Studies of dijet and photon-jet properties in pp, pPb, and PbPb collisions with CMS

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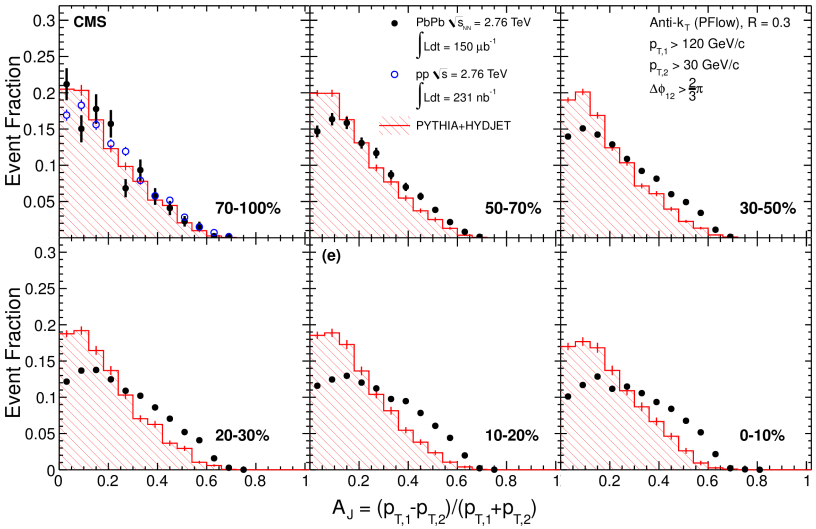
Motivations

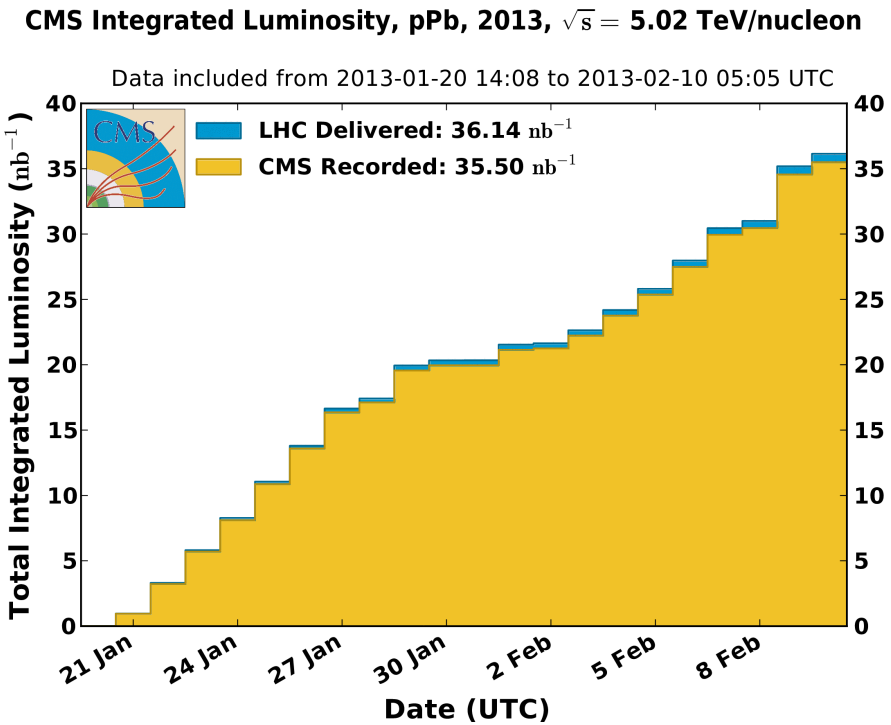
- There is jet quenching in PbPb
- pPb dijets and photon-jets
  - Is there jet quenching in pPb? (Final state effects?)
  - If not, can we constrain nPDFs? (Initial state effects?)
- Photon-jets in pp and PbPb
  - With a clean, unbiased sample can we investigate the energy loss mechanism in the QGP?



Phys. Lett. B 712 (2012) 176

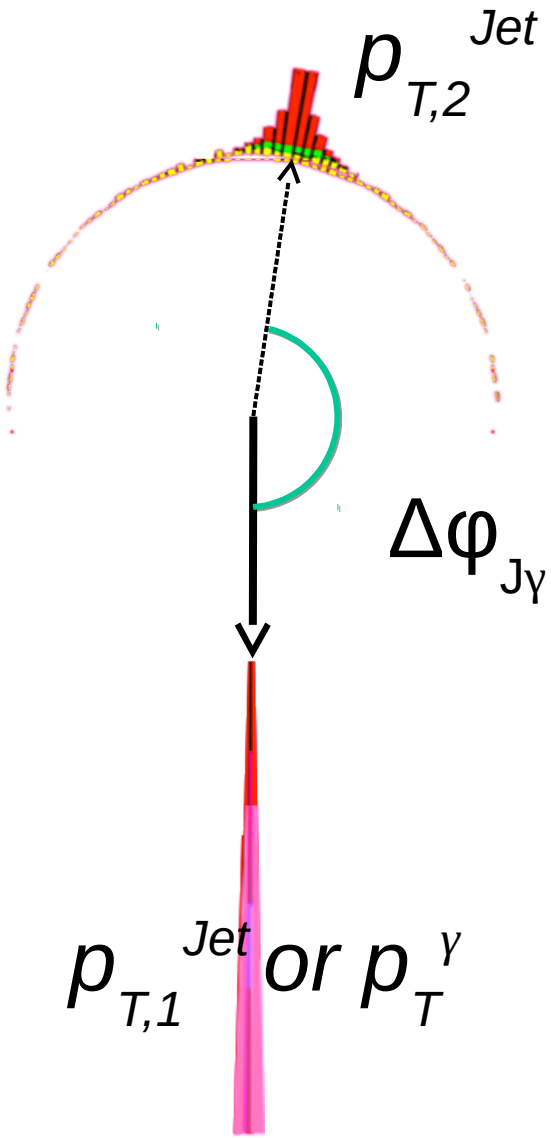
Data samples and goals

- Data used in these analyses:
  - 2011 PbPb at 2.76 TeV, 150 μb^{-1}
  - 2013 pp at 2.76 TeV, 5.3 pb^{-1}
  - 2013 pPb at 5.02 TeV, 35 nb^{-1}
- Dijets in pPb arxiv:1401.4433
  - Constrain the NLO nPDFs
- Photon-jet CMS-PAS-HIN-13-006
  - Update of the previous CMS photon-jet analysis, Phys. Lett. B 718 (2013) 773, with new pp data reference
  - p_T^y dependent analysis accesses energy loss as a function of initial parton momentum
  - pPb offers insight into cold nuclear matter effects

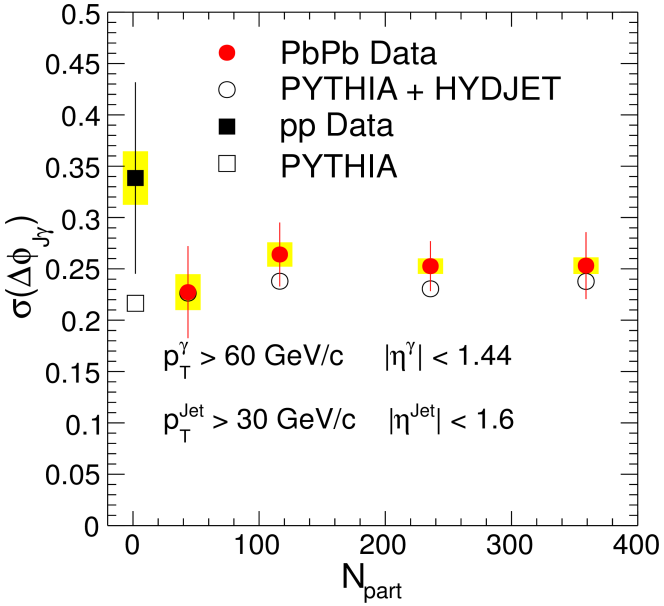


Observables

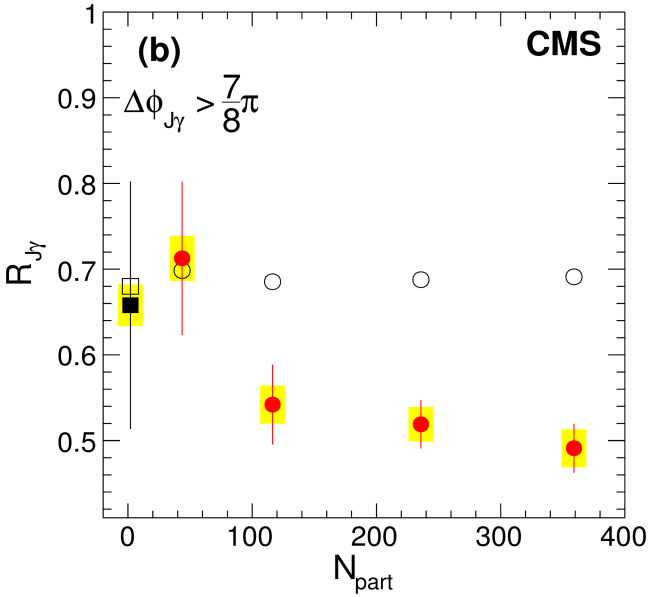
- Azimuthal decorrelation: $\Delta\varphi_{J\gamma}$, and its parametrized width $\sigma(\Delta\varphi_{J\gamma})$
- Transverse momentum ratio: $x_{J\gamma}=p_T^{Jet}/p_T^{\gamma}$, and its mean $\langle x_{J\gamma}\rangle$
- $\eta_{dijet} = (\eta_1+\eta_2)/2$
- Fraction of photons with associated jets: $R_{J\gamma}$
- Ratio of jet yield, Jet I_{AA}: number of jets in each p_T^{γ} and p_T^{Jet} bin in PbPb over the number in pp.



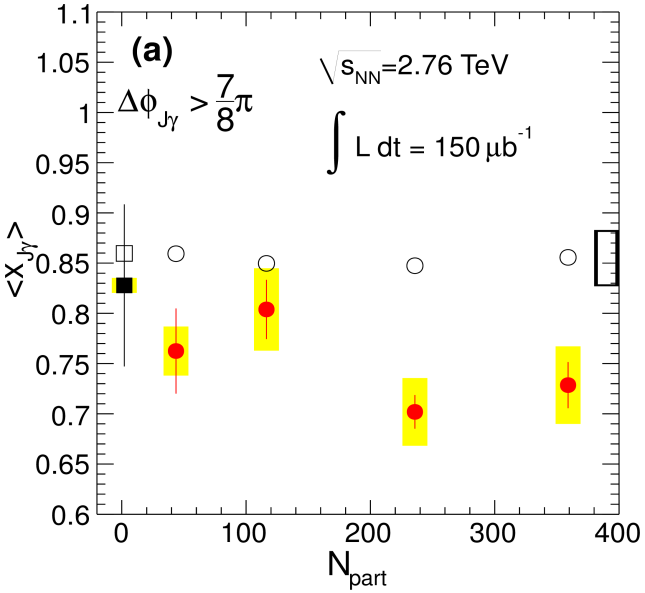
No jet deflection, but loss of jet partners in PbPb



$\sigma(\Delta\varphi_{J\gamma})$ = azimuthal correlation



$R_{J\gamma}$ = Fraction of photons with jet partner



$x_{J\gamma} = p_T^{Jet}/p_T^{\gamma}$

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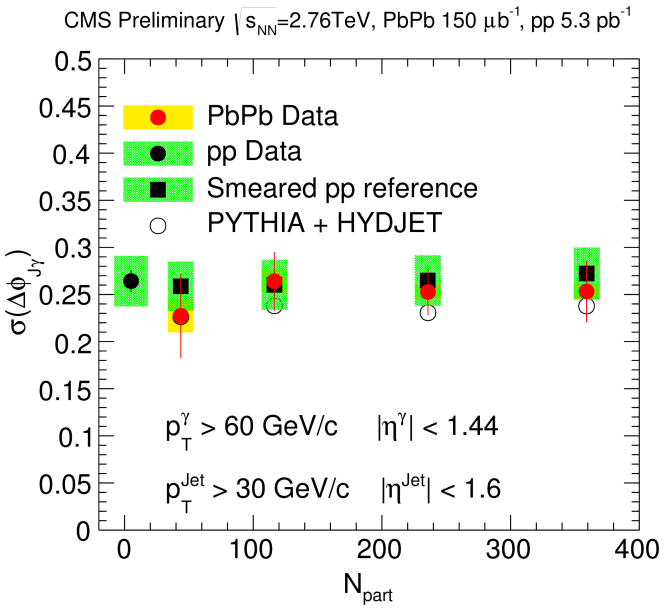
No jet deflection, but loss of jet partners in PbPb



