Transverse and Longitudinal dynamics at RHIC

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Outline

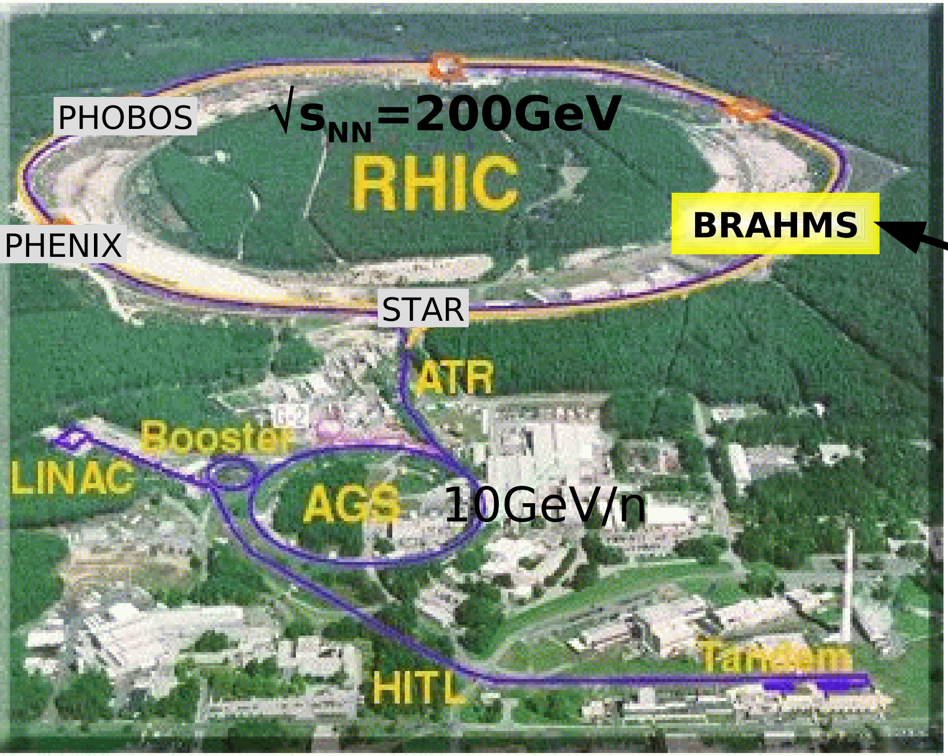
1. BRAHMS experimental setup

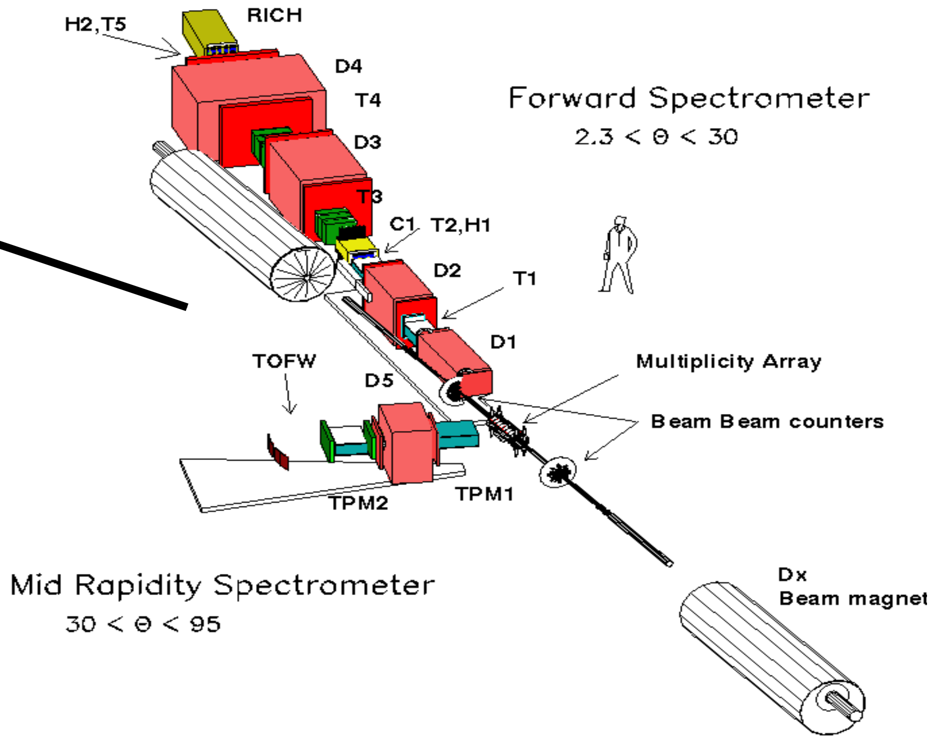
2. Introduction: some lessons from BRAHMS
   a) produced and "primary" matter
   b) hadron chemistry

3. Recent results and model comparisons on baryons stopping and proton to pion ratios

4. Summary

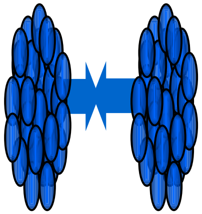
Relativistic Heavy Ion Collider w BNL



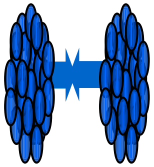


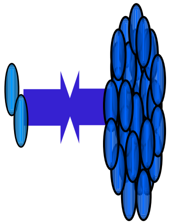
Energies:
$\sqrt{s_{NN}}$=62GeV,
$\sqrt{s_{NN}}$=130GeV,
$\sqrt{s_{NN}}$=200GeV

Au+Au

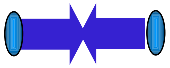


Cu+Cu





d+Au



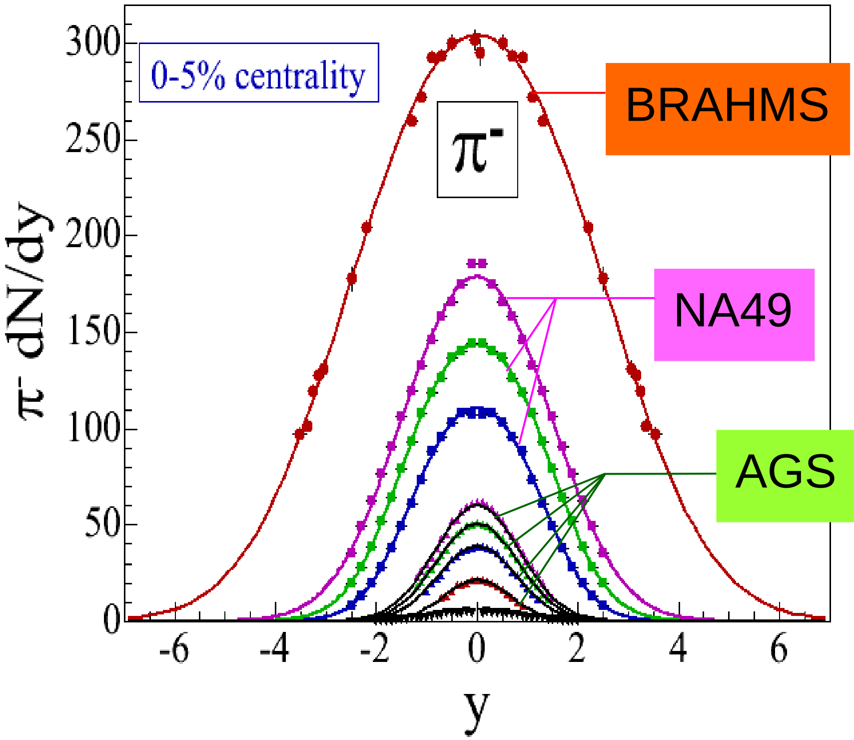
p+p

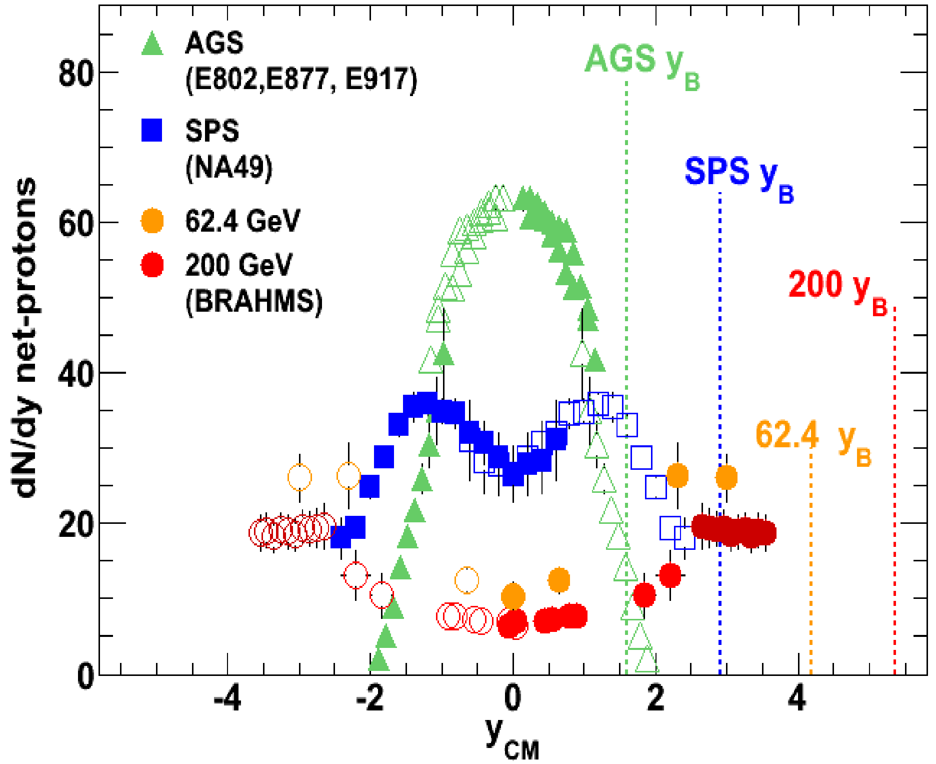
Particle production versus stopping

Produces matter peaks at y=0, this matter is charge symmetric. No significant change is shape from AGS to RHIC

