Jet Substructure measurements at CMS

BOOST 2021 - Short talk

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On behalf of the CMS Collaboration

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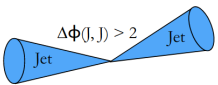
Quark/Gluon Jet Substructure studies (CMS-PAS-SMP-20-010)

- Understanding of quark and gluon jets is a vital part of SM and BSM measurements and searches.
- Studies motivated by Systematics of Quark-Gluon tagging (Gras et al), 1704.03878.
- The goal of this study is to measure these jet substructure variables, across a wide range of phase space, to provide a useful theoretical understanding and improve our tuning simulations.
- We studied these variables in two different environments in order to study different parton compositions:

Selections

Gluon-enriched jets from **dijet** region:

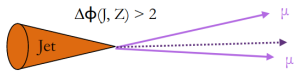
2+ jets
Leading & subleading jets must pass p_T, $|y|$ cuts



$\Delta p_T / \sum p_T < 0.3$
(avoids cutting on 3rd jet explicitly)

Quark-enriched jets from **Z(μμ) + jets** region:

1+ jets, 2+ muons
Leading jet must pass p_T, $|y|$ cuts,
not overlap with Z muons

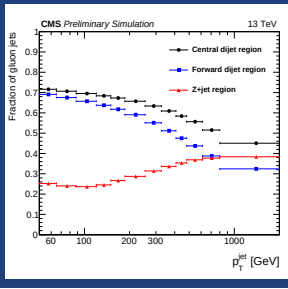


$|p_T(J) - p_T(Z)| / \sum p_T < 0.3$

$|m_{\mu\mu} - 90| < 20$ GeV

$p_T^{\mu\mu} > 30$ GeV

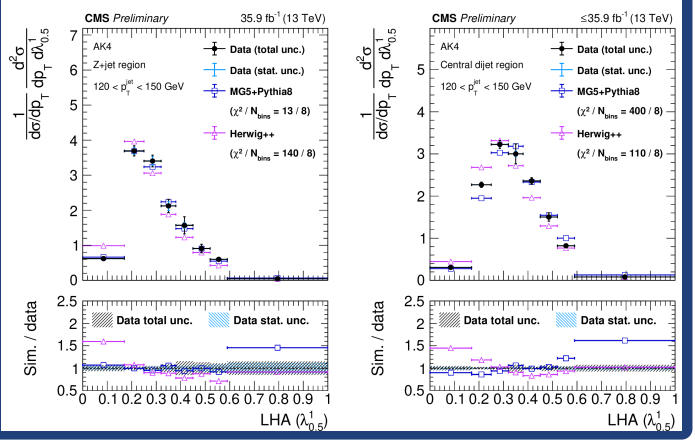
Quark/Gluon composition



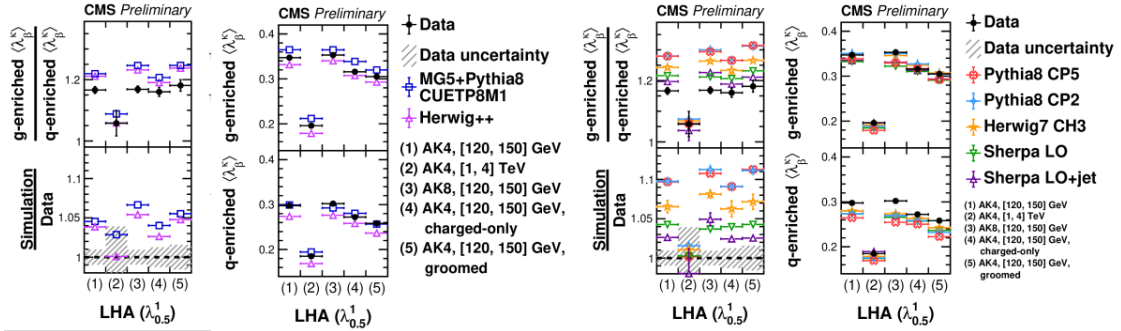
The phase space of this study is:

- 5 λ substructure variables,
- Jets with charged+neutral and charged-only constituents,
- AK4 and AK8 jets
- Differential in pt,
- Ungroomed and groomed (softdrop) jets,
- Different quark/gluon compositions.

