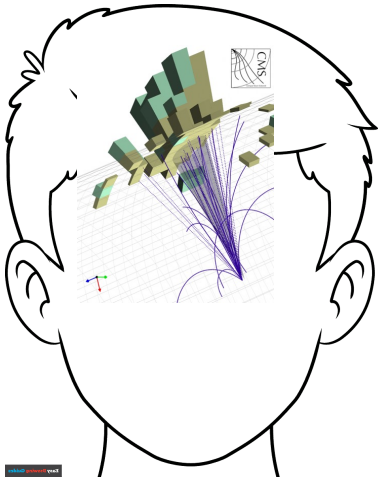
Jet substructure studies

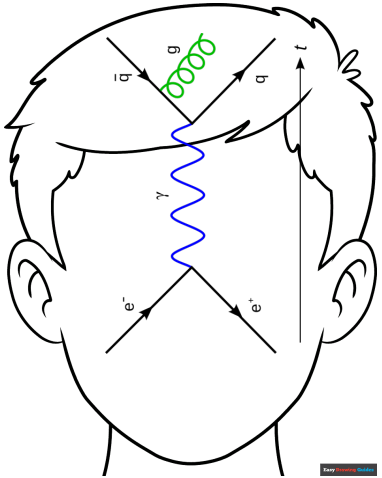
Les Houches 2023

Andreas Hinzmann, Simone Marzani

Jet substructure studies

Generally, closely related and shared with MC/Tools/ML group, 100% overlap





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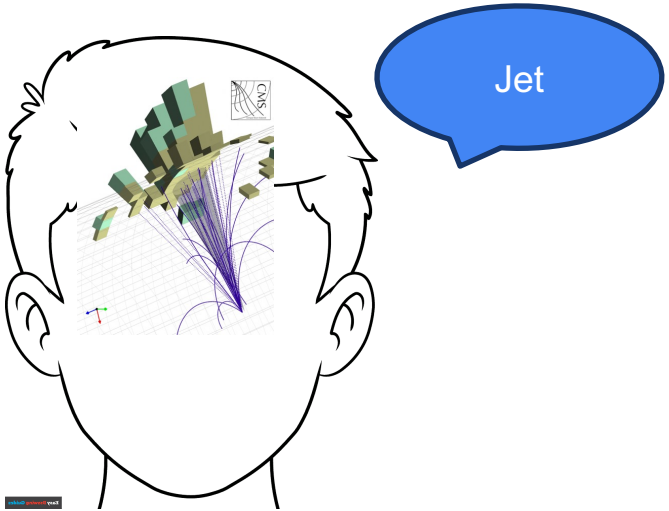

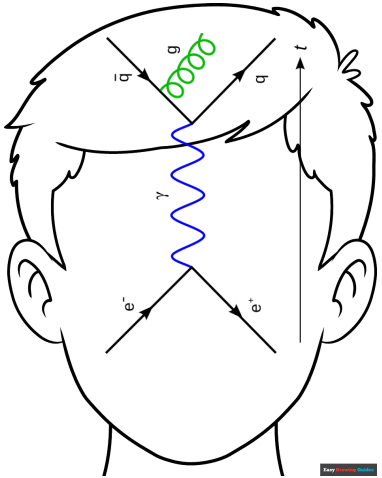

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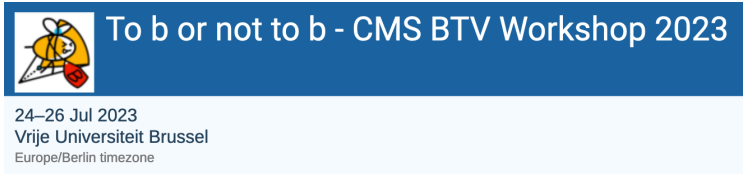

