Baryon-to-meson production in a wide range of baryo-chemical potential at RHIC

Paweł Staszel,
Marian Smoluchowski Institute of Physics
Jagiellonian University

BRAHMS

EPS-HEP 2009
Kraków, 16.07–22.07.2009

Outline

1. Introduction
2. BRAHMS experimental setup
3. Data analysis on p/π ratios
4. Results:
   a) Au+Au and p+p at 200 GeV
   b) Au+Au: 200 GeV versus 62 GeV
   c) Au+Au and p+p at 62 GeV and forward rapidity
5. Summary

Introduction

High baryon to meson ratio (~1) at intermediate p_T discovered at RHIC in Au+Au reactions was inconsistent with pQCD predictions.
(K. Adcox, et al.,[PHENIX] PRL 88 (2002) 242301)

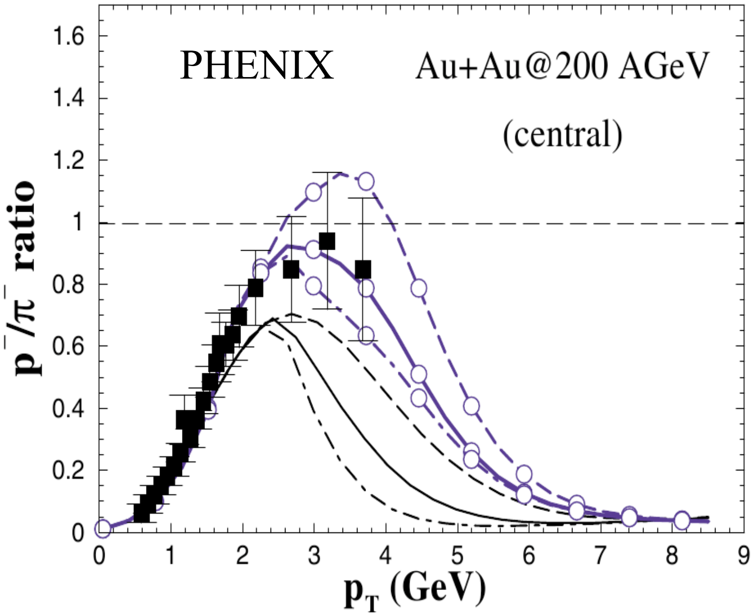
It was pointed out that baryon to meson ratio p_T dependence should be sensitive to:

hadronization scenario

baryon: 3 valence quarks,
meson: quark – anti quark

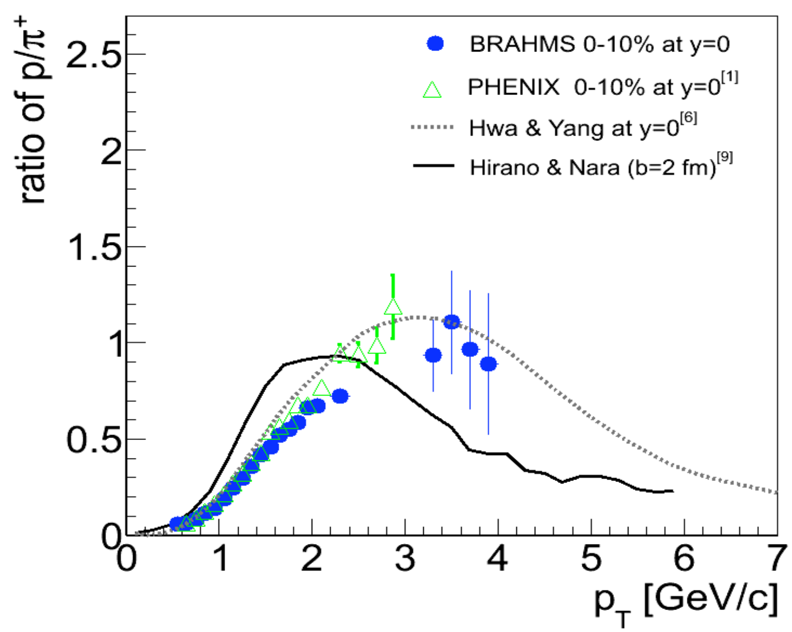
radial flow of bulk medium proton mass >> pion mass

A bit of history



Quark coalescence can explain large mid-rapidity pbar/π ratio at intermediate p_T range when allow mini-jet partons to coalescence with QGP (thermal) partons

(V. Greco, C.M. Ko, and P. Levai, PRL90 (2003) 022302)



Reasonable description by quark coalescence model (Hwa and Yang)

Hydro model over predicts mid-rapidity p/π ratio at low p_T (<2 GeV/c) and underpredicts at p_T>2.5.

(E.J. Kim, et al., Nucl. Phys. A 774 (2006) 493)

Introduction cnt.

In this talk we will present results on centrality dependence of p/π^+ and pbar/π^- ratios with special focus on their evolution with rapidity - and compare the data with:

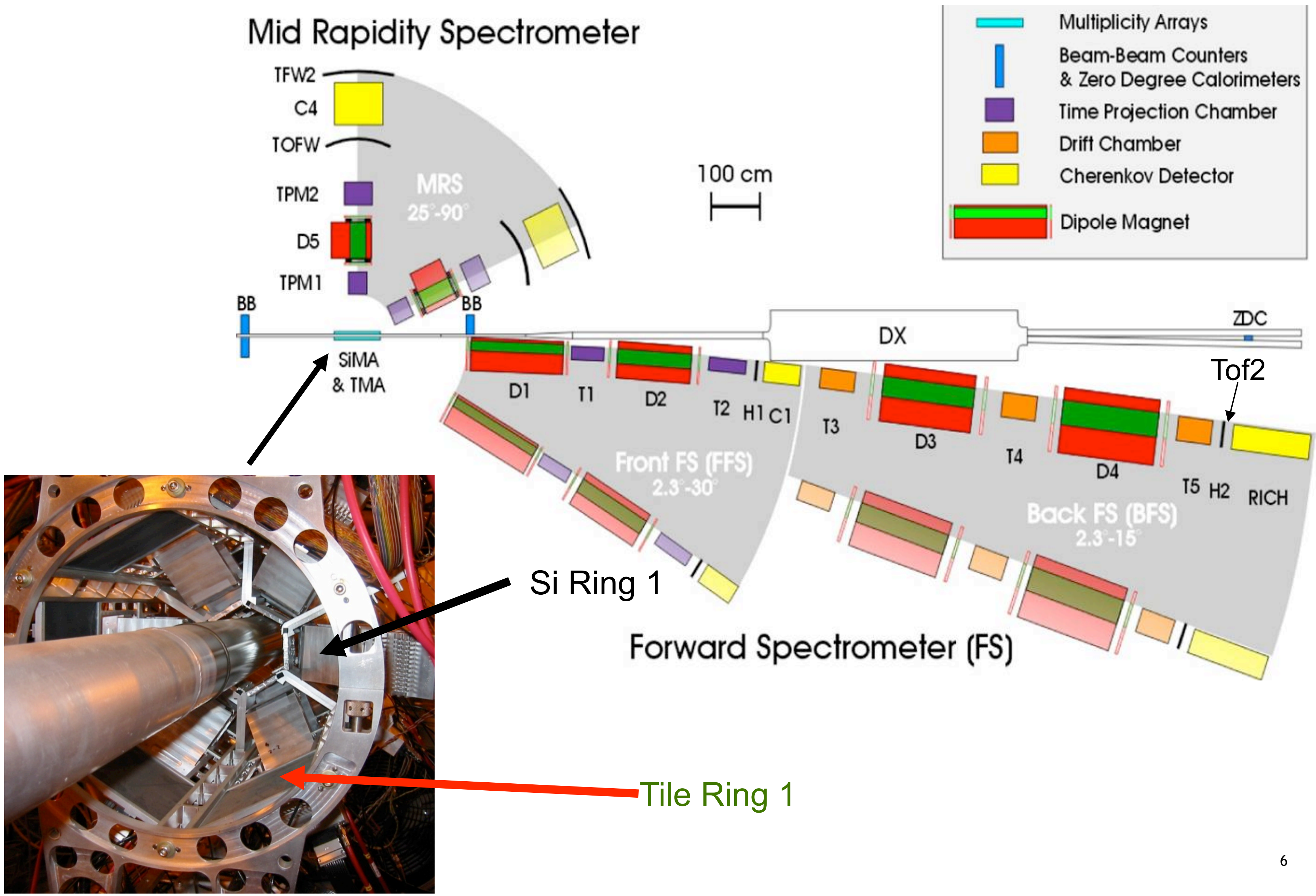
THERMINATOR model that incorporates rapidity dependence of statistical particle production imposed on the hydro-dynamical flow.

W. Broniowski and W. Florkowski, PRL 87, 272302 (2001),
B. Biedroń and W. Broniowski, PRC 75, 054905 (2007)

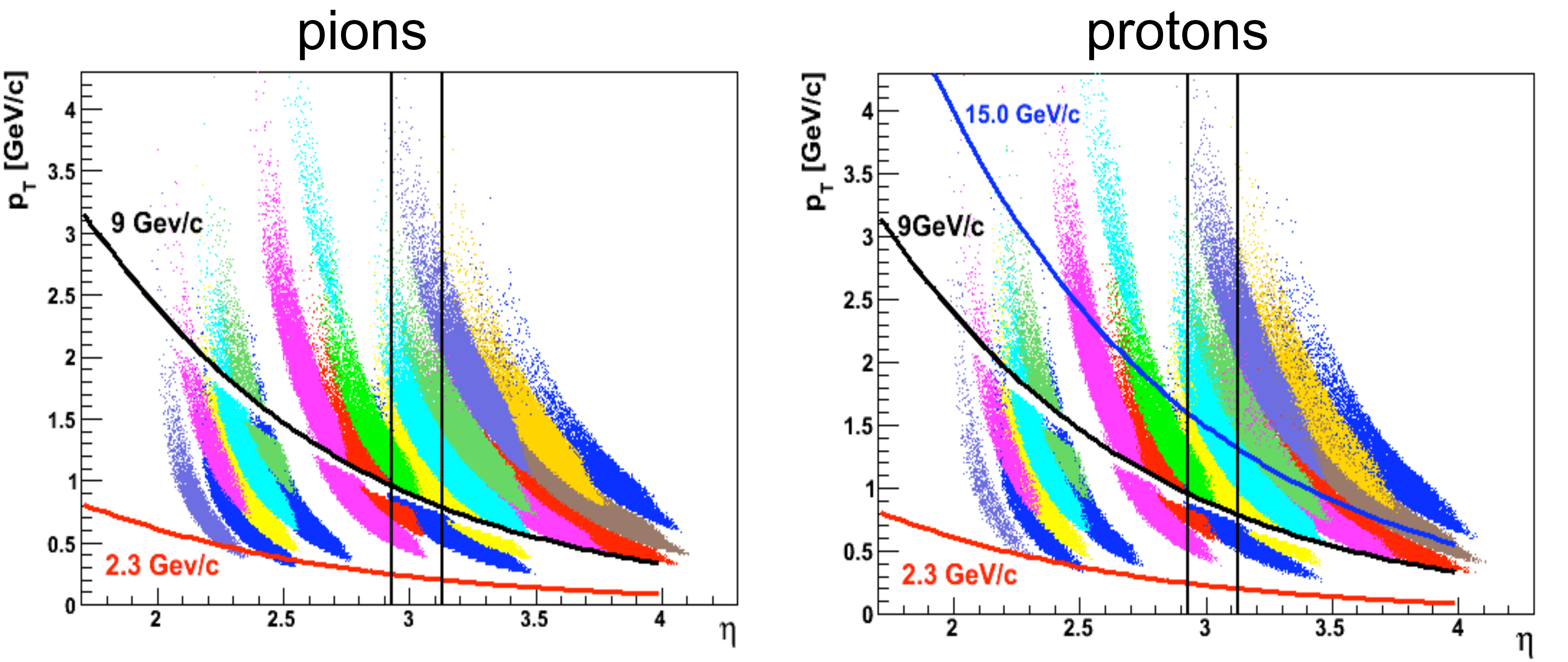
AMPT (**A** **M**ulti-Phase **P**arton **T**ransport model) a rather complex model that includes mini-jet parton, parton dynamics, hadronization and final state hadron interactions.

