

# PHENIX Highlights from QM'08



Justin Frantz

BNL QM08 Symposium

2/27/2008



Thanks!!!

Note this talk is not for beginners! Please see the talks at the link below for more detail:

<http://www.vecal.ernet.in/qm2008.html>

Of course I borrowed heavily, including entire slides from all the PHENIX speakers, esp. A. Franz & T. Awes

# What did we see in Jaipur?

- Elephants, Camels, Cobra's!
  - Armies of Auto-rickshaws!
  - Bollywood!
  - Beautiful ancient, medeval, modern Indian sights
  - ...
- 
- PHENIX: Several "new" results
  - Mostly incremental but important progress
    - Shortening time in between QM's is having an effect!

# Results (Categories)

- Flow
- Fluctuations/Bulk Correlations
- Hadronic Production
- Jet Correlations
- Heavy Quark Measurements
- Di-electron Measurements
- Direct Photon Measurements

# What did we learn in Jaipur?

- How to negotiate a price
- NY Traffic is actually pretty boring on the worldwide spectrum (including Shanghai too)
- ...
- We are steadily making progress on many fronts, with several new pieces of the picture being shored up
  - More questions being answered than raised?

# Physics Questions

I'll address 2 Types of Questions

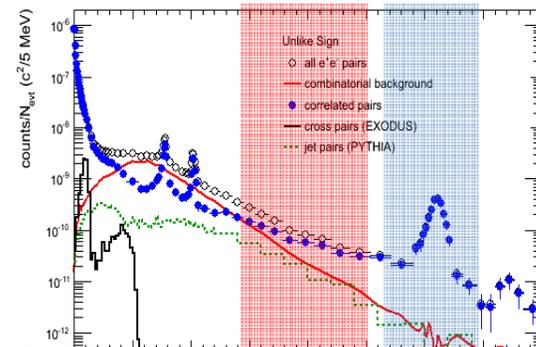
- **Characterizing the Medium “directly”:**
  - What's it's made of?
  - Information about phase transitions spacetime evolution?
  - Constrain thermo properties (e.g.  $T$ , viscosity)?
- **Exploring QCD Phenomena along with the Medium**
  - What mechanisms cause hadron suppression/energy loss in hard scattering?
    - In jets
    - In heavy quarks
  - What is the geometry of suppression
  - What is the origin of exotic phenomena?
    - Shoulder
    - Ridge
    - Baryon Enhancement
    - Dilepton Enhancement
  - What is the geometry of the exotic phenomena
  - What mechanisms affect Quarkonia production

# Questions

- **Characterizing the Medium “directly”:**
  - What’s it’s made of?
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  - Properties like T, viscosity?
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# Result Categories

- Flow
- Fluctuations/Bulk Correlations
- Hadronic Spectra
- Jet Correlations
- Heavy Quark Measurements
- Di-electron Measurements
- Direct Photon Measurements



**Two things happen : left gets longer, right gets more arrows**

# Physics Questions

- **Characterizing the Medium “directly”:**

- What's it's made of?

- Information about phase transitions spacetime evolution?

- Constrain its properties?

- **Exploring QCD Phenomena along with the Medium**

- What mechanisms cause hadron suppression/energy loss in hard scattering?

- In jets

- In heavy quarks

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- Baryon Enhancement

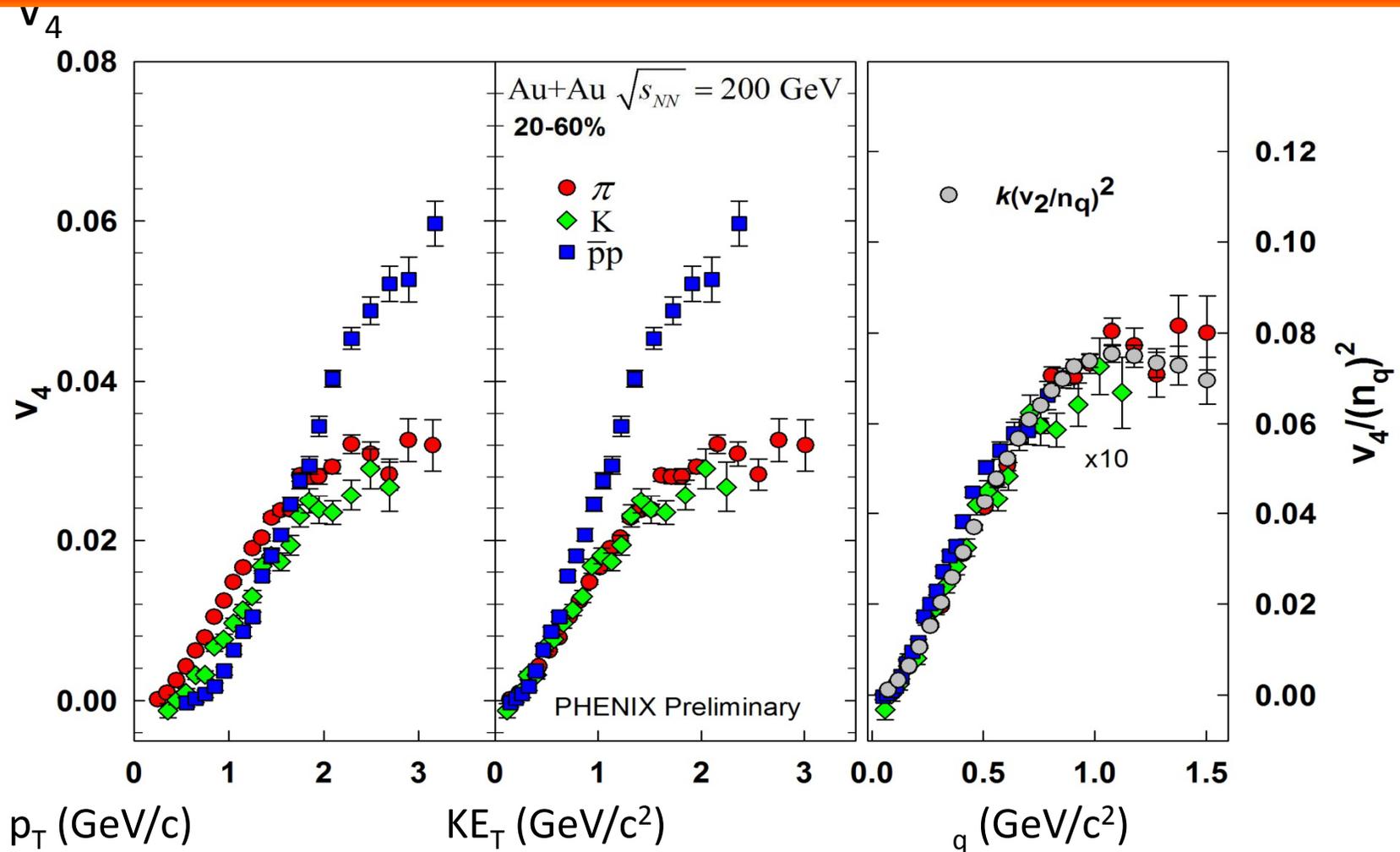
- Dilepton Enhancement

- What is the geometry of the exotic phenomena

- What mechanisms affect Quarkonia production

# $v_4$ - scales like $v_2$

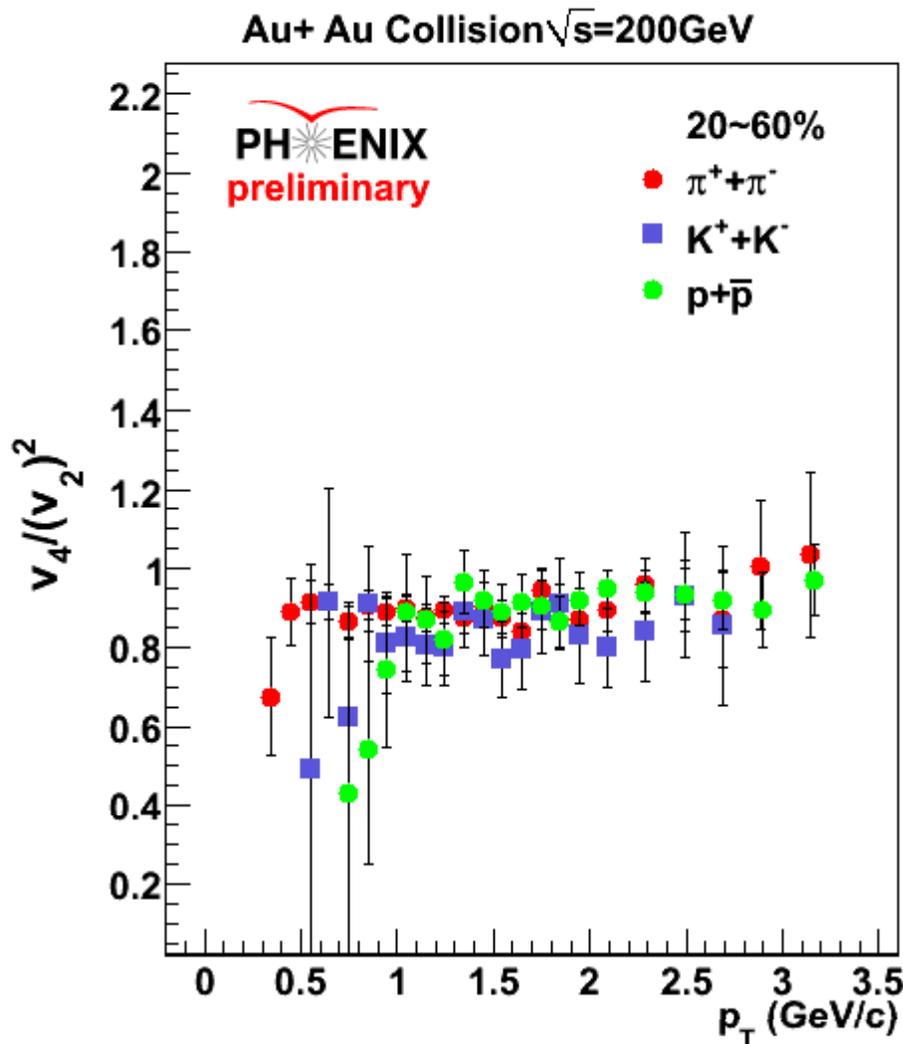
Talk by S. Huang



$v_2$  scales with  $n_q$ ,  $v_4$  with  $n_q^2$  partonic degree of freedom

# Confirming partonic flow

Talk by S. Huang



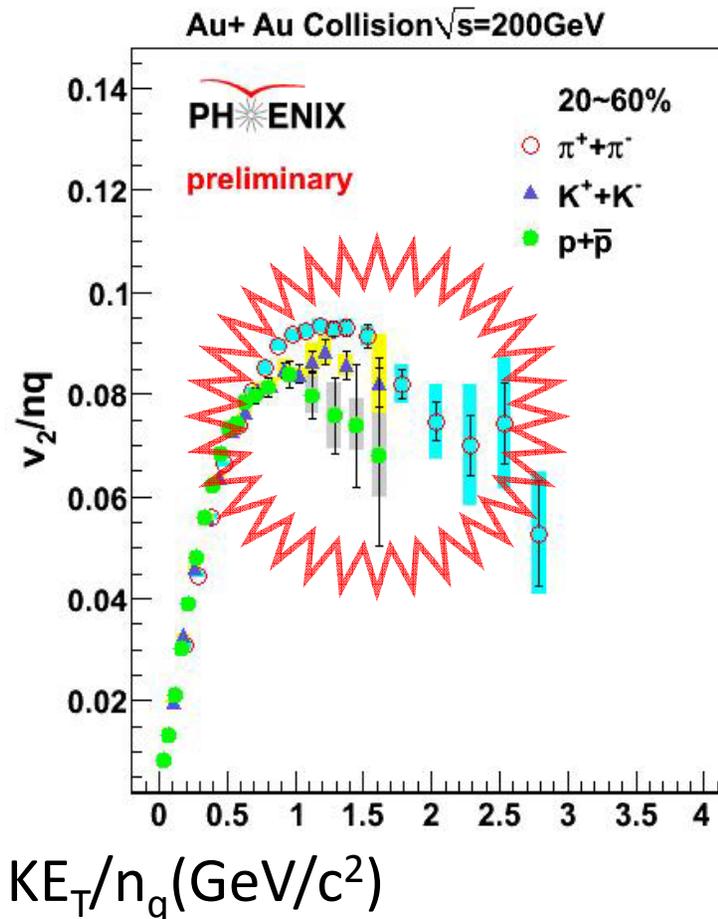
- The ratio of  $v_4/(v_2)^2$  is close to 0.9 for the  $\pi$ , K and p
- Mesons and baryons have similar  $v_4/(v_2)^2$  ratio
- Simultaneous eq.'s allow one to solve for ratio

$$\frac{v_{4,M}(2p_T)}{v_{2,M}^2(2p_T)} \approx \frac{1}{2} \frac{v_{4,q}(p_T)}{v_{2,q}^2(p_T)}$$

$$\frac{v_{4,B}(3p_T)}{v_{2,B}^2(3p_T)} \approx \alpha \left( \frac{1}{3} + \frac{1}{3} \times \frac{v_{4,q}(p_T)}{v_{2,q}^2(p_T)} \right)$$

# $v_2$ - high $p_T$ - rescaled

Talk by S. Huang



New Run 7 Results!  
Using higher  
resolution RXNP  
Reaction Plane  
detector!

$KE_T$  scaling seems breaks for  $KE_T/n_q > 1\text{GeV}/c^2 = p_T \sim 3.5\text{GeV}/c$  for  $p$   
change in underlying process: hard scattering ?

# Physics Questions

- **Characterizing the Medium “directly”:**

- What’s it’s made of?

## Answers: (not complete)

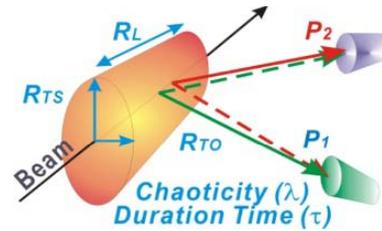
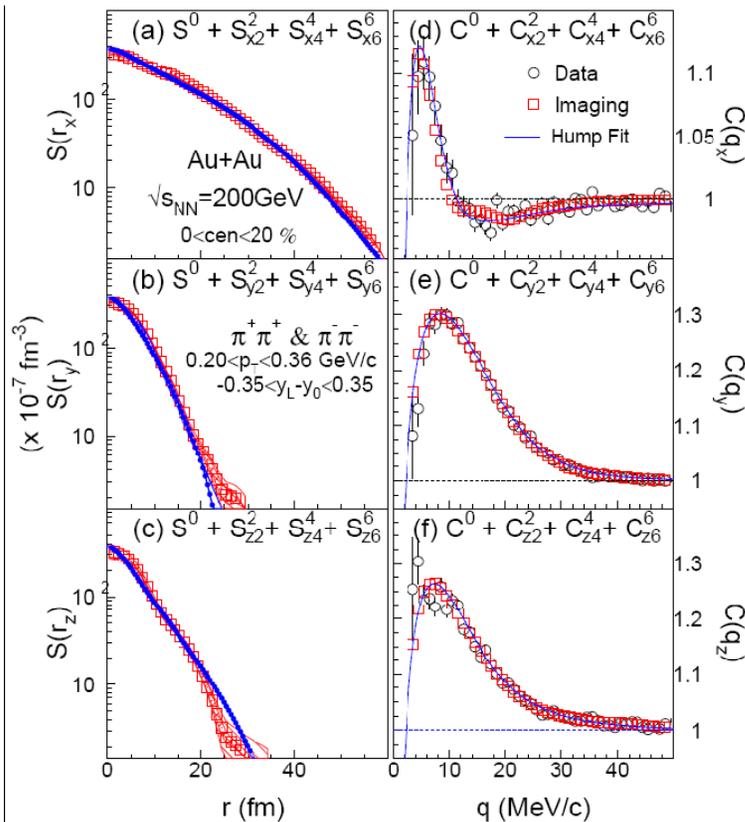
- **Scaling breaks ~at intermediate/high pt border**
- **From flow data and hydro models, it appears to be “partonic” in nature at flow time**
- **KE<sub>T</sub> scaling works for v<sub>2</sub> and now v<sub>4</sub>**
- **Consistent with hydrodynamic expectations of “parton/constituent quarks”**
- **(baryon enhancement/recomb) informs**

# Physics Questions

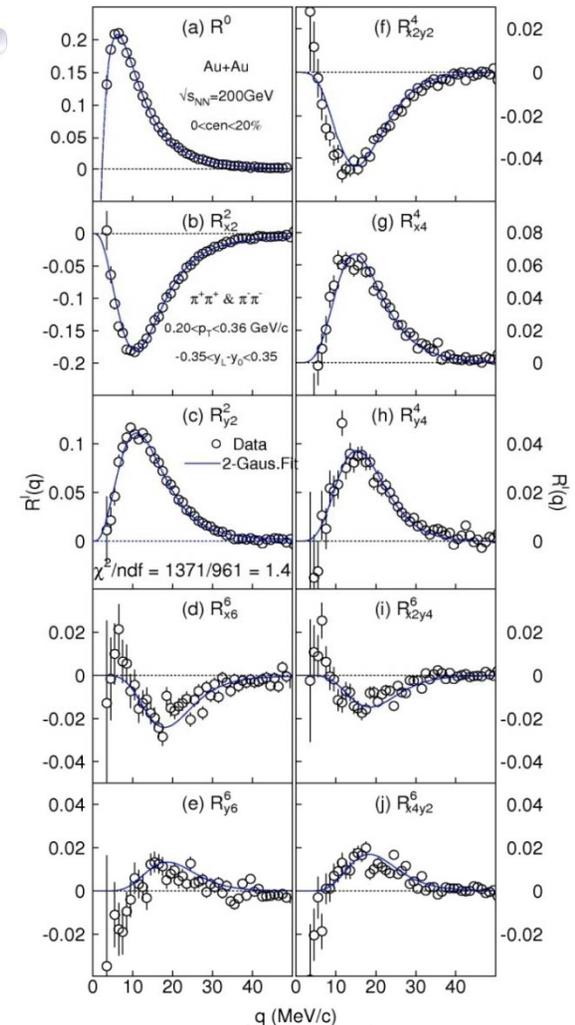
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# HBT breakthrough w/ source imaging

