

Single High p_T Particles at RHIC

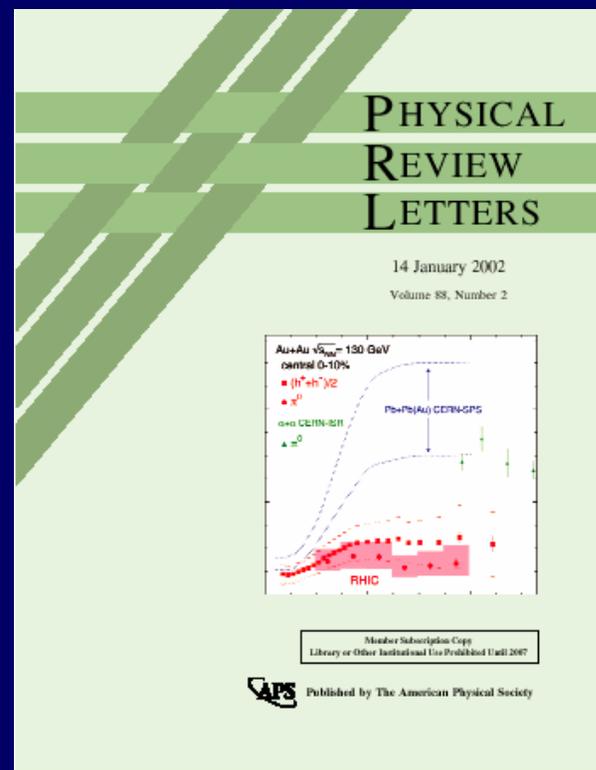
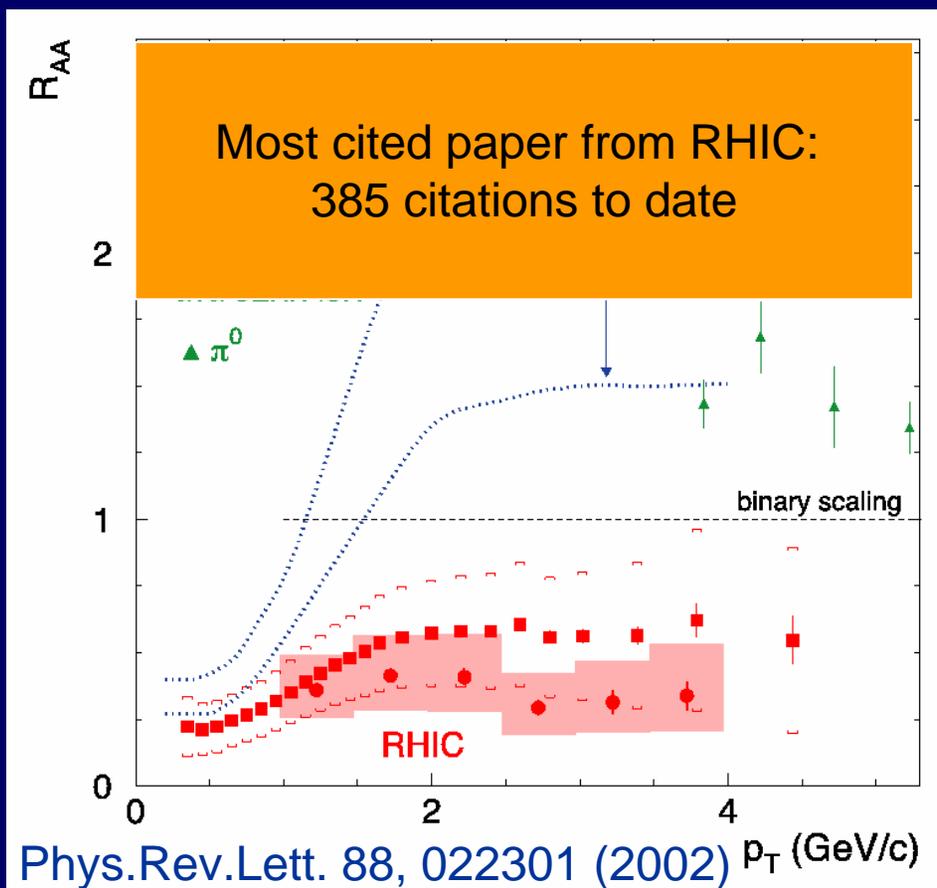
Stefan Bathe
UC Riverside

RHIC-AGS Users' Meeting 2007

Hypothesis

“The discovery phase for single high p_T particles is over. All left to do are precision measurements.”

. . . to be tested in the following

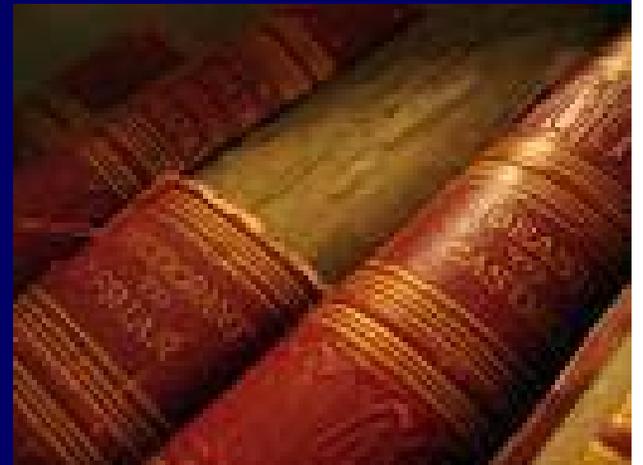


featured on cover of *Physical Review Letters* (14 January 2002)

What we think we know

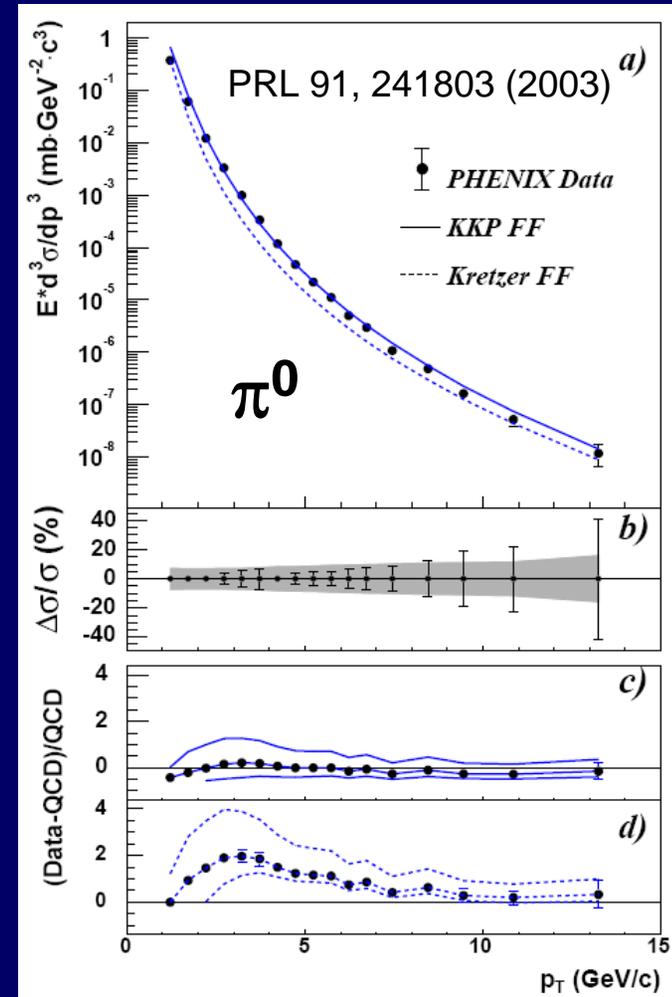
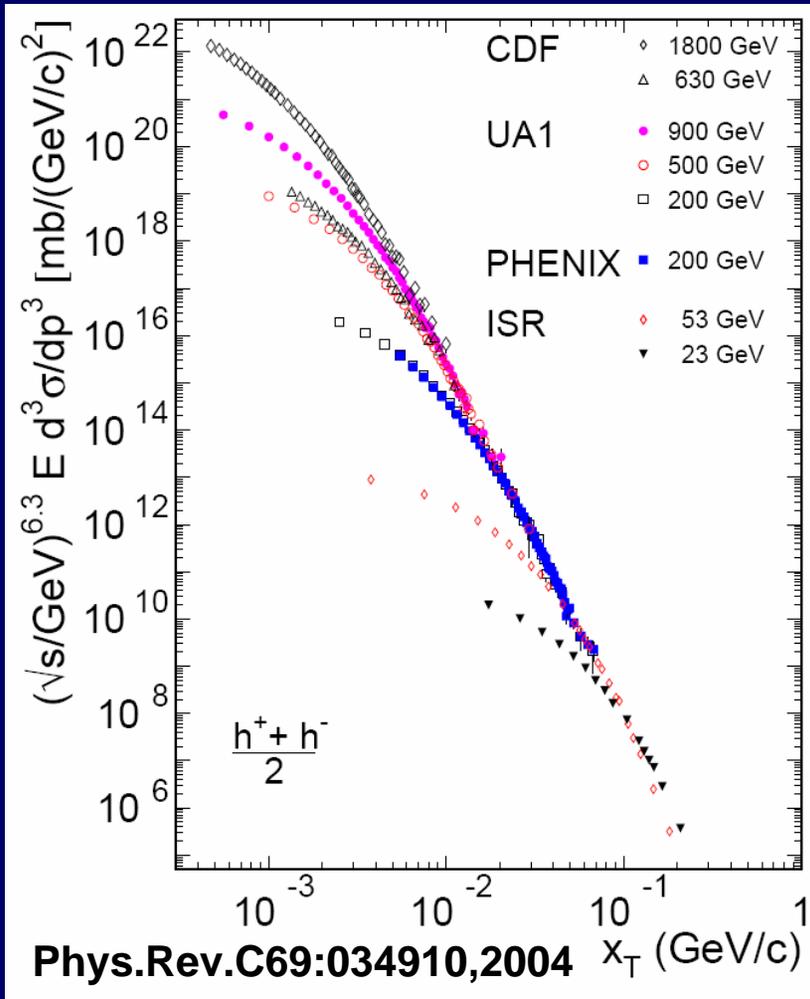
- Conclusions from RHIC discovery phase (first three years)
 - ◆ It's a discovery
 - “Strong suppression of high- p_T particle production at RHIC is unique phenomenon that has not been previously observed.”
 - ◆ Density
 - Have created matter of unprecedented density ($\varepsilon > 10 \varepsilon_0$)
 - ◆ E-loss mechanism
 - Medium-induced E-loss, primarily via gluon bremsstrahlung, only known mechanism to describe magnitude and p_T dependence