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- Accord for treatment of shower/hadronization uncertainties for jets/substructure short/mid/long-term
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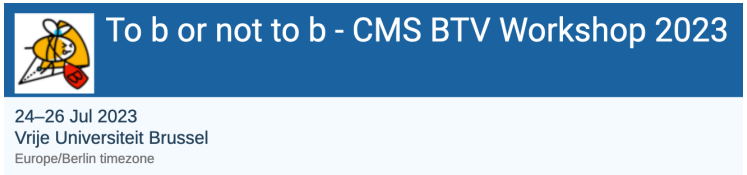

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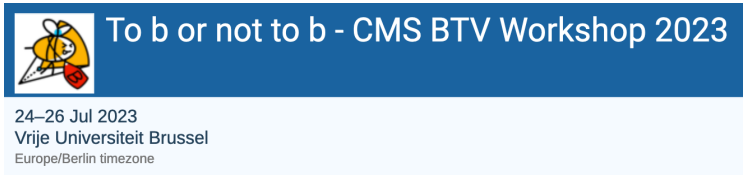

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  → see Flavour summary
- Accord for treatment of shower/hadronization uncertainties for jets/substructure short/mid/long-term
  → see MC/Tools/ML summary
- Folding knowledge of existing jet substructure measurements into MC generator uncertainties
  → Study MC variations comparing to measured JSS observables

Main wishes from MC developers:

- Measurements/rivets of observables for understanding hadronization of quark/gluon jets
  → Correlators

People interested: Simone, Simon, Andrzej, Matt, Jenifer, Stefan K., Andreas, Maria V., … Philippe

JSS measurements

- Measurement list: https://phystev.cnrs.fr/wiki/2023:groups:smjets:jss-measurements:start
- Event samples: Dijets covering p_T>50 to >675, Z+Jet p_T>50

ATLAS Multijets (higher priority)

```
ATLAS_2020_I1790256 – 13 TeV Lund jet plane
    Dijets, pT > 675 GeV
ATLAS_2020_I1808726 – 13 TeV Event Shapes (Thrust etc.)
    Multijets, HT2 > 1 TeV
ATLAS_2019_I1772062 – 13 TeV Soft-drop mass, rg, zg
    Dijets, pT > 300 GeV
ATLAS_2019_I1724098[MODE="DJ"] – 13 TeV jet tagging observables
    Dijets, pT > 400 GeV
ATLAS_2019_I1740909 – 13 TeV nTrk, fragmentation functions
    Dijets, pT > 300 GeV
ATLAS_2018_I1634970 – 13 TeV Inclusive Jets ?
    Inclusive jets, pT > 100 GeV
```

Multijets (lower priority)

```
ATLAS_2021_I1913061 – 13 TeV exclusive b-fragmentation (B->J/Psi K)
    Dijets, pT > 50 GeV
ATLAS_2018_I1711114 – 13 TeV g(bb)
    Dijets, pT > 50 GeV
```

CMS Multijets (higher priority)

```
CMS_2021_I1920187 [MODE="DIJET"] angularities in Z+jet and multijets
    pT > 50 GeV binned up to 1 TeV
CMS_2018_I1682495 jet mass in dijets
    pT > 200 GeV
CMS_2021_I1972986 13 TeV inclusive jets
    pT > 97 GeV
```

Z+jets (higher priority)

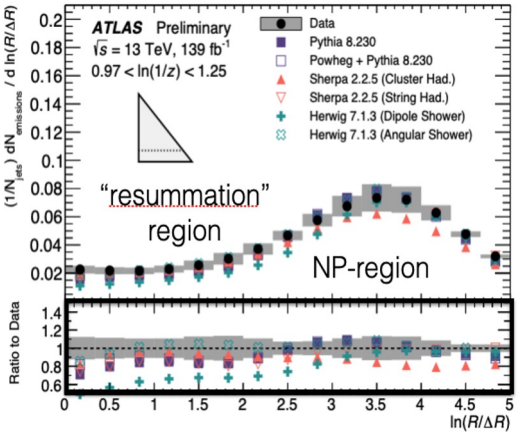
```
CMS_2021_I1920187 [MODE="ZJET"] angularities in Z+jet and multijets
    pT > 50 GeV binned up to 1 TeV
```

