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Data-driven identification of light signals from low-energy recoils in a LAr TPC using self-supervised machine learning

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The Recoil Directionality (ReD) project, within the Global Argon Dark Matter Collaboration, aims to characterize the response of an argon double-phase Time Projection Chamber (LAr TPC) to low energy neutron-induced nuclear recoils (NR). Signals collected by Silicon Photomultipliers (SiPMs) in the LAr TPC are the prompt scintillation light in liquid (S1) and the delayed electroluminescence (S2) in gas. S2 signal is due to the electrons produced by ionization in liquid and drifted by an electric field towards the gas-liquid interface. For NRs in the few-keV range, the S1 signal is difficult to observe, thus making it crucial to measure effectively the ionization yield in argon.
A new data-driven technique involving self-supervised machine learning, in particular convolutional autoencoders (CAE), has been developed to improve the background rejection in S2-only events. A CAE is a feed-forward neural network composed of two parts: an encoder, that compresses the information into a compact representation of reduced dimensionality, and a decoder, that aims to reconstruct the input from the reduced representation. In this analysis, the CAE is trained on a dataset of signals produced in the ReD TPC by neutrons and gamma-rays of a ^{252}Cf source, reducing each raw waveform (averaged over the SiPMs) into a 4-dimensional vector. The features of such compressed representation have been studied, developing a method to tag traces without pulses with a sensitivity, in the low-energy recoils region, comparable to the ReD conventional reconstruction.

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