Bulk Properties and Flow

Conference Highlights

Zhangbu Xu

BNL

Disclaimer: since the scientific results presented in this conference are overwhelming, there is no way I will be able to summarize all the important physics in 30minutes. I would only present some selected highlights and they are personally biased!

Outline

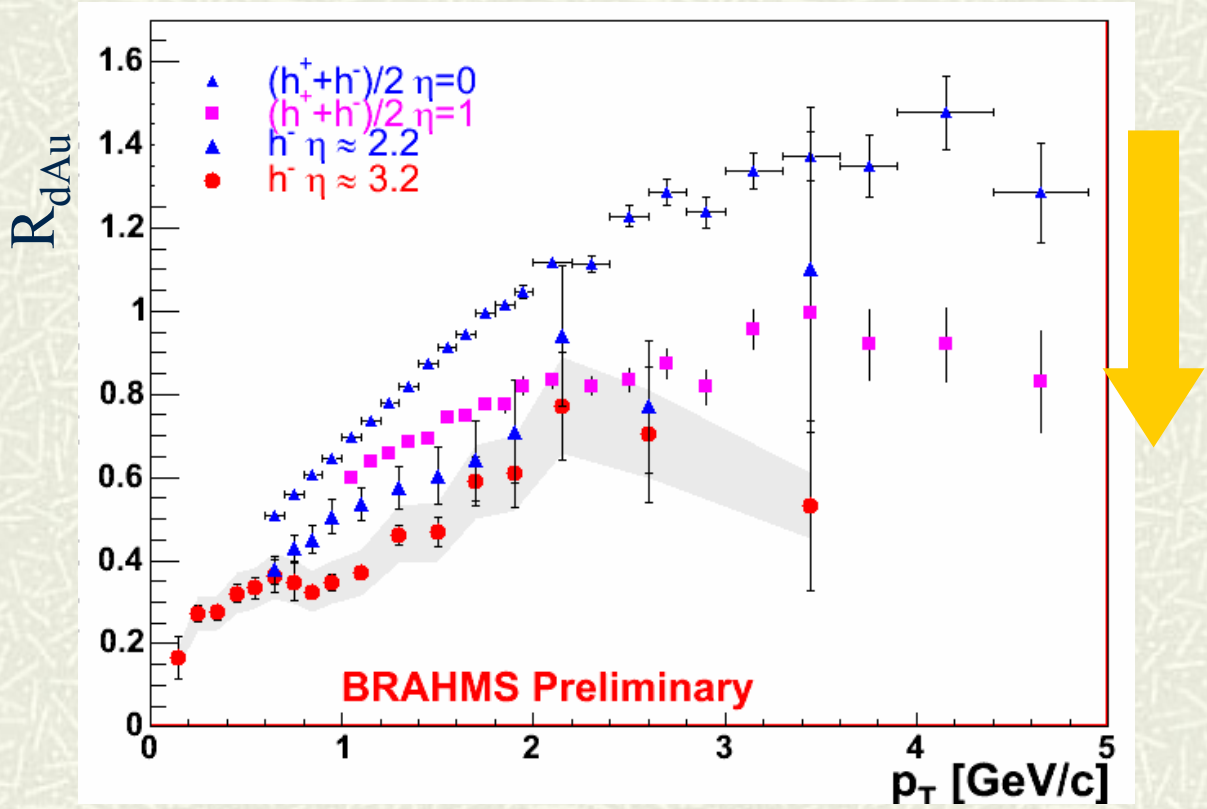
- Global Observables
  - Multiplicity (-5⟨η⟨5)
  - Forward Rapidity

  } Initial Condition (CGC, stopping)
- Particle Yields and Spectra
  - Chemical Properties
  - Radial Flow and Freeze-outs
  - Particle Compositions at intermediate pT p+p⇒d+Au⇒Au+Au
- Anisotropic Flow
  - Decomposition of the anisotropy (vn)
  - Identified Particle v2

  } Partonic Collectivity
- Low pT "jet" Spectra
  - Energy loss and thermalization
- Summary and Outlook

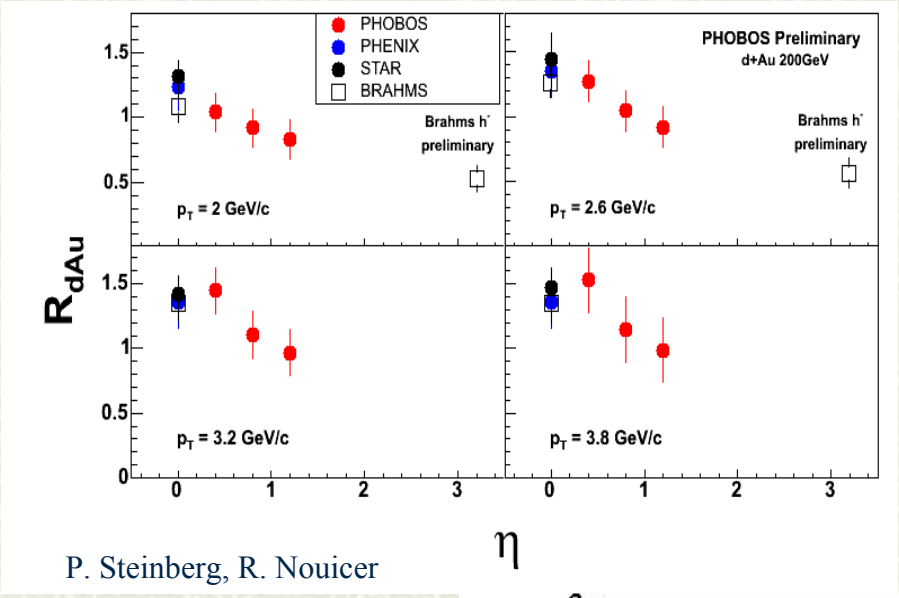
Thermalization

Forward Spectra in d+Au

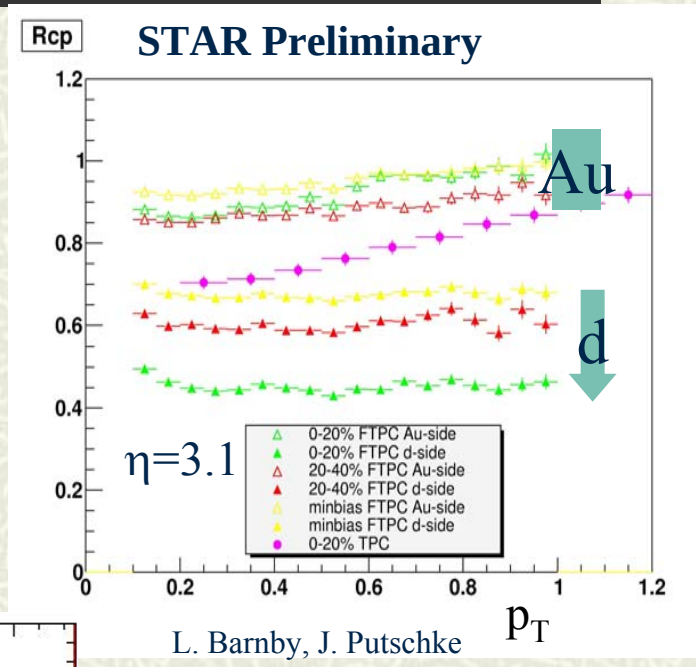


R. Debbe, M. Murray

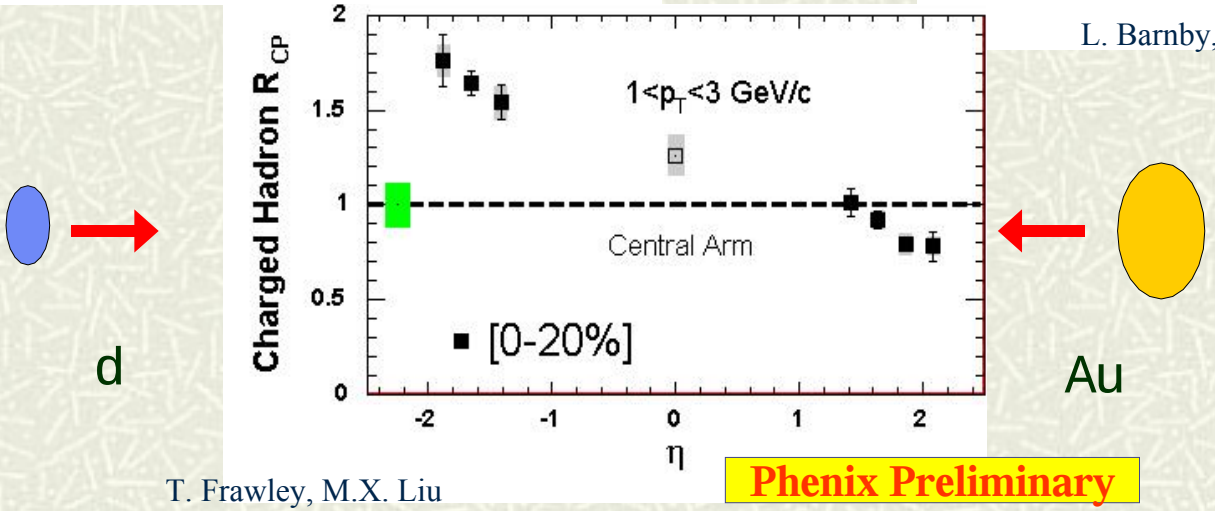
Forward Spectra in d+Au



P. Steinberg, R. Nouicer

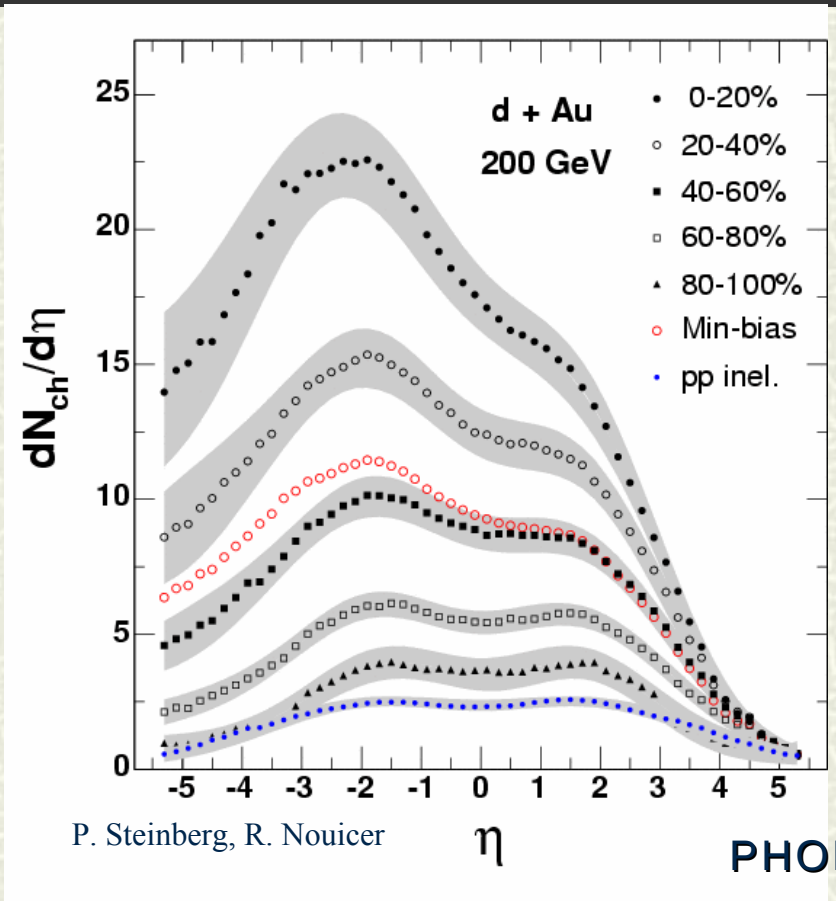


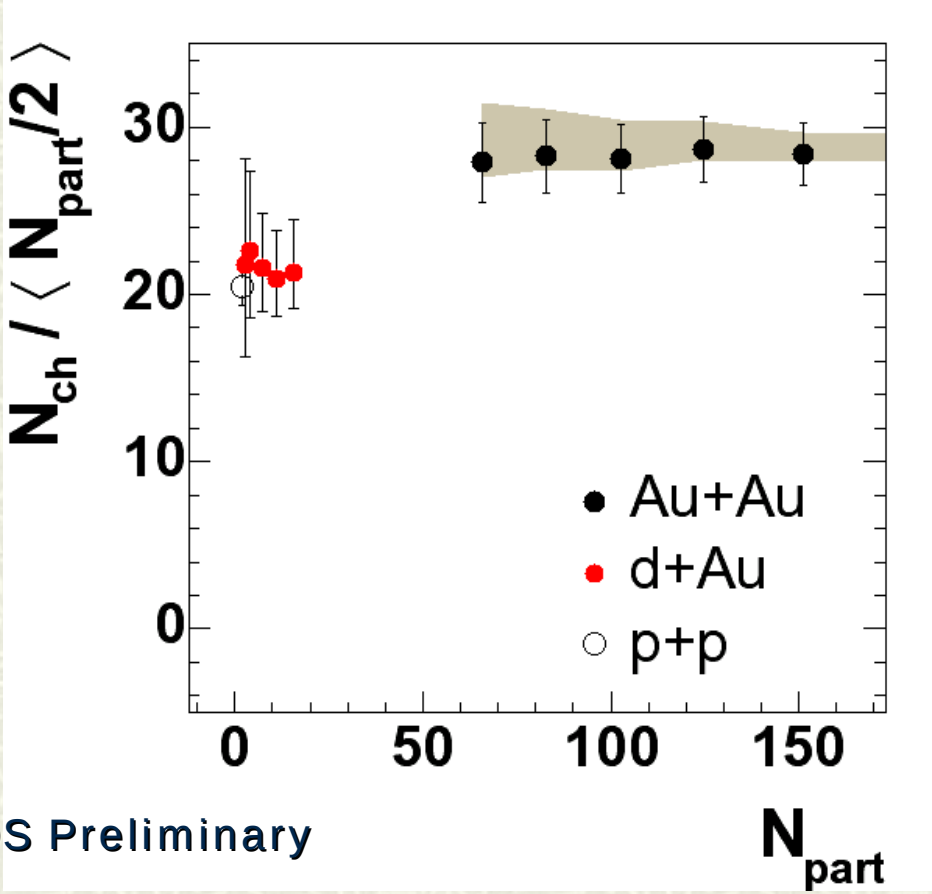
L. Barnby, J. Putschke



T. Frawley, M.X. Liu

d+Au dN/dη

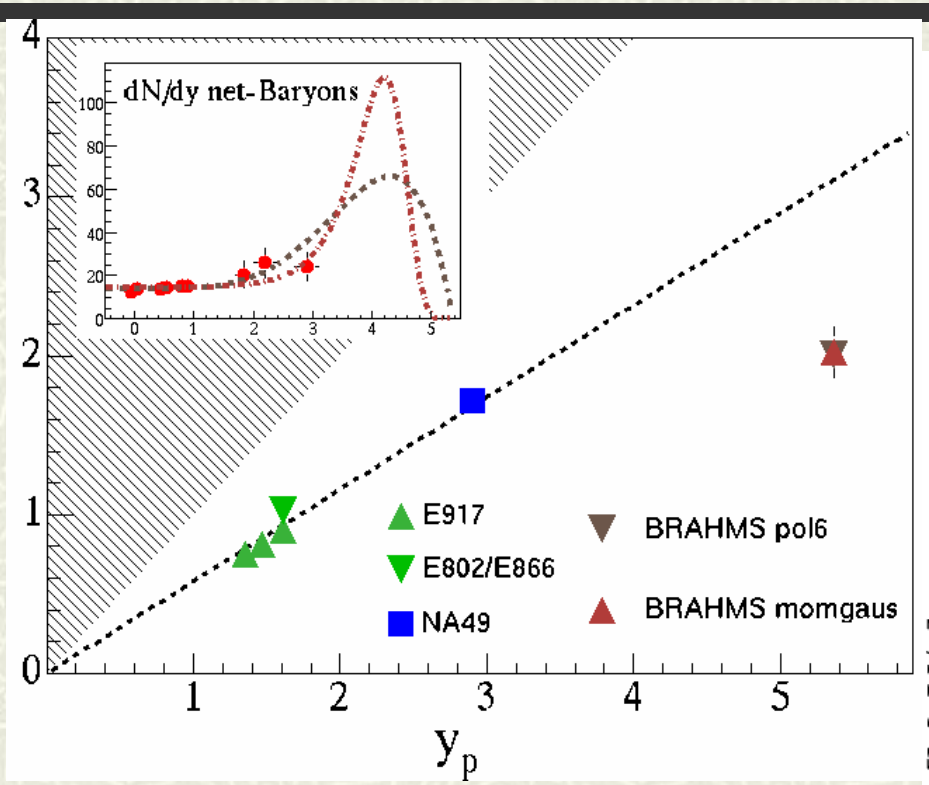


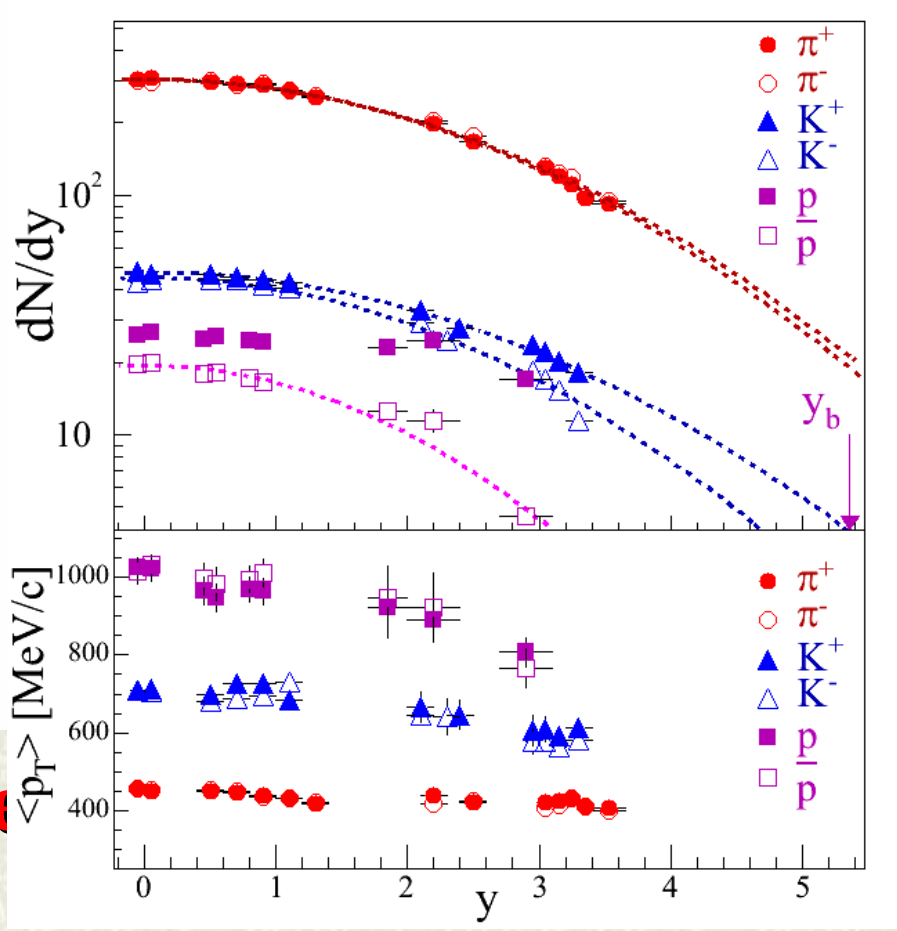


- Multiplicity (η, N_{part}) (PHOBOS, BRAHMS, STAR, PHENIX)

Where do the projectile nucleons go?

