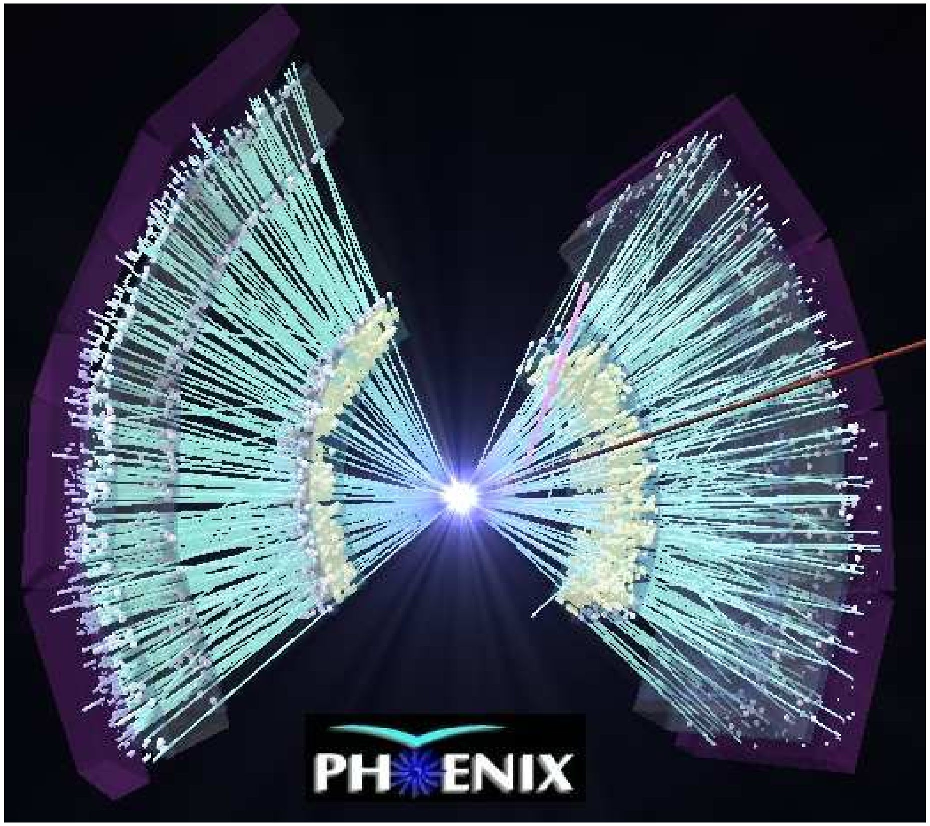
PHENIX Highlights

Quark Matter 2004, January 2004

A. D. Frawley

for the PHENIX Collaboration



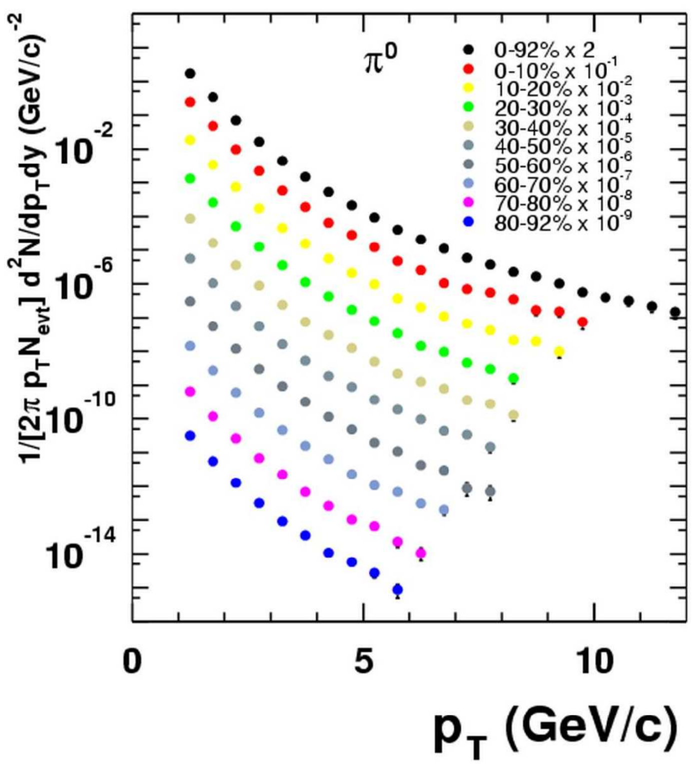
PHENIX capabilities

PHENIX design was optimized for **electron, muon and photon** physics.

But in addition to those rare probes, PHENIX has excellent capabilities for measuring both soft and hard physics over an enormous dynamic range.

200 GeV Au+Au

PRL **91**,072301 (2003)



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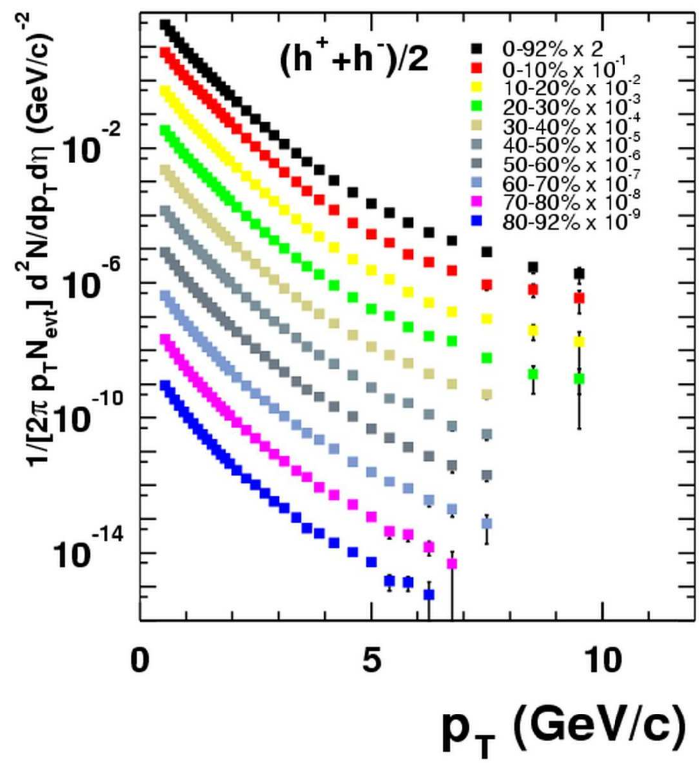
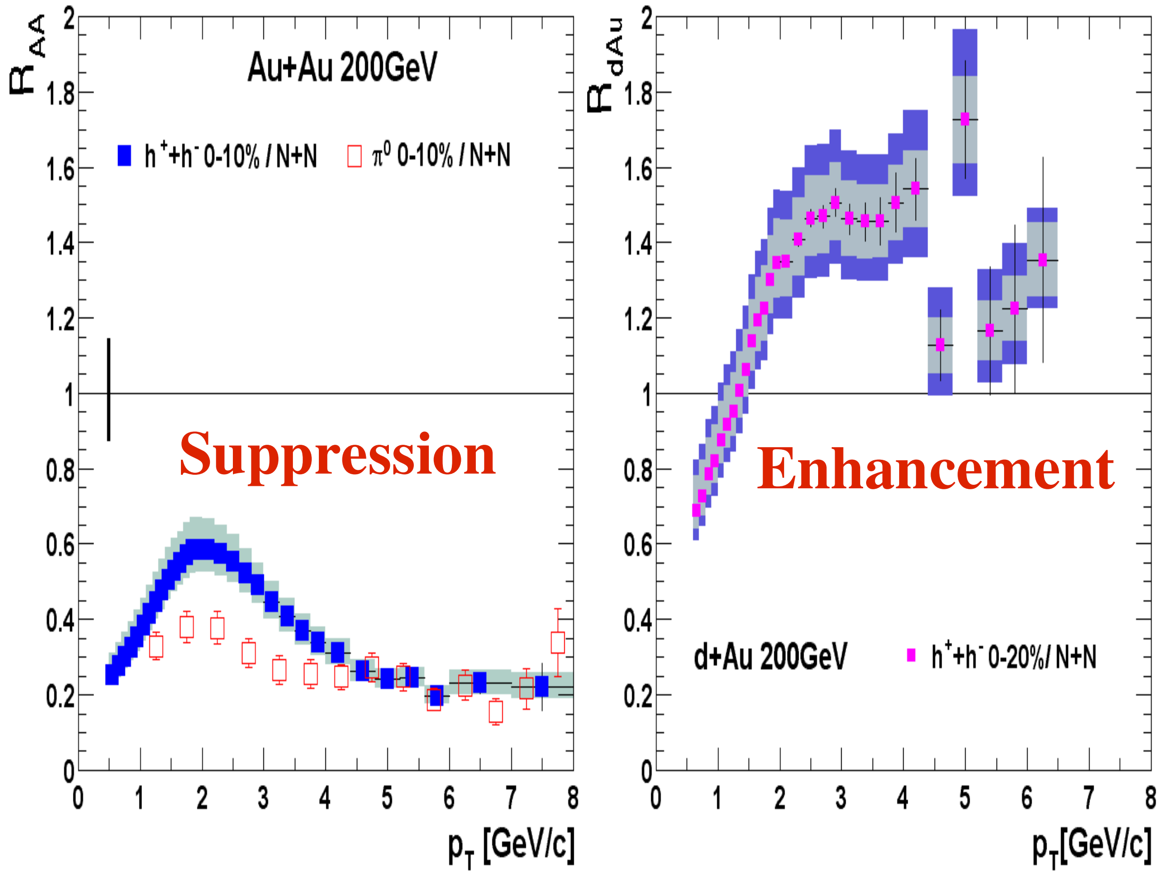


The major event of the last year was the discovery from RHIC Run 3 d+Au data that the dramatic suppression of hadrons in central AuAu collisions is **not caused by initial state effects**.

$$R_{AA} = \frac{\sigma_{AuAu}(\text{central})/\text{Ncoll}}{\sigma_{pp}}$$

$$R_{dA} = \frac{\sigma_{dAu}(\text{central})/\text{Ncoll}}{\sigma_{pp}}$$

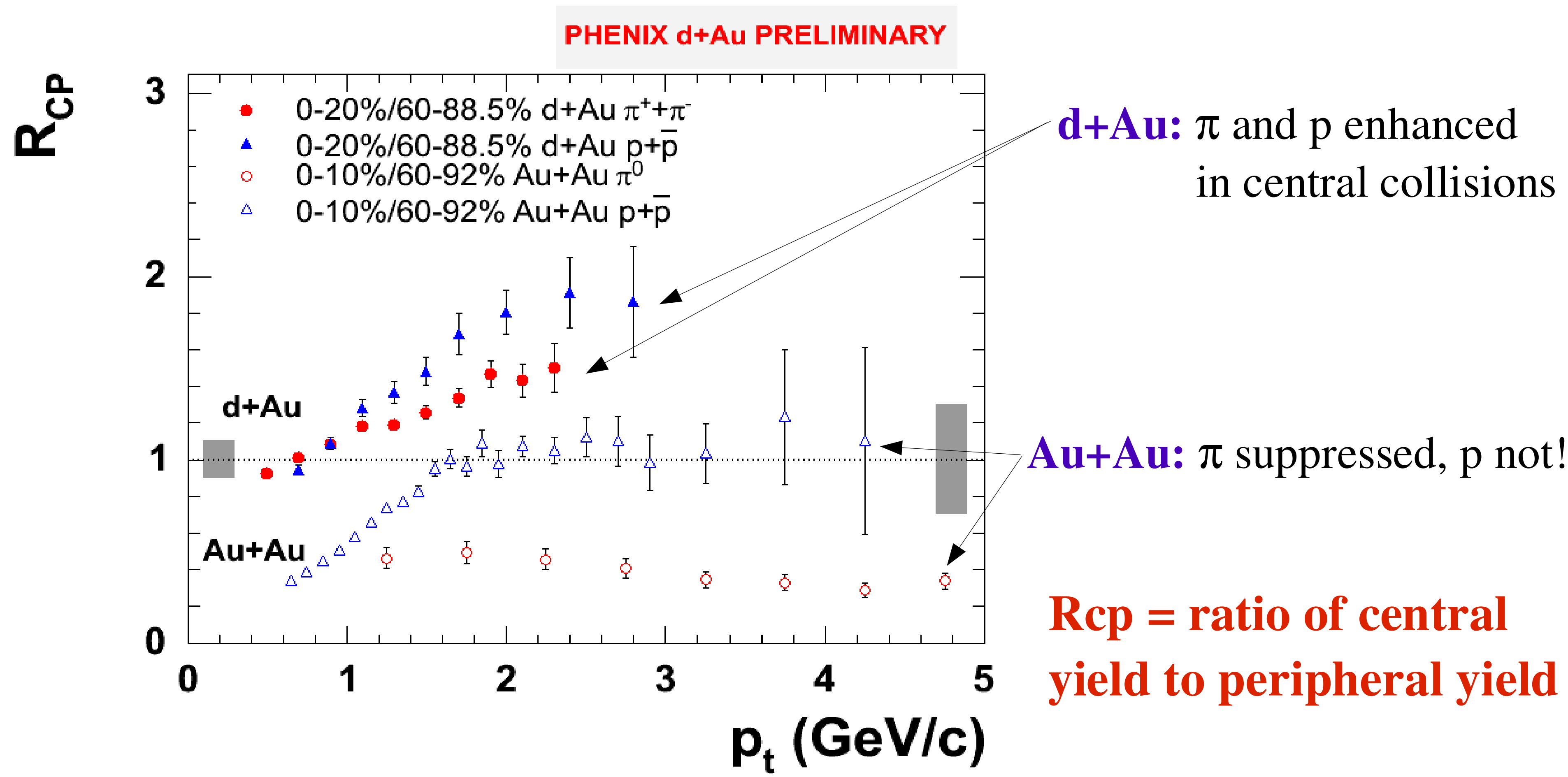
$$R_{CP} = \frac{\sigma_{AuAu}(\text{central})/\text{Ncoll}}{\sigma_{AuAu}(\text{peripheral})/\text{Ncoll}}$$



Since then, PHENIX analysis efforts have been focused in three main areas:

- Improving some important Run 2 Au+Au analyses to better characterize the **final state** effects in central AuAu.
- Extending the Run 3 d+Au and p+p analyses to provide the highest quality **comparison data** for Run 2, and for the anticipated Run 4, Au+Au data.
- Pursuing analyses of Run 3 d+Au and p+p data aimed at finding any **initial state effects** at high rapidity - ie. at large momentum-fraction asymmetry for the colliding partons.

