centrality in jet studies in pA collisions:
the need to understand kinematical biases

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[with Néstor Armesto and Doğa Gülhan]
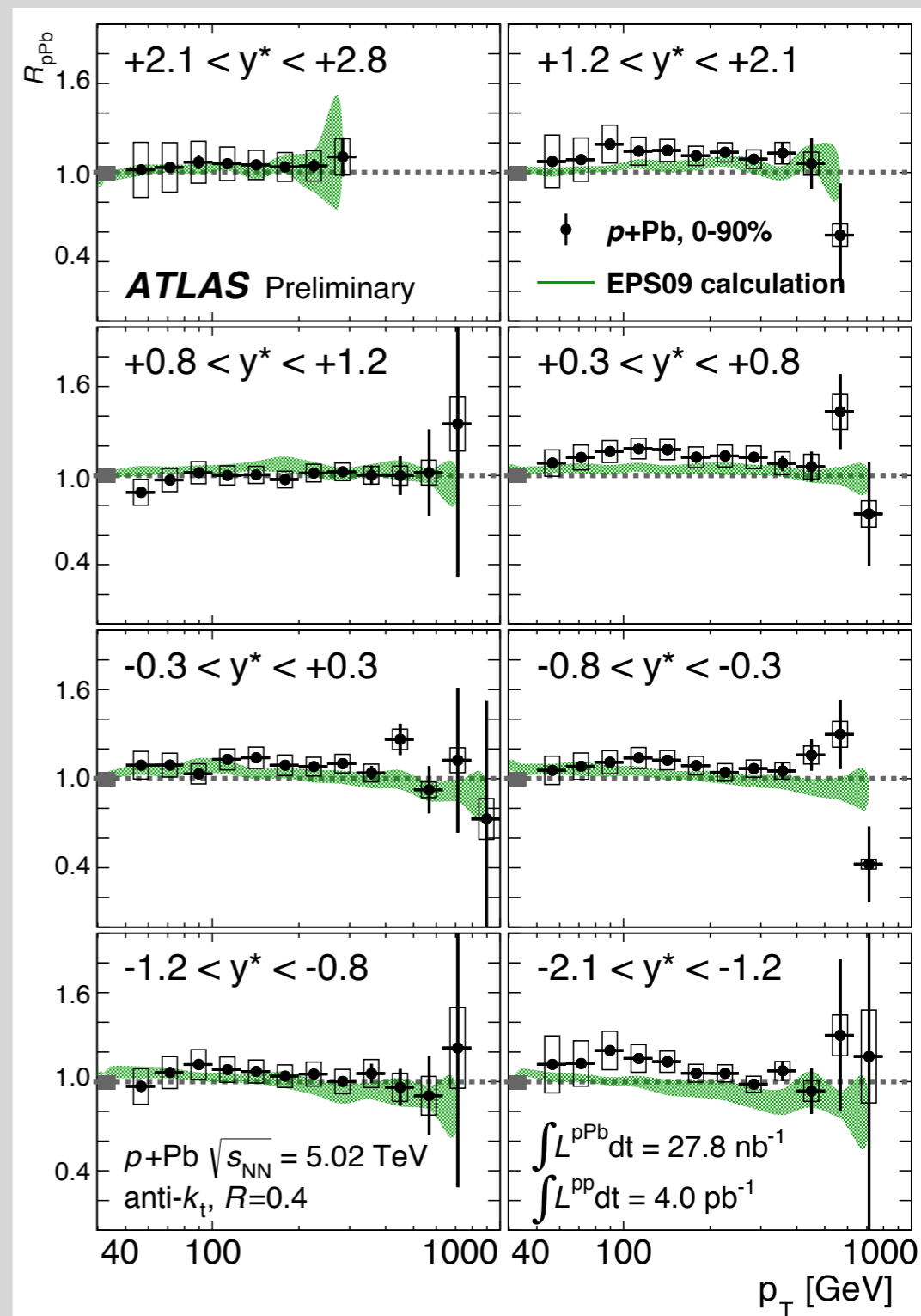
IS2014, Napa, 6th December 2014
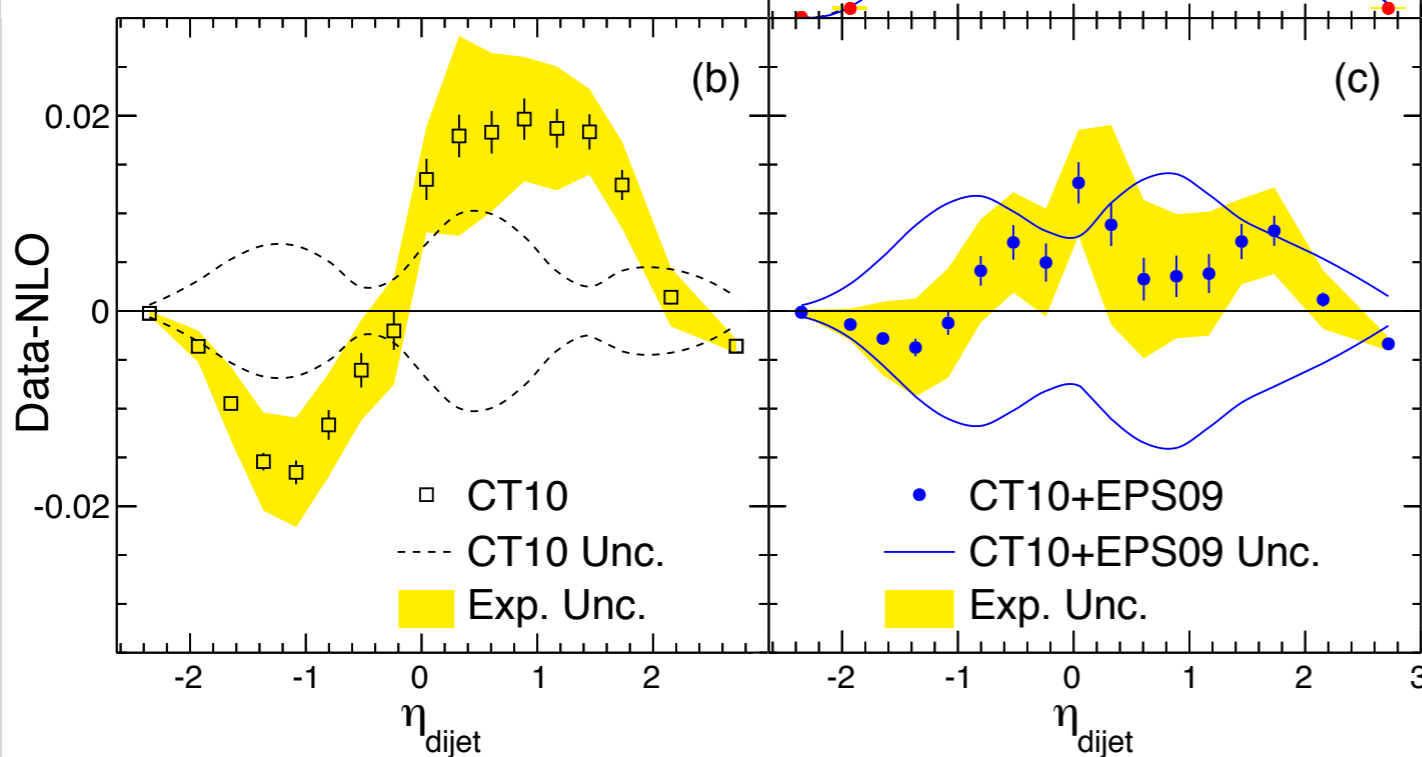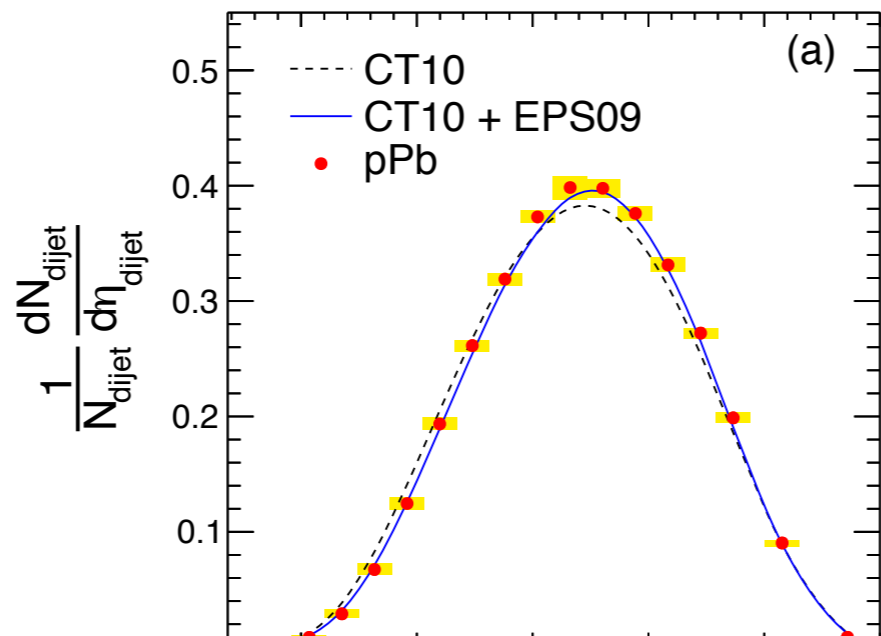
success of nPDFs [EPS09]

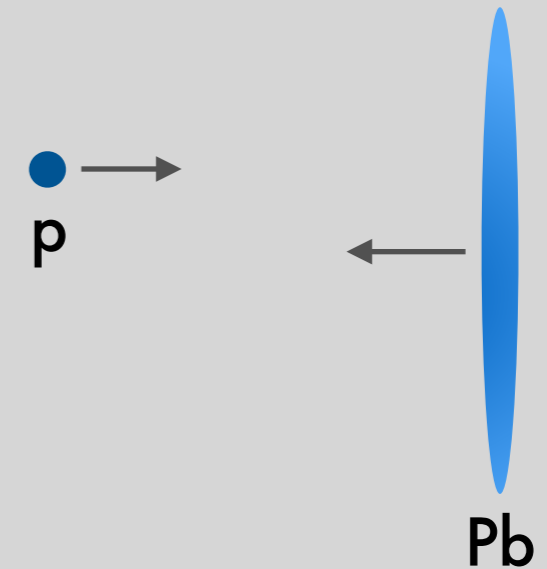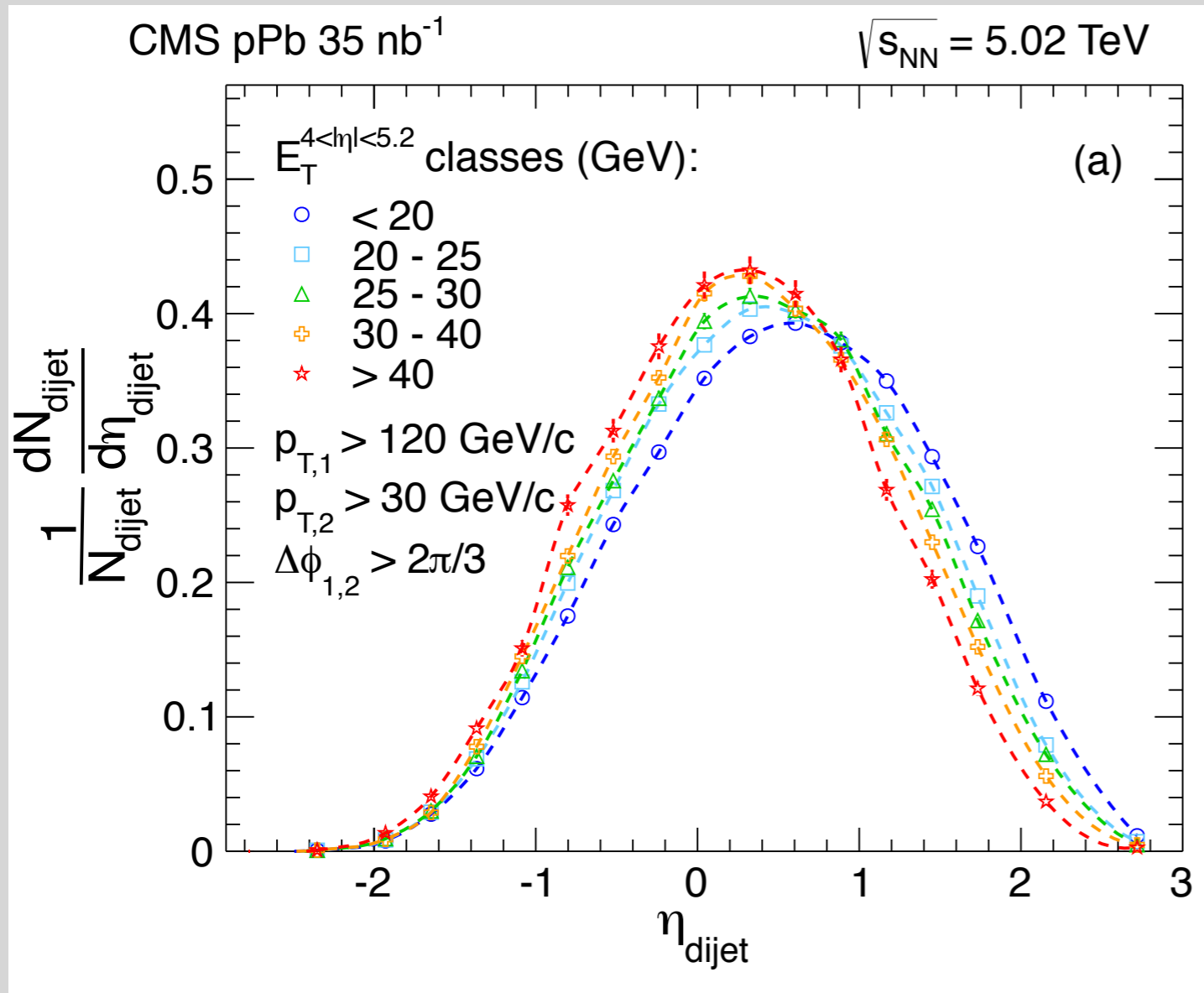CMS pPb 35 nb⁻¹

