Studies of photon-tagged jets with the CMS experiment

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Soft Jet 2024

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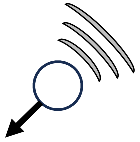
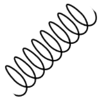
MITHIG's work was supported by US DOE-NP

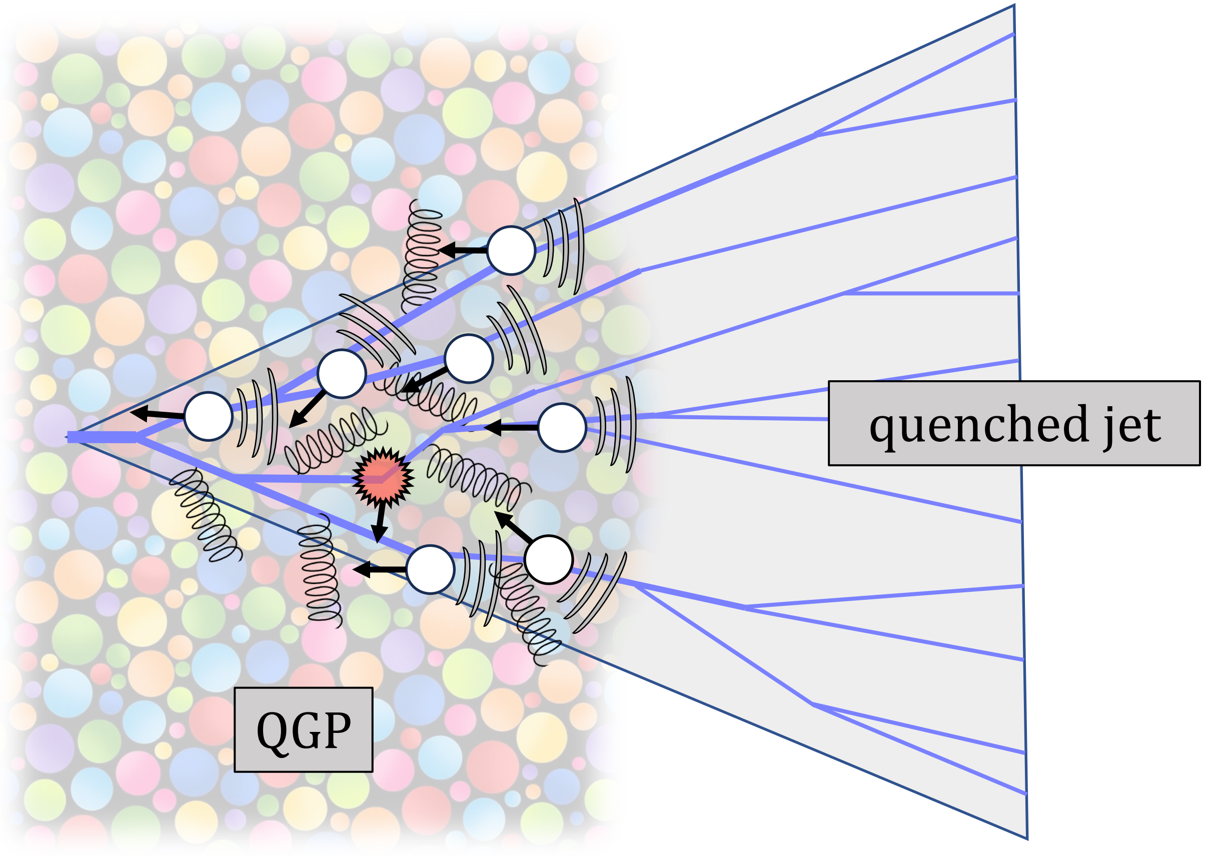
Jet interactions with the QGP

Jet quenching causes modification of the jet radiation pattern

- **Collisional energy loss** 
  - from 2 → 2 scatterings with medium
- **Radiative energy loss** 
  - from medium-induced gluon radiation

Interactions induce wake in the QGP

How can we use jets to learn about the QGP?

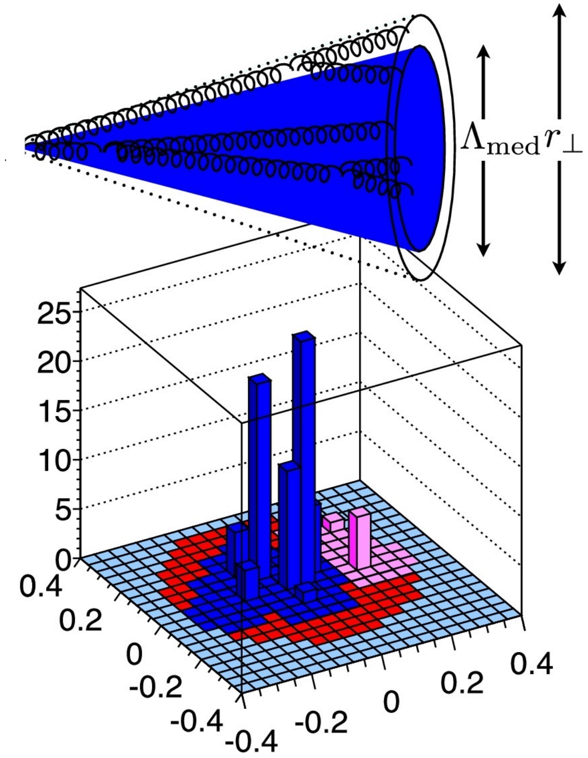


Based on figure from Yen-Jie

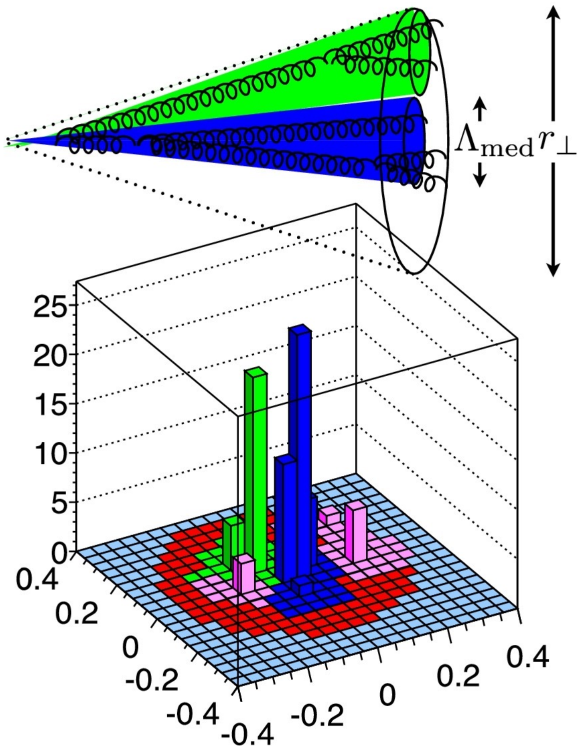
Color coherence

- **Medium resolution length** affects if jet constituents interact a single charge or multiple charges
- Modulates differences in quark and gluon jet quenching
- Jets which have more resolved constituents or are wider may be more strongly quenched

resolved as a single charge
→ less quenching

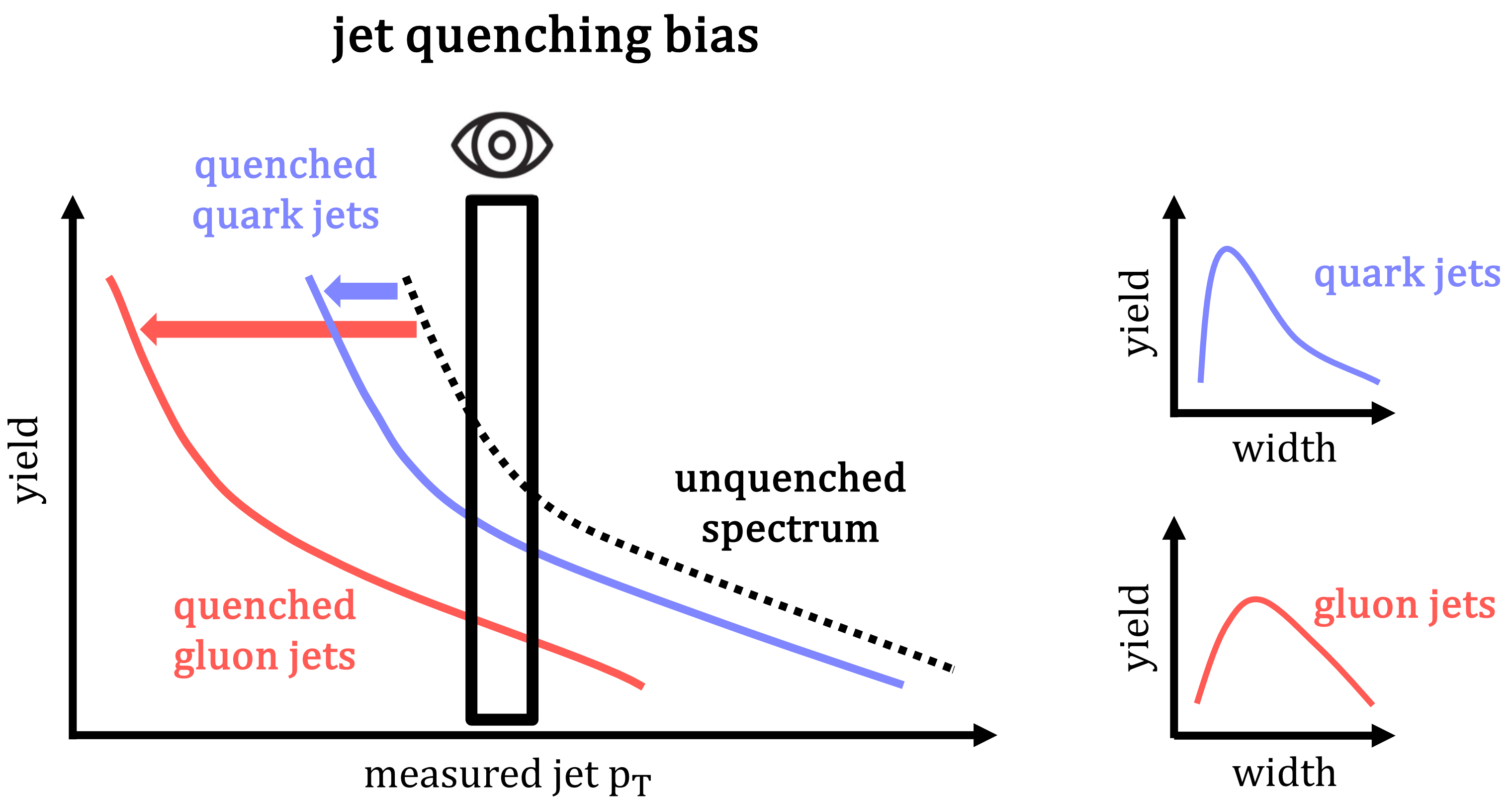


resolved as two charges
→ more quenching



Diagrams from
J. Casalderrey-Solana,
Y. Mehtar-Tani,
C. A. Salgado,
K. Tywoniuk:
arXiv:1210.7765

Selection bias



Based on figure from CMS: PAS-HIN-23-001

- Gluon jets (wider) more strongly quenched than quark jets (narrower) due to color factor

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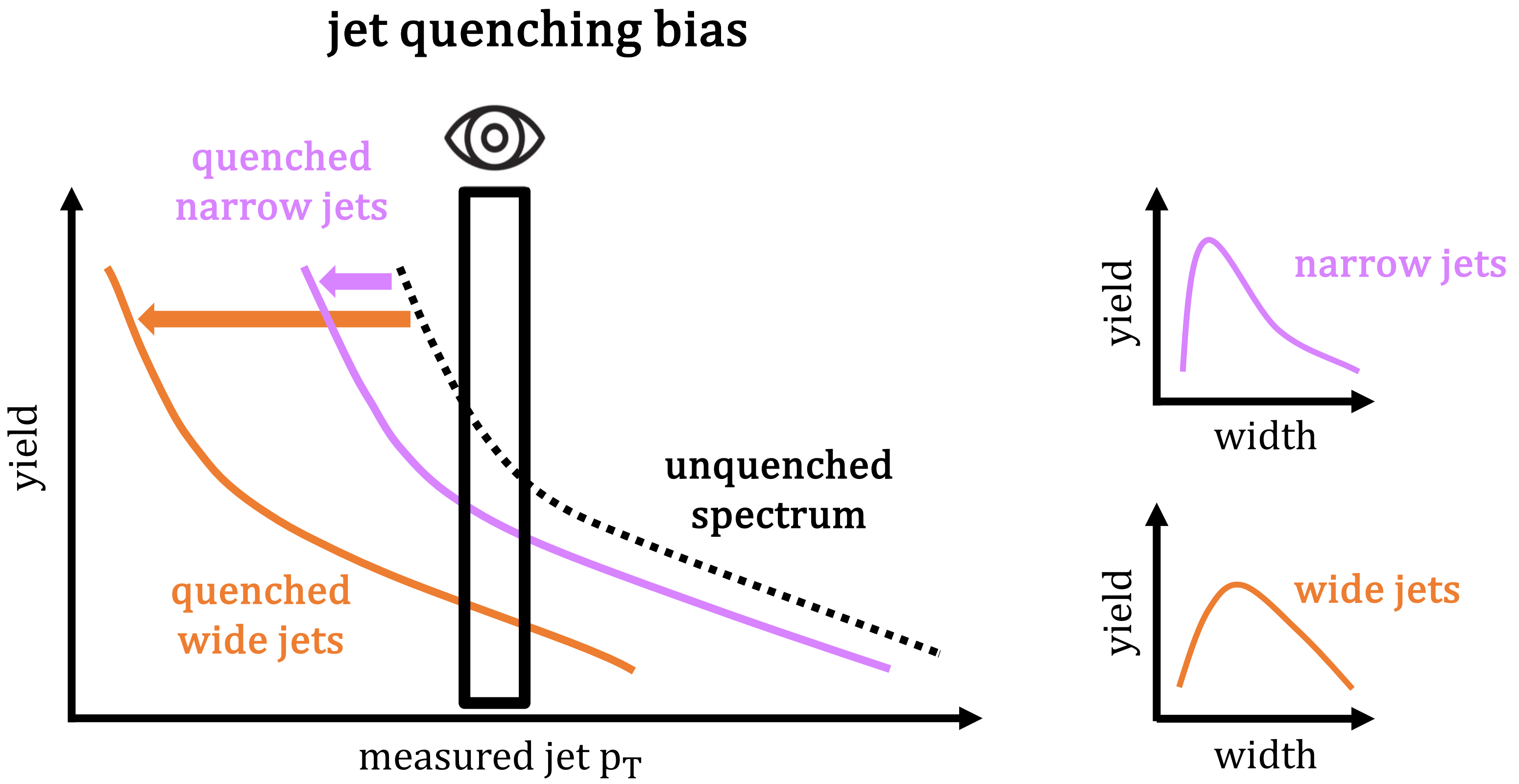

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- Broader jets may also be **more quenched** than narrower jets due to **finite** resolution length

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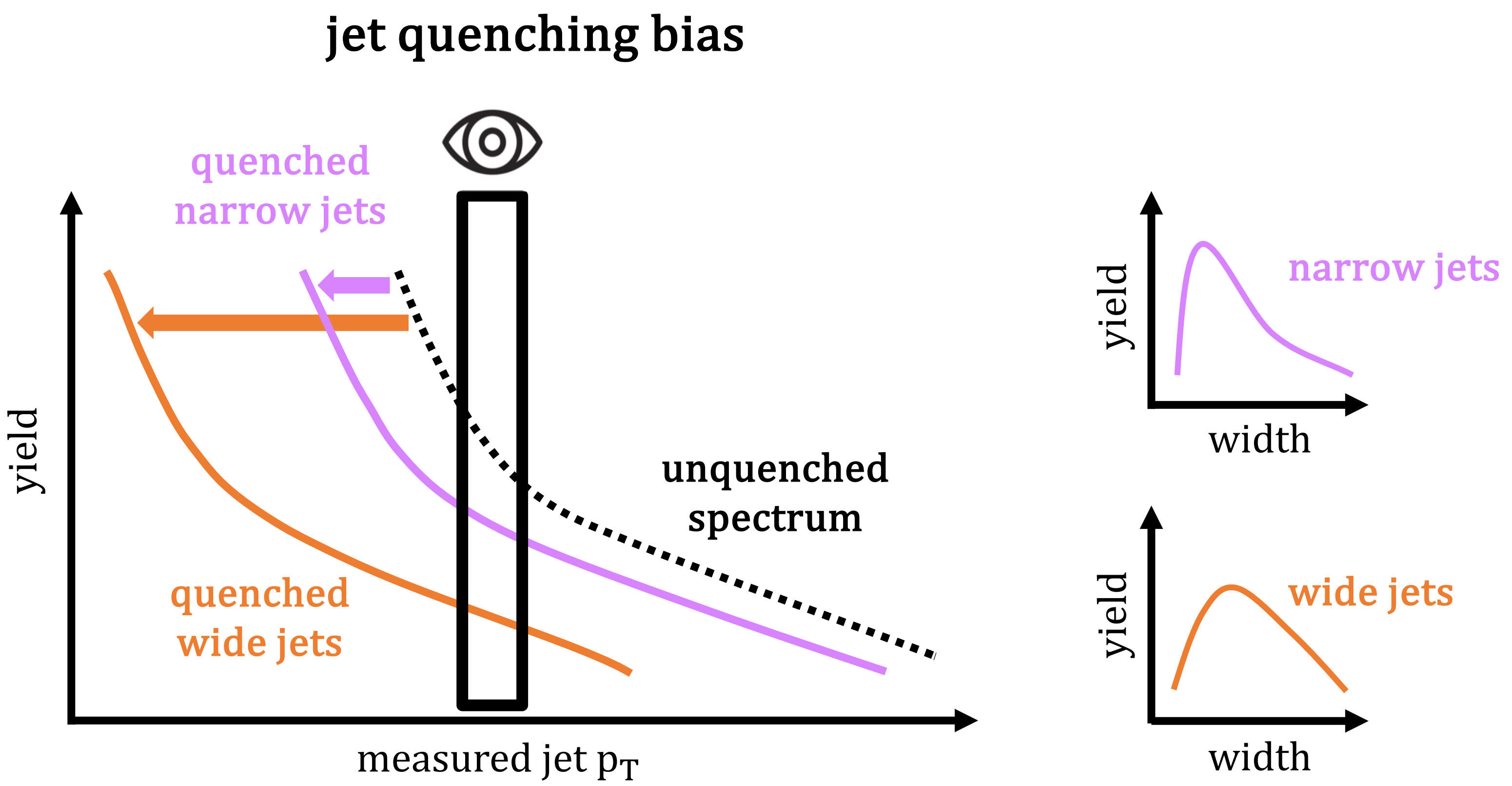

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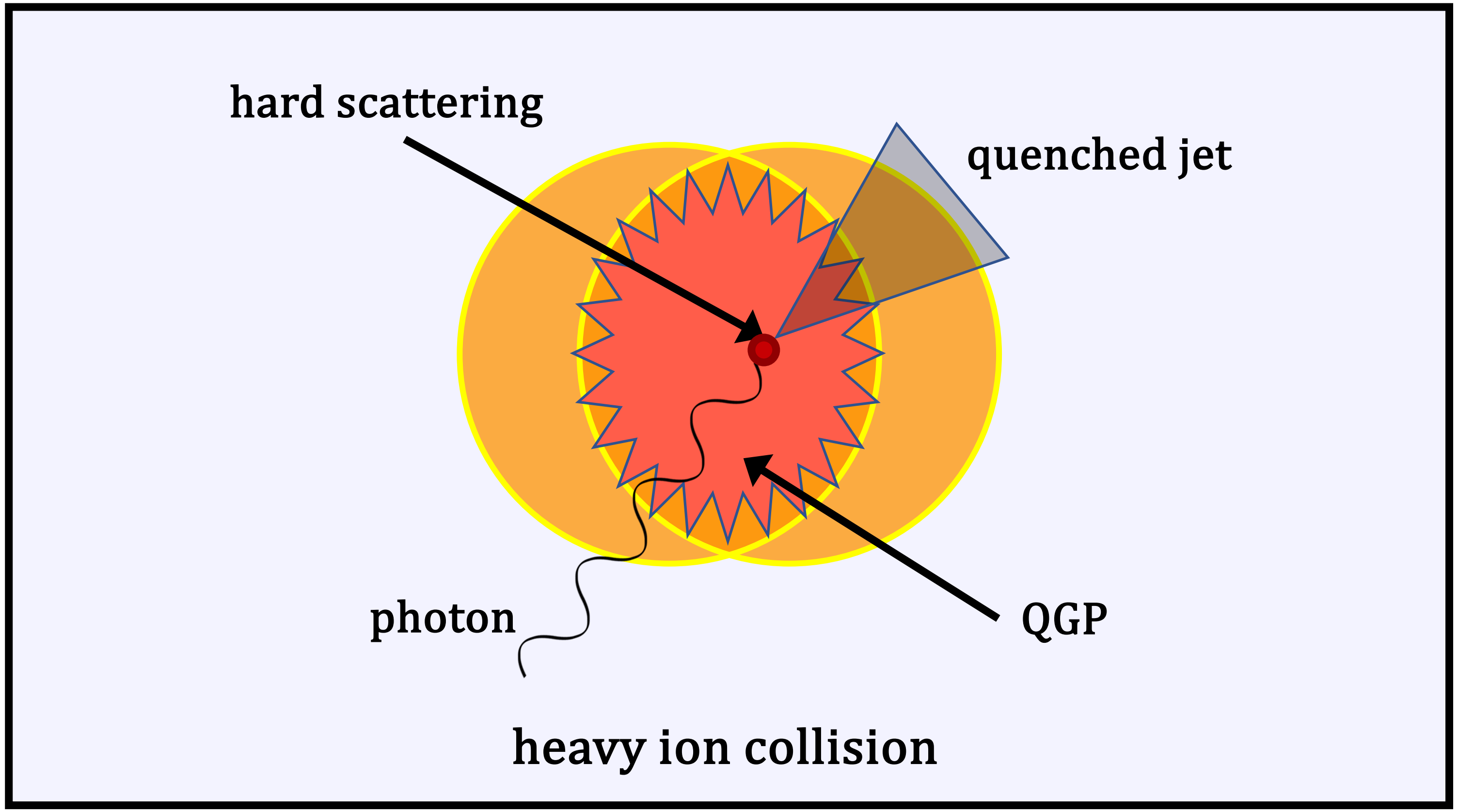
- Gluon jets (wider) more strongly quenched than quark jets (narrower) due to color factor
- Broader jets may also be **more quenched** than narrower jets due to **finite** resolution length
- Potential effect in a measured jet p_T bin → **higher population of narrow jets**

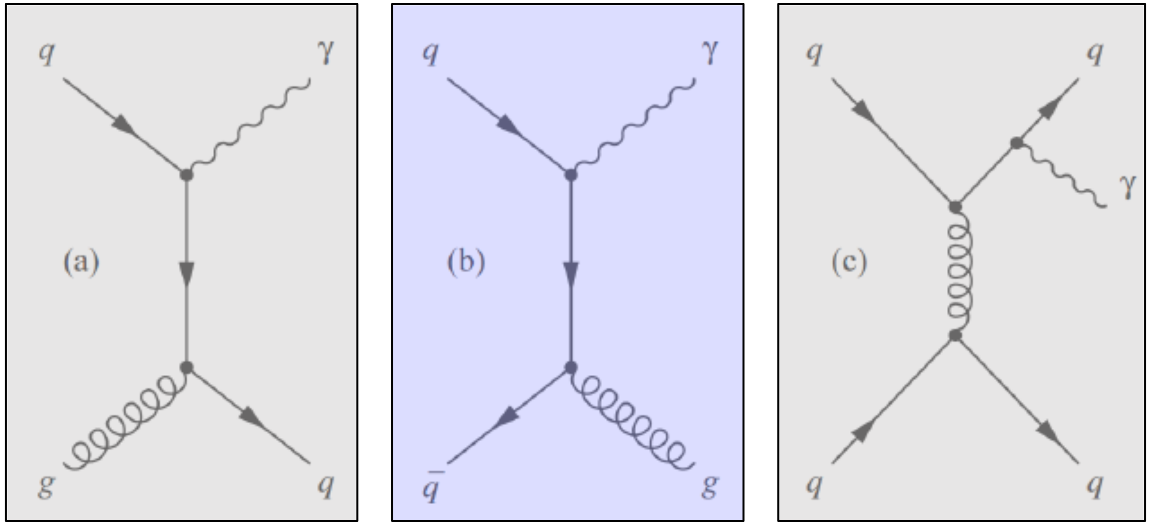
Photon-tagged jets



- Photon does not interact strongly with QGP → **does not lose energy**
- Photon energy ~ initial recoil parton p_T
- **No selection bias** comparing PbPb to pp … except we still have jet selections

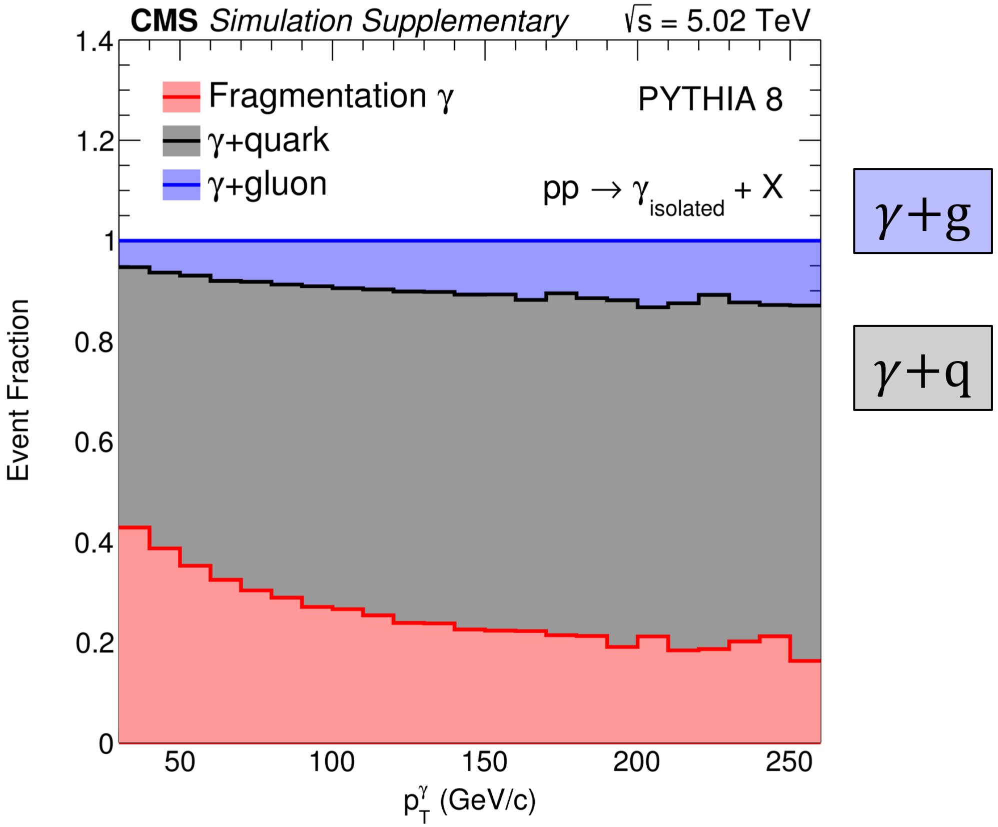
Photon production

- Photon production is well understood
- Dominated by photons recoiling from **quark jets**
- Con: impurity from jet fragmentation photons and neutral meson decays, must be subtracted
- Pro: more statistics than Z-bosons

