STEPS FROM QUALITATIVE TO QUANTITATIVE: PROMPT PHOTON PRODUCTION AND PHOTON-JET γ-HADRON CORRELATIONS IN PHENIX

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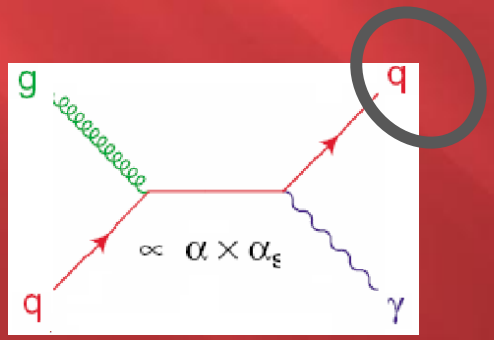
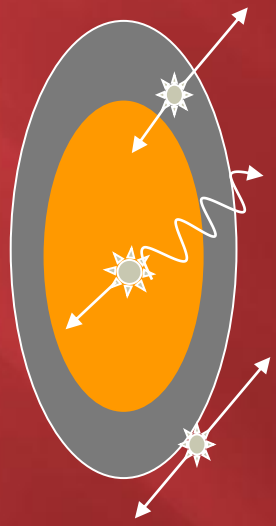
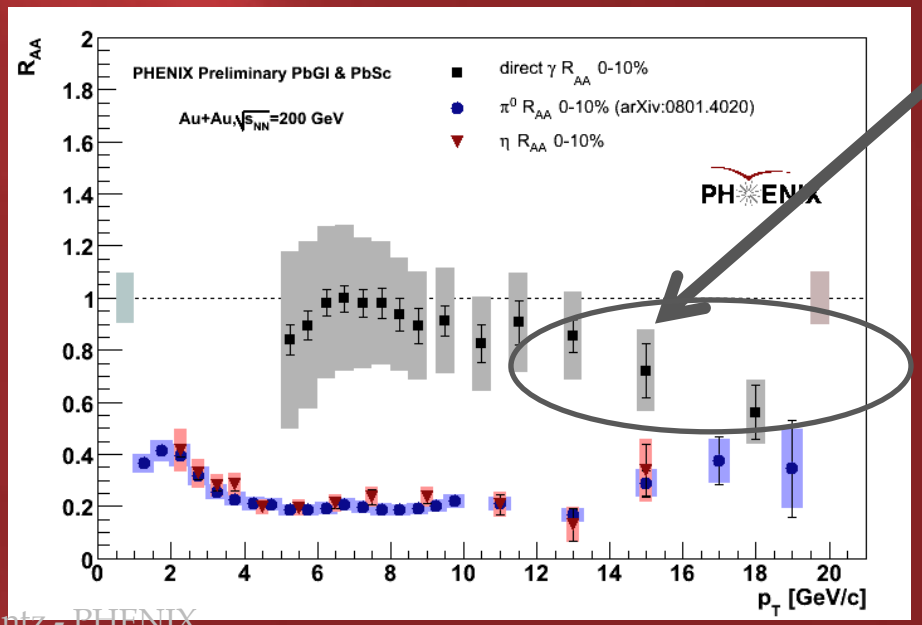
A "golden" HI jet E_{loss} channel: γ-Jet

- Trigger γ E calibrates the partner jet to leading order
- Purely jet/hadronic observables clouded → triggers themselves are modified
  - Geometric ***surface bias*** of the single jet, *di-jet* ?
  - Direct γ production unmodified by medium: **no surface bias for γ vertices**
- Plus dominant partonic type becomes purely ***q-jets*** compared mainly γ-jet/mix in jet-jet (q vs g E_{loss} differs)



Compton Diagram





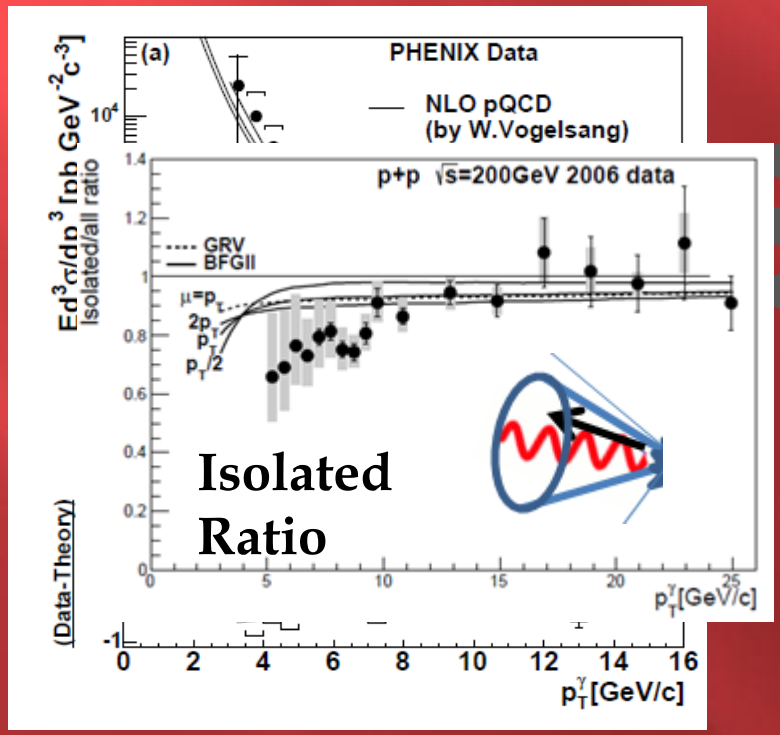
How to make direct photon results more quantitative

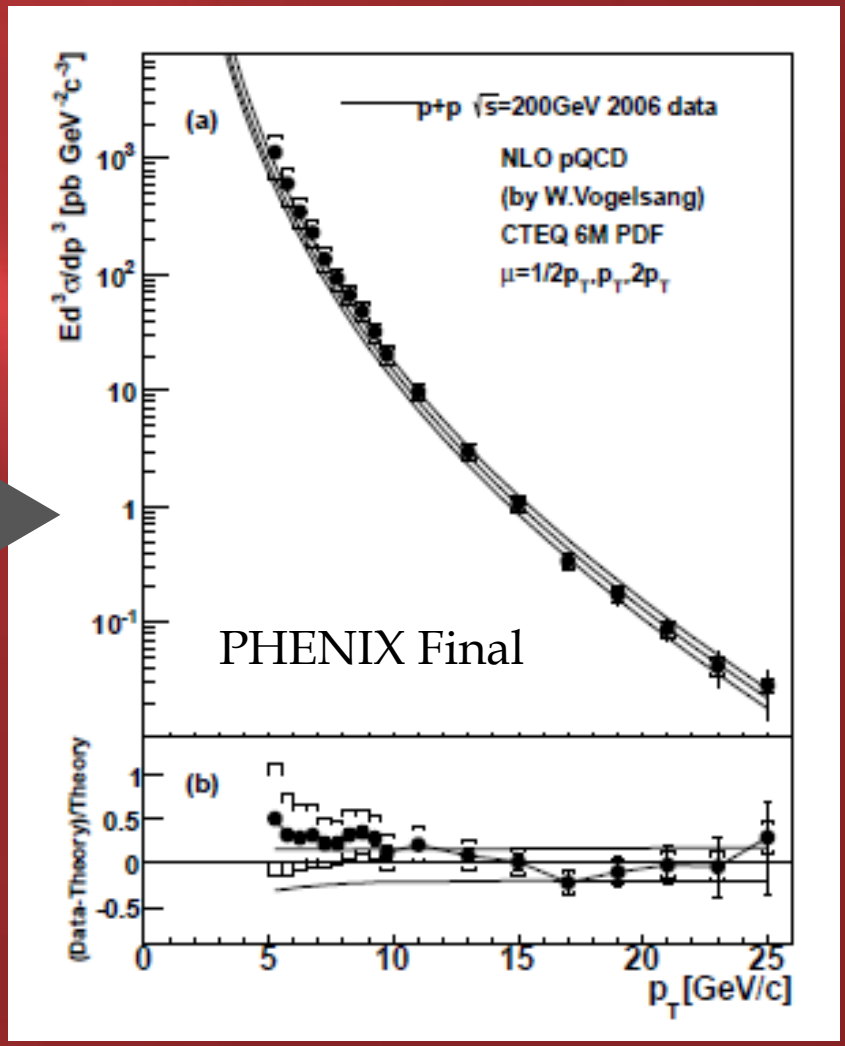
- Step 1: strengthen baseline from elementary p+p collisions

Strong New p+p measurement!

- New high statistics dataset
  - p_T range x2
  - Precision Improved > x 2
- More precise isolated fraction
- ~90% Iso in R = 0.5 cone

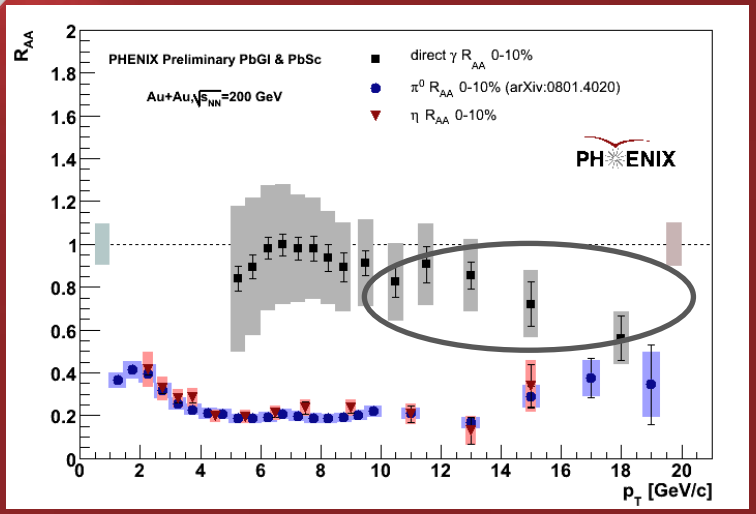
Submitted PRD arXiv:1205.5533





How to make direct photon results more quantitative

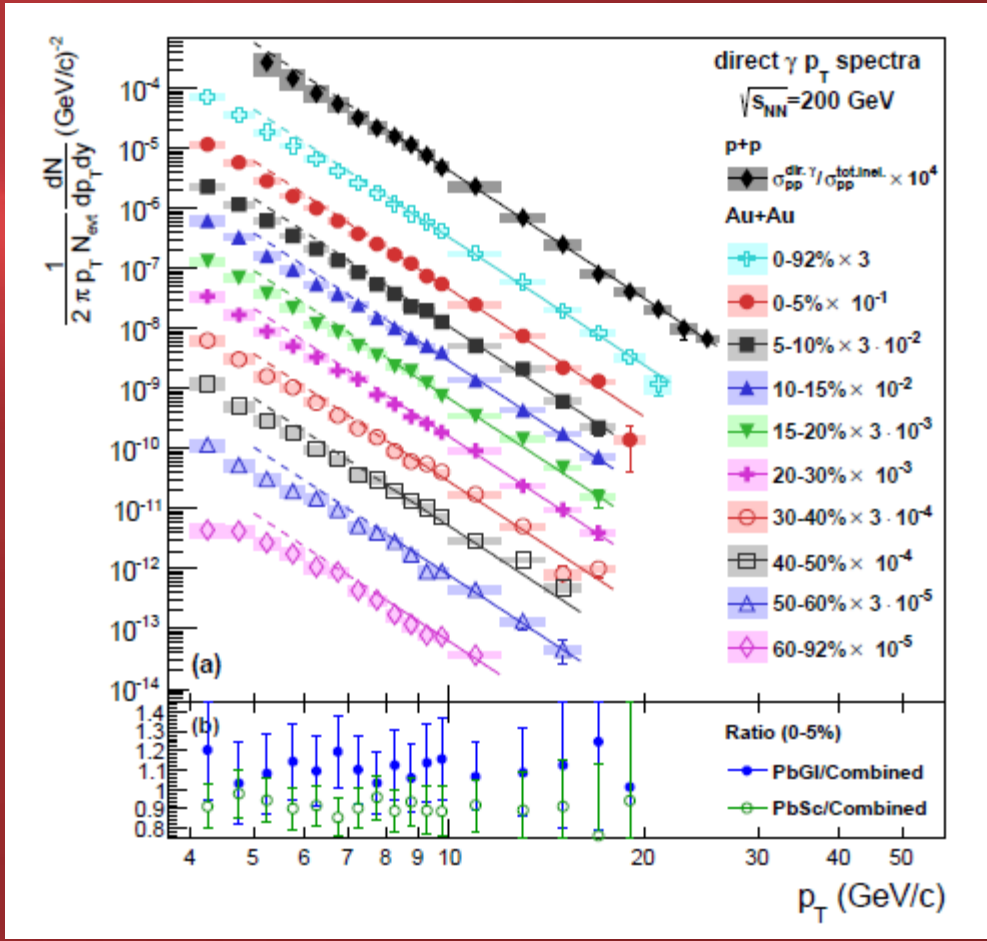
- Step 2: Master your systematics and finalize 2004 golden dataset analysis