Rapidity Loss



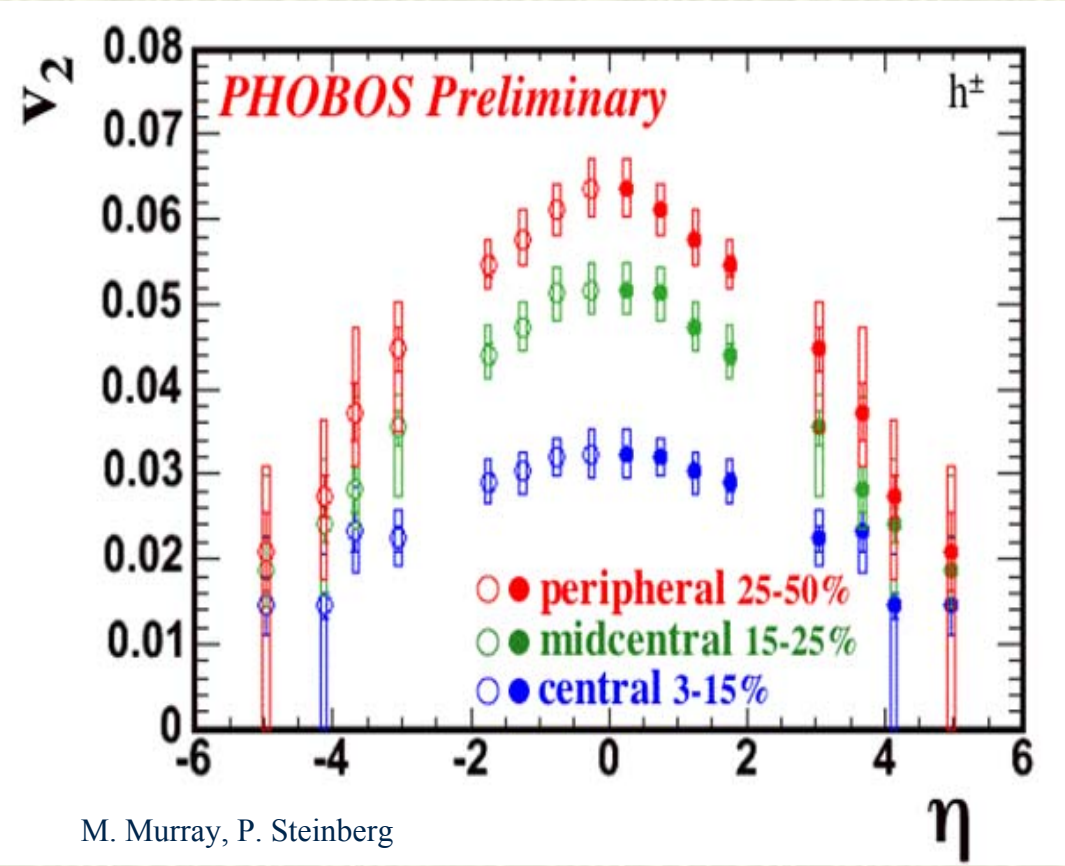


25 ± 1 (25 ± 5) TeV is stoppe
for particle production

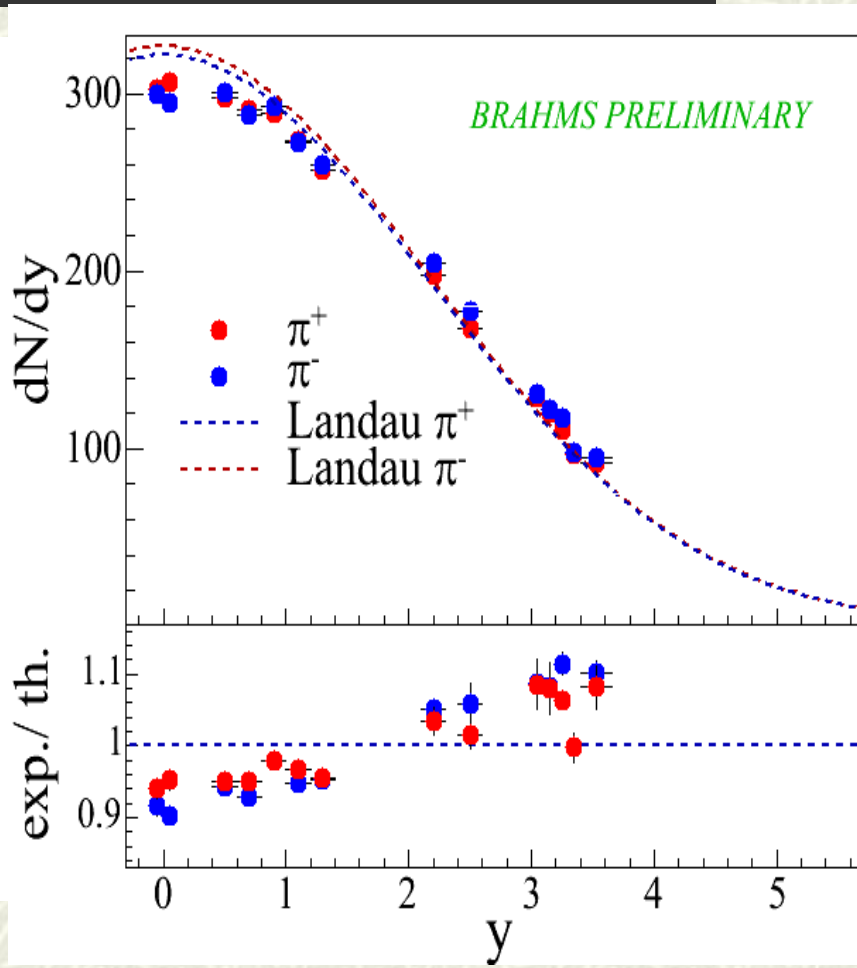
72 GeV/N!!!

D. Ouerdane, M. Murray

Particle Production Along the Beam Axis



M. Murray, P. Steinberg



Strong rapidity dependence
Multiplicity & flow correlated

Measured σ =2.26±0.02

Observations

1. Energy stopped per nucleon(BRAHMS)
   Au+Au 0.72
   p+p 0.5
   Leading hadron energy from Fragmentation: 0.75
   Au+Au/p+p = 0.72/0.5=1.44
2. Charged Multiplicity/Participant
   Au+Au, e^+e^- ~28
   p+p, d+Au ~20
   Au+Au/p+p = 28/20=1.4
3. dN/dy Gaussian (BRAHMS)
   $\sigma = \mathrm{sqrt}(\ln(\gamma_{beam}))=2.16$
   Measured $\sigma = 2.26 \pm 0.02$
4. v2 "Gaussian" (PHOBOS)

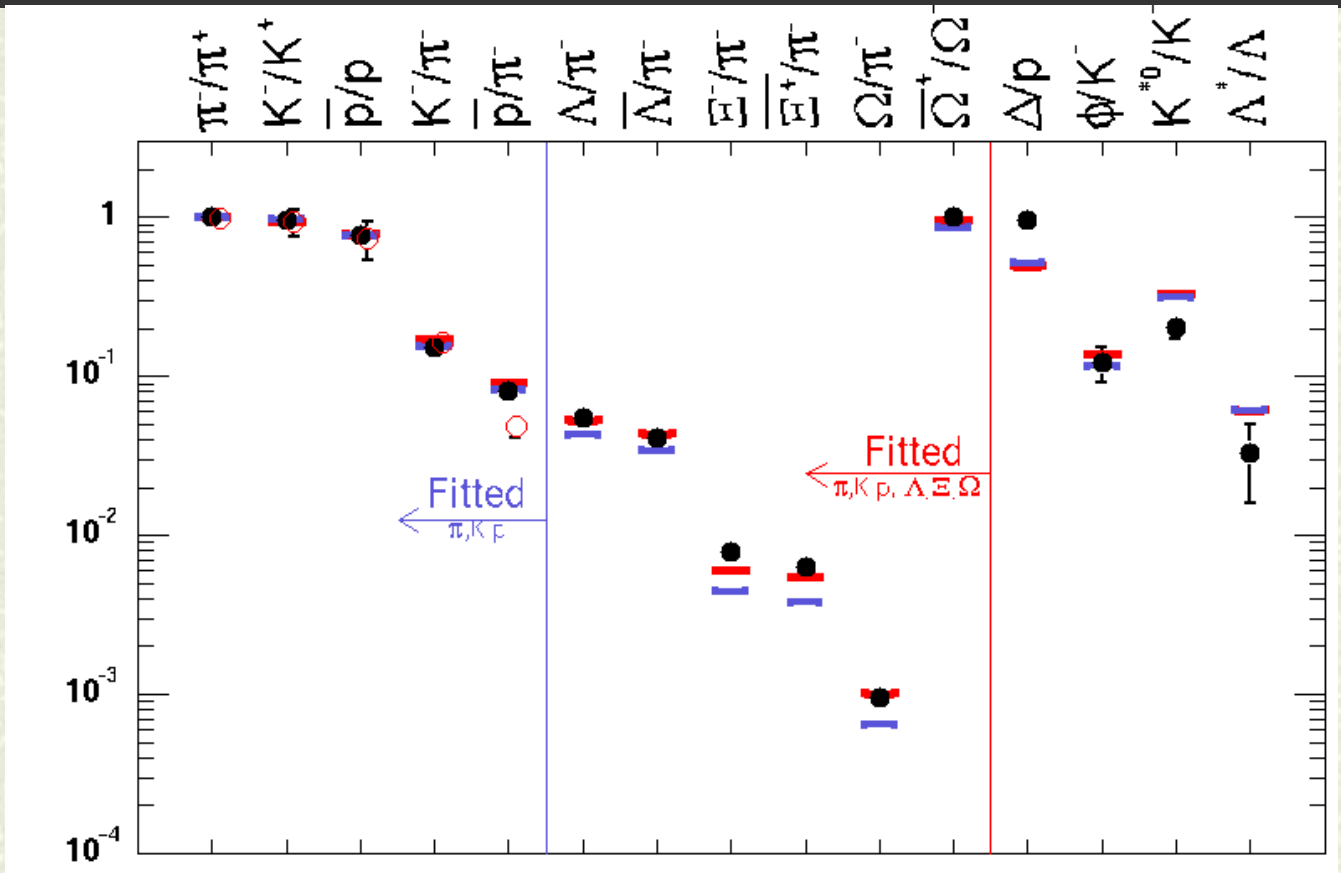
Related??

Bjorken, Landau???

M. Murray, P. Steinberg, F. Wang, J. Dunlop

Chemically Thermalized?

STAR
PHENIX



K. Schweda, O. Barannikova

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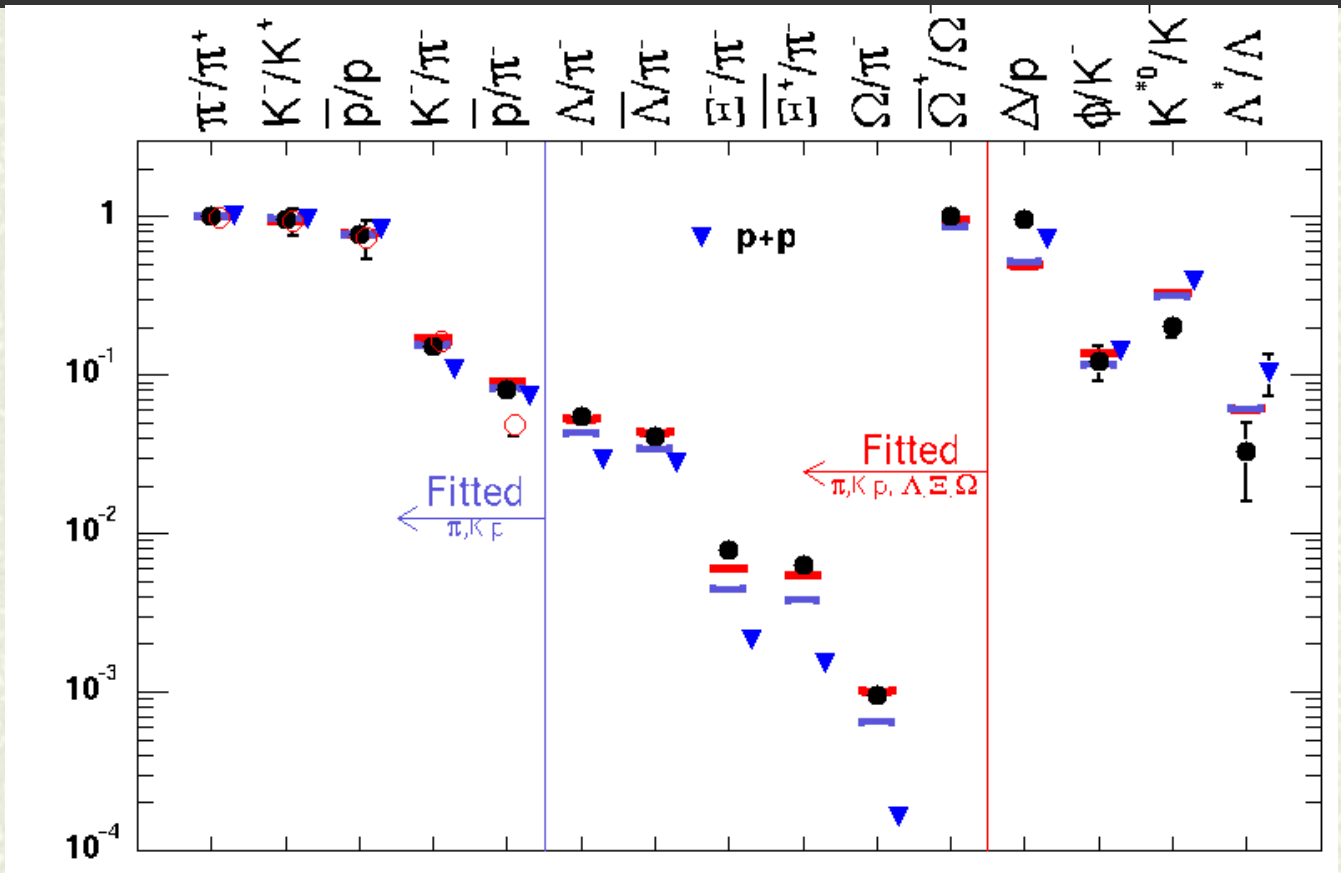
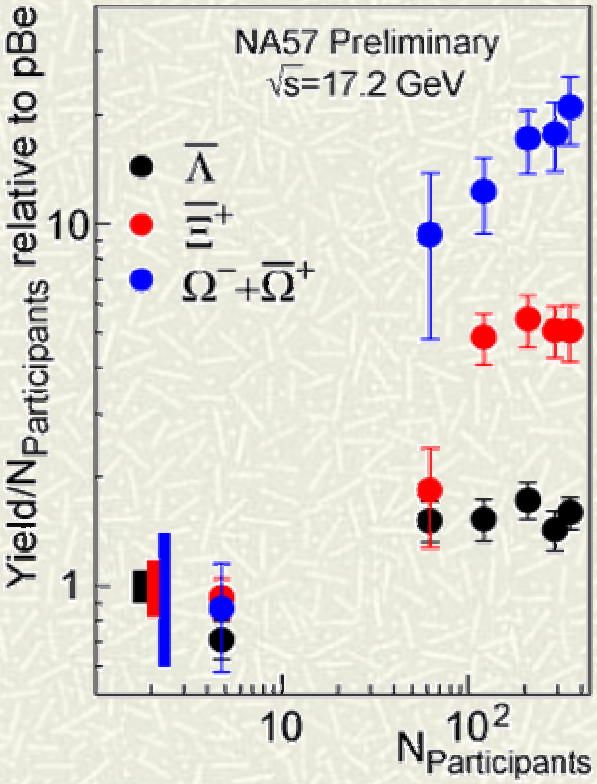


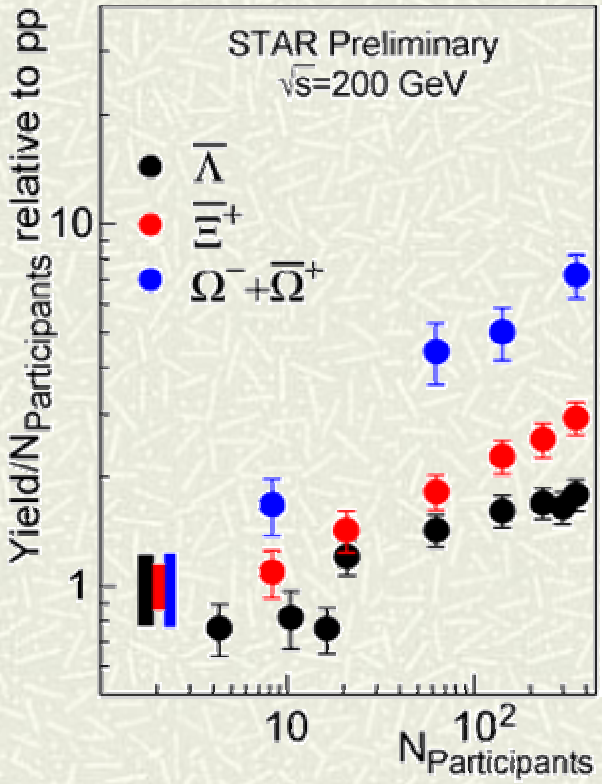
Strangeness Enhancement **Resonance Suppression**

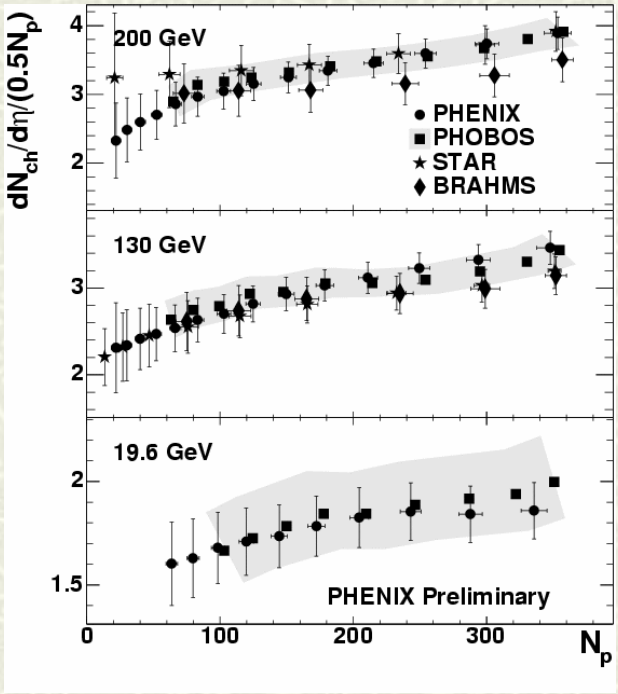
Au+Au, p+p, Thermal Fit; Feed-down

K. Schweda, O. Barannikova

Strangeness Production





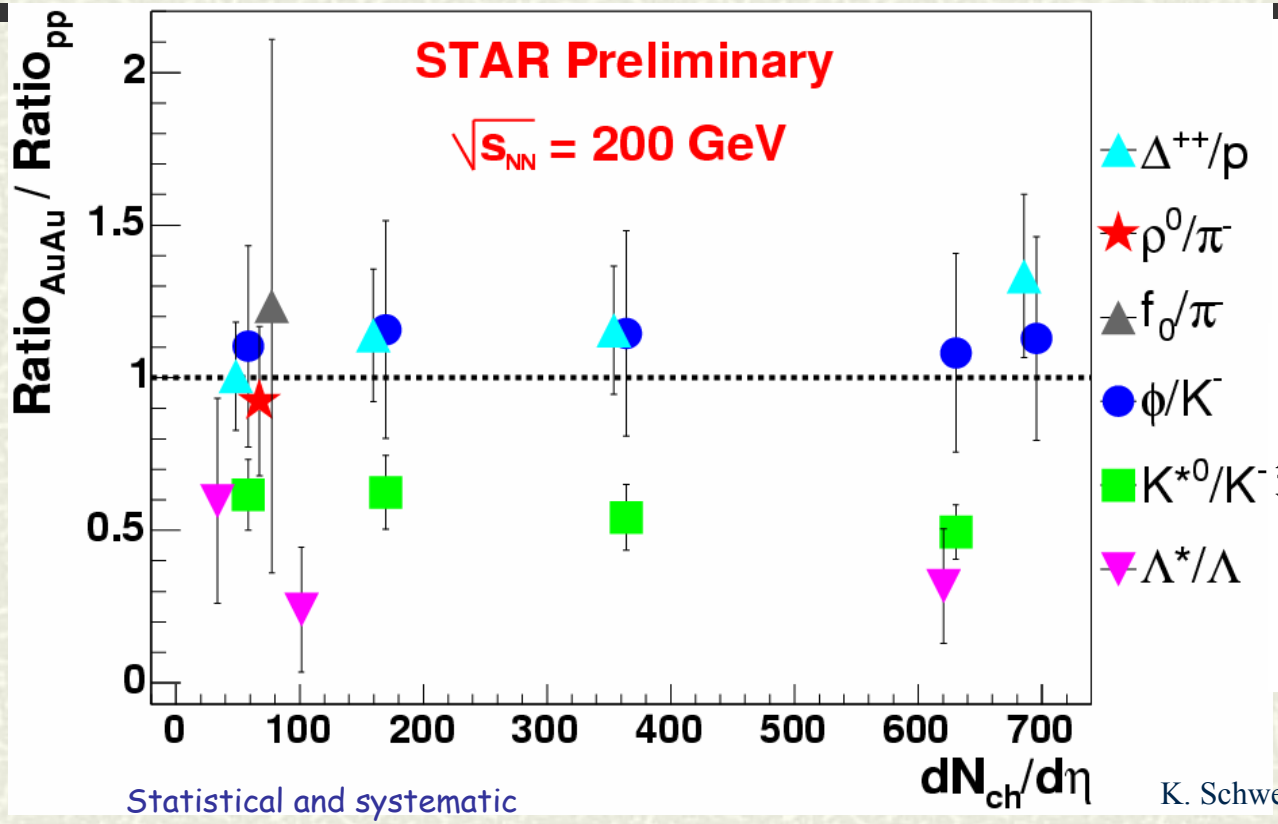


F. Antinori, G. Bruno,S. Milov, K. Schweda

Log scale

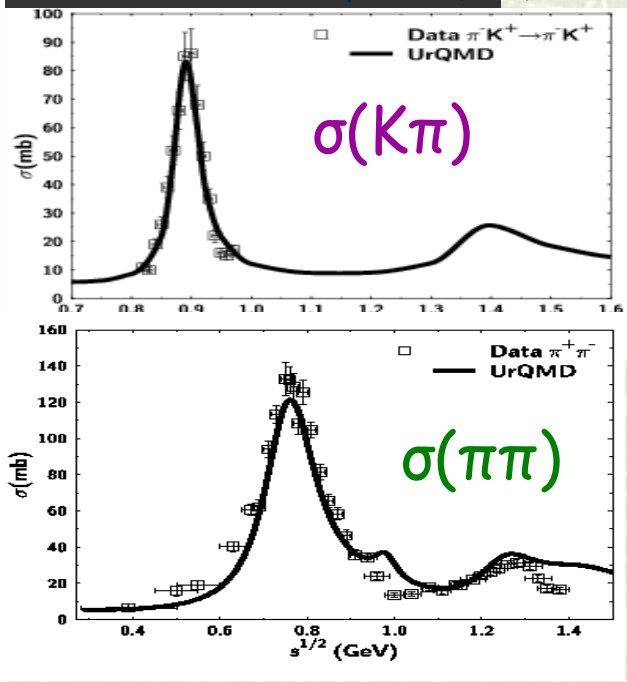
- Strangeness reaches **GRAND Canonical?**
- What is the right reference: **N_{part}, Nch, E_T**

