Prompt 3: Option Pricing in Finance

Part of The Mil'HaQ Fest 2025

The goal of this prompt is to **calculate the price of options using quantum computers.**

There are two tracks :

- **Track 1** : Quantum random walk for put and call options pricing;

- **Track 2** : Swaptions option pricing with quantum machine learning.

Track 1 : Quantum random walk for put and call options

Track 1 : Quantum random walk for put and call options

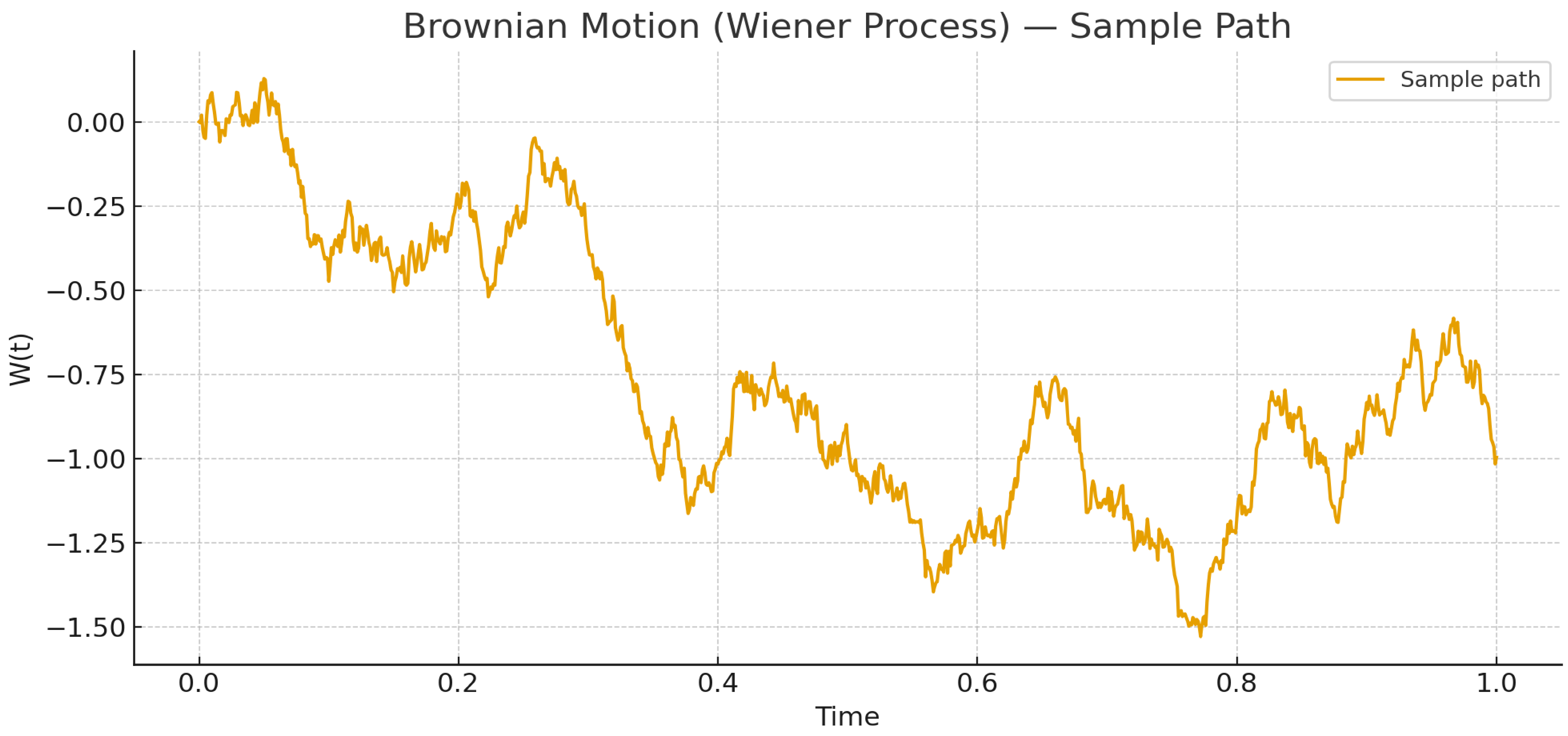
- The goal of the student is to **calculate the price of put or call options** using a quantum random walk.

- In this track, we use the Black-Scholes model to calculate option prices with **constant interest rate and volatility**.

- The calculated option prices can be **approximate**.

