hard-soft correlations in pA collisions

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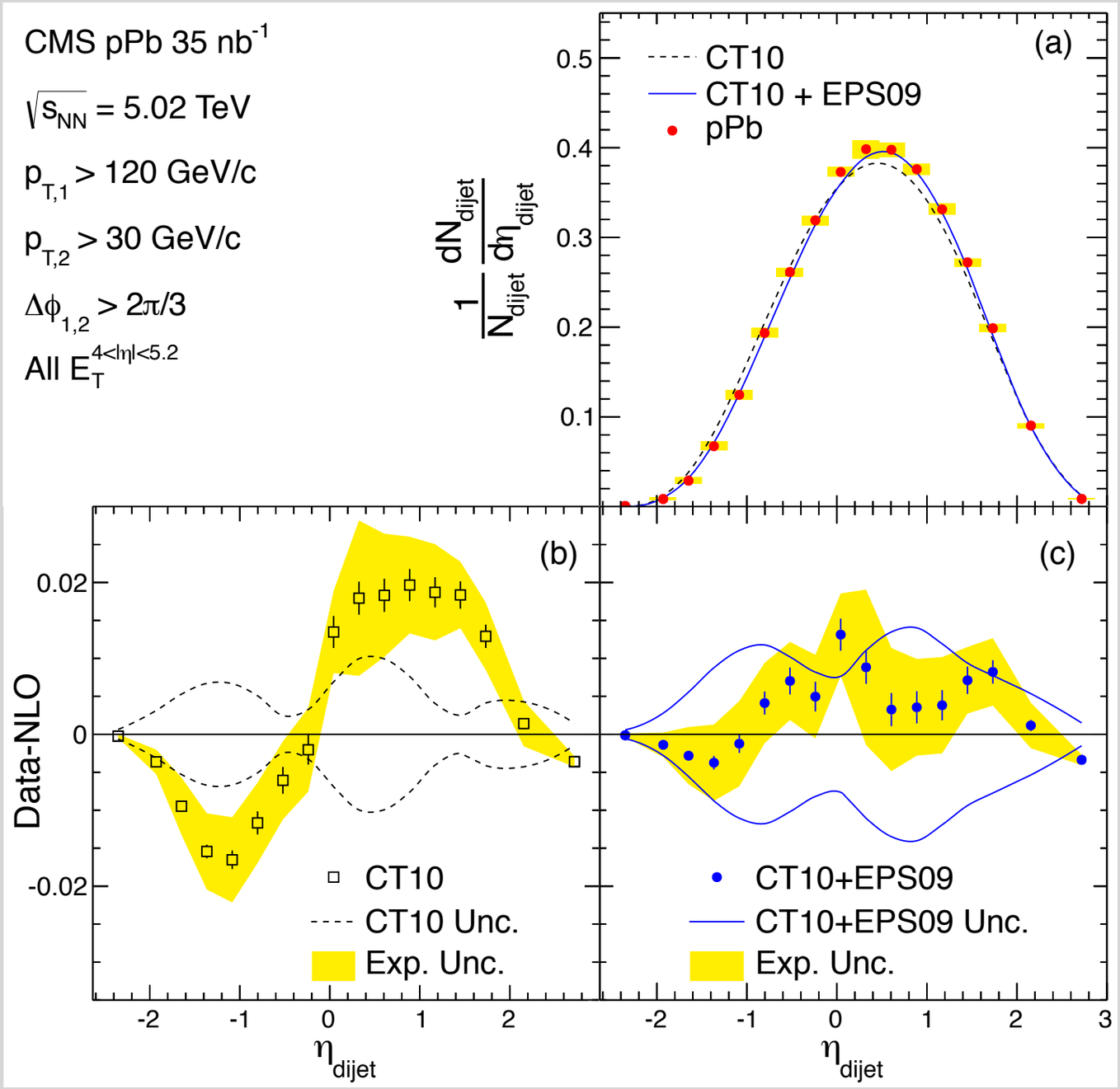
Correlations and fluctuations, INT, 23rd July 2015

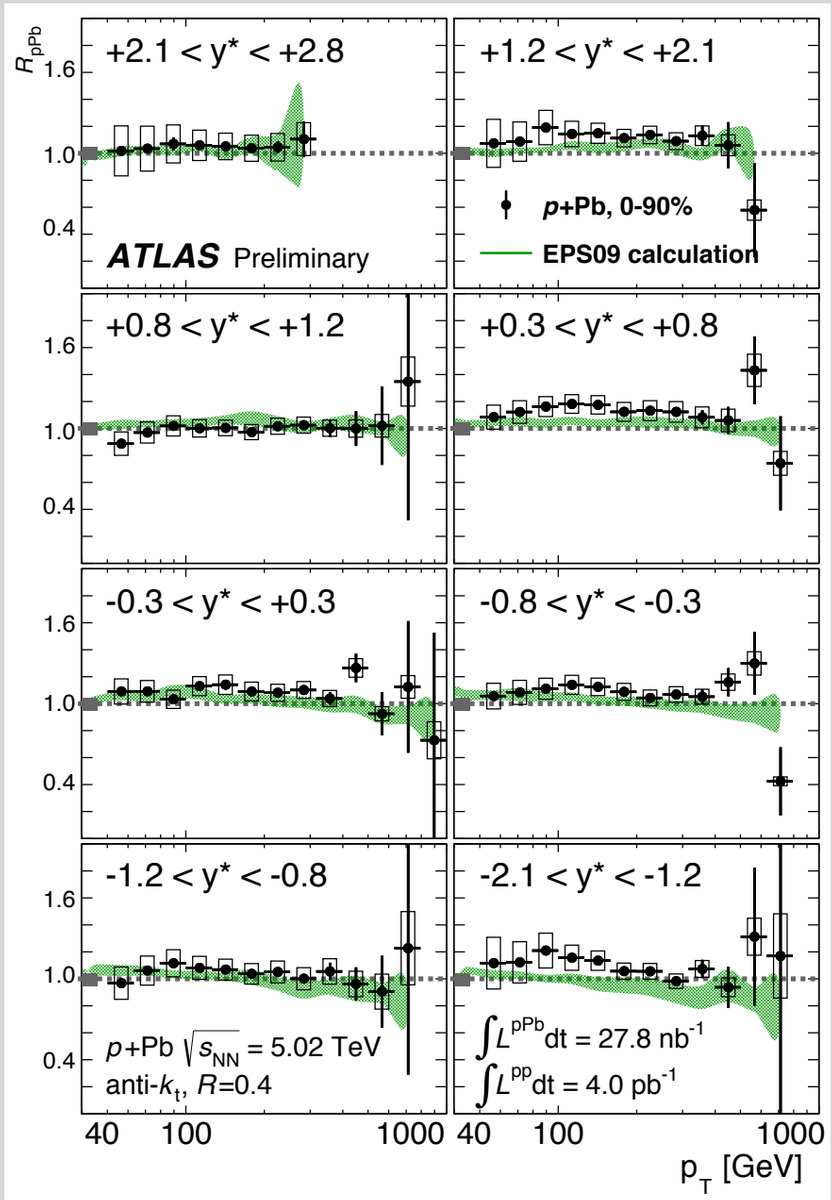
b-dependent nPDFs

:: impact parameter /centrality

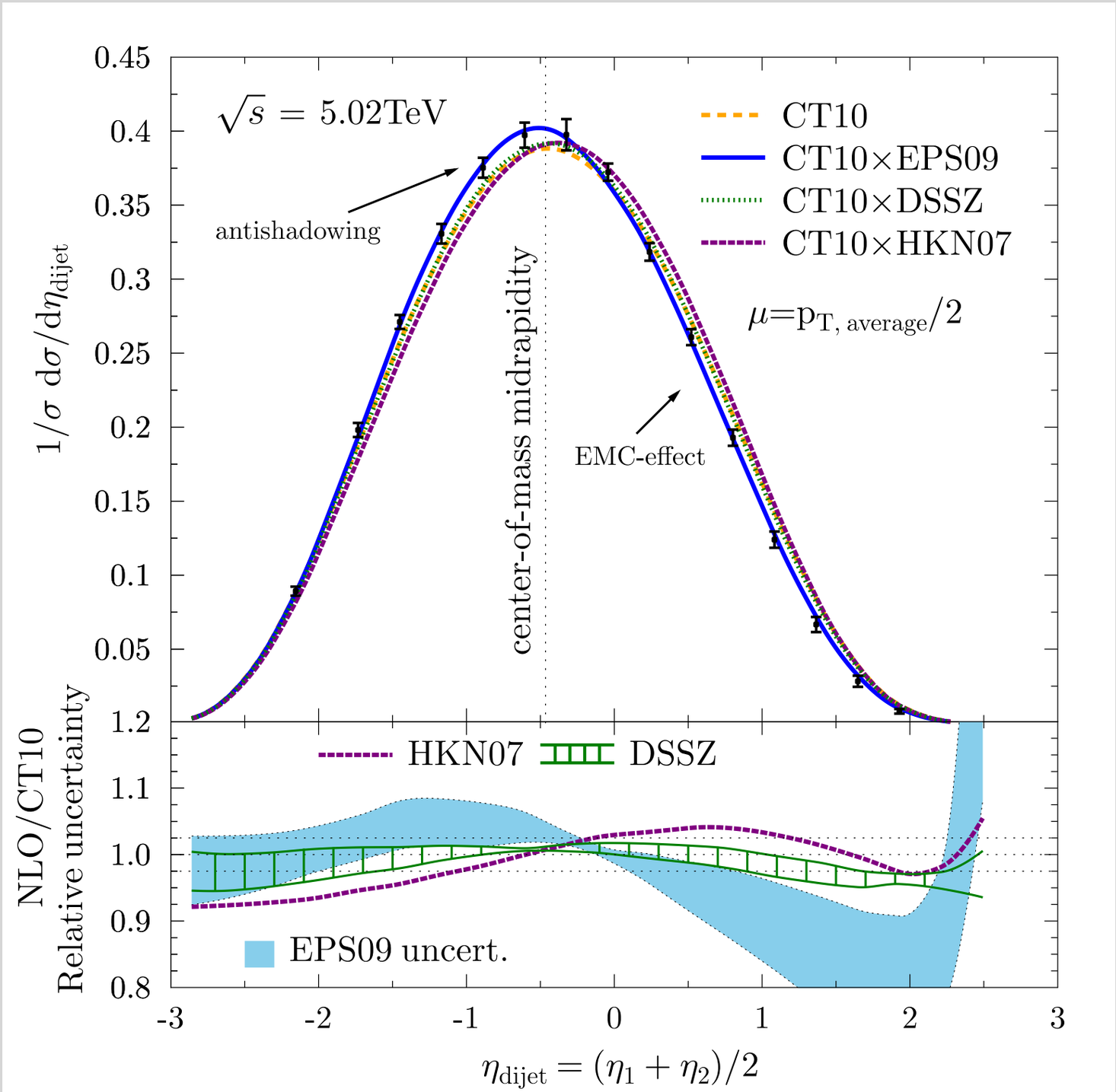
pA dijets and nPDFs :: how successful?



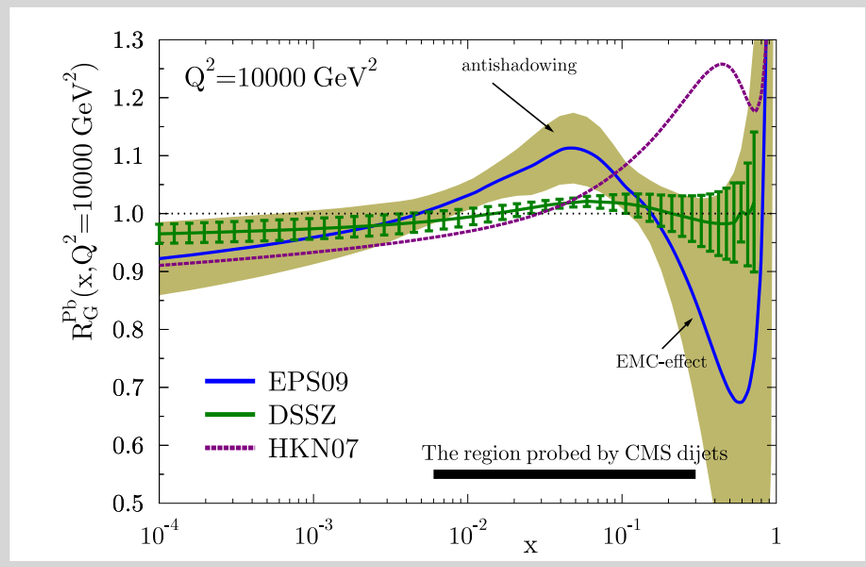
- nuclear effects are small within the probed kinematics but essential to describe data



pA dijets and nPDFs :: how successful?

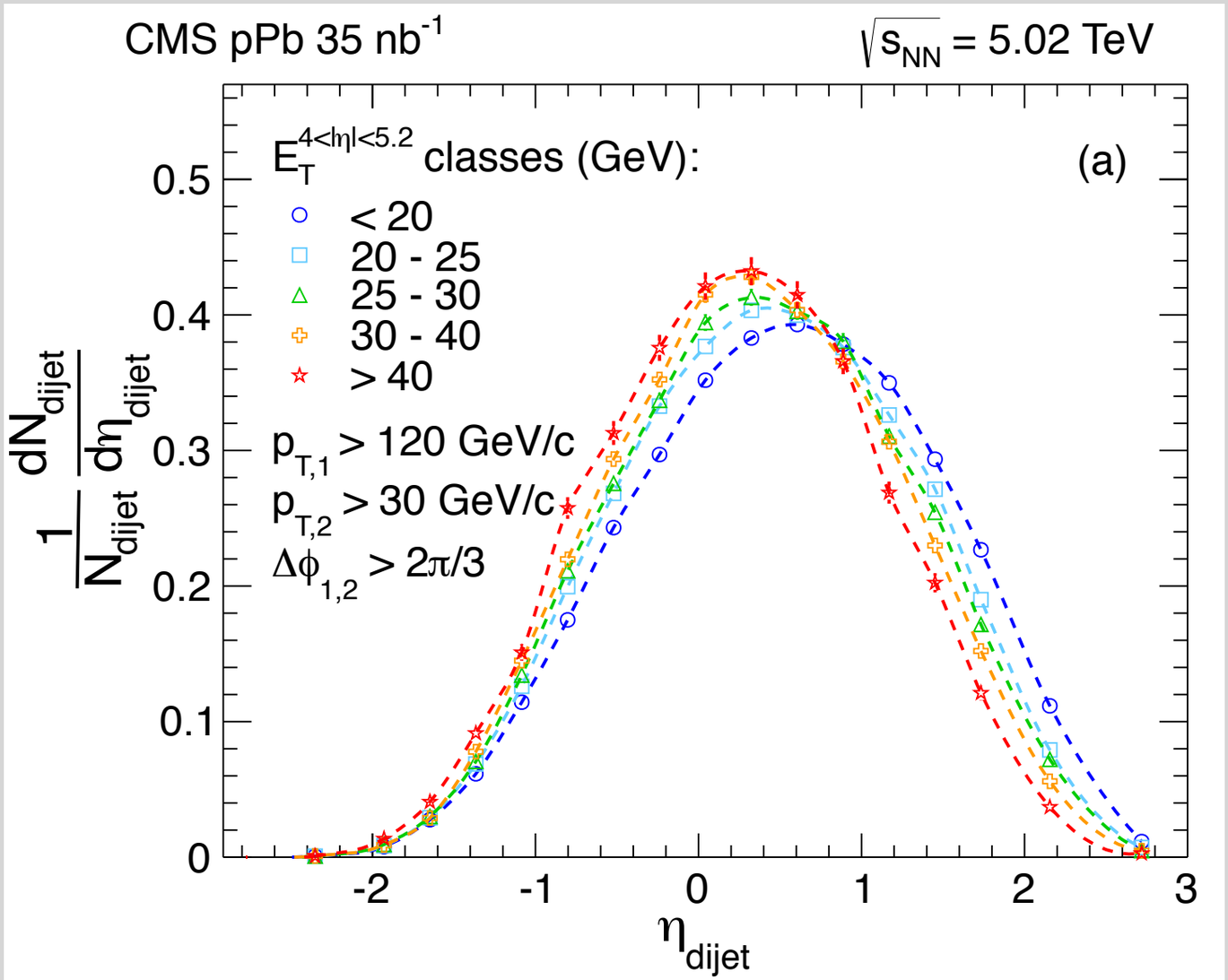


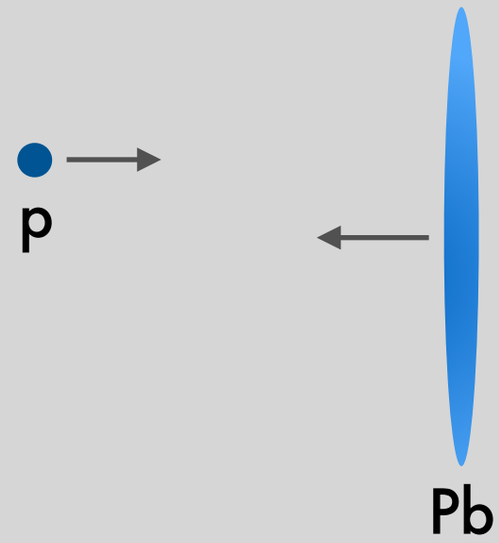
- EPS09 successful, others not [note anti-shadowing in EPS]



Paukkunen, Eskola, Salgado :: 1408.4563 [hep-ph]

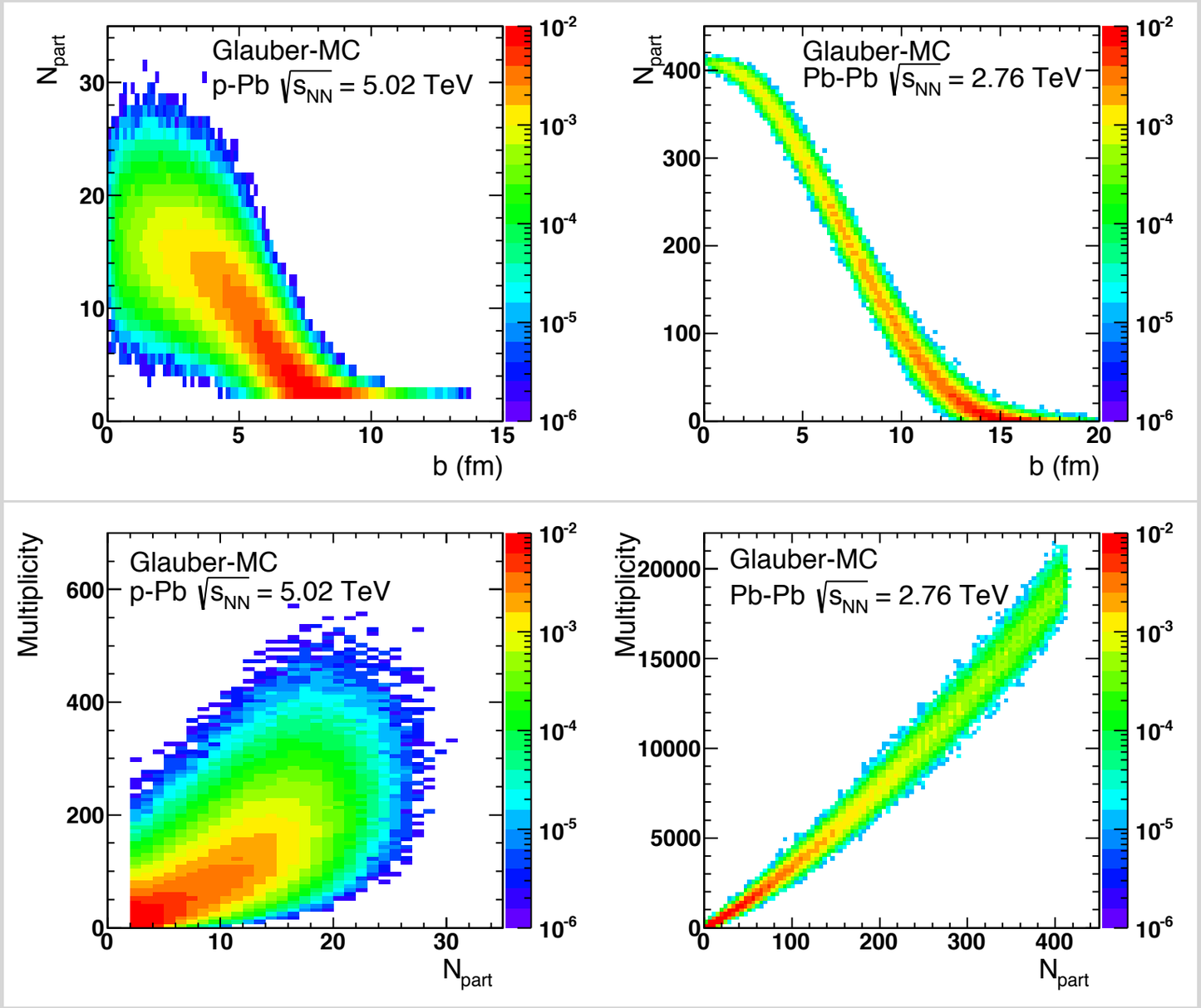
impact parameter dependence of nPDFs

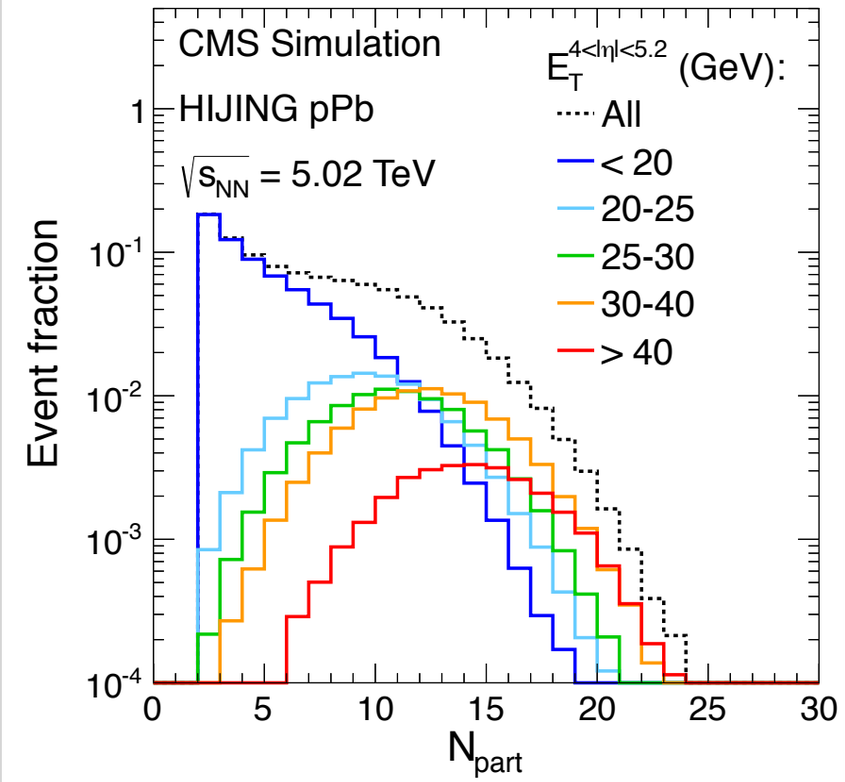




- impact parameter dependence of nPDFs [1205.5359] cannot account for large ‘centrality’ dependence of dijet η distributions

