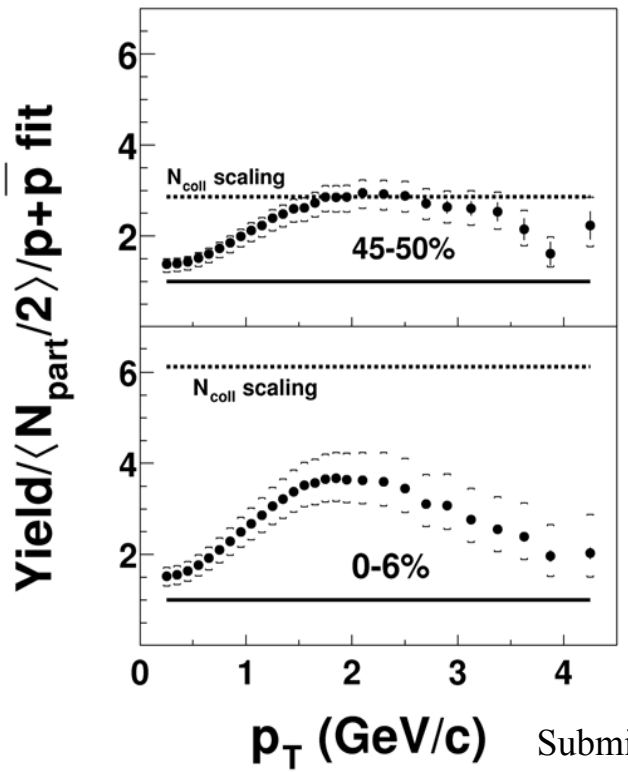
1. Energy scan





Where located?



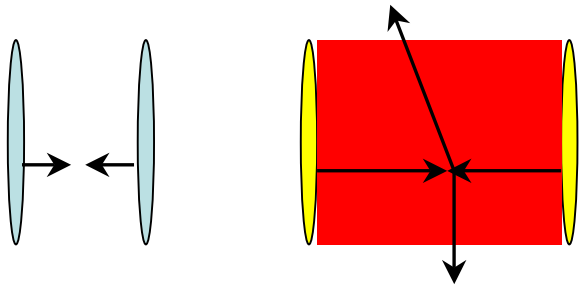


At what energy does jet-quenching switch off?

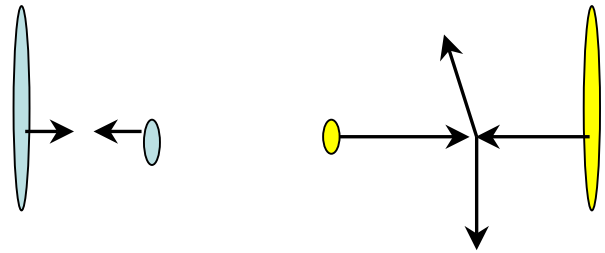
Submitted to Phys. Lett. B

2. Species scan

AuAu



dAu



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.

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

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