Al Mueller's 70th birthday Oct. 2009

# DIRECT EVIDENCE OF SATURATION IN PHOBOS DATA

Wit Busza

MIT

More appropriate  title:

Lest he decide to take it easy after this splendid occasion

TWO QUESTIONS FOR AL

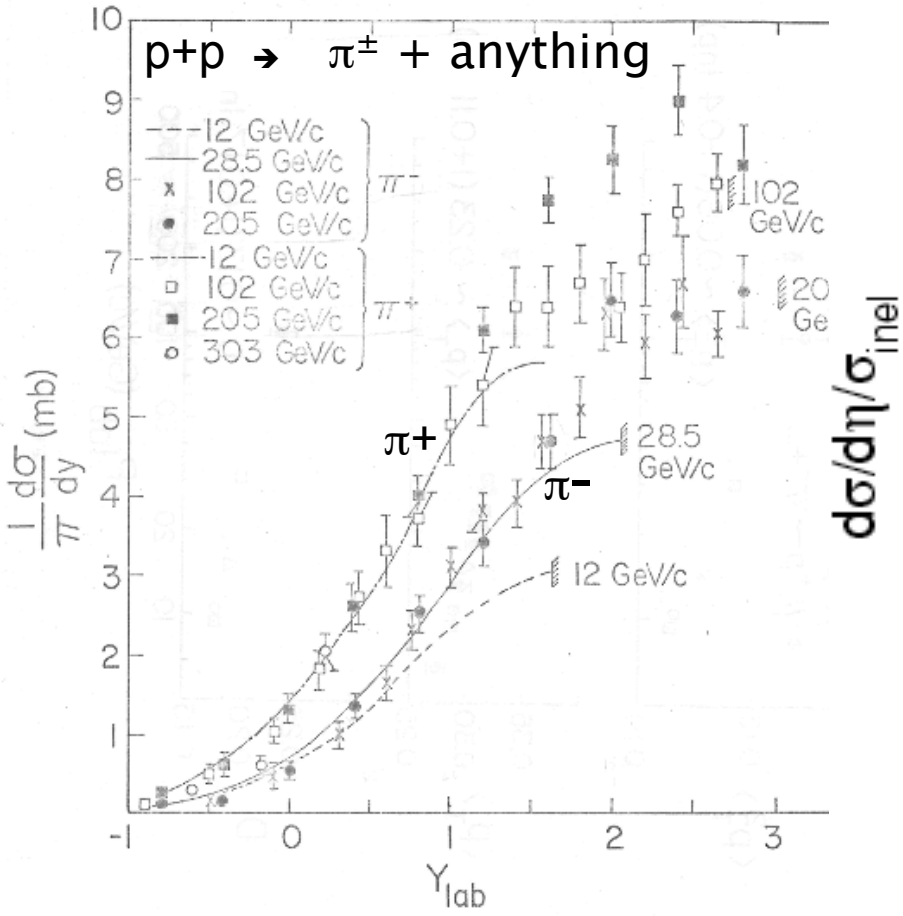
In 1969 Benecke, Chou, Yang and Yen proposed the:

"Hypothesis of Limiting Fragmentation in High Energy Collisions"

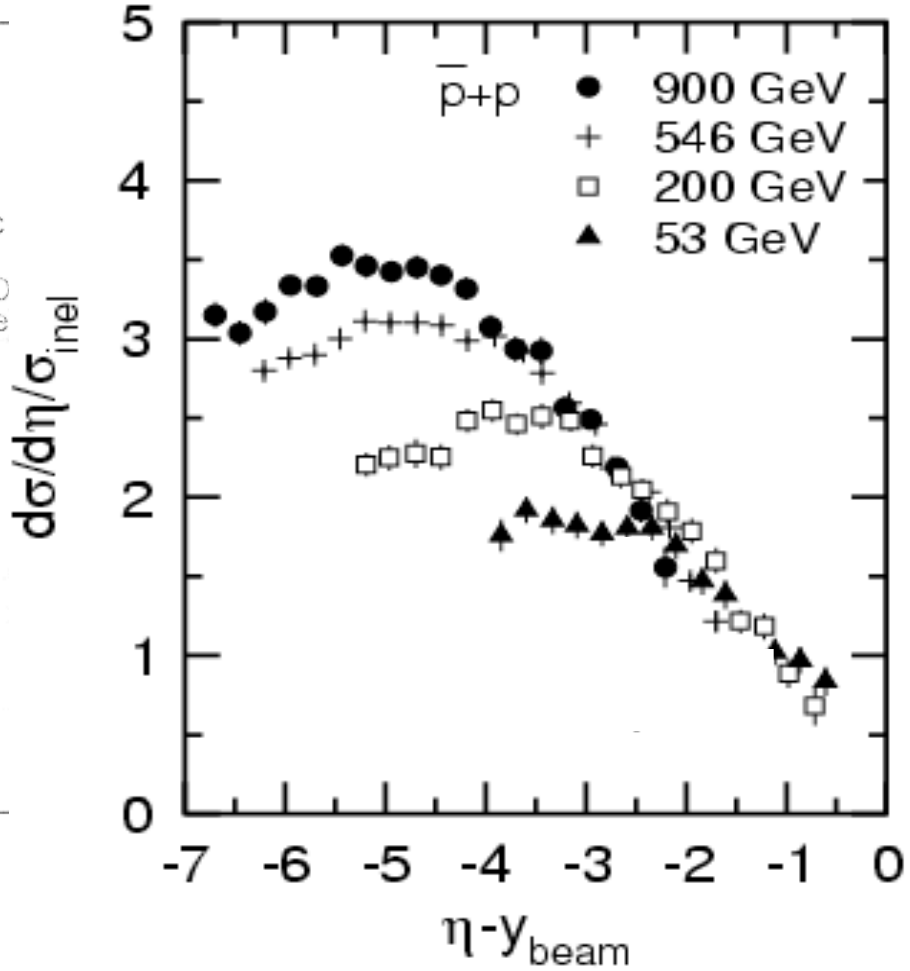
It was based on the "two-fireball model" used to explain cosmic ray physics

And the "intuitive picture of a high-energy collision process as two extended objects going through each other, breaking into fragments in the process……"

Hypothesis of limiting fragmentation clearly established in elementary collisions:

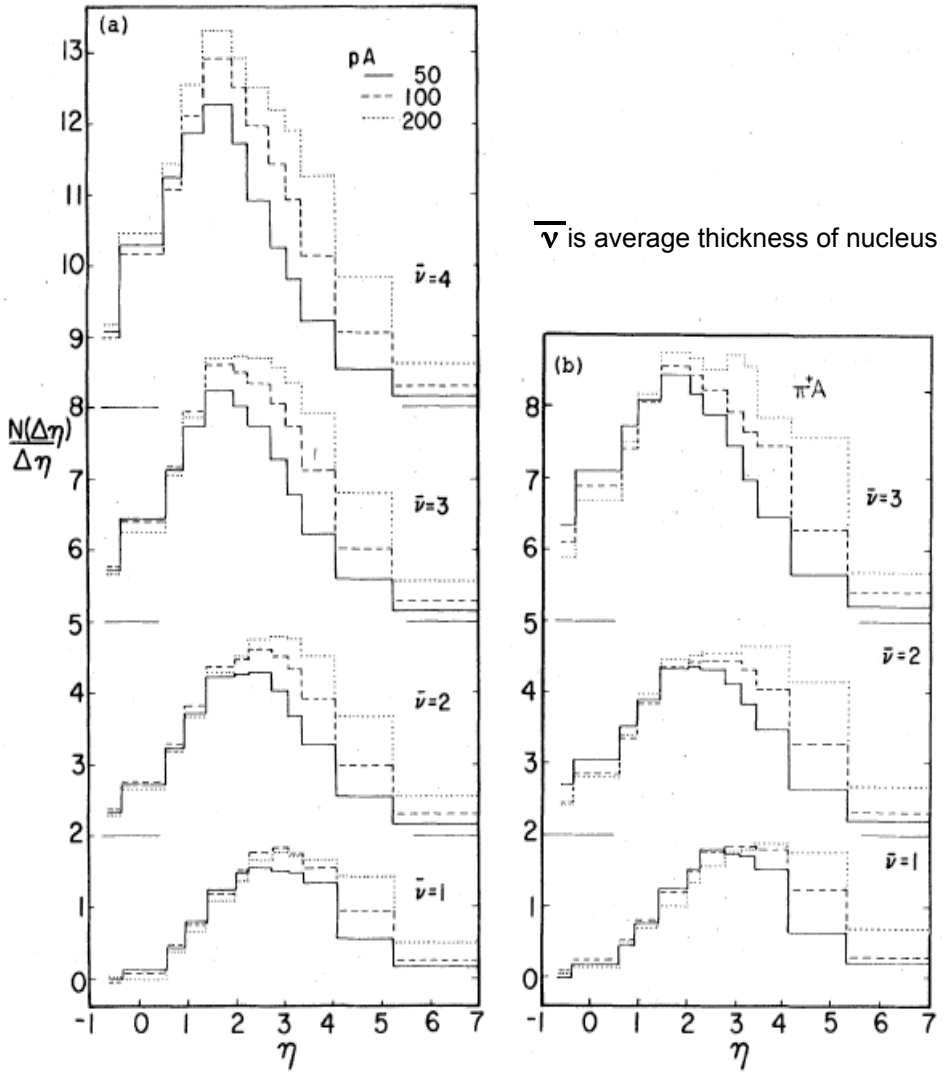



J.Whitmore, Physics Reports 10C (1974)