Z. Lin, PRC 72 (2005) 064901

Broad Range Hadron Magnetic Spectrometers



Data Analysis



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 and trigger normalization factors cancel out in the ratio.

Remaining corrections:

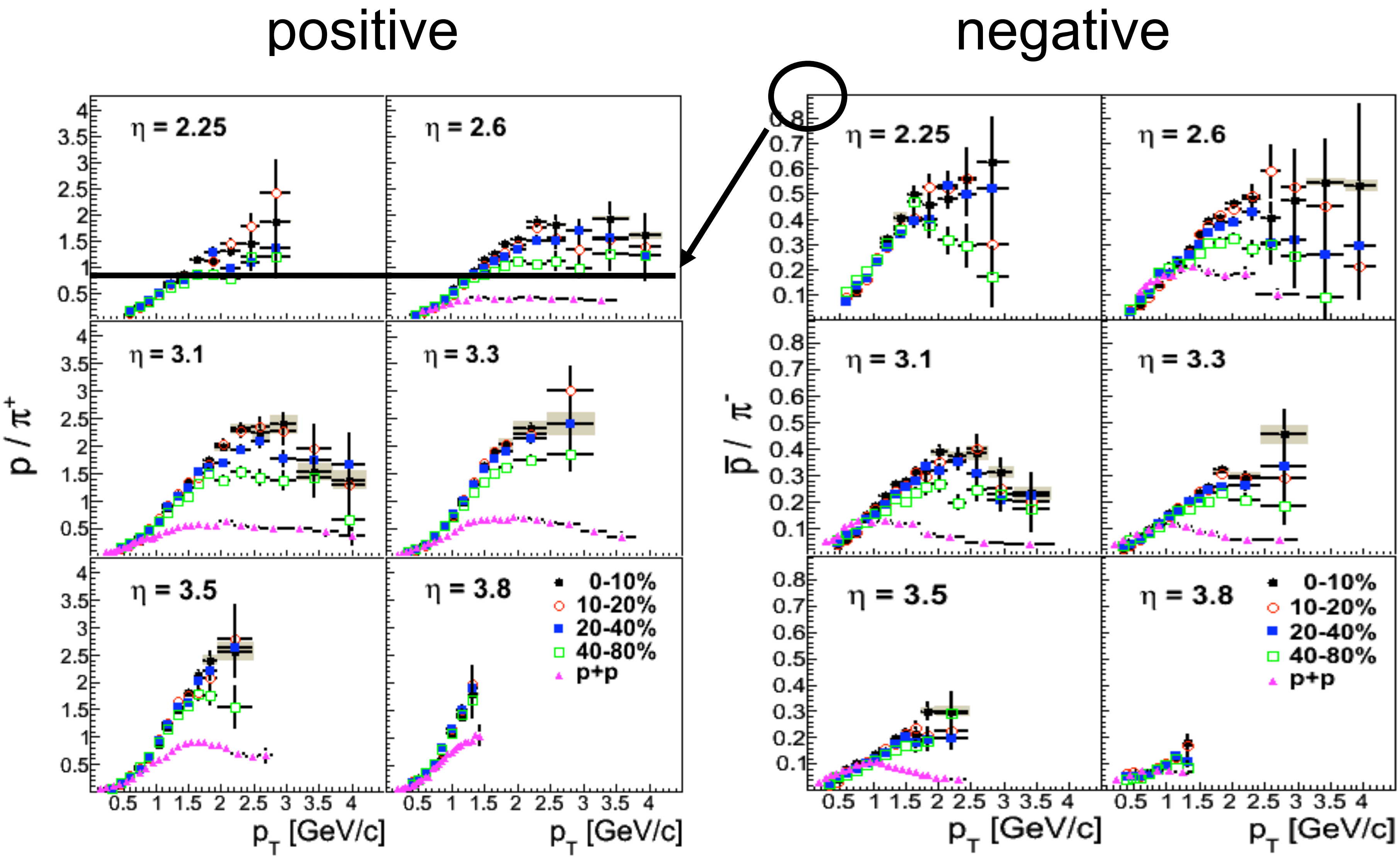
i) decay in flight, interaction in the beam pipe and detector material (GEANT calculation)

ii) correction for PID: pion contamination in Tof2 and RICH (limited mass resolution)

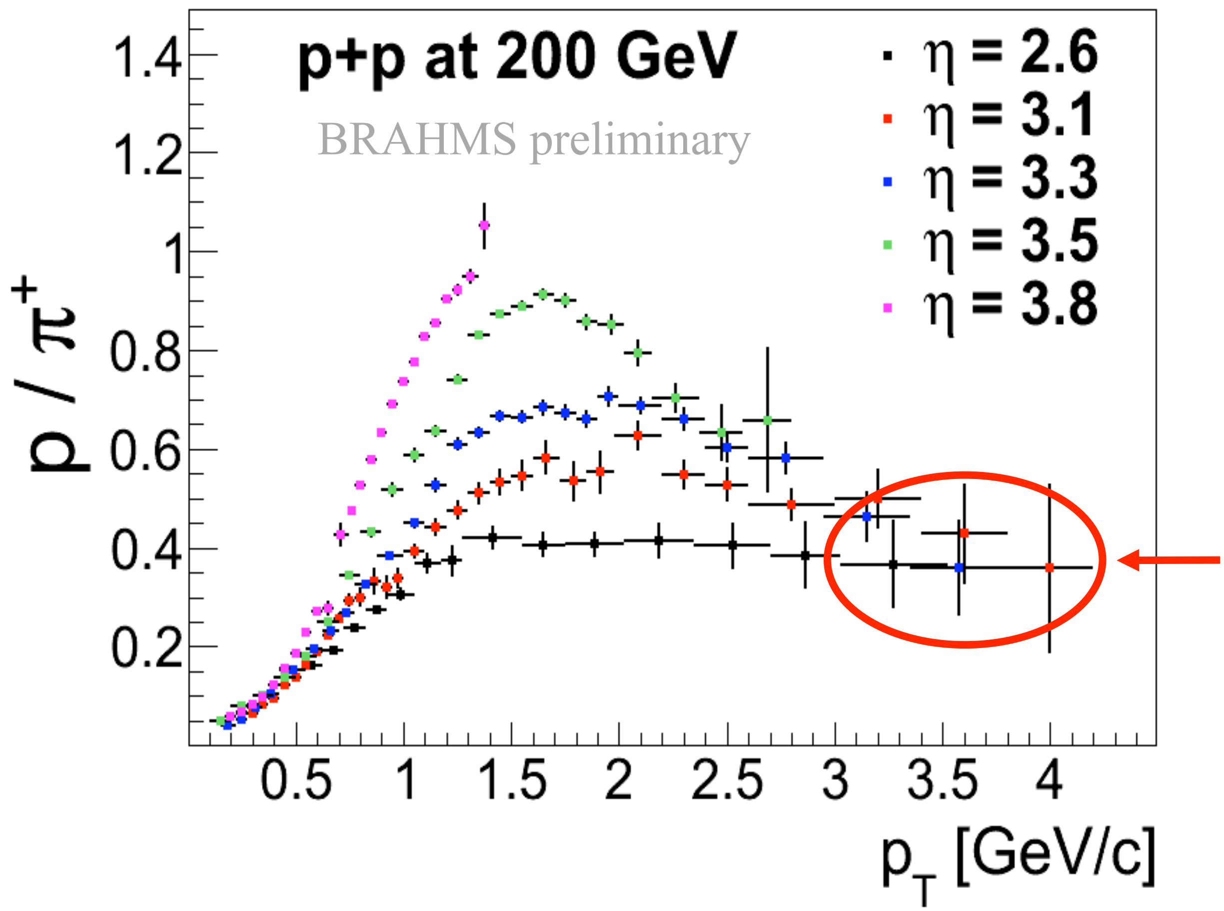
veto-proton contamination by pions and kaons (RICH efficiency ~ 97%)

