

Substructure-based classification of medium-modified jets

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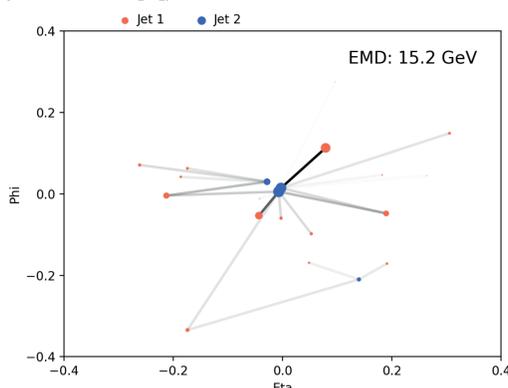


Introduction

The Earth Mover's Distance (EMD) in the jet context [1,2]: the *minimum* amount of “work” required to transform one jet J_1 into another J_2 by movements of energy f_{ij} from constituent $i \in J_1$ to constituent $j \in J_2$:

$$\text{EMD}(J_1, J_2) = \min_{\{f_{ij}\}} \sum_{i \in J_1} \sum_{j \in J_2} f_{ij} \frac{R_{ij}}{R} + \left| \sum_{i \in J_1} p_{T,i} - \sum_{j \in J_2} p_{T,j} \right|$$

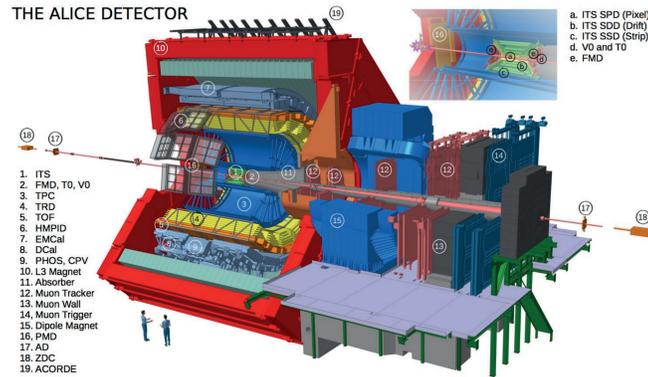
Illustration: EMD between two random PYTHIA jets (adapted from [3])



Goal: study the feasibility of the EMD-based jet classification in the environment of central heavy-ion collisions. **Method:** embed simulated PYTHIA jets into real Pb-Pb events.

Jet Reconstruction in ALICE

THE ALICE DETECTOR



ITS+TPC: charged particle tracking down to $p_T = 150 \text{ MeV}/c$
 $|\eta| < 0.9, 0 < \varphi < 2\pi$

Analysis

Event sample

- PYTHIA8 embedded into Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02 \text{ TeV}$, 0–10%
- Reconstructed (background-subtracted) jets (“Reco” sample) are matched to particle level jets (“Probe” sample)
- Background subtraction: Constituent Subtraction jet-by-jet [4]

Jet Reconstruction

- charged tracks $p_T > 0.15 \text{ GeV}/c$
- anti- k_T clustering with $R = 0.4$
- jets in the fiducial TPC acceptance:
 $|\eta_{\text{jet}}| < 0.5$

EMD Calculation

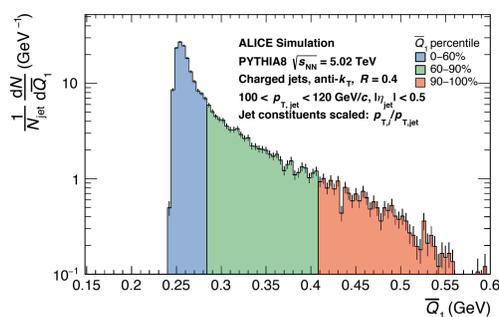
- Python package ENERGYFLOW [3]
- jets rotated and boosted such that
 $\eta_{\text{jet}} = 0, \varphi_{\text{jet}} = 0$
- jet constituents scaled: $p_{T,i}/p_{T,\text{jet}}$
(removes the second term in the EMD)

Results

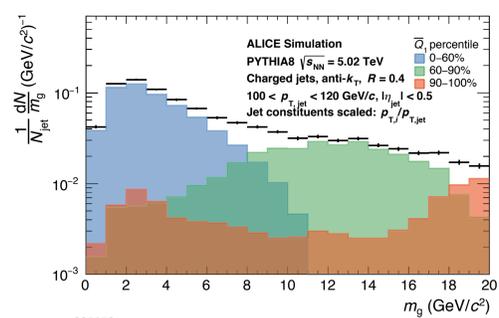
PYTHIA8 Particle Level

For each jet J_i calculate $\bar{Q}_1(J_i)$ — the average value of EMDs to all jets in the same sample.

Small/large \bar{Q}_1 values correspond to **common/rare** jet substructure configurations.

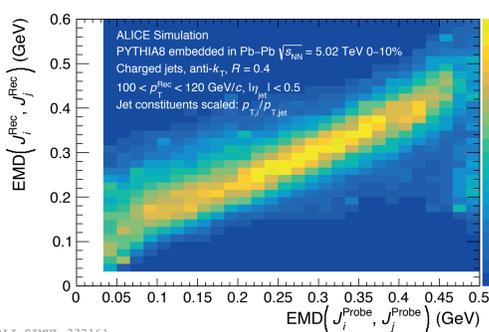


Example: projections onto groomed jet mass

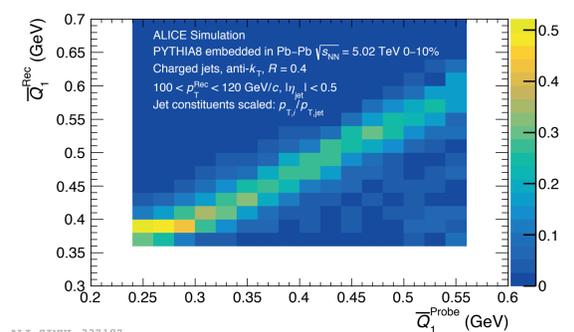


PYTHIA8 Embedded into Pb-Pb events

EMD smearing in the presence of detector effects and background fluctuations:



Relating \bar{Q}_1 at particle and reconstructed levels:



Conclusion:

EMD-based observables retain information about original jet substructure in the presence of detector and background effects characteristic for central Pb-Pb collisions measured with ALICE at $\sqrt{s_{NN}} = 5.02 \text{ TeV}$.

Outlook:

- Application to jet samples measured in pp, p-Pb, and Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02 \text{ TeV}$.
- Jet Substructure studies with \bar{Q}_1 selection (explore common vs rare jet configurations).
- Application to (groomed) subjet configurations.

References

- [1] P. T. Komiske, E. M. Metodiev, and J. Thaler, Phys. Rev. Lett. 123, 041801 (2019).
- [2] P. T. Komiske, R. Mastandrea, E. M. Metodiev, P. Naik and J. Thaler, arXiv:1908.08542.
- [3] <https://energyflow.network>
- [4] P. Berta, M. Spousta, D. W. Miller and R. Leitner, JHEP 1406, 092 (2014).