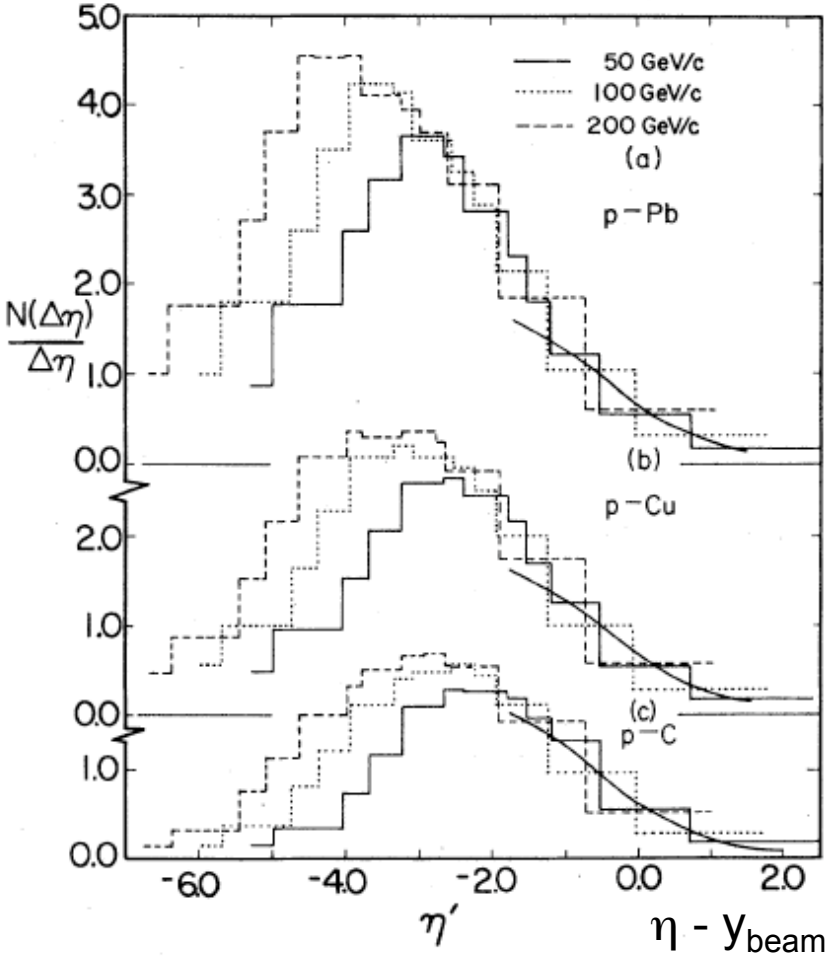



UA5, ZPC 33(1986); CDF, PRD 41 (1990)