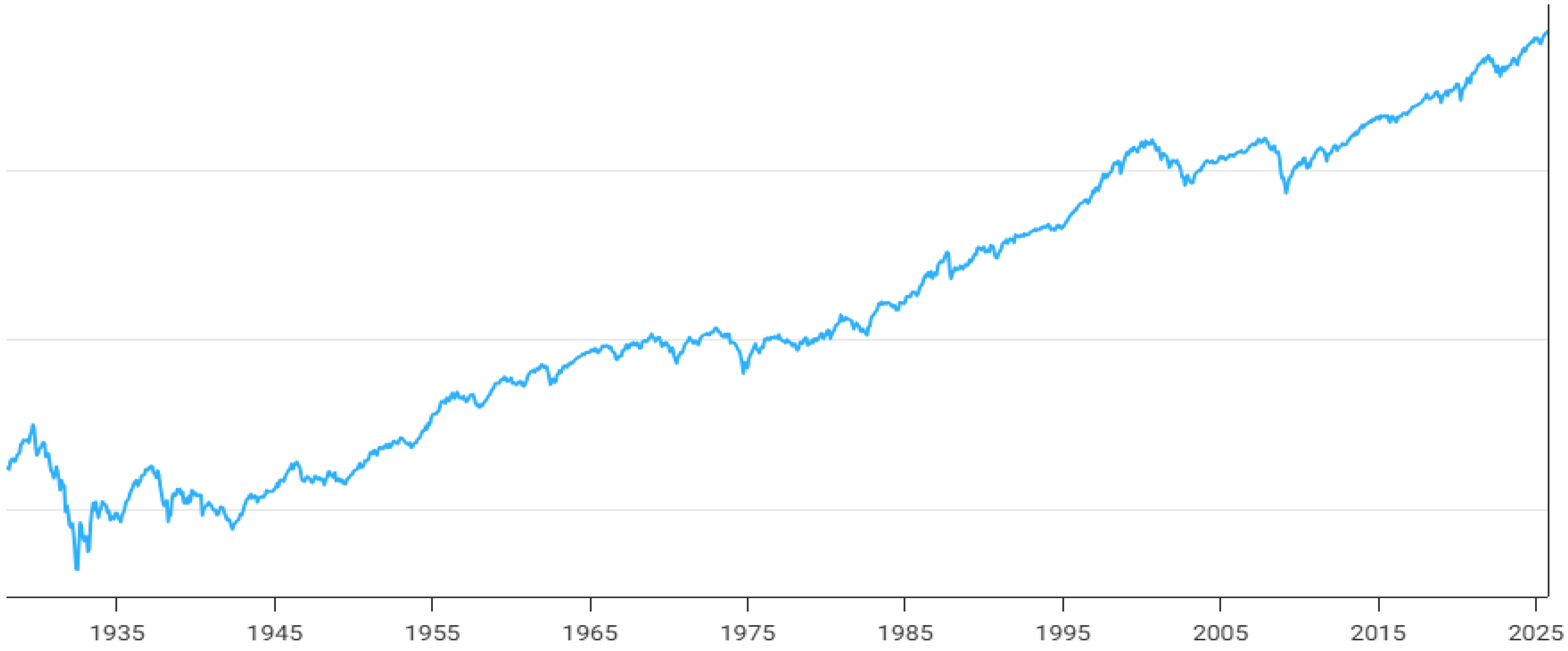
Track 1 : Quantum random walk for put and call options

