Boson+Jet Correlation and Boson-Tagged Jet Substructure in pp and PbPb collisions at 5.02 TeV with CMS

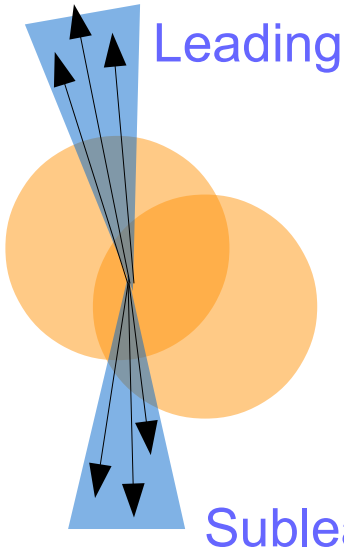
Austin Baty (MIT)

on behalf of the CMS Collaboration

Initial Stages 2017
September 20th
Polish Academy of Arts and Sciences
Kraków, Poland

Introduction

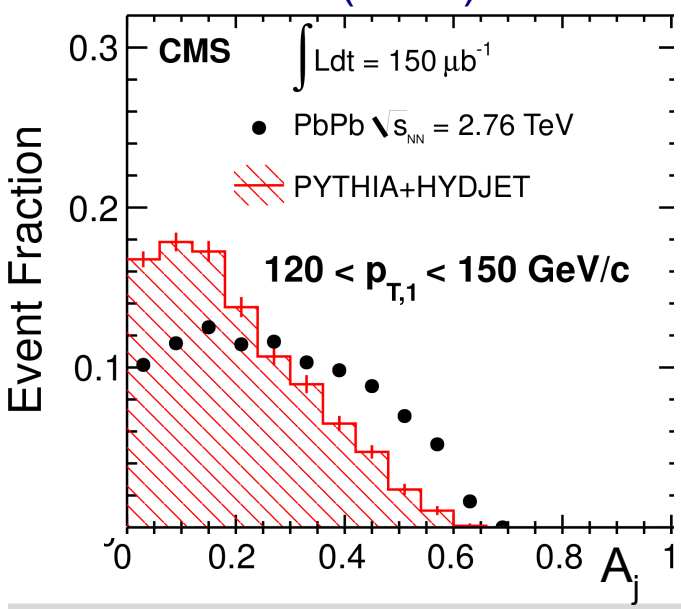
- Jet quenching in PbPb collisions at LHC has been firmly established using dijets
- Examined in detail using inclusive jet fragmentation function
  - Information on jet longitudinal substructure
- Initial energy of quenched jet can't be precisely determined in dijet or inclusive jet events



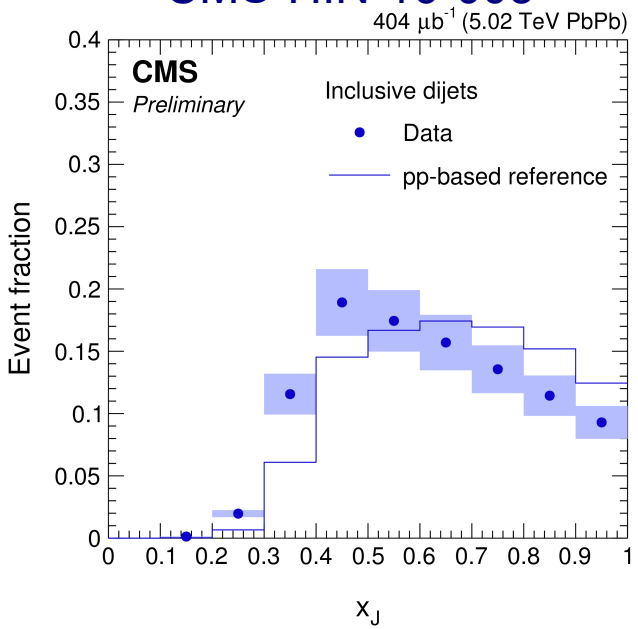
$$A_j = \frac{p_T^{lead} - p_T^{sublead}}{p_T^{lead} + p_T^{sublead}}$$

$$X_j = \frac{p_T^{sublead}}{p_T^{lead}}$$

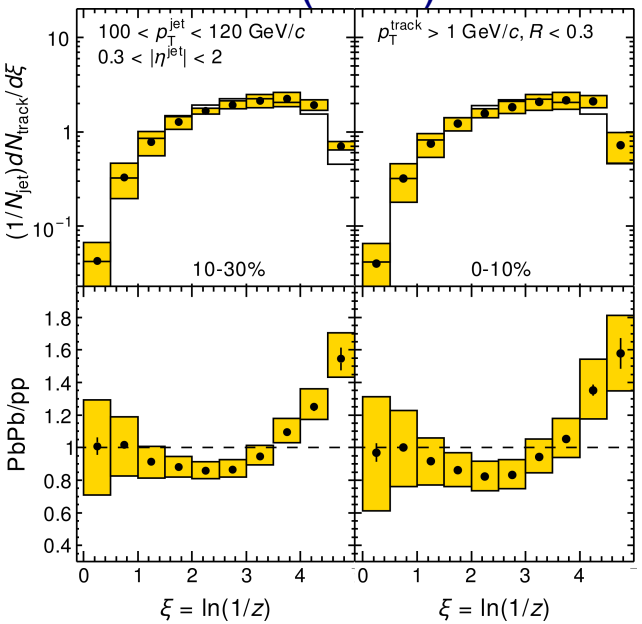
PLB 712 (2012) 176-197



CMS-HIN-16-005

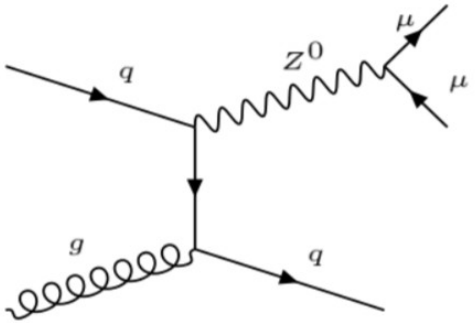


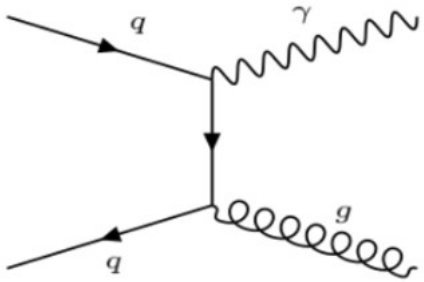
PRC 90 (2014) 024908

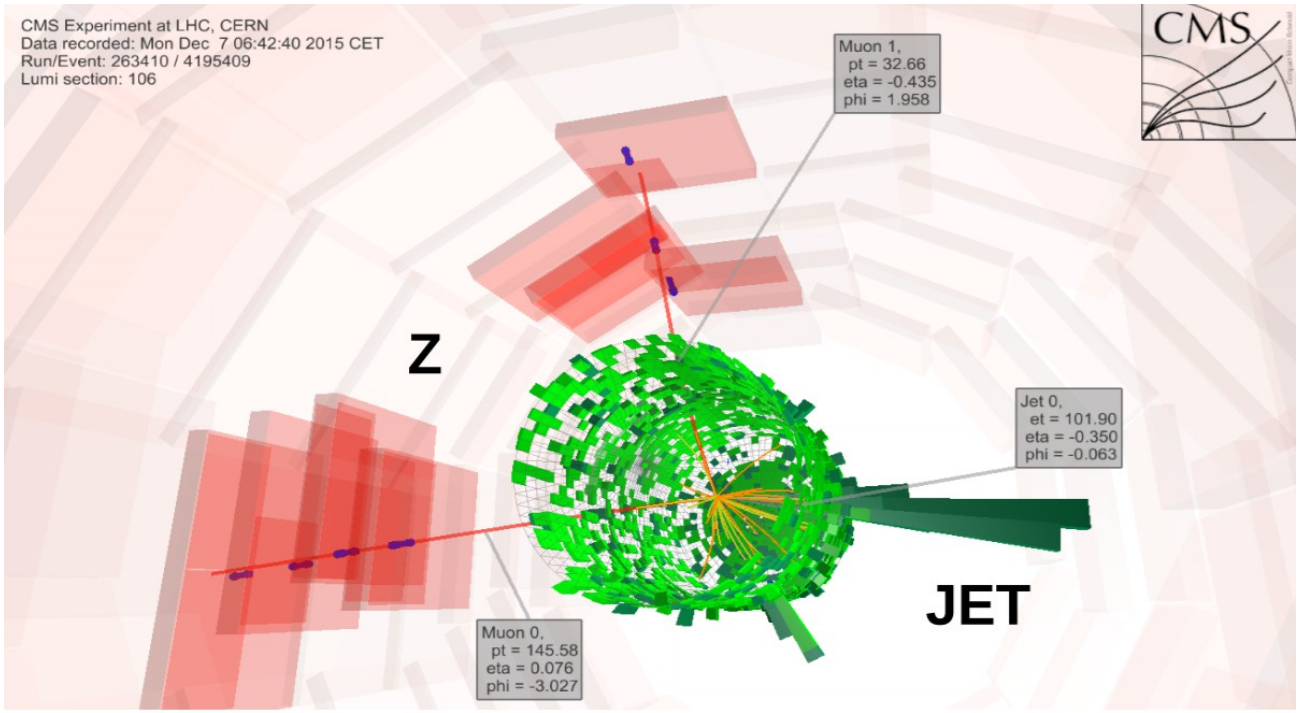


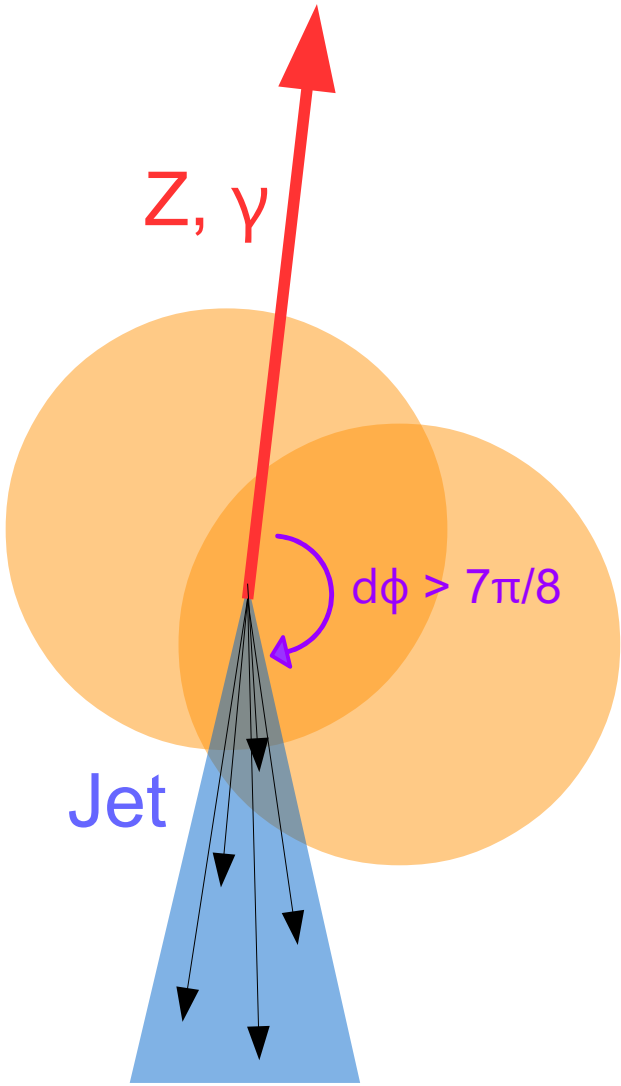
Introduction (II)

