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Infra-red and collinear safe Graph Neural Networks

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Hadronic signals of new-physics origin at the Large Hadron Collider can remain hidden within the copiously produced hadronic jets. Unveiling such signatures require highly performant deep-learning algorithms. We construct a class of Graph Neural Networks (GNN) in the message-passing formalism that makes the network output infra-red and collinear (IRC) safe, an important criterion satisfied within perturbative QCD calculations. Including IRC safety of the network output as a requirement in constructing the GNN improves its explainability and robustness against theoretical uncertainties in the data. We generalise Energy Flow Networks (EFN), an IRC-safe deep-learning algorithm on a point cloud, defining energy-weighted local and global readouts on GNNs. Applying the simplest of such networks to identify top quarks, W bosons and quark/gluon jets, we find that it outperforms state-of-the-art EFNs. Additionally, we obtain a general class of graph construction algorithms that give structurally invariant graphs in the IRC limit, a necessary criterion for the IRC safety of the GNN output.

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