Primary matter: evolution from lower to higher energies. At mid rapidity evolution from baryon (AGS) to meson (RHIC) dominated medium

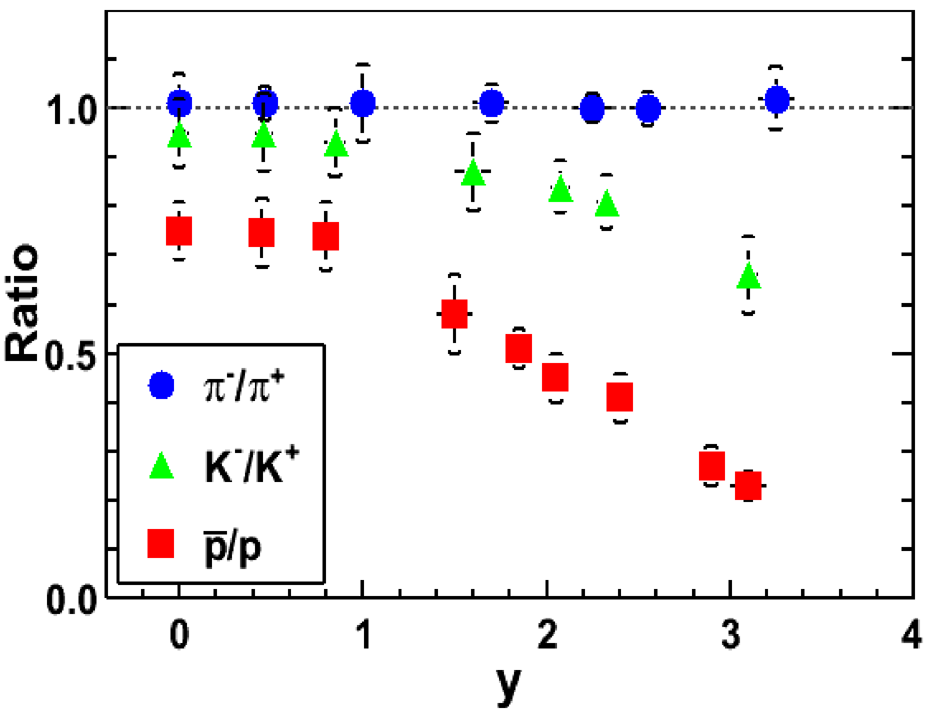
$\sqrt{s_{NN}}$ = 4.7 17.3 200 GeV

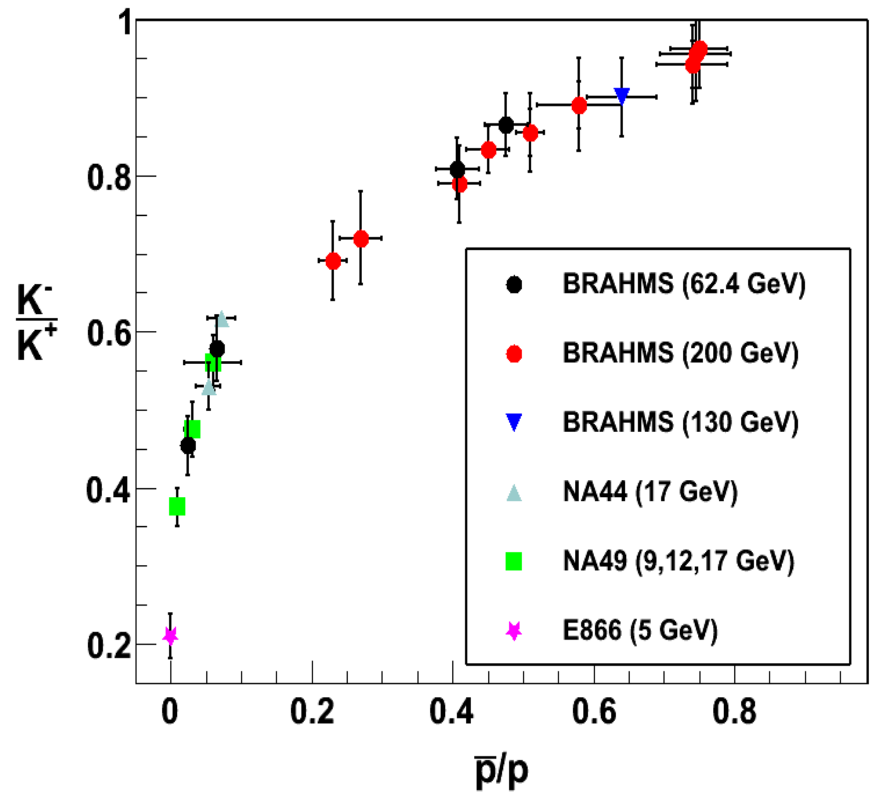




Particle ratios and hadron chemistry

central Au + Au at 200 GeV





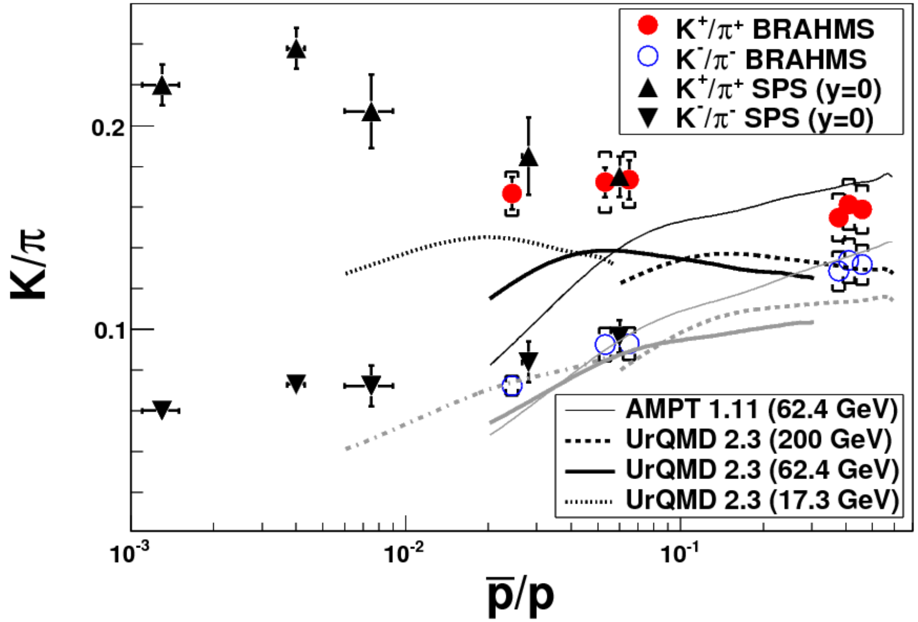
Proton and kaon ratios decreases towards forward rapidity

Pion ratios are consistent with unity

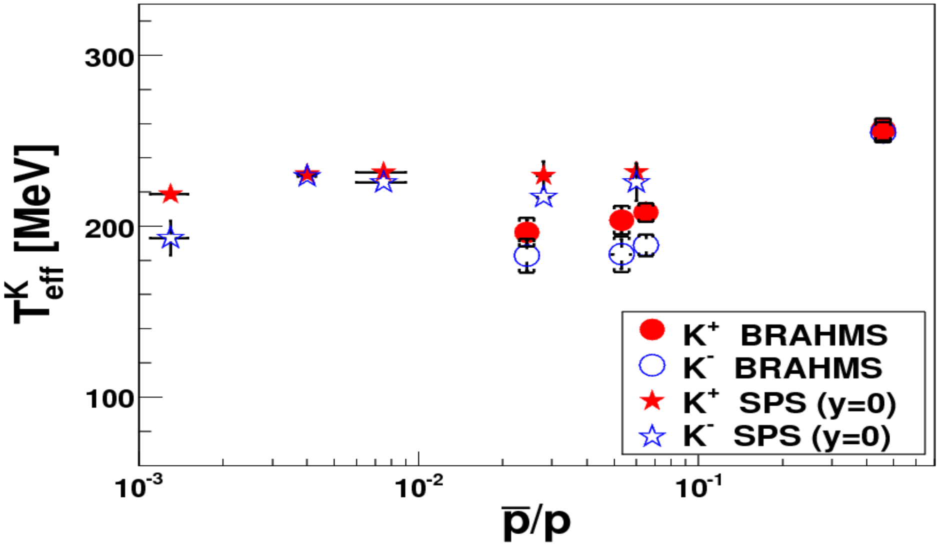
Correlation between the BRAHMS kaon and proton ratios over 3 units of rapidity.

