γ/Z^0-jet correlations

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Jet Modification in the RHIC and LHC Era

Wayne State University

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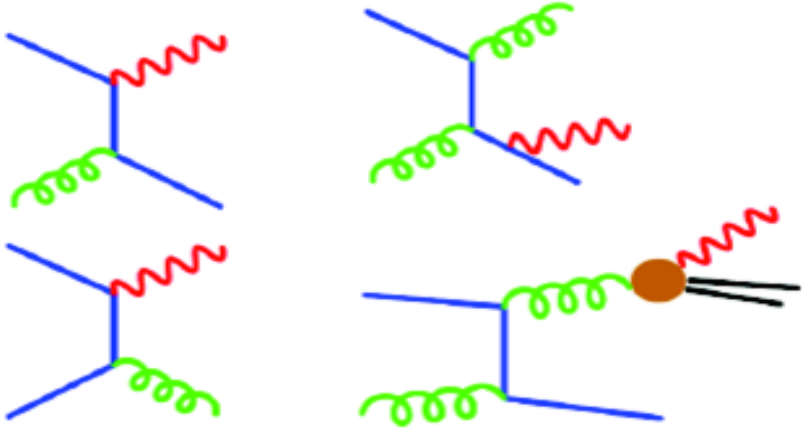
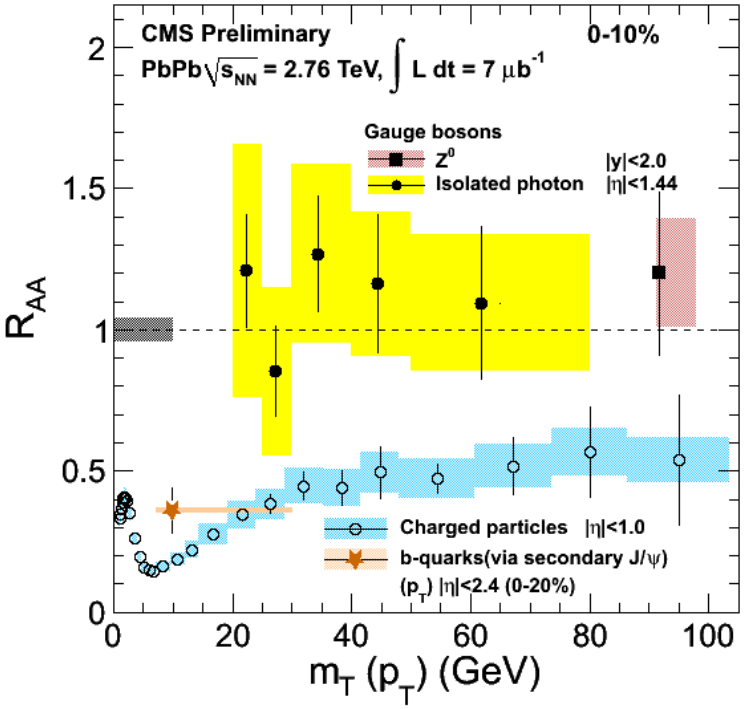
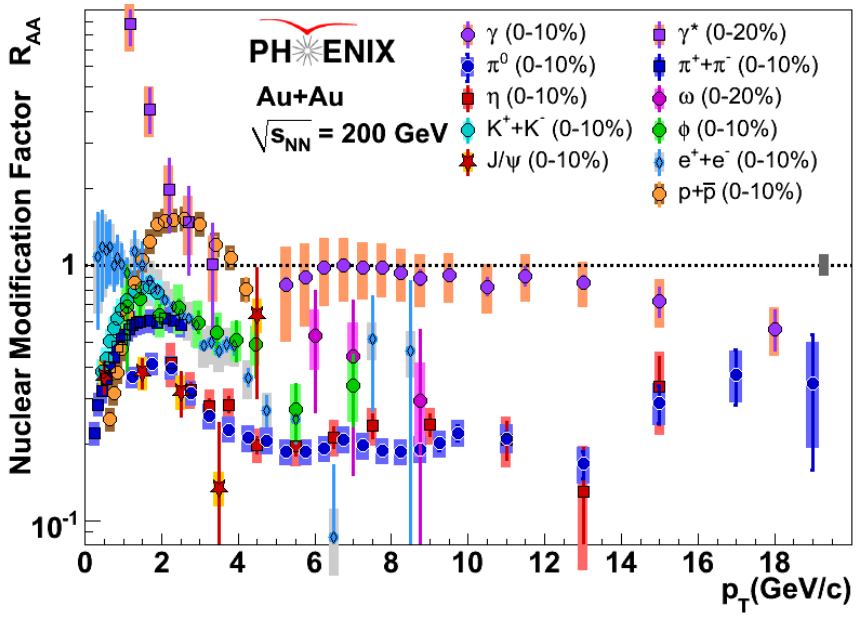
Photons and electroweak probes

- ***Mainly produced from initial hard collisions***
- ***No final state interaction once produced***
- ***Baseline for jet quenching***



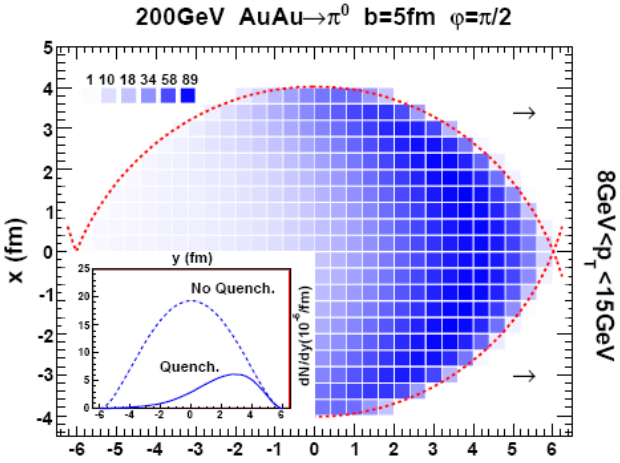


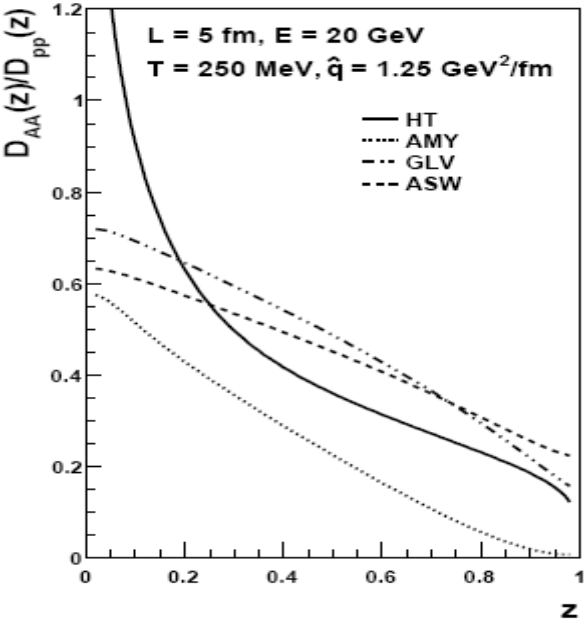


γ/Z^0-tagged jets

- *"Golden" channel for studying jet-medium interaction*
- *Provide better control of the initial jet information (p_T direction)*
- *Remove a lot of bias (deep-falling spectrum, surface emission)*
- *Many more observables (energy asymmetry, missing pairs, triggered FF, k_T broadening …)*
- *More discriminative power on jet energy loss models*

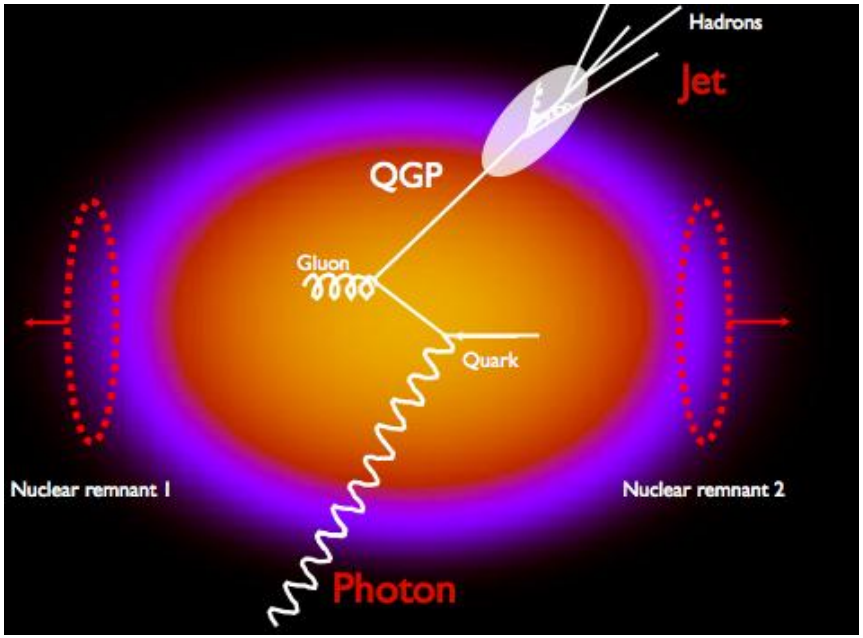
Zhang, Owens, Wang, Wang, PRL, 2008
Majuder, Van Leeuwen, arXiv:1002.2206





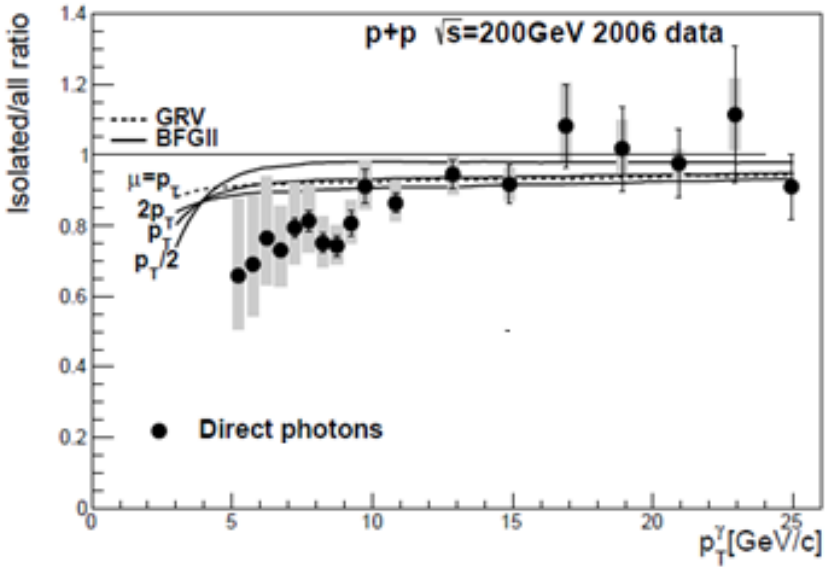
What we need?

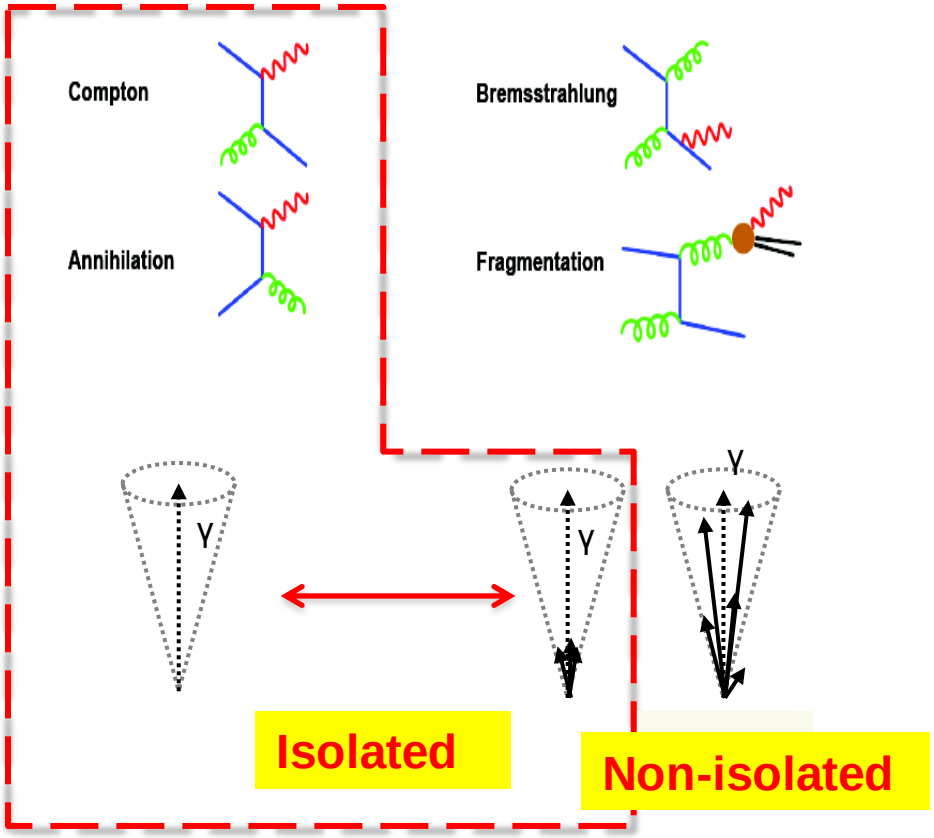
- ***How jets and photons, Z^0 are created?***
  - ***Perturabtive calculation***
  - ***Identify the contribution from different photon sources***
- ***How jets propagate and change in the medium?***
  - ***Jet energy loss theory and models***
  - ***Medium evolution profile (hydro)***
- ***The response of medium to jet-deposited energy and momentum may affect the background***



