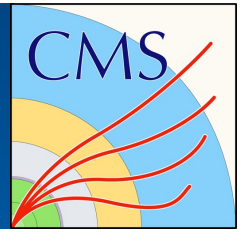
Flavor dynamics & partonic energy loss studies with b-jet shapes measurements in pp and PbPb collision data from CMS



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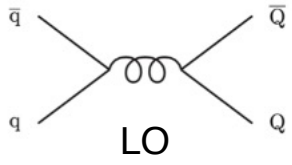
b-quark jets

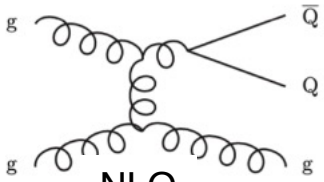
Ideally: A jet "initiated by a heavy quark"

In practice: A jet associated to one or more b-hadrons



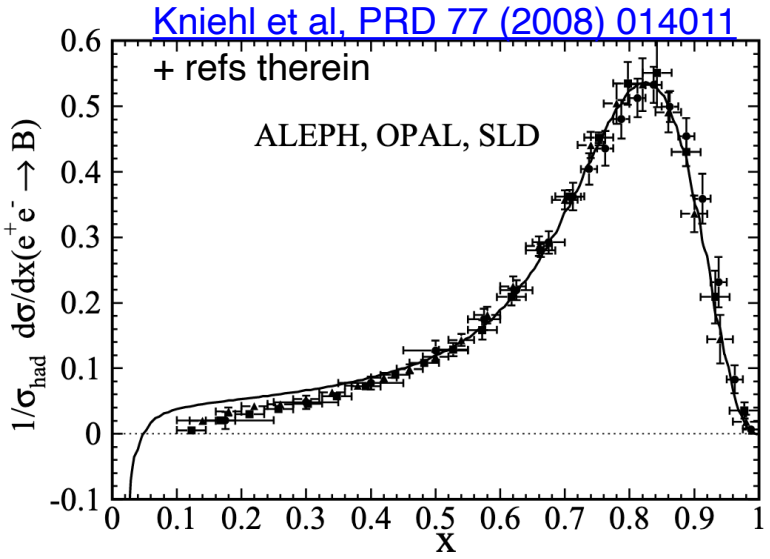
LO

Beyond leading order in QCD can be produced from gluons, including bb in a single jet



NLO

- Characterized by hard fragmentation & suppression of small angle radiation
- Compensated by decay kinematics of b-hadrons, which "fill" the dead cone



b-jet ID is a standard HEP tool, e.g., for top, H→bb, many BSM signatures

Flavor dependence of energy loss

Energy loss should depend on parton species

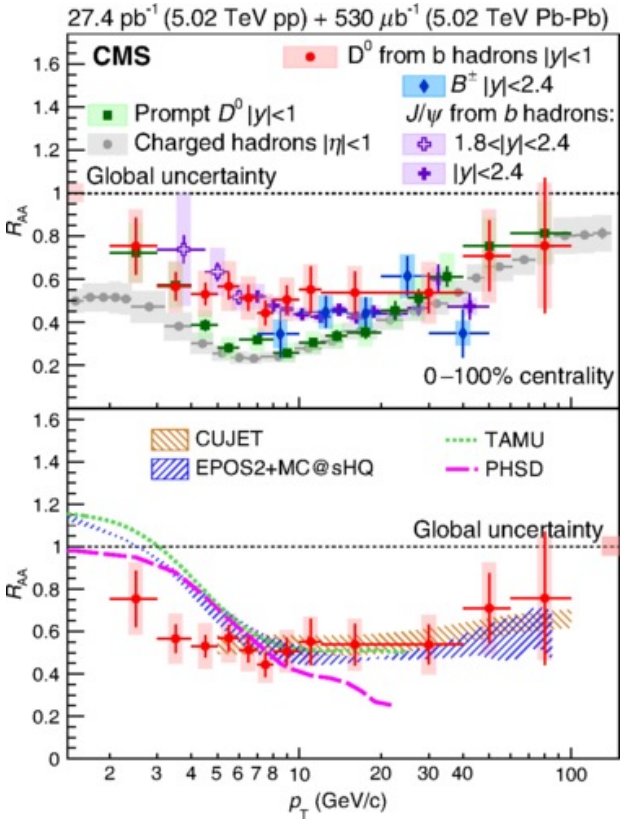
- Quark mass dependent radiation pattern
- Different color factor of quarks and gluons

These effects provide excellent constraints on jet quenching models, e.g., radiative vs. collisional processes →