- Boson-jet events allow clean tag of initial parton energy
  - High statistics analysis possible with LHC Run 2 data





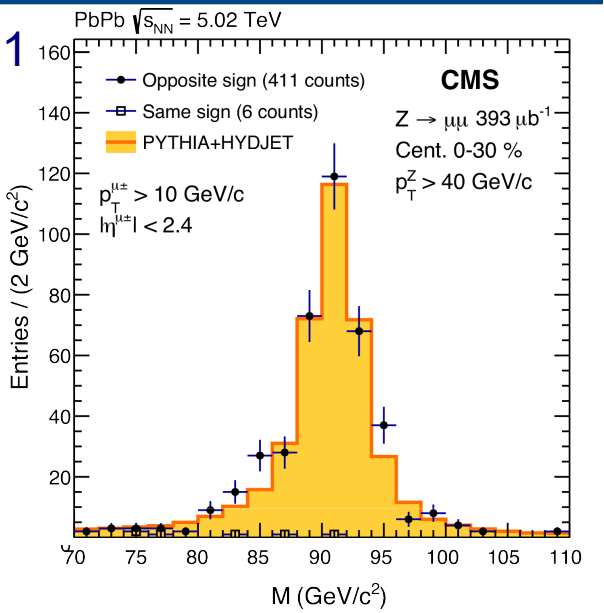




Tracks for Fragmentation Function

Boson Reconstruction

PRL 119 (2017) 082301



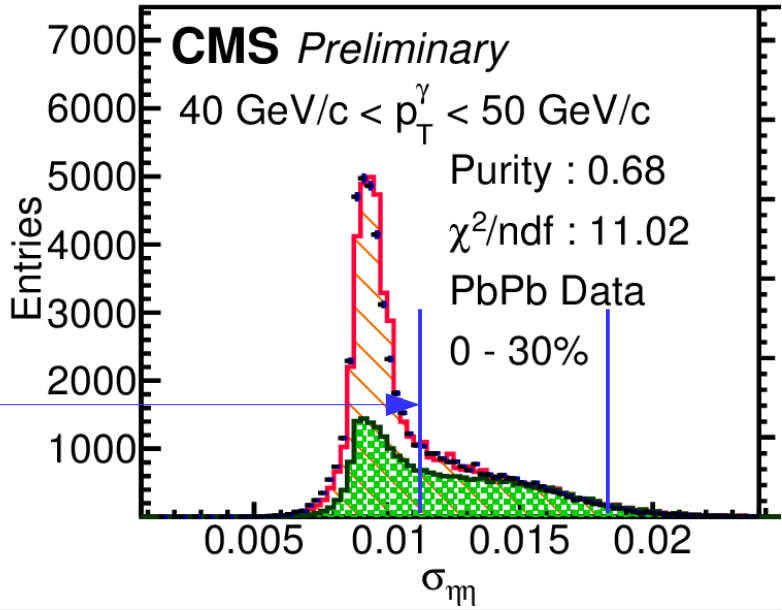
- Z reconstructed in μμ and ee channels for PbPb and pp data
  - 536 Z candidates passing PbPb analysis cuts
  - Essentially no background

- Photons required to pass isolation cuts
  - Suppresses neutral hadron decays mimicking prompt photon signal
- $|\eta_\gamma| < 1.44$

- Purity of remaining photons estimated using MC-based template fit
  - ~70% in central events

- Correct for purity using large shower-shape sideband region

CMS-HIN-16-002



Jet Reconstruction

- Jet cuts for all results shown here:
  - anti-k_T, R=0.3
  - $p_T^{jet} > 30$ GeV/c
  - $|\eta_{jet}| < 1.6$
  - $\Delta\varphi$(boson, jet) > 7π /8

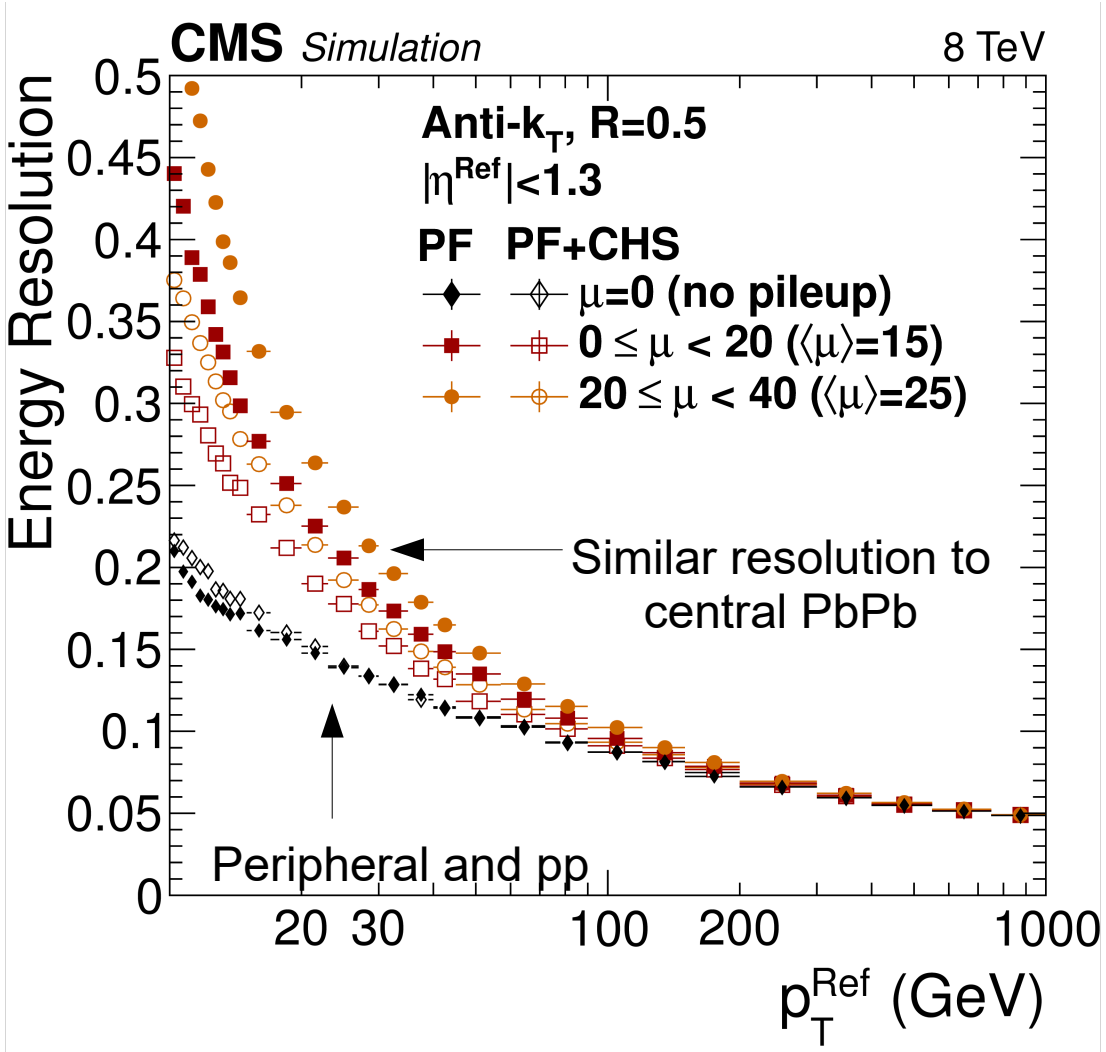
- Smear the pp to match the PbPb jet energy resolution:

$$\sigma^2_{rel} = (C^2_{PbPb} - C^2_{pp}) + \frac{(S^2_{PbPb} - S^2_{pp})}{p_T^{GEN}} + \frac{(N^2_{PbPb} - N^2_{pp})}{(p_T^{GEN})^2}$$

