QuantHad: An analog quantum simulator for hadron and nuclear physics

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Introduction to the IGFAE-CESGA lab

The Galician Institute of High Energy Physics (IGFAE) and the Galician Supercomputing Center (CESGA) have created a common laboratory to foster quantum simulation for particle and nuclear physics research.

- IGFAE is a joint research center of University of Santiago de Compostela and Xunta de Galicia (the Galician Autonomous Government), officially created on July 2, 1999.

- CESGA is a research and technology center in Galicia, Spain. It provides high-performance computing, communications, and quantum information technologies to researchers in Spain since 1993.

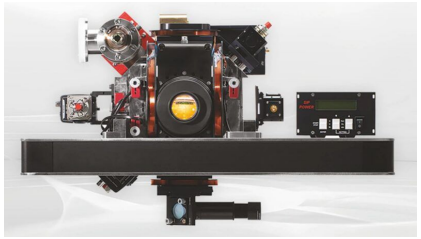
Introduction to the IGFAE-CESGA lab

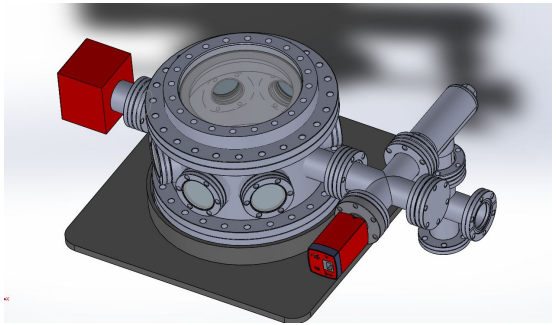
The IGFAE-CESGA laboratory features a trap-ion computer device provided by Alpine Quantum Technologies (AQT), spin-off from the University of Innsbruck and the Institute of Quantum Optics and Quantum Information at the Austrian Academy of Sciences.

In January 2026, an AQT Pine Set-Up will be installed at the new IGFAE-CESGA laboratory. Moreover, an independent R&D program on trapping devices will be launched by commissioning an additional ion trap setup, which will support the scaling of services and enable an intense R&D program within the laboratory.

It is expected that the facility will be available in July 2026, in time for the start of the **HORIZON-INFRA-2025-01-SERV-03** action.

AQT





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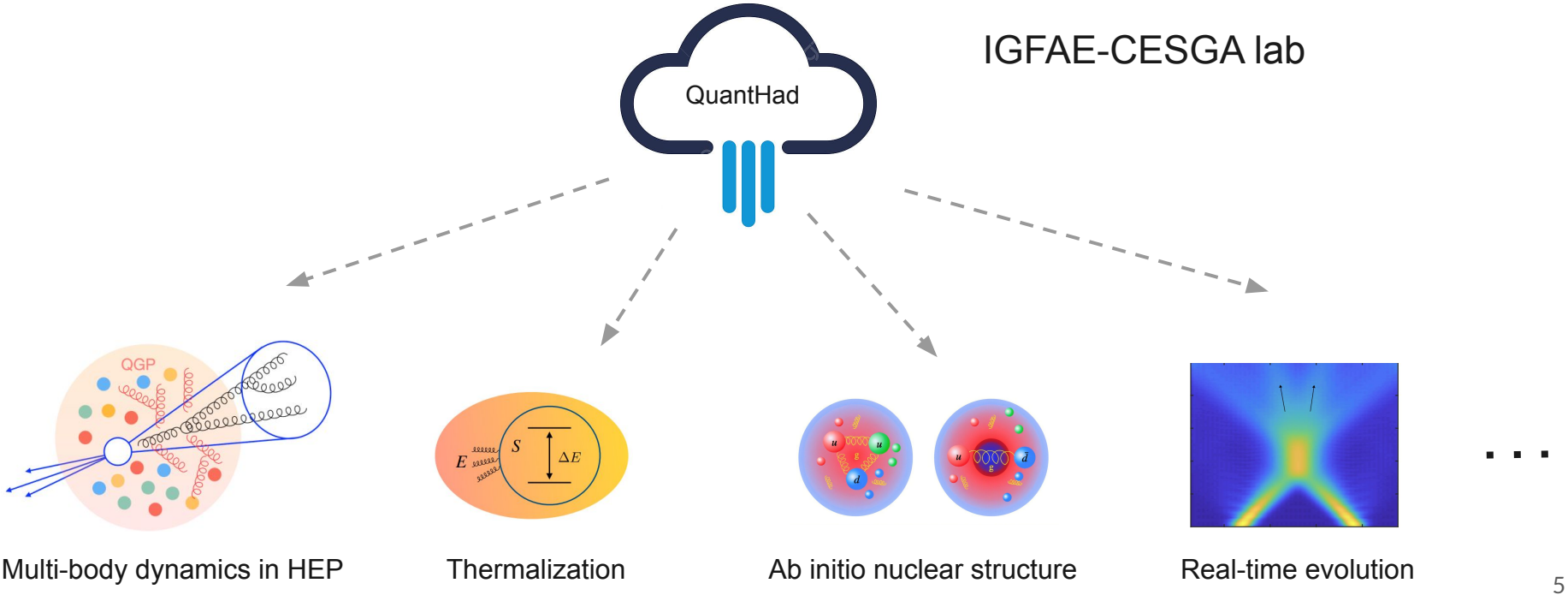
Introduction to the IGFAE-CESGA lab




