Graph Neural Networks: The Next Tool to Uncover the Top Quark

By Anthony Little
University of Sydney
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What's there to uncover and why?

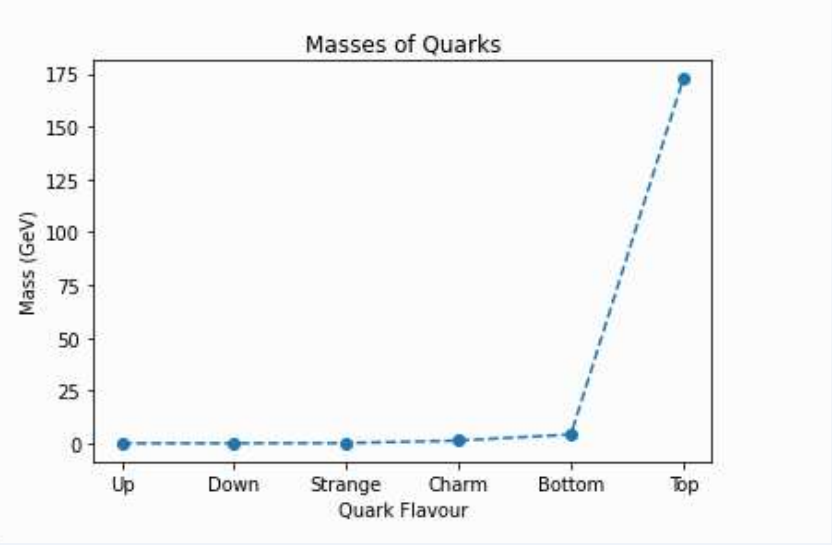

Figure: Masses of all quarks

D. Chakraborty *et al.* Top Quark Physics, Annu. Rev. Nucl. Part. Sci. 2003, **53**:301-51
R.L. Workman *et al.* (Particle Data Group), to be published in Prog. Theor. Exp. Phys. 2022, 083C01.

- The Top quark is the heaviest fundamental particle
- Mass much larger than any other fermion, similar to a gold atom in mass
- Mass result of large Yukawa Coupling with Higgs Field
- Beyond Standard Processes may decay into the Top
- Research into the Top may lead to New Physics in these areas

Why are Graphical Neural Networks an answer?

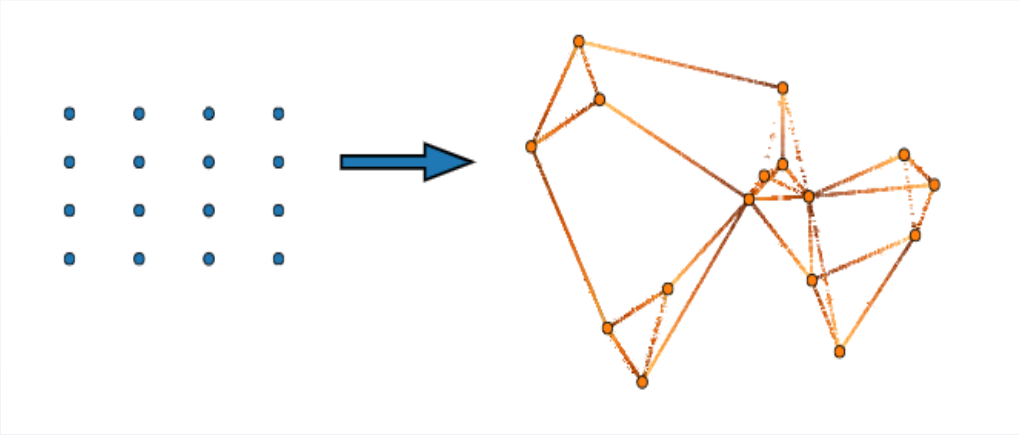

Figure: GNN connecting neighbouring nodes through shared quantities

Jonathan Shlomi *et al.* Mach. Learn.: Sci. Technol. 2021, **2** 021001

- Graphs are flexible for particle detection data which is naturally unordered and heterogenous
  - Used for other processes beyond my own
- Outputs can be made on node, edge and graph-level data
- Through message passing nodes can update their properties to be better identified
  - Identify decay products to reconstruct Top quark
- Attention mechanisms help determine strengthen of connections
  - Which nodes are important and can be grouped to create subgraph

How do we know they will work?

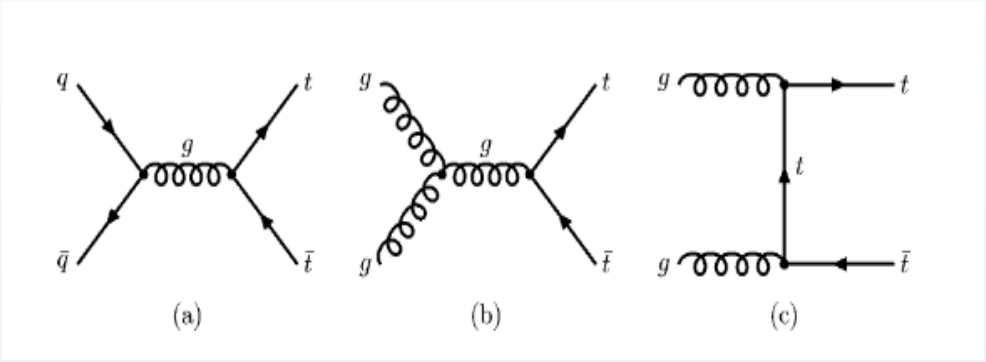

Figure: Leading Order processes of Top pair production

D. Chakraborty *et al.* Top Quark Physics, Annu. Rev. Nucl. Part. Sci. 2003, **53**:301-51

- Graph Neural Networks within Particles physics is fast growing field
- Have only been tested on simulated data, but have shown much promise
- My work will test GNN's on a very common process: Top pair production
- This process is very common background for many unknown and BSM processes

My Work and the Future

- I will be using fast, simple and generic (not detector specific) Monte Carlo simulation
  - MadGraph/Pythia (Particle Generation)
  - Delphes (Detector Simulation)

- This Monte Carlo simulation paired with the Top pair process is overall not breaking into New Physics

- It is testing the efficiency and ability of GNN's prediction of the data
  - How well can it predict the amount of Top quarks and their properties?
  - How well can it distinguish different events?

- Produces evidence of a basic level of GNN's capabilities and adaptability