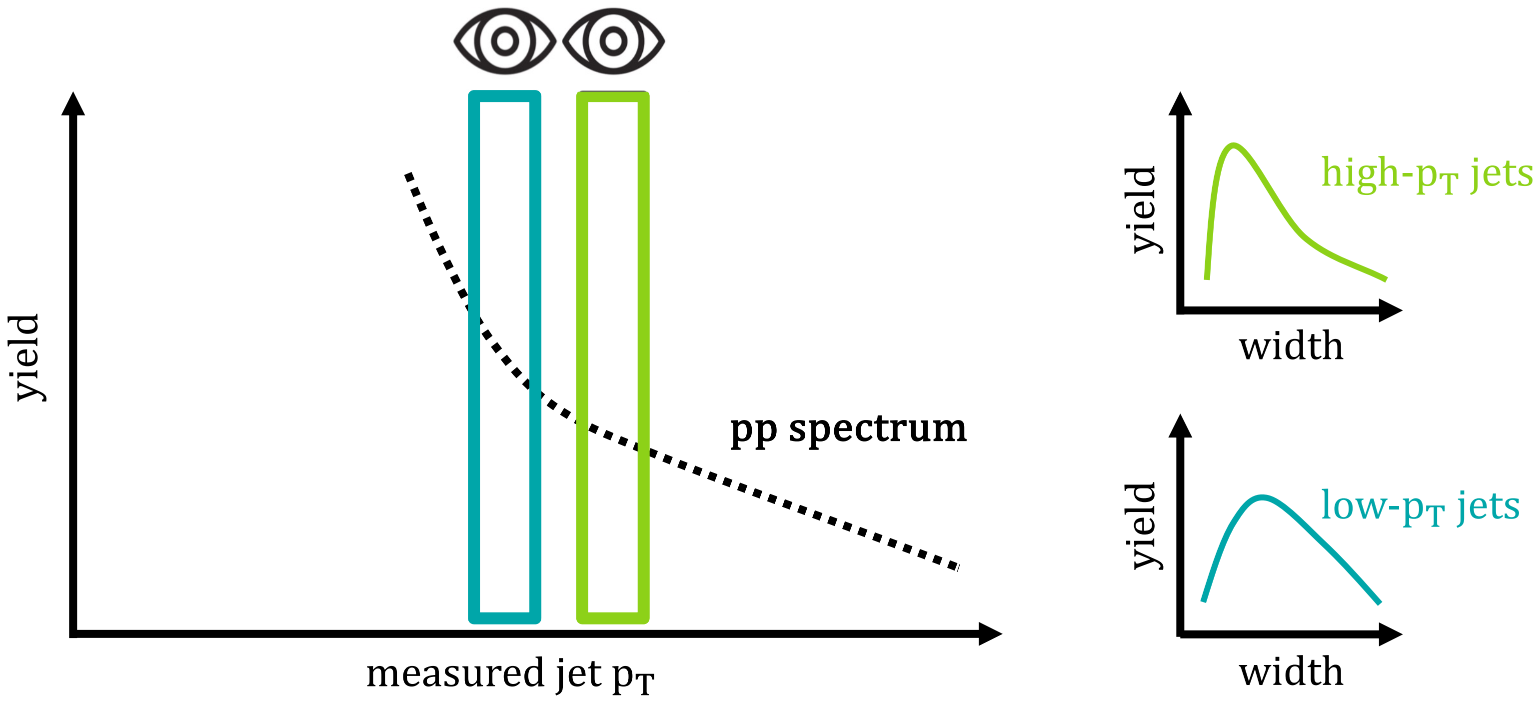


CMS: PRL 122 (2019) 152001

composition of events with isolated photons



Additional effects



Inspired by figure from Raghav

- Additional effect: higher-p_T jets are more boosted and thus **narrower** than lower-p_T jets

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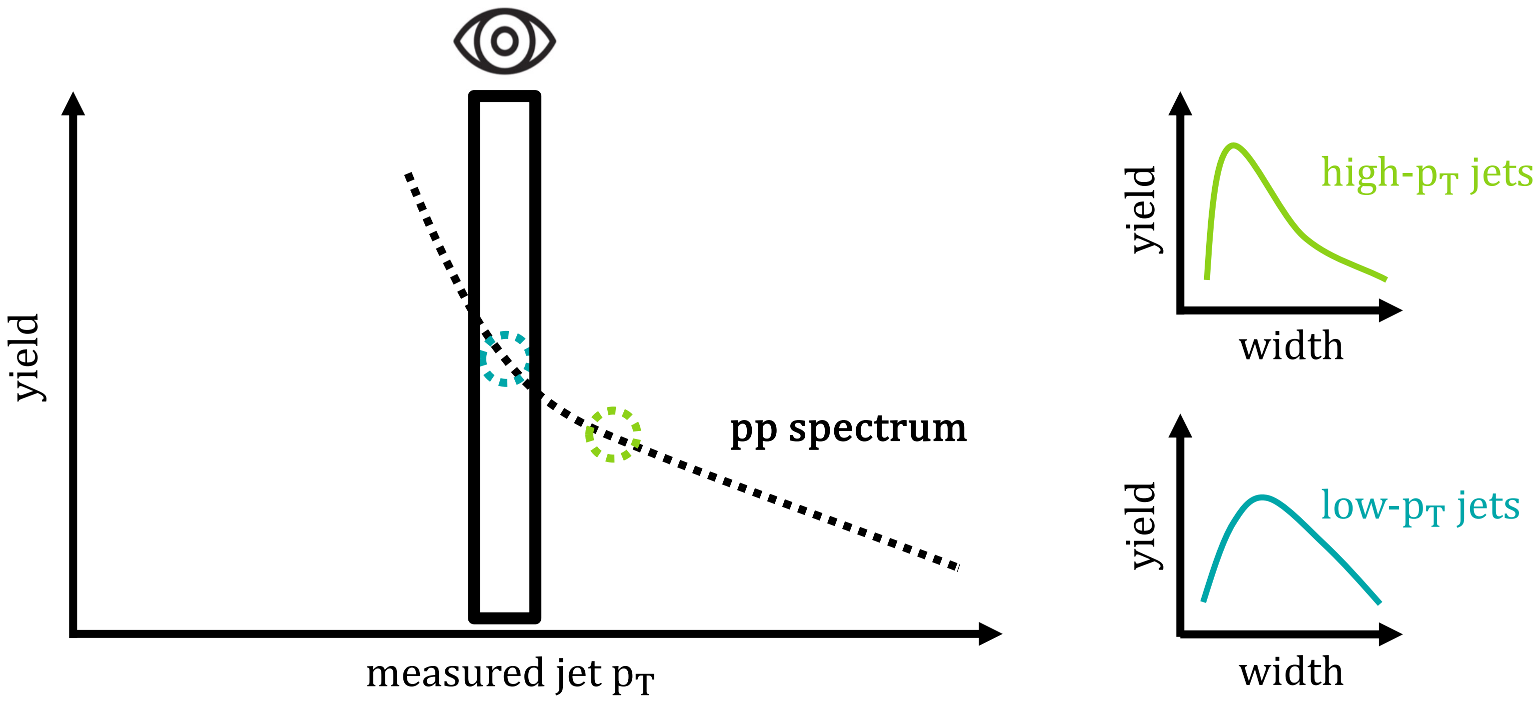

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- If these jets lose energy, could contribute to narrowing in a measured jet p_T bin

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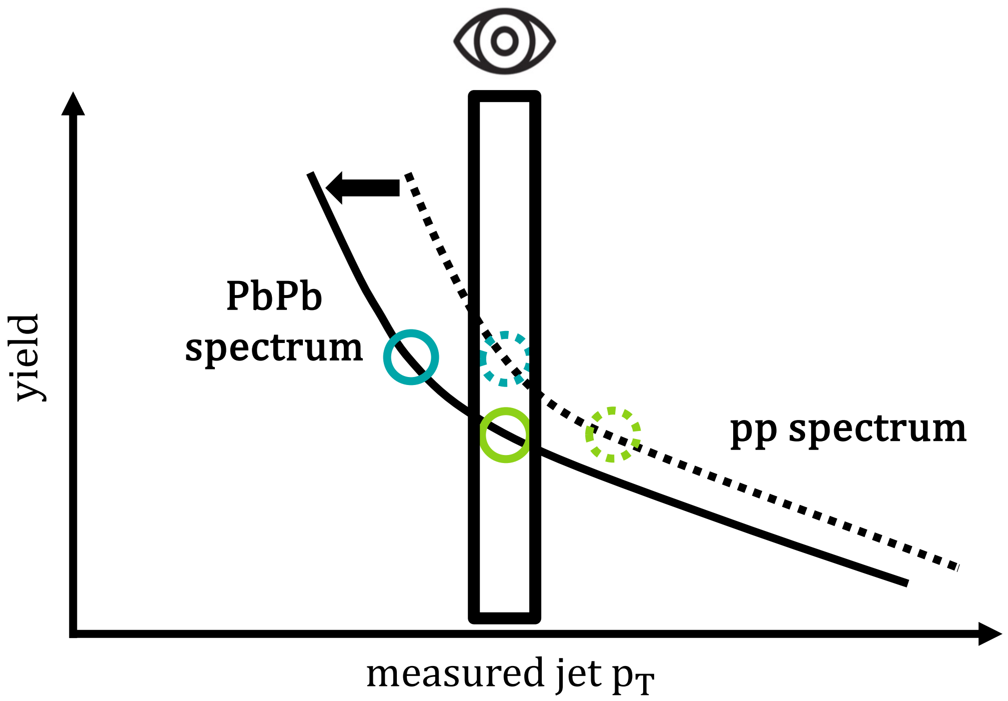
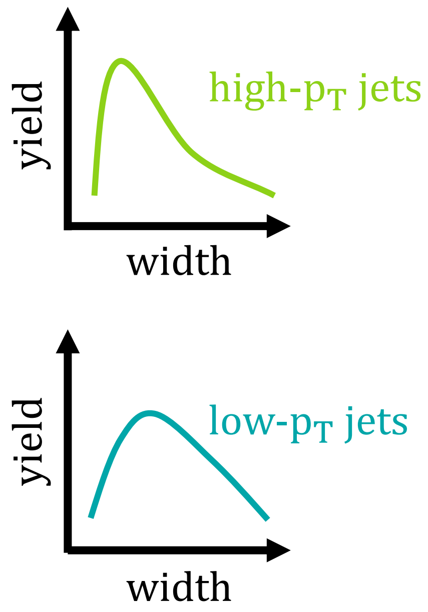




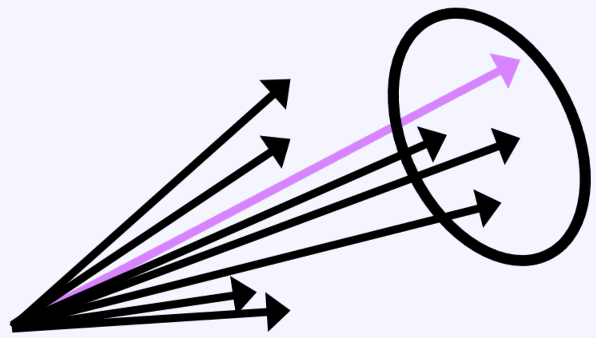
Inspired by figure from Raghav

- Additional effect: higher-p_T jets are more boosted and thus **narrower** than lower-p_T jets
- If these jets lose energy, could contribute to narrowing in a measured jet p_T bin
- How do we isolate the physical effects from medium interaction?

Jet substructure

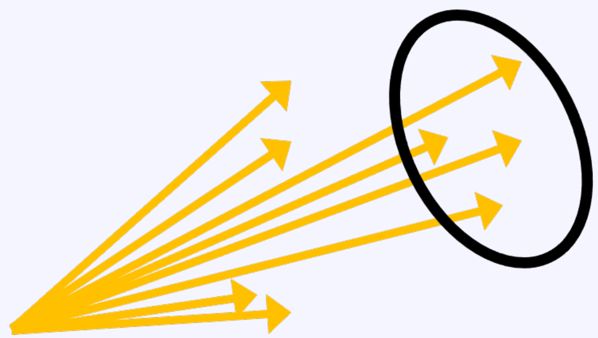
- Jet substructure observables map constituent four-momenta onto meaningful observables
- Different substructure observables are sensitive to different effects

Fragmentation functions



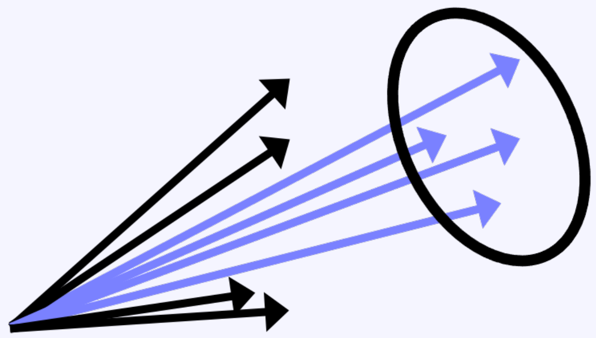
Single hadron

Classic jet shapes



All hadrons

Groomed observables



Subset of hadrons

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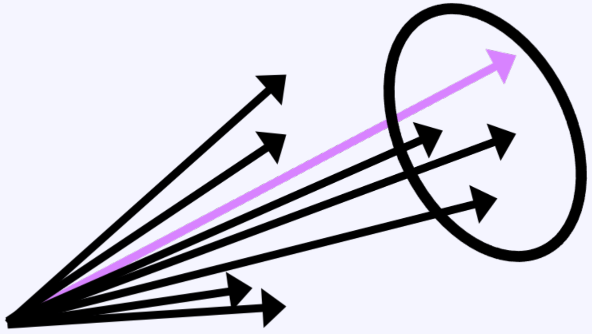

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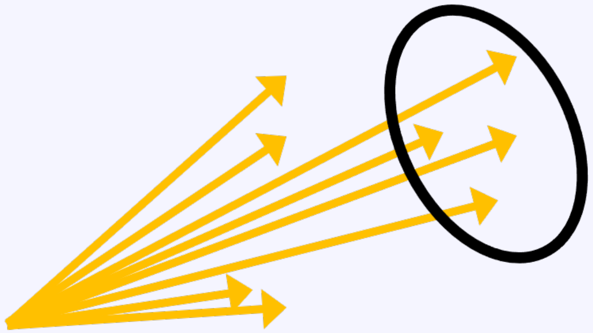

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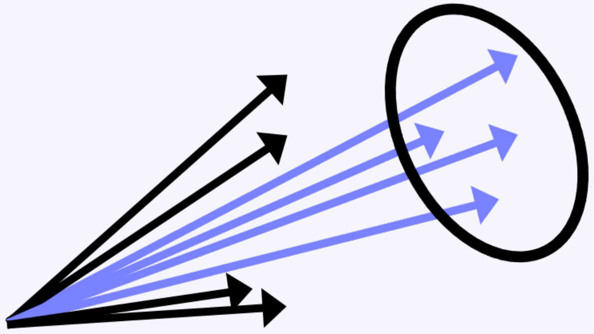

Subset of hadrons

longitudinal energy distribution

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photon-tagged

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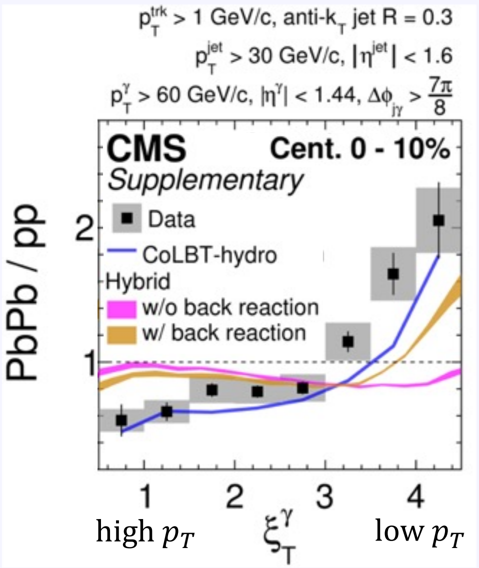

CMS: PRL 121 (2018) 242301

longitudinal energy distribution

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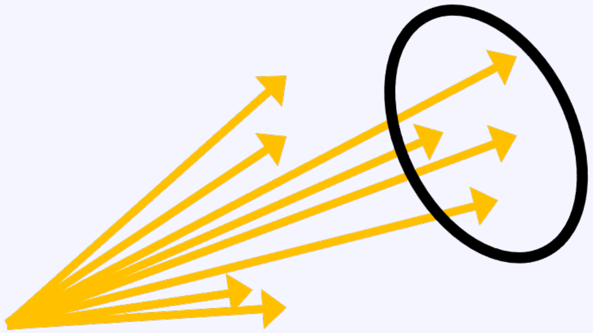

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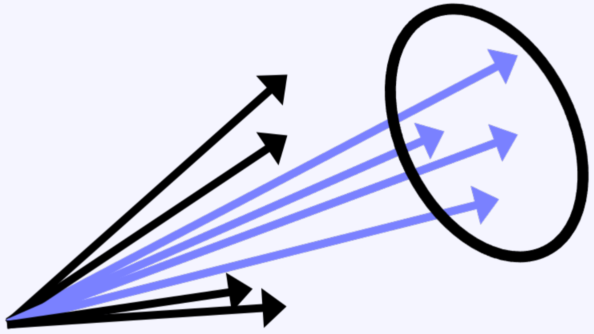

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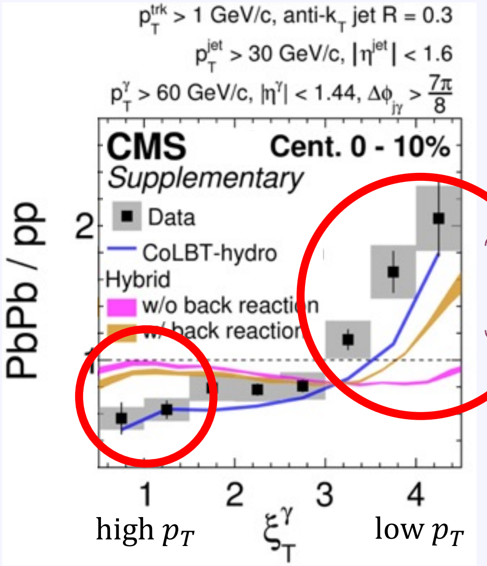

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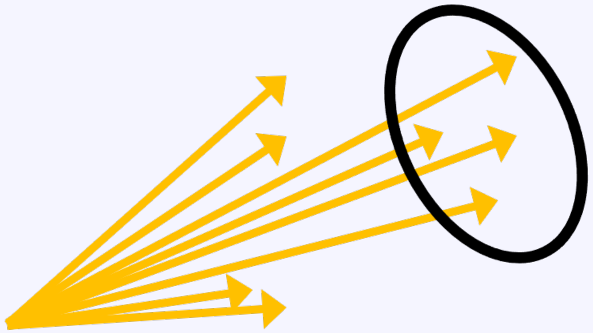

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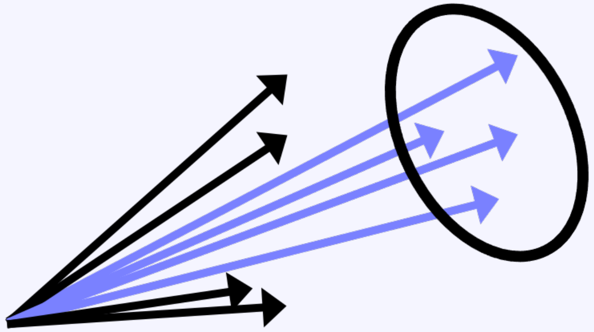

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inclusive

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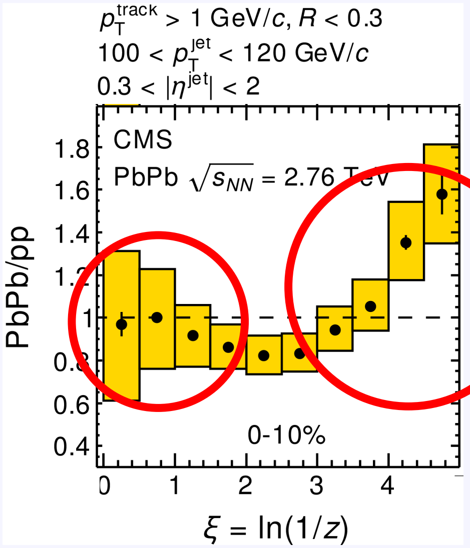

CMS: PRC 90 (2014) 024908

longitudinal energy distribution

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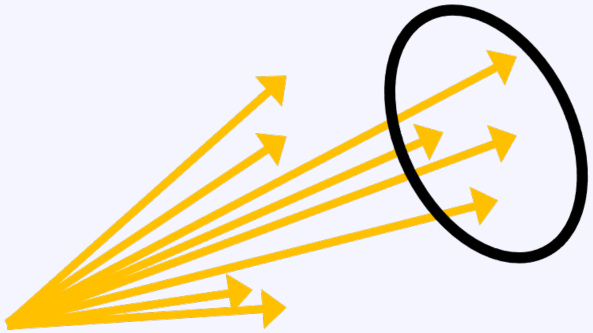

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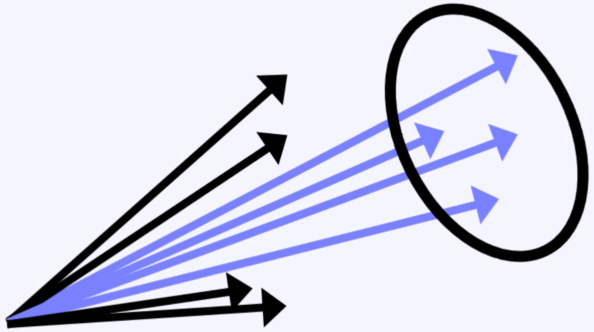

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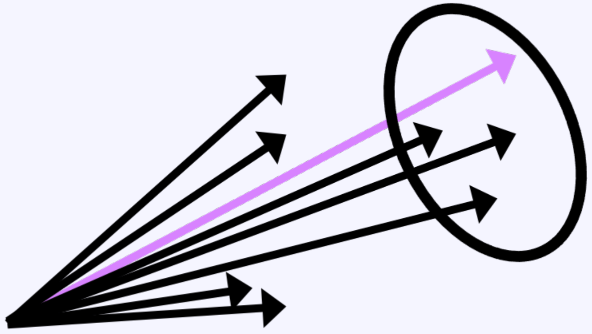

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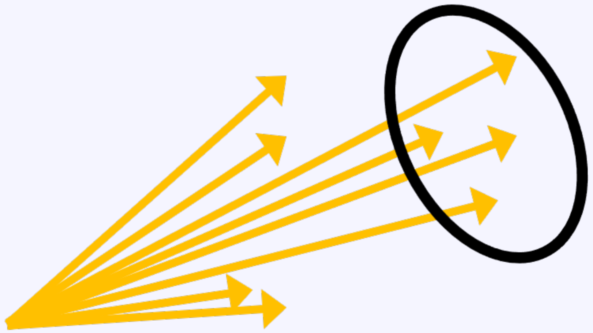

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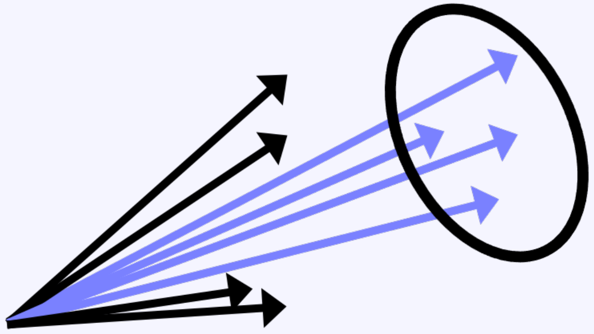

Subset of hadrons

transverse energy distribution

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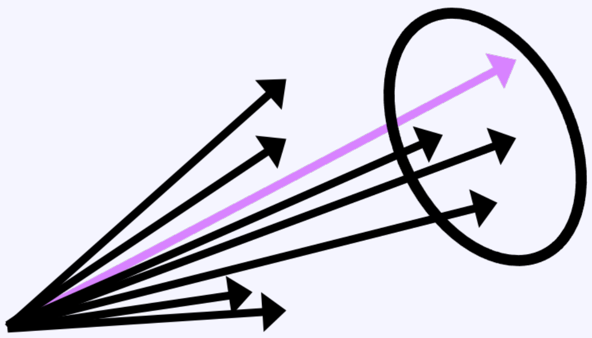

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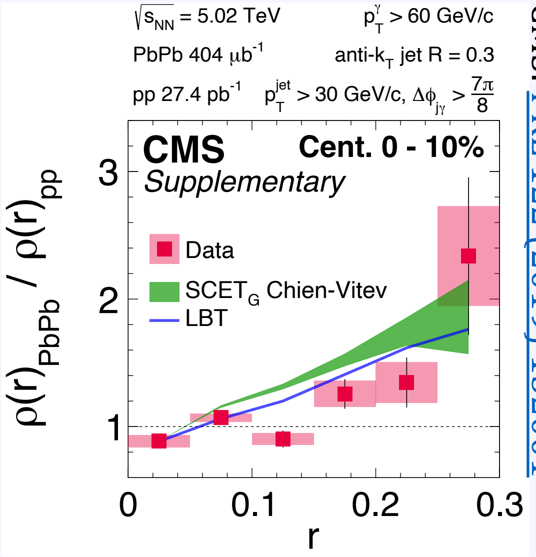

CMS: PRL 122 (2019) 152001

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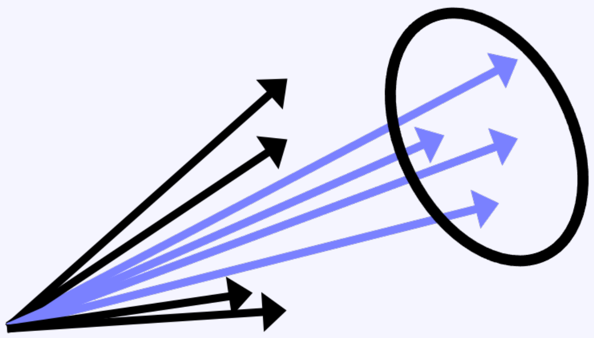

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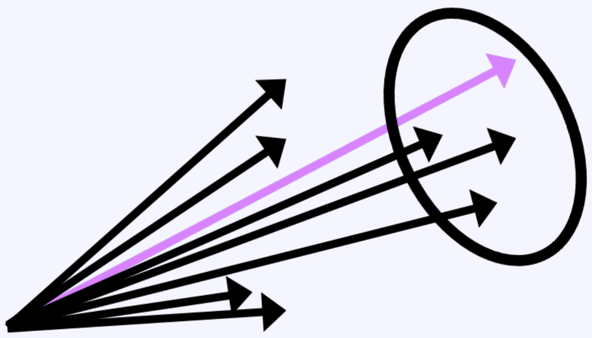

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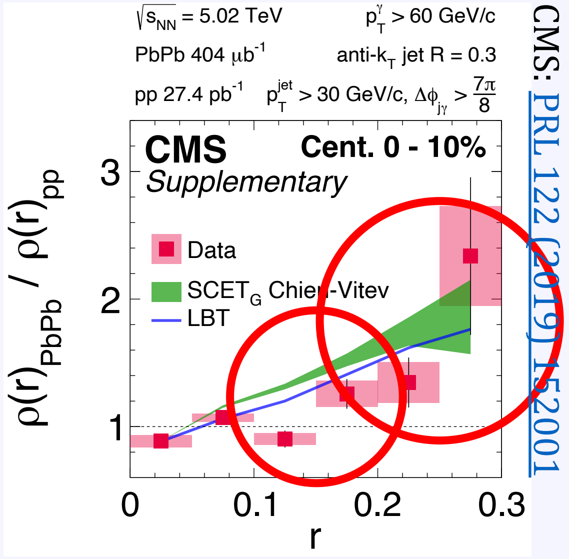

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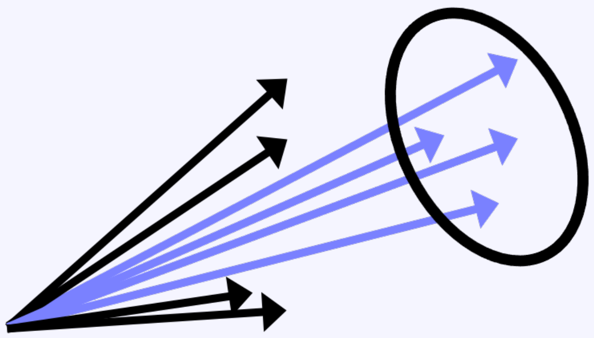