Random walk



Track 1 : Quantum random walk for put and call options

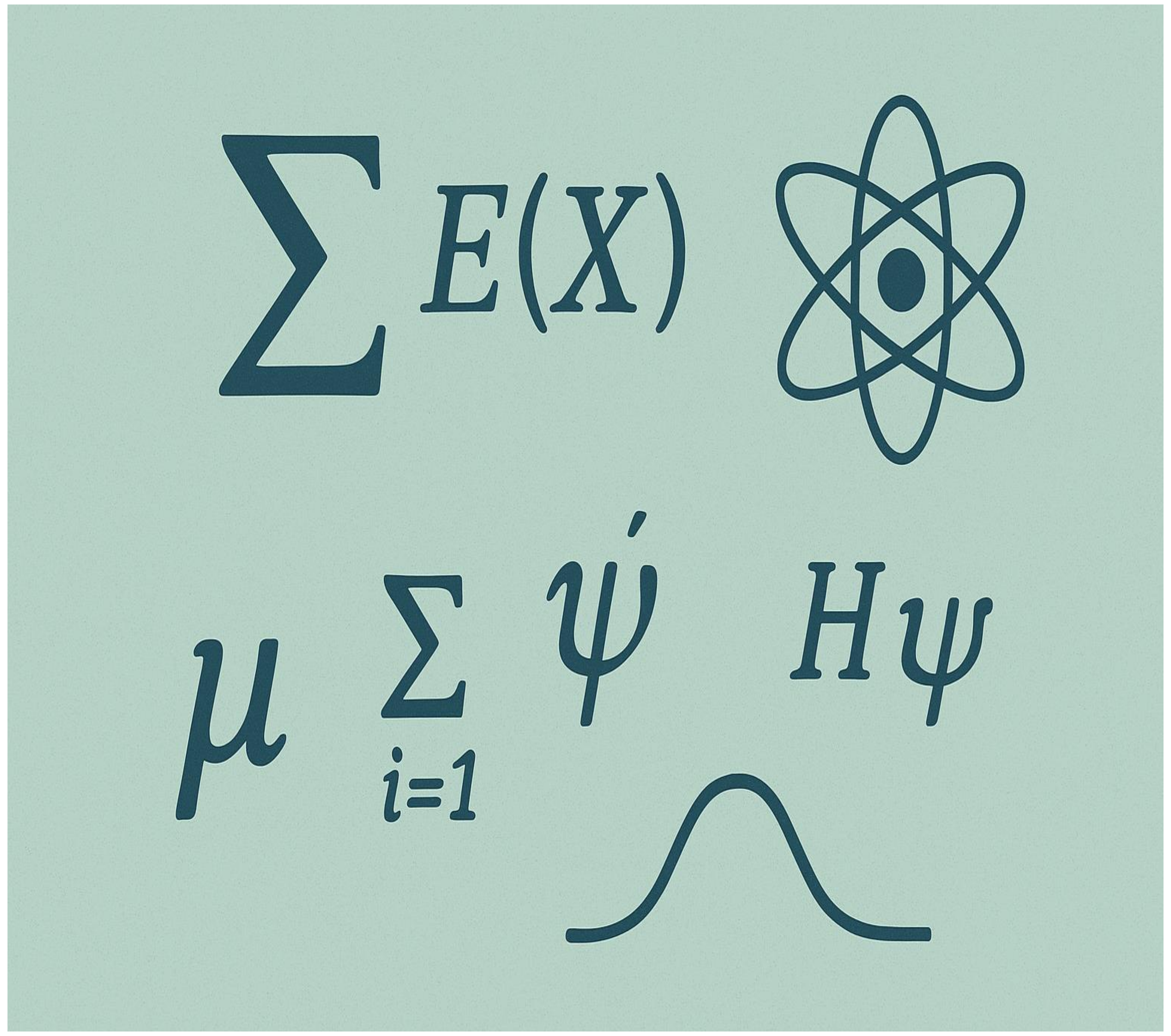
S&P500 Return



See https://www.macrotrends.net/2324/sp-500-historical-chart-data

Track 1 : Quantum random walk for put and call options

- A call option is an option to buy an asset at a specific price at a specific point in time.
- A put option is an option to sell an asset at a specific price at a specific point in time.
- The specific price is the strike price.
- *For example, we can have a call option to buy one share of the S&P500 at 10000$ in 3 months.*