Photons in p+p

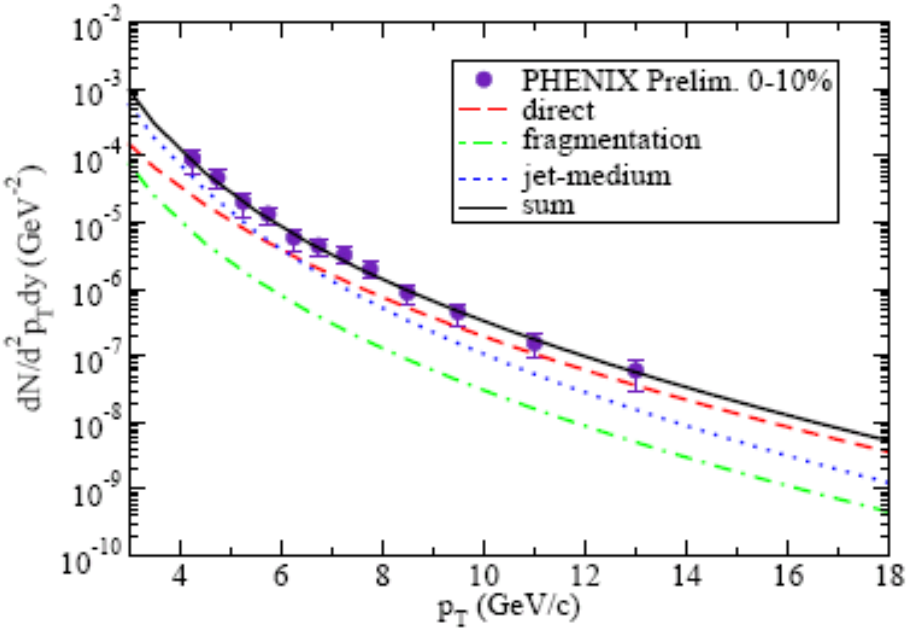
- *About 90% are isolated photons in R = 0.5 cone*
- *Need consistence between theory and experiment*
- *What is this number for A+A collisions?*



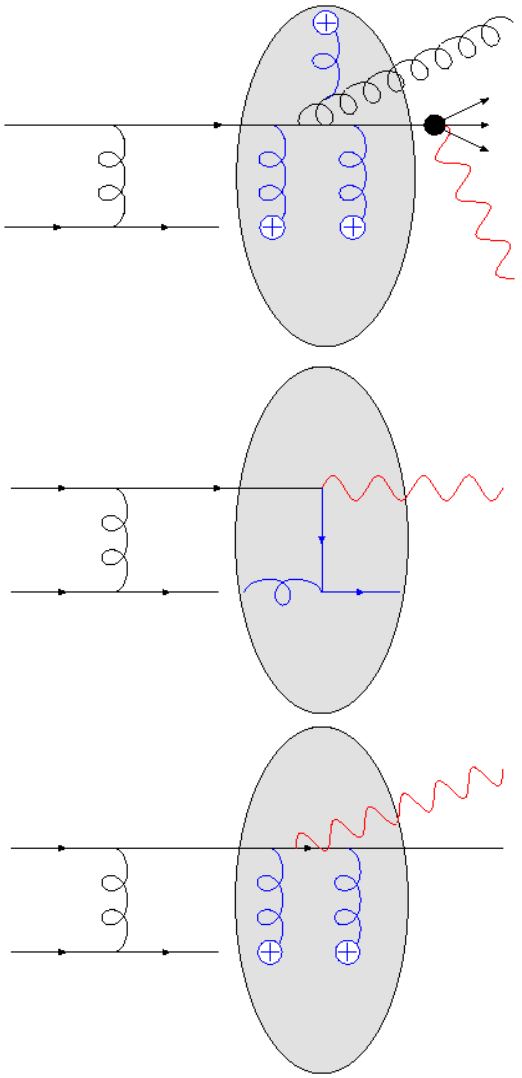


Photons in A+A

- ***Sizable contribution from jet-medium photons at intermediate p_T***
- ***Non-prompt photon-trigged jets may have different shapes compared to prompt photons***
- ***Measure both cases (with and without isolation cut?)***



GYQ, Ruppert, Gale, Jeon, Moore, PRC, 2009



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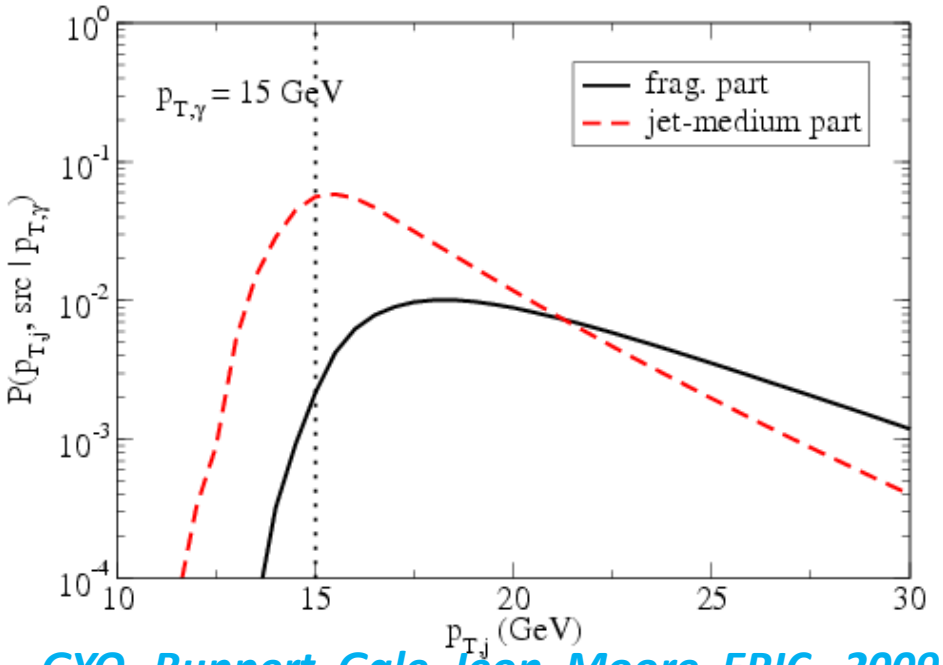

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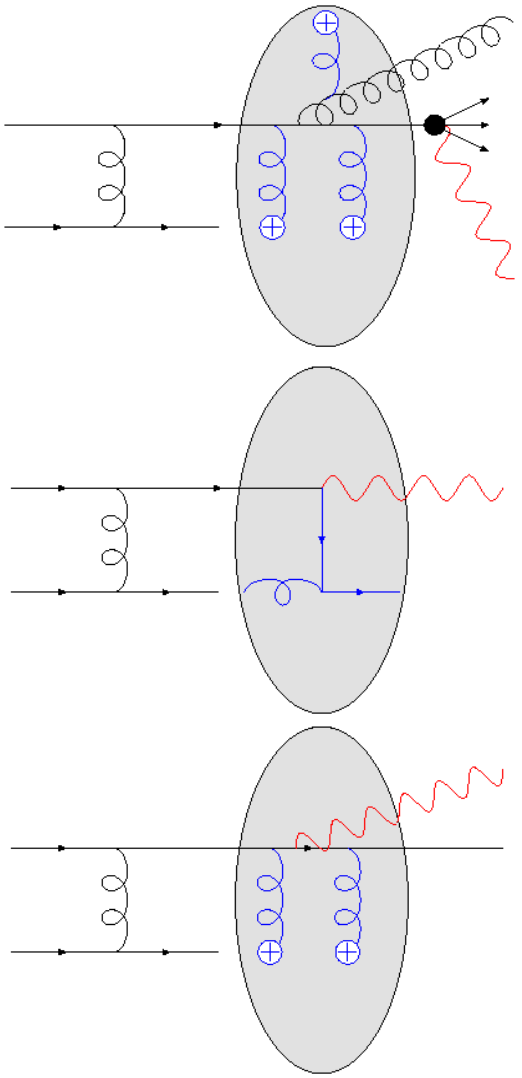
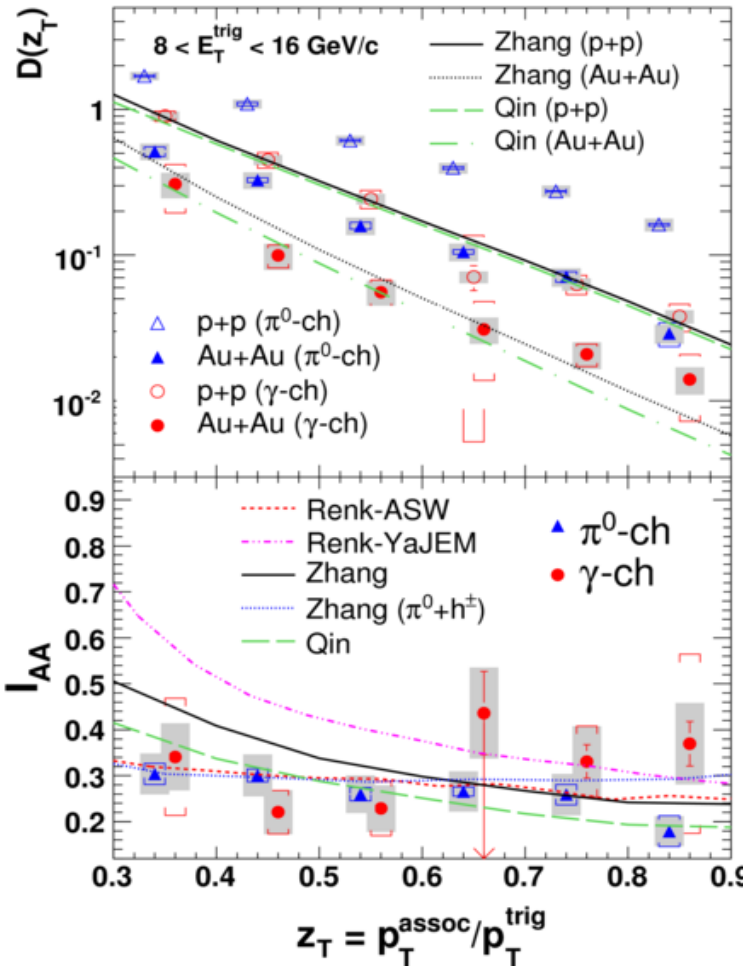
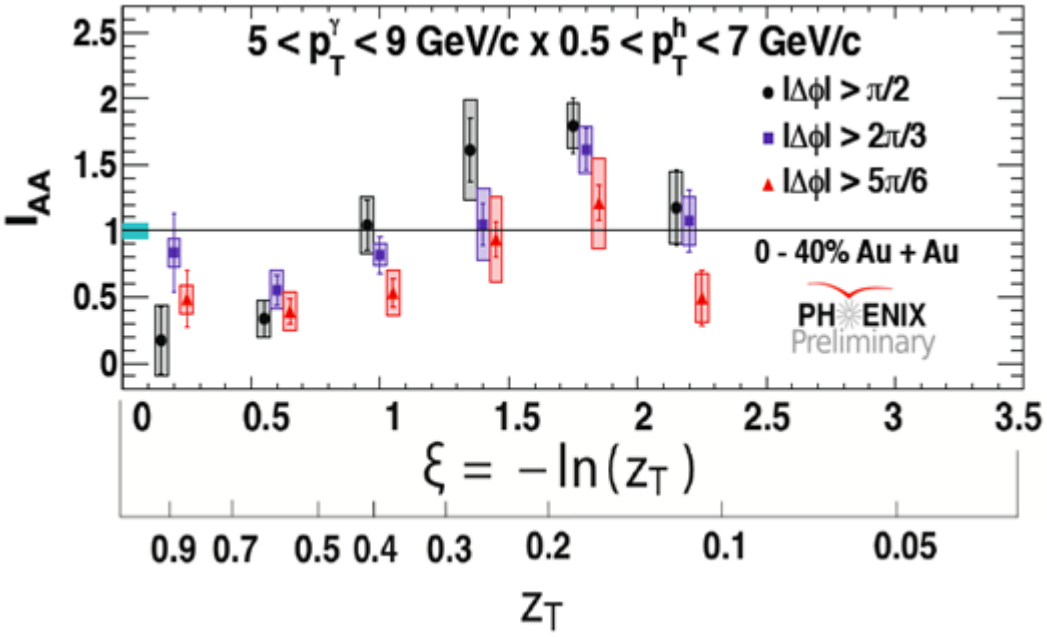


Photon-triggered FF

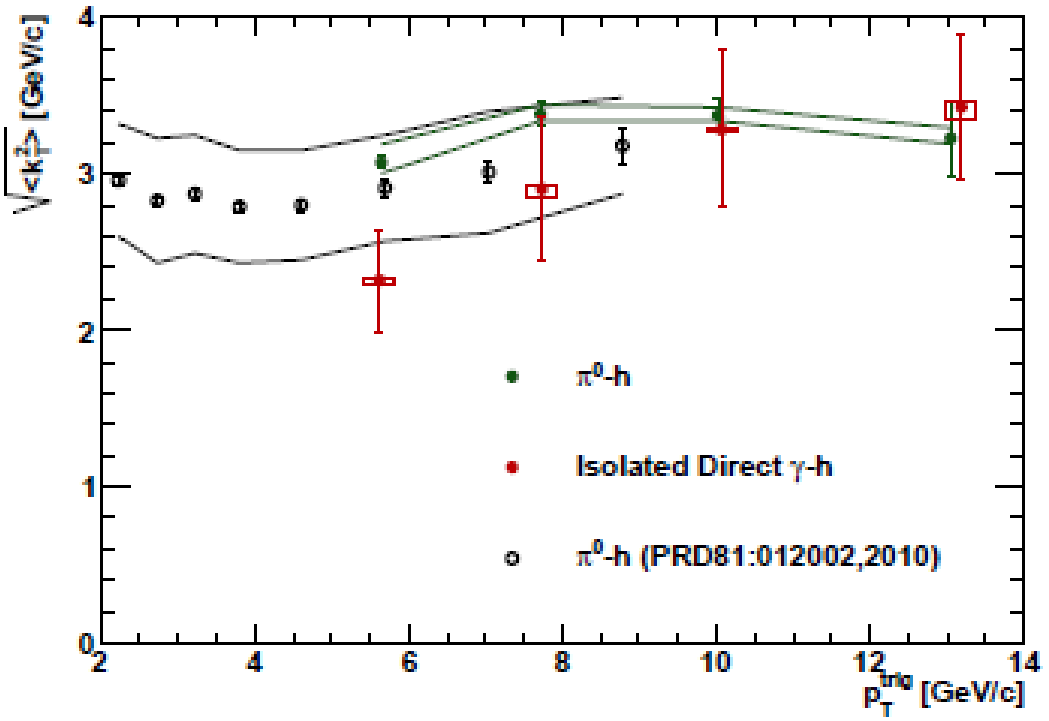


- ***Good approximation of medium-modified fragmentation function***
- ***Suppression at high z_T and enhancement at low z_T***
- ***Consistent with the picture of jet energy loss and redistribution of lost energy from jet***



