Can ϕ-mesons give an answer to baryon puzzle at RHIC ?

Julia Velkovska *(PHENIX)*

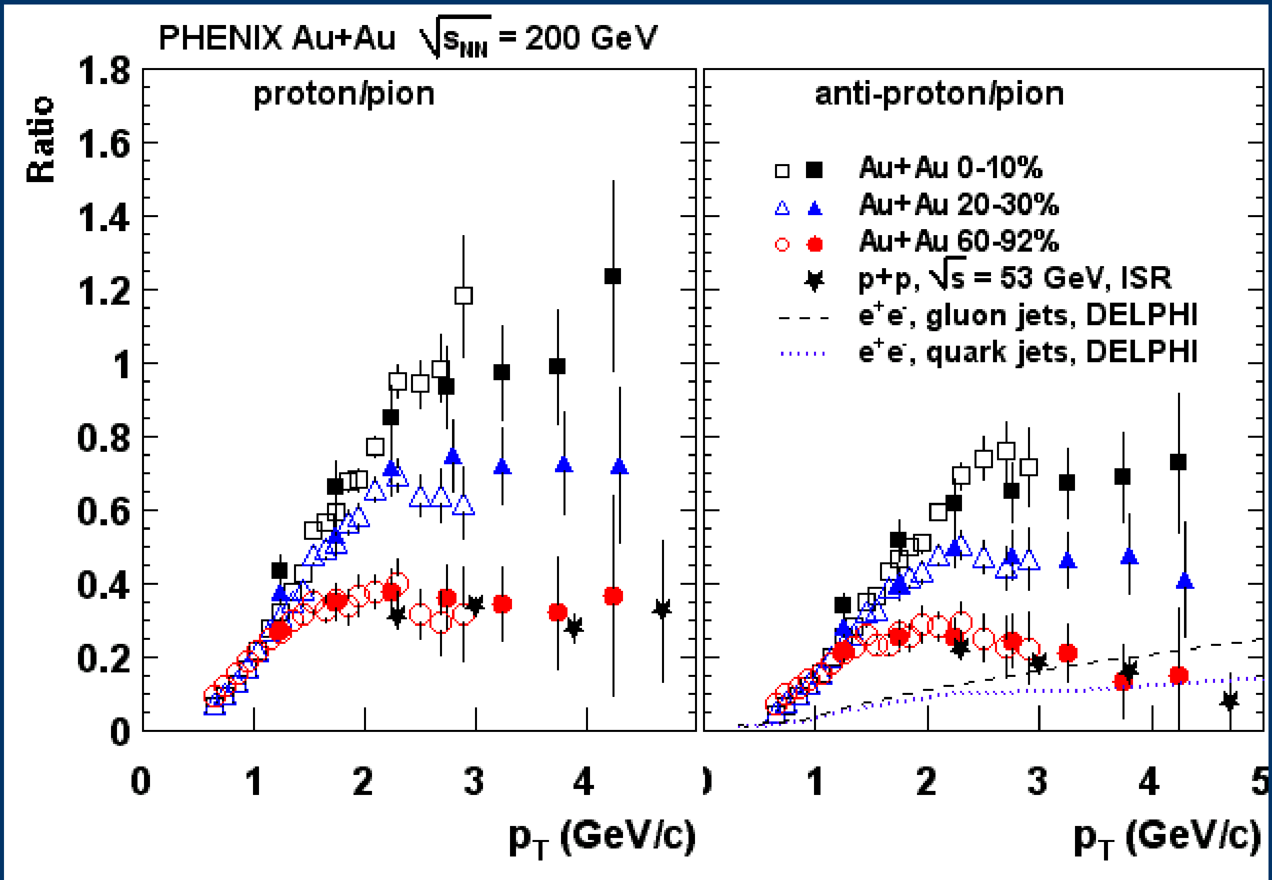
VANDERBILT UNIVERSITY

Outline

- What's puzzling about the baryons?
  - Particle ratios at high p_T
  - Scaling properties of yields
  - Jet correlations of baryons and mesons
  - Elliptic flow
  - The role of baryon transport
- Φ-mesons as test particles: mass vs baryon number
  - Does phi flow?
  - Centrality scaling of yields
  - Elliptic flow – prospects from run 4 data
- Conclusions

Large!!! baryon/meson ratios

Phys. Rev. Lett 91, 172301 (2003).

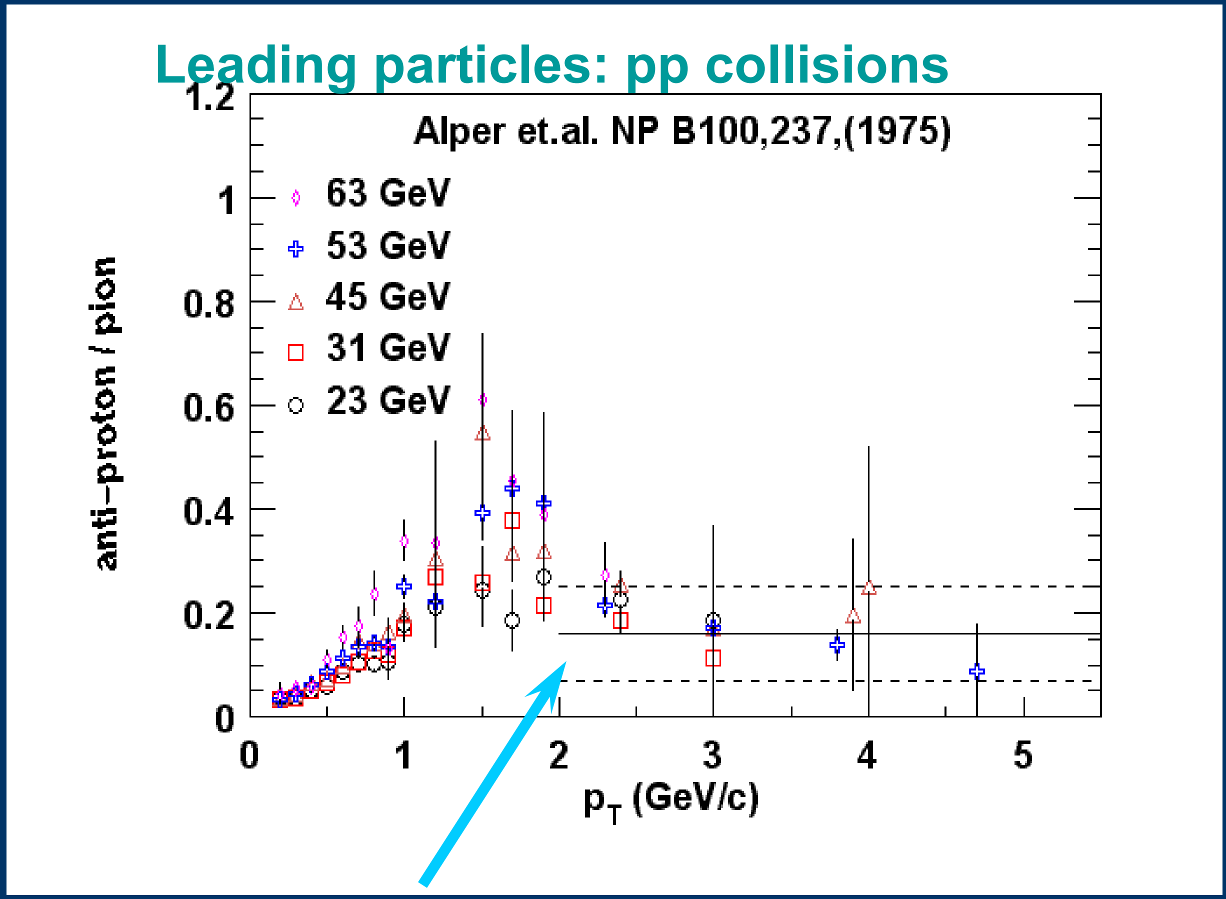


Peripheral: consistent with standard fragmentation

Central: a factor ~ 3 higher than peripheral, e^+e^- and ISR pp data

p and pbar at p_T 2-5 GeV/c : SOFT OR HARD ?

