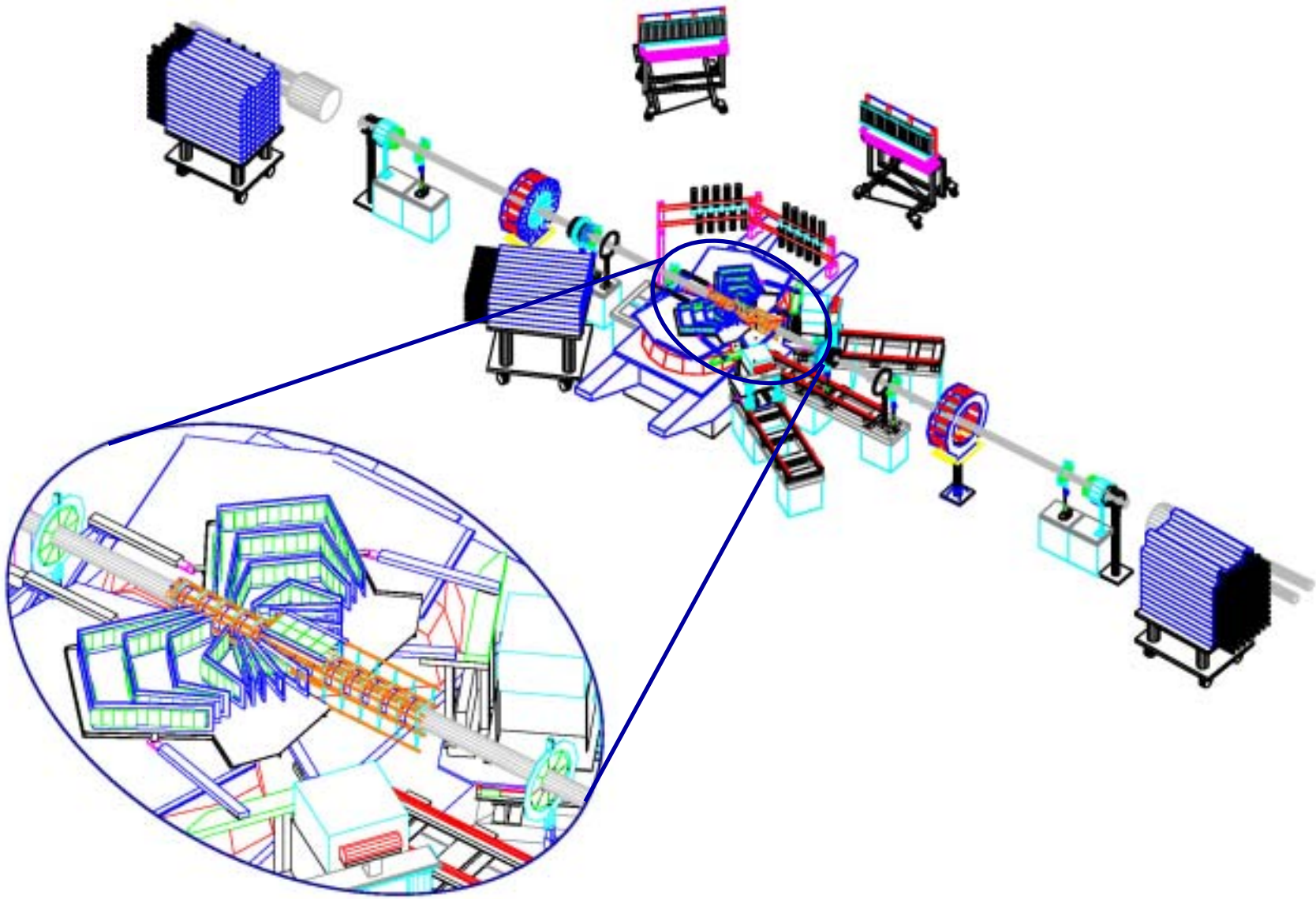
Phobos

Wit Busza

4π charged particle detectors, two spectrometers near y=0 with PID and low Pt capability, $8M



The PHOBOS Collaboration (June 2005)



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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
UNIVERSITY OF ILLINOIS AT CHICAGO
UNIVERSITY OF ROCHESTER

PHOBOS

In June 2005 almost certainly Phobos took its last data

It is a good time to take a “bird’s eye view” of the whole Phobos Project

PAC, BNL and DoE showed wisdom and foresight in the choice of detectors for initial RHIC research Program

BRAHMS, PHENIX, PHOBOS and STAR have the right mix of complementarity and overlap!

RHIC is a superb accelerator!

We appreciate and are thankful to those responsible for the design, construction and operation of RHIC for five years of glorious physics data.

5 years of PHOBOS…

Data we took in various runs:

GeV \ system	p+p	d+Au	Cu+Cu	Au+Au
410	5			
200	2,3,4,5	3	5	2,4
130				1
62.4			5	4
55.9				1
22.5			5	
19.6				2

PHOBOS: number of events on tape…

[in millions]

GeV \ system	p+p	d+Au	Cu+Cu	Au+Au
410	**20**			
200	**100**	**150**	**400**	**250**
130				**4.3**
62.4			**110**	**22**
55.9				**1.8**
22.5			**20**	
19.6				**~1**

Today I have no doubt that by the time the last Phobos result is published we will have fulfilled our mission in its entirety

- Early global look at RHIC physics
- 21 peer reviewed publications (10 PRL) including first physics results from every run. Expect > 20 more in next few years.
- >1000 citations (two with >100 citations)
- Unique lasting results
- 13 PhDs (to-date none have left research!)
- >10 PhDs to come
- >4 members have become leaders in the field
- Major impact on overall RHIC Program
  - Crucial energy and system scans (20GeV AuAu and 410GeV pp took place only because of Phobos).
  - Analysis of data (today ROOT, and I predict that in the future PROOF will have a similar impact)

Physics Results

PHOBOS physics publications

24 papers, including 11 in Phys. Rev. Letters

(published plus submitted)

The PHOBOS Perspective on Discoveries at RHIC
Scaling of Charged Particle Production in d+Au Collisions at sqrt(s_NN)=200 GeV
Charged antiparticle to particle ratios near midrapidity in p+p collisions at sqrt(s_NN) = 200 GeV
Transverse momentum and rapidity dependence of HBT correlations in Au+Au collisions at sqrt(s_NN) = 62.4 and 200 GeV
Centrality and pseudorapidity dependence of elliptic flow for charged hadrons in Au+Au collisions at sqrt(s_NN)= 200 GeV
Energy dependence of elliptic flow over a large pseudorapidity range in Au+Au collisions at RHIC
Pseudorapidity dependence of charged hadron transverse momentum spectra in d+Au collisions at sqrt(s_NN)=200 GeV
Collision Geometry Scaling of Au+Au pseudorapidity density from sqrt(s_NN) = 19.6 to 200 GeV
Centrality dependence of charged hadron transverse momentum spectra in Au+Au collisions from sqrt(s_NN) = 62.4 to 200 GeV
Particle production at very low transverse momenta in Au+Au collisions at sqrt(s_NN)=200 GeV
Pseudorapidity Distribution of Charged Particles in d+Au collisions at sqrt(s_NN)=200 GeV
Centrality dependence of charged antiparticle to particle ratios near mid-rapidity in d+Au collisions at sqrt(s_NN)=200 GeV
Centrality Dependence of the Charged Hadron Transverse Momentum Spectra in d+Au Collisions at sqrt(s_{NN})=200 GeV
Charged hadron transverse momentum distributions in Au+Au collisions at sqrt(s_NN) = 200 GeV
Comparison of the Total Charged-Particle Multiplicity in High-Energy Heavy Ion Collisions with e+e- and pp/pbar-p Data
Significance of the fragmentation region in ultrarelativistic heavy ion collisions
Ratios of charged antiparticles to particles near mid-rapidity in Au+Au collisions at sqrt(s_{NN})=200 GeV
Pseudorapidity and centrality dependence of the collective flow of charged particles in Au+Au collisions at sqrt(s_{NN})=130 GeV
Centrality Dependence of the Charged Particle Multiplicity near Mid-Rapidity in Au+Au Collisions at sqrt(s_{NN})=130 and 200 GeV
Energy dependence of particle multiplicities near mid-rapidity in central Au+Au collisions
Centrality Dependence of Charged Particle Multiplicity at Midrapidity in Au+Au Collisions at sqrt(s_{NN})=130 GeV
Charged-particle pseudorapidity density distributions from Au+Au collisions at sqrt(s_{NN})=130 GeV
Ratios of charged particles to antiparticles near mid-rapidity in Au+Au collisions at sqrt(s_{NN})=130 GeV
Charged particle multiplicity near mid-rapidity in central Au+Au collisions at sqrt(s) = 56 and 130 AGeV