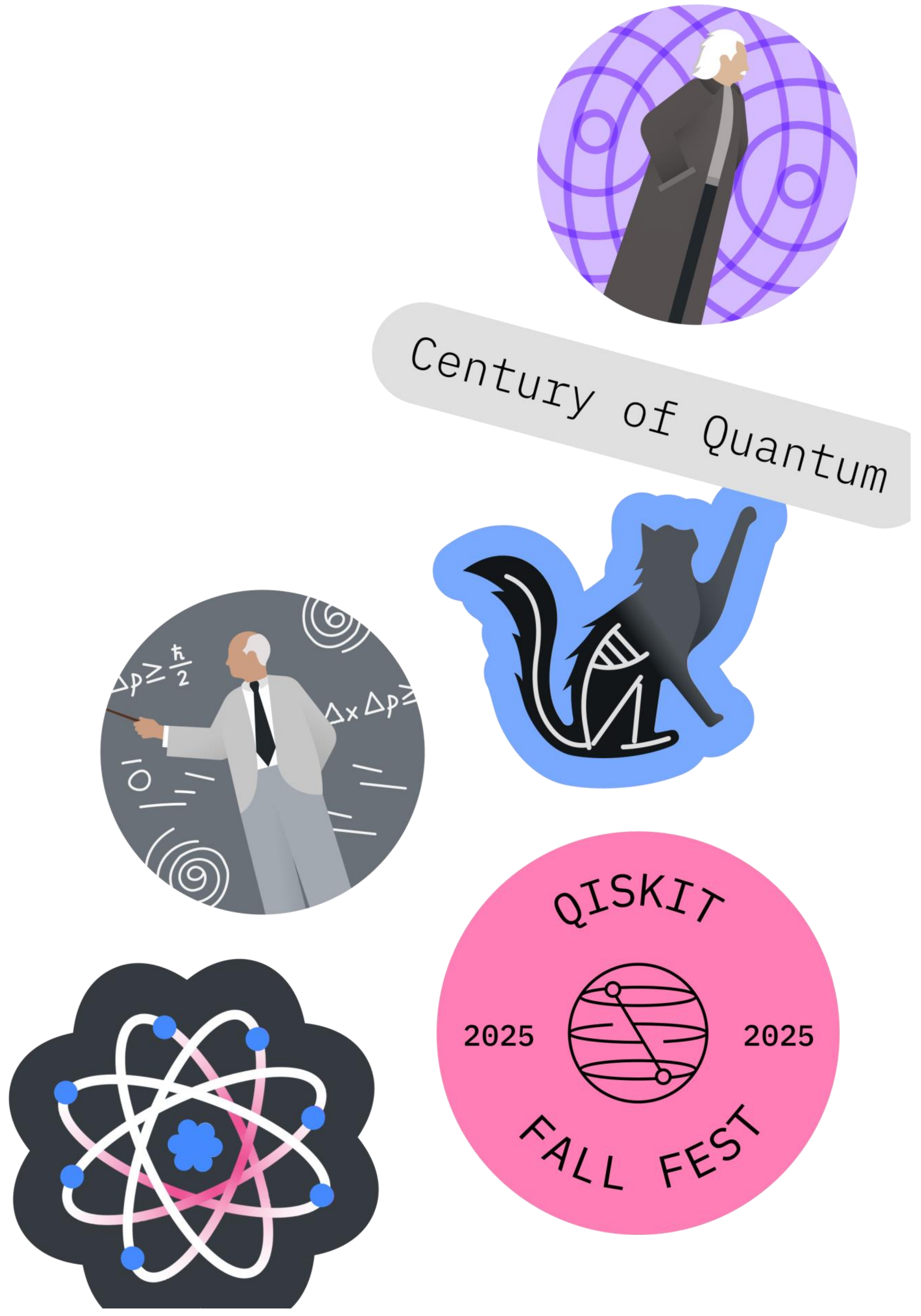


Track 1 : Quantum random walk for put and call options

- The analytical formula to calculate put and call options for the Black-Scholes model will be provided;

- A code for a classical computer will be provided to calculate the exact price of put and call options for the Black-Scholes model;

- Parameters will be provided to calculate the price of the options (i. e. strike price, asset price, interest rate, volatility, time to maturity, etc.);



Track 1 : Quantum random walk for put and call options

- The goal of the students is to obtain an approximate price for put and call options using a quantum random walk for a given set of parameters.

- We will <u>not</u> provide a dataset of option prices for track 1.

- See "Han, Q., & Song, X. (2025). Quantum walk option pricing model based on binary tree. *Physica A: Statistical Mechanics and its Applications*, *658*, 130205 ".

Track 2 : Swaptions option pricing with quantum machine learning

Where QML fits in finance (today)

Portfolio and credit risk

Combinatorial optimization (VQE/QAOA)

Market modeling

Quantum kernels/QSVMs for small structured datasets

Time series

Quantum Reservoir Computing (QRC) and variatioinal circuits for forecasting imputation

Reality check

Near-term results often match or trail strong classical baselines

[1] Sakurai, A., Hayashi, A., Munro, W. J., & Nemoto, K. (2025). Quantum optical reservoir computing powered by boson sampling. *Optica Quantum*, *3*(3), 238-245.

