Deep Learning at Colliders
Hands-on session

IN2P3 School Of Statistics 2021
18-29 Jan, 2021

Jean-Roch Vlimant (California Institute of Technology)
jvlimant@caltech.edu @vlimant

Overview

I. Model Quantization

II. Likelihood Free Inference

III. Anomaly Detection

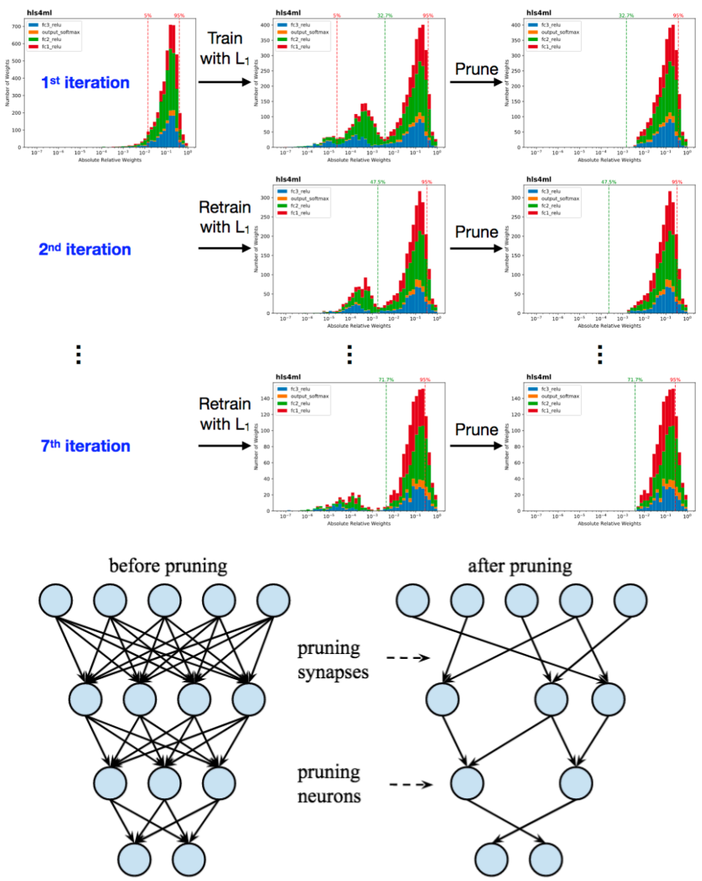
IV. Tracking with GNN

All hands-on are majorly inspired from already existing material, and reproduced with the authors agreement.