Forward rapidity 62.4 GeV data overlap with mid-rapidity data from SPS

Particle ratios and hadron chemistry



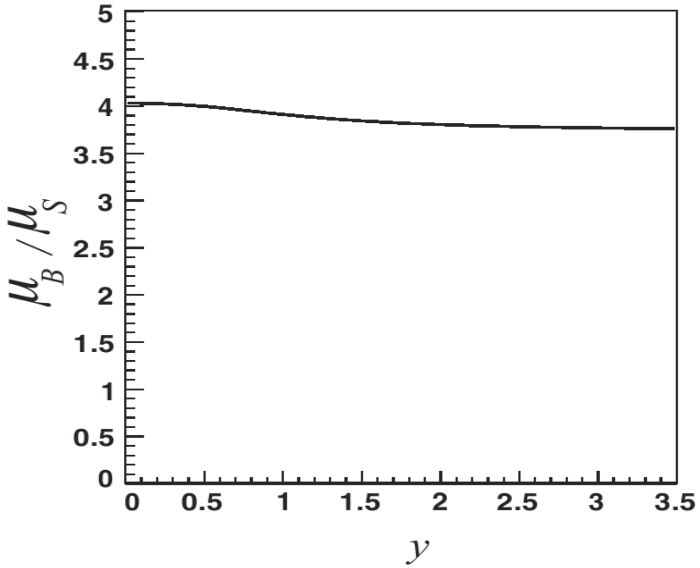
Forward rapidity K/π ratios measured at 62 GeV overlap with the same ratios measured at SPS
As you can see the models that we had tried can not described that effect.   **PLB 867 (2010) 36**



However, the systems have different sizes. The softer kaon spectra suggest that the radial expansion is slower for the forward RHIC collisions

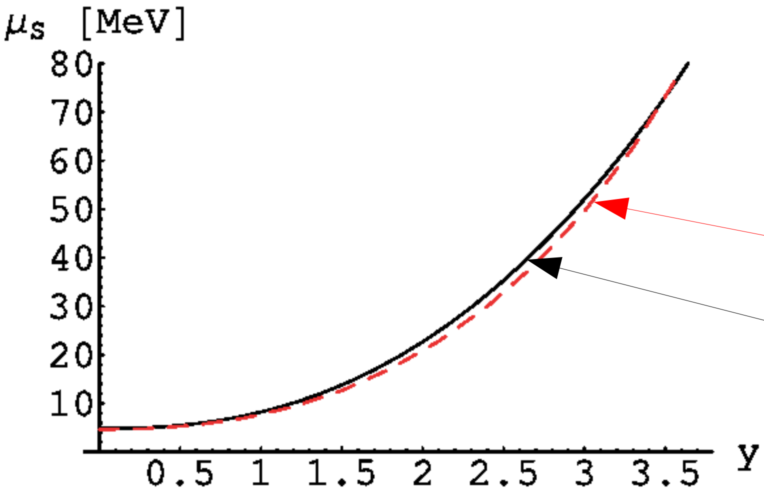
Statistical model fit to BRAHMS data

→ μ_s vserus μ_B



Fits with statistical model provide μ_B/μ_Sratio with weak dependency on y.

B. Bieron and W. Broniowski Phys. Rev. C75 (2007) 054905



This result is consistent with local net-strangeness conservation

red line - $\rho_{s\text{-}sbar} = 0$

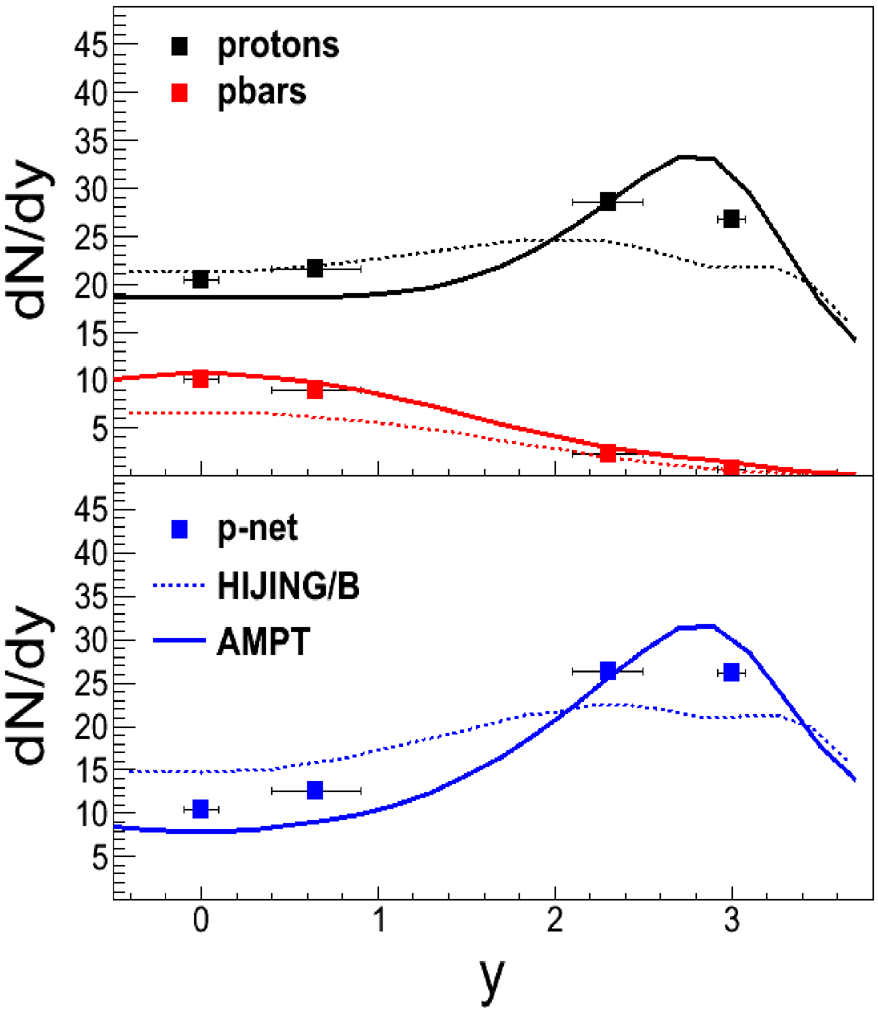
black line – fit to BRAHMS data

Baryon transport – short review

As I tried to explain the baryon stopping determines density and chemical composition of the produced media in high energy A+A collisions.

- Standard mechanism used for description of baryon transport is breaking of q – qq configuration. In this case the baryon number is associated with valence quarks.
- However this mechanism alone is not able to move net-baryon number over a large range of rapidity.
- ISR pp and HERA (non-zero baryon asymmetry of $\approx$8% in γp reactions at more that 8 units of rapidity) demonstrated that additional mechanisms with a slower y dependence are needed to account for the data. Baryon junctions is one mechanism that can move baryon number over a large rapidity range

Stopping 62 GeV

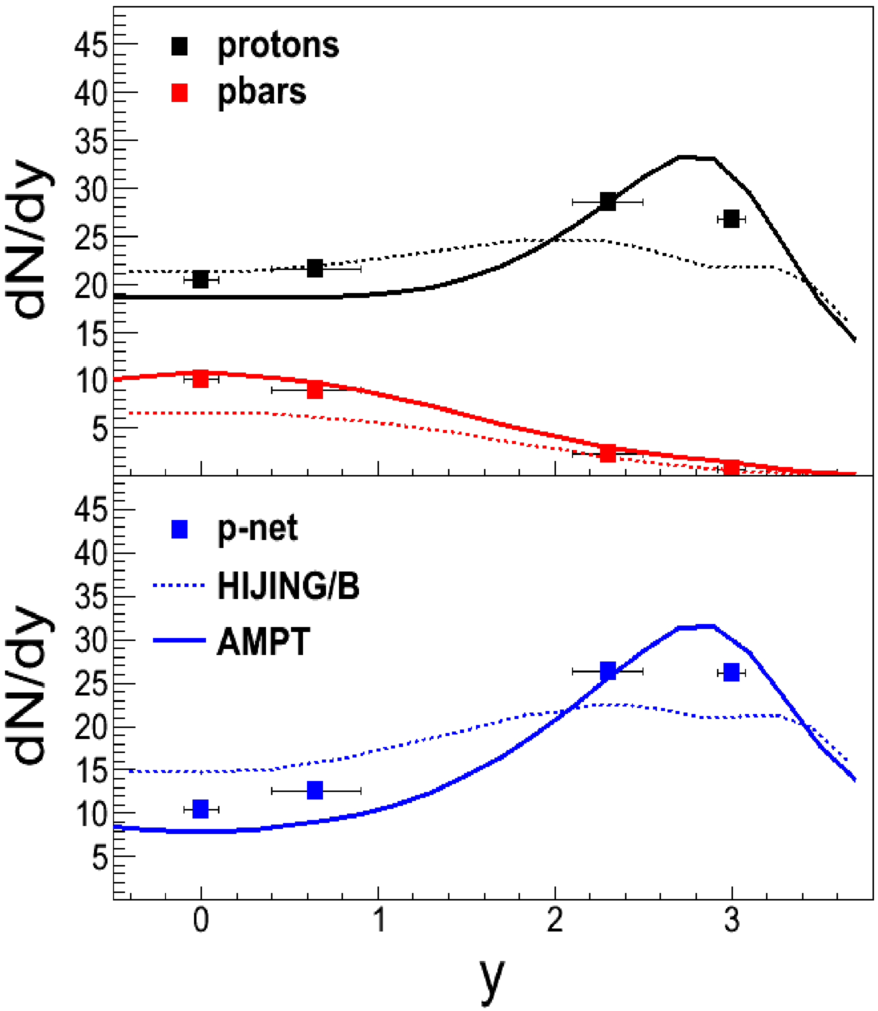


Measurement from y = 0 to ~3 overlaps fragmentation region (y_b=4.2)
PLB 677 (2009) 267

AMPT model incorporates q-qq breaking mechanism → over all good description but it underestimates net-protons at mid-rapidity

HIJING/B incorporates baryon junctions to can account for the large stopping. Parameters tuned to data from SPS. **PLB 443 (1998) 45**

