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# Collider neutrinos on the horizon

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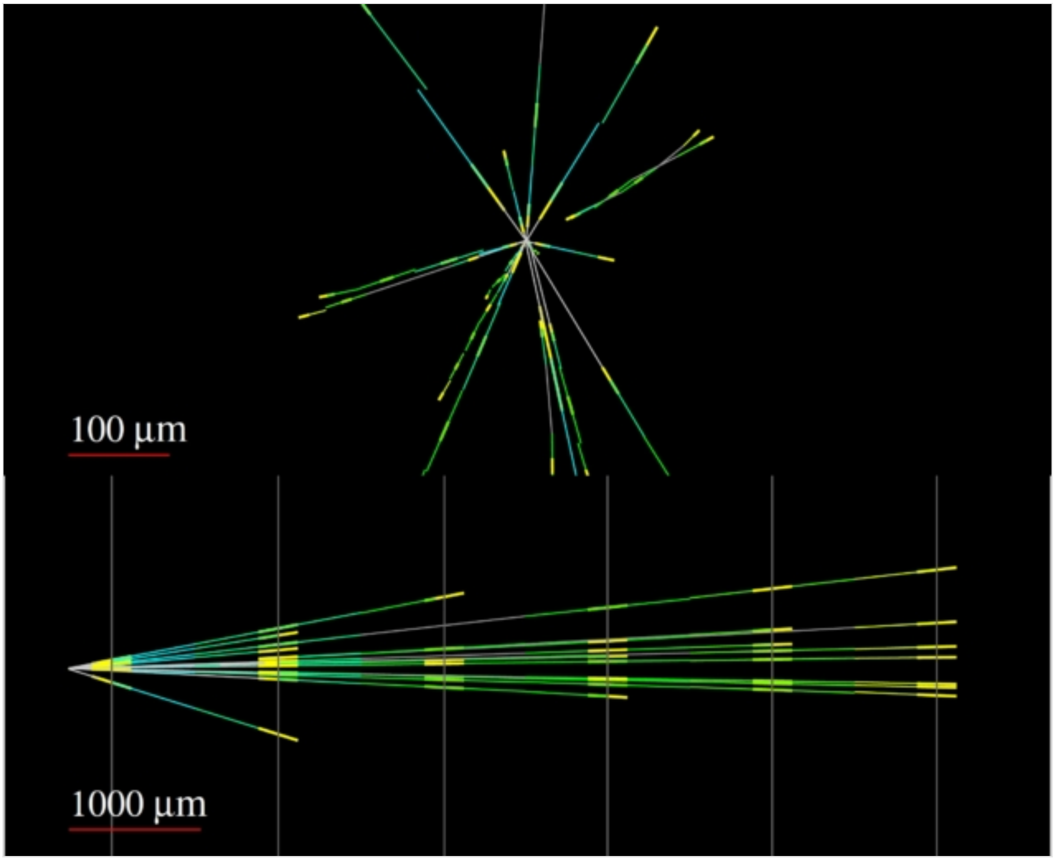



**New territory** Two candidate collider-neutrino events from the FASERν pilot detector in the plane longitudinal to (top) and transverse to (bottom) the beam direction. The different lines in each event show charged-particle tracks originating from the neutrino interaction point. Credit: FASER Collaboration.

Think "neutrino detector" and images of giant installations come to mind, necessary to compensate for the vanishingly small interaction probability of neutrinos with matter. The extreme luminosity of proton-proton collisions at the LHC, however, produces a large neutrino flux in the forward direction, with energies leading to cross-sections high enough for neutrinos to be detected using a much more compact apparatus.

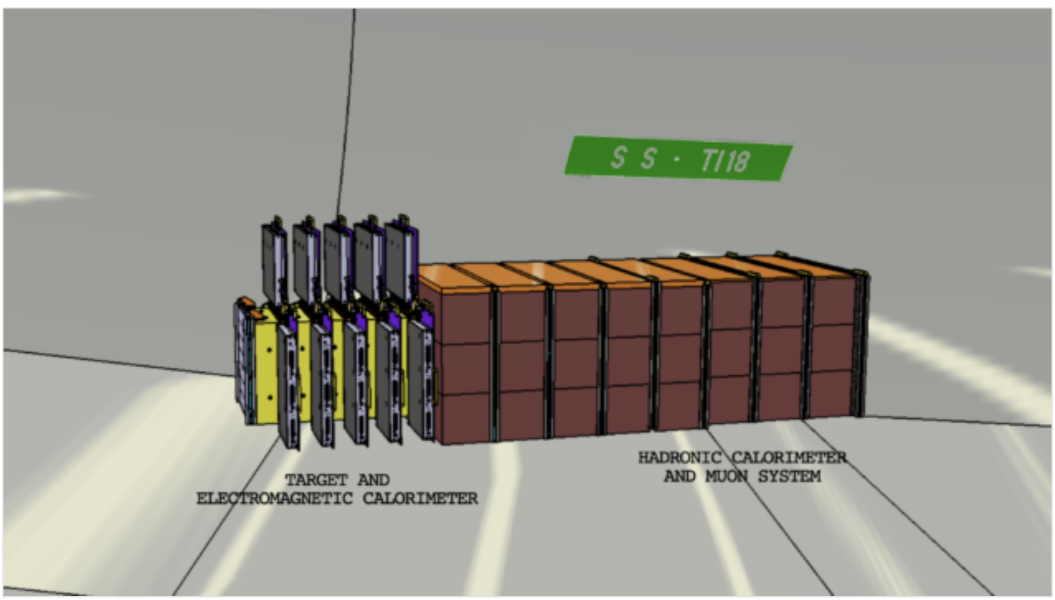
In March, the CERN research board approved the Scattering and Neutrino Detector (SND@LHC) for installation in an unused tunnel that links the LHC to the SPS, 480 m downstream from the ATLAS experiment. Designed to detect neutrinos produced in a hitherto unexplored pseudo-rapidity range ($7.2 < \eta < 8.6$), the experiment will complement and extend the physics reach of the other LHC experiments — in particular FASERν, which was approved last year. Construction of FASERν, which is located in an unused service tunnel on the opposite side of ATLAS along the LHC beamline (covering $|\eta|>9.1$), was completed in March, while installation of SND@LHC is about to begin.