Identified particle data show that protons are not suppressed in central AuAu

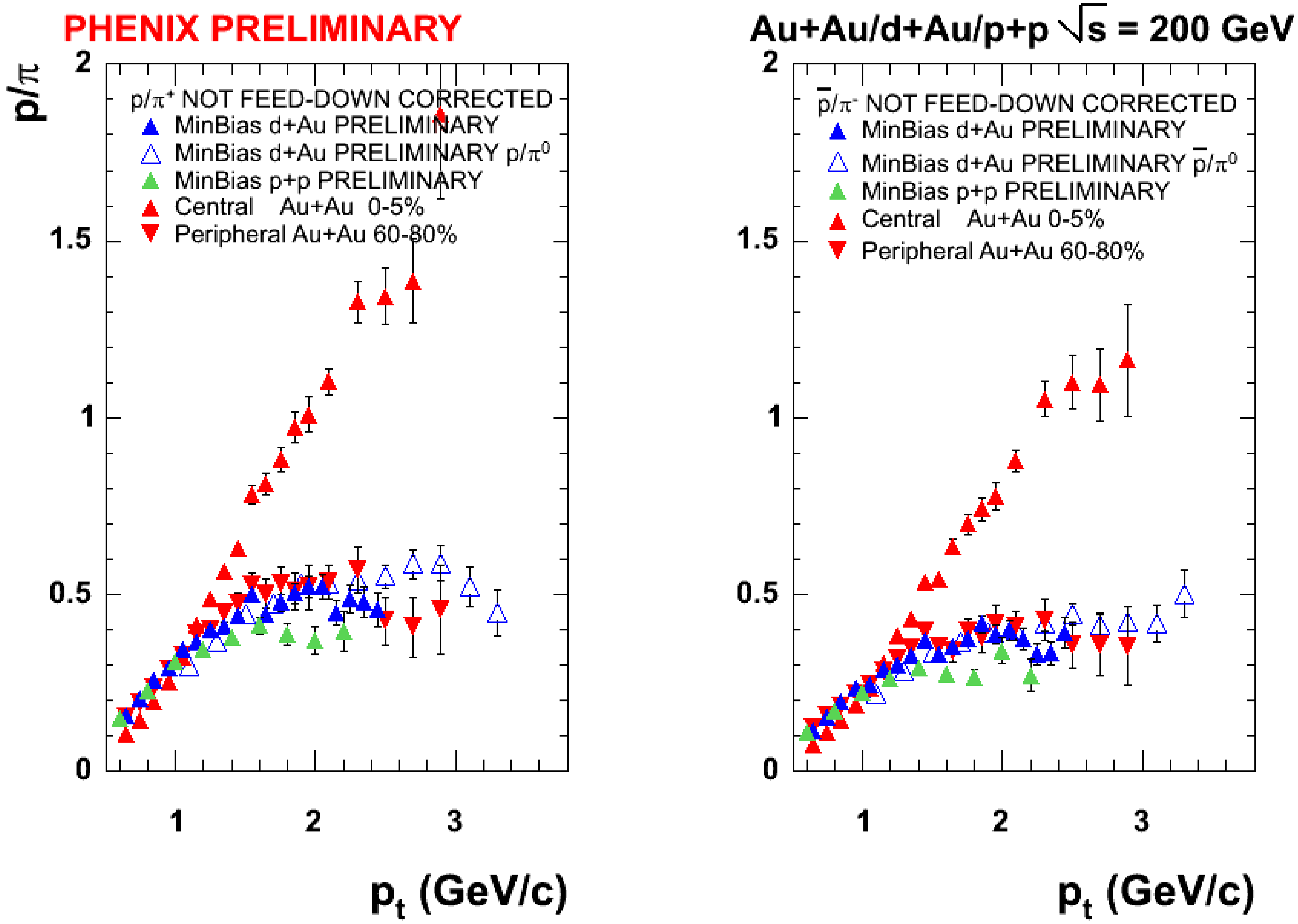


Rcp = ratio of central yield to peripheral yield

Shows π suppression is not an initial state effect

But protons behave **very** differently in 1< p_T < 4.5 GeV/c - why?

Identified particle data show that p/π ratio increases a lot in central Au+Au



But: h/π^0 ratio shows that p is enhanced only < 5 GeV/c

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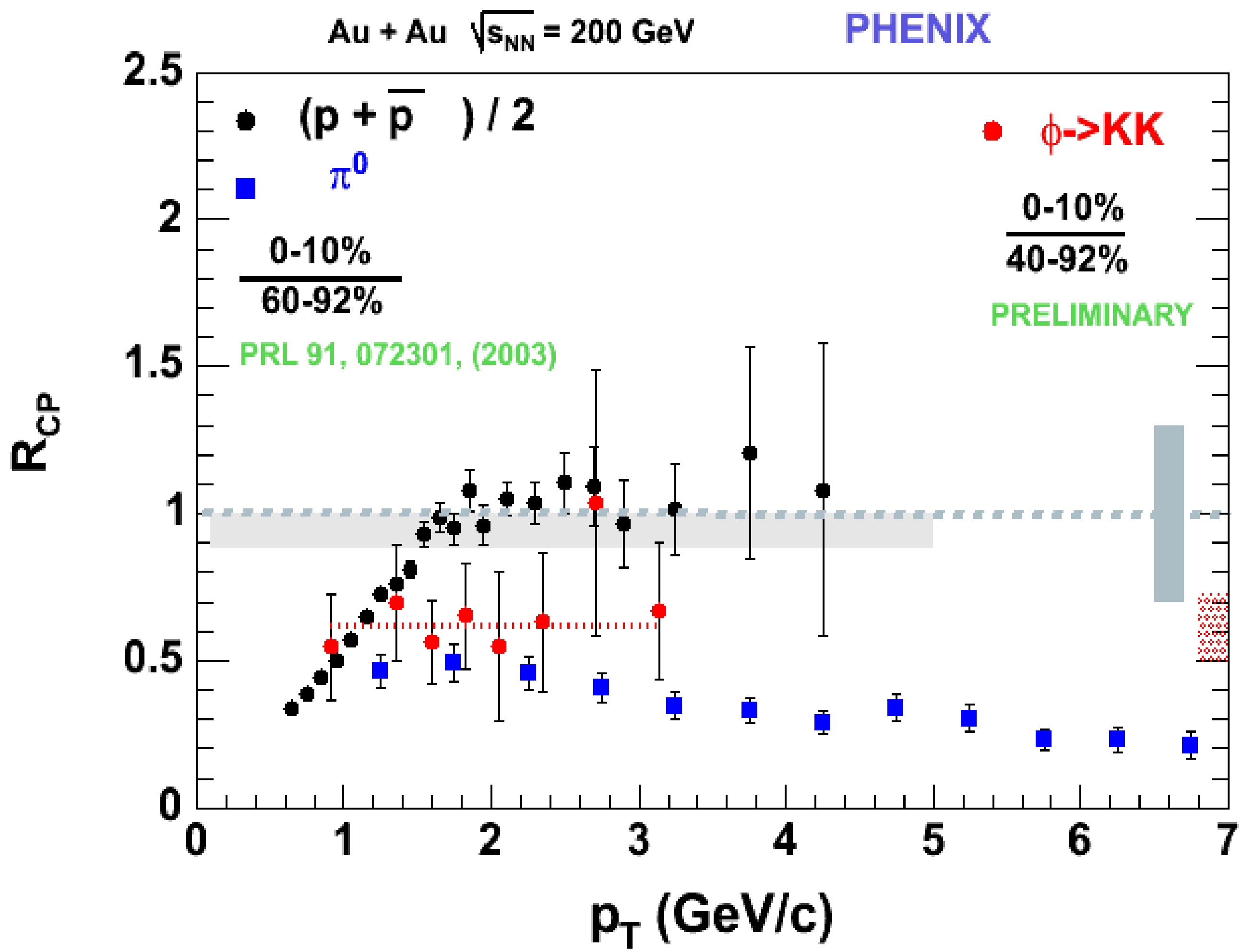
What about the ϕ R_{cp} ?



Interesting because the ϕ is a meson that has a mass similar to the proton.

The ϕ is suppressed, so the effect appears to be a meson/baryon thing, not a mass thing.

The "peripheral" bin used for the ϕ was dictated by low statistics. If we could use 60-92%, as for the others, we would expect the ϕ R_{cp} to decrease.

Hadron R_{CP} for d+Au

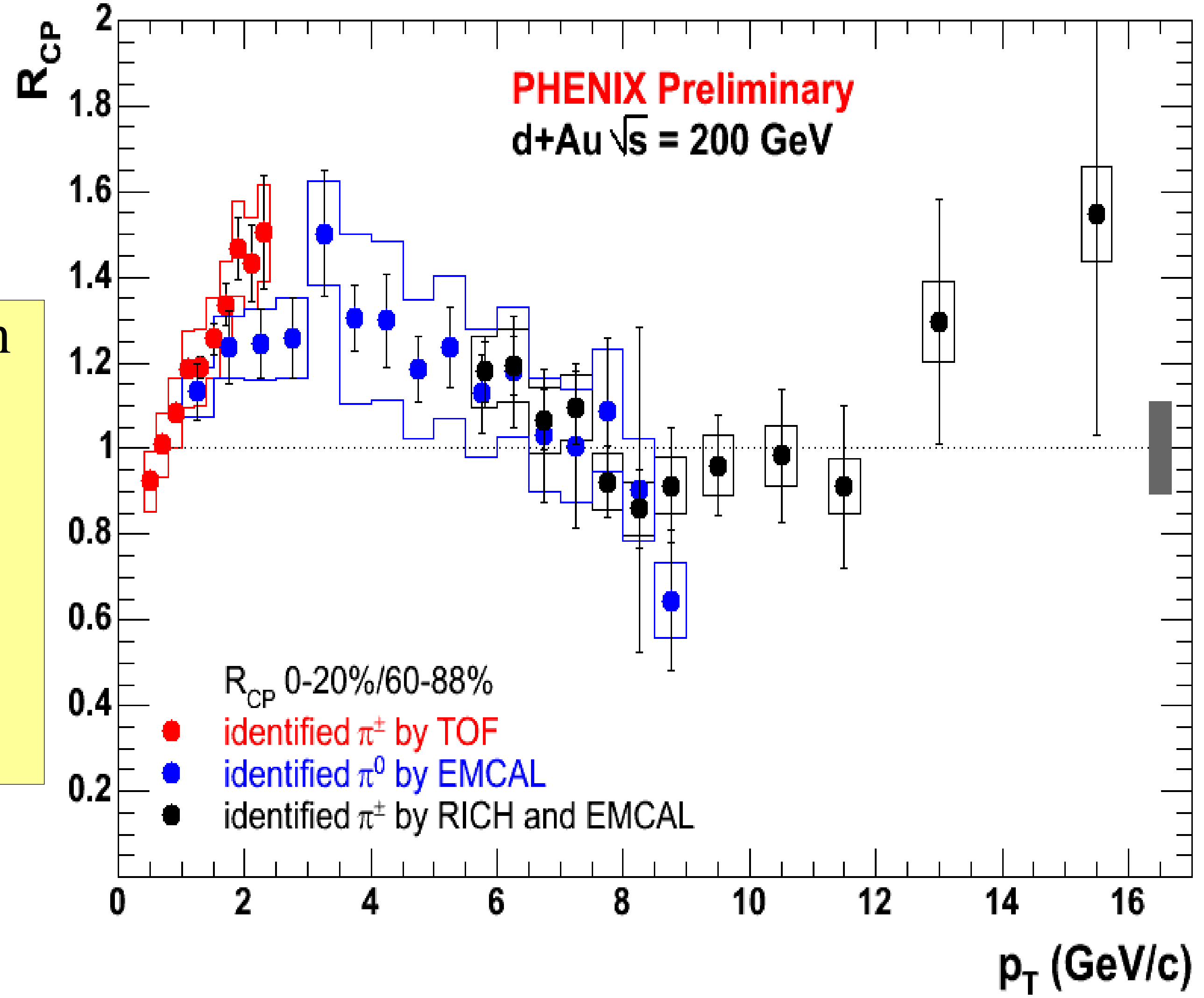
There is great interest in looking for **entrance channel effects** in the d+Au data from Run 3 as a function of centrality.

This pushes us to:

- Extend our **identified particle** range to higher p_T to fully map out the pT distribution for mesons and baryons (Cronin).
- Extend our **rapidity coverage** away from mid-rapidity to increase the x asymmetry between the colliding partons, so we sample a larger range of x values in nuclear matter (shadowing, gluon saturation).

Pion R_{CP} at mid-rapidity from 3 different techniques:

Have measured the Cronin scattering curve beyond where it drops back to a ratio of 1 for **identified** pions by overlapping data from several different techniques.



Extended rapidity coverage for hadron Rcp

PHENIX has recently developed techniques to extract hadron yields using our muon detectors (covering **$-2.2 < \eta < -1.2$ and $1.2 < \eta < 2.2$**).

This has been done in two ways:

- By detecting muons from **decays** of light mesons (π, K).
- By directly measuring hadrons that do not interact until they are in the Muon Identifier (**punch-through** hadrons).

See the talk by Ming Liu for details of the method.

See Ming Liu's talk
Thursday parallel 2

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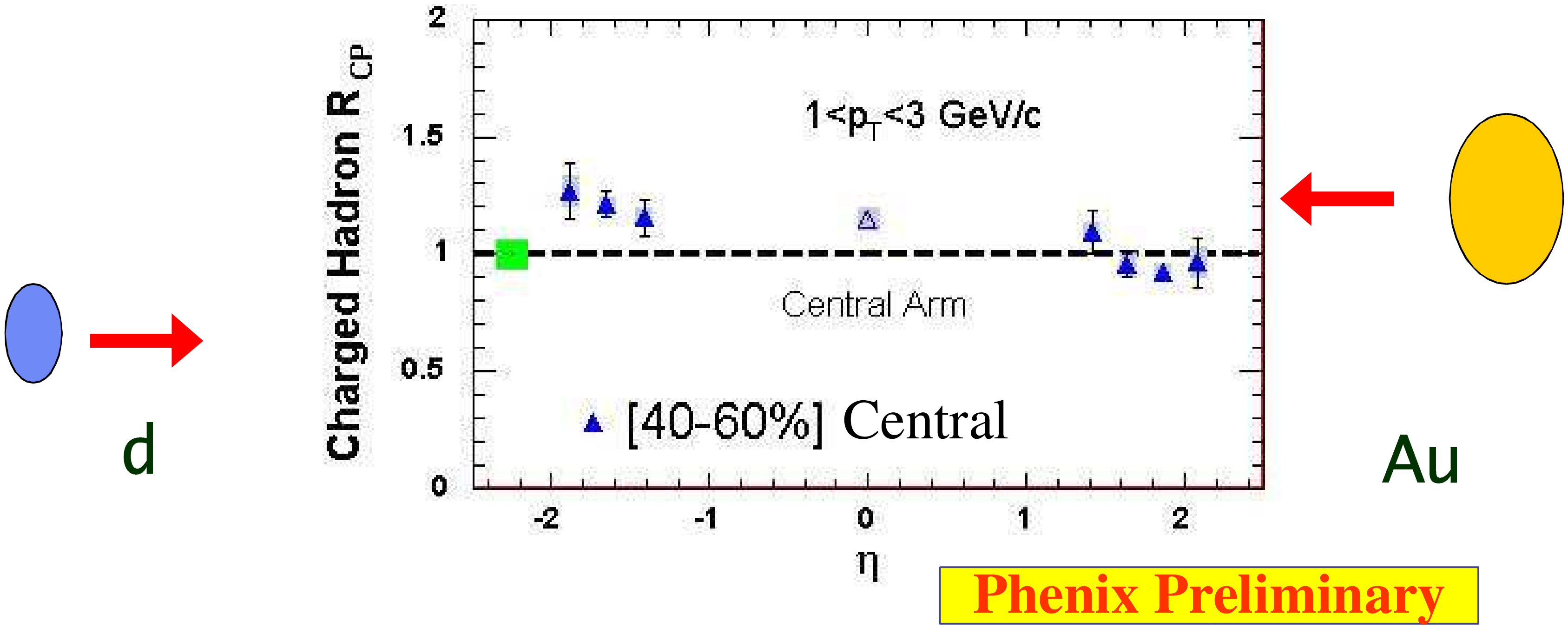
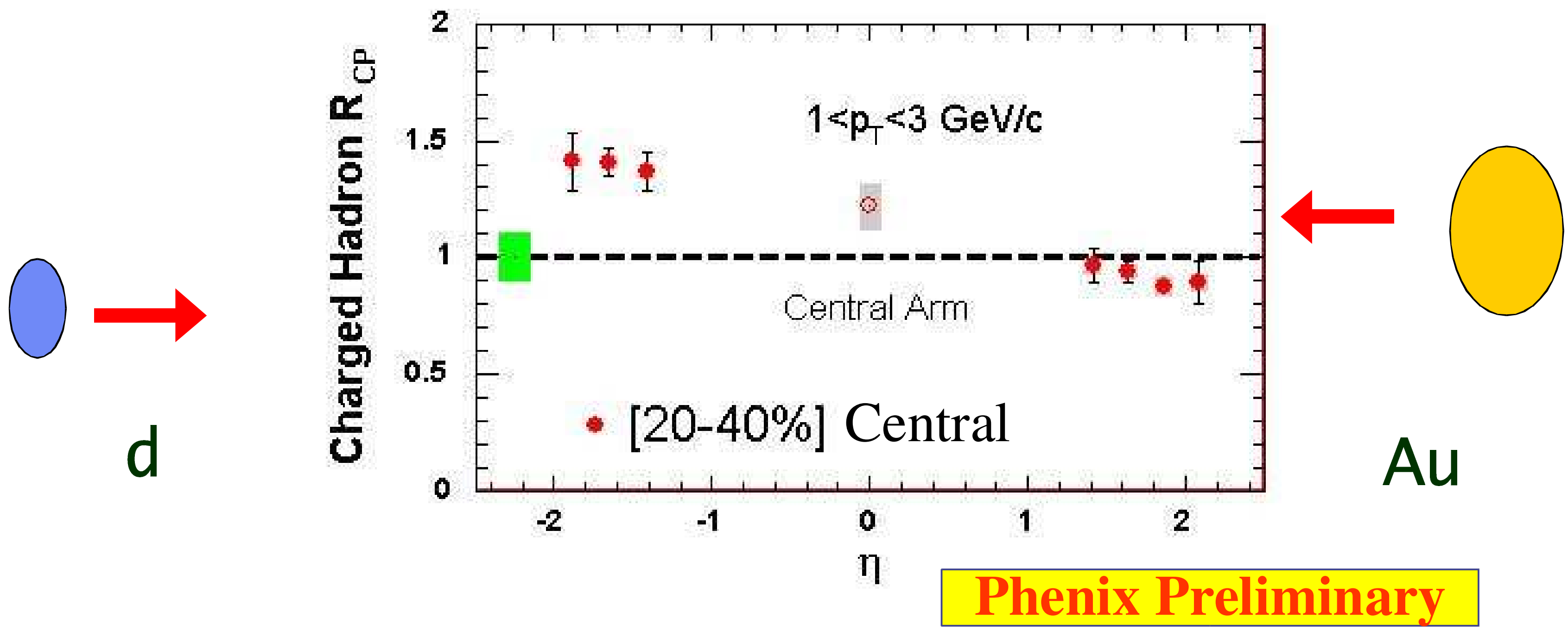
200 Gev d+Au unidentified hadron Rcp



