Jet energy loss in boson-jet events in PbPb collisions at 5.02 TeV with CMS

QUARK MATTER 2017

CHICAGO, USA

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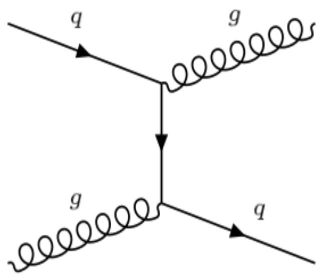
CMS COLLABORATION

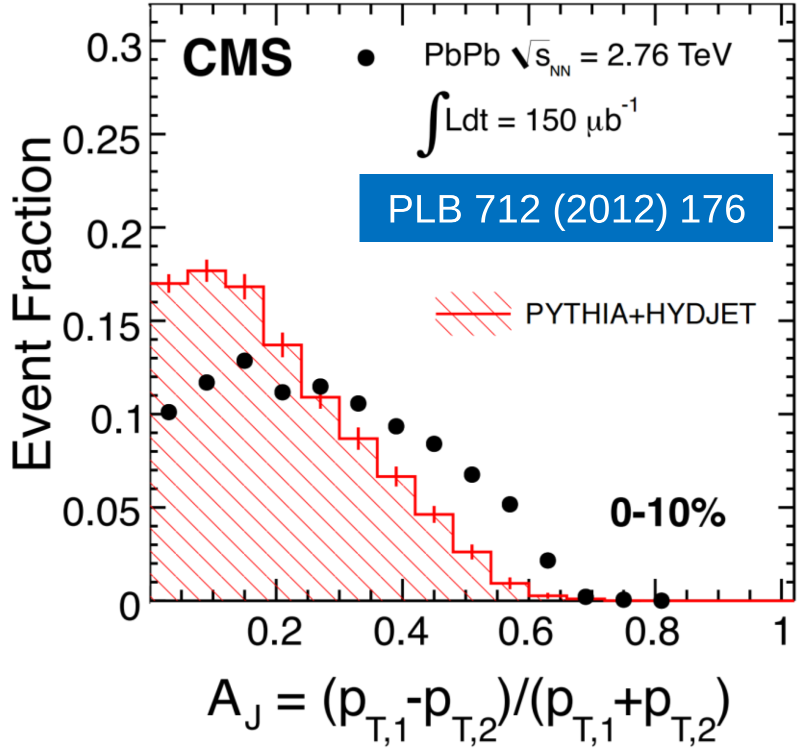
Energy loss in PbPb dijet events

- High energy quarks and gluons are used to study the properties of the quark-gluon plasma

- Dijet asymmetry measured in PbPb collisions

- Both jets are modified when passing through the medium

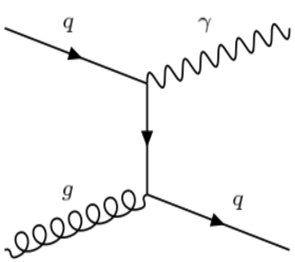




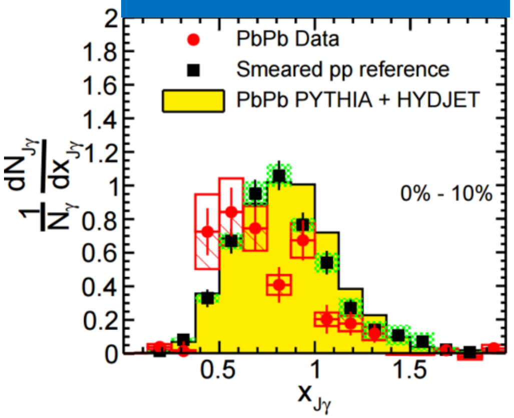
Energy loss in PbPb boson-jet events

- Bosons in boson-jet events do not interact with the medium
- Clean tag of the initial parton energy

- Photons:
  - Higher statistics
  - Background processes have to be subtracted:
    - Neutral meson decay
    - Fragmentation photons

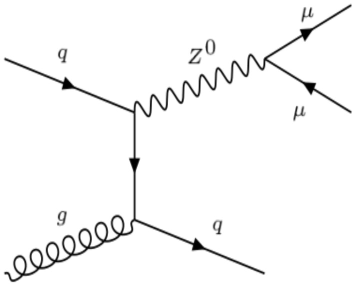


2.76 TeV PAS-HIN-13-006



5.02 TeV PAS-HIN-16-002

- Z bosons:
  - No contamination
  - Low statistics



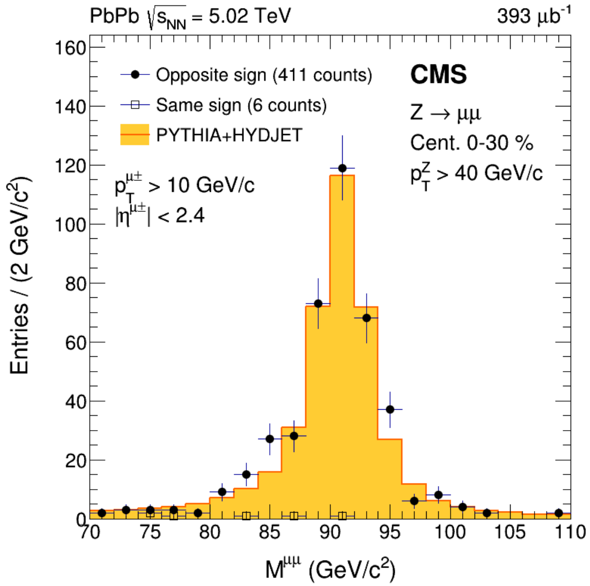
5.02 TeV HIN-15-013 arXiv: 1702.01060

CMS FINAL QM17

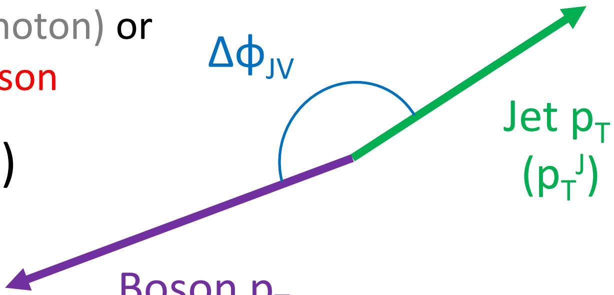
Analysis

- Reconstruct bosons, jets
- Pair selected bosons with every jet in event (boson-inclusive jet measurement)
- Smear the pp jet spectra
- Subtract contributions from background processes (underlying event, neutral meson decays)

HIN-15-013
arXiv: 1702.01060



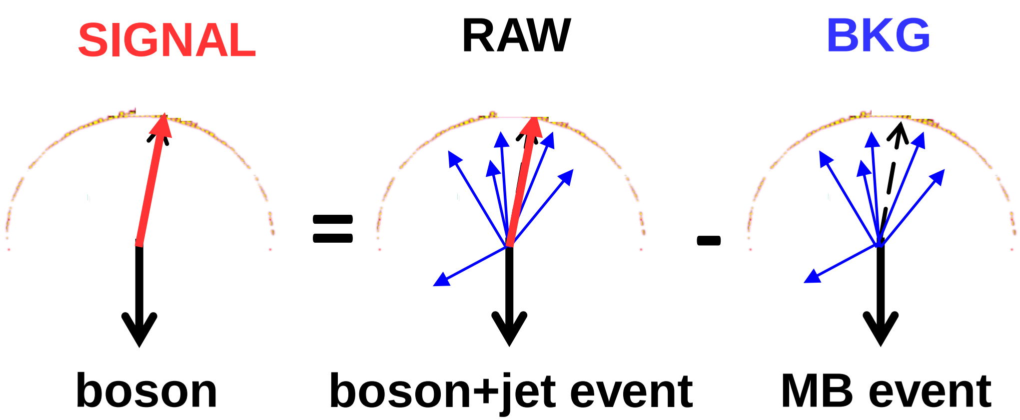
- Observables:
  - Azimuthal correlation ($\Delta\phi_{JV}$)
  - Transverse momentum imbalance ($x_{JV} = p_T^J/p_T^V$)
    - R_{JV}: Average number of jets per boson
  - Jet spectra ratio (I_{AA})

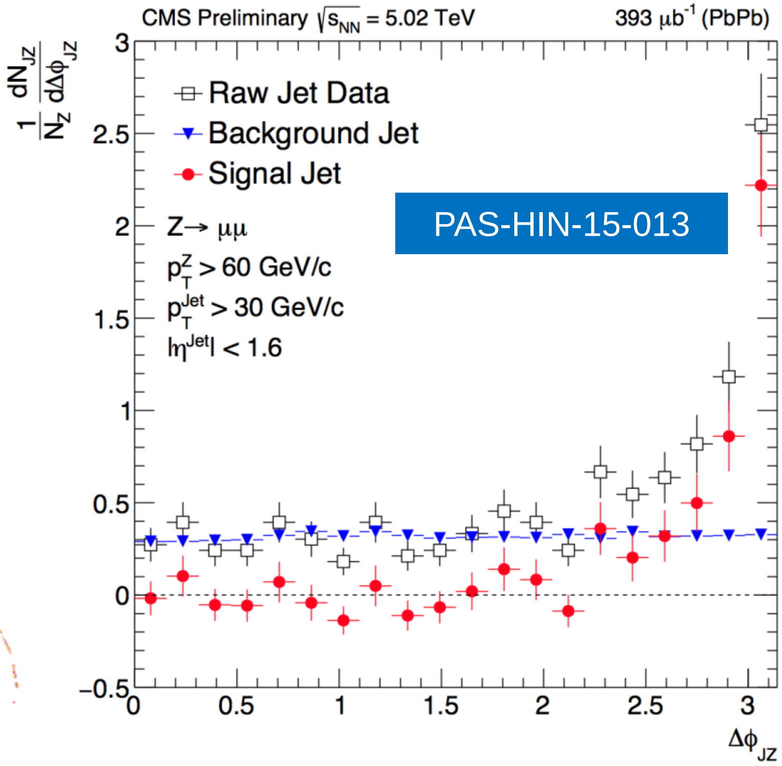


Mixed-event background subtraction

Background jets from the underlying event

- Jets from the underlying event are not correlated with the boson
- Estimate this contribution by embedding the boson into minimum bias events

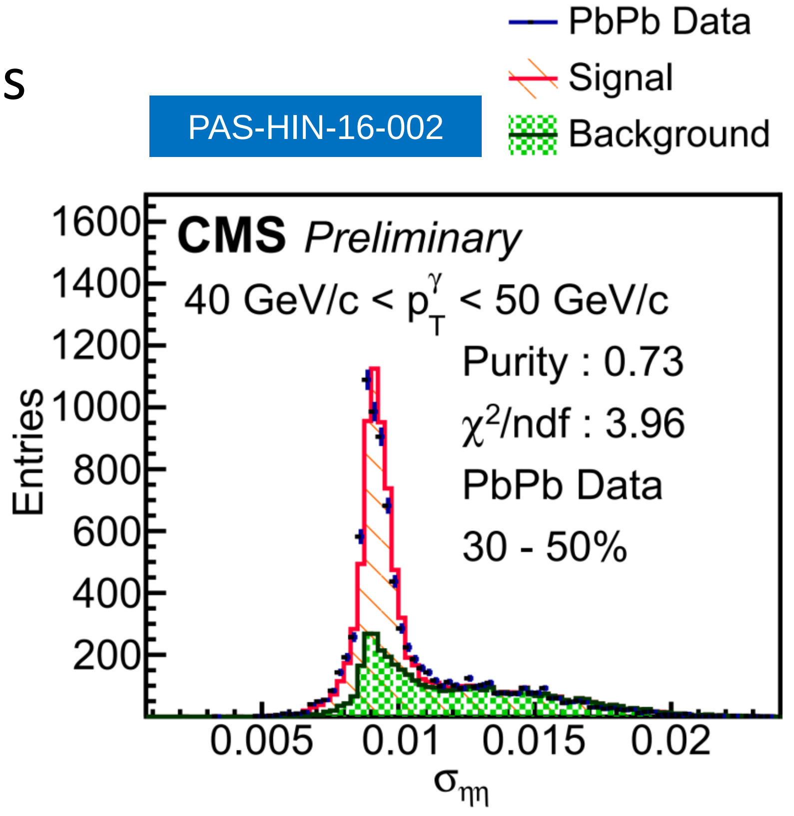




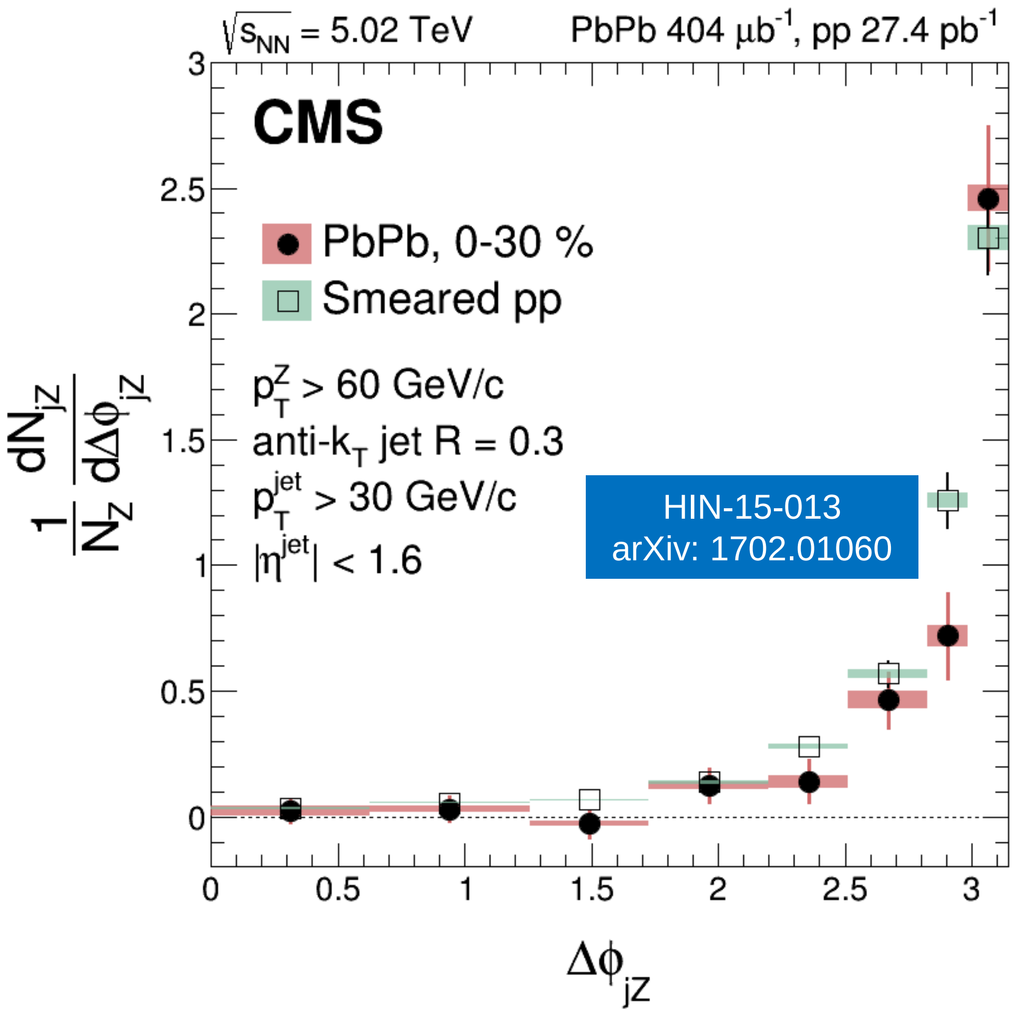
Photon purity (photon-jet only)

