Search for the onset of baryon anomaly at RHIC-PHENIX

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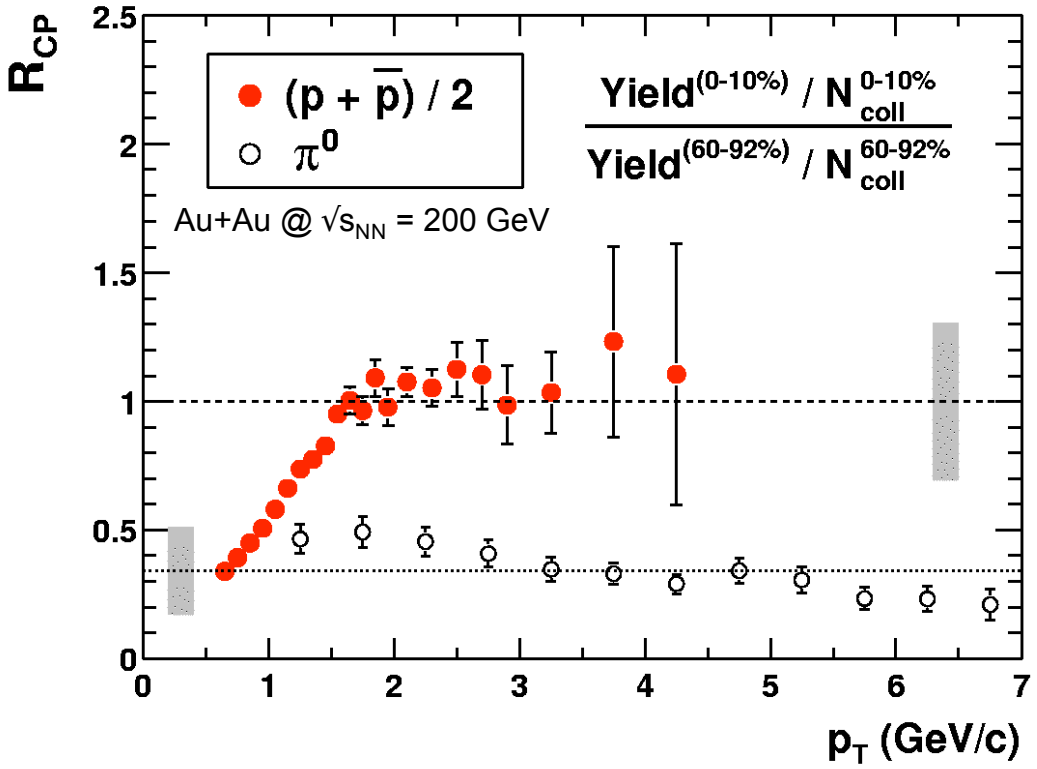
Introduction

~ Baryon Anomaly at RHIC ~

PHENIX: PRL 91, 172301 (2003), PRC 69, 034909 (2004)



Nuclear Modification Factor

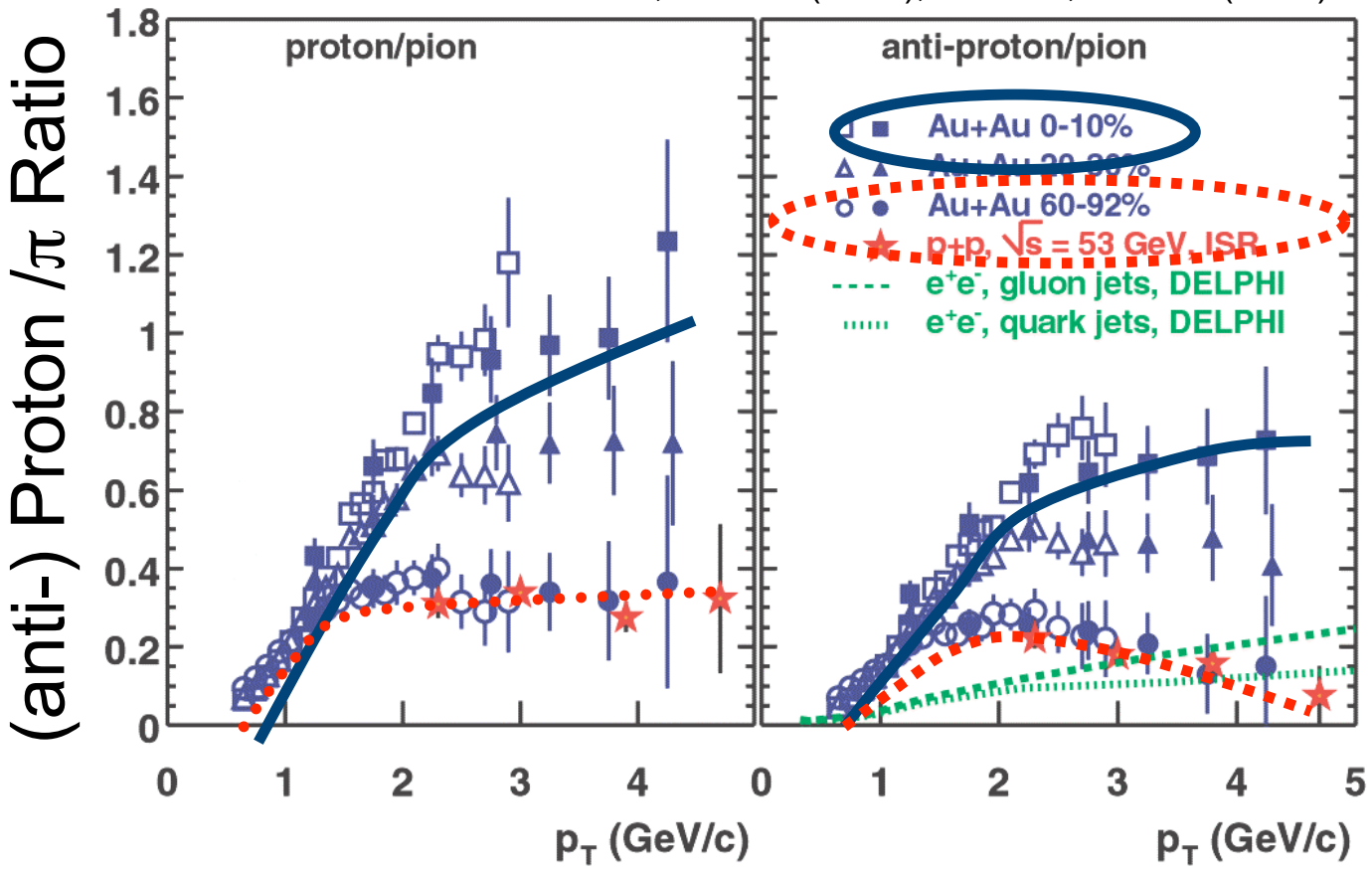
$$R_{AA}(p_T) = \frac{yield(AuAu)/N_{coll}}{yield(pp)} \sim R_{CP}$$

- In Au+Au $\sqrt{s_{NN}}$ = 200 GeV central collisions:
  - Pions: Strong suppression of yields above p_T ~ 2 GeV/c, due to jet quenching effect.
  - Protons: No suppression for at intermediate p_T (2-5 GeV/c).
- **Called "Baryon anomaly at RHIC".**
- **Quark recombination models** reproduce the data qualitatively.

p/π ratios in Au+Au 200 GeV

More (anti) baryons than pions at moderate p_T (2-5 GeV/c).
Does not look like vacuum jet fragmentation.

PHENIX: PRL 91, 172301 (2003), PRC 69, 034909 (2004)



Central

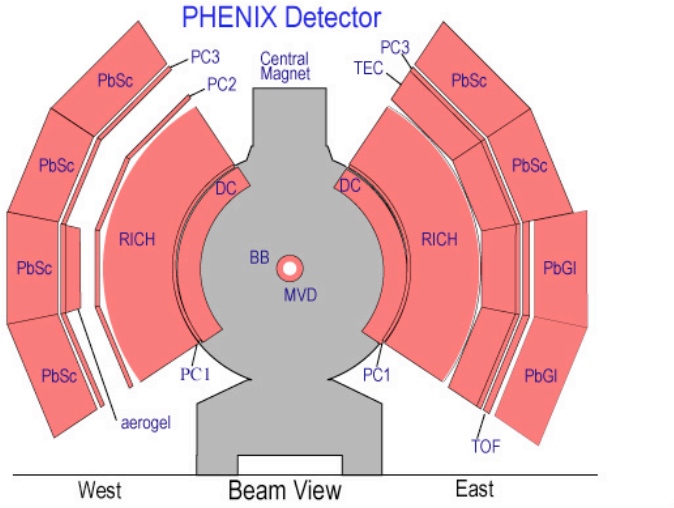
Peripheral

Where is the onset of the baryon anomaly at RHIC?

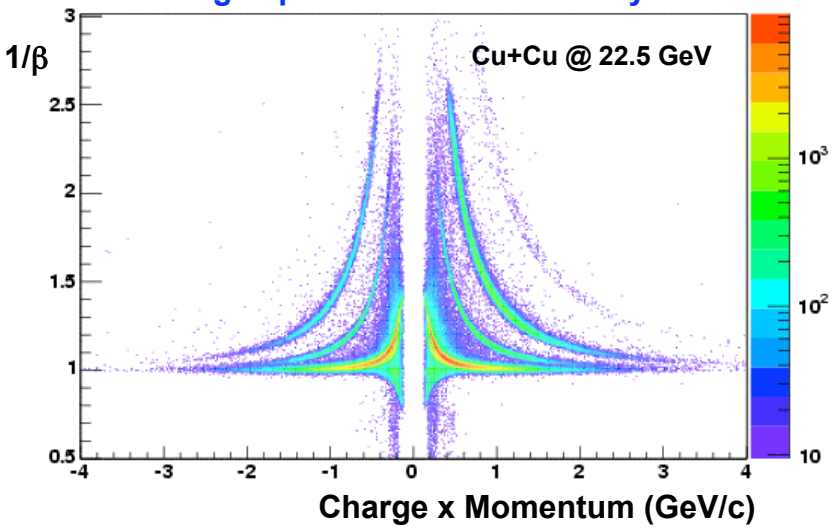
→New Cu+Cu data at lower $\sqrt{s_{NN}}$ may give an answer...

Data Analysis

- **Data set:**
  - RHIC Run-5 (2005), measured by the PHENIX experiment.
    - **Cu+Cu at 22.5 GeV.**
    - **Cu+Cu at 62.4 GeV.**
- **Detectors:**
  - Drift Chamber, PC1, BBC and TOF for PID charged analysis.
- **Centrality:**
  - Subdivided minimum bias triggered events, based on BBC charge (62 GeV), or the number of PC1 hit (22 GeV).
- **Corrections:**
  - Geometrical acceptance, in flight decay.
  - NOTE: No weak decay feed-down correction applied.



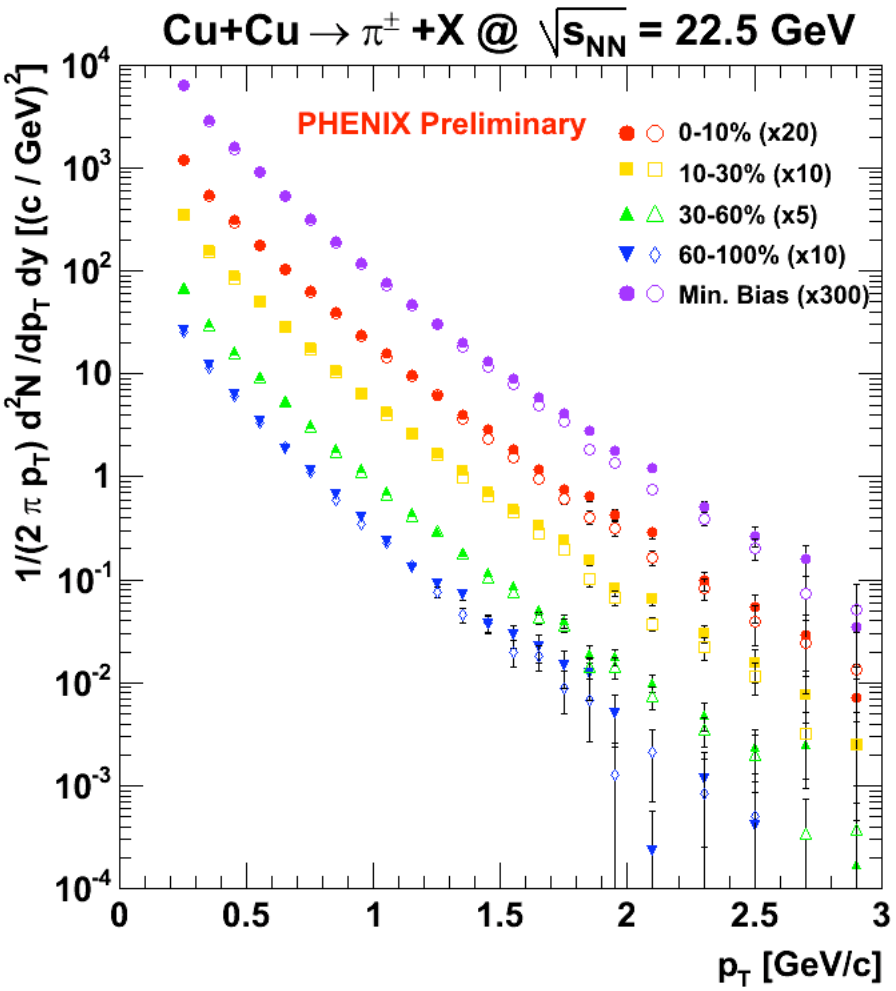
Charged particle identification by TOF

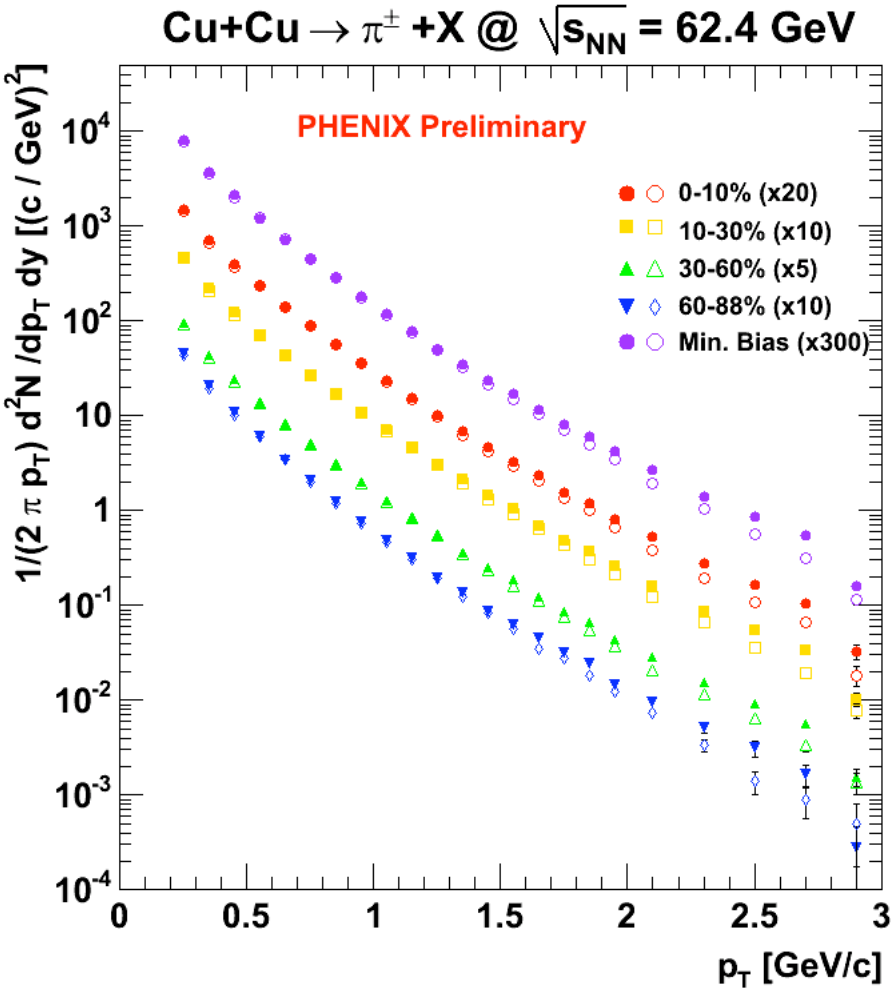


Results

1. p_T spectra in Cu+Cu at $\sqrt{s_{NN}}$ = 22.5 and 62.4 GeV.
2. p/π^+ and $\bar{p}/\pi^-$ ratios vs. p_T.
3. Nuclear modification factor: R_{AA}.