Results

Au+Au and p+p at 200 GeV, BRAHMS preliminary



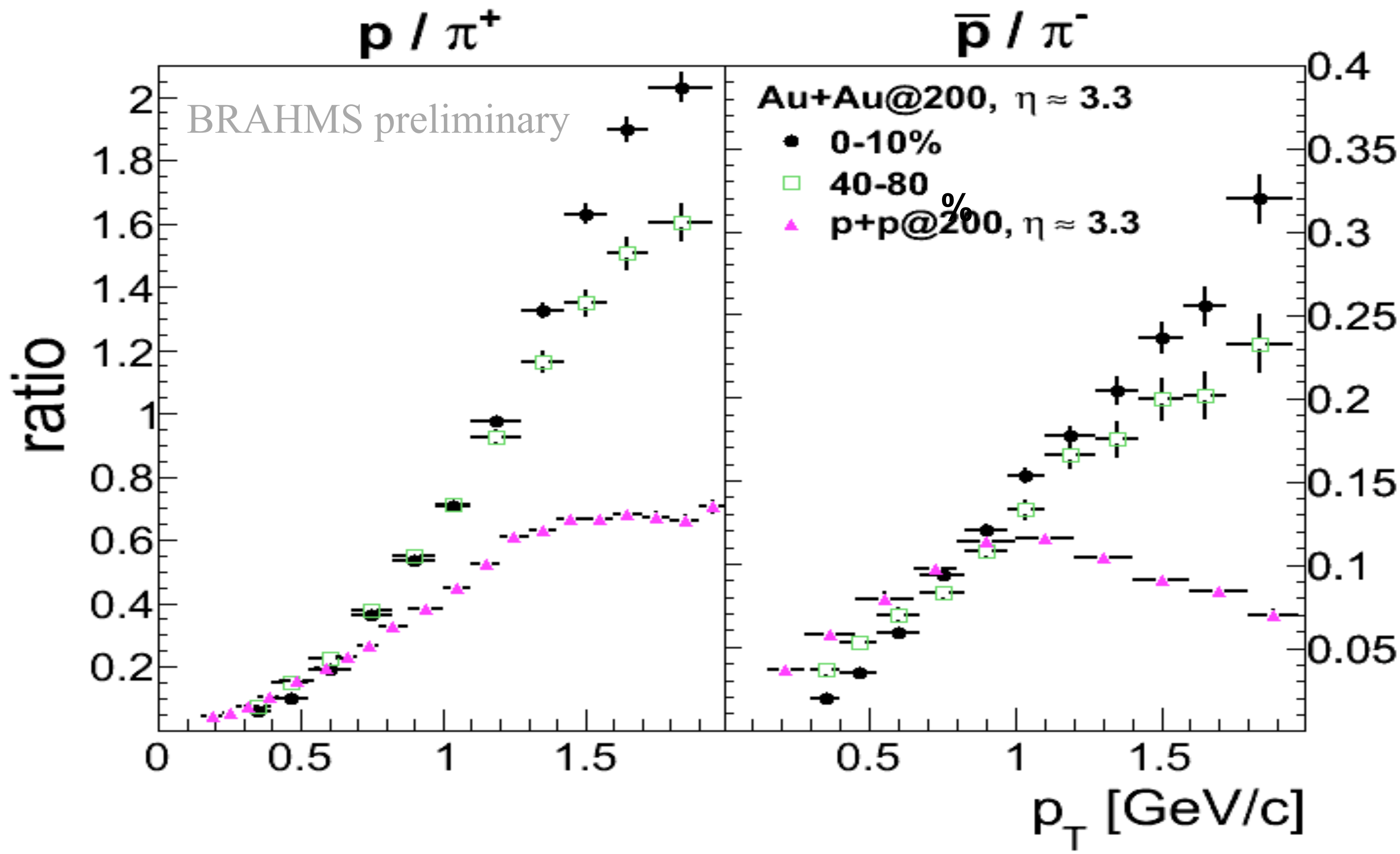
Results: p+p at 200 GeV versus rapidity



Strong rapidity dependence at intermediate p_T

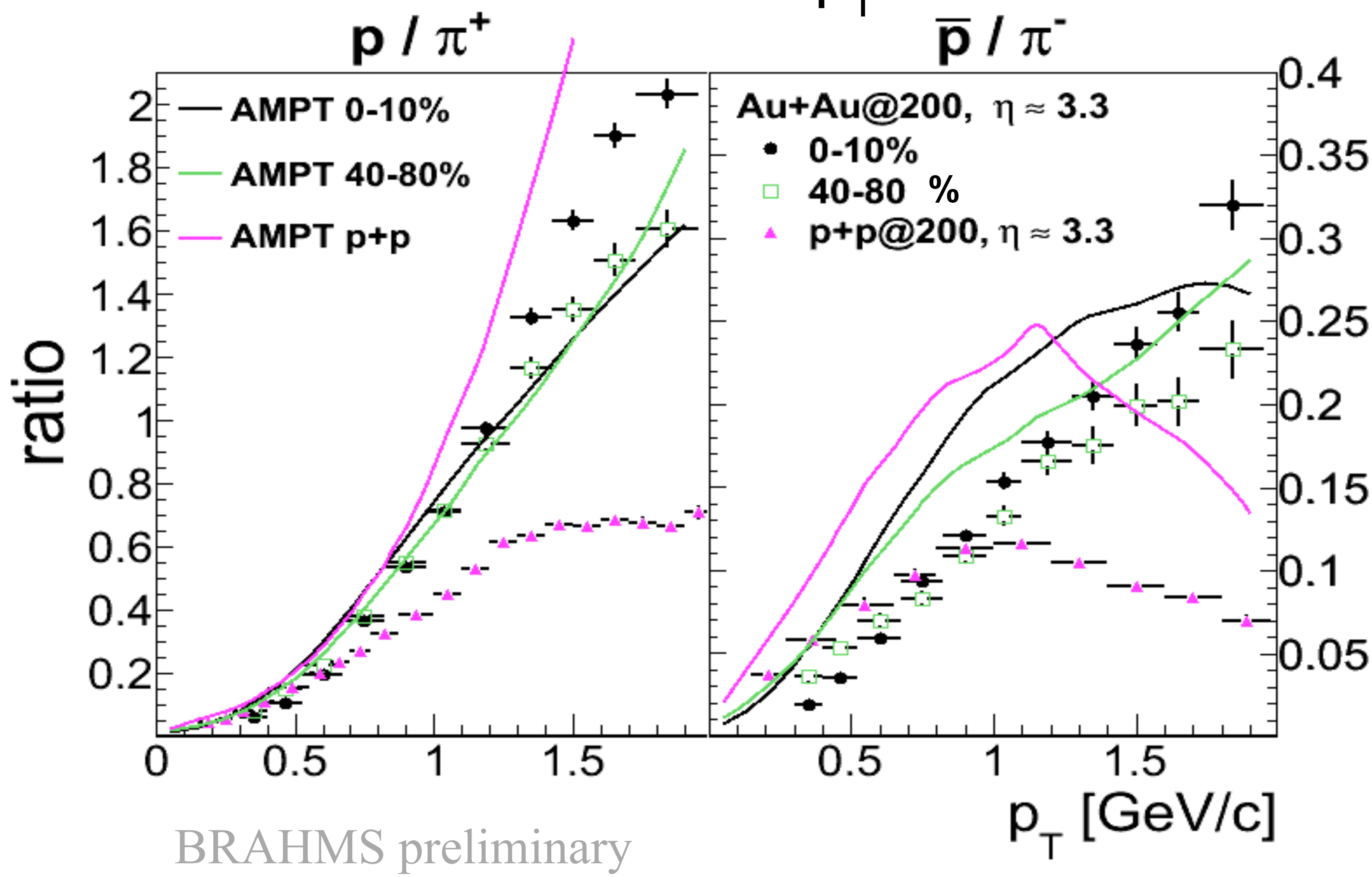
At hight p_T ratios seem to converge to common value of ~0.4 → consistent with pQCD predictions

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

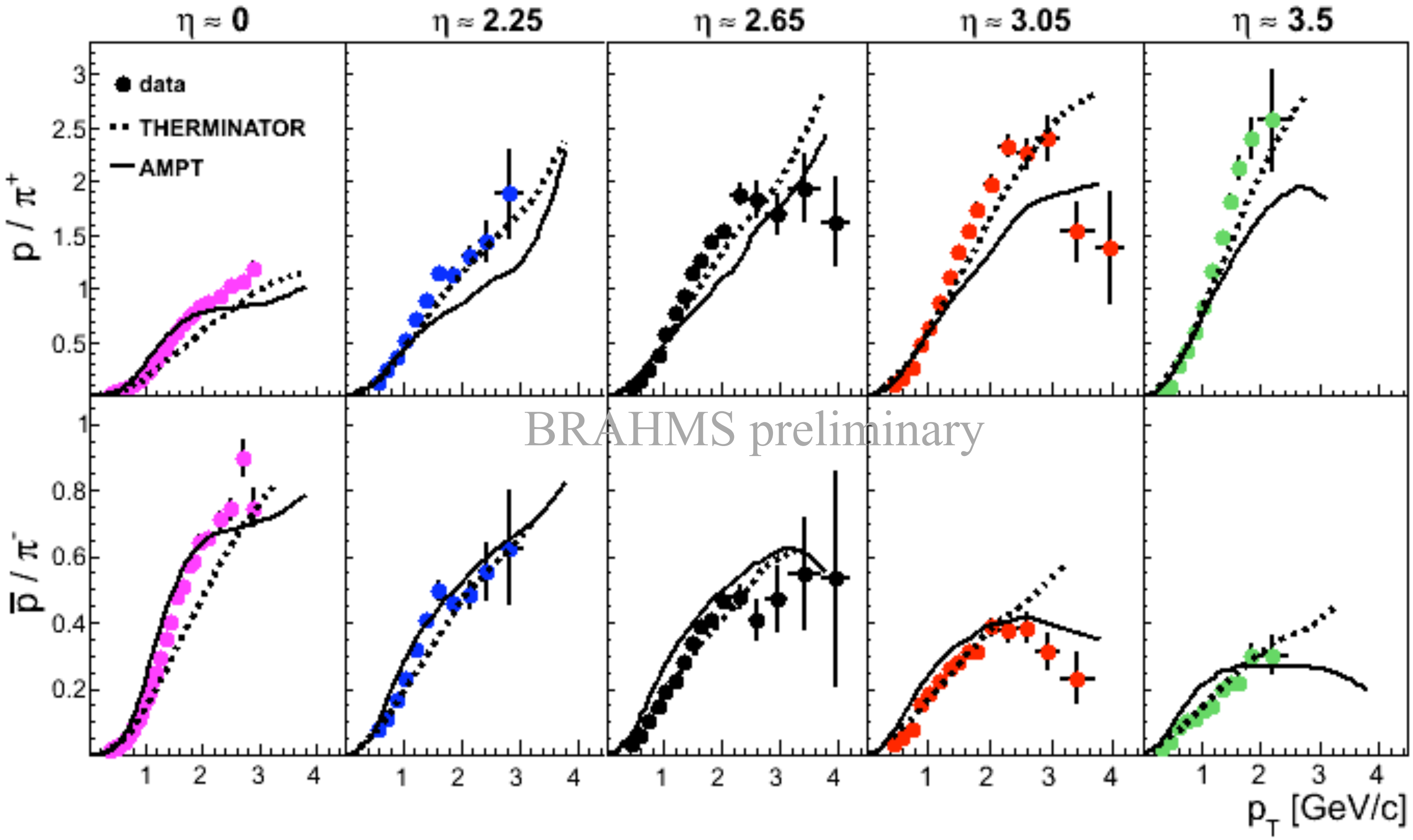


pbar/π ratio: at low p_T (<0.5GeV/c)
p+p > 40-80% > 0-10% , crossing point at ~0.9 GeV/c.
How sensitive are models in this p_T range
(**hydro versus quark coalescence scenario ?**)

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



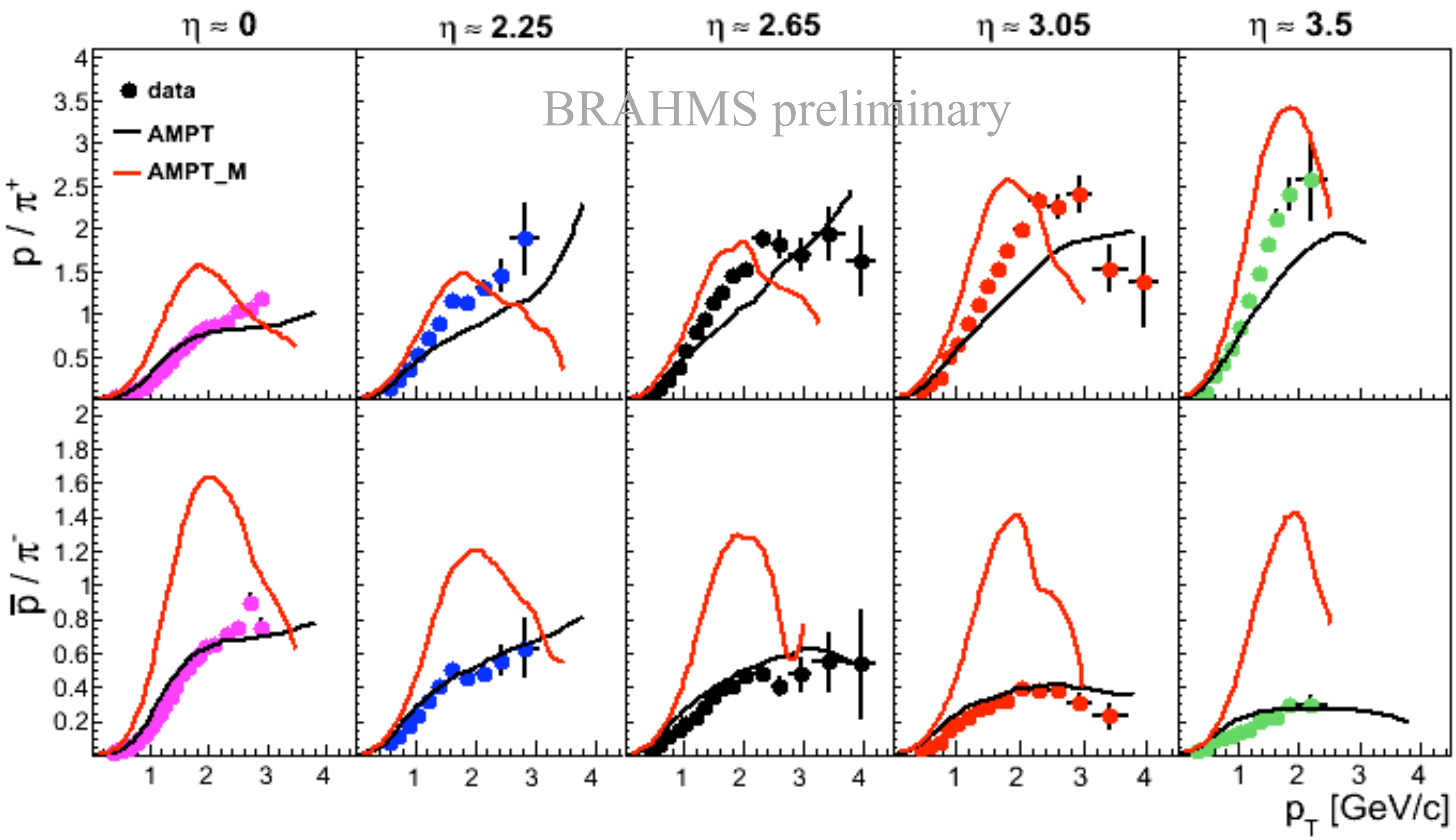
Central Au+Au at 200GeV: p/π^+ rapidity evolution – comparison with models



