

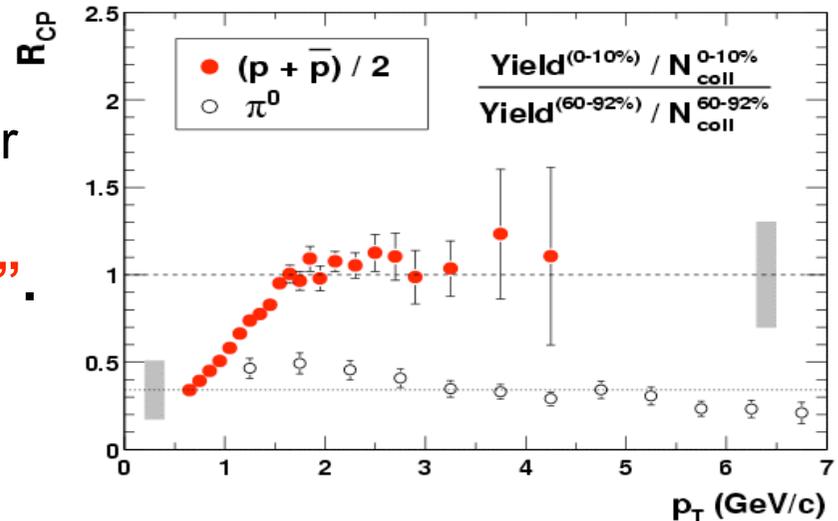
# Systematic Study of Identified Particle Production in PHENIX

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Univ. of Tsukuba, for the PHENIX Collaboration

- Physics Motivation
- Method
- New Data Set: Cu+Cu 200GeV
- Results and Comparisons:
  - Baryon Enhancement
  - Energy dependence
  - $N_{\text{part}}$  Scaling (Particle Ratio)
  - $N_{\text{part}}$  Scaling ( $R_{AA}$ )
- Summary

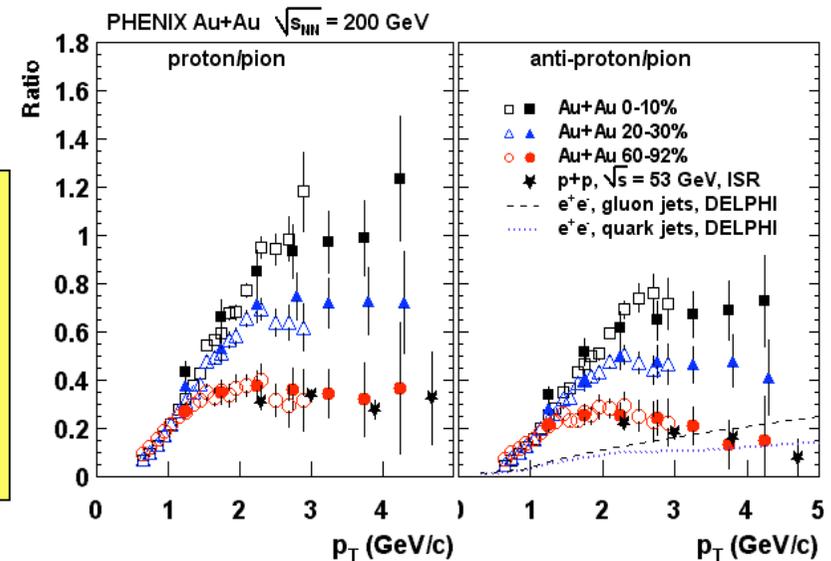
# Physics Motivation

- Strong suppression of  $\pi^0$  yields above  $p_T$   $R_{CP}$   
 $\sim 2$  GeV/c at RHIC, but no suppression for  
 proton and antiproton at intermediate  $p_T$   
 (2-5 GeV/c): **“Baryon Anomaly at RHIC”**.
- The possible explanations:  
 Quark recombination,  
 Baryon junction, Strong radial flow ...



For Systematic Study:

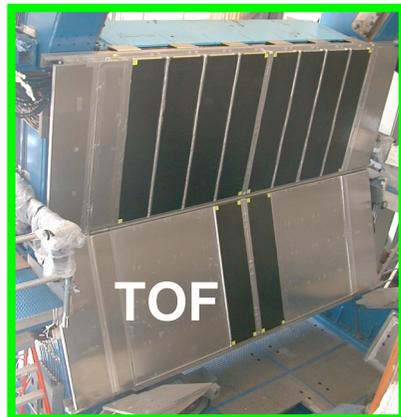
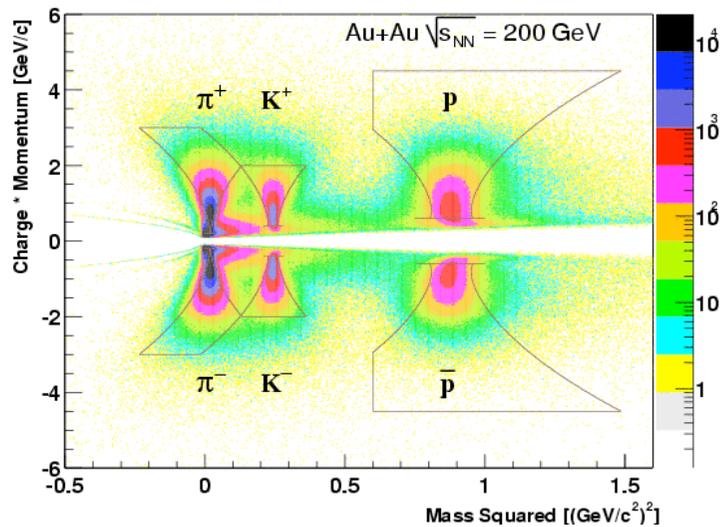
- **Energy dependence**  
 62.4 GeV vs. 200 GeV (Au+Au)
- **System Size dependence**  
 Cu+Cu vs. Au+Au (200 GeV)



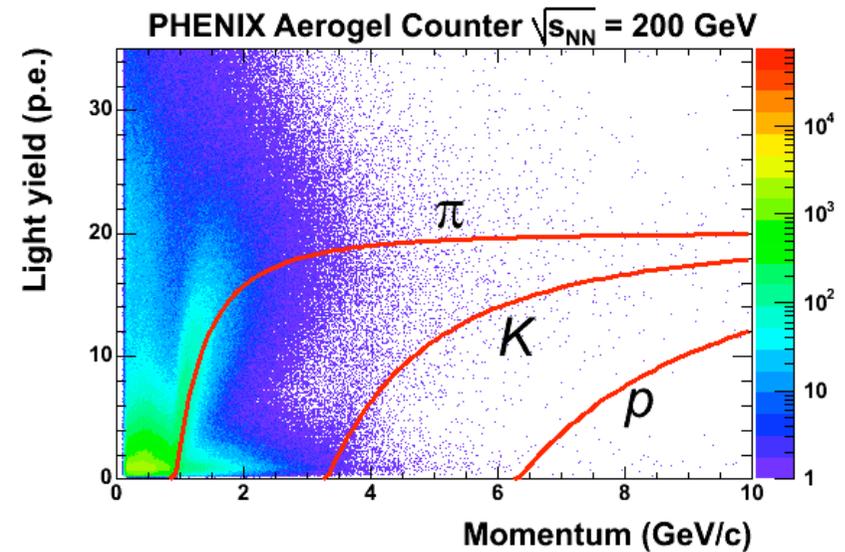
# Method: Charged Hadron PID



## Time of Flight ( $\sigma=120\text{ps}$ )



## Aerogel Cherenkov ( $n=1.011$ )



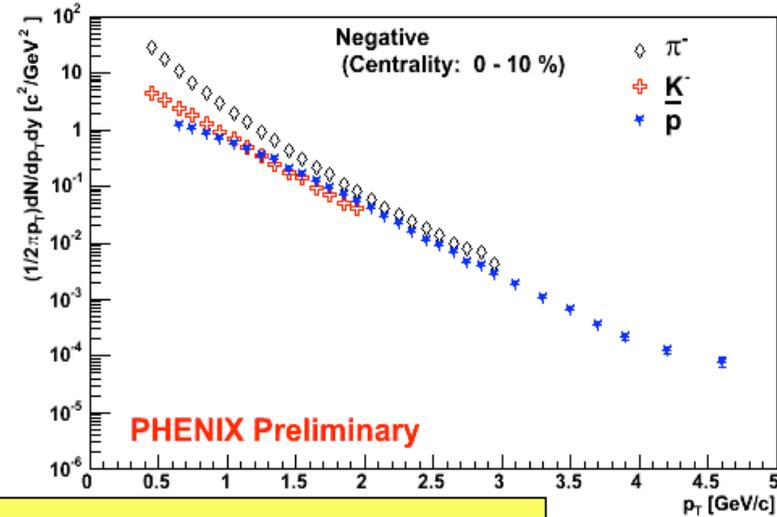
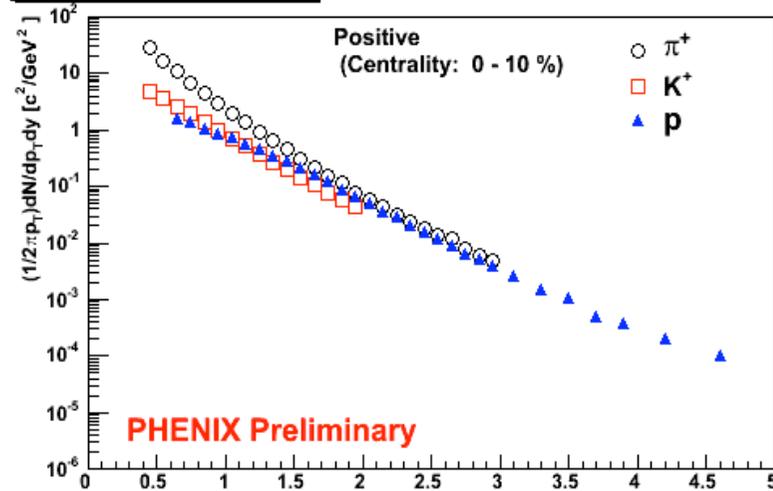
# New Data Set: Cu+Cu 200 GeV