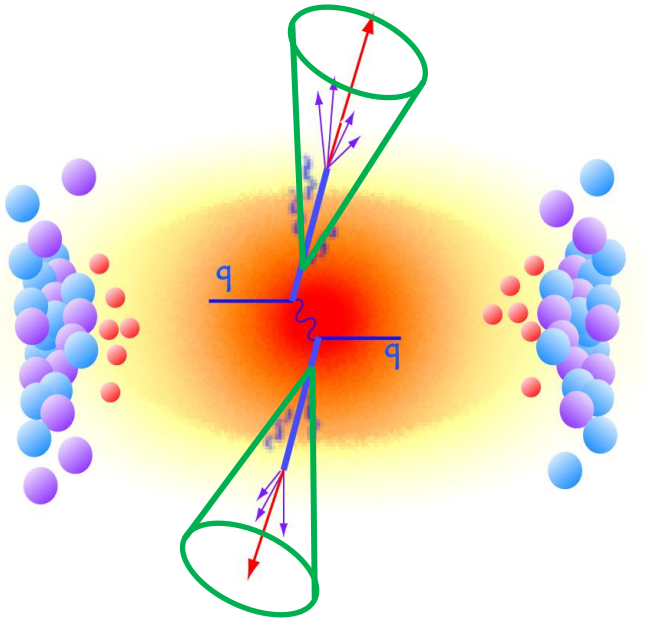
k_T brodening

- ***Both radiative energy loss and k_T broadening are controlled by $\hat{q}$***
- ***Longitudinal scatterings may be as important as transverse scattering (change jet energy loss and jet shape)***
- ***Measuring jet shape in three dimensions provide better constraint on jet energy loss models***



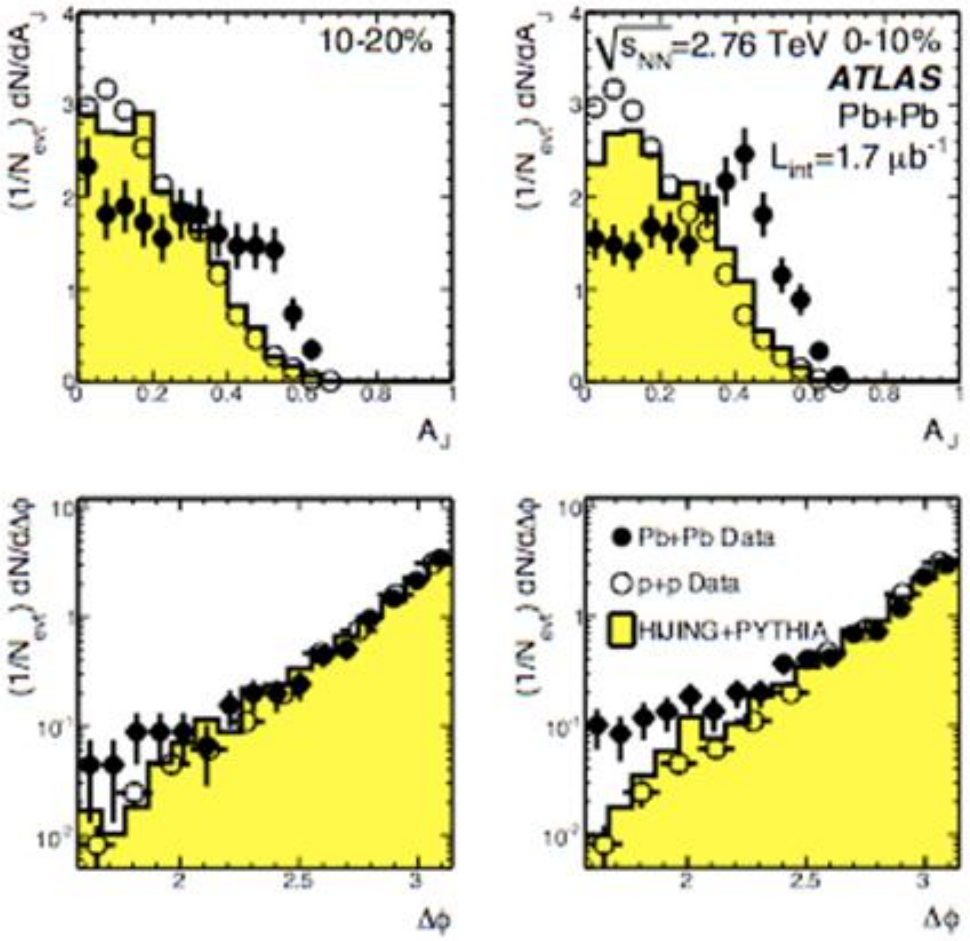
Fully reconstructed jets

- ***Capture both leading and sub-leading fragments inside the jet***
- ***New observables provide more discriminating power against jet energy loss models***
- ***Require running jet finders***
- ***Need to disentangle jets from soft background***
- ***Jets and the background may be correlated (initial production, jet-medium interaction)***

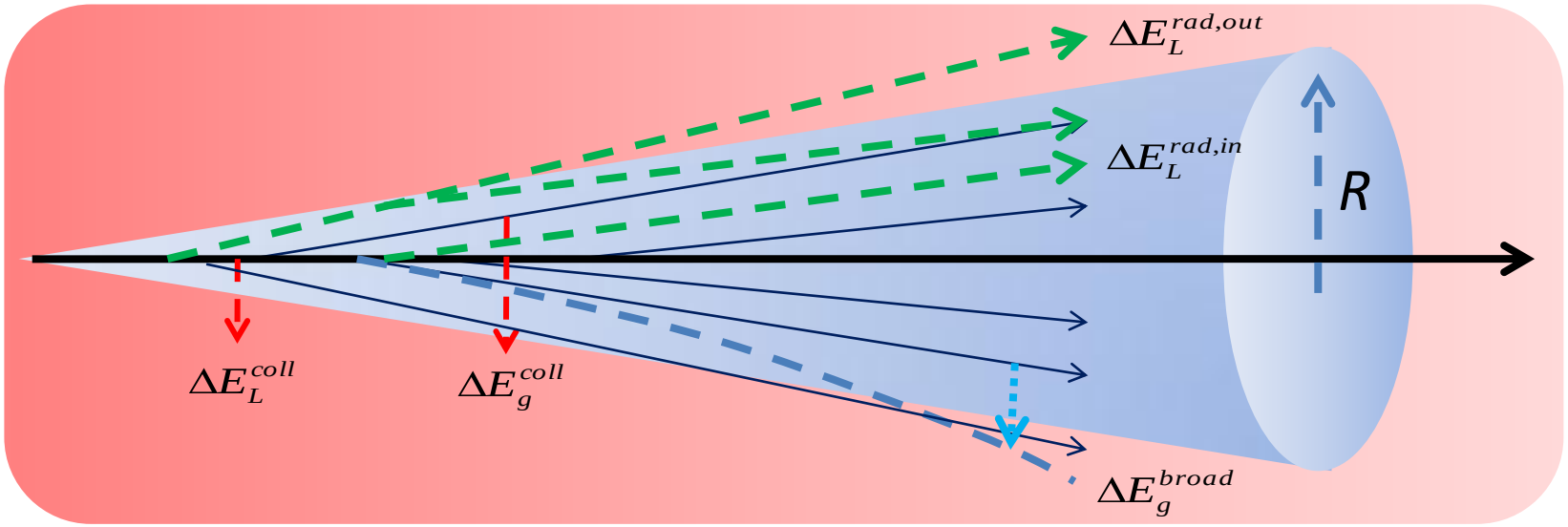


Dijet @ LHC

- ***Dijet energy imbalance increases as one moves to more central collisions***
- ***Dijet angular distribution largely unchanged***
- ***Many other results for full jet measurements***



Jet shower evolution in medium



Leading parton:

Transfers energy to medium by elastic collisions

Medium-induced gluon radiation (inside and outside jet cone)

Radiated gluons (vacuum & medium-induced):

Transfer energy to medium by elastic collisions

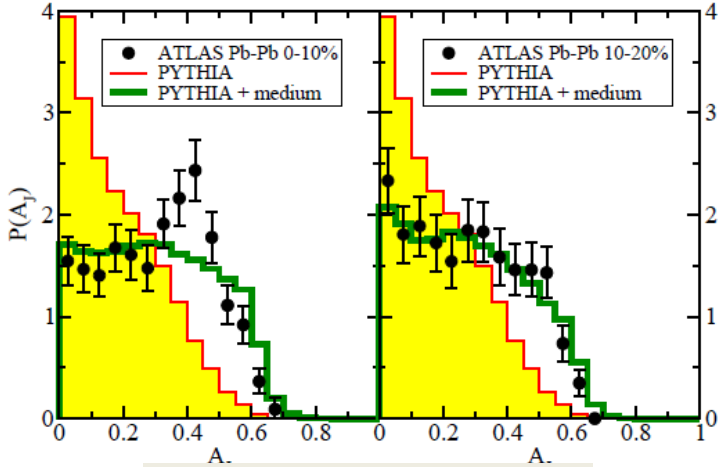
Be kicked out of the jet cone by multiple scatterings after emission

$$E_L(t) = E_L(t_i) - \int \hat{e}_L dt - \int \omega d\omega dk_\perp^2 dt \frac{dN_g^{med}}{d\omega dk_\perp^2 dt}$$

$$\frac{df_g(\omega, k_\perp^2, t)}{dt} = \hat{e}\frac{\partial f_g}{\partial \omega} + \frac{1}{4}\hat{q}\nabla_{k_\perp}^2 f_g + \frac{dN_g^{med}}{d\omega dk_\perp^2 dt}$$

GYQ, Muller, PRL, 2011

Theory postdictions for dijet asymmetry



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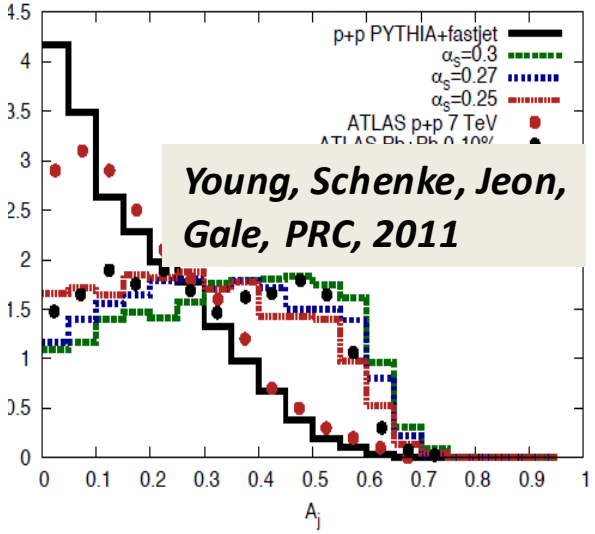
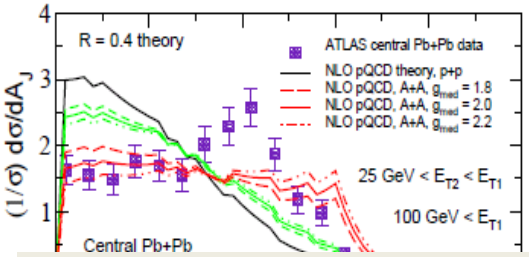
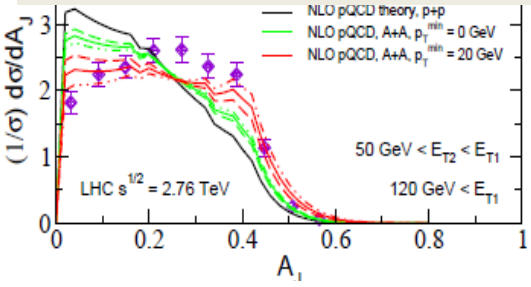
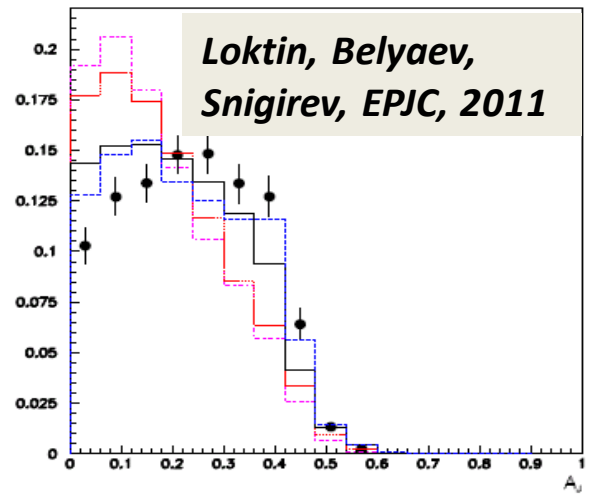