## Limiting fragmentation in pA data (Experiment E178) $\sqrt{s_{NN}}$ = 10 - 20 GeV




$\bar{\nu}$ is average thickness of nucleus

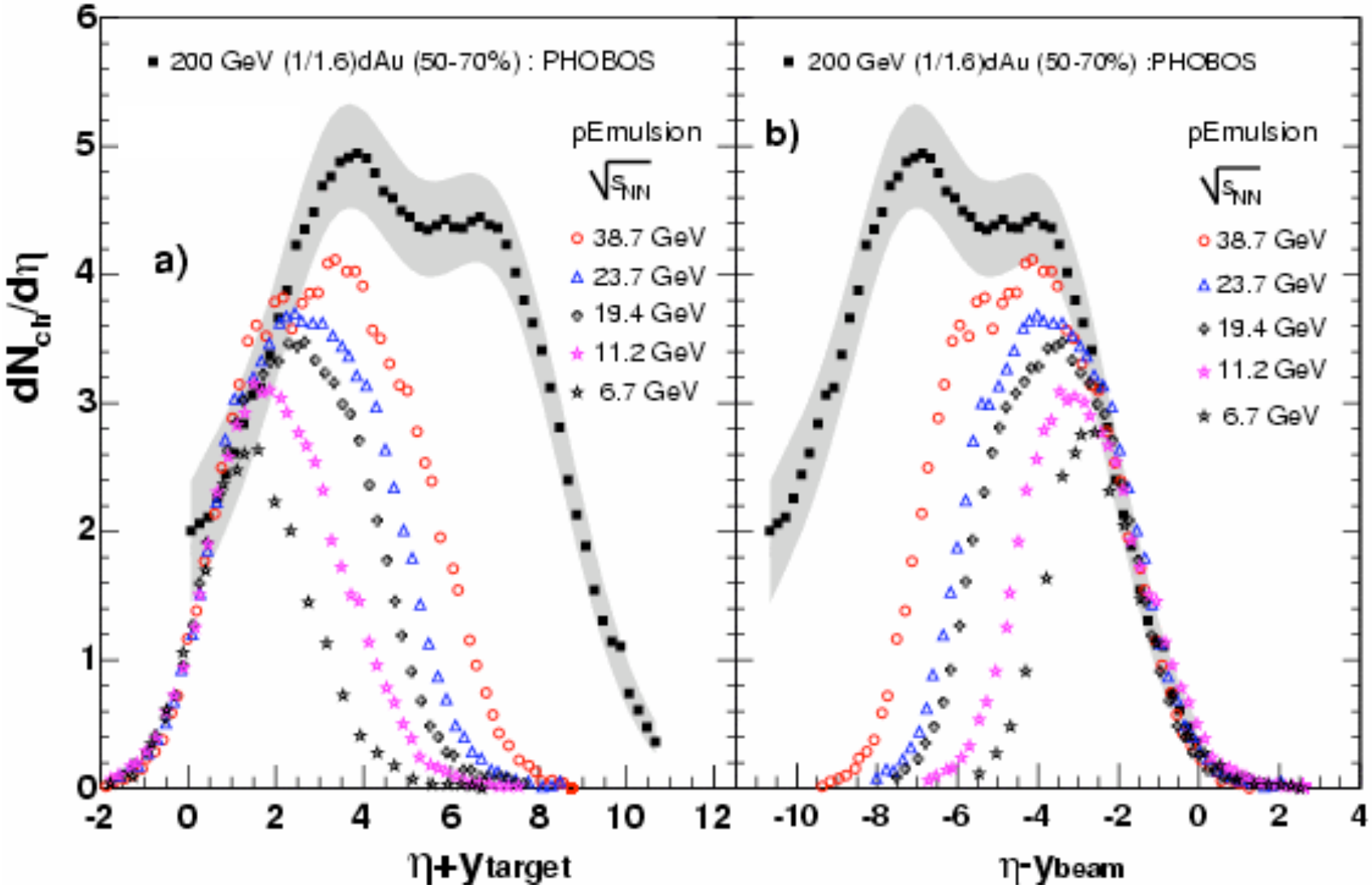



Nucleus rest frame

Projectile rest frame

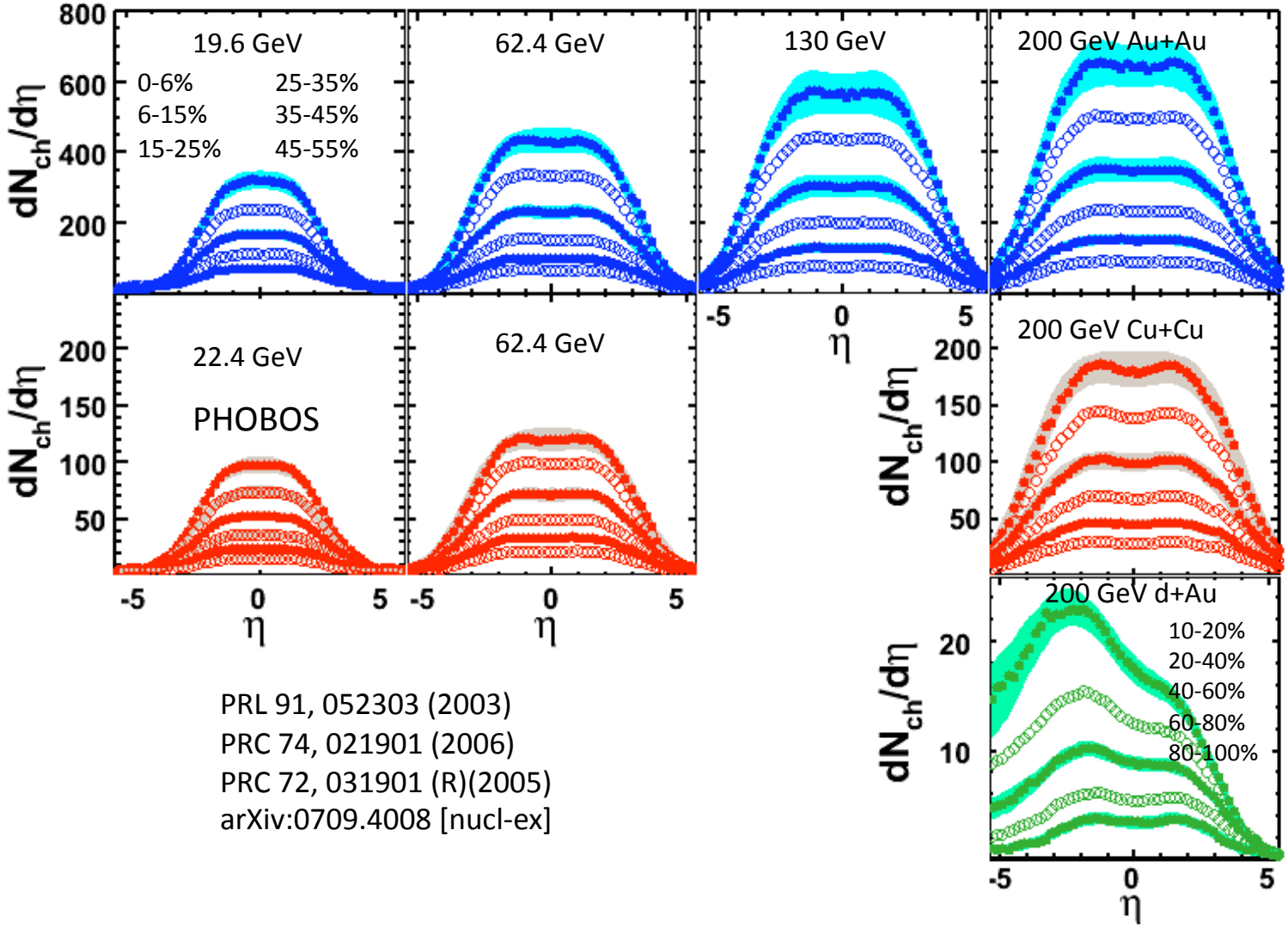
W.B., J. Elias et al., (E178 B) PR D22 (1980) 13

# Limiting fragmentation in p(d)+A collisions




PHOBOS, Phys. Rev. C72, 031901(R) (2005)

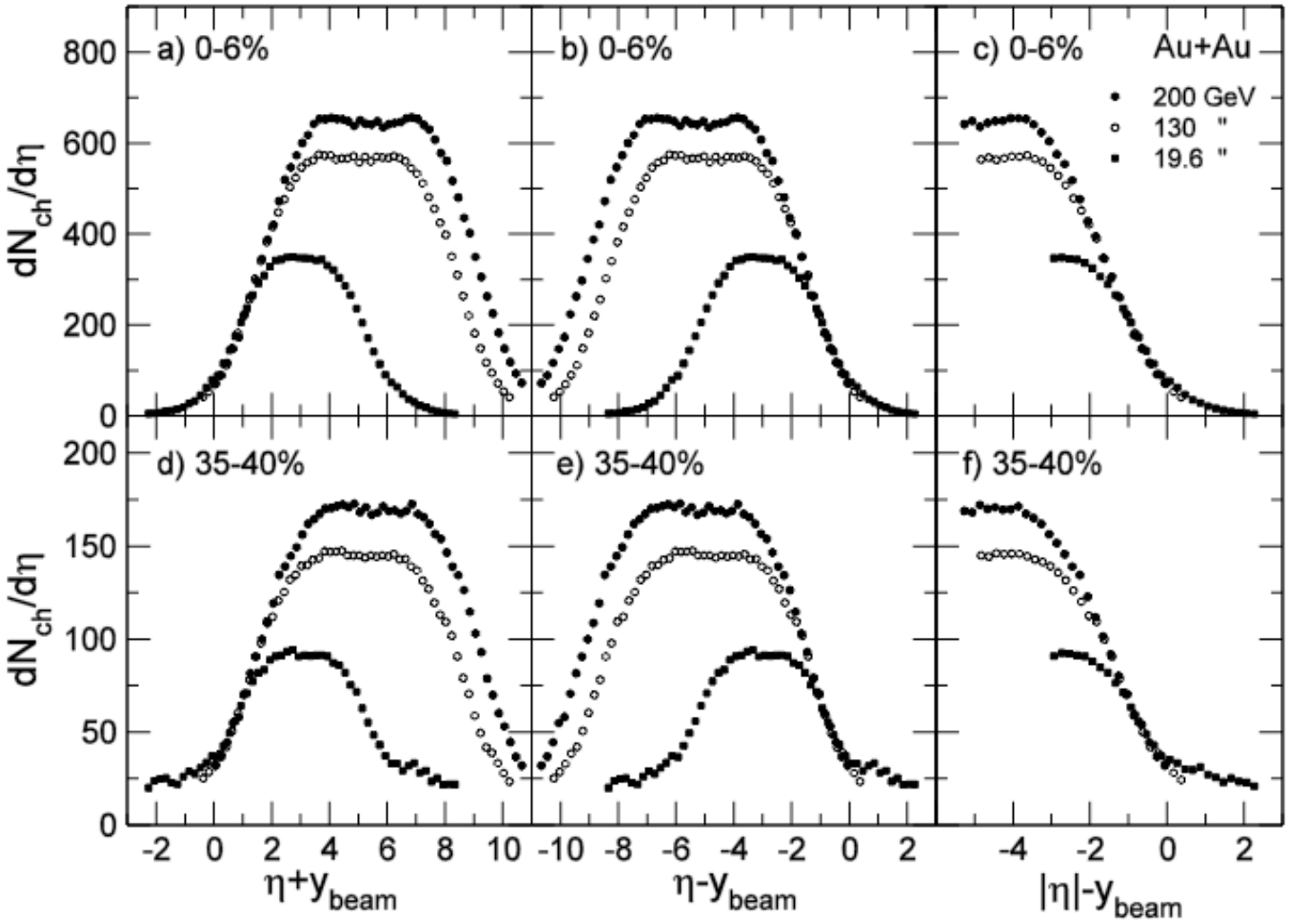
# PHOBOS Data on Pseudorapidity Distributions




PRL 91, 052303 (2003)
PRC 74, 021901 (2006)
PRC 72, 031901 (R)(2005)
arXiv:0709.4008 [nucl-ex]

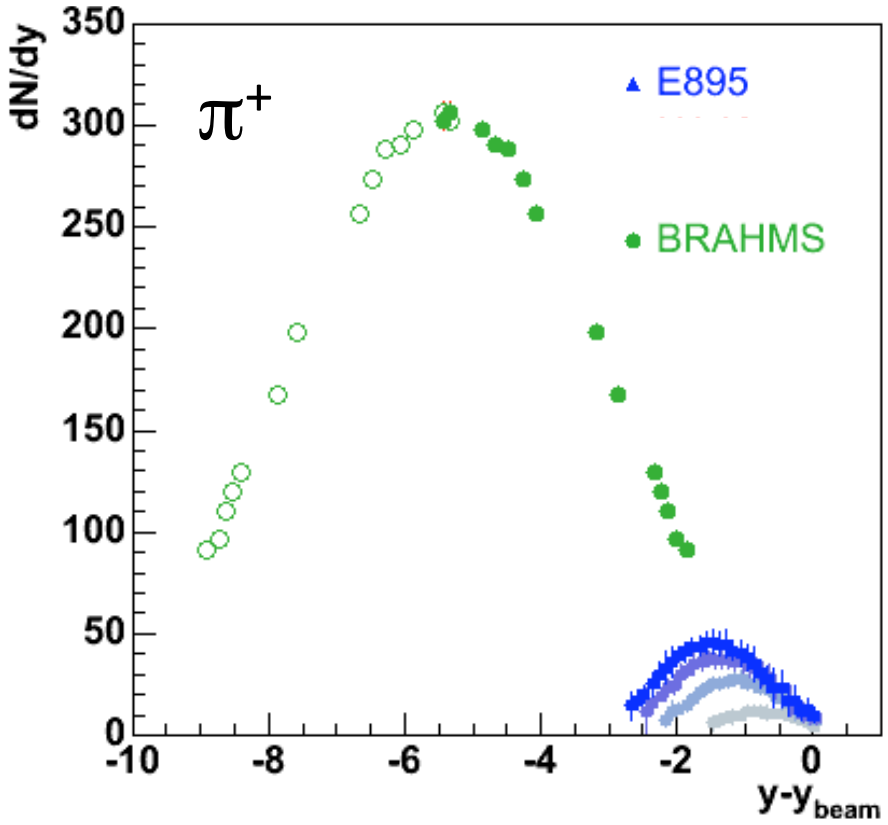
# Limiting Fragmentation in AA Collisions

