Application of the Quantum Machine Learning on Particle IDentification for Collider Experiments

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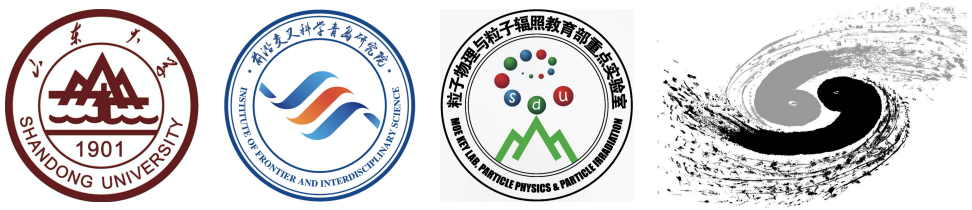
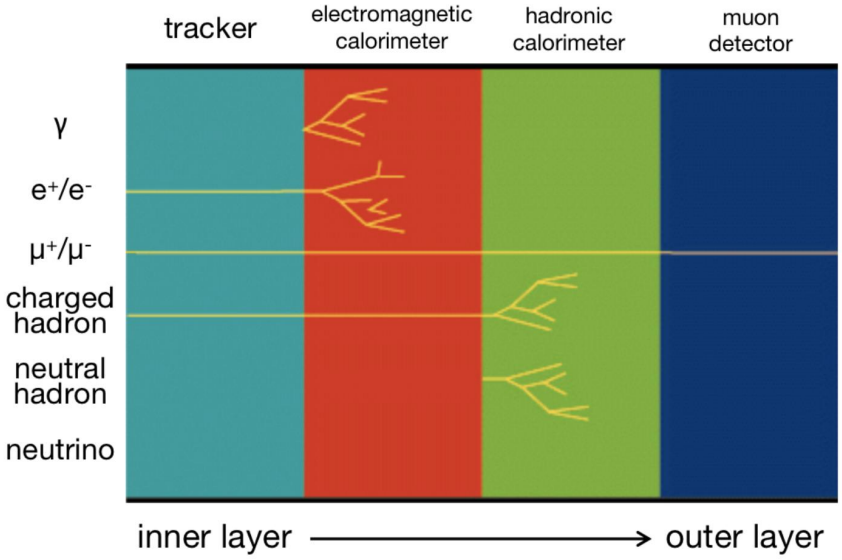


Motivation: Particle Identification

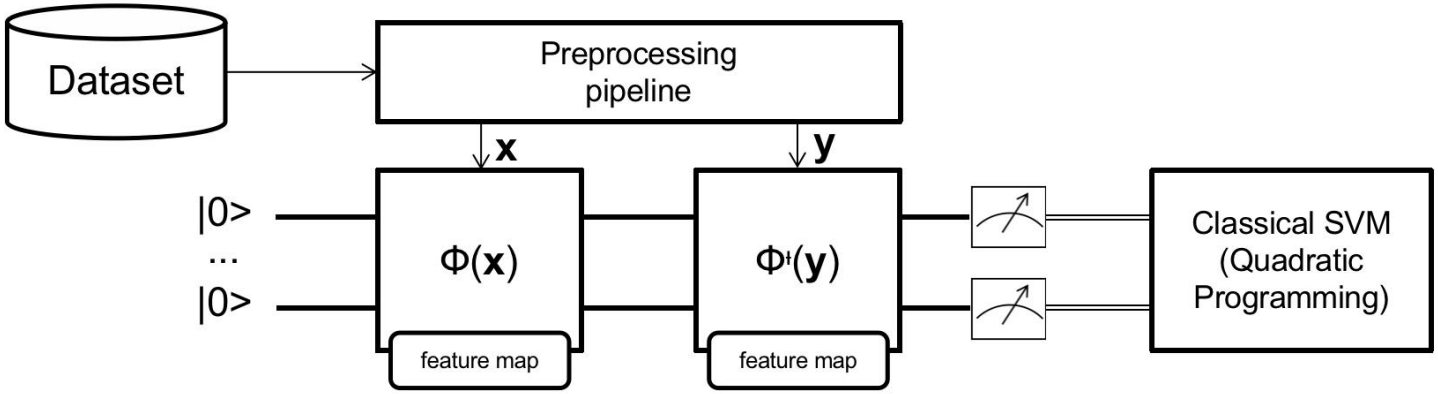
- PID performance is crucial for various collider physics experiments
- Machine learning has armed PID with a powerful toolbox
  - Frequently used models include deep NN and tree based models
  - Good at combining information of multiple sub-detectors, especially for hard PID tasks
- QML techniques provide potential advantages:
  - Potential speed-up for training [1]
  - Data is processed in a high dimensional Hilbert spaces that is intractable on classical computers [2]
- Study QML as a proof of concept
  - Using BESIII μ/π seperation problem as an example
  - Explore and demonstrate of the potential of quantum computer in HEP experiments