Young, Schenke, Jeon, Gale, PRC, 2011

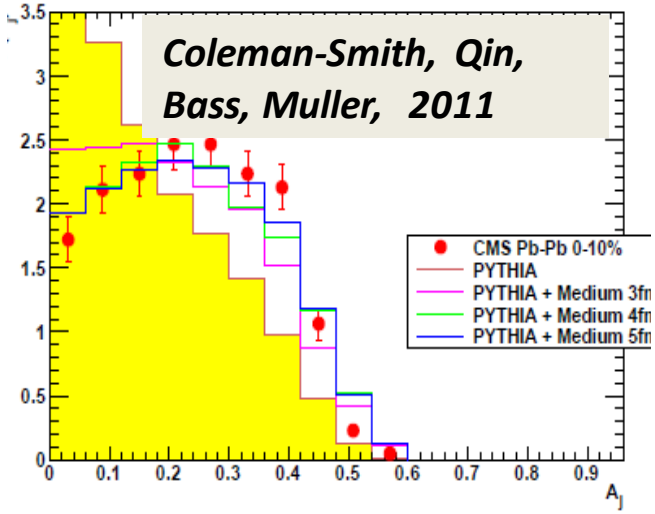


He, Vitev, Zhang, 2011

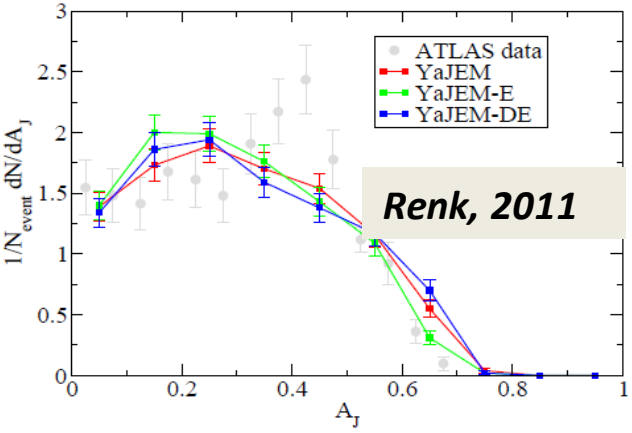




Loktin, Belyaev, Snigirev, EPJC, 2011



Coleman-Smith, Qin, Bass, Muller, 2011



Renk, 2011

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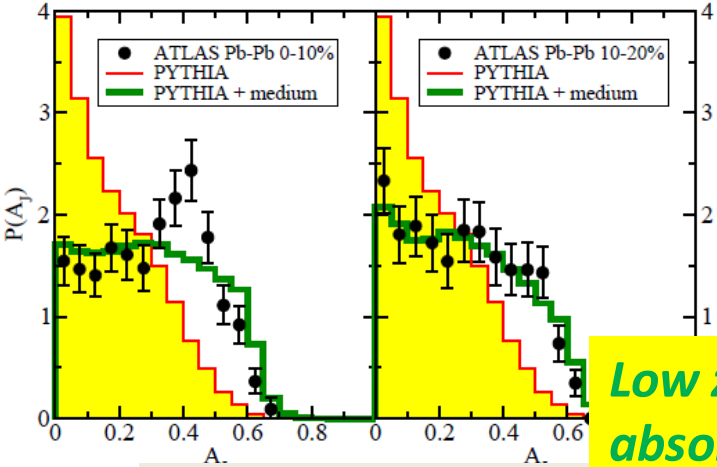

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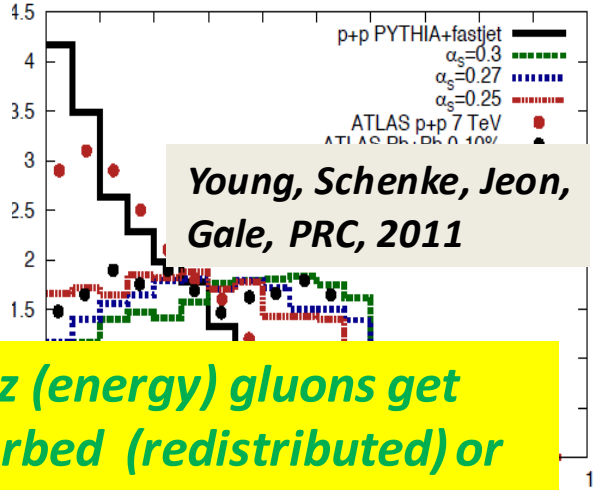
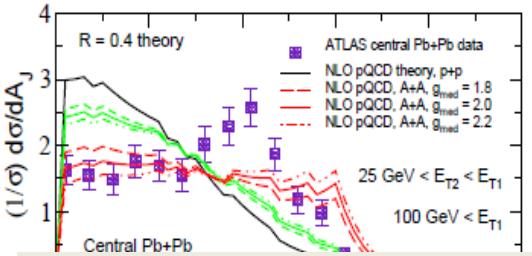


Young, Schenke, Jeon, Gale, PRC, 2011

Low z (energy) gluons get absorbed (redistributed) or scattered out of the jet cone



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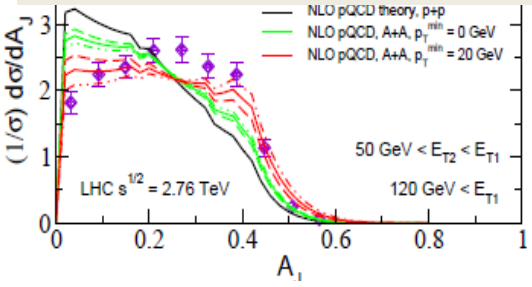

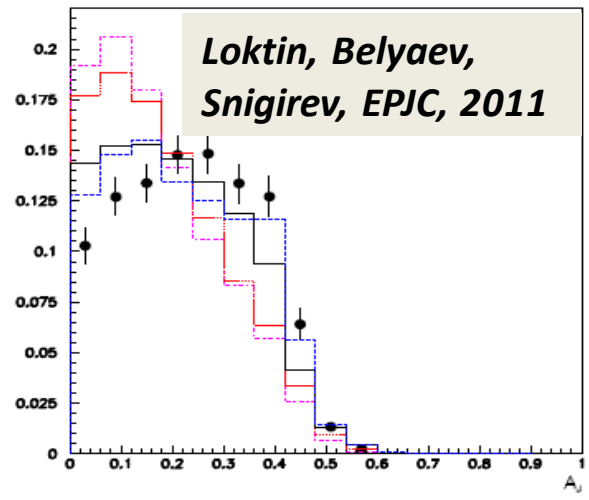

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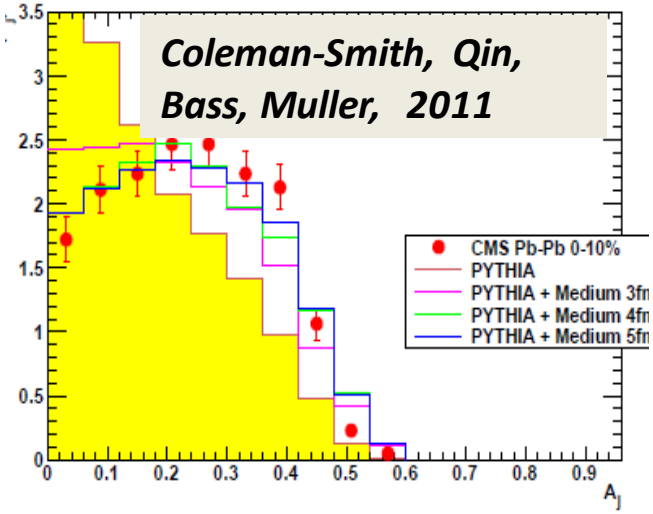

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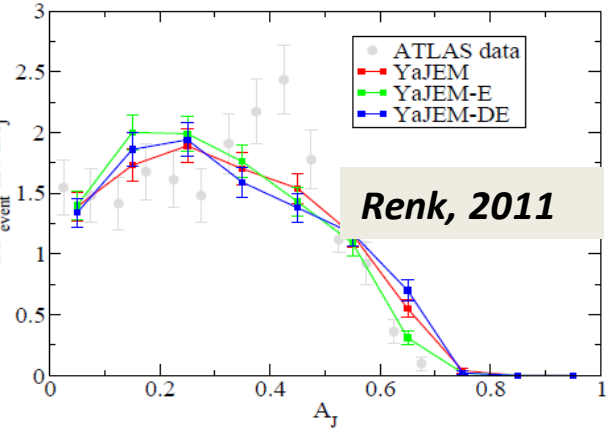
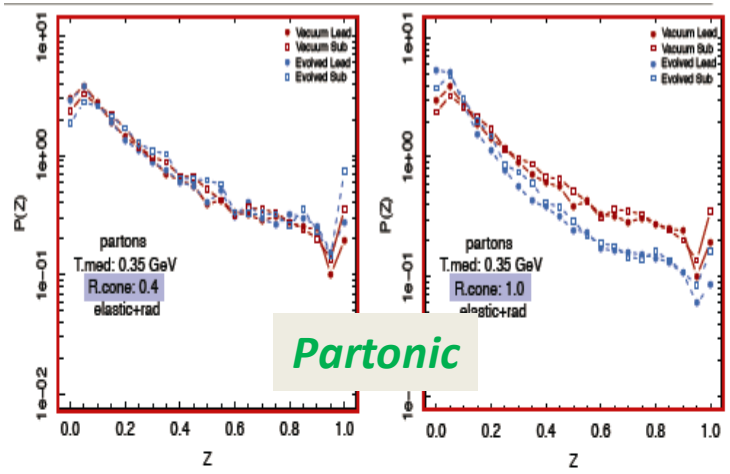


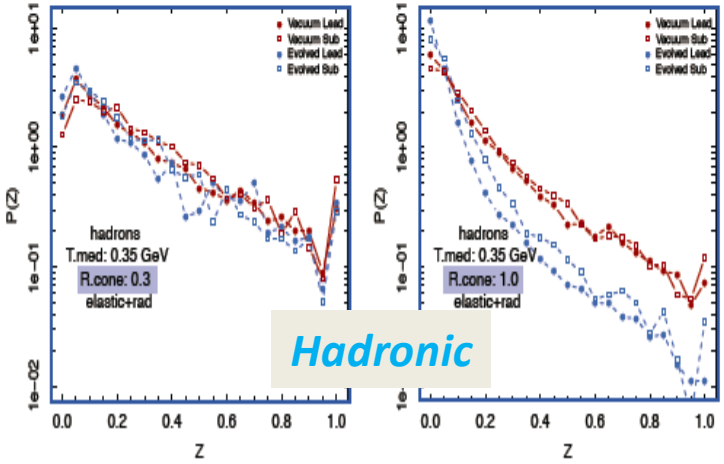
Renk, 2011

Jet fragment profile

Longitudinal ***Coleman-Smith, QM 2012*** ***Transverse***



Partonic

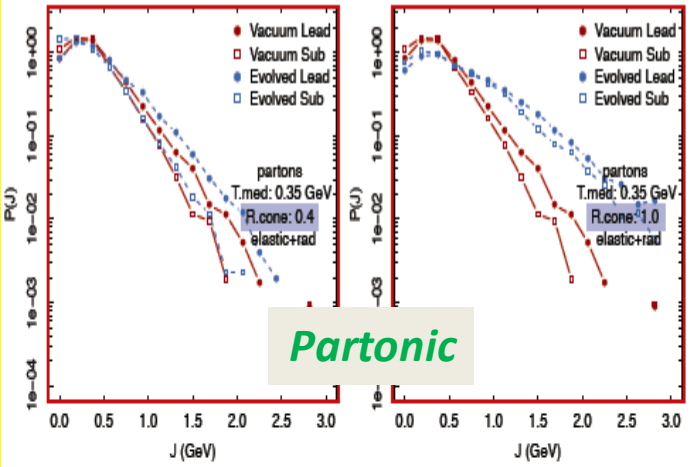


Hadronic

Narrower jets are similar to vacuum ones

Medium-modified jets are softer and broader than vacuum ones for larger jet size

Hadronization changes jet shapes, the effect is larger for large jet size



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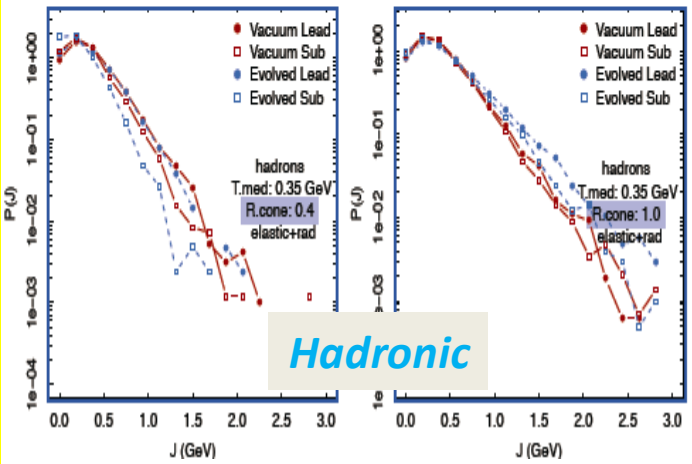
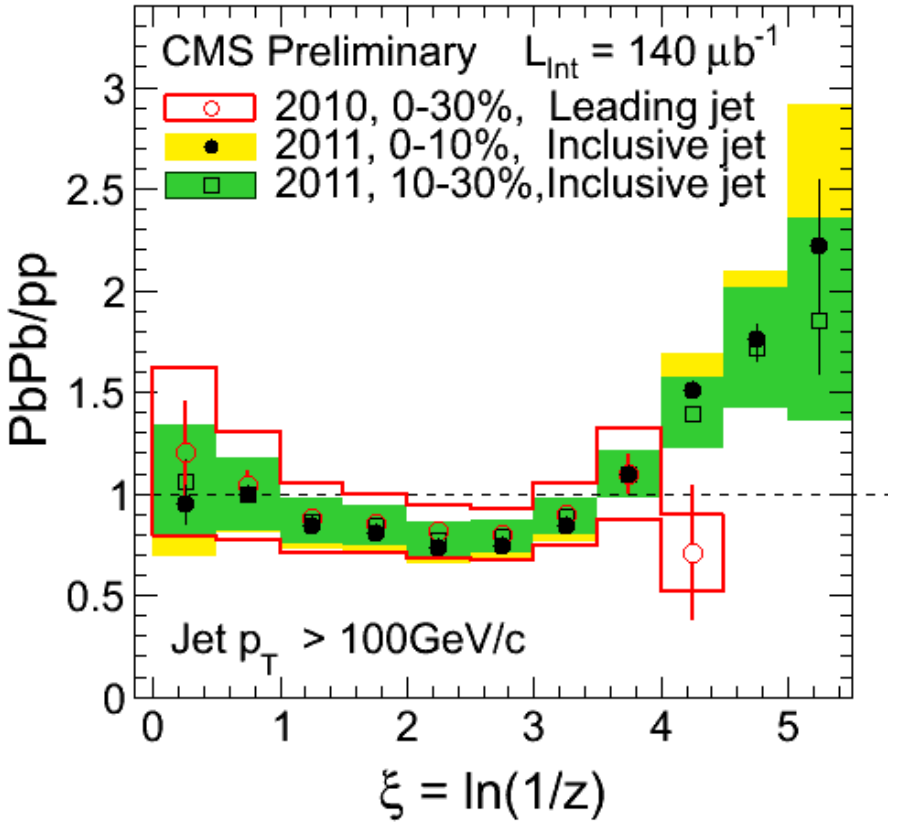
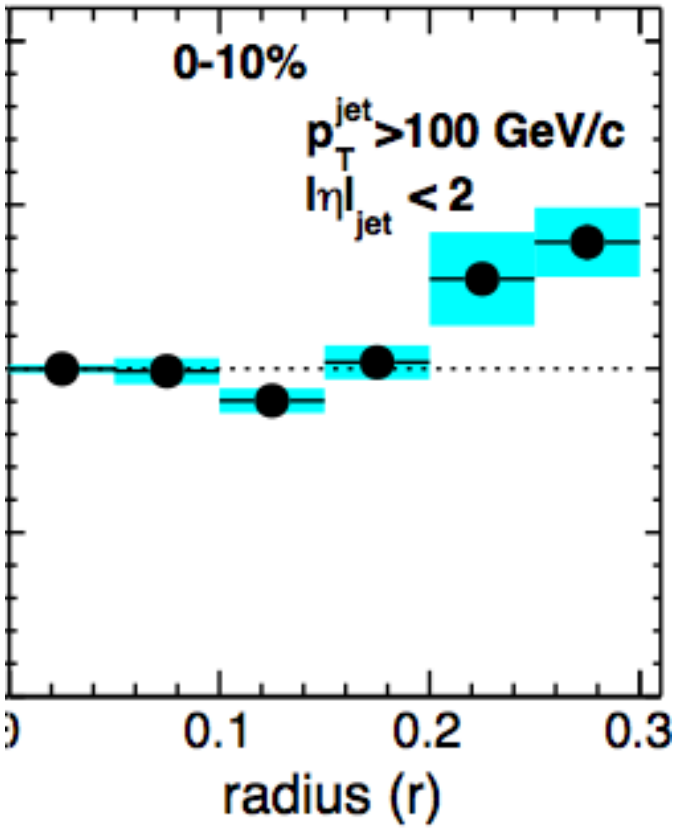


