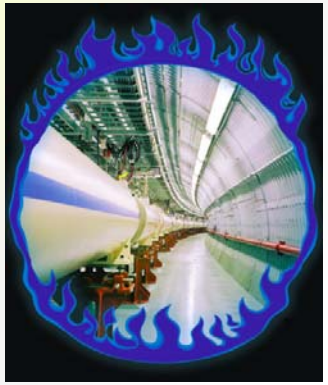


(Other)

wikipedia.org

High p_T Physics at RHIC

Outline:
1) High pt (spectra)
2) 2-p / Gamma-jet results
3) sPHENIX

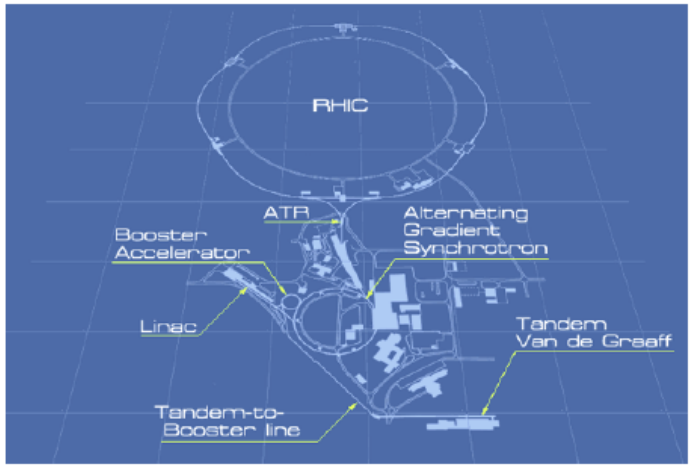
Justin Frantz

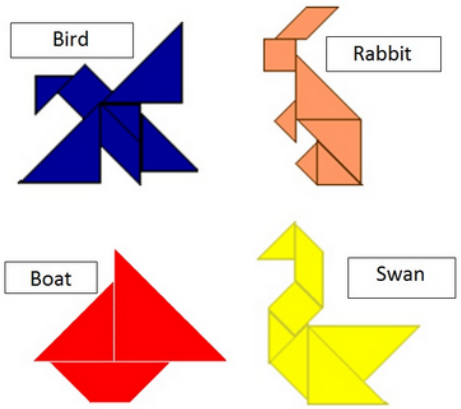
Ohio University

RHIC/AGS Users Meeting

June 26, 2013

RHIC In The 2010's





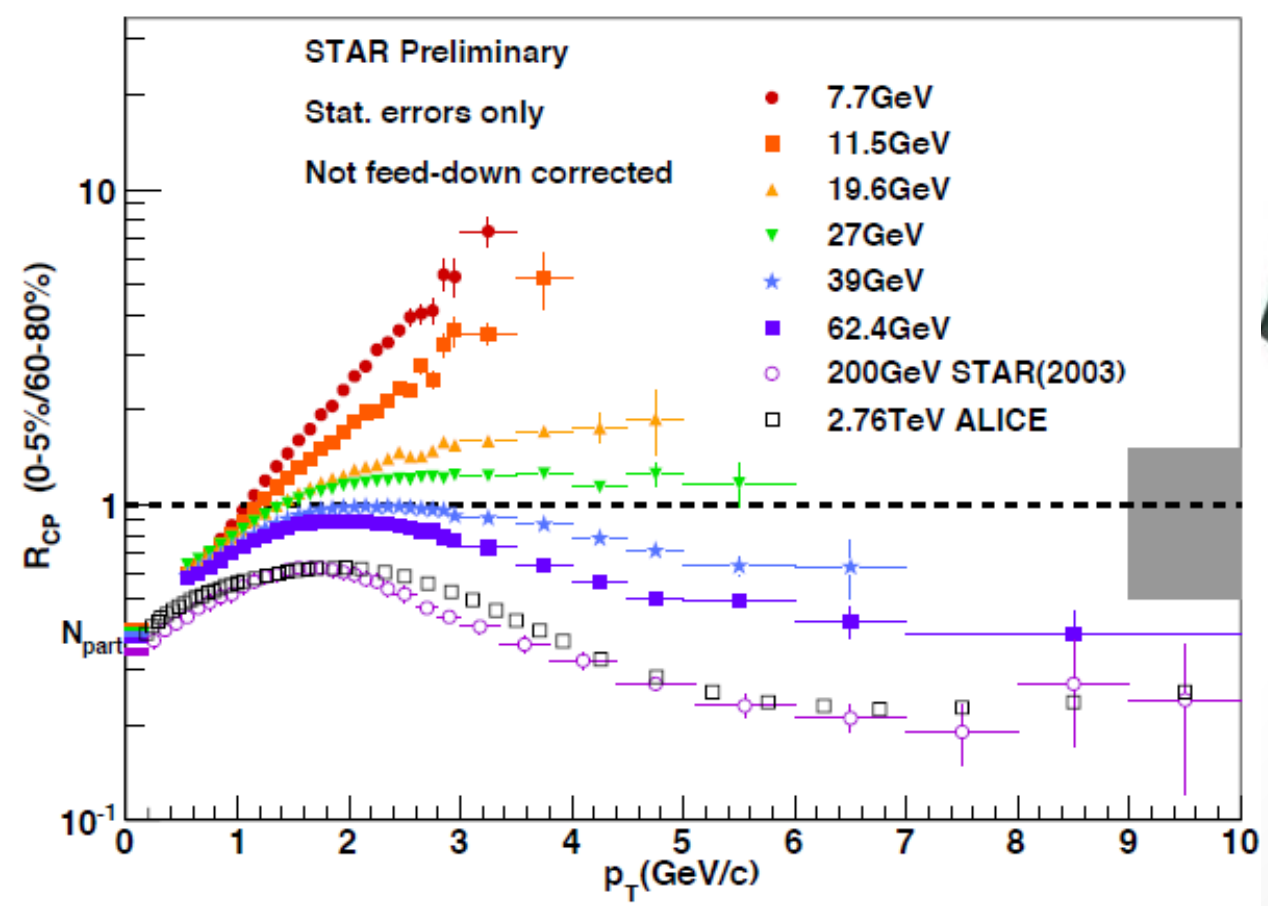
http://sewverysimple.blogspot.com

- Exploit RHIC's **Flexibility** to study different systems, small and large
- Geometry: Exotics CuCu, CuAu, UU, dAu, He^3Au?
- The BES : Phase Transition Physics
- **High p_T / For jet quenching studies:** exploit the large collision energy difference within RHIC and between RHIC and LHC to understand the physics of quenching
- Robustness of theory and more! (sPHENIX goal): understand the emergence of interactions by varying time spent near T_C.
- Understand **Geometrical** and **Initial State Effects In Quenching**!

Part 1
High p_T Spectra Results from Energy and Geometry Scans

New Results Exploiting RHIC's Flexibility in s

- Another T-shirt Plot?

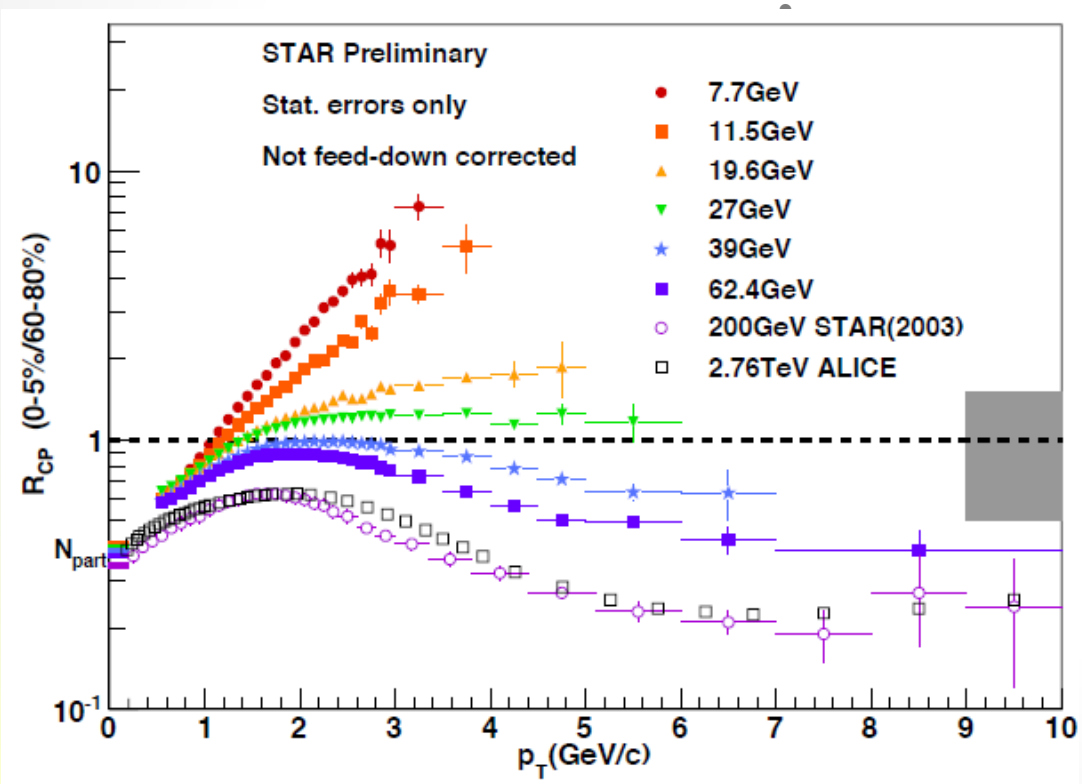


Understanding Cronin?

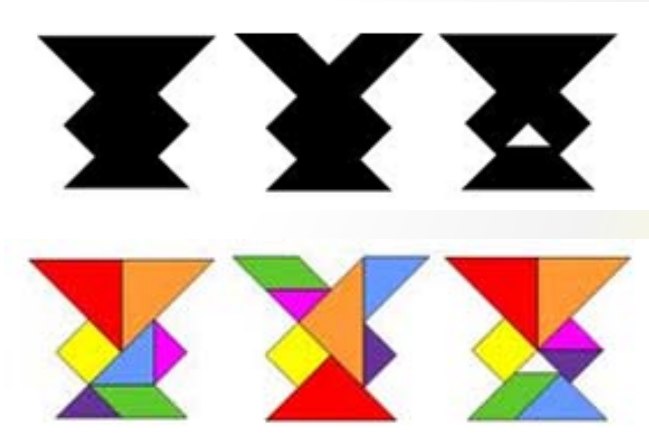
- Presumably there is still quenching below ~30 GeV
- Cronin Effect blows up at low $\sqrt{s}$ → (k_T ($\sqrt{s}$))
  - But note, not necessarily in p+A! See WA 98 next slide
- Quote from April Workshop:

  "It's time we understand the Cronin Effect"…

  -G. Barnafoldi



(Tangram paradoxes)

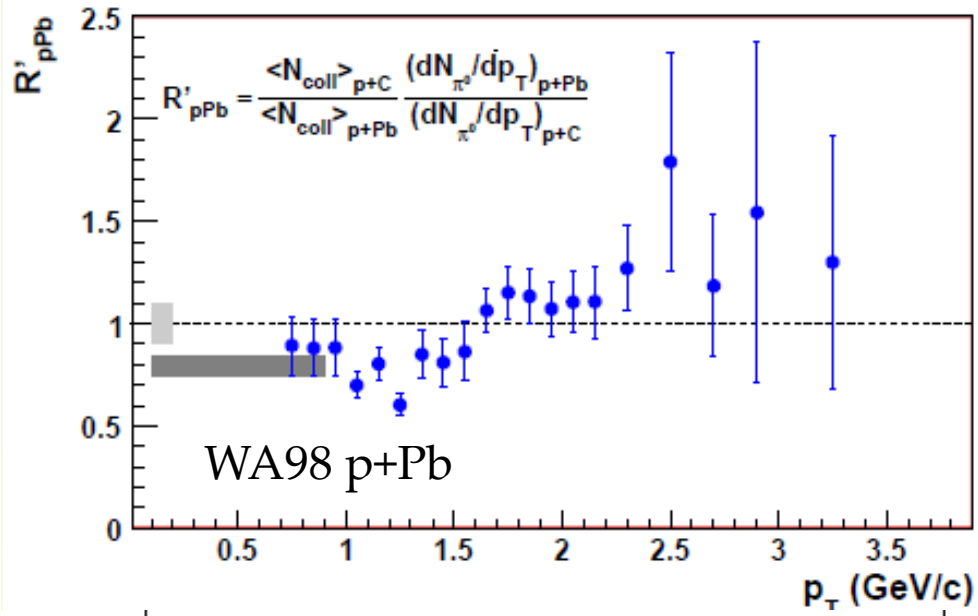


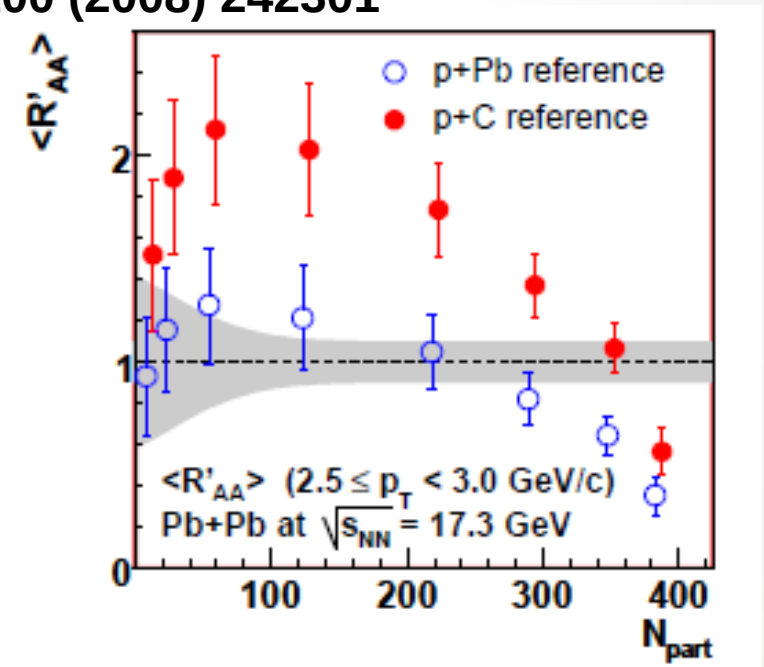
wikipedia.org

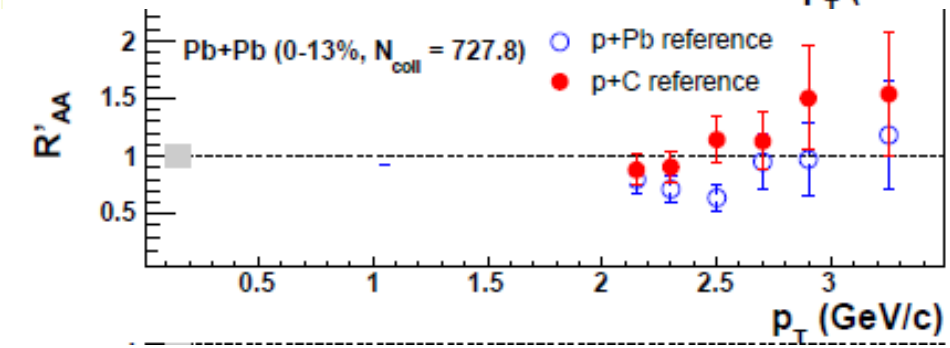
Useful New Context for WA98

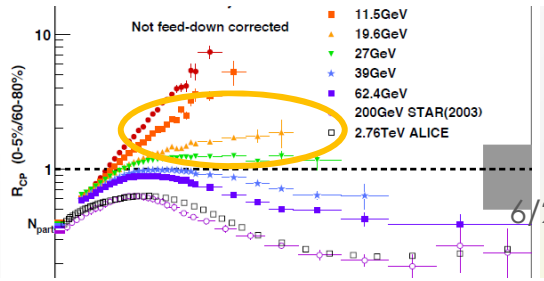
- WA98 LEDA: A RHIC Detector Too !
  - (Now PHENIX PbGl – JF/ Ohio U Manage Pbgl Operations ;> !)
- √s 17.4 Cronin Blowup starts only above N_{part} > ~50