# $p_T$ Spectra

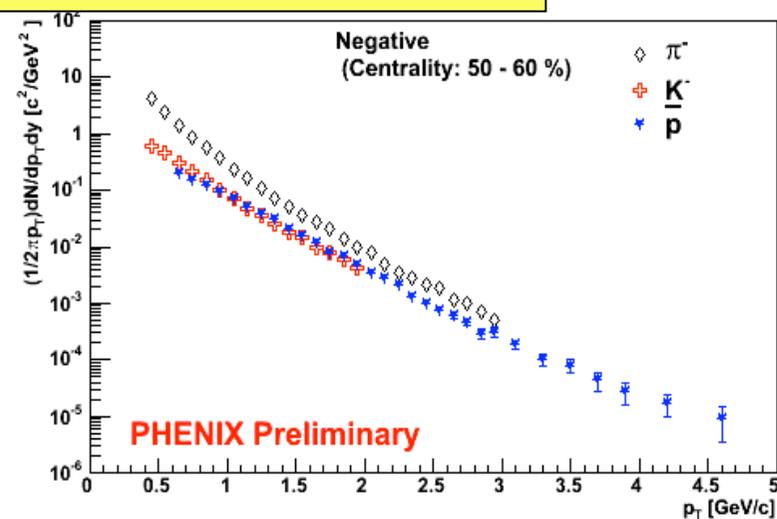
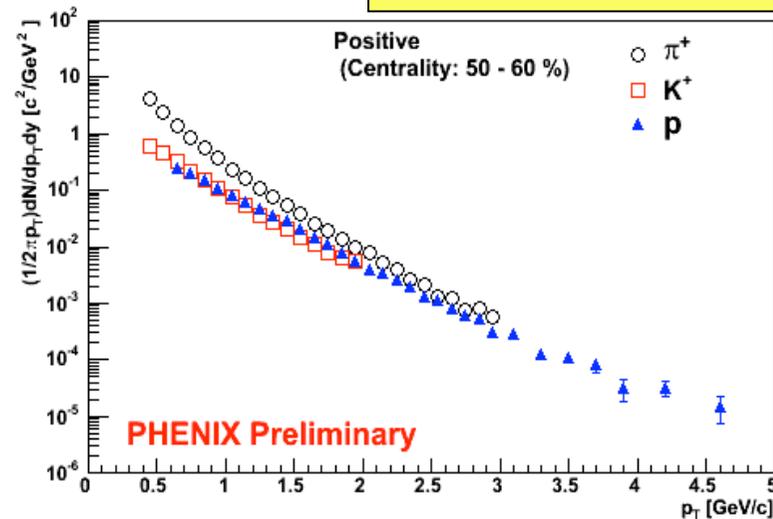
## Cu+Cu 200 GeV



Cu+Cu  $\sqrt{s_{NN}} = 200$  GeV



Similar shapes as those in Au+Au.



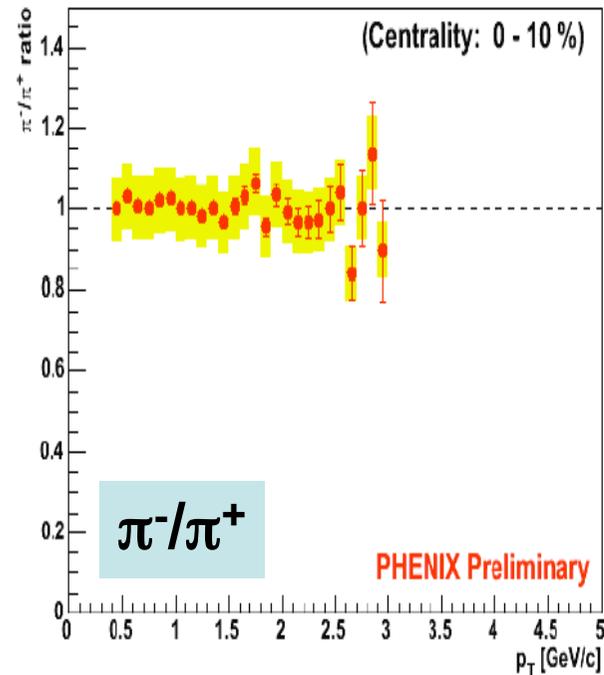
NOTE: No weak decay feed-down correction applied.

# -/+ Ratios vs. $p_T$

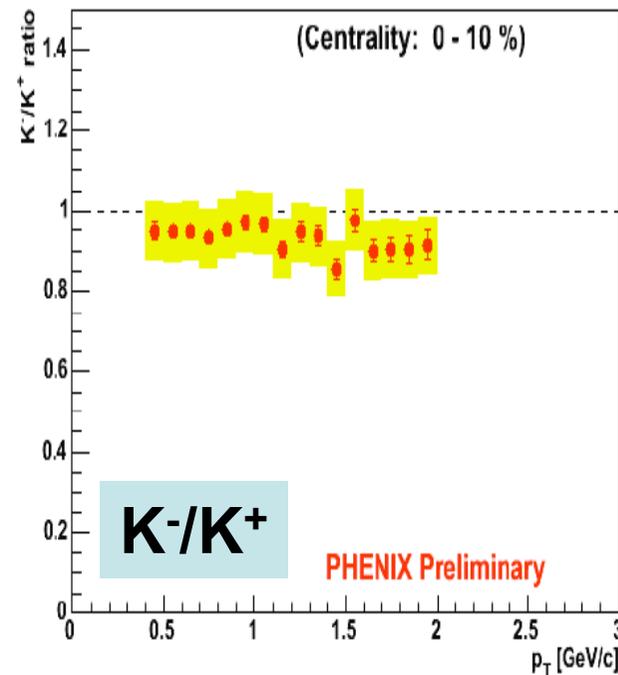
Cu+Cu 200 GeV



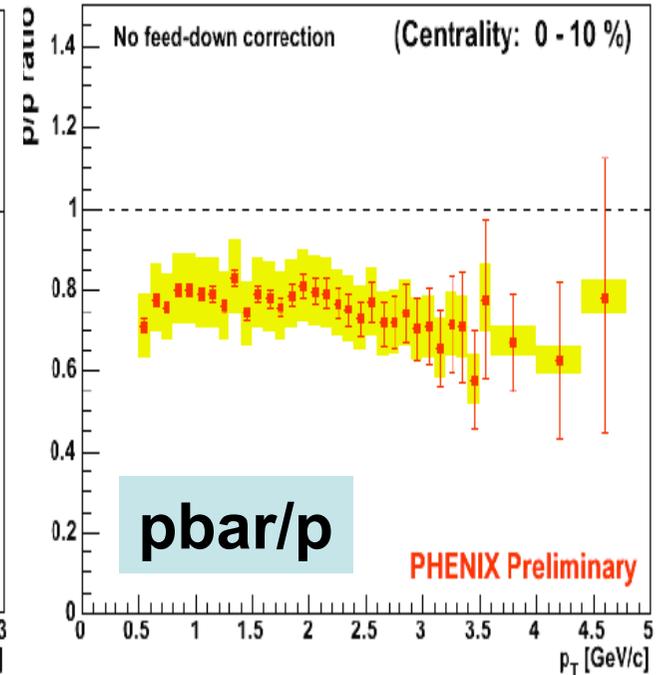
$\pi^-/\pi^+$  ratio (Cu+Cu  $\sqrt{s_{NN}} = 200$  GeV)



$K^-/K^+$  ratio (Cu+Cu  $\sqrt{s_{NN}} = 200$  GeV)



$\bar{p}/p$  ratio (Cu+Cu  $\sqrt{s_{NN}} = 200$  GeV)



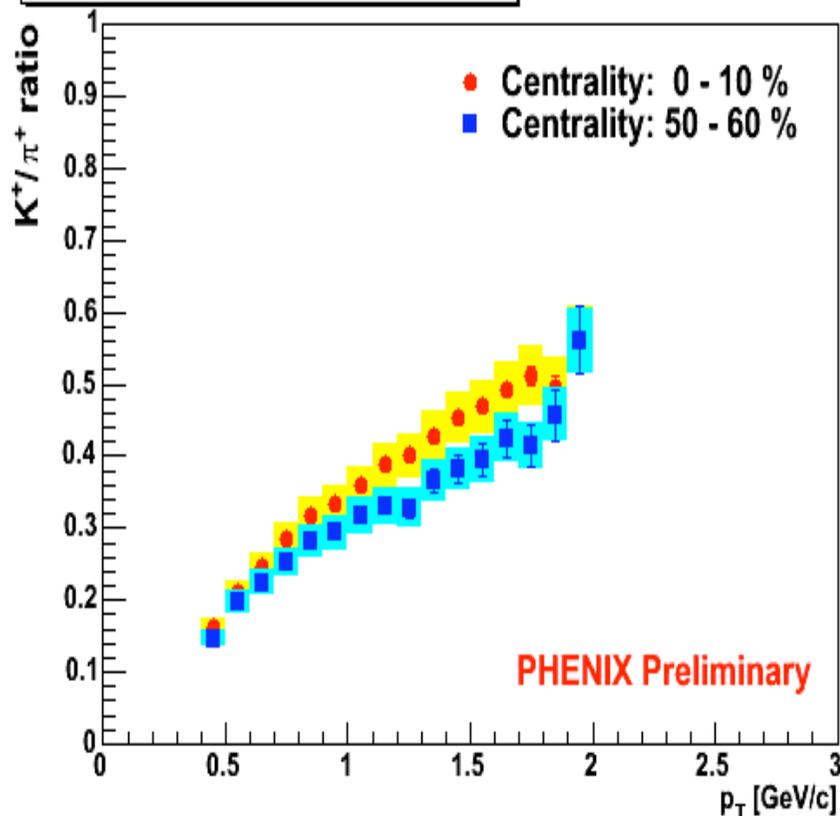
- Flat  $p_T$  dependence for pions, kaons.
- Slightly decreasing with  $p_T$  for protons.
- Flat centrality dependence also seen (0-60%).

