Two-Particle Correlations with π^0 and Direct Photon Triggers

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Thesis Defense

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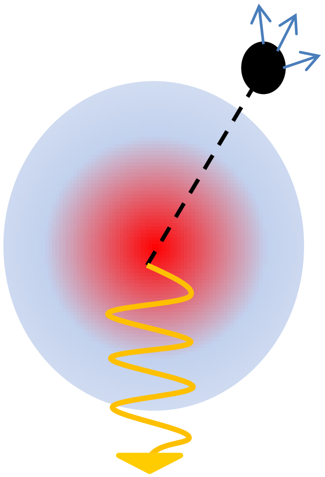
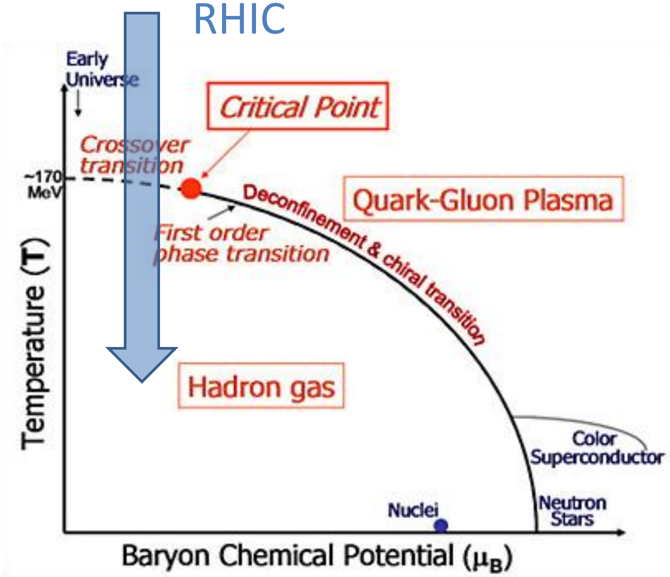
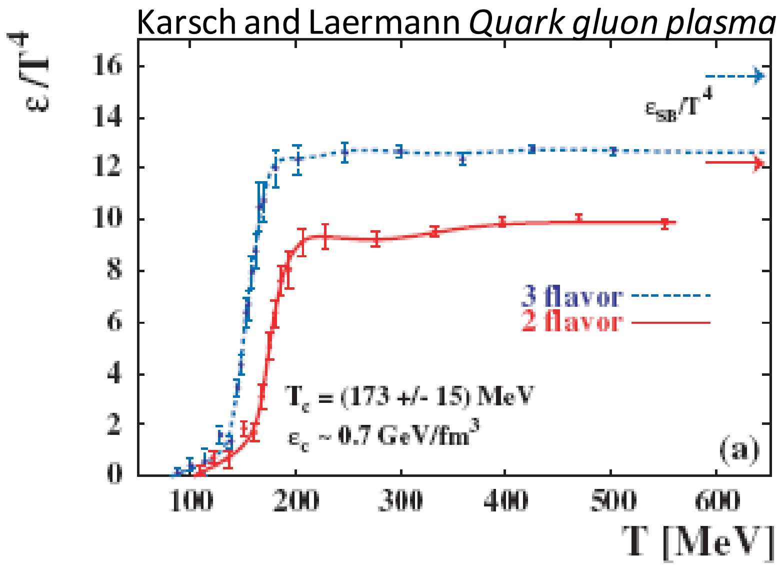
Overview

- Introduction
  - QGP, PHENIX, etc.
  - Measuring parton energy loss with two-particle correlations
  - Direct photons in elementary and HI collisions
- Analysis
  - Direct γ correlation subtraction methods
  - Hard scattering kinematics and observables
- Correlation Results
  - Nuclear effects
    - Constraints on near-side production
    - Suppression of back-to-back correlations
    - Comparison to other constraints on parton energy loss
  - Vacuum QCD effects
    - k_T effect in γ correlations
    - γ correlations as a quark jet tag
    - Measuring the FF's with γ and π^0 triggered correlations
- Conclusions



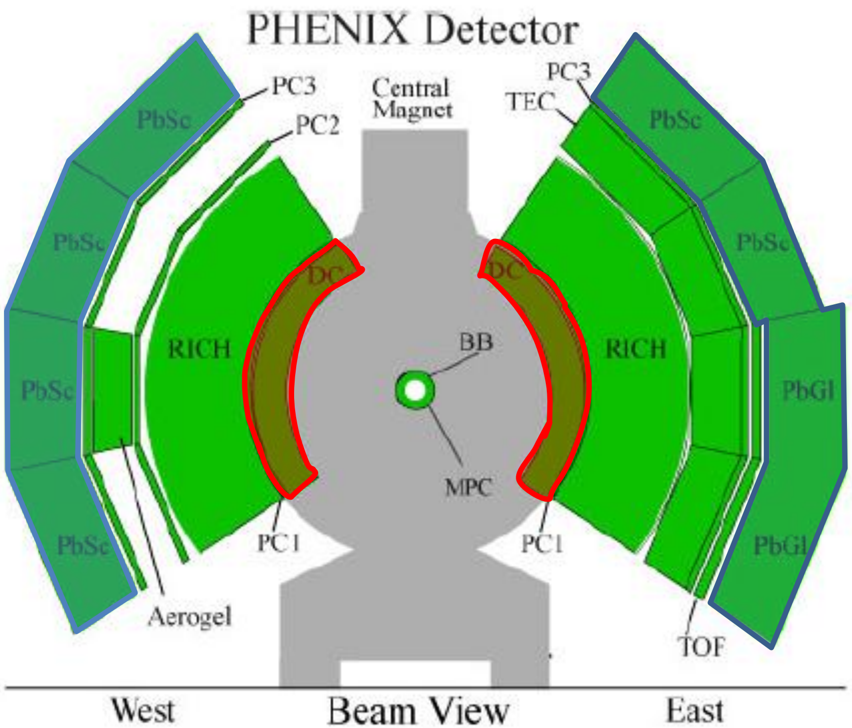
The QCD phase diagram





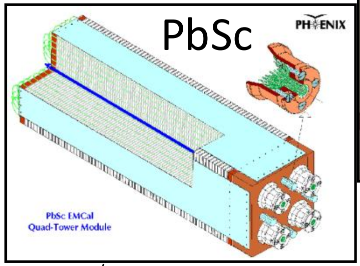
- Based on asymptotic freedom, expect deconfinement at high T/density
- Expect same conditions in early universe / neutron stars
- Lattice calculations indicate phase transition @ ~ 170 MeV
- However, ε/T^4 does not saturate the Boltzmann limit → not an ideal gas
- No evidence for 1st order phase transition: No smoking gun
- QGP expected to be highly opaque to colored objects → jet quenching
- Can use correlations of high p_T particles to map out the medium

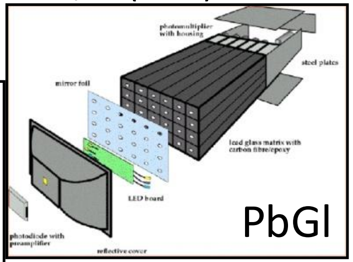
PHENIX



Electromagnetic Calorimetry

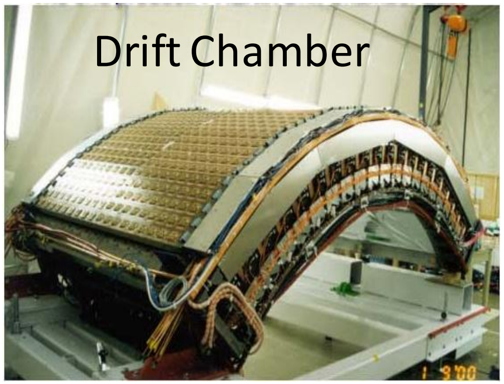
$5.9/\sqrt{E(\text{GeV})} \oplus 0.8\,\%$





$8.1/\sqrt{E(\text{GeV})} \oplus 2.1\,\%$

Central Tracking: Drift Charmber and Pad Chambers



$dp/p \approx 0.7 \otimes 1.0\% p$ (GeV/c)

Other detectors used:

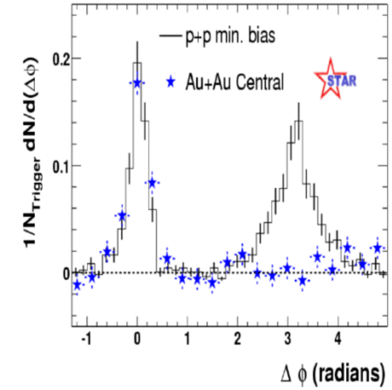
- BBC: triggering, centrality determination
- ZDC: centrality
- RICH: electron veto by Chrenkov radiation
- TOF: Identify hadrons by time-of-flight

The modified Jet Landscape

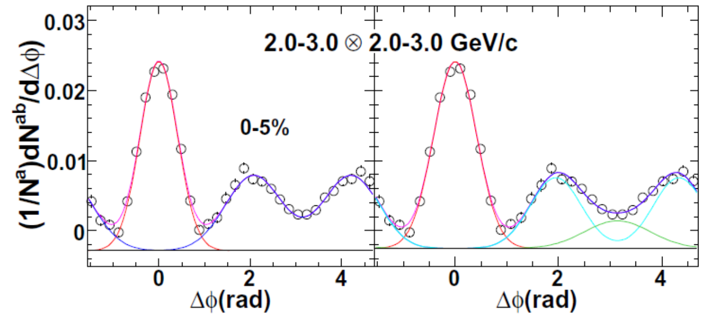
- What was expected:
  - Partons would lose some energy and fragment as normal (effectively modified FF's)

$$D'(z) = D\left(\frac{z}{1-\Delta E/E}\right)$$

  - Jets would interact and emerge wider (k_T broadening)
- Instead:
  - Away-side jet disappeared entirely
  - Missing energy showed up at low p_T as a very non jet-like medium response
    - A "cone" in $\Delta\phi$
    - A "ridge"in $\Delta\eta$
  - Jets reappear at high p_T



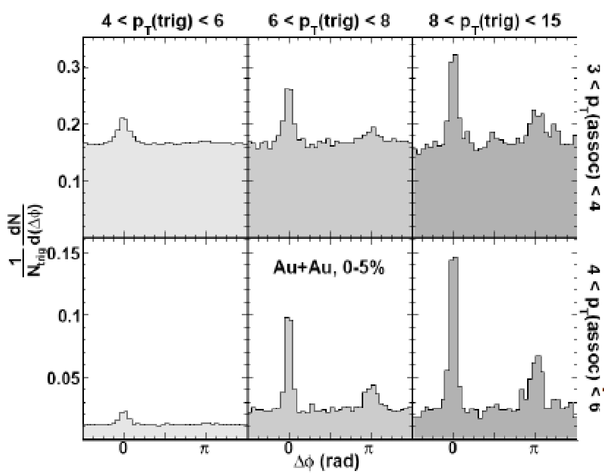
STAR PRL 90, 082302 (2002)



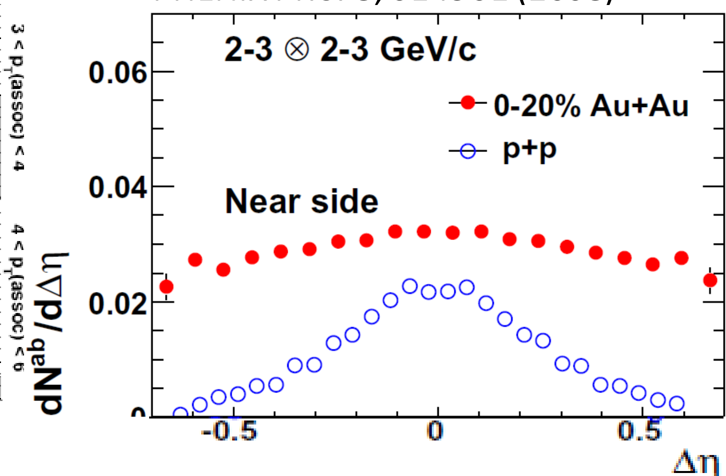
PHENIX PRC78, 014901 (2008)

Open questions:

- Are observed away-side jet correlations "punch-through" or are they produced at the surface?
- Are the ridge and the cone two aspects of the same phenomenon? A bell is a cup until it is struck.



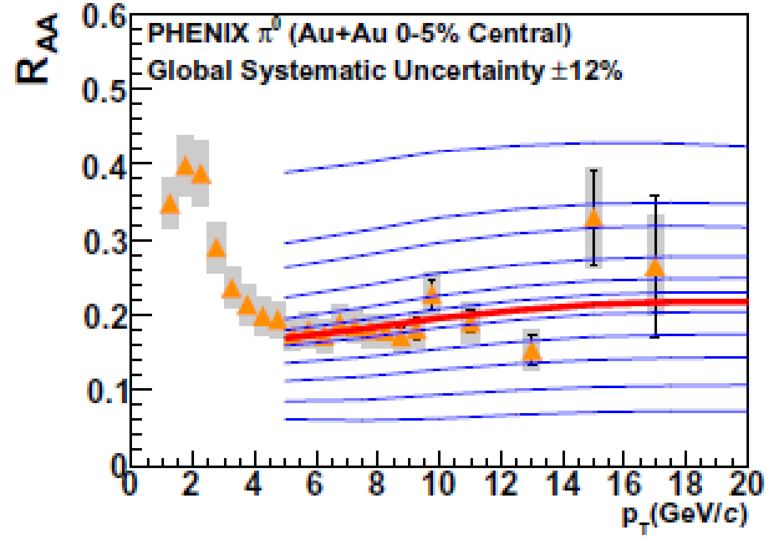
STAR PRL 97, 162301 (2006)



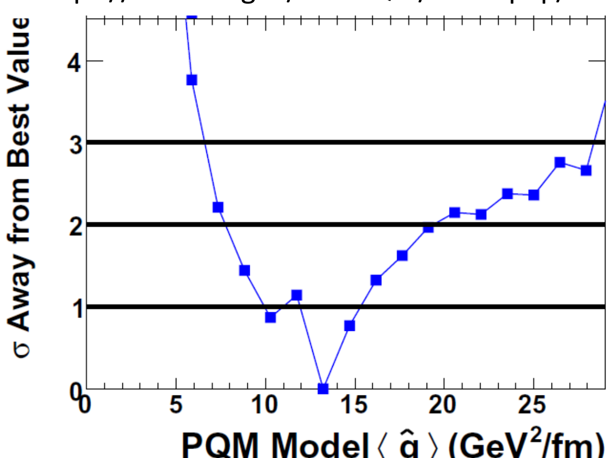
Parton Energy Loss

- Several models on the market
- Compare R_{AA} to several models of parton energy loss
- Two original models give limiting behavior
  - GLV: Few hard scatterings (thin medium)
  - BDMPS: Multiple soft scatterings (thick medium)
- Not yet consensus on relationship between observed suppression and properties of the medium. Are we probing the medium or the model?
- R_{AA} alone can't tell us, need additional constraints.

PHENIX Phys.Rev.C77:064907,2008



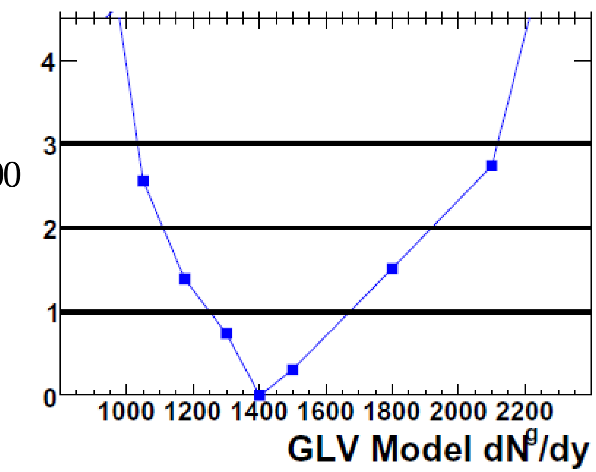
For the latest in parton Eloss see:
https://wiki.bnl.gov/TECHQM/index.php/Main_Page



=(BDMPS based)

$$\langle \hat{q} \rangle = 10 \text{ GeV}^2/\text{fm} \overset{?}{\leftrightarrow} \frac{dN^g}{dy} \approx 1800$$

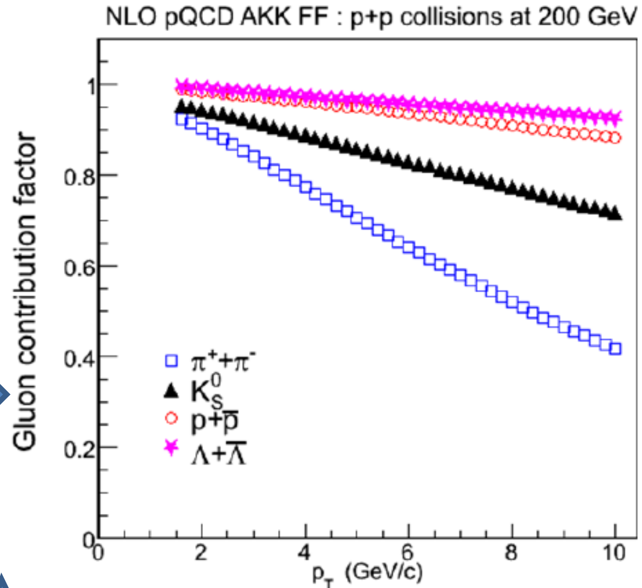
Estimate from:
Wiedemann
Hard Probes 2006

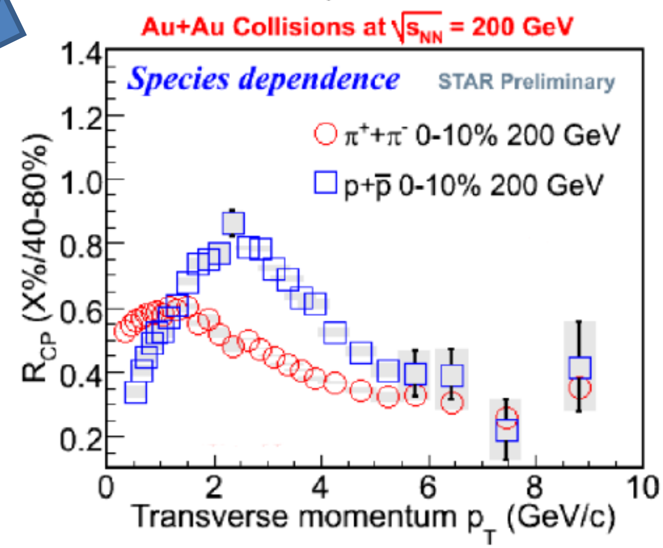


Flavor Dependence of E-loss

<u>A mystery: Flavor Dependence</u>

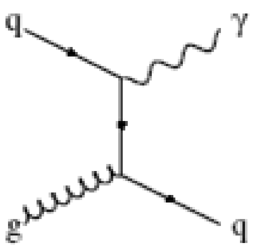
- From color factor expect 9/4 more energy loss for gluon jets
- So far no evidence
- Frequent claim: Protons come from gluon jets (AKK '05)
- If so, why don't we see less proton than pions at high p_T?
- 3 possibilities:
  - Both quarks and gluons always lose all their energy
  - Flavor conversion by rescattering
  - All protons don't come from pions!
- It would be useful to have a less ambiguous tag of parton flavor



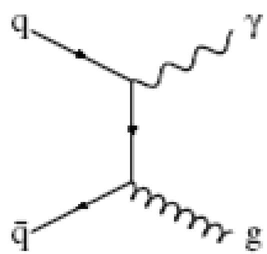


STAR PRL97, 152301 (2006)

