Quantum-classical models and time series forecasts

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Insurance Data Science Conference

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01

PART ONE

Why Quantum AI

The case for a new kind of compute — and where it earns its place.

Classical ML is hitting structural limits on certain problem shapes. Quantum offers a different representational primitive.

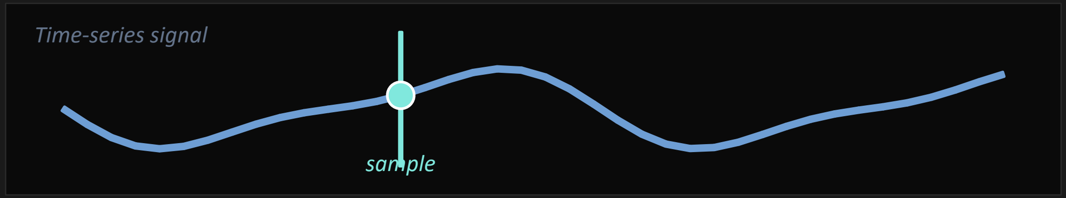
DATA ENCODING

One qubit holds more than one bit

Classical ML keeps every time-series sample encoded in 0s and 1s. Quantum encoding maps each sample into a continuous state — thereby using phase, amplitude, and feature interactions in the data representation itself. This allows for **different forms of computation and pattern recognition**.

CLASSICAL ENCODING

Each value → string of bits



↓

0	1	1	0	1	0	0	1

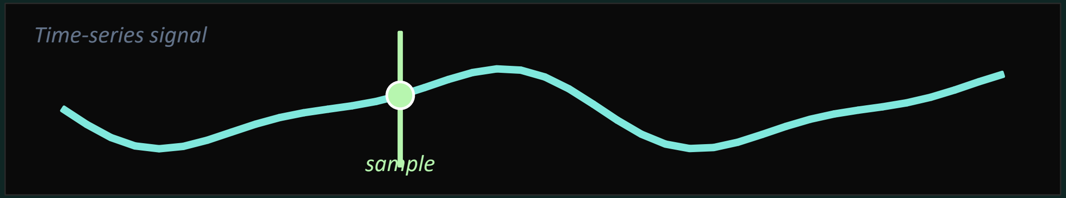
Discrete bit encoding

INFORMATION PER UNIT

`1 bit = one of {0, 1}`

QUANTUM ENCODING

Each value → continuous quantum state



$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$

$\alpha, \beta \in \mathbb{C}$

$|\alpha|^2 + |\beta|^2 = 1$

CONTINUOUS PARAMETERS

- Amplitude
- Phase
- Entanglement

INFORMATION PER UNIT

1 qubit = state on the Bloch sphere

Richer encoding means the AI model sees a different signal — n qubits represent 2^n states simultaneously, vs n bits for one classical value.

WHY QUANTUM AI

Quantum sees patterns classical models miss

Each dot is a card transaction. When points fall *off the diagonal*, the two models disagree — and combining them outperforms either alone.