Moving Forward…Finalized Au+Au

- More precise spectra measurement published!
- 2004 Dataset systematics (e.g. π^0 merging) studied in great detail

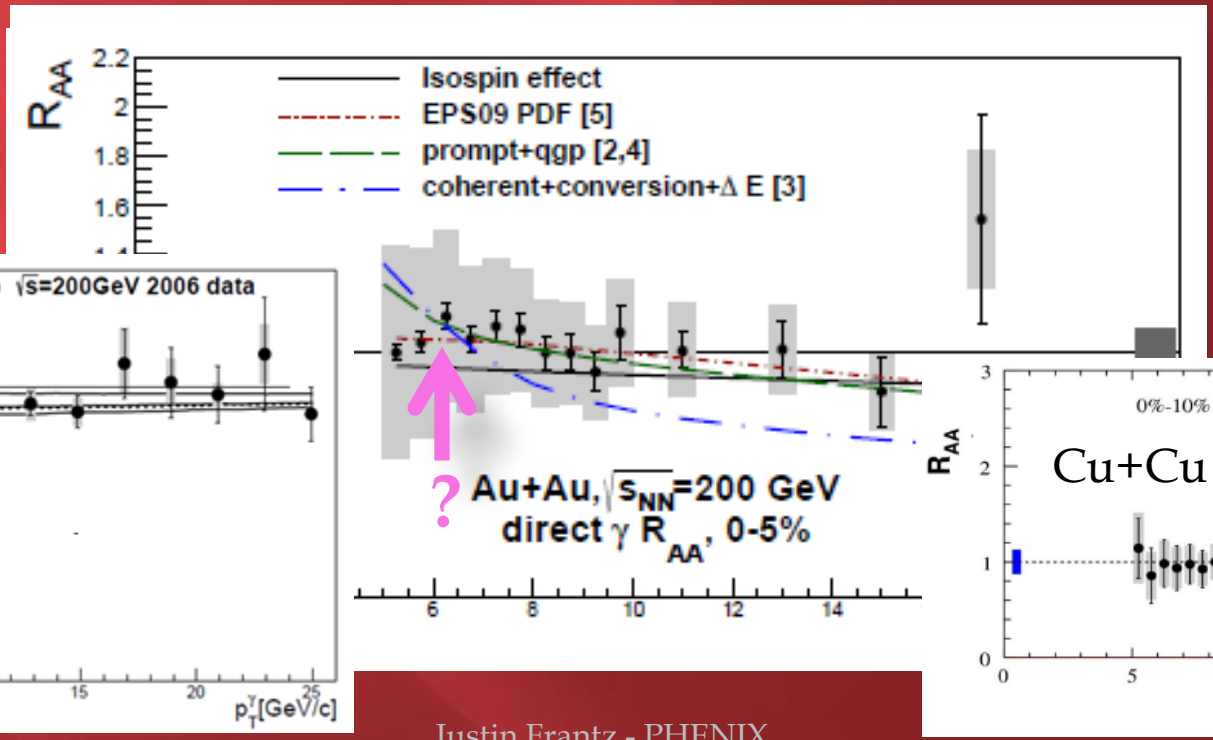
Submitted PRL arXiv:1205.5759



Final Au+Au R_{AA}

- Lack of suppression re-confirmed
- Substantial high p_T suppression in prompt photon no longer looking viable (esp. combining with other data)
- Should we be using iso component as p+p reference?
  - More Jet-Medium-like enhancement?

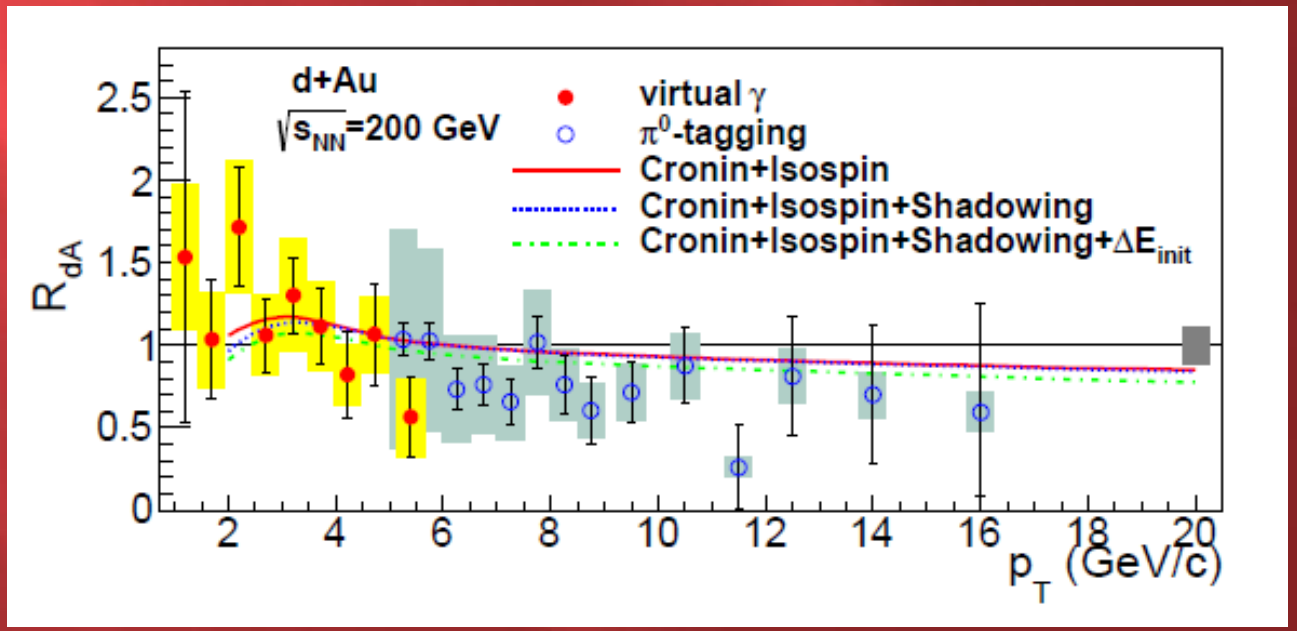
Submitted PRL arXiv:1205.5759



See poster 24
B. Sahlmueller

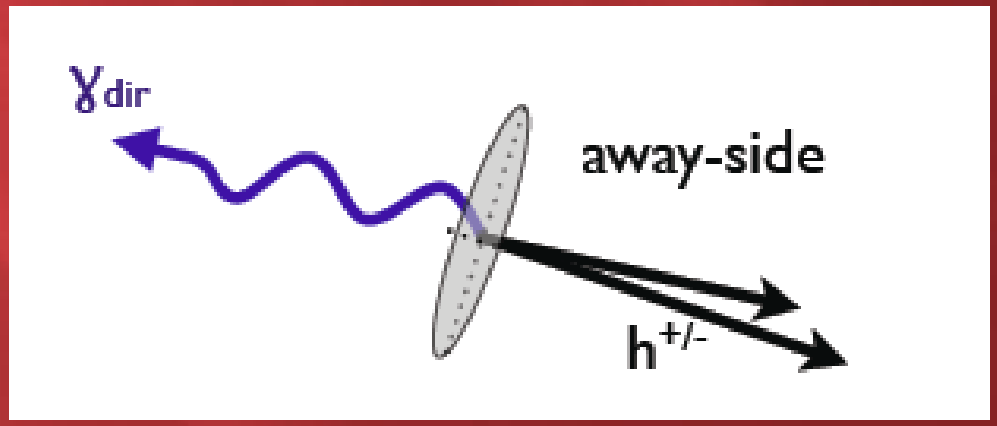
"New" d+Au Direct γ Result: High p_T

- **Direct photons: d+Au, A+A initial state effect tester!**
- At low p_T using PHENIX-invented virtual γ di-electron method (yellow error bars)
  - Up to moderate p_T—not just soft! Confirmation of method
- High p_T newly finalized 2003 Calorimeter data
- 2003 d+Au R_{dA} made more precise by new p+p
- Consistent dAu R_{dA} vs AuAu R_{AA}



From control to hot medium modification observable: Photon-Hadron results

- Use the "unmodified" photon as calibration for the modified awayside jet

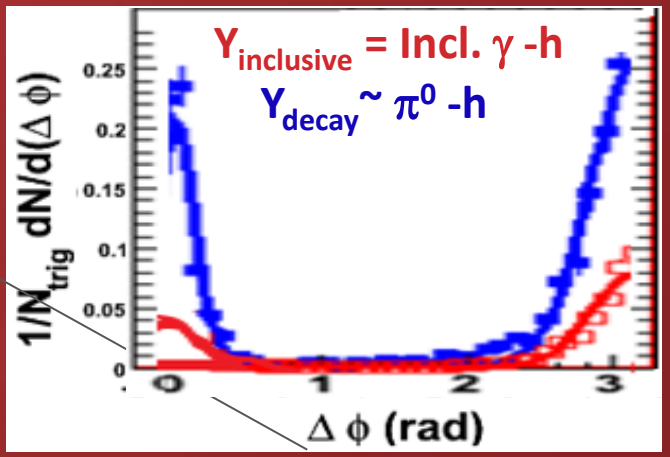


2-particle Statistical Method

γ-h: subtraction of 2-p $\Delta\phi_{12}$ measurements

→ **Rγ** directly from new single direct γ analysis

$$Y_{direct} = \frac{R_\gamma Y_{inclusive} - Y_{decay}}{R_\gamma - 1}$$



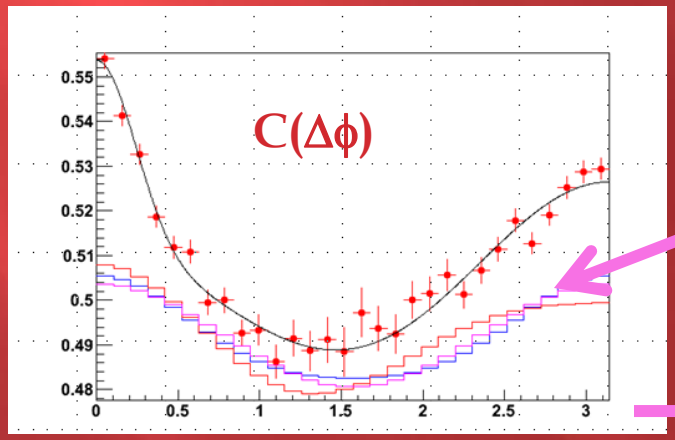
$$Y_{direct} \propto C_{incl} - Bkg_{incl}(Flow) - [\, C_{decay} - Bkg_{decay}(Flow) \,]$$

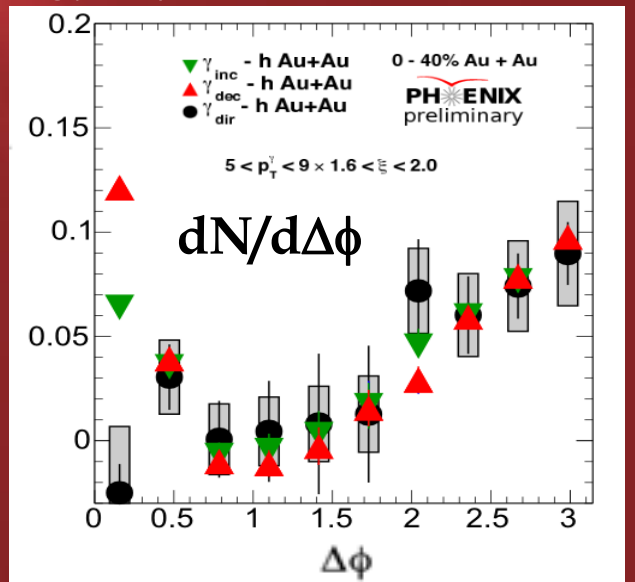
$$\equiv C(\Delta\phi) - \xi(1 + 2\langle v_2^\gamma \rangle \langle v_2^h \rangle \cos 2\Delta\phi)$$

