Development of a muon reconstruction algorithm for JUNO using joint information from all sub-detectors

The experimental observation of neutrino oscillations was an essential discovery at the end of the last century. This discovery demonstrated that neutrinos have a non-zero mass in disagreement to the expectation from the Standard Model of Particle Physics. Neutrino oscillations are described by the PMNS mixing matrix (parametrized by 3 mixing angles and 1 CP violating phase) and the squared mass difference between the different mass states. Since the discovery of neutrino oscillations several of those parameters have been measured, however there are still two unknowns: the CP violating phase and the neutrino mass ordering, that is which neutrino is the lightest. JUNO [1] is currently in construction in China with its main goal to measure the neutrino mass ordering using reactor neutrinos.

The JUNO detector is composed of 3 different parts: the Central Detector (CD), the Water Cherenkov Detector (WCD), and the Top Tracker (TT). The CD is the part of JUNO where neutrinos are measured, while the TT and WCD are part of the Veto System of JUNO that is designed to identify and suppress the external backgrounds. One of the main backgrounds in JUNO, to measure reactor neutrino oscillations, is cosmogenic isotopes produced in JUNO's CD by the passage of atmospheric muons. The difficulty of rejecting these events comes from the fact that, from the detector point of view, they have the same characteristics as the neutrino interactions of interest. In order to effectively reject them, it is necessary that we track almost all atmospheric muons crossing the CD and then reject events looking like neutrinos that are correlated in space and time to these muons.

The TT is a plastic scintillator detector placed on top of the WCD, which surrounds the CD, to track atmospheric muons passing through it's volume. Historically, the TT was built at IPHC for the OPERA experiment, and after the end of OPERA it is being re-purposed to be used in JUNO. Thanks to this history, the IPHC is one of the leading contributors to the development of the TT within JUNO and is responsible for the good working condition of this detector.

The goal of this internship is to develop a reconstruction method for the muons using information from the CD, WCD and TT. All three detectors will record the information about any passing muons independently using different experimental techniques. While there are already several existing algorithms to reconstruct muons in each detector, they currently work independently and it's not trivial to properly combine the information from all subsystems. In the beginning of the internship the student will need to understand the various methods already available to then propose a method to combine the information of all detectors. This method should then be implemented and tested using simulation.

This internship might be followed by a related PhD thesis in the Neutrino group.

[1] JUNO Collaboration, Prog. Part. Nucl. Phys. **123** (2022), 103927 [arXiv:2104.02565].

Practical infos:

- Application deadline: December 31st, 2021
- Start date: March 1st, 2022

Contacts:
João Pedro A. M. de André • jpandre@iphc.cnrs.fr
Rebin Karaparambil • rebin.karaparambil@iphc.cnrs.fr