Resonance driven by Cross Section



Statistical and systematic errors added in quadrature

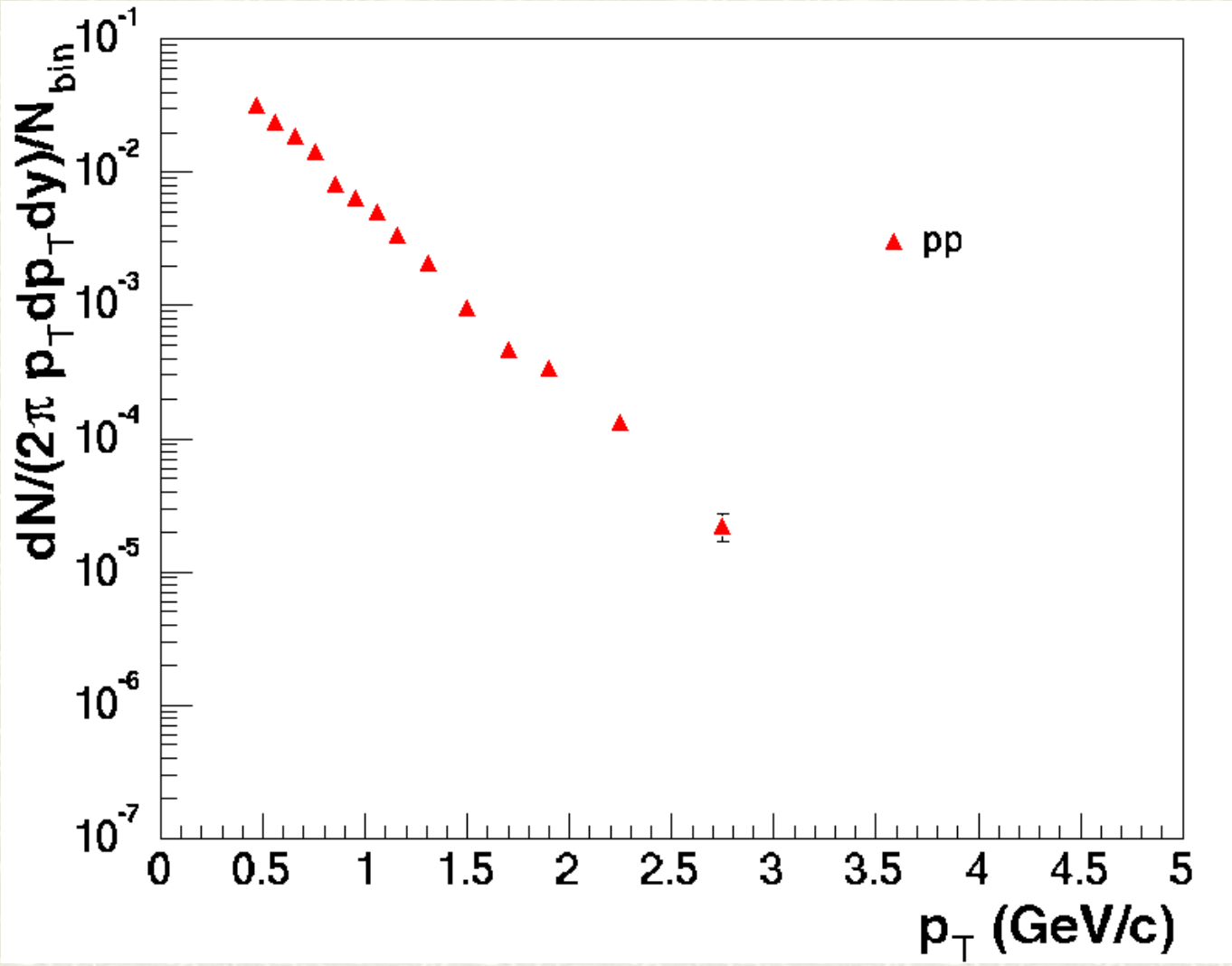
M. Bleicher *et al.* J. Phys. G 25 (1999) 1859



K. Schweda, P. Fachini, C. Markert, H. Zhang

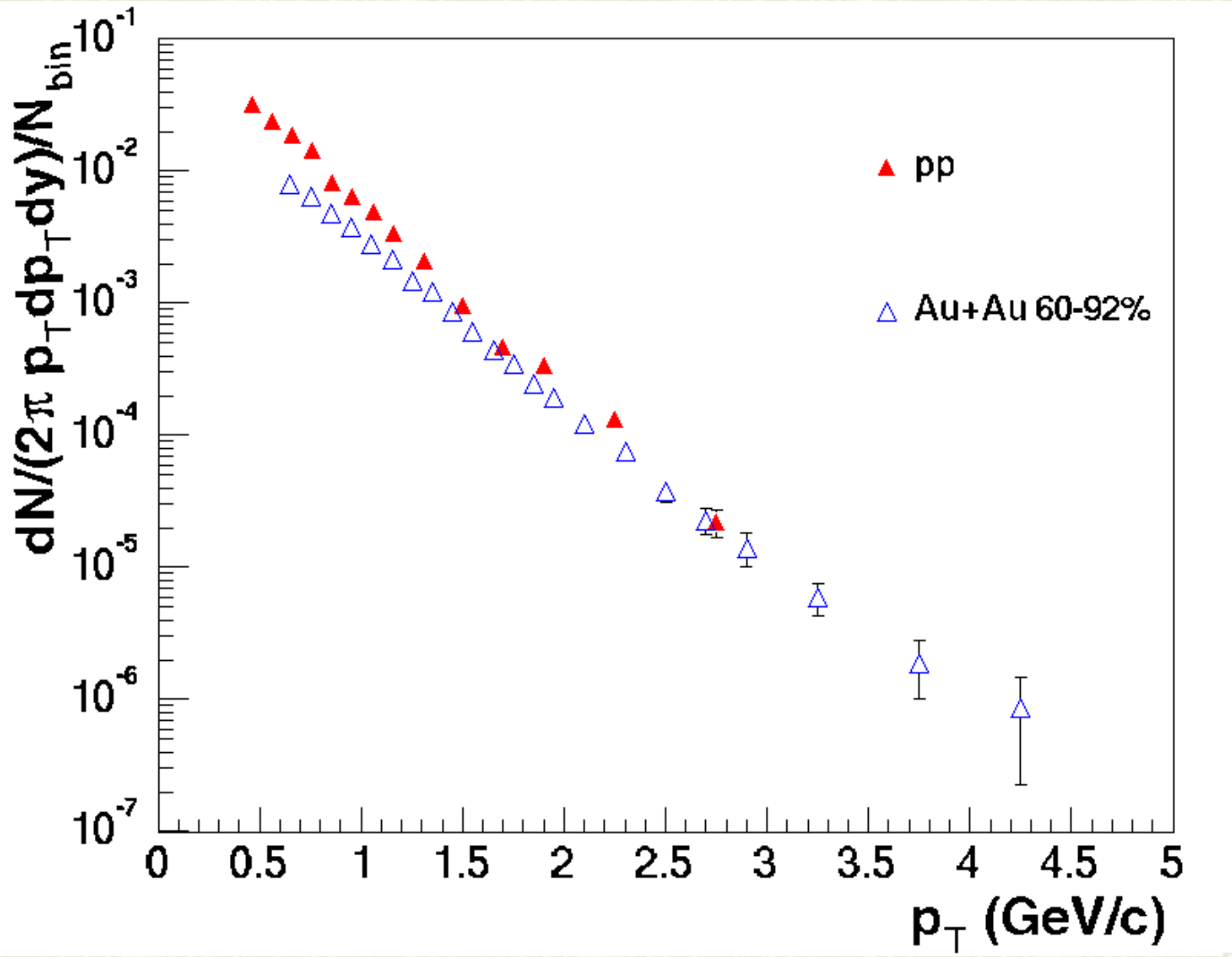
- Finite Interaction Cross Section ⇒ Breakdown of Ideal fluid?
- Different Cross Section ⇒ regeneration or rescattering ?
- Different Cross Section ⇒ Flow at hadron stage

Flow Effect on Spectra



PHENIX,
STAR Preliminary

Flow Effect on Spectra



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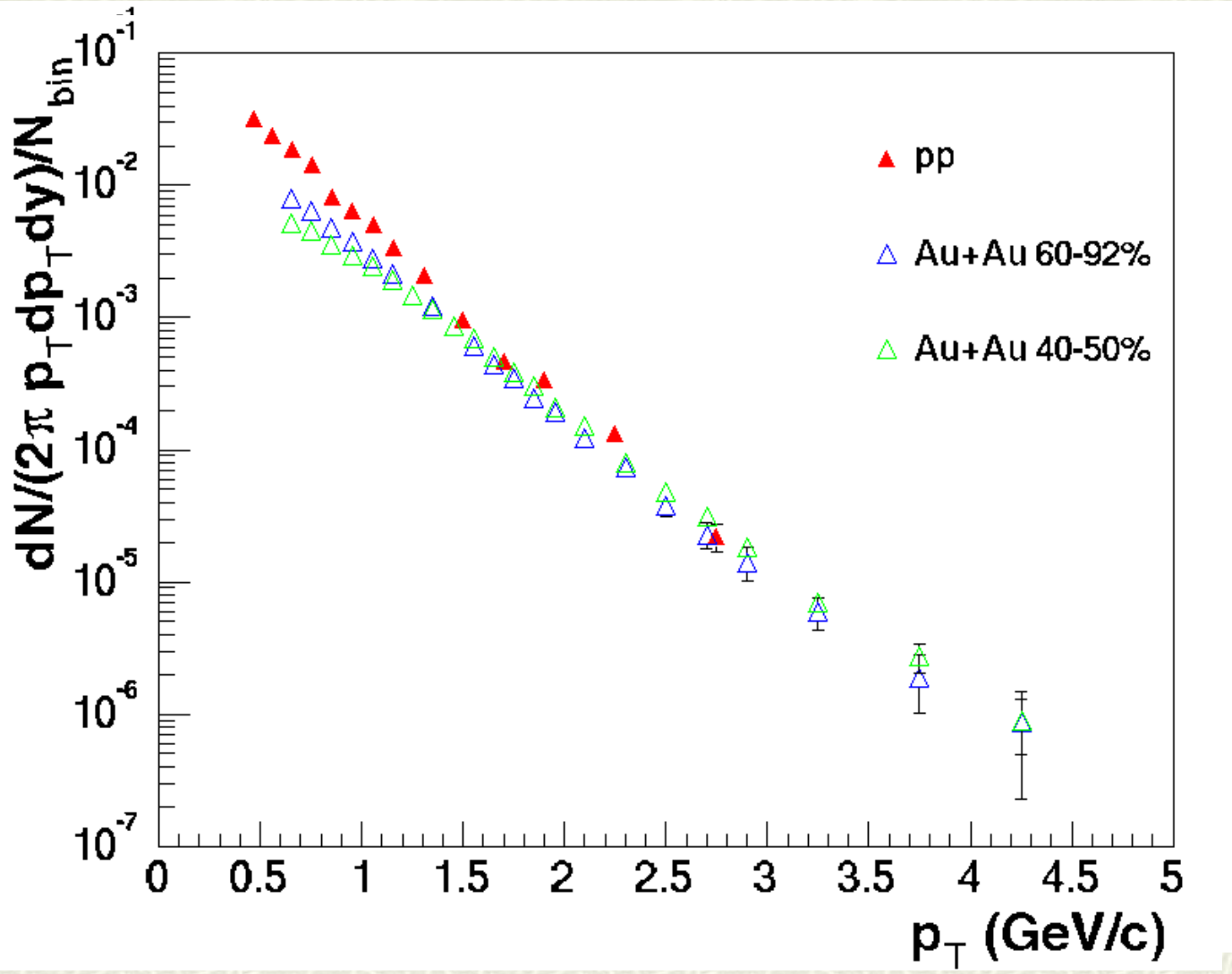

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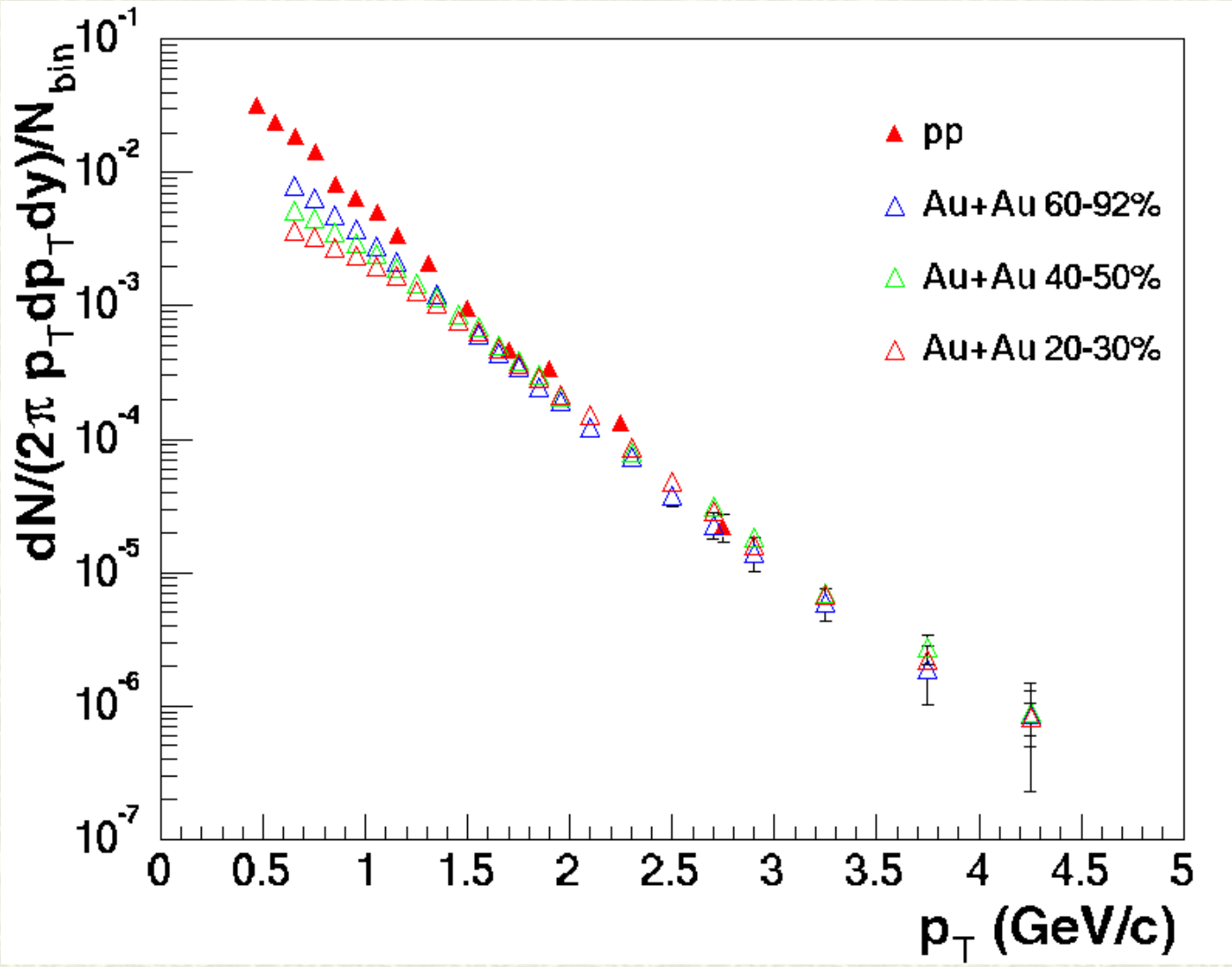

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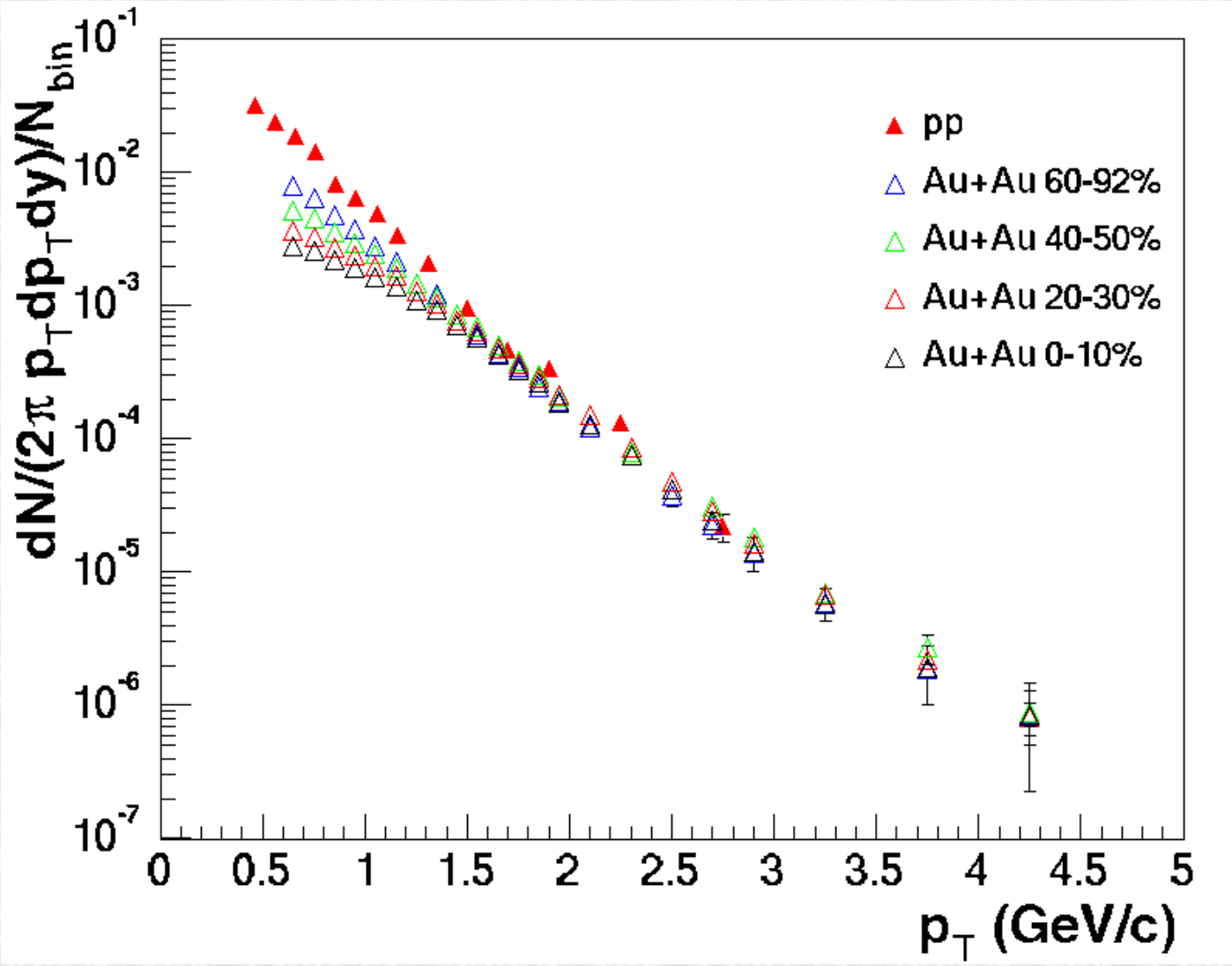

