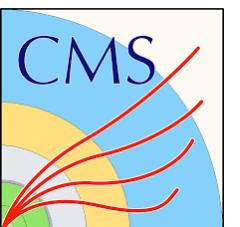
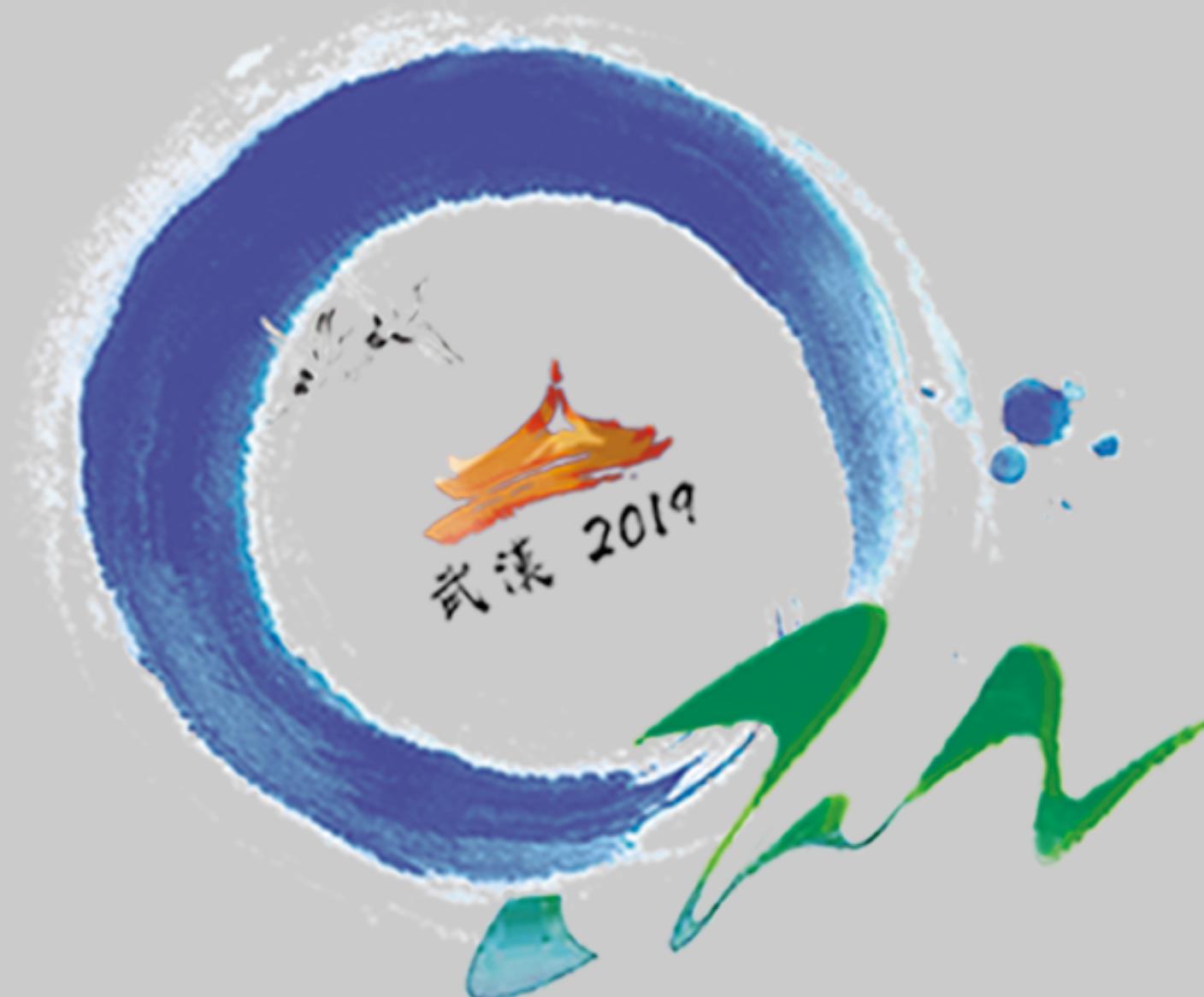


HIT



PARTON MODIFICATION AND MEDIUM RESPONSE STUDIES USING EW-BOSON-TAGGED JETS AND HADRONS



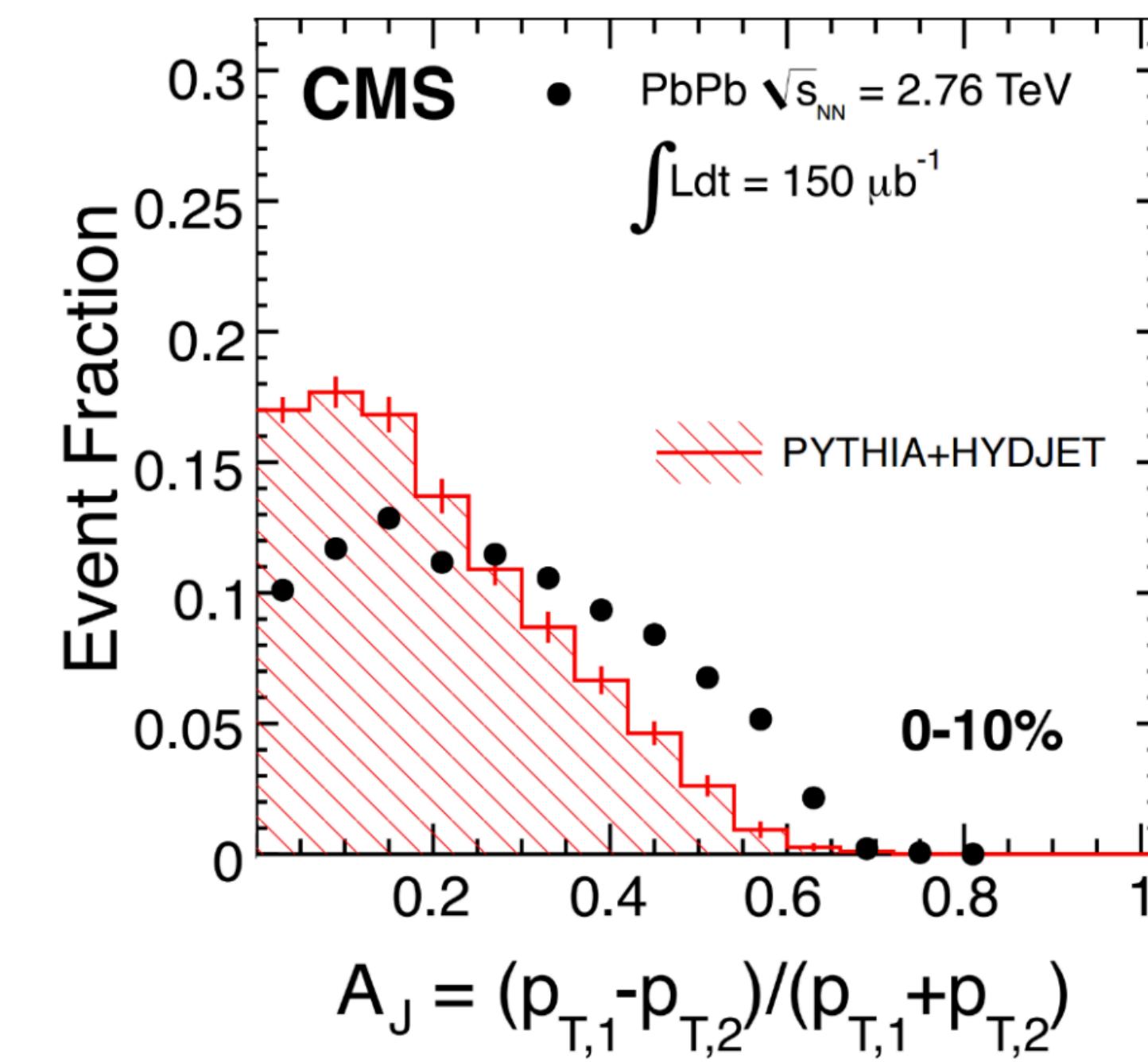
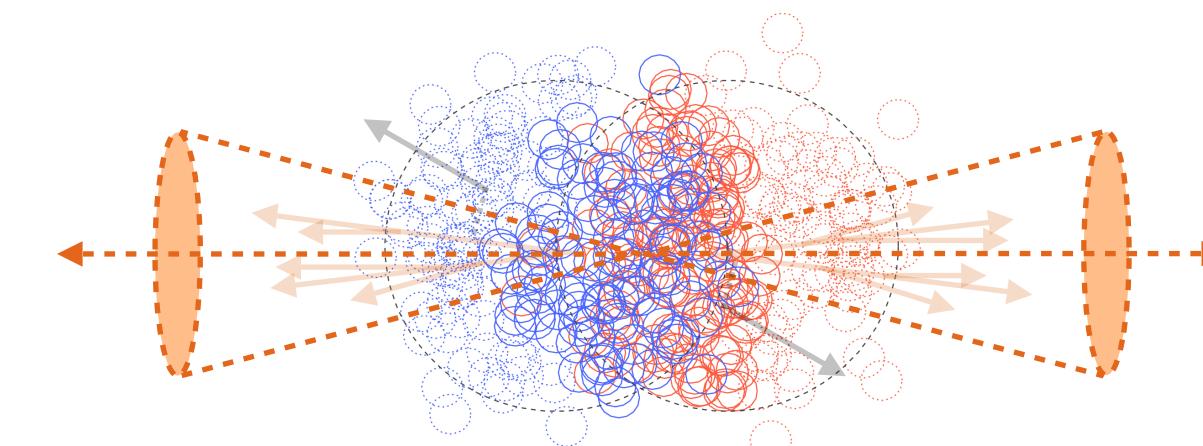
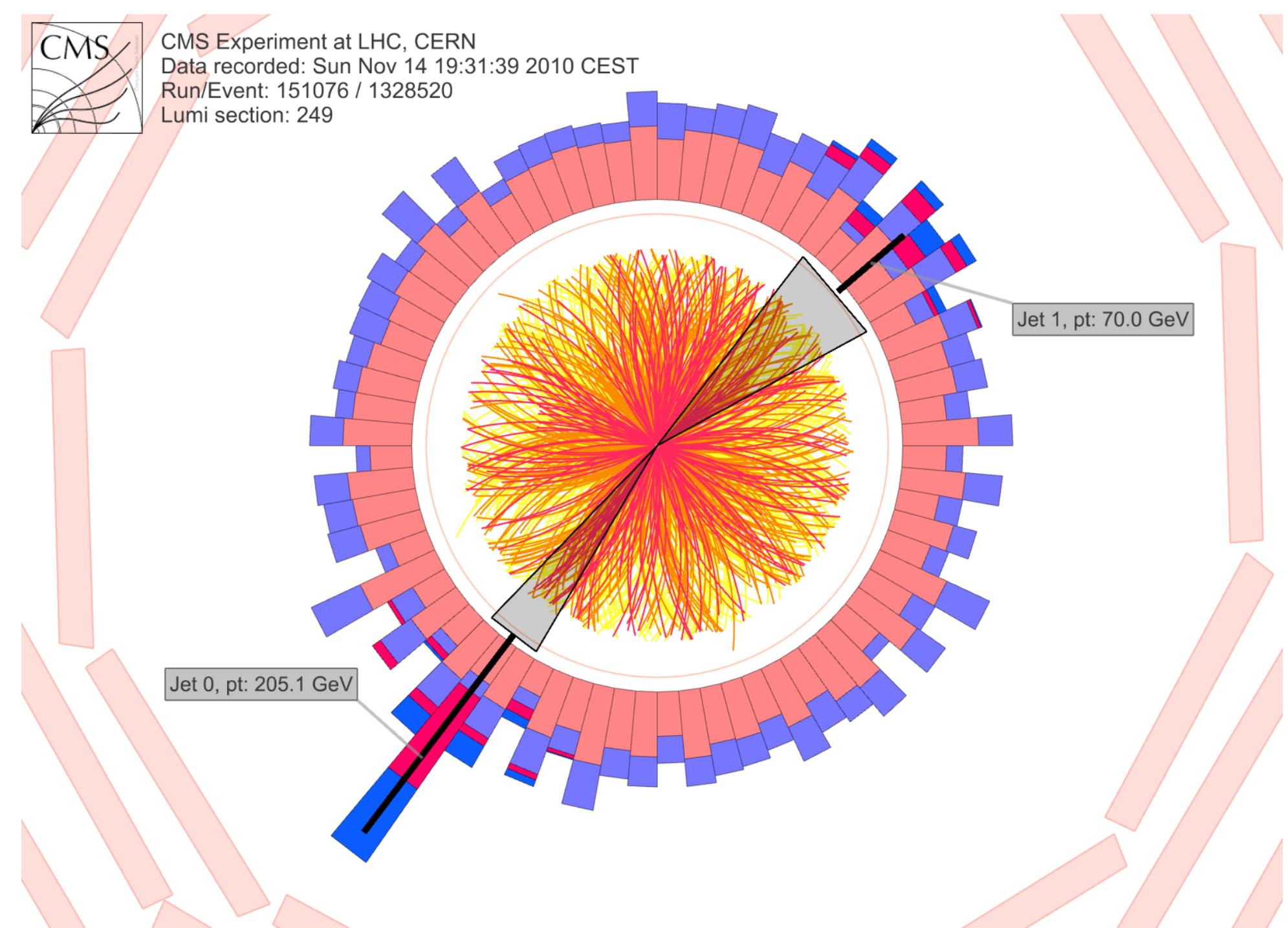
Ran Bi
on behalf of Kaya Tatar
and the CMS Collaboration

Quark Matter 2019
6 Nov 2019
Wuhan, China

ENERGY LOSS IN INCLUSIVE DIJET EVENTS

PLB 712 (2012) 176

- jet quenching is a characteristic feature of the QGP
 - observed through measurements of jet asymmetry in dijet systems

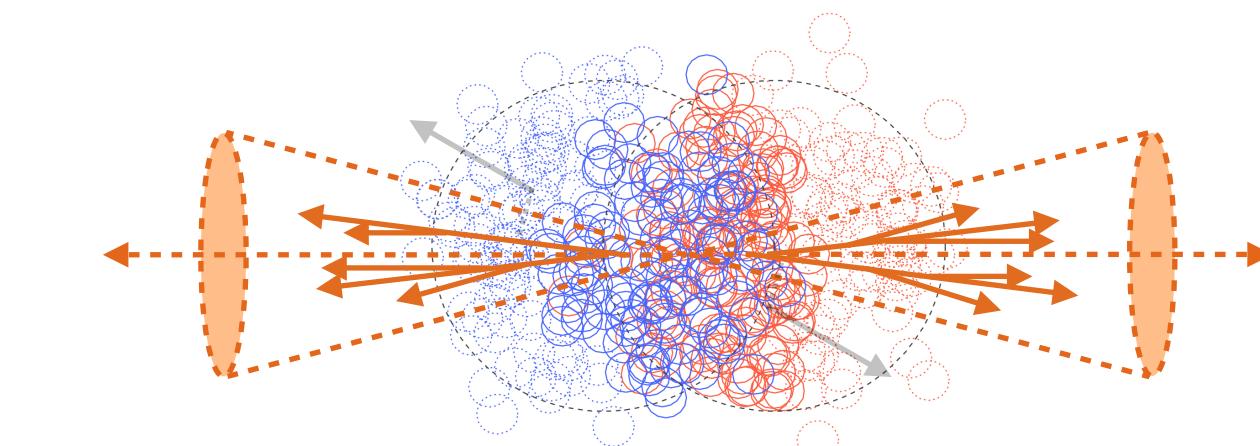


JET SUBSTRUCTURE IN PbPb COLLISIONS (INCLUSIVE JETS)

