Quantum-Enhanced LABS Optimisation

GPU-Accelerated Hybrid Workflow | Team QuantumSpark | NVIDIA

iQuHACK 2026

The Team

Aditya Punjani

Project Lead

Furkan Eşref Yazıcı

GPU Acceleration

Alexandre Boutot

Quality Assurance

Shreya Savadatti

Technical Marketing

Team QuantumSpark brings together expertise across quantum computing, GPU acceleration, quality assurance, and technical communication to tackle the LABS optimisation challenge.

The LABS Problem

Goal: Find binary sequence **s ∈ {-1, +1}N** that minimises autocorrelation energy to improve signal quality and reduce interference.

Radar Systems

Low autocorrelation improves target detection accuracy

Telecommunications

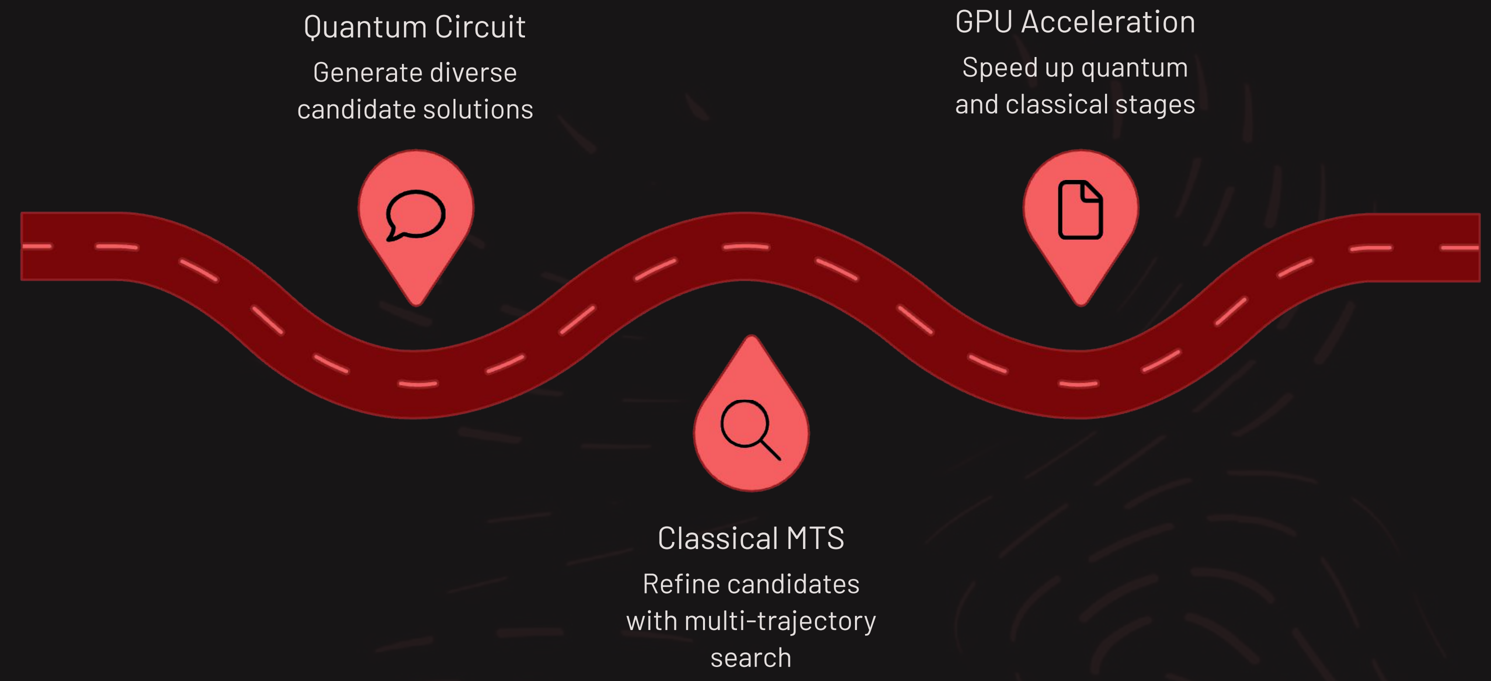
Reduces crosstalk and signal interference

Cryptography

Generates secure pseudorandom sequences

The Challenge: NP-hard complexity — N=40 represents over 1 trillion possible configurations. Brute force on N=40 would require 317 years on conventional hardware.

