Jets and high-p_T hadrons in CMS

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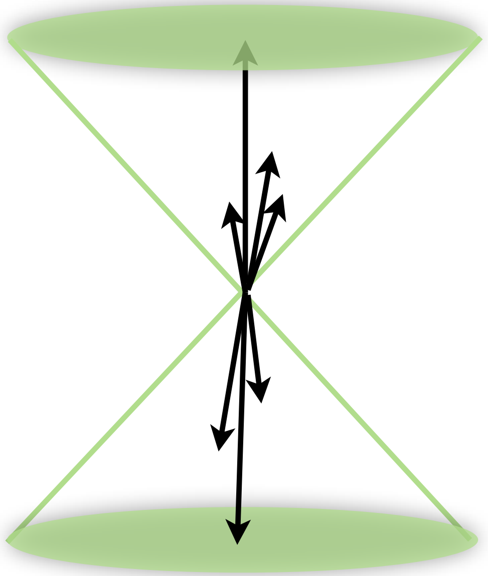
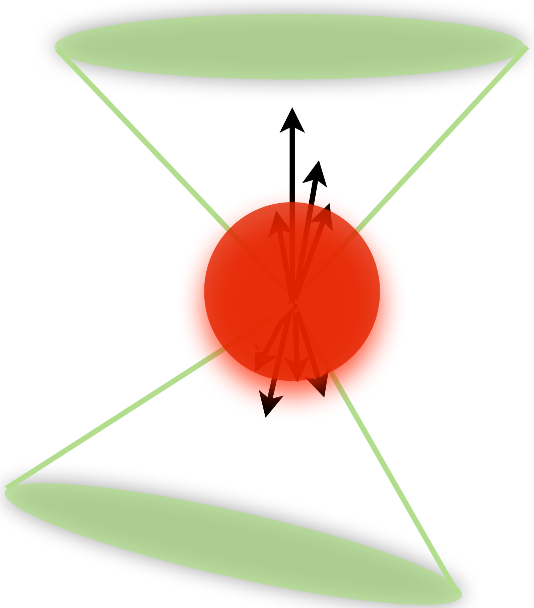
for the CMS Collaboration

VANDERBILT UNIVERSITY

International Conference on the Initial Stages in High-Energy Nuclear Collisions
September 8th-14th, 2013

Objective

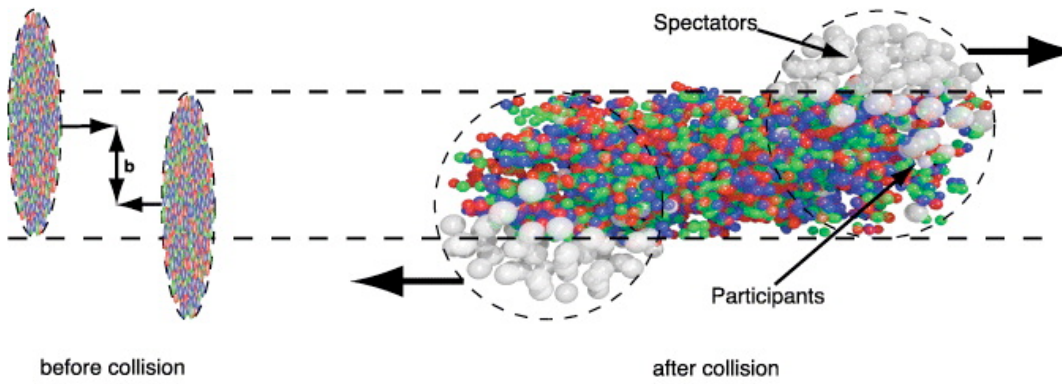




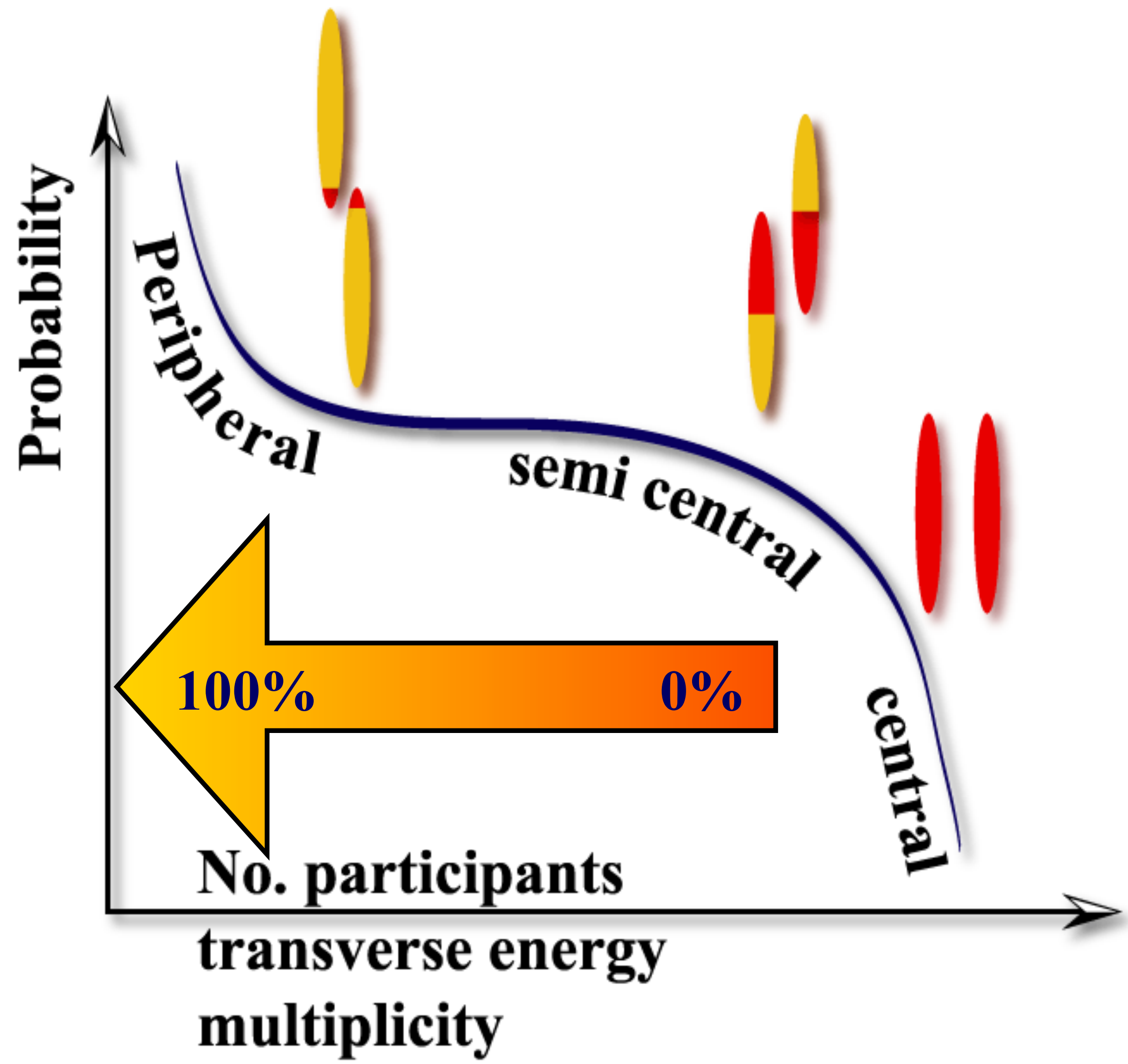
- Exploit high p_T particles and jets to understand initial and final state properties of heavy-ion collisions:
  - High p_T partons produced in hard interactions in the initial phase of the collision...
    - in pp: understand and characterize the probe
  - ...Undergo multiple interaction inside the collision region prior to hadronization
    - in pA: benchmark for AA, disentangle initial from final state effects
    - in AA: probe the QCD medium created in the collision, identify final state effects

Centrality and comparisons to p+p

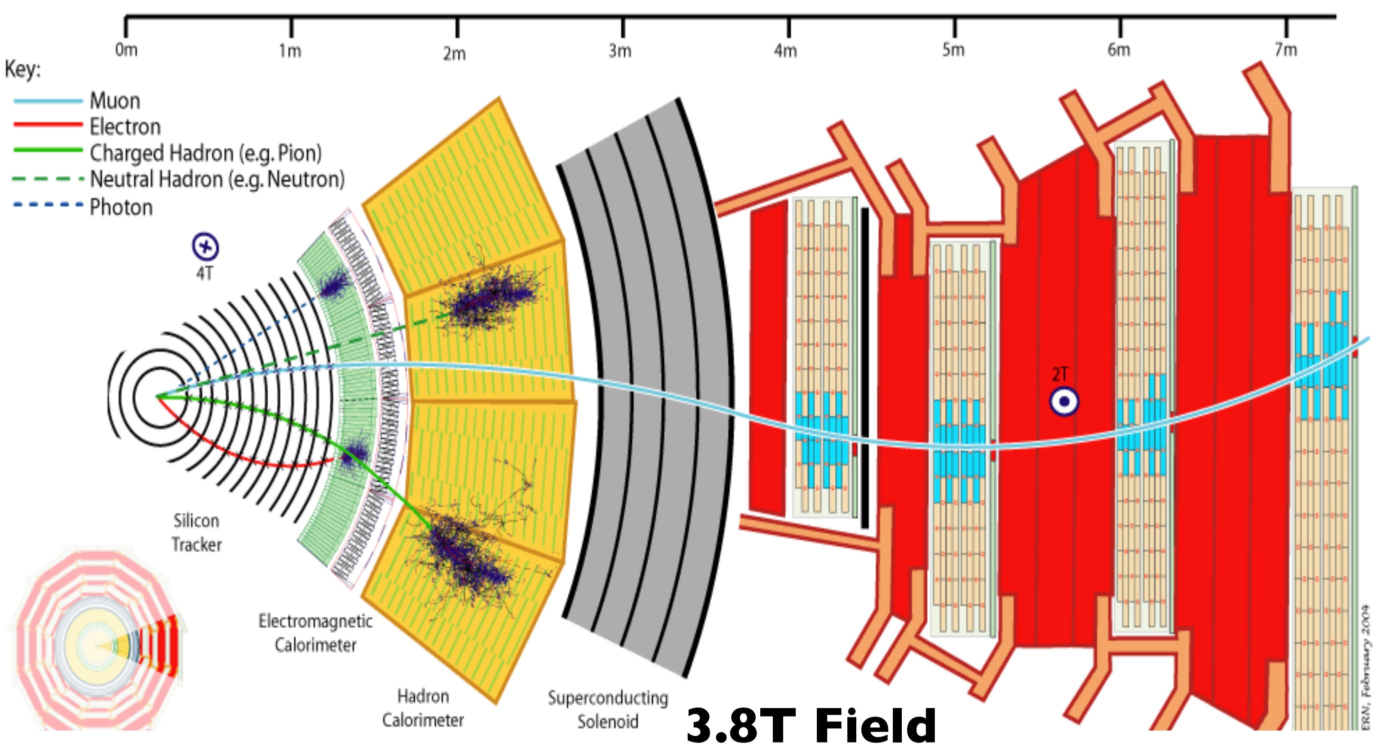
- Scaling factor to compare to p+p measurements
  - N_{part}: number of participant nucleons
  - N_{coll}: number of binary N+N collisions
    - both depend on the impact parameter (centrality) in pA and AA

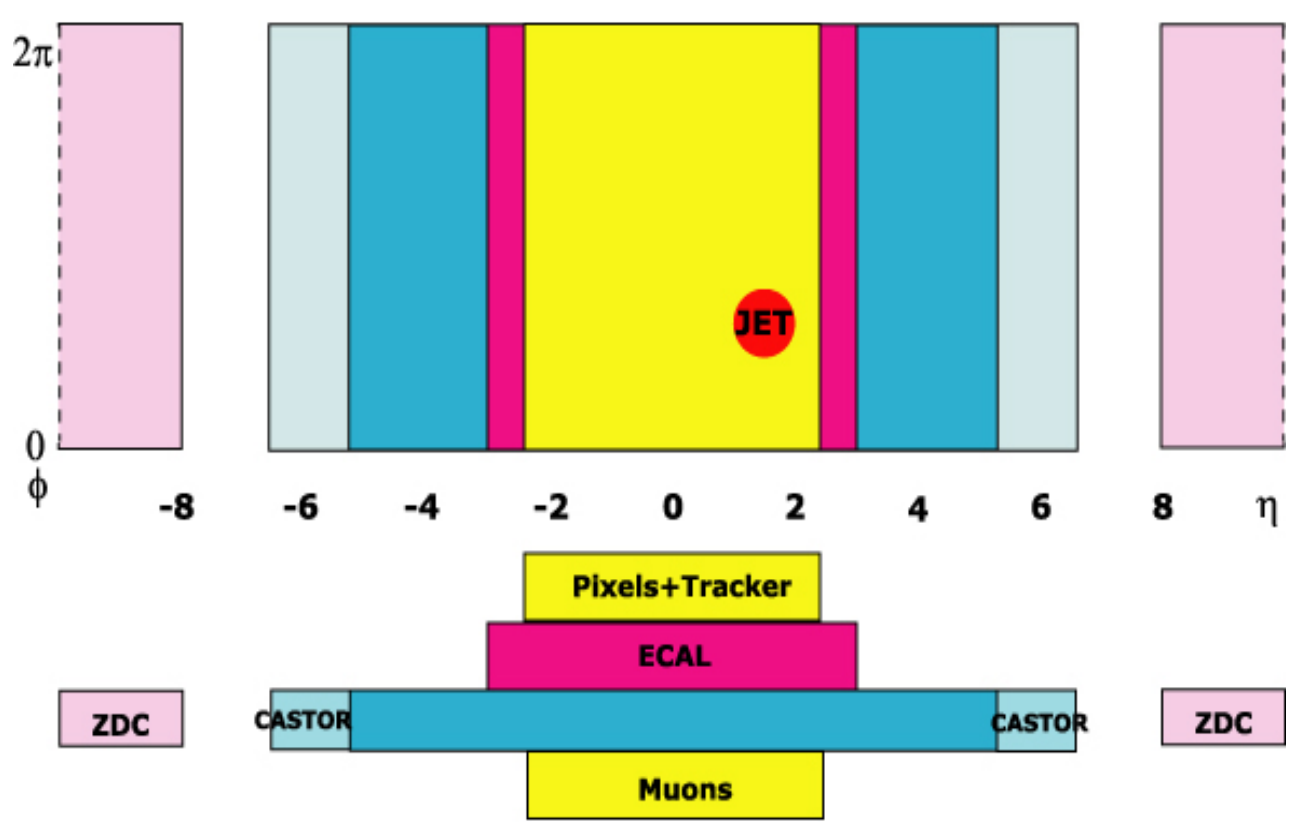


- Centrality estimation:
  - slicing the x-sec in forward energy
  - Simulation
  - Glauber model
    - ➡ see Shengquan Tuo's talk



CMS Detector capabilities



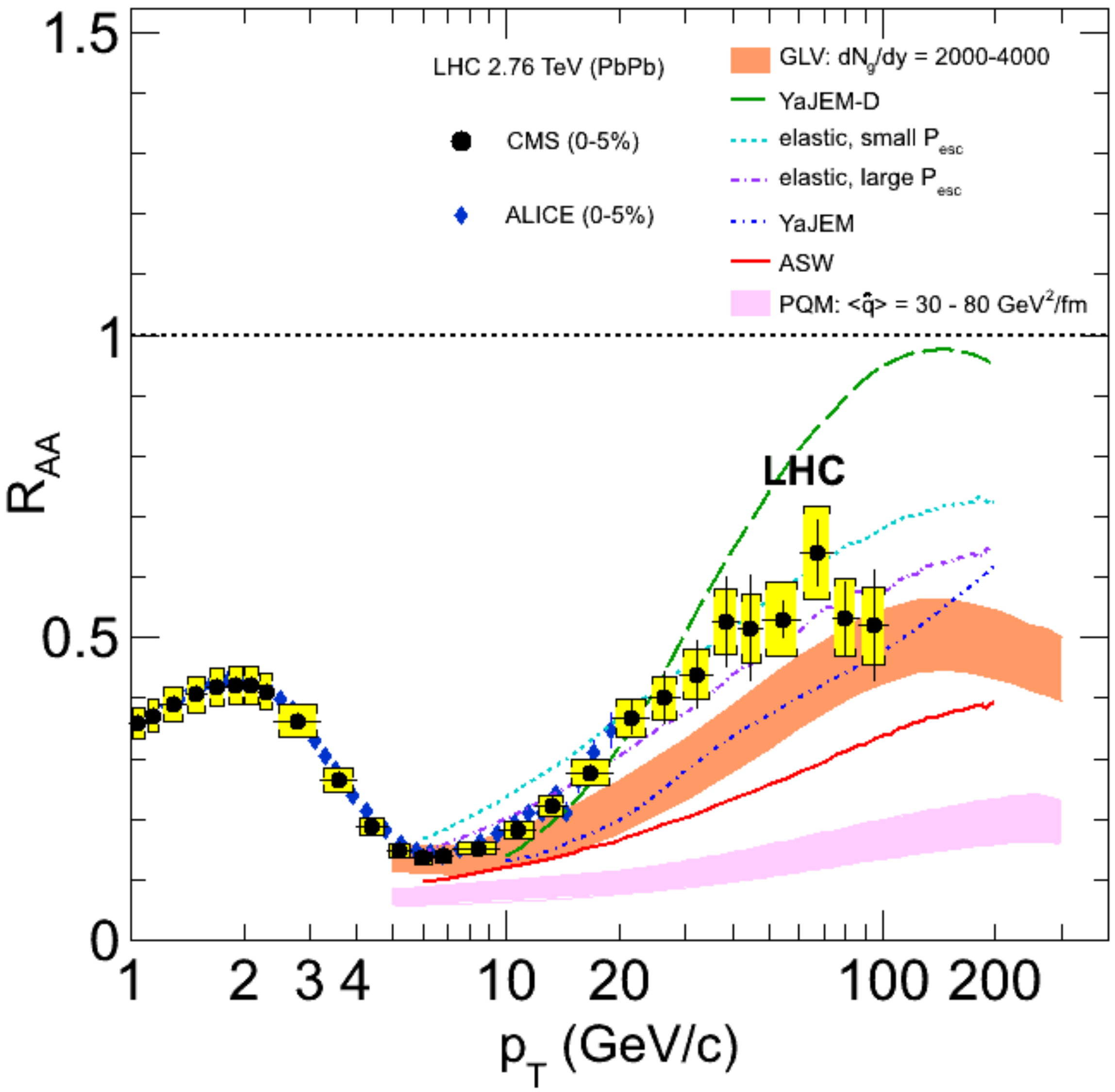


CMS is a multi-layer detector

- Excellent tracking capabilities
  - Momentum resolution of 1-2% to 100GeV/c
  - Displaced vertices for heavy flavor
- High-granularity calorimetry
  - Directly identifiable jets
  - γ-jet studies
- High Level Trigger
  - Higher energy reach
  - Ultra-central events
  - Improved J/ψ, Z^0, ϒ