centrality is not impact parameter



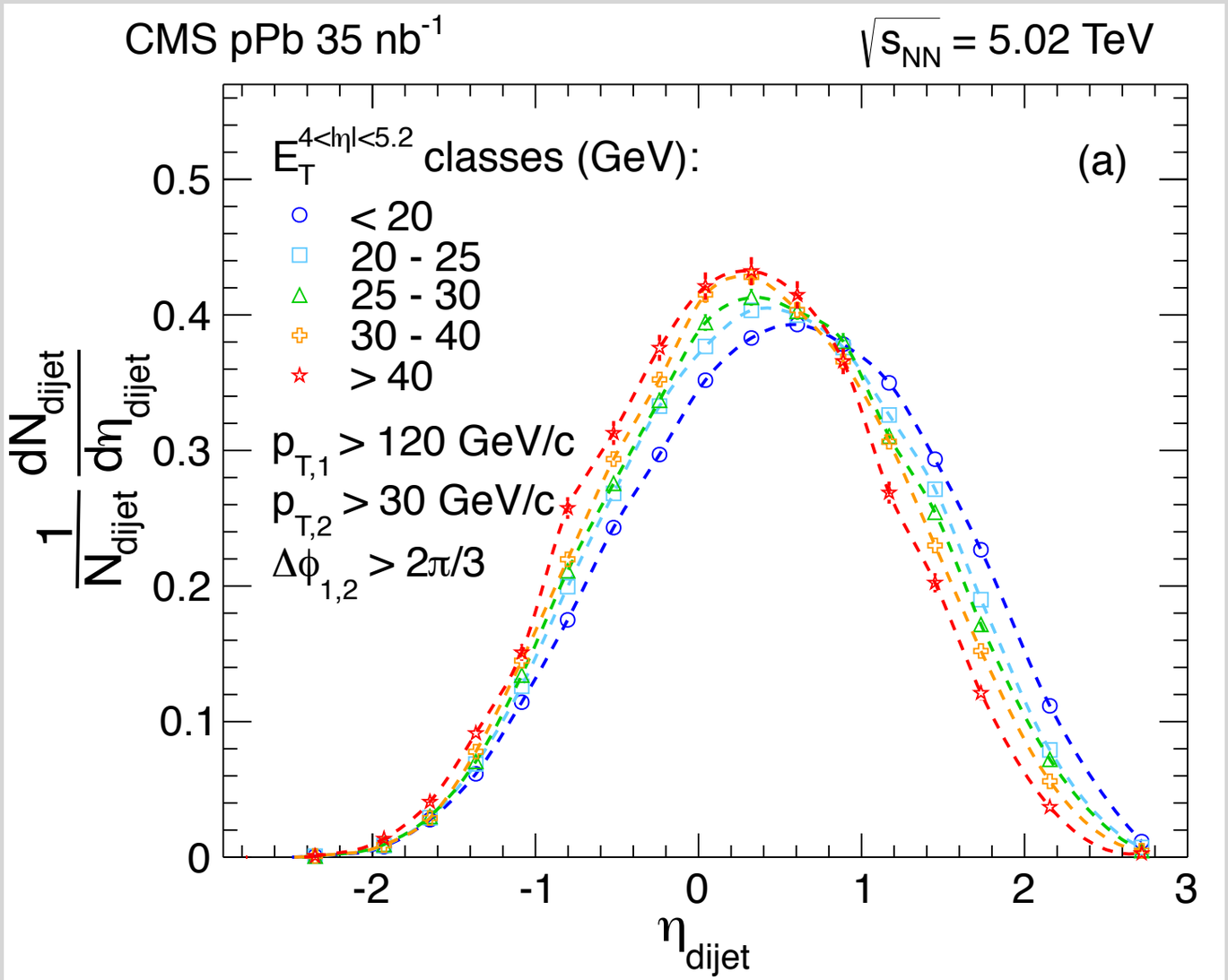


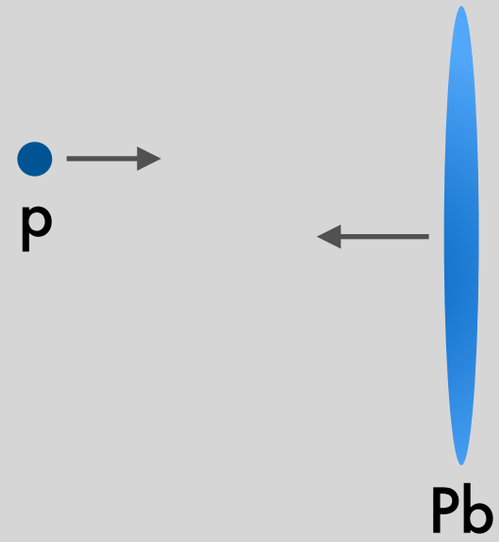
CMS :: 1401.4433 [nucl-ex]

ALICE :: 1412.6828 [nucl-ex]

- unlike in AA, multiplicity [or activity] not tightly correlated to N_{part} and N_{part} not tightly correlated to impact parameter
- 'centrality' classes necessarily mix wide range of impact parameters…
- both RHIC and LHC data show hallmarks of 'centrality' fuzziness

impact parameter dependence of nPDFs





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- impact parameter dependence of nPDFs [1205.5359] cannot account for large 'centrality' dependence of dijet η distributions

$$\eta_{\text{dijet}} = 2\,, \quad p_T = 100\,\text{GeV} \Longrightarrow x_p \sim 0.3\,(E_p \sim 1.2\,\text{TeV})$$

what is going on ?

Physics scenarios

Presence of high-x_p jet is correlated with downward shift in Pb-going ΣE_T → more jets in peripheral bins, fewer jets in central bins

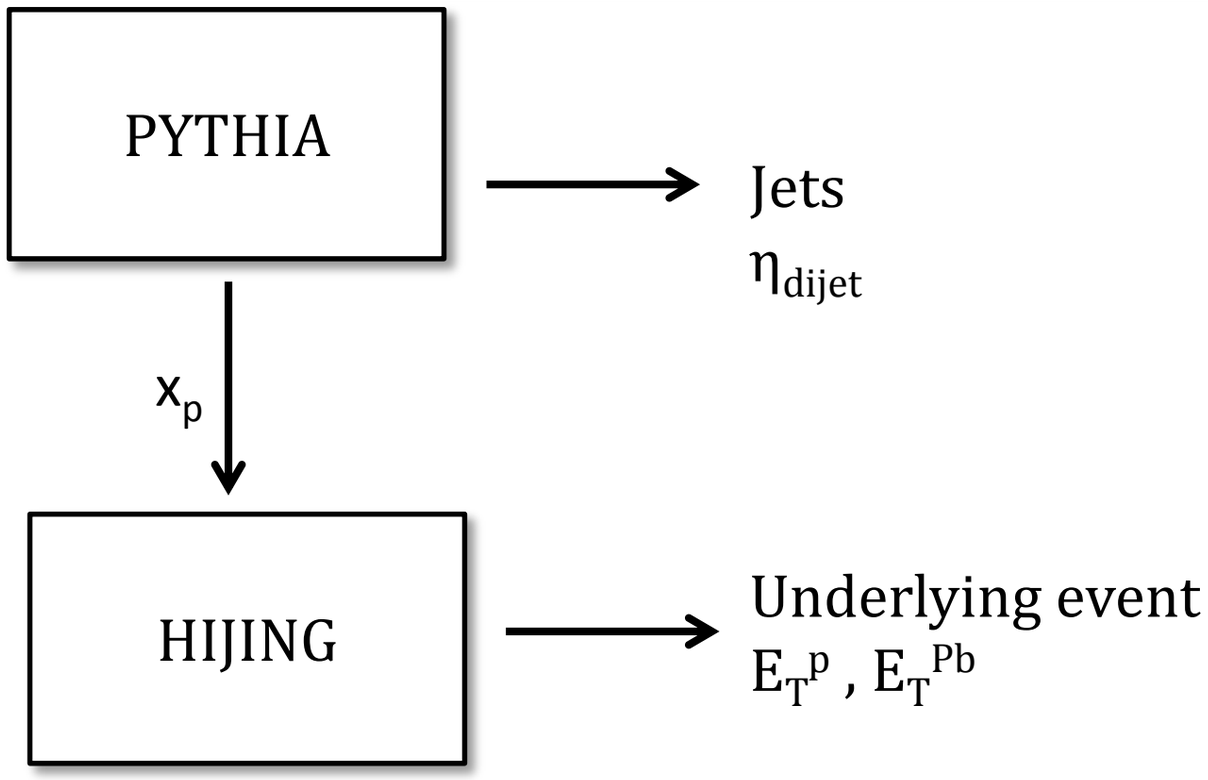
- Alvioli et al, arxiv:1409.7381:
  - Reduction in size of proton configuration for events when a high-x parton is available for scattering - **reduces N_{coll} and multiplicity**
- Armesto et al, arxiv:1502.02986
  - Reduction in CM energy of proton, due to removal of high-x parton - **reduces multiplicity and shifts CM rapidity**
- Bathe et al, arxiv:1408.3156
  - Reduction in gluon content of projectile proton undergoing a high-x parton-parton scattering - **reduces multiplicity**
- Kordell & Majumder - previous talk

Each of these can explain aspects of existing data:
how do we explore this experimentally?

simple proof of principle

Armesto, Gulhan, Milhano:: 1502.02986 [hep-ph]

Event by event matching



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

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

- The energy that goes in hard scattering from one proton in PYTHIA taken away from proton in HIJING
- x_{Pb} is not taken into account in HIJING
- Good approximation when N_{coll} is large and x_{Pb} is small

simple proof of principle

Armesto, Gulhan, Milhano:: 1502.02986 [hep-ph]

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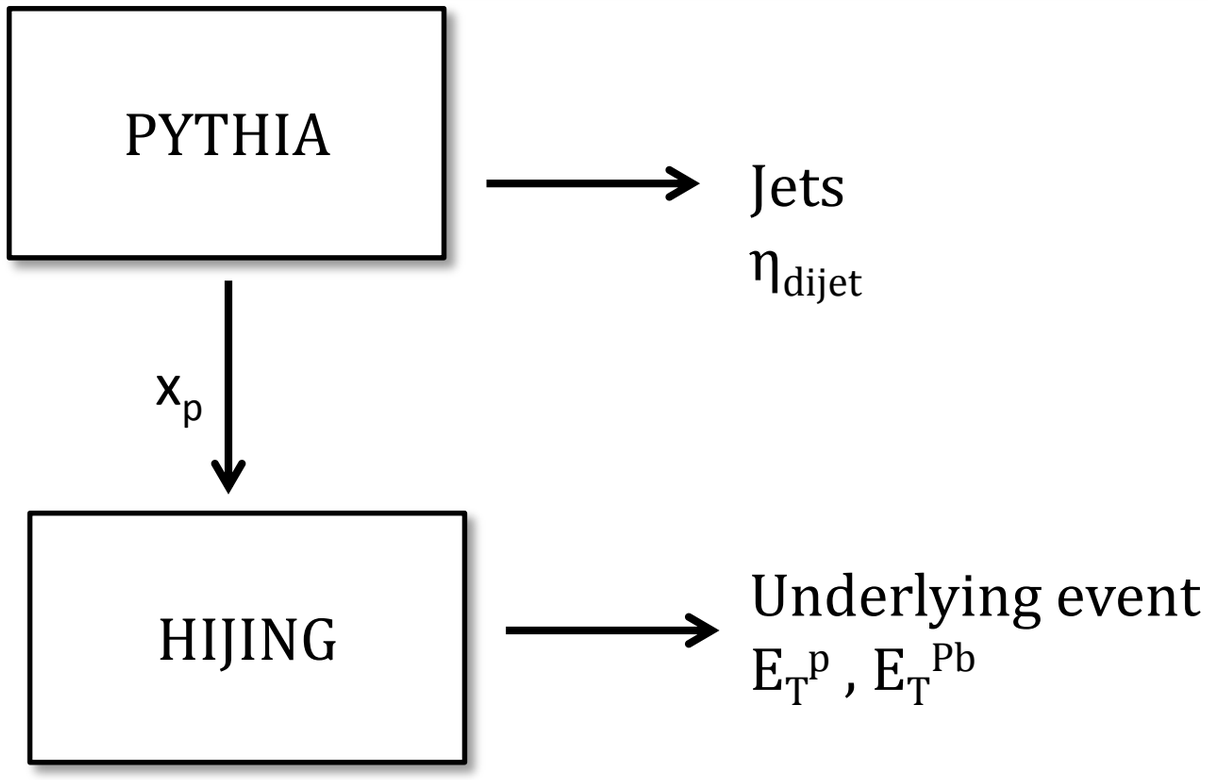

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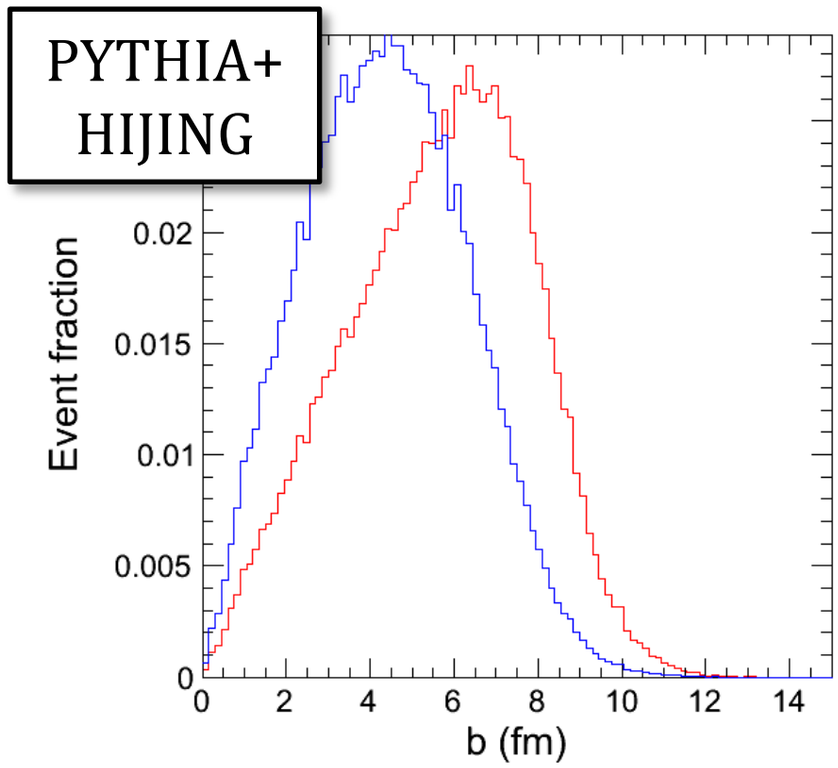
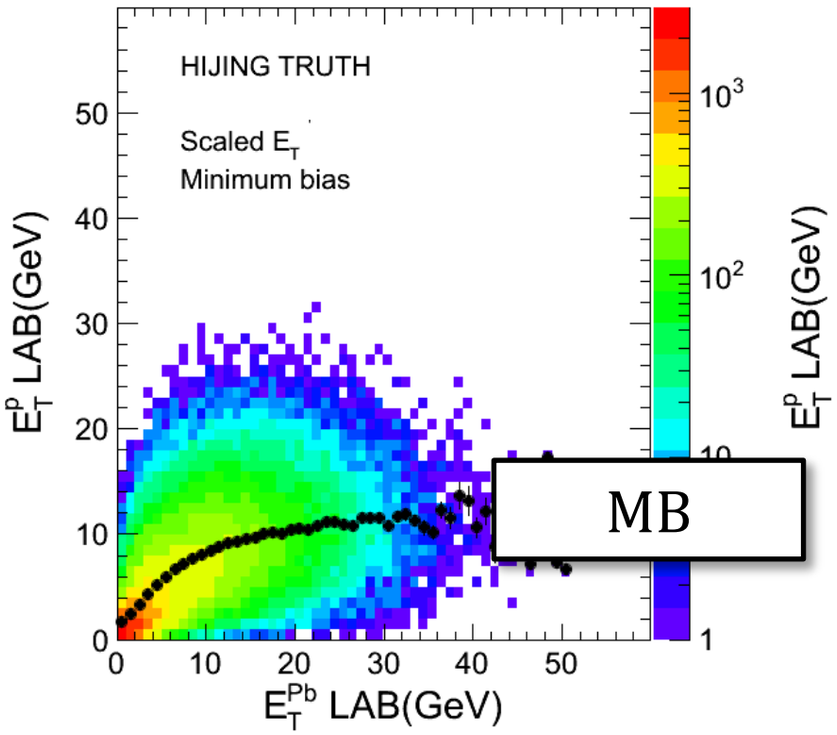
- The energy that goes
  from proton in HIJIN
- x_{Pb} is not taken into a
- Good approximation

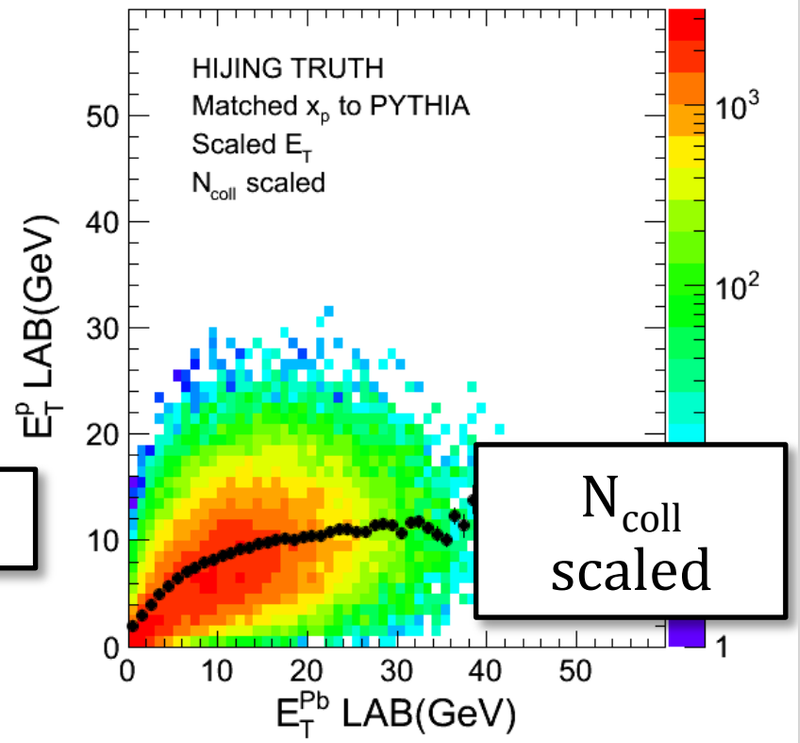
- E_T^{truth} : Sum of p_T of particles at large η from HIJING MB events
- Separate in centrality classes by slicing E_T^{truth} in same fractions as in data
- Scale the E_T^{truth} values with a constant so that the lower bound of highest centrality class in data and MC match (e.g. Scale factor ~ 0.7 for CMS dijet measurement)
- Obtain E_T^{raw} comparable to what is measured by experiment

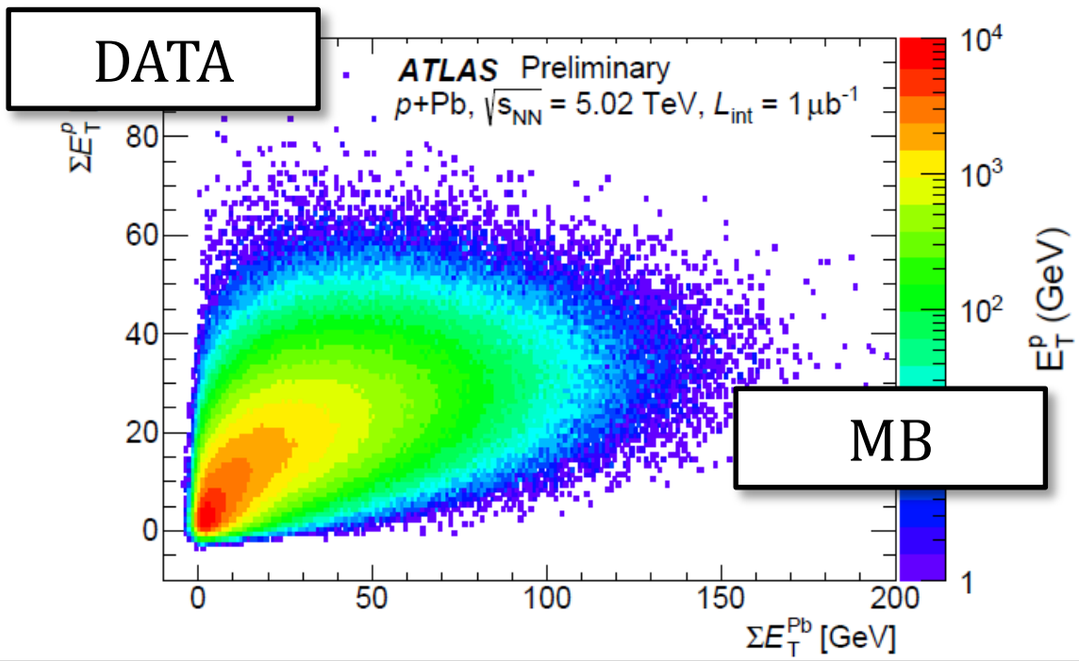
MB vs dijet events

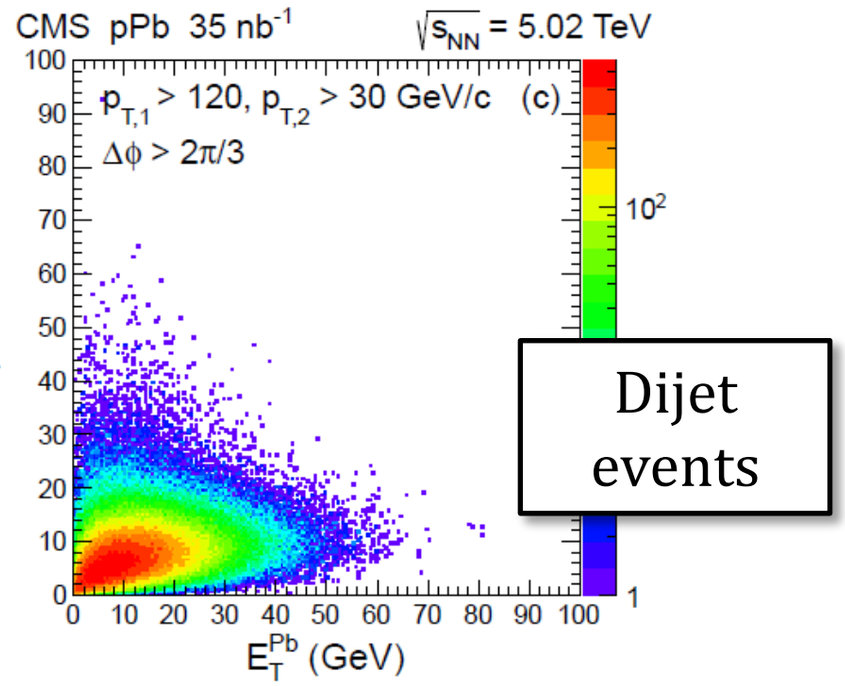
- Bias towards small impact parameter collisions with higher E_T on both sides.



