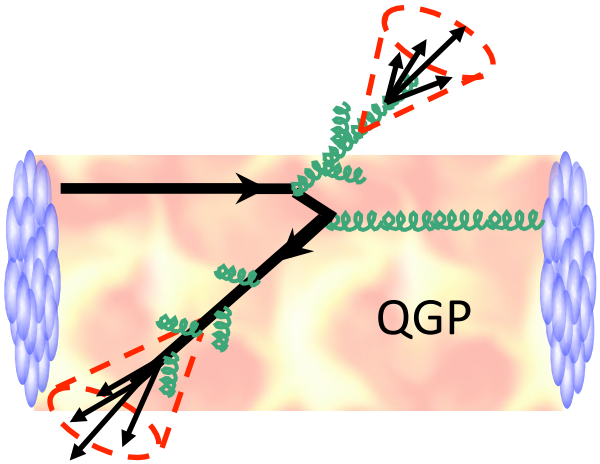
# Dijet results from CMS (mostly pPb)

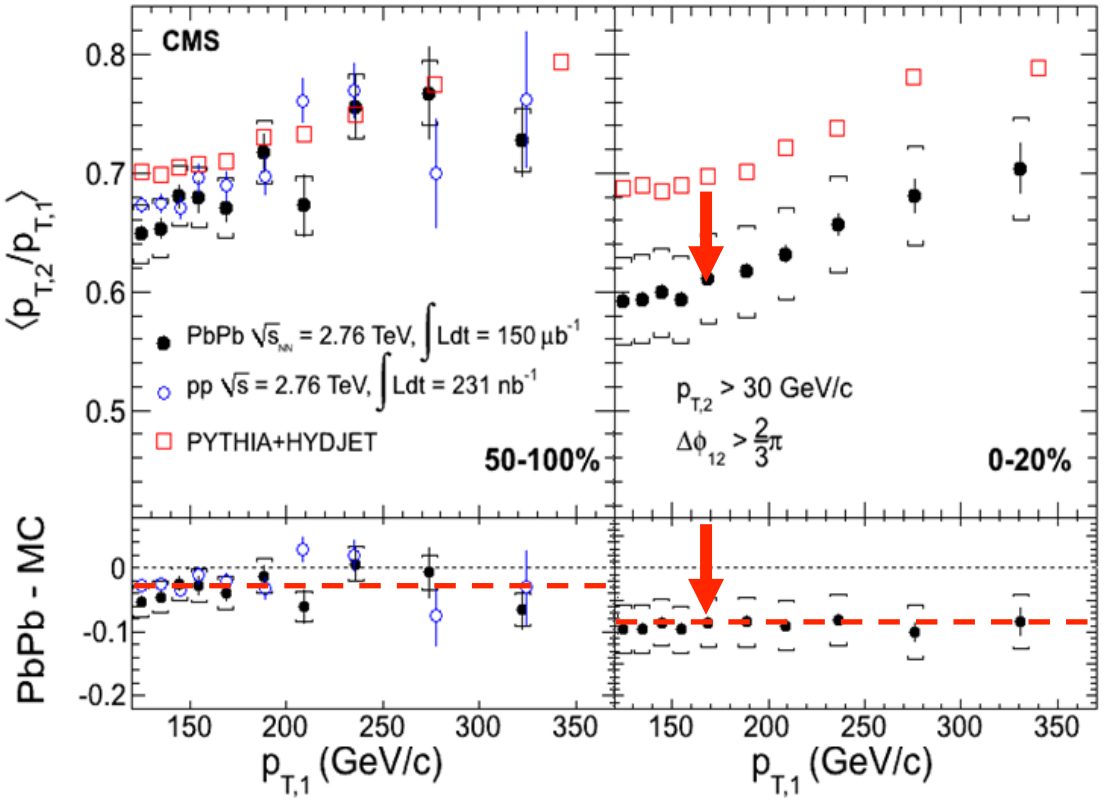
Yetkin Yilmaz

# Quenching in PbPb



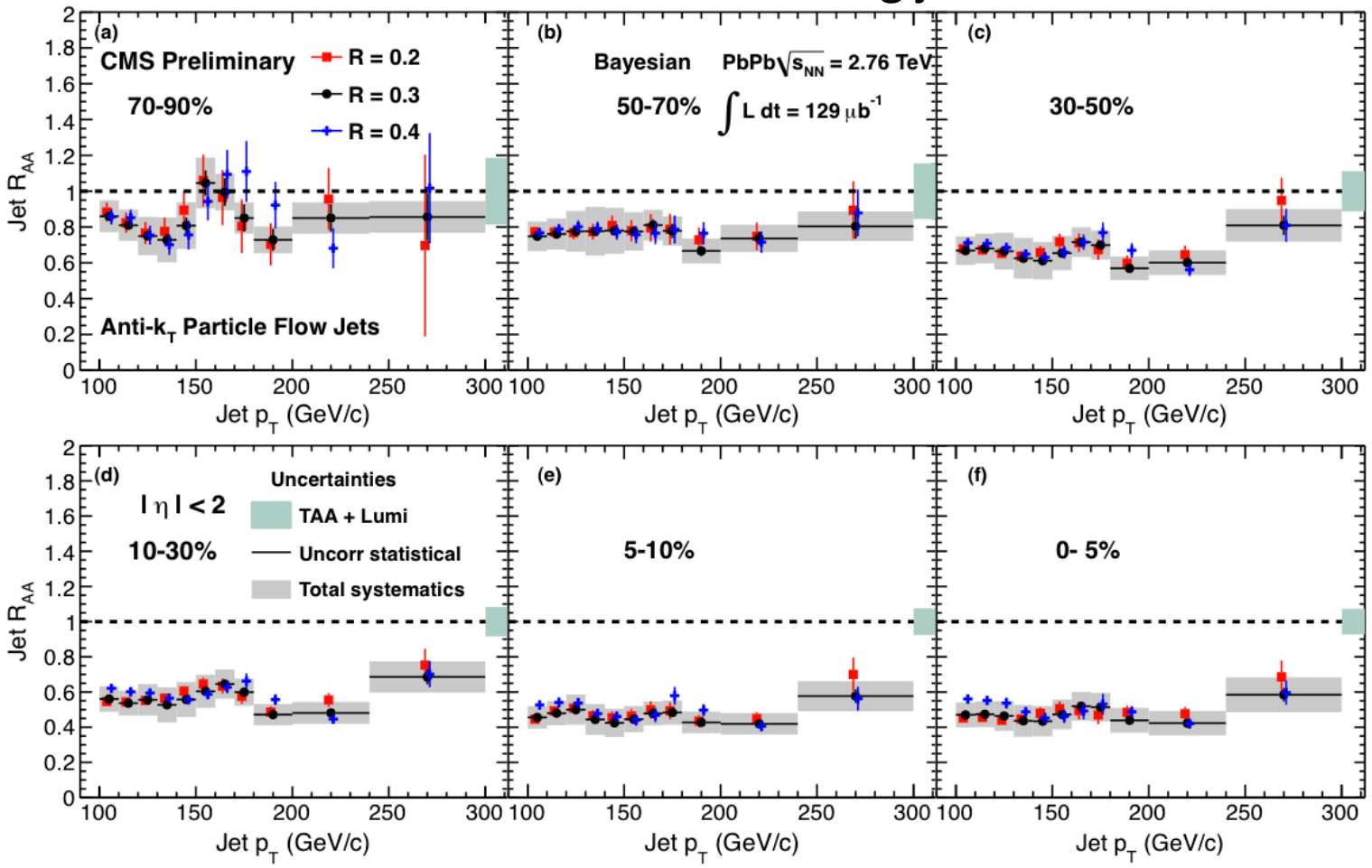

- How much energy lost on average?
- How much does it vary?
- What is the path-length dependence?

PLB 712 (2012) 176



# Jet $R_{AA}$:

## How much E does the leading jet lose?

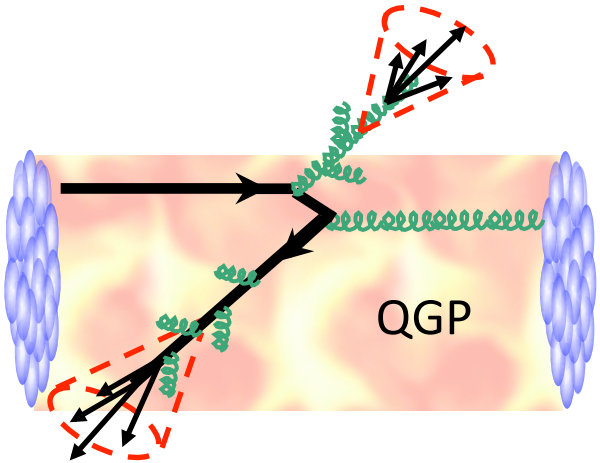



Jet $p_T$ spectrum suppressed in PbPb, w.r.t. pp

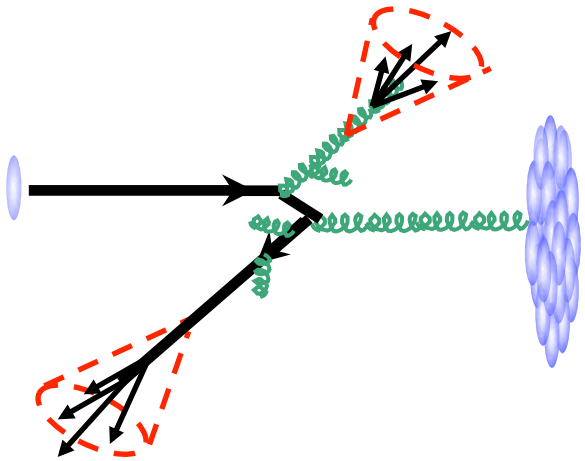
OK, what does this tell us about energy loss?