PHENIX White Paper, Nucl. Phys. A 757 (2005) 184



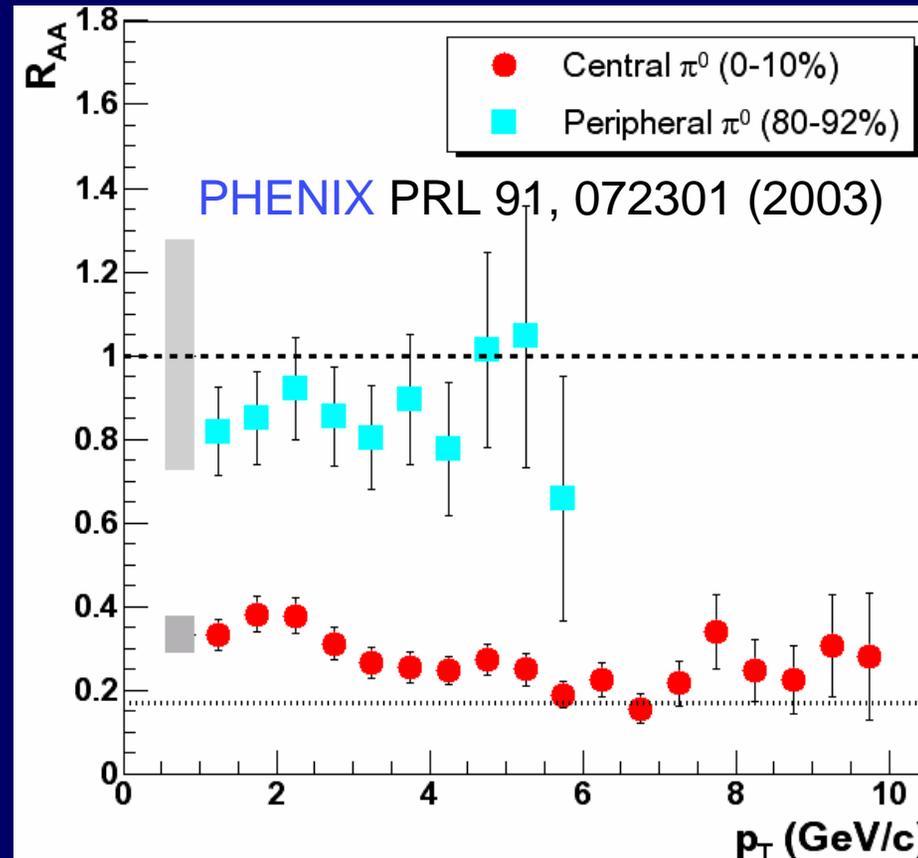
What is the evidence?

- Evidence 1/6
 - ◆ Hard scattering at play in p+p



What is the evidence?

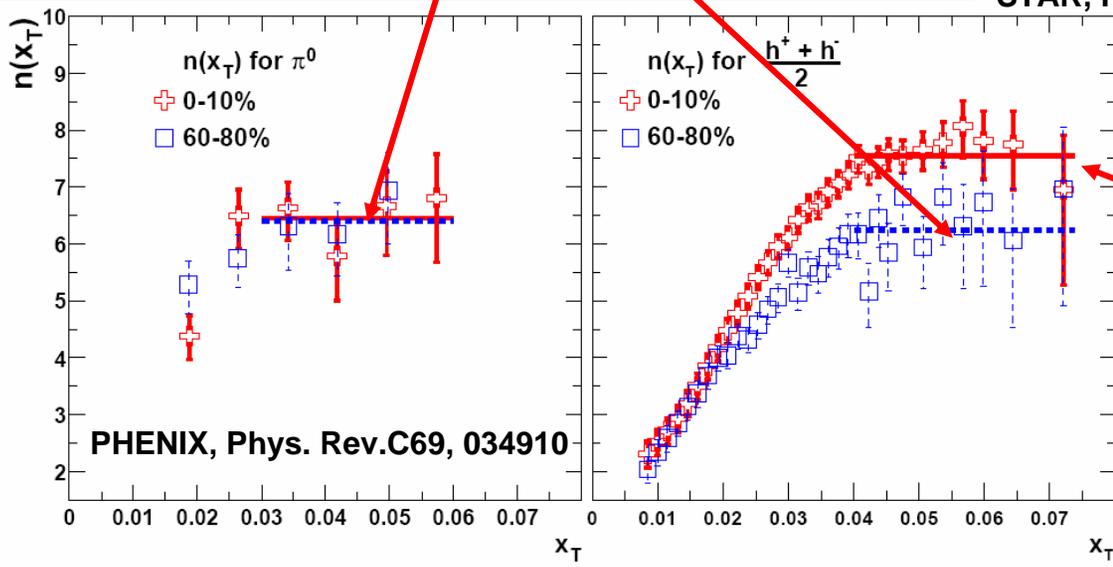
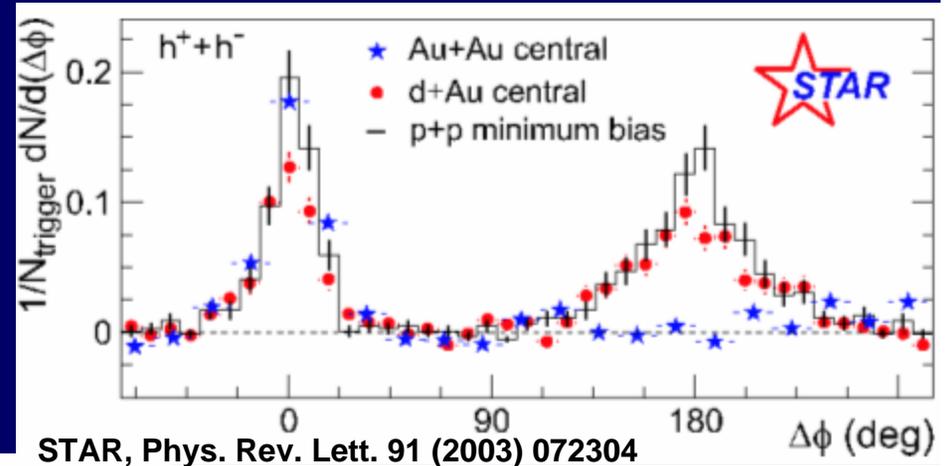
- Evidence 2/6
 - ◆ Suppression in central Au+Au, no suppression in peripheral



What is the evidence?