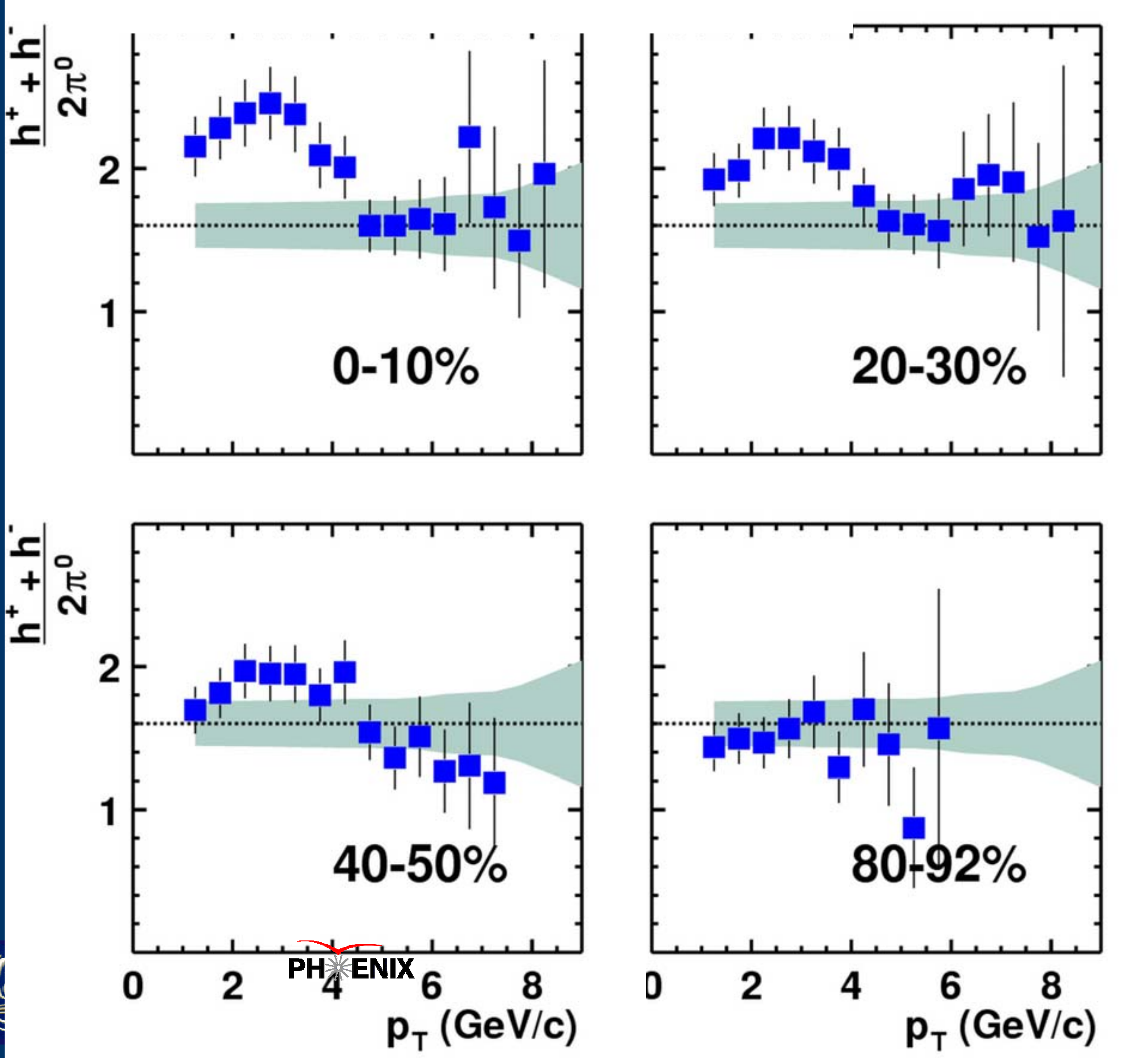
Standard fragmentation



Soft to hard transition in $\bar{p}/\pi$ ratio

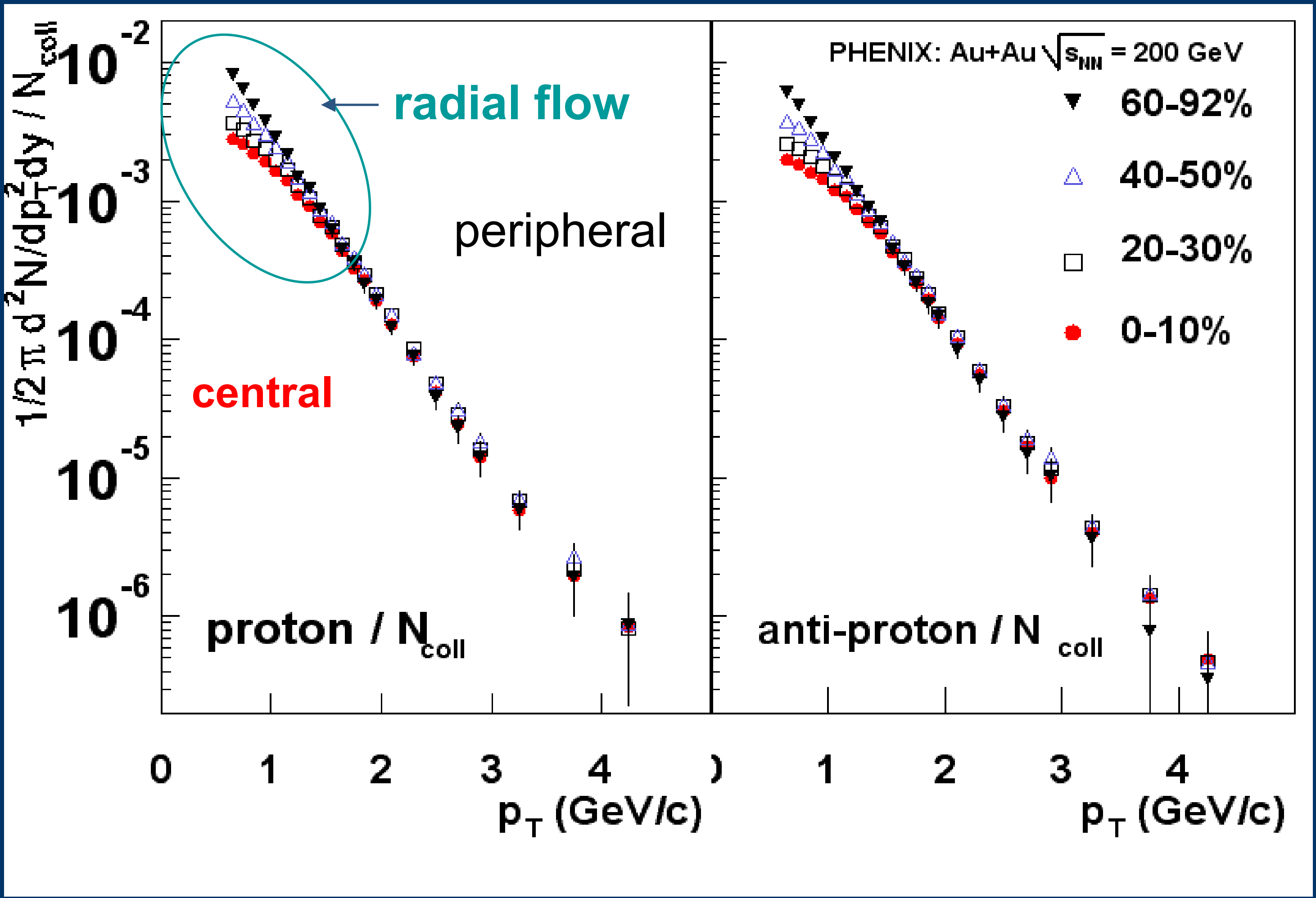
The proton "bump" in the h/π ratios

Au+Au @ 200AGeV nucl-ex/0310005



- **Expectation (pp, e^+e^-):** $h/\pi \approx 1.6$
- **Above 5 GeV/c and in peripheral collisions:**
  - **recover standard fragmentation**