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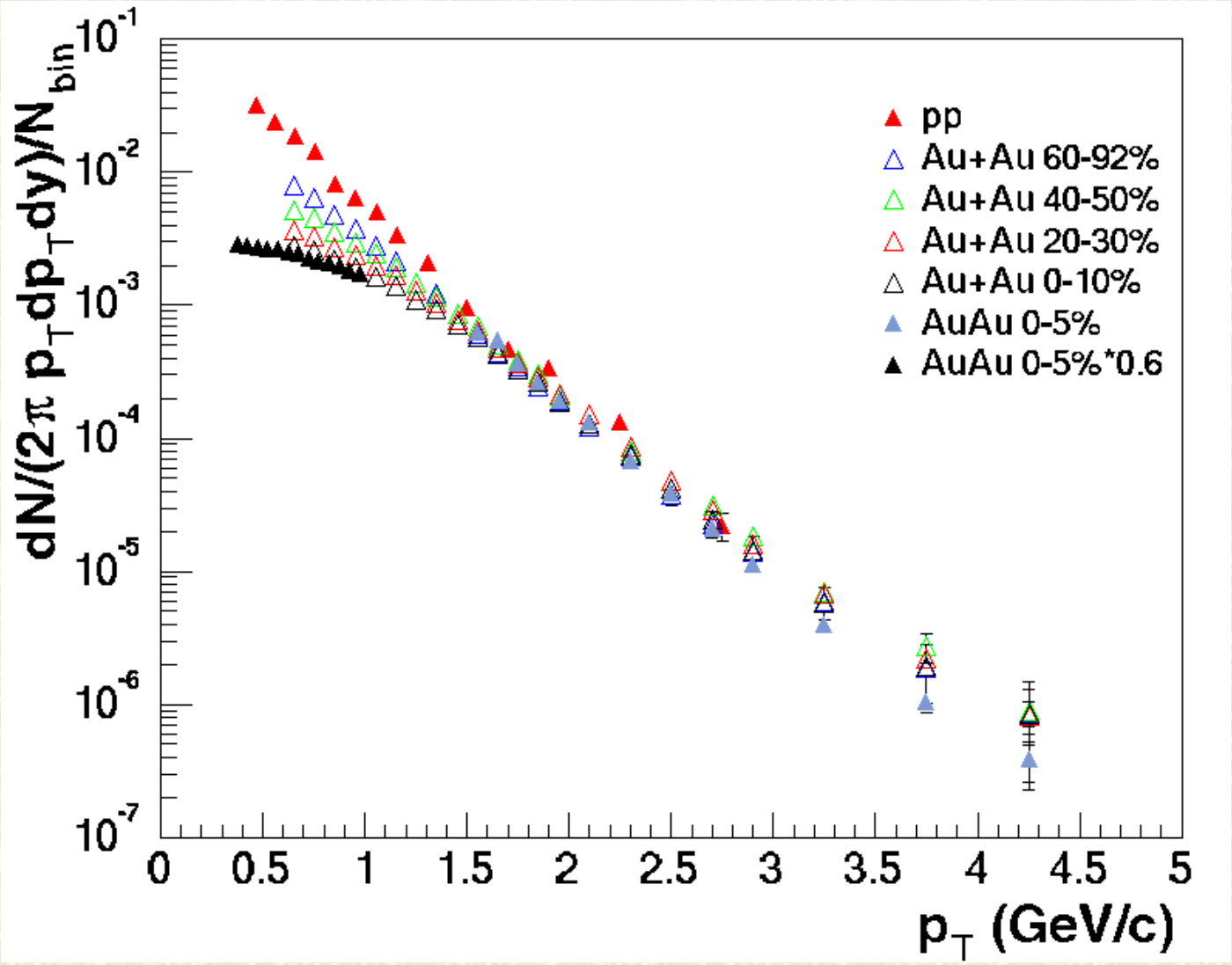

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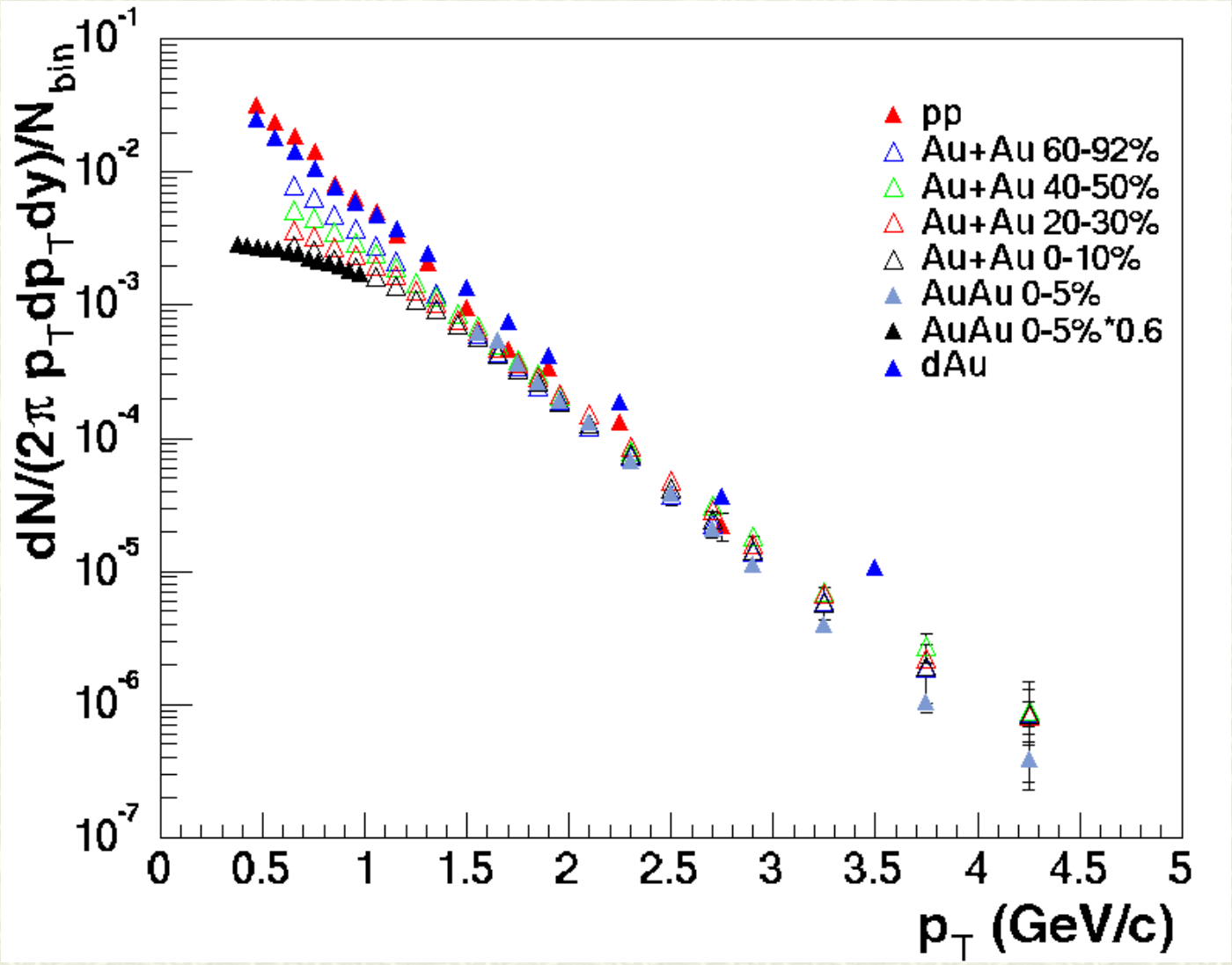
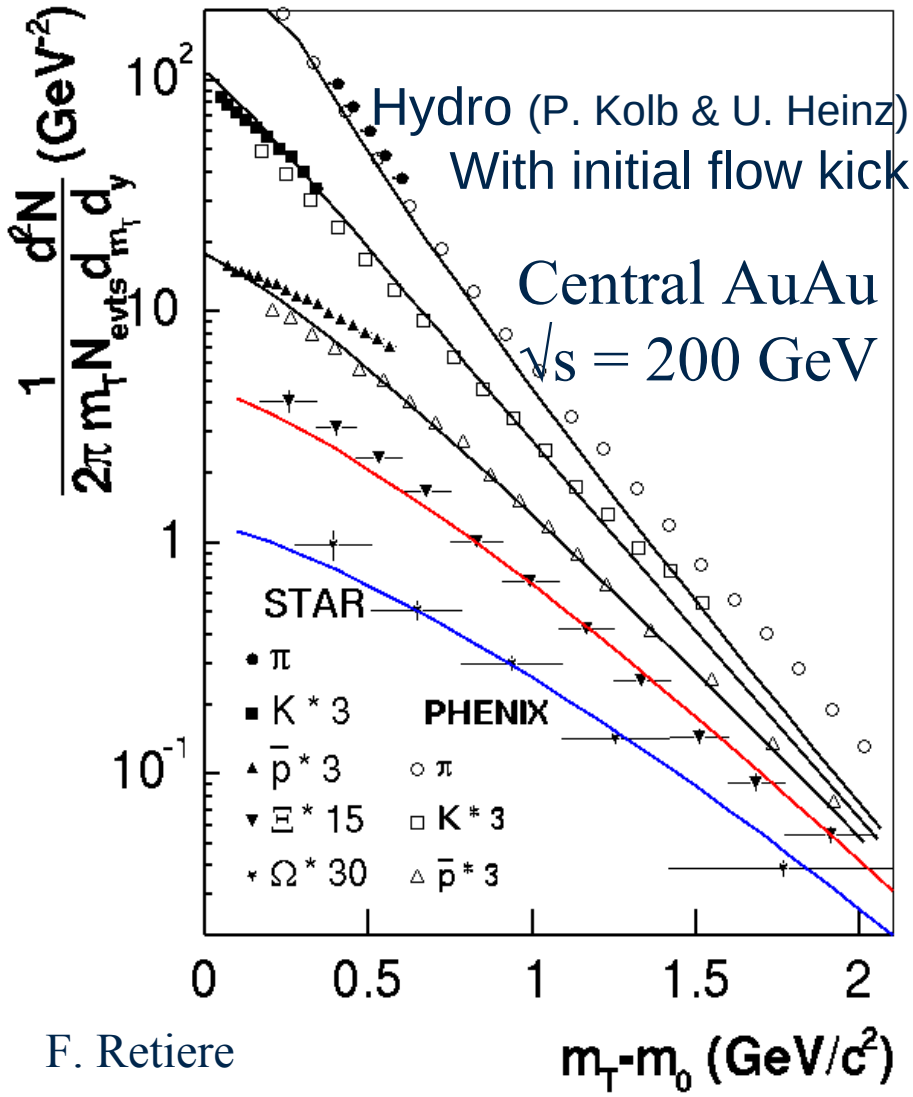


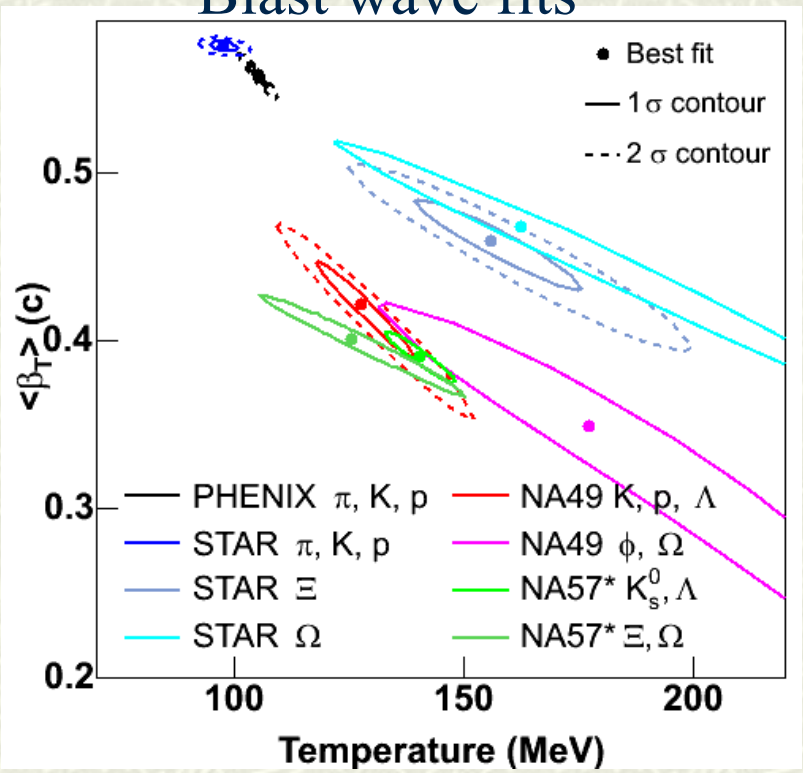
PHENIX,
STAR Preliminary

Do Ξ and Ω flow as π, K, p?



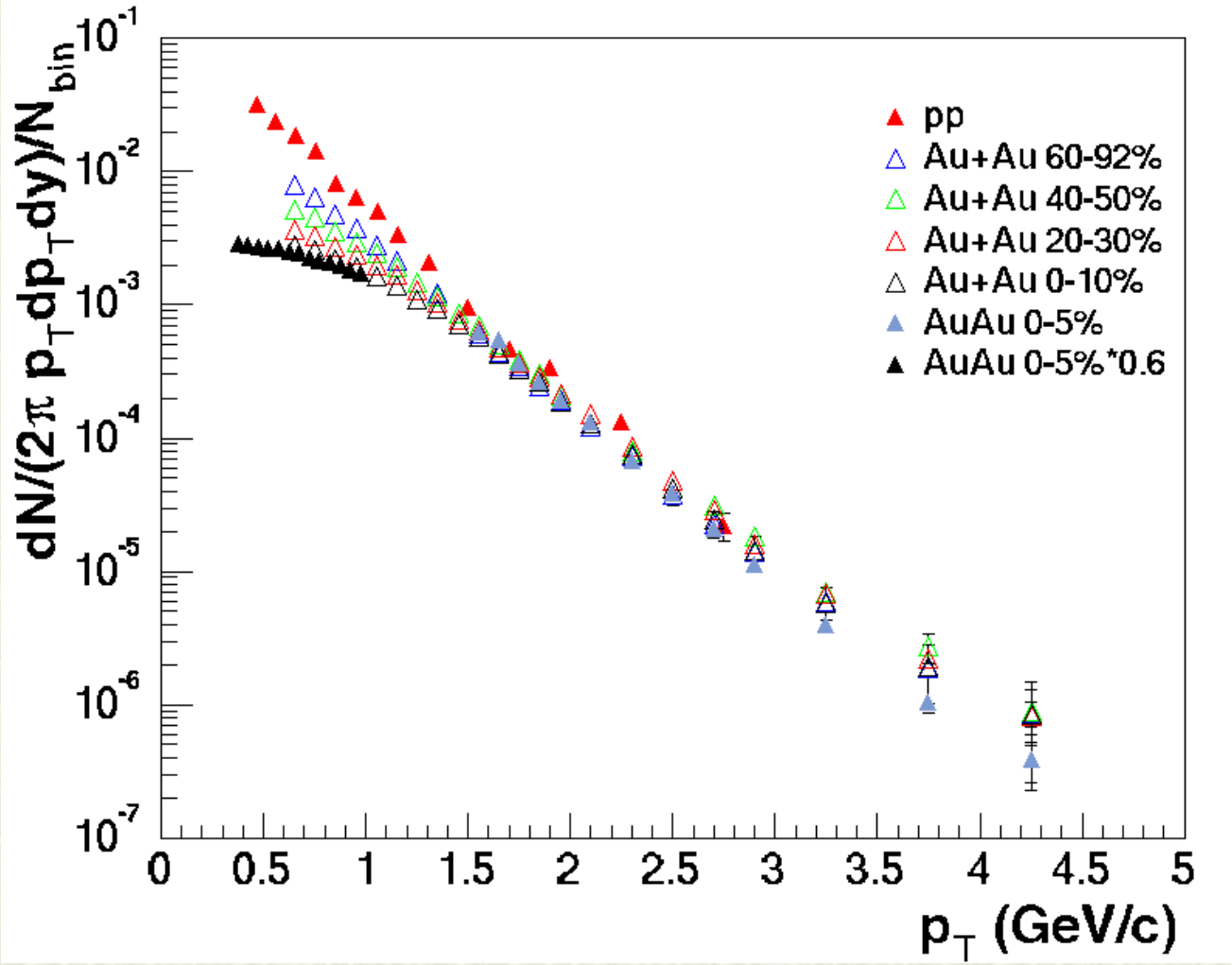
F. Retiere

Blast wave fits



Ξ and Ω, STAR preliminary
Preliminary NA57 and NA49 data
Different flow profile for NA57