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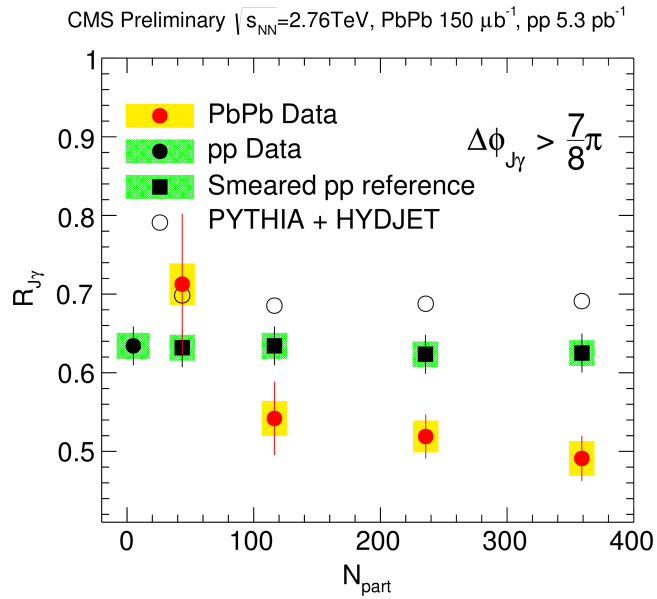

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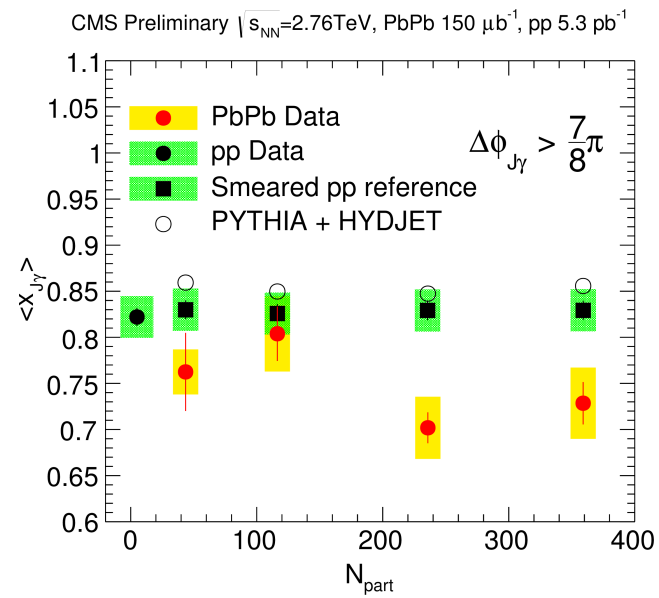

$x_{J\gamma} = p_T^{Jet}/p_T^{\gamma}$

Note: pp reference is smeared to match PbPb jet energy resolution in each centrality bin.

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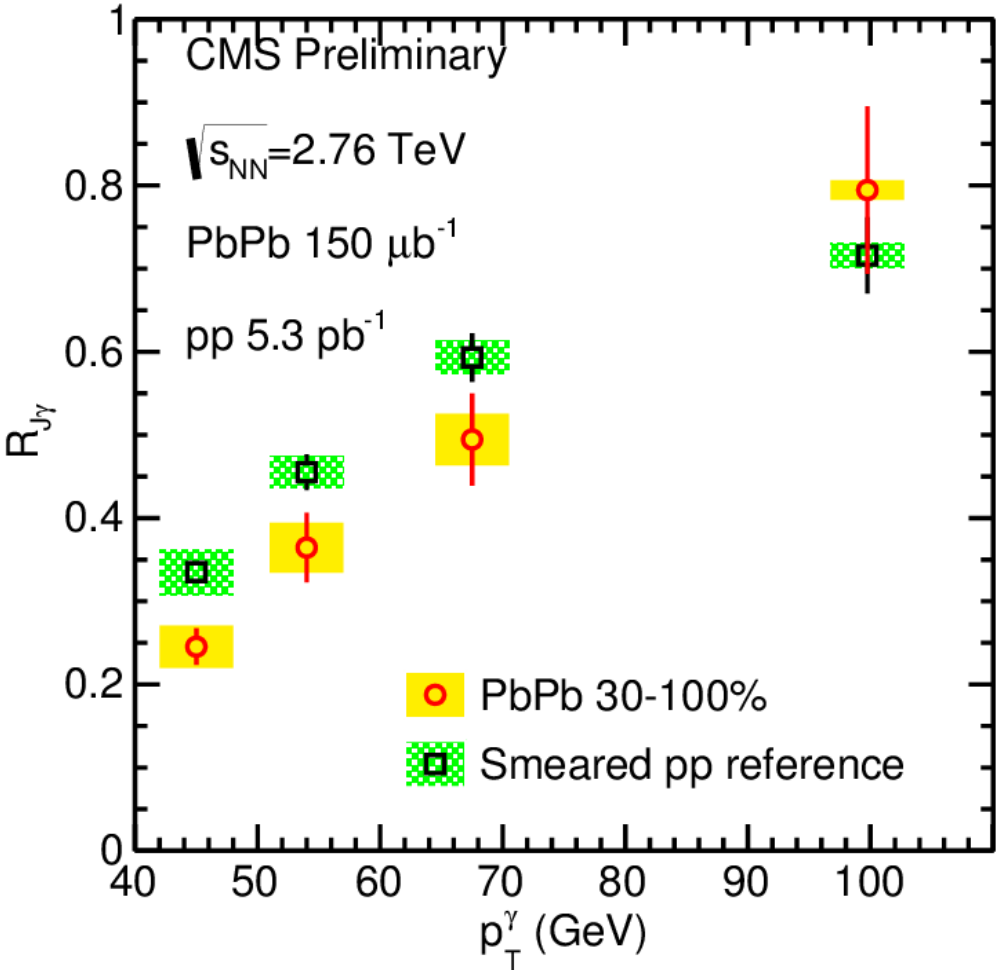
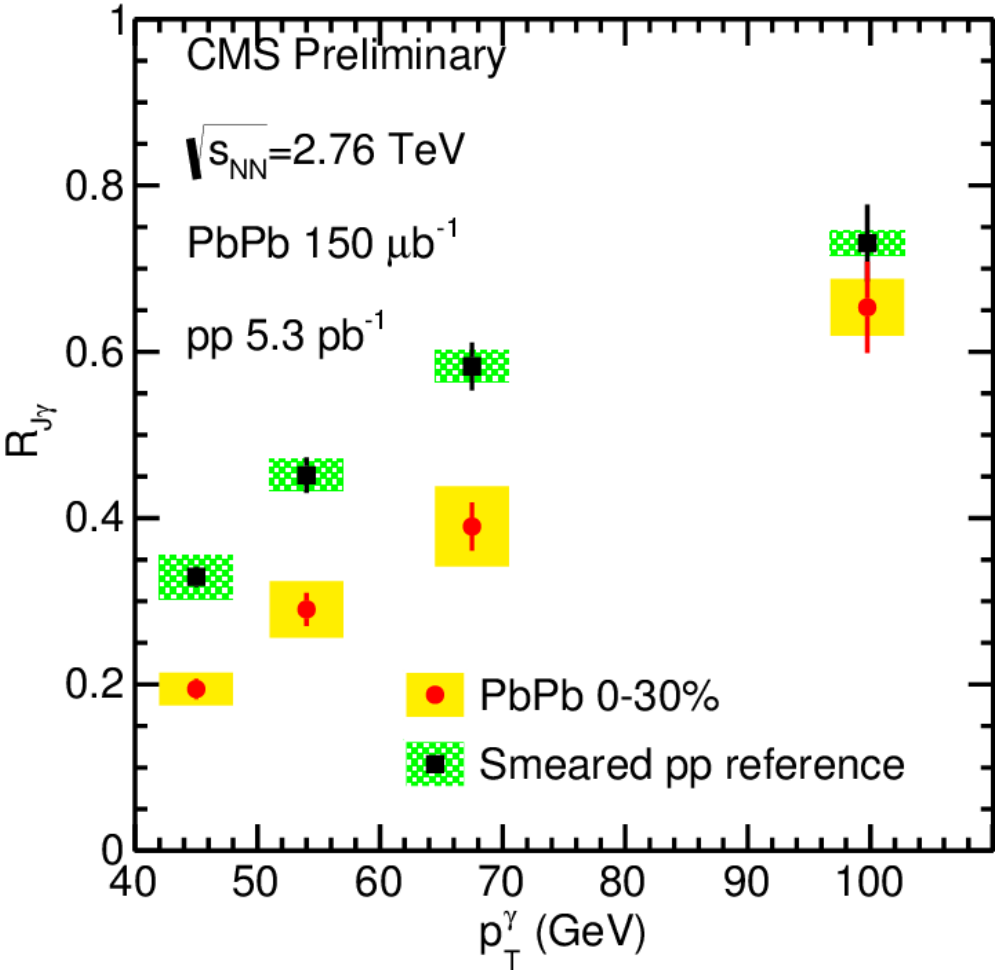
Loss of jet partners constant over p_T^{γ} in PbPb





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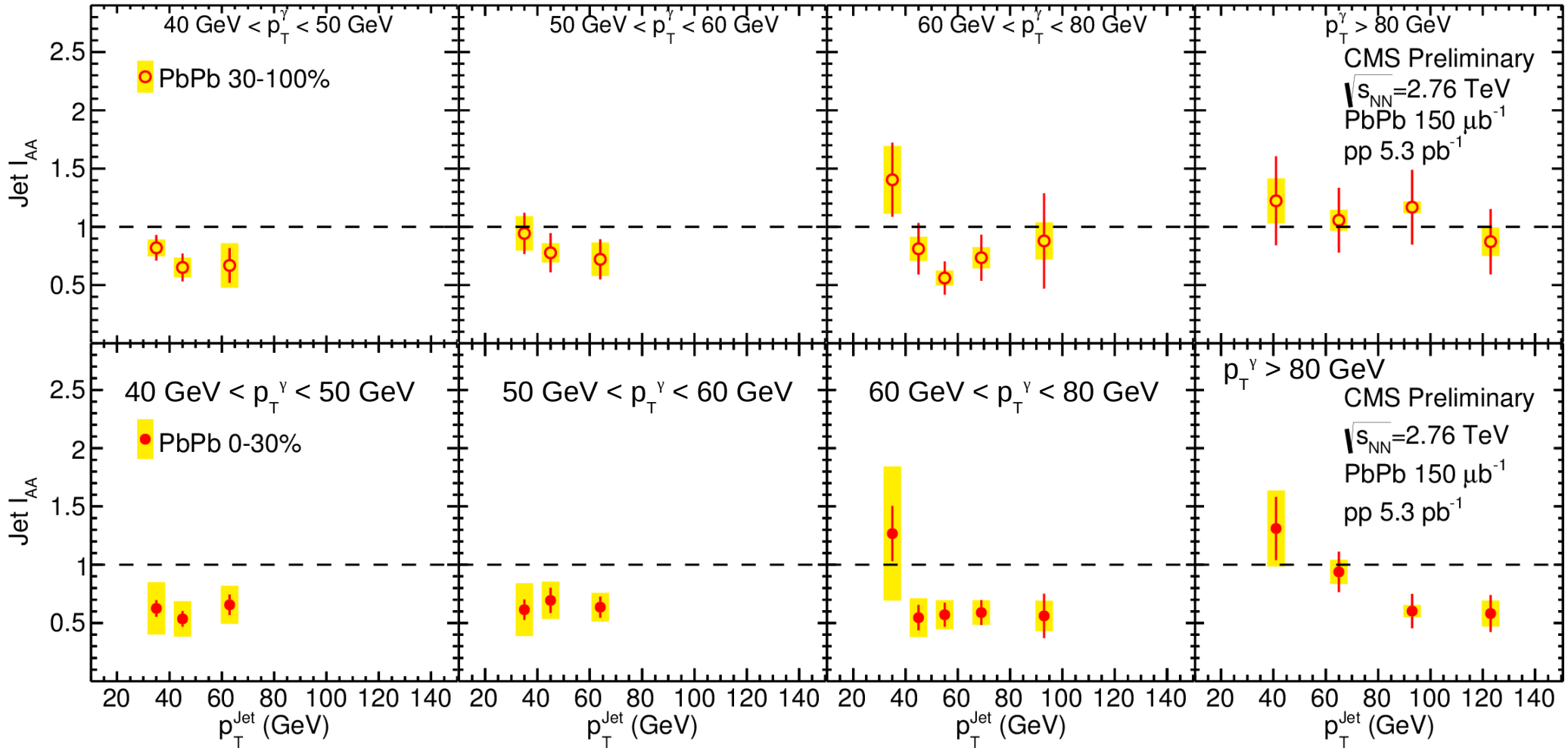
Jet Yield shifted to lower p_T^{Jet} in PbPb