Ideally, want to study the structure of jets for different parton species

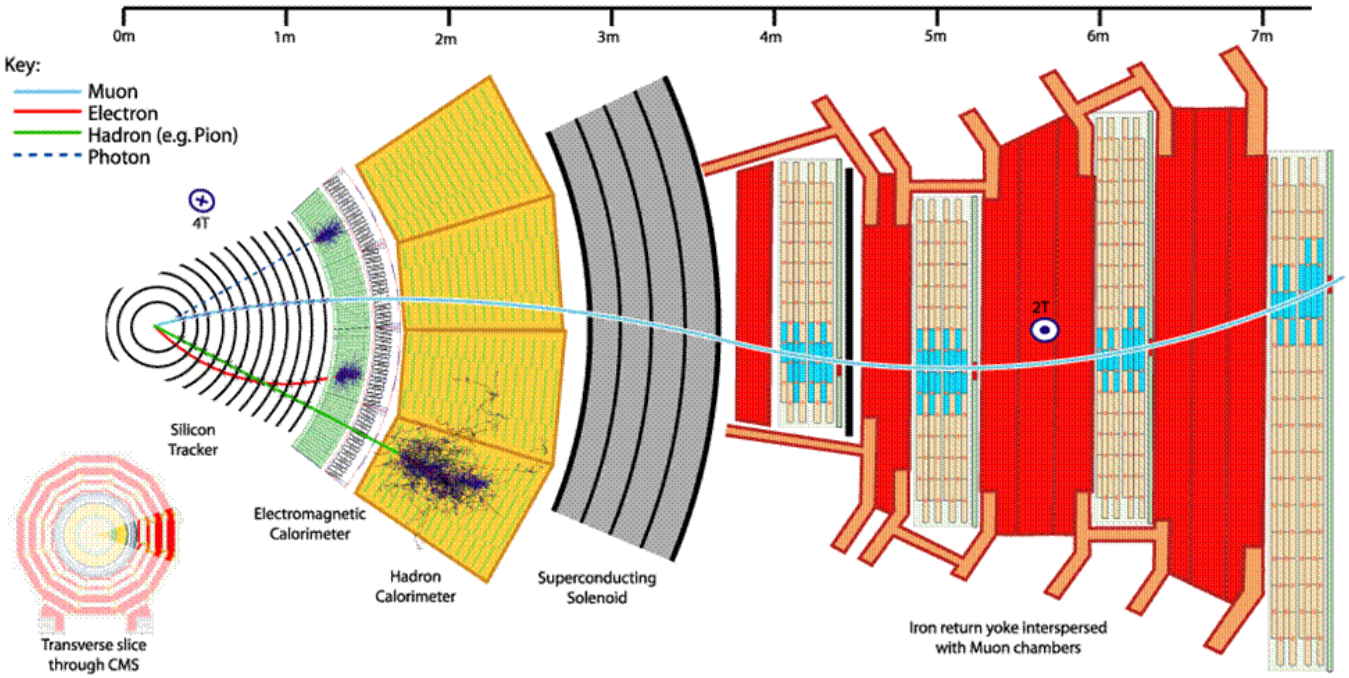
Although parton species is in general not directly measurable, b-quark jets can be identified

Single hadron nuclear modification factors



PRL 123 (2019) 022001

Compact Muon Solenoid



CMS features a 3.8T magnetic field w/ precision charged particle silicon tracking

→ p_T resolution of around 1%, depending on p_T and η

→ Typical impact parameter resolution of 10's of microns

Particle flow based jet reconstruction combines information from all subsystems, making optimal use of excellent charged particle tracking

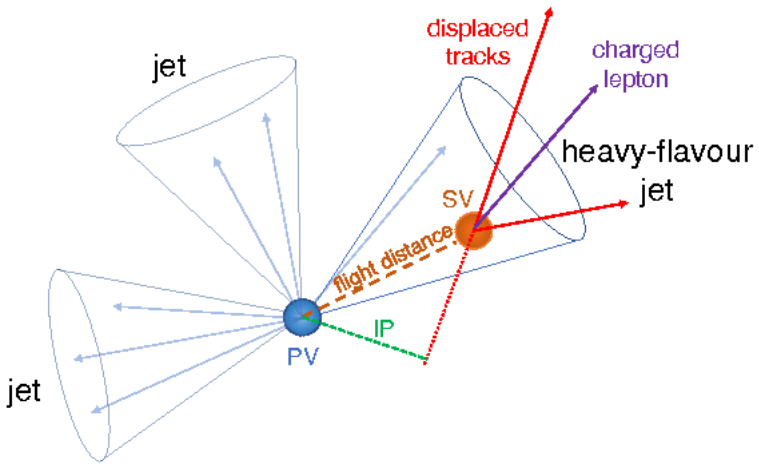
Identification of b-jets w/ CMS

b-tagging relies of long-lifetime of b-hadron decays

→ Reconstructed secondary vertices

→ Large impact parameter tracks

→ Soft leptons (muons & electrons)