Hadronic

Measurement: jet fragment profile



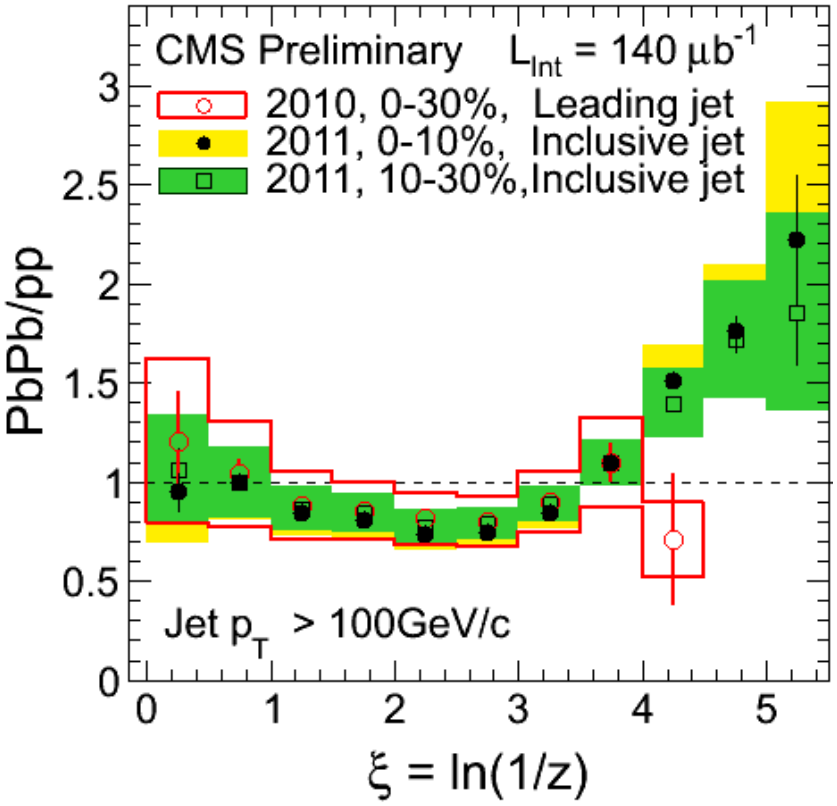


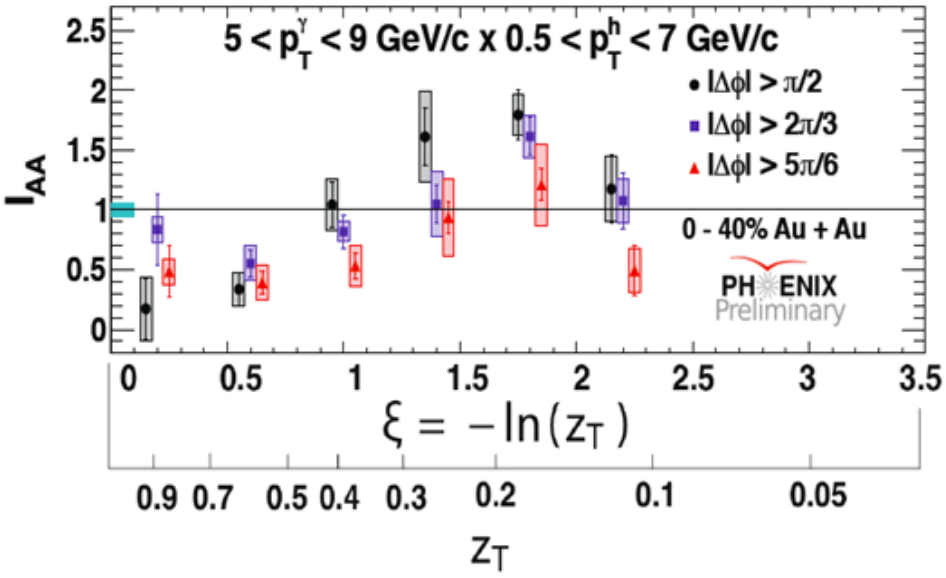
No change at high p_T and small r

Depletion/narrower at intermediate p_T and intermediate r

Excess/broadening at low p_T, large r

Compare to photon-triggered FF





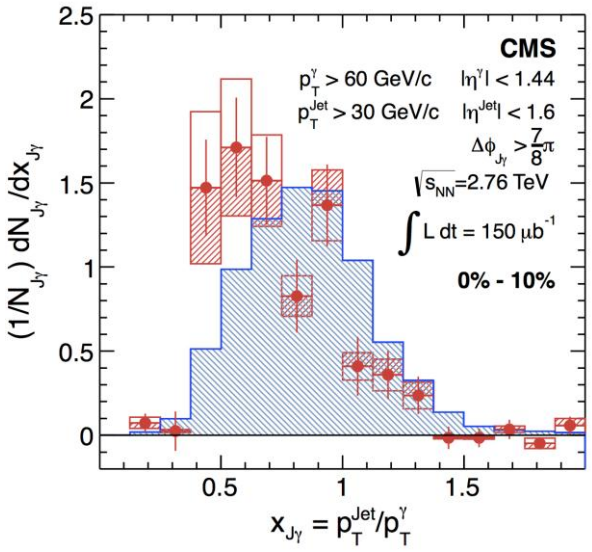
The reconstructed jet energy is not the energy at the production vertex

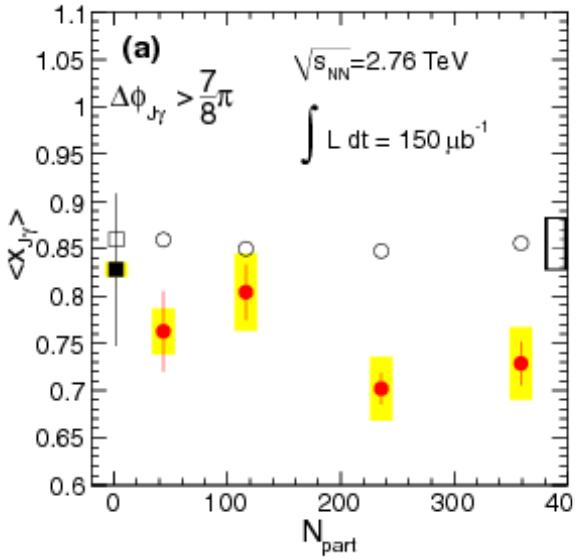
Photon-triggered FF: suppression at high z_T, enhancement at low z_T

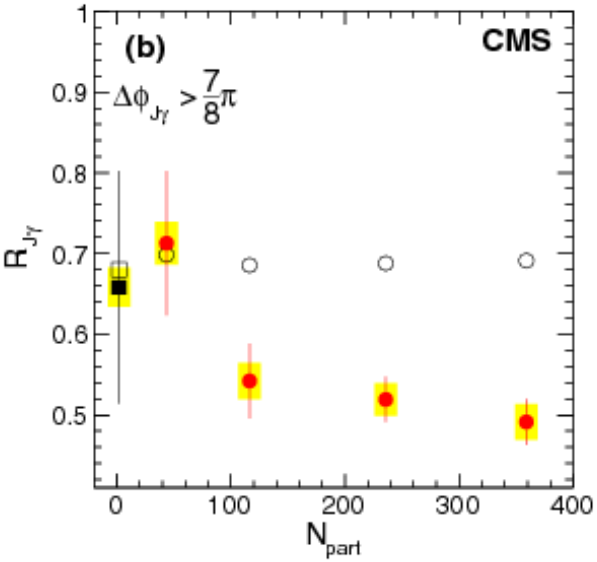
Using photon triggered full jets

Also increasing jet size might bring the ratio smaller than unity

Measurement: γ-jet correlations



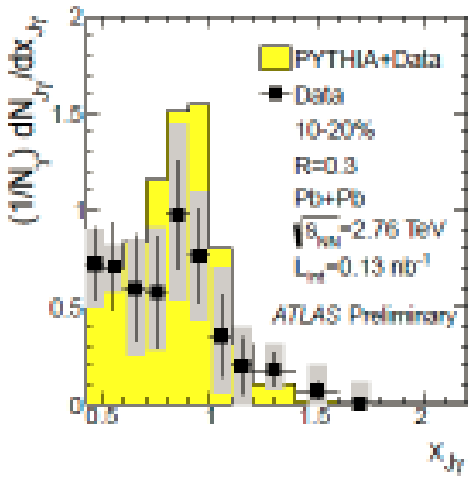


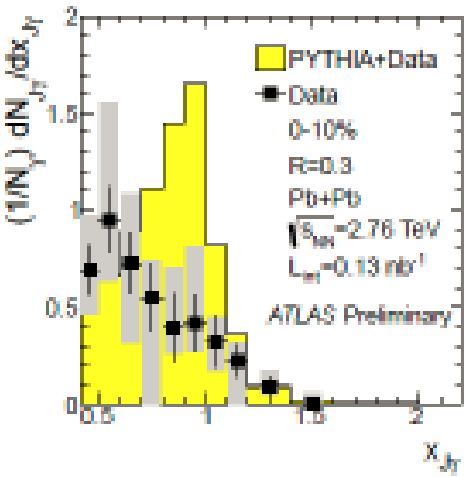


The distribution shift towards smaller x_J

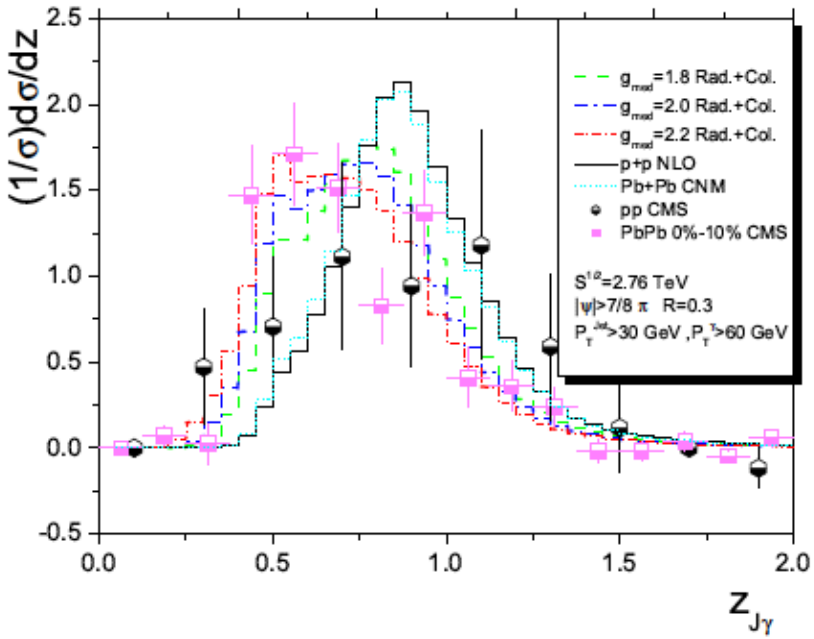
Missing pairs (the integral is smaller for ATLAS)

