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**Description of the thesis topic**

Precision measurement of oscillation parameters and first mass ordering measurement with JUNO

The study of the phenomenon of neutrino oscillations allows the exploration of leptonic flavor mixing within the framework of the Standard Model (SM) of particle physics. The SM does not predict the oscillation parameters, which therefore need to be measured experimentally. This began with the SuperKamiokande and SNO experiments, awarded the Nobel Prize in Physics in 2015. Today, almost all experimental results fit into this three-flavor paradigm (e, mu, tau), and the parameters are increasingly well known, although the mass ordering (which neutrino is the lightest) and the CP violation phase (is the mixing the same for neutrinos and antineutrinos) are yet to be determined. The JUNO experiment, which will start in China in 2025, involves nearly 500 international scientists. It is one of the priority projects of CNRS/IN2P3. Its main goal is the ultra-precise measurement of the "oscillation" of antineutrinos produced by nuclear reactors 53 km from the detector. The latter consists of a 35 m diameter sphere filled with 20 kt of liquid scintillator, read by a grid of 40,000 photomultipliers.
The quantum phenomenon of oscillation, spontaneously changing the type of neutrinos, depends on parameters whose measurement informs us about the fundamental laws of particle physics. In 6 years, JUNO will improve the precision of these parameters by nearly an order of magnitude, and, above all, will determine the "mass ordering" of neutrinos at 3 sigma. This involves measuring the energy spectrum of antineutrinos with unprecedented precision.

**Work Context**

The proposed thesis within the Neutrino team at Subatech will focus on two main areas: the precise measurement of neutrino oscillation parameters and the initial attempt to determine the mass ordering with the JUNO experiment. This study will cover the first two years of data collection.
The use of advanced statistical methods is essential to analyze the spectrum with the required precision. The development of these methods began at Subatech using a statistical analysis framework adapted from the Double Chooz experiment. The first phase of the thesis will involve setting up this analysis framework for the first measurement (100 days of data) of the oscillation parameters, which will be crucial for the credibility of JUNO. These initial measurements will enable JUNO to possess the most precise measurements of the accessible oscillation parameters (θ12, Δm²31, and Δm²21).
The second phase will involve improving this framework for a second measurement (over 2 years) to bring the precision of all parameters below one percent. The third objective will be to develop it to credibly combine JUNO's data with those from other leading global experiments. This could constrain the mass ordering to better than 3 sigma well before the 6 years required if JUNO were alone.
Another crucial aspect will be the precise and reliable reconstruction of the energy of each antineutrino. The thesis will develop dual-calorimetry techniques based on JUNO's double readout system, of which the Subatech team is one of the pioneers, to control associated errors and biases. Similarly, we will continue exploring innovative deep learning methods emerging from pioneering work within this team.

The candidate (M/F) must :
- have a Master's degree in particle physics, hadronic physics or nuclear physics
- experience in computer programming (proficiency in C++ and Python)
- Good listening, writing and speaking skills in English
- Ability to work as part of a team and within a large scientific collaboration