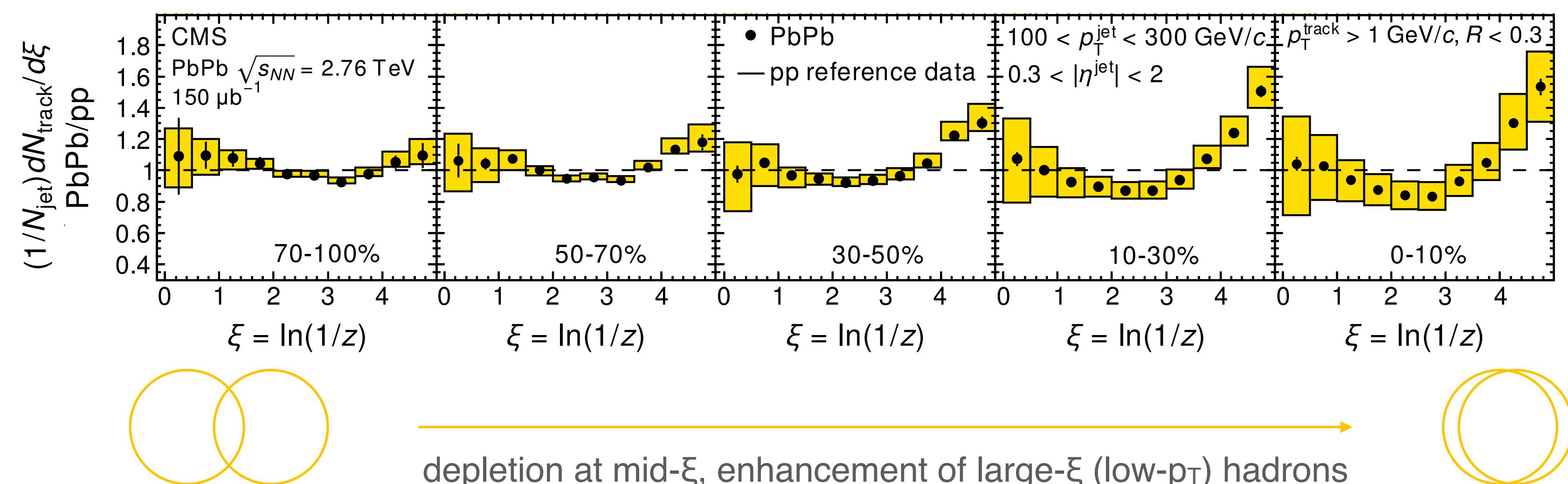
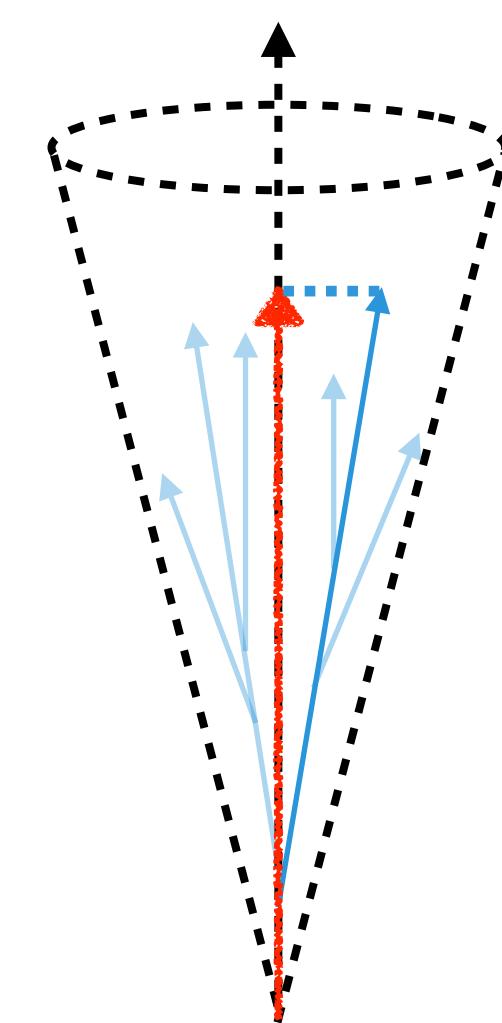
PRC 90 (2014) 024908

- differentiate between different energy loss mechanisms
- jet fragmentation function

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



projection of
track momentum
onto jet axis

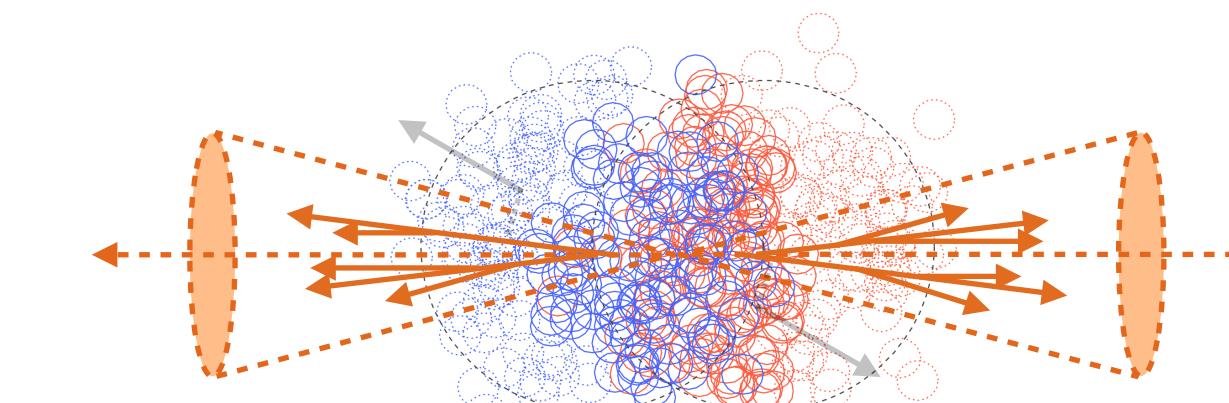


JET SUBSTRUCTURE IN PbPb COLLISIONS (INCLUSIVE JETS)

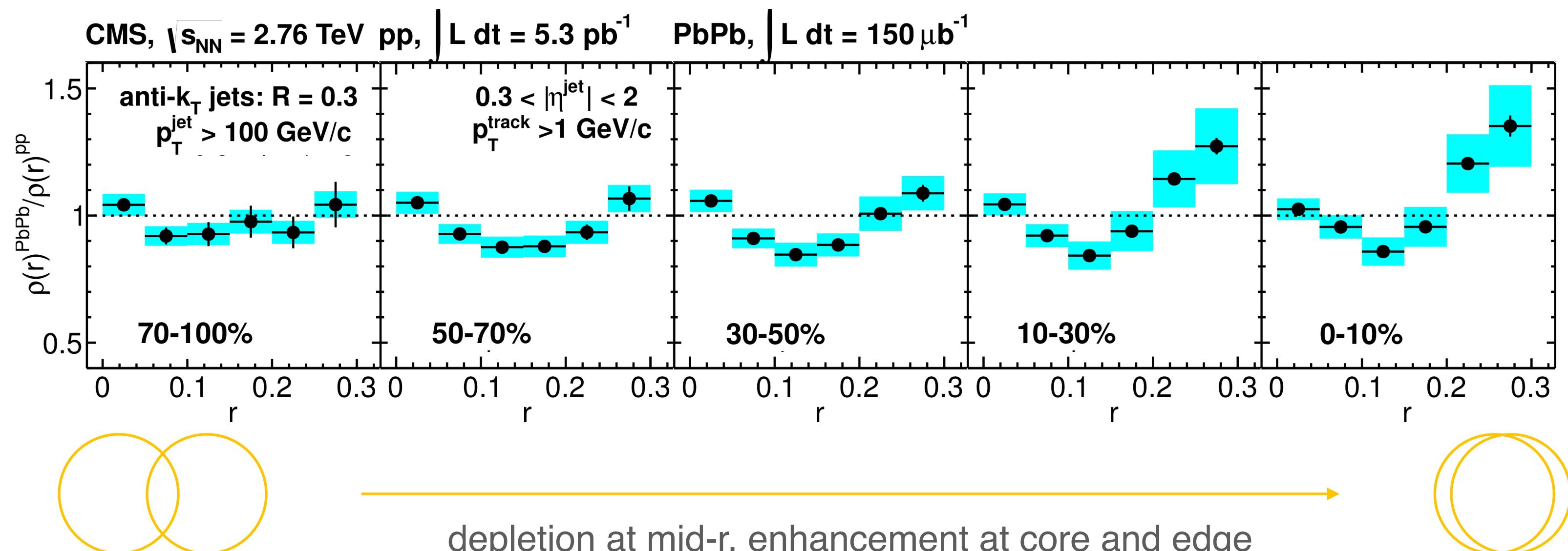
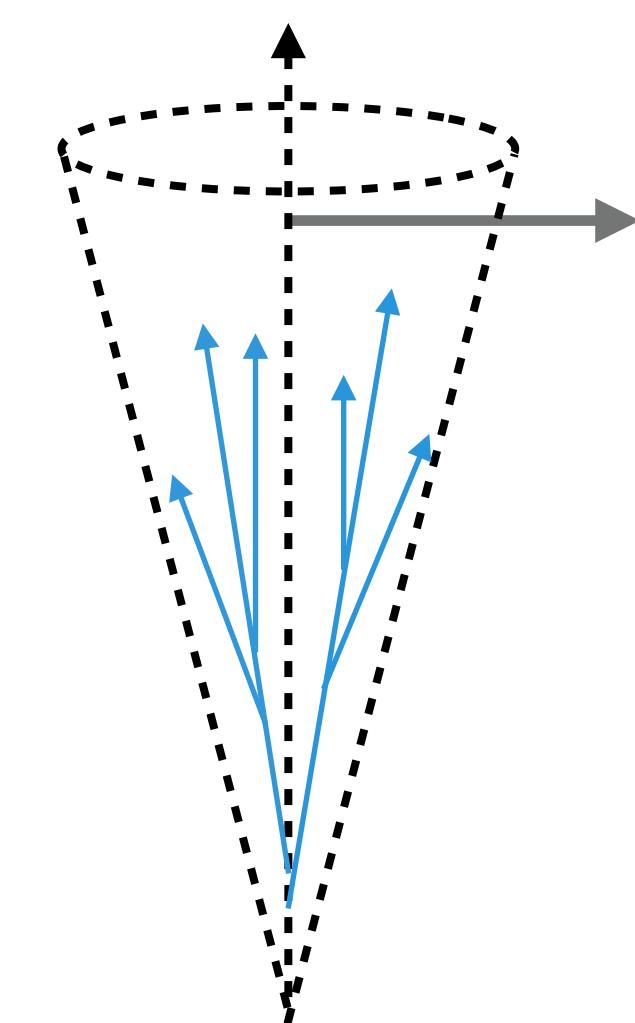
PLB 730 (2014) 243

- differentiate between different energy loss mechanisms
- jet shape

$$\rho(r) = \frac{1}{\delta r} \frac{\sum_{\text{jets}} \sum_{r_a < r < r_b} (p_T^{\text{trk}} / p_T^{\text{jet}})}{\sum_{\text{jets}} \sum_{0 < r < r_f} (p_T^{\text{trk}} / p_T^{\text{jet}})}, \quad r = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$



p_T -weighted
track distribution
around axis



INCLUSIVE DIJETS IN PBPB COLLISIONS

- inclusive dijets are good probes of the medium, with caveats
 - coloured - both jets are subject to medium-induced energy loss
 - “surface bias” - selections based on final state momentum biases jet population
 - parton flavour dependence - quark and gluon jets quench different