200 Gev d+Au unidentified hadron Rcp



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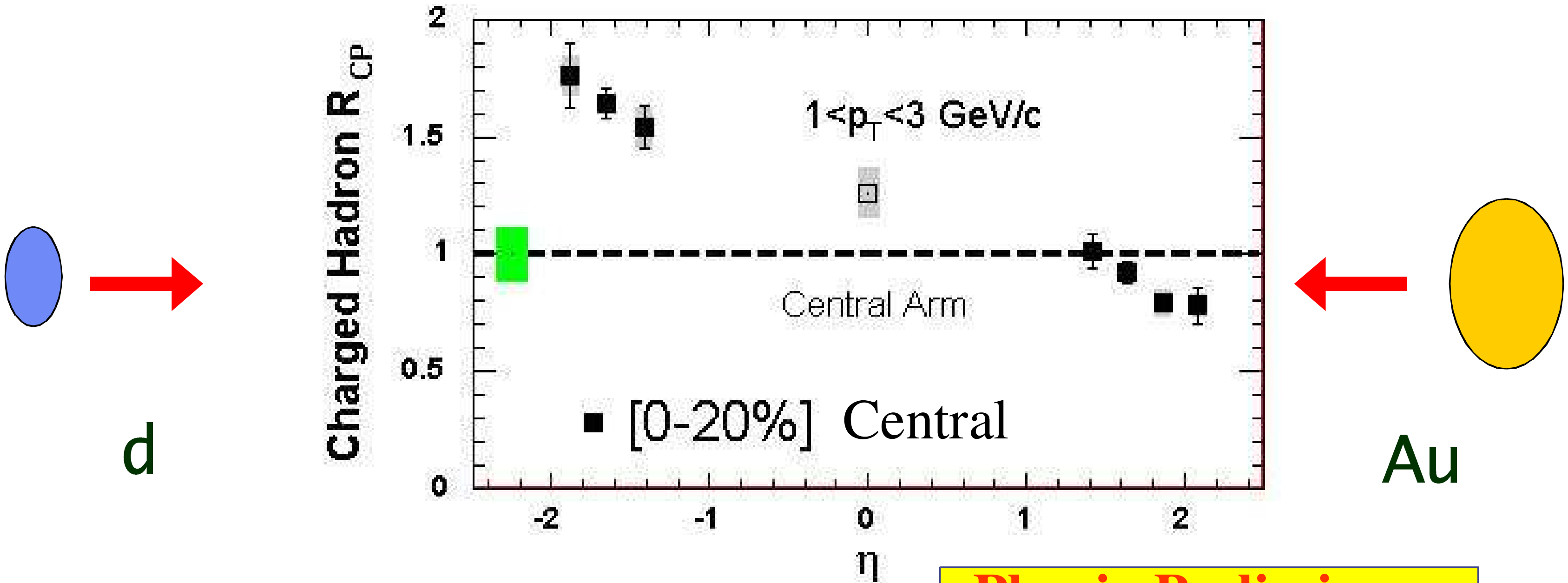
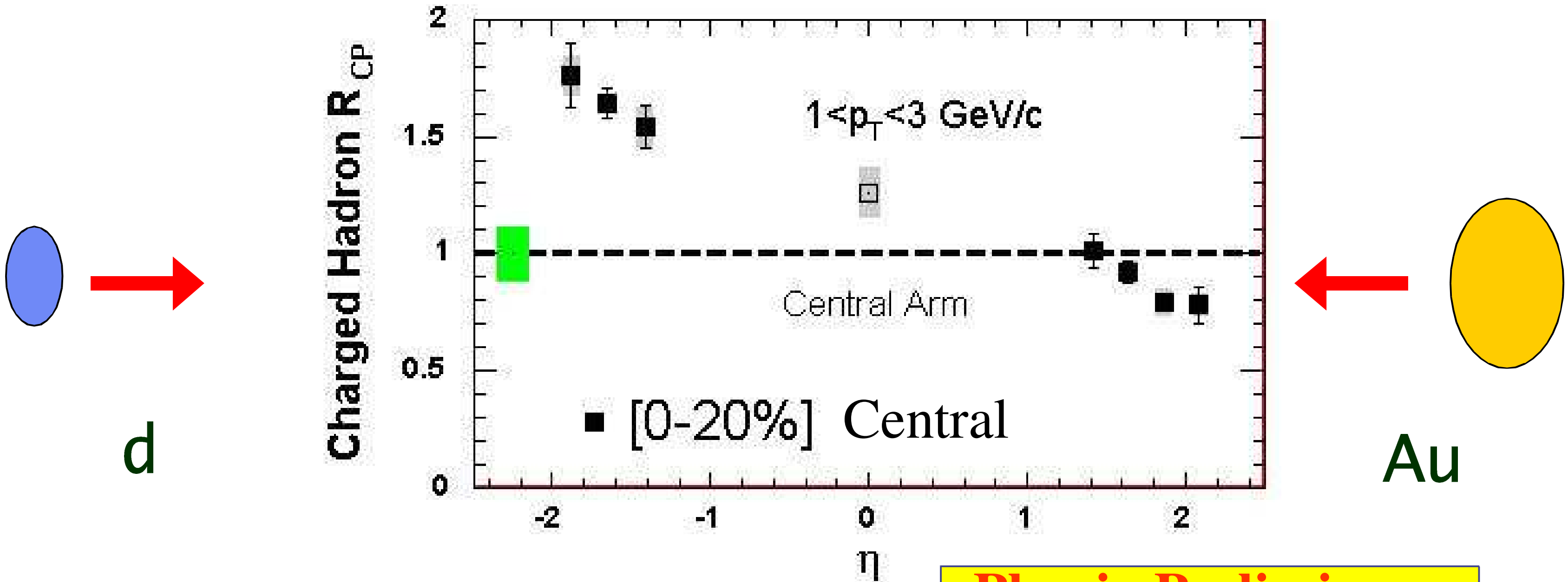


Phenix Preliminary

200 Gev d+Au unidentified hadron Rcp

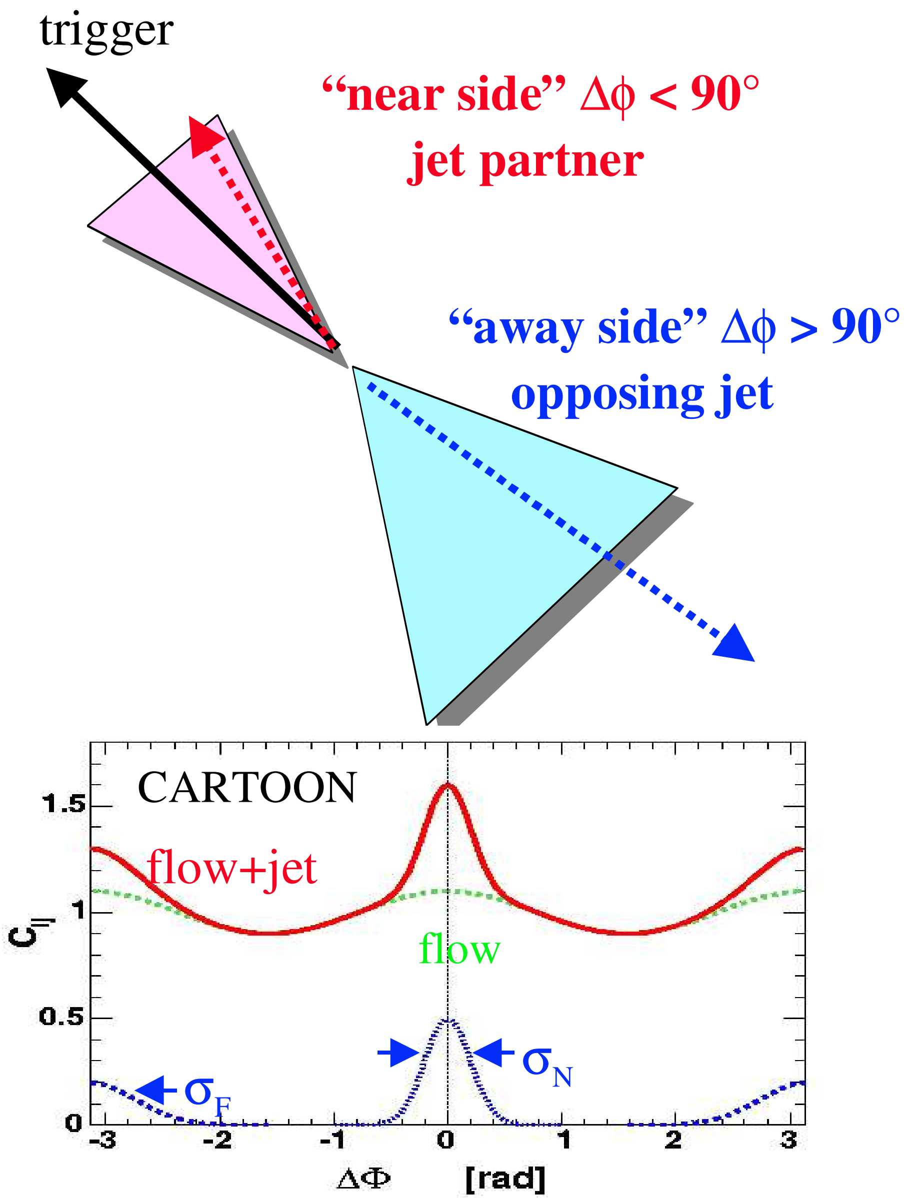


Phenix Preliminary

- Enhancement on the Au-going rapidity side **(ie. higher x partons in Au).**
- Depletion on the d-going side **(ie. lower x partons in Au).**
- Effect of soft physics contributions? Particle mix?

See Ming Liu's talk
Thursday parallel 2

Jet physics in PHENIX



Trigger:
hadron with p_T > 2.5 GeV/c

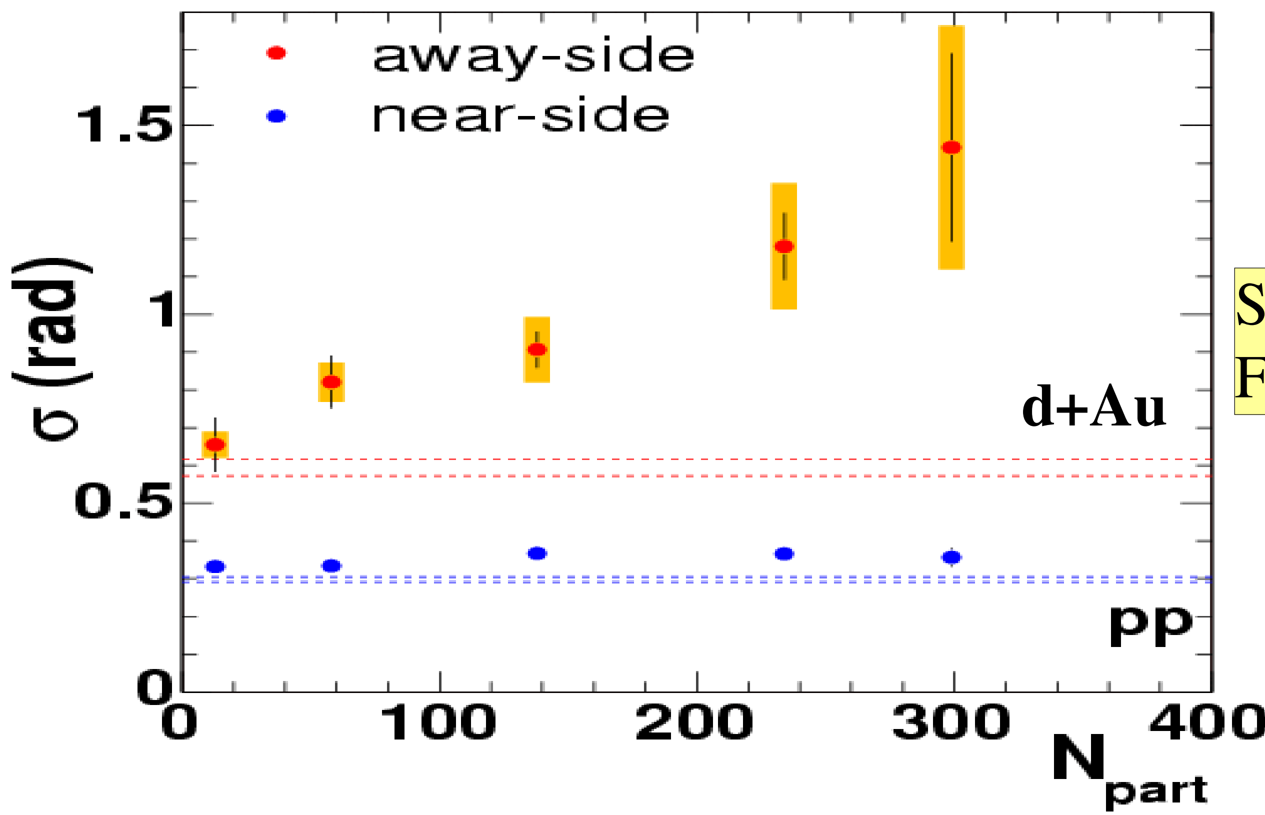
Count associated particles for each trigger at lower p_T (> 1 GeV/c)
→ "conditional yield"