- Evidence 3/6
 - ◆ Observation of x_T scaling and 2-particle azimuthal correlations confirm dominant role of hard scattering and subsequent jet fragmentation

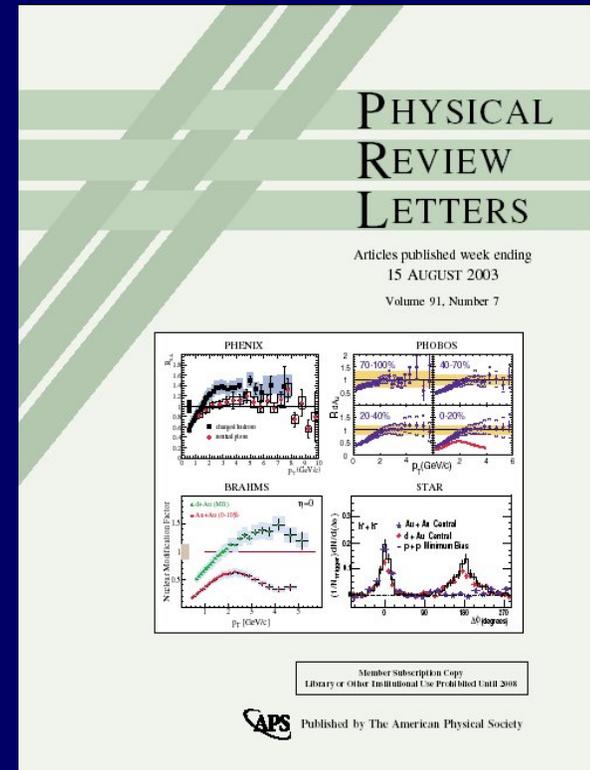
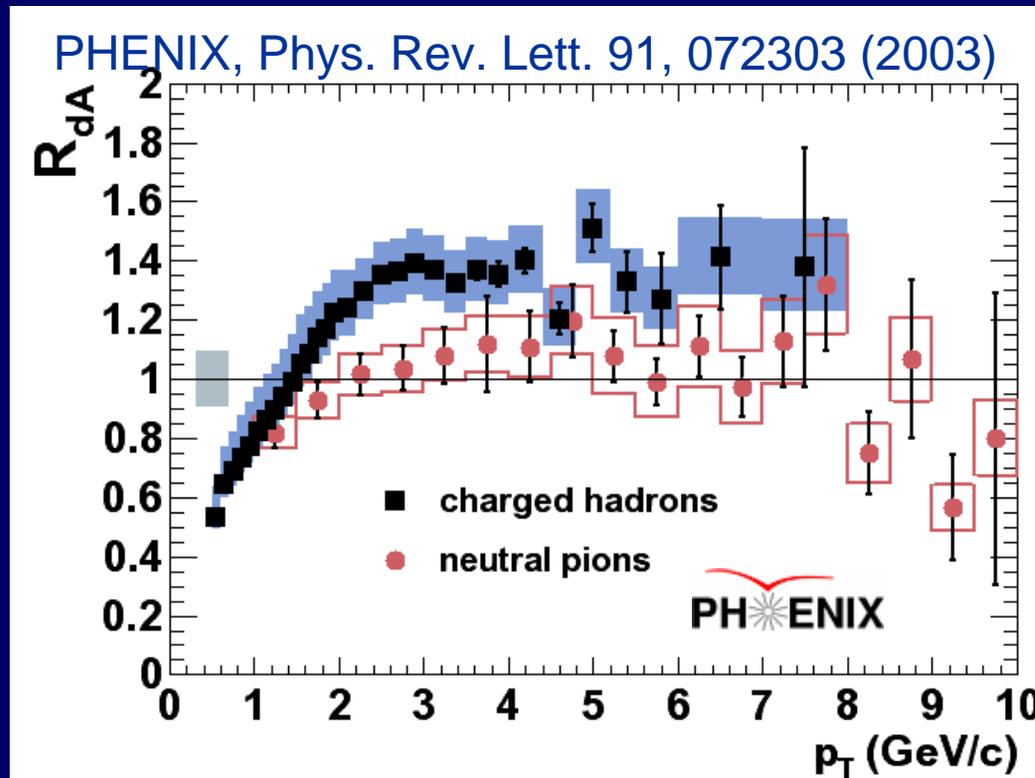
Same exponent as for p+p:
Hard scattering at work for π^0 and peripheral h^\pm



different exponent for central h^\pm :
different physics

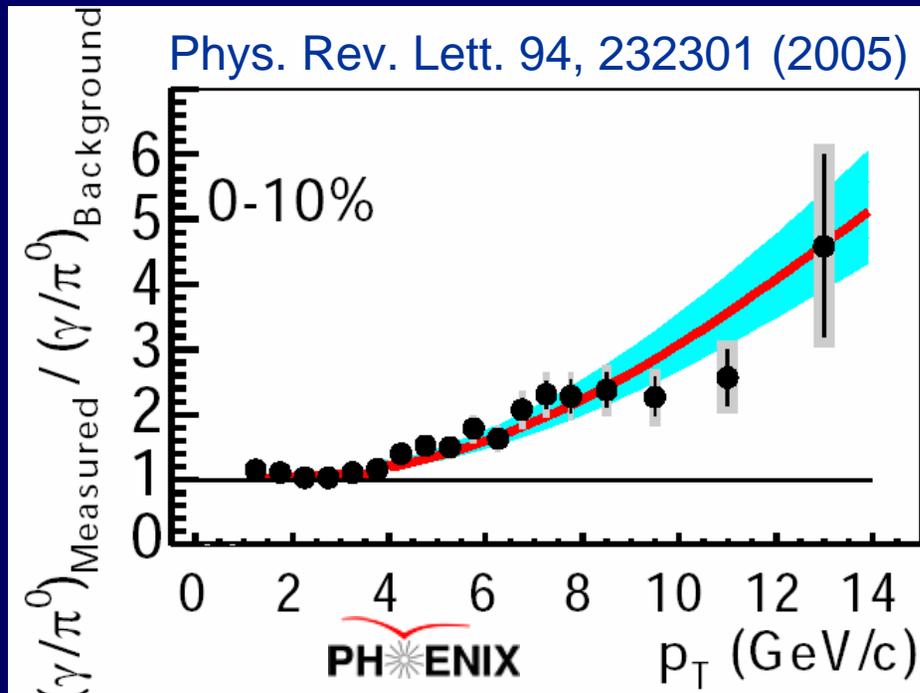
What is the evidence?

- Evidence 4/6
 - ◆ d+Au measurements demonstrate initial-state nuclear effects on pdf's small



What is the evidence?

- Evidence 5/6
 - ◆ Confirmed by T_{AB} scaling of direct photons



- Evidence 6/6
 - ◆ Final state hadronic interactions can only account for small fraction of high- p_T suppression (theoretical considerations)

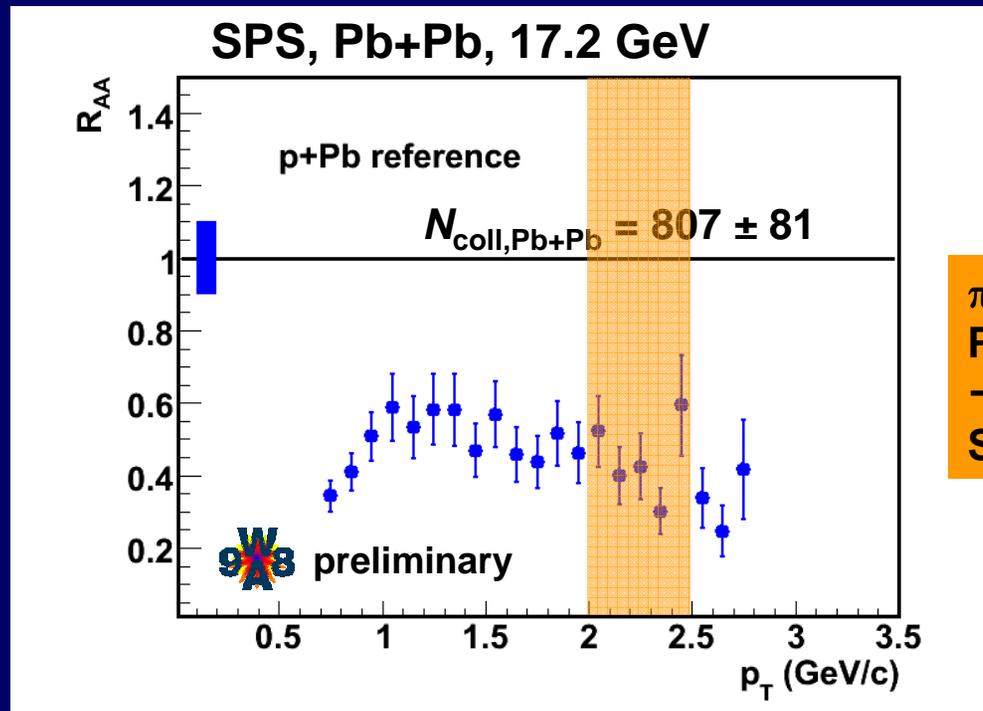
**Now, what if we look
more quantitatively?**

closer look



Is it a discovery?

- Jet quenching never observed before?
- True, but Cronin effect has never been as small, either
- What if we try to take it out?