ELECTROWEAK BOSONS IN PBPB COLLISIONS

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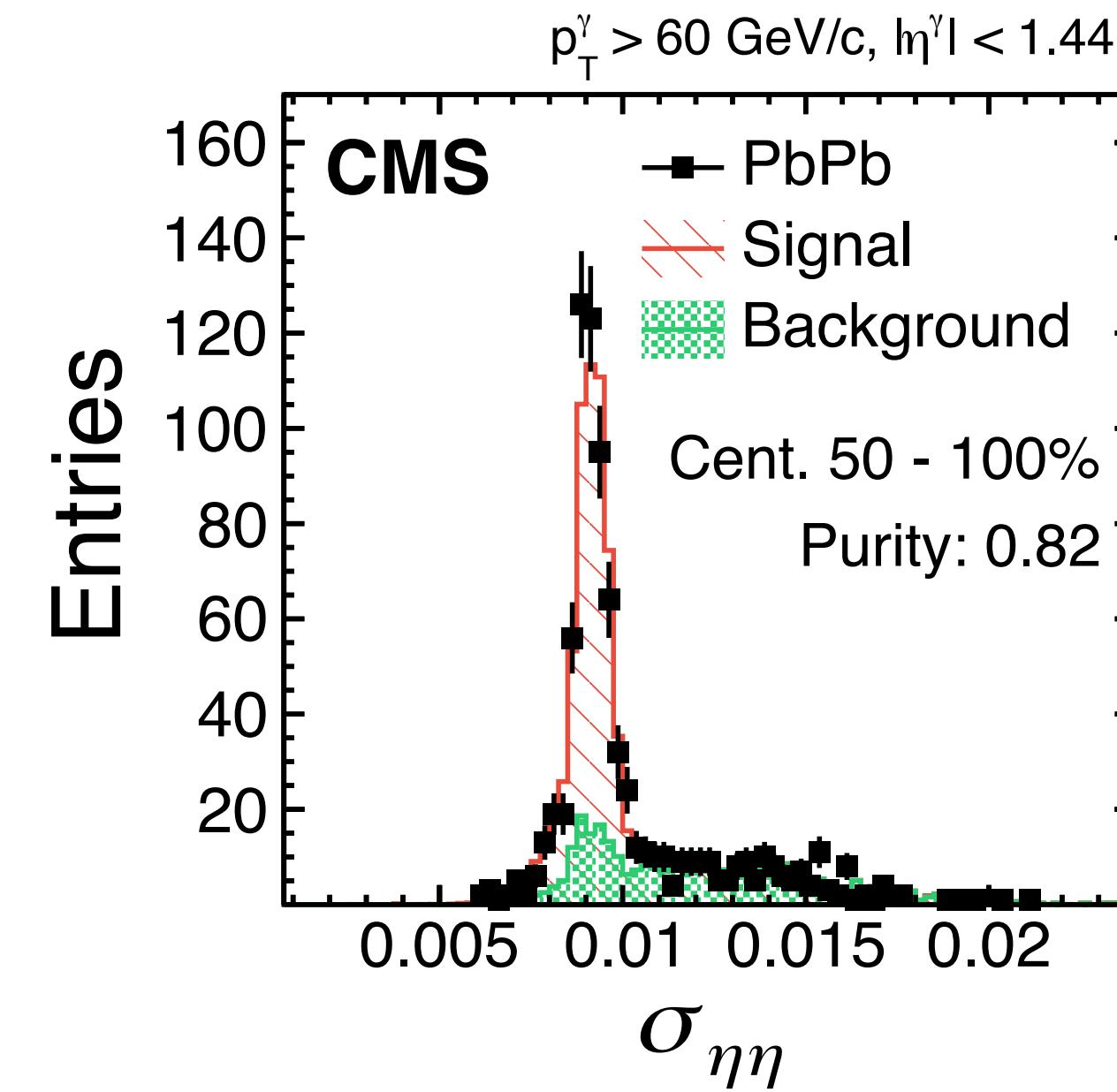
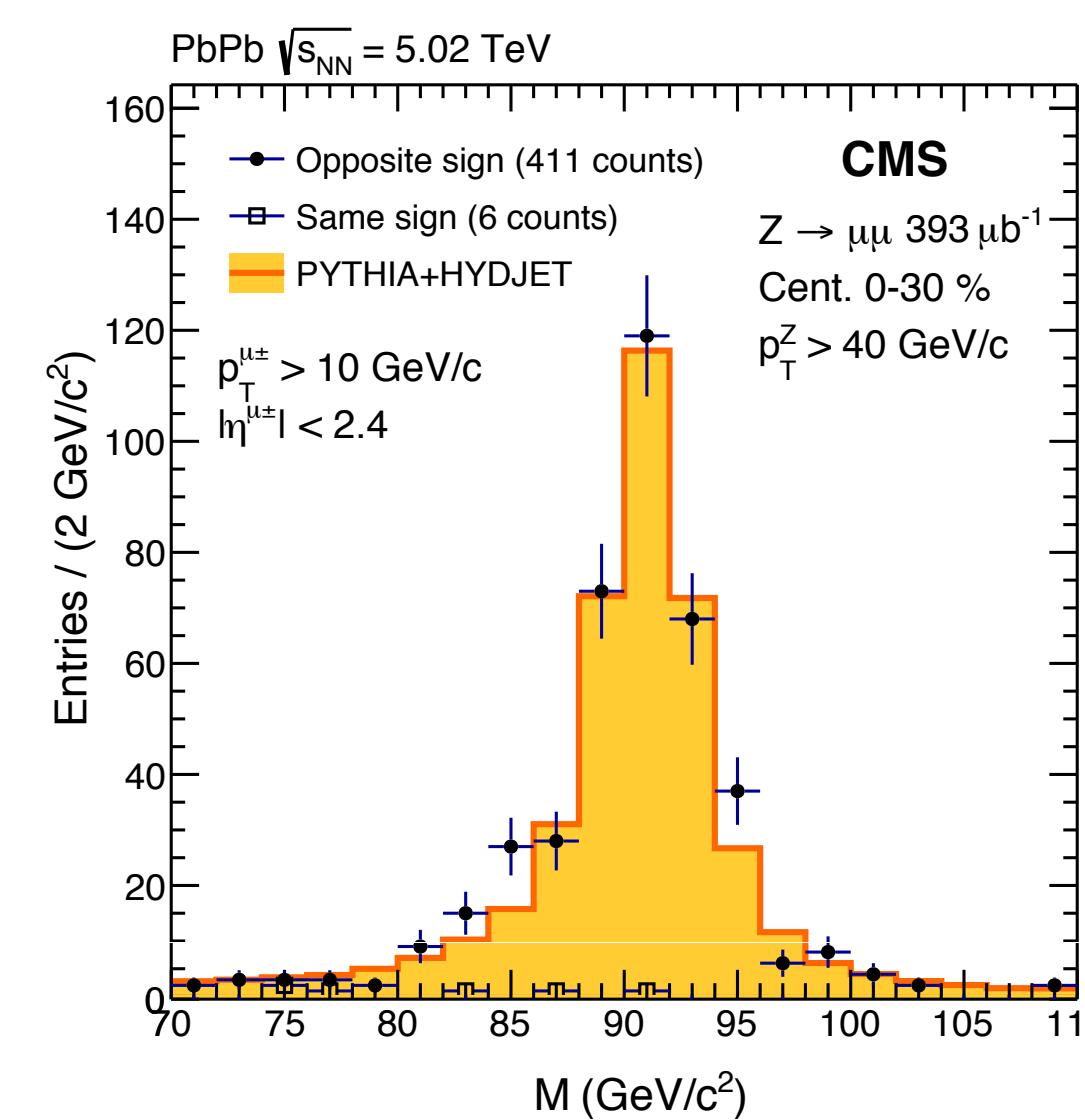
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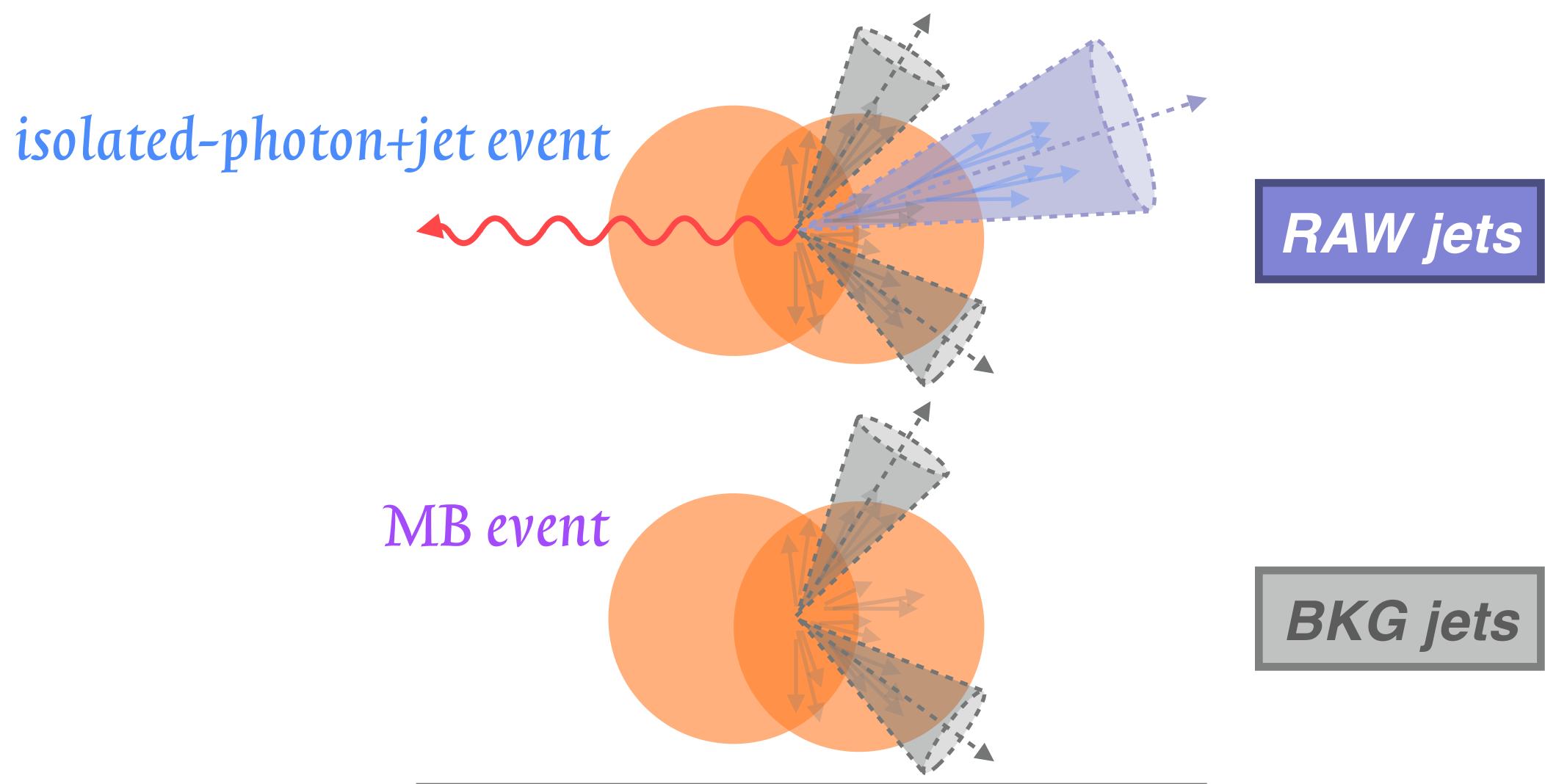
ELECTROWEAK BOSONS IN PbPb COLLISIONS

- electroweak bosons are good probes of the medium
 - colourless - not subject to medium-induced energy loss
 - good proxy of the initial energy of partons produced in the hard scattering
 - production processes constrain quark/gluon fraction of recoil parton
 - cross sections: photons > Z bosons; background: photons > Z bosons
- Z bosons
 - reconstructed through dilepton channels
 - photons (isolated photons)
 - background mostly from neutral meson decays
 - subtracted using a template fit method
 - signal template: Monte Carlo, background: data sideband



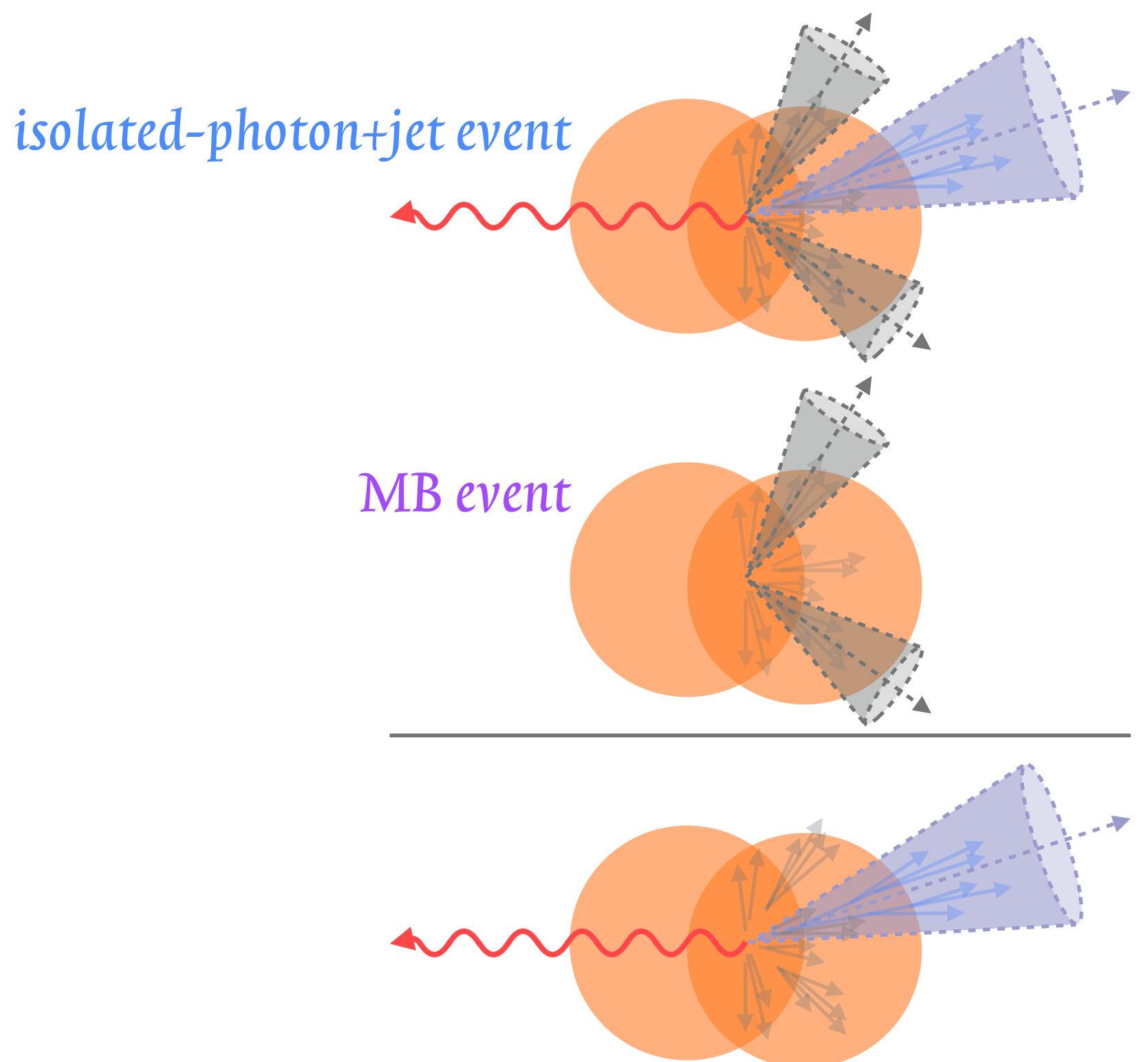
BACKGROUND SUBTRACTION (EVENT MIXING)

- jets and tracks from the underlying event are uncorrelated with the photon
 - minimum bias (MB) events are another source of uncorrelated jets and tracks
 - estimate contribution of background by embedding the photon into MB events
 - select events with similar characteristics: event activity, vertex position, event plane
- subtraction for jet-based observables is straightforward