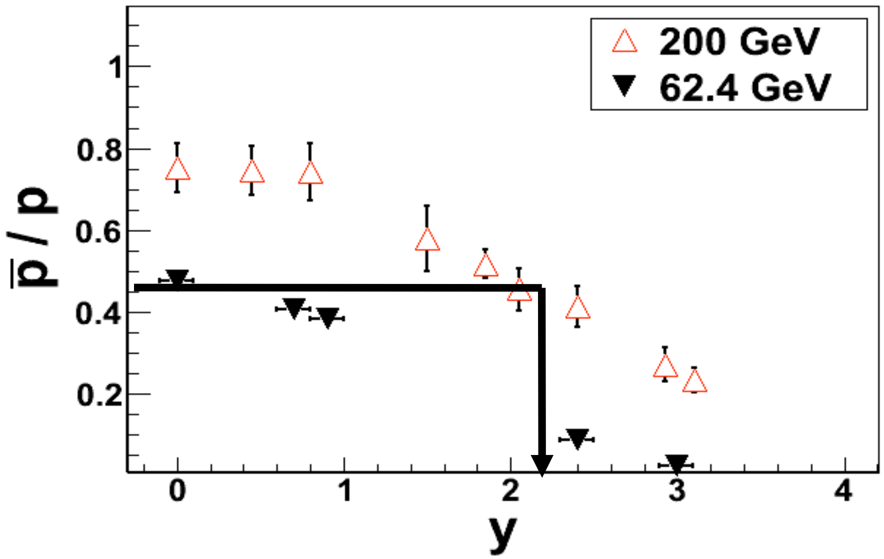
THERMINATOR: provides good description at forward rapidities (particularly for pbar/π^-), but under predicts data at mid-rapidity.

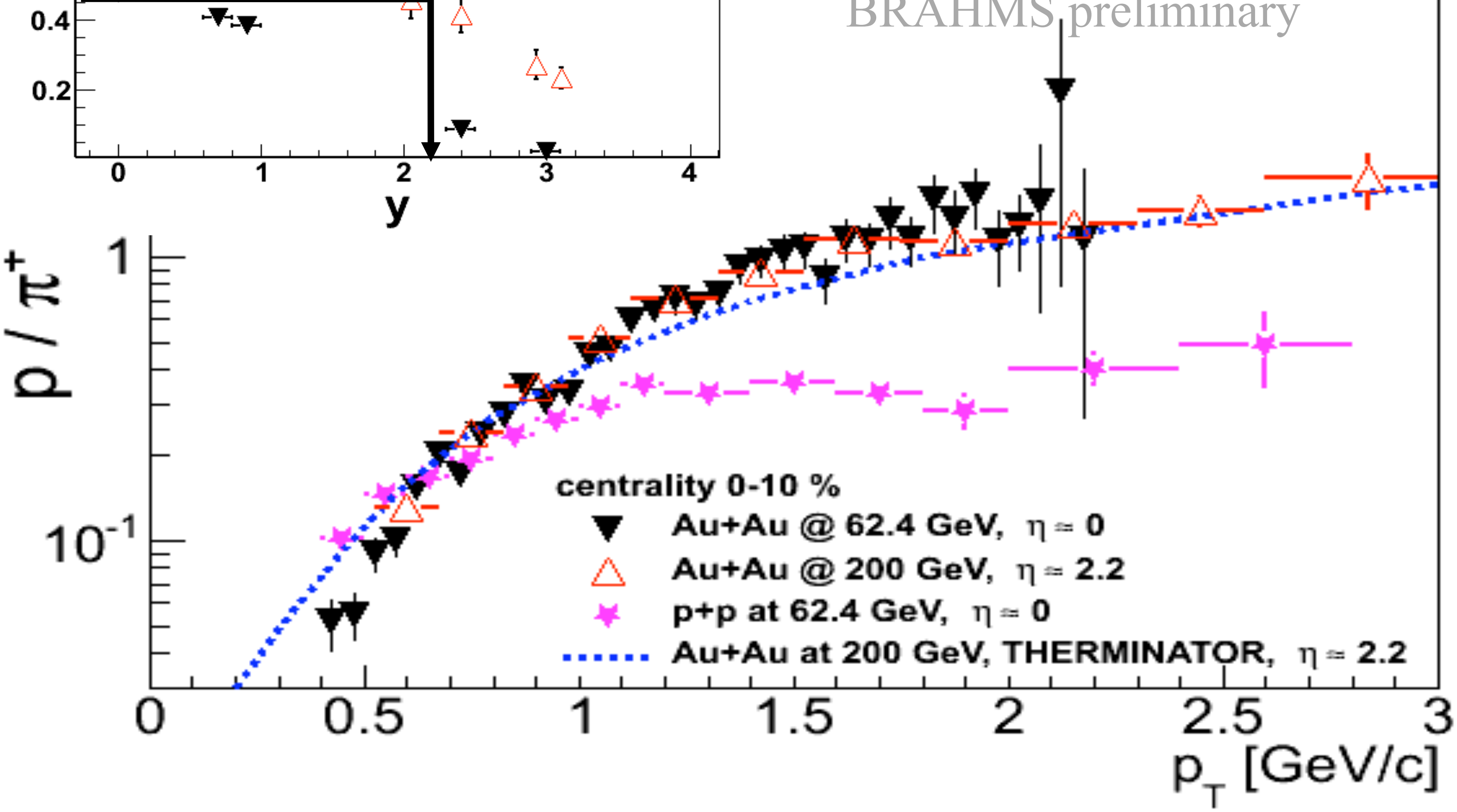
AMPT: qualitatively describes trends in rapidity evolution but fails in quantitative description (in general AMPT under predicts p/π^+ and over predicts pbar/π^-)

p/π^+ rapidity evolution – AMPT: string fragmentation versus string melting



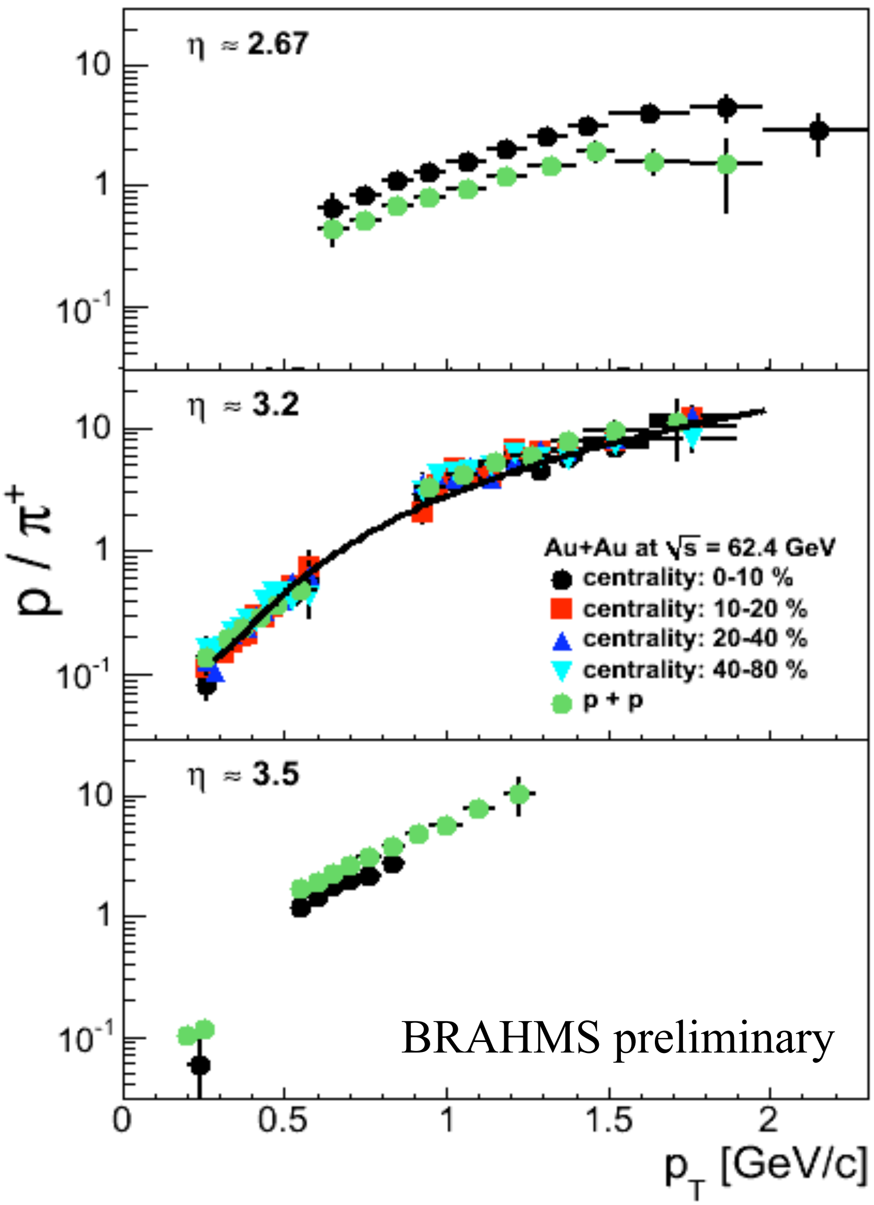
Au+Au: 62 GeV, η=0 versus 200 GeV, η=2.2





Same pbar/p for bulk medium => same p/π^+ up to 2 GeV/c

Au+Au and p+p at 62 GeV at forward rapidity



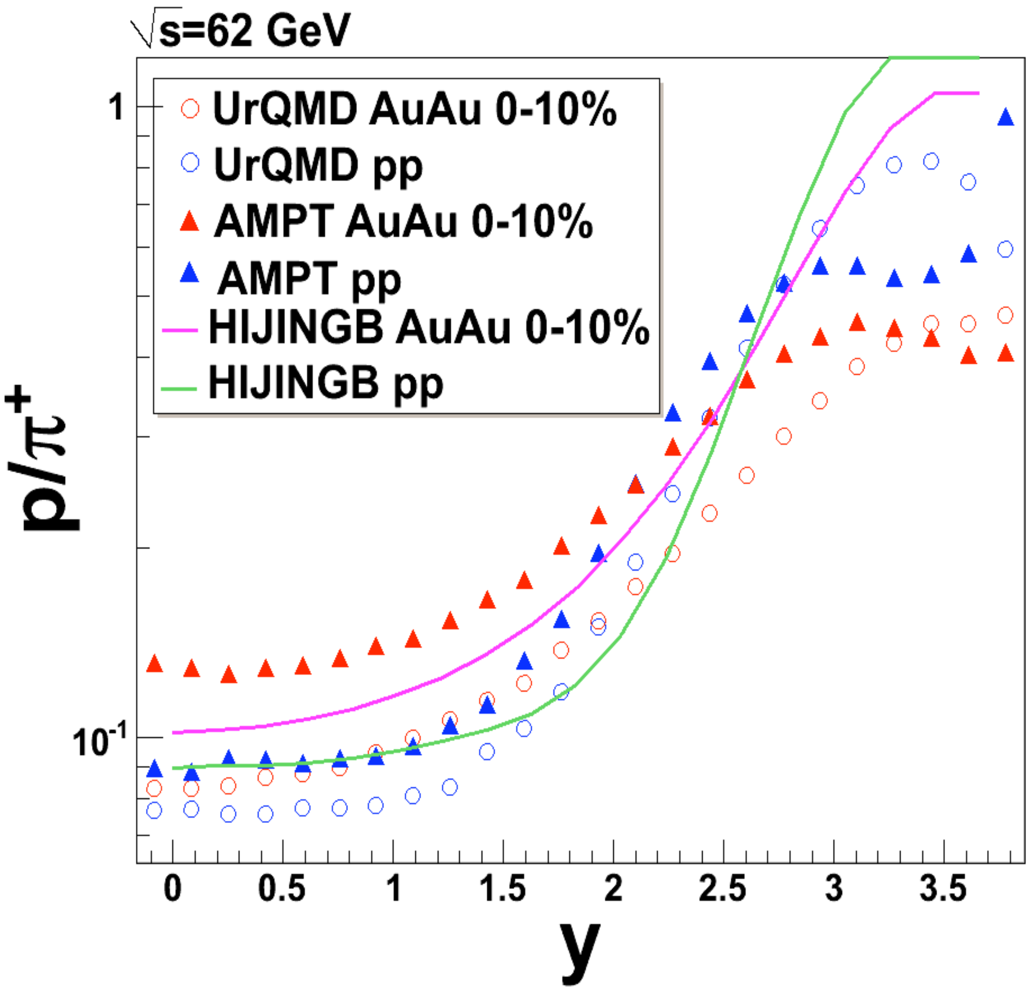
High value (~10) of proton-to-pion ratio is observed.

