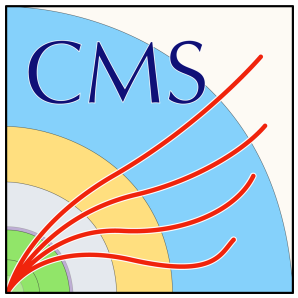


Identification of Heavy Quark Antennae Using Groomed-Jet Substructure

Kurt Jung, University of Illinois at Chicago

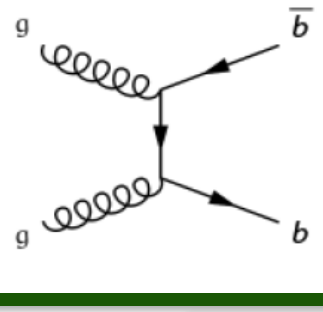
for the CMS Collaboration

Quark Matter 2018

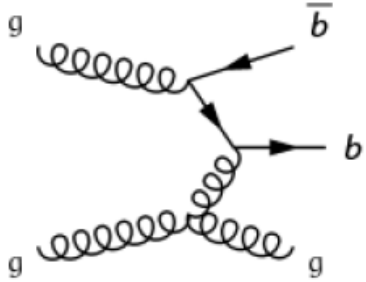
Lido, Venice, Italy

B-Jet Production Mechanisms

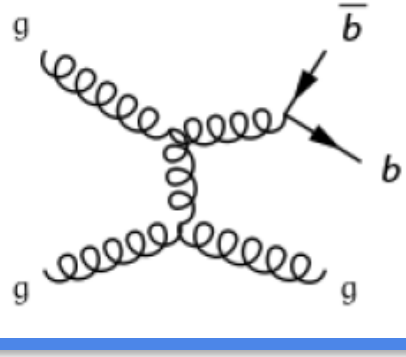
Flavor Creation ("FCR")

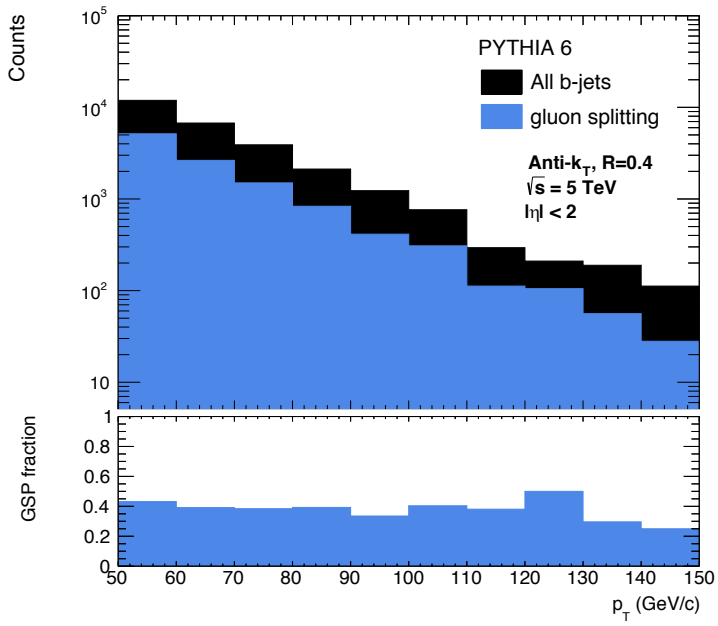


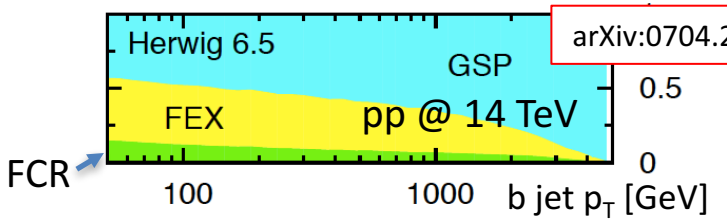
Flavor Excitation ("FEX")



Gluon Splitting ("GSP")



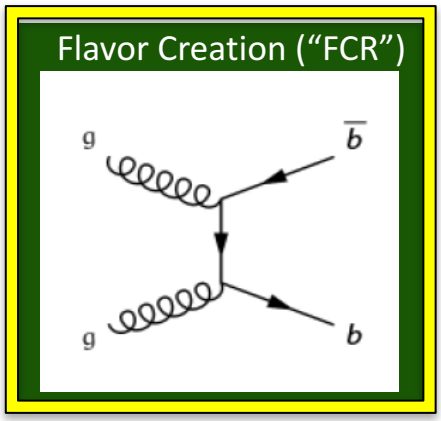


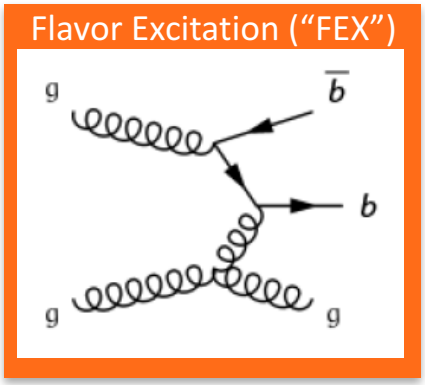


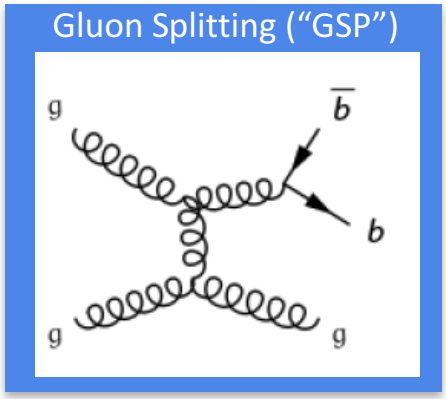
arXiv:0704.2999

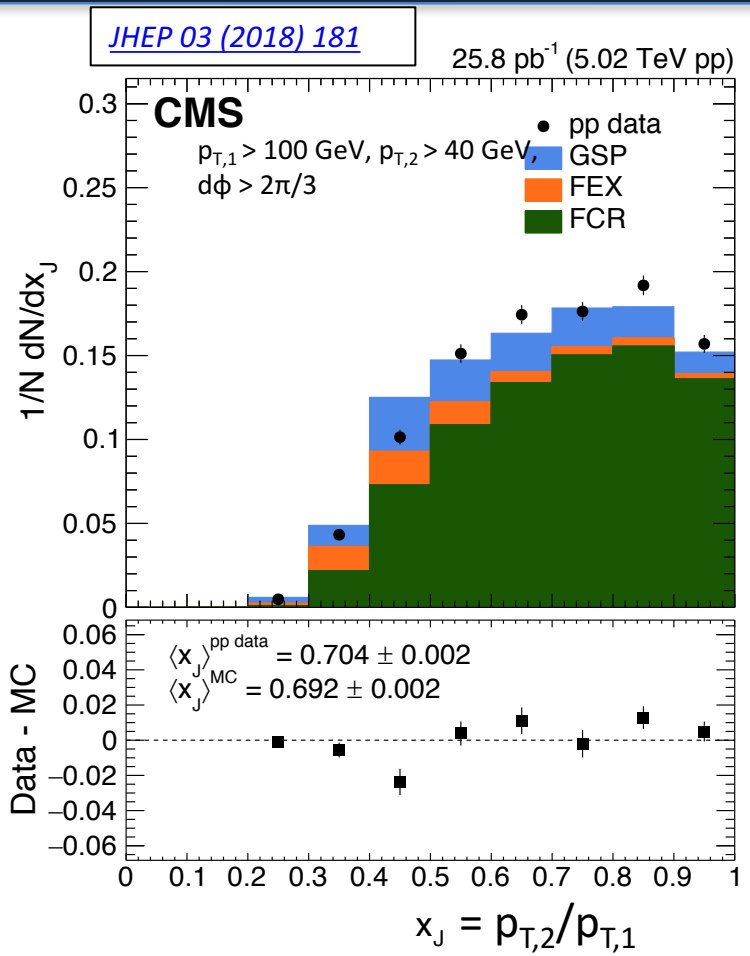
- Classic R_{AA} measurements convolute large contributions from NLO b-quark production processes
  - Most MC generators predict large NLO components at high-p_T
- Recent measurements have tried to isolate LO production