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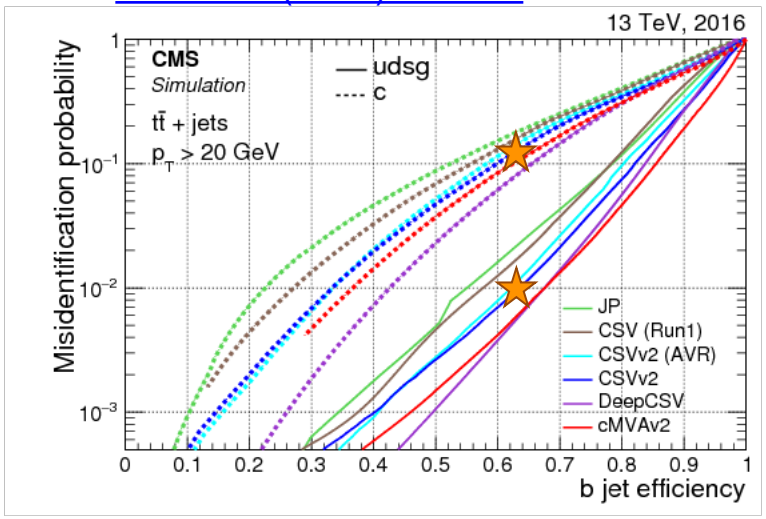


Combined Secondary Vertex (CSVv2) multivariate tagger, standard for early Run 2 analyses

Working point: ≈100x light jet rejection, ≈10x for charm jets, depending on pp, PbPb, centrality

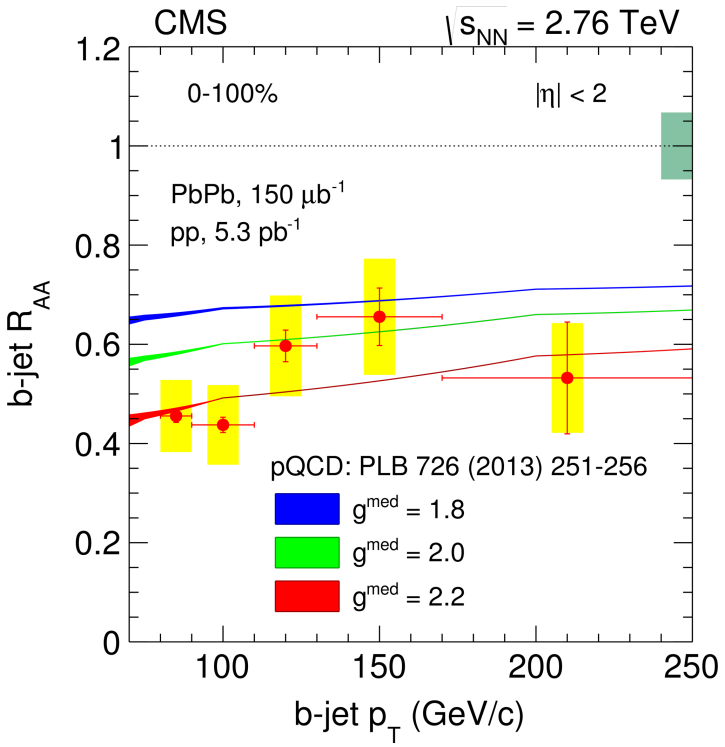
Corresponds to around 60% b-tagging efficiency

Light jet mis-ID is verified in data using “negative tagger” w/ inverted track quantities