Stopping 62 GeV



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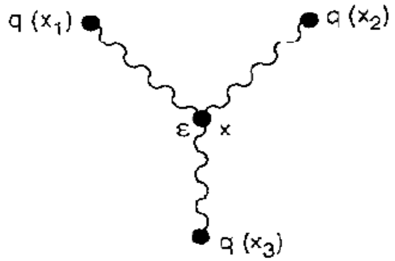
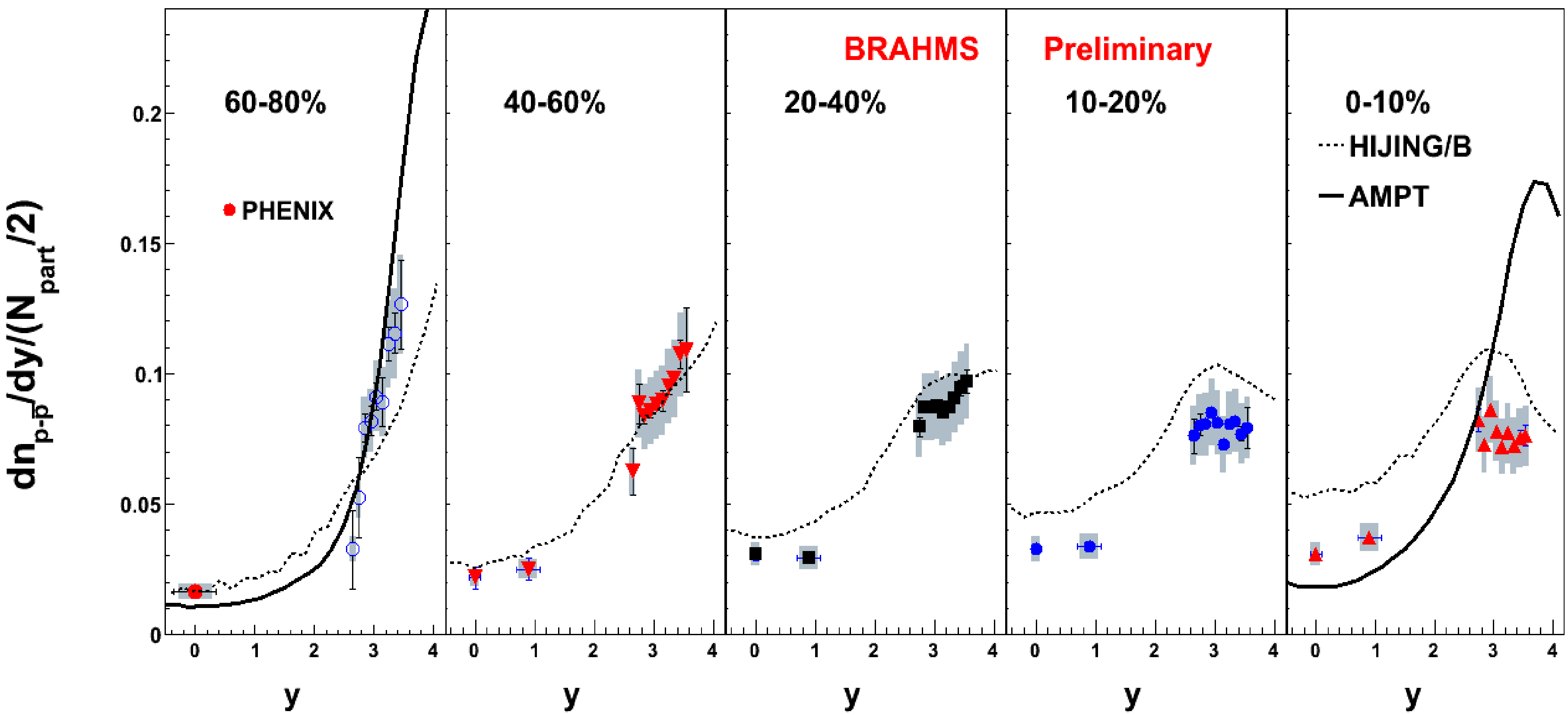


Stopping at 200 GeV



AMPT does quite a good job for peripheral Au+Au at 200 GeV, it however can not describe data for central reactions.

Hijing/B seems to reproduce the trend with centrality, however, it tends to overestimates net-proton data for more central reactions.

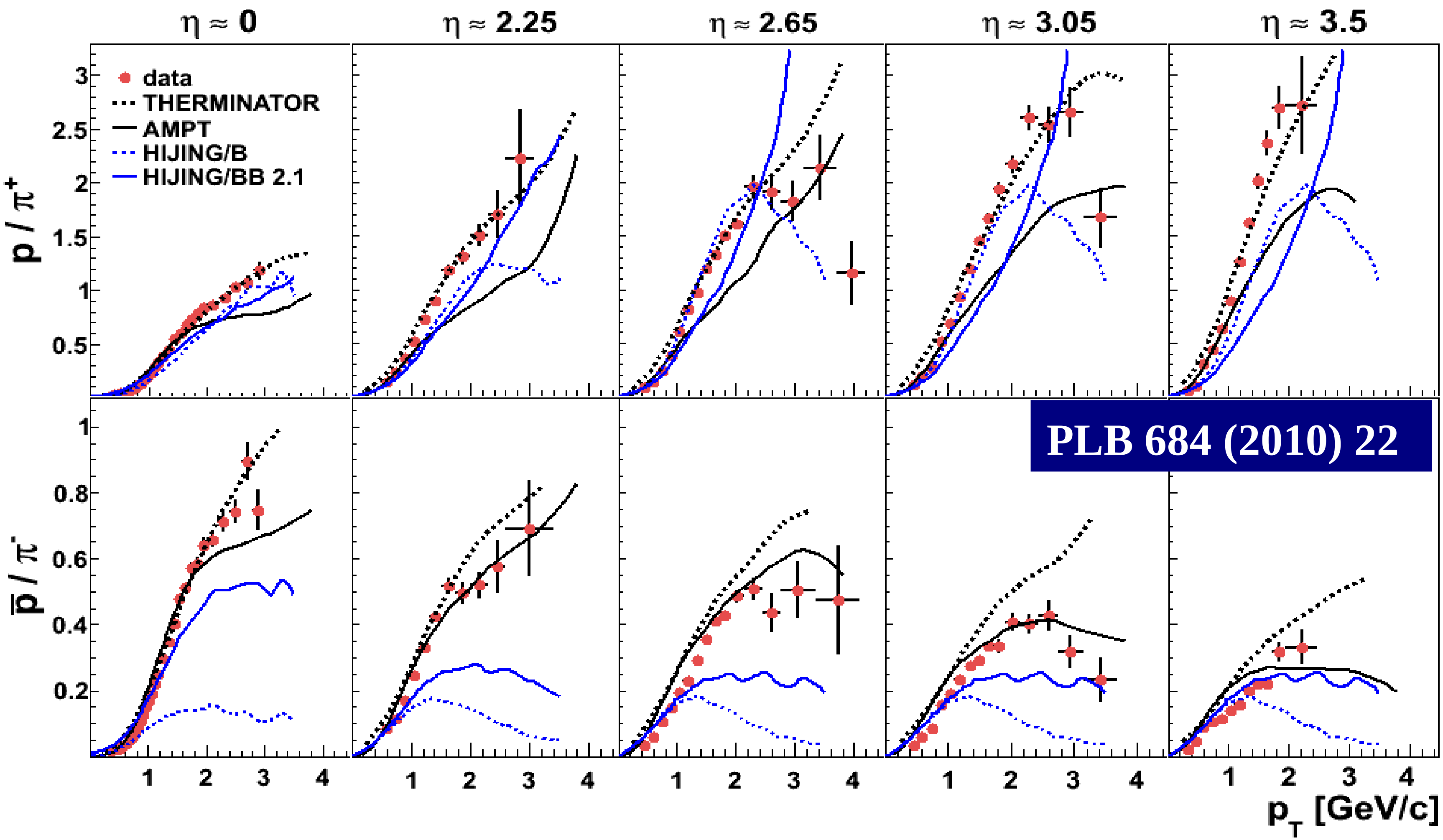
Proton to pion ratios vs y and p_T

Mechanisms responsible for the baryon stopping determine also the energy dissipation in the collision → pion production.

Mechanisms like baryon junction and baryon junction loops (JJbar loops included in HIJING/BBbar1.0 and 2.1) incorporate transverse baryon dynamics.

This is all reflected in p_T and rapidity dependence of p/π ratios

p/π ratios vs y and p_T



BRAHMS

Summary

- Brahms provide measurement of baryon number transport in the p+p and Au+Au reactions at RHIC energies
- Net-p measured in p+p are consistent with quark – di-quark breaking mechanism
- Au+Au data suggest additional mechanisms for baryon transport. (baryon junction, popcorn, di-quark breaking)
- To disentangle between different scenarios one has to study transverse dynamics of the baryon number transport
- There is no model on the market which could simultaneously describe all available data (net-protons and p/π ratios, hyperon spectra)

The BRAHMS Collaboration

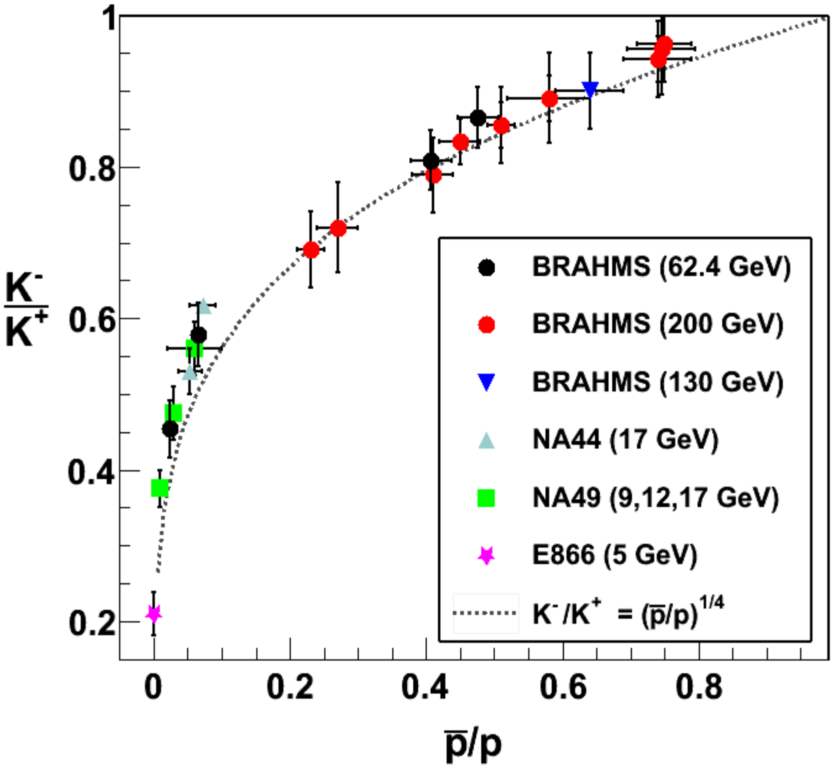
I.Arsene[7], I.G. Bearden[6], D. Beavis[1], S. Bekele[6] , C. Besliu[9], B. Budick[5], H. Bøggild[6] , C. Chasman[1], C. H. Christensen[6], P. Christiansen[6], R. Clarke[9], R.Debbe[1], J. J. Gaardhøje[6], K. Hagel[7], H. Ito[10], A. Jipa[9], J. I. Jordre[9], F. Jundt[2], E.B. Johnson[10], C.E.Jørgensen[6], R. Karabowicz[3], N. Katryńska[3], E. J. Kim[4], T.M.Larsen[11], J. H. Lee[1], Y. K. Lee[4], S.Lindal[11], G. Løvhøjden[2], Z. Majka[3], M. Murray[10], J. Natowitz[7], B.S.Nielsen[6], D. Ouerdane[6], R.Planeta[3], F. Rami[2], C. Ristea[6], O. Ristea[9], D. Röhrich[8], B. H. Samset[11], D. Sandberg[6], S. J. Sanders[10], R.A.Sheetz[1], P. Staszel[3], T.S. Tveter[11], F.Videbæk[1], R. Wada[7], H. Yang[6], Z. Yin[8], and I. S. Zgura[9]