“White Paper”: summary of PHOBOS results

nucl-ex/0410022, Nucl. Phys. A 757, 28

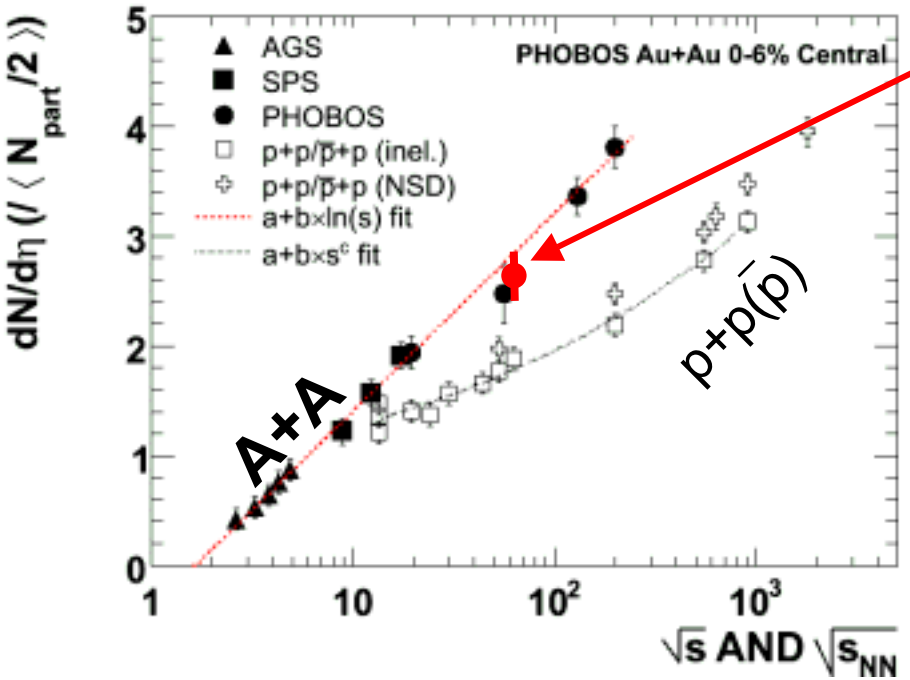
- We have created a state of matter at RHIC with high energy-density, that is nearly net-baryon free and interacting very strongly.

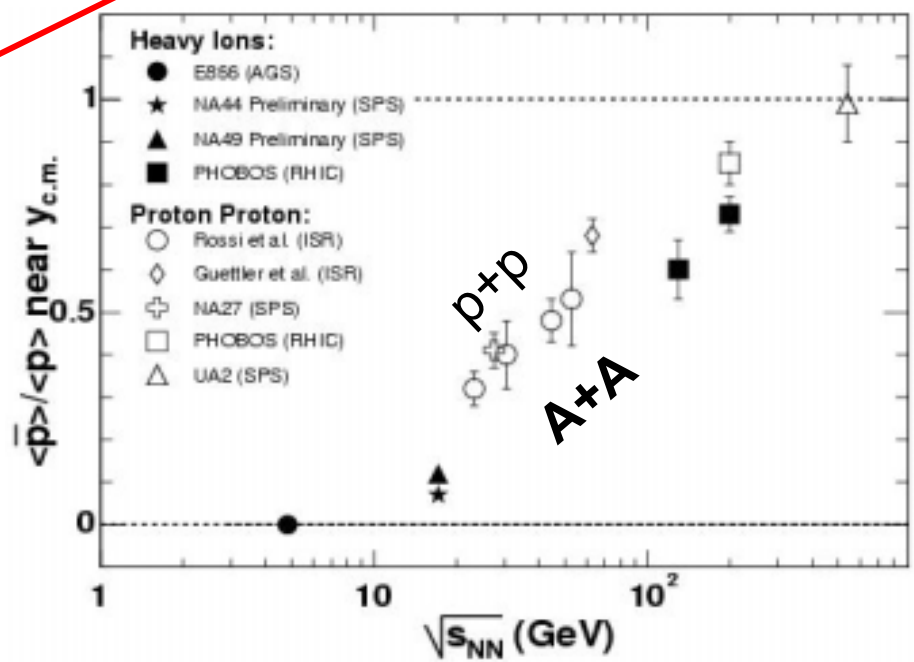
- Transition to this high-energy state of matter does not create abrupt changes in observables at RHIC energies.

- The data exhibit “simple” scaling behavior and factorization.
  → suggests strong global constraints and illustrates the importance of the collision geometry in the initial state and the early evolution of the colliding system.

High energy density & nearly baryon-free matter

New phobos point (preliminary)