	Au+Au/p+p
at $\eta \sim 2.7$ Au+Au > p+p	1.6
at $\eta \sim 3.2$ Au+Au = p+p	1.0
at $\eta \sim 3.5$ Au+Au < p+p	0.7

The crossing point at which p/π^+ ratios for Au+Au and p+p are consistent with each other is located at $\eta \sim 3.2$

The crossing occurs simultaneously for all Au+Au centralities and p+p in the covered p_T range (0.3 – 1.8 GeV/c)

Au+Au and p+p at 62 GeV – model predictions



Models predict p/π^+ crossing but in the interval 2.0 < y <2.5

They can not predict simultaneous crossing in the whole (covered) p_T range

→ strong experimental constrain on the theoretical description of baryon number transport and associated energy dissipation

Summary

We presented results on p/π (p_T) ratio versus rapidity and collision centrality for Au+Au at 200 and 62.4 GeV and for p+p at 200 GeV

1) weak dependency on collision centrality for Au+Au at 200 GeV at low p_T up to ~1.5 GeV/c.

Below p_T ~0.9 GeV/c the pbar/π^- ratios for p+p are larger than these measured in Au+Au.

2) the dependency on centrality (as documented by N_{part} scaling) reveals above p_T>1.5 GeV/c

3) For central Au+Au at 200 GeV p/π^+ shows increasing trend with increasing rapidity from 1.0 (η~0, p_T=3 GeV/c) to about 2.5 (η~3, p_T=3 GeV/c). In opposite, pbar/π^- decreases with increasing rapidity (from ~1 at η~0 to 0.4 at η~3).

4) The p/π ratios are remarkably similar for $\sqrt{s_{NN}}$=200 GeV at η=2.2, and for $\sqrt{s_{NN}}$=62.4 GeV at η=0, where the bulk medium is characterized by the same value pbar/p

5) At $\sqrt{s_{NN}}$=62.4 GeV the p/π^+ ratios for p+p and for all analyzed Au+Au centralities cross simultaneously at the same η~3.2.

Data comparison with models:

The THERMINATOR model provides reasonable quantitative description of the data except for p_T>3 GeV/c and mid-rapidity where it under predicts the ratios → transition from parton coalescence scheme at low μ_B to a hydrodynamical description at large μ_B due to final state hadron interaction.

The AMPT(default) model provides qualitative description of the trends in rapidity evolution but can not describe dependency on centrality including p+p results.

The BRAHMS Collaboration

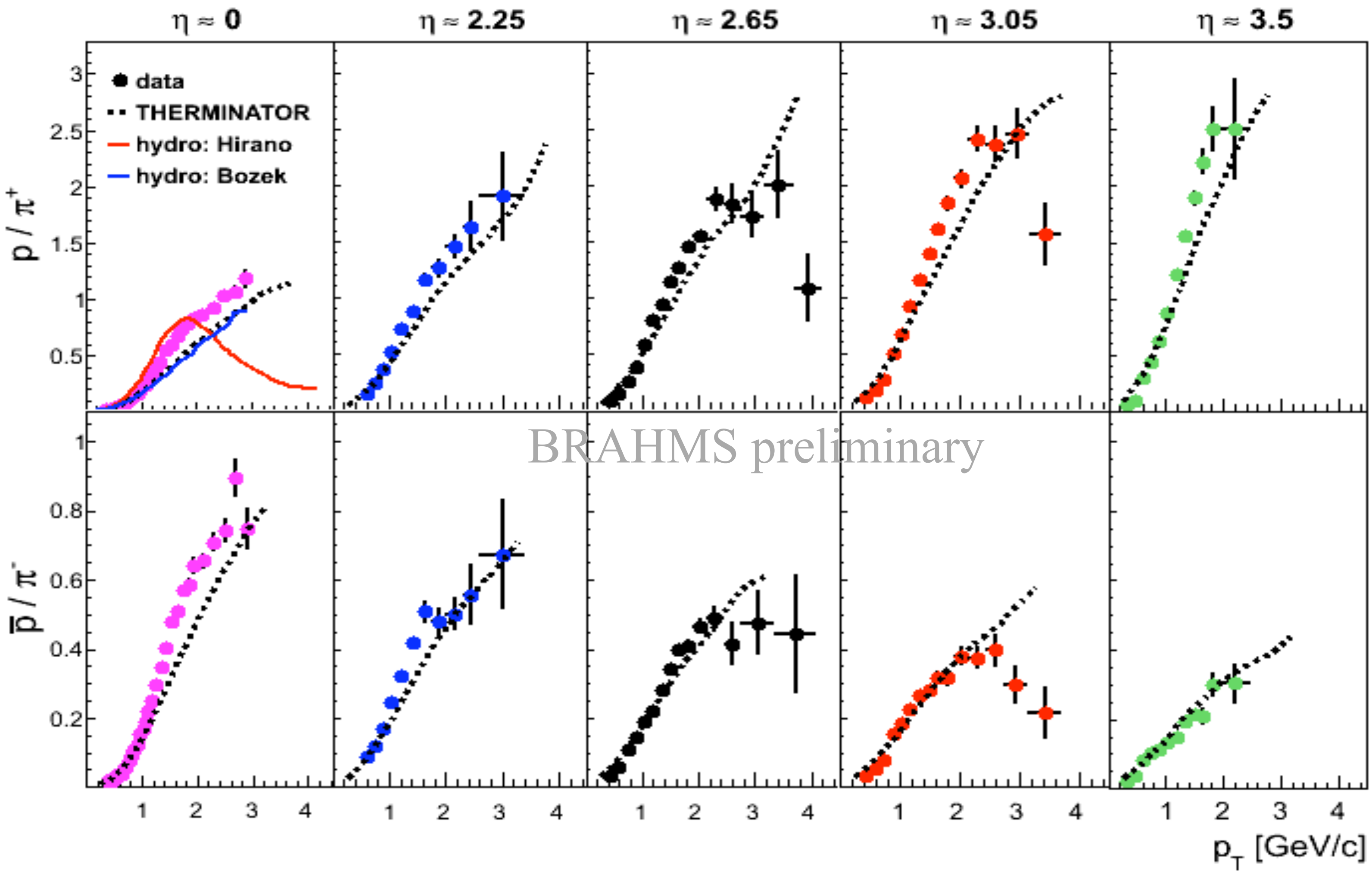
I.Arsene , I.G. Bearden , D. Beavis , S. Bekele , C. Besliu , B. Budick , H. Bøggild , C. Chasman , C. H. Christensen , P. Christiansen , R. Clarke , R.Debbe , J. J. Gaardhøje , K. Hagel , H. Ito , A. Jipa , J. I. Jordre , F. Jundt , E.B. Johnson , C.E.Jørgensen , R. Karabowicz , N. Katryńska , E. J.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

Brookhaven National Laboratory, USA, IReS and Université Louis Pasteur, Strasbourg, France
Jagiellonian University, Kraków, Poland,
Johns Hopkins University, Baltimore, USA, New York University, USA
Niels Bohr Institute, University of Copenhagen, Denmark
Texas A&M University, College Station. USA, University of Bergen, Norway
University of Bucharest, Romania, University of Kansas, Lawrence,USA
University of Oslo Norway

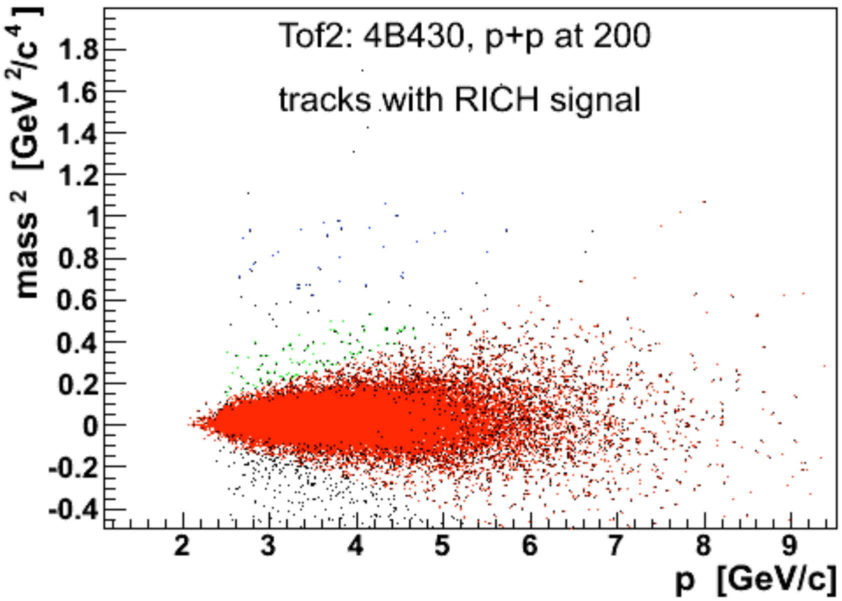
~50 physicists from 11 institutions

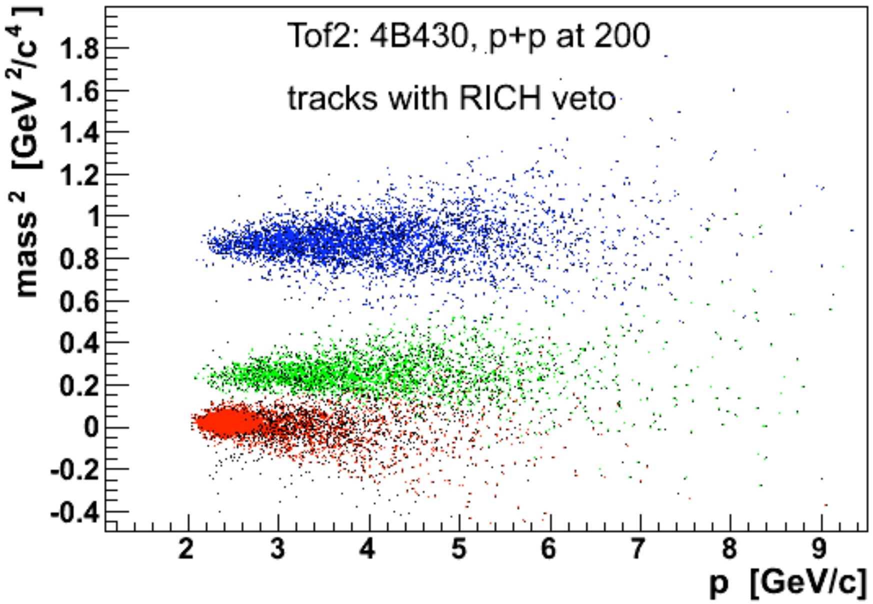
BACKUP SLIDES

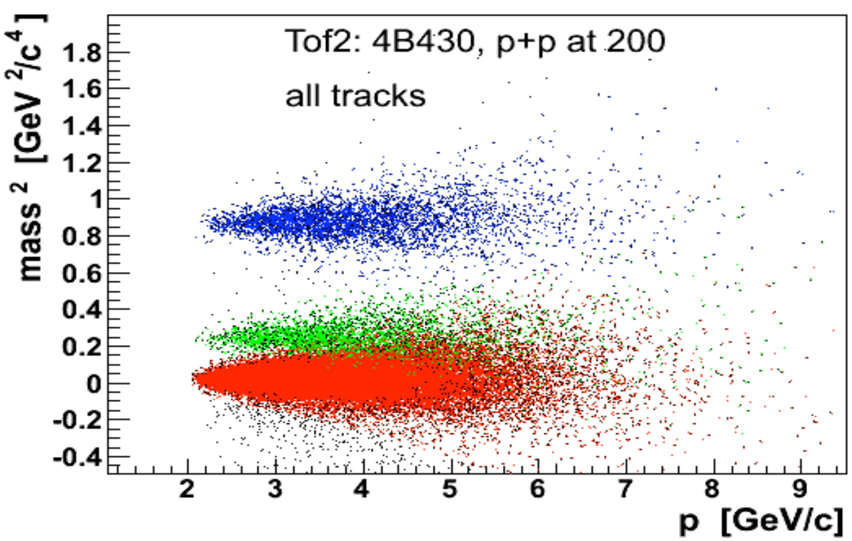
p/π⁺ at mid-rapidity, Hirano versus Bożek