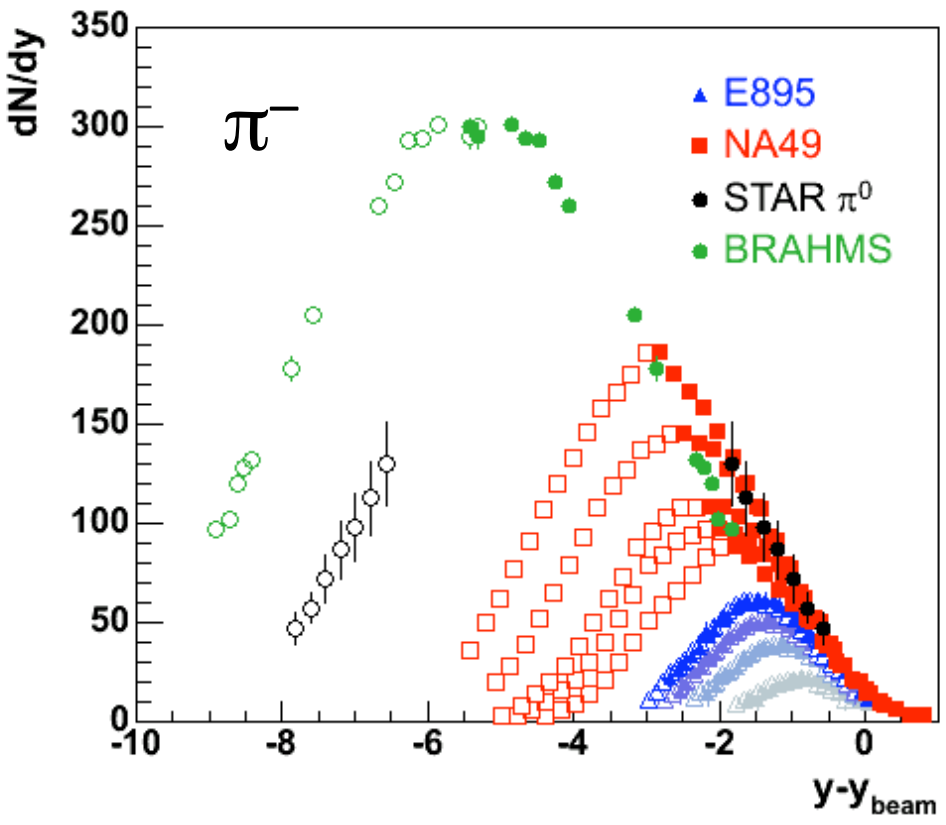
Renamed by PHOBOS "Extended Longitudinal Scaling"because of the broad range in rapidity in which it is seen.




PHOBOS Phys. Rev. Lett. 91, 052303 (2003) / Nucl. Phys. A757, 28 (2005)

# Extended Longitudinal Scaling seen in inclusive processes in AA collisions



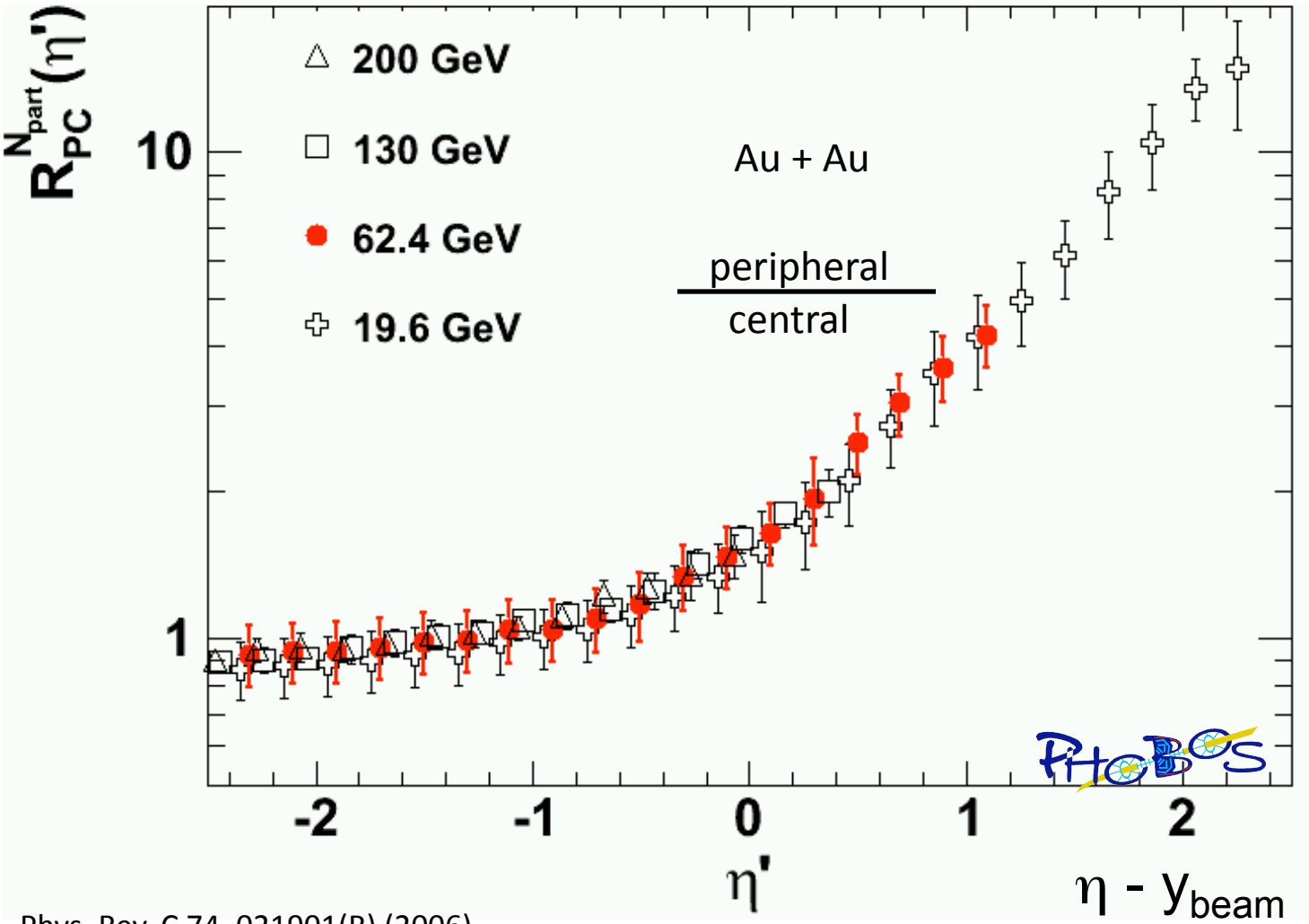




NA49: PRC 66 054902
Brahms: PRL 94 162301 (2005)
E895: PRC 68 054905 (2003)

$\sqrt{s}$=2.63, 3.28, 3.84, 4.29,
6.27,7.62,8.76,12.32,17.27,200 GeV

Au+Au, Pb+Pb

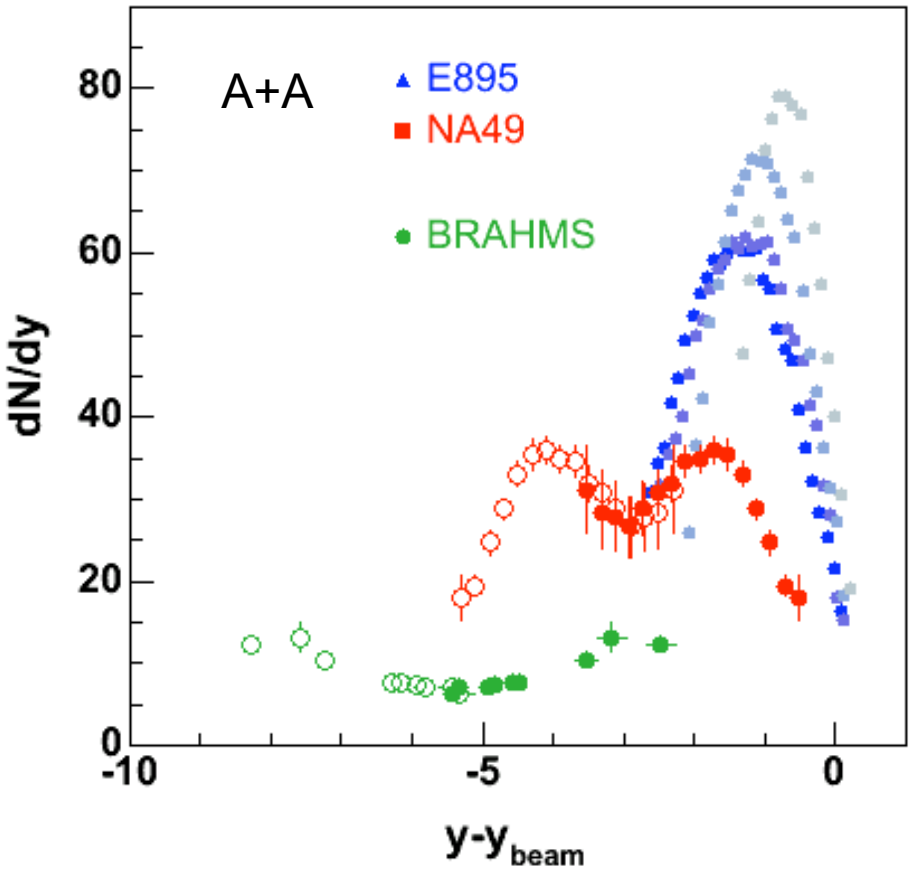
From Gábor Veres QM05




Phys. Rev. C 74, 021901(R) (2006)

arXiv:0709.4008 [nucl-ex]