Both experiments will be able to detect neutrinos of all types, with SND@LHC positioned off the beamline to detect neutrinos produced at slightly larger angles. Expected to commence data-taking during LHC Run 3 in spring 2022, these latest additions to the LHC-experiment family are poised to make the first observations of collider neutrinos while opening new searches for feebly interacting particles and other new physics.



**Neutrinos galore**

SND@LHC will comprise 800 kg of tungsten plates interleaved with emulsion films and electronic tracker planes based on scintillating fibres. The emulsion acts as vertex detector with micron resolution while the tracker provides a time stamp, the two subdetectors acting as a sampling electromagnetic calorimeter. The target volume will be immediately followed by planes of scintillating bars interleaved with iron blocks serving as a hadron calorimeter, followed downstream by a muon-identification system.



The SND@LHC detector, which is about to begin installation. Credit: SND@LHC.

During its first phase of operation, SND@LHC is expected to collect an integrated luminosity of 150 $fb^{-1}$, corresponding to more than 1000 high-energy neutrino interactions. Since electron neutrinos and antineutrinos are predominantly produced by charmed-hadron decays in the pseudorapidity range explored, the experiment will enable the gluon parton-density function to be constrained in an unexplored region of very small x. With projected statistical and systematic uncertainties of 30% and 22% in the ratio between $\nu_e$ and $\nu_\tau$, and about 10% for both uncertainties in the ratio between $\nu_e$ and $\nu_\mu$ at high energies, the Run-3 data will also provide unique tests of lepton flavour universality with neutrinos, and have sensitivity in the search for feebly interacting particles via scattering signatures in the detector target.

"The angular range that SND@LHC will cover is currently unexplored," says SND@LHC spokesperson Giovanni De Lellis. "And because a large fraction of the neutrinos produced in this range come from the decays of particles made of heavy quarks, these neutrinos can be used to study heavy-quark particle production in an angular range that the other LHC experiments can't access. These measurements are also relevant for the prediction of very high-energy neutrinos produced in cosmic-ray interactions, so the experiment is also acting as a bridge between accelerator and astroparticle physics."

**A FASER first**

FASERν is an addition to the Forward Search Experiment (FASER), which was approved in March 2019 to search for light and weakly interacting long-lived particles at solid angles beyond the reach of conventional collider detectors. Comprising a small and inexpensive stack of emulsion films and tungsten plates measuring 0.25 x 0.25 x 1.35 m and weighing 1.2 tonnes, FASERν is already undergoing tests. Smaller than SND, the detector is positioned on the beam-collision axis to maximise the neutrino flux, and should detect a total of around 20,000 muon neutrinos, 1300 electron neutrinos and 20 tau neutrinos in an unexplored energy regime at the TeV scale. This will allow measurements of the interaction cross-sections of all neutrino flavours, provide constraints on non-standard neutrino interactions, and improve measurements of proton parton-density functions in certain phase-space regions.

## The final detector should do much better — it will be a hundred times bigger

**Jamie Boyd**

In May, based on an analysis of pilot emulsion data taken in 2018 using a target mass of just 10 kg, the FASERν team reported the detection of the first neutrino-interaction candidates, based on a measured $2.7\sigma$ excess of a neutrino-like signal above muon-induced backgrounds. The result paves the way for high-energy neutrino measurements at the LHC and future colliders, explains FASER co-spokesperson Jamie Boyd: "The final detector should do much better — it will be a hundred times bigger, be exposed to much more luminosity, have muon identification capability, and be able to link observed neutrino interactions in the emulsion to the FASER spectrometer. It is quite impressive that such a small and simple detector can detect neutrinos given that usual neutrino detectors have masses measured in kilotons."

**Further reading**

FASER Collaboration 2021 arXiv:2105.06197.

SHiP Collaboration 2020 arXiv:2002.08722.

**Matthew Chalmers**, editor