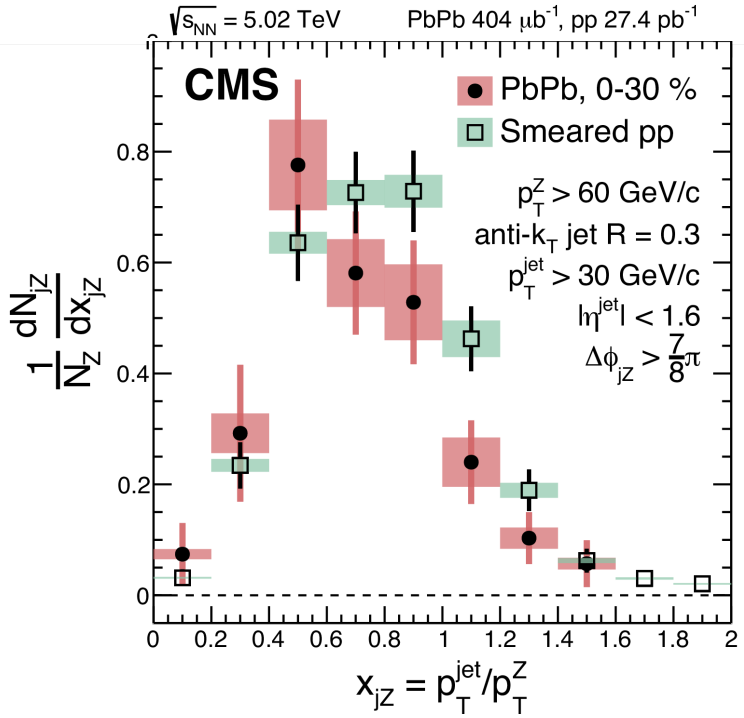
~0 ~0.63/p_T ~65/p_T^2

Values from Z-jet analysis:
PRL 119 (2017) 082301

CMS-PRF-14-001



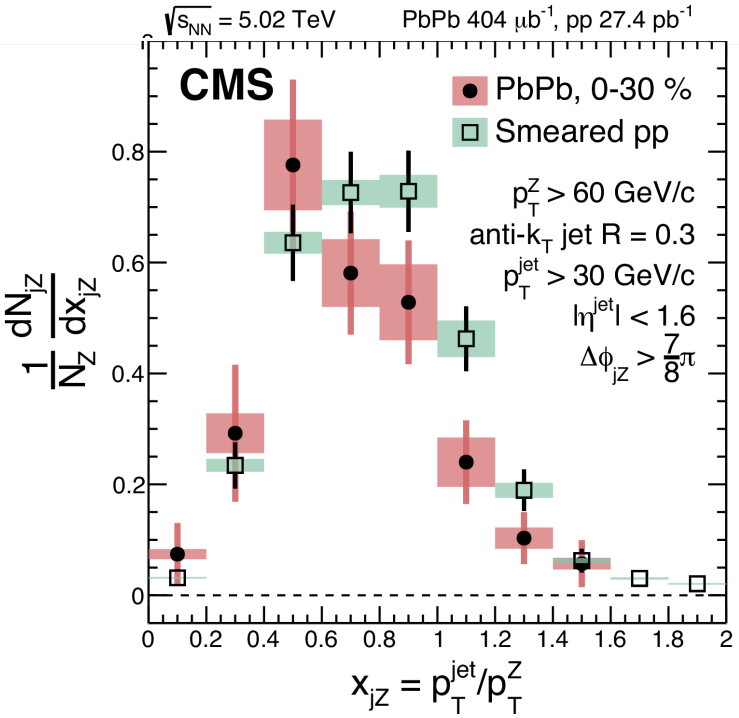
Z + jet



PRL 119 (2017) 082301

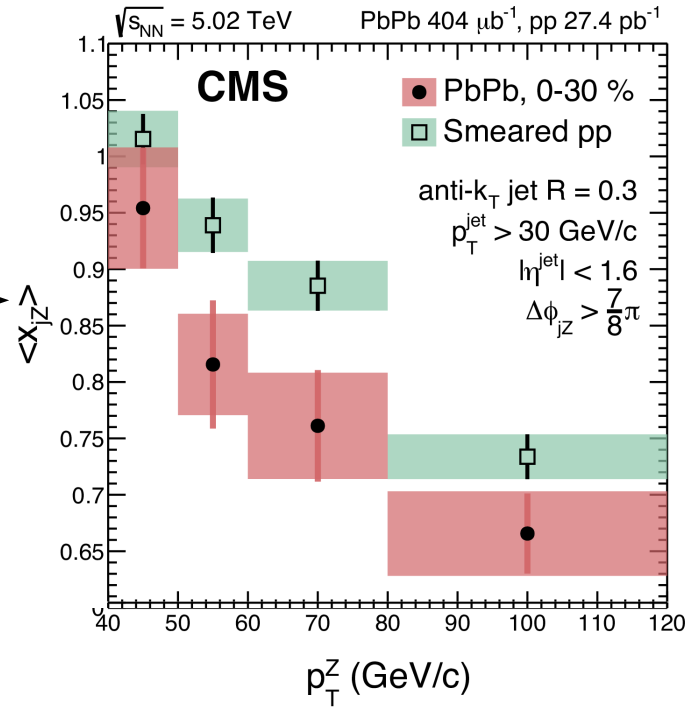
- Per-Z yield of Z-jet pairs calculated vs. $X_{jZ} = p_T^{jet}/p_T^{Z}$
- Shift to lower values observed in X_{jZ} vs. pp reference

Z + jet



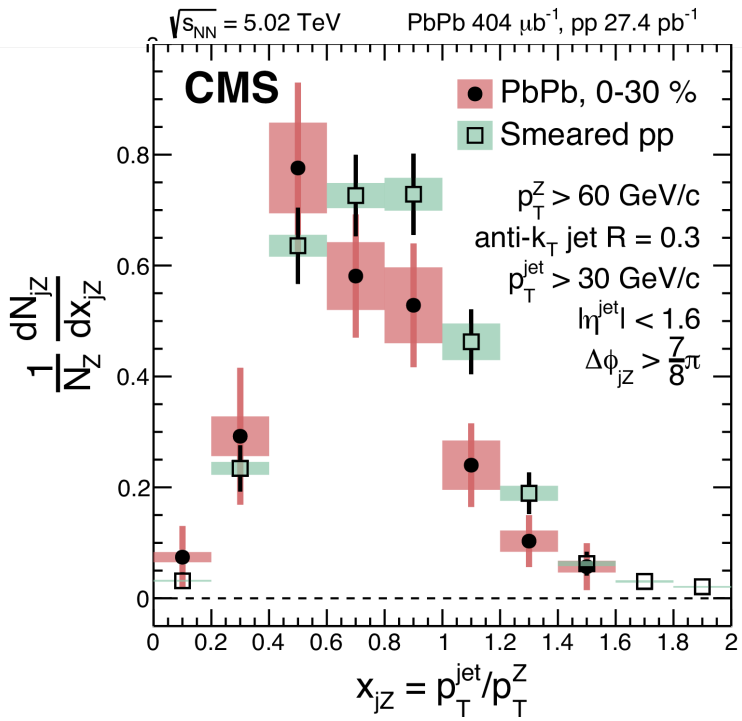
PRL 119 (2017) 082301

Average for different Z p_T



- Per-Z yield of Z-jet pairs calculated vs. $X_{jZ} = p_T^{jet}/p_T^{Z}$
- Shift to lower values observed in X_{jZ} vs. pp reference
  - $\langle X_{jZ} \rangle$ is ~10% lower in PbPb than in pp

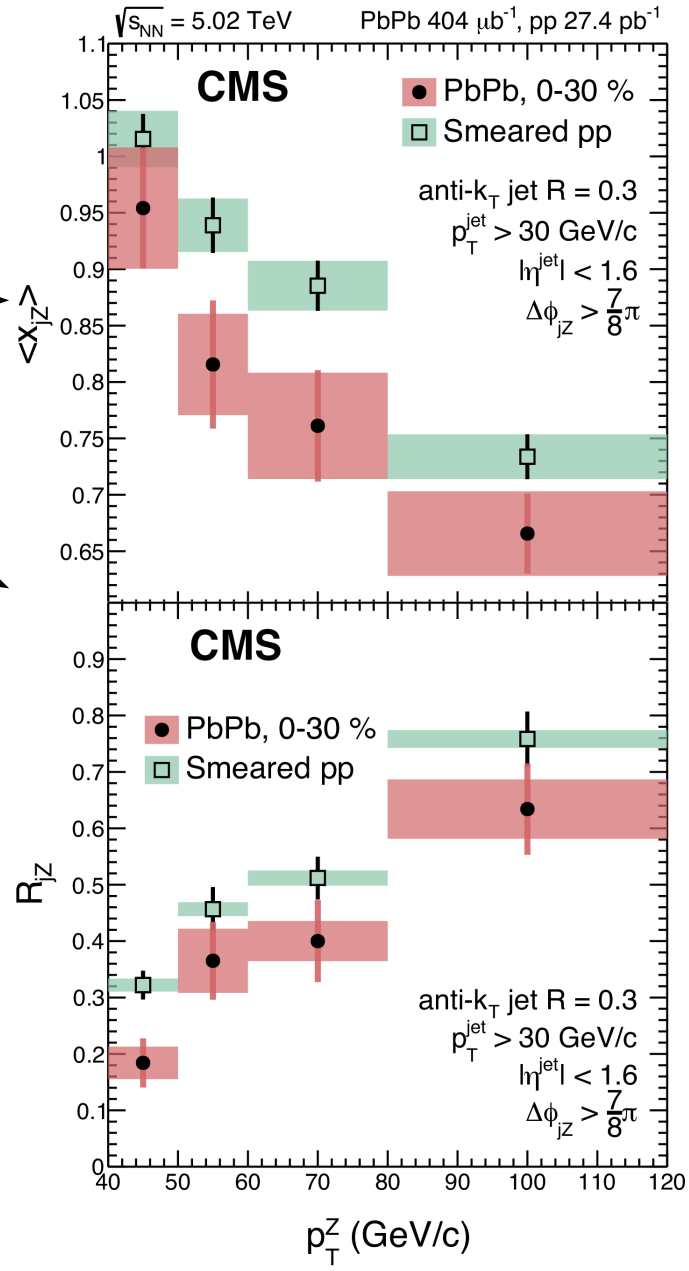
Z + jet



PRL 119 (2017) 082301

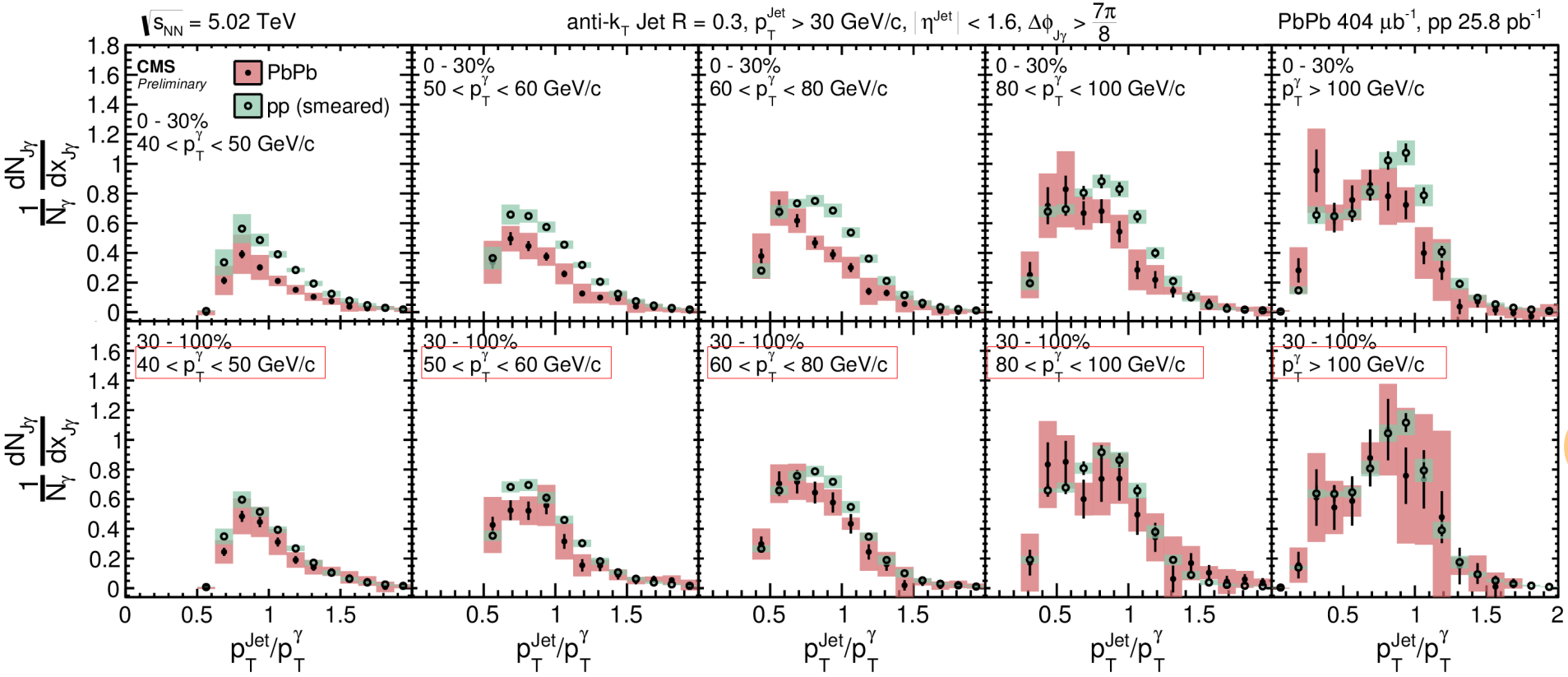
Average for different Z p_T

Integral for different Z p_T



- Per-Z yield of Z-jet pairs calculated vs. $X_{jZ} = p_T^{jet}/p_T^{Z}$
- Shift to lower values observed in X_{jZ} vs. pp reference
  - $\langle X_{jZ} \rangle$ is ~10% lower in PbPb than in pp
- R_{jZ} – average number of jets passing cuts and recoiling from the Z
- Lower value indicates jets are quenched under p_T cut