# $K/\pi$ vs. $p_T$

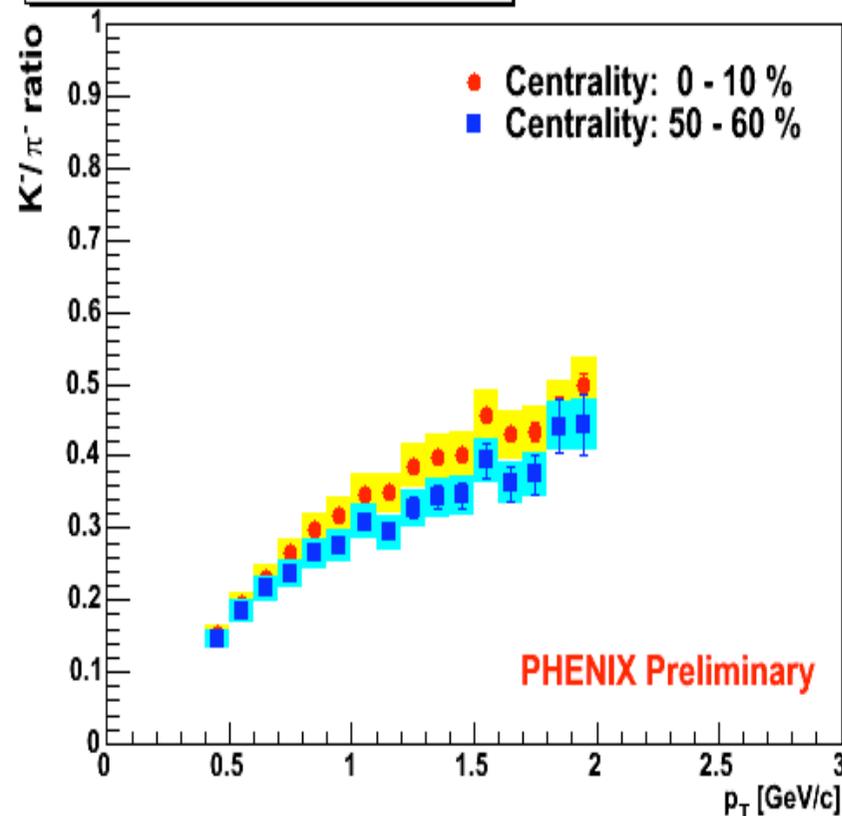
Cu+Cu 200 GeV



$K^+/\pi^+$  ratio (Cu+Cu  $\sqrt{s_{NN}} = 200$  GeV)



$K^-/\pi^-$  ratio (Cu+Cu  $\sqrt{s_{NN}} = 200$  GeV)

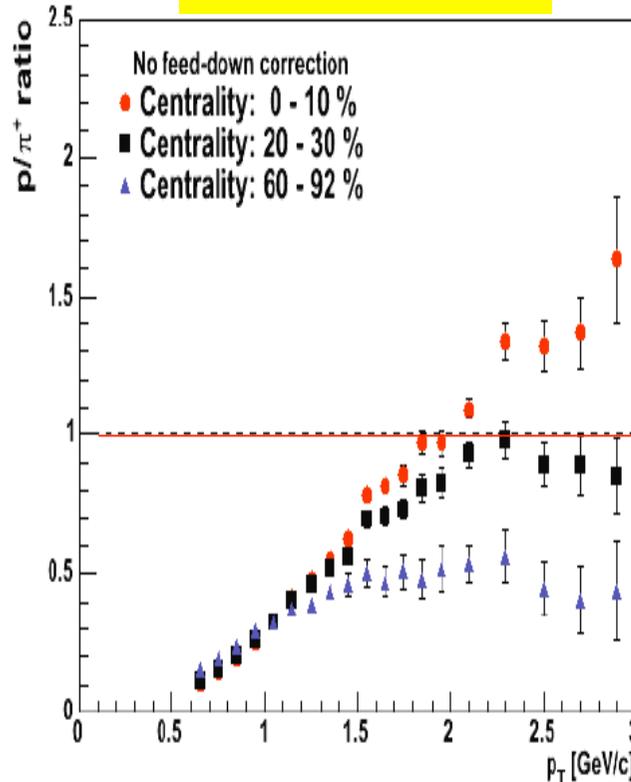


- Increasing steady with  $p_T$ .
- No apparent indication of saturation in this  $p_T$  region.

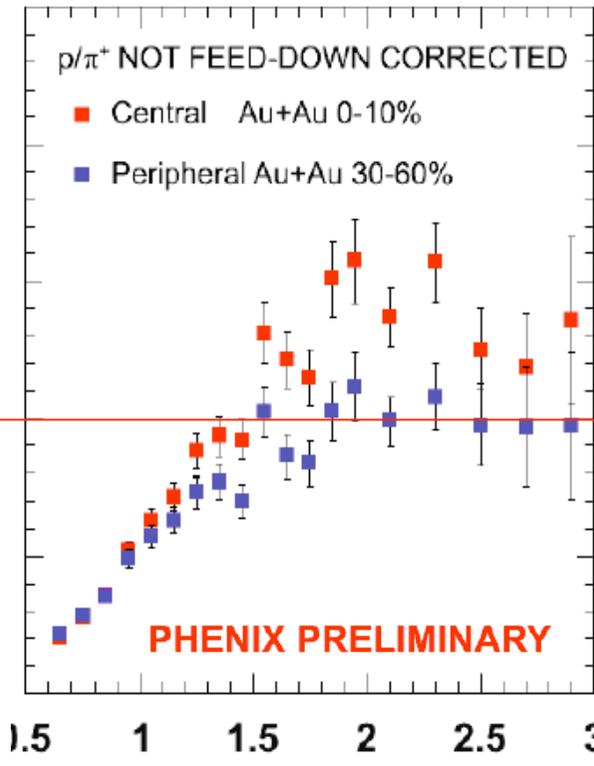
# Baryon Enhancement

# $\rho/\pi^+$ vs. $p_T$

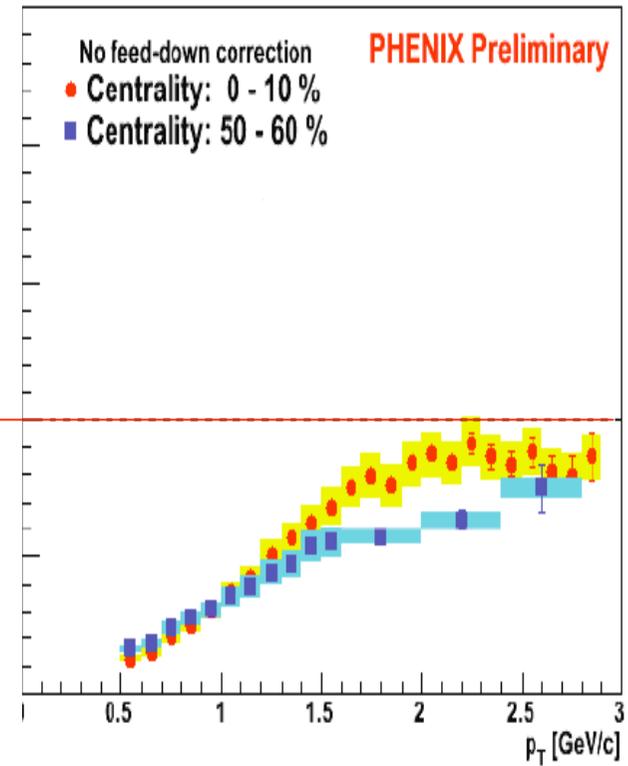
Au+Au 200GeV



Au+Au 62GeV



Cu+Cu 200GeV

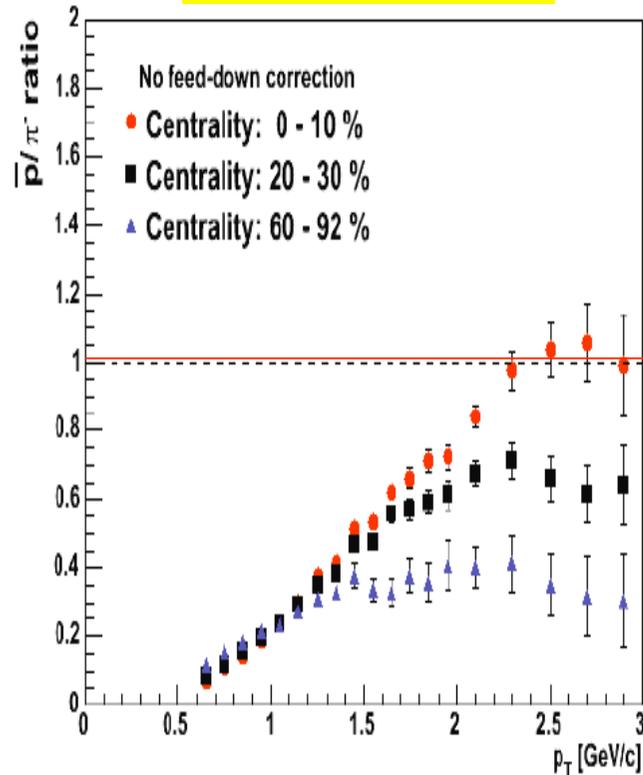


- Baryon enhancement observed in all collisions systems.
- Rapidly increasing with  $p_T$  for 62 GeV.
- $p_T$  dependence in Cu+Cu is similar to that in Au+Au. (See  $N_{part}$ -scaling)
- Weaker centrality dependences (62GeV) than those of 200 GeV.

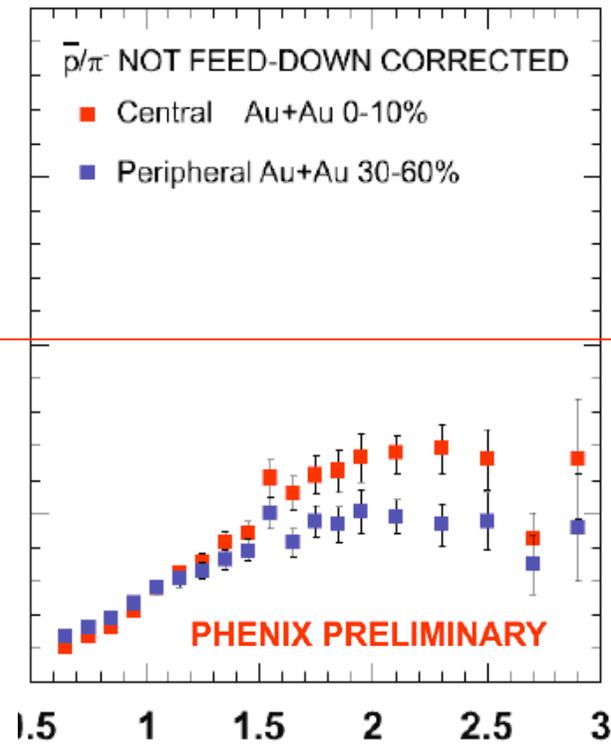
**NOTE: No weak decay feed-down correction applied.**