$\sqrt{s_{NN}}$ = 5.02 TeV

$p_{T,1}$ > 120 GeV/c

$p_{T,2}$ > 30 GeV/c

$\Delta\phi_{1,2}$ > 2π/3

All $E_T^{4<|\eta|<5.2}$

(a)
- - - CT10
——— CT10 + EPS09
● pPb

$\frac{1}{N_{dijet}}\frac{dN_{dijet}}{d\eta_{dijet}}$

(b)
Data–NLO

□ CT10
- - - CT10 Unc.
Exp. Unc.

(c)
● CT10+EPS09
——— CT10+EPS09 Unc.
Exp. Unc.

η_{dijet}

R_{pPb}

+2.1 < y* < +2.8

ATLAS Preliminary

+1.2 < y* < +2.1

● p+Pb, 0-90%
——— EPS09 calculation

+0.8 < y* < +1.2

+0.3 < y* < +0.8

-0.3 < y* < +0.3

-0.8 < y* < -0.3

-1.2 < y* < -0.8

p+Pb $\sqrt{s_{NN}}$ = 5.02 TeV
anti-k_t, R=0.4

-2.1 < y* < -1.2

$\int L^{pPb}dt$ = 27.8 nb⁻¹
$\int L^{pp}dt$ = 4.0 pb⁻¹

p_T [GeV]

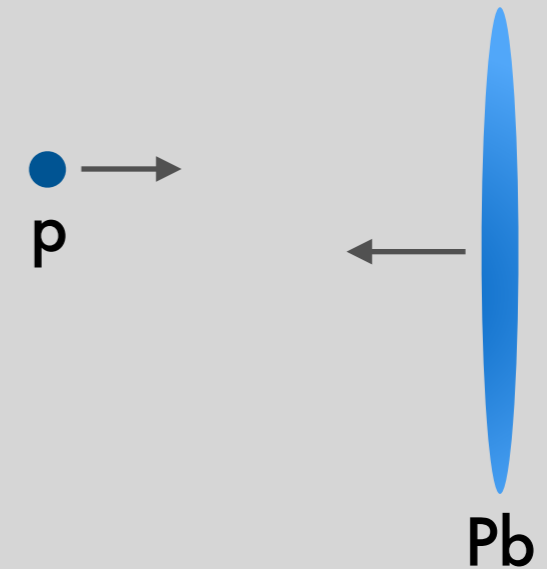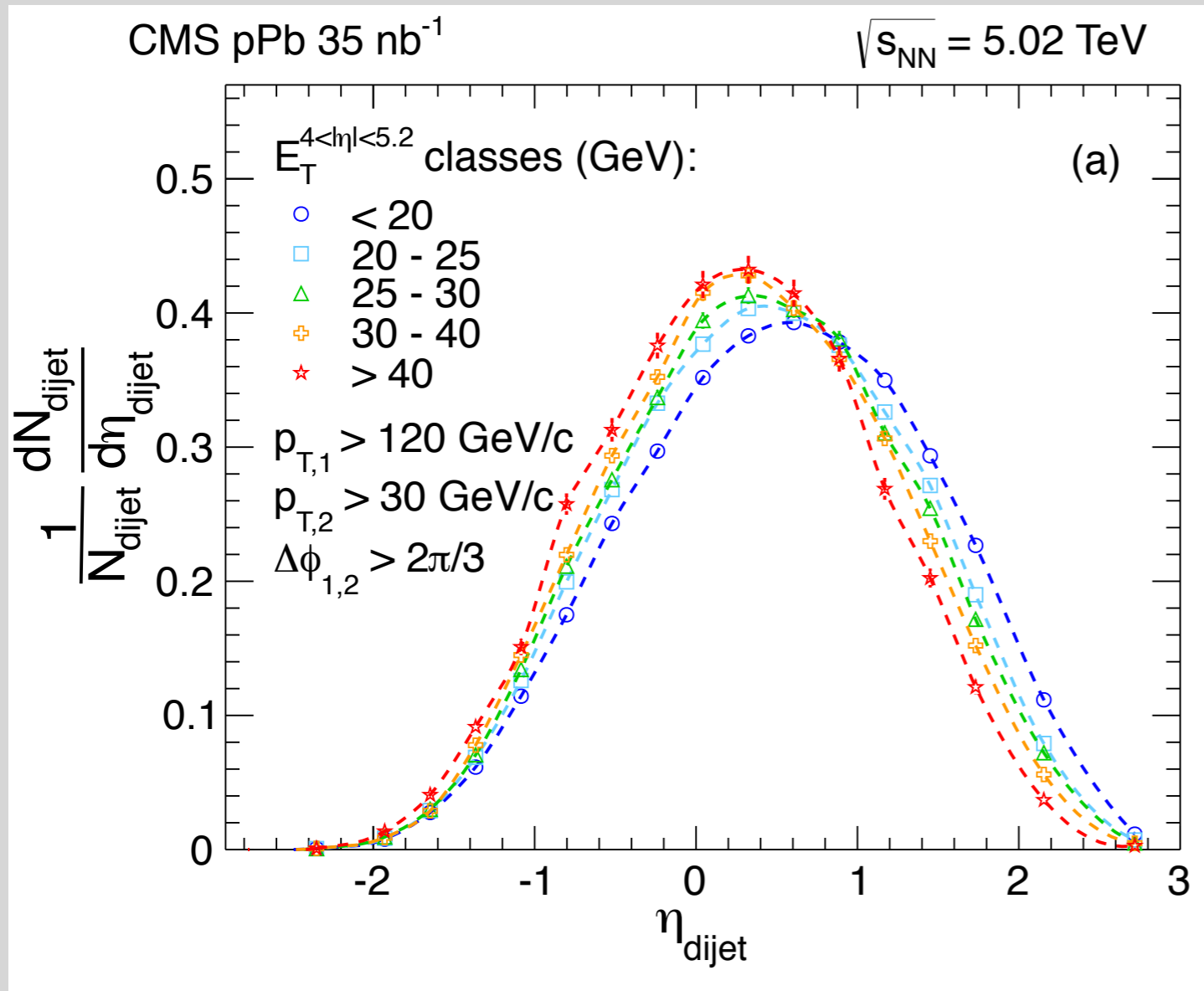# however

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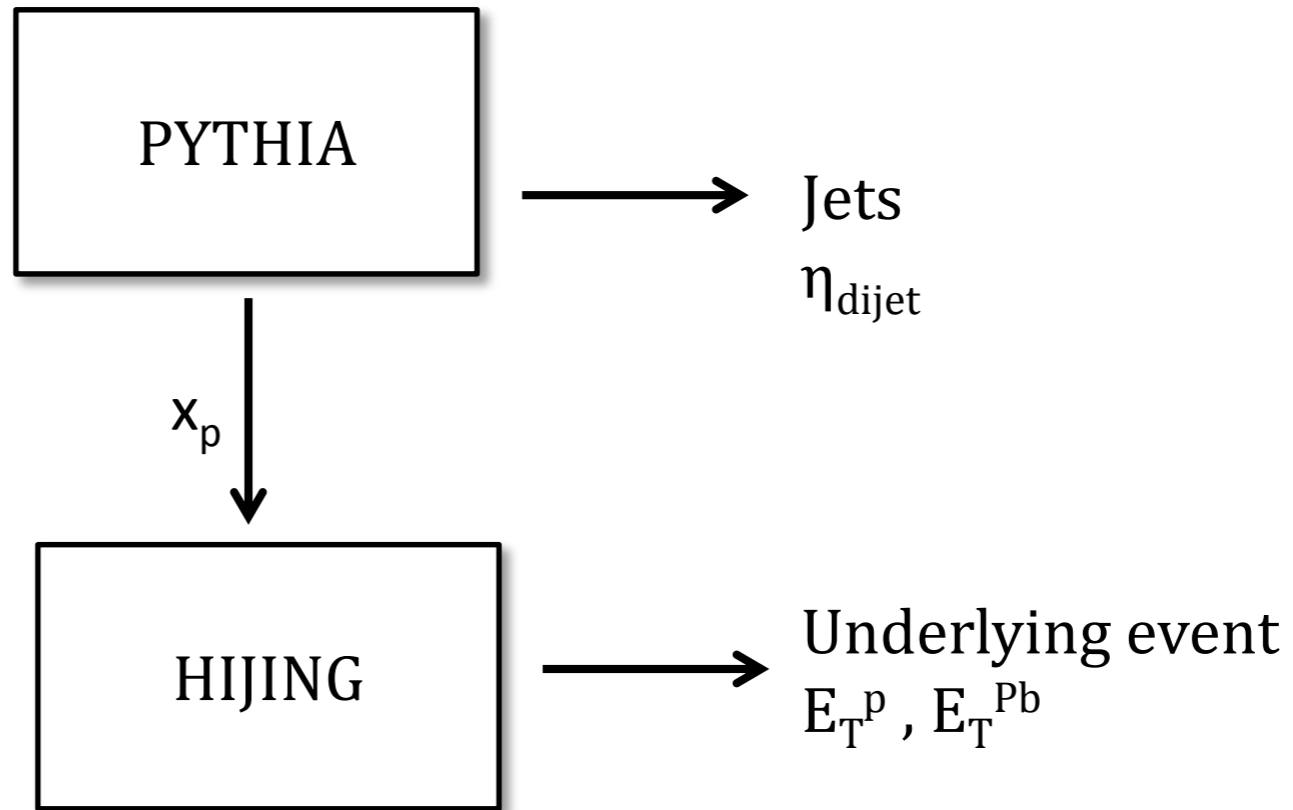
however

CMS pPb 35 nb^{-1} $\sqrt{s_{NN}}$ = 5.02 TeV

$E_T^{4<|\eta|<5.2}$ classes (GeV):   (a)
- ○ < 20
- □ 20 - 25
- △ 25 - 30
- ✚ 30 - 40
- ★ > 40