Photons produced by neutral meson decays

- Generally have wider shower shapes
- Estimate this contribution by using a template fit on the width of the shower shape:
    - Signal template from Monte-Carlo
    - Background template from non-isolated sideband in data

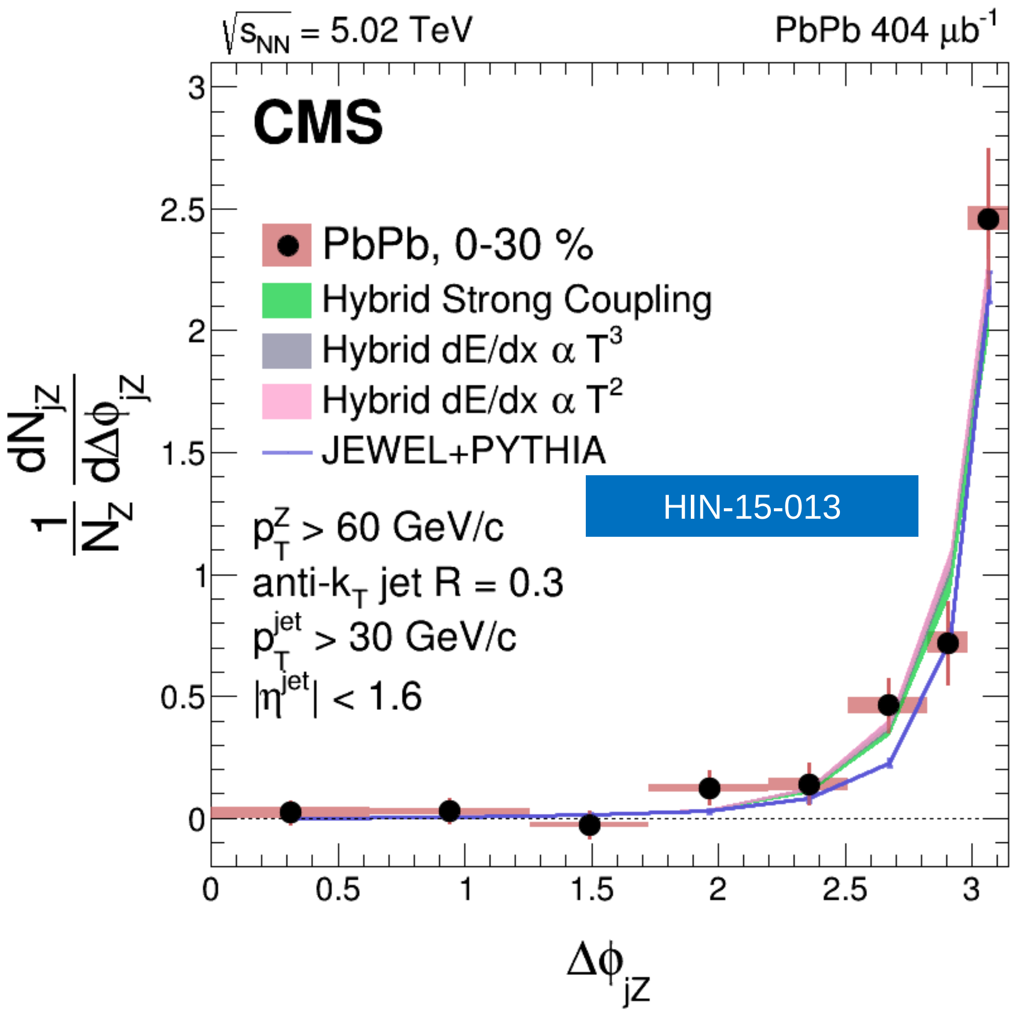


Azimuthal correlation $\Delta\phi_{JZ}$ (Z-jet events)



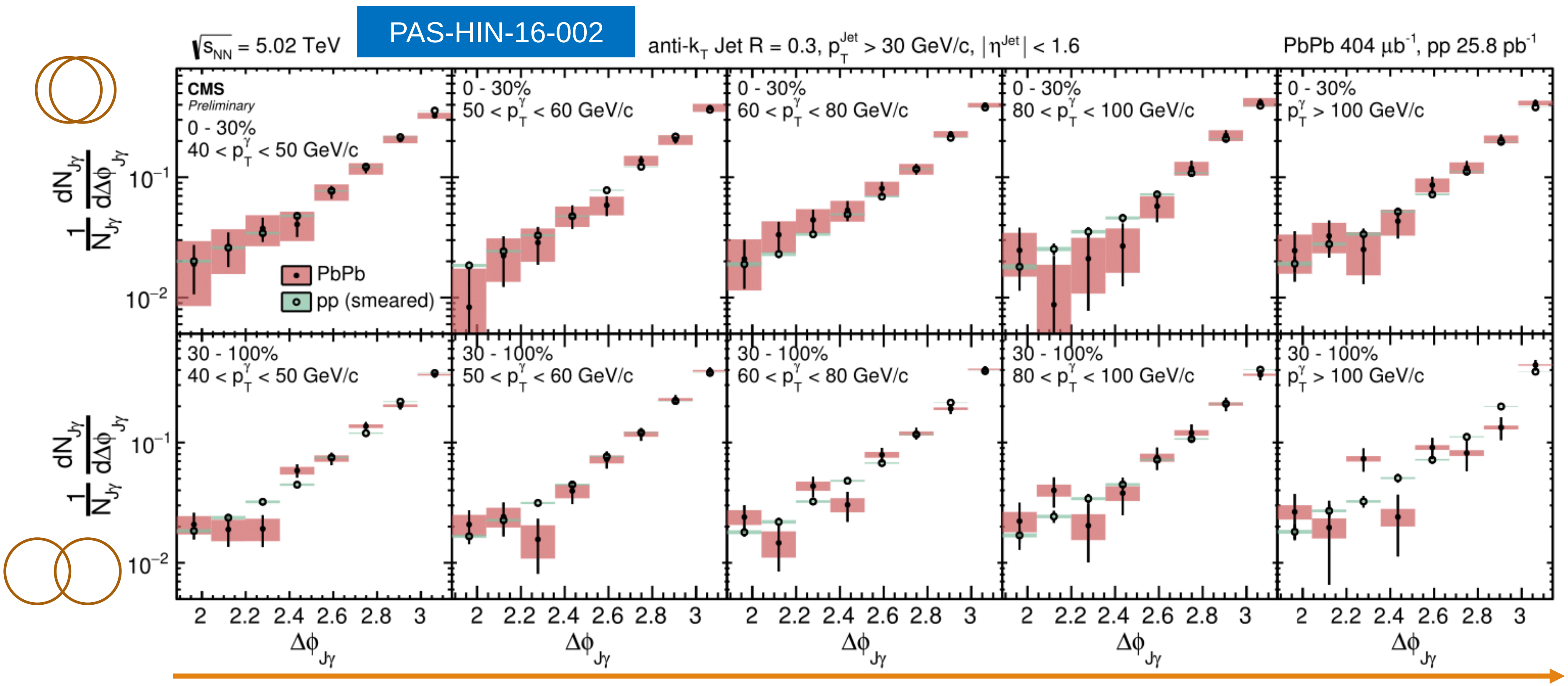
- No broadening of the $\Delta\phi_{JZ}$ distribution within uncertainties
- **Not** statistically significant, p-value of 0.14

Theory comparisons - $\Delta\phi_{JZ}$



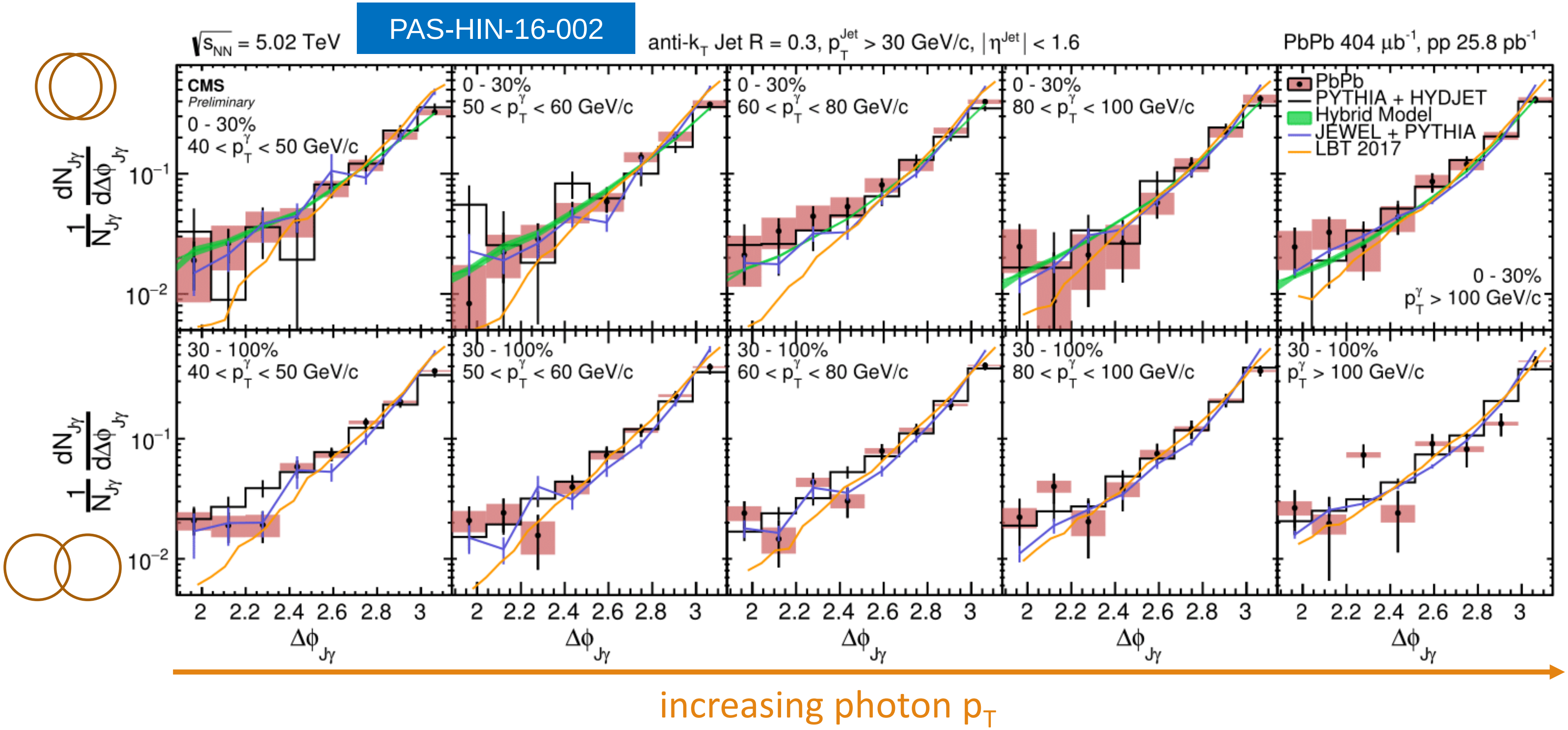
- Consistent with both pQCD (JEWEL + PYTHIA) and hybrid strong/weak coupling (Hybrid) models within uncertainties

Azimuthal correlation $\Delta\phi_{J\gamma}$ (photon-jet)



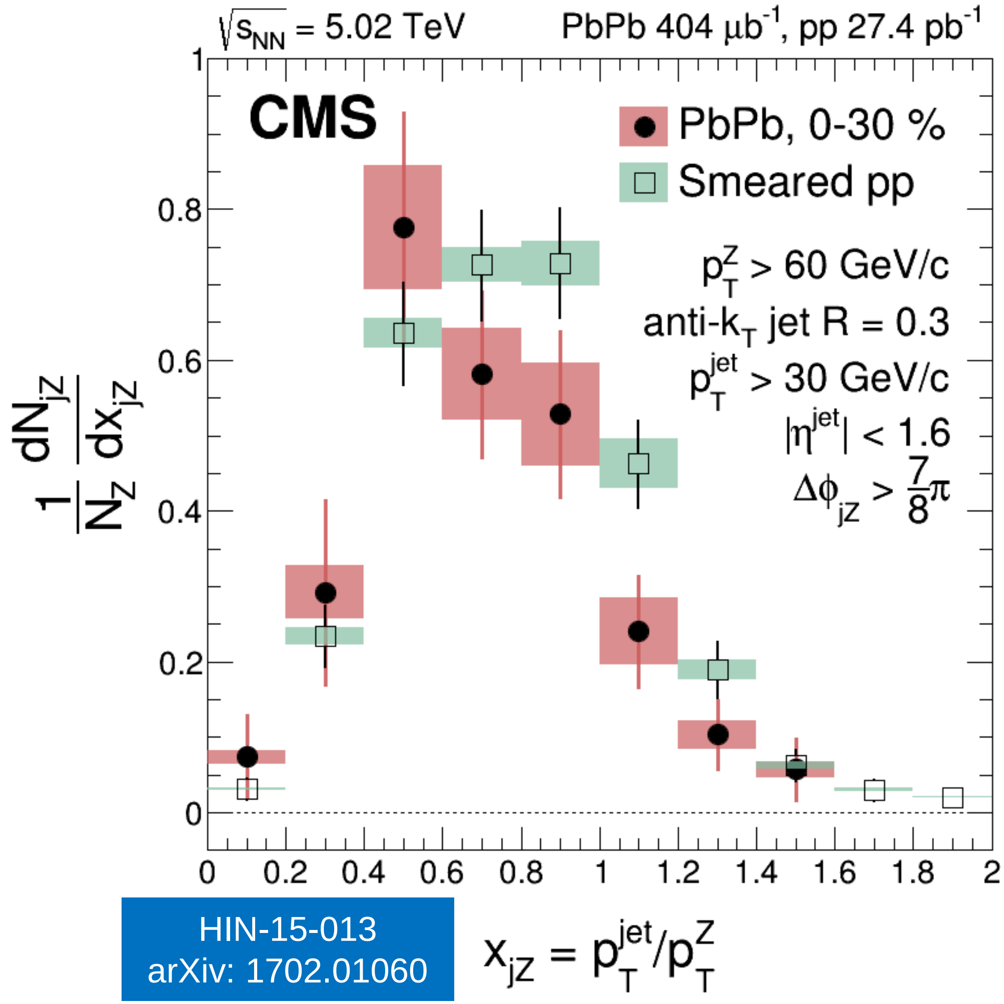
- No broadening observed in photon-jet events in PbPb collisions relative to pp collisions

Theory comparison - $\Delta\phi_{J\gamma}$



- LBT – pQCD model which keeps track of recoil thermal partons
- All models are in good agreement with data

Transverse momentum imbalance (x_{JZ})