γ + jet: $x_{j\gamma}$



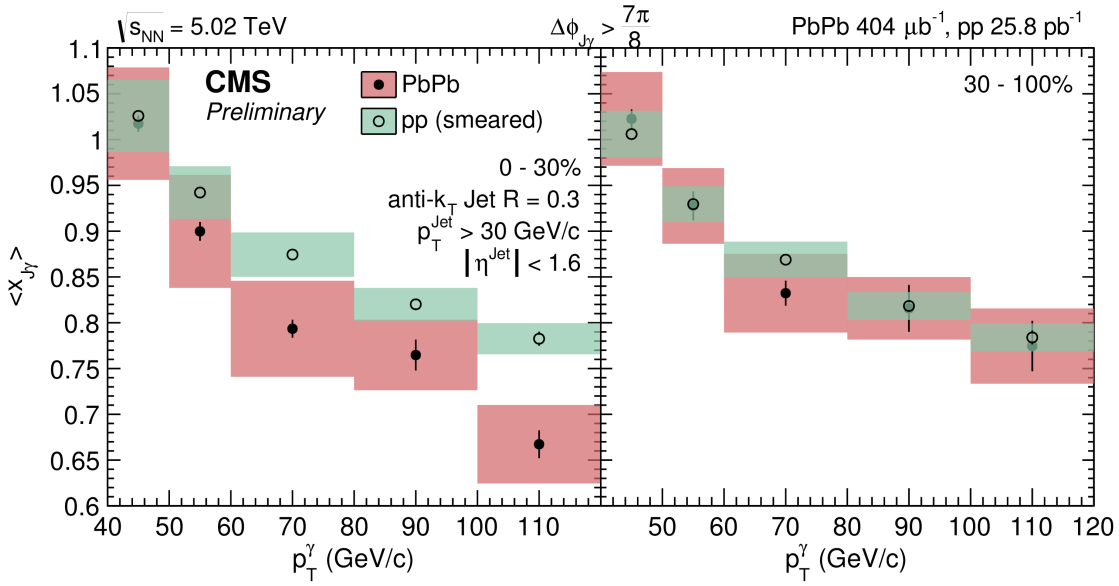
- Strong shift in $X_{j\gamma}$ seen in 0-30% PbPb relative to pp for 5 photon p_T bins
- Stronger quenching in 0-30% events compared to 30-100%

- Dominant systematic uncertainty: jet energy scale
  - Followed by jet energy resolution and photon purity

CMS-HIN-16-002

γ + jet: $\langle x_{j\gamma} \rangle$ and $R_{j\gamma}$

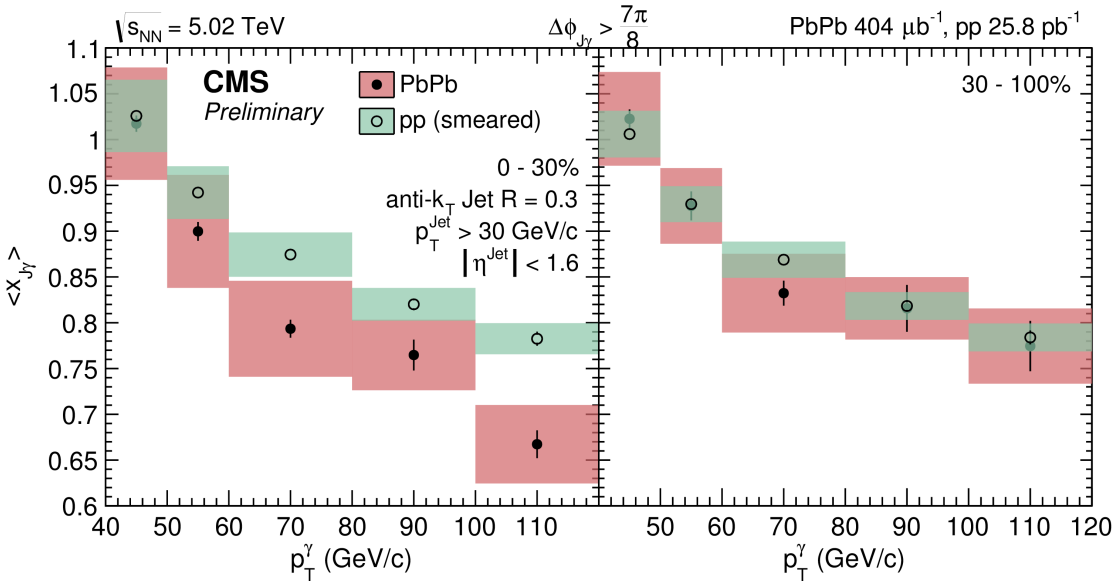
- Average $X_{j\gamma}$ similar to values seen in Z-jet
- Peripheral points compatible with pp
- Compared to pp, central PbPb values consistently lower for large photon p_T



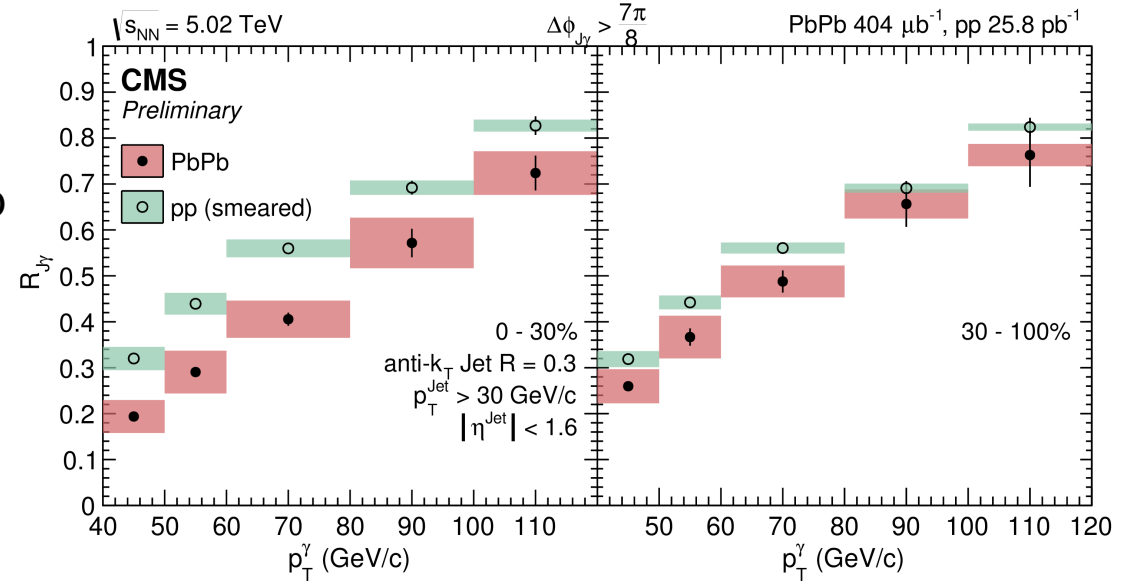
CMS-HIN-16-002

γ + jet: $\langle x_{j\gamma} \rangle$ and $R_{j\gamma}$

- Average $X_{j\gamma}$ similar to values seen in Z-jet
- Peripheral points compatible with pp
- Compared to pp, central PbPb values consistently lower for large photon p_T



- Central PbPb $R_{j\gamma}$ significantly lower than pp for all photon p_T bins
- Ordering of 0-30% < 30-100% < pp



Similar story as Z-jet, but more differential!

CMS-HIN-16-002

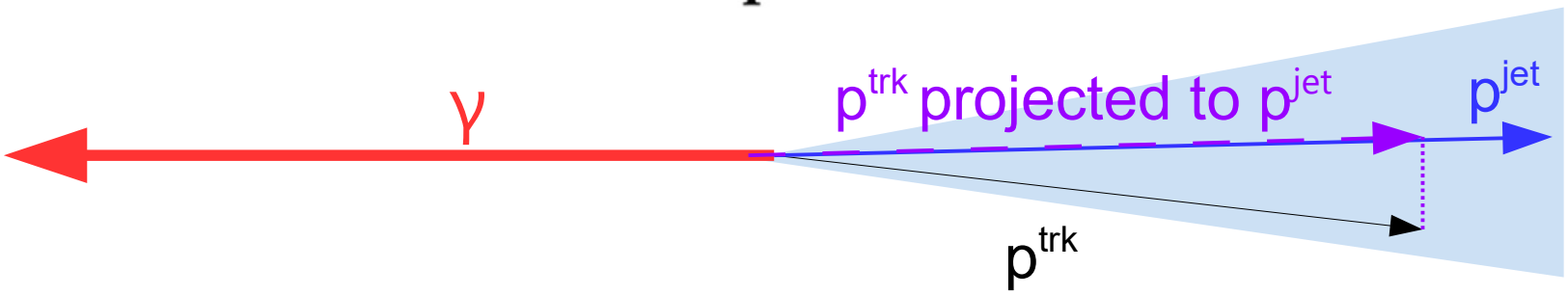
Fragmentation Function Definition

- Photon-tagged fragmentation function:
  - Per-jet yield of charged particles in the jet cone vs two variables:

$$\xi^{\text{jet}} = \ln \frac{|\mathbf{p}^{\text{jet}}|^2}{\mathbf{p}^{\text{trk}} \cdot \mathbf{p}^{\text{jet}}}$$

$\mathbf{p}^{\text{jet}}$: 3-momentum vector of the jet

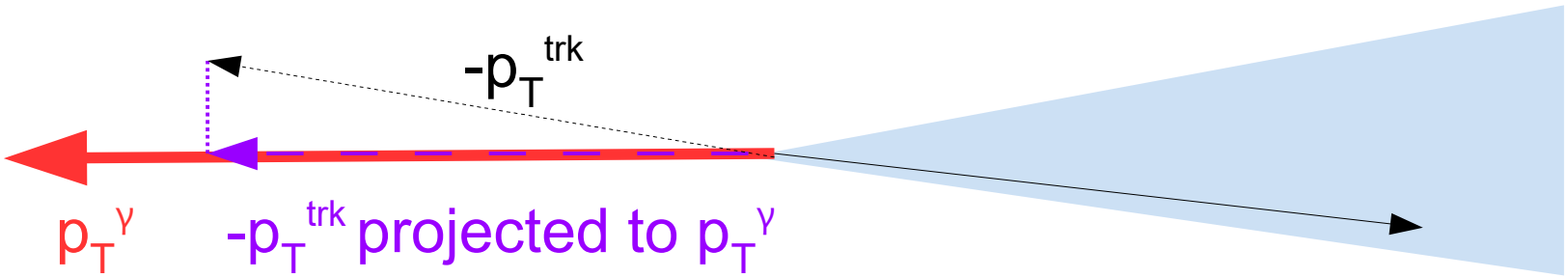
$\mathbf{p}^{\text{trk}}$: 3-momentum vector of the track



$$\xi_{\text{T}}^{\gamma} = \ln \frac{-|\mathbf{p}_{\text{T}}^{\gamma}|^2}{\mathbf{p}_{\text{T}}^{\text{trk}} \cdot \mathbf{p}_{\text{T}}^{\gamma}}$$