Norm

Bkg(Flow)

$+v_3 + v_4 \cdots$





- Subtraction w/ flow modulation included
- → Abs. Norm subtraction

Pre-QM12: 2007 Result

- $\Delta\phi$-Integrated yield plotted *vs.* z_T

$$z_T = p_{Th}/p_{T\gamma}$$

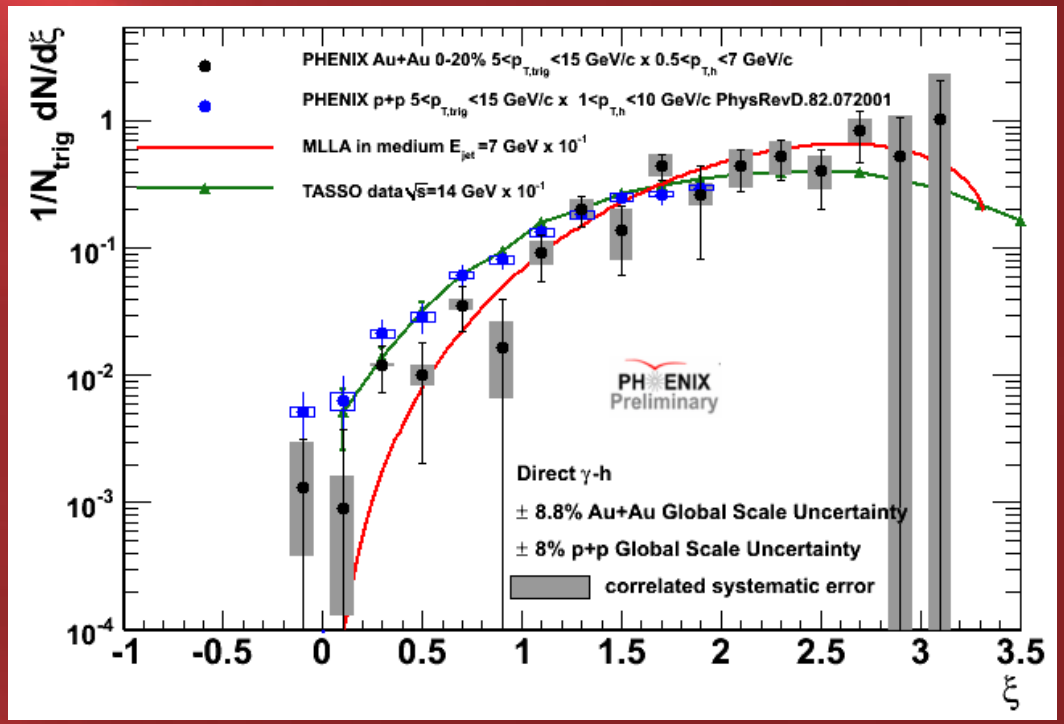
or $\xi = \ln(1/z_T)$

- → Frag Fn !

$D(z_T)$ or $D(\xi)$

- Suppression signal: clear at low z (high ξ)
- **Hint** at rise in shape/ enhancement
- **(Qualitative!)**

γ-h Fragmentation Function

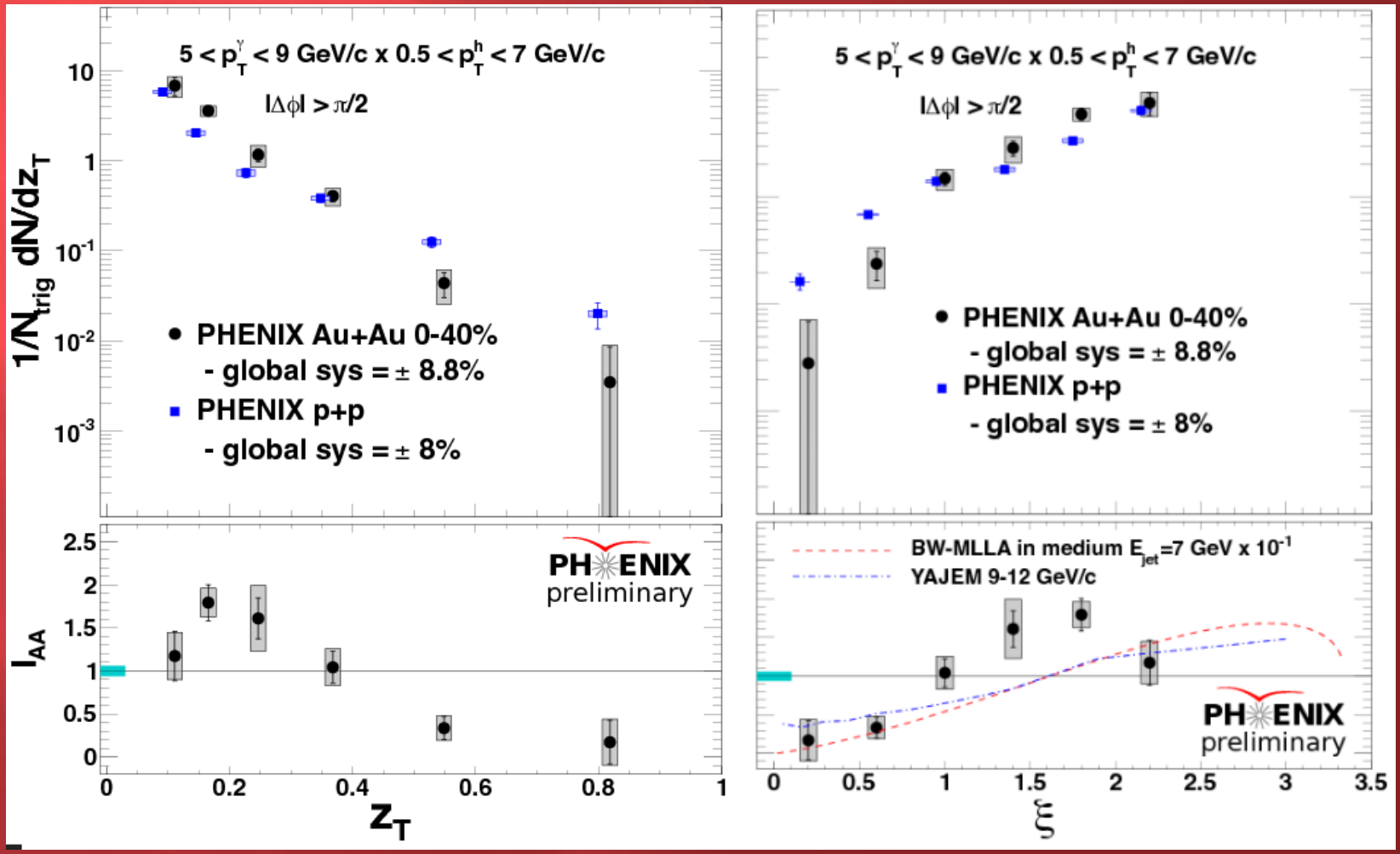


How to make *this result* more quantitive

- Add 2010 dataset
  - Combined statistics of 2007 + 2010 datasets
- Combine centrality 0-20% + 20-40%

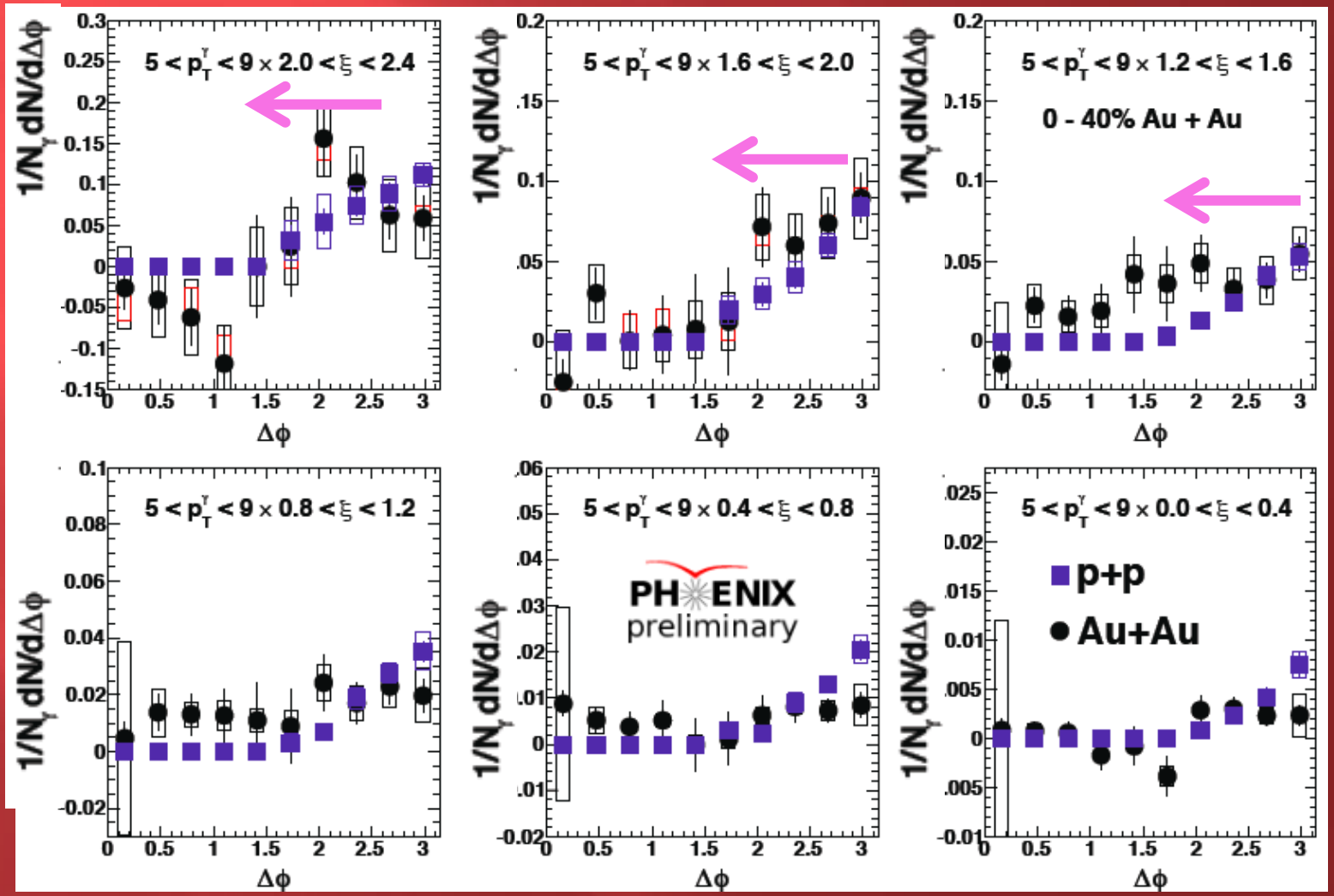
Pied de Resistance!

- Suppression at high z, low ξ -- universal 2-p phenomenon
  - LHC non-effect at z = 1 is **only** ***within*** ID'd jets
  - 2-p method I_{AA} includes/accounts for "lost" jets and particles
- **Enhancement signal at low z, high ξ now statistically significant!**
- Theory qualitatively similar : recovery of lost/radiated energy



Where is this enhancement?