One example:

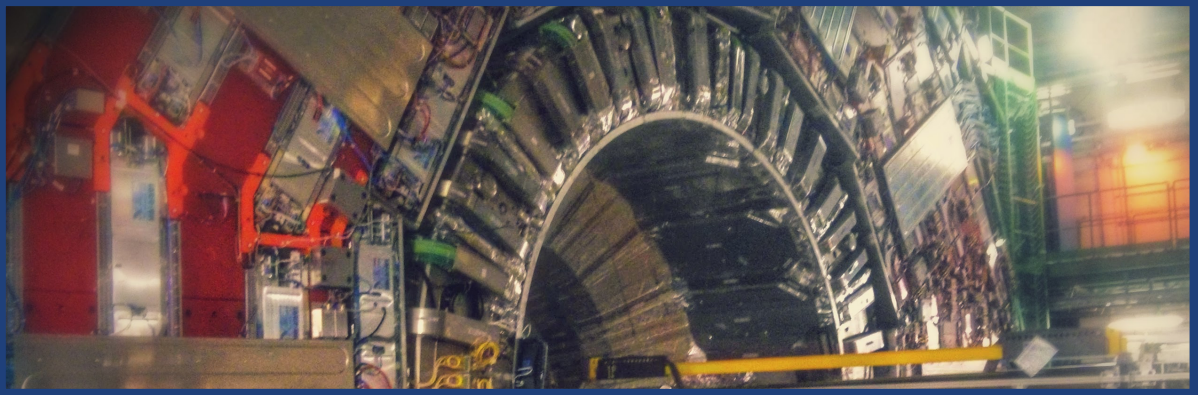


Quark/Gluon Jet Substructure studies (CMS-PAS-SMP-20-010)



- Comprehensive study between "old" (left) and "new" (right) simulations.
- Neither old or new simulators describe quark/guon difference perfectly. Newer is better tuned for gluons, while older looks better tuned for quarks.
- Grooming seems to not have a significant impact in the data to simulation agreement.

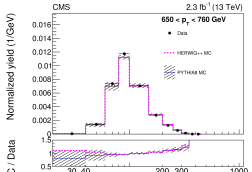
Thank you for the attention...

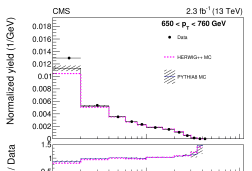


... questions?

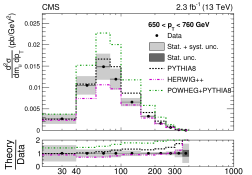
Jet mass in dijet events (JHEP 11 (2018) 113)

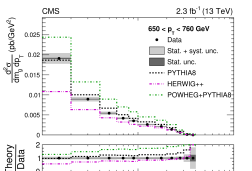
Data to simulation



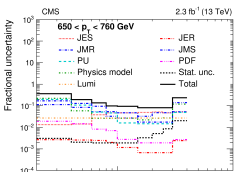


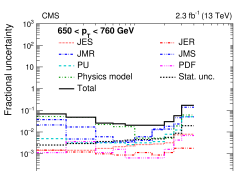
Data unfold





Uncertainties

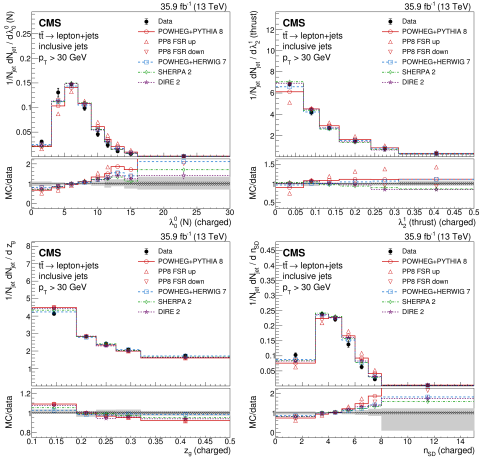




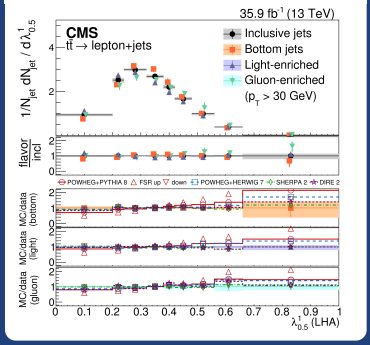
Differential jet groomed and ungroomed mass measurement in bins of transverse momentum

Jet observables in ttbar events (Phys. Rev. D 98 (2018) 092014)

Many substructure variables unfolded



Flavor differences



Comprehensive study of many substructure variables, measured for different jet flavors, inclusive in pt.

