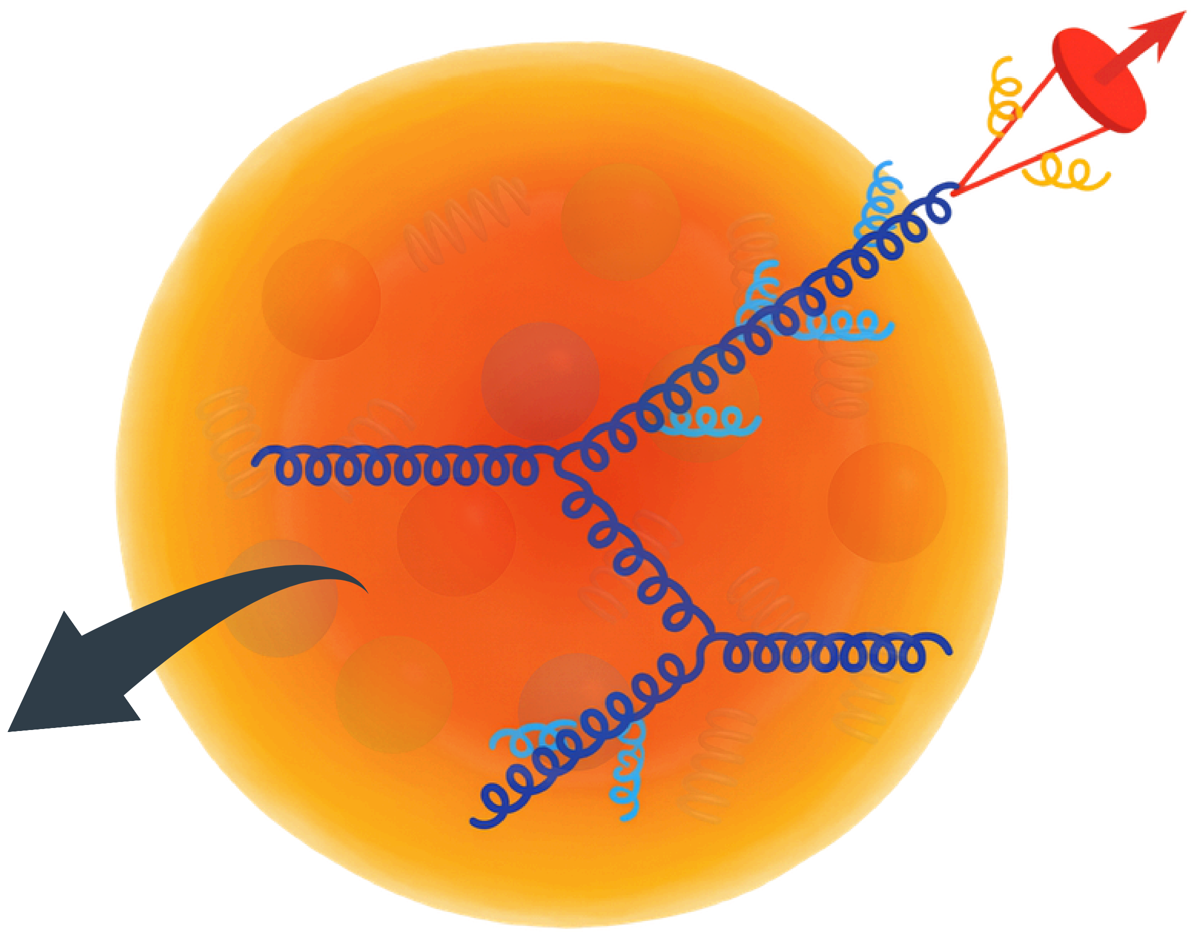
A JET-BY-JET STUDY OF ENERGY LOSS IN JEWEL

Jet Quenching

- Jets can be used for probing QGP properties;
- Parton energy loss in the QGP; ⟷ **Quenching**

Fig. from [1, 2] (Adapted)



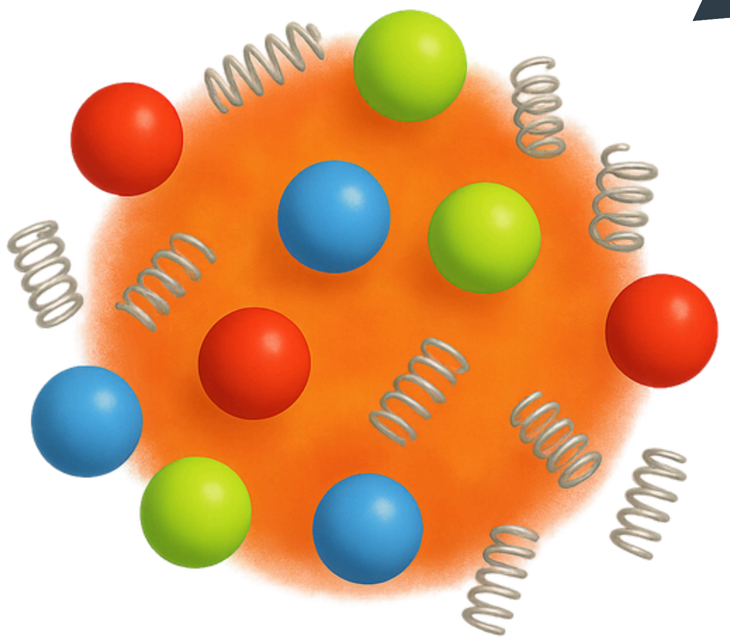


Fig. from [1] (Adapted)

Jet Quenching

- Jets can be used for probing QGP properties;
- Parton energy loss in the QGP; ⟷ **Quenching**
- Collisional process + Gluon radiation;