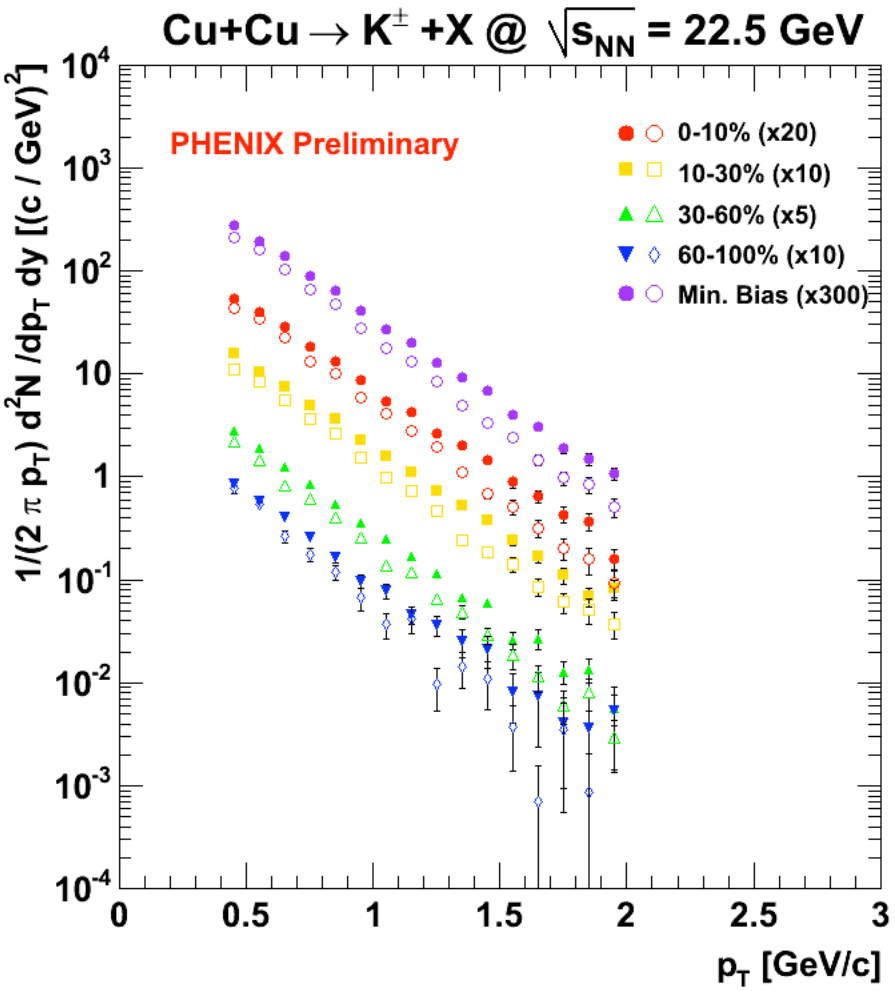
p_T spectra for pions

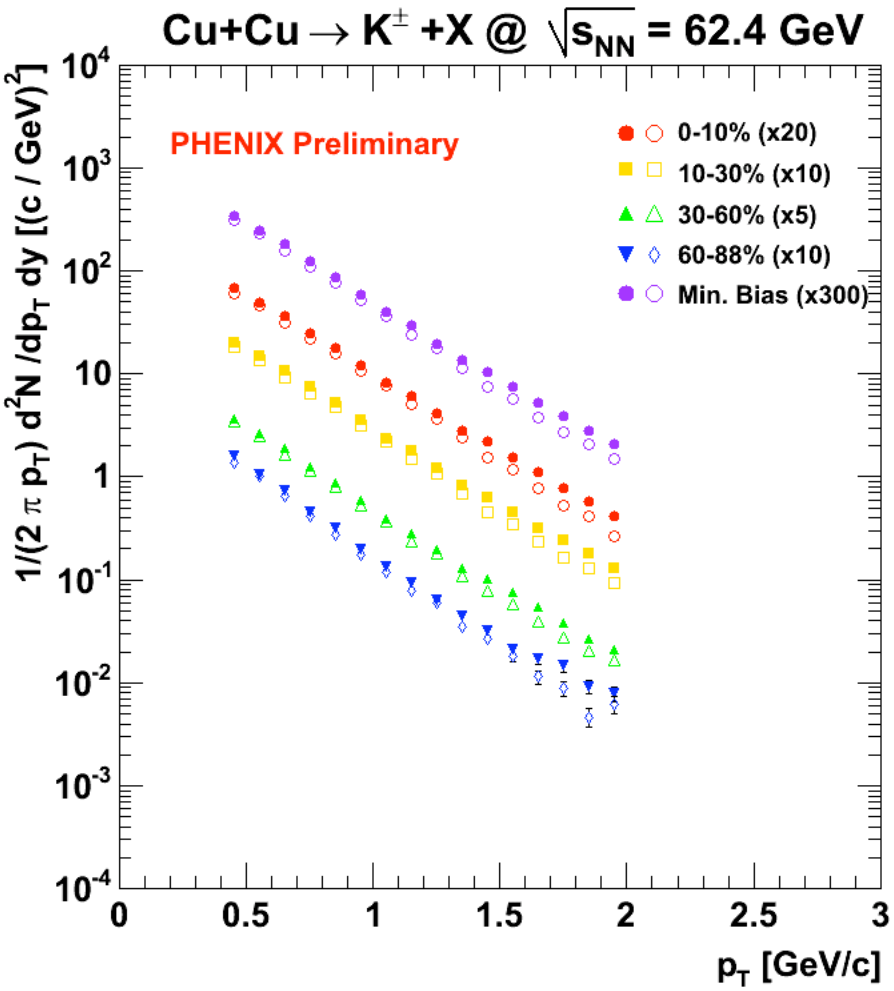




Filled symbols : π^+
Open symbols : π^-

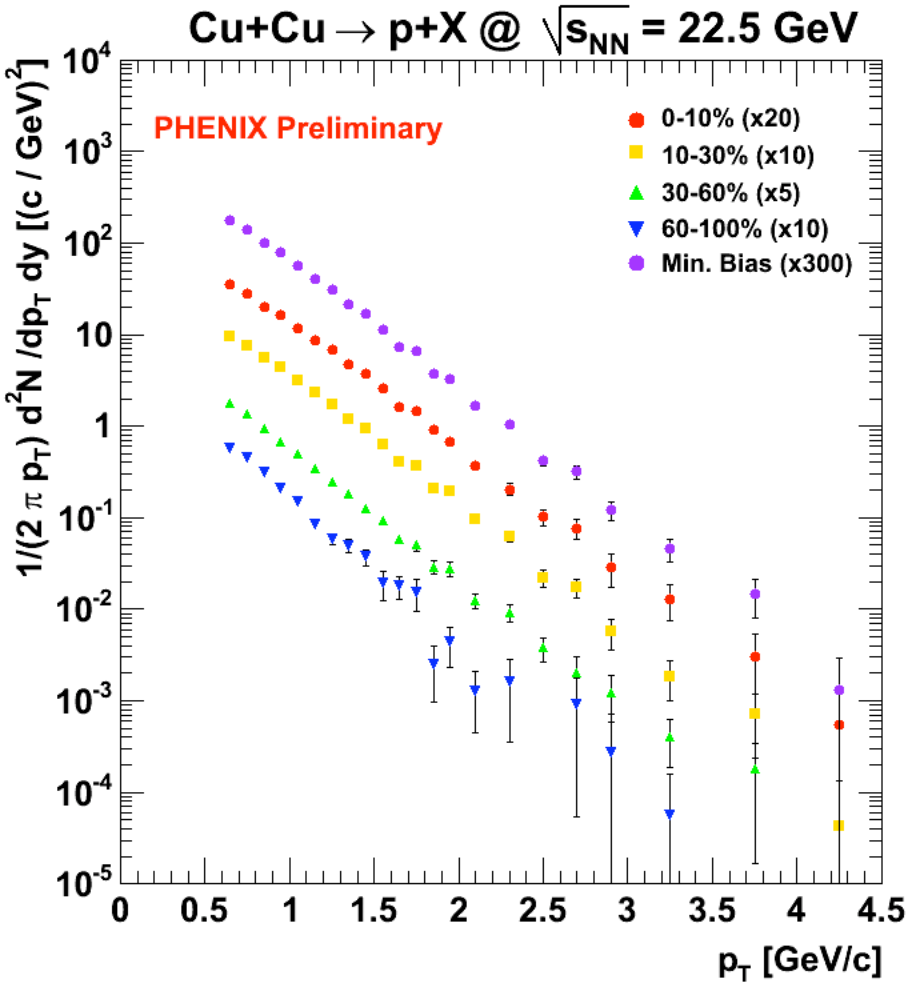
p_T spectra for kaons

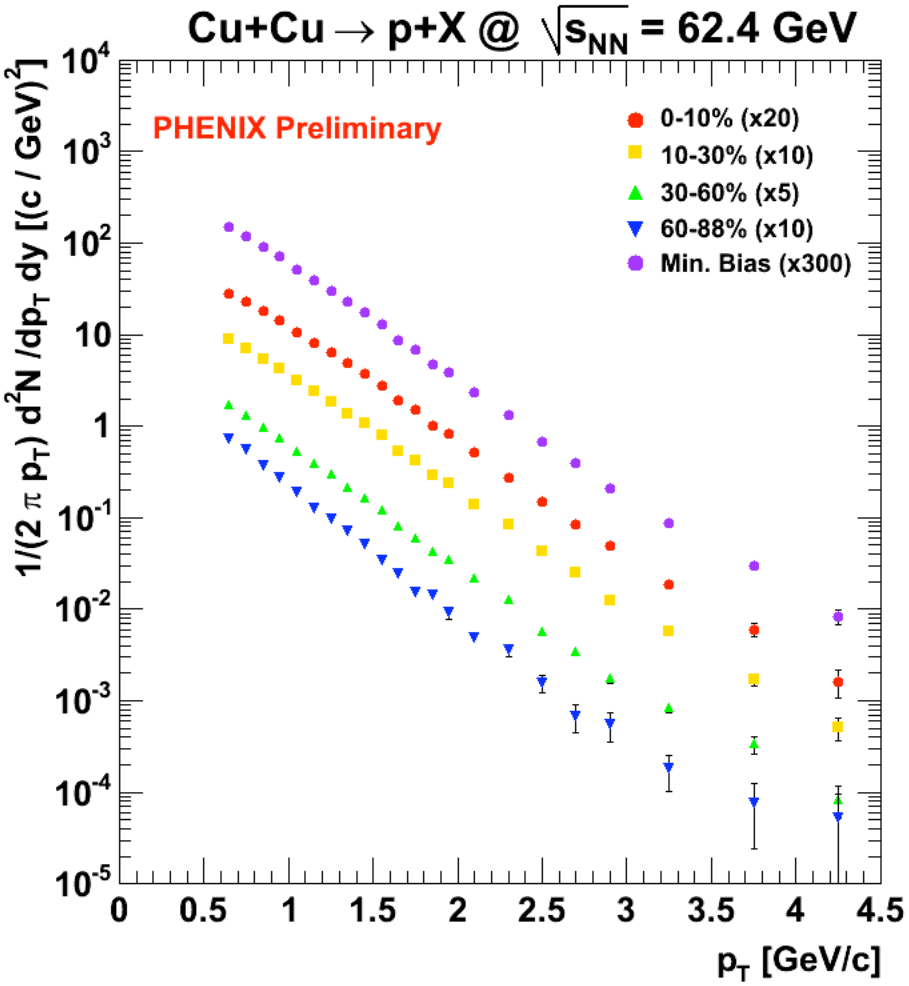




Filled symbols : K^+
Open symbols : K^-

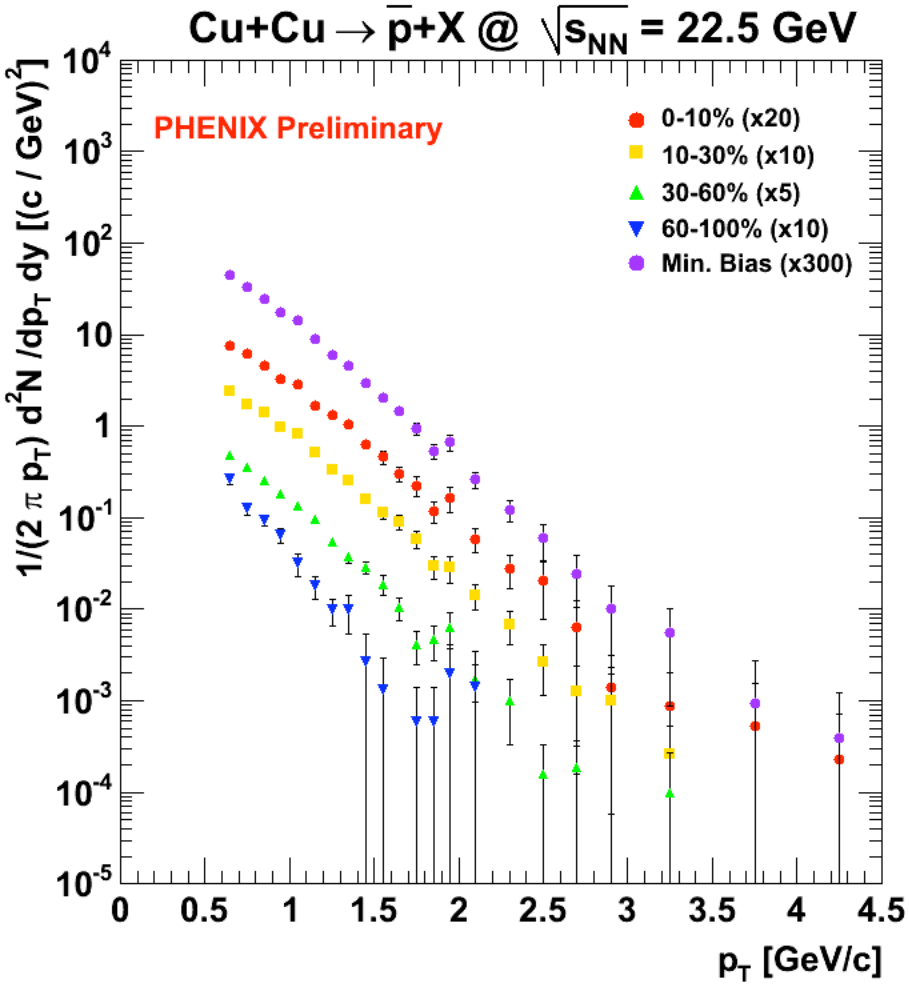
p_T spectra for protons

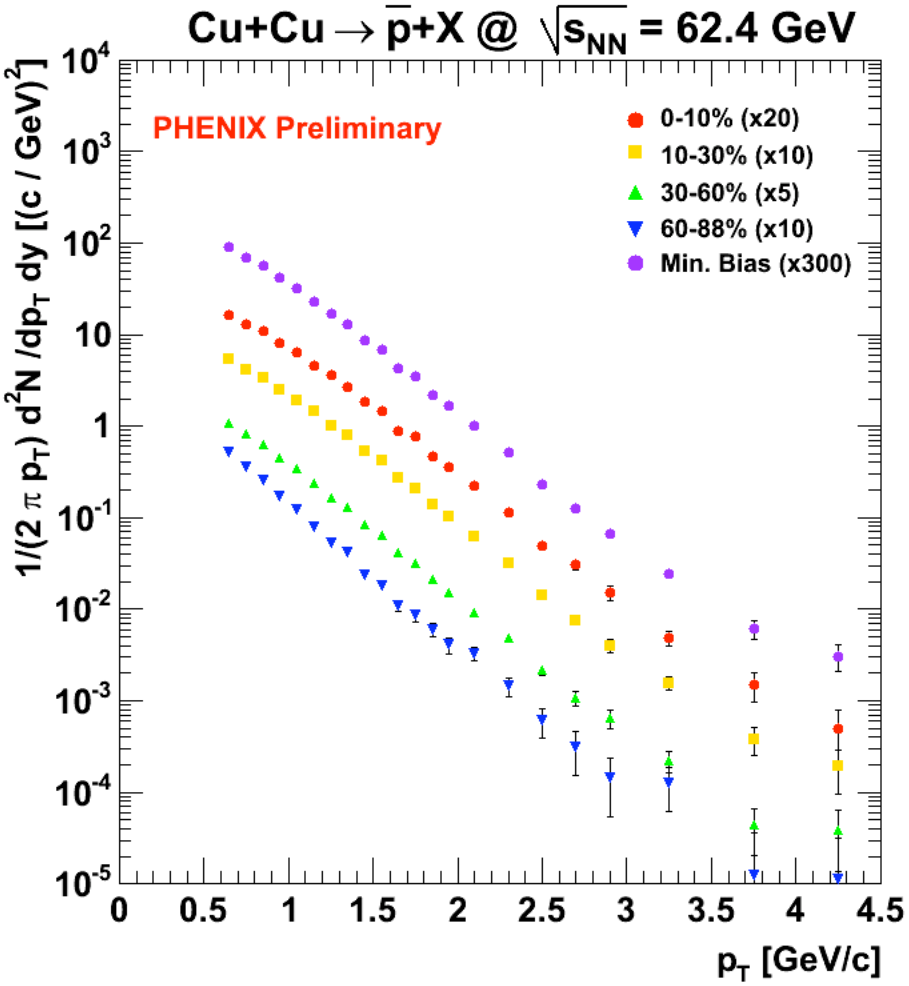




*** No weak decay feed-down correction applied**

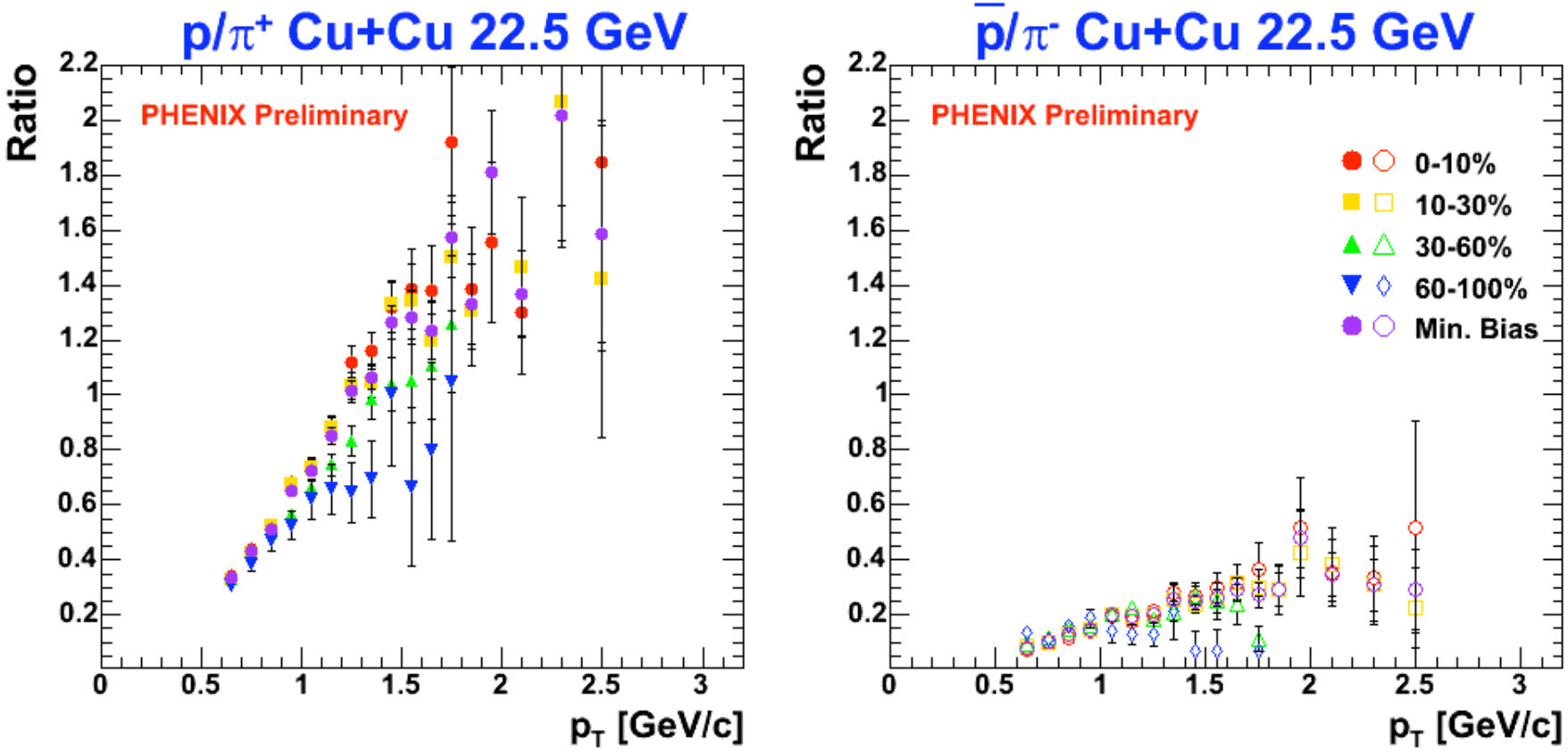
p_T spectra for antiprotons





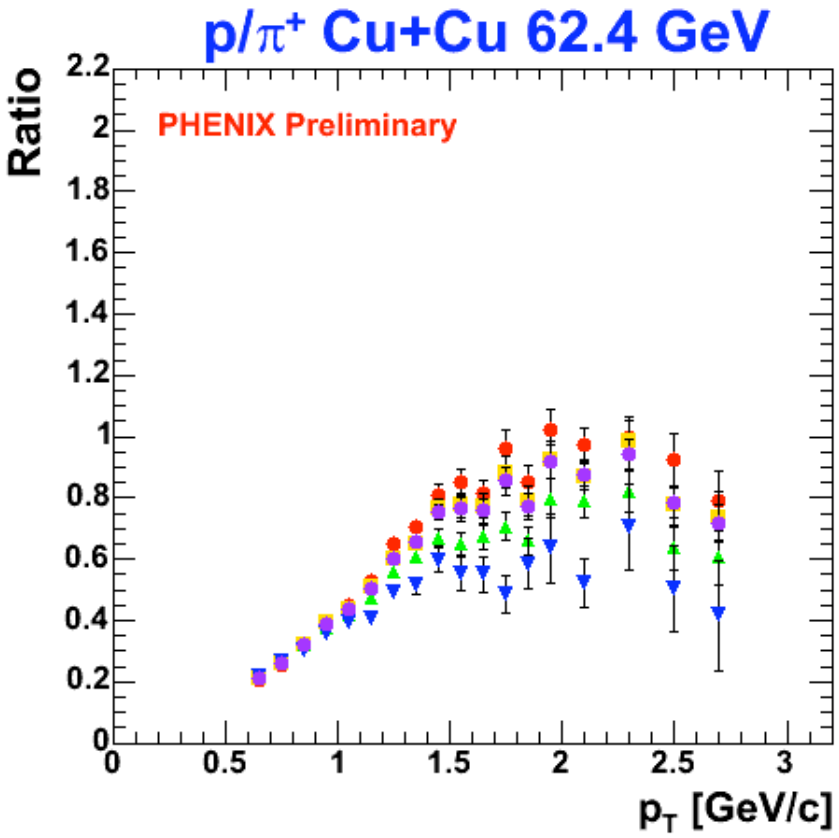
*** No weak decay feed-down correction applied**

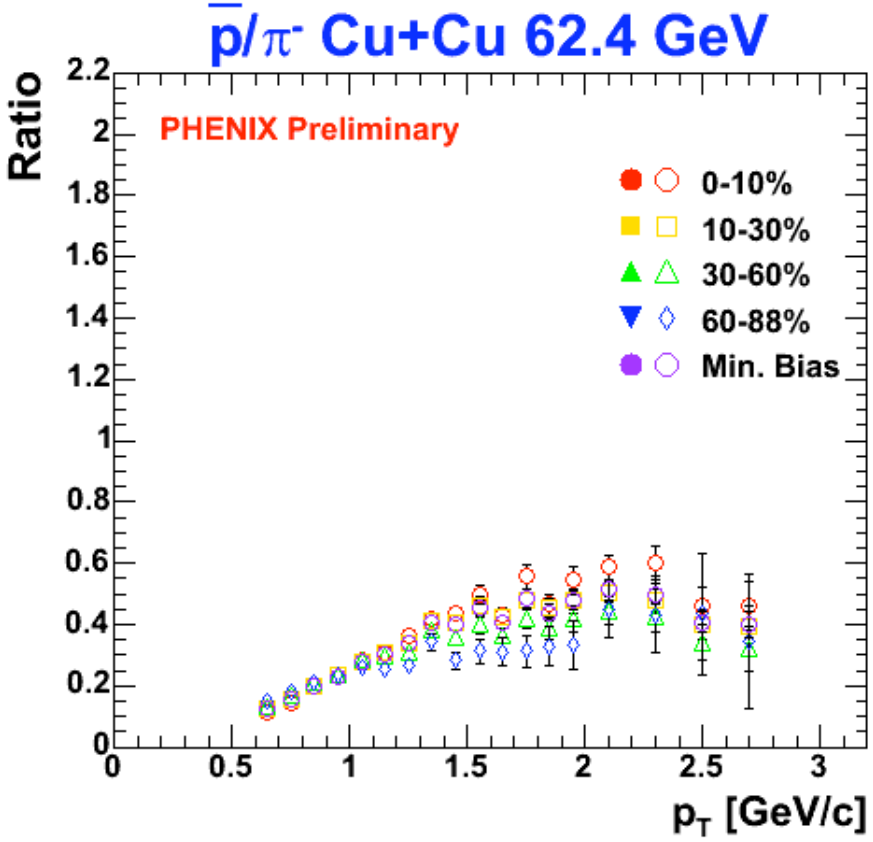
p/π in Cu+Cu 22.5 GeV