Near side yield: number of jet associated particles from same jet in specified p_T bin

Away side yield: jet fragments from opposing jet

Away side width in AuAu

$(2.5<p_{Ttrigg}<4.0)$@ $(1.0<p_{Ttrigg}<2.5)$



See Jan Rak's talk
Friday parallel 1

Near-side width is constant, far-side width increases with centrality.
These widths can be related to the standard jet correlation parameters $\langle|j_{Ty}|\rangle$ and $\langle|k_{Ty}|\rangle$. **See Jan Rak's talk.**

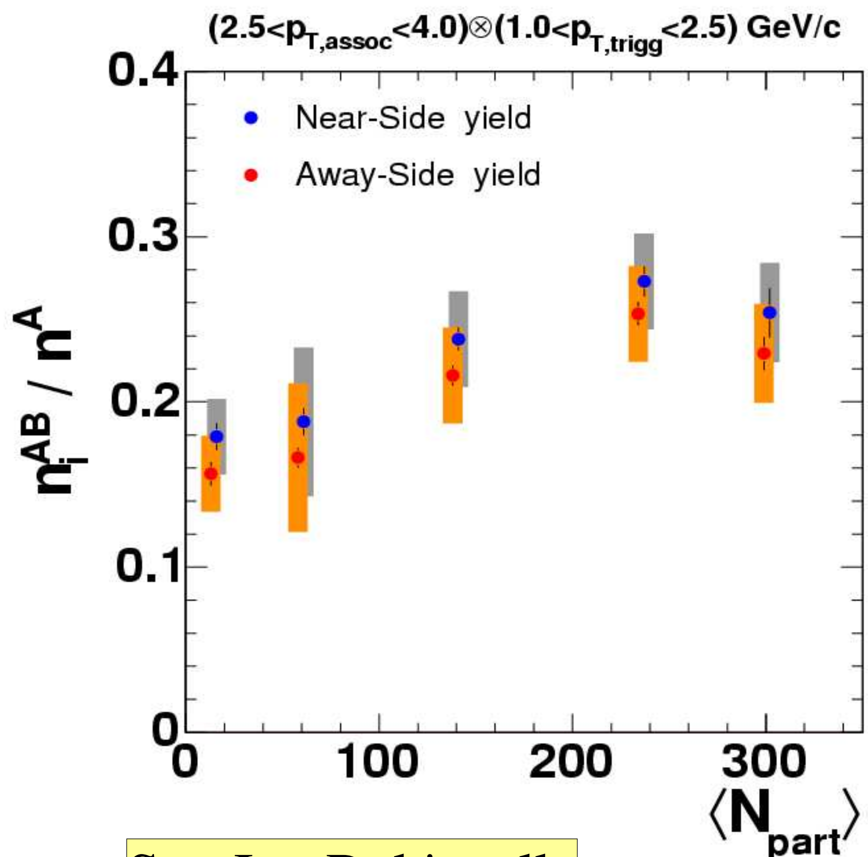
AuAu associated yields

(Number of particle pairs per trigger particle in AuAu)

The near-side width is independent of centrality.

The away-side width is a strong function of centrality.

But if we integrate the **entire Gaussian** for the away-side, the away-side associated yields **change in step** with the near side associated yields as they increase with centrality.



See Jan Rak's talk Friday parallel 1

Do mid-p_T baryons come from jets?

- Use jet correlation technique to study source of baryon excess at p_T = 2-4 GeV/c
  - **Identify trigger particle**
  - **Count associated particles per trigger**
- If baryon excess is due to quark recombination (coalescence)
  - **Expect fewer jet-like associated particles (coalescence of flowing partons in models).**
  - **So yield of associated particles should decrease when coalescence contribution increases with centrality.**

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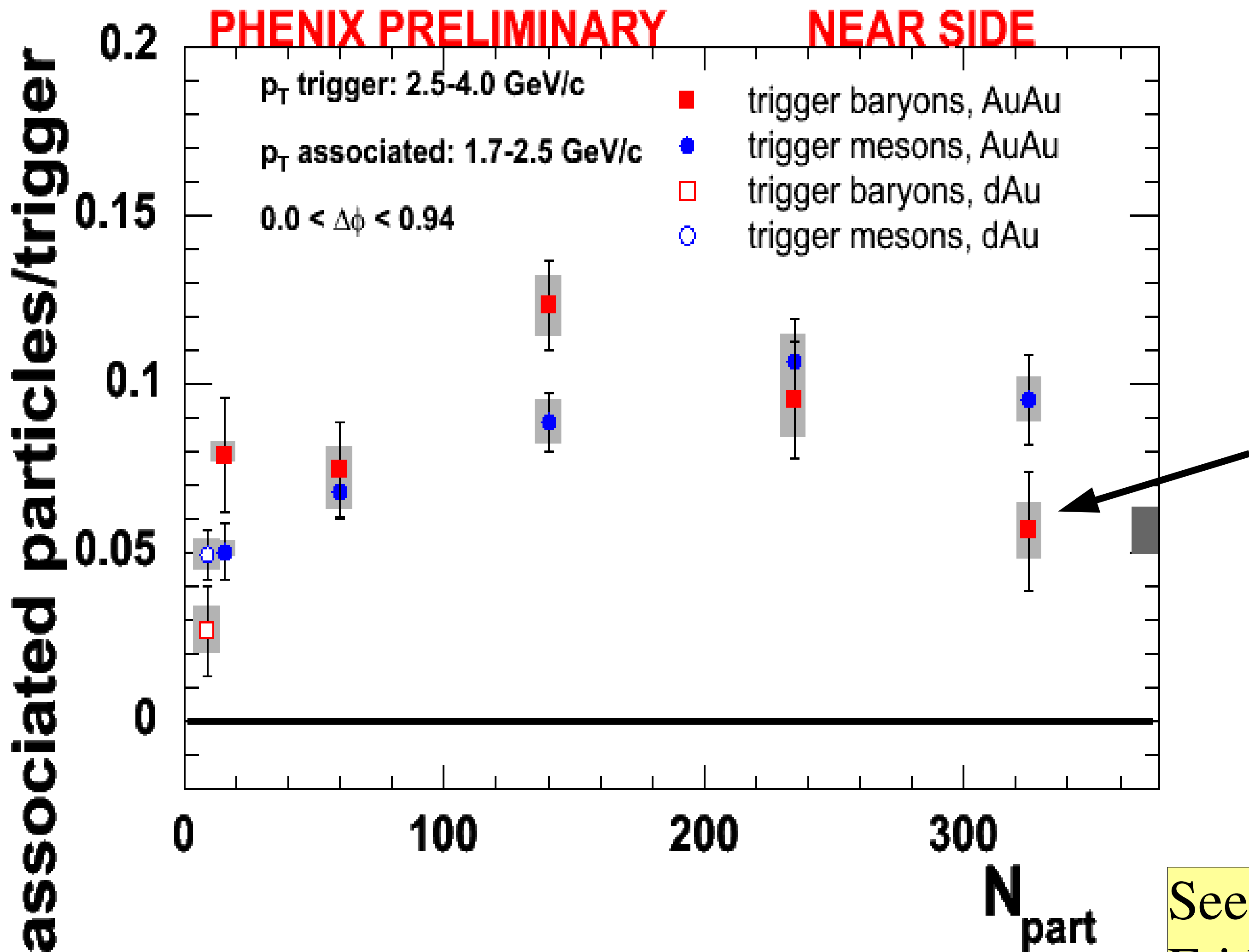
Identified trigger particle

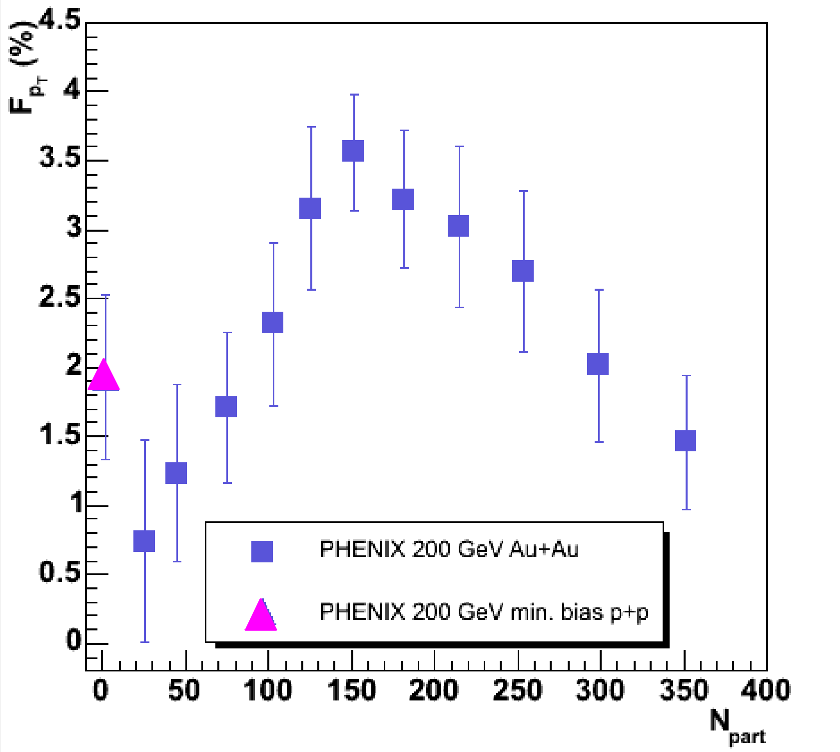


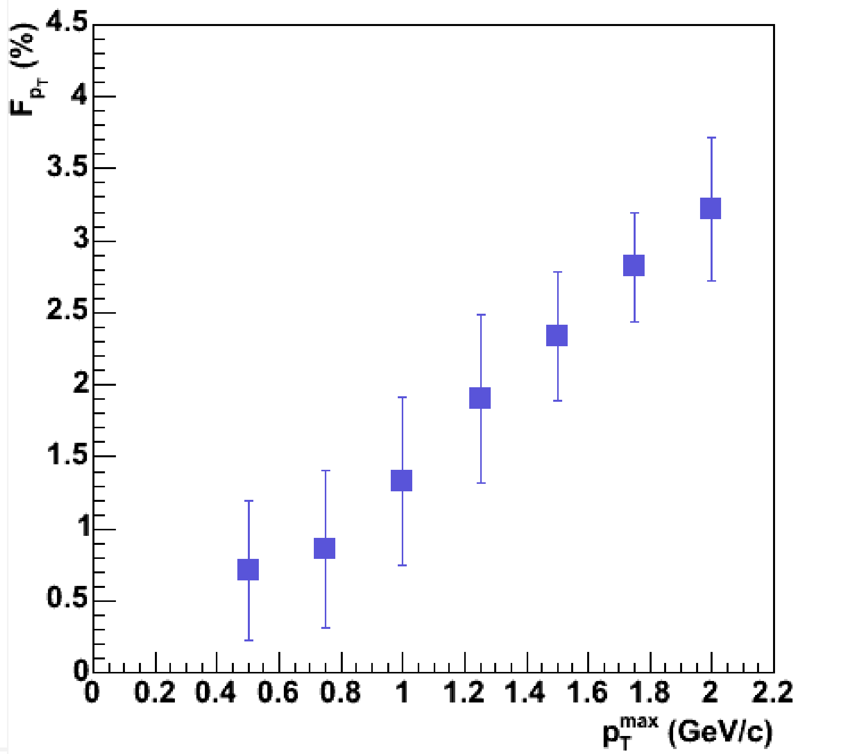
- jet partner equally likely for trigger baryons & mesons
- no significant decrease of baryon associated particles with centrality!

See Anne Sickles' talk Friday parallel 1

Event-by-Event average p_T Non-Random Fluctuations are a few percent of random rms (σ_{MpT})

Interesting variation with N_{part} and p_{Tmax}





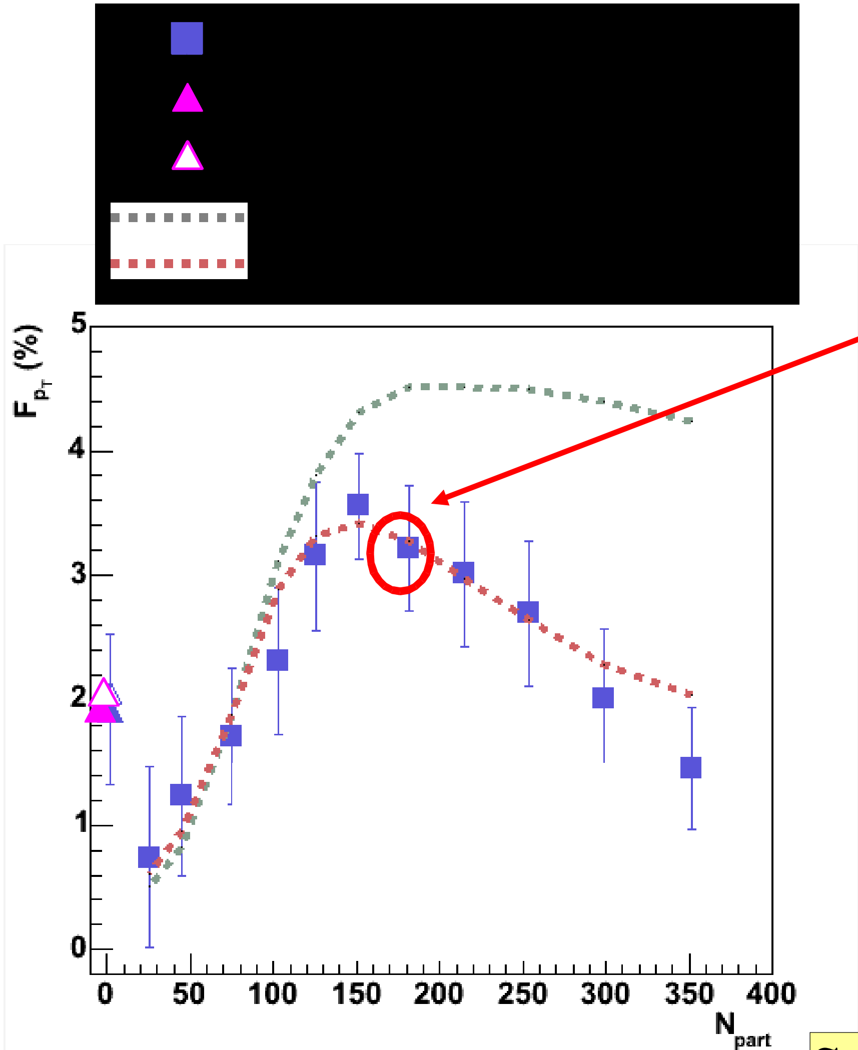
n >3 $0.2 < p_T < 2.0$ GeV/c

0.2 GeV/c $< p_T < p_T^{max}$

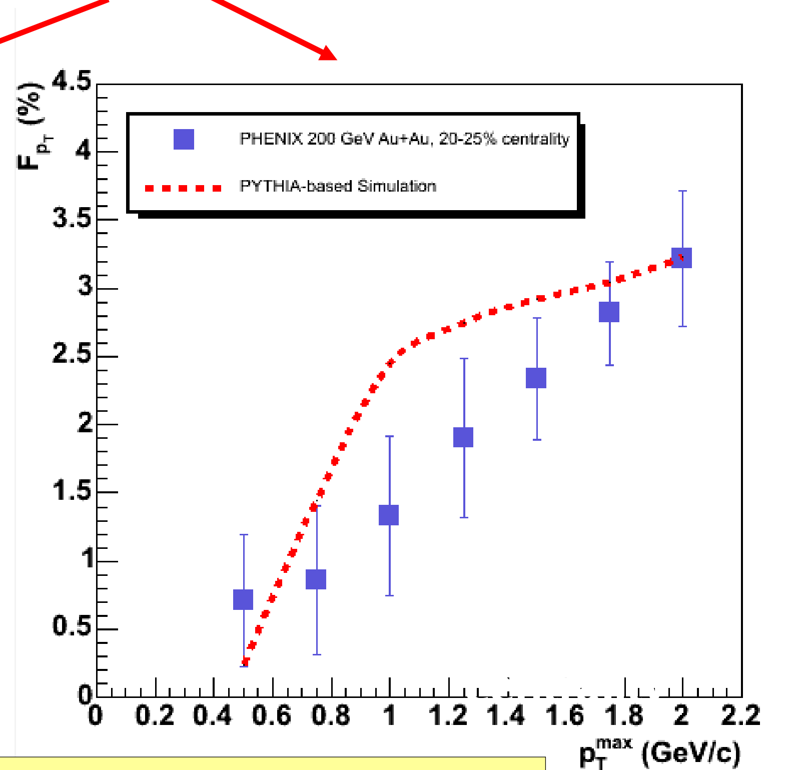
Errors are totally systematic from run-run r.m.s variations