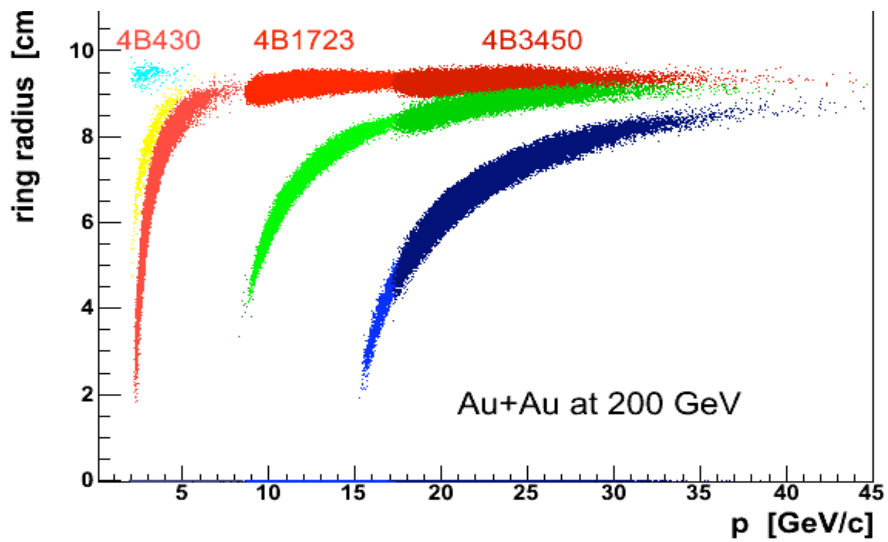


Data Analysis: Tof2 and RICH Pid

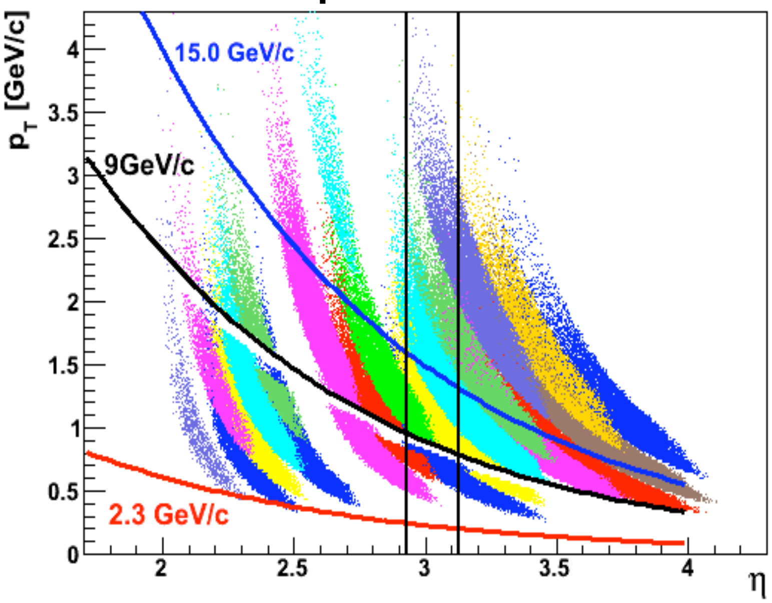




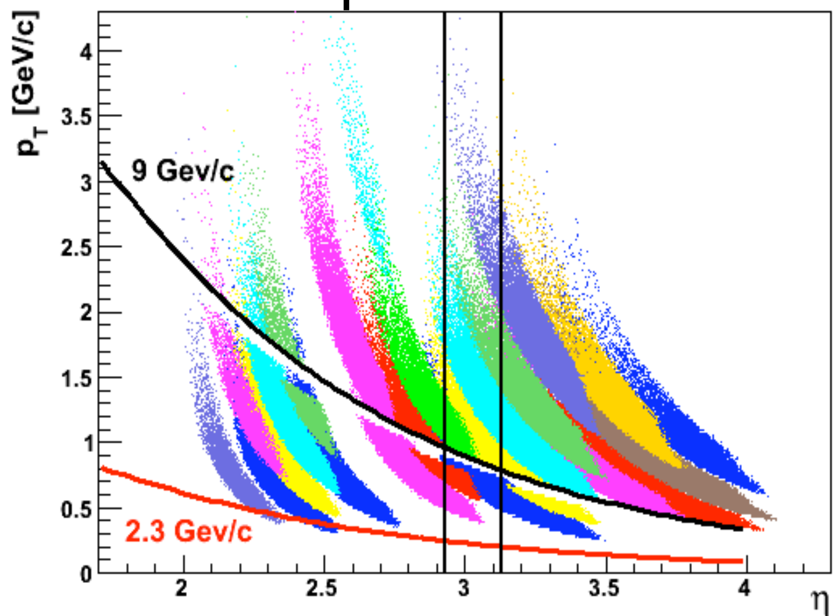


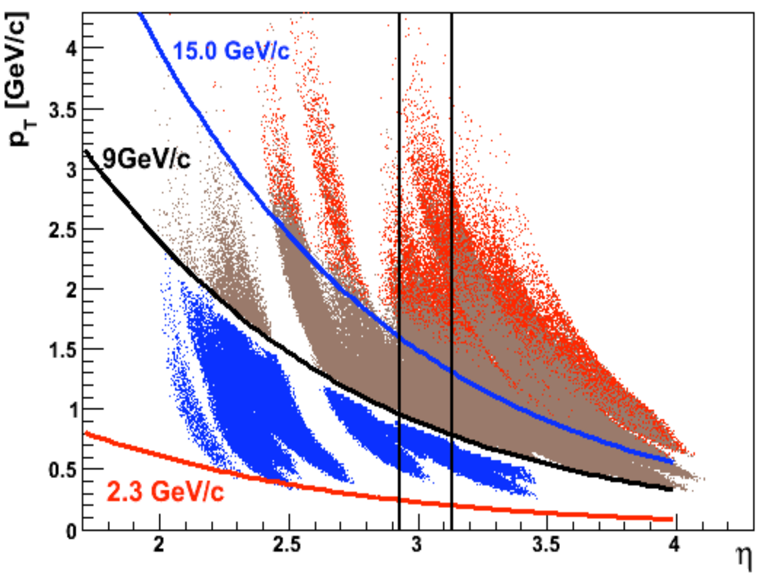


protons



pions





Same acceptance for pions and protons in the real time measurements. For given η-p 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.

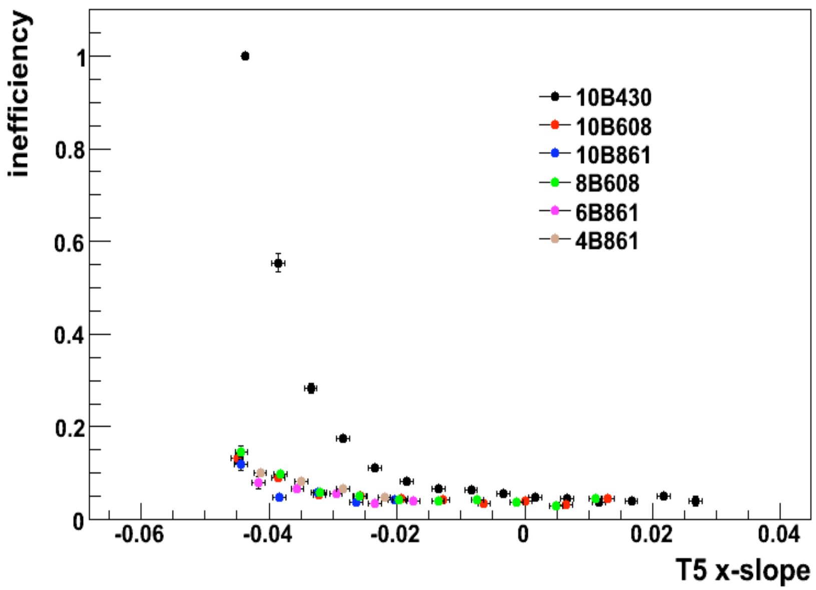
Remaining corrections:

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

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

Data Analysis: RICH inefficiency

Low field runs



1. Identify pions with no RICH ring (RICH veto pions) in tof2.

ineffic = veto pions / all pions

2. two relevant dependencies are found:

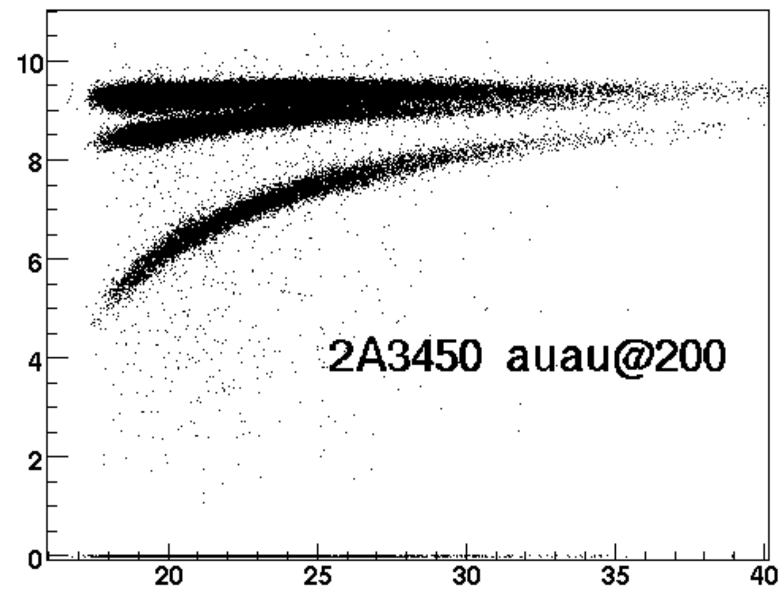
a) dependency on p/p (Cherenkov threshold effect)

b) dependency on track x-slope (geometrical effect)

3. For fields like 608 and 861 p/p >>1 and geometrical effect can be studied alone. Then in can be use to disentangle Cherenkov threshold effect for lower field run (430) where both effect play a role.