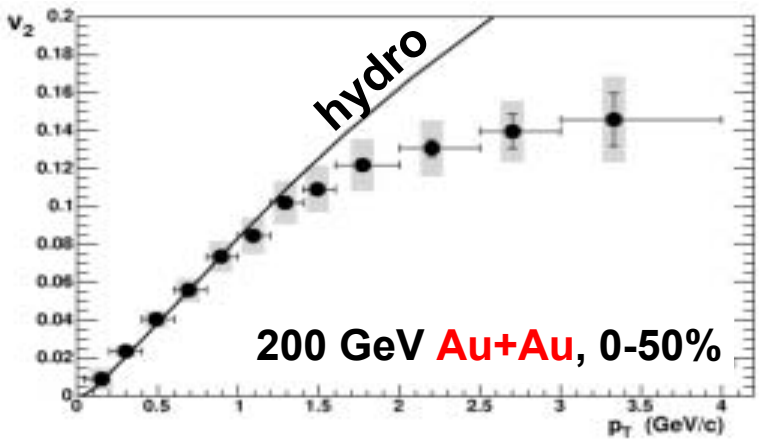




Strongly interacting matter…

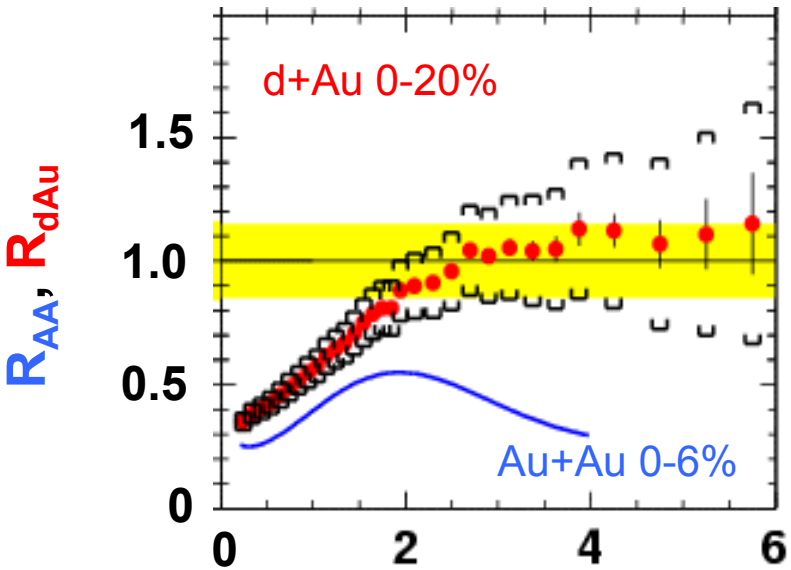
…flow

PHOBOS nucl-ex/0407012

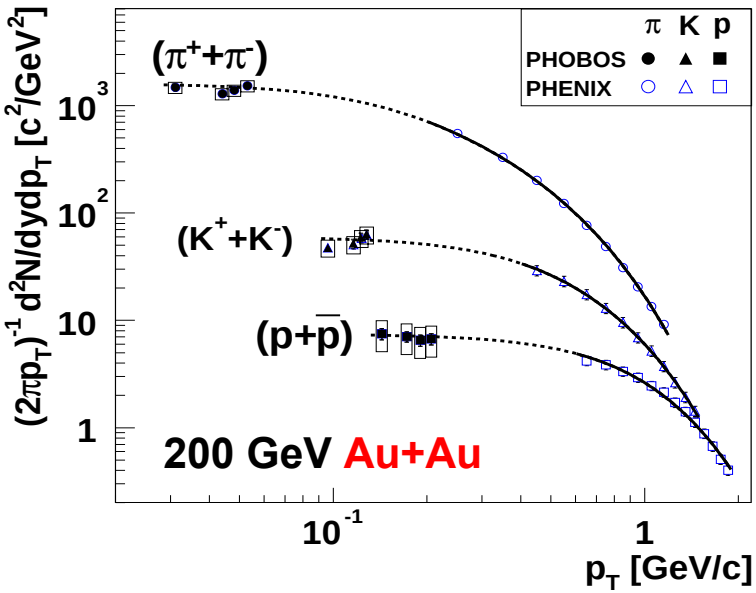


- Elliptic flow reaches hydro limit
- Suppressed high-p_T production
- No enhanced low-p_T production

…high-p_T PHOBOS PRL 91, 072302

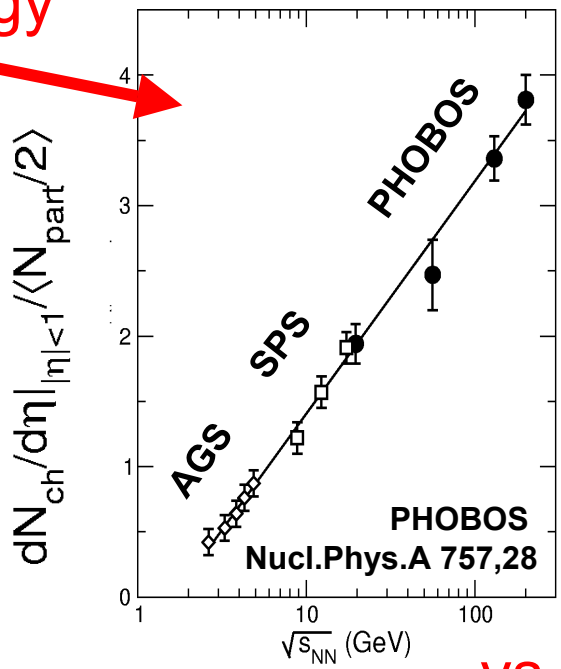


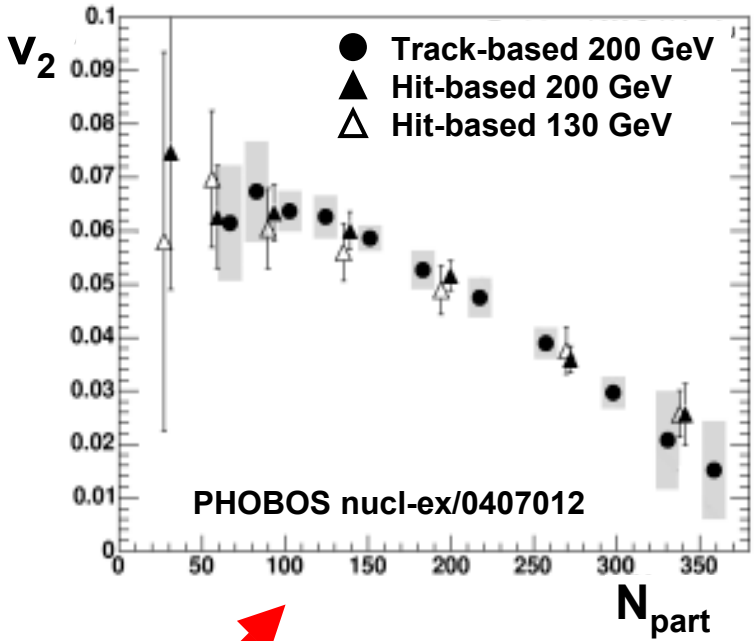
…low-p_T PHOBOS PRC 70, 051901(R)



