Perspectives on centrality and jets at the LHC

Doğa Gülhan (MIT)

2015 RHIC & AGS Annual Users' Meeting
"Exotic and Highly Asymmetric Collisions at RHIC"
BNL, 10 June 2015

A perspective on centrality and jets at the LHC

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With

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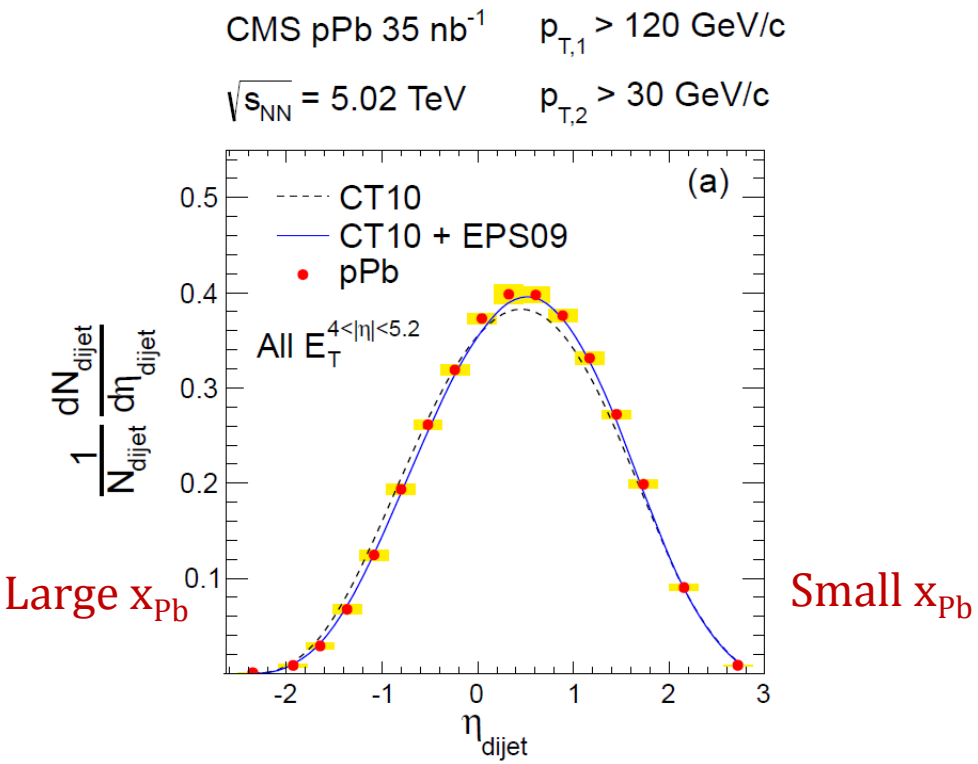
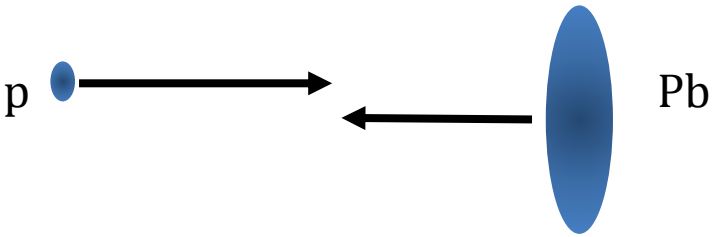
Jets probe nuclear modifications of PDFs



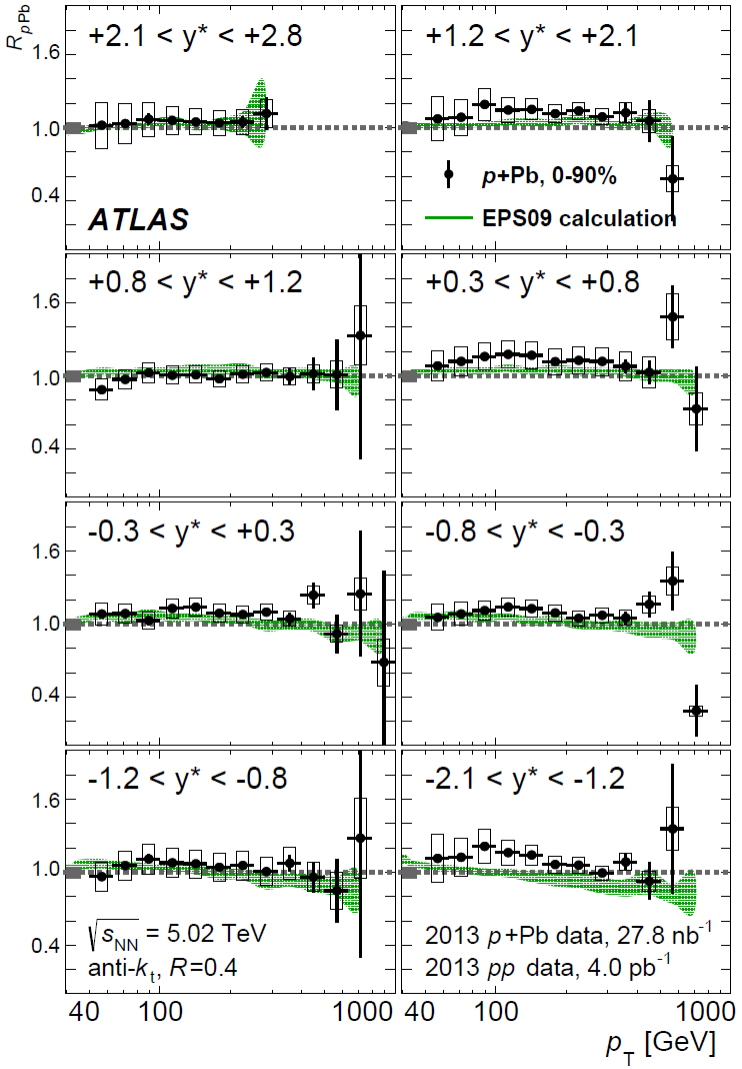
Large x_{Pb}

Small x_{Pb}

$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2} \approx \frac{\log {}^{x_p}/_{x_{Pb}}}{2}$$