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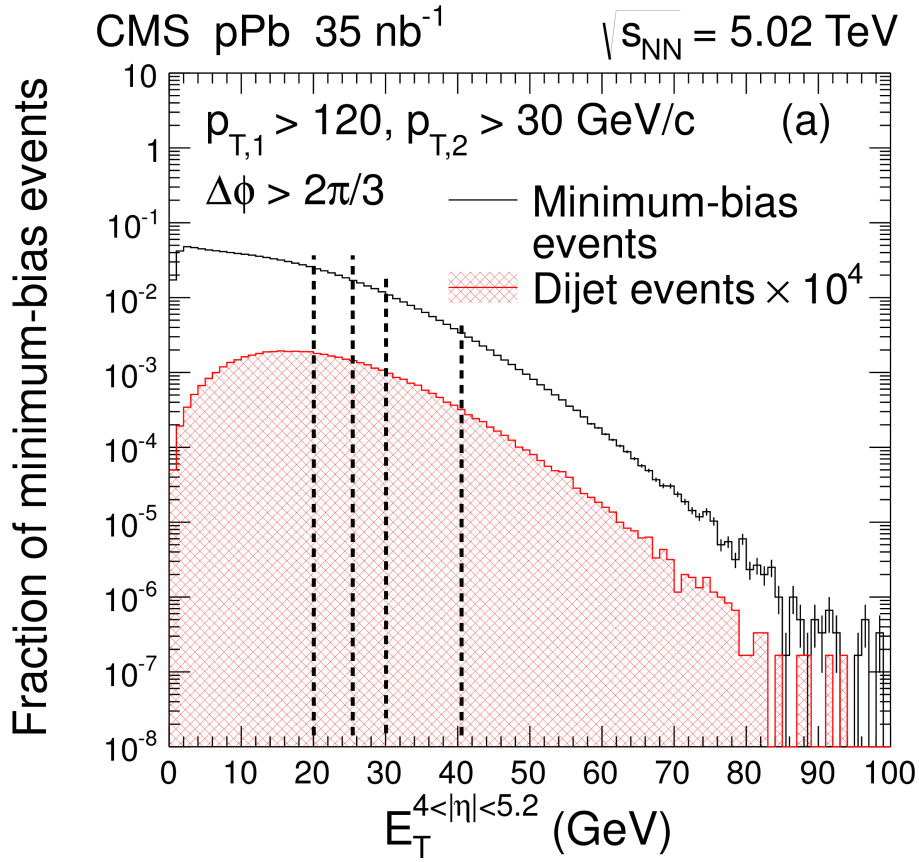
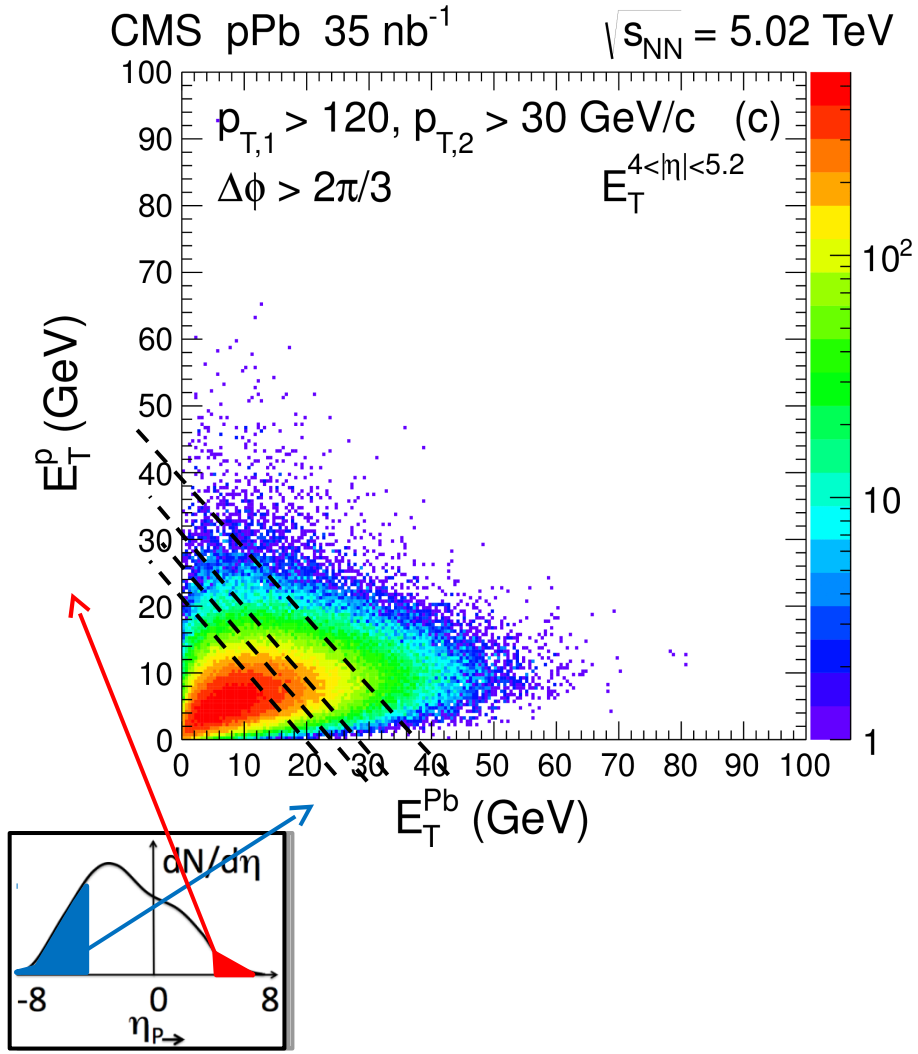
- Jet yield pushed to lower p_T^{Jet} relative to p_T^γ

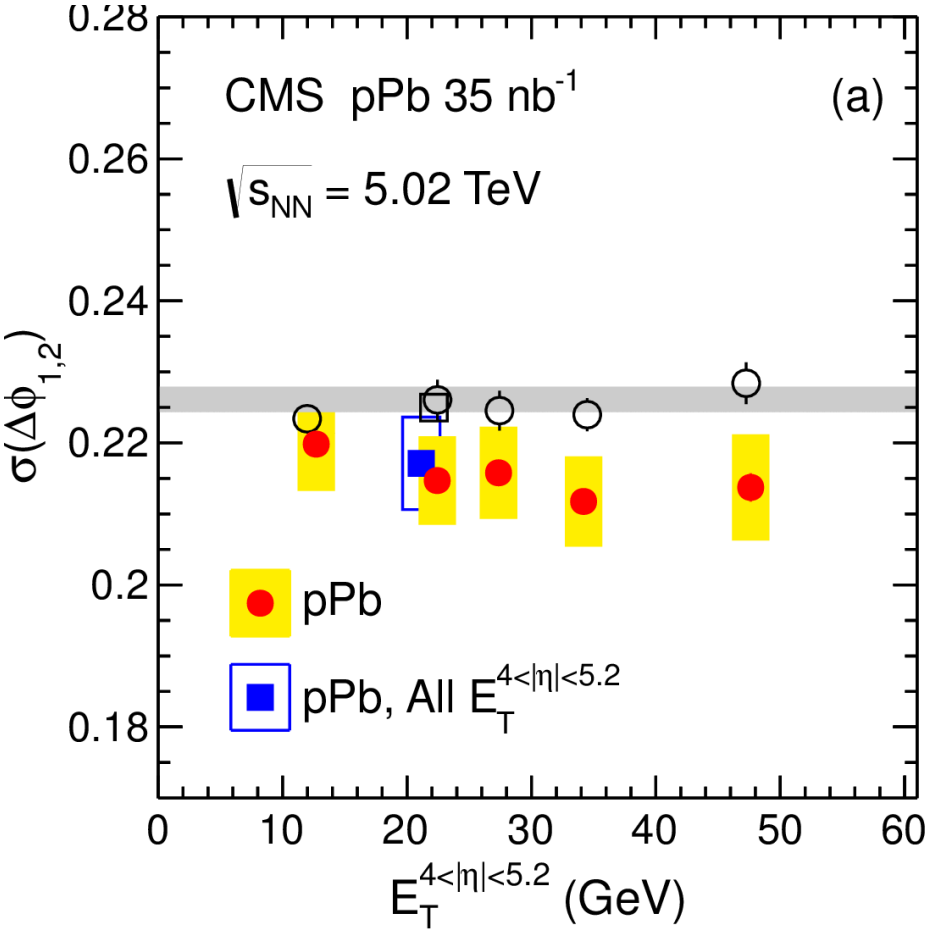
Event Classification in pPb dijets

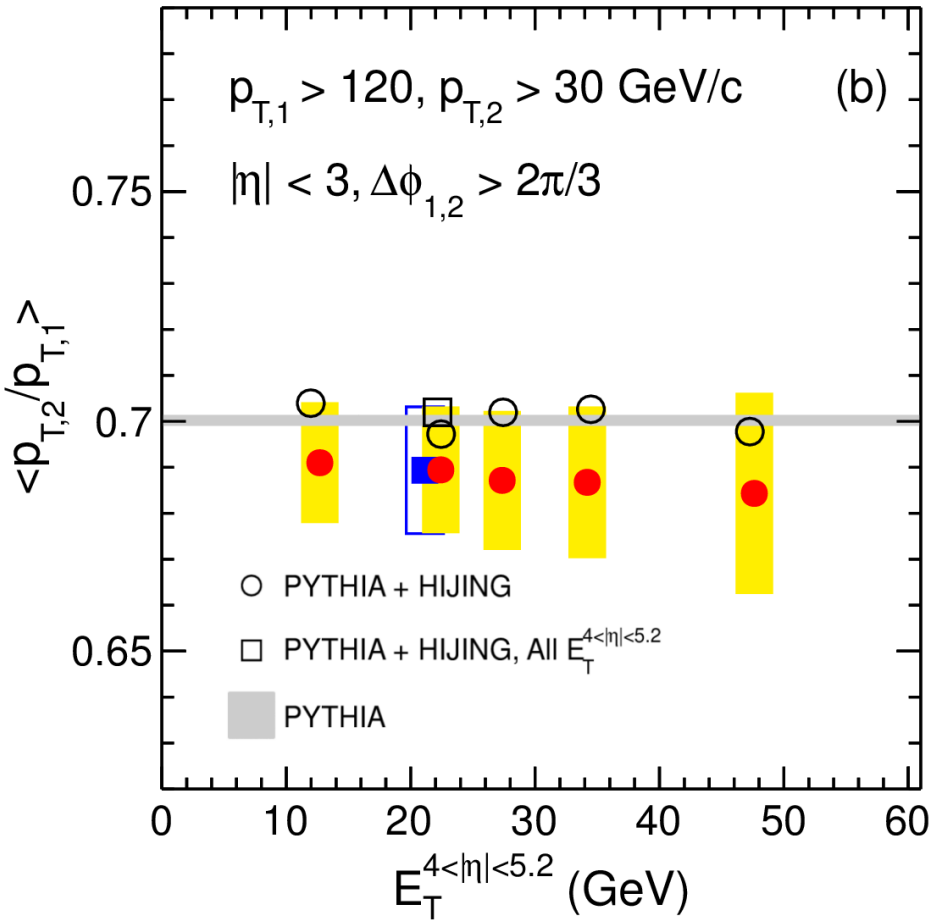




- Events classified by energy in HF beyond pseudorapidity gap: $E_T^{4<|\eta|<5.2}$

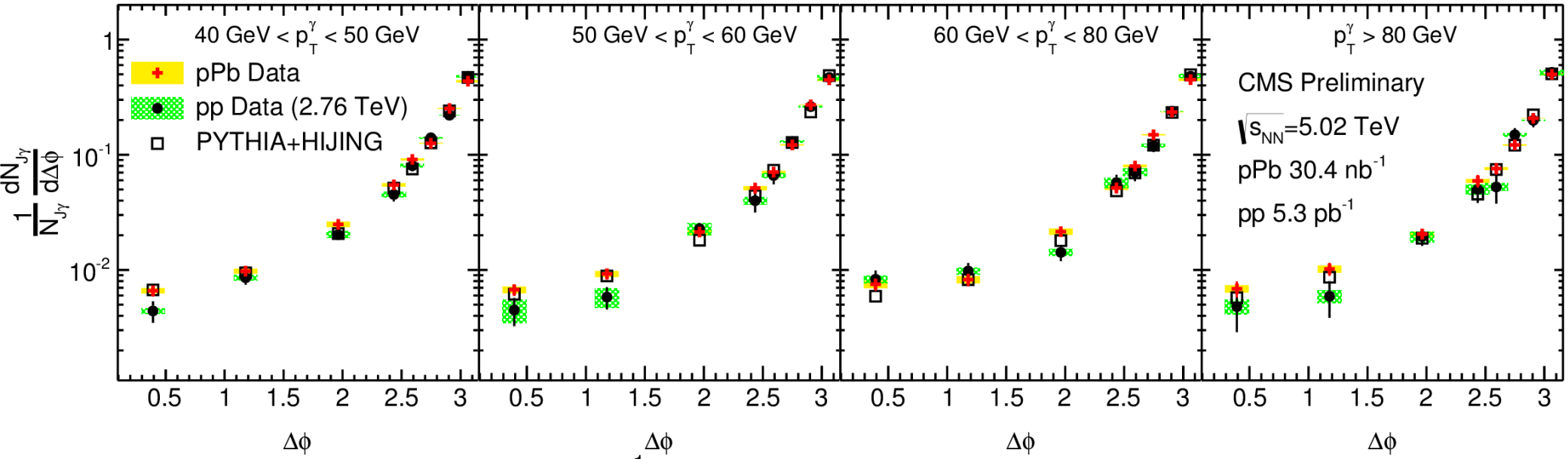
No jet deflection, no energy loss in pPb from dijet