(200 GeV)nucl-ex/0310005 subm. PRL cf. PRC **66** 024901 (2002) ($\sqrt{s_{NN}}$=130 GeV)

PHENIX fluctuations are consistent with being due to Jets

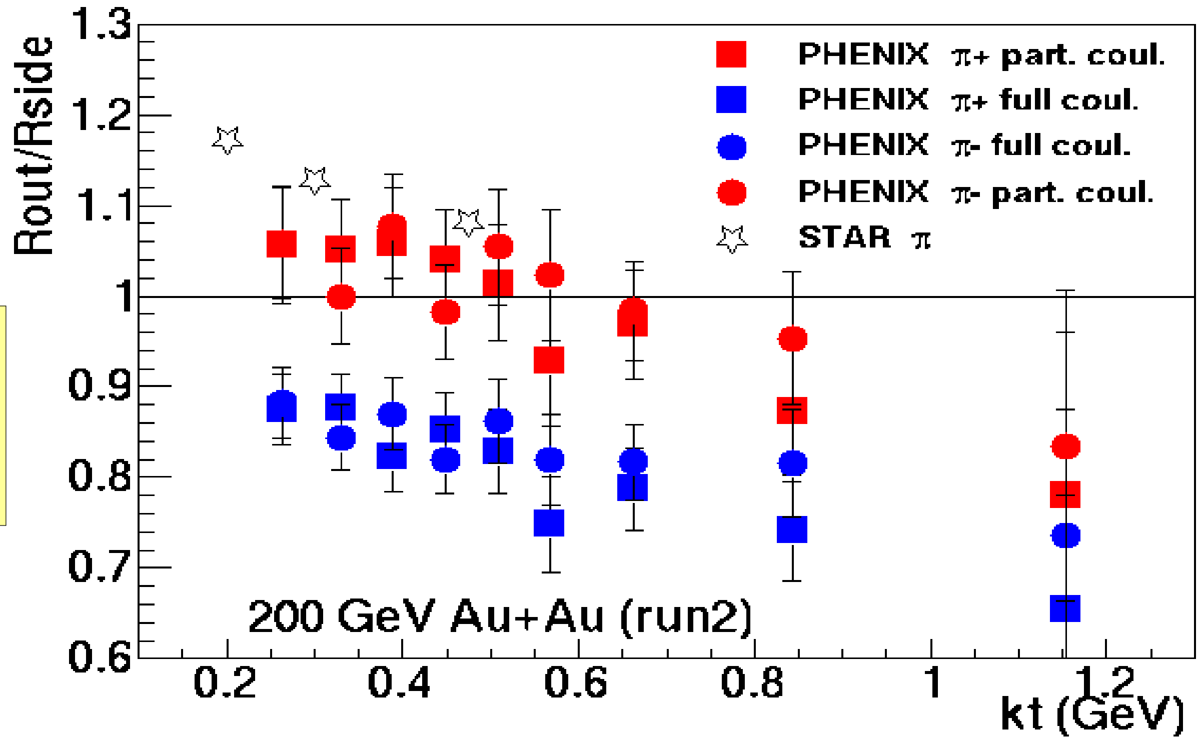


One parameter is initially adjusted so that F_{pT} from the simulation matches F_{pT} from the data for 20-25% centrality.



See Mike Tannenbaum's talk Friday parallel 4

R_{out}/R_{side} from HBT



See Mike Heffner's talk Tuesday parallel 3

This recent analysis shows the change in R_{out}/R_{side} when the **partial Coulomb correction** is used instead of the **full Coulomb correction**.

The ratio moves in the direction of the models, but only increases to about one. **Note the large k_T reach of the data.** See **Mike Heffner's talk** for detailed discussion of this and other HBT topics.

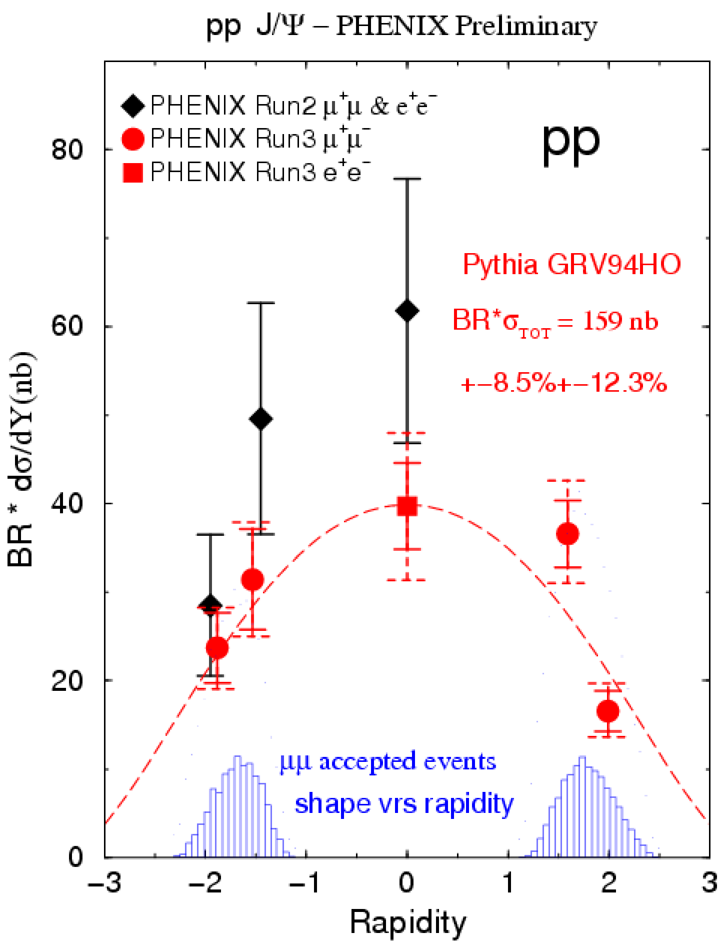
J/ψ production in p+p and d+Au

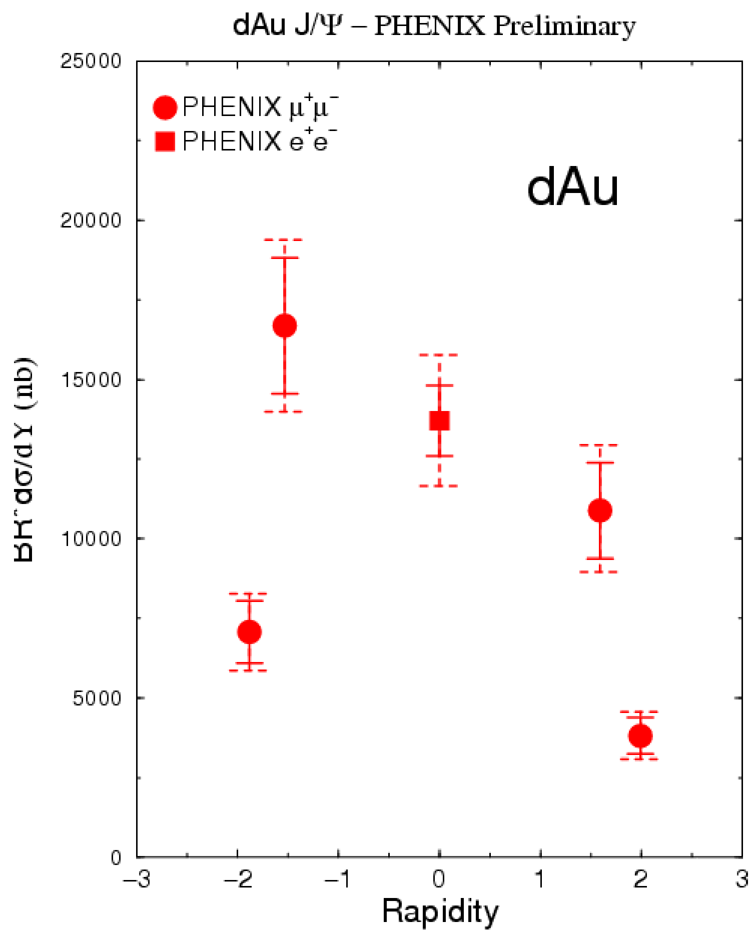
Run 3 provided the first sizable samples of J/ψ for PHENIX (**~ 1700** in d+Au and **~ 500** in p+p).

Because J/ψ are produced primarily in hard interactions between gluons, their simultaneous measurement in the PHENIX central arms and muon arms provides a good opportunity to test ideas about **initial state nuclear effects** such as shadowing and gluon saturation, as well as investigating **final state absorption** in cold nuclear matter at RHIC energies.

See R. G. de Cassagnac's talk Friday parallel 2

J/ψ cross section versus rapidity

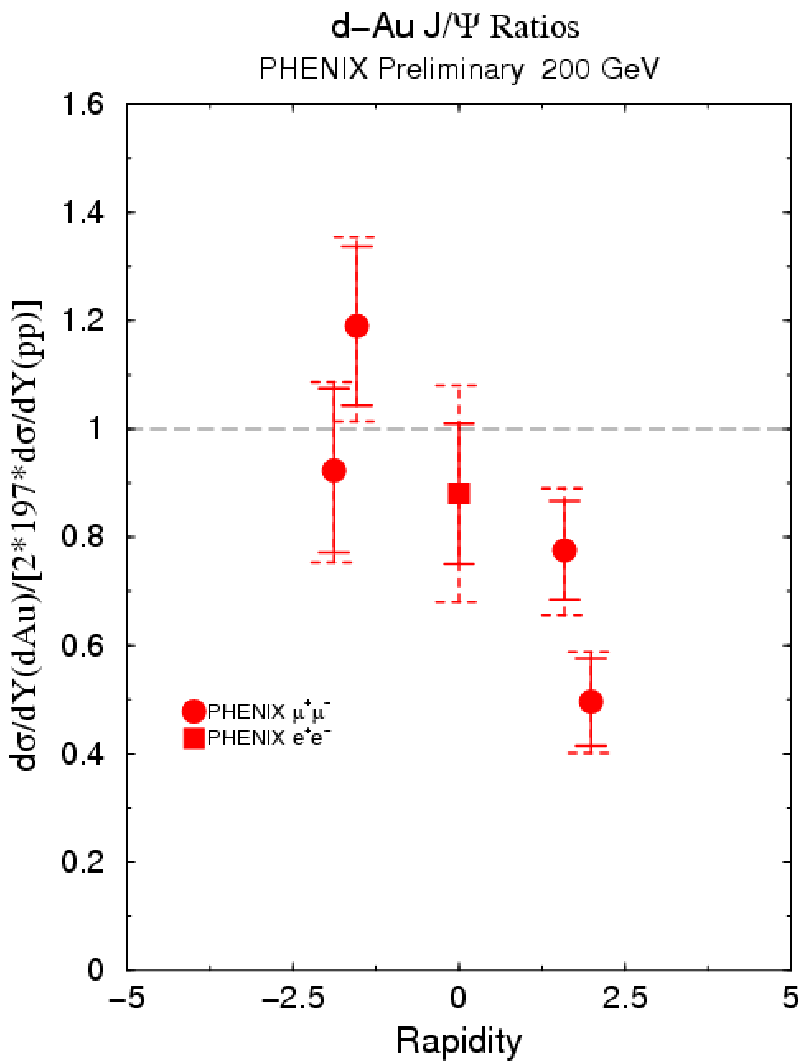




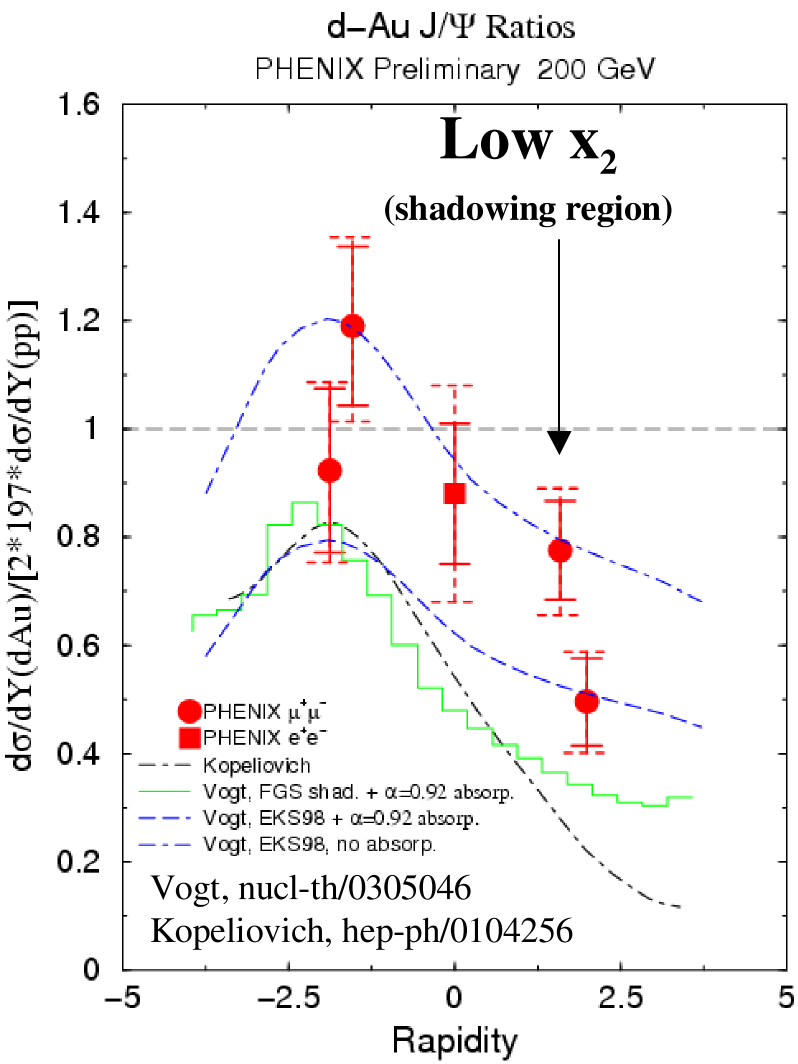
- Total cross section :