$p_{T,1}$ > 120 GeV/c
$p_{T,2}$ > 30 GeV/c
$\Delta\phi_{1,2}$ > 2π/3

$\frac{1}{N_{dijet}} \frac{dN_{dijet}}{d\eta_{dijet}}$

η_{dijet}

p

Pb

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

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

simple setup

Event by event matching

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

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

PYTHIA → Jets η_{dijet}
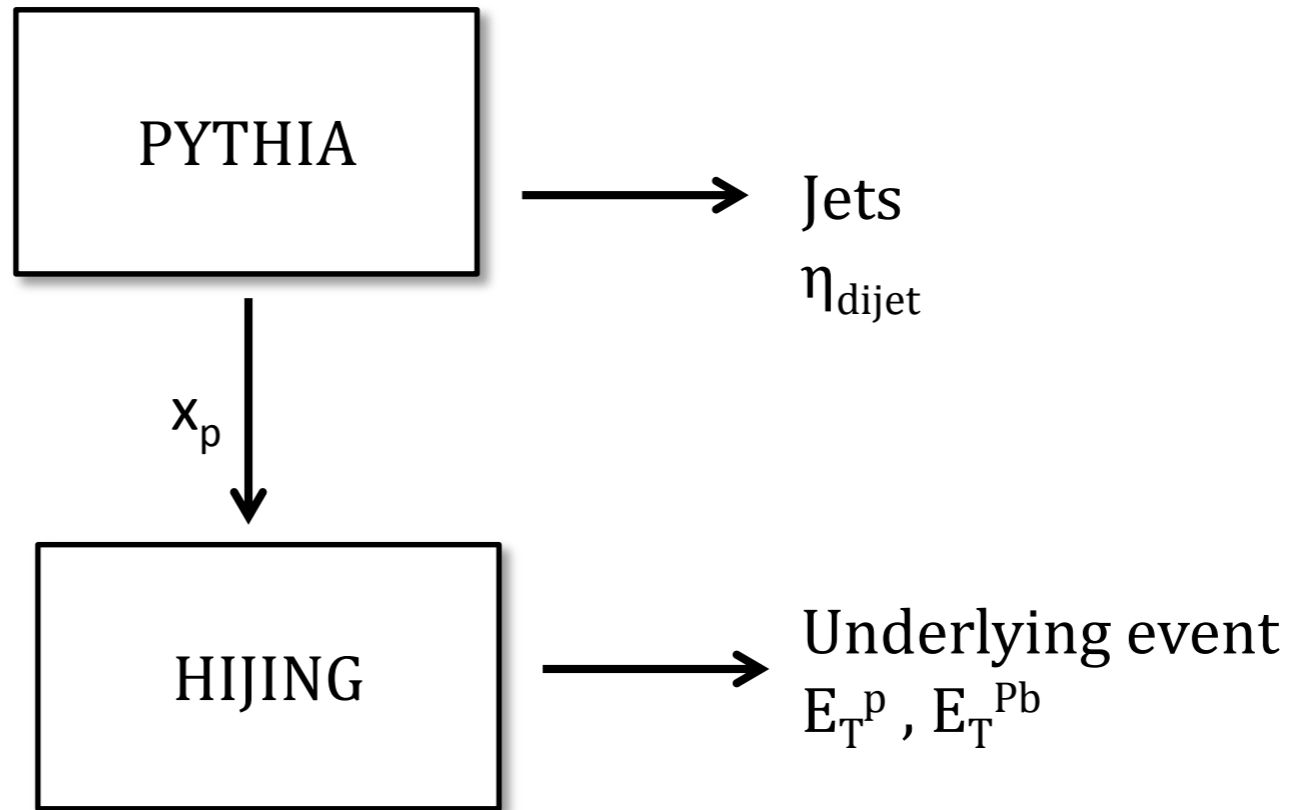
x_p

HIJING → Underlying event E_T^p, E_T^{Pb}

- 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
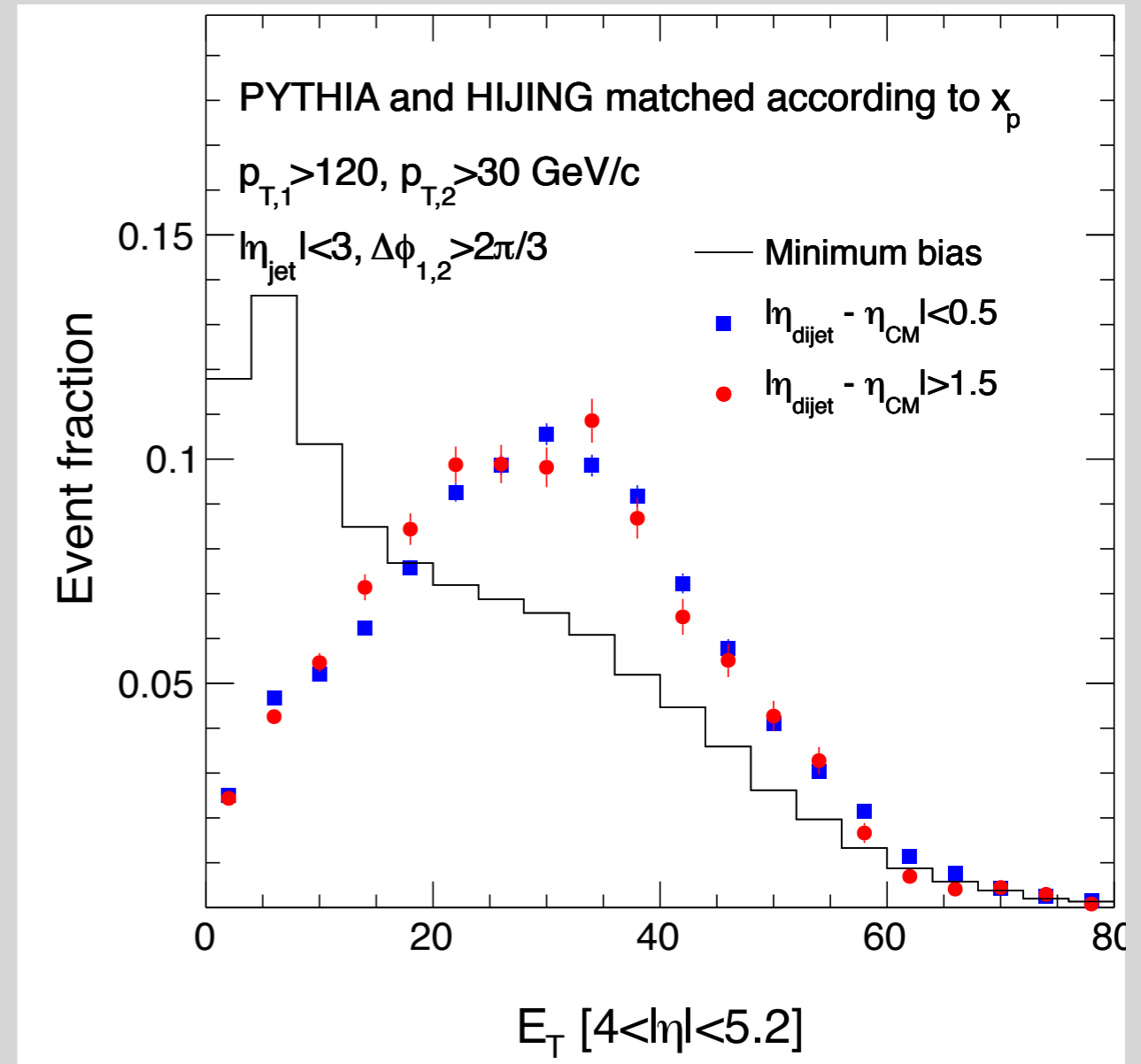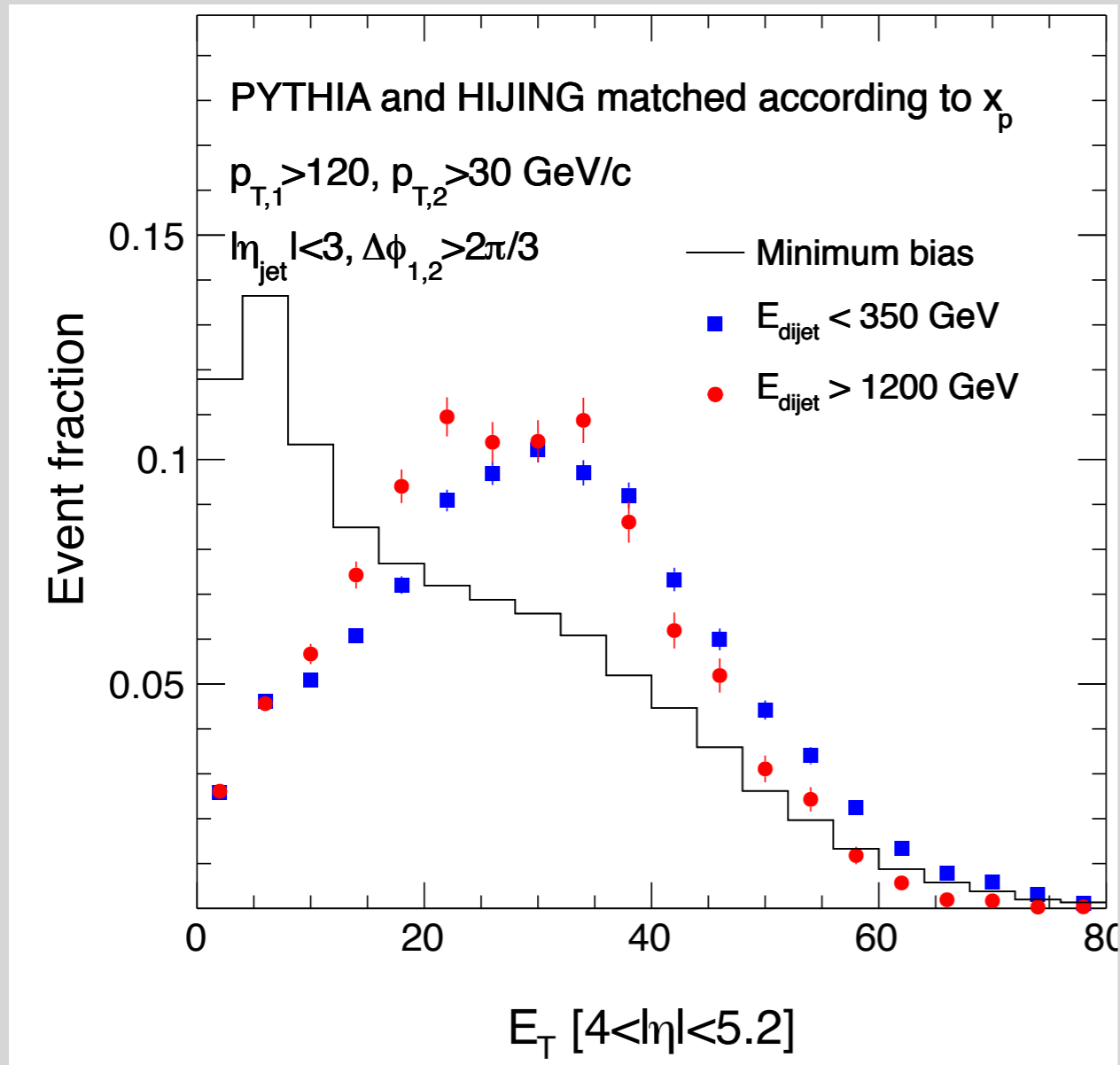
simple setup