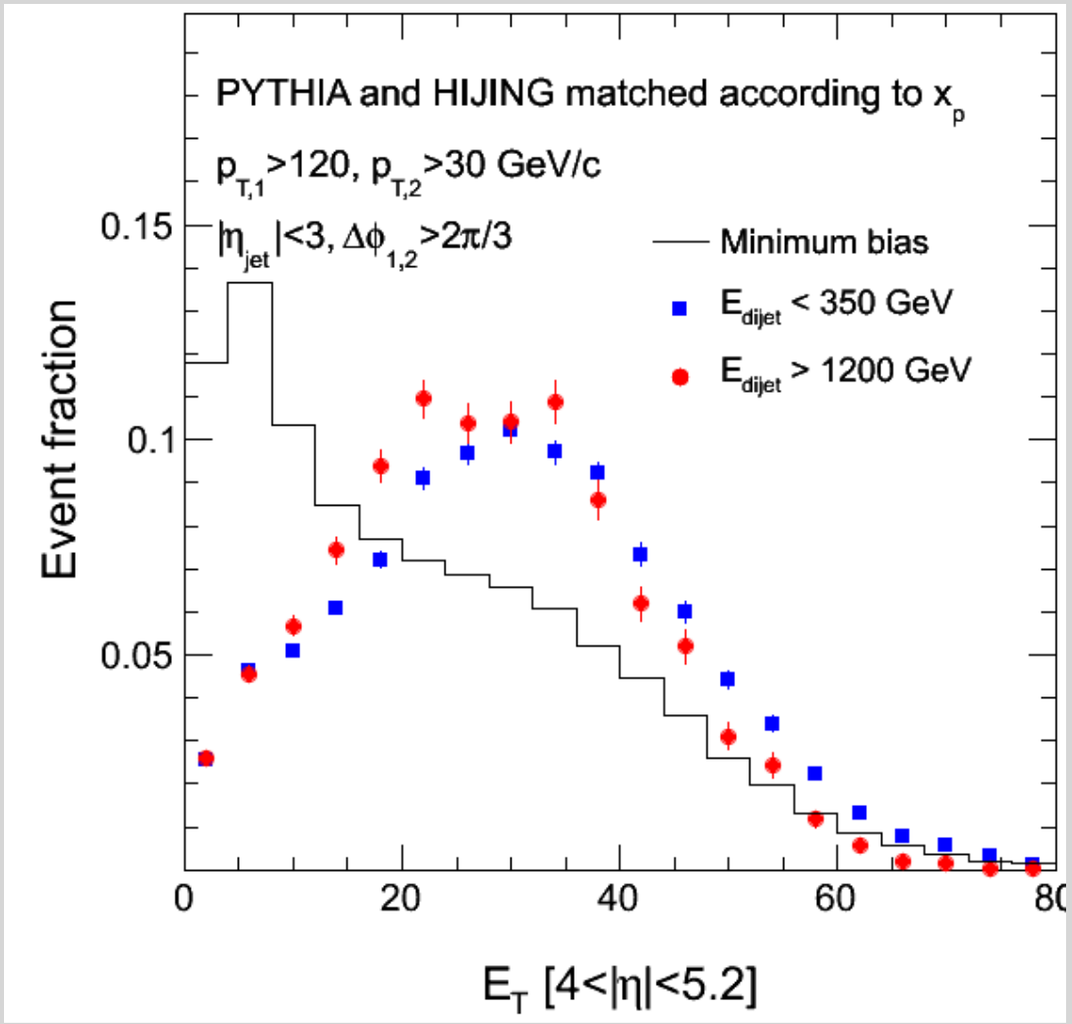


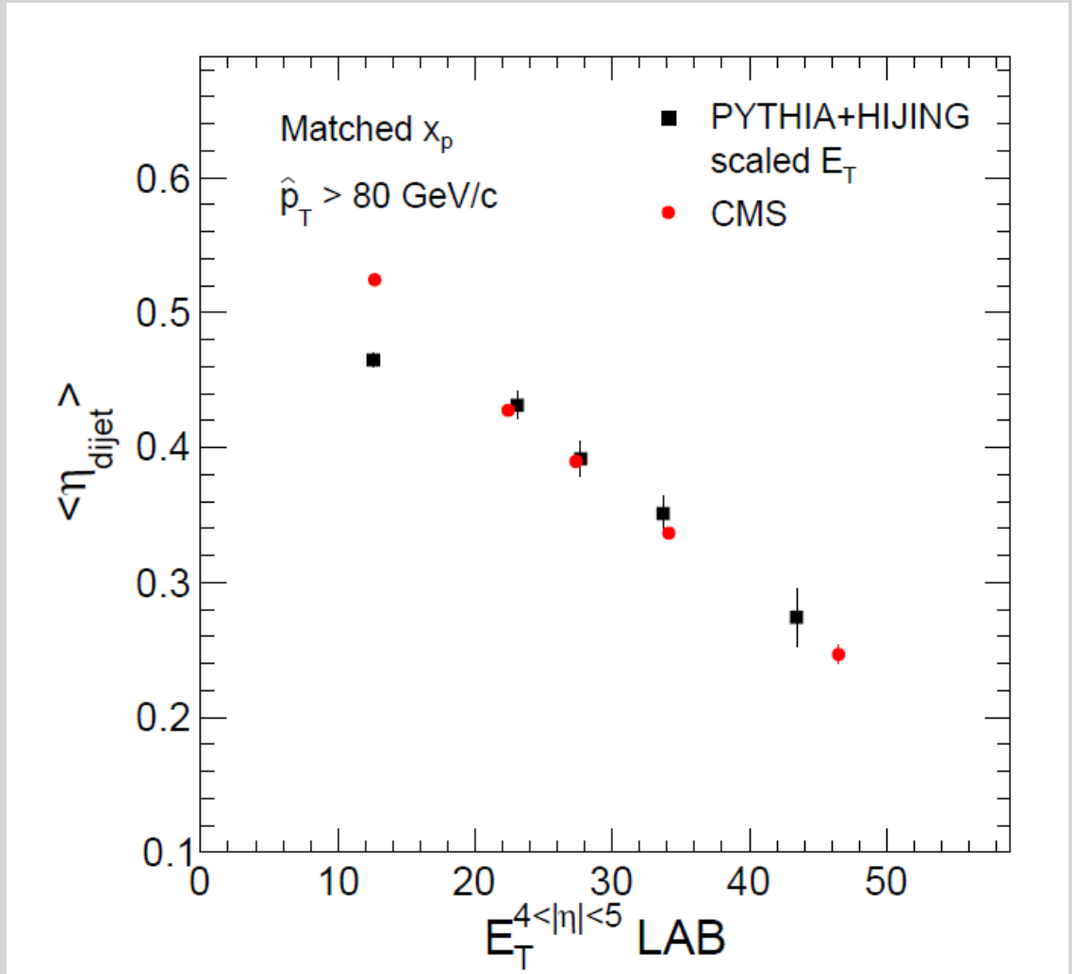






dijet η shift [CMS]





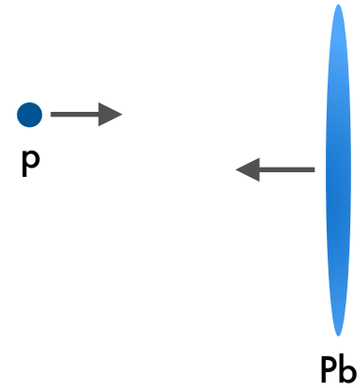
- large dijet energy requirement shifts E_T down
- for low E_T [peripheral] events model fails as Pb energy depletion becomes important to calculate activity

η dijet distributions

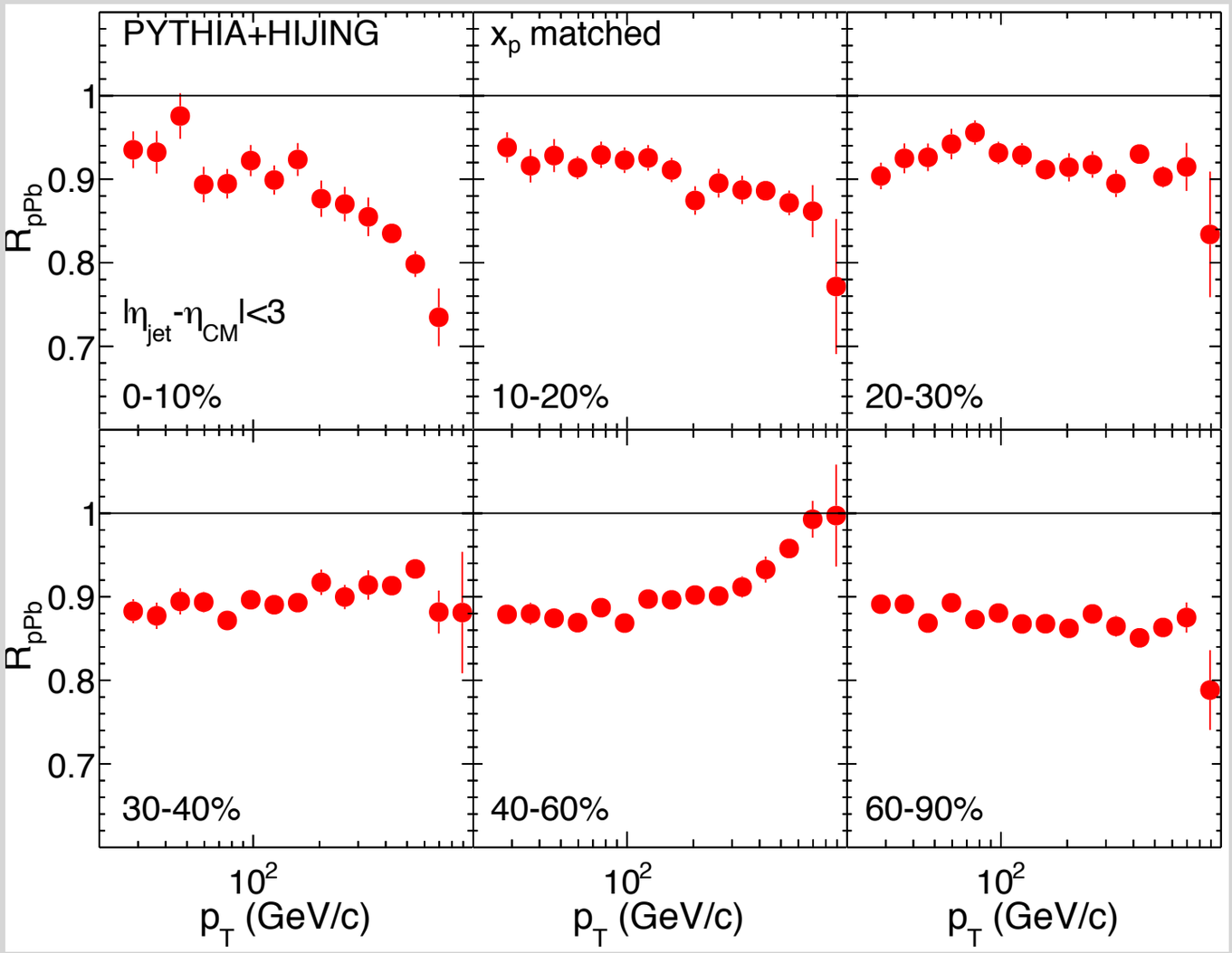
- PYTHIA+HIJING

  x_p matched

- CMS

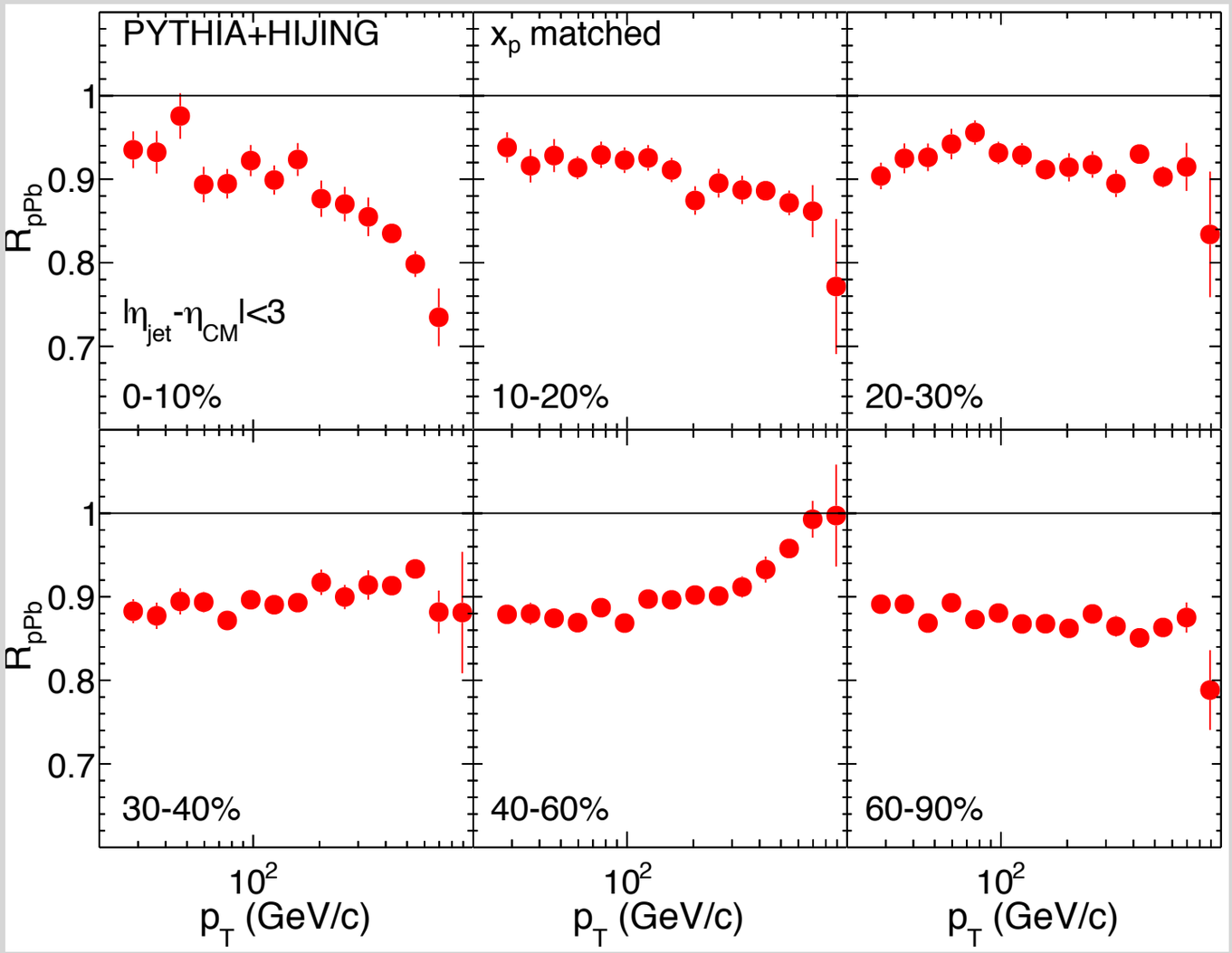


R_{pPb} [ATLAS] :: η inclusive



NOTE: 'centrality' determination from only Pb side

R_{pPb} [ATLAS] :: η inclusive



- N_{coll} from ATLAS [model dependent] :: don't add to unity

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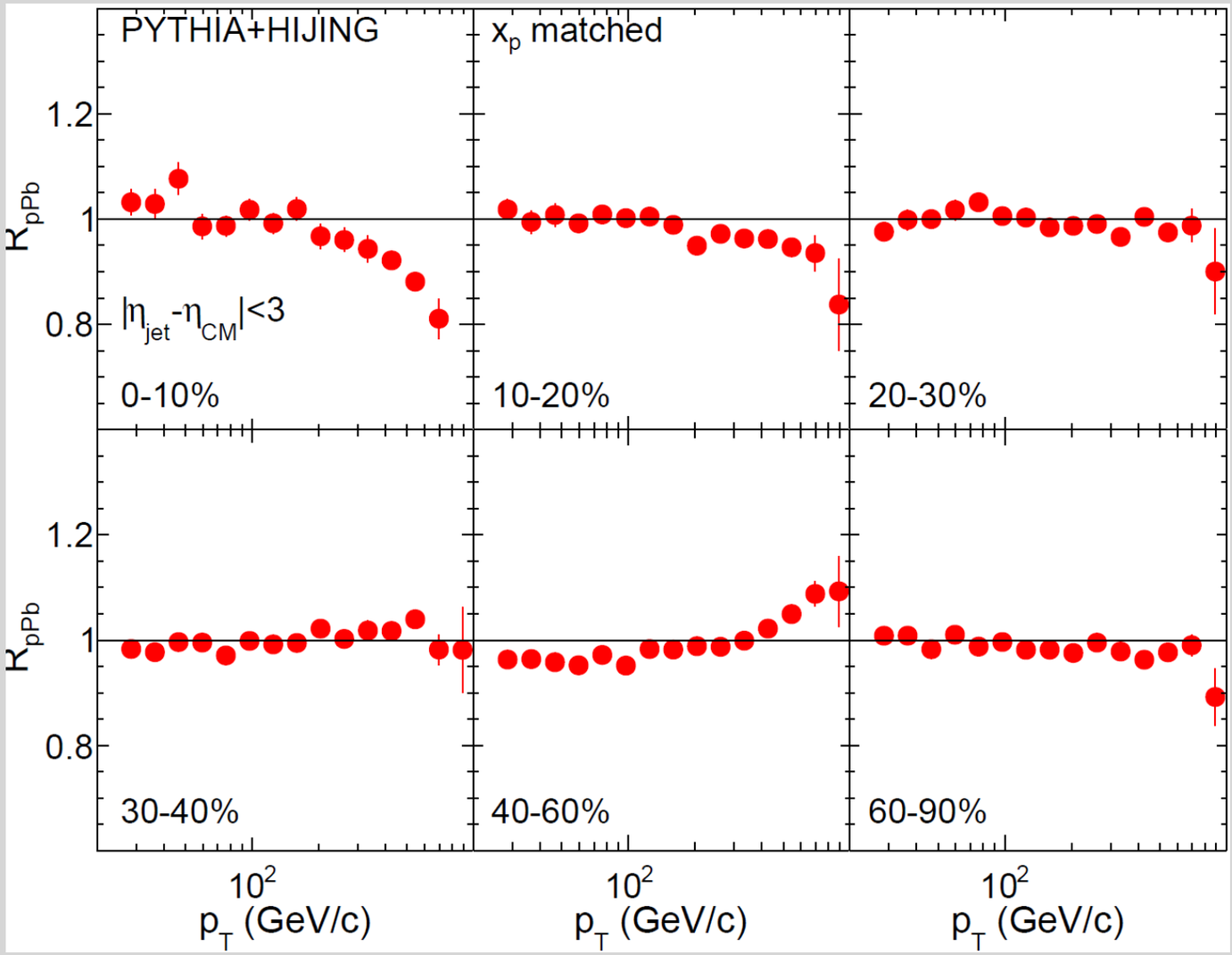
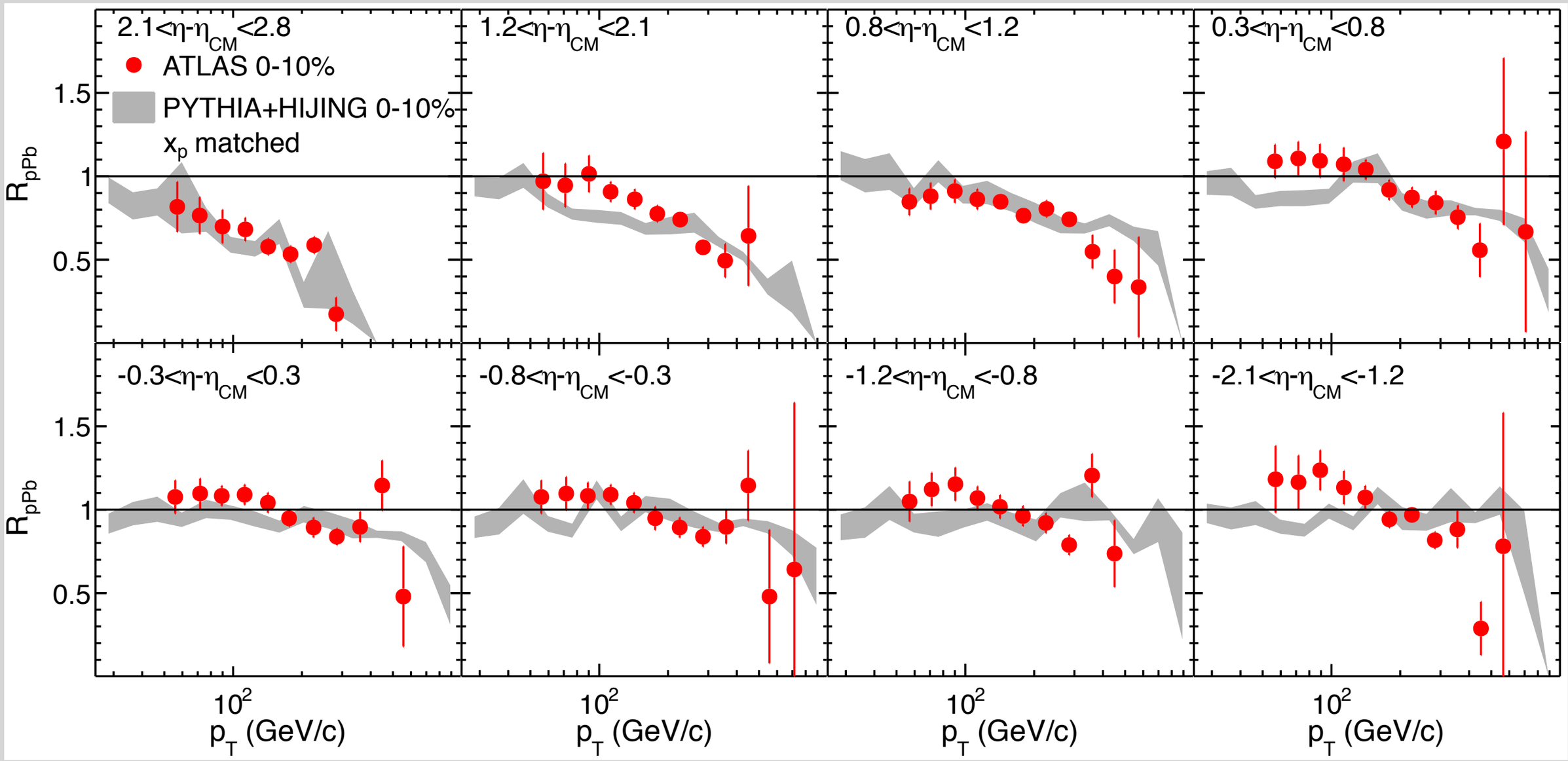