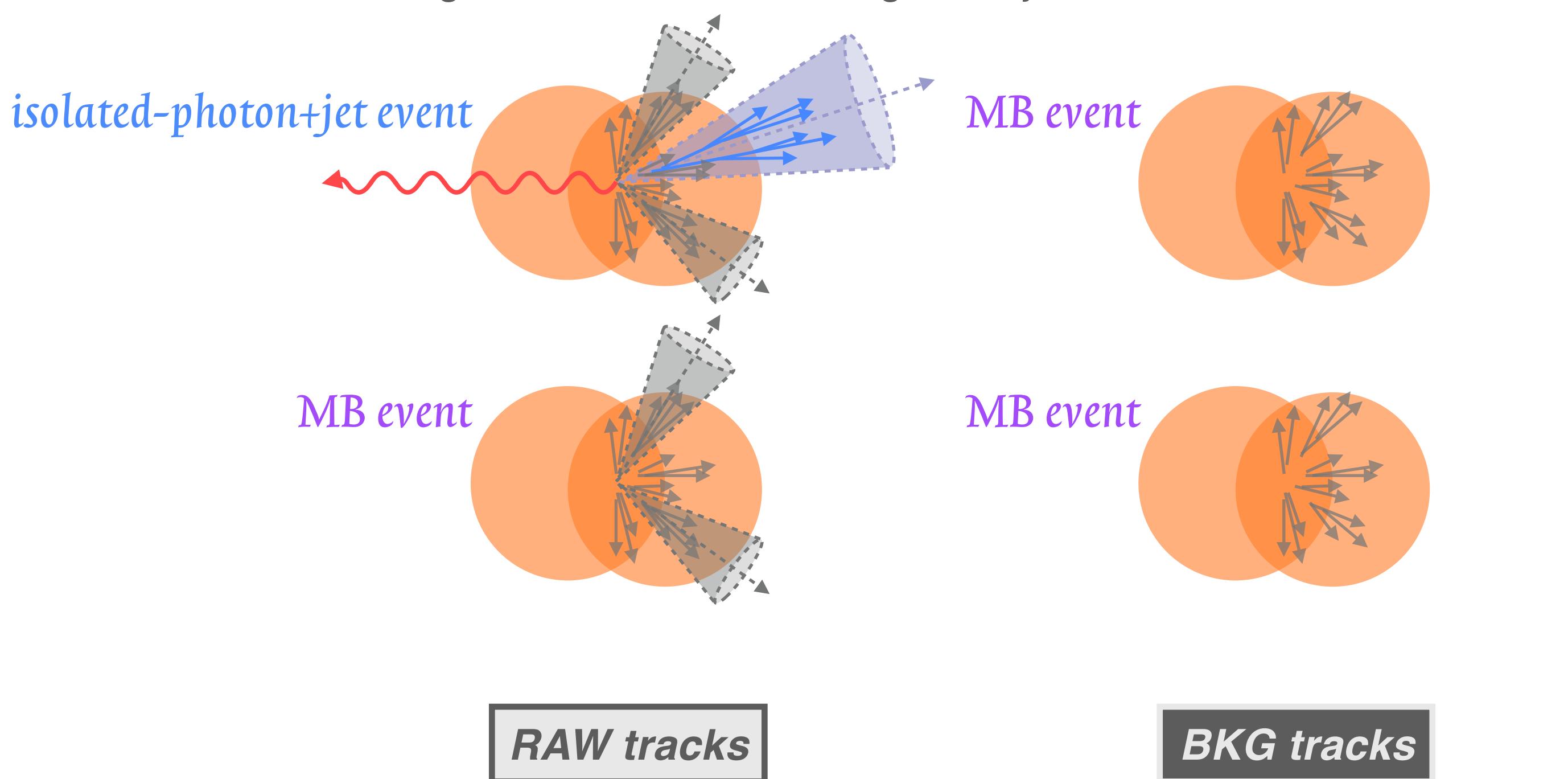
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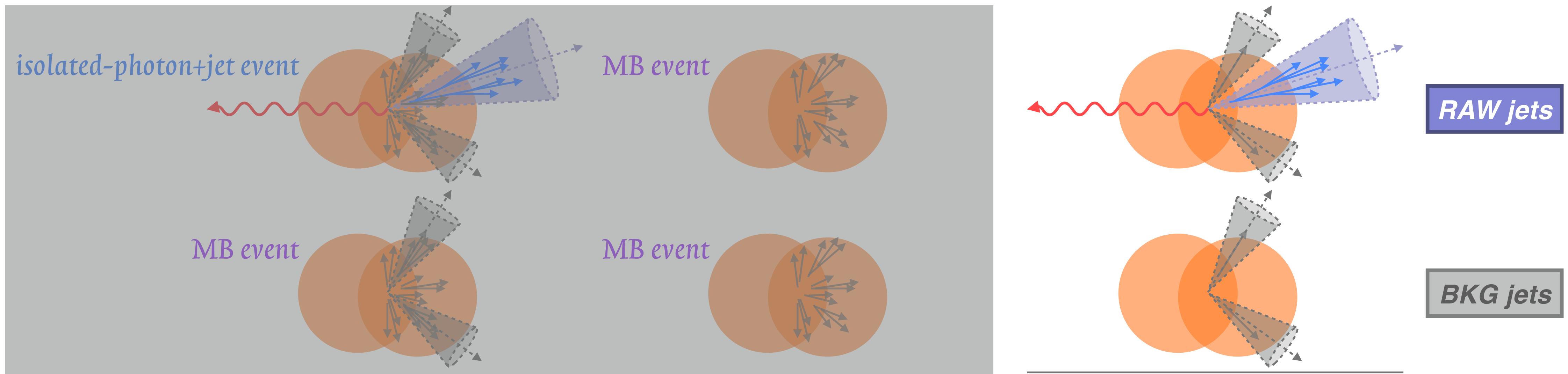
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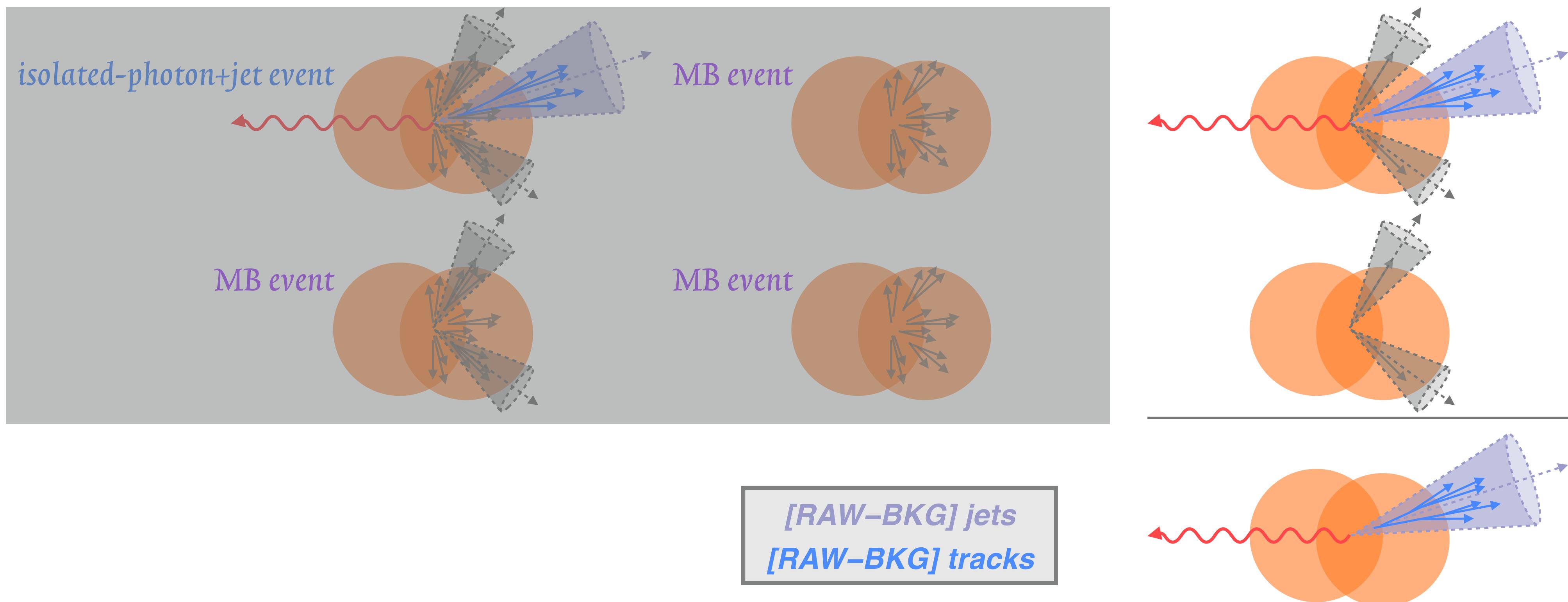
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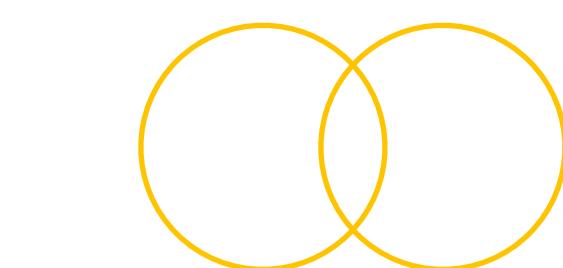
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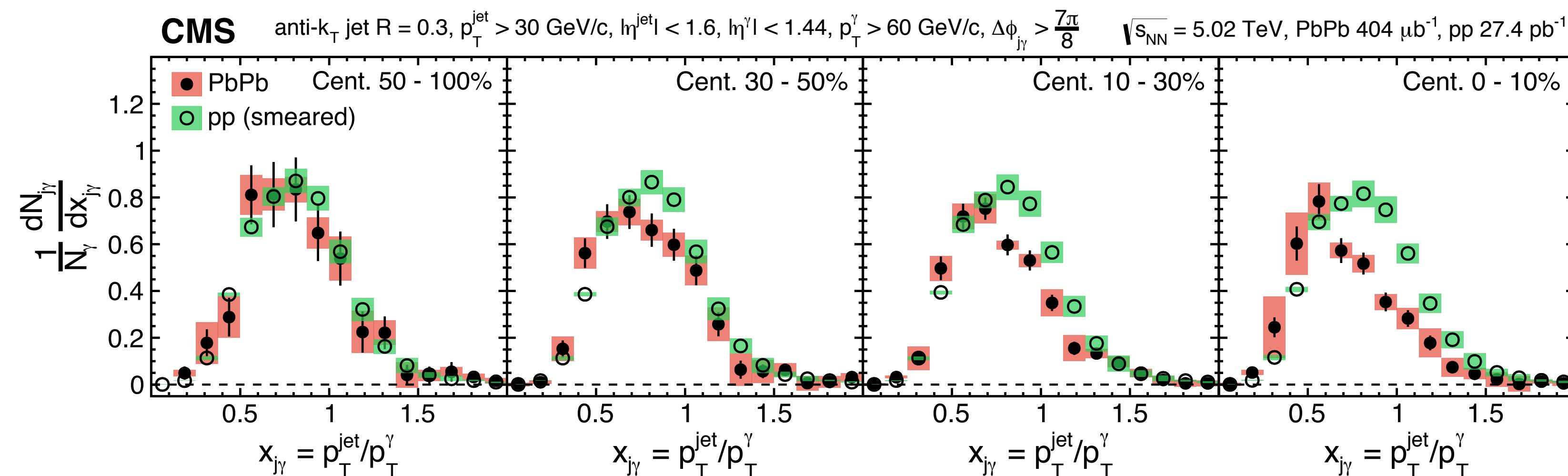
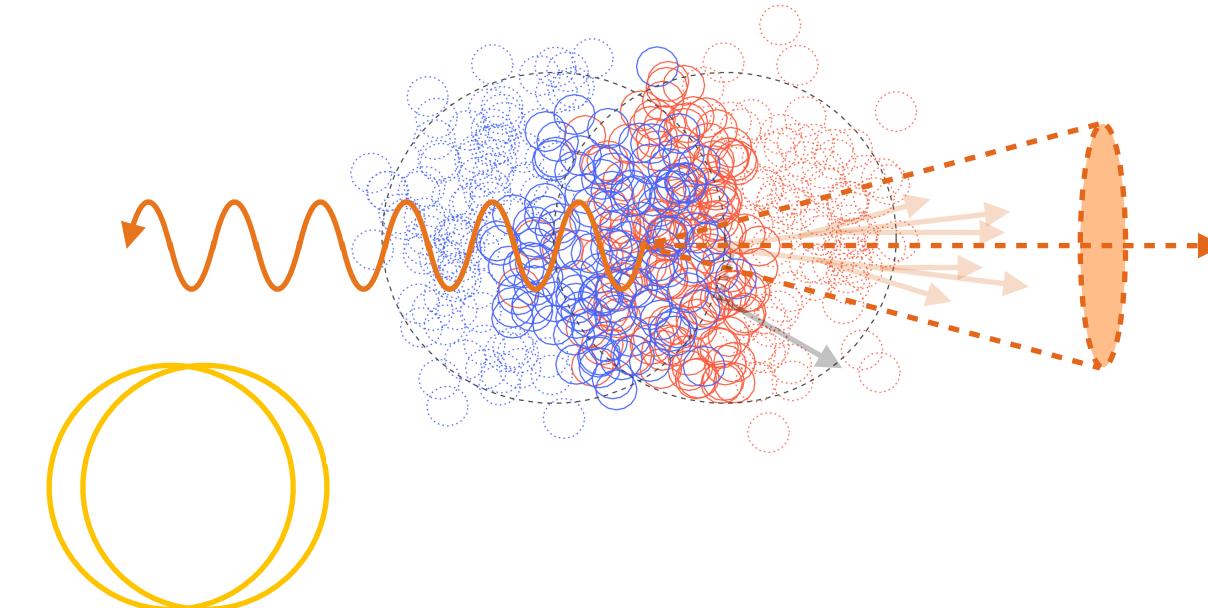


MOMENTUM IMBALANCE IN PbPb COLLISIONS

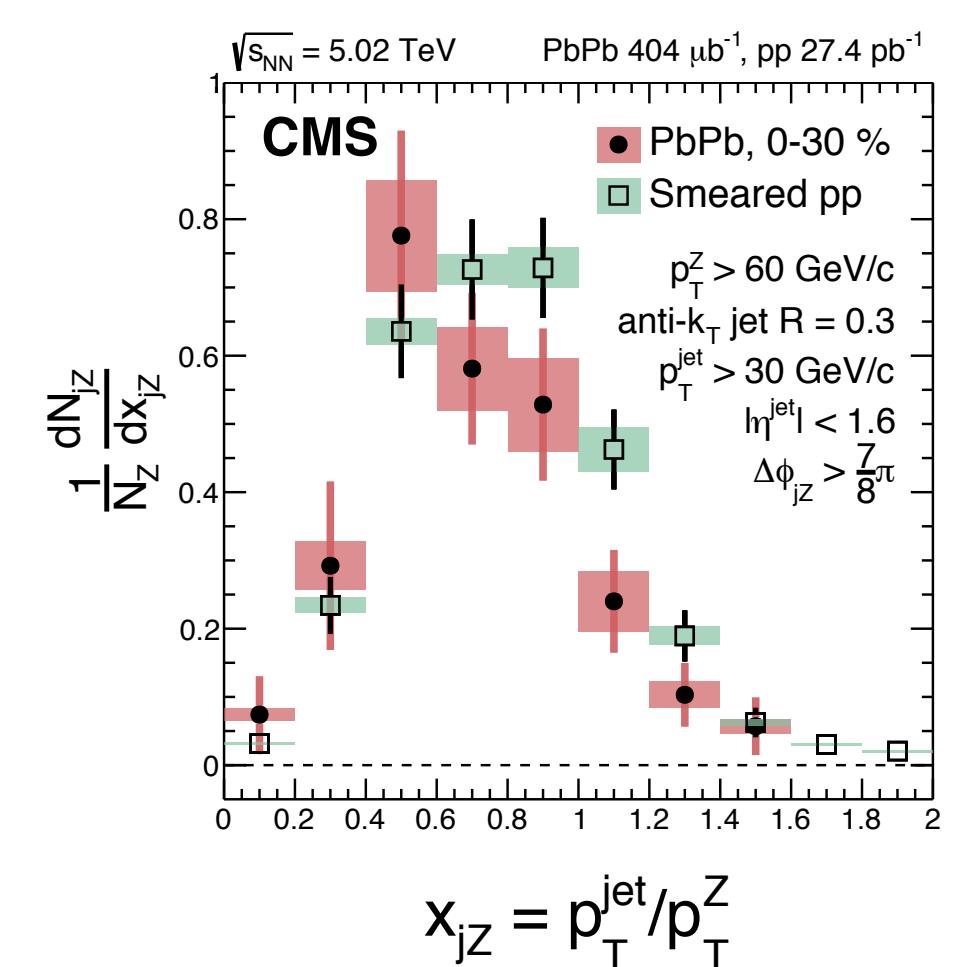
- isolated-photon/Z-boson + jet correlations in PbPb @ 5.02 TeV
 - clear evidence for in-medium jet energy loss



mean $x_{j\gamma}$ shifts to lower values, integral is suppressed



photon-jet



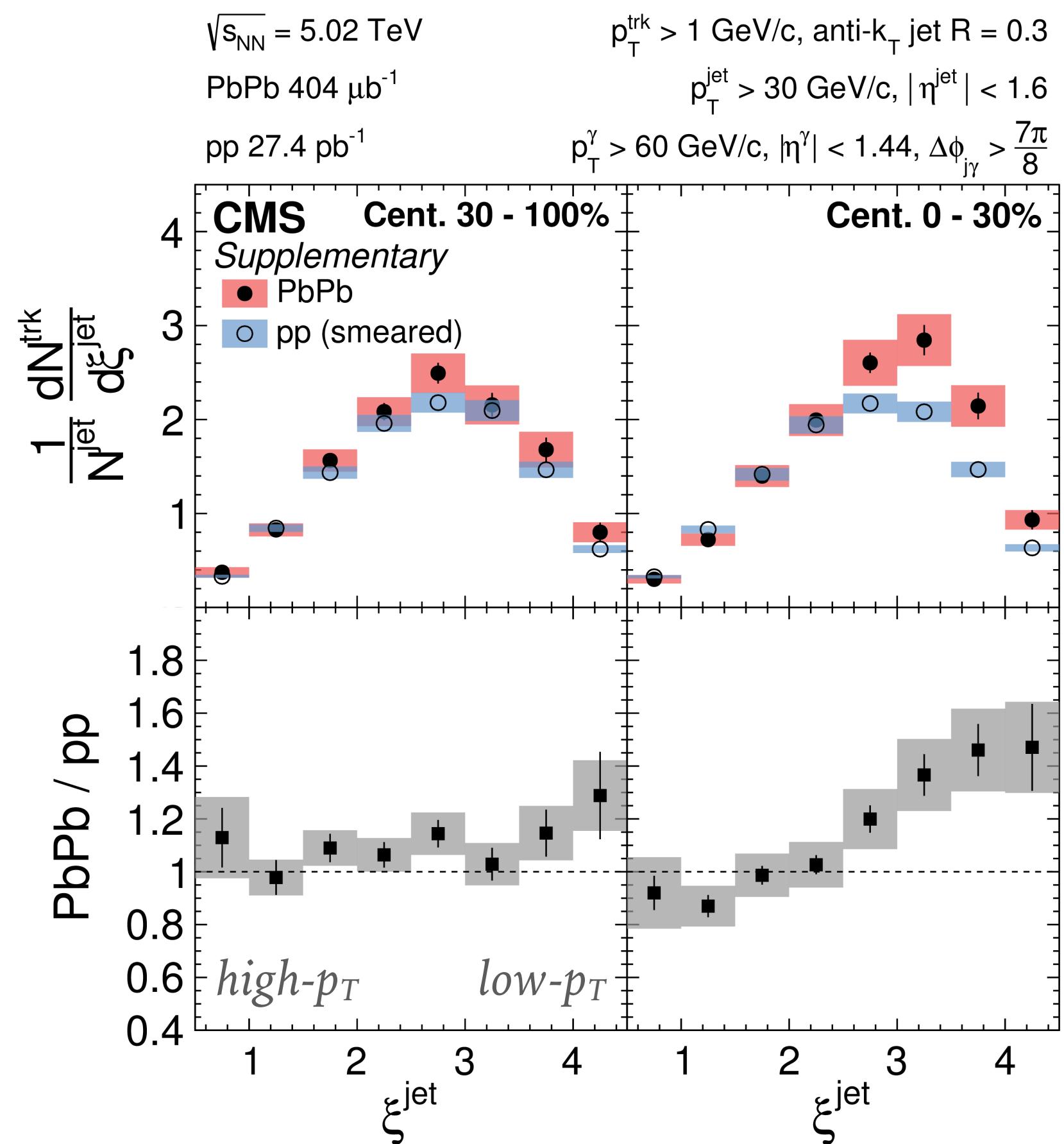
Z-jet

- results give a crude picture of jet quenching
 - more detailed measurements required for a complete description