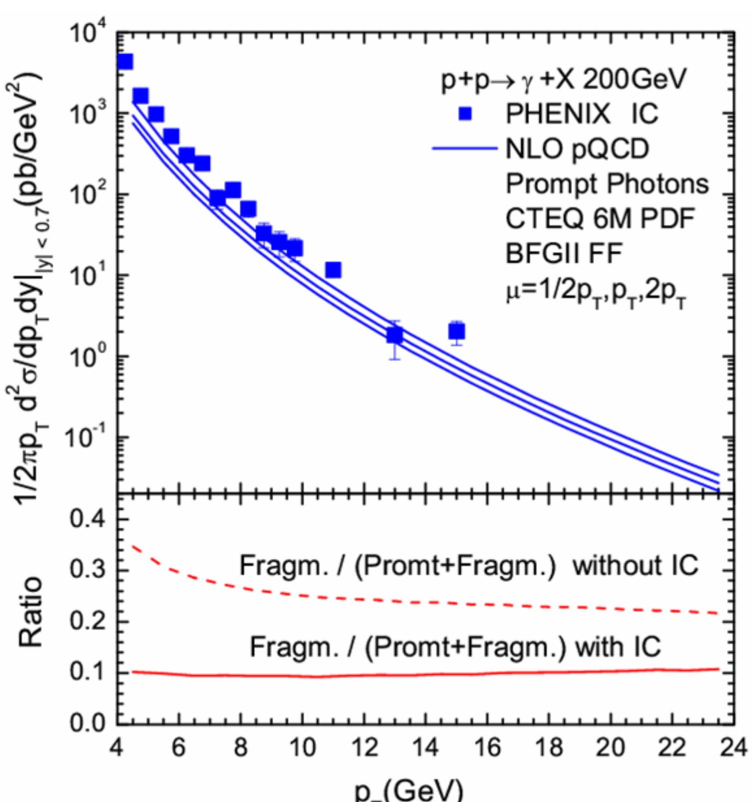
'Direct' Photons



Compton



Annihilation



H-Z Zhang, ATHIC 2008

At Leading Order

- Compton scattering dominant
  - Probe the gluon distribution
  - Usually (up) quark jets

  → use to study quark E-loss in Au+Au
- Exactly balance momentum of recoil jet + transparent to medium

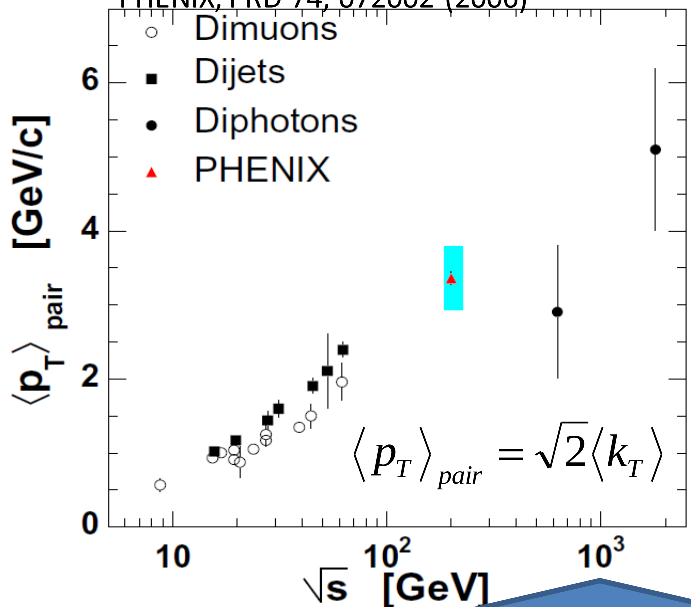
  → Initial energy of away-side parton known

Beyond Leading Order

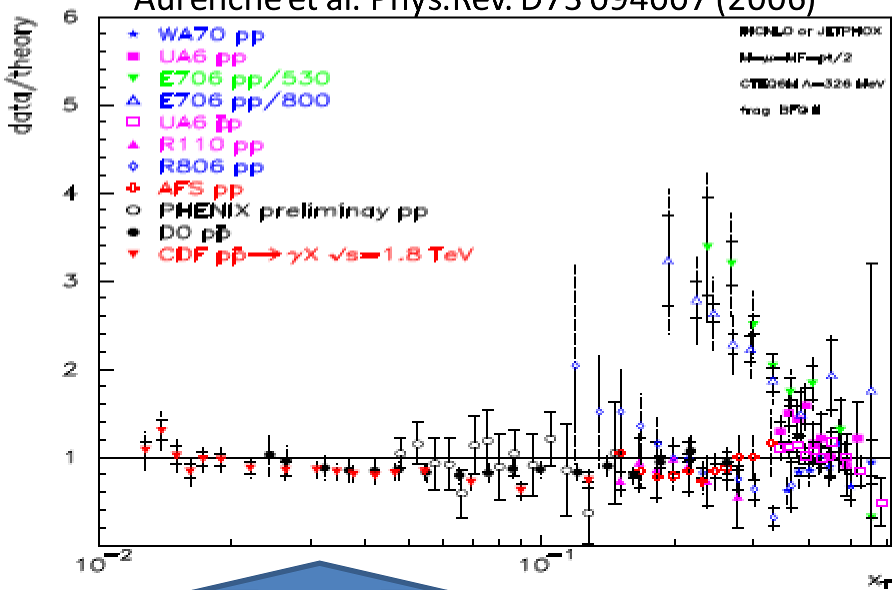
- Fragmentation photons
  - Partially removed by Isolation Criterion
  - Should be suppressed by parton E-loss
- k_T Effect
  - Initial state radiation spoils momentum balance
  - May be larger than calculated by NLO

k_T Effects in γ Production

Apanasevich et al., PRD 59, 074007 (1999)
PHENIX, PRD 74, 072002 (2006)



Aurenche et al. Phys.Rev. D73 094007 (2006)



Measurement of pair p_T (k_T) indicate need for extra transverse kick beyond NLO

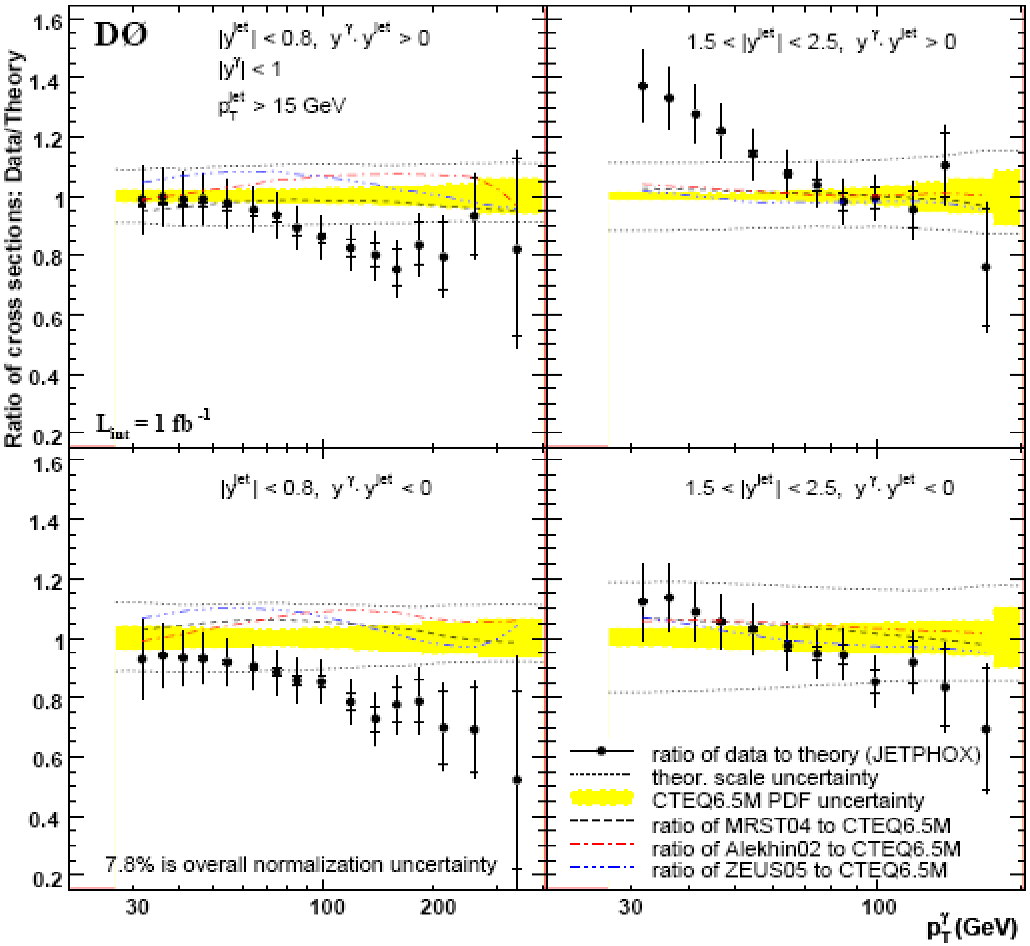
World data can be described by NLO only with exception of certain fixed target data

- γ+jet disused in global fits to gluon PDF → debate not settled
- In this study: Use LO + k_T and compare to NLO from theorists
- PHENIX is the highest energy hadron collider that measures inclusive and isolated γ's → QCD needs us!

Latest in γ+jet

New γ+jet cross sections from D0

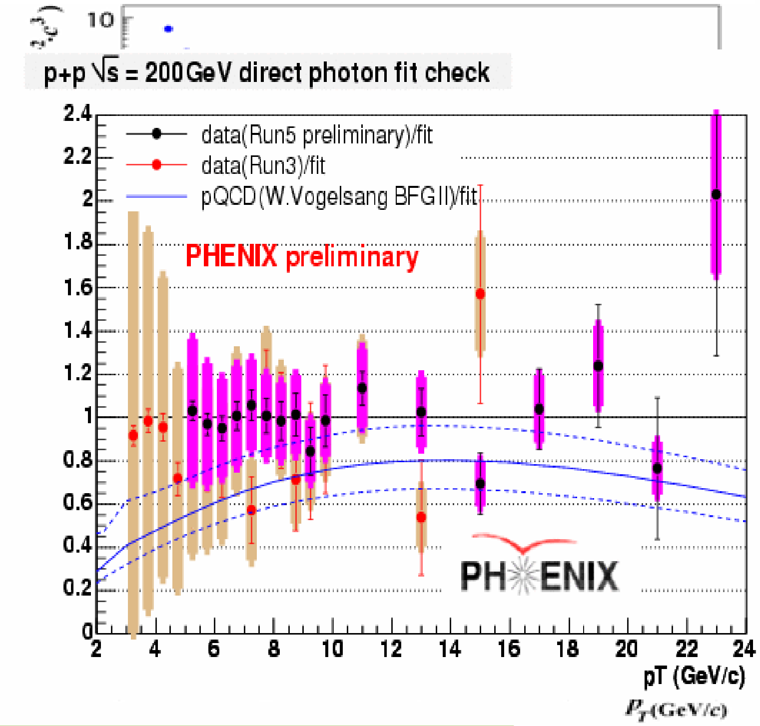
D0, PLB666, 435 (2008)

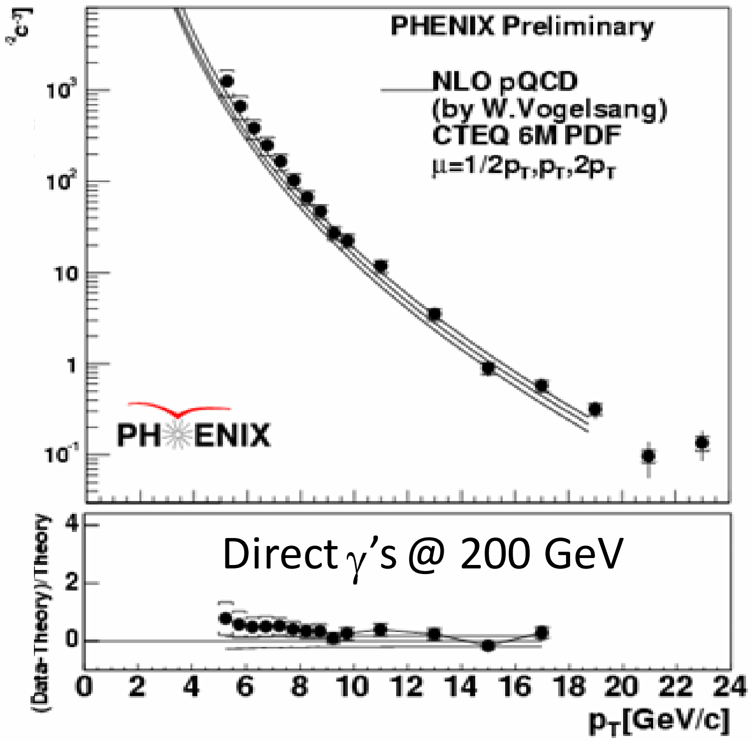


- Currently only constraint on gluon PDF at high x is jet cross-section
- We may be absorbing beyond Standard Model effects into PDF
  → Need cross check from γ+jet
- Compare to JETPHOX:
  NLO with isolation cuts
- By measuring different rapidity ranges NLO shown not to be fully compatible with data
- Not due to uncertainty in the PDF
- Also too large discrepancy for scale dependence
- NLO should really work at such large energy

pQCD @ RHIC

NLO works great! within errors



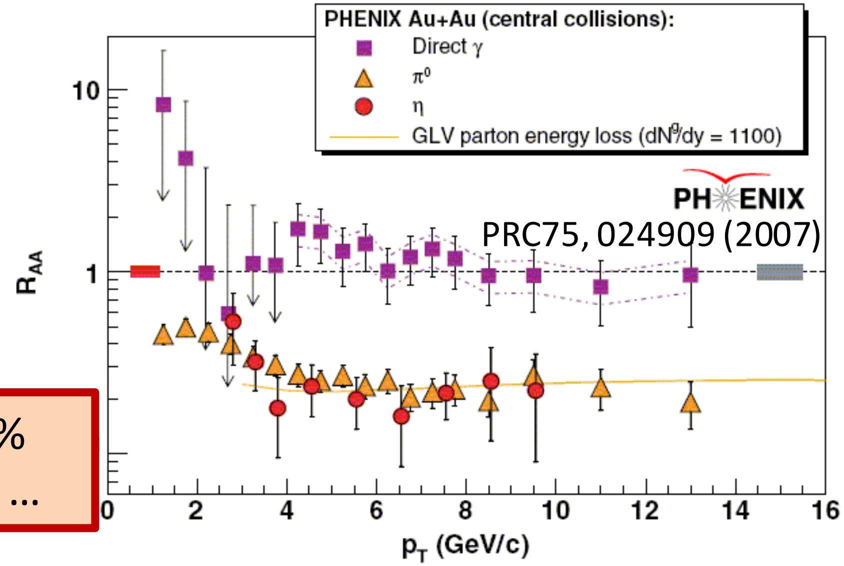


For π^0's @ 62 GeV
NLO works but
resummation drastically
reduces scale uncertainty

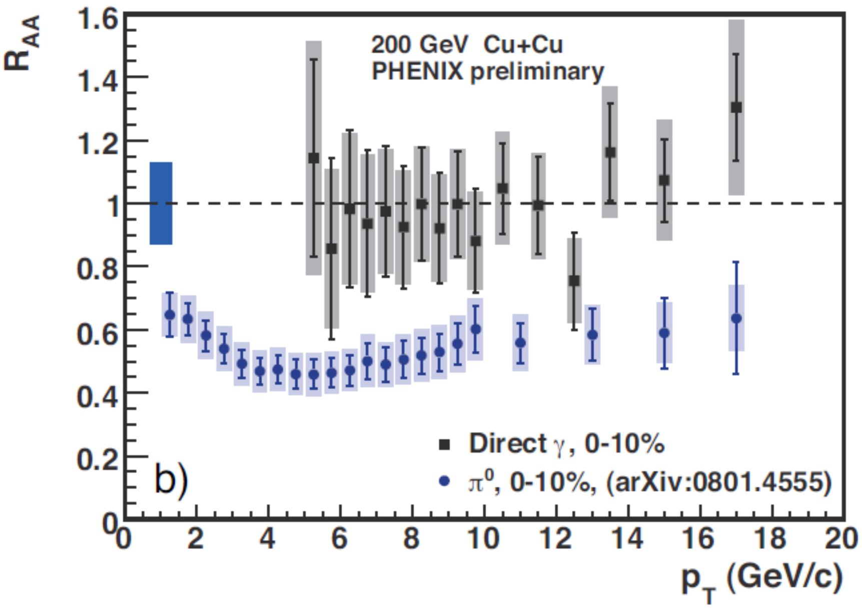
Scale uncertainties are smaller for 200 GeV direct γ's
But there is still room for ~40% effects

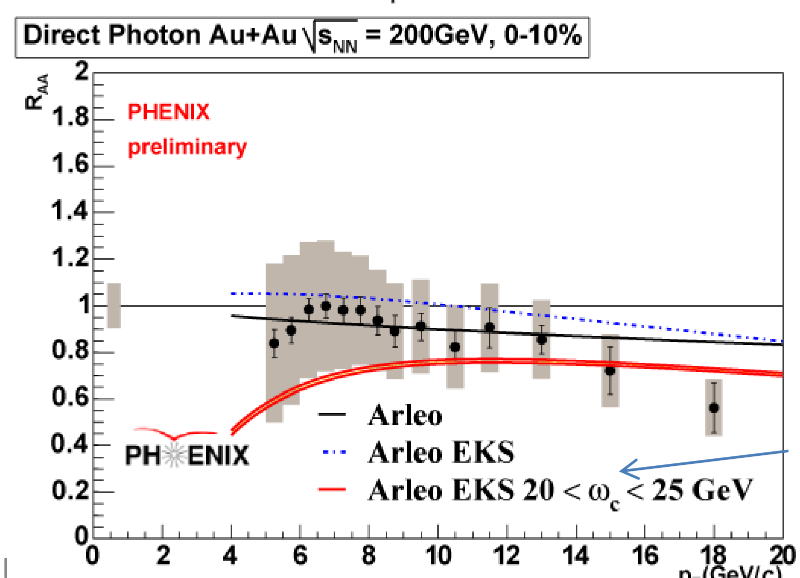
γ's in HI Collisions

- Out to 12 GeV data confirm LO picture → R_{AA} = 1 for direct γ's
- Newer data show hint of suppression at high p_T? → Marginally compatible w/ energy loss (BDMPS) + initial state effects



By the way, γ R_{AA} in Cu+Cu is dead flat +- 20%
Still room for effects, but the door is closing …





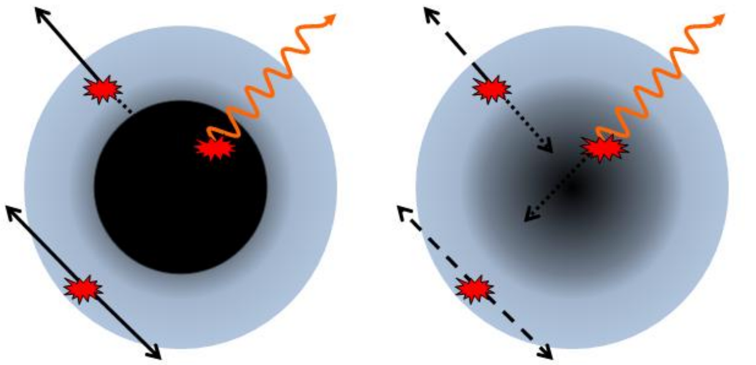
BDMPS

JHEP 0609, 015 (2006)

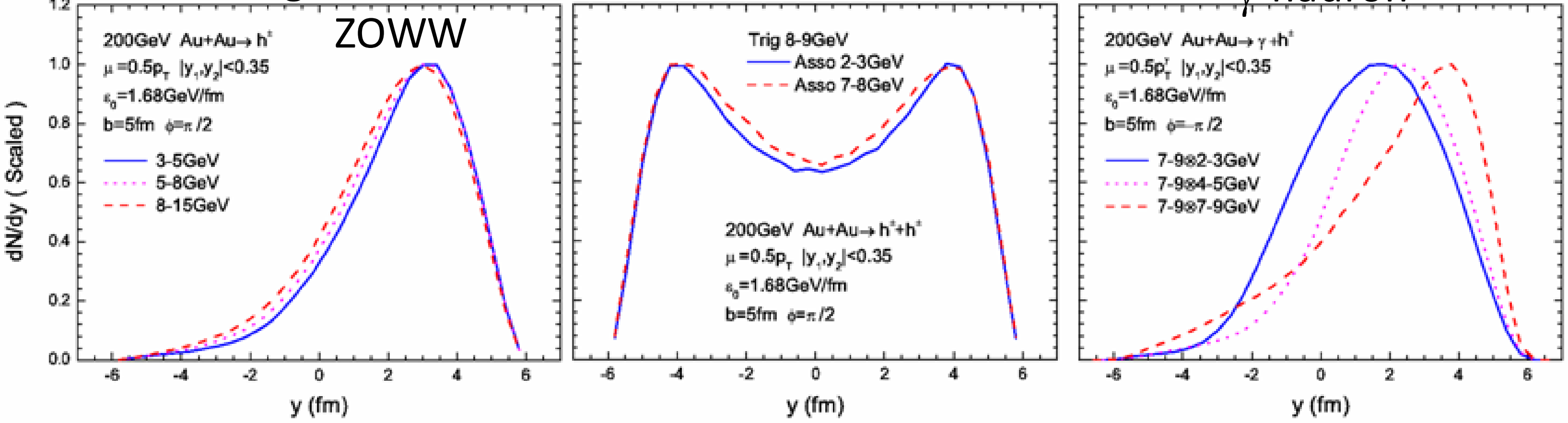
What to expect from γ-h

- Compare 3 different observables:
- γ-h I_{AA}, di-hadron I_{AA}, hadron R_{AA}
- In the black core limit γ-h I_{AA} = hadron R_{AA}
- Each samples a different depth of the medium:
- Surface vs tangential vs core emission
- → Must compare to a model