$BR\ \sigma_{pp}$ = 159 nb ± 8.5 % (fit) ± 12.3% (abs)

dAu/pp versus rapidity



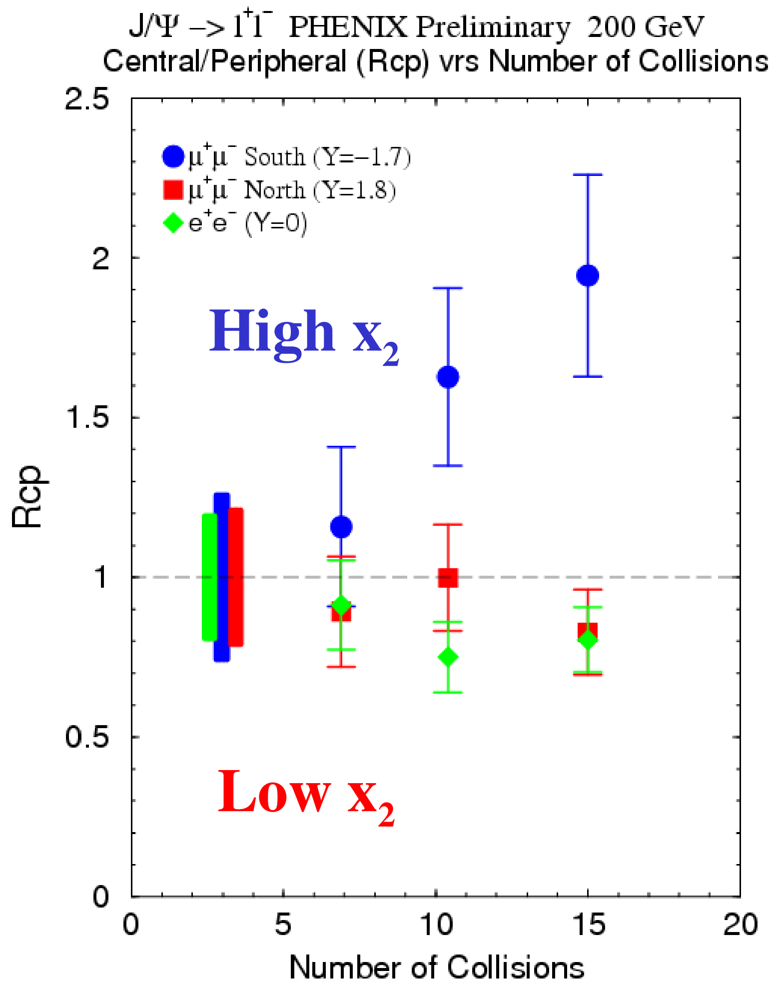
dAu/pp versus rapidity



- x_2 is the momentum fraction of the parton **from the Au nucleus**.
- Data favours (weak) shadowing + (weak) absorption ($\alpha > 0.92$)
- With limited statistics, difficult to disentangle small nuclear effects.

See R. G. de Cassagnac's talk Friday parallel 2

Central/peripheral versus Ncoll



See R. G. de Cassagnac's talk Friday parallel 2

- First measurement of J/ψ vs Ncoll in pA(dA)!
- **Low** and **med** x_2 have small variation with Ncoll
  - Weak nuclear effects
- **High x_2** has a steep rising shape - no clear explanation at present, see **Raphael G. de Cassagnac's talk**.

Direct photons in RHIC Au+Au and p+p collisions with PHENIX.

The most spectacular example of an improved analysis of Run 2 Au+Au data, after bringing in level 2 triggered data and improving systematics.

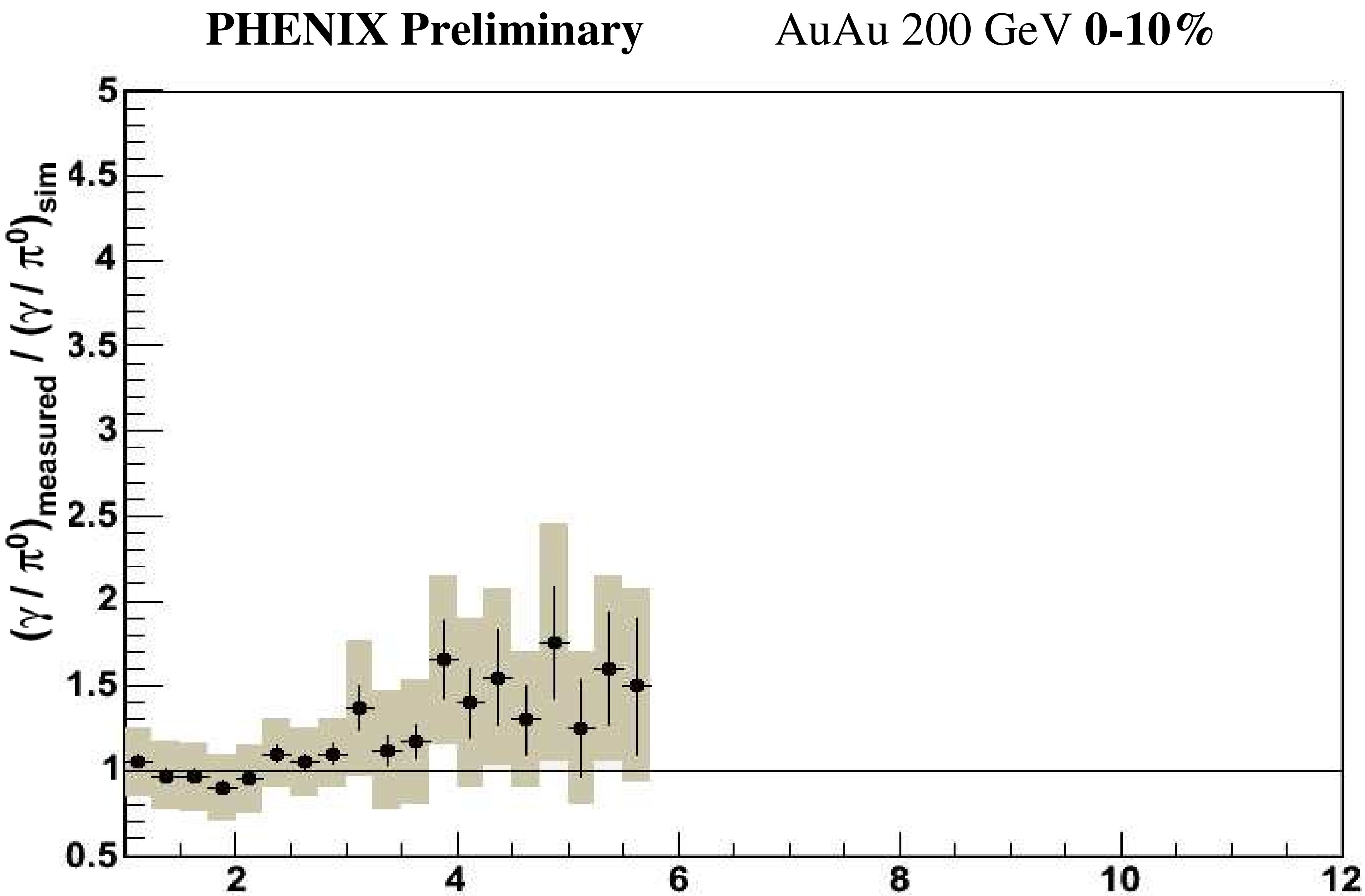
To cancel out as many systematic errors as possible, here we look at ratios of:

$$\frac{\gamma(\text{measured})/\pi^0(\text{measured})}{\gamma(\text{background})/\pi^0(\text{fit to measured})} = \frac{\gamma(\text{measured})}{\gamma(\text{background})}$$

where γ(background) includes π^0, η^0,..

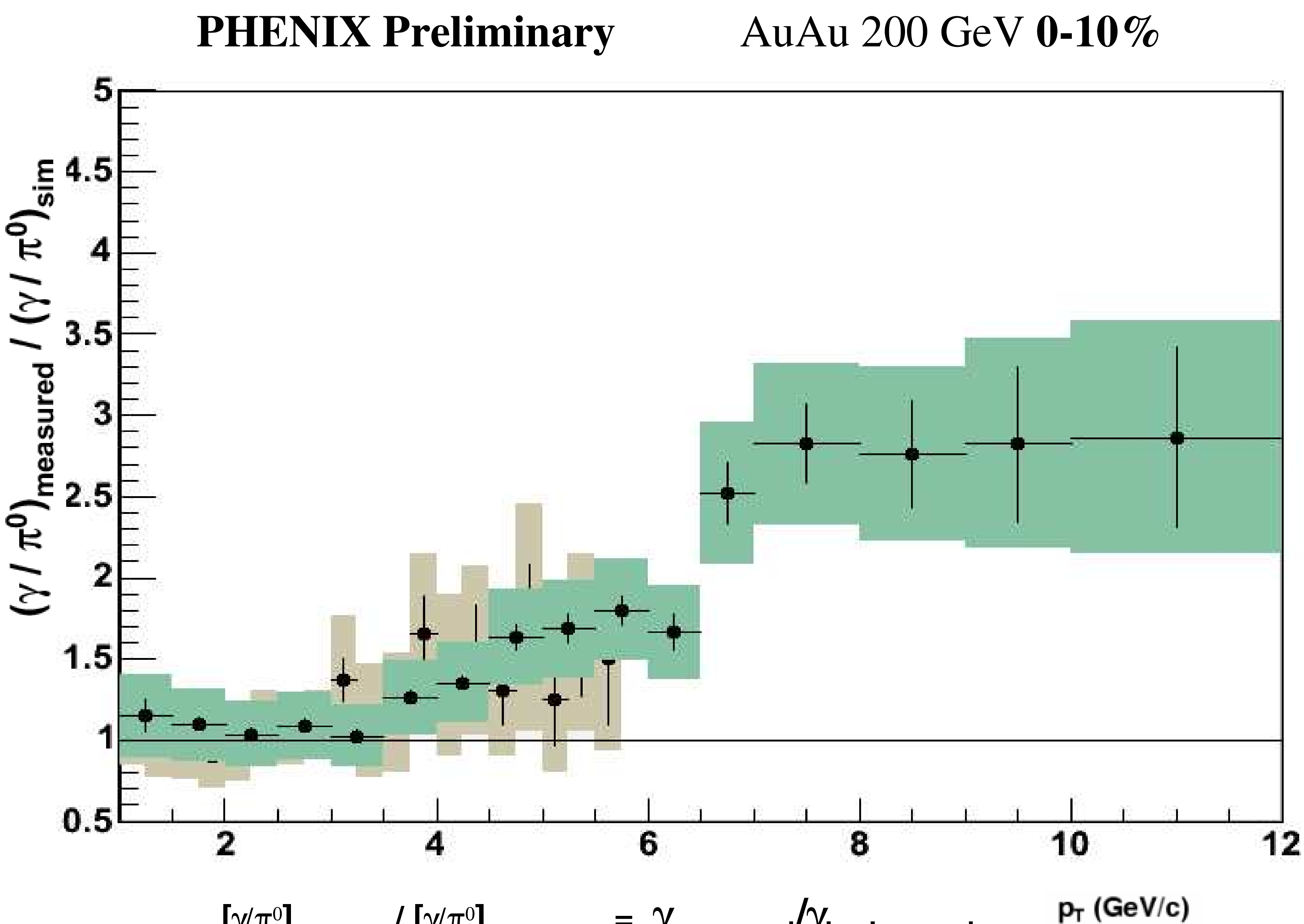
See Justin Frantz talk on Friday afternoon

QM02 Results



$$[\gamma/\pi^0]_{measured} / [\gamma/\pi^0]_{background} = \gamma_{measured}/\gamma_{background}$$

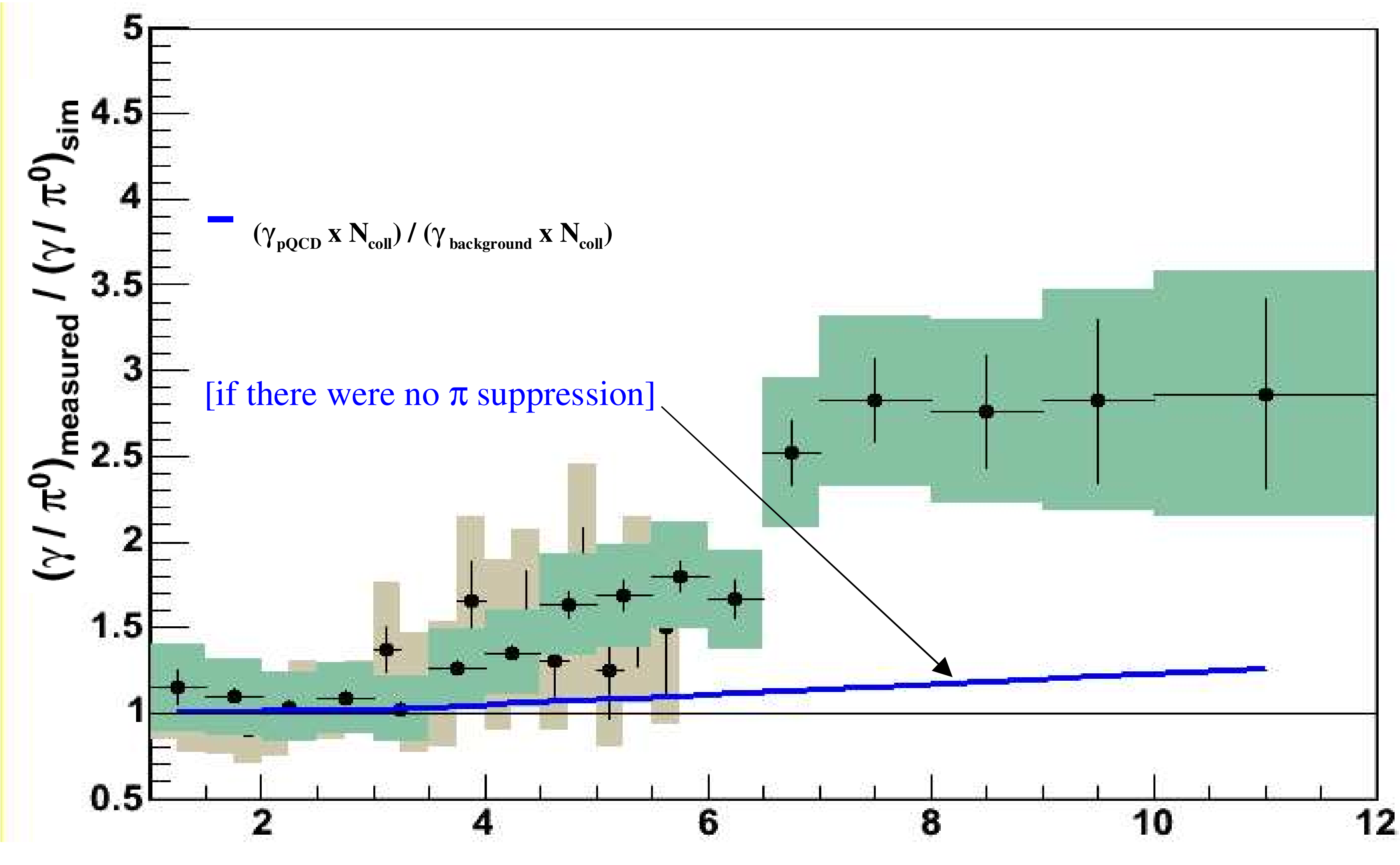
New Results



$[\gamma/\pi^0]_{measured} / [\gamma/\pi^0]_{background} = \gamma_{measured}/\gamma_{background}$