Talk by Lacey



## Correlation Moments



Contributions from  $l > 6$  is negligible

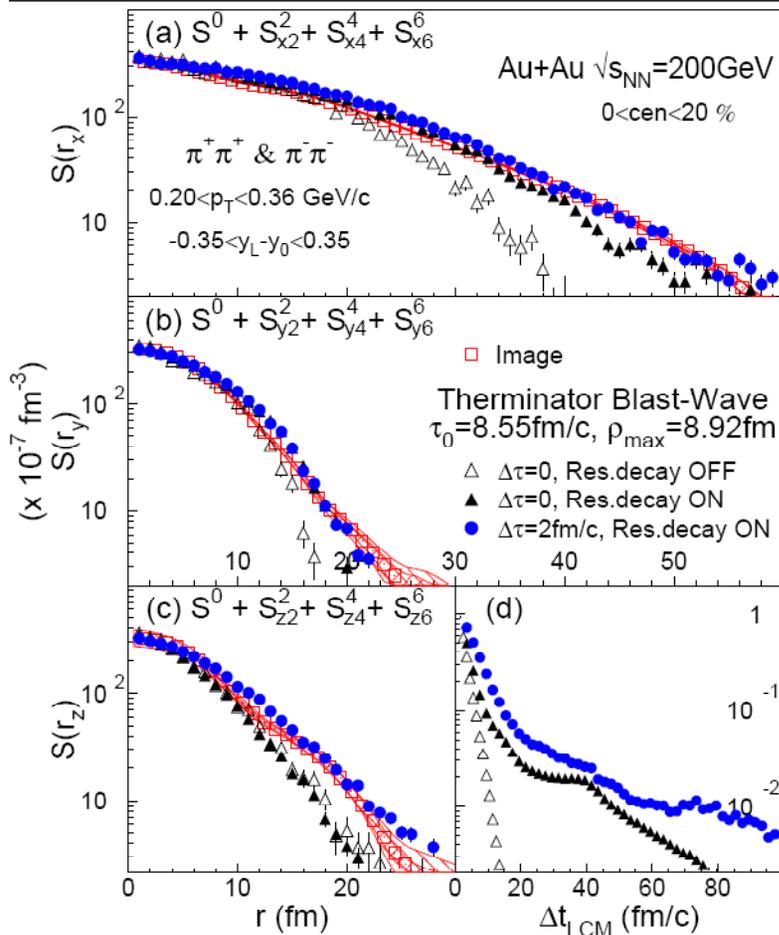
$$R(\vec{q}) = \sum_l \sum_{\alpha_1 \dots \alpha_l} R_{\alpha_1 \dots \alpha_l}^l(q) A_{\alpha_1 \dots \alpha_l}^l(\Omega_q)$$

$$S(\vec{r}) = \sum_l \sum_{\alpha_1 \dots \alpha_l} S_{\alpha_1 \dots \alpha_l}^l(r) A_{\alpha_1 \dots \alpha_l}^l(\Omega_r)$$

**Robust Experimental Source Functions obtained from moments**

# Can solve HBT Puzzle, points to crossover transition

Talk by Lacey



## Model Comparison

Therminator:

A.Kisiel et al. Comput.Phys.Commun.174, 669 (2006)

**Thermal model with Bjorken longitudinal expansion and transverse Flow**

$$\tau \sim 9 \text{ fm}$$

$$\Delta\tau \sim 2 \text{ fm}$$

$$\langle \Delta t_{\text{LCM}} \rangle \sim 12 \text{ fm}$$

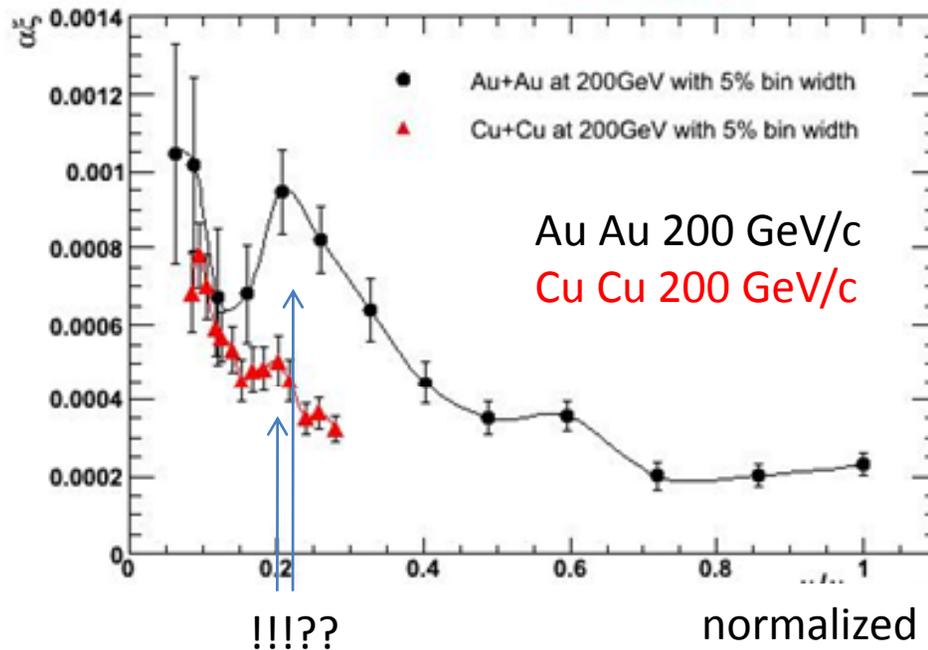
Outside-in burning

**Source Function Comparison to Models Give robust life time estimates  $\rightarrow$  Consistent with Crossover transition**

# Fluctuations: “mixed results”

Talk by Homma

Sharp critical behavior not conclusive: but some present?



Particle Ratio  
Fluctuations show  
similar story

$\alpha \cdot \xi$  = correlation length • correlation strength varies monotonically unless a critical phenomena is reached

No strong indicators of critical phenomena over central to mid central

# Physics Questions

- **Characterizing the Medium “directly”:**
  - What’s it’s made of?
  - Information about phase transitions spacetime evolution?

- **Answers: (not complete)**
  - **HBT (w/ Source imaging & model) now consistent with slower burn/ crossover transition**
    - **Deuteron Production Coalescence param. (not shown – Valle talk) similar interp.**
  - **Fluctuation information: inconclusive indications of critical behavior (consistent with the previous statement?)**

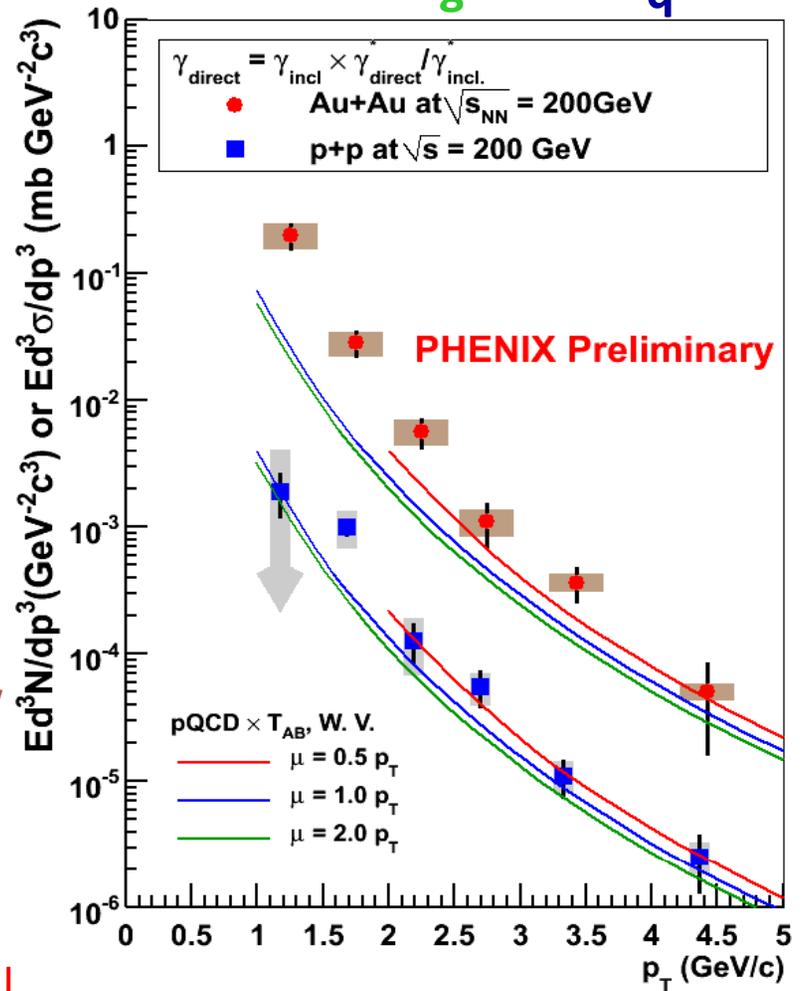
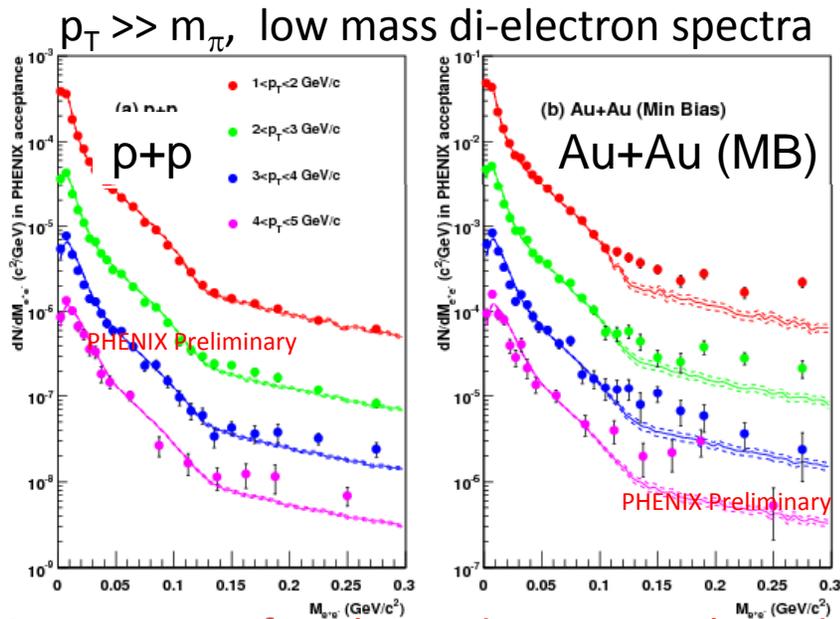
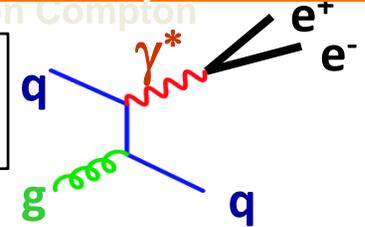
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# Thermal Photons !! : Temperature

Award Talk by Dahms

EM Cal direct Direct Photon systematics too large at soft momenta:  
Turn to di-electron based measurement: nearly finalized!!!



- Any source of *real*  $\gamma$  produces *virtual*  $\gamma$  with very low mass
- Assuming internal conversion of direct photon  $\rightarrow$  extract the fraction of direct photon
- p+p: follows pQCD
- Au+Au: clear **excess** above pQCD  $\rightarrow$  signal of **thermal photons?**

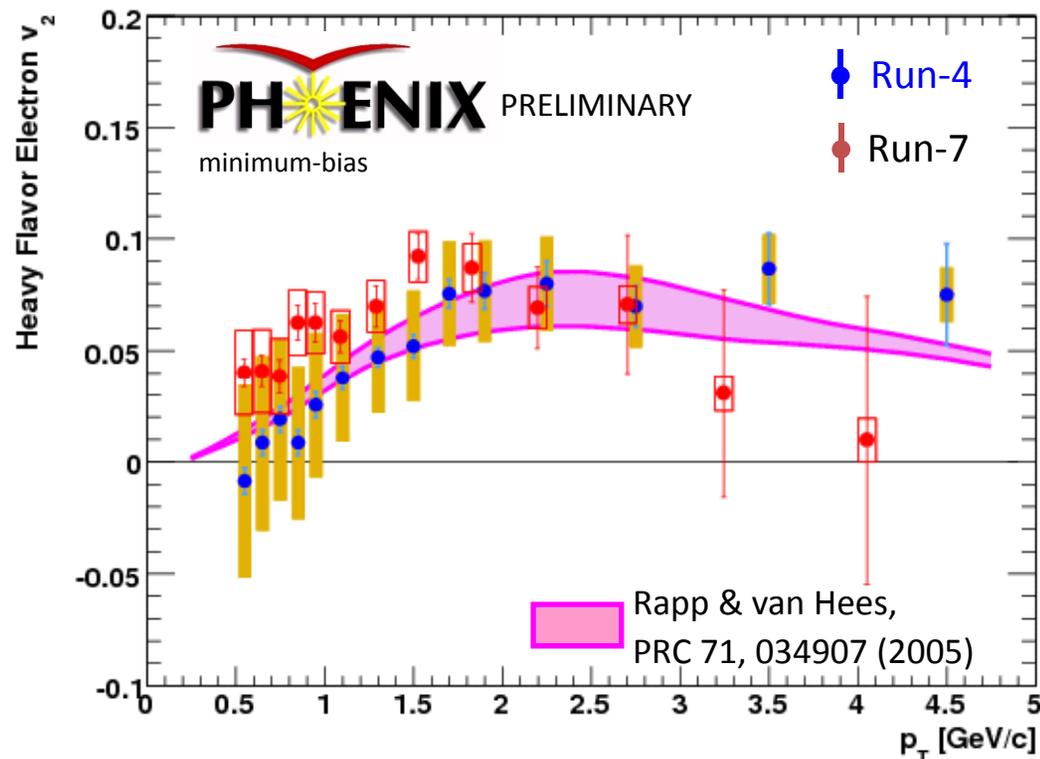
2/27/2008

# Viscosity from Heavy Flavor

Talk by Averbeck

- elliptic flow of  $e^\pm$  from heavy-flavor decays

- non-zero  $v_2$  (RHIC Run-4)



- progress in Run-7

- improved reaction plane resolution
- (increased statistics)

- data are consistent within uncertainties

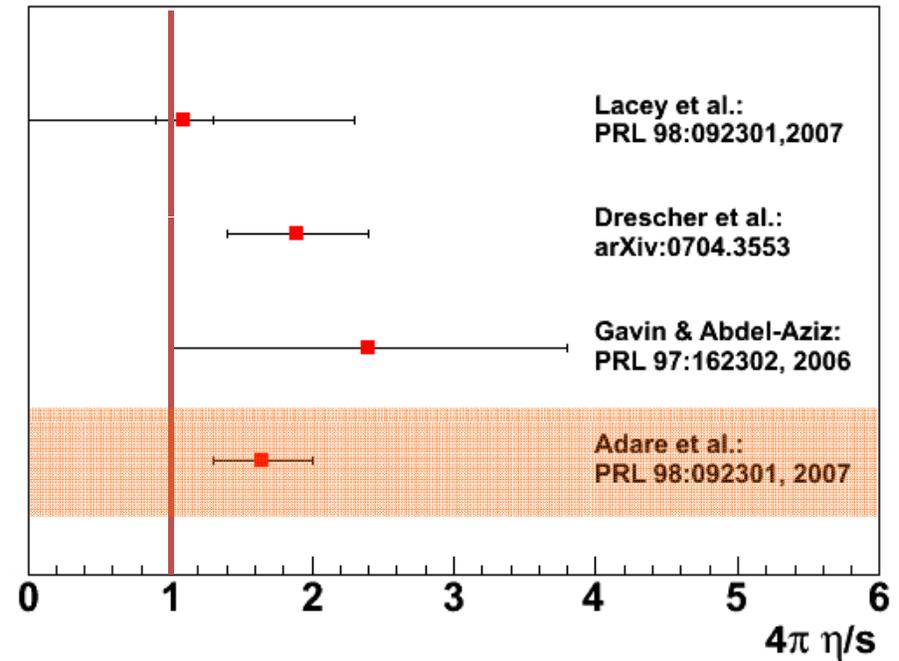
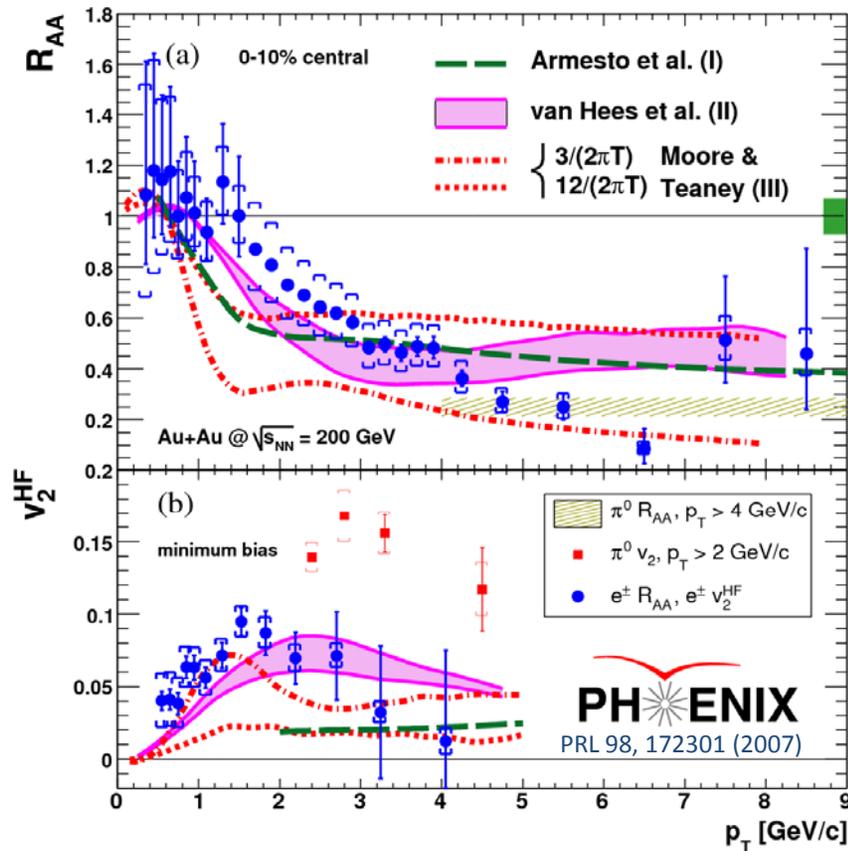
- indication for non-zero  $v_2$  at high  $p_T$  (charm vs. bottom)

- also available:  $v_2$  vs. centrality

- good agreement with Langevin based transport calculation including resonant elastic scattering

# Providing more information: $\eta/s$ constraints...

Talk by Averbeck



Good Consistency w/ and  $\sim$  better than other estimators:  $\eta/s$  is low: Perfect Liquid!!!