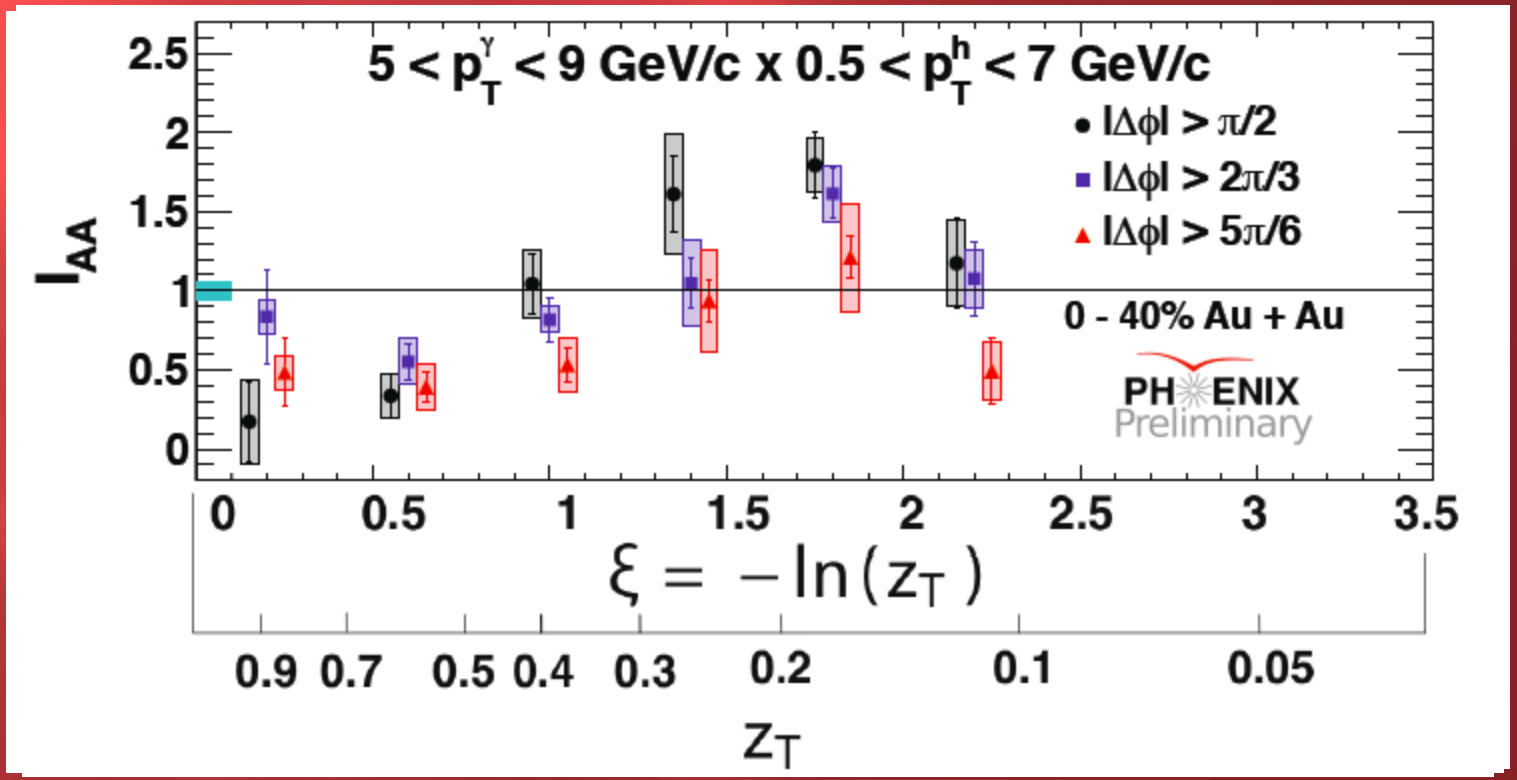
- Low z → Low associated hadron p_T
- Enhancement increasing at larger angles from away jet



Integrations in different $\Delta\phi$ ranges

Quantitative-ness

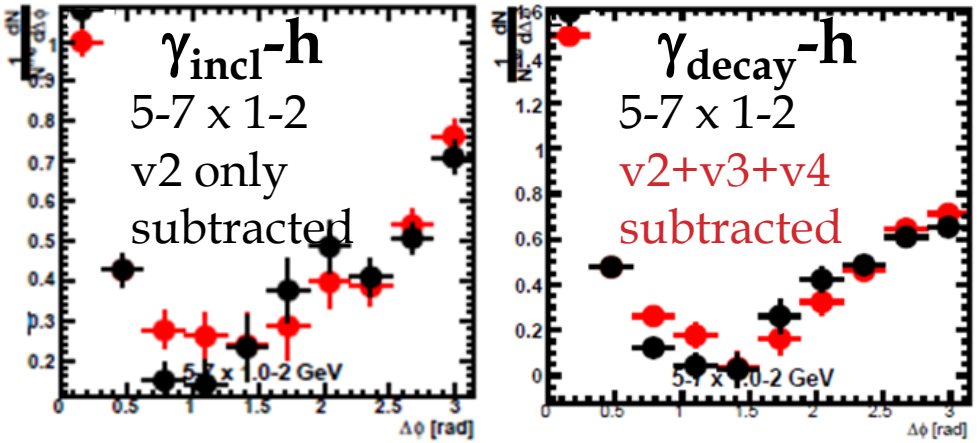
- Integrating in different ranges shows **quantitative** evolution with awayside angle
- Qualitatively consistent: Rise from low xi to high xi present in all integration ranges
- Less in the "head" region!
- Broadening of the awayside fragmentation!



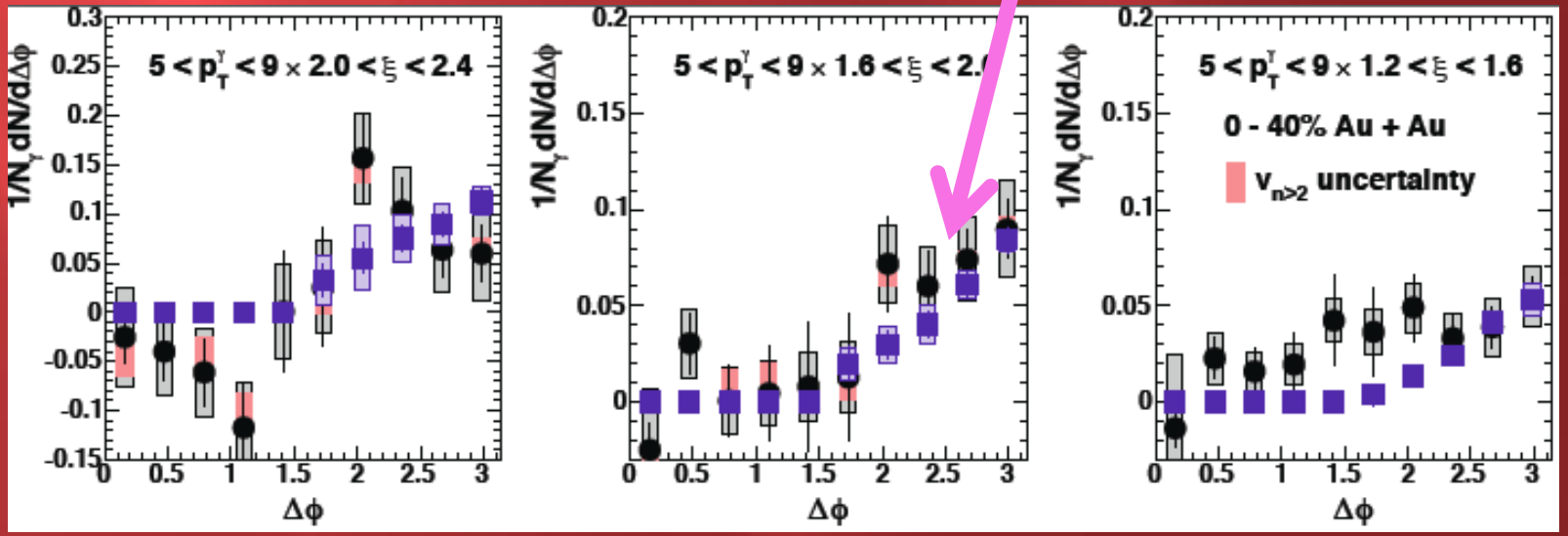
Posters:
N. Riveli 21
B. Xia – 23

Just Effect of v_n ?

All of broadening due to v_3? No!



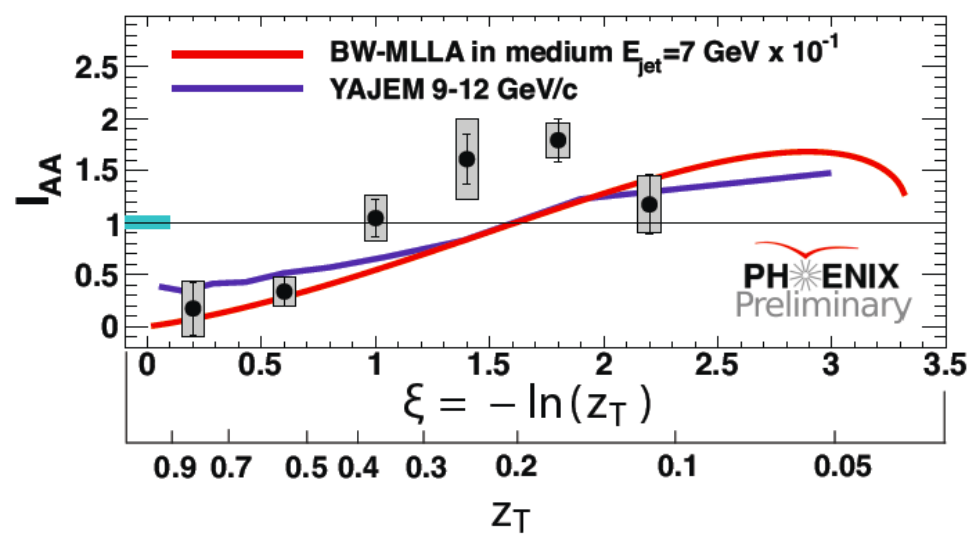
- Test: Conservatively large guestimate for high p_T $v_{3,4}$ (RHIC measure unavailable)
- Visible change for γ_{dec}-h (h-h) and γ_{incl}-h but broadening still present
- Mostly cancels in γ subtraction
  - Assuming direct γ v_n = 0.5 v_n of π^0 chosen as max v_n RHIC
  - Integrated yields difference generally much less (v_3 effect in Δφ of 2pi/3 → ~ 0!)



v_1 effect should be small too. e.g. see T. Todoraki parallel talk 6D

Conclusions

- Au+Au single Direct γ non-suppression re-confirmed w/ more precise finalized p+p and Au+Au data
  - Isolated reference for p+p: enhancement in the Jet-Medium area?
- New d+ Au, A+A single direct γ interesting to compare CNM effects seen in jets
- Fragmentation Function modification seen with statistical significance!
  - Enhancement at low z/high ξ: recovery of lost energy?
  - Increasing at wide angles from away jet direction



Backups

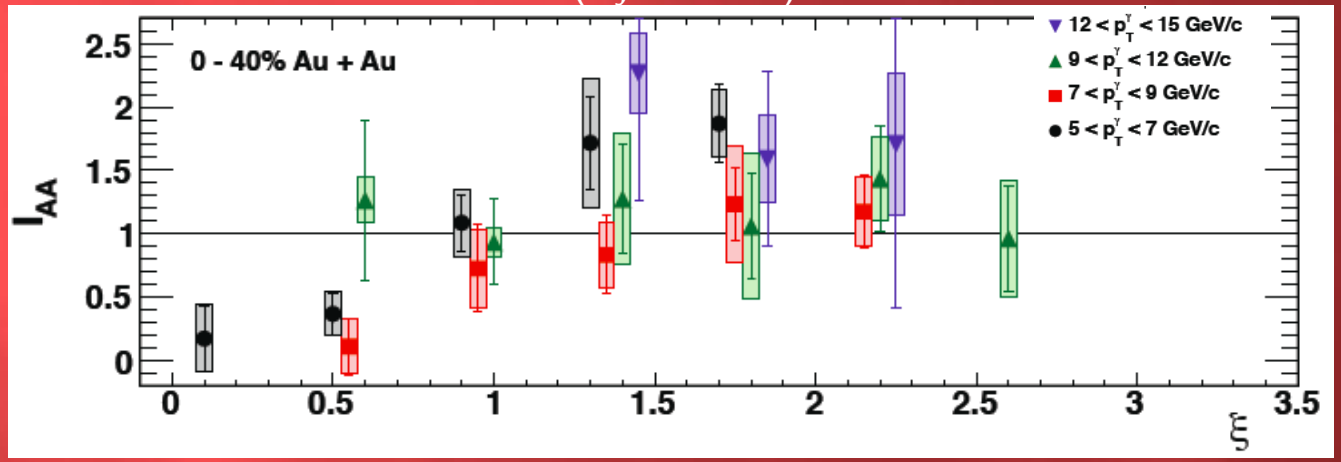
"Hate and the killer were not successful. He wanted to divide and we have come together."
PRABHJOT SINGH, co-founder of the Sikh Coalition, at a memorial service for six worshipers slain at a Sikh temple in Oak Creek, Wis.