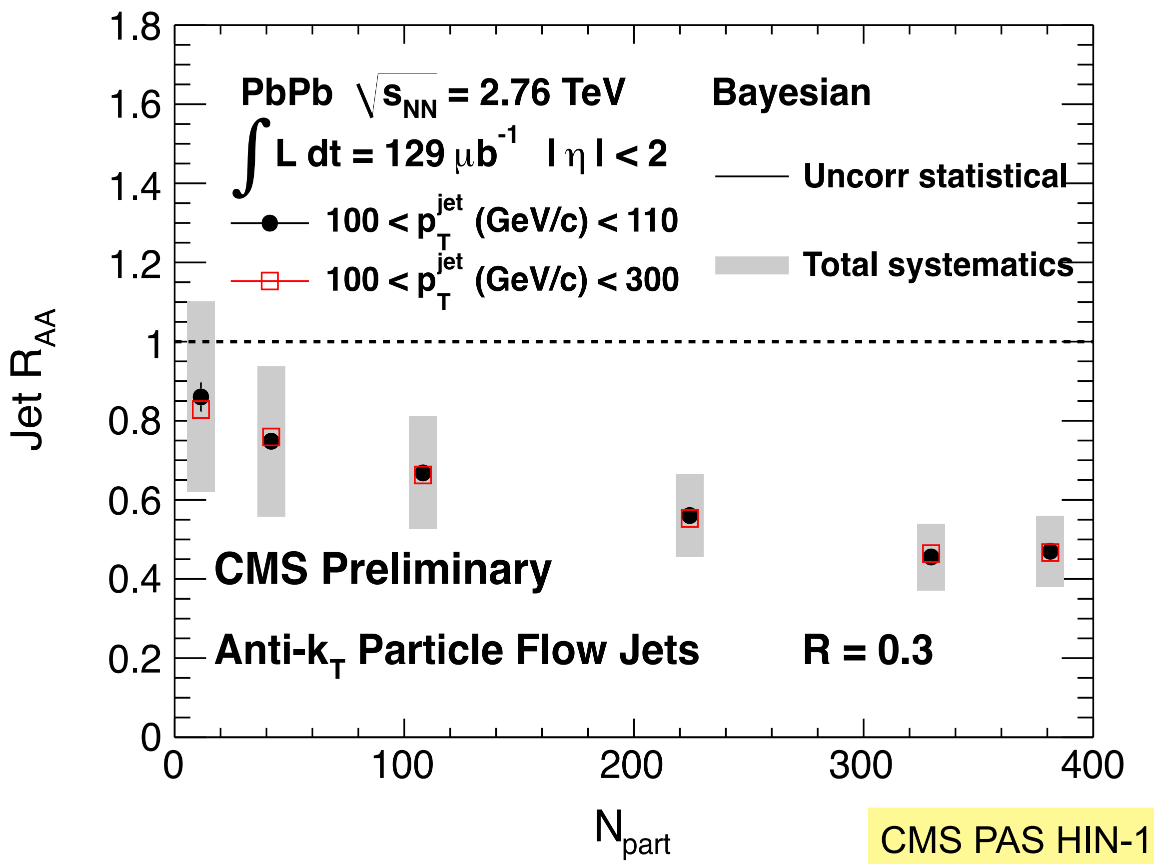
Lessons from HI particles and jets production

EPJC 72 (2012) 1945



- R_{AA}: Nuclear modification factor

$$R_{AA} = \frac{\sigma_{pp}^{inel}}{\langle N_{coll} \rangle} \frac{d^2 N_{AA}/dp_T d\eta}{d^2 \sigma_{pp}/dp_T d\eta}$$

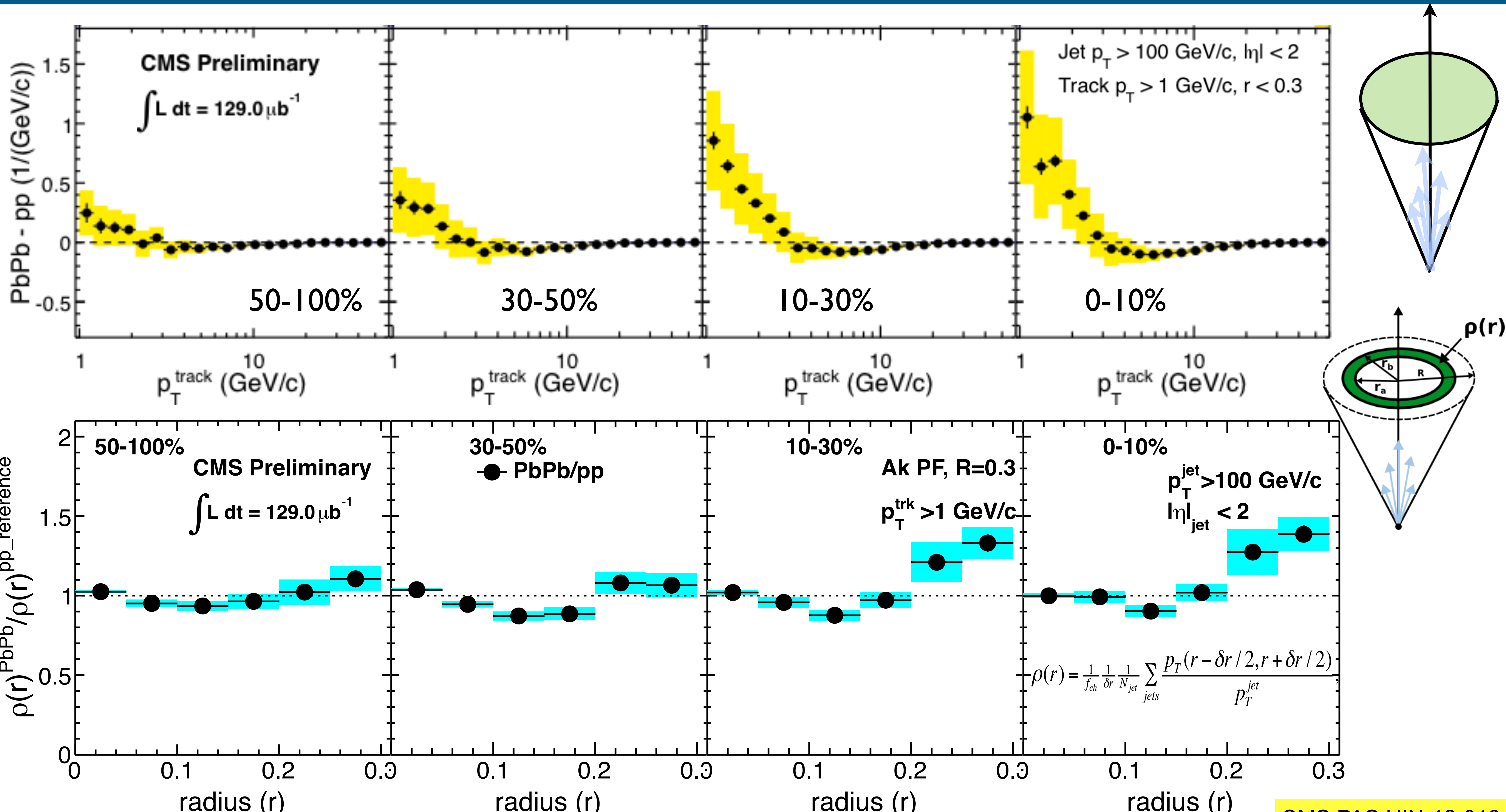


CMS PAS HIN-12-004

- High p_T final state hadrons are strongly suppressed (R_{AA} ~ 0.5 for p_T >50 GeV/c)
- About 50% of jets (R_{AA} ~ 0.5) are lost at a given p_T in most central PbPb

➡ Jet quenching observed in PbPb collisions

Lessons from HI jet fragmentation and shapes

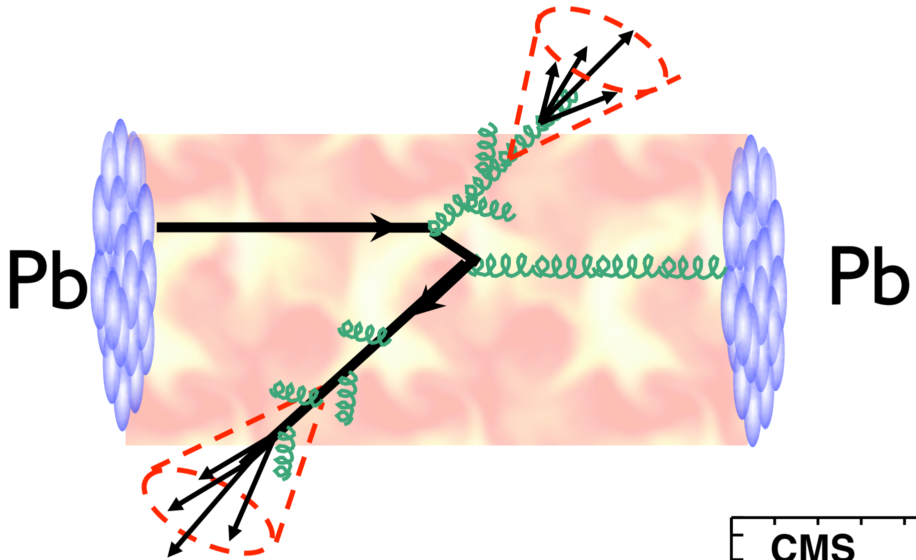


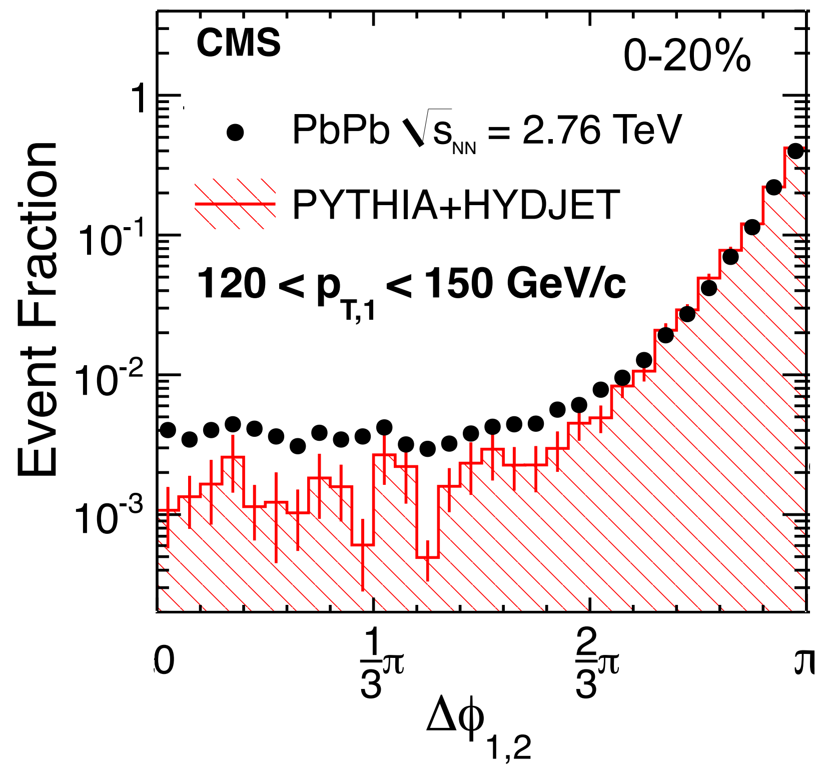
CMS PAS HIN-12-013

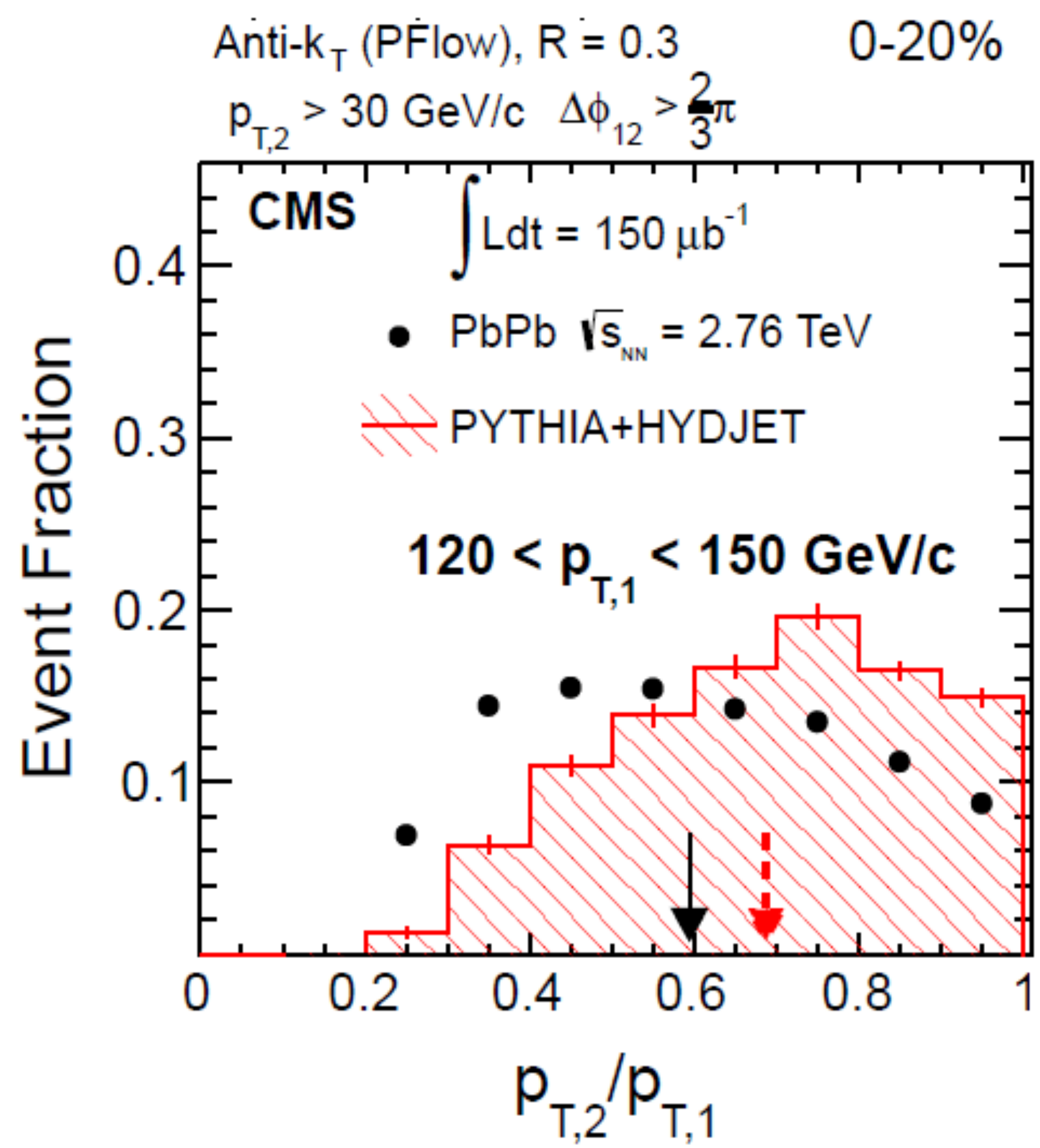
- Jet fragments into more low p_T hadrons with less intermediate p_T hadrons
- Jet energy re-distributed to large distance from jet axis

Lessons from HI dijets production

PLB 712 (2012) 176







- Jet quenching is observed as a pronounced dijet p_T imbalance in central collision, with no visible angular decorrelation

Lessons from HI dijets imbalance

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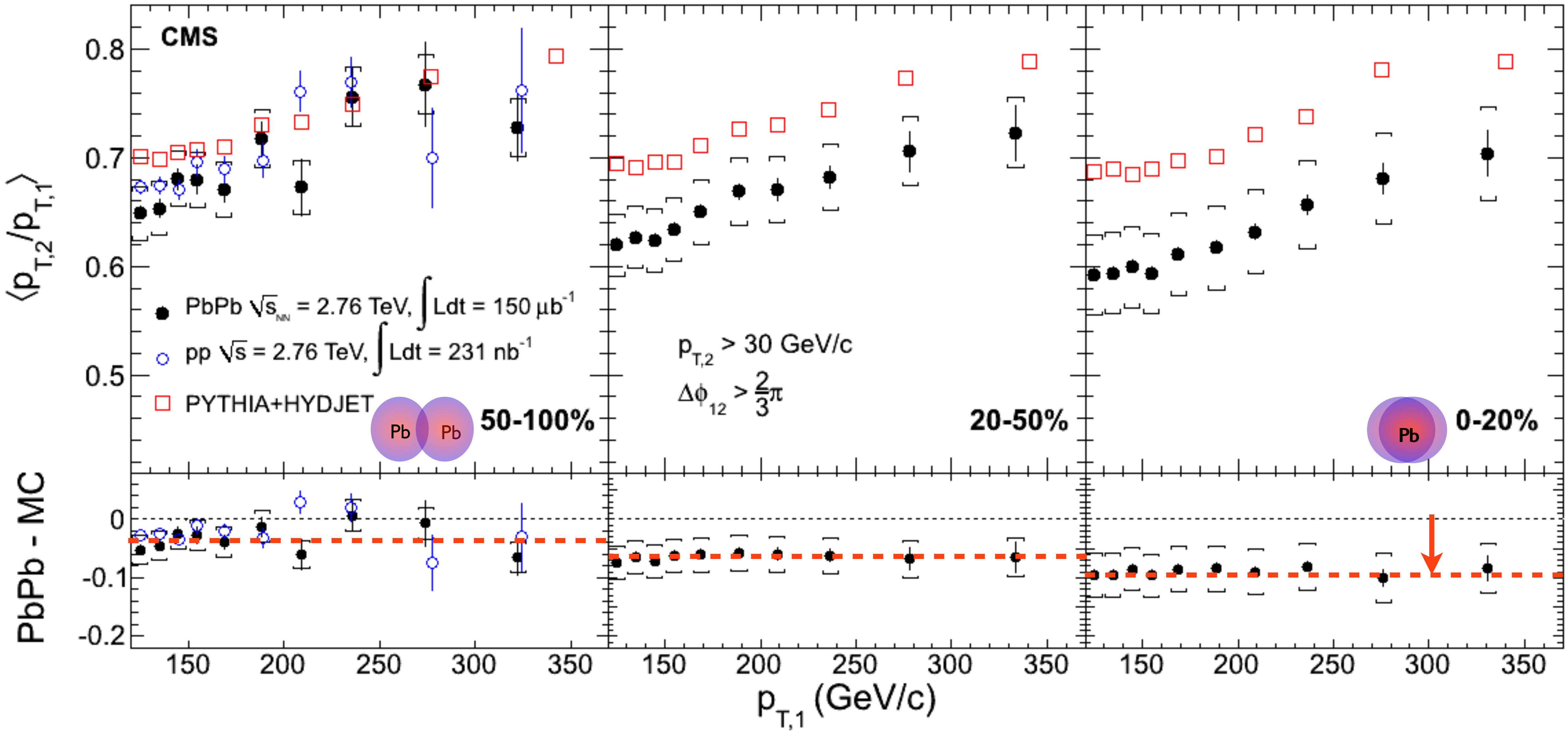
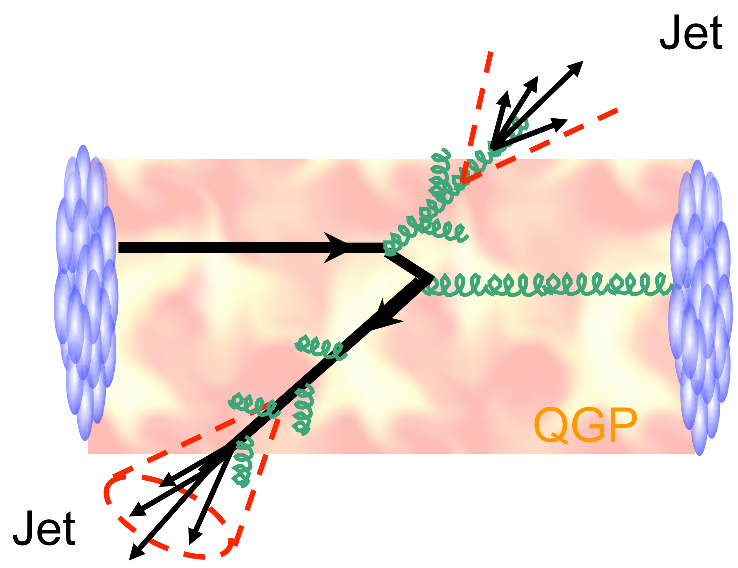