# $\bar{p}/\pi^-$ Ratios

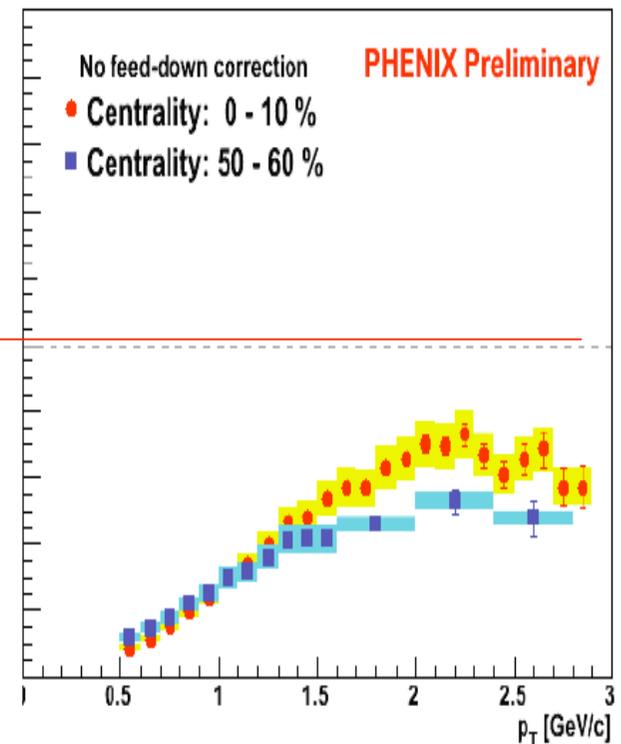
Au+Au 200GeV



Au+Au 62GeV



Cu+Cu 200GeV



- Less for antiproton compared to proton for all systems
- Significant difference for p and pbar at 62 GeV  
(Indicating more baryon transport and less p-pbar pair production at 62 GeV than 200 GeV.)

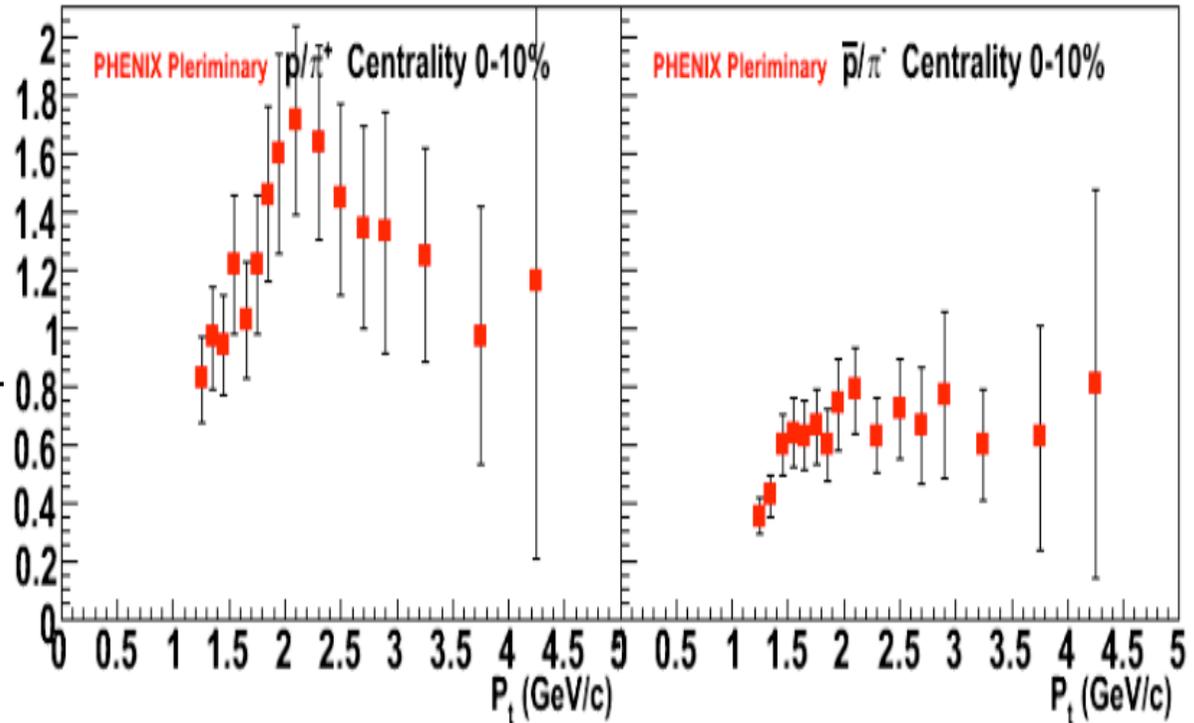
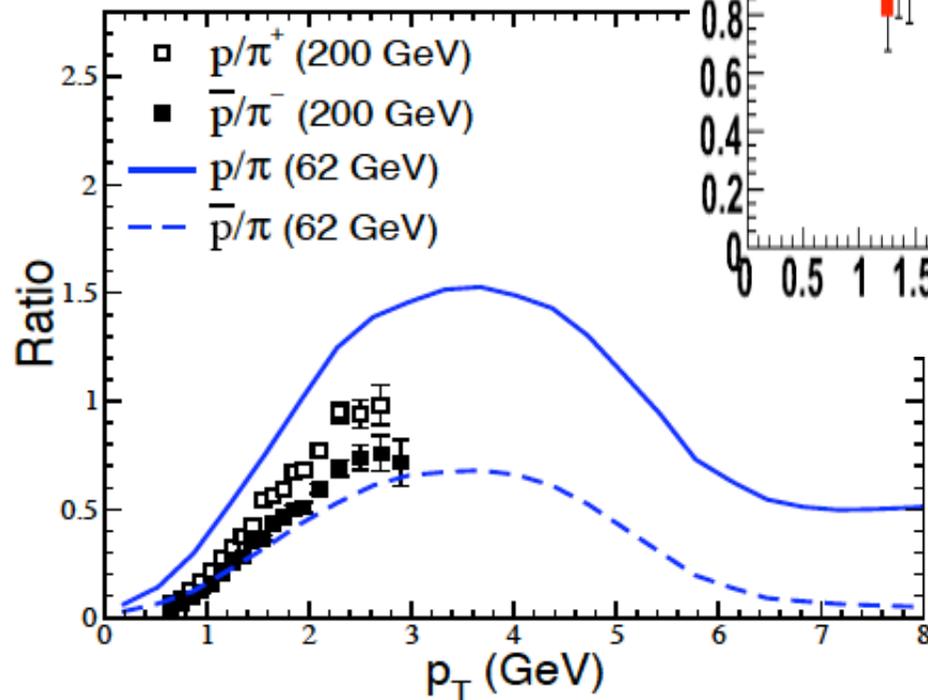
**NOTE: No weak decay feed-down correction applied.**

# $\rho/\pi$ Ratios (62 GeV)

Au+Au 62GeV



nucl-th/0412043

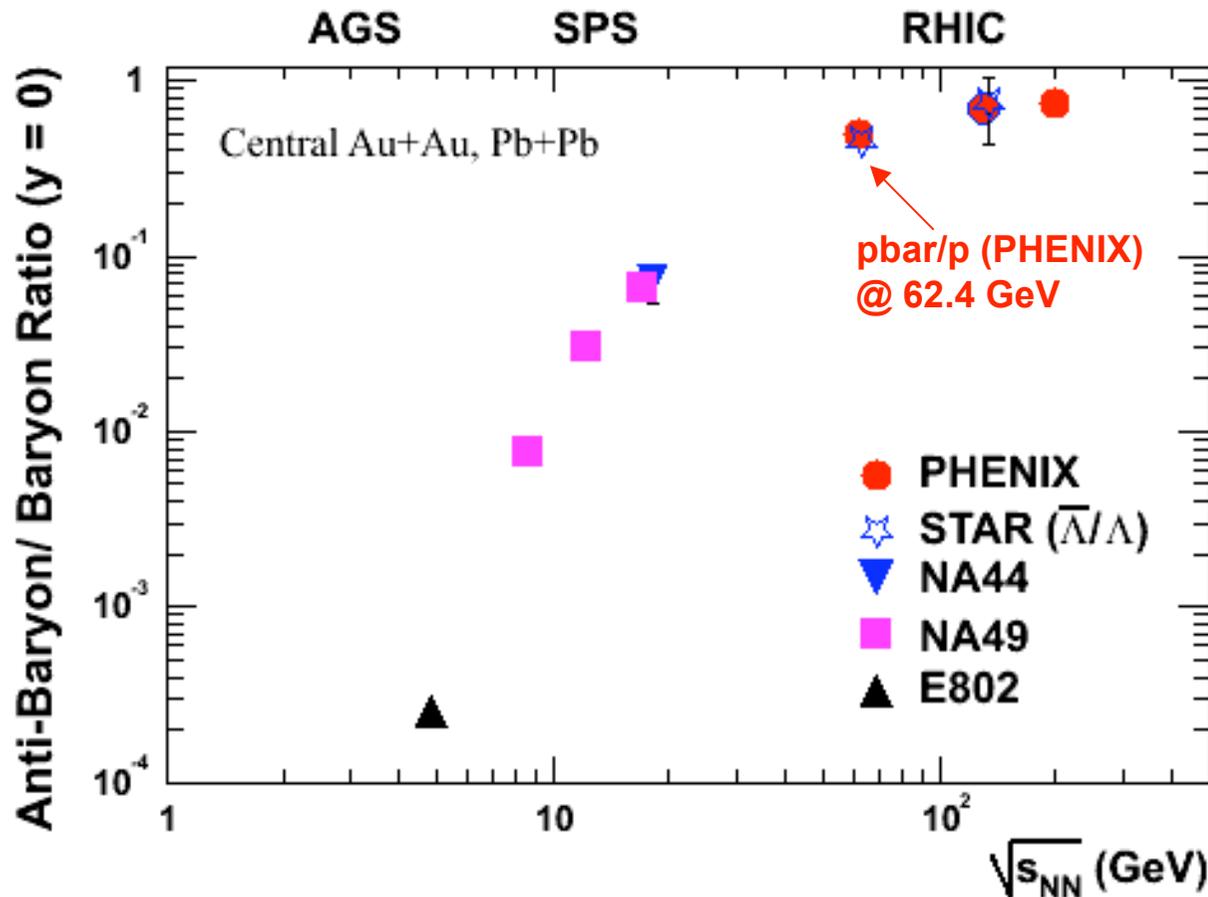


- Described by coalescence model:
  - $p_T$  dependence
  - $p$  and  $pbar$  difference

coalescence model

# Energy dependence

# Antibaryon/ baryon ratios vs. $\sqrt{s_{NN}}$



## Experimental Data:

### AGS:

- E802, 2650 PRL 83, (1998)

### SPS:

- NA44: PRC 66, 044907 (2002)
- NA49: J. of Phys. G 30, S357 (2004)

### RHIC:

- PHENIX

62 GeV (preliminary, no feed-down)

PRL 88, 242301 (2002), PRC 69, 034909 (2003), PRL 89 092302 (2002).