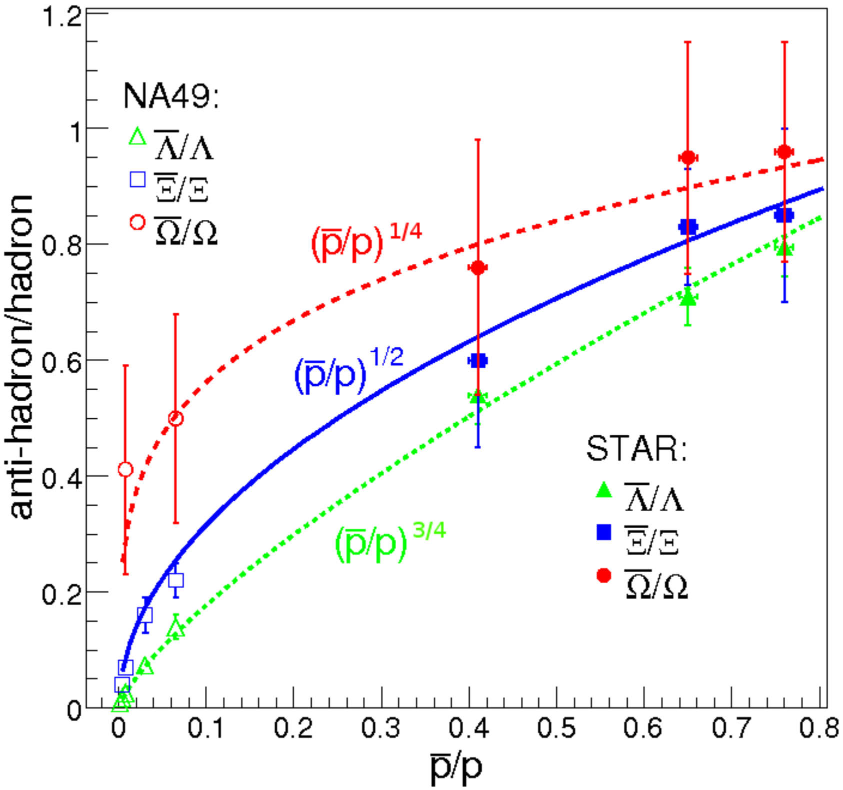
[1]Brookhaven National Laboratory, USA, [2]IReS and Université Louis Pasteur, Strasbourg, France
[3]Jagiellonian University, Cracow, Poland,
[4]Johns Hopkins University, Baltimore, USA, [5]New York University, USA
[6]Niels Bohr Institute, University of Copenhagen, Denmark
[7]Texas A&M University, College Station. USA, [8]University of Bergen, Norway
[9]University of Bucharest, Romania, [10]University of Kansas, Lawrence,USA
[11] University of Oslo Norway

48 physicists from 11 institutions

BACKUP SLIDES

Predictive power of $\mu_s \approx 1/4\ \mu_B$





We have have good description of kaon data

$\mu_S \approx ¼\ \mu_B \rightarrow$

$K^-/K^+ = (\text{pbar}/p)^{1/4}$

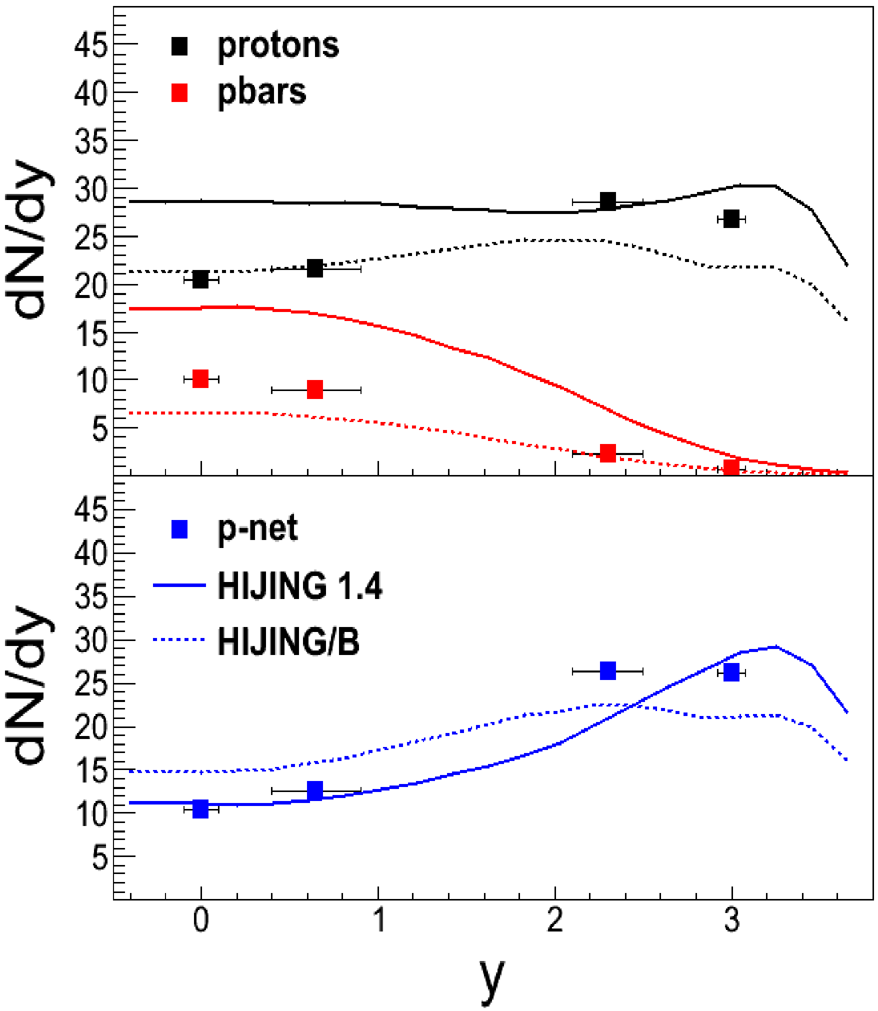
How $\mu_S \approx ¼\ \mu_B$ will work for hyperons?

Hbar/H $= (\text{pbar}/p)^{3/4}$ for Λ

$= (\text{pbar}/p)^{1/2}$ for Ξ

$= (\text{pbar}/p)^{1/4}$ for Ω

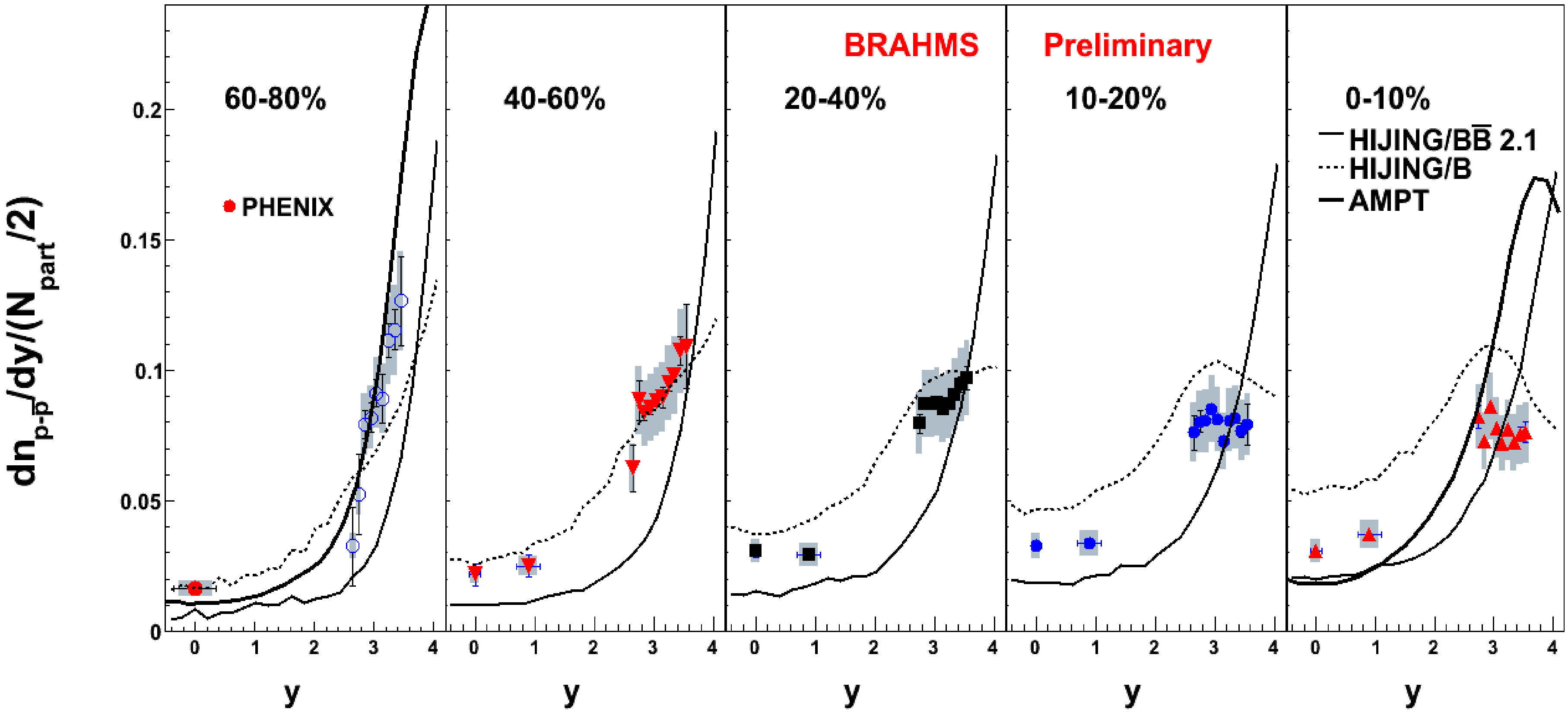
Stopping 62 GeV



Incidentally pure HIJING (without the junction) can describe the net-p at y~0 but underestimates the experimental <Δy>.