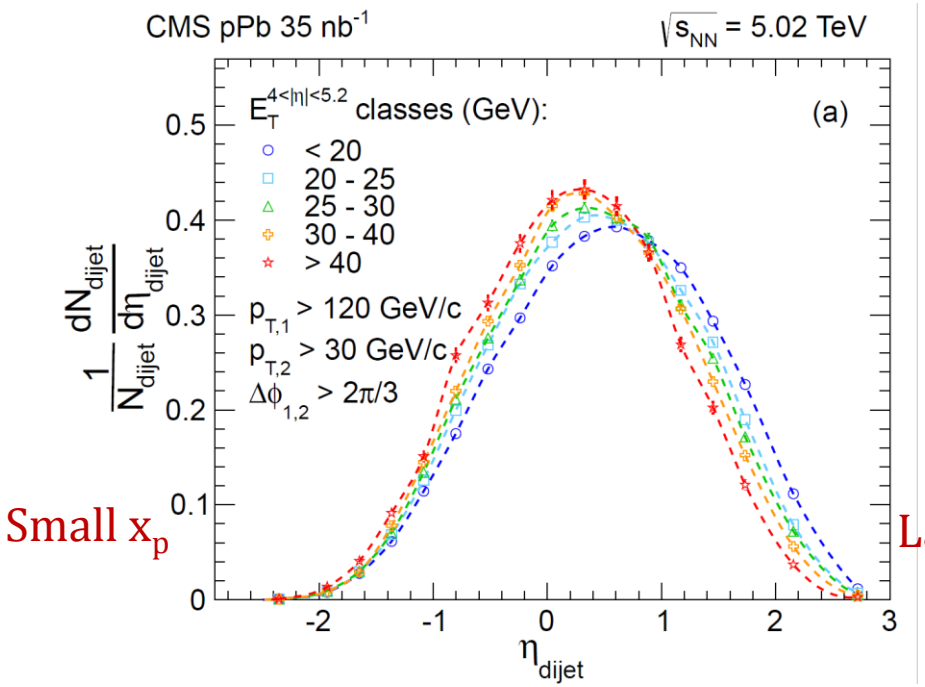


Small x_{Pb}



Large x_{Pb}

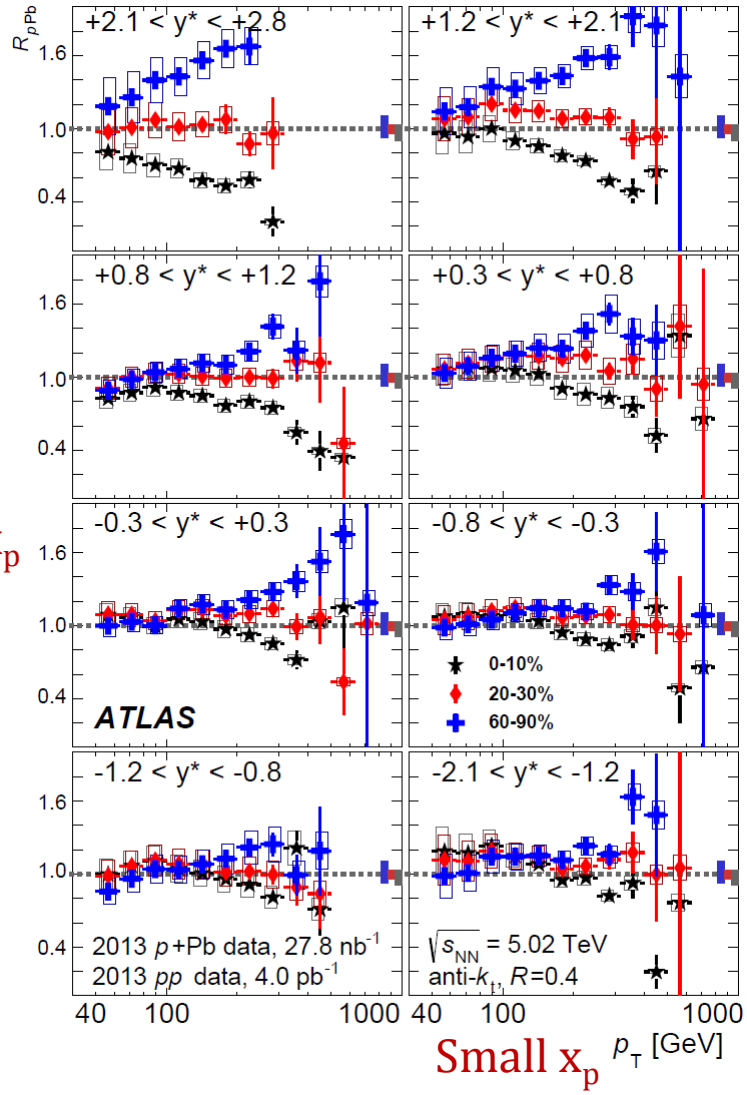
However with centrality selection…



Small x_p

Large x_p

Large x_p

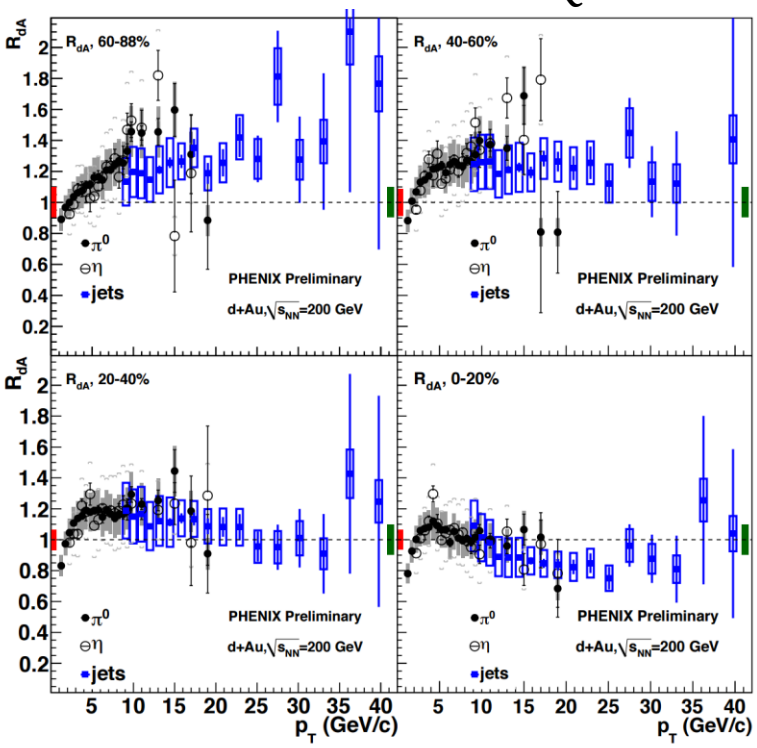


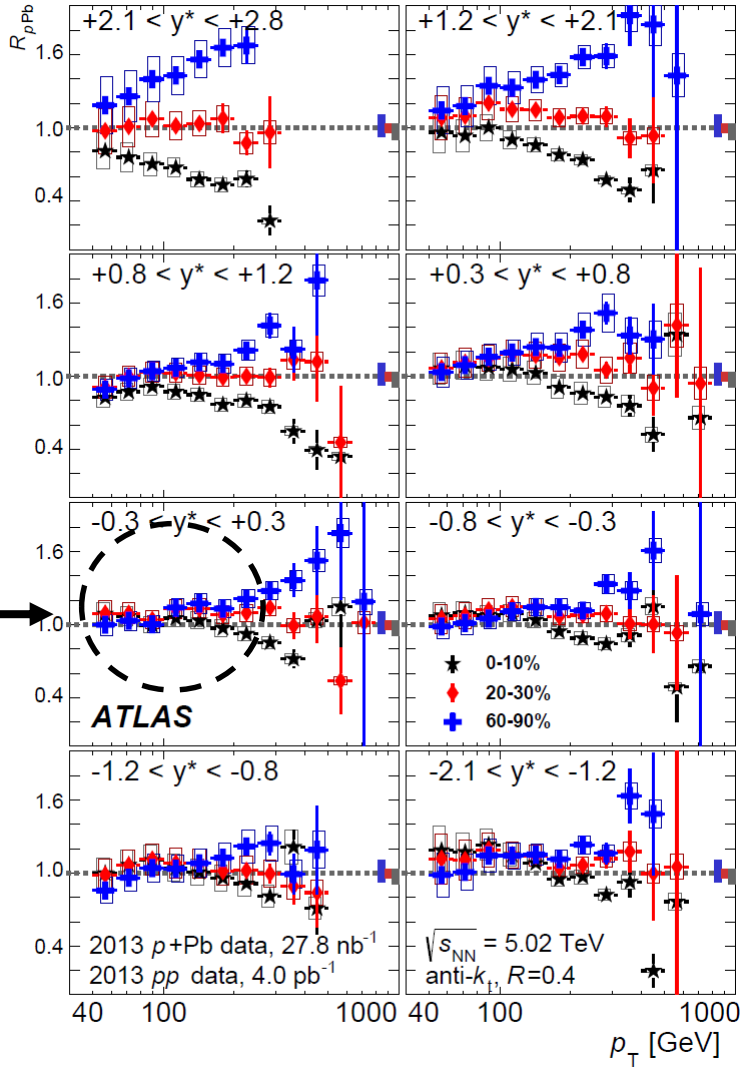
Small x_p

- Very large centrality dependence compared to estimated impact parameter related effects on nPDFs [1205.5359]
- Especially on the side where x_p is large

Previously observed at RHIC

QM 2012

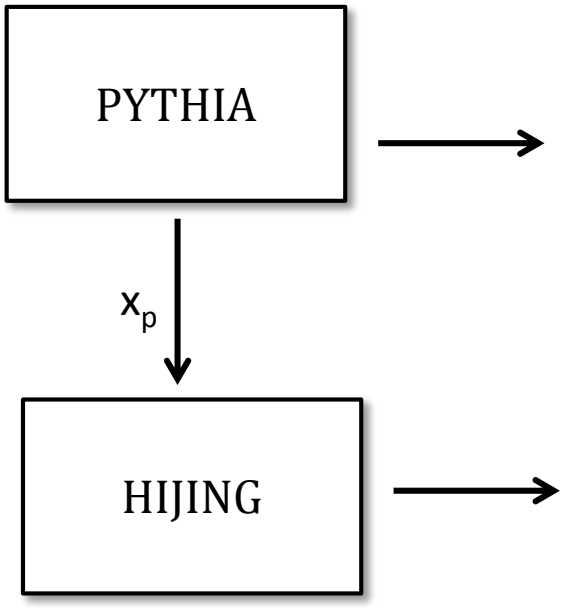




- Effect is enhanced at the LHC
  - Larger pseudorapidity range
  - Higher p_T reach

Simple setup to test the kinematic biases

Event by event matching



$$\sqrt{s_{NN}} = 2\sqrt{E_p E_{Pb}(1 - x_p)}$$

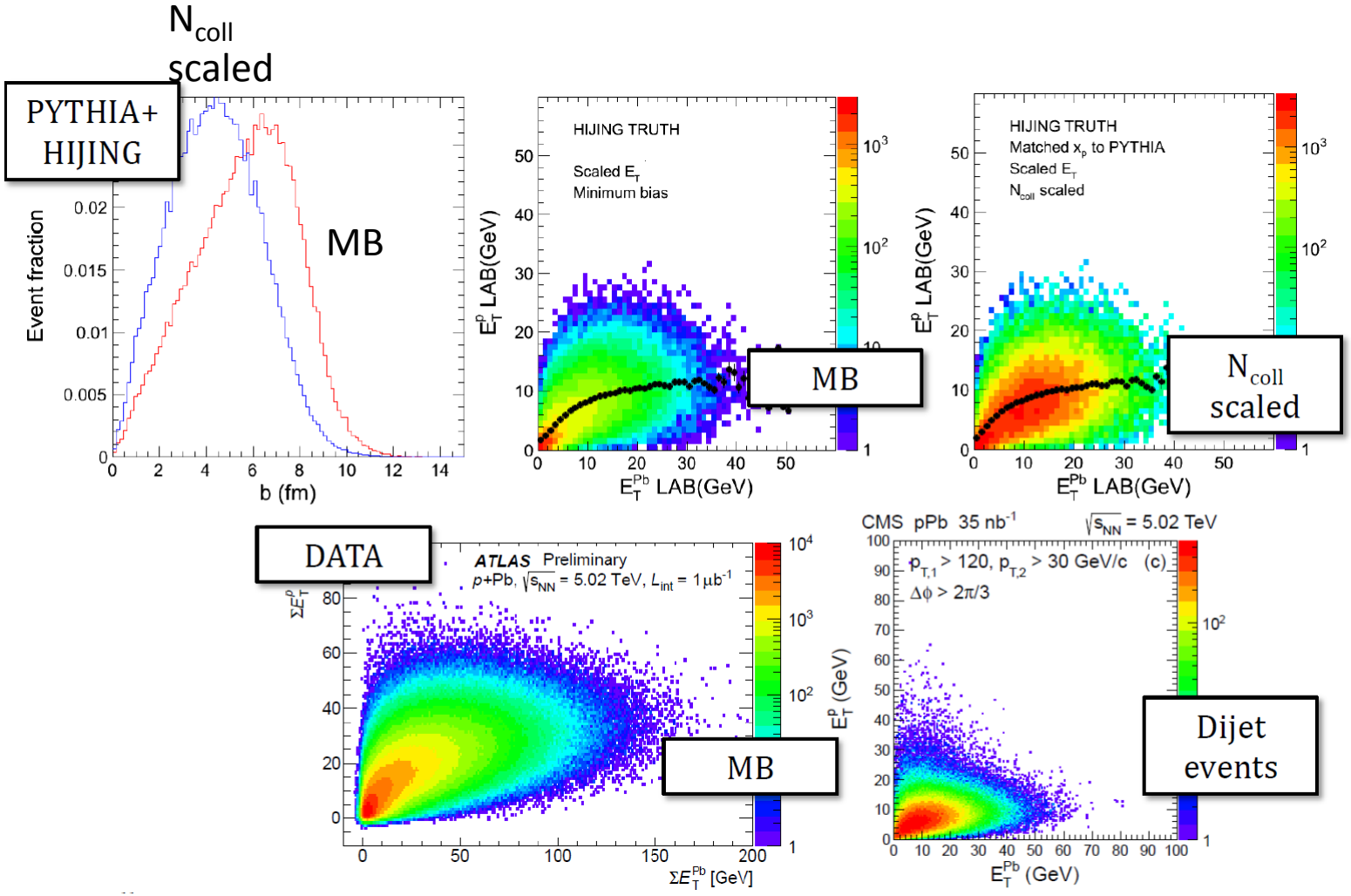
$$\eta_{CM} = 0.5 \log\left(\frac{E_p(1 - x_p)}{E_{Pb}}\right)$$

Underlying event
Centrality classification related quantities

CMS: Forward energy in both beam directions, smeared to account for detector response
ATLAS: Forward energy in Pb beam direction

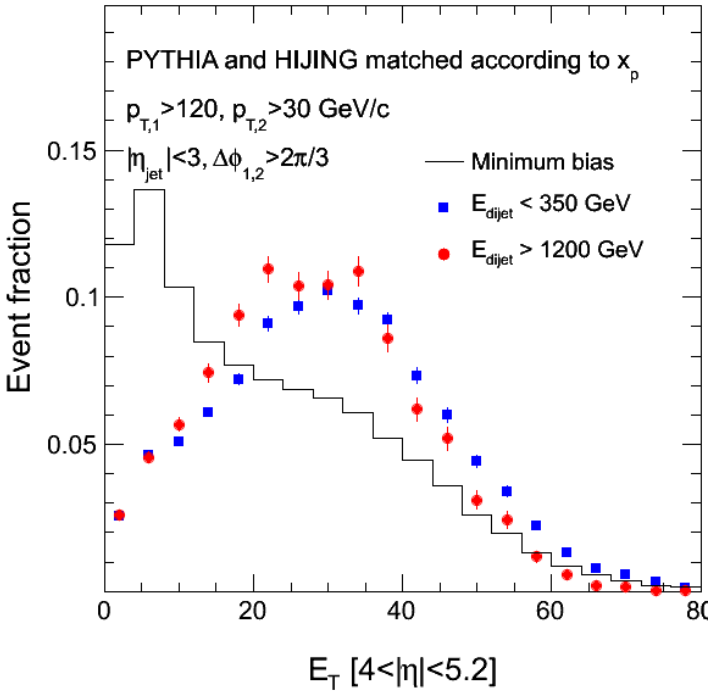
- The energy that goes in the hard scattering is taken away from the proton
- x_{Pb} is not taken into account, good approximation when N_{coll} is large

Yield of jets is assumed to scale with N_{coll}

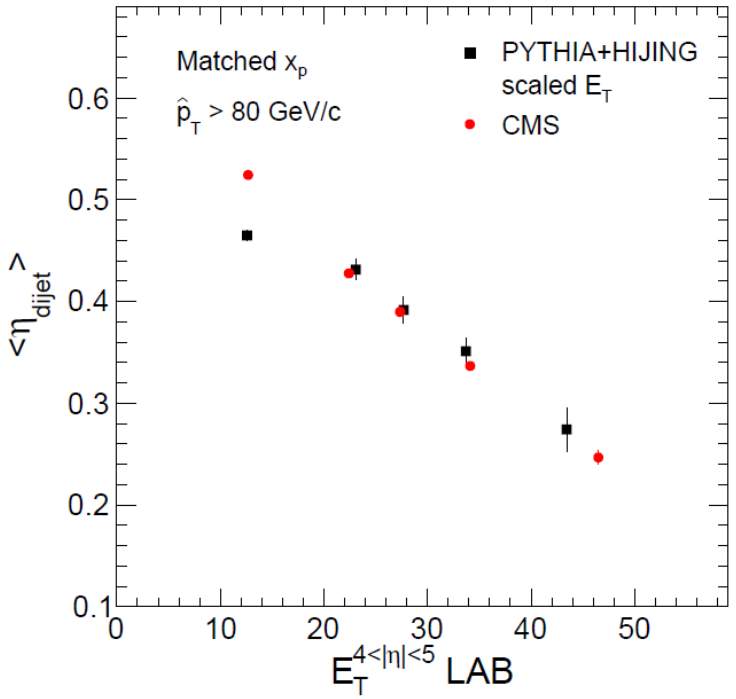


- Same as the uncorrelated model in [1412.0976] where: $Y_{N\mathrm{coll}}(E_{\mathrm{T}}) = \sum_{j=1}^{N_{\mathrm{coll}}} Y_j = CN_{\mathrm{coll}}.$