Transition is gradual, not abrupt…

…vs. energy

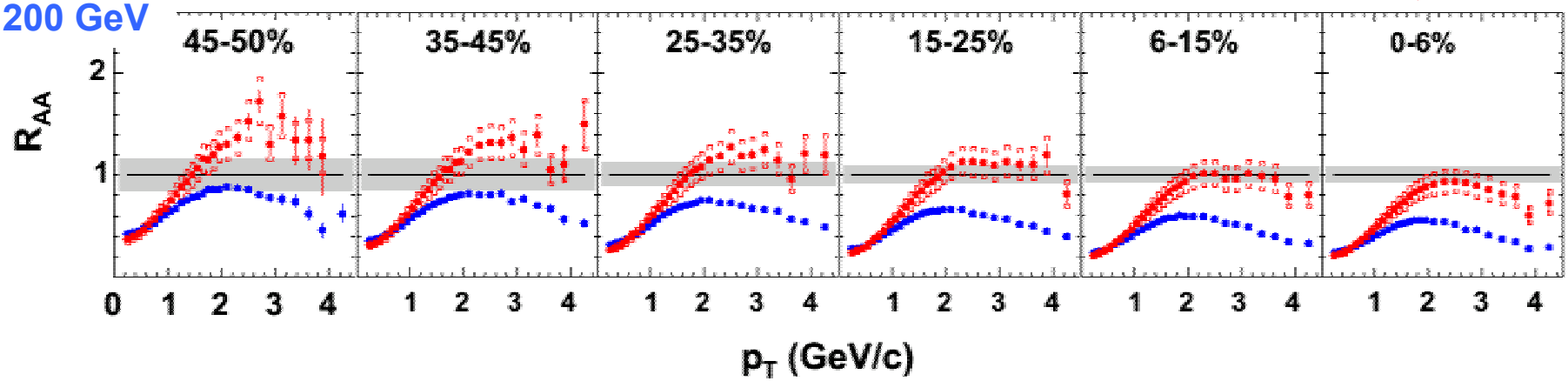




…vs. centrality

62.4 GeV Au+Au
200 GeV

PHOBOS PRL 94, 082304



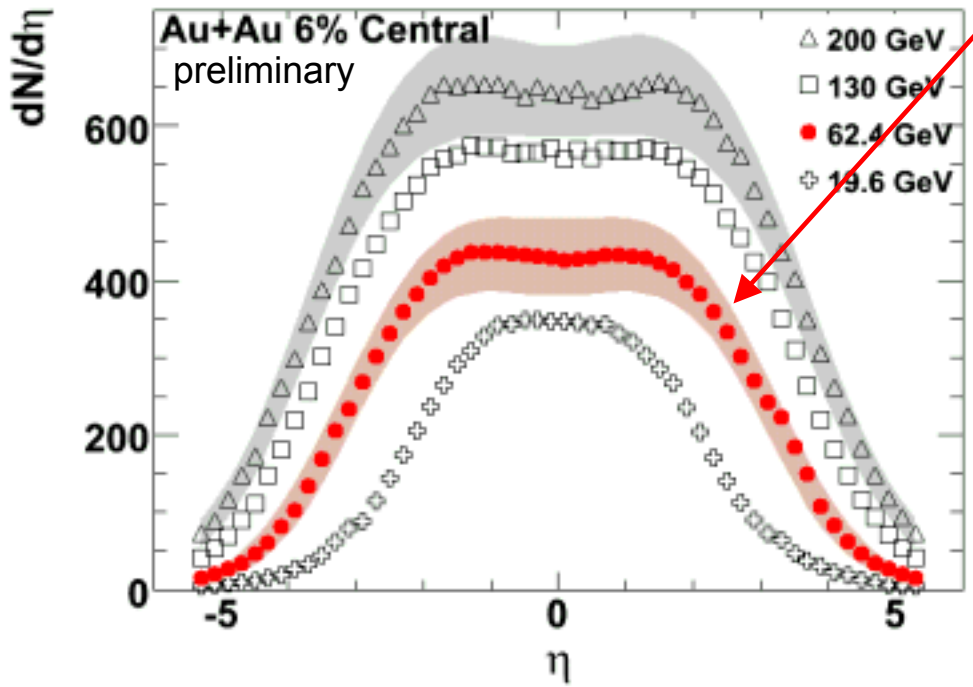
Phobos Results with lasting value

- Systematics of the system and energy dependence of the total multiplicity
- Systematics of the system and energy dependence of longitudinal and transverse features of multiparticle production
- Measurements at low Pt
- Scaling Laws:
  - logarithmic rise with energy of the mid rapidity particle density
  - Npart scaling
  - extended longitudinal scaling (limiting fragmentation) in dndη',v2(η'), and v1(η')
- Factorization of energy and geometry for many processes