- Energy imbalance increases with centrality
- p_T-ratio deviates from the unquenched reference in a p_T-independent way

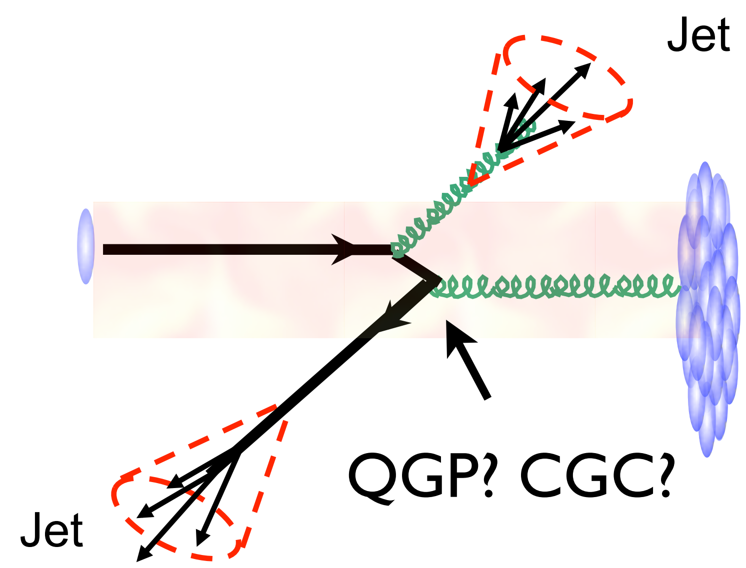
Baseline for HI collisions

PbPb collisions



- Clear signature of the formation of Quark-Gluon Plasma (QGP)
- Strongly interacting particles affected by the presence of QGP
  - quenched high p_T particles/jets
  - changed jet fragmentation functions/shapes
  - Imbalanced dijets

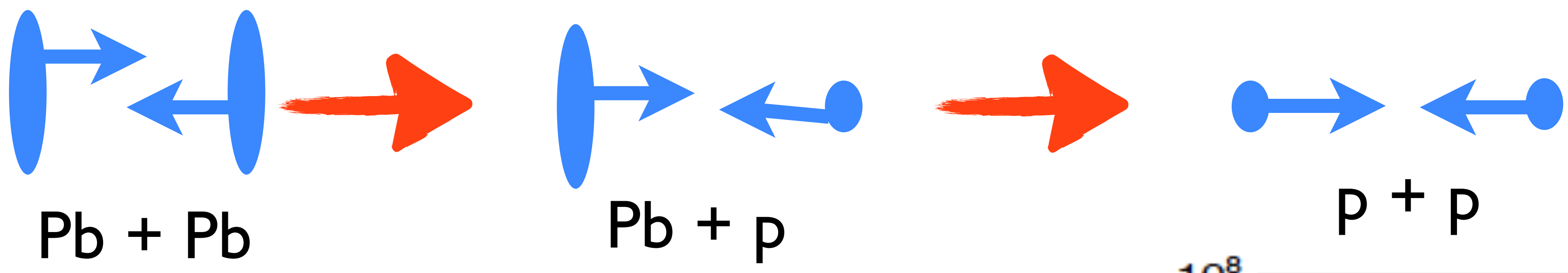
pPb collisions



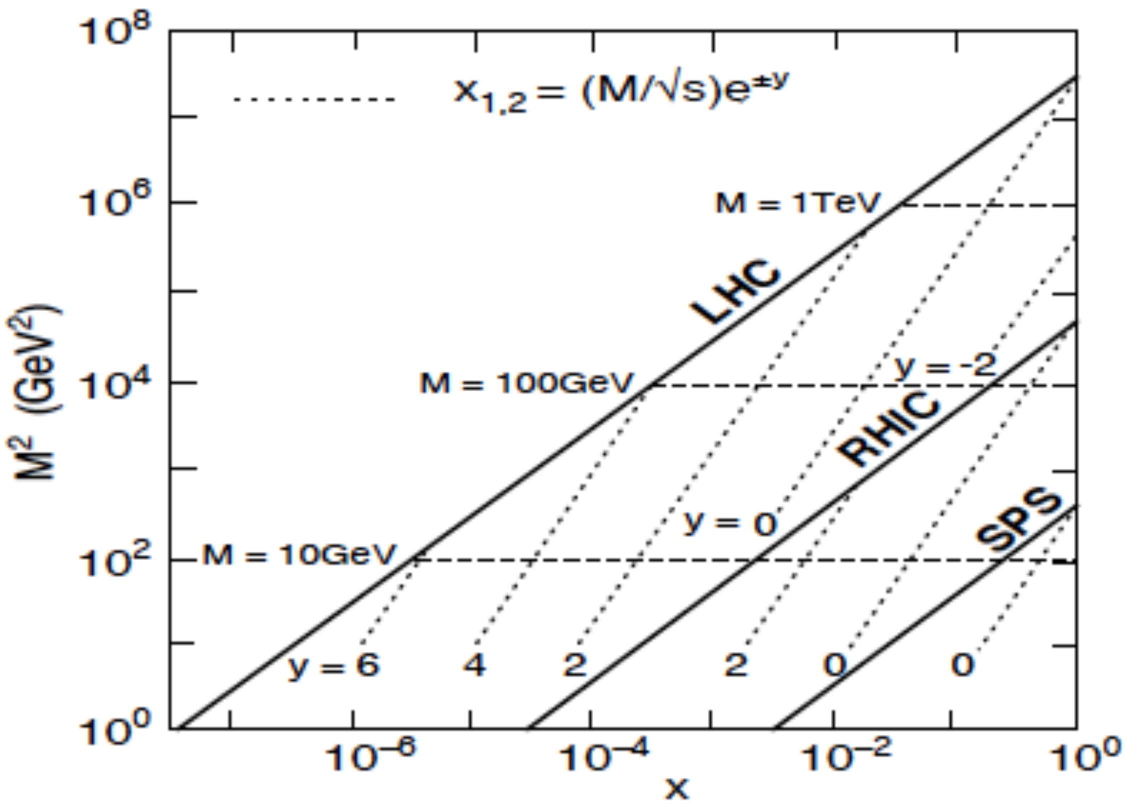
- Can we understand the baseline for PbPb?
- How do strongly interacting particles behave in cold nuclear matter? quenching?
- Can we observe effects due to the nuclear structure at small x?

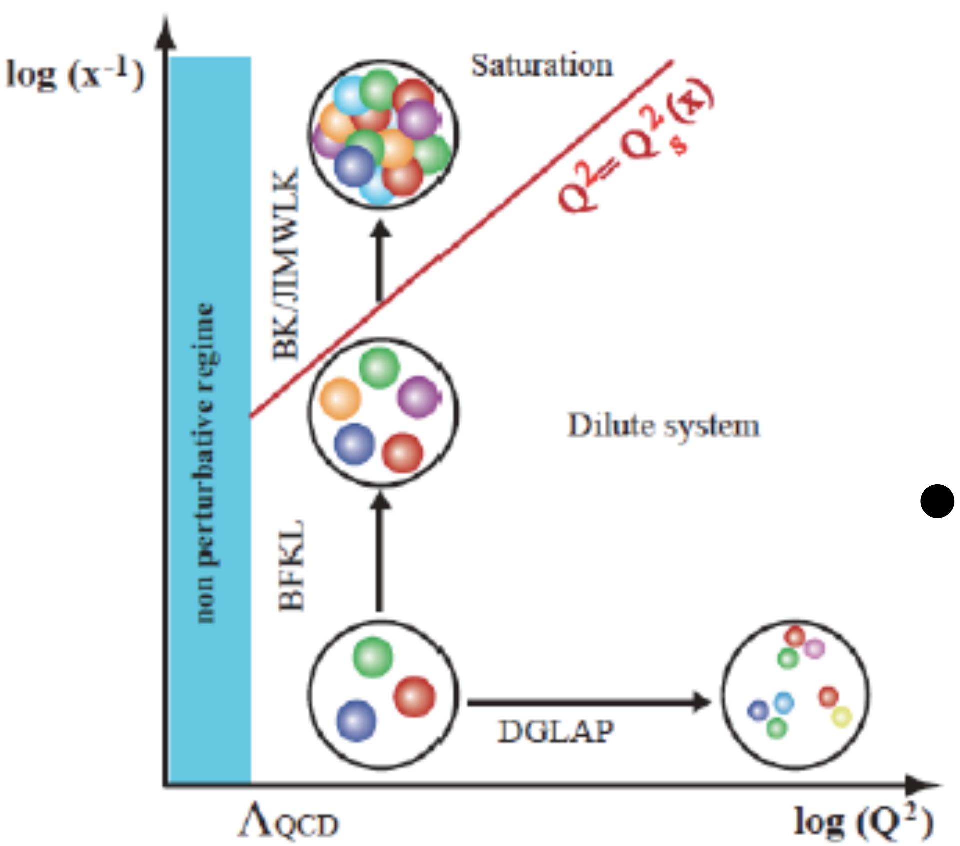
Motivation for pPb at LHC

- Elements of proton-proton as well as HI collisions



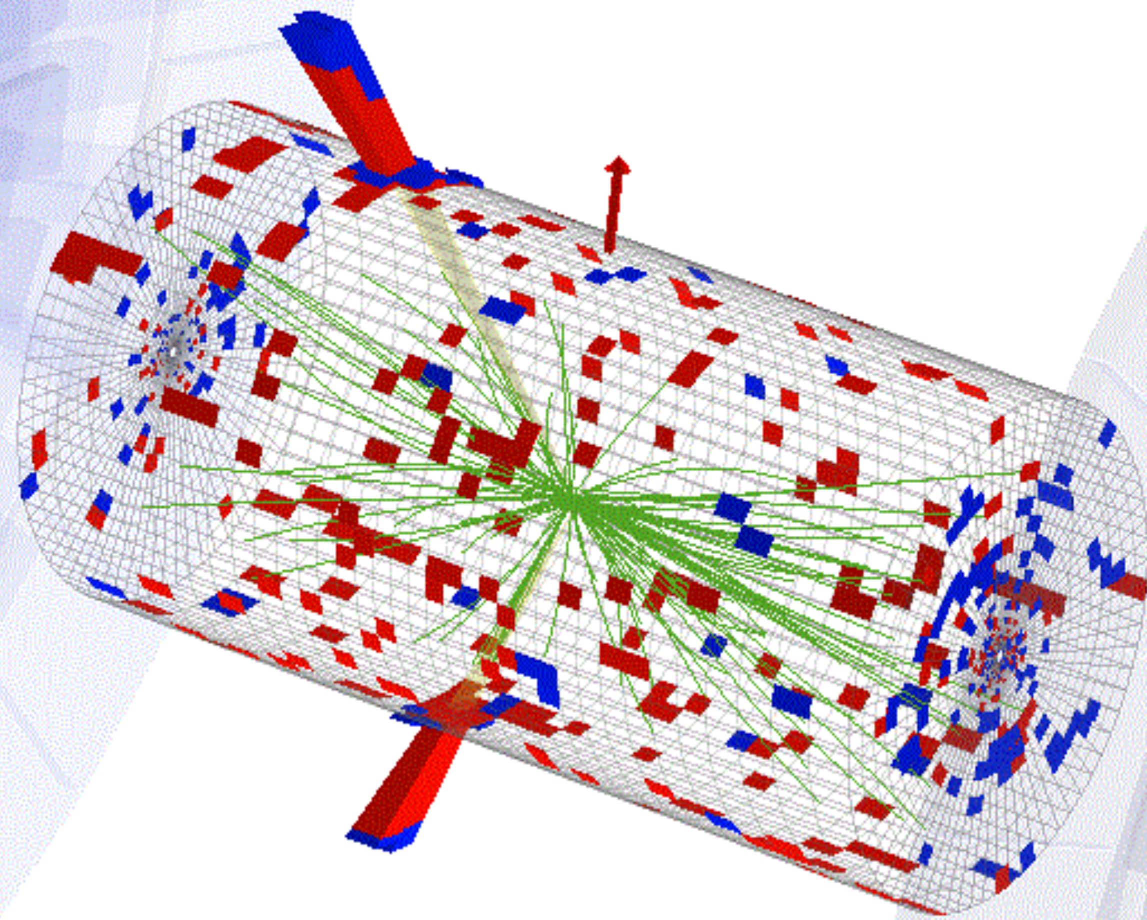
- Disentangle initial and final state effects
- Characterize nuclear PDFs at small-x

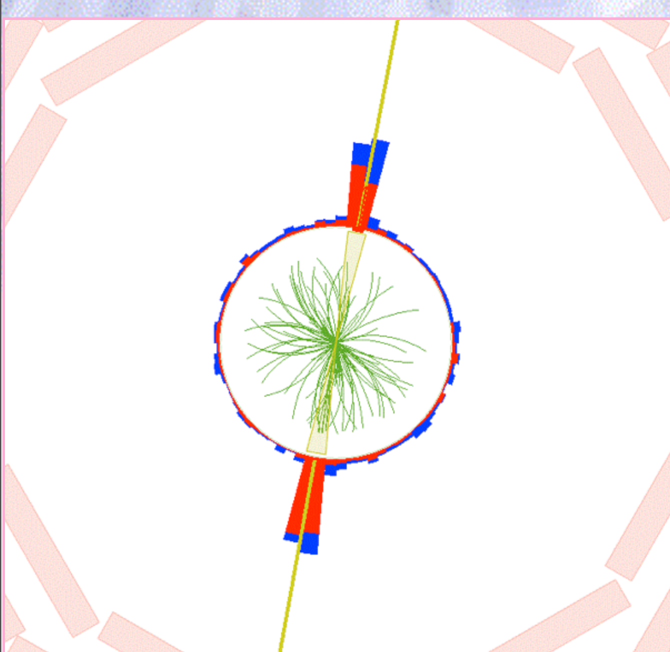


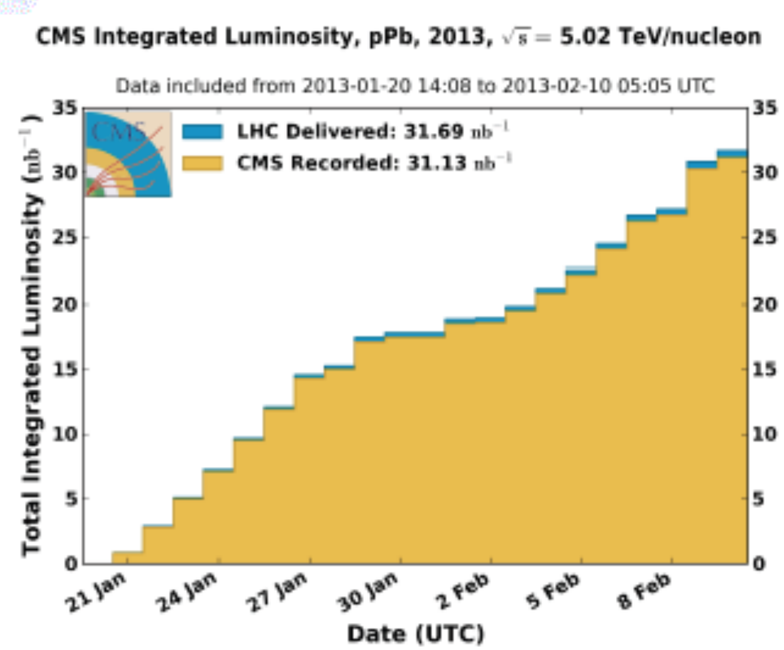


- Investigate QCD at high gluon density: shadowing and gluon saturation
  - saturation scale (Q_s) enhanced by $A^{1/3}$ in nucleus A
    - at LHC (^{208}Pb): $Q_s \sim$ 2-3 GeV/c, x~10^{-4} at η=0

Dijet in pPb collisions recorded by CMS







Dijet event classes in pPb

See Doga's talk

- Using HF energy deposition in the most forward and backward regions of the calorimeter as a centrality proxy

- Required double sided selection (DS): at least one particle with E > 3 GeV in both forward calorimeters (3 < |η| < 5)