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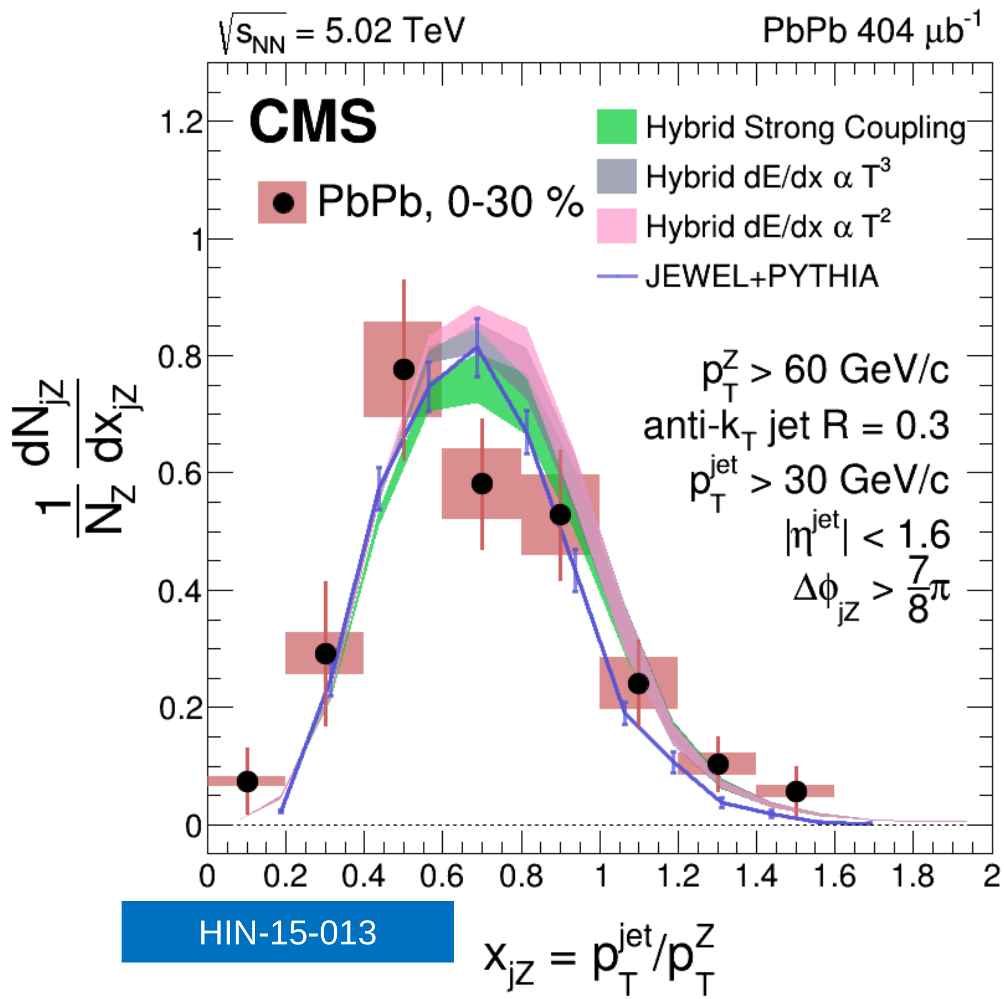
arXiv: 1702.01060

- Select only back-to-back jets ($\Delta\phi_{JZ} > {}^{7\pi}/_{8}$)
- x_{JZ} distribution in central PbPb collisions is shifted towards lower values, compared to pp collisions

Theory comparisons - x_{JZ}



- Predictions for the pp reference can be found in the backup slides

Transverse momentum imbalance ($x_{J\gamma}$)

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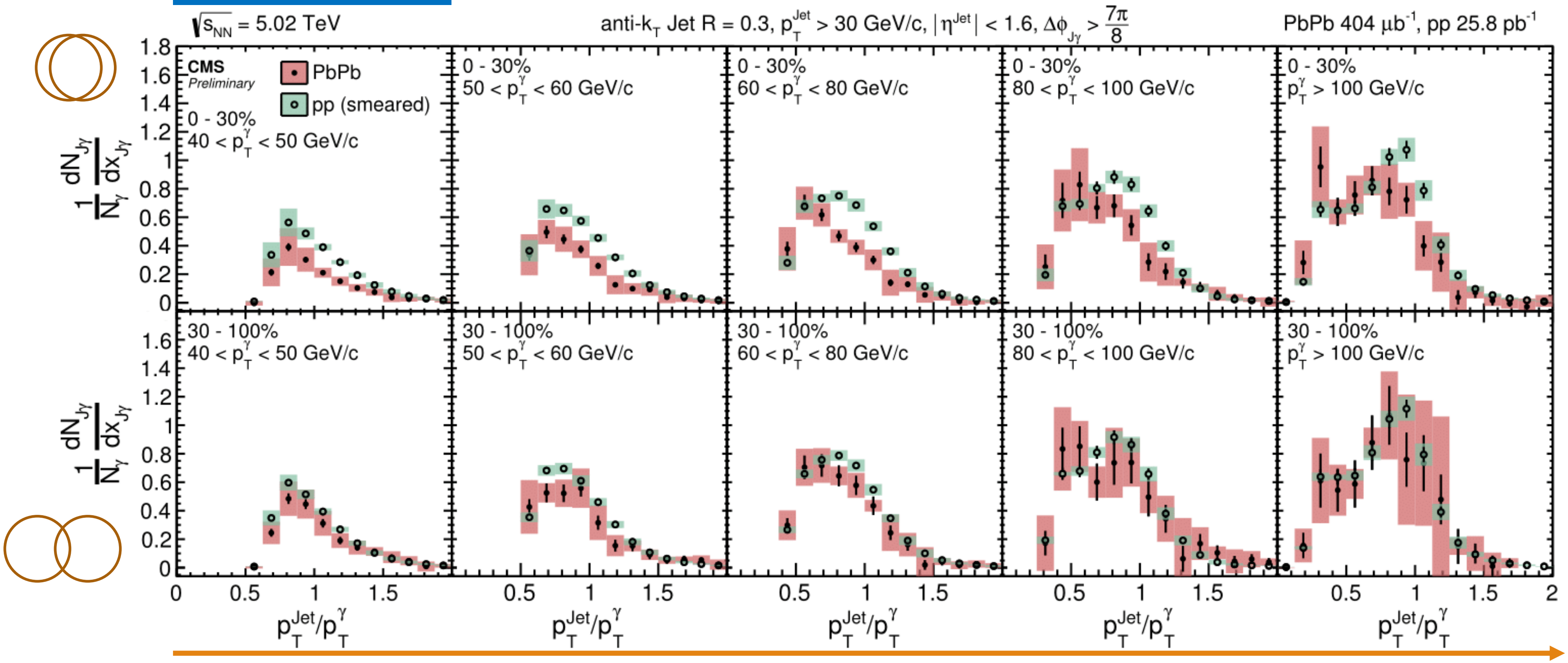
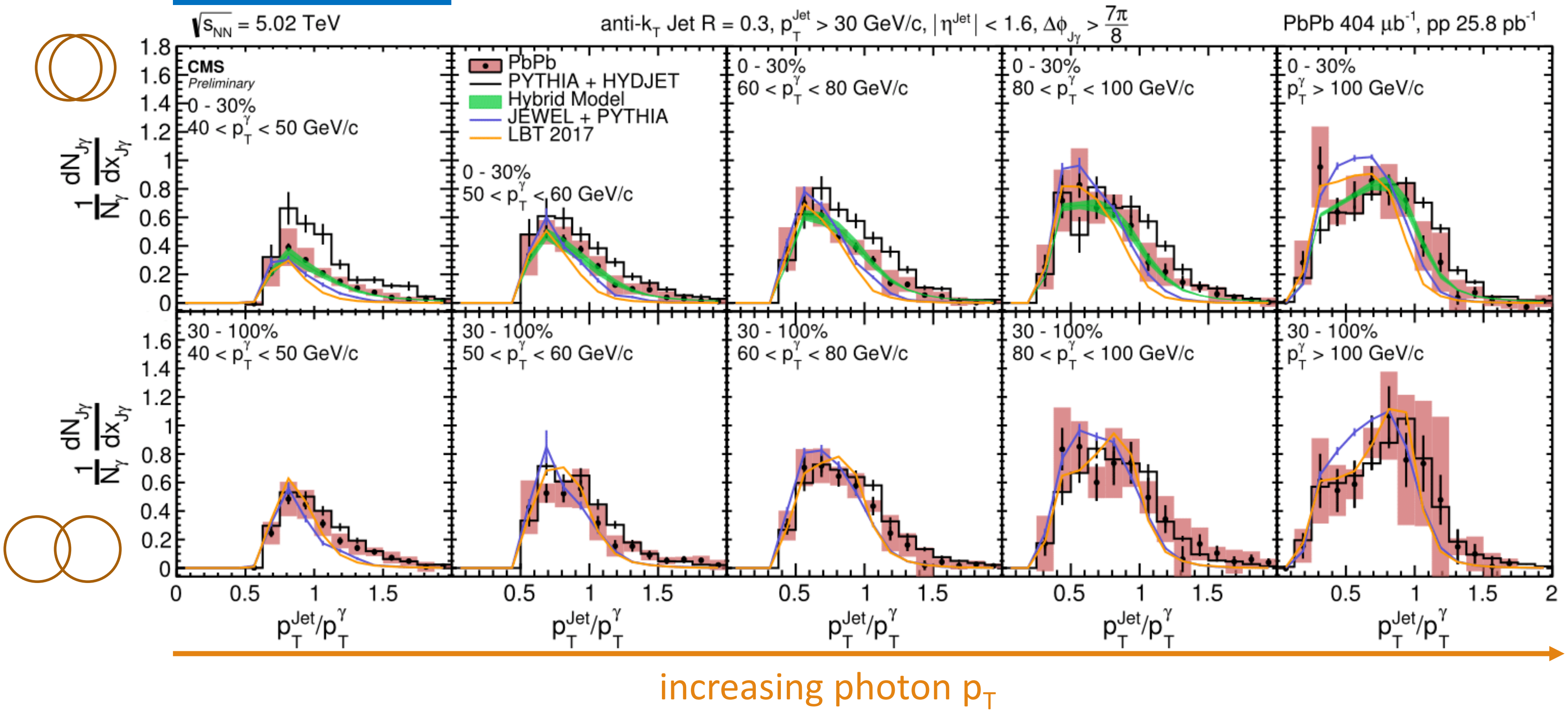


increasing photon p_T

- $x_{J\gamma}$ distribution is suppressed at low photon p_T but shifted to lower values at high photon p_T

Theory comparison - $x_{J\gamma}$

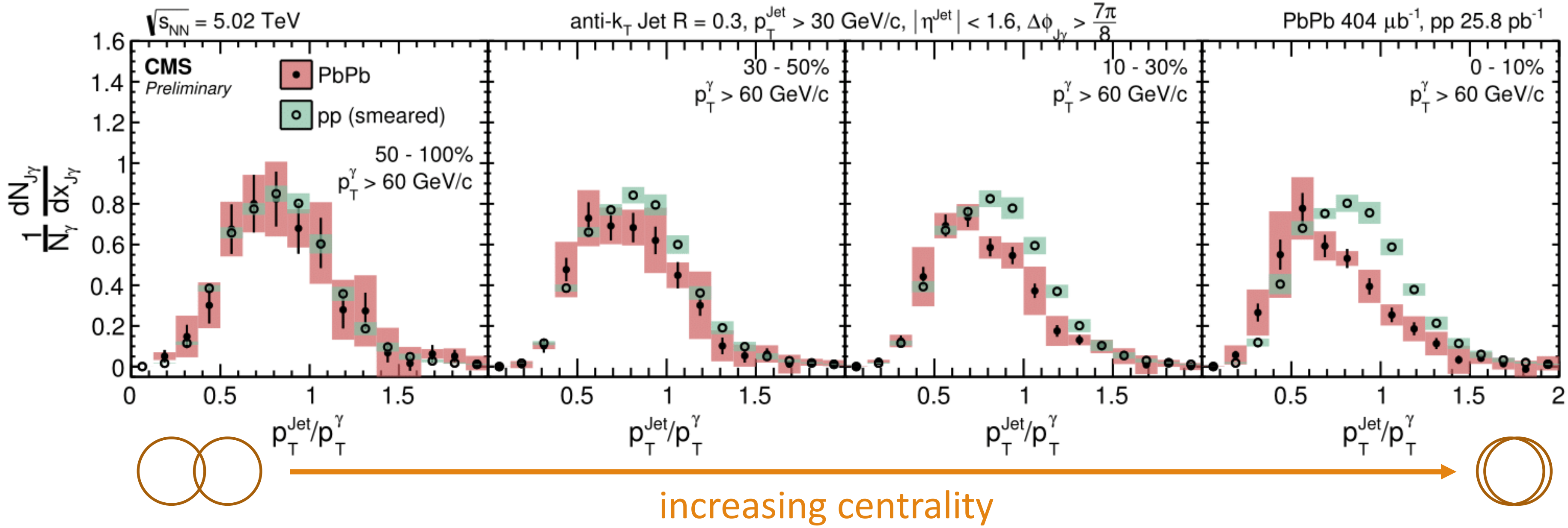
PAS-HIN-16-002



- Main features of $x_{J\gamma}$ distributions are reproduced by all models

Transverse momentum imbalance ($x_{J\gamma}$)

PAS-HIN-16-002

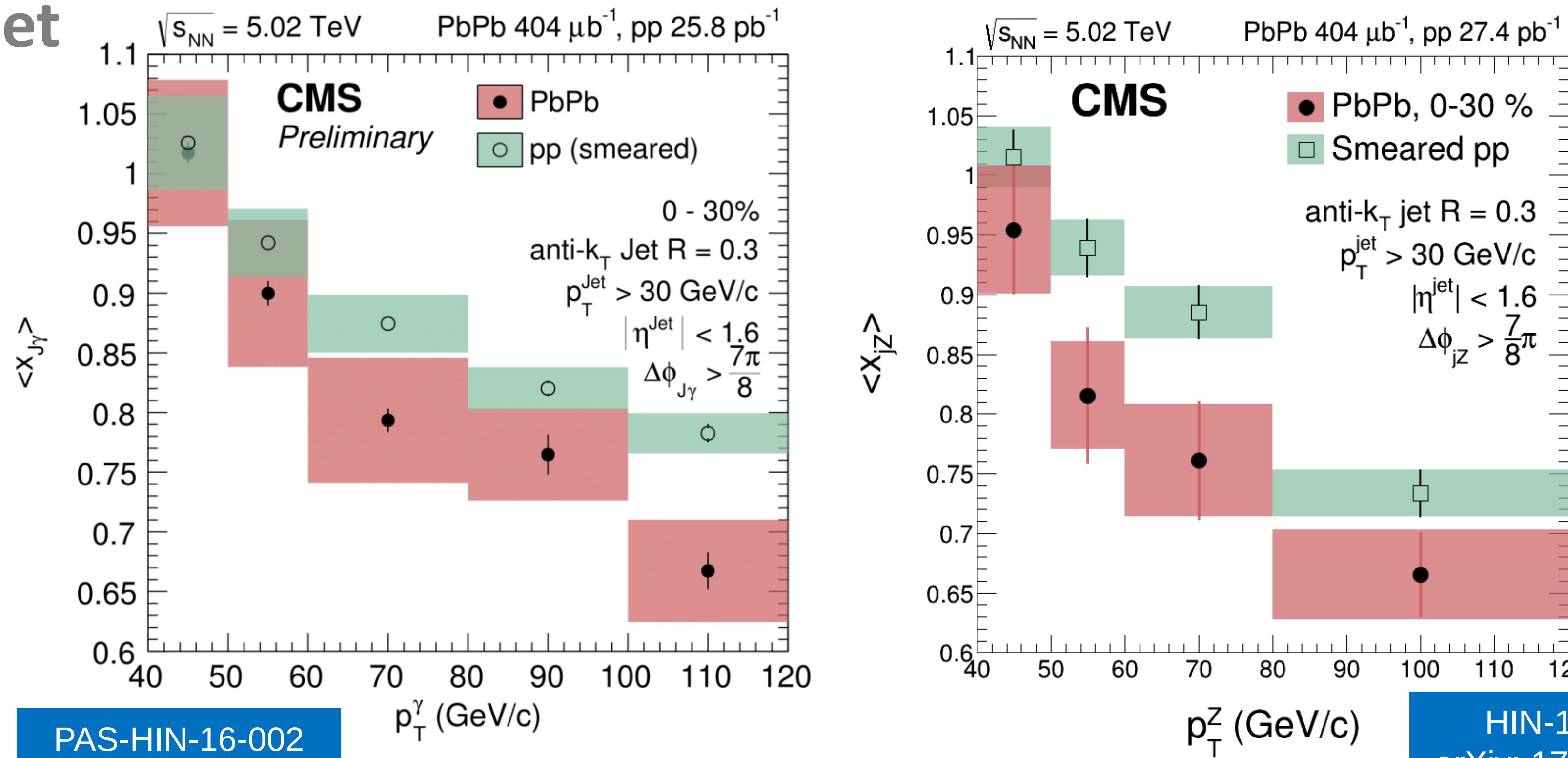


- $x_{J\gamma}$ distributions with more differential centrality binning
- Greater suppression and shifting of the $x_{J\gamma}$ distribution as the centrality increases