Shift in $<\eta_{dijet}>$ due to reduction of energy

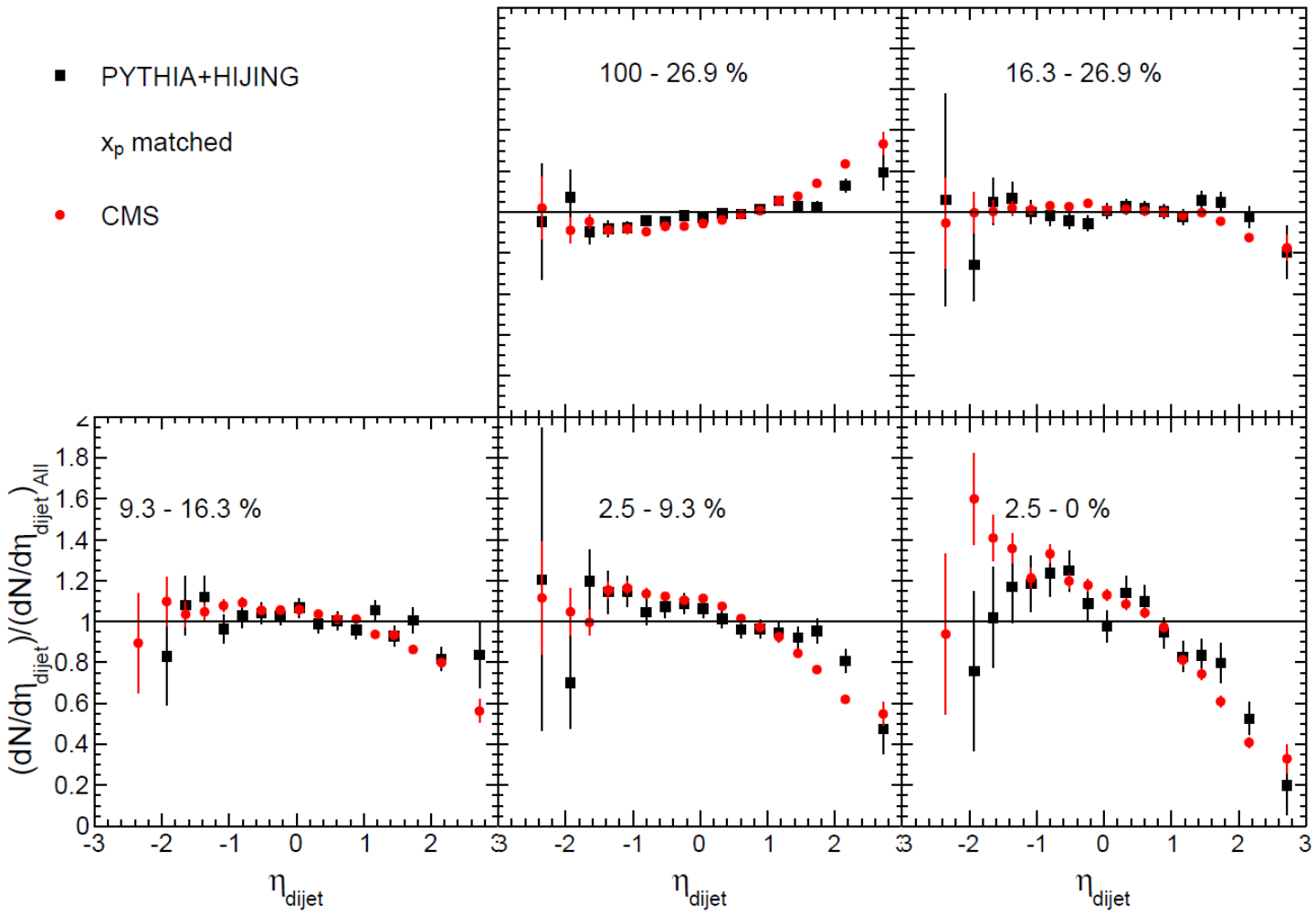


$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2} \approx \frac{\log {}^{x_p}/_{x_{Pb}}}{2}$$



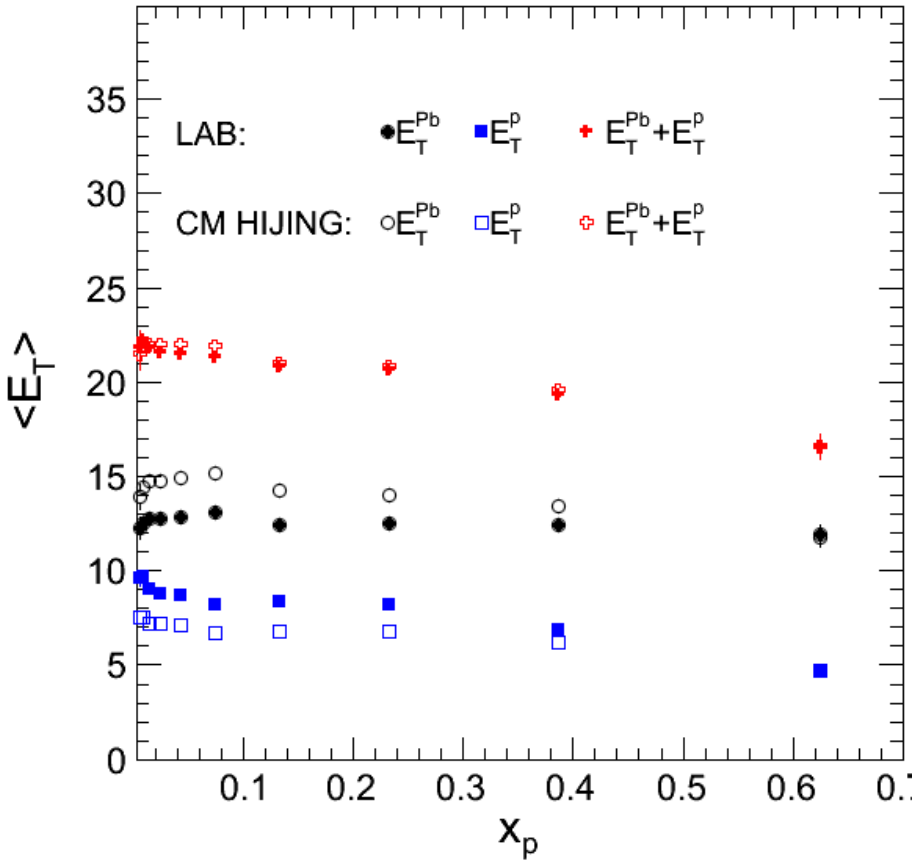
- Requiring large dijet energy shifts forward E_T to smaller values
- For peripheral events: Model fails because energy taken away with x_{Pb} becomes significant for calculating the accurate E_T values

Modification of η_{dijet} distributions



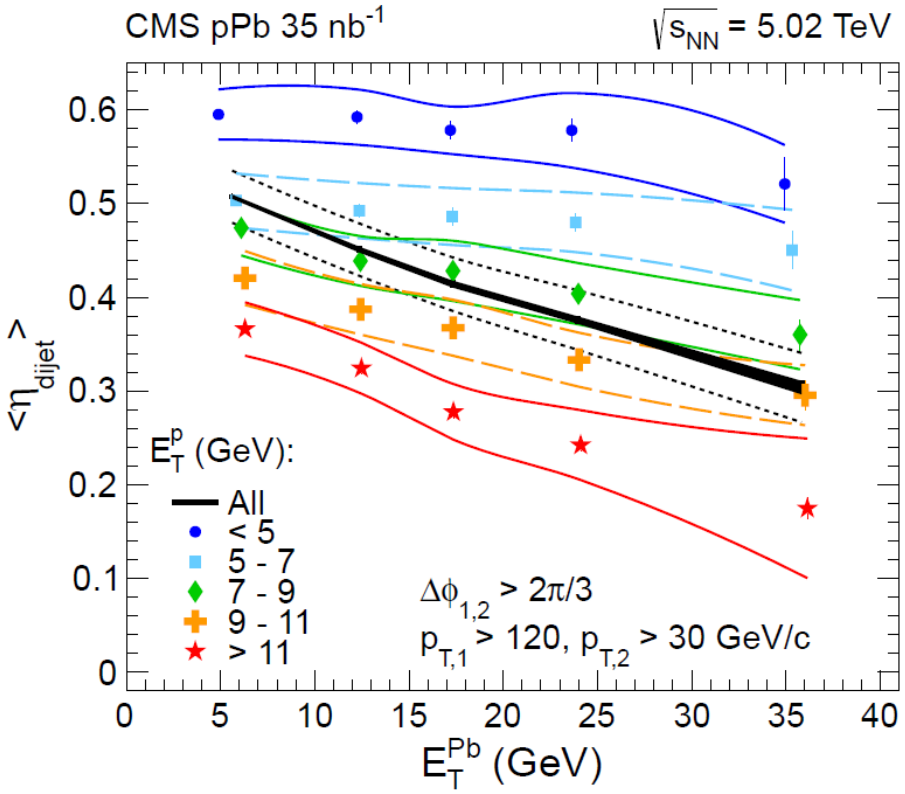
- Shape of distributions in each centrality bin are compared to the inclusive centrality bin results in data agree with MC.

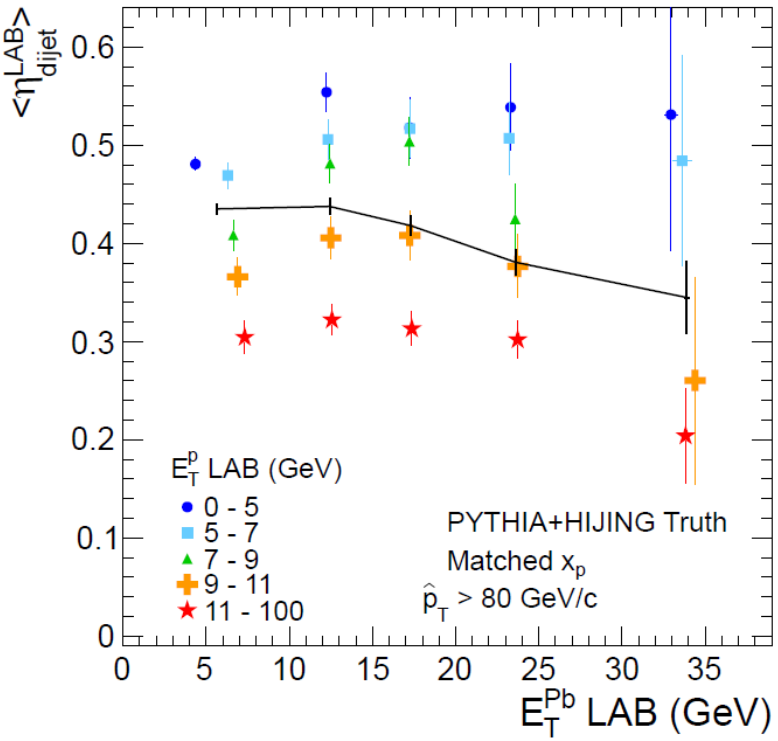
Recoil of the UE



- As x_p increases:
  - Total energy left for UE decreases
  - HIJING UE recoils in Pb direction
- E_T on both sides:
  - With the recoil energy reduces on one side increases on the other compensates the effect
- E_T in the Pb direction:
  - Recoil reduces the dependence on x_p
- E_T in the p direction:
  - Recoil increases the dependence on x_p

