

# Assignment 2

QCG × 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  $\rho$  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  $\rho$  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).