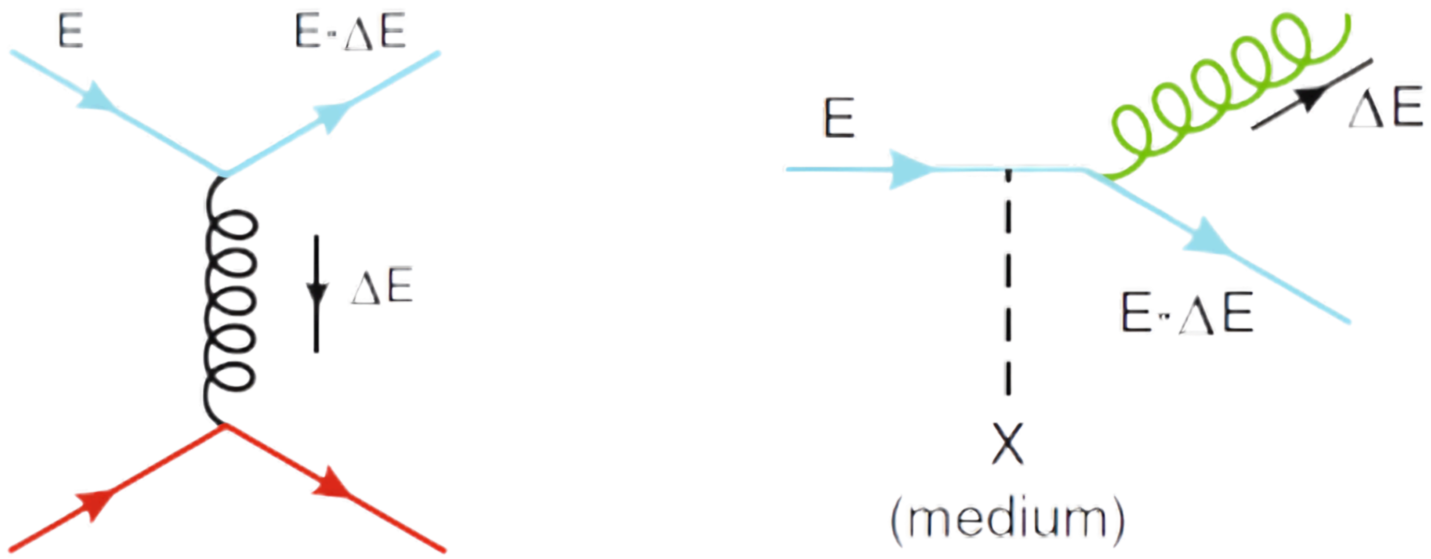
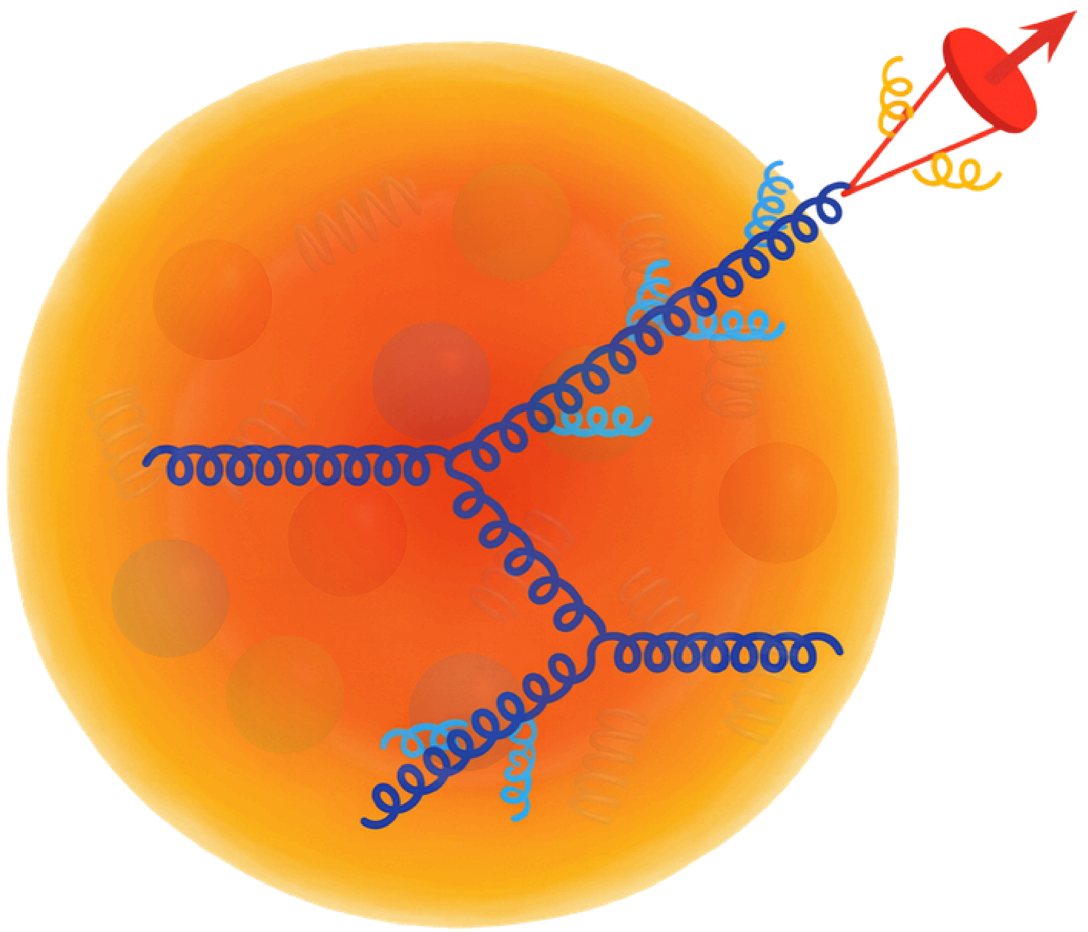


Fig. from [3]

- Evidenced by jet supression, di-jet assymetry and substructure modifications.

Fig. from [3, 4] (Adapted)



Can we use machine learning model to identify jet quenching?

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Identifying quenched jets in heavy ion collisions with machine learning

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Jet substructure observables for jet quenching in Quark Gluon Plasma: a Machine Learning driven analysis

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Validating a Machine Learning Approach to Identify Quenched Jets in Heavy-Ion Collisions

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Overview: Jet quenching with machine learning

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YES

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- **Investigate and compare the performance of supervised machine learning architectures in the classification of the quenched jets problem;**