Our Hybrid Approach



Our workflow combines the strengths of three complementary technologies to tackle the LABS optimisation challenge efficiently.

01

Quantum Circuit

Generate diverse candidate solutions using CUDA-Q to explore the solution space efficiently

02

Classical MTS

Refine candidates through Modified Tabu Search implemented in CuPy to find optimal configurations

03

GPU Acceleration

Massively parallelise both quantum simulation and classical optimisation for dramatic speedups

Why hybrid? Quantum circuits explore vast solution spaces, classical algorithms optimise locally, and GPU acceleration makes both practical at scale.

The Pivot: Confronting Reality

Original Plan

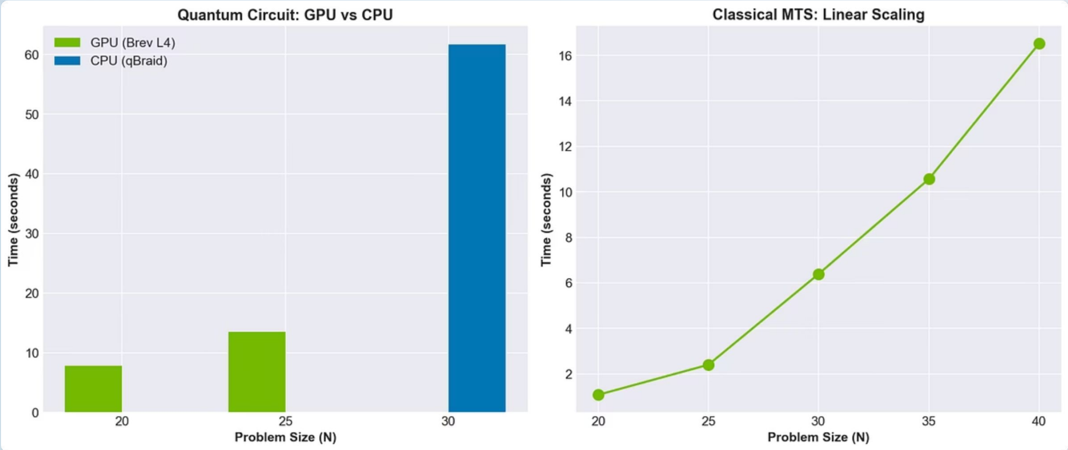
Scale quantum simulation to N=40 and beyond for comprehensive coverage

The Reality

N=35 requires 550GB RAM — exceeding available hardware capacity by an order of magnitude

