Graph Neural Networks for studying processes involving top quarks at colliders

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In recent years, machine learning techniques have penetrated a variety of research disciplines, including experimental high energy particle physics. Most algorithms encode input variables into some latent feature phase space via Multi-Layered-Perceptrons (MLP), and exploit convolution or pooling kernels between layers to further generalize features and make final predictions. Convolutional Neural Networks (CNNs), for instance, leverage this approach for image classification, where adjacent entries in pixel bins are generally sampled homogenously. In the context of collider experiments such as the ATLAS experiment at CERN's Large Hadron Collider [1], sampled data is inherently inhomogeneous due to, for example, the large ensemble of components involved within the detector and the varying number of particles produced in collisions. Data is noisy, making it difficult to separate rare signals from very large backgrounds when searching for signs of physics beyond the Standard Model of Particle Physics.

A relatively new class of machine learning algorithm, namely Graph Neural Networks (GNNs), abstract concepts from MLPs/CNNs and Graph Theory and are increasingly being deployed in order to address some of the issues presented when analysing collider data and data from other particle physics experiments [2]. In this framework, nodes can represent particle observables (p_T, η, ϕ, energy, etc.) and edges can represent possible relationships, thereby forming a connected graph. Connected nodes with mutual features can also be encoded using MLPs, and broadcasted to adjacent nodes, permitting information to flow to non-connected nodes and for nodes to subsequently grouped into clusters. This clustering is particularly useful in the context of reconstructing higher-level physics objects build from the particles actually identified by the detector, for example top quarks built from particle jets, or high-mass resonances built from top quarks, as favoured by some new physics scenarios [3]. We will present preliminary studies involving the application of GNNs to the problem of identifying processes involving top quarks in a collider environment.

[1] G. Aad et al., *Journal of Instrumentation* **3**:S08003, (2008).

[2] See, for example, J. Shlomi, P. Battaglia and J.-R. Vlimant, *Mach. Learn.: Sci. Technol.* **2** 021001 (2021). arXiV:2007.13681[hep-ex].

[3] An example scenario is J.H. Kim et al., *Phys. Rev. Lett. D* **94** 035023 (2016).