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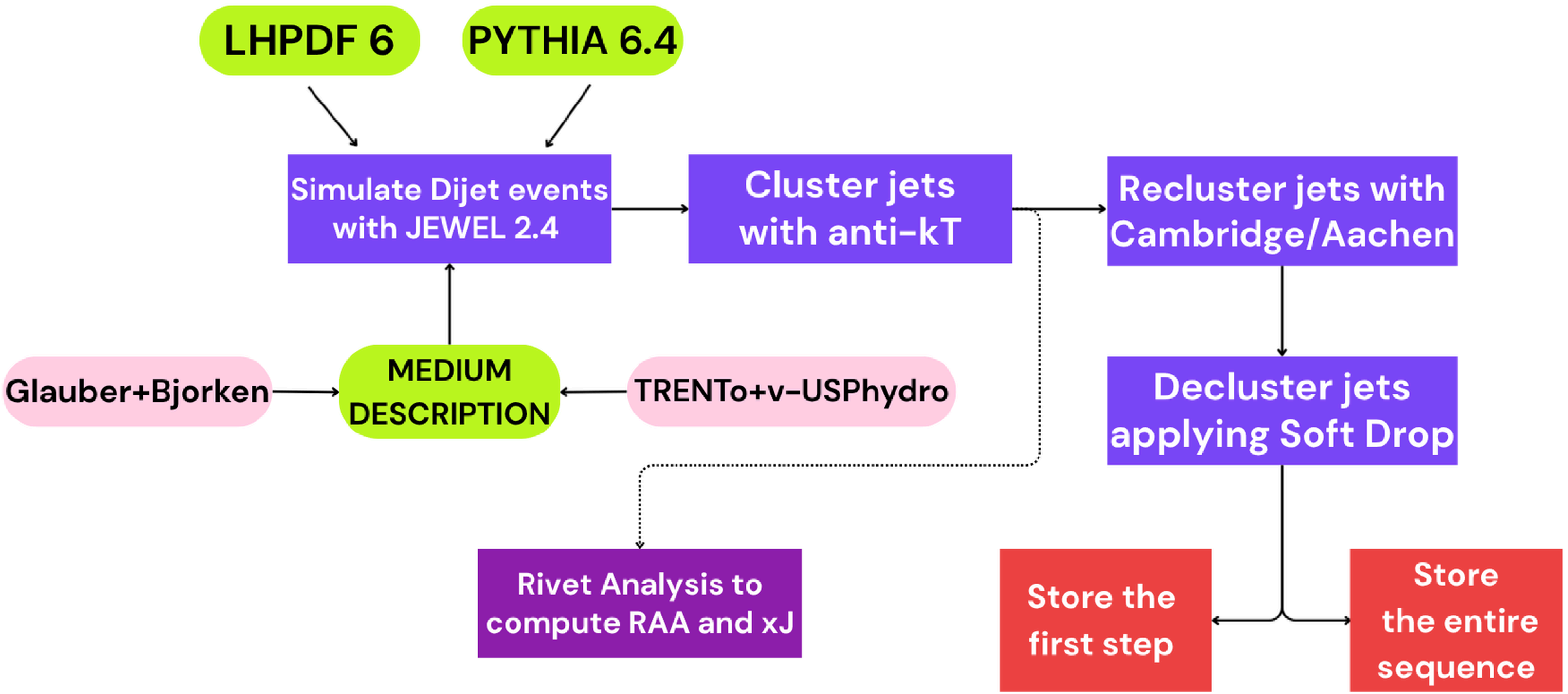
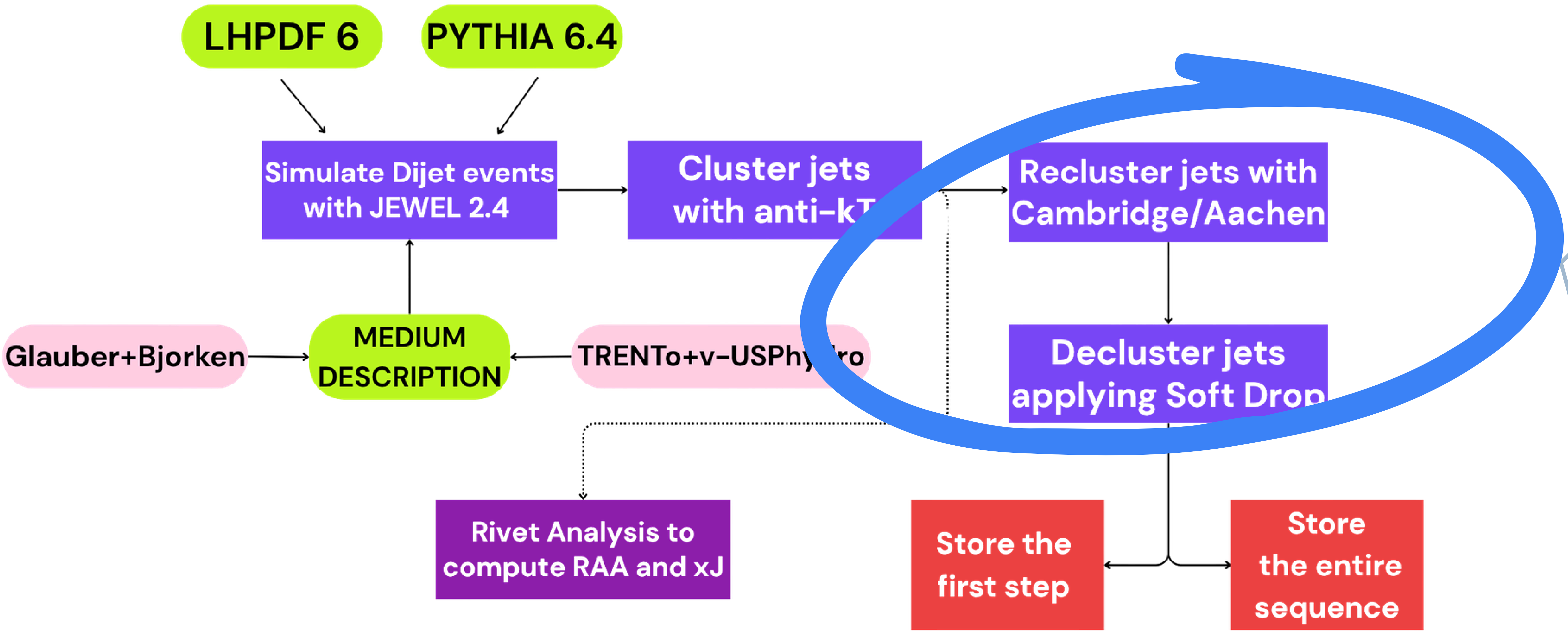
- **Compare non-sequential and sequential ML models;**
- **Analyze the performance of these models using two different media descriptions of the QGP;**
- **Use unsupervised machine learning models to identify quenched jets.**

Methodology



Methodology



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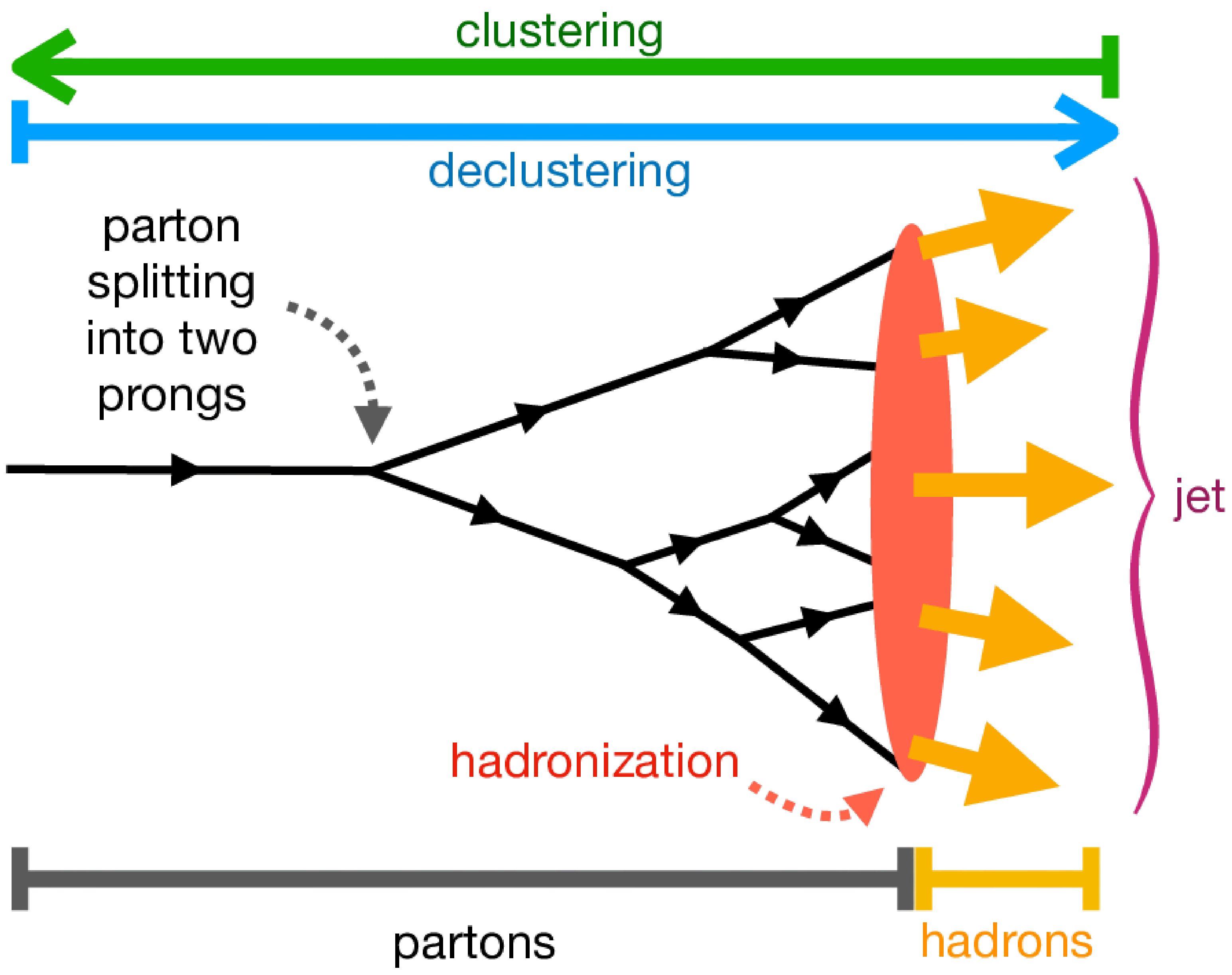