Isolating Leading-Order Production









- Selections of back-to-back jets dramatically improve leading-order "purity"
  - Removes the bulk of gluon-splitting (GSP) contributions to measurement
  - Isolates pure b-quark energy loss (though w/ contributions from late gluon emission)

Toward more sensitive observables

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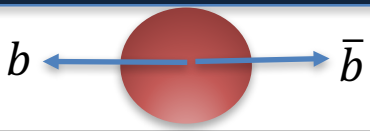
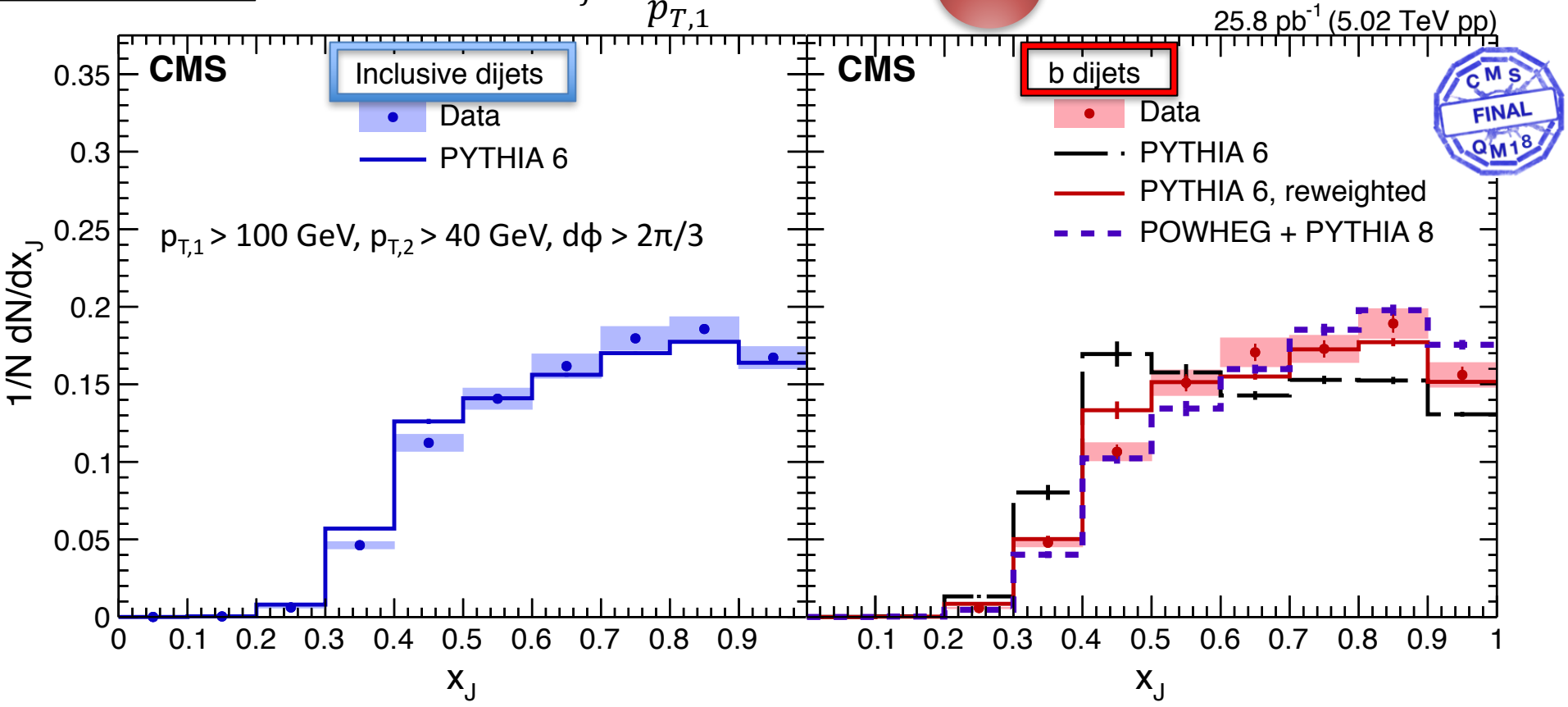
$$x_J = \frac{p_{T,2}}{p_{T,1}}$$





- b-dijet R_{AA} removes ambiguity regarding production mechanisms ->
- Probes **leading-order** jet production component
  - No significant differences with respect to inclusive jets, seen also by POWHEG