WA98 0708.2630 PRL 100 (2008) 242301



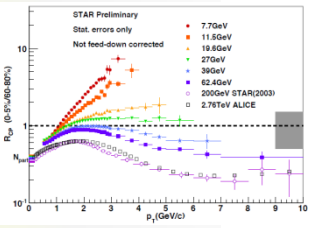


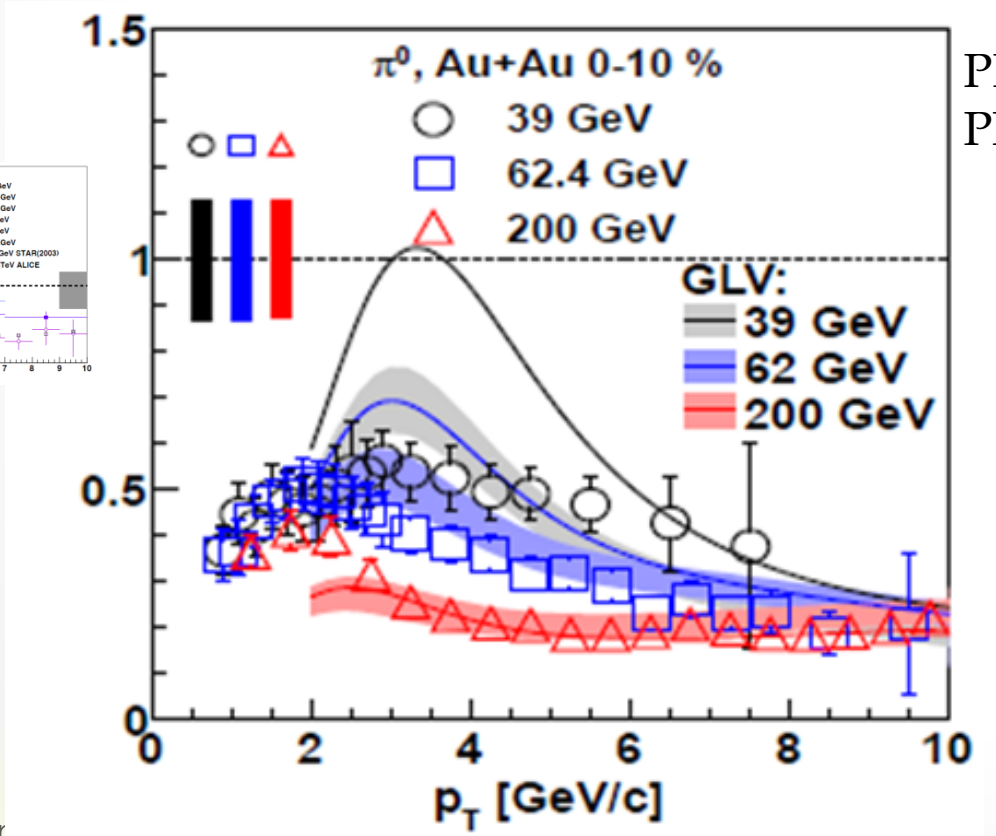




R_{CP} vs R_{AA}: References!

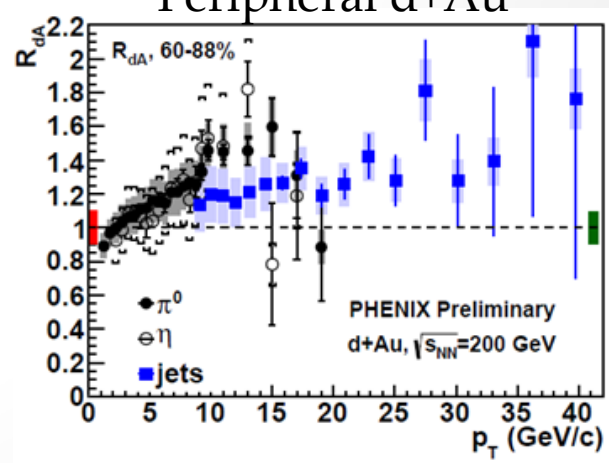
- Draw back for R_{CP} → Peripheral spectra might be the hardest to get right theoretically : preferably use R_{AA}
  - Note PHENIX Data below using Fermilab E706
- These A+A studies need references! p+p and …





PHENIX 1204.1526
PRL 109, 152301 (2012)

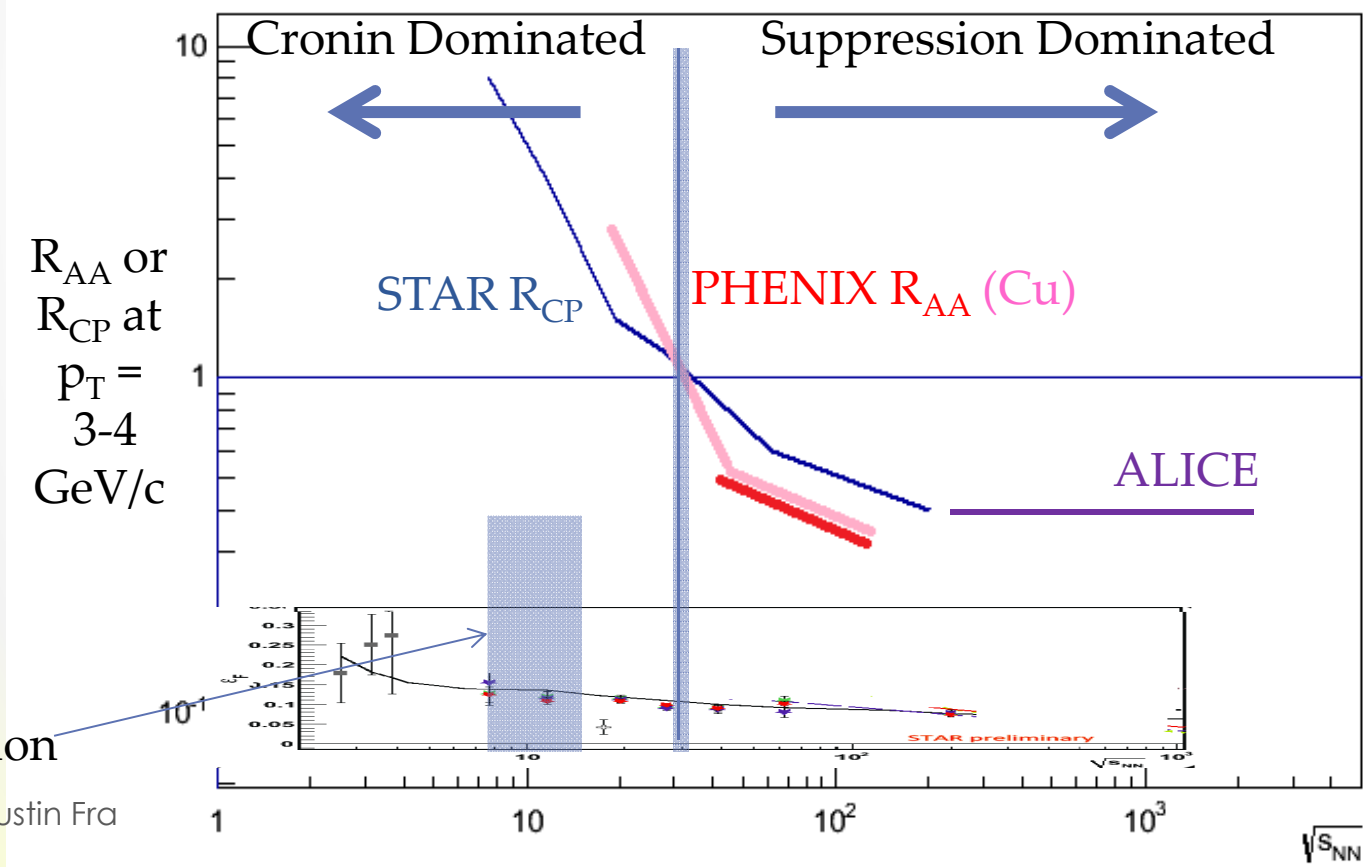
Peripheral d+Au



High p_T pp/pA Energy "Scan"?

- Significant critical mass of theorists interested in CNM developing? April Workshop very successful!
- RHIC should continue to lead this effort!
- Short term "Scan" ?: Get p+p and p+A ~one point above and below ~ 30 GeV ?
- Longer term sPHENIX can contribute with full Jet studies → a key observable?

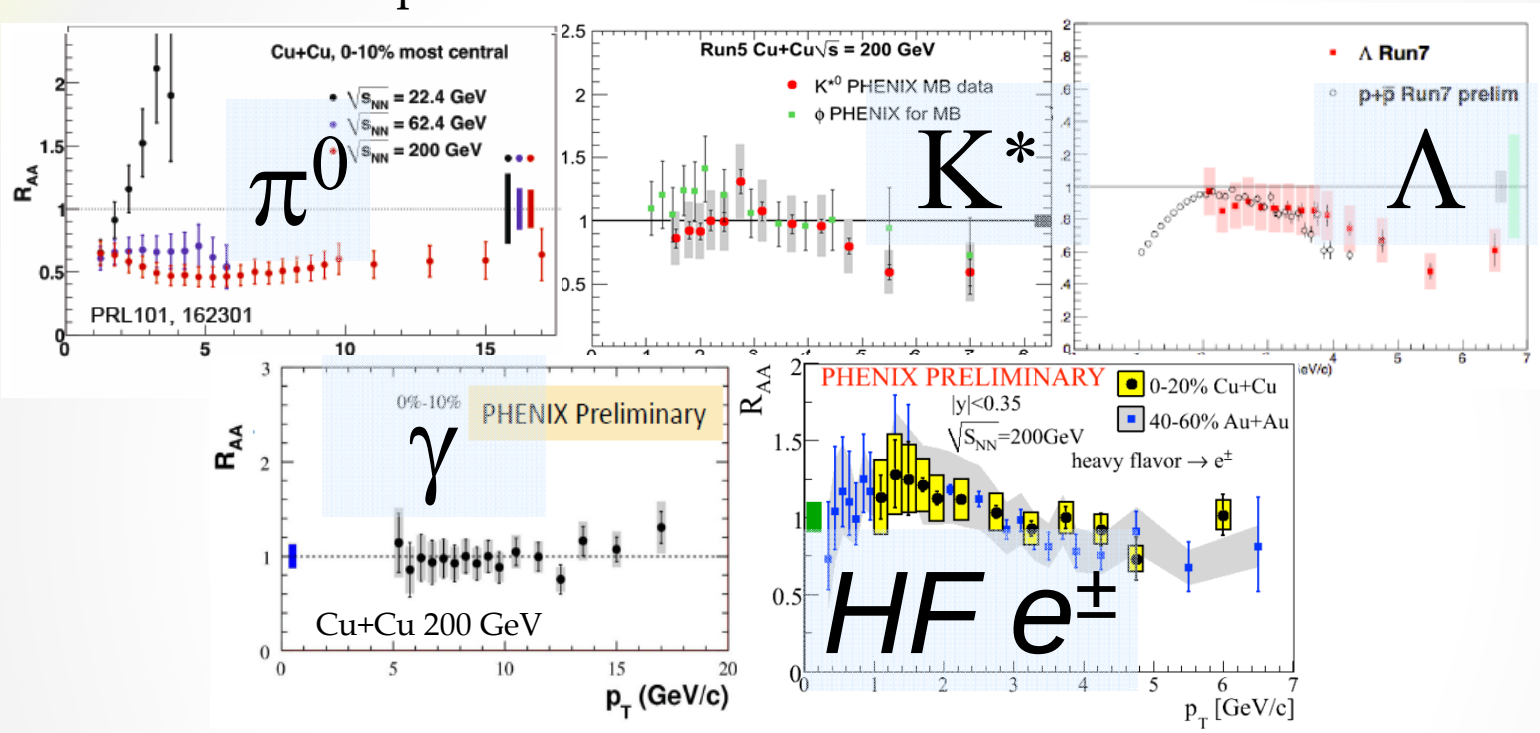
think color tranparency effects



Phase transition

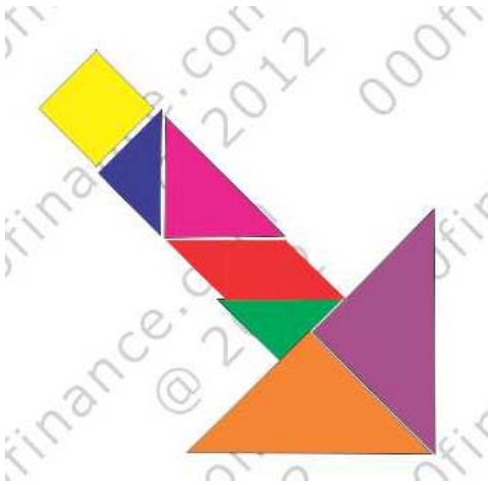
Expanding the Geometry Dimension…

Comprehensive 2005 Cu+Cu Results from PHENIX



- New HI Geometries Cu+Au, U+U: p+Si, C, Au,
- Whole workshop this morning right now – Organizers Hui Wang, Shengli Huang

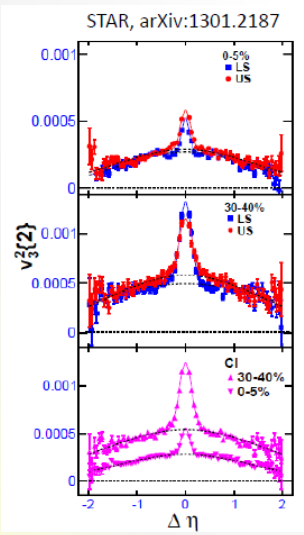
Part 2: 2-particle Measurements and Jets

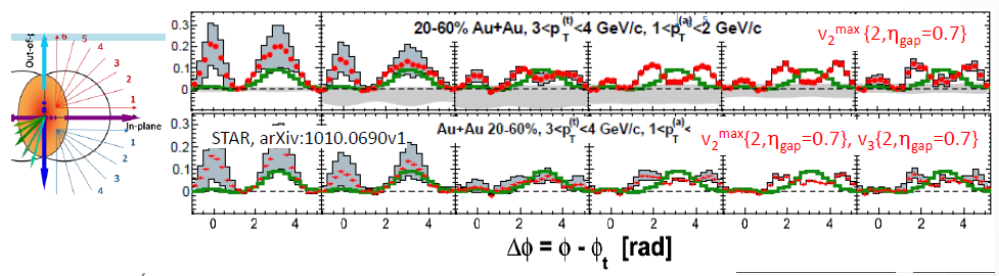


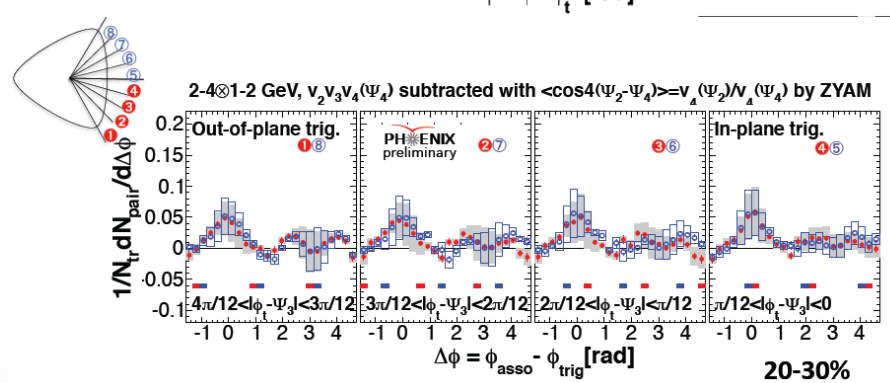
http://w.000finance.com/

Di-hadrons are undergoing surgery

- RHIC continues to explore di-hadron correlations but currently there is some noise that needs (and is being) resolved (related to Jet-Medium coupling—see next talk) before we can apply to quenching constraints.







A Different Complimentarity?