- **Larger p/π⁺ ratios** than those in Au+Au 200 GeV (0.5 @ p_T = 1.5 GeV).
  - **Affected by the participant protons (not produced protons) at lower $\sqrt{s_{NN}}$.**
- **$\bar{p}/\pi^-$ ratios are ~0.3-0.4 at p_T = 2 GeV/c,** which is close to the fragmentation expectations in p+p.
  - **Almost no centrality dependence.**

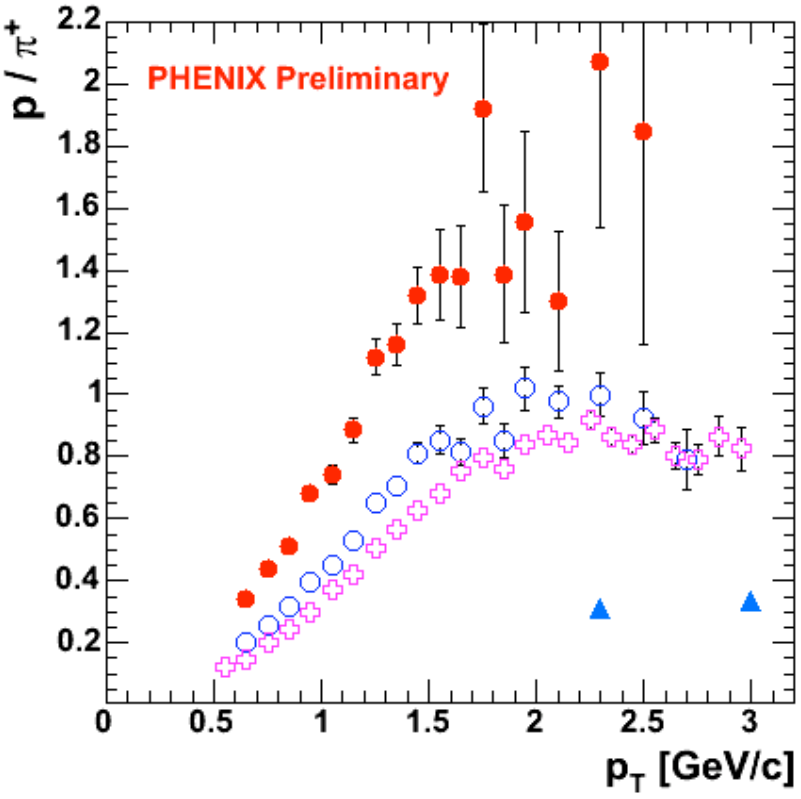
p/π in Cu+Cu 62.4 GeV

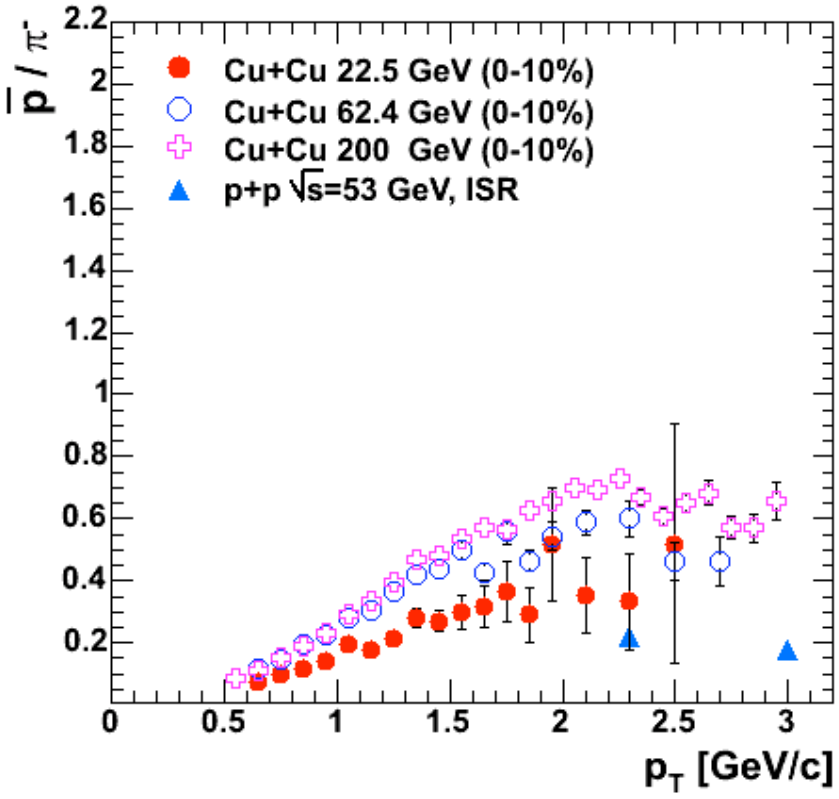




- **p/π^+ ratios are reduced**, compared to those in Cu+Cu 22 GeV.
- **$\bar{p}/\pi^-$ ratio in most central collisions reaches R=~0.6 at p_T = 2 GeV/c**.
  - Centrality dependence is seen.
  - Peripheral pbar/π^-: consistent with p+p value.

