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Search for Heavy Neutral Leptons in KM3NeT/ORCA using Graph Neural Networks

KM3NeT is an underwater neutrino telescope consisting of two detectors, ARCA and ORCA, situated off the coast of Italy and France respectively, which detect neutrinos through Cherenkov radiation. The detectors, each an array of vertical detection lines, are being deployed while already taking data.

Neutrino oscillations, implying neutrino masses, are clear evidence of physics beyond the Standard Model. One class of models that explains these masses introduces right-handed sterile neutrinos, much heavier than the standard neutrinos, also known as Heavy Neutral Leptons (HNLs). In this work, we consider the dipole portal, in which the HNL couples to neutrinos through a transition magnetic dipole operator. In ORCA, this can produce a first shower at the interaction vertex. The HNL would have a certain lifetime and further decay to a photon, thereby producing a secondary shower. Hence, the signal would be a double shower, with a separation ranging from few to a few hundred metres, to be compared with the 20m spacing between ORCA's detection lines.

To search for these rare double-shower events we use a machine learning approach. A Graph Neural Network is trained in several stages, first for classification of HNL samples from atmospheric neutrinos, and then to regress the distance travelled by the HNL and the interaction point of the first shower. The obtained observables will then be fed into a boosted decision tree, to isolate a background-free HNL sample. Using this selection, we derive ORCA's sensitivity to the dipole portal model with the current 18-line configuration, with further improvement expected as the detector, and its dataset, continue to grow.

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