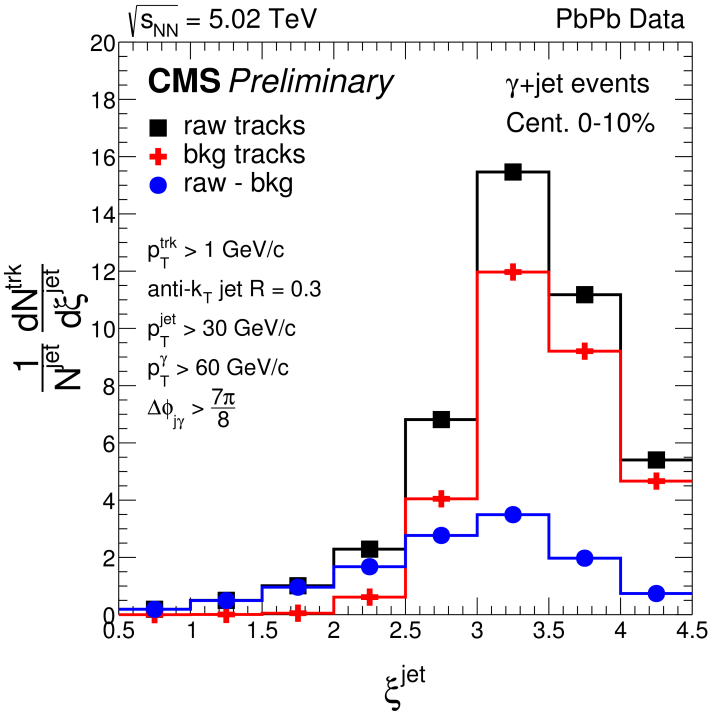
$\mathbf{p}_{\text{T}}^{\gamma}$: transverse momentum vector of the photon

$\mathbf{p}_{\text{T}}^{\text{trk}}$: transverse momentum vector of the track



Background Subtraction

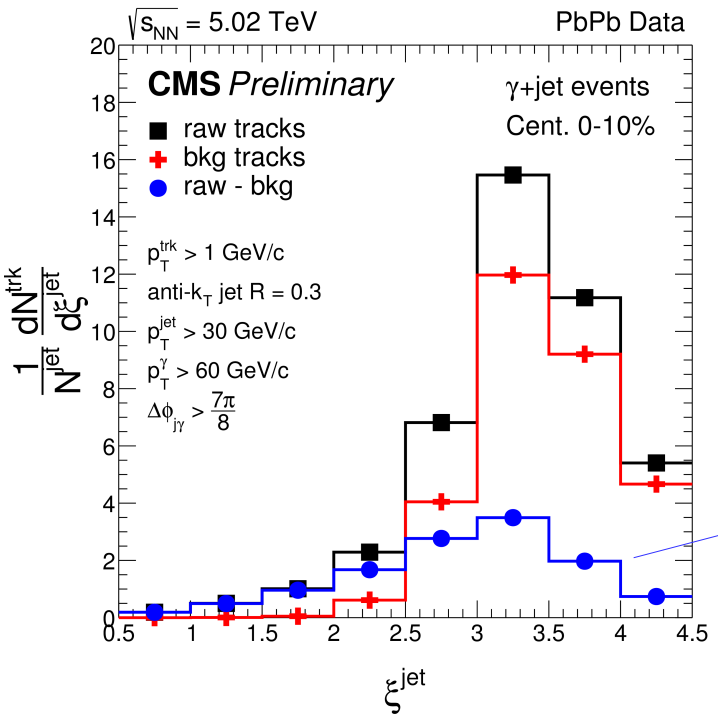
- Underlying event background removed with Min Bias event mixing
  - First remove background tracks to get signal tracks



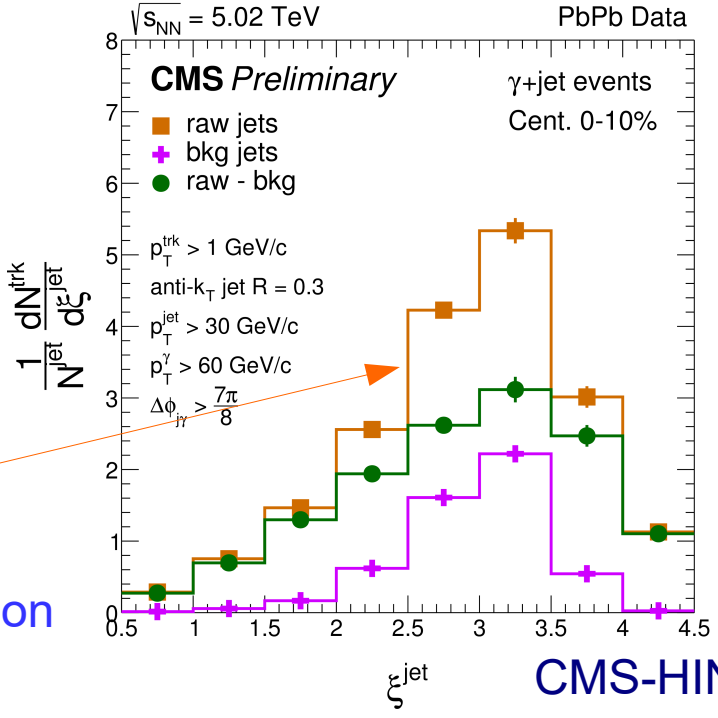
CMS-HIN-16-014

Background Subtraction

- Underlying event background removed with Min Bias event mixing
  - First remove background tracks to get signal tracks
- Some jets are still due to UE jets or fluctuations
  - Repeat same procedure in MB events
- Subtract background jet contribution to get signal jets w/ signal tracks