Ring radius vs p

High field runs



1. ineffic = veto/all

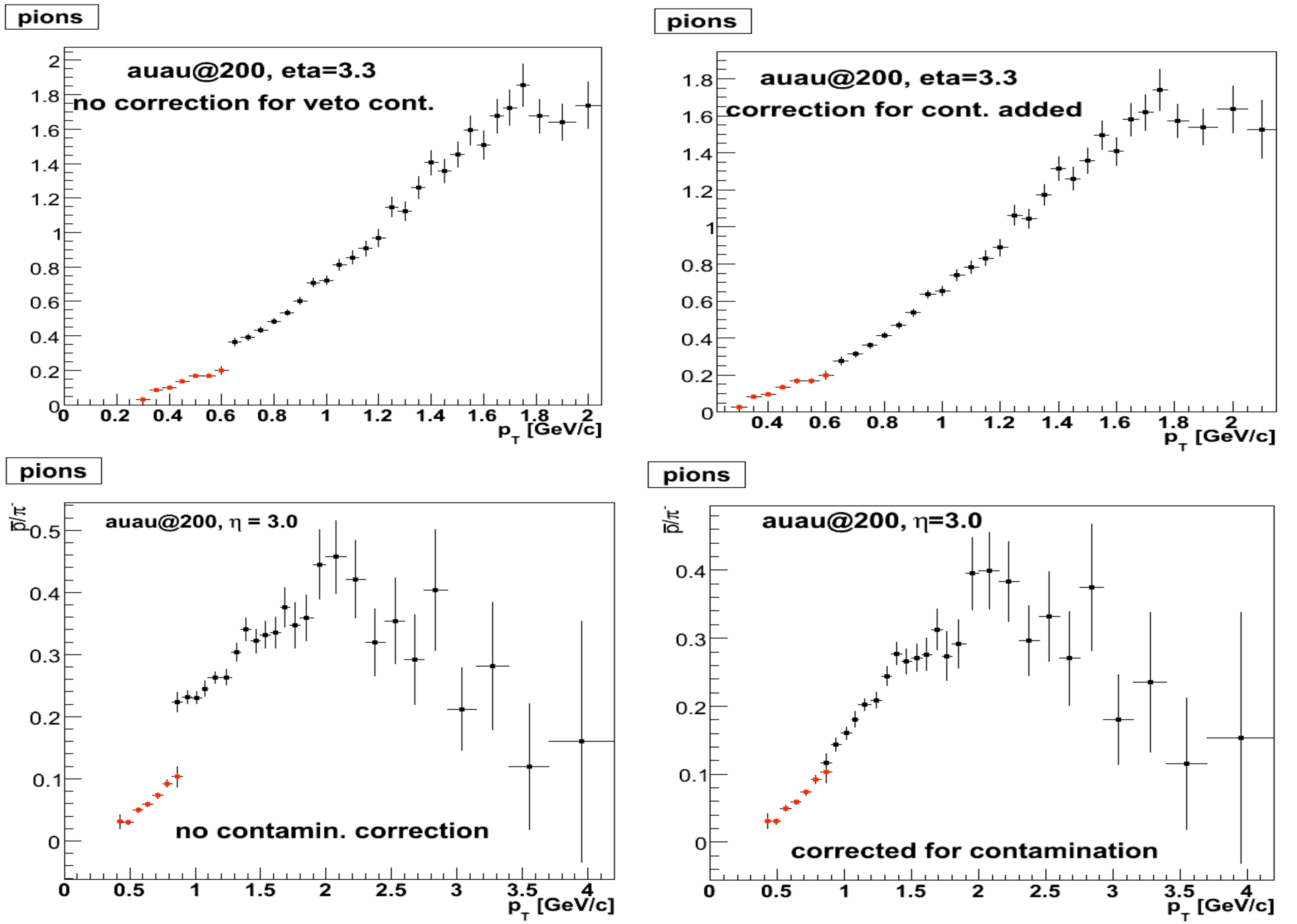
2. Additional control of specie dependence by comparing A (less protons) and B (more protons) polarities:

$$y^A_{\pi+K}\ f_\pi + y^A_p\ f_p = y^A_{veto}$$

$$y^B_{\pi+K}\ f_\pi + y^B_p\ f_p = y^B_{veto}$$

3. observed dependency on T5 x-slope, similar to that encountered at low field runs

Test of corrections for veto-protons



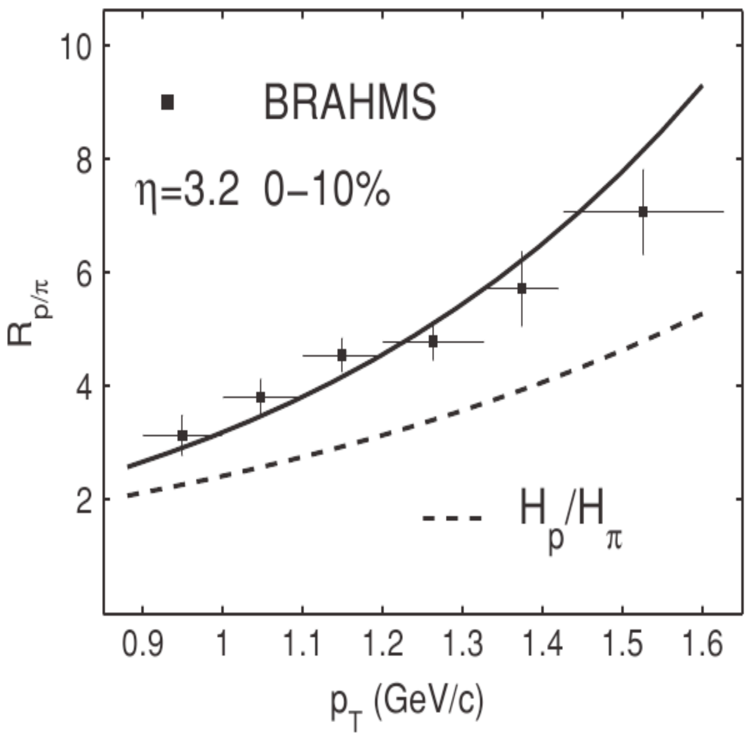
Data Analysis – related systematic uncertainties

$\eta \approx 2.27$		$\eta \approx 2.65$		$\eta \approx 3.04$		$\eta \approx 3.3$		$\eta \approx 3.5$		$\eta \approx 3.7$	
p_T	p/π^+	p_T	p/π^+	p_T	p/π^+	p_T	p/π^+	p_T	p/π^+	p_T	p/π^+
0.5-0.8	< 1	0.5-0.7	< 2	0.4-0.6	< 3	0.3	3	0.3	3	0.4	**5**
1.0	2	0.9	2	0.8	**4.5**	0.45	4	0.4	6	0.5	**3.5**
1.2	3	1.15	3	0.9	**2**	0.6	6	0.55	**4**	0.6	**2**
1.6	**5**	1.2	**4**	1.1-2.0	< **1**	0.7-2.0	< **2**	0.7-1.7	< **3**	> 0.75	< **2**
> 1.7	< **1**	> 1.3	< **1**	> 2.2	**4**	3.0	6	2	**4**		
p_T	$\bar{p}/\pi^-$	p_T	$\bar{p}/\pi^-$	p_T	$\bar{p}/\pi^-$	p_T	$\bar{p}/\pi^-$	p_T	$\bar{p}/\pi^-$	p_T	$\bar{p}/\pi^-$
0.5-0.8	< 1	0.5-0.7	< 2	0.4-0.6	< 3	0.3	3	0.3	3	0.4	**14**
1.0	2	0.9	2	0.7	5	0.45	4	0.4	6	0.5	**11**
1.2	3	1.15	5	0.8	**6**	0.6	7	0.55	**12**	0.6	**8**
1.6	**5**	1.2	**3**	0.9	**4**	0.7	**7**	0.7	**7**	0.85	**5**
1.7	**2**	1.3	**2**	1.15-2.2	**3**	0.9-2.0	< **3**	1.0-1.7	< **4**	1.0	**3**
> 2.0	< **1**	> 1.7	< **1**	> 2.2	**4**	3.0	**6**	2.0	**4**	> 1.2	< **2**

Table 1: Estimated PID systematic errors shown as a per-cent of the measured p/π^+ and $\bar{p}/\pi^-$ ratios presented in this letter. Regular and bold fonts refer to PID based o time-of-flight and Cherenkov measurement technique, respectively.

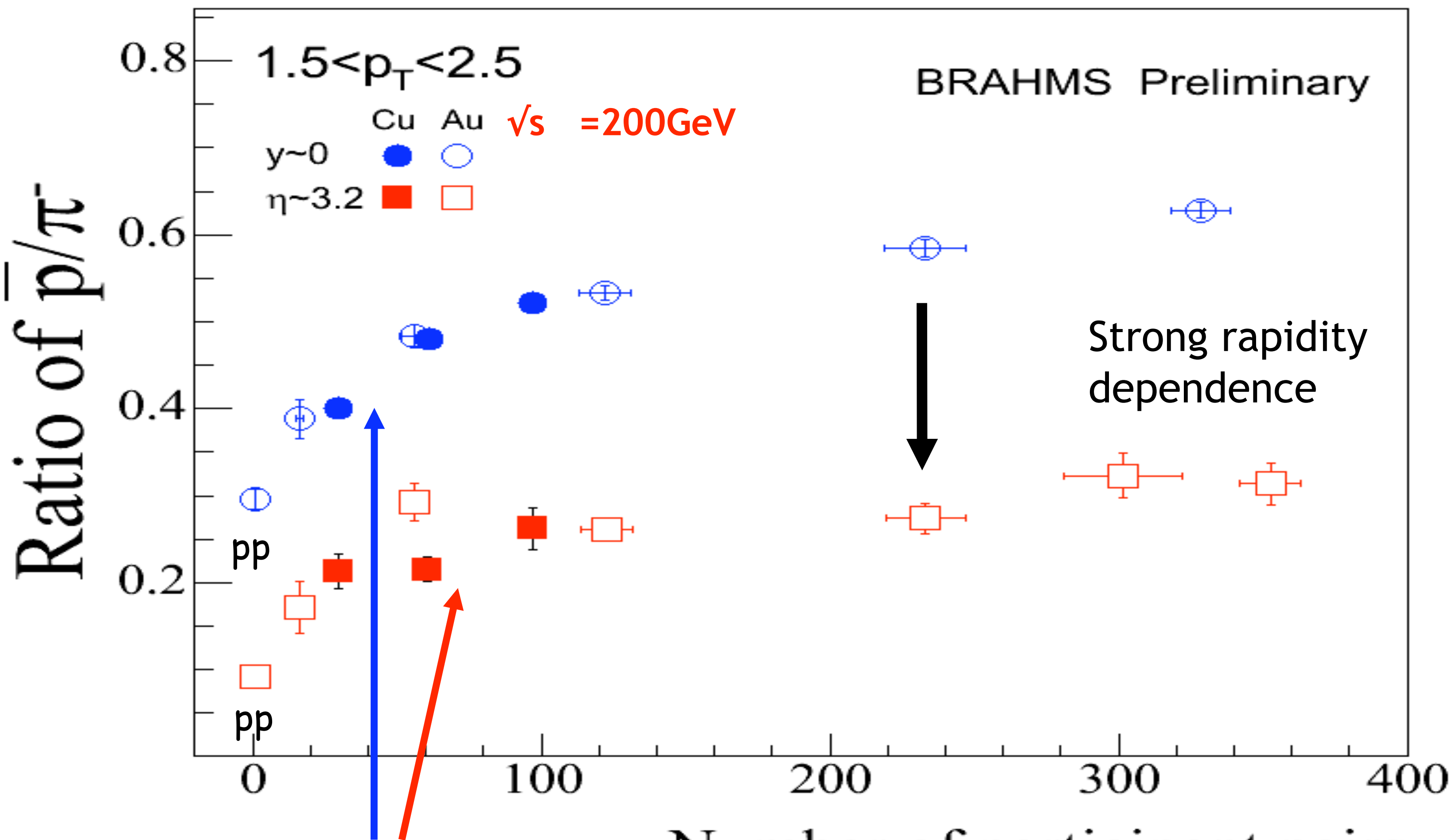
At mid-rapidity an overall systematic error is 5%