Event by event matching

PYTHIA → Jets η_{dijet}

x_p

HIJING → Underlying event E_T^p, E_T^{Pb}

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

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

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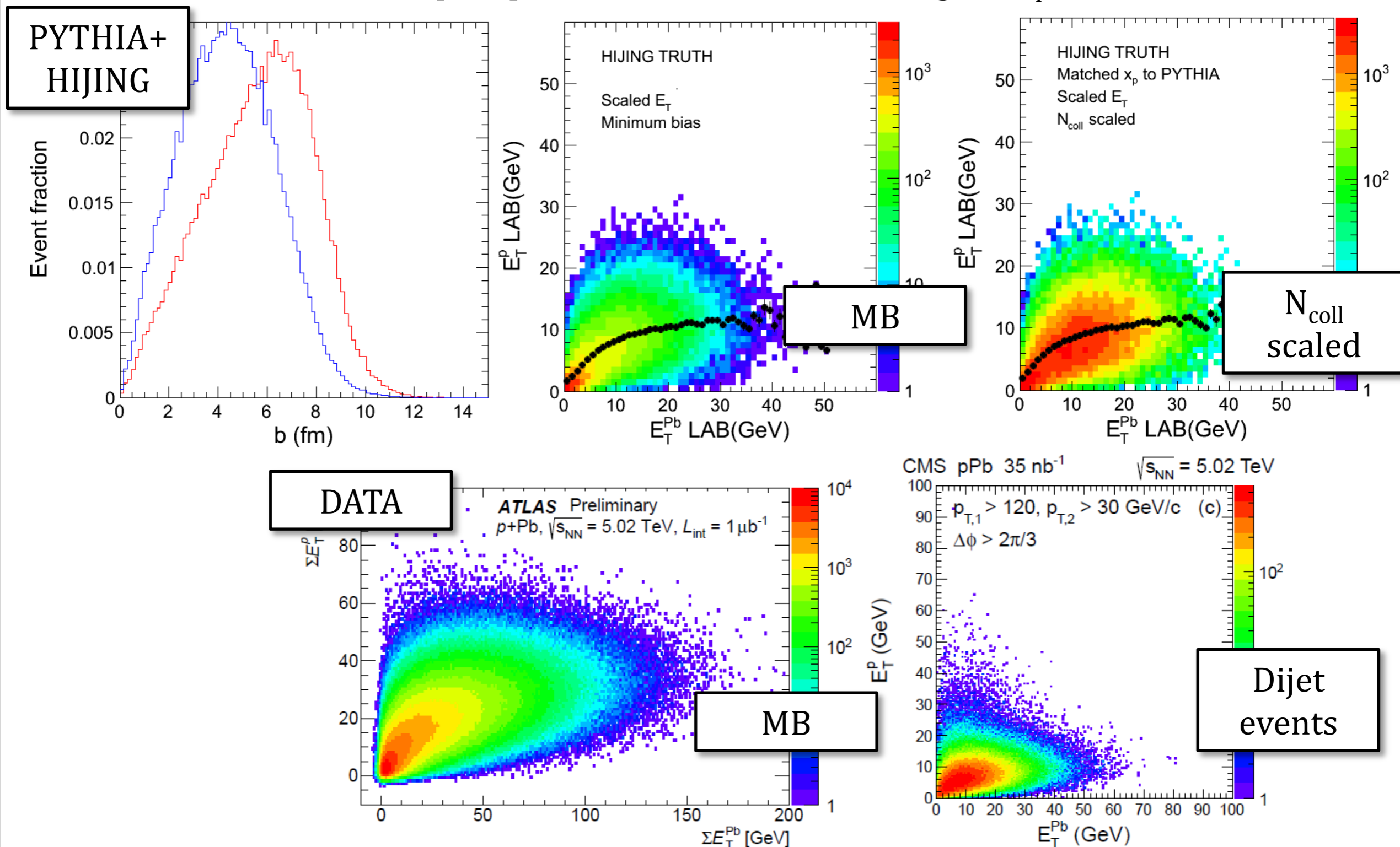- x_{Pb} is not taken into a
- Good approximation

- 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

hard process / UE ['centrality'] correlation

MB vs dijet events

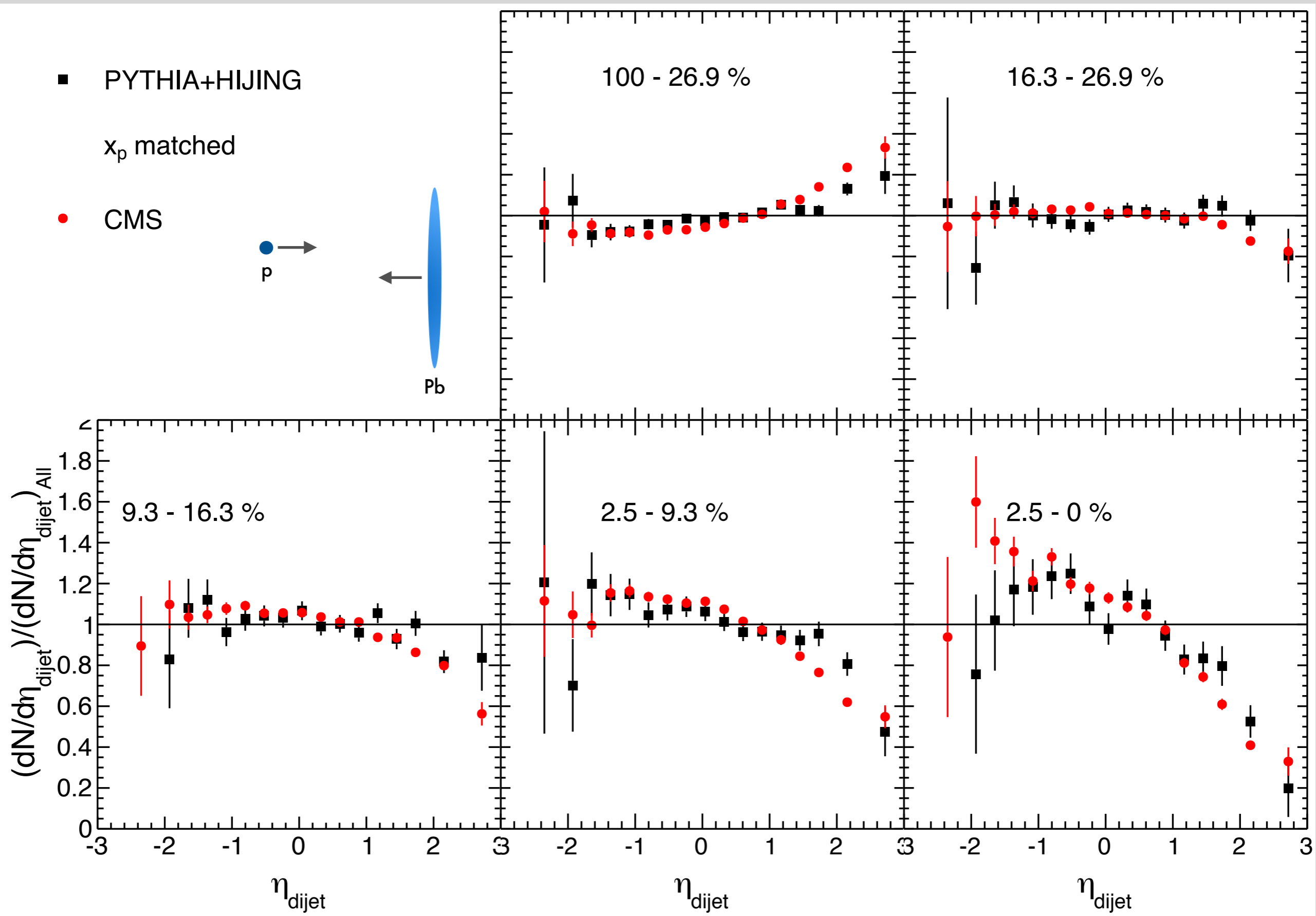- Bias towards small impact parameter collisions with higher E_T on both sides.
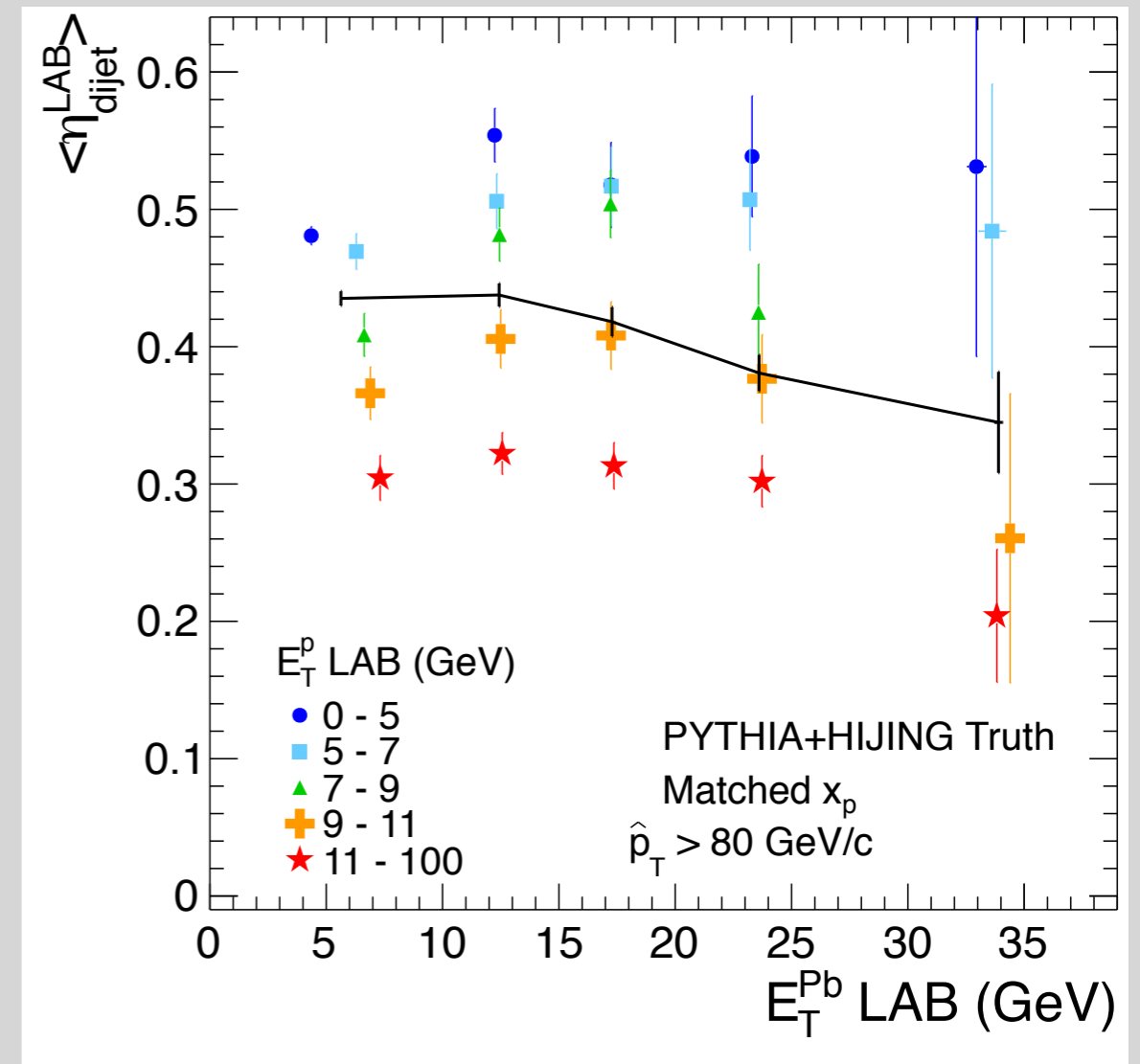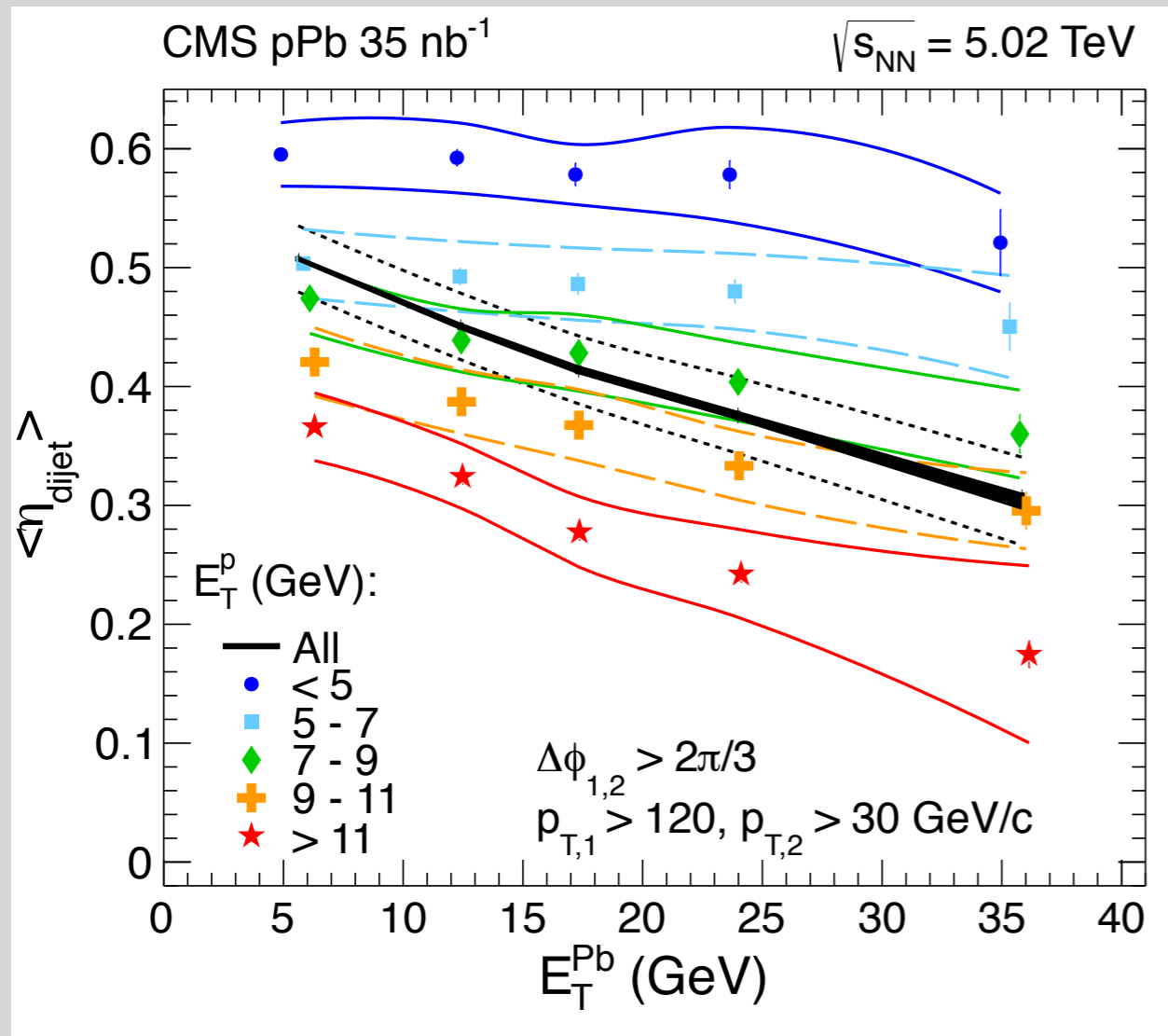
dijet η shift [CMS]