# Energy dependence of net proton production




conserved quantity, different from produced particles

No scaling is observed at high η…

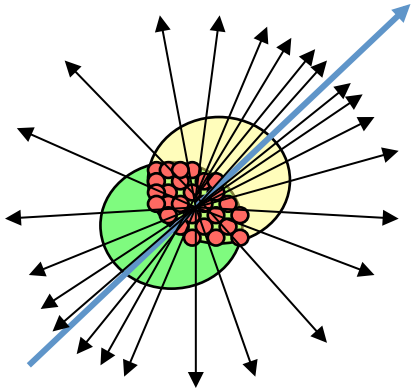
Brahms: PRL 93 102301 (2004)
NA49: PRL 82, 2471 (1999)
E895: PR C66 054905 (2003)

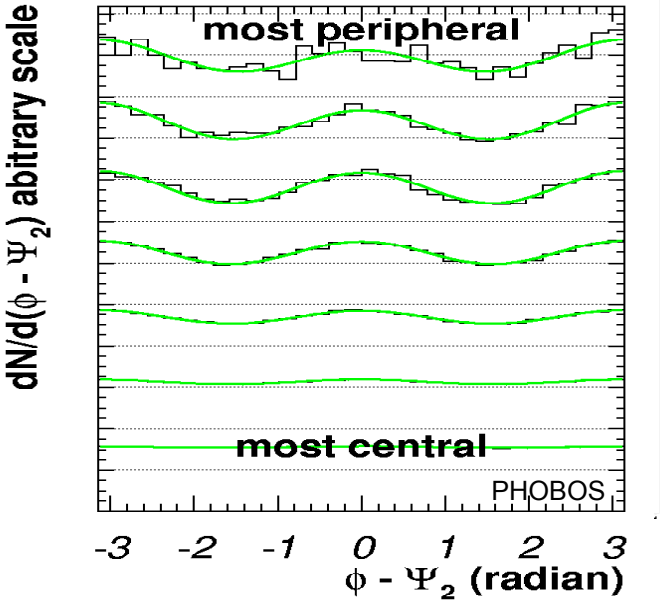
From Gábor Veres QM05

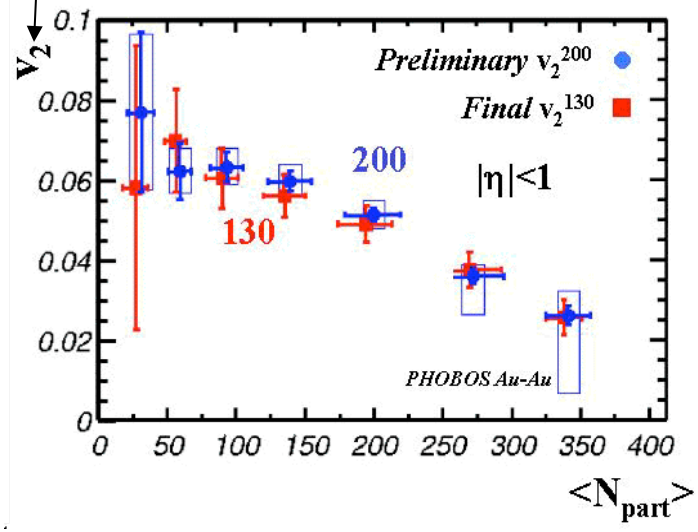
# Azimuthal Angular Distributions

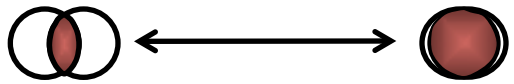
Amplitude of oscillations

$$\frac{dN}{p_T dp_T dy d\varphi}(p_T,\varphi,b) = \frac{dN}{2\pi p_T dp_T dy}\left(1 + 2v_2(p_T;b)\cos(2\varphi) + \ldots\right)$$