Black Core / Corona vs. Diffuse Medium



Single hadron | di-hadron | γ-hadron



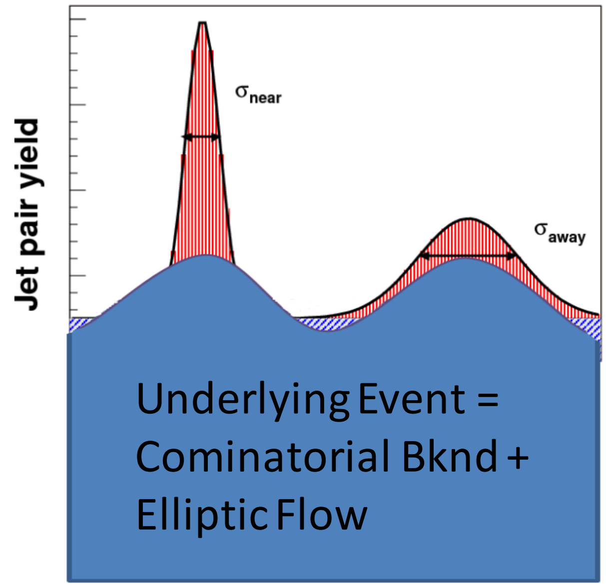
ZOWW → Model of energy loss using effective FF's EPJC (2008) + ref's therein

Analysis

Two-Particle Correlations

In p+p collisions:

- Azimuthal correlations in p+p show di-jet structure on ~ flat background (pedestal)
- Fit to remove pedestal – may be taken as definition What is the pedestal? See:CDF PRD 65 9 (2002)



In A+A collsions:

- Two-source model: Jet + comb. Bknd

$$\frac{dN_{total}}{d\Delta\phi} = \frac{dN_{jet}}{d\Delta\phi} + \frac{dN_{bknd}}{d\Delta\phi}$$

Estimate background by event-mixing
Background has correlations: It flows!

$$\frac{dN_{bknd}}{d\Delta\phi} = \frac{dN_{mix}}{d\Delta\phi}\left(1 + 2v_2^{trigger}v_2^{partner}\cos(2\Delta\phi)\right)$$

Also false correlation from multiplicity resolution:

$$\frac{dN_{bknd}}{d\Delta\phi} = \xi\frac{dN_{mix}}{d\Delta\phi}\left(1 + 2v_2^{trigger}v_2^{partner}\cos(2\Delta\phi)\right)$$

Note: Alternate normalization, ZYAM, gives same results in central collisions PHENIX PRC78, 014901 (2008)

Adding in efficiency and acceptance corrections:

$$Y \equiv \frac{1}{n^{triggers}}\frac{dN_{jet}}{d\Delta\phi} = \frac{\epsilon^{partner}}{n^{triggers}}\left[\frac{1}{A(\Delta\phi)}\frac{dN_{total}}{d\Delta\phi} - \frac{\xi}{A(\Delta\phi)}\frac{dN_{mix}}{d\Delta\phi}\left(1 + 2v_2^{trigger}v_2^{partner}\cos(2\Delta\phi)\right)\right]$$

γ-h Statistical Subtraction Method

Inclusive γ PTY is just a weight sum of decay and direct contribution
Note: Direct defined to be everything not decay

$$Y_{inclusive} = \frac{N_{direct}}{N_{incusive}} Y_{direct} + \frac{N_{decay}}{N_{incusive}} Y_{decay}$$

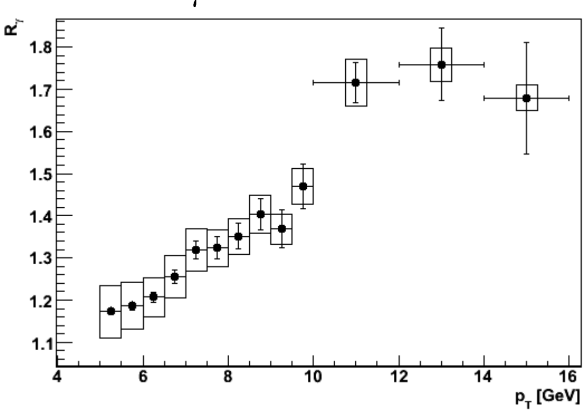
Rearrange and express in terms of the "direct photon excess" $R_{\gamma} = N_{inclusive}/N_{decay}$

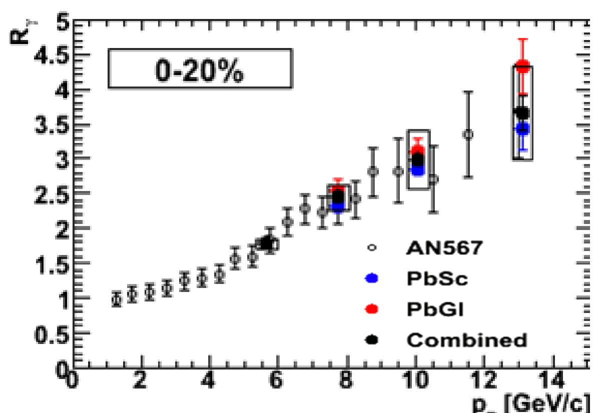
Golden equation for golden channel:

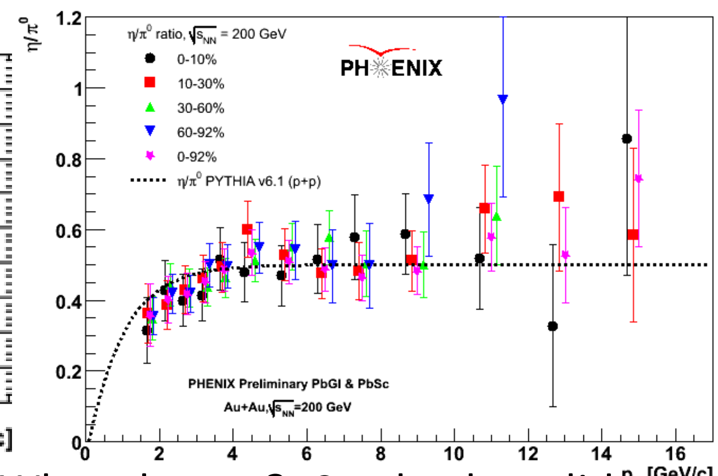
$$Y_{direct} = \frac{R_{\gamma}}{R_{\gamma} - 1} Y_{inclusive} + \frac{1}{R_{\gamma} - 1} Y_{decay}$$

PHENIX also measures x-sections for > 99% of the decay photon sources so estimating Y_{decay} should be easy…

R_{γ} is measured in PHENIX (not by me)



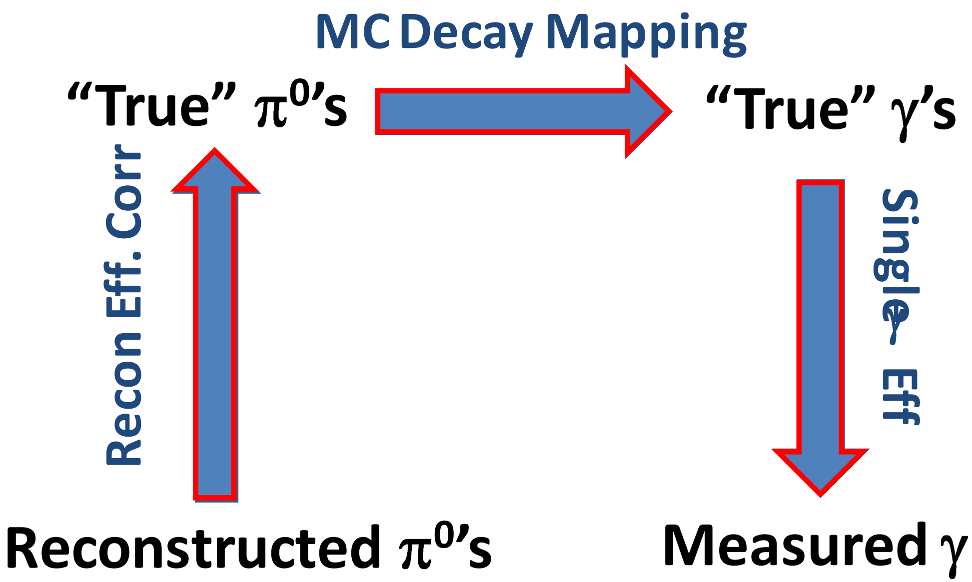


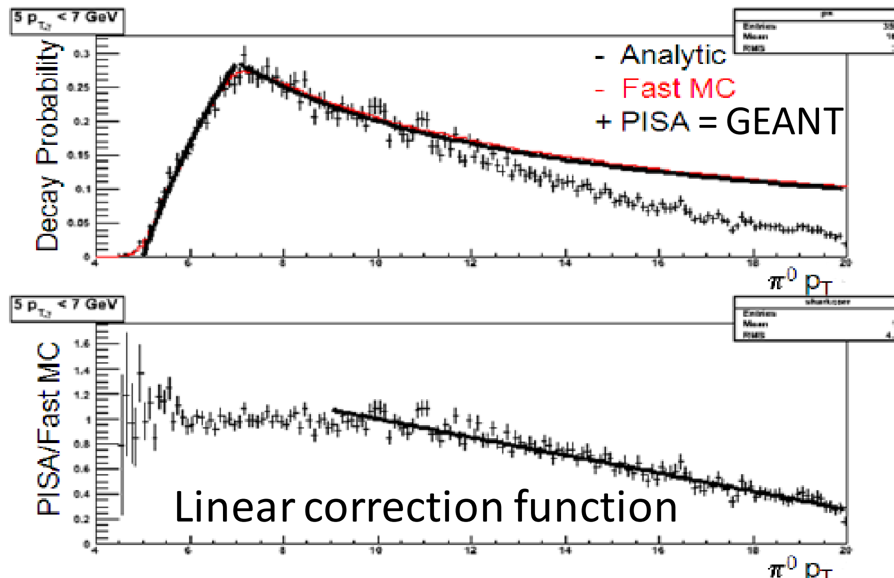


What about η? See backup slides

Decay Photon Estimate

How to obtain the unbiased decay γ associated yield using a pair-by-pair weighting





π^0 in p+p: PRD76, 051106 (2007)
In Au+Au: PRC76, 034904 (2007)

π^0 reconstruction by invariant mass gives a biased distribution

→Use the known shape of the π^0 distribution to apply a efficiency correction

Need correlation as function of decay γ pt

→Decay π^0's in Monte Carlo to take into account detector effect

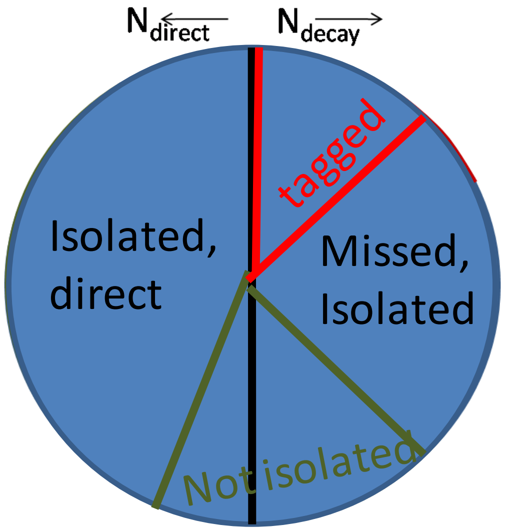
Single decay γ dist. is also biased b/c some γ's not reconstructed due to cluster merging

→Apply single γ efficiency from GEANT simulation

Isolation Method

Can obtain higher precision by identifying γ's event-by event: Isolation Method

Isolation Cut: Total track momentum + cluster energy in cone of 0.5 radians < 10% E of photon



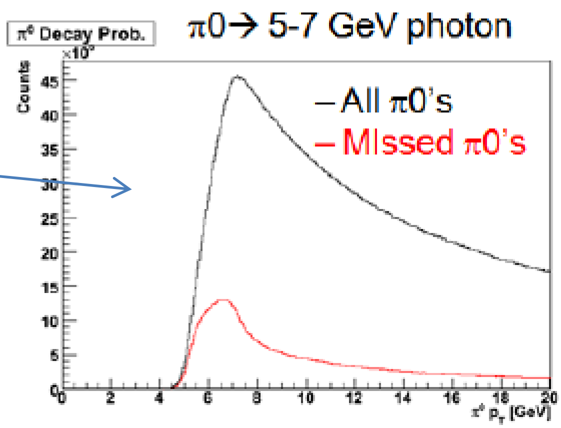
Decay γ tagging: Remove π^0 and η by invariant mass reconstruction

Note: Not ALL background can be removed e-by-e.
Still need to perform residual statistical subtraction!
Need to know how much signal and background was removed

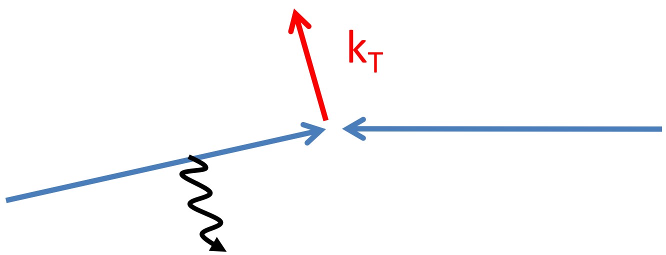
Note: Some direct γ's are also removed by isolation cut.
It's actually a different measurement!
Difference between inclusive and isolated direct γ yields → indirect measurement of fragmentation γ correlations (see backup)

Estimate efficiency of isolation cut on decay γ's with recon. π^0's

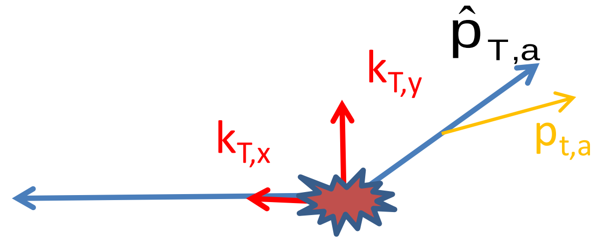
Need to re-evaluate decay γ probability for only γ's which survive cuts



Hard Scattering Kinematics



Initial State Radiation:
k_T is a transverse momentum in the initial parton pair frame

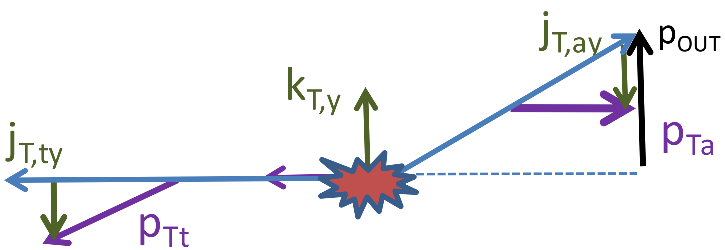


Fragmentation Function:

$$D(z) \equiv \frac{dP}{dz} \quad \text{where } z = \frac{p_{\parallel,a}}{p_{jet}}$$

Note: k_T has a longitudinal component in the outgoing frame, too

We can't measure these quantities directly with correlations, so:



Momentum Balance:

$$x_E = -\frac{\vec{p}_{Tt} \cdot \vec{p}_{Ta}}{|\vec{p}_{Tt}|^2} = -\frac{|\vec{p}_{Ta}| \cos\Delta\phi}{|\vec{p}_{Tt}|}$$

Out-of-plane momentum:

$$p_{OUT} = p_{Ta} \sin\Delta\phi$$

Sensitive to $k_{T,y}$, but also $j_{T,y}$ and momentum imbalance

$$\langle | p_{OUT} |^2 \rangle = x_E^2 \left[2\langle | k_{Ty} |^2 \rangle + \langle | j_{Ty} |^2 \rangle \right] + \langle | j_{Ty} |^2 \rangle$$

Should* measure the FF by using $p_{T,t}$ as a proxy for p_{jet}.

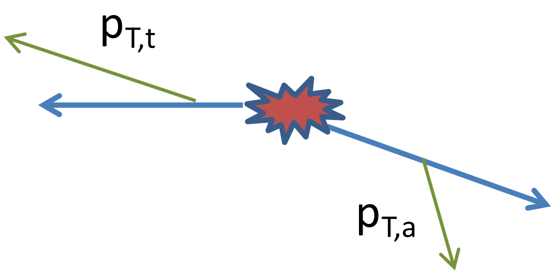
...oduces a dependence on $k_{T,x}$.

...ly, nature is not so kind (see

Both x_E and p_{OUT} are not the "basis vectors" of the system
→ There is some admixture of fragmentation and k_T in both

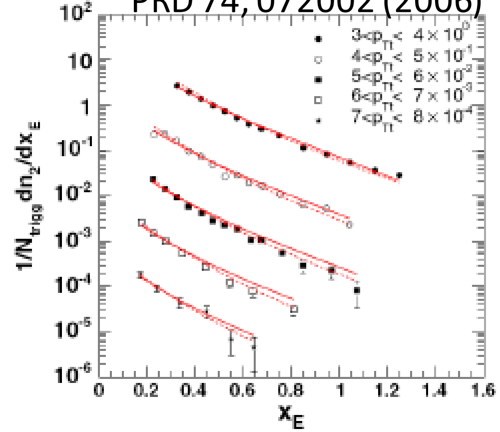
Whack-a-mole with the FF

In di-hadron measurements we can fix $p_{T,t}$ and try to measure the FF by scanning over $p_{T,a}$. We need the jet momentum to stay fixed.