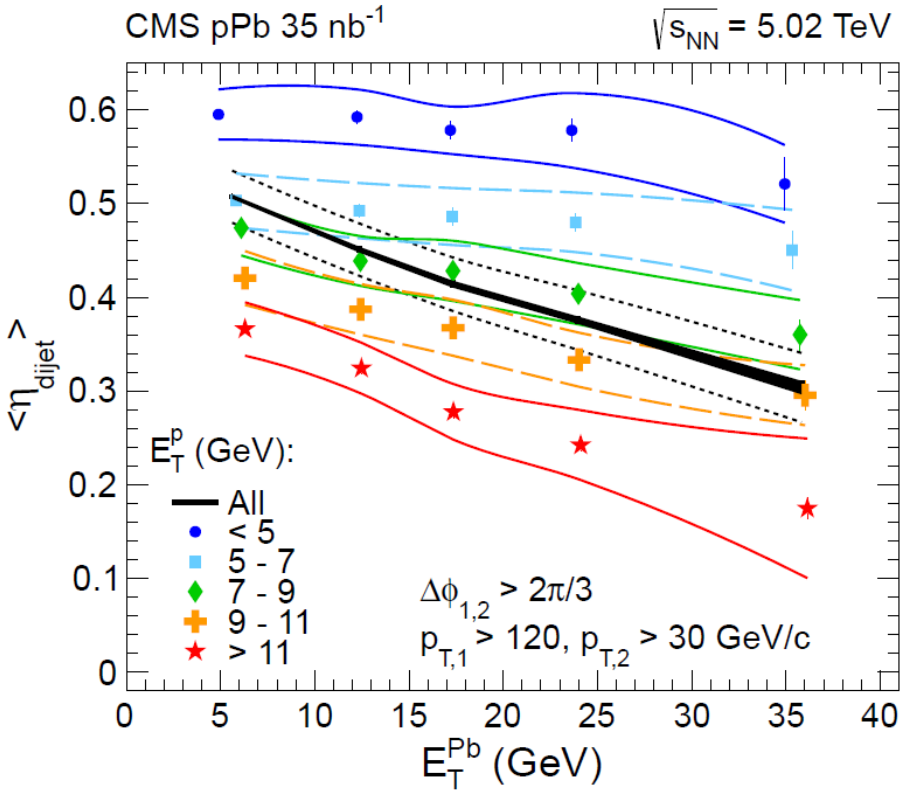
Observing recoil of UE with

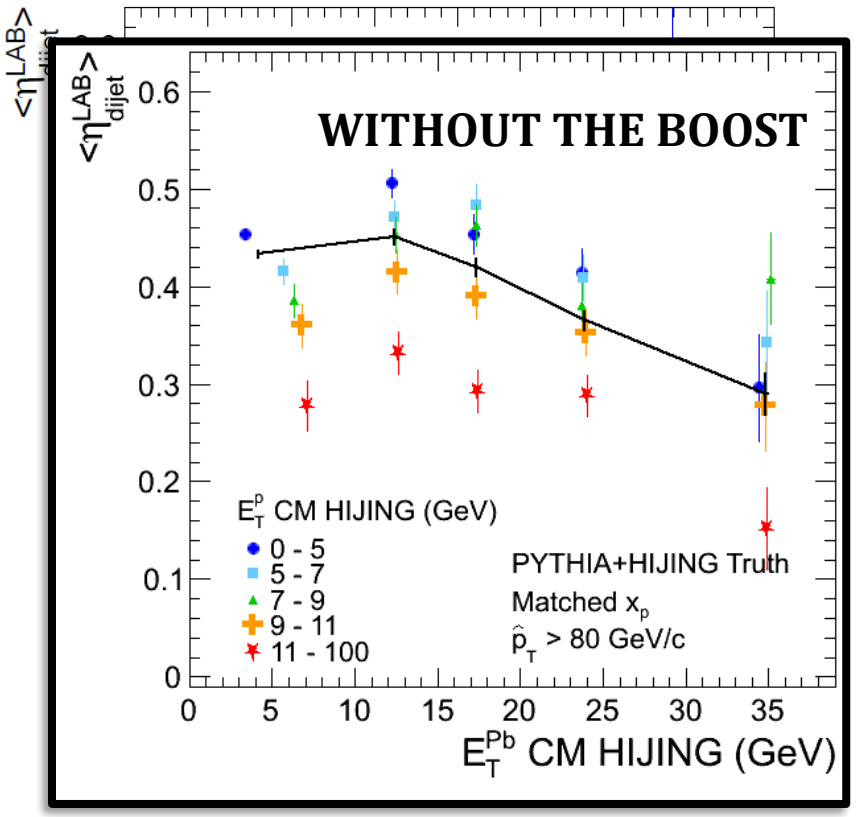




- The difference in the slope of $\langle\eta_{dijet}\rangle$ as a function of E_T^{Pb} for different E_T^p values is due to the recoil

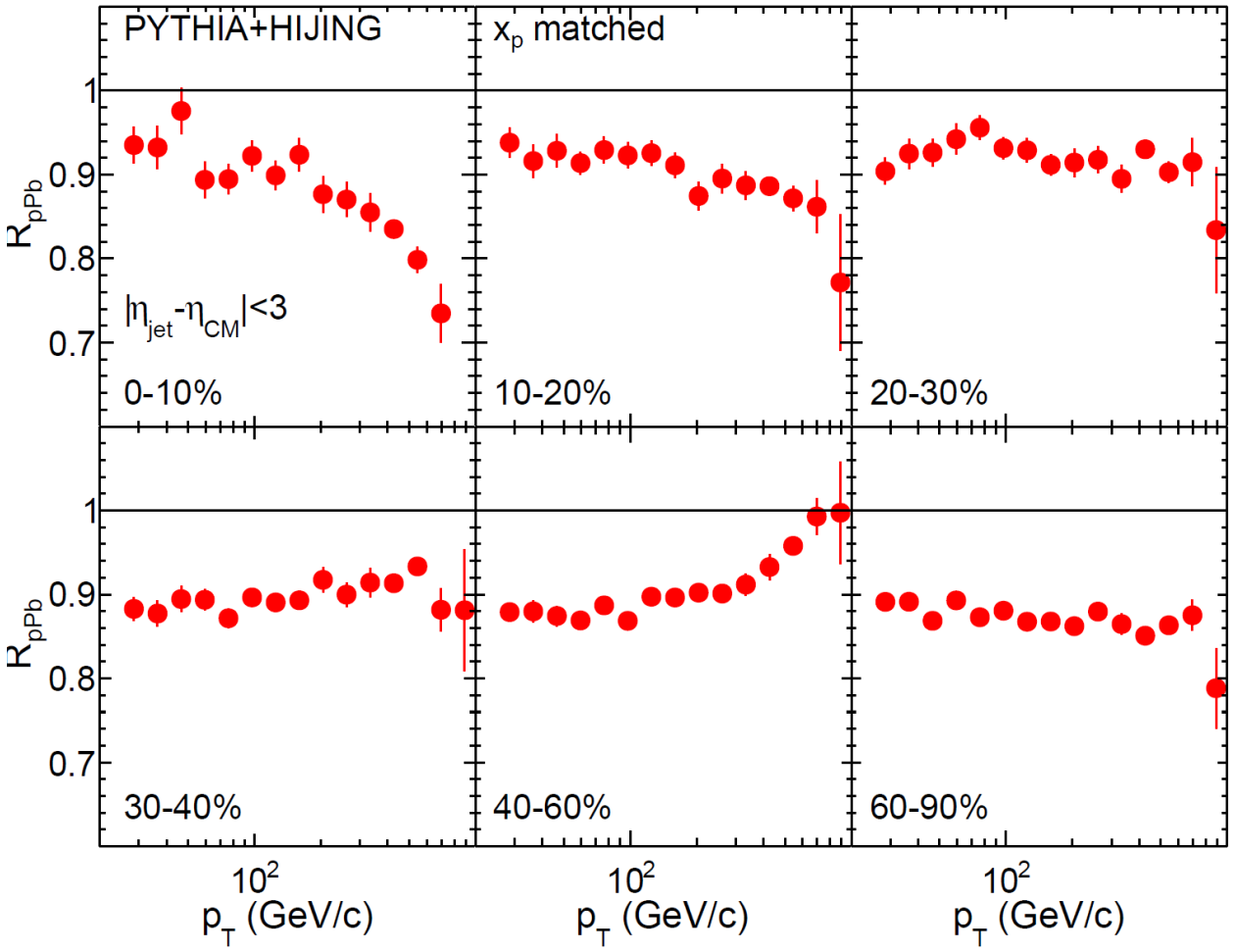
Observing recoil of UE with





- The difference in the slope of $\langle\eta_{dijet}\rangle$ as a function of E_T^{Pb} for different E_T^p values is due to the recoil

Centrality dependence of RpPb

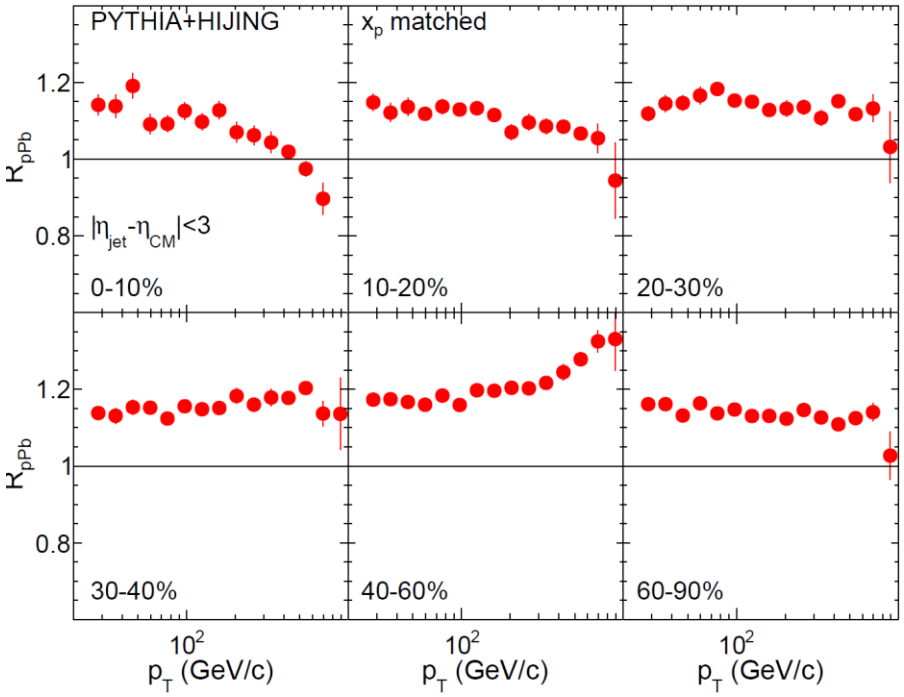


$$R_{\mathrm{pPb}} = \frac{1}{N_{coll}} \frac{d^2N_{jet}^{pA}/dp_T d\eta}{d^2N_{jet}^{pp}/dp_T d\eta}$$

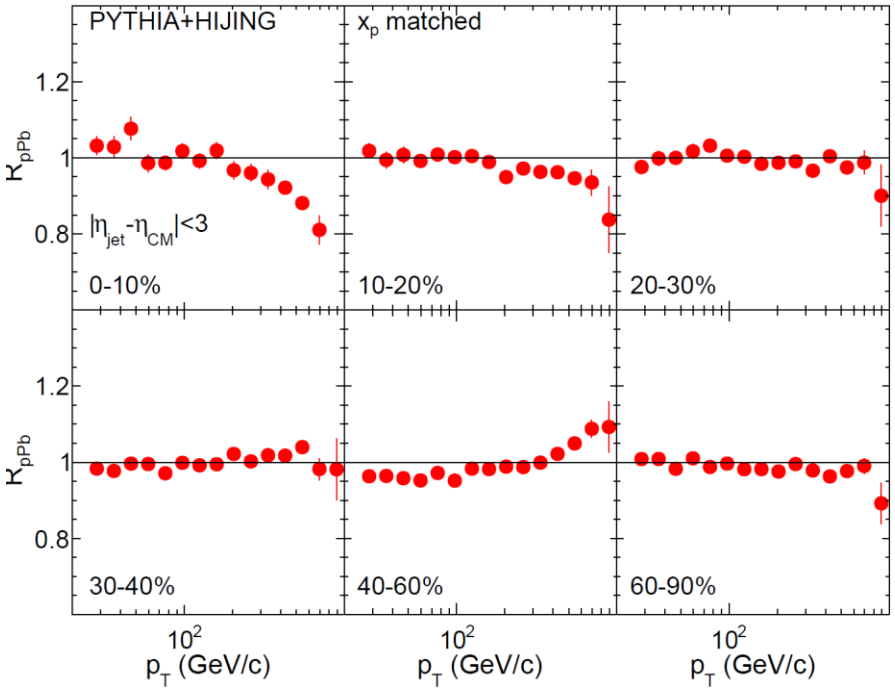
- ATLAS <Ncoll> values are used [1412.4092] in order to be able to compare to the data
- Therefore centrality bins don't add up to unity