CMS-PAS-HIN-12-004

## PbPb collisions

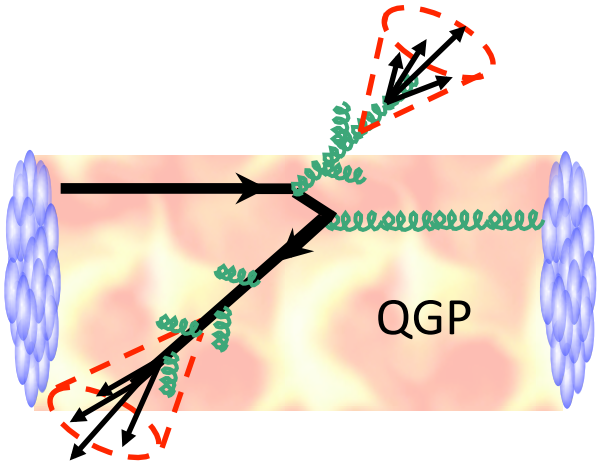



## pPb collisions

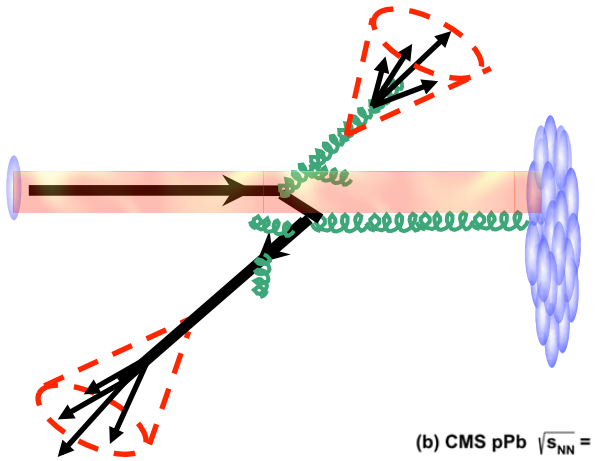


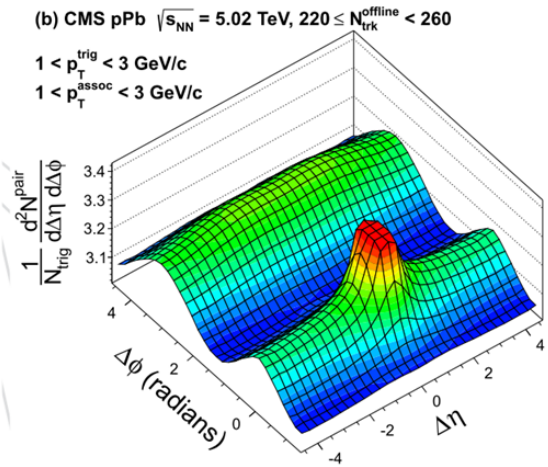
- Baseline for PbPb collisions
  - Cold nuclear effects, nPDFs

## PbPb collisions




## pPb collisions



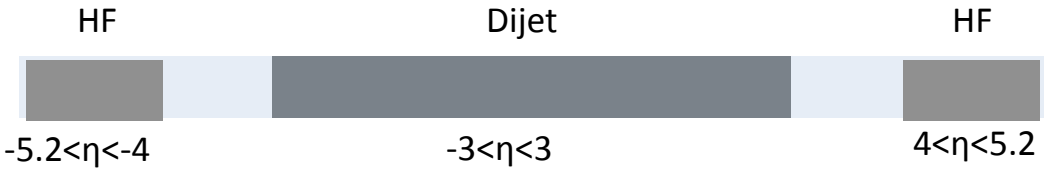



- Baseline for PbPb collisions
  - Cold nuclear effects, nPDFs

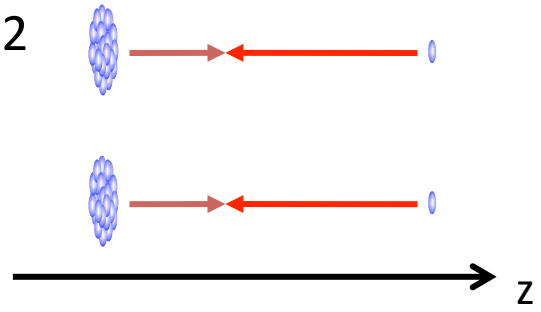
**Do we ALSO see an onset of density effects in pPb already?**

# Event characterization

- ZDC based variables (spectators)
  - Not very well-correlated to the energy density at mid-rapidity
- Mid-rapidity based variables
  - Significant auto-correlation with jet configuration
- Forward calorimeter based variables:
  - Single side?
  - Two sides together?



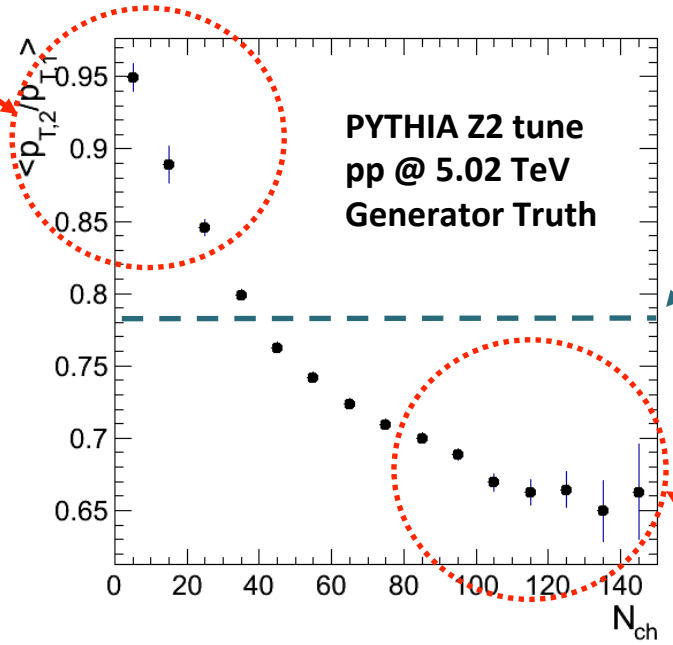

**Final choice:** $E_T$ measured in $4<|\eta|<5.2$



# Tracker based variables

- Introduce bias on number of jets and their fragmentation:

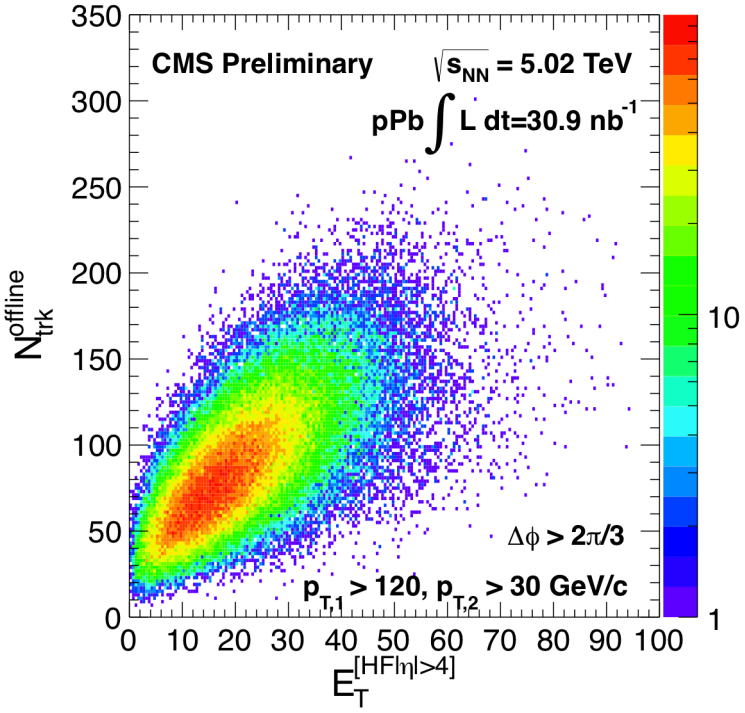
Event less likely to have 3 (or more) jets

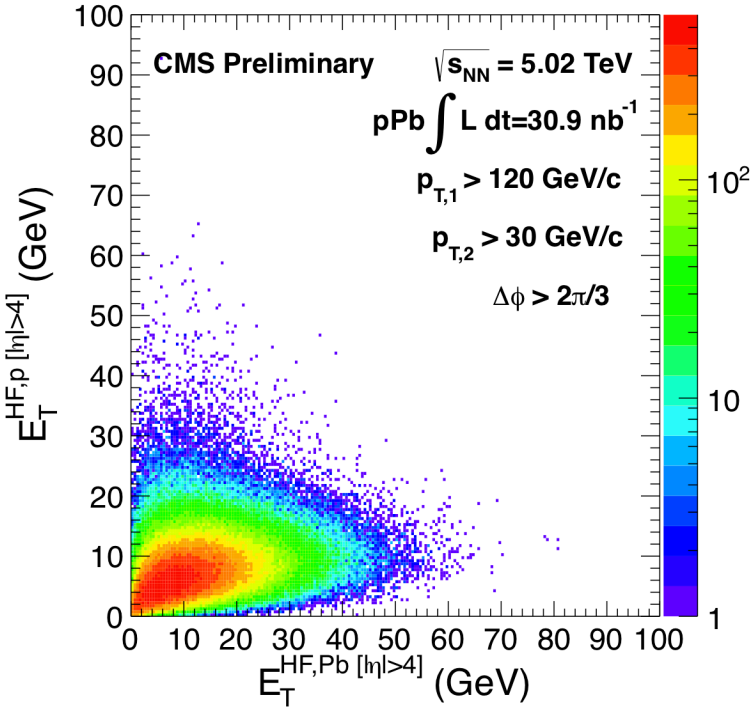



Mean value for all generated dijets

Event more likely to have 3 (or more) jets
Each jet means additional $N_{ch}$ ~ 10.