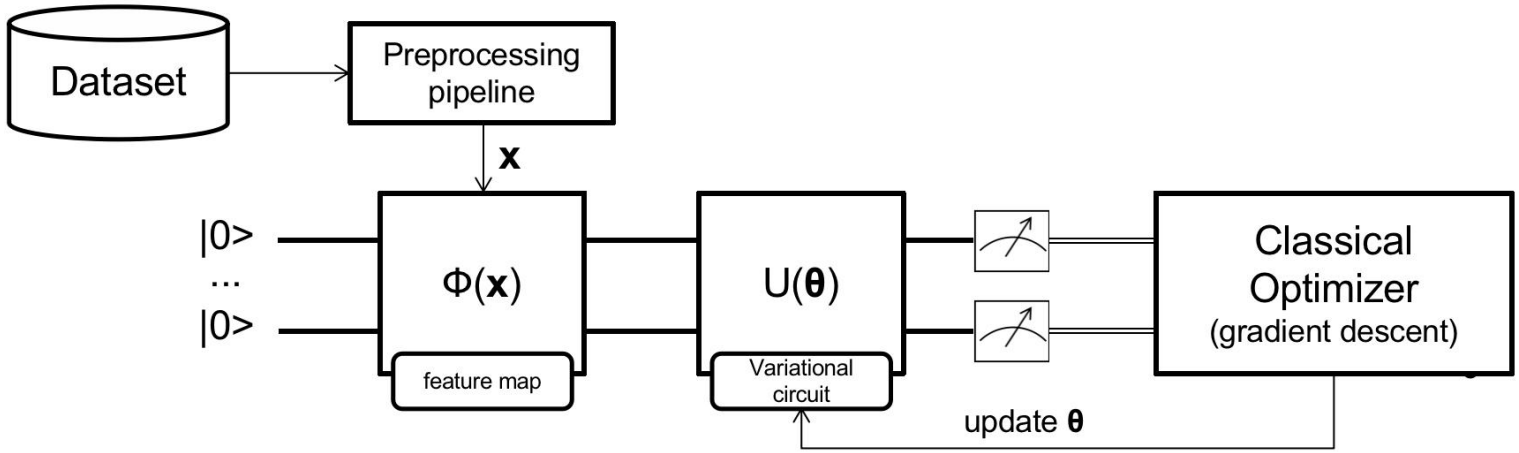
Characters of particles in sub-detectors

Proposed/ On-going Studies

- **Quantum Support Vector Machine** [3]