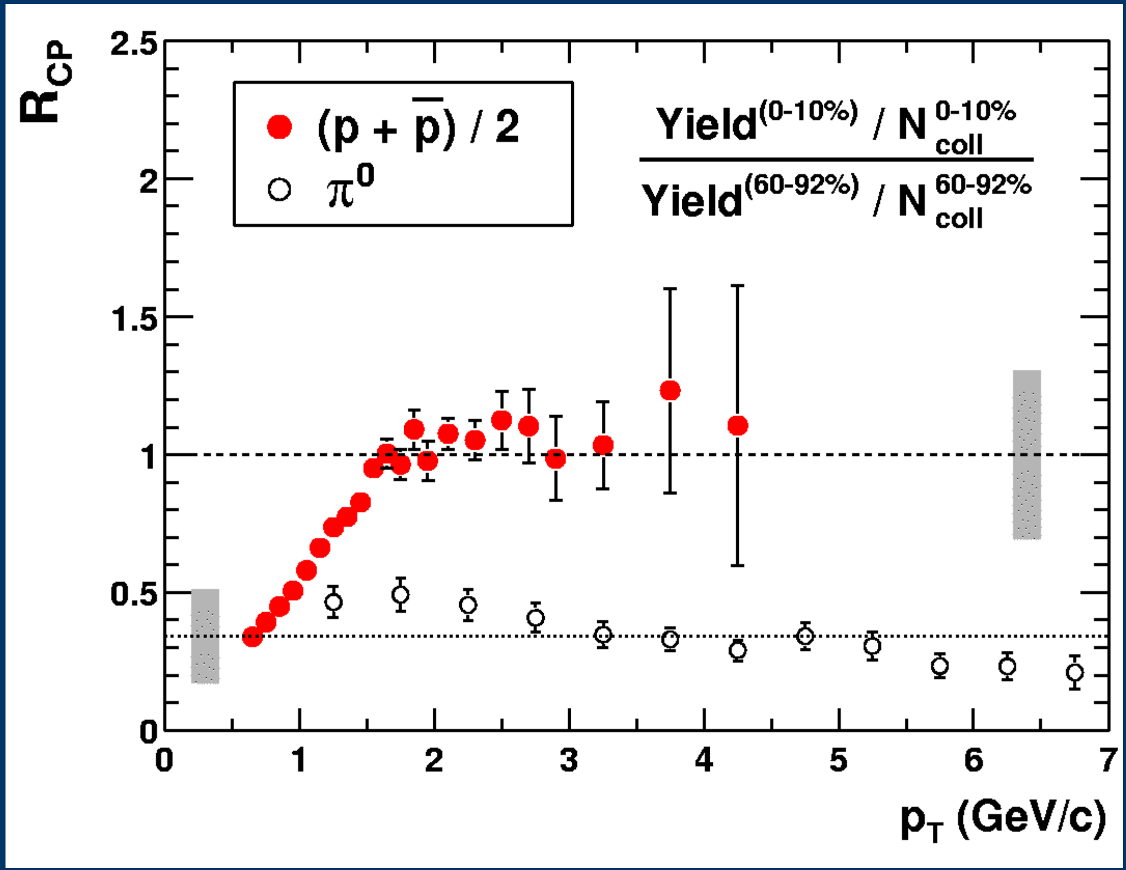
Protons and anti-protons scaled by N_{coll}



Does radial flow cause apparent N_{coll} scaling ?

Nuclear modification R_{cp}

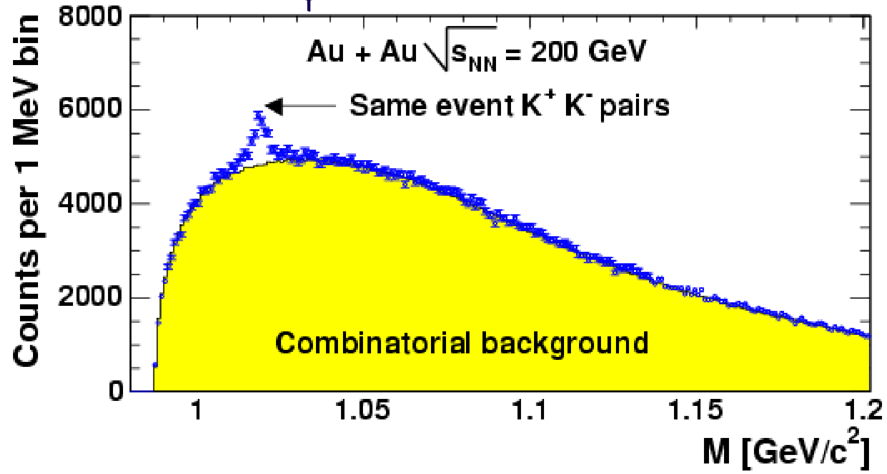
- Pions and (anti)protons are different!
- Mass or baryon number effect ?
- We need a heavy meson as a test particle.