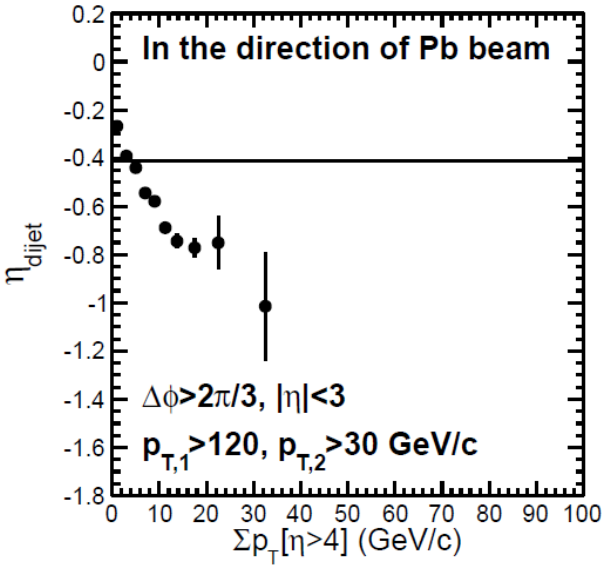
# Forward energy based variables

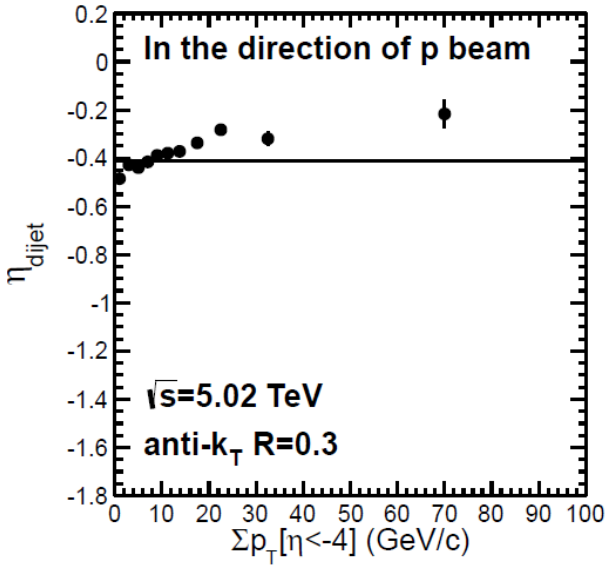


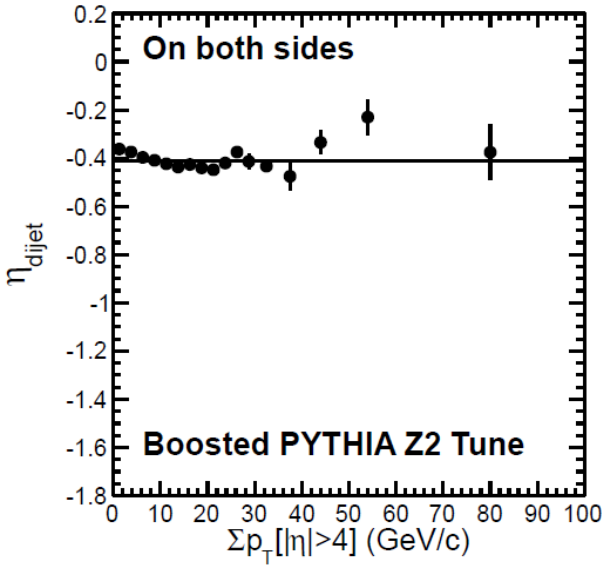



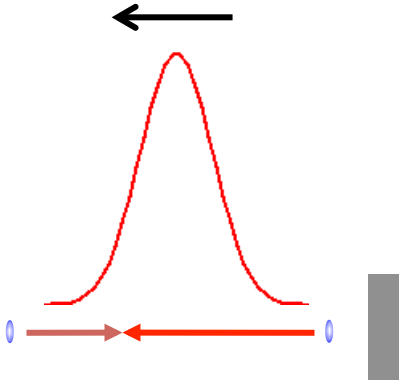
# Forward energy based variables

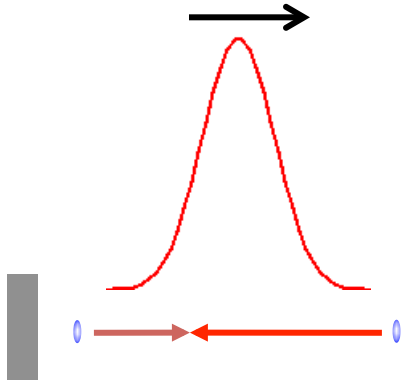
$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2}$$



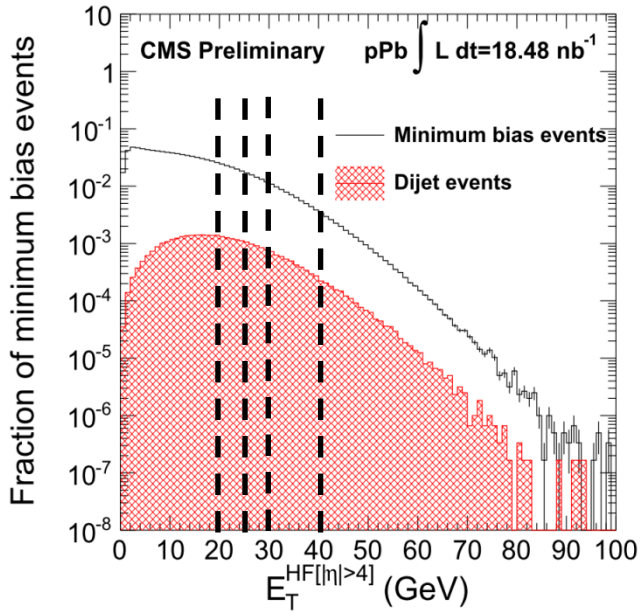



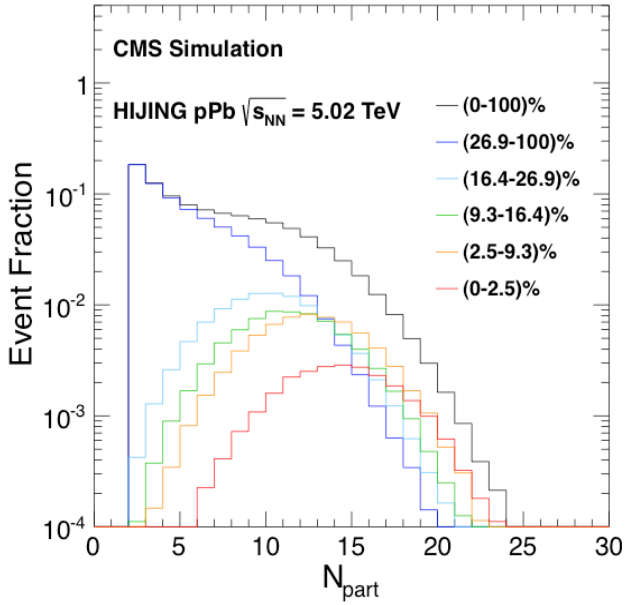





## Energy momentum conservation:

When a large deposit on one side is required the dijet pseudorapidity shifts towards the other direction.

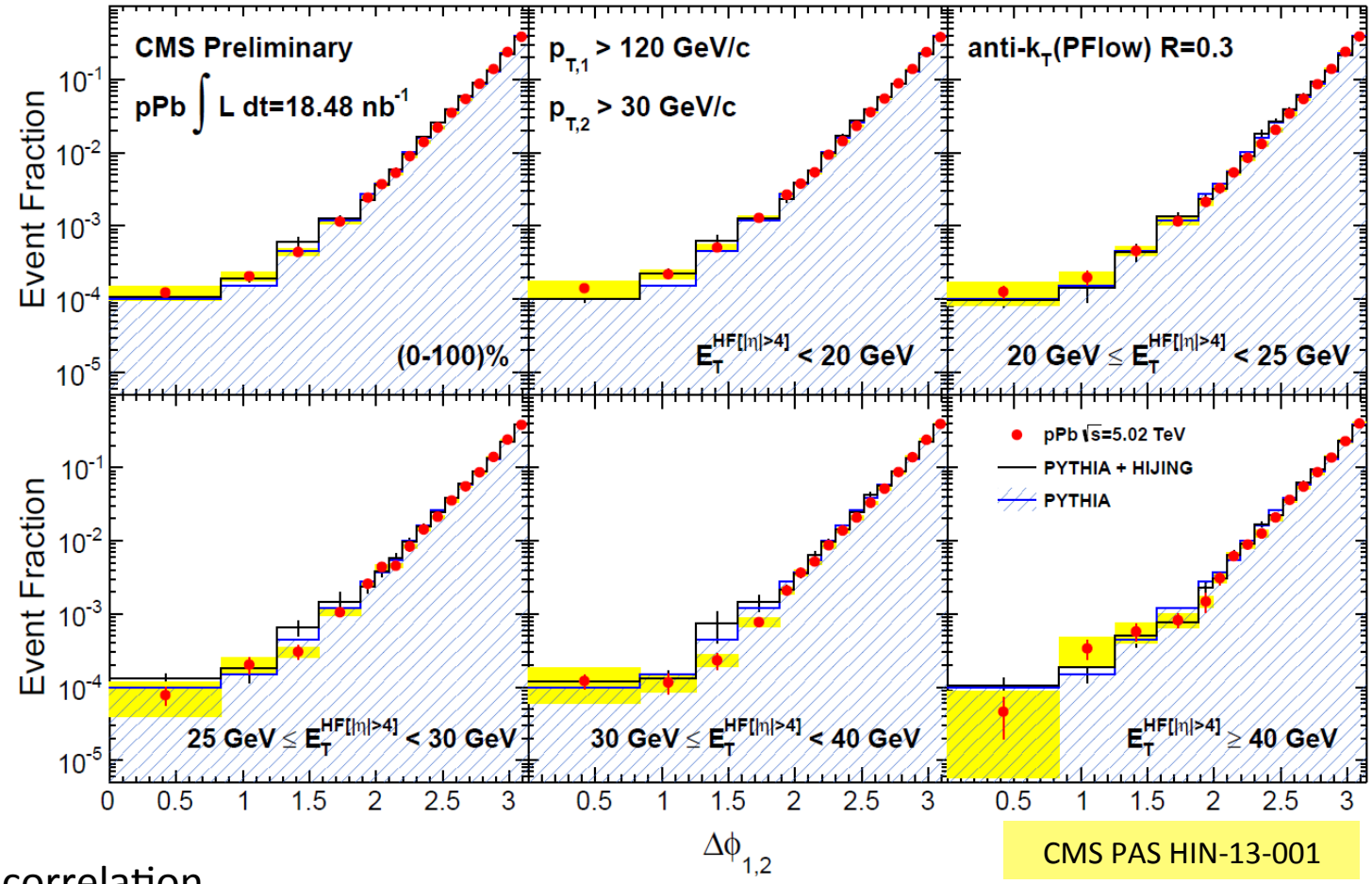



| $E_T^{HF[\lvert\eta\rvert>4]}$ range (GeV) | Fraction of DS events | Fraction of dijet events | $\langle N_{trk}^{corrected} \rangle$ in DS events |
|---|---|---|---|
| 0-20 | 73.1% | 52.6% | 33±2 |
| 20-25 | 10.5% | 16.8% | 74±3 |
| 25-30 | 7.1% | 12.7% | 88±4 |
| 30-40 | 6.8% | 13.0% | 106 ±5 |
| 40-100 | 2.5% | 4.9% | 135 ±6 |

$N_{part}$ has a weak dependence on forward calorimeter energy in pPb.