More quenching towards central collisions

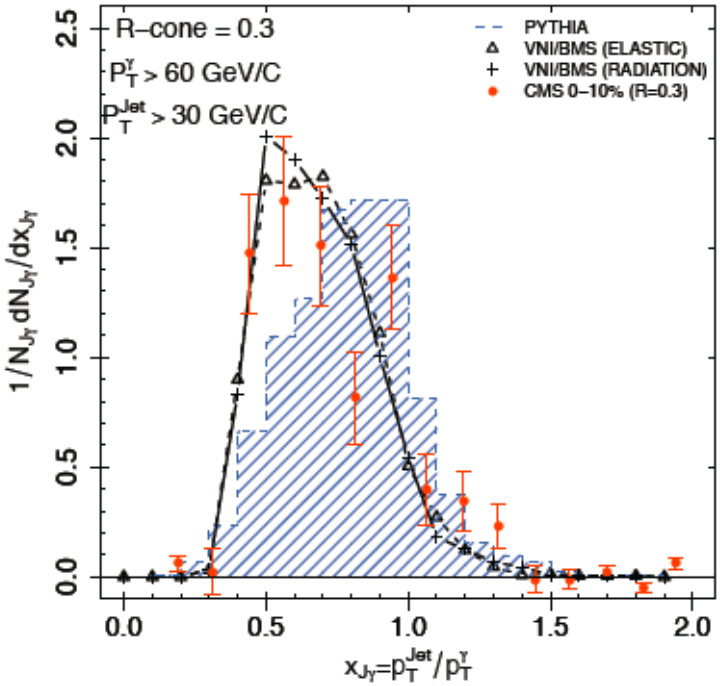




Calculation: γ-tagged jets



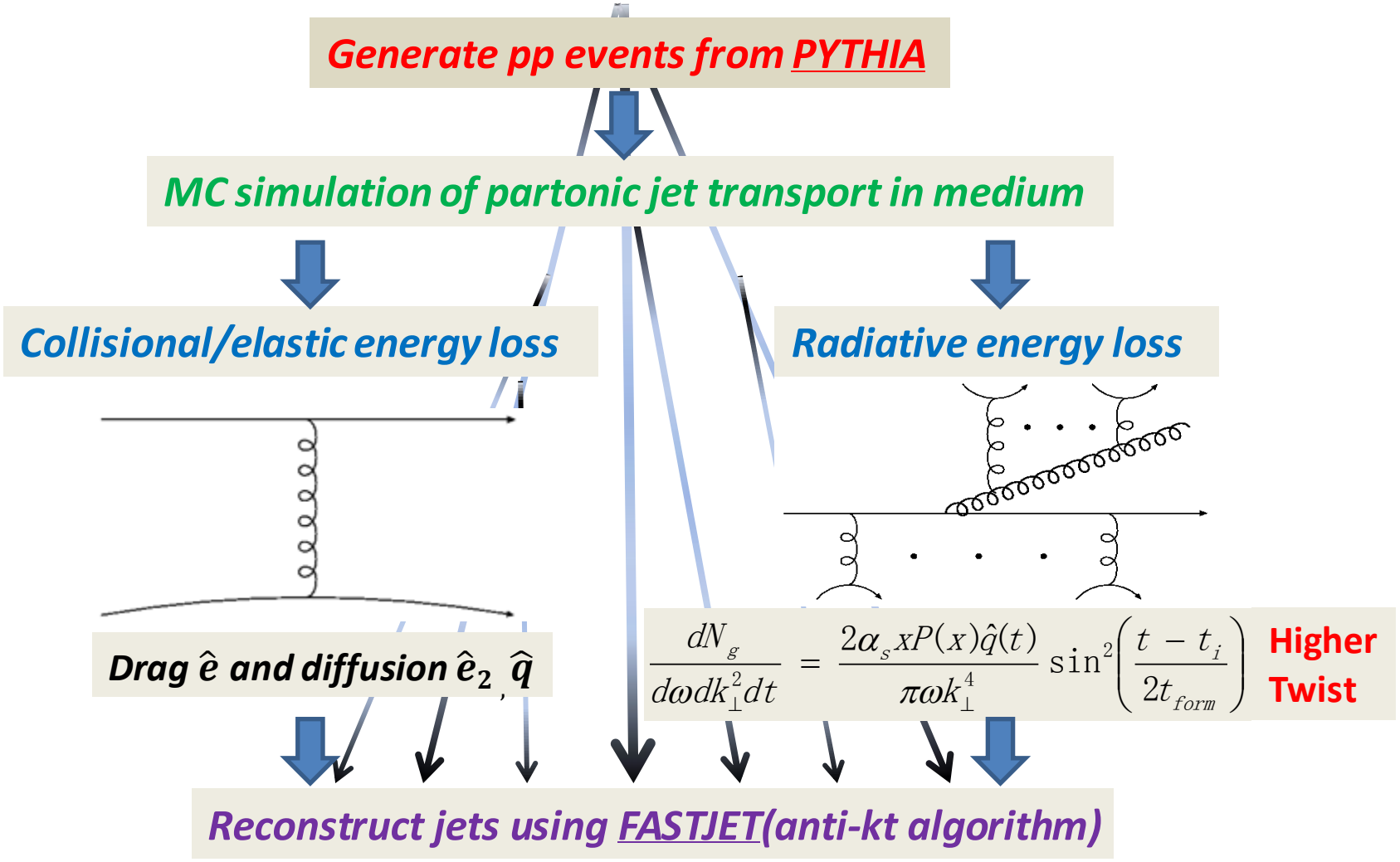
Dai, Vitev, Zhang (2012)



Coleman-Smith, QM 2012

- ***Energy loss of the tagged jets leads to the shift of x_J distribution***
- ***More detailed information (missing pairs, cone size dependence, centrality dependence…)***

Simulating γ/Z^0-jets



Setup

- ***Jet shower evolution and jet cone energy loss are controlled by***

$$\hat{q} = \frac{d(\Delta p_T)^2}{dt}, \hat{e} = \frac{dE}{dt}, \hat{e}_2 = \frac{d(\Delta E)^2}{dt}$$

- ***Relate them by***

$$\hat{q} = 2\hat{e}_2 = 4T\hat{e}$$

- ***These transport coefficient, e.g., $\hat{q}$, can be calculated from Lattice QCD (Majumder, 2012)***

- ***Different parameterizations for transport coefficients***

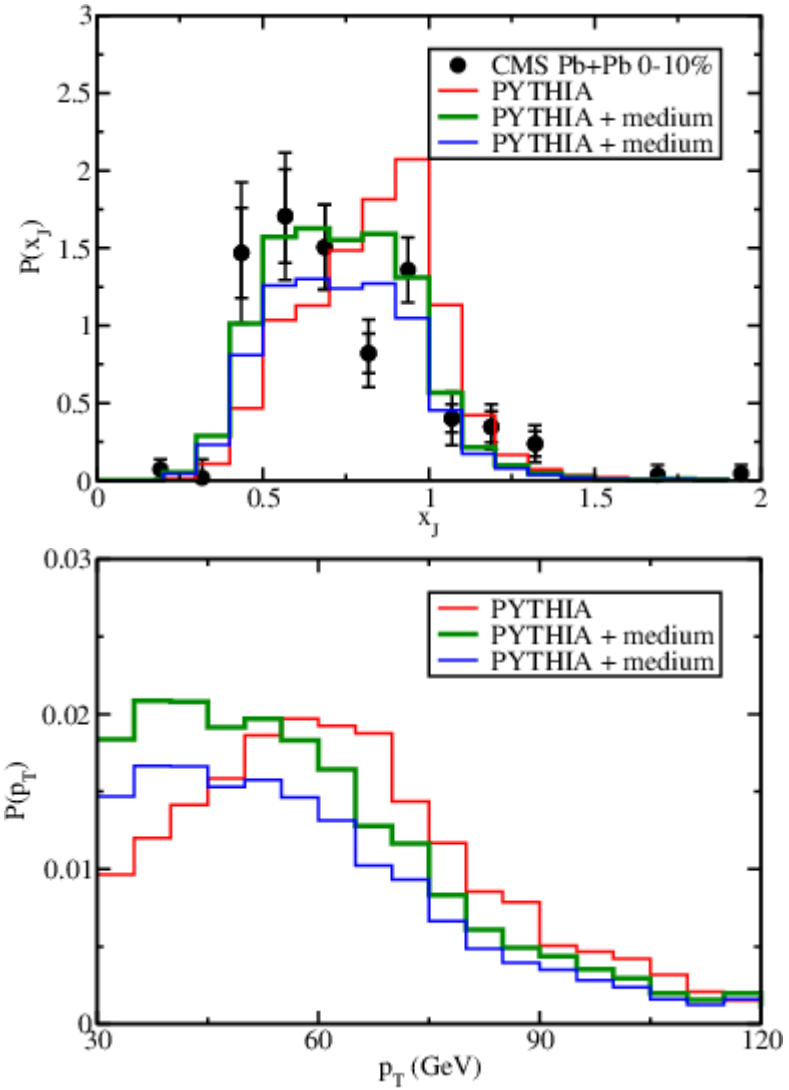
$$(a)\hat{q} \propto T^3 \quad (b)\hat{q} \propto T^3 \log(E/T) \quad (c)\hat{q} \propto ET^2$$

Energy imbalance for γ-jet

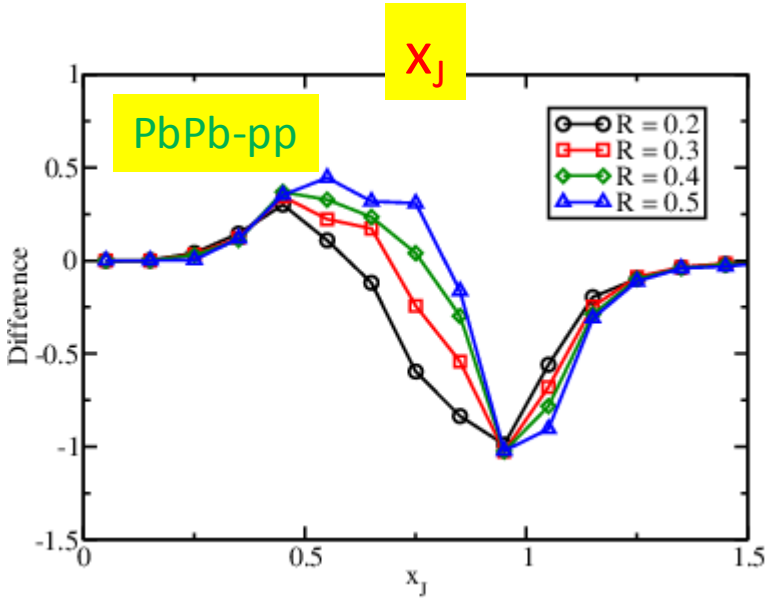
- ***Jets lose energy in medium; x_T distribution shifts (about 20% missing pairs)***
- ***The blue lines take 20% missing pairs into account for normalization***

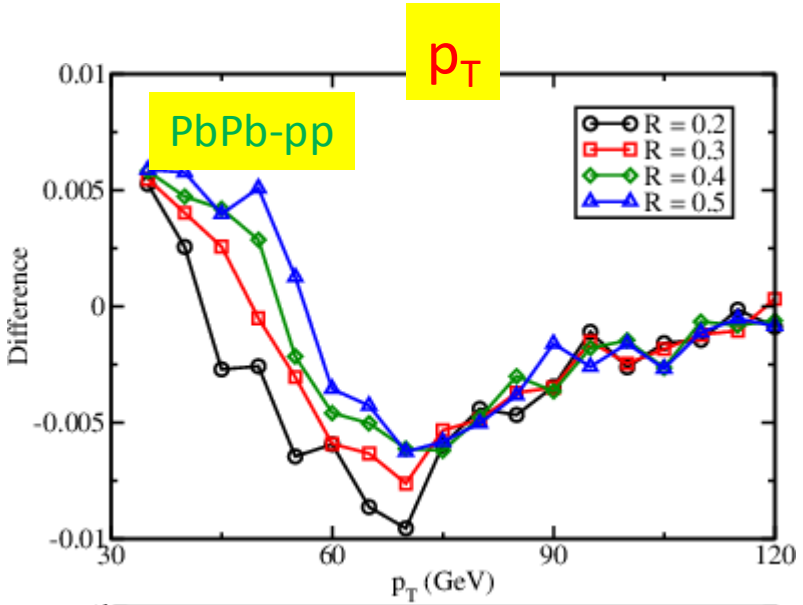
$$\hat{q} \propto T^3$$

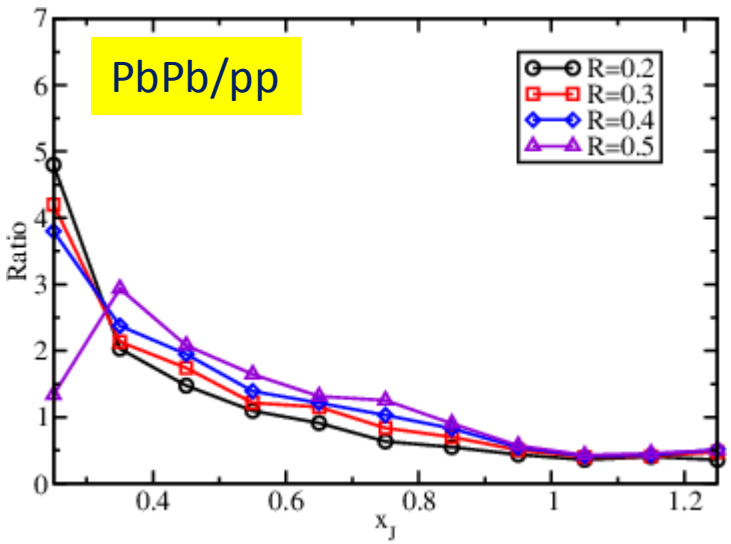
- ***Same information contained in p_T distribution***

