Deep neural networks help to identify the neutrinoless double beta decay signal

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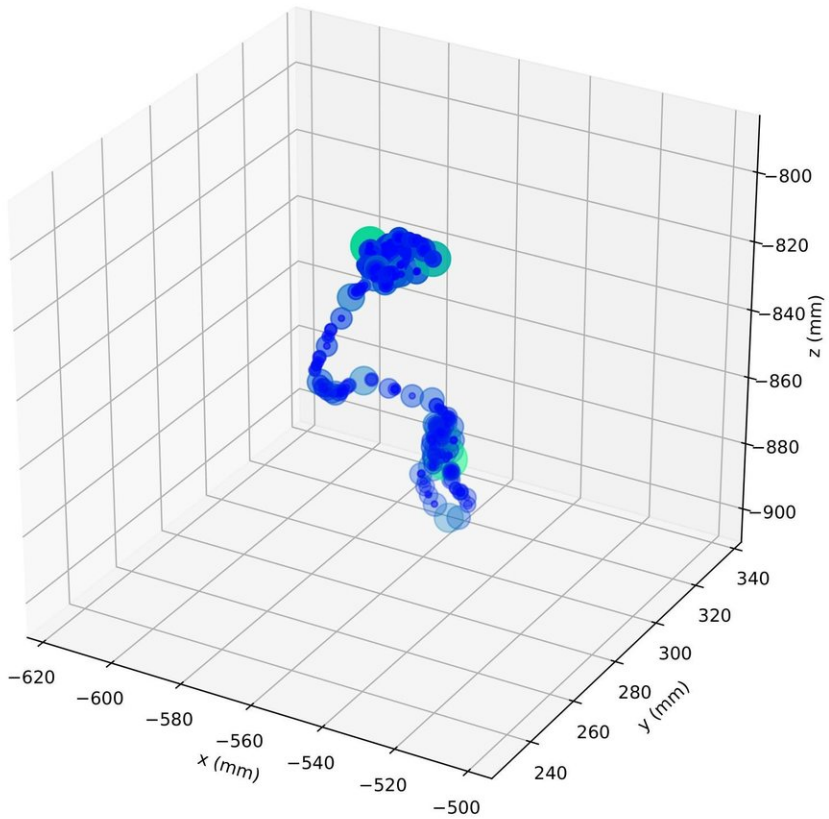


The simulated tracks resulted from electrons emitted in a neutrinoless double

beta decay event. Credit: ©Science China Press

A group of researchers from Shanghai Jiao Tong University and Peking University greatly improved the discrimination power of tracks from different particles passing through the gaseous detector with the help of deep convolutional neural networks. The work will help to improve the sensitivity of detection for the PandaX-III neutrinoless double beta decay experiment, and deepen our knowledge of the nature of neutrinos.

This work is published by *Science China Physics, Mechanics & Astronomy* (SCPMA) with the title "Signal-background discrimination with convolutional neural networks in the PandaX-III experiment using MC simulation." Hao Qiao, a master student from Peking University, is the first author.