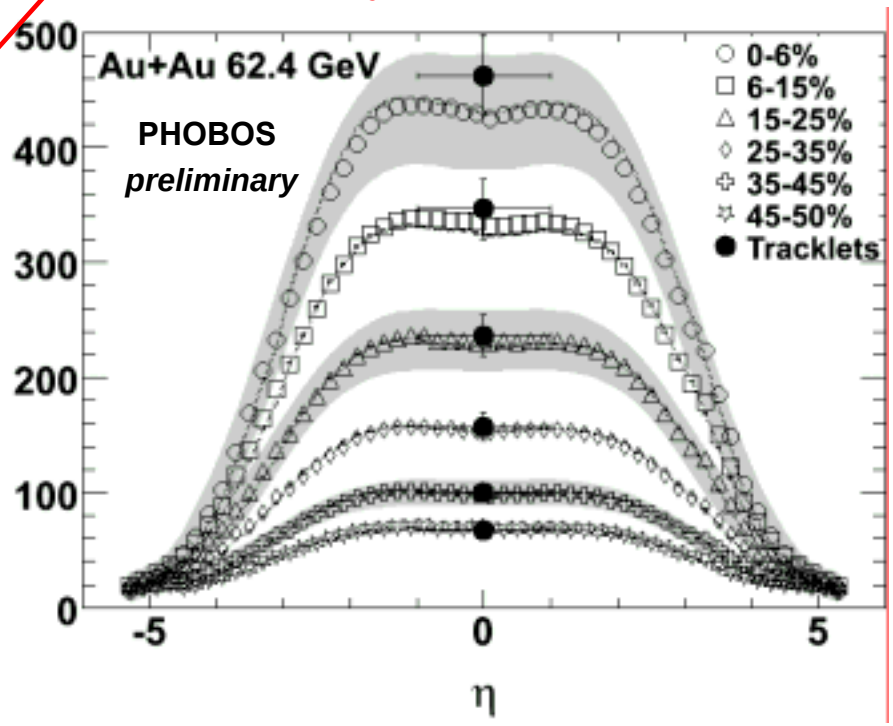
Systematics

New result

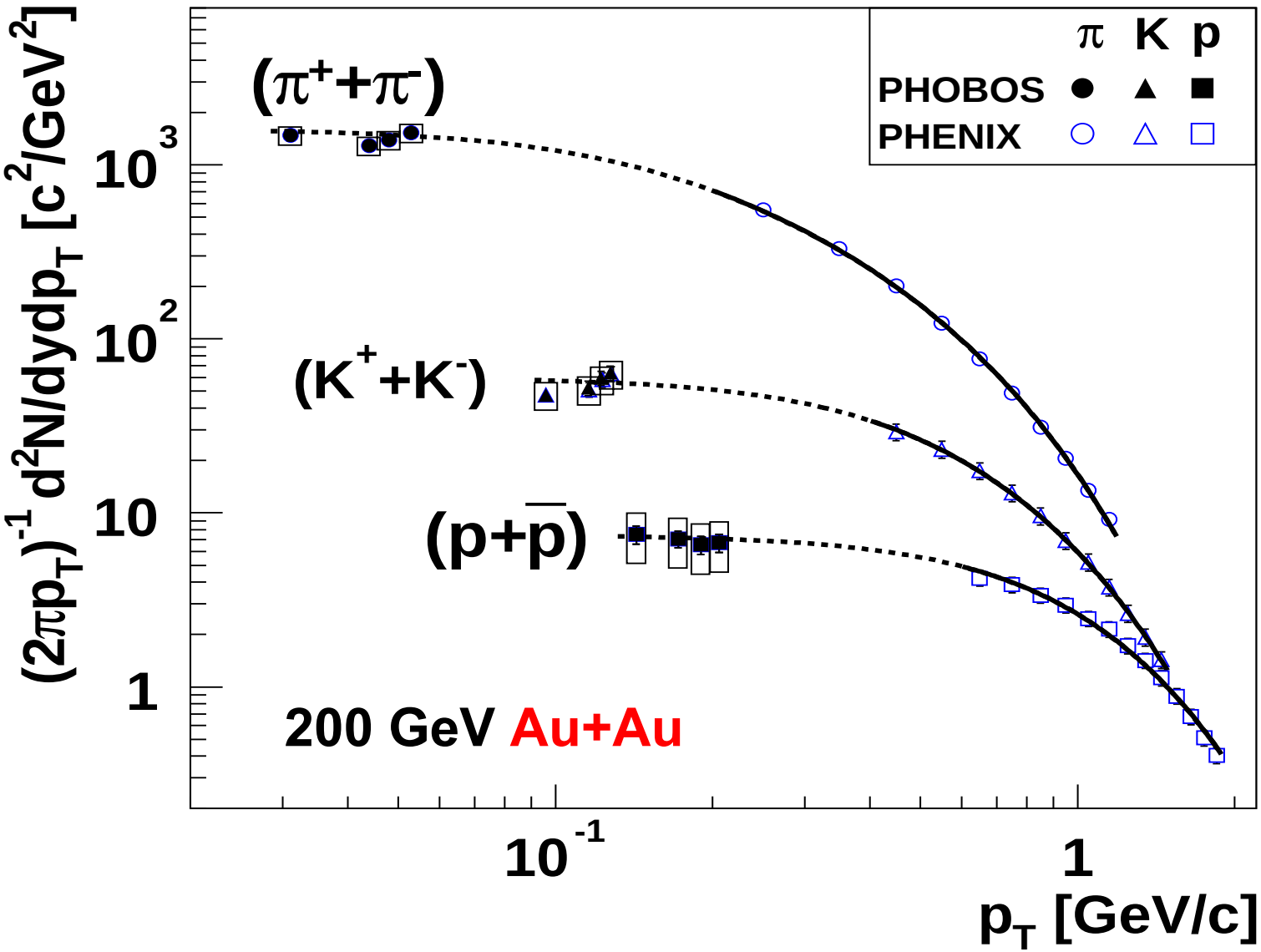
Energy dependence



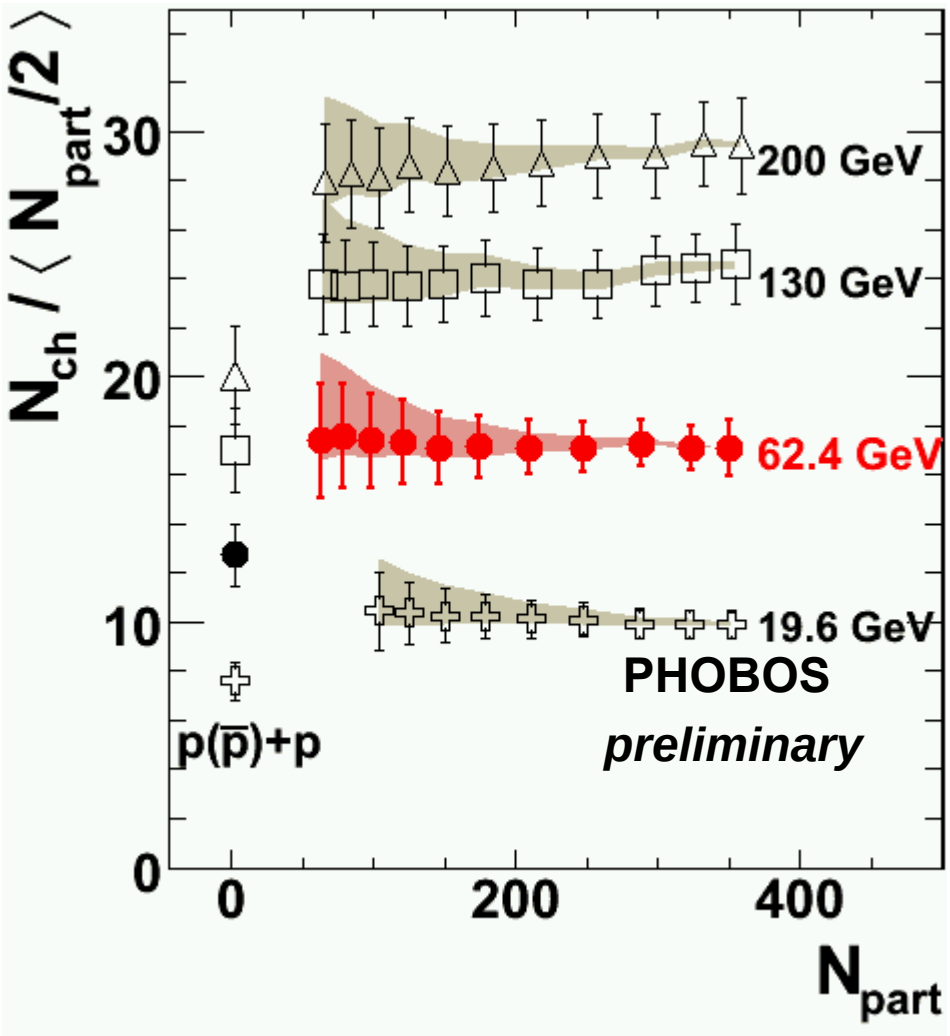
Centrality dependence

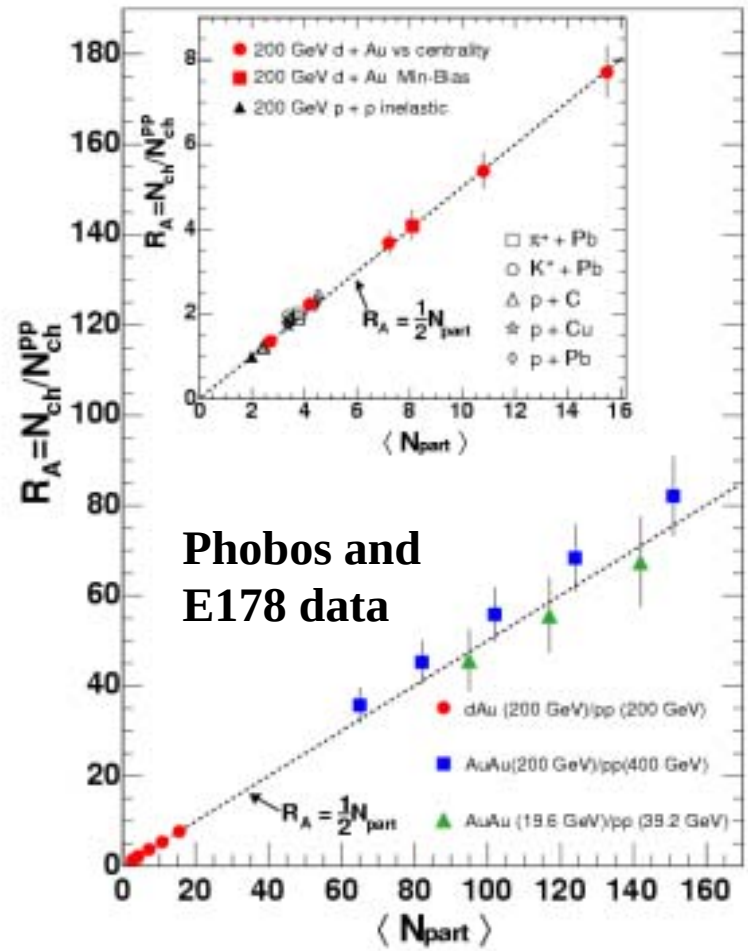


Unique Low Pt measurements



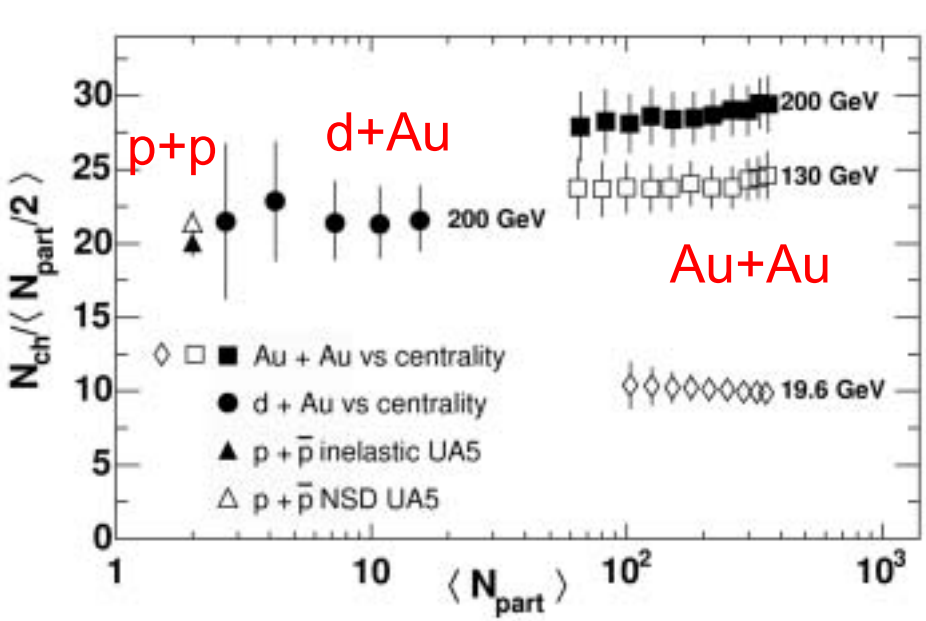
N_{part} scaling of Total charged particle yields