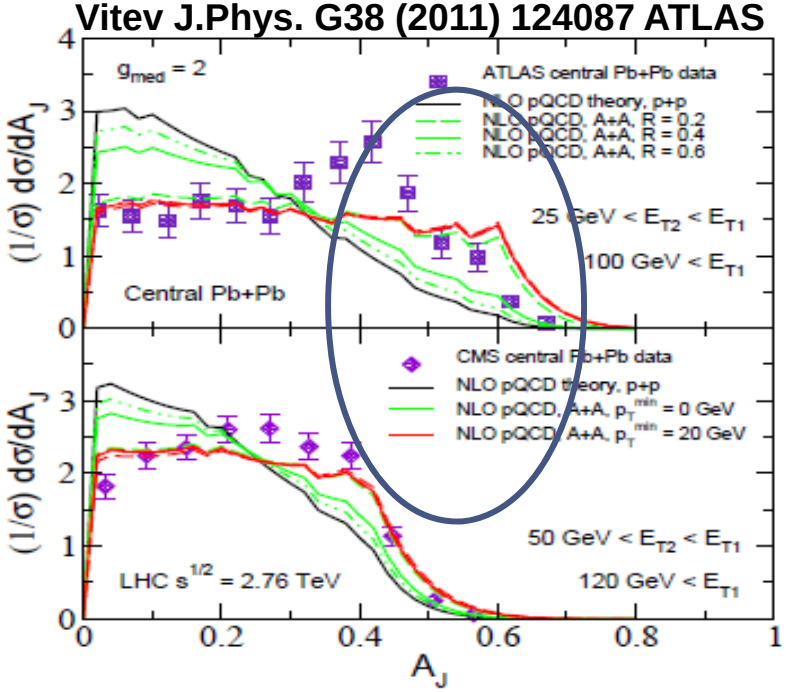
- Jet-h and γ-h 2-p Correlations Can be used and should!
- **My Opinion:**
- Jet Reconstruction is crucial for final understandings of Jet Quenching → Modifications to Showering Process
  - sPHENIX!
- In the short term **DANGER** **:** Don't let jet quenching studies (RHIC/LHC) become too Jet Reco- biased!
- We first need to learn what quenched jets look like!
  - May need completely new jet finding techniques to study quenched jets
- Complimentarity: Jet Finding + Angular Correlation (Jet-h and γ-h) Measurements
  - We can study when modification is mostly NOT there with jet finding: e.g. Energy Asymm
  - Don't ignore modification just because it not seen w/ jet finding observables

Example: "Jet" Finding + Correlations

- **Event by Event CHOOSE Jets with quenching $A_J/x_{\gamma J}$**
- The Ultimate Tool? Identify perturbative quenching regions, vary the quenching fraction?
- Look for shape of quenched jets in regions of di-jet asymmetry Direct γ-jet/di-jet different systematics
  - Di-jet A_J Gamma-jet $x_{j\gamma}$ cut
- Need to do it with and without quench reco axis!

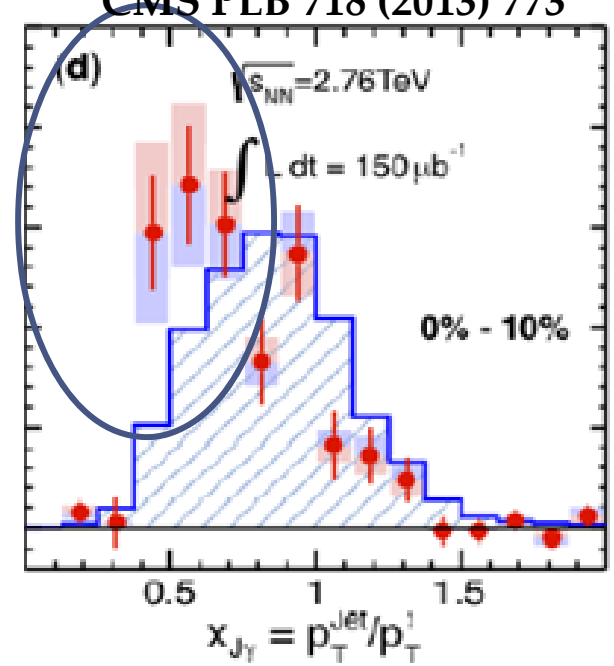
Di-jet Asymmetry Distribution

Vitev J.Phys. G38 (2011) 124087 ATLAS



γ-jet Asymmetry Distribution

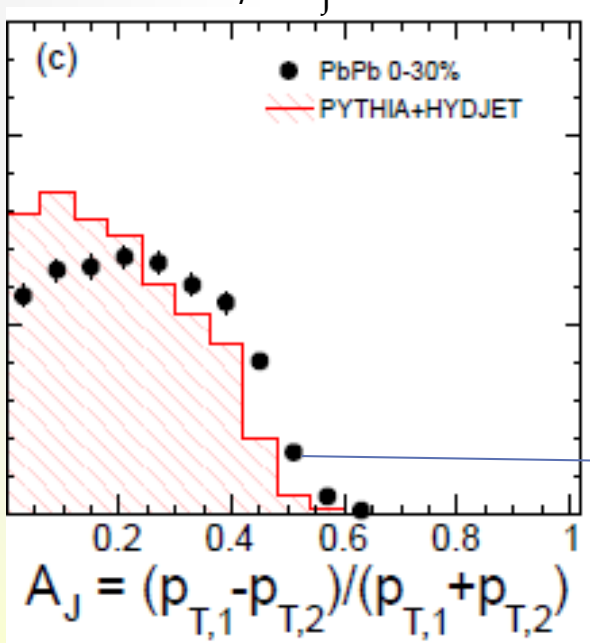
CMS PLB 718 (2013) 773



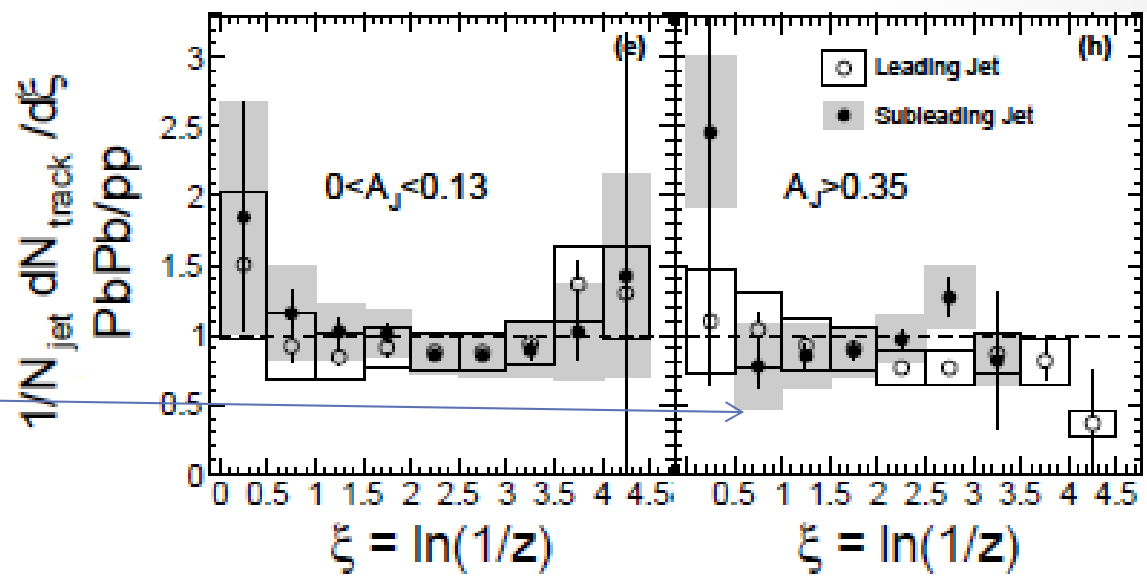
"Jet" Finding + Correlations

- Wait… what about current measurements
- LHC FF Modification Correlates with Large A_J? No?
- Bias of found jets
  - → **Look outside jet cone!**
  - → **Look below jet finding cutoff**

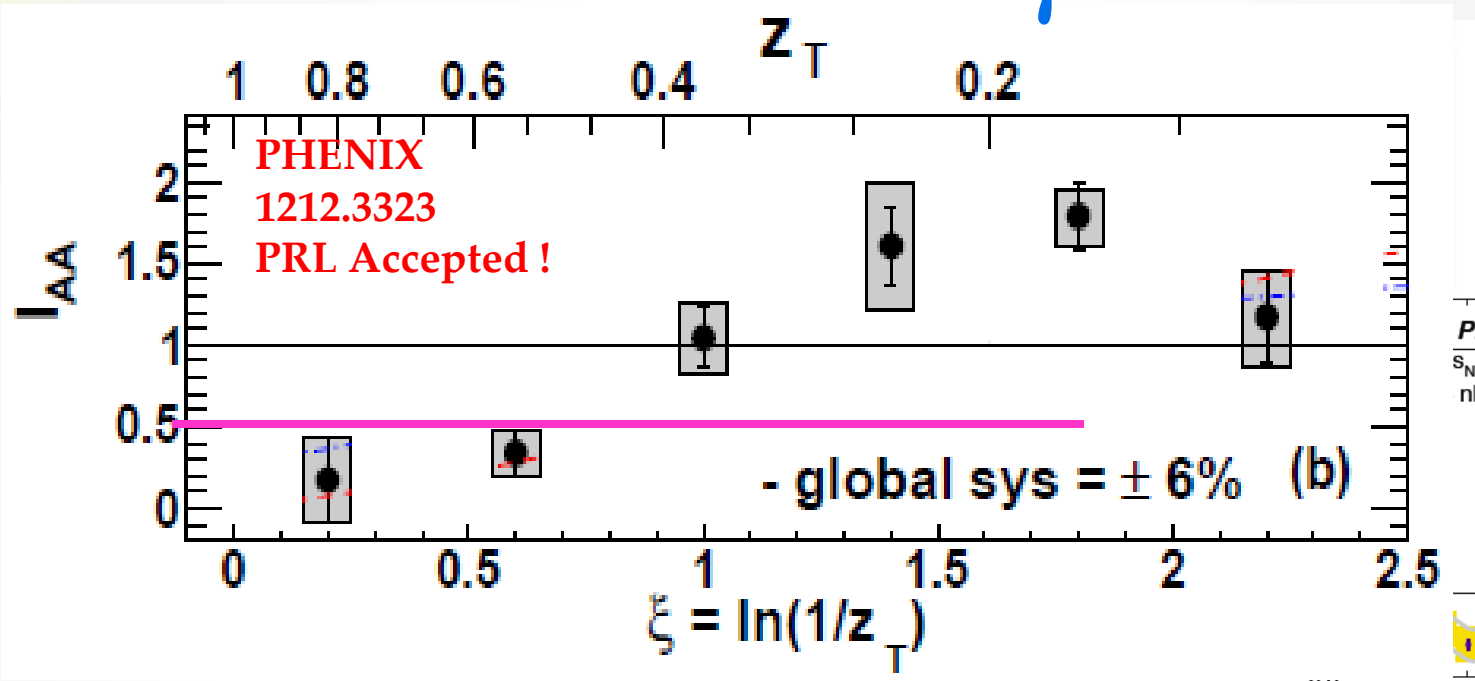
dN/dA_J

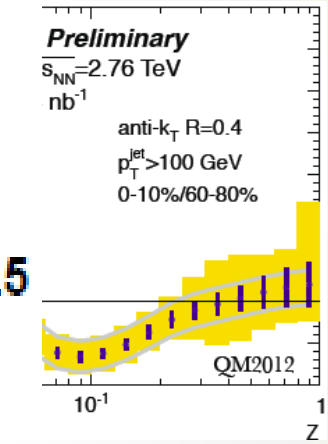


Ratio FF Pb+Pb / p+p = 1 → No mod?

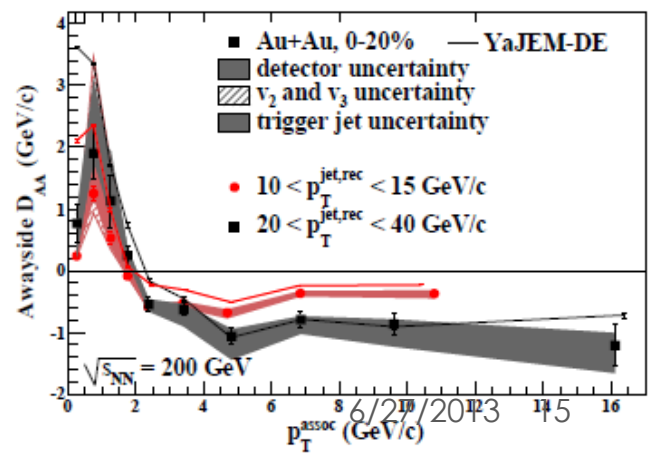


PHENIX Direct γ-Hadron





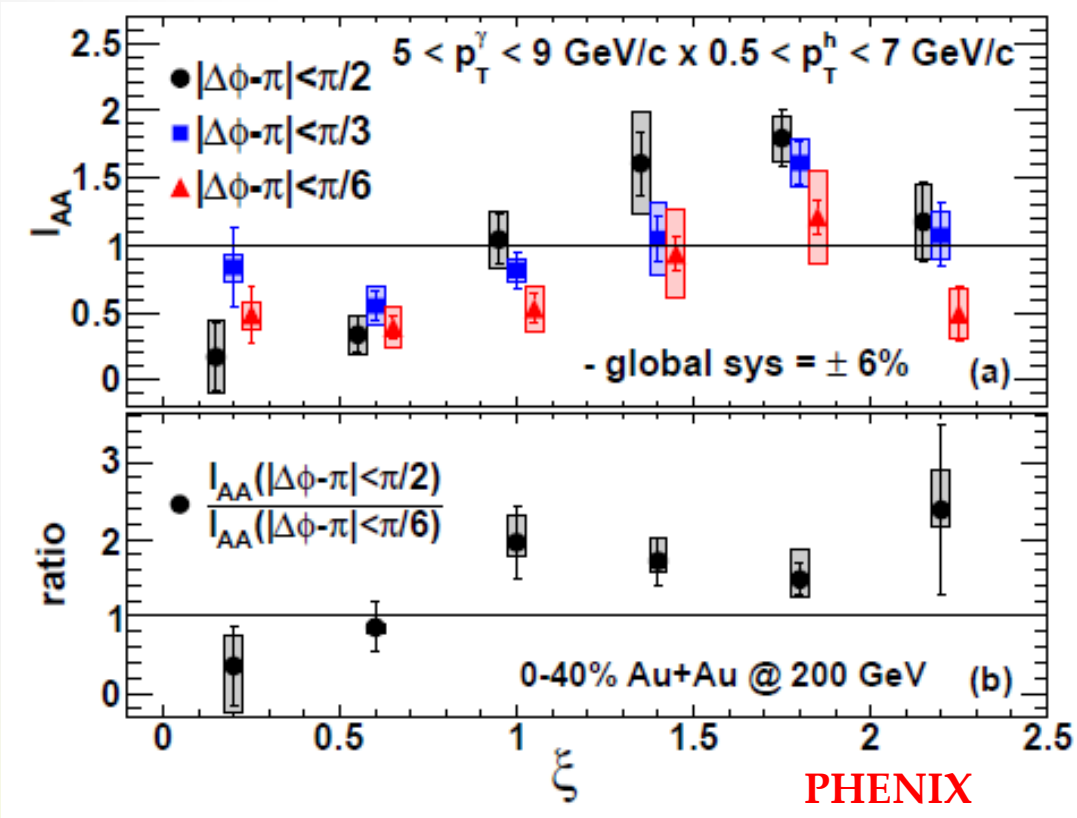
STAR 1302.6184

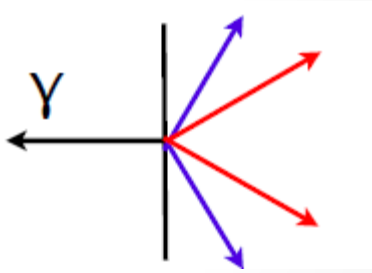


- Photon Hadron FragFn Modification!
- Low z Enhancement
- Very Similar to LHC Jet-reco
  - **LHC FF=1 ~= Jet RAA**
- ~Consistent with STAR Jet-hadron
  - RHIC-RHIC Consistency!
- These analyses are important!
- **Reco jets != All Jet Suppression (?)**

There's more information

- Modified FF isn't the whole story (don't stop there!)
- Correlations: angular shape