- N_{coll} from ATLAS [model dependent] :: don't add to unity
- self-consistent determination of N_{coll} [events that pass the cuts in in the model]adds to unity

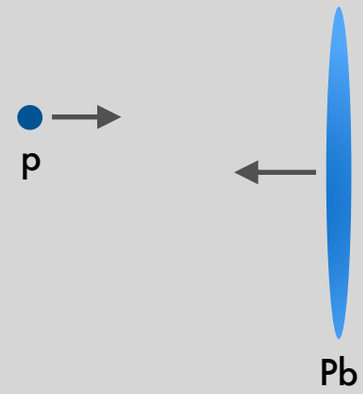
NOTE: 'centrality' determination from only Pb side

R_{pPb} [ATLAS] :: 'central'

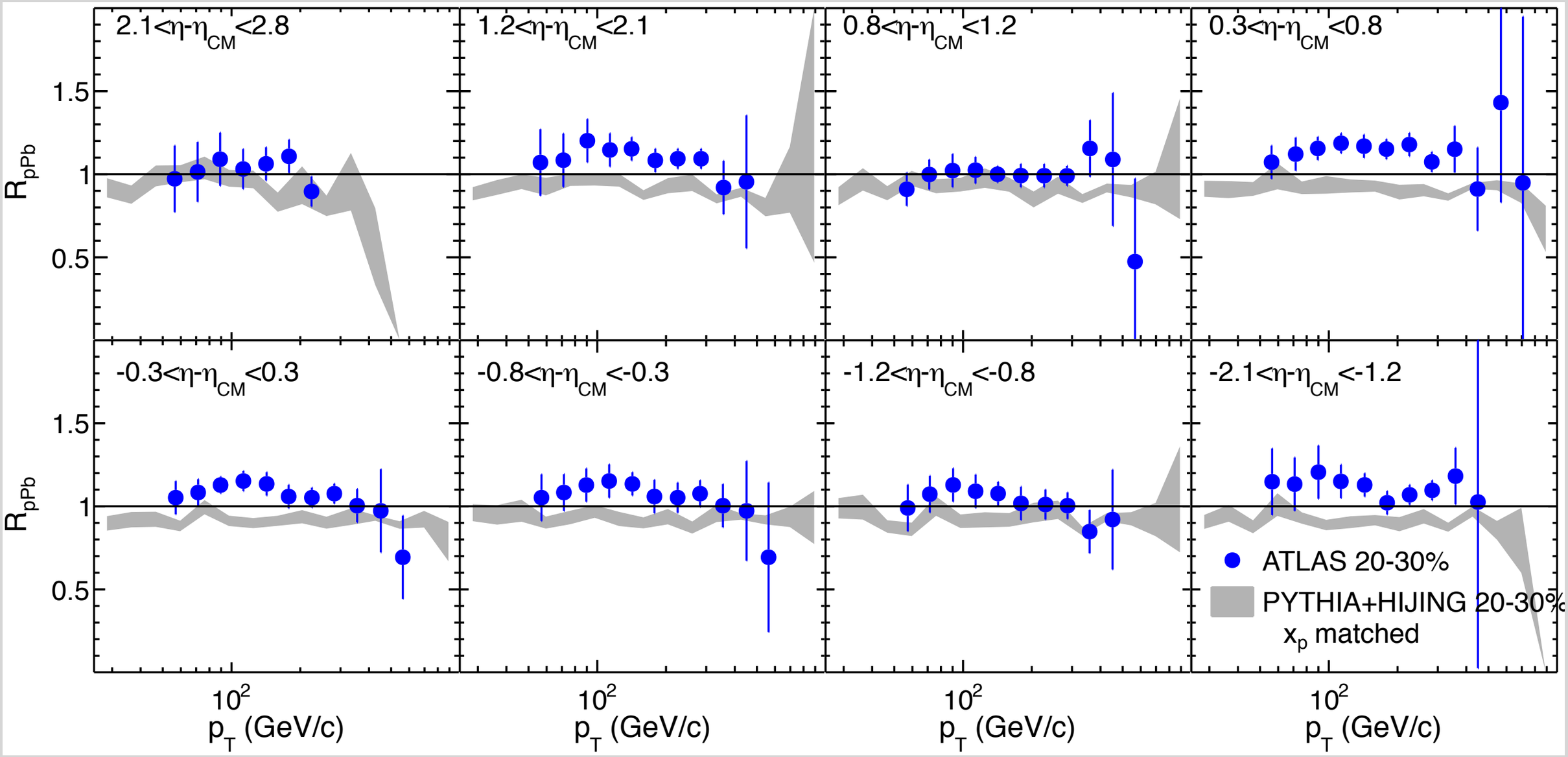


excellent overall description [N_{coll} from ATLAS]

↳ deviations on Pb side :: same model limitation as before

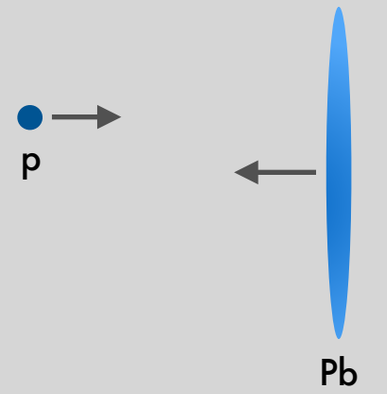


R_{pPb} [ATLAS] :: 'mid-central'

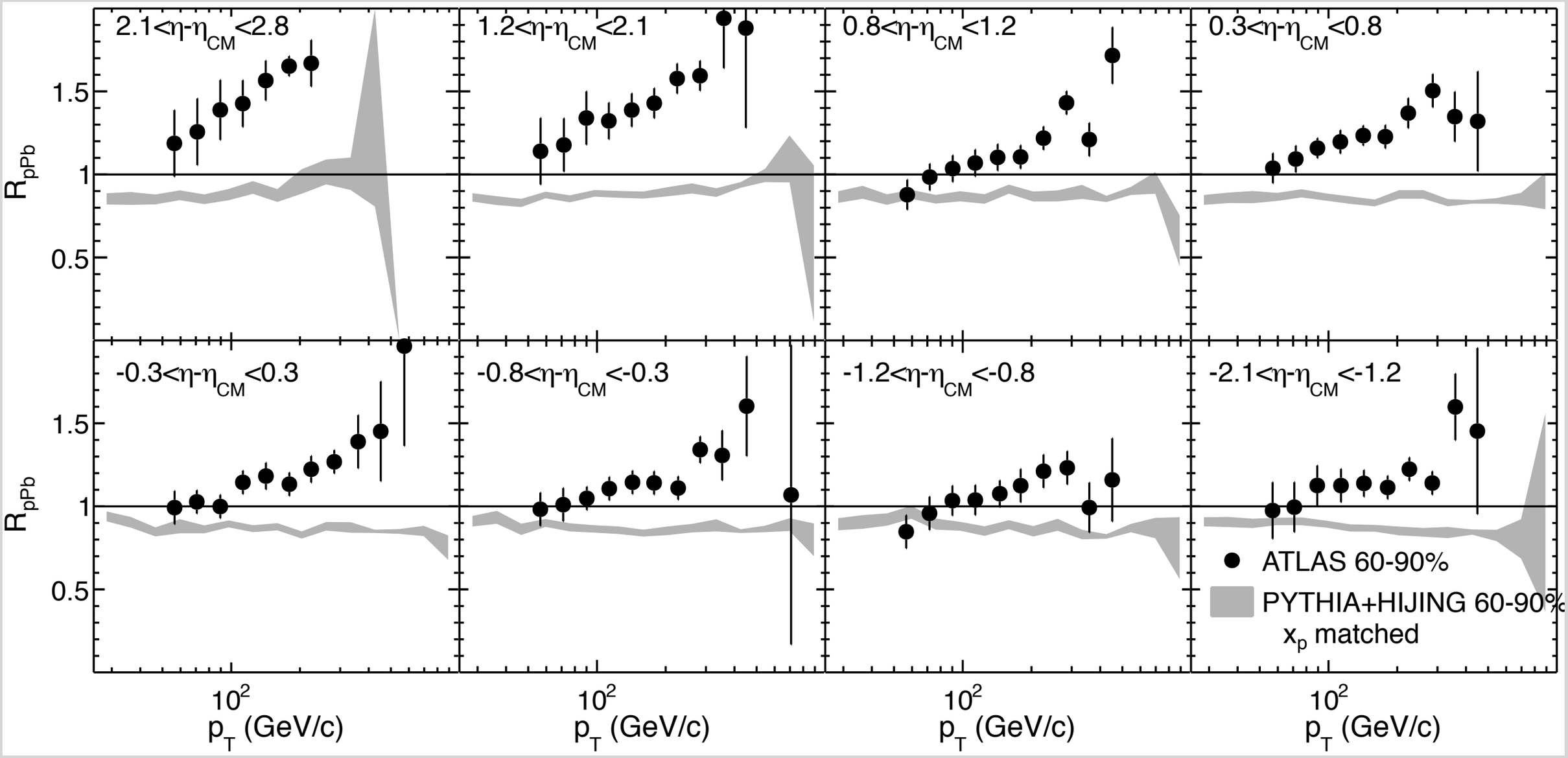


deviations due to neglecting of nPDF effects [anti-shadowing]

↪ proton PDFs used for both proton and nucleon from Pb

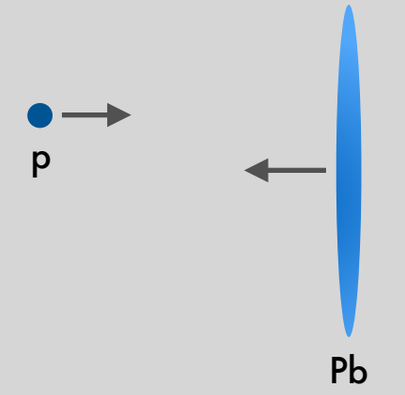


R_{pPb} [ATLAS] :: 'peripheral'



not good

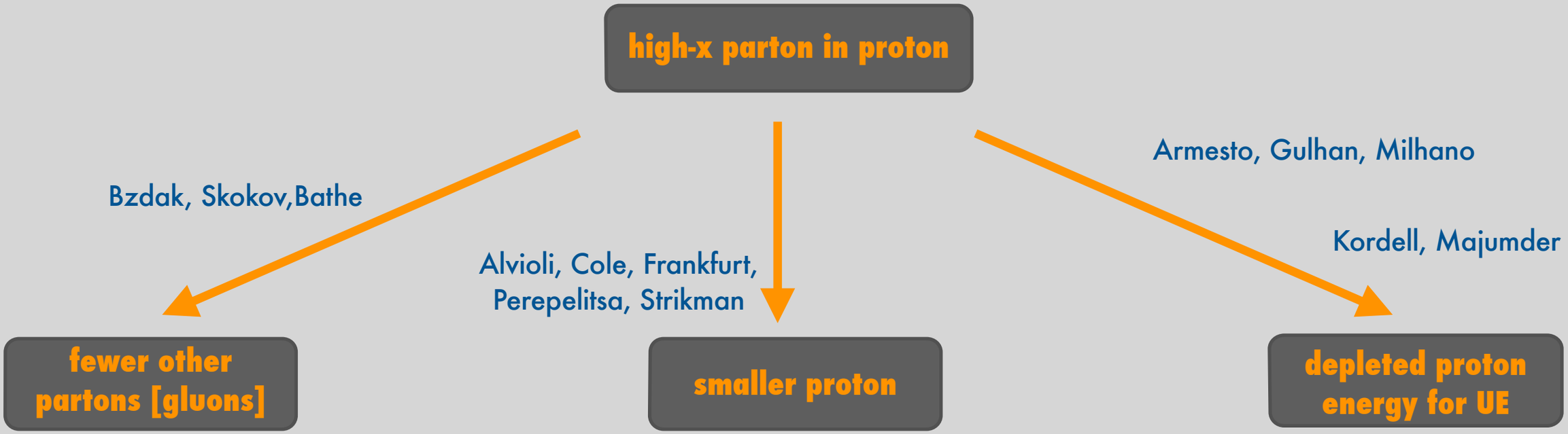
↳ outside 'model' applicability [N_{coll} peaks at 1, x_{Pb} becomes important]



physics scenarios and implementation

high-x parton in proton

physics scenarios and implementation



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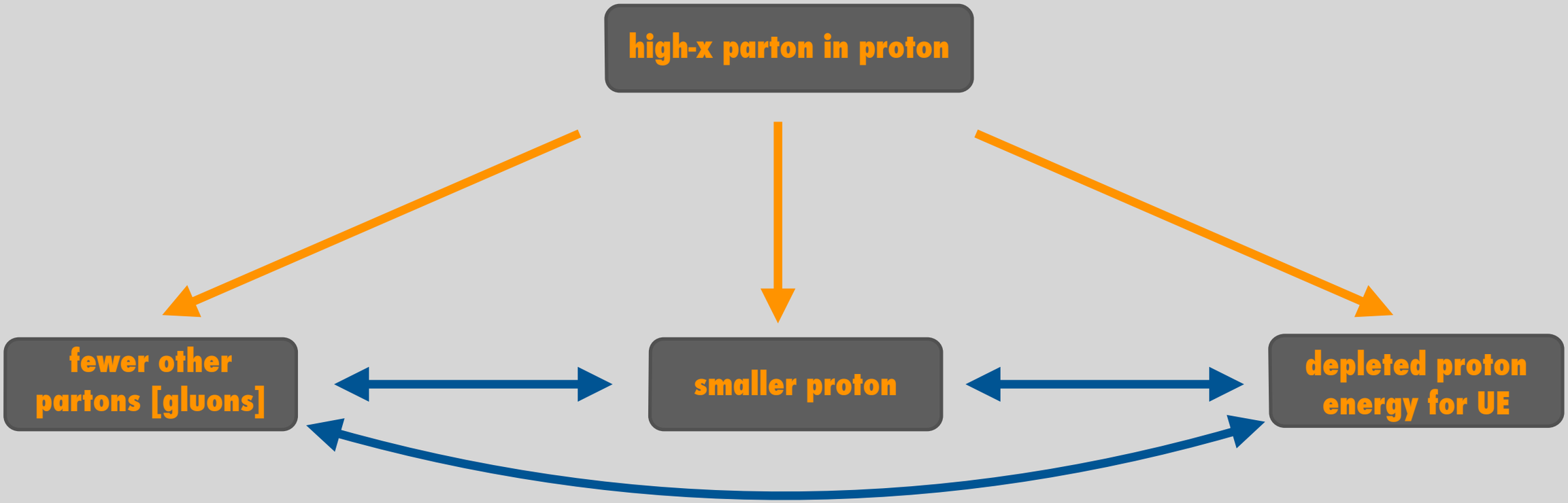

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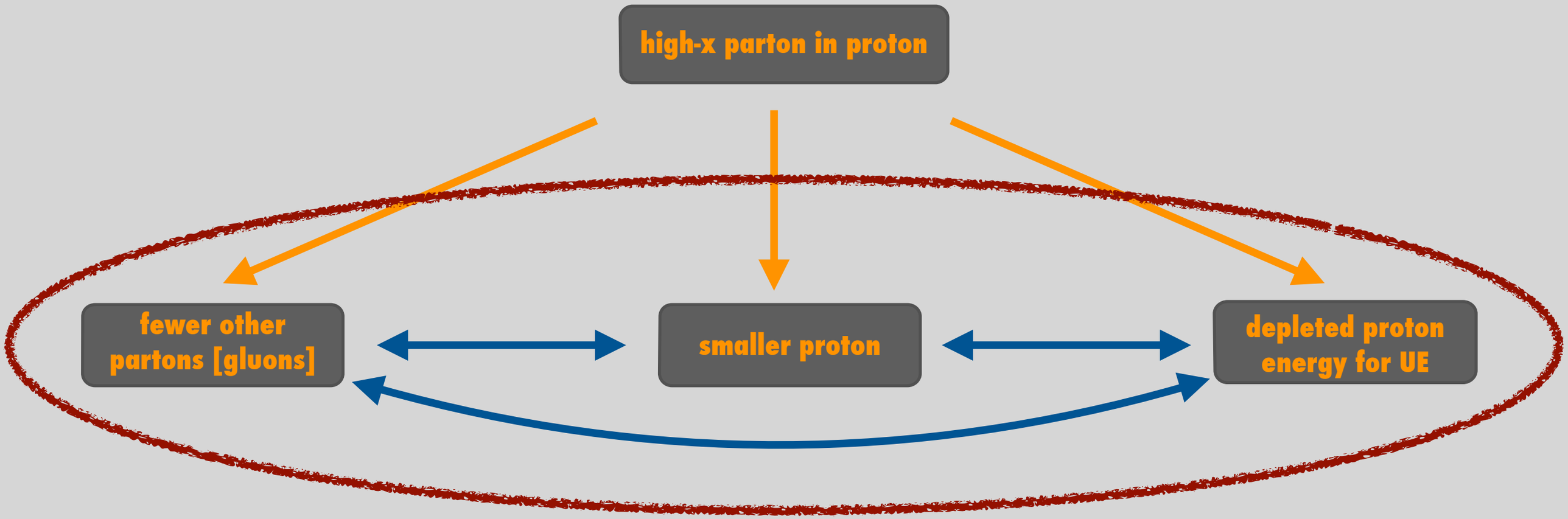