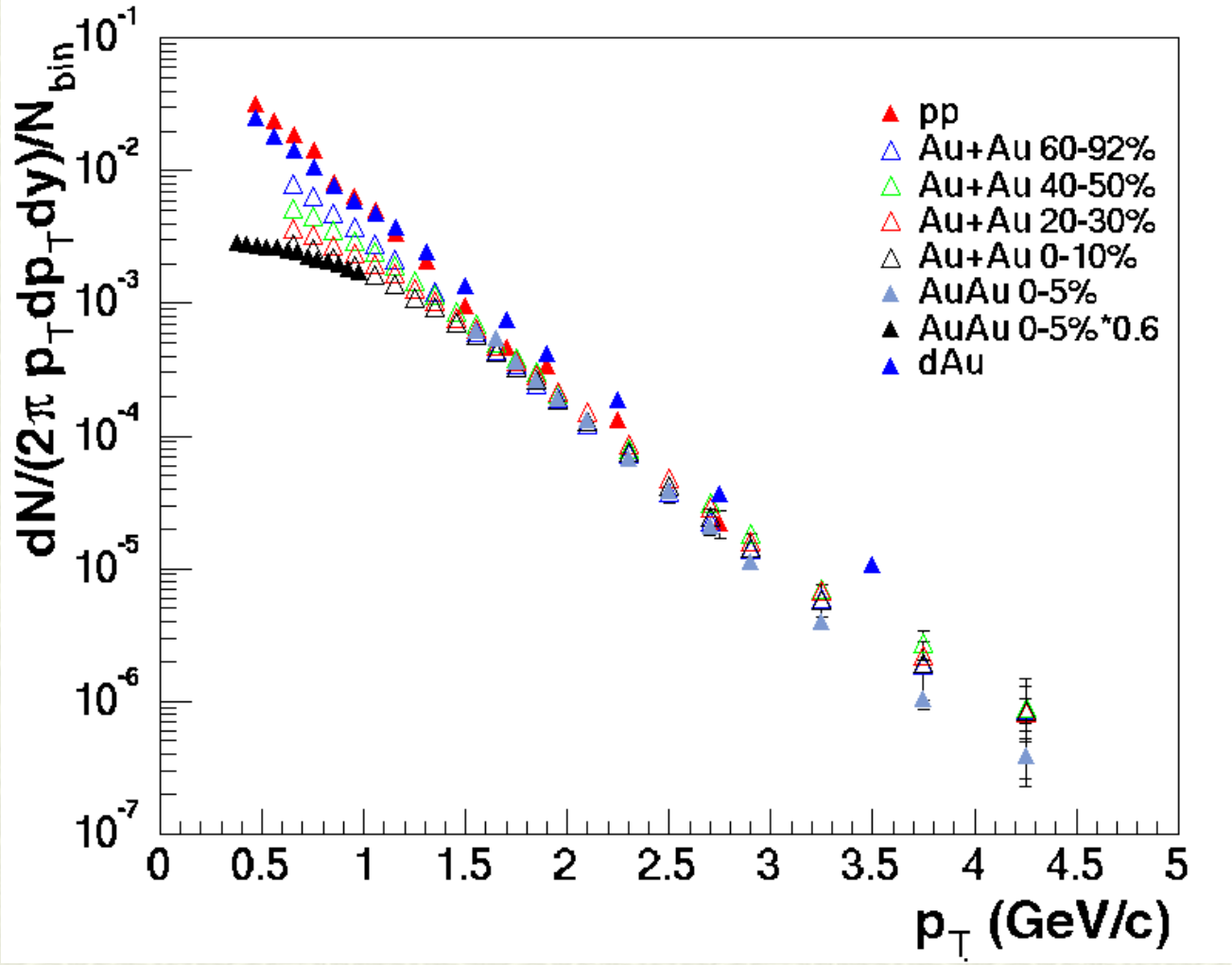
Scaling of Protons



PHENIX
STAR Preliminary

J. Velkovska

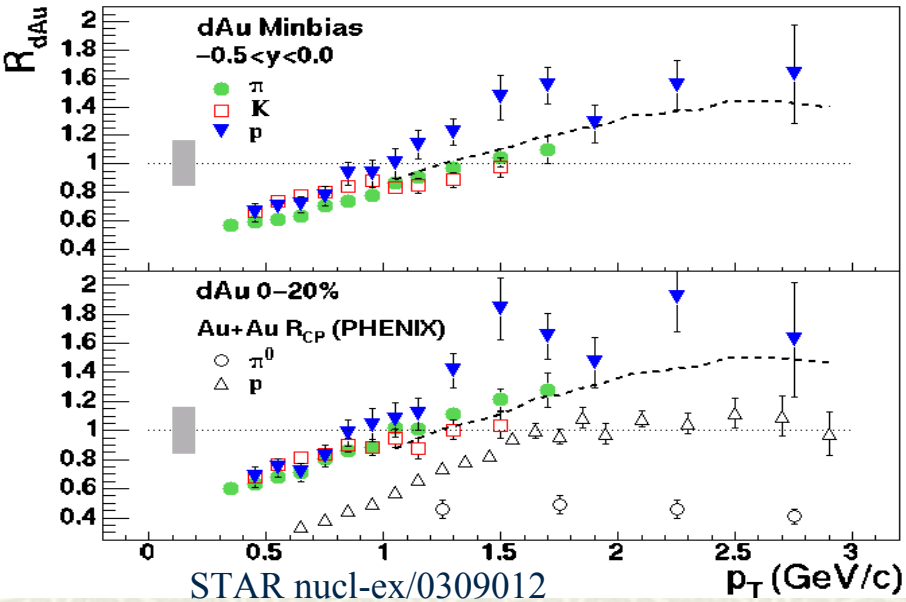
Scaling of Protons



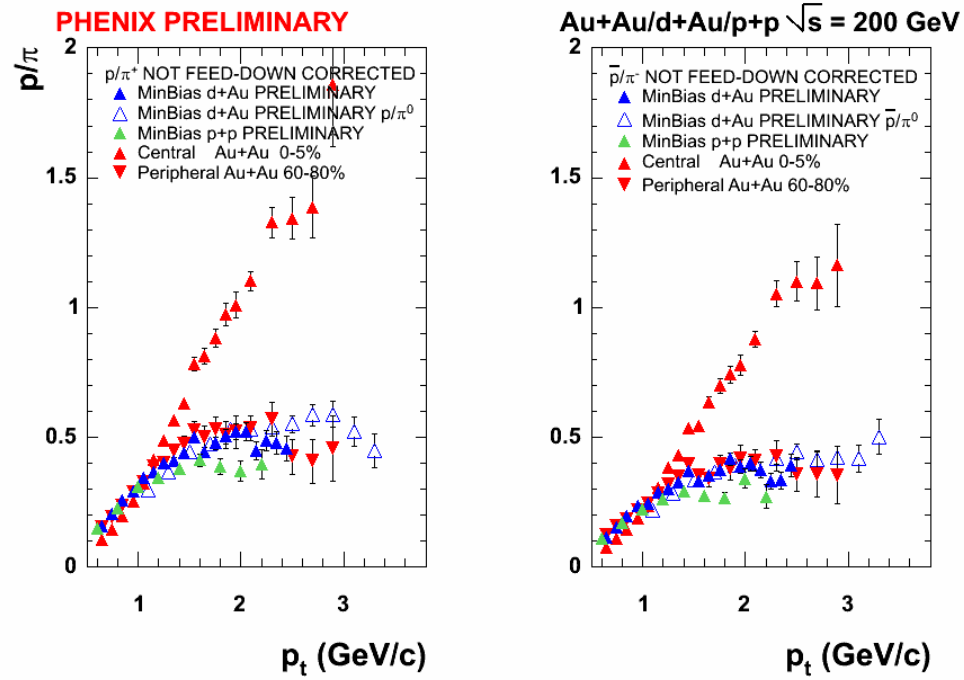
PHENIX
STAR Preliminary

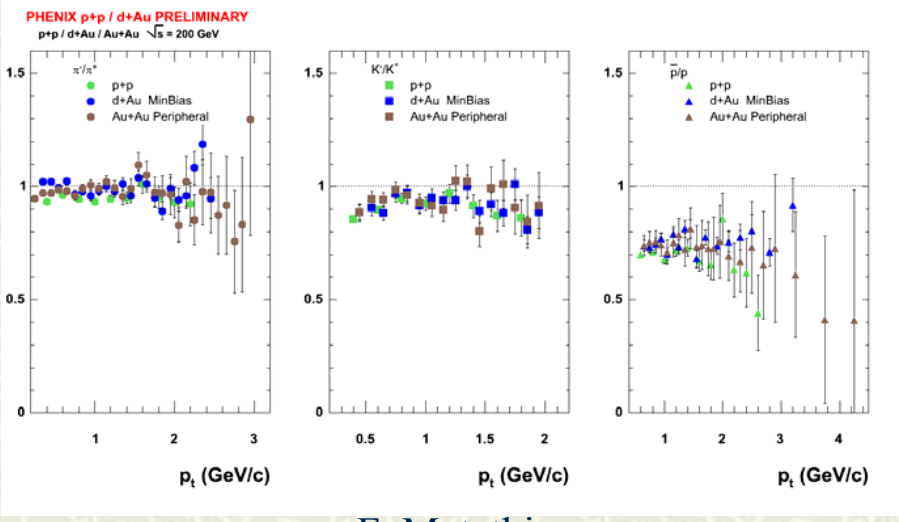
J. Velkovska

PID Cronin Effect



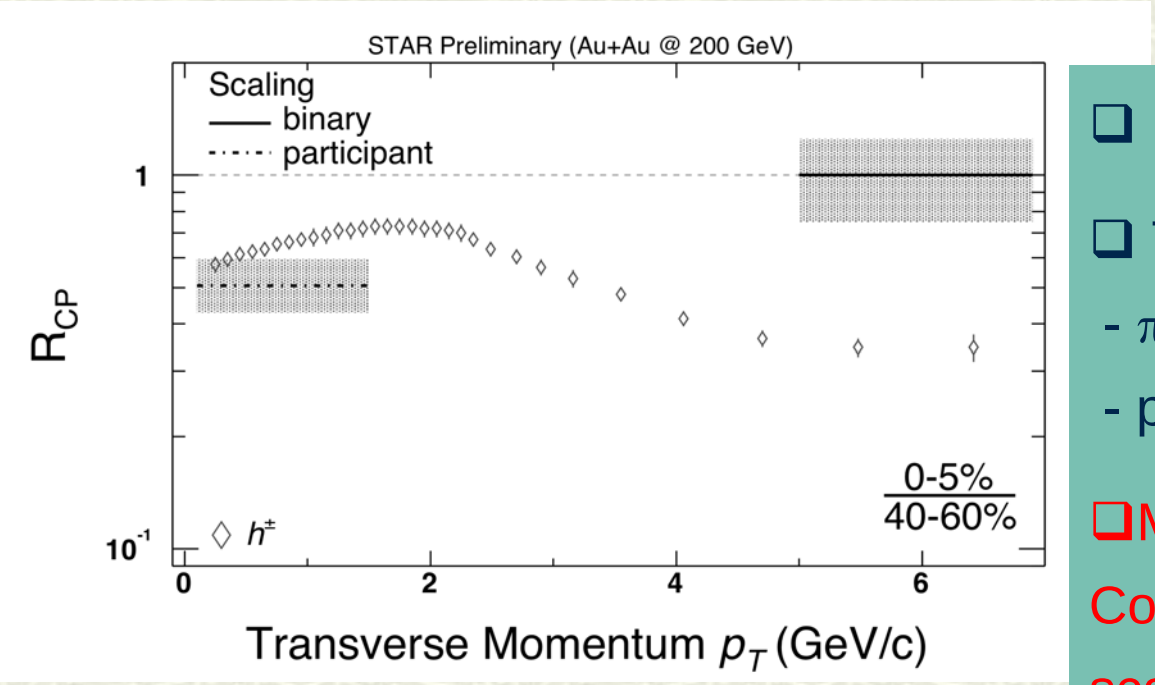
STAR nucl-ex/0309012





- Baryon Enhancement (meson suppression) due to FSI
- Proton Binary Scaling due to FSI
- Anti-particle/particle ratio flat p+p, d+Au, Au+Au

Mass or B/M?



- R_{CP} flattens at intermediate p_T
- Two groups ($2<p_t<6$GeV/c):
  - π,K^0_s, $K^{\pm}$, K^*, ϕ → mesons
  - p,Λ, Ξ, Ω → baryons
- Meson/Baryon Effect!

  Collective velocity is not the only scale
- quark coalescence ?

M. A.C. Lamont, H. Long, H. Zhang, P. Sorensen, T. Frawley, R. Seto, D. Kotchetkov

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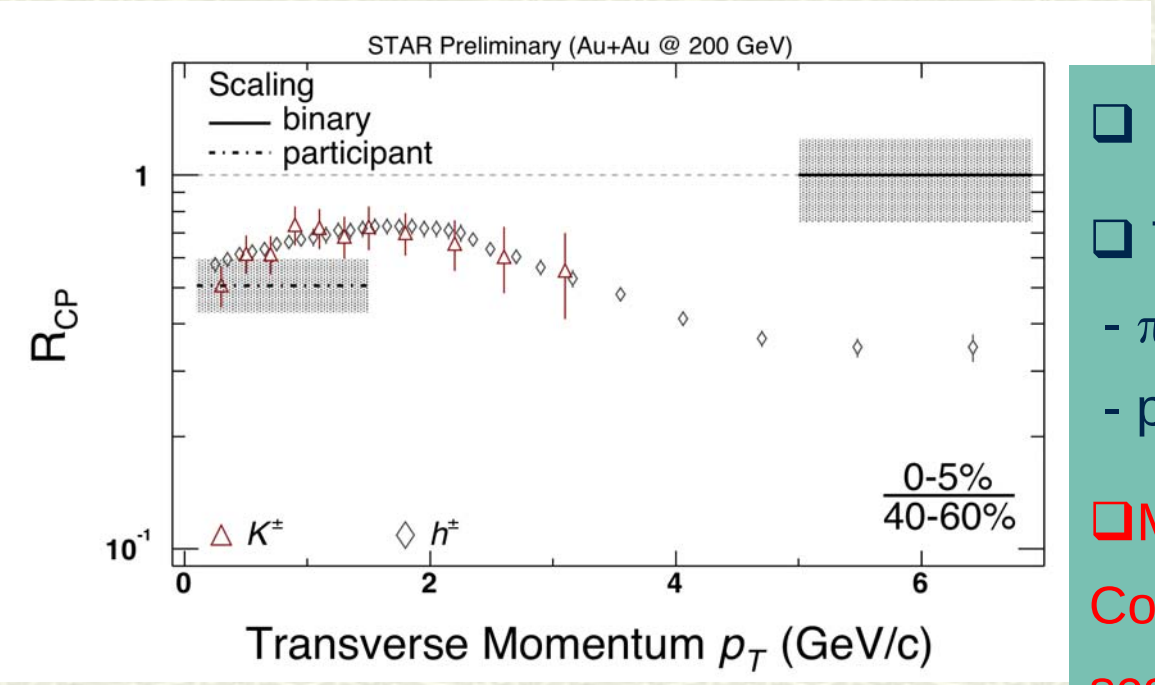

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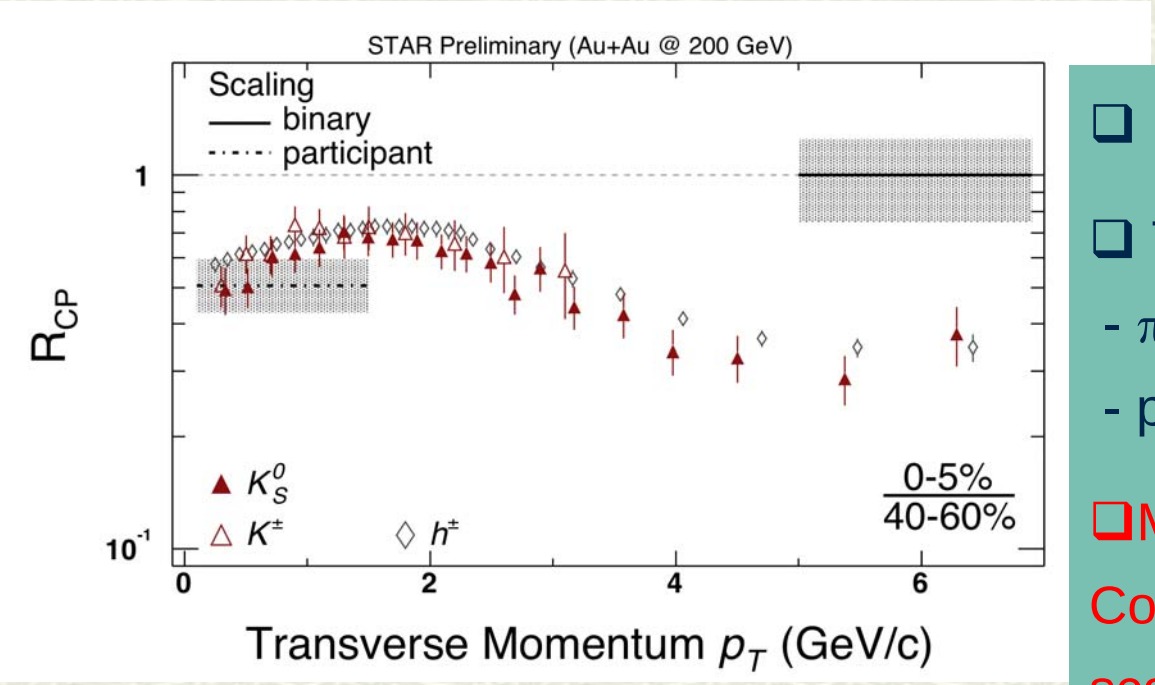

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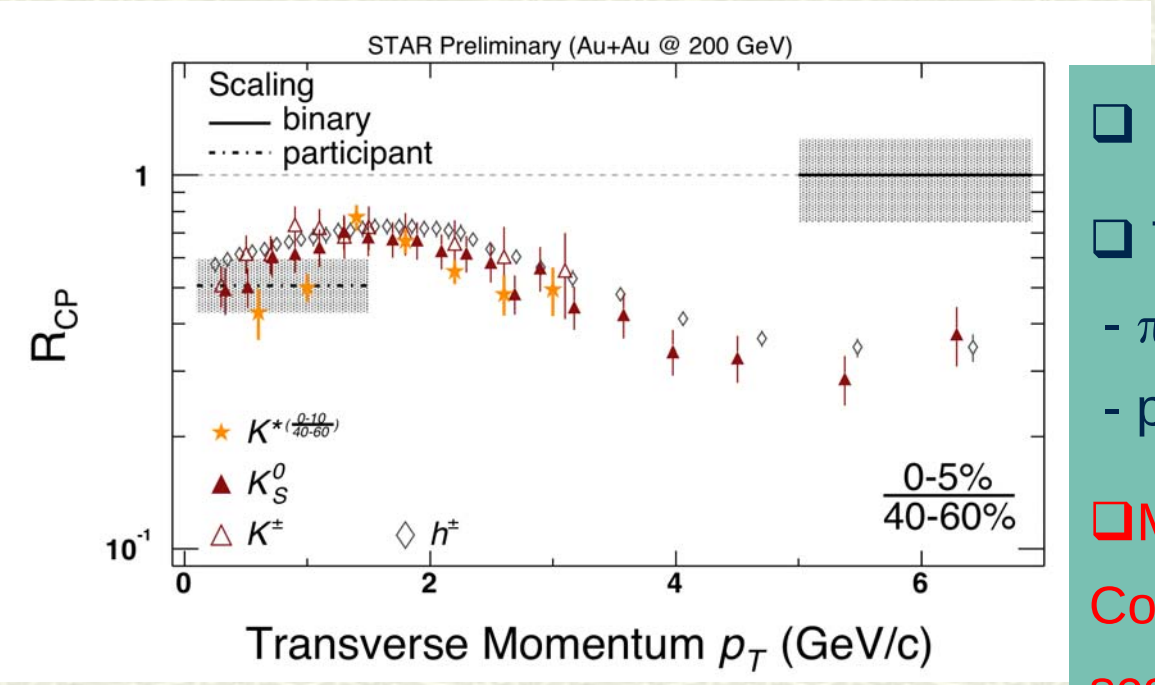

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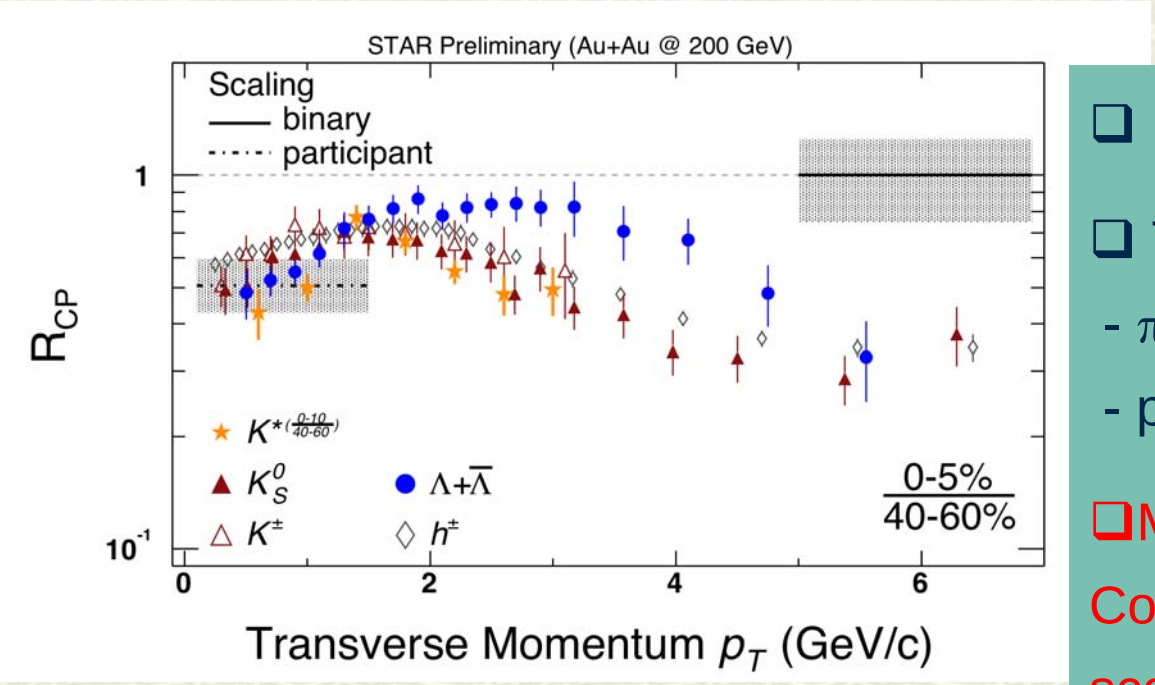