b Dijets

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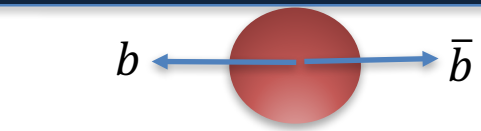
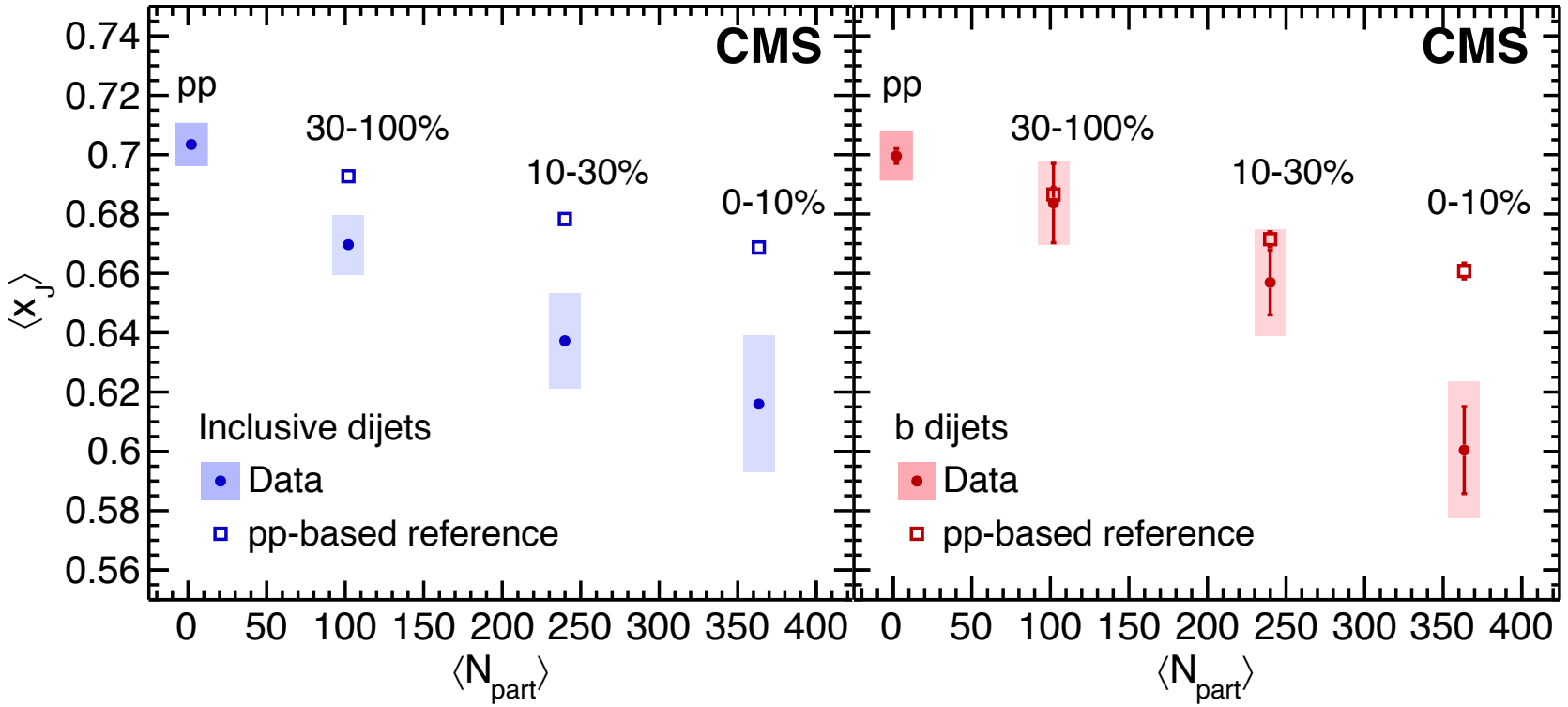
$$x_J = \frac{p_{T,2}}{p_{T,1}}$$



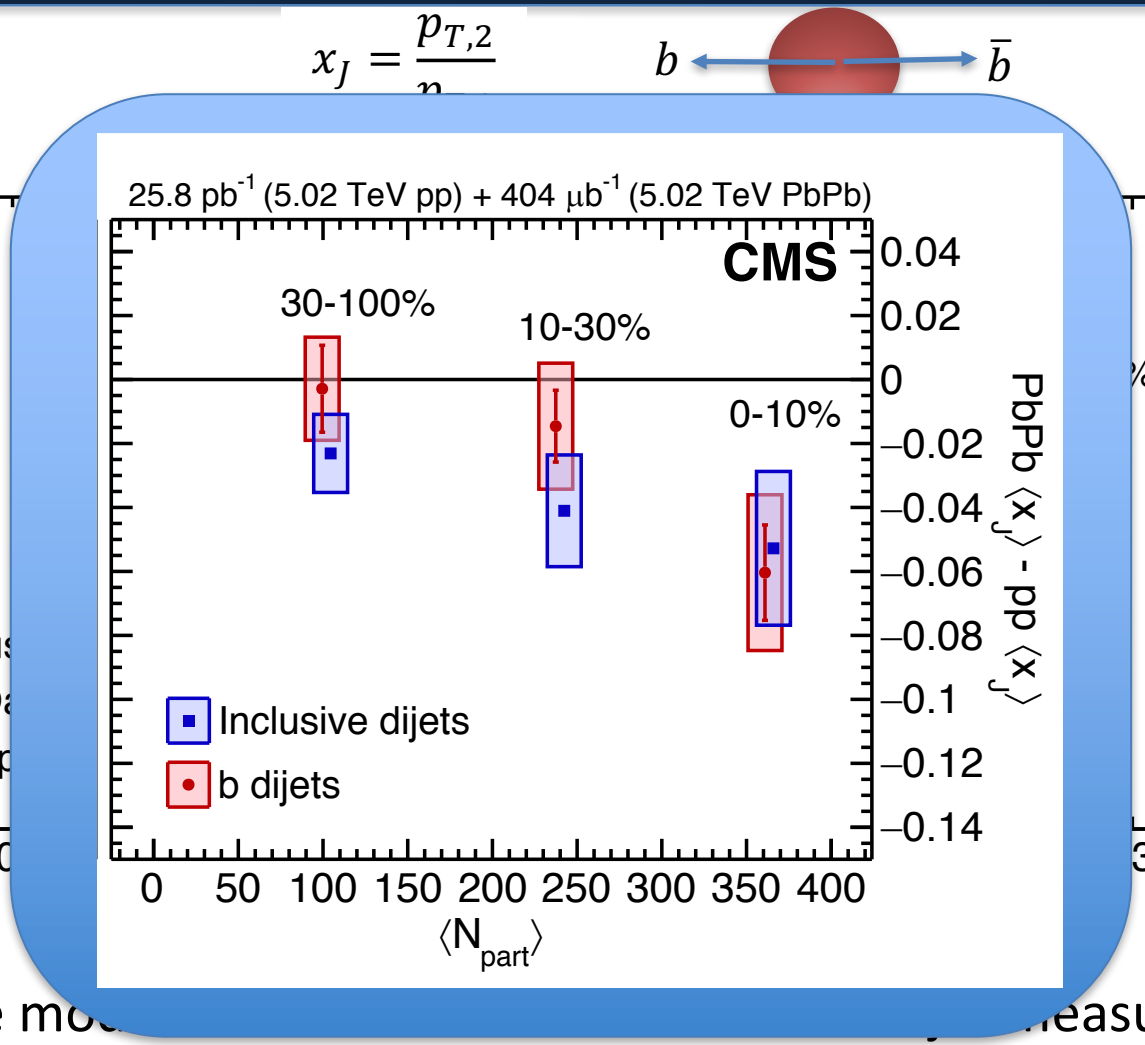


- Observe modification ***consistent with inclusive-jet*** measurements
- Directly comparing b dijet/inclusive dijet PbPb shows virtually no effect as a function of centrality