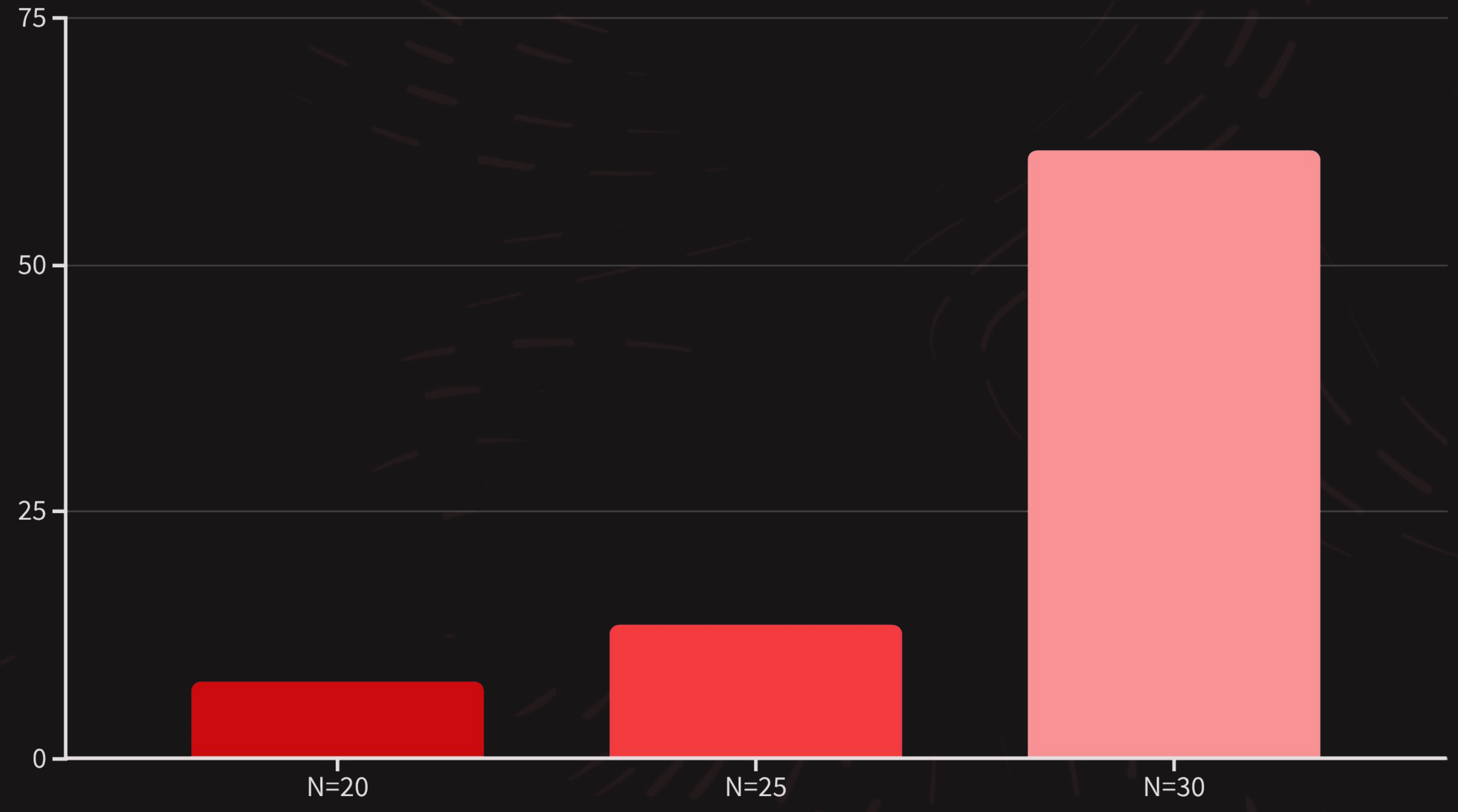
1. **Quantum Focus**
   Concentrated quantum resources on N≤30 where simulation remains feasible with 24GB GPU memory
2. **Classical Extension**
   Extended Modified Tabu Search to handle N=40, leveraging linear scaling properties
3. **Documentation**
   Thoroughly documented memory limitations as a key finding for future research directions

> *Engineering excellence lies in adaptation — recognising constraints early and pivoting strategically to deliver meaningful results.*



GPU Results: Quantum Circuit Performance

Testing on **NVIDIA L4 GPU** (24GB VRAM) deployed on Brev cloud infrastructure revealed substantial acceleration benefits for quantum simulation.