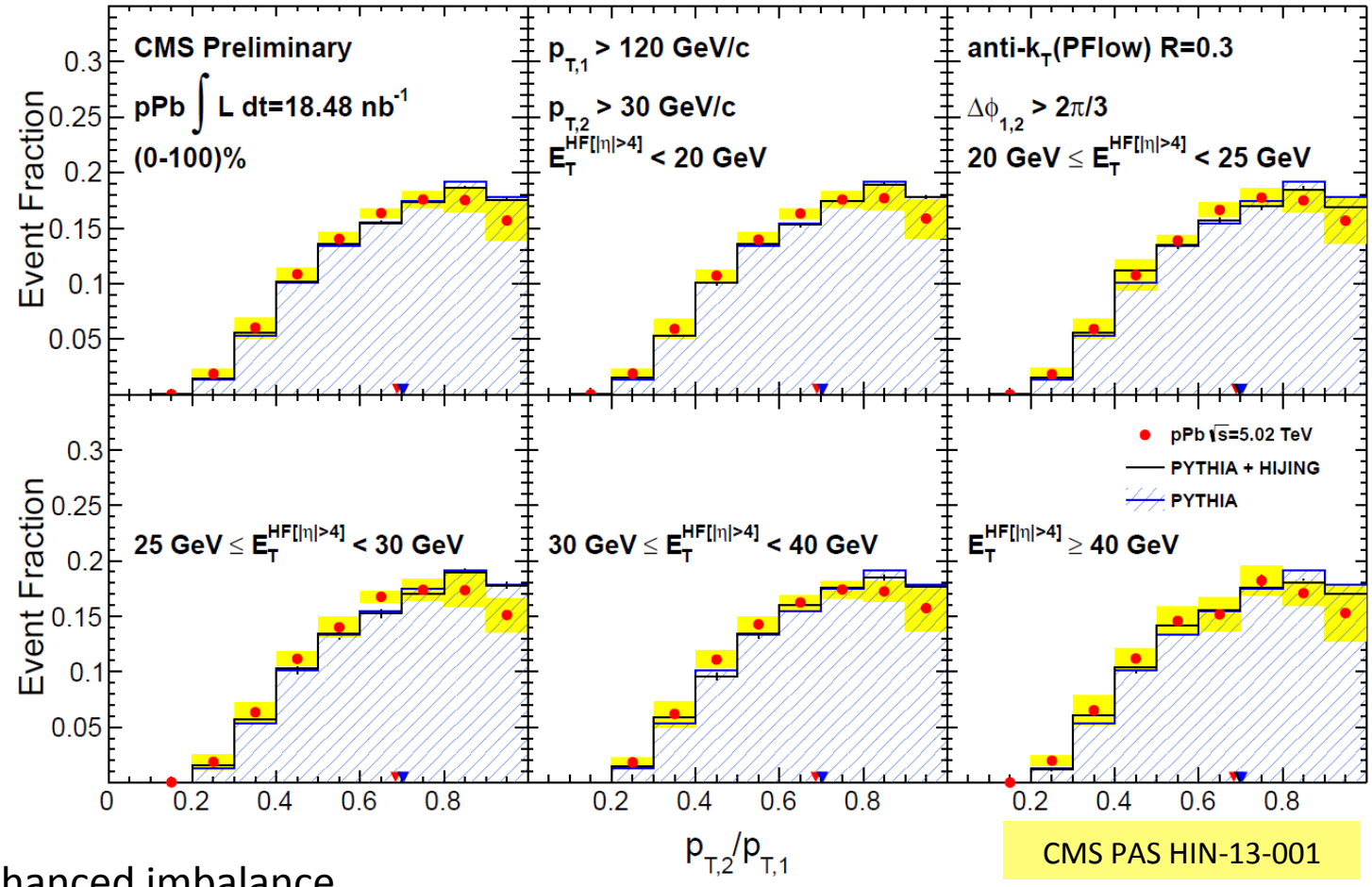
# Dijet angular correlations




CMS PAS HIN-13-001

Cannot see a decorrelation.

# Dijet momentum balance



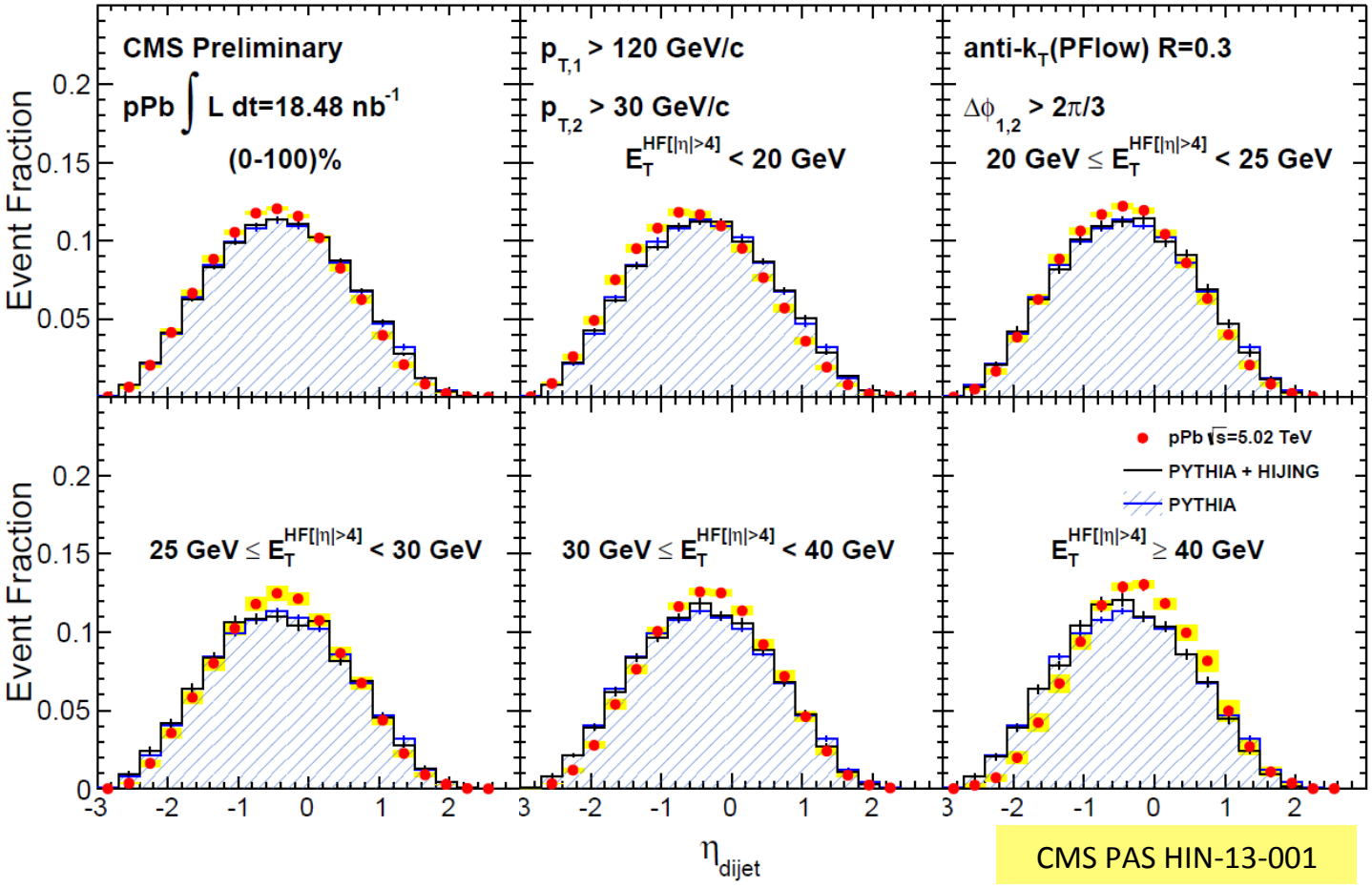

CMS PAS HIN-13-001

Cannot see an enhanced imbalance

# Dijet system pseudorapidity

$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2}$$

(an approximation to rapidity of the parton system)