b Dijets

JHEP 03 (2018) 181

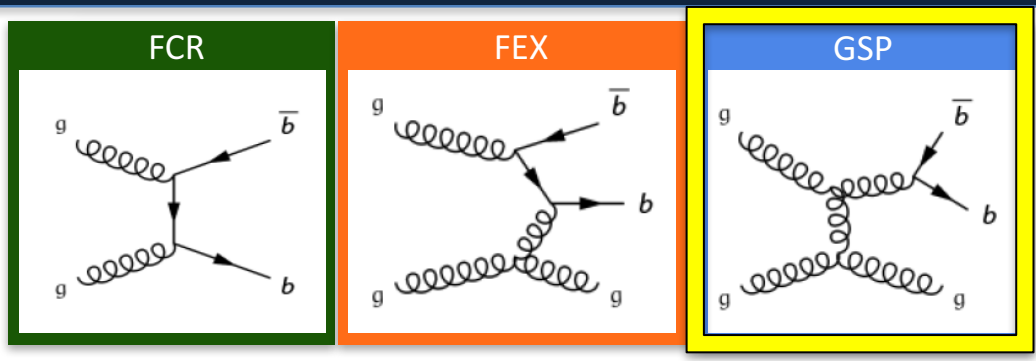
$x_J = \frac{p_{T,2}}{p_{T,1}}$

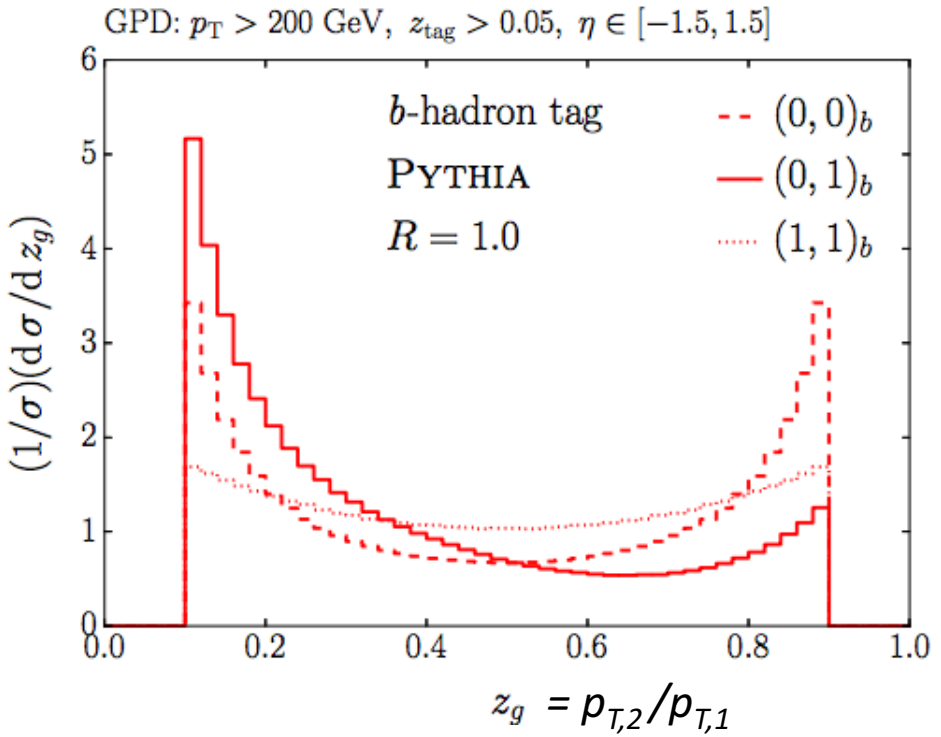


- Observe mo… …easurements
- Directly comparing b dijet/inclusive dijet PbPb shows virtually no effect as a function of centrality

What About NLO?

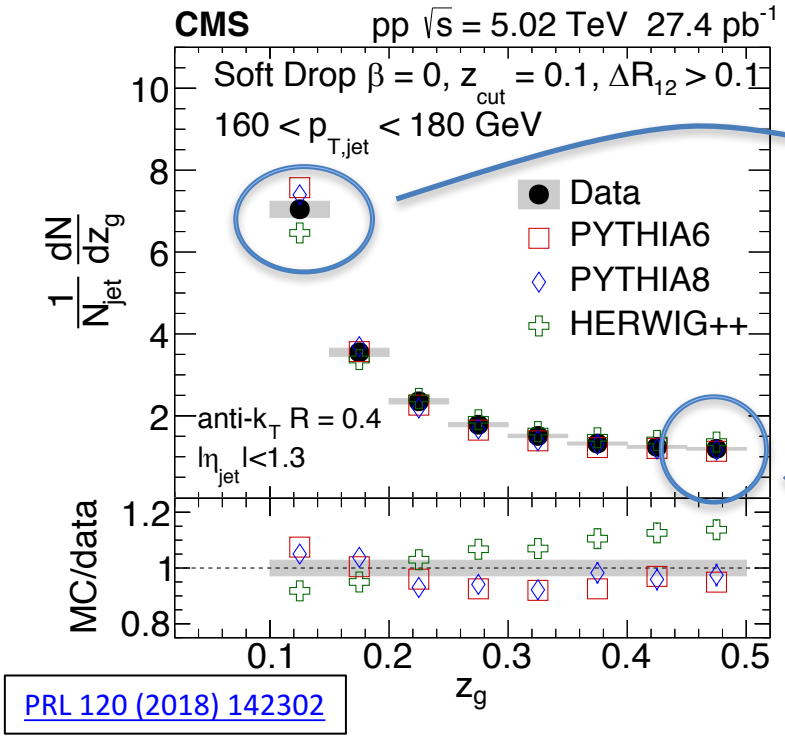
- *Subjet double-b tagging provides access to the final-state gluon-splitting (g->bb) subprocess*
  - Direct access to parton splitting
    - B hadron identification removes ambiguities from subjets of soft gluon emission
  - Pure source of gluon jets
    - Opportunities to explicitly quantify characteristics of highly virtual gluons
  - Opportunity to identify small-angle double-b production through ***subjet reconstruction***