Previous b-jet measurements w/ CMS

b-jet nuclear modification factor

PRL115 (2014) 029903



b-dijet p_T asymmetry

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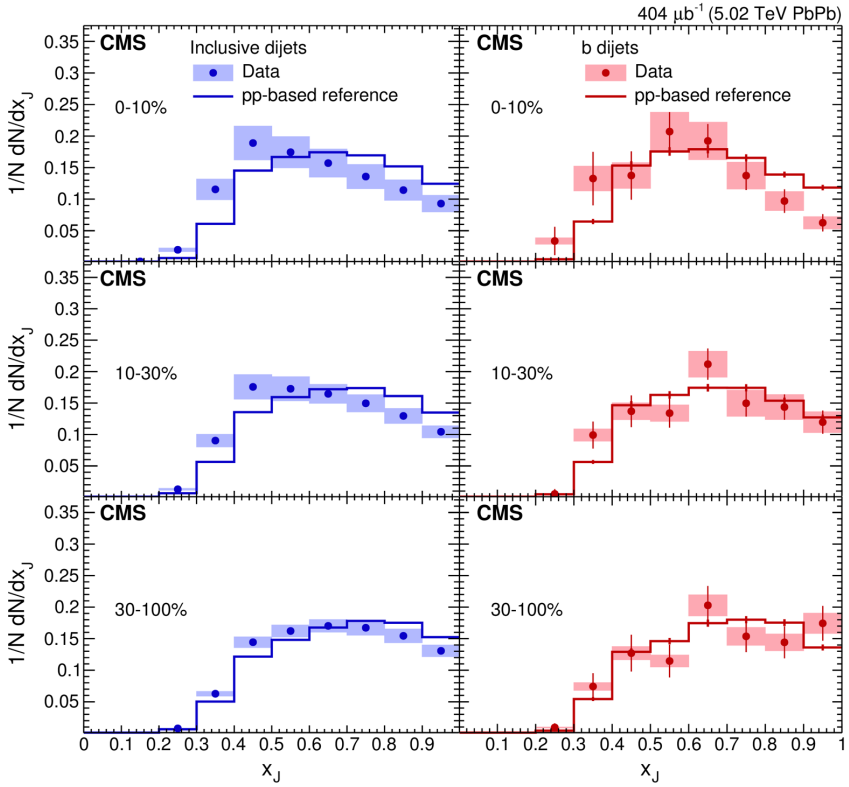


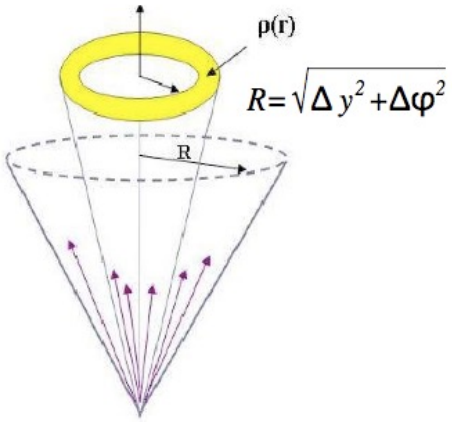
Slightly less quenching than inclusive jets (mix of quarks of gluons)