$\pi^0 R_{AA} \sim 0.4$ in 1% most central Pb+Pb collisions (p+Pb reference)
→ Substantial suppression also at SPS energies

- Caveat: Cronin effect does not necessarily scale with T_{AB}

closer look

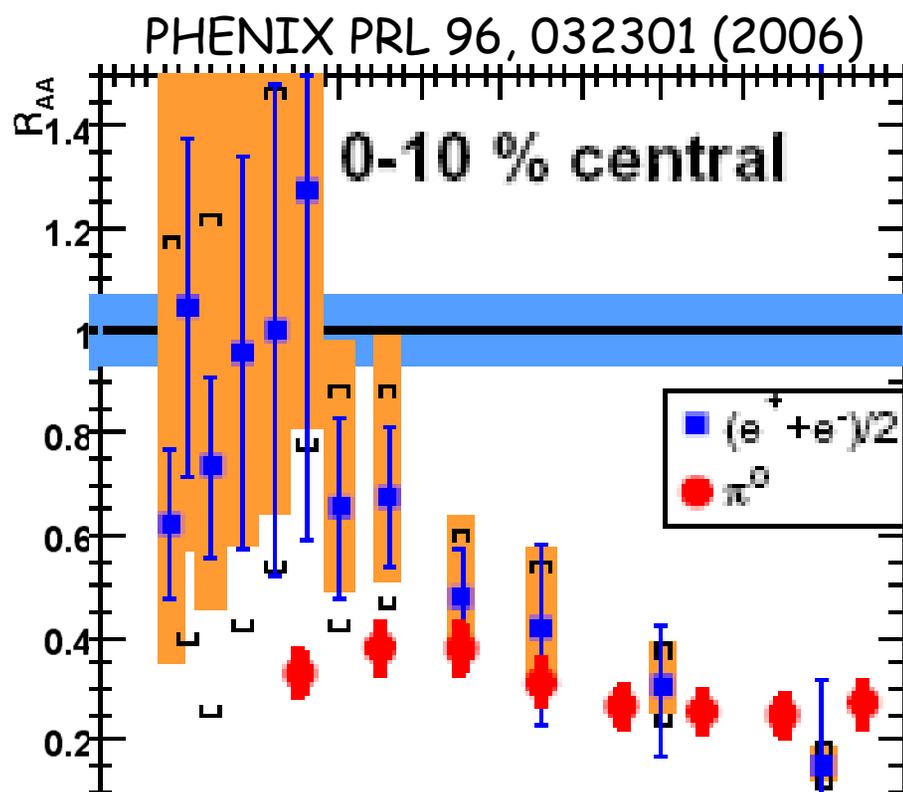


E-loss mechanism: heavy quarks

- Gluon bremsstrahlung only mechanism?

“Non-photonic” e^+e^-
Measure for c, b

Open Charm (Beauty) R_{AA}



With charm alone, suppression could be explained (1b,c)

N. Armesto et al., PRD 71, 054027

However, significant beauty contribution expected for $p_T > 3$ GeV/c (2a,b)

Djordjevic et al., nucl-th/0507019

Suppression not explained by radiative energy loss

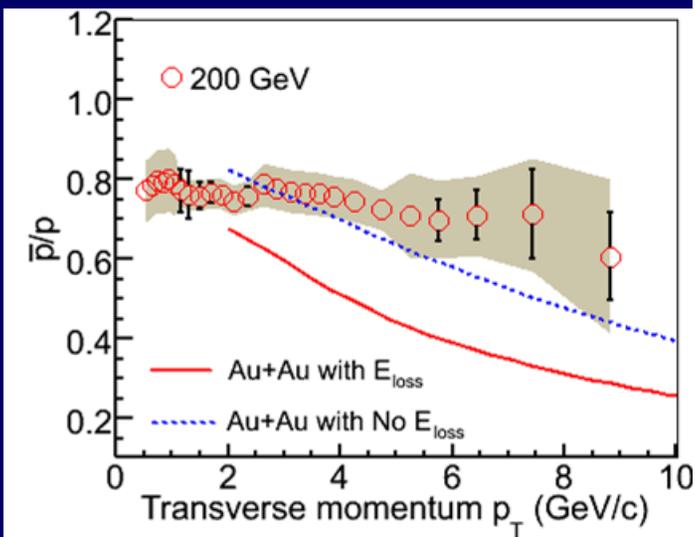
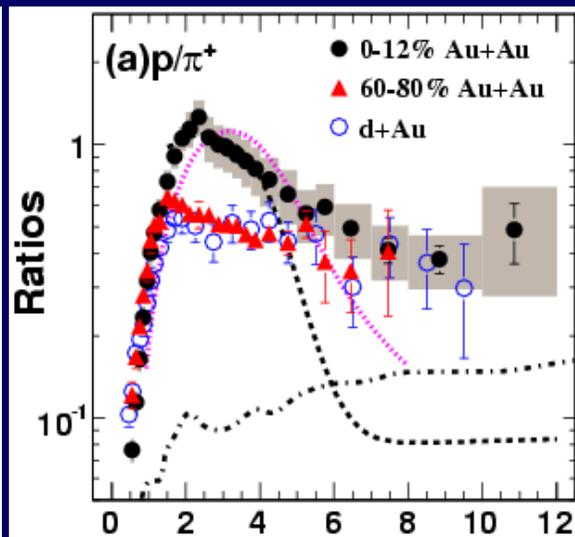
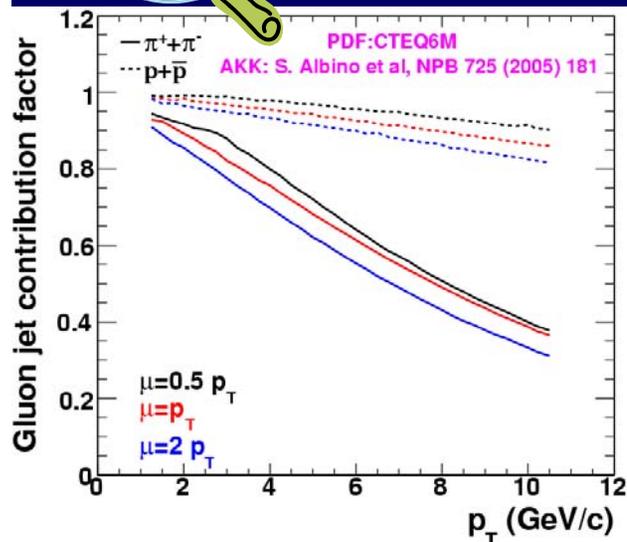
Even heavy quarks (c+b) are suppressed

closer look



E-loss Mechanism: Quark vs. Gluon Jets

E-loss curves: Wang, PRC 58, 2321, (1998)



90% of p from gluons
40% of π from gluons

STAR, PRL 97, 152301 (2006)

STAR, arXiv:0705.0953 [nucl-ex]

Gluon jet contribution: $\bar{p} > p > \pi$

No sign of stronger gluon energy loss in p/π or \bar{p}/p ratios

Medium modifications to FF?

X.N. Wang and X.F. Guo, NPA 696, 788 (2001)

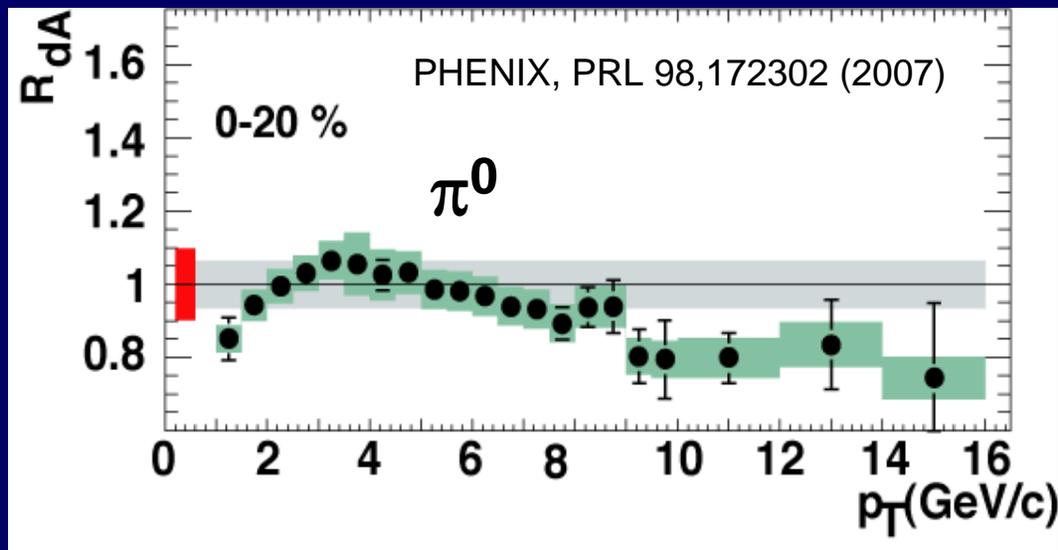
W. Liu, C.M. Ko, B.W. Zhang, nucl-th/0607047