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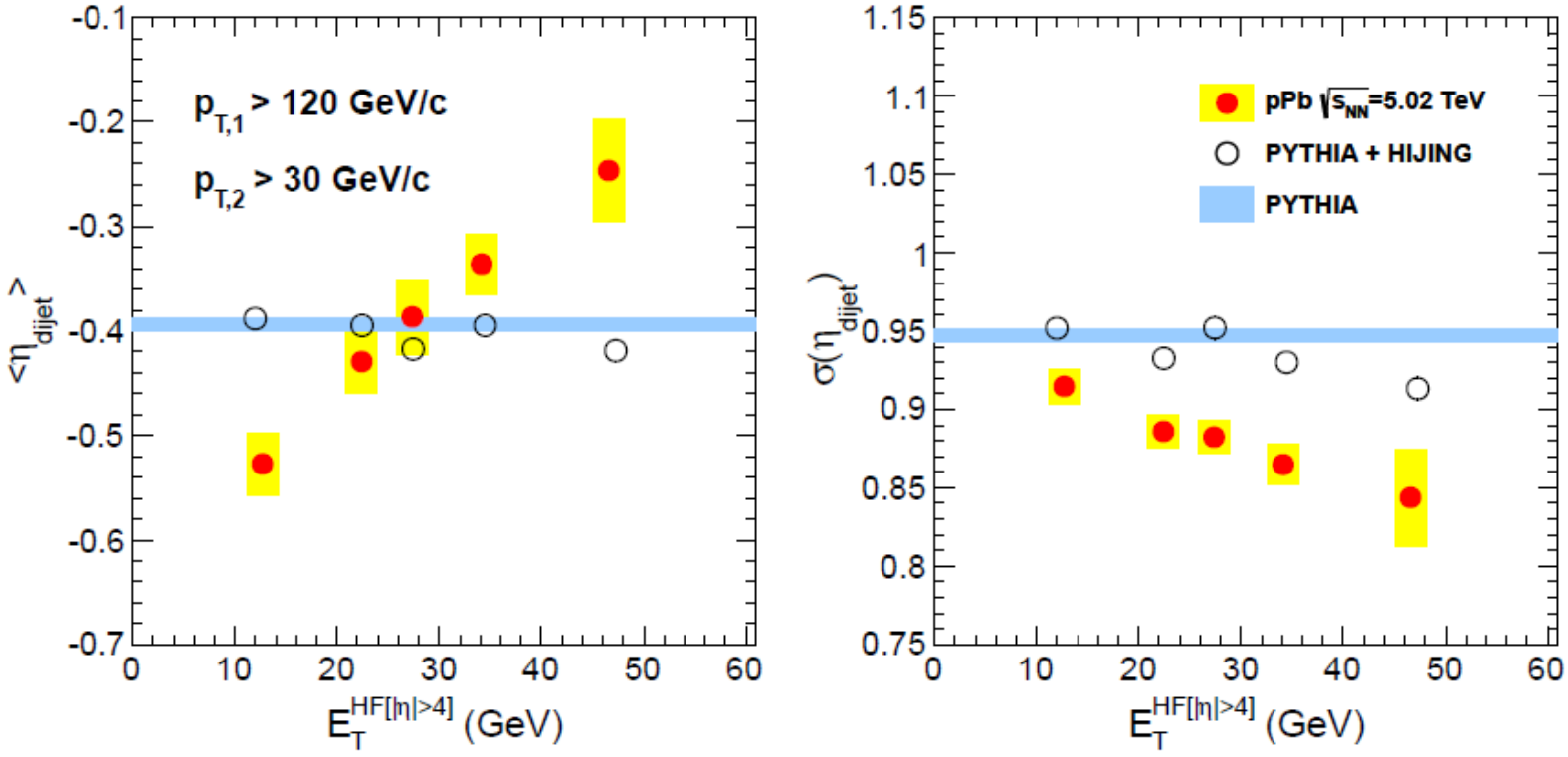
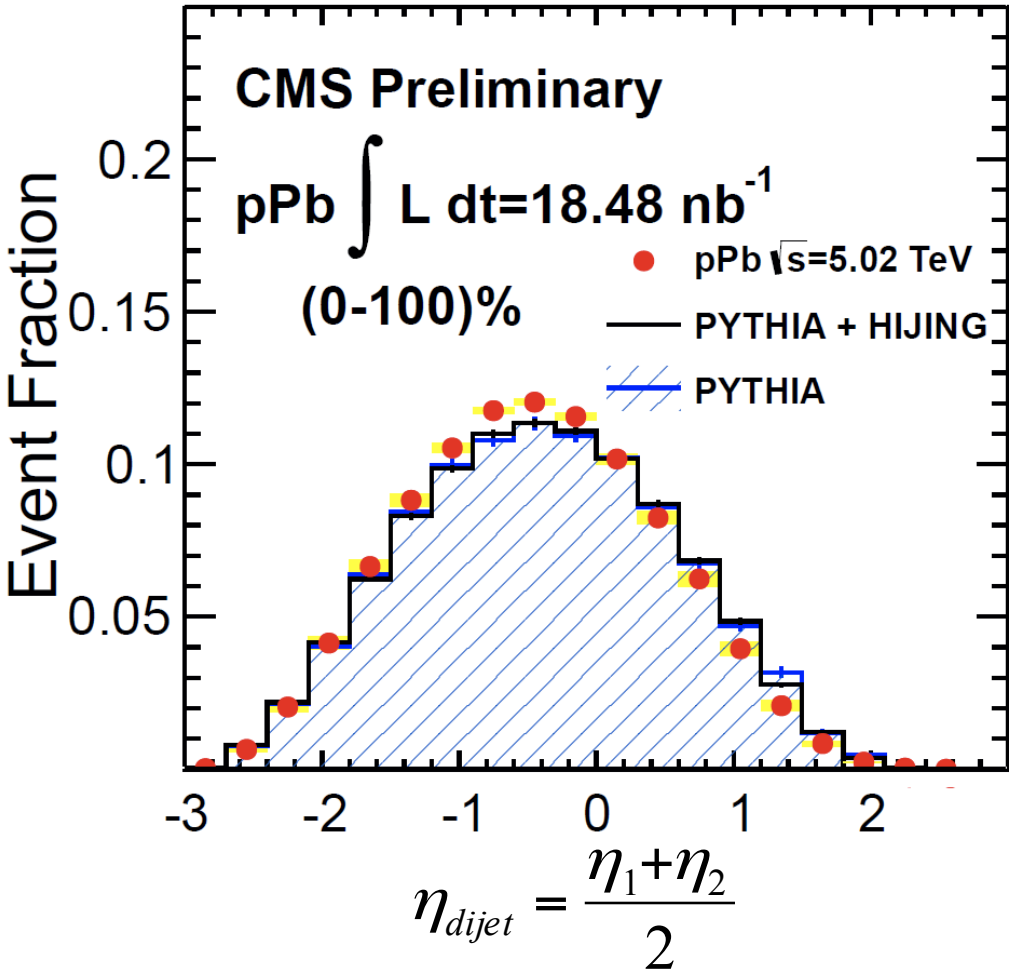
Observation of modification to the pseudorapidity distribution

# Summary of dijet eta vs HF




- Mean of $\eta_{dijet}$ increases v.s. forward calorimeter energy
- Width of $\eta_{dijet}$ decreases v.s. forward calorimeter energy (also in MC reference)

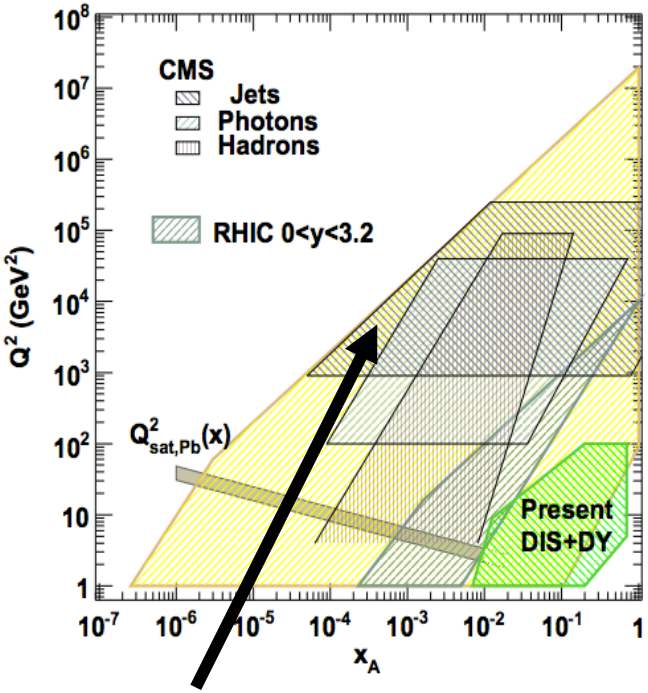
# Dijet eta for 0-100%




- The modification in eta is significant in 0-100% selection, without any bias.

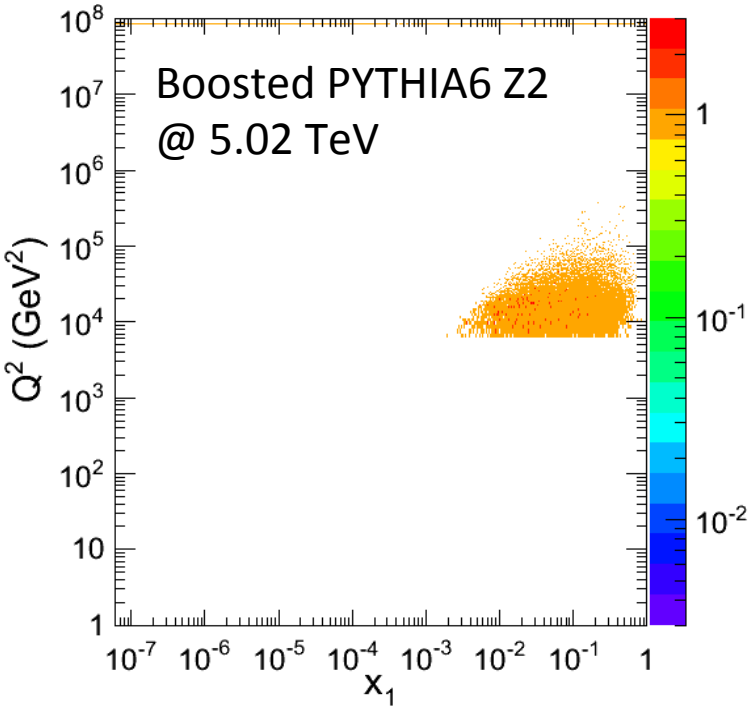
# Probing PDFs

Kinematic reach for CMS, pPb @ √s = 8.8 TeV (0.1 $pb^{-1}$)




Jets cover high $Q^2$ and $10^{-4}<x<1$.

C.A. Salgado, et. al. J.Phys. G39 (2012) 015010

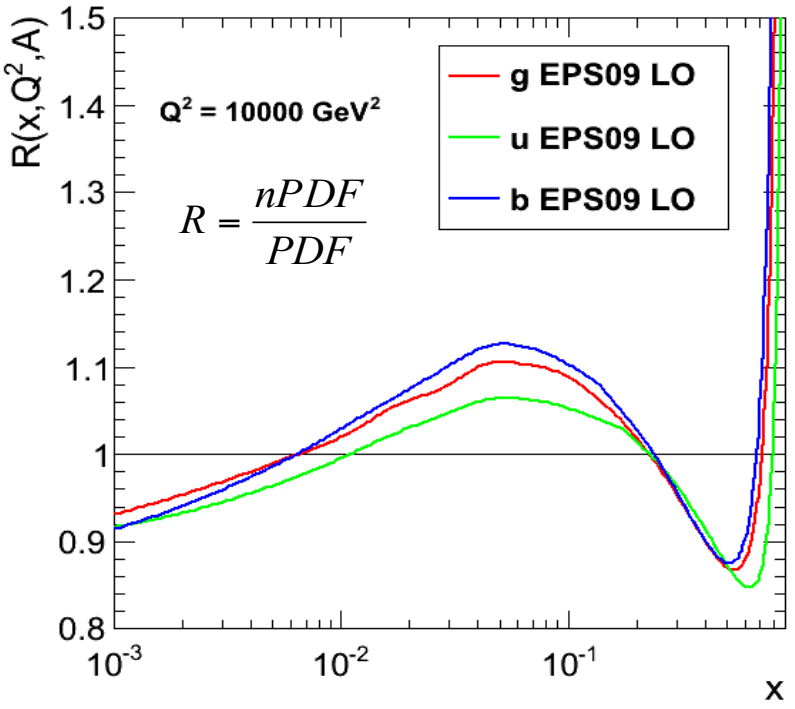



With the dijet selection of the analysis:

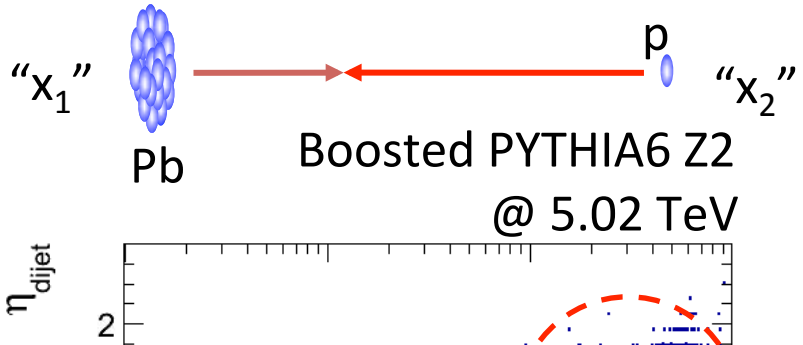
$p_{T,1} > 120$ GeV/c, $p_{T,2} > 30$ GeV/c,
$\Delta\phi_{12} > 2\pi/3$

# Dijet η ←→ x

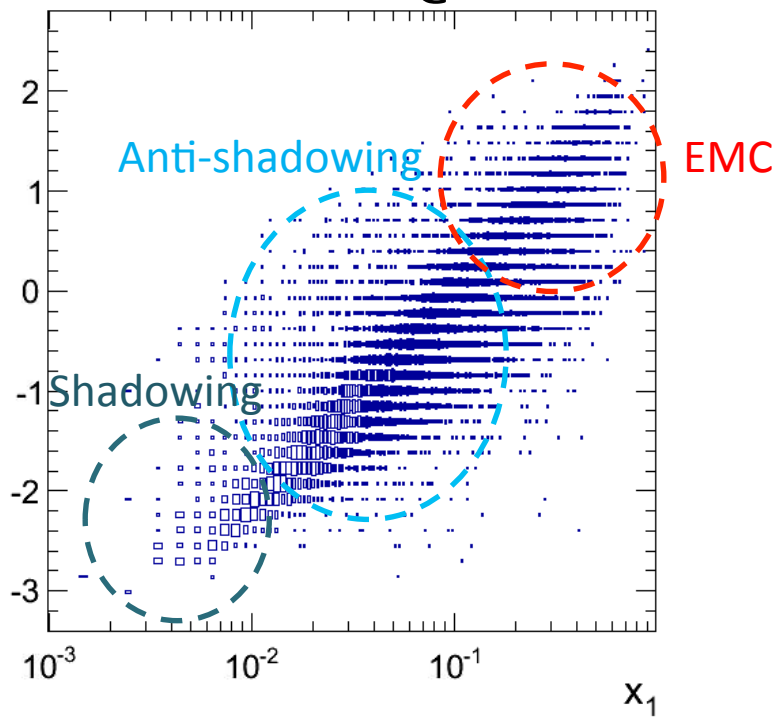
François Arleo and Jean-Philippe Guillet
http://lapth.cnrs.fr/npdfgenerator/



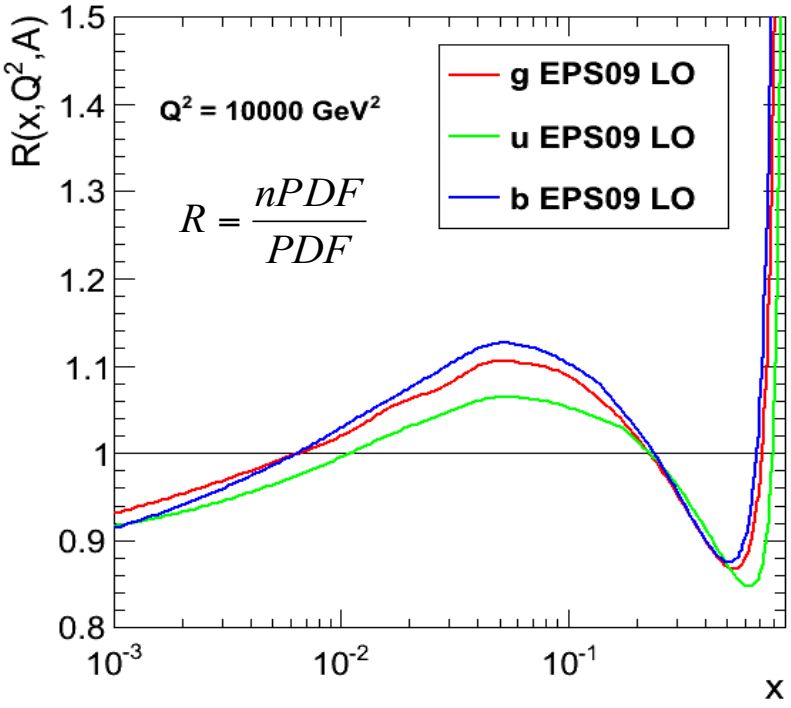

$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2}$$



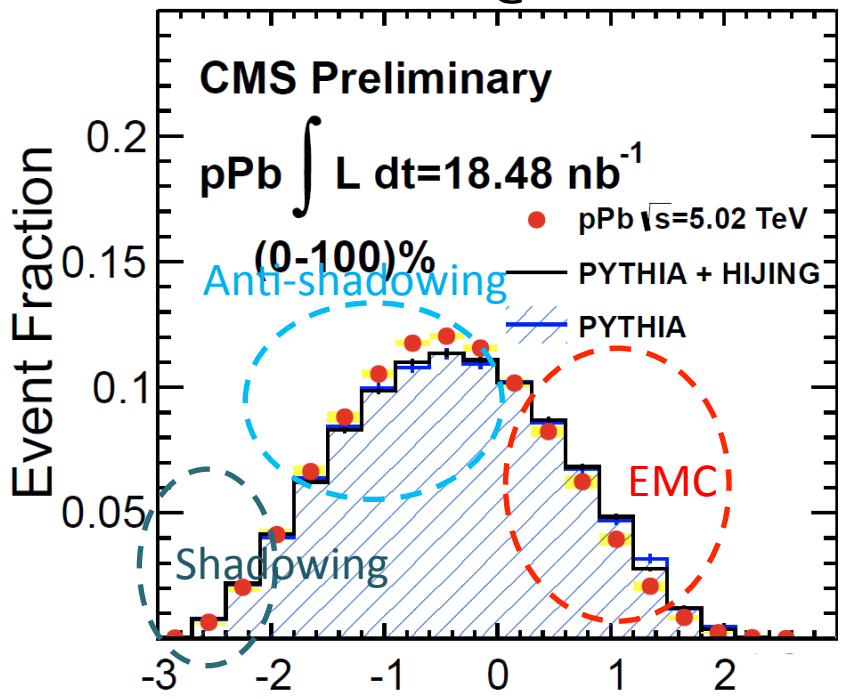

Boosted PYTHIA6 Z2
@ 5.02 TeV



# Expected nPDF effects



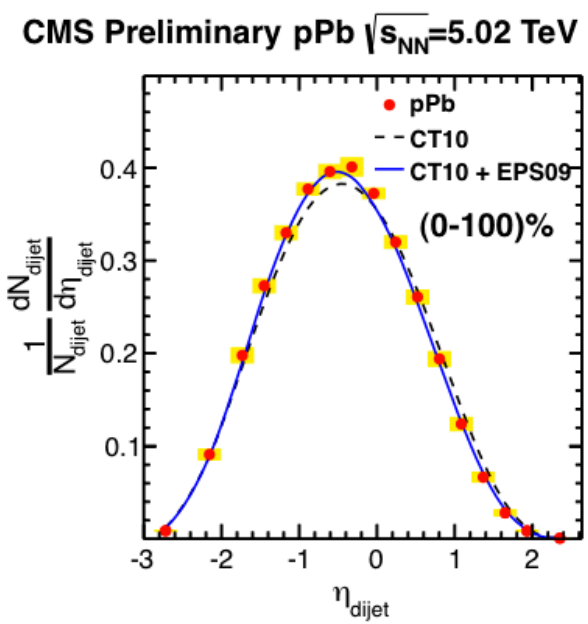


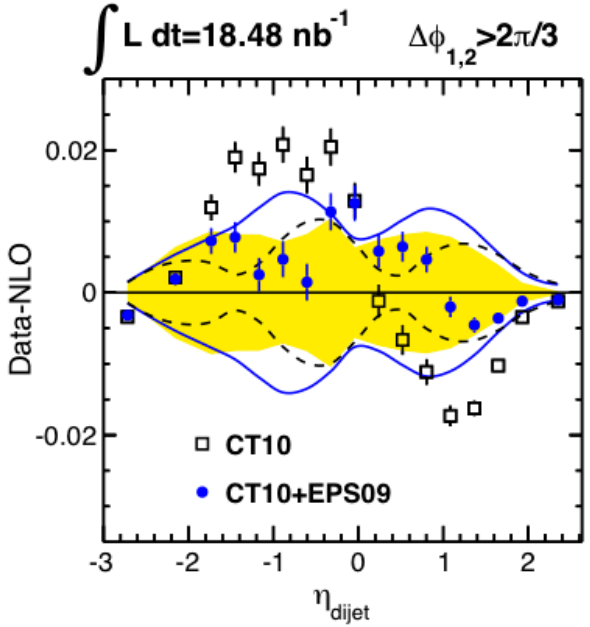


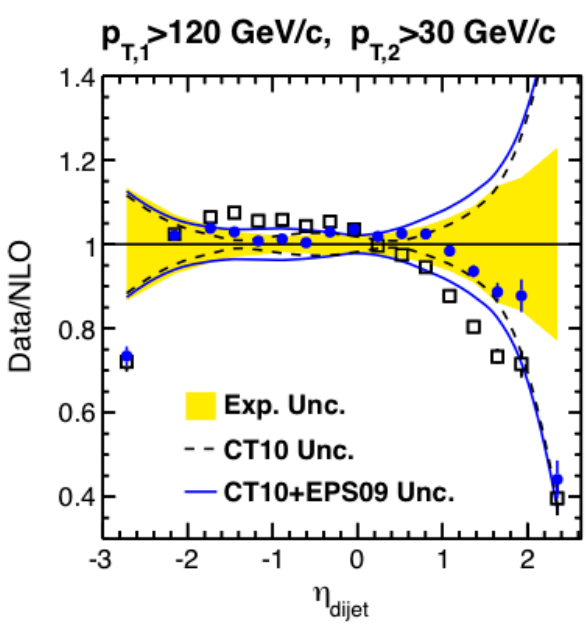

- Observe similar enhancement/suppression in dijet η as predicted for parton x by EPS09 collaboration.