Indication of role of color factor in radiative energy loss

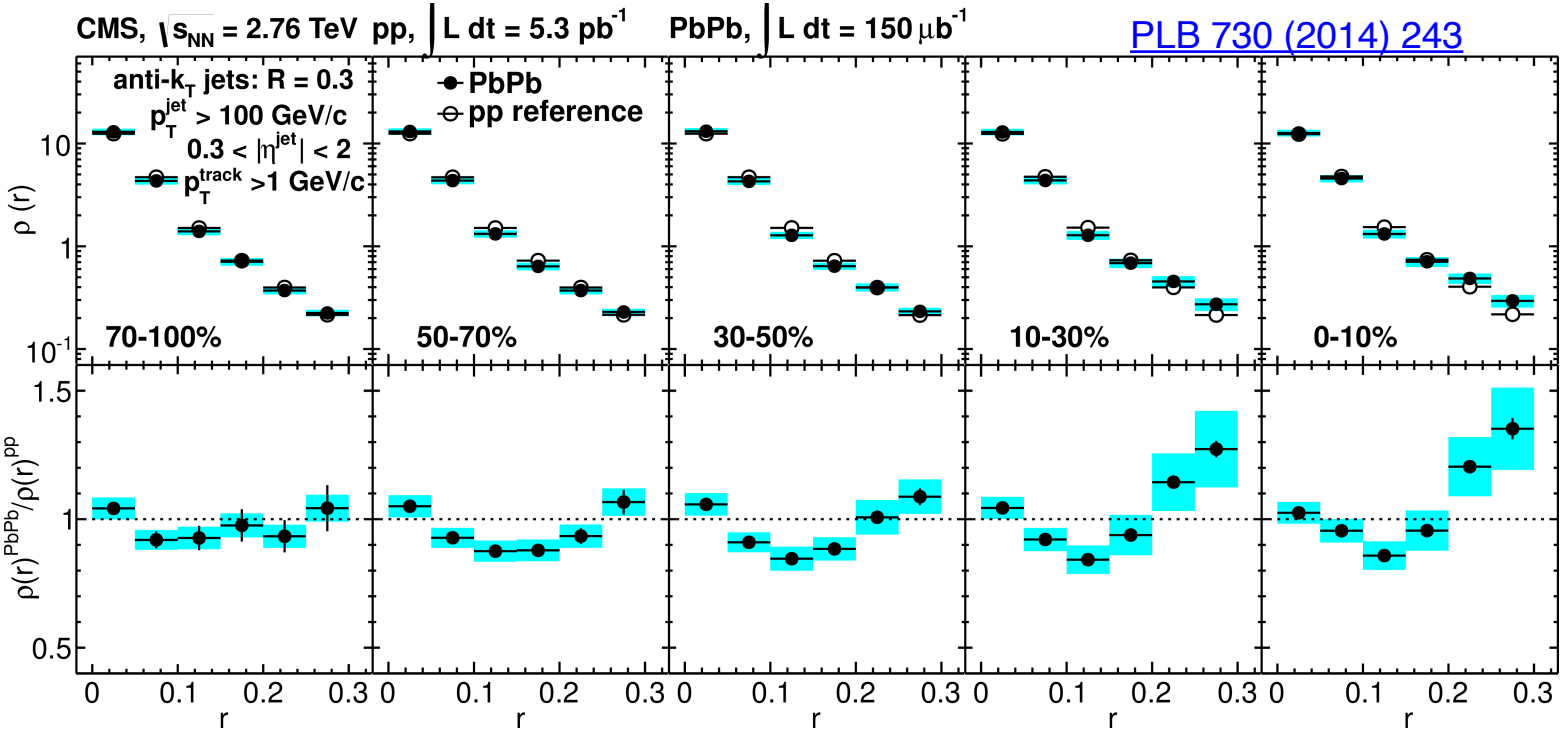
Jet shapes

Differential jet shapes quantify how energy is distributed transverse to the jet axis

$$\rho(r) = \frac{1}{\delta r}\frac{1}{N_{jet}}\sum_{jets}\frac{P_T(r-\delta r/2, r+\delta r/2)}{P_T(0,R)}$$



Inclusive jets show relative narrowing of core & a redistribution to large angle in central PbPb

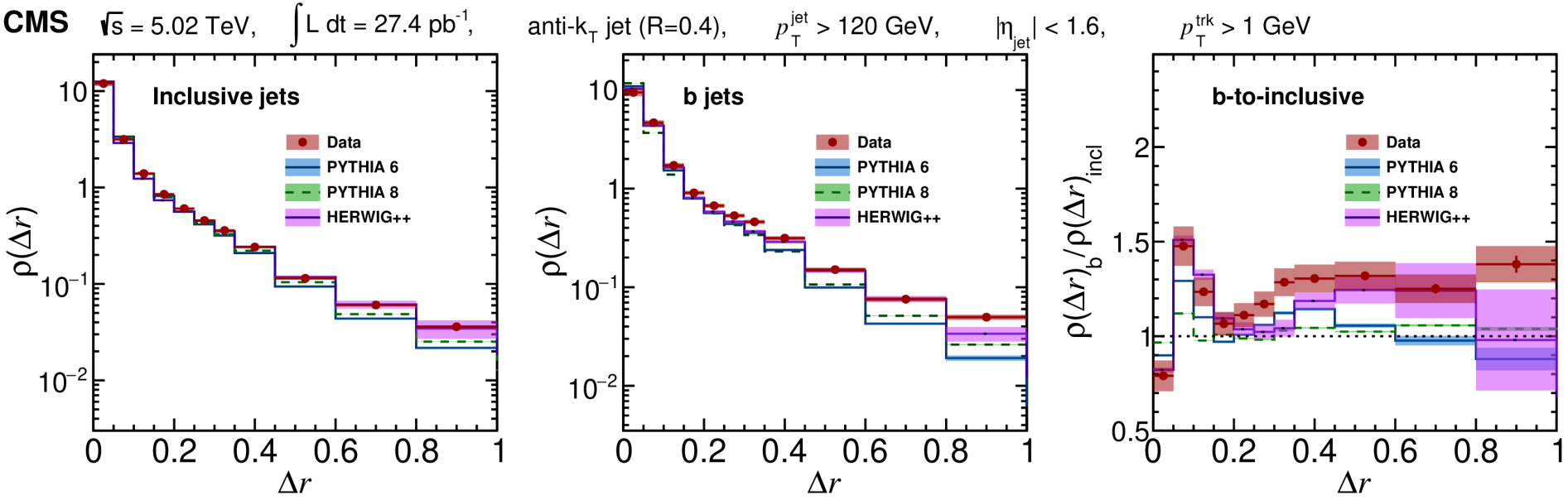


PLB 730 (2014) 243

b-jet shapes in pp collisions

- Jet shapes are measured up to large angle using event mixing
- b-jet shapes are somewhat different than inclusive jets
  - Sensitive to very different b-quark fragmentation & hadronization
  - Also sensitive to b-hadron decay kinematics, which fill dead cone