PHOTON-TAGGED JET FRAGMENTATION FUNCTION

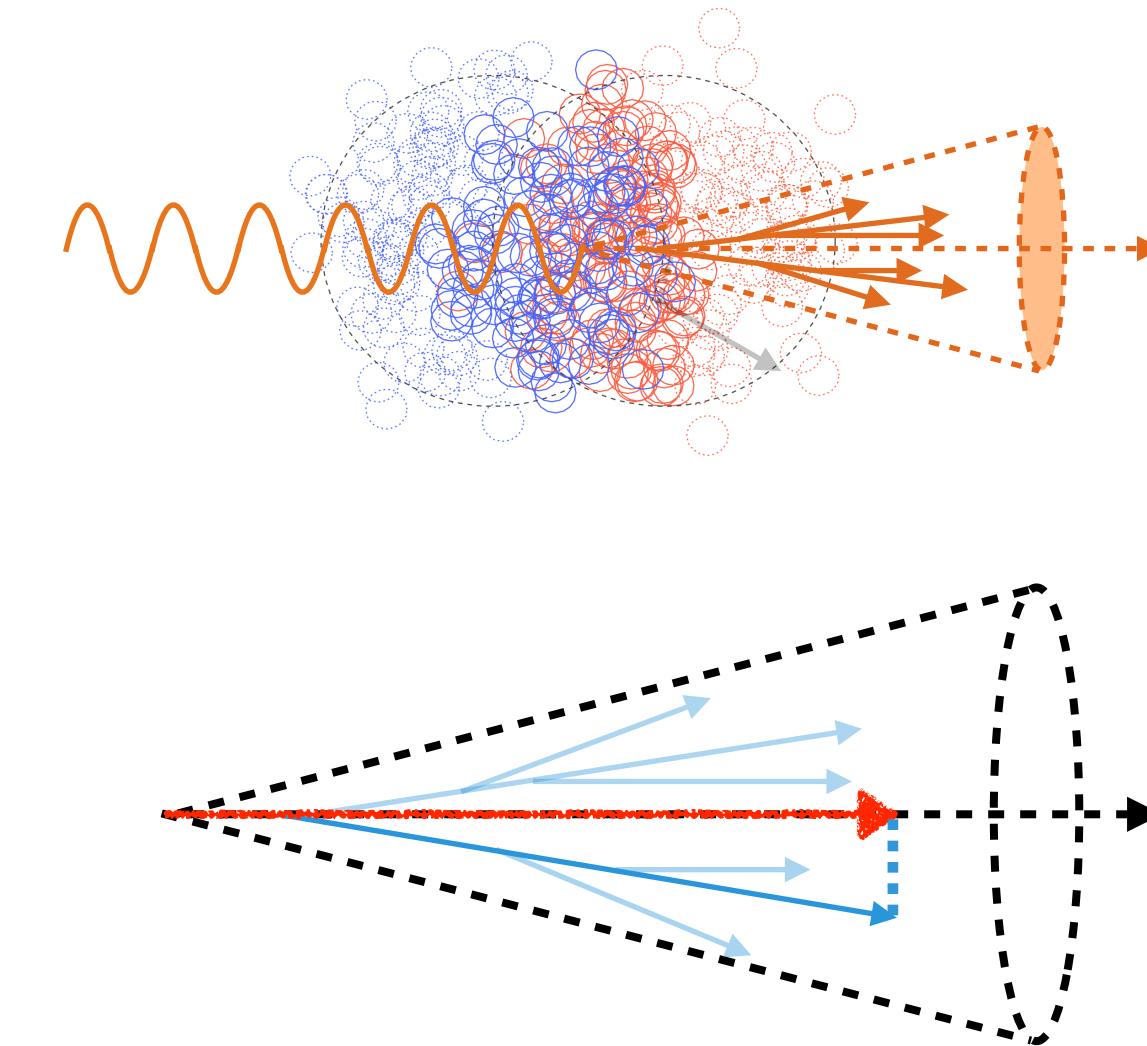
PRL 121 (2018) 242301

- enhancement of low- p_T particles, depletion of high- p_T particles



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

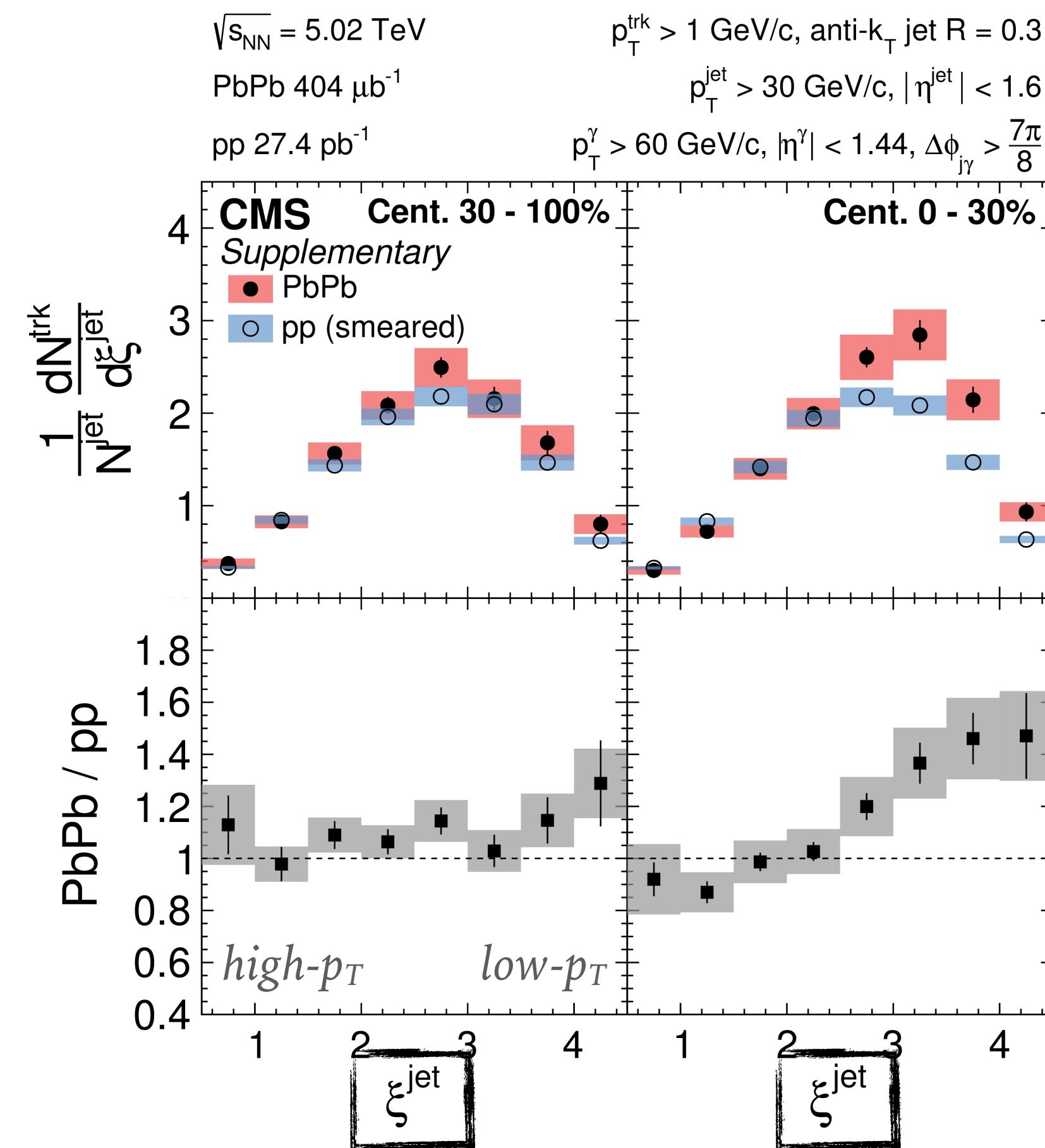
projection of track momentum onto jet axis



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PRL 121 (2018) 242301

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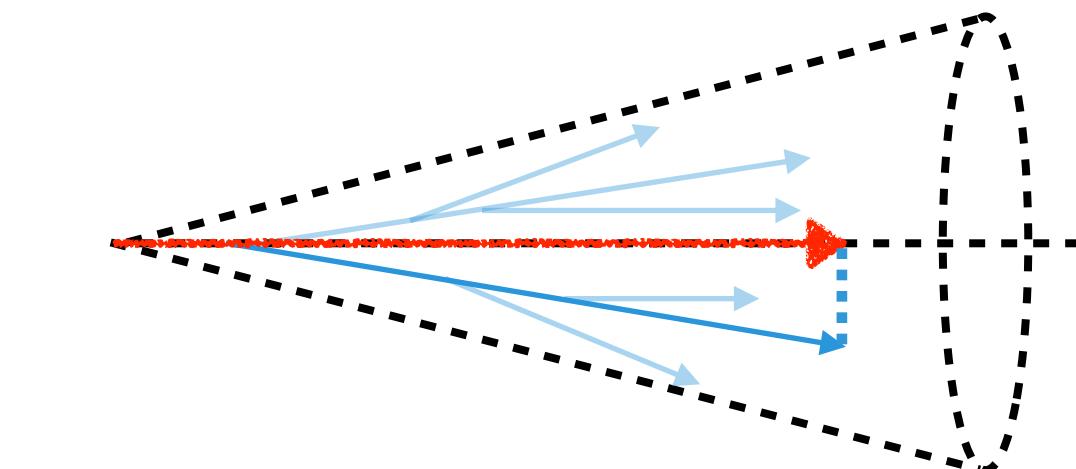
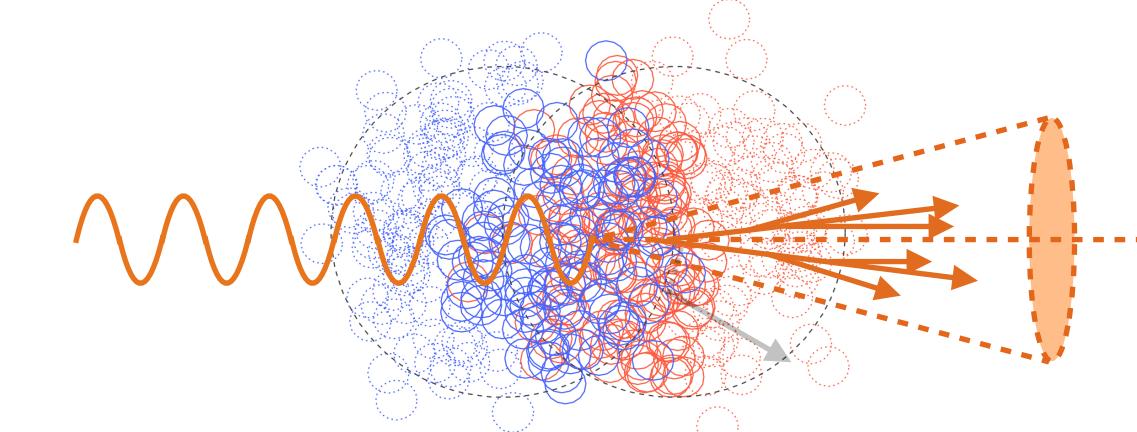


$$\xi_{\text{jet}}^{\gamma} = \ln \frac{|\mathbf{p}_{\text{jet}}|^2}{\mathbf{p}_{\text{trk}} \cdot \mathbf{p}_{\text{jet}}}$$

projection of track momentum onto jet axis

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

projection of track transverse momentum onto photon axis



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

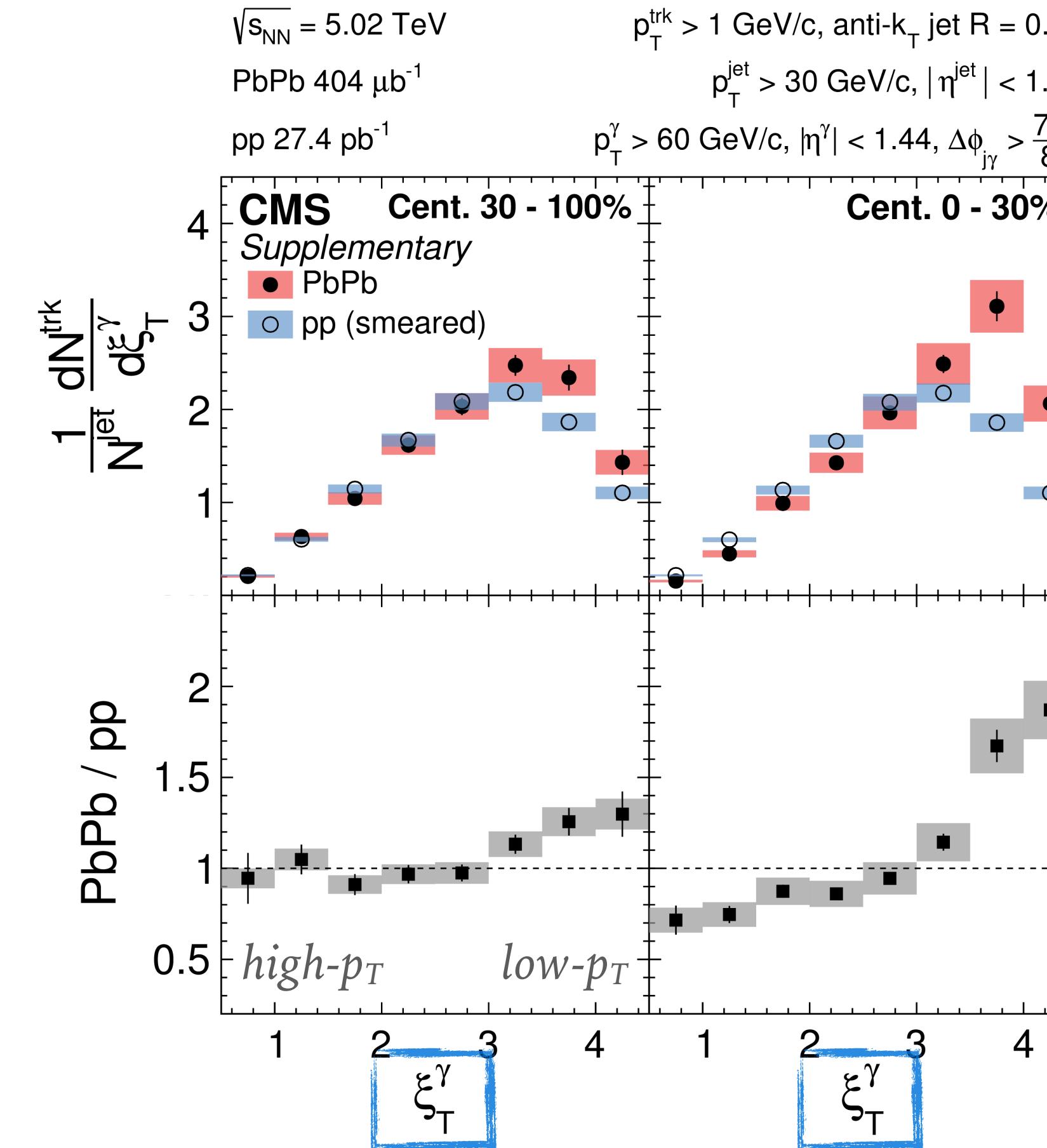
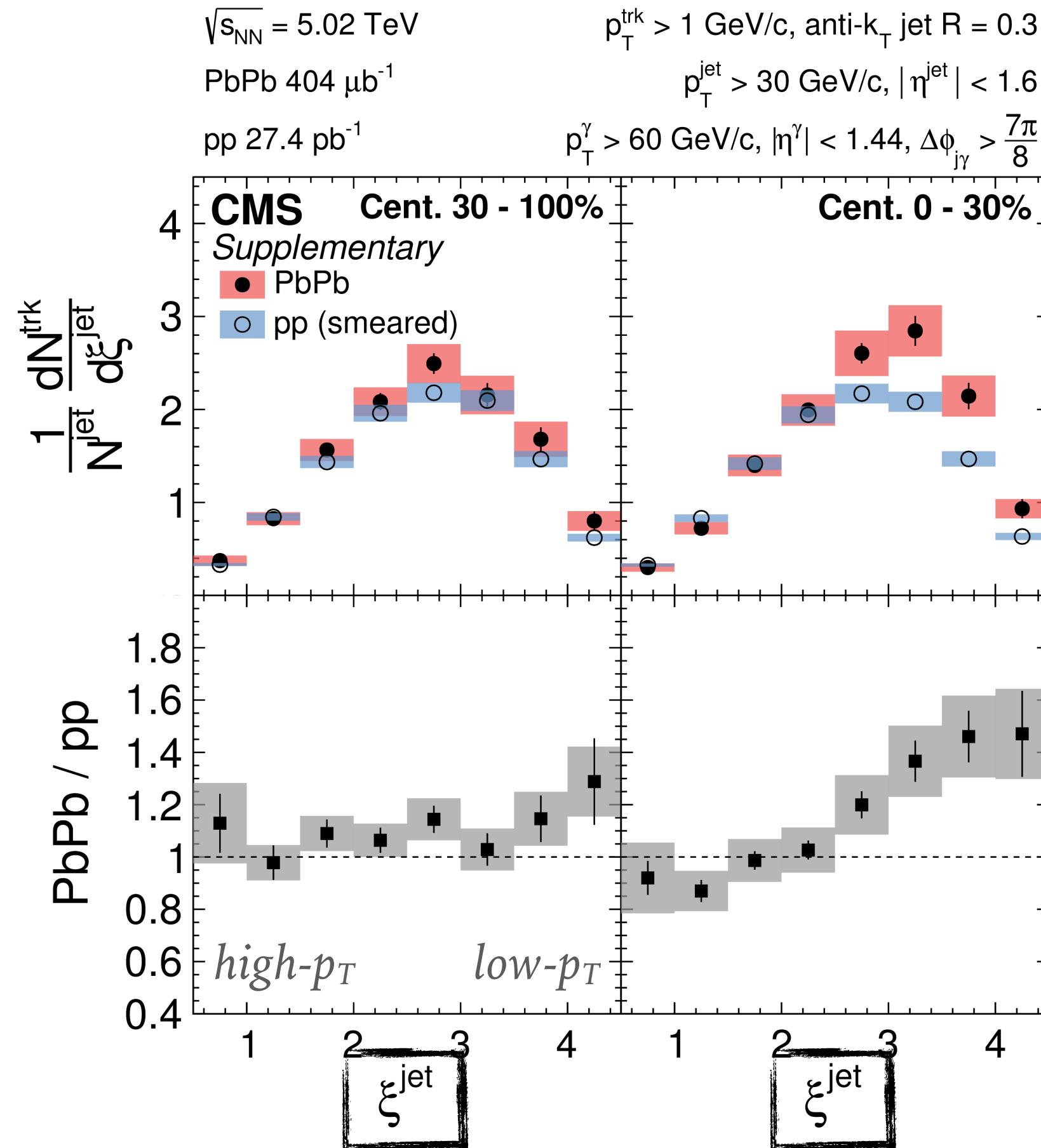
$$\xi_{\text{T}}^{\gamma} = \ln \frac{-|\mathbf{p}_{\text{T}}|^2}{\mathbf{p}_{\text{trk}} \cdot \mathbf{p}_{\text{T}}}$$