# Physics Questions

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## Answers: (not complete)

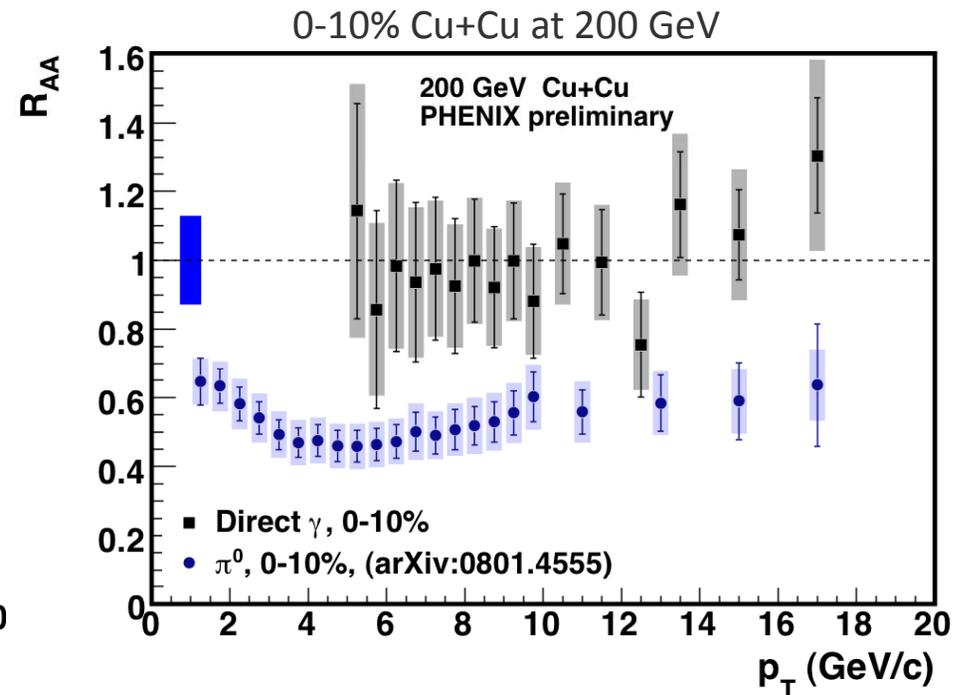
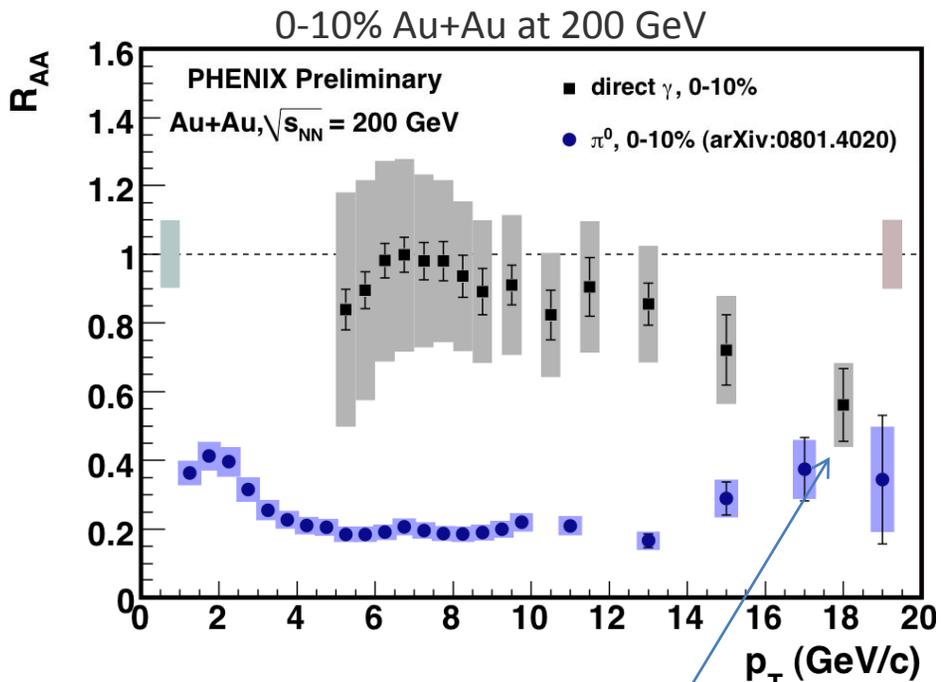
- **Thermal photons now pdf reveal thermodynamic information**
  - Interpretations TBD
- **Heavy quark flow/yields confirming low viscosity/s**

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# Test of $T_{AB}$ Scaling in A+A: Direct Photons at High(est!) $p_T$

Talk by  
Reyers

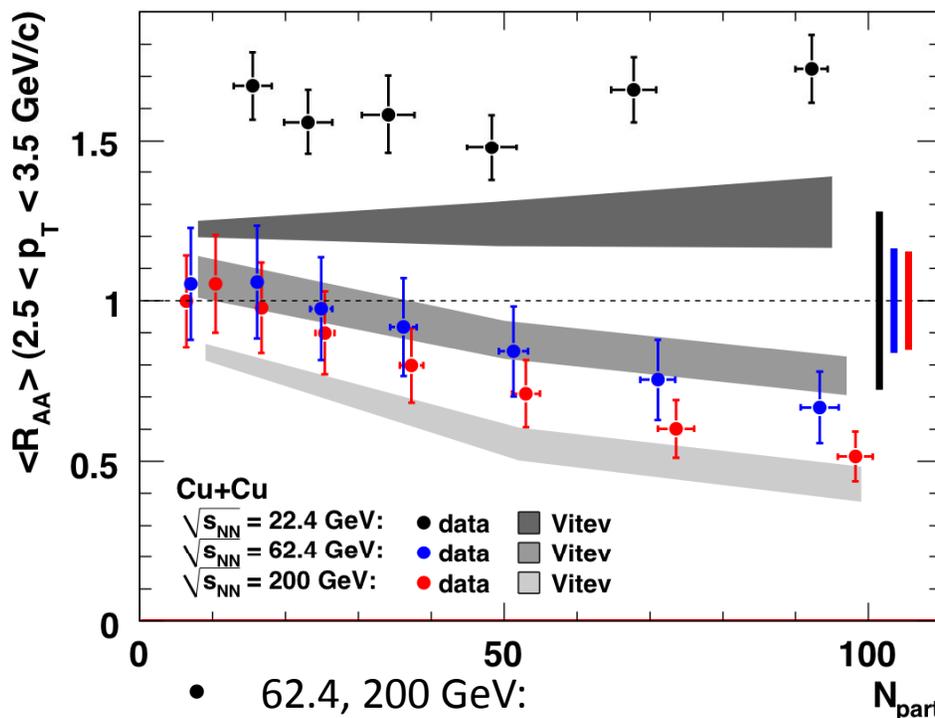
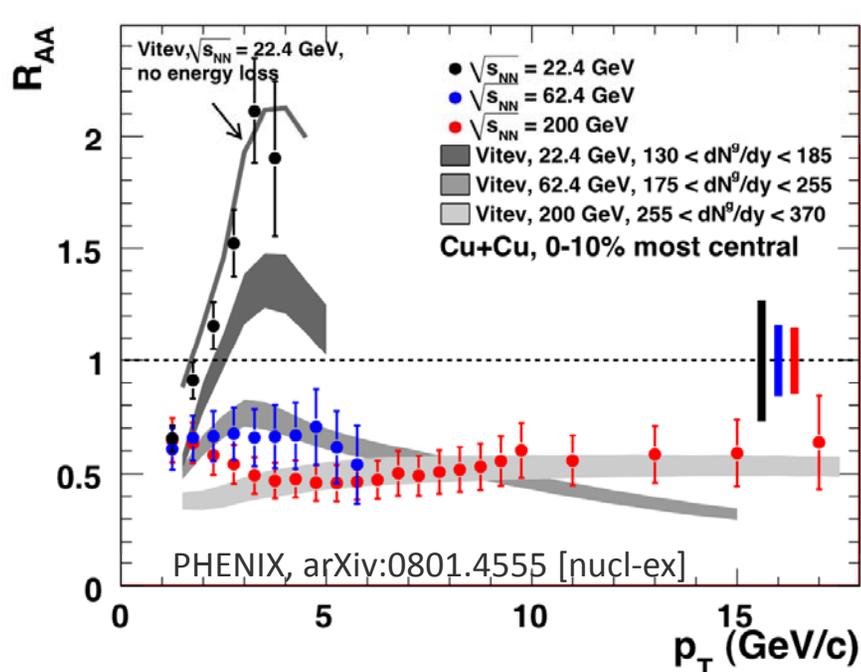


- Au+Au: Direct  $\gamma$   $R_{AA} < 1$  at  $p_T \approx 18$  GeV/c?

My take: Systematics on Cu+Cu & difference in system size--uncertainty still too large to confirm/deny:  
But sways opinion towards smaller shadowing-type effects / downward fluctuation/sys on highest Au point

# $\sqrt{s_{NN}}$ vs $p_T$ , Cent Dependence of $\pi^0 R_{AA}$ in Cu+Cu

Talk by Reygers



- 62.4, 200 GeV:
  - Suppression consistent with parton energy loss for  $p_T > 3$  GeV/c
- 22.4 GeV: **(SPS Energy @ RHIC!)**
  - No suppression
  - Enhancement consistent with calculation that describes Cronin enhancement in p+A
- Parton energy loss starts to prevail over Cronin enhancement between 22.4 and 62.4 GeV

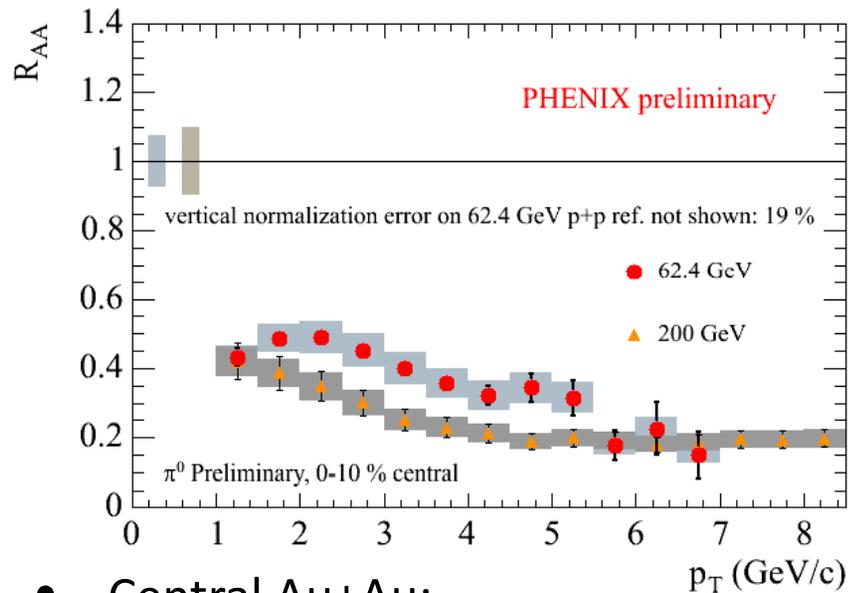
$S_{loss}$  treatment: more suppression @ 22 GeV?

- 62.4, 200 GeV:
  - $N_{part}$  Dependence of  $R_{AA}$  consistent with parton energy loss
- 22.4 GeV
  - Enhancement independent of centrality
  - Possible explanations
    - Weak centrality dependence of Cronin enhancement
    - Cronin enhancement offset by parton energy loss

# Other $R_{AA}$ Analyses Updated

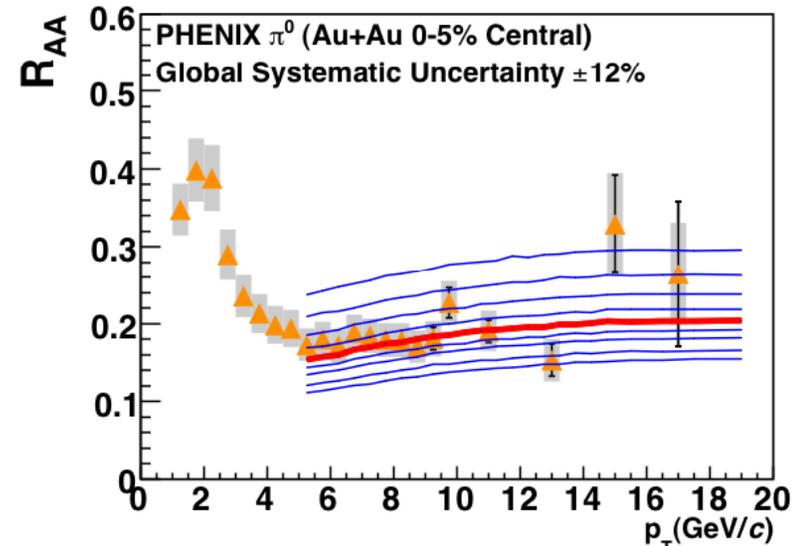
Talk by Reygers

New PHENIX 62 GeV  $\pi$  p+p reference !



- Central Au+Au:  
Similar  $R_{AA}$  at 62.4 and 200 GeV (for  $p_T > 6$  GeV/c)
- Possible reason: Smaller parton  $dE/dx$  in conjunction with steeper parton  $p_T$  spectrum at 62 GeV
  - $S_{loss}$  analysis accounts for this shows larger difference?

Final Run4 Data/Eloss Fitting Constraint Ana!

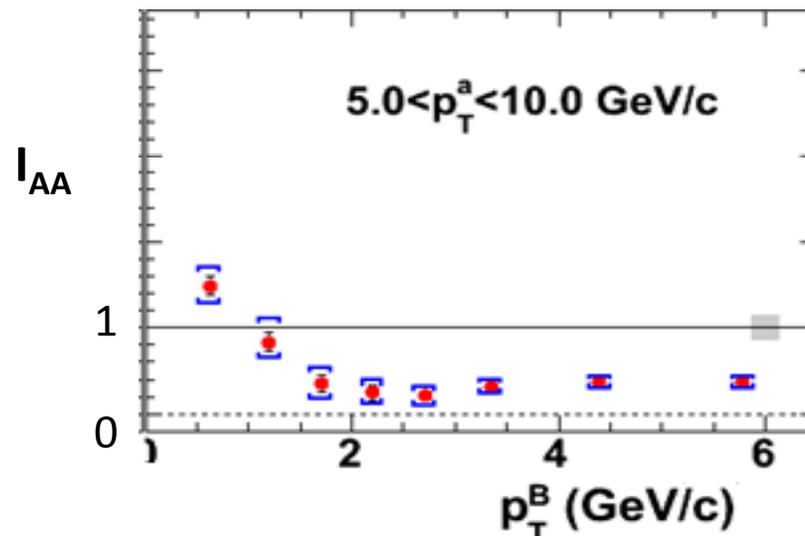


- Fit parameters within models constrained
  - $\hat{q}/dN_g$  constrained within  $\pm 20-25\%$  at the  $1\sigma$  level
  - But this doesn't include theoretical uncertainty

# Beyond $R_{AA}$ : di-Jet Corr $I_{AA}$

Talks by Jia, Pei

- Yields of di-jet correlations : tighter constraints on  $E_{\text{loss}}$  models
- Ratio of Yields A+A/p+p: normalized Per Trigger:  $I_{AA}$
- So far still not able to distinguish  $E_{\text{loss}}$  models w/  $I_{AA}$

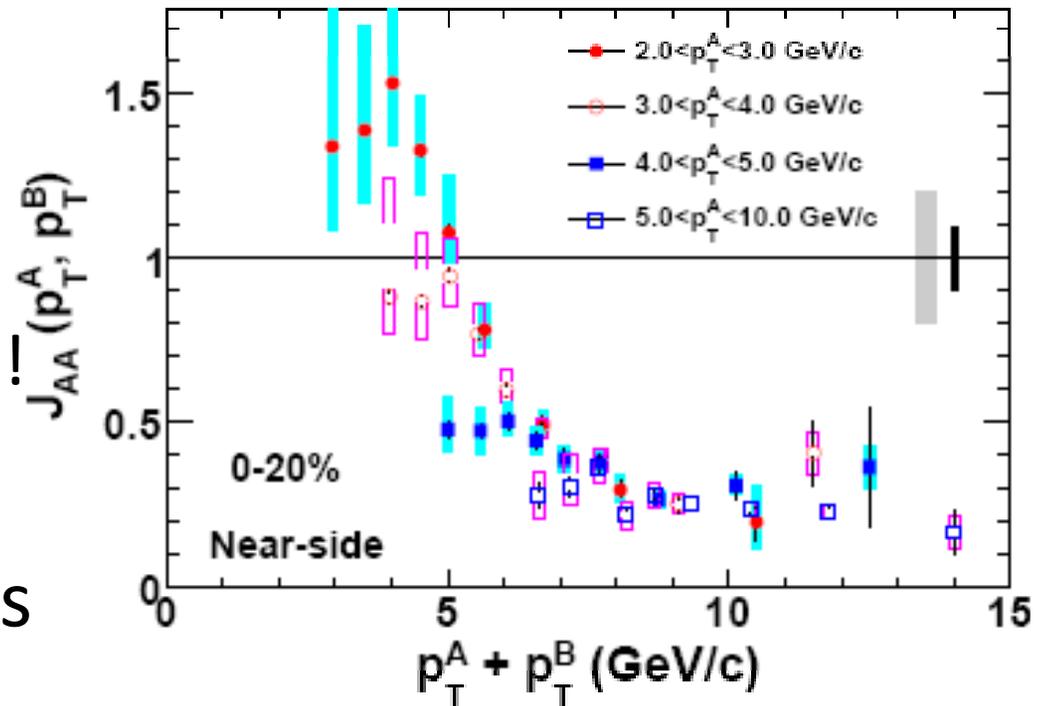


[arXiv:0801.4545v1](https://arxiv.org/abs/0801.4545v1)  
[nucl-ex]

# Beyond IAA? (1): $J_{AA}$

Talks by Jia, Pei

- Solves some deficiencies of  $I_{AA}$  at low  $p_T/z$ 
  - Triggers also modified!
- Scales vs  $p_{T1}+p_{T2}$ ?
- Higher  $p_T$  value always approaches  $R_{AA}$  Non NearSide



$$J_{AA}(p_T^a, p_T^b, \Delta\phi) = \frac{J_{PY}^{A+A}}{\langle N_{coll} \rangle J_{PY}^{p+p}}$$

[arXiv:0801.4545v1](https://arxiv.org/abs/0801.4545v1)  
[nucl-ex]

