Machine Learning in High Energy Physics: the Search for Vector-Like Quarks

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Terminology

**Vector-Like Quarks (VLQ)**
- Predicted particle in many new physics theories

**Machine Learning**
- Algorithmic “learning” from patterns and structures within datasets

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**Fig 1: Feynman diagram of VLQ pair production**

**Fig 2: Neural Network learning model**
Background:
Searching for Particles
The ATLAS Detector at the Large Hadron Collider

1 billion collisions(events)/sec $\rightarrow$ 200 interesting events/sec

Source: ATLAS Outreach
Research Question

How much can generalized **machine learning algorithms** improve **sensitivity** in VLQ detection?

How can we separate VLQ (**signal**) from all other physics events (**background**)?
Methodology

Data Acquisition
(or Monte Carlo modeling)

Data Storage + analysis

Data Cleaning

Model development+ testing
Feature Selection

Past experiments and current theories inform specific independent variables (features) to use (“feed”) in our models to best predict VLQ events.
Evaluating ML Performance
Next Steps and Future Efforts

• Apply model to data to either find evidence for VLQ or put better limits on masses

• Continue to tune algorithms to improve ML performance (precision!)

**Fig 12: Current limits on VLQ mass (ATLAS Experiment)**

- **ATLAS Internal**
  - $\sqrt{s} = 13$ TeV, $36.1$ fb$^{-1}$
  - SS dilepton / trilepton + b-jets

- Observed limit
- Expected limit
  - ± 1 $\sigma$
  - ± 2 $\sigma$
- Theory (NNLO)
Thank you