Quantum Generative Adversarial Networks on $t\bar{t}H(b\bar{b})$ Process Data Generation

CERN Summer Student Session 2021

CERN openlab

QUANTUM TECHNOLOGY INITIATIVE

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github.com/eraraya-ricardo/CERN-QGAN

***Presenter**

Introduction

Dataset

Current Progress

Next Work Plans

Outline

Introduction:

- Background
- Goal & Related Works

Dataset:

- Dataset Introduction
- A Closer Look Into the Dataset

Current Progress:

- Classical Benchmark

Next Work Plans:

- The Quantum Models

Introduction: Background

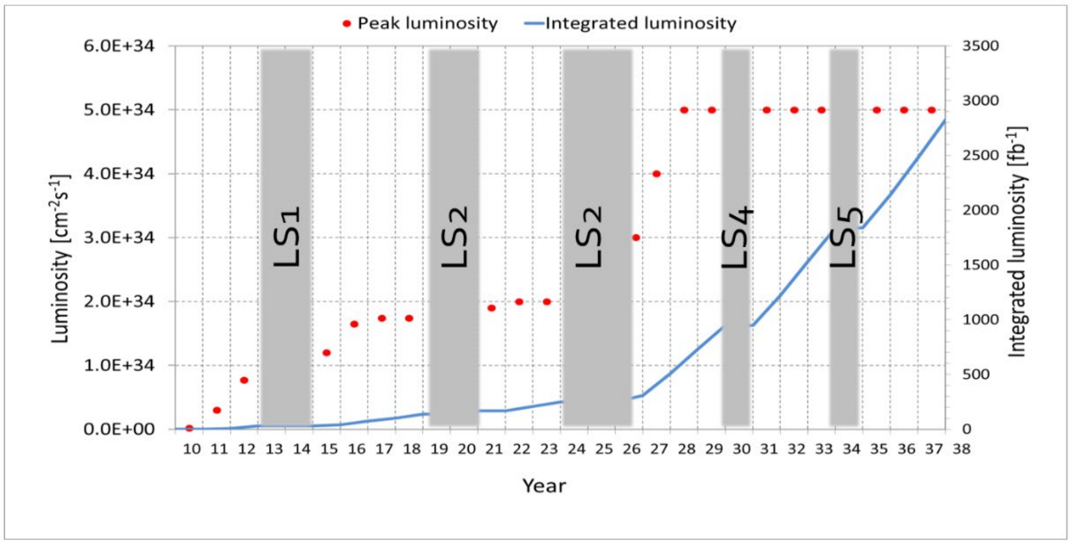
01

HL-LHC upgrades at CERN will **require enormous computing resources**[1]

02

Quantum computing has potential in improving performance of data processing and ML[2]

Can it improves HEP simulation and data analysis?



Projected LHC performance through 2038
the amount of data will increase at least 10x
more luminosity = produce more data[1]

[1] Burkhard Schmidt 2016 *J. Phys.: Conf. Ser.* 706 022002.
[2] Biamonte J, et al. *Nature* 2017;549.

Introduction

Project's Goal

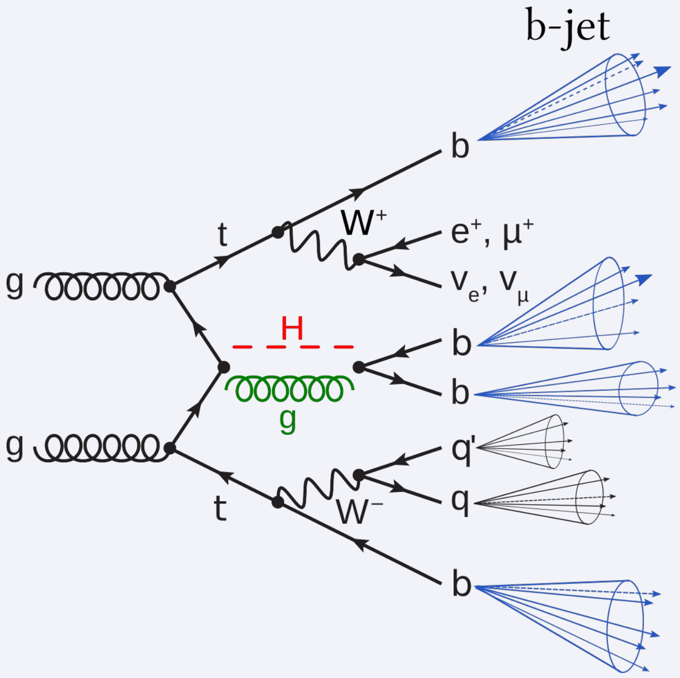
Explore Quantum Generative Adversarial Networks (QGAN) performance on high-energy physics data simulation, compared to the classical GAN.