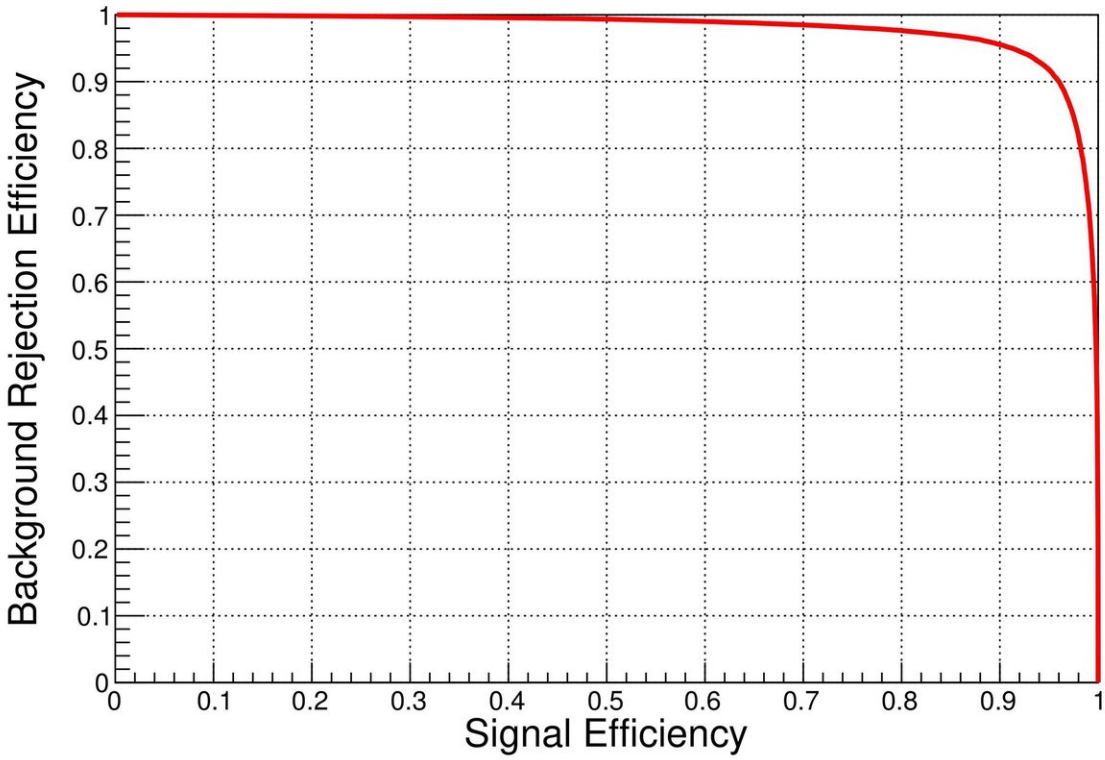
Double beta decay is a phenomenon in which two electrons and two neutrinos are emitted. The so called neutrinoless double beta decay, without the emission of neutrinos, is directly related to the nature of the neutrino itself, and has not been observed in any experiments. The process is only possible when neutrino is Majorana fermion, or, neutrino and anti-neutrino are the same. Scientists suspect that such property is also key to understanding the asymmetry between matter and antimatter in our universe.

Specially designed experiments might be able to find the rare neutrinoless double beta decay process. Among them, the PandaX-III experiment plans to search for the neutrinoless double beta decay of the Xe-136 isotope with a high pressure gaseous xenon time projection chamber. It will not only record the energy of the electrons produced in the process, but also take "snapshot" of their tracks in the detector, obtaining the projections on two mutually perpendicular planes parallel

to the drifting direction. The features of the tracks can be used for the discrimination between desired signals and backgrounds. But the stochastic property makes it challenging to define and identify the features of neutrinoless double beta decay signals. One example of the simulated tracks resulted from a neutrinoless double beta decay event is shown in Fig. 1.

"The traditional topological method for track discrimination employs only two widely used parameters. More features are desirable, but are difficult to find out," said Siguang Wang, associated professor of Peking University and author of this work.

On the other hand, great improvements have been achieved in image classification with technologies based on the convolutional neural networks. This inspired the researchers of this work to apply these technologies in the discrimination of different particle tracks. The corresponding author, Xun Chen, assistant research fellow in Shanghai Jiao Tong University, thought that it might lead to better results in comparison with the traditional method.



The curve of background rejection efficiency versus signal efficiency from the trained model. Credit: ©Science China Press

The researchers constructed a detailed simulation of the PandaX-III detector in a computer and generated data of both signal and background events. The data were converted to images, and the snapshots taken by the detector were encoded to the color channels of the images.

Hao explained, "You need to consider the spatial and time distribution of the detected signal simultaneously and make a cut on them when converting the data to images, because the neutral network limits the size of the input image."

About 560,000 images of the neutrinoless double beta decay events and the same number of images for the high energy gamma backgrounds were generated. The researchers used 80 percent of the data set to train the neural network models.

"We started from a simple model with only three layers, and then tried more complicated models. We finally chose the ResNet50 model for our studies," said Chunyu Lu, an undergraduate student from Shanghai Jiao Tong University, co-author of the article.

The final trained model showed excellent signal-background discrimination power. Relative high signal efficiency is retained with a high background rejection efficiency, as shown in Fig. 2. The efficiency has been improved by 62 percent in comparison with the baseline method defined in the design of PandaX-III experiment. This also implies that the detection sensitivity of the neutrinoless double beta decay process in the PandaX-III experiment could be improved greatly.

Ke Han, a distinguished research fellow of Shanghai Jiao Tong University and a co-author, commented, "CNN mades the tracking capability of PandaX-III more distinctive and attractive in the crowded field of neutrinoless double beta decay experiments."

More information: Hao Qiao et al, Signal-background discrimination with convolutional neural networks in the PandaX-III experiment using MC simulation, *Science China Physics, Mechanics & Astronomy* (2018). DOI: 10.1007/s11433-018-9233-5

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