Hadronic Event Generators

- PYTHIA
- HERWIG
- ISAJET
- Sherpa

Inputs:
- PDFs (QCD)
- FFs (QCD)
- Factorization
- QED
- Tune to match experiment...
ETHER: An Agnostic Event Generator

- No theory input on vertex interactions
- Generative Adversarial Networks (GANs)
- Inputs: electron and proton
- Outputs: long-lived (detectable) particles
- Train generator against existing data
- Leverage recent major advances in Generative Machine Learning

Diagram:

- Electron (e-) to Generative Neural Network
- Proton (p) to Generative Neural Network
- Outputs: leptons, nucleons, pions, kaons, photons

Training Data:

- Leptons
- Nucleons
- Pions
- Kaons
- Photons
ETHER Flowchart

Nature

Events: vertex level

Experimental detector

Events: detector level

ETHER

Events: vertex level

neural net detector

Events: detector level

distortion

distortion
Nature

Events: vertex level

Experimental detector

distortion

Detector simulator

Events: detector level

ETHER

Events: vertex level

neural net detector

distortion

Events: detector level
ETHER Flowchart

Nature

Events: vertex level

Experimental detector

Detector simulator

Likelihood analysis

Ether

Events: vertex level

Events: detector level

neural net

detector

Distortion

Distortion
ETHER Flowchart

Nature

Events: vertex level

Experimental detector

Events: detector level

Detector simulator

Events: detector level

Likelihood analysis

ETHER

data compression

distortion

distortion

Likelihood analysis
ETHER Collaboration

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Dual GAN

![Graph showing the normalized yield comparison between Pythia and GAN. The x-axis represents the energy (E') and the y-axis represents the normalized yield. The graph compares the probabilities of various particles such as $\gamma$, $e^-$, $e^+$, $\mu^-$, $\mu^+$, $\nu_e$, $\bar{\nu}_e$, $\nu_\mu$, $\bar{\nu}_\mu$, $\nu_\tau$, $\bar{\nu}_\tau$, $p$, $\bar{p}$, $n$, $\bar{n}$, $\pi^+$, $\pi^-$, $K^+$, $K^-$, $K^0$, $L$, $\bar{K}^0_L$. The data points are shown for both Pythia and GAN, with Pythia represented by black squares and GAN by red triangles. The graph includes a legend indicating the different particles and their probabilities.]

McClellan
Empirically Trained Hadronic Event Regenerator
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Outlook

**Full Exclusive Event**
- R&D on data representation and GAN architecture for full exclusive events
- R&D: make generators *conditional* on $\sqrt{s}$
- **Challenges:**
  - Variable number of particles
  - Discrete (PID) and continuous (4-vector) variables

**Simpler, Inclusive Final States**
- Develop inclusive GANs for specific reactions
- One GAN per final state:
  - $p(e, e')X$
  - $p(e, e'\pi^+)X$
  - $p(e, e'\pi^+\pi^-)X$
  - ...
- R&D: make generators *conditional* on $\sqrt{s}$