<Ncoll> depends on kinematic selections

<Ncoll> for MB events

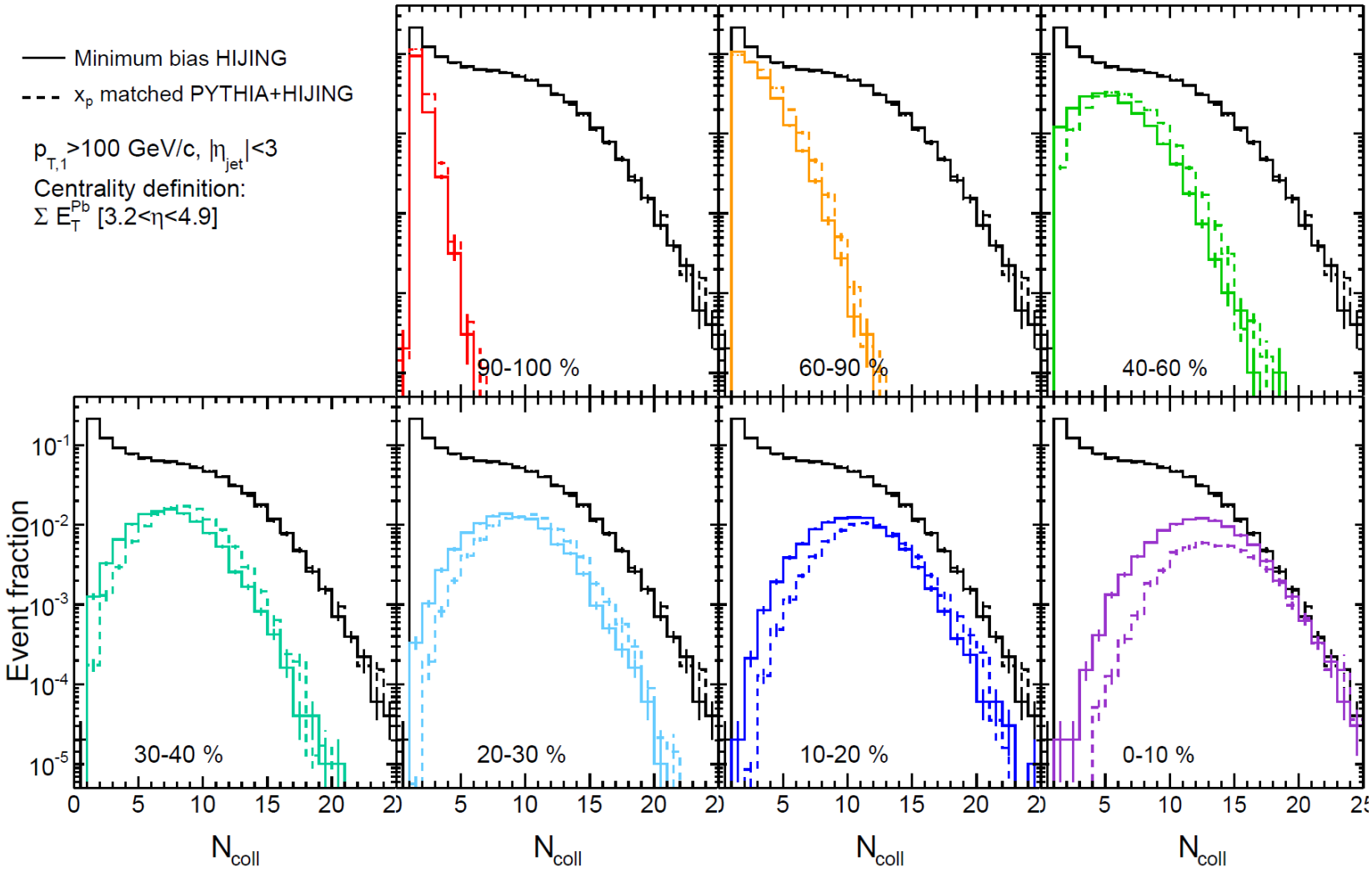


<Ncoll> for events that pass kinematic selections



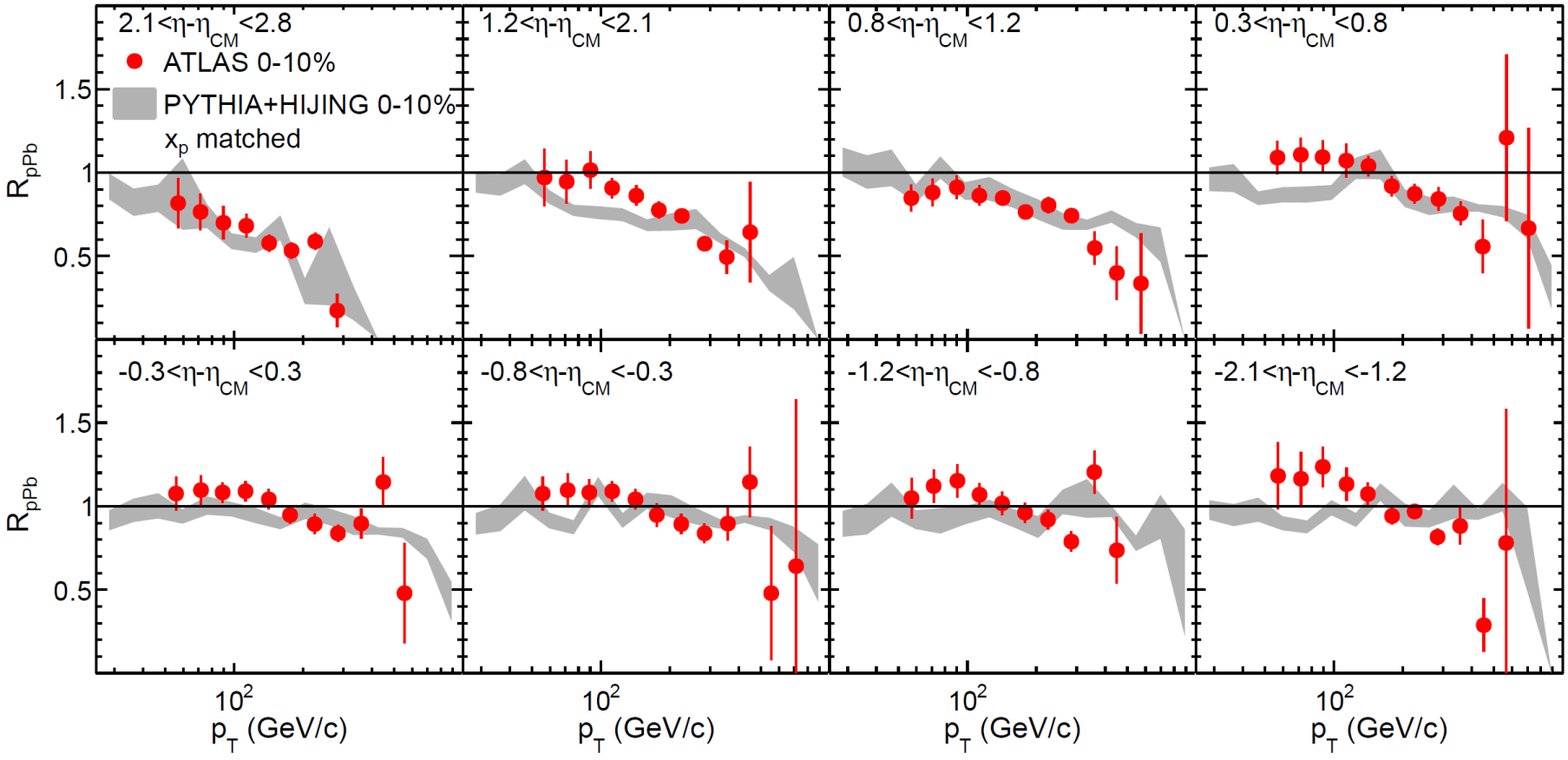
- The boundaries for E_T^{Pb} for centrality classes are determined using MB HIJING
- <Ncoll> per centrality class is larger when kinematic biases are taken into account
- However, in either case it is not as large as values used by ATLAS

<Ncoll> is larger for events with jets



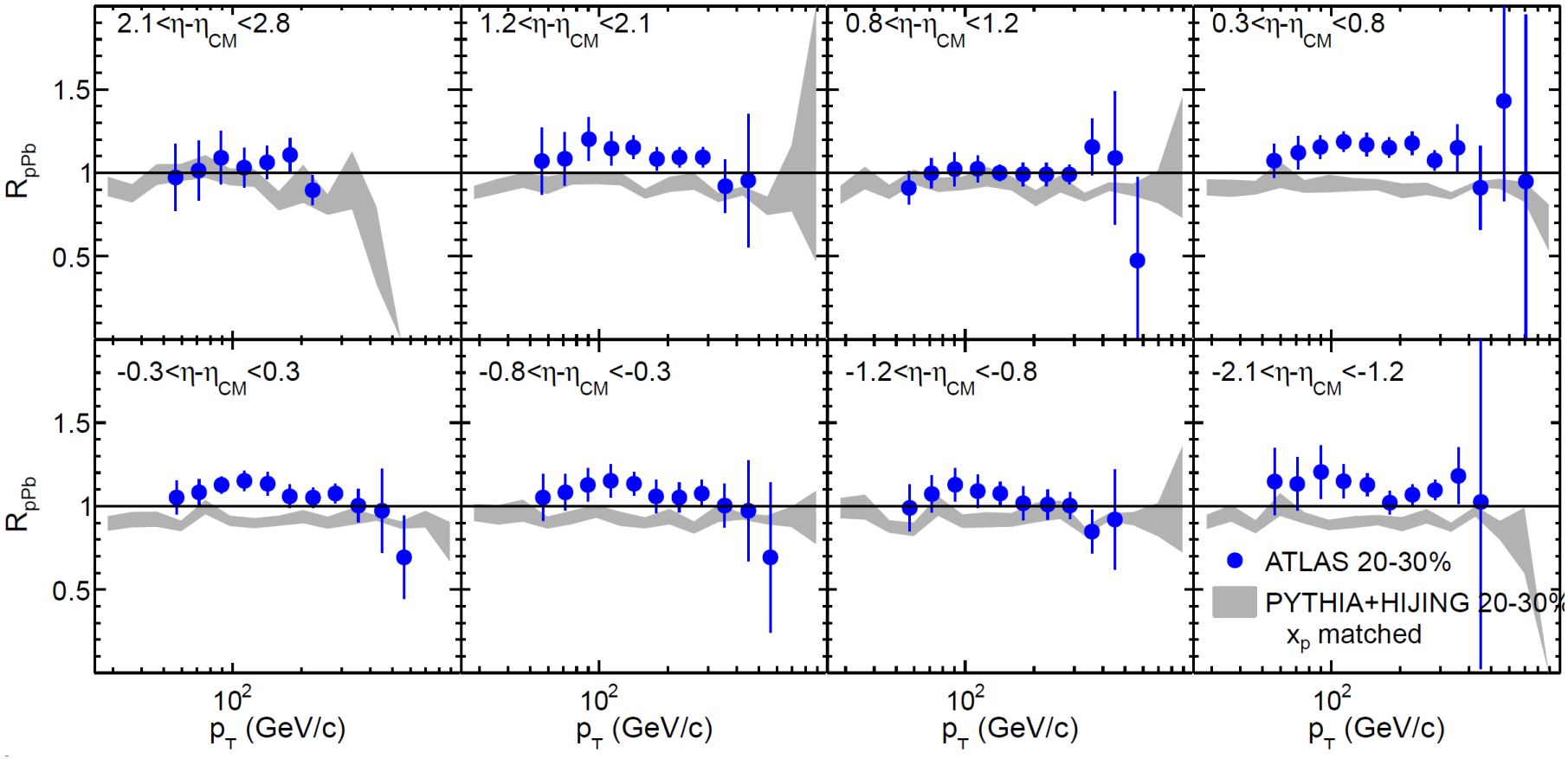
- The overall N_{coll} distribution is not modified but events are shuffled between different centrality classes