But it doesn't! As we scan $p_{T,a}$, we sample different Q^2

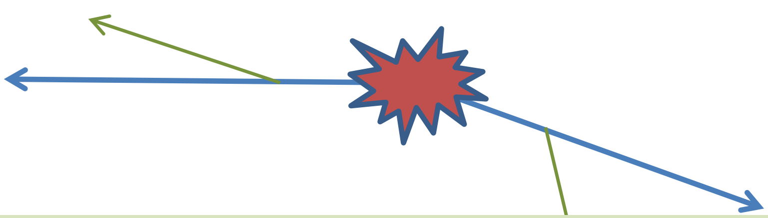
PRD 74, 072002 (2006)

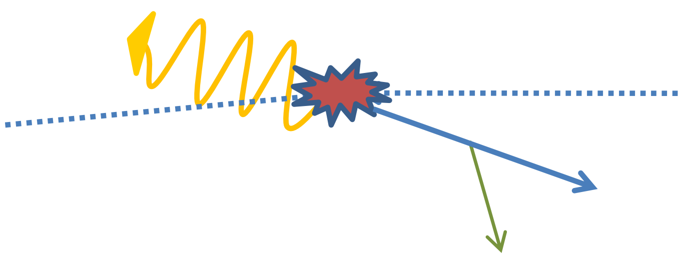


This is because we're sensitive to the steeply falling jet x-section rather than the FF

Solution:

Use prompt γ's to fix the hard scattering

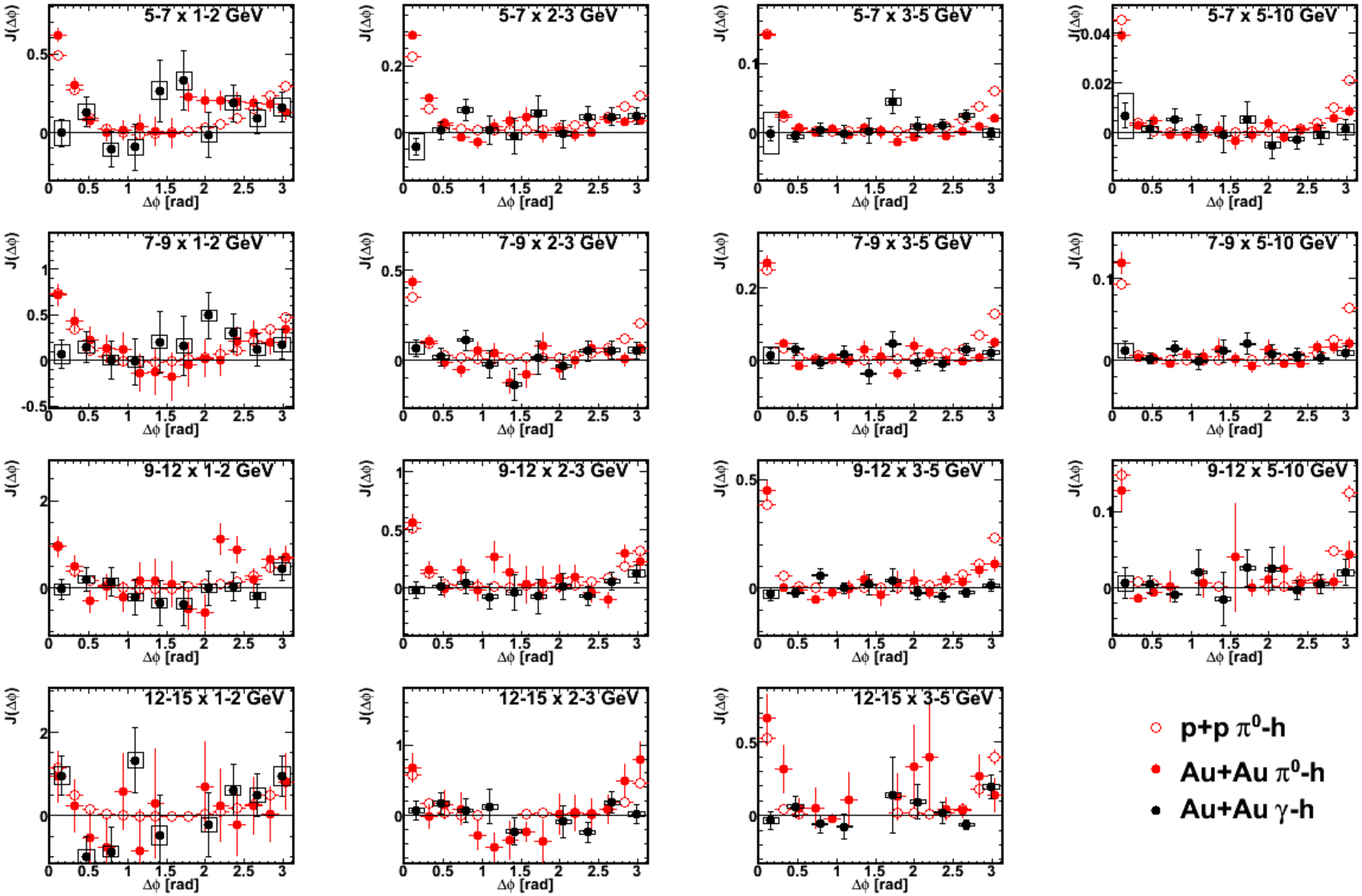




Actually, I found out that the di-hadron x_E does depend on the FFs

Results I:
Nuclear Effects

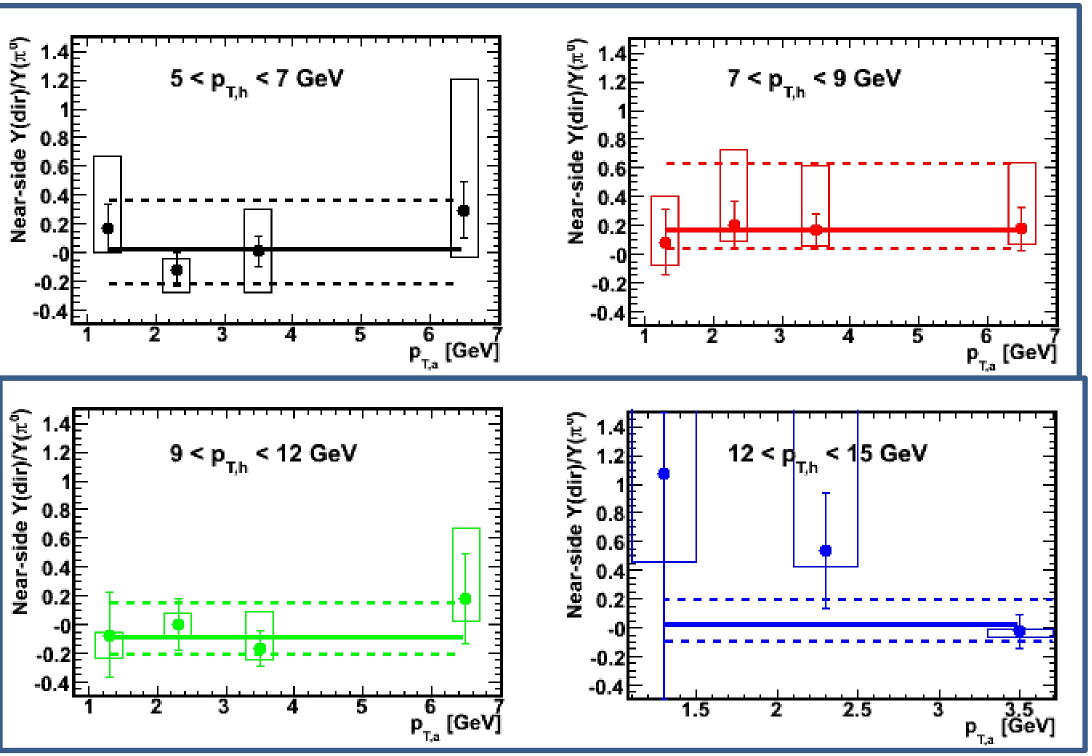
γ-h Jet Correlations



No near-side correlations

Away-side correlations suppressed like π^0

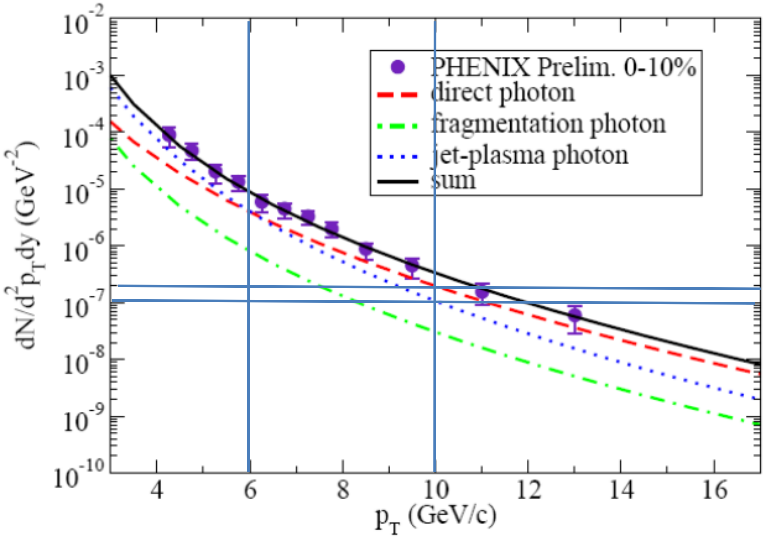
γ-h Near-side Correlations



- Near-side direct γ-h/π^0-h ($\Delta\phi$ <0.5 rad)
- Everywhere consistent with zero → no positive evidence for medium induced sources

At low pT:

- Theory predicts 50-50 prompt/medium
- Fit with a constant across p_{Ta}
- At low p_T, constraint is poor
→ up to ~ 50% near-side OK



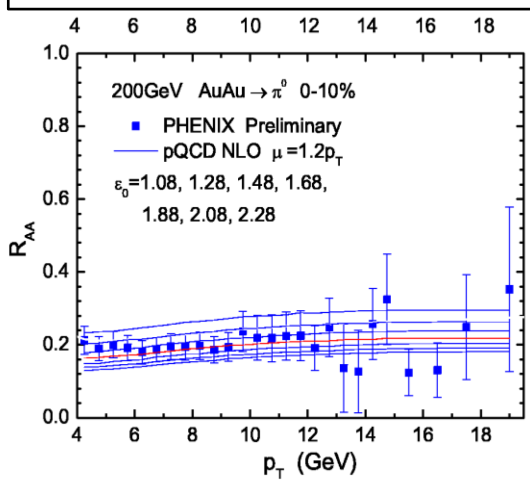
At high pT:

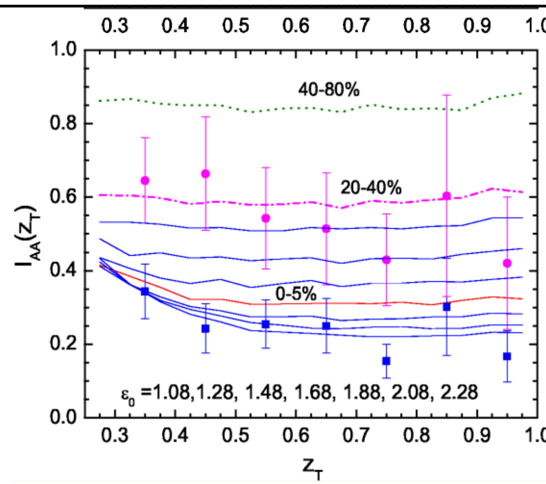
- γ-h < 20% π^0-h
- Theory predicts ~ 1/3 medium induced
- If there are medium induced photons they act like direct photons anyway
- Rules out large induced brems.

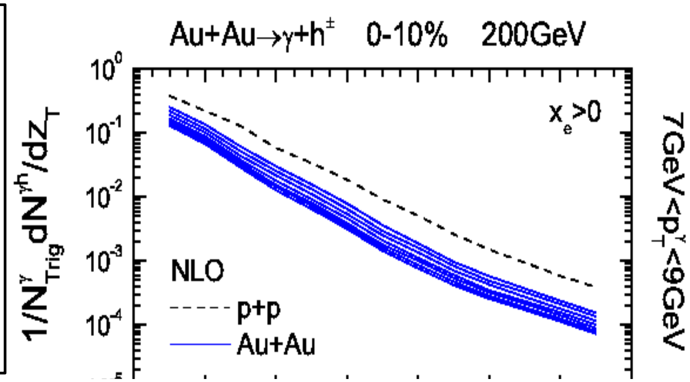
Another piece to the puzzle

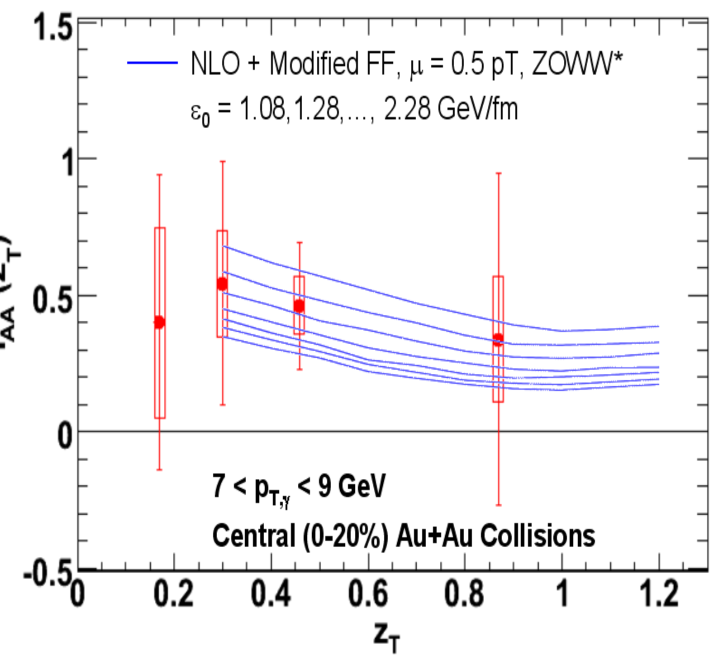
Single hadron **Dihadron** **Photon-hadron**

- Compare constraints from γ-h to single & di-hadron
- Not there yet, but not THAT far
- Factor of ~ 4 from Run 7 + implementation of tagging method in Au+Au → constraints for QM08?
- Is this the best data we have from Run 4?



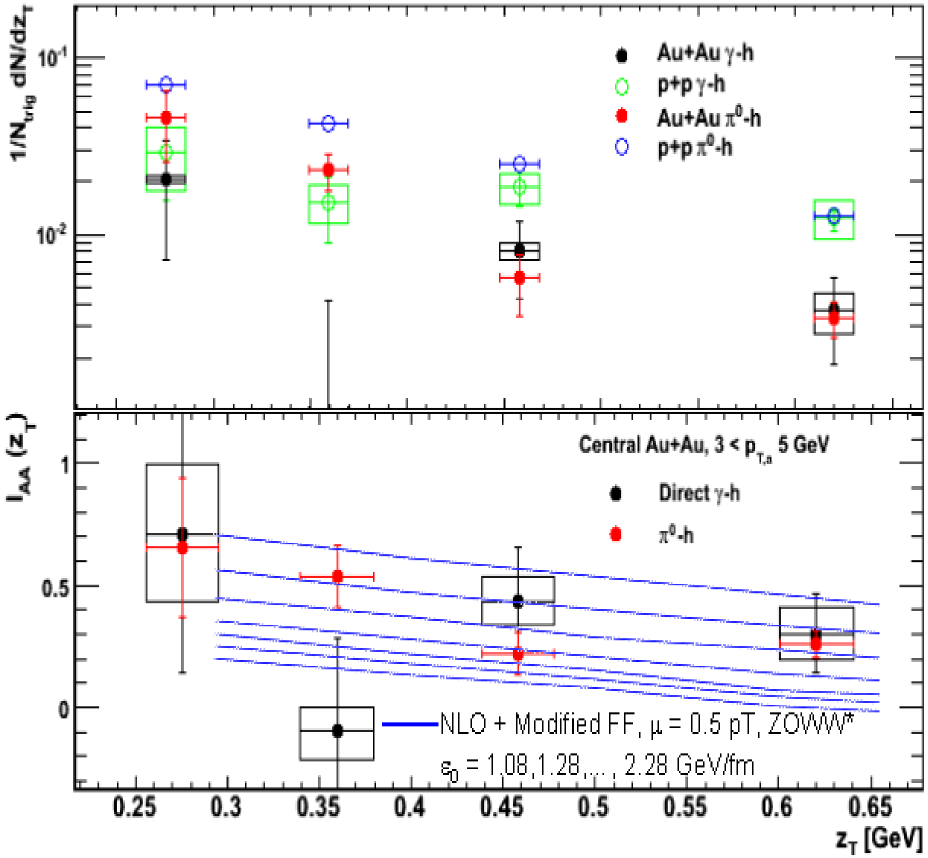






Slide from H.-Z. Zhang, Int'l workshop for QCD /HIC

Getting the most out of Run 4



*Theory curves are for different p_T selection
For illustration purposes only

Uncertainties vary bin-to-bin

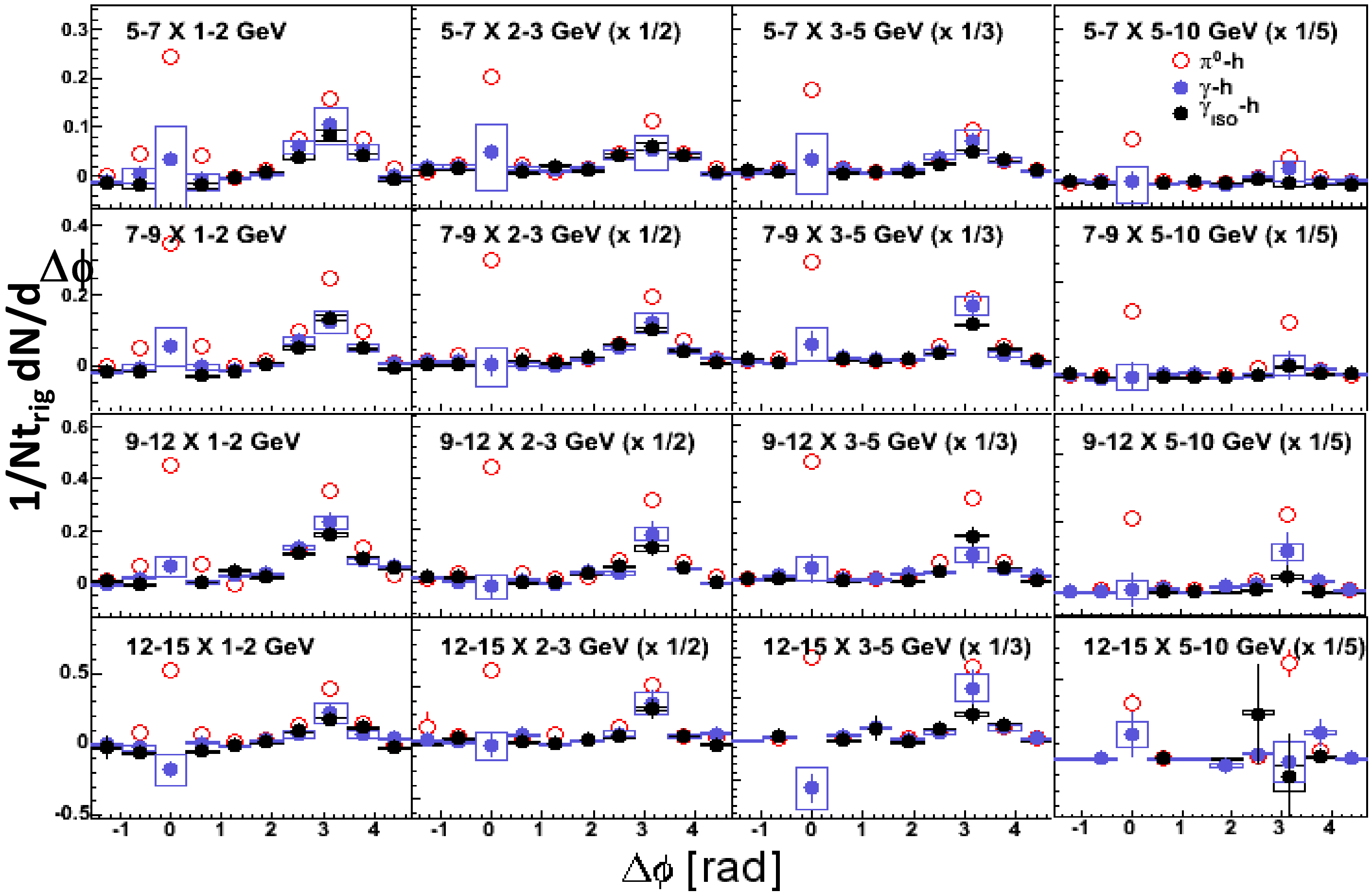
Variety of backgrounds in the γ-h measurement: jet underlying event, decay correlations, π^0 combinatorial background, etc.

Can obtain a much more precise scan of z_T by fixing p_{Ta} (3-5 GeV) and varying $p_{T,t}$.

Calculate χ^2 for simultaneous fit to γ-h I_{AA}, π^0 I_{AA} and π^0 I_{AA}?