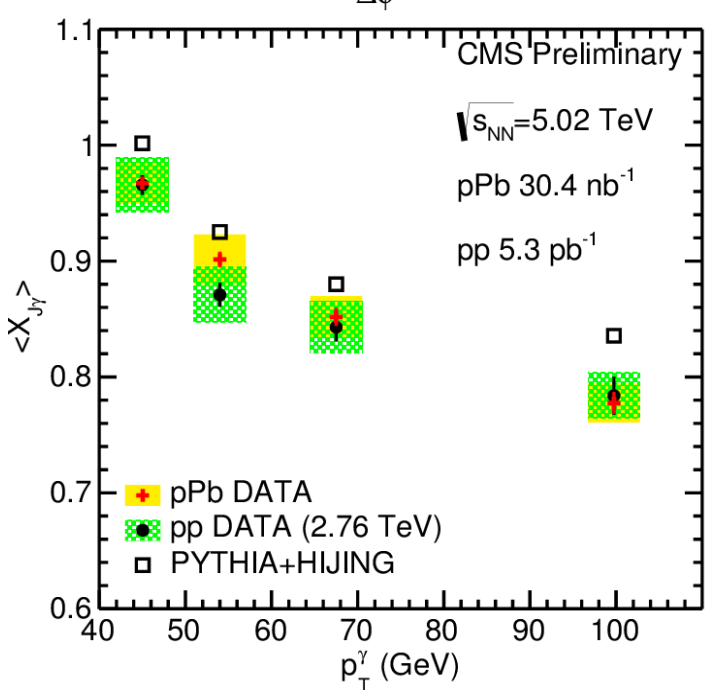


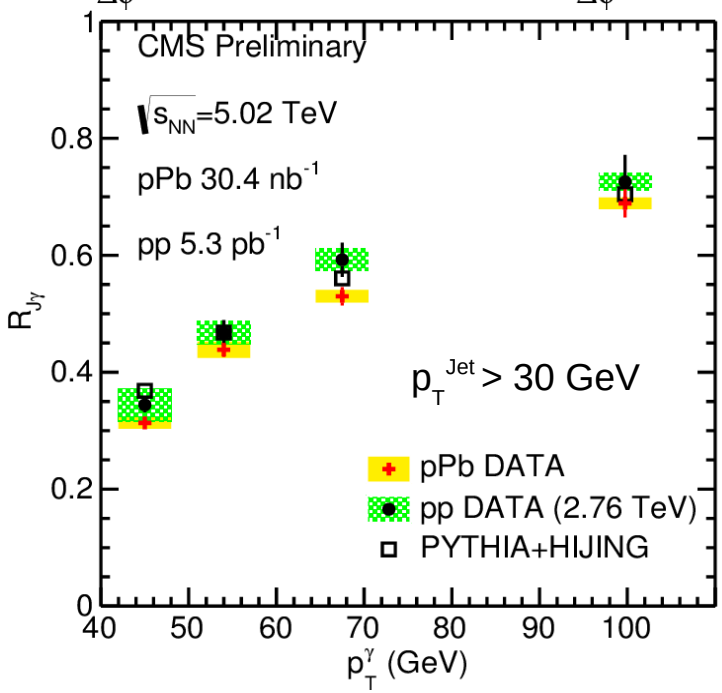


arxiv:1401.4433

No jet deflection, no energy loss in pPb from photon-jet







- $x_{J\gamma} = p_T^{Jet}/p_T^{\gamma}$
- $R_{J\gamma}$ = Fraction of photons with jet partner

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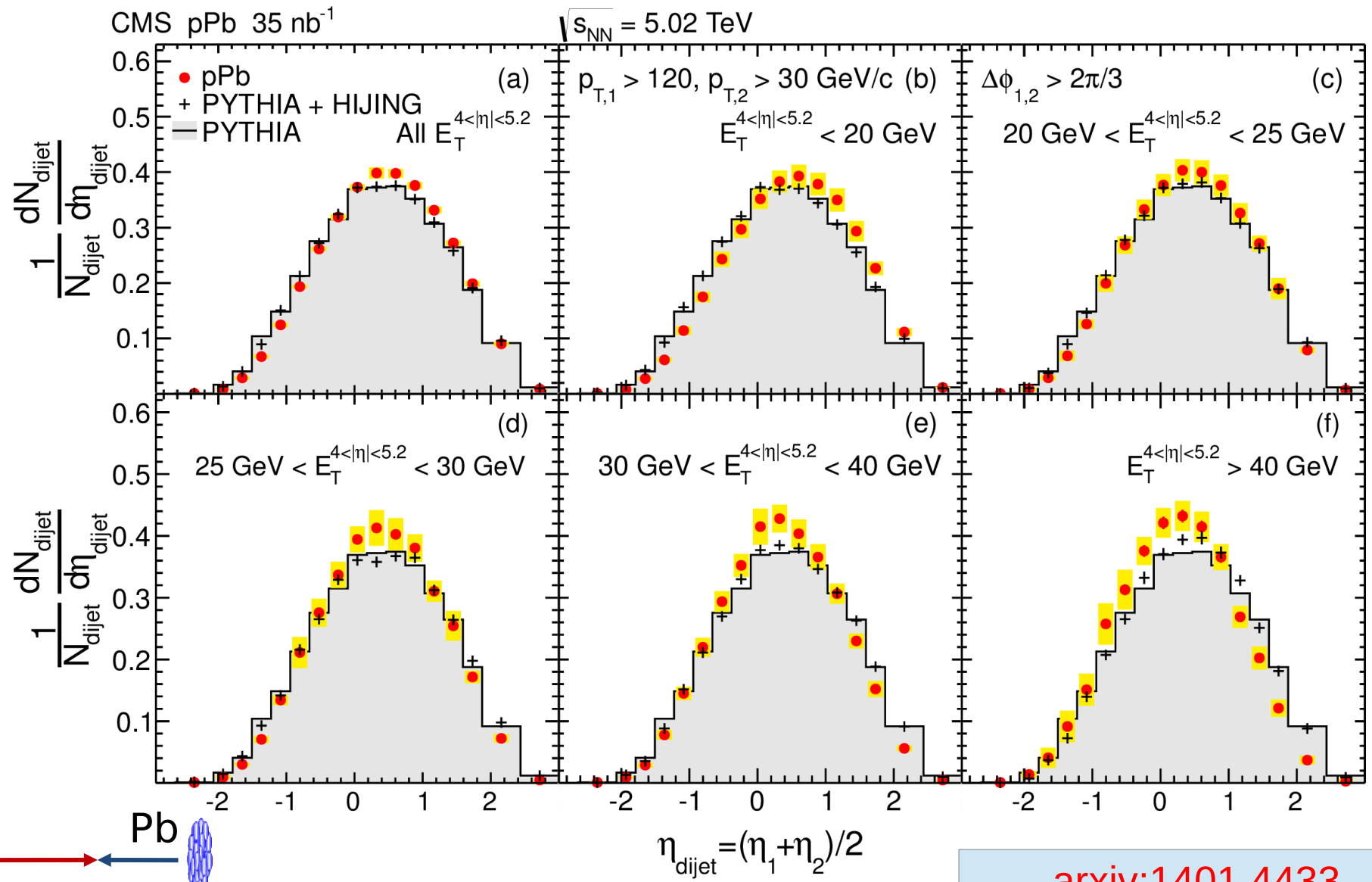
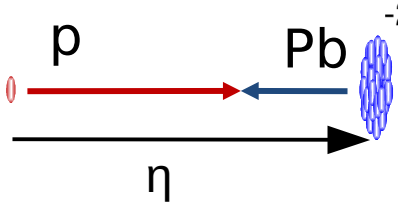
Shift of η_{dijet} with activity





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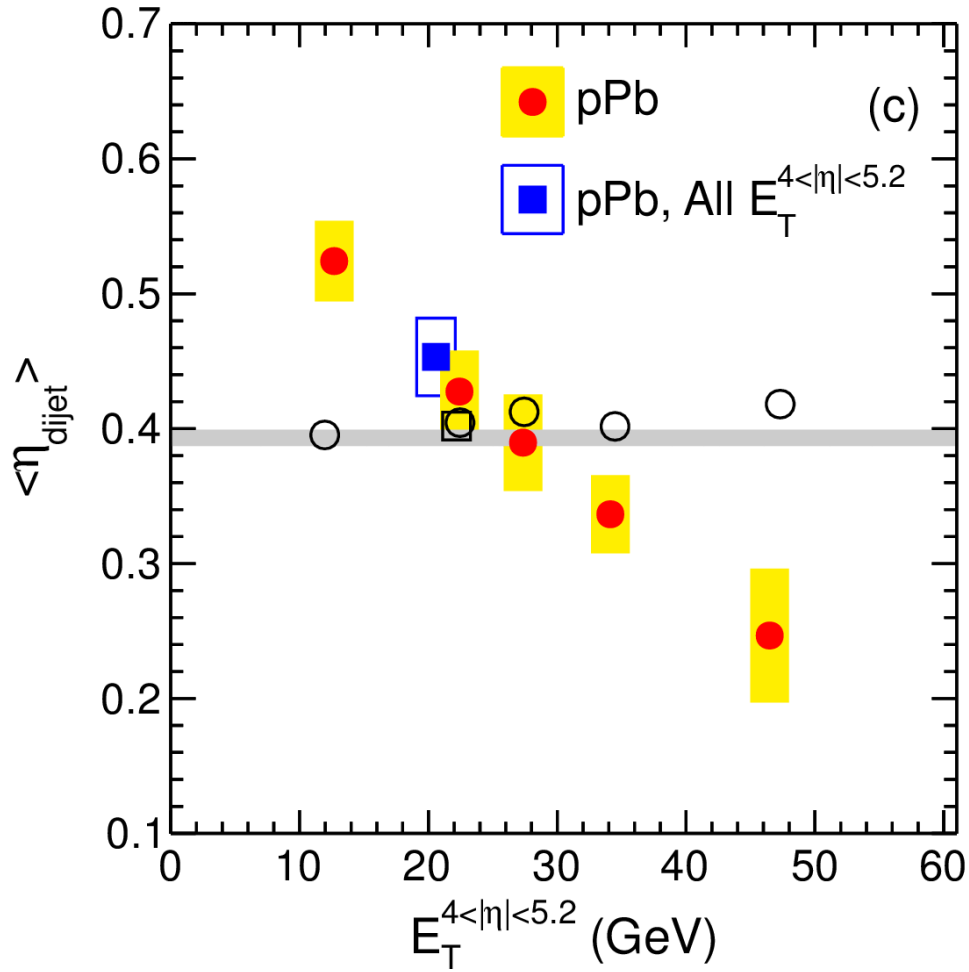