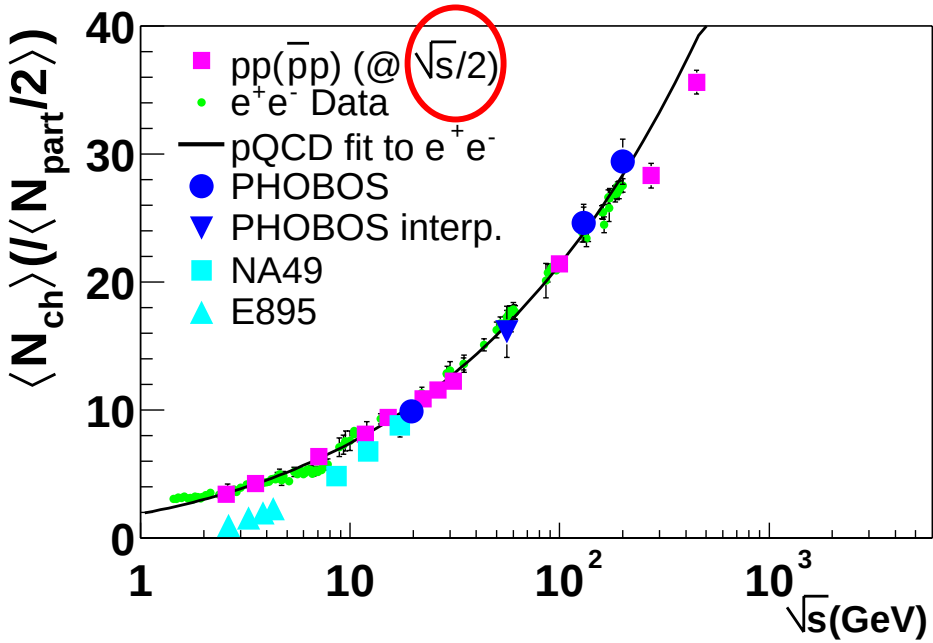


Universality of N_{ch}

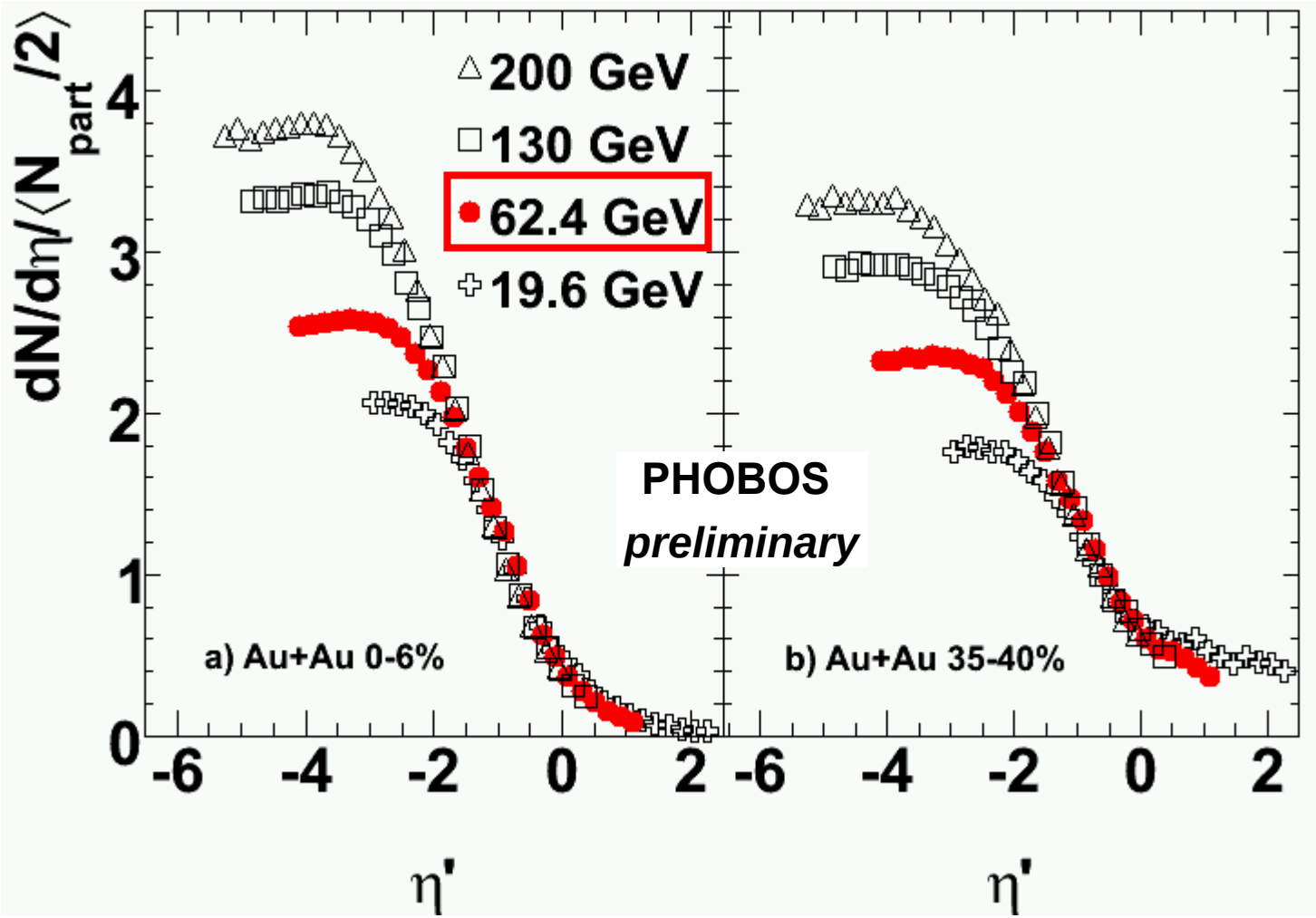
N_{part} scaling: Au+Au, d+Au



e^+e^-, p+p, A+A data produces the same N_{ch}



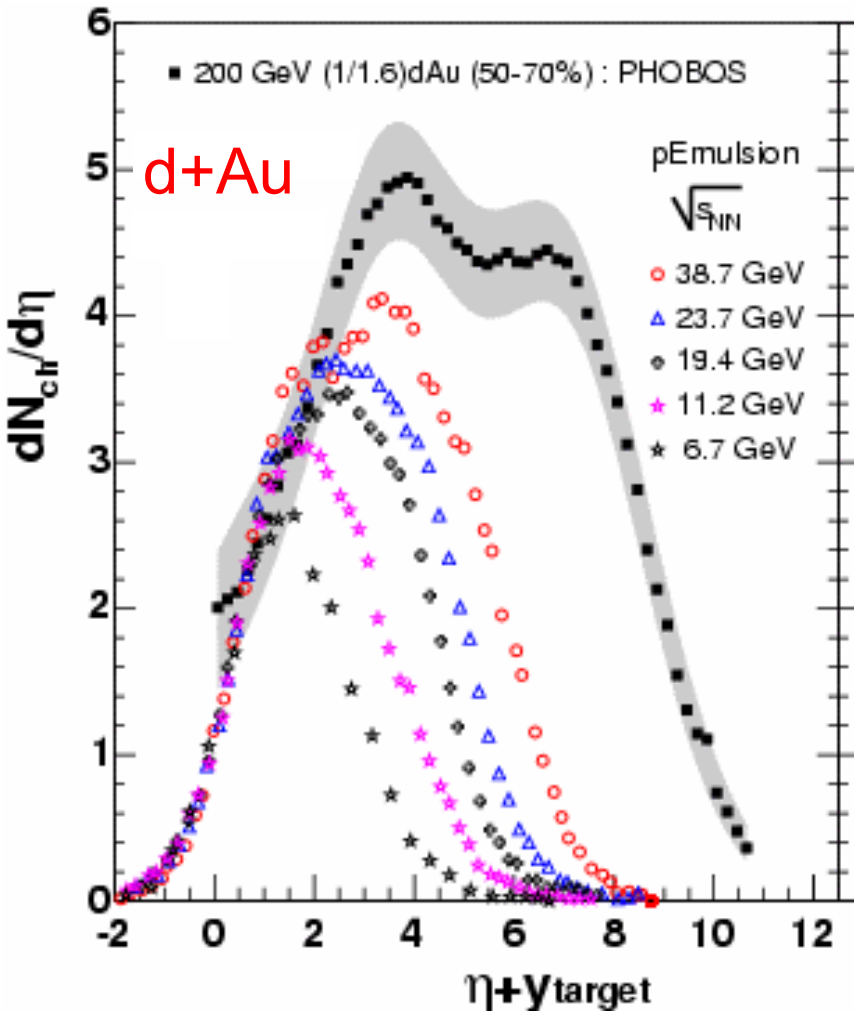
Extended longitudinal scaling of charged hadrons



