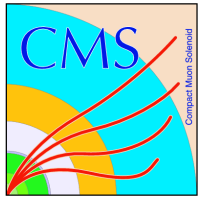
Z+Jet Correlations in pp and PbPb collisions at 5.02 TeV with CMS

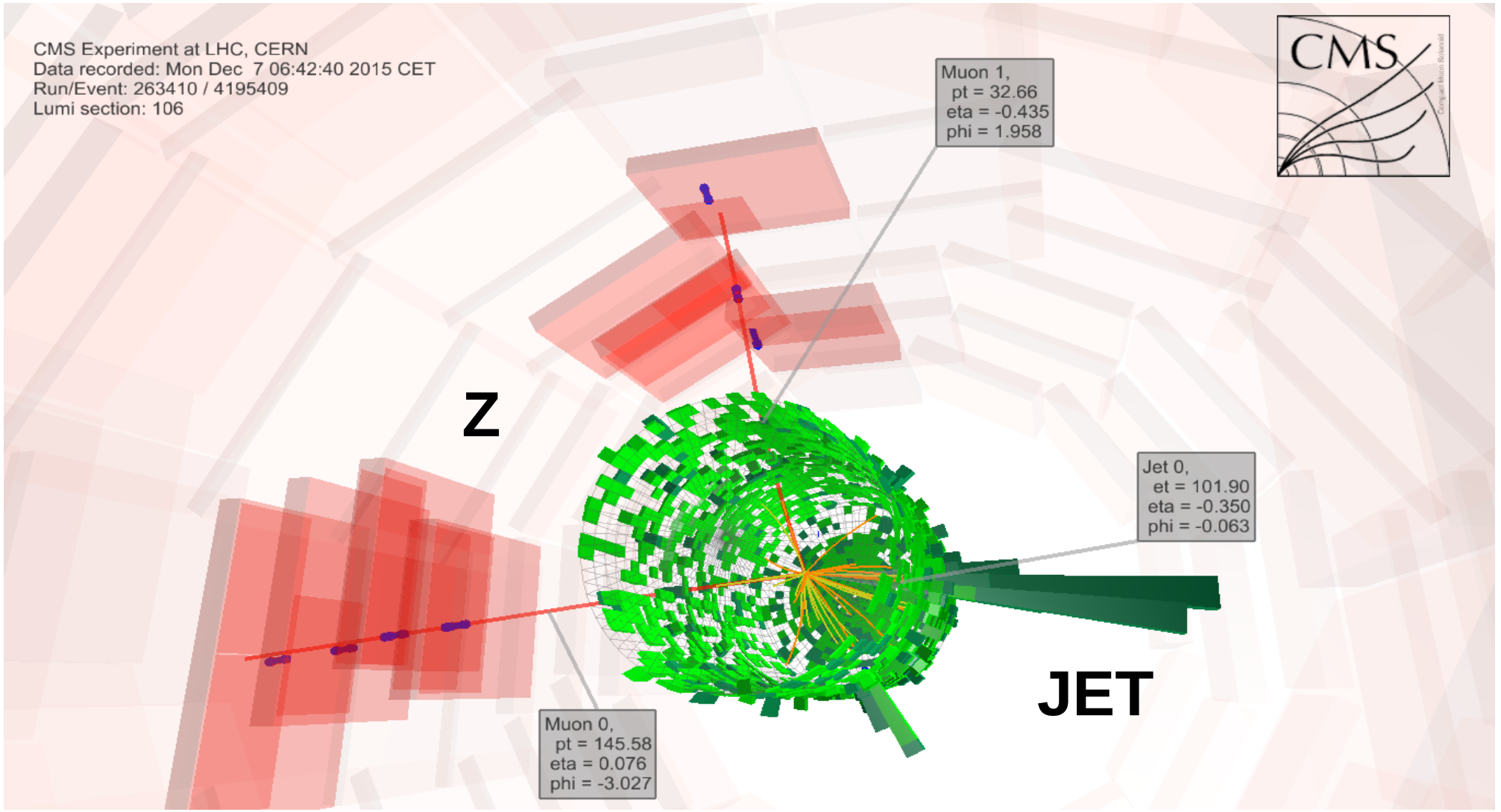


Kaya Tatar
Massachusetts Institute of Technology
for the CMS Collaboration

Hard Probes 2016, Wuhan, China
September 24, 2016

Introduction

Motivation : characterization of the jet energy loss using Z+jet pairs

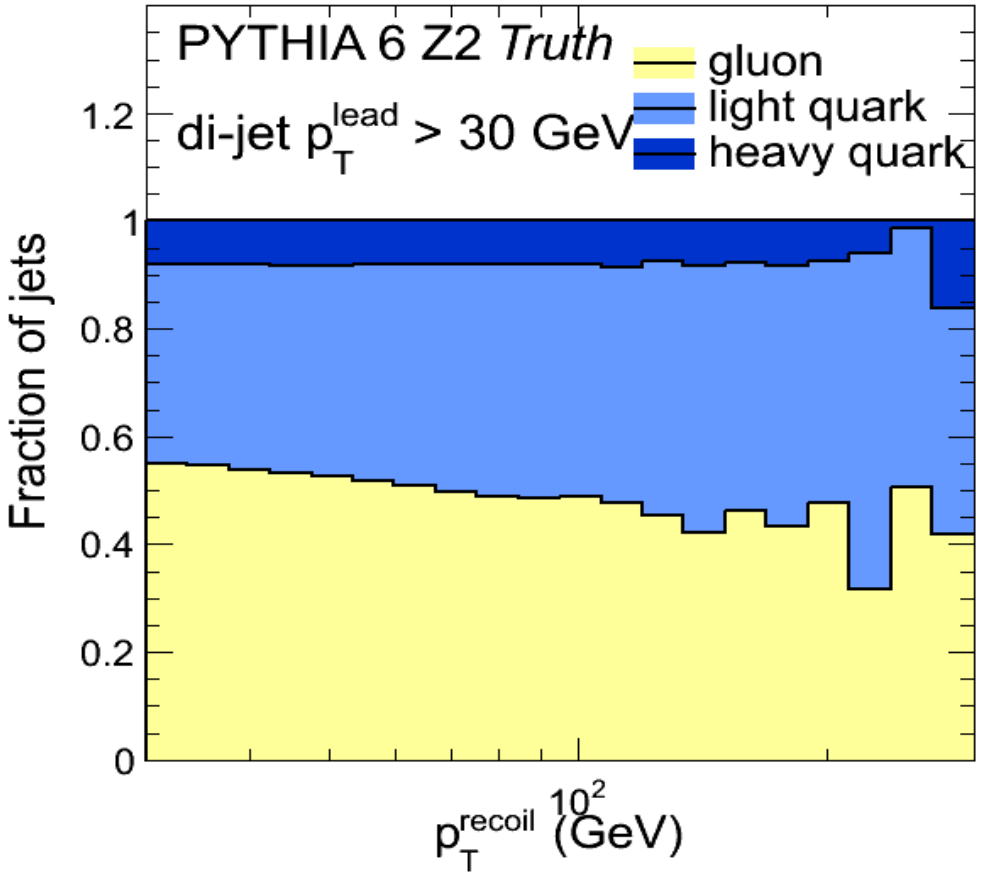


Jet energy loss - dijet

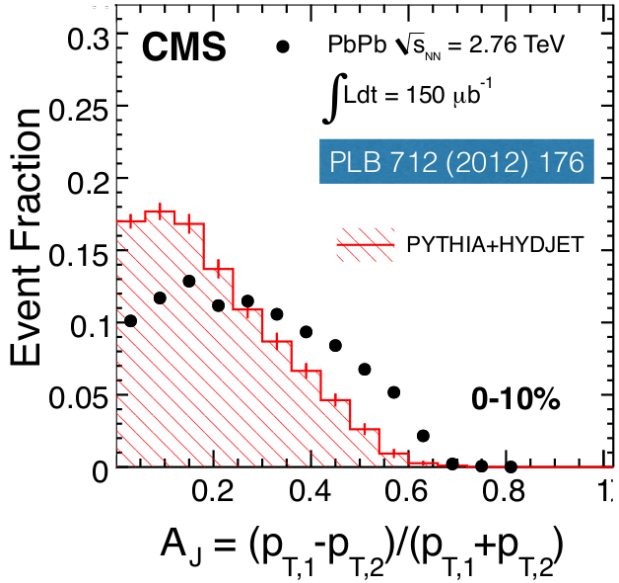
Dijet

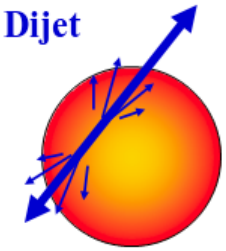
q/g interact with the medium

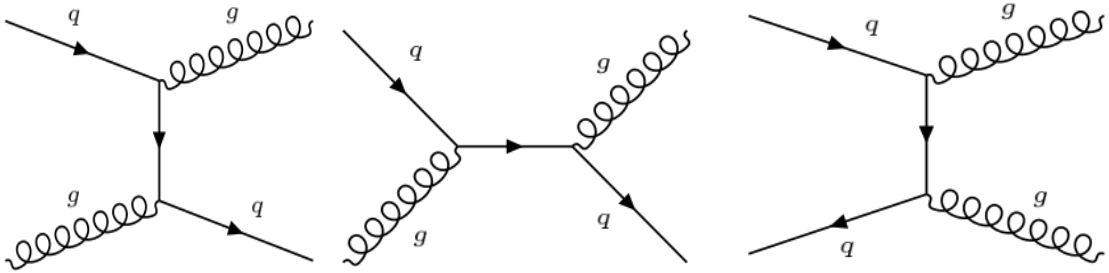
Study only relative energy loss



PLB 712 (2012) 176







Jet energy loss - photon+jet

Photon+jet

γ : No strong interaction

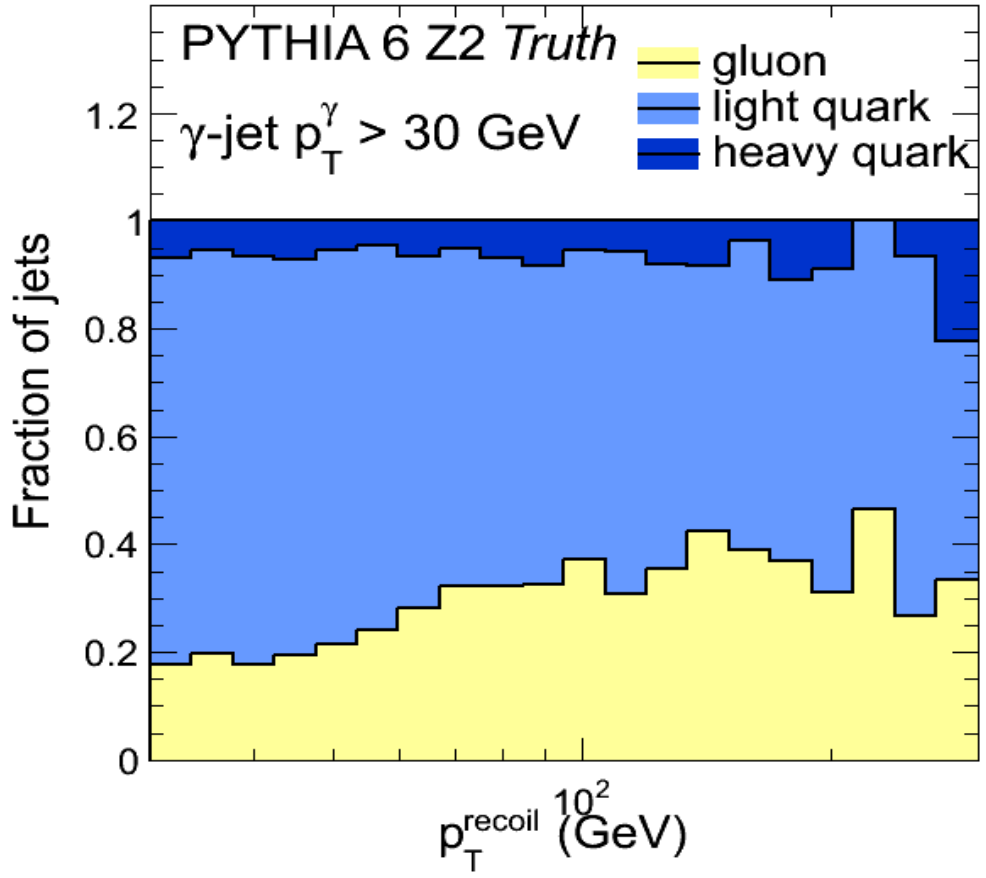
Clean probe

Higher quark jet fraction

