# Master Thesis/Internship/Hiwi:

**Hybrid Quantum Anomaly Detection for Scientific Sensor Data using Qiskit and CUDA-Q**

Quantum computing is emerging as a promising paradigm for enhancing machine learning applications, particularly in domains characterized by high-dimensional, noisy, and complex data. Large-scale scientific experiments, such as the KATRIN neutrino mass experiment, continuously generate vast sensor streams that require robust and responsive anomaly detection systems. Traditional classical methods often face limitations in capturing nonlinear dependencies and rare patterns under real-world noise conditions.

This project investigates **hybrid quantum-classical approaches** to anomaly detection by developing **variational quantum circuits (VQCs)** capable of encoding and scoring rare behaviors in time-series sensor data. The models will be implemented in **two leading quantum software frameworks**: **Qiskit** (IBM), which emphasizes accessibility and educational value, and **CUDA-Q** (NVIDIA), designed for high-performance GPU-accelerated quantum simulation.

The objective is to evaluate these hybrid models against established classical baselines (e.g., Isolation Forests, Autoencoders) and analyze their effectiveness, scalability, and interpretability on both simulated and (where available) real sensor data from scientific instrumentation.

Depending on the student's background and interests, the project may focus on one or more of the following aspects:

- **Quantum Circuit Design**: Implement and optimize VQCs tailored to anomaly detection tasks.
- **Hybrid Integration**: Combine quantum subroutines with classical pre/post-processing for effective anomaly scoring.
- **Framework Comparison**: Evaluate Qiskit vs. CUDA-Q in terms of usability, runtime performance, and extensibility.
- **Benchmarking**: Test on synthetic and/or real datasets, comparing against classical ML approaches.
- **(Optional)** Educational Perspective: Develop a reproducible demo or teaching material to highlight hybrid workflows.

## Required Skills

- Proficiency in Python and familiarity with machine learning concepts.
- Basic understanding of quantum computing or willingness to learn (e.g., via Qiskit tutorials).
- Interest in scientific computing, anomaly detection, or hybrid ML systems.

## Duration & Collaboration

The project is expected to last six months and offers opportunities for interdisciplinary collaboration across quantum computing, AI, and scientific instrumentation.

## Contacts

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