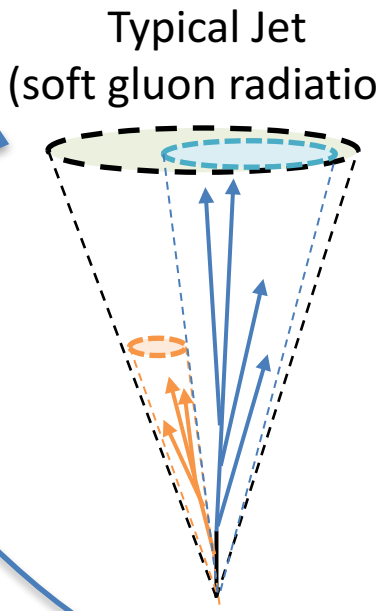


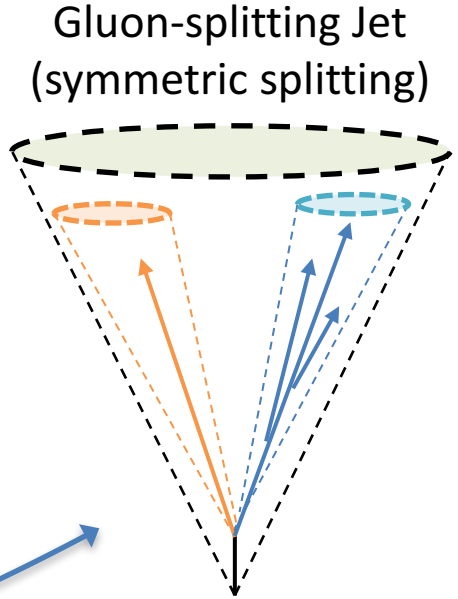
PRD 96 (2017) 054019

Additional Motivation



PRL 120 (2018) 142302





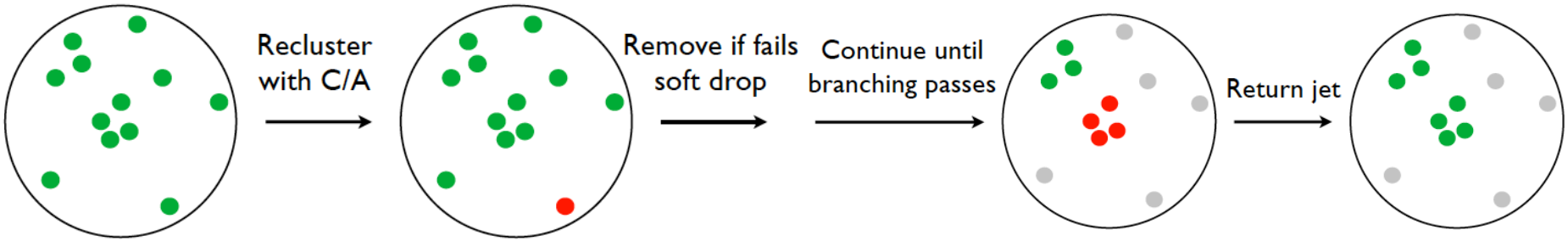
- Two effects can be probed through extension of analysis to PbPb
  - Probe coherence effects, where energy loss of wide vs narrow jets can be seen
  - Isolation of gluon-jet quenching effects
- CMS presents a proof of principle of subjet flavor identification in pp
  - Useful for *measuring groomed structure* in pp for flavored vs inclusive jets

Subjet Reconstruction

[1]: JHEP 9708 (1997) 001

- Jet grooming removes soft divergences and uncorrelated background
- "Soft-drop" primarily removes late-stage soft gluon emission
- Common technique in HEP - introduced in heavy-ion collisions

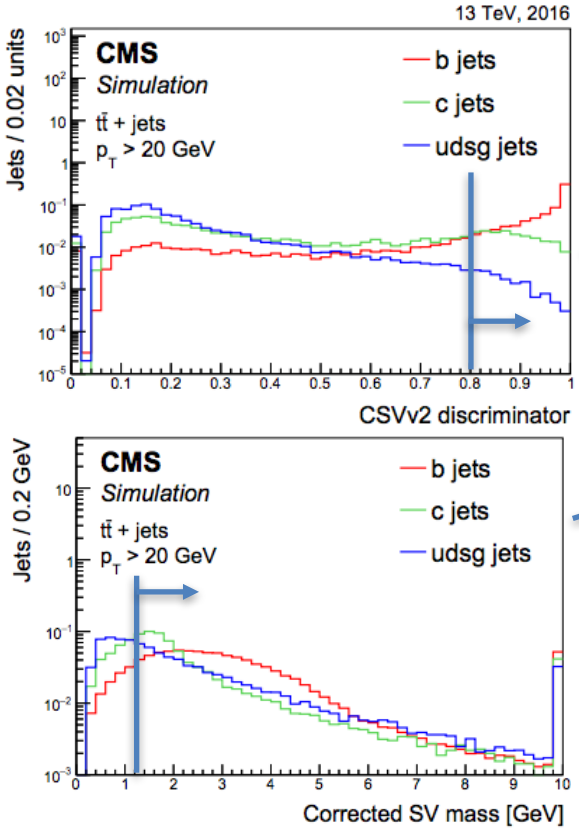
$$z = z_{cut}\theta^{\beta}, \quad \text{where} \quad z_{cut} = p_{T,2}/p_{T,1}$$

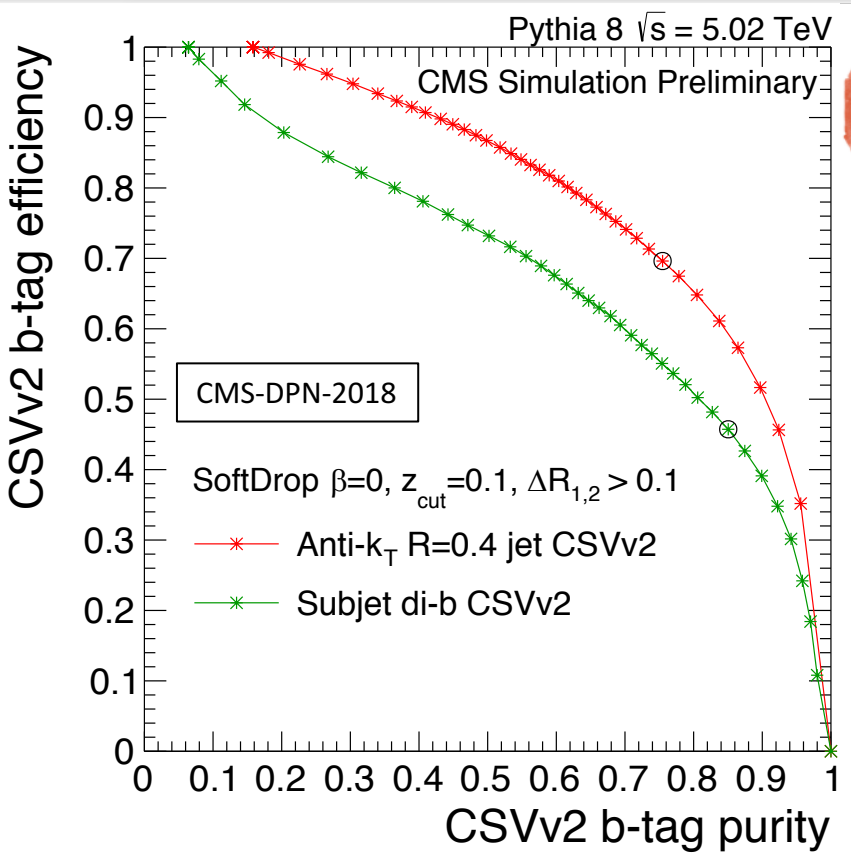


- Subjets reconstructed using constituents of full jets, reclustered via C/A algorithm[1] to impose ***angularly-ordered structure***

- Clustering iterates up the jet fragmentation chain, discarding branches until a pair is found that satisfies the "SoftDrop" identification criteria
  - This performance study uses $p_{T,2}/p_{T,1} > 0.1$ with no angular selection ($\beta=0$)

