Letter of Interest for Snowmass 2021

August 30, 2020

Energy reconstruction technique for very high energy muons with a liquid-argon TPC using neural networks

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This LOI describes the development of a new energy reconstruction technique for very high energy muons in an experiment like the Deep Underground Neutrino Experiment. DUNE will be a world-class neutrino observatory and nucleon decay detector, designed to answer fundamental questions about the nature of elementary particles and their role in the Universe with ability to detect Supernova (SN) burst neutrinos and atmospheric neutrinos. Measurements of neutrino oscillation parameters will be made by comparing the detected event rates in the far detector with the predicted rates as obtained from the un-oscillated neutrino flux measured at the near detector. At a depth of around 1480 m (4.30 km.w.e) underground, the DUNE far detector will be the biggest liquid argon time projection chamber (TPC). It can be used to study astrophysical objects through cosmic neutrinos that can hardly be observed through other messenger particles. It will also search for Weakly Interacting Massive Particles (WIMPs) using neutrino-induced upward through-going muons. The energies of the incoming neutrinos that interact in the far detector are unknown and they must be reconstructed precisely (low energy for oscillation physics and "high" energy for WIMP searches).

The existing direct and indirect methods of muon spectrometry at accelerator-based and at cosmic rays (magnetic spectrometers, transition radiation detectors) experiments involve certain technical problems and limitations in the higher energy region. These disadvantages vanish in this alternate method where the muon energy is estimated by measuring the energy of secondary cascades formed by muons losing their energy in the matter, mainly due to the Bremsstrahlung process [1]. In our research work, we are attempting to implement this technique to reconstruct the energy of the muon (in the TeV range) and its direction at LArTPC proposed for an experiment like DUNE as described above. Some preliminary analysis work using GEANT4 and LArSoft toolkit used for simulation and the reconstruction of high energy muons in the TeV range based on the traditional technique can be found in [2]. Recently the IceCube collaboration demonstrated how deep learning techniques such as those used in image recognition can be applied to IceCube pulses in order to reconstruct muon-neutrino events [3, 4]. These methods can be generalized to other physics experiments that have large-volume liquid argon TPCs, such as DUNE.

References

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