R. Hwa and L. Zhu, PRC 78, (2008) 024907



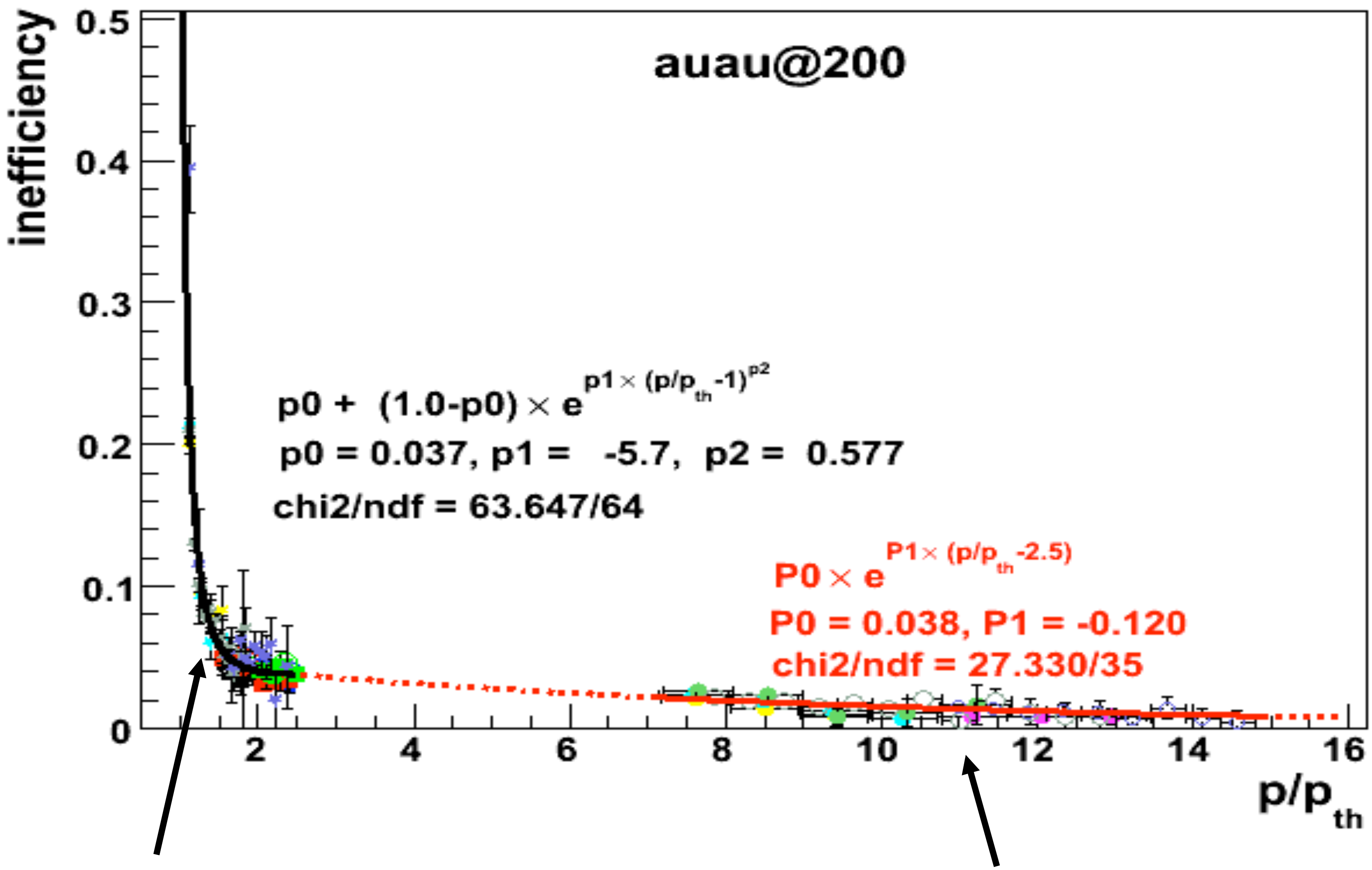
Quark recombination incorporating partn momentum **degradation** and sea quark **regeneration**.
Degradation parameter
K ≅**0.68** from fit to data

pbar/π scaling with N



CuCu data consistent with AuAu for the same N

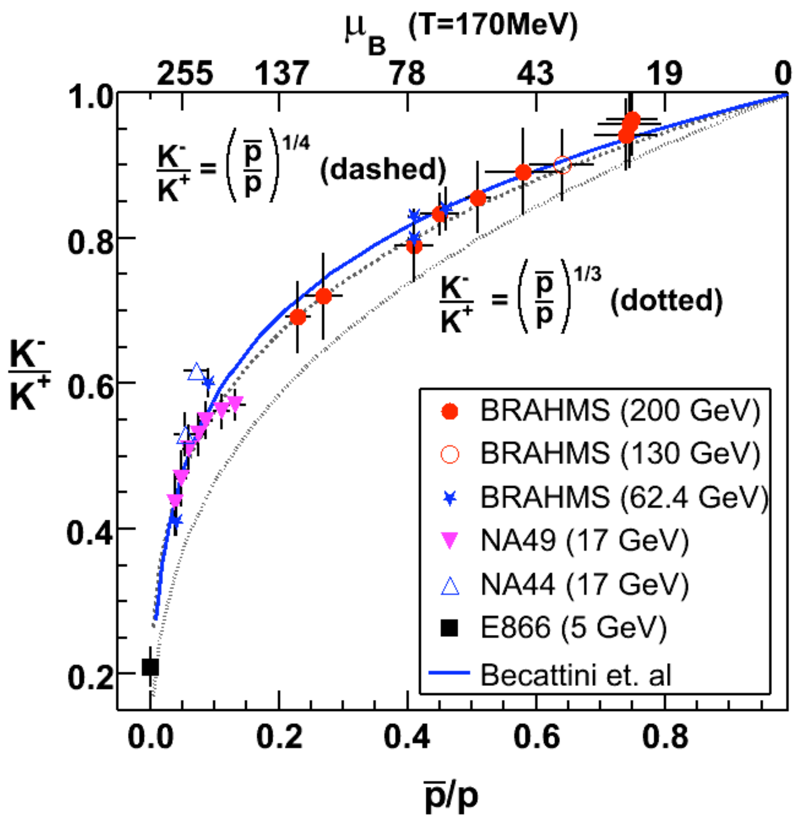
RICH inefficiency scaling with p/p

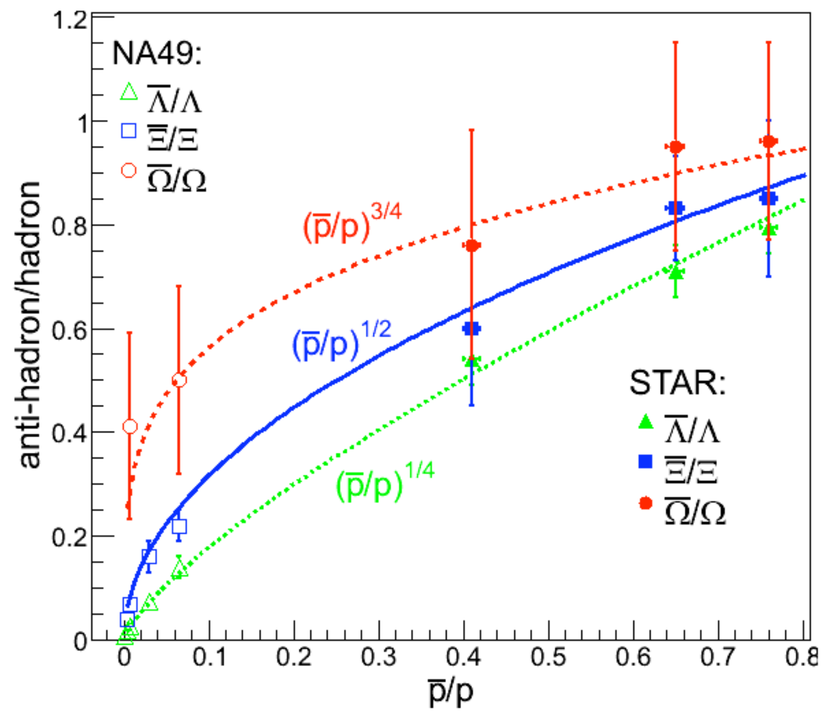


Usual inefficiency formula

Ordinary exponent with build-in matching to low p/p

K /K and antihyperon/hyperon

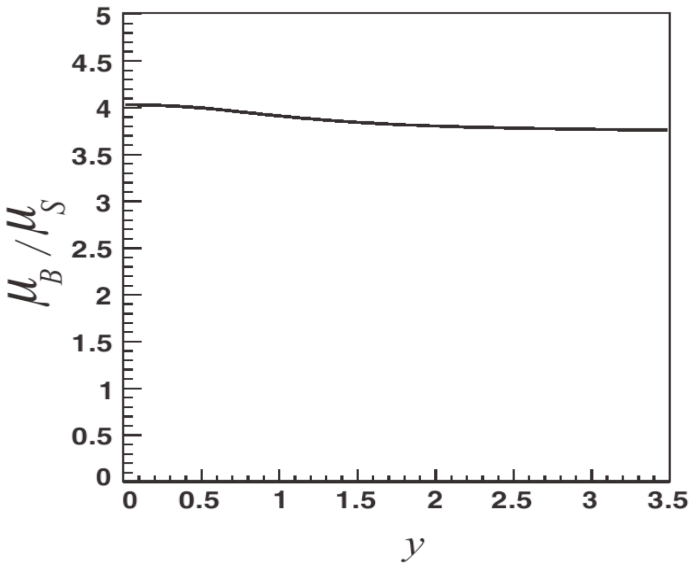




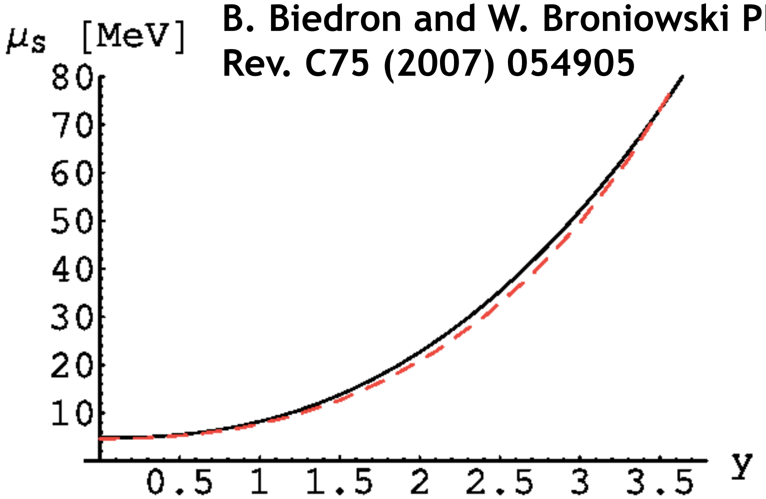
K /K = exp((2μ - 2μ)/T)
pbar/p = exp(-6μ /T)
μ =0 ⇒ K /K = (pbar/p)
Fit shows that K /K = (pbar/p)
⇒ μ = ¼ μ

How μ = ¼ μ will work for hyperons?
Hbar/H = (pbar/p) for Λ
= (pbar/p) for Ξ
= (pbar/p) for Ω

Statistical model and μ vserus μ



Fits with statistical model provide similar μ /μ ratio with weak dependency on y.



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

This result is consistent with local net-strangeness conservation

red line - ρ = 0

black line – fit to BRAHMS data