Related Works

- Classical GAN to simulate LHC QCD dijet events has been explored[3]
- Quantum Classifiers had been explored to classify the $t\bar{t}H(b\bar{b})$ dataset, with performance comparable to the classical counterparts (SVM, Random Forest, AdaBoost)[4]

[3] Di Sipio, R., et al. *J. High Energ. Phys.* 2019.
[4] Belis, V., et al. arXiv:2104.07692

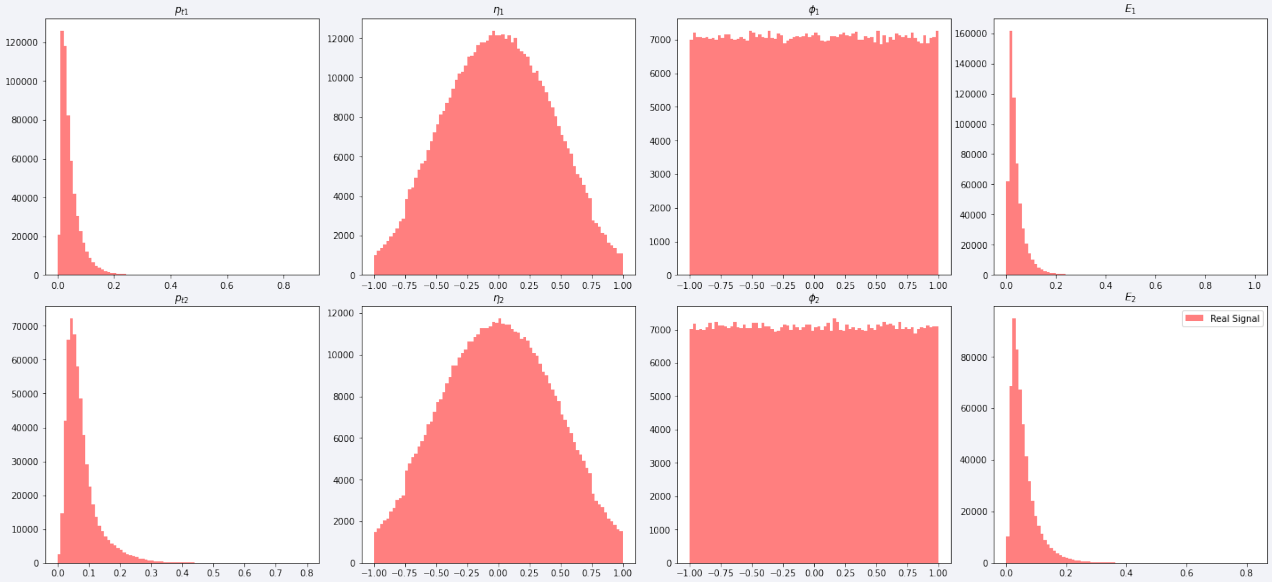
Dataset: Introduction



Feynman diagram of the signal process in red and the dominant background process in green

- Higgs Boson is produced in association with $t\bar{t}$ via gluon fusion and it decays to $b\bar{b}$
- We focused only on the simulation of two b-jets from the Higgs
- We also focused only to simulate the positive event (not the background)