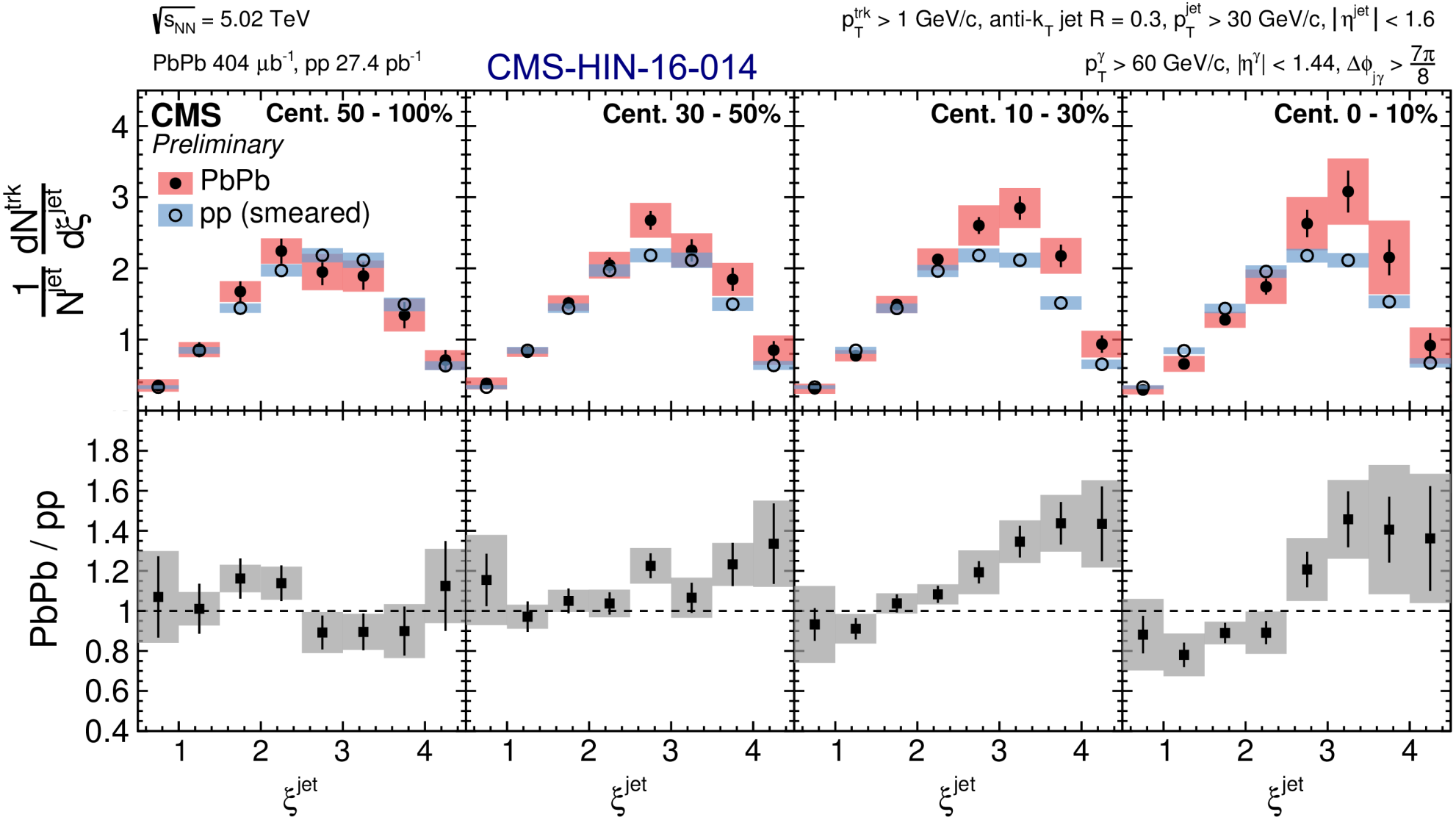


Change Normalization



CMS-HIN-16-014

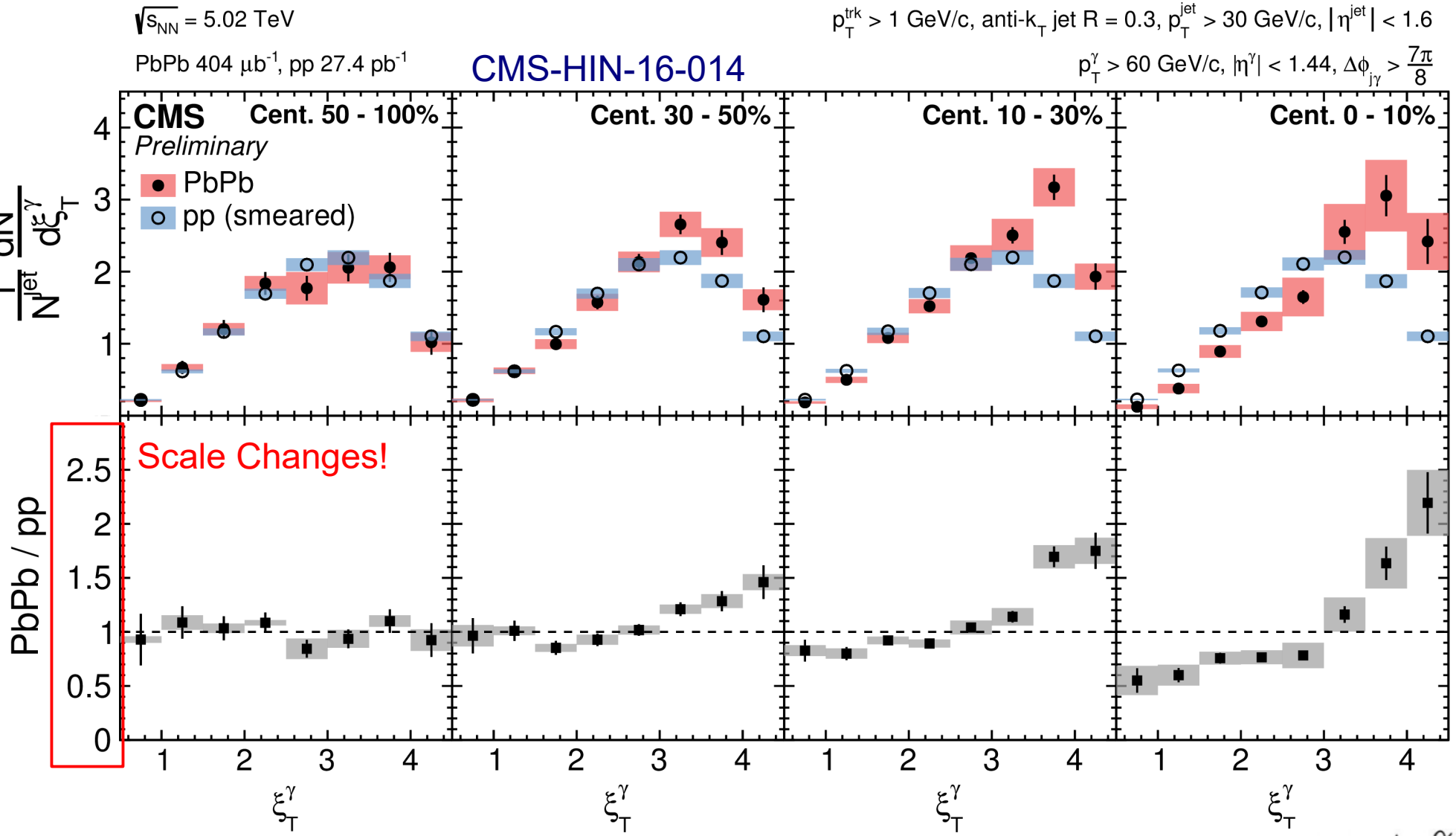
Fragmentation Function vs ξ^{jet}



- Enhancement of low-p_T particles observed for central events
- Largest systematic uncertainty: jet energy scale (8% on average)

$$\xi^{jet} = \ln \frac{|\mathbf{p}^{jet}|^2}{\mathbf{p}^{trk} \cdot \mathbf{p}^{jet}}$$

Fragmentation Function vs ξ^{γ}

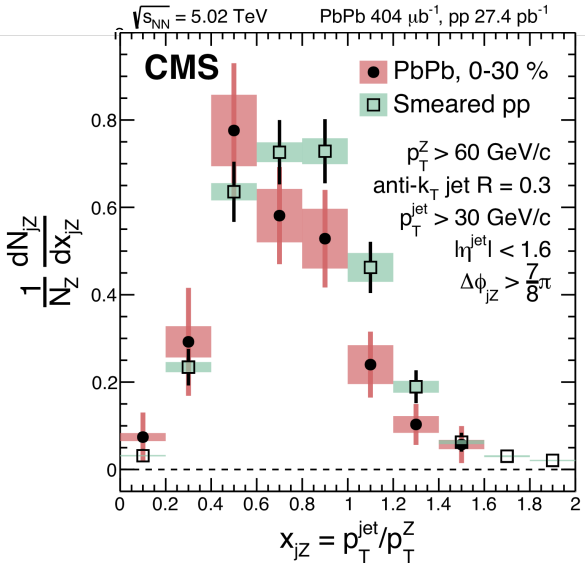


- Larger enhancement when comparing to unquenched photon p_T
- Reduced systematic uncertainty from less dependence on jet energy

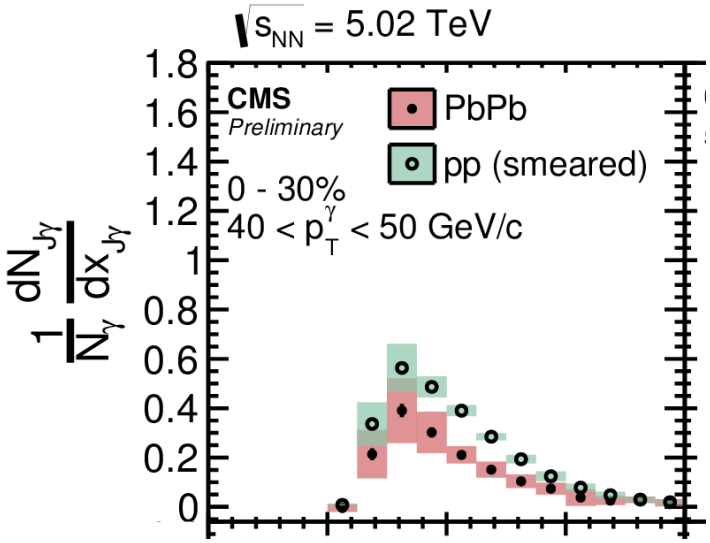
$$\xi_T^{\gamma} = \ln \frac{-|\mathbf{p}_T^{\gamma}|^2}{\mathbf{p}_T^{trk} \cdot \mathbf{p}_T^{\gamma}}$$

Conclusions

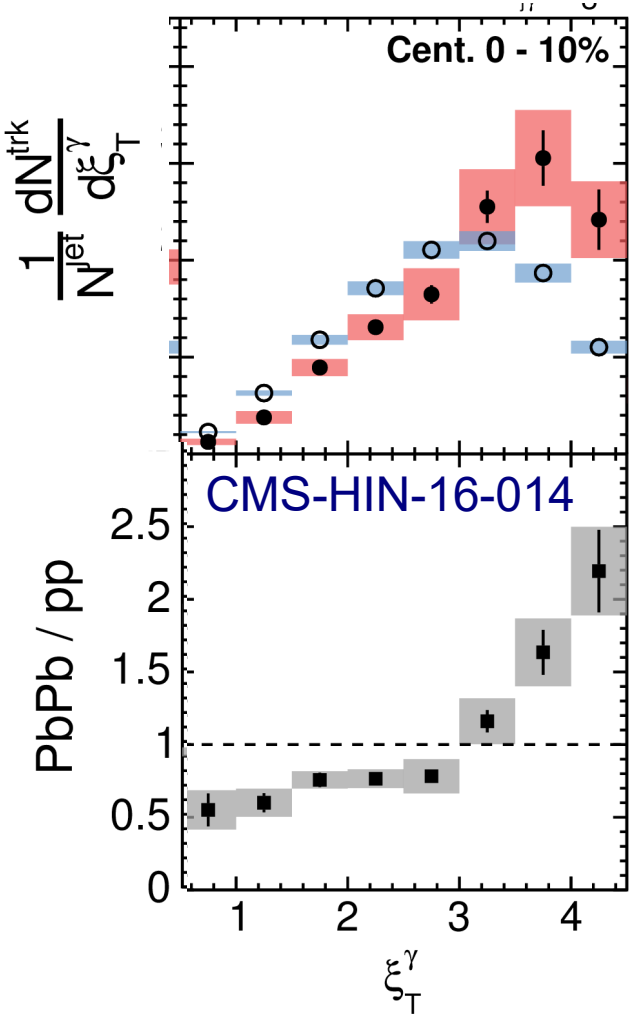
- CMS has measurements of X_{jV} in two production channels
  - Jet p_T reduction on the order of ~10% larger in central PbPb than in pp
  - Average number of jets > 30 GeV matched to a boson in central PbPb reduced vs. pp
- First measurement of photon-tagged jet fragmentation function
  - Small enhancement at high ξ^{jet} observed
  - Same enhancement much more significant vs ξ^{γ}
- At the start of an exciting new era of jet measurements