Fig. from [4]

Declustering

- Undo the clustering steps;
- Traces back the jet's formation tree;
- Reveals the jet's internal structure

✳ **Clustering is putting the jet puzzle together, while declustering is taking it apart to see how it was built**

Methodology

$$\frac{\min[p_{T,i}, p_{T,j}]}{p_{T,i} + p_{T,j}} > z_{cut} \left(\frac{R_{i,j}}{R_0}\right)^{\beta}$$

Soft Drop condition

Jet Variables

$$z = \frac{\min(p_{\mathrm{T,i}}, p_{\mathrm{T,j}})}{p_{\mathrm{T,i}} + p_{\mathrm{T,j}}},$$

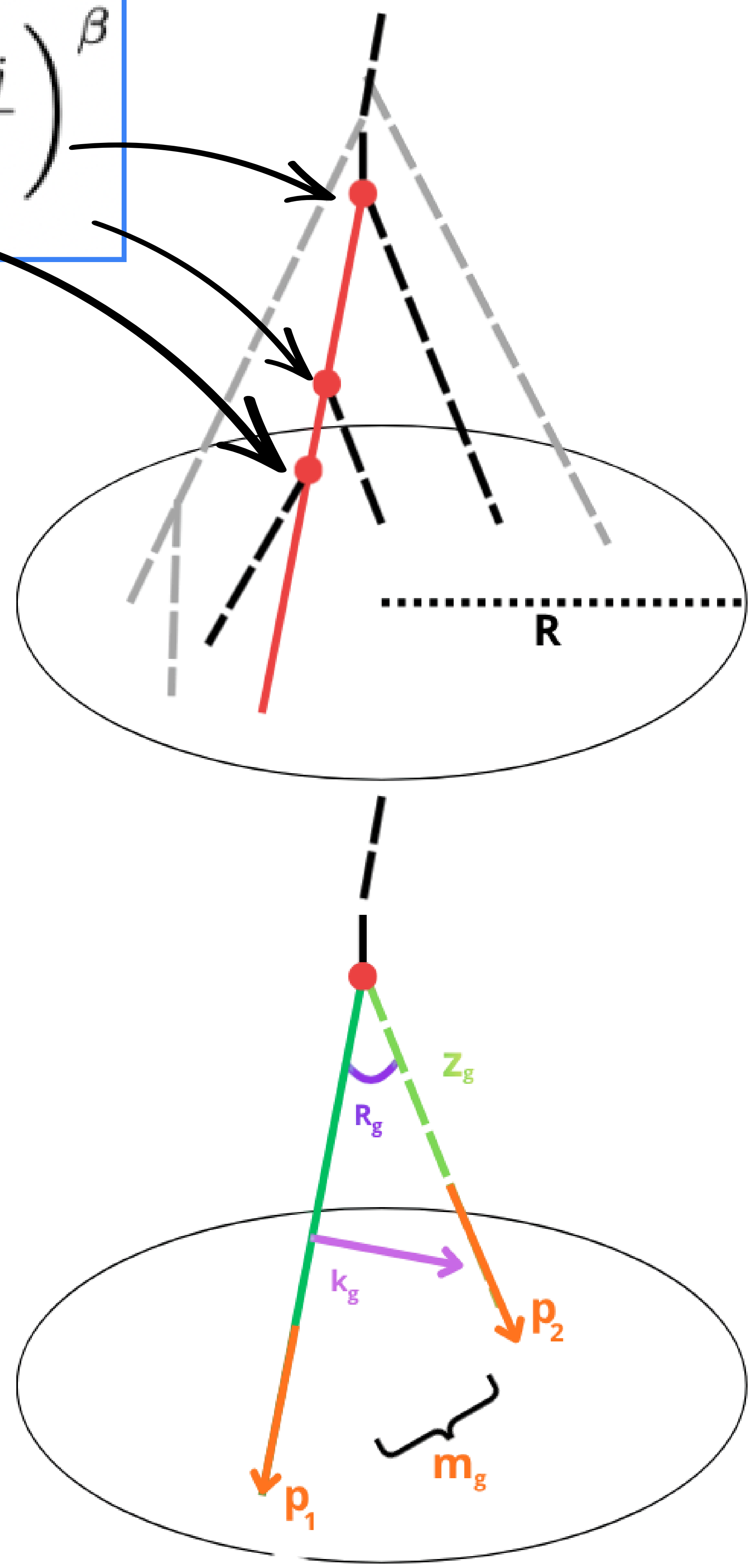
$$\Delta R = \sqrt{(\phi_{\mathrm{i}} - \phi_{\mathrm{j}})^2 + (\eta_{\mathrm{i}} - \eta_{\mathrm{j}})^2},$$

$$k_{\perp} = \min(p_{\mathrm{T,i}}, p_{\mathrm{T,j}}) * \Delta R,$$

$$m_{\mathrm{inv}} = \sqrt{(E_{\mathrm{i}} + E_{\mathrm{j}})^2 - (\mathbf{p}_{\mathrm{i}} + \mathbf{p}_{\mathrm{j}})^2},$$