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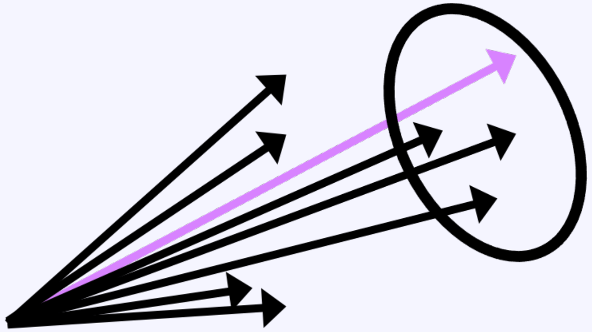

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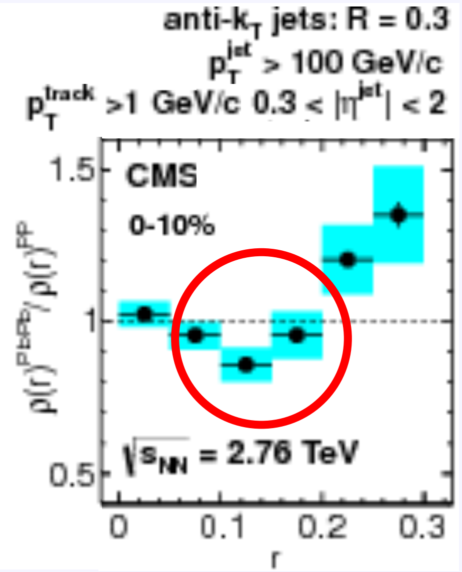
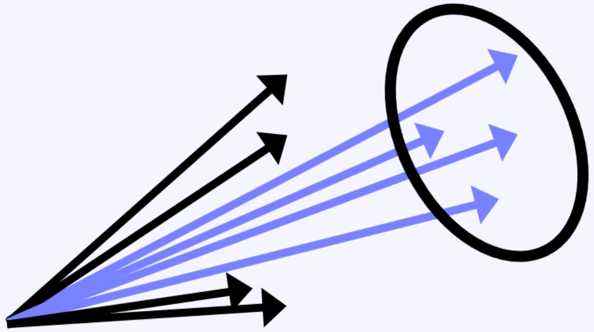


CMS: PLB 730 (2014) 243

Groomed observables



Subset of hadrons

transverse energy distribution

Groomed jet radius

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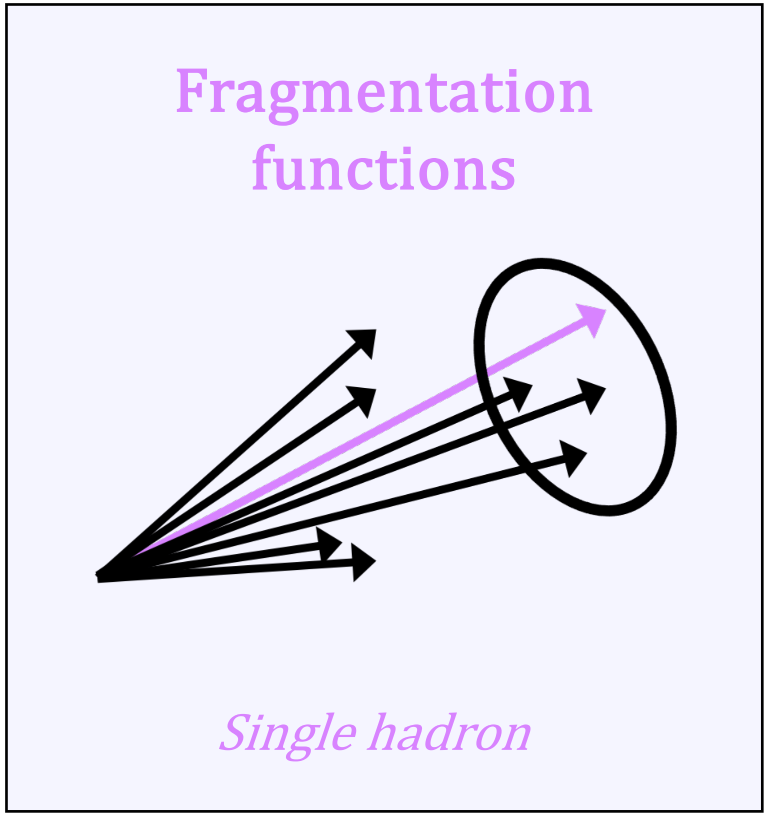
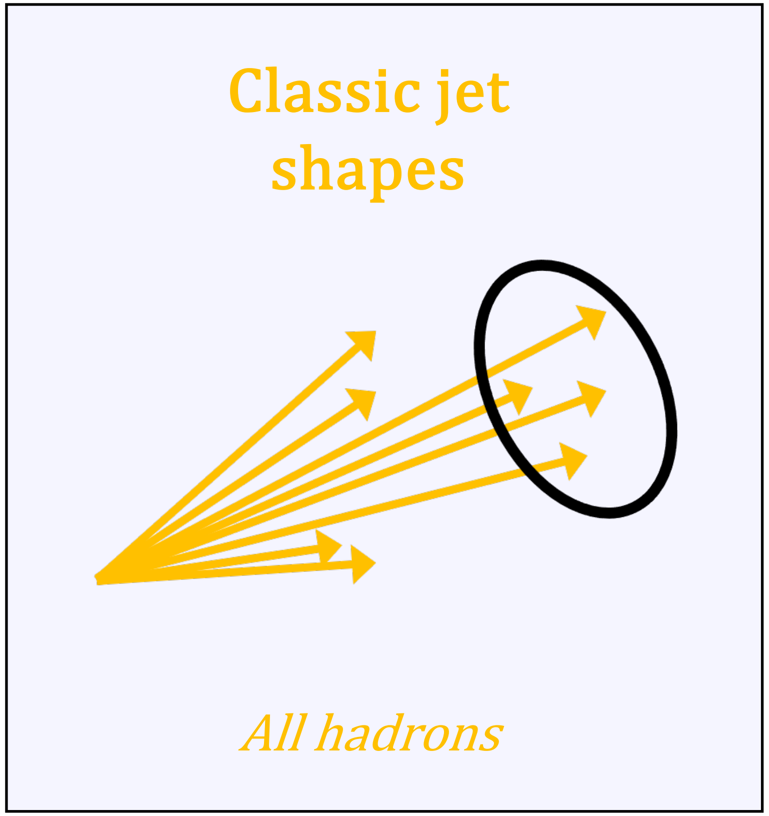
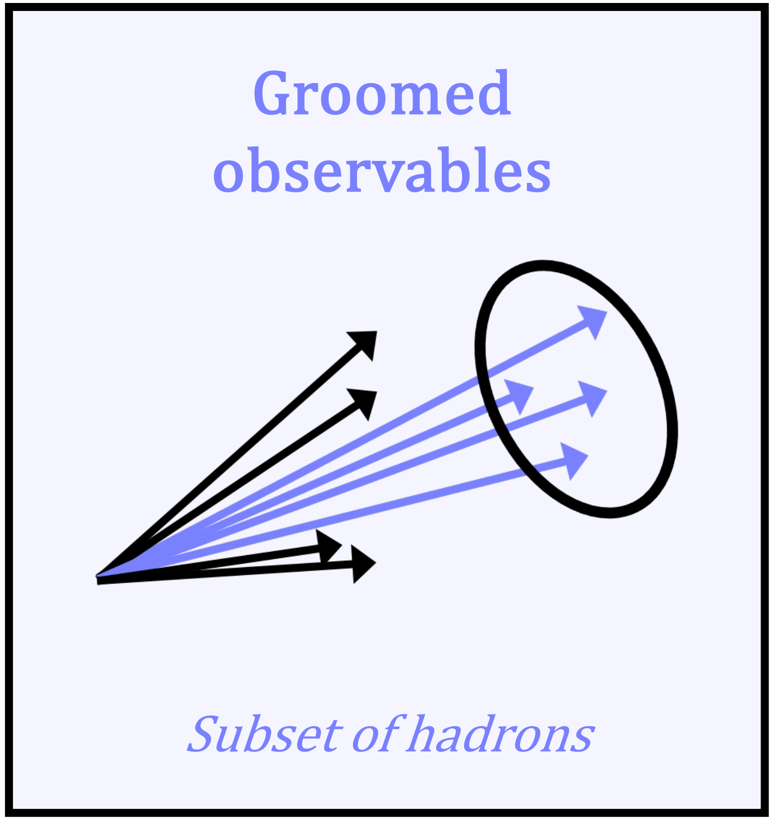






hard components

Groomed jet radius

Groomed jet radius (R_g) is the angle between the first two subjets that pass the soft drop condition

Proxy for the hardest 1 → 2 splitting in the jet shower

$$z_g \stackrel{\text{def}}{=} \frac{\min(p_T^1, p_T^2)}{p_T^1 + p_T^2} > 0.2 \qquad R_g \stackrel{\text{def}}{=} \Delta R_{12}$$

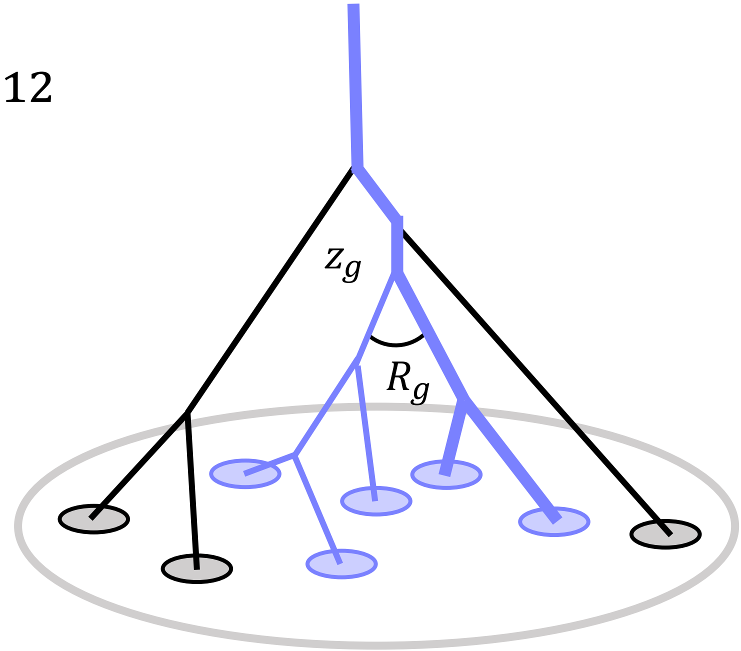
Potentially **sensitive** to **elastic scattering** effects in the QGP

Insensitive to **soft contribution** within the jet

If no there were no bias...

- Medium doesn't resolve jet substructure → flat suppression
- Medium does resolve jet substructure → increasing suppression

Can measure the medium resolution length?



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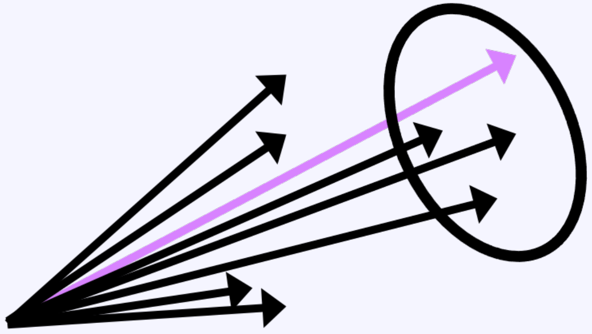

Single hadron

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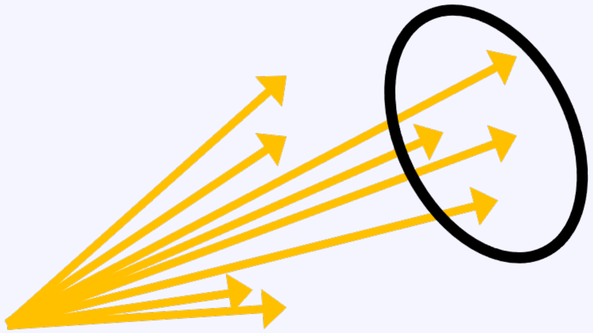
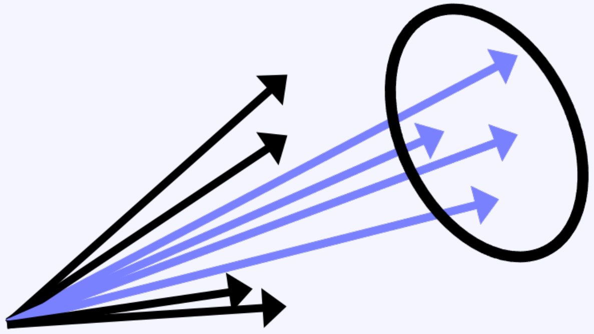


All hadrons

Groomed observables



Subset of hadrons

transverse energy distribution

Jet axis decorrelation

Jet axis decorrelation (Δj) is the angular difference between the WTA and E-Scheme jet axes

WTA axis = direction of leading energy flow **E-Scheme axis** = direction of average energy flow

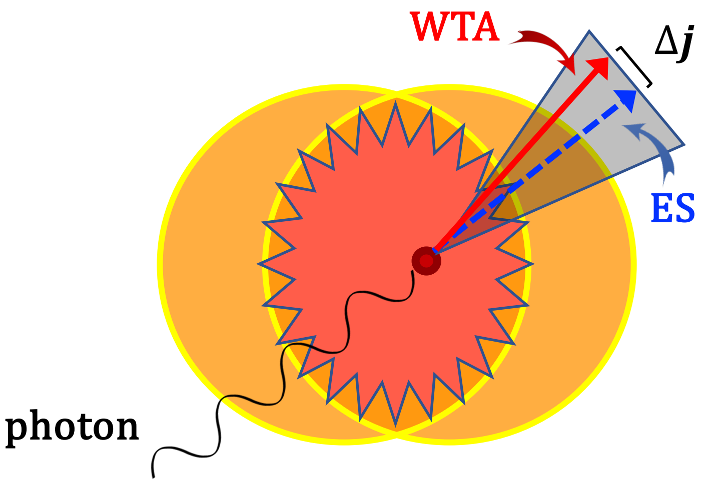
$$\Delta j = \sqrt{(\eta^{E-Scheme} - \eta^{WTA})^2 + (\phi^{E-Scheme} - \phi^{WTA})^2}$$

Potentially sensitive to **elastic scattering** effects in the QGP

Still includes information from **soft** jet constituents

Compare to R_g to see if soft jet component is important to understand elastic scattering

jet axis decorrelation

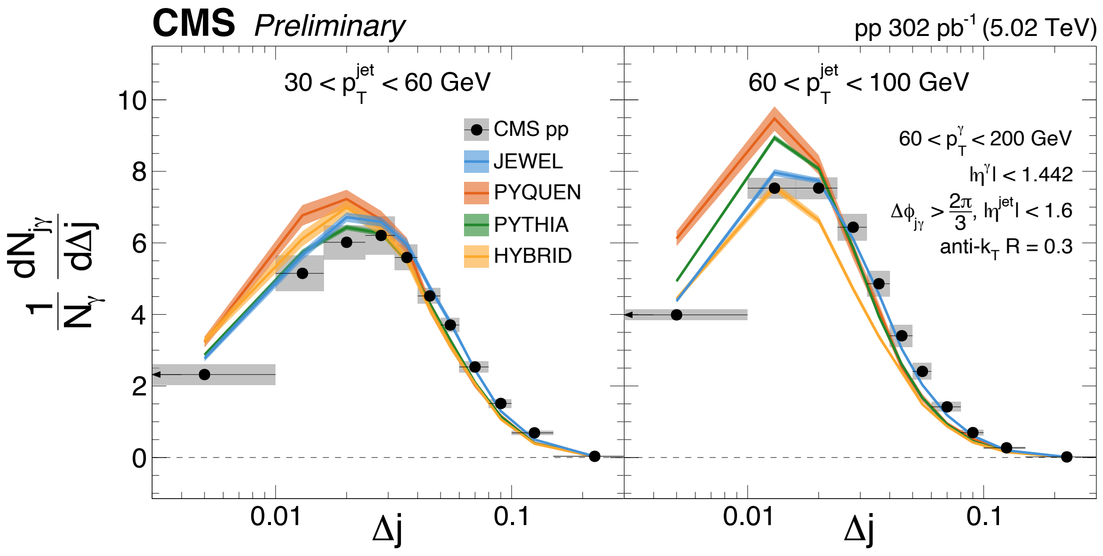


Photon-tagged results in pp collisions

CMS: PAS-HIN-21-019

jet axis decorrelation

$30 < p_T^{jet} < 60$ GeV $60 < p_T^{jet} < 100$ GeV



Pythia: Pythia 8.230 with the CP5 tune

Hybrid: based on Pythia 8.3 with the Monash tune

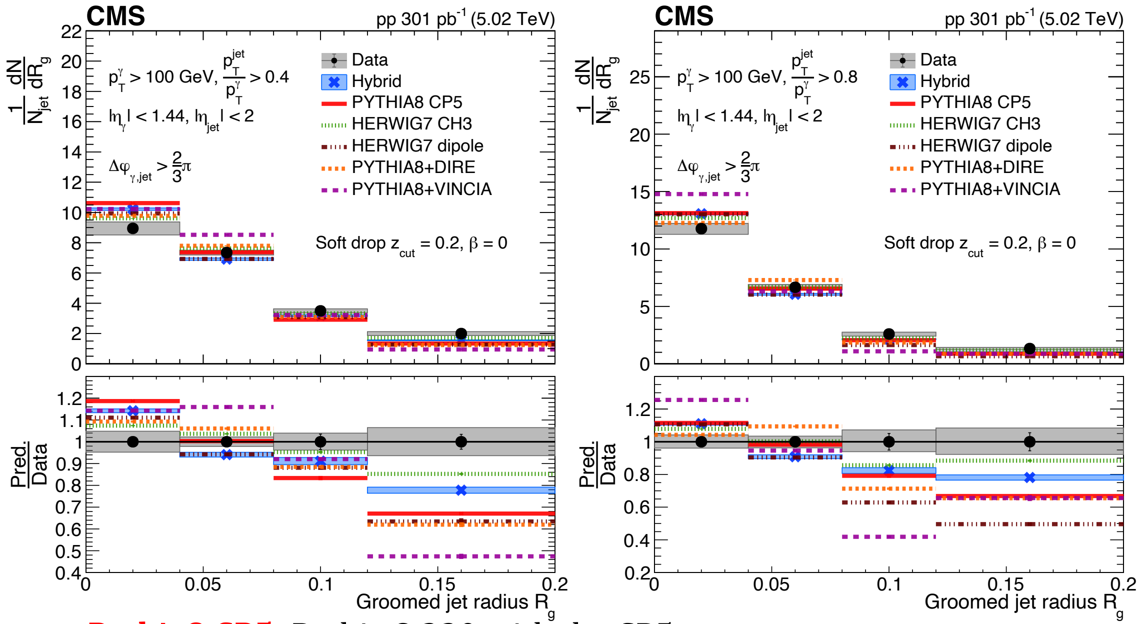
Jewel: based on Pythia 6.4

Pyquen: based on Pythia 6.4

CMS: arXiv:2405.02737

groomed jet radius

$x_{j\gamma} > 0.4$ $x_{j\gamma} > 0.8$



Pythia8 CP5: Pythia 8.230 with the CP5 tune

Hybrid: based on Pythia 8.3 with the Monash tune

Herwig7 CH3 **Herwig7 dipole** **Pythia8+DIRE** **Pythia8+VINCIA**

- Predictions are too narrow to describe R_g or Δj, need higher order terms
- Predictions miss overall jet yield, visible with Δj measurement normalized per photon

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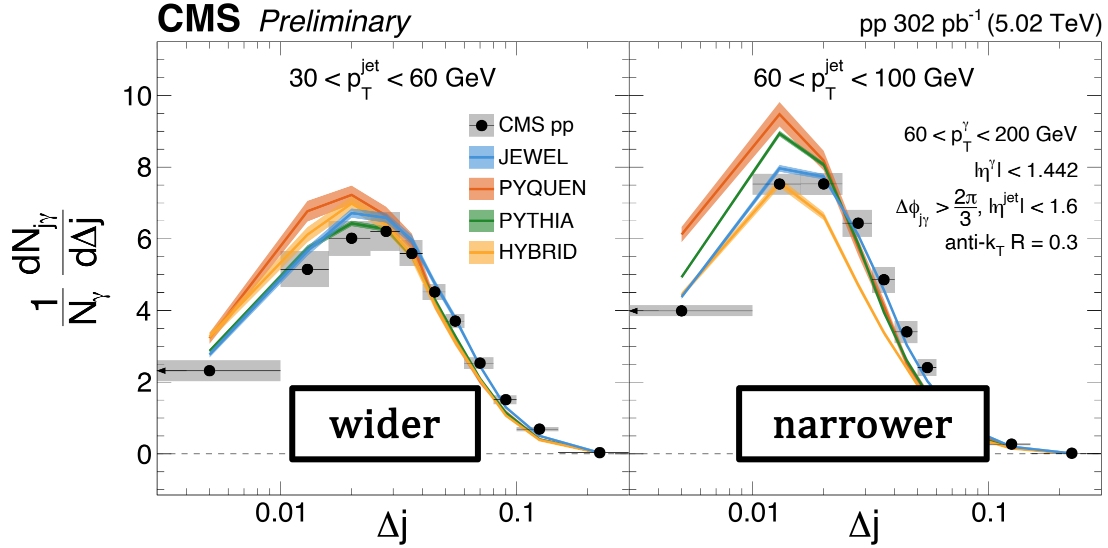

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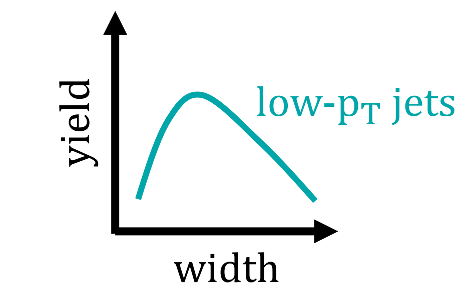

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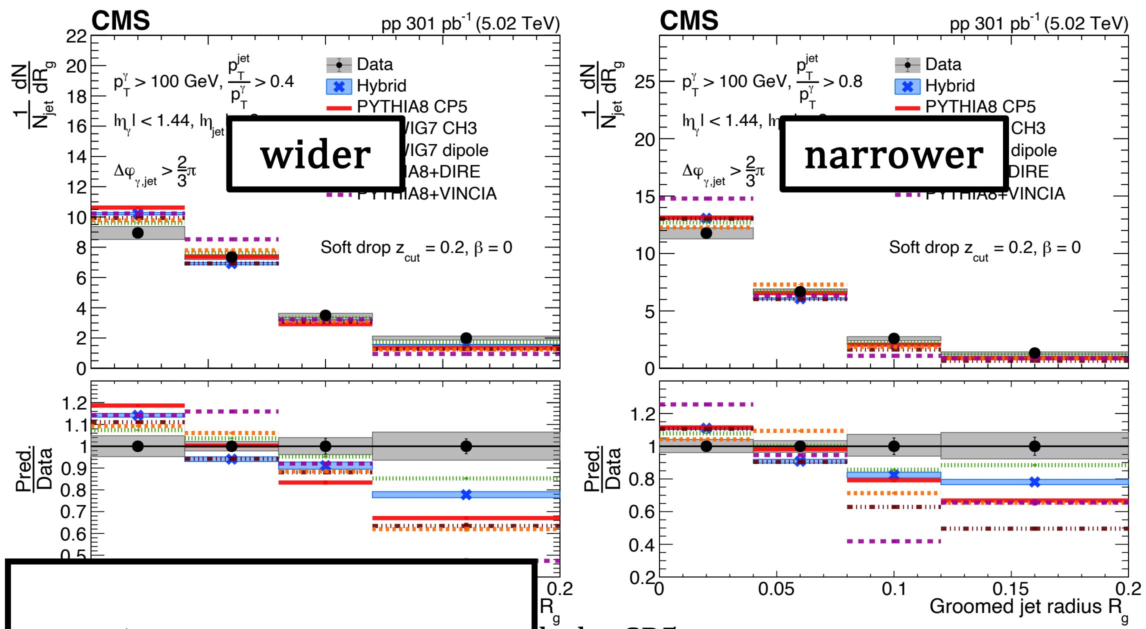

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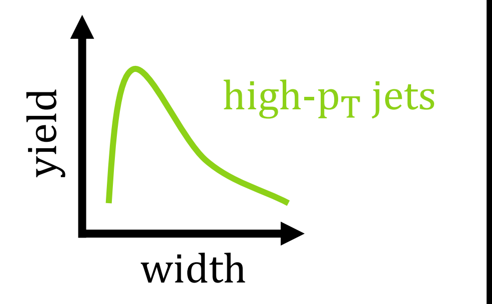
ith the Monash tune