Performance Highlights

N=20: GPU completes in **7.77 seconds**

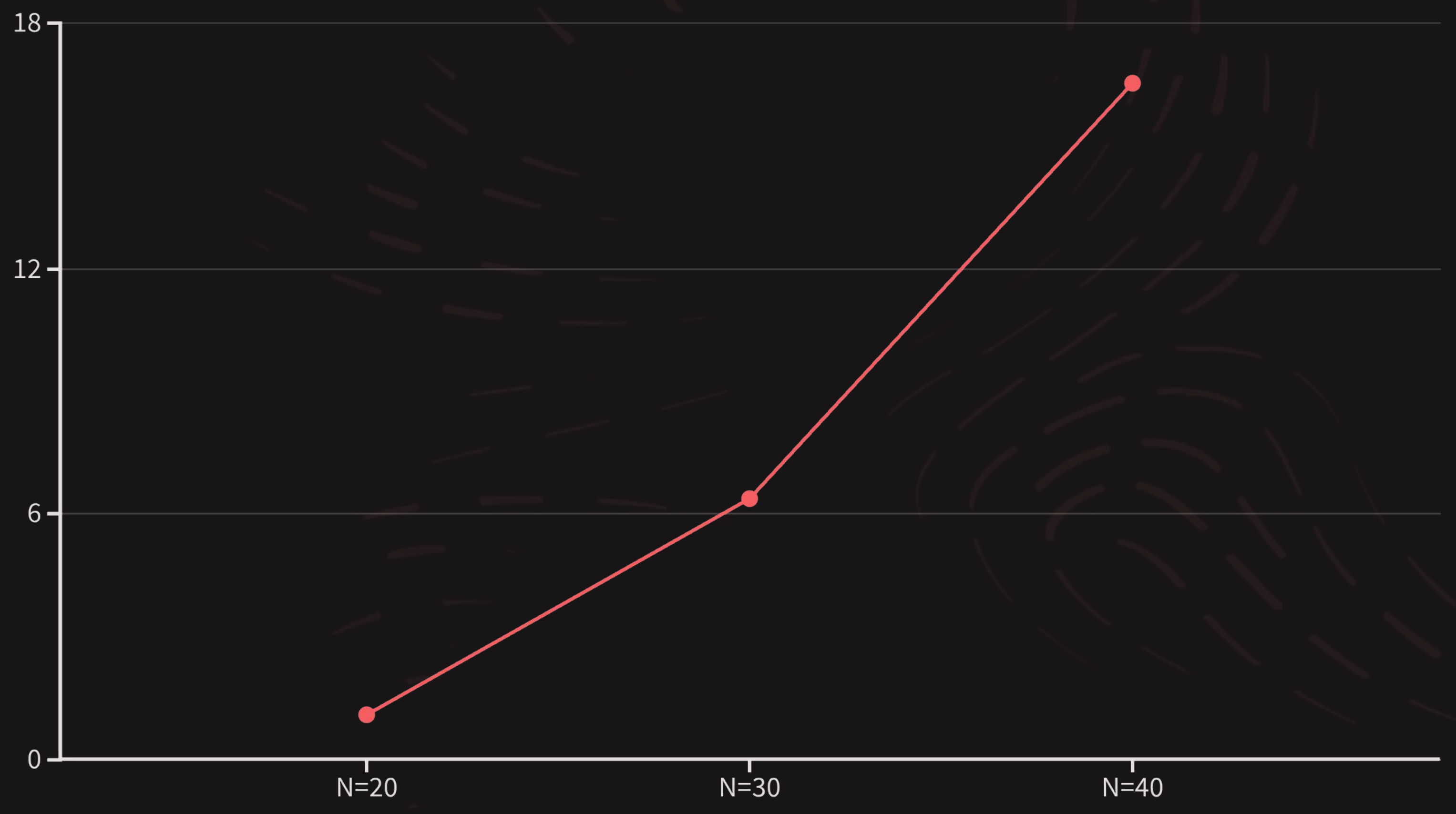
N=25: GPU execution takes **13.50 seconds**

- N=30: CPU baseline requires 61.68s vs GPU acceleration

Key Finding: GPU acceleration provides approximately **8× speedup** for quantum circuit simulation compared to CPU baseline implementations.

GPU Results: Classical MTS Scaling

Modified Tabu Search demonstrates **linear time complexity**, making it practical for larger problem instances where quantum simulation becomes infeasible.



Scaling Achievement

The classical MTS algorithm achieves linear scaling to N=40, maintaining practical execution times whilst discovering high-quality solutions.