RpPb in central events



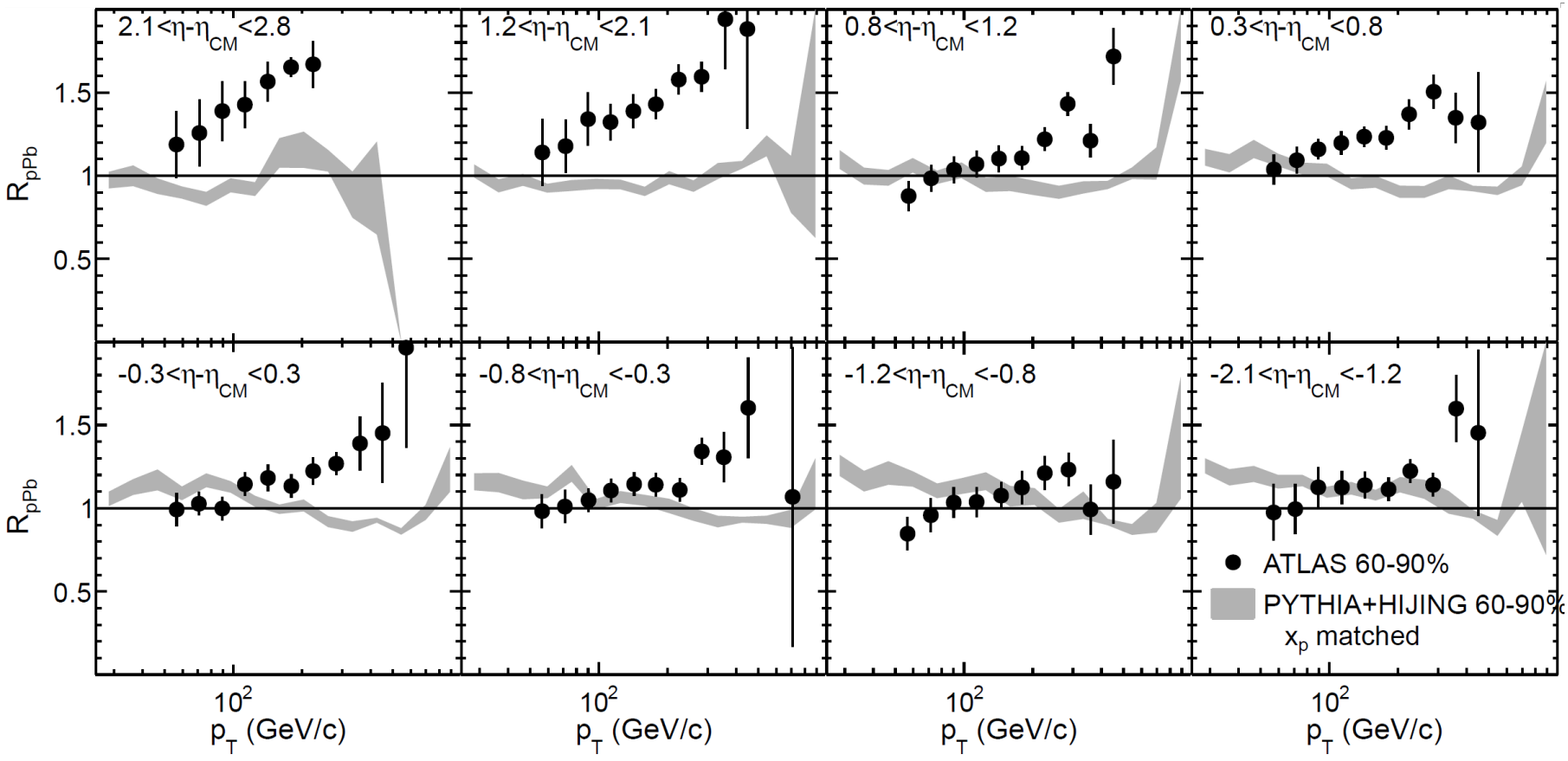
- Suppression of high p_T jets is explained well in all pseudorapidity ranges

RpPb in mid-central events



- Keep in mind that there is no nPDF for the MC

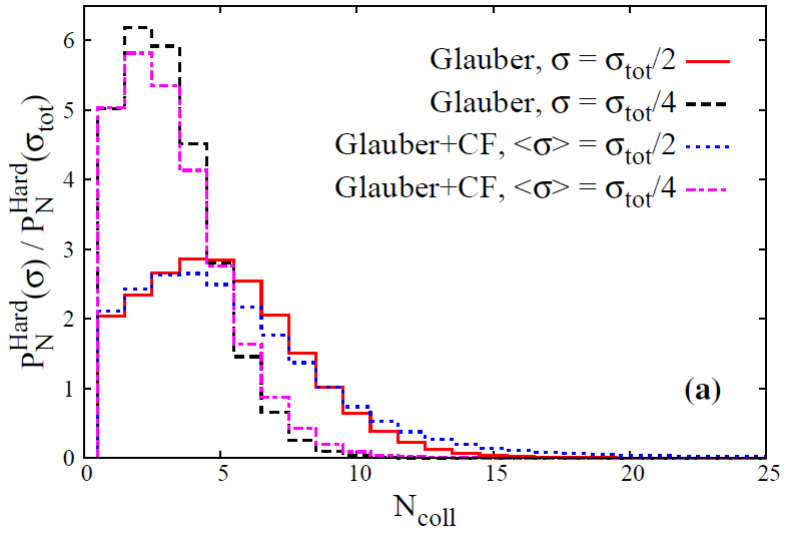
RpPb in peripheral events

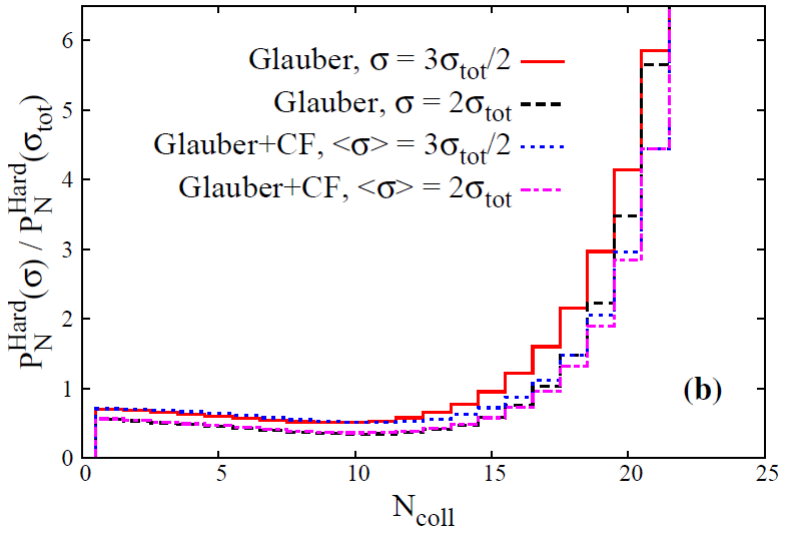


- Model fails due to the lack of consideration of the energy that goes into hard scattering from the parton in the Pb nucleus.
- N_{coll} peaks at 1 for this centrality class..

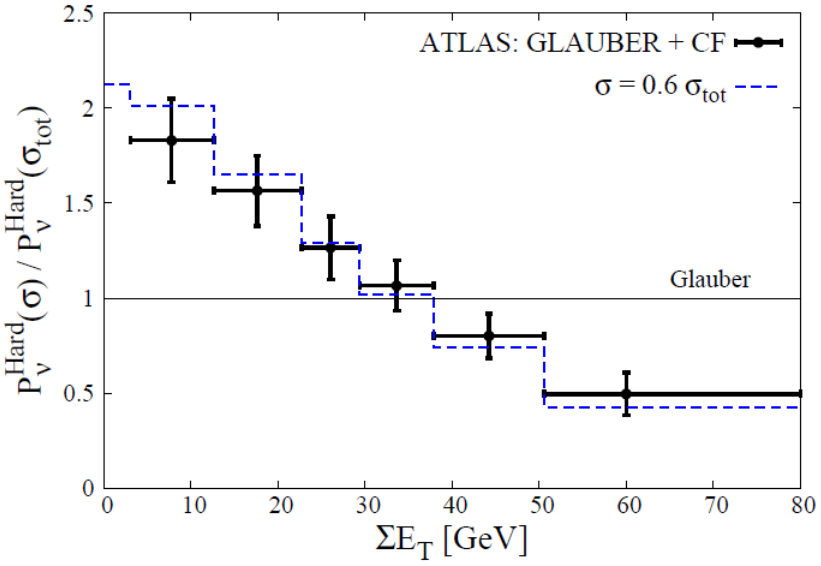
Color fluctuations

[1402.2868]





[1409.7381]

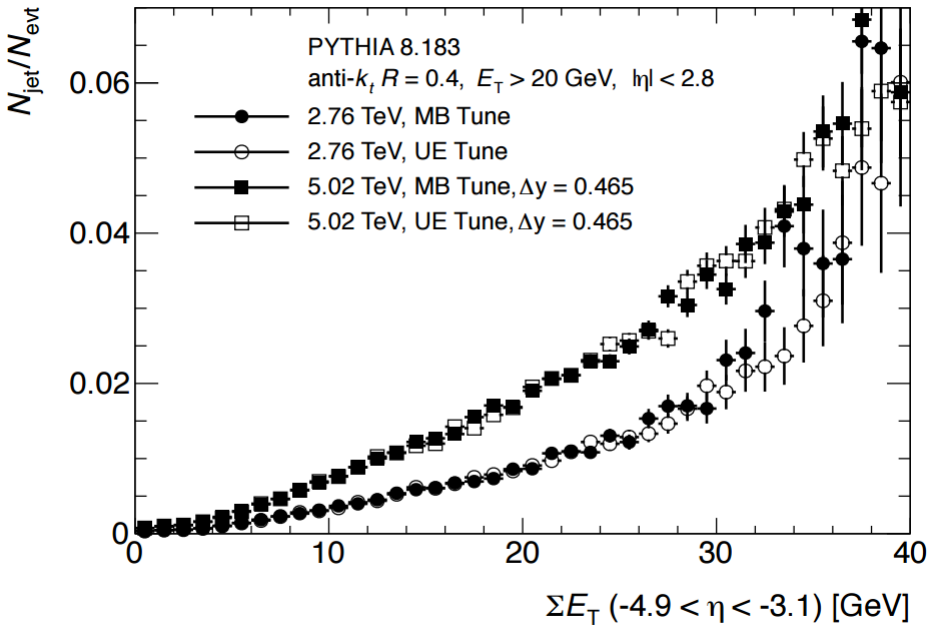


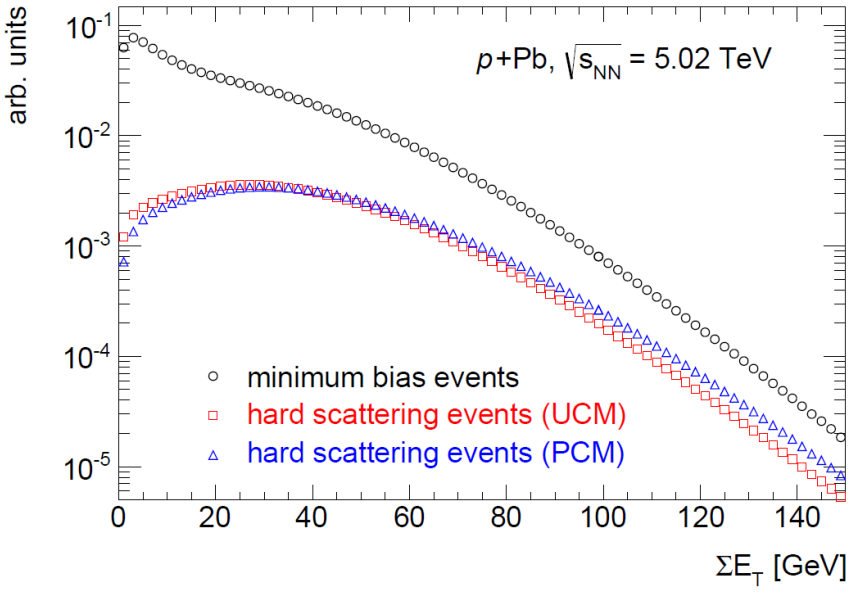
- Small σ (Large x_p) → Small N_{coll} → Peripheral
- Large σ (Small x_p) → Large N_{coll} → Central
- PDFs take into account the fluctuations in σ, but interesting to see the value that explains the data the best