Mean $x_{J\gamma}/x_{JZ}$

γ-jet

Z-jet



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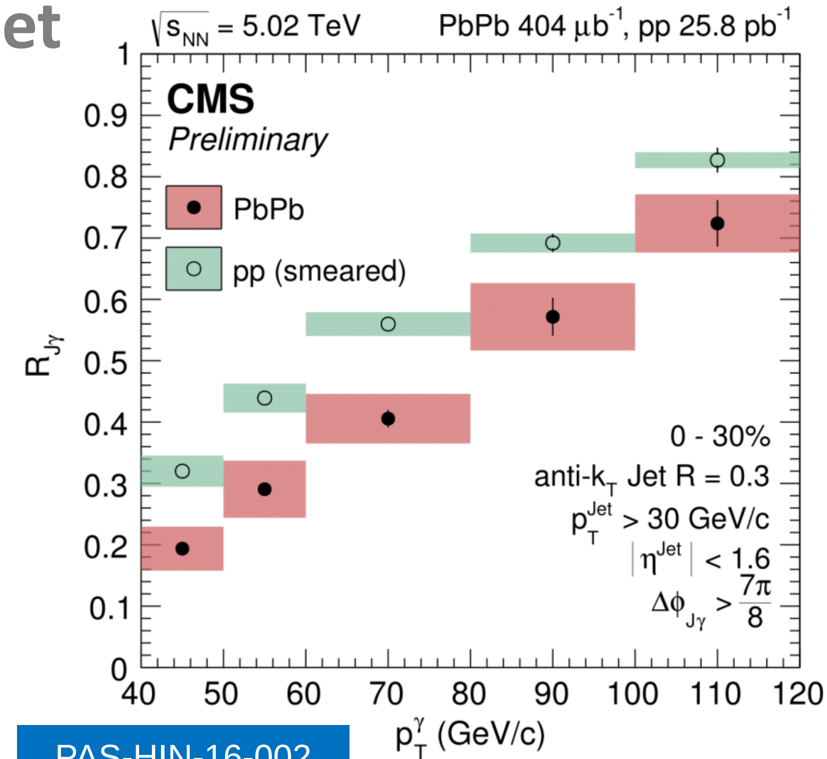
- Lower mean $x_{J\gamma}/x_{JZ}$ in central PbPb collisions than in pp collisions
- Results consistent between photon-jet and Z-jet analyses

Average number of jets per boson ($R_{J\gamma}/R_{JZ}$)

- Mean $x_{J\gamma}/x_{JZ}$ characterizes the energy loss of jets
- $R_{J\gamma}/R_{JZ}$ is defined as the integral of the $x_{J\gamma}/x_{JZ}$ distributions, and represents the average number of jets per boson
- Jets that lose energy and fall below the jet p_T threshold of 30 GeV/c result in a lower $R_{J\gamma}/R_{JZ}$

Average number of jets per boson ($R_{J\gamma}$/ R_{JZ})

γ-jet



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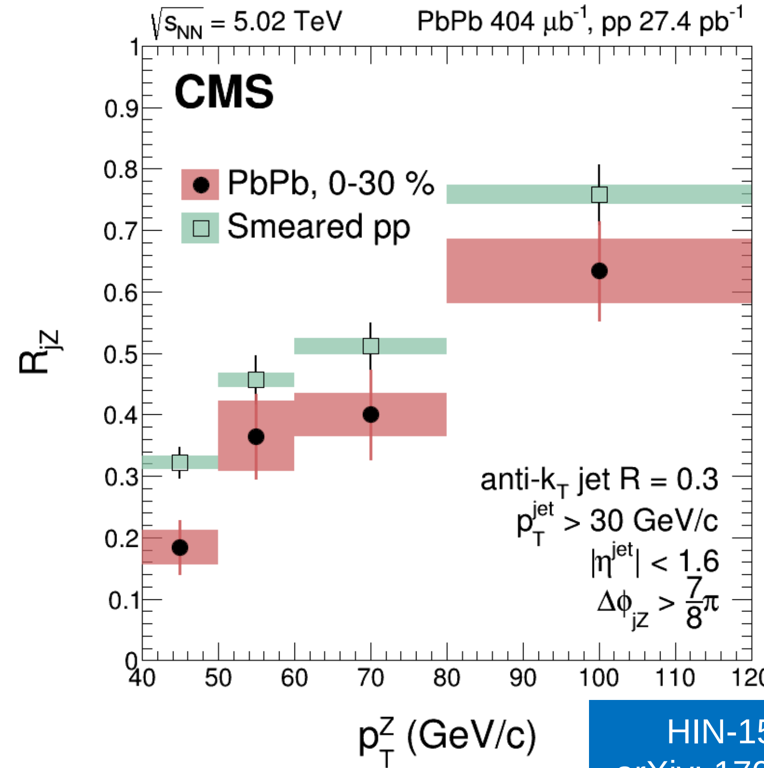
Z-jet



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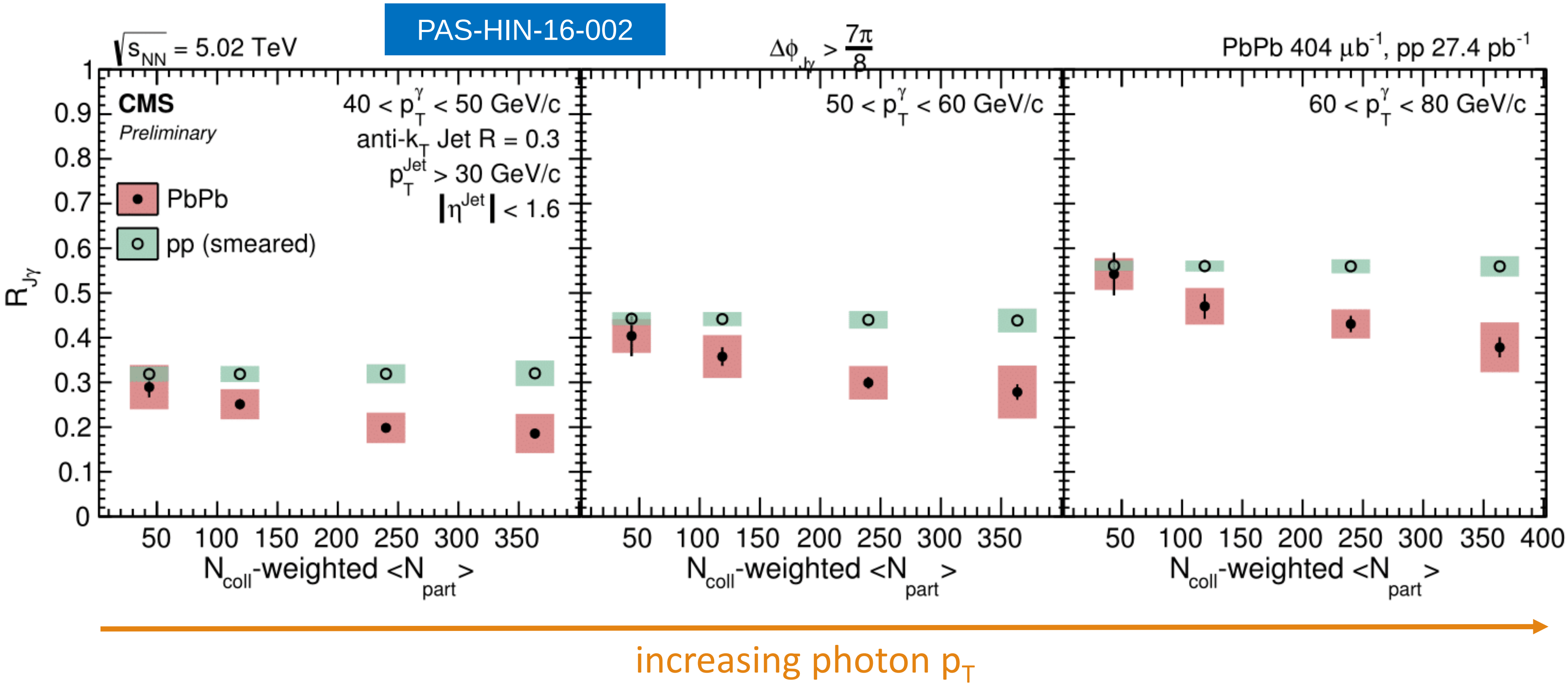
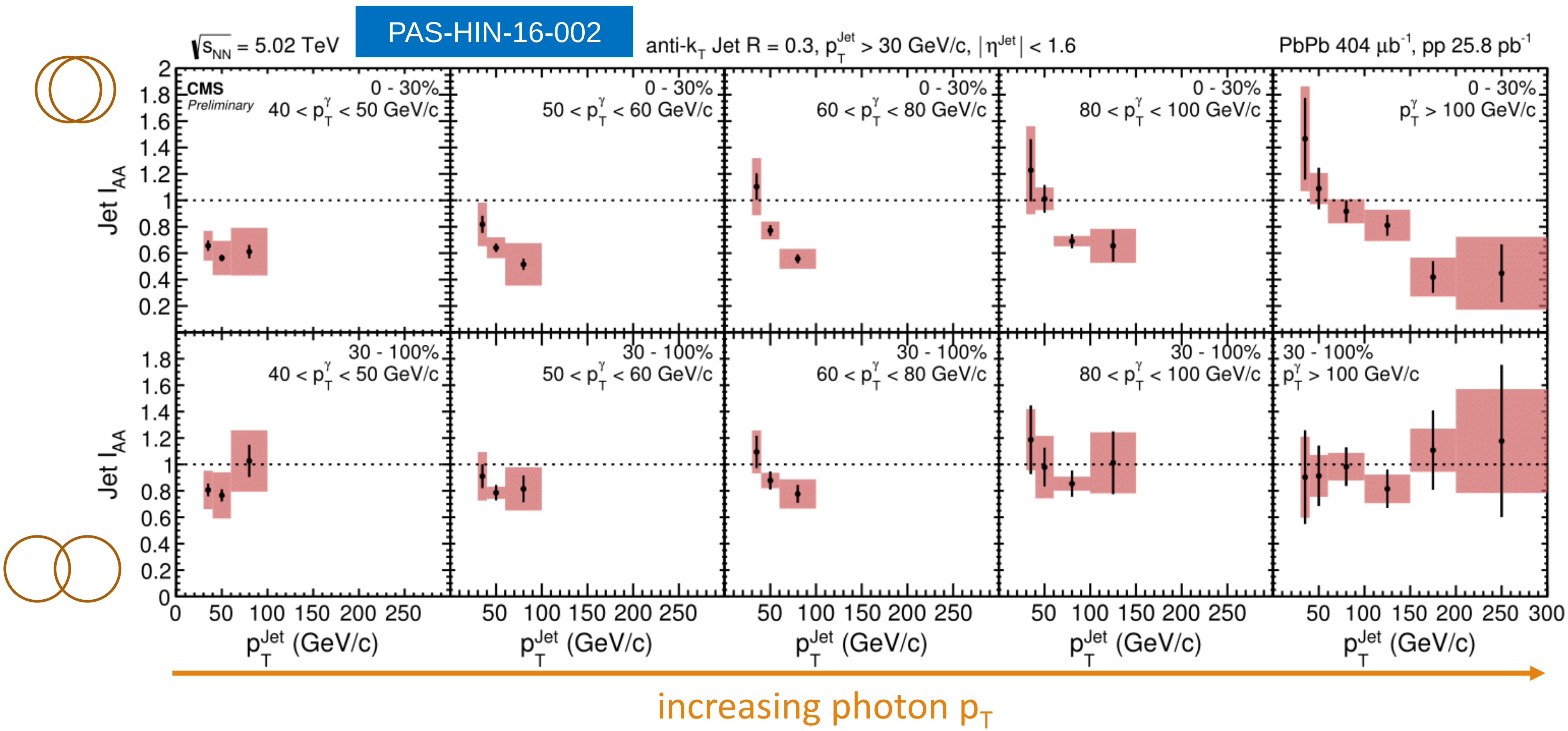
- Lower $R_{J\gamma}/R_{JZ}$ in central PbPb collisions than in pp collisions
- Results consistent between photon-jet and Z-jet analyses

$R_{J\gamma}$ (as function of centrality)



- Clear dependence of $R_{J\gamma}$ on both centrality and photon p_T

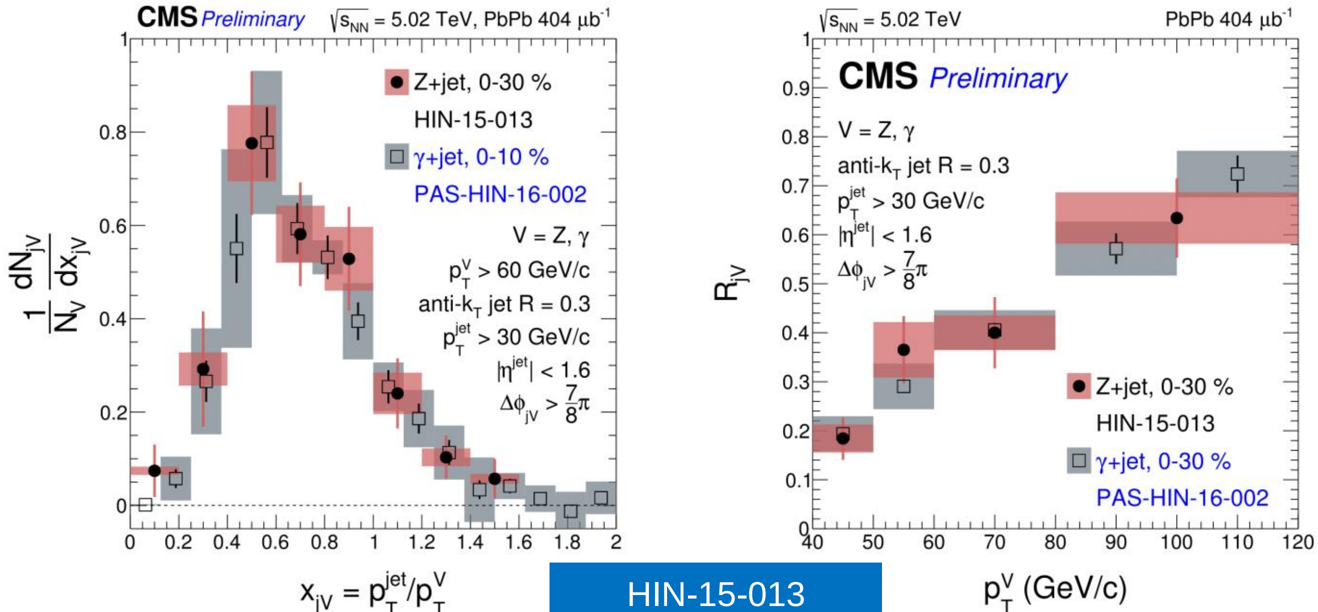
Jet I_{AA} (photon-jet events)



- I_{AA} (ratio of jet spectra in PbPb to pp) adds information about jet energy loss over the kinematic range

Summary

- Photon-jet and Z-jet correlations were studied with PbPb and pp data at 5.02 TeV
- No evidence of broadening of the Δϕ distributions
- $x_{J\gamma}/x_{JZ}$ distributions are suppressed and shifted to lower p_T in PbPb collisions versus pp collisions