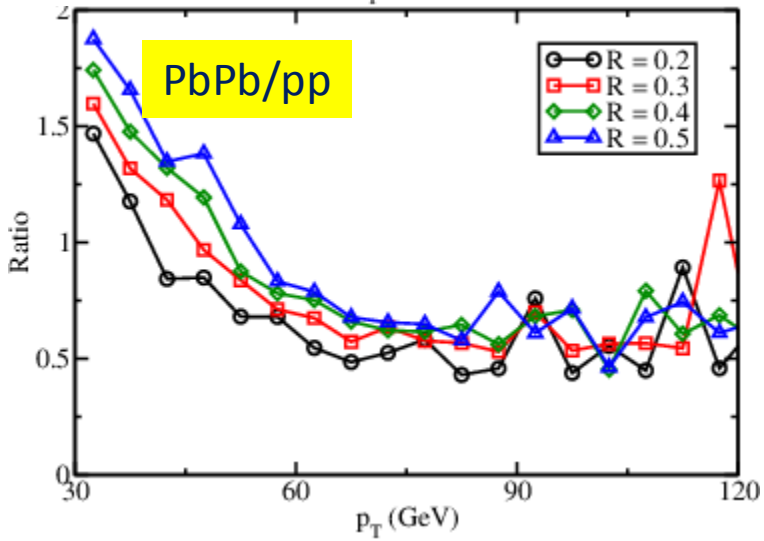


Take the difference and ratio



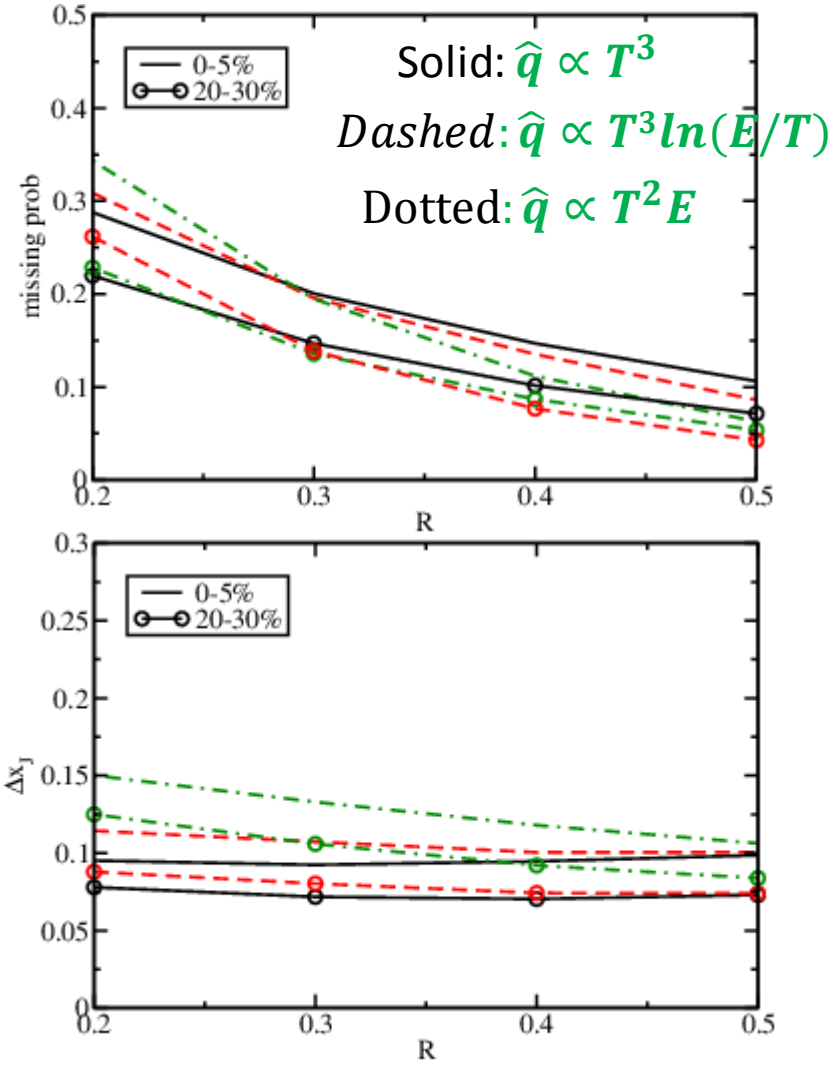






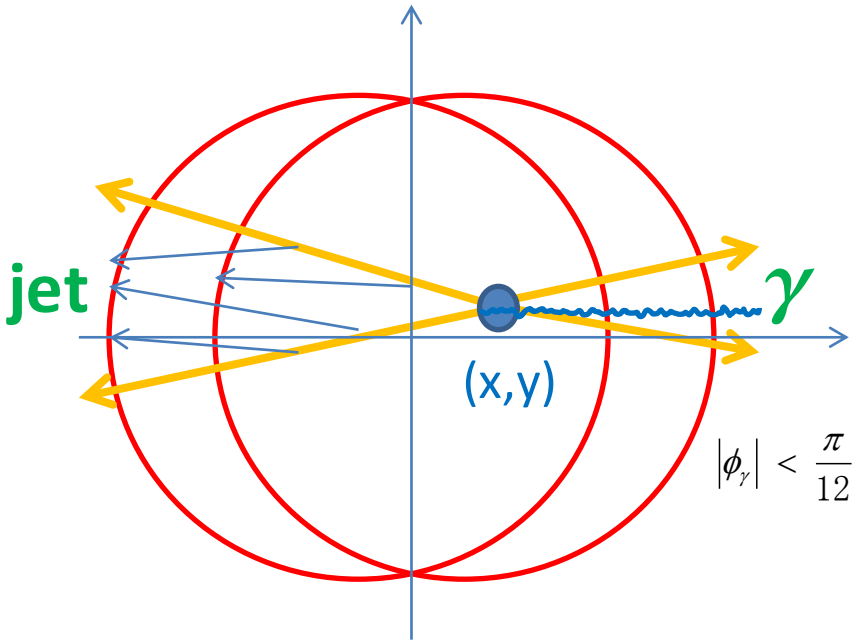
Missing pairs and momentum fraction

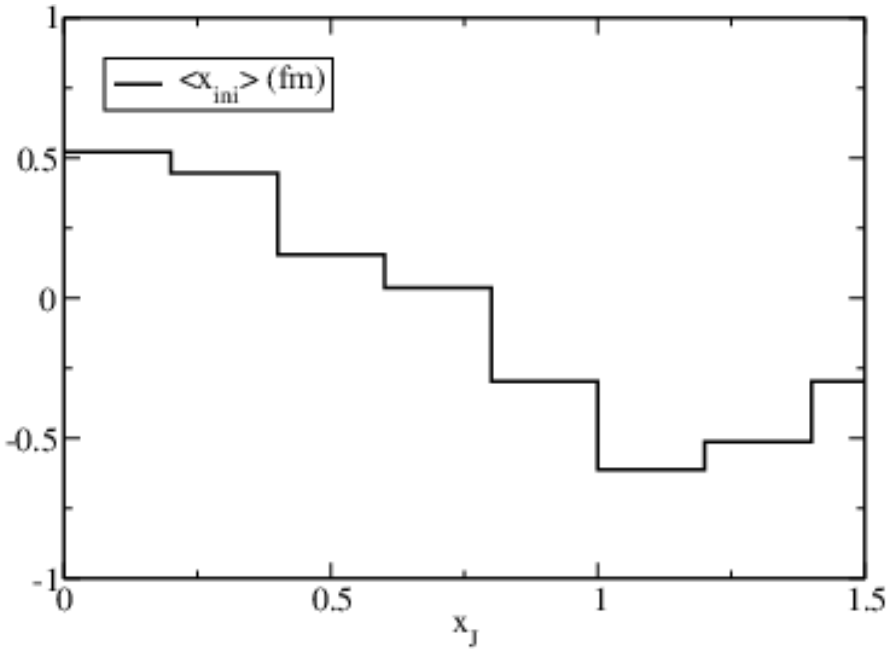
- ***Larger energy loss for central collisions***
- ***Stronger cone size dependence for $\hat{q} \propto T^2 E$ than $\hat{q} \propto T^3 ln(E/T)$ than $\hat{q} \propto T^3$***
- ***Cone size dependence may be used to probe the transport property $\hat{q}$***
- ***Energy, centrality, reaction plane dependence …***



γ-jet tomography

- ***The trigger γ propagates in-plane (+x) direction, and the away-side jet propagate roughly (-x) direction***

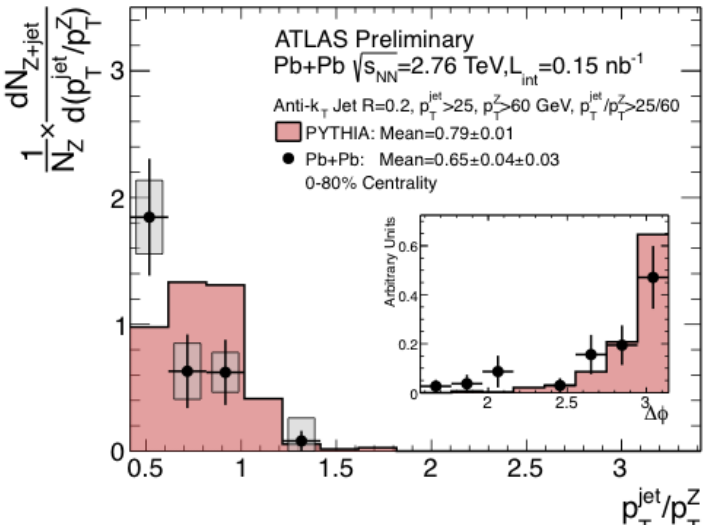


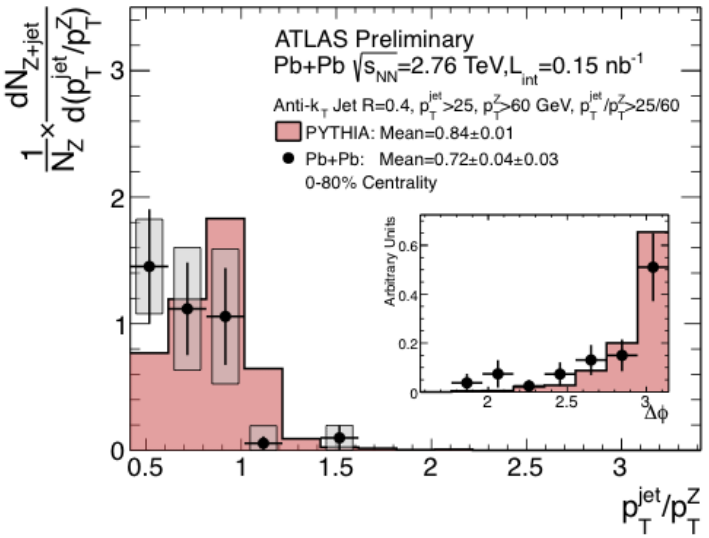


Final x_J

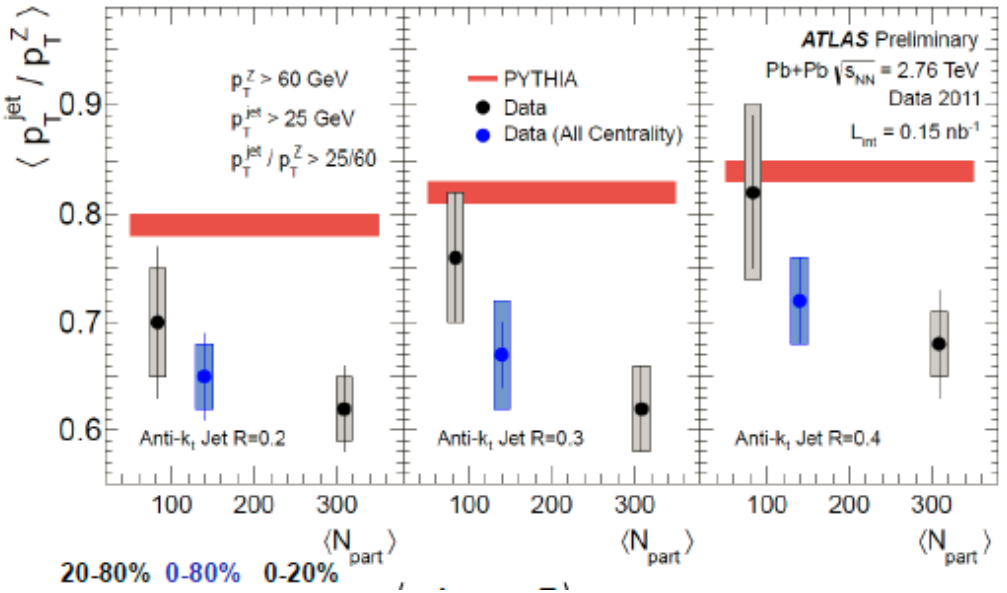
- ***Different average x_J probe different path lengths:***
- ***May be combined with different directions to probe different areas of the collision zone***

Measurement: Z^0/γ^*-tagged jets





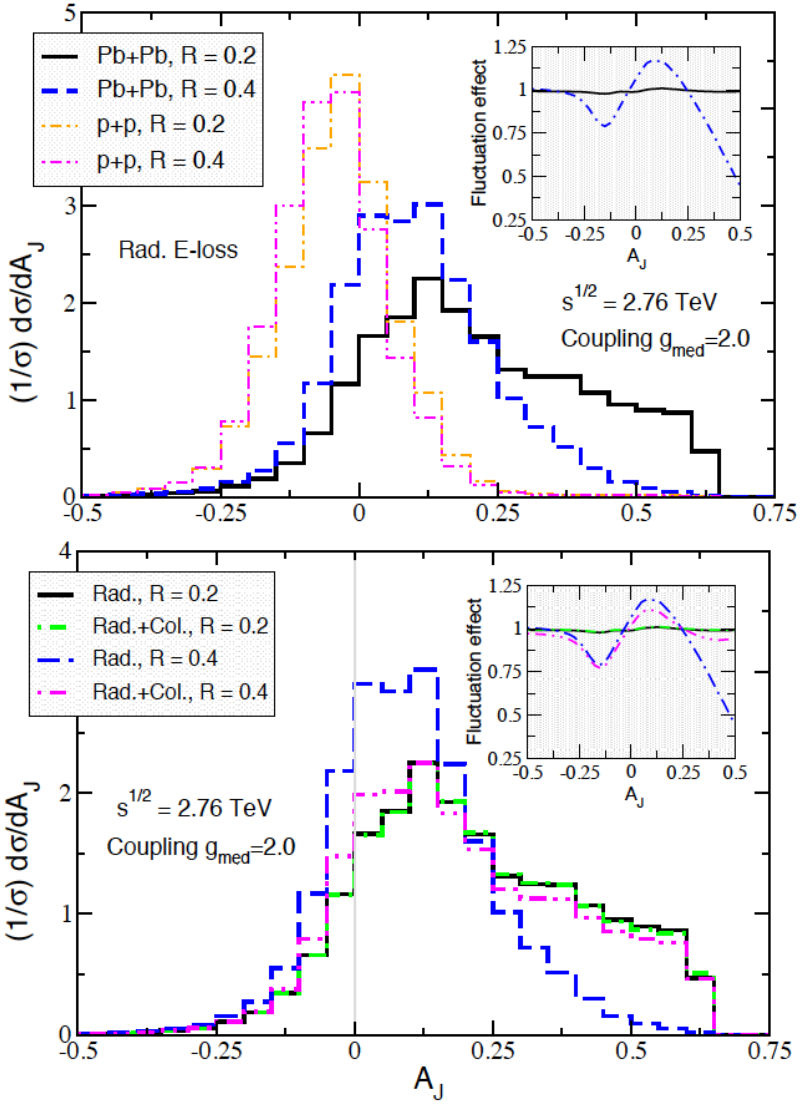
- ***Cleaner but less Z^0-tagged jets events***
- ***Away-side jets are quenched (the distribution shift to left, mean xT smaller than PYTHIA)***
- ***The suppression increases for more central collisions***