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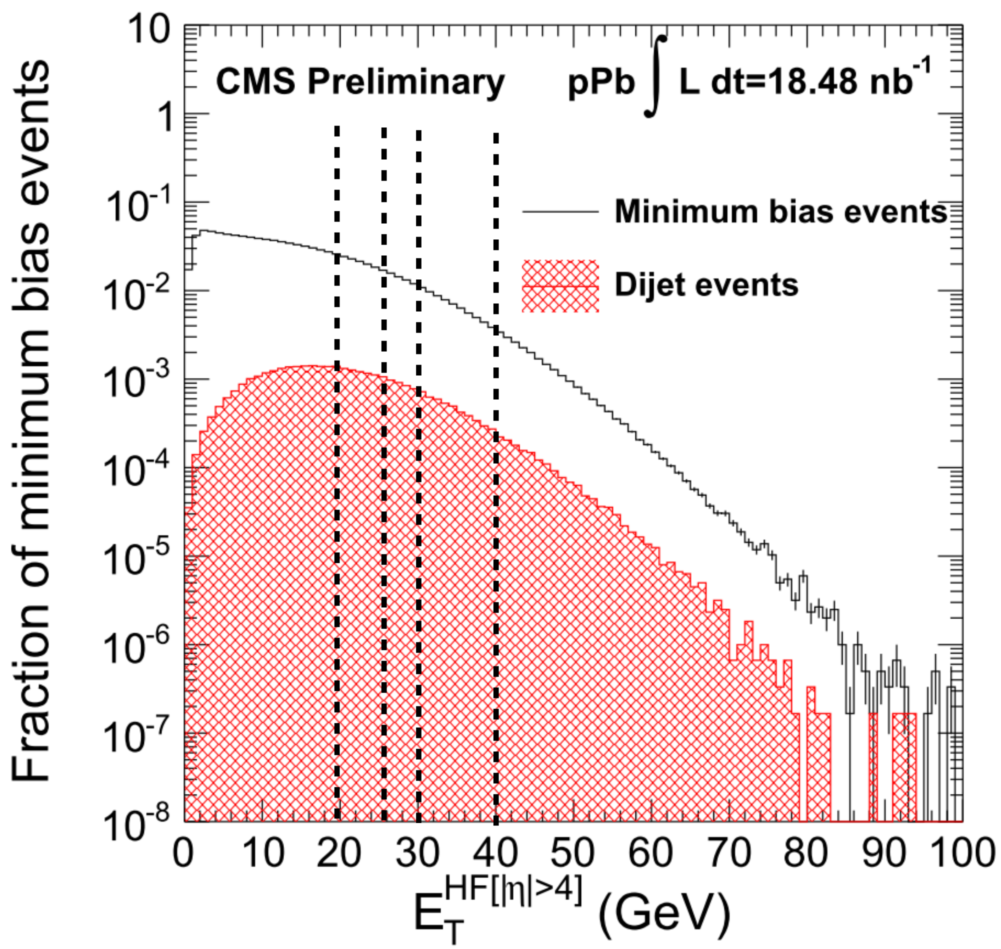
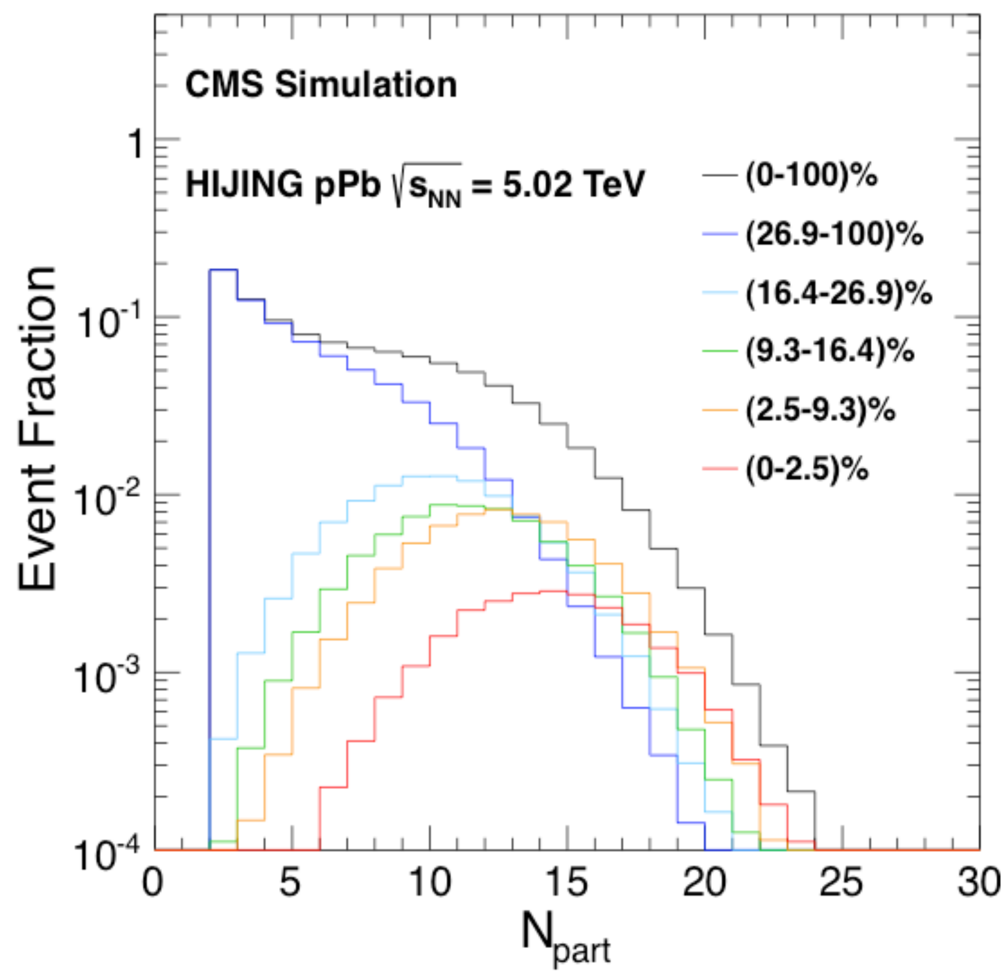
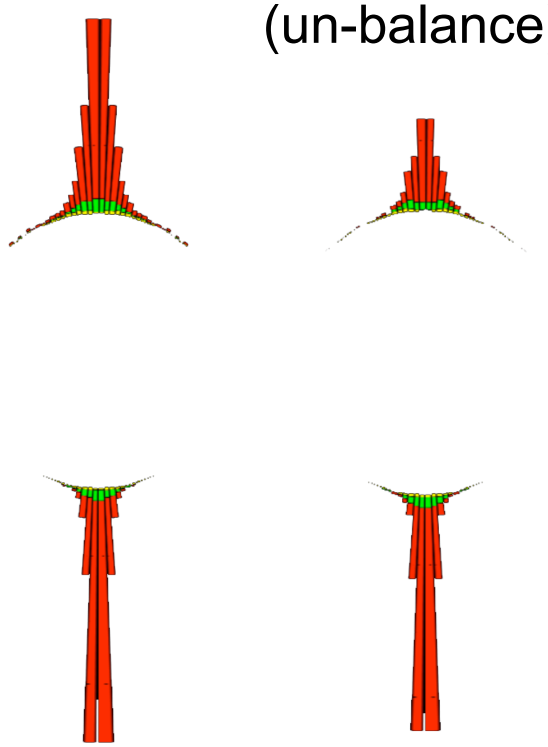


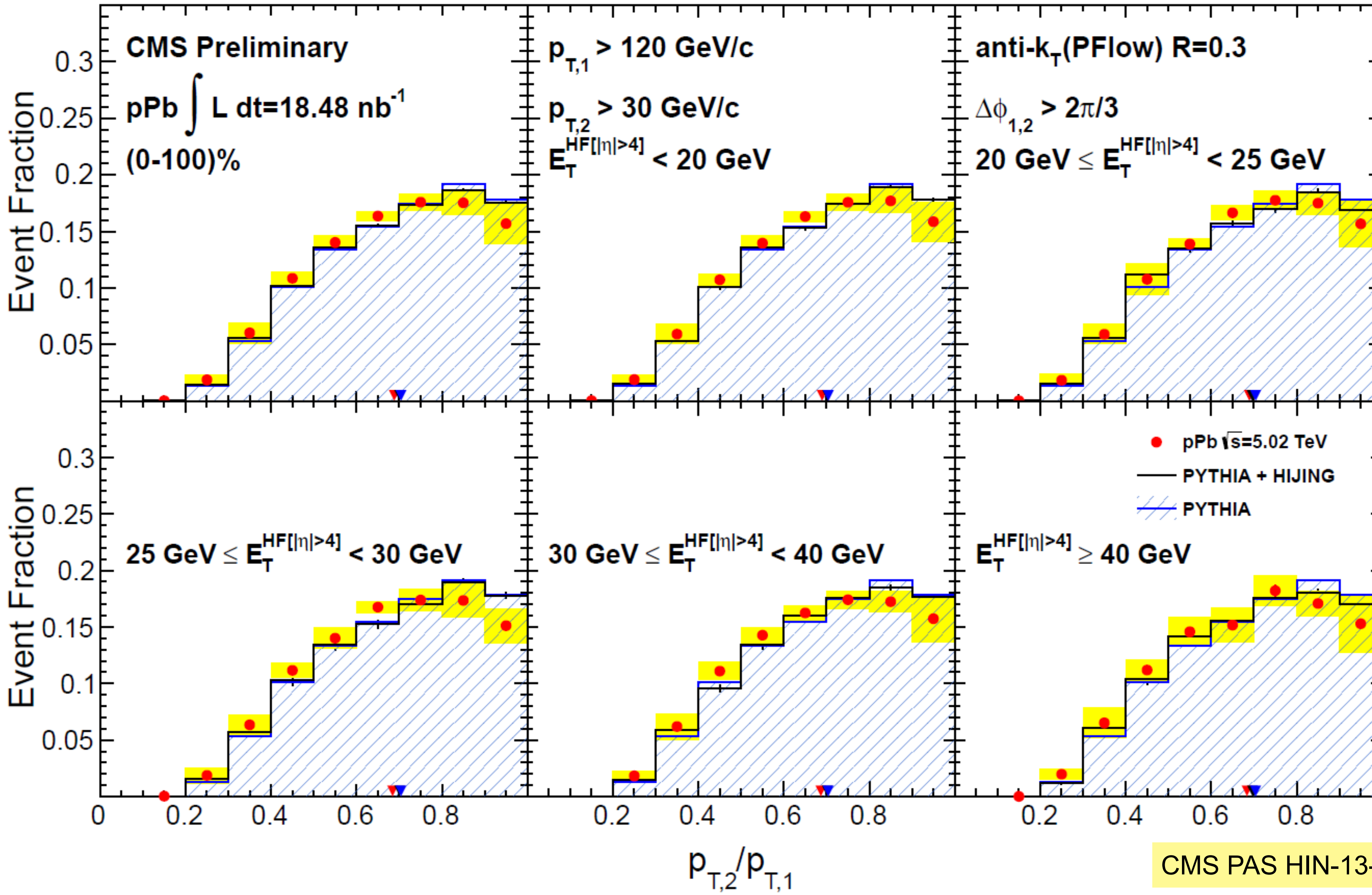


Dijet p_T ratios

Small p_T ratio
(un-balance)



Large p_T ratio
(balanced)



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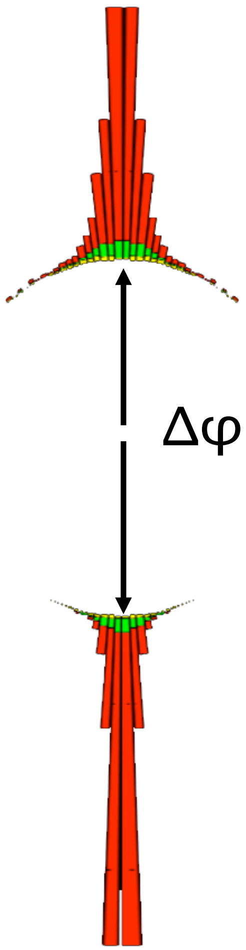
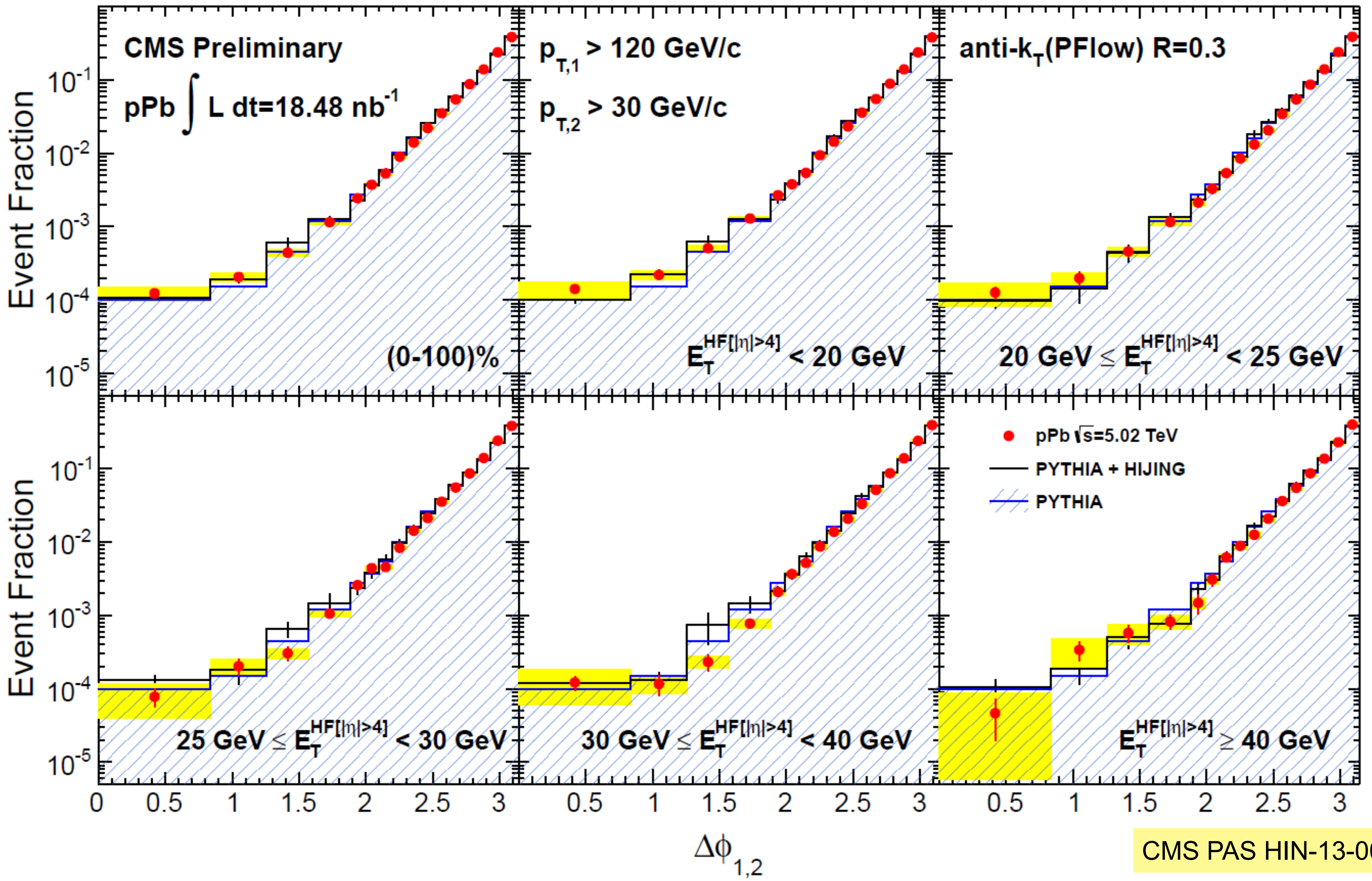
- No modification is observed in dijet p_T ratio up to $E_T^{HF[|\eta|>4]}$ > 40 GeV (top 0-2.5%)

➡ (Not enough statistics to check PbPb collisions in the same $E_T^{HF[|\eta|>4]}$ interval)

Dijet Δφ





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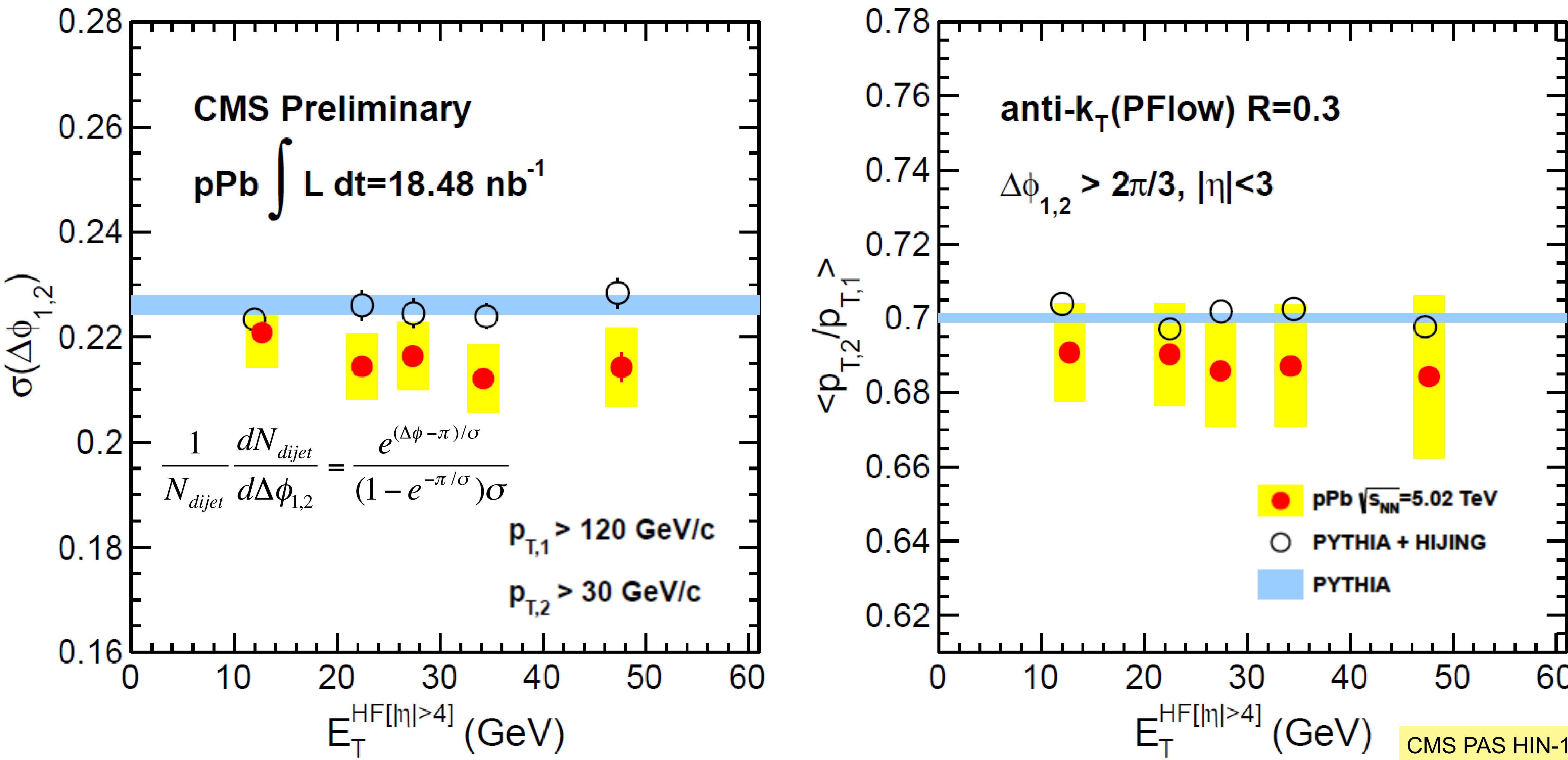
- Δϕ distribution stays unchanged w.r.t. HF energy compared to pp reference