-NYT

Jet pt, angular ranges, and centrality?

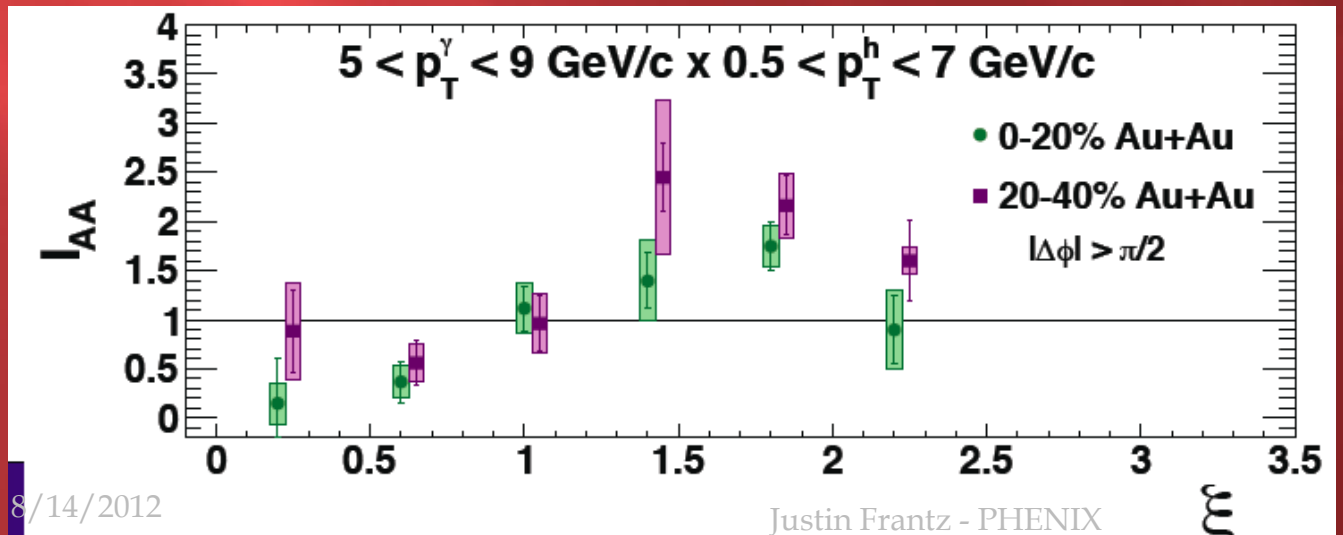
- With more statistics try to study various differential dependences…

TRIGGER PHOTON (~JET PT?) DEPENDENCE

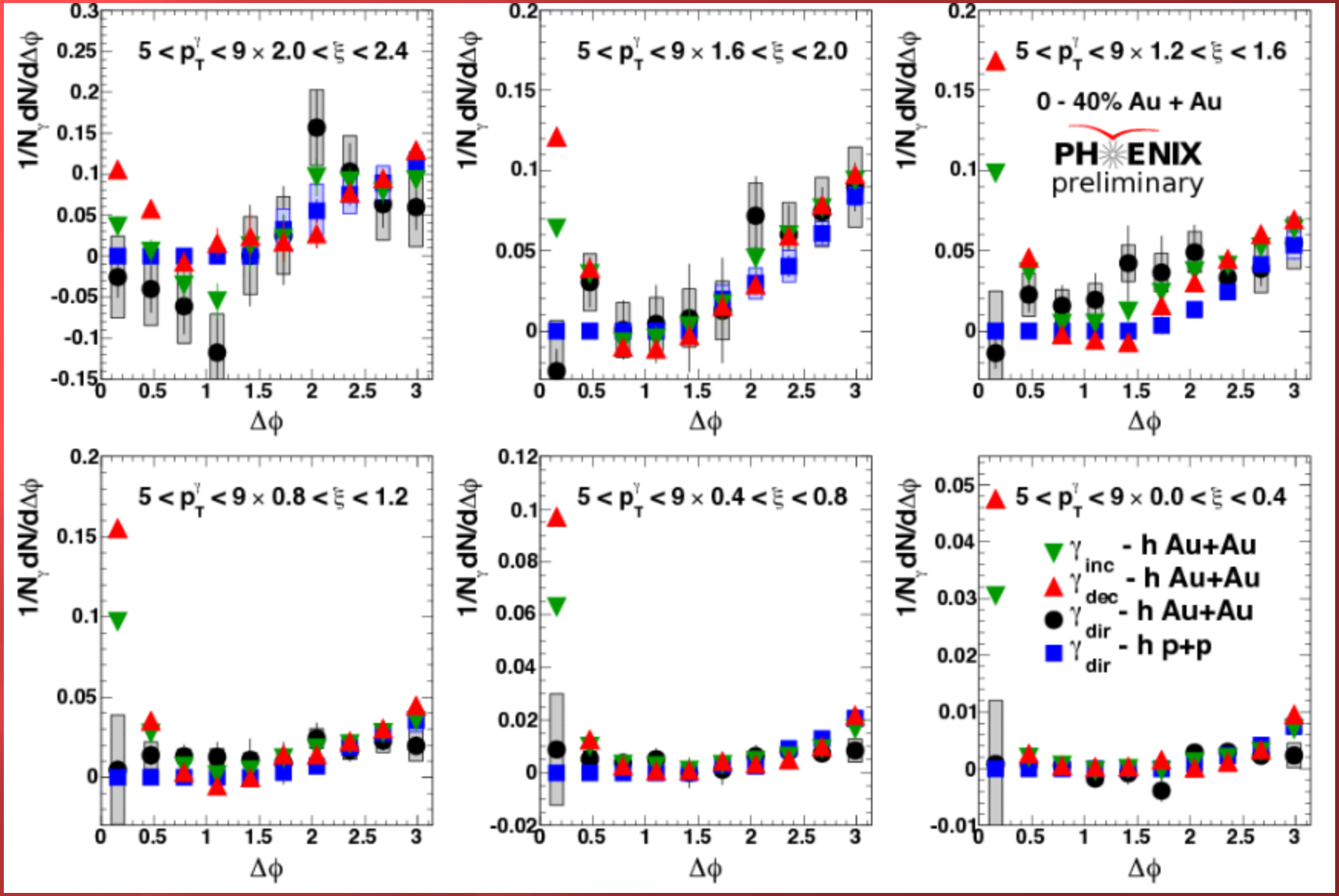


-Consistent qualitative trends
-Hint of enhancement at diff xi (p_{Ta}, p_{Tt} dep)?

CENTRALITY DEPENDENCE

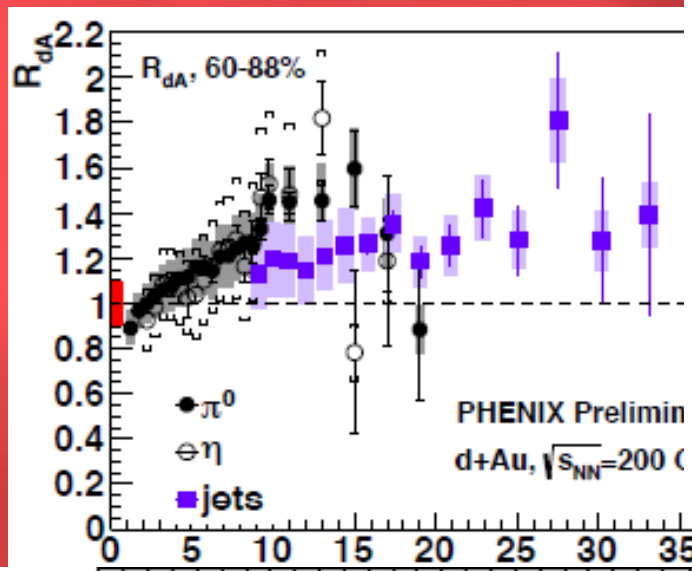


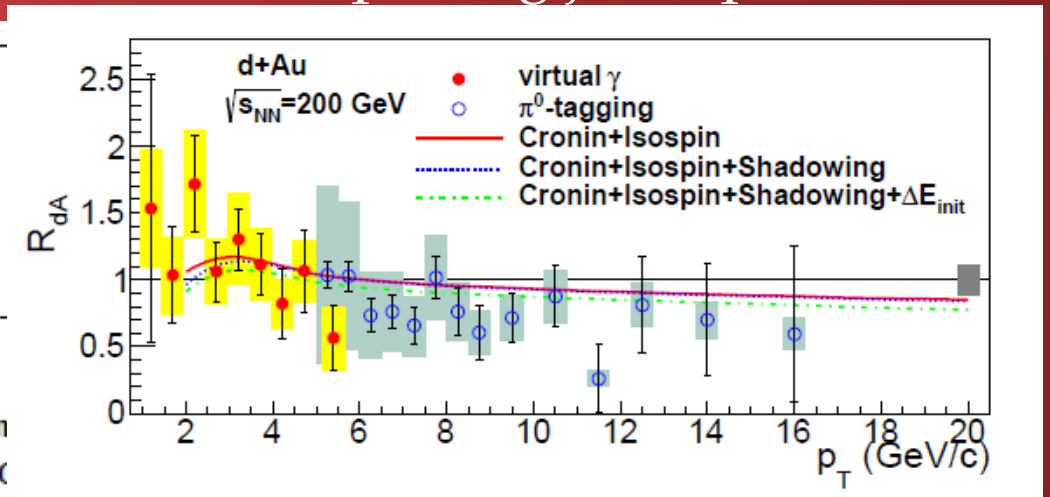
-Low z/high z suppression dependence consistent w/ expectations?
-Hint of enhancement at diff xi (pta,ptt dep?
-Enhancement persists

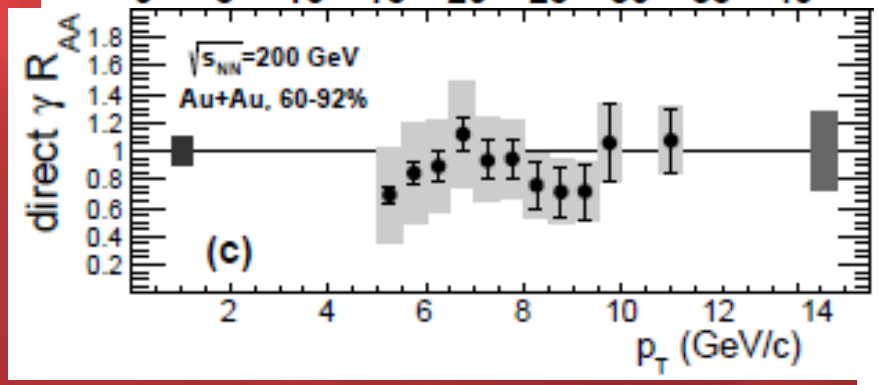

$5 < p_T^\gamma < 9 \times 2.0 < \xi < 2.4$
$5 < p_T^\gamma < 9 \times 1.6 < \xi < 2.0$
$5 < p_T^\gamma < 9 \times 1.2 < \xi < 1.6$
0 - 40% Au + Au
PHENIX
preliminary
$5 < p_T^\gamma < 9 \times 0.8 < \xi < 1.2$
$5 < p_T^\gamma < 9 \times 0.4 < \xi < 0.8$
$5 < p_T^\gamma < 9 \times 0.0 < \xi < 0.4$
γ_{inc} - h Au+Au
γ_{dec} - h Au+Au
γ_{dir} - h Au+Au
γ_{dir} - h p+p
$1/N_\gamma\, dN/d\Delta\phi$
$\Delta\phi$

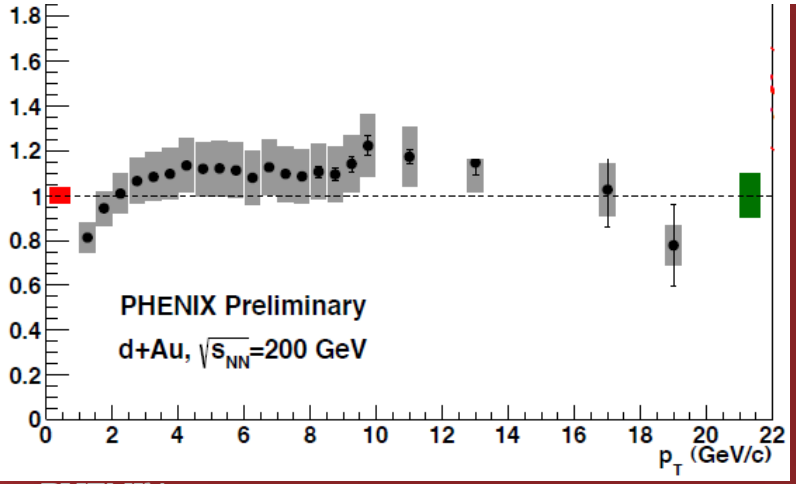
Initial state effect? Like jets?