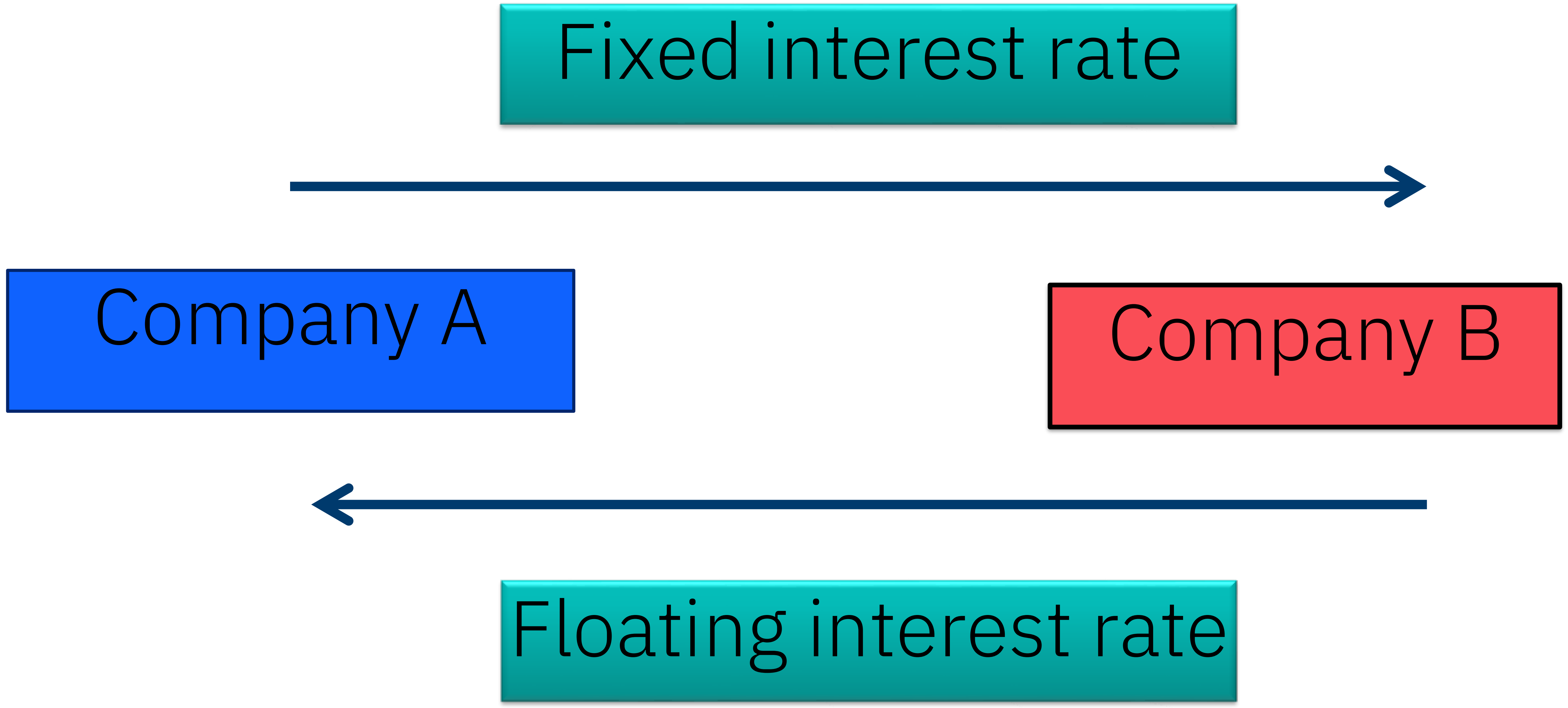
[2] Fellner, T., Kreplin, D., Tovey, S., & Holm, C. (2025). Quantum vs. classical: A comprehensive benchmark study for predicting time series with variational quantum machine learning. *arXiv preprint arXiv:2504.12416*.

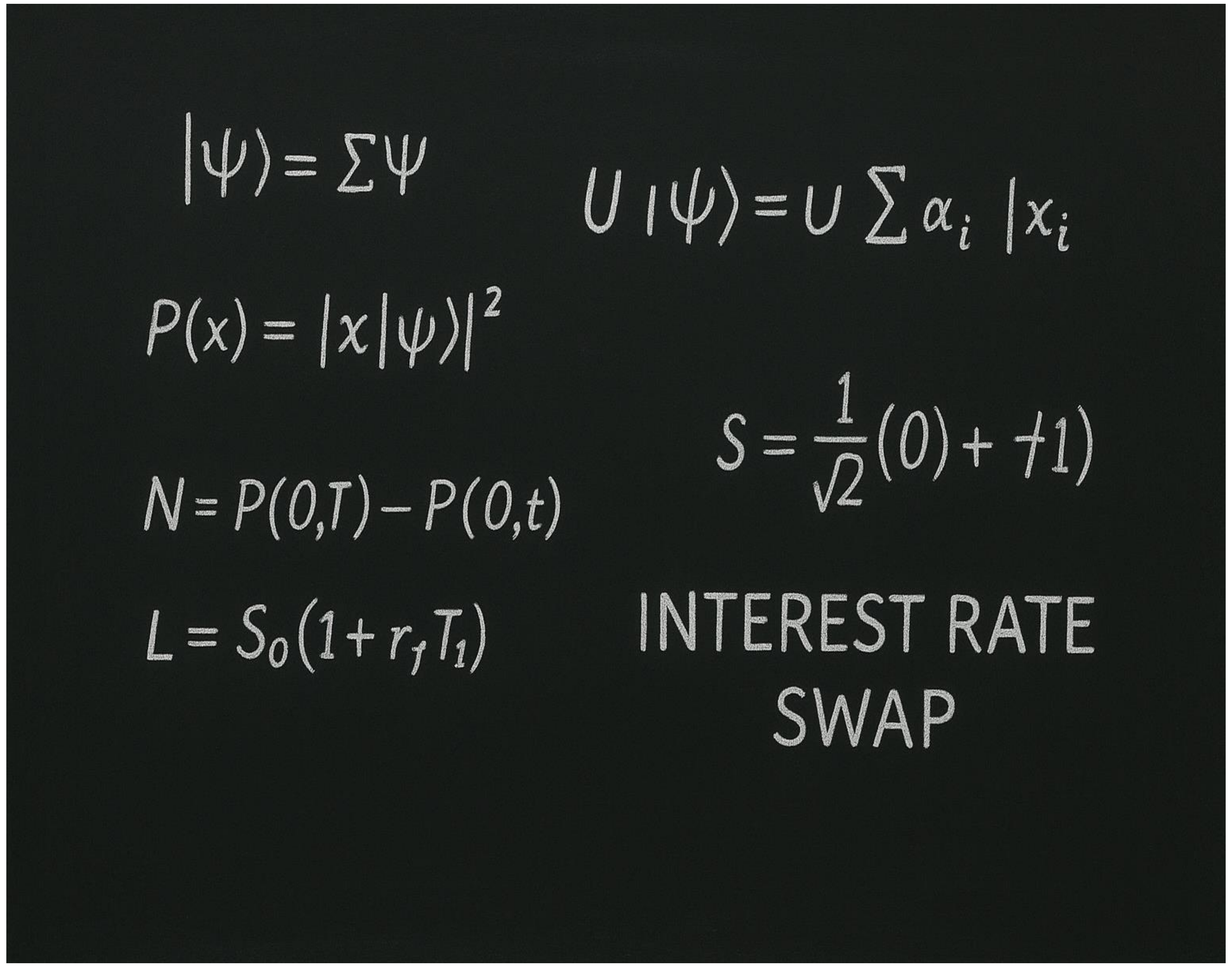
[3] Nerenberg, S., Neill, O. D., Marcucci, G., & Faccio, D. (2025). Photon number-resolving quantum reservoir computing. *Optica Quantum*, *3*(2), 201-210.