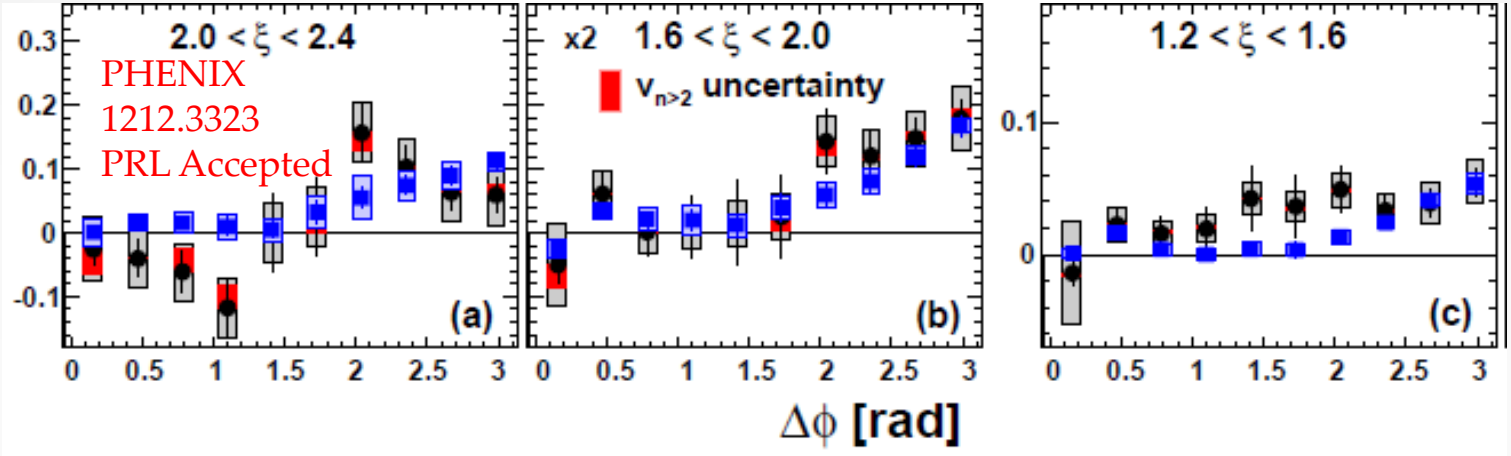




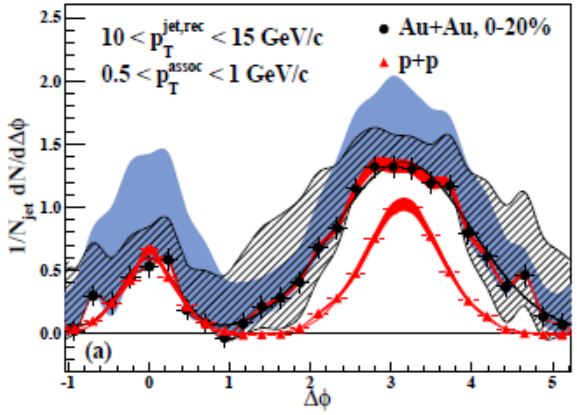
PHENIX
1212.3323
PRL Accepted

Angular distributions

γ-h



Jet –h



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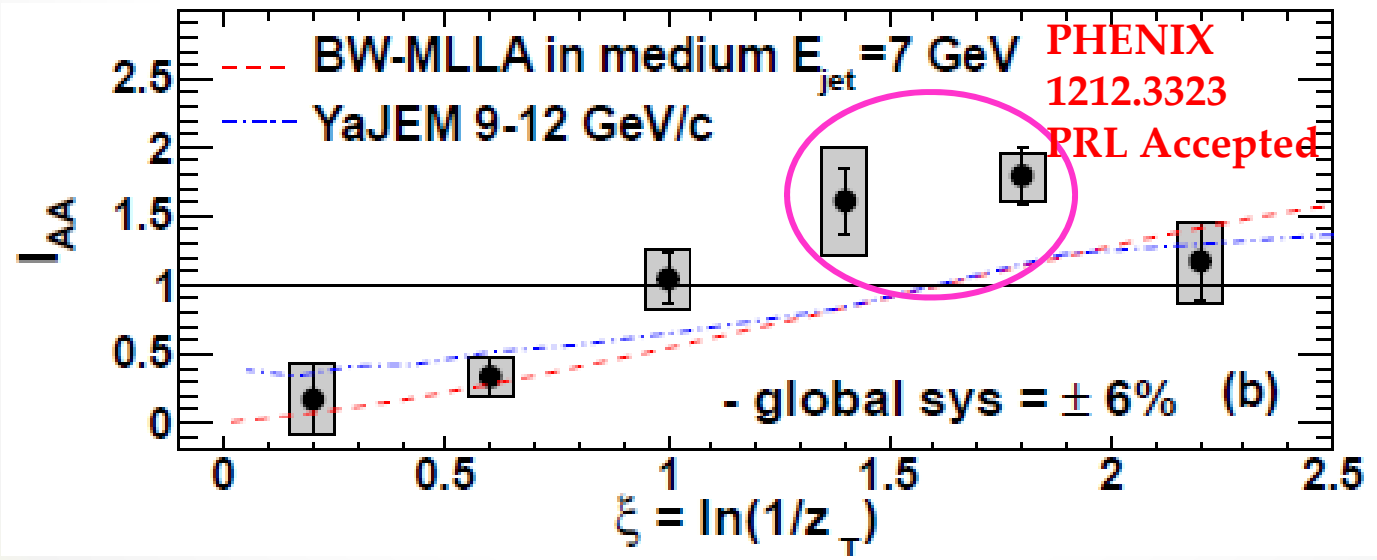
So much broadening too "weird"?

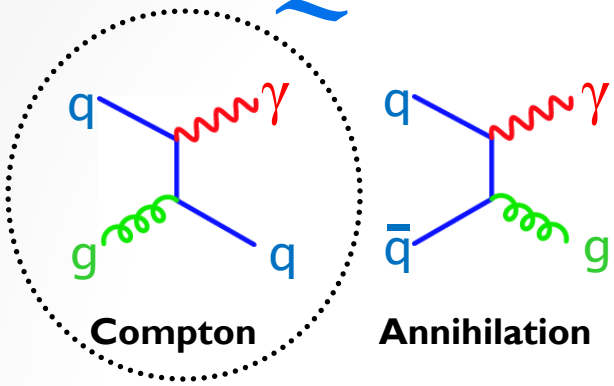
-There's a lot of interesting stuff at R > 0.8!

Also Keep in Mind

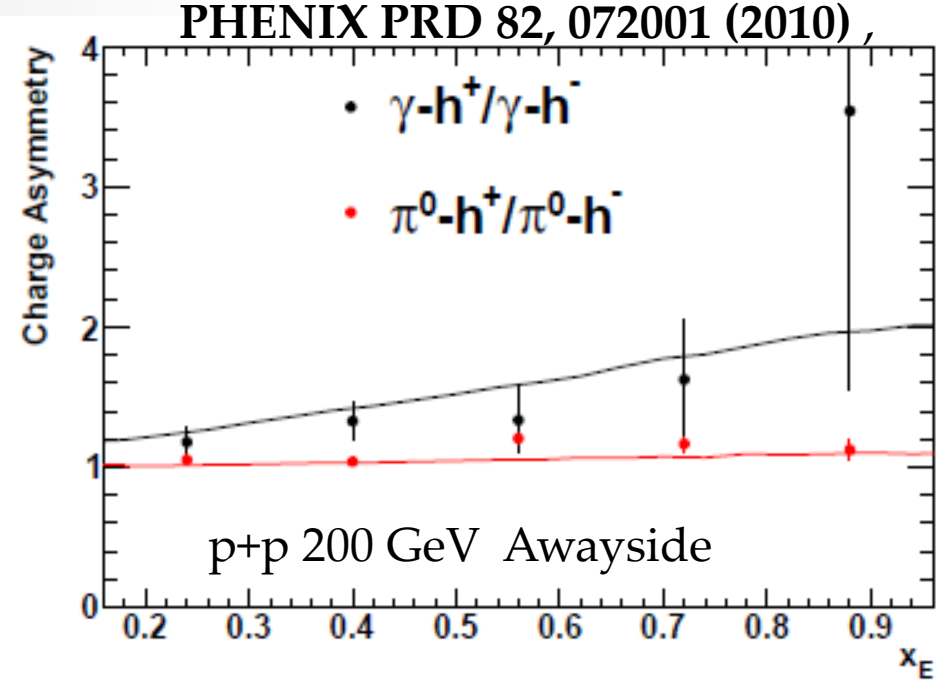
- Results dominated by $\langle p_T \rangle \sim 6$ GeV Jets with an RMS O(2GeV) due to k_T
  - < 2 X Lower Than STAR Jet-*h*
  - << than LHC Results
- No Isolation Cut applied: other photons sources: e.g. more fragmentation photons (Iso coming soon)



Correlations + "Jet"(γ) 2: Quark Tagging



PHENIX PRD 82, 072001 (2010) ,

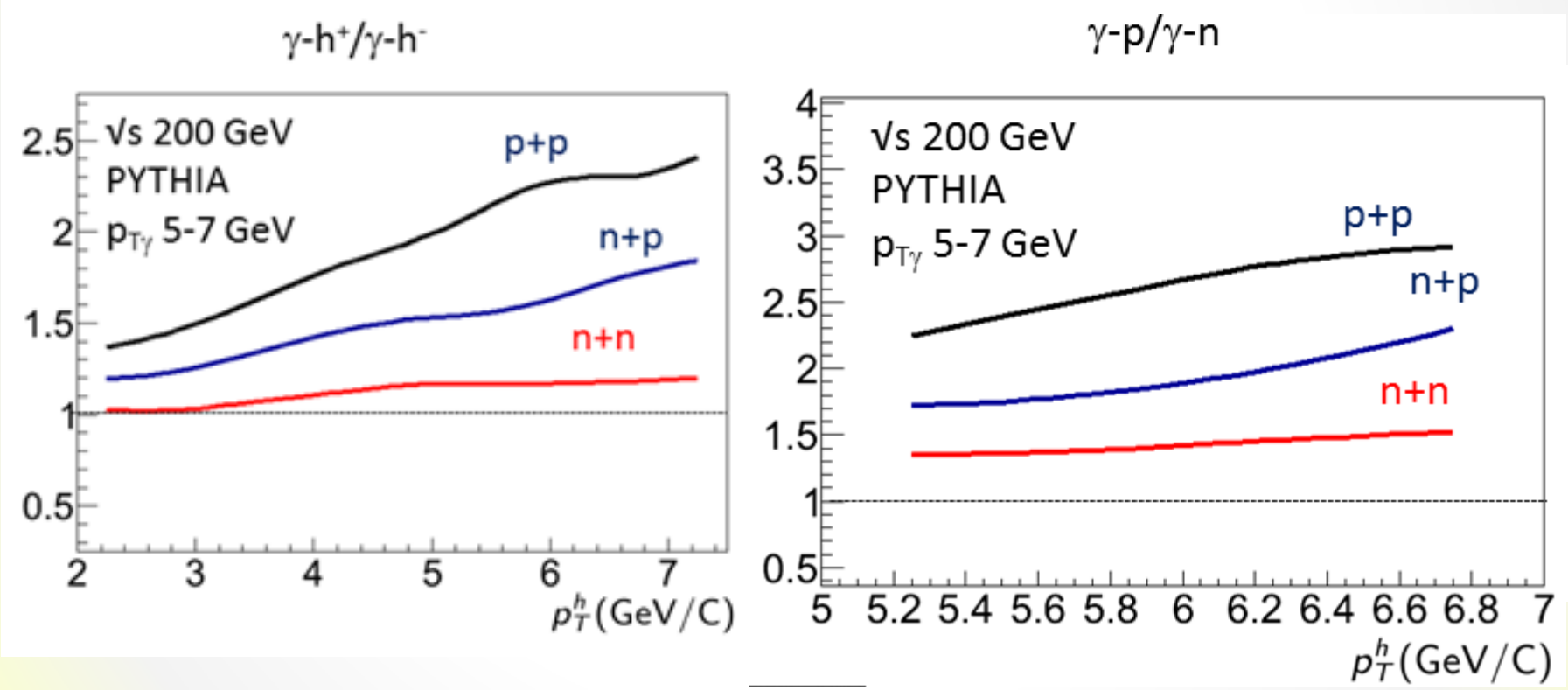


- In γ-h Compton scattering means **quark jet tag**
- Charge asymmetry of cross section and valence *u vs d* quark should be reflect in final state charged hadrons

SEEN IN p+p 2-p @ PHENIX
Allow q vs g Eloss study in AuAu

Charge Asymmetry

- Applying Iso Cut allows selection of Compton-- u, d quark counting should govern expected scale of asymmetry
  - o : $d\sigma \sim Z_q^2$ u:d → 8:1 p+p, A+A, d+Au : 4.7-6.2
- Assoc p vs n similar - independent



- How do these go together (d+A → p+A)?

Part 3 sPHENIX

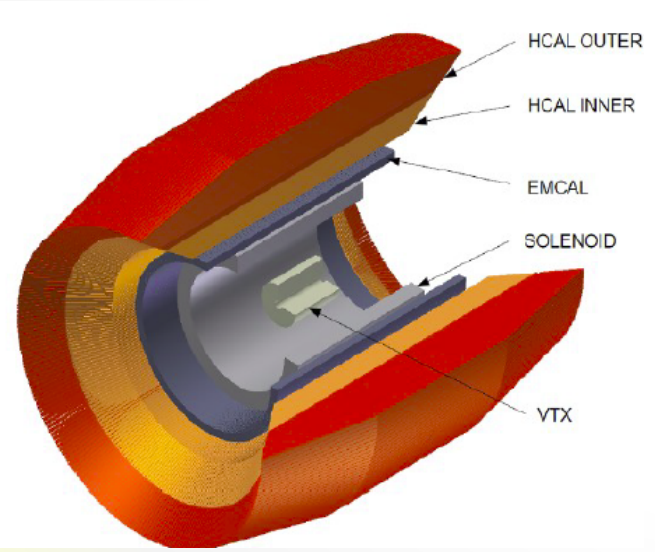
- How PHENIX can access jet finding tools…

http://w.000finance.com/

→ Coincidence?

sPHENIX

- Upgrade optimized around jet/di-jet/photon/HF measurements
- **Compact**, High rate, large **uniform** acceptance over $|\eta| < 1$
- Submitted by BNL to DOE for MIE CD-0 review in ~Feb
- Opportunity for detector building experience:
- Prototyping is already underway! Join us!