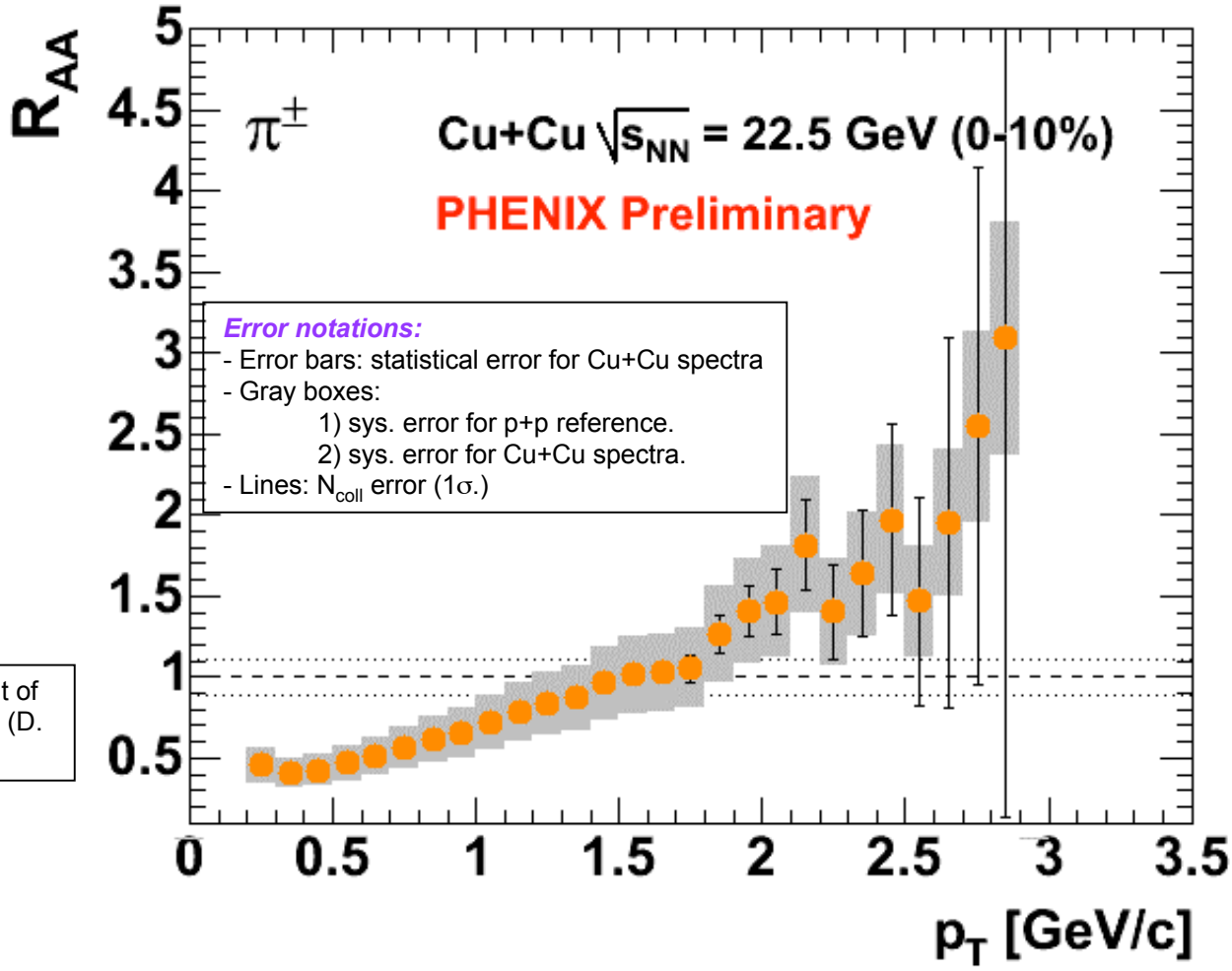
Beam energy dep. in Cu+Cu





- **p/π⁺ ratio** : decreasing as a function of $\sqrt{s_{NN}}$.
- **$\bar{p}$/π⁻ ratio** : increasing as a function $\sqrt{s_{NN}}$.
  - Cu+Cu 22.5 GeV central data reaches the p+p values.
  - Cu+Cu 62.4 GeV central data is higher than that in 22.5 GeV.

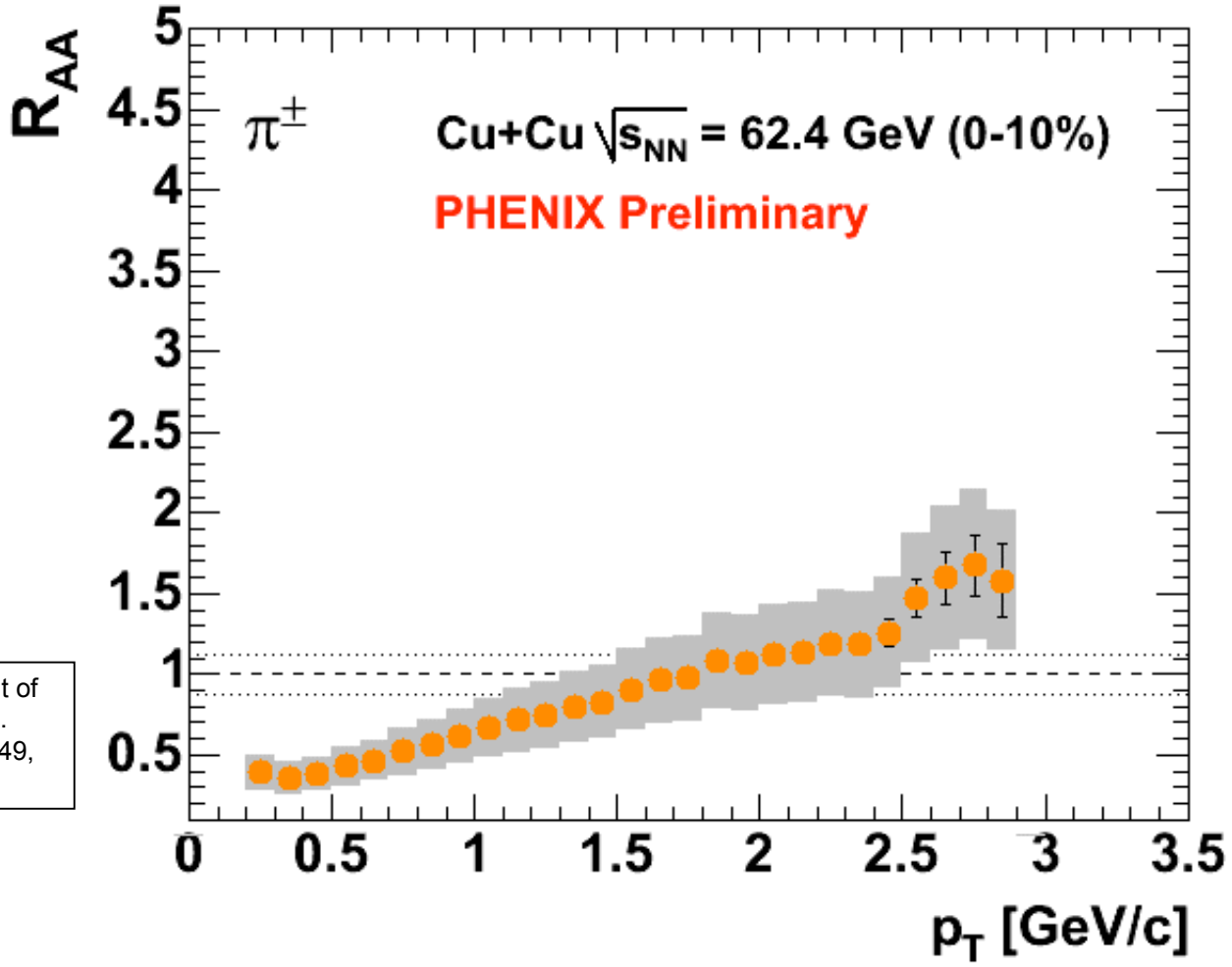
R_{AA} for pions (22 GeV)



• p+p reference: global fit of pion data at √s ~23 GeV (D. d'Enterria).

• p+p reference: global fit of pion data at √s ~22 GeV in p+p.
• R_{AA} is ~1.5 at p_T = 2 GeV/c, **no suppression**.

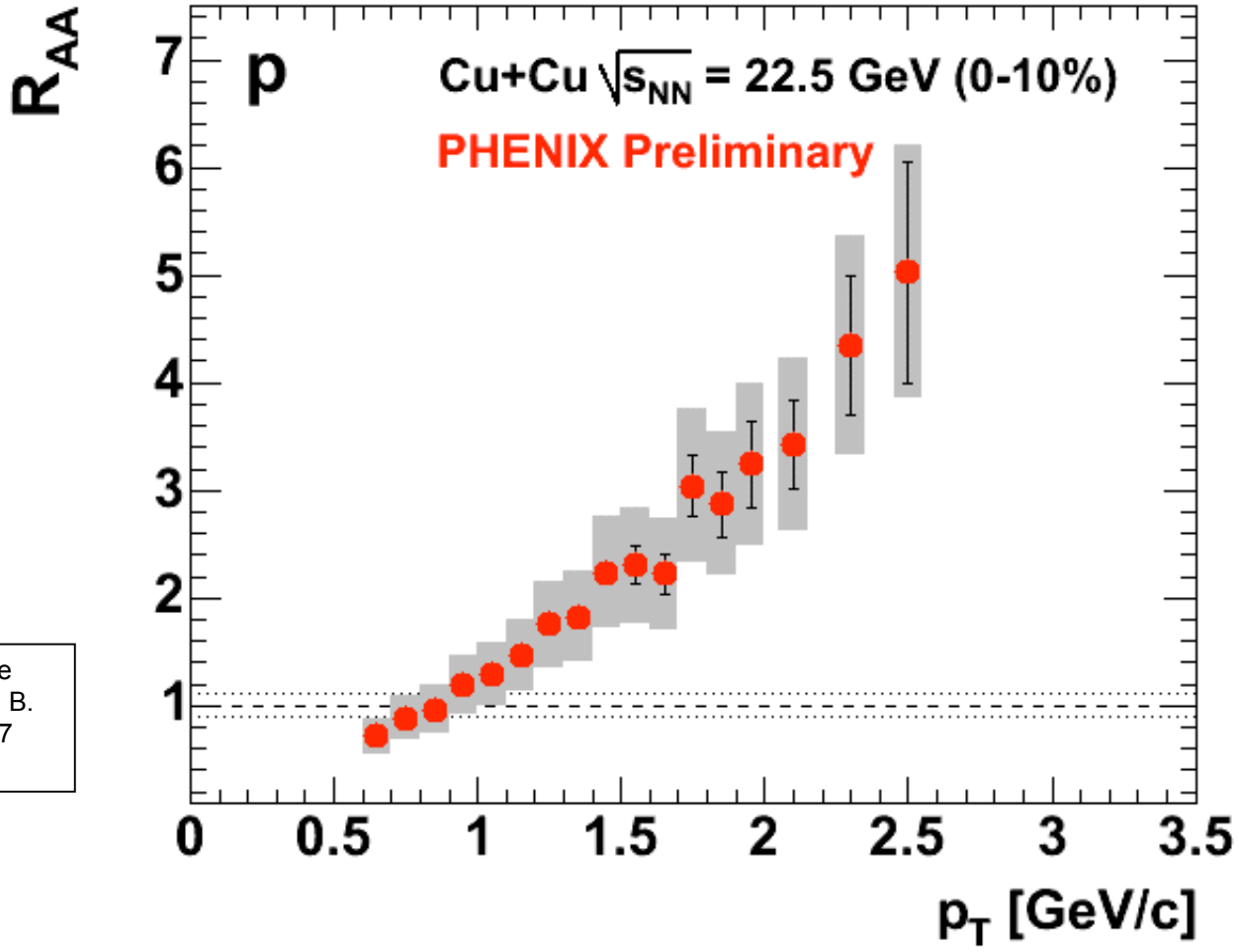
R_{AA} for pions (62 GeV)



- p+p reference: global fit of pion data at √s ~62 GeV.
- nucl-ex/ nucl-ex/0411049, D. d'Enterria.

- Similar, might be slightly smaller than that in 22 GeV.

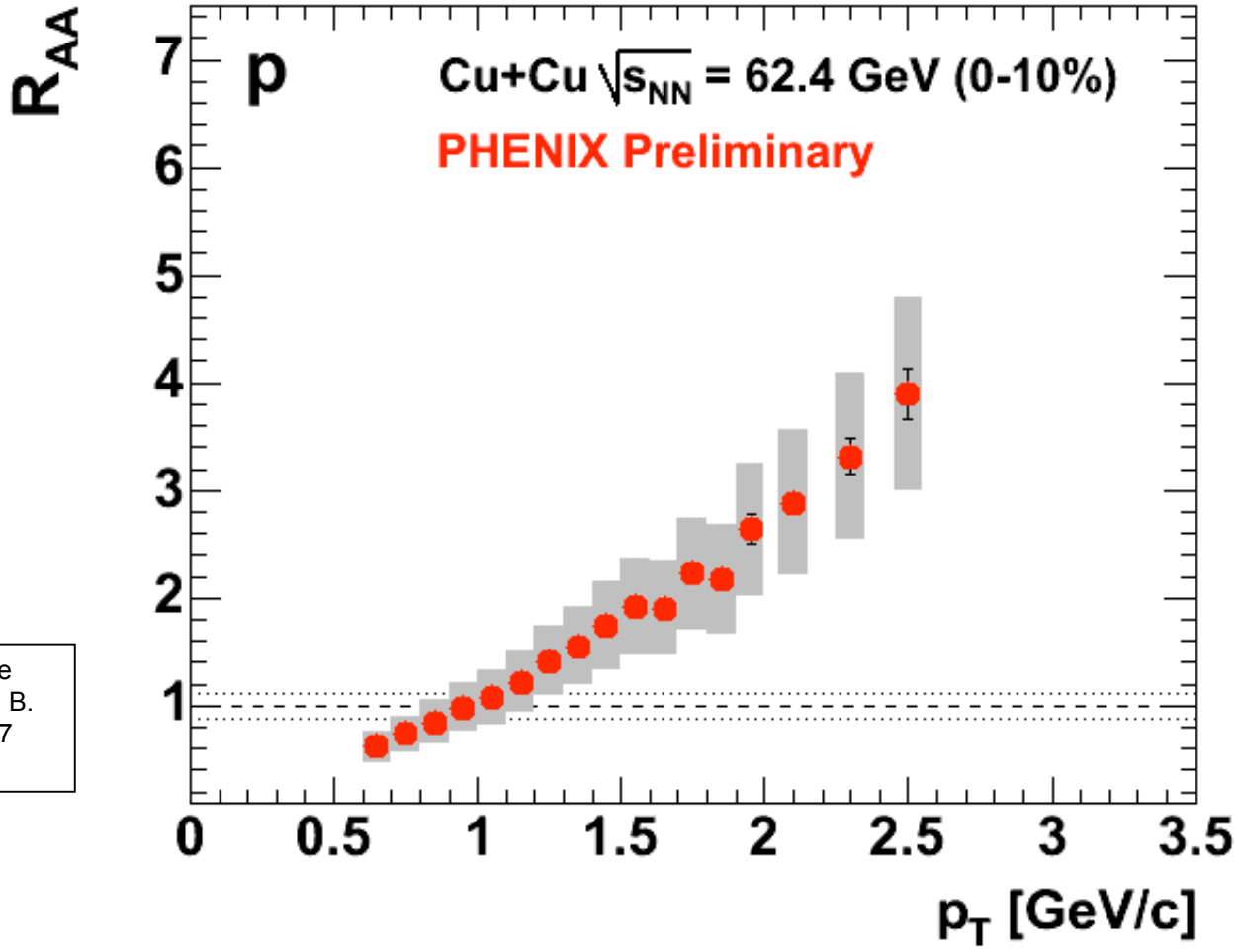
R_{AA} for proton (22 GeV)



• p+p reference: fitted the ISR data in p+p 23 GeV, B. Alper et al, NPB 100, 237 (1975).