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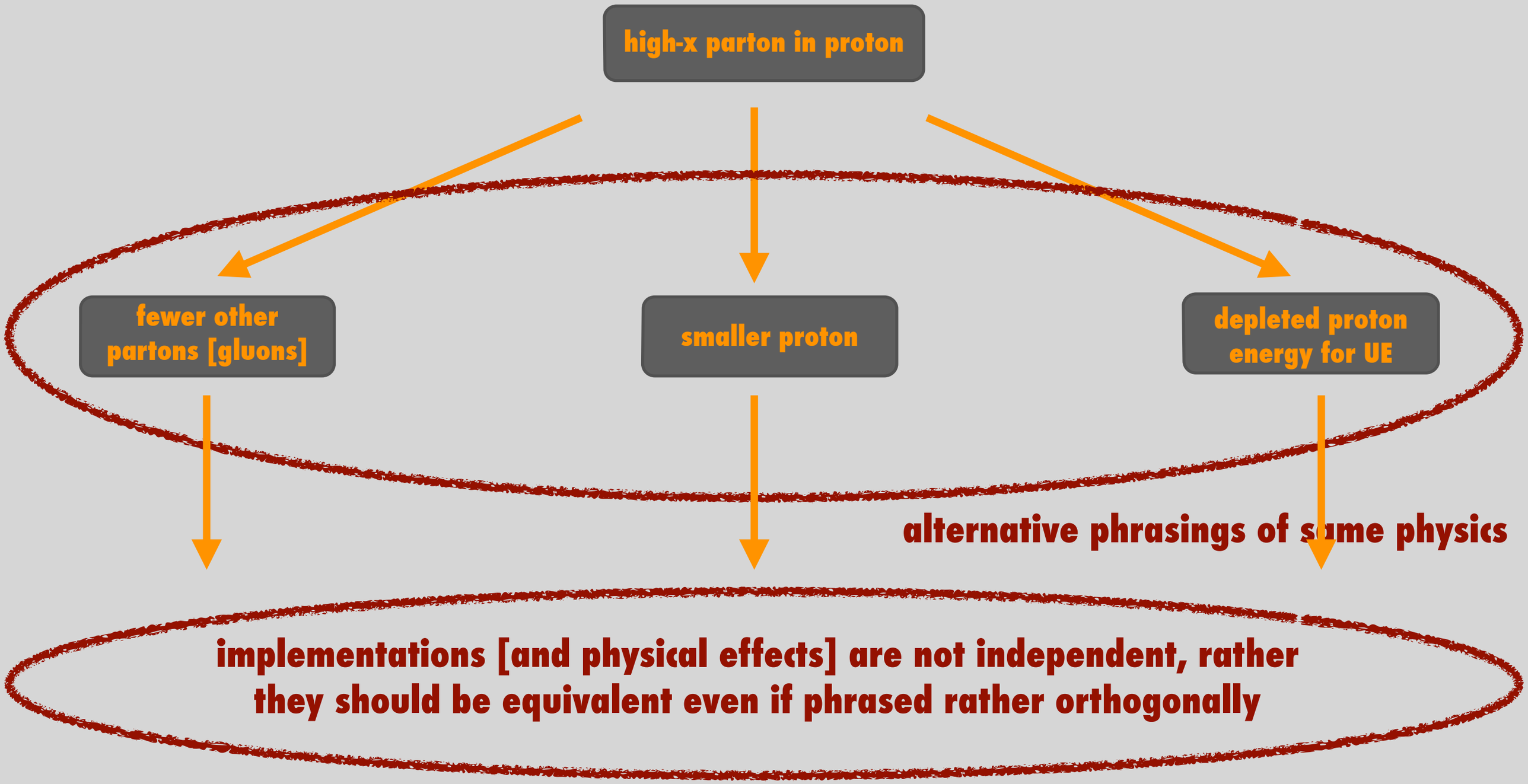

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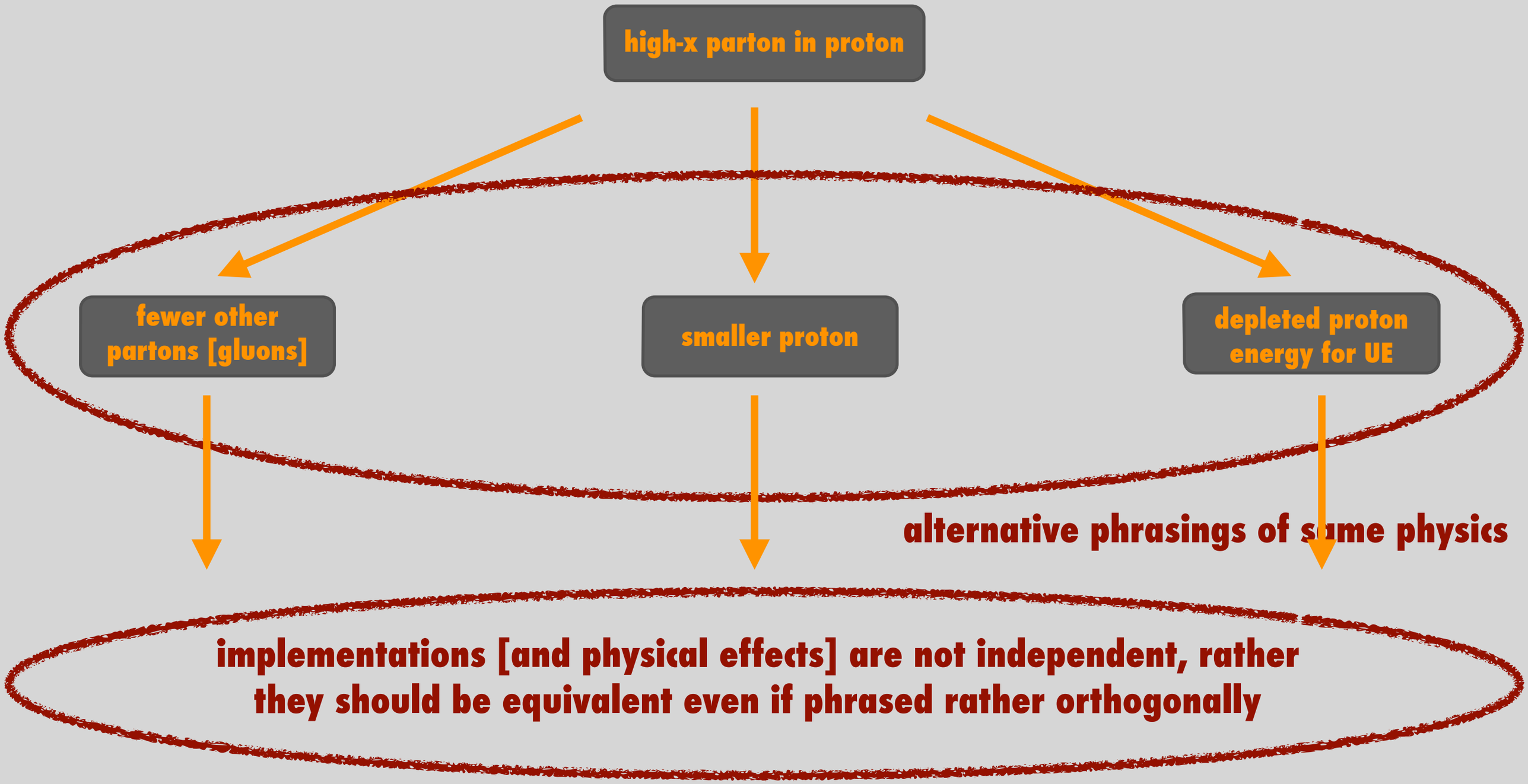
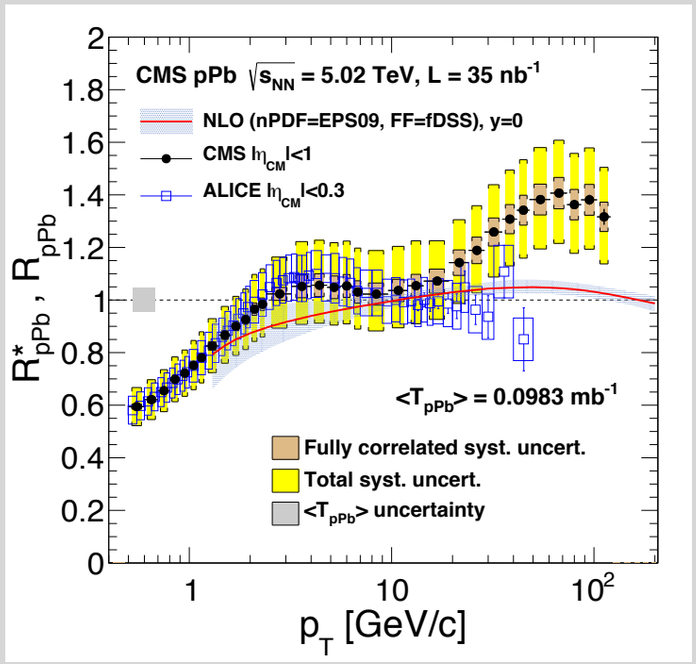


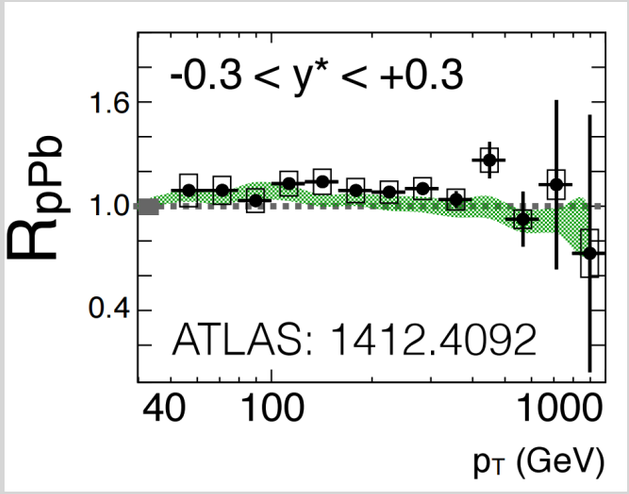
- formal equivalence not straightforward to show [possibly a spurious exercise]
- implementations SHOULD NOT, CANNOT be combined :: results should be compared

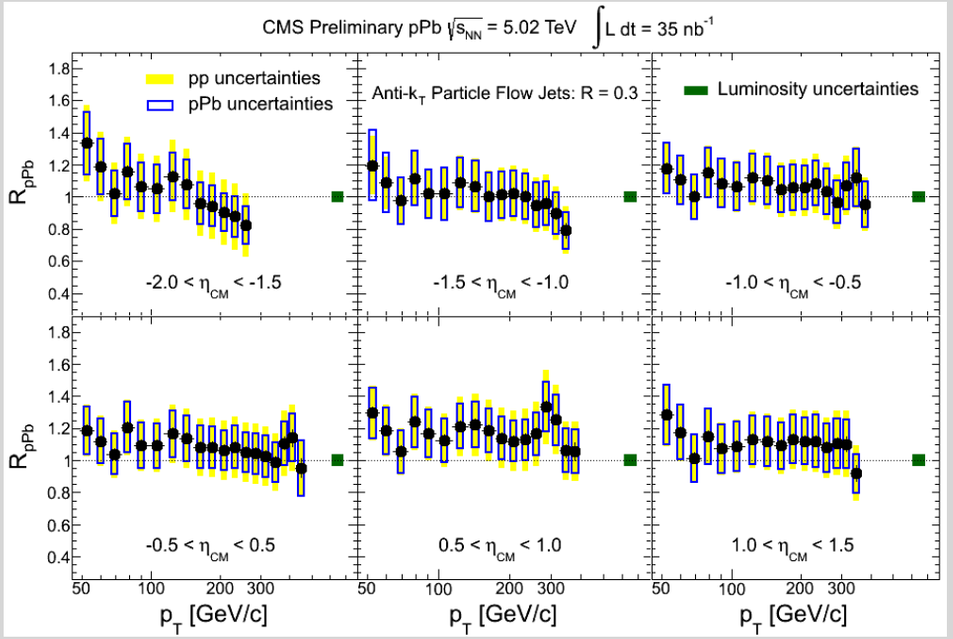
jet R_{pA} / hadron R_{pA} / jet FFs

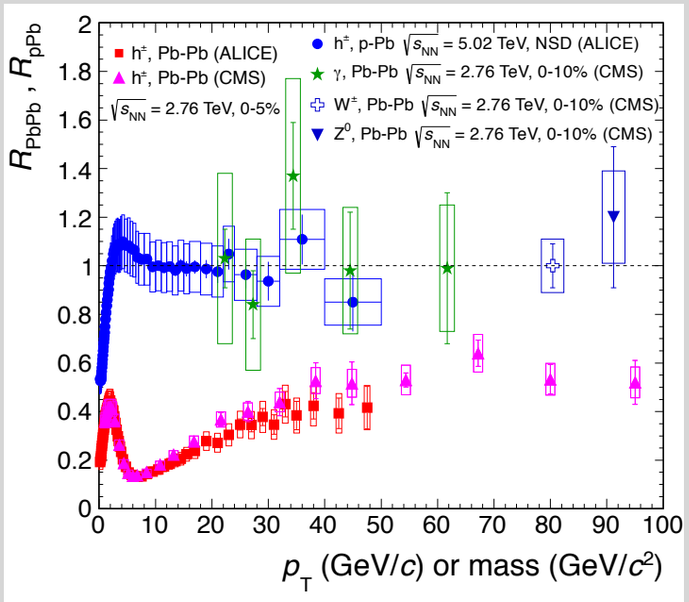
jet R_{pA} / hadron R_{pA} / ~~jet FFs~~

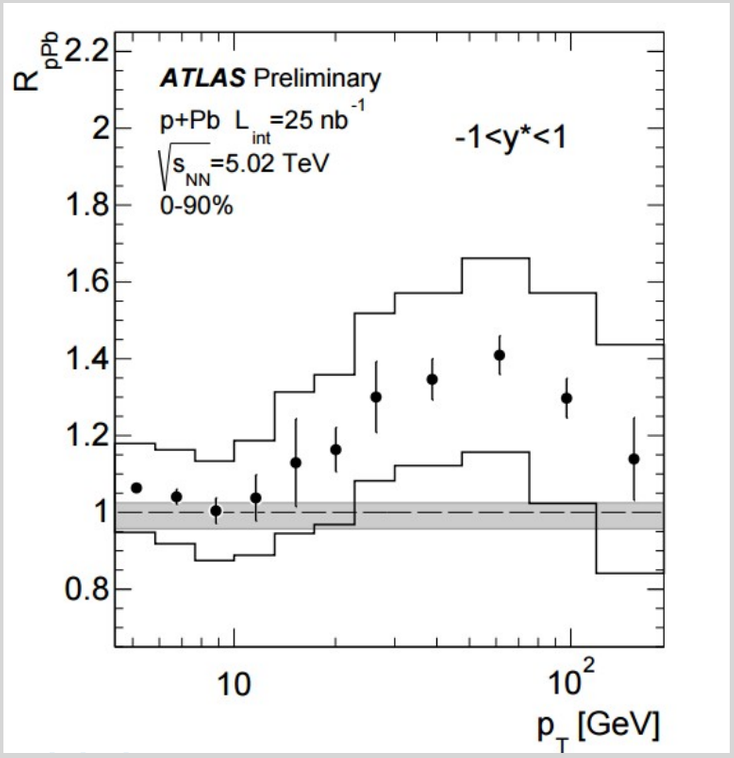
what is going on?

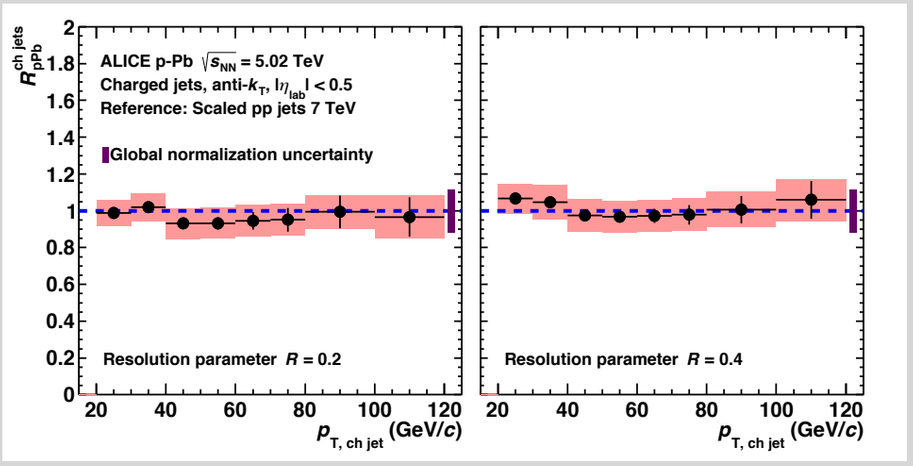






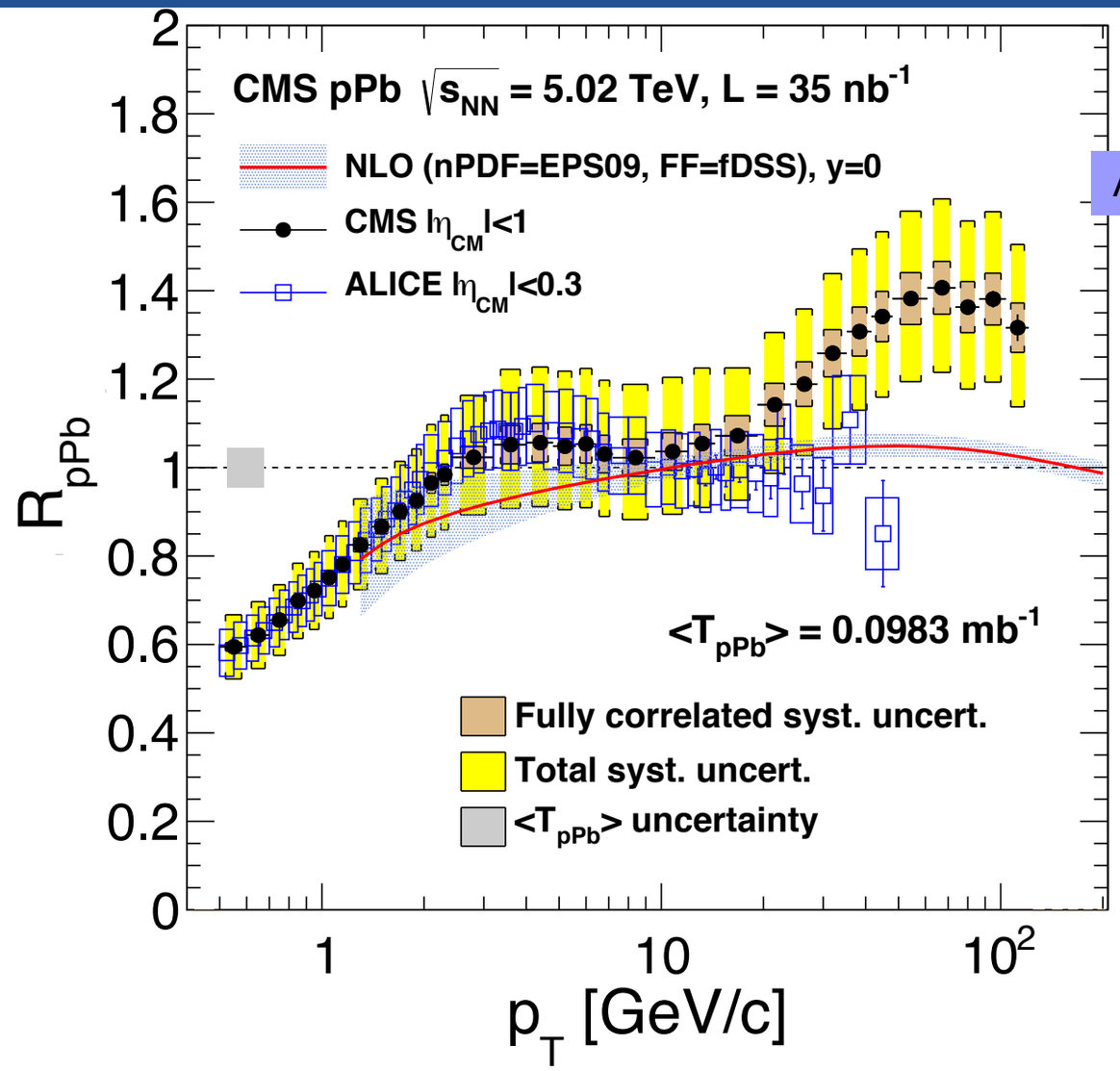






what is going on?

Charged hadron R_{pPb}



CMS EPJC 72 (2012) 1945

Paukkunen arxiv.org:1408.4657

ALICE EurPhysJ C**74** (2014) 3054

ALICE-CMS differences primarily from pp reference

- Low p_T (<2 GeV/c) particle production dominated by softer scattering
- Mid p_T (2-5 GeV/c) range R_{pPb} is ≈1
- High p_T rise beyond theoretical explanation

what is going on?