Inner Radius 70 cm
B = 2 T

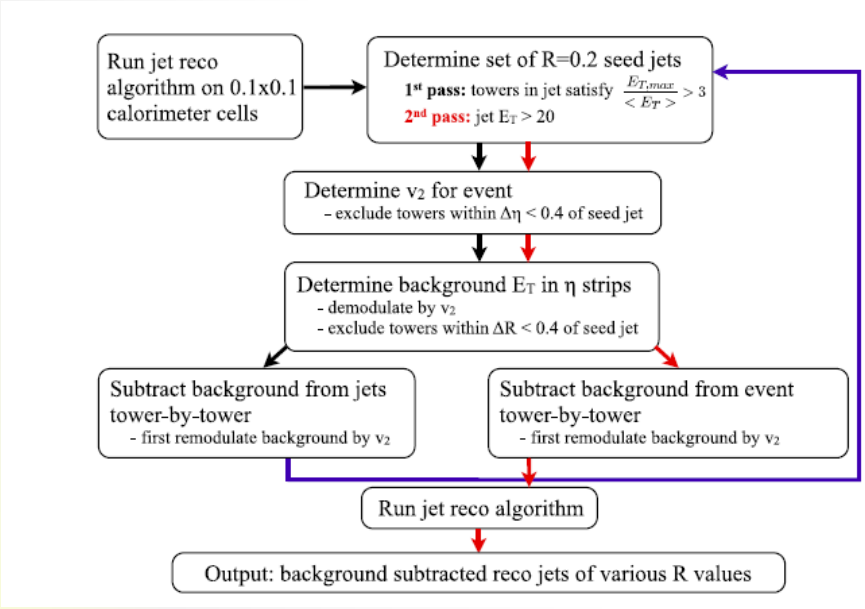
Fe-Scint Hcal Unique Design

Prototyping underway
(Previous Design Beam Tested Dec 2012) OHIO UNIVERSITY

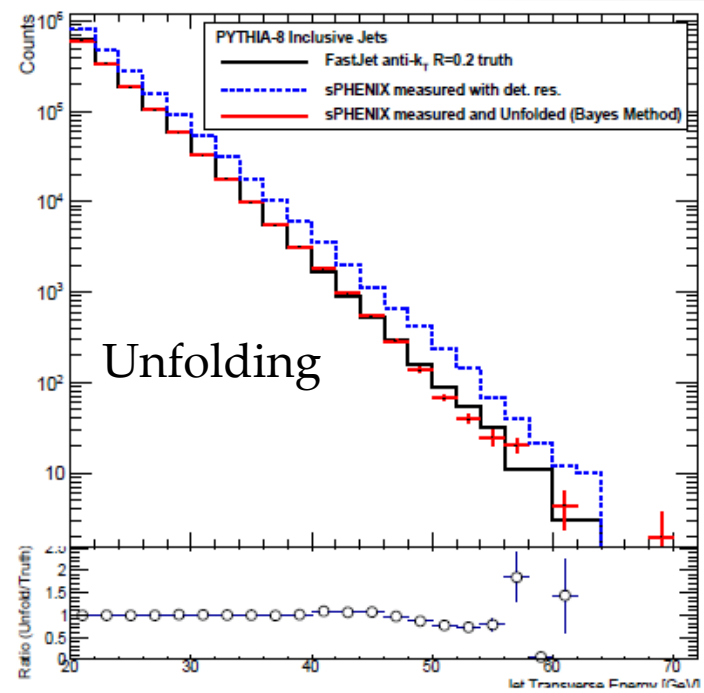
W-Sc EMCal – Accordion Design

sPHENIX MIE Proposal

- CD-0 DOE MIE Proposal: 60/120 pages: Generic RHIC Physics Discussion!
  - (A good read! link to mie pdf)
- The crucial physics offered by an LHC-like detector at RHIC using LHC-like Jet Reconstruction Methods

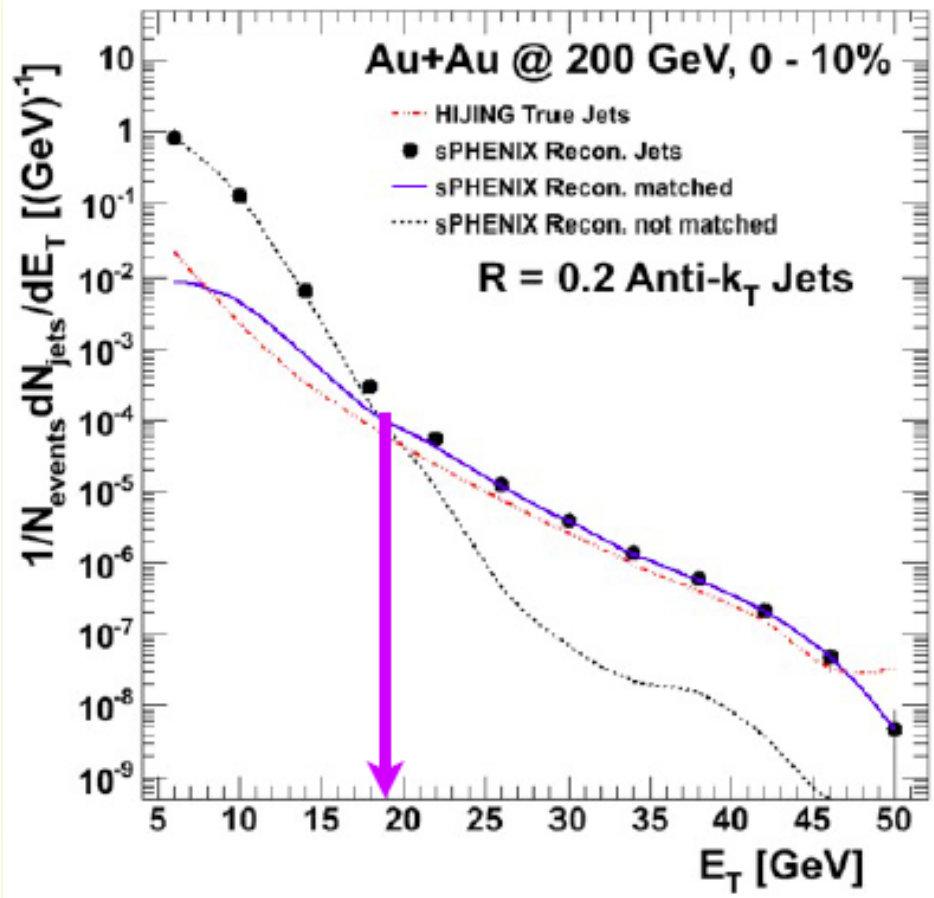


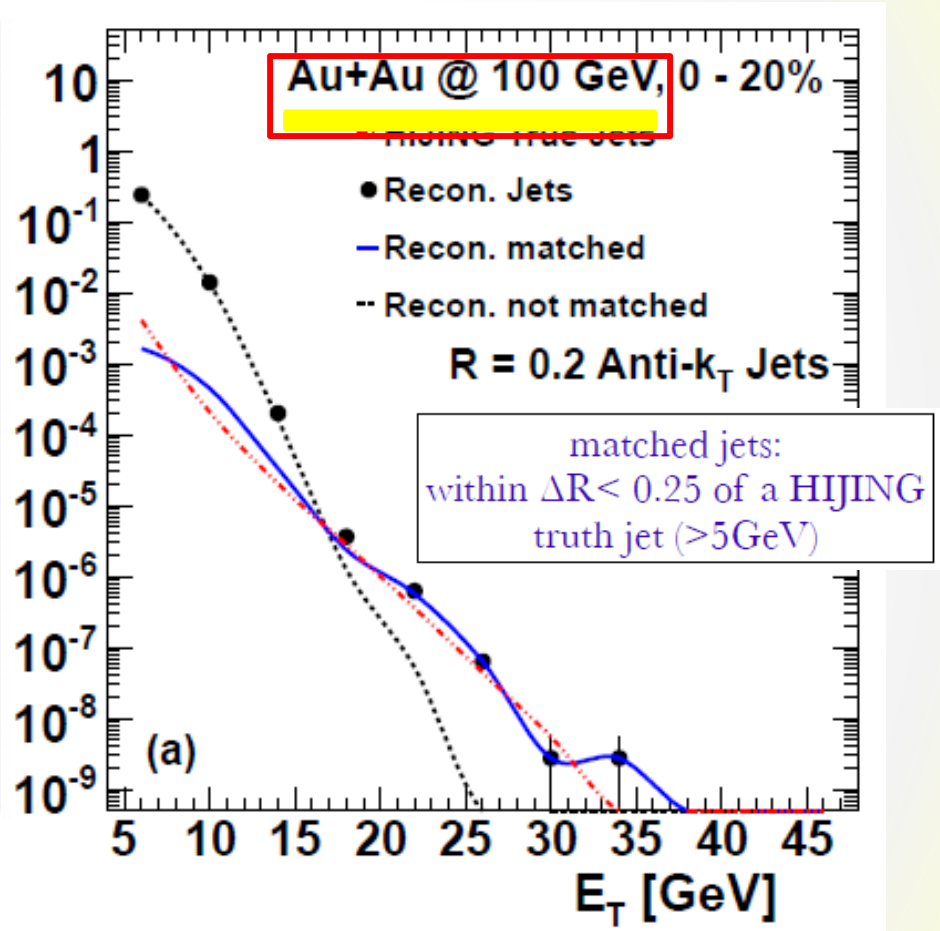
Bkg Subtraction



Possible "in Principle"?

- Too many Fake Jets? **NOPE!** Even at √s = 100 GeV

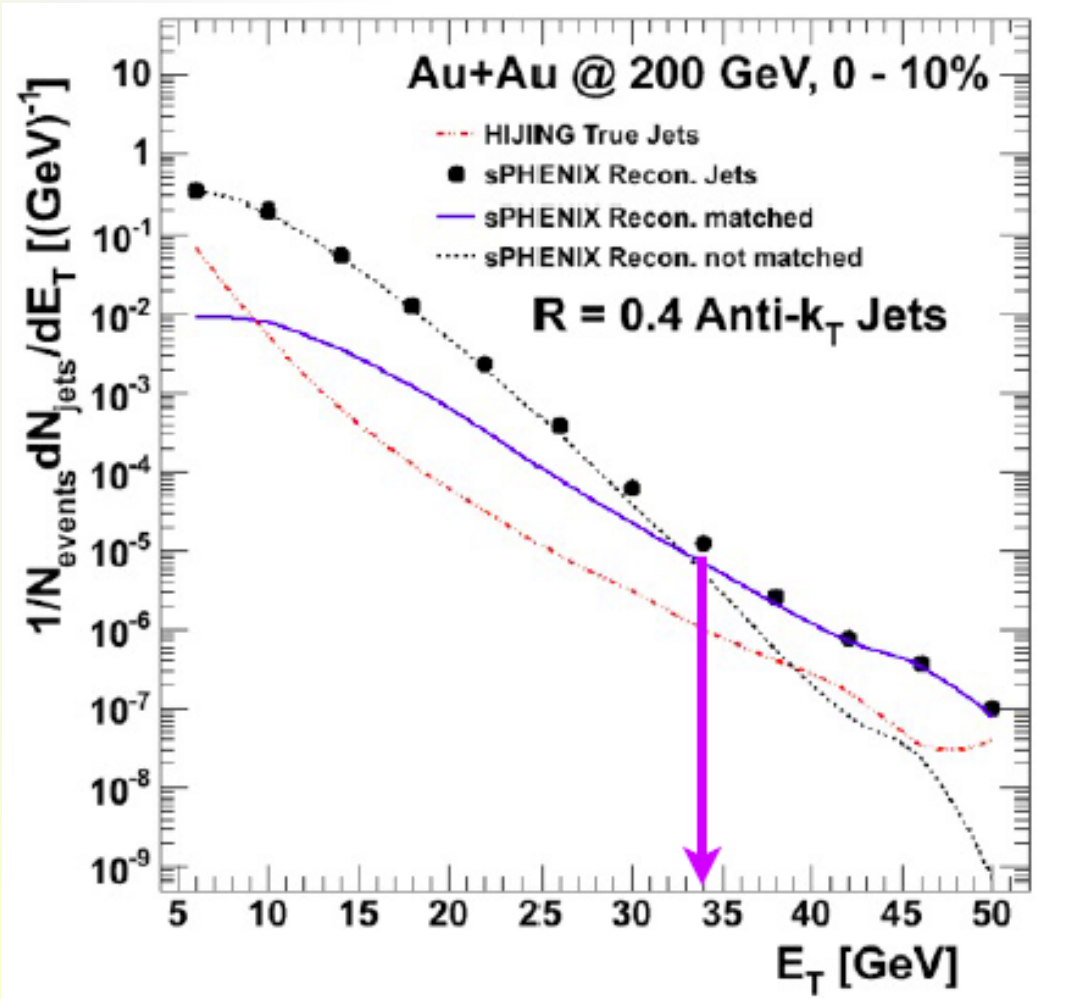


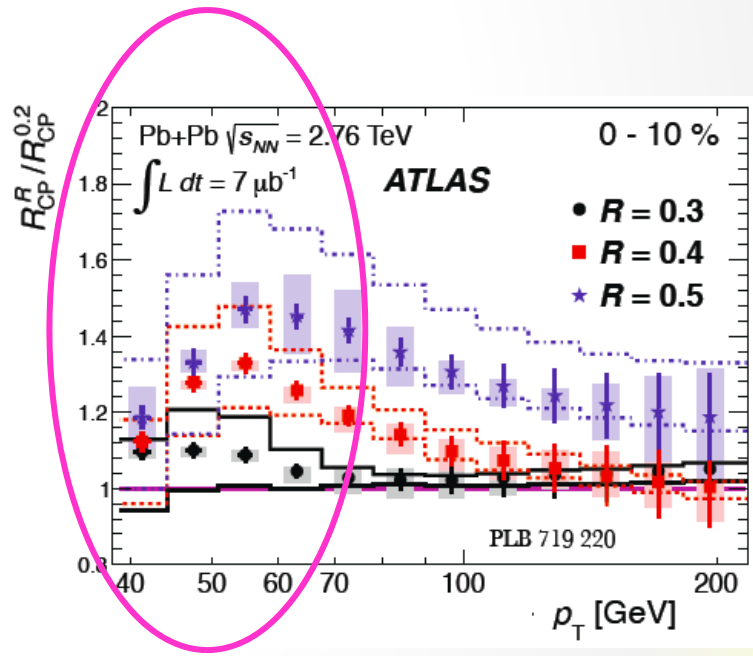


- -vs LHC: Lower underlying event wins over steeper production spectra for E > ~18 GeV
- **Lower E limited by stats not fake jets? (& stats good down to 100!)**

Larger Cone Sizes?

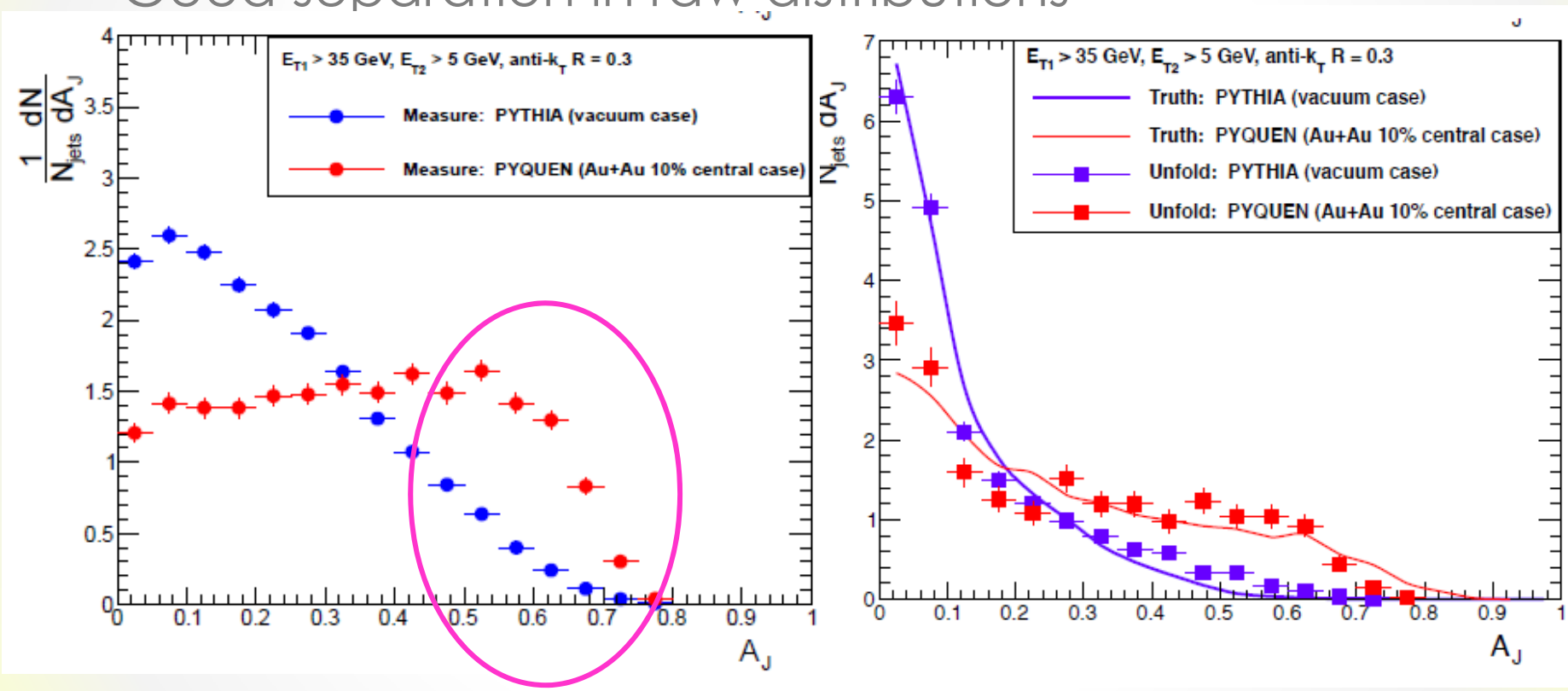
- Yes: baseline for 0.4: $E_{min\ from\ bkg}$ = 35 –> fake rejection should lower this
- LHC Interesting stuff at these cones, sPHENIX energies