- Except the events with small E_T , good agreement between data and MC
- For small E_T events N_{coll} is small and the energy the hard scattering takes away from Pb becomes important
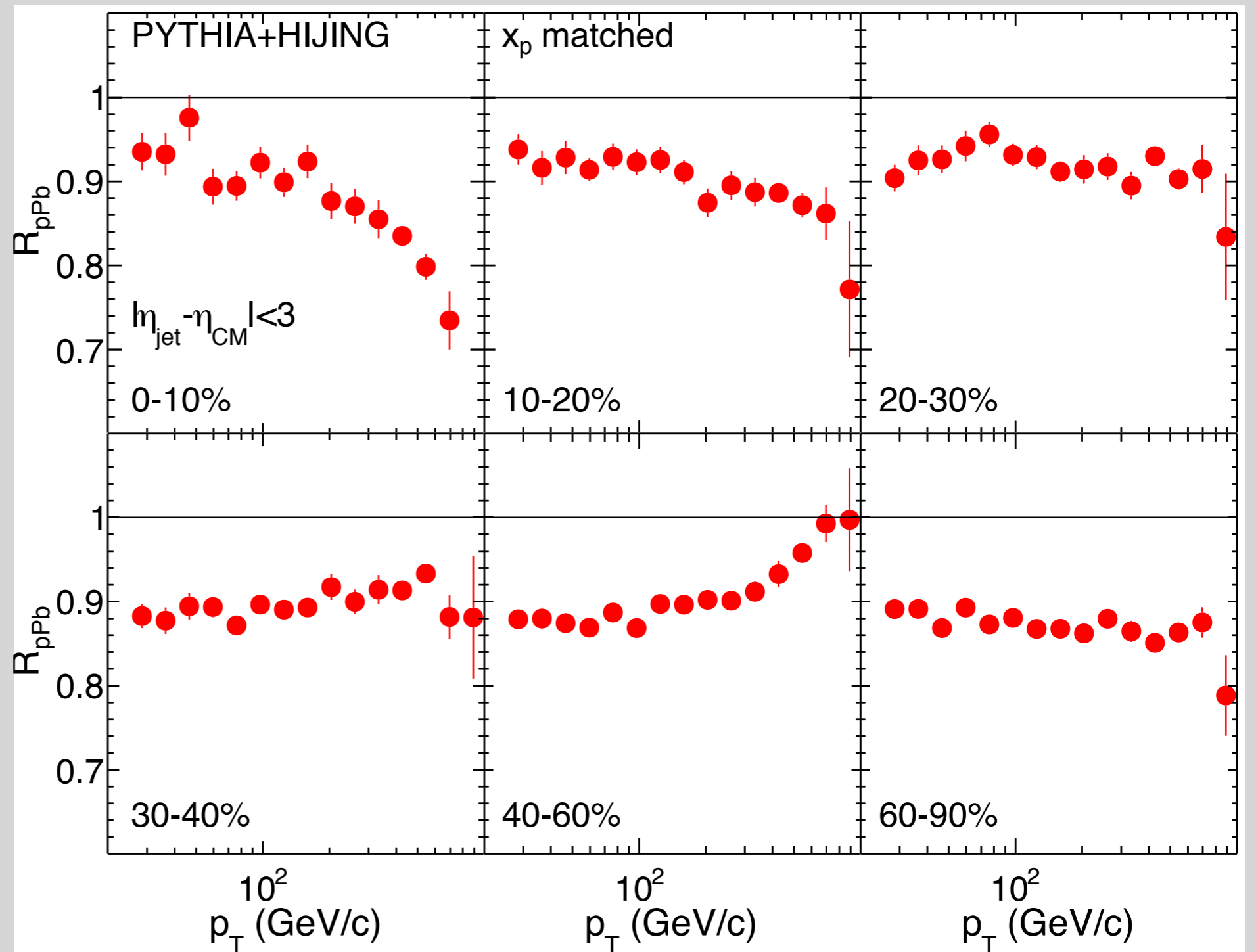
η dijet distributions

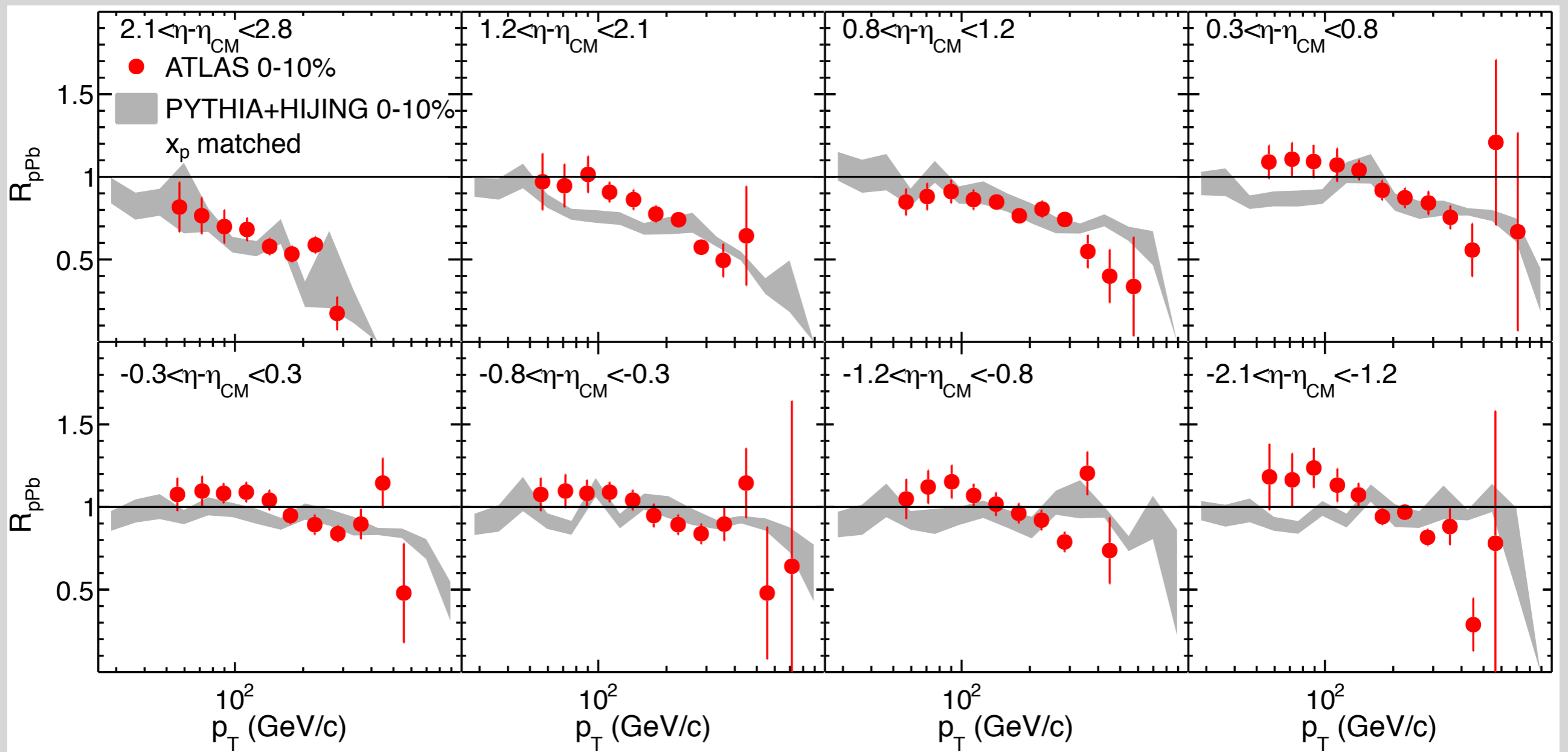# with fixed proton side E_T

- —o—same trend and magnitudes in data and MC
- —o—lowest activity [lowest N_{coll}] not described :: over simplistic treatment of Pb
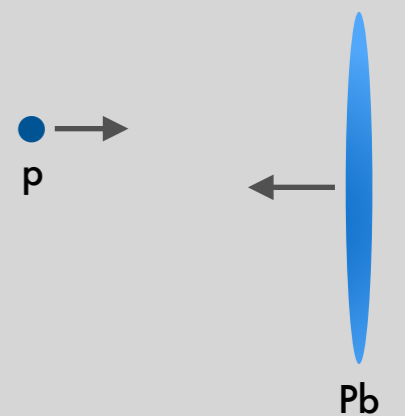
R_{pPb} [ATLAS] :: η inclusive

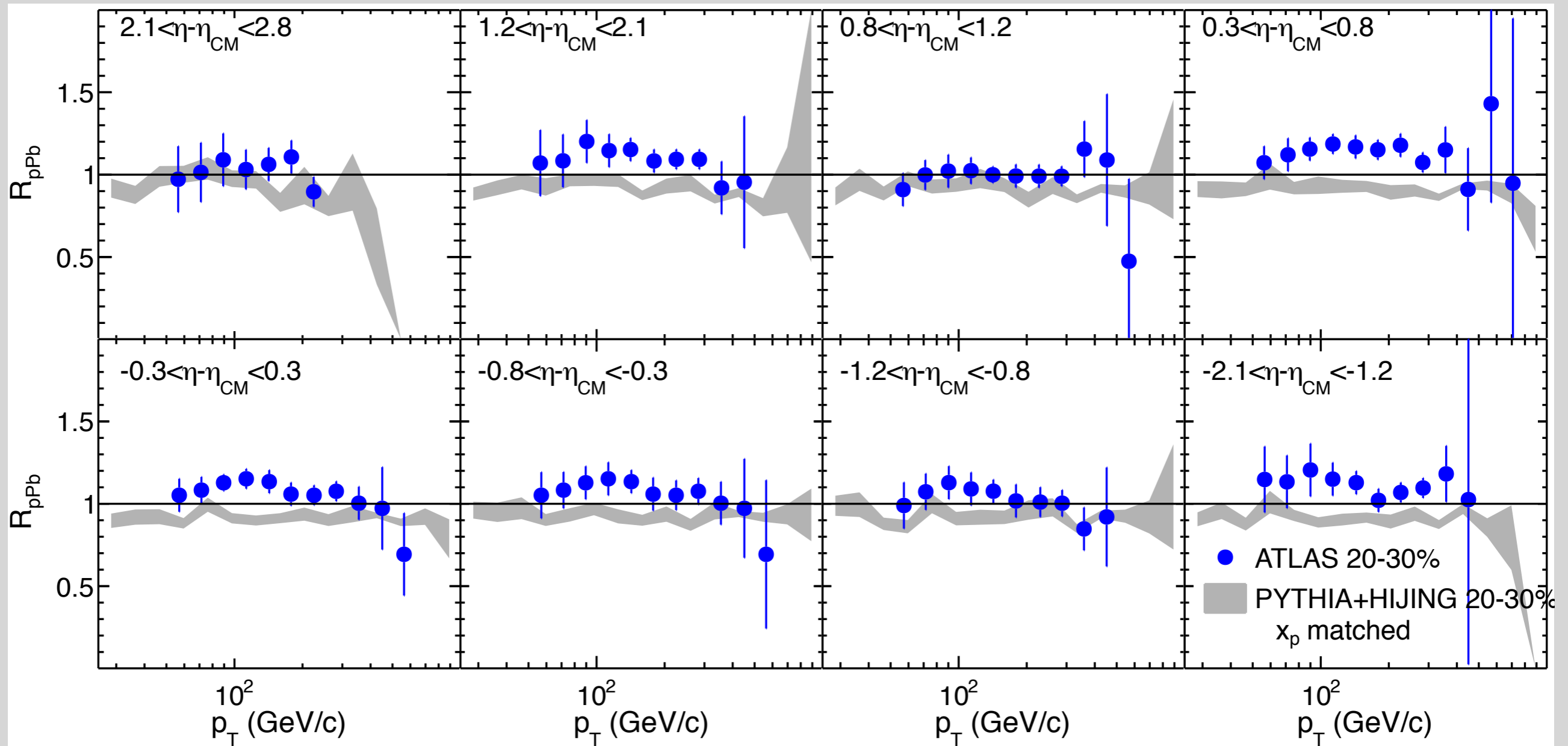**NOTE: 'centrality' determination from only Pb side**