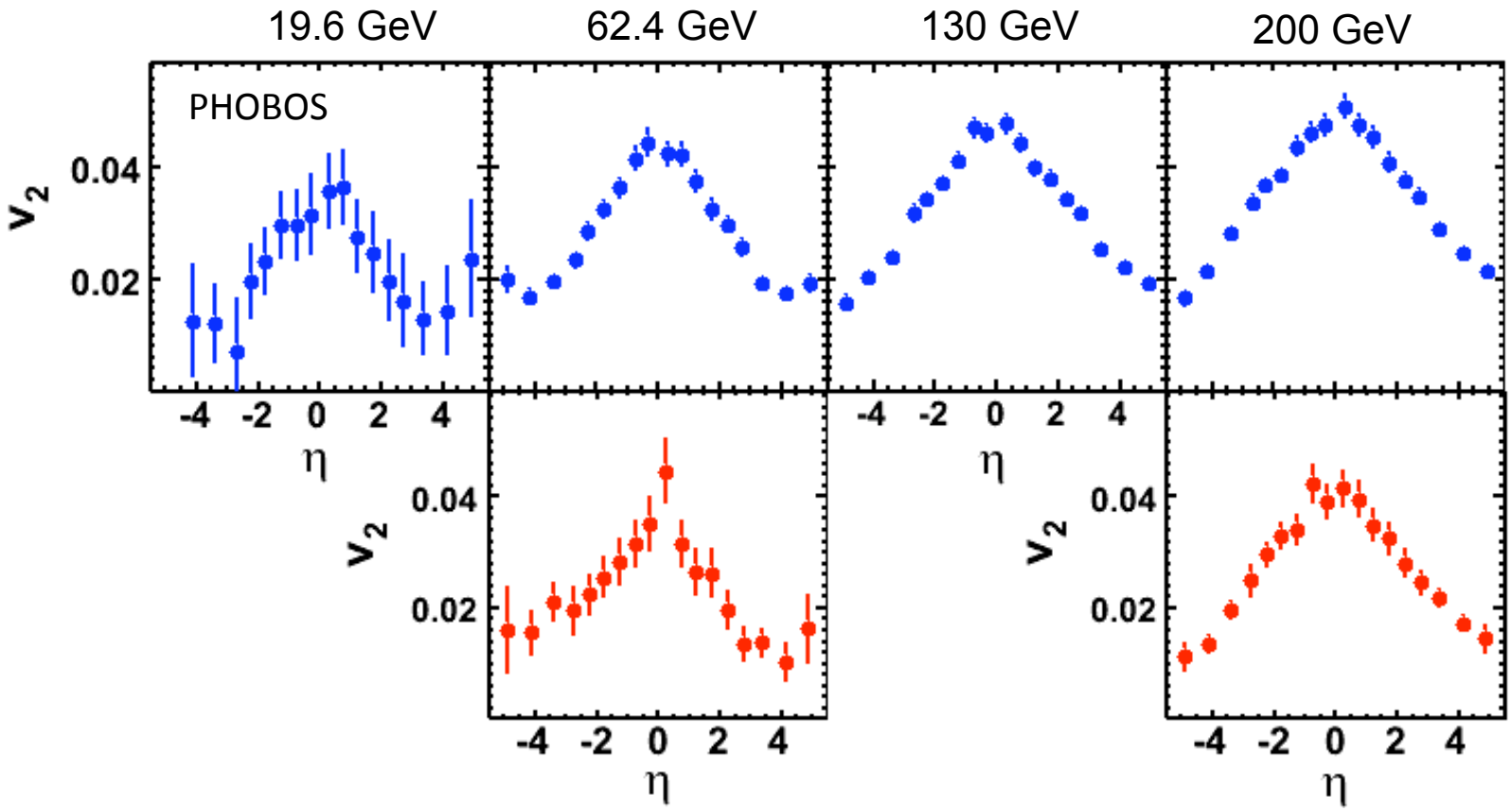



Peripheral Central

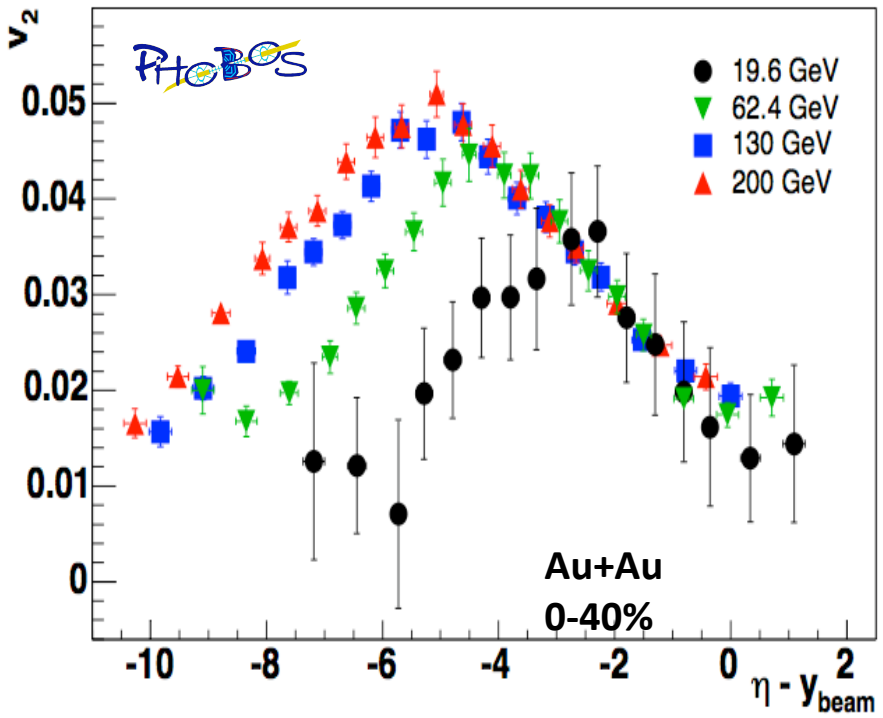
"head on" view of colliding nuclei

# Phobos data on elliptic flow of charged particles

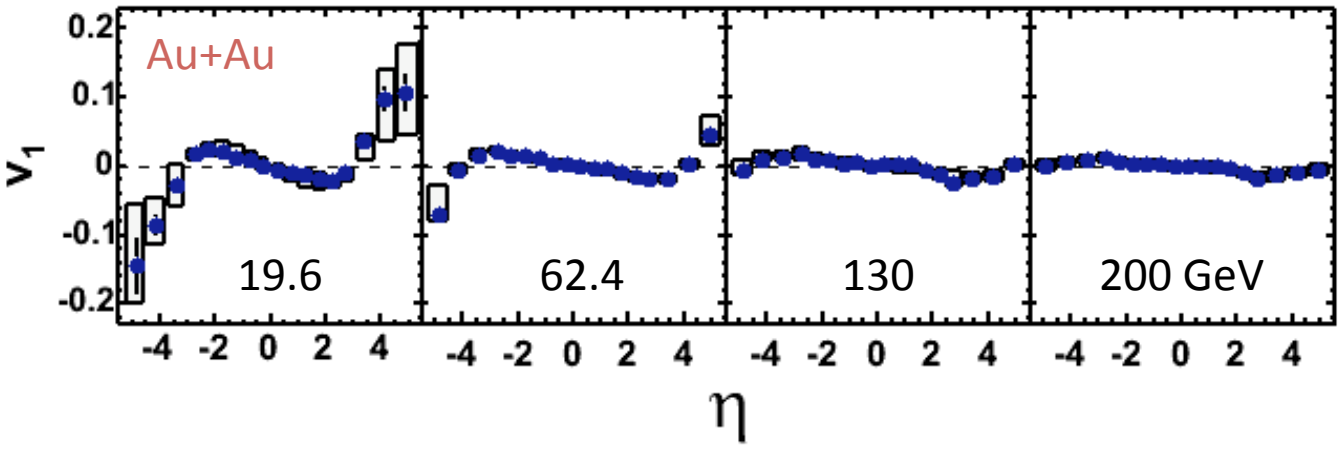



AuAu: PHOBOS: PRL 94 122303 (2005)
CuCu: PHOBOS: PRL 98, 242302 (2007)

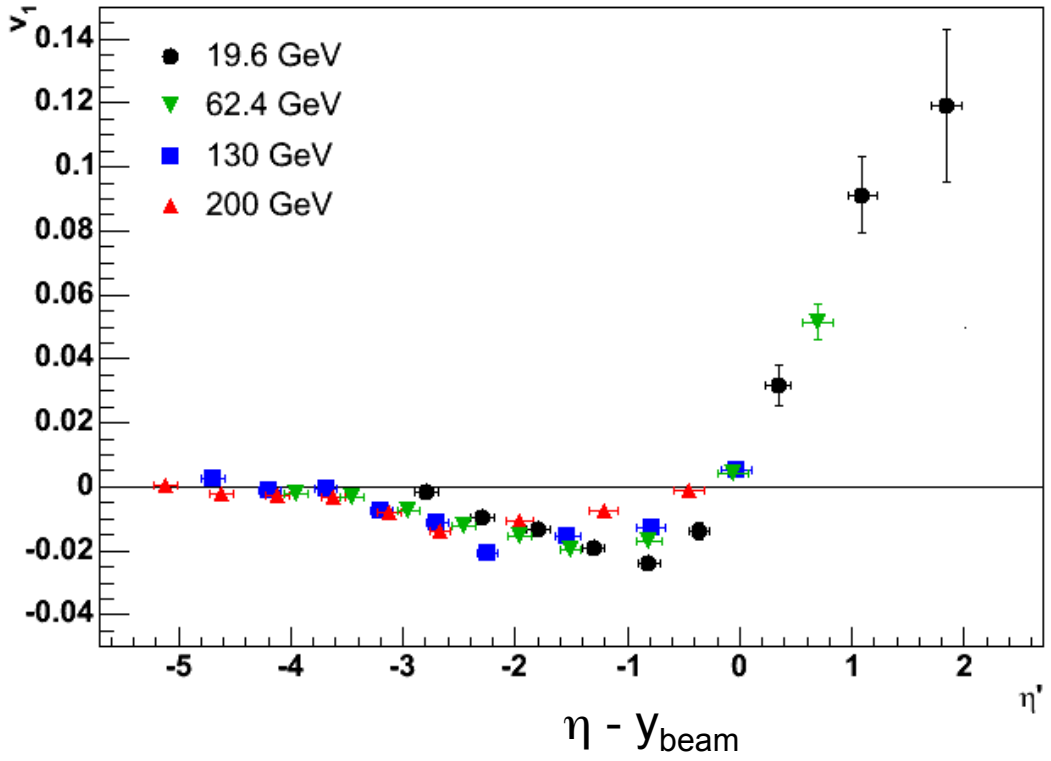
# Extended longitudinal scaling seen in transverse properties of produced particles




PRL94, 122303(2005)



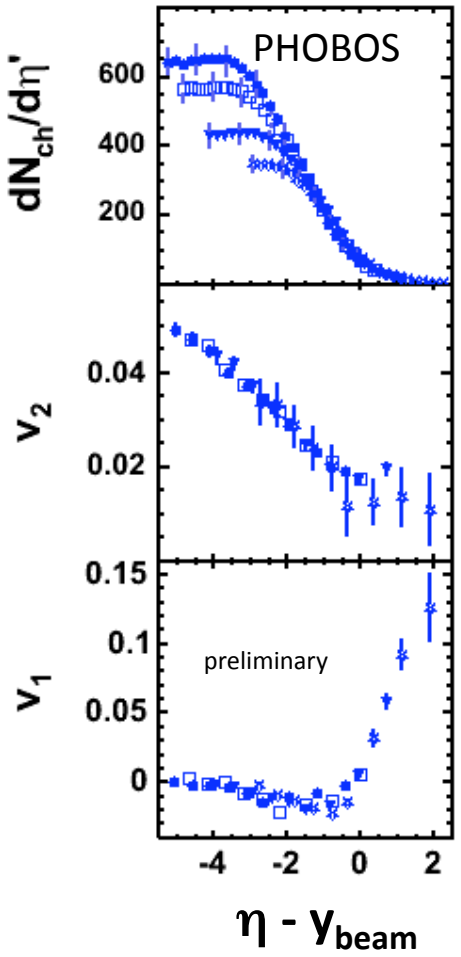

PHOBOS
0-40% centrality

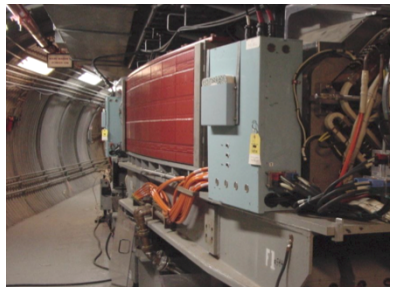


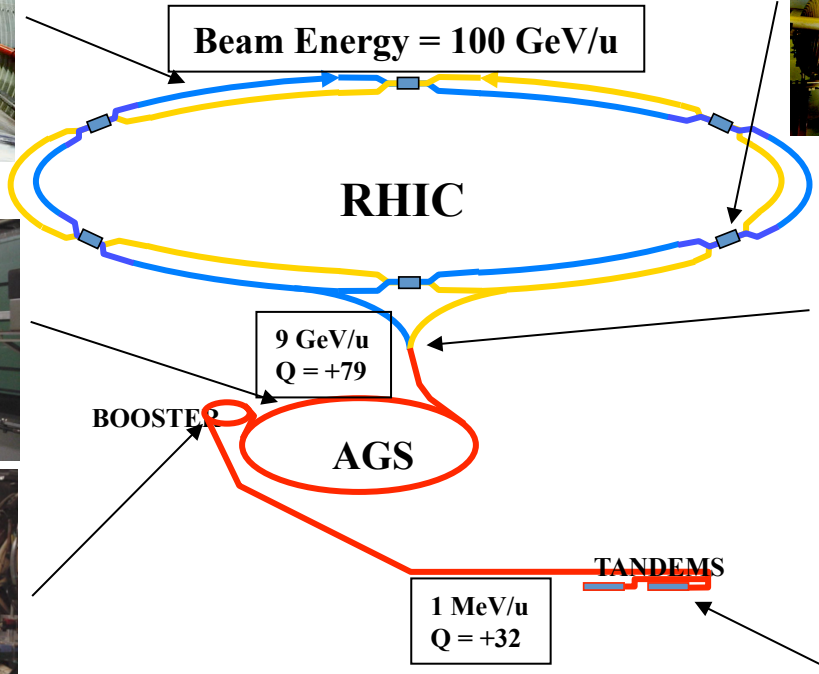
First question for AI:

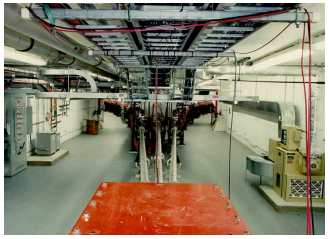
The conventional wisdom is that in AA collisions at RHIC energies, in the early stages of the collision, a strongly interacting system is produced.