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Backup

Z mass peaks

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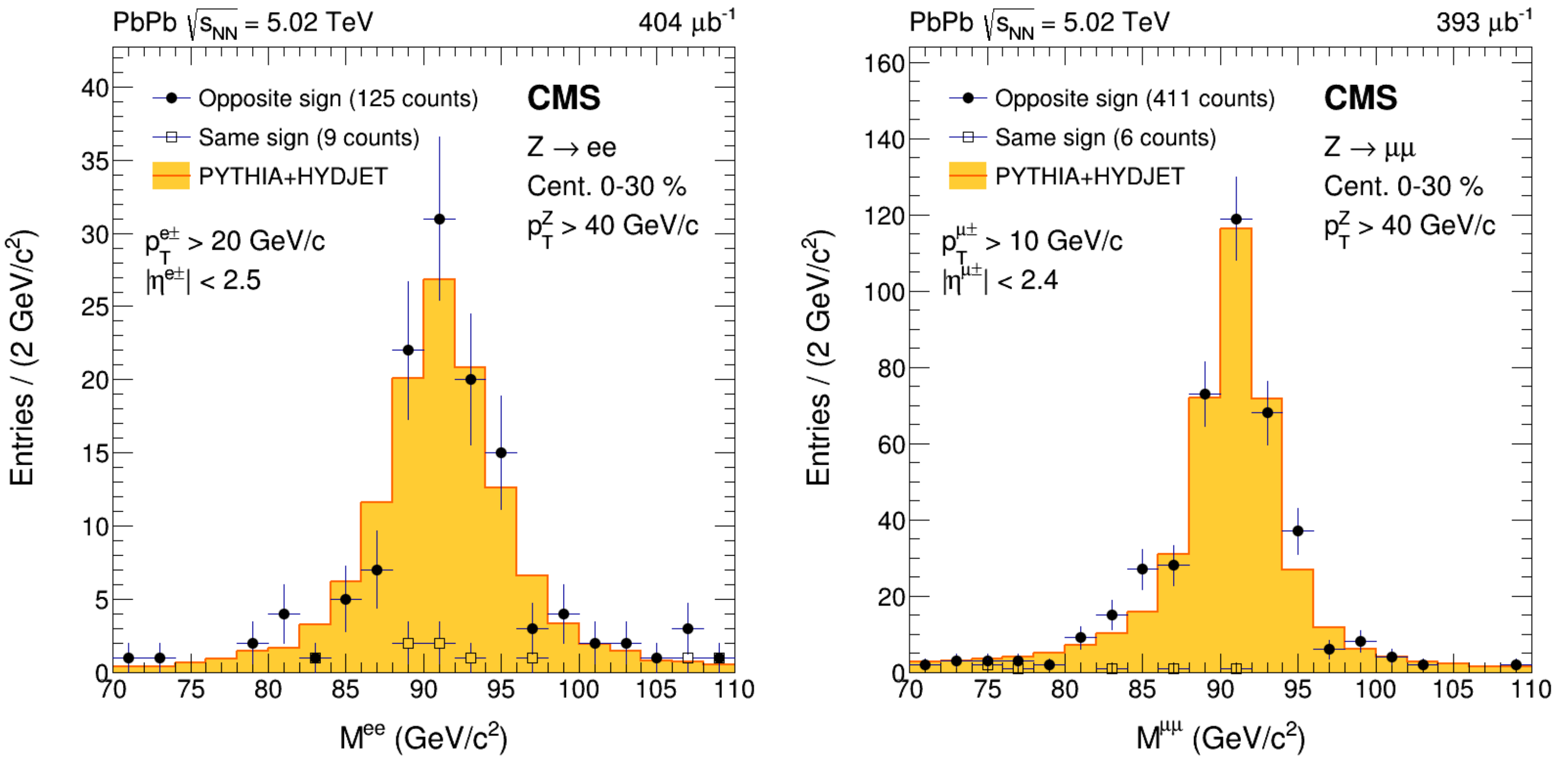
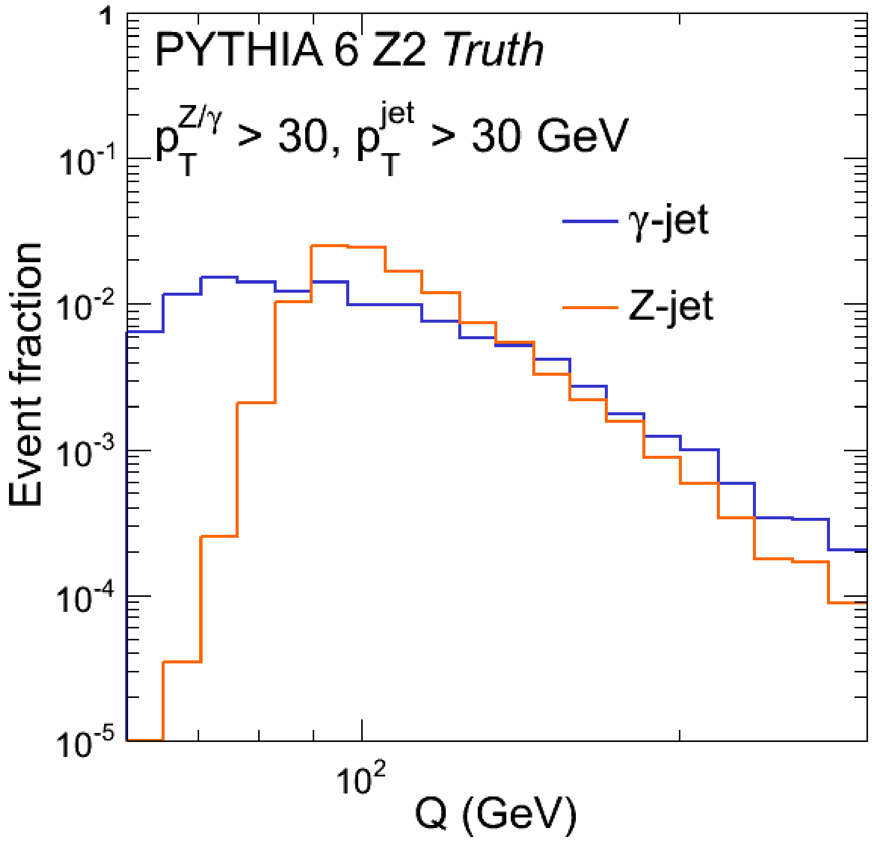


Q Scale

- Z+jet events have higher Q scale than photon+jet

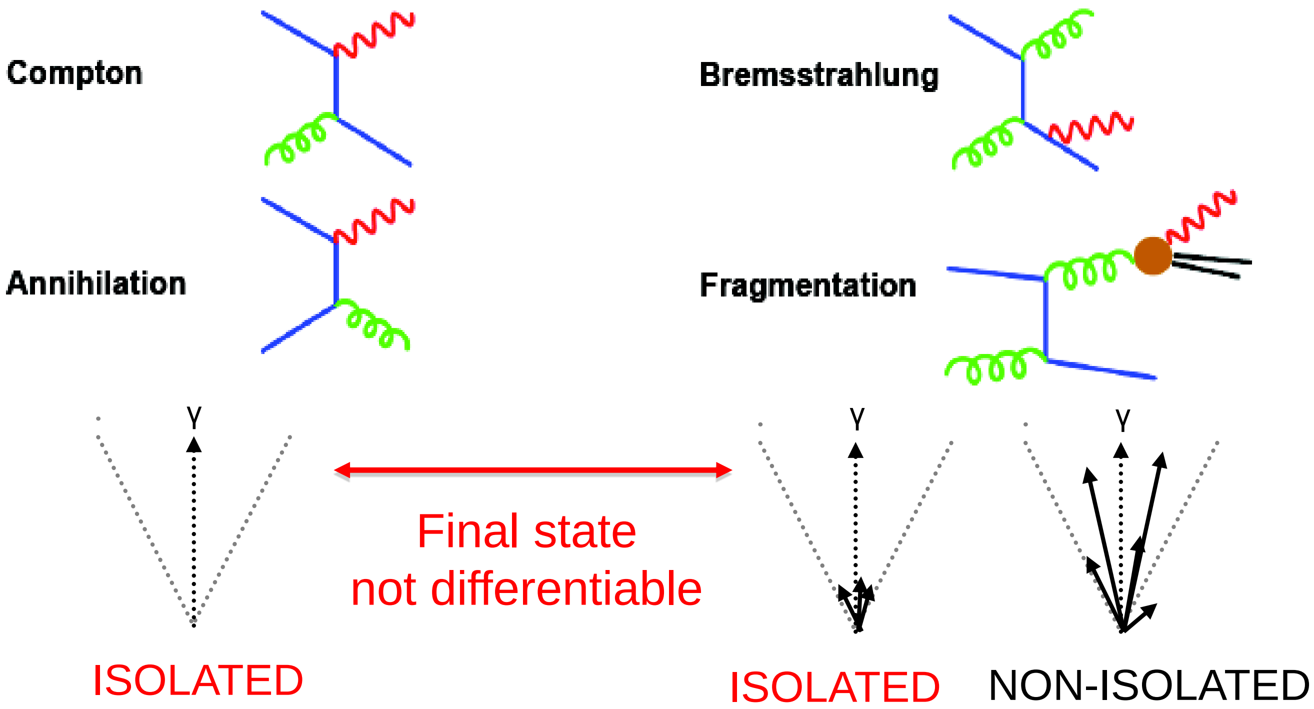


Signal Photon

Identify signal photons by :

- Isolation requirement based on calorimeter energy deposits
- Extract fraction of signal photons based on shower shape

Leading order **Higher orders**



Jet smearing for jets in pp collisions

- Different jet energy and angular resolutions for PbPb and pp collisions
  - Smear the pp jet spectra to match that of PbPb

- Parametrize the jet energy resolution with the C, S and N parameters:

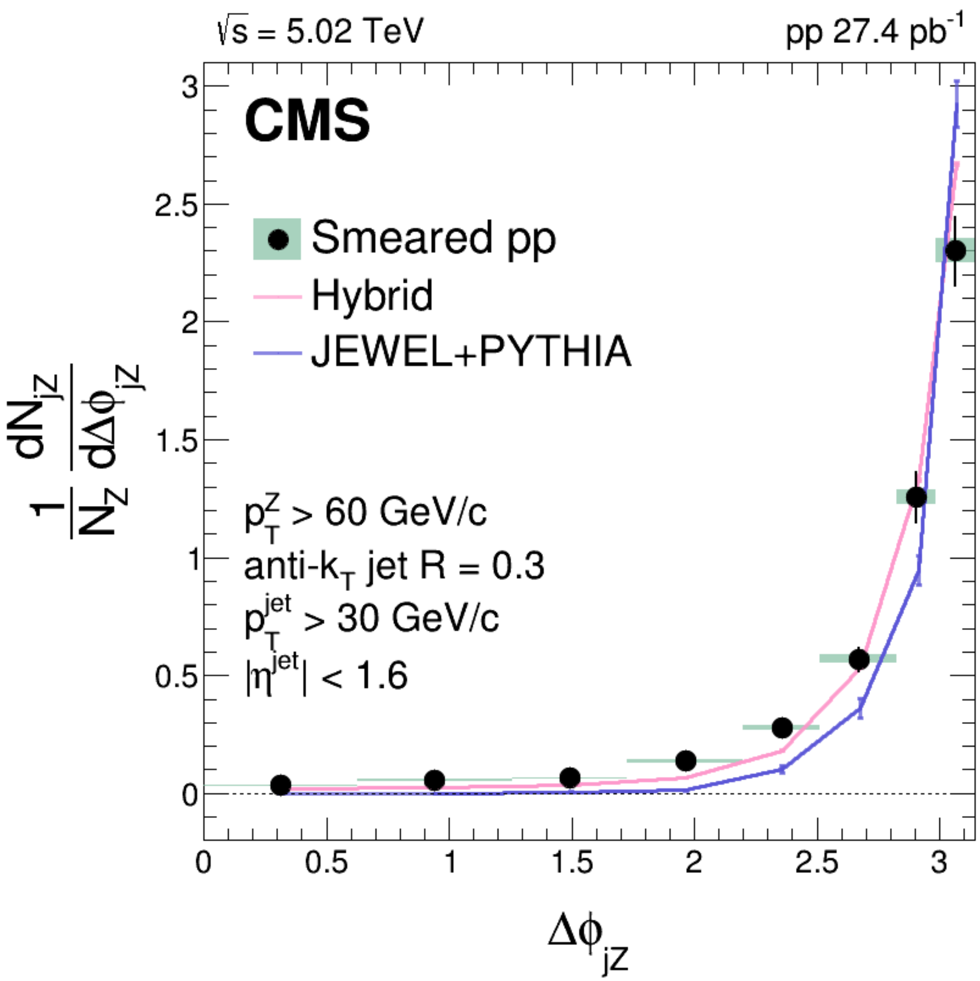
$$\sigma\left(\frac{p_T^{RECO}}{p_T^{GEN}}\right)=\sqrt{C^2+\frac{S^2}{p_T^{GEN}}+\frac{N^2}{(p_T^{GEN})^2}}$$

- Smear the jet spectra by the relative resolutions:

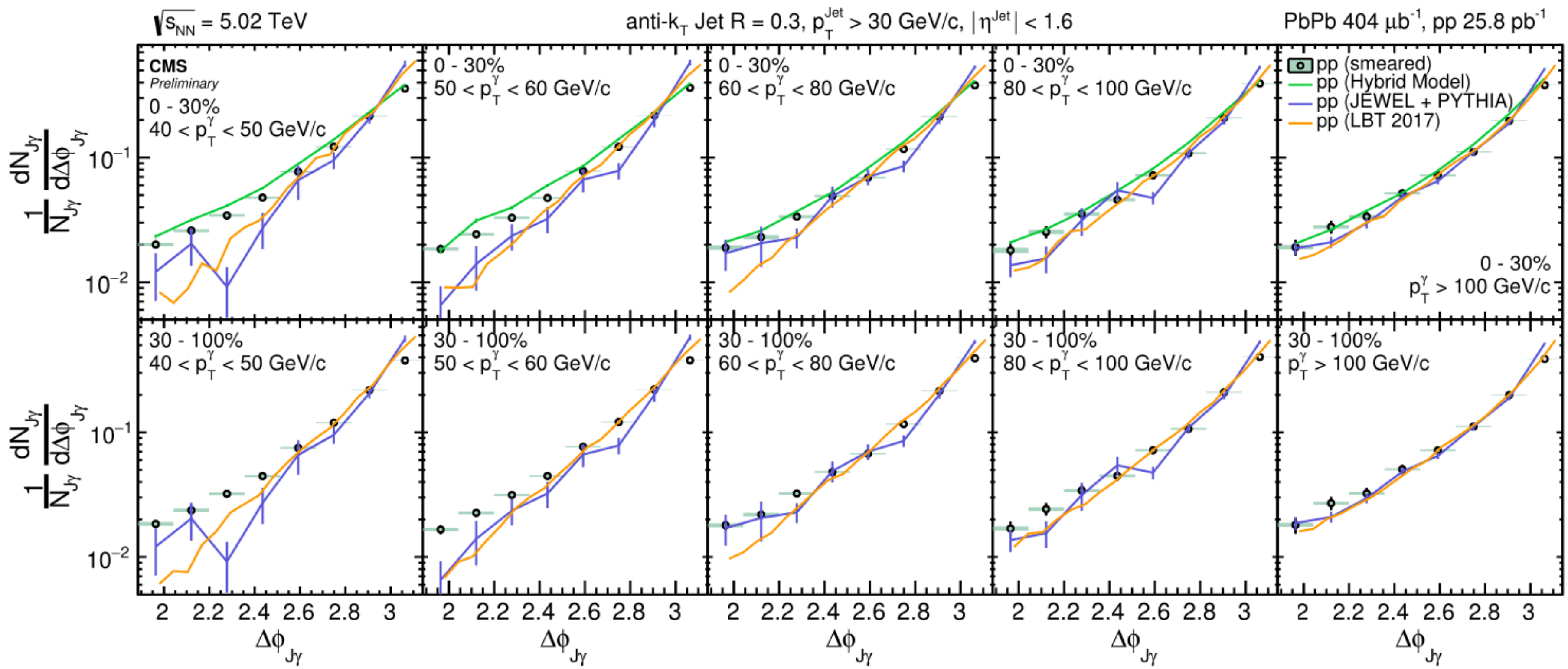
$$\sigma_{rel}=\sqrt{(C_{PbPb}^2-C_{pp}^2)+\frac{(S_{PbPb}^2-S_{pp}^2)}{p_T^{GEN}}+\frac{(N_{PbPb}^2-N_{pp}^2)}{(p_T^{GEN})^2}}$$