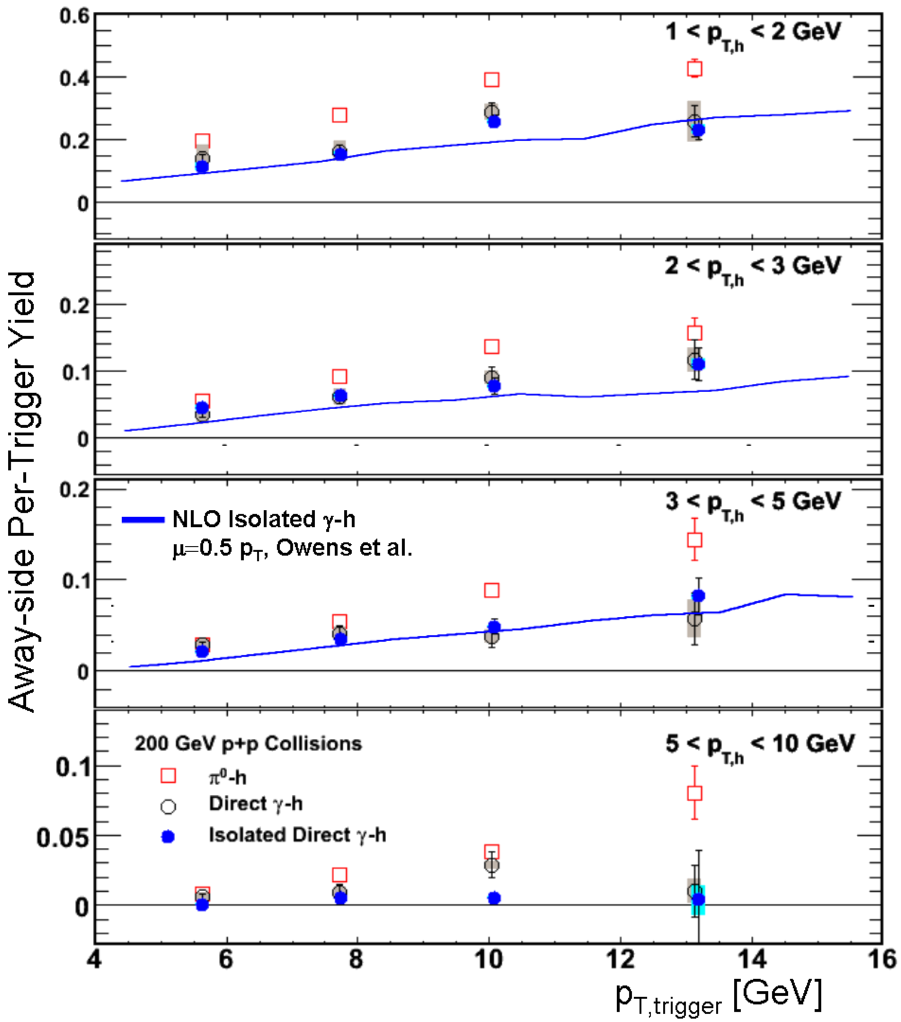
Results II:
Vacuum QCD Effects

Isolated γ-h Correlations



Isolated direct γ away-side looks smaller than inclusive direct
Error bars touch, but they're correlated
(you can estimate the fragmentation associated yield from their difference)

NLO Comparison



Away-side PTY for inclusive and isolated direct and π^0 triggered

Direct γ yields are smaller
→ smaller jet energy and less particles b/c they're quark jets

NLO calculation has an isolation cut and uses KKP FF's

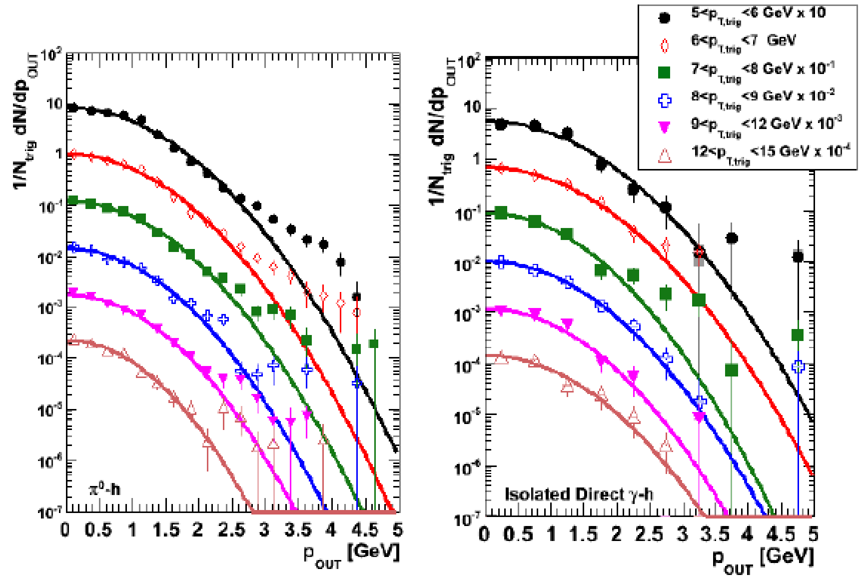
NLO should mostly cancel out in PTY

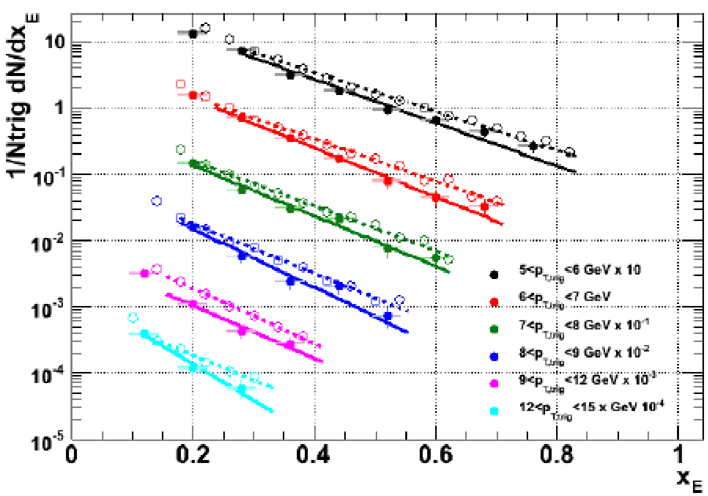
Still, agreement is remarkable.
No evidence for large missing k_T

Can this generator do π^0-h?

x_E/P_{OUT} Distributions

- p_{OUT} distributions are well described by a Gaussian out to ~ 3 GeV
- π^0 has a tail→ hard gluon radiation, maybe the closest thing you can see to a 3 jet event from our data
- Do isolated γ's also have a tail?
  (See backup slides)





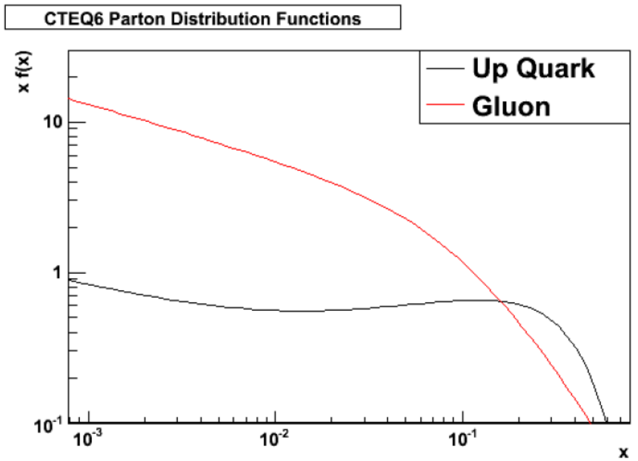
Open symbols = π^0
Closed = direct γ

- x_E distributions are fit with an exponential which fits well in data and MC (again backup slides)
- How do x_E distributions relate to FFs?
- Compare to pQCD using LO + k_T Monte Carlo generator

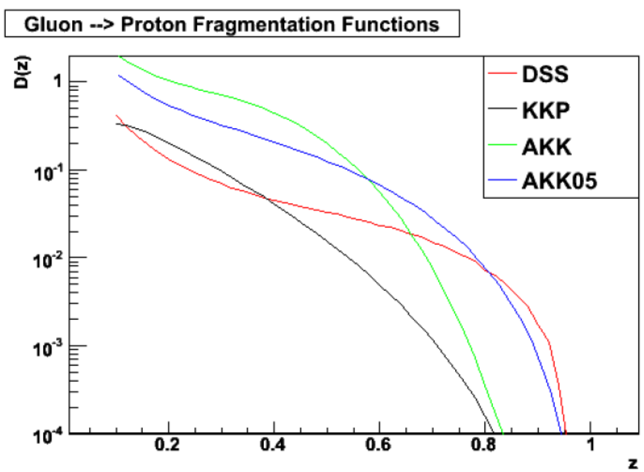
LO + k_T MC Generator

$$\frac{d^5\sigma}{dx_1 dx_2 d\cos\theta^* dz_3 dz_4} = \sum_{a,b,c,d} F_a(x_1)F_b(x_2)G(\vec{k}_T)\frac{\pi\alpha^2(Q^2)}{\hat{s}}\hat{\Sigma}_{a,b}(\cos\theta^*)D_c(z_3)D_d(z_4)$$

- Start with general expression for back-to-back two-particle cross section assuming independent fragmentation
- Using LO cross section for γ+jet and di-jet
- Sum over all flavor permutations
- Add Gaussian k_T/j_T smearing (only k_T shown)
- Using CTEQ6 PDFs
- Try different FFs (KKP, DSS, AKK05/08)

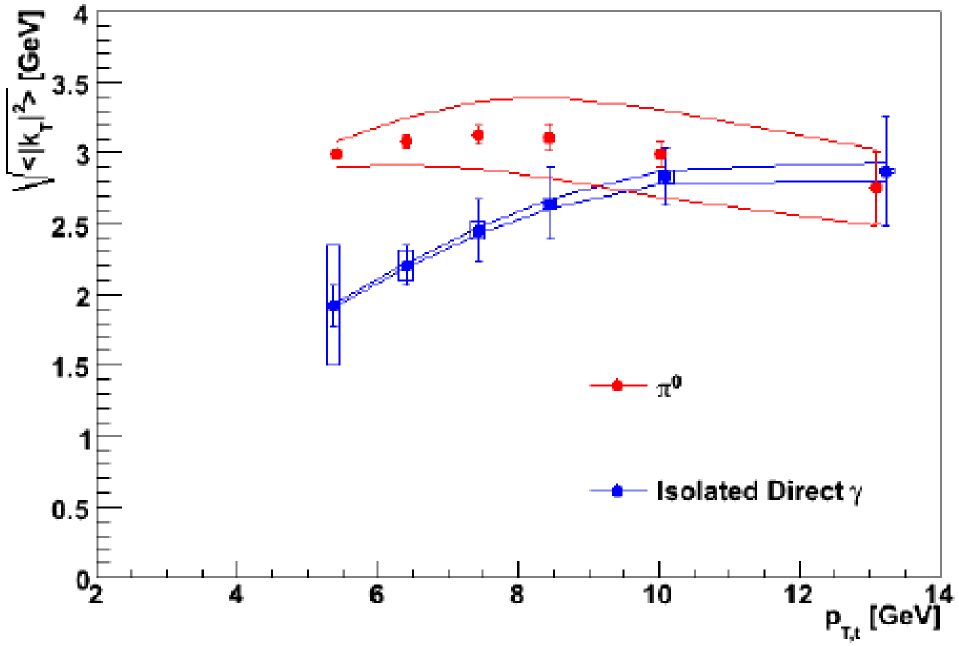


Examples of PDFs and FFs @ Q=7 GeV



Getting k_T from p_{OUT}

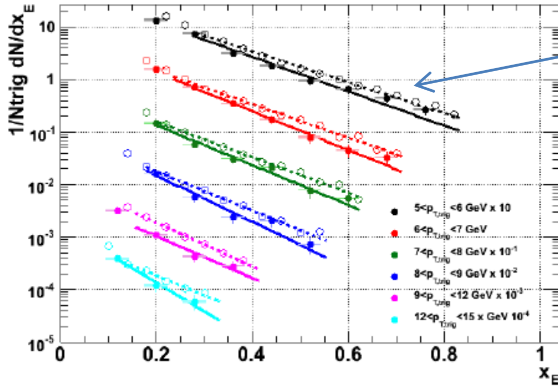
1) Run MC using each set of FF's for many different value of k_T
2) Find χ^2 as a function of k_T for set
3) Take best χ^2 from each FF set and find k_T as a function of $p_{T,t}$ (what we actually observe)
4) Use the spread given by different FF's as systematic



k_T for γ's smaller than for π^0's → k_T bias effect particle correlations differently

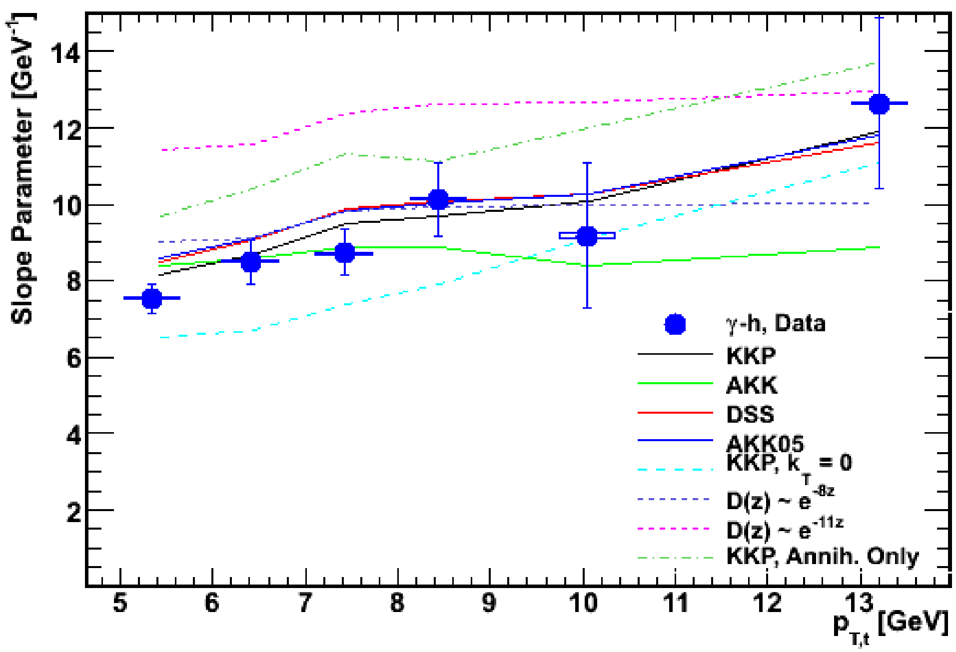
k_T for isolated γ's has smaller errors → quark FF better constrained than gluon (topic of next slide)

γ Momentum Balance



γ = closed points

All FF set describe isolated γ fairly well



k_T effect matters, LO by itself doesn't cut it

Shape of input FF matter → we are measuring the FF!

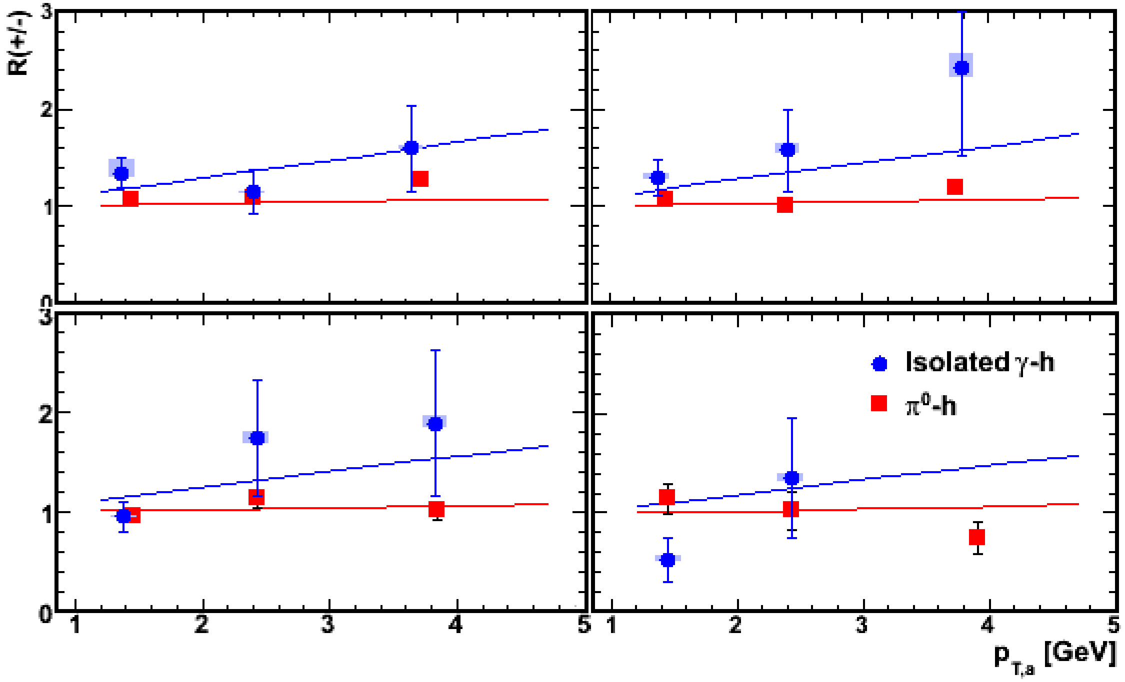
However, mix of processes does Annih. only finds a steeper slope than data → we are looking at Compton scattering

Would be great to put NLO on this plot

Recoil jets have more + than – charge (see backup)

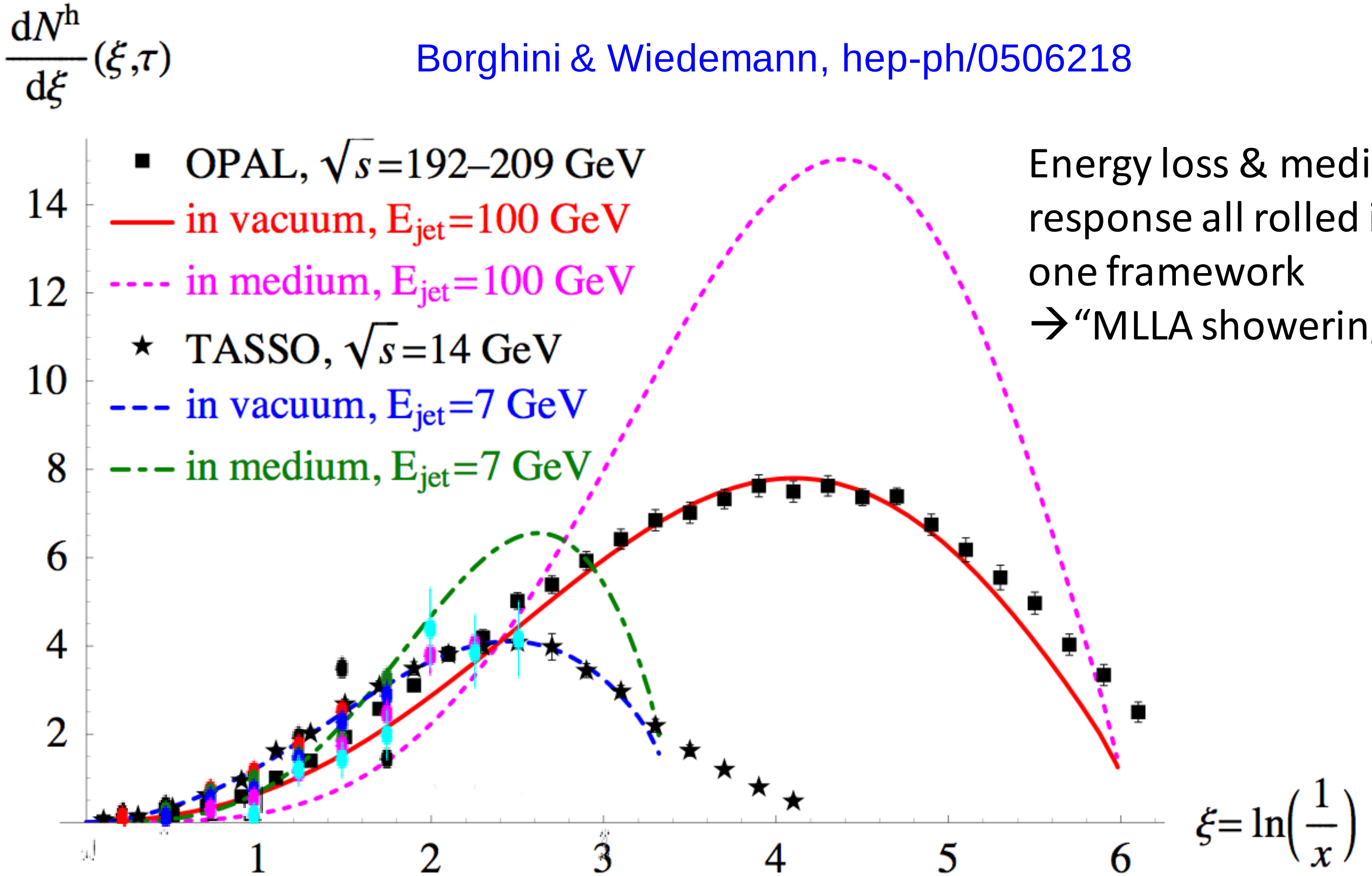
Charge Asymmetry

Why more + than – charge for γ's?
Compton diagram has a factor of electric charge squared in the coupling
Up = (2/3)^2 = 4/9   Down = 1/9
Also, there are twice as many up quarks in the proton so you have 8:1 up:down



γ triggers are associated with more positive charge than negative
→ They tag up quark jets

Medium Response

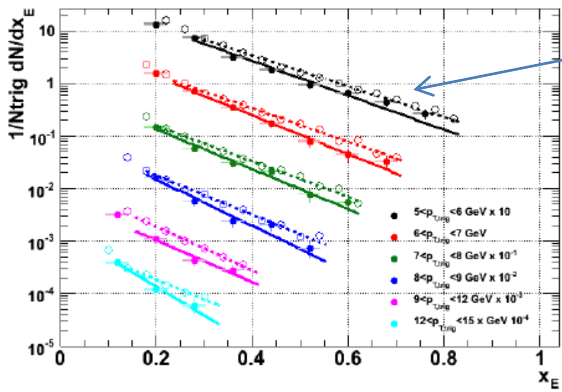


Borghini & Wiedemann, hep-ph/0506218

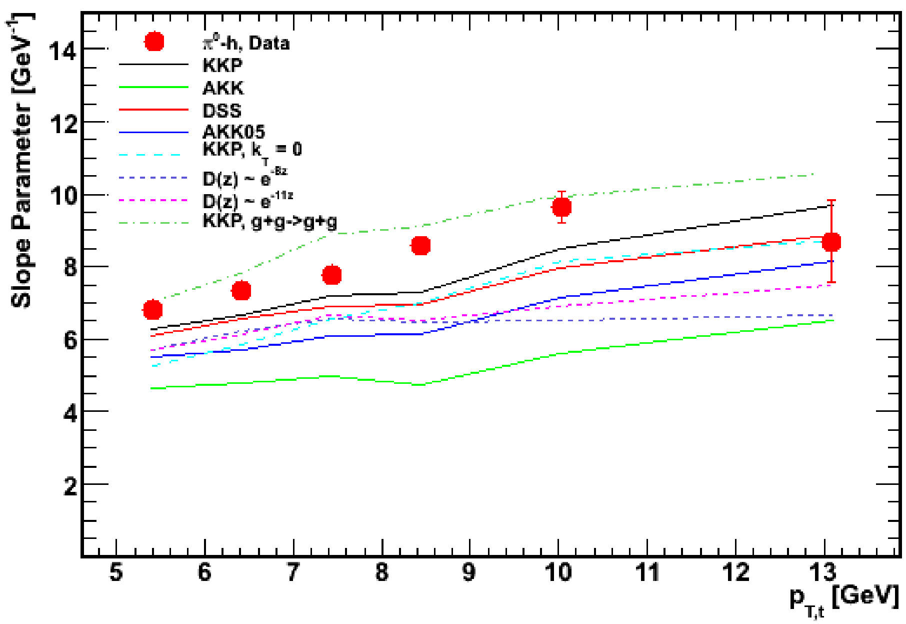
Energy loss & medium response all rolled into one framework
→"MLLA showering"

With current p+p data we just reach the "hump-backed plateau".
At LHC need 100 GeV with 1 GeV partners to hit the peak
→This is a tough measurement at any collider
If we see medium response at lower ξ will it match this theory?