PRL 119 (2017) 082301



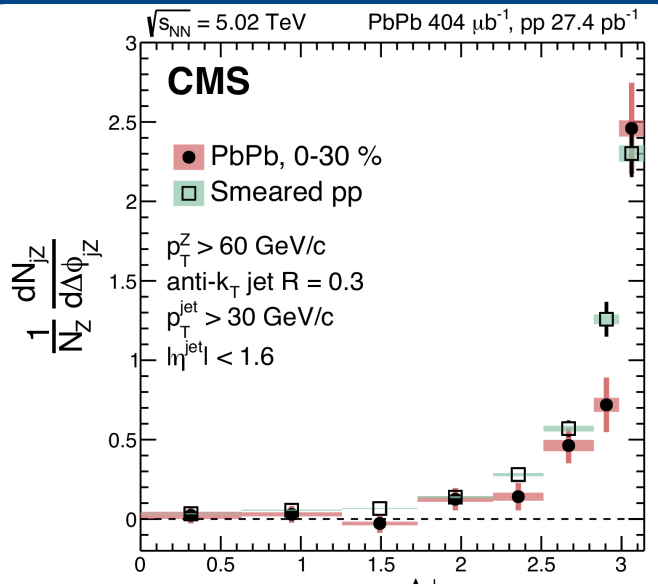
CMS-HIN-16-002

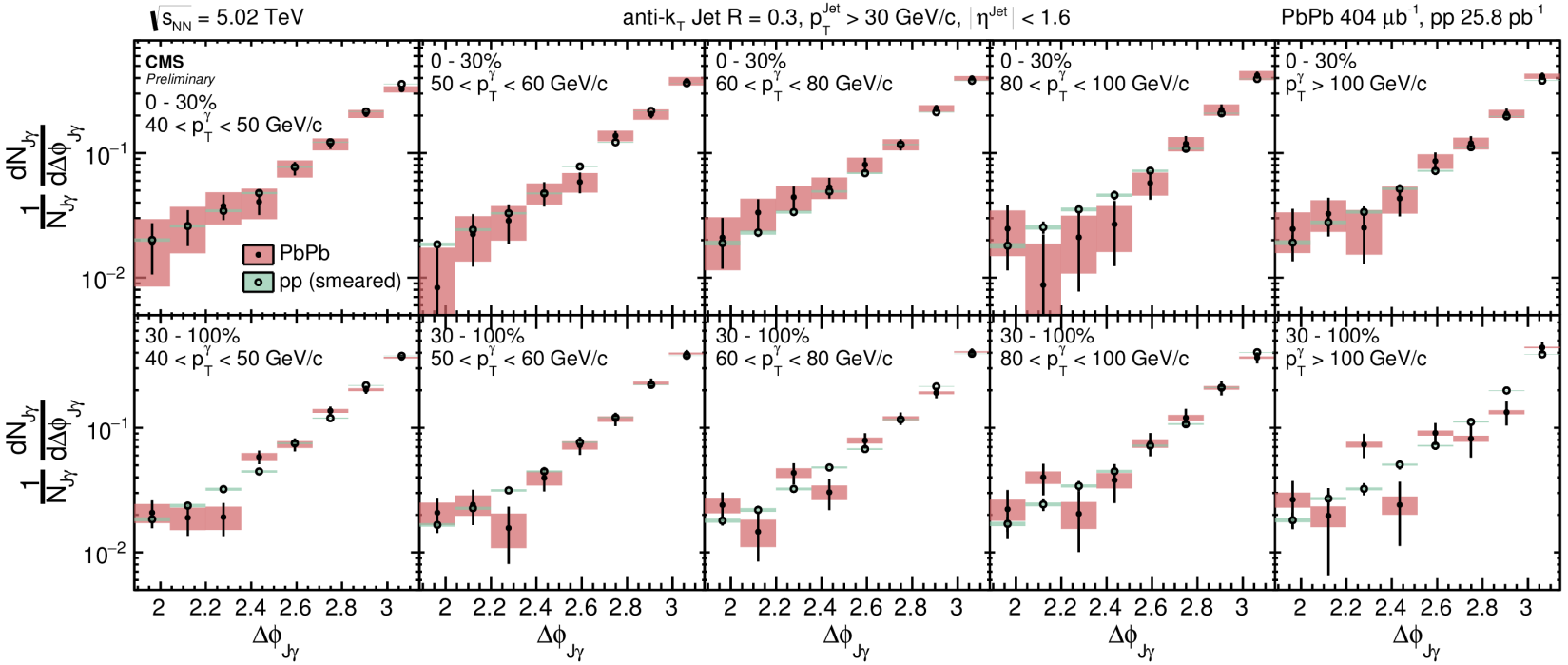


Backup

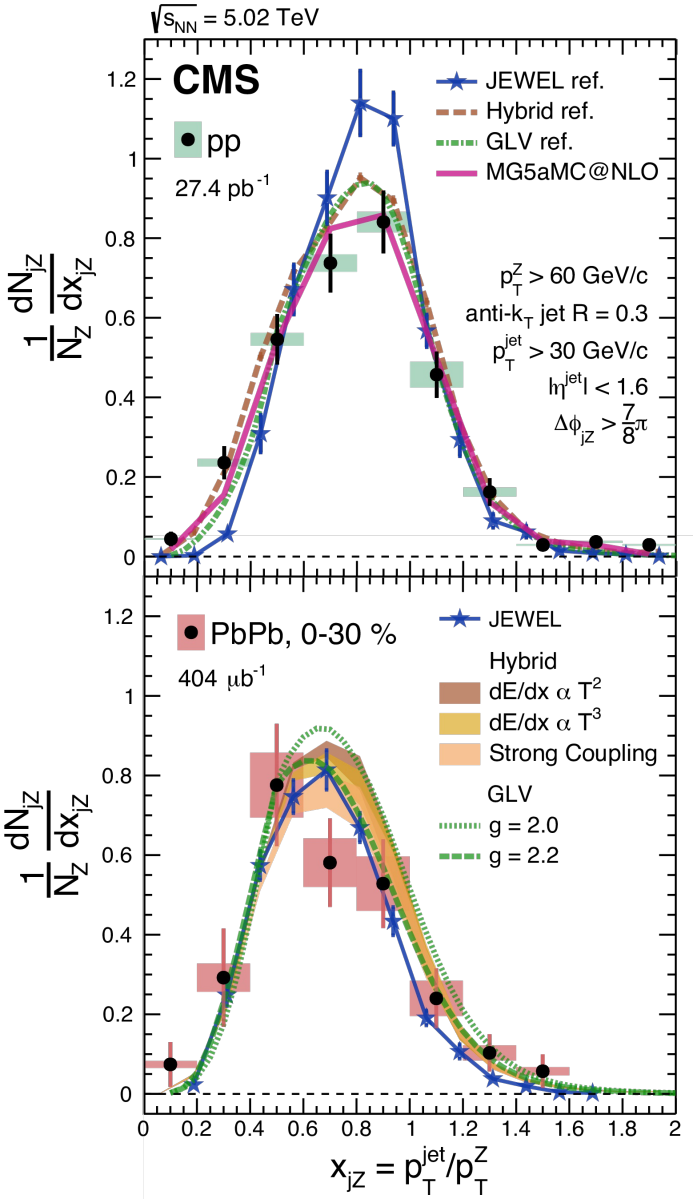
Acoplanarity

No significant deviation in dPhi observed in either system

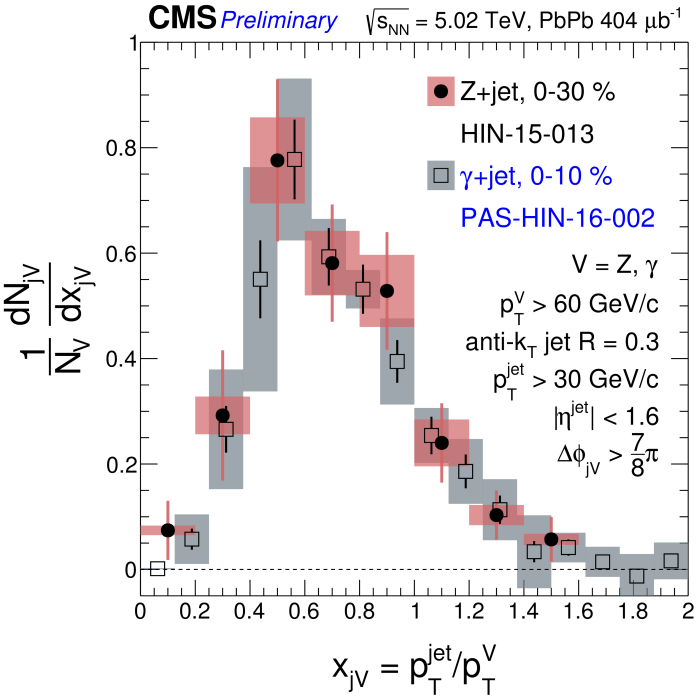


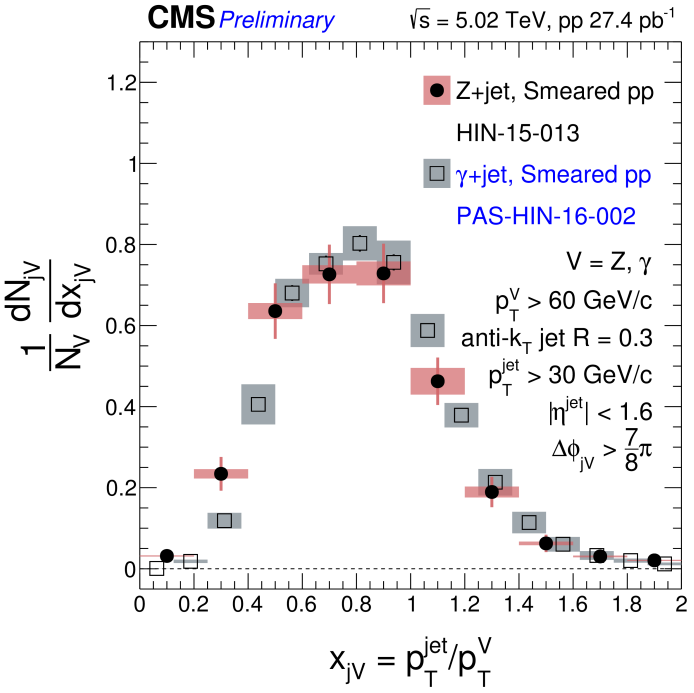


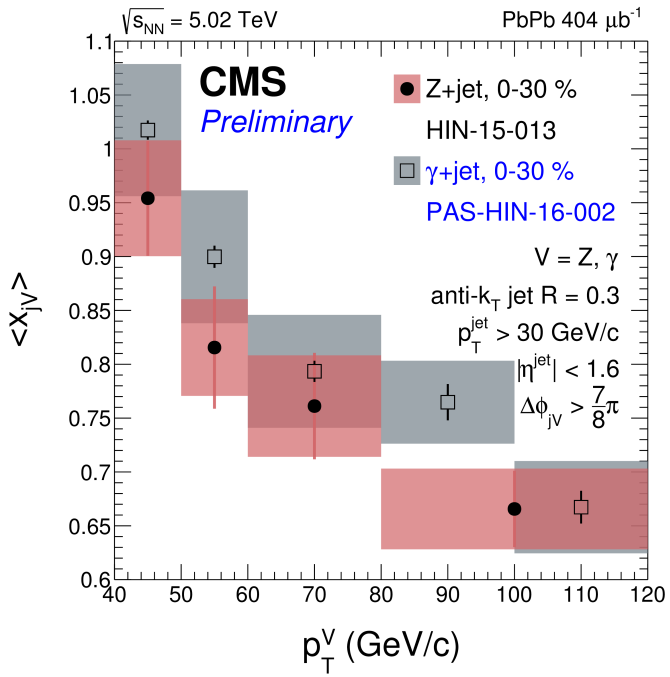