$$x_t = [z, \Delta R, k_{\perp}, m_{\mathrm{inv}}]$$

$$x = [x_1, x_2, \ldots, x_t, \ldots, x_n]$$



Results

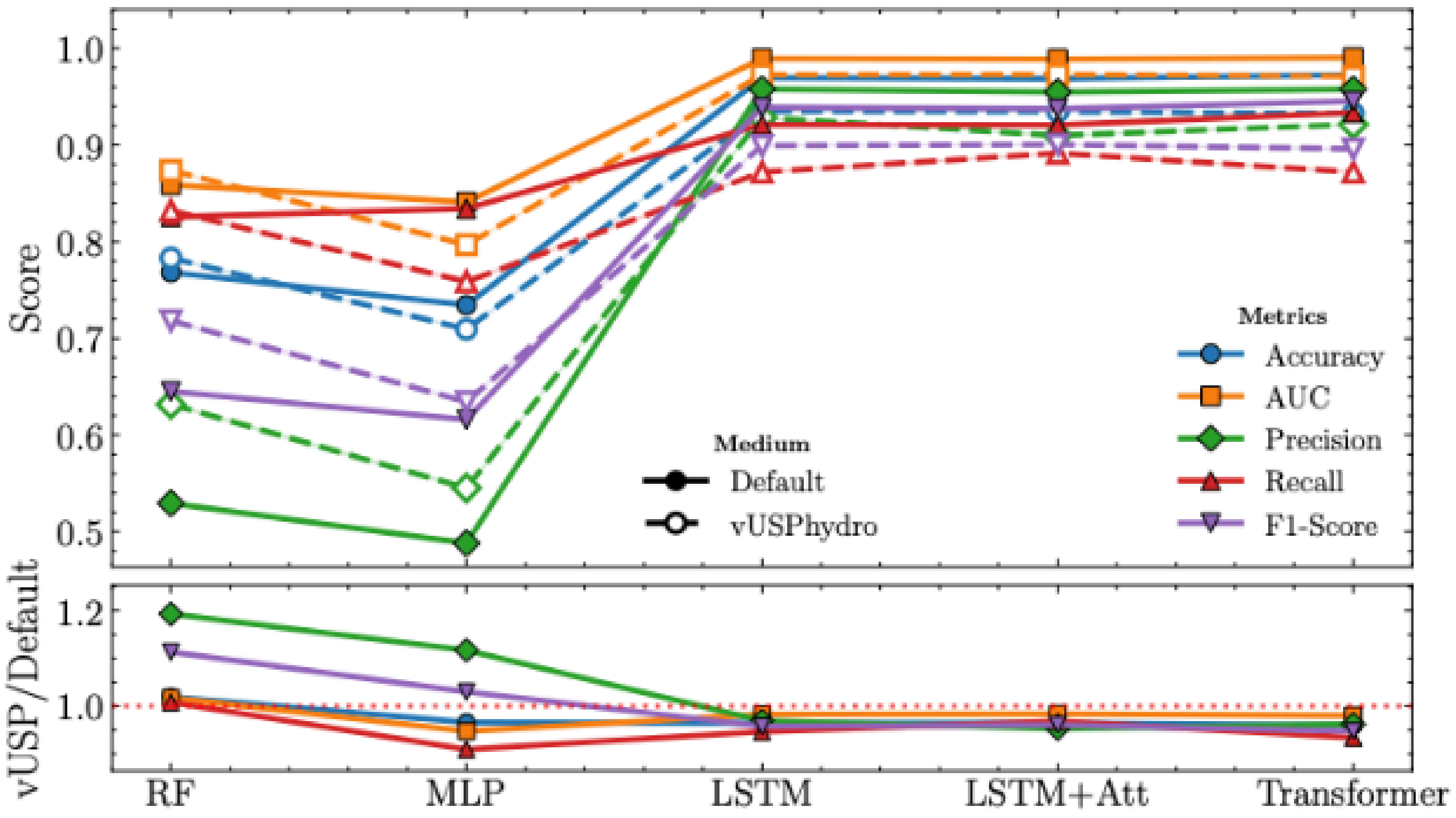


FIGURE: $p_T \in [40, 60]$ GeV

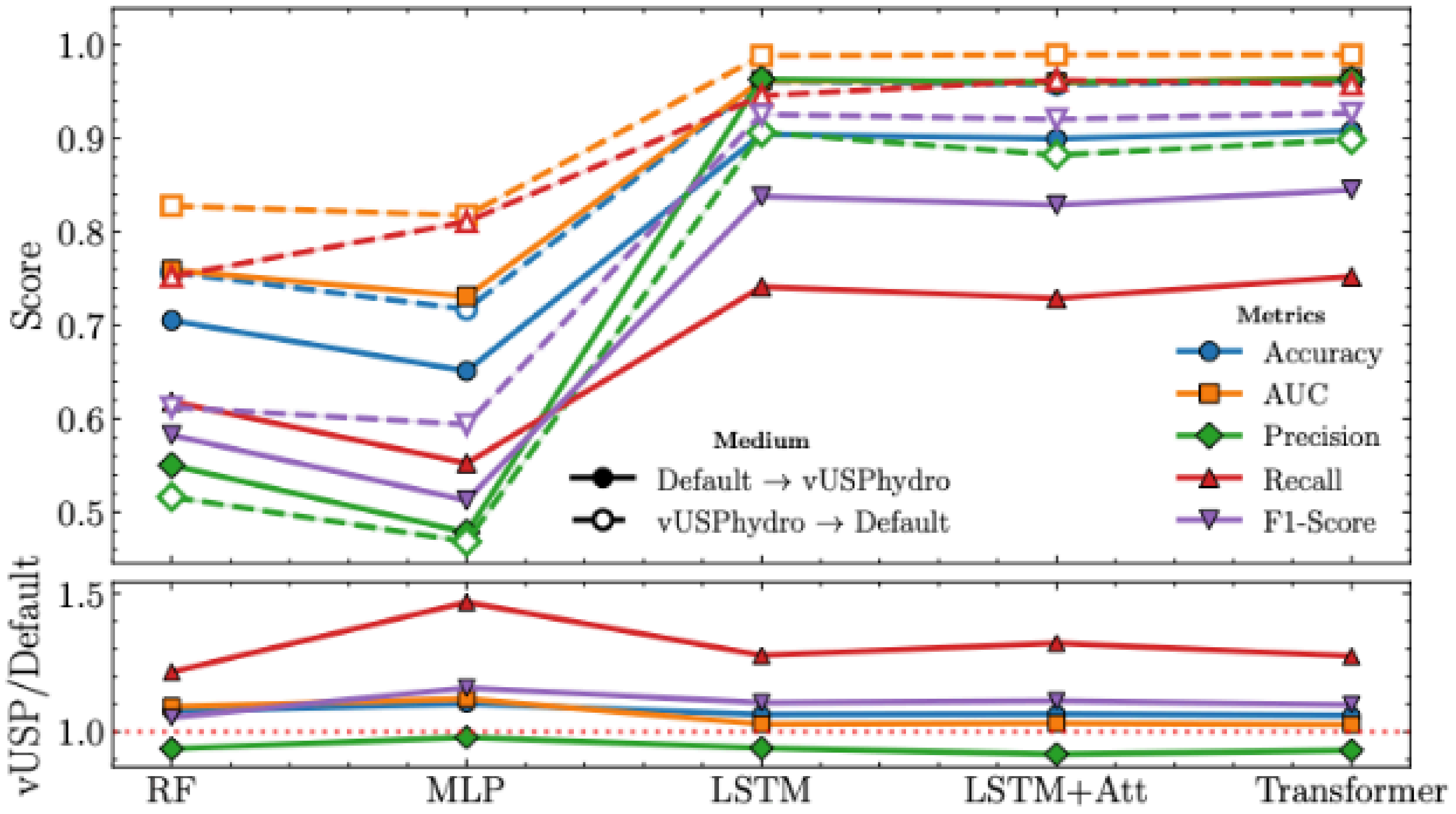
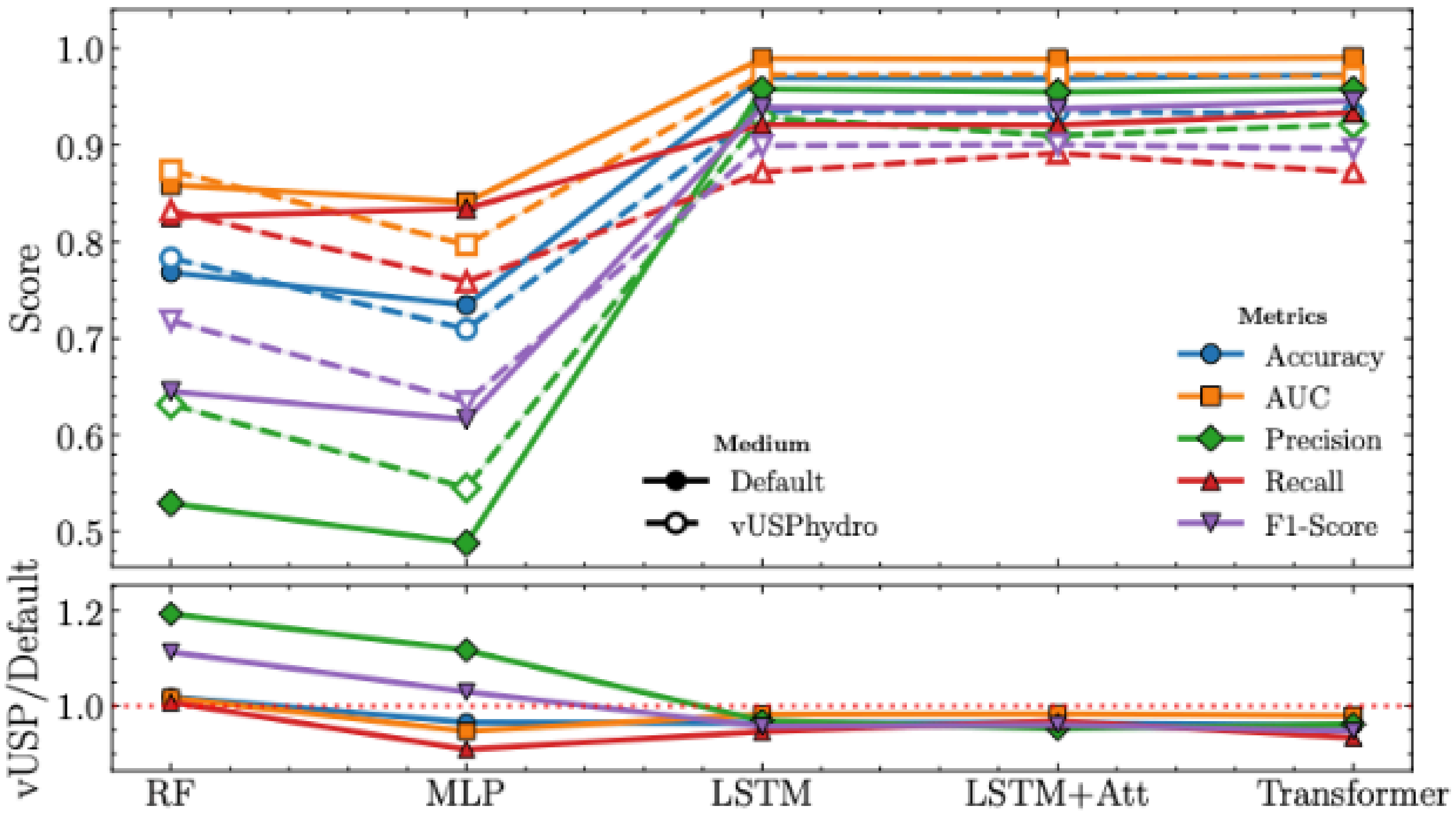