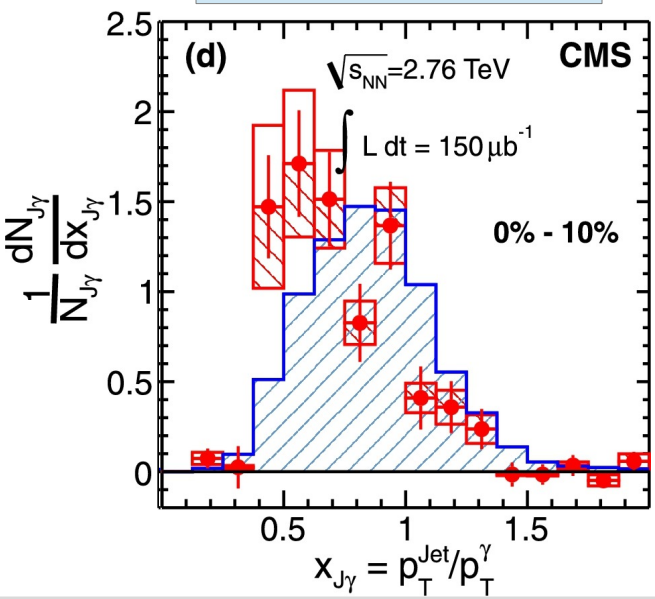
Background

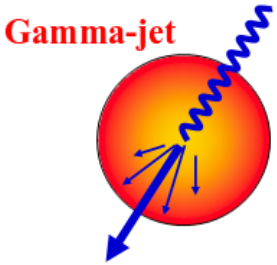
Jet fragmentation

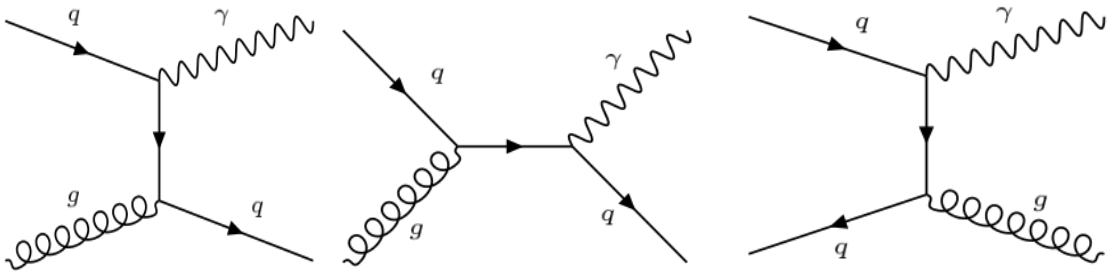
Neutral meson decay



PLB 718 (2013) 773







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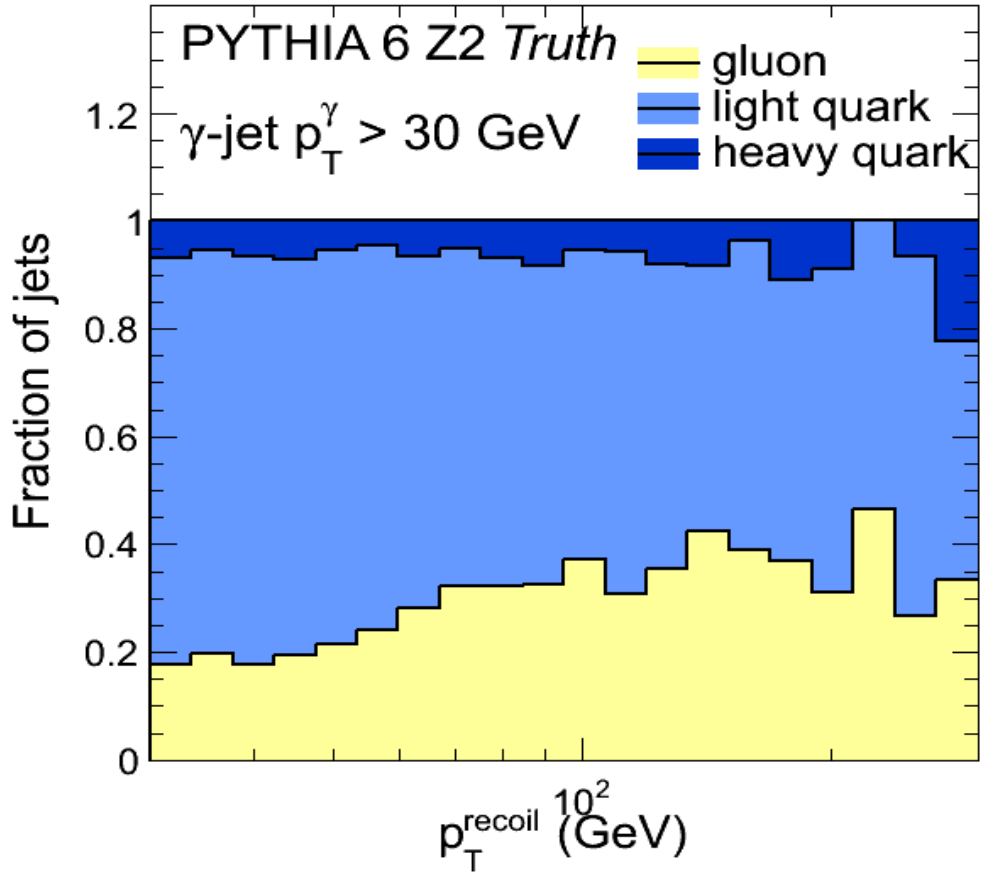
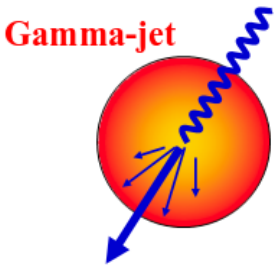
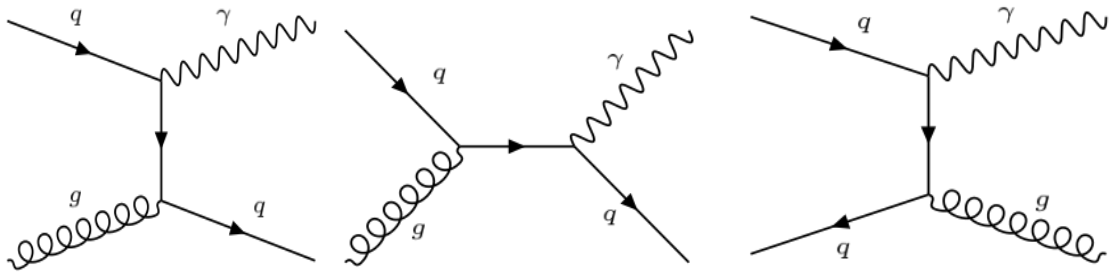


Latest photon+jet results,
Chris McGinn's talk in the next session :
"Photon-Jet Correlations in pp and PbPb collisions at 5.02 TeV with CMS"

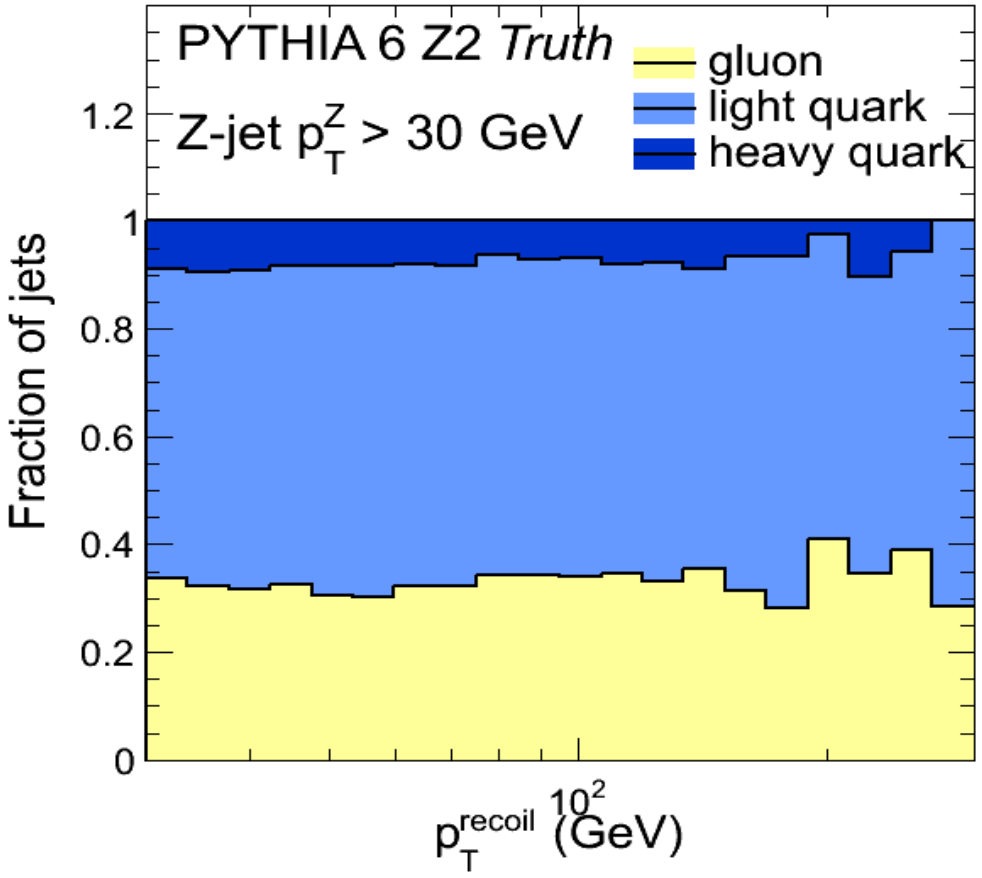


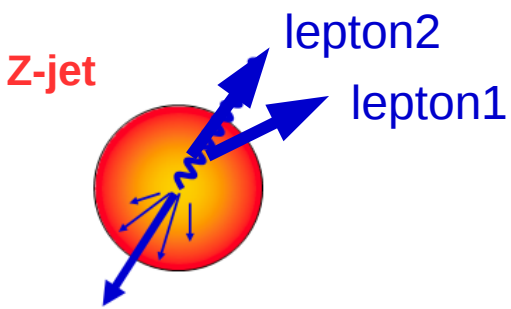


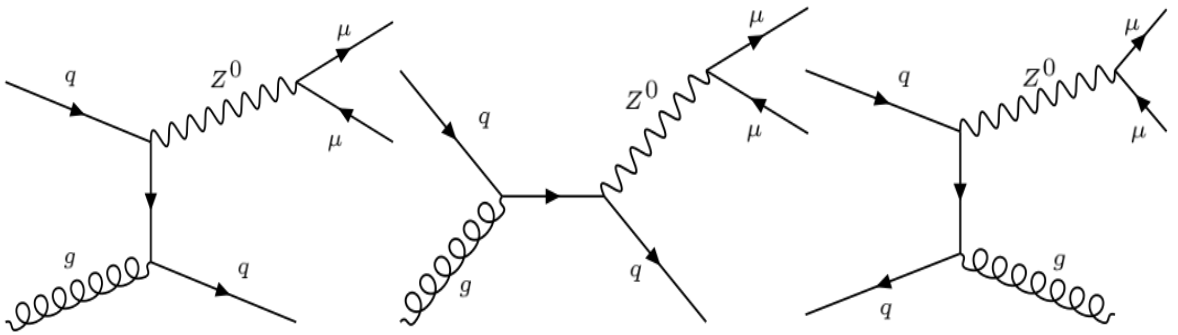
Jet energy loss - Z+jet

Z+jet

- **Z - > ll :** No strong interaction
- Clean probe
- Higher quark jet fraction
- **NO** Background
- **Low** production cross-section