$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2}$$

# Comparison to NLO calculations



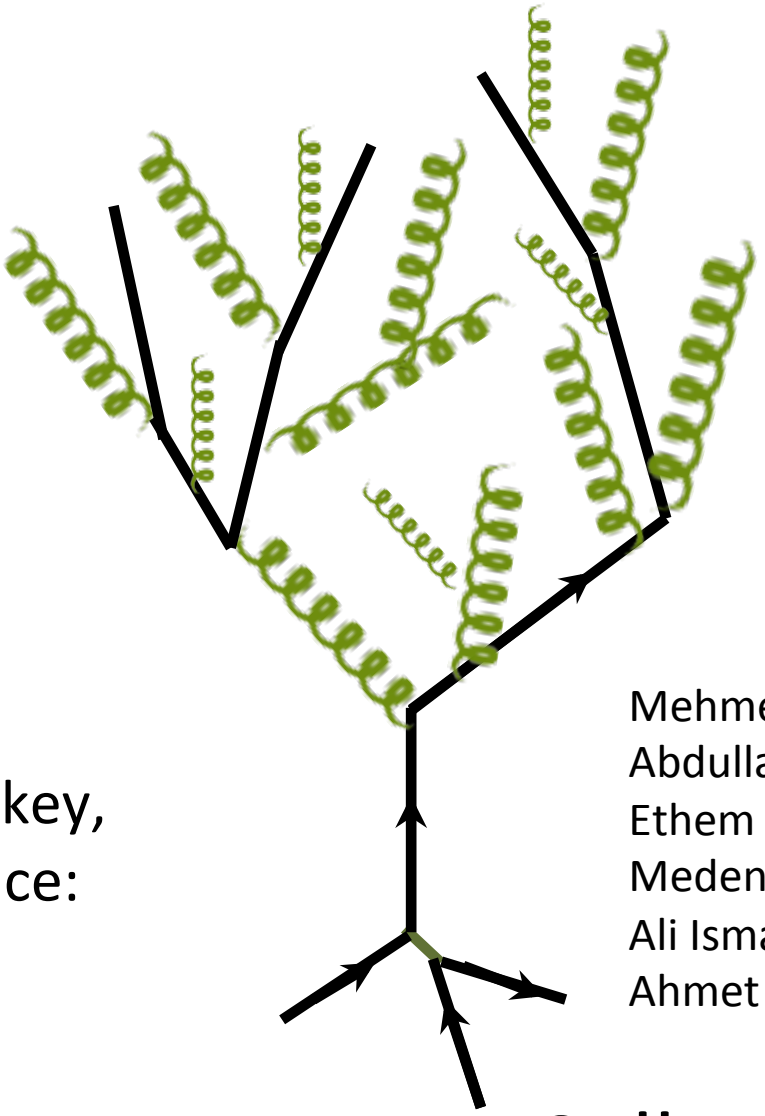




- Results are compatible with EPS09 prediction
- Not compatible without EPS09

# Conclusions

- pPb data is rich in physics
- The classification of dijet events in terms of their bulk properties is a challenging task
- No quenching effects observed
- Possibly initial-state effects observed in dijet kinematics
- The average eta of the dijet system is shifted towards the side of Pb fragments
  - The low-x PDF in proton may be suppressed

# IN MEMORY OF...

... the
TREEHUGGERS of Turkey,
killed by police violence:

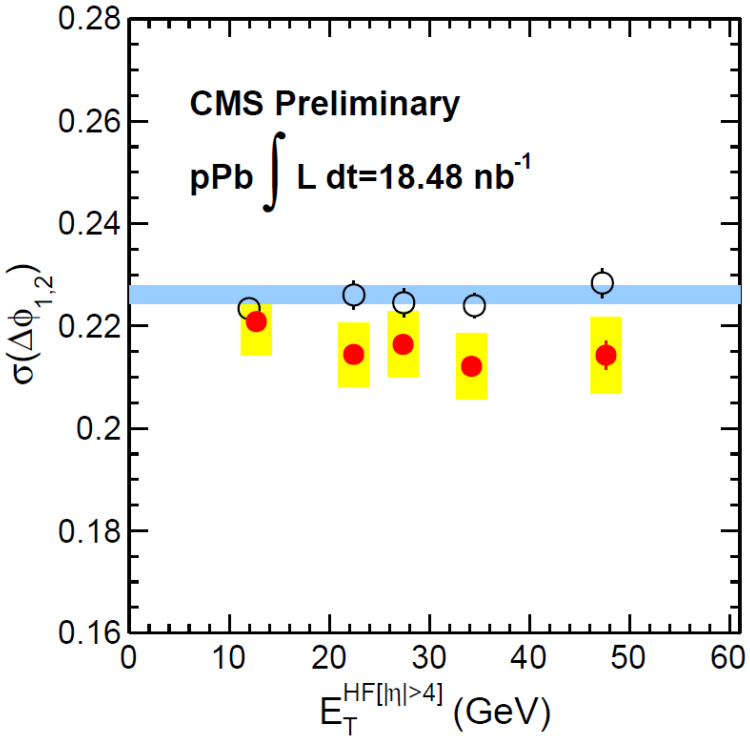
Mehmet Ayvalitas (3 June 2013)
Abdullah Comert (4 June 2013)
Ethem Sarisuluk (12 June 2013)
Medeni Yildirim (28 June 2013)
Ali Ismail Korkmaz (10 July 2013)
Ahmet Atakan (9 September 2013)

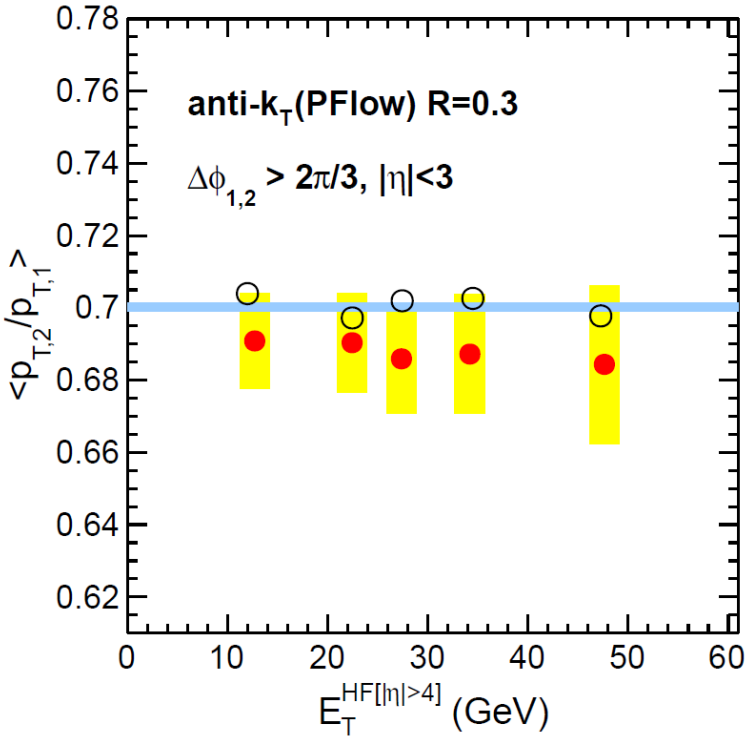
info: https://www.facebook.com/CollectifDeTaksim

# back up

# Summary of $p_T$ ratios and $\Delta\phi$

CMS PAS HIN-13-001

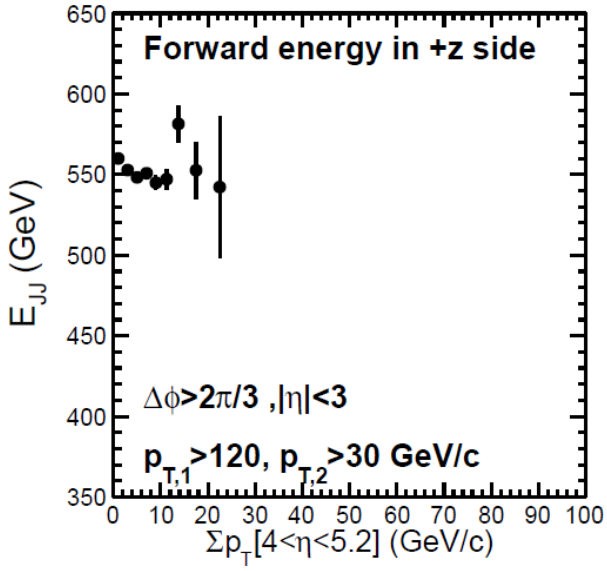


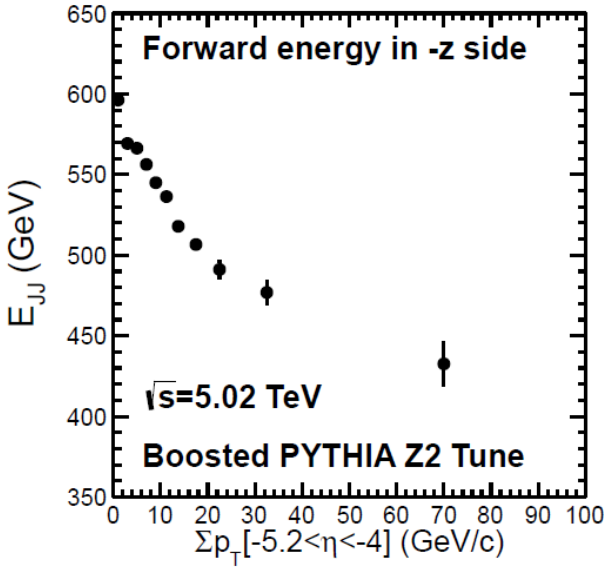



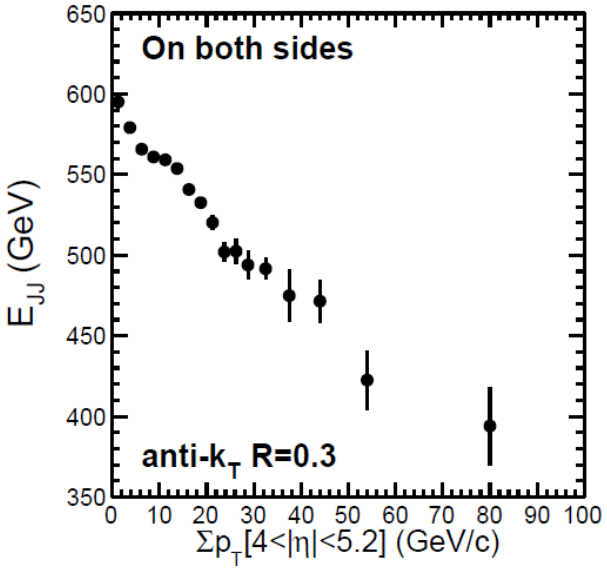

- With the current systematic uncertainty, no detectable change in $\langle p_{T,2}/p_{T,1}\rangle$ and $\Delta\phi$ width larger than 2% as a function of forward calorimeter energy,
- **These results allow us to use jets for nPDF determination.**

# Bias due EM conservation?

Why does the dijet pseudorapidity get narrower by increasing forward energy?