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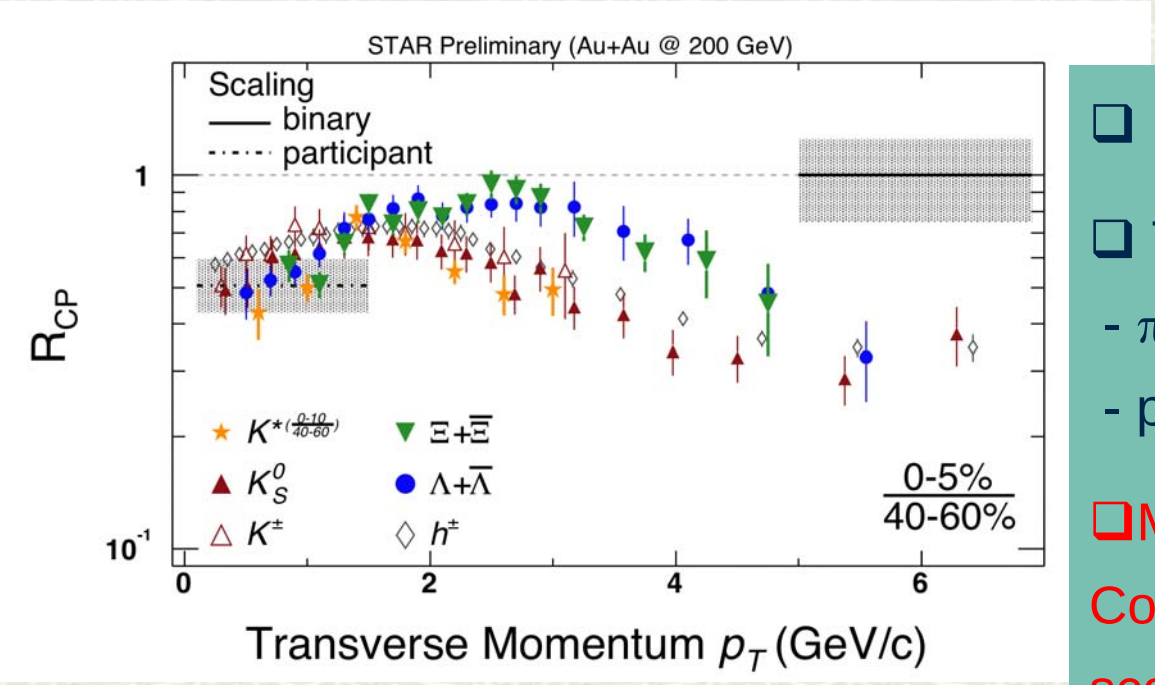

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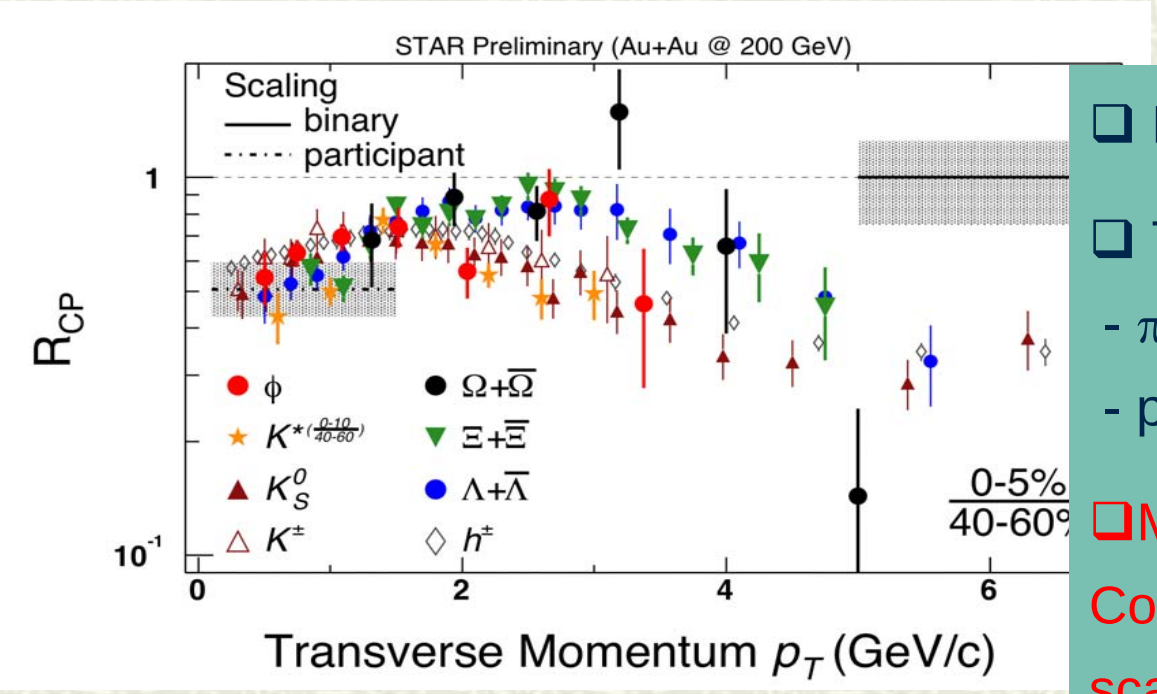

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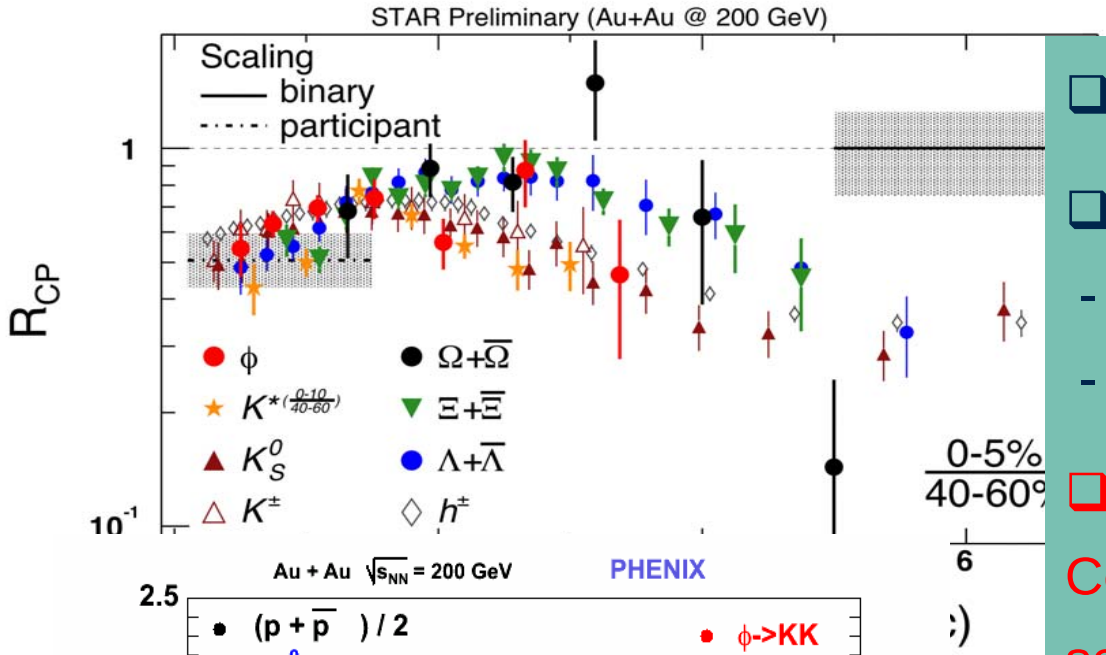

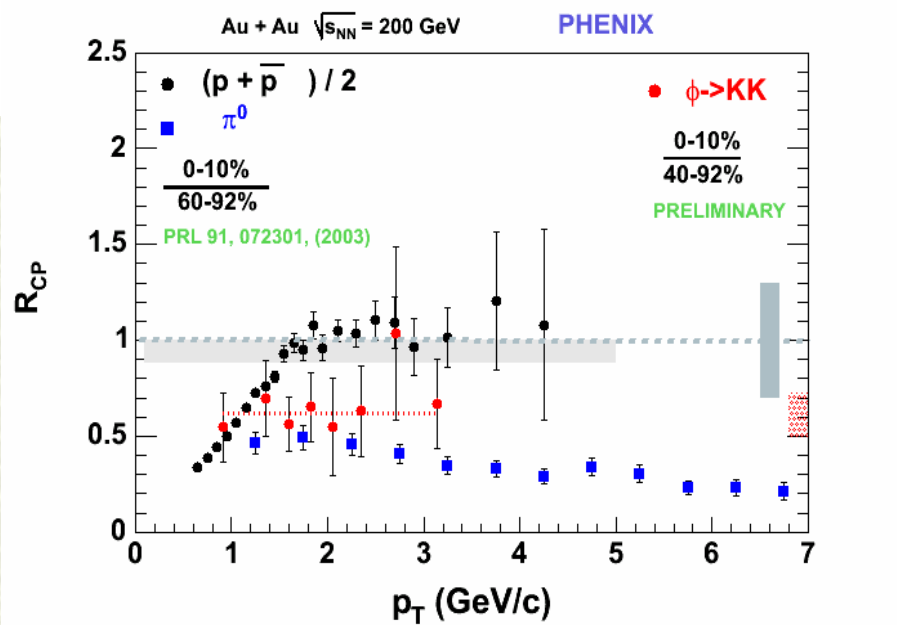

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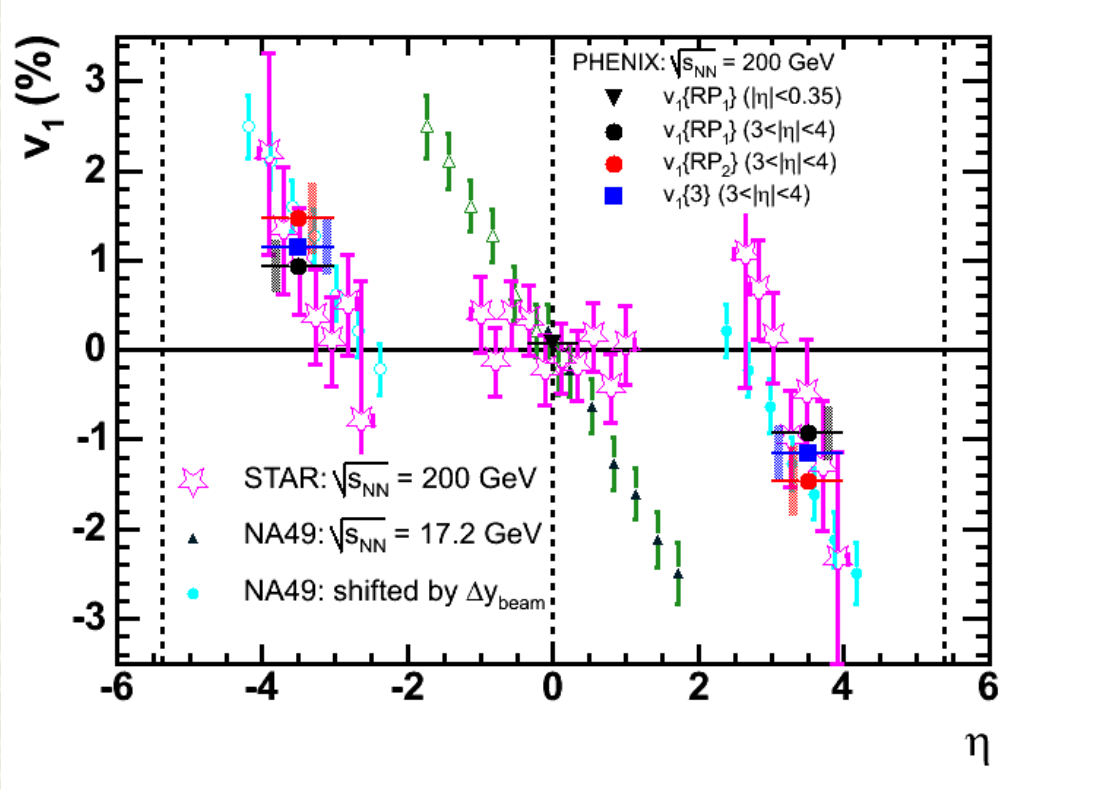
Chemical and Kinetic Properties

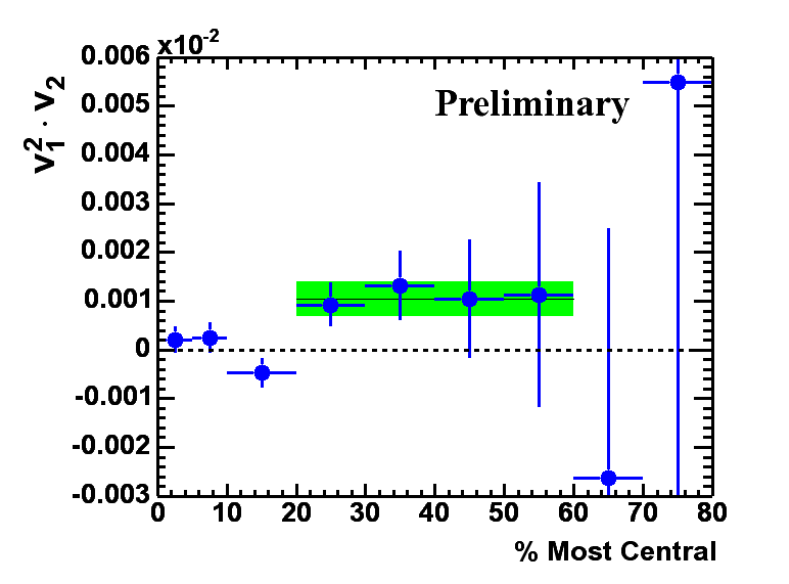
- Strangeness comes (close) to chemical equilibrium
- Finite Cross Section Effect Observed via Resonance

- Particle Production at Intermediate pT meson/Baryon (scale w/ #quarks)

Directed flow v_1

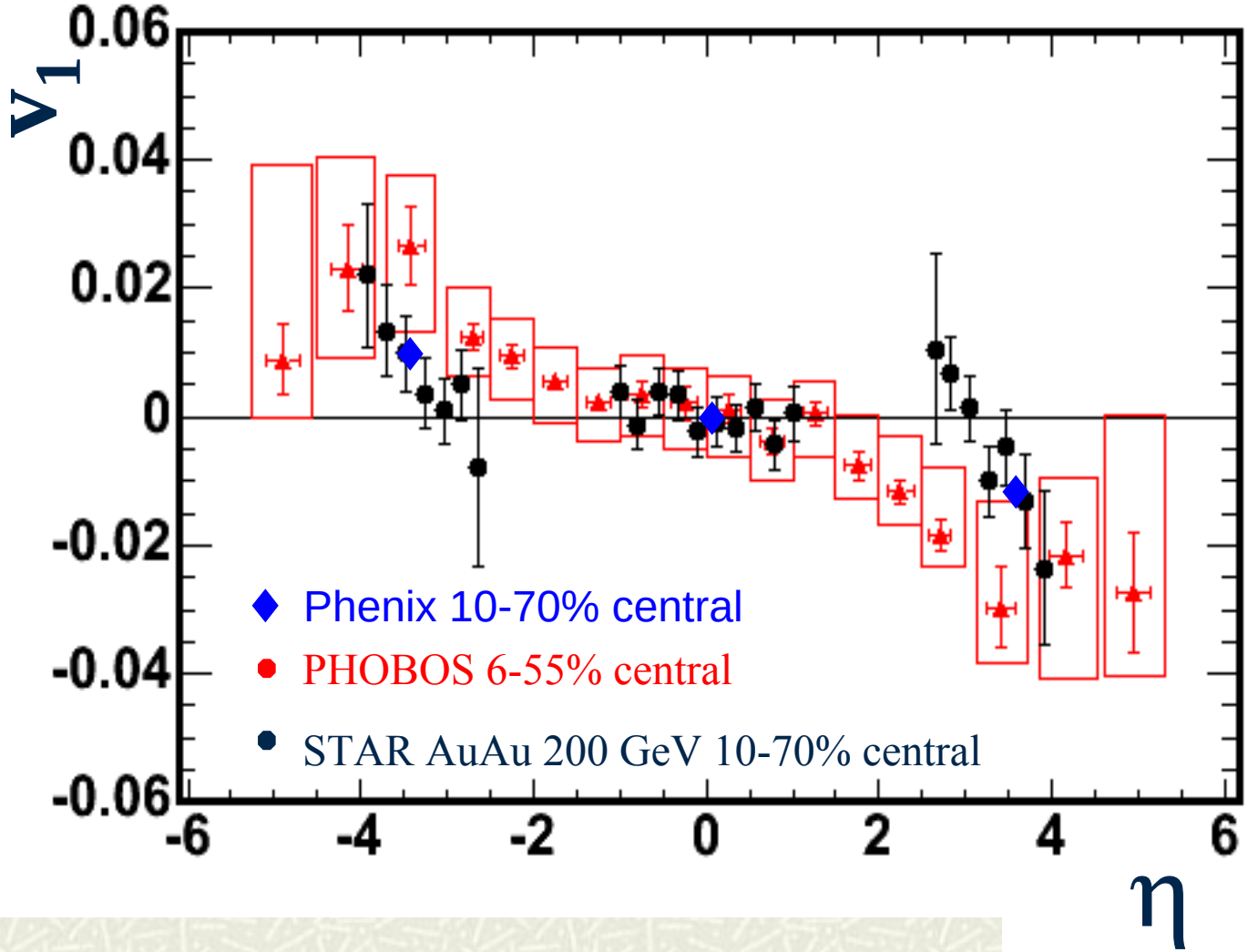


- v_1 signal at large η
- v_2 is positive



M.B. Tonjes, M. Kaneta, A. Tang, A. Poskanzer, M. Oldenburg

Directed flow v_1



- v_1 signal at large η
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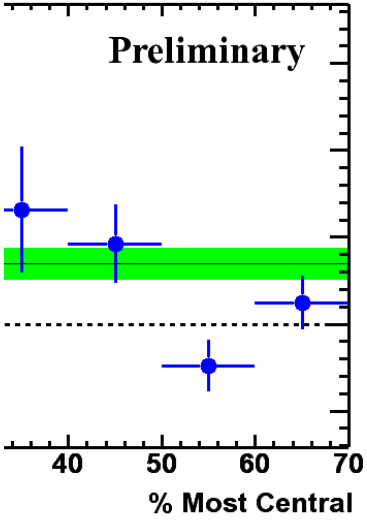
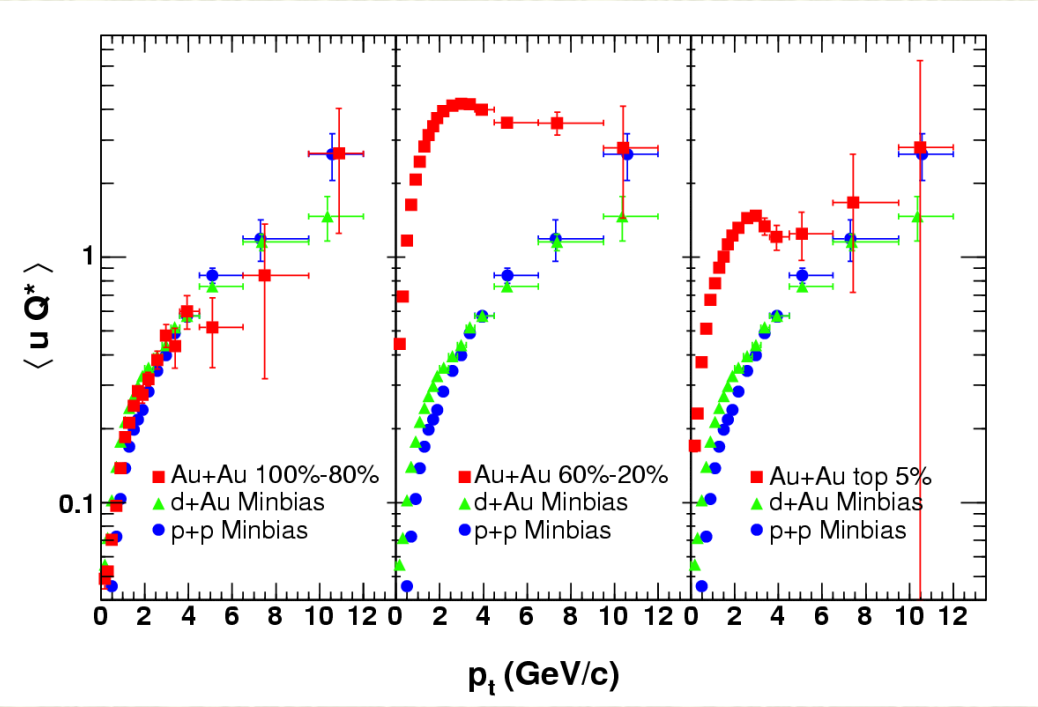
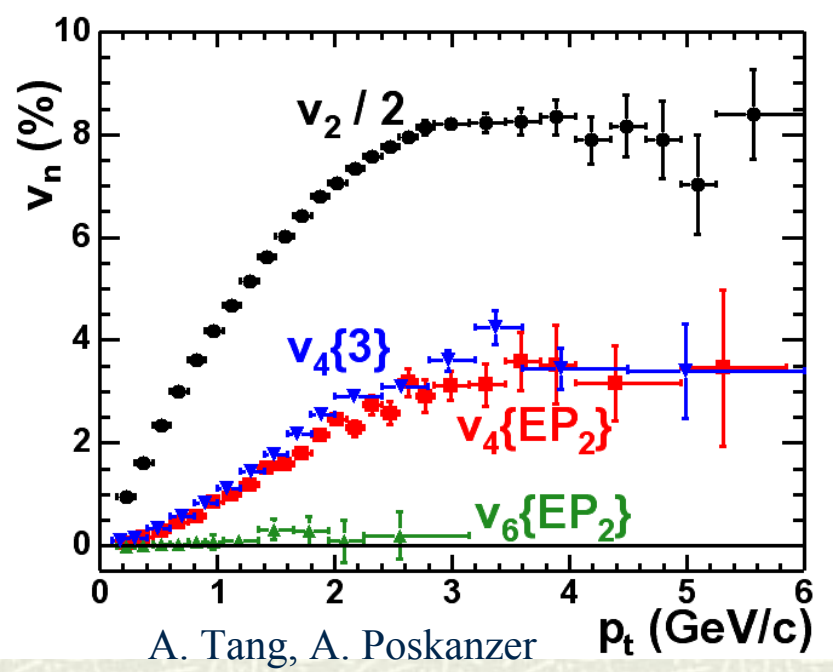


M.B. Tonjes, M. Kaneta, A. Tang, A. Poskanzer, M. Oldenburg

Flow (non-Flow)?