'central'

excellent overall description
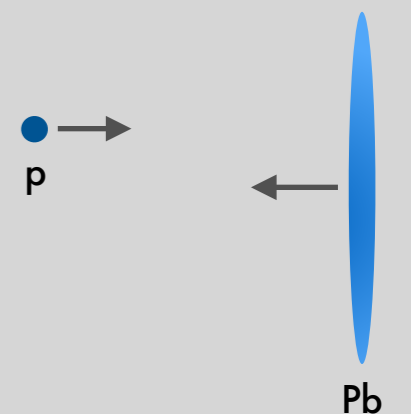
deviations on Pb side :: same model limitation as before
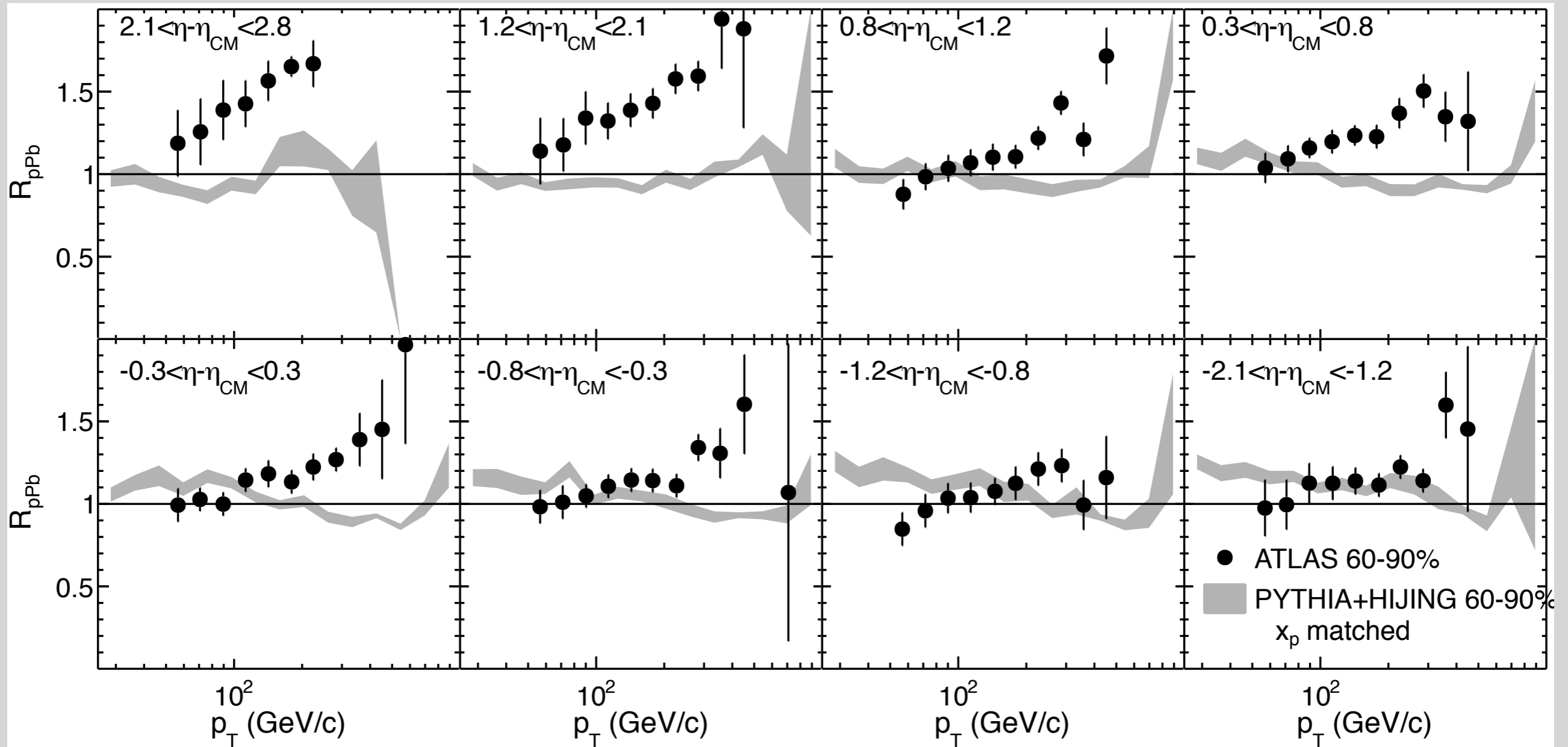
'mid-central'

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

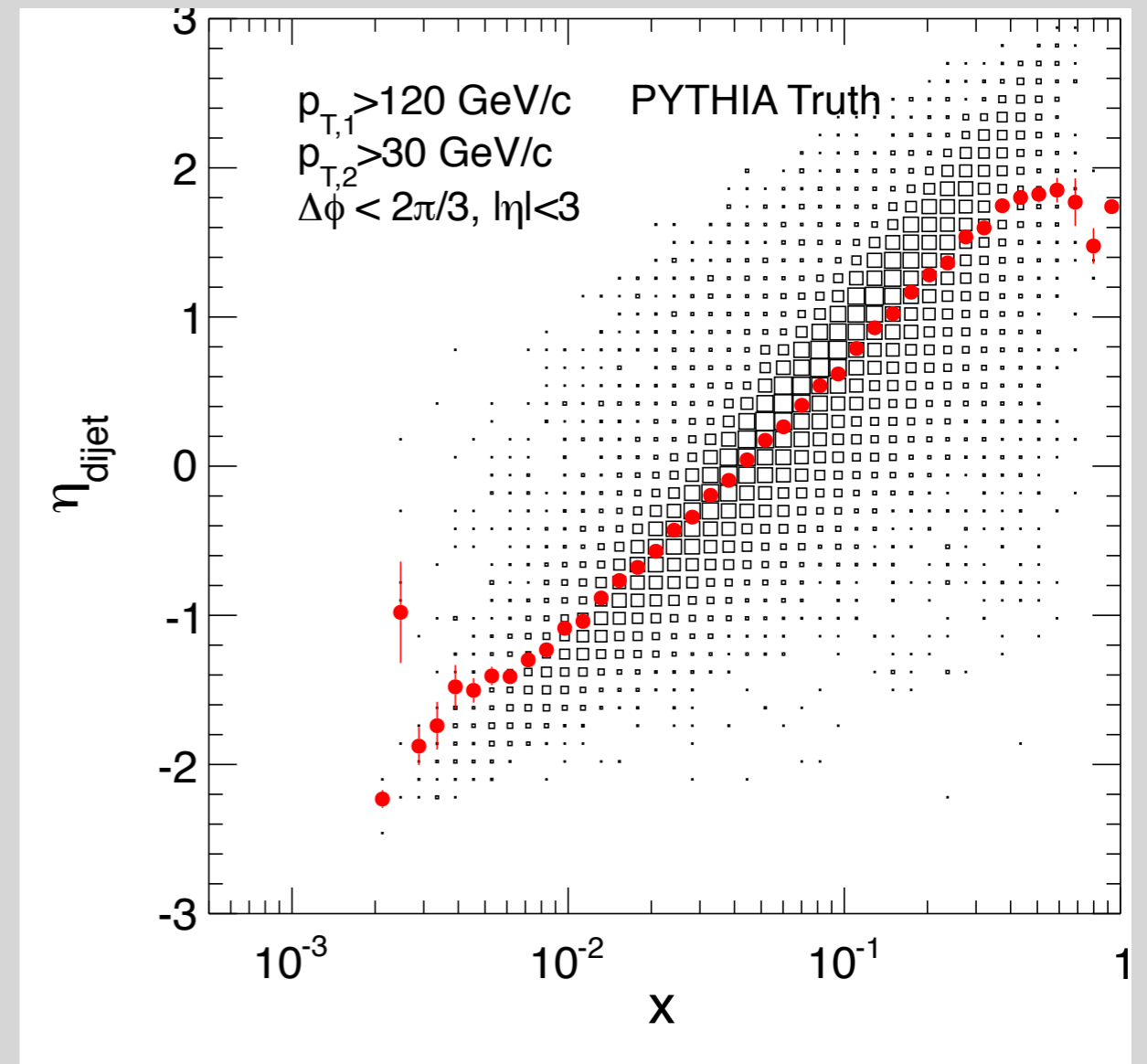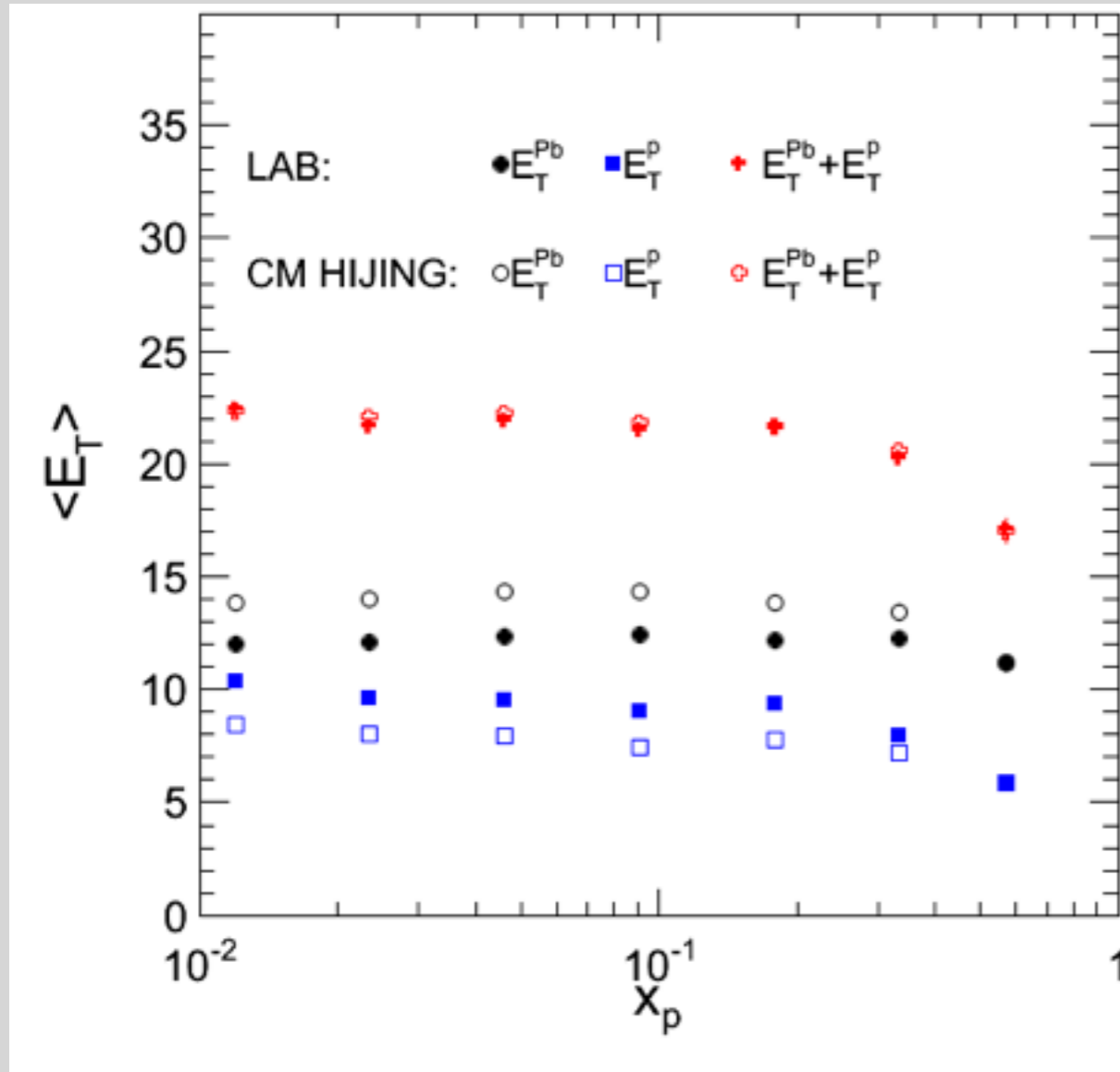proton PDFs used for both proton and nucleon from Pb
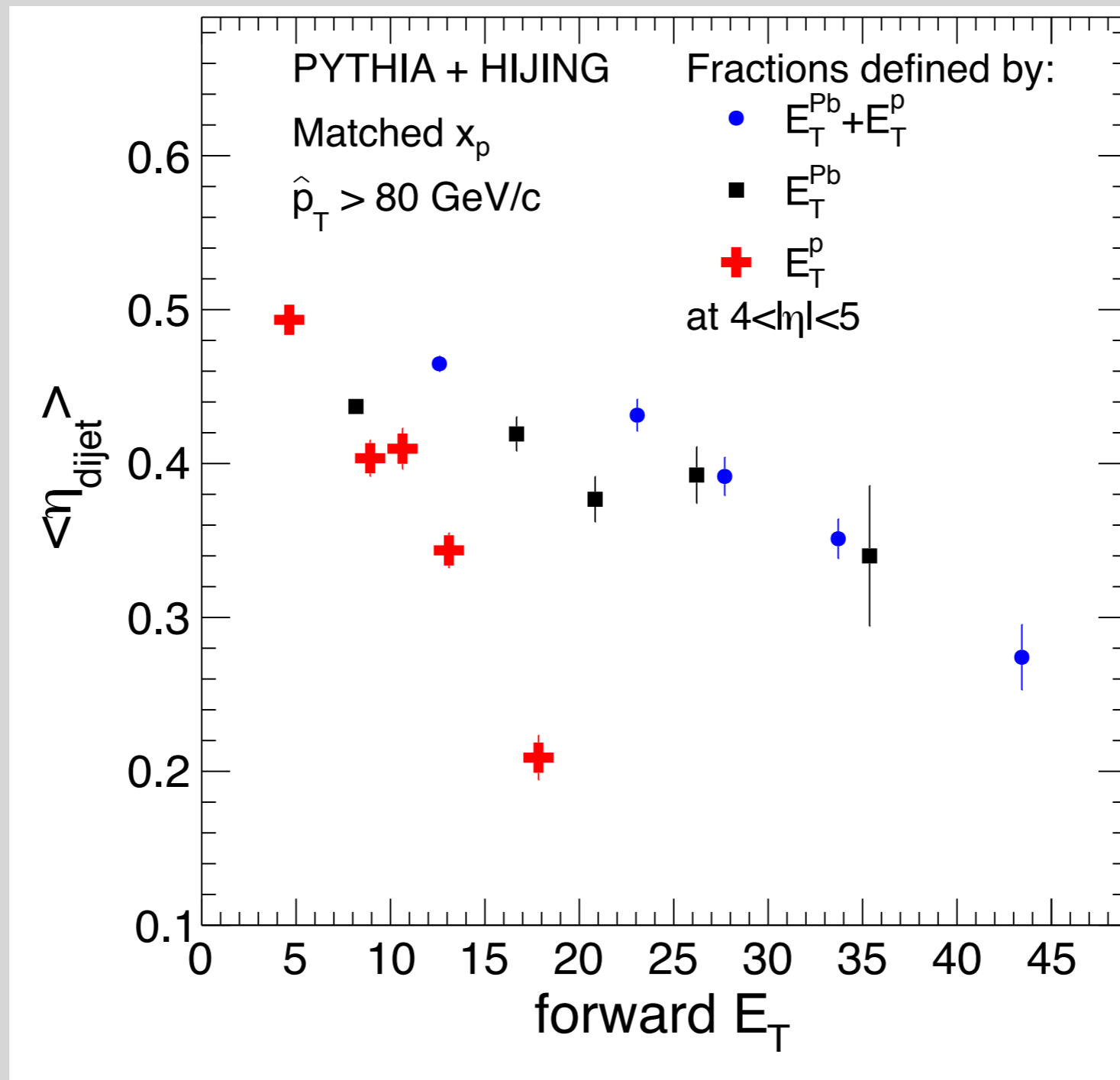
'peripheral'