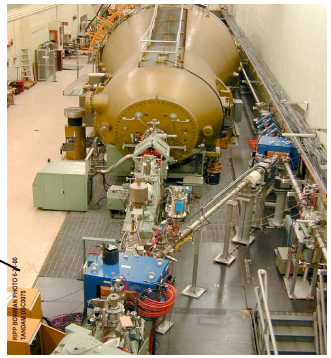
How is it that over a very broad range of rapidity (over most of the phase space) the particles are produced as if the incoming matter passed through each other?





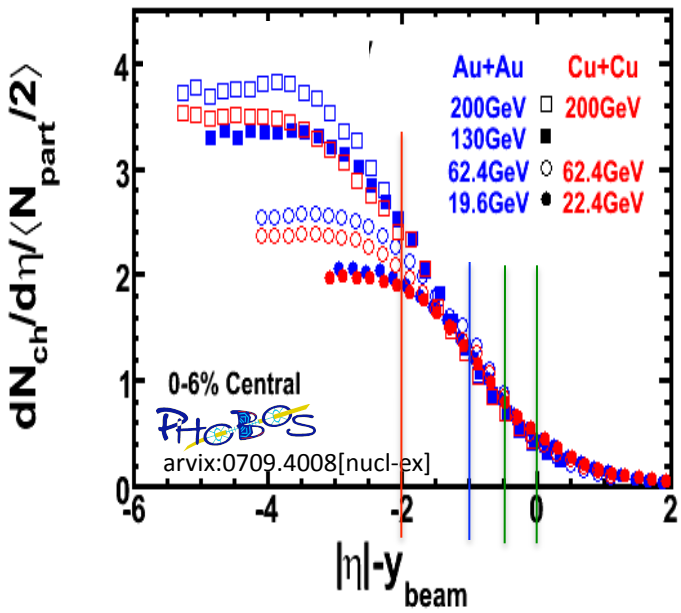


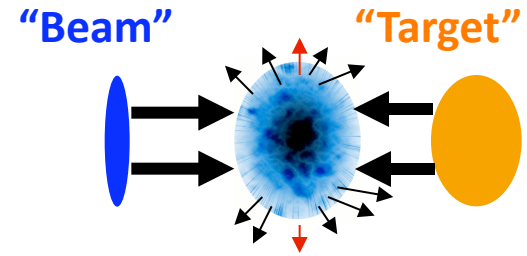


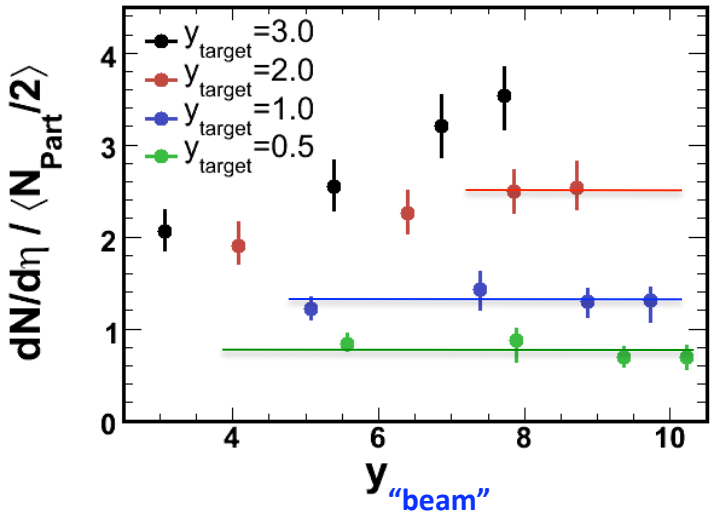
From Tom Roser

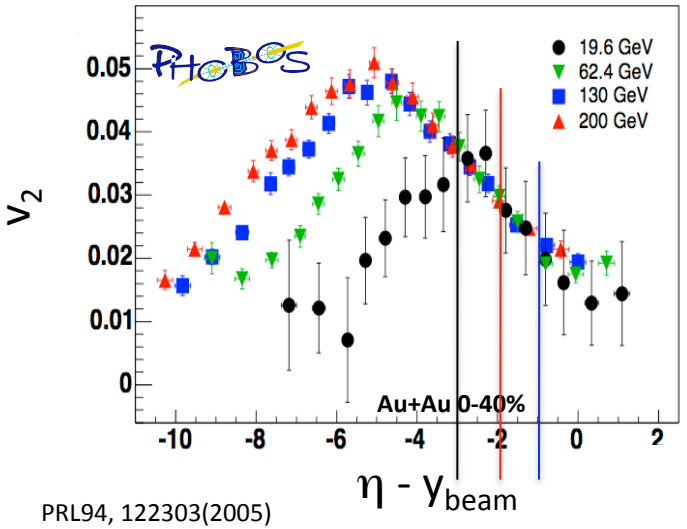
# Direct manifestation of the saturation of particle production