It also significantly overestimates Production of protons and anti-protons

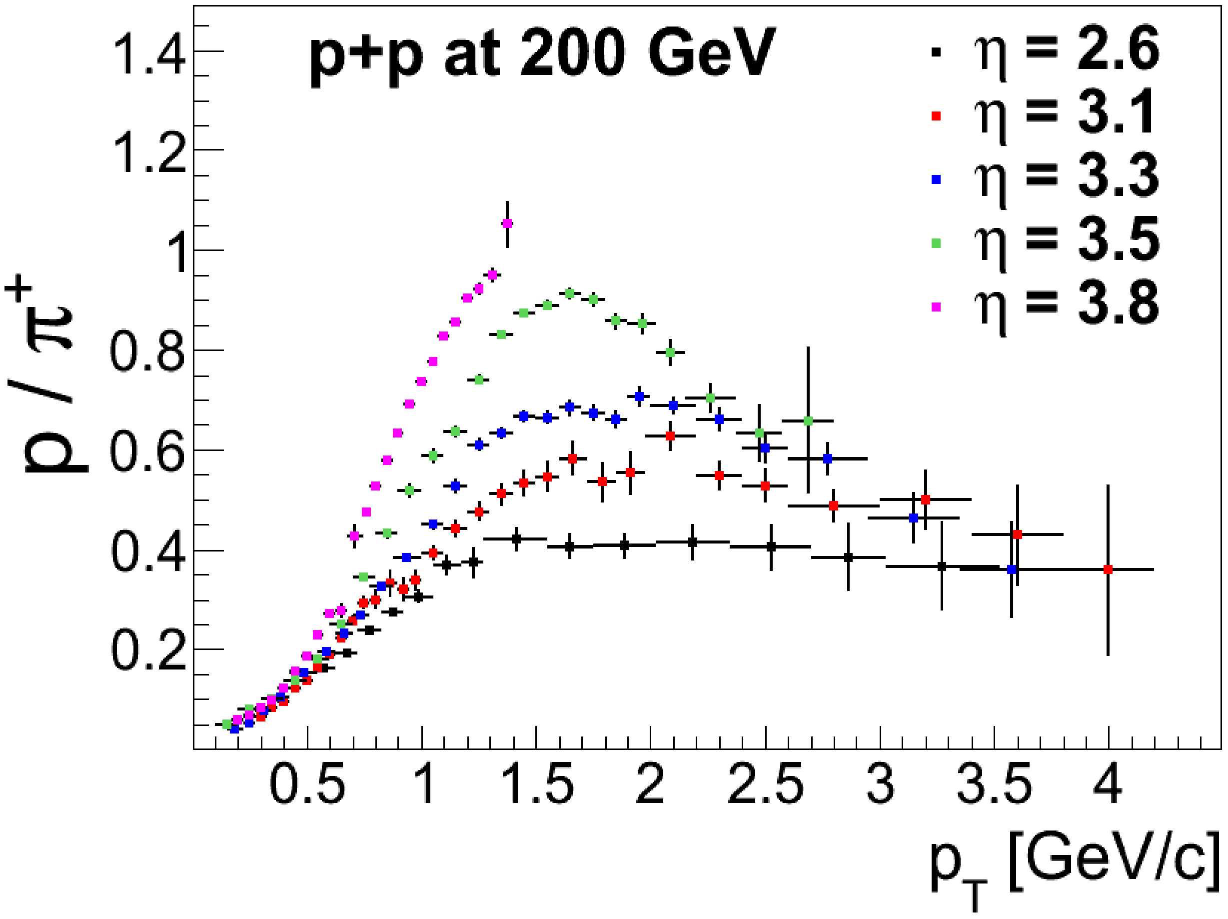
Stopping at 200 GeV



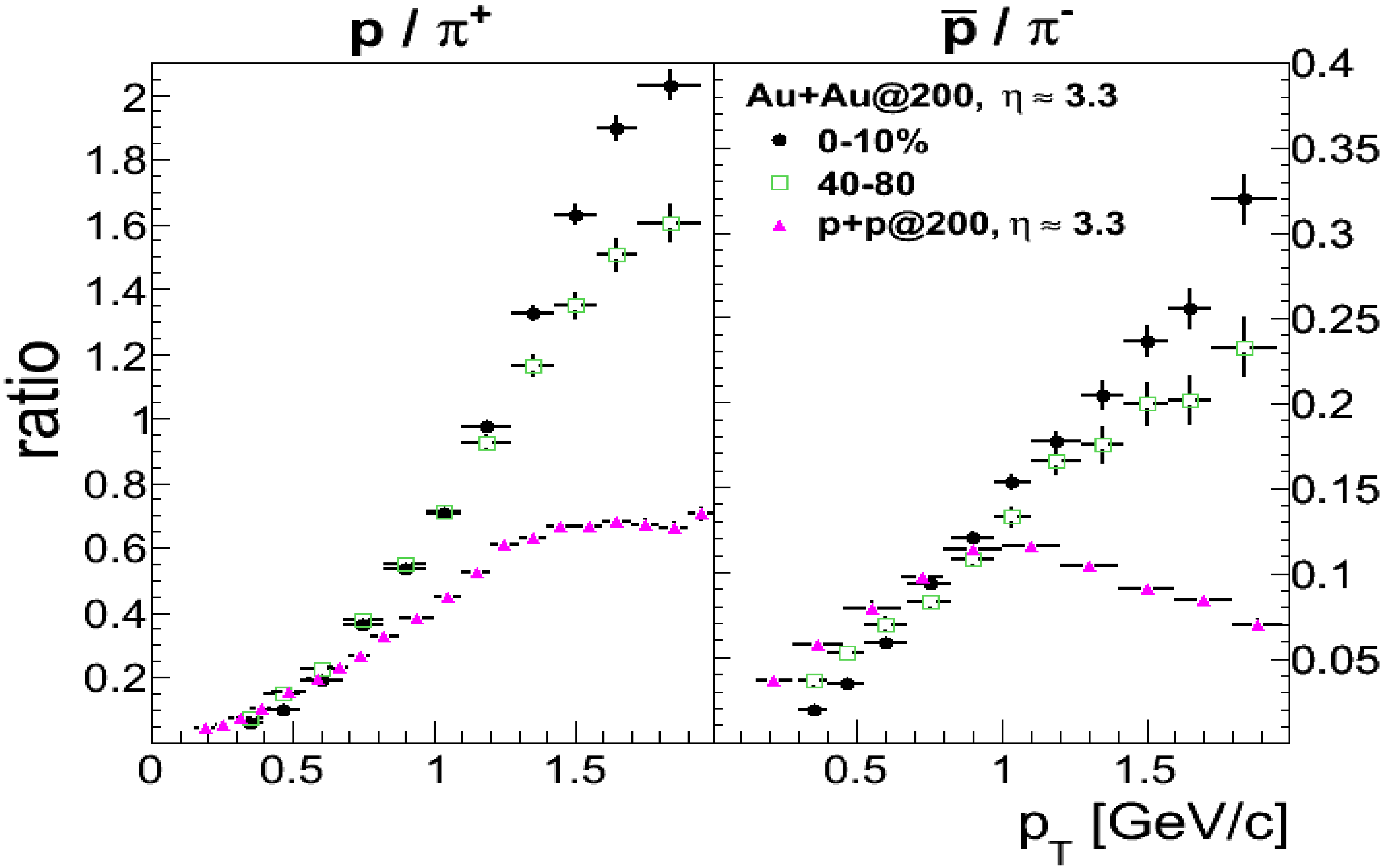
Hijing/BBbar 2.1: modified baryon junction phenomenology to account for better description of hyperon m_T spectra. **PRC 70 (2004) 064906**