Successes are theirs, failures are mines…

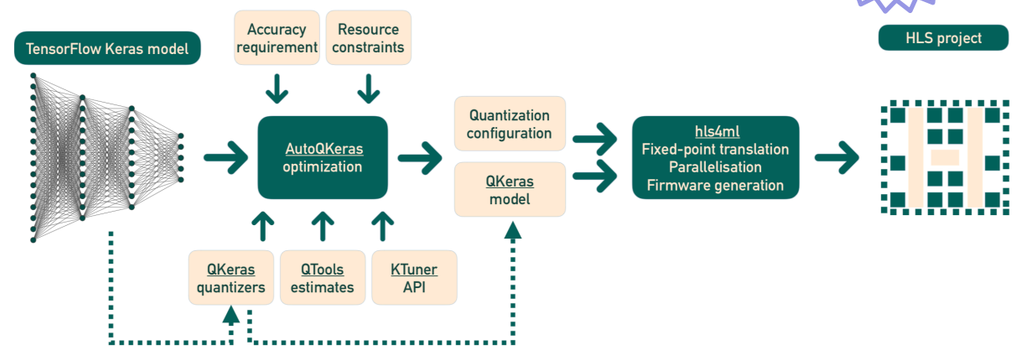
Model Compression

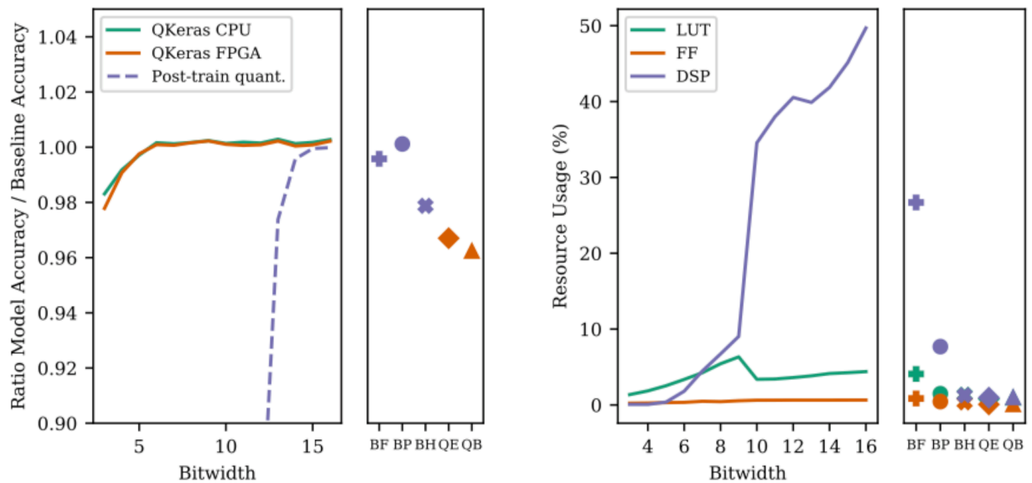
Pruning weights [1804.06913]



Quantization [2006.10159]

Hands-on





Model inference can be accelerated by reducing the number and size of operations.

Mondel Quantization

Original Material:

- https://arxiv.org/abs/2006.10159
- https://github.com/google/qkeras
- https://indico.cern.ch/event/924283/sessions/353274/#20201203
- http://cern.ch/ssummers/hls4ml-tutorial

Hands-on Material:

➡https://github.com/vlimant/AIColliderSOS2021/tree/master/qKeras

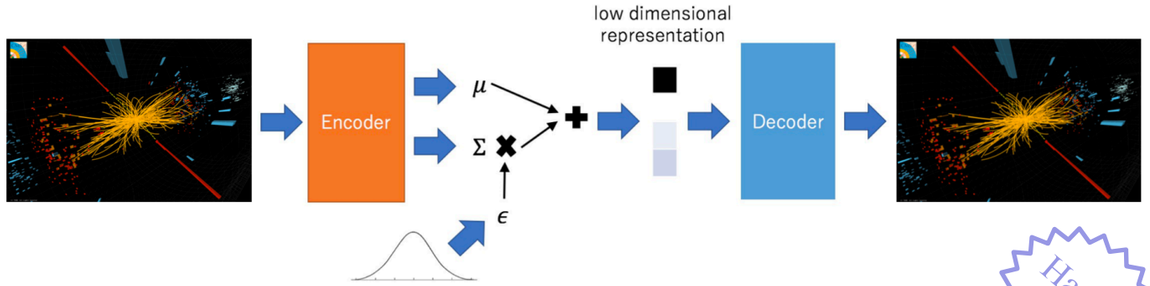
Instructions:

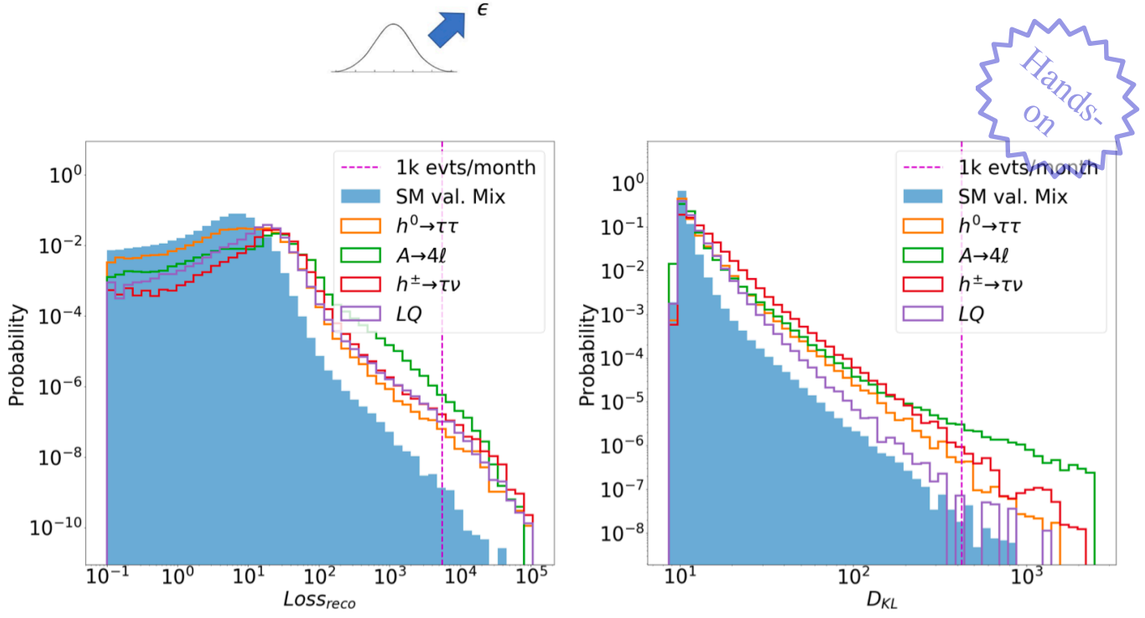
✓Start the notebook in colab from the github notebook.

✓The advantage of quantization comes through an FPGA firmware (the hls4ml tutorial should be available)

Thanks to Sioni Summers et al. for the help putting this together

Acquiring Data





Use of variational auto-encoders directly on data to marginalize outlier events, for anomalous event hotline operation.
[doi:0.1007/JHEP05(2019)036]

- Machine learning since long deployed in the trigger for selected signatures.
- Further potential for background trigger rate reduction.
- Emerging opportunity for triggering on unknown signatures.
- More promising R&D and experiment adoption.

Anomaly Detection

Original Material:

- https://www.ggi.infn.it/ggilectures/ggilectures2021/
- https://github.com/pierinim/tutorials/tree/master/GGI_Jan2021/Lecture5

Hands-on Material:

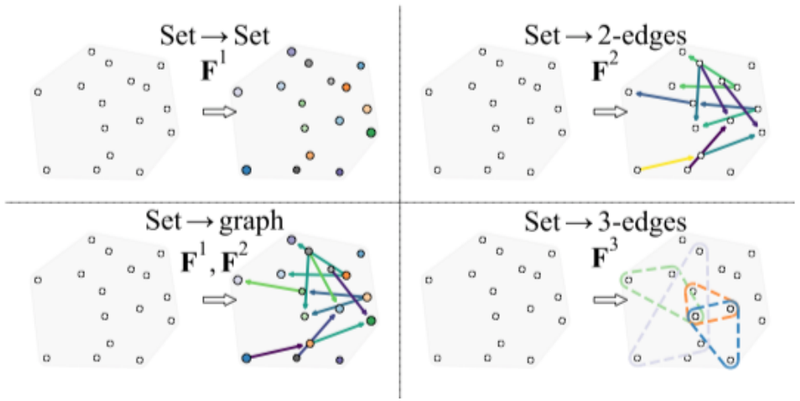
➡https://github.com/vlimant/AIColliderSOS2021/tree/master/lhcAnomaly

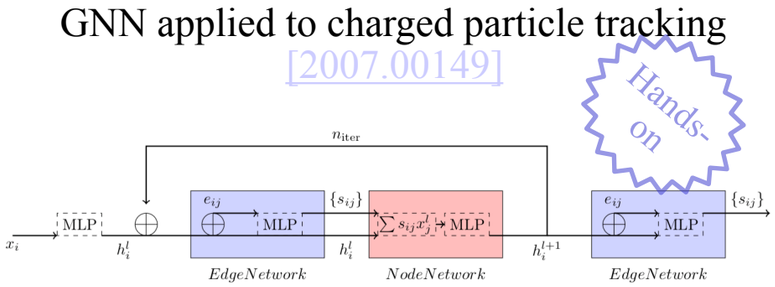
Instructions:

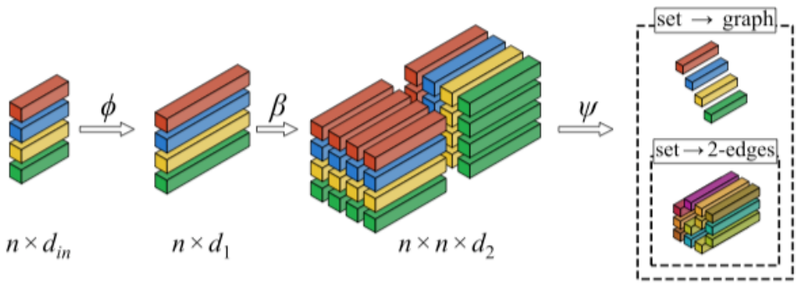
✓Start the notebook (AE or VAE) in colab from the notebook in github
✓Explore changes in anomaly ROC when varying “beta”
✓Quantize the model

Thanks to Maurizio Pierini et al. for the help putting this together

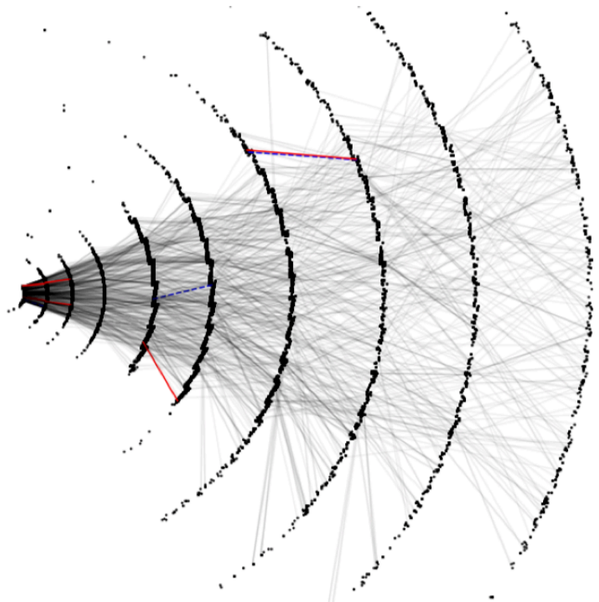
Reconstructing Data







Learning graphs from sets, applied to vertexing
[2002.08772]



Much more relevant work going on.
https://iml-wg.github.io/HEPML-LivingReview/

- Event reconstruction is pattern recognition to a large extend. Advanced machine learning techniques can help.
- Learn from the simulation, and/or data.
- Learn from existing "slow reconstruction" or simulation ground truth.
- Automatically adapt algorithm to new detector design.
- Image base methods evolving towards graph-based methods.
- Accelerating R&D to exploit full potential.

Tracking with GNN

Original Material:

- https://indico.cern.ch/event/852553/contributions/4062229/

Hands-on Material:

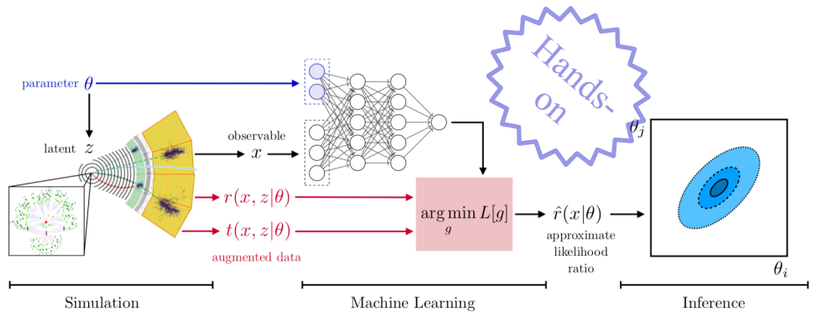
➡https://github.com/vlimant/AIColliderSOS2021/tree/master/gnnTracking

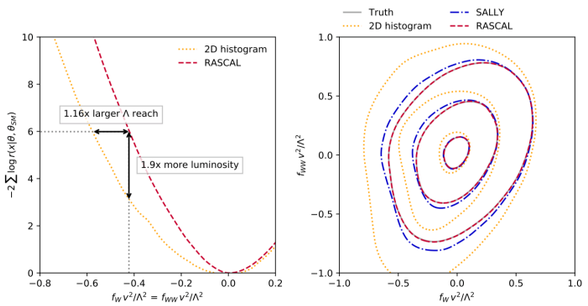
Instructions:

✓Start the notebook in colab from the notebook in github (with GPU)
✓First part of software installation is a little painful
✓Get a feel for the complexity of GNN

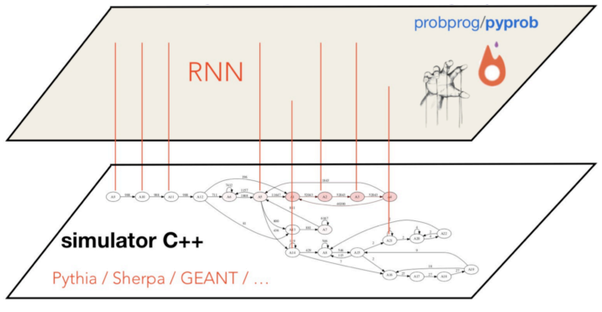
Thanks to Xiangyang Ju et al. for the help putting this together

Theory Behind the Data

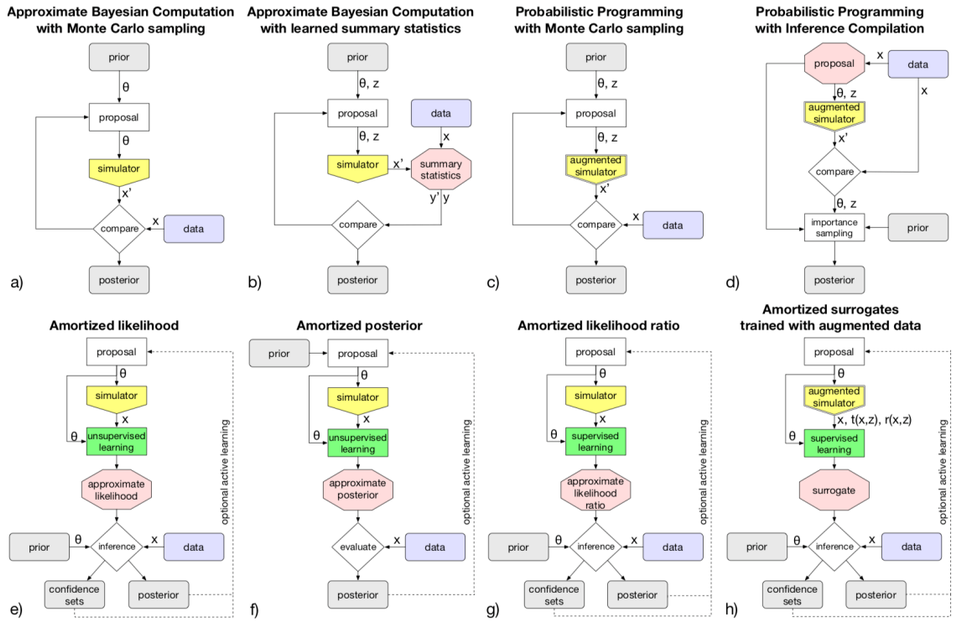




Constraining EFT with ML
[1805.00013]



https://github.com/probprog/pyprob



The frontiers of simulation-based inference
[1911.01429]

- Hypothesis testing is the core of HEP analysis.
- Intractable likelihood hinders solving the inverse problem.
- Going beyond the standard approach using machine learning and additional information from the simulator.
- More precise evaluation of the priors on theory's parameters.
- May involve probabilistic programming instrumentation of HEP simulator.
- R&D to bring this in the experiment.

Likelihood Free Inference

Original Material:

- http://theoryandpractice.org/madminer-tutorial/intro
- https://github.com/diana-hep/madminer

Hands-on Material:

➡Some GitHub url here

Instructions:

✓Start the notebook in colab from the notebook in GitHub
✓Get MG5_aMC_v2.8.3.tar at https://launchpad.net/mg5amcnlo
✓Upload and install mg5 to run the tutorial

Thanks to Gilles Louppe et al. for the help putting this together