DISAGREEMENT

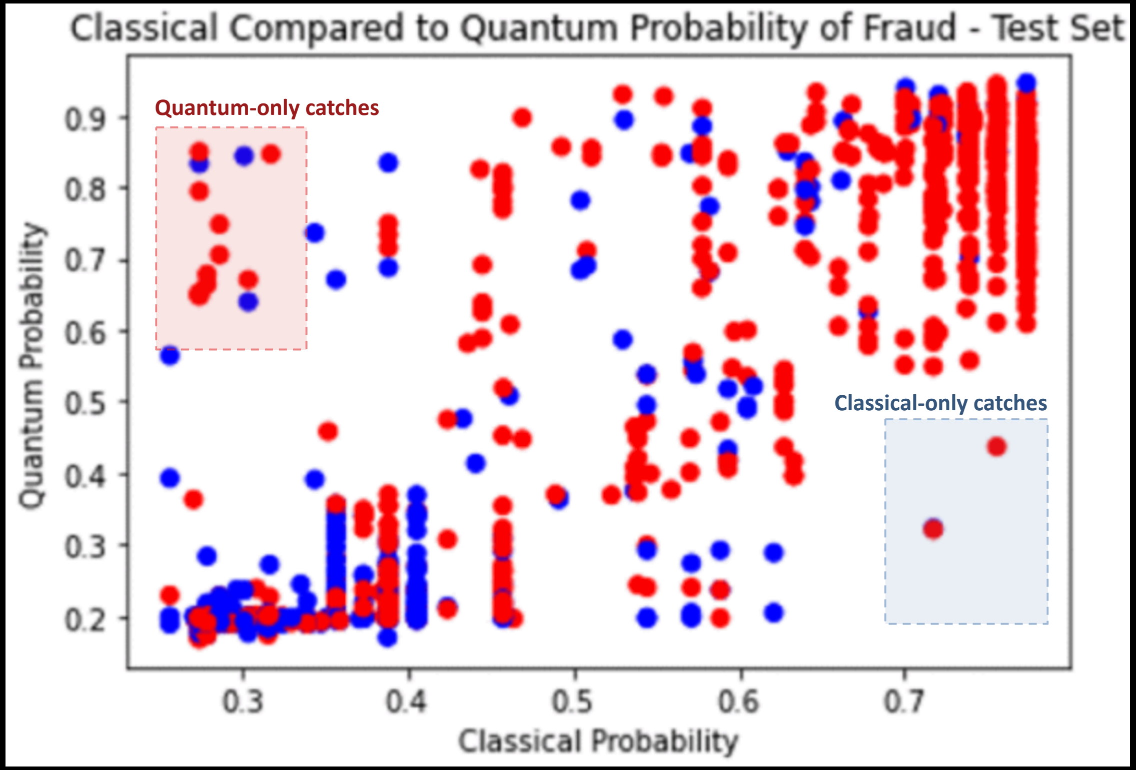
5.5%

of test transactions

HYBRID ENSEMBLE INCREASE

2.0 – 7.0%

best of all — quantum + classical



UPPER-LEFT ZONE

Real fraud the classical model scored as routine — caught only by quantum.

LOWER-RIGHT ZONE

Fraud the quantum model missed but classical correctly flagged. They're complementary.

Source: Grossi et al., "Mixed Quantum–Classical Method for Fraud Detection," IEEE Trans. Quantum Engineering, 2022.

02

PART TWO

Quantum-enhanced AI

How quantum slots into the ML pipeline — without replacing what works.

Encoding, feature selection, kernels, and inference. Specific stages, specific gains, hybrid by design.

WHERE QUANTUM PLUGS IN

ML pipeline for time-series — with quantum integration points

Quantum doesn't replace the pipeline — it slots into specific stages where its structure beats classical compute. Highlighted stages are where quantum methods have shown measurable advantage.

01
Data Ingestion
Streaming ticks, sensors, transactions

02
Preprocessing
Cleaning, alignment, normalization

03
Feature Engineering
Embeddings, transforms, kernels

04
Feature Selection
Pick most informative inputs

05
Model Training
Pattern learning, optimization

06
Model Compression
Shrink for deployment

07
Inference
Forecast, classify, anomaly score

08
Monitoring
Drift detection, retraining

FEATURE ENGINEERING

Quantum kernels

Map data into Hilbert space — capture feature interactions classical kernels miss.

TECHNIQUE
QSVM, quantum feature maps

+15% F1 on fraud (Grossi 2022)

FEATURE SELECTION

QUBO-based selection

Encode feature relevance as a QUBO problem; quantum annealer picks optimal feature subset.

TECHNIQUE
QUBO, quantum annealing

Used in Grossi 2022

MODEL TRAINING

Variational circuits

Train parameterized quantum circuits as a learning model with different inductive bias.

TECHNIQUE
VQC, QNN, hybrid networks

6–32% fewer parameters

MODEL COMPRESSION

Tensor-network compression

Quantum-inspired tensor networks shrink large models while preserving accuracy.

TECHNIQUE
MPS, tree tensor networks

10–100× compression typical

INFERENCE

Anomaly detection

Quantum models flag patterns classical scored as routine — strong at the long-tail.