JHEP 05 (2021) 054

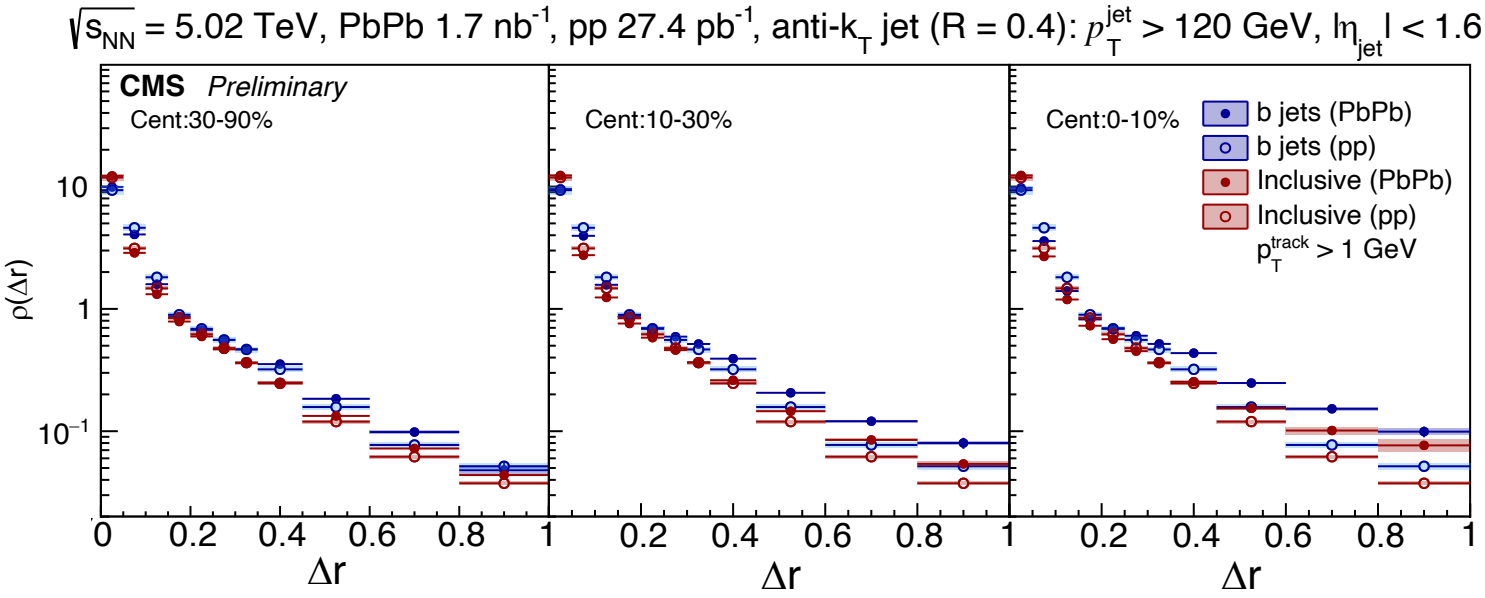


✓ b-jet shapes reasonably well-described by hadronization models

Herwig does a better job than Pythia with large angle production

b-jet shapes in PbPb collisions

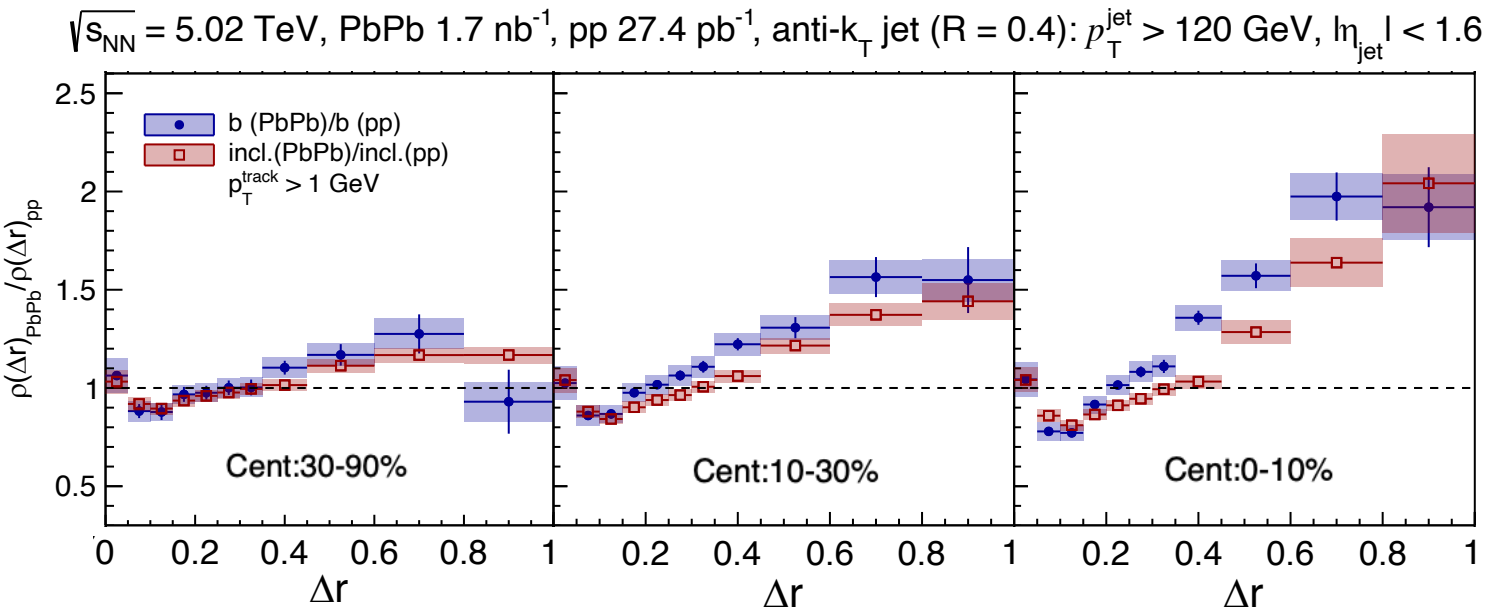
b-jets show a qualitatively similar broadening to