- Similar procedure is applied for the angular resolution

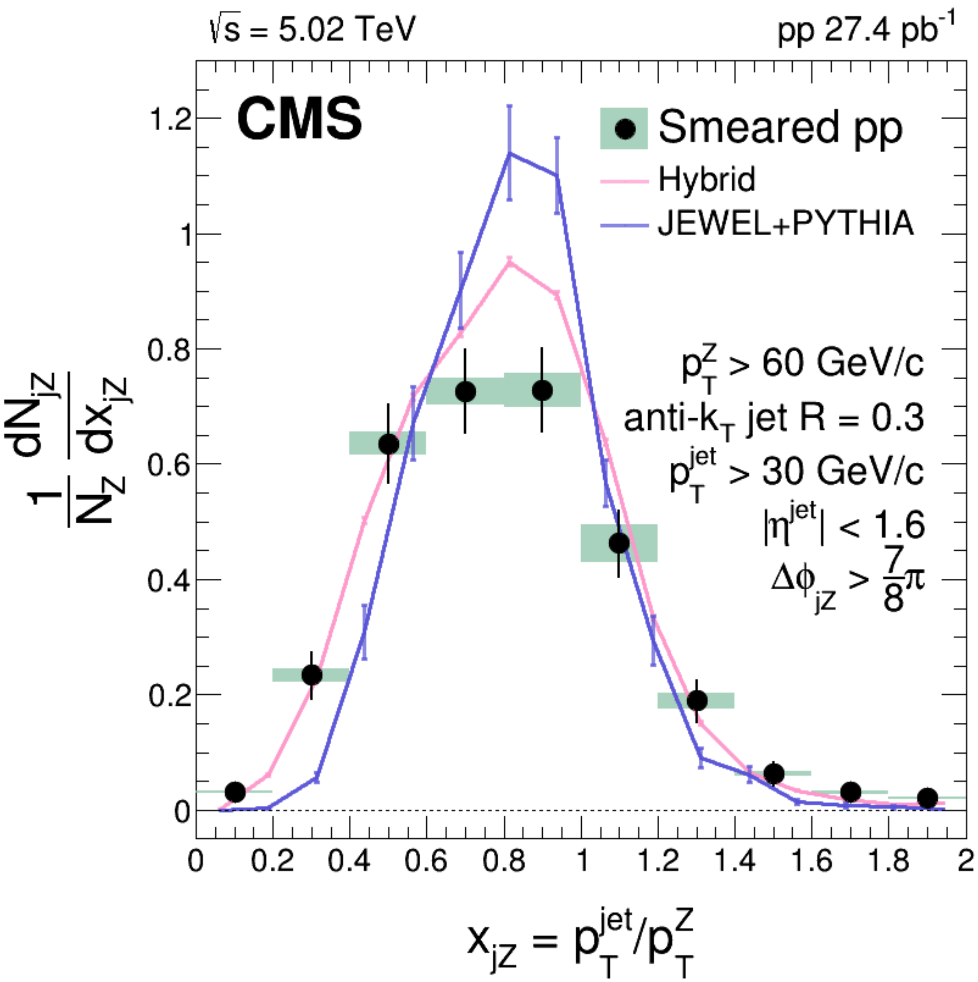
Theory comparisons – $\Delta\phi_{JZ}$ (pp)



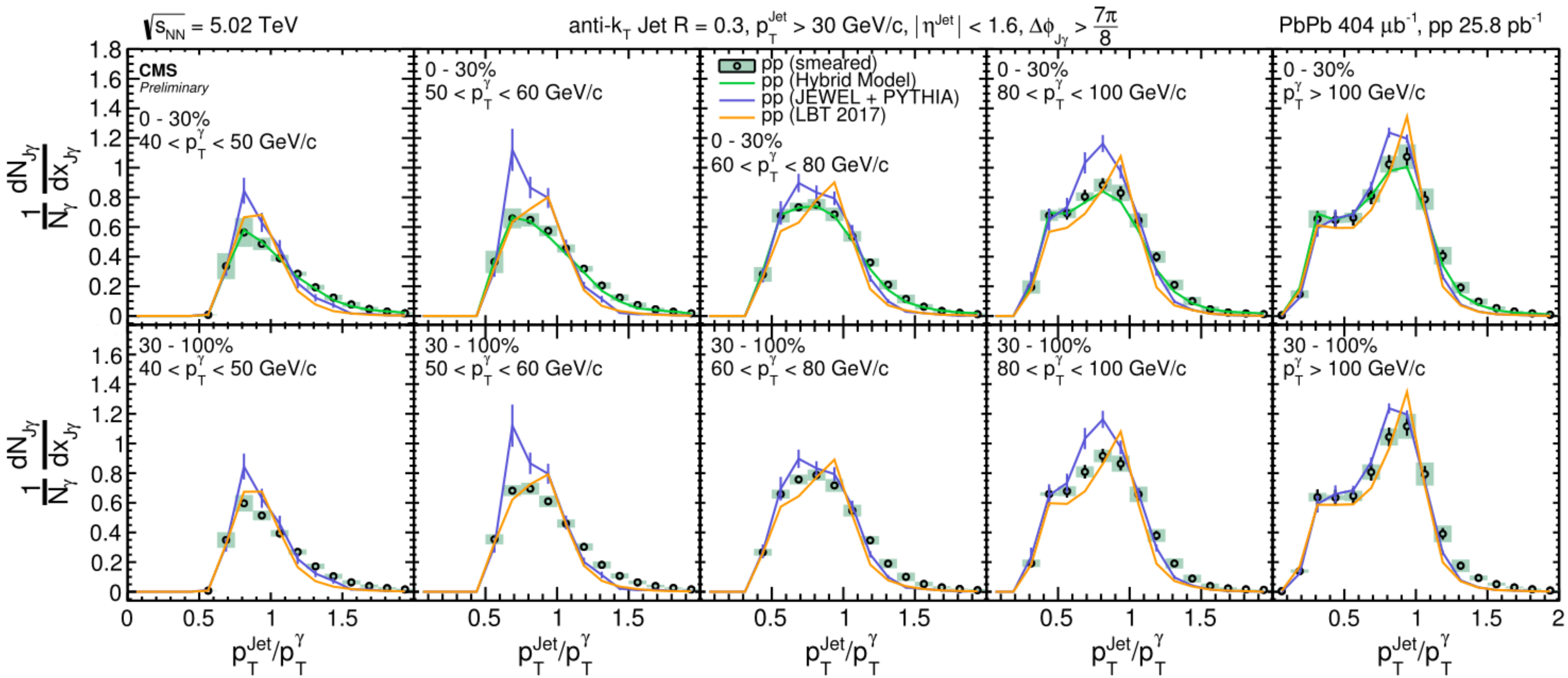
Theory comparisons – $\Delta\phi_{J\gamma}$ (pp)



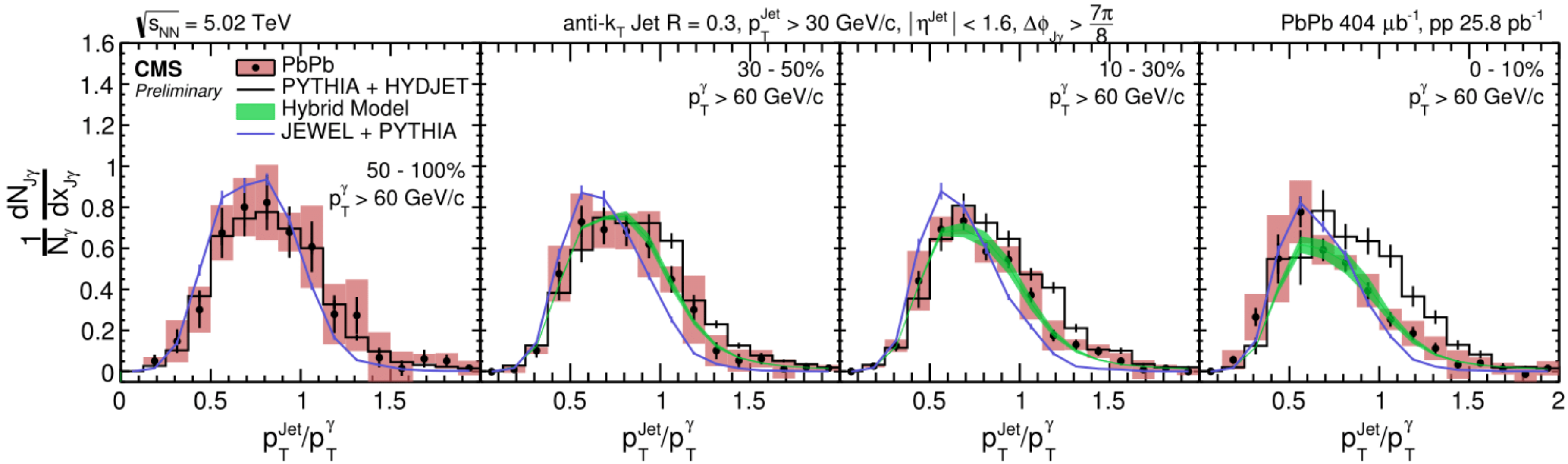
Theory comparison – x_{JZ} (pp reference)



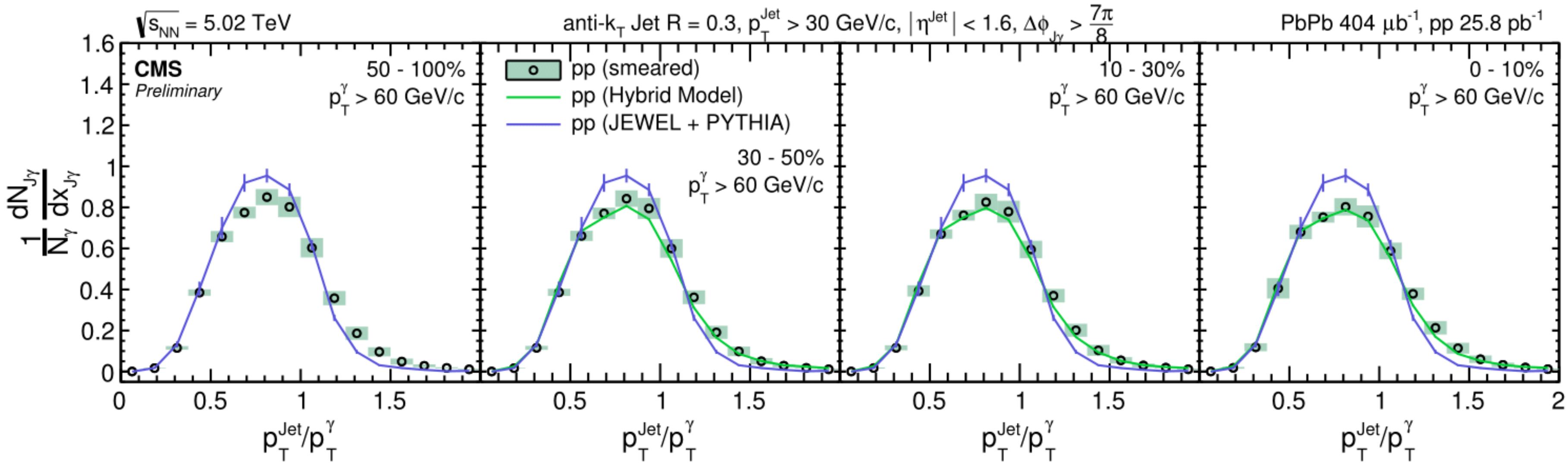
Theory comparison – $x_{J\gamma}$ (pp reference)