Double b-Tagging Performance

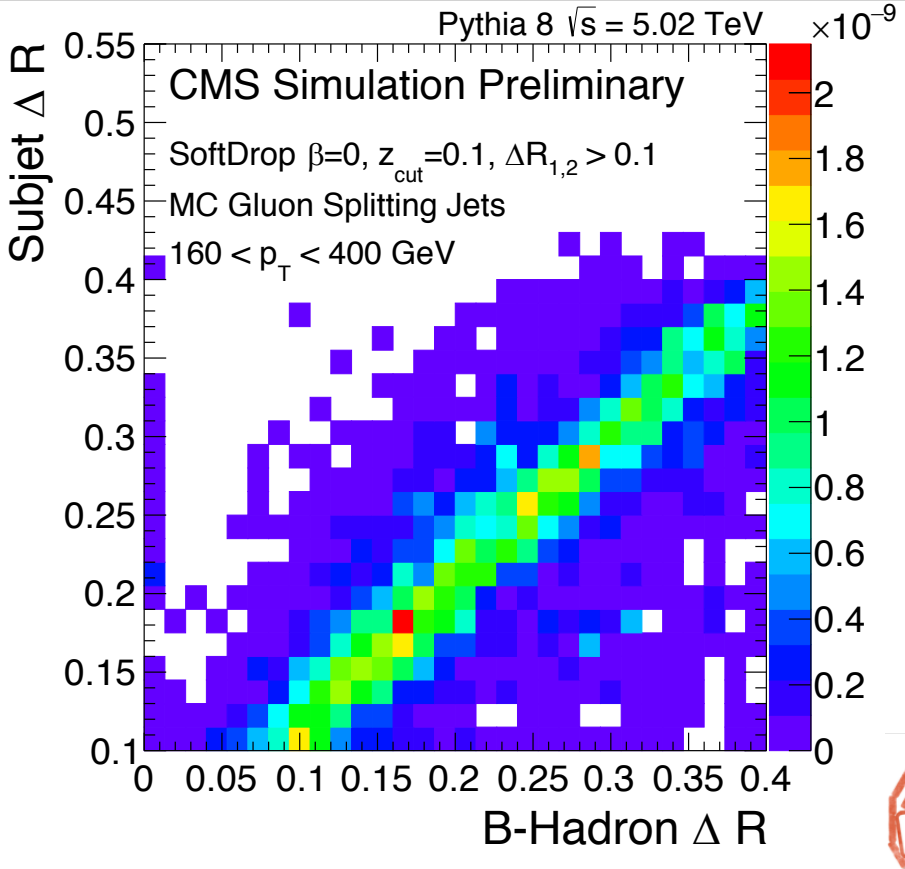


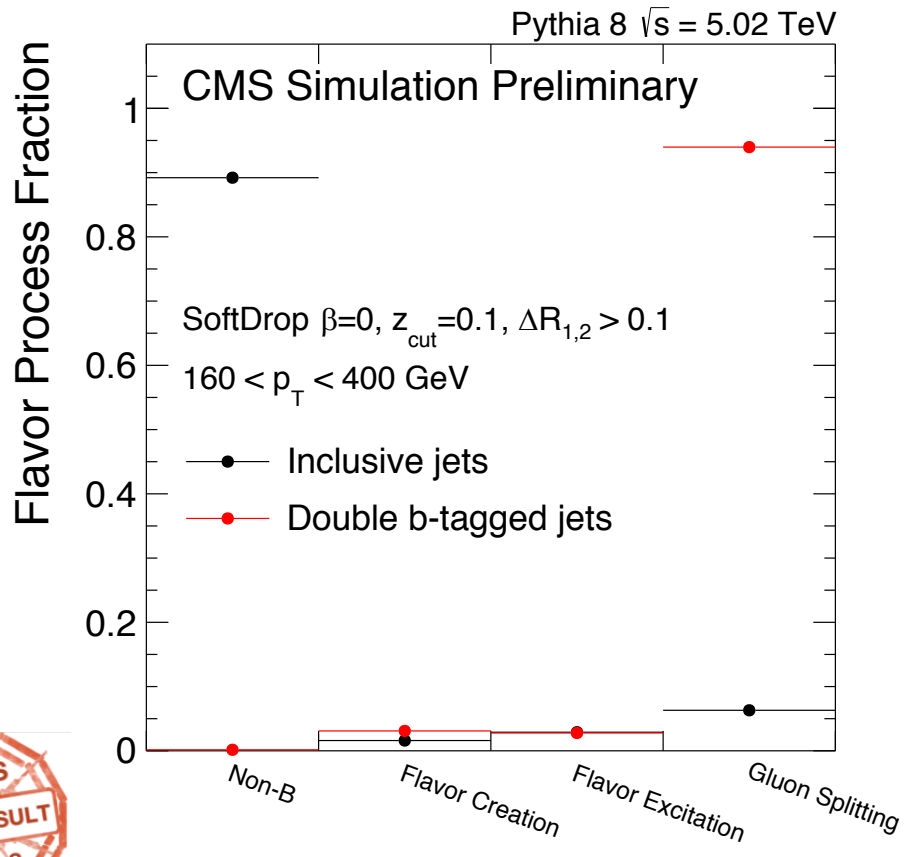


- Both subjets are tagged independently with "CSVv2" algorithm[1]
  - Selections on secondary vertex mass and subjet $\Delta R_{1,2} > 0.1$[2]
- Tagger performance quantified by comparing subjet double-b-tagging efficiency vs purity

[1]: (CMS) arXiv: 1712.07158 [2]: (CMS) arXiv: 1708.09429

Double b-Tagging Performance





- Strong correlation between hadron and subjet opening angle indicates that subjet reconstruction is properly associated with B hadron production
- After tagging, GSP purity in MC jumps to ~95%

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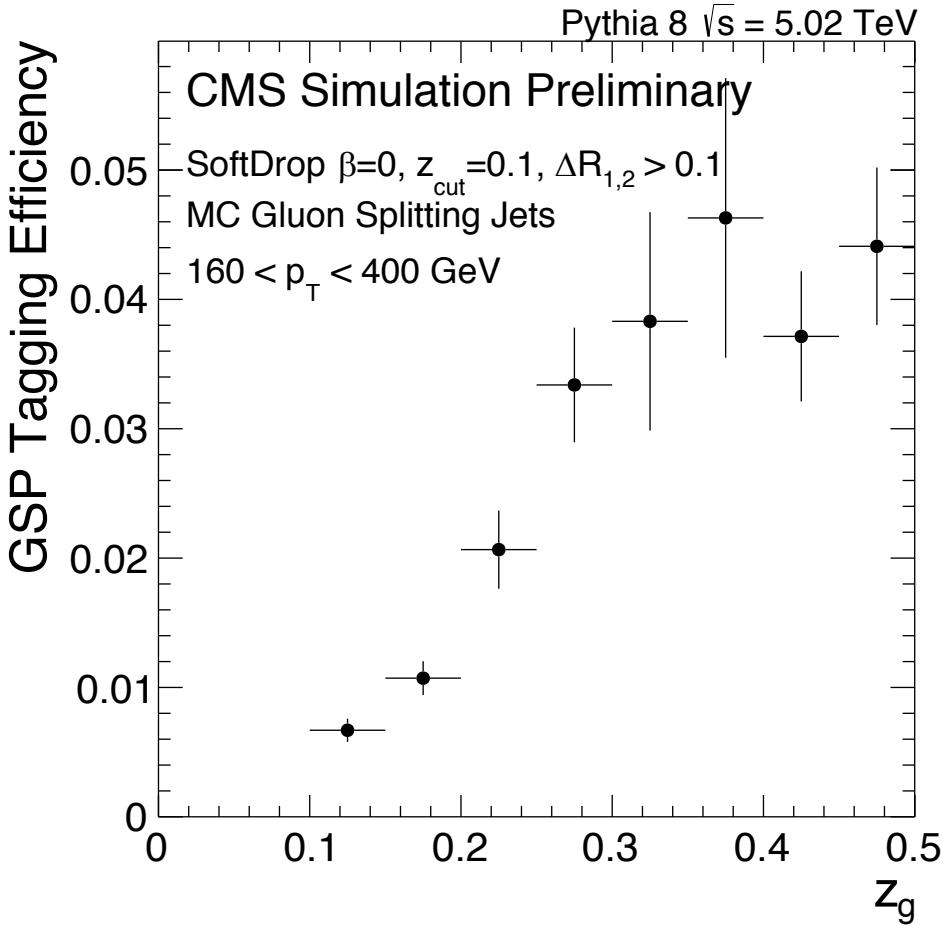
b-Tagging Efficiency (vs GSP jets)