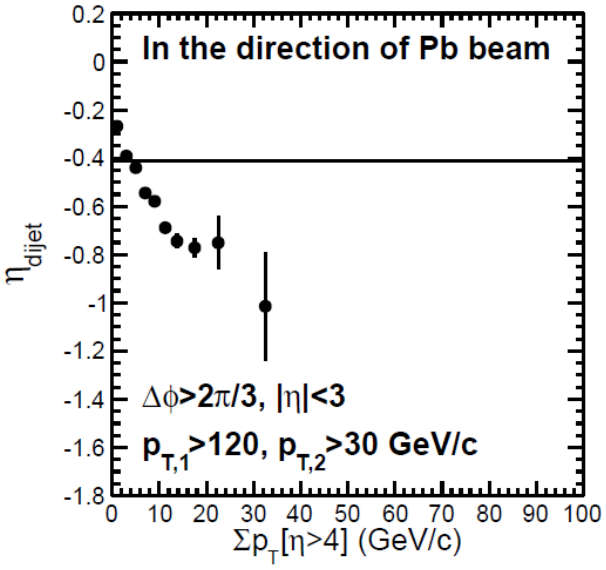

$$E_{JJ} = p_{T,1}\cosh(\eta_2) + p_{T,1}\cosh(\eta_2)$$

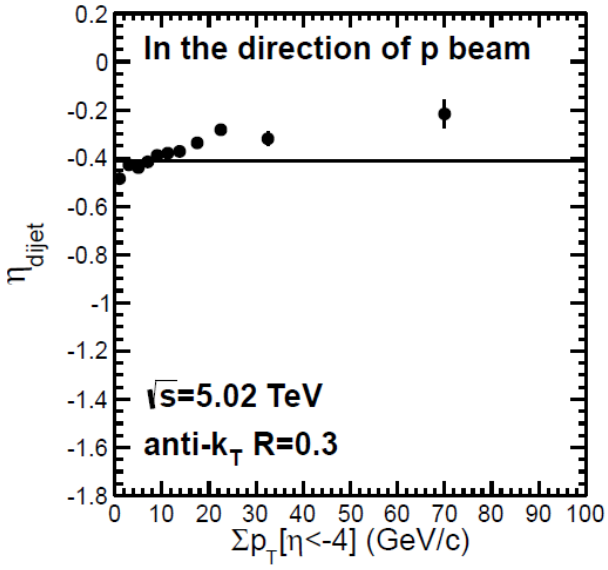
As forward energy in the event increases the energy that is left to dijet pair decreases.

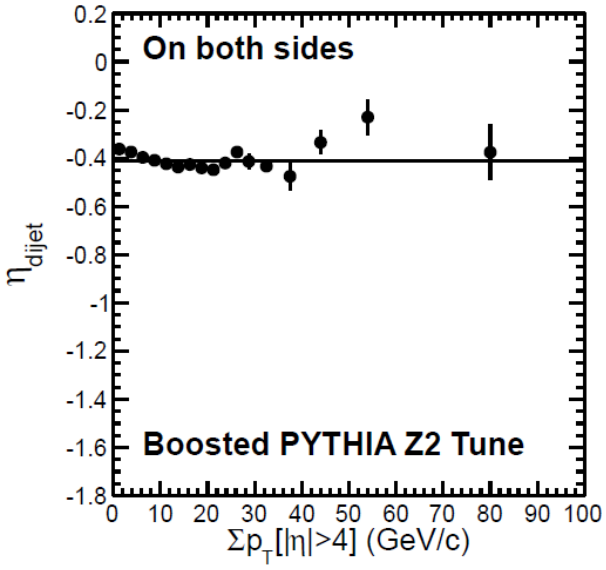
This trend is smaller if you look at +z side. Why ?

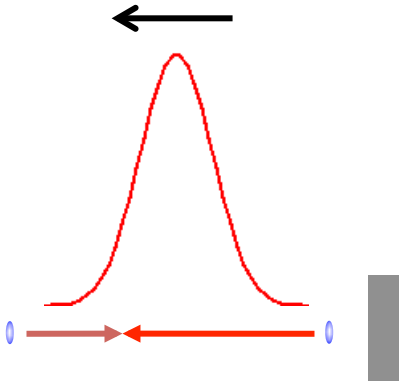
# Forward energy deposit

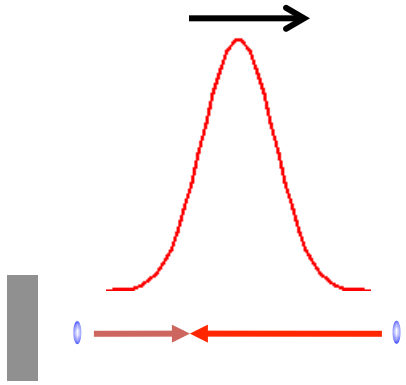
$$\eta_{dijet} = \frac{\eta_1+\eta_2}{2}$$



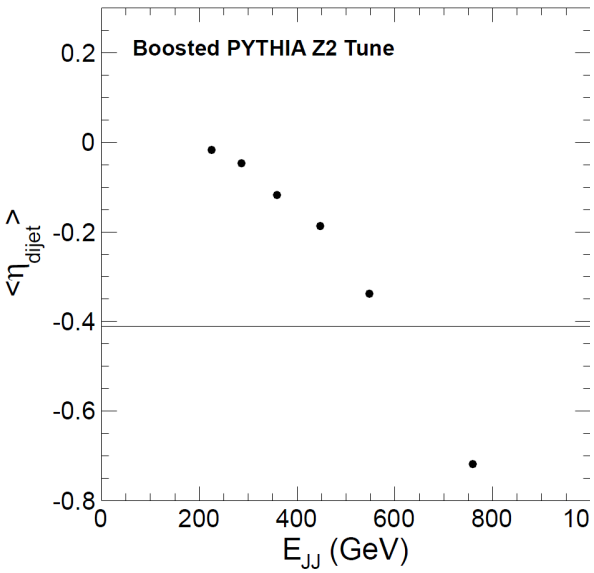


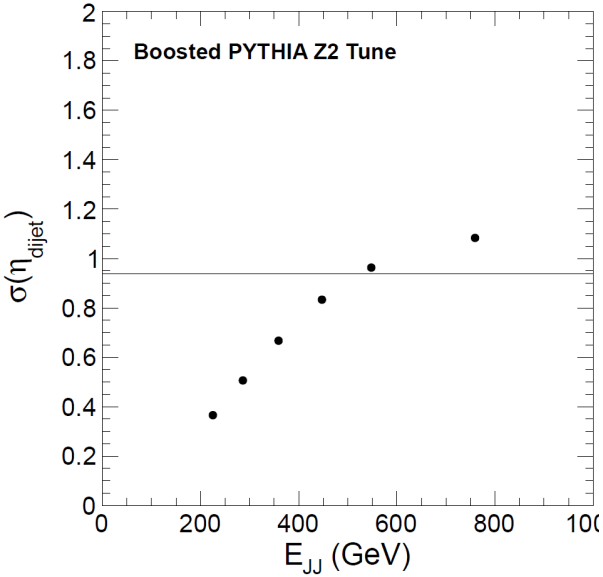
## Energy momentum conservation:

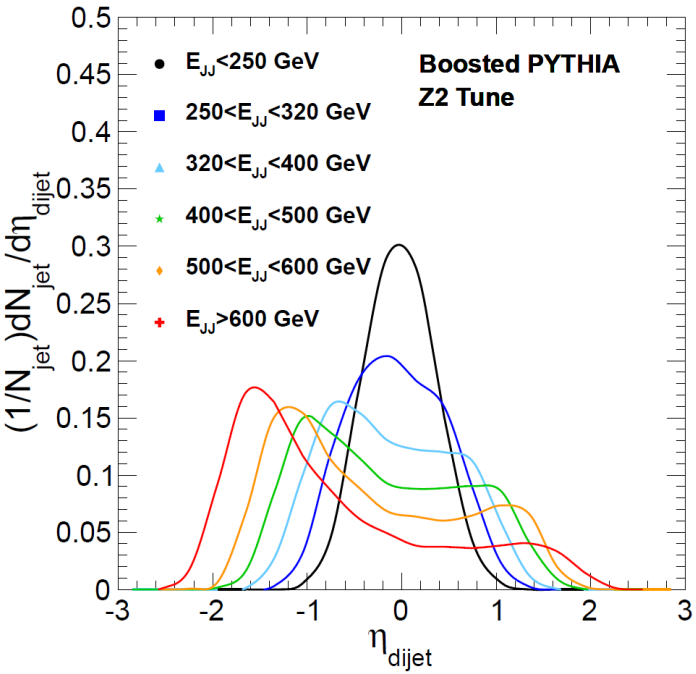
When a large deposit on one side is required the dijet pseudorapidity shifts towards the other direction.

# Bias due EM conservation?

Does this also result in a shift?




$E_{JJ} = p_{T,1} \cosh(\eta_2) + p_{T,1} \cosh(\eta_2)$

Could be the case? How much of an effect?