# Beyond IAA? (2): $x_h$

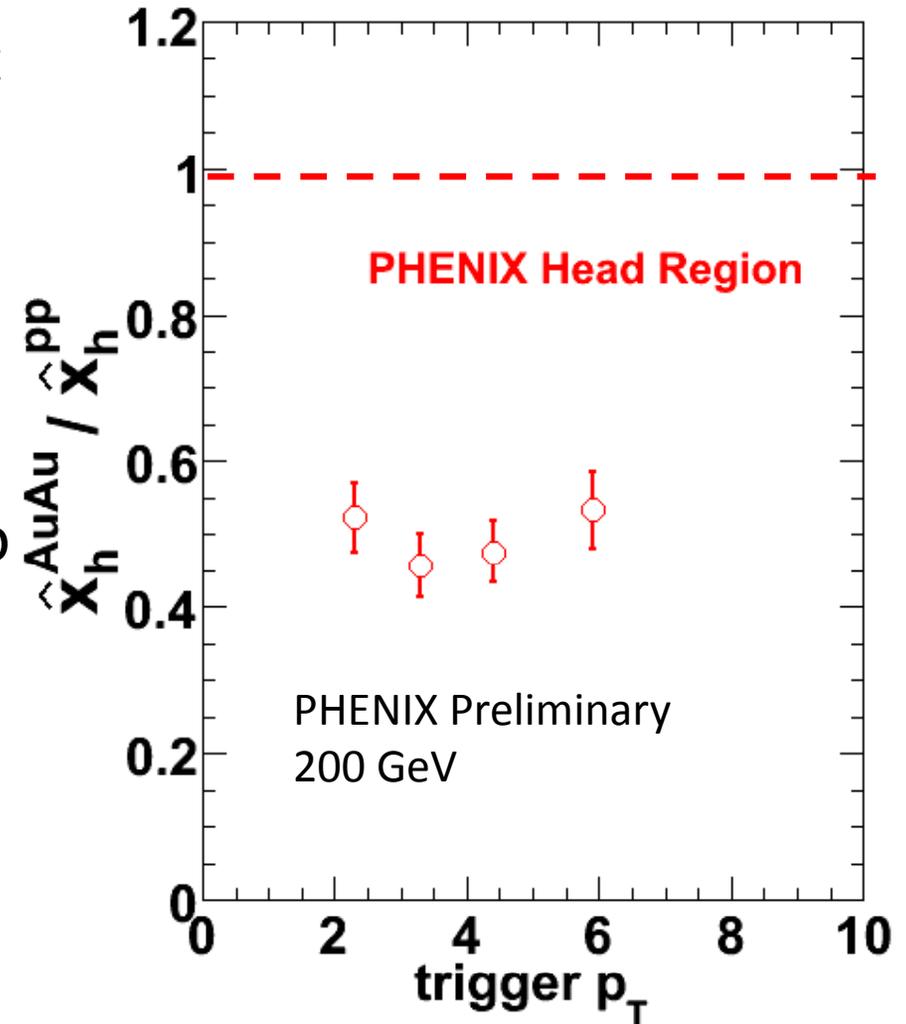
Talk by Pei

- Fitting Per Trigger Yield vs  $x_E$  Yield

$$x_E = \frac{-\mathbf{p}_{T_a} \cos \Delta\phi}{\mathbf{p}_{T_t}} \approx \frac{\mathbf{p}_{T_a}}{\mathbf{p}_{T_t}} = \frac{z_a \widehat{\mathbf{p}}_{T_a}}{z_t \widehat{\mathbf{p}}_{T_t}}$$

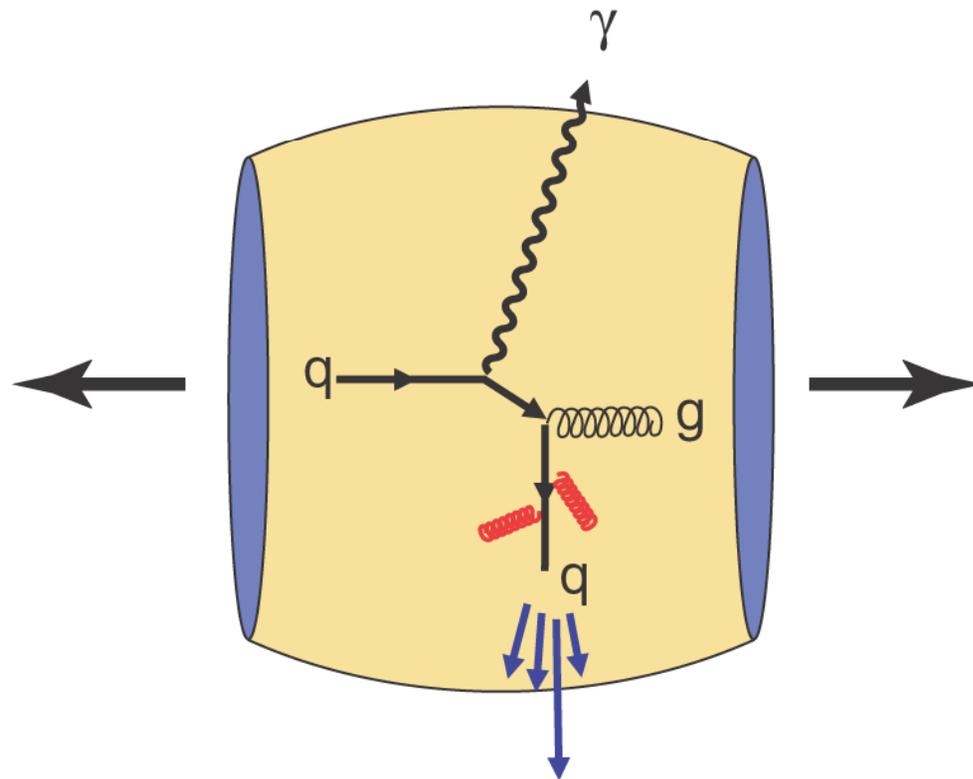
extracts  $x_h$   $\hat{x}_h = \frac{\hat{p}_{T_a}}{\hat{p}_{T_t}}$

- Direct measurement of ratio of the away-side to nearside parton momenta
- Ratio p+p to A+A is new way to quantify AS suppression (0.5)
  - More accurate/sensitive?



# Other Avenue to Study Jet $E_{\text{loss}}$

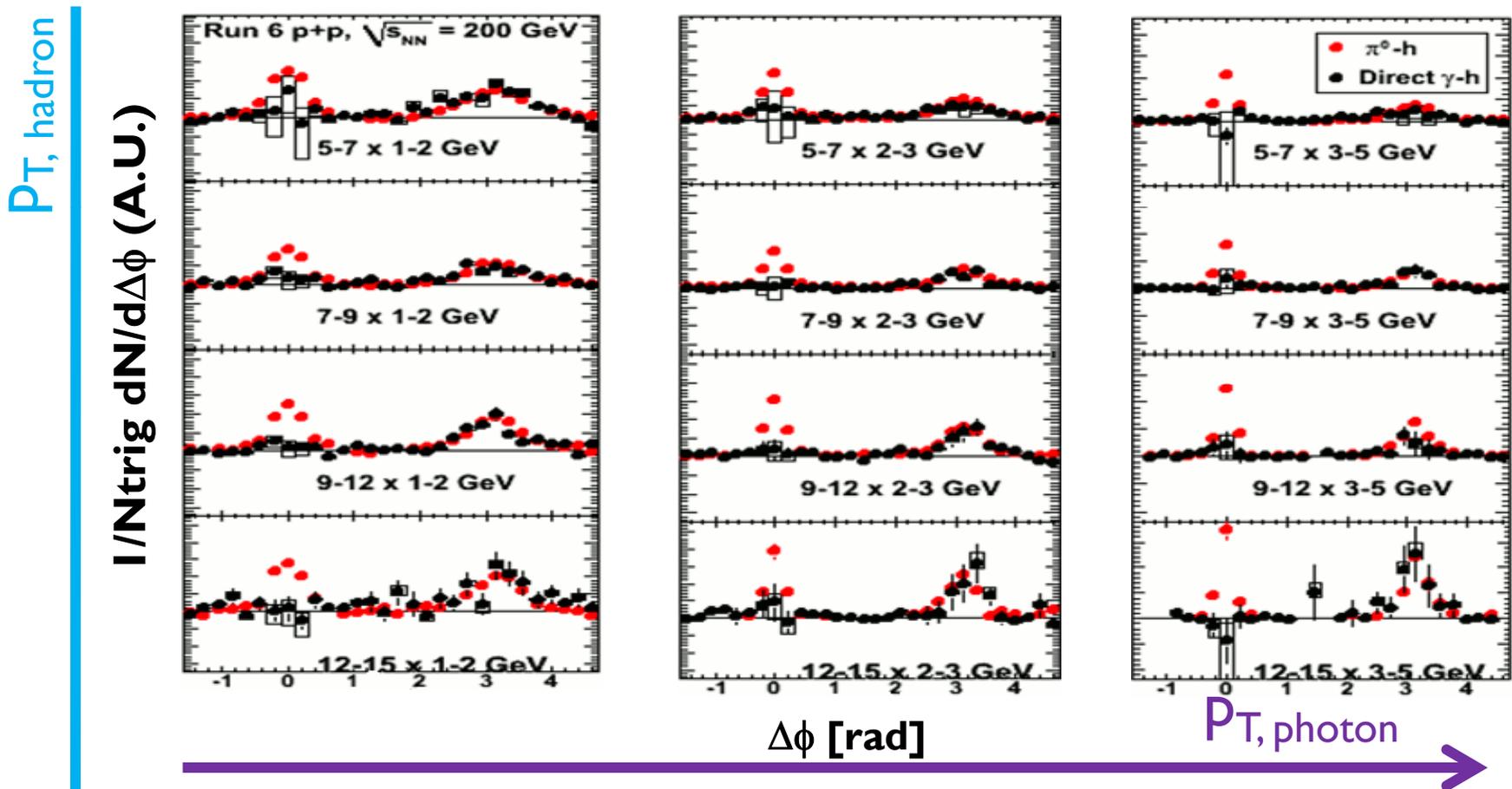
- Direct Photon-Jet Correlations!



# Direct Photon-Jet $\Delta\phi$ Correlations

Talk by Nguyen

p+p baseline well-established with new Run 6 data!!!

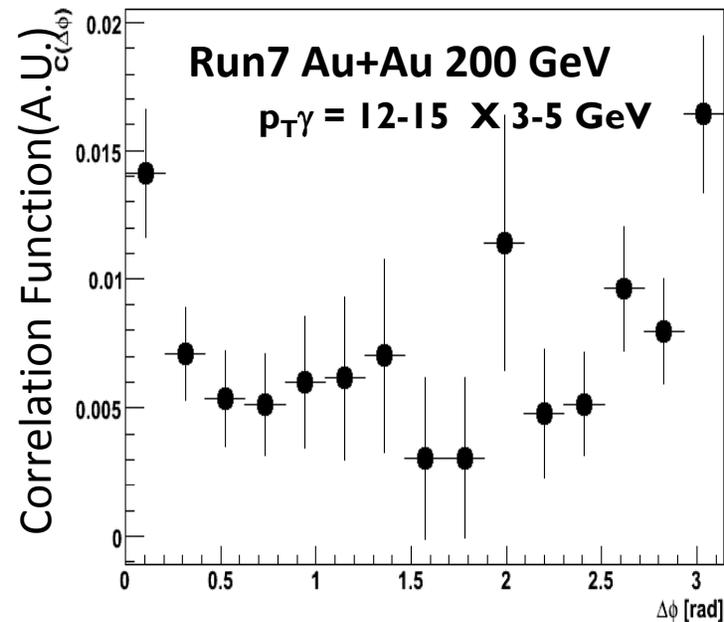
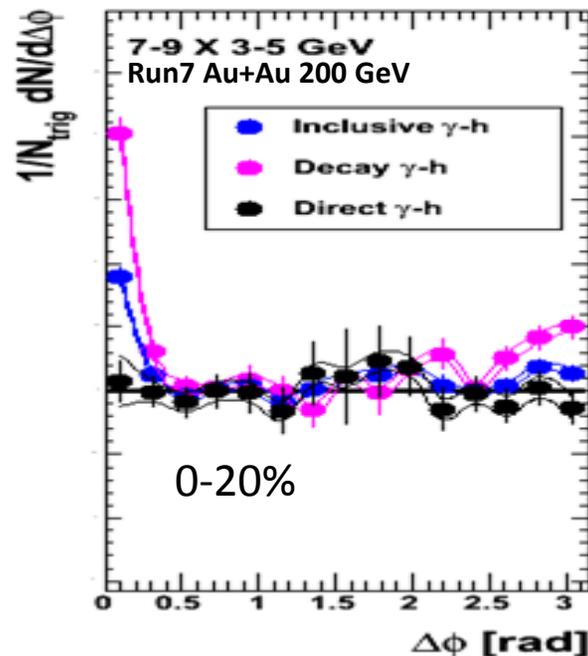


Subtraction technique works over wide range of  $p_T$ !

# First look at Run 7 Au+Au

Talk by Nguyen

- Suppression of  $\gamma$ -h correlation appears relatively strong and thus should be quite measurable

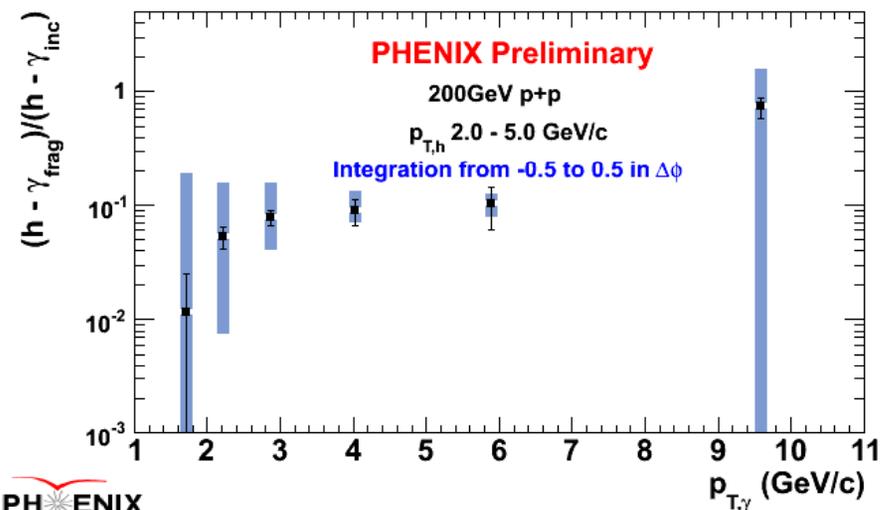
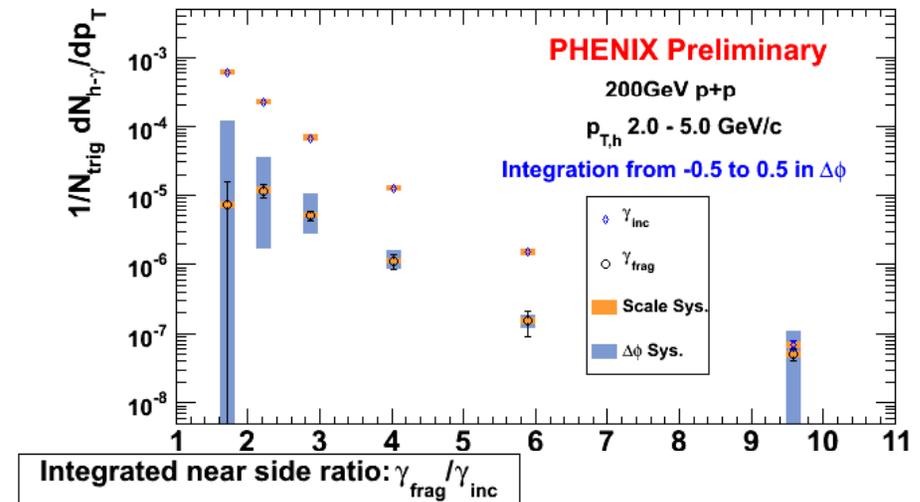


- With Run7 should be able to take result to much higher photon  $p_T$  trig & smaller systematics

# p+p Baseline II: Going after Fragmentation Photons

Talk by Nguyen

- First measurement of it's kind at RHIC!
- Will measure jet shape distributions, e.g.  $x_E$ ,  $p_{out}$
- Constrain photon FF?
- In same jet as 2 GeV h,  $N_{frag}/N_{inc} \approx 0.1$  at intermediate  $p_T$
- Note this is not the same as  $N_{frag}/N_{direct}$  or  $N_{direct}/N_{tot \gamma}$  !
- TBD: Measure in Au+Au



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## Answers: (not complete)

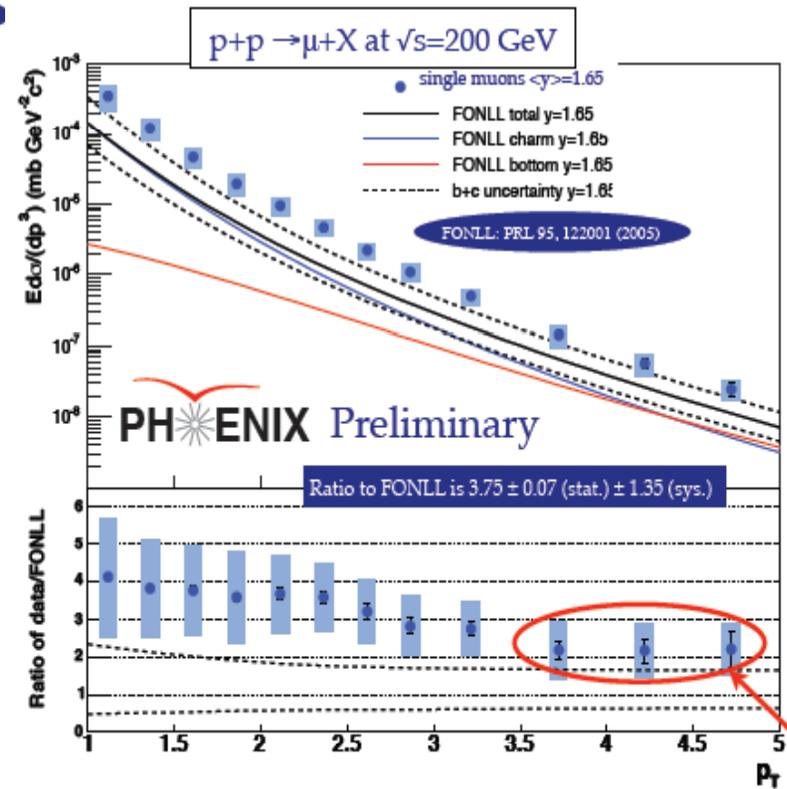
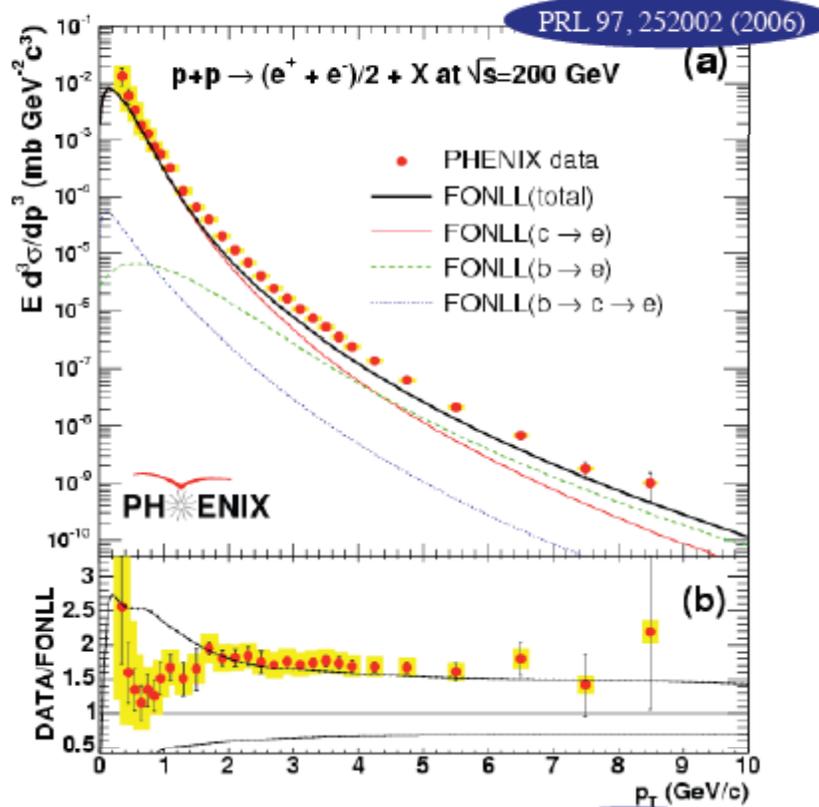
- **Slowly collecting more quantitative, differential information to distinguish Eloss models w/ high pt/jet  $\gamma$ -jet data**
  - **My guess: there’s already enough**