No consistent generators+tunes between CMS+ATLAS

Since last comparison of ATLAS Lund plane:

- improved dipole shower with Herwig 7.2
- retuned Sherpa to LEP-baryon-fraction

No Rivet plugins from ALICE so far despite multiple interesting JSS results
→ Followup after Les Houches

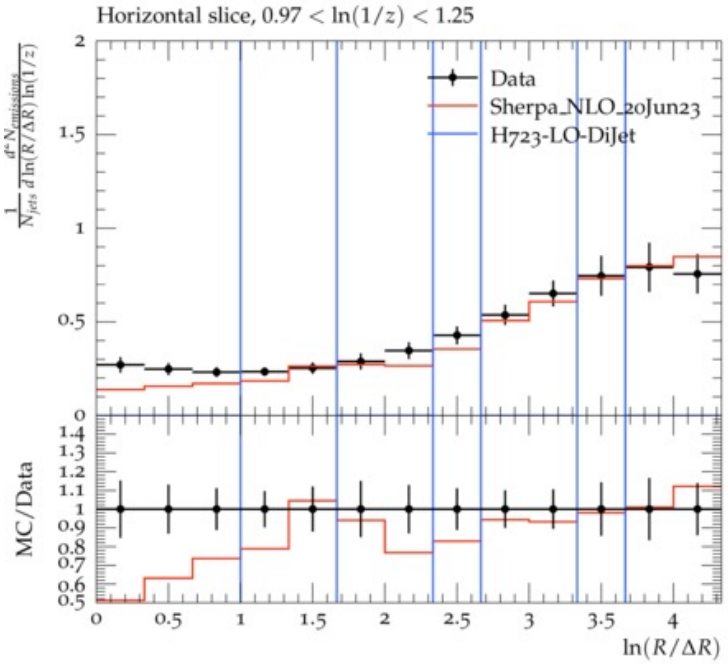


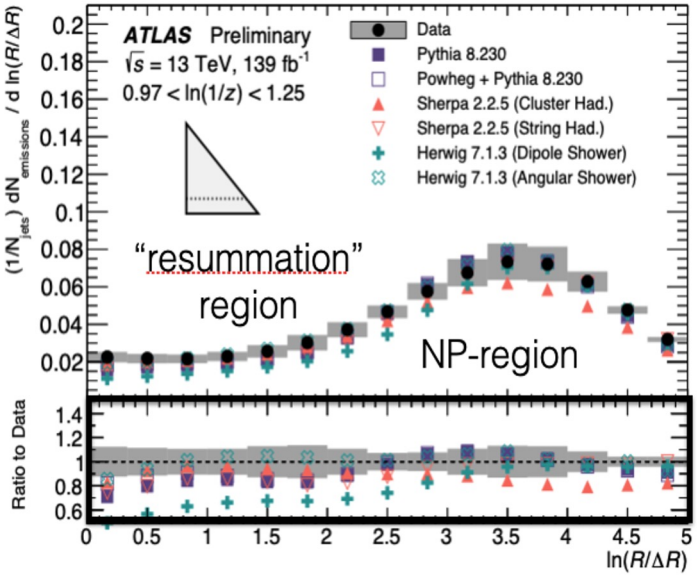
▲ vs. ▽ hadronization

✚ vs. ⊠ parton shower

First plots

Dijet pT>675 GeV



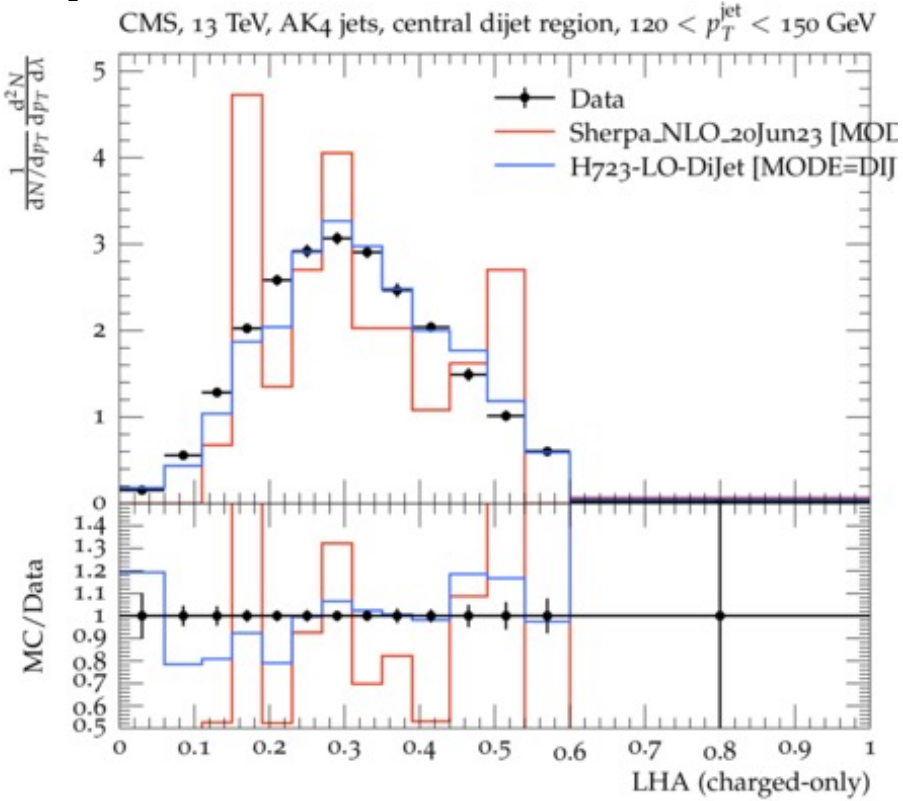


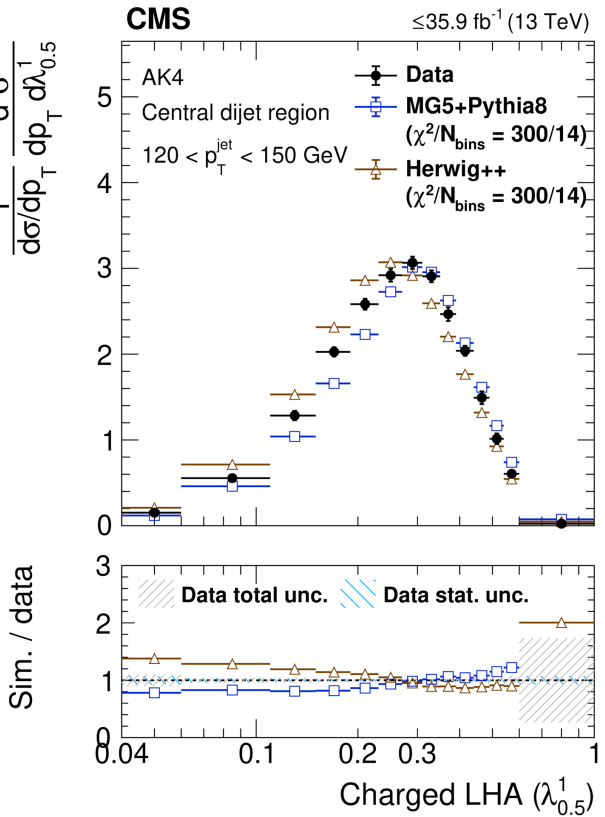
▲ vs. ▽ hadronization

✚ vs. ✖ parton shower

First plots

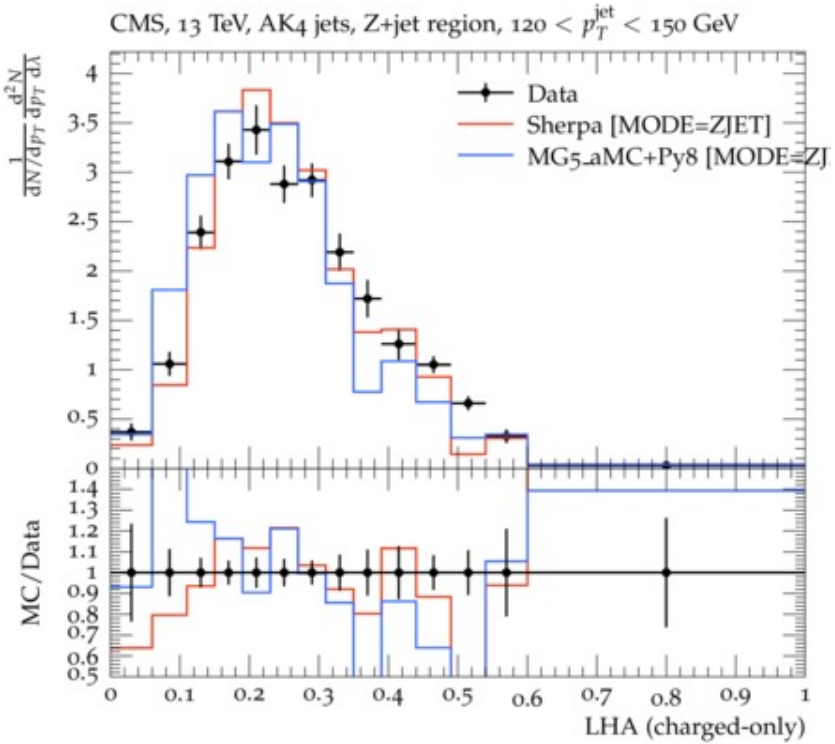
Dijet pT>120 GeV
quark-enriched

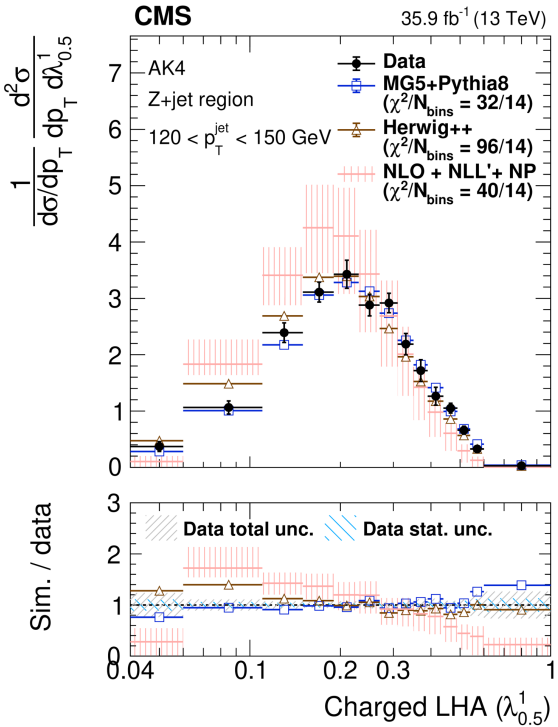




First plots

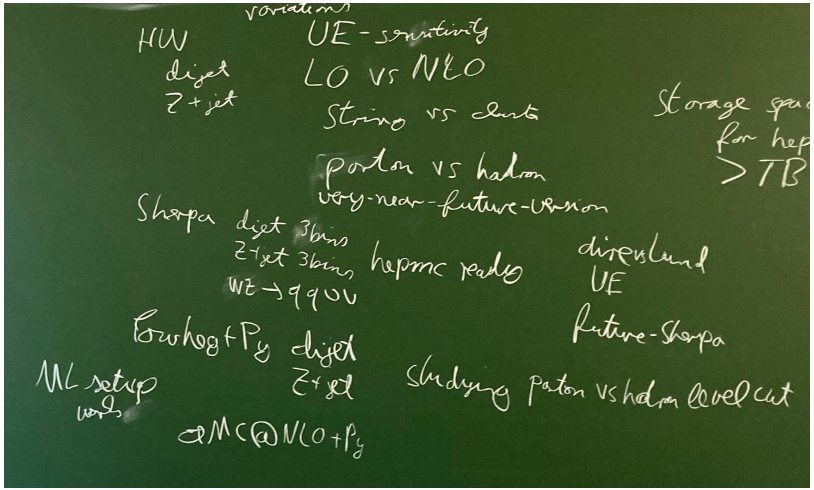
Z+Jets pT>120 GeV
quark-enriched





Planned studies

- Comparison of JSS measurements to state-of-the-art MC
- Lund plane and new showers
- Variations of MC generators
- Different enriched samples: q/g discrimination