Need new calculations with better baryon FF (AKK)

closer look



Initial-state effects in d+Au

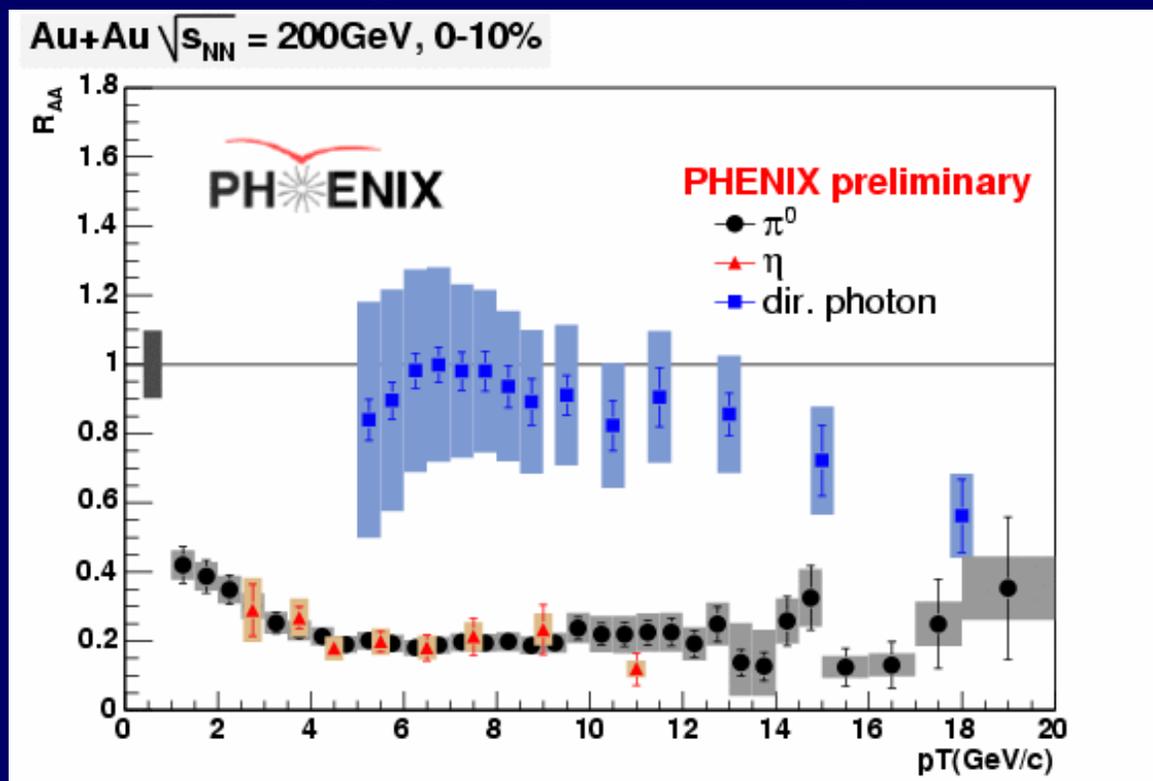


- Higher-precision d+Au measurement leaves room for ~20% initial state modifications at high p_T

closer look



Scaling of direct photons



- New direct photon measurement shows modification of high- p_T R_{AA}
- Direct photons and π^0 touch at highest p_T
- Is energy loss really constant fraction?

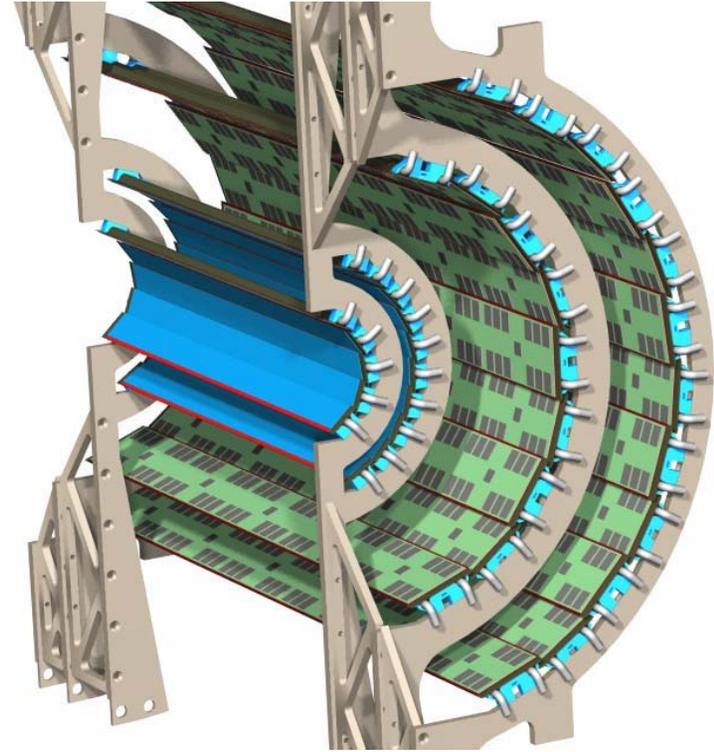
Modified Hypothesis

“Precision measurements have revealed many puzzles. We need to increase precision and extend systematic studies to resolve them. This could well lead to new discoveries!”

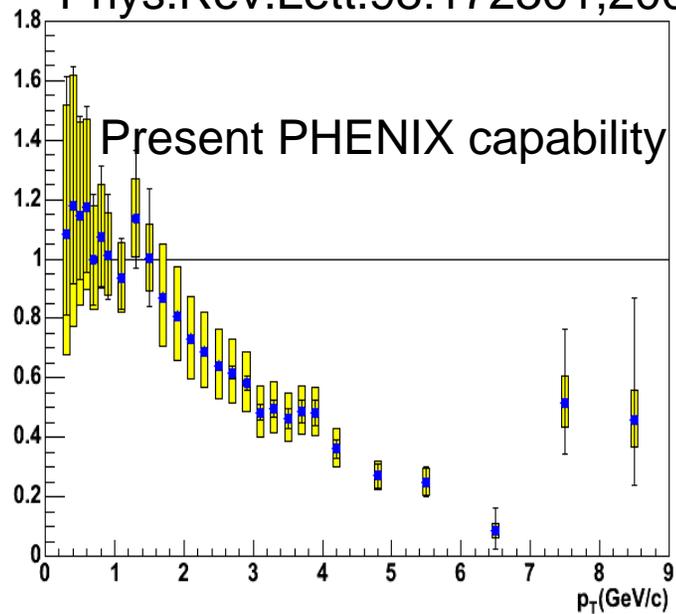
New Detectors
So, what can we do to
learn more?
New Runs
New Methods

Heavy Quarks

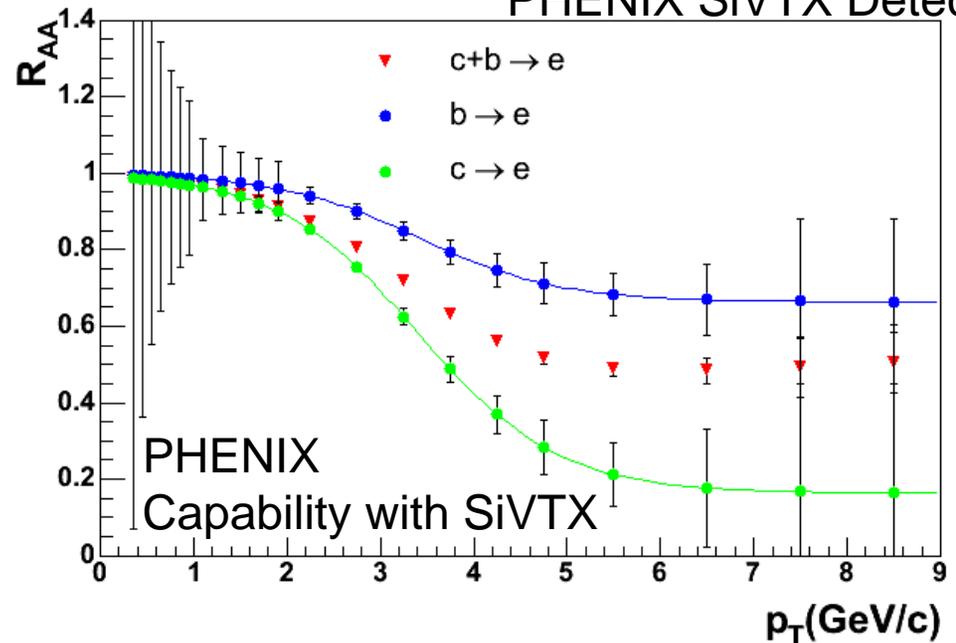
- PHENIX and STAR silicon upgrades will allow separation of charm and beauty