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# Well Established Baselines in p+p

Talk by Hornback

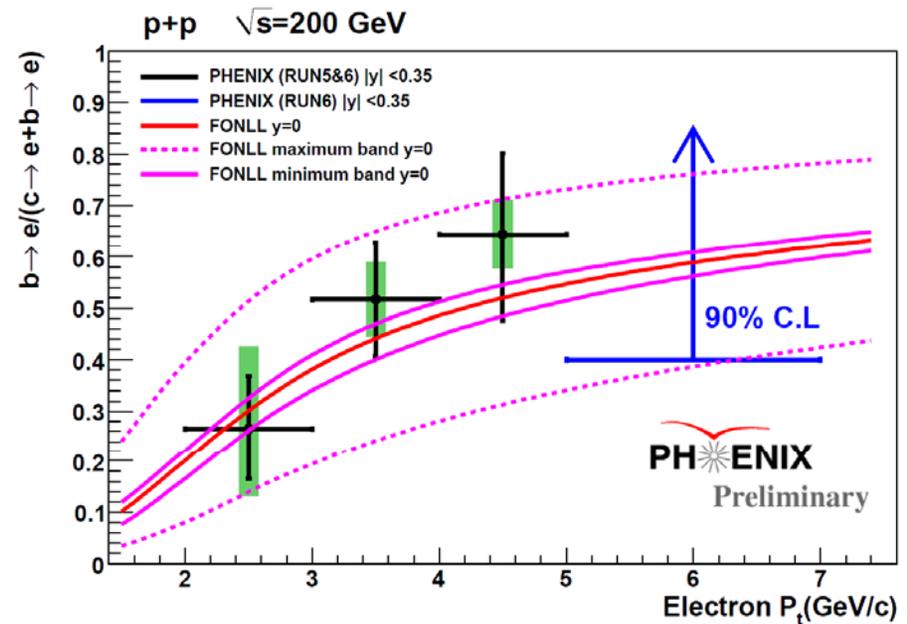
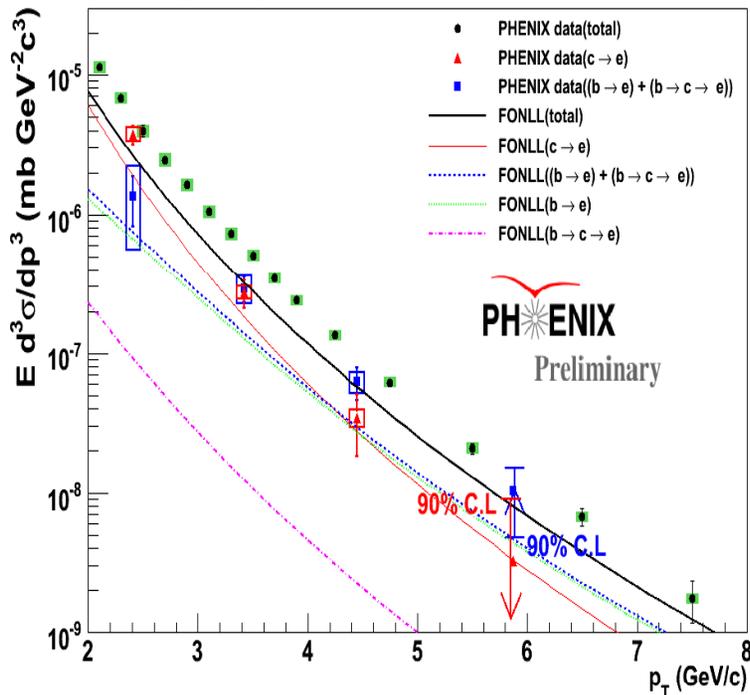


- To p+p single electrons, now add forward single muon measurement
- Looks a little higher compared to FONLL @ low  $p_T$ , but  $\sim$ same for higher  $p_T$

# Bottom/Charm Separation

Talk by Morino

p+p 200 GeV Charm and bottom extracted via e-h mass analysis  
 $p+p \rightarrow (e^+ + e^-)/2 + X$  at  $\sqrt{s}=200$  GeV



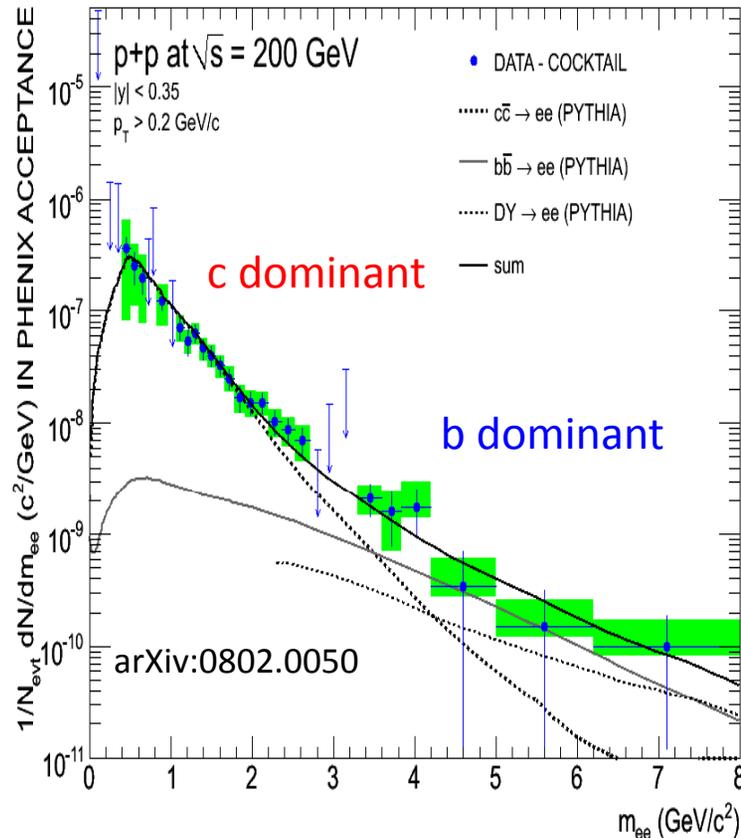
$$\sigma_{bb} = 4.61 \pm 1.31(stat)_{-2.22}^{+2.57}(sys) \mu b$$

- Charm and bottom spectra both  $\sim x2$  above FONLL calculations
  - But ratio is in good agreement with FONLL

# New Addition: HQ via e+e-

Talk by Toia

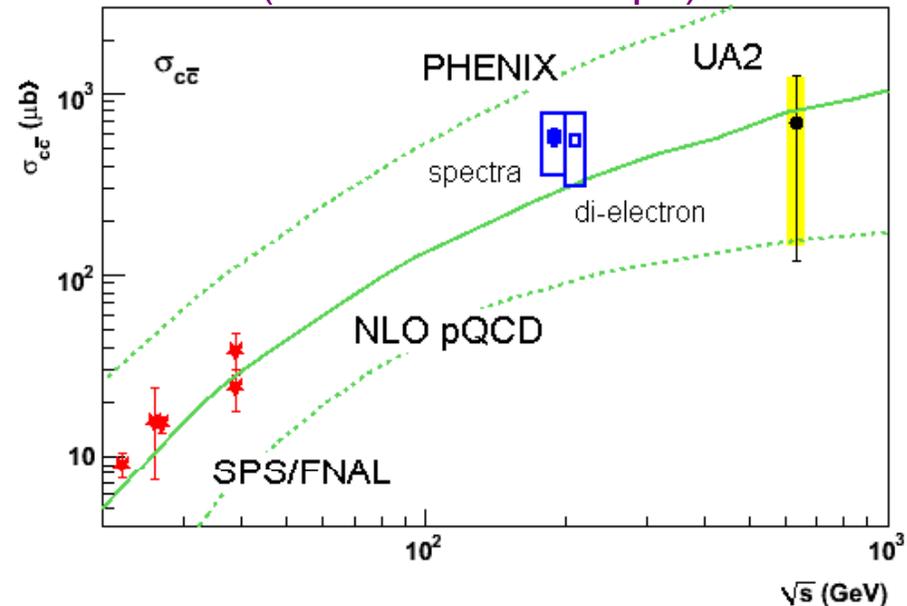
After subtraction of Cocktail -



$$\sigma_{c\bar{c}} = 518 \pm 47(stat) \pm 135(sys) \pm 190(model) \mu b$$

$$\sigma_{b\bar{b}} = 3.9 \pm 2.5(stat)_{-2}^{+3}(sys) \mu b$$

Fit to a\*charm+ b\*bottom  
(with PYTHIA shape)

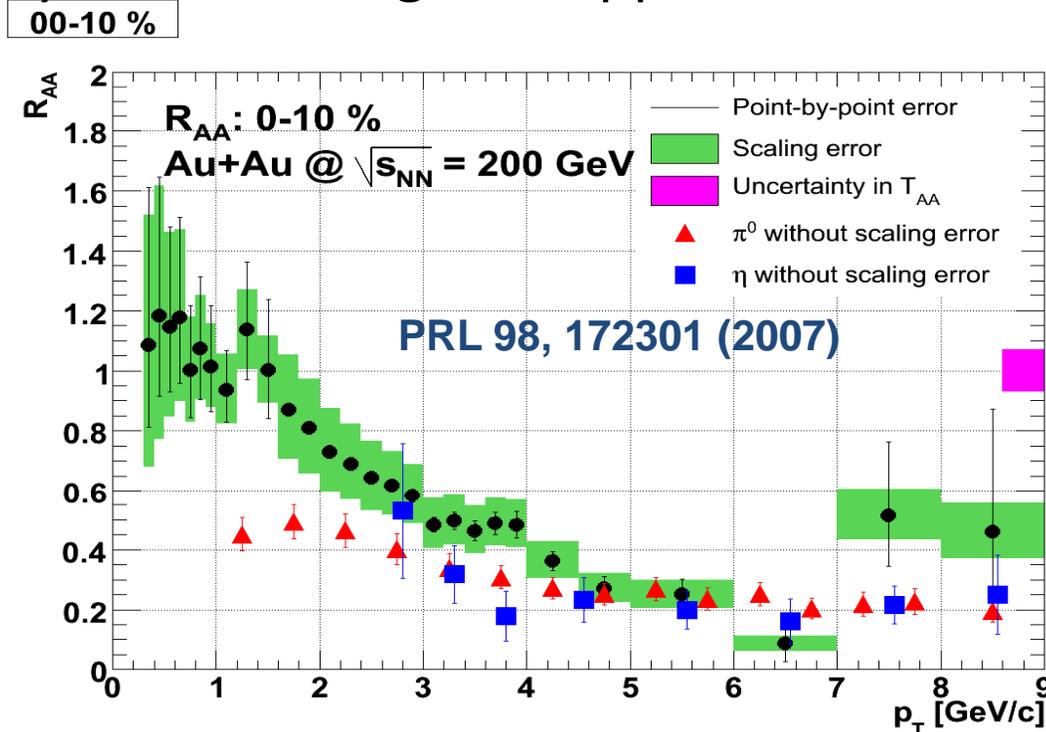


- Good agreement with single e results
- Also new analyses via e-h coincidences, single muons, and direct charm measurement
- **AND Bottom!!!!**

# Final Data Single e suppression

Talk by Averbeck

- Recently finalized single e suppression



- Awaits further interpretation
  - Now quite well established b/c separation should help
- Collisional component of Eloss important?
- Non-perturbative components?

# Physics Questions

- **Characterizing the Medium “directly”:**
  - What’s it’s made of?
  - Information about phase transitions spacetime evolution?
  - What’s it’s temperature?
- **Exploring QCD Phenomena along with the Medium**
  - What mechanisms cause hadron suppression/energy loss in hard scattering?
    - In jets
    - In heavy quarks

## Answers: (not complete)

- **It’s still unclear but progress is being made:**
  - **HQ suppression level finalized, well confirmed**
- **p+p control Baseline progress:**
  - **b/c contribution to electrons established**
  - **Consistent (understood?) FONLL disagreement persists**

# Physics Questions

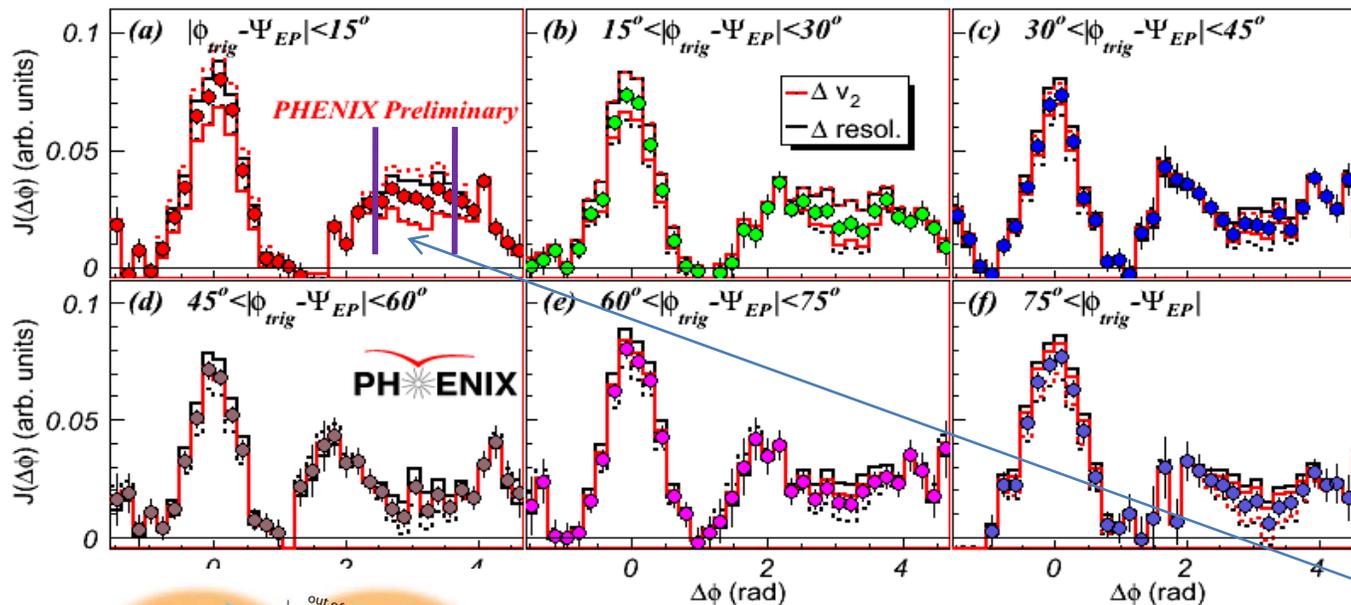
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  - What is the origin of exotic phenomena?
    - Shoulder
    - Ridge
    - Baryon Enhancement
    - Dilepton Enhancement
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# Another handle on path-length: Reaction plane dependence

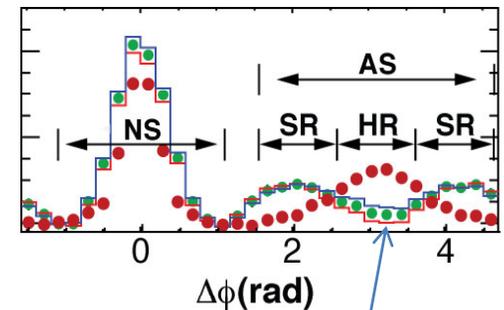
Talks by Pei, McCumber

New rxnp

**n-Plane** Au+Au  $\sqrt{s_{NN}}=200\text{GeV}$ , Cent=30-40%,  $1 < p_{T,assoc} < 2 \text{ GeV}/c$ ,  $3 < p_{T,trig} < 4 \text{ GeV}/c$



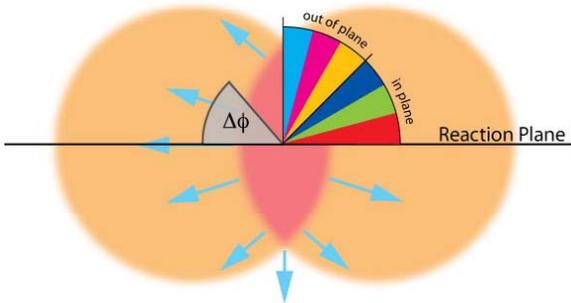
Phys.Rev. C 77, 011901 (2008)