remarks

- *simple physical bias that must be removed*

- *next step :: requires simulating UE where one nucleon from Pb has decreased energy*
  - *strong constraint for hard+UE pA MC :: seems worth the trouble*

- *several other ideas in the market*
  - *'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]*
  - *'Evidence for x dependent proton color fluctuations in pA collisions at the LHC'; Alvioli, Cole, Frankfurt, Strikman; [1409.7381]*
  - *'Calculation of centrality bias factors...'; Perepelitsa, Steinberg; [1412.0976]*
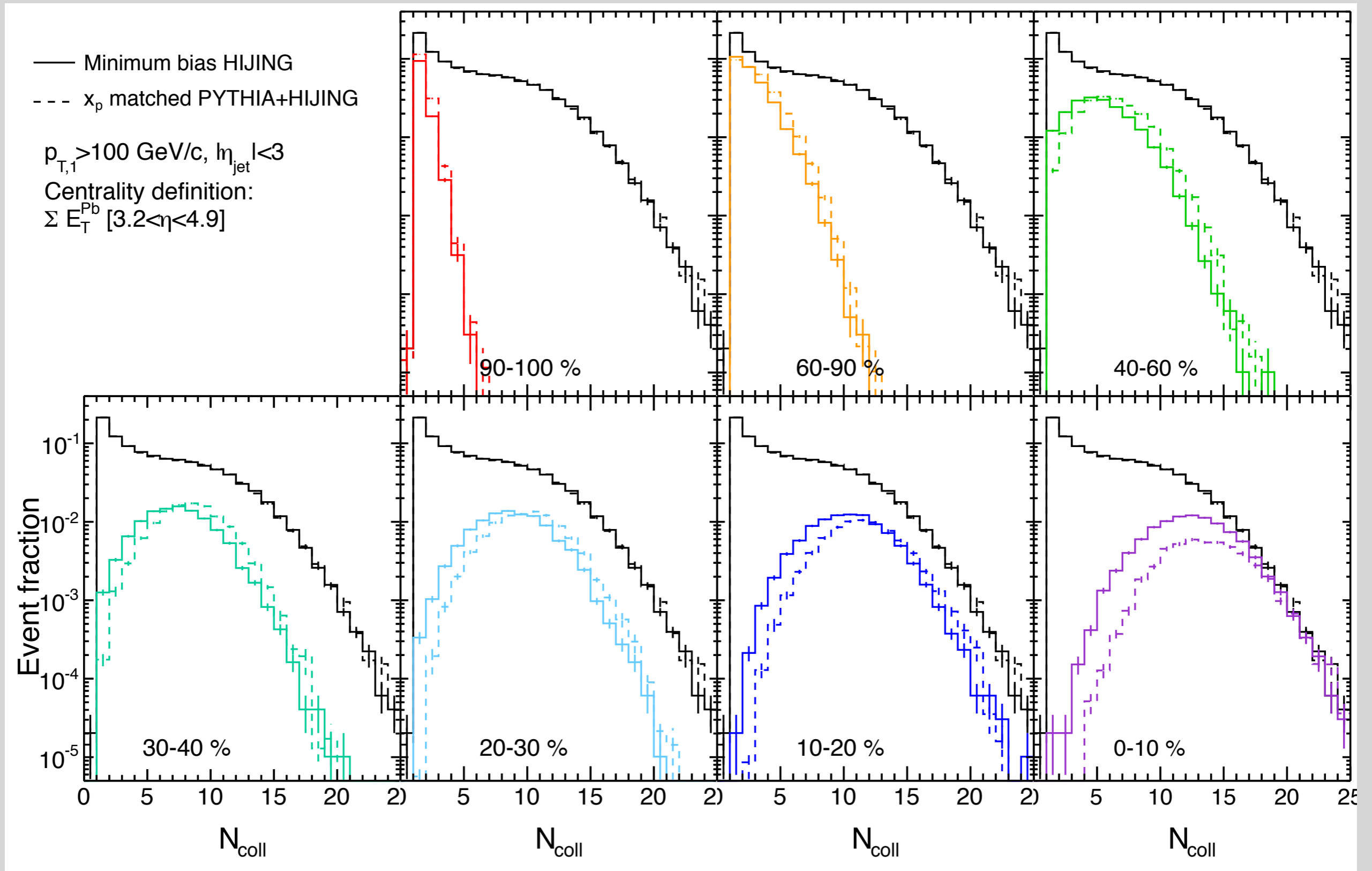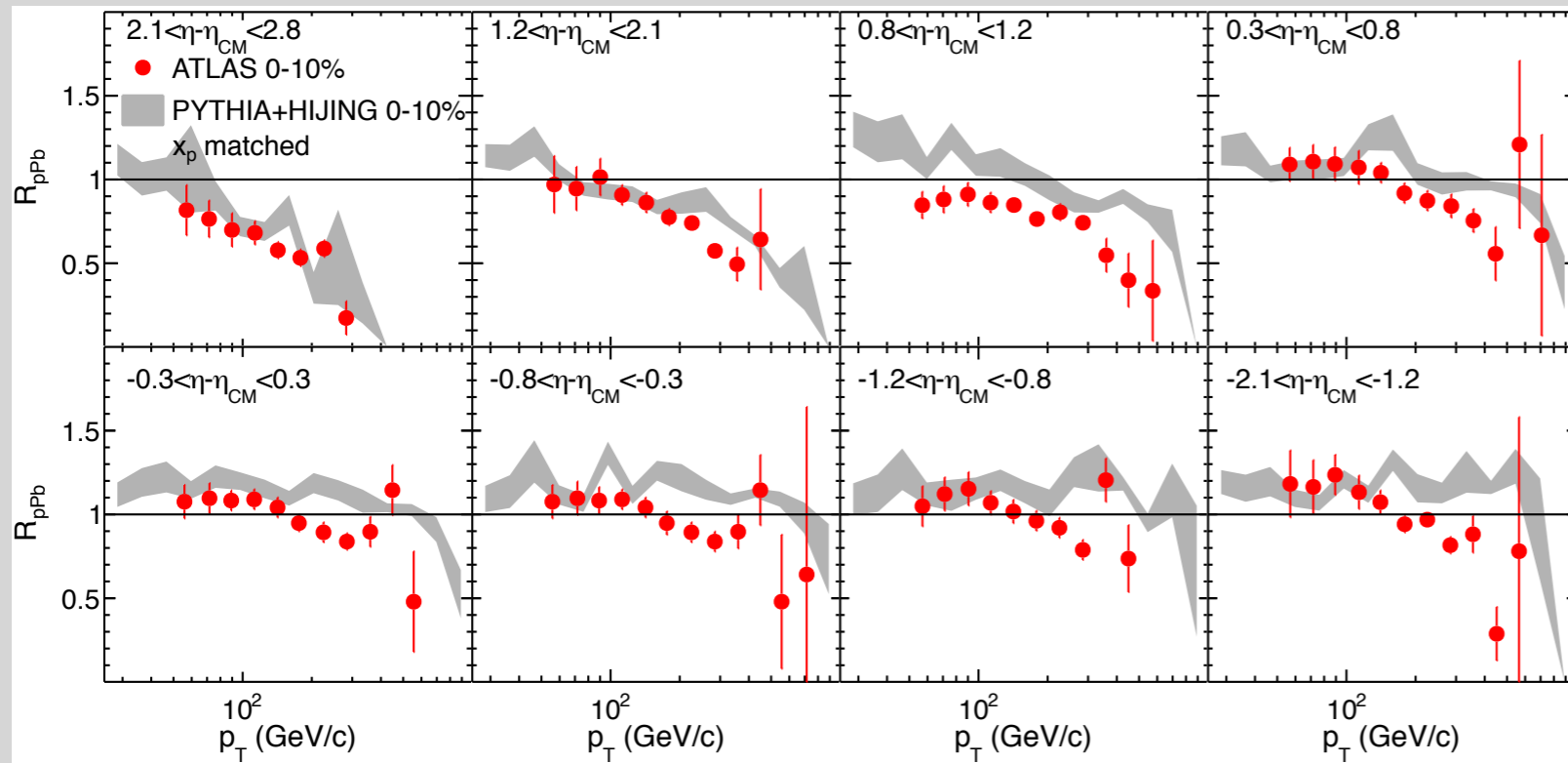
backups