Z-jet theory comparisons



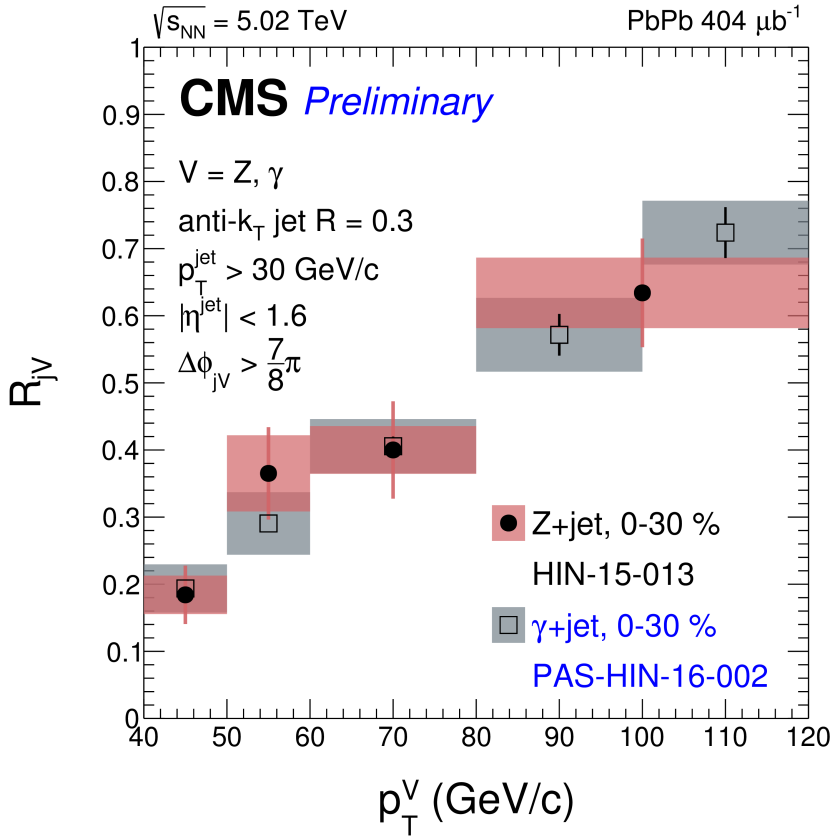
Z-jet vs photon jet

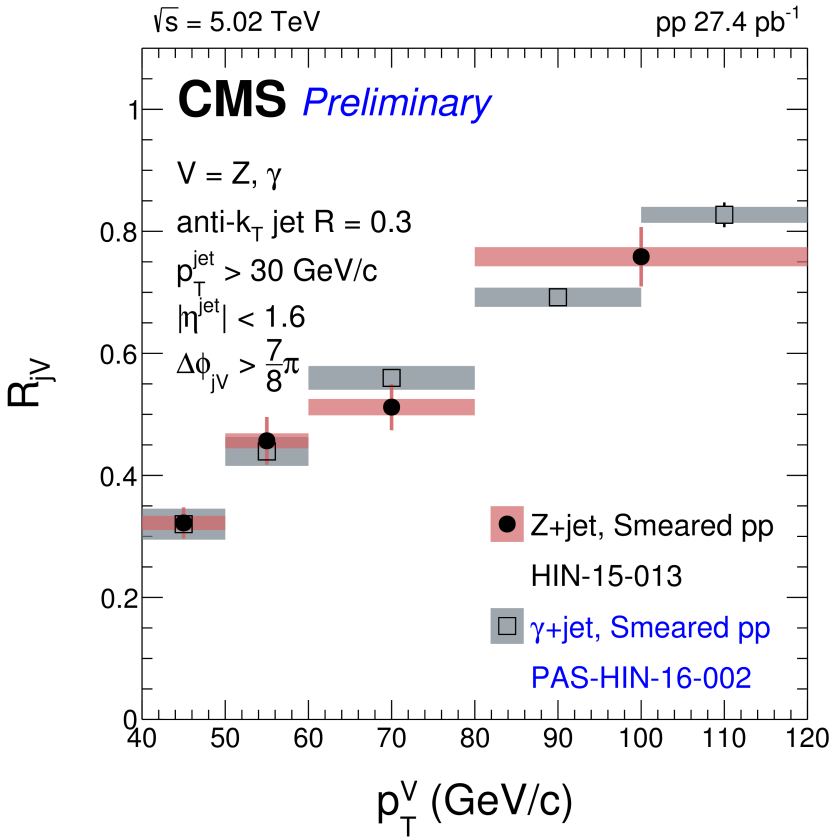




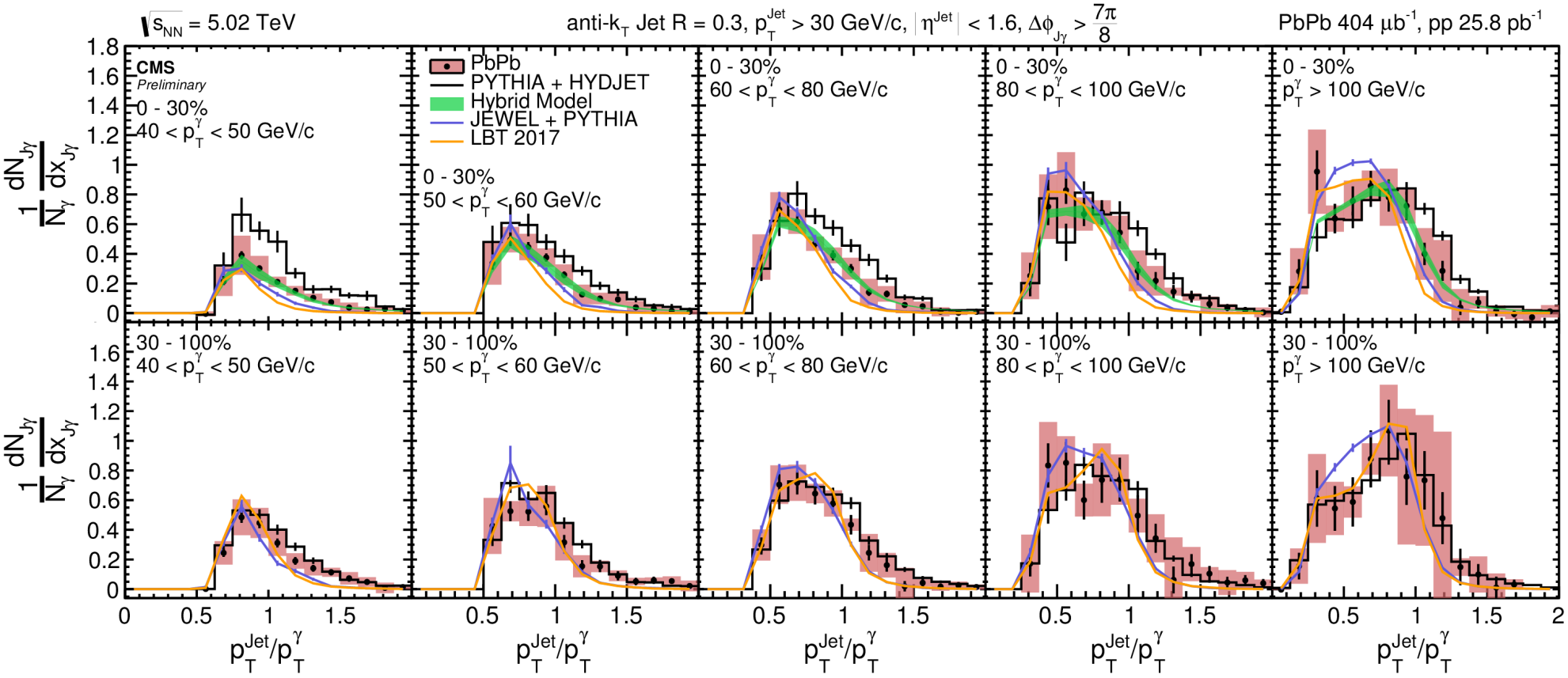


Z-jet vs photon jet

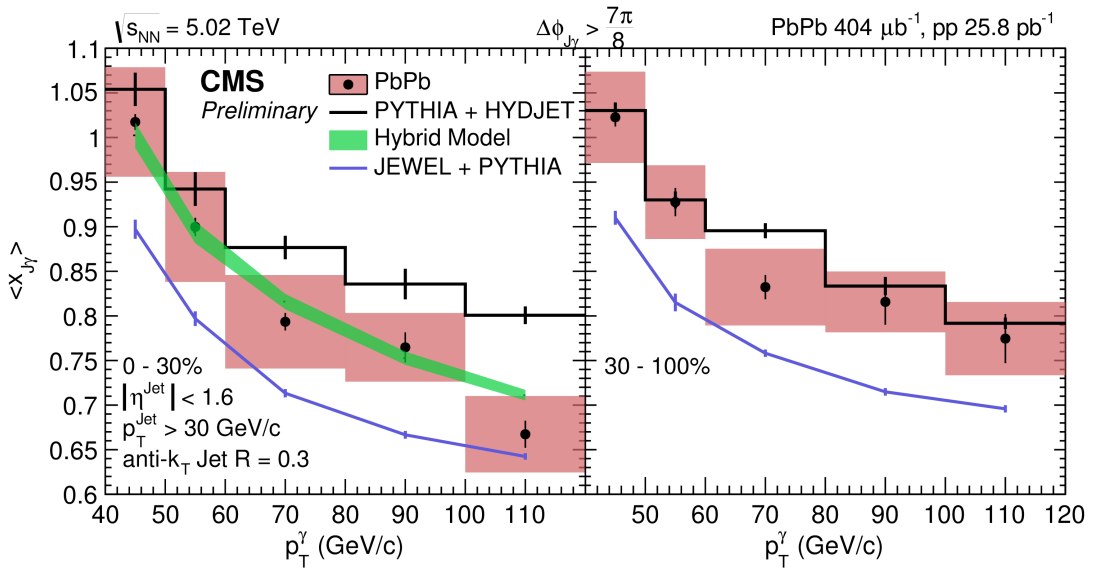


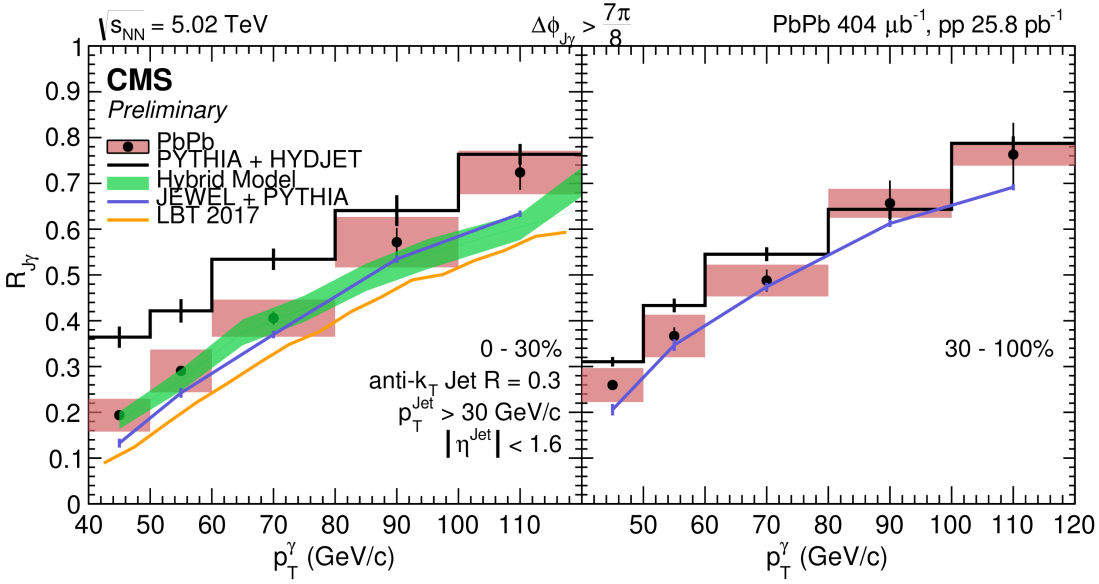


Photon-jet vs theory



Photon-jet vs theory





Frag. Function Kinematics