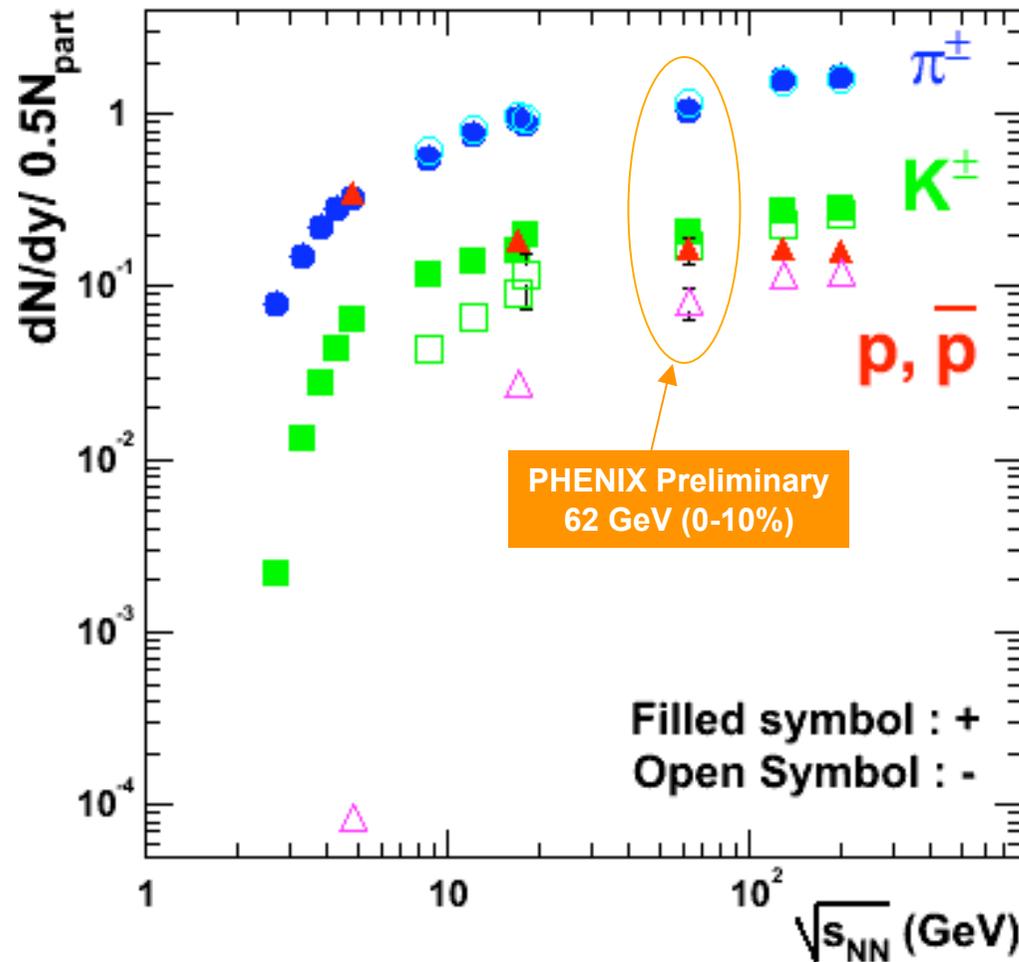
- STAR

62 GeV (Preliminary, HQ2004); 130 GeV PRL 89, 092301 (2002).

- Follow the smooth curve from SPS to RHIC.
- Consistent with  $\bar{\Lambda}/\Lambda$  (STAR preliminary) at 62 GeV.

**NOTE: No weak decay feed-down correction applied.**

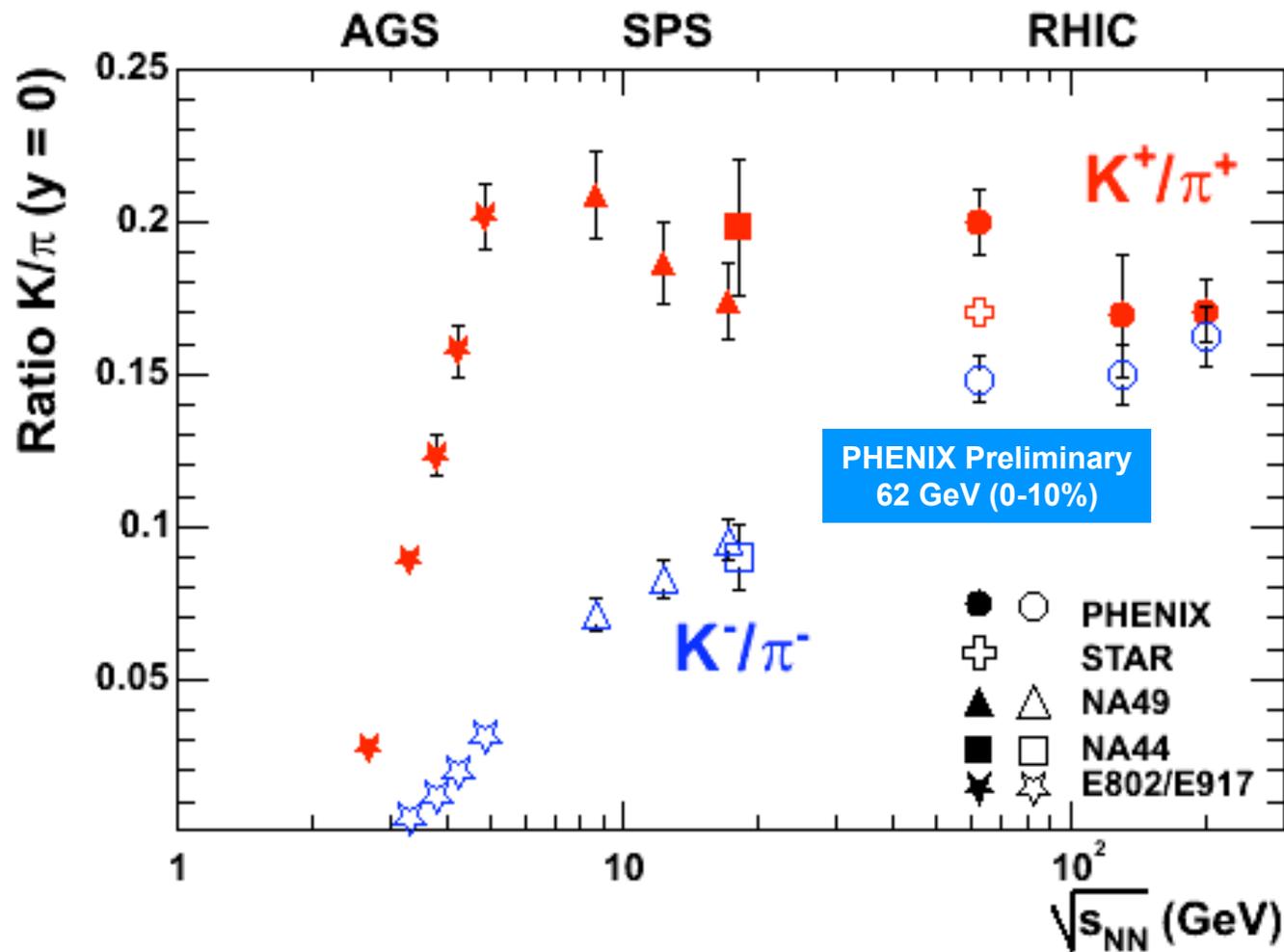
# $dN/dy$ vs. $\sqrt{s_{NN}}$ (central)



RHIC: PHENIX  
SPS: NA44, NA49  
AGS: E866, E917

$dN/dy$  per  $N_{part}$  pair: smooth energy dependence from SPS to RHIC.