π^0 Momentum Balance



π^0 = open points



FF sets give a much larger spread in predictions than did AKK
KKP and DSS come closest

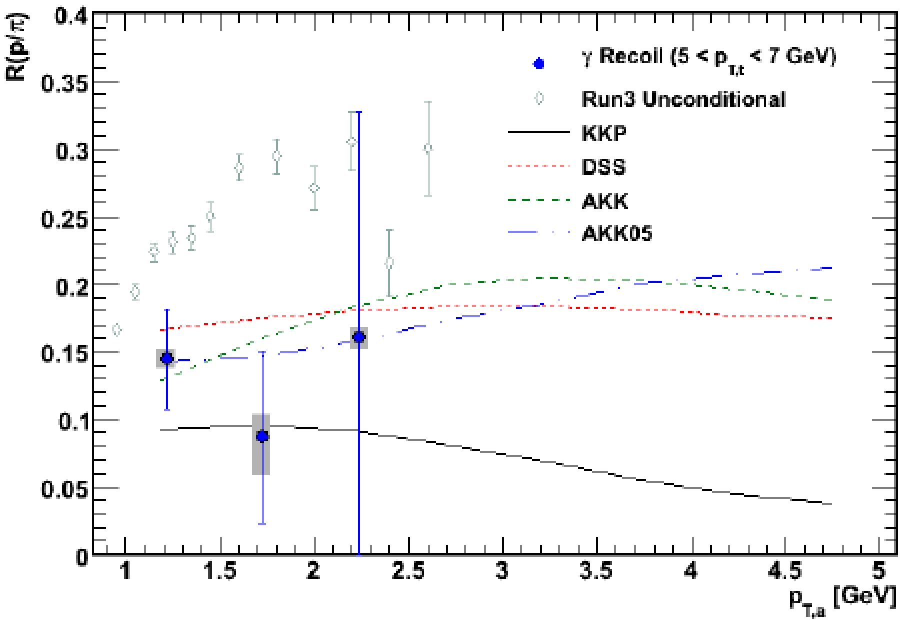
k_T matters although not as much as choice of FF set

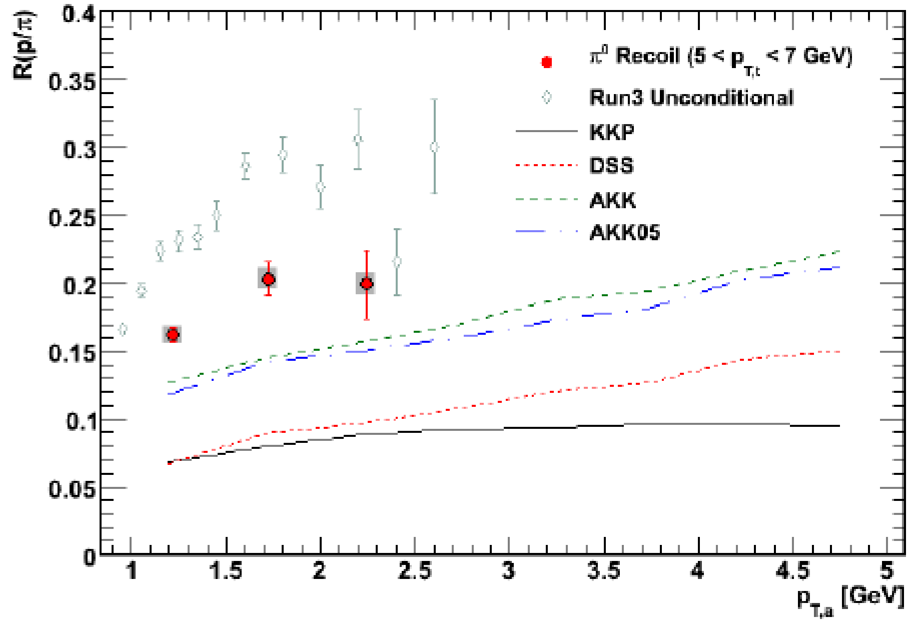
Overall shape of FF doesn't matter, consistent with previous PHENIX measurement

However, mix of processes does matter → relative shape of quark vs gluon FF matters

Conditional Proton:Pion

Identifying the partner targets specific FF's , e.g., gluon → proton
So far only low z data, a region not probed by single particle measurements





Conditional p/π smaller than unconditional
FF sets fairly consistent with each other, data doesn't distinguish

p/π off by 2x for DSS and KKP
(they got the momentum balance right)
AKK does better, but still undershoots by a bit
(they got the momentum balance wrong)

Conditional p/π will be very interesting to look at in Run 7 Au+Au (coming soon)

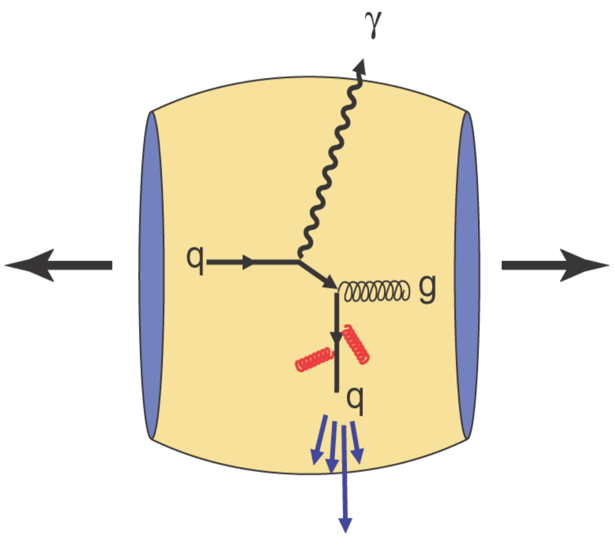
Conclusions

- Developed a method of extracting γ-h correlation in Au+Au
- No evidence for large contribution from medium induced photon production
- Suppression observed in γ+jet channel, need more data, better methods for quantitative constraints
- Further developed methodology in p+p collisions with isolation and tagging cuts
- Isolated γ baseline well described by theory
- Isolated γ-h sensitive to FF and is well described by quark fragmentation → γ's are a good quark jet tag
- Magnitude of k_T effect for γ triggers comparable to π^0
- π^0 triggered correlations are not well-described by any available FF's (at least with LO + kT) → useful to constrain gluon FF's

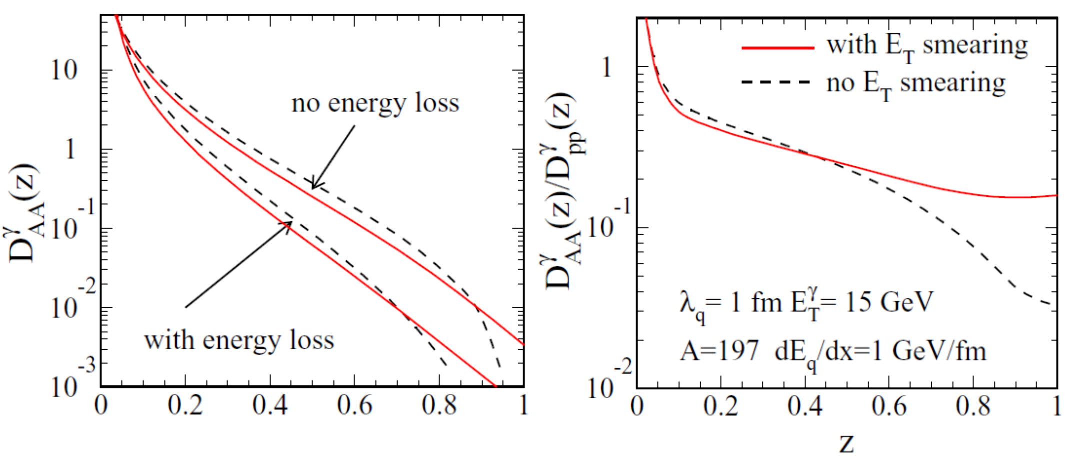
Backup Slides

γ+Jet in HI: Jet Tomography

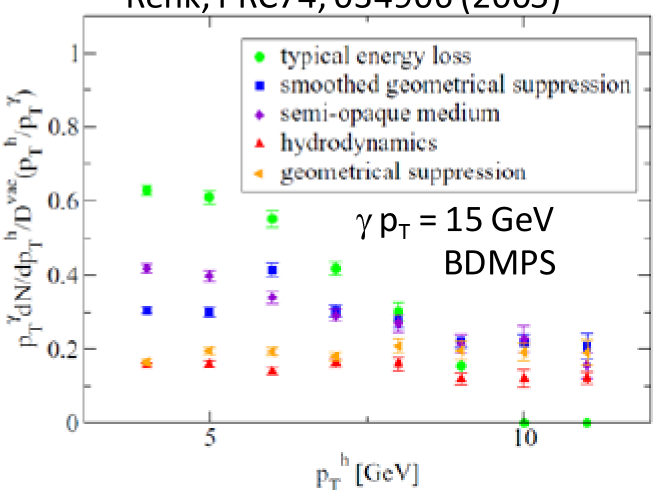
- LO picture: direct γ correlation can be used to map the E-loss profile → jet tomography
- Fractional E-loss will appear as effective modification to FF
- Effect depends more strongly on E-loss profile than single and di-hadrons
- Isolation cut would force LO, but is very difficult in Heavy-Ion
- Higher order effects (fragmentation and medium sources) should give rise to near-side correlation



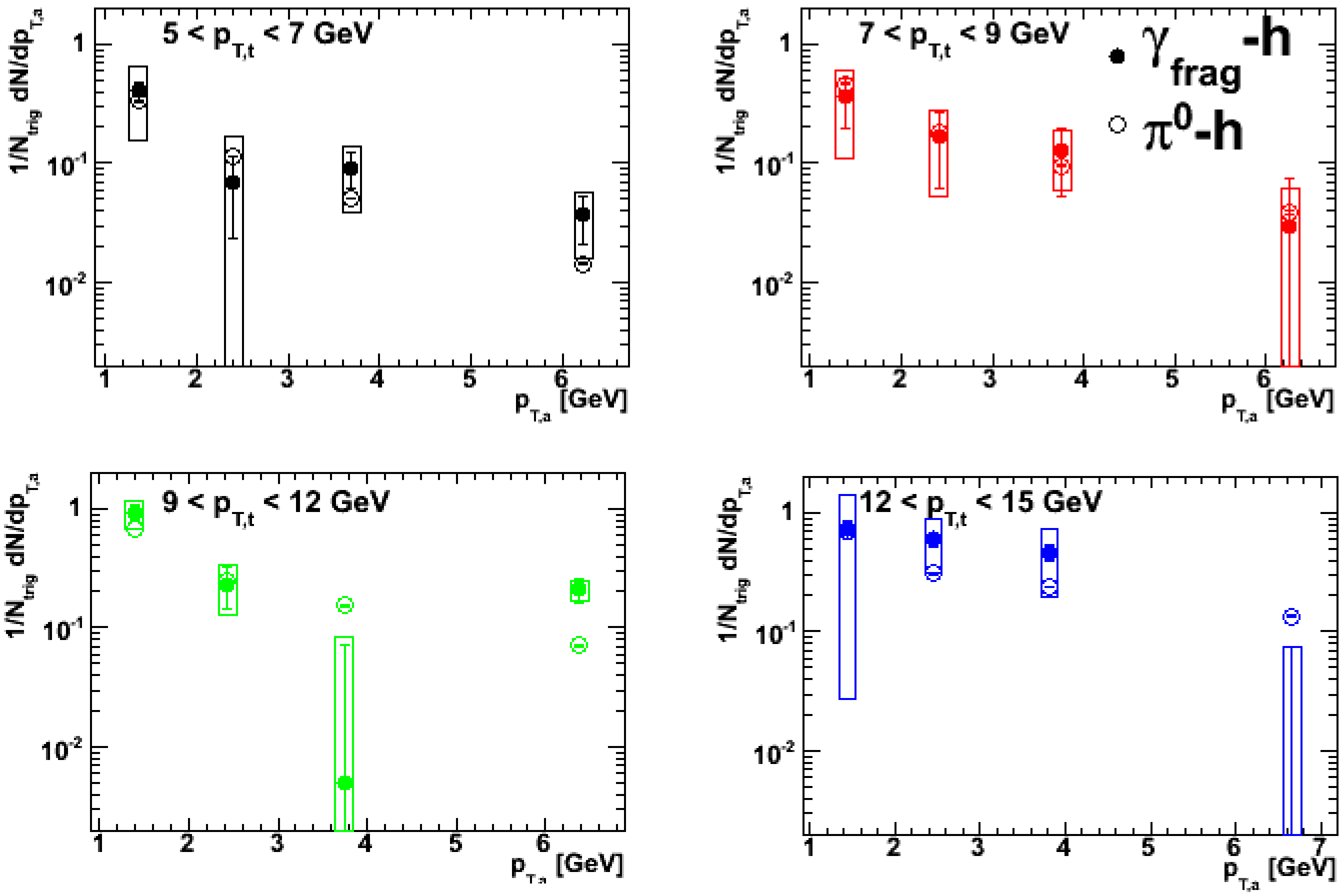
X-N Wang et al, PRC 55, 3047, 1997



Renk, PRC74, 034906 (2005)



γ_{frag}-h Away-side correlations



$$Y_{frag} = \frac{1}{1 - \frac{1-f^{inc}_{frag}}{1-f^{iso}_{frag}}} Y_{inc} - \frac{1}{\frac{1-f^{iso}_{frag}}{1-f^{inc}_{frag}} - 1} Y_{iso}$$

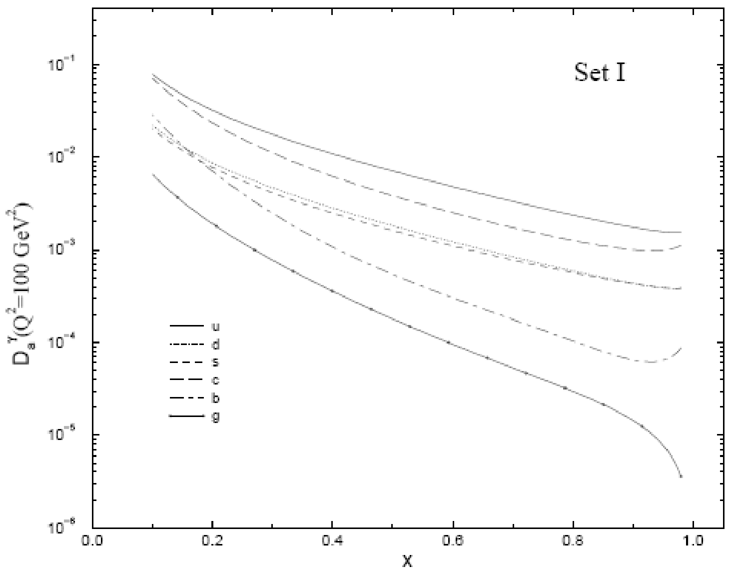
Inc = Inclusive Direct

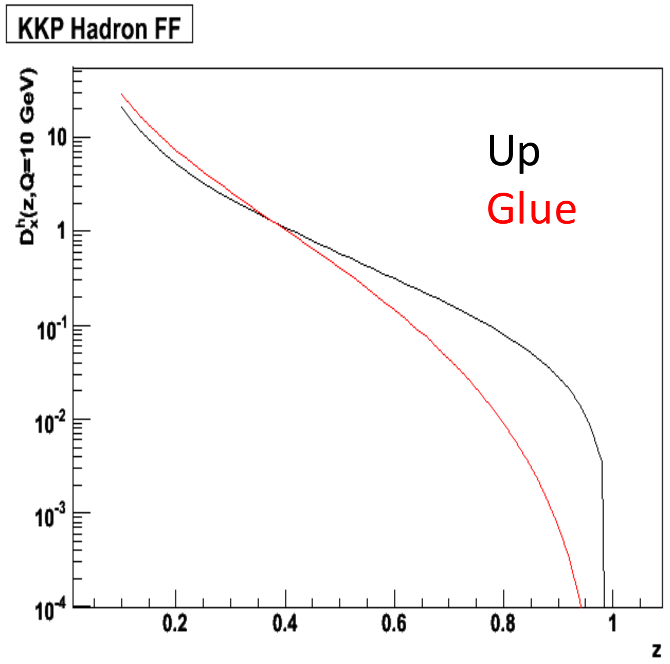
I cheated and used pQCD to get the fraction of isolated direct photons

Still cute though, ask Ali for the "real" answer

Photon FF

From BFG, EPJ C2 529 1998



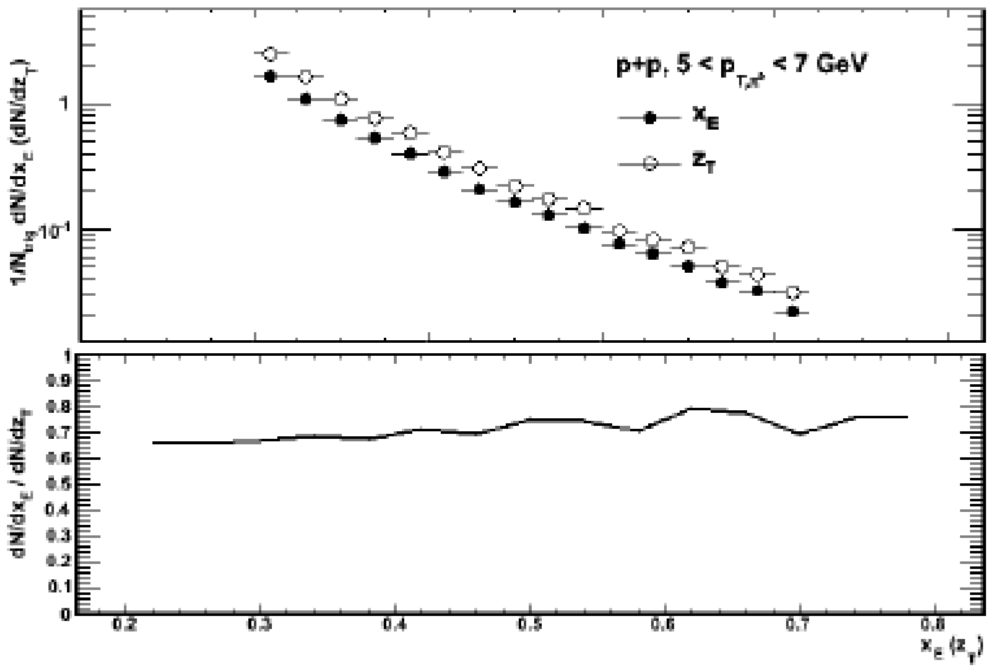


Does the photon FF look like a "real" FF?