Jet energy loss - Z+jet

Z+jet

Z - > ll : No strong interaction

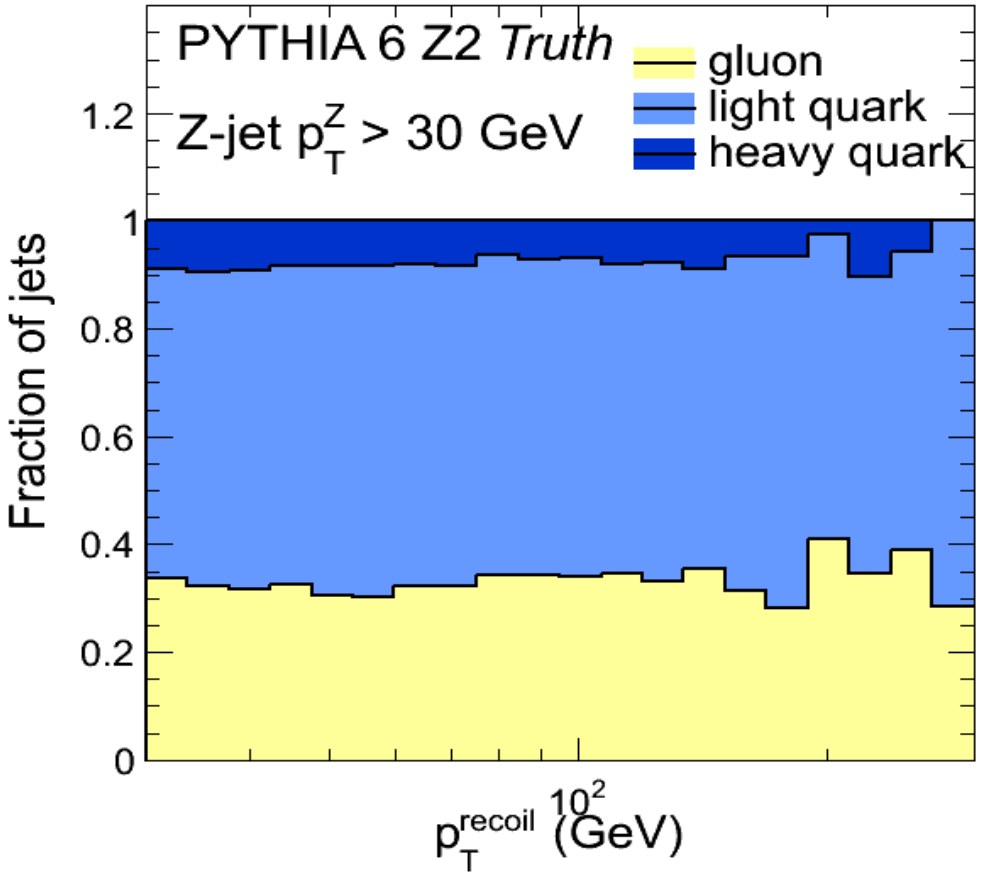
Clean probe

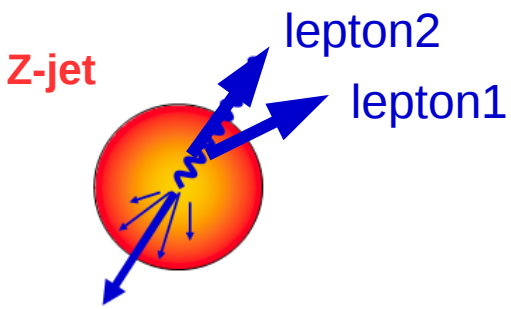
Higher quark jet fraction

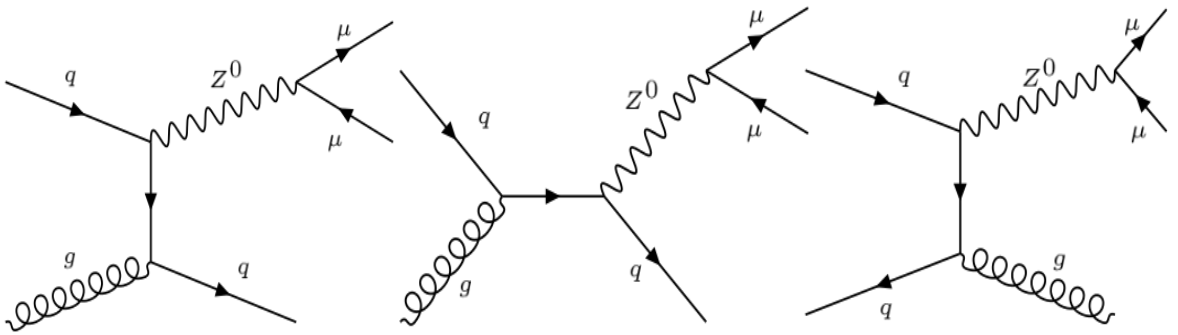
NO Background

Low production cross-section

Possible with the high statistics PbPb and pp data at sqrt(s) = 5.02 TeV







Analysis : Z+jet

- Data used in Z+jet analysis:

  2015 PbPb data at 5.02 TeV, 404 μb^{-1}

  focus on 0-30 % centrality

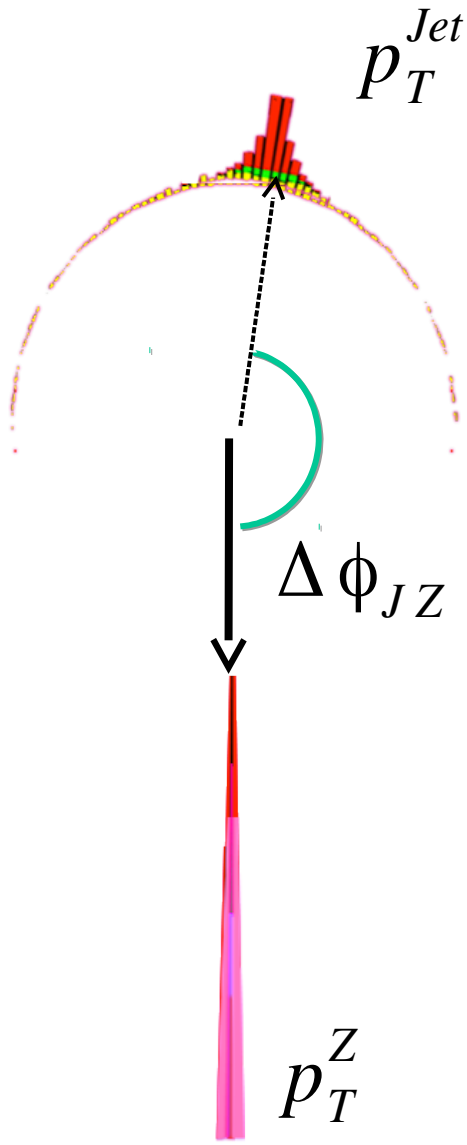
  2015 pp data at 5.02 TeV, 25.8 pb^{-1}

- Analysis steps :

  1. Select electron and muon triggered data
  2. Reconstruct Z bosons, reconstruct jets
     - Smear jet spectra in pp
  3. Make Z+jet pairs
     - Background subtraction (for PbPb only)
  4. Combine Z+jet pairs from muon and electron channels

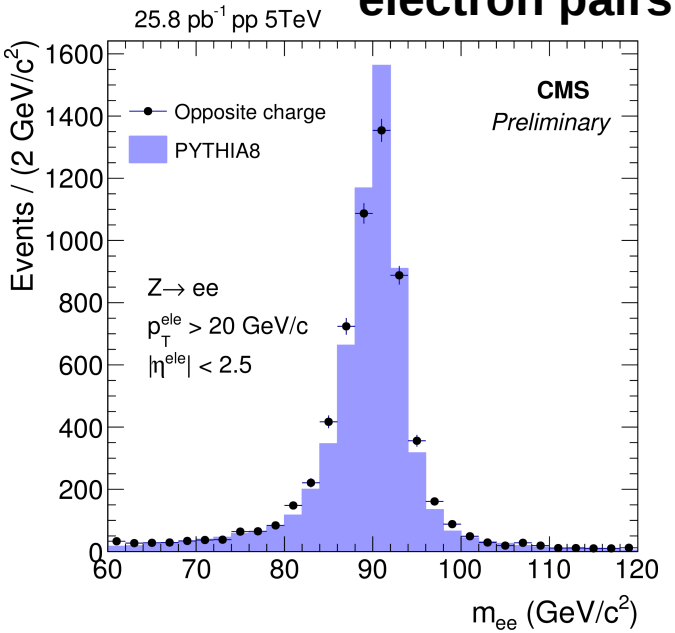
  Final plots :

  Distributions are normalized by number of Z events.

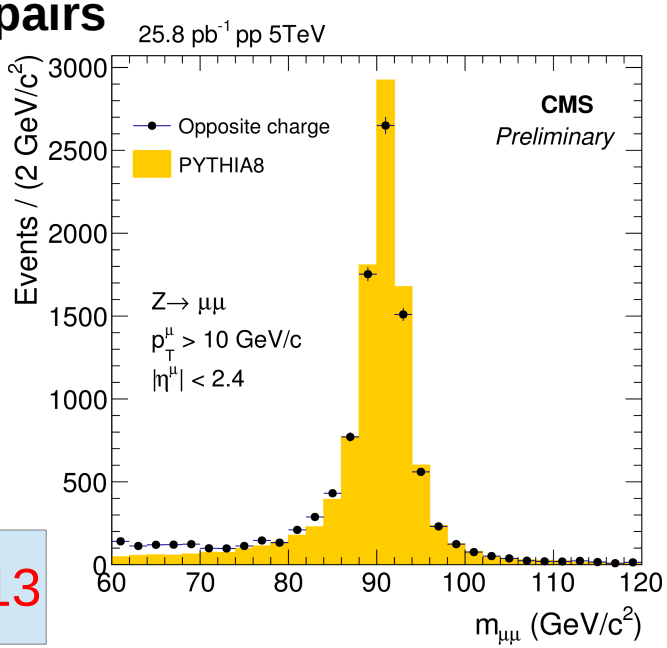


Z Boson reconstruction

electron pairs



muon pairs



pp

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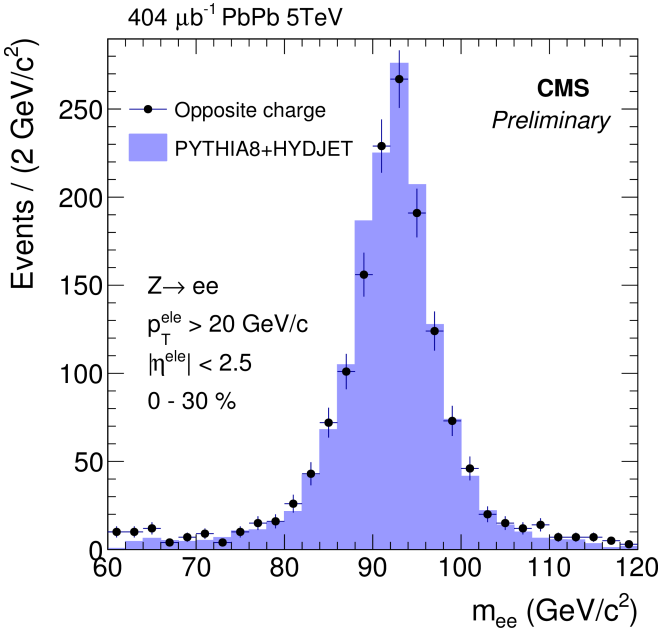
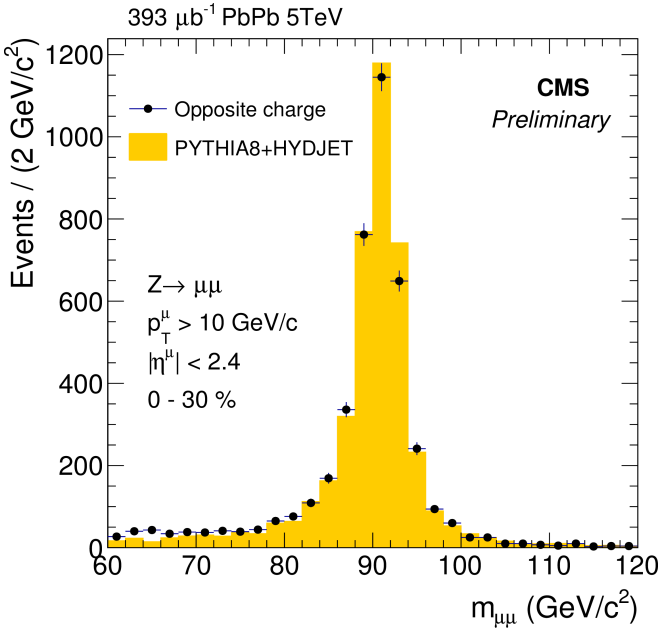
PbPb





Smearing jet spectra

- **Jet energy resolution** and **jet angular resolution** differ between pp and PbPb due to underlying event, so

  Estimate relative resolution between pp and PbPb using simulations

  Smear jet spectra in pp using this relative resolution

- Smearing **jet energy**

  Parametrize jet energy resolution via

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

  Fit C, S and N parameters and apply relative resolution via

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

- Smearing **jet azimuthal angle**

  Use same parametrization as in jet energy resolution $\sigma\left(|\phi^{RECO}-\phi^{GEN}|\right)=\sqrt{C^2+\frac{S^2}{p_T^{GEN}}+\frac{N^2}{(p_T^{GEN})^2}}$