[4] https://merlinquantum.ai/notebooks/quantum_reservoir.html

Track 2 : Swaptions option pricing with quantum machine learning

An interest rate swap is a contract for which one party will pay a fixed interest rate and the other will pay a floating interest rate.



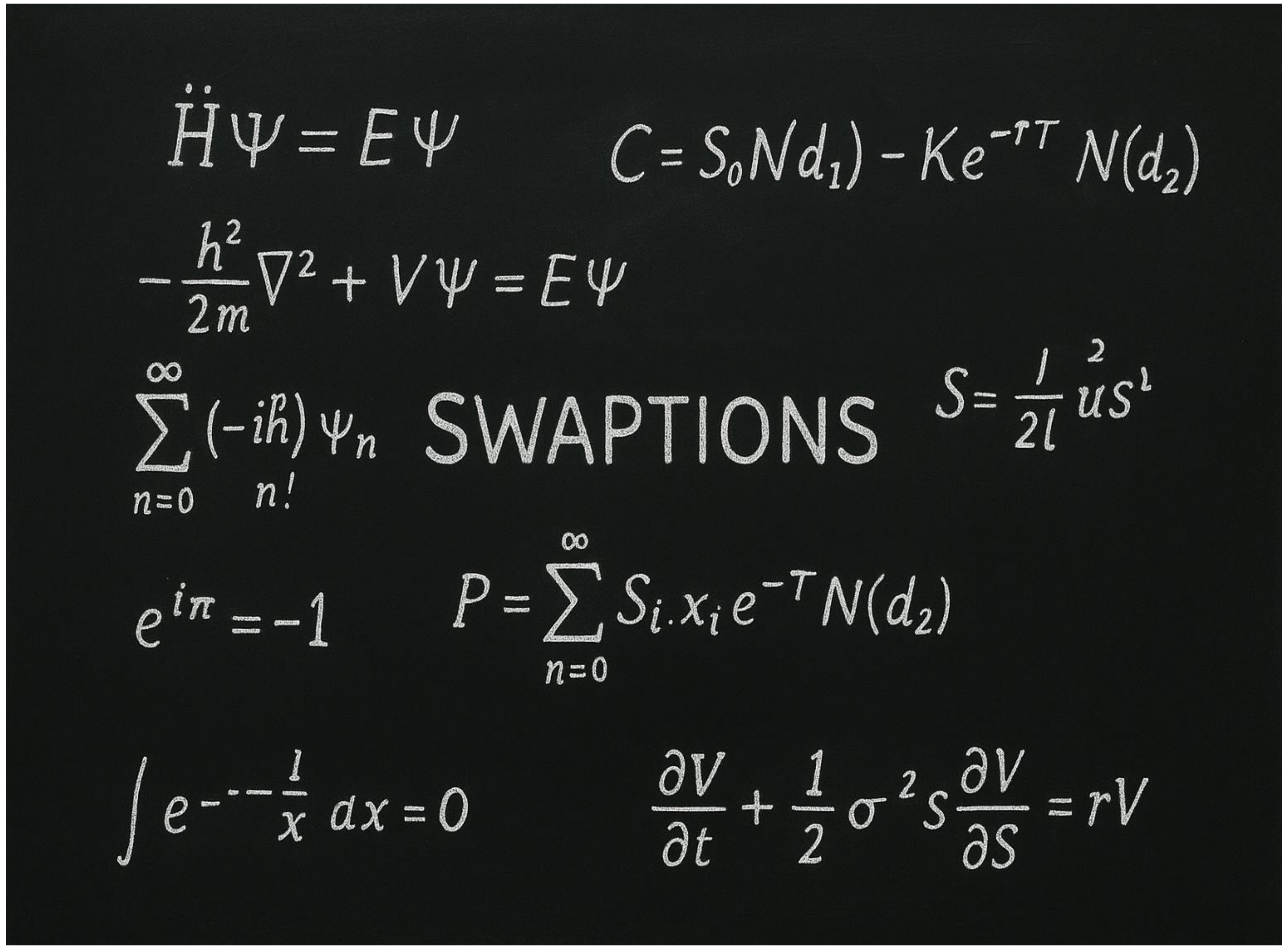


Track 2 : Swaptions option pricing with quantum machine learning

A synthetic dataset of swaptions prices that was generated with a **realistic** model will be provided to the students