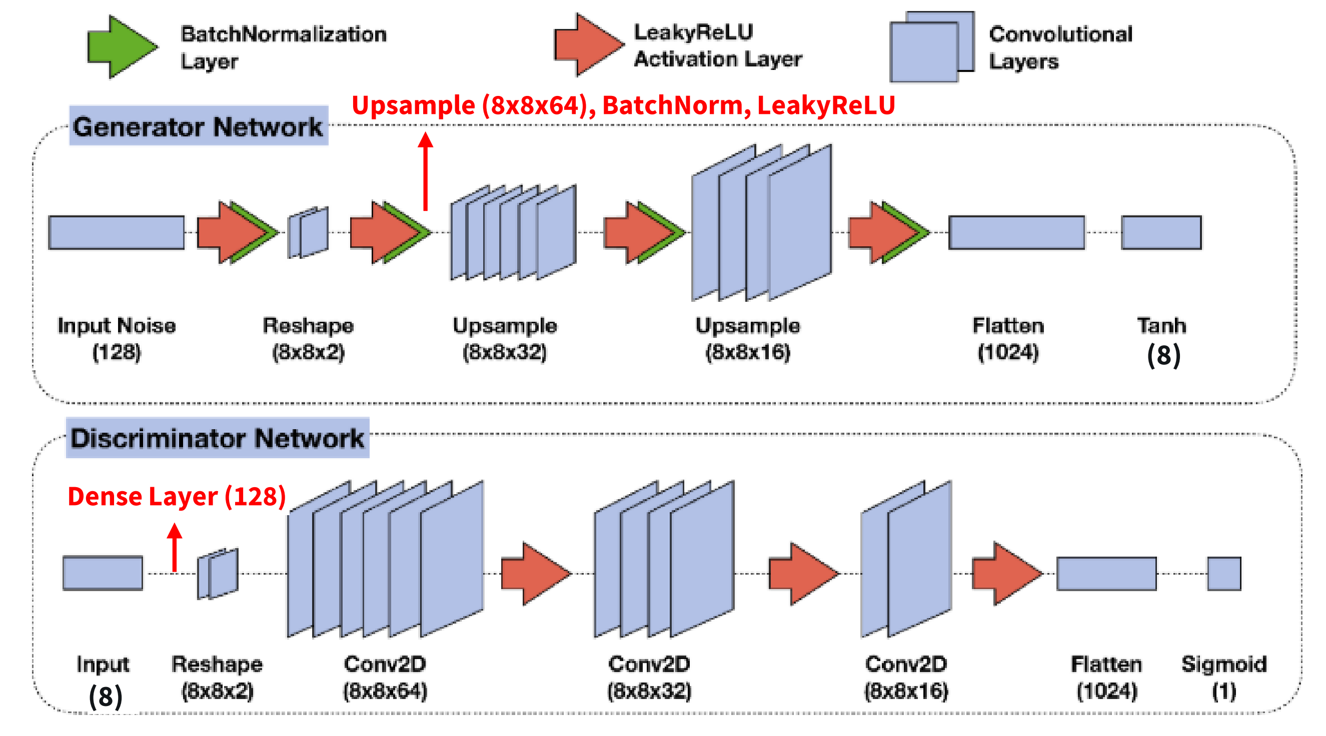
Dataset: A closer look



- The dataset is from numerical Monte Carlo simulations
- We limit the problem to just 4 features for each b-jet (from 8)
- Normalized into either [-1, 1] or [0, 1] range
- The features that we select are:
  - transverse momentum Pt
  - *pseudo-rapidity* η
  - azimuthal angle ϕ
  - energy E

Classical Benchmark

(Modified) DijetGAN[5]