projection of track transverse momentum onto photon axis

PHOTON-TAGGED JET FRAGMENTATION FUNCTION

PRL 121 (2018) 242301

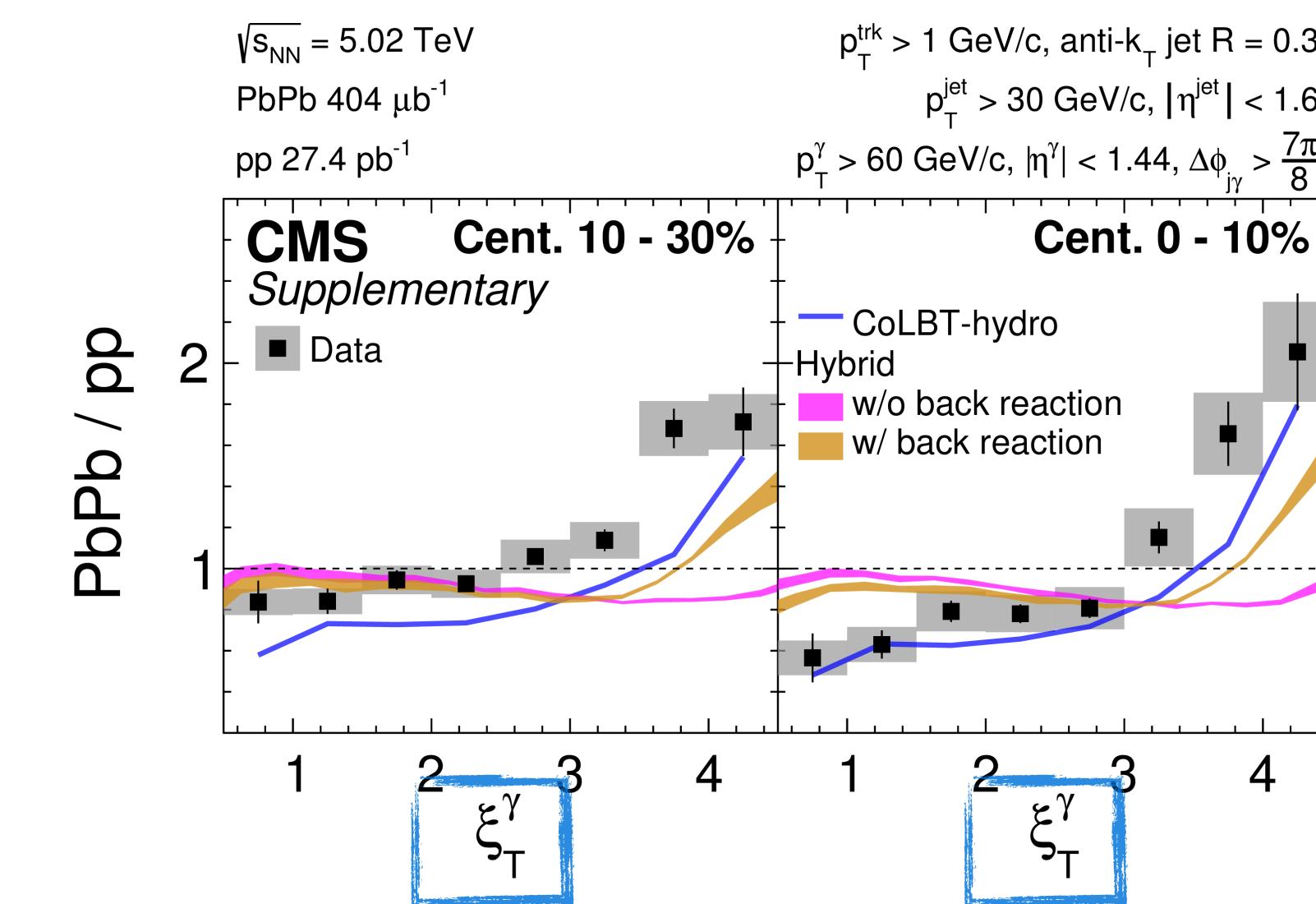
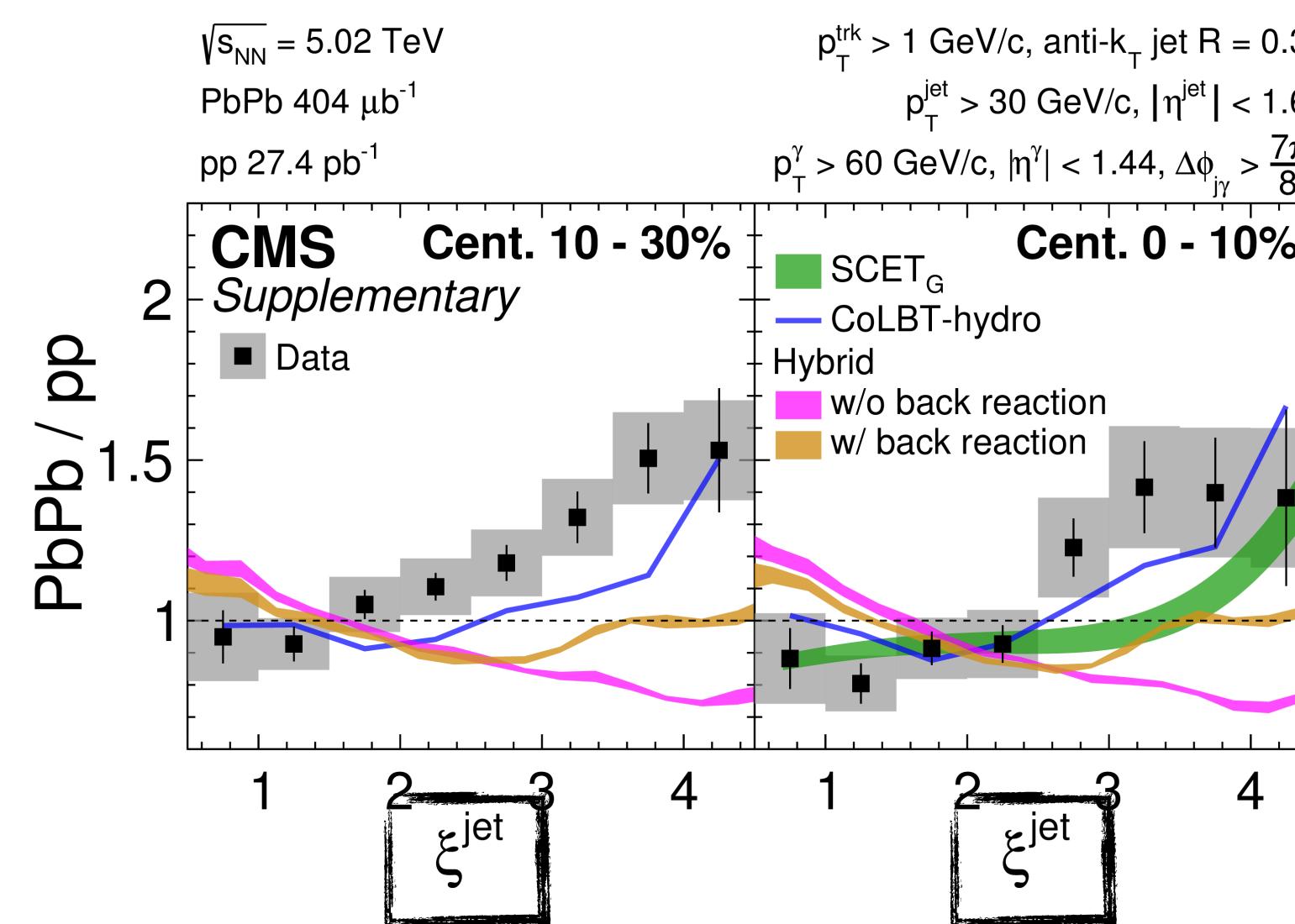
- stronger modification for ξ_T^γ than for ξ_{jet} - jets are quenched



MODEL PREDICTIONS (FRAGMENTATION FUNCTION)

PRL 121 (2018) 242301

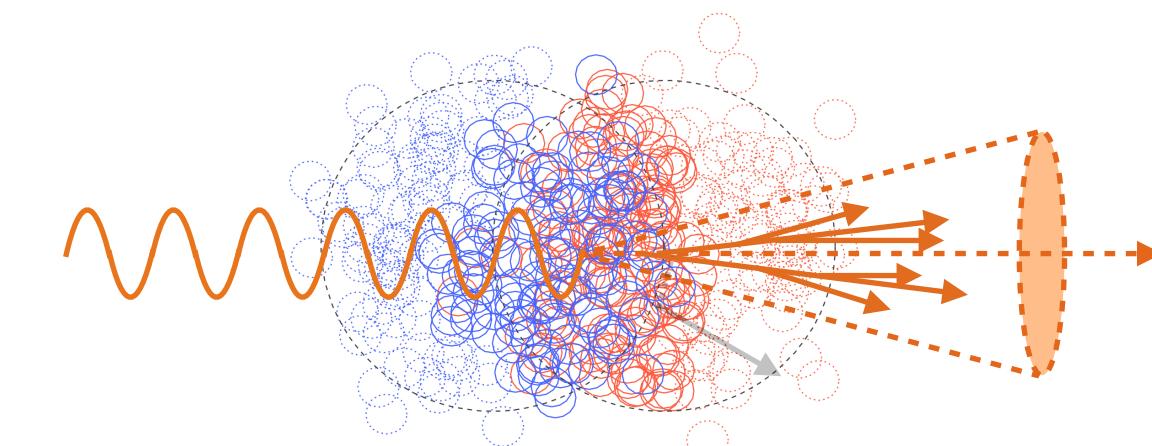
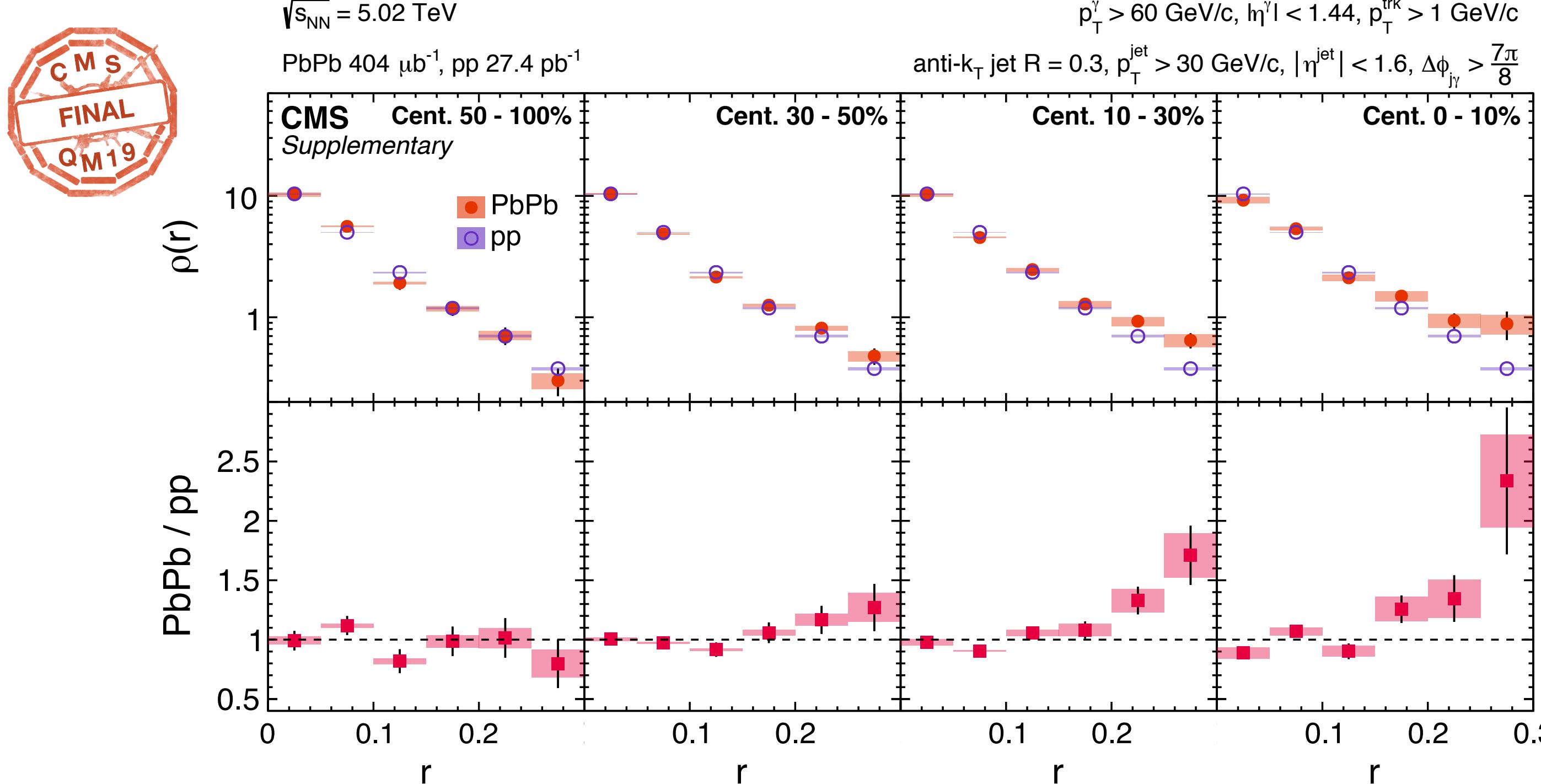
- models describe data to different extents
 - enhancement at large ξ (low- p_T particles) underestimated
 - $SCET_G$ and CoLBT-hydro models describe trend of observables
 - back reaction improves agreement of hybrid model with data