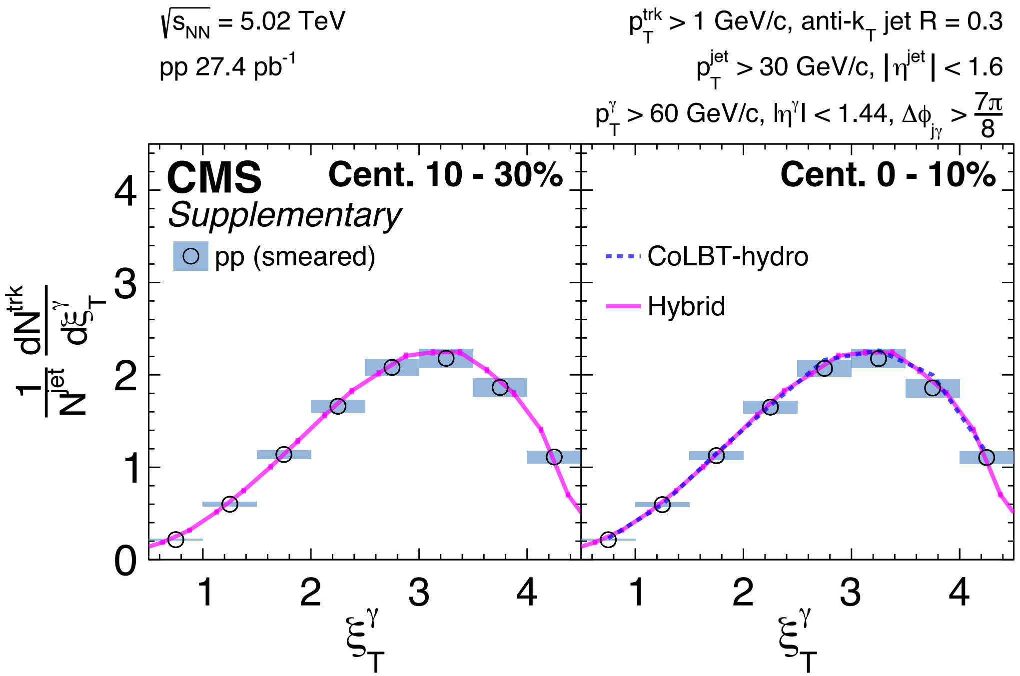
le Pythia8+DIRE Pythia8+VINCIA



Photon-tagged results in pp collisions

CMS: PRL 121 (2018) 242301

fragmentation function

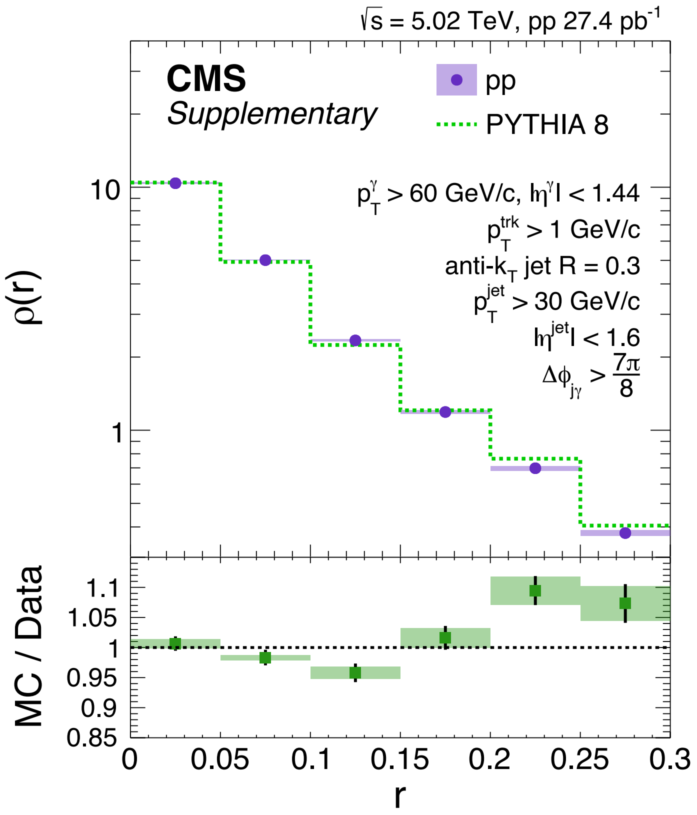


Hybrid: based on Pythia 8.183 with the Monash tune, no MPI, 1 GeV cutoff for FSR

CoLBT-hydro: based on Pythia 8

CMS: PRL 122 (2019) 152001

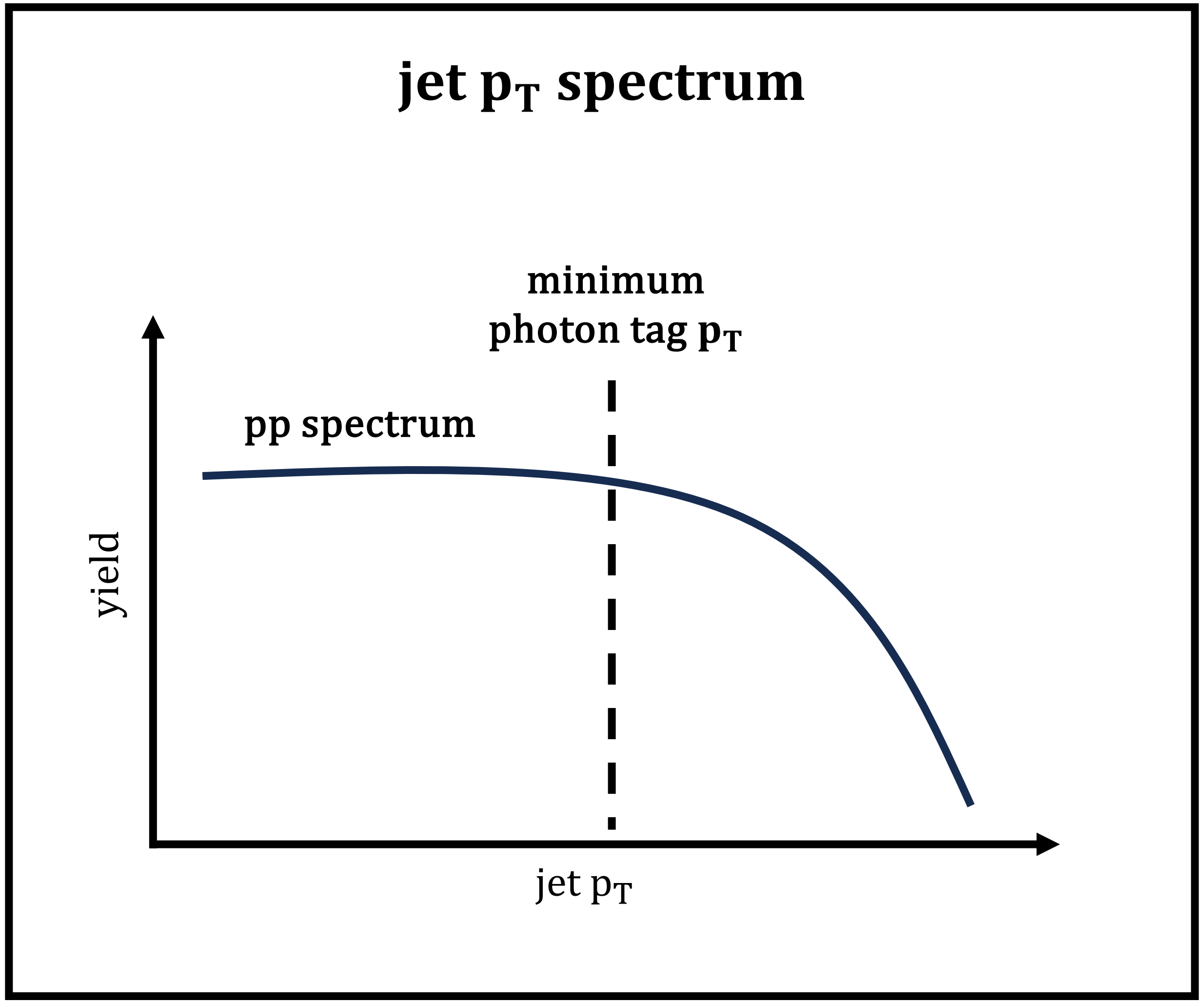
jet shape



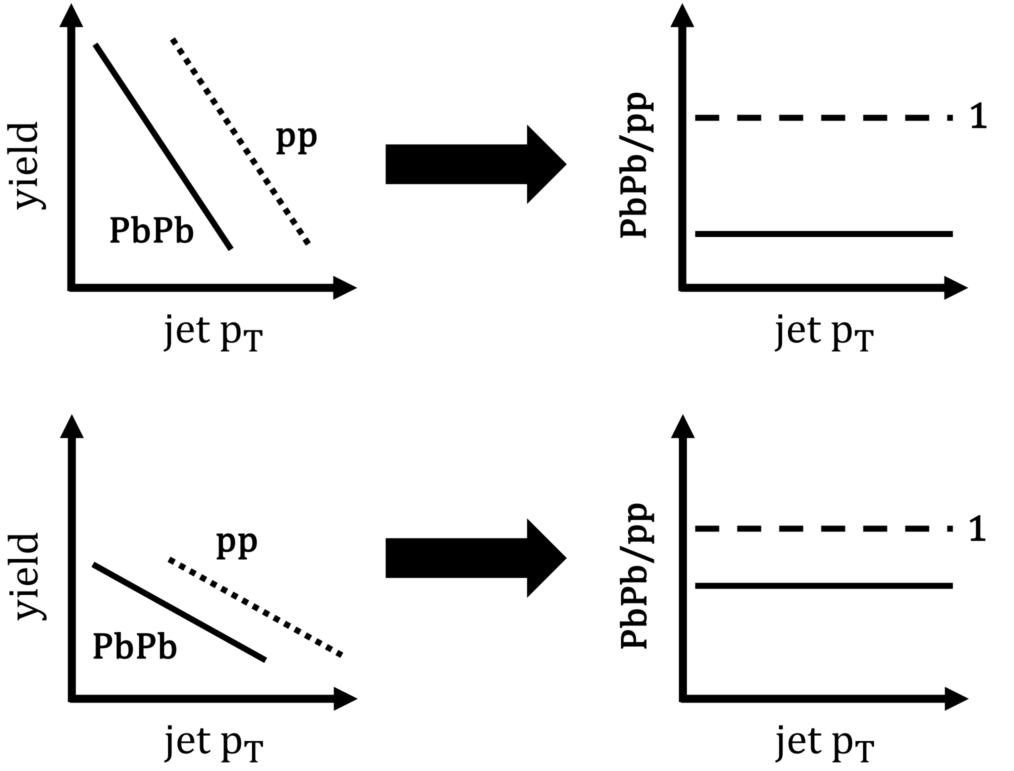
Pythia: Pythia 8.212 with the CUETP8M1 tune

- Pythia tuned to recreate particle spectra, underlying event, etc
- Describes fragmentation function and jet shape well, but it is missing higher order terms...

Photon-tagged results in pp collisions

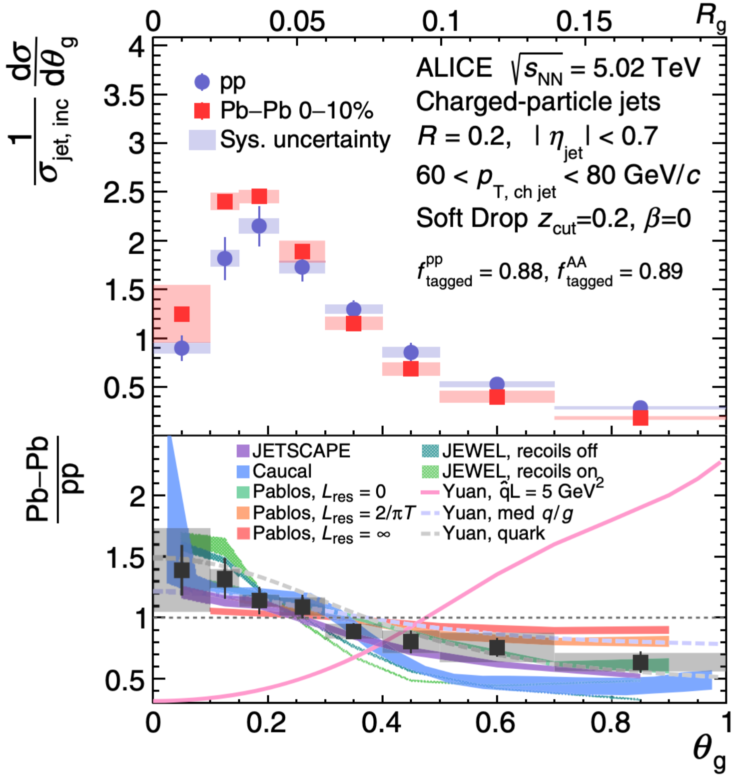


- Need accurate pp spectrum to get correct modification in PbPb
- Higher order predictions could be useful



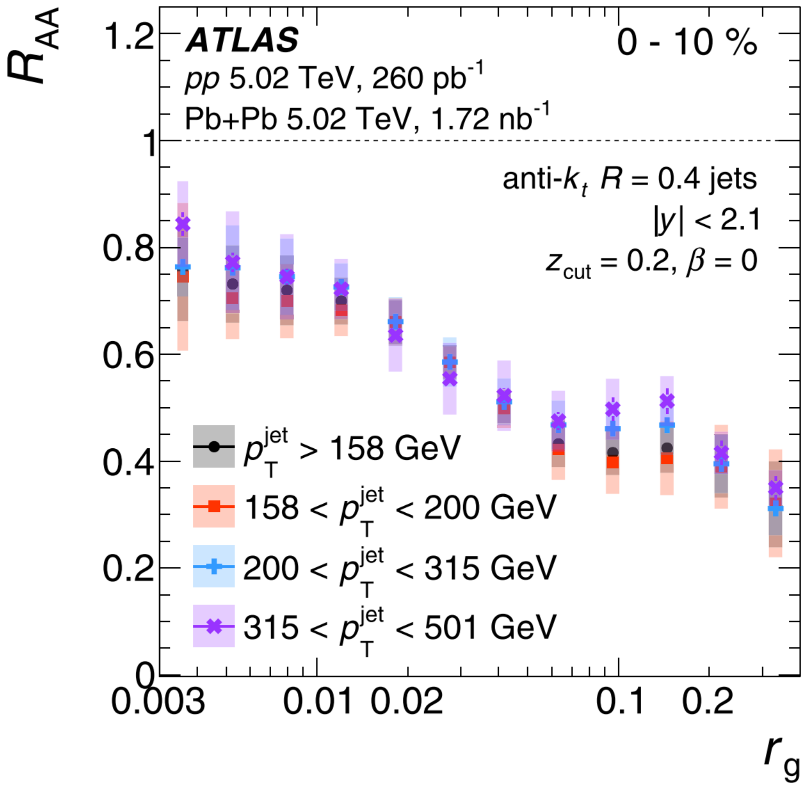
Inclusive groomed jet radius

normalized groomed jet radius



ALICE: PRL 128, 102001 (2022)

groomed jet radius R_{AA}



ATLAS: PRC 107 (2023) 054909

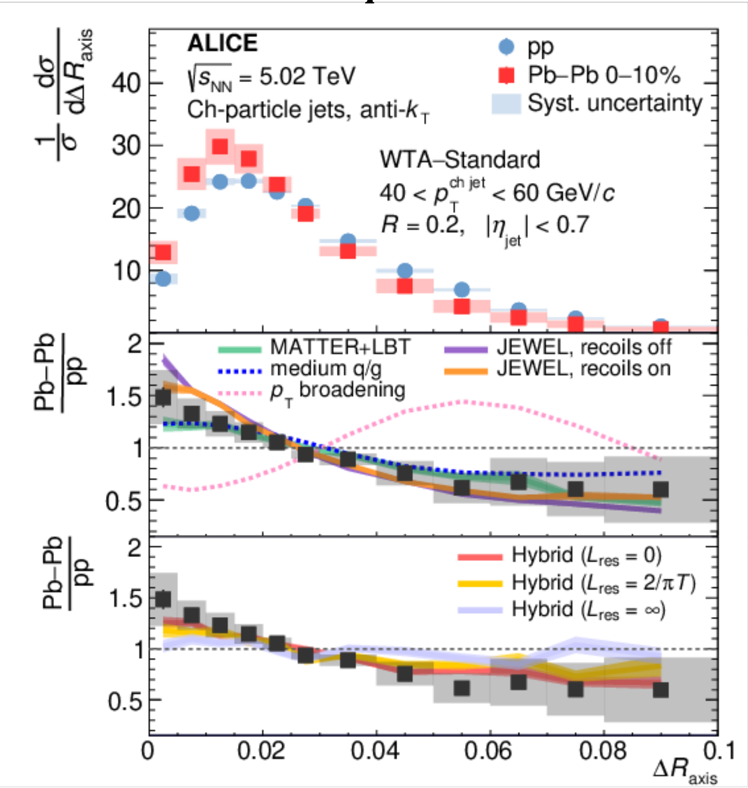
In inclusive jets, we do see suppression dependence on R_g → narrowing of PbPb R_g

Is it because we are cutting out the soft jet constituents, leaving us with narrow PbPb jets?

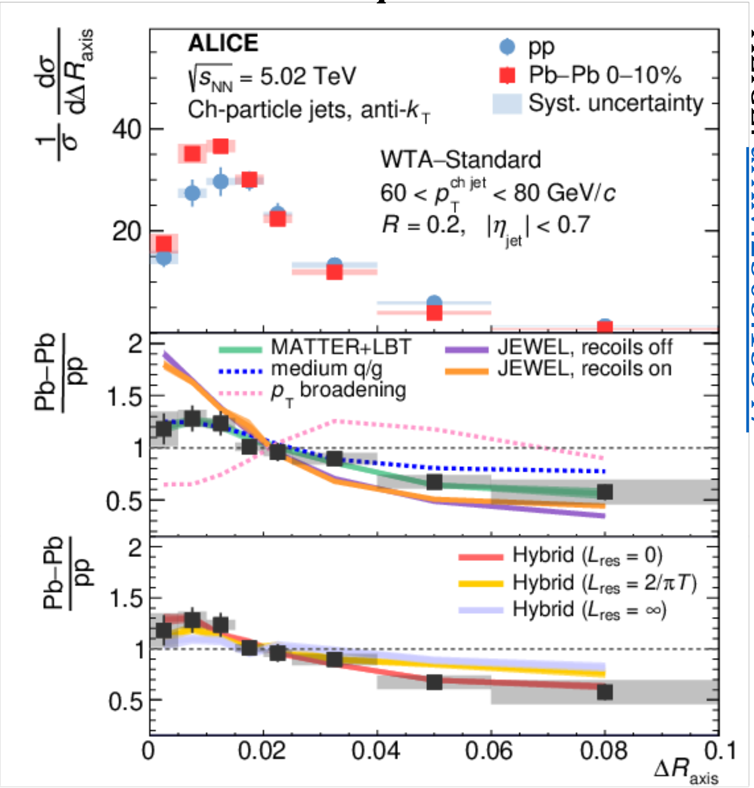
Is it due to the difference in quark/gluon jet quenching?

Inclusive jet axis decorrelation

$40 < p_T^{jet} < 60$ GeV



$60 < p_T^{jet} < 80$ GeV



ALICE: arXiv:2303.13347

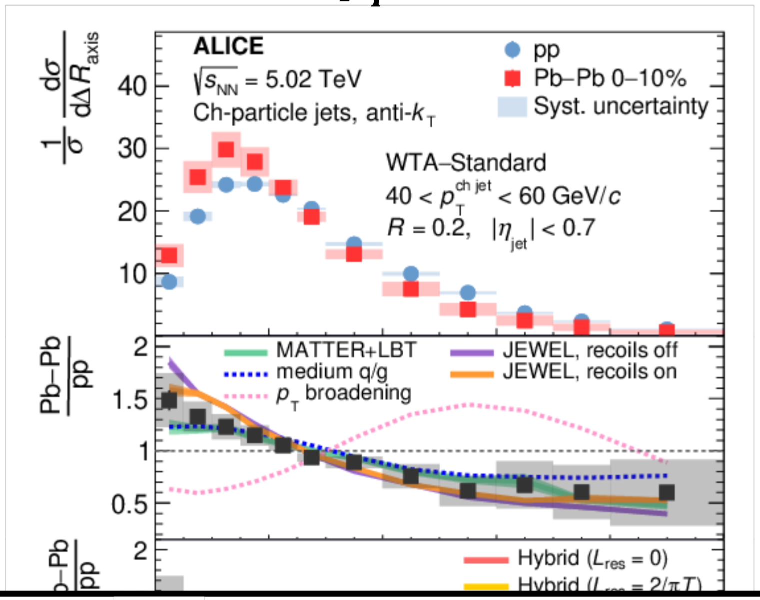
In inclusive jets, we also see narrowing in the Δj

Now soft jet constituents are somewhat considered, since they affect the E-scheme axis

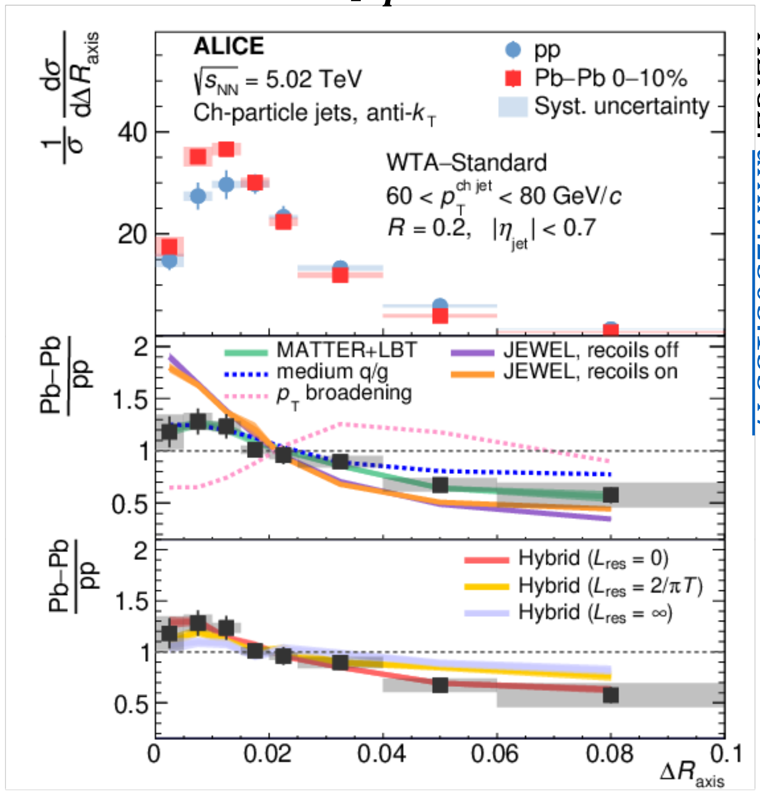
Is it due to the difference in quark/gluon jet quenching?

Inclusive jet axis decorrelation

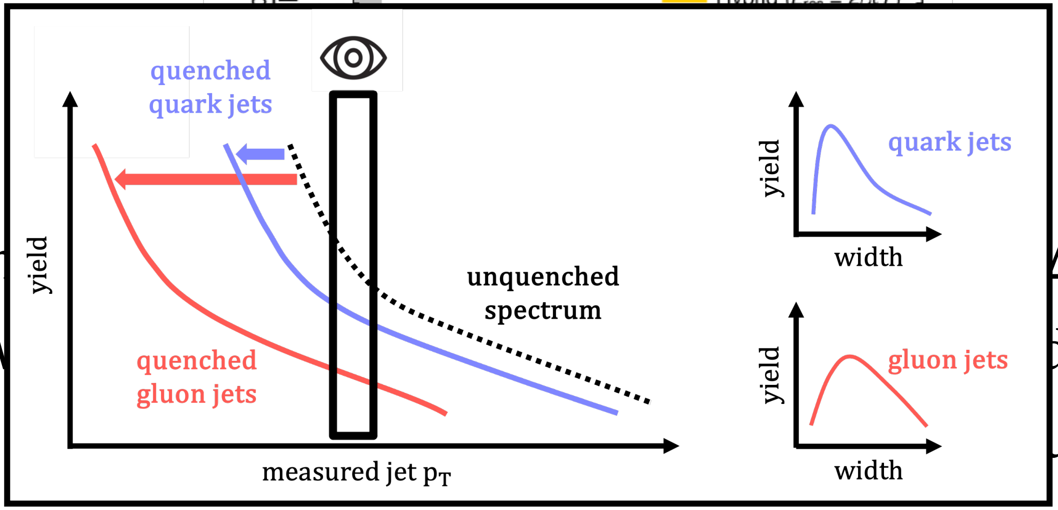
$40 < p_T^{jet} < 60$ GeV



$60 < p_T^{jet} < 80$ GeV



ALICE: arXiv:2303.13347



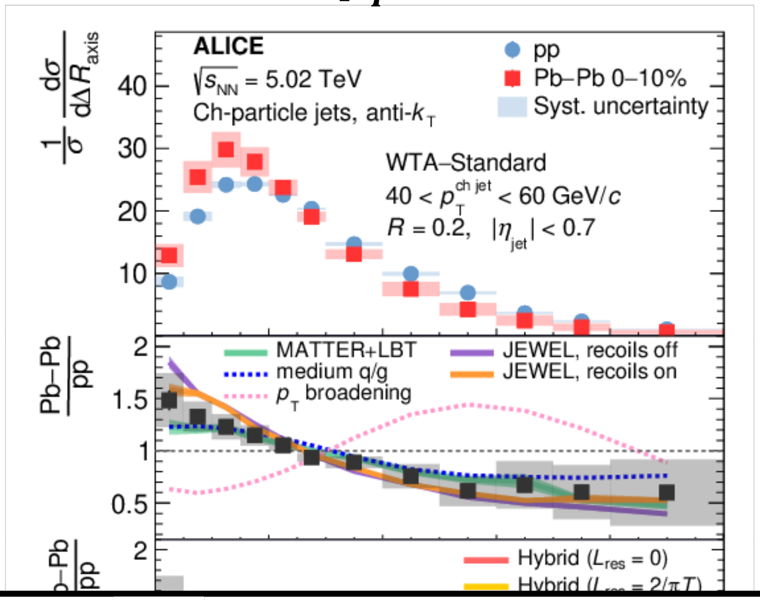
In in… Δj

Now… dered, since they affect the E-scheme axis

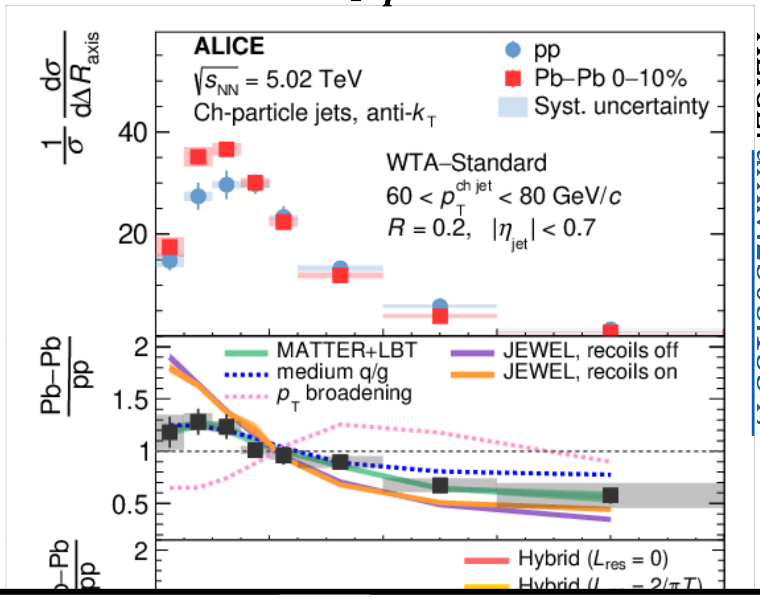
Is it… uenching?