- Identify configuration that best describes data and carry out ML studies on this → next slide

- Study new observables → later slide

→ see MC/Tools/ML summary

Interested people: Loukas, Huilin, Anna, …

Planned studies with machine learning

- Starting point: ML q-vs-g and W-vs-q/g discriminators in jet processes worse described than robust observables
- Train W-vs-q/g and q-vs-g with state-of-the-art generators
- Consider training dijet vs Z+jet vs W(qq) without any use of “flavor-truth” to remain generator independent. cross check with CMS-style-parton-flavor-definition
- Reweight to different observables in measurements, check performance
- Make a rivet plugin of a ML-tagger as testbed to MC generators
- Identify which part of the hadronization process shows the largest discrepancy between the generators
- Correlations study: what if we train two classifiers using two different generators, and do inference on the other sample? Do the cross-correlations teach us anything? What do jets that are tagged by one classifier and mistagged by the other teach us?
- What if we change a couple of parameters in the hadronisation model of Pythia, and train classifiers to discriminate between the settings? Can we use these classifiers and our measured distributions to ‘tune’ the settings? Can these classifiers be decorrelated from each other?

Interested people: Jennifer, Simon, …

Observables for shower/hadronization models

- Rivet routine for correlators in jets: https://gitlab.com/jroloff/leshouches2023
- Hadron-correlations within jets
  - Currently just the dR between particles within jets (Suggestion from Simon)
- dPsi for leading particles within jets (Suggestion from Sylvia)
  - Similar to Figure 3b of https://arxiv.org/abs/2207.09467
- Hadron multiplicities and energy fractions, with inspiration taken from
  - https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2022-021/
- Energy-energy correlators