Summary from dijet p_T ratio and $\Delta\varphi$



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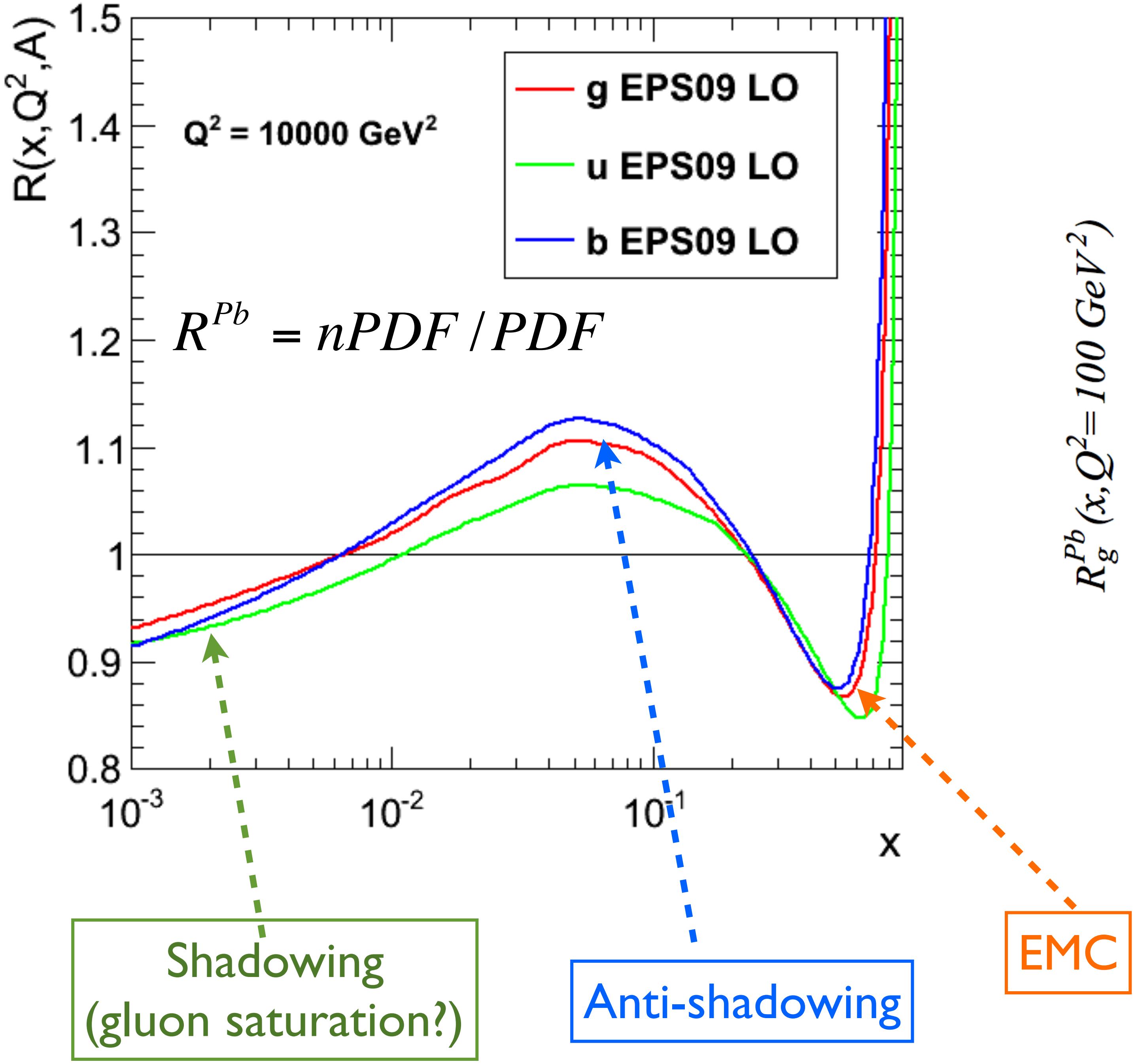
- With the current systematic uncertainty, no detectable change in $\langle p_{T,2}/p_{T,1}\rangle$ and $\Delta\varphi$ width as a function of forward calorimeter energy

  ➡ No jet quenching observed in pPb collisions in all centralities

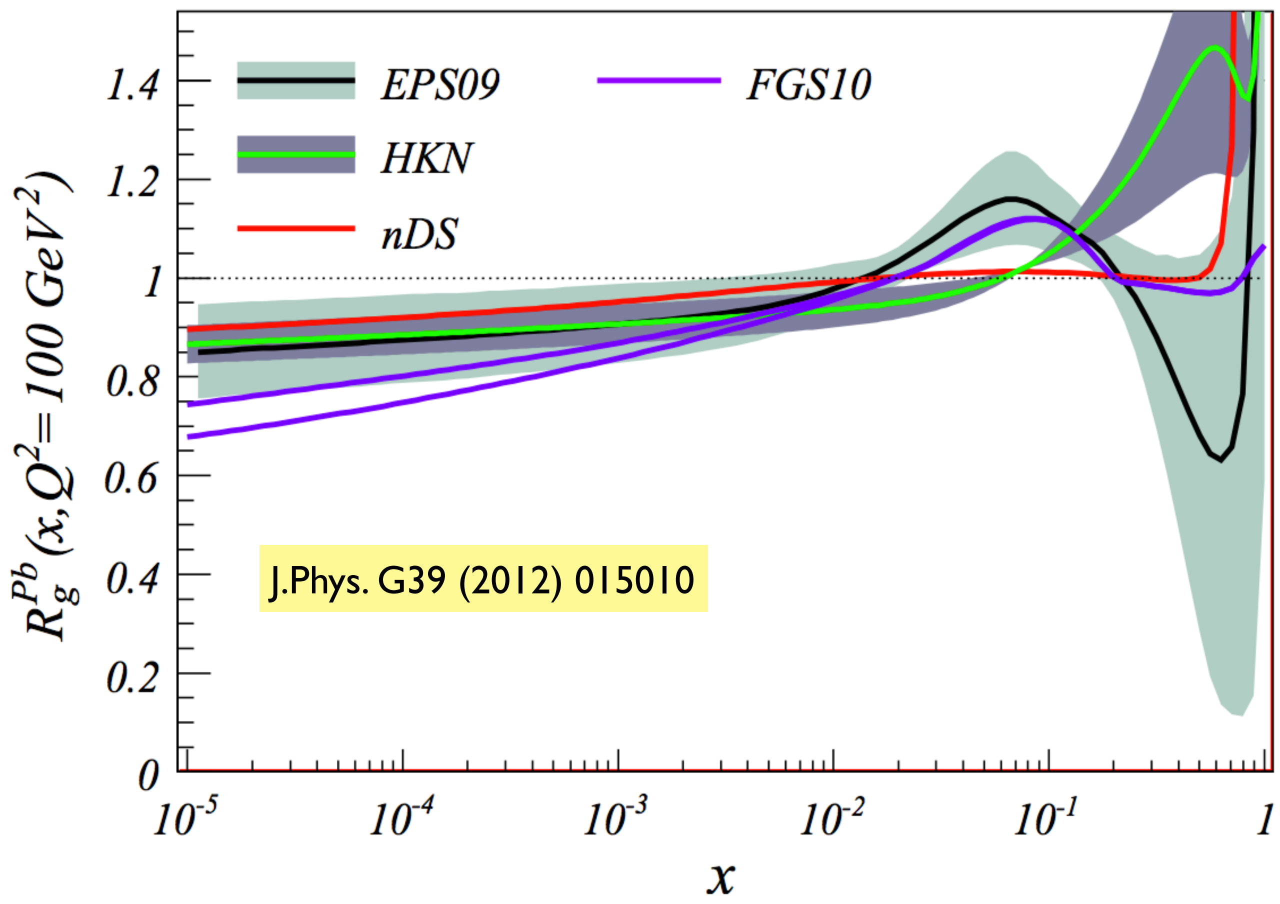
- Establish the basis to use the jets for nPDF determination

Nuclear PDF Predictions at LHC

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



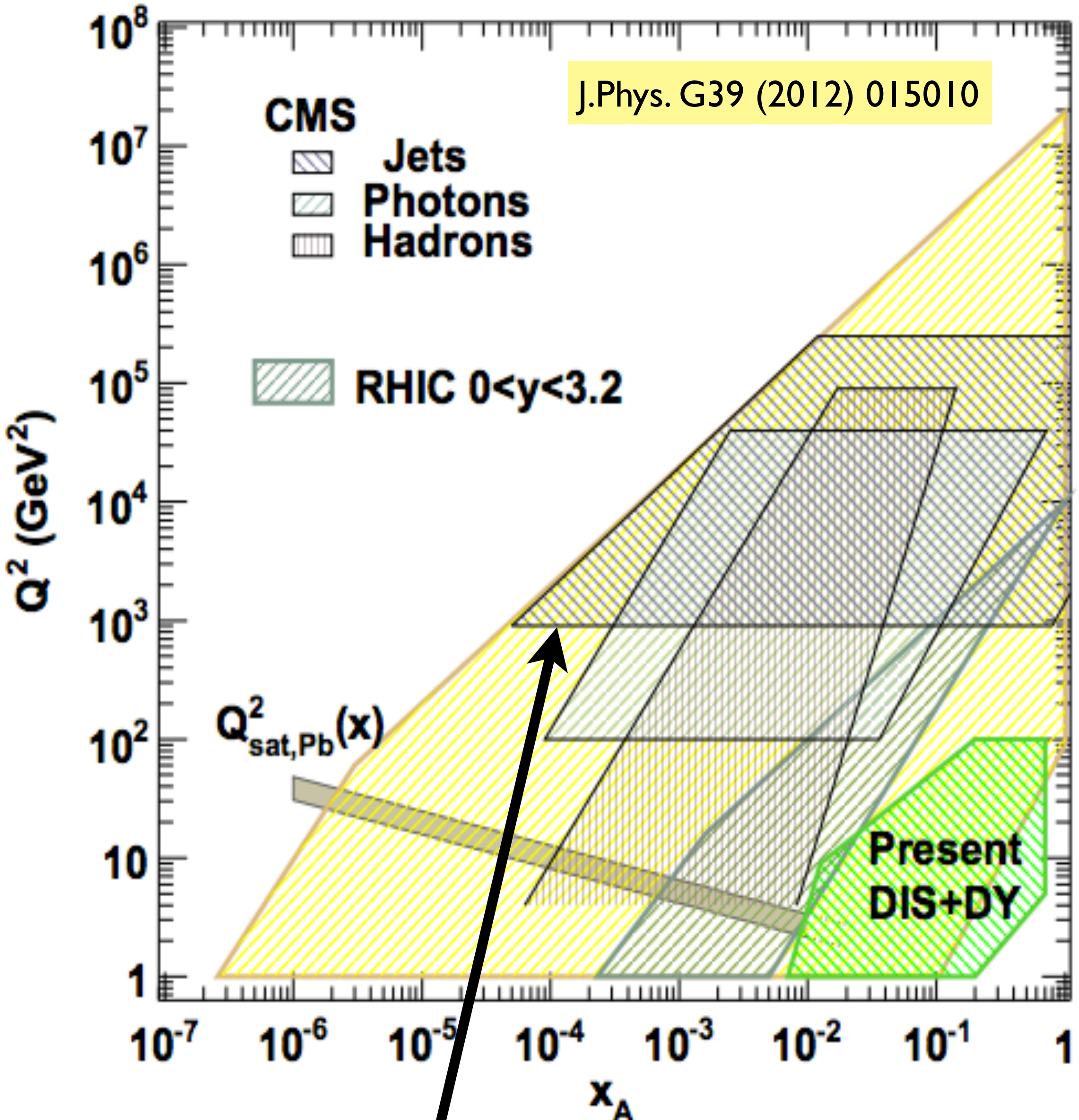
gluons: Q^2 = 100 GeV^2



- At LHC energies, the R^{Pb} is expected to have significant shadowing/anti-shadowing effects

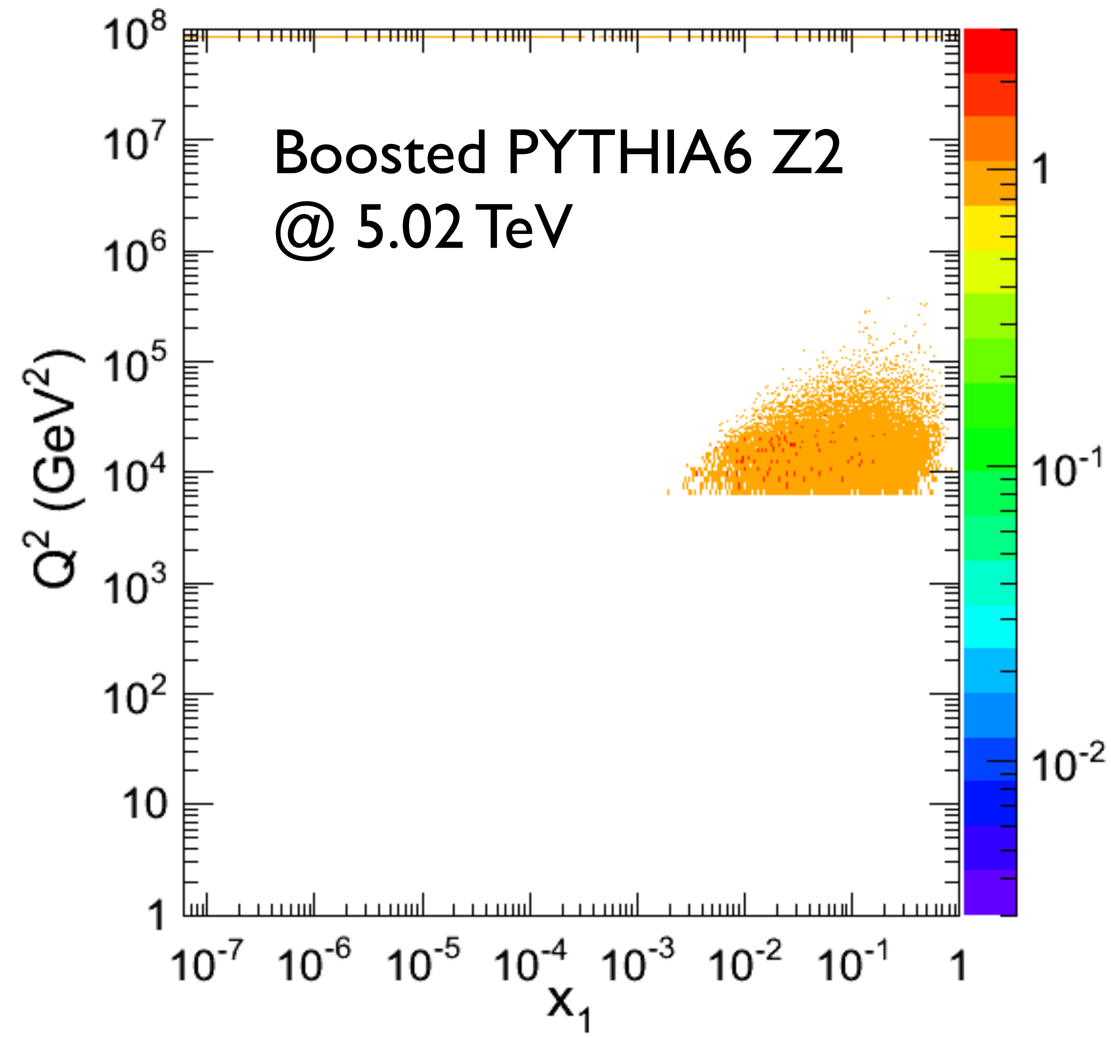
PDF - Kinematic reach in CMS

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

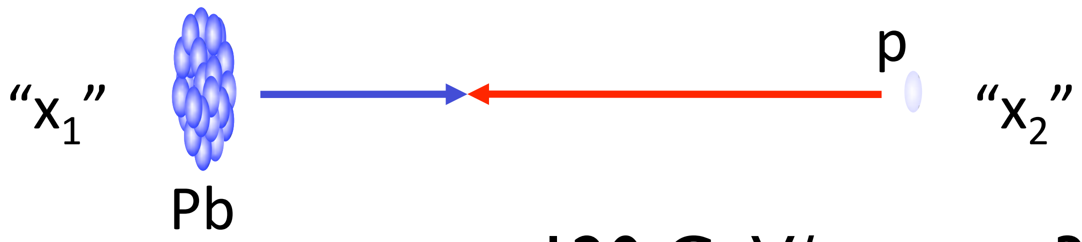


Observables using jets:
covers high Q^2 and $10^{-4}<x<1$

Kinematic range with the dijet selection:
$p_{T,1} > 120$ GeV/c, $p_{T,2} > 30$ GeV/c, $\Delta\varphi_{12} > 2\pi/3$



