

Assignment 2

QCG \times PaAC Open Project, Winter 2025–2026

January 10, 2026

Objective

The primary goal of this assignment is to develop and train a computational model capable of reconstructing a density matrix ρ from measurement data. The model must strictly enforce physical constraints (Hermitian, Positive Semi-Definite, Unit Trace) and be documented for full reproducibility.

1 Part 1: Model Selection & Training

Choose any **one** of the following tracks:

- **Track 1 (Classical Shadows):** Transformer or GNN architecture.
- **Track 2 (Hardware-Centric):** Quantized MLP or CNN (optimized for FPGA).
- **Track 3 (Neuromorphic):** Spiking Neural Network (SNN) using LIF neurons.

2 Part 2: Enforcing Physical Constraints

The model must output a lower triangular matrix L to reconstruct ρ via the Cholesky decomposition:

$$\rho = \frac{LL^\dagger}{\text{Tr}(LL^\dagger)} \quad (1)$$

Performance will be evaluated using **Quantum Fidelity** $F(\rho, \sigma)$ and **Trace Distance**.

3 Part 3: Submission Deliverables

3.1 GitHub Repository Structure

Your repository must be organized as follows:

- **/src:** Core source code for the model, data generation, and training loops.
- **/outputs:** Saved model weights (`.pkl` or `.pt`) and hardware simulation files (`.vcd`).
- **/docs:** Detailed documentation (Markdown or HTML format).

3.2 Documentation Requirements

Your documentation must be split into two distinct parts:

1. **Model Working:** Explain the mathematical and architectural logic of your choice. For Track 3, include the temporal dynamics of the LIF neuron; for Track 2, explain the high-level math to hardware logic transition (e.g., Vitis HLS).
2. **Replication Guide:** A step-by-step technical manual on how to recreate your results. This must include environment setup (dependencies), dataset generation commands, and training execution.

3.3 AI Attribution Policy

Transparency in using AI tools (like ChatGPT, Claude, or GitHub Copilot) is mandatory.

- **Disclosure:** Create an `AI_USAGE.md` file or a section in your README.
- **Prompt Links:** Provide links to chat shared-logs or a list of specific prompts used for code generation, debugging, or documentation.
- **Verification:** Briefly state how you verified the accuracy of the AI-generated components.

4 Part 4: Required Metrics

Report the following in your final report:

1. **Mean Fidelity** and **Trace Distance** across the test set.
2. **Inference Latency** (Time taken per reconstruction).