Highlight of 2nd Workshop of Quantum Computing and High Energy Physics

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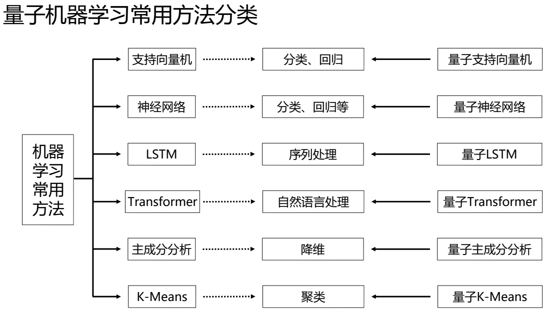
Link :https://indico.ihep.ac.cn/event/19239/

Outline

- Platform
  - Origin Quantum Company
  - Quafu by BAQIS
  - Simulator platform from IHEP
- High Energy Physics
  - Experiment QSVM QCNN QGAN QGNN, QTransformer
  - Theory : Lattice QCD, Simulation of gauge theory
- Other
  - Nuclear Physics, Condensed Matter Physics

Platform —OriginQ

- The company has already developed a Quantum Machine Learning framework — VQNet. It supports quantum simulator and quantum hardware.
- The framework already includes many machine learning methods.
- Usefull links : cloud of OriginQ



Platform — Quafu

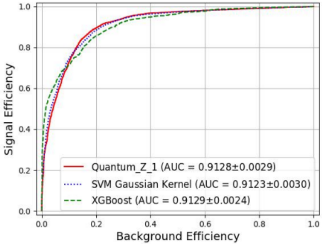
- Link : quafu cloud
- The new 136 qubit machine is already online!
- User can submit task asynchronously.

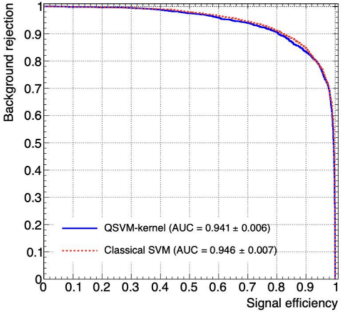
Platform — IHEP Simulator

- IHEP simulator is based on the existing GPU and AFS system. It can support the simulator with 38 qubits.
- The platform supports online composer, jupyter and batch system.
- Document : https://qc.ihep.ac.cn/docs/zh/
- Website : https://quantum.ihep.ac.cn

QSVM

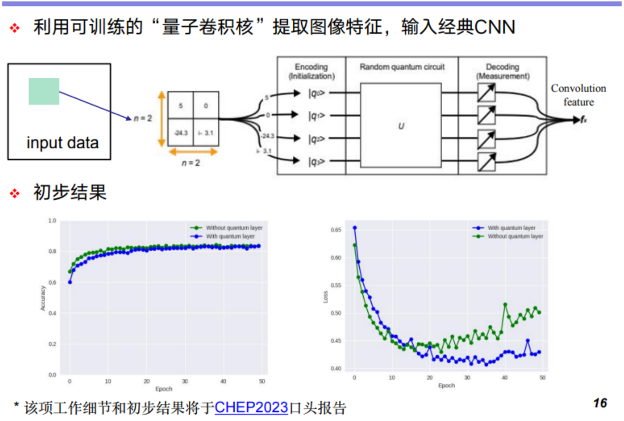
- Employ quantum kernel to classify signal and background events.
- Currently the performance of QSVM is similar to the classical machine learning algorithm
- Left is BES PID, right is CEPC $ZH \to qq\gamma\gamma$





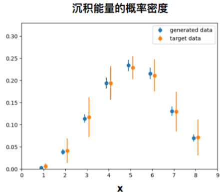
QCNN

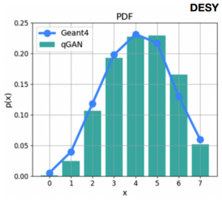
- Utilize the trainable quantum convolution kernel to extract the feature in an image.
- It is used in object identification in STCF DTOF.