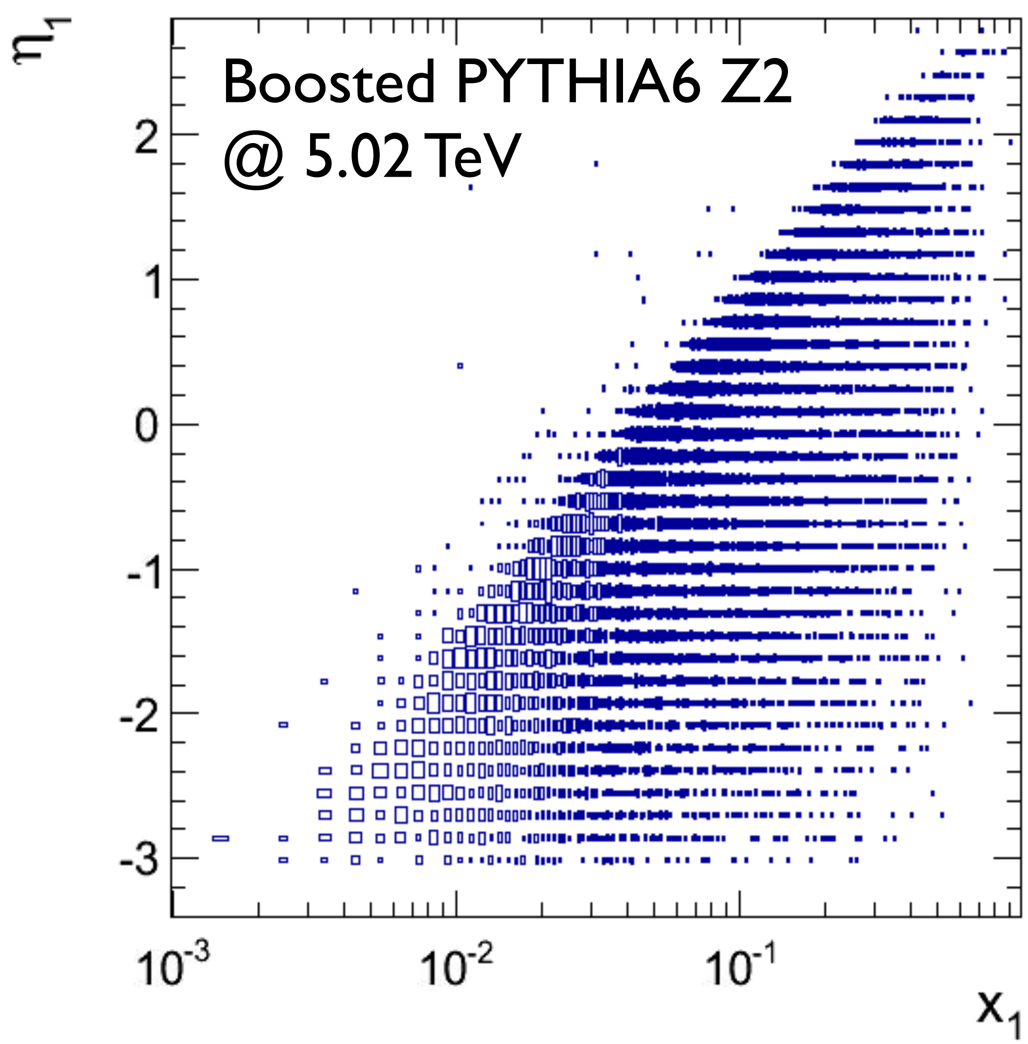
Choice of pseudorapidity observable



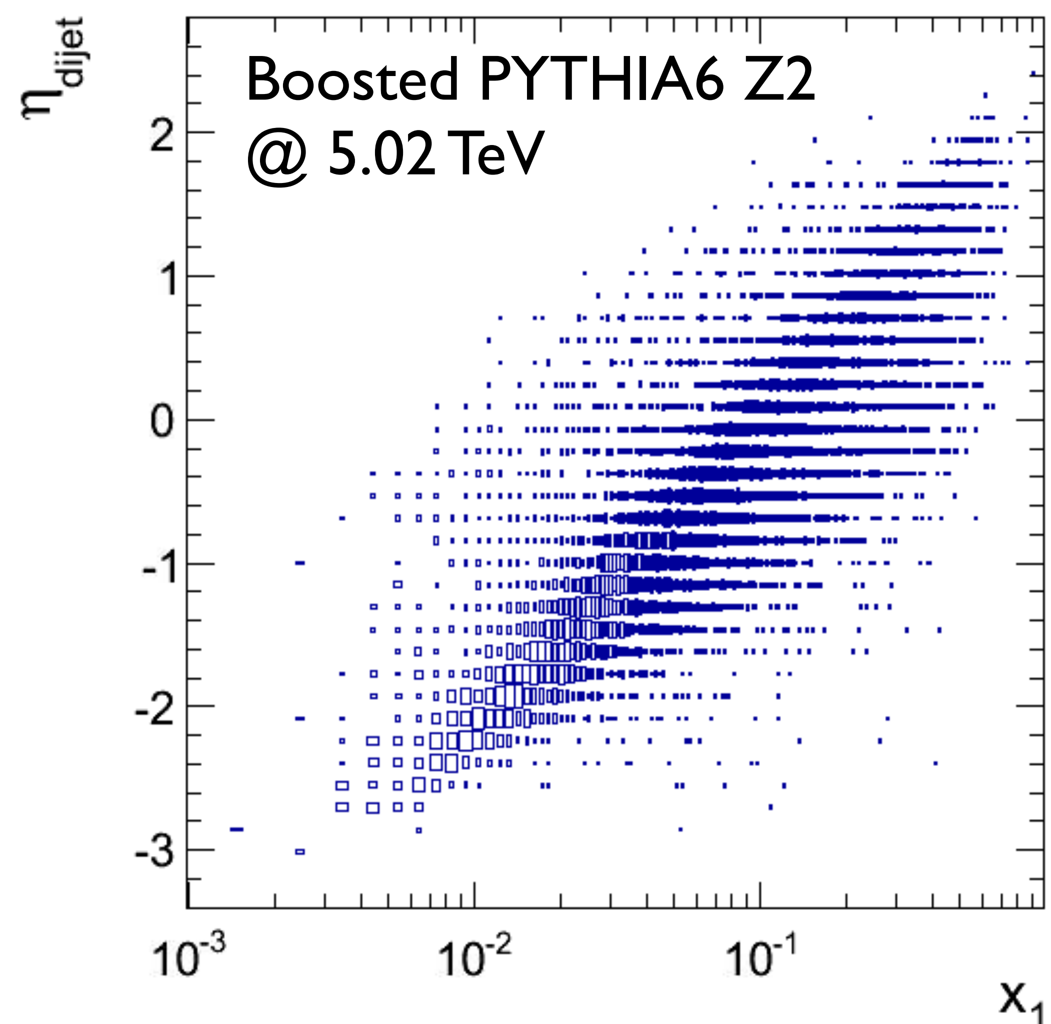
$p_{T,1} > 120$ GeV/c, $p_{T,2} > 30$ GeV/c, $\Delta\varphi_{12} > 2\pi/3$

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

Leading jet pseudorapidity

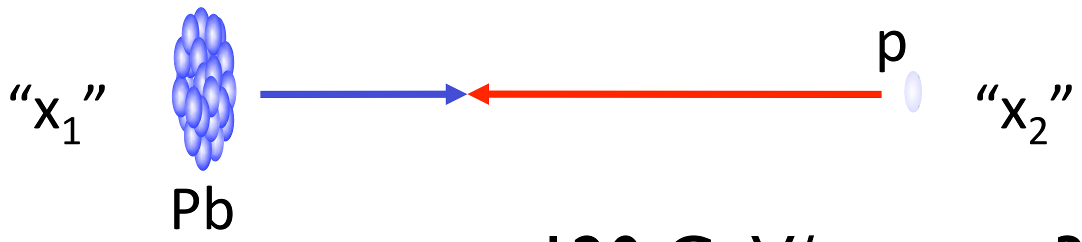


Dijet pseudorapidity



- Dijet pseudorapidity has tighter correlation with parton x compared to single jet pseudorapidity.

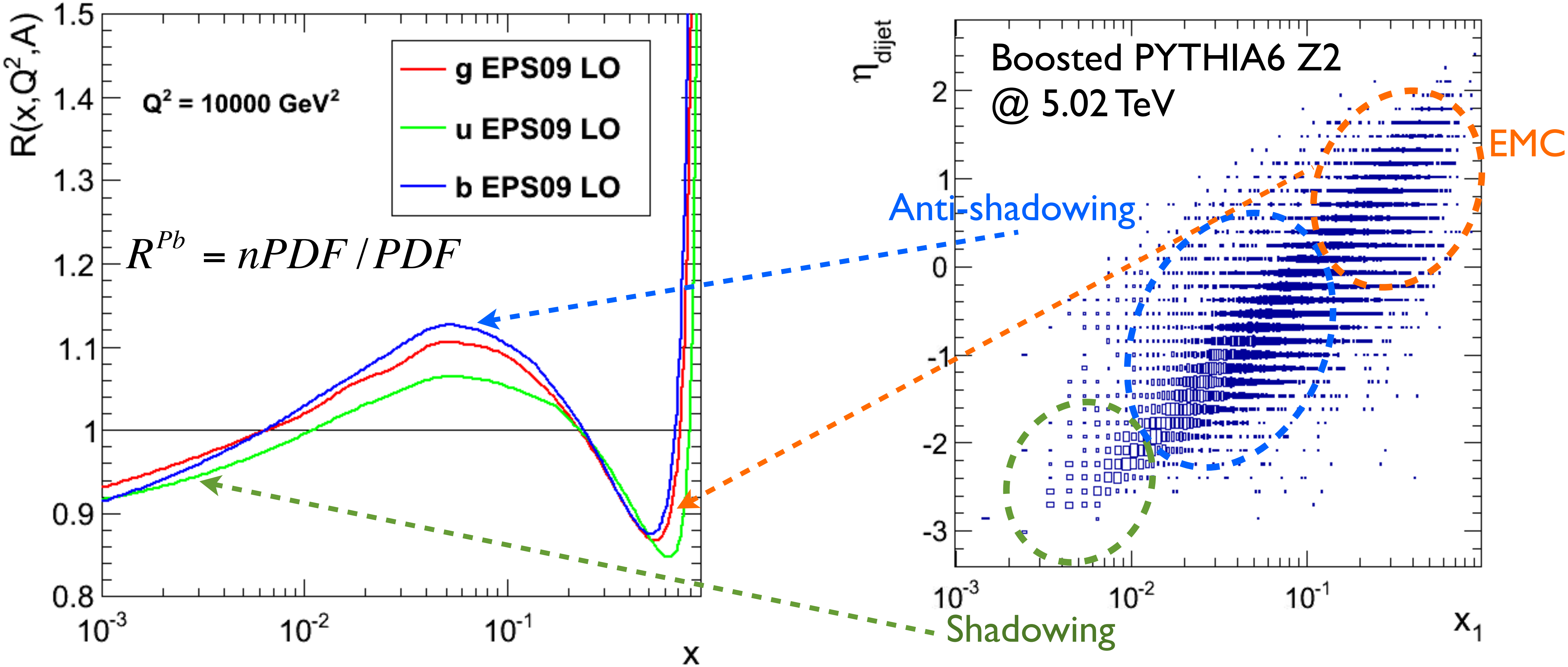
$x_1 \leftrightarrow \eta_{dijet}$



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

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

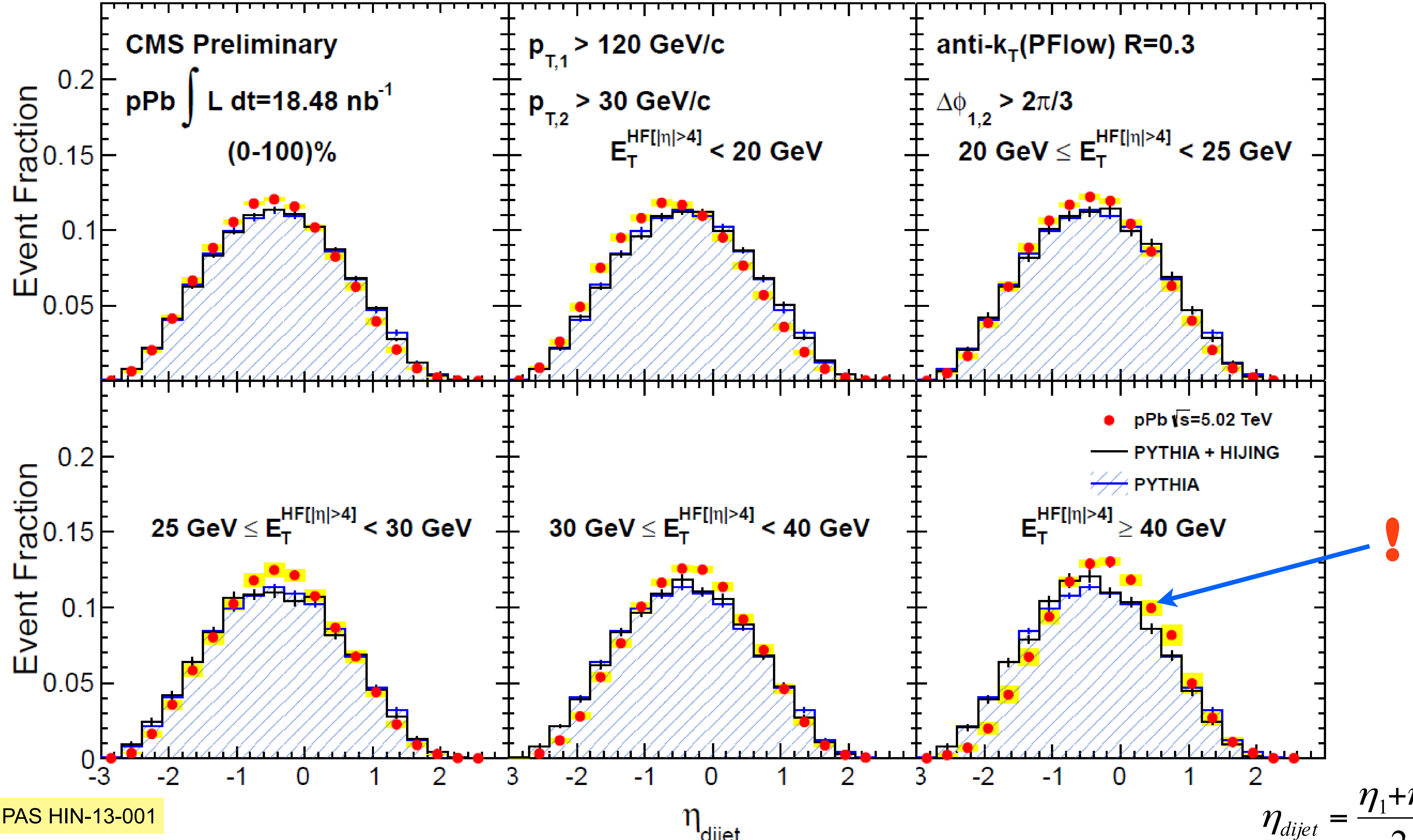
Translation from η_{dijet} to x_1



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

- Different η_{dijet} probes different effects with different x

Dijet η v.s. forward calorimeter energy

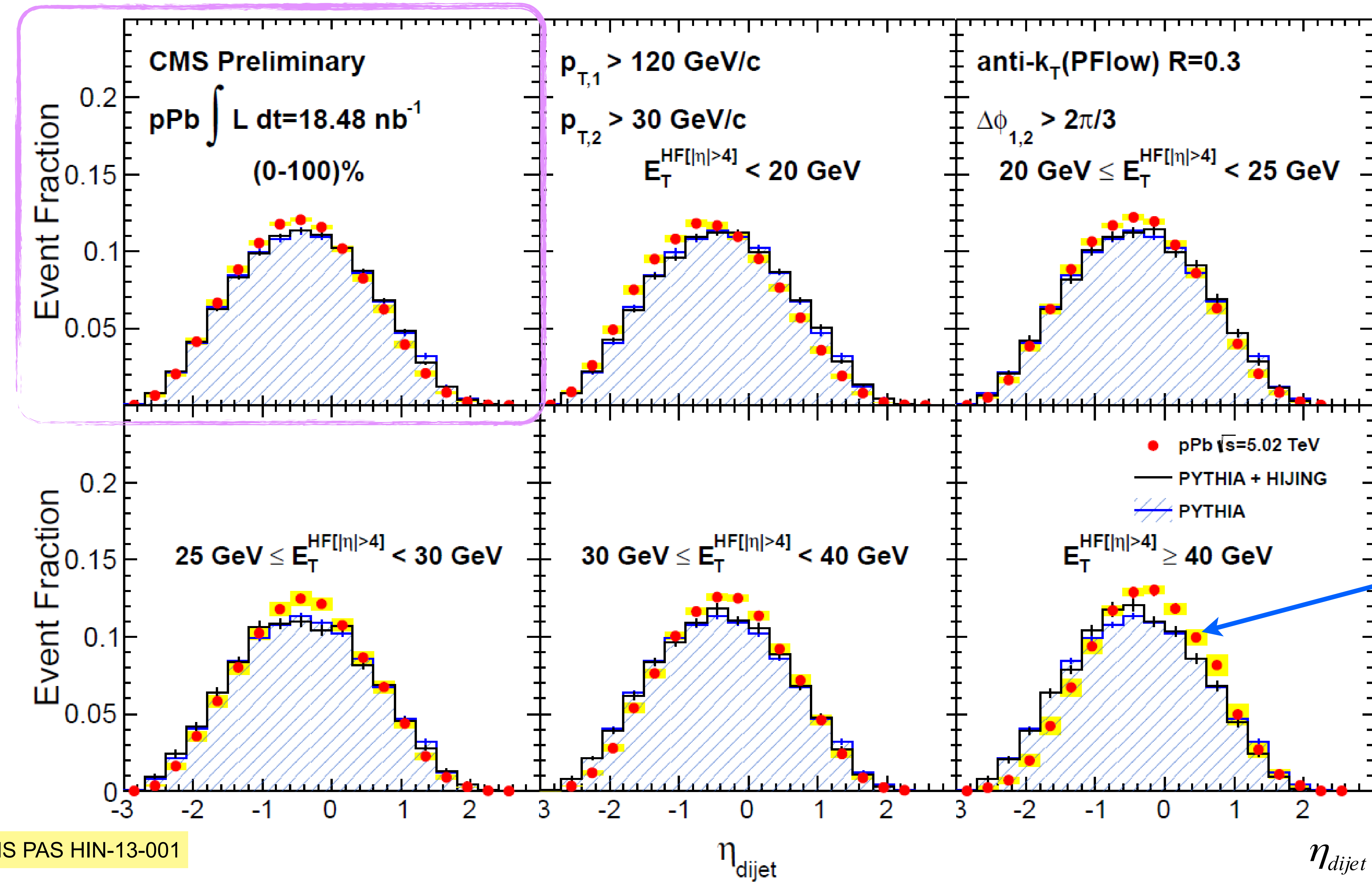


CMS PAS HIN-13-001

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

- η_{dijet} distributions plotted against PYTHIA references
- A systematic shift to the Pb going direction vs HF energy

Dijet η v.s. forward calorimeter energy



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Anatomy of the dijet η distribution