• **Larger than pions significantly**, which suggests the large contributions of participant protons.

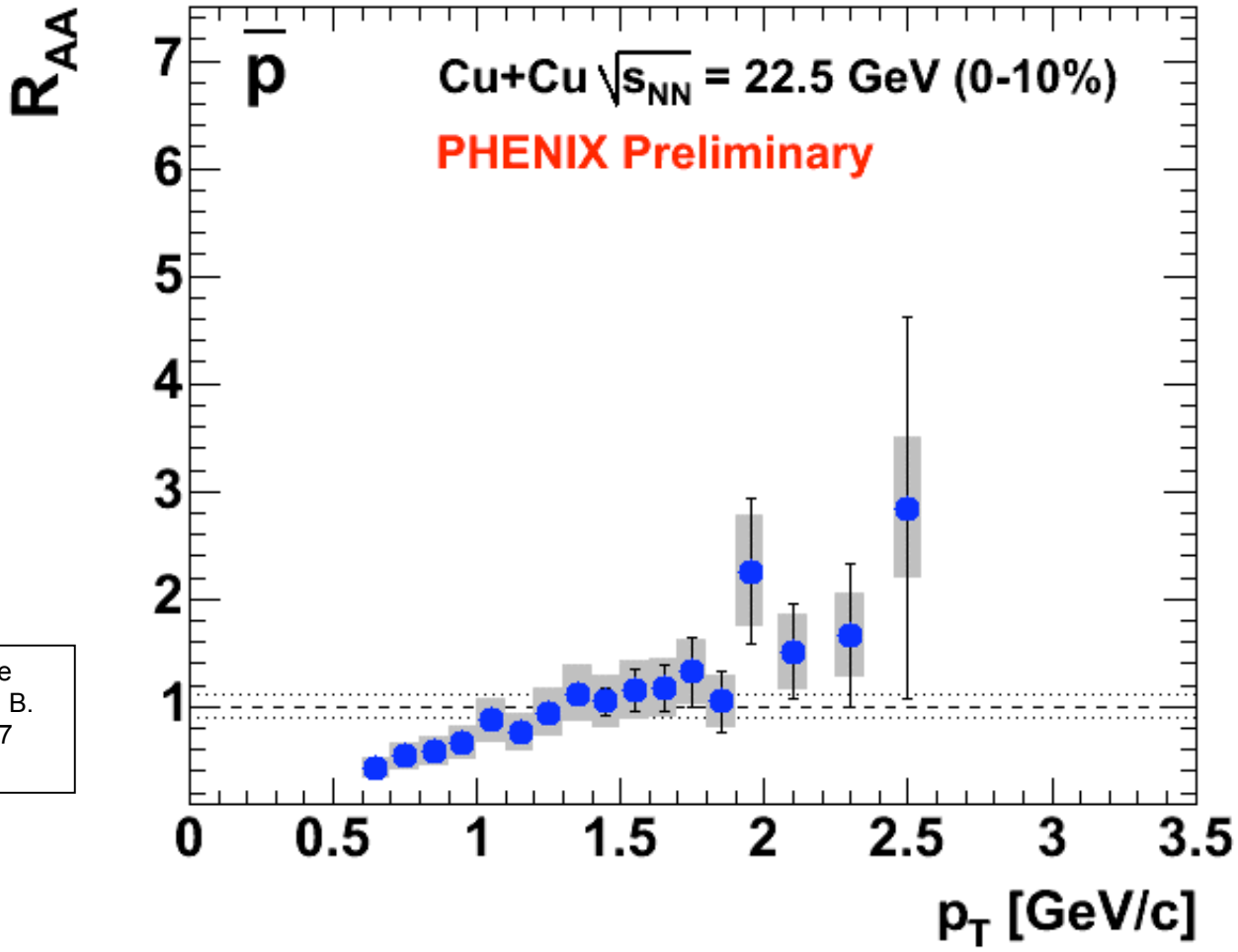
R_{AA} for proton (62 GeV)



• p+p reference: fitted the ISR data in p+p 63 GeV, B. Alper et al, NPB 100, 237 (1975).

• Similar as in 22.5 GeV, but slightly smaller value.

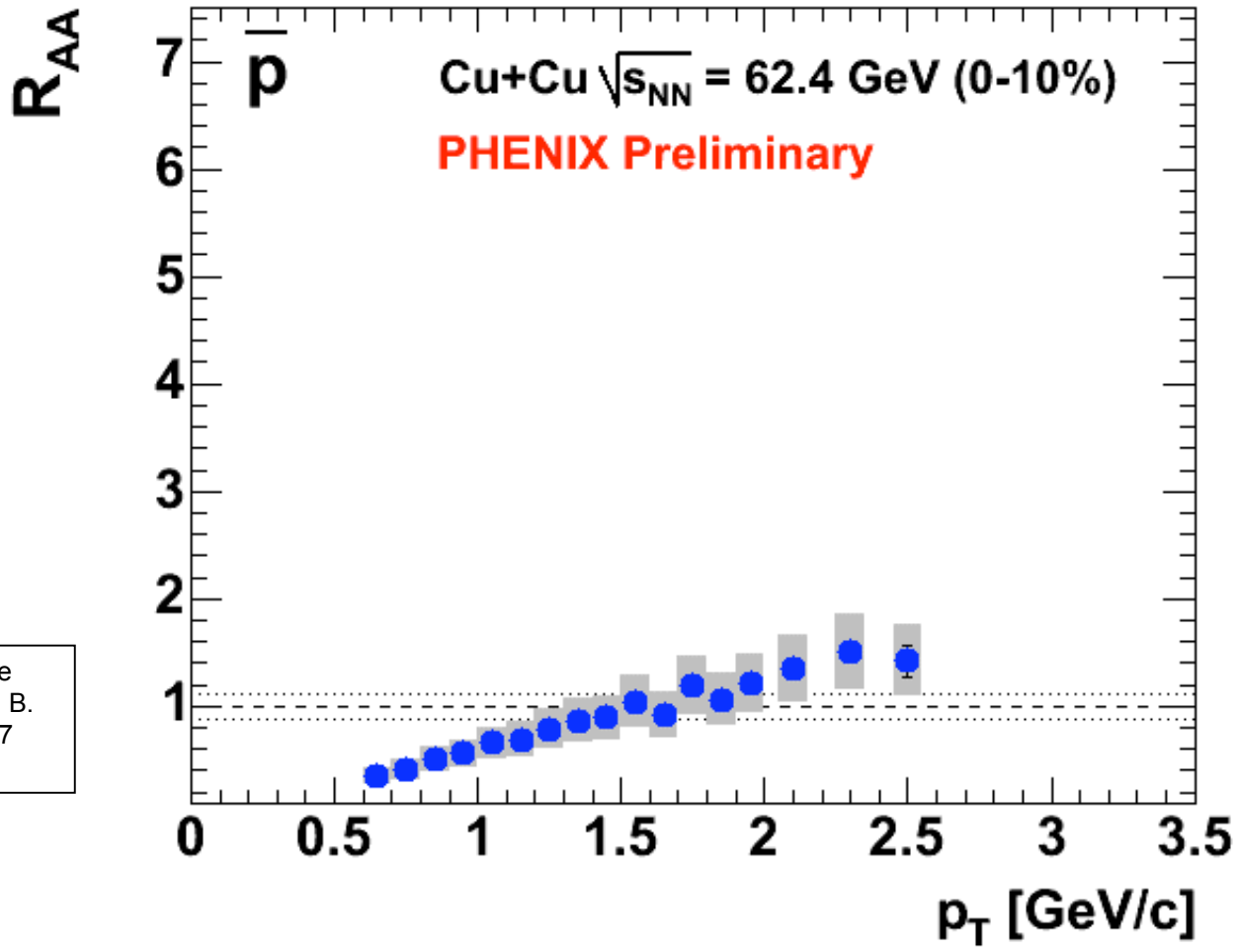
R_{AA} for antiproton (22 GeV)



• p+p reference: fitted the ISR data in p+p 23 GeV, B. Alper et al, NPB 100, 237 (1975).

- **Different p_T dependence from protons.**
- **R_{AA} ~ 1 (similar to pions' R_{AA}),** binary collision scaling worked?

R_{AA} for antiproton (62 GeV)



• p+p reference: fitted the ISR data in p+p 63 GeV, B. Alper et al, NPB 100, 237 (1975).

• Similar to that for 22 GeV (and also pion's R_{AA}).

Summary

Measured p_T spectra for $\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$ in Cu+Cu at $\sqrt{s_{NN}}$ = 22.5 and 62.4 GeV in PHENIX.

- **p/π^+ ratio** : **decreasing** as a function of $\sqrt{s_{NN}}$ in Cu+Cu.
  - Suggests a significant contribution of paticipant protons (not by the produced protons) in lower energies Cu+Cu.
- **$\bar{p}/\pi^-$ ratio** : **increasing** as a function $\sqrt{s_{NN}}$ in Cu+Cu.
  - Cu+Cu 22.5 GeV shows that there is (almost) **no centrality dependence**, and central Cu+Cu already reaches to the p+p values.
  - Cu+Cu 62.4 GeV central data is higher than that in 22.5 GeV, centrality dependence is seen.
- **R_{AA}** : depends on particle type.
  - **π : no suppression at both 22.5 and 62.4 GeV in Cu+Cu.**
  - **p: enhanced (mostly due to the participant nucleons).**
  - **$\bar{p}$: binary scaling, very similar to pion's R_{AA}.**
- ***New reference p+p data at 62.4 GeV will be taken in June 2006 (2 weeks).***

PHENIX

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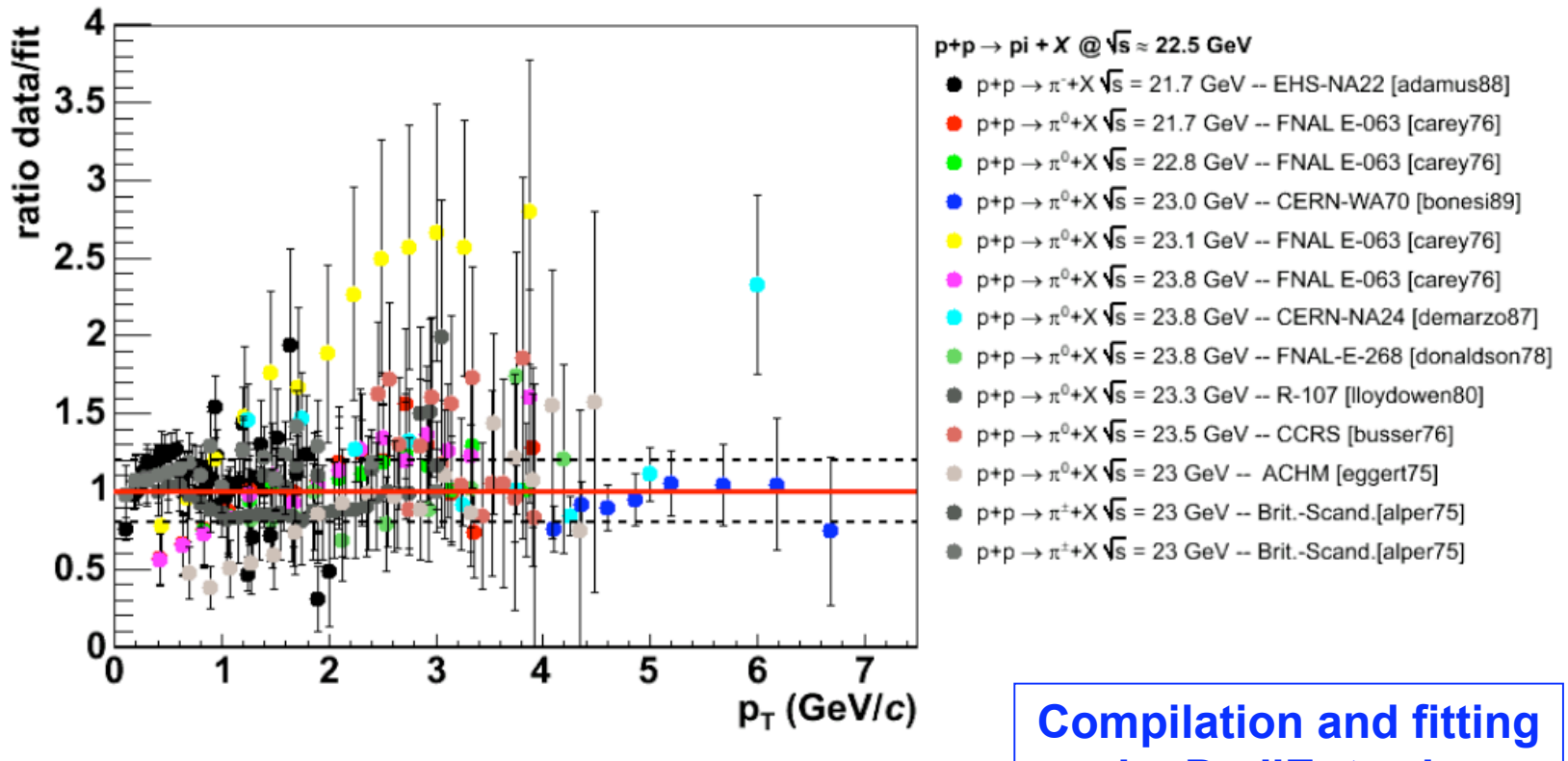
***as of March 2005**

Backup Slides

p+p fit at √s = 22.5 GeV (pions)



Compilation and fitting by D. d'Enterria

R_{AA} for π^0 in Cu+Cu 22.5 GeV

PbSc (0-10%)