The QuantHad proposal

With this LoI we would like to propose virtual access to this IGFAE-CESGA lab, thereby providing access to the hadronic and nuclear physics community in Europe with the opportunity to explore and benefit from the advances enabled by quantum computing.



The QuantHad proposal

Background:

Quantum computing is becoming an increasingly interesting tool in our field. While the available technology is still far from being useful for the applications in particle and nuclear physics, developing new algorithms is paralleled with new theoretical implementations.

A very promising avenue is to use the quantum devices as analog computers in which a target Hamiltonian containing the problem to solve is mapped into a physical Hamiltonian for which the hardware has to be configured.

The device to be installed at the IGFAE-CESGA Quantum Lab will work both as an analog and digital quantum computer.

The access to such infrastructures is still difficult for most of the European groups in our field, especially those interested in analog quantum computing.

The QuantHad proposal

How does it work:

This QuantHad proposal aims to introduce researchers in the field of hadron physics to this innovative technology, enabling them to gain hands-on experience and fostering the development of a new emerging community interested in exploring these advanced solutions.

The capabilities of this laboratory will be boosted by introducing a **unique** collaboration scheme: researchers may request assistance to map complex nuclear Hamiltonians onto ion-trap analogue simulators, leveraging the expertise of IGFAE-CESGA scientists in quantum control and simulation techniques to model nuclear interactions, explore many-body phenomena, and validate theoretical predictions through precise, experimentally accessible quantum simulations.

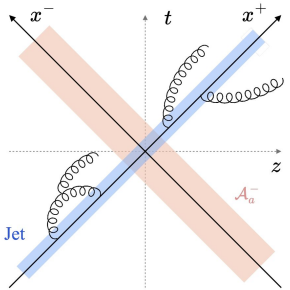
One possible example of application

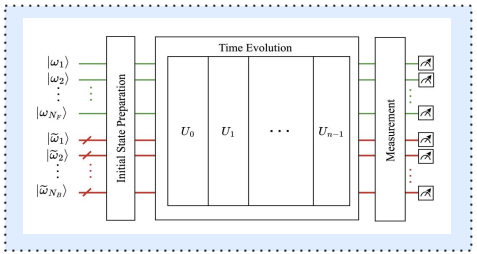
Simulating HEP jet phenomenology on analog quantum computer (JET-AQC)

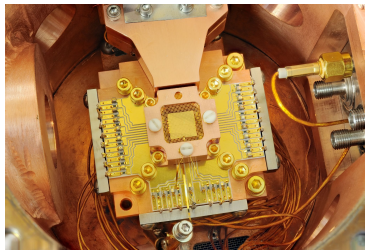
Goal:

Use trapped-ion analog quantum simulators to model real-time jet dynamics in high-energy physics, focusing on non-perturbative effects beyond reach of classical and digital methods.

- Analog quantum devices naturally evolve Hamiltonians, offering efficient, scalable simulations.
- Longer coherence times and continuous degrees of freedom make AQCs ideal for modeling jet–medium interactions.







Of course, there can be many different interesting research applications…

Estimated budget

We propose to provide a minimum 15% of the available computing time of the infrastructure to the present network – another 25% is reserved for access within the Spanish Supercomputing Network and the remaining 60% will be provided to local users.

- Operation costs are still to be computed, but an estimate would be 100 Euro/hour, including the time of the technicians, consumables, electricity, etc. Assuming a conservative 800h of efficient time per year, we estimate 12.000 Euros/year the cost to be funded by the present grant.

- The hiring of a PhD (3 years) and a postdoc (2 years), in charge of the development and mapping the quantum algorithms and providing support to the external users will be made, with an estimated cost of 200.000 Euros.

- Three workshops will be organized at IGFAE.

  A first startup meeting to make the infrastructure known to the whole community; and two meetings during the rest of the period reporting on actual calculations performed by the community which can be useful for other users. These workshops will be co-funded by IGFAE and CESGA. Total cost 50.000 Euros

Total request: 298.000 Euros

Collaborations