correlations detailed

correlation detailed :: different estimators
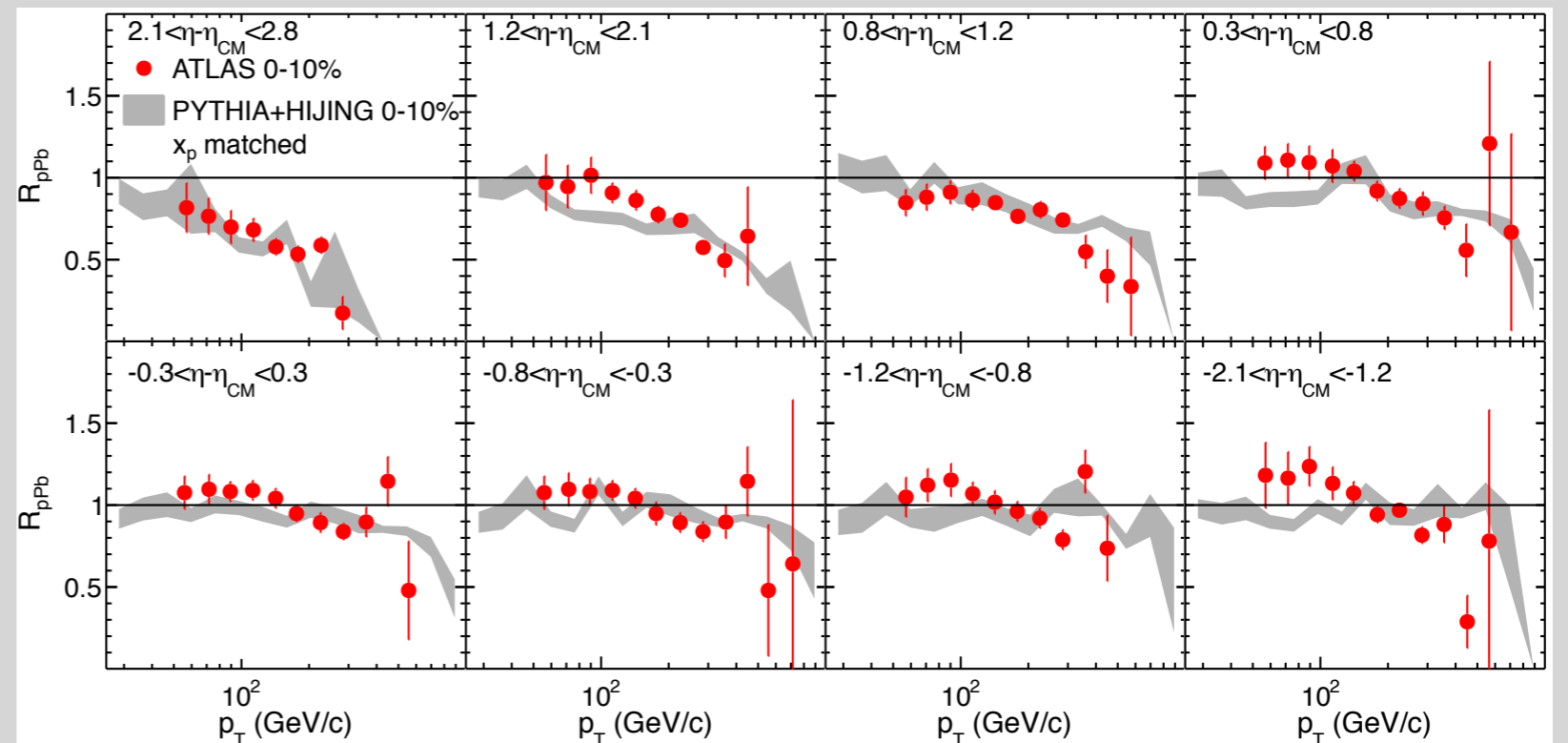
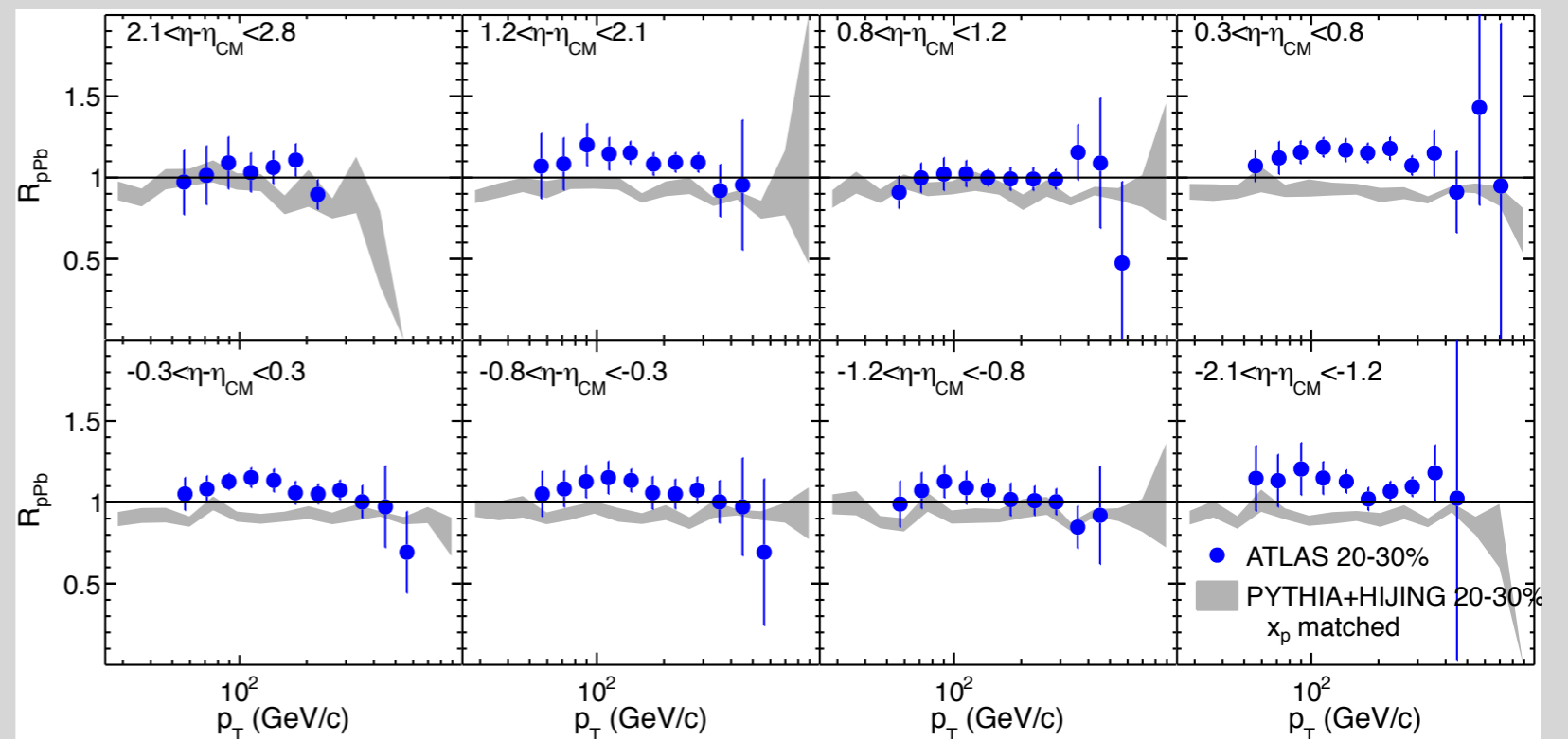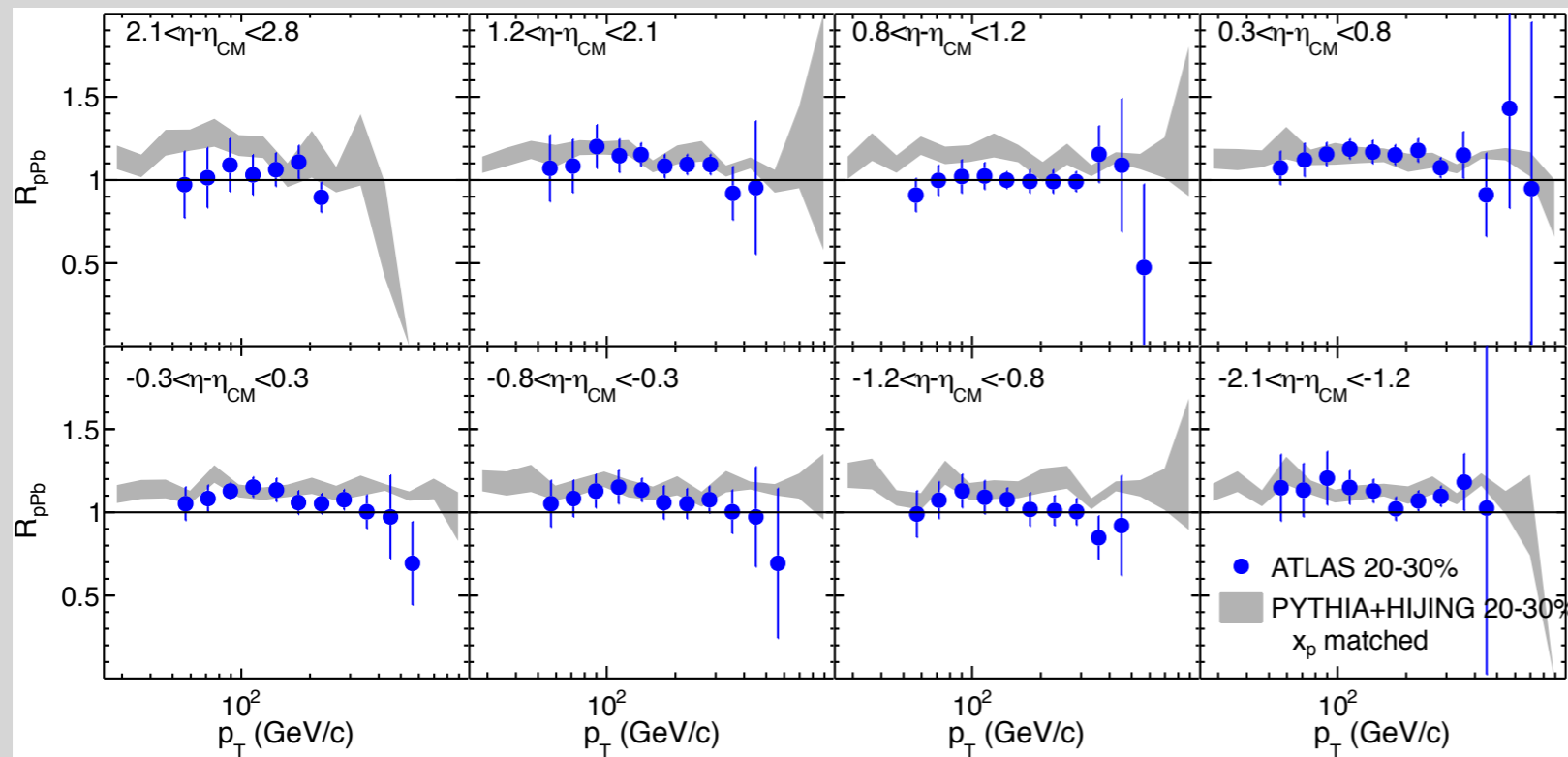# N$_{coll}$ centrality dependence

HIJING N_coll vs ATLAS N_coll :: 0-10%

HIJING N_coll vs ATLAS N_coll :: 20-30%

HIJING N_coll vs ATLAS N_coll :: 60-90%

HIJING

ATLAS