Inclusive jet axis decorrelation

$40 < p_T^{jet} < 60$ GeV



$60 < p_T^{jet} < 80$ GeV

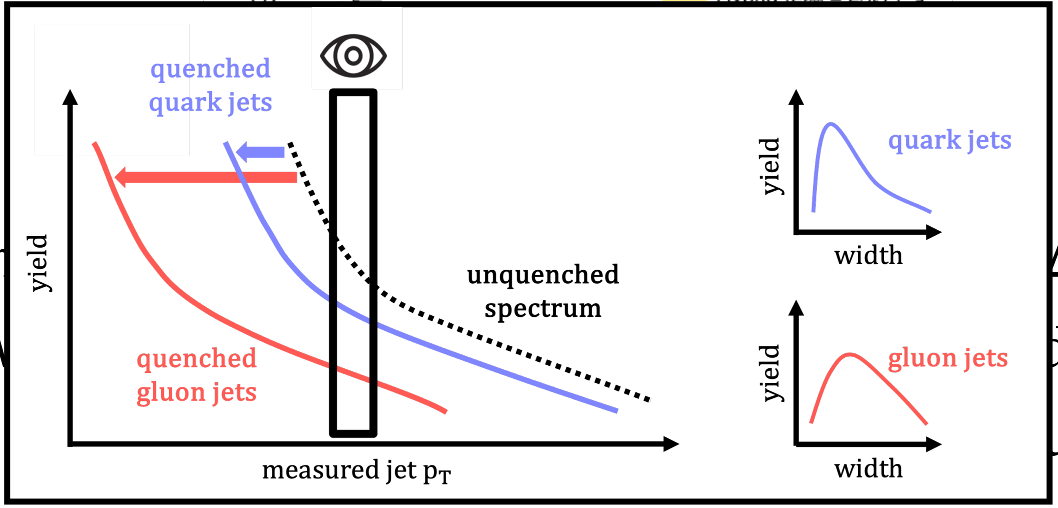


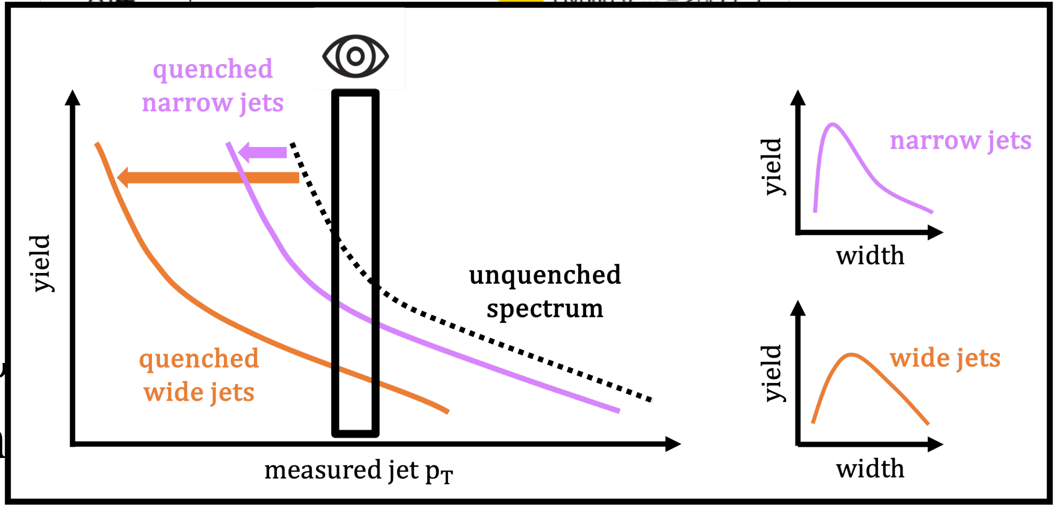
ALICE: arXiv:2303.13347

In ir ... Δj

Now ... dered,

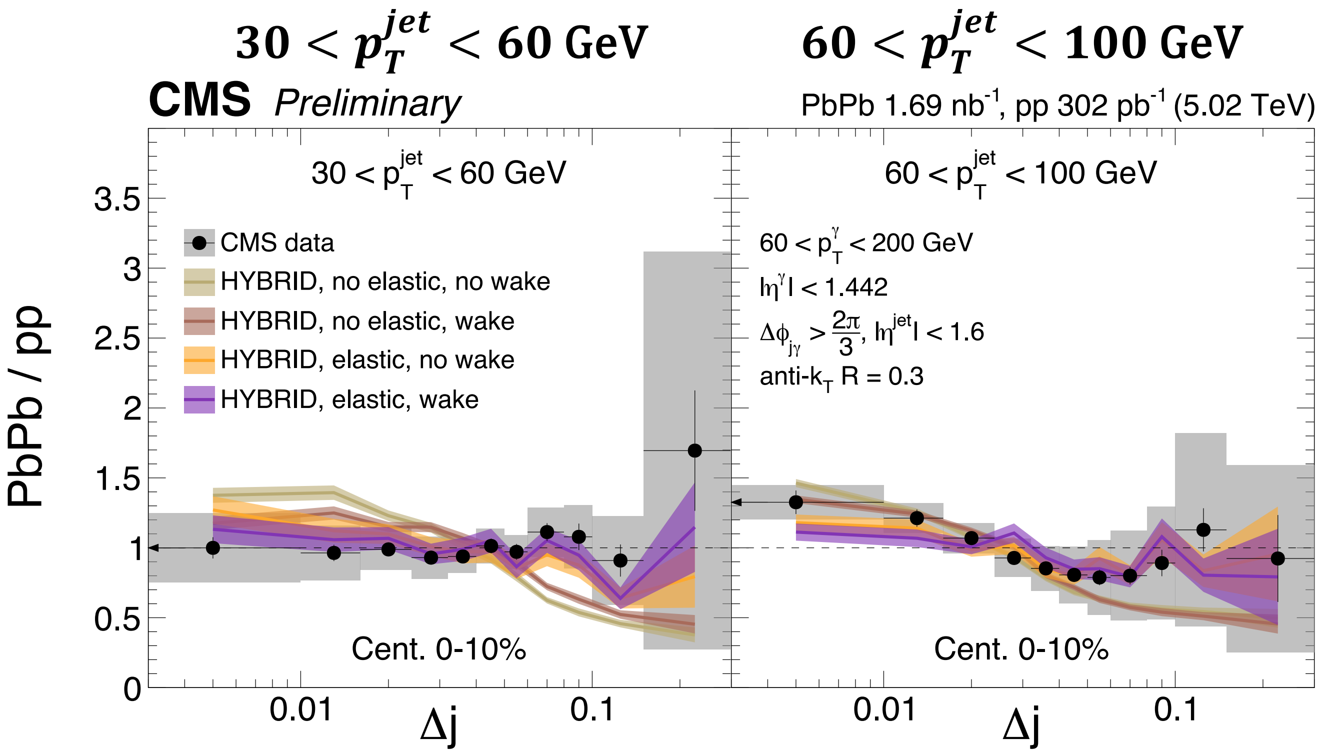
Is it ... uench





Photon-tagged jet axis decorrelation

CMS: PAS-HIN-21-019



Hybrid, no elastic, no wake: strongly-coupled model of jet quenching

Hybrid, no elastic, wake: conservation of energy imposed

Hybrid, elastic, no wake: scattering from medium particles

Hybrid, elastic, wake: conservation of energy + scattering within medium

See narrowing emerge in high jet p_T interval

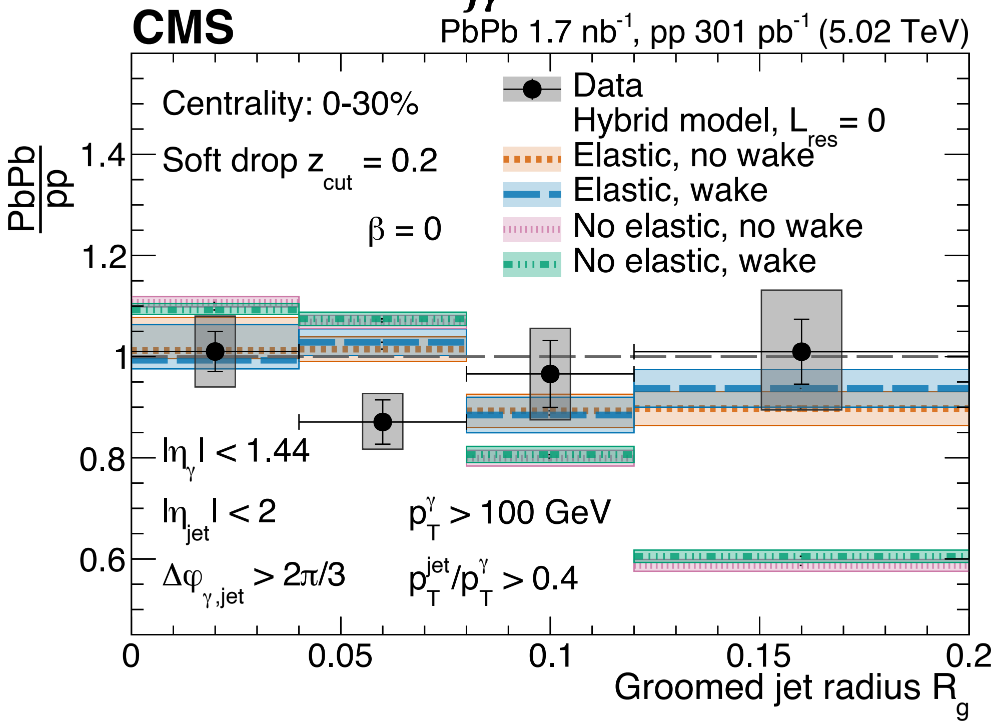
Narrowing even in sample dominated by quark jets → suppression depends on width?

Favors inclusion of elastic scatterings in the Hybrid model

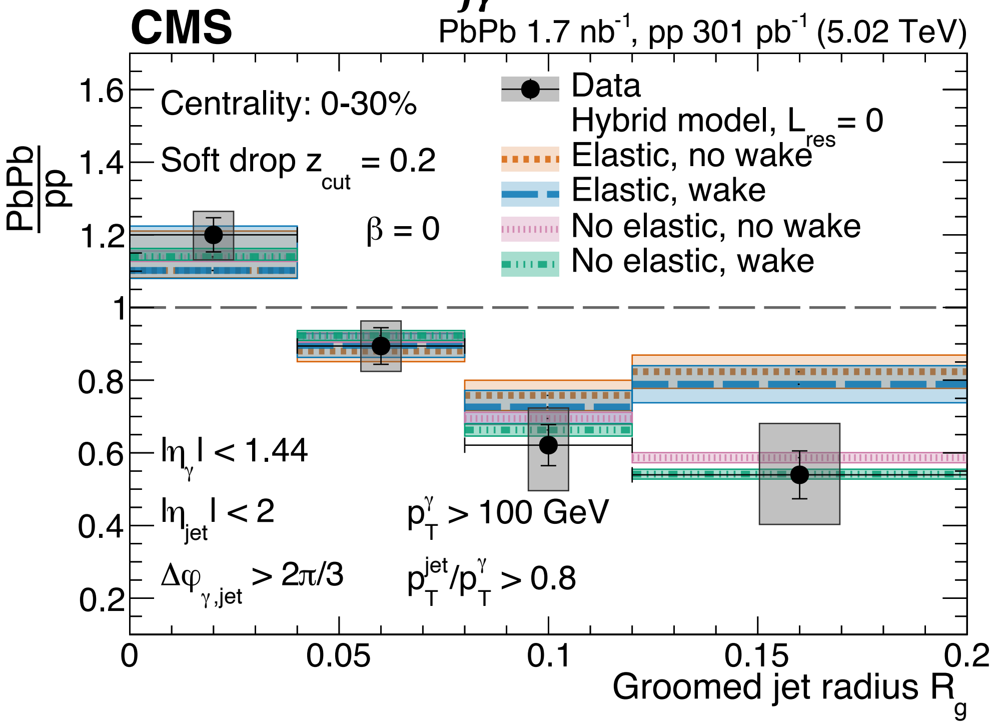
Photon-tagged groomed jet radius

CMS: [arXiv:2405.02737](https://arxiv.org/abs/2405.02737)

$x_{j\gamma} > 0.4$



$x_{j\gamma} > 0.8$



Hybrid, no elastic, no wake: strongly-coupled model of jet quenching

Hybrid, no elastic, wake: conservation of energy imposed

Hybrid, elastic, no wake: scattering from medium particles

Hybrid, elastic, wake: conservation of energy + scattering within medium

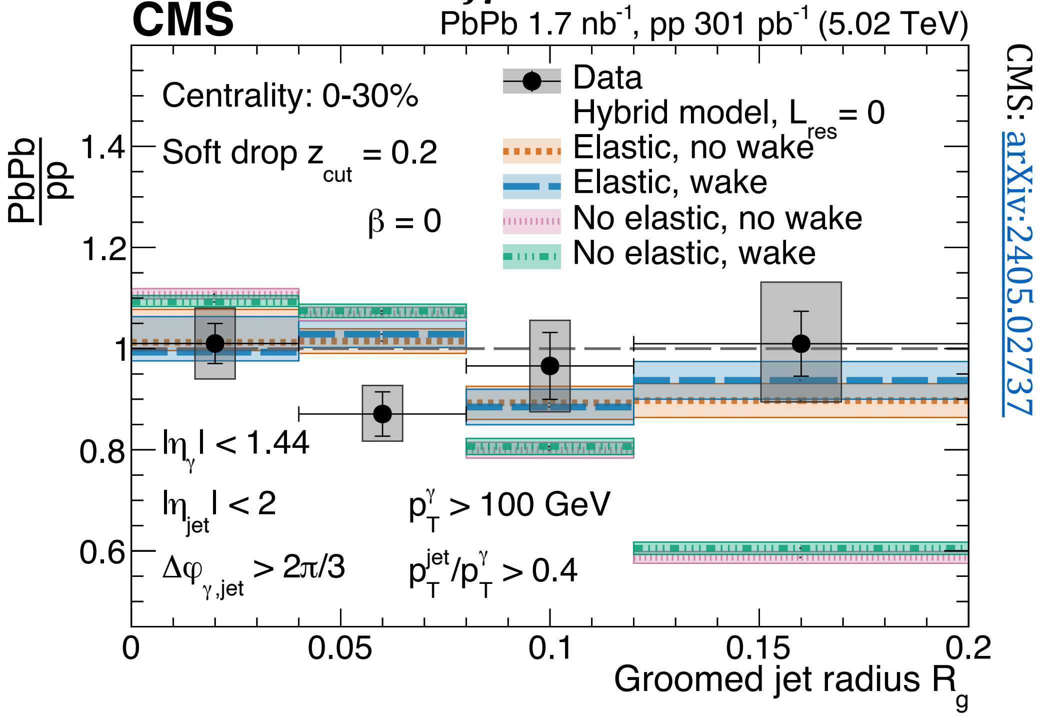
See narrowing emerge after minimum $x_{j\gamma}$ increases from 0.4 to 0.8

Narrowing even in sample dominated by quark jets → suppression depends on width?

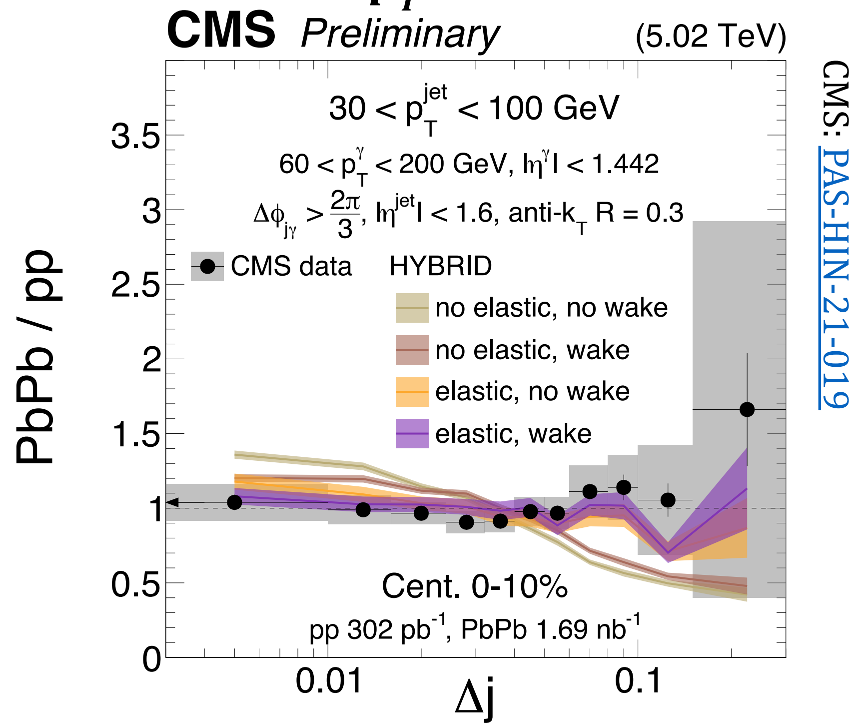
Tension in agreement with Hybrid model, need to match the $x_{j\gamma}$ distribution with data

Comparison with Hybrid

$x_{j\gamma} > 0.4$



$30 < p_T^{jet} < 100$ GeV



Hybrid, no elastic, no wake: strongly-coupled model of jet quenching

Hybrid, no elastic, wake: conservation of energy imposed

Hybrid, elastic, no wake: scattering from medium particles

Hybrid, elastic, wake: conservation of energy + scattering within medium

Hybrid, no elastic, no wake: strongly-coupled model of jet quenching

Hybrid, no elastic, wake: conservation of energy imposed

Hybrid, elastic, no wake: scattering from medium particles

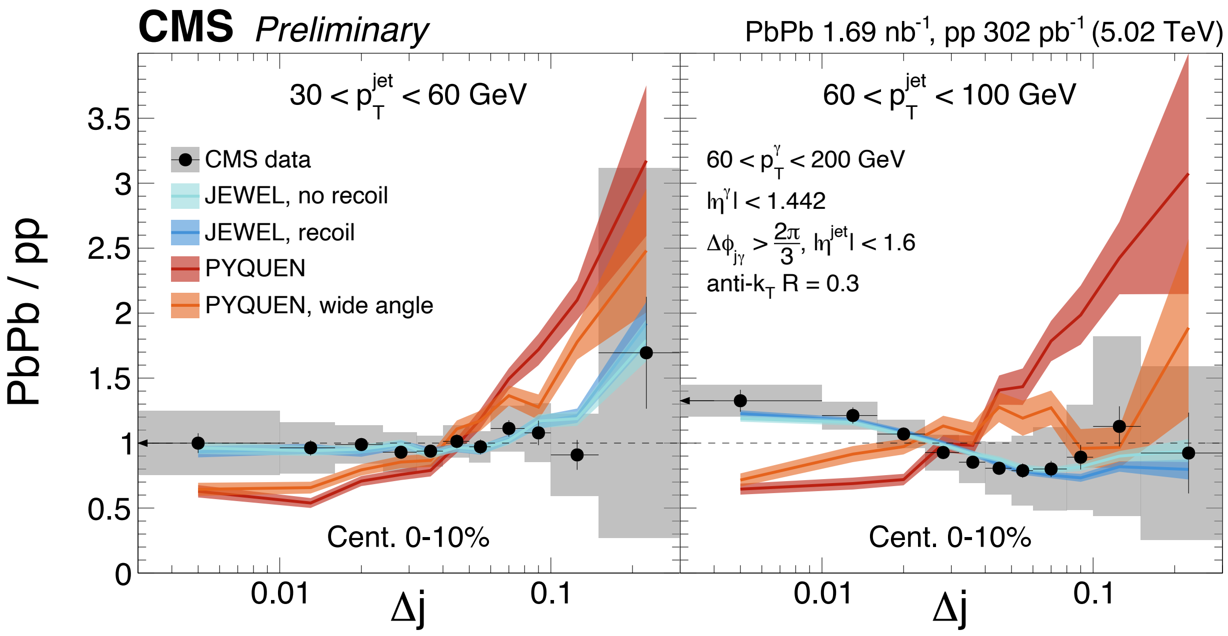
Hybrid, elastic, wake: conservation of energy + scattering within medium

Data with lower jet p_T thresholds favors Hybrid with elastic scattering

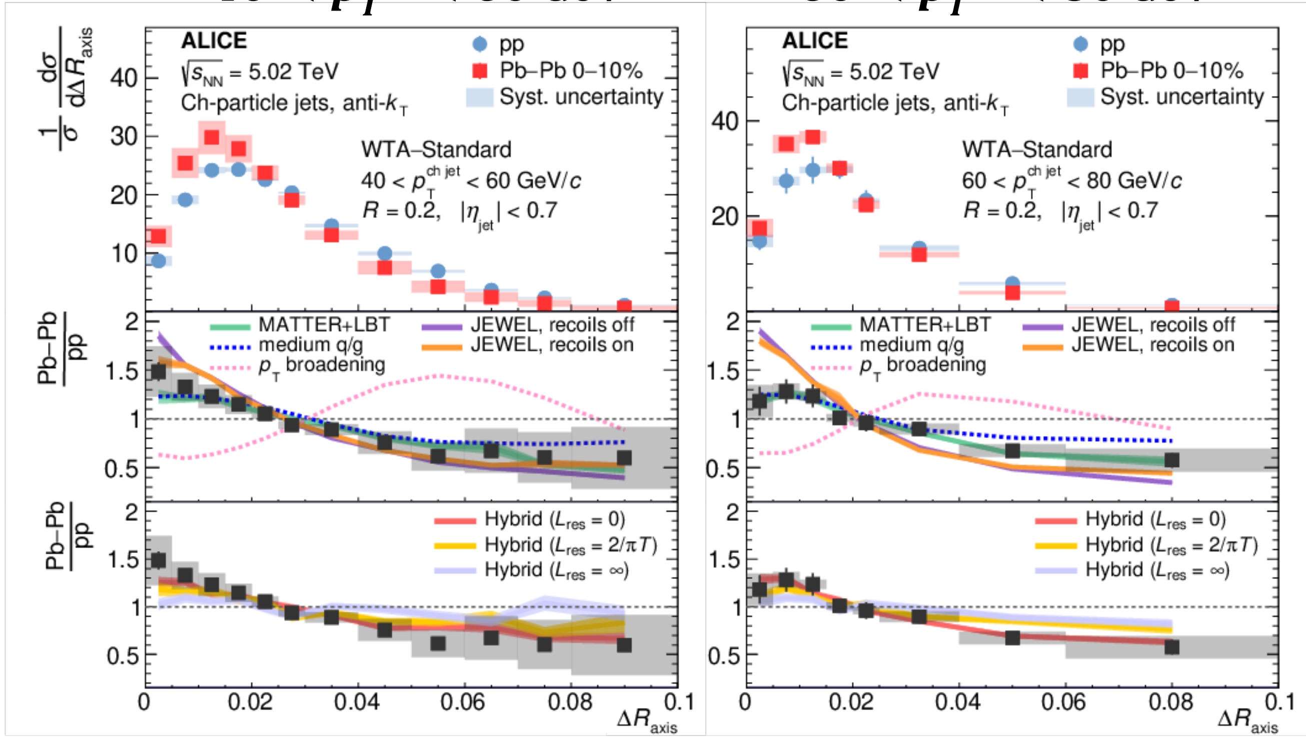
Can't conclude physics message from single measurement when sensitive to many effects

Photon-tagged jet axis decorrelation

$30 < p_T^{jet} < 60$ GeV $\quad$ $60 < p_T^{jet} < 100$ GeV



$40 < p_T^{jet} < 60$ GeV $\quad$ $60 < p_T^{jet} < 80$ GeV



Jewel, recoil: medium recoil particles included and subtracted

Jewel, no recoil: medium recoil particles ignored

Pyquen: baseline model of jet quenching

Pyquen, wide angle: additional wide angle gluon radiation

Jewel, recoil: medium recoil particles included and subtracted

Jewel, no recoil: medium recoil particles ignored

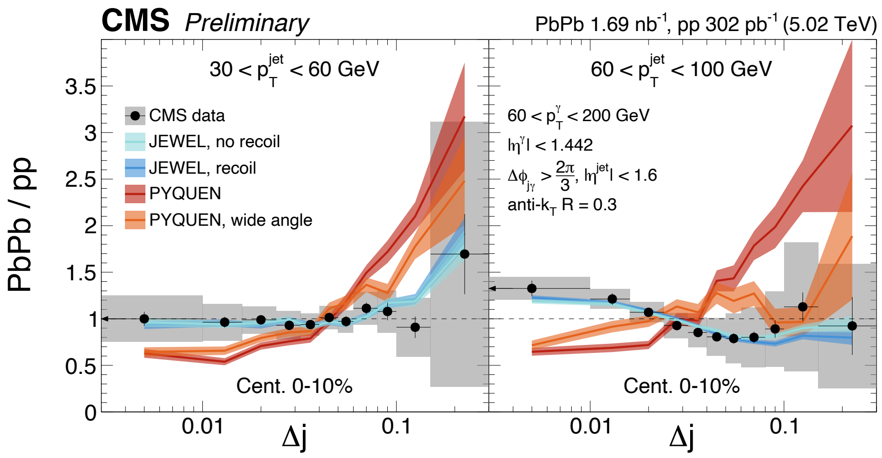
Pyquen model can be ruled out, also disagrees with many other jet observables

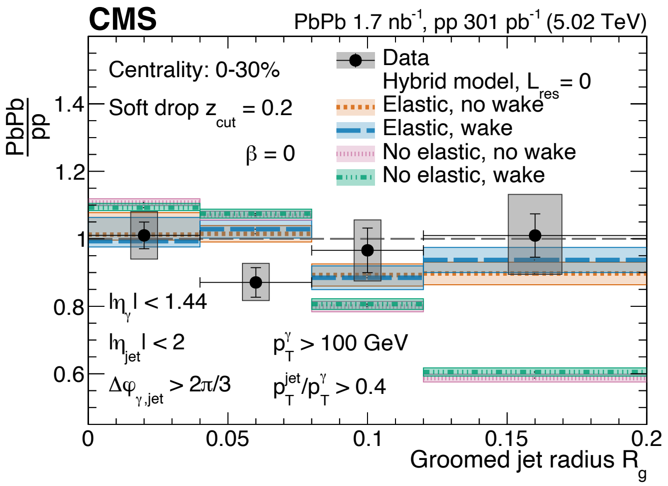
Tension in agreement with **Jewel** model

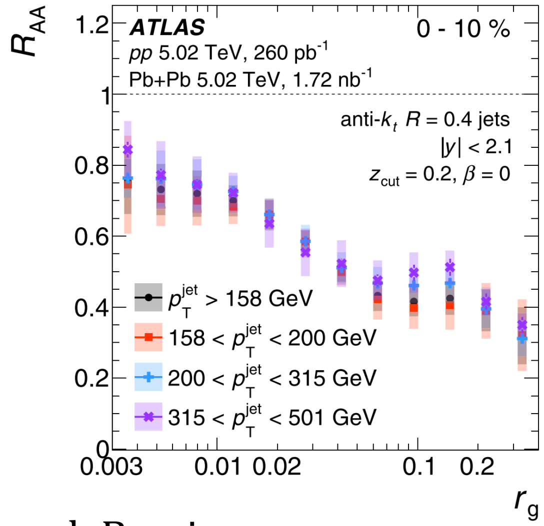
Summary

- Photon-jet measurements help mitigate selection biases
  - See narrowing even when q/g fraction is controlled → preferential quenching of wide jets
  - Will we start to see broadening if we access more quenched jets?
- Need better pp photon-jet predictions
  - Will affect the relative modification in PbPb
  - Need NLO terms to capture the width of the hard part of the jet
- Cannot conclude physics messages from single measurements when sensitive to many different effects
  - Looking at multiple measurements, favor the inclusion of elastic scattering effects
  - Pyquen can be ruled out