The goal of the students is to use quantum machine learning models to :

- 🔎 goal 1 : predict the values of missing data in the dataset;
- 🔭 goal 2 : predict the future swaptions prices for the next two weeks.



Track 2 : Swaptions option pricing with quantum machine learning

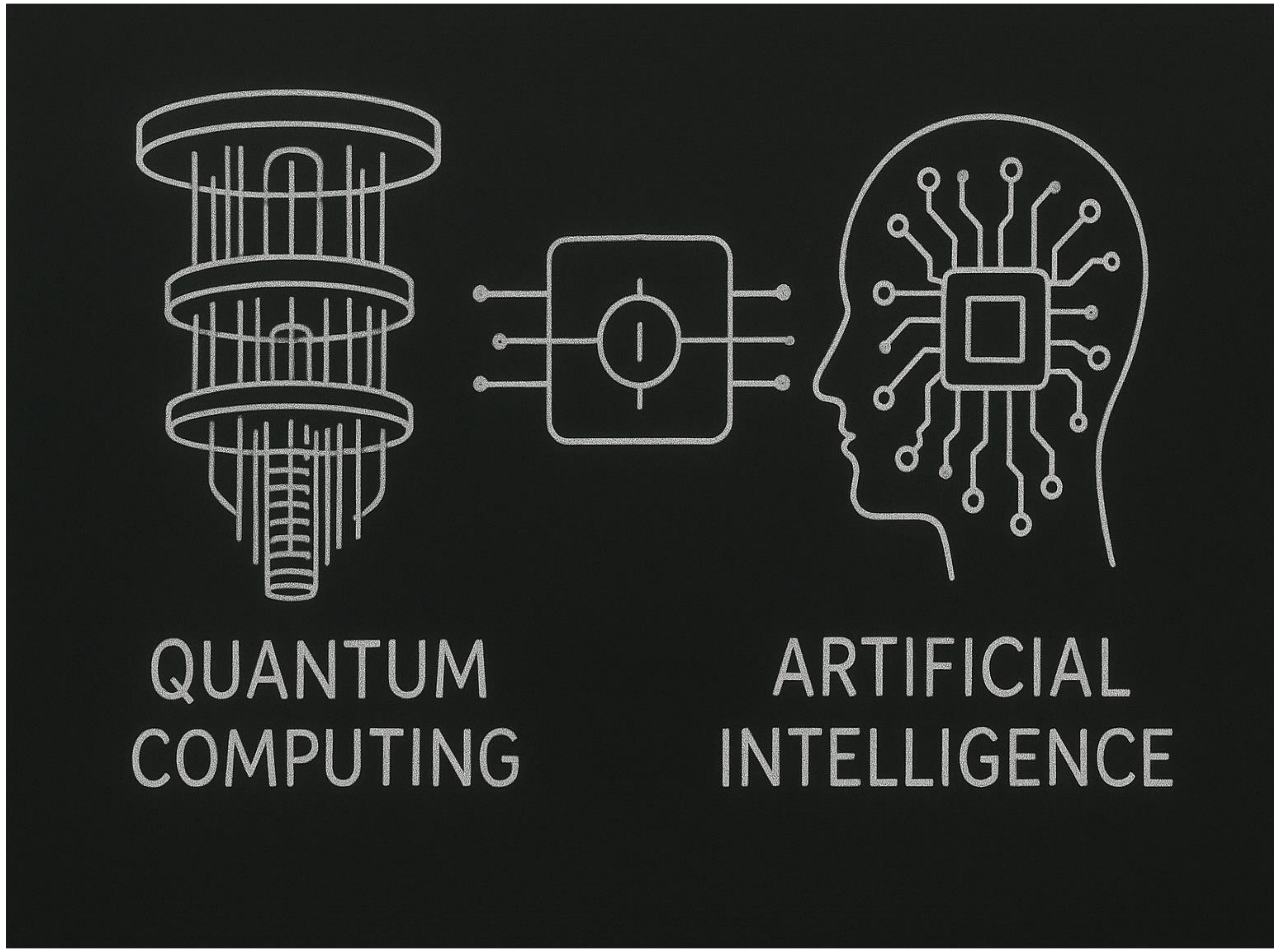
- The options on interest rate swaps (i. e. swaptions) have a tenor and a maturity.
- The maturity is the moment at which an option can be exercised.
- The tenor is the length of time of the interest rate swap payments.