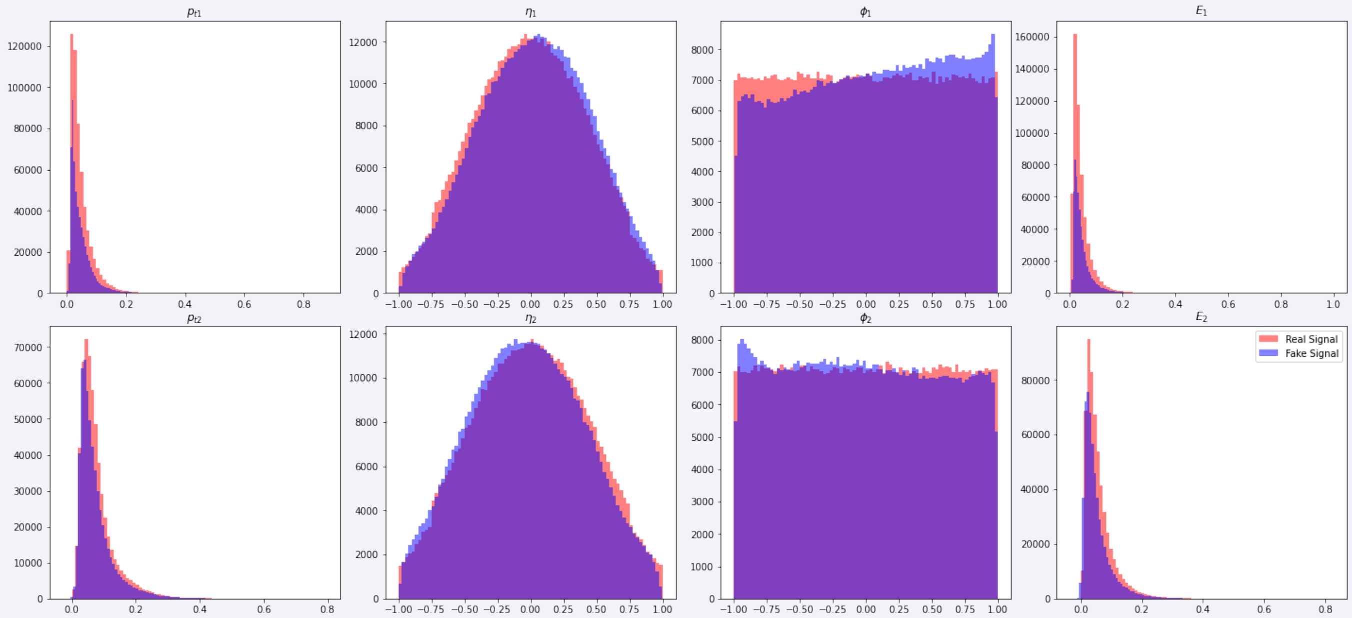


[5] Di Sipio, R., et al. *J. High Energ. Phys.* 2019.

Classical Benchmark

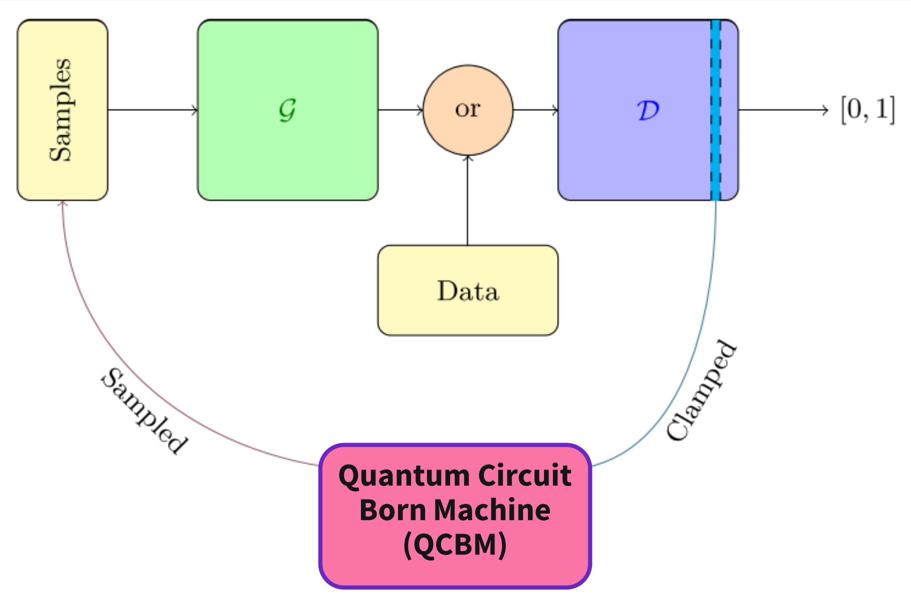
Best Result (so far)

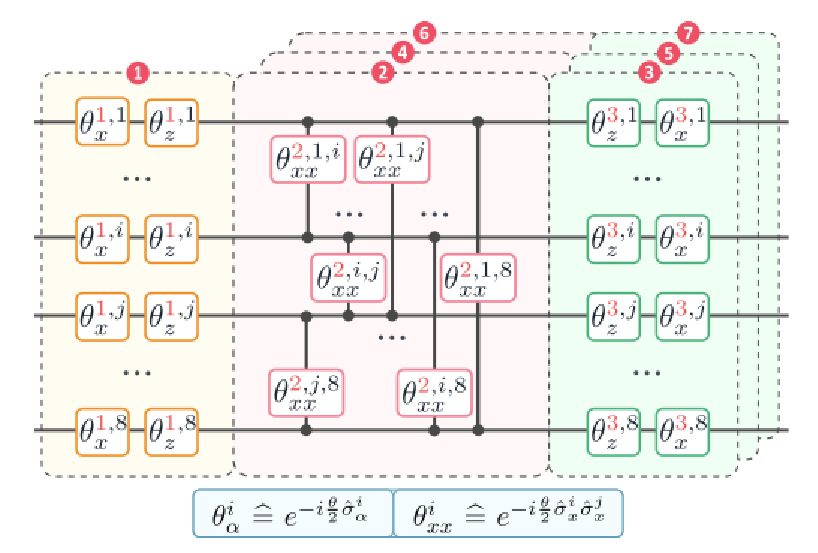
- Filter size for Conv2D and Upsample: 3x3, with stride 1x1
- Cross-entropy loss
- Adam with $lr = 10^{-5}$, $\beta_1 = 0.5, \beta_2 = 0.9$
- Wasserstein distance: 0.040866