QGAN

- Calorimeter simulation is the most time consuming part of HEP computing especially in future high granularity calorimeter.
- GAN(Generative Advaversarial Network) is already used for fast simulation in ATLAS Collaboration.
- QGAN may further improve the accuracy and speed.
- Compared with DESY group, IHEP group already reduces the training time.





- ~30 epoch左右，损失函数趋于稳定 (DESY: ~100 epoch)
- 因为体元的划分不一致，训练数据的分布和DESY有差别
- 量子对抗生成网络可以生成平均的能量分布（3个量子比特 -> 8个体元）

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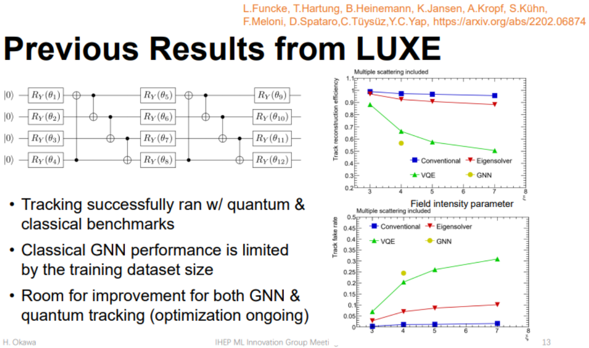
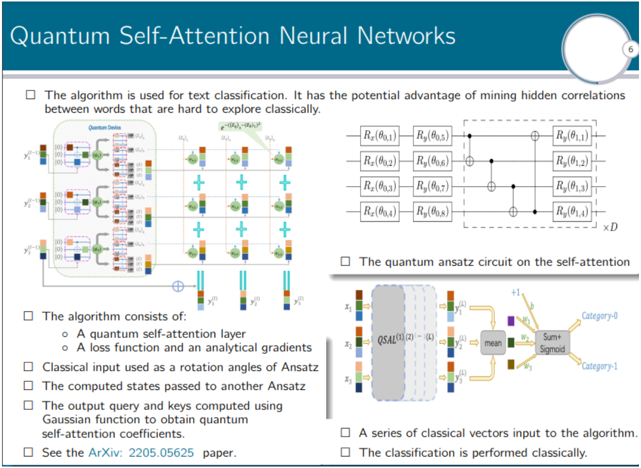
QGNN

- QGNN is already applied for track reconstruction.
- This project is in collaboration with DESY.
- Quantum annealing machine is interesting.
- Some results are already available.



- Particle transformer is demonstrated to be poweroful in jet tagging in CMS Collaboration.
- It is possible to build a quantum version



QEM 算法

已知:

- 2 比特门的错误率比 1 比特门大很多
- 量子计算机的底层实现，一般只需要一种 2 比特门，其他都可以用它构造出来
- 连着放 2 个 CX 门，理论上会互相抵消

模型假设:

- 所有噪声都来自于 CX 门
- 多个 CX 门叠加，信号以指数形式衰减
- 衰减到完全没有信号的时候，每个状态是均等的

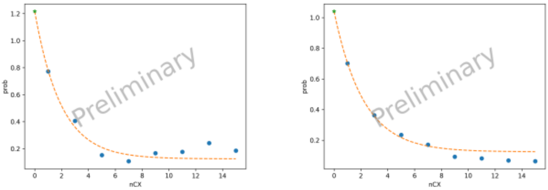
算法:

- 把电路中的每个 CX 门分别换成 1 个、3 个、5 个、……个 CX 门，分别运行
- 把结果对 CX 门的个数进行拟合:

$$(A - 1/2^{n_{bit}})e^{-BN_{CX}} + 1/2^{n_{bit}}$$

- 将拟合结果外推到 CX 门个数为 0 的地方，得到最终结果

QEM 实机测试结果：求逆



Other

- Shijie Wei, quantum computing package of nuclei shell model
- Zhenghang Sun, Analog Quantum Simulation Based on Superconducting Quantum Processo
- Yanwu Gu, Noise-resilient phase estimation with randomized compiling

Summary

- The workshop is full of fresh results and active discussions between quantum hardware experts, HEP experimentalist and theorist
- Many quantum machine learning algorithms have already been used in HEP and the performance is comparable with classical algorithms.
- With more qubits and better fidelity, we expect better performance of quantum algorithms and more area to use quantum algorithms.