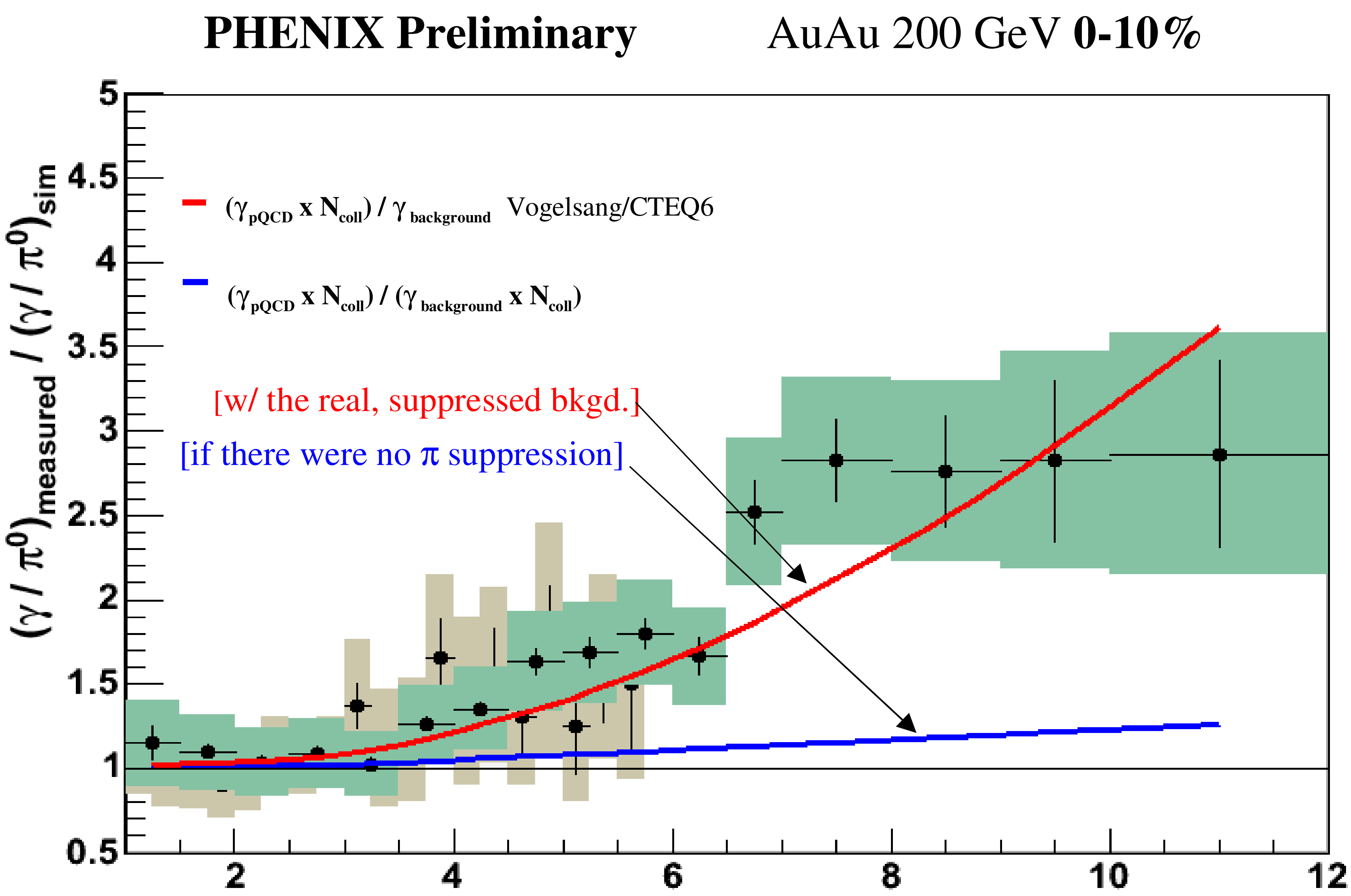
New Results

PHENIX Preliminary AuAu 200 GeV **0-10%**



$[\gamma/\pi^0]_{measured} / [\gamma/\pi^0]_{background} = \gamma_{measured}/\gamma_{background}$

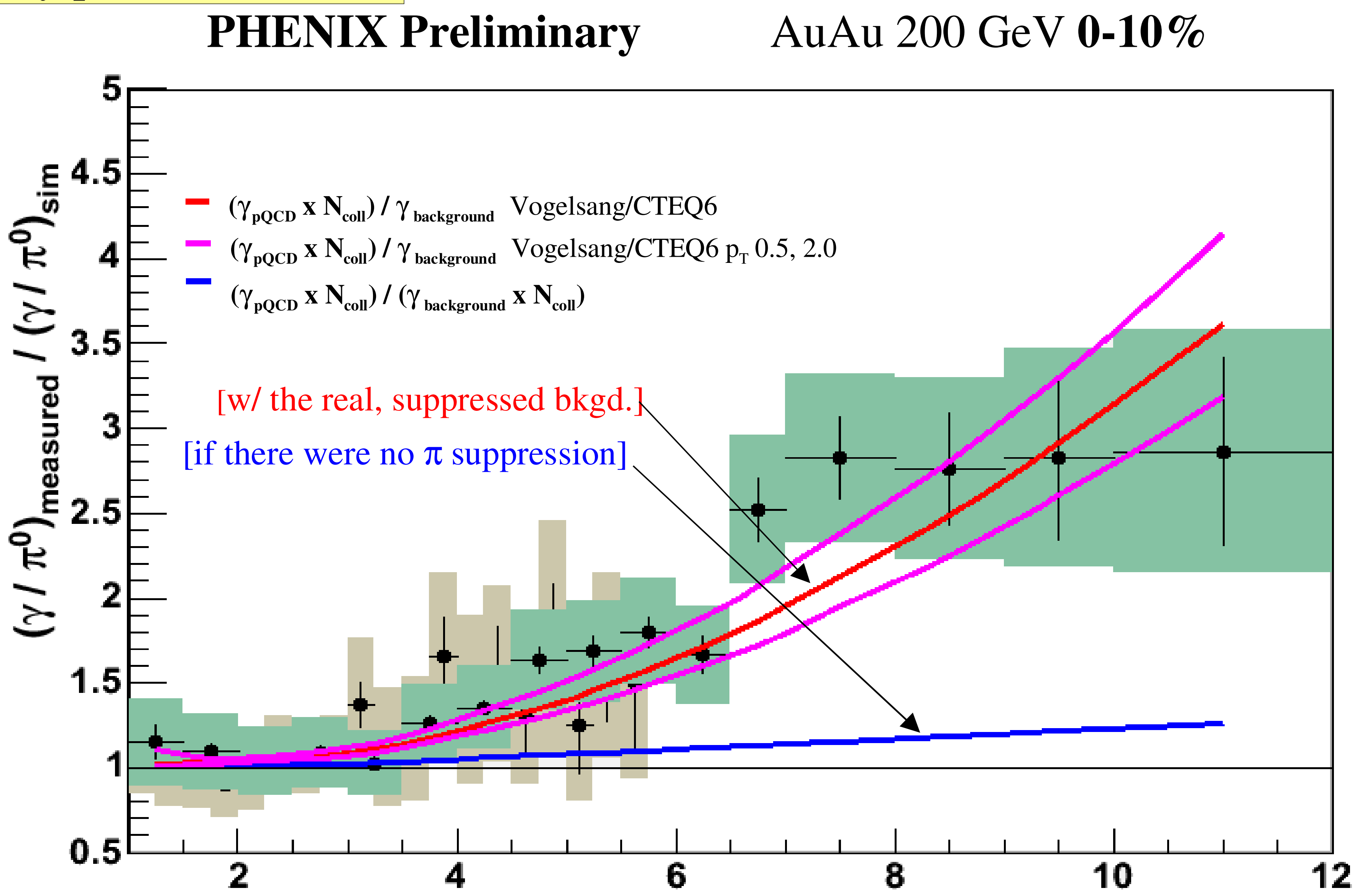
New Results



$[\gamma/\pi^0]_{measured} / [\gamma/\pi^0]_{background} = \gamma_{measured}/\gamma_{background}$

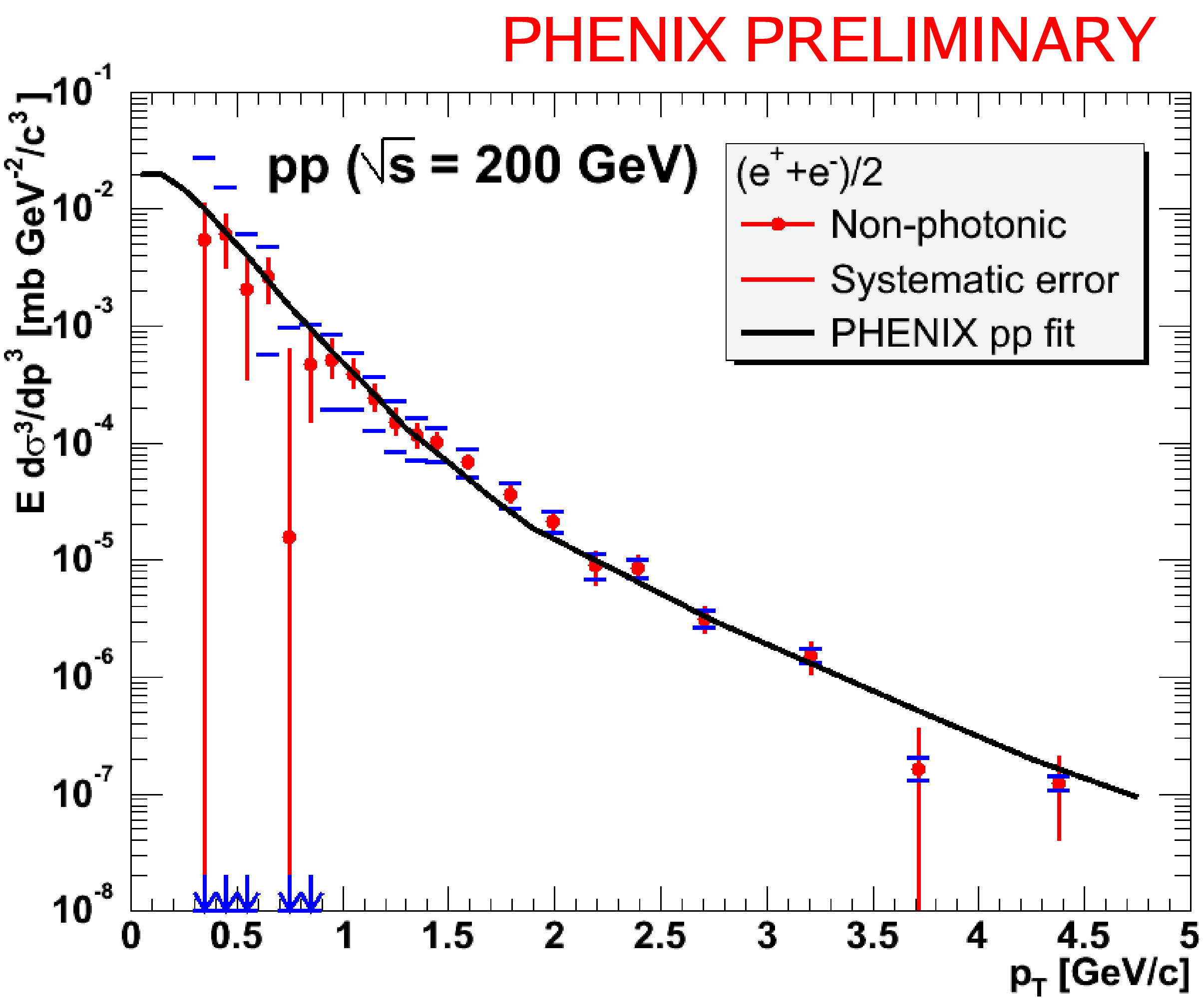
See Justin Frantz talk
Tuesday parallel 2

New Results



$[\gamma/\pi^0]_{measured} / [\gamma/\pi^0]_{background} = \gamma_{measured}/\gamma_{background}$

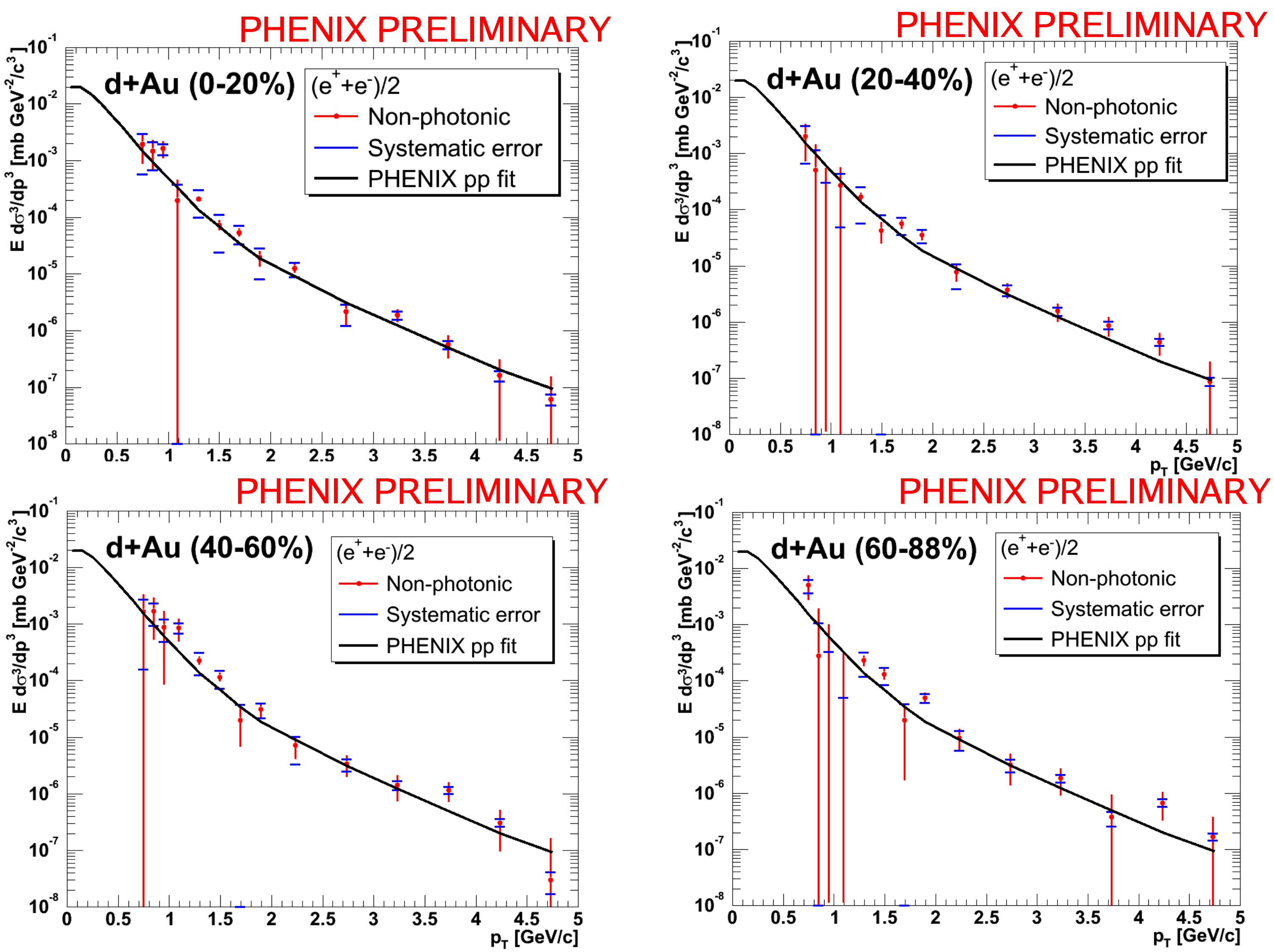
Charm Production in Au+Au, d+Au and p+p collisions



Start with p+p data and **fit it** to get the baseline for d+Au and Au+Au.