TECHNIQUE
QML inference, ensembles

+1pp via hybrid ensemble

Quantum is a co-processor for the middle of the pipeline — keep ingestion and monitoring classical, target the stages where representation power matters.

Strategic Blueprint

The AI & Quantum Opportunity in Insurance

AI TODAY

Claims, Underwriting & Efficiency

The immediate value generator. Automates documentation and optimizes risk evaluation.

- Automated claim processing
- Instant anomaly/fraud flags
- IoT & medical record processing

THE BRIDGE

Actuarial, Pricing & Capital

Where AI workflows today lay the ground data architecture for quantum-powered simulation scaling tomorrow.

- Hyper-accurate reserving
- Accelerated Solvency calculations
- Actuarial model validation

QUANTUM HORIZON

Portfolio, Reinsurance & Catastrophe

Future-state breakthroughs built to resolve multi-variable, highly complex, and volatile climate models.

- High-dimensional optimization
- Reinsurance cost structures
- Global climate threat simulation
- Future-proof portfolio hedging

STRATEGIC NARRATIVE

AI delivers today's bottom-line operational ROI, establishing a modern data foundation. Meanwhile, positioning early for Quantum computing secures tomorrow's strategic breakthrough in complex global simulation, pricing, and macro climate optimization.

03

PART THREE

Case Studies

Where it's already working — and where the field is heading.

PILOT BLUEPRINT

AI-driven Claims & Reserve forecasting — quantum-enhanced

A four-step pipeline that combines Internal claims history, external signals (catastrophe, claims inflation, demographic), quantum-enhanced feature engineering, and domain-expert validation — delivered as an interactive scenario dashboard.

01

Train Baseline Model

INPUT

Internal claims history

Establish the foundation

Historic internal claims data trains an initial classical AI forecasting model — sets the performance baseline.

02

QUANTUM

Feature Engineering and fine tuning

INPUT

External signals (catastrophe, claims inflation, demographic)

Quantum-enhanced

Insurance signals (climate patterns, medical cost indices, demographics) feed quantum-enhanced feature engineering — surfaces correlations classical methods miss and fine-tuned

03

Domain Expert Cycle

VALIDATE

Insurance experts

Refine with actuarial judgment

Actuaries and insurance experts validate which external factors truly impact claims — improves model relevance, not just accuracy.

04

Forecast & Scenarios

DELIVER

Interactive dashboard

Decision support

Enhanced model powers a scenario builder where users view forecasts and run what-if analyses for strategic planning.

Quantum slots in where it earns its place — feature engineering on noisy external signals — while the rest of the pipeline stays classical and production-ready.