- Looking for initial state effects in γ is especially interesting given jet sector results
- 2003→2008 dataset will allow for centrality dependence for γ_{dir} R_{dAu}. Different than surprising jet dependence?









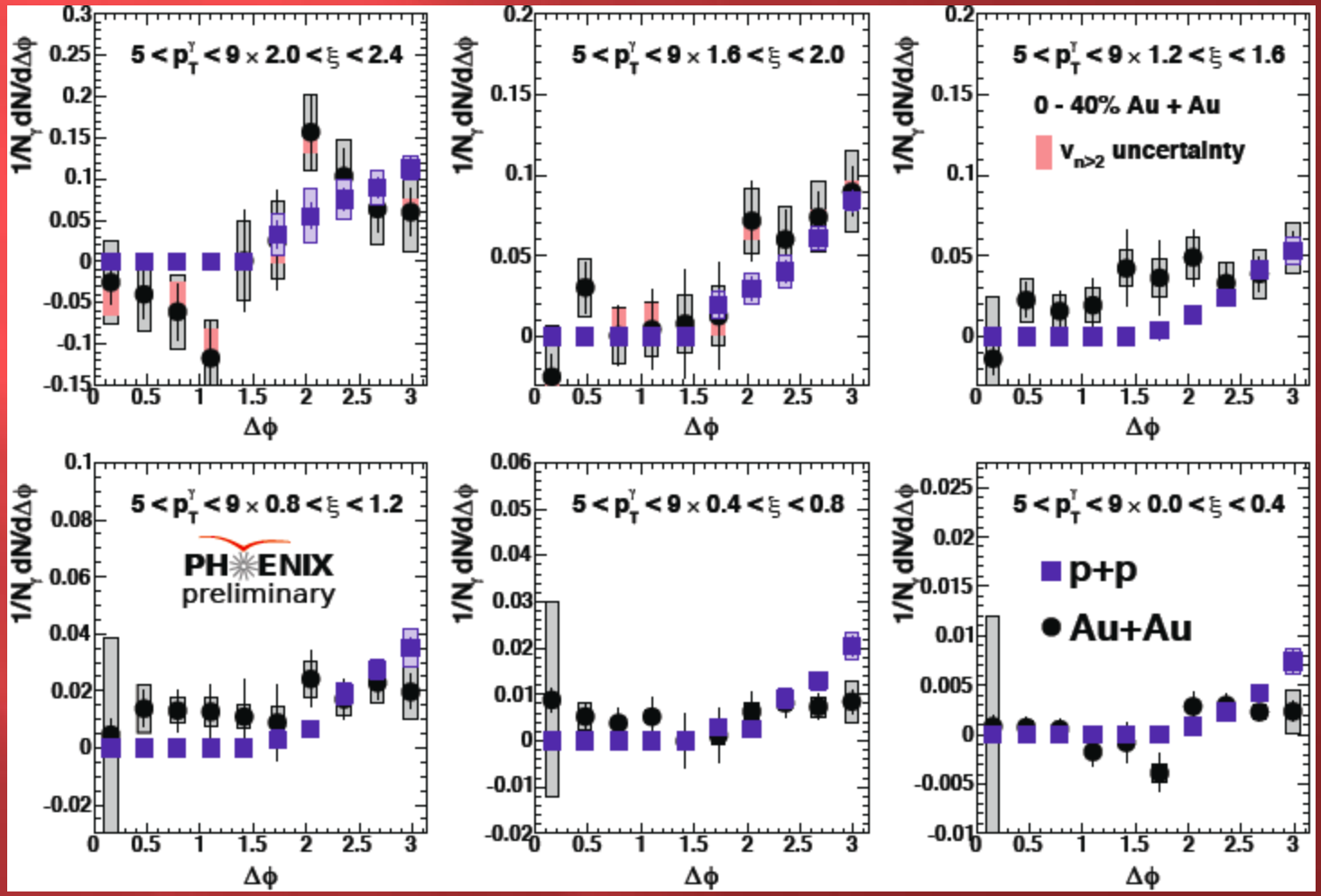
Direct γ Motivation II

- A+A Initial state effect tester!
- In A+A this is the only modification possible (for Compton/Iso component)!

- Big step: understand initial state/ CNM effects for jets

- To understand CNM effects in A+A start with to p+A, d+A

Jet Fn's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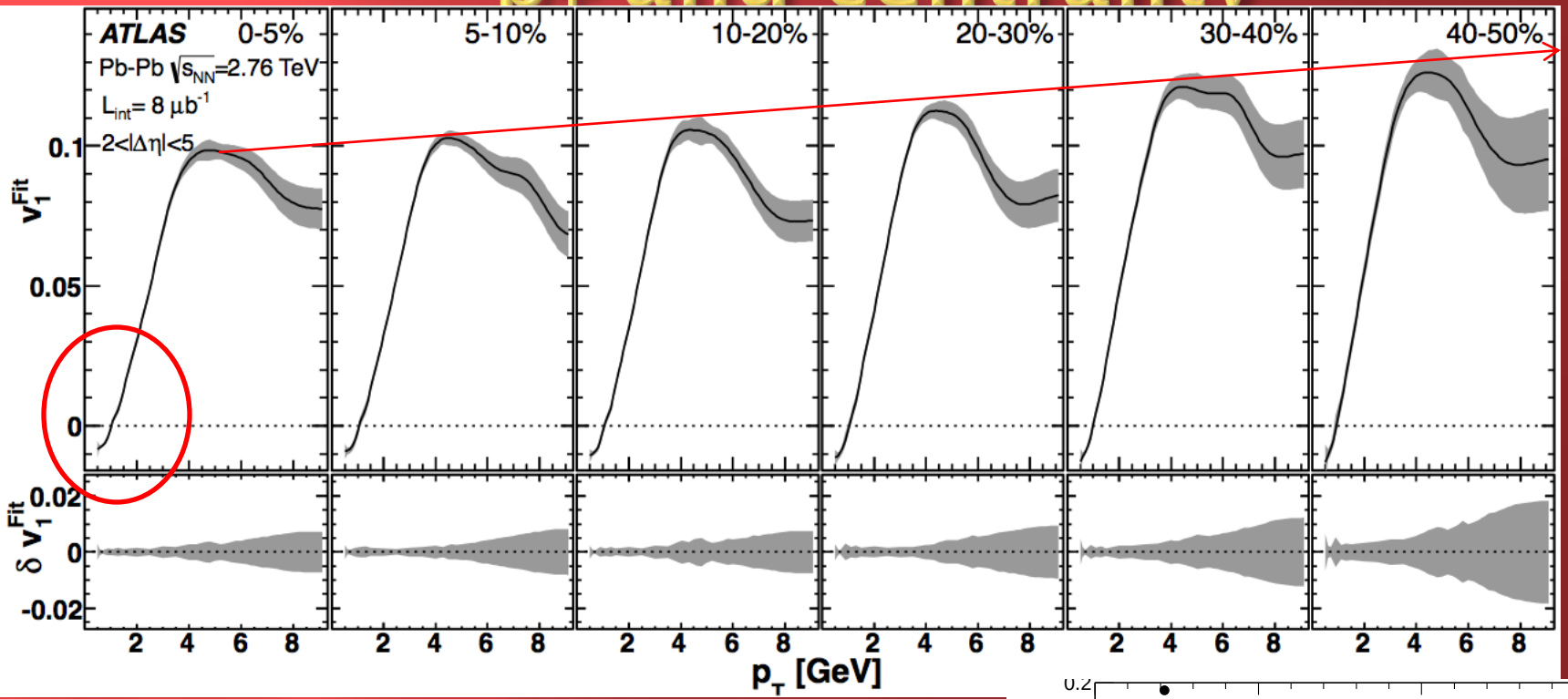
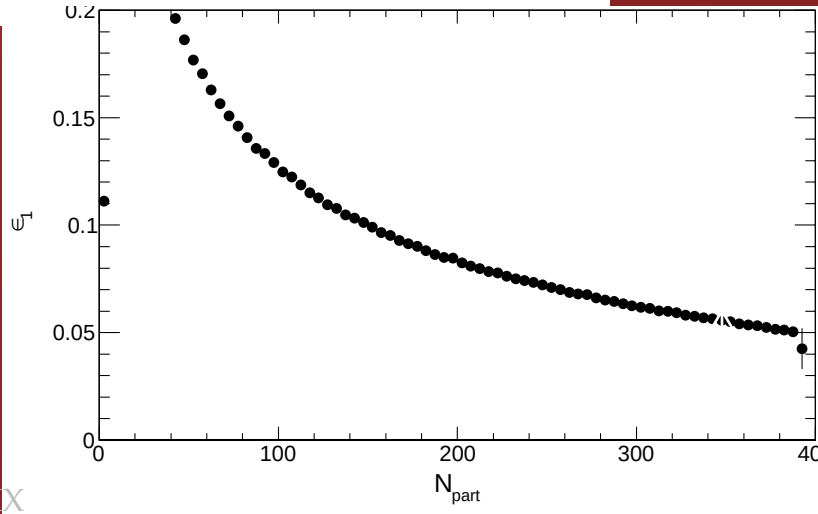
0 - 40% Au + Au
$v_{n>2}$ uncertainty
$5 < p_T^\gamma < 9 \times 0.8 < \xi < 1.2$
PHENIX
preliminary
$5 < p_T^\gamma < 9 \times 0.4 < \xi < 0.8$
$5 < p_T^\gamma < 9 \times 0.0 < \xi < 0.4$
p+p
Au+Au
$1/N_\gamma\, dN/d\Delta\phi$
$\Delta\phi$

Jia: wwnd12: v1 slide: Fit result vs p_T and centrality



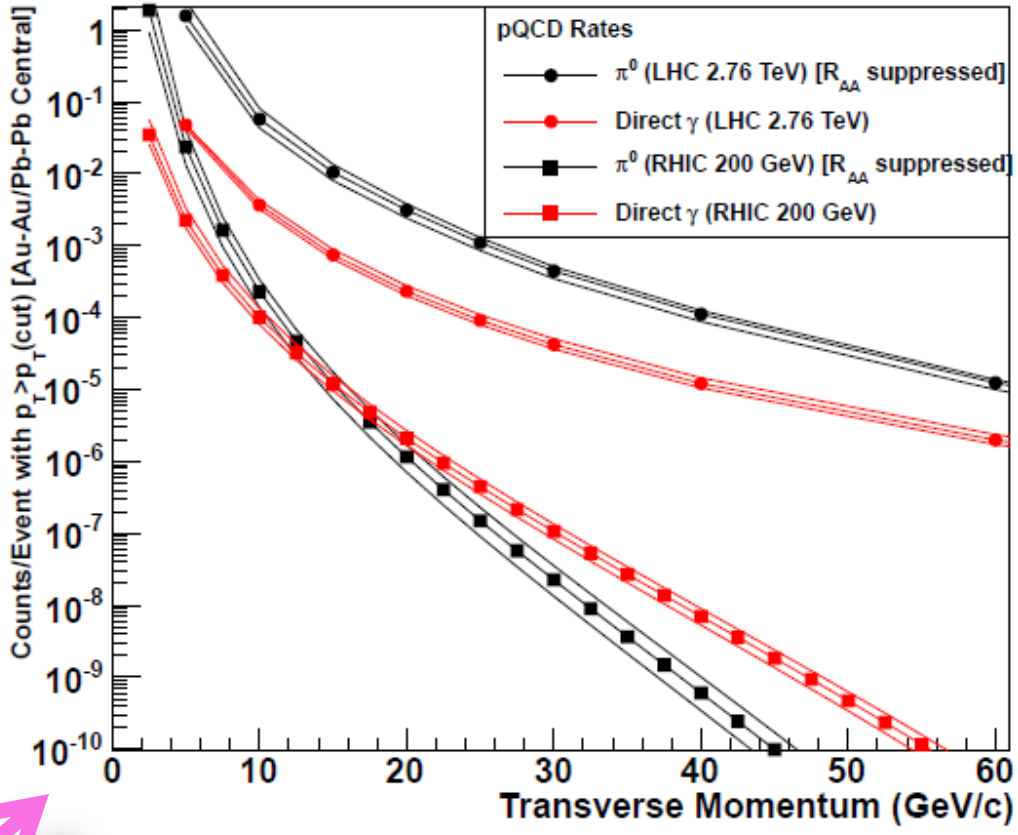
- $v_1^{Fit}(p_T)$ peaks around 4-5 GeV, peak-value increases with centrality by about 20%.
  - Less viscosity damping, reflecting the increase in ε_1?



sPHENIX (?)