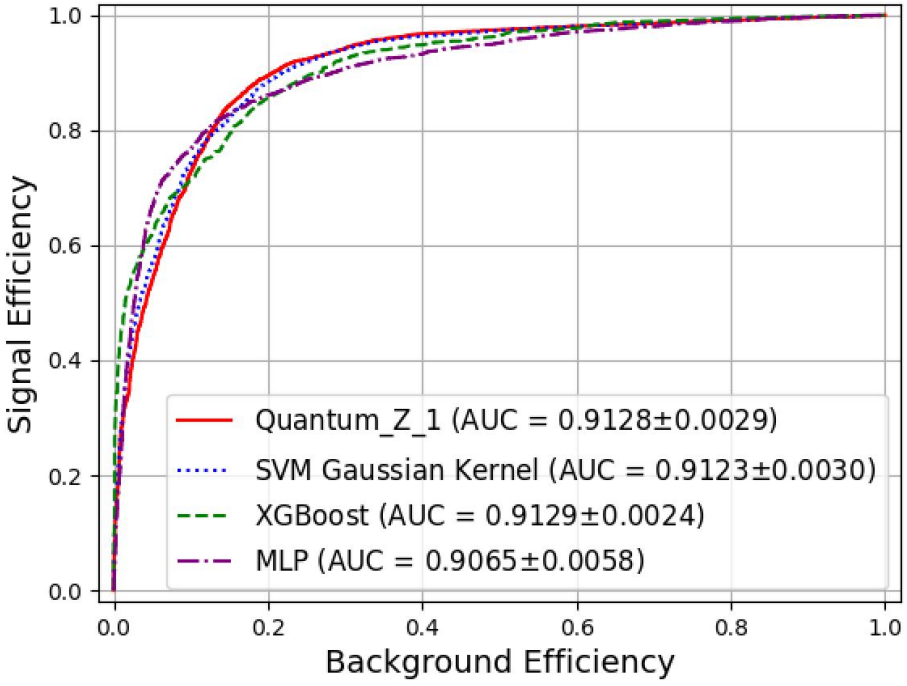


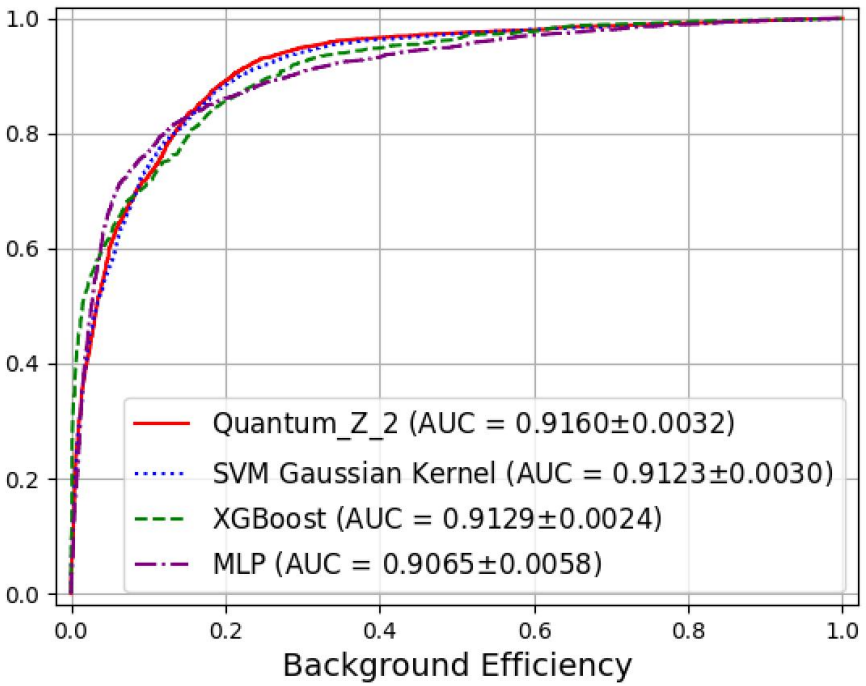
- **Variational Quantum Classifier**



Phased Results: Quantum SVM

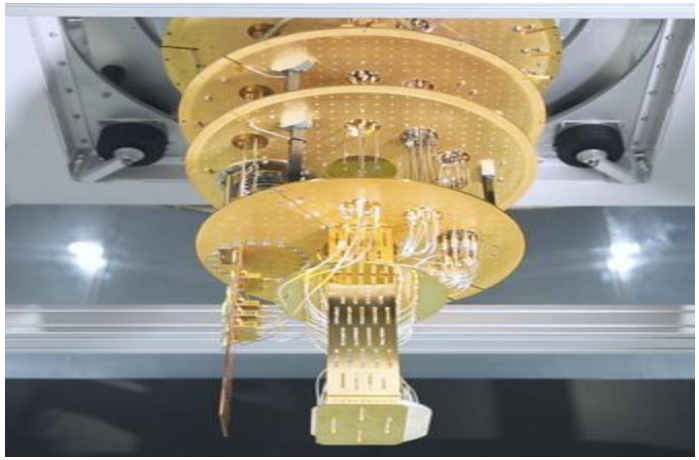
- **The discrimination power of simulated QSM and traditional ML models are compared**
  - After the fine tuning of hyper-parameters
  - Similar discrimination power can be achieved