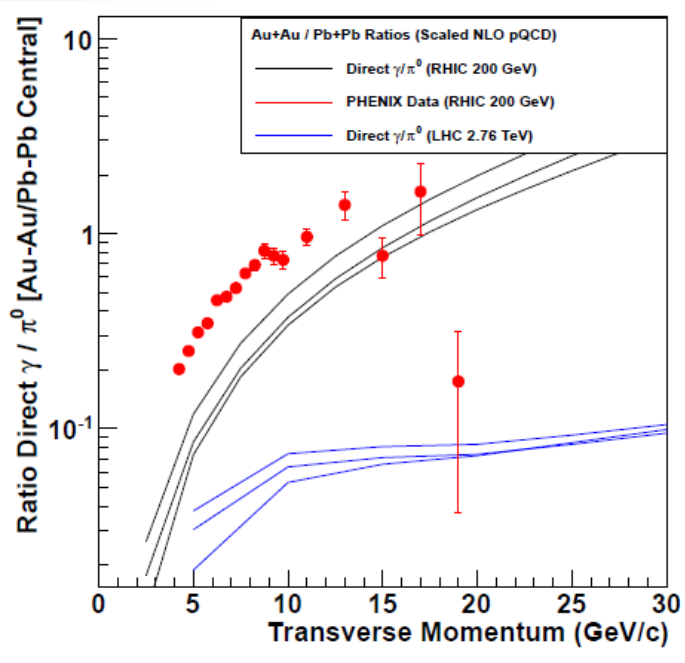
Event By Event Opportunities

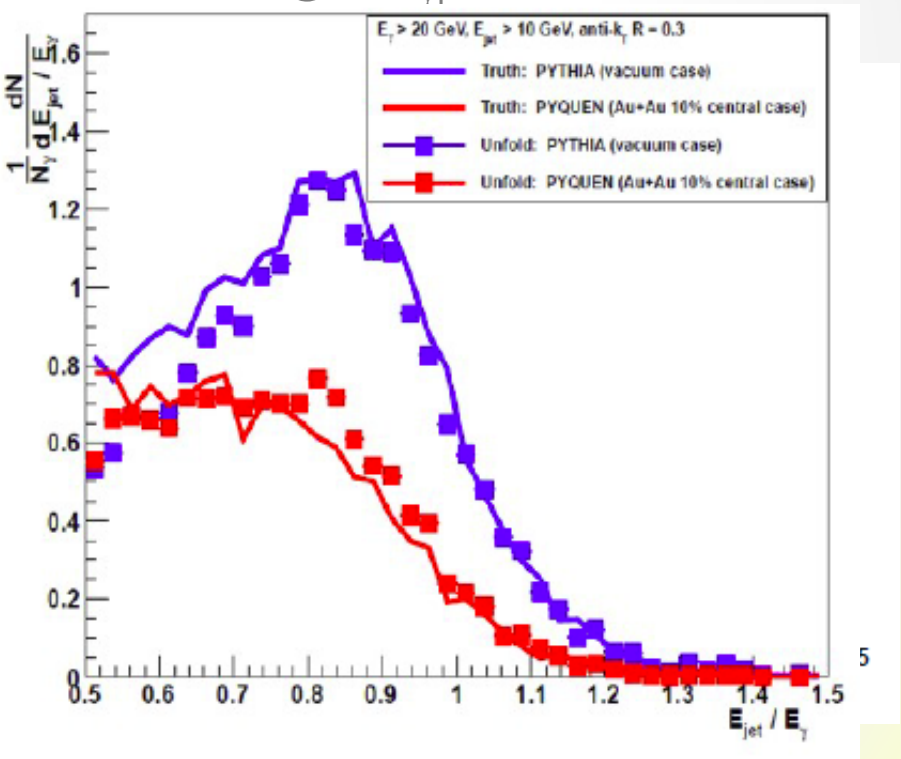
- Dijet A_J : 0-10 % HIJING Embedding—Unfolding procedure works well
- Good separation in raw distributions



γ-Jet in SPHENIX

- Access high stats…
- Clear Modification signal, comparable to current LHC Results
- Separation in raw distributions at large $x_{\gamma j}$

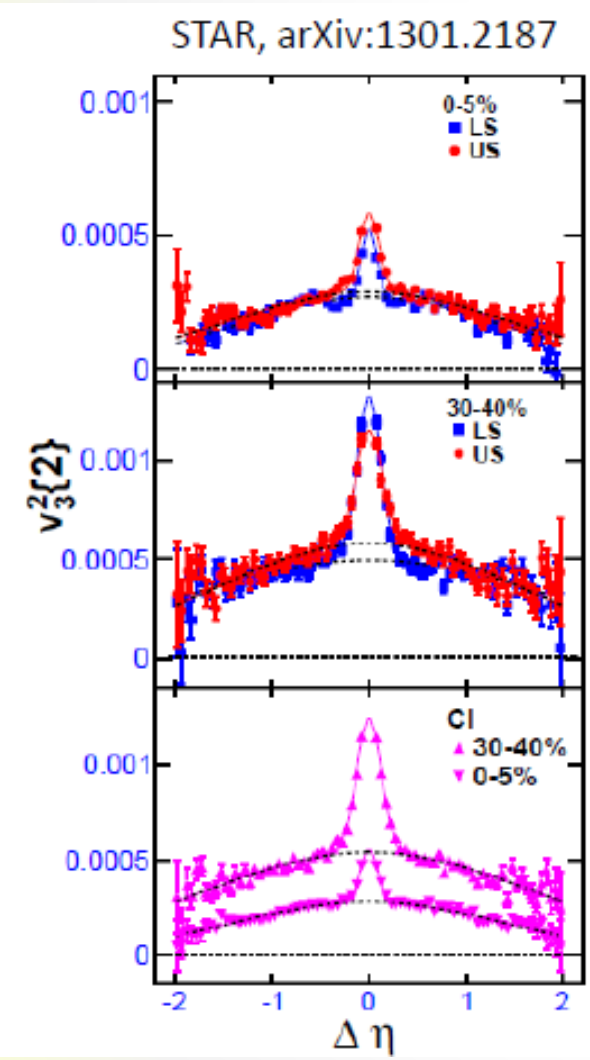




Back to Di-Hadron?

- The status of di-hadron correlations:

2-Particle Correlations

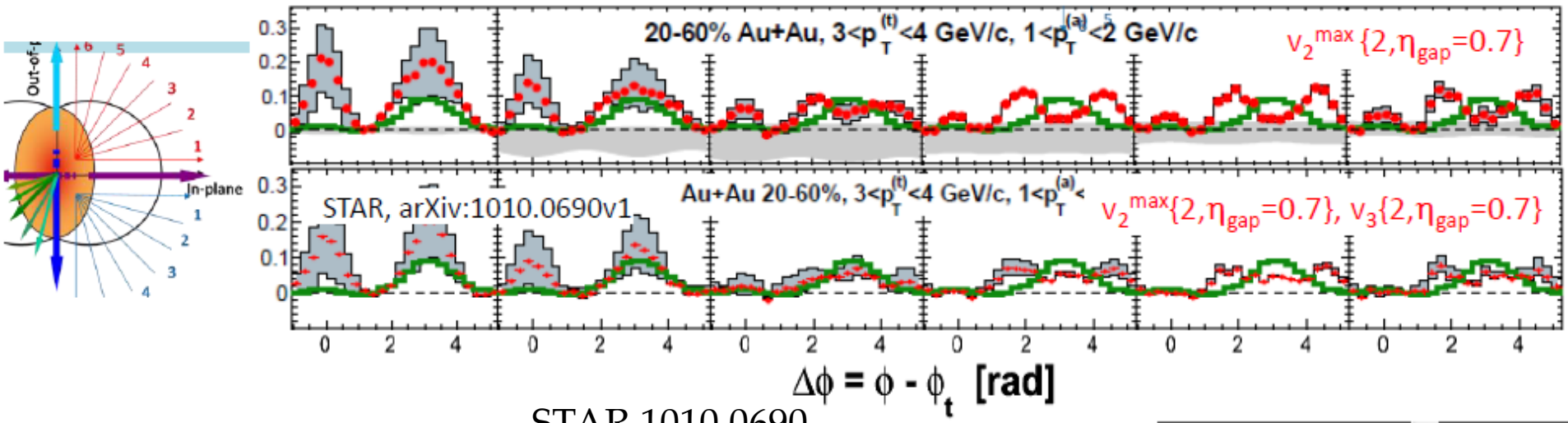


- Hadron-Hadron @ RHIC:
- Currently taking time off from jet quenching studies to understand medium and jet Medium
- Strategy : understand Jet Coupling to the Medium…
  - Short of that: systematics thereof?
- This effort continues at RHIC

- Example: 2-p vs Reaction Plane
- Quenching Shape vs RXNP! (Pretty important constraint on E_{loss} models —at least qualitative agreement is needed)

2-p vs Reaction Planes

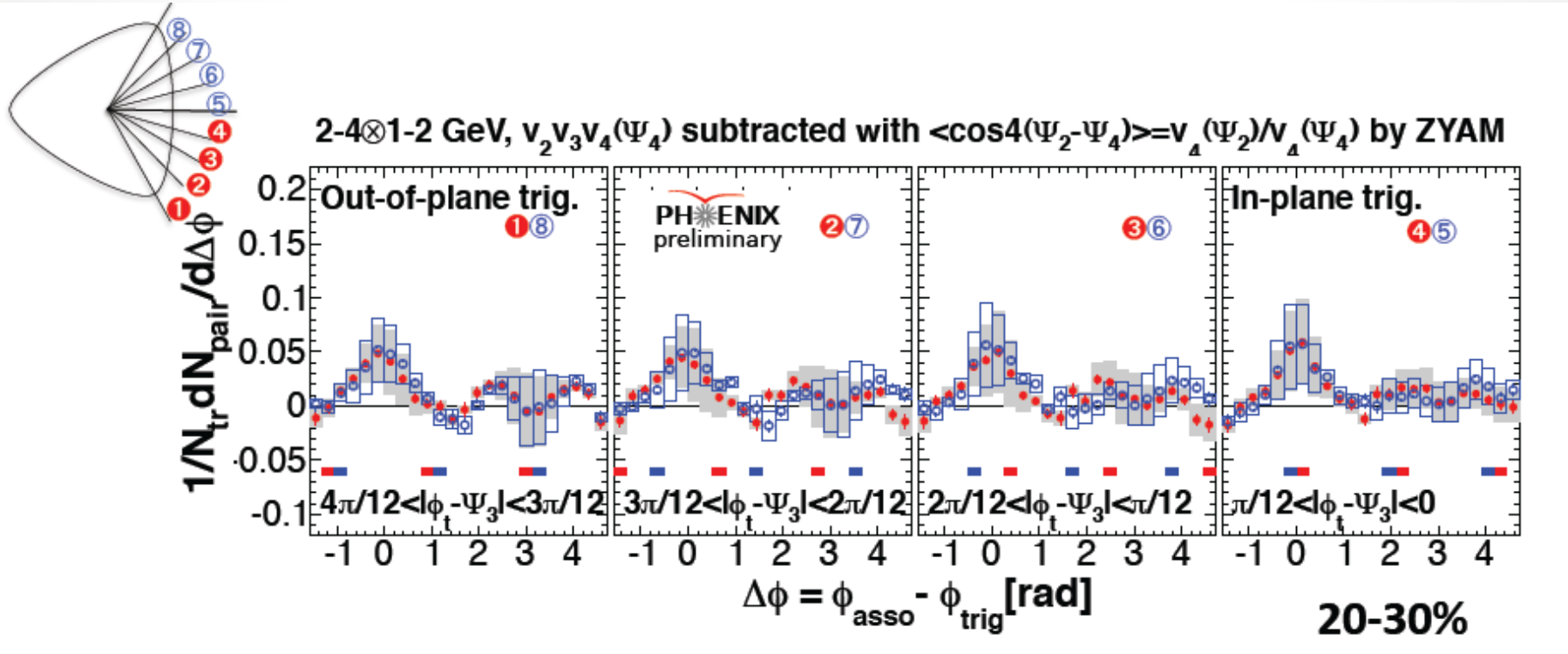
- Initial Measurements WITH FULL v_n subtractions need finalized? (Modulo experimental Q's)
- Theory still addressing fundamental q's about
- Headed for good convergence of Theory and Experiment in a few years? (Understand Init. State Fluctuations/Volume → Apply to quenching models



STAR 1010.0690

2-p vs n=3 Rxn Plane

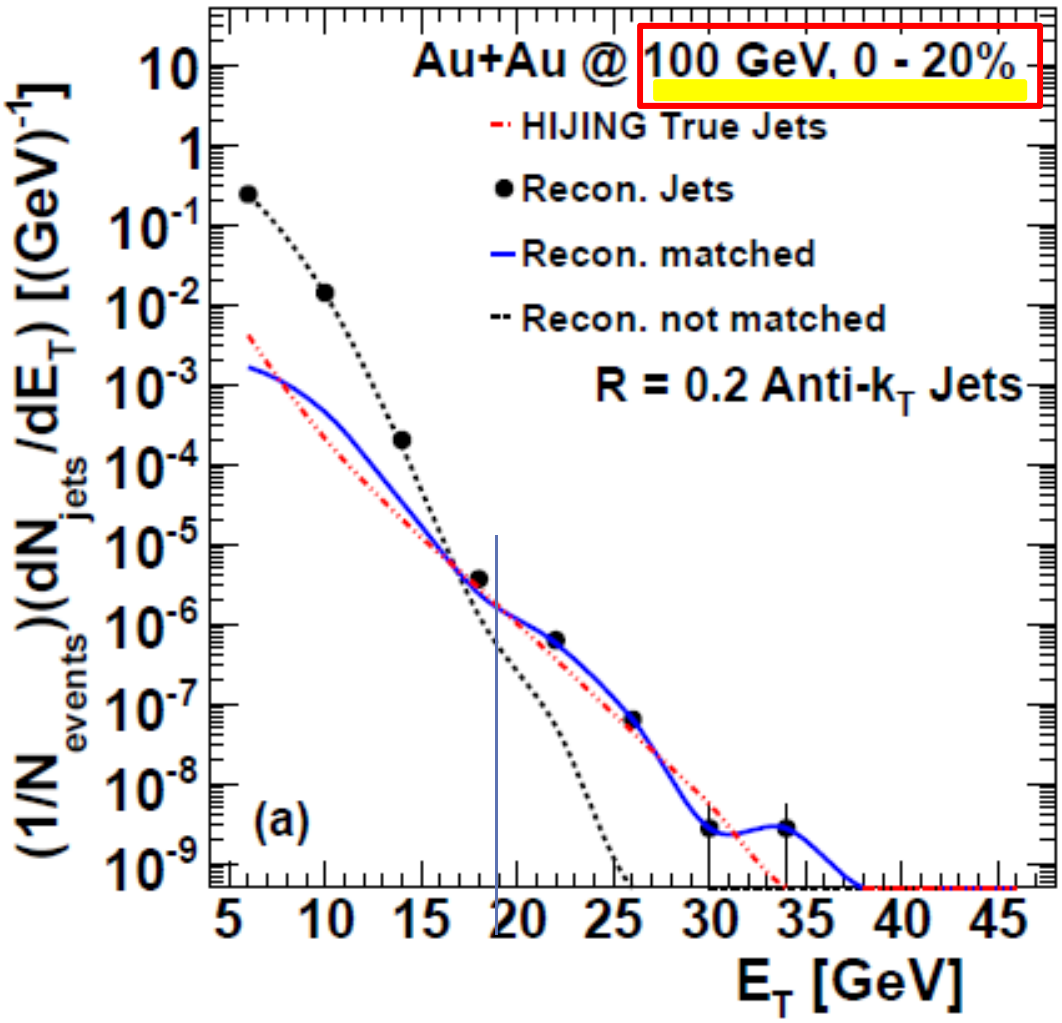
- Initial Measurements WITH FULL vn subtractions need finalized?
- Headed for good convergence of Theory and Experiment in Few Years?