Yield of jets per NN interaction increases E_T

Not taken into account but could be…

[1412.0976]





- In PYTHIA and pp collisions N_{jet} per event increases as E^T_{Pb} increases approximately linearly

$$Y_{N\mathrm{coll}}(E_{\mathrm{T}}) = \frac{C}{2k\theta} \sum_{j=1}^{N_{\mathrm{coll}}} \left(E_{\mathrm{T}}^{j} + E_{\mathrm{T}}^{j(p)} \right).$$

- Produces and opposite effect
- Larger number of hard scattering in large ET effects
- However this bias is independent of mean yield per collision so it will create an overall scale with respect to p_T

Summary

- Simple kinematic bias that must be removed to be able to search for impact parameter dependent effects in small systems

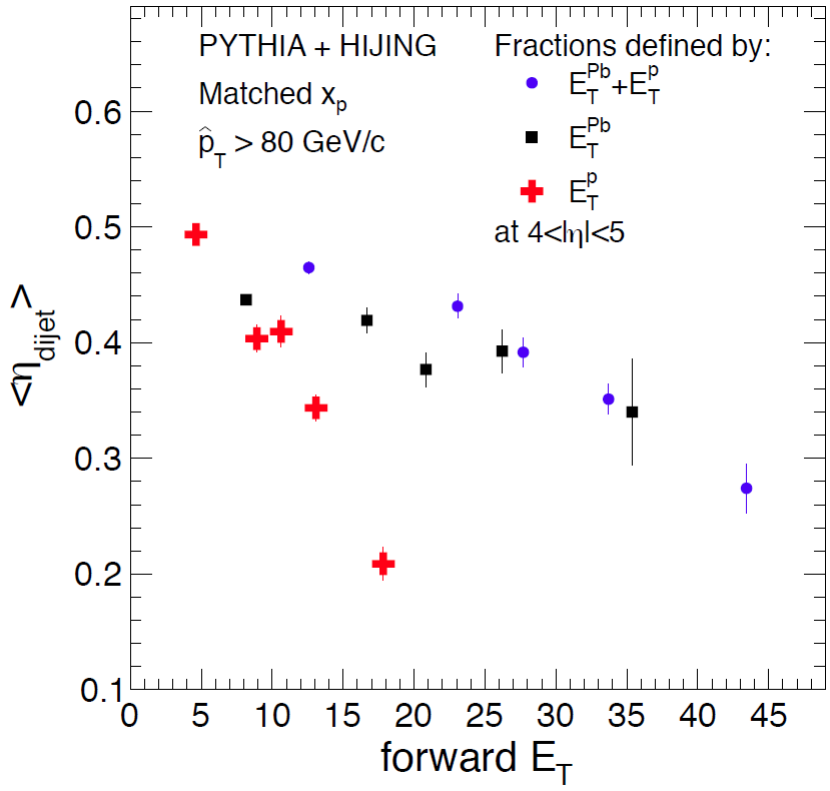
- Next step is adding the feature for one nucleon from Pb to lose energy

Some other perspectives:

- "Particle rapidity distribution in proton-nucleus collisions using the proton contributor reference frame' Martínez-García [1408.3108]
- "Centrality dependence of high energy jets in p+Pb collisions at the LHC" Bzdak, Skokov, Bathe [1408.3156]

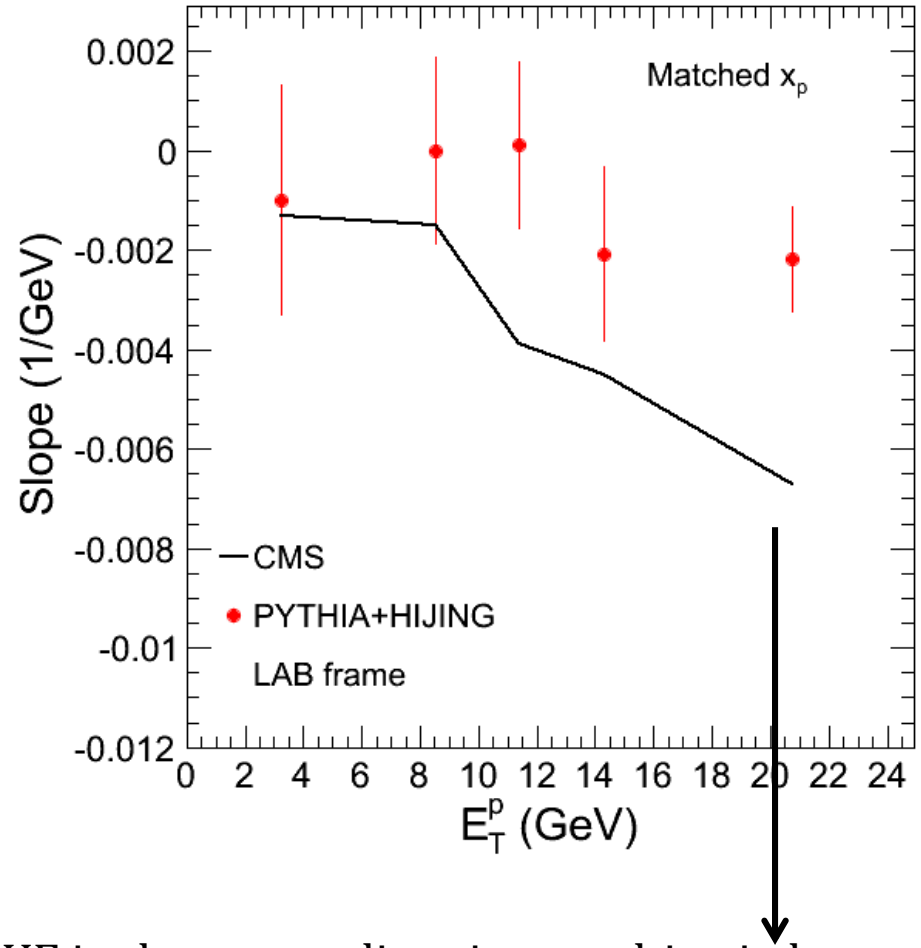
Back up

Dijet pseudorapidity shift for different ET choices



- Largest shift for E_T^p and smallest for E_T^{Pb} as slide 10 suggests

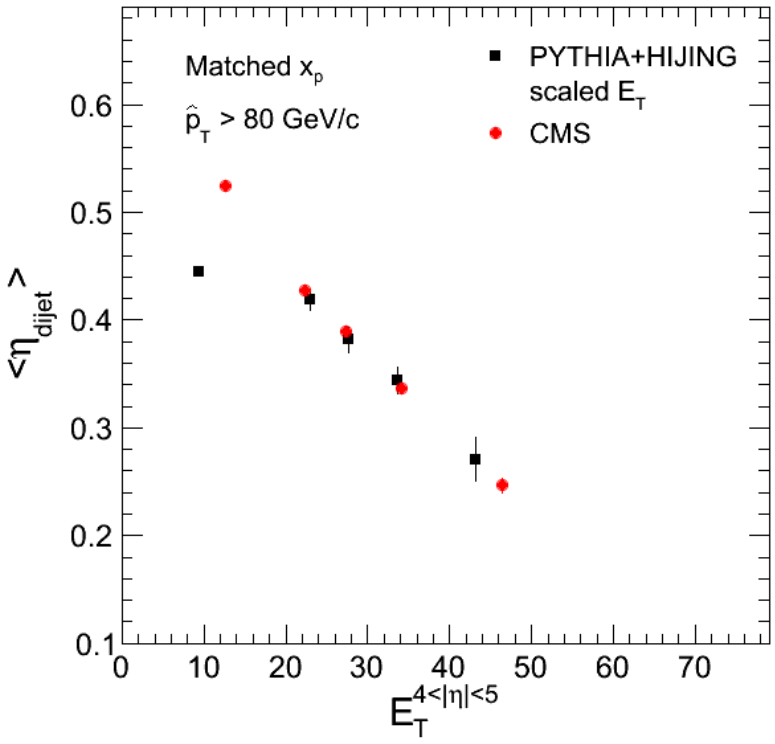
Slopes of dijet pseudorapidity shift



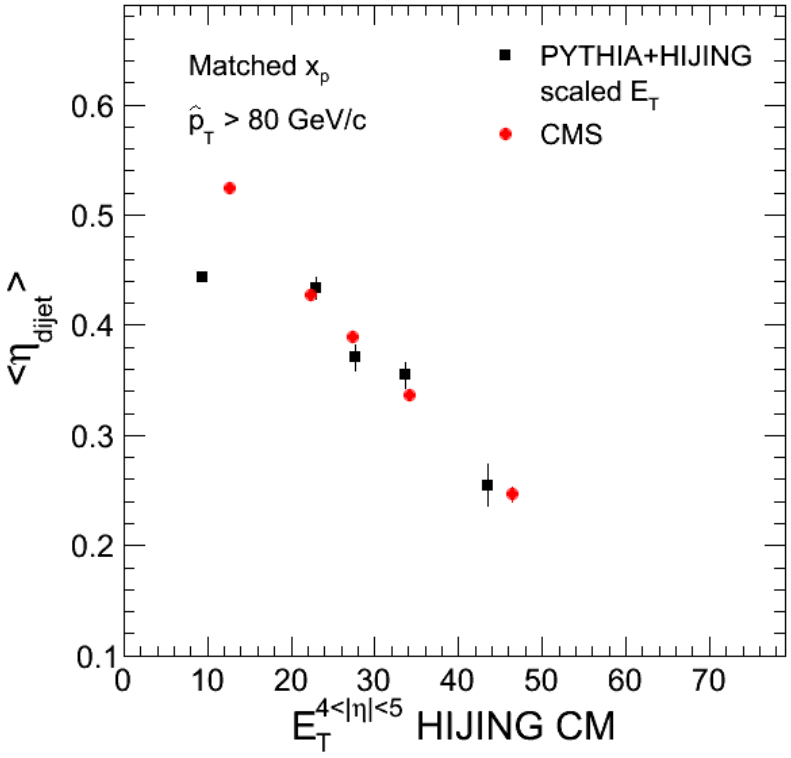
- Large x_{Pb} Shifts the UE in the proton direction resulting in larger E_T^p values
- At large x_{Pb} the approximation doesn't perform well.