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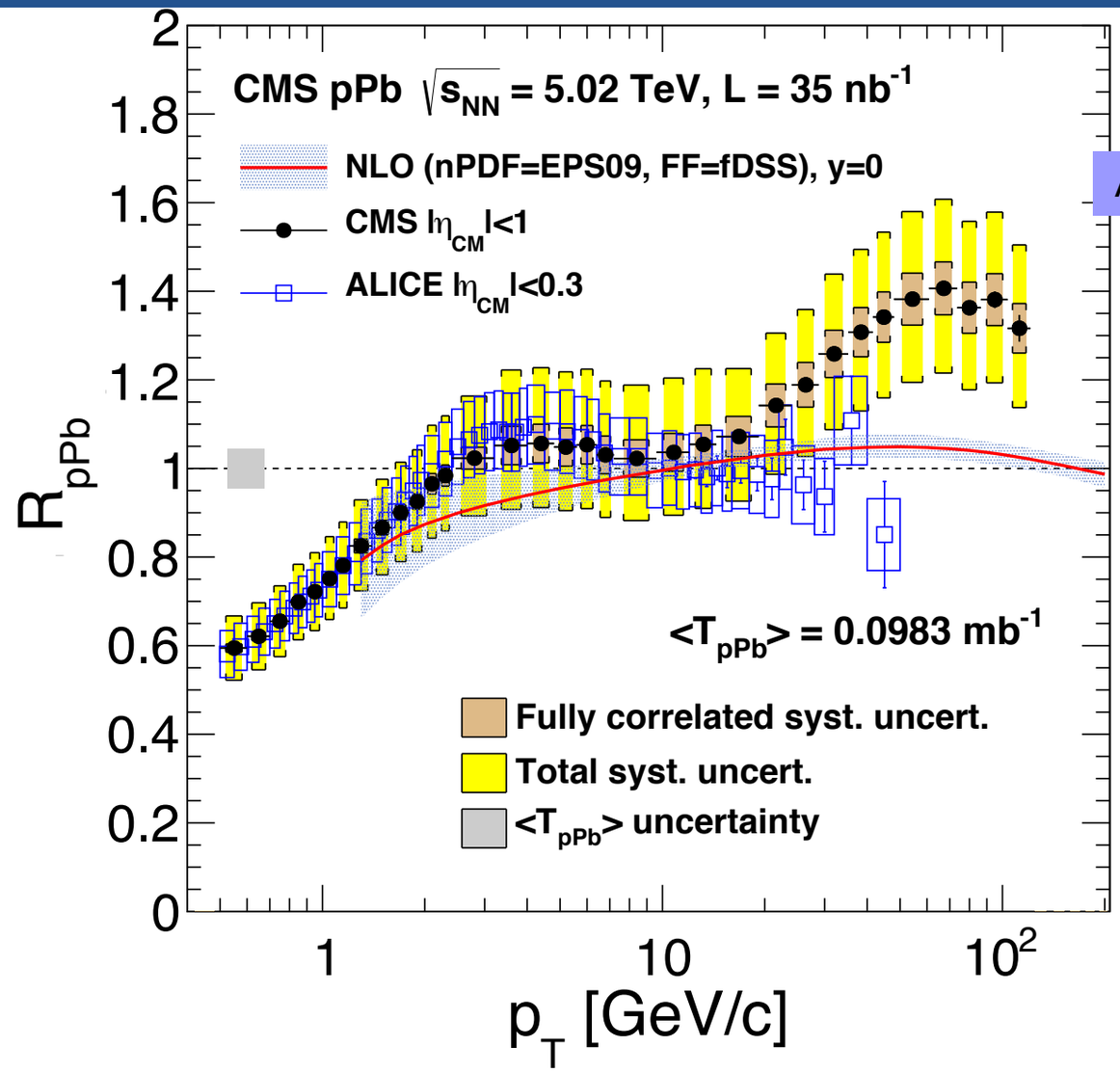

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IS IT ?

what is going on? [vox populi]

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- [exotic] mechanism in pA produces high-p_t pions [not from a jet]
  - ↪ such pions would be reconstructed as jets and show up also in jet spectrum

- [standard] physics is being overlooked

at a risk …

at a risk …

Milhano, Wiedemann, **Zapp**

- modification of hadron spectrum without modification of jet spectra can only originate at the hadronization stage

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At hadronization stage pA and pp differ in magnitude of UE and colour correlations of partons

at a risk …

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- colour reconnections are an essential prescription for description of average p_t / low p_t spectrum

  ↪ colour reconnections :: possibility of colour neutralization involving partons with different colour histories that happen to be close in (η,φ) plane

- no available [validated] pA event generator

  ↪ use pp generator with augmented UE [2÷3 times MB pp] and scrambled initial colour correlations

At hadronization stage pA and pp differ in magnitude of UE and colour correlations of partons

colour reconnections and high-p_t

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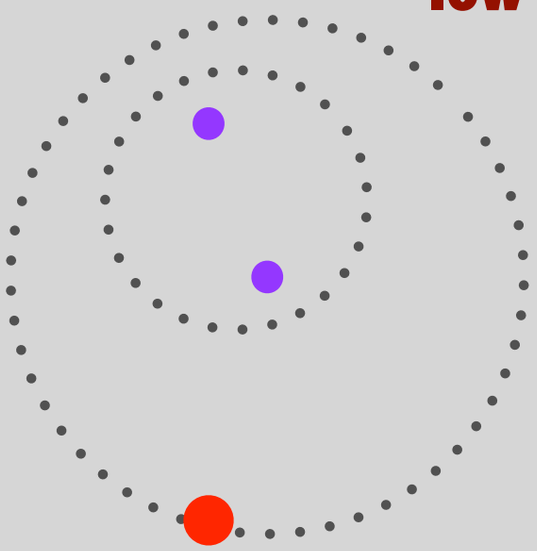
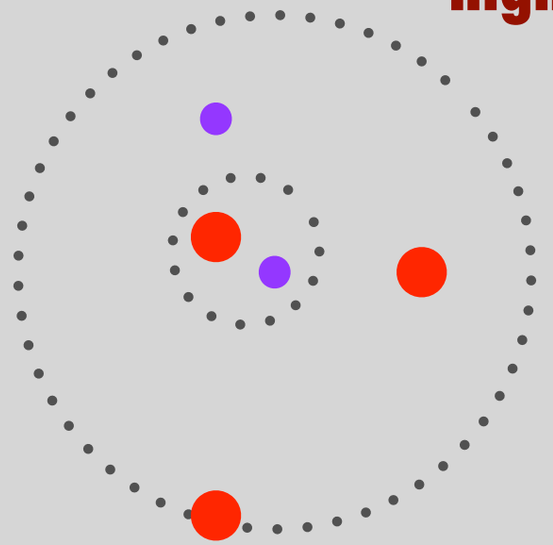
  - ↪ high-p_t hadrons originate from low invariant mass clusters/strings where high-p_t parton retains most [or all] of its momentum
  - ↪ colour neutralization of high-p_t parton with low-p_t parton from UE favours production of hard hadrons

low UE



higher invariant mass :: higher multiplicity :: softer

high UE



lower invariant mass :: lower multiplicity :: harder

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effect dies out much slower than other power corrections

generic effect [very difficult to argue away]

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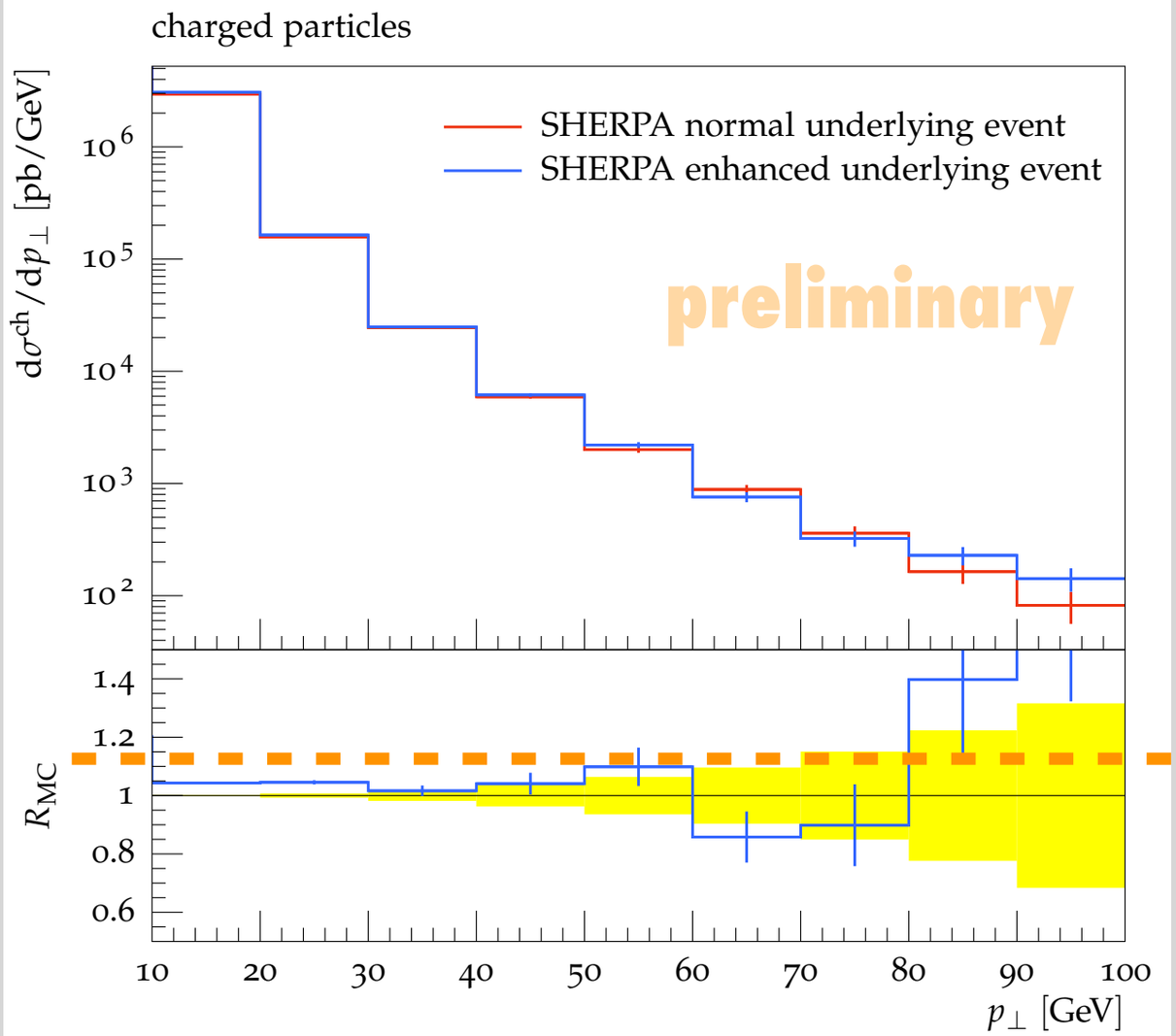
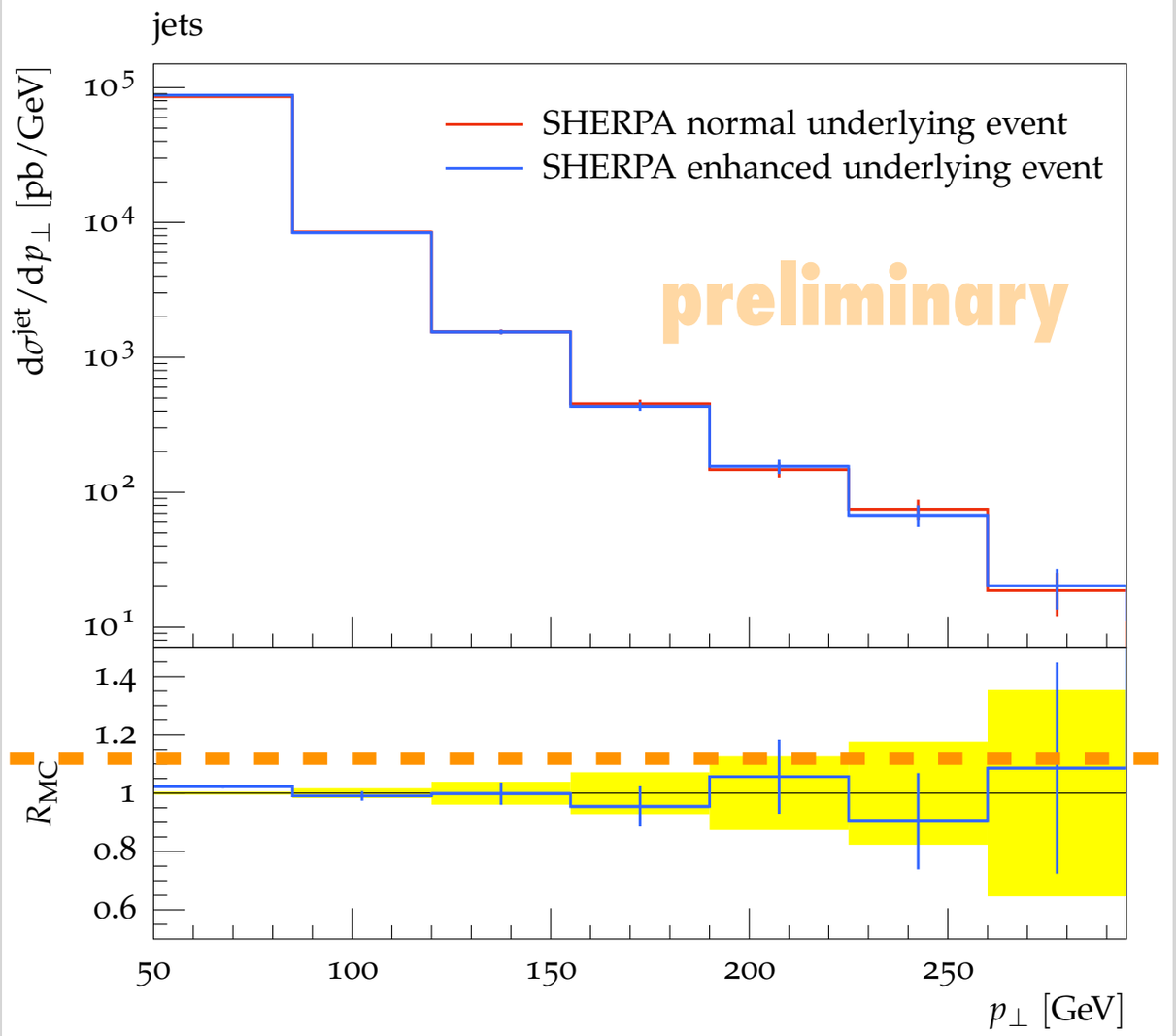
does it work ?

event generator evidence [SHERPA]





smaller than in data but clear effect :: much more statistics needed
[only very conservative CR considered]

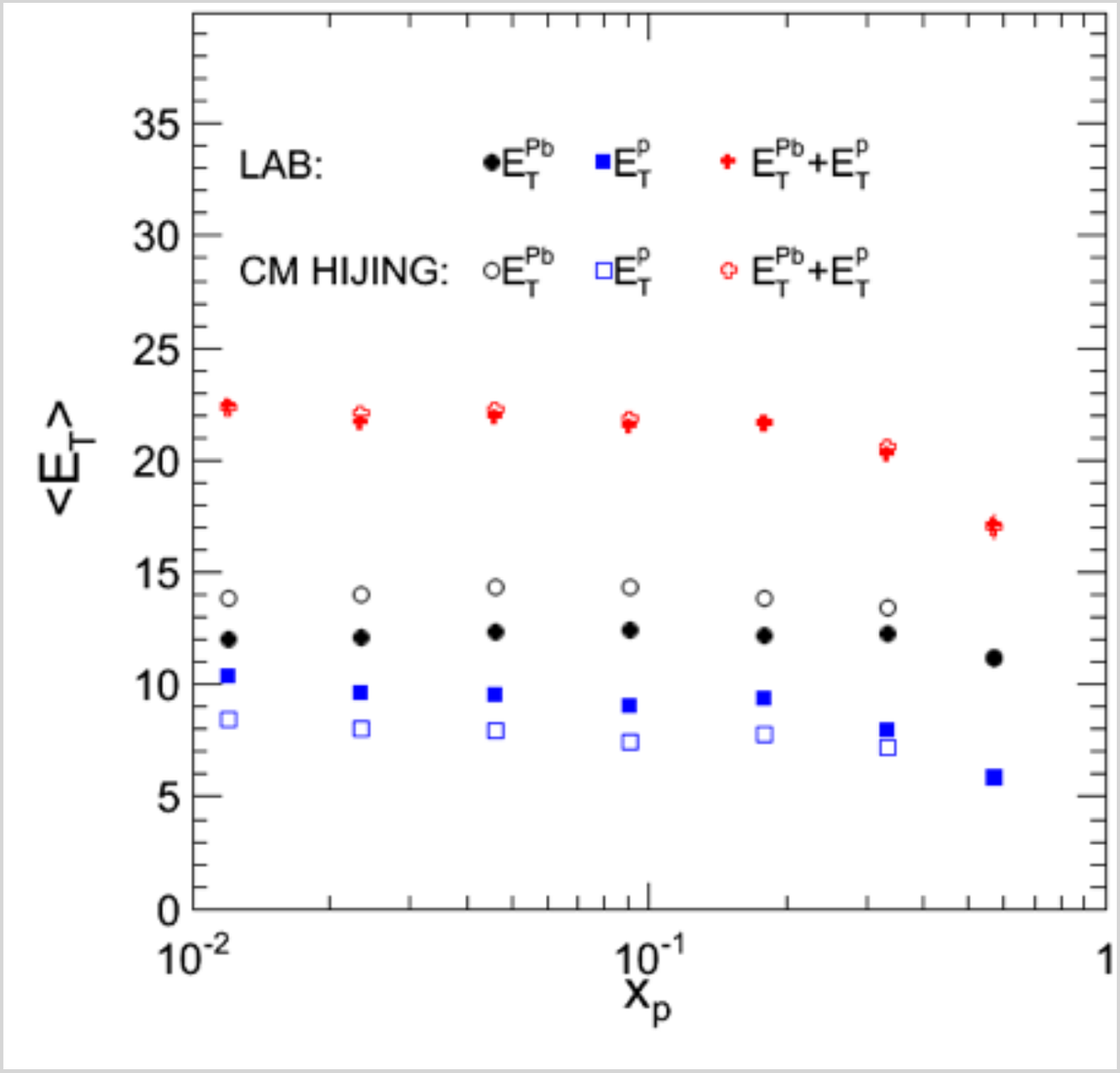
outlook

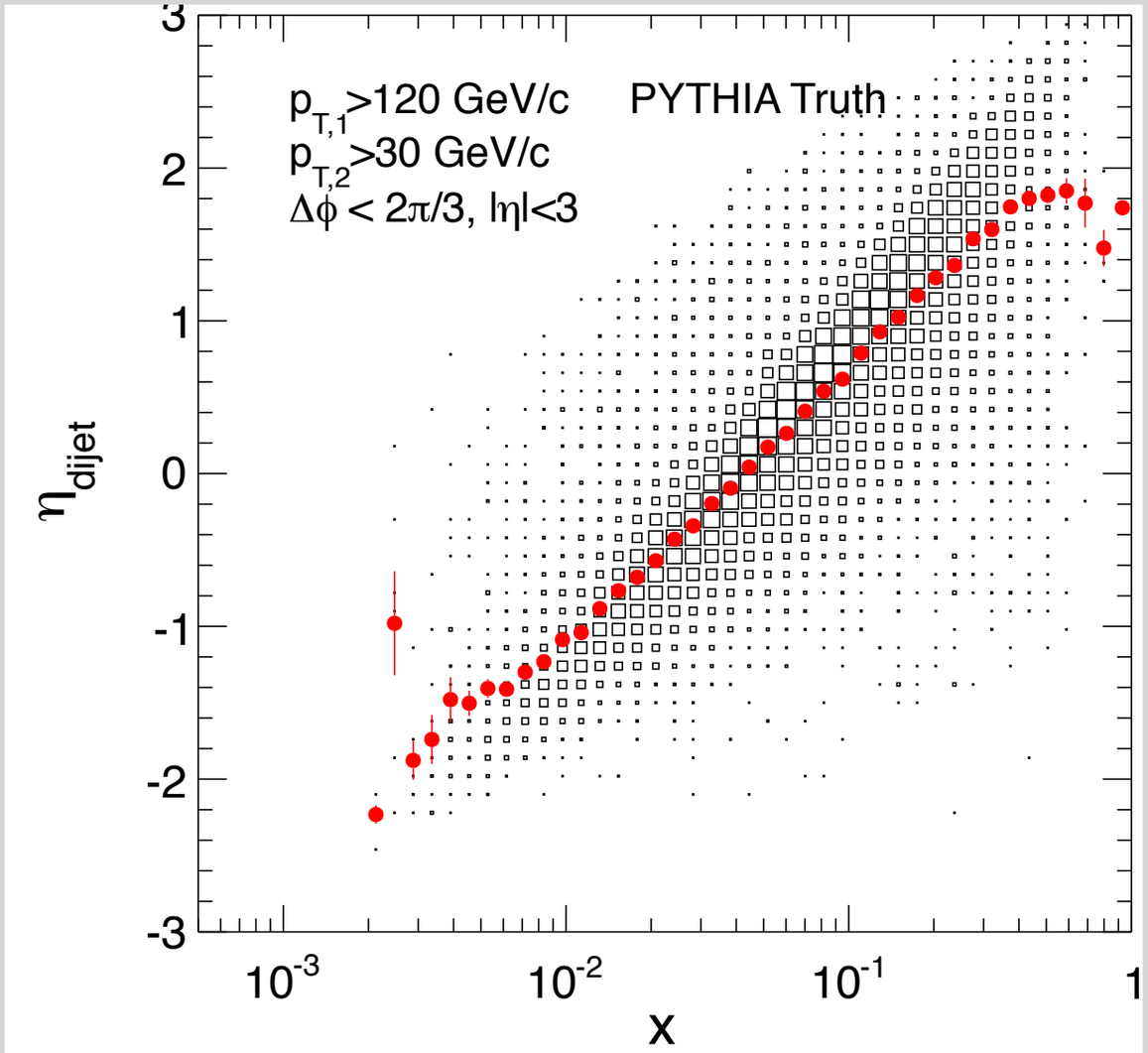
- *origin of 'centrality' binning problems pinned down to hard+UE strong correlation*
  - *strong constraint for hard+UE pA MC :: seems worth the trouble as essential to access impact parameter dependence*
  - *a laboratory for 'proton-size' studies :: no clear path put forward*

- *R_{pA} meets R_{pA} conundrum may have natural explanation*
  - *very difficult to argue away*
  - *violation of universality of FFs :: fundamental physics opportunity*
  - *can be checked in high multiplicity pp*
  - *need validated pA MC*

