QuantHEP

Quantum Computing Solutions for High-Energy Physics

GOALS

The key goal of the QuantHEP project is to develop quantum algorithms as a solution to the increasingly challenging, and soon intractable, problem of analysing and simulating events from large particle-physics experiments.

QuantHEP will develop:

- **QUANTUM ALGORITHMS FOR EVENT SELECTION AND EVENT RECONSTRUCTION**
  - performing proof-of-principle analysis of real data from CERN
  - benchmarking the potential advantage of this novel quantum-enhanced processing
- **QUANTUM SIMULATION OF SCATTERING PROCESSES**
  - developing software libraries as building blocks to simulate particle physics' objects (elementary particles, composite particles, jets)
  - performing proof-of-principle scattering quantum simulation
  - benchmarking our approach against CERN classical simulations to characterize a quantum advantage threshold for HEP processes

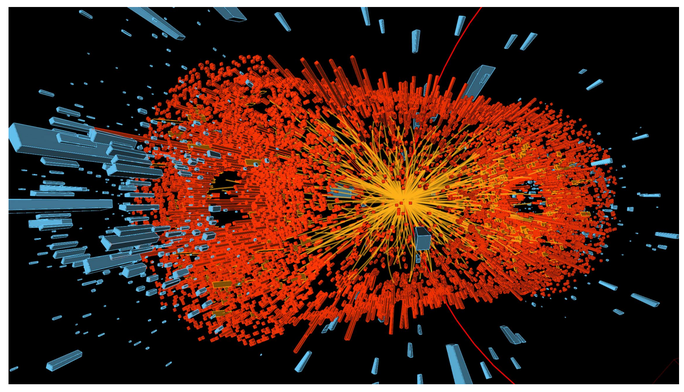


Figure: illustration of scattering event at CERN.

THE NAME

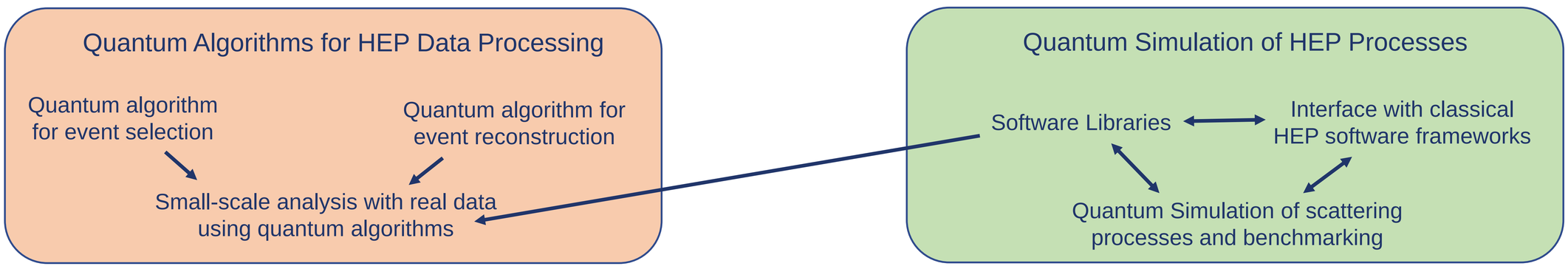
The acronym QuantHEP comes from the merging of the names of the sections of the arXiv used by the two communities involved in this project: Quantum Physics (quant-ph), and High-Energy Physics (hep-ex, hep-lat, hep-ph, hep-th). It is meant to highlight the interdisciplinary nature of the project.

STRUCTURE

QuantHEP is organized in two scientific work packages:

- **Quantum algorithms for HEP Data Processing** - aims at developing quantum algorithms for HEP event selection and for HEP event reconstruction, establish their theoretical scaling, and benchmark them in terms of accuracy, speed and scalability against simulated and real data from CERN. We will explore different approaches to find the best quantum algorithms for these tasks. We will then combine them for small-scale analysis with real data, and benchmark the performance of our combined quantum algorithms.
- **Quantum Simulation of HEP Processes** - aims at developing the quantum simulation of scattering processes, and benchmark it against the classical solution. We will start by developing the corresponding ingredients, namely software libraries for particle physics objects. Finally, it will be crucial to interface our quantum simulation with the classical HEP software frameworks currently used by the HEP community.

This is summarized below:



CONSORTIUM

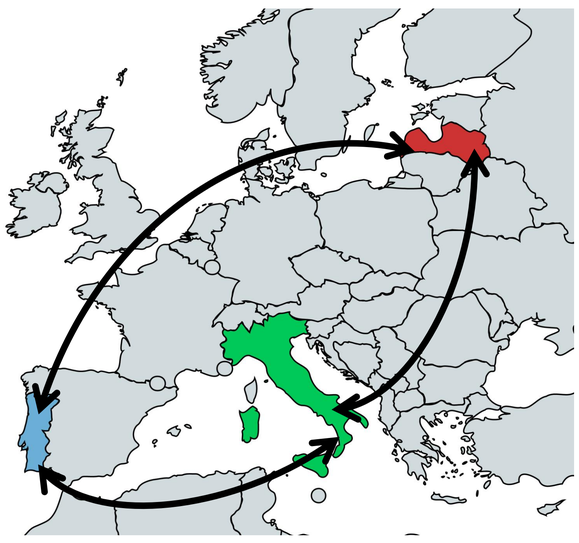


Figure: map highlighting the members of the consortium.

To tackle these challenges, project QuantHEP brings together an interdisciplinary and experienced team whose expertise spans quantum information theory, quantum algorithms, quantum computational complexity, quantum analog and digital computing, quantum simulation, theoretical high-energy physics, experimental (data analysis) high-energy physics, including the corresponding state-of-the-art classical algorithms and neural network methods.

- **IT, Lisbon (Portugal) - Yasser Omar (coordinator), João Seixas** : Quantum Computation, High-Energy Physics
- **INFNPD, Padova (Italy) - Simone Montangero, Paolo Facchi** : Quantum Simulation, Tensor-Network Methods
- **ULatvia, Riga (Latvia) - Andris Ambainis** : Quantum Algorithms, Quantum Computational Complexity

ACKNOWLEDGEMENTS

We thank the support from the EU H2020 QuantERA ERA-NET Cofund in Quantum Technologies.

Authors: Duarte Magano and the QuantHEP Consortium