MITHIG's work was supported by US DOE-NP

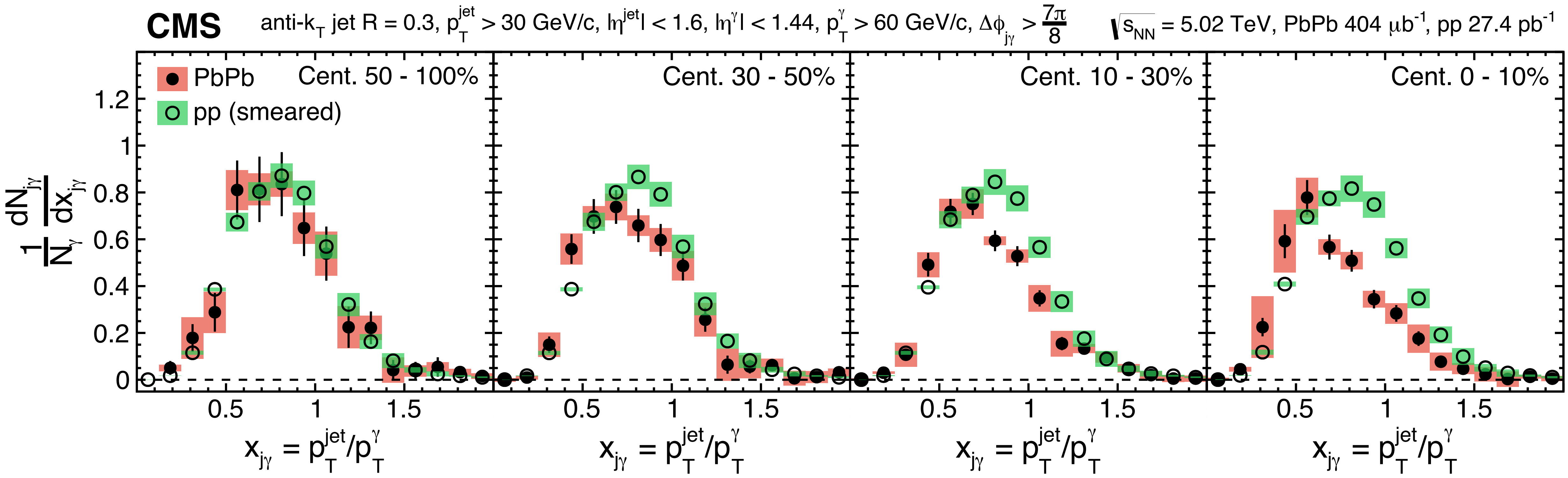


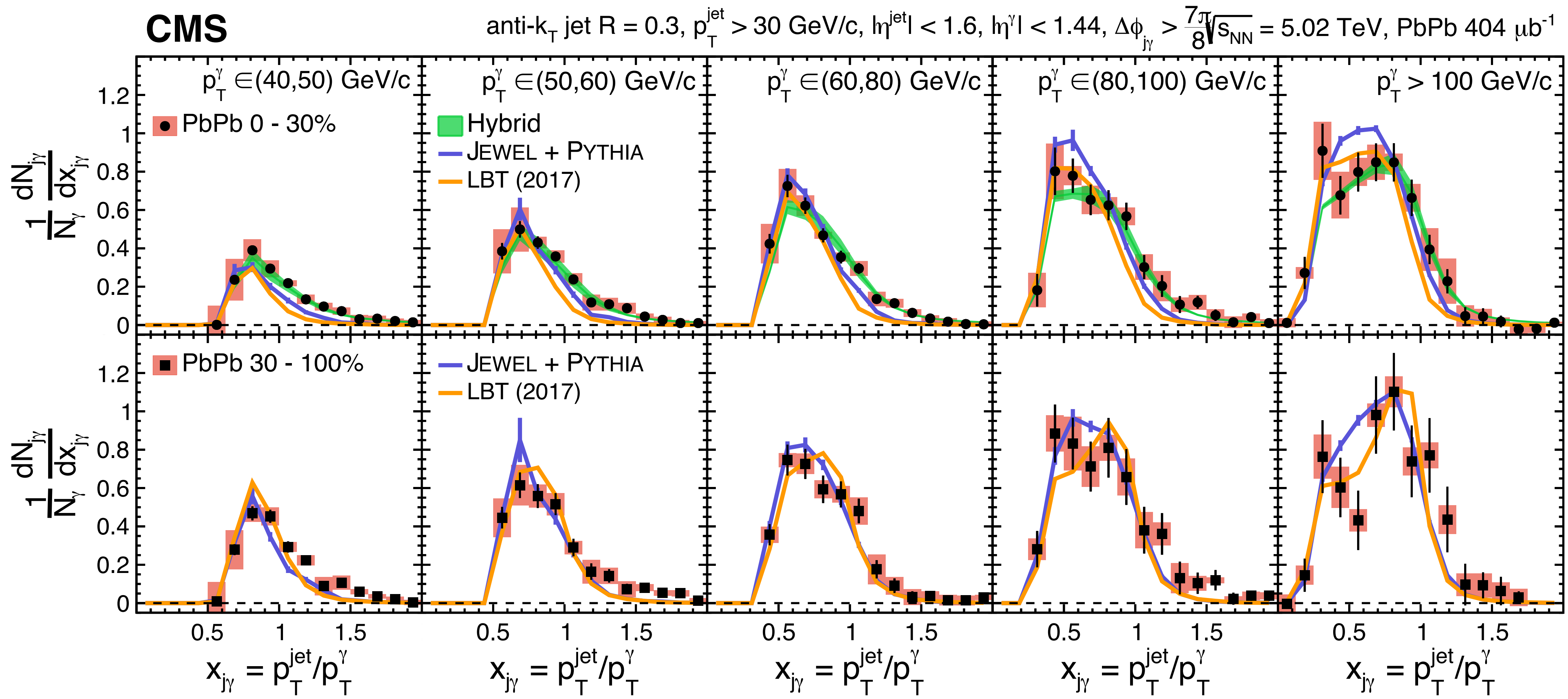


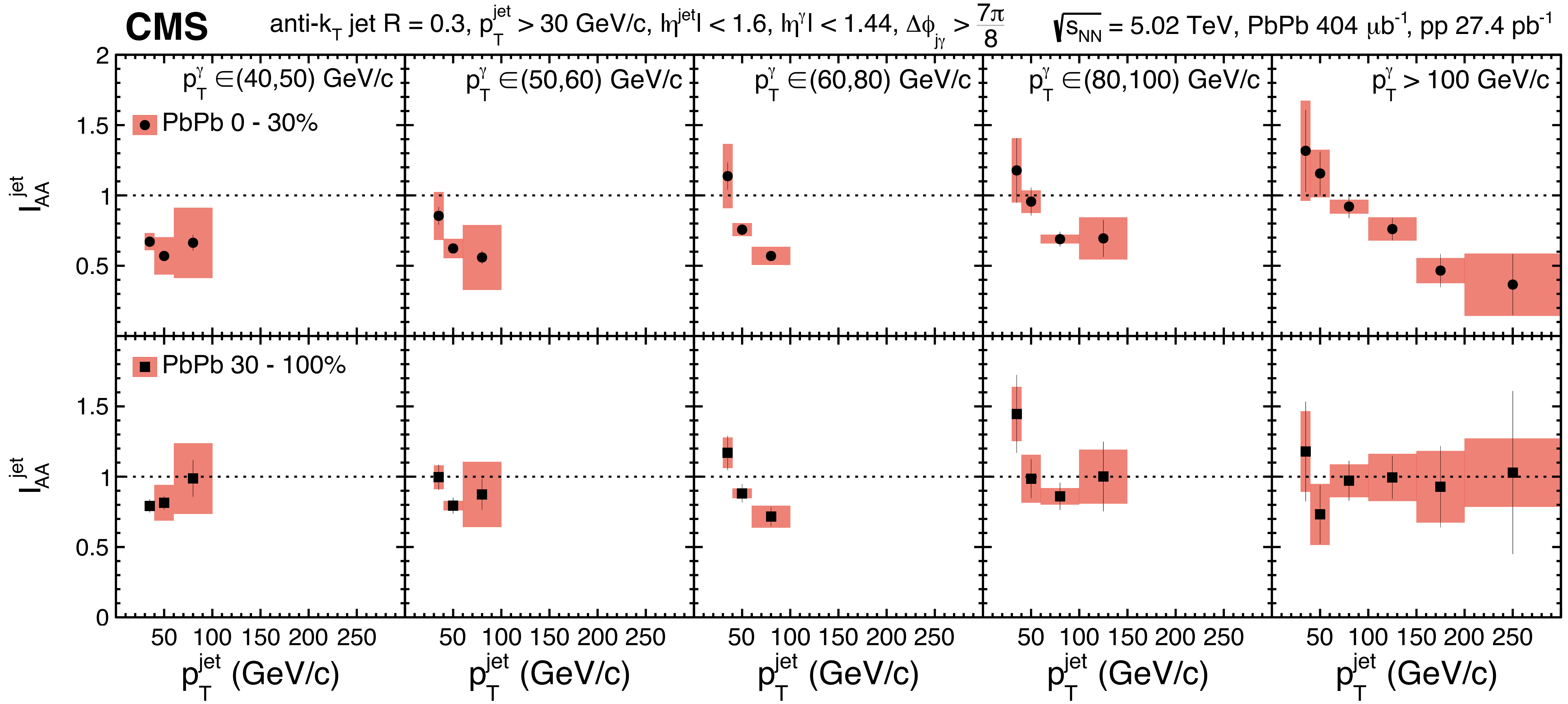


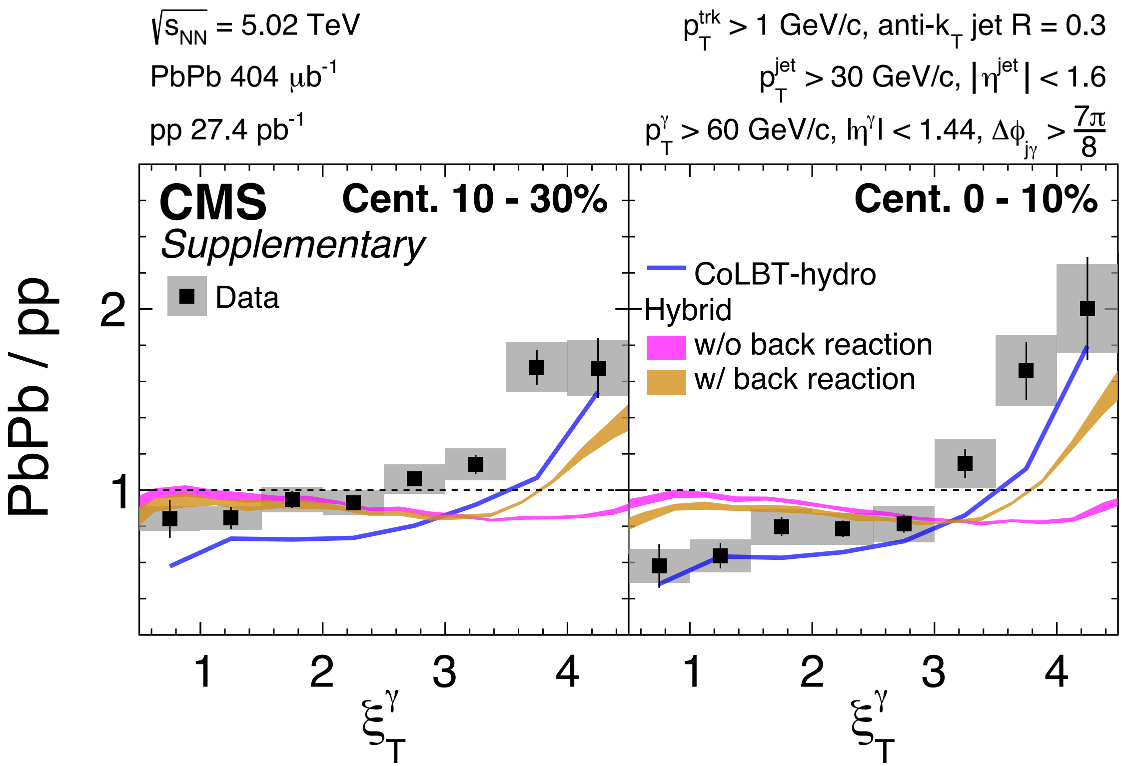
Acknowledgements: Yen-Jie Lee, Yi Chen, Chris McGinn, and Hannah Bossi

Backup

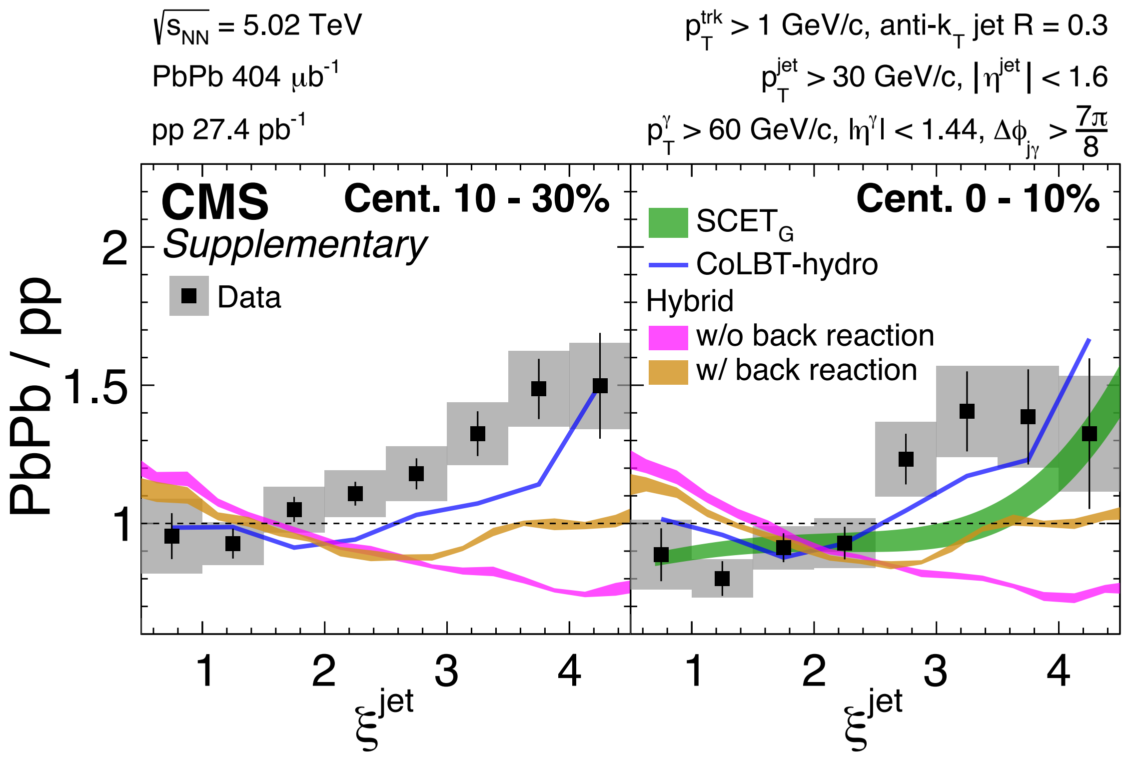

CMS
anti-k$_T$ jet R = 0.3, p_T^{jet} > 30 GeV/c, $|\eta^{jet}|$ < 1.6, $|\eta^{\gamma}|$ < 1.44, p_T^{γ} > 60 GeV/c, $\Delta\phi_{j\gamma} > \frac{7\pi}{8}$
$\sqrt{s_{NN}}$ = 5.02 TeV, PbPb 404 μb^{-1}, pp 27.4 pb^{-1}
PbPb
pp (smeared)
Cent. 50 - 100%
Cent. 30 - 50%
Cent. 10 - 30%
Cent. 0 - 10%
$\frac{1}{N_\gamma}\frac{dN_{j\gamma}}{dx_{j\gamma}}$
$x_{j\gamma} = p_T^{jet}/p_T^{\gamma}$


CMS
anti-kT jet R = 0.3, pT^jet > 30 GeV/c, |η^jet| < 1.6, |η^γ| < 1.44, Δφjγ > 7π/8 √sNN = 5.02 TeV, PbPb 404 μb^-1
pT^γ ∈(40,50) GeV/c
pT^γ ∈(50,60) GeV/c
pT^γ ∈(60,80) GeV/c
pT^γ ∈(80,100) GeV/c
pT^γ > 100 GeV/c
PbPb 0 - 30%
Hybrid
JEWEL + PYTHIA
LBT (2017)
PbPb 30 - 100%
JEWEL + PYTHIA
LBT (2017)
1/Nγ dNjγ/dxjγ
xjγ = pT^jet/pT^γ

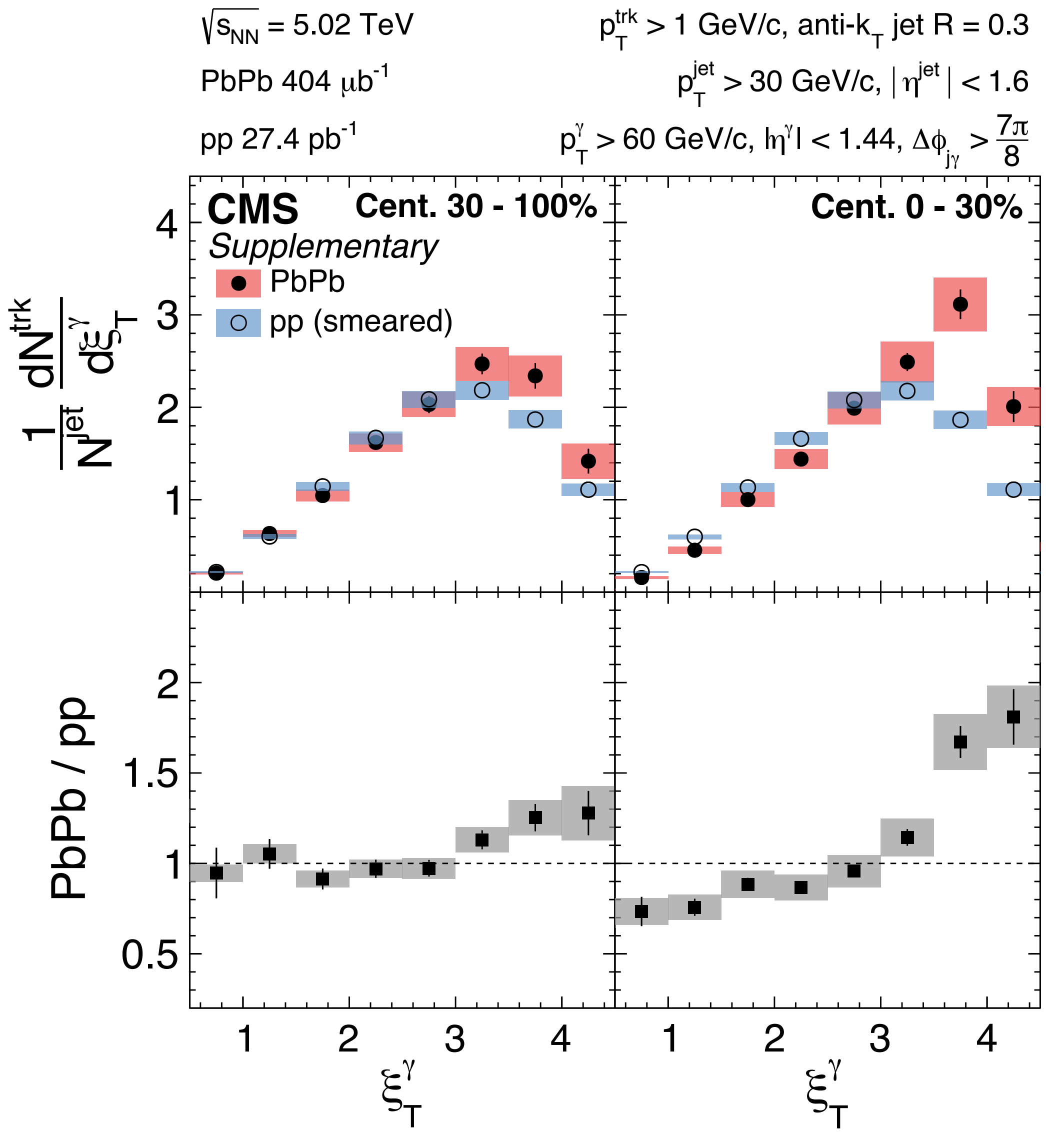

CMS
anti-k_T jet R = 0.3, p_T^{jet} > 30 GeV/c, $|\eta^{jet}|$ < 1.6, $|\eta^{\gamma}|$ < 1.44, $\Delta\phi_{j\gamma} > \frac{7\pi}{8}$
$\sqrt{s_{NN}}$ = 5.02 TeV, PbPb 404 μb^{-1}, pp 27.4 pb^{-1}
$p_T^{\gamma} \in$(40,50) GeV/c
$p_T^{\gamma} \in$(50,60) GeV/c
$p_T^{\gamma} \in$(60,80) GeV/c
$p_T^{\gamma} \in$(80,100) GeV/c
p_T^{γ} > 100 GeV/c
PbPb 0 - 30%
PbPb 30 - 100%
I_{AA}^{jet}
p_T^{jet} (GeV/c)



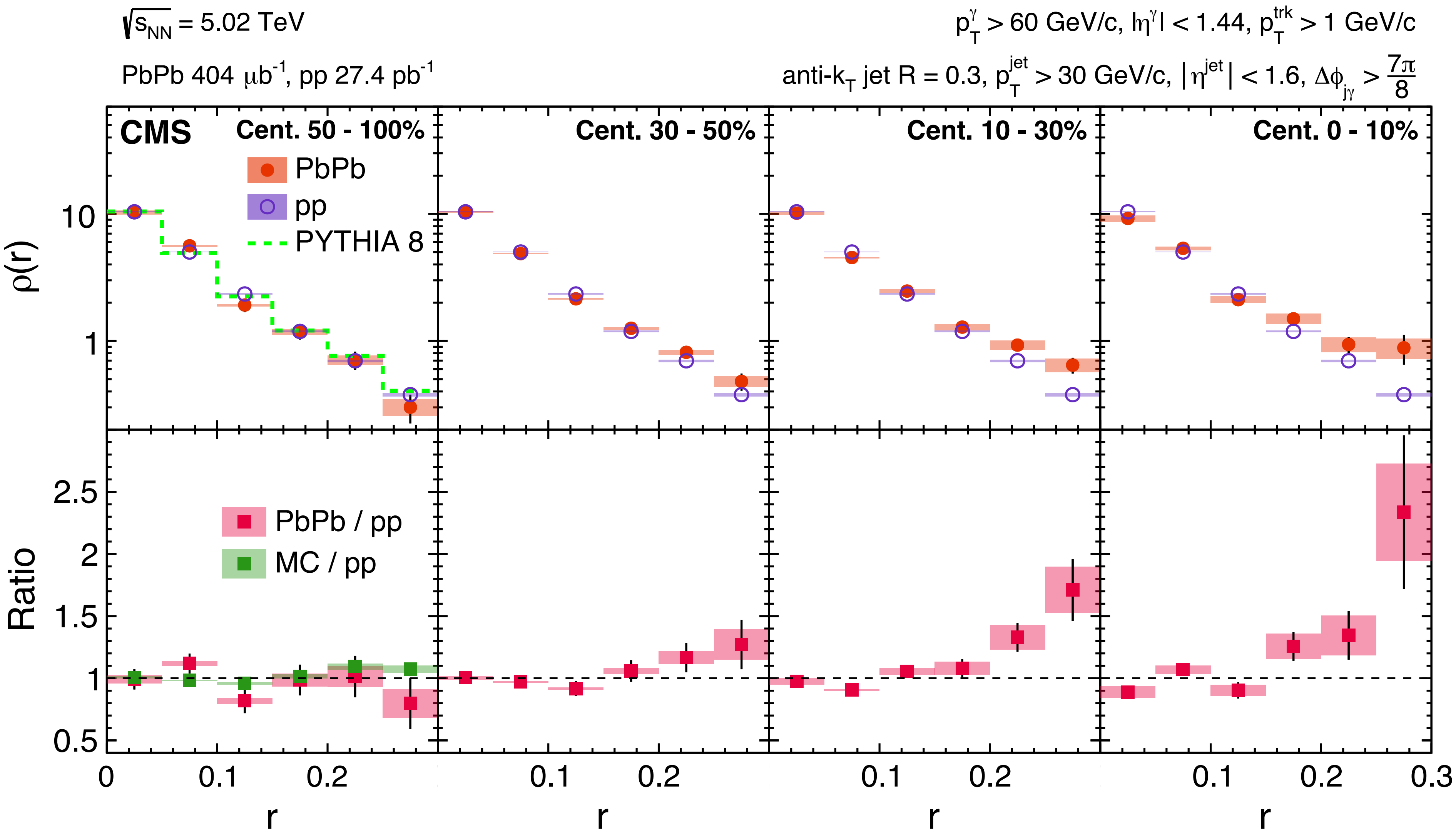
√sNN = 5.02 TeV
PbPb 404 μb-1
pp 27.4 pb-1
pTtrk > 1 GeV/c, anti-kT jet R = 0.3
pTjet > 30 GeV/c, |ηjet| < 1.6
pTγ > 60 GeV/c, |ηγ| < 1.44, Δφjγ > 7π/8
CMS
Supplementary
Cent. 10 - 30%
Cent. 0 - 10%
Data
CoLBT-hydro
Hybrid
w/o back reaction
w/ back reaction
PbPb / pp
ξTγ



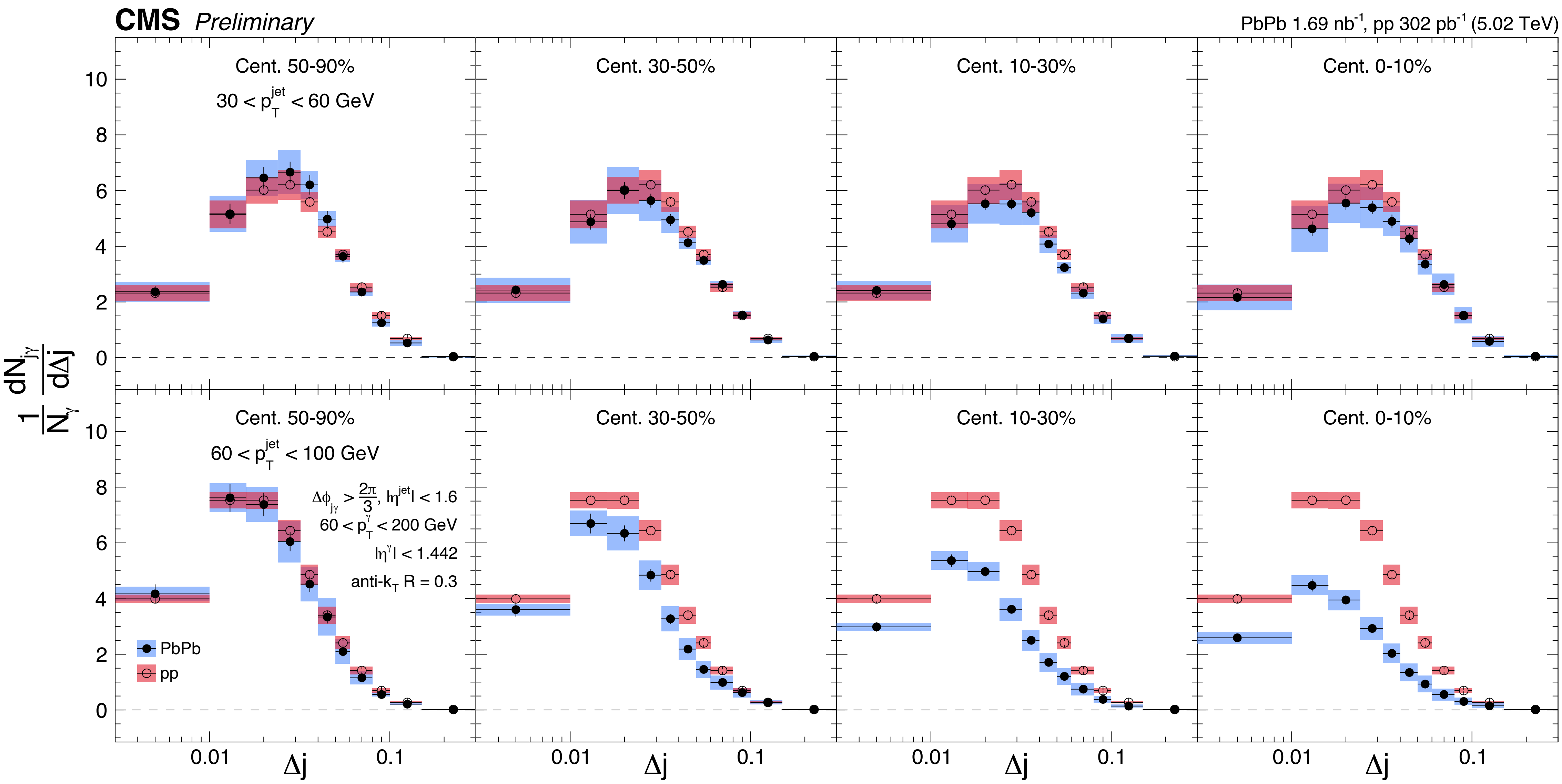
√sNN = 5.02 TeV
PbPb 404 μb-1
pp 27.4 pb-1
pTtrk > 1 GeV/c, anti-kT jet R = 0.3
pTjet > 30 GeV/c, |ηjet| < 1.6
pTγ > 60 GeV/c, |ηγ| < 1.44, Δφjγ > 7π/8
CMS
Supplementary
Cent. 10 - 30%
Cent. 0 - 10%
Data
SCETG
CoLBT-hydro
Hybrid
w/o back reaction
w/ back reaction
PbPb / pp
ξjet