PHOTON-TAGGED JET SHAPE

PRL 122 (2019) 152001

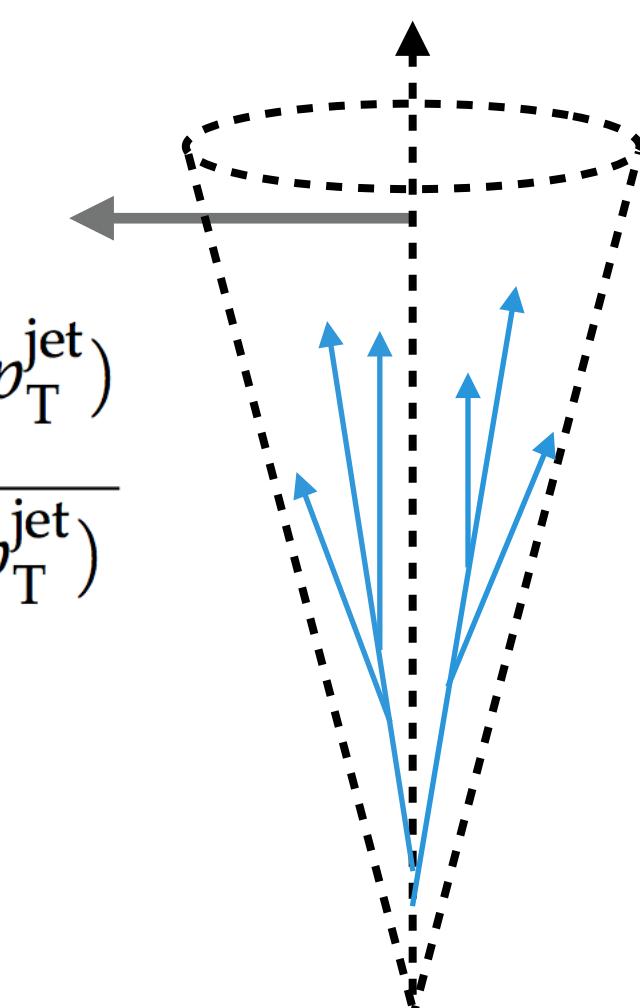
- distribution of jet energy in transverse direction with respect to jet axis
 - complementary information to jet fragmentation function



$$r = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

$$\rho(r) = \frac{1}{\delta r} \sum_{\text{jets}} \sum_{r_a < r < r_b} \left(\frac{p_T^{\text{trk}}}{p_T^{\text{jet}}} \right)$$

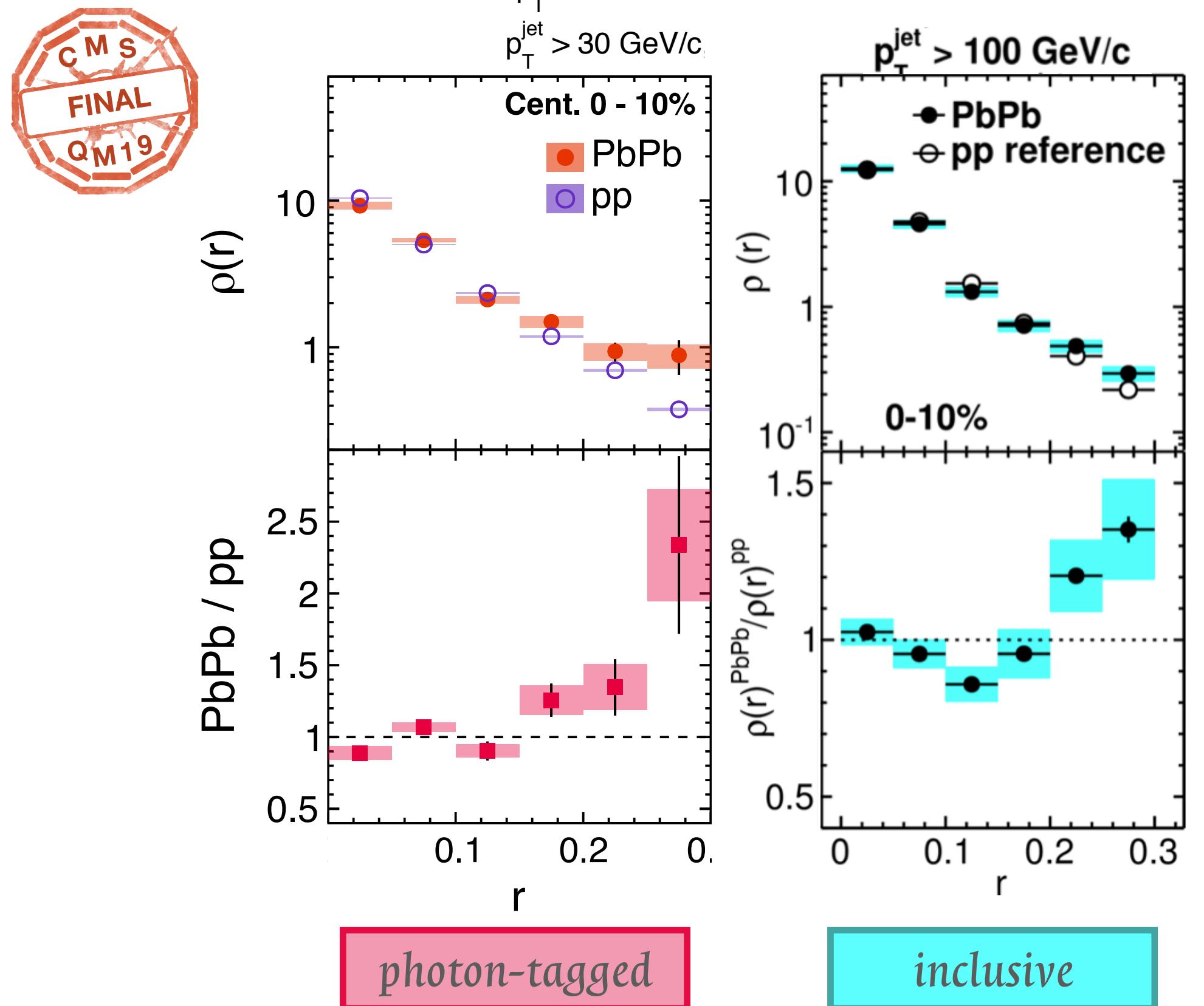
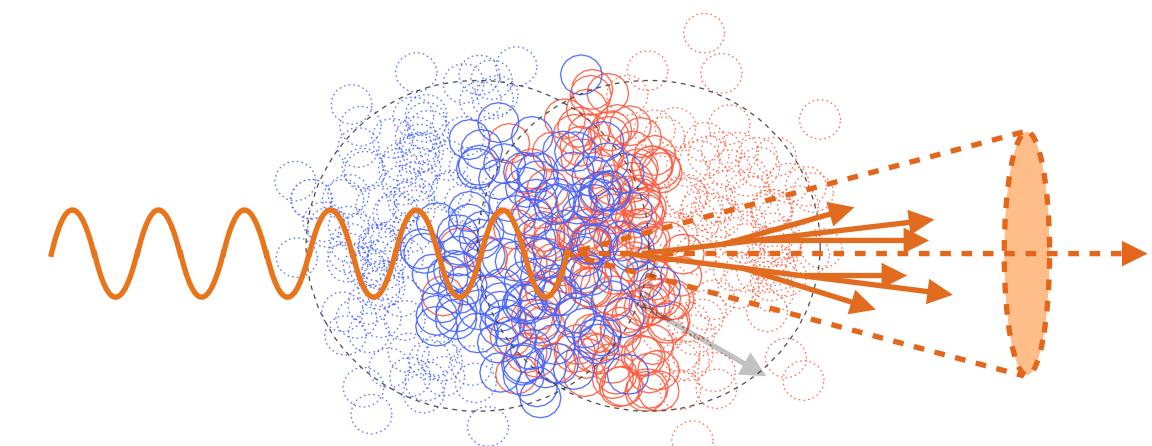
**p_T -weighted
track distribution
around axis**



PHOTON-TAGGED JET SHAPE (COMPARISONS)

PRL 122 (2019) 152001

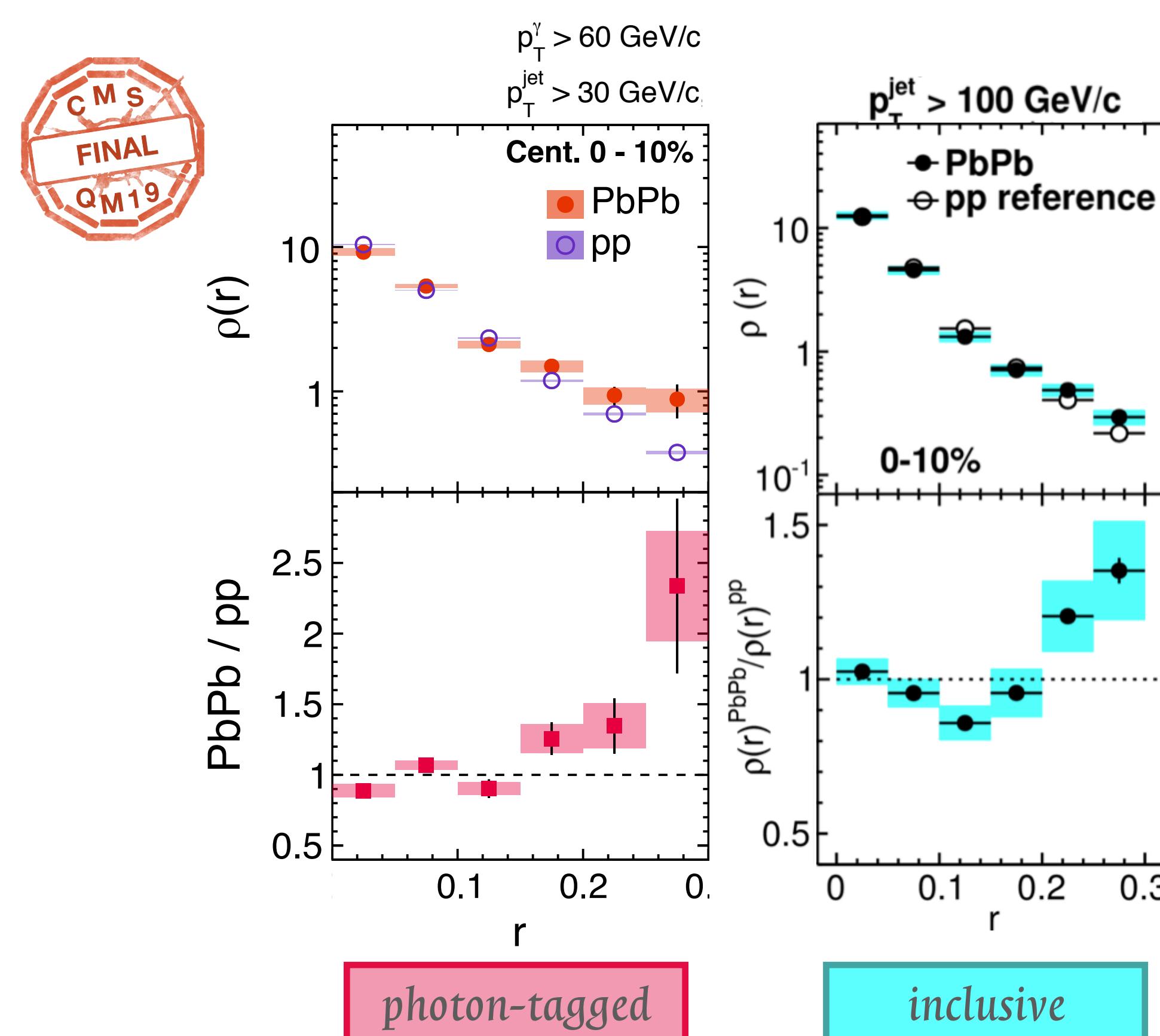
- comparison to inclusive jet shapes - no dip at intermediate r
 - increased quark/gluon ratio
 - lower jet p_T threshold - jets lose more energy