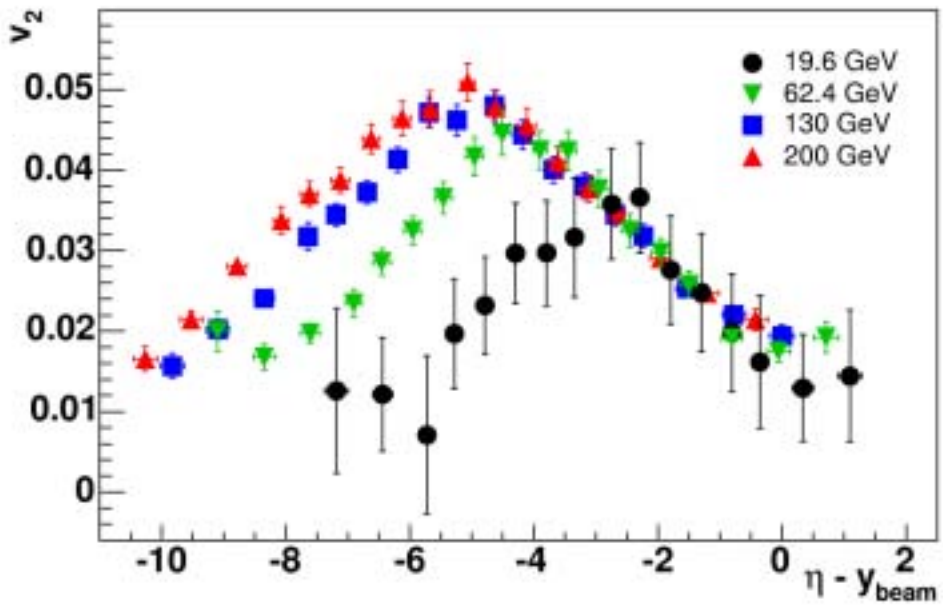
ie η in rest frame of one of the nuclei

Extended longitudinal scaling…

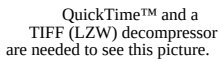
…in dN/dη (p+p, d+Au, Au+Au):



…in v_2 (elliptic flow):



WB's Prediction for LHC, based on various scalings observed in Phobos

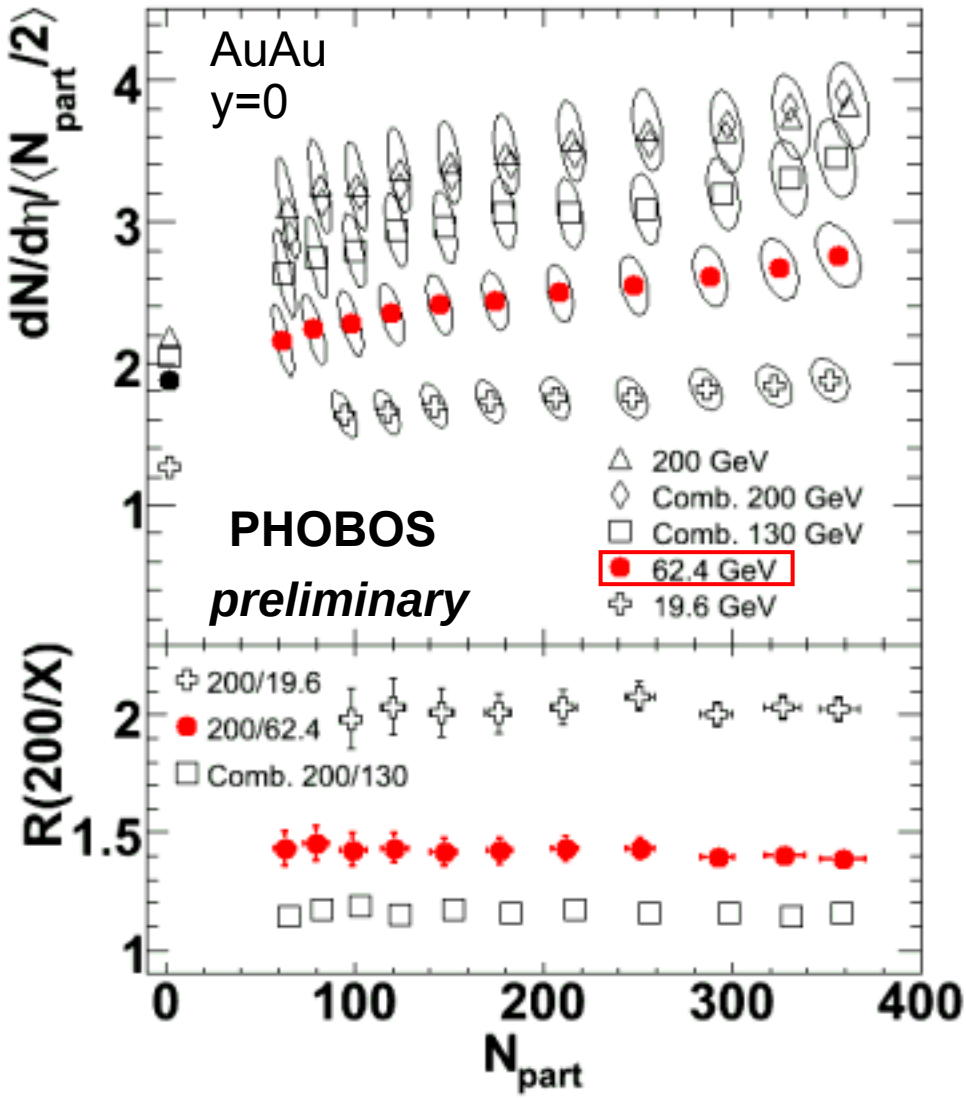


WB Acta Phys. Polon. B **35**, 2873

Factorization of beam energy and collision geometry

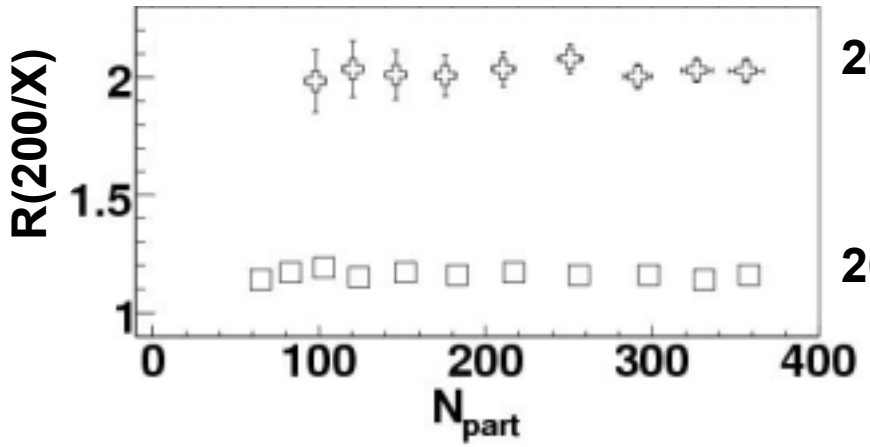
- **at higher energies, hard collisions should be more dominant**
- **N_{coll}/N_{part} increases with centrality**
- **still, energy-independent centrality evolution**