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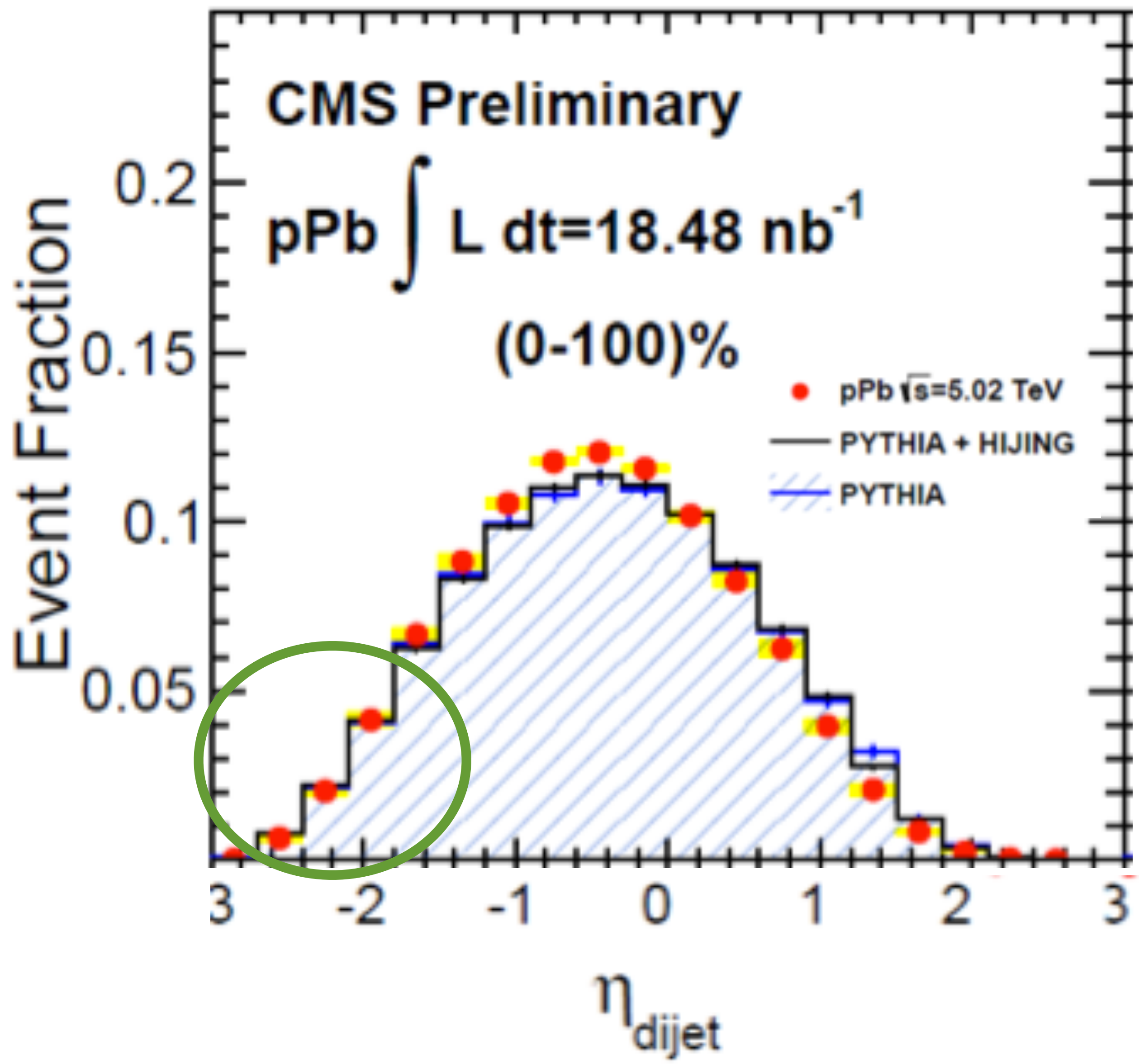

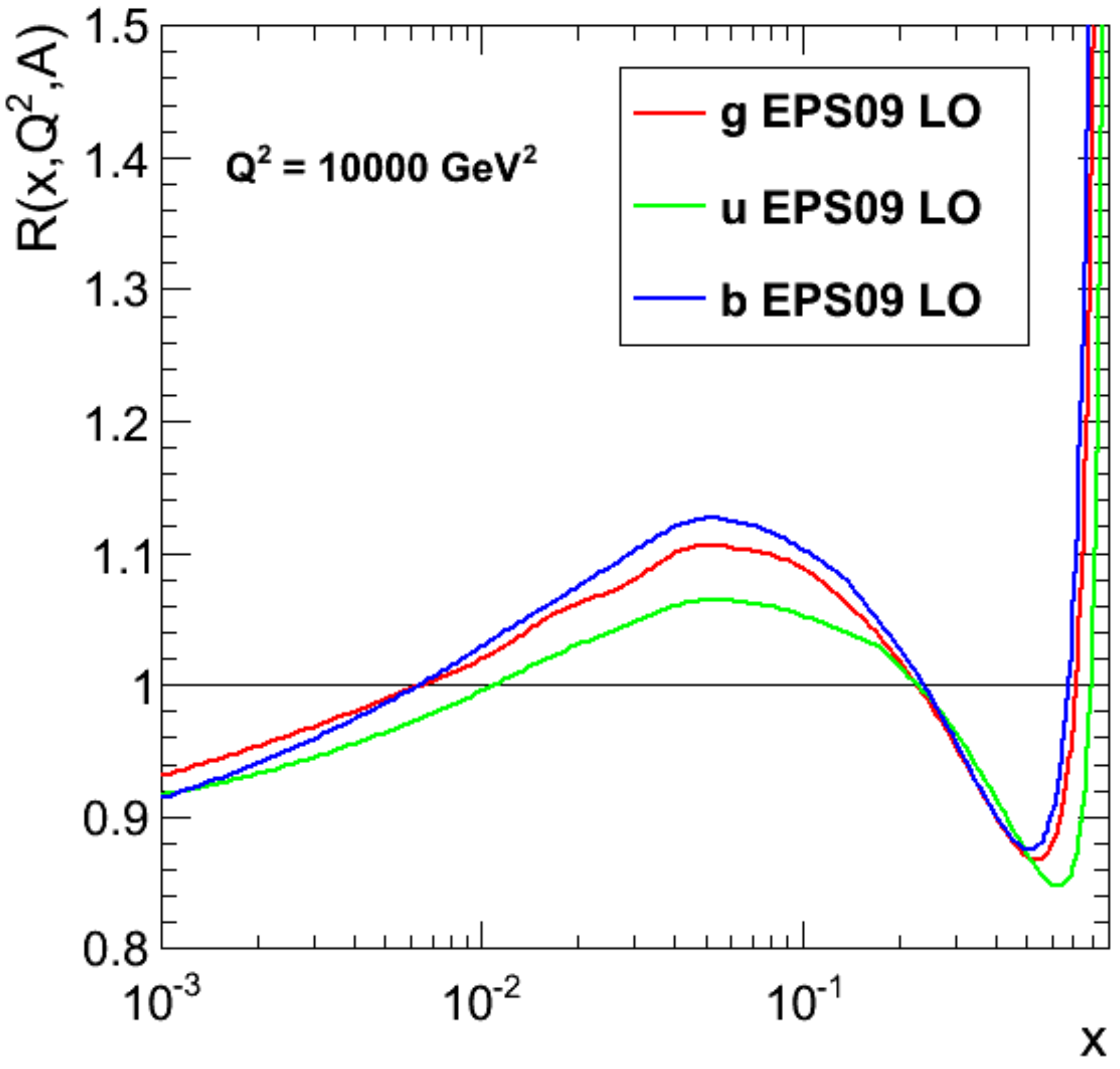

Anatomy of the dijet η distribution

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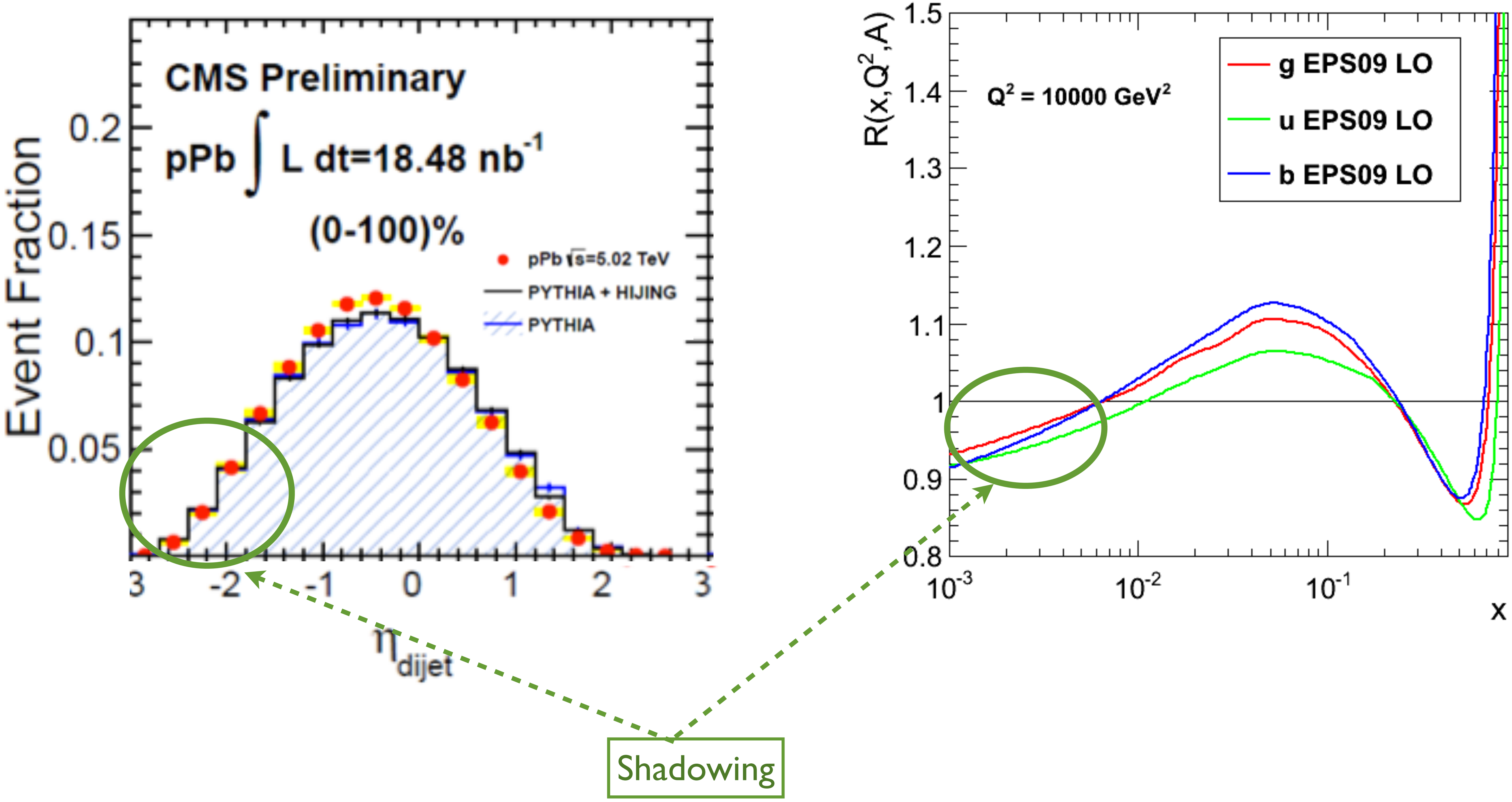
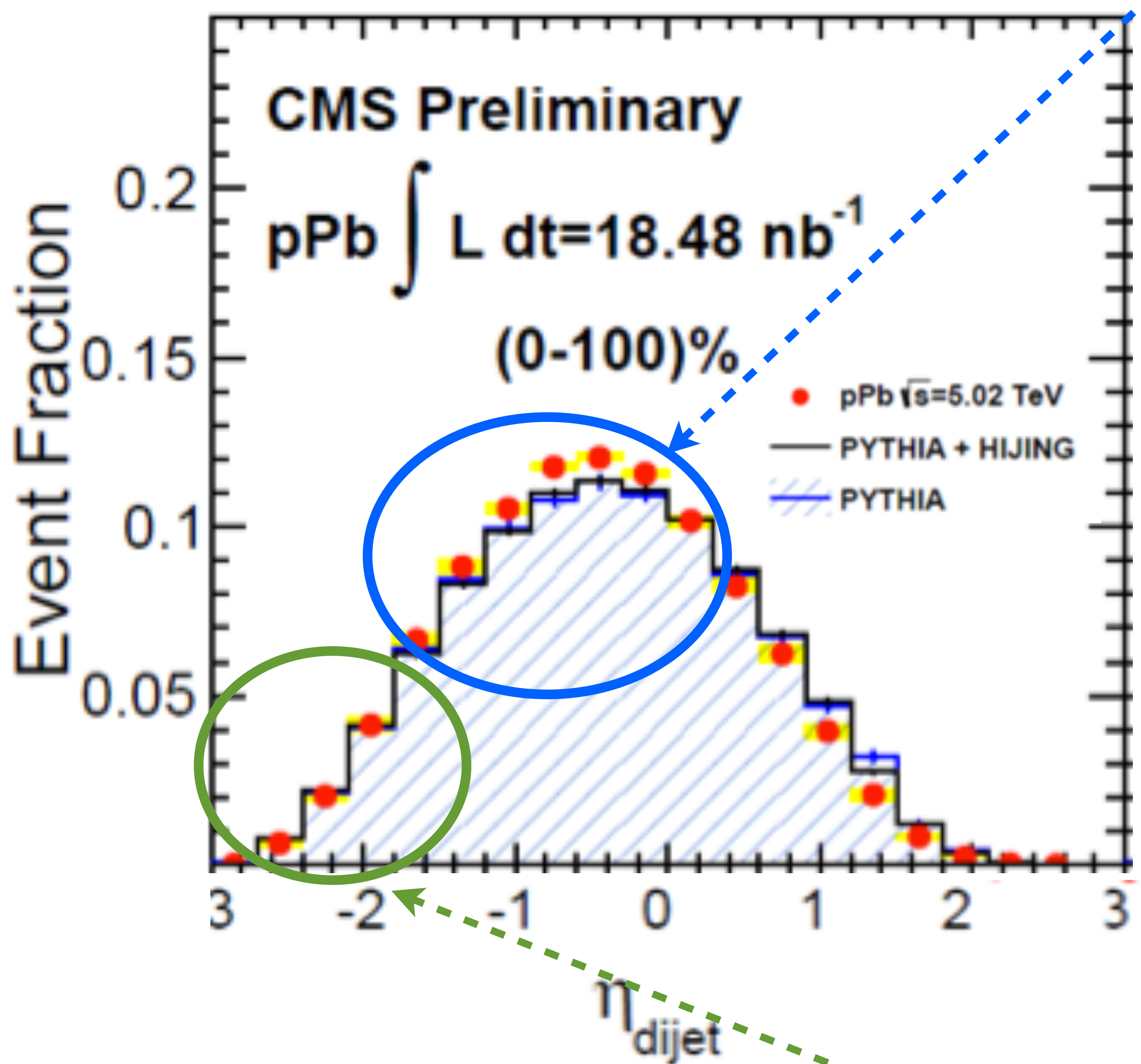
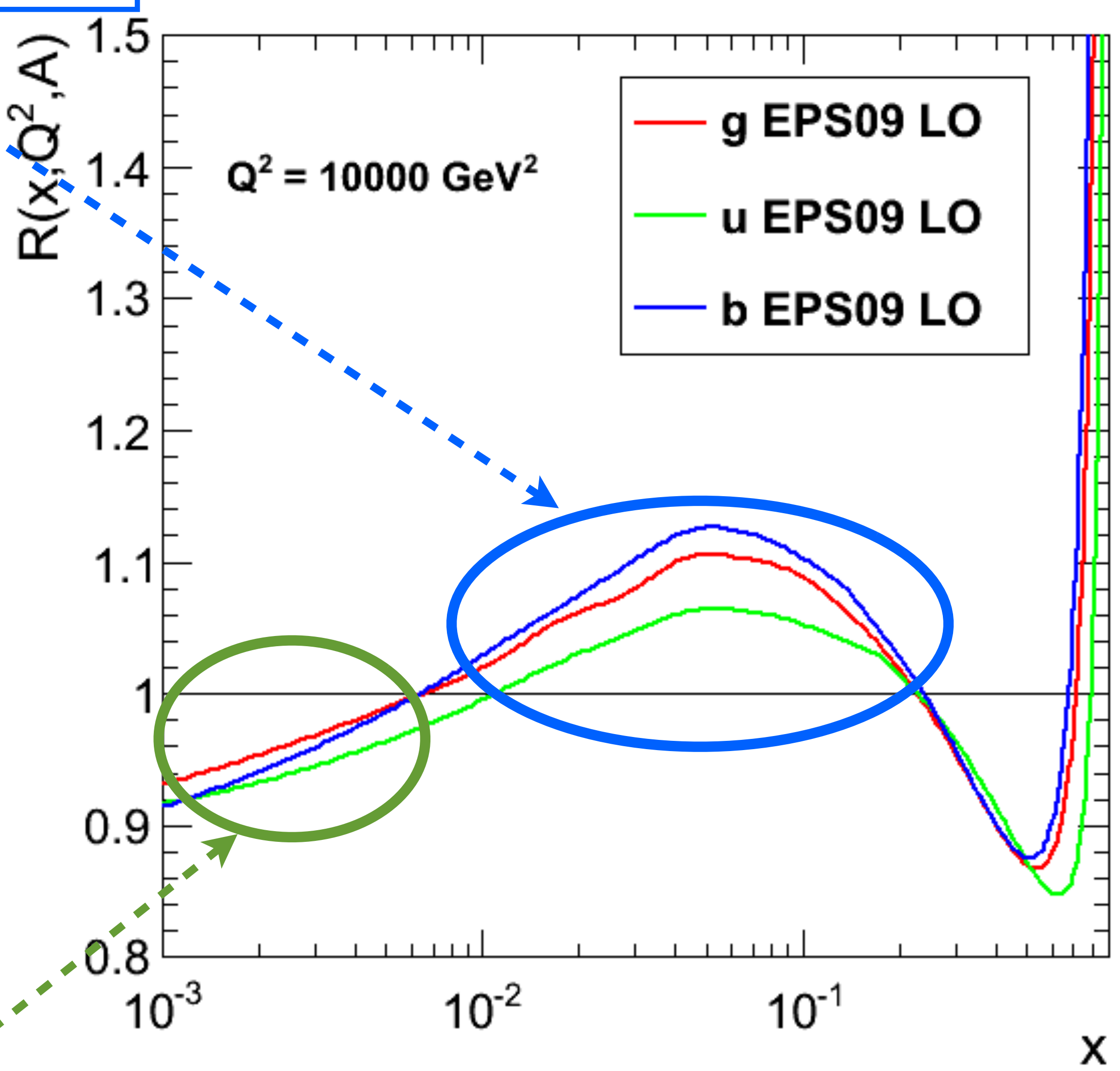