**Out-Plane**

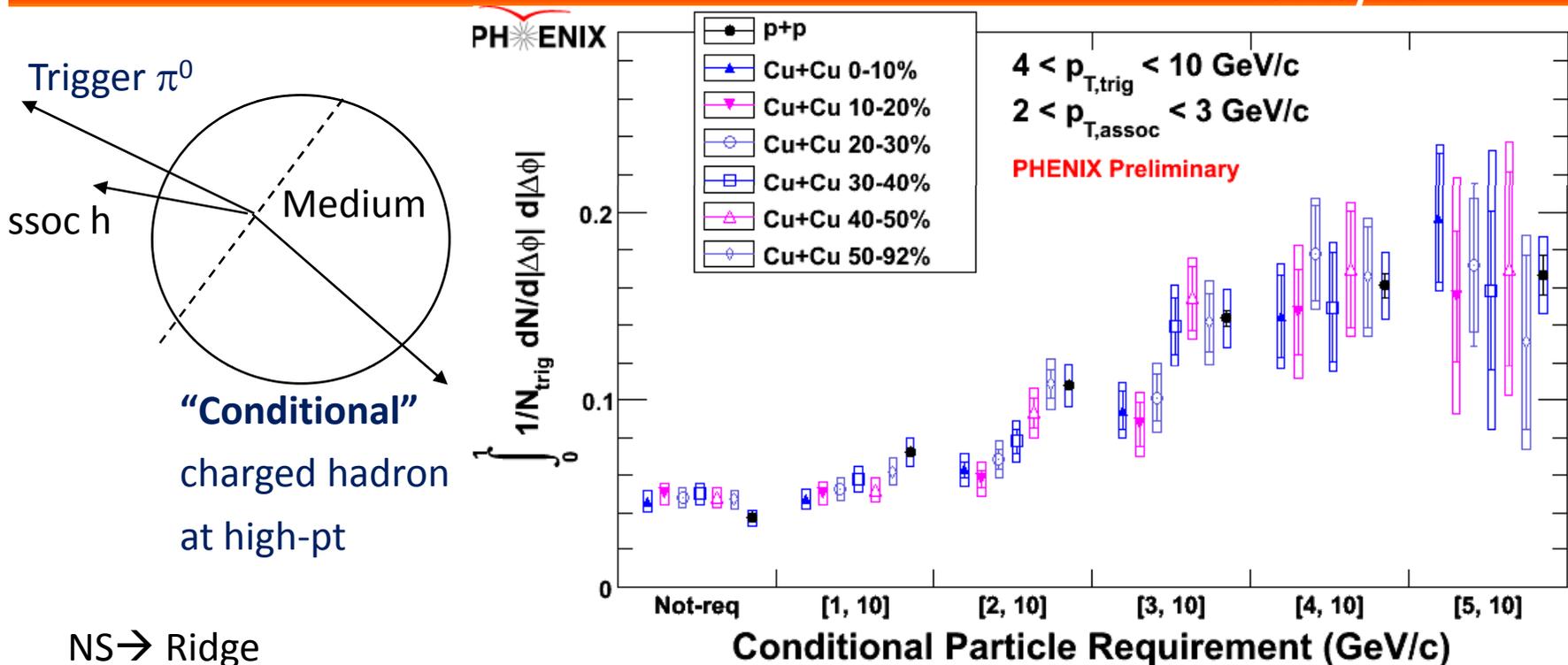
Evolution of “Head Region” (Back to back) is observed. (as opposed to Shoulder Region SR)

Need more work to quantify that



# Constraining geometry: “2+1” near-side yields

Talk by Pei



NS → Ridge

Cu+Cu yield increases from central (left) to peripheral (right) in each bin and approaches p+p (most right point in each bin)

The fact that Cu+Cu yield is reduced at central is possibly due to

- 1) weaker surface-bias, 2) more “+1” particles from underlying event

More work underway!

# Physics Questions

- **Answers: (not complete)**
  - **Indication of dependence of di-jet suppression wrt RP angle? (reduce systematics)**
  - **PHENIX 2+1 Studies underway: hint of geometric modification in 2+1 cent dependence?**

- What is the geometry of suppression
- What is the origin of exotic phenomena?
  - Shoulder
  - Ridge
  - Baryon Enhancement
  - Dilepton Enhancement
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# Physics Questions

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# Extensive Shoulder Characterizations

Talk by McCumber

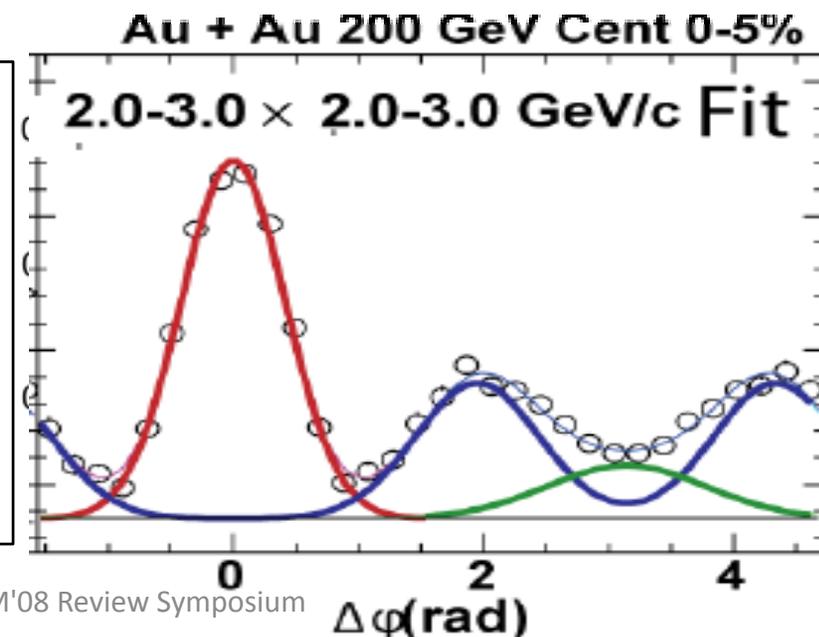
- Detailed studies of Shoulder Shape and Yields Finalized/(almost finished?) Over Past Year:
  - Location of Displaced Peak  $\sim$ independent of Collision Energy, Species,  $p_T^{\text{trig}}$ , Produced hadronic species
  - Momentum dependence much softer than jet, but slightly harder than bulk
  - Baryon/Meson make up similar to bulk (Baryon Enhanced)

New Studies of the definitions of “shoulder” yield

New Fit Decomposition:

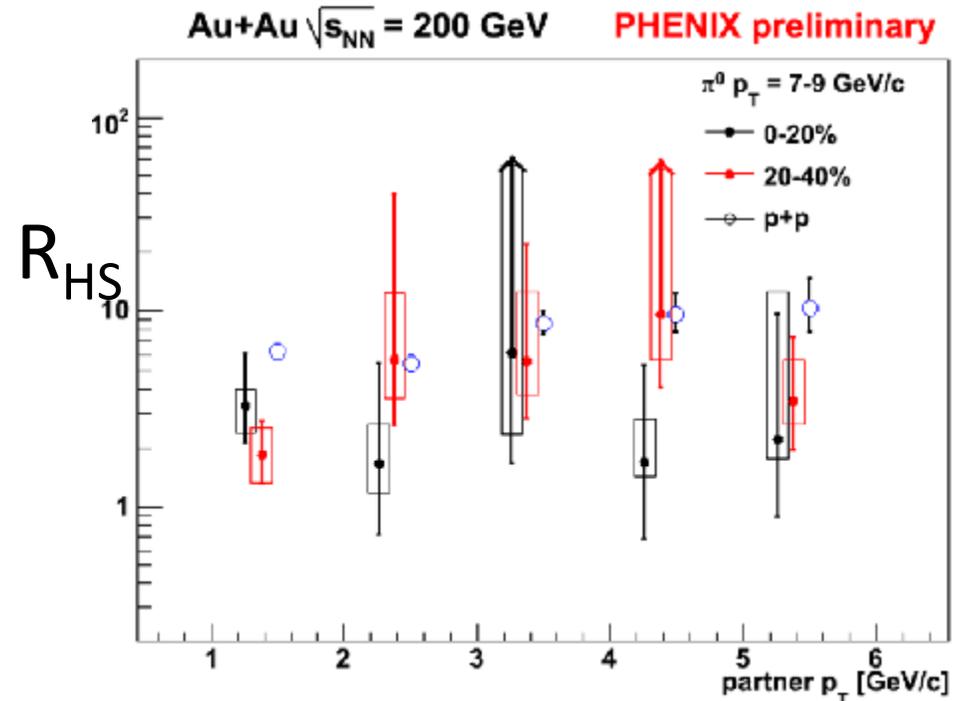
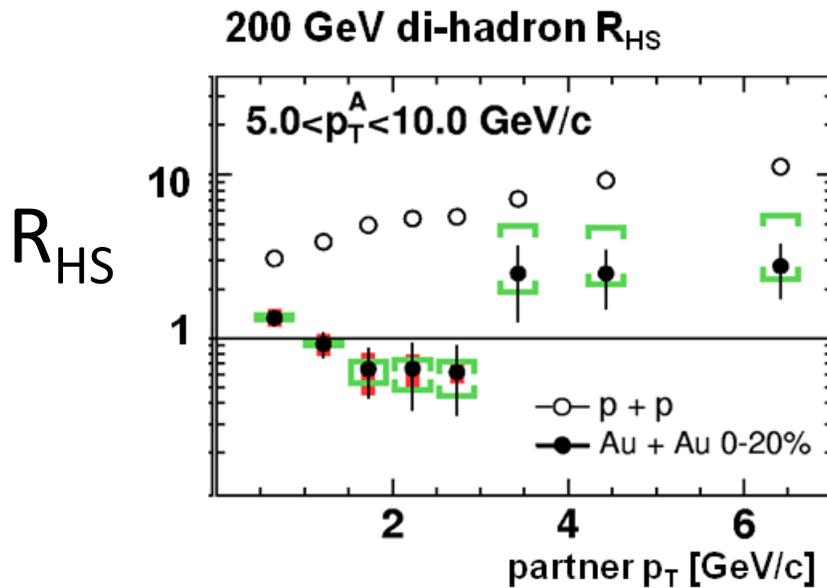
Model dependent

Reduces bleed in across regions



# $p_T$ dropoff of Shoulder Phenomena?

Talk by Adare

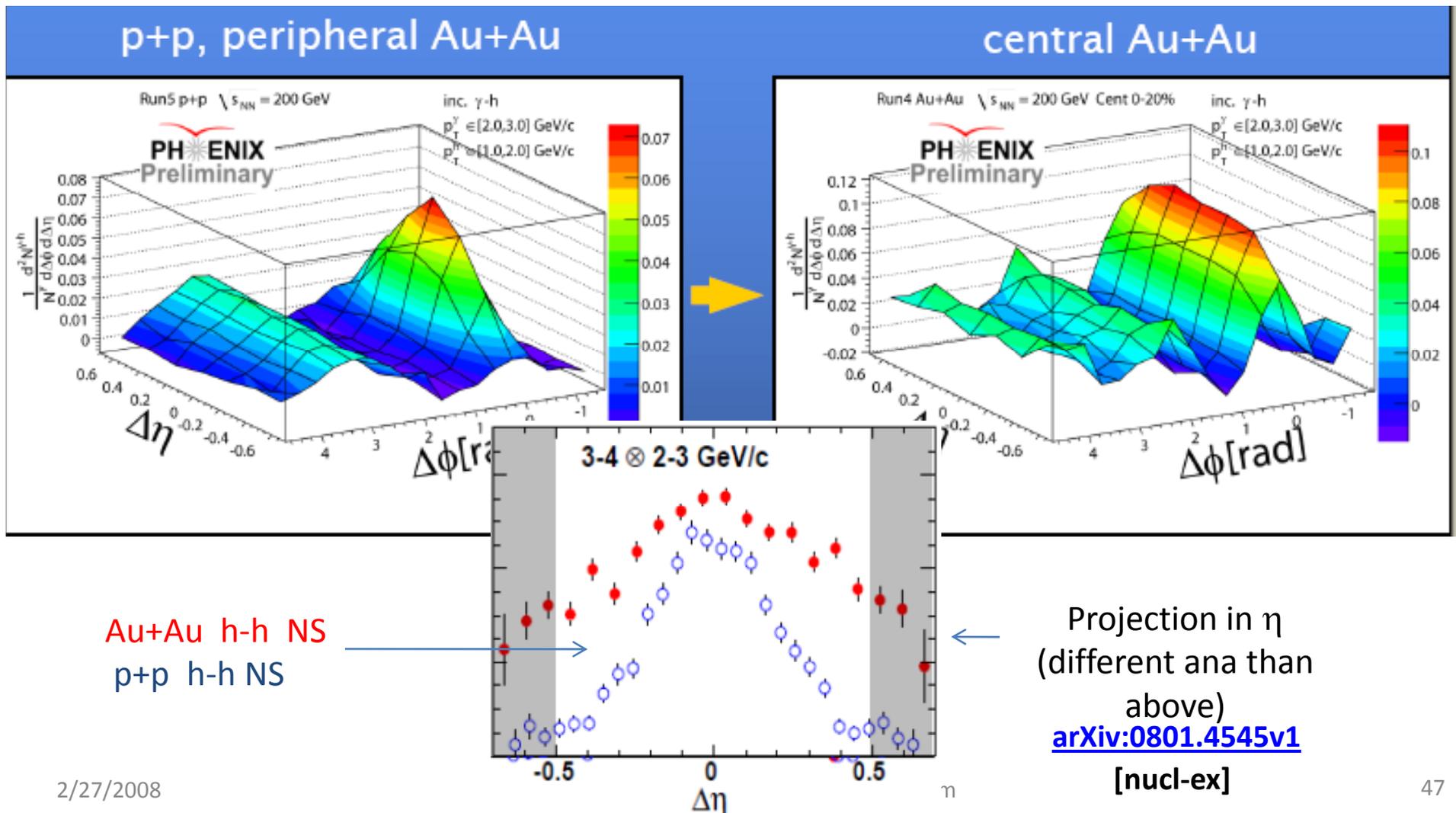


- $R_{HS}$  Head to Shoulder ratio: indicator of shoulder enhancement
- Apply Run 7  $\pi^0$ -h higher  $p_T$  results looking for more precise upper limit in  $p_T^{\text{partner}}$  : btw 5-7 GeV?

# PHENIX Ridge (?) (!) Studies

Talk by McCumber

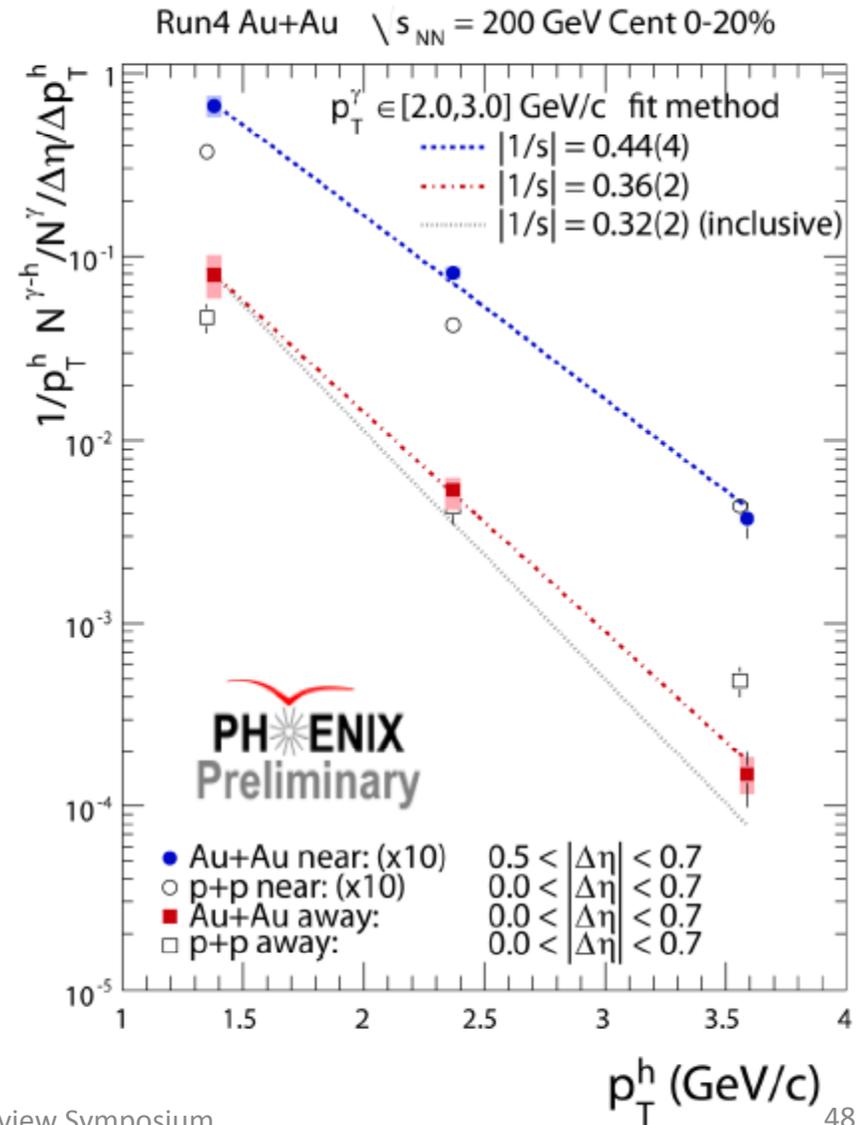
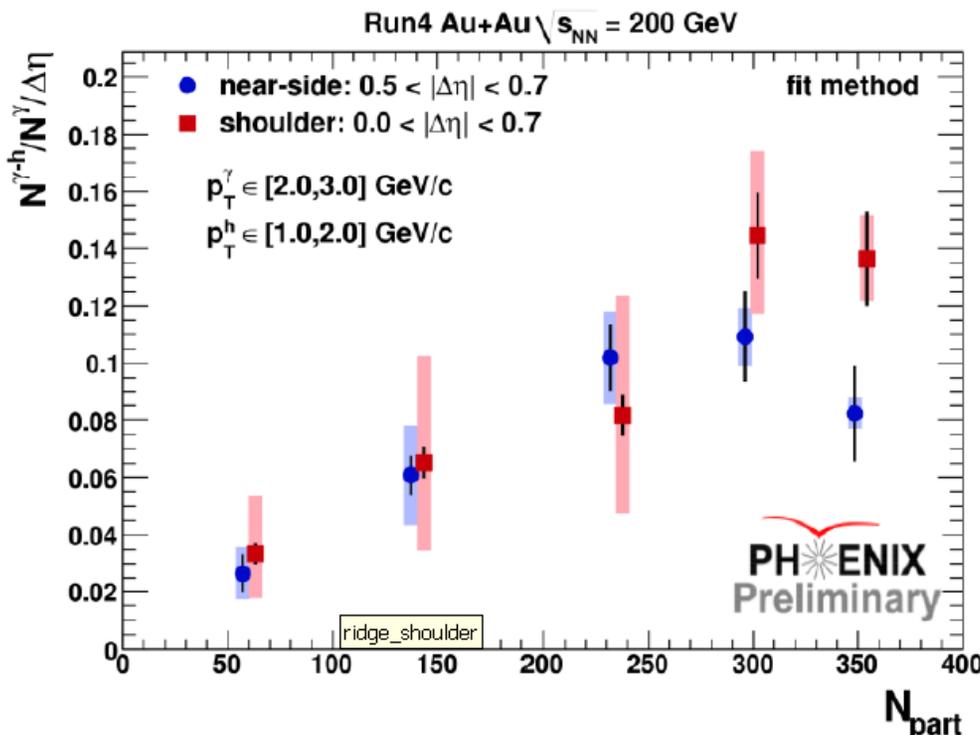
- PHENIX can study ridge even within small eta acceptance