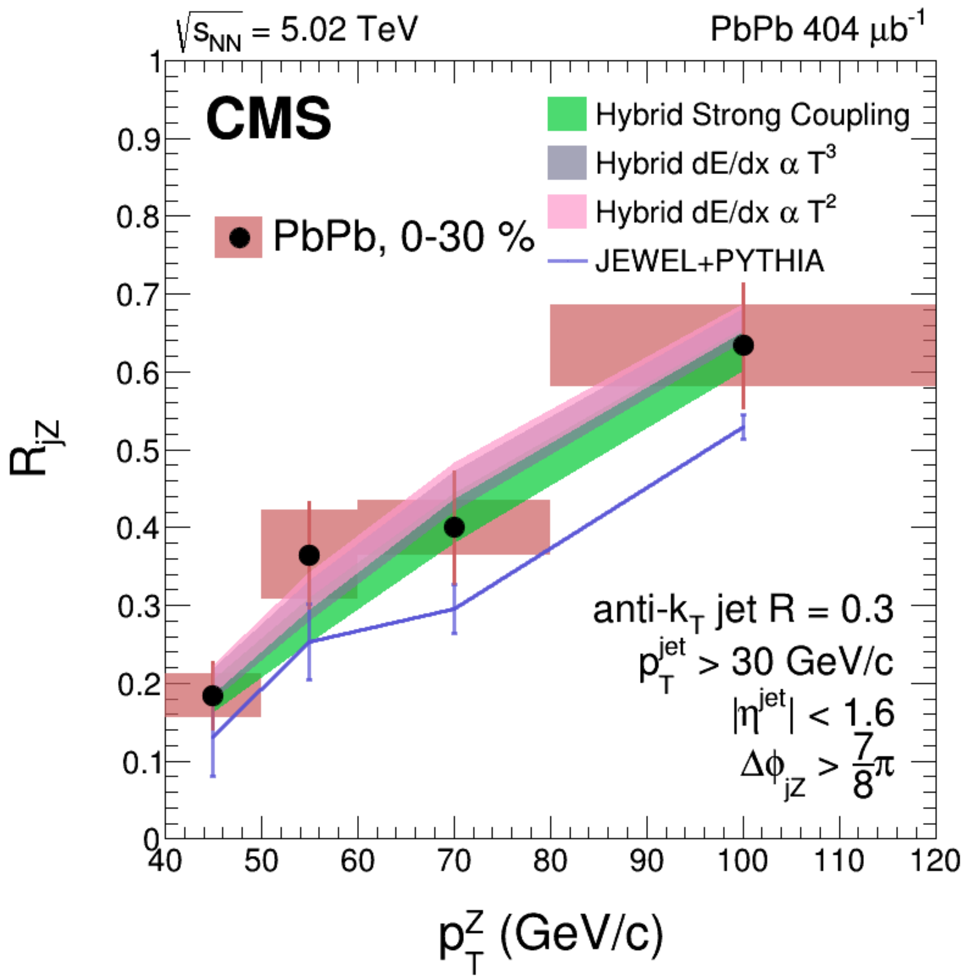
Theory comparison – $x_{J\gamma}$



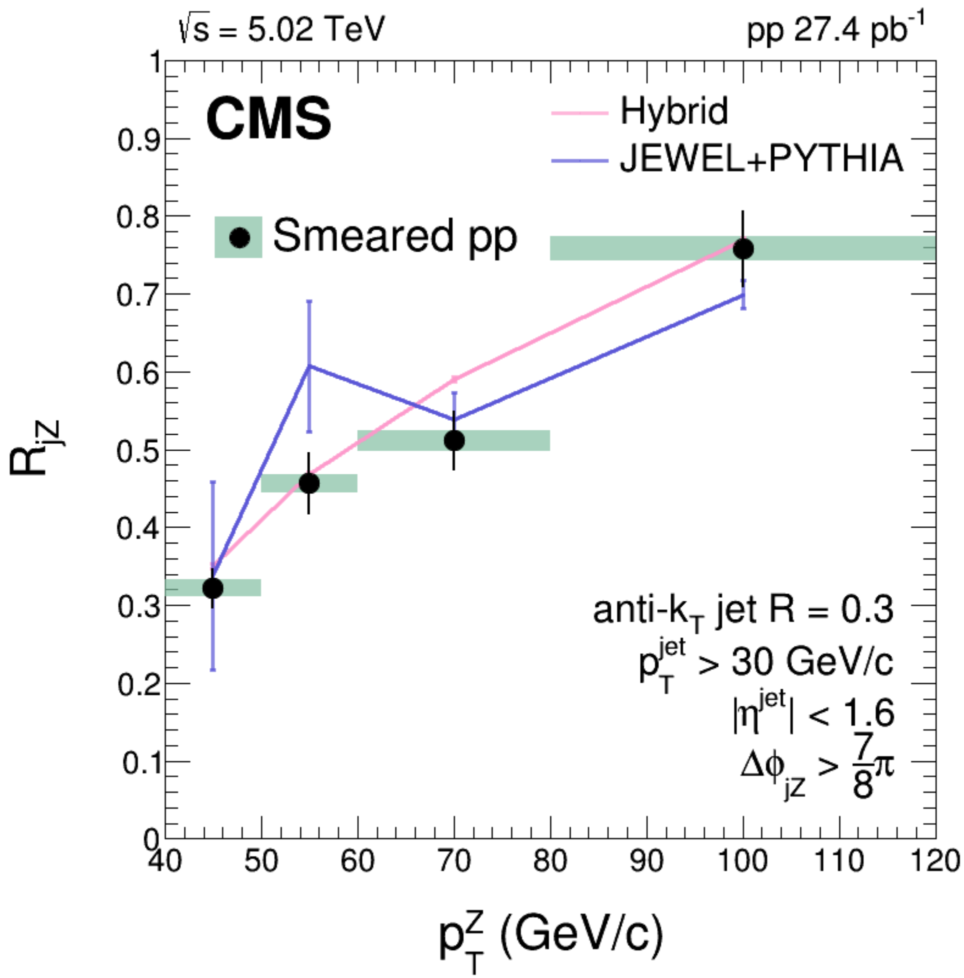
Theory comparison – $x_{J\gamma}$ (pp reference)



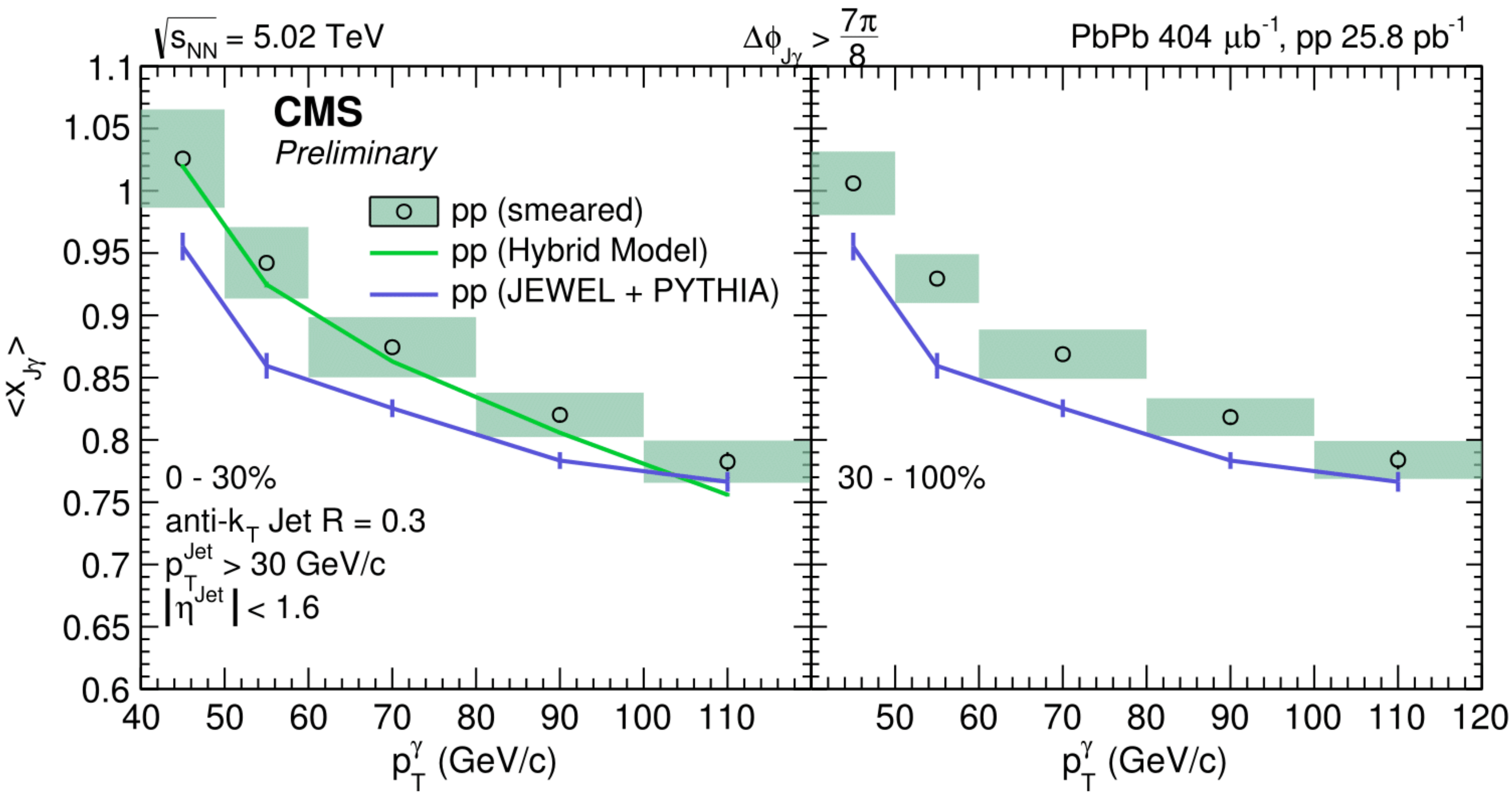
Theory comparison - R_{JZ}



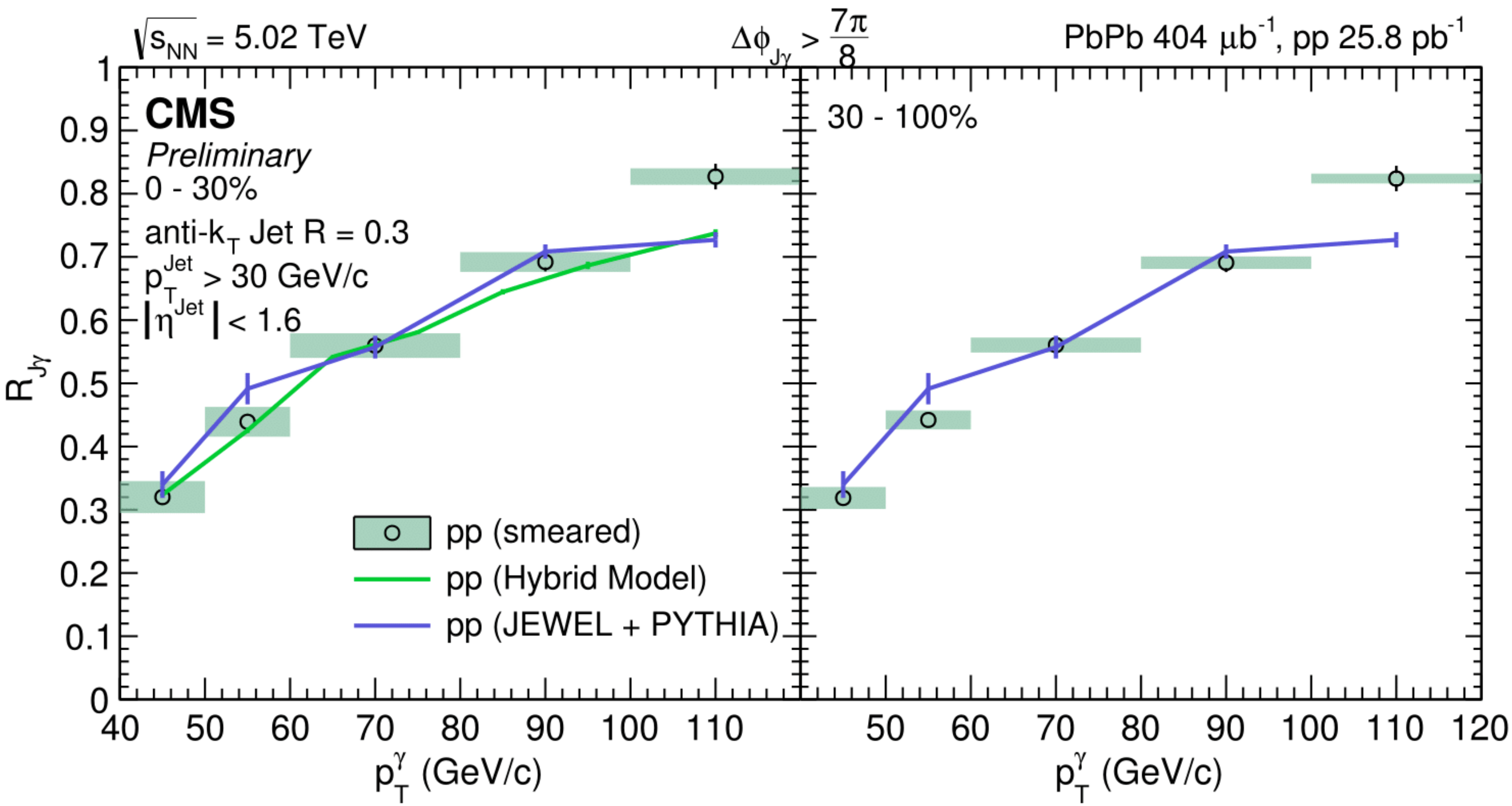
Theory comparison – R_{JZ} (pp reference)



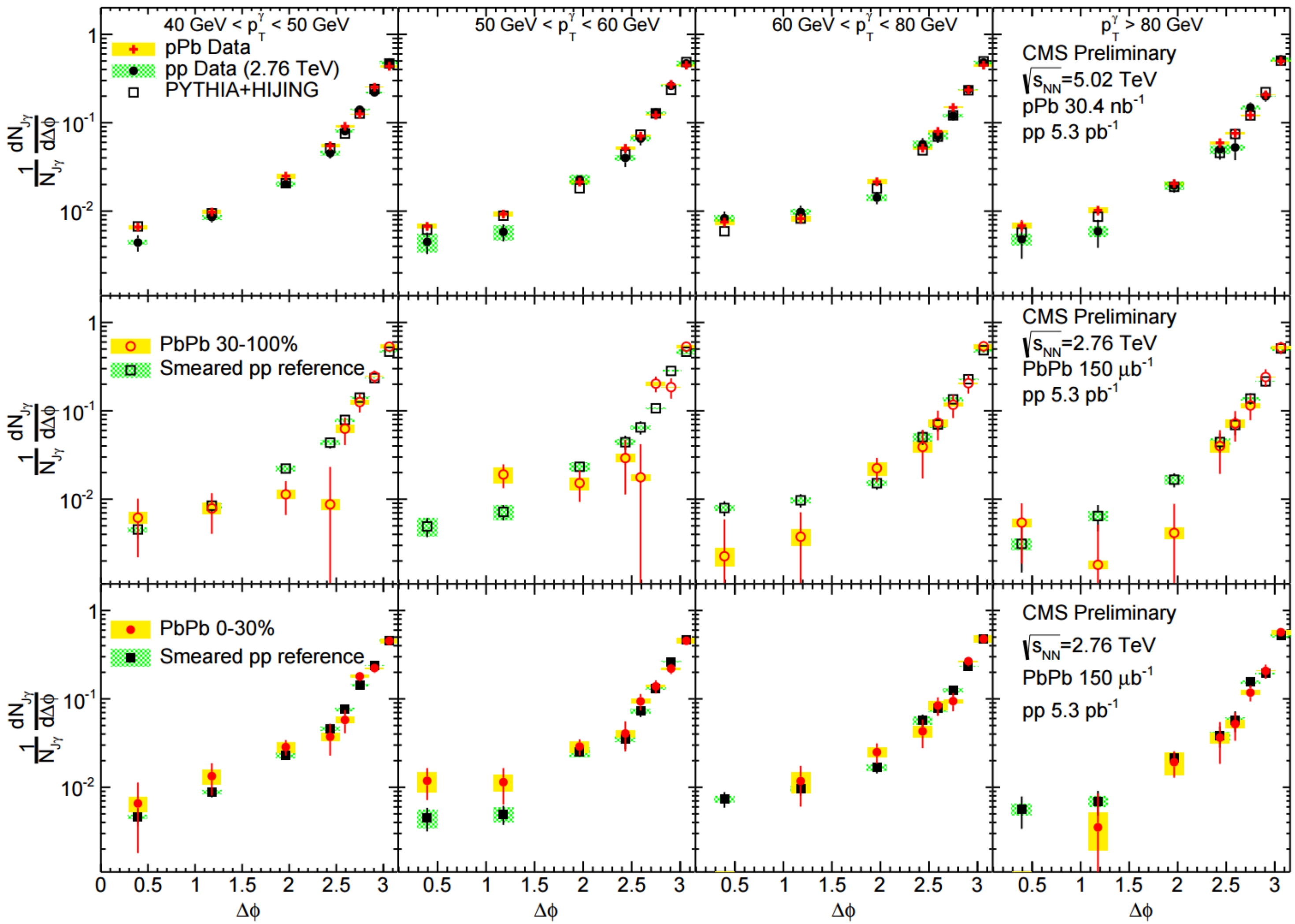
Theory comparison – <$x_{J\gamma}$> (pp reference)