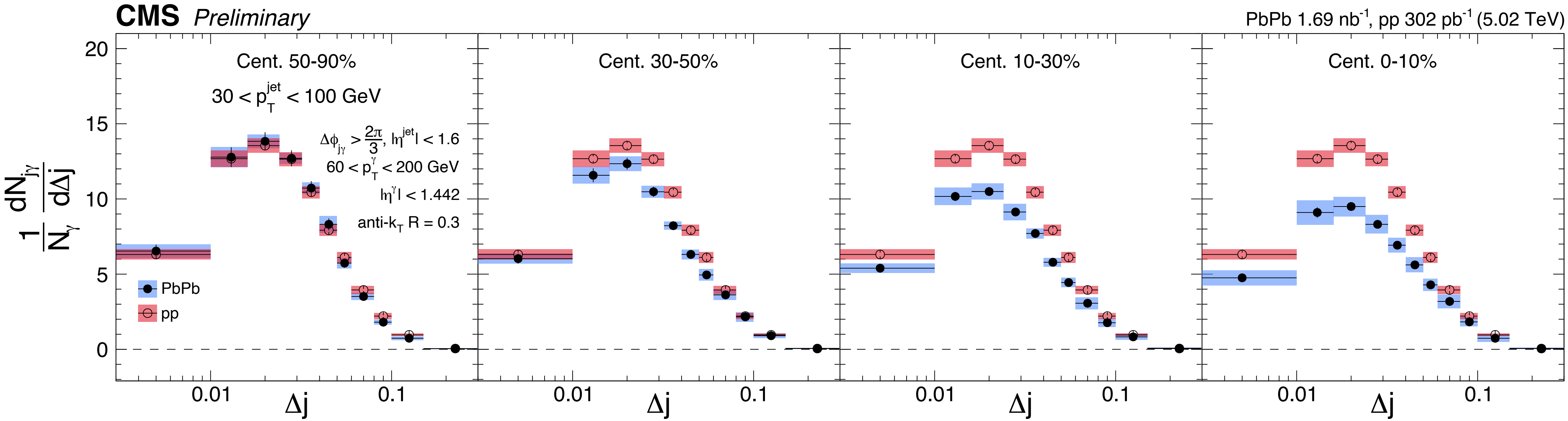


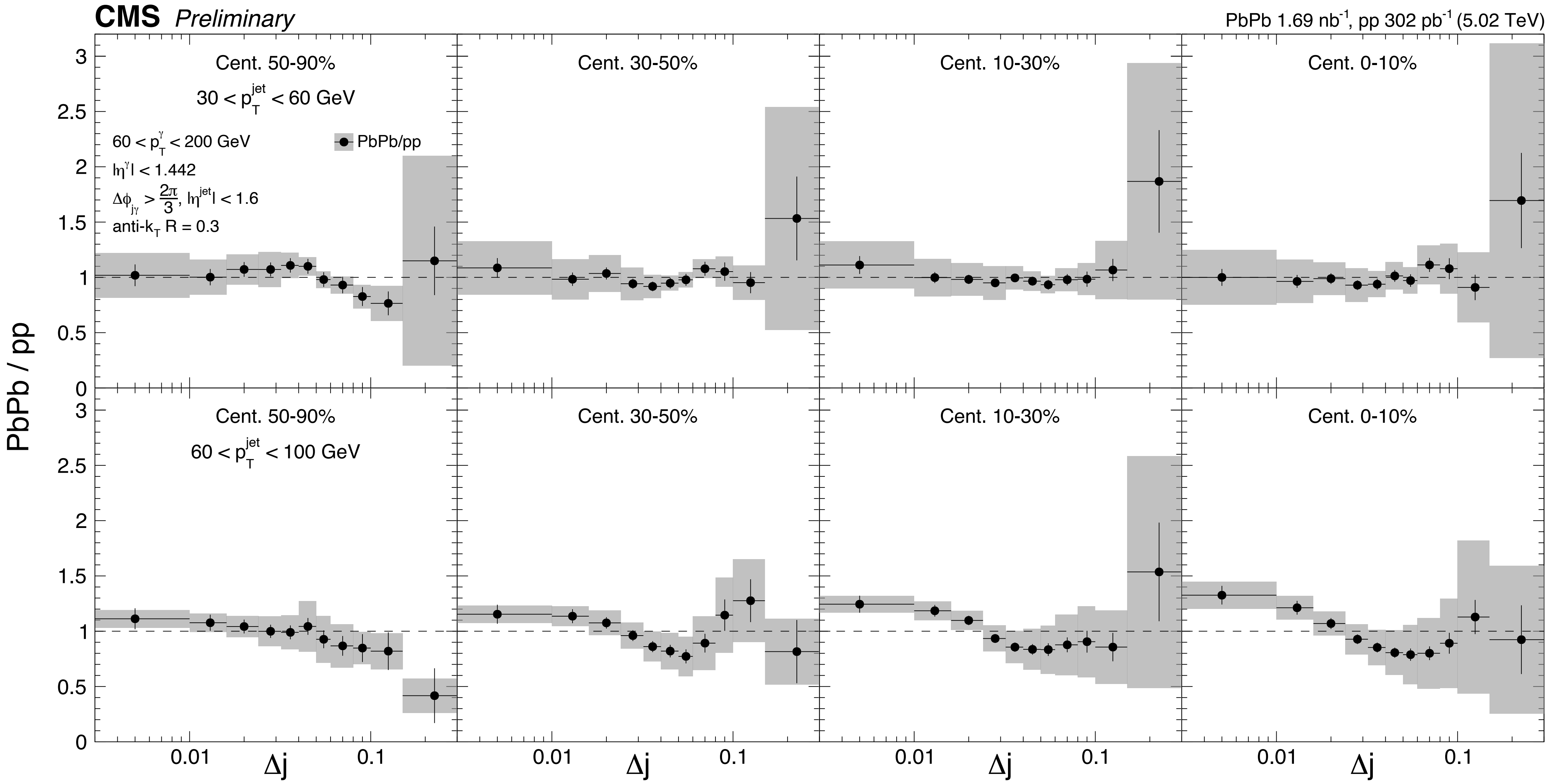
$\sqrt{s_{NN}}$ = 5.02 TeV
PbPb 404 μb^{-1}
pp 27.4 pb^{-1}
p_T^{trk} > 1 GeV/c, anti-k_T jet R = 0.3
p_T^{jet} > 30 GeV/c, $|\eta^{jet}|$ < 1.6
p_T^{γ} > 60 GeV/c, $|\eta^{\gamma}|$ < 1.44, $\Delta\phi_{j\gamma} > \frac{7\pi}{8}$
CMS
Supplementary
Cent. 30 - 100%
Cent. 0 - 30%
PbPb
pp (smeared)
$\frac{1}{N^{jet}}\frac{dN^{trk}}{d\xi_T^{\gamma}}$
PbPb / pp
ξ_T^{γ}

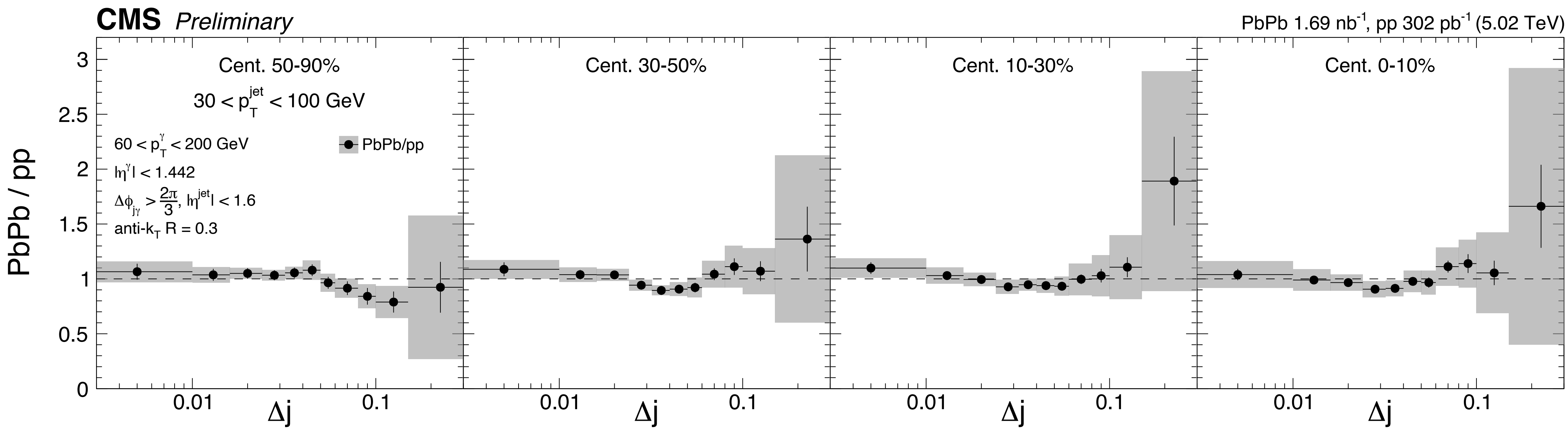


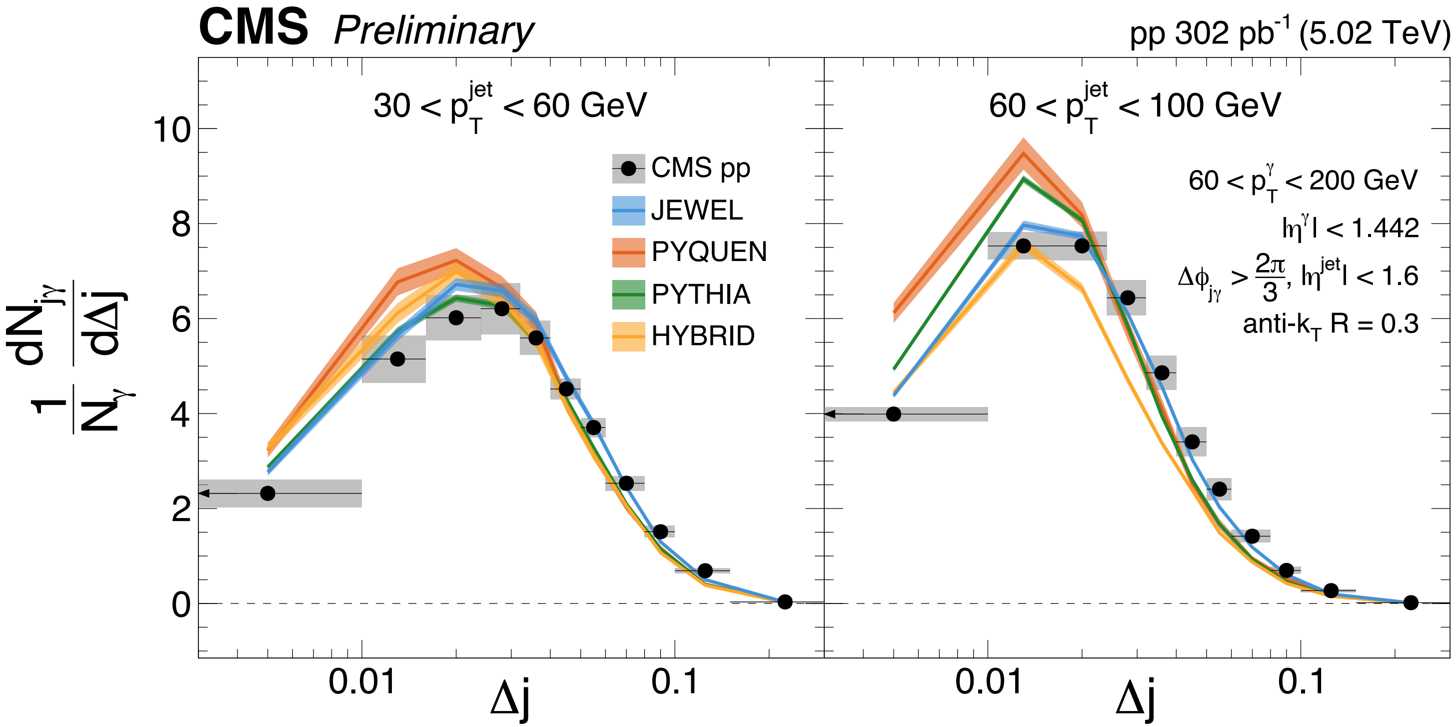
$\sqrt{s_{NN}}$ = 5.02 TeV
PbPb 404 μb^{-1}, pp 27.4 pb^{-1}
p_T^{γ} > 60 GeV/c, |η^{γ}| < 1.44, p_T^{trk} > 1 GeV/c
anti-k_T jet R = 0.3, p_T^{jet} > 30 GeV/c, |η^{jet}| < 1.6, $\Delta\phi_{j\gamma} > \frac{7\pi}{8}$
CMS
Cent. 50 - 100%
Cent. 30 - 50%
Cent. 10 - 30%
Cent. 0 - 10%
PbPb
pp
PYTHIA 8
ρ(r)
PbPb / pp
MC / pp
Ratio
r

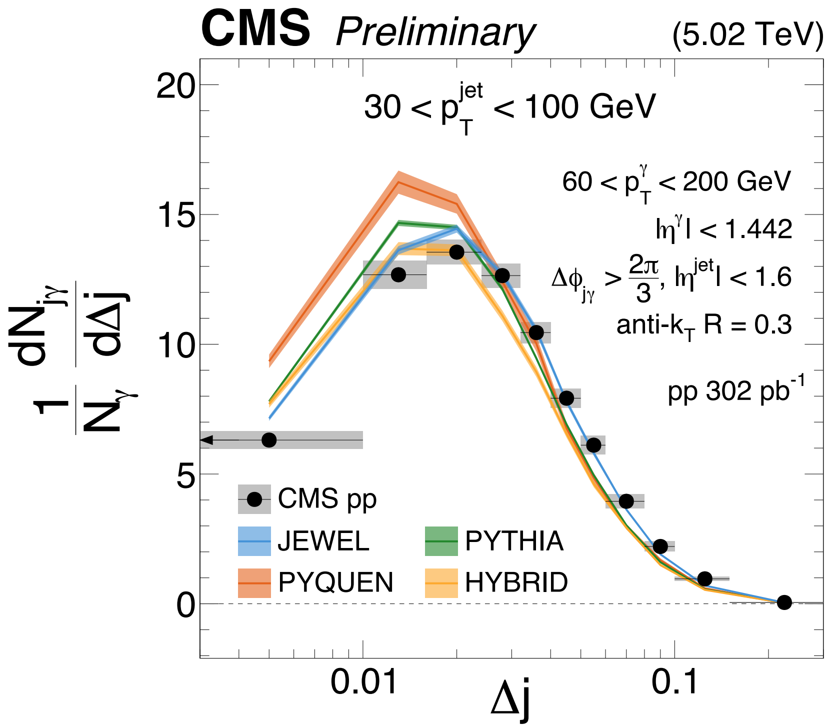

CMS Preliminary
PbPb 1.69 nb-1, pp 302 pb-1 (5.02 TeV)
Cent. 50-90%
30 < pTjet < 60 GeV
Cent. 30-50%
Cent. 10-30%
Cent. 0-10%
Cent. 50-90%
60 < pTjet < 100 GeV
Δφjγ > 2π/3, |ηjet| < 1.6
60 < pTγ < 200 GeV
|ηγ| < 1.442
anti-kT R = 0.3
PbPb
pp
Cent. 30-50%
Cent. 10-30%
Cent. 0-10%
1/Nγ dNjγ/dΔj
Δj
0.01
0.1

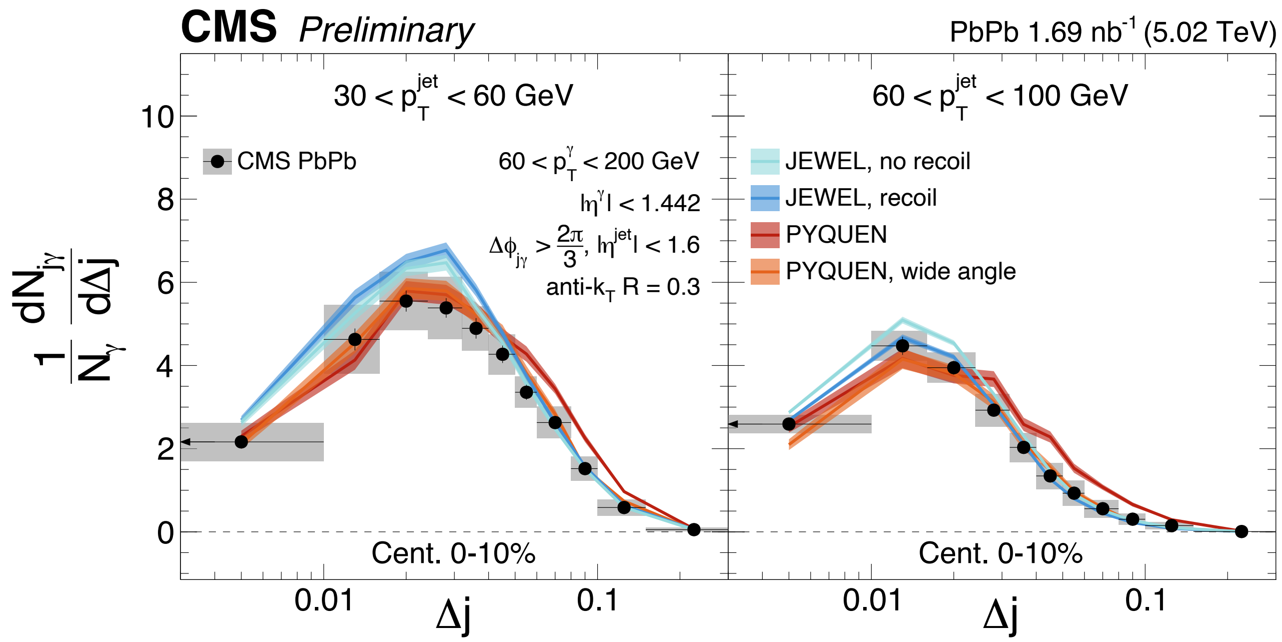

CMS Preliminary
PbPb 1.69 nb^-1, pp 302 pb^-1 (5.02 TeV)
Cent. 50-90%
Cent. 30-50%
Cent. 10-30%
Cent. 0-10%
30 < p_T^jet < 100 GeV
Δφ_jγ > 2π/3, |η^jet| < 1.6
60 < p_T^γ < 200 GeV
|η^γ| < 1.442
anti-k_T R = 0.3
PbPb
pp
Δj
(1/N_γ) dN_jγ/dΔj

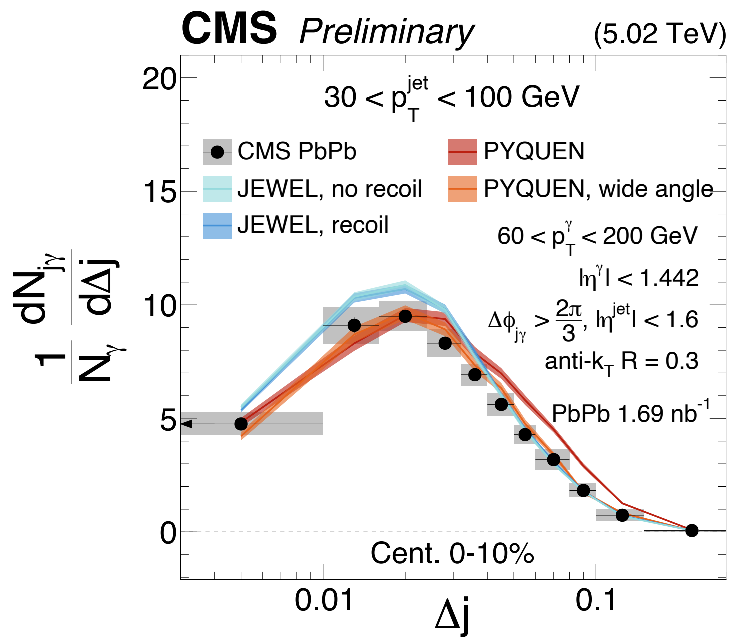

CMS Preliminary
PbPb 1.69 nb-1, pp 302 pb-1 (5.02 TeV)
PbPb / pp
Cent. 50-90%
Cent. 30-50%
Cent. 10-30%
Cent. 0-10%
30 < pT jet < 60 GeV
60 < pT jet < 100 GeV
60 < pT γ < 200 GeV
|ηγ| < 1.442
Δφjγ > 2π/3, |ηjet| < 1.6
anti-kT R = 0.3
PbPb/pp
Δj
0.01
0.1

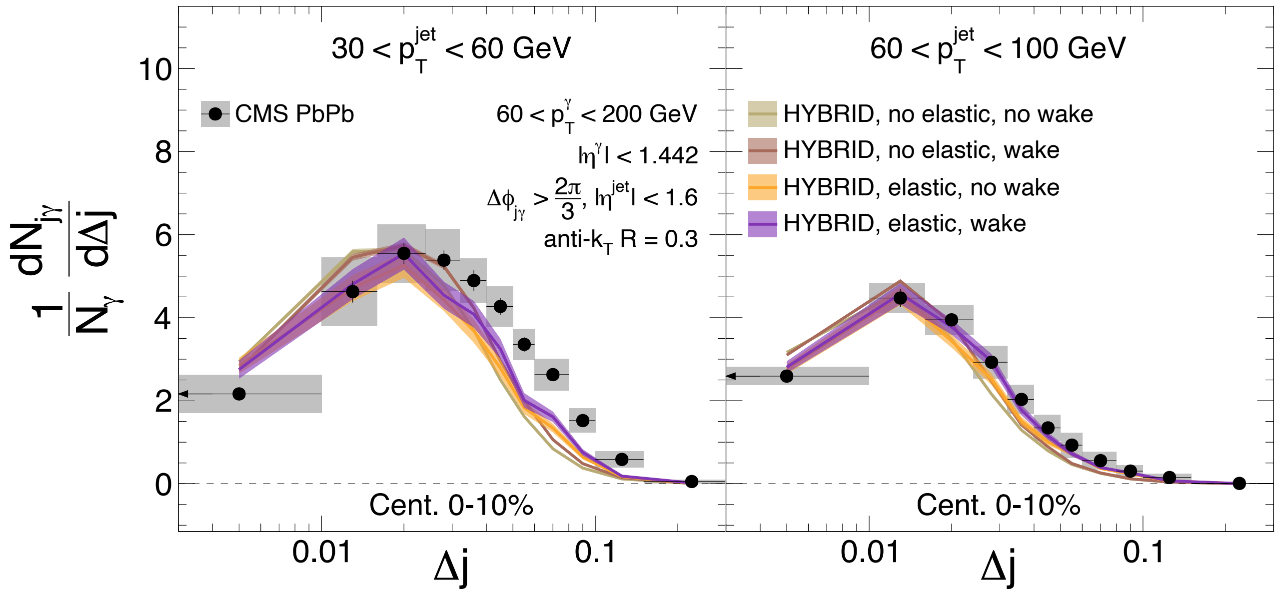

CMS Preliminary
PbPb 1.69 nb^{-1}, pp 302 pb^{-1} (5.02 TeV)
Cent. 50-90%
$30 < p_T^{jet} < 100$ GeV
$60 < p_T^{\gamma} < 200$ GeV
$|\eta^{\gamma}| < 1.442$
$\Delta\phi_{j\gamma} > \frac{2\pi}{3}$, $|\eta^{jet}| < 1.6$
anti-k_T R = 0.3
PbPb/pp
Cent. 30-50%
Cent. 10-30%
Cent. 0-10%
PbPb / pp
Δj
0
0.5
1
1.5
2
2.5
3
0.01
0.1

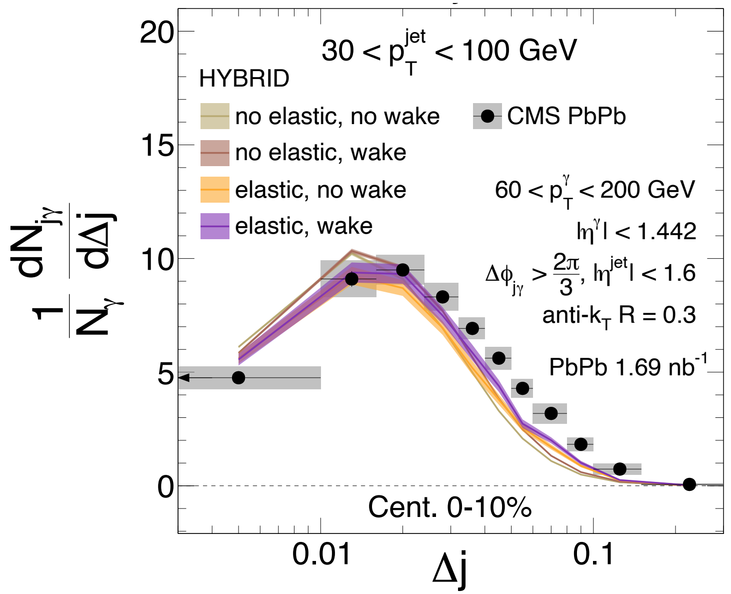

CMS Preliminary
pp 302 pb-1 (5.02 TeV)
30 < p_T^jet < 60 GeV
60 < p_T^jet < 100 GeV
CMS pp
JEWEL
PYQUEN
PYTHIA
HYBRID
60 < p_T^γ < 200 GeV
|η^γ| < 1.442
Δφ_jγ > 2π/3, |η^jet| < 1.6
anti-k_T R = 0.3
1/N_γ dN_jγ/dΔj
Δj

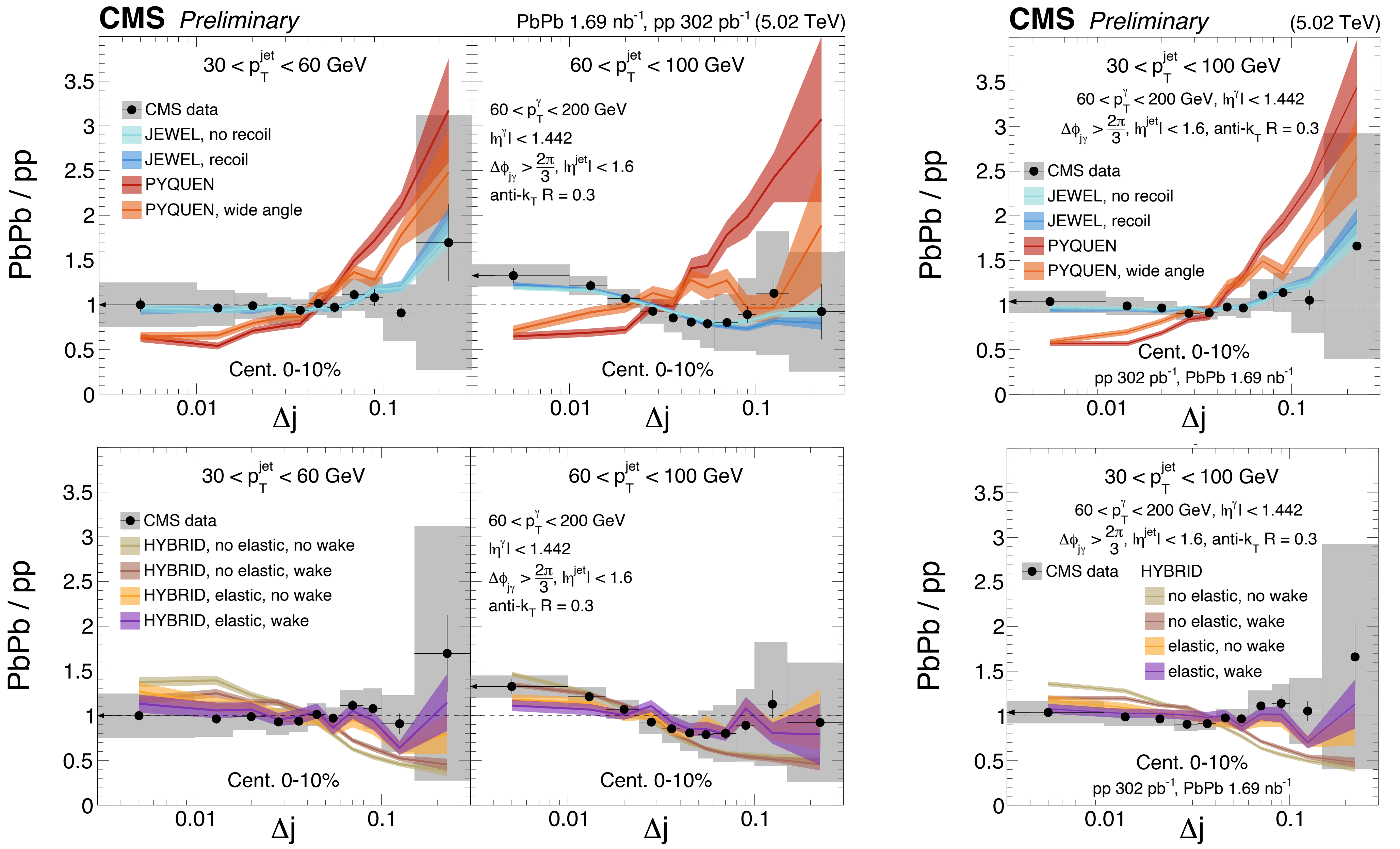

CMS Preliminary
(5.02 TeV)
30 < p_T^jet < 100 GeV
60 < p_T^γ < 200 GeV
|η^γ| < 1.442
Δφ_jγ > 2π/3, |η^jet| < 1.6
anti-k_T R = 0.3
pp 302 pb-1
CMS pp
JEWEL
PYTHIA
PYQUEN
HYBRID
1/N_γ dN_jγ/dΔj
Δj