Quark/Gluon Jet Substructure studies (CMS-PAS-SMP-20-010)

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λ variables in a nutshell

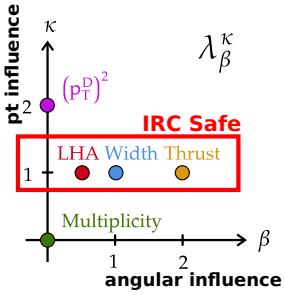
$$\lambda_\beta^\kappa = \sum_{i \in jet} (z_i)^\kappa \, (\theta_i)^\beta$$

$$z_i = p_{T\,i} / \sum p_{T\,j}$$

Constituent p_T-fraction

$$\theta_i = \Delta R_{i,\hat{n}} / R_{jet}$$

Displacement from jet axis
- $\beta \leq 1$: Winner-Takes-All (WTA) axis
- $\beta > 1$: anti-k_T axis - akin to jet mass



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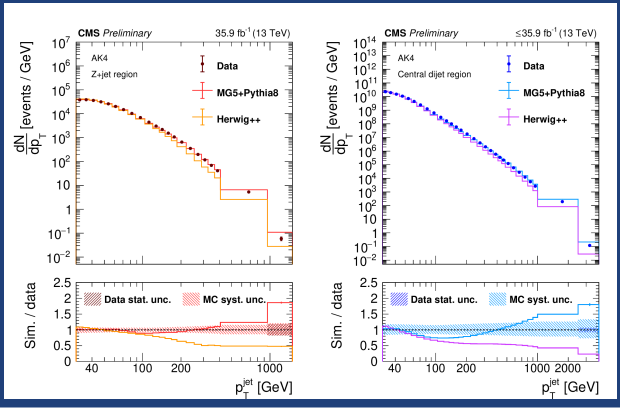
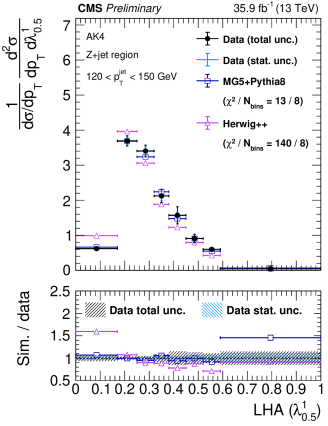
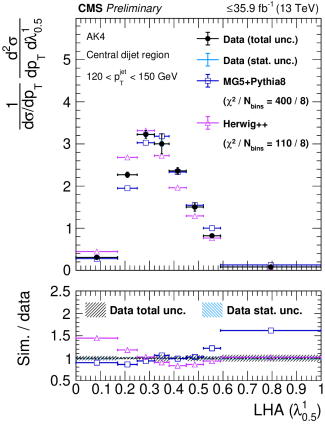
Data to simulation comparisons

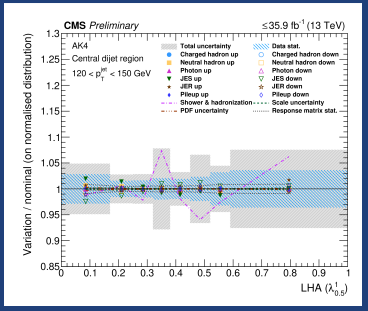


Quark/Gluon Jet Substructure studies (CMS-PAS-SMP-20-010)



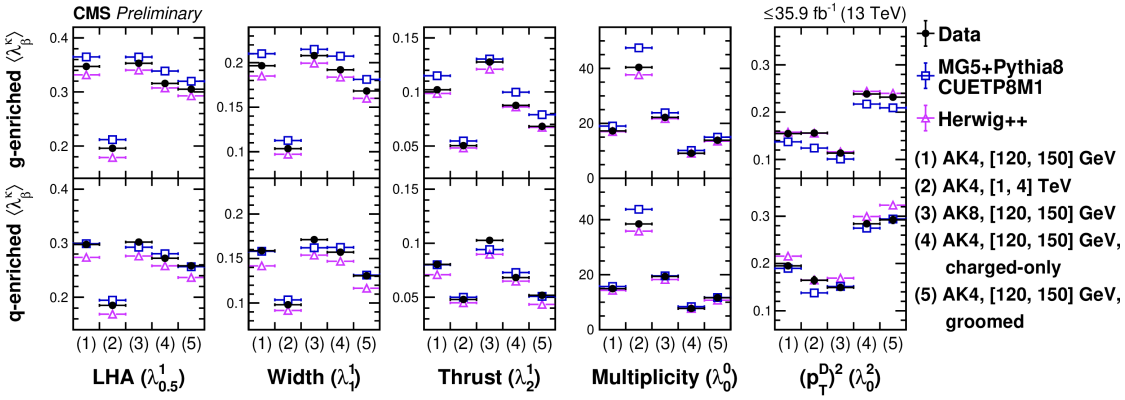


Uncertainties



Largest source of uncertainty comes from shower and hadronization. Stats is also dominant in Z+jets.