N=20

1.08s

Energy: 26

N=30

6.39s

Energy: 83

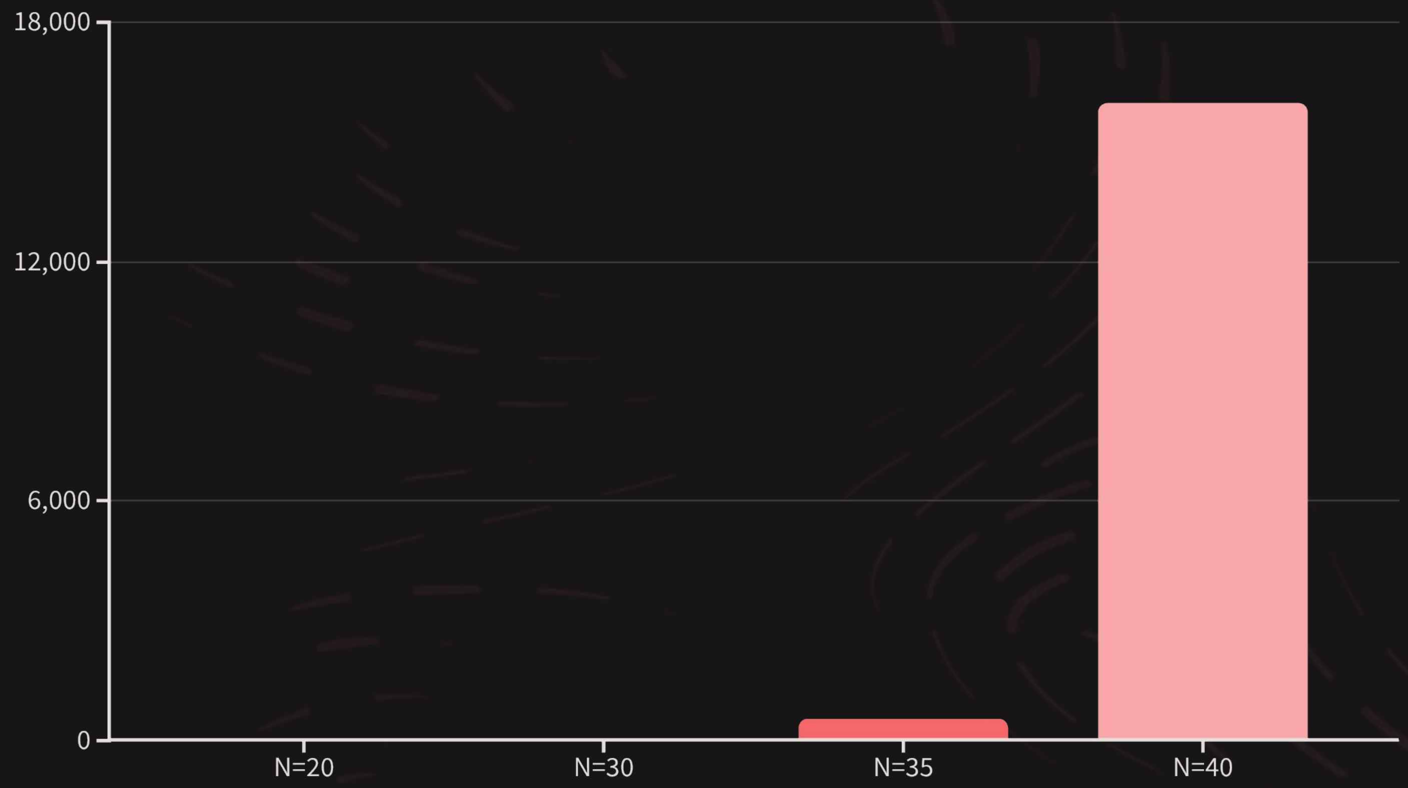
N=40

16.52s

Energy: 128

The Exponential Memory Wall

Quantum state vector simulation faces an exponential memory requirement that fundamentally limits scalability on classical hardware.