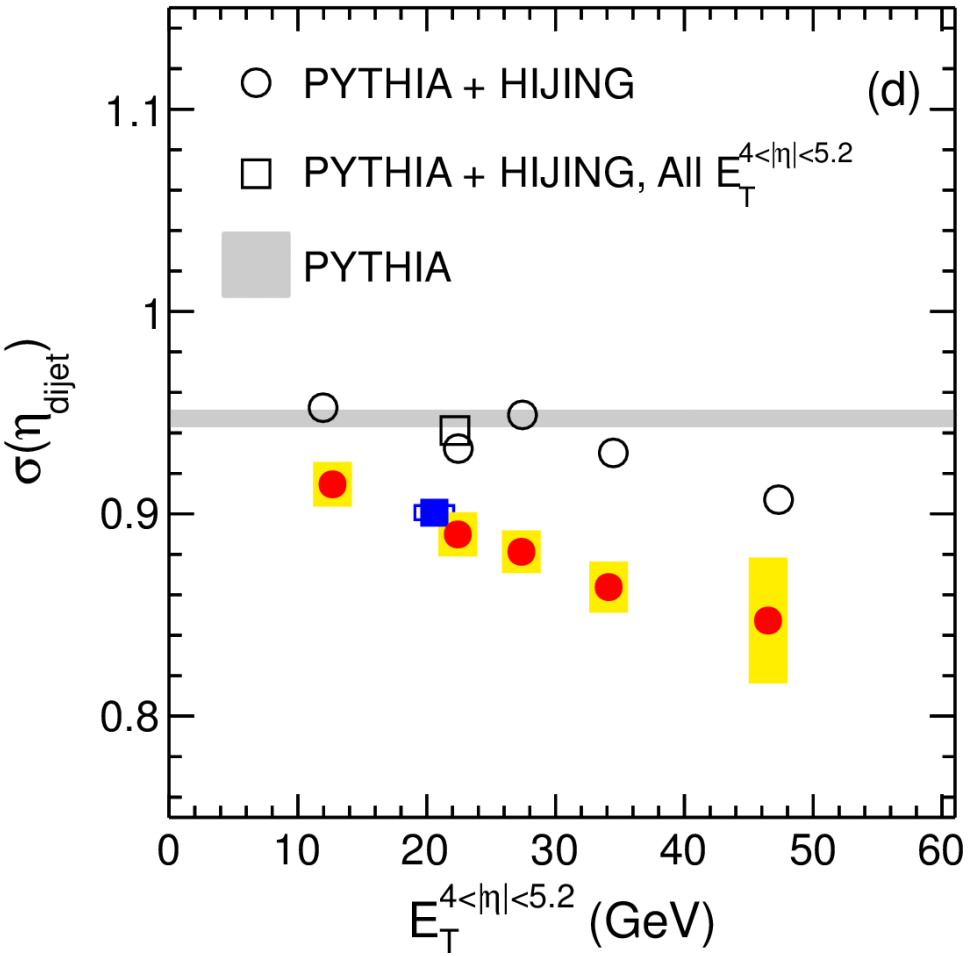

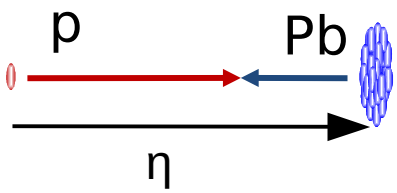

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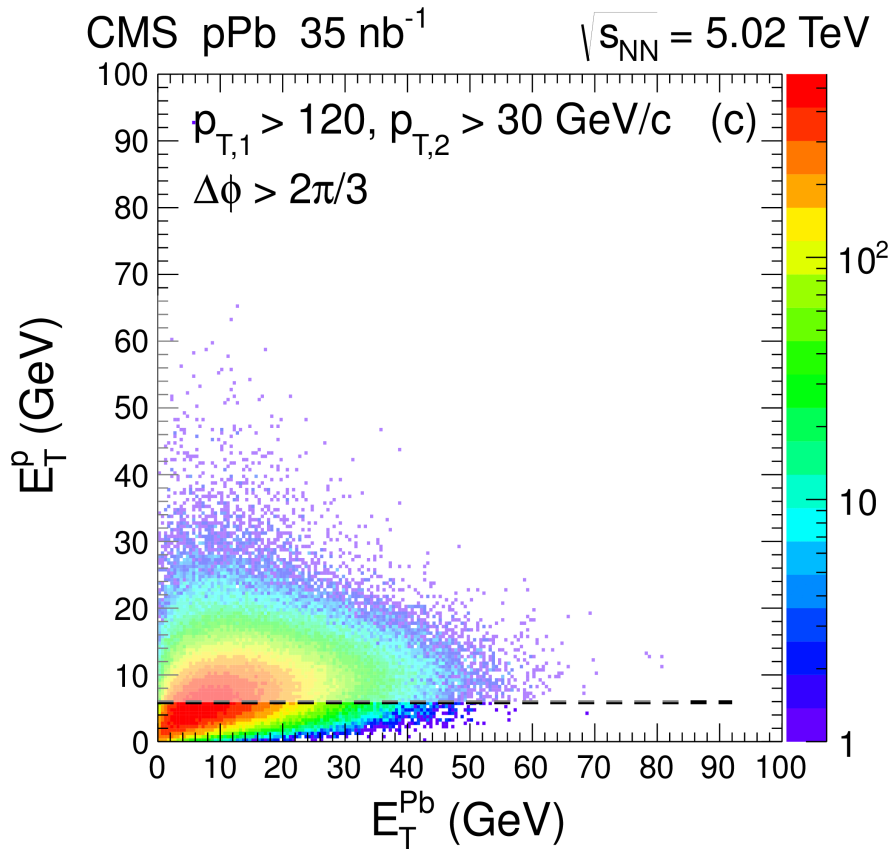
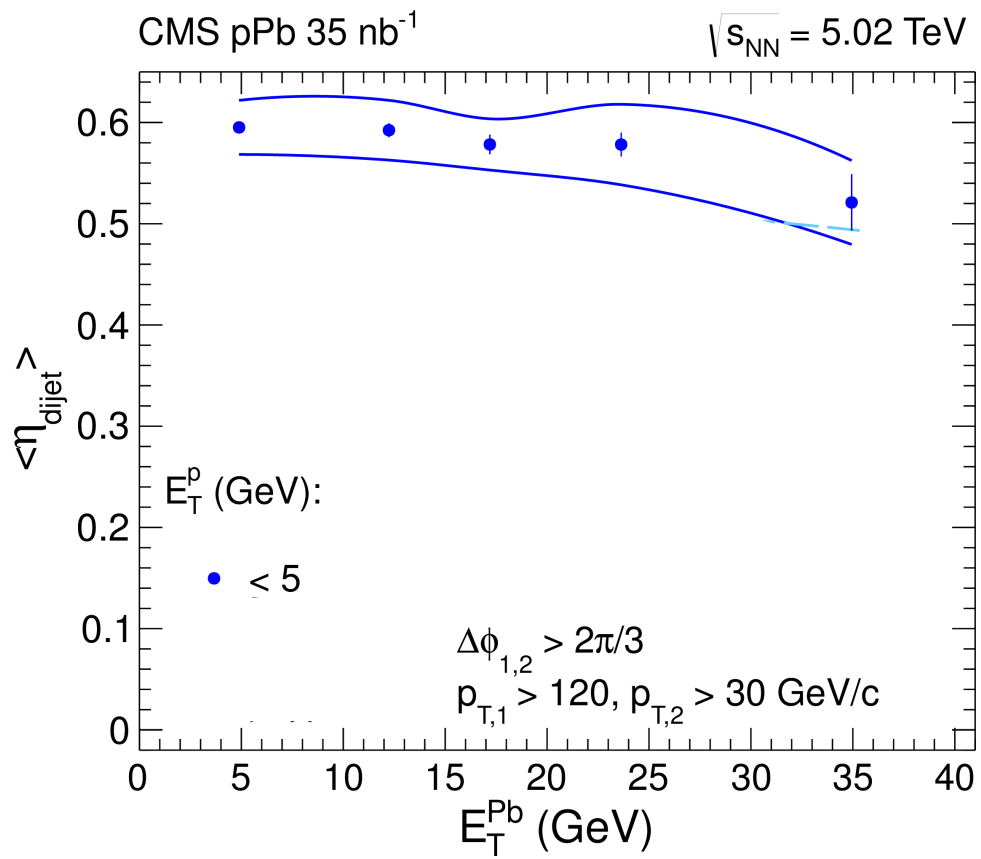
E_T^p drives physics of η_{dijet}





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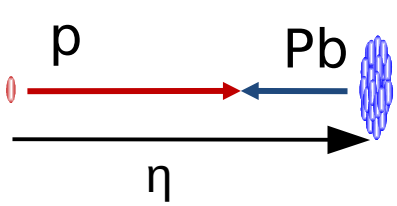
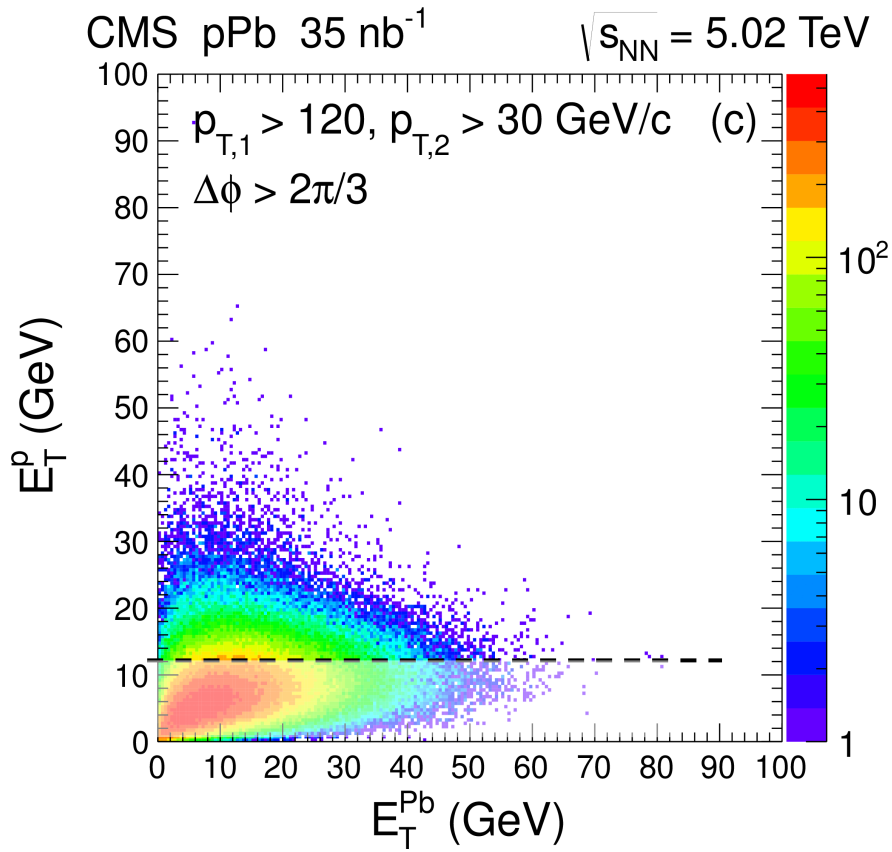
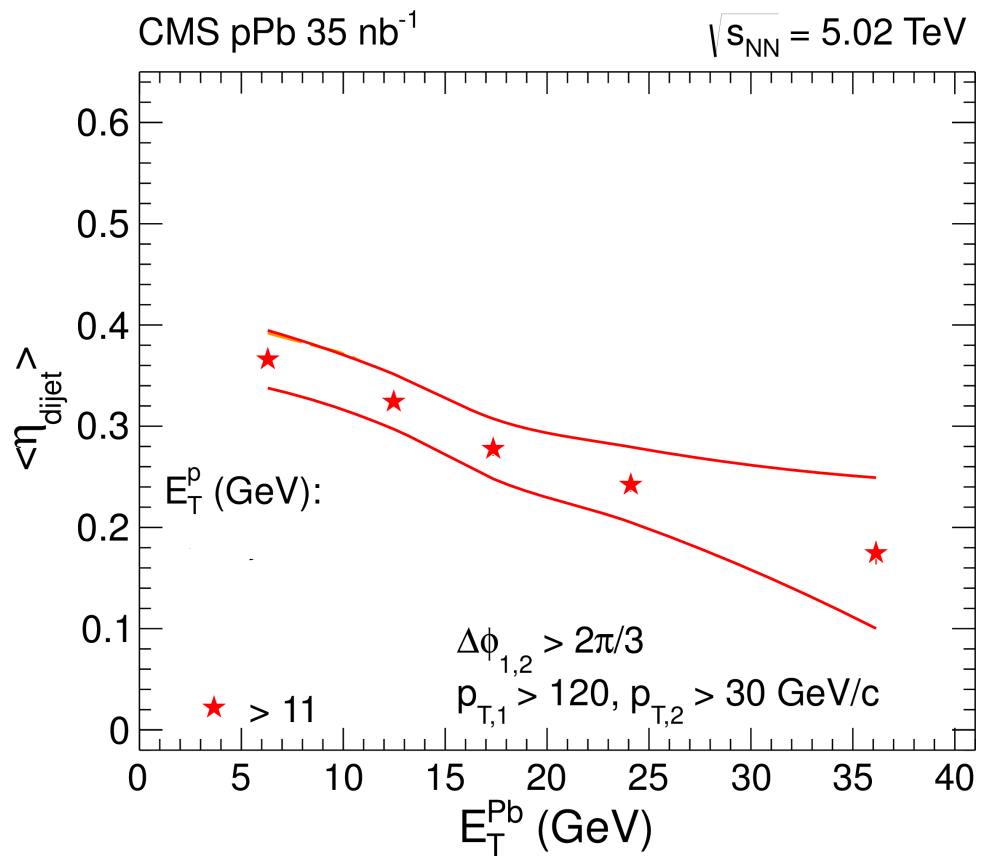


- η_{dijet} constant when fixing small E_T^p

E_T^p drives physics of η_{dijet}





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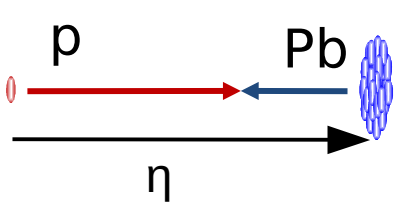
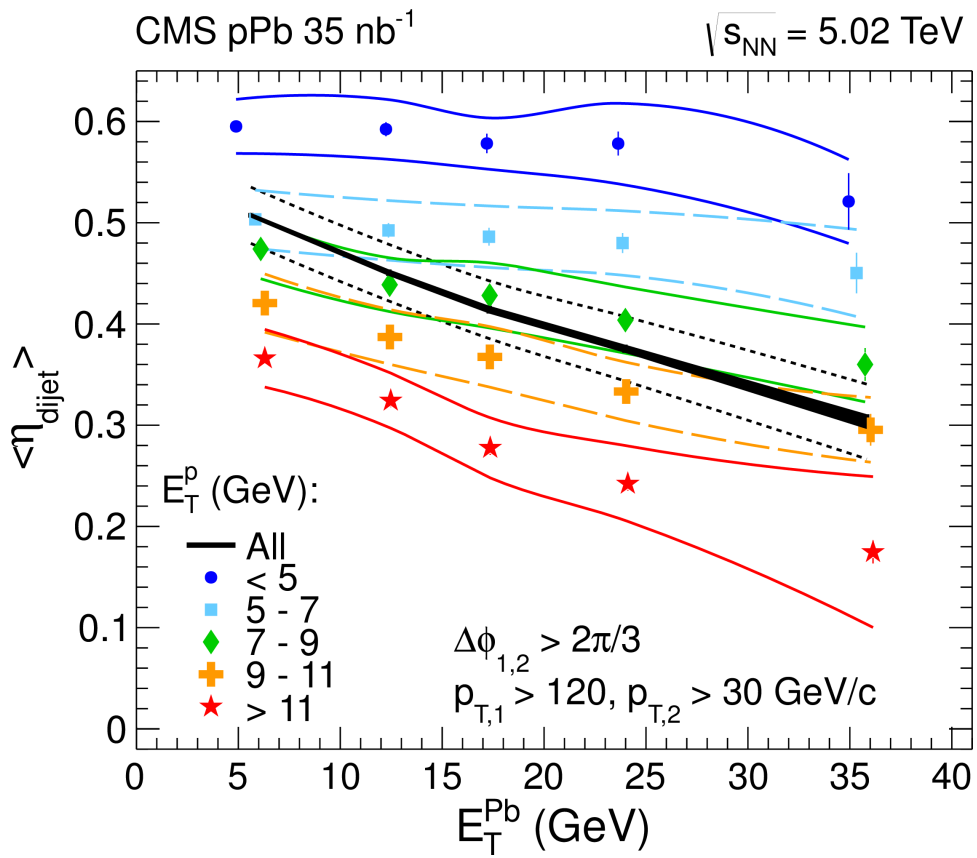


