Transformer Networks for Constituent-Based b-jet Calibration with the ATLAS Detector





Jet p_⊤ prediction

Jet mass

b-Jet Calibration

- b-jets differ from light quark and gluon jets due to high mass and large semileptonic branching fraction, requiring specific *b*-jet calibration
- Precise measurement of *b*-quarks is critical to physics program, e.g. small-R jets for $HH \to b\overline{b}b\overline{b}$, large-R $b\overline{b}$ -jet for boosted $H \to b\overline{b}$
- Transformers proven powerful for tasks like b-jet tagging

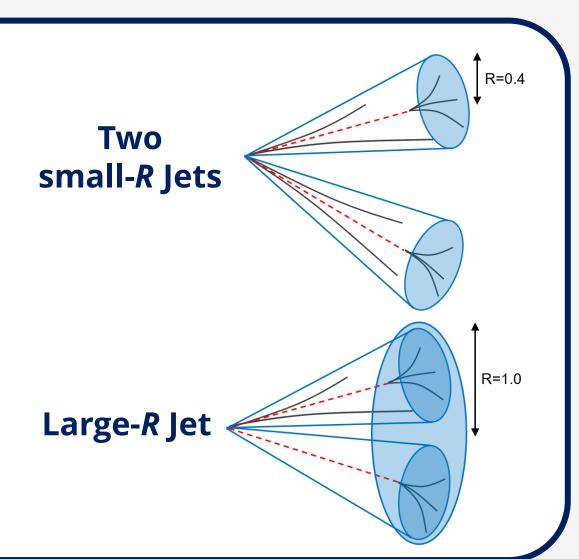
Large-R: + charged & neutral UFOs

— Small-R Regression

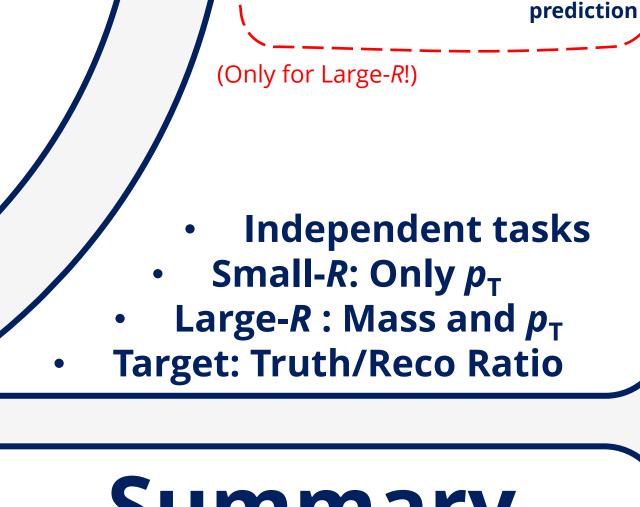
 $\sqrt{s} = 13 \text{ TeV}, t\bar{t} \text{ Powheg+Pythia}$

b-jet $p_{T, truth} > 20 \text{ GeV}$, |n| < 2.5

anti-kt R=0.4 PFlow jets



Architecture **Regression Tasks Inputs Charged Flow Objects Transformer Encoder Neutral Flow Objects Conditional Constituent** (Additional) Tracks Representation **Inputs combined Constituents-Jet vectors Initial Track Combined** Representation Inputs **Produces conditional representations Global jet representation Initialised separately** → weighted sum over constituents Common: jets + tracks Small-R: + soft lepton features



Pooled Jet Representation

Pooled let Representation

Performance

 $\sqrt{s} = 13 \text{ TeV}$, anti- $k_t \text{ R=0.4 PFlow jet}$

0.02 m_{bb} [GeV] $0.14 - \sqrt{s} = 13$ TeV, anti- k_t R=1.0 UFO CS+SK Soft-Drop jets $\sqrt{s} = 13$ TeV, Mixed Jet Sample Large-R Regression anti-k+ R=1.0 UFO CS+SK Soft-Drop jets $400 < p_T^{\text{Reg}} < 1500 \text{ GeV}, 40 < m_L^{\text{Reg}} < 300 \text{ GeV}$ $200 < p_{\rm T}^{\rm Reg} < 1500 \text{ GeV}, 40 < m_{\rm I}^{\rm Reg} < 300 \text{ GeV}$ — H → bb̄

Small-R:

- 18-31% better $\sigma_{p_{\mathrm{T}}}^{\mathrm{response}}$ (10% over μ +PtReco)
- 22% narrower *m* peaks (5% over μ +PtReco)

Large-R:

- 25-35% better $\sigma_{n_{\pi}}^{response}$
- 26-33% better $\sigma_m^{\text{response}}$
- 10-15% narrower *m* peaks

Glossary:

Response – reconstructed/truth ratio of m or p_T σ^{response} - relative resolution of m or p_T response μ+PtReco – *Muon-in-jet* and *PtReco*, common methods for small-R jet energy correction

Summary

- **New transformer-based** model for calibrating *b*-jets
 - Yields more precise b-jet kinematics in both resolved & boosted regimes

Next steps:

- **In-situ calibration**
- Adding muon information (Large-R)