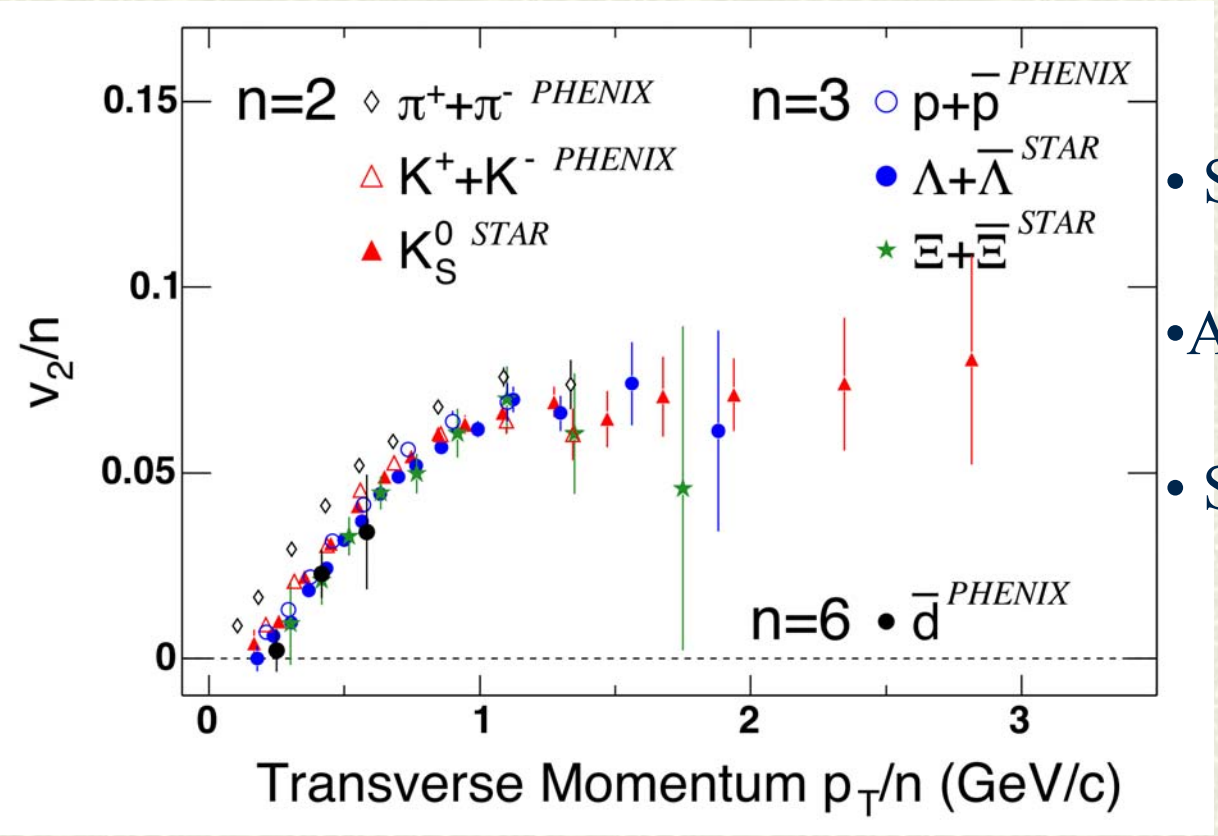




A. Tang, A. Poskanzer

- Strong Collectivity (>>non-flow)
- v_4, v_6 more sensitive to initial conditions

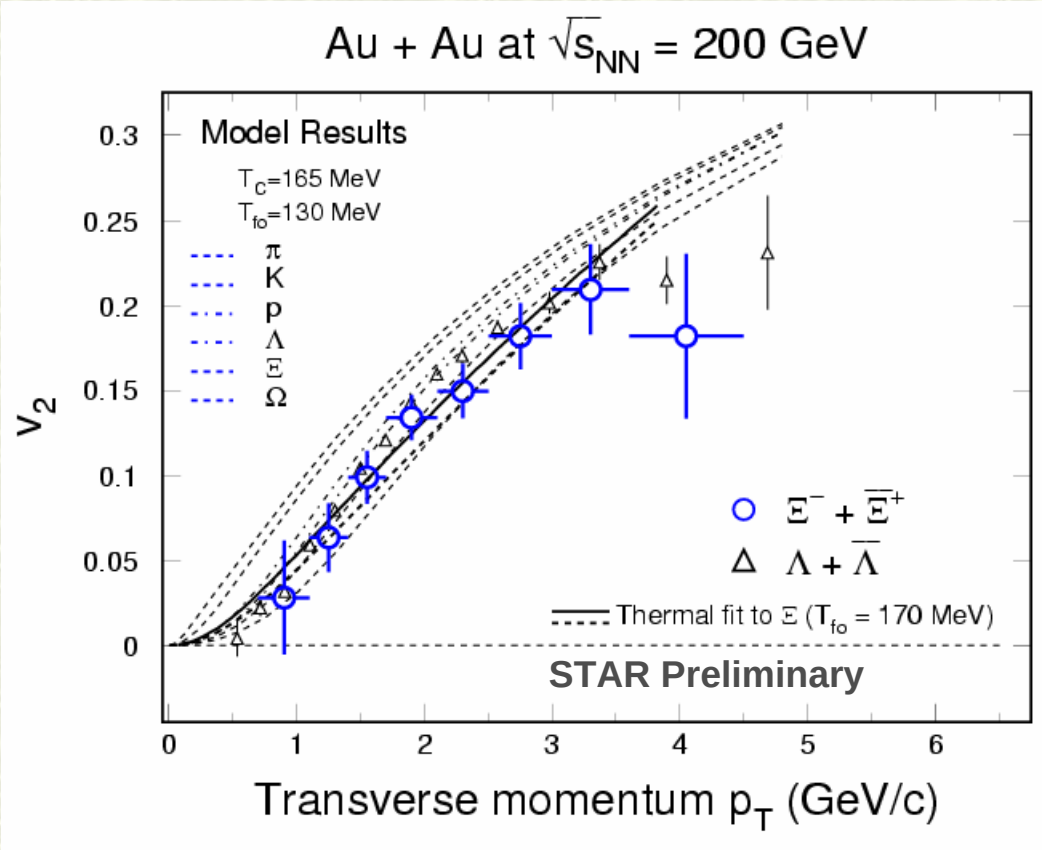
Scaling of v2



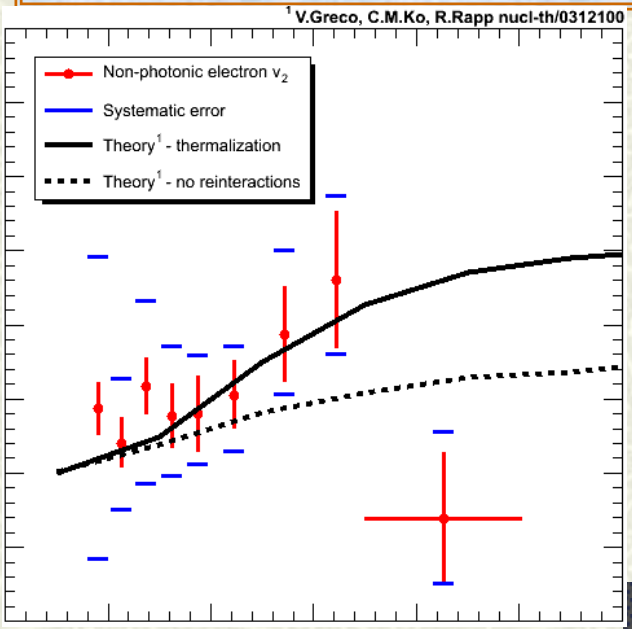
- Scale well except π
- Again, Quark Coalescence?
- Sensitive to ρ, Δ flow?

R.Fries, P. Sorensen

Multi-Strange Baryons v_2

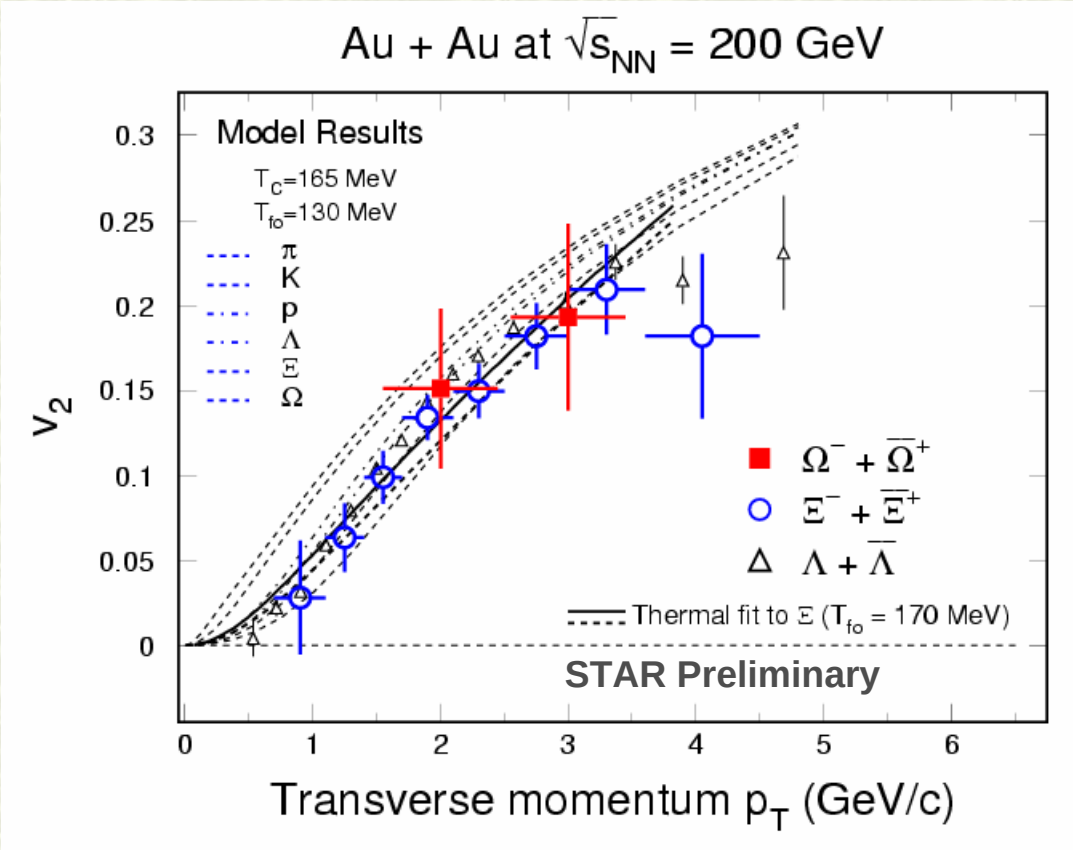


- Multi-strange baryons show collectivity !
- But have small hadron Cross Section
- How about Charm v2



J. Castillo, M. Kaneta,

Multi-Strange Baryons v_2



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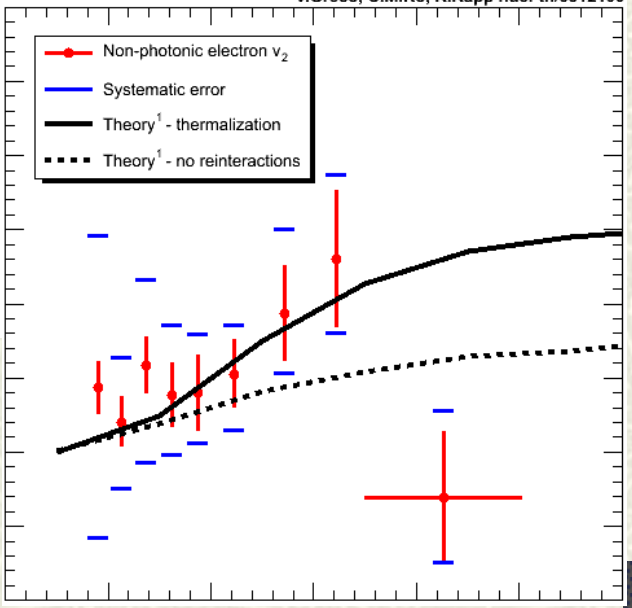
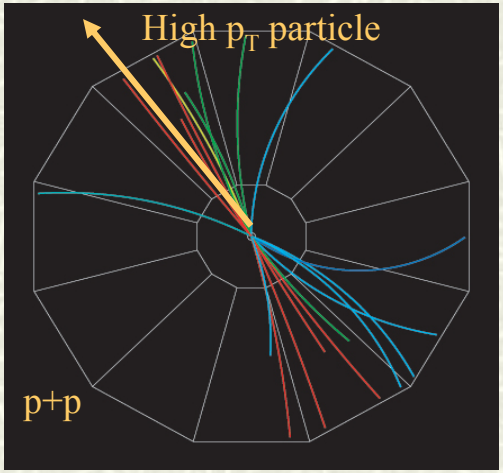
[1] V.Greco, C.M.Ko, R.Rapp nucl-th/0312100

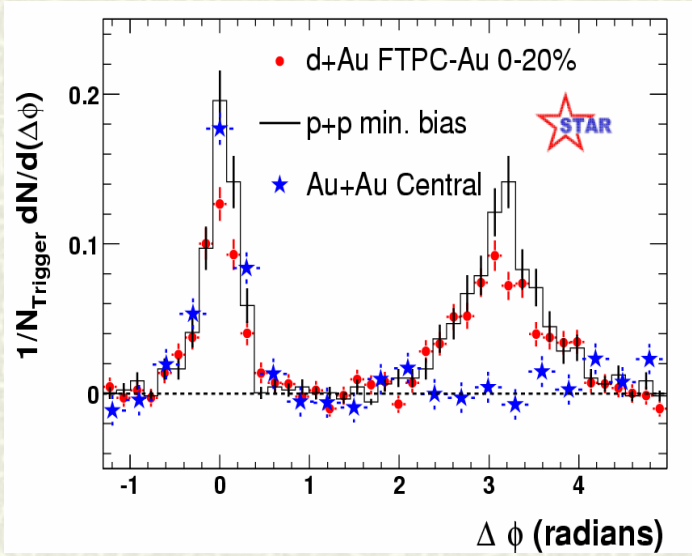


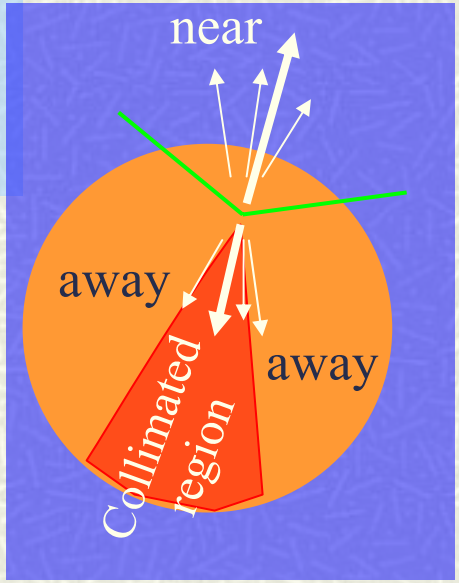
J. Castillo, M. Kaneta,

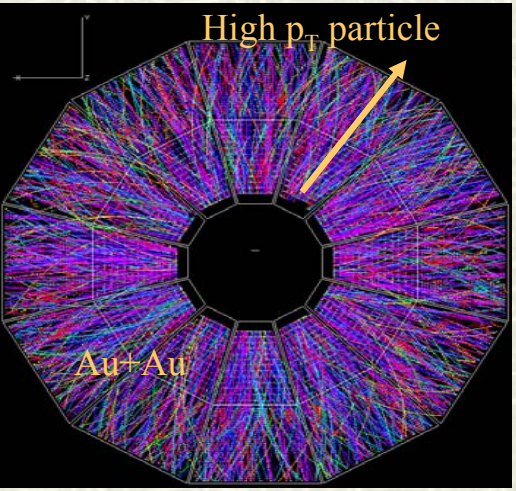
Jet Energy Loss



How can we use jet energy loss as a tool in soft spectra?