FIGURE: $p_T \in [40, 60]$ GeV

Results

- **Training on the v-USPhydro domain leads to better generalization than training on the default JEWEL domain.**



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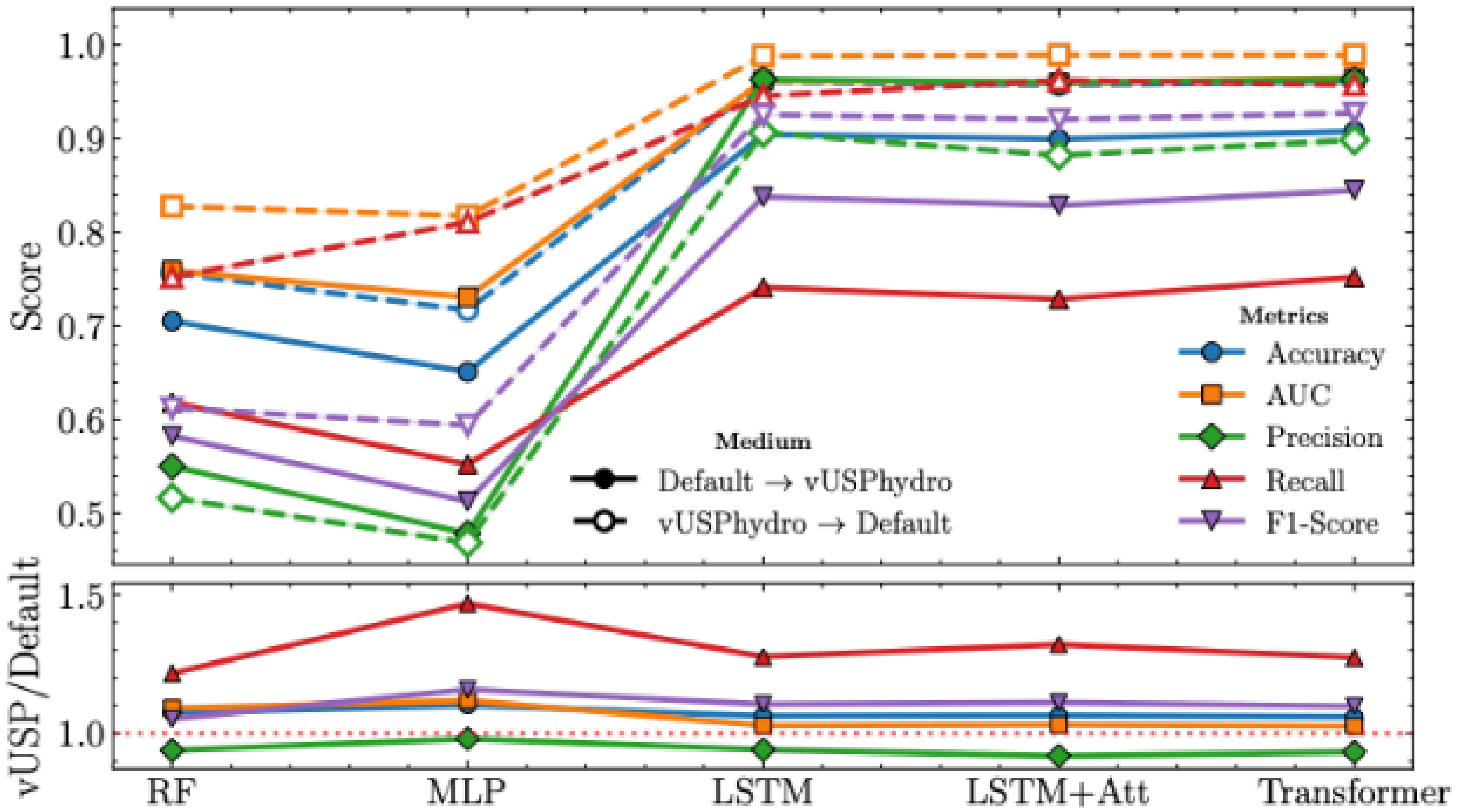