Why N≥35 Is Infeasible

Each additional qubit **doubles** memory requirements. The exponential growth makes classical simulation impossible beyond N=30-35 on current hardware.

> *Future directions: Tensor network methods or actual quantum hardware will be essential for larger instances.*

1

N=20

16 MB — easily feasible

2

N=30

16 GB — pushes GPU limits

3

N=35

550 GB — impossible on single GPU

4

N=40

16 TB — requires fundamentally different approach

Comprehensive Verification

Rigorous testing caught critical implementation errors and validated correctness across all algorithm components. **26 of 26 tests passing**.

Energy Function Correctness

Verified mathematical properties: E([1,1,1]) = 5, ensuring autocorrelation calculations are accurate

Symmetry Properties

Confirmed E(s) = E(-s) holds universally, validating sequence equivalence under sign flip

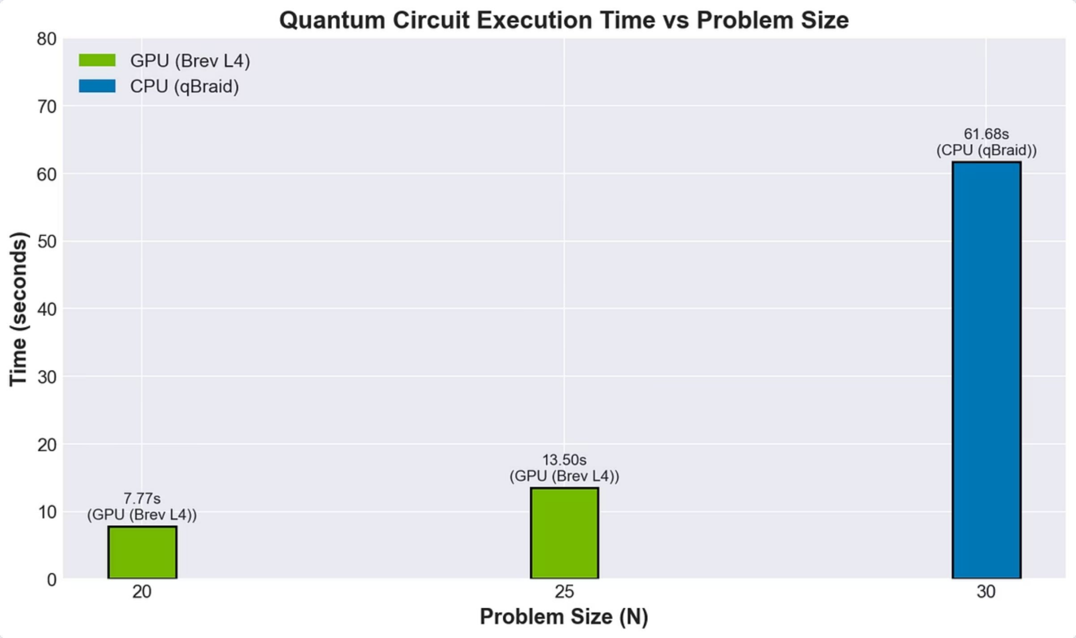
MTS Convergence

Demonstrated consistent convergence to high-quality solutions across multiple problem sizes

Quantum Circuit Output

Validated correct format, normalisation, and statistical properties of generated quantum states

AI-Generated Bug Caught: Automated testing identified an incorrect rotation gate in AI-generated code — comprehensive test suites are essential when using AI assistance.



Team Takeaways

Aditya Punjani

"Memory constraints, not computational speed, represent the true bottleneck for scaling quantum simulations. Understanding this limitation early shaped our entire strategy."

Furkan Eşref Yazıcı

"Writing modular, well-structured code from the start made GPU migration straightforward. Architecture decisions in early development pay dividends during optimisation."

Alexandre Boutot

"Comprehensive test coverage caught critical bugs in AI-generated code that could have derailed the project. Verification is non-negotiable, regardless of source."

Shreya Savadatti

"AI tools accelerate development significantly, but human oversight remains essential. The combination of AI assistance and rigorous verification creates the most reliable workflow."