# $K/\pi$ vs. $\sqrt{s_{NN}}$

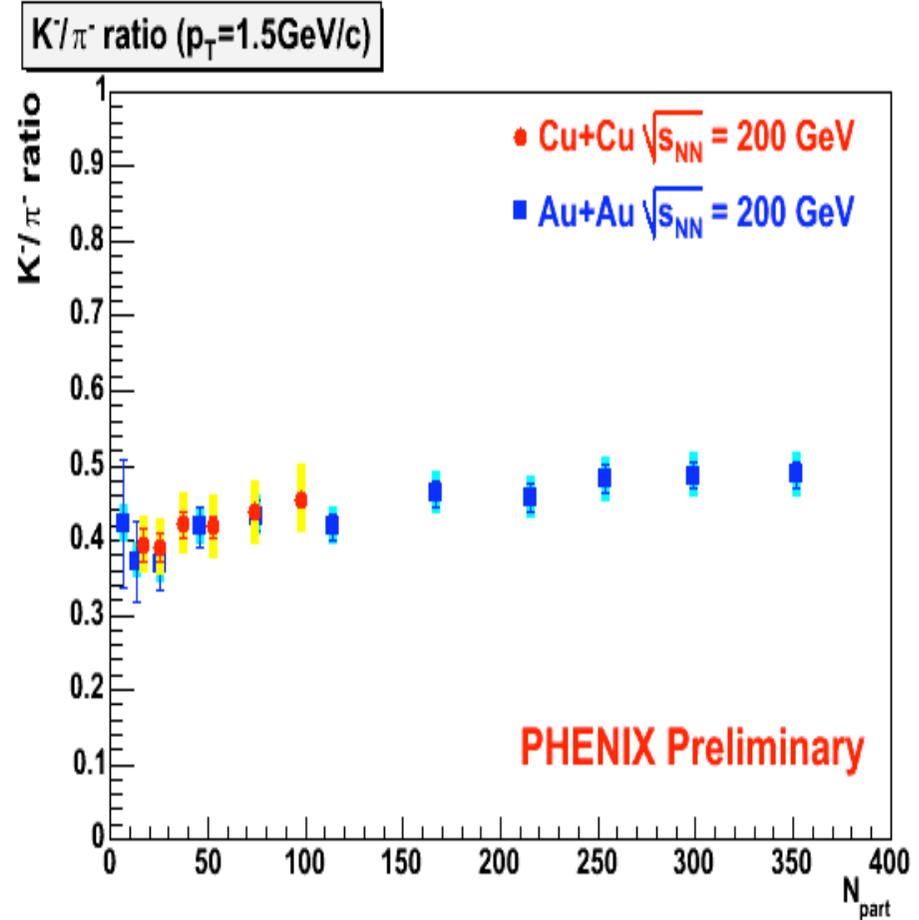
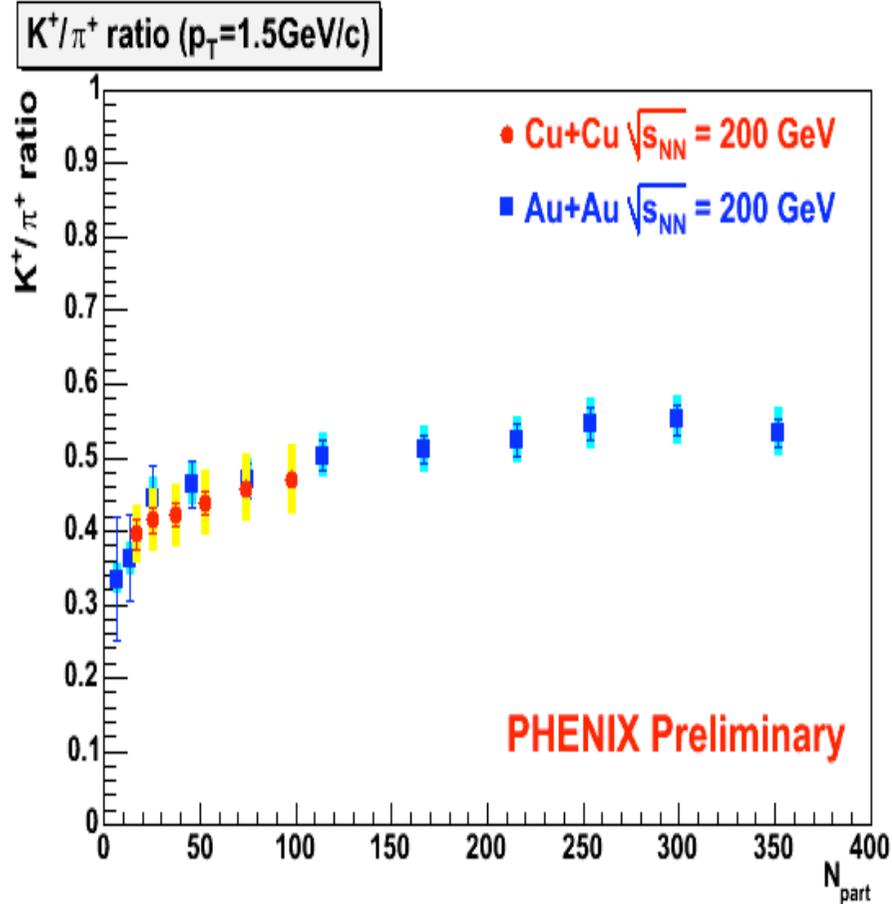


\* STAR  $K^+/\pi^+$ : preliminary data from SQM04, J. Takahashi

- $K^-/\pi^-$  : follow the smooth curve from SPS to RHIC.
- $K^+/\pi^+$ : similar to SPS top energy.

# $N_{\text{part}}$ Scaling (Particle Ratio)

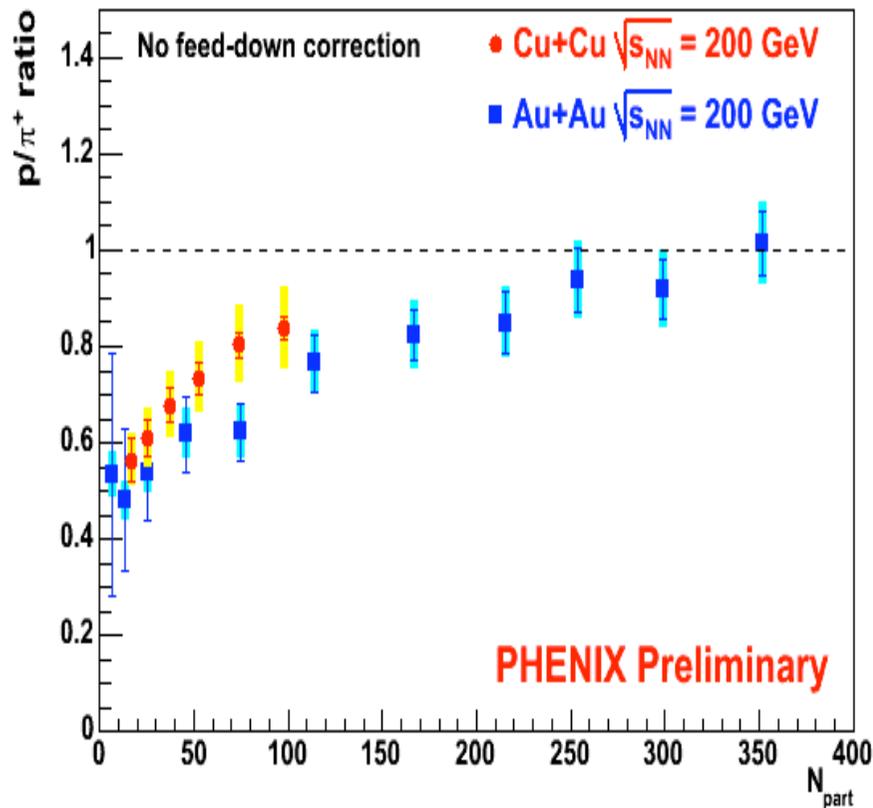
# $K/\pi$ vs. $N_{part}$



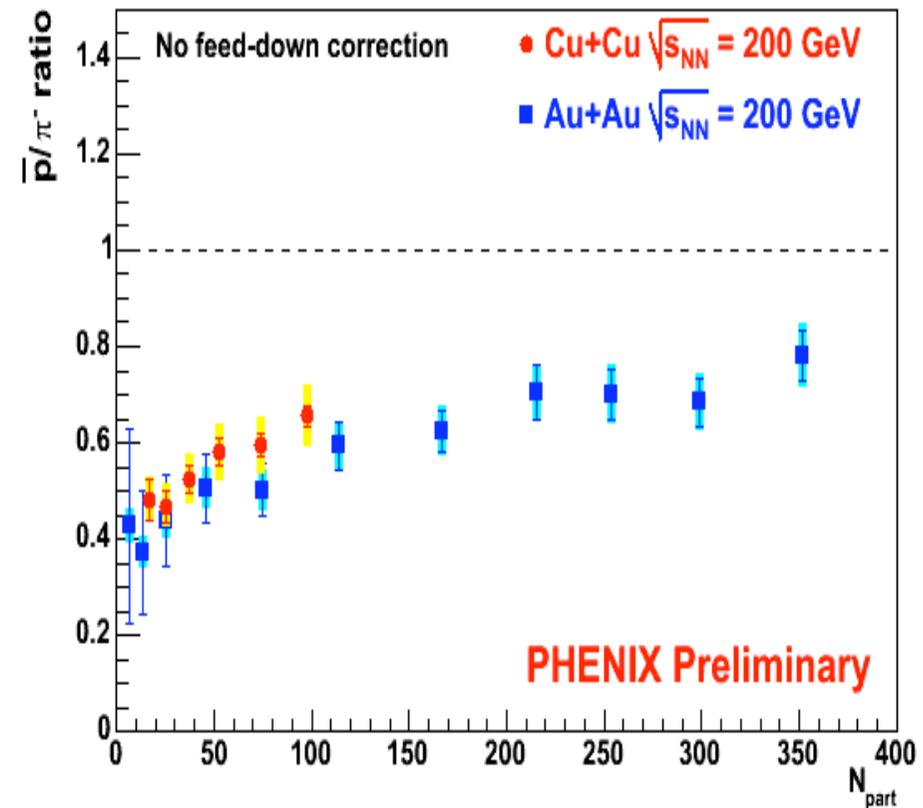
$N_{part}$  dependence is almost same as in Au+Au.

# $\rho/\pi$ vs. $N_{\text{part}}$

$\rho/\pi^+$  ratio ( $p_T=2\text{GeV}/c$ )



$\bar{\rho}/\pi^-$  ratio ( $p_T=2\text{GeV}/c$ )

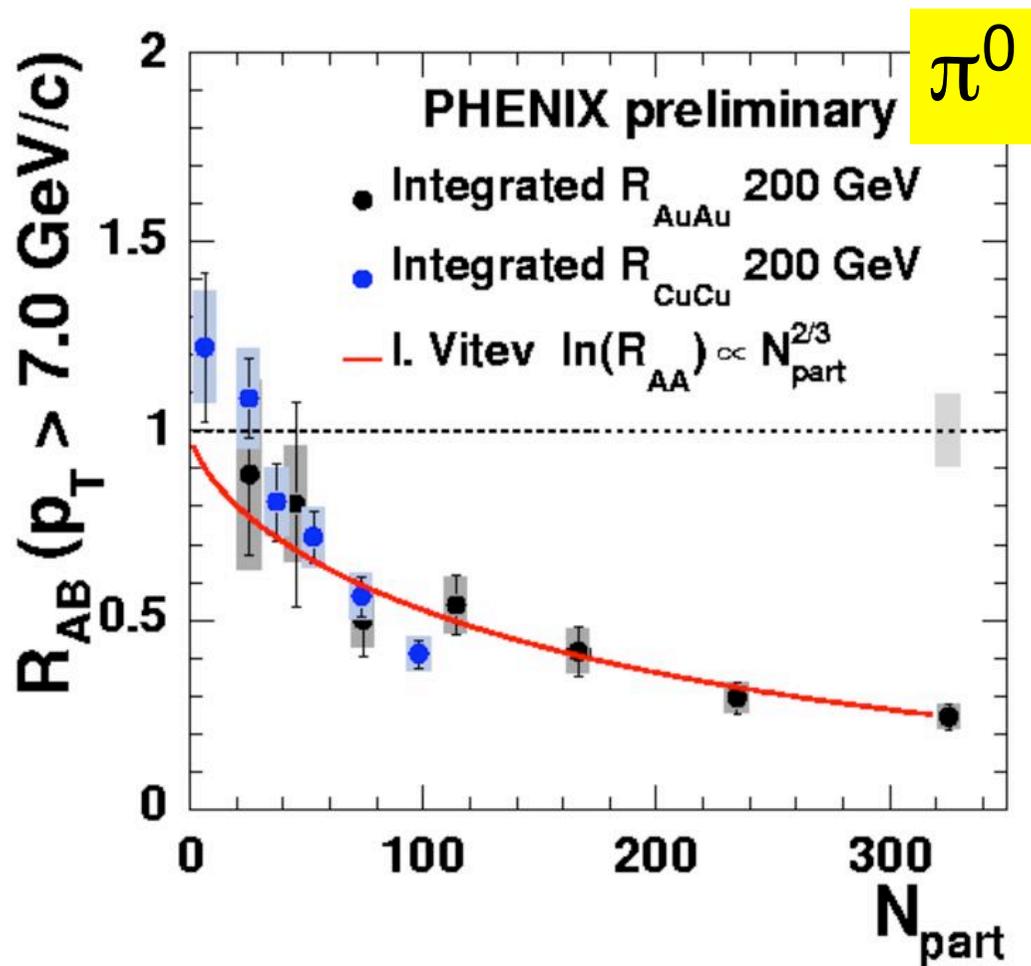


- $N_{\text{part}}$  dependence looks similar to that in Au+Au.
- Slight difference in the magnitude seen.