Anatomy of the dijet η distribution

CMS PAS HIN-13-001



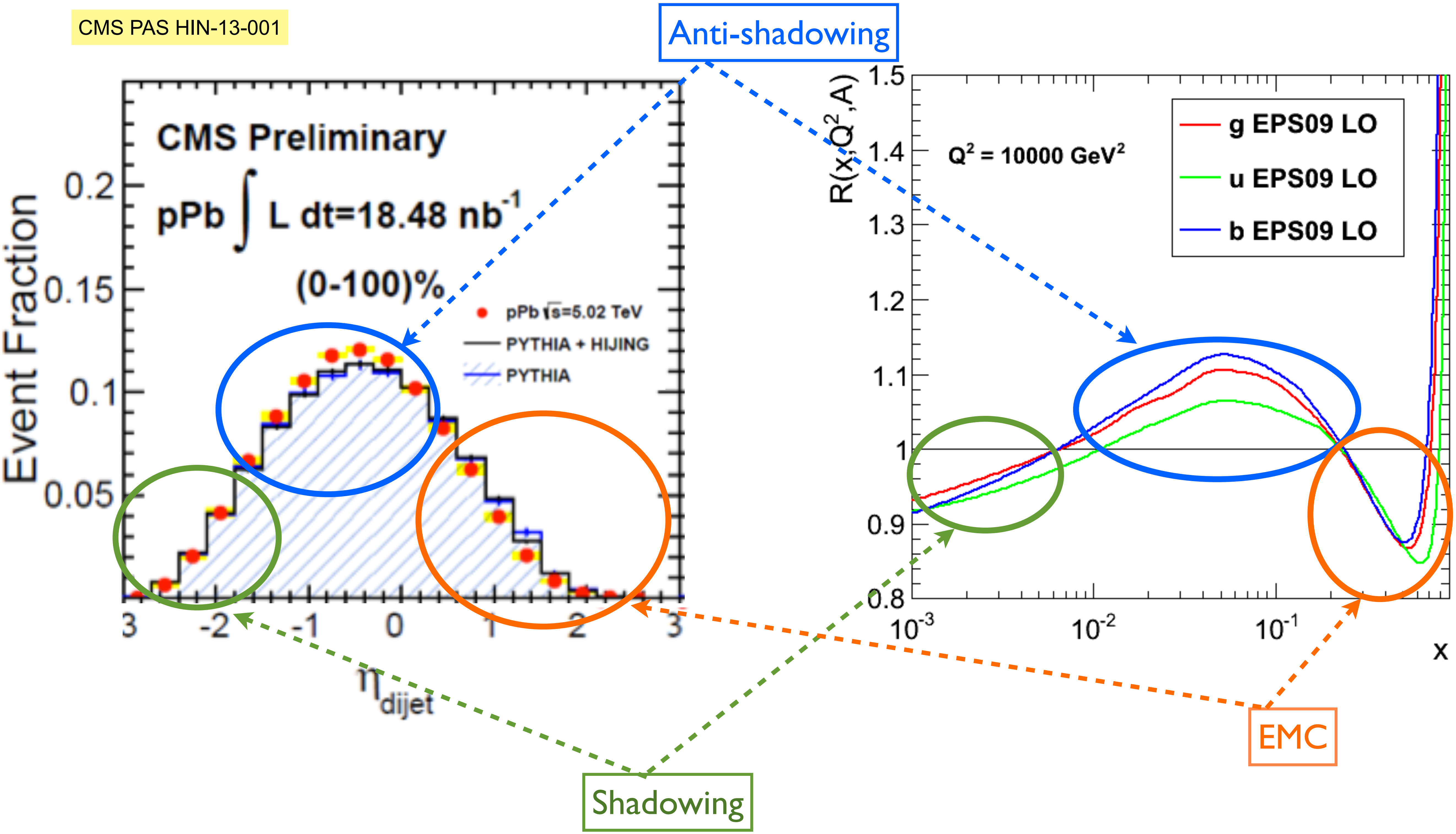
Anti-shadowing



Shadowing

Anatomy of the dijet η distribution

CMS PAS HIN-13-001



Summary from dijet η

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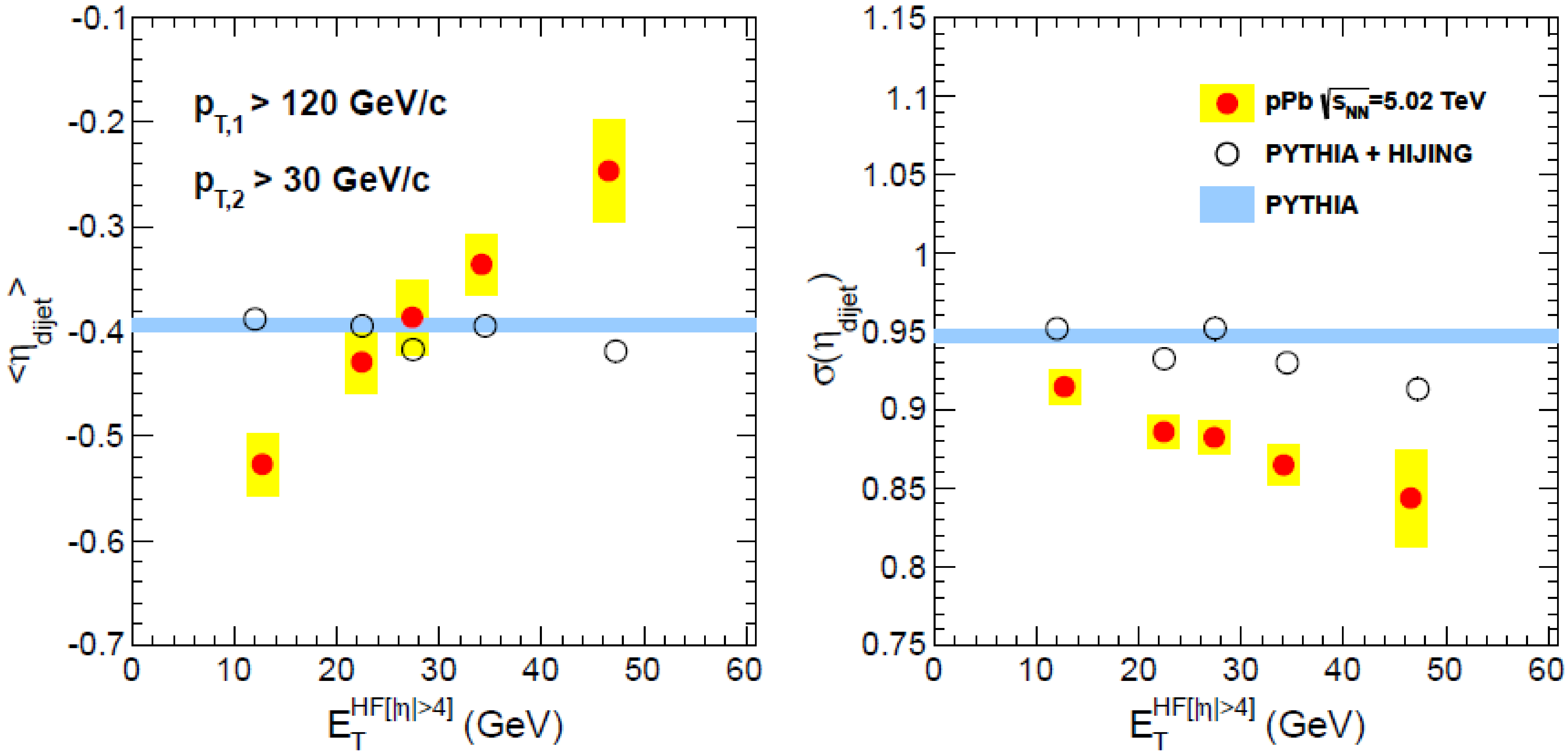


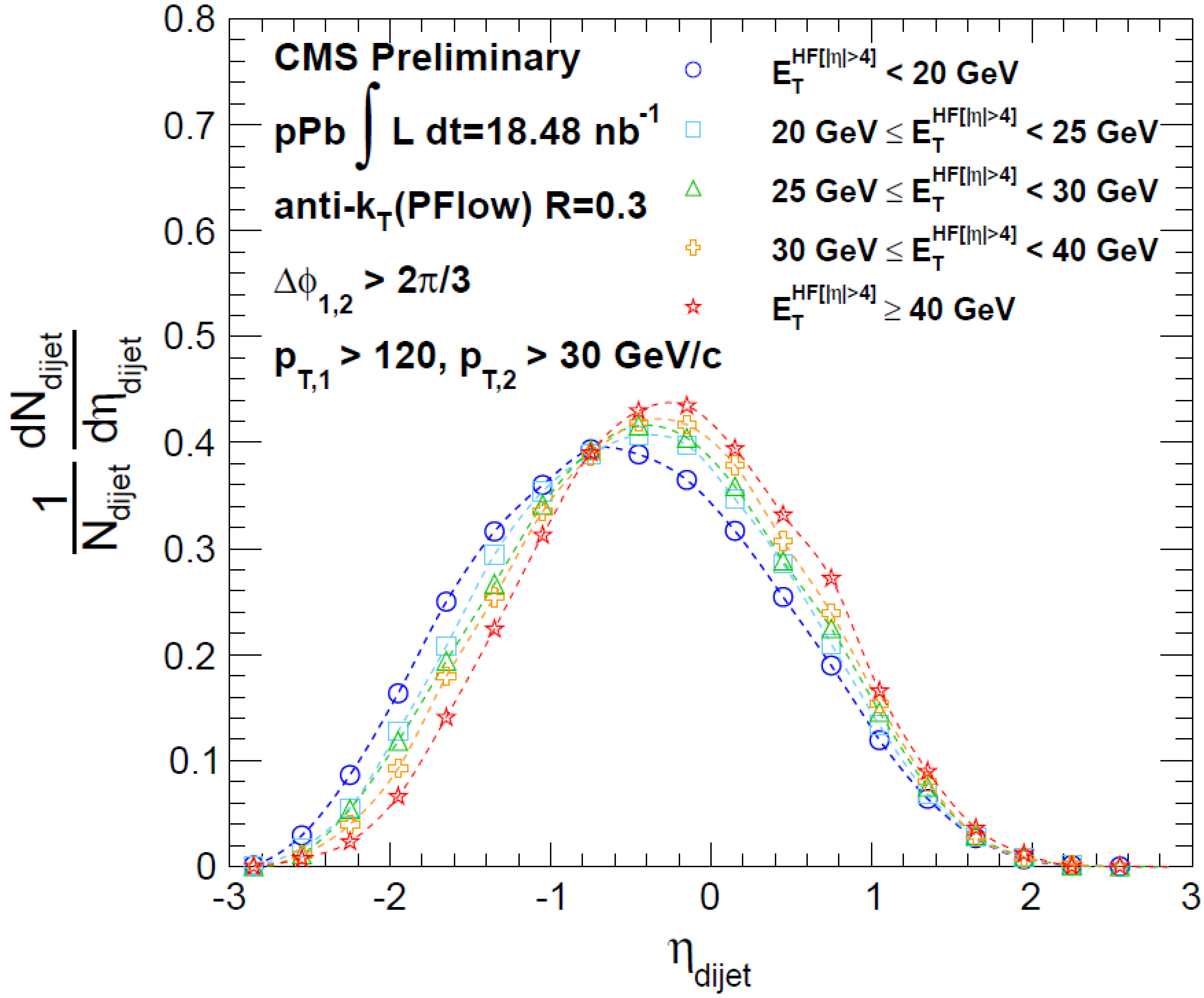
$$\eta_{dijet} = \frac{\eta_1+\eta_2}{2}$$

- Mean of η_{dijet} increases v.s. forward calorimeter energy
- Width of η_{dijet} decreases v.s. forward calorimeter energy

Scaling in EMC region

CMS PAS HIN-13-001

Normalized by N_{dijet}

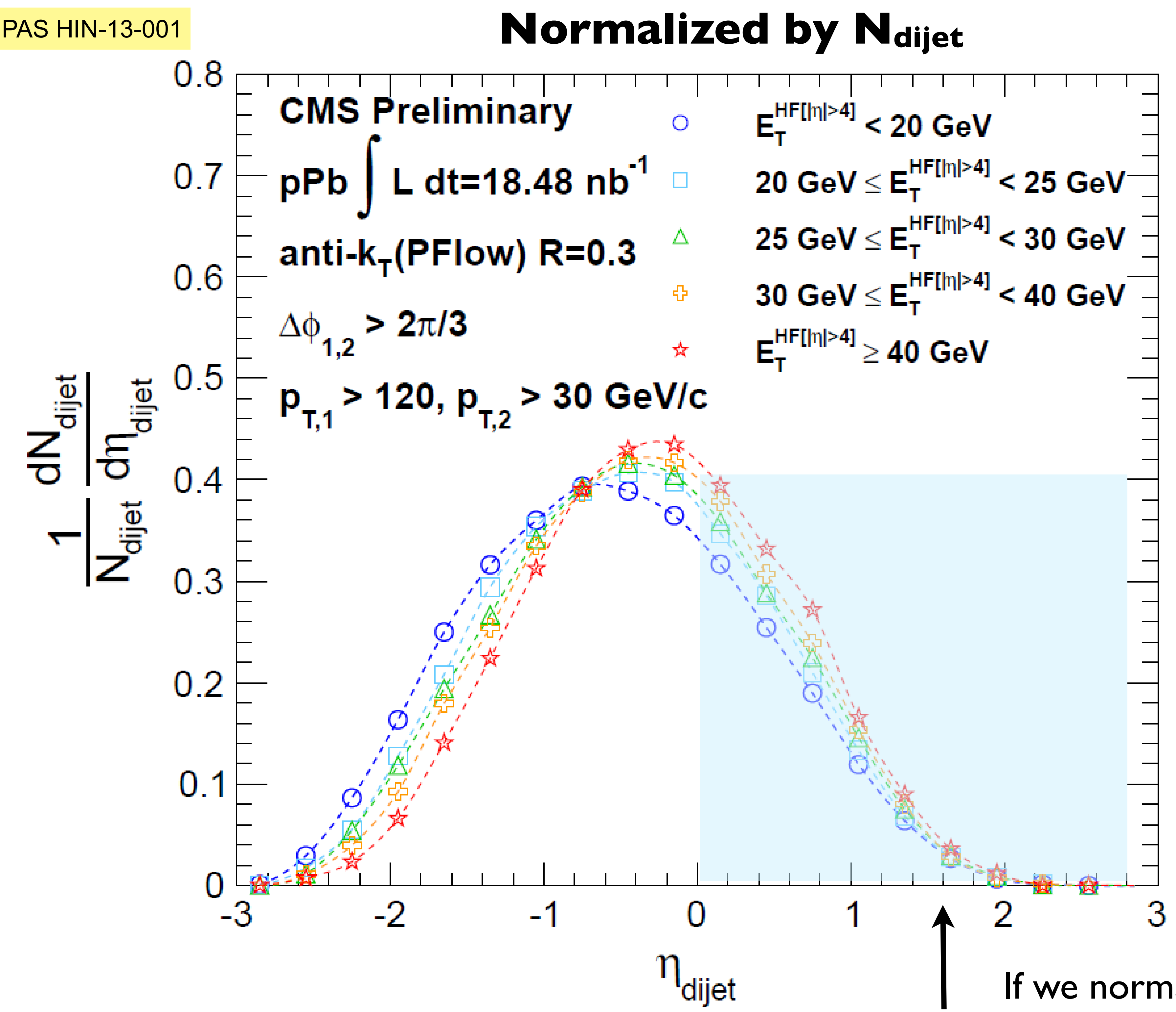


$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2}$$

- Evolution of η shift vs HF energy in full η_{dijet}

Scaling in EMC region

CMS PAS HIN-13-001



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

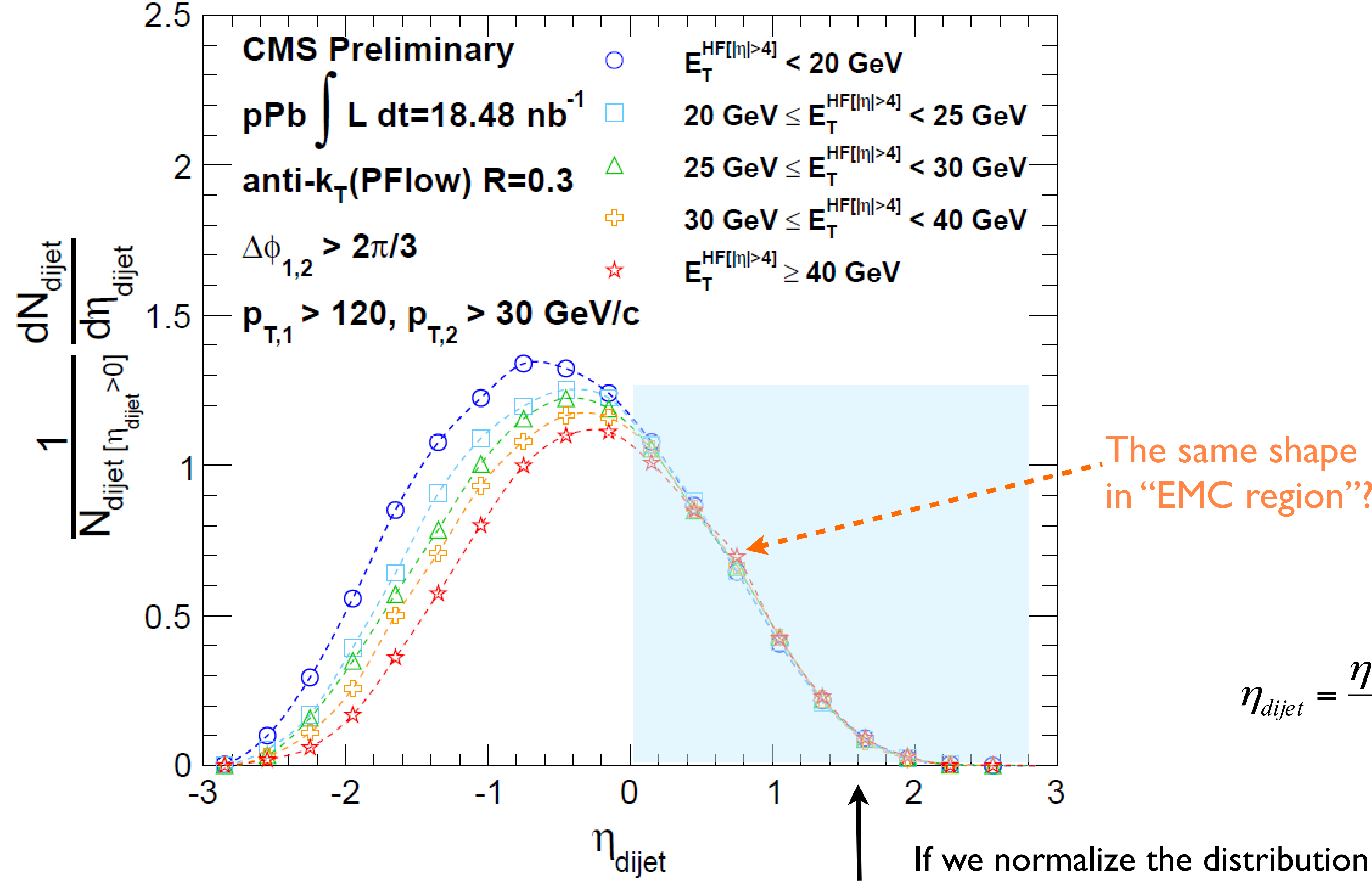
If we normalize the distribution by the area in the interval $\eta_{dijet} > 0$

- Evolution of η shift vs HF energy in full η_{dijet}

Scaling in EMC region

CMS PAS HIN-13-001

Normalized by N_{dijet}



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

If we normalize the distribution by the area in the interval $\eta_{dijet} > 0$

- Evolution of η shift vs HF energy remains in "shadowing regime"

Summary

- Jet quenching:
  - No significant modification observed in dijet p_T ratio and azimuthal angle correlation in pPb collisions
  - A final state effect due to hot QCD medium produced in HI collisions
- Dijet pseudorapidity distributions:
  - Provide strong constraints for nPDF determination
  - Interesting trend in η_{dijet} v.s. forward calorimeter energy is observed in the shadowing and EMC regions
- More results to come in the future, please stay tuned!

Thanks for your attention!

backup