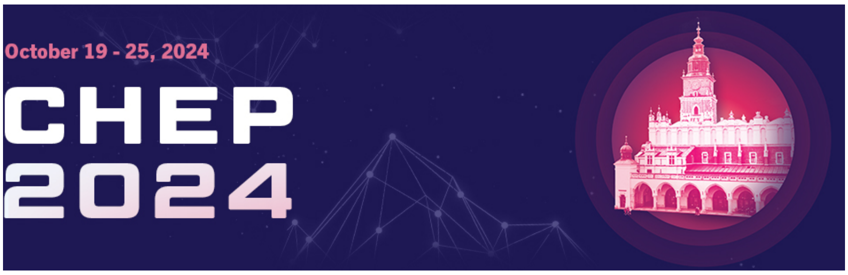

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Track classification in Active Target Time Projection Chamber using supervised machine learning methods

In low-energy nuclear physics experiments, an Active Target Time Projection Chamber (AT-TPC) [1] can be advantageous for studying nuclear reaction kinematics. The α-cluster decay of ^{12}C is one such reaction requiring careful investigation due to its vital role in producing heavy elements through astrophysical processes [2]. The breakup mechanism of the Hoyle state, a highly α-clustered state at 7.65 MeV in ^{12}C, has long been an important case of study using different experimental techniques to investigate its decaying branch ratio. The direct decay of the Hoyle state into three α-particles and the sequential decay via the ^{8}Be ground state into three α-particles can be identified by tracking the α-particles and measuring their energies, which can be accomplished with AT-TPC.
In this work, a numerical model using Hough transformation and neural network models for track separation and classification has been developed for identifying the breakup of Hoyle state ^{12}C into three α-particles from the background scattering events in the active volume. The reaction kinematics of the decay of ^{12}C have been determined using low-energy non-relativistic scattering of α-particles on ^{12}C. The event tracks in the active gas medium of the AT-TPC have been generated through primary ionization created by the α-particles produced in the aforementioned reaction. This has been carried out using the Geant4 [3] simulation framework. The three α-tracks have then been individually separated from the others and the background (uniform random noise generated) using the Hough transformation. Each α-track has been fitted with a CrystalBall function to extract the features useful for training the Artificial Neural Network (ANN) model. A Convolutional Neural Network (CNN) model has also been developed to identify all possible scattering events of ^{4}He and ^{12}C in the lab frame which are labeled as background events. These events have been further labeled by binary and multi-class classification models, which have been trained using simulated data. For this purpose, a fully connected ANN and CNN with hidden layers have been implemented using the high-level deep learning library Keras, written in Python [4]. The model has been tested on the events generated using simulation. Thus, it has been possible to precisely classify the Hoyle state α-particles from background events. This model can also be beneficial as an automated analysis framework for tagging and separating events from experimental data.

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[2] M. Freer, Reports on Progress in Physics 70, 2149 (2007)

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Primary author: DAS, Pralay Kumar

Co-authors: MAJUMDAR, Nayana (Saha Institute of Nuclear Physics); MUKHOPADHYAY, Supratik

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