→ Factorization of energy and collision geometry

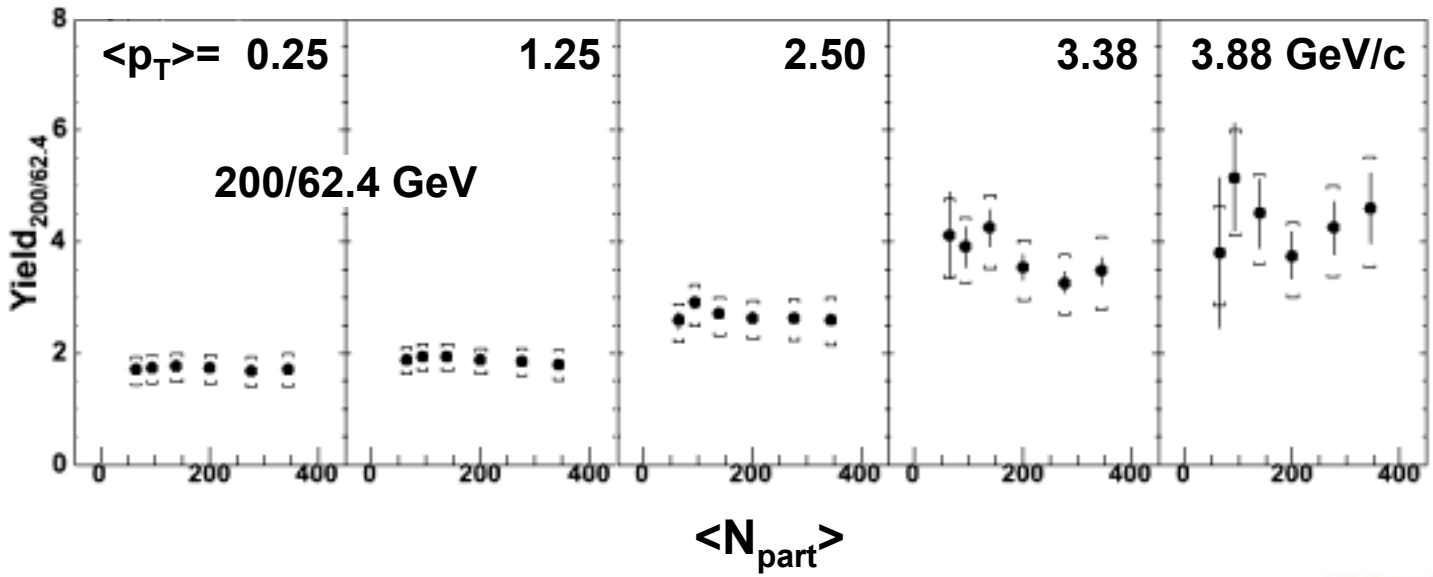


Factorization of geometry and energy

Ratio of $dN/d\eta|_{\eta=0}$ at different energies:

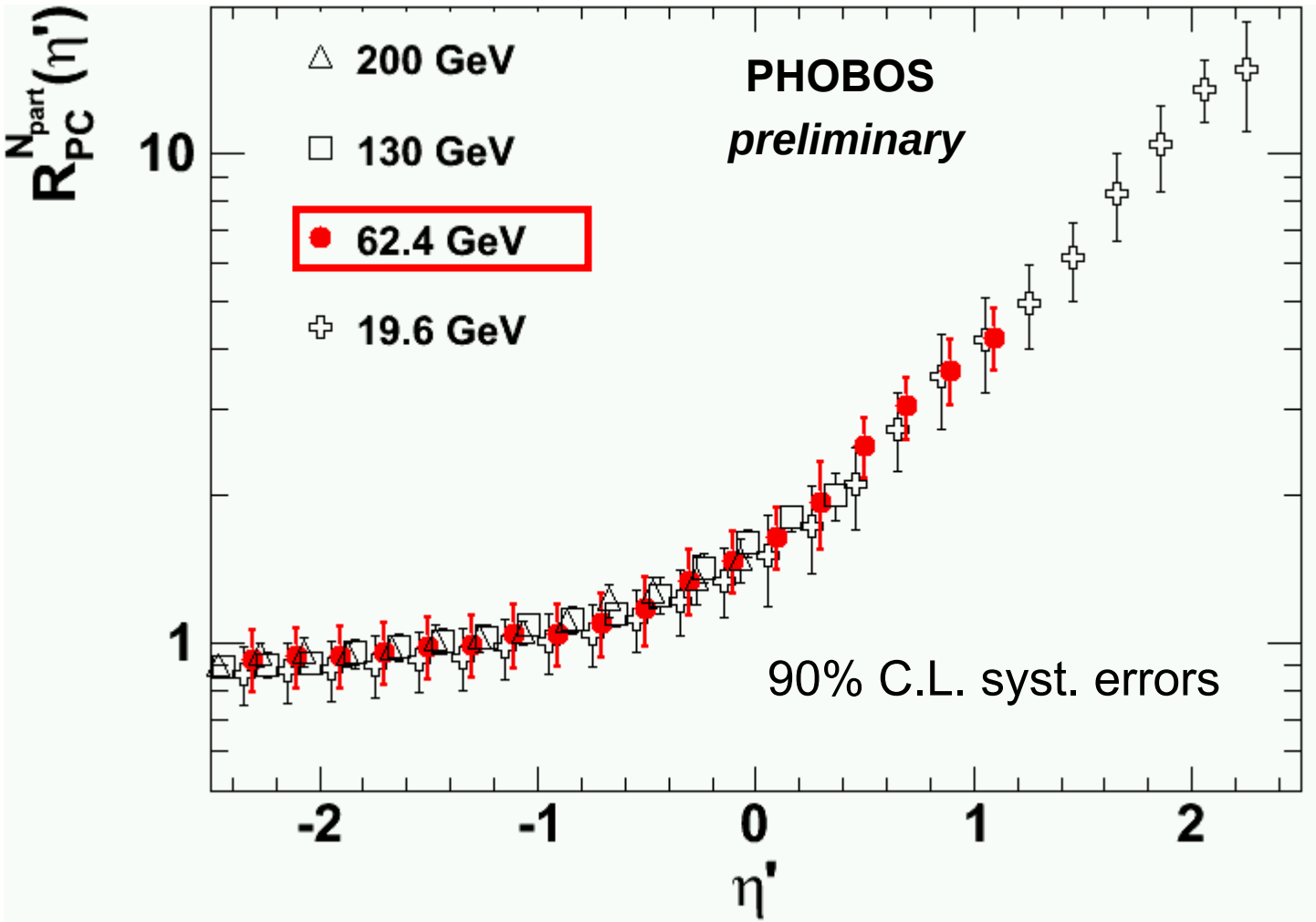


Also differentially,
at various p_T values:



$R_{PC}^{N_{part}}$ is precisely energy independent

Ratio of 0-6% and 35-40% centrality bins, each normalized by N_{part}



Future Plans and Needs

Data taking for PHOBOS has ended, but…

…lots of data on tape, still to be analyzed in the next years:

- **Charged hadron spectra in Cu+Cu, p+Au, n+Au collisions**
- **Identified spectra and particle/antiparticle ratios (Cu+Cu, Au+Au)**
- **Particle production at very low p_T**
- **Measurement of the Φ meson**
- **Multiplicity analysis using 'tracklets' and digital/analog method**
- **Event-by-event multiplicity fluctuations**
- **Two-particle correlations in d+Au collisions**
- **Elliptic and directed flow measurements**
- **Rare event searches**
- **HBT at very low p_T**
- **etc…**