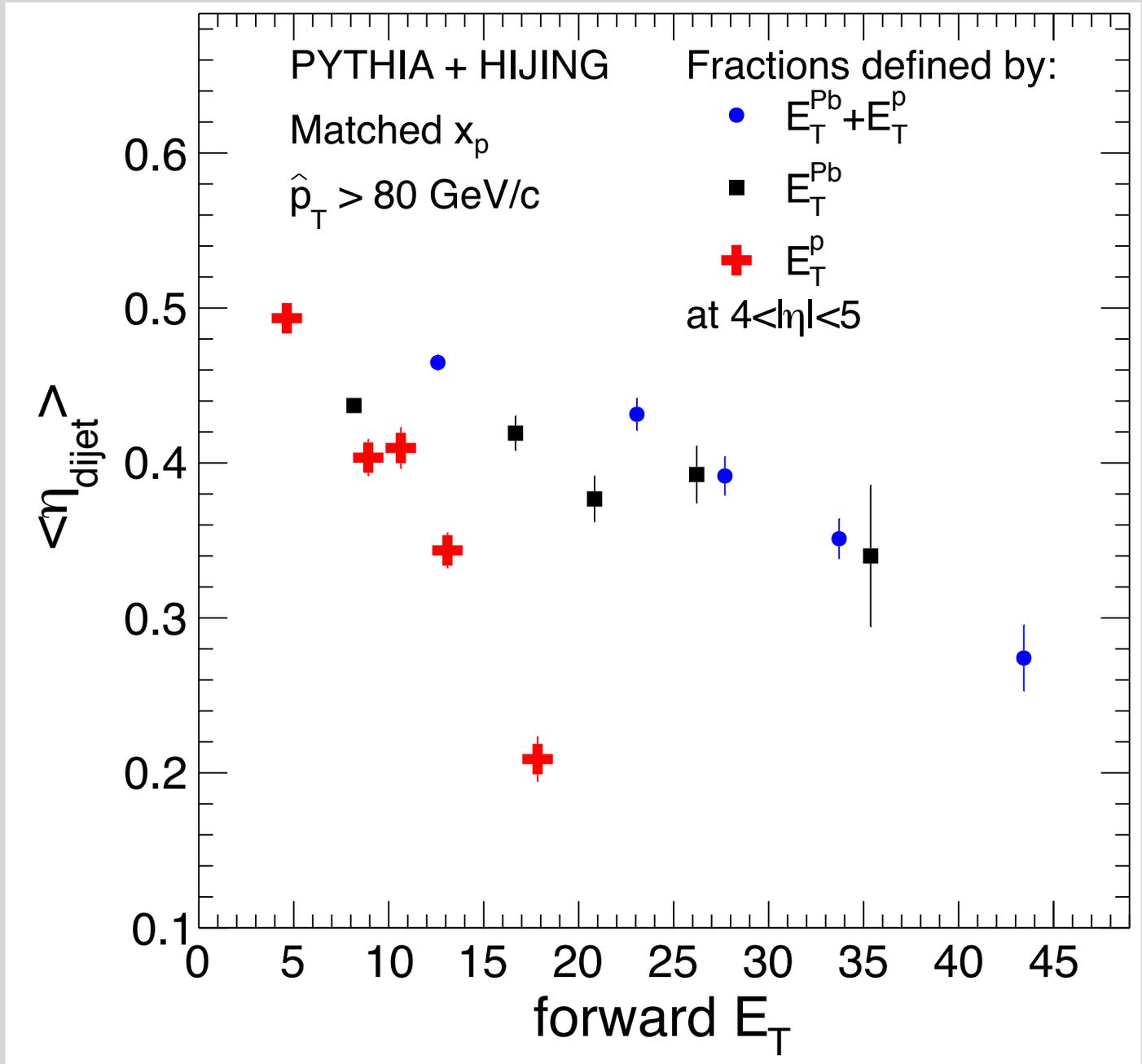
backups

correlations detailed

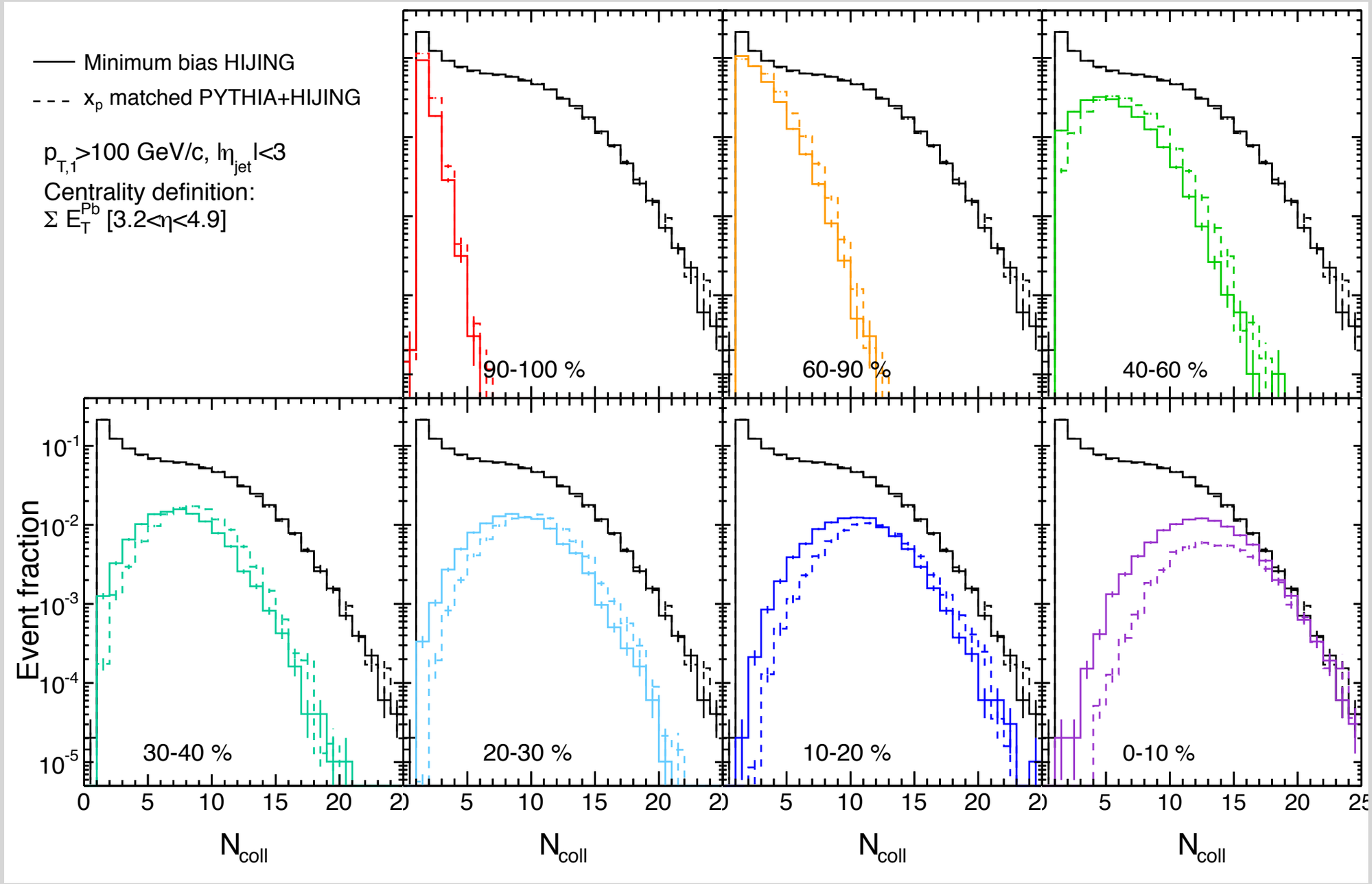




correlation detailed :: different estimators

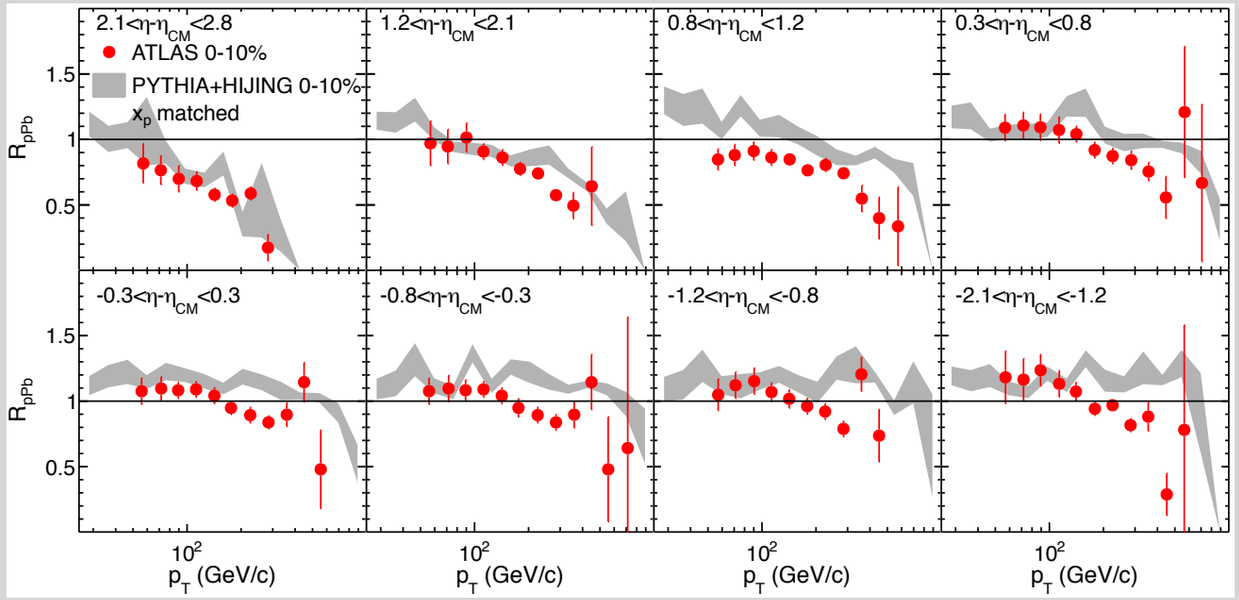


N_{coll} centrality dependence



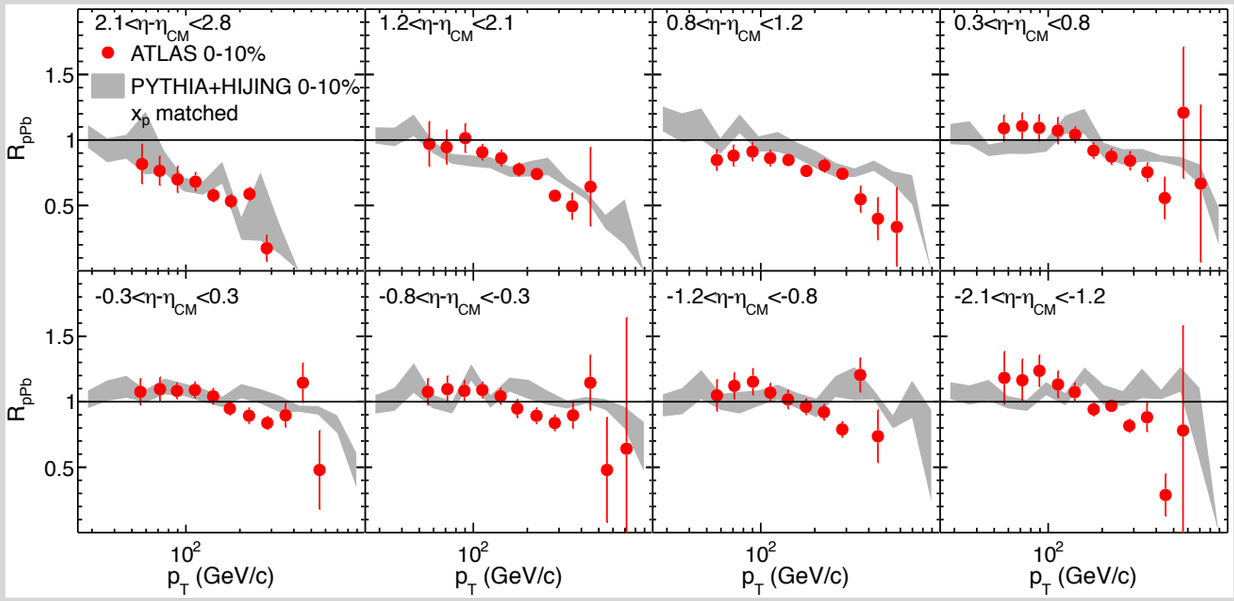
- bin migration but overall distribution unchanged