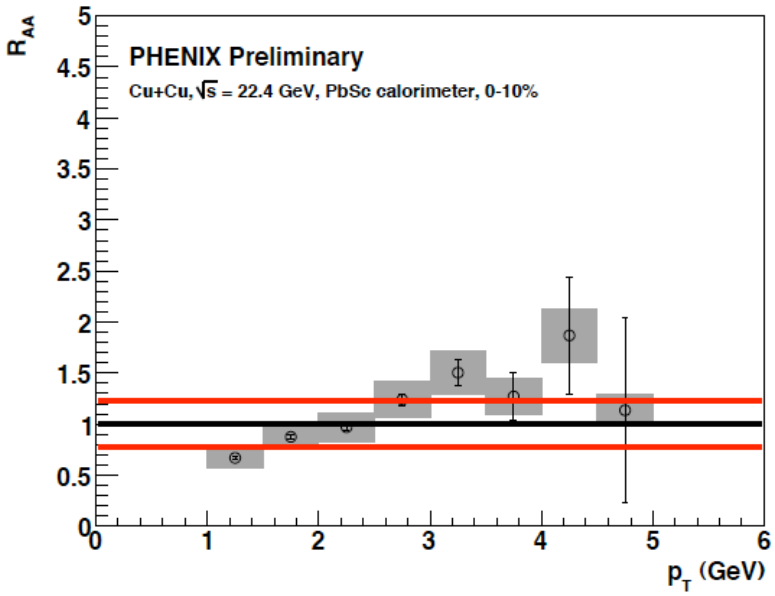


Figure 10: R_{AA} for the PbSc calorimeter and the Centrality Class 0-10%

PbGl (0-10%)

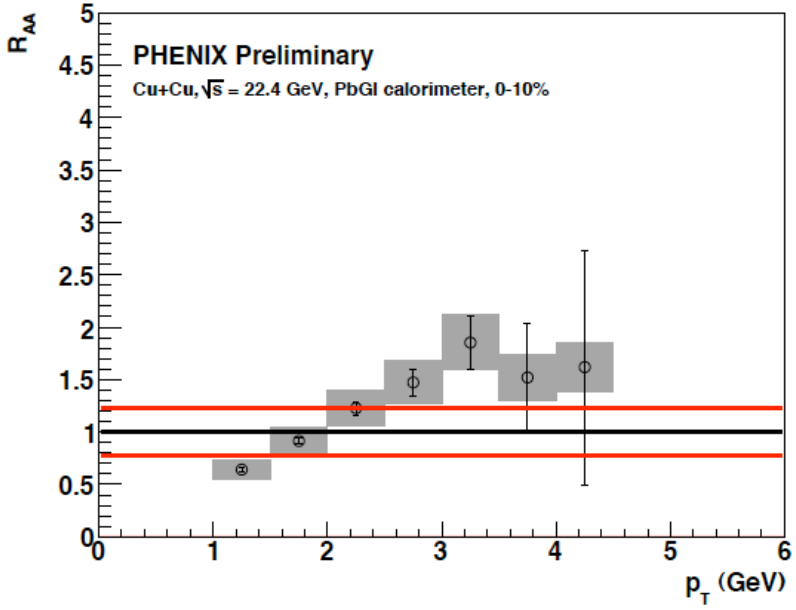


Figure 14: R_{AA} for the PbGl calorimeter and the Centrality Class 0-10%

SPS and AGS

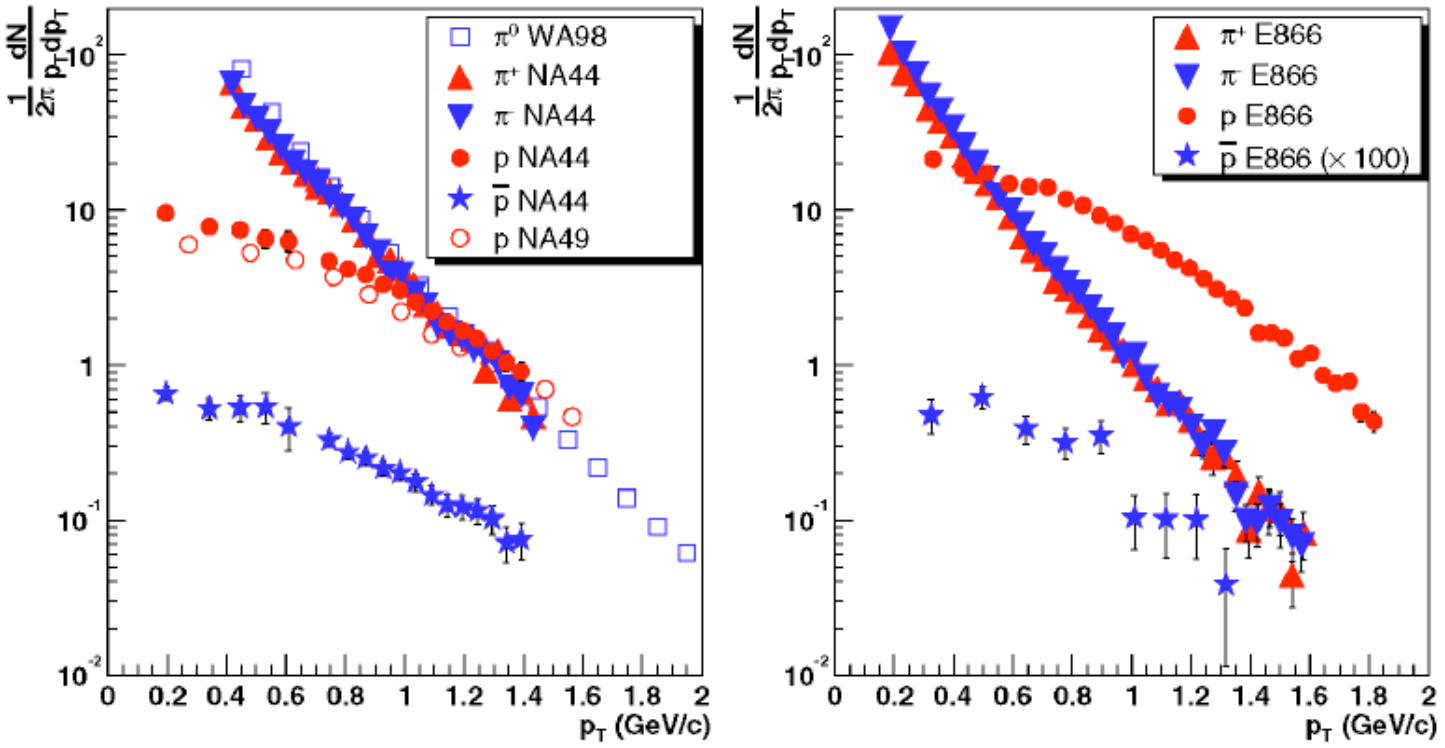


Fig. 47. Invariant yields of p, $\bar{p}$, and π as function of p_T in central Pb + Pb collisions at the SPS ($\sqrt{s_{NN}} = 17$ GeV) (left panel) and in central Au + Au collisions at the AGS ($\sqrt{s_{NN}} = 5$ GeV) (right panel). The $\bar{p}$ spectrum from the AGS is scaled up by a factor 100. All data are at mid-rapidity ($y - y_{cm} \approx 0$) and are from W98 [163], NA44 [226], NA49 [227], and E866 [228,229].

Nucl. Phys. A 757, 184 (2005), PHENIX, nucl-ex/0410003

NA49 data

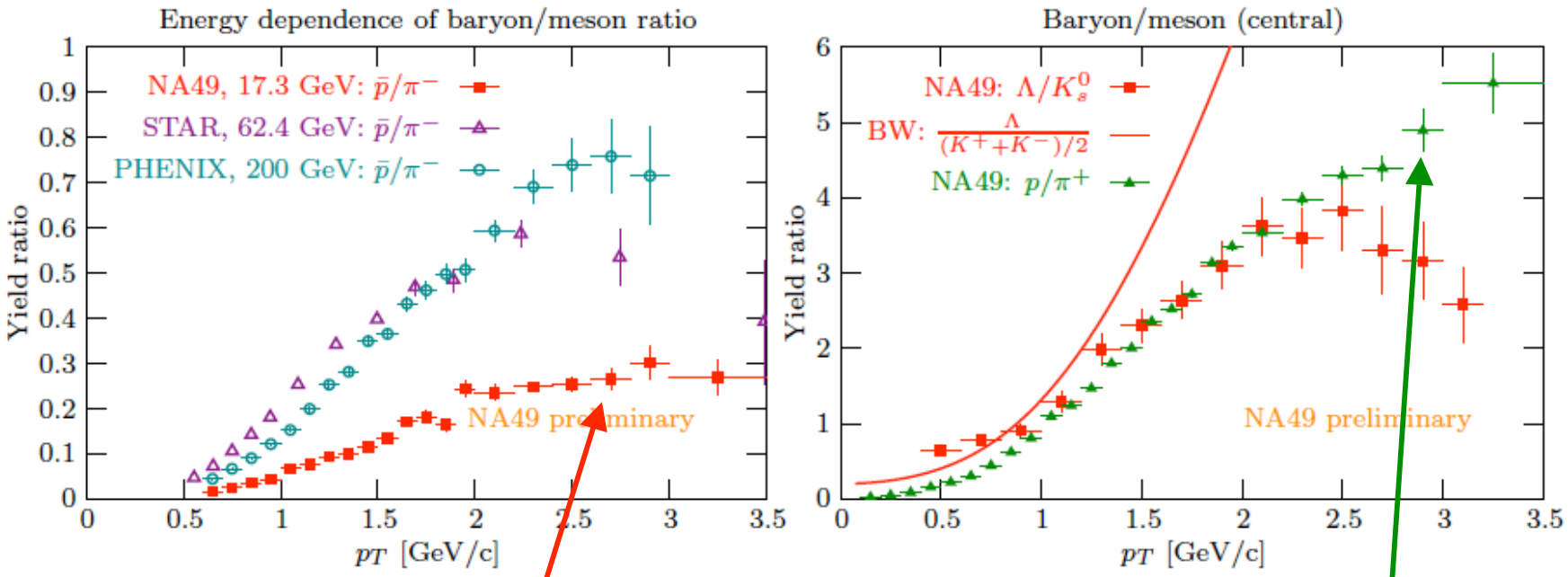


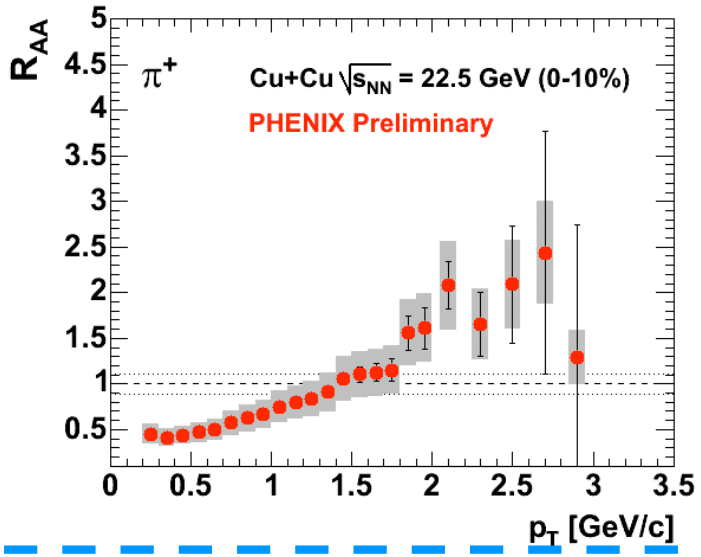
Figure 2. The energy dependence of proton/pion ratios (left panel), and a comparison of the baryon/meson ratios at top SPS energy to a Blast-Wave parametrization (right panel).

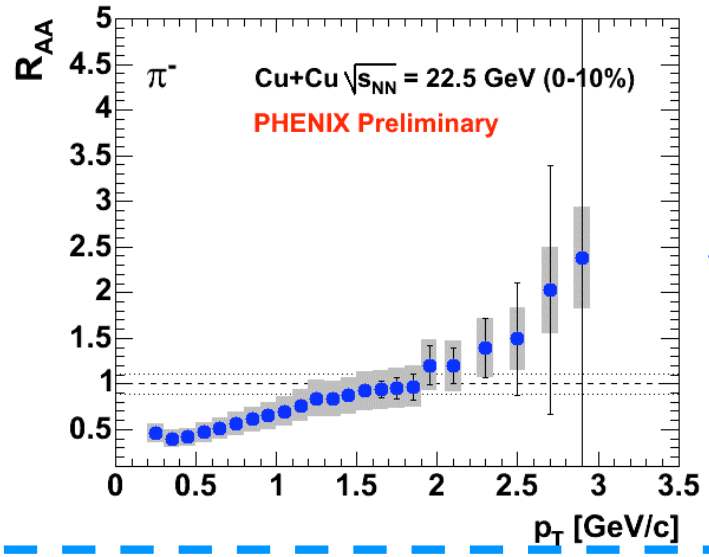
$\bar{p}/\pi^-$ (NA49)

p/π^+ (NA49)