Hermes Case Study: Advanced Forecasting with Quantum-enhanced AI Models

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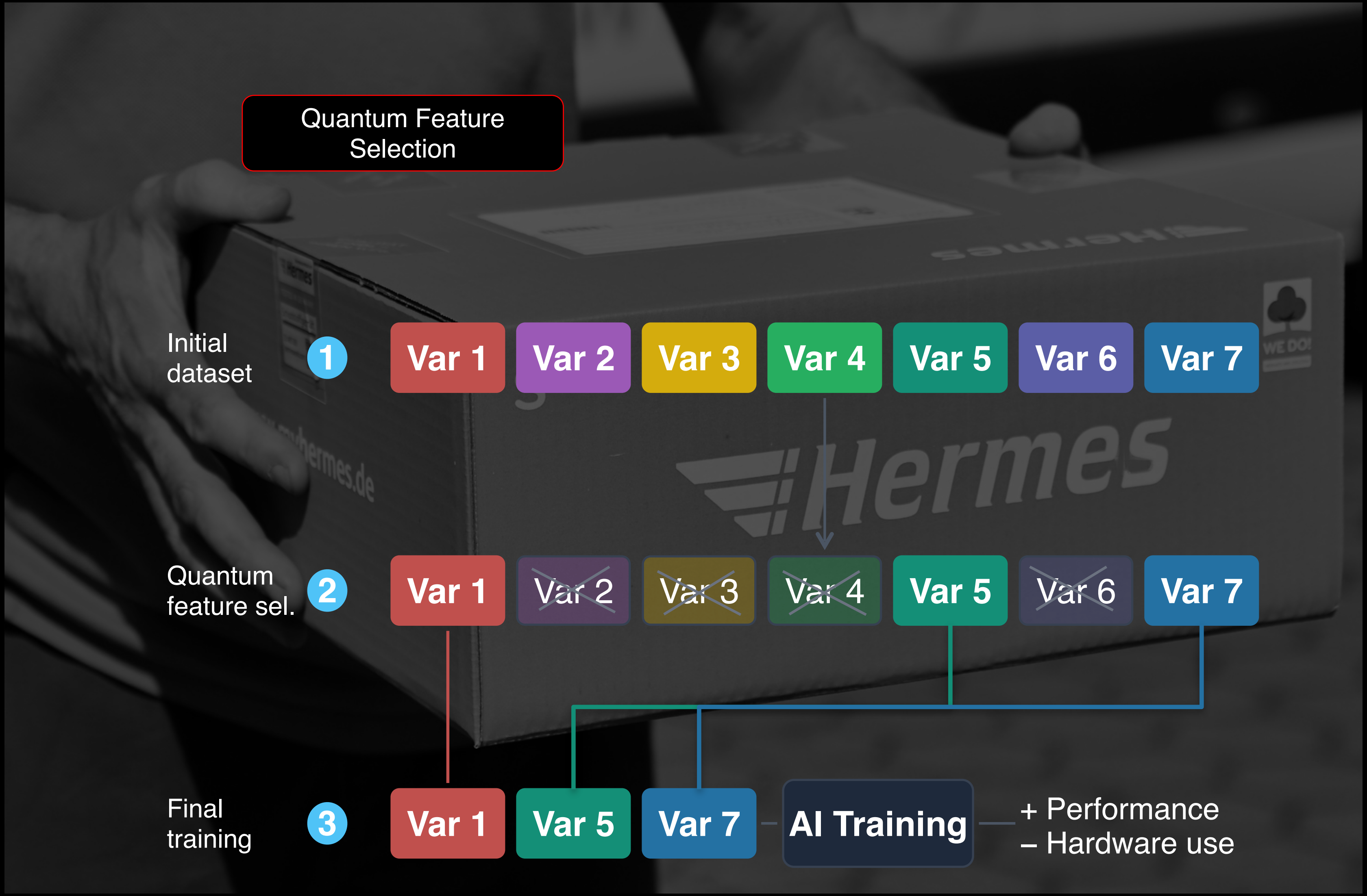