N_{coll} definitions :: 0-10%

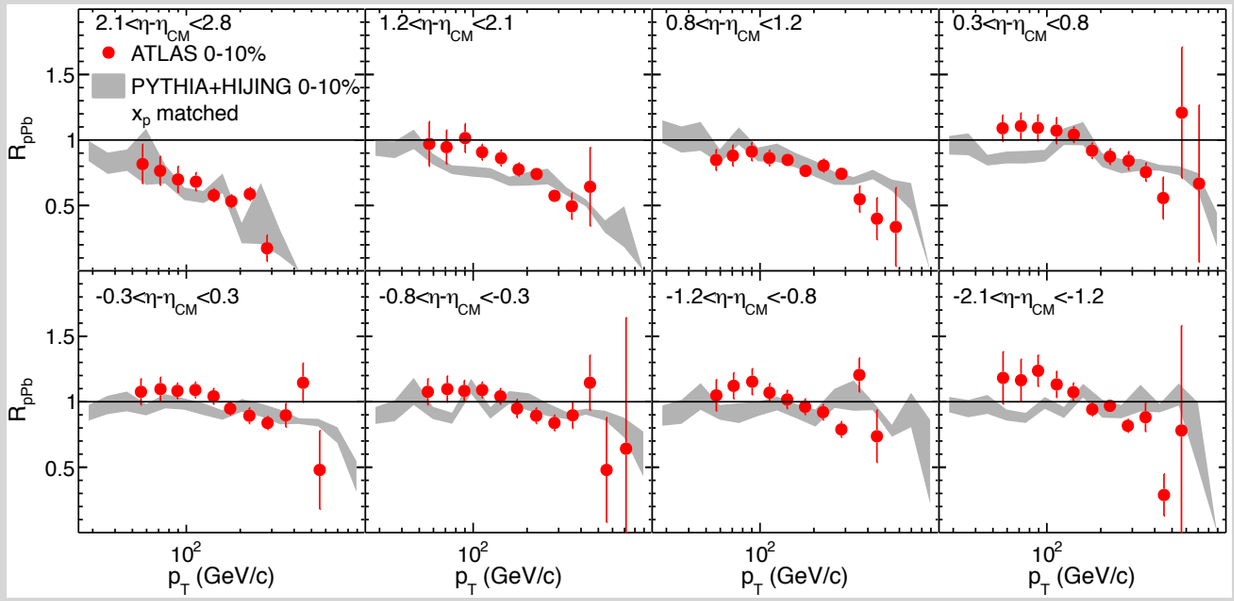


HIJING

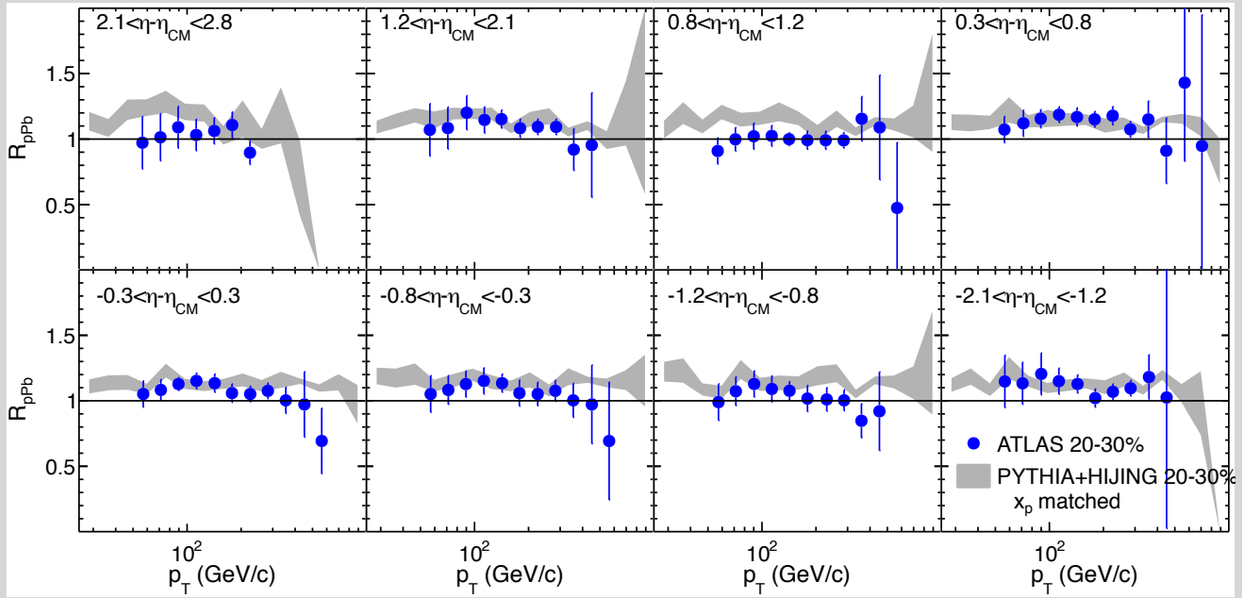
same event



ATLAS

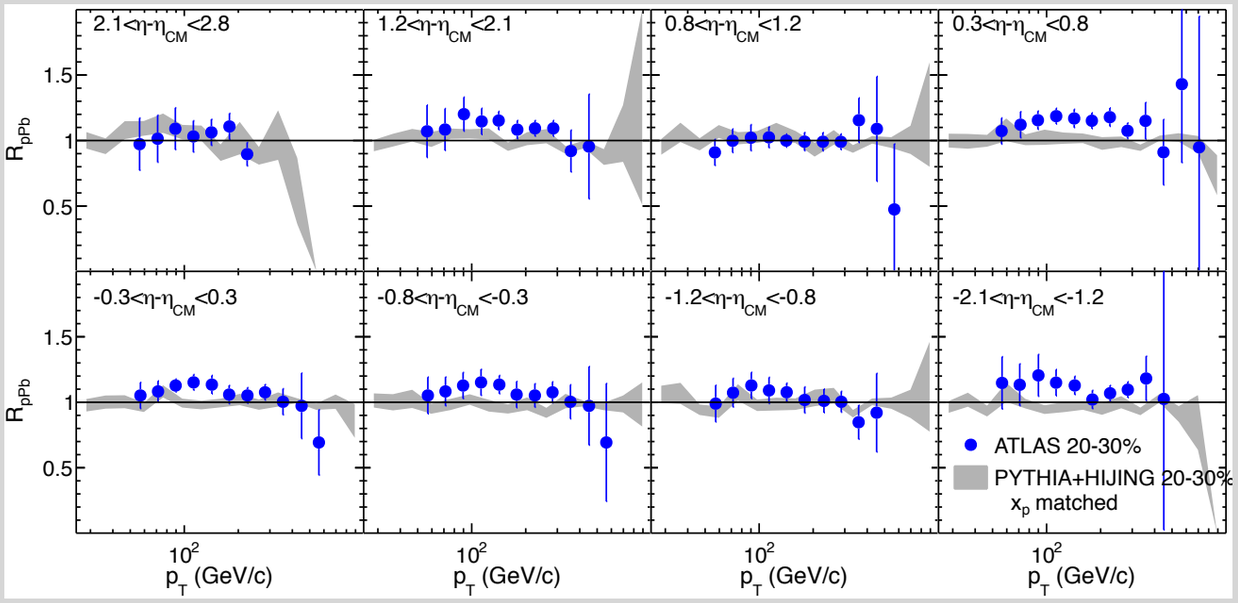


N_{coll} definitions :: 20-30%



HIJING

same event



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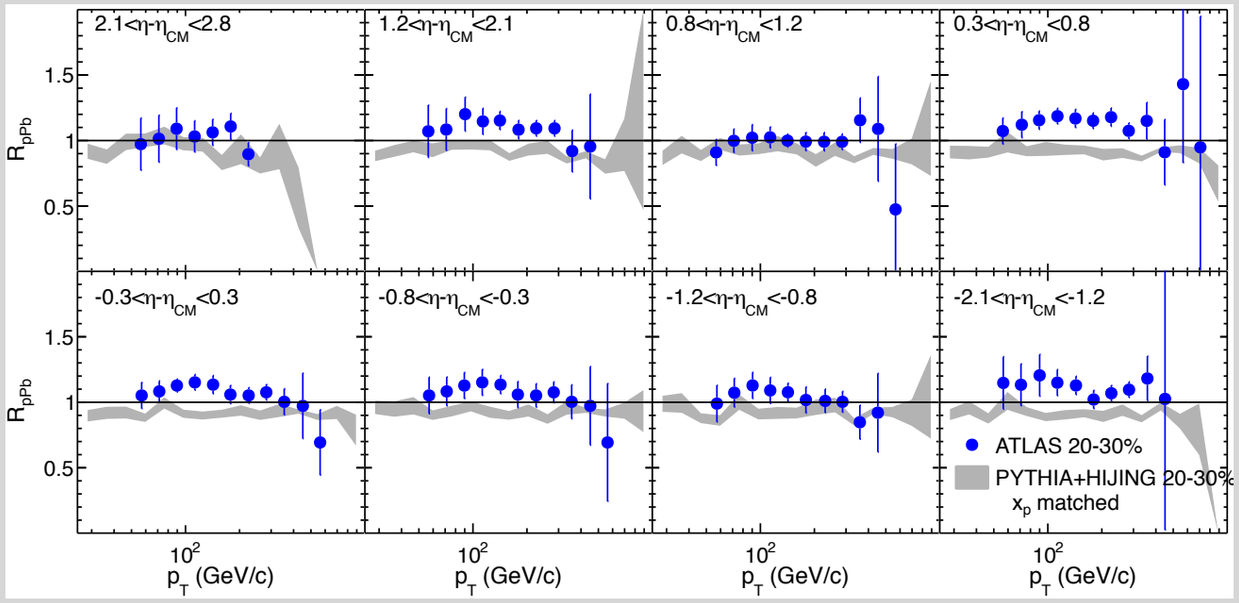
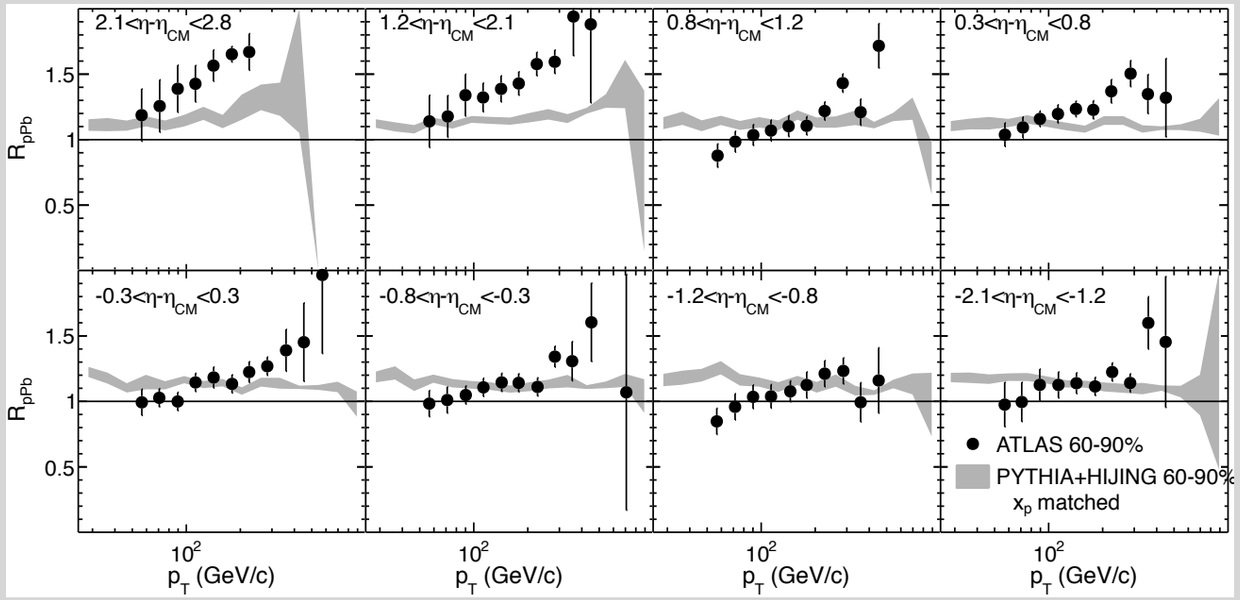
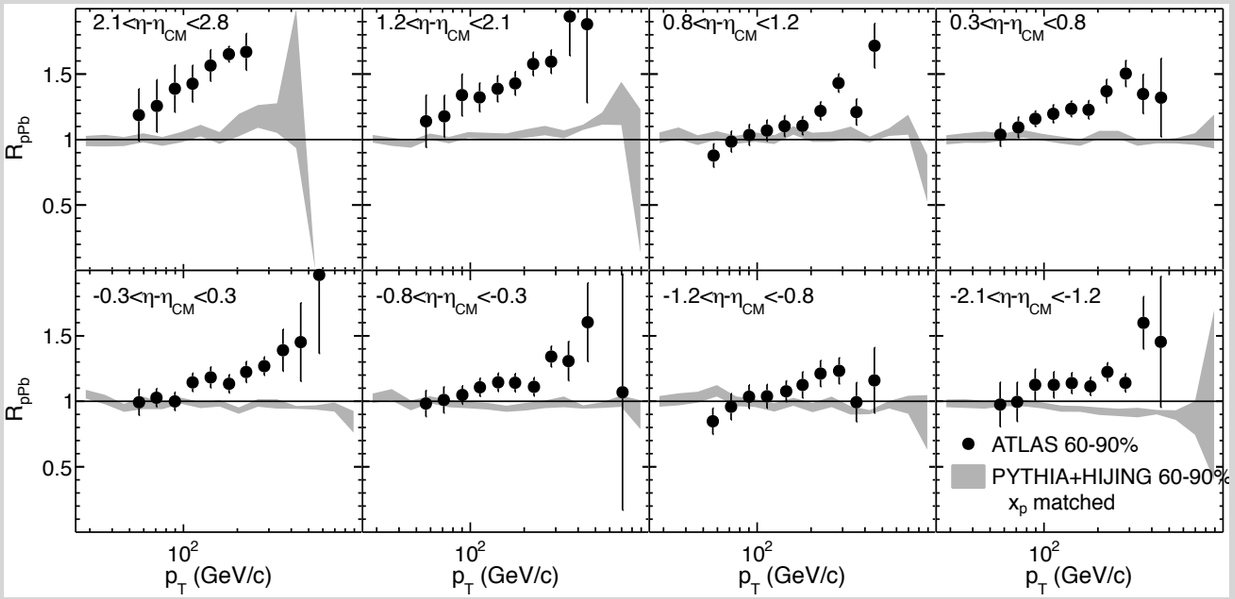


N_{coll} definitions :: 60-90%

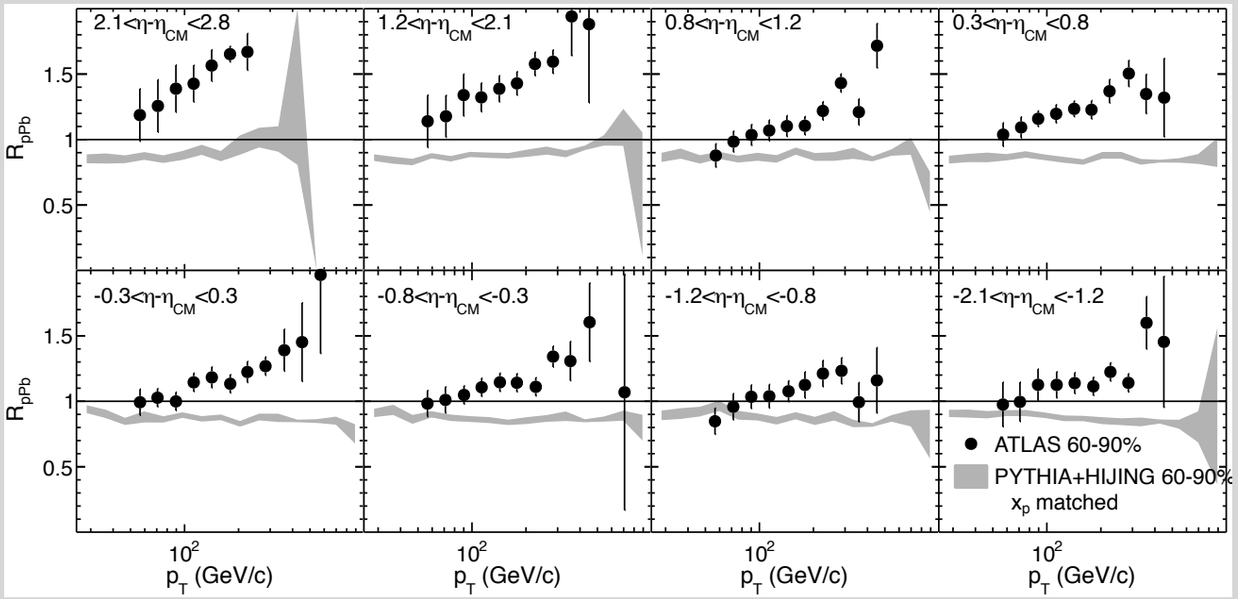


HIJING

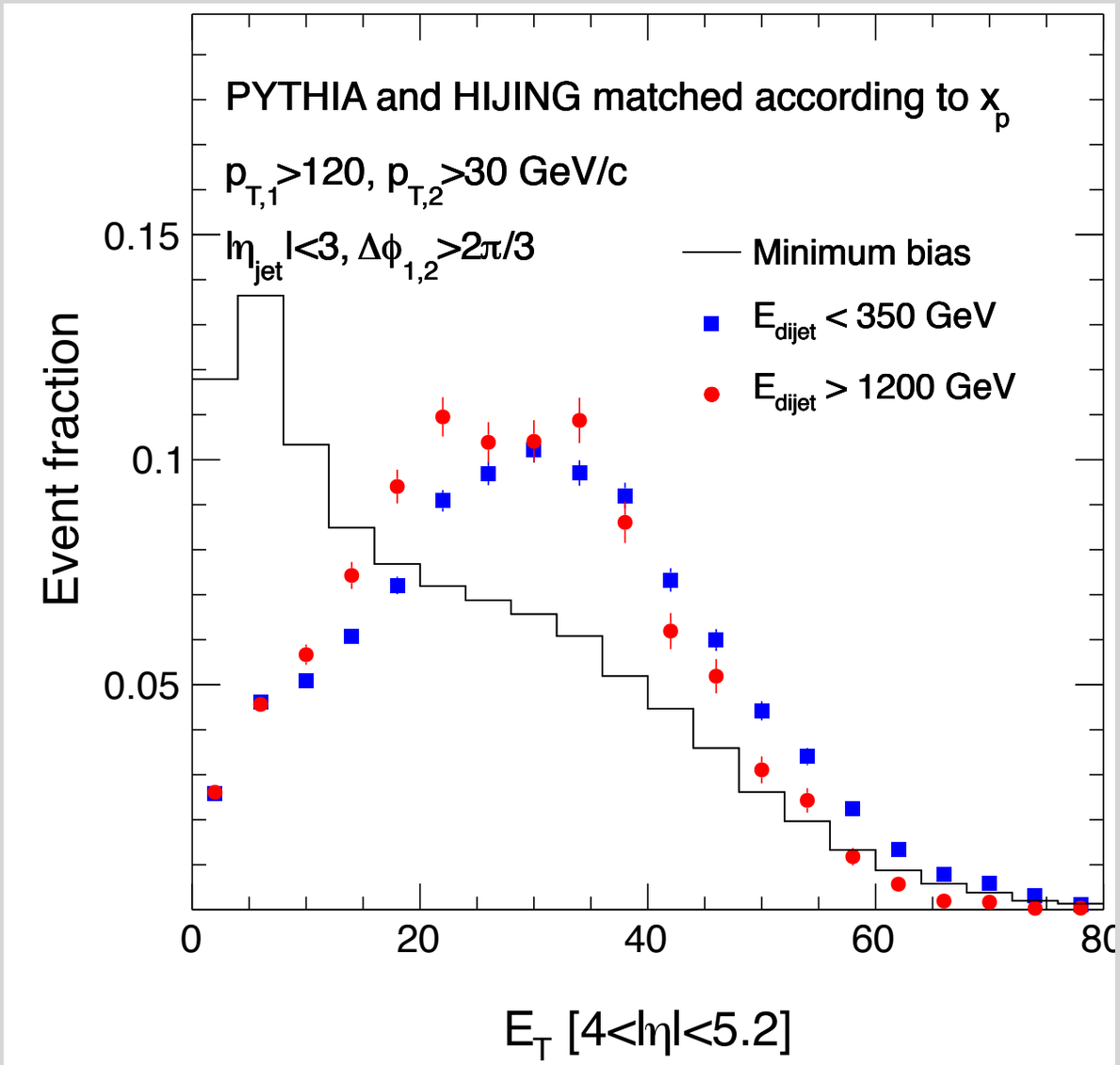
same event

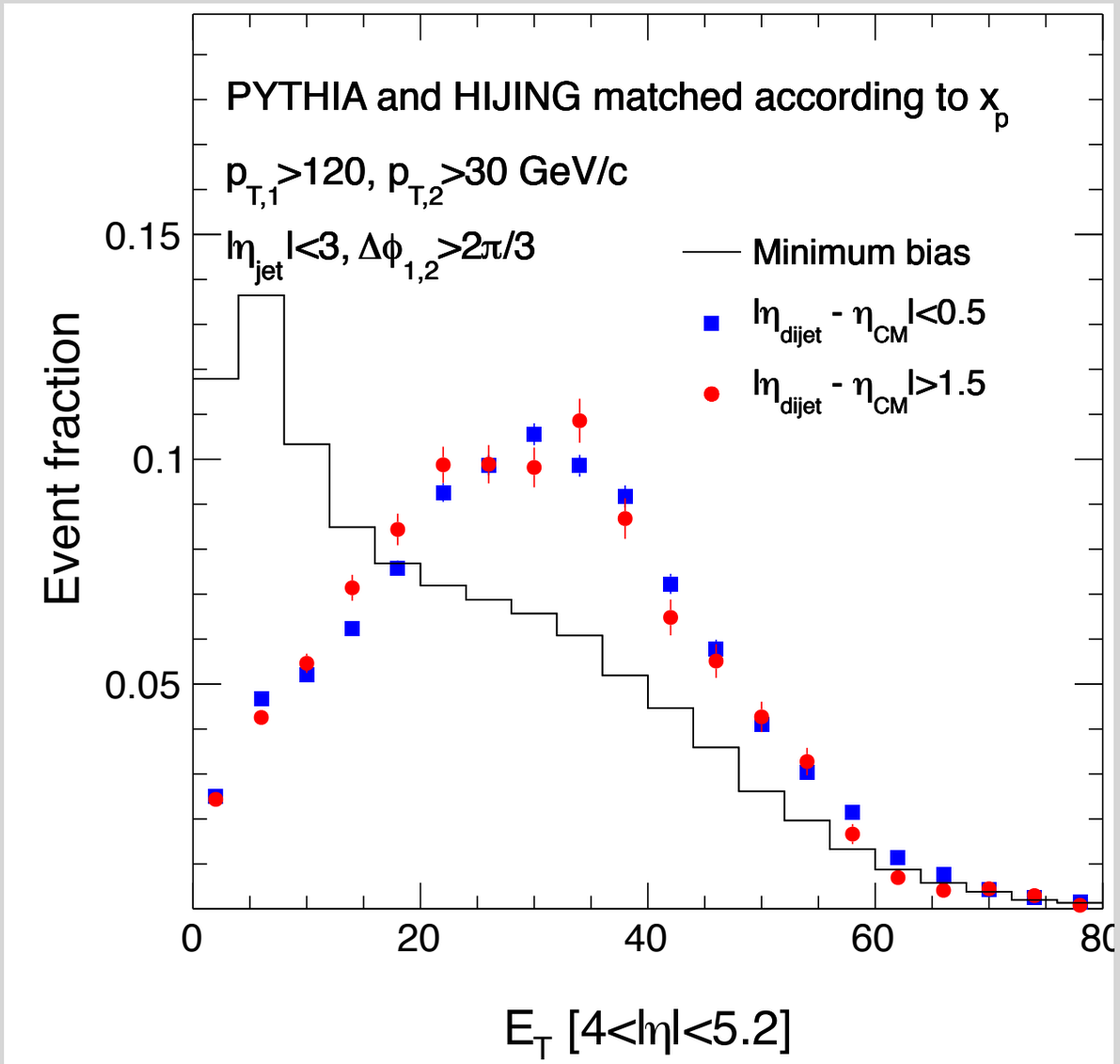


ATLAS

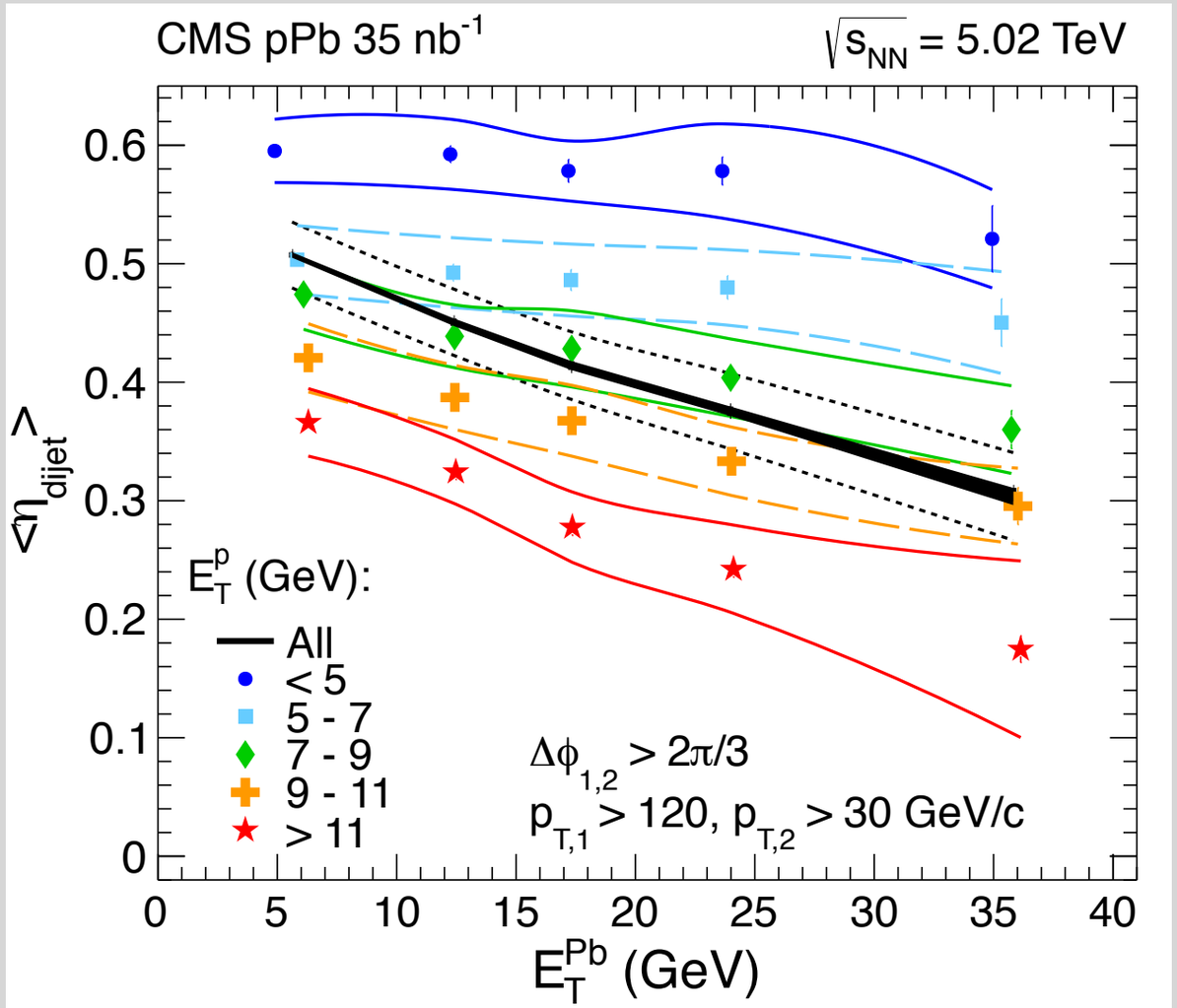


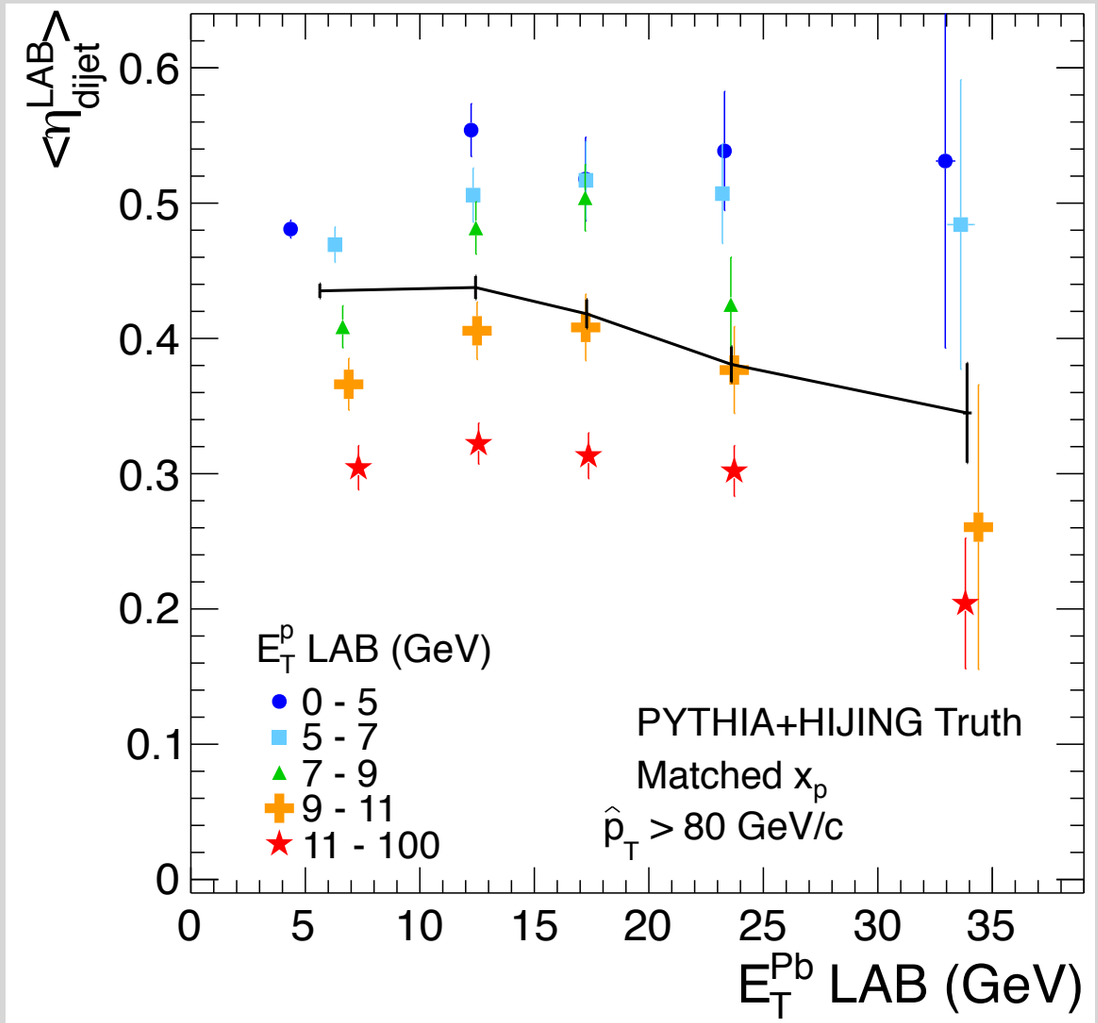
hard process / UE ['centrality'] correlation





with fixed proton side E_T





- same trend and magnitudes in data and MC
- lowest activity [lowest N_{coll}] not described :: over simplistic treatment of Pb
- see recoil of UE [different slope for each E_T^p class]

no CR vs CR [not colour scrambled]