A dual-phase argon detector for the long-baseline neutrino experiment DUNE

Author : Raphaël Bajou - APC laboratory, Université de Paris

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Abstract : More elusive than any other observed particles, neutrinos propagate through any medium (space, earth rock, water, human body, etc.) with a very low probability of interacting weakly with an electron or a nucleus.

Whilst neutrinos are Standard Model particles existing under three types, so-called flavors, not all of their properties have been thoroughly explored. We know that they are massive particles since the discovery of neutrino oscillations, phenomenon that describes the change of flavor along neutrinos propagation. However we only know about how tiny is the sum of neutrinos masses ($\Sigma m_\nu < 0.1$ eV). It is also very likely that neutrinos oscillate differently as anti-neutrinos, meaning that the Charge-Parity (CP) symmetry is violated. Large CP violation, as expected for neutrinos, is one necessary ingredient to explain the matter dominance over anti-matter in our Universe.

The Deep Underground Neutrino Experiment (DUNE) will shed light on this while making precision measurements of neutrino oscillation parameters, by addressing the neutrinos elusiveness with a future gigantic argon detector of 40 kilotons. The neutrinos coming from an intense beam emitted 1300km away at Fermilab, will reveal their presence thanks to a high-resolution 3D imaging of particles tracks produced by neutrinos interactions on argon nuclei.

The design of this final far detector (FD) will be the outcome of an intense R&D program, the ProtoDUNE experiment, currently on-going at CERN. ProtoDUNE aims to demonstrate that the detection technology is able to match the requirements for the rich DUNE physics program.

My thesis fits into the study of a new neutrino detector prototype, called ProtoDUNE Dual-Phase. Among multiple advantages, the Dual-Phase design offers a large, fully active, and uniform liquid argon detection volume, which would maximize the number of neutrino events to be seen in DUNE. This is achieved by the presence of a gaseous argon phase on the top of the liquid phase allowing produced ionization tracks signals to be amplified and well reconstructed.

ProtoDUNE Dual-Phase, commissioned in August 2019, is now taking data coming from cosmic muons, whose analysis will lead to a better understanding of the Dual-Phase performances, and unveil its great detection potential for DUNE.