Nuclear emulsion tasks in the SND@LHC experiment

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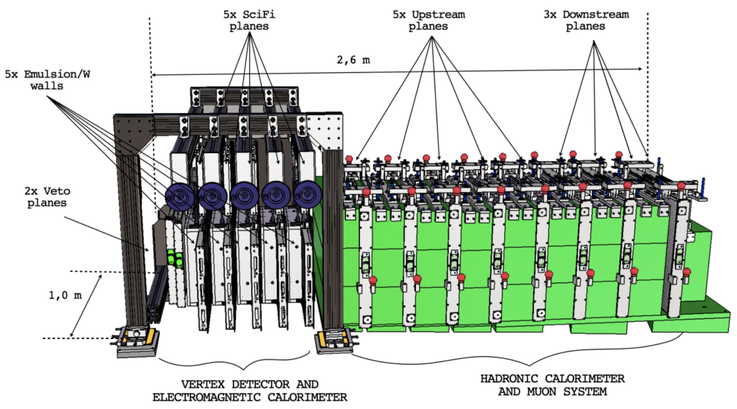
SND (Scattering and Neutrino Detector)



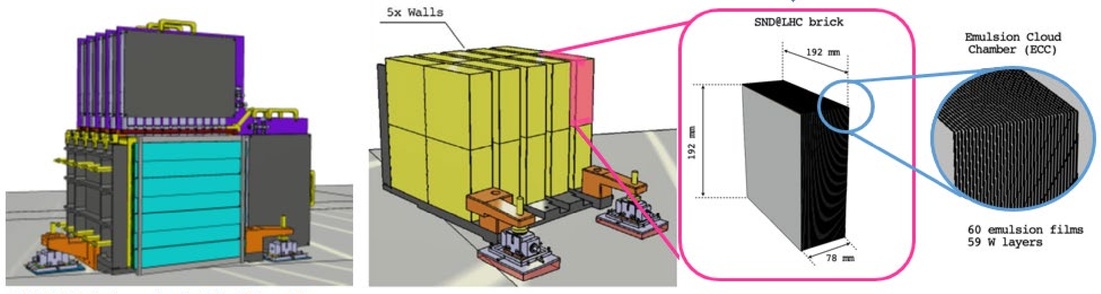
Emulsion-Counter Hybrid detector optimized for the identification of 3 neutrino flavors and for the detection of feebly interacting particles (FIPs).

ECC (Emulsion Cloud Chamber) target

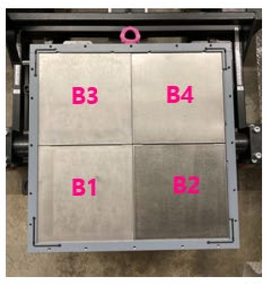
- **5 ECC Brick walls**
  - 2 x 2 bricks x 5 walls
  - weight 830 kg (~40 X_0)
  - surface 44 m²

⇒ Replace every ~25 fb^{-1} (total ~290 fb^{-1} in 4 yrs)
~3 times replacements / yr

- **ECC Brick**
  - **56 Tungsten layers** (1 mm-thick each) & **57 Emulsion films** (310 μm-thick each)
  - Surface **19.2 x 19.2 cm²**



5 ECC brick walls & 5 SciFi walls



1 wall (4 bricks inside)

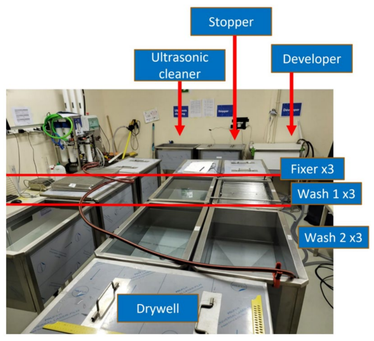
41.5 kg

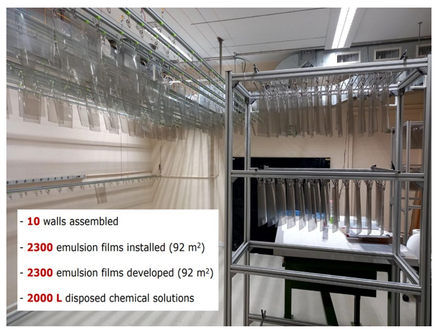
Emulsion works at CERN

ECC target assembly → Installation → Beam exposure → Extraction → ECC disassembling → Labeling → Emulsion film development → Drying → Surface cleaning → Packing

Chemical development