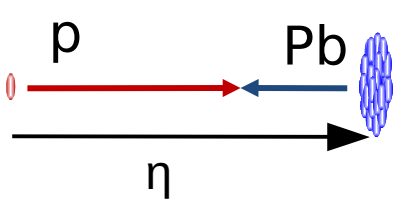
- η_{dijet} highly dependent on E_T^{Pb} when fixing large E_T^p

E_T^p drives physics of η_{dijet}

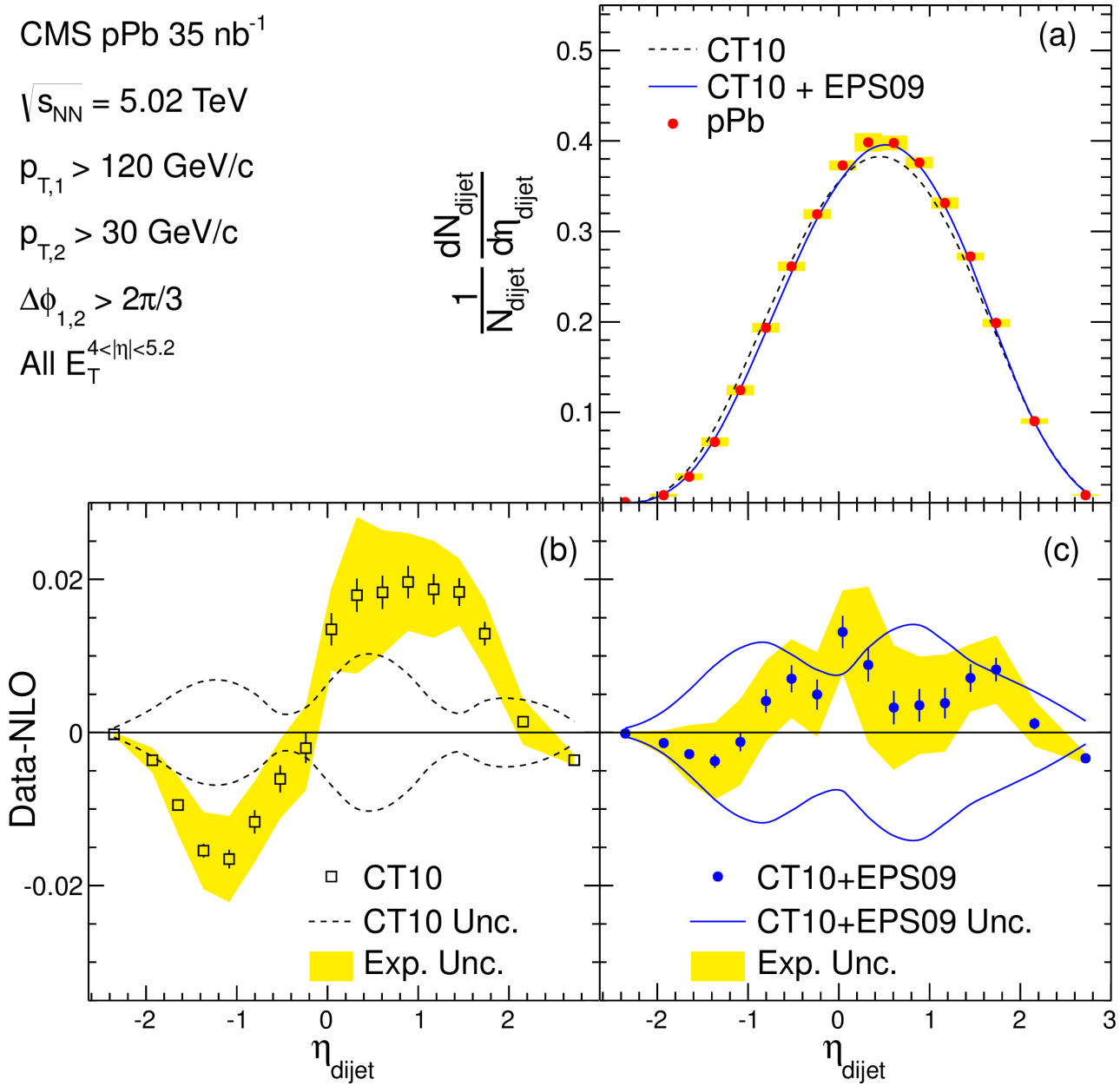


arxiv:1401.4433

- η_{dijet} constant when fixing small E_T^p
- η_{dijet} highly dependent on E_T^{Pb} when fixing large E_t^p
- Large shift as a function of $E_T^{4<|\eta|<5.2}$ cannot be explained by impact parameter dependence of nPDFs
- Slope for inclusive sample is steeper than any subset:
  - Requirement for large E_T^p may have conservation of energy effects at midrapidity



Inclusive η_{dijet} constrains nPDFs

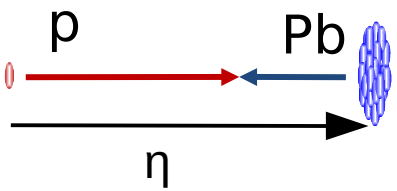


arxiv:1401.4433

CTEQ collaboration
arXiv:1007.2241

Escola, Paukkunen, Salgado.
arxiv:1308.6733

- CT10 excluded
- CT10+EPS09 in agreement within uncertainties.



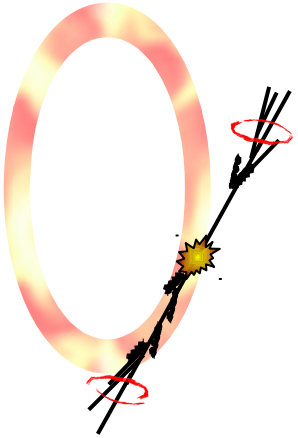
Conclusions

- PbPb
  - Update of pp reference agrees with previous conclusions from PLB 718 (2013) 773:
    - No deflection of jets
    - Decrease in number of partner jets with centrality
  - p_T^y – dependent results show:
    - Jet yields show a shift to lower p_T^{Jet}
    - Loss of jet partners roughly constant across p_T^y
- pPb
  - No jet deflection or quenching observed
  - Shift in η_{dijet} with activity
  - Significant constraint put on nPDF distributions.

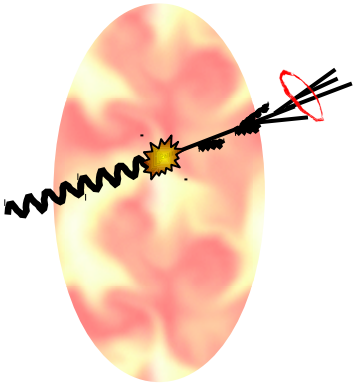
Backup

Strong probes have surface bias

- Colored probes (dijets) occur frequently
- Dijets have two drawbacks:
  - Surface bias of data sample
  - Loss of information about initial energy
- Solution: tag strong probe (jet) with EW probe (photon)



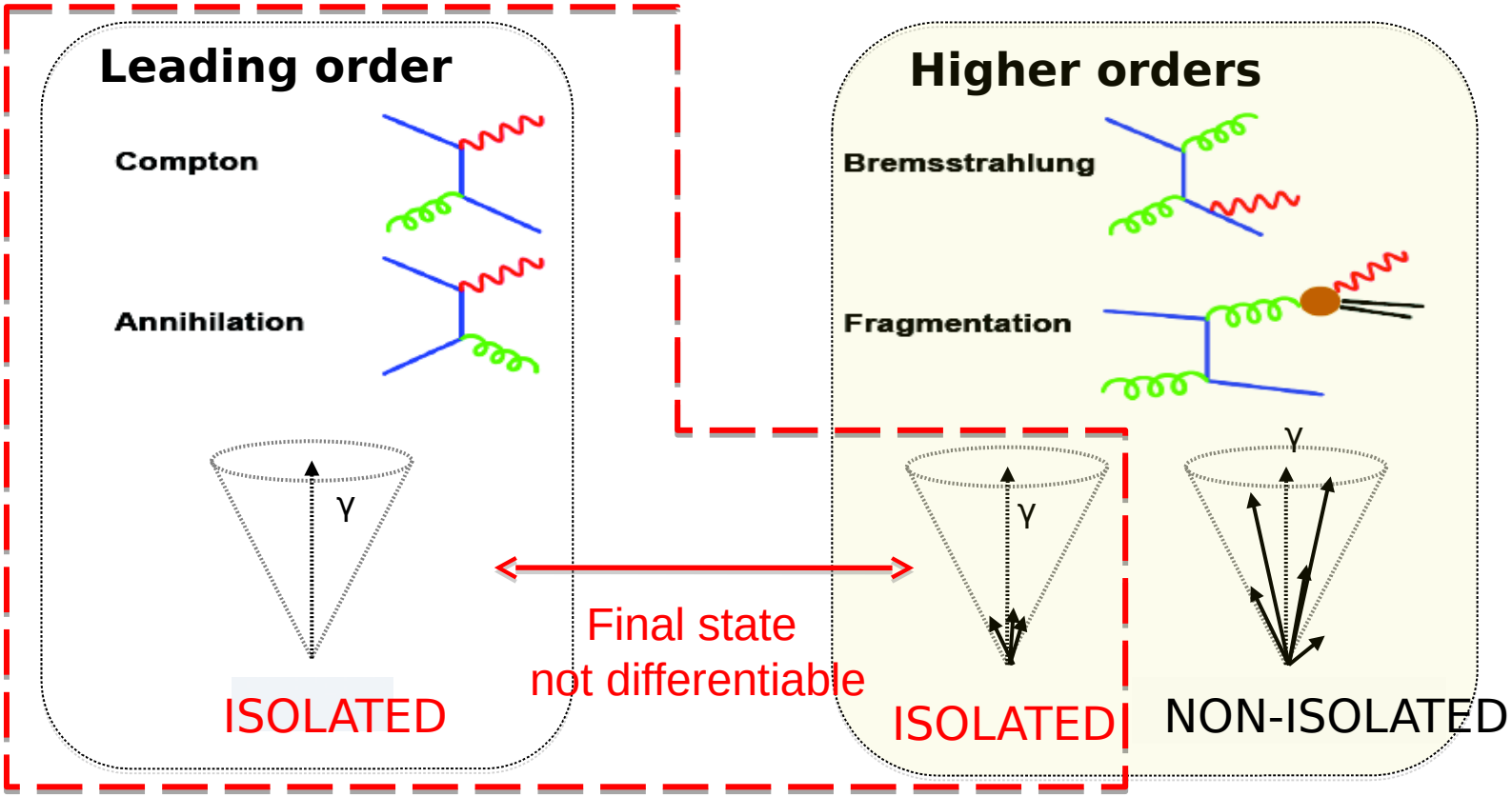
High statistics, with surface bias



Lower statistics, without surface bias

Signal definition

- Signal – isolated photons
- Background – suppressed by isolation requirement



Analysis

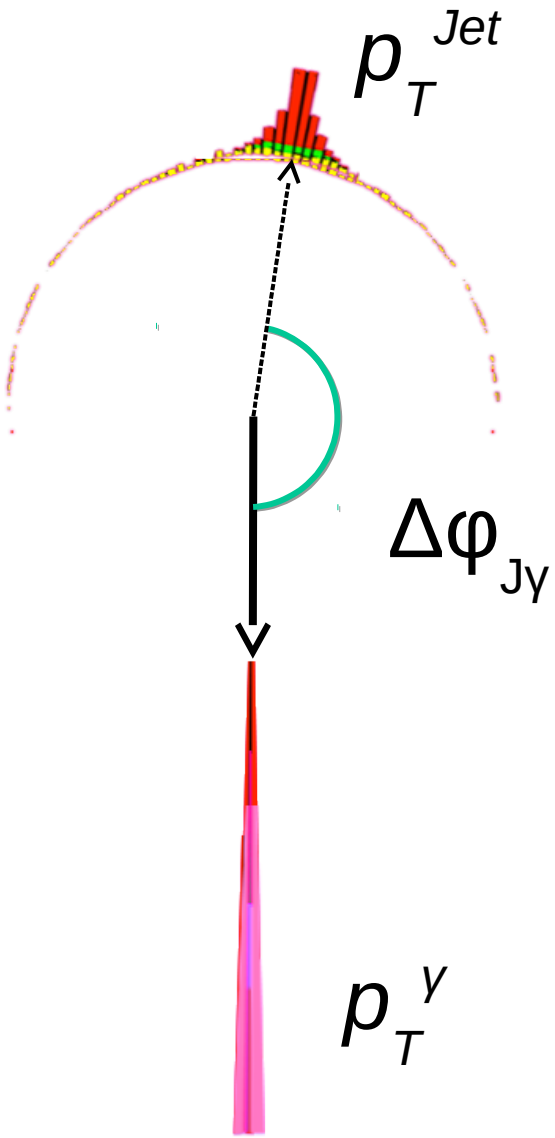
- Select leading isolated photon in event, correlate with all jets in event
- Apply background subtraction
  - Background from:
    - Decay/fragmentation photons (π^0, η)
    - Fake jets in underlying event
  - Rejected using
    - Isolation requirement (after a UE subtraction in PbPb)
    - Statistical subtraction of background photons based on purity
    - Subtraction of jets from mixed event