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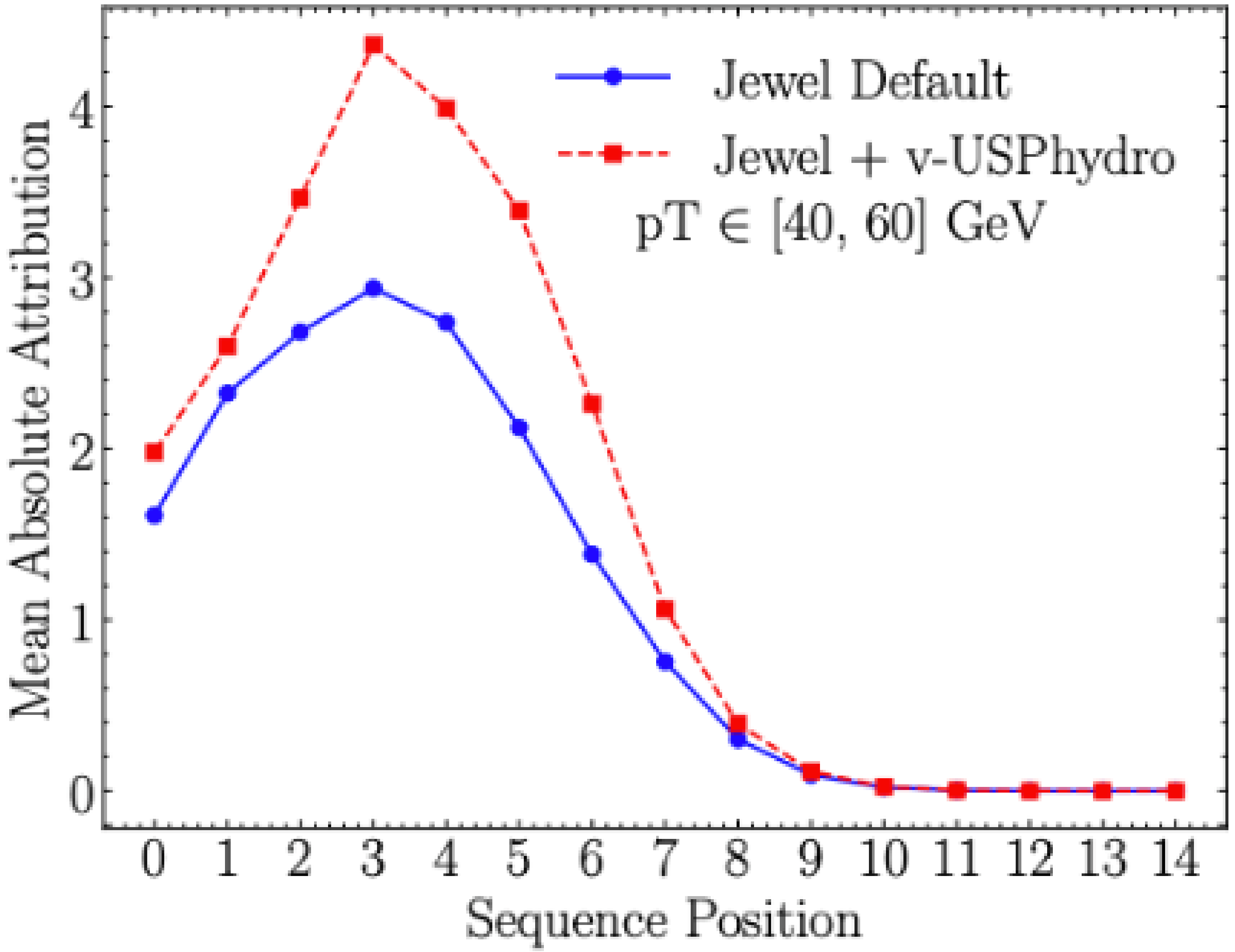
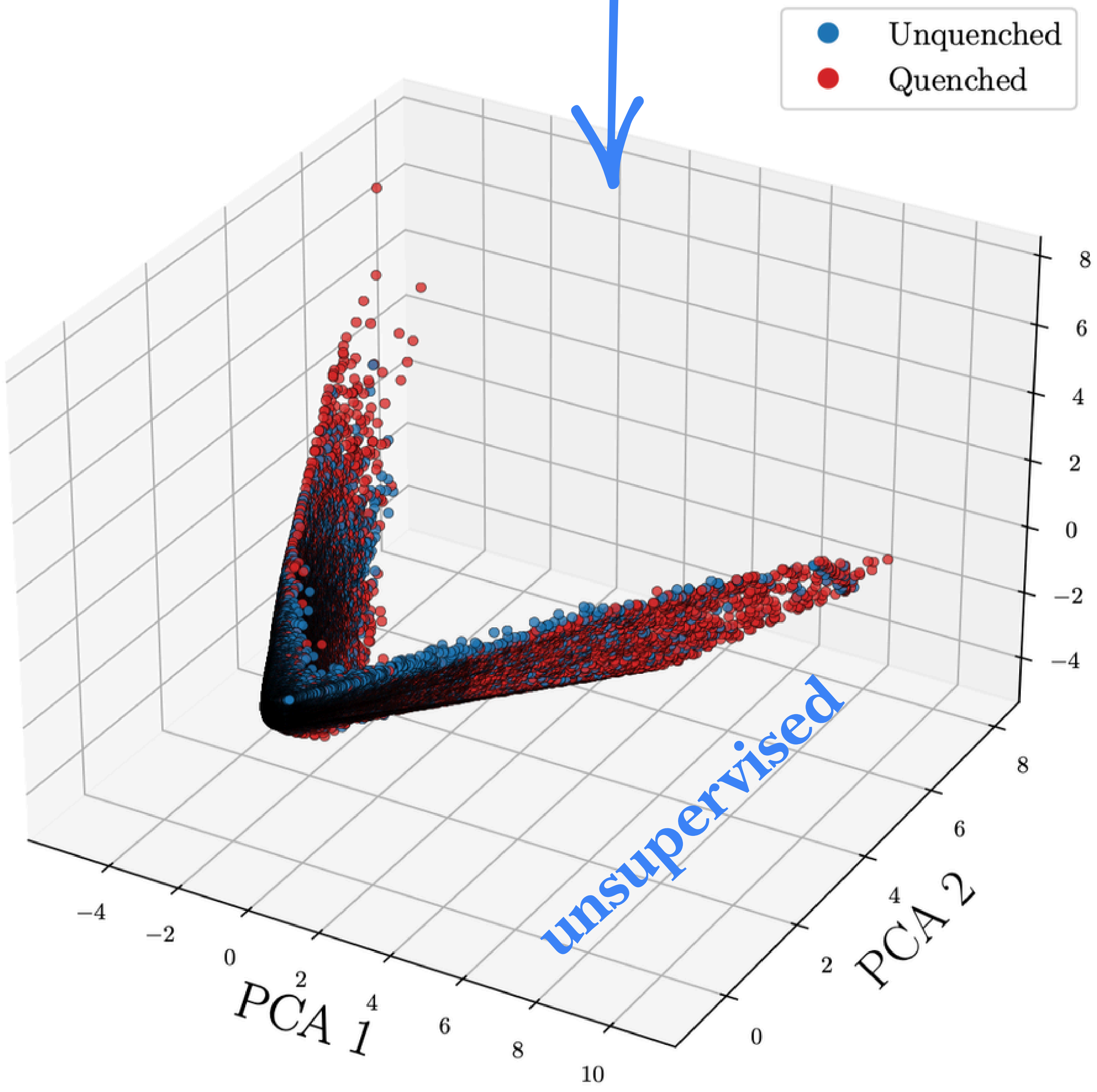