Quark/Gluon Jet Substructure studies (CMS-PAS-SMP-20-010)



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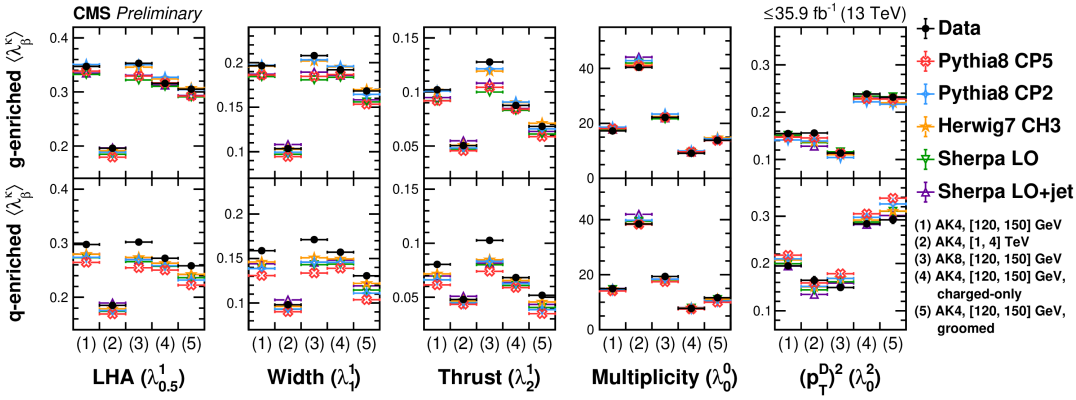

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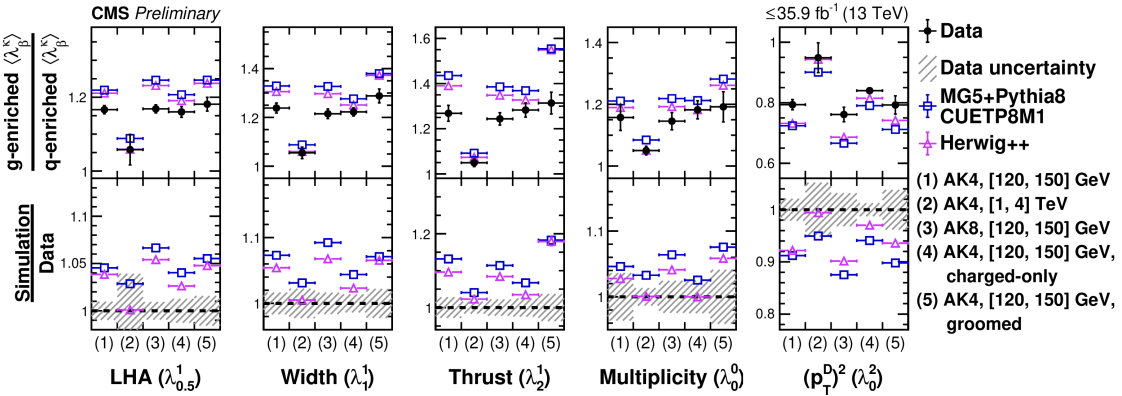

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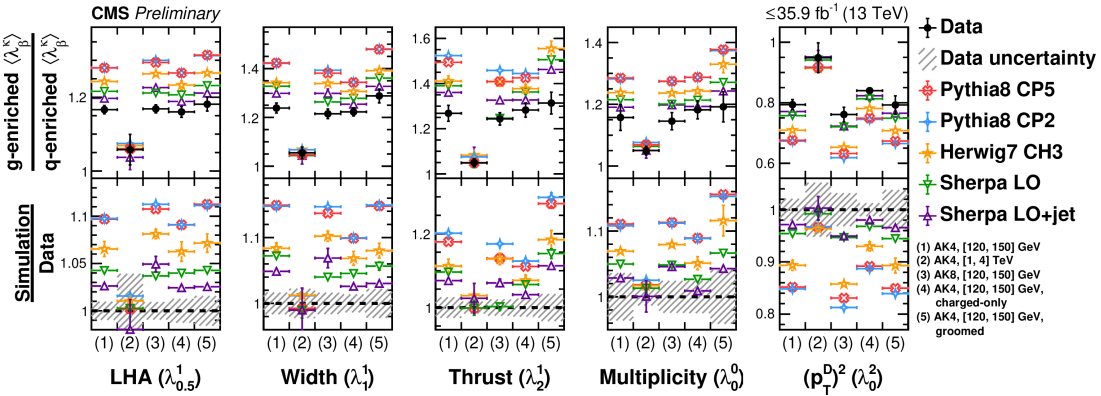

Z+jets jet pt spectrum (Eur. Phys. J. C 78 (2018) 965)