R_{AA} Phys.Rev.Lett.98:172301,2007

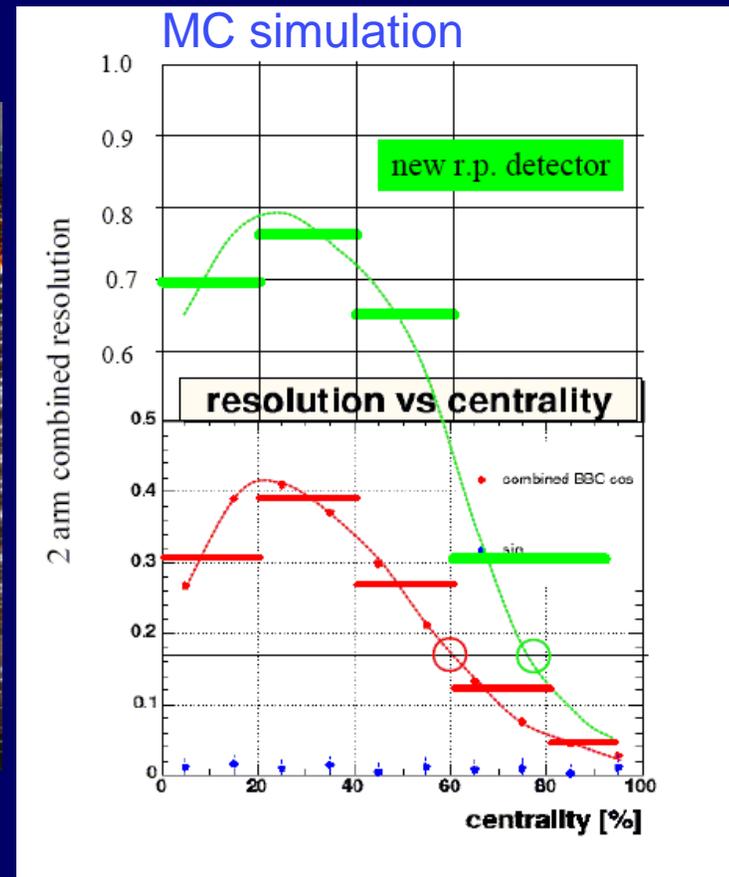


PHENIX SiVTX Detector



Path Length Dependence

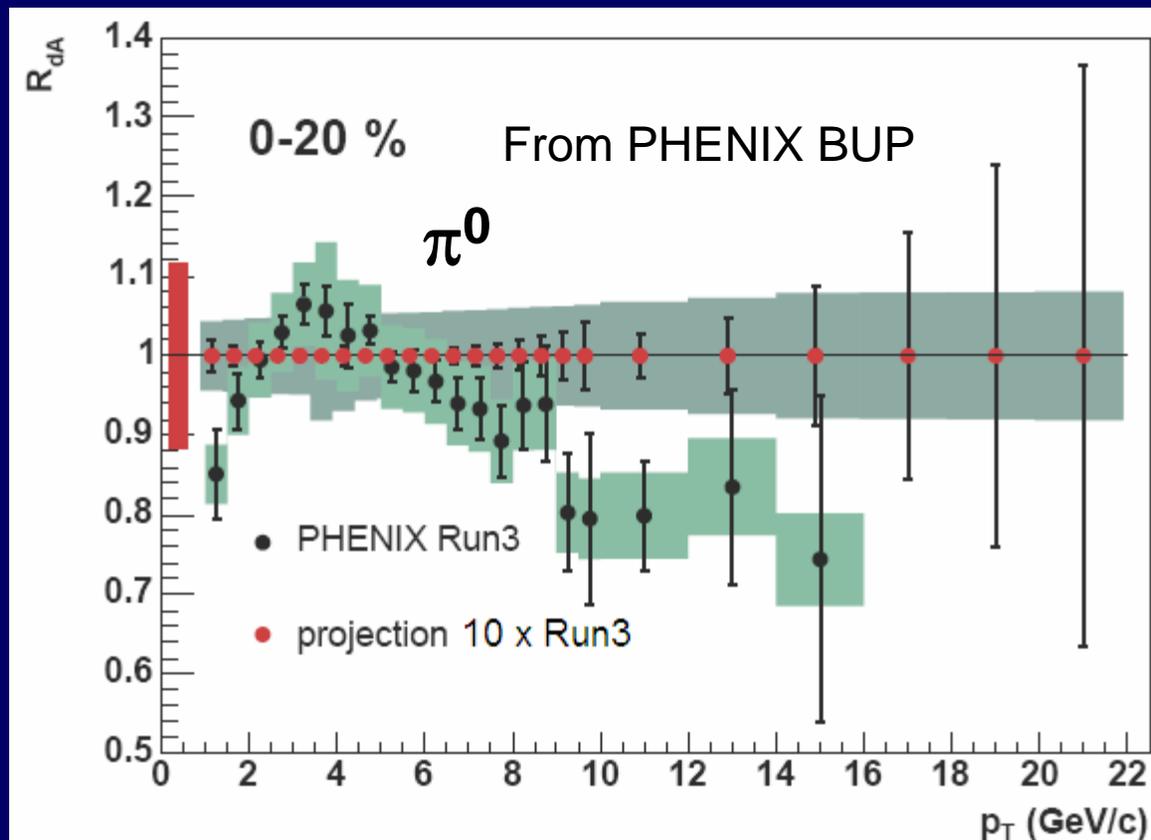
- PHENIX RxNP detector upgrade will allow to study path length dependence of R_{AA} to higher precision (factor 2 better resolution)



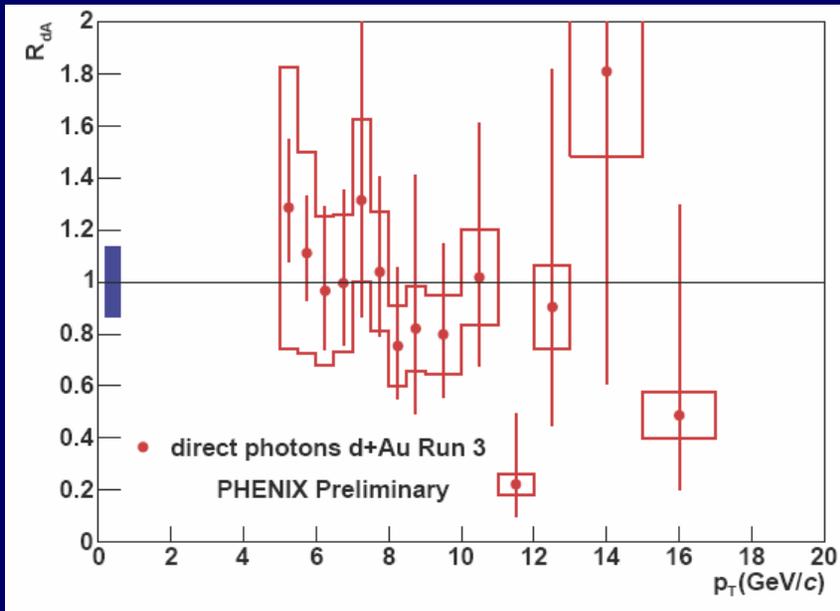
New Runs

Initial state: $\pi^0 R_{dA}$

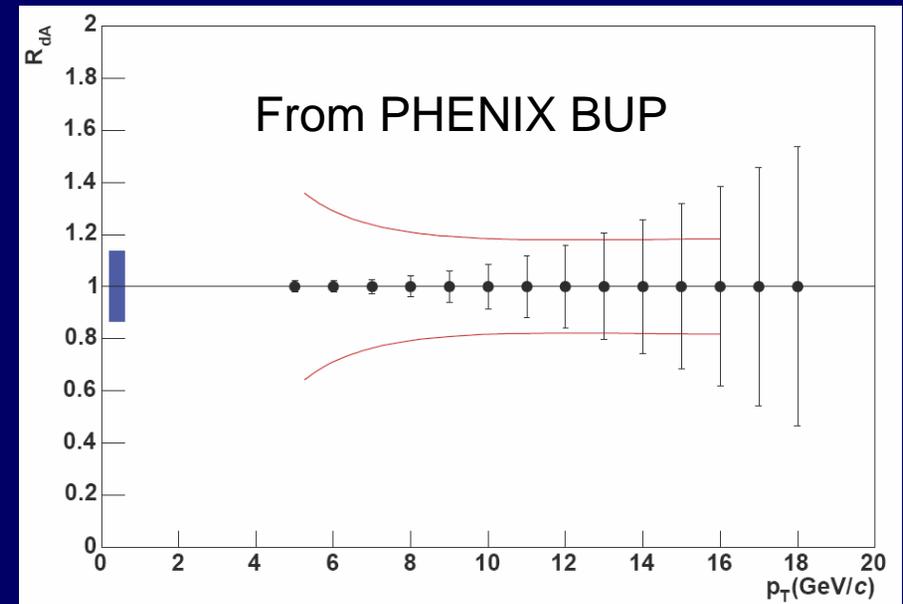
- Need high precision d+A (better p+A) reference run to improve measurement of initial-state modifications of pdf's for π^0 and direct photons
- Requested by both PHENIX and STAR for Run-8 with factor 10 higher luminosity than in Run-3