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QUANTUM FEATURE SELECTION
USE CASE: TIME SERIES FORECASTING

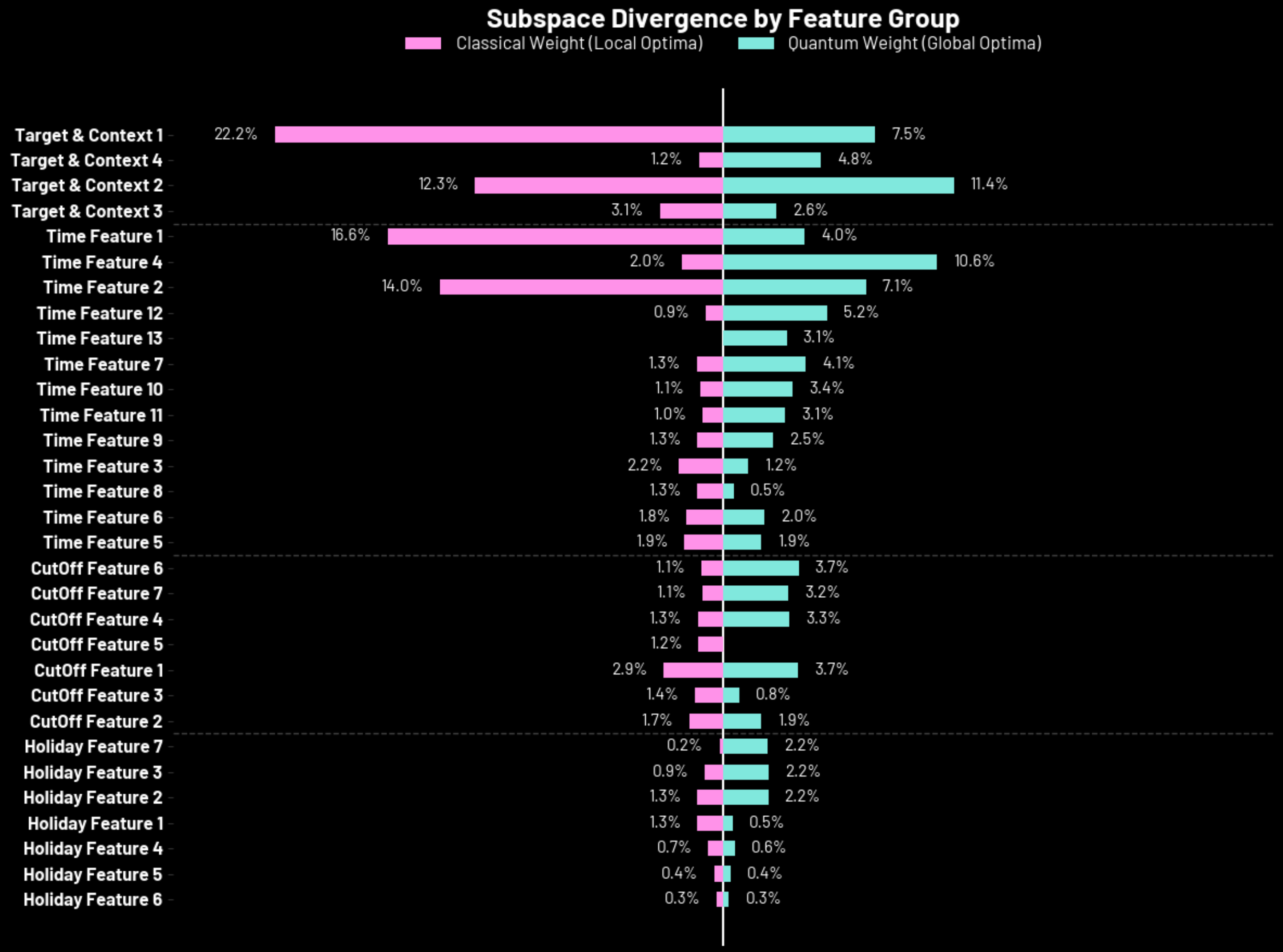
KEY METRICS after 400+ Runs

IMPROVED MODEL EFFICIENCY

26% Higher Compression (Smaller models, same performance)

COMPARABLE ACCURACY (MASE)

57.2% Overall Quantum Win Rate



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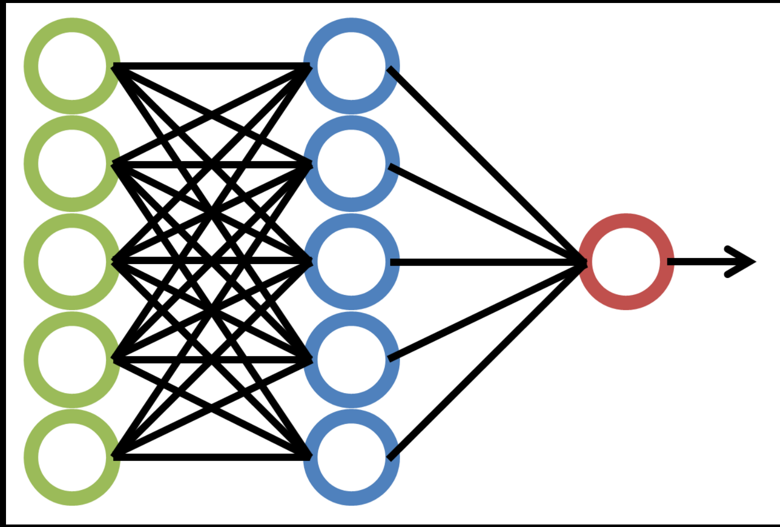
FINE-TUNING: UNLOCKING VALUE FROM LIMITED DATA

Traditional Models Break Down with Limited Data

- Many real-world time-series contain a large number of rich, high-dimensional signals but relatively few data points—creating a classic **"too many features, not enough samples"** situation.