# Combining with Shoulder Studies

Talk by McCumber

- Striking Similarities!
- Ridge yields track shoulder yields vs Centrality
- Spectral shape  $\sim$ the same



# Physics Questions

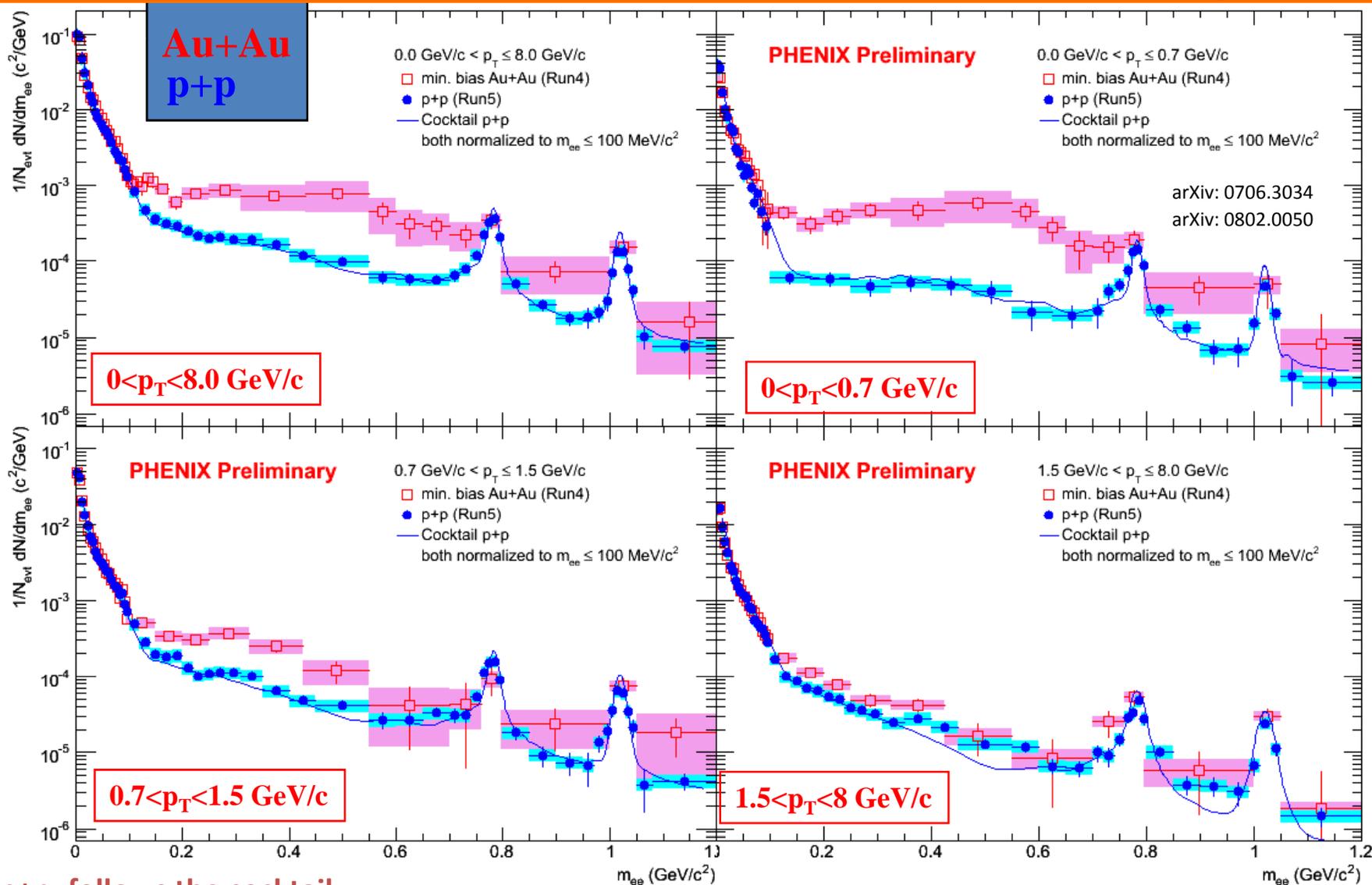
- Answers: (not complete)
  - Information about phase transitions spacetime evolution?
  - What's its temperature?
- Exploring QCD Phenomena along with the Medium
  - What mechanisms cause hadron suppression/energy loss in hard scattering?
    - In light hadrons
    - In heavy quarks
  - What is the geometry of suppression
    - What is the origin of exotic phenomena?
      - Shoulder
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      - Baryon Enhancement
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# Enhancement! Now w/ $p_T$ dependency

Talk by Toia, Dahms



p+p: follows the cocktail

Au+Au: enhancement concentrated at low  $p_T$

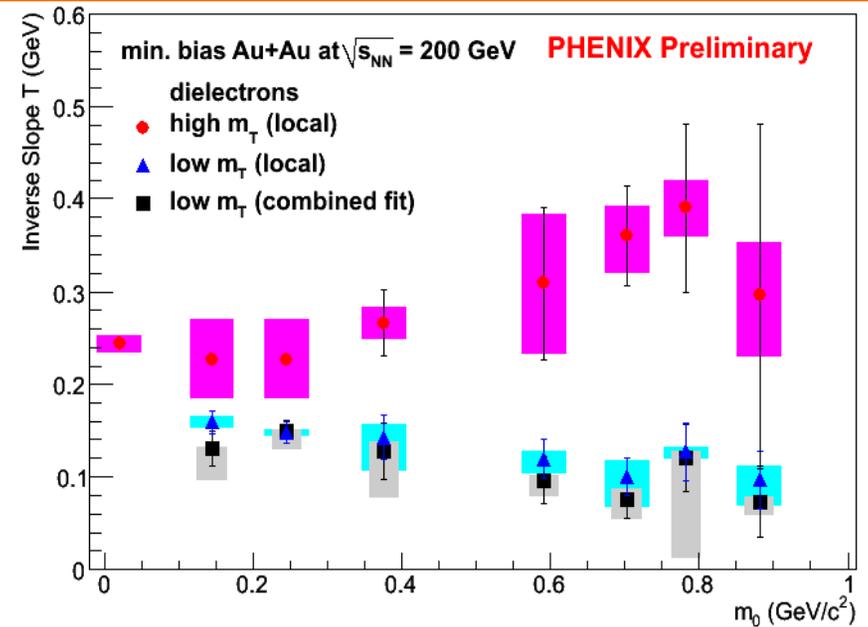
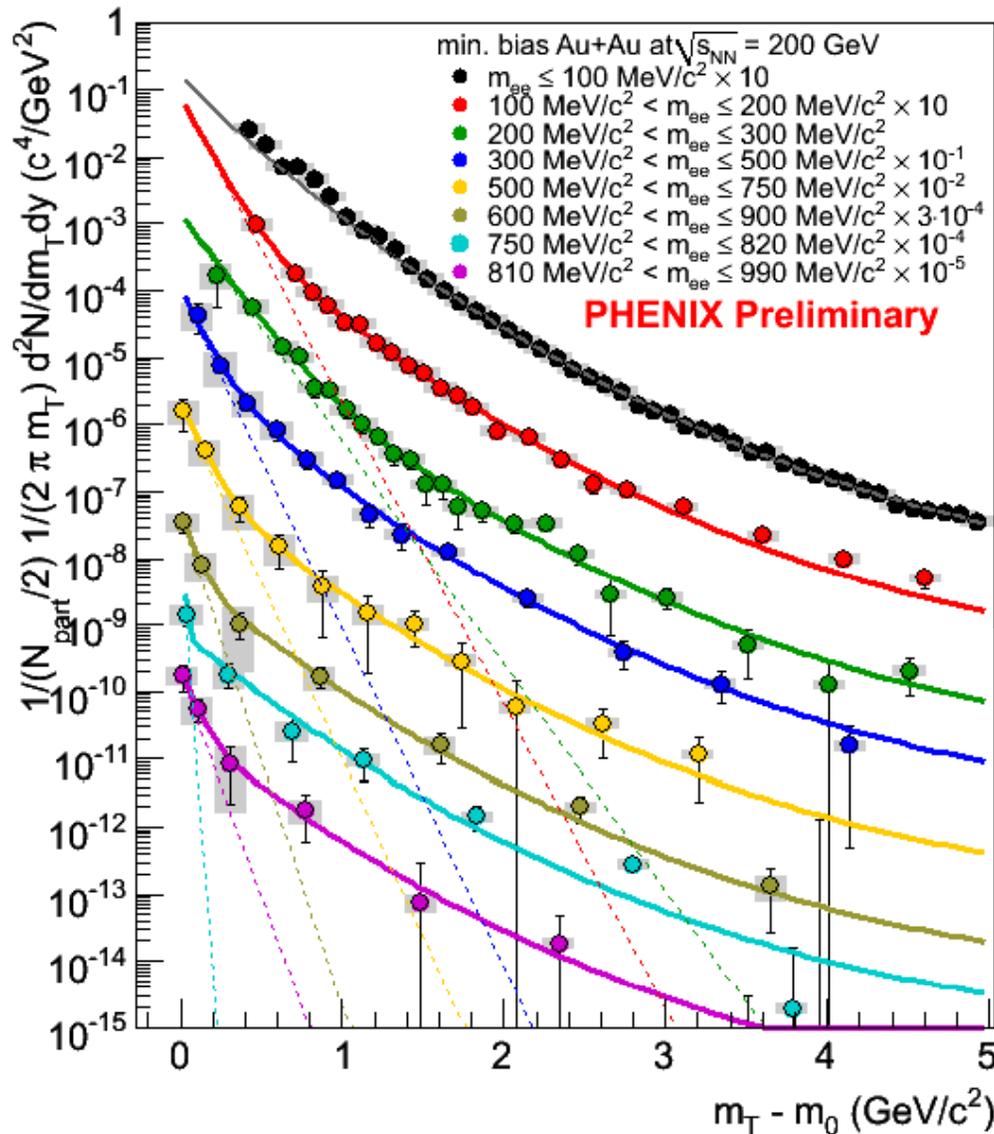
2/27/2008

Justin Frantz BNL QM'08 Review Symposium

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# Thermal Dilepton Radiation?

Talk by Toia



Low- $p_T$ :  $0 < m_T < 1$  GeV

Intermediate  $p_T$ :  $1 < m_T < 2$  GeV

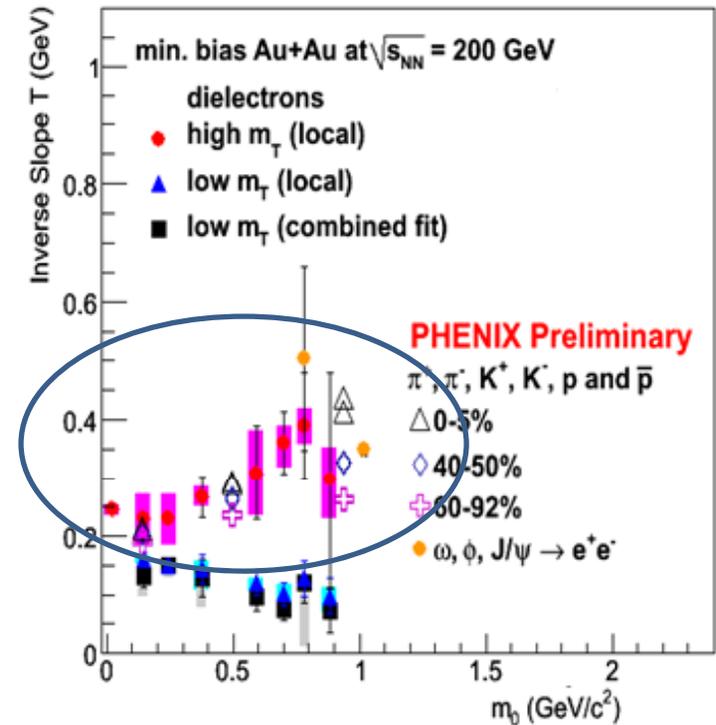
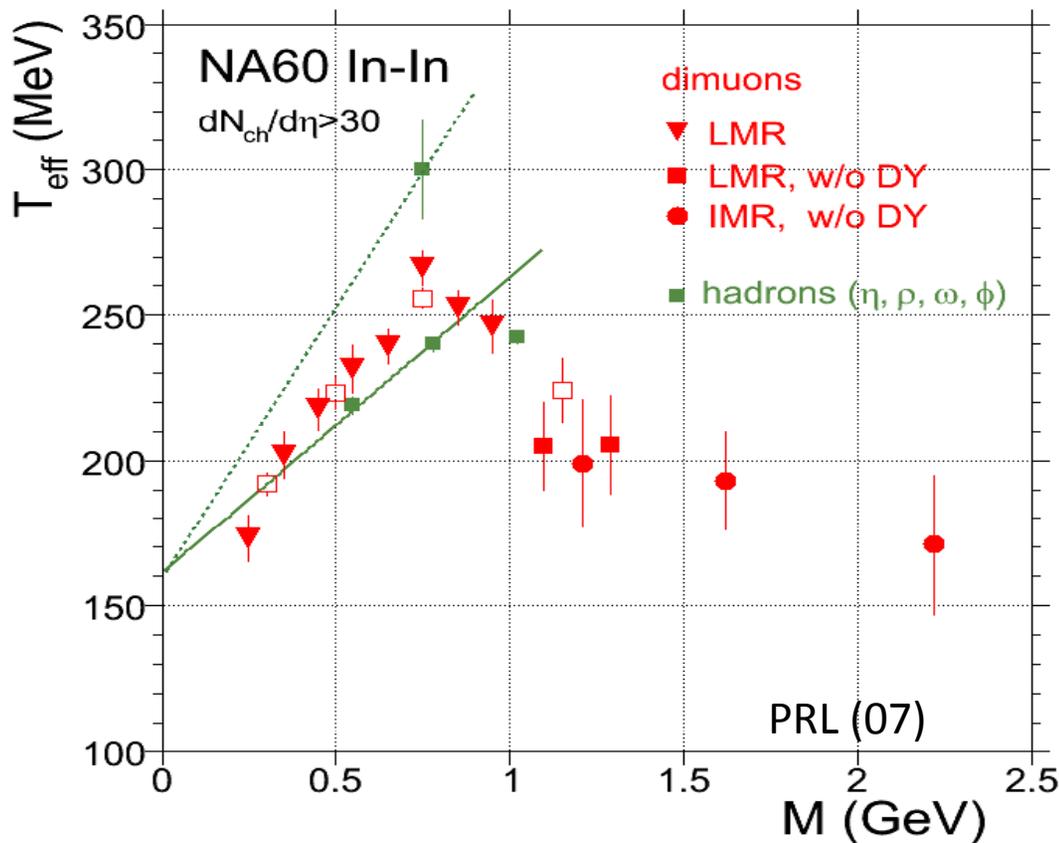
- Intermediate  $p_T$ : inverse slope increase with mass, consistent with radial flow

- Low  $p_T$ :

- inverse slope of  $\sim 120$  MeV

# As w/SPS, richly informative

Any similarities with SPS ? Ceres/NA60 People: Skepticism about thermal fit, but clearly something interesting is going on here too just as at SPS



# Physics Questions

- **Answers: (not complete)**
  - **Dilepton Enhancement in the medium has recently been established with p+p control measurement**
  - **Differential studies to enhancements in Dilepton production hint at Thermal nature?**
    - What is the origin of exotic phenomena?
      - Shoulder
      - Ridge
      - Baryon Enhancement
      - Dilepton Enhancement
    - What is the geometry of the exotic phenomena
    - What mechanisms affect Quarkonia production in the medium

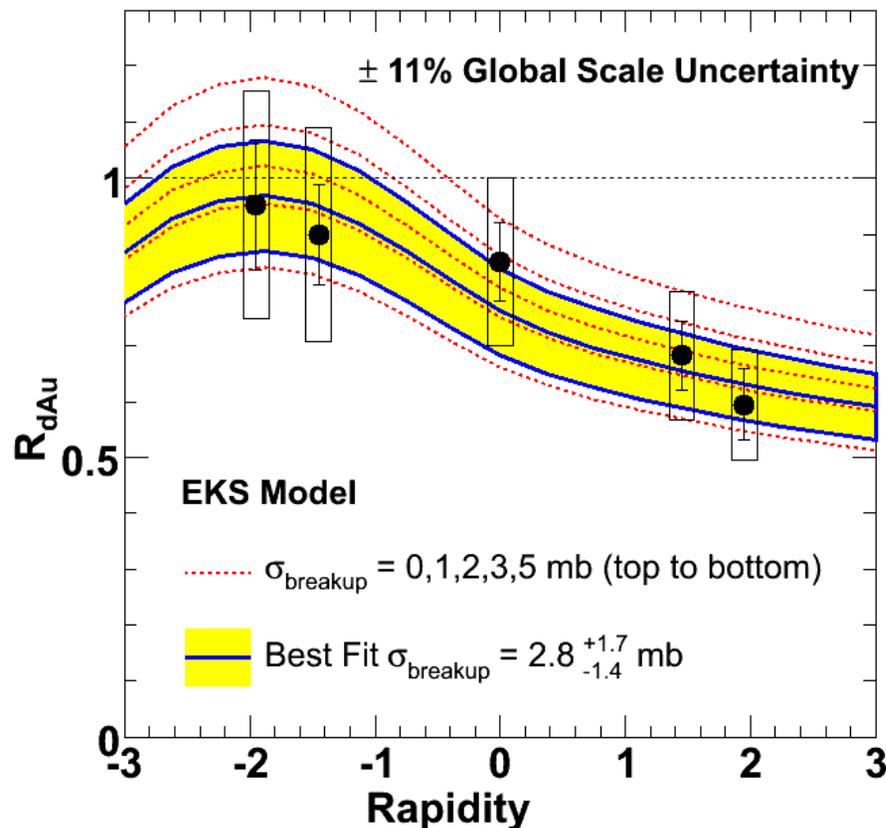
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# J/ψ d+Au: Cold Nuclear Matter