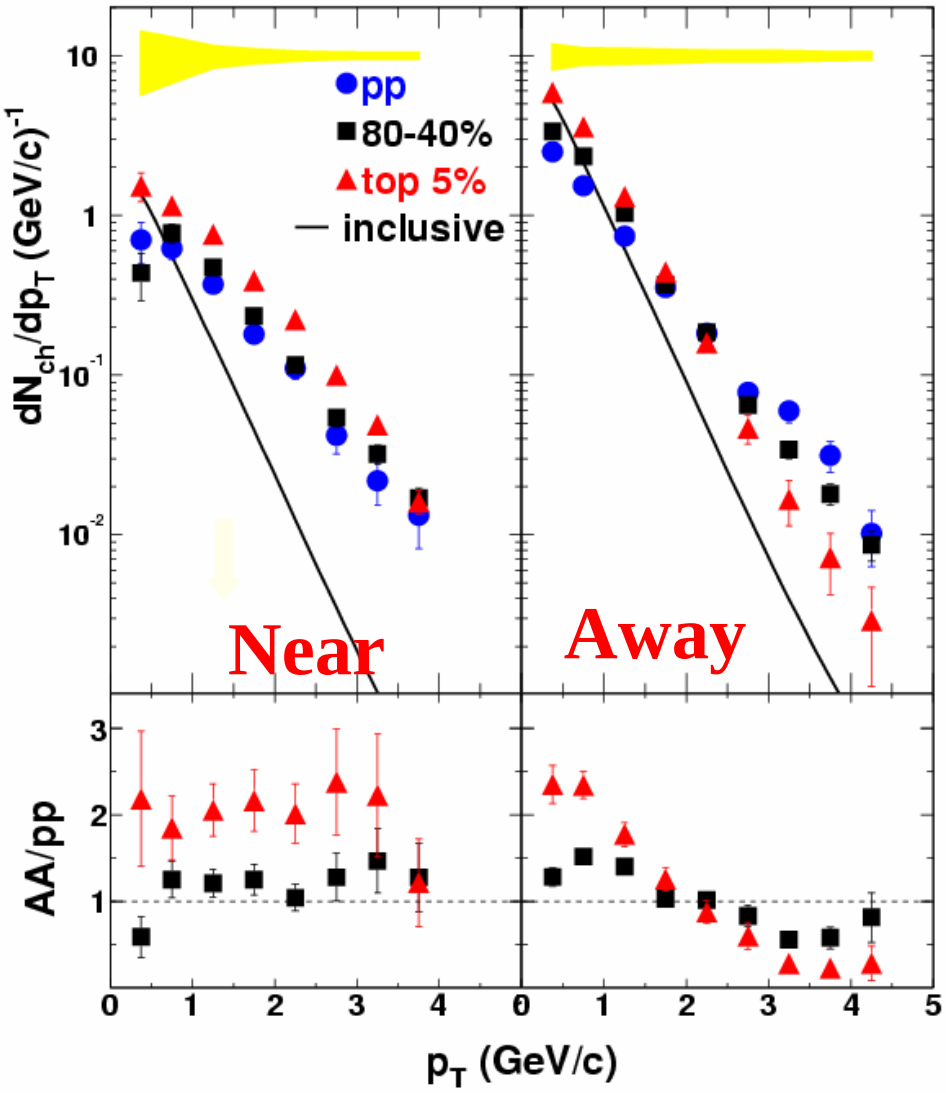






ucting hadrons associated with a large p_T particle

Associated particles p_T distributions



Away side:

energy from the initial parton has been converted to lower p_T particles

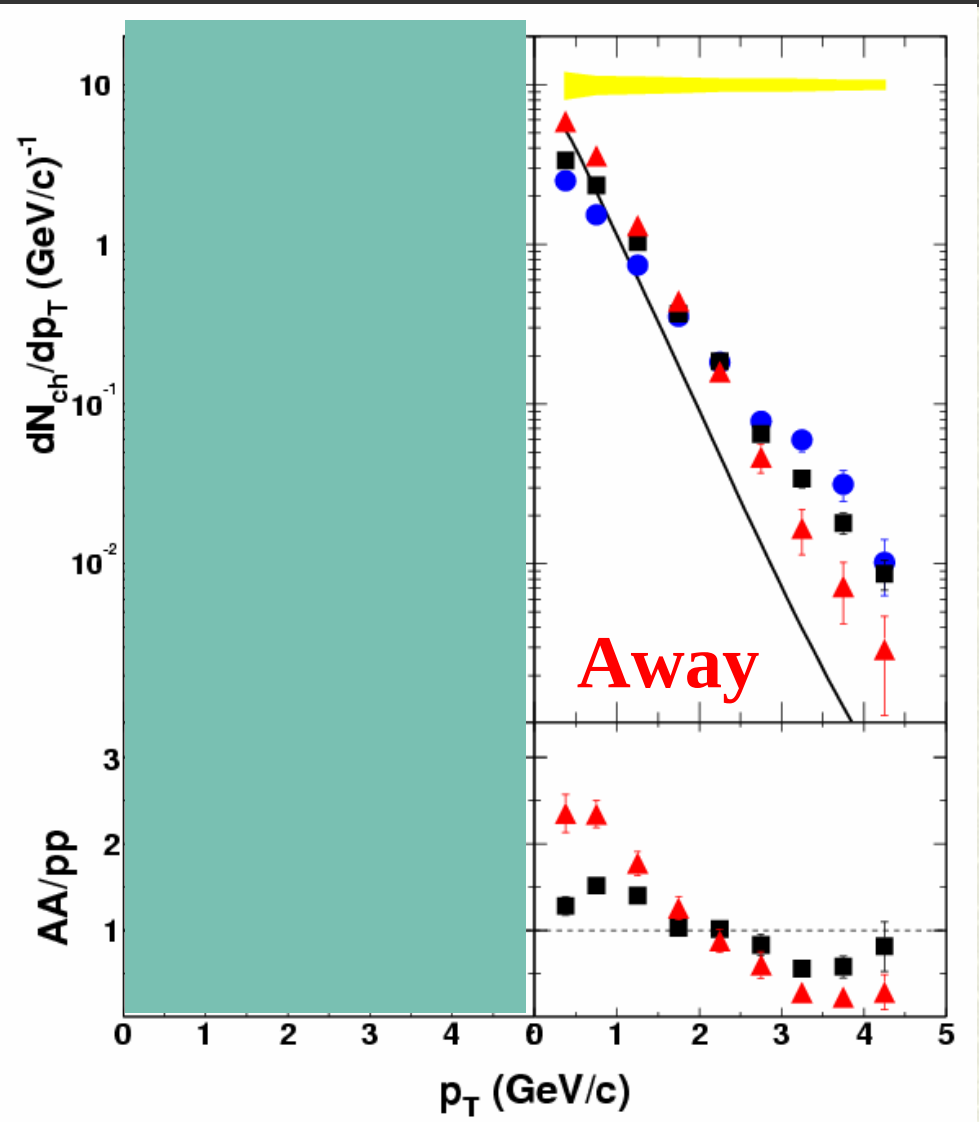
energy loss in medium!

Study chemical composition and spectra of the low pT particle

STAR Preliminary

F. Wang

Associated particles p_T distributions



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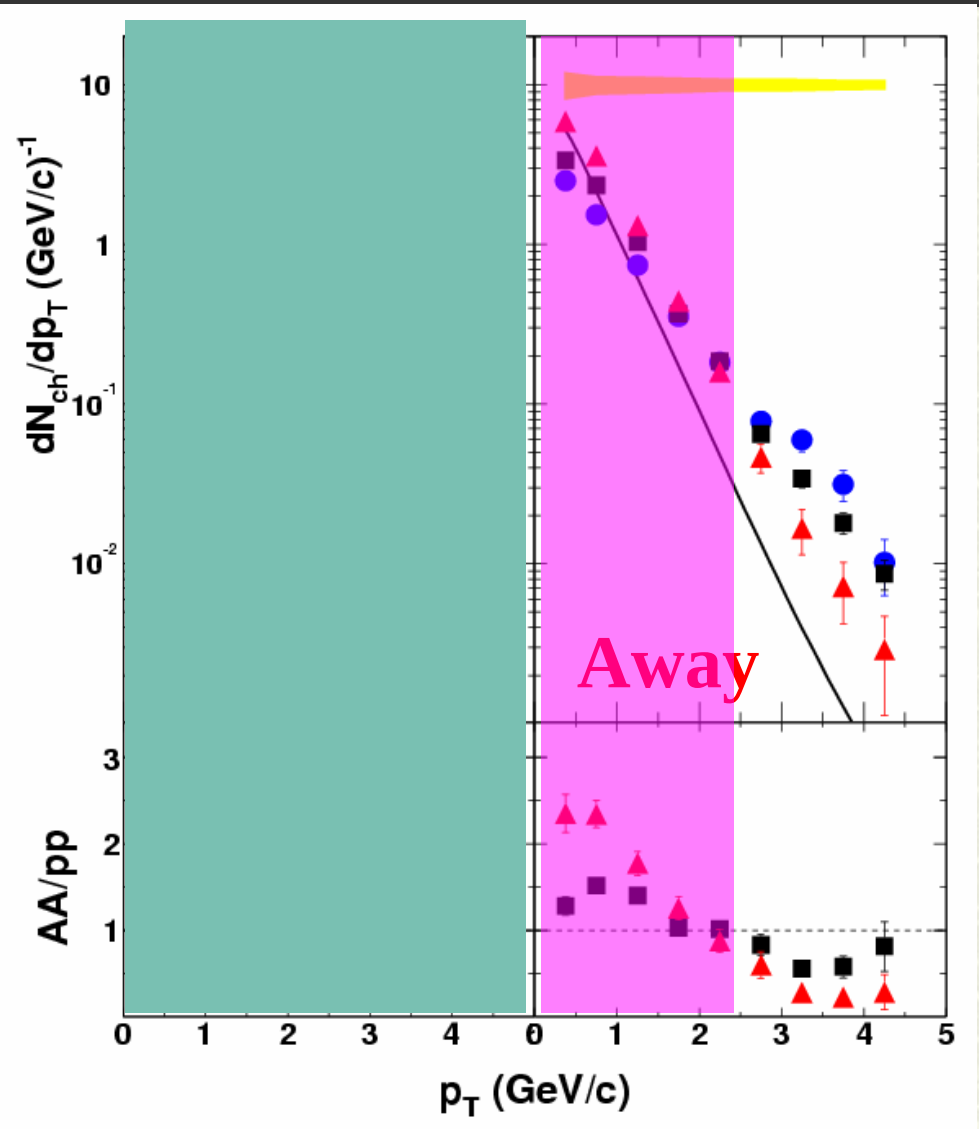

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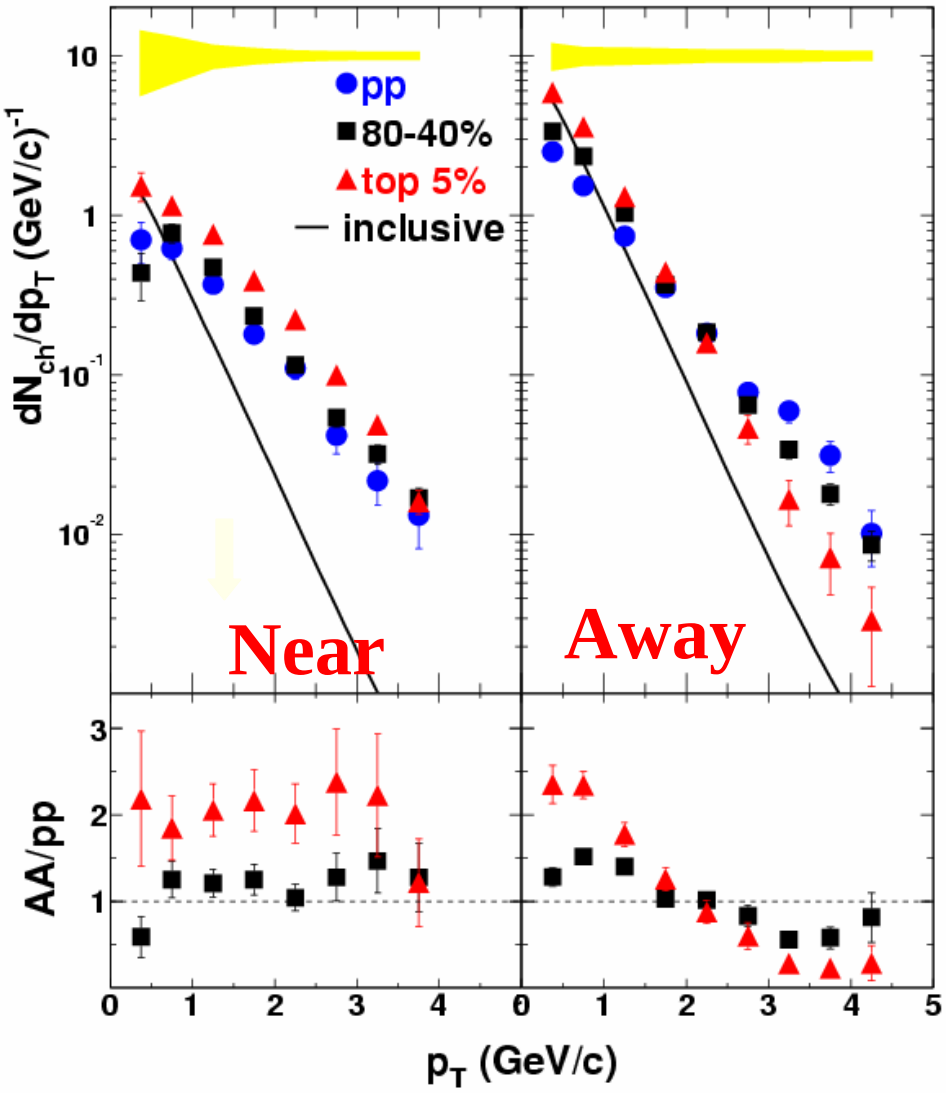

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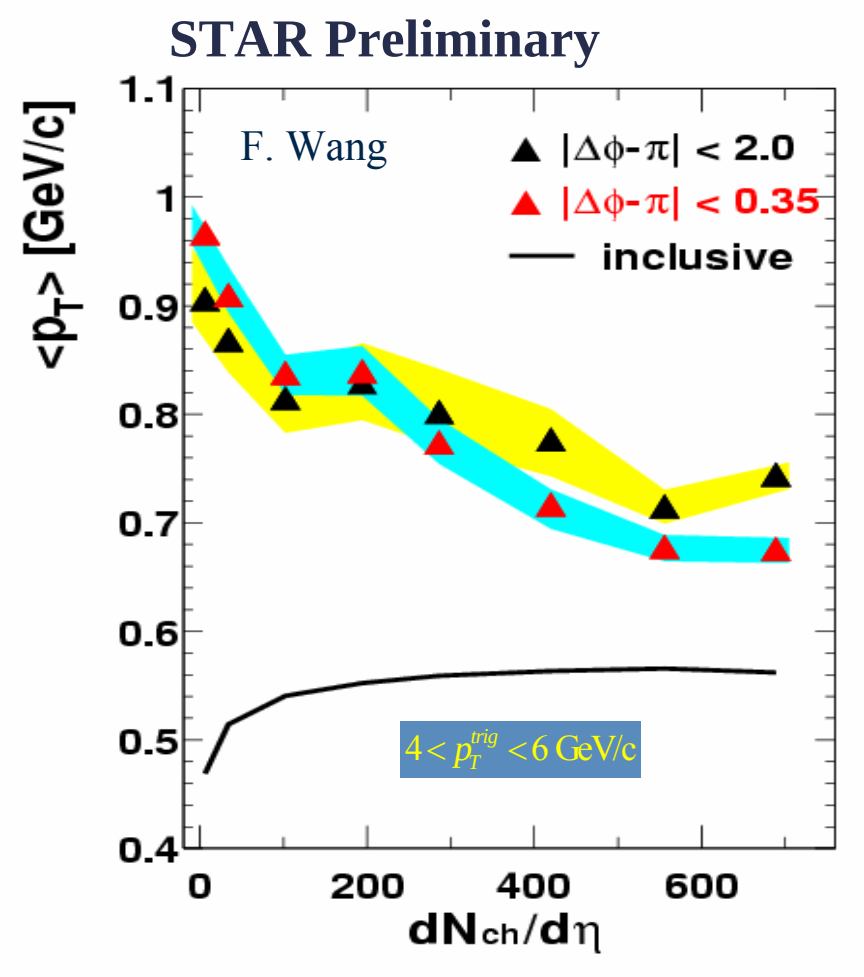
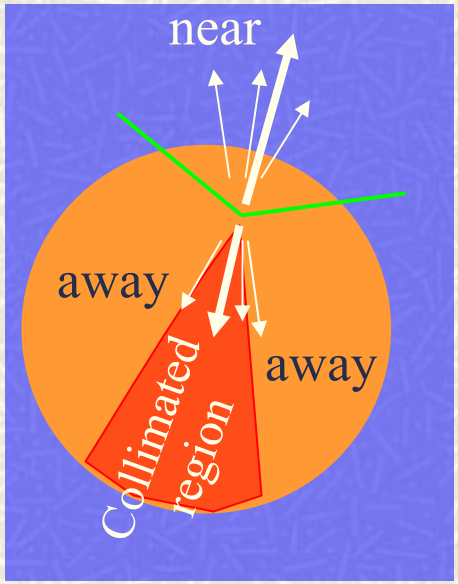
STAR Preliminary

F. Wang

Energy loss and thermalization





Strangeness Enhancement!
Canonical vs grand canonical
PID Spectra

- Away side $<p_T>$ decreases with centrality. $\langle pT \rangle_{AuAu,jet} = 80\% \langle pT \rangle_{bulk} + 20\% \langle pT \rangle_{pp,jet}$
- Away side $<p_T>$ is still larger than that from the inclusive result.

→ Towards thermalization in more central collisions!

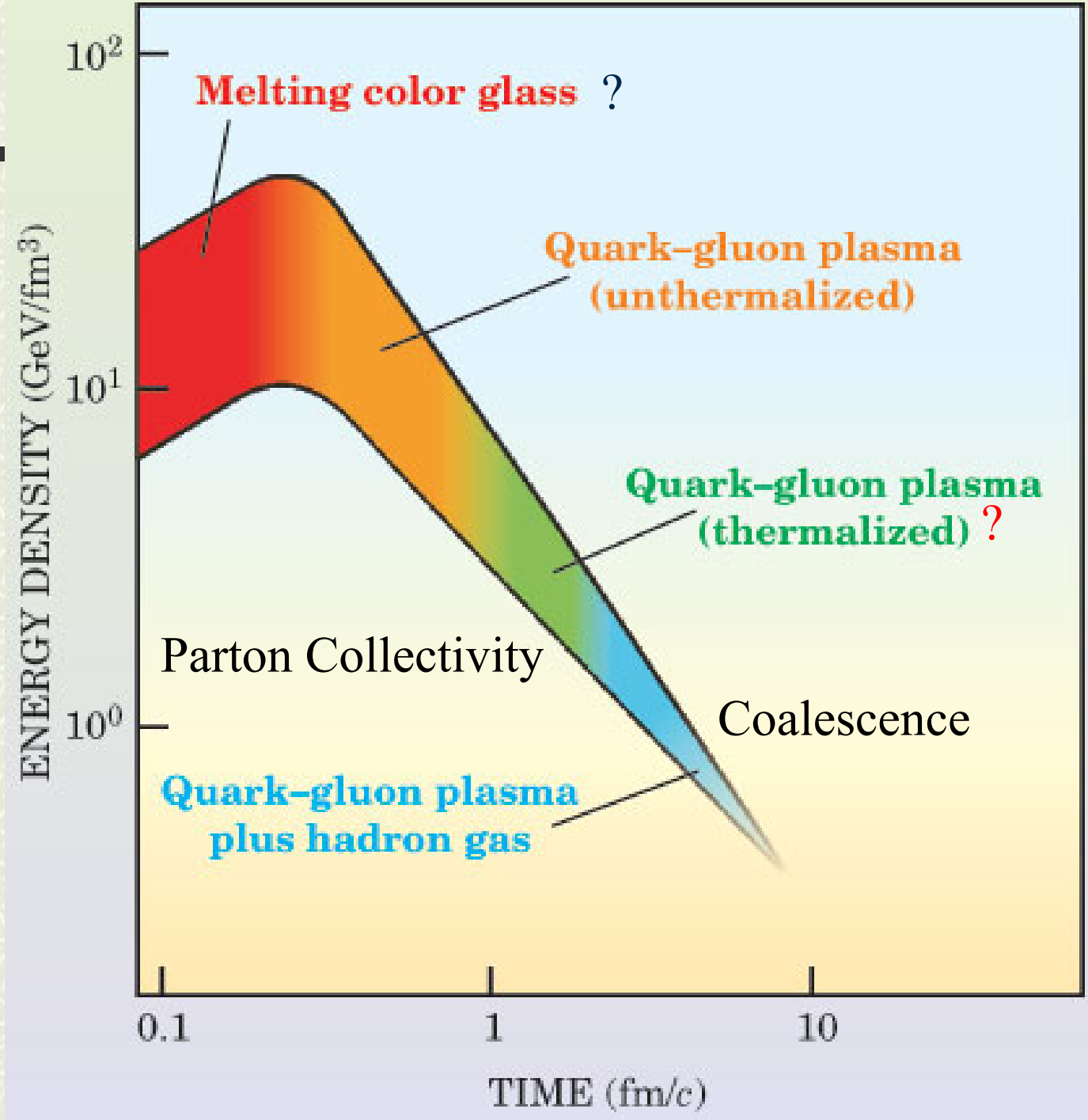
Summary

- Forward Rapidity exhibits different features from mid-rapidity in d+Au!!!
  Further theoretical comparisons
- Global Observations:
  Many Simple Scalings! Accidental??
- Chemical Equilibrium
- Resonance $\Rightarrow$ Finite Cross Section
- Ω flows
- Soft Spectra from "jet" thermalizing with system

Outlook

- Forward Rapidity
- Charm Flow
- High statistics ϕ, η, K*, Ω R_{AA}, v2
- Identified particle v1, v4, v6
- Identified particle spectra
  in the away-side soft particle
- More Resonances, pentaquarks
  (hadronic & leptonic decay)
- Energy Scan

A possible time line for Au+Au collisions?



Phys. Today 10/03

McLarren+Ludlum