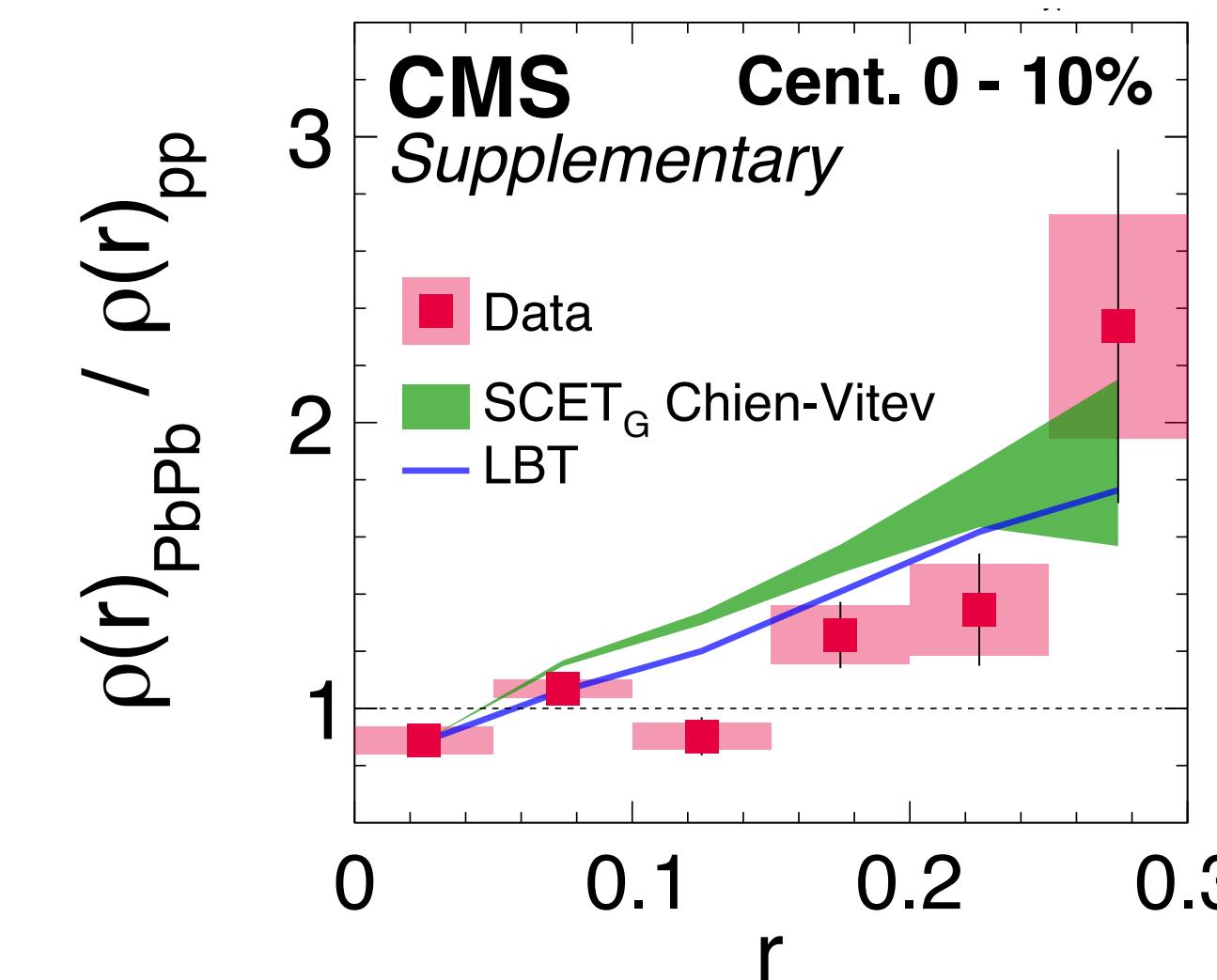
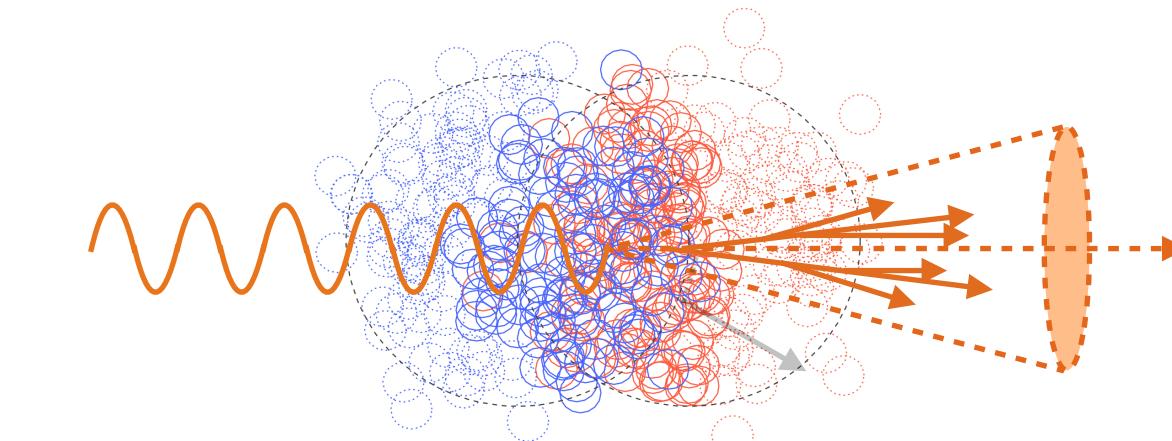
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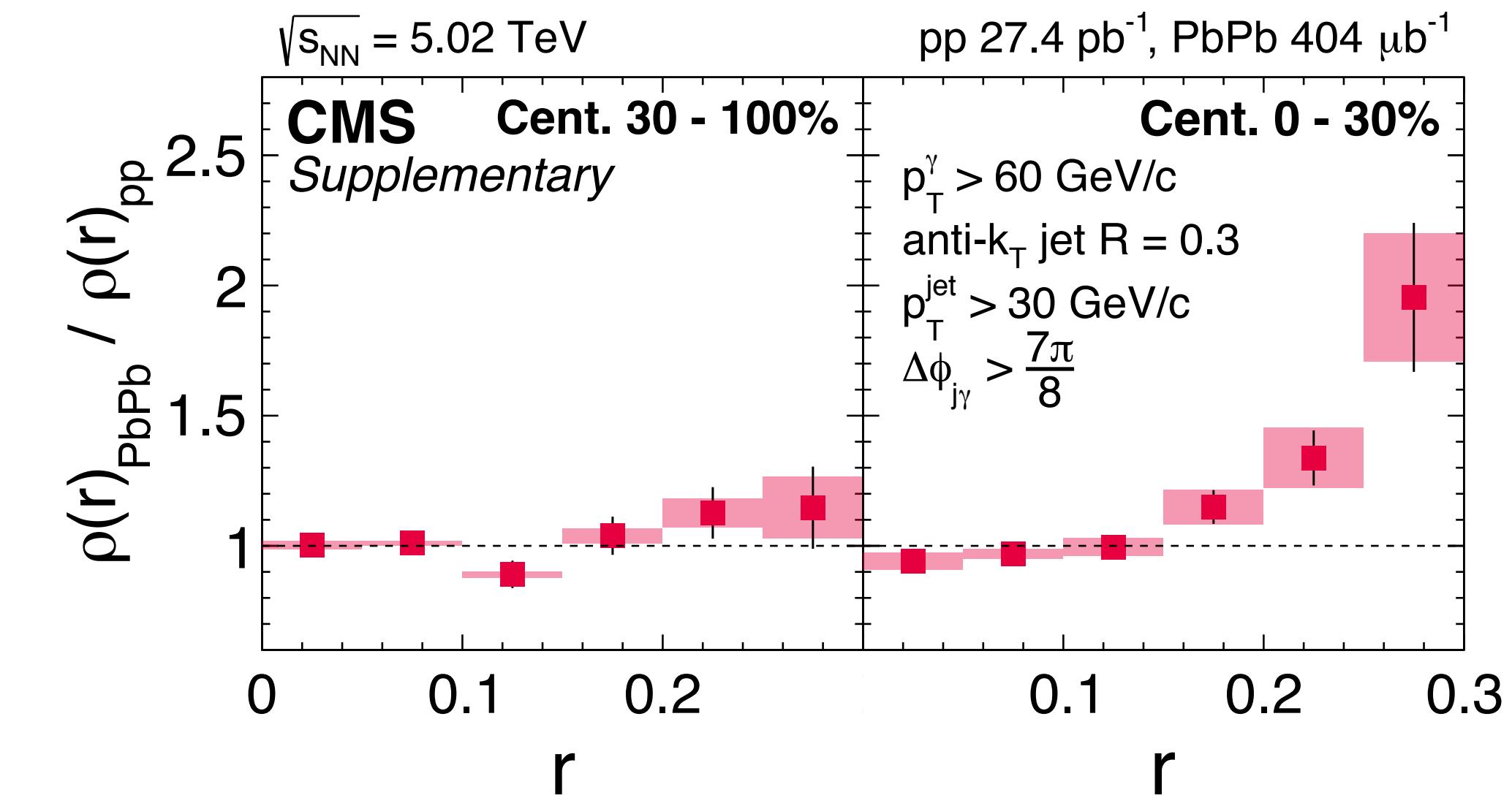
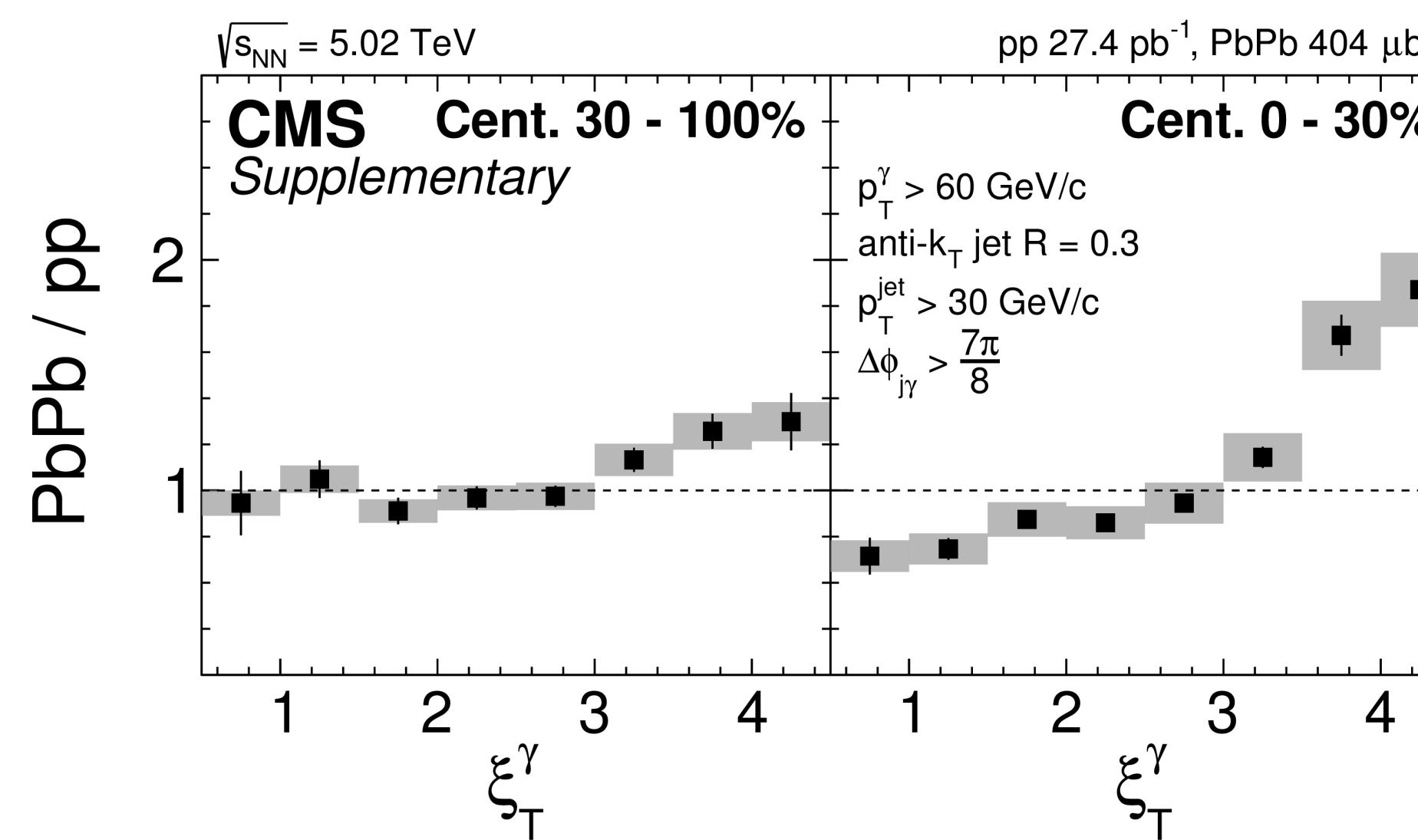


- comparison to models
 - SCET_G/LBT both describe trend
 - different mechanisms, interpretations



SUMMARY

- jet substructure is a good probe of parton modifications and medium response
 - EW bosons constrain initial parton momentum and quark/gluon fractions
- in-medium jet energy loss and modifications of jet fragmentation functions and jet shape
 - relatively unmodified jet core
 - depletion of intermediate p_T particles
 - enhancement of low p_T particles away from the jet axis

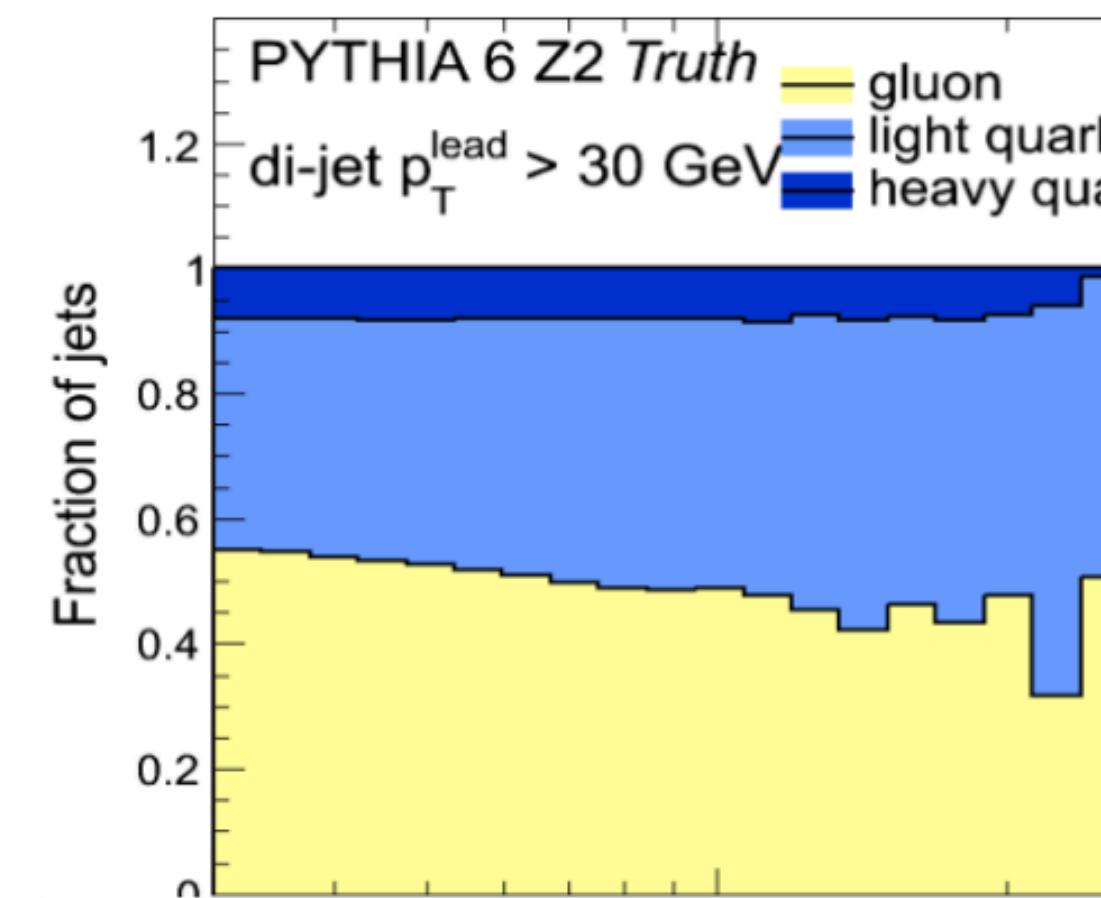


This work is supported by the DOE Office of Science

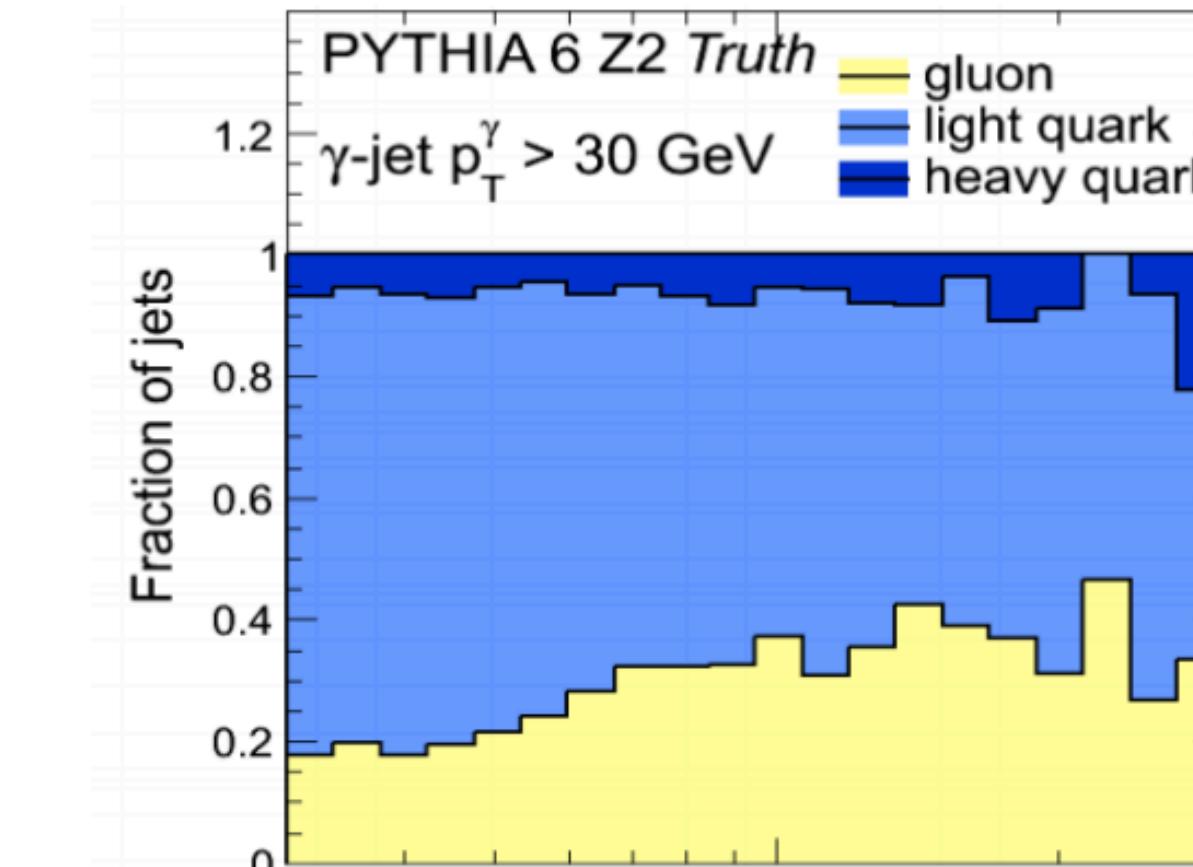
BACKUP

QUARK/GLUON FRACTIONS

dijets



γ -jets



Z-jets