Tenor : 10; Maturity : 30	Tenor : 15; Maturity : 30	Tenor : 20; Maturity : 30	Tenor : 25; Maturity : 30	Tenor : 30; Maturity : 30	Date
0,32239296	0,34585919	0,35916232	0,34667048	0,33767007	01-01-2050
0,3281438	Missing data !!	0,36519689	0,35099282	0,3408224	01-02-2050
0,32543597	0,34891453	0,36223568	Missing data !!	0,33902681	01-03-2050
0,32977101	0,3532459	0,36610005	0,3514044	0,34046496	01-05-2050
Future data	Future data	Future data	Future data	Future data	01-06-2050
Future data	Future data	Future data	Future data	Future data	01-08-2050

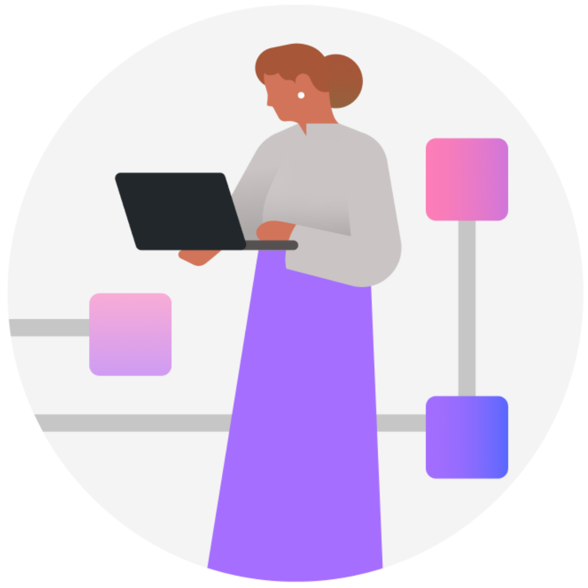
Track 2 : Swaptions option pricing with quantum machine learning

- The students can use quantum machine learning techniques such as quantum reservoir or other techniques.

- The goal of the students is to predict the value of missing data and predict future values of swaptions prices by training a quantum machine learning model.



Practical recipe (QRC baseline for swaptions)



- **Encode** input window (e.g., past 20 trading days of features) into an optical/quantum reservoir or simulated QRC.
- **Collect reservoir states** (e.g., photon-count histograms / mode quadratures / qubit expectation values).
- **Train linear readout** (ridge/Lasso) to: (a) impute gaps; (b) predict 1–10 day horizon prices. Use walk-forward CV, **compare** to gradient boosted trees, and small LSTMs.
- **Report** accuracy + memory capacity vs. reservoir parameters (depth, nonlinearity, noise).

Material provided

Track 1 : Quantum Random Walk

Video and documentation: finance background (put, call, volatility, Black Scholes model)

Data: parameters of the Black Scholes model (asset, strike price, volatility, interest rate, maturity)

Additional resources: function to compute the option price with Black Scholes formula

Track 2: Quantum Machine Learning

Video and documentation: finance background (swaptions)

Data: csv file with the dataset of swaption praced (datapoints at different time steps, with different tenors and maturities)

Contact Us !

Do not hesitate to ask questions on the general-discussion channel !

Discover the website for our event, organized around this prompt:
The Mil'HaQ Fest
November 21st in Montreal (QC, Canada)
https://sites.google.com/view/the-milhaq-fest/