This version fails to description of stopping

Results: p+p at 200 GeV versus rapidity



Results: Au+Au and p+p at 200 GeV at low p_T



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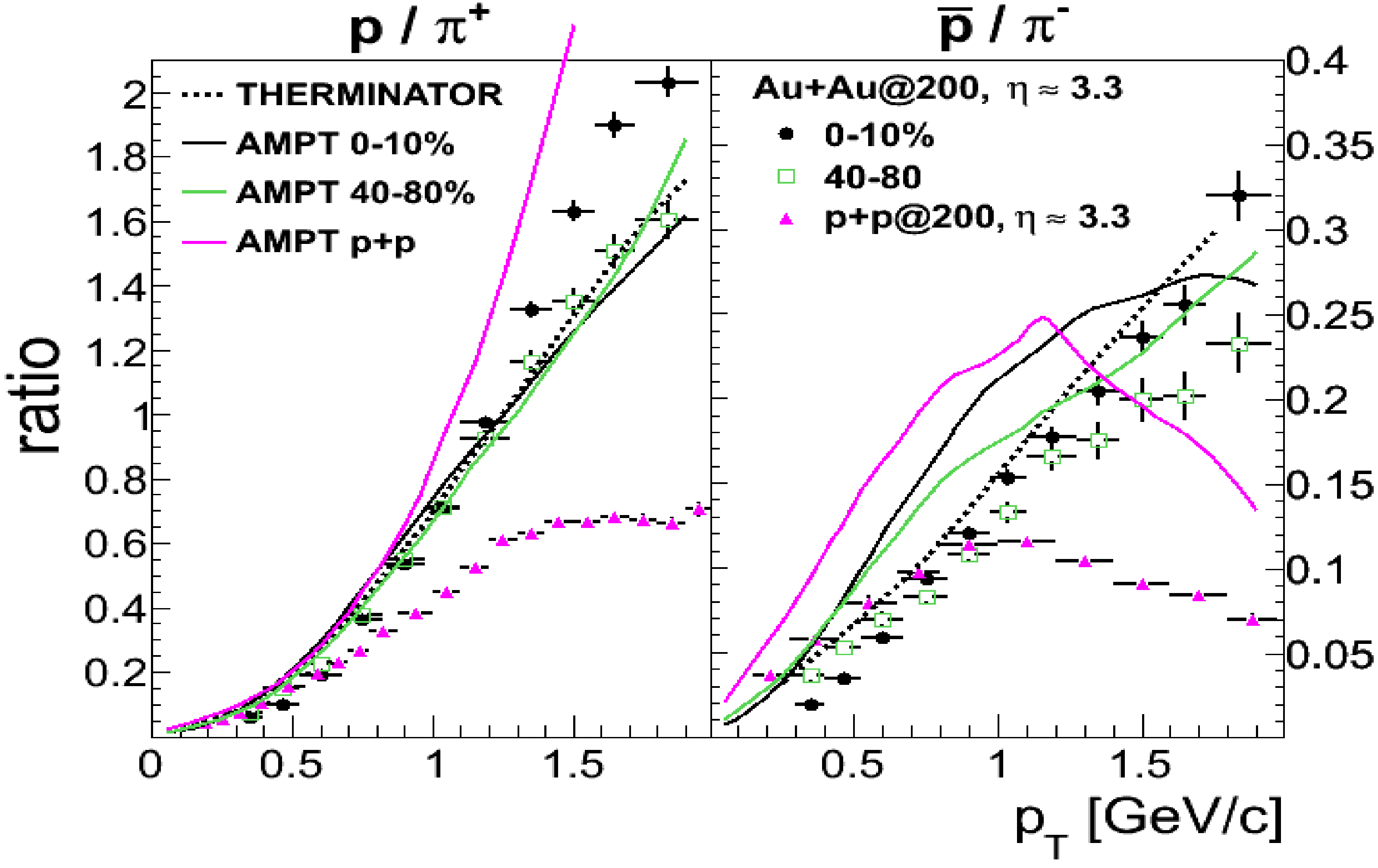
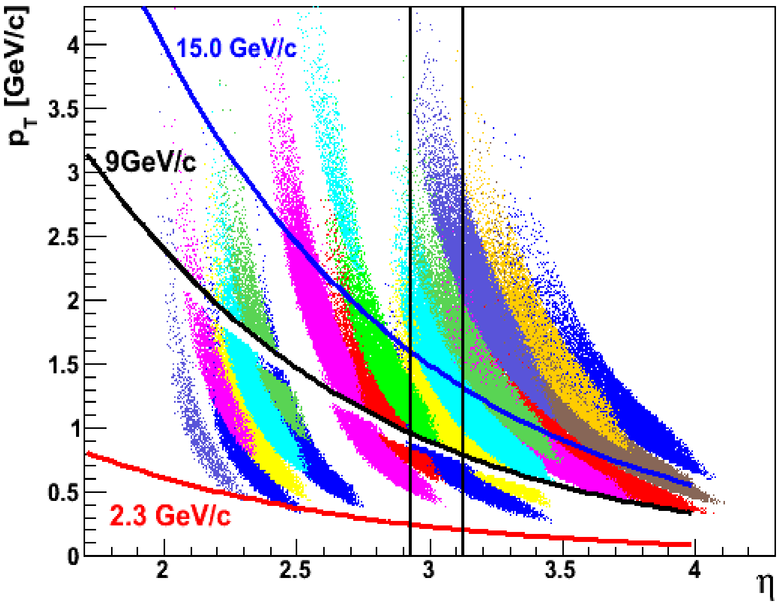
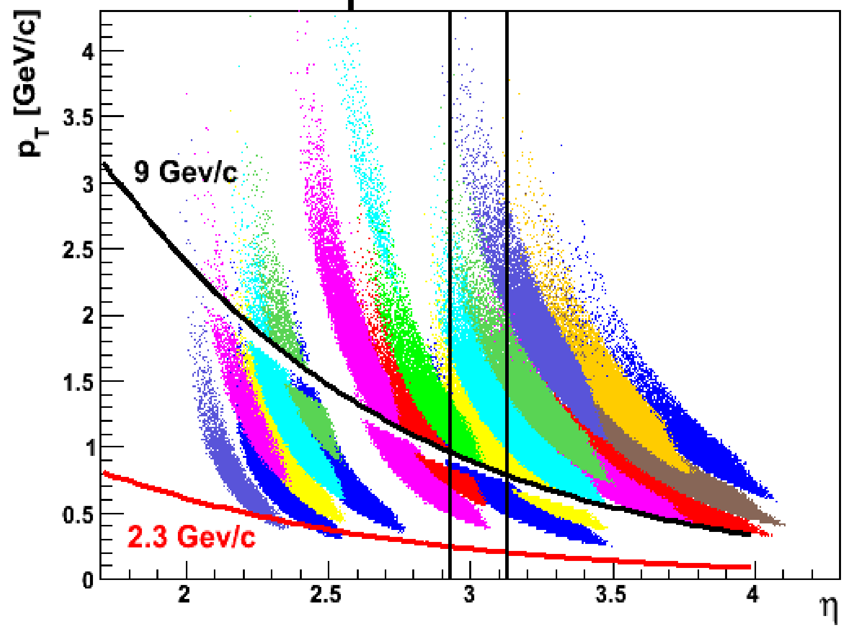
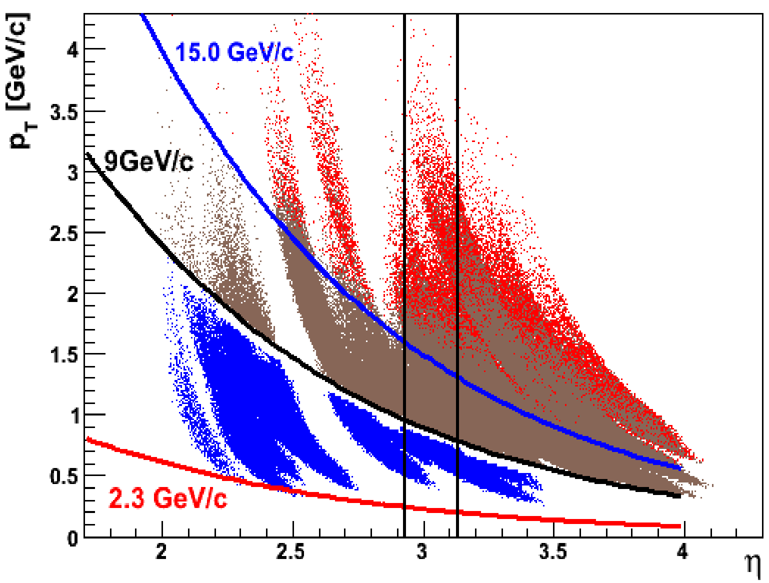


protons



pions





Same acceptance for pions and protons in the real time measurements. For given η-p_T bin p/π ratio is calculated on setting by setting basis using same pid technique:

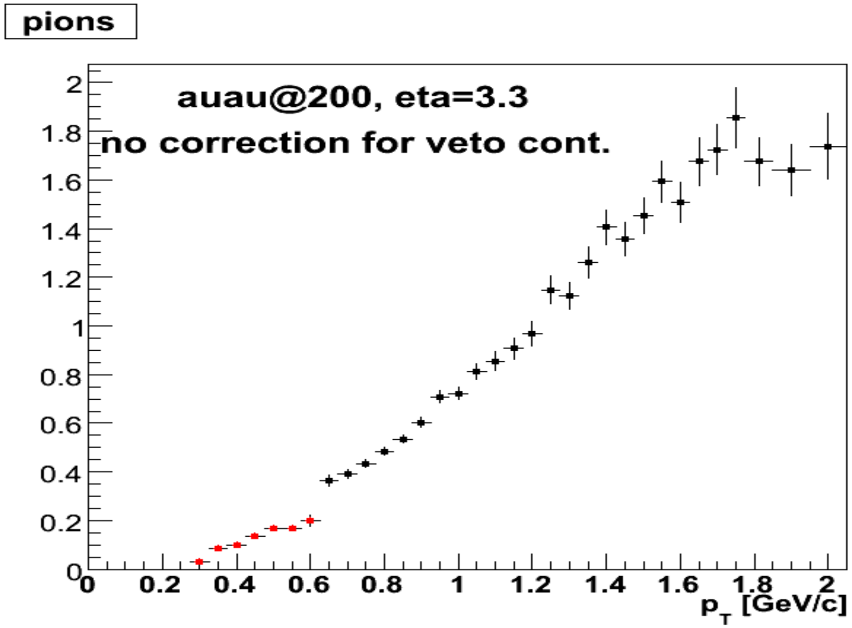
Tof2: 2.3->~8GeV/c, RICH: above 9 GeV/c, thus acceptance corrections, tracking efficiency trigger normalization canceled out in the ratio.