inclusive jets, going from peripheral to central PbPb events



CMS-PAS-HIN-12-003

Jet shape modification

b-jets show a slightly larger modification to inclusive jets at large angles



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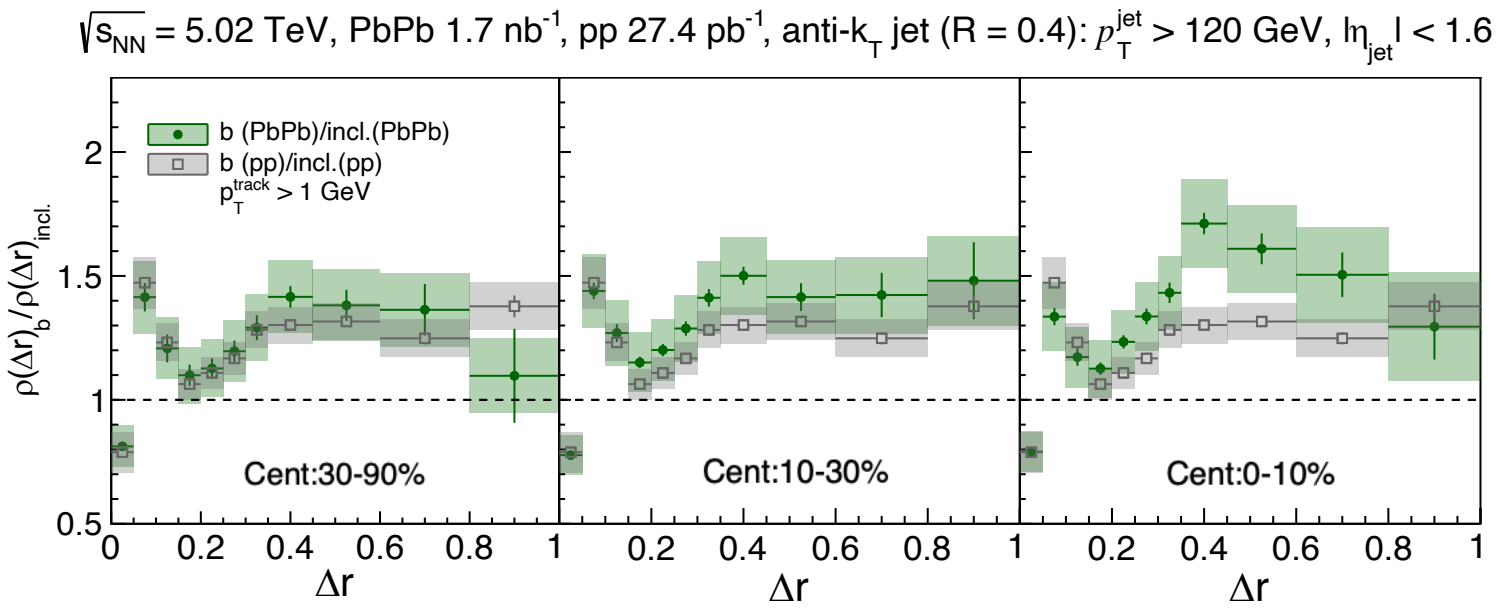
b-jet / inclusive jet double ratio