  Apply relative resolution in the same fashion

Kinematics

Z Bosons

- electron channel : $p_T^e > 20$ GeV/c², $|\eta^e| < 2.5$
- muon channel : $p_T^\mu > 10$ GeV/c², $|\eta^\mu| < 2.4$
- opposite charge pairs
- $p_T^Z > 60$ GeV/c (for $\Delta\varphi_{JZ}$ and x_{JZ} distributions)
- $70 < M_Z < 110$ GeV/c² ==> 232 Z boson events in PbPb
  673 Z boson events in pp

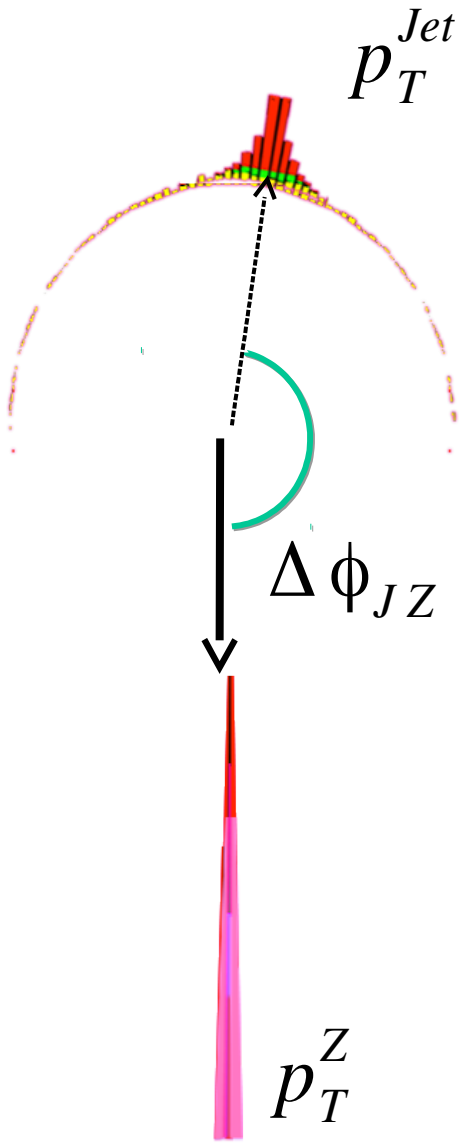
Jets

- Anti-k_T jets, R=0.3
- $p_T^{Jet} > 30$ GeV/c
- $|\eta^{Jet}| < 1.6$

Z+jet pairs

- **All** jets which meet the given kinematics are included, **not just leading**.

  Apply MinBias event mixing to subtract background (PbPb only)



Background Subtraction

Background source : Jets from underlying event

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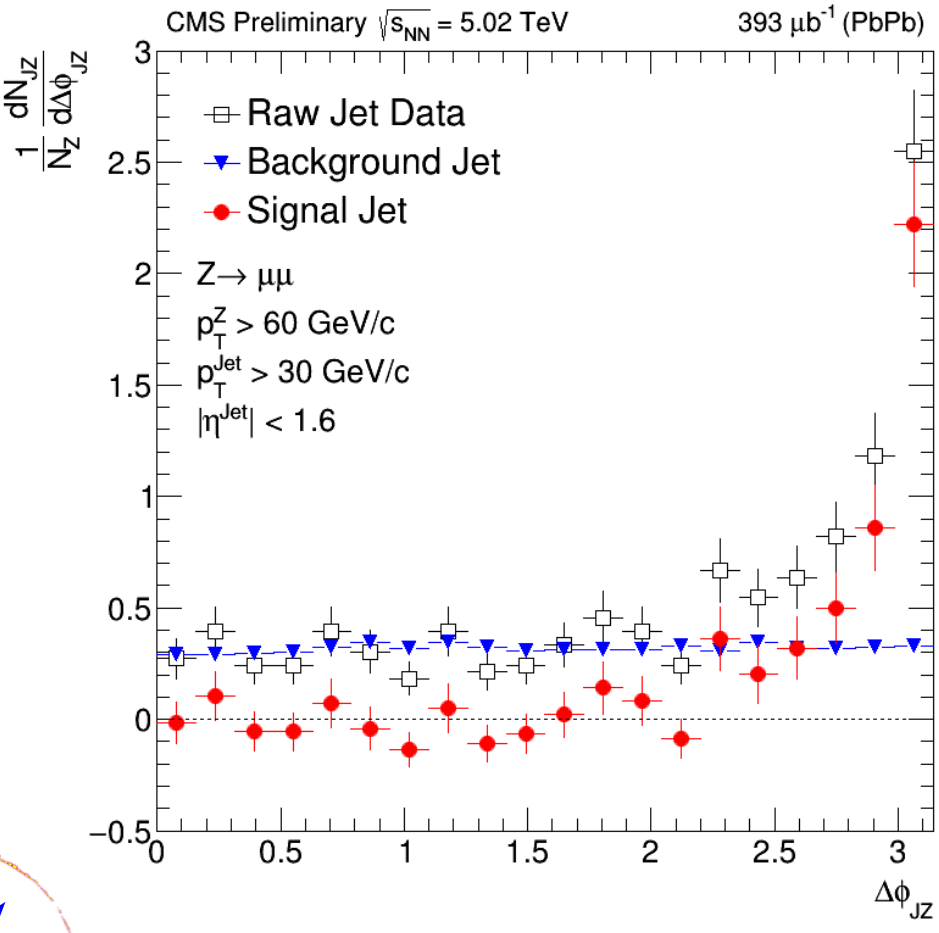
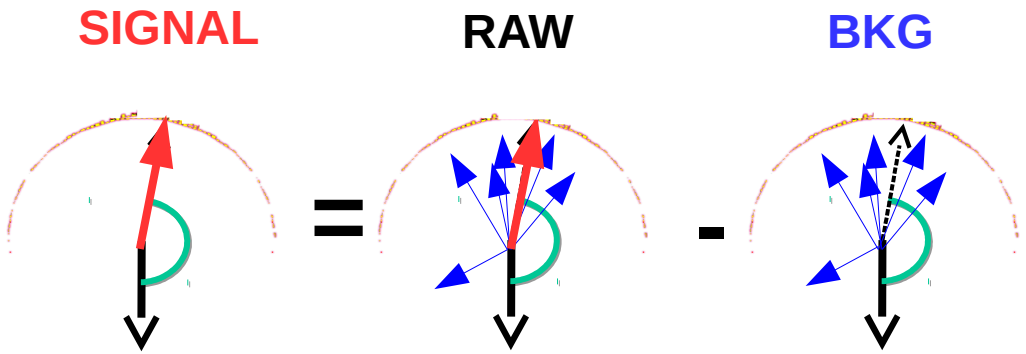
Subtraction method :

Minimum bias event mixing technique

- Background contribution is by definition not correlated to the Z boson
- Estimate this contribution by correlating the Z boson to jets from matching minbias events





Azimuthal Correlation

Azimuthal correlation

Deflection of jet ?

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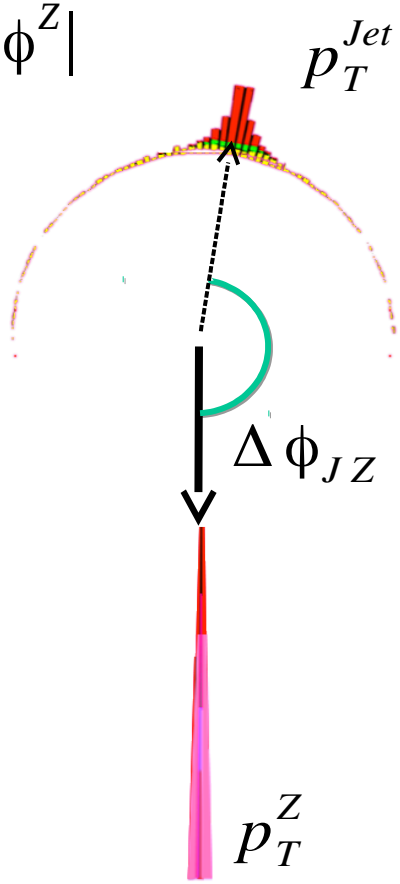
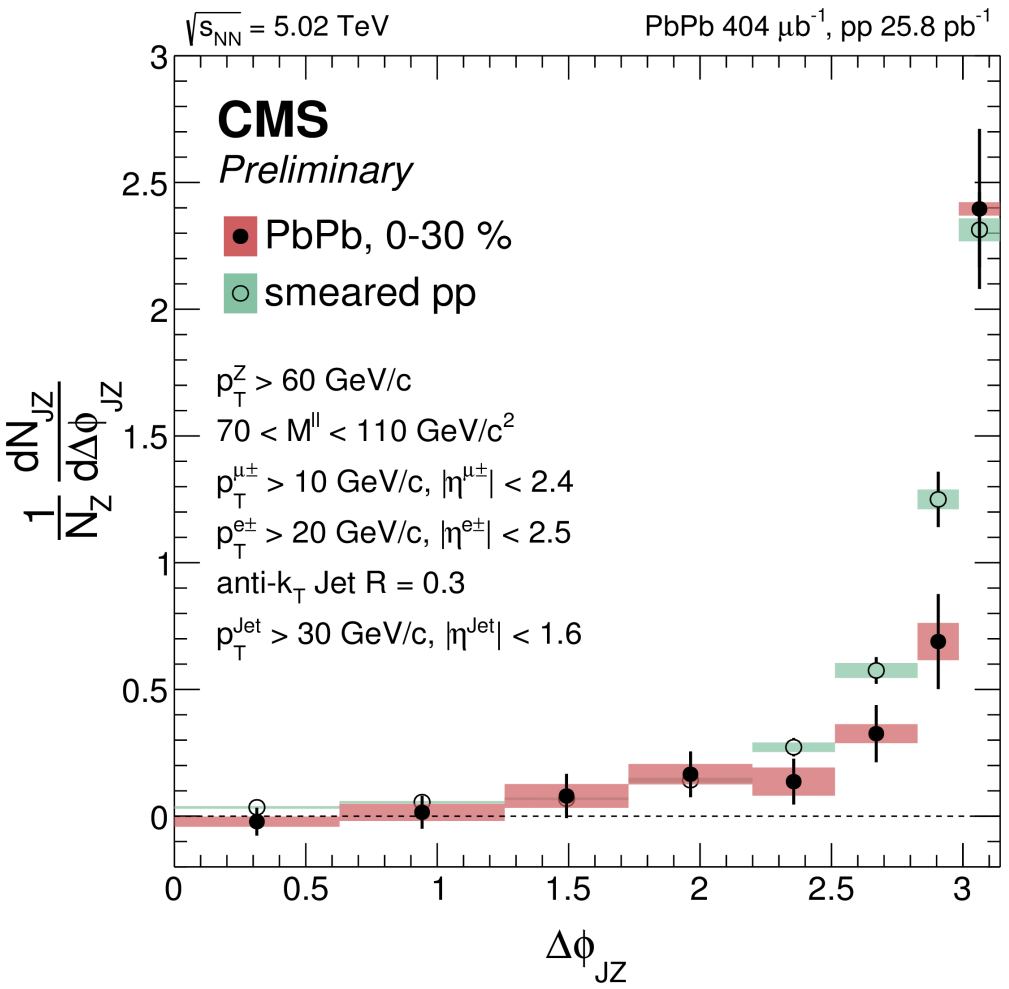
$$\Delta\phi_{JZ} = |\phi^{Jet} - \phi^{Z}|$$





Similar shape in general.

0-30% PbPb has slightly narrower shape at large $\Delta\varphi_{JZ}$.

Transverse Momentum Imbalance

Transverse momentum imbalance

energy loss ?