Next Work Plans, The Quantum (fun) Part

Near-term Quantum-Classical Associative Adversarial Networks (QAAN)[6]



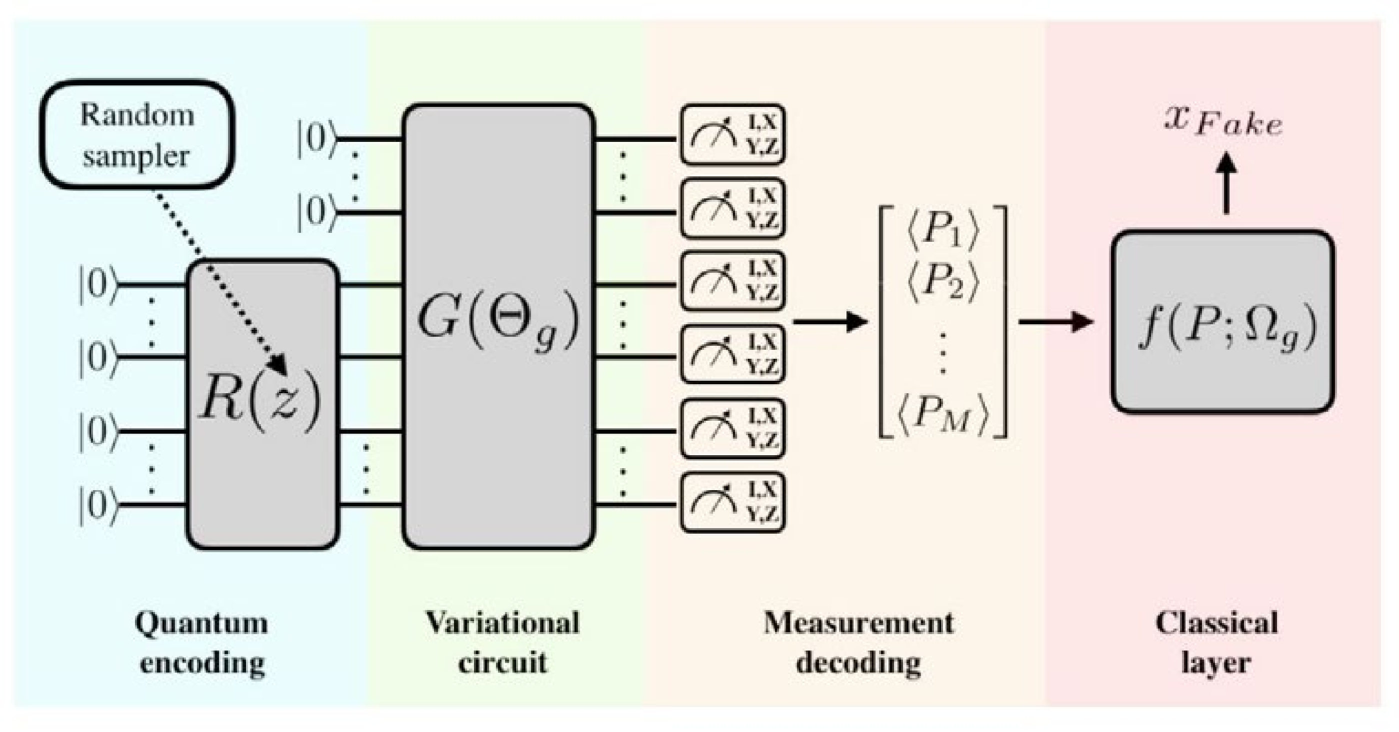


Variational Quantum Circuit for the QCBM[7]

[6] Eric R. Anschuetz and Cristian Zanoci. Phys. Rev. A 100, 052327.
[7] Rudolph, M. S., et al. arXiv:2012.03924v2

Next Work Plans, The Quantum (fun) Part

Variational Quantum Generators[8]



[8] Romero, J. and Aspuru-Guzik, A. (2021), Adv. Quantum Technol., 4: 2000003.

Thank You!
Any Questions?