The GSP tagging efficiency via the double-b-tagger is shown vs z_g in Pythia 8

- Tagging + subjet reconstruction limitations significantly reduce the tagging efficiency of gluon-splitting jets
  - Efficiency has significant bias vs z_g

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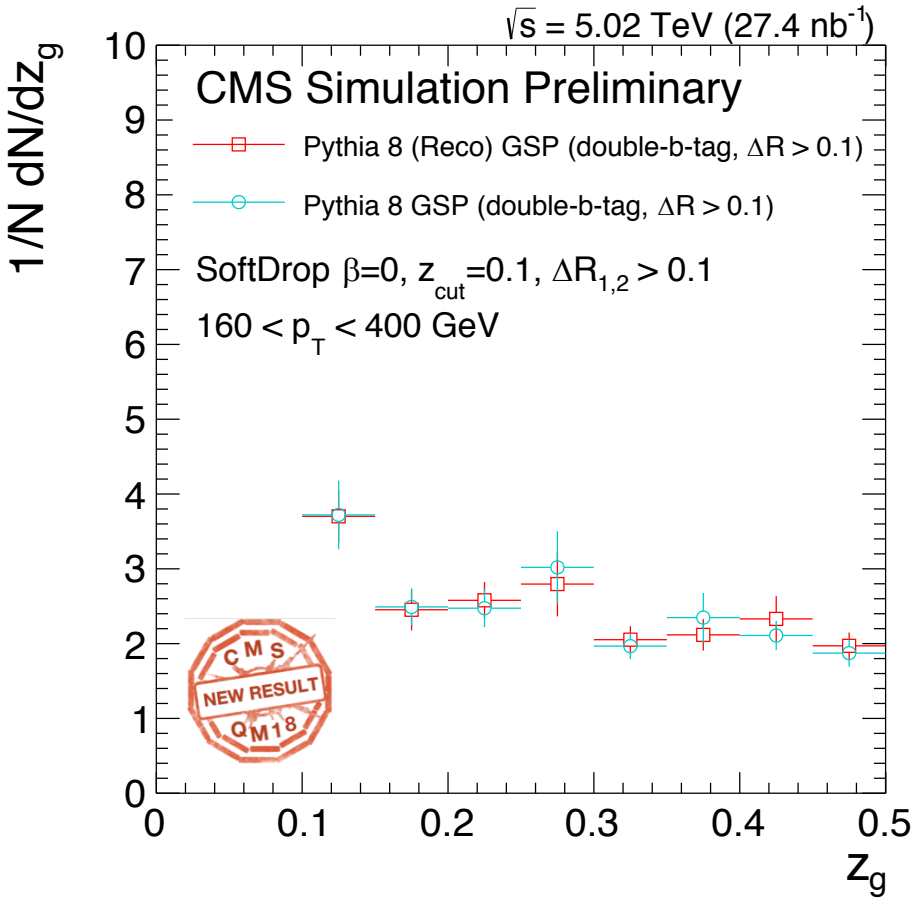
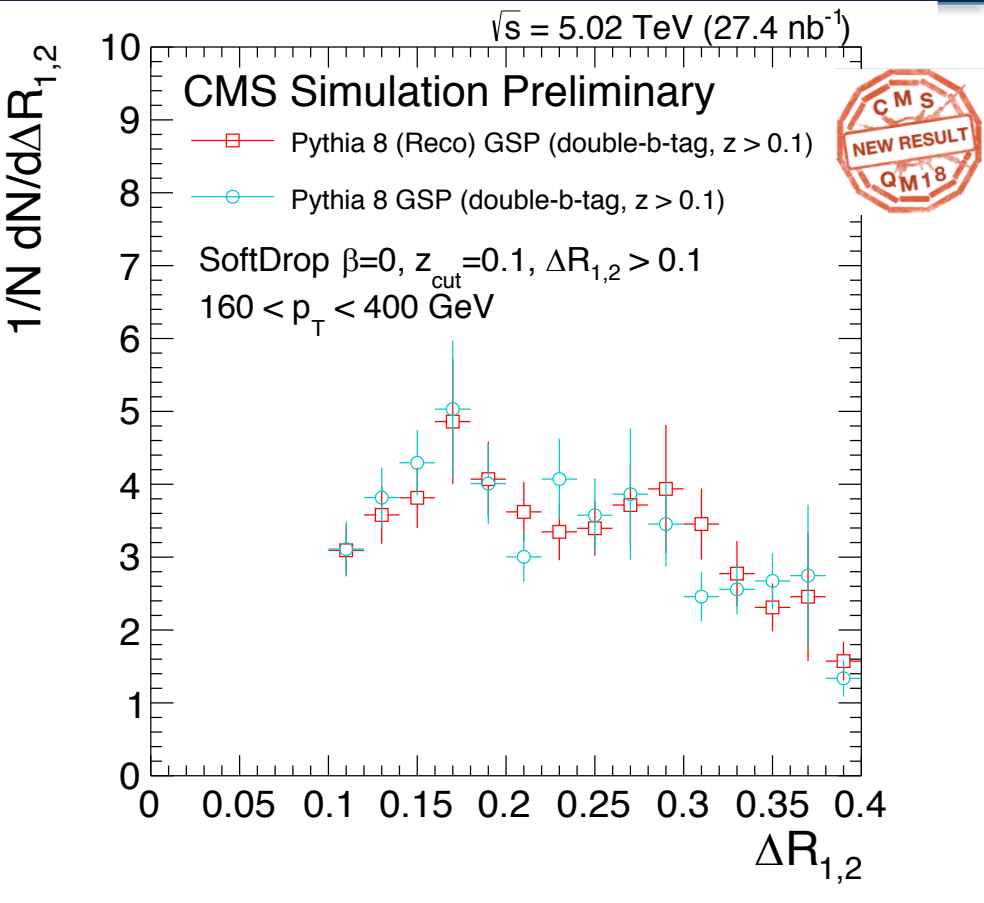
Subjet Splitting Results





- Wide-angle gluon-splitting jets ($\Delta R_{1,2} \sim 0.2$) have a balanced subjet splitting distribution
  - Important to note that ***this is a small subset*** of total GSP jet contribution
  - B-tagging + reconstruction methodology confirmed by Pythia8 simulation