**NOTE: No weak decay feed-down correction applied.**

# $N_{\text{part}}$ Scaling ( $R_{AA}$ )

# $R_{AA}$ vs. $N_{part}$



Cu+Cu data follow the Au+Au data.

# $R_{AA}$ vs. $p_T$

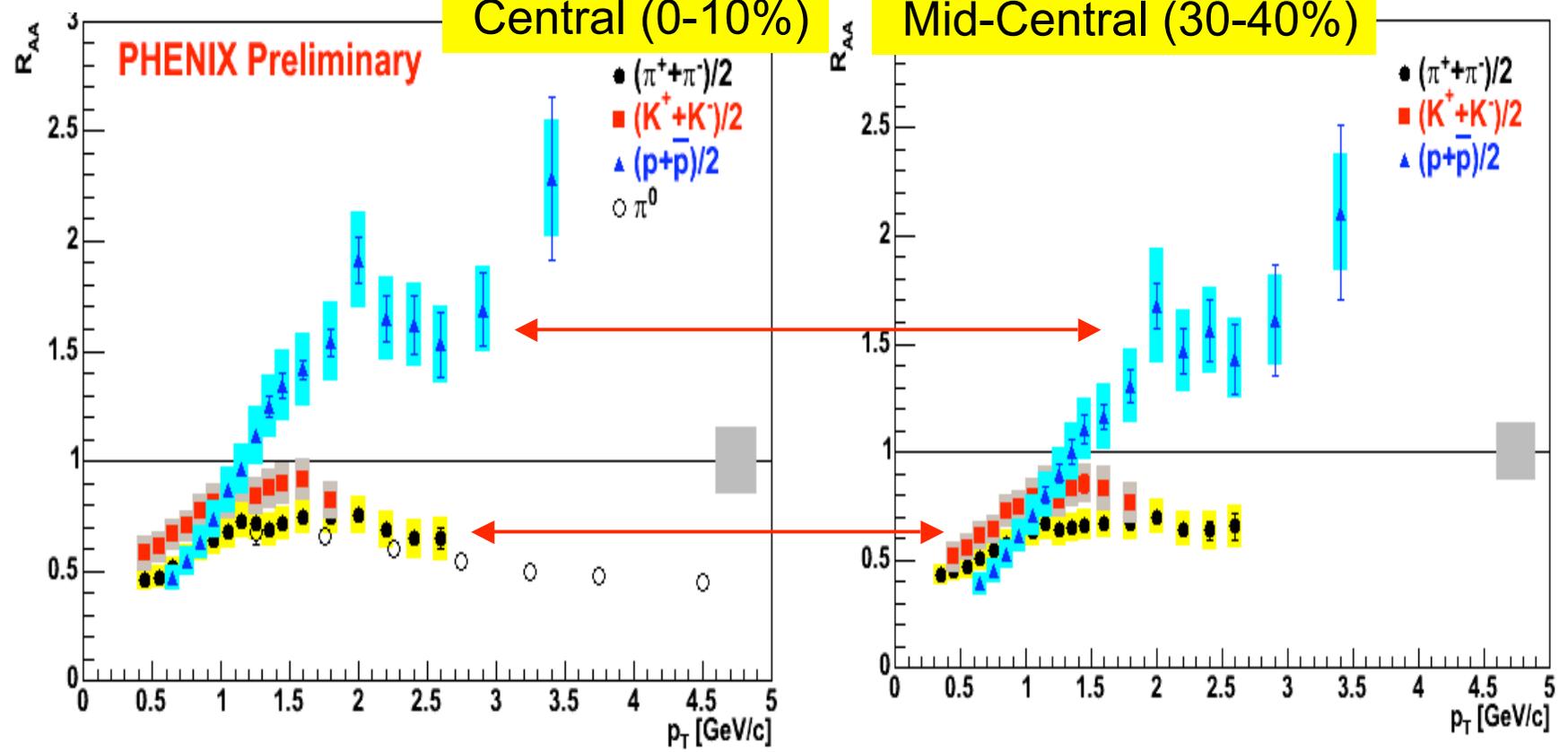
$N_{part} \sim 98$

$N_{part} \sim 114$



Cu+Cu 200 GeV  
Central (0-10%)

Au+Au 200 GeV  
Mid-Central (30-40%)



- Similarity seen in Cu+Cu and Au+Au:
  - The magnitude of enhancement/suppression
  - Particle type dependence

**NOTE: No weak decay feed-down correction applied.**

## *Energy dependence:*

### *62.4 GeV vs. 200 GeV (Au+Au)*

- Observed a large proton contribution at intermediate  $p_T$ , as seen in 200 GeV data, but less for antiprotons.
- Antiproton-to-proton ratio is  $\sim 0.5$  at 62 GeV, which indicates less p-pbar pair production and relatively larger baryon transport than 200 GeV.
- Smooth excitation function for both yields and ratios from SPS to RHIC.

## *System Size dependence:*

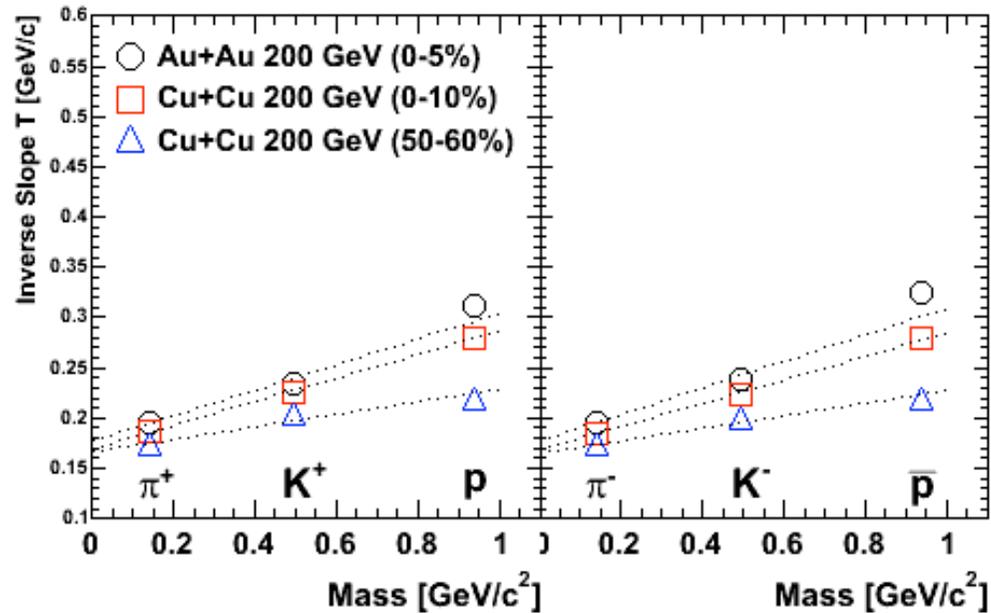
### *Cu+Cu vs. Au+Au (200 GeV)*

- Observed a large p,pbar contribution at intermediate  $p_T$ , as seen in 200 GeV data.
- $N_{part}$  dependences on particle ratios have similar trend as in Au+Au ( $N_{part}$  scaling).
- Similarity on  $R_{AA}$  seen in Cu+Cu and Au+Au (System size):
  - the magnitude and its particle dependence.