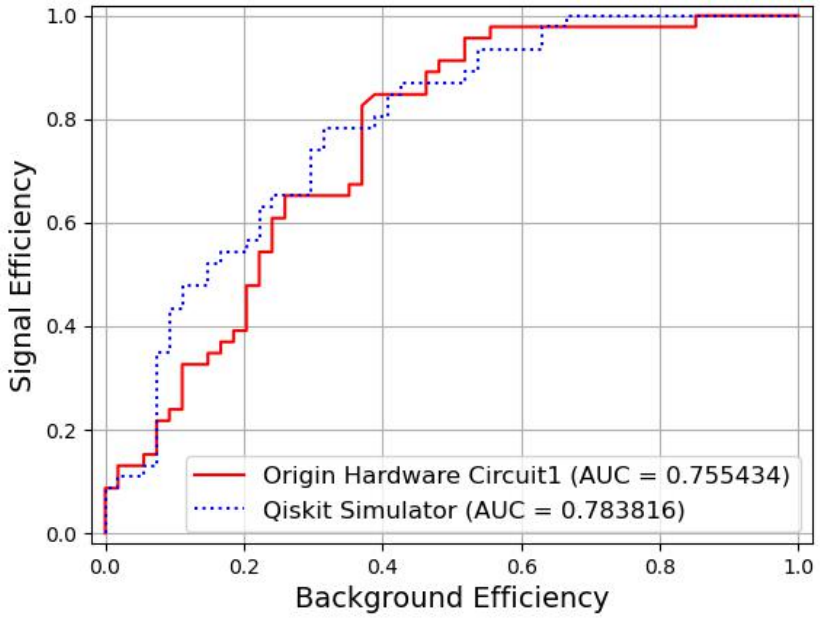


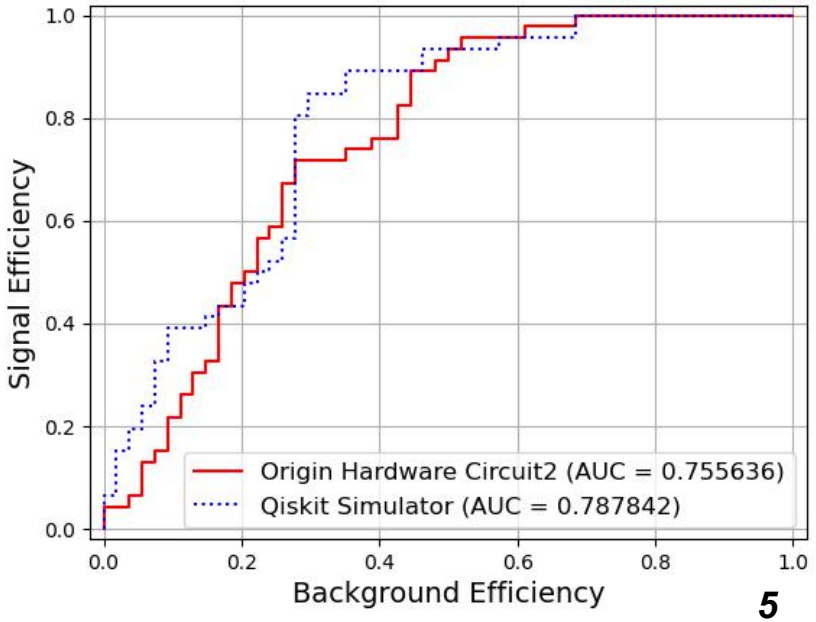


Phased Results: Quantum SVM

- The OriginQ Wuyuan system based at Hefei, China [4]
  - Based on super-conducting technology
  - 6 qubits, controlled by QPanda API
  - Open to public
- Results from Origin Wuyuan







Summary and Work in Progress

- **Summary**
  - Two methods for PID based on QML are proposed
  - A μ/π classifier based on QSVM is developed and studied, under both simulator and real hardware
  - Similar discrimination power could be reached using small datasets
- **Work in progress**
  - A VQC (quantum neural network) model is being studied

Thanks for listening!

References

[1] Quantum support vector machine for big data classification, Phys. Rev. Lett. 113, 130503 (2014)

[2] Effect of data encoding on the expressive power of variational quantum-machine-learning models, Phys. Rev. A 103, 032430 (2021)

[3] ACAT2021, https://indico.cern.ch/event/855454/contributions/4598429/

[4] https://qcloud.originqc.com.cn/computing (2021.11)