3-D-printed neutrino detectors

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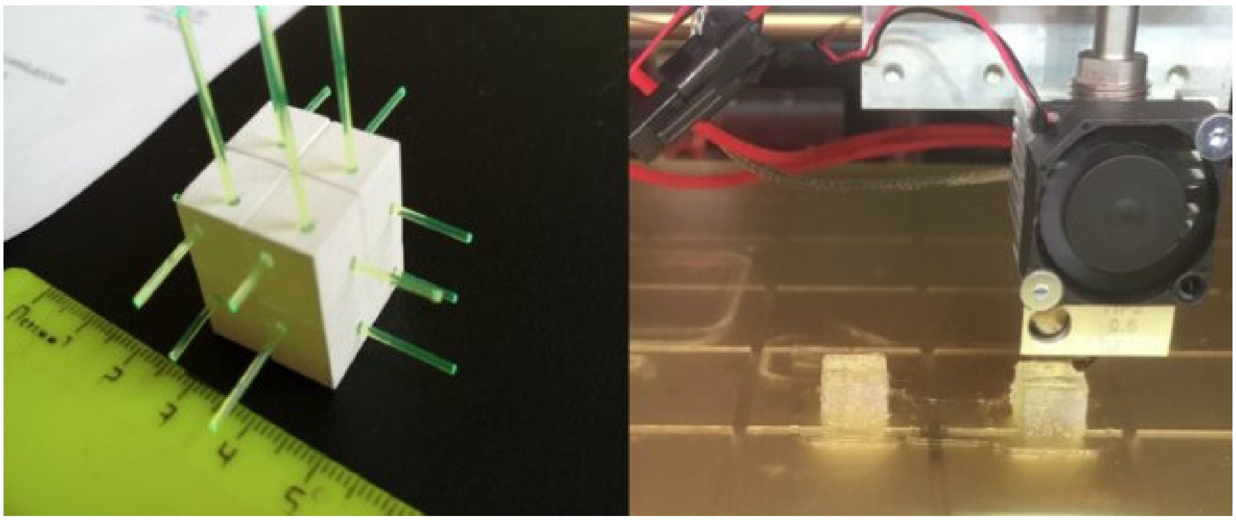

Example of a plastic Scintillator detector (left) and a stage of its 3D-printing process (right). Credit: CERN

Plastic scintillators are one of the most used active materials in high-energy physics. Their properties make it possible to track and distinguish between particle topologies. Among other things, scintillators are used in the detectors of neutrino oscillation experiments, where they reconstruct the final state of the neutrino interaction. Measurements of oscillation phenomena are carried out through comparison of observations of neutrinos in near detectors (close to the target) and far detectors (up to several hundred kilometers away).

CERN is strongly involved in the T2K experiment, the current worldleading neutrino oscillation experiment, in Japan, which recently released promising results. A future upgrade of the experiment's near detector will pave the way for more precise results. The novel detector will comprise a two-ton polystyrene-based plastic scintillator detector segmented into 1 x 1 x 1 cm^3 cubes, leading to a total of around two million sensitive elements: the smaller the cubes, the more precise the results. This technology could be adopted for other projects, such as the DUNE near detector. However, more precise measurements would require finer granularity, making the detector assembly harder.

This is where the CERN EP-Neutrino group—led by Albert De Roeck—steps in, developing a new plastic scintillator production technique that involves additive manufacturing. The R&D is carried out in collaboration with the Institute for Scintillation Materials (ISMA) of the National Academy of Science of Ukraine, which has strong expertise in the development of scintillator materials, and the Haute École d'Ingénierie et Gestion du Canton de Vaud (HEIG-VD), which is expert in additive manufacturing. The final goal is to 3-D-print a "super-cube," that is, a single massive block of scintillator containing many optically independent cubes. 3-D-printing would solve the issue of assembling the individual cubes, which could thus be produced in any size, including smaller than 1 cm^3, and relatively quickly (volumes bigger than 20 x 20 x 20 cm^3 can be produced in about a day).

So far, the collaboration has been fruitful. A preliminary test gave the first proof of concept: the scintillation light yield of a polystyrene-based scintillator 3-D-printed with fused deposition modeling has been found to be comparable to that of a traditional scintillator. But the road towards a ready-to-use super-cube is still long. Further optimisation of the scintillator parameters and tuning of the 3-D-printer configuration, followed by a full characterisation of the 3-D-printed scintillator, will need to be achieved before the light reflector material for optically isolating the cubes can be developed.

This new technique could also open up new possibilities for the field of particle detection. A successful 3-D-printed plastic scintillator detector could pave the way for a broader use of this technology in detector building, which could shake up the field of high-energy physics, as well as that of medicine, where particle detectors are used, for instance, in cancer therapy. Moreover, the greatly cost-effective 3-D-printer could be replicated quite easily and used in a vast number of settings. Umut Kose, from the EP-neutrino group and Neutrino Platform at CERN, explains: "Our dream goes beyond the super-cube. We like to think that, in a few years, 3-D-printing will allow high-school students to make their own radiation detection systems. The outreach potential of this technology is mind-blowing."

Davide Sgalaberna, now at ETH Zurich, cannot hide his enthusiasm for this adventure: "This is the first time that 3-D-printing could be used for real particle detectors. We are transforming our personal will into a project, and we are hopeful that this could lead to a breakthrough. That is thrilling." This thrill is shared by Davide's colleagues, who are more than ready to resume work on the 3-D-printed detector once the easing of lockdown allows everyone to return to CERN.

Provided by CERN