

# Preparing the Quantum Computing Revolution

Bogdan Vulpescu (LPC), D. Lacroix (IJCLab), A. Sartirana (LLR) on behalf of the QC2I project

*This prospective is part of the QC2I project objectives. Two contributions of the members of this project will present the other topics, one on the simulation of N-body complex quantum systems and another one on quantum machine learning.*

## Abstract:

With the arrival of the first quantum computer demonstrators, the field of quantum computing (QC) is rapidly gaining interest and visibility. Quantum computers are expected to be a disruptive technology allowing to perform computing tasks that are out of reach for classical machines (quantum supremacy) or tasks which can be far more efficiently solved on a quantum device than with a classical machine algorithm (quantum advantage). On the other hand, programming such devices is a formidable challenge that requires a radical change of paradigm in the IT science. The main goal of the QC2I project, created in January 2021, is to prepare the transition towards this “second quantum revolution”, for the technicians, engineers and researchers from the laboratories of IN2P3 who are interested in entering this emerging field. In this document we present the specific actions which we have planned for the coming years in order to reach this goal.

## Encourage and help the training and the qualification of QC experts

One of the topics of the QC2I project is to help the current and future experts to step into this subject, by providing common tools and a collaboration framework, towards building a strong QC community inside the IN2P3.

A special attention is given to the fact that this new type of informatics has very little in common with the “classical” informatics as we know from the past decades. The word “revolution” indicates, above all, the need to make a big effort in learning the fundamentals of this new kind of information technology and to open new views in understanding the role of the computing algorithms for the research domains which are specific to the laboratories at IN2P3. In this respect, the project will try to federate technicians, engineers and researchers and to facilitate their access to the needed resources in terms of theoretical training and hardware infrastructures.

To this purpose, several steps have been already accomplished and some possible actions are under study. Today, the QC2I project provides:

- a web site grouping information about the QC2I project, as well as a list of resources of general interest (<https://qc.pages.in2p3.fr/web/>):
  - a list of web tutorials, videos of lectures, seminars and other online learning resources,
  - references on a number of quantum processors providers,
  - textbooks on the theory of quantum computing: PDF files, book references, websites,
  - software resources for simulators and programming frameworks,



- specific tools, like QC “libraries” for the Quantum Machine Learning,
- places for exchanging information on QC, like forums,
- sites related to QC in France and abroad, of general interest and on subjects related to the research domains of IN2P3.
- a mailing list, a newsletter, a calendar, a channel on Mattermost (CERN) and a category on “indico” for the meetings,
- a GitLab (IN2P3) group with several projects and a Wiki page.

On the occasion of the announcement of the creation of the project, a survey has been launched among the 17 laboratories of IN2P3, proposing a list of questions aiming to evaluate the current interest for the domain of QC, the status of the knowledge and the availability in investing time and effort on a regular basis.

For the next future, the QC2I project is planning the following actions:

- organize workshops and schools with external interventions from the main national and international actors in the domain, on the model of the workshop organized in December 2019 at Orsay,
- open several “antennas” in the IN2P3 labs for the diffusion of the theoretical basis of QC, especially among the non-specialist IT personnel with no or little knowledge in the field of quantum mechanics and the mathematical tools involved,
- better define and understand the concept of “programming” and “programming language” in the case of the QC, for the usage of the software developers who must adapt their understanding in asking new questions about solving a problem relevant for a scientific project; as this part is today strongly dependent on the type of the quantum processor (technology used and topology), the fact that the definition of a “standard” is still far away raises the need to stay “alert” and follow closely the evolution of all the languages (high and low level equally) which are currently on the emerging market,
- facilitate access to hardware resources from the main providers (their number being in continuous evolution), especially to those parts which are not in free access, through possible academic agreements, wherever this will be possible,
- put a sizeable effort into growing experience on simulators, which represent an important step in understanding the sources of errors and the influence of the “lifetime” of the qubit states in quantum processors, but are very difficult to simulate on classical resources, starting from a given number of qubits; special technologies in classical computing may help this kind of studies, if we only think about using processing architectures based on Graphical Processing Units (GPU) or with Field Programmable Gate Arrays (FPGA) accelerators. The computing center of IN2P3 may play an important role in this respect,
- last but not least, connect the IT specialists to real thematic subjects for the application of QC on topics which are specific to the IN2P3 field of research (see the two other QC2I contributions).



In conclusion, after an initial campaign on advertising and searching for potential collaborators, we are on the path to create a critical size of the project and ready to start actions with echoes in several laboratories of IN2P3, according to the initial planning.

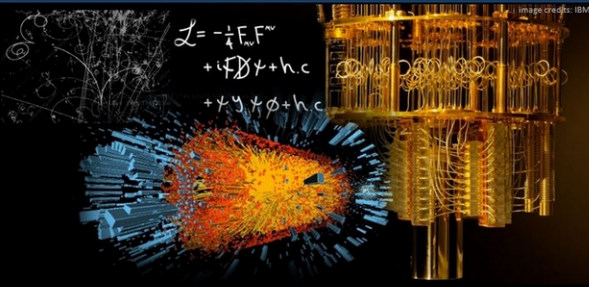
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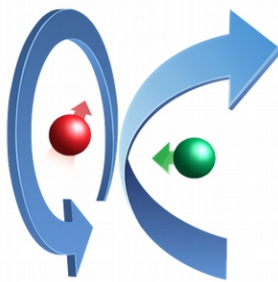
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# QC2I:

## Quantum Computing for the two Infinities





QC2I is a computing project supported by [IN2P3](#), the French national nuclear and particle physics institute. Its goal is to explore the possible applications of the emerging quantum computing technologies to particles and nuclear physics problems as well as astrophysics. The main tasks are:

- to identify, within IN2P3, scientists/engineers/technicians who are interested in using quantum technologies,
- to facilitate the access and training on quantum computers,
- to identify milestones applications for nuclear/particle physics and astrophysics,
- to design dedicated algorithms and proof of principle applications.

The project action has three main directions: **Prepare the Quantum Computing Revolution (PQCR)**, **Quantum Machine Learning (QML)**, **Complex Quantum Systems Simulation (CQSS)**