Initial State: Direct Photon R_{dA}



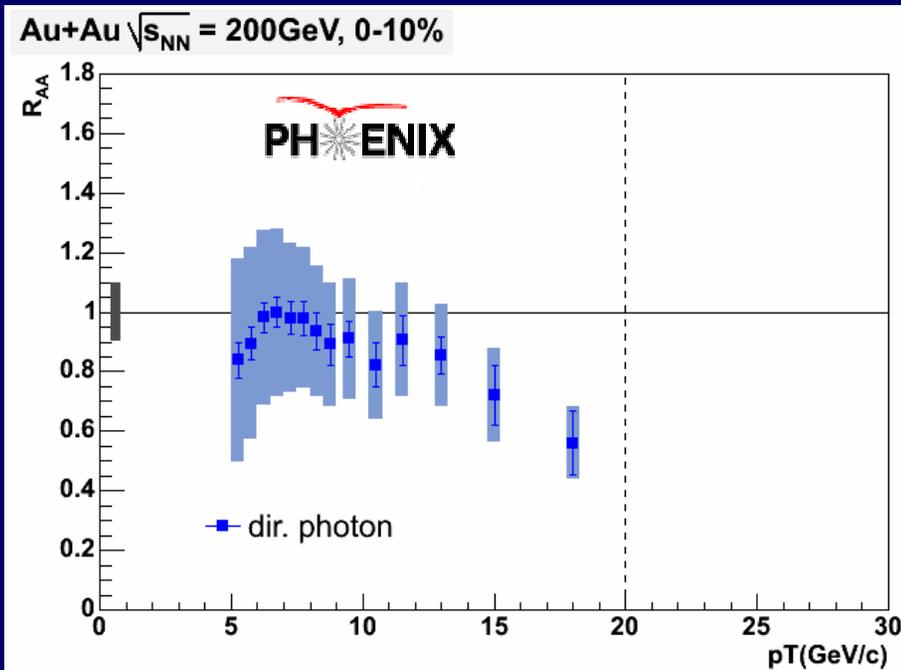
Current result



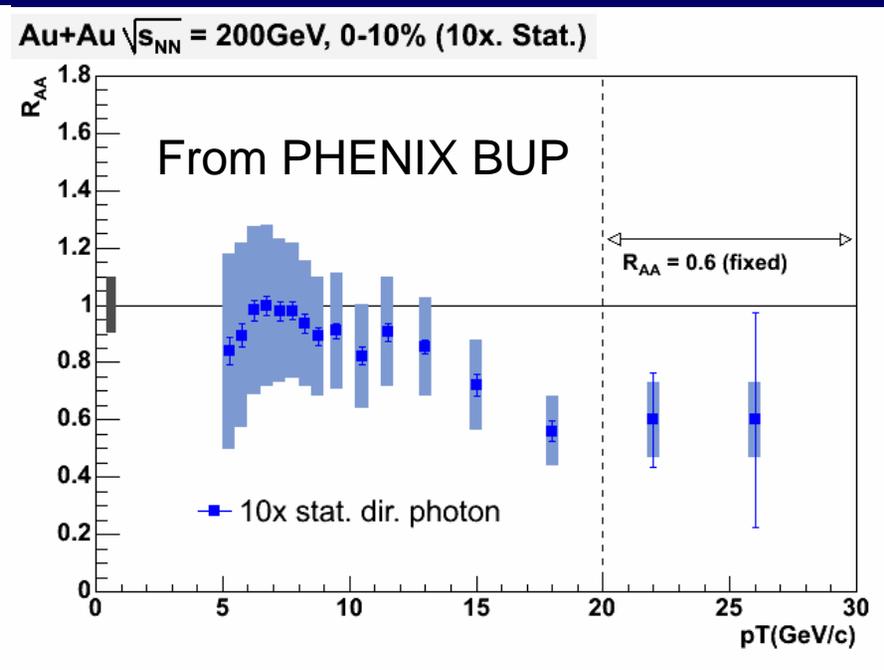
w/ 10x Run3 Stats

Initial state: Direct Photon R_{AA}

- 10 times Run-4 Au+Au statistics (collected in Runs 7, 8) will improve direct photon measurement



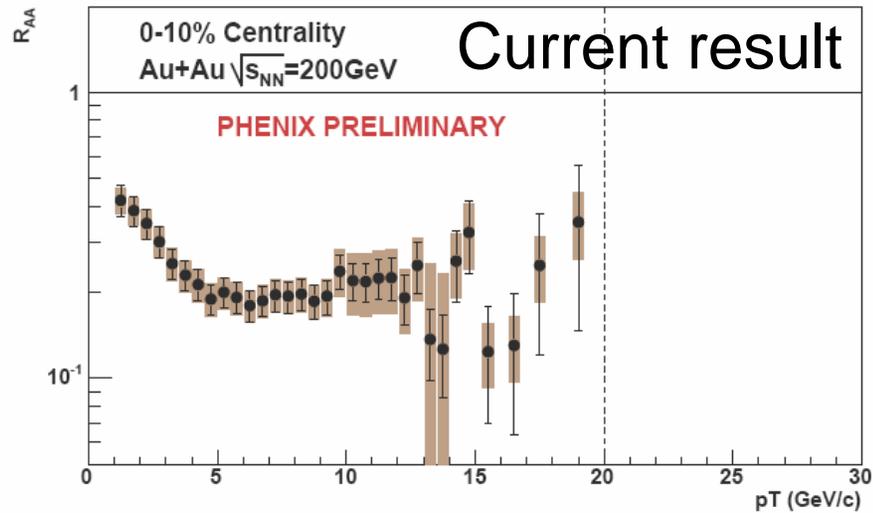
Current result



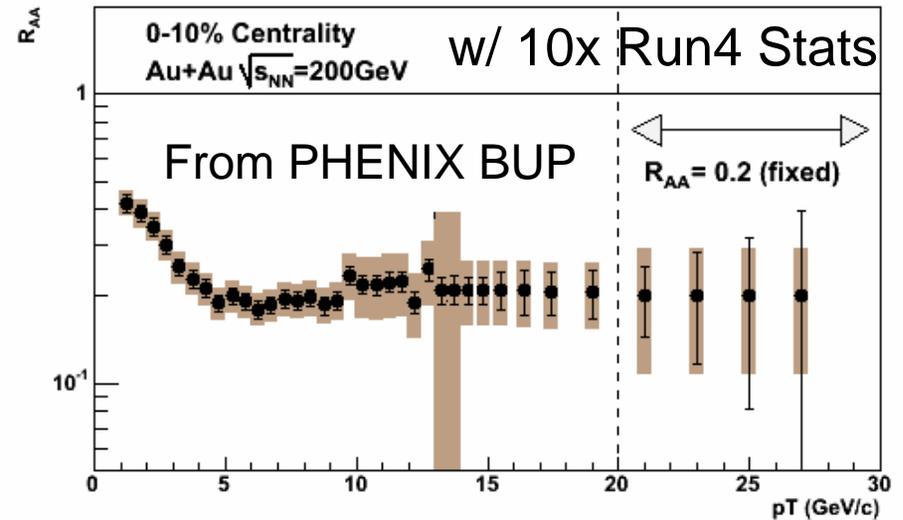
w/ 10x Run4 Stats

Au+Au π^0 R_{AA}

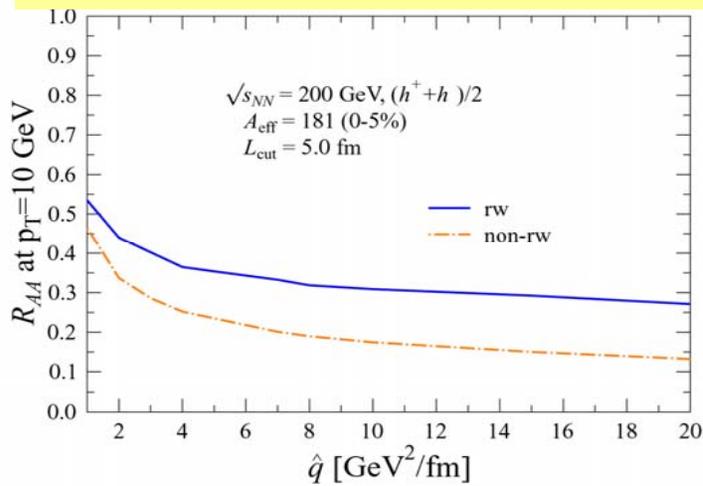
π^0 R_{AA} Current data



π^0 R_{AA} with 10x statistics

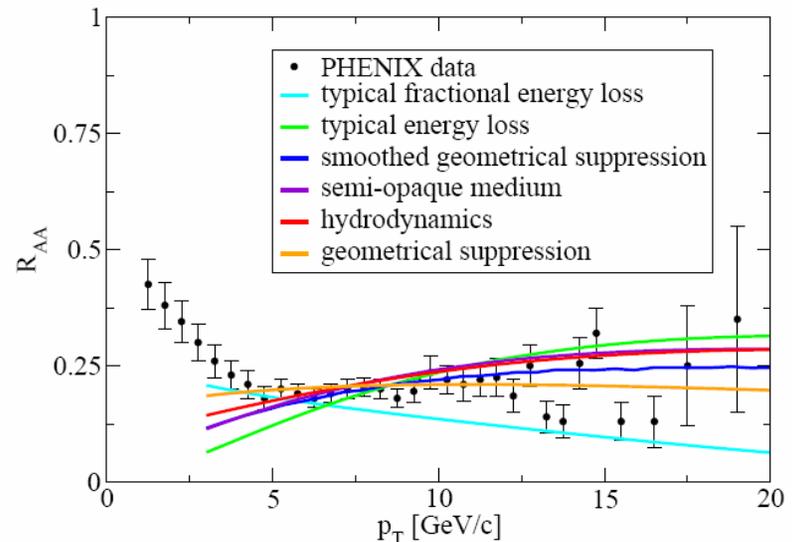


Eskola et al, hep-ph/0406319



Increasing density \longrightarrow

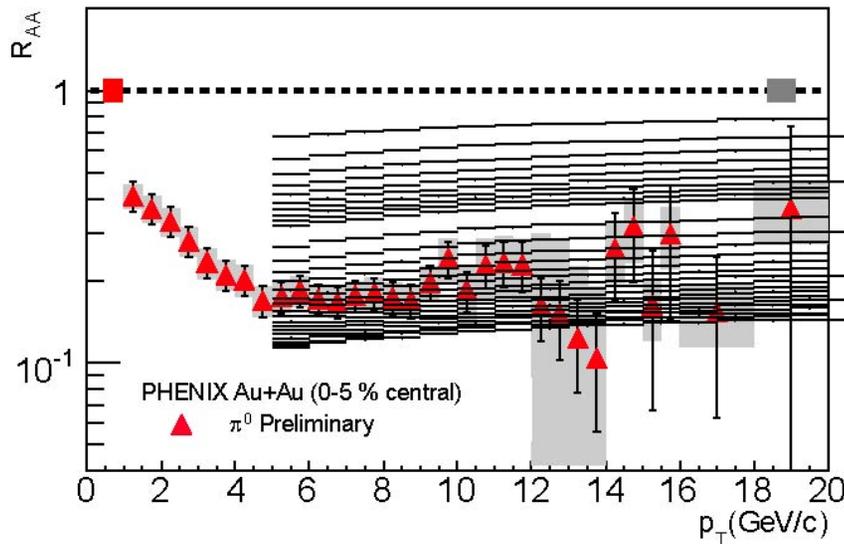
T. Renk, arXiv:0704.3879 [hep-ph]