Background subtraction

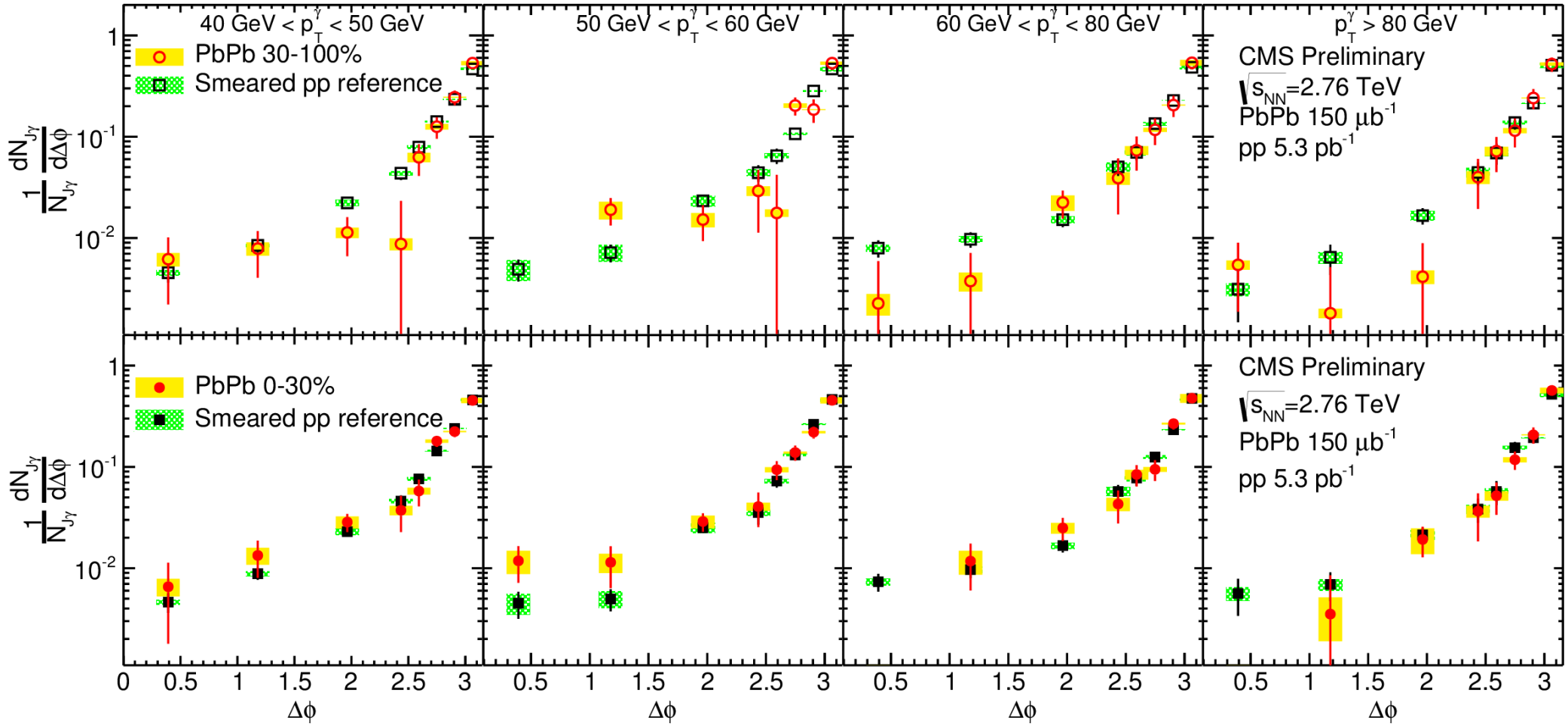
- UE subtraction of photon isolation in PbPb
  - Isolation calculated as energy in cone of R=0.4
  - Avg. energy in area containing cone but extending to full 2π is subtracted from isolation
- Subtraction of uncorrelated jets
  - Photons correlated with jets from a different hard scattering
  - Correlation from second hard scattering subtracted
- Statistical subtraction of decay photons
  - Photon purity calculated with template method in calorimeter shower-shape variable
  - Each observable subtracted using background-enriched sample from shower-shape sideband

Kinematics

- Photons
  - p_T^{γ} > 40 GeV (> 60 GeV for p_t^{γ} inclusive plots)
  - $|\eta^{\gamma}| < 1.44$
  - p_T^{γ} bins: [40-50], [50-60], [60-80], [80+] GeV
- Jets
  - Anti-k_T particle-flow jets, R=0.3, UE subtracted
  - p_T^{Jet} > 30 GeV
  - $|\eta^{Jet}| < 1.6$
  - ALL jets in each event which meet criteria are included, not just leading.
- Photon-jet pairs
  - $\Delta\varphi > 7\pi/8$
  - Centrality bins: [100-50], [50-30], [30-10], [10-0]%

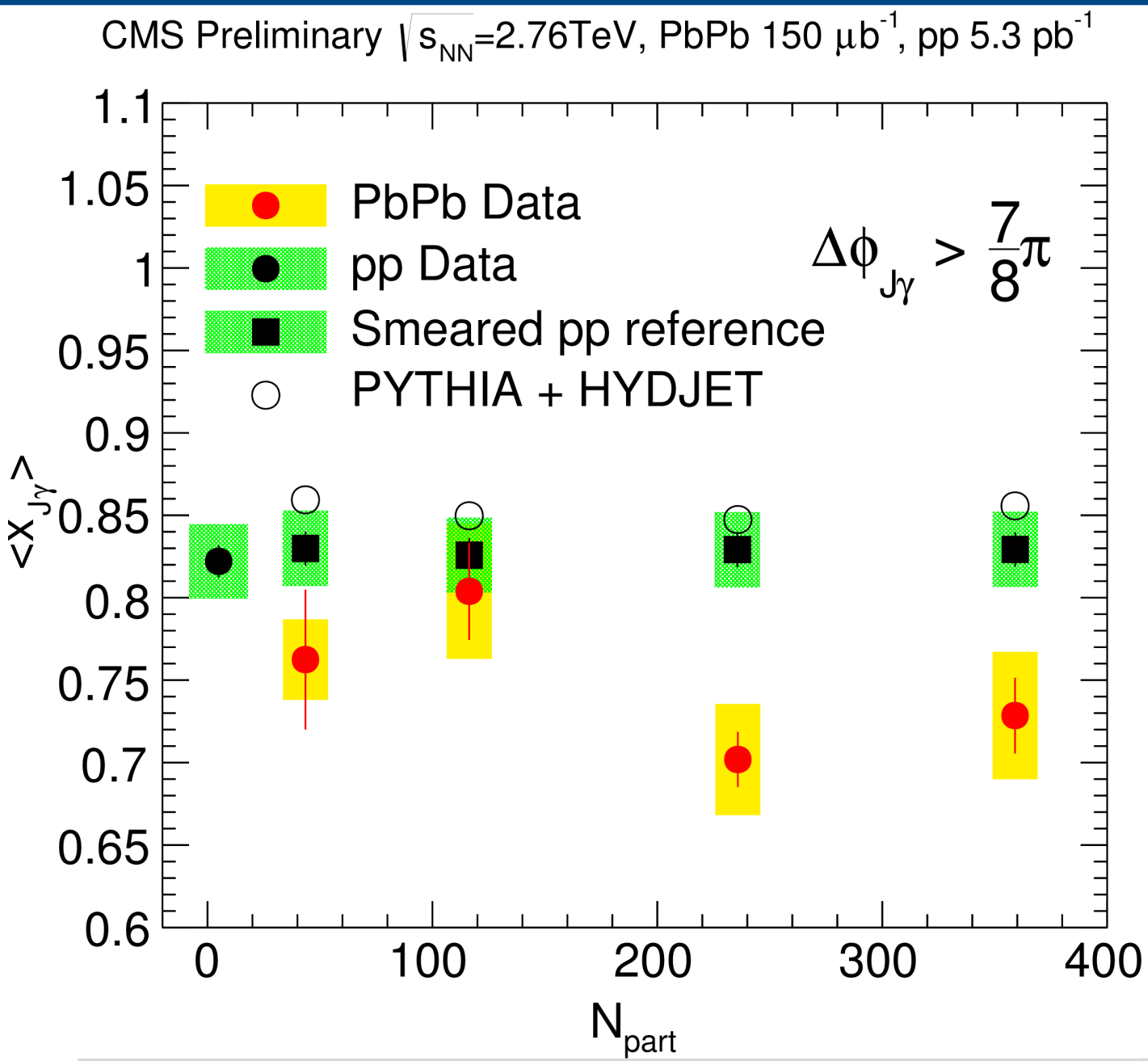


No jet deflection observed



CMS-PAS-HIN-13-006

Shift to lower $x_{J\gamma}$ with centrality



$$x_{J\gamma} = p_T^{Jet}/p_T^{\gamma}$$

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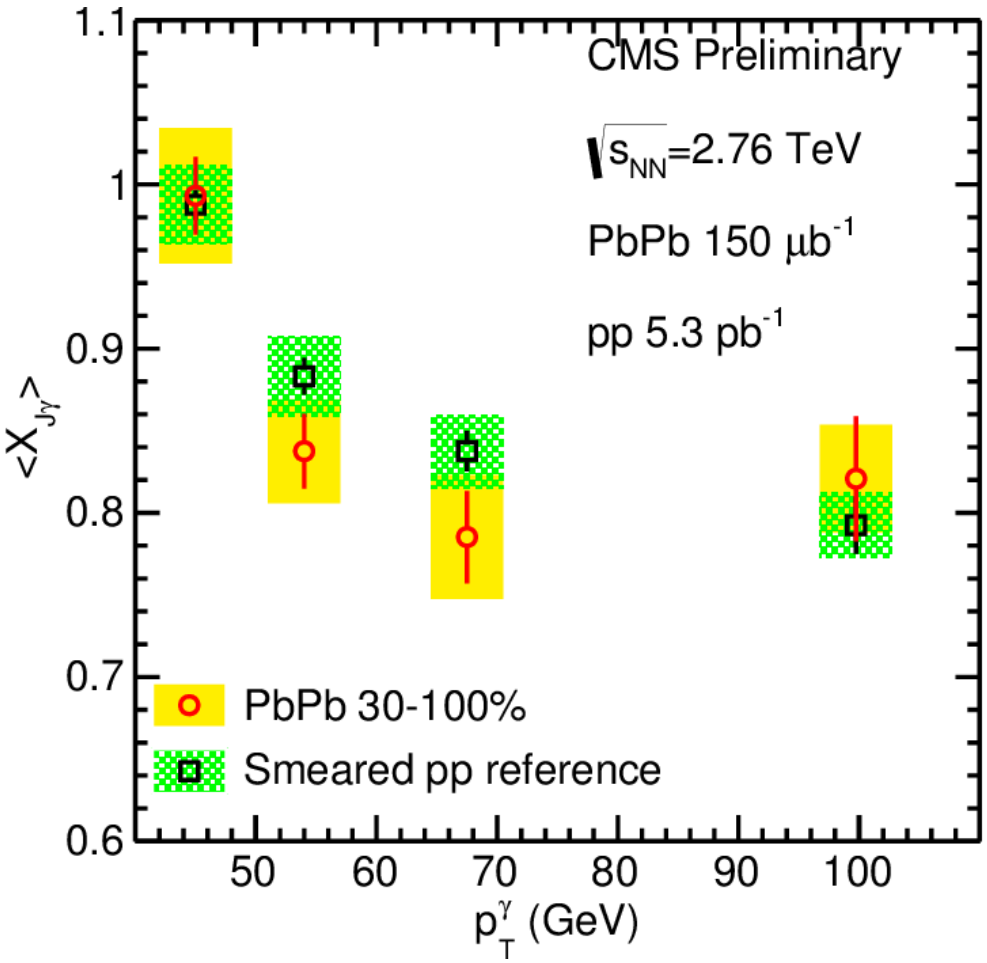
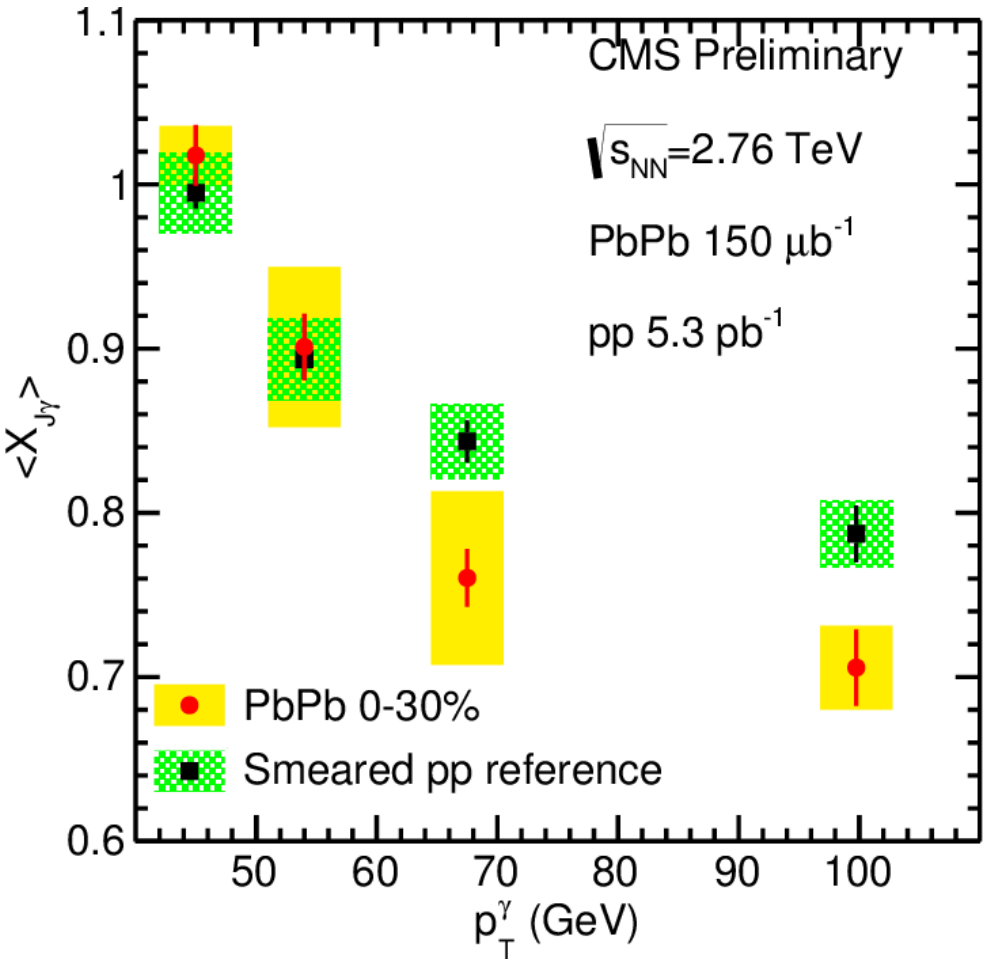
Shift to lower $x_{J\gamma}$ with p_T^{γ} in central PbPb