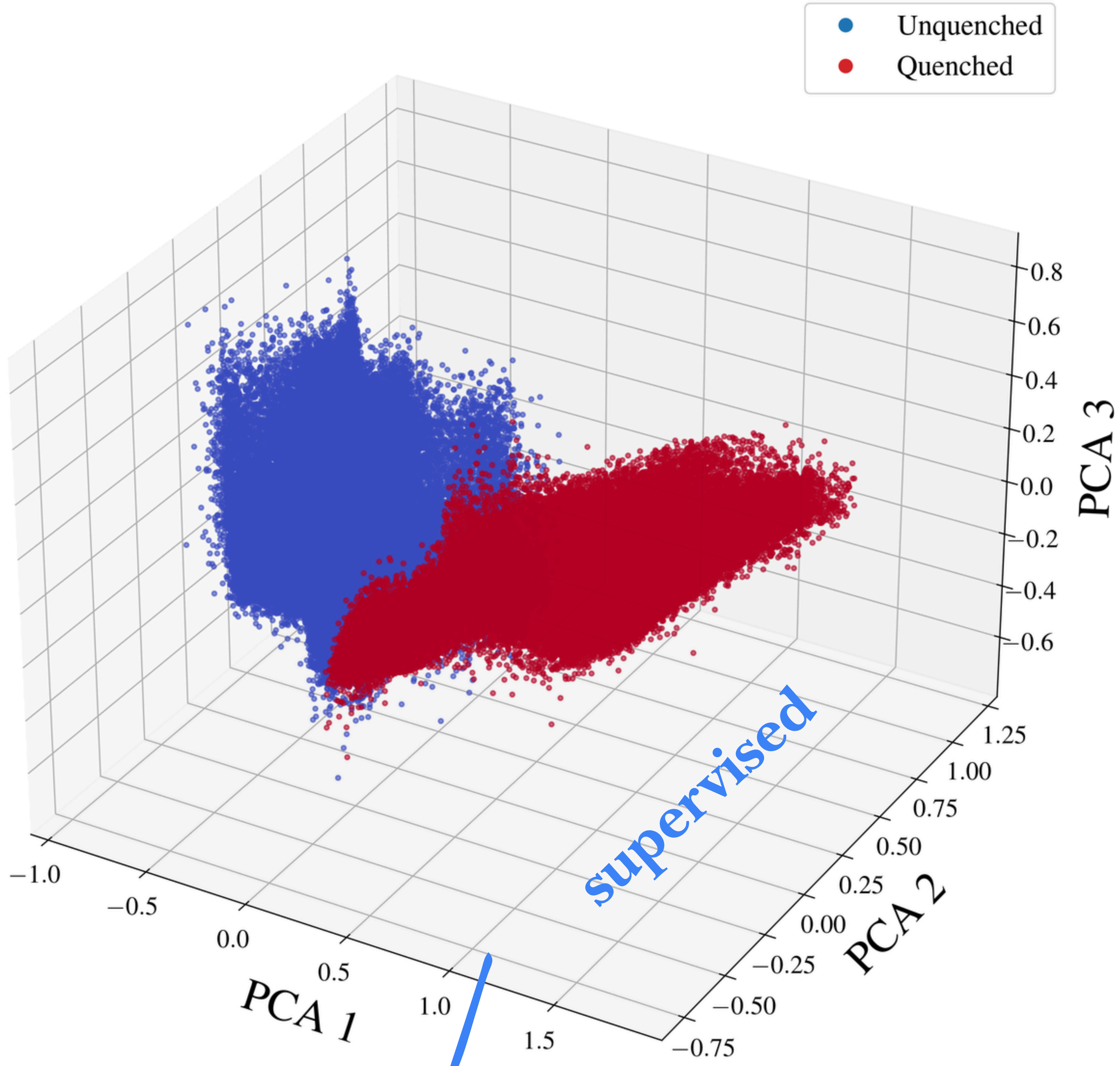
SHAP Analysis

LSTM temporal evolution

Results

Autoencoder latent space





LSTM latent space

Conclusions

- **We can identify quenched jets using machine learning;**
- **The initial declustering steps are more relevant to distinguish quenched and unquenched jets;**
- **Sequential models outperform non-sequential ones;**
- **Training in the v-USPhydro medium results in a more generalized model, with great performance in both media. However, the opposite is not true;**
- **The models show sensitivity to the underlying hydrodynamics;**
- **The unsupervised techniques chosen in this work have failed to recover the quenched/unquenched labels;**

Limitations

- **Lack of realistic thermal background;**
- **We do not simulate the detectors;**
- **All ML models are trained on Monte Carlo events, thus nothing can be inferred about the performance of these models in experimental data;**
- **Not all jets from Pb-Pb collisions are quenched;**
- **Our analysis is limited to the energy 5.02 TeV, one centrality range (0-10%) and one jet radius (R=0.4).**

Future steps

- **Quantify energy loss of each jet;**
- **Simulate more realistic conditions: thermal background and detectors;**
- **Employ machine learning models on experimental data.**

Thank you!

References

[1] Rafelski, Johann. (2015). Melting Hadrons, Boiling Quarks. The European Physical Journal A. 51. 10.1140/epja/i2015-15114-0.

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[4] ALICE Collaboration (S. Acharya et al.), "Measurement of the angle between jet axes in Pb–Pb collisions at $\sqrt{s_{nn}}$ = 5.02 TeV," Preprint arXiv:2303.13347, CERN-EP-2023-046 (March 16, 2023).