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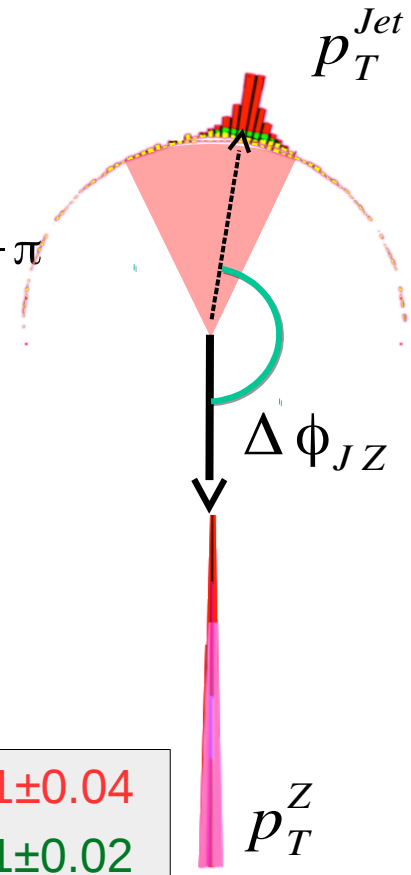
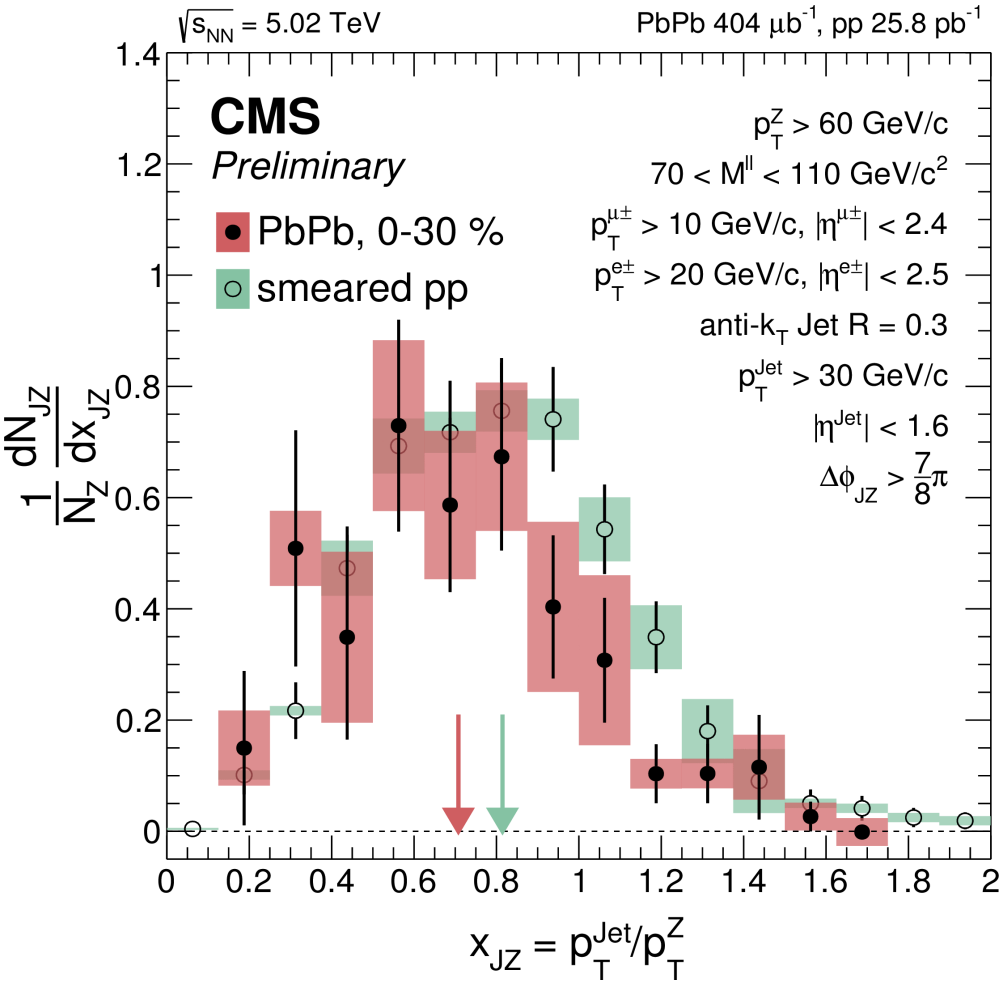
$$x_{JZ} = \frac{p_T^{Jet}}{p_T^Z}$$

$$\Delta\phi_{JZ} > \frac{7}{8}\pi$$





PbPb, 0-30% : $\langle x_{JZ} \rangle = 0.71 \pm 0.04$

pp : $\langle x_{JZ} \rangle = 0.81 \pm 0.02$

x_{JZ} in 0-30% PbPb shifts to lower values wrt. pp.

Mean Value of Momentum Imbalance

$\langle x_{JZ} \rangle$: Mean value of transverse momentum imbalance

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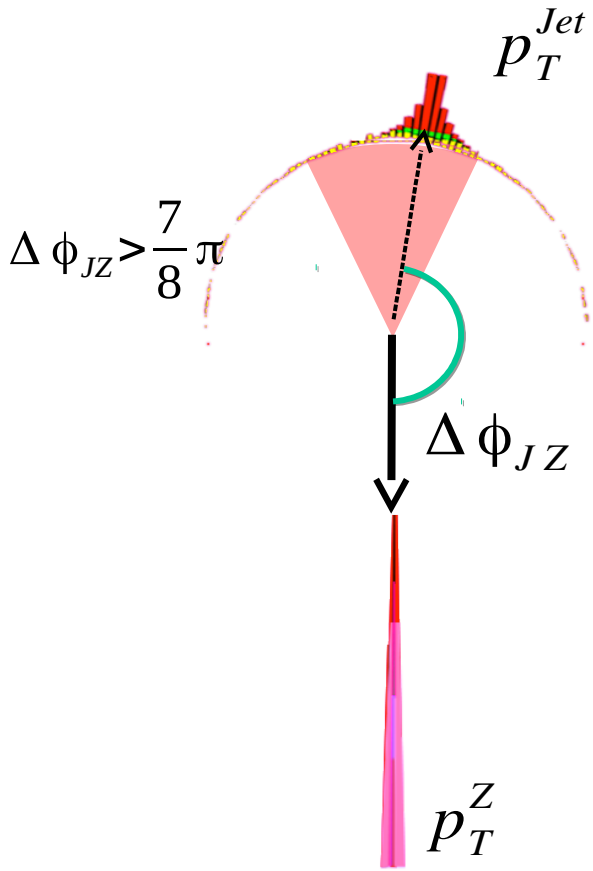

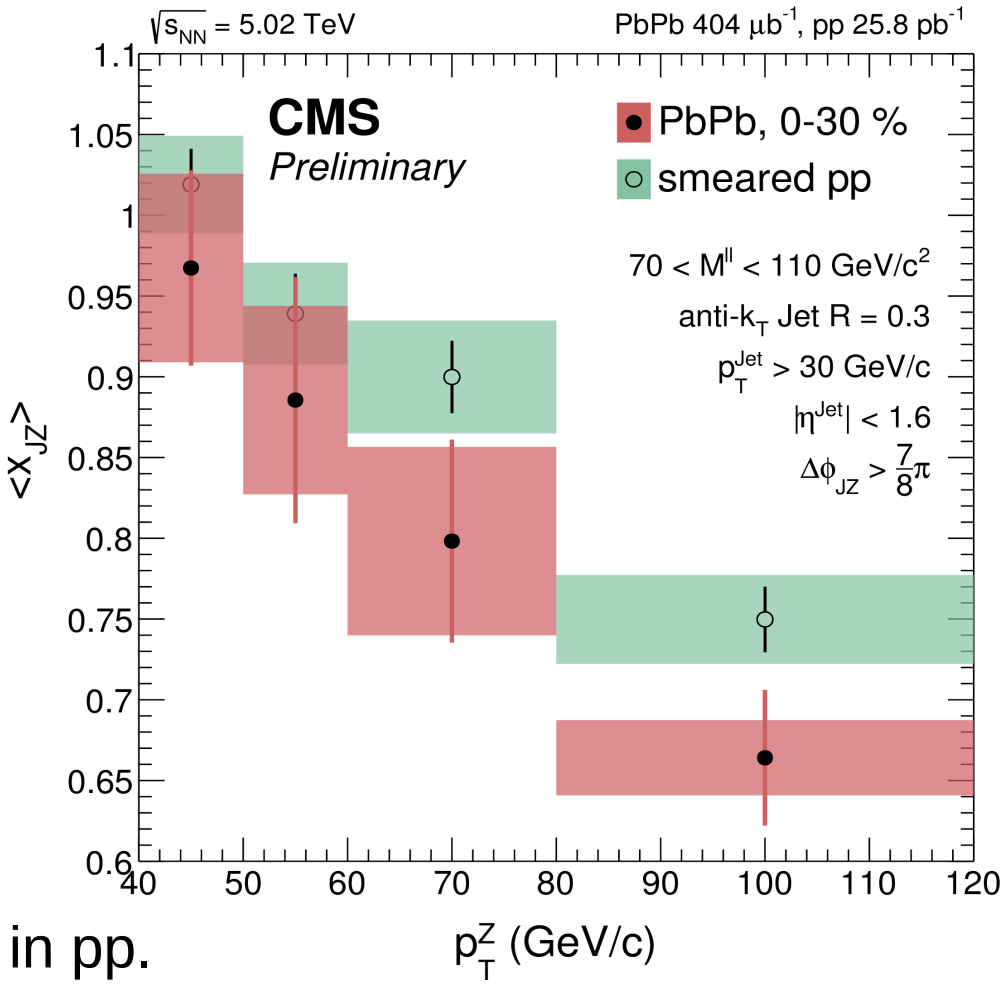

$\langle x_{JZ} \rangle$ in 0-30% PbPb is smaller than in pp.

[80+] GeV/c bin : lower by 12%.

Average Number of Jets per Z Boson

R_{JZ} : Average number of jets per Z boson

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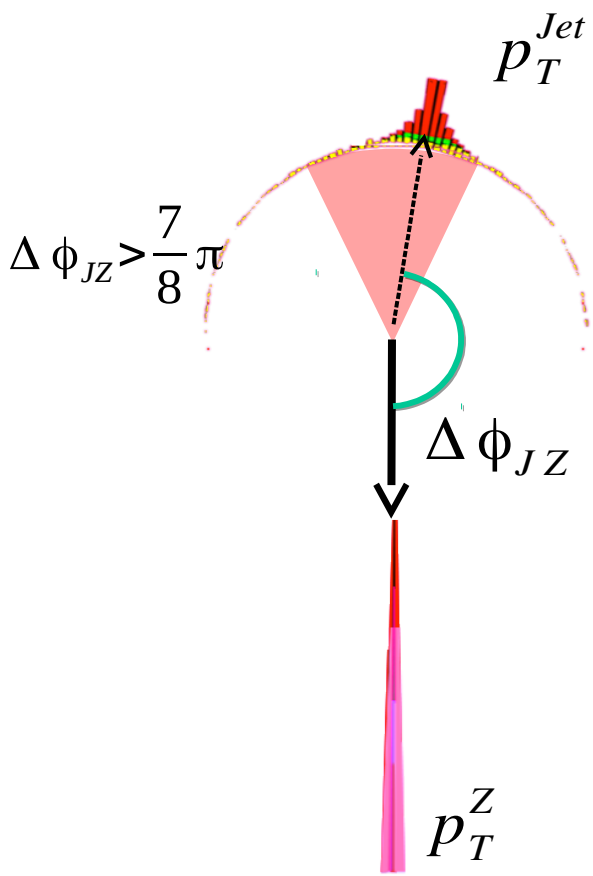

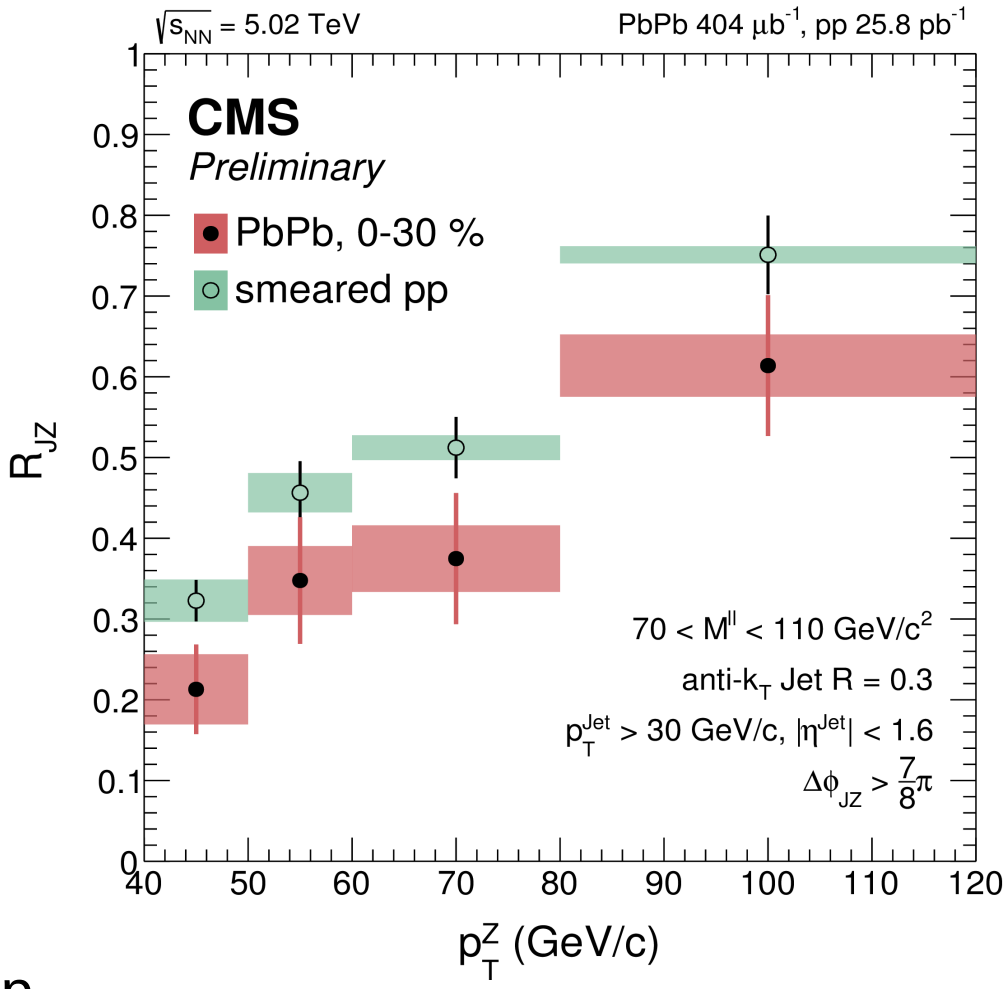

R_{JZ} in 0-30% PbPb is lower than in pp.