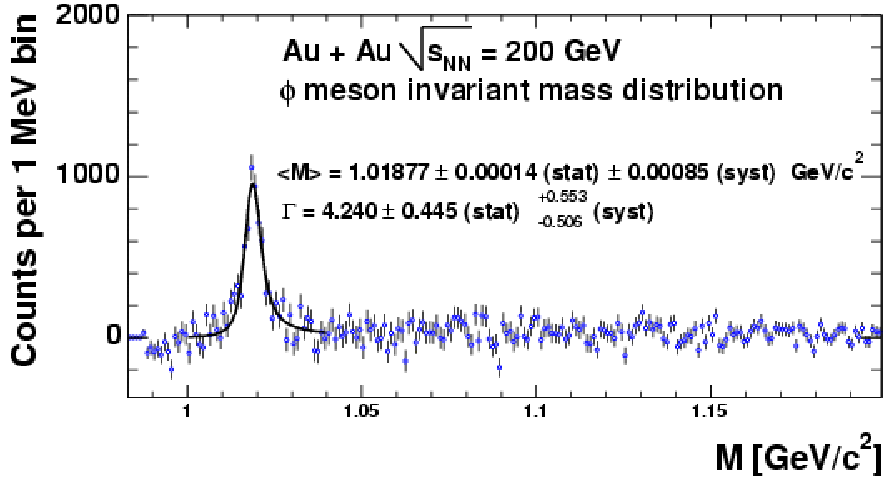


PHENIX

ϕ mesons in PHENIX

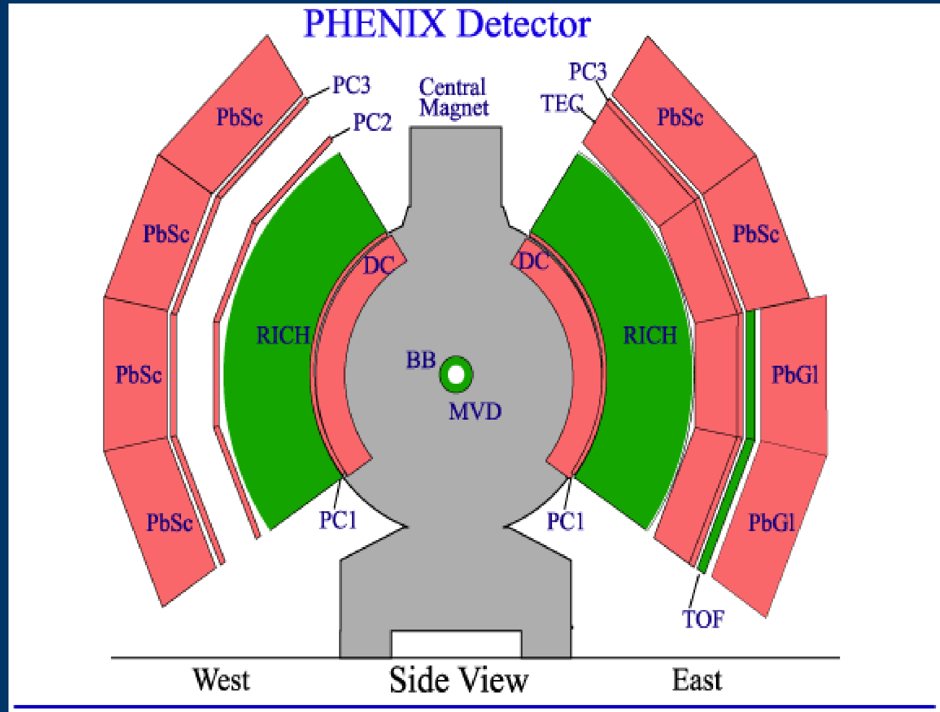
$\phi \rightarrow K^+K^-$



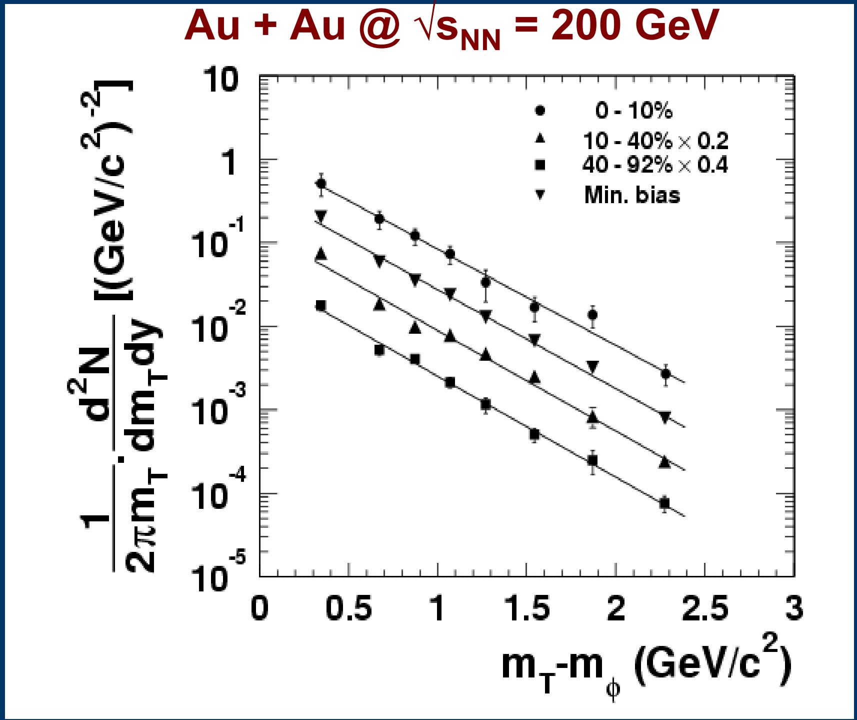


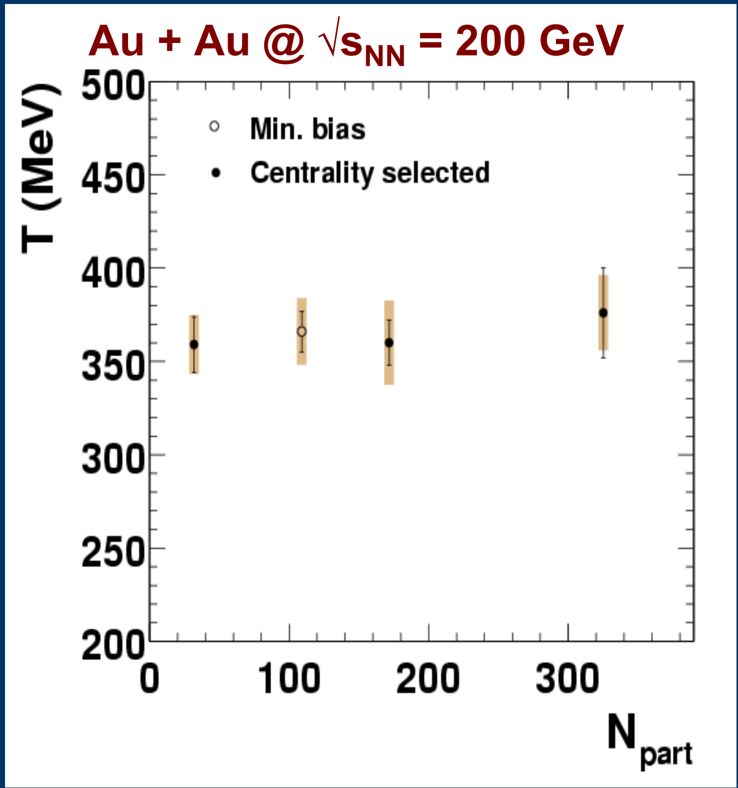
PHENIX (nucl-ex/0410012)