Calculation: Z^0/γ^*-tagged jets

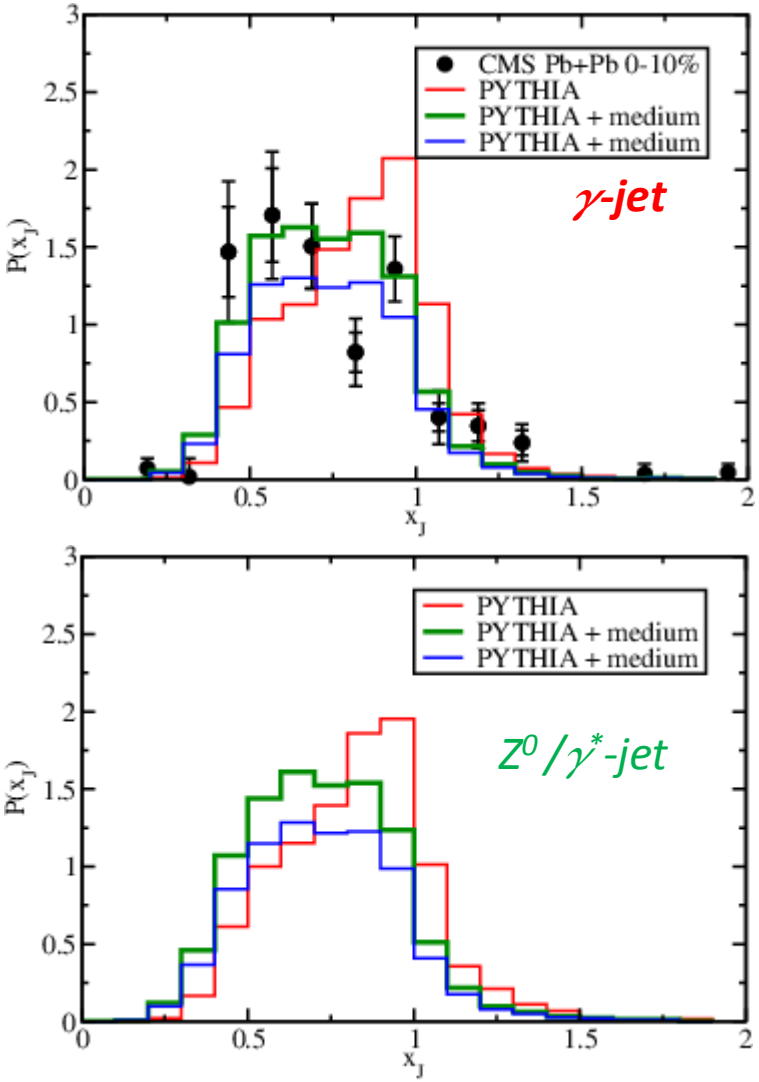
- ***Energy loss of the tagged jets leads to the shift of A_J distribution to the right***
- ***Sensitivity to background fluctuations is not big***
- ***Cone size dependence are different on different energy loss mechanisms***

Neufeld, Vitev, PRL (2012)

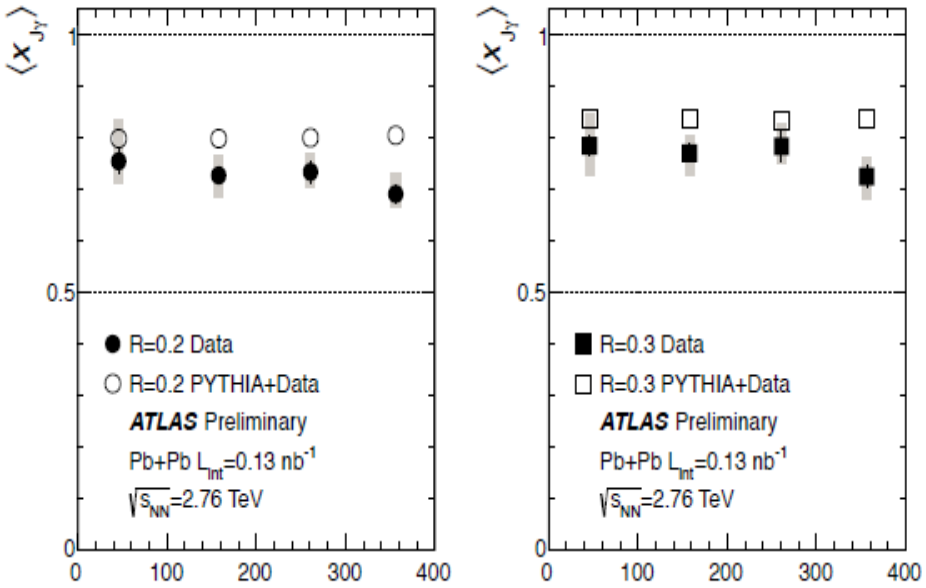


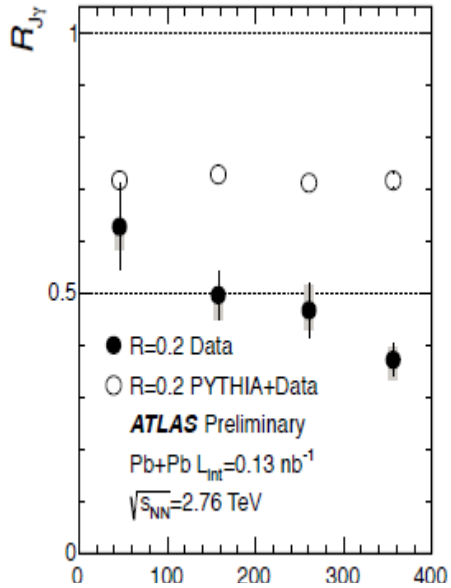
Calculation: Z^0/γ^*-tagged jets

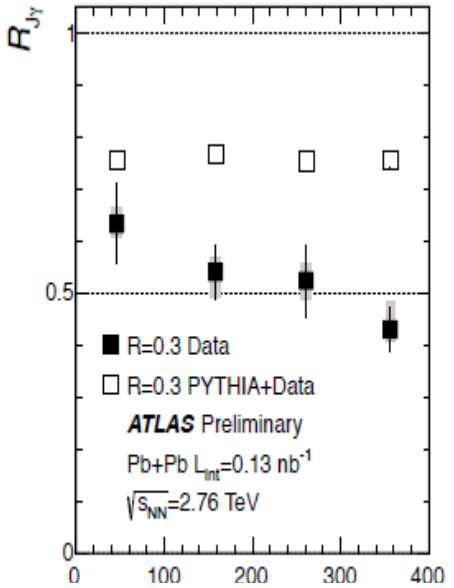
- ***Similar to γ-jet correlations (for the same pt cuts), the Z^0-tagged is a little broader***
- ***What else effect does the kinematics introduce?***
- ***Compare γ-jet and Z^0-jet***

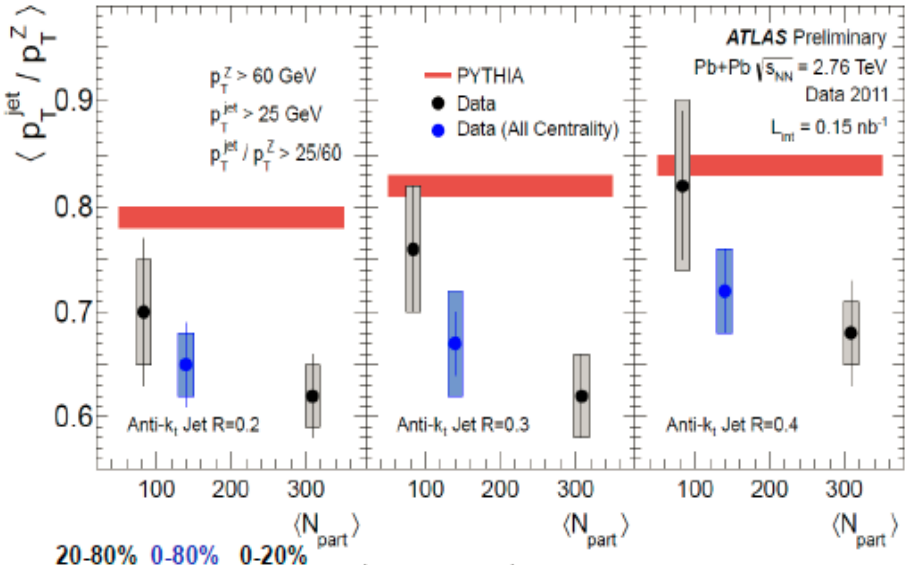


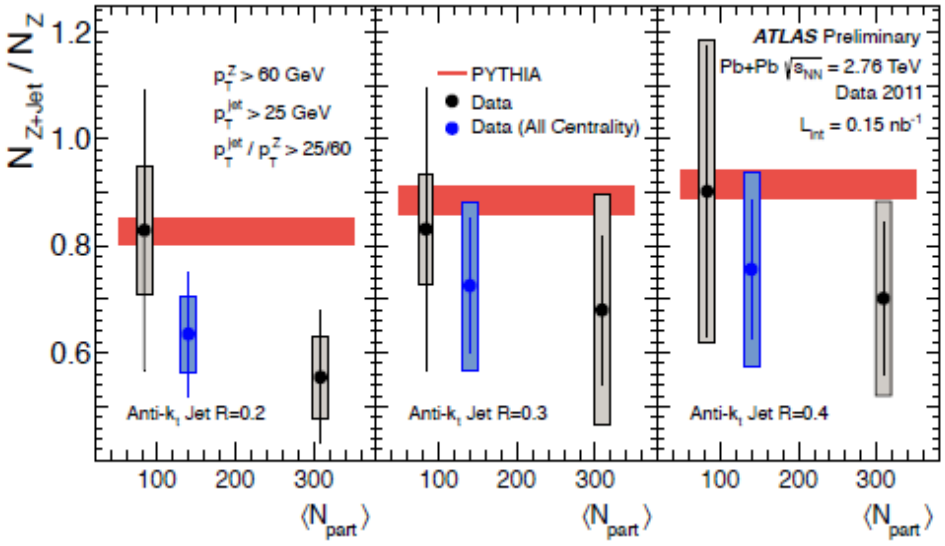
Compare γ and Z^0/γ^*-tagged jets











Summary

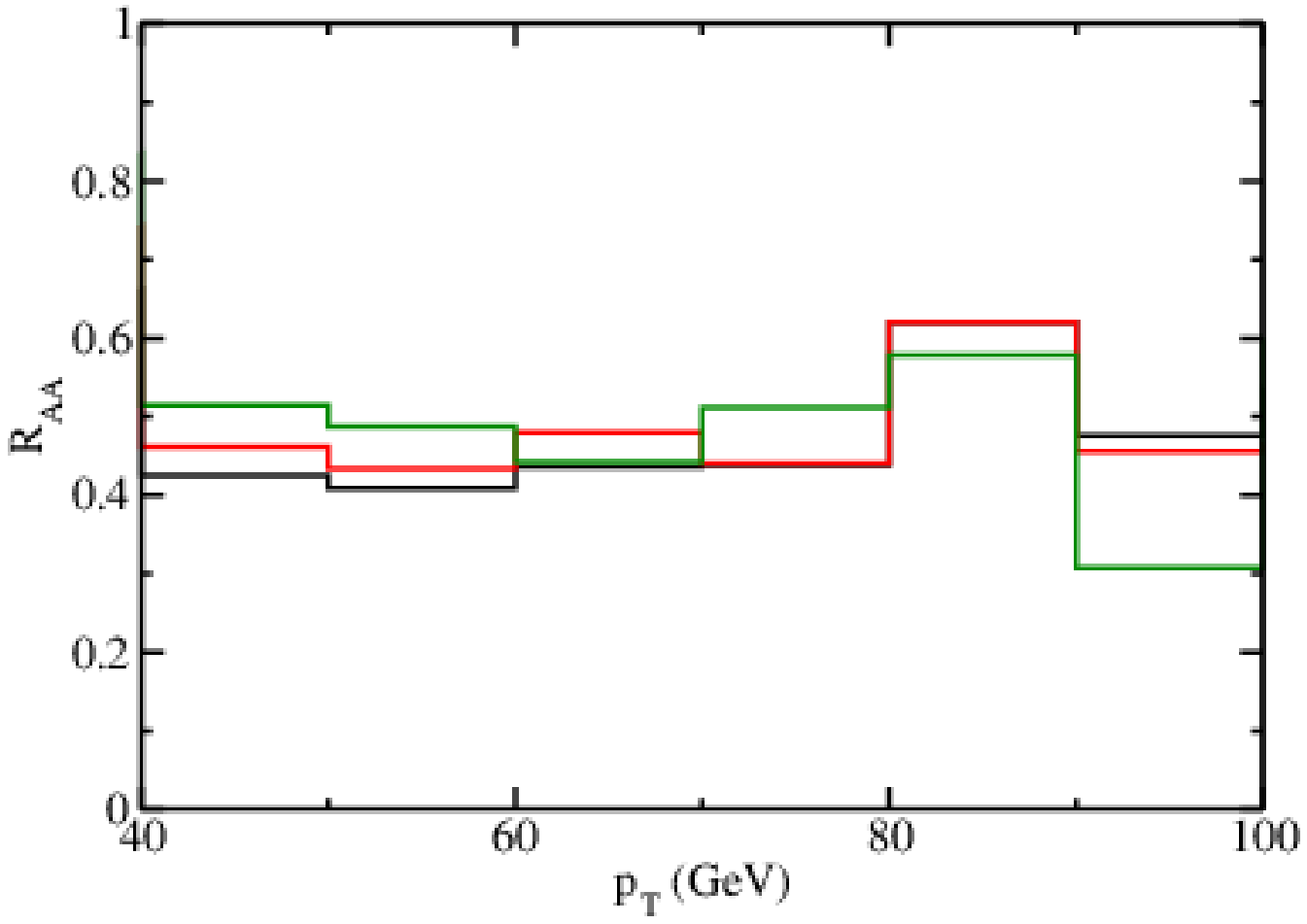
- ***Photons and electroweak bosons and tagged jets are very useful in studying jet-medium interaction (jet tomography)***

- ***Many observables***
  - ***Triggered FF, k_T broadening***
  - ***Energy imbalance, angular correlations, missing pairs***
  - ***Jet fragment shape in both longitudinal and transverse directions***
  - ***System size, reaction plane, energy, and cone size dependence***

- ***Other things***
  - ***Contribution from jet-medium photons***
  - ***Medium response to jet transport (energy/momentum deposition)***
  - ***Compare γ and Z^0 triggers***

- ***Need consistent description of multiple observables simultaneously***

Jet R_{AA}



Z^0/γ^*-tagged jets