Decrease in the available E_T

Lab frame



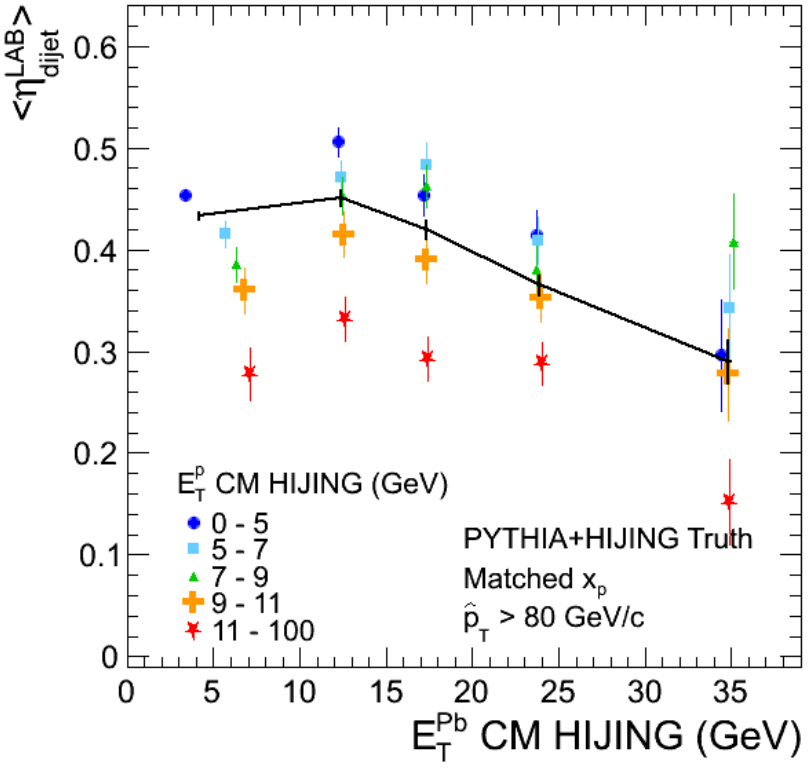
Unphysical test: Dijet in the LAB frame, E_T in the HIJING nucleon-nucleon CM frame

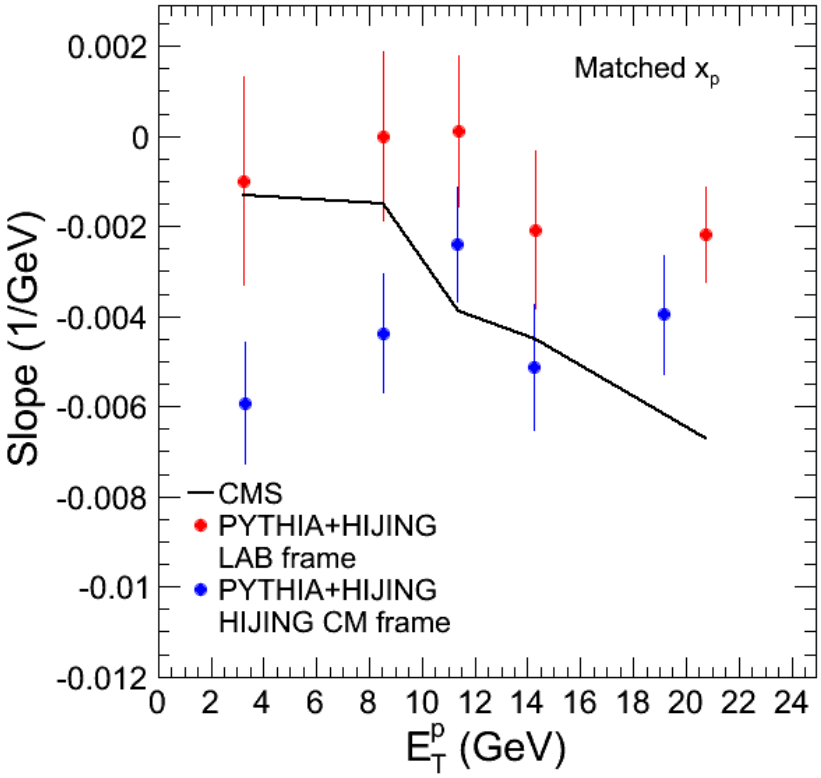


- The shift is due to reduction of overall E_T rather than the recoil of the UE with respect to the hard scattering.

Recoil of the UE

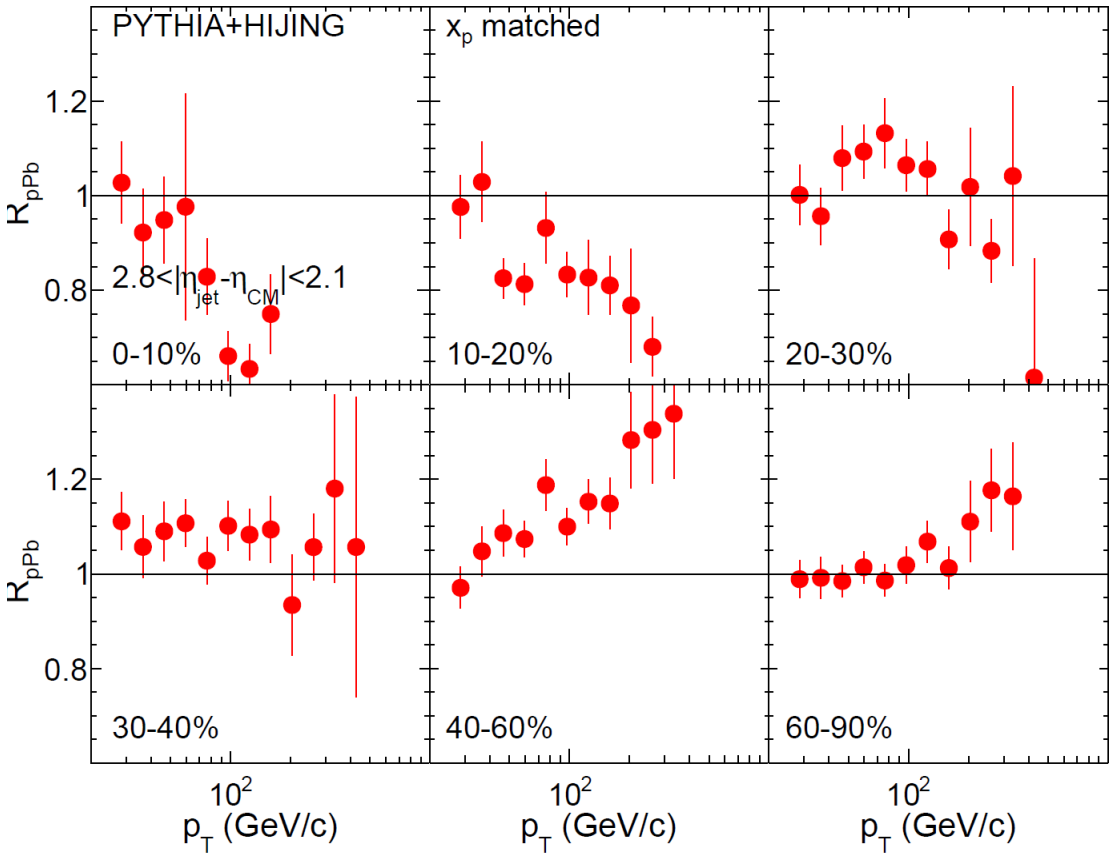
Unphysical test: Dijet in the LAB frame, E_T in the HIJING nucleon-nucleon CM frame





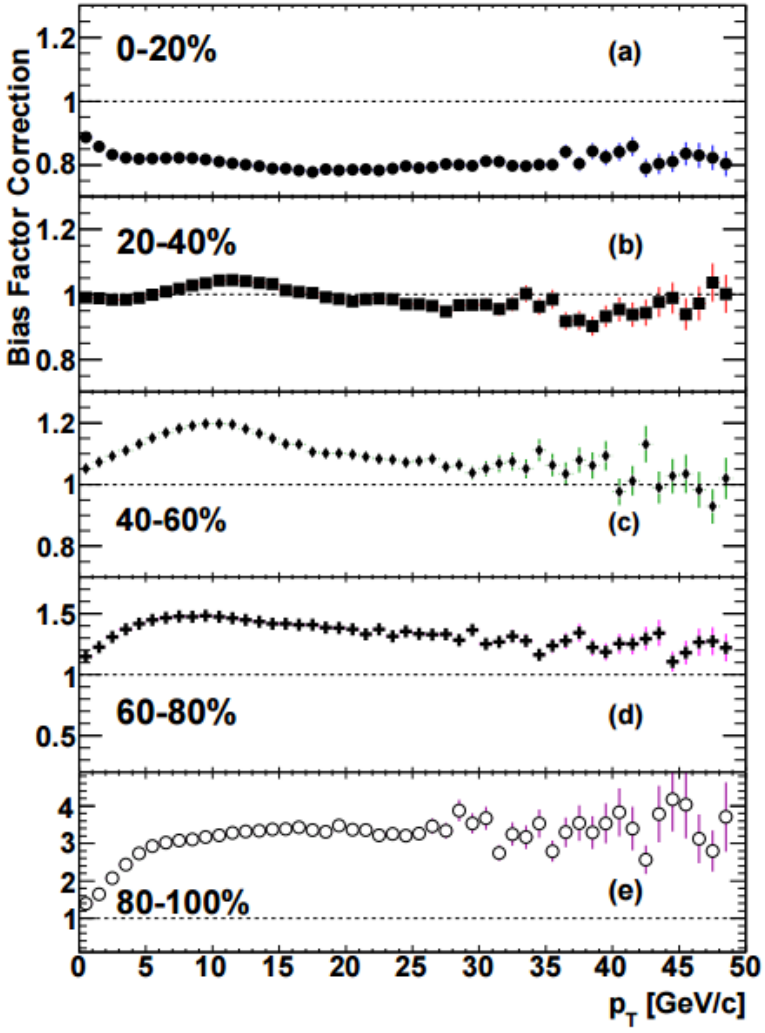
- Sensitive to the recoil of the UE.

Centrality dependence for forward jet

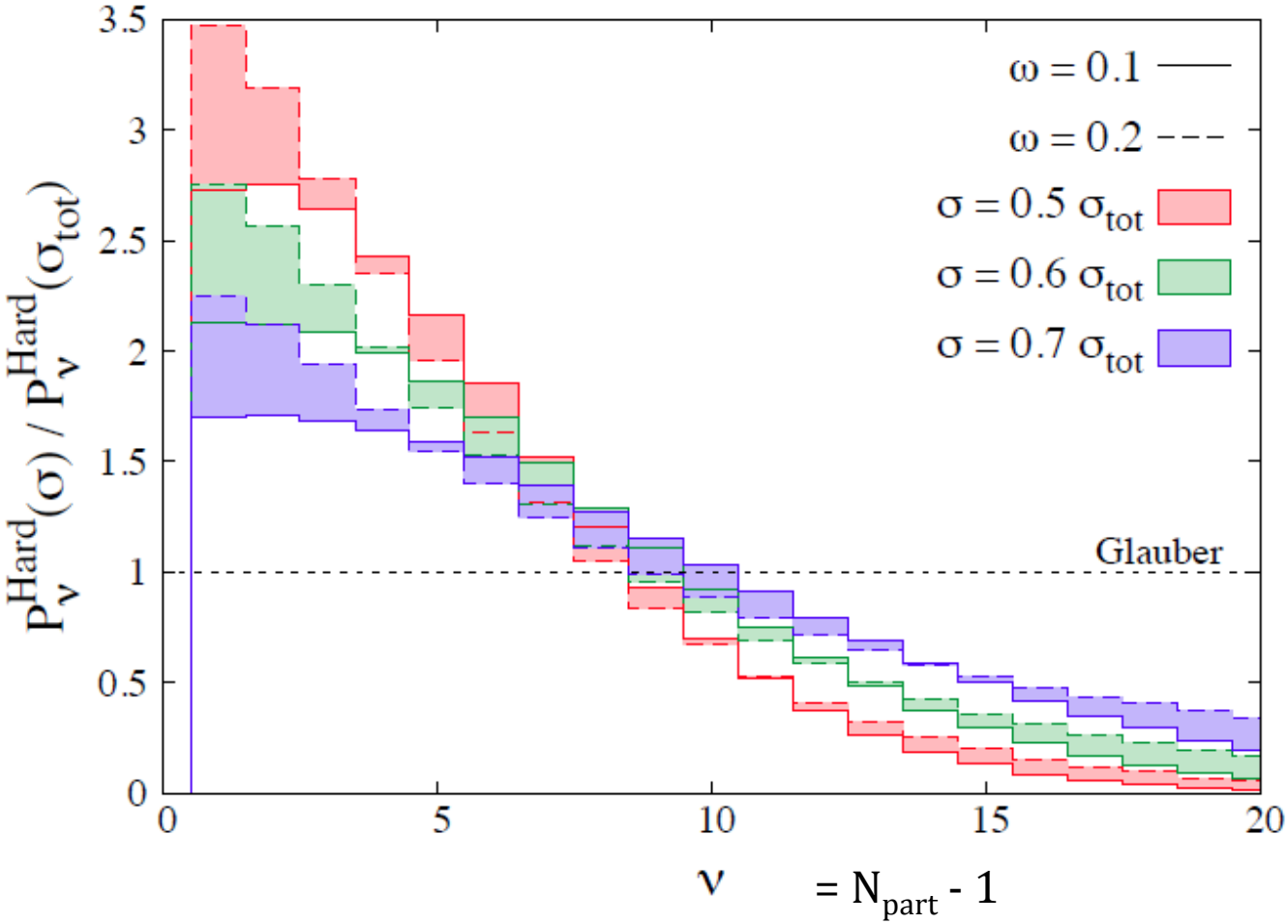


- Ncoll values from selected events are used instead of MB values
- There is an enhancement in peripheral bins but it's reduced at the most peripheral compared to 40-60 %

Very similar approach by PHENIX



Very peripheral events



Enhancement going down also in CF calculation