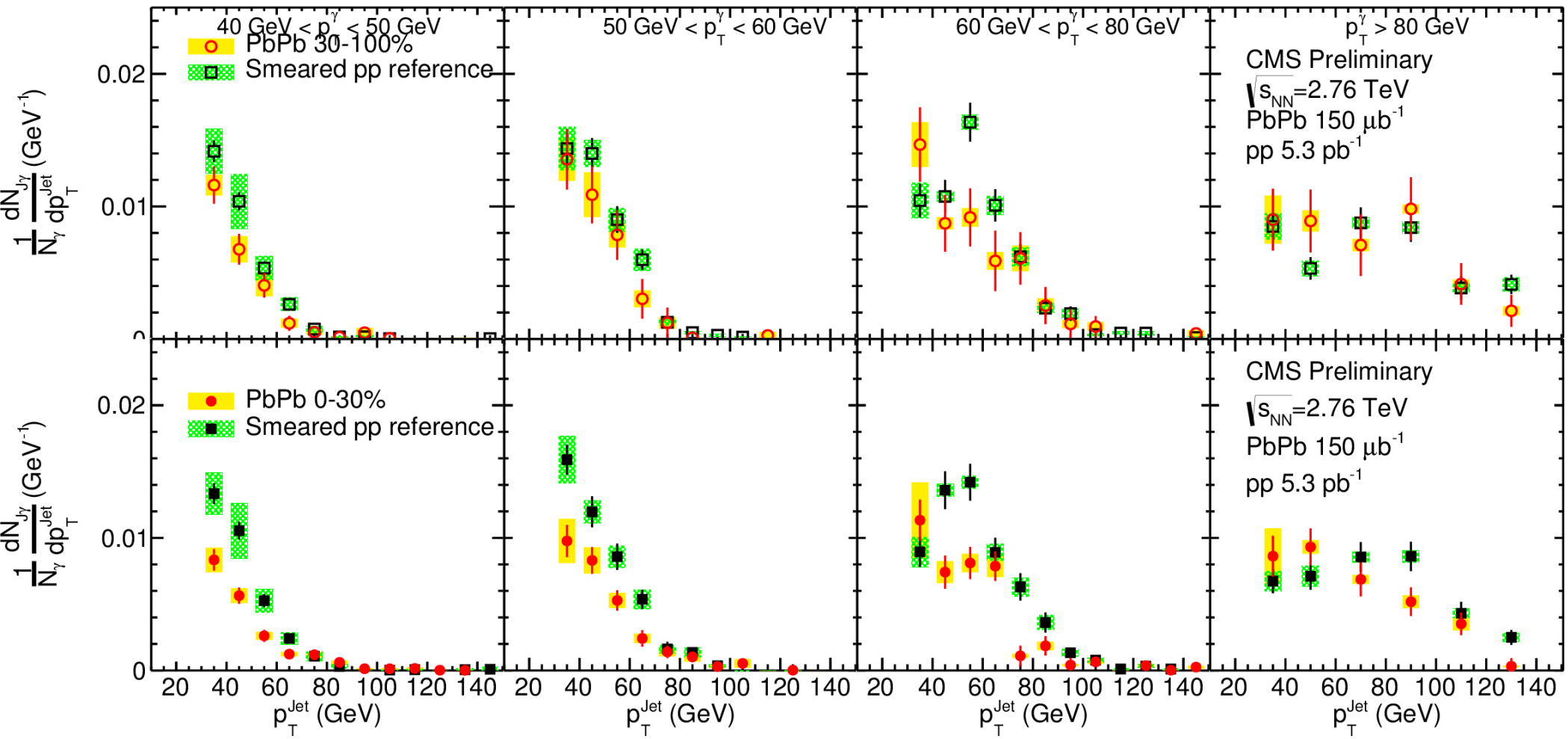


$$x_{J\gamma} = p_T^{Jet}/p_T^{\gamma}$$

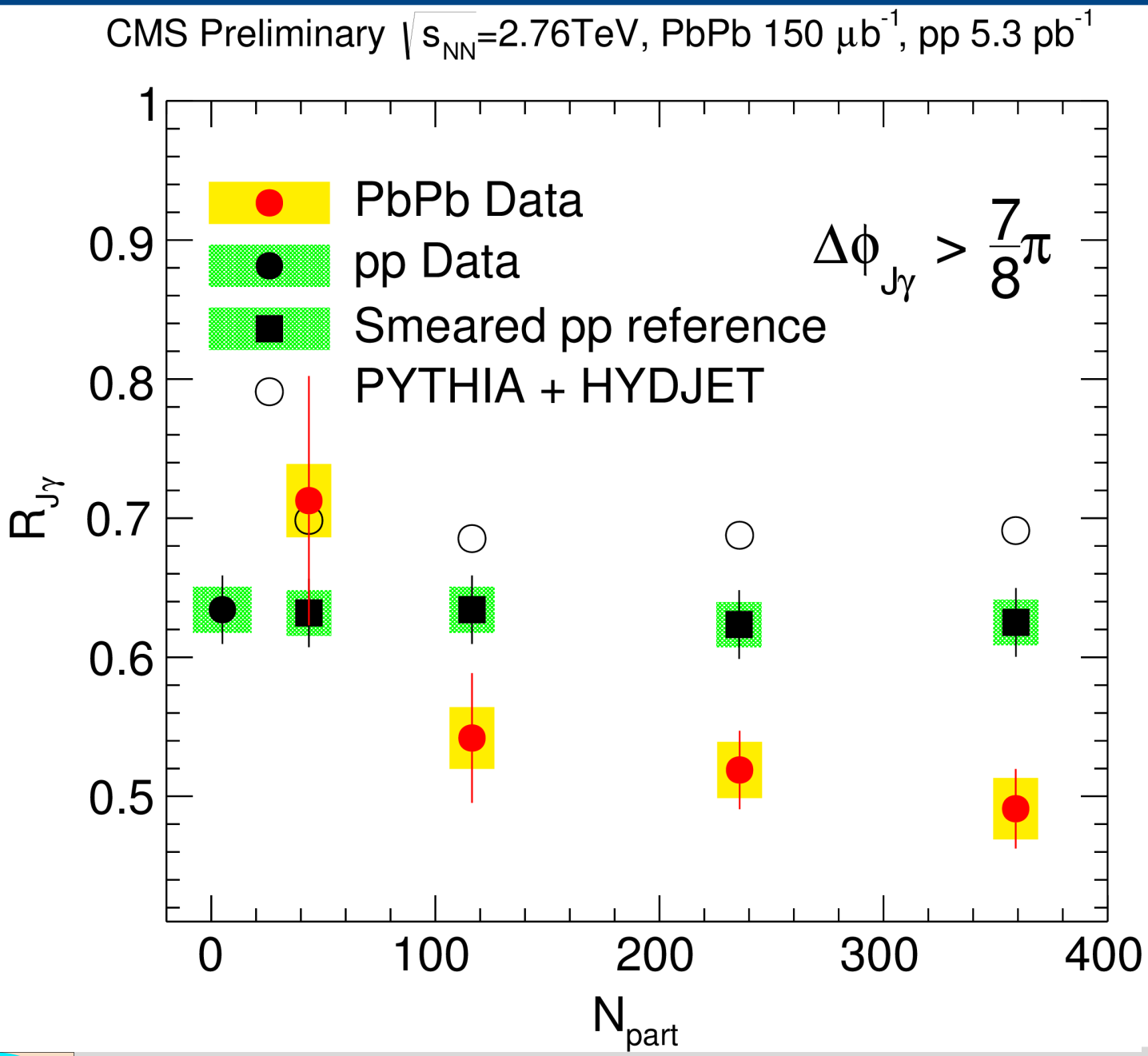
CMS-PAS-HIN-13-006

Jet spectra heavily modified

CMS-PAS-HIN-13-006



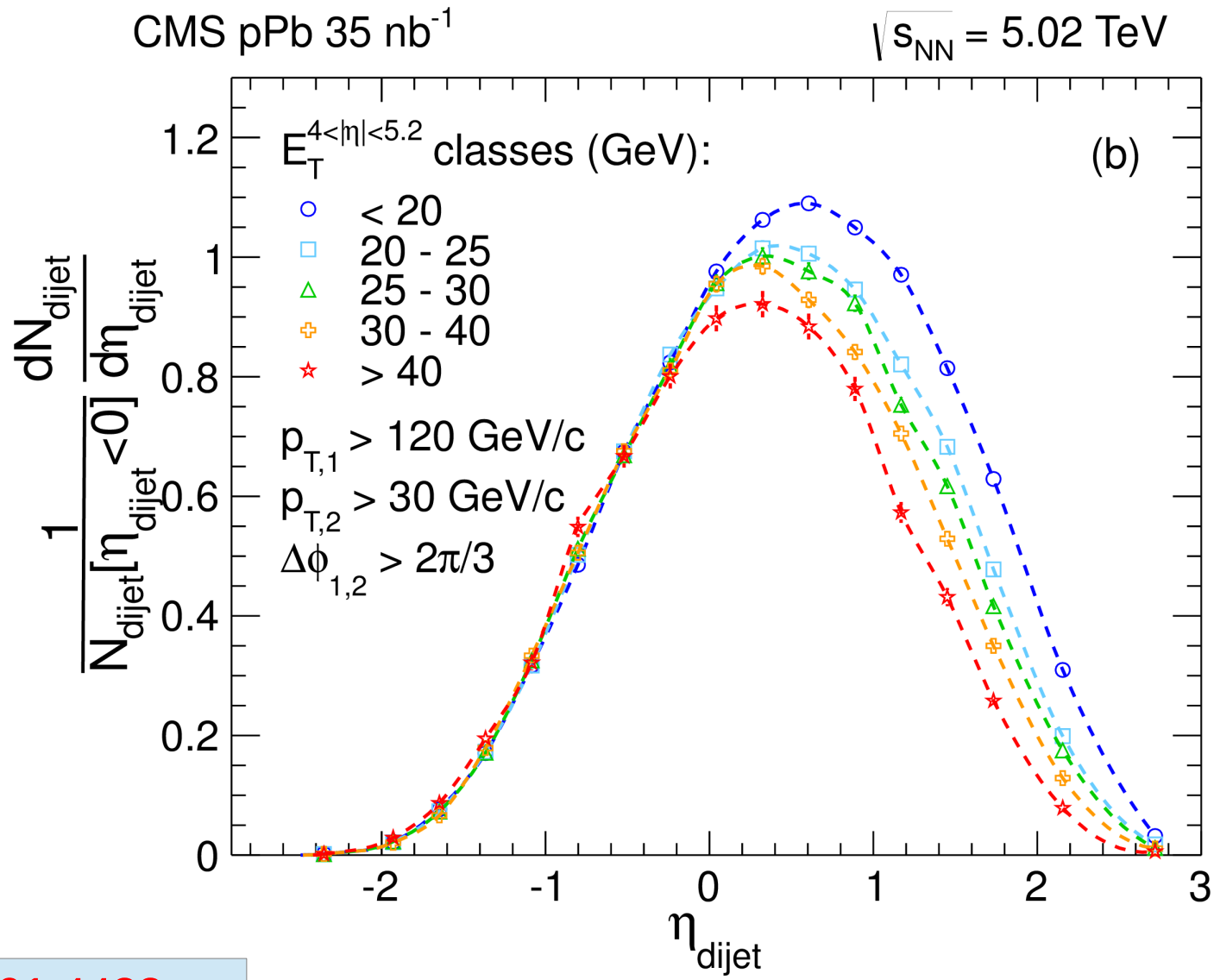
Significant loss of jet partners with centrality



$R_{J\gamma}$ = Fraction of photons with jet partner

CMS-PAS-HIN-13-006

Normalizing by Pb side shows scaling



arxiv:1401.4433