5100 ϕ reconstructed



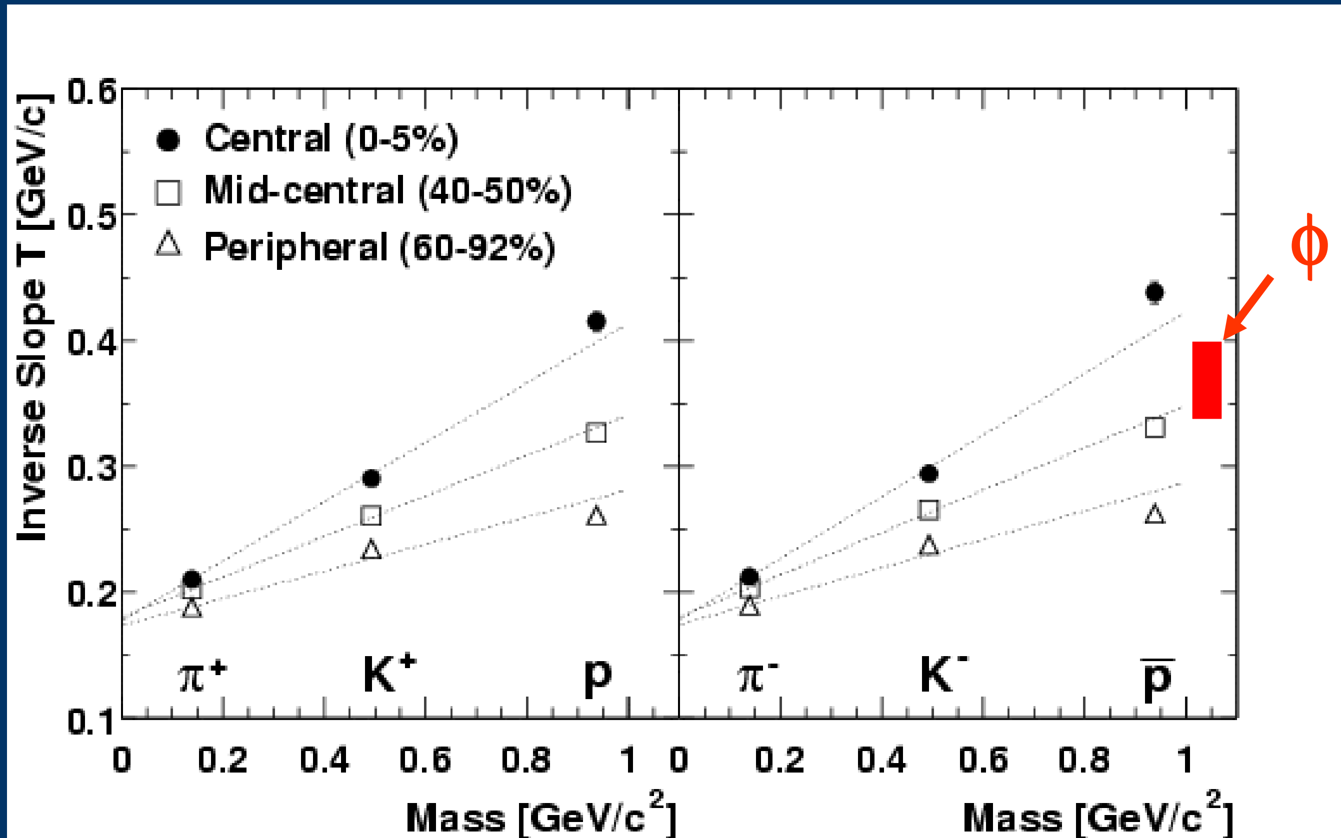
Φ transverse mass spectra





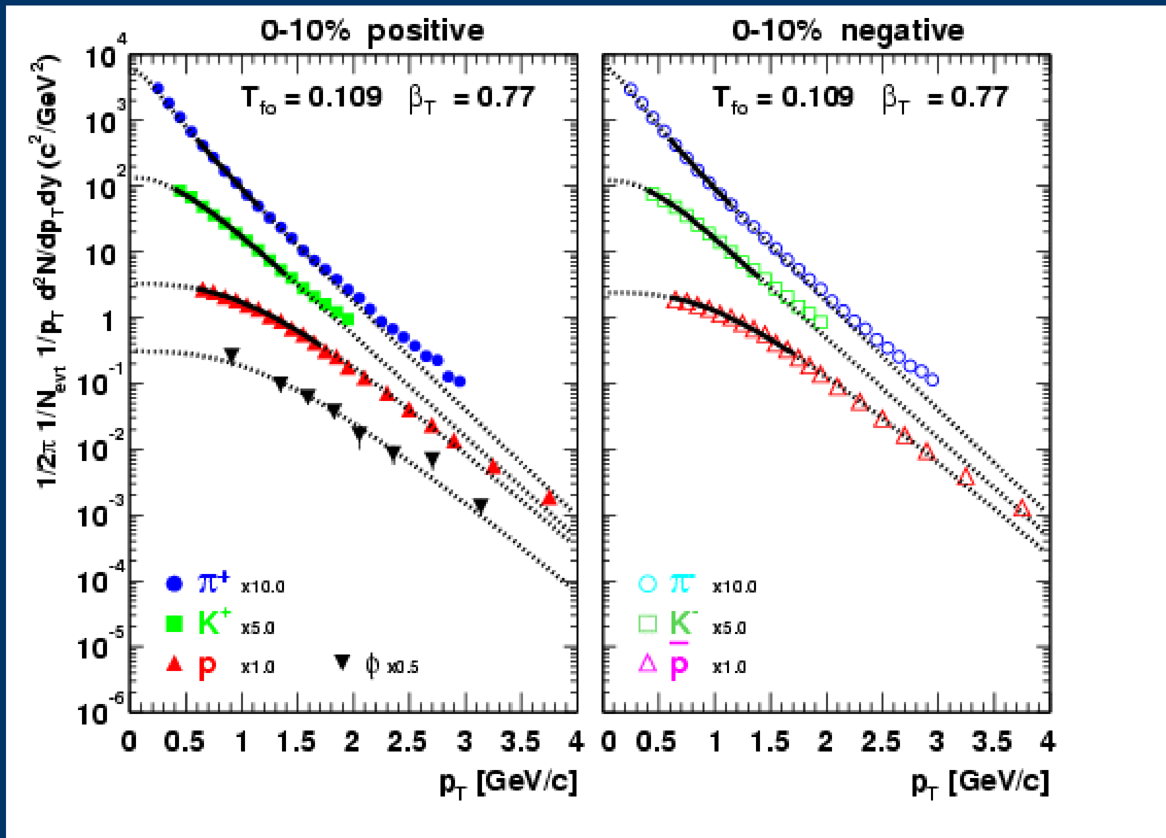
- **Measured in 4 centrality classes**
- **Shape is independent of centrality in the measured m_T range**
- **The crucial question: does ϕ flow ? If it doesn't, then it is NOT a good test particle (can not compare soft yields of protons and ϕ).**

Is there a discrepancy in the p and ϕ slopes ?



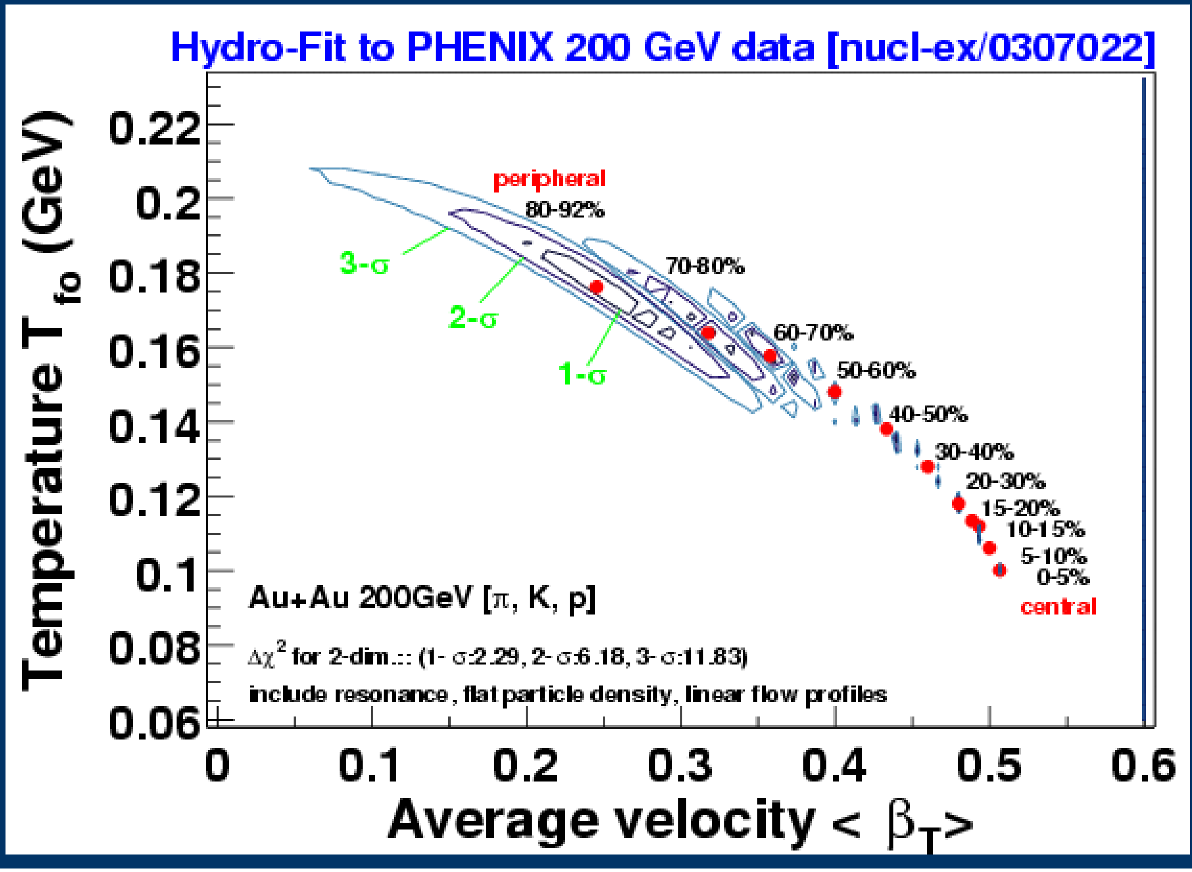
- π,K,p :fitting range: $0.1 < m_T - m_0 < 1$ GeV/c² → **Low m_T measured.**
- ϕ : $0.4 < m_T - m_0 < 2.5$ GeV/c²
- **Fitting range makes a big difference in the extracted slope!**