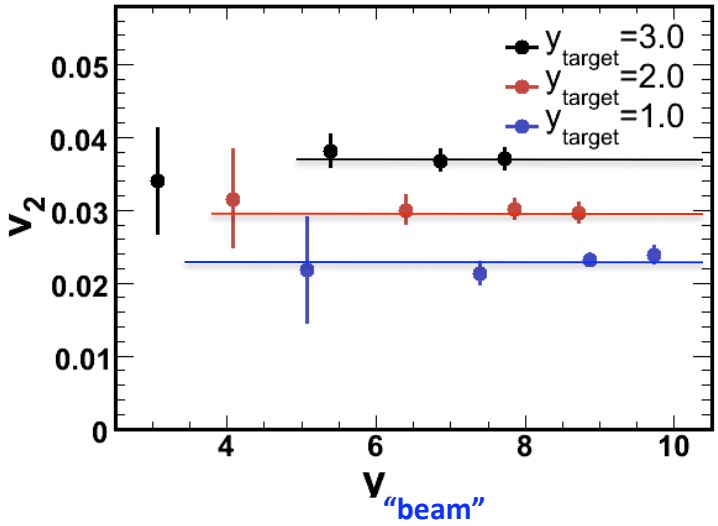

Taking y≈η

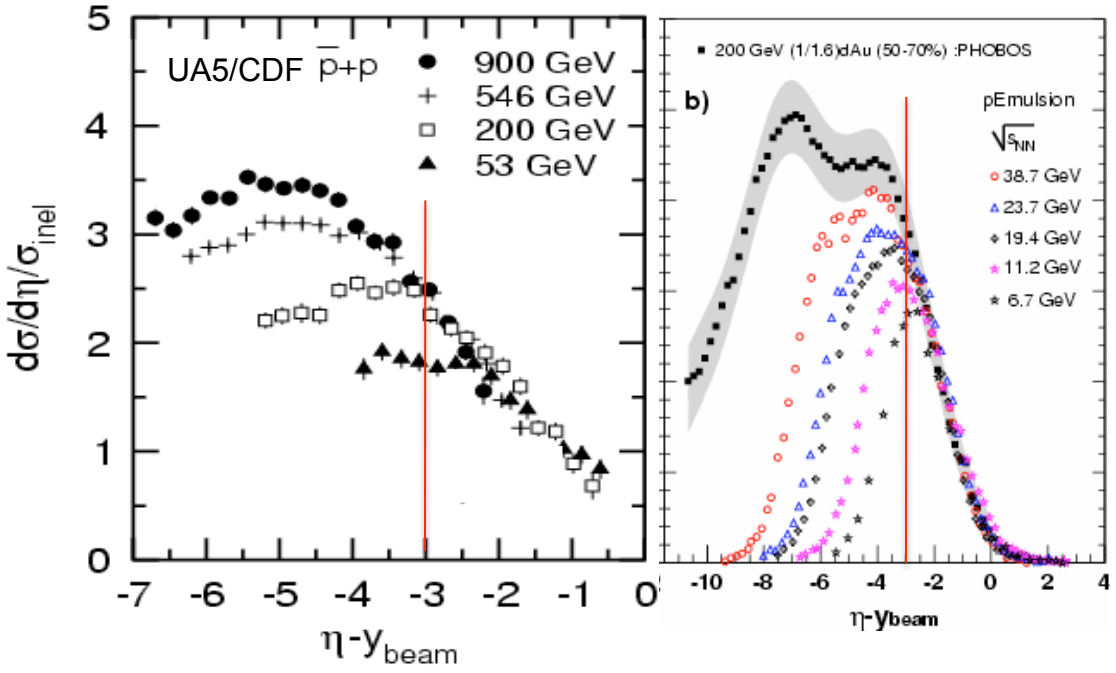


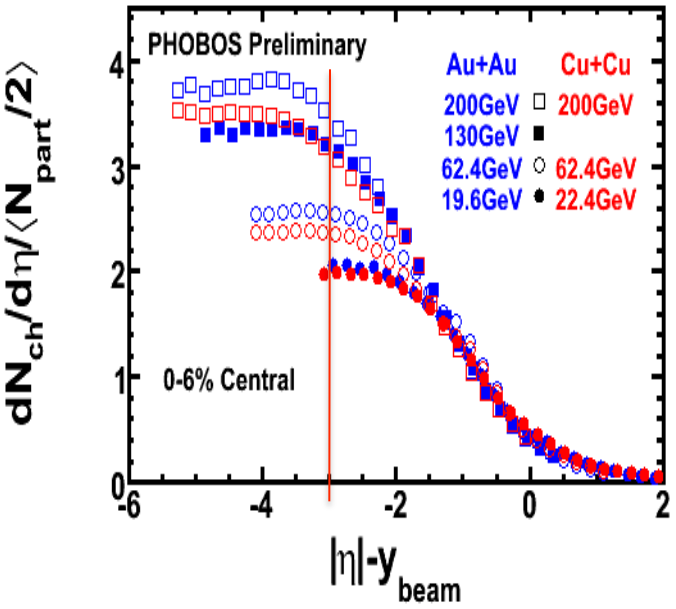



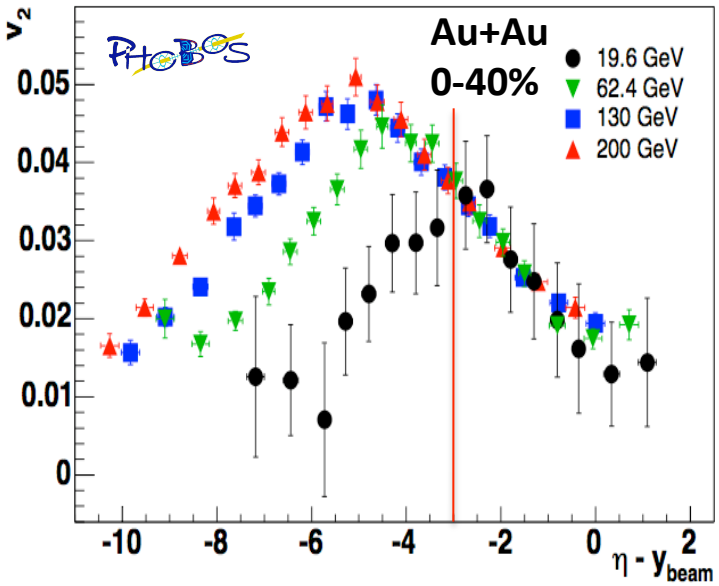




PRL94, 122303(2005)





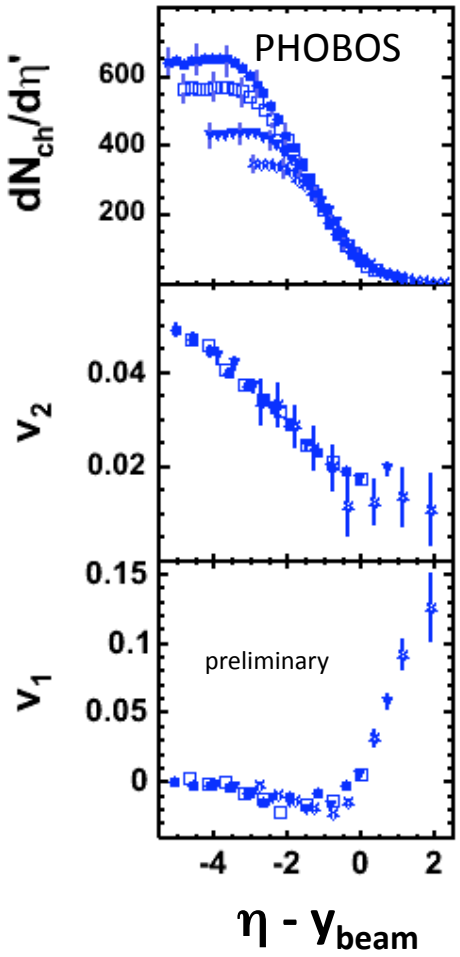



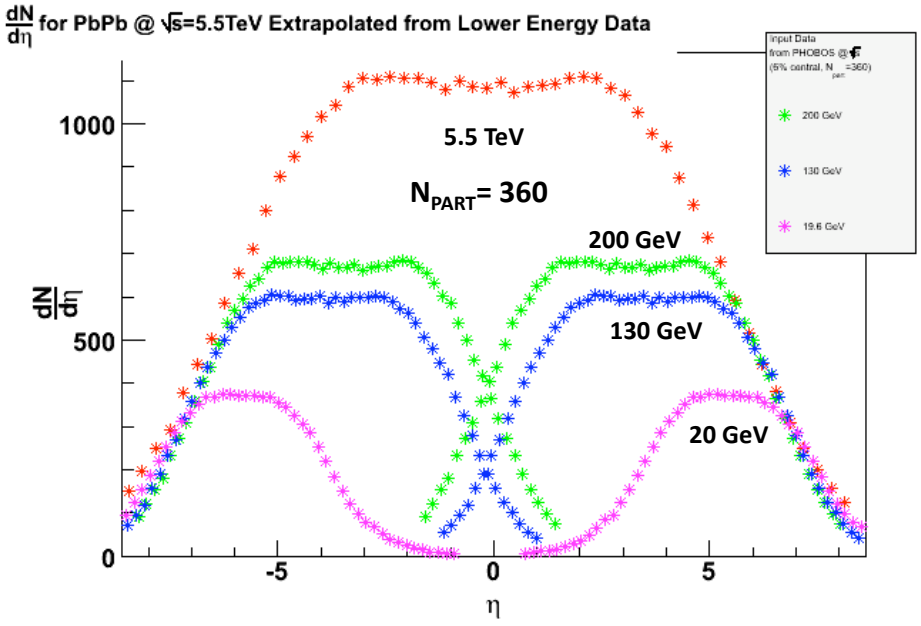

Direct evidence of saturation in pp, pA and AA

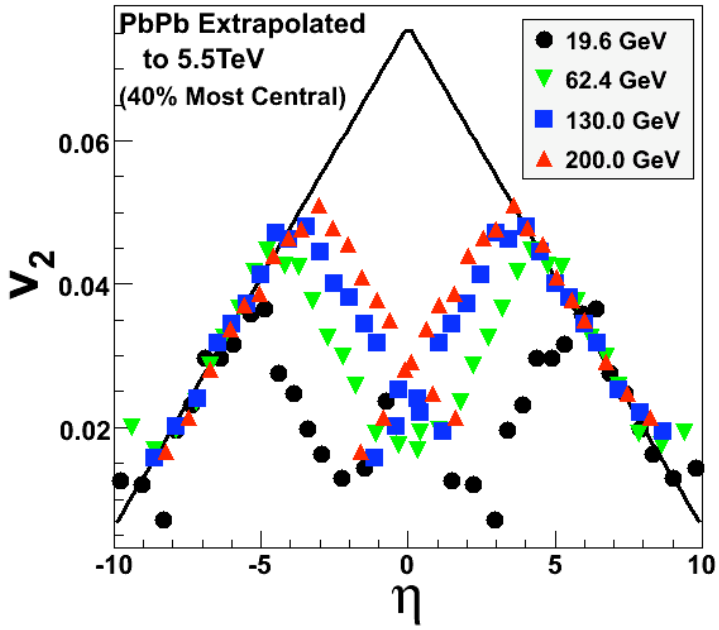
## Second (follow up) question:

If there is a phase transition why is the energy dependence of dn/dη and $v_2$, in particular of $v_2$, so smooth ?



# Extrapolation of PHOBOS data to LHC energies




Total charged multiplicity in central ($N_{part}$ = 386) PbPb collisions at $\sqrt{S}$ = 5.5 TeV = 15000 ± 1000

Mid-rapidity dN/dη in central ($N_{part}$ = 386) PbPb collisions at $\sqrt{S}$ = 5.5 TeV = 1200 ± 100

Total charged multiplicity in inelastic pp collisions at $\sqrt{S}$ = 14 TeV (10 TeV ) = 60 ± 10 (56 ± 9)

AuAu Data from PHOBOS, Nucl. Phys. A757 (2005) 28

Extrapolation: WB J. Phys. G35, 044040 (2008).