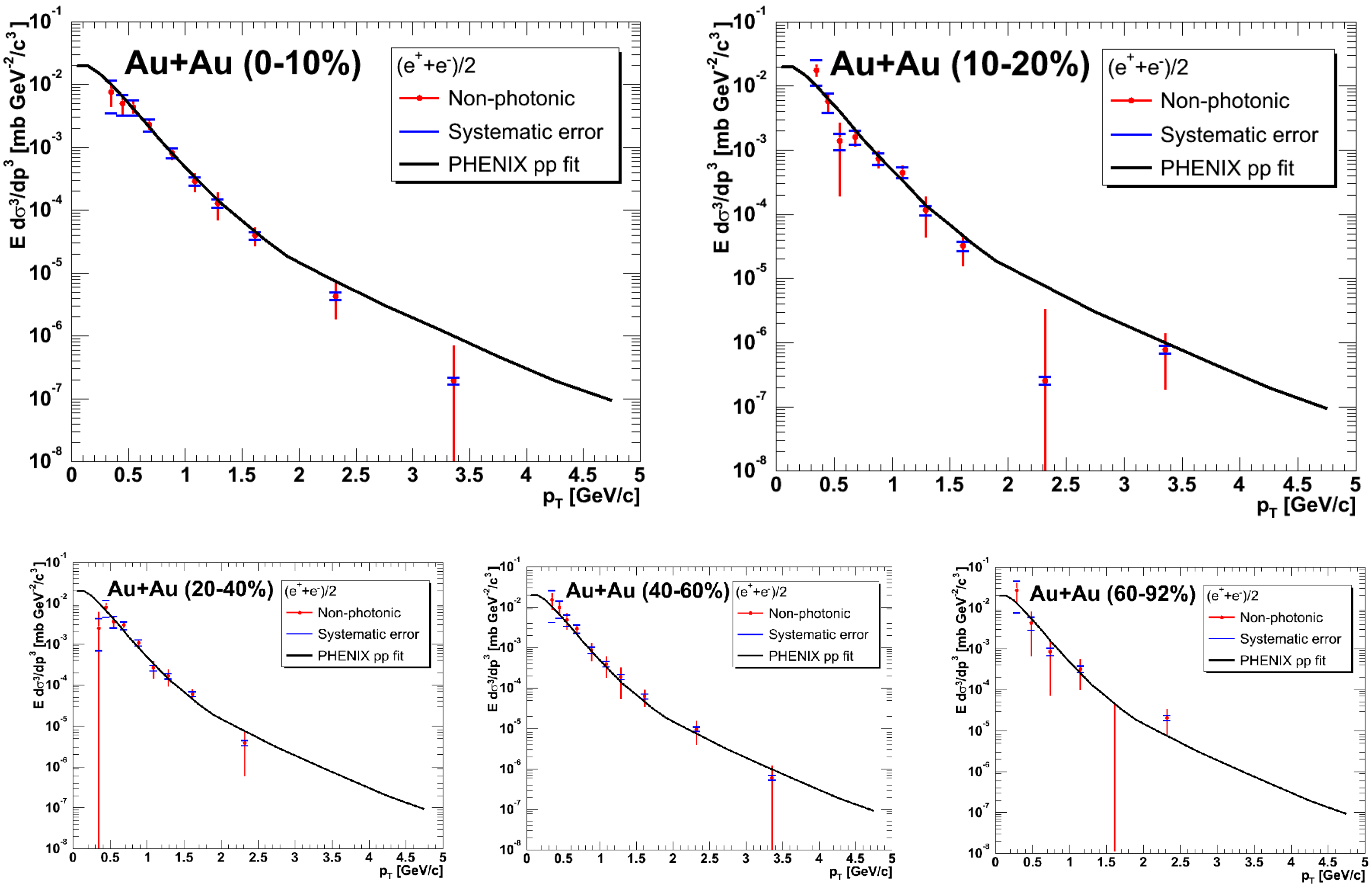
See Sean Kelly's talk Thursday parallel 2

d+Au data vs centrality



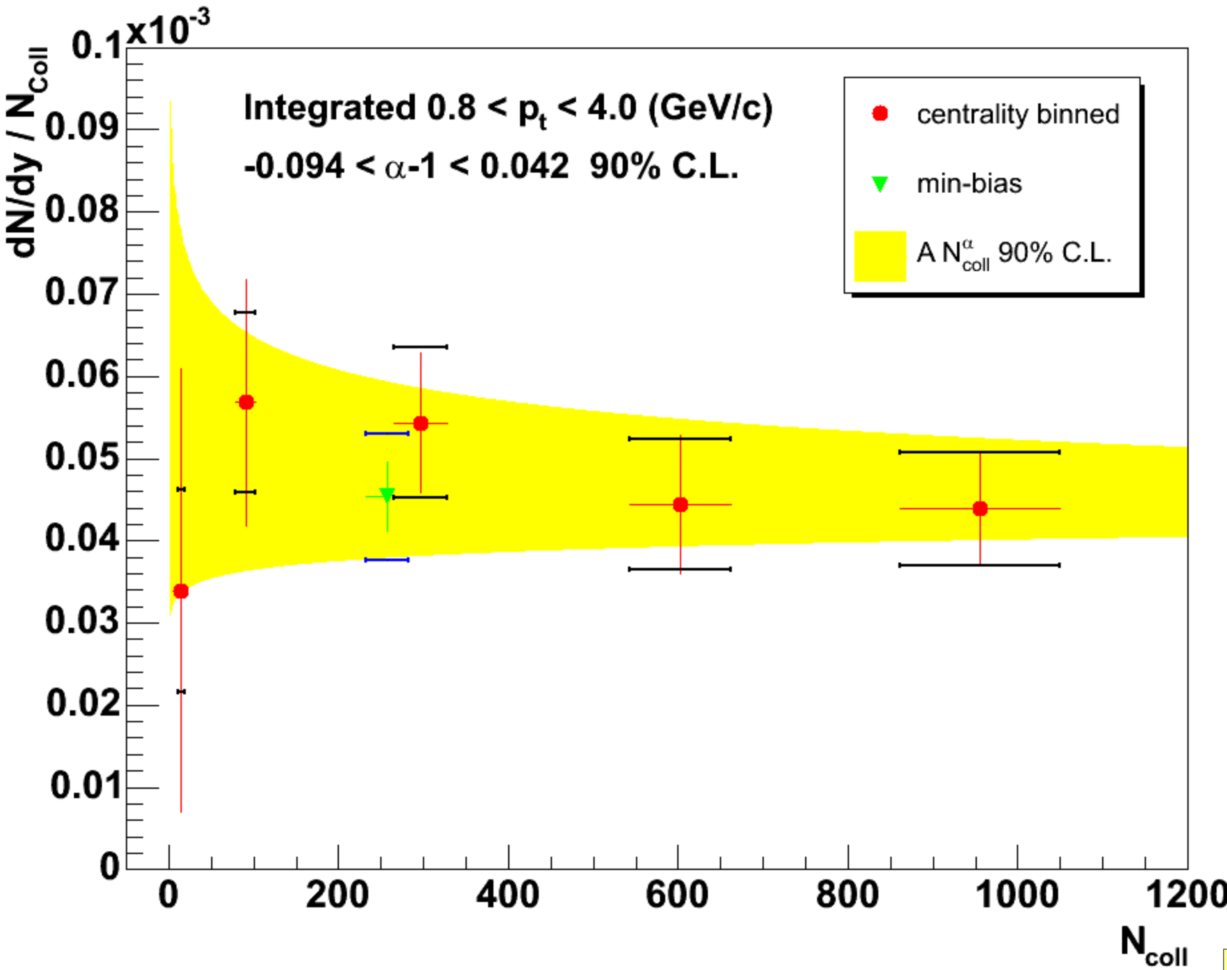
The curves are the p+p fit, binary scaled.

Au+Au data vs centrality



The curves are the p+p fit, binary scaled.

Au+Au dN/dy, binary scaled



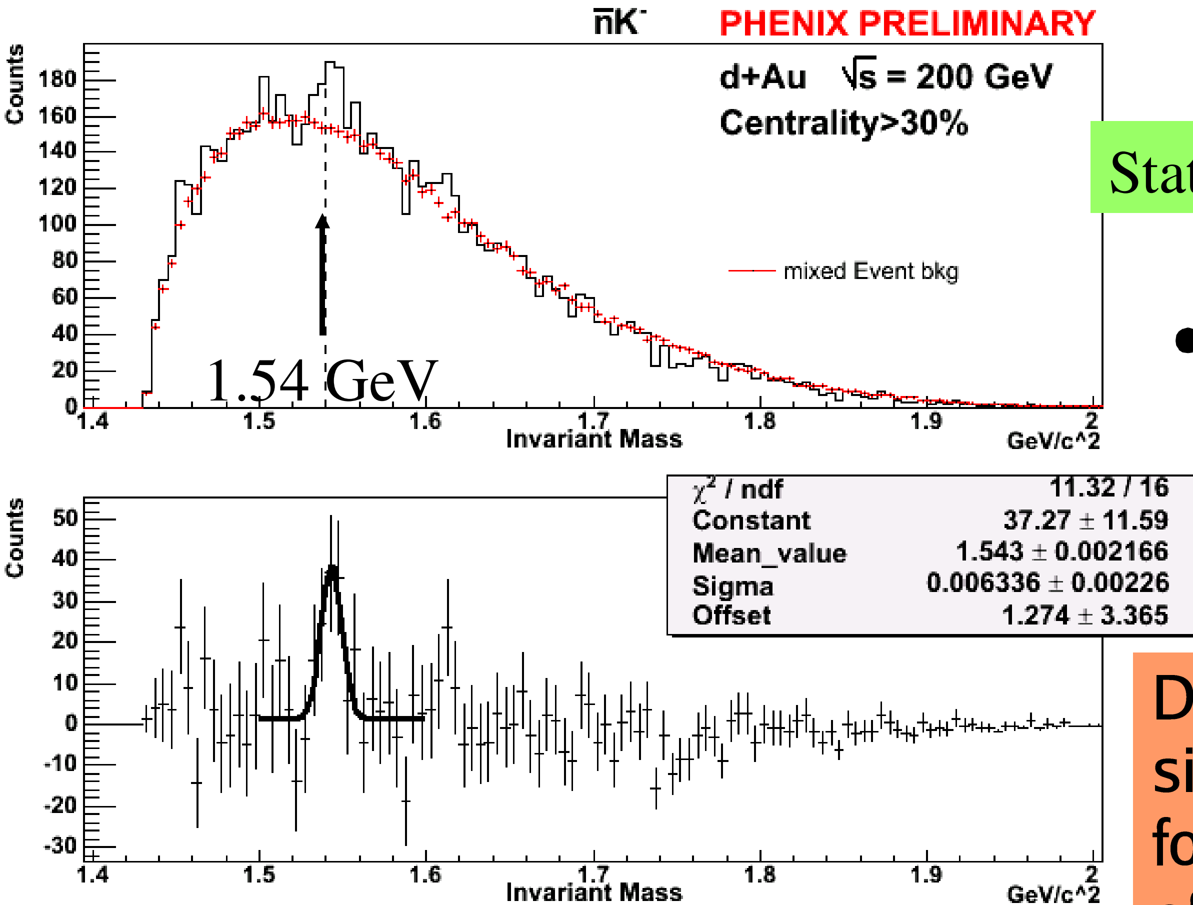
The yellow band represents the set of alpha values consistent with the data at the 90% Confidence Level.

See Sean Kelly's talk Thursday parallel 2

And now for something completely different......

Anti Penta Quarks with PHENIX?

$\Theta^- \rightarrow \bar{n} + K^-$



Statistically it's a 4σ effect

- No estimate of systematic Error yet
- No estimate of Efficiency yet

Determining statistical significance of peak will follow from the ongoing effort to understand the systematic errors

See Chris Pinkenburg poster

In this short talk we touched on:

- Unidentified hadron RCP in d+Au collisions for η from -2.2 to +2.2
  - **Strong rapidity dependence for central d+Au**
- Identified pions to 16 GeV at mid-rapidity in d+Au
- Origin of the baryon excess in central Au+Au collisions
  - **Identified hadron comparisons of Au+Au, d+Au and p+p to > 3 GeV/c**
  - **Rcp for ϕ mesons shows they are suppressed – it is not the mass**
- Associated jet yields with summing of the full Gaussians
  - **Away-side jet suppression in reality is strong broadening**
- Associated jet yields w/ identified trigger **- no meson/baryon difference**
  - **Argues against coalescence of baryon excess from flowing partons**
- Event by event p_T fluctuations consistent with being due to jets
- The Rout/Rside ratio in AuAu after partial Coulomb **– still ~ 1**
- Jpsi production in d+Au and p+p vs centrality
  - **RCP shows strong enhancement with Ncoll at low x in the Au**
- Open charm at midrapidity vs centrality in p+p, d+Au, Au+Au
  - **No apparent energy loss and dN/dy ~ Ncoll**
- First observation of **large direct photon signal** in heavy ion collisions – **wow!**
  - **Yield versus centrality in Au+Au consistent with pQCD calculations**
- Observation of an anti-pentaquark, the Θ^-? Stay tuned

PHENIX Talks at QM04

T. Frawley:	Experimental Highlights - PHENIX
C. Klein-Boesing:	Neutral pions and charged hadrons with large transverse momentum in Au+Au and d+Au collisions at 200 GeV.
J. Frantz:	Direct photons in RHIC AuAu and p-p collisions with PHENIX.
R. Seto:	Light Vector Mesons in dAu and pp Collisions at RHIC.
M. Heffner:	Two-particle interferometry of 200 GeV Au+Au collisions at PHENIX.
F. Matathias:	/K/p production and Cronin effect from p-p, d-Au and Au-Au at 200 GeV.
S. Kelly:	Charm production in Au-Au, d-Au and p-p reactions.
Anne Sickles:	Identified particle angular correlations in p+p, d+Au, and Au+Au at RHIC.
J. Rak:	Measurement of jet properties and their modification in heavy-ion collisions.
D. Kotchetkov:	Study of K_s and produced in p-p and d-Au collisions and Lambda and Lambda-bar produced in Au-Au collisions at 200 GeV at PHENIX.
R. G. de Cassagnac:	J/ production and nuclear effects for d-Au and p-p collisions at RHIC.
M. Tannenbaum:	Event-by-Event p_T fluctuations in Au+Au and p+p collisions: PHENIX measurements and suppressed jet contributions.
M. Kaneta:	Event anisotropy of identified π^0, photon and electron compared to charged π, K, p and dueteron.
M. Liu	Muon Production in Forward and Backward Rapidity in dAu Collisions at RHIC