Development of a reconstruction algorithm for the JUNO Top Tracker

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. One key component in this strategy is the TT.

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.

In this internship the student will be led to develop a reconstruction algorithm for the JUNO TT. The current existing reconstruction method is based on a χ^2 fit of the data, however it can become very inefficient in case there is an increased noise rate in the detector. Given that noise induced PMT triggers will typically be distributed randomly, while PMT triggers from muons are expected to be aligned, we can profit of this topological difference to select which PMT triggers belong to the muon track we need to reconstruct. One possible method to do this selection is the Hough method. During the internship the student will start by implementing this method and tuning it to work in the context of the Top Tracker. Provided the implementation and tuning of the Hough method are completed, alternative methods using other techniques (likelihood, machine learning, ...) can also be studied.

[1] F. An *et al.* [JUNO], J. Phys. G **43** (2016) no.3, 030401 [arXiv:1507.05613].

Practical infos:

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

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