Fine-Tuning Pretrained Time-Series Foundation Models

- Fine-tuned foundation models[1,2] are a solution—combining the power of large-scale pretraining with customization for your specific use case.

Boosting Fine-Tuning with Quantum Neural Layers

- Emerging evidence hints that a **quantum neural network head** added during fine-tuning has the potential to boost performance by capturing complex temporal patterns more effectively[3].

1 Amazon Science. Chronos: Pretrained Models for Time Series Forecasting. GitHub.
2 Google Research. TimesFM: Time Series Foundation Model. GitHub.
3 IonQ Inc.Quantum Large Language Model Fine-Tuning. arXiv:2504.08732 (2025).

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RESULTS WITH REAL-WORLD DATA ("EASY")

Data	Benchmark (accuracy)	QB Classical (accuracy[1])	QB Quantum (accuracy[1])
Automotive Anomaly Detection (Engine noise)	92.3%[2]	**94.5% ± 0.9%**	94.0% ± 1.3%
Epilepsy Detection (Wrist Accelerometer Data)	**100.0% ± 0.3%[3]**	96.4% ± 4.5%	94.2 ± 4.3%

[1]5-fold cross validation accuracies
[2]Ismail Fawaz, H., Forestier, G., Weber, J., Idoumghar, L., & Muller, P.-A. (2019). Deep learning for time series classification: a review. Data Mining and Knowledge Discovery, 33(4), 917–963
[3]Ruiz, A. P., Flynn, M., Large, J., Middlehurst, M., & Bagnall, A. (2020). The great multivariate time series classification bake off: a review and experimental evaluation of recent algorithmic advances. Data Mining and Knowledge Discovery, 35(2), 401–449.

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RESULTS WITH REAL-WORLD DATA (“HARD”)

Data	Benchmark (accuracy)	QB Classical (accuracy[1])	QB Quantum (accuracy[1])
Medical Anomaly Detection (Heartbeat)	76.5% ± 0.3%[2]	**80.4% ± 3.3%**	77.0% ± 4.9%
Energy Grid Anomaly Detection (PMU recordings), PSML dataset 5 class balanced accuracy	74.2% ± 2.9%[3]	**76.7% ± 3.6%**	work in progress

[1]5-fold cross validation accuracies

[2]Ruiz, A. P., Flynn, M., Large, J., Middlehurst, M., & Bagnall, A. (2020). The great multivariate time series classification bake off: a review and experimental evaluation of recent algorithmic advances. Data Mining and Knowledge Discovery, 35(2), 401–449.

[3]Zheng, X., Xu, N., Trinh, L., Wu, D., Huang, T., Sivaranjani, S., Liu, Y., & Xie, L. (2022). A multi-scale time-series dataset with benchmark for machine learning in decarbonized energy grids. Scientific Data, 9(1).

[4]The test data refers to 158 data points that the model had never seen during its training or hyperparameter tuning. The test run was just run once on the data using the final model, hence why there is no standard deviation.

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PART FOUR

Looking into the future

Where the exponential gain will come from

WHEN QUANTUM WINS BIG

A million-fold size advantage, on real ML data

A 60-qubit quantum machine matches the prediction quality of classical systems with *exponentially more memory*. Proven for classification and dimension reduction — the building blocks of modern ML.