- Rates for Direct γ are 1/1000 of Jets → But still sufficient statistics at RHIC for good overlap of jet, leading particle results
- Because of spectral shapes RHIC → has better S/B for Direct Gamma (/Pi0) than LHC: better high p_T stats than Pi0 !

…from sPHENIX Proposal 2012:



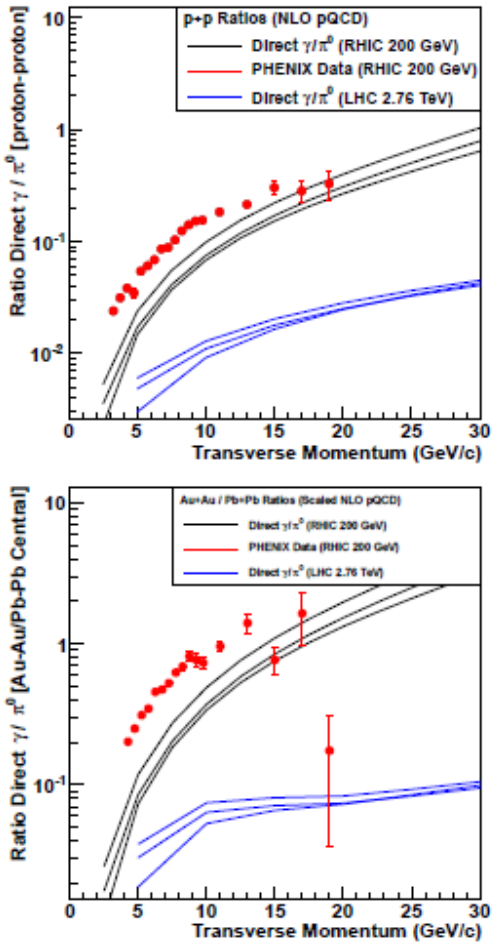
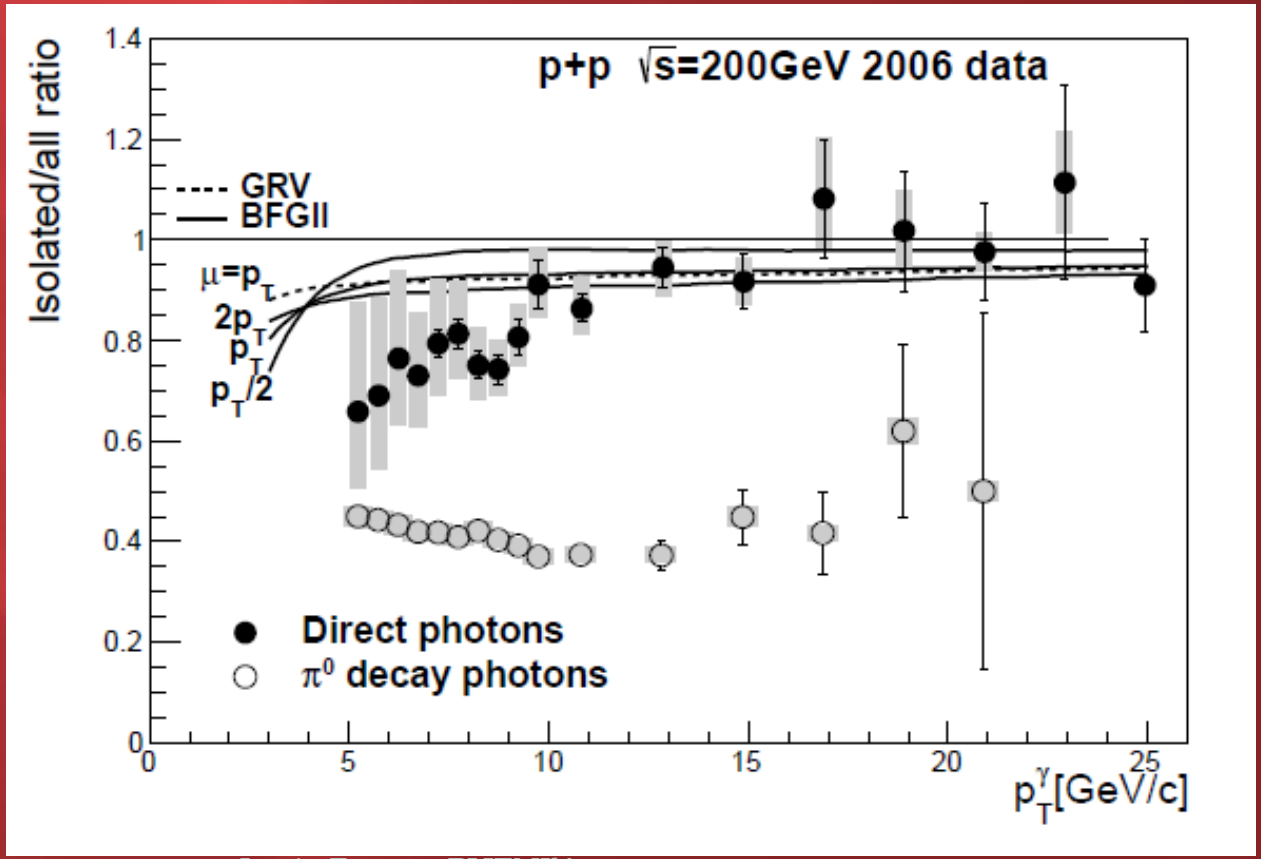


Figure 1.22: NLO pQCD calculations of direct photons and π^0 for RHIC and LHC. The