Not really, it's much harder and doesn't go to zero as z→ 1

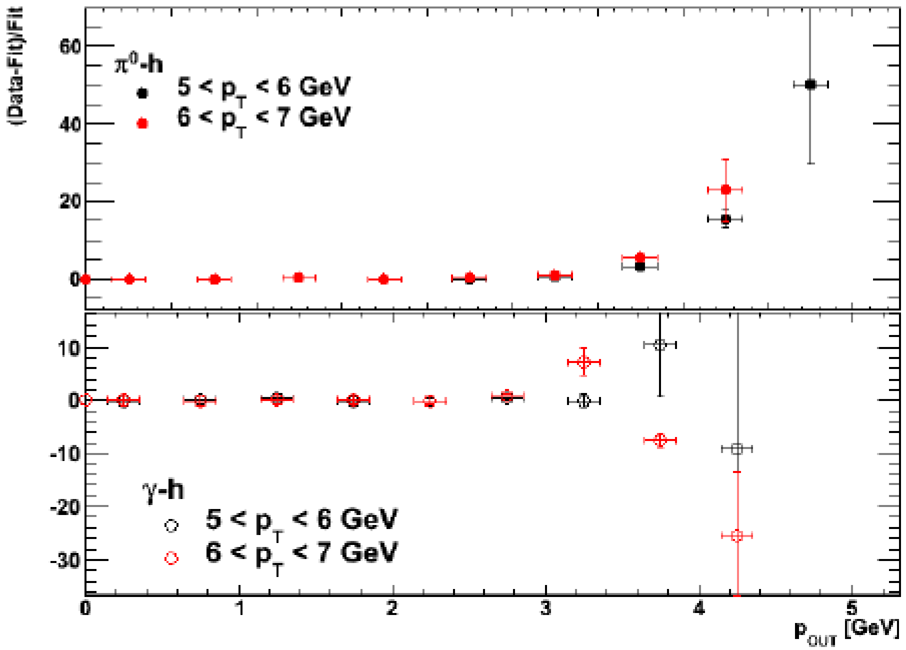
Actually, fragmentation photons are a pretty good up quark tag, too

z_T VS x_E



eh, same thing

Does the γ p_{OUT} have a tail?



As pout approaches p_{Tt} it drops off: Prompt γ+jet can't emit a 5 GeV gluon at 90 degrees

However, there is a bump around 3 GeV

It looks like isolation criterion restricts the phase space for 2→ 3 emission

What I learned at Summer Camp (CTEQ04)

From talk by Jeff Owens posted at:
http://www.phys.psu.edu/~cteq/schools/summer04/

Why we expect a different rapidity distribution for γ+jet

γ-jet correlations

- Examine the jet rapidity distribution for different values of the photon rapidity
- Compare to the case where the photon is replaced by a jet
- $\eta_\gamma = \eta_{jet}$ corresponds to $\theta^* = \pi/2$ whereas forward η_γ and backwards η_{jet} corresponds to $\theta^* \to 0$
- QCD Compton and annihilation subprocess both behave as

$$\frac{d\sigma}{d\hat{t}} \sim (1 - \cos(\theta^*))^{-1} \text{ as } \cos(\theta^*) \to 1$$

- Other parton-parton scattering subprocesses ($qq \to qq, qg \to qg, gg \to gg$, etc.) behave as

$$(1 - \cos(\theta^*))^{-2}$$

- This means that η_{jet} will be more likely to follow η_γ as it moves toward the forward direction than is the case in purely hadronic dijet production

Why effectively fragmentation photons contribute at leading order

A nagging question

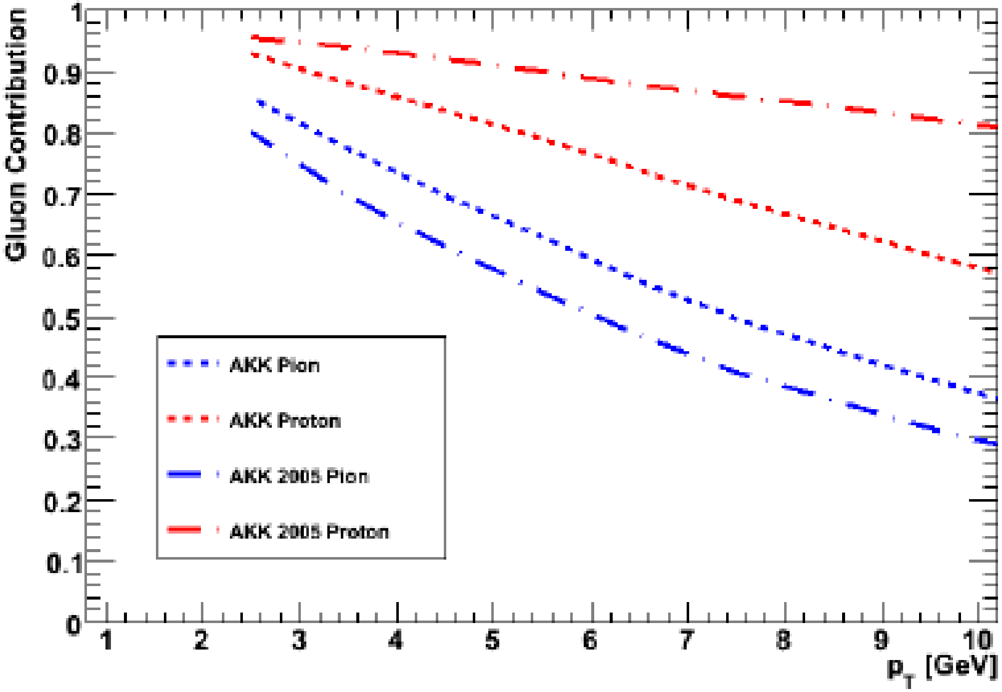
- The perturbative part of the photon fragmentation functions first showed up in our examples at the next to leading order in α_s, that is, one order beyond the Born term. Are they just higher order corrections then?
- Not really. When one examines solutions of the relevant evolution equations, it becomes apparent that the leading behavior of the perturbative part of the solutions goes as $\ln Q^2$. This is quite different from the usual hadronic behavior where we are used to seeing the distributions decrease at large x and slowly increase at small x. (See additional notes at the end of the lecture)
- The factor of $\ln Q^2$ effectively cancels out one factor of α_s, so that the fragmentation and direct contributions end up having similar dependences on Q^2. We should have included these pieces even at the lowest order!

So, to our list of contributions add those involving photon fragmentation functions

- $\mathcal{O}(\alpha\alpha_s) : \frac{d\sigma}{d\hat{t}}(ab \to cd) \otimes D_{\gamma/c}$
- $\mathcal{O}(\alpha\alpha_s^2) : \frac{d\sigma}{d\hat{t}}(ab \to cde) \otimes D_{\gamma/c}$

I also got a nifty QCD travel mug, which I lost ☹

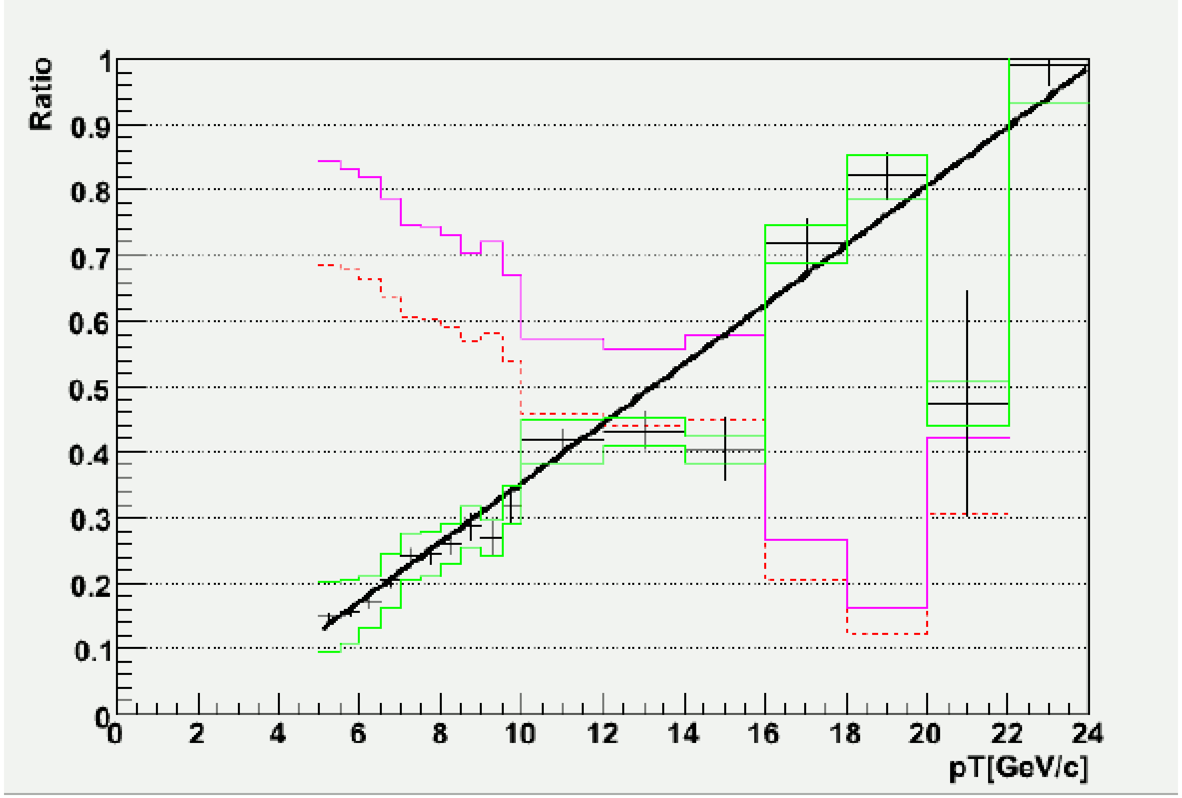
AKK: Old vs New



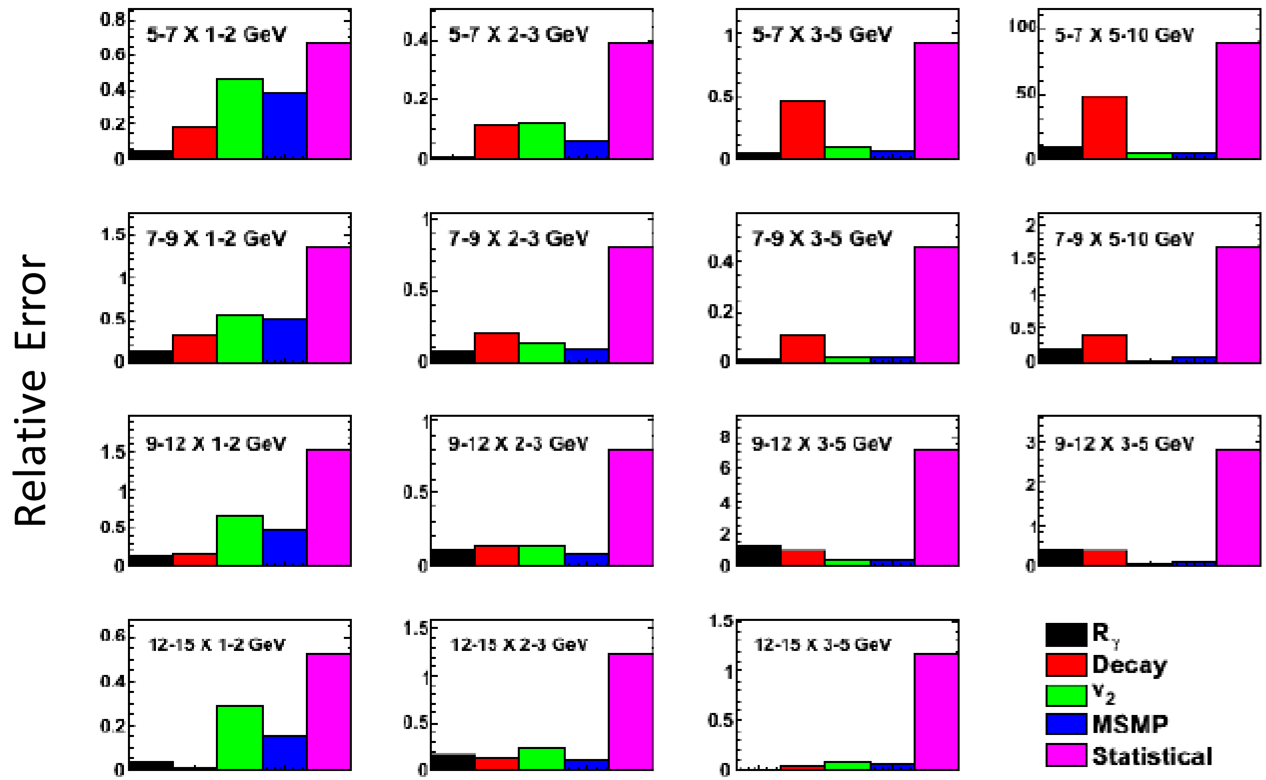
Looks like they changed their minds about the whole "all protons come from gluon jets" thing

Why does no one point this out?   I guess dog bites man isn't interesting news

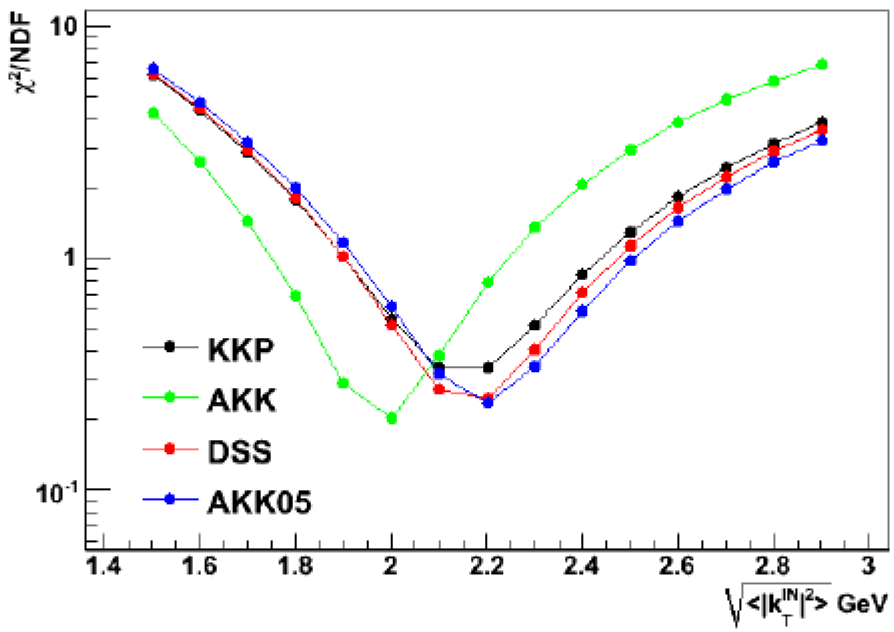
$N_{direct}/N_{inclusive}$



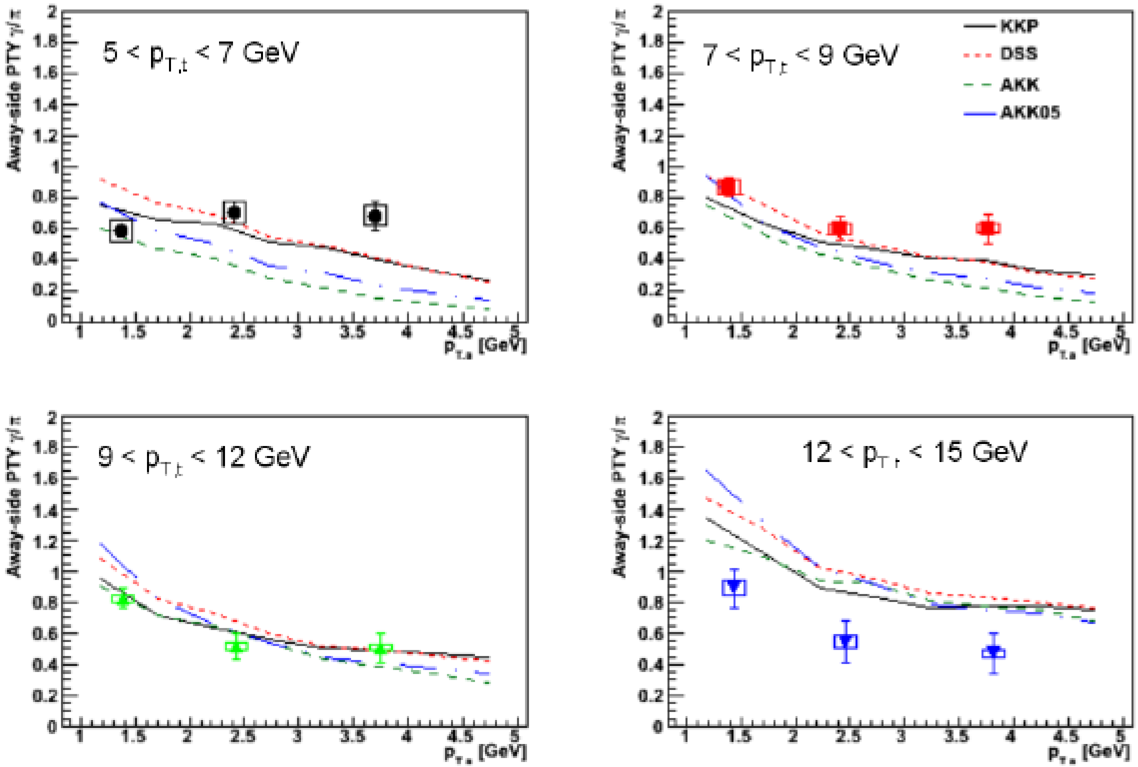
Au+Au Away-side Systematic Errors



χ^2 for isolated γ p_{OUT}

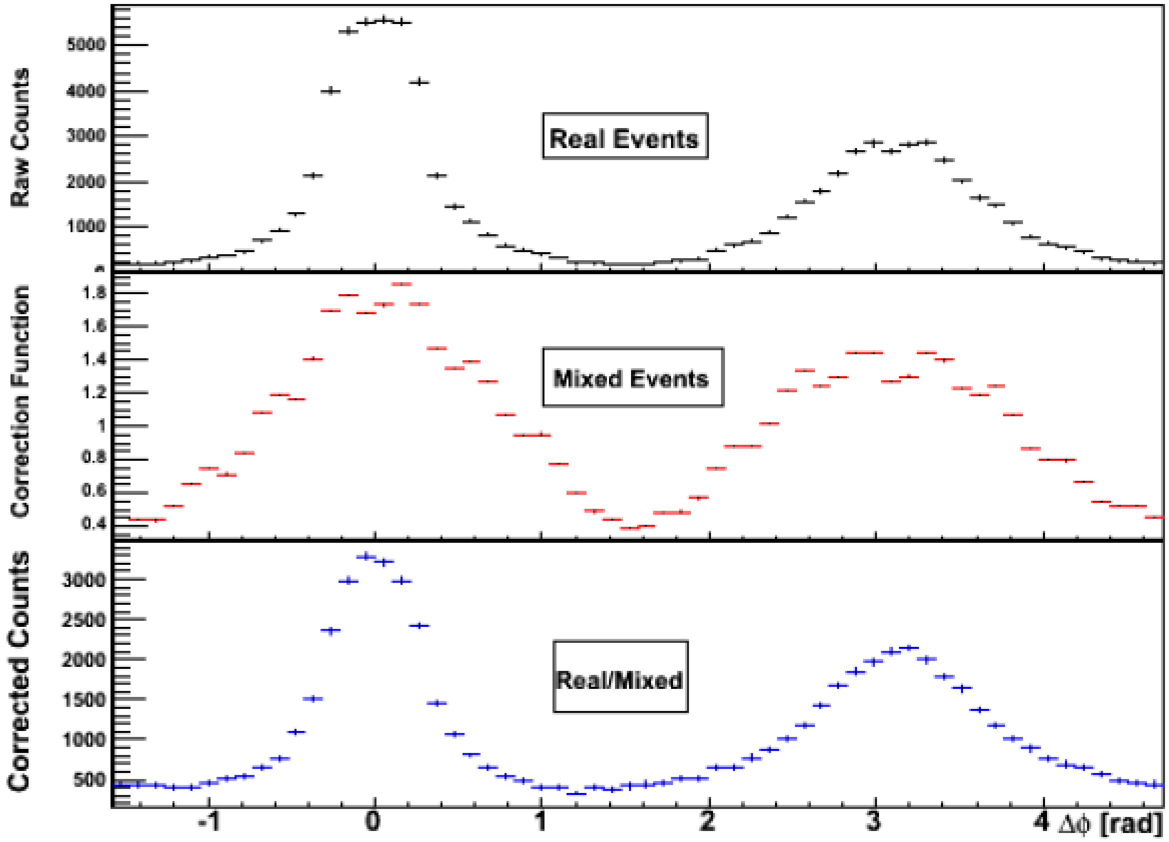


Jet Muliplicty



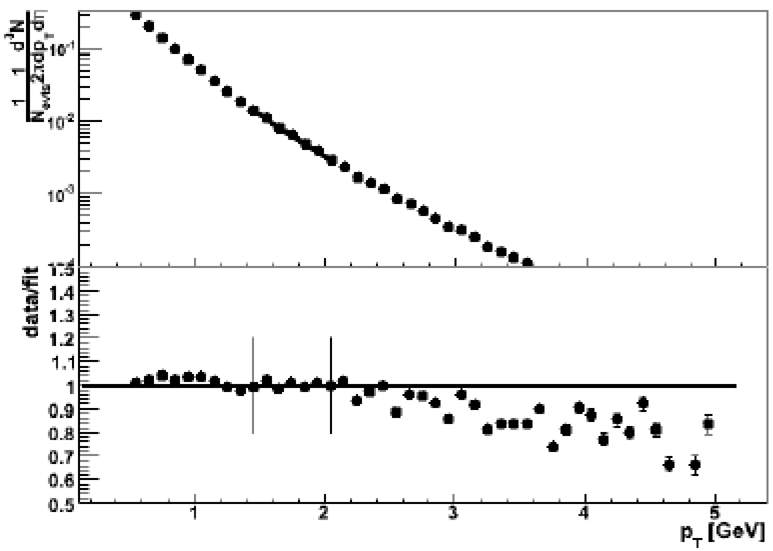
Plotted is the ratio of away-side associated yield of isolated γ's comparted to π^0's