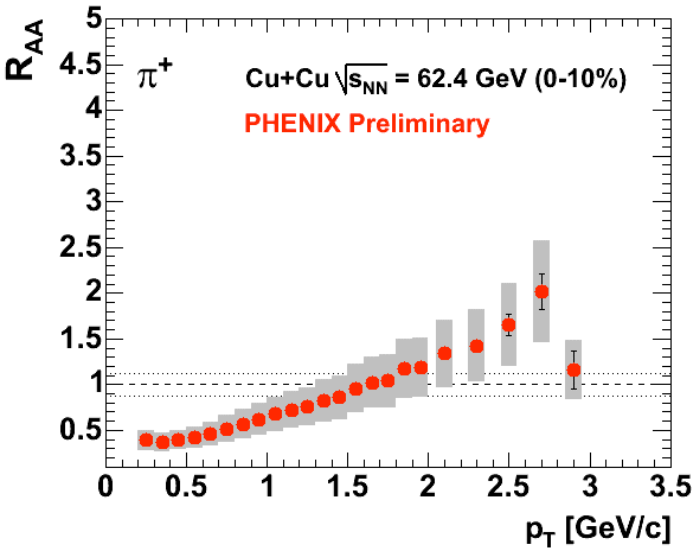
NA49 collaboration, nucl-ex/0510054

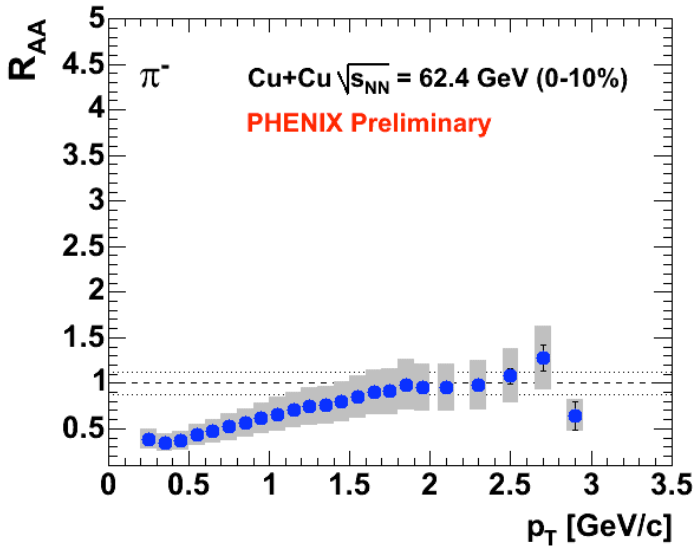
R_{AA} for pions





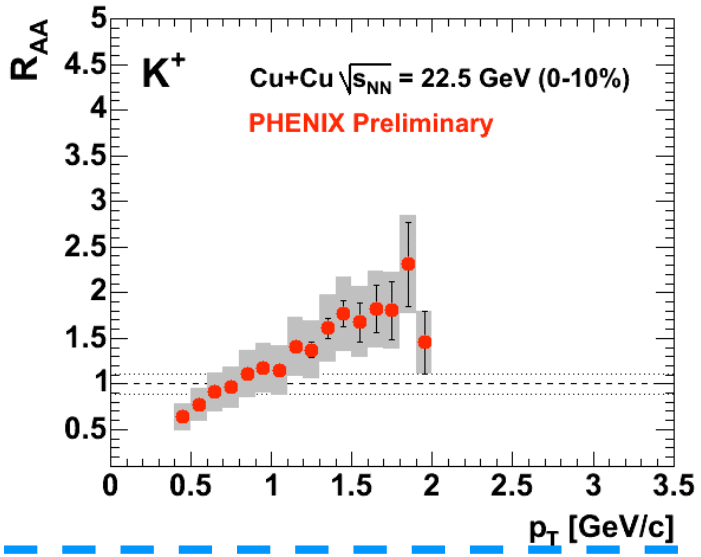
22.5 GeV

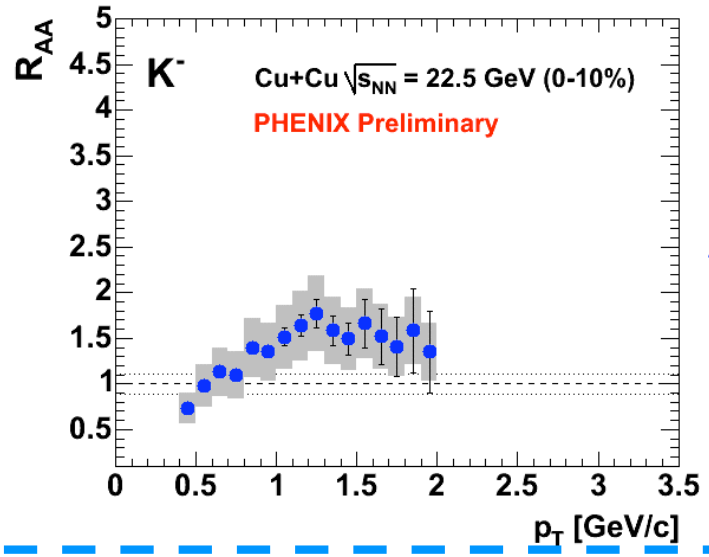




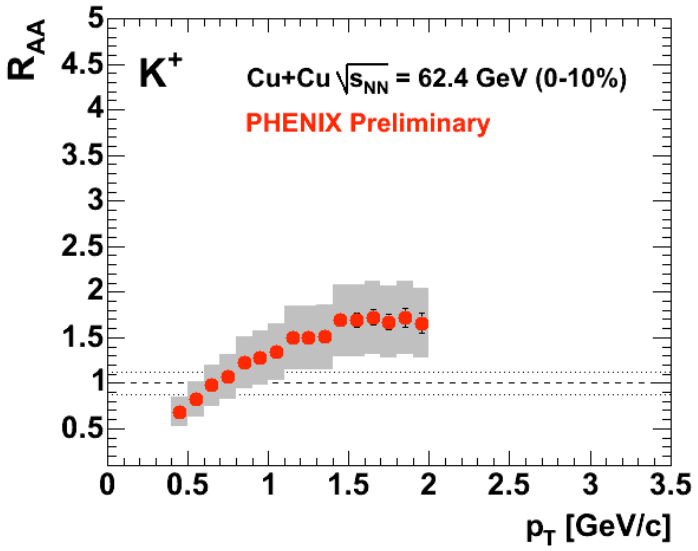
62.4 GeV

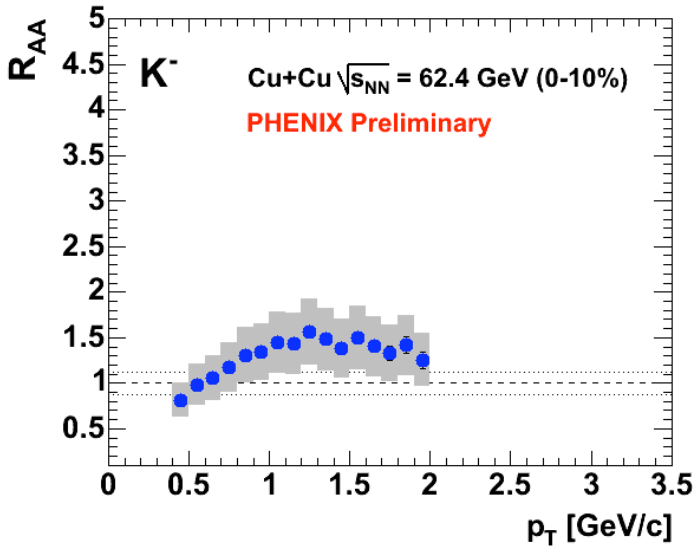
R_{AA} for kaons





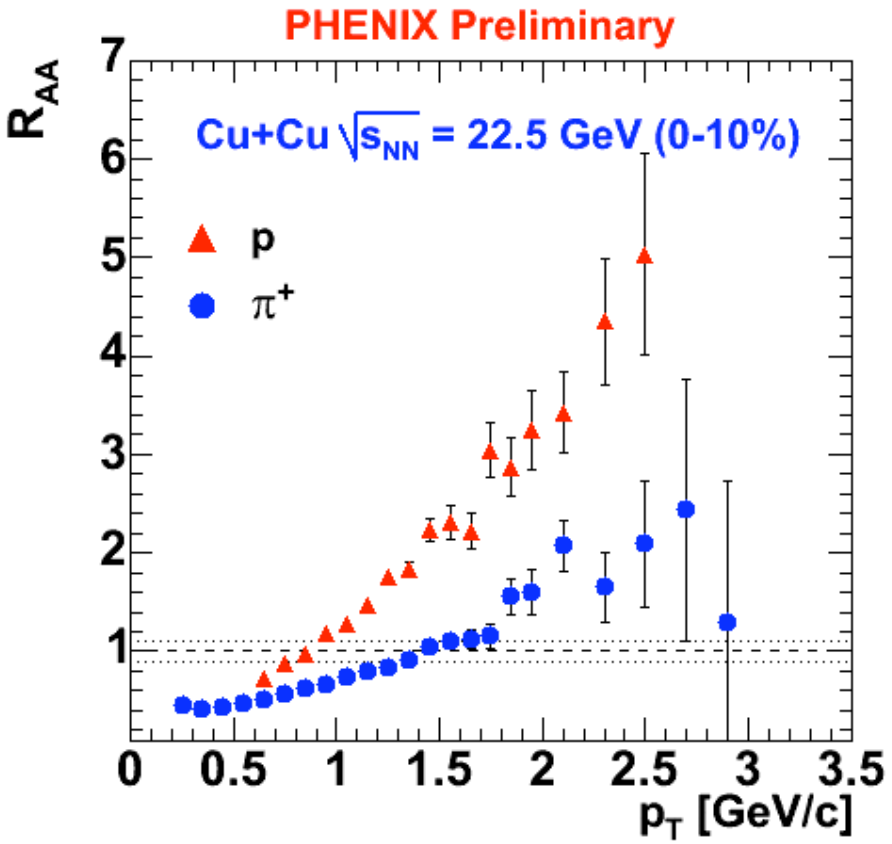
22.5 GeV

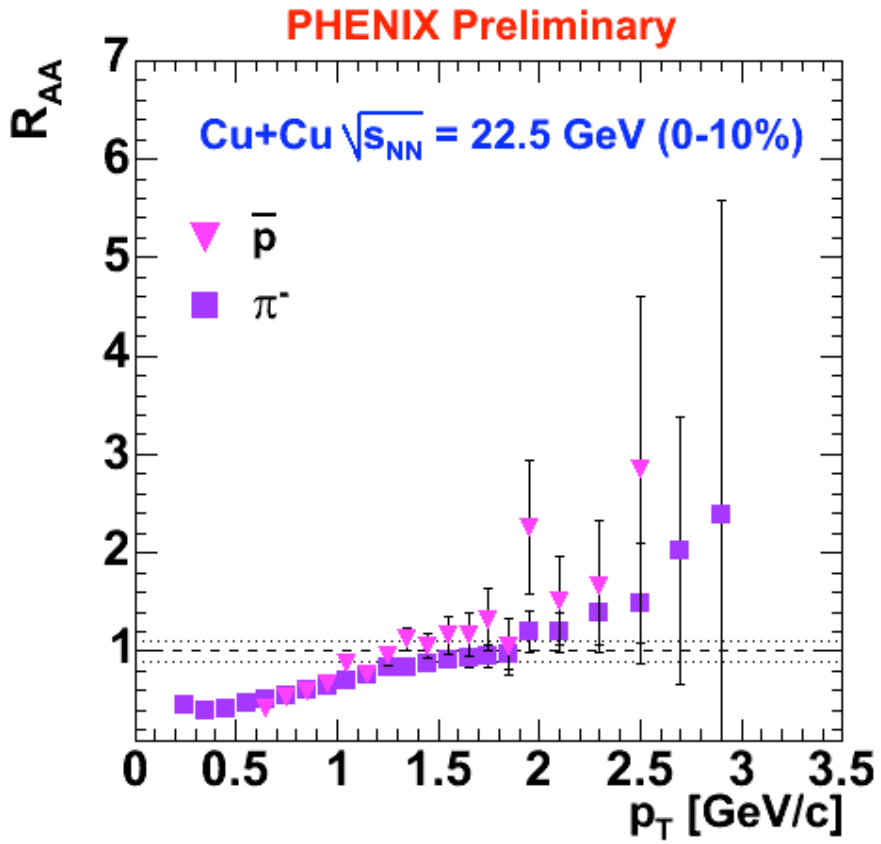




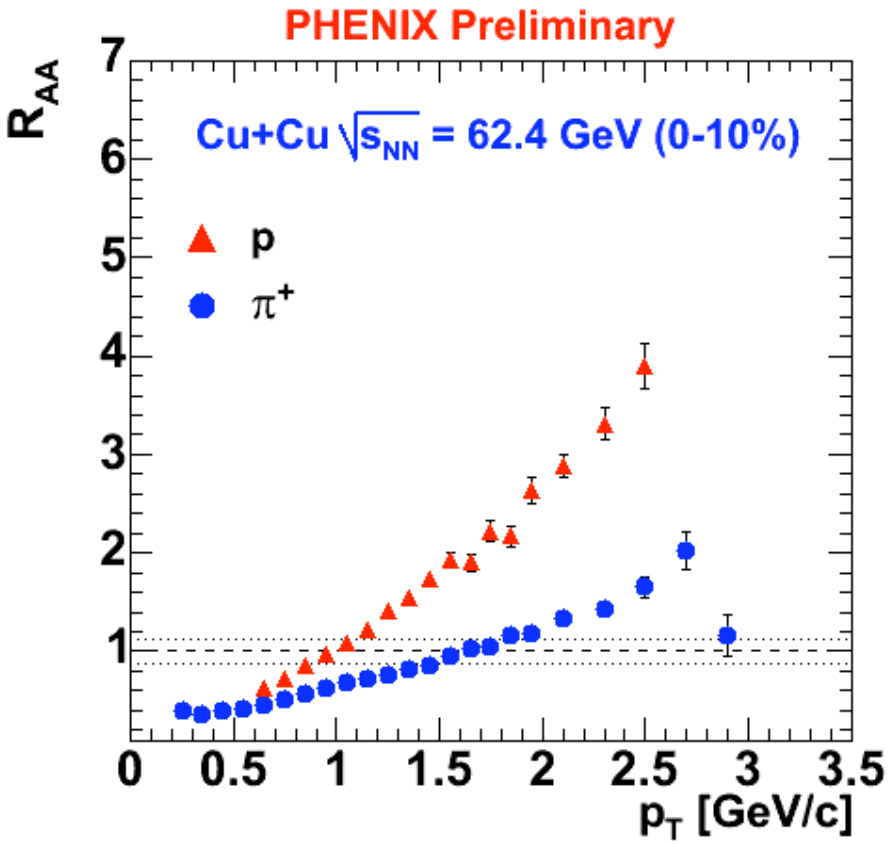
62.4 GeV

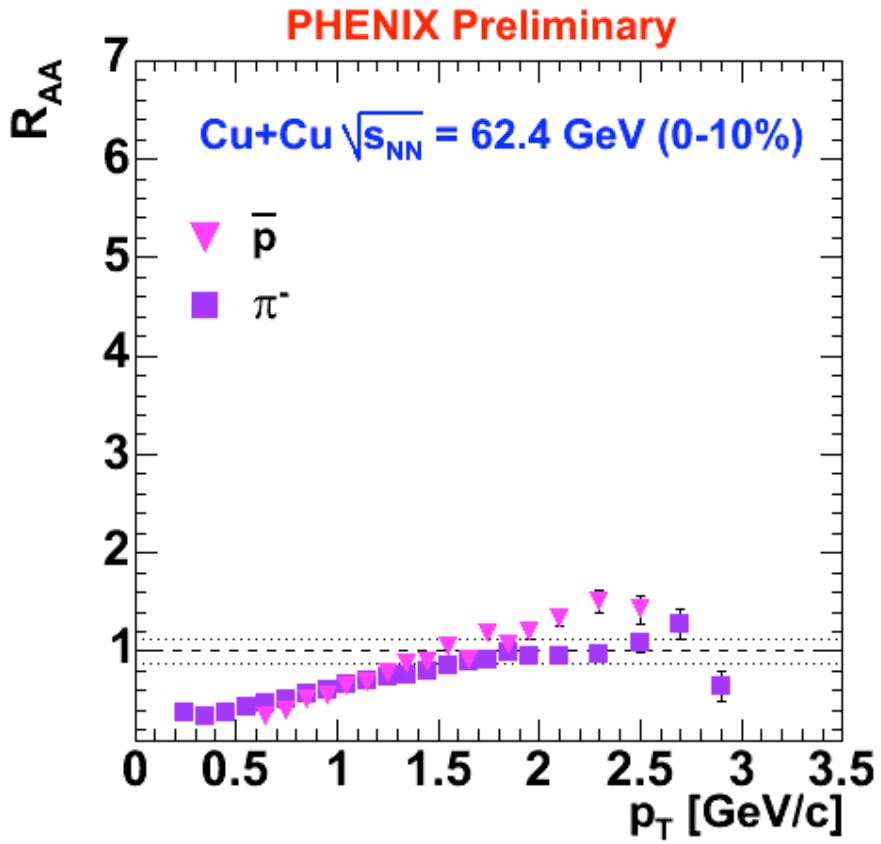
R_{AA} summary (22 GeV)



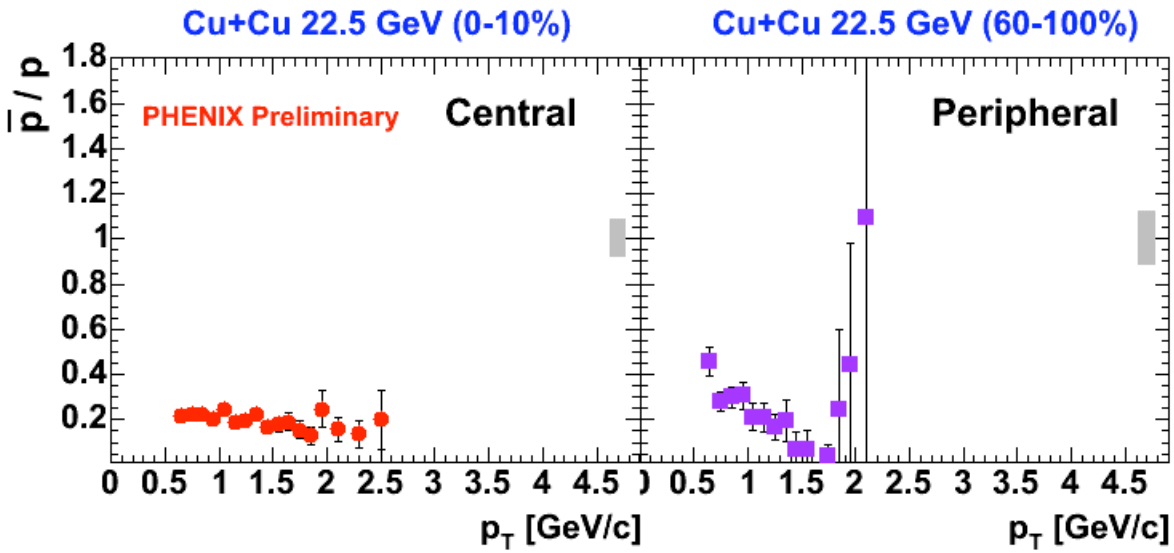


R_{AA} summary (62 GeV)