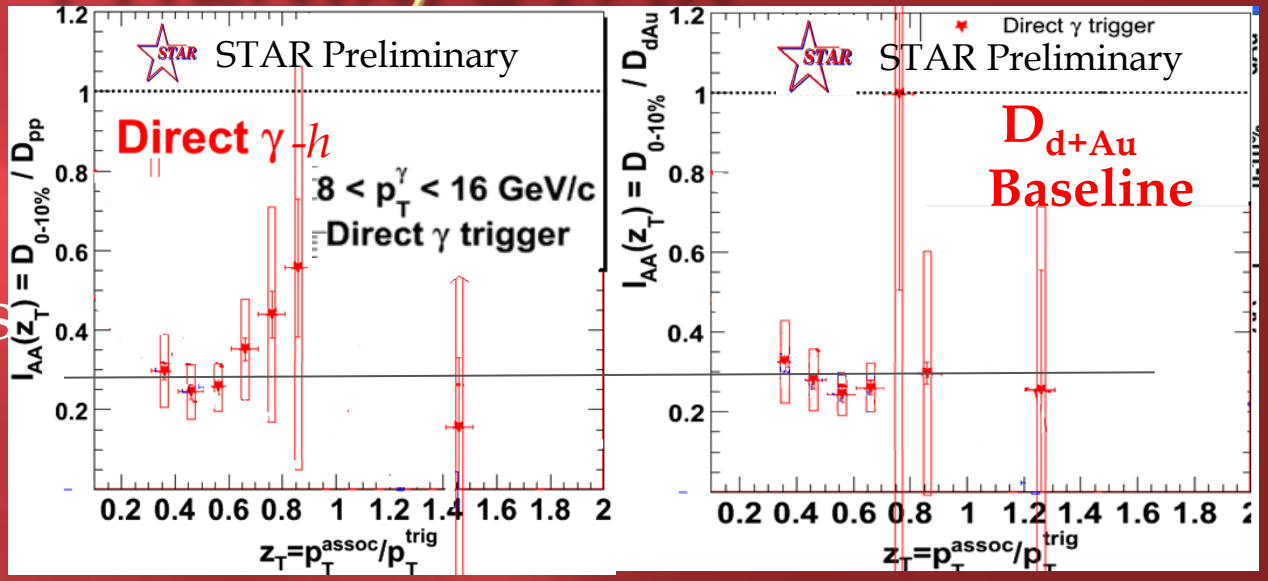
Isolation cut

- Isolation cuts in p+p
- New cone size 0.3 → 0.5



Good Agreement PHENIX/STAR

- Strong Suppression Signal both collaborations
- At about ~0.3



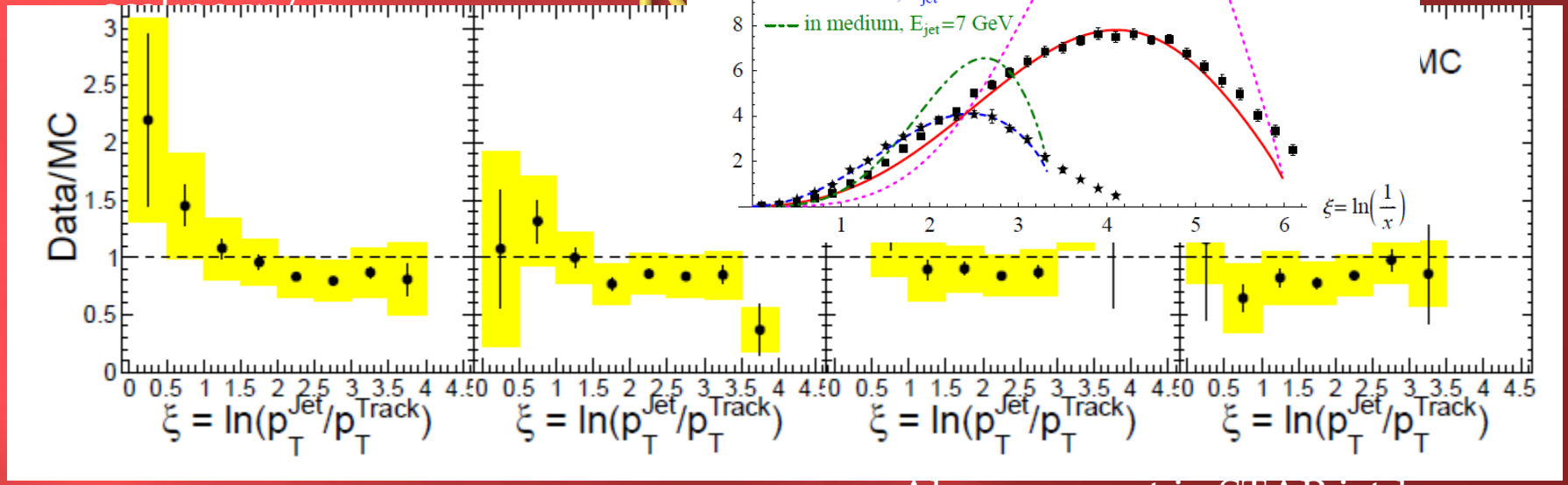
PHENIX split into smaller trigger bins

I_{AA}

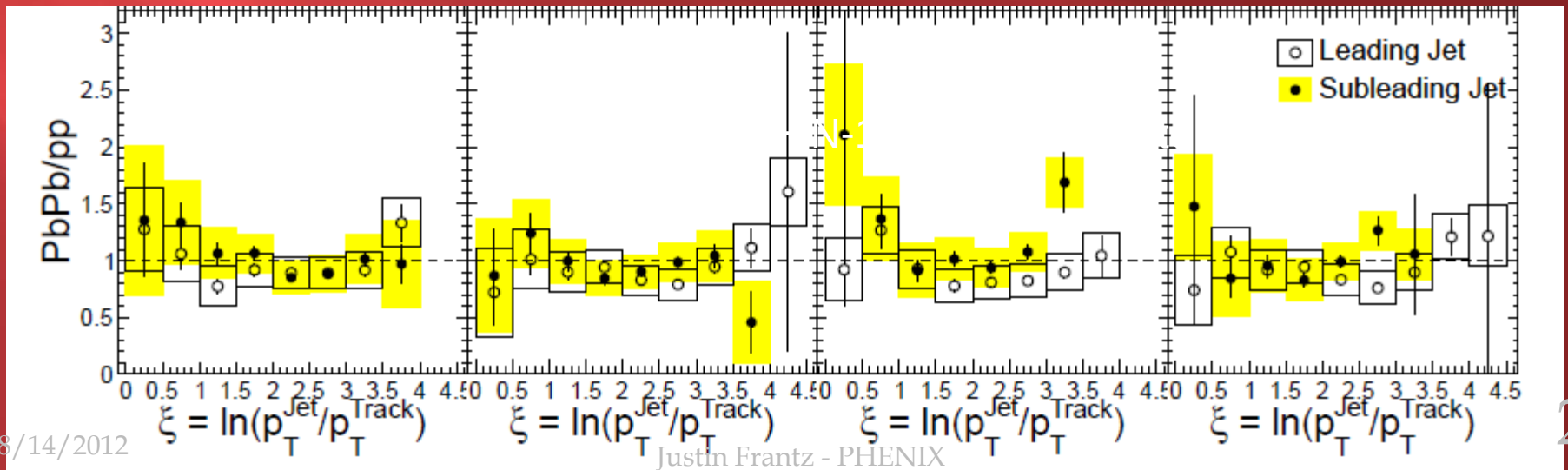
$$z_T = \frac{p_T^h}{p_T^{trig}}$$

Compare to C… …n

- Comparing to the CMS data mi… …on, not



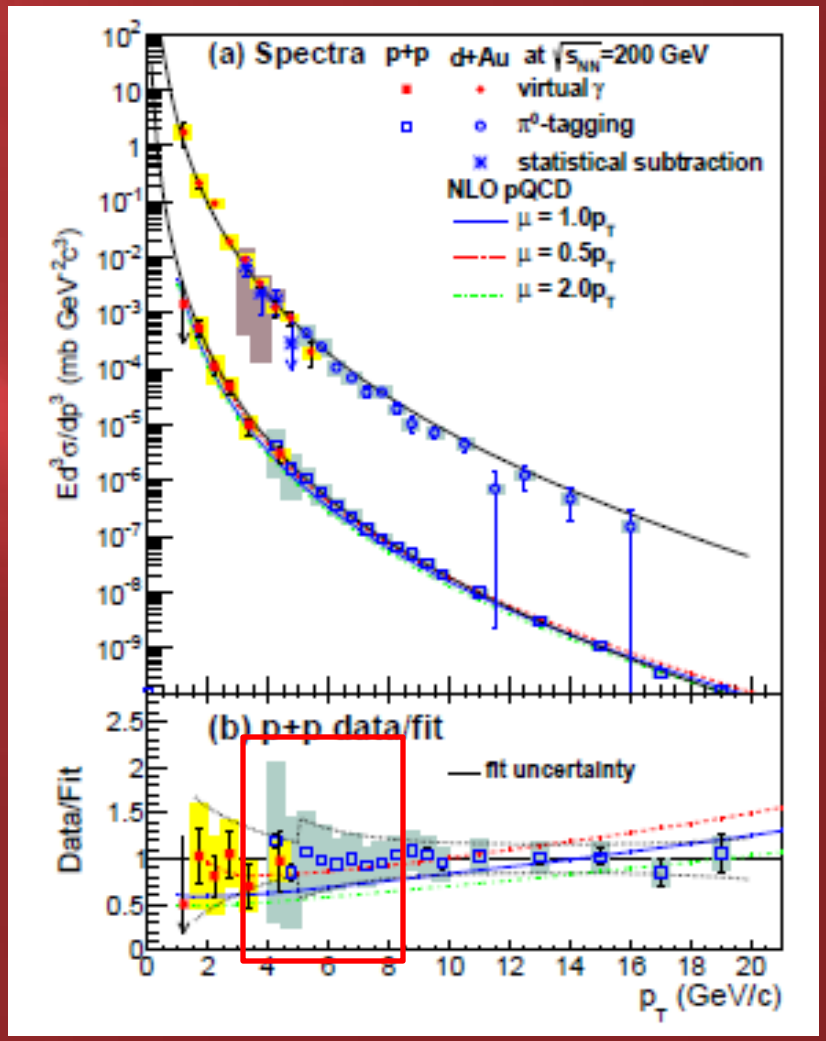
Also apparent in STAR jet-h …



New d+Au Direct Photon

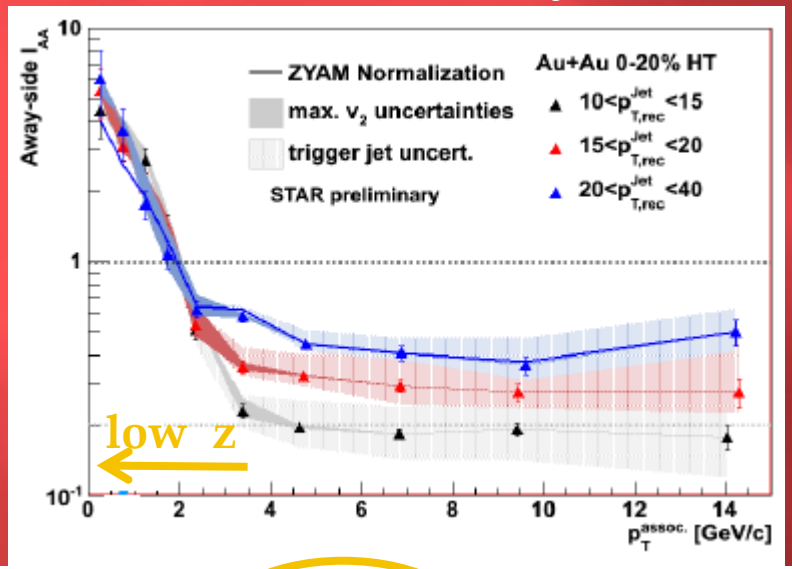
Submitted PRL arXiv:1208.1234

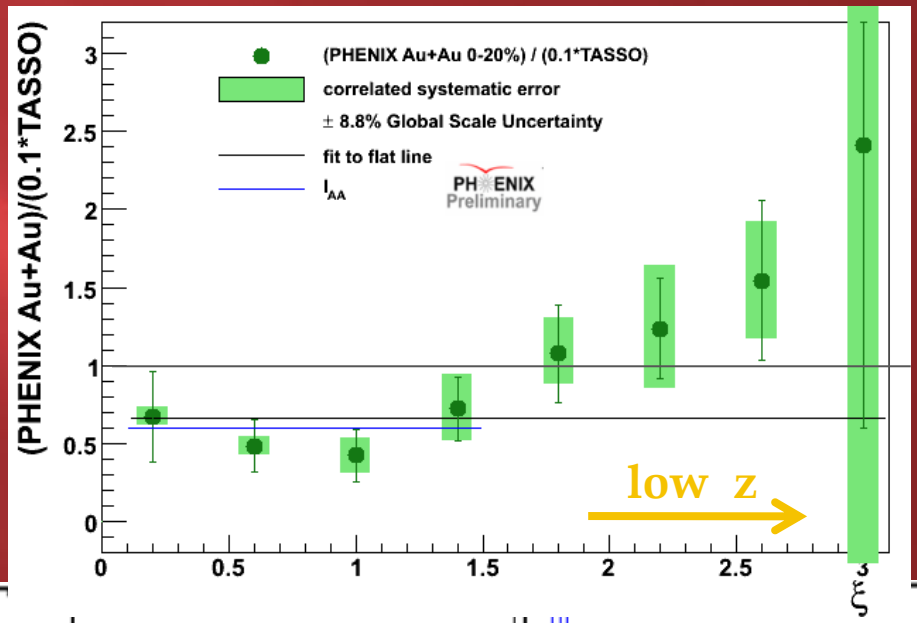
- At low p_T using virtual di-electron method
  - Up to moderate pt— not just soft!
- High p_T newly finalized 2003 Calorimeter data
  - Newly relevant due to much better p+p data

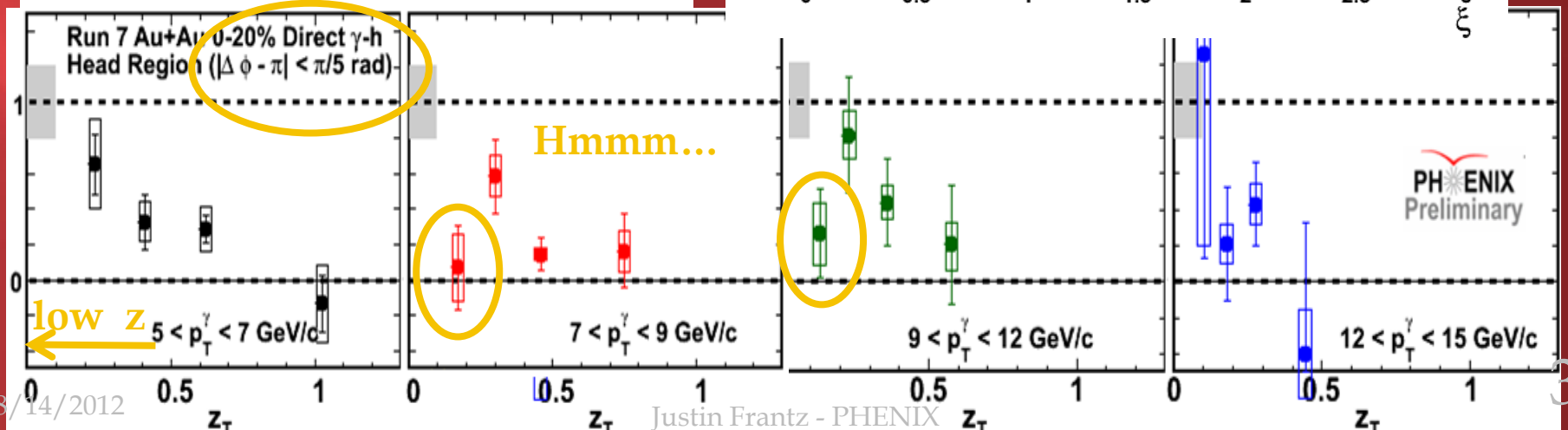


Compare to Reco'd Jet-h RHIC TO RHIC

- Interesting to compare results to jet reco
- Qualitatively similar → Same conclusions

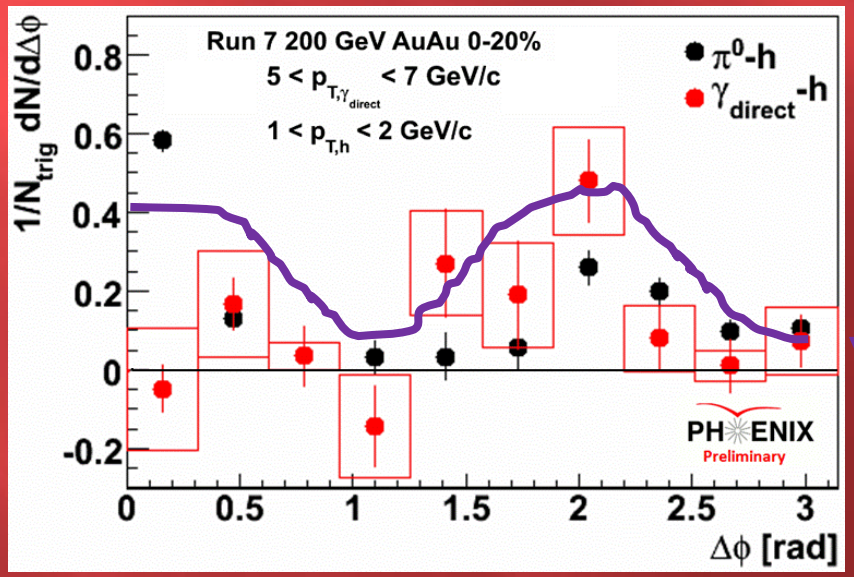






Don't forget Δϕ Shapes Themselves

- **Some of Reco Jet I_{AA} enhancement is coming in ~same Δϕ region as "ridge"/"shoulder"/ (probably) "v3" ?** Needs further investigation
- Direct γ–h too? I know for both analyses work is well underway…



v_3?