Spotting accelerator-produced neutrinos in a cosmic haystack

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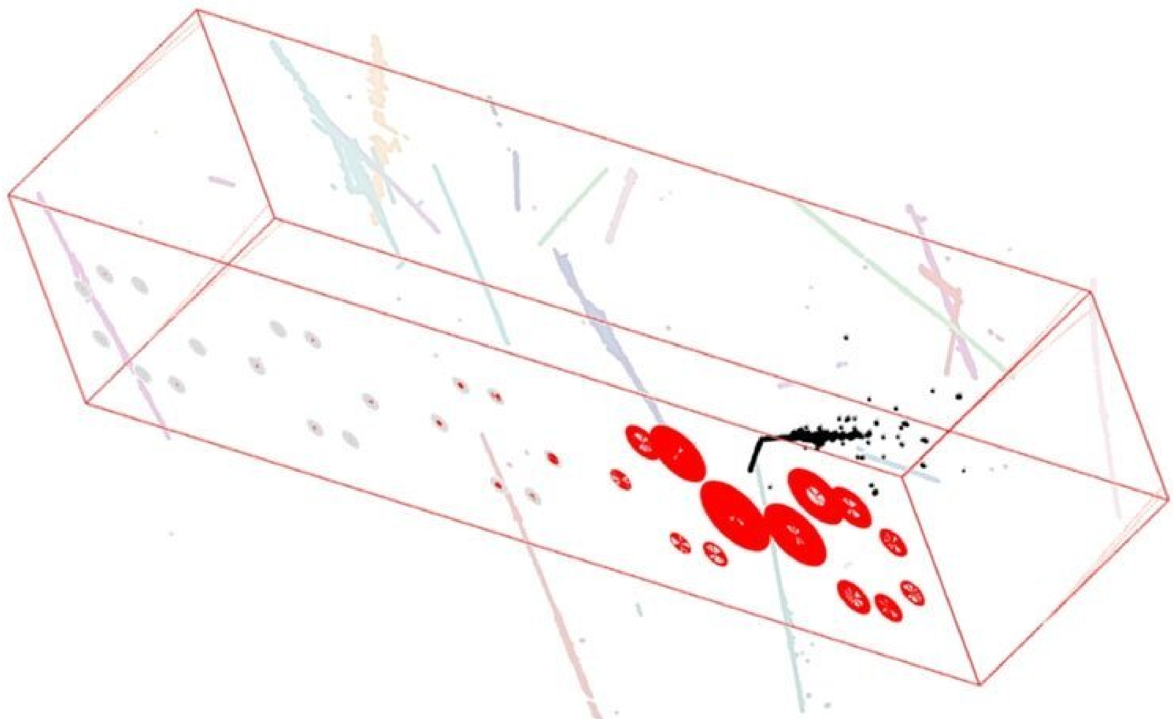

In these MicroBooNE data, electron-neutrino interaction tracks (black) paired with the corresponding light signals from photomultiplier tubes (red circles) stand out clearly from the many tracks produced by cosmic rays (dimly colored lines). Credit: MicroBooNE experiment

Physicists have developed new tools to help tone down the cosmic "noise" when searching for signs of particles called neutrinos in detectors located near Earth's surface. This method combines data-sifting techniques with image reconstruction methods similar to the computerized tomography (CT) scans used in medicine. It makes the signals of neutrinos produced by a particle accelerator stand out against the "web" of tracks produced by cosmic rays. These cosmic travelers are 20,000 times more numerous than neutrino interactions in the detector. Filtering out the many tracks from cosmic rays should improve experiments on the Earth's surface that are seeking to understand the behavior of the subatomic neutrinos.

Scientists developed the new technique for the MicroBooNE detector. MicroBooNE is one of three detectors that are tracking neutrinos produced by an accelerator at Fermilab. Scientists are trying to understand how these subatomic particles change among three "flavors" by counting the number of each type at different distances from the accelerator. Spotting discrepancies in neutrino counts could help scientists understand the mechanism of flavor-shifting, called oscillation. It might also indicate the existence of a fourth neutrino variety. The approach should work at all surface-based neutrino detectors, where cosmic rays can obscure signals, and it will benefit the entire U.S. neutrino research program.

Neutrino detectors at Earth's surface need to pick out the signals of elusive neutrino interactions from the background "noise" of cosmic rays. MicroBooNE detects tracks produced when charged particles from neutrino interactions ionize argon atoms in the detector. Three planes of wires in the MicroBooNE experiment are sensitive to electrons in the ionization trails. Each plane captures an image of the track in two dimensions. Computers assemble the 2D images into 3D tracks—similar to the way computed tomography (CT) scanners reconstruct 3D images of internal organs from 2D "slice-like" snapshots of the human body. At MicroBooNE, the shape of the track tells scientists which flavor of neutrino triggered the interaction. To weed out thousands of tracks produced by cosmic rays, scientists first match the track signals with flashes of light also produced in neutrino interactions. The team developed algorithms to help compare the timing and light patterns for each photomultiplier tube in the detector with the locations of all of the particles' tracks. No match means it's not a neutrino event. They also developed methods to eliminate tracks that completely traverse the detector and spot tracks that originate in the detector, rather than outside, completing the job of zeroing in on the neutrino events.

More information: P. Abratenko et al, Cosmic Ray Background Rejection with Wire-Cell LArTPC Event Reconstruction in the MicroBooNE Detector, *Physical Review Applied* (2021). DOI: 10.1103/PhysRevApplied.15.064071

P. Abratenko et al, Neutrino event selection in the MicroBooNE liquid argon time projection chamber using Wire-Cell 3D imaging, clustering, and charge-light matching, *Journal of Instrumentation* (2021). DOI: 10.1088/1748-0221/16/06/P06043

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