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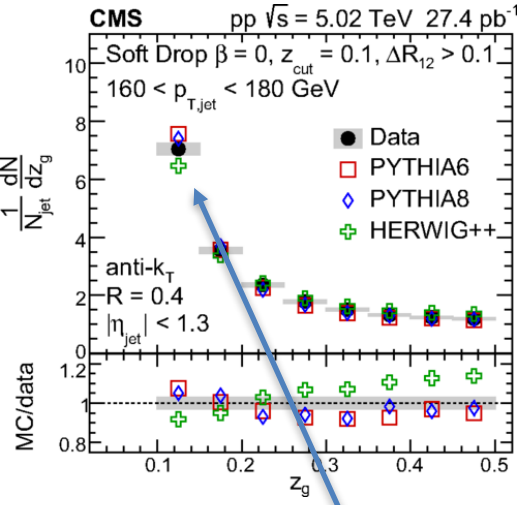
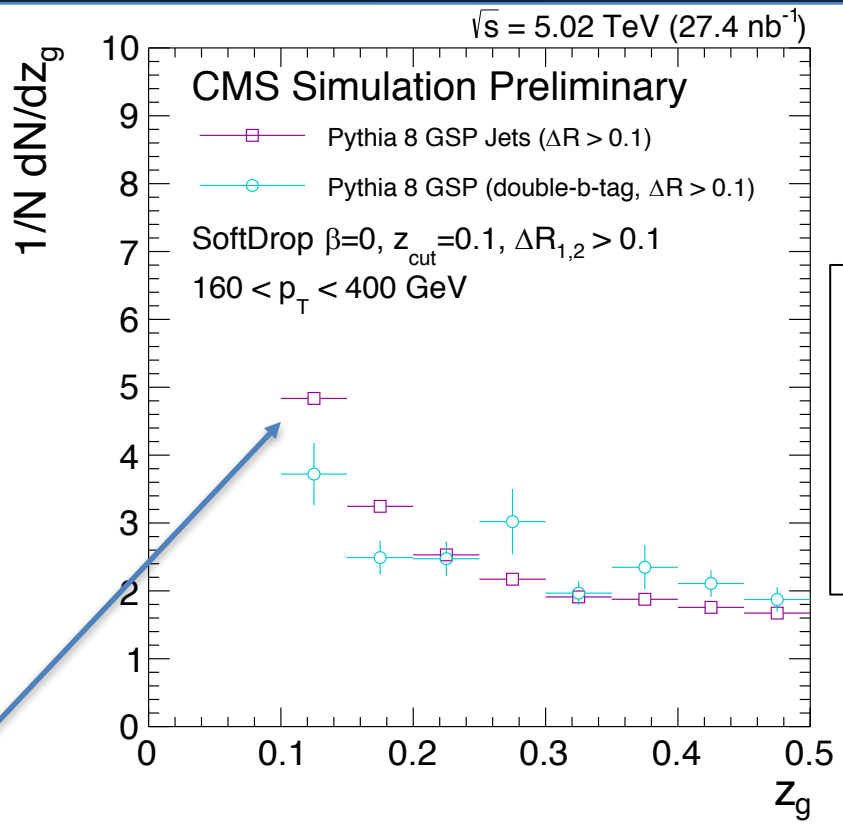
Tagged vs Untagged GSP Jets

PRL 120 (2018) 142302





The subjet splitting function (z_g) is shown for **inclusive Pythia 8 GSP jets (purple)**

and **double-b-tagged Pythia 8 GSP jets (cyan).**

- Tagged GSP jets (larger opening angle) have a more balanced subjet splitting distribution than all GSP jets
  - Pythia GSP jets are slightly flatter than inclusive jets
  - *Double-b-tagging prefers finding more isolated b-quarks*, due to secondary vertex reconstruction performance

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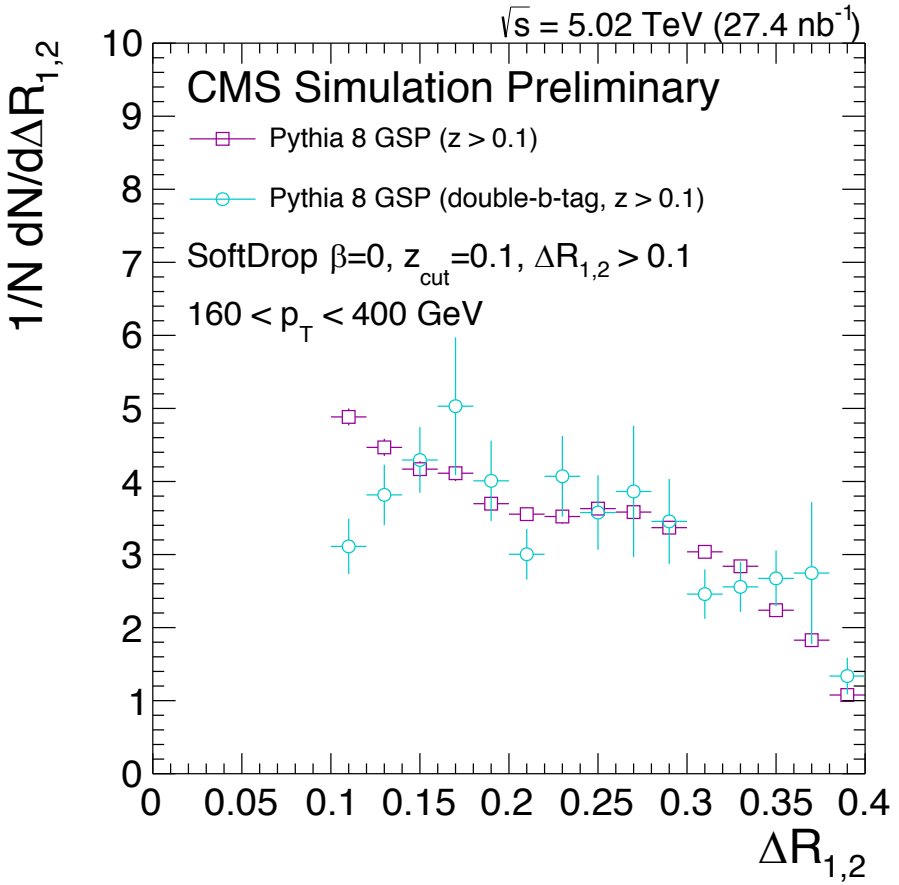
Tagged vs Untagged GSP Jets

The subjet opening angle ($\Delta R_{1,2}$) is shown for **inclusive Pythia 8 GSP jets (purple)**

and **double-b-tagged Pythia 8 GSP jets (cyan).**



- Angular distribution of double b-tagged GSP subjets is more broad than inclusive GSP subjets
  - Significant tagging bias -> wide-angle subjets
  - Large fraction of Pythia 8 GSP jets below $\Delta R_{1,2} < 0.1$

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Conclusions

- Identified methodologies to isolate both b dijets and gluon-splitting b jets at CMS
- Subjet splitting function for this specific subset of gluon-splitting jets is *very balanced*
  - Wide angle subjets -> more balanced p_T distributions
- Repetition of the analysis in PbPb can investigate *subjet coherence* effects