Hydrodynamics description of spectra



- **Two tests:** PHENIX (nucl-ex/0410012) Au + Au @ $\sqrt{s_{NN}}$ = 200 GeV
  - **Simultaneous fit of π,K,p and anti-particles: "predict "φ (shown above)**
  - **Simultaneous fit of π,K,p and anti-particles and φ.**
- **All spectra can be described by common T_{fo} and $<\beta_T>$**

Centrality dependence of hydro parameters



- T_{fo} and β_T vary with centrality, but the ϕ slopes are almost constant ?
- Answer: we measure ϕ spectra at high p_T – asymptotic behavior

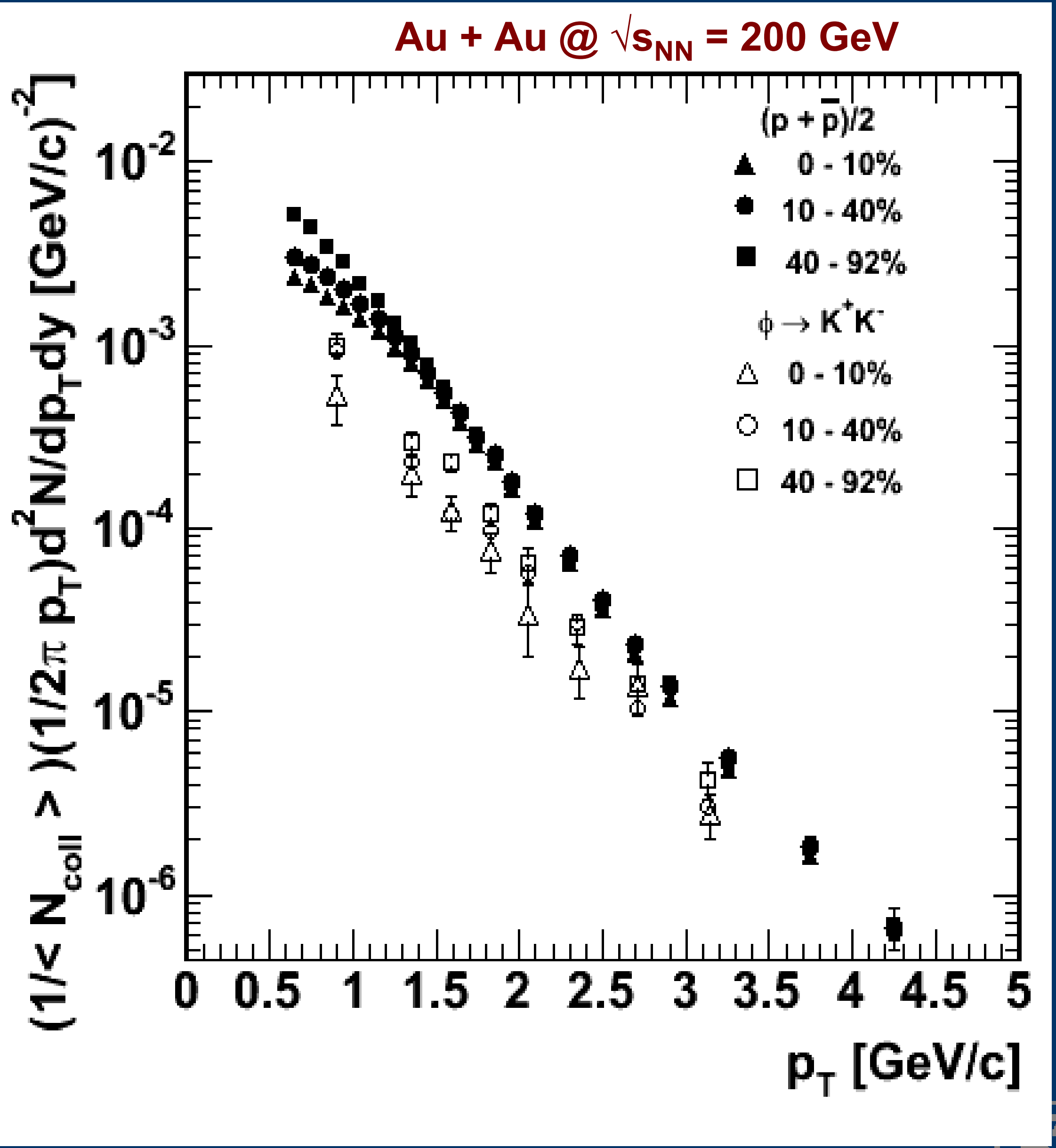
$T \sim T_{fo}$ sqrt $[(1+\beta)/(1-\beta)]$; β goes up, T_{fo} goes down with centrality

=> T is approximately constant independent of mass or centrality

Proton and ϕ meson spectra

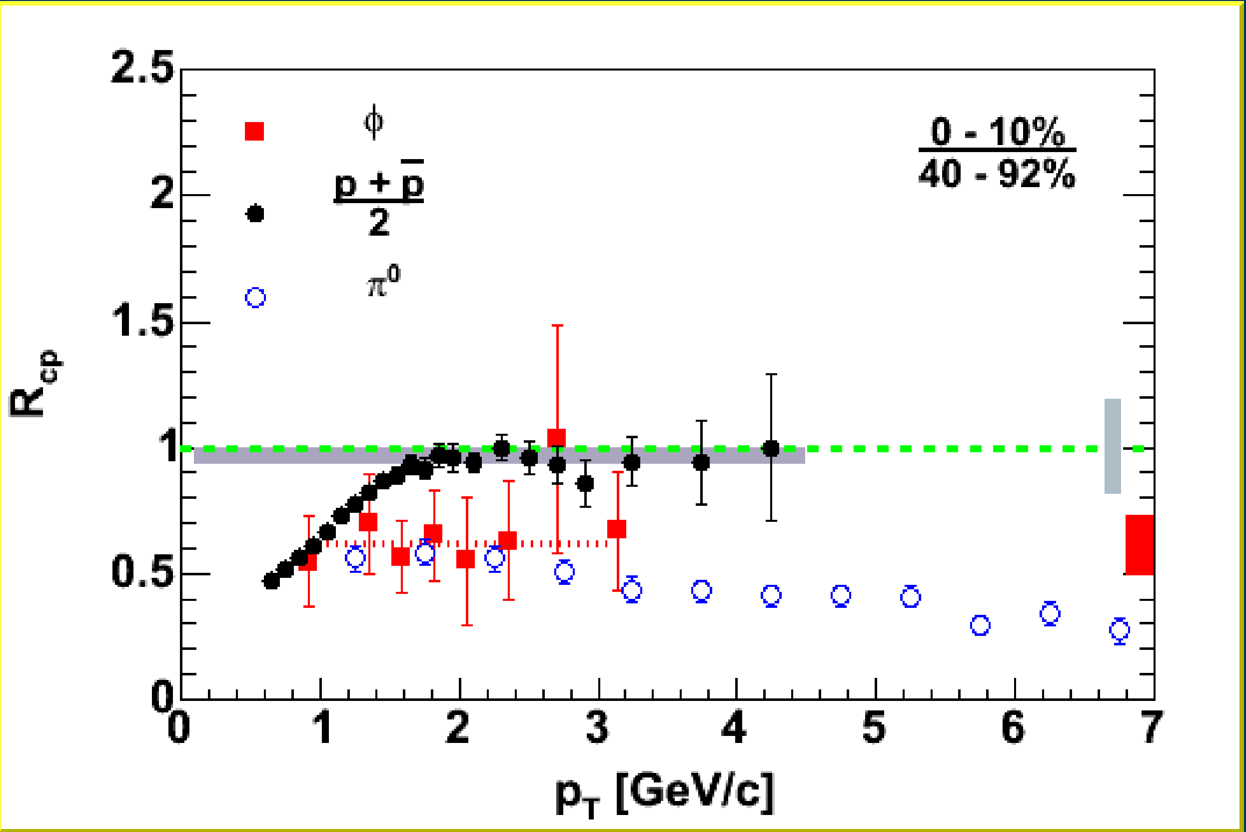
- **Spectral shapes of ϕ and p consistent with hydro**
- **But scaling of yields is very different**