Talk by Wysocki

J/ψ  $R_{dAu}$  200 GeV



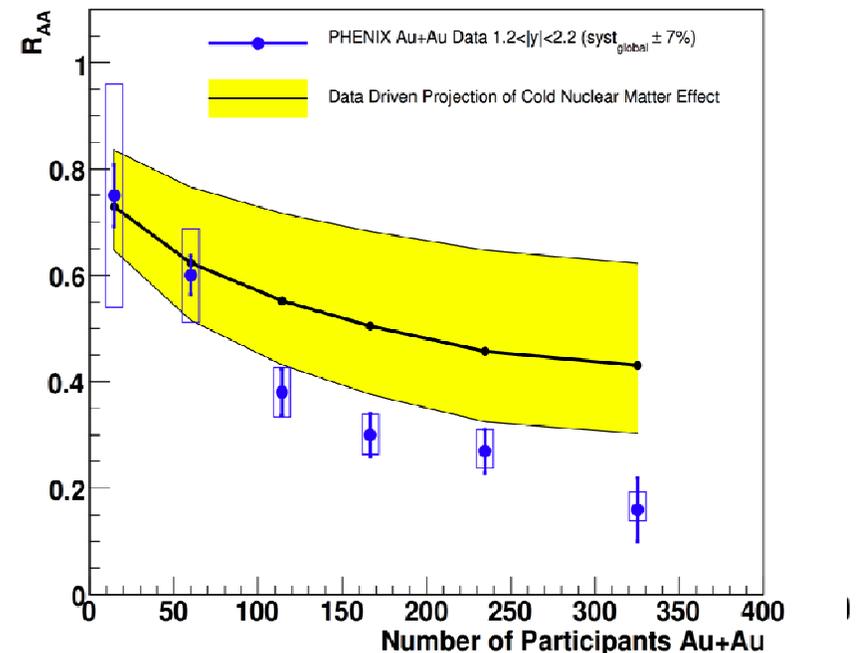
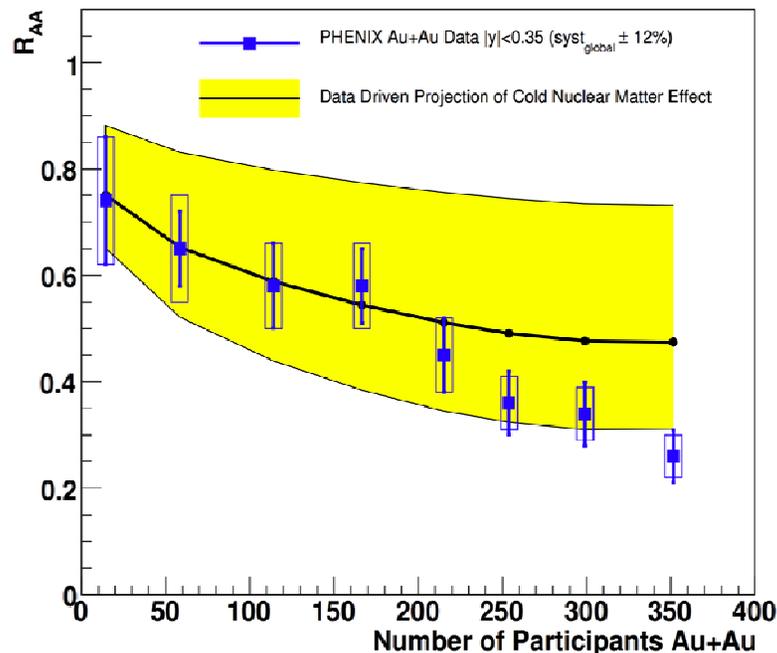
- Increased Run 5 p+p statistics (x10 Run 3)
- Improved & consistent p+p and dAu analysis
  - Improved alignment, resolution, yield extraction,...
  - Cancellation of systematic errors in  $R_{dAu}$
- Result: CNM = Shadowing(EKS) +  $\sigma_{\text{Breakup}} = 2.8^{+1.7}_{-1.4}$  mb
  - Consistent within errors with previous results

arXiv:0711.3917

# J/ψ Au+Au: beyond CNM Effects?

Talk by Wysocki

## J/ψ $R_{AuAu}$ 200 GeV (Run4)

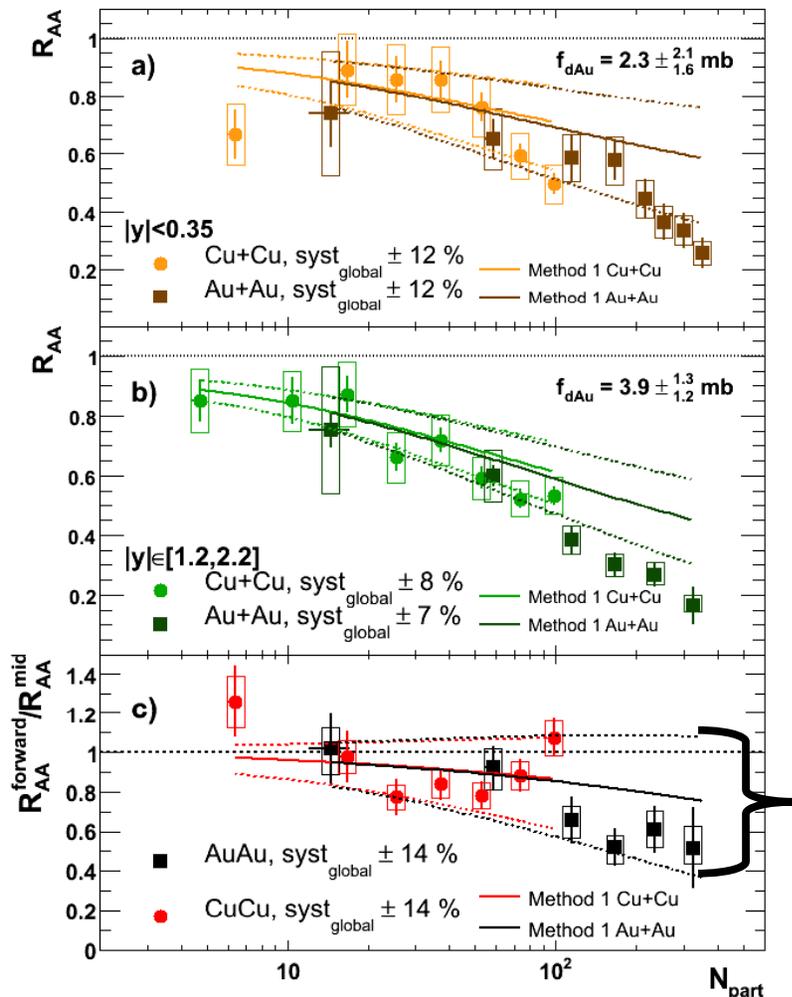


- Large errors still (need Run 8 d+Au, Run 7 Au+Au) arXiv:0711.3917
  - Comparison suggests more forward suppression beyond CNM than at mid-rapidity
  - BUT models shown don't describe  $R_{dAu}$  impact parameter dependence
- However Data Driven Method, (No models) not as significant

# J/ψ R<sub>AA</sub> Cu+Cu and Au+Au

Talk by S. Oda

## J/ψ R<sub>AA</sub> 200 GeV



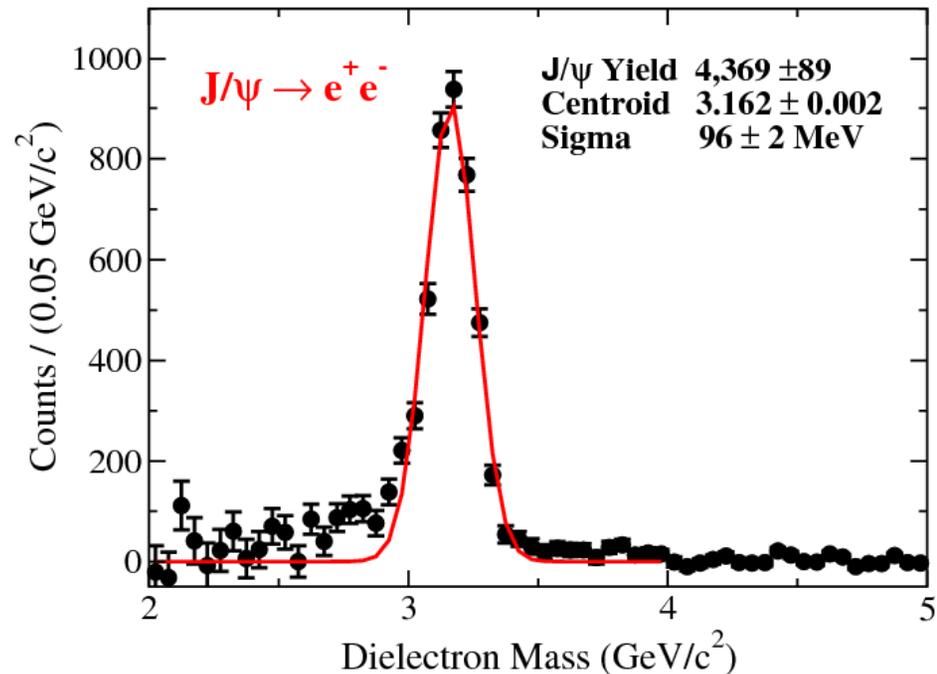
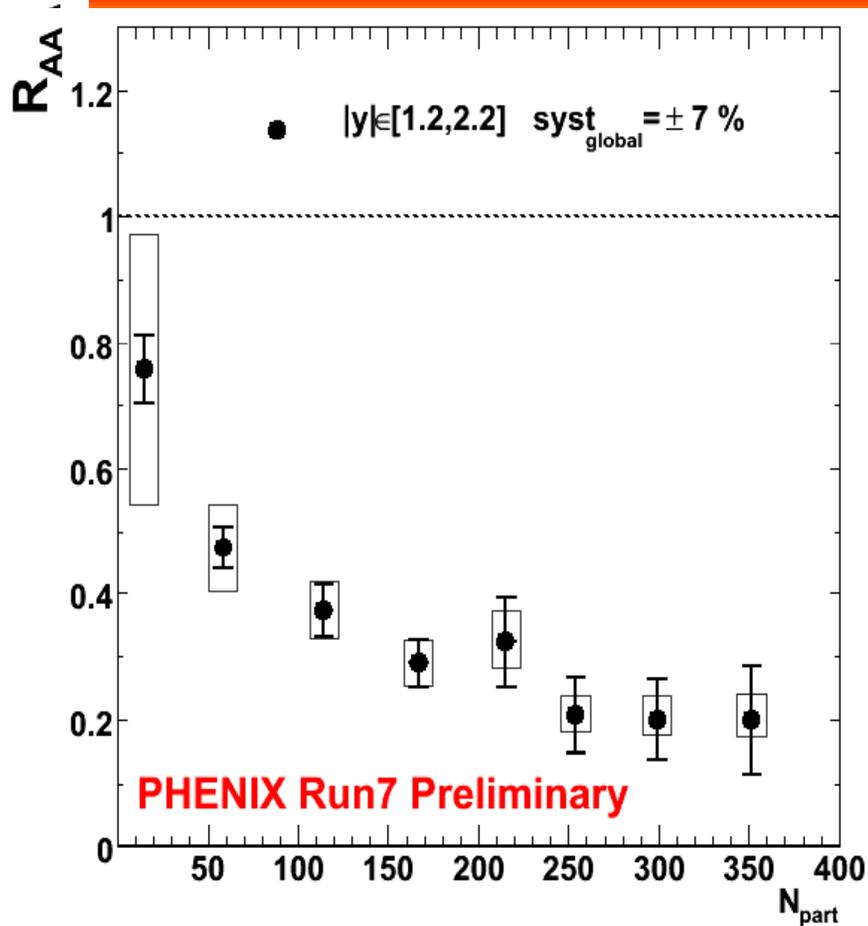
- Approx 2x more J/ψ in Cu+Cu sample than Au+Au sample
  - More precise  $N_{part} < 100$  info
- Curves show  $R_{AA}$  prediction from **ad hoc** CNM fit to  $R_{dAu}$  separately at  $y=0$  and  $y > 1.2$
- CNM from  $R_{dAu}$  fit describes suppression for  $N_{part} < 100$ .

$R_{dAu}$  constraints are **not sufficient** to say if suppression beyond cold nuclear matter is stronger at forward rapidity

arXiv:0801.0220

# New Data from Run 7 & Run 8

Talks by Oda, Wysocki



Statistics will increase by a factor of 3 from Run-4 data.  
Preliminary Run-7 result  
at forward rapidity is consistent with published Run-4 result.

30 times larger statistics will  
reduce uncertainties of CNM  
effects.

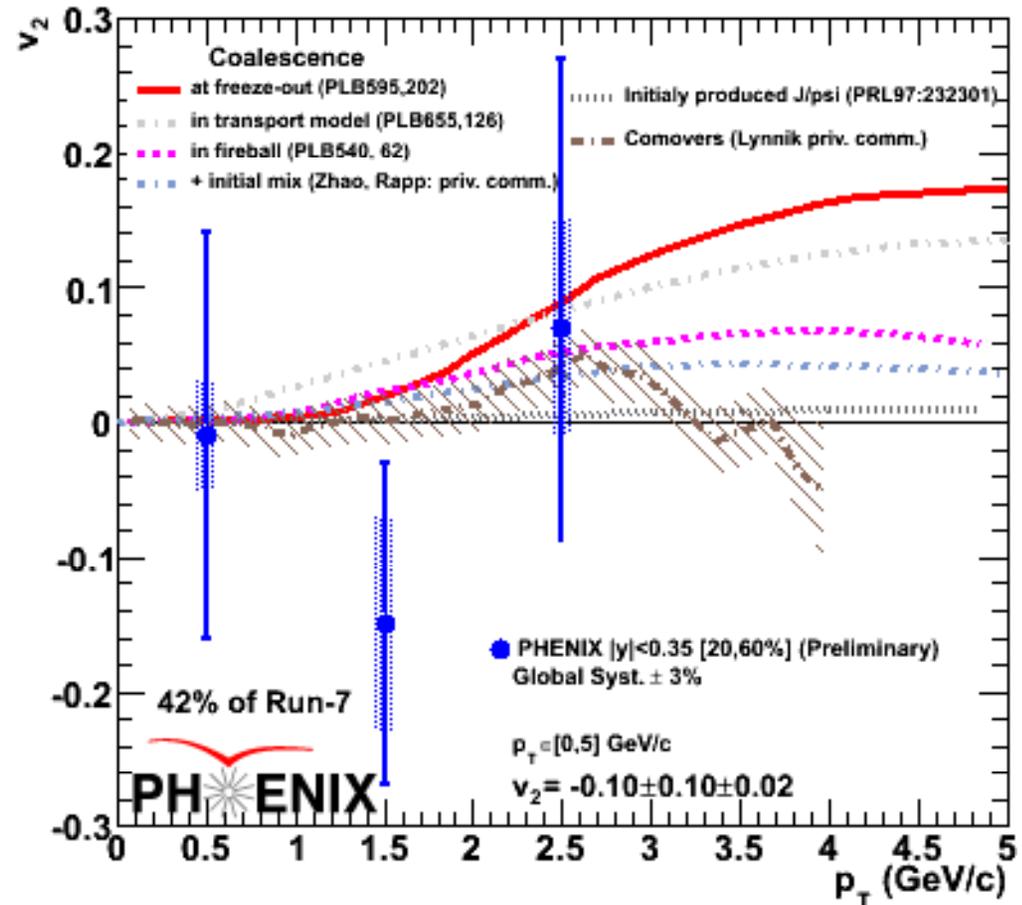
# $v_2 - J/\Psi \rightarrow e^+e^-$

Talk by Silvestre

First ever at RHIC,

$v_2 - J/\Psi \rightarrow \mu^+\mu^-$  coming soon

J/Psi coalescence? Various model predictions depending on the amount of recombination/coalescence considered



Work in process, less than half the dataset, muons will help no clear model predictions

# Physics Questions

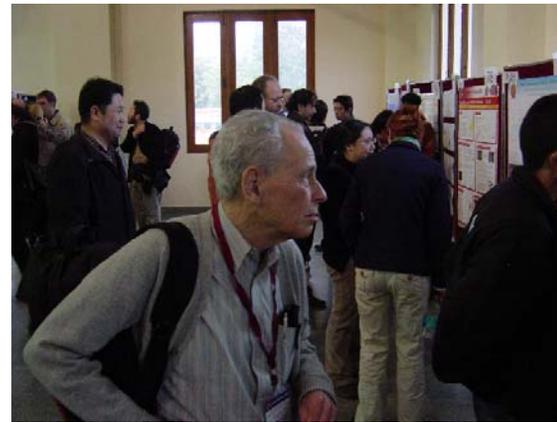
- **Answers: (not complete)**
  - There appears to (at least at  $\sim 1\sigma$ ) suppression beyond Cold Nuclear effects at forward rapidity
  - Rapidity dependence of this suppression is still unclear due to CNM effects expected from d+Au measurements
  - First Measurement of  $J/\psi$  flow should eventually help constrain the role of coalescence
  - Improvements on the way from Run7 Au+Au and Run 8 d+Au should resolve many open questions
    - What mechanisms affect Quarkonia production

# Summary & Outlook

- More detailed conclusions already given
- Lots of new light shed
  - Starting to see coherent pictures on many fronts!
- Filling in the details, confirming the emerging pictures with more precision
  - w/ Run7, Run8, and certainly beyond!

# In Memoriam: Zeev Fraenkel

Shortly after Quark Matter, PHENIX and the community suffered a great loss in the passing of Zeev Fraenkel



**“[A] friend and colleague for more than thirty years”**  
**“Zeev was everything a physicist should be, and, much more importantly, everything a man should be. I will truly miss him, and so wish I had had a chance to say goodbye.”**

**“I’m so glad that he was able to attend the last collaboration meeting and QM’08, doing physics until the last.”**

**“I’ll remember him a very proud and humble man and let peace be with him. “**

**“Zeev was intelligent, witty, talented, spry, inspirational, and wise. He will be sorely missed.”**

2/27/2008

**“We will all miss Zeev.”**

**“Zeev was one of the founding fathers of the study of nuclear matter, and his scientific influence was broad and deep. Zeev was a mentor, friend and inspiration to so many. “**

**“I always enjoyed speaking to him about PHENIX, physics etc. because he always had a very different perspective based on his long experience as a practicing physicist. It is particularly saddening to lose elder statesmen like Zeev [...]”**

**“He will be greatly missed - I am glad however, that he came to QM - so we all saw him “**

**“his scientific productivity was amazing[....] My ‘what is new in PHENIX’ has been usually from discussions with Zeev every morning there, now I’ll miss it ...”**

**“It still makes me smile when I think of [him].”**