Backup

# Inverse Slope T

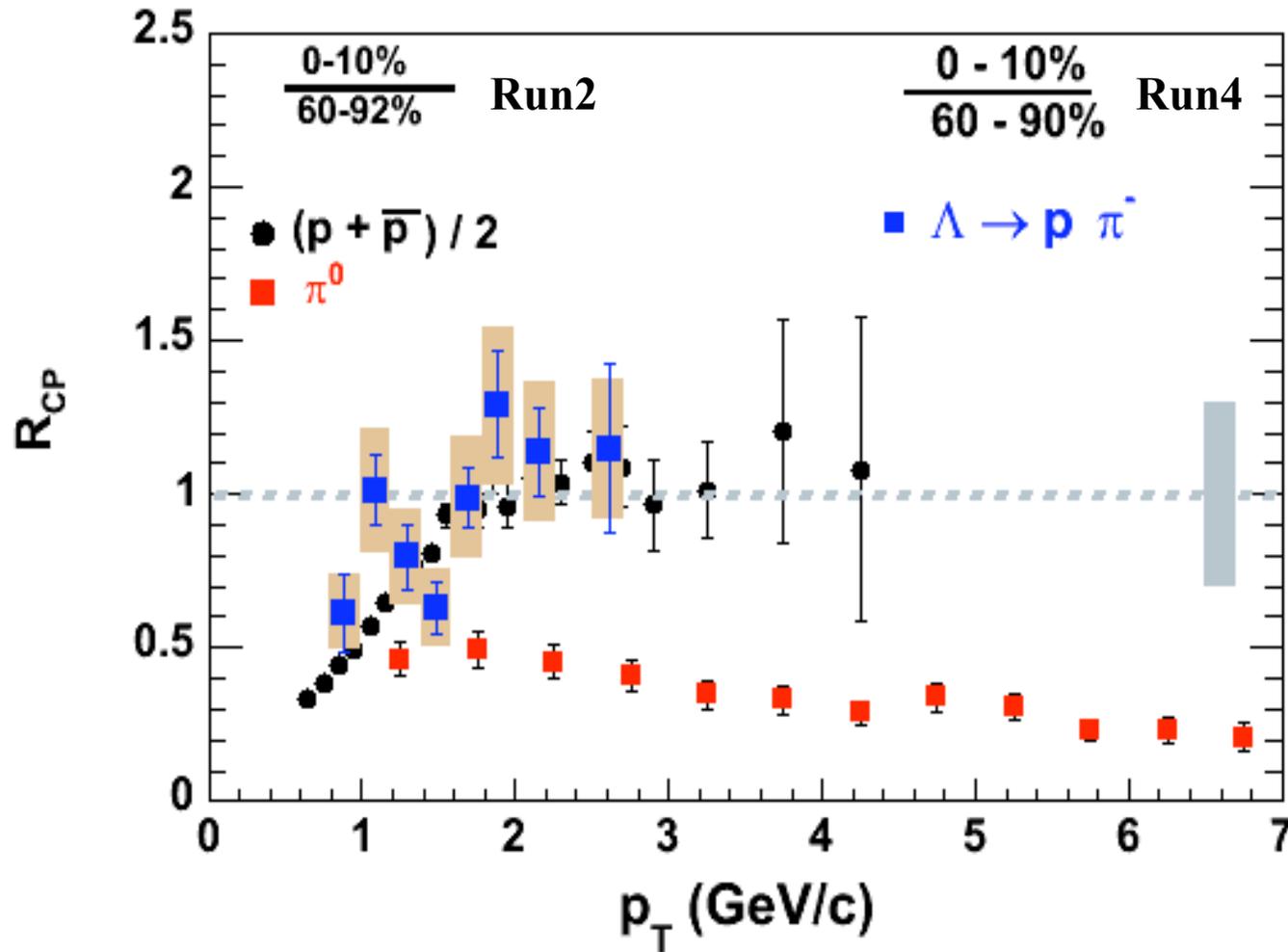
Cu+Cu 200 GeV



Fitted by  $m_T$  exponential function.

- Fit range:
  - $\pi$ : 0.3(0.2) - 1.0 GeV/c<sup>2</sup>.
  - p and K: 0.2(0.1) - 1.0 GeV/c<sup>2</sup>.

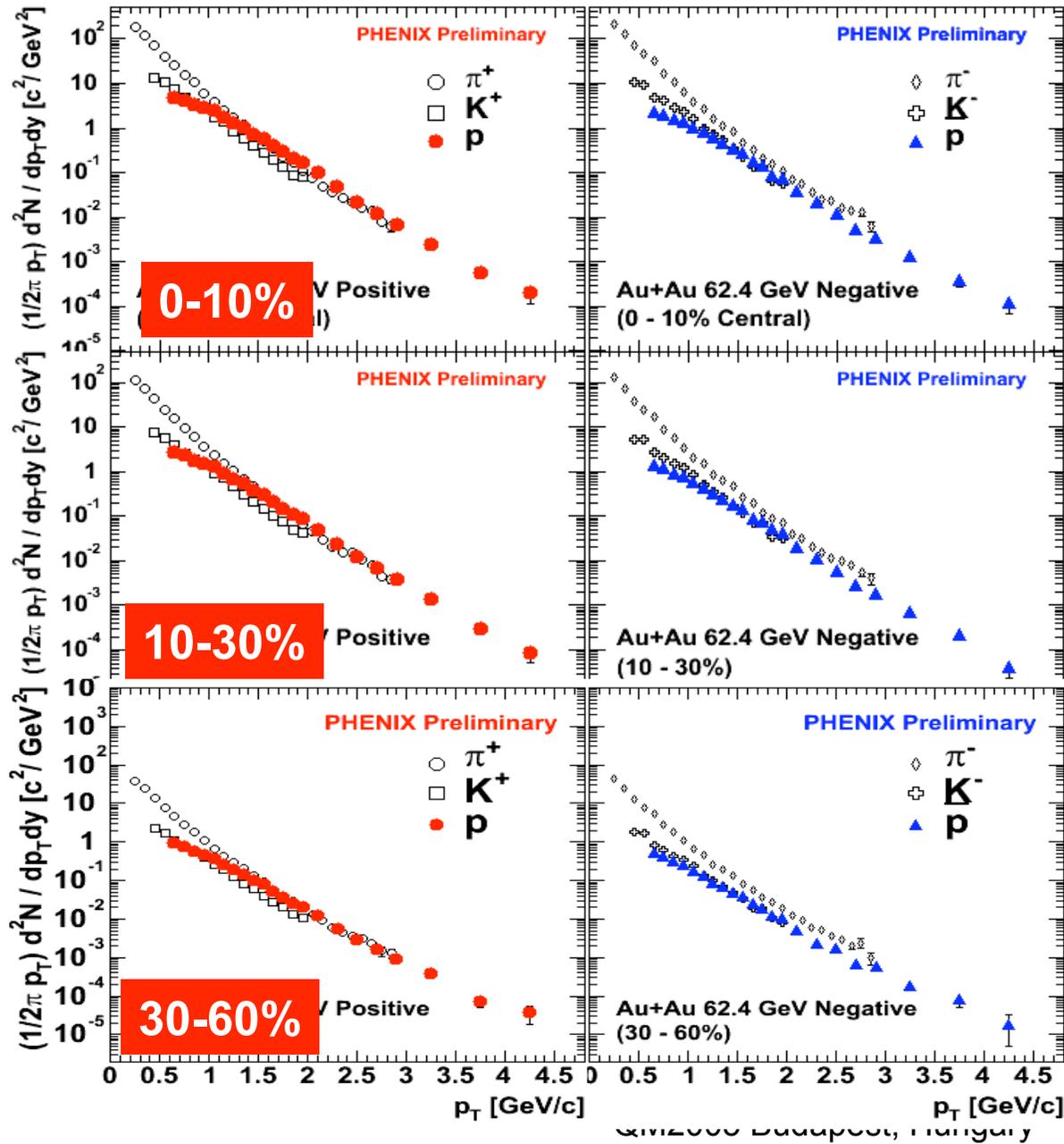
• Extracted inverse slopes



**Rcp of Lambdas is similar to protons**

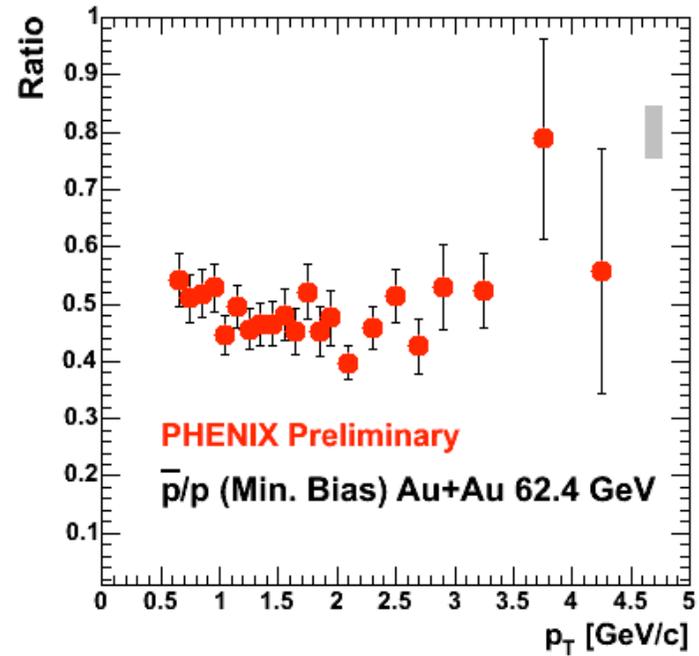
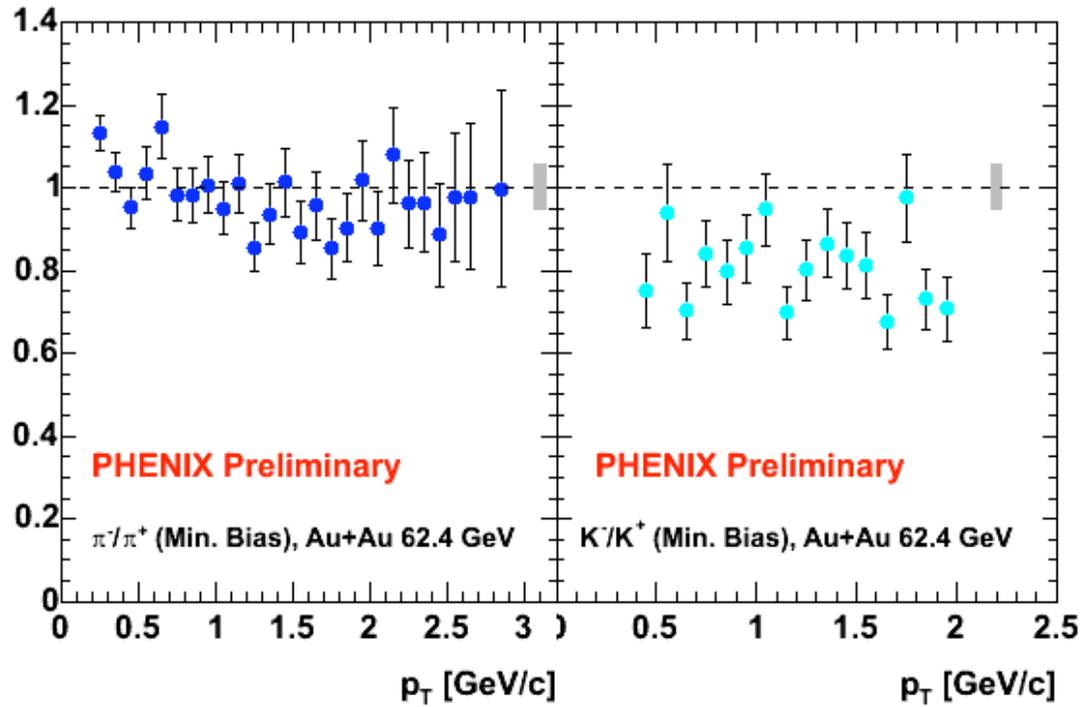
# $p_T$ Spectra

# Au+Au 62 GeV



# -/+ Ratios

## Au+Au 62 GeV



# -/+ Ratios (Centrality dep.)

Au+Au 62 GeV