[80+] GeV/c bin : lower by 19%.

Comparison with photon+jet results

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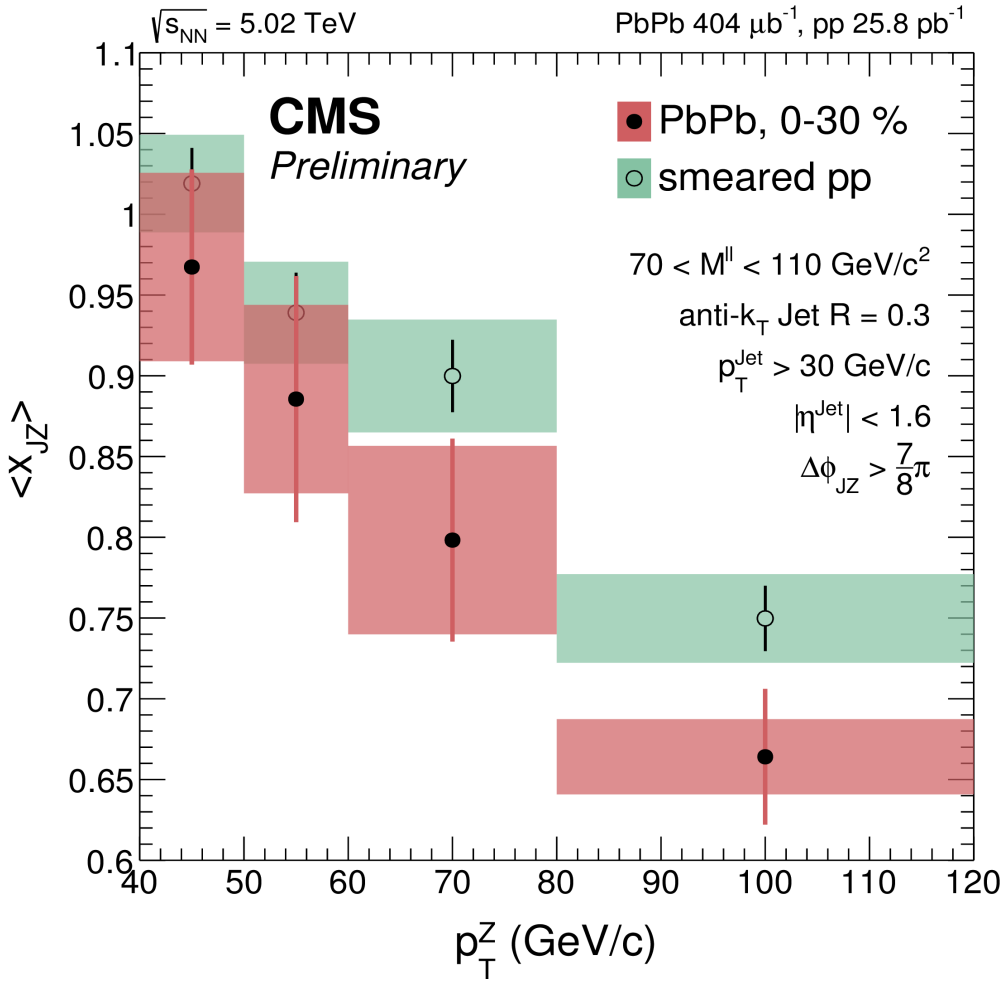
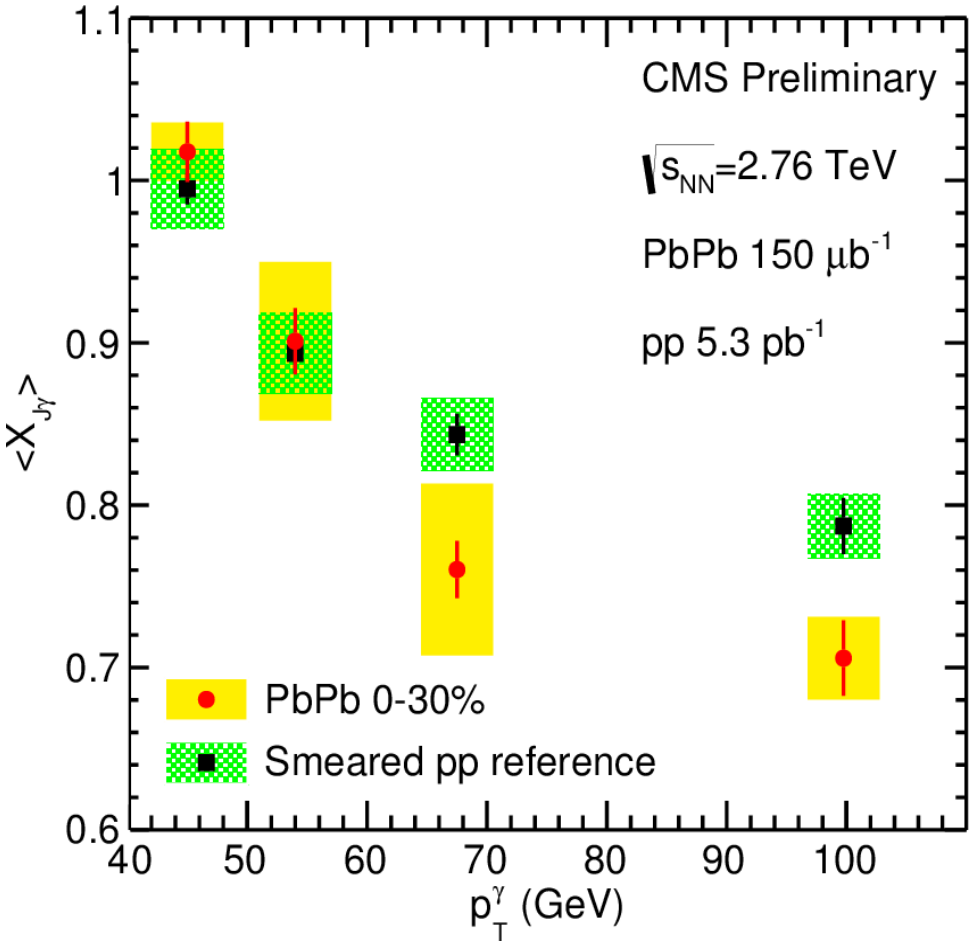


CMS-PAS-HIN-13-006



Z+jet at 5.02 TeV vs photon+jet at 2.76 TeV

Photon rapidity : $|\eta^{\gamma}| < 1.44$

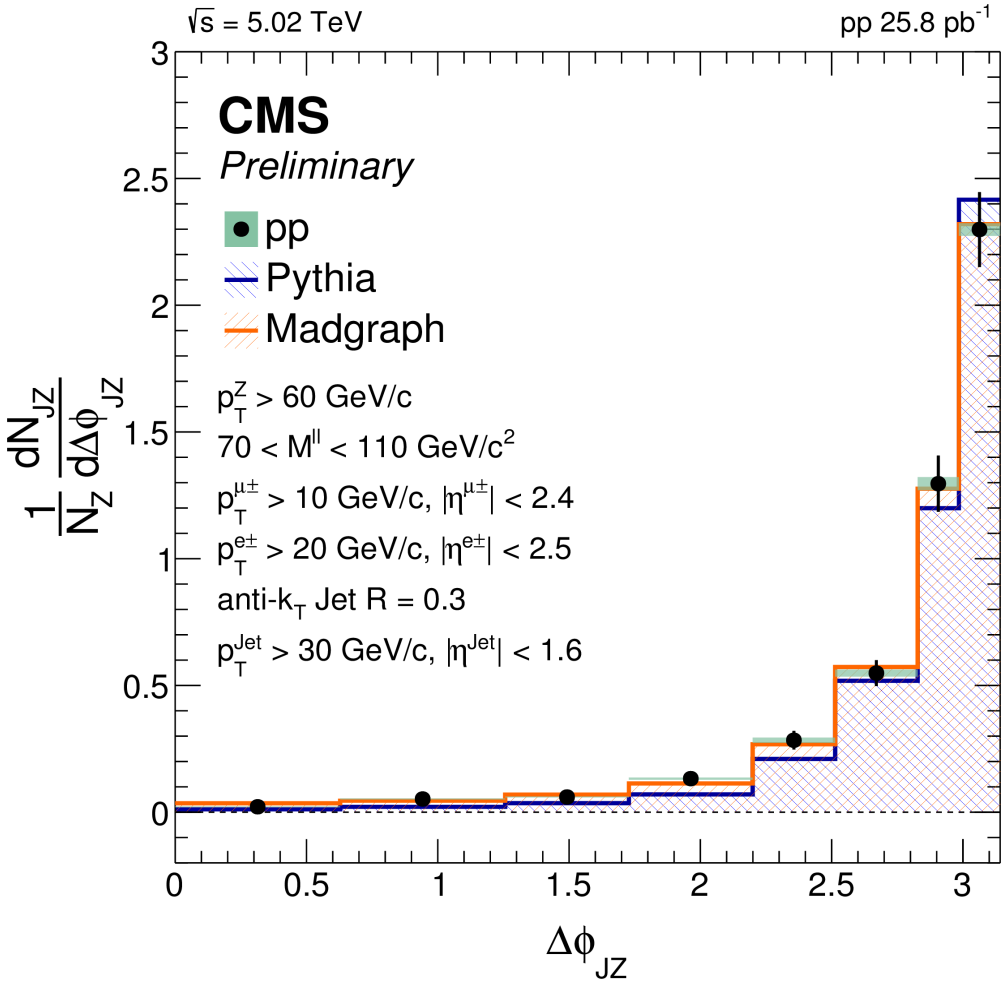
Same kinematic selections for jets.