PHENIX (nucl-ex/0410012)



Nuclear modification R_{cp}

$$R_{cp} = \frac{\text{Yield } (0-10\%)/N_{coll}(0-10\%)}{\text{Yield } (40-92\%)/N_{coll}(40-92\%)}$$



- Similar behavior for ϕ and π
- Consistent with recombination models

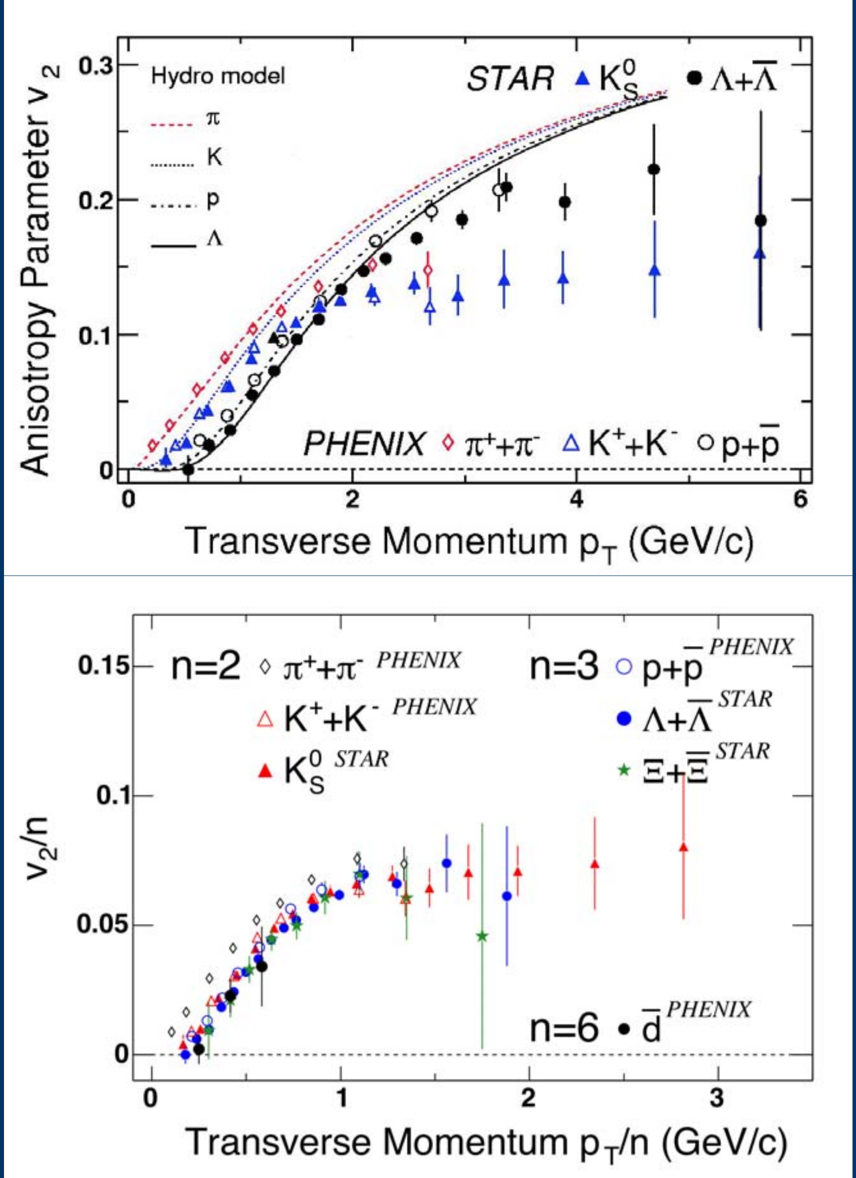
Elliptic Flow of baryons and mesons

At low p_T hydro works remarkably well

Above ~ 2 GeV/c : a split between mesons and baryons

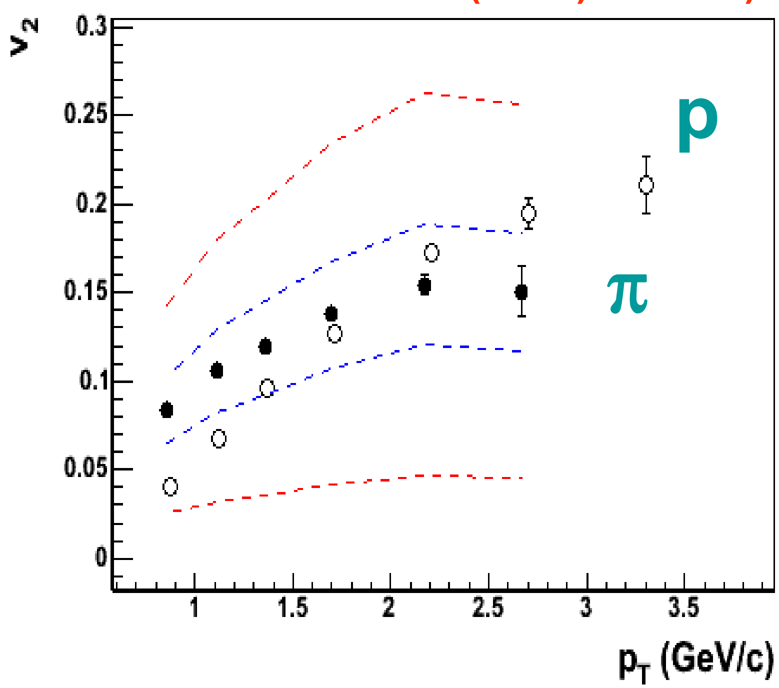
Universal behavior in flow per quark: expected from recombination

Need to measure v2 of ϕ



Scope to study v_2 of ϕ: Run4 data

PRL 91(2003) 182301).



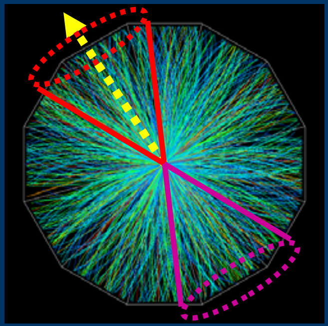
Run2 (Au + Au):
Predicted statistical error (~70%) on ϕ
[assuming $v_2(\phi) = v_2(\pi^-)$]