Conclusions

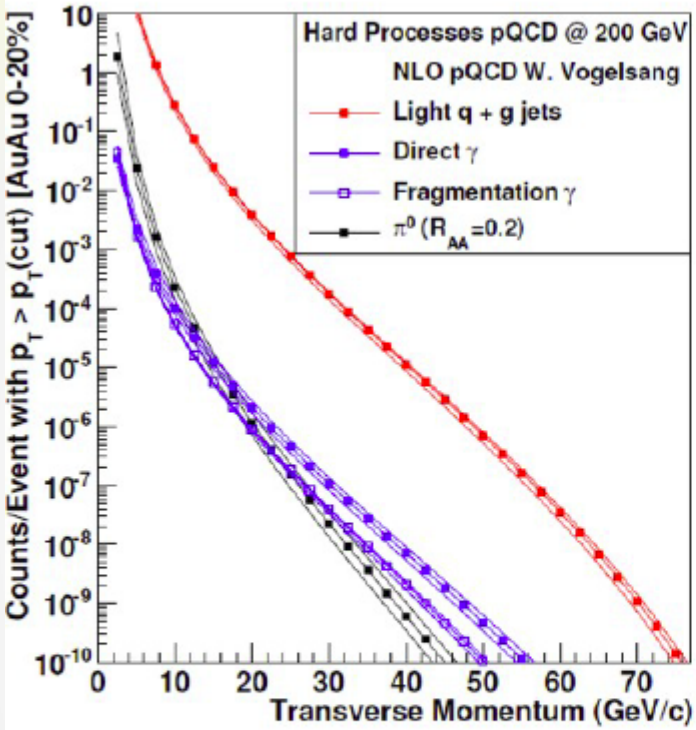
- Jet Quenching Studies at RHIC are and should exploit RHIC's Flexibility
- Spectra:
  - Both STAR and PHENIX have nice comprehensive spectral data that can be a nice starting point for finally understanding Cronin Effect
    - With sufficient theoretical interest!
  - RHIC spans the key energy range to do this uniquely!
- Two particle Correlations
  - Di-hadrons at intermediate p_T are focused on understanding medium/jet medium systematics, not so much quenching itself
  - Could this be largely resolved within a few years?
  - Direct γ-hadron and Jet-h and ARE important to quenching considerations NOW and shouldn't be disregarded because of bias in field towards pure jet reconstruction
- sPHENIX!
  - A powerful new detector to understand robust physics of jet quenching across 2 orders of magnitude in $\sqrt{s}$ at RHIC and the LHC

sPHENIX @ √s 100 GeV?



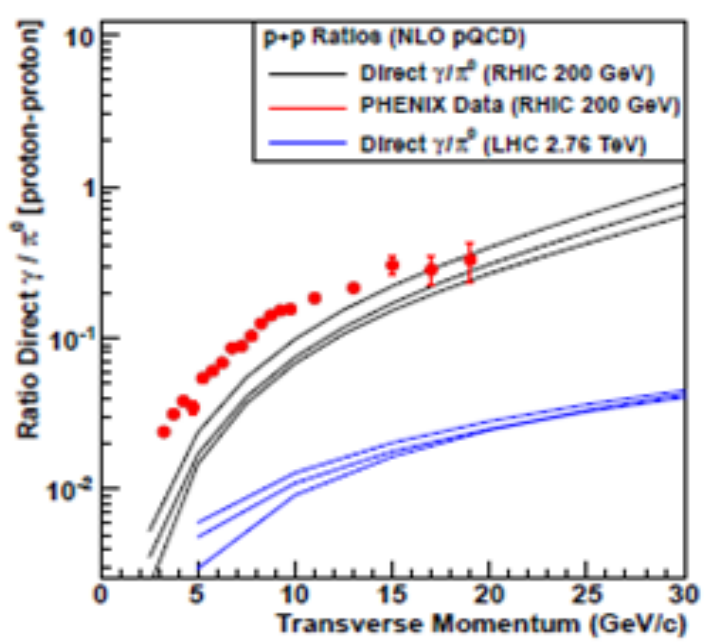
- fake-jet dominance subsides at ~same E
- Lower UE wins again!
- Stats > 20 GeV ~1/50 compared to 200
- Still 10^5-10^6 Jets > 20
- **Even Lower E limited by stats not fake jets?**
- How would this addt'l factor of 2 in √s leverage for theory ?

sPHENIX: u & d-jet "tagger"



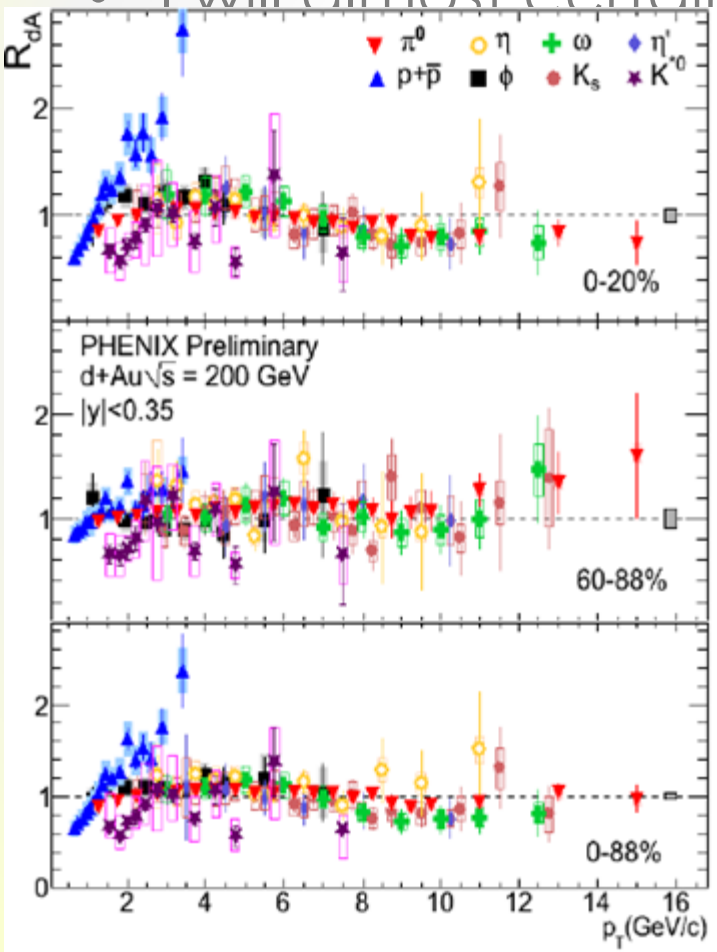
rates based on full stochastic cooling, but no additional accelerator upgrades

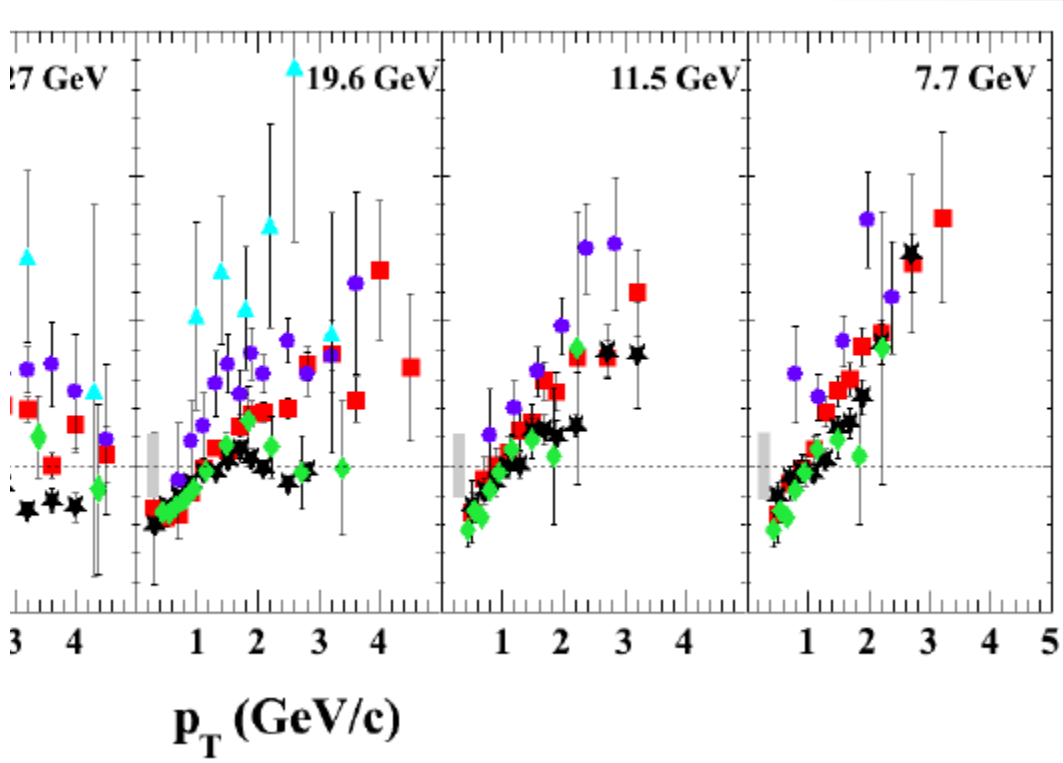
	Au+Au (central 20%)	p+p	d+Au
>20GeV	10^7 jets 10^4 photons	10^6 jets 10^3 photons	10^7 jets 10^4 photons
>30GeV	10^6 jets 10^3 photons	10^5 jets 10^2 photons	10^6 jets 10^3 photons
>40GeV	10^5 jets	10^4 jets	10^5 jets
>50GeV	10^4 jets	10^3 jets	10^4 jets



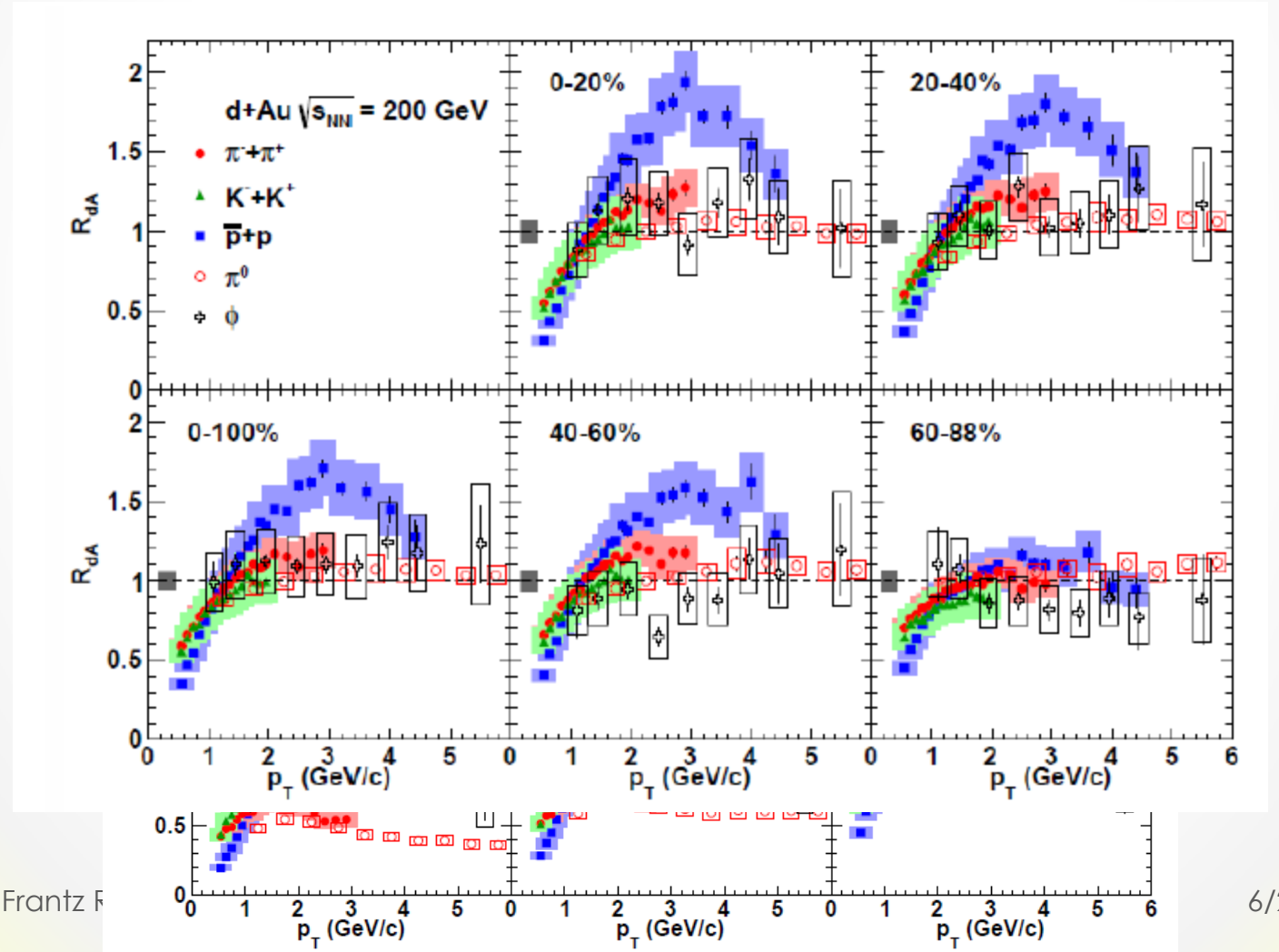
Cronin Mass Effect Strangeness?

- I will almost certainfl

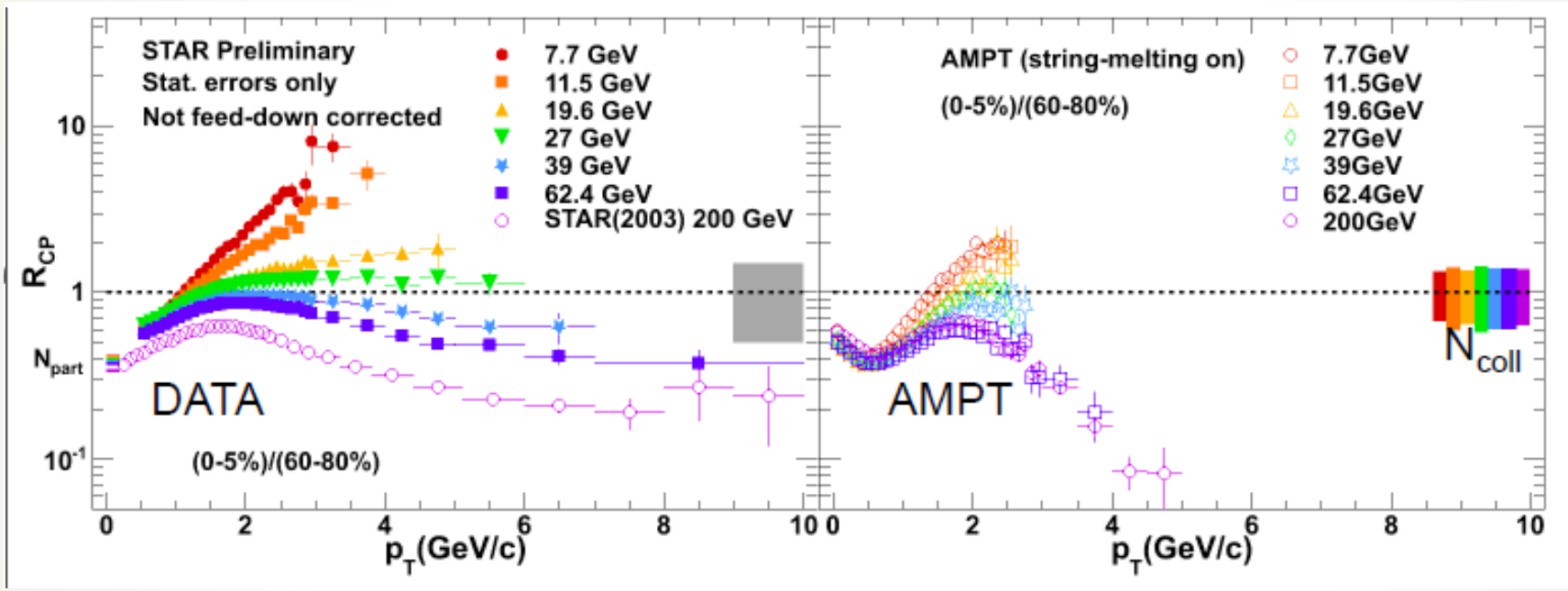




Cronin Mass Effect Strangeness



How do the models compare?

