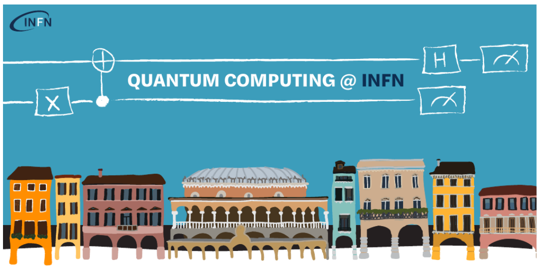

Contribution ID: **6** Type: **not specified**

Backend-tailored quantum feature maps optimization through genetic algorithms in neutrino physics

Tuesday, 29 October 2024 18:20 (20 minutes)

Machine Learning (ML) techniques for background event rejection in Liquid Argon Time Projection Chambers (LArTPCs) have been extensively studied for various physics channels [1,2], yielding promising results. In this contribution, we highlight the performance of Quantum Machine Learning (QML)-based background mitigation strategies to enhance the sensitivity of kton-scale LArTPCs for rare event searches in the few-MeV energy range. We emphasize their potential in the search for neutrinoless double beta decay ($0\nu\beta\beta$) of the 136Xe isotope within the Deep Underground Neutrino Experiment (DUNE) These low-energy events generate very short, undersampled tracks in LArTPCs that are difficult to analyze [3].
We present the application of QML algorithms, particularly Quantum Support Vector Machines (QSVMs) [4]. QSVMs exploit quantum computation to map original features into a higher-dimensional vector space so that the resulting hyperplane would allow better separation within classes. The choice of this transformation called feature map is critical, and results in a positive, semidefinite scalar function called kernel.
QSVMs exhibit competitive performance but require careful design of their kernel functions. Optimizing a quantum kernel for specific classification tasks remains an open challenge in QML. We address this problem by employing powerful meta-heuristic genetic optimization algorithms, which allow for the discovery of quantum kernel functions tailored to both the dataset and the quantum hardware in use. Specifically, we propose mono-objective and multi-objective fitness function optimization strategies that consider the constraints of current Noisy Intermediate-Scale Quantum (NISQ) devices, optimizing feature maps to align with the specific qubit connectivity and available basis gates.
Our study provides deeper insights into the feasibility of performing genetic optimizations directly on quantum hardware. We evaluate the impact of noise through experiments conducted on different IBM quantum backends with over 100 qubits. We further explore the feasibility of partitioning quantum devices to compute multiple independent quantum kernels in parallel, achieving significant acceleration in the genetic optimization process. This approach demonstrates that genetic optimization on modern quantum hardware is feasible under certain conditions, leading to a substantial speed-up and contributing to the pioneering of quantum hardware parallelization.

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References

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Sessione

Quantum Machine Learning

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