QUBITS NEEDED

<60

logical qubits

VS. STREAMING ML

10,000×

smaller machine size

VS. CLASSICAL / QRAM

1,000,000×

smaller machine size

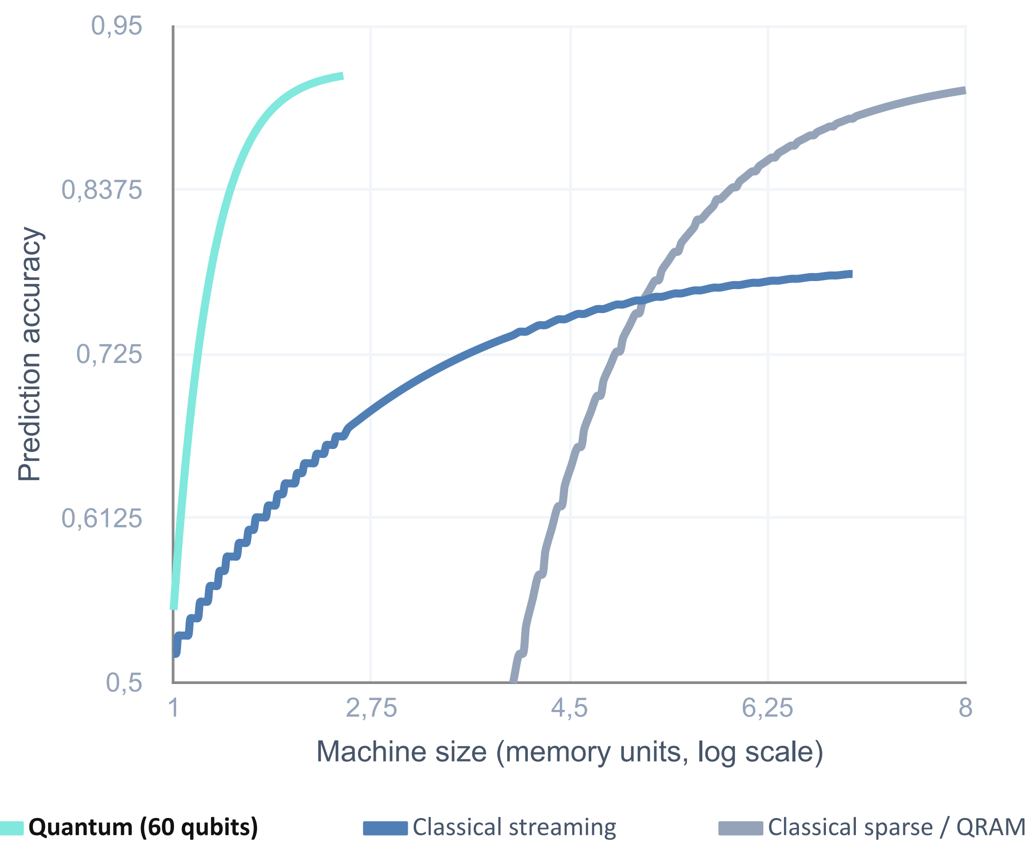
ADVANTAGE TYPE

Provable

unconditional, info-theoretic

Machine size needed for high prediction accuracy

IMDb sentiment classification — log scale



WHAT WAS TESTED

IMDb movie review sentiment + single-cell RNA sequencing of human blood cells.

WHY IT MATTERS

Holds even if classical computers are infinitely fast — relies only on quantum mechanics.

Source: Zhao, Zlokapa, Neven, Babbush, Preskill, McClean & Huang, "Exponential quantum advantage in processing massive classical data," arXiv:2604.07639, April 2026.

Pushing the boundaries

Research & Innovation

R&I Partners

Showing 5 of 24 Publications

Baglio, Haddad, et al. | 2026 | arXiv

Latent Style-based Quantum Wasserstein GAN for Drug Design

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Mittal, Kumar, et al. | 2026 | IEEE

Experimental Validation of Dequantization of Hybrid Quantum Machine Learning Models Using Classical Surrogates

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Liepelt & Baglio | 2026 | arXiv

Exponential capacity scaling of classical GANs compared to hybrid latent style-based quantum GANs

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Bose, Rhrissorrakrai, et al. | 2026 | Nature Reviews Molecular Cell Biology (Nat Rev Mol Cell Biol)

Advancing single-cell omics and cell-based therapeutics with quantum computing

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Burov, Baglio, et al. | 2025 | arXiv

Large circuit execution for NMR spectroscopy simulation on NISQ quantum hardware

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Business-ready AI projects and R&I quantum projects

1. Business-ready projects made with AI with a quantum addition – 90 day
2. Business-ready AI projects along with exploration of quantum for future impact – 3-6 months
3. Research and innovation projects to explore exponential advantage for in the longer term– 6-12 month projects

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LET'S TALK

Thank you!

Questions, pushback, ideas — all welcome.