CMS Preliminary
PbPb 1.69 nb^{-1} (5.02 TeV)
$30 < p_T^{jet} < 60$ GeV
$60 < p_T^{jet} < 100$ GeV
CMS PbPb
$60 < p_T^{\gamma} < 200$ GeV
$|\eta^{\gamma}| < 1.442$
$\Delta\phi_{j\gamma} > \frac{2\pi}{3}$, $|\eta^{jet}| < 1.6$
anti-k_T R = 0.3
JEWEL, no recoil
JEWEL, recoil
PYQUEN
PYQUEN, wide angle
Cent. 0-10%
$\frac{1}{N_\gamma}\frac{dN_{j\gamma}}{d\Delta j}$
Δj


CMS Preliminary
(5.02 TeV)
$30 < p_T^{jet} < 100$ GeV
CMS PbPb
JEWEL, no recoil
JEWEL, recoil
PYQUEN
PYQUEN, wide angle
$60 < p_T^{\gamma} < 200$ GeV
$|\eta^{\gamma}| < 1.442$
$\Delta\phi_{j\gamma} > \frac{2\pi}{3}$, $|\eta^{jet}| < 1.6$
anti-k_T R = 0.3
PbPb 1.69 nb^{-1}
Cent. 0-10%
$\frac{1}{N_\gamma}\frac{dN_{j\gamma}}{d\Delta j}$
Δj

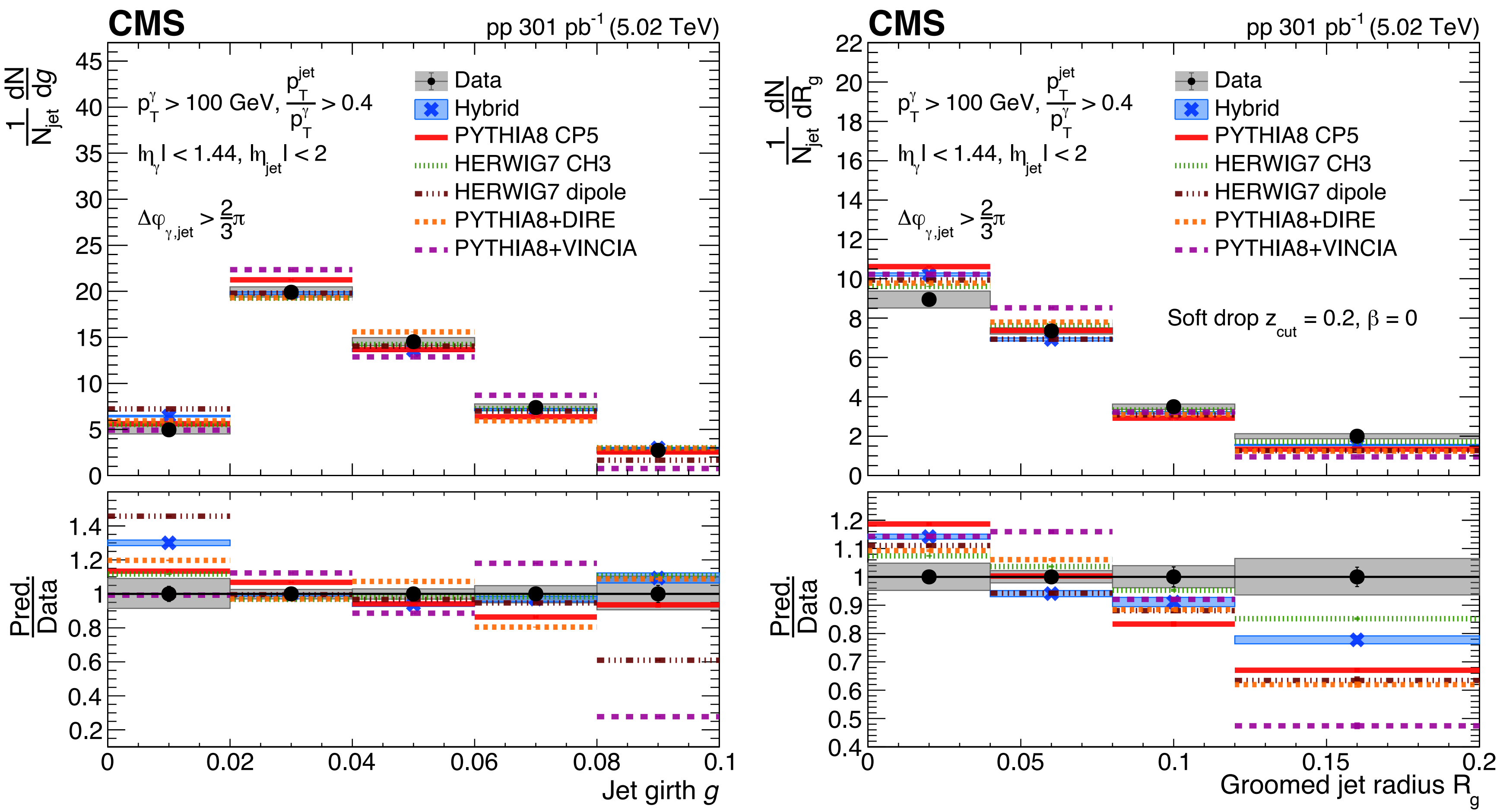

$30 < p_T^{jet} < 60$ GeV
$60 < p_T^{jet} < 100$ GeV
CMS PbPb
$60 < p_T^{\gamma} < 200$ GeV
$|\eta^{\gamma}| < 1.442$
$\Delta\phi_{j\gamma} > \frac{2\pi}{3}$, $|\eta^{jet}| < 1.6$
anti-k_T R = 0.3
HYBRID, no elastic, no wake
HYBRID, no elastic, wake
HYBRID, elastic, no wake
HYBRID, elastic, wake
Cent. 0-10%
$\frac{1}{N_\gamma}\frac{dN_{j\gamma}}{d\Delta j}$
Δj

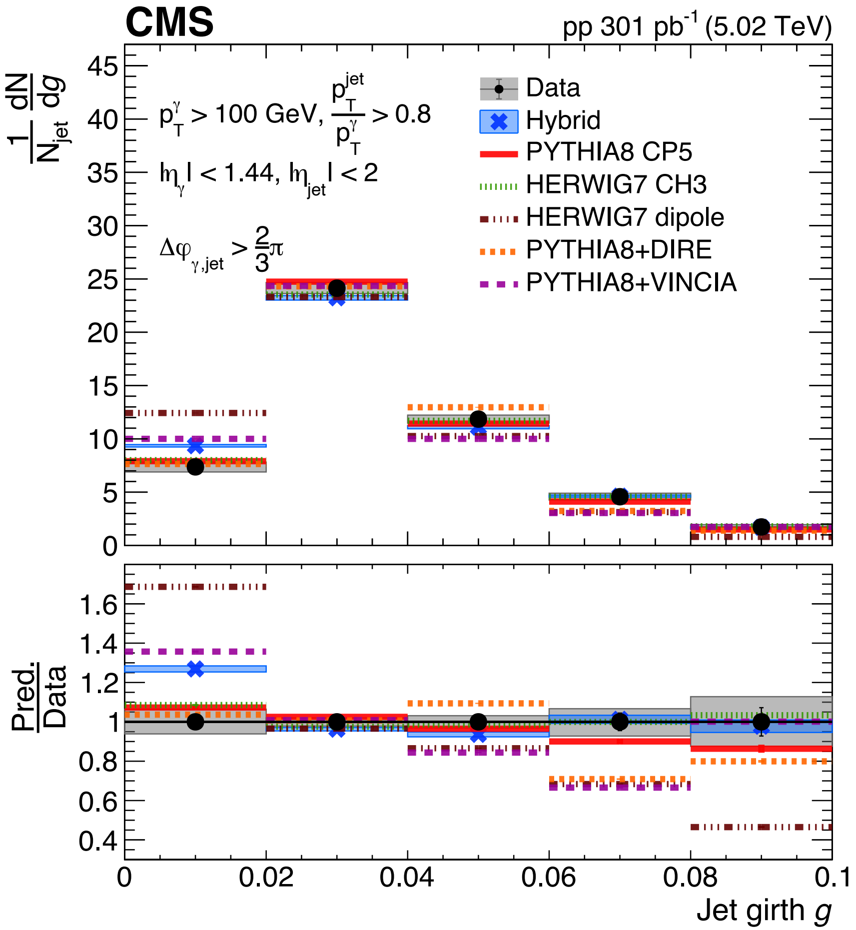

$30 < p_T^{jet} < 100$ GeV
HYBRID
no elastic, no wake
no elastic, wake
elastic, no wake
elastic, wake
CMS PbPb
$60 < p_T^{\gamma} < 200$ GeV
$|\eta^{\gamma}| < 1.442$
$\Delta\phi_{j\gamma} > \frac{2\pi}{3}$, $|\eta^{jet}| < 1.6$
anti-k_T R = 0.3
PbPb 1.69 nb^{-1}
Cent. 0-10%
$\frac{1}{N_\gamma}\frac{dN_{j\gamma}}{d\Delta j}$
Δj

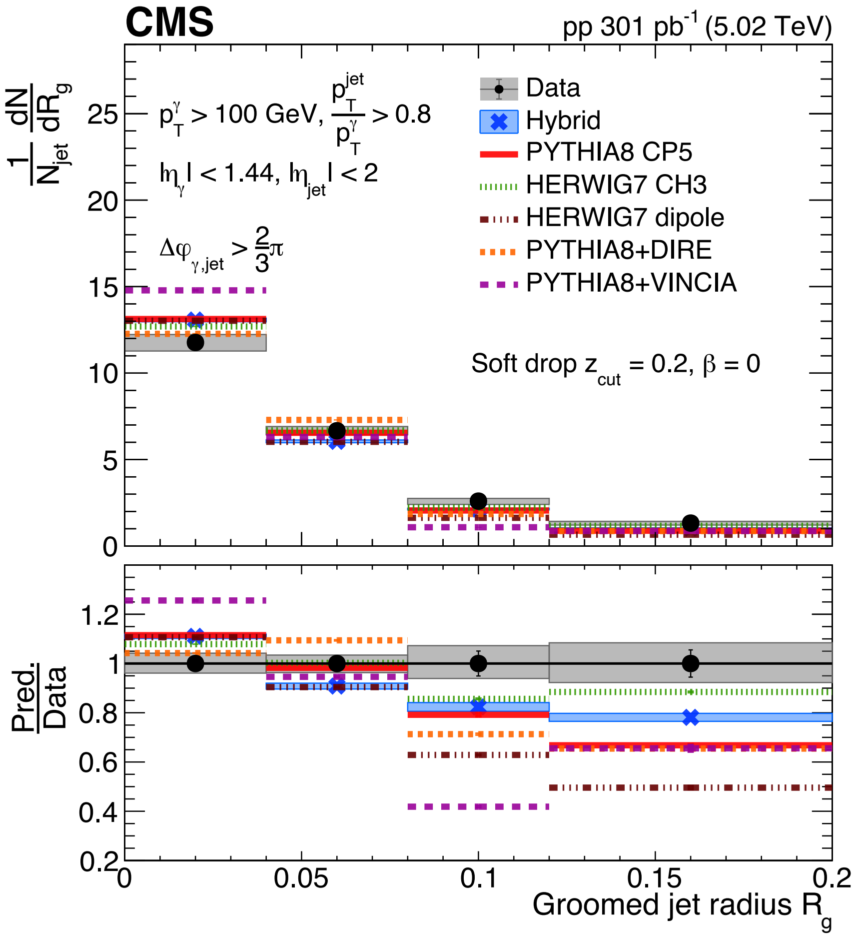


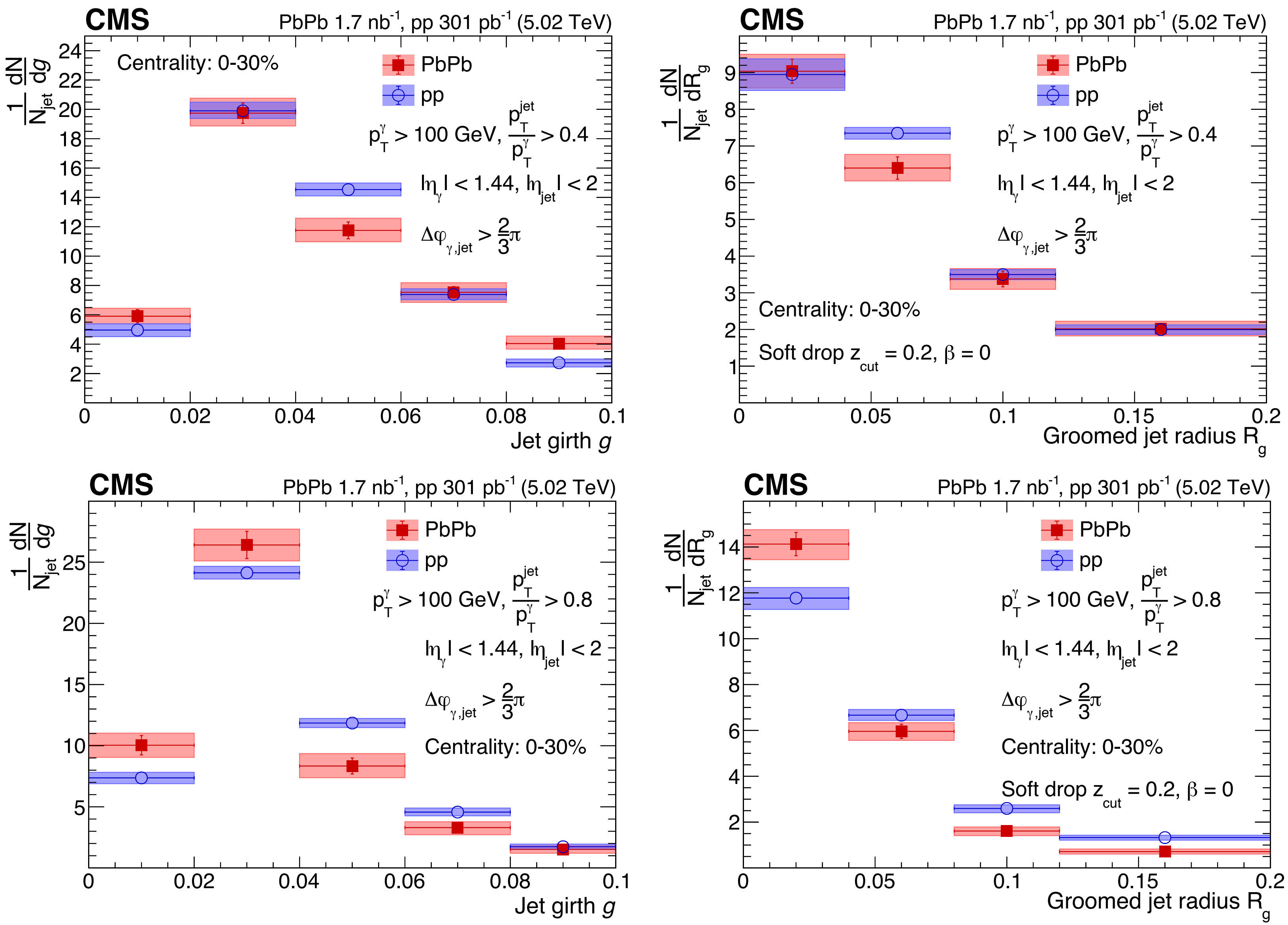
CMS Preliminary
PbPb 1.69 nb-1, pp 302 pb-1 (5.02 TeV)
30 < pTjet < 60 GeV
60 < pTjet < 100 GeV
CMS data
JEWEL, no recoil
JEWEL, recoil
PYQUEN
PYQUEN, wide angle
60 < pTγ < 200 GeV
|ηγ| < 1.442
Δφjγ > 2π/3, |ηjet| < 1.6
anti-kT R = 0.3
Cent. 0-10%
PbPb / pp
Δj
CMS Preliminary
(5.02 TeV)
30 < pTjet < 100 GeV
60 < pTγ < 200 GeV, |ηγ| < 1.442
Δφjγ > 2π/3, |ηjet| < 1.6, anti-kT R = 0.3
pp 302 pb-1, PbPb 1.69 nb-1
HYBRID, no elastic, no wake
HYBRID, no elastic, wake
HYBRID, elastic, no wake
HYBRID, elastic, wake
HYBRID
no elastic, no wake
no elastic, wake
elastic, no wake
elastic, wake

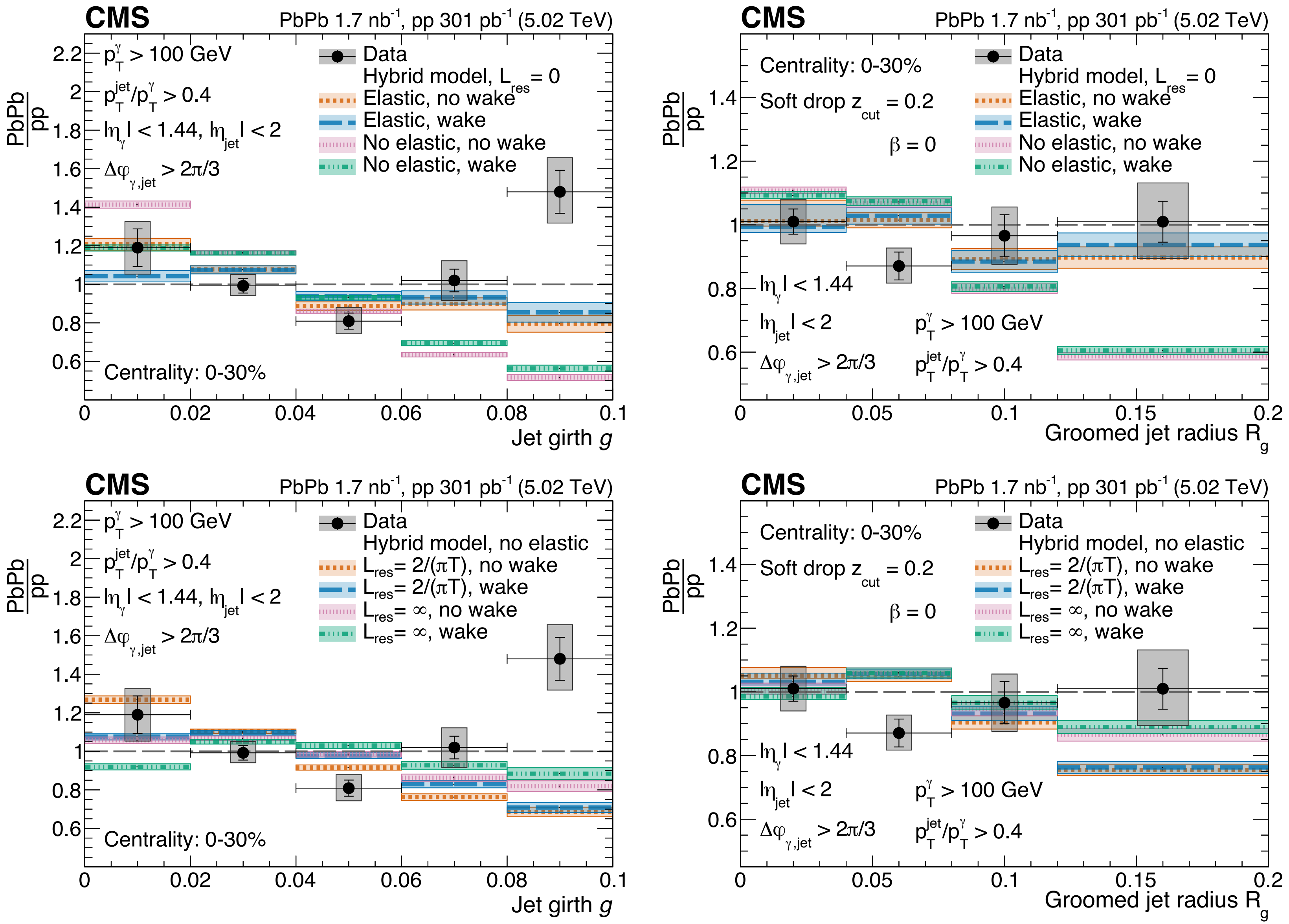
024

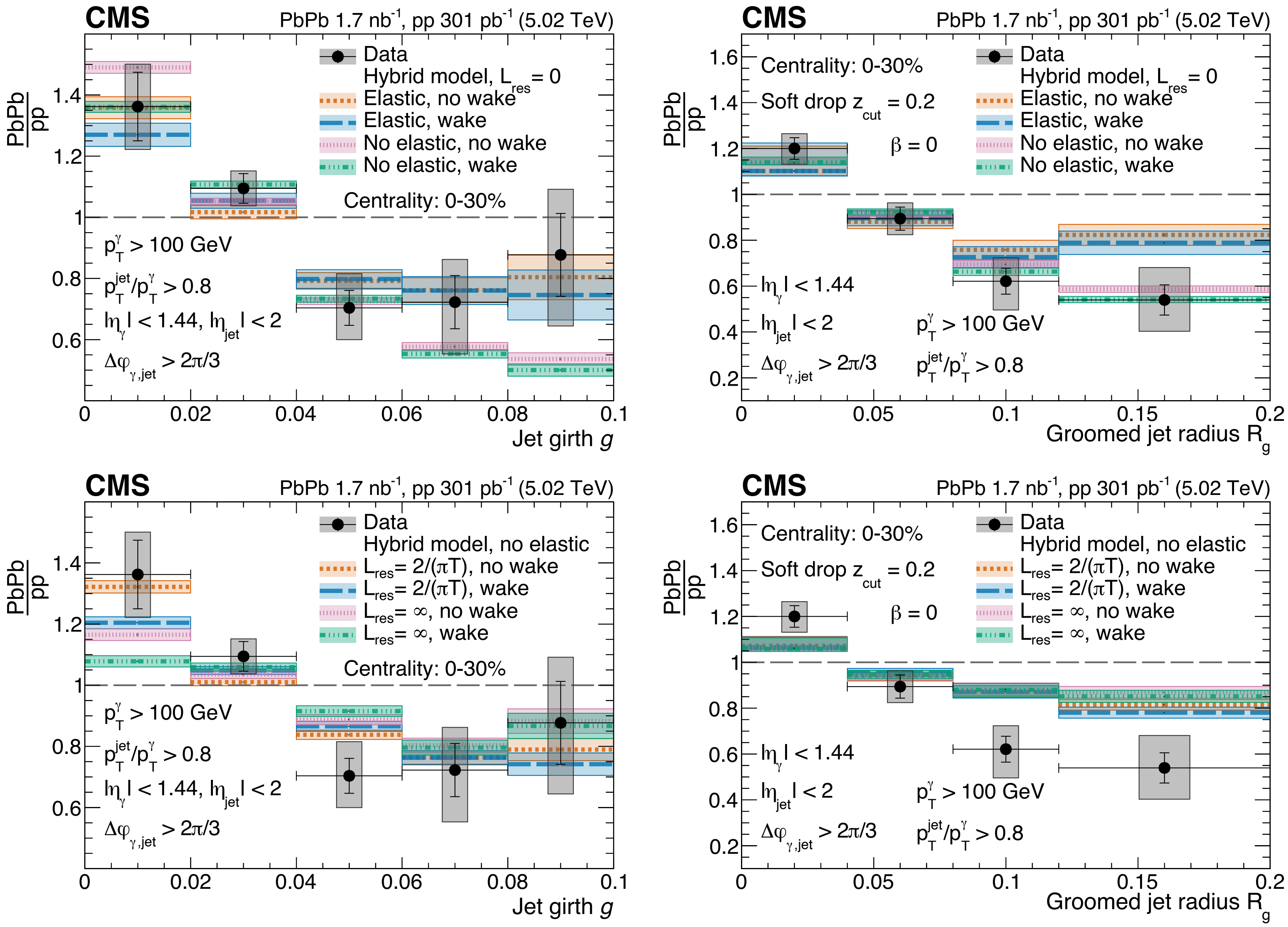

CMS
pp 301 pb-1 (5.02 TeV)
Data
Hybrid
PYTHIA8 CP5
HERWIG7 CH3
HERWIG7 dipole
PYTHIA8+DIRE
PYTHIA8+VINCIA
Soft drop z_cut = 0.2, β = 0
Pred./Data
Jet girth g
Groomed jet radius R_g


CMS
pp 301 pb^{-1} (5.02 TeV)
$p_T^{\gamma} > 100$ GeV, $\frac{p_T^{jet}}{p_T^{\gamma}} > 0.8$
$|\eta_{\gamma}| < 1.44$, $|\eta_{jet}| < 2$
$\Delta\varphi_{\gamma,jet} > \frac{2}{3}\pi$
Data
Hybrid
PYTHIA8 CP5
HERWIG7 CH3
HERWIG7 dipole
PYTHIA8+DIRE
PYTHIA8+VINCIA
$\frac{1}{N_{jet}}\frac{dN}{dg}$
Pred./Data
Jet girth g


CMS
pp 301 pb^{-1} (5.02 TeV)
$p_T^{\gamma} > 100$ GeV, $\frac{p_T^{jet}}{p_T^{\gamma}} > 0.8$
$|\eta_{\gamma}| < 1.44$, $|\eta_{jet}| < 2$
$\Delta\varphi_{\gamma,jet} > \frac{2}{3}\pi$
Data
Hybrid
PYTHIA8 CP5
HERWIG7 CH3
HERWIG7 dipole
PYTHIA8+DIRE
PYTHIA8+VINCIA
Soft drop $z_{cut} = 0.2$, $\beta = 0$
$\frac{1}{N_{jet}}\frac{dN}{dR_g}$
Pred./Data
Groomed jet radius R_g


CMS
PbPb 1.7 nb-1, pp 301 pb-1 (5.02 TeV)
Centrality: 0-30%
PbPb
pp
pTγ > 100 GeV, pTjet/pTγ > 0.4
|ηγ| < 1.44, |ηjet| < 2
Δφγ,jet > 2/3π
1/Njet dN/dg
Jet girth g
CMS
PbPb 1.7 nb-1, pp 301 pb-1 (5.02 TeV)
PbPb
pp
pTγ > 100 GeV, pTjet/pTγ > 0.4
|ηγ| < 1.44, |ηjet| < 2
Δφγ,jet > 2/3π
Centrality: 0-30%
Soft drop zcut = 0.2, β = 0
1/Njet dN/dRg
Groomed jet radius Rg
CMS
PbPb 1.7 nb-1, pp 301 pb-1 (5.02 TeV)
PbPb
pp
pTγ > 100 GeV, pTjet/pTγ > 0.8
|ηγ| < 1.44, |ηjet| < 2
Δφγ,jet > 2/3π
Centrality: 0-30%
1/Njet dN/dg
Jet girth g
CMS
PbPb 1.7 nb-1, pp 301 pb-1 (5.02 TeV)
PbPb
pp
pTγ > 100 GeV, pTjet/pTγ > 0.8
|ηγ| < 1.44, |ηjet| < 2
Δφγ,jet > 2/3π
Centrality: 0-30%
Soft drop zcut = 0.2, β = 0
1/Njet dN/dRg
Groomed jet radius Rg


CMS
PbPb 1.7 nb-1, pp 301 pb-1 (5.02 TeV)
pT γ > 100 GeV
pT jet/pT γ > 0.4
|ηγ| < 1.44, |ηjet| < 2
Δφγ,jet > 2π/3
Data
Hybrid model, Lres = 0
Elastic, no wake
Elastic, wake
No elastic, no wake
No elastic, wake
Centrality: 0-30%
Jet girth g
PbPb/pp
Soft drop zcut = 0.2
β = 0
Groomed jet radius Rg
Hybrid model, no elastic
Lres = 2/(πT), no wake
Lres = 2/(πT), wake
Lres = ∞, no wake
Lres = ∞, wake


CMS
PbPb 1.7 nb-1, pp 301 pb-1 (5.02 TeV)
PbPb/pp
Data
Hybrid model, Lres = 0
Elastic, no wake
Elastic, wake
No elastic, no wake
No elastic, wake
Centrality: 0-30%
pTγ > 100 GeV
pTjet/pTγ > 0.8
|ηγ| < 1.44, |ηjet| < 2
Δφγ,jet > 2π/3
Jet girth g
Soft drop zcut = 0.2
β = 0
|ηγ| < 1.44
|ηjet| < 2
Groomed jet radius Rg
Hybrid model, no elastic
Lres= 2/(πT), no wake
Lres= 2/(πT), wake
Lres= ∞, no wake
Lres= ∞, wake