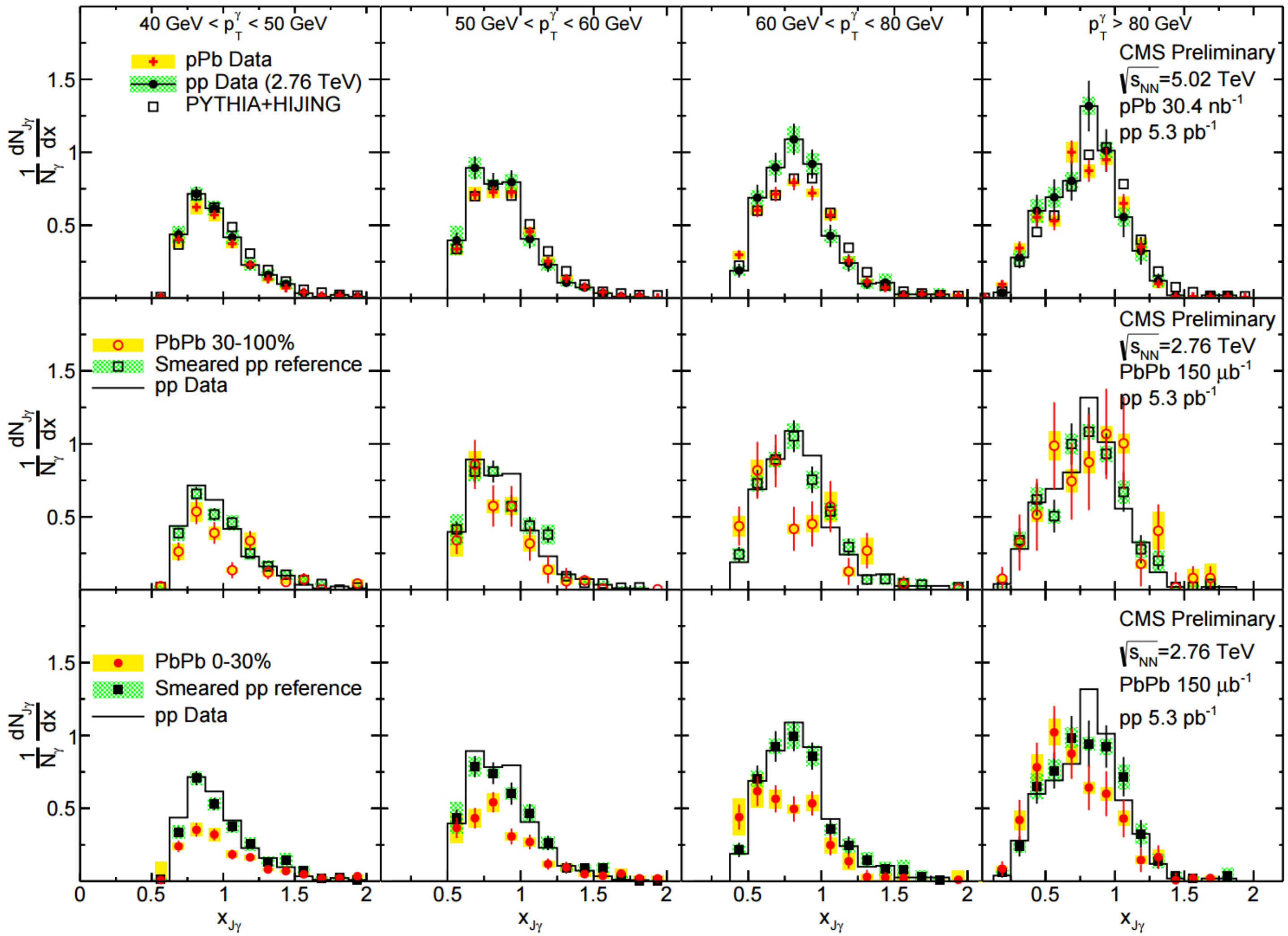
Theory comparison – $R_{J\gamma}$ (pp reference)



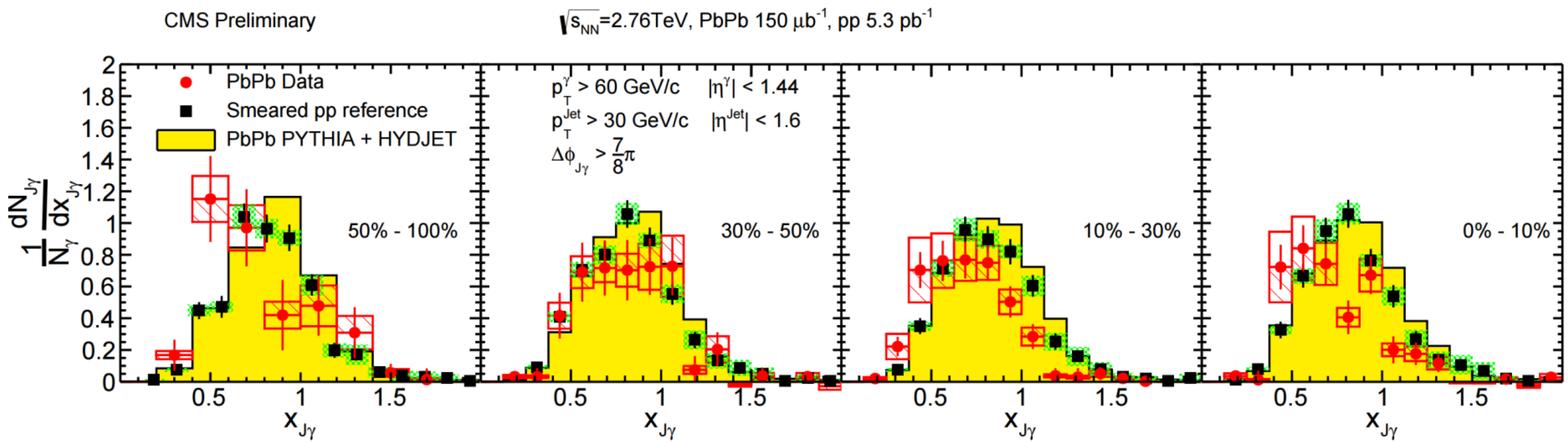
Previous results - $\Delta\phi_{J\gamma}$



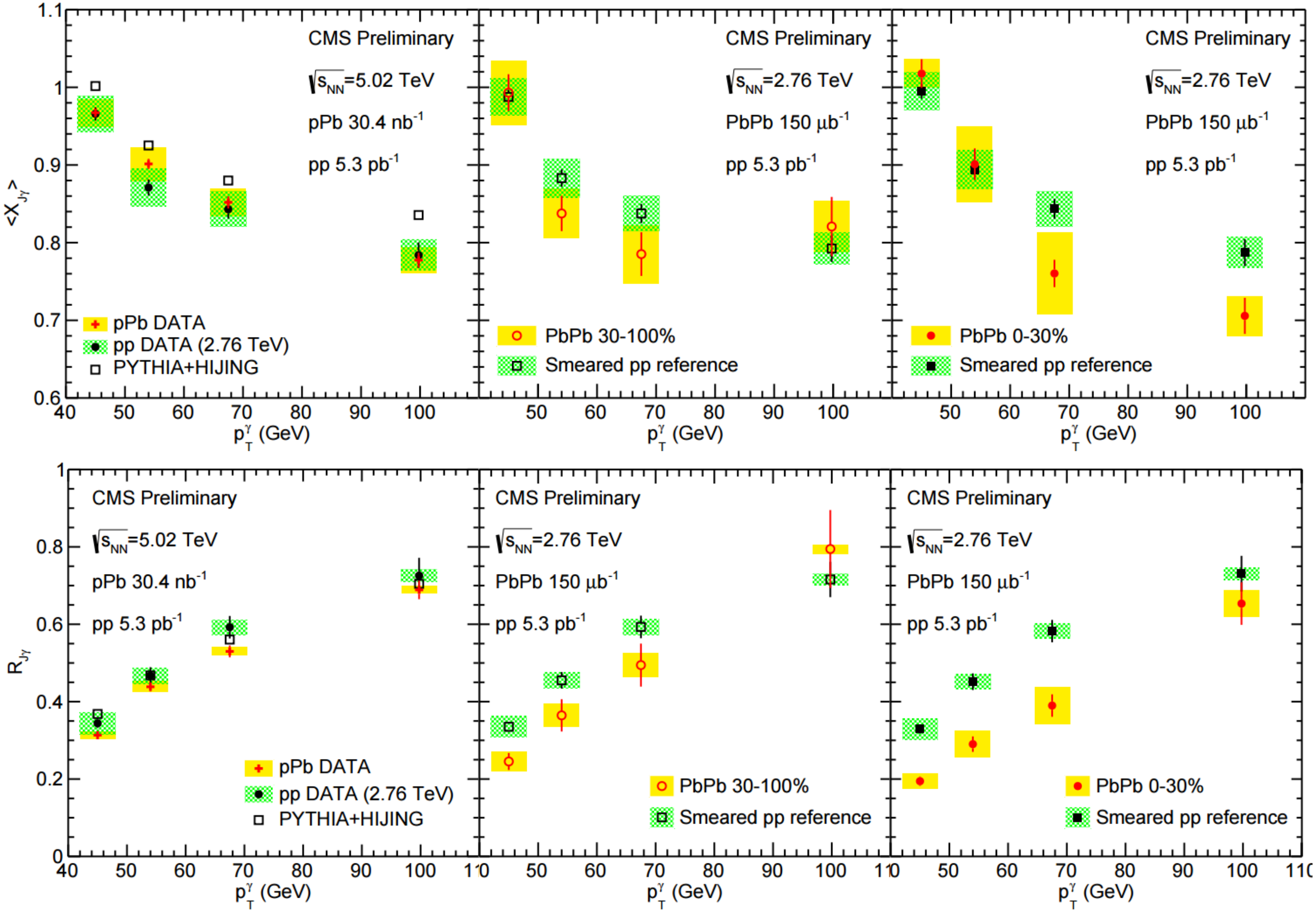
Previous results - $x_{J\gamma}$



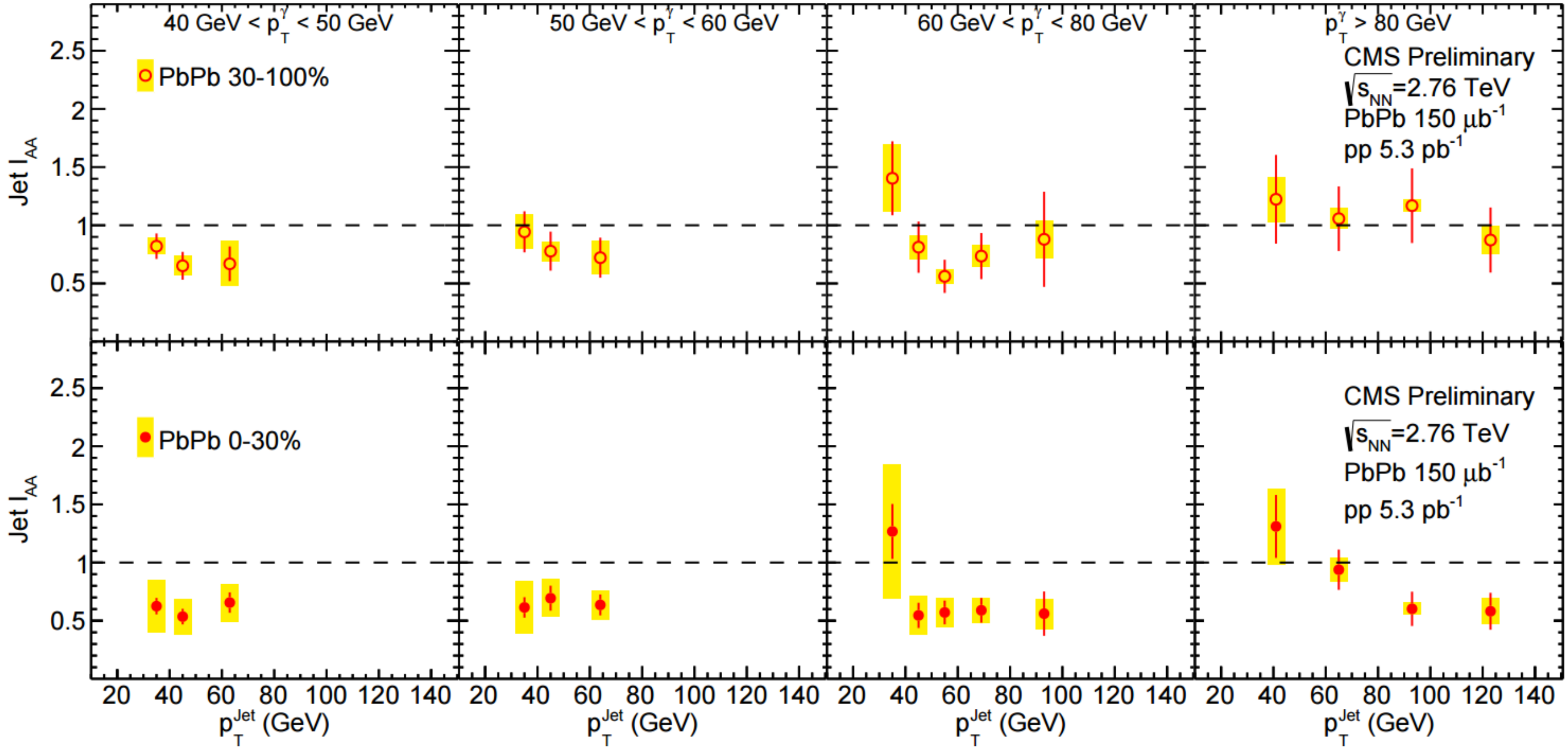
Previous results - $x_{J\gamma}$



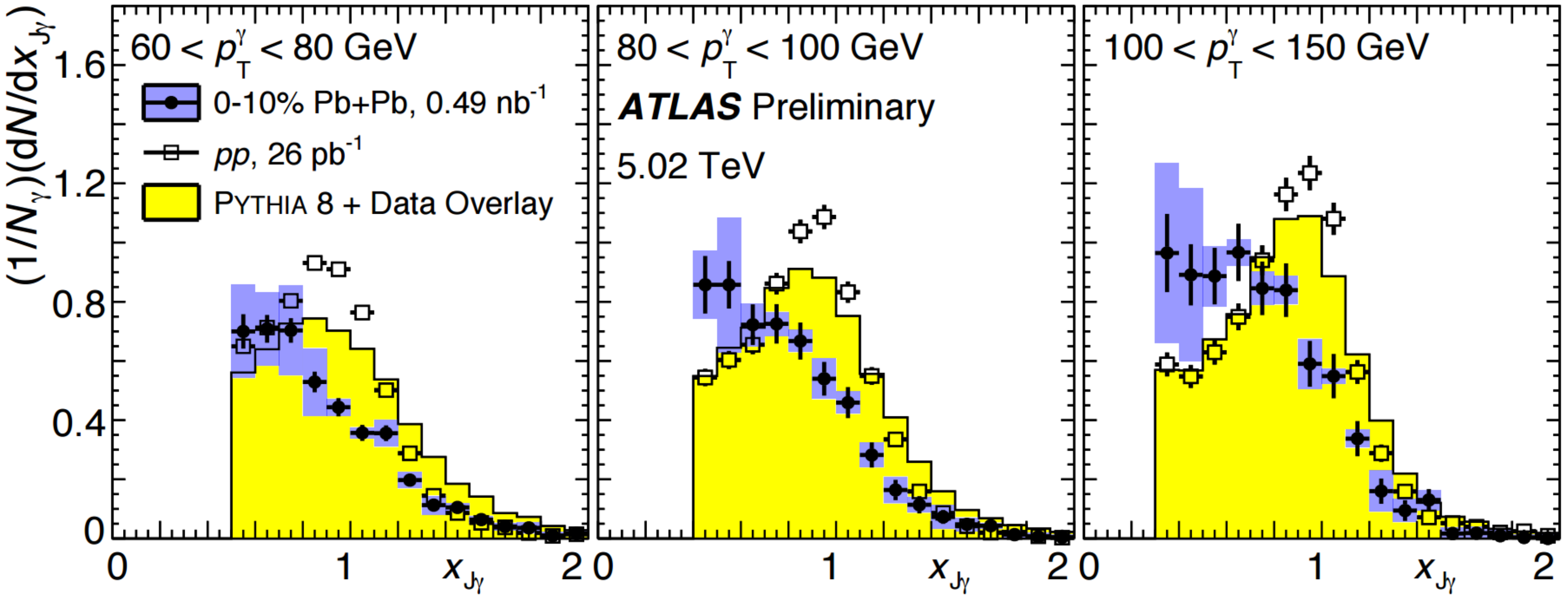
Previous results – $<x_{J\gamma}>/R_{J\gamma}$



Previous results – Jet I_{AA}



Other results – ATLAS $x_{J\gamma}$



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