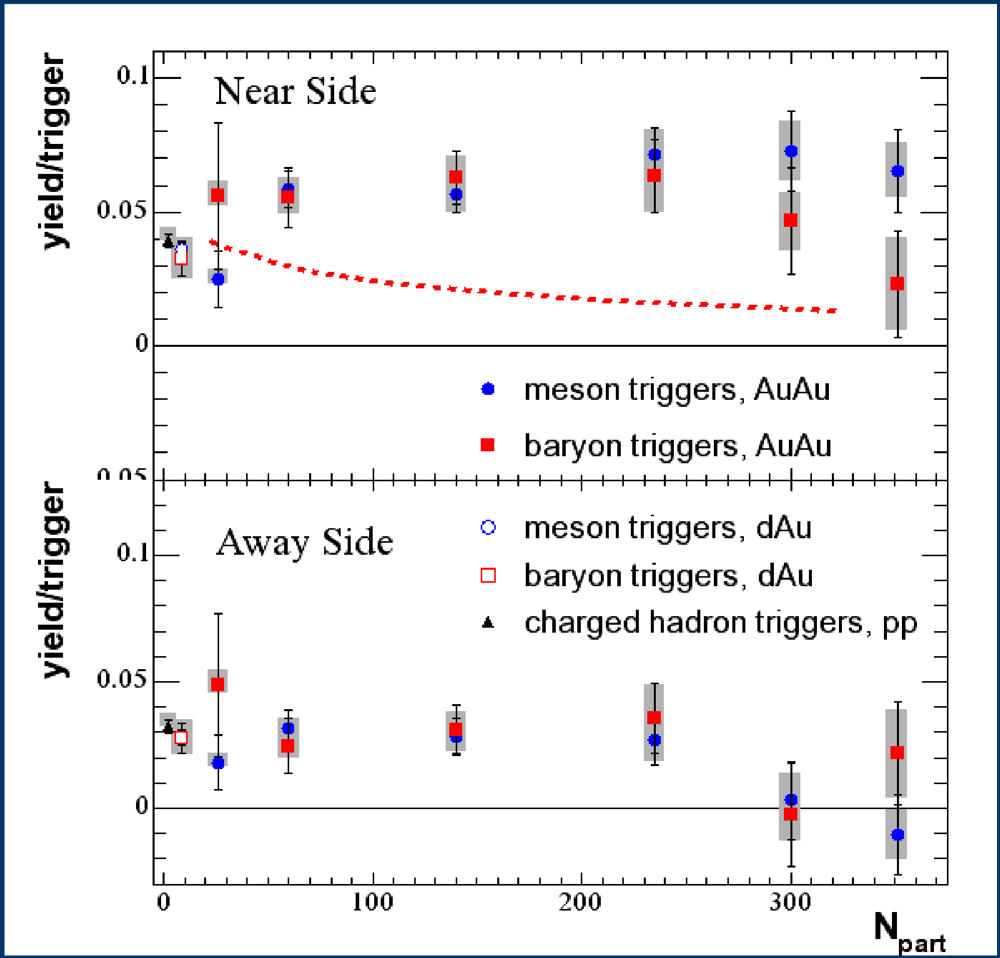
Run4 (Au + Au):
Predicted statistical error on ϕ [assuming $v_2(\phi) = v_2(\pi^-)$]

This assumes a factor of ~10 (very conservative) more available statistics in Run4 compared to Run2.

➔ Ability to measure a statistically significant v_2 of ϕ.

Jet correlations with identified mesons and baryons



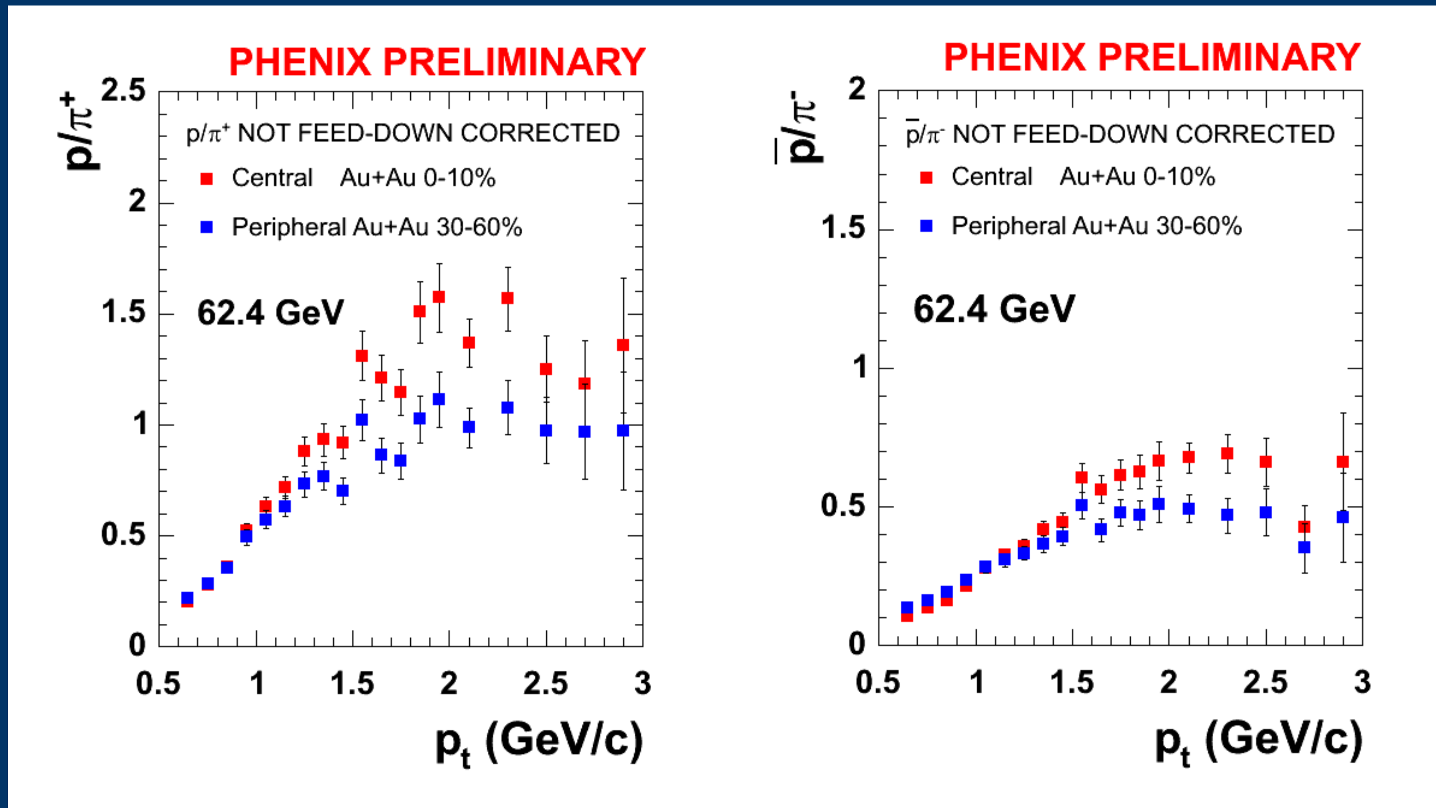


A. Sickles

- jet partner equally likely for trigger baryons & mesons
- ▪ ▪ ▪ expected from purely thermal recombination (nucl-th/0306027)

Need partons from jets to explain the data!!

The effect of baryon transport and pair production



- $p/\pi^+ > 1$, but p-bar/π^- ~ 0.7 (not feed-down corrected yet, so will go down from these values)
- p-bar/p = 0.495+/- 0.012(stat) +/- 0.029 (syst) PHENIX prelim
- Less pair production than at 200 GeV and less enhancement in p-bar/π !
- The transported baryons contribute out to high p_T

Conclusion

- We have observed enhancement of baryon production at intermediate p_T (2-5GeV/c)
- Strong radial flow
- N_{coll} scaling of proton/ anti-proton yields
- Similar jet-like correlations with trigger baryons and mesons
- Elliptic flow of protons exceeds v2 of pions at $p_T > 2$ GeV/c
- Φ –meson spectral shapes consistent with common flow for all particle species
- Φ–meson centrality scaling of yields is consistent with that of pions – lends support to recombination models
- Baryon transport influences the baryon/meson ratios out to high p_T

- Extra

Fragmentation from Z^0 decay

PHYSICAL REVIEW D, VOLUME 59, 052001

$X_p = p_{hadron}/E_{beam}$

here: $E_{beam} = 1/2M_Z{}^0$

$D_z(z,Q^2)$

$z = p_{hadron}/p_{quark}$

So, $z = x_p$

For the p_T range considered here,

RHIC 200 GeV <z> ~ 0.6-0.7

	π	p	ϕ
$1/N\ dN/dx_p$	0.145	0.02	0.017

$p/\pi \sim 0.14$

$\phi/\pi \sim 0.12$