  - https://arxiv.org/abs/2203.07113, https://arxiv.org/pdf/2201.07800.pdf
  - **Long discussion on how to unfold them, non-trivial, follow-up/summary useful**
- Lund and Cambridge multiplicities (Suggestion (and code) from Matt LeBlanc)
- Double-differential w.r.t jet axis
- Different jet axes
- **Understand what is experimental feasibility?**
- **Study what can help improve hadronization models**

The way forward

- Goal: proceedings/publication with the initiated studies
- Overleaf to develop proceedings/publication: https://www.overleaf.com/project/648ab3e1c164ede47c68c368
- Mattermost channel for communication with preservation of history: https://mattermost.web.cern.ch/signup_user_complete/?id=u6kbnk3nu3yjmgtyzdu19t1whh&md=link&sbr=su

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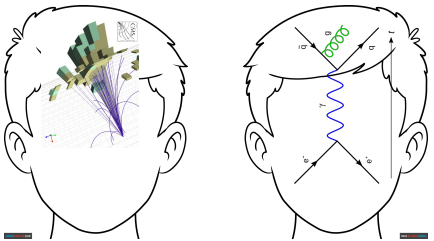
- Marry or not to marry?



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- Marry or not to marry?
- Let's just stay friends and
  start another study Les Houches 2025