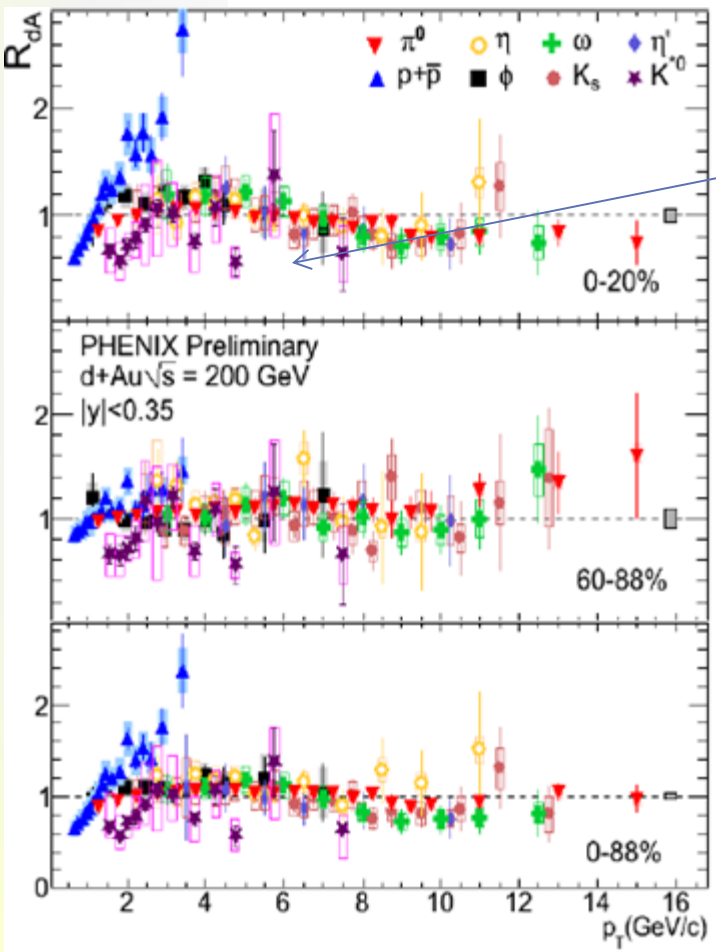


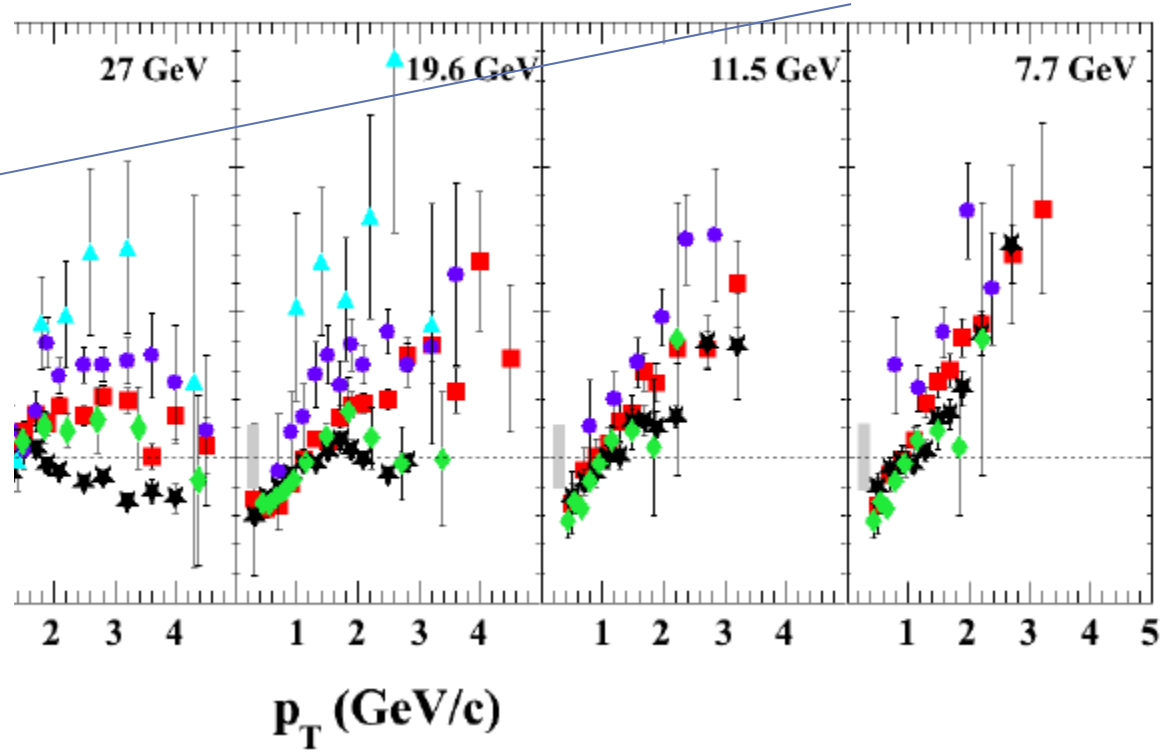
- Models get some qualitative features right but are all over the map--affected a lot by hadronization
- Use other hard observables (e.g. open HF) at higher √s's (talks yesterday p+A pre-workshop)

Cronin Mass Effect Strangeness?

- I will almost certainly skip combine with next

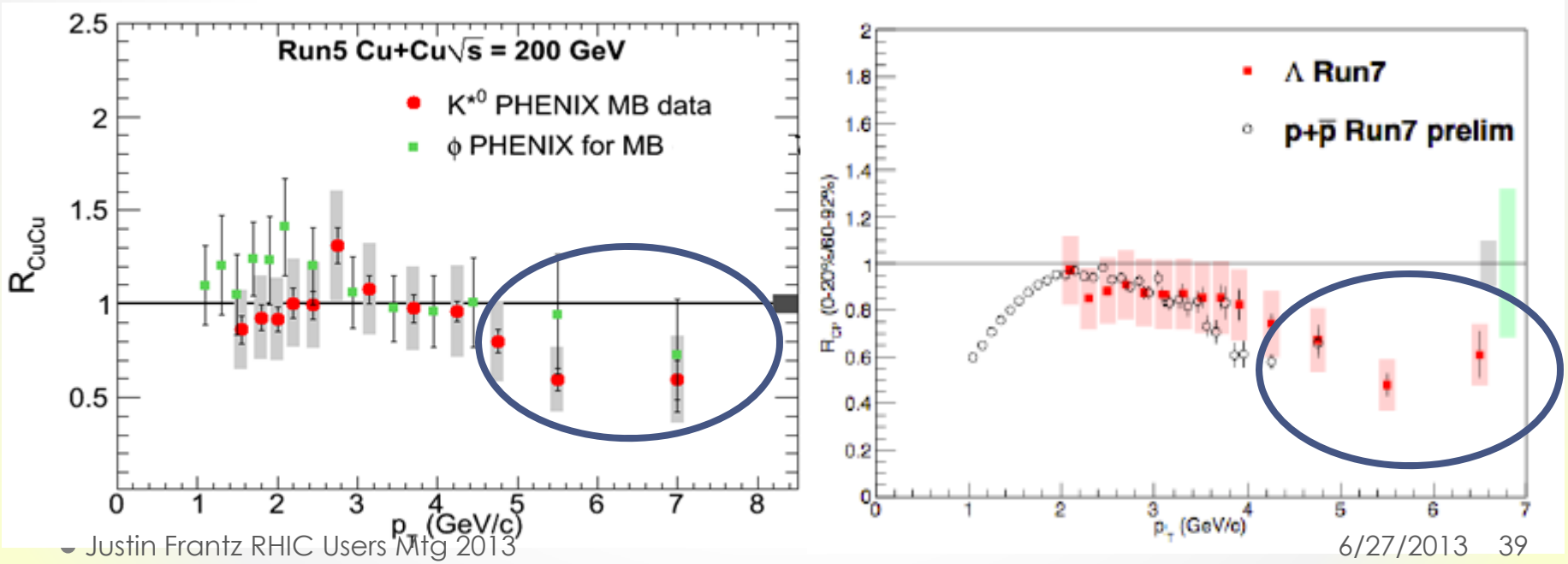
p+p reference!





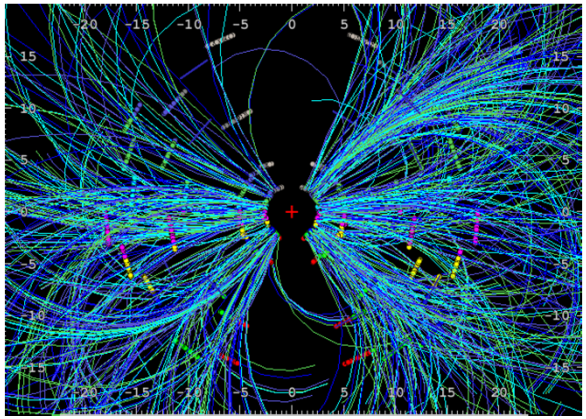
Don't forget Geometry Axis!!!

- Geometries Cu+Au U+U
- See Talks by Aneta, Jeff

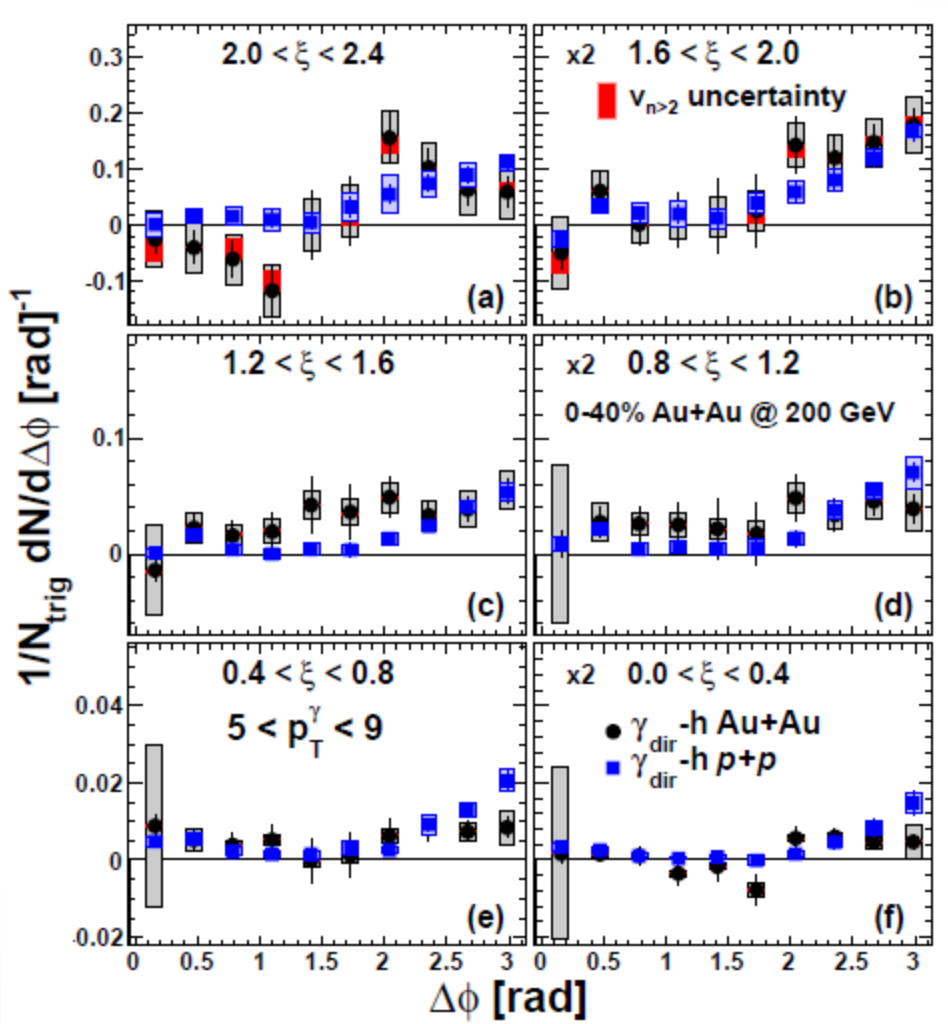


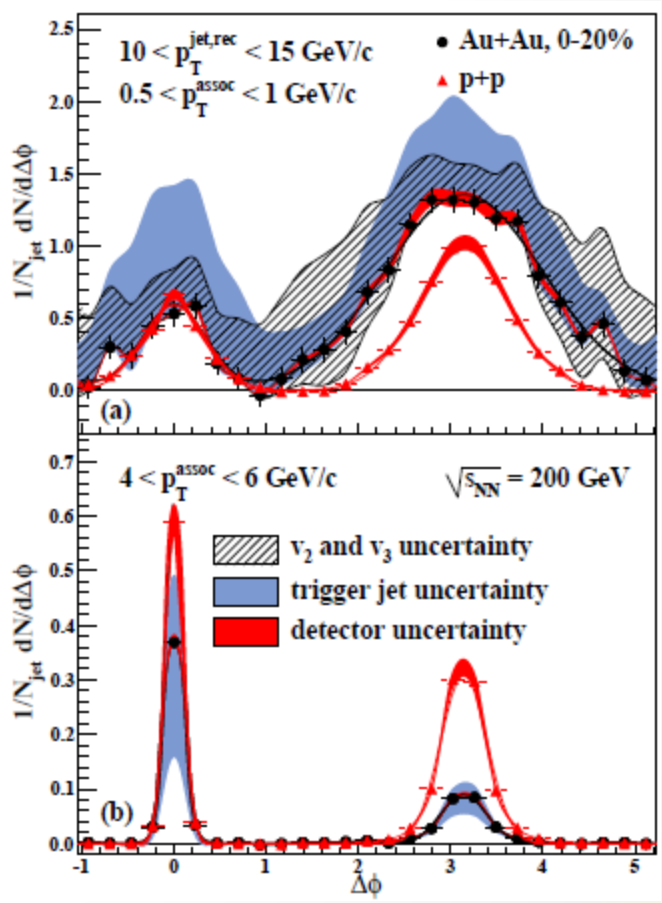
What's on the ~2-yr horizon for PHENIX γ-jet

- Run 11/14 VTX installed : 10 x stats (acceptance) for γ-jet associated hadron acceptance ~
- And ~3 x Integrated Lumi Run 7/10 Current Result



- Isolation cut in Au+Au analysis well underway
  - Should improve precision in peripheral collisions→ towards centrality dependence of enhancement


2.0 < ξ < 2.4
x2 1.6 < ξ < 2.0
v_{n>2} uncertainty
1.2 < ξ < 1.6
x2 0.8 < ξ < 1.2
0-40% Au+Au @ 200 GeV
0.4 < ξ < 0.8
5 < p_T^γ < 9
x2 0.0 < ξ < 0.4
γ_dir-h Au+Au
γ_dir-h p+p
(a)
(b)
(c)
(d)
(e)
(f)
1/N_trig dN/dΔφ [rad]^-1
Δφ [rad]


$10 < p_T^{jet,rec} < 15$ GeV/c
$0.5 < p_T^{assoc} < 1$ GeV/c
Au+Au, 0-20%
p+p
(a)
$4 < p_T^{assoc} < 6$ GeV/c
$\sqrt{s_{NN}} = 200$ GeV
v_2 and v_3 uncertainty
trigger jet uncertainty
detector uncertainty
(b)
$1/N_{jet}\ dN/d\Delta\phi$
$\Delta\phi$