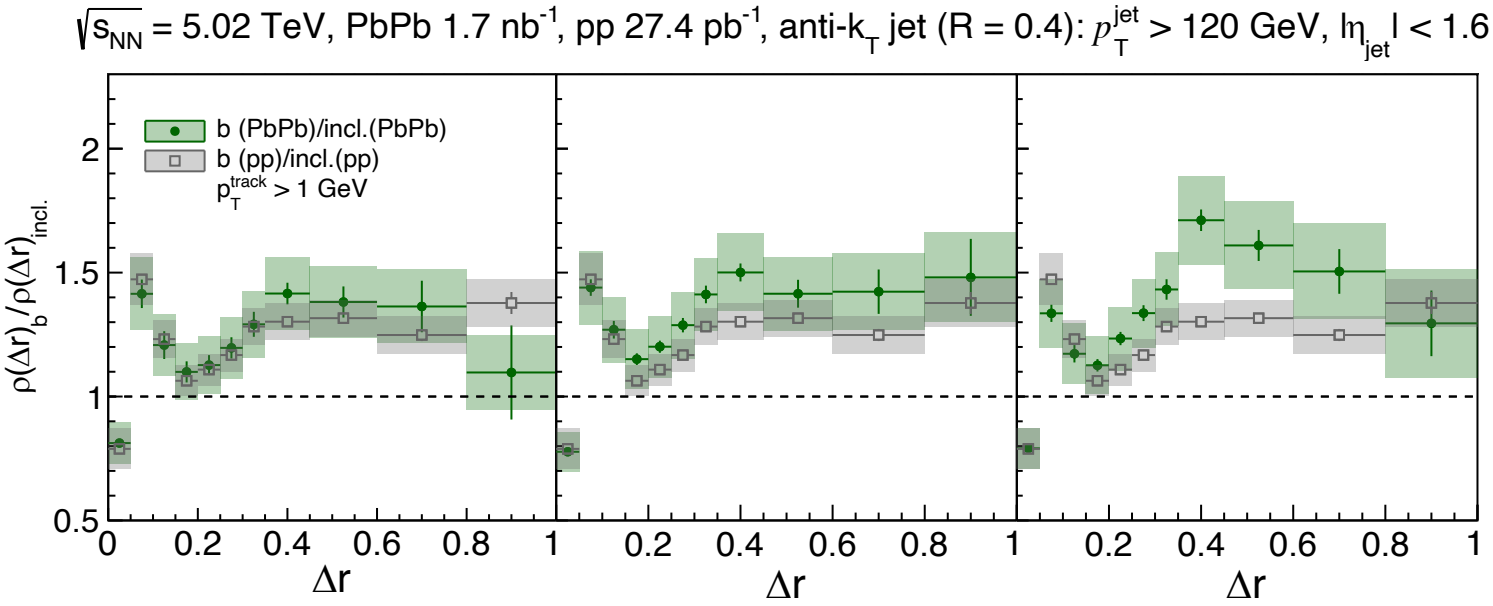
Similar jet shape modification in the core, larger excess at large angle for b-jets



CMS-PAS-HIN-12-003

Conclusions

- CMS has gone beyond b-jet spectra & correlations exploring the internal structure of b-jets, which is sensitive to details of parton energy loss
- b-jet shape was measured in pp collisions & is well-described by models
- Jet quenching modifies the b-jet shape differently than inclusive jets, with a relatively larger degree of transverse momentum shifted to large angles
- Will be interesting to see if quenching models reproduce the flavor dependent effects seen in our measurements



Thank you for your attention!