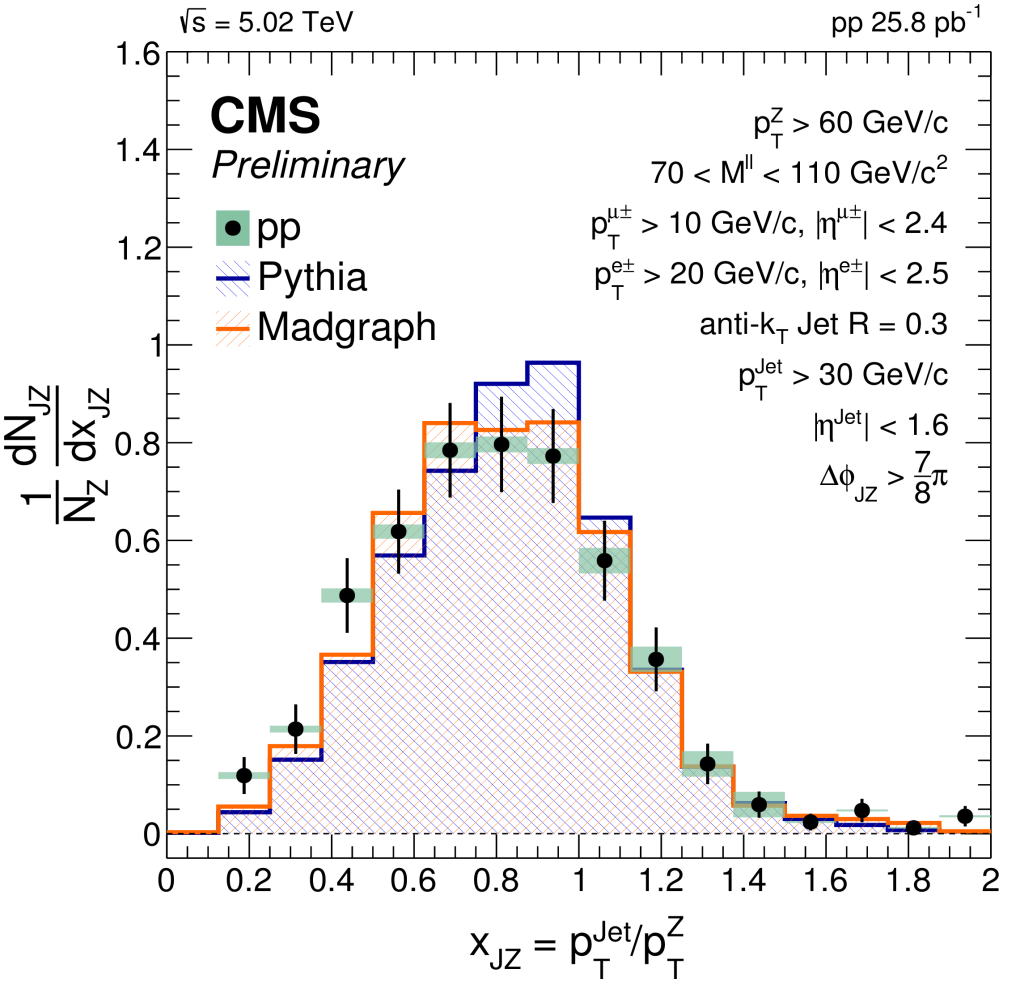
Agreement within statistical uncertainties

photon+jet results at 5.02 TeV :
Chris McGinn's talk in the next session

Comparison between pp and MC

CMS-PAS-HIN-15-013





Compared pp data to PYTHIA and MADGRAPH NLO models.
MADGRAPH NLO is in good agreement with data

Summary

Studied Z+jet pairs in pp and 0-30% centrality PbPb data at 5.02 TeV

Comparison between pp data and MC model :

- MADGRAPH NLO is in good agreement with data

Characterization of jet energy loss using Z+jet pairs :

- Compared PbPb data with pp data

Transverse momentum imbalance :

- x_{JZ} in PbPb has a shift to lower values.
- $\langle x_{JZ} \rangle$ in PbPb is lower than in pp.

  In agreement with jet quenching effects

Average number of jets per Z boson :

- R_{JZ} in PbPb is lower than in pp.

  Suggests that in PbPb larger fraction of associated jets lost energy and fell below the jet p_T threshold

Comparison with photon+jet results at 2.76 TeV

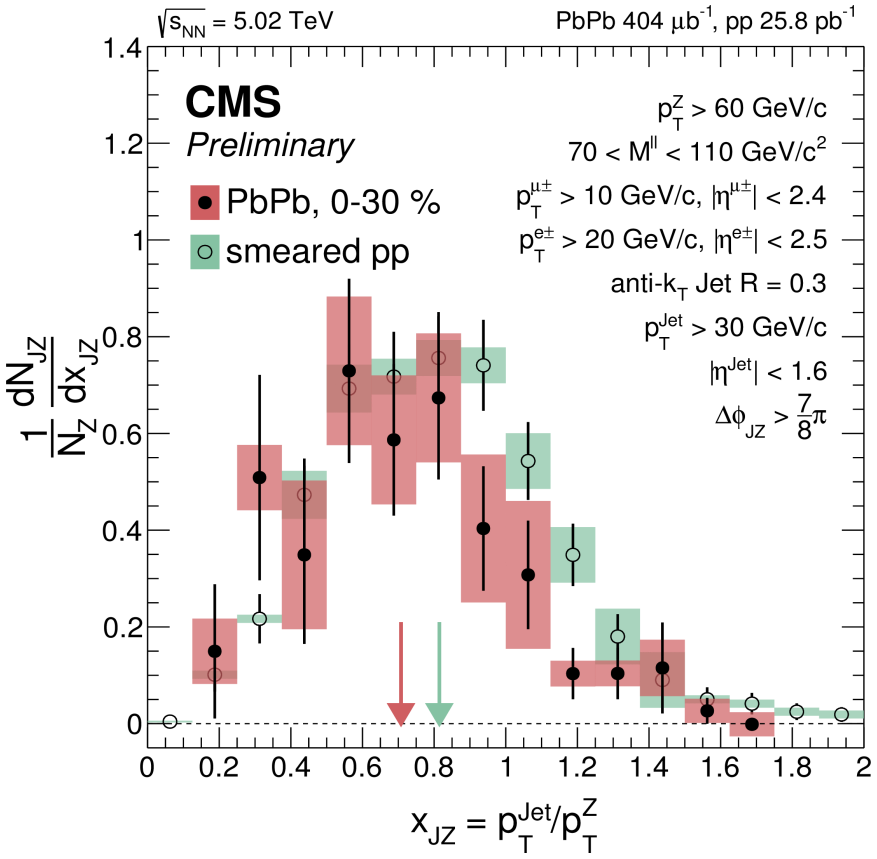
- Agreement within statistical uncertainties

Links :