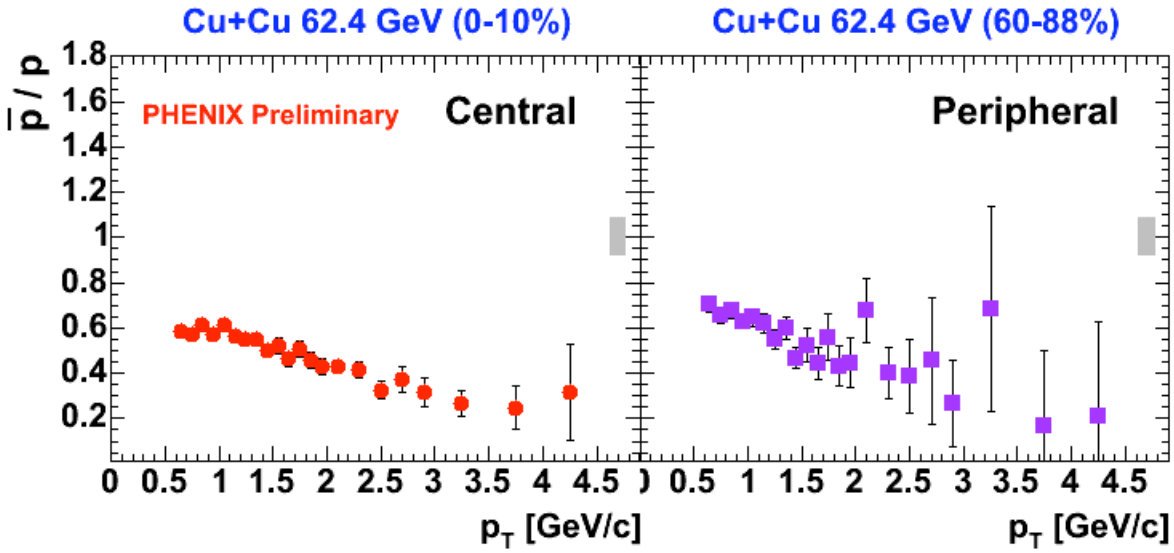




$\bar{p}/p$ ratio vs. p_T

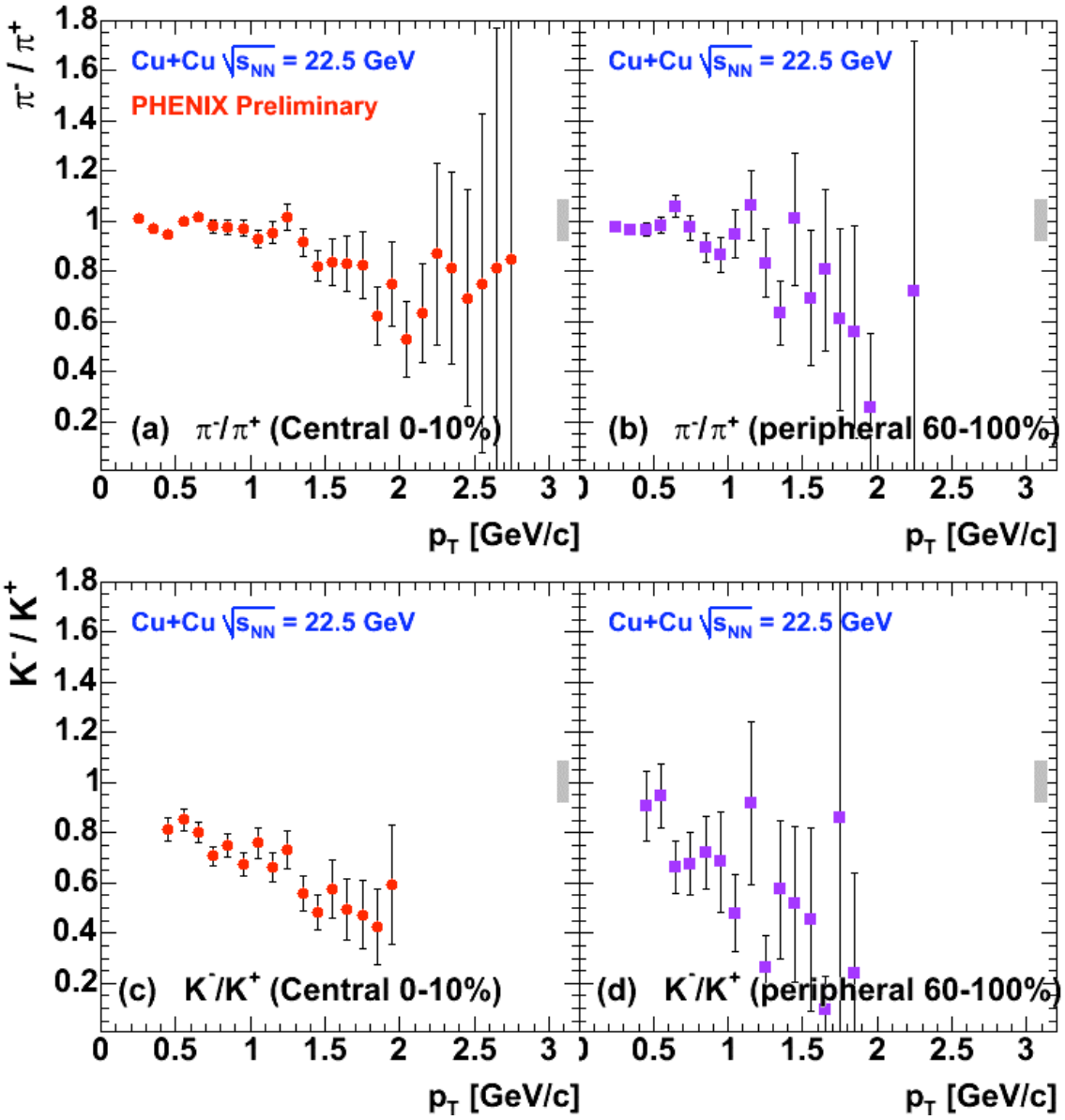


22.5 GeV

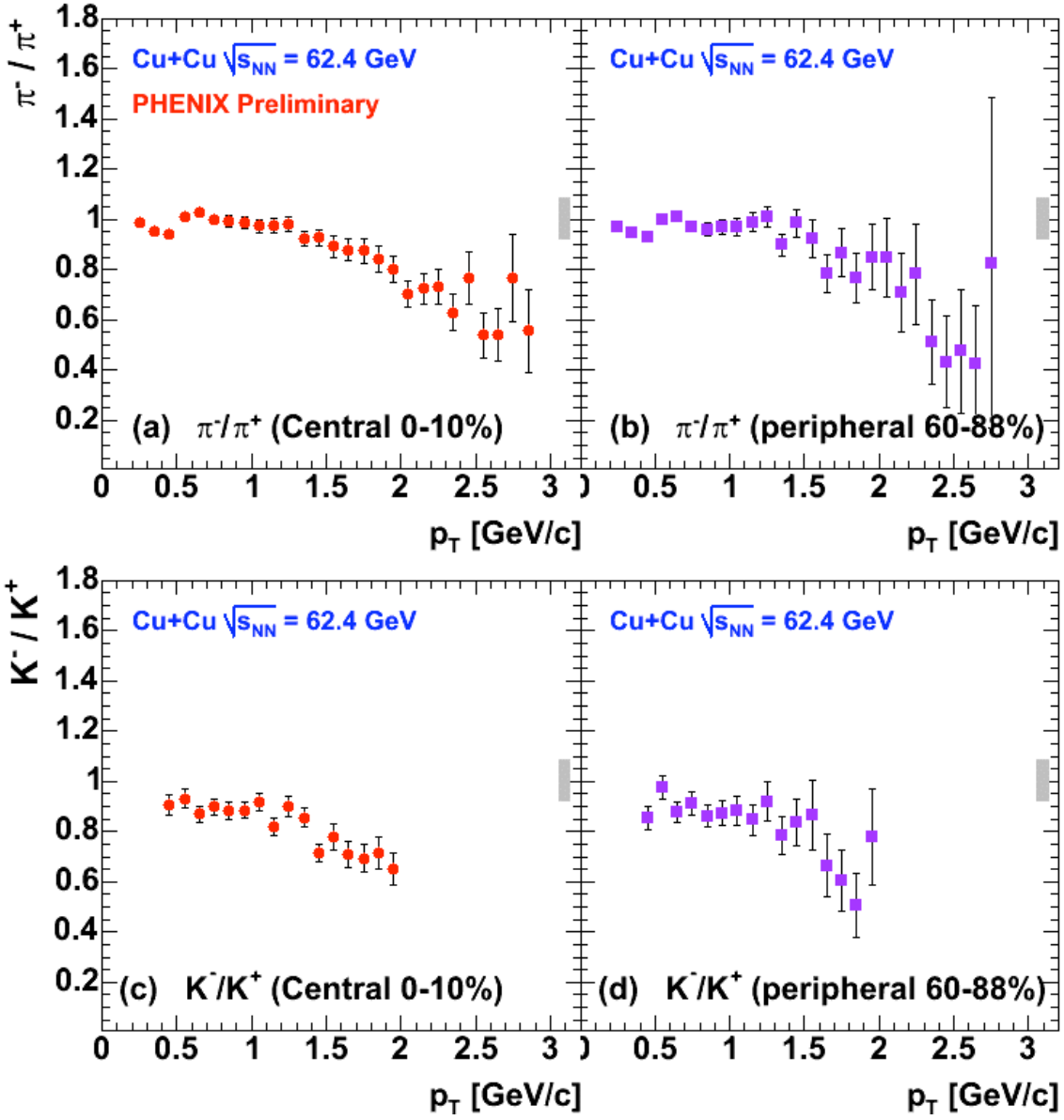


62.4 GeV

π^-/π^+, K^-/K^+ vs. p_T (22.5 GeV)

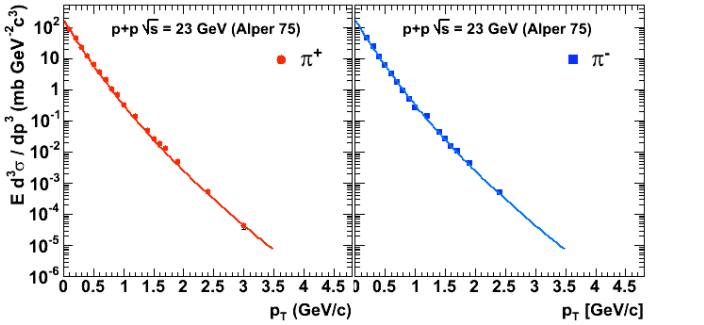


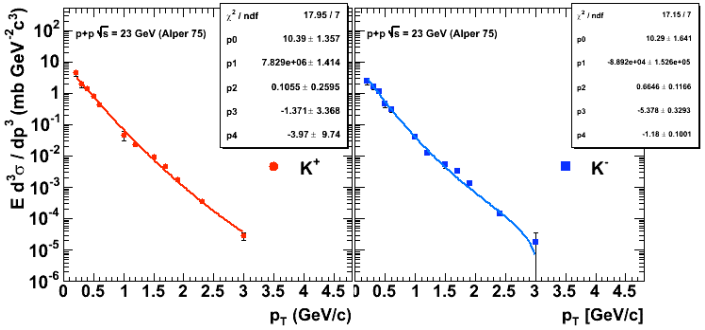
π^-/π^+, K^-/K^+ vs. p_T (62.4 GeV)

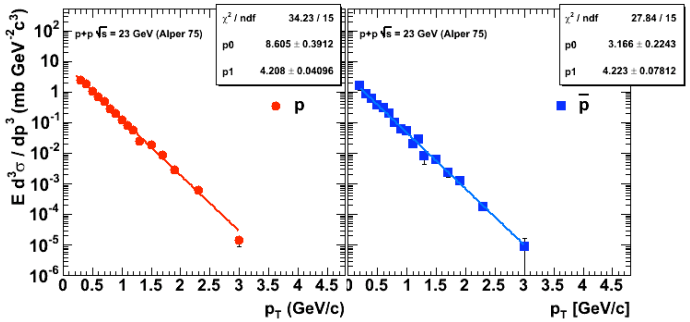


p+p reference data (with fit)

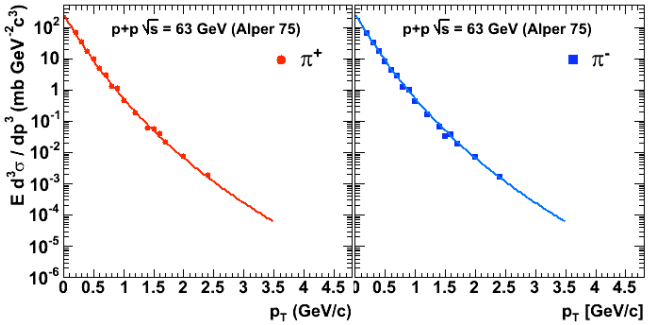
23 GeV

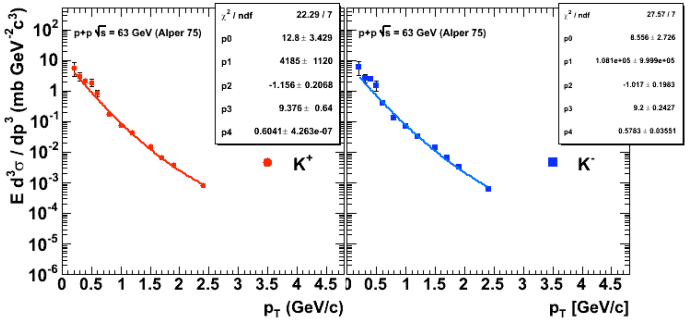


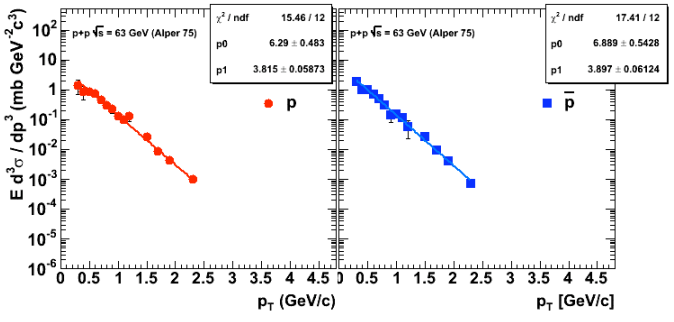




63 GeV







Kaons and protons: Fit results of ISR p+p 63 GeV data. B. Alper et al, NPB100(1975)237.
pions: global fits of p+p data, e.g. nucl-ex/0411049, D. d'Enterria.