New Methods

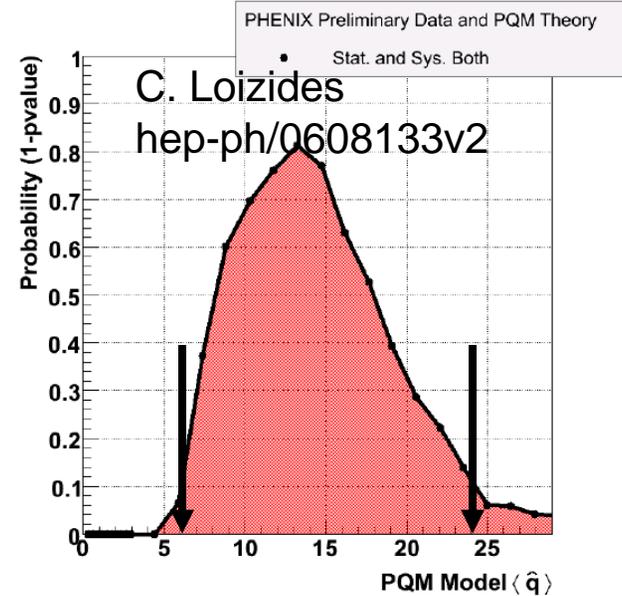
•More statistics will help some

A successful step



PQM Model, $\langle \hat{q} \rangle$ values

0.59	0.29			
2.06	1.76	1.47	1.18	0.88
5.88	4.41	2.94	2.65	2.35
13.23	11.76	10.29	8.82	7.35
20.59	19.12	17.65	16.17	14.70
27.94	26.47	25.00	23.53	22.06

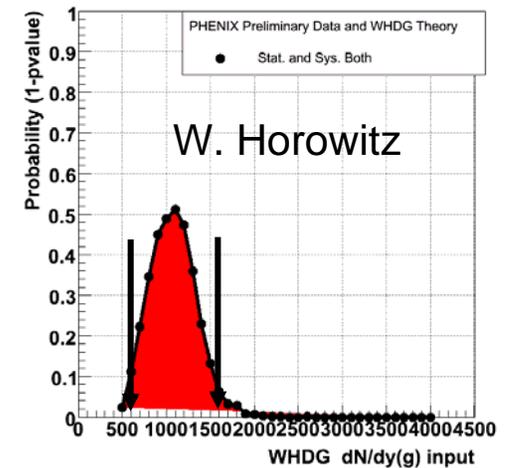
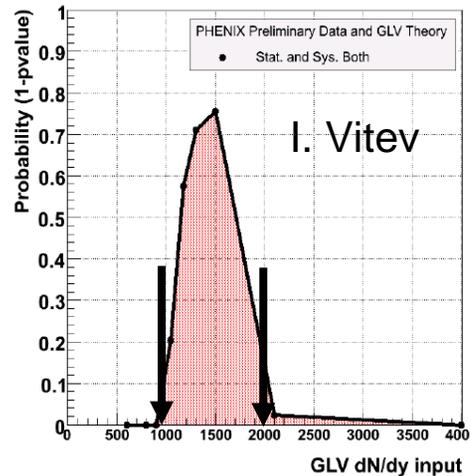


From R_{AA} average density of medium:

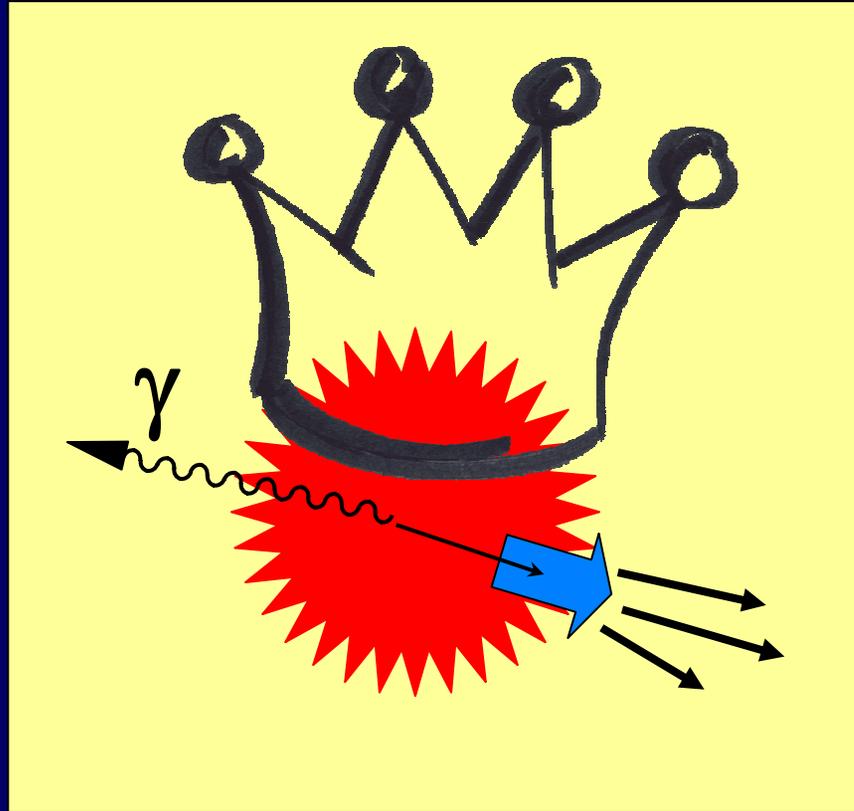
I. Vitev: $1000 < dN_g/dy < 2000$

W. Horowitz: $600 < dN_g/dy < 1600$

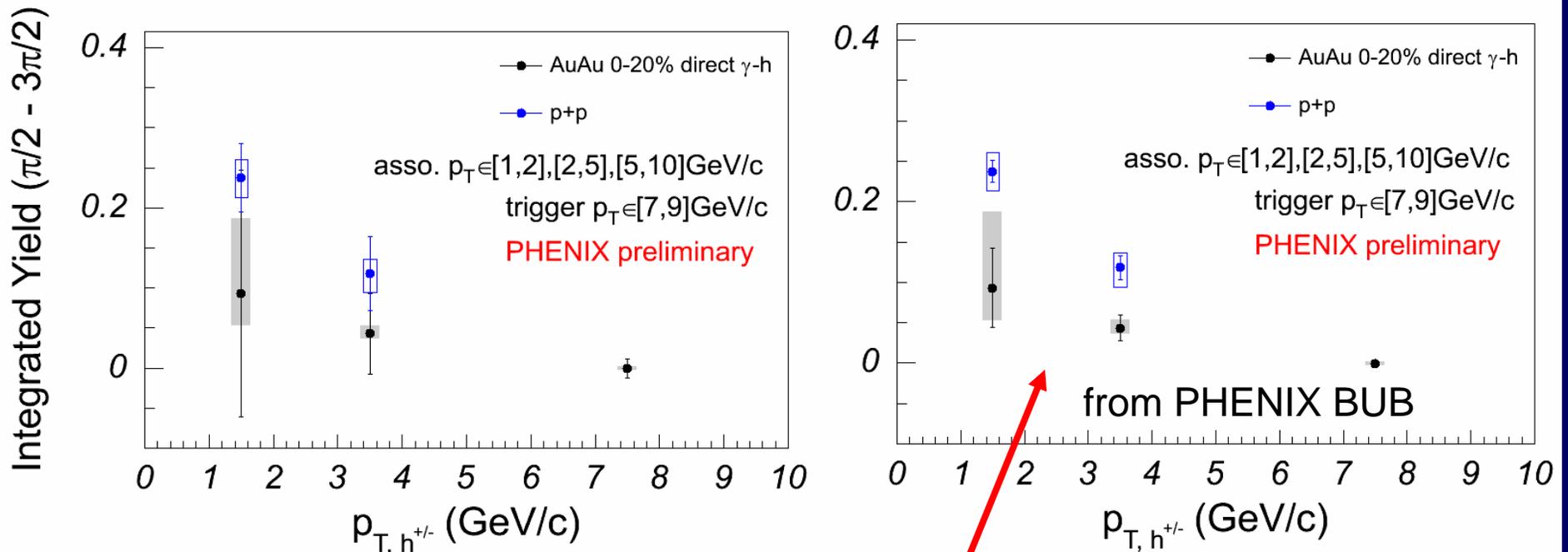
C. Loizides: $6 < \hat{q} < 24 \text{ GeV}^2/\text{fm}$



Started discussion: Disagreement, papers, suggestions



Direct Photon-Jet Awayside Yields



Current result

w/ 10x Run4 Stats

Dividing these two would result in a reasonable I_{AA}

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