CMS-PAS-HIN-15-013

Z+jet at 5.02 TeV

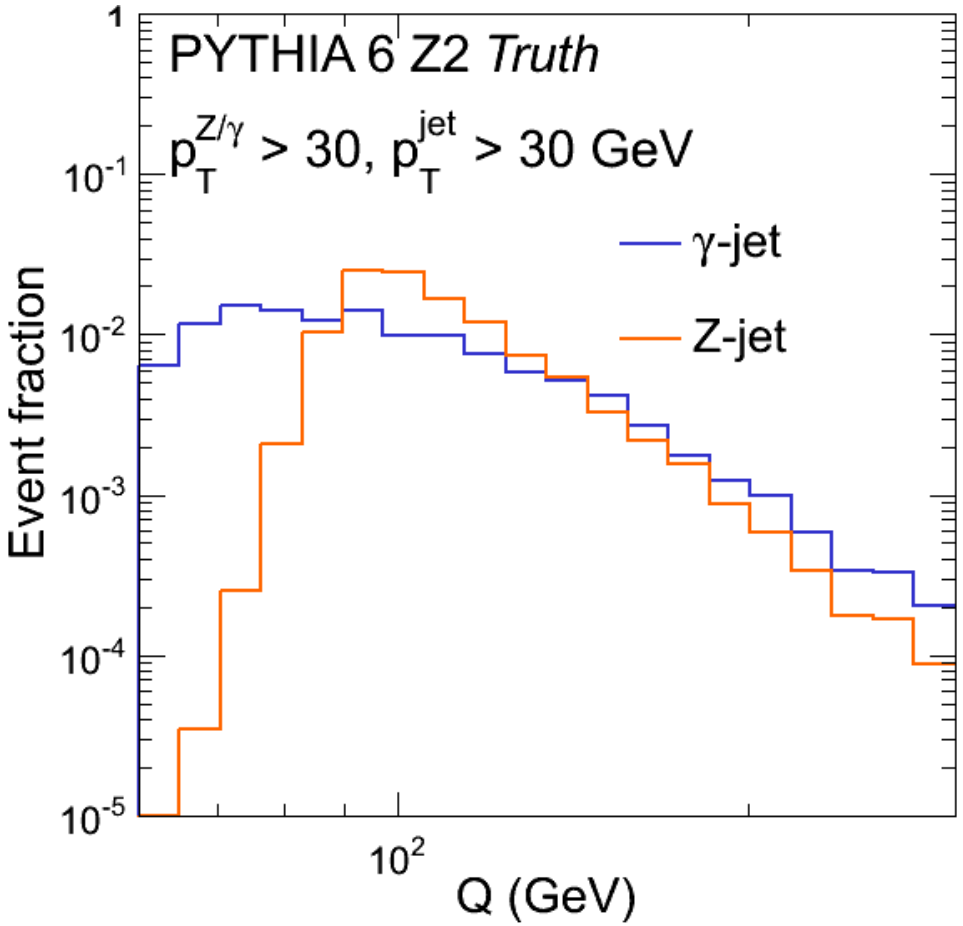
CMS-PAS-HIN-15-013



BACKUP

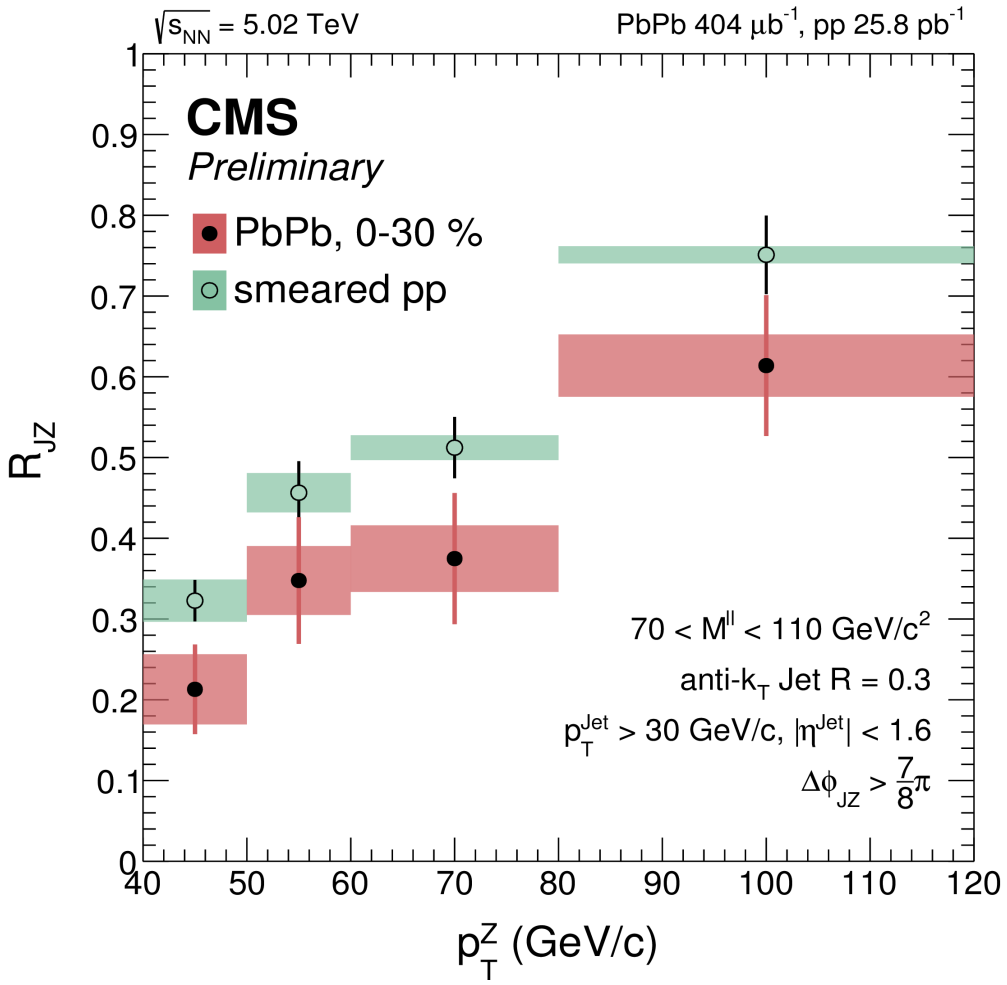
Q scale

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

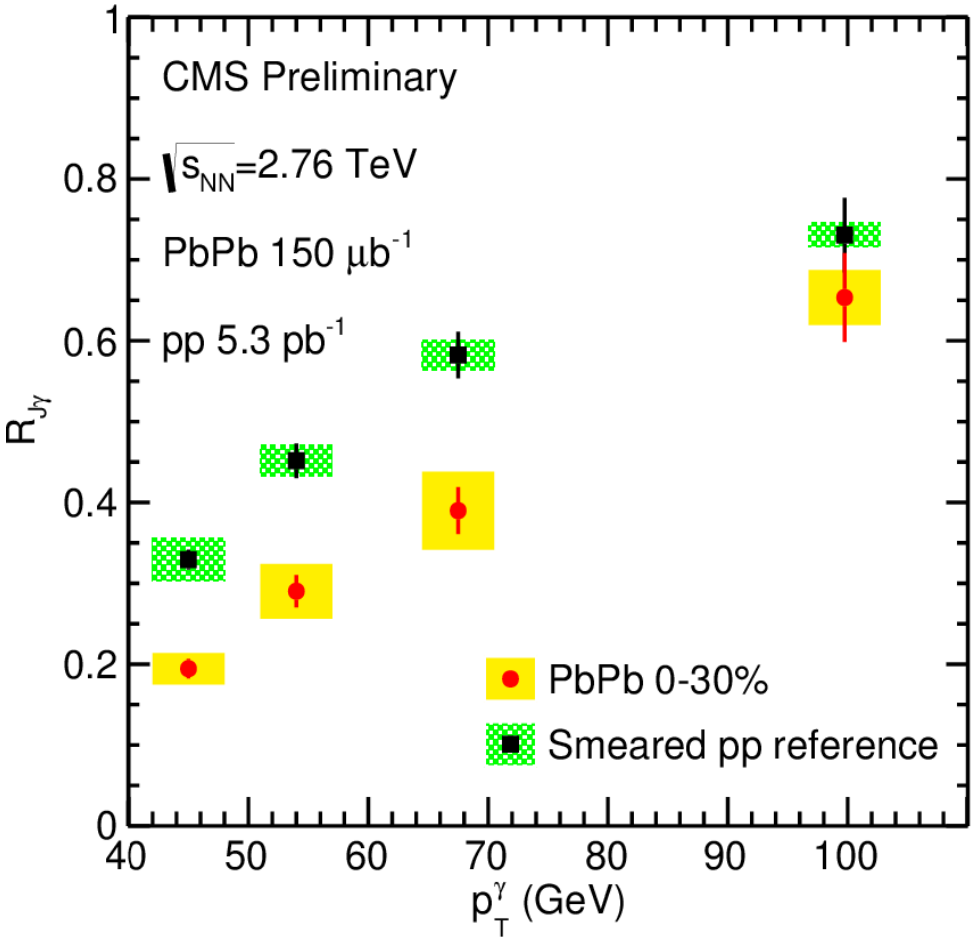


Comparison with photon+jet results

CMS-PAS-HIN-15-013



CMS-PAS-HIN-13-006



Z+jet at 5.02 TeV vs photon+jet at 2.76 TeV

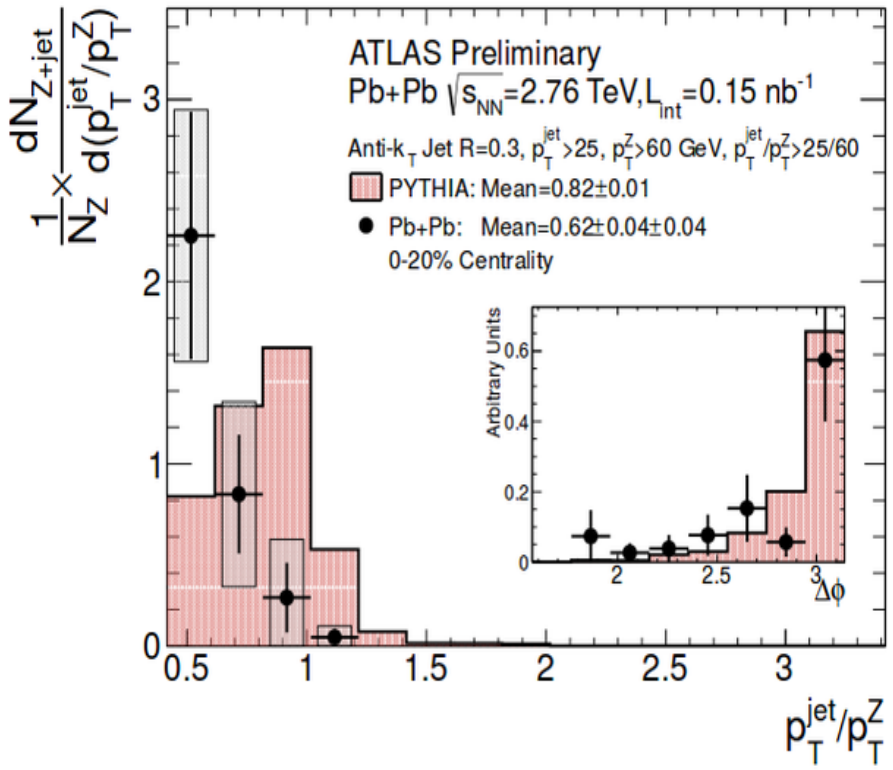
Same kinematic selections for jets. Photon pseudo-rapidity : $|\eta^\gamma| < 1.44$

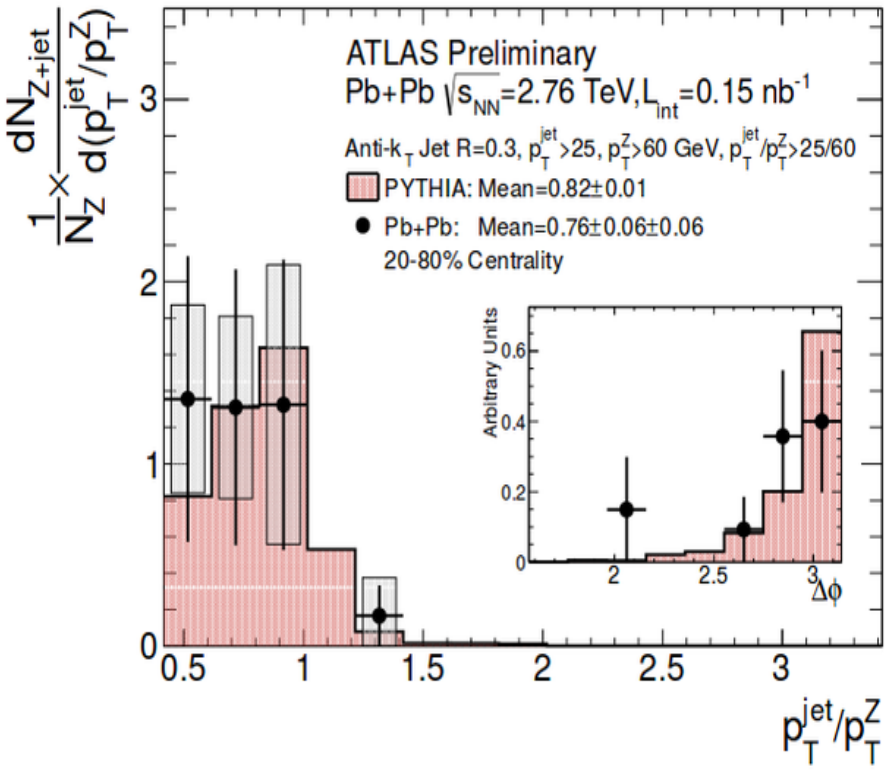
agreement within statistical uncertainties

Relevant Results

- ATLAS collaboration
- 2011 PbPb, 2.76 TeV
- 36 **Z+jet** events

ATLAS-CONF-2012-119

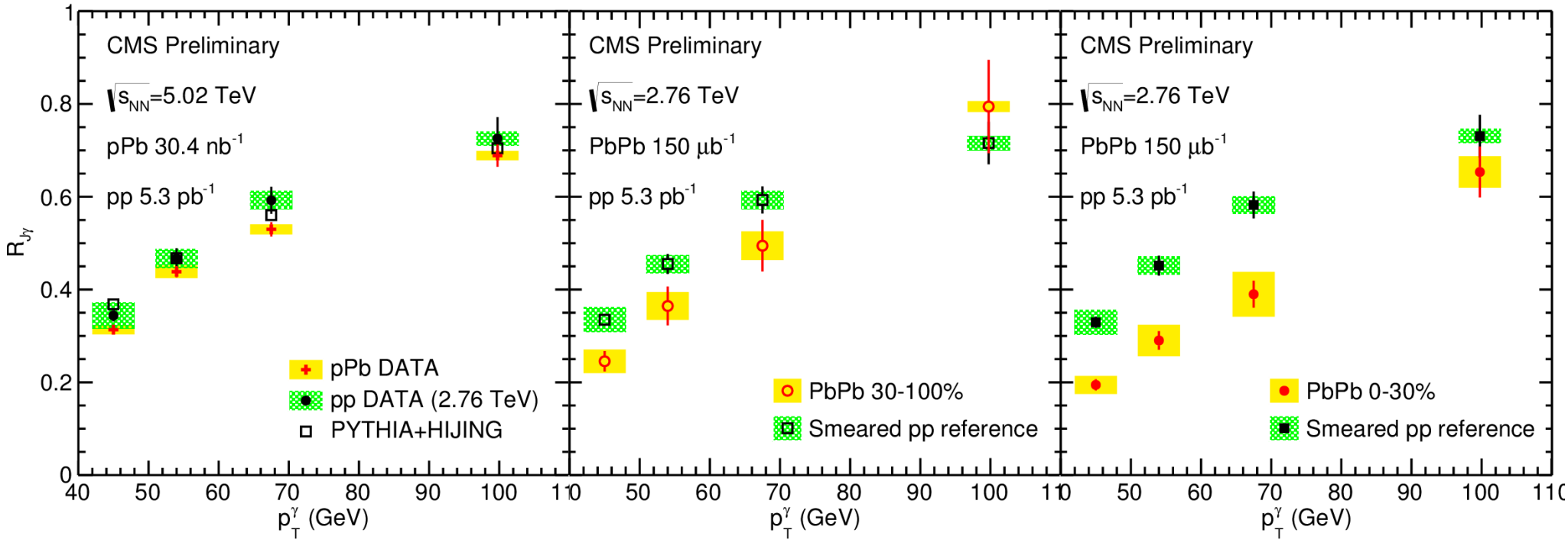




Relevant Results

- CMS collaboration
- 2011 PbPb, 2.76 TeV
- **photon+jet** events

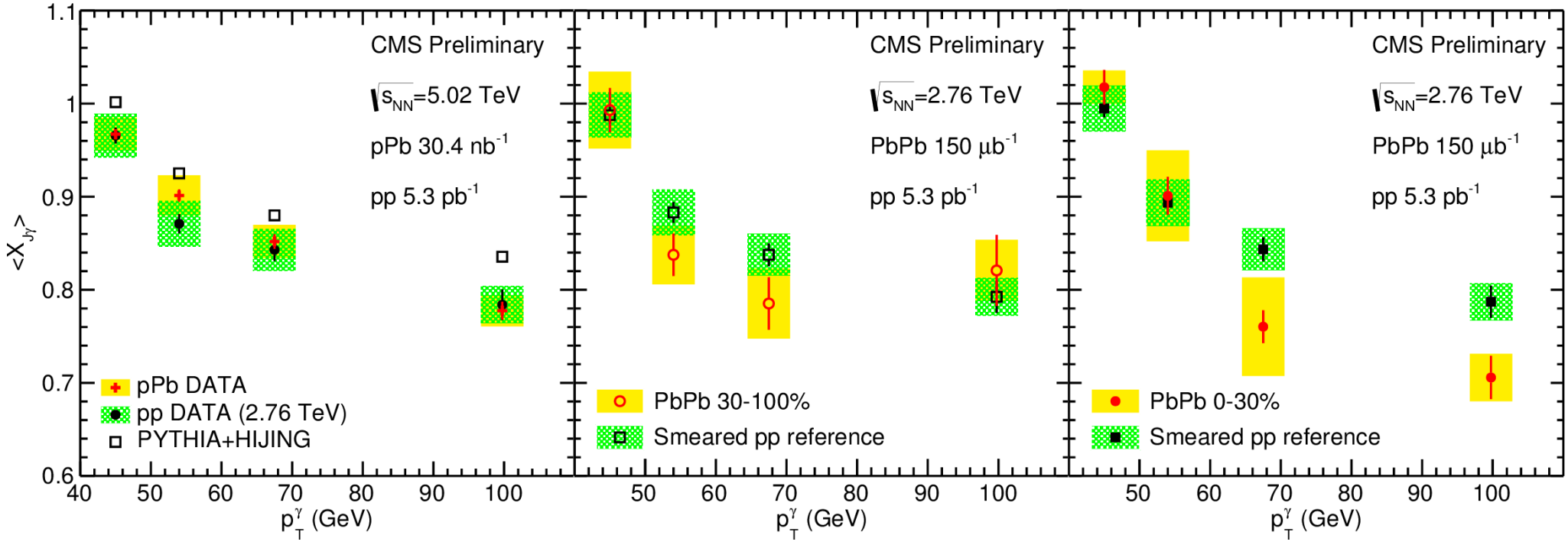
CMS-PAS-HIN-13-006



Relevant Results

- CMS collaboration
- 2011 PbPb, 2.76 TeV
- **photon+jet** events

CMS-PAS-HIN-13-006



Relevant Results

Studies of jet quenching using isolated-photon + jet correlations in PbPb and pp collisions at sqrt(s[NN]) = 2.76 TeV

- CMS collaboration
- 2011 PbPb, 2.76 TeV
- **photon+jet** events

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