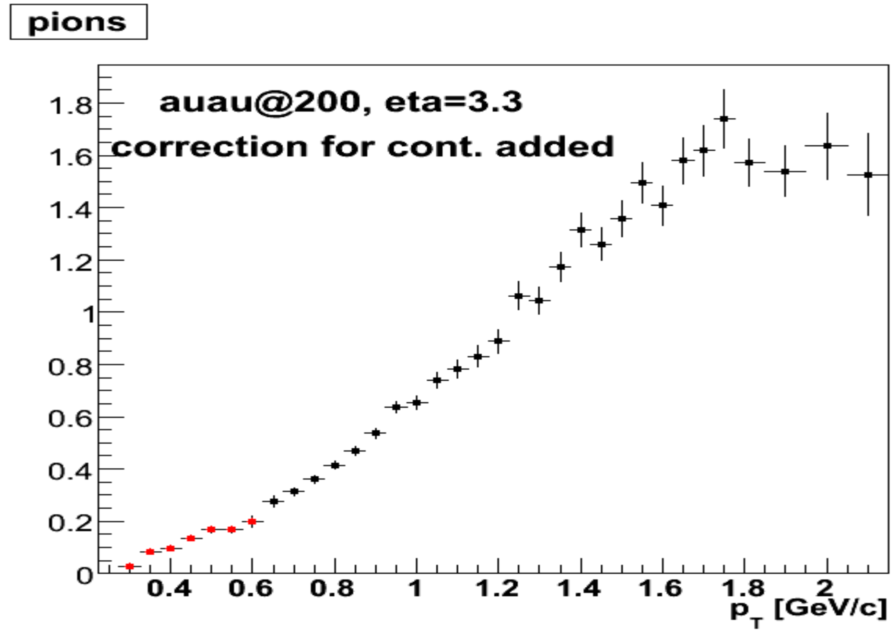
Remaining corrections:

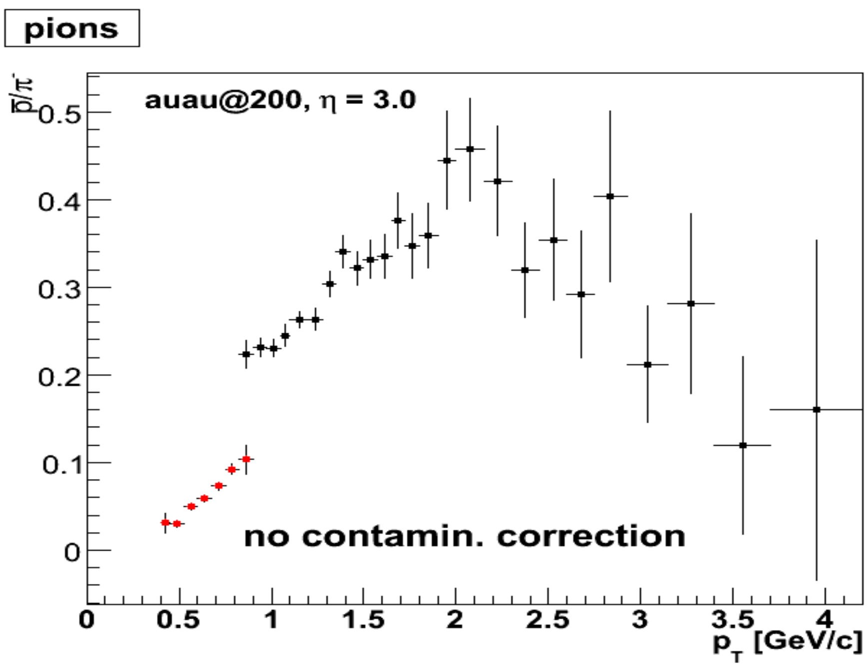
i) decay in flight, interaction in beam pipe and material budged (GEANT calculation)

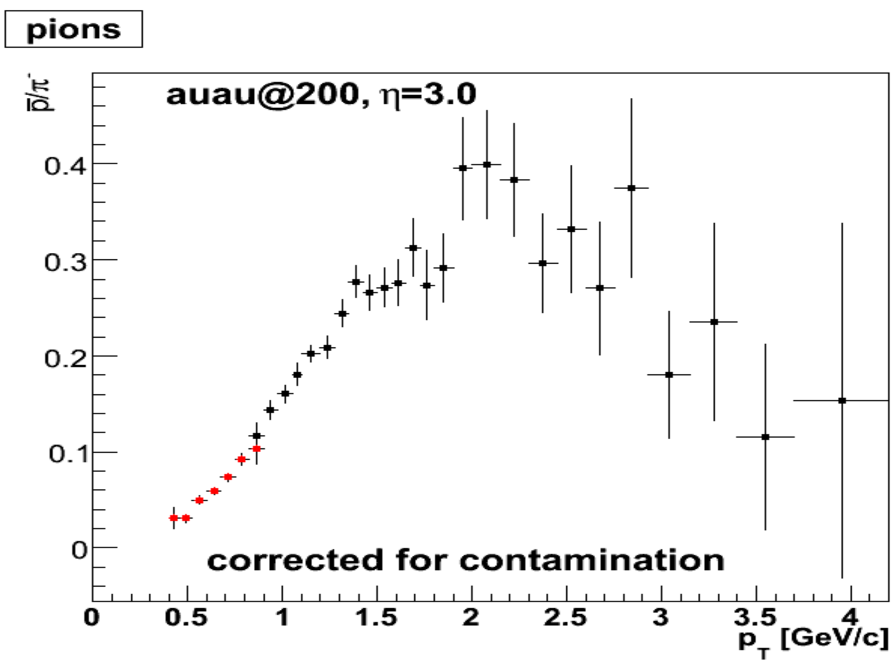
ii) correction for PID efficiency and contamination (limited specie resolution)

Test of corrections for veto-protons

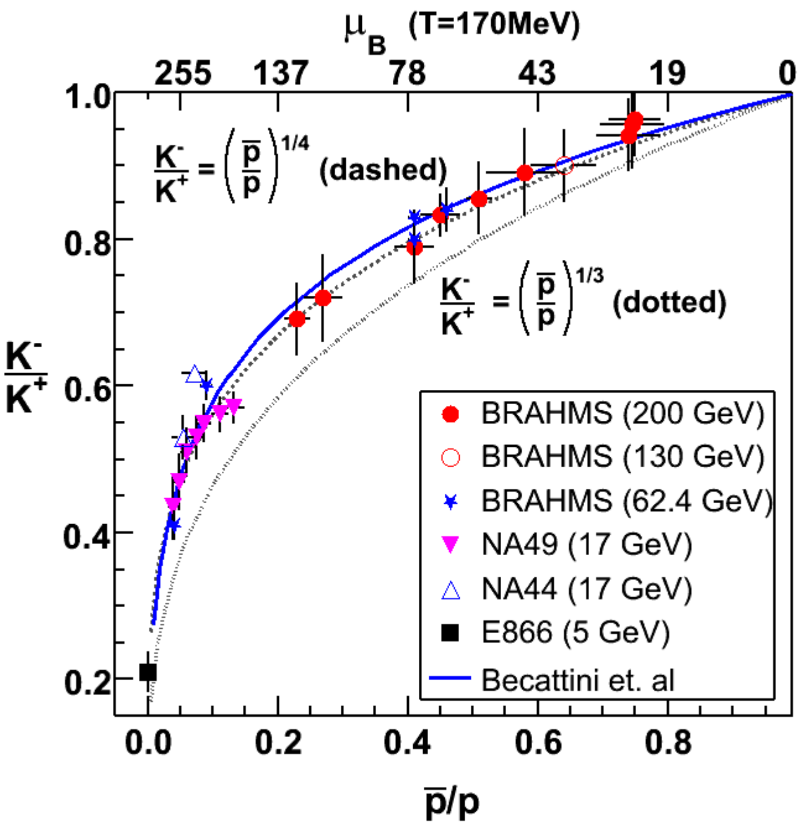


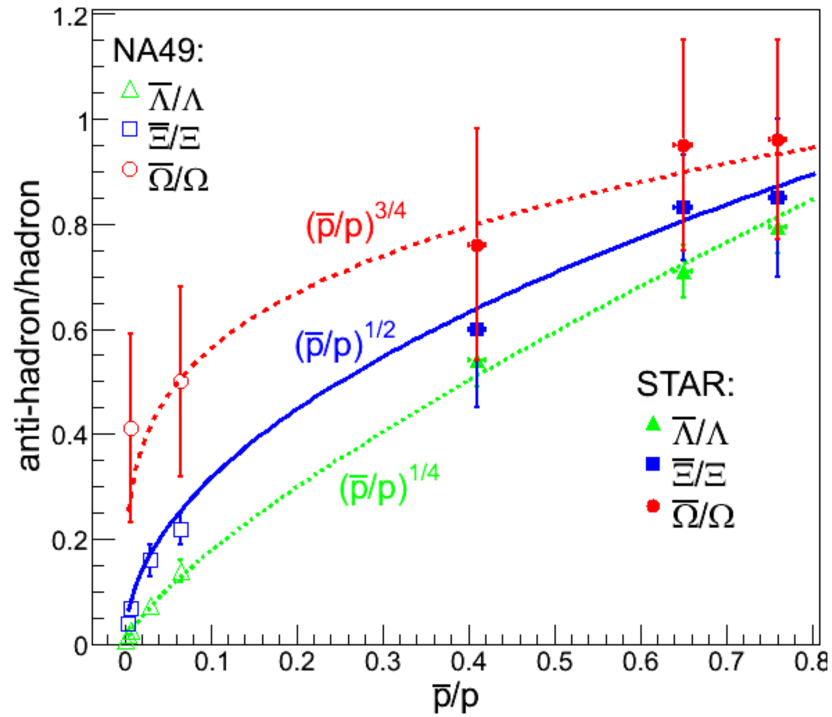






K^-/K^+ and antihyperon/hyperon





$K^-/K^+ = \exp((2\mu_s - 2\mu_{u,d})/T)$

pbar/p = $\exp(-6\mu_{u,d}/T)$

$\mu_s=0 \Rightarrow K^-/K^+ = (\text{pbar}/p)^{1/3}$

Fit shows that $K^-/K^+ = (\text{pbar}/p)^{1/4}$

$\Rightarrow \mu_s = \frac{1}{4}\mu_{u,d}$

How $\mu_s = \frac{1}{4}\mu_{u,d}$ will work for hyperons?

Hbar/H $= (\text{pbar}/p)^{3/4}$ for Λ

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$= (\text{pbar}/p)^{1/4}$ for Ω

Broad Range Hadron Magnetic Spectrometers