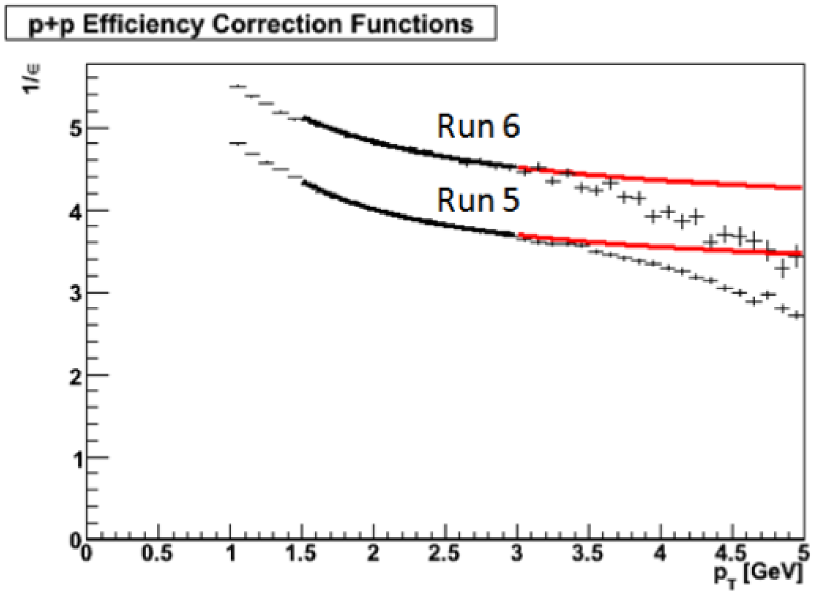
Acceptance Correction



Acceptance correction is the ratio of real/mixed events normalized by area

Charged Hadron Efficiency

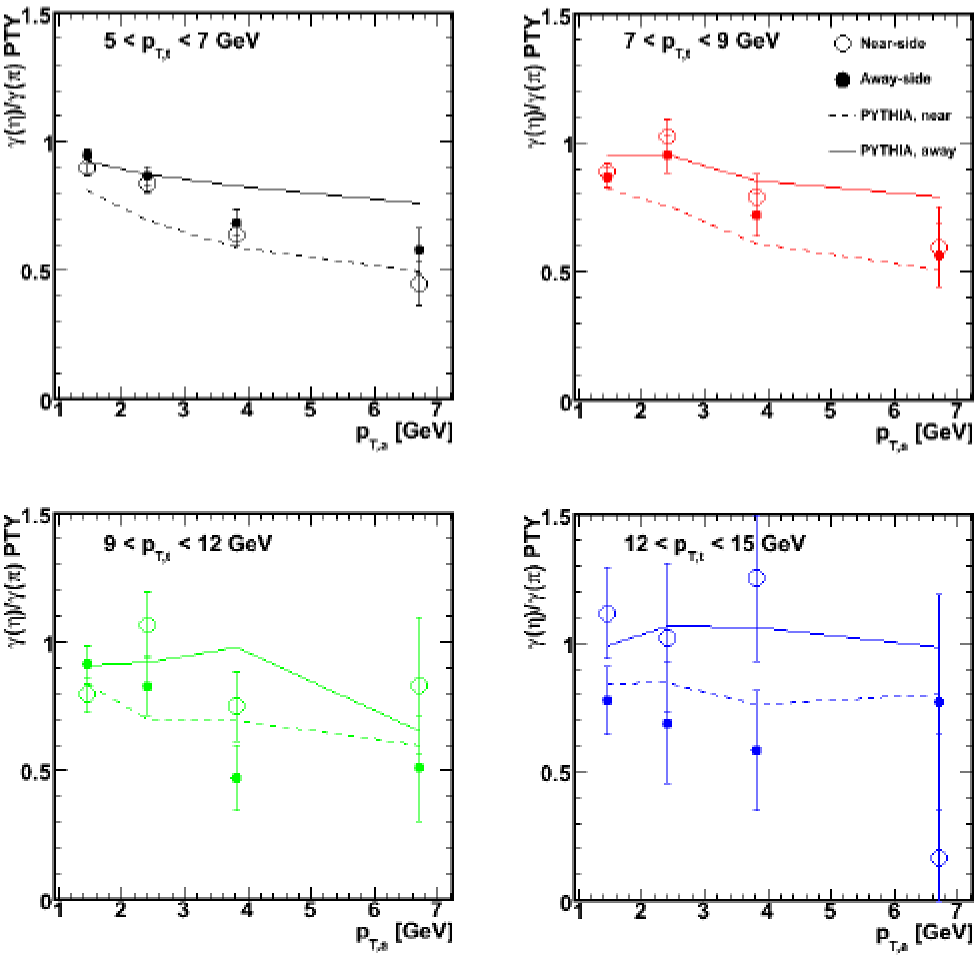




Charged hardon efficiency is evaluated by "bootstrapping" to published spectra
An extrapolation is performed at high pT were there is a background from off-vertex tracks
Extrapolation uses functional form known to work in simulation
Deviation between raw correction function and extrapolation is taken as systematic error

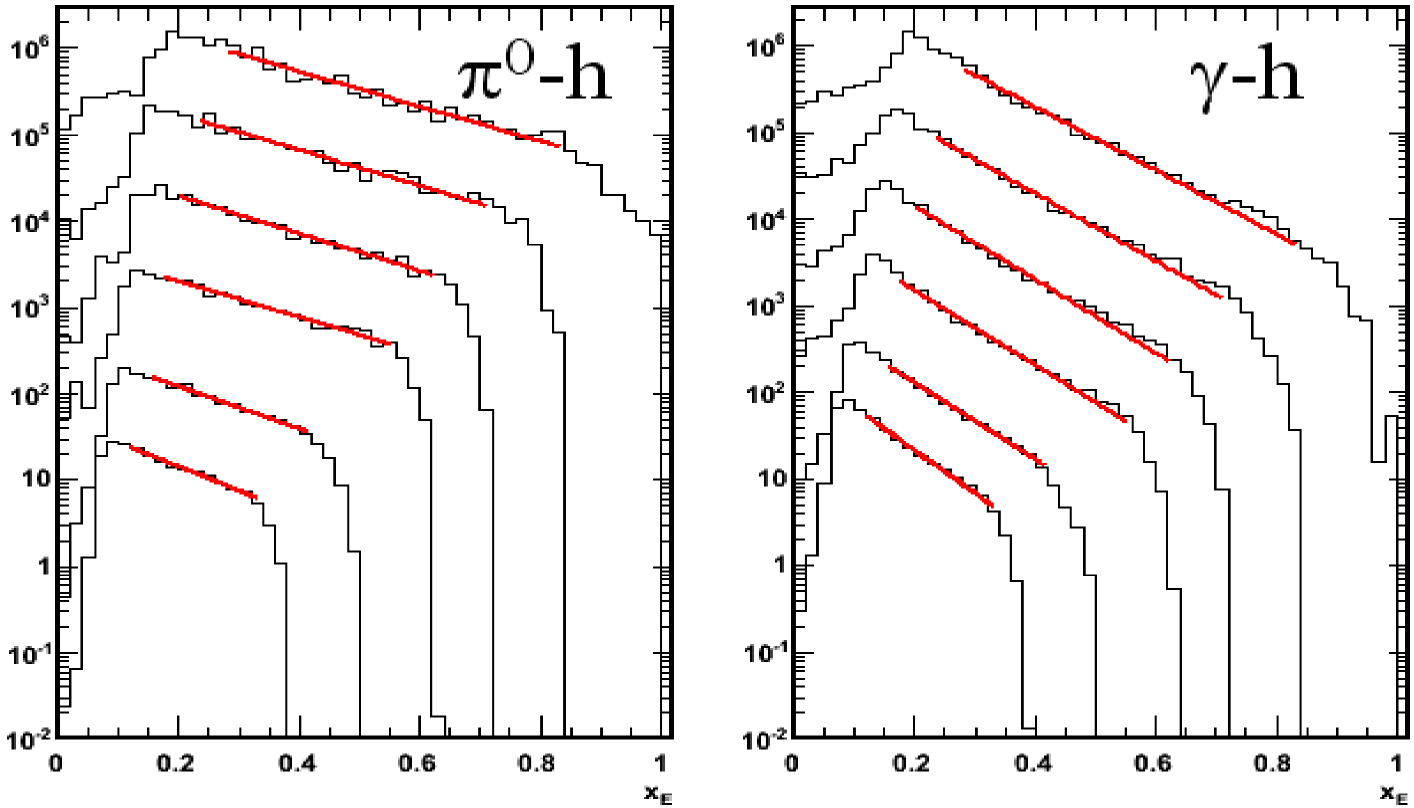
η Correlations

η-h/π^0-h



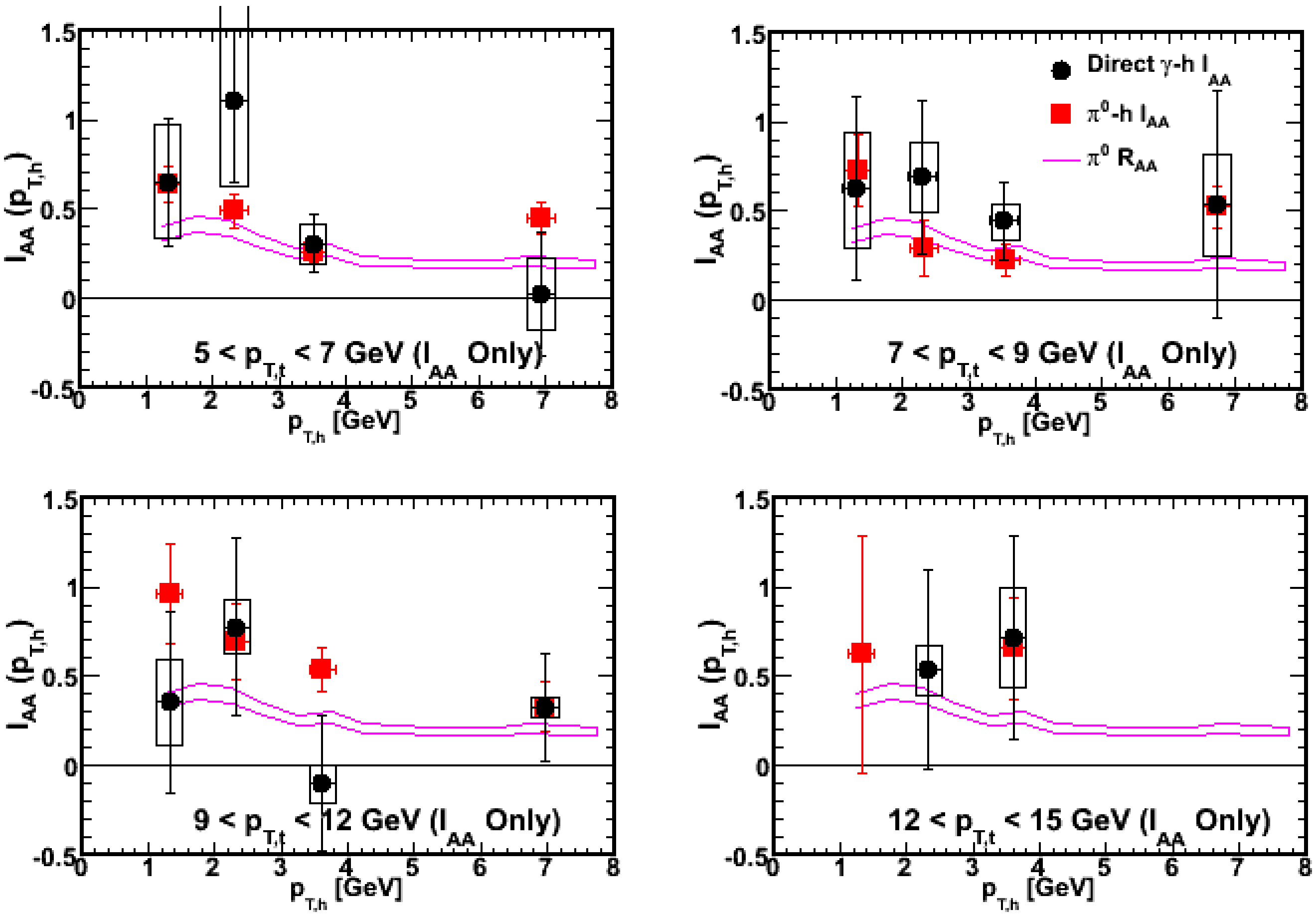
- η correlations are performed in p+p collisions
- False η matches are subtracted using the side-band correlations
- The procedure is checked in PYTHIA and found to give ~10% agreement between input and subtracted per-trigger yields which is assigned as the systematic error
- The ratio of the η to π^0 associated yields in p+p is applied as a correction factor in Au+Au where h correlations are not measureable
- The similar suppression pattern for η and π^0 supports this procedure

Is x_E exponential?



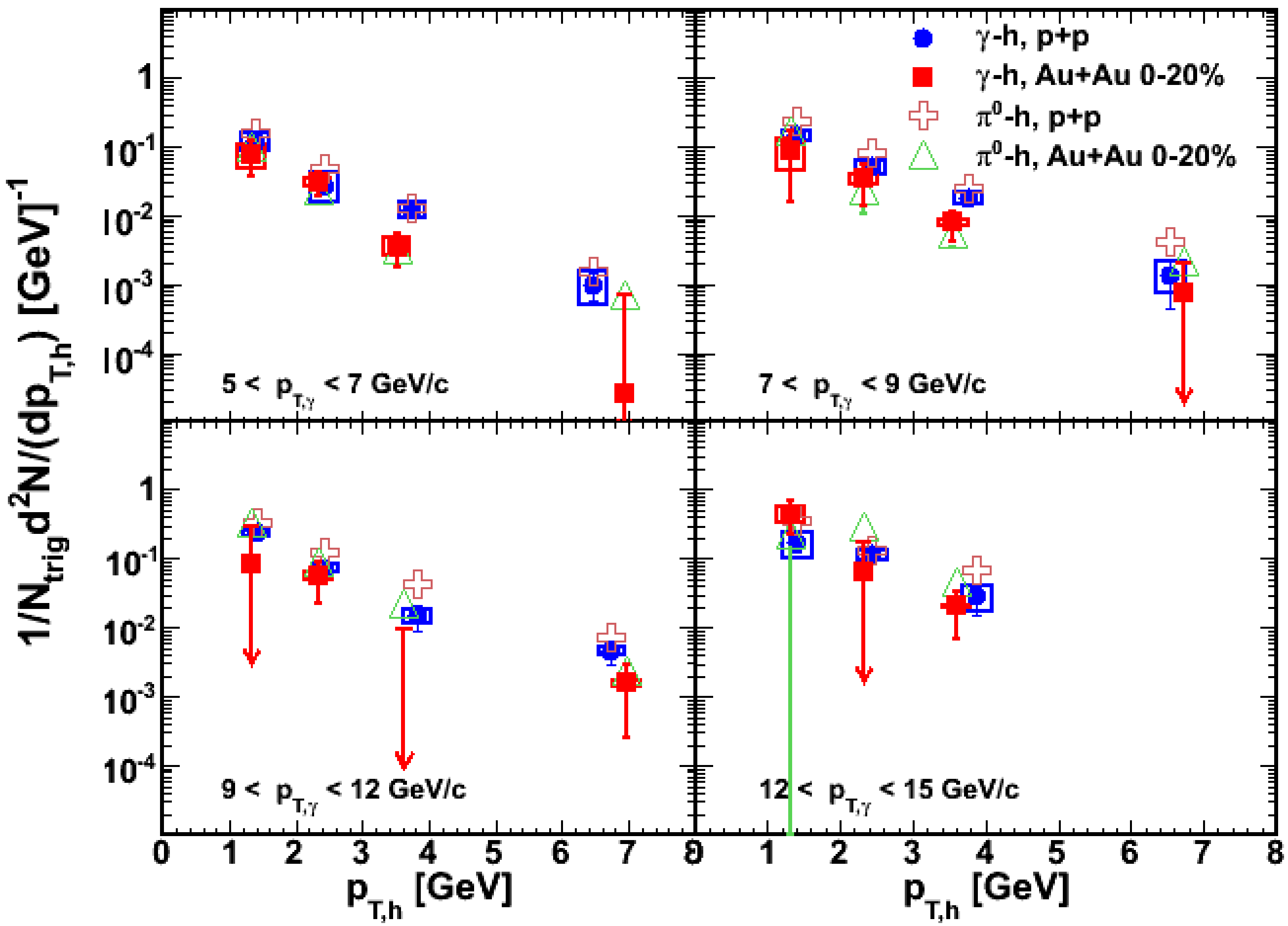
MC says exponential works pretty well (here using DSS, but holds for all)
Direct photon shows a hump at large x_E, but we can't resolve that yet anyway.
Dropoffs are caused by kinematic cut $1 < p_{Ta} < 5$ GeV
Curves are scaled for visibility

I_{AA} and R_{AA}



Direct γ-h I_{AA}
π^0-h I_{AA}
π^0 R_{AA}
$5 < p_{T,t} < 7$ GeV (I_{AA} Only)
$7 < p_{T,t} < 9$ GeV (I_{AA} Only)
$9 < p_{T,t} < 12$ GeV (I_{AA} Only)
$12 < p_{T,t} < 15$ GeV (I_{AA} Only)
I_{AA} ($p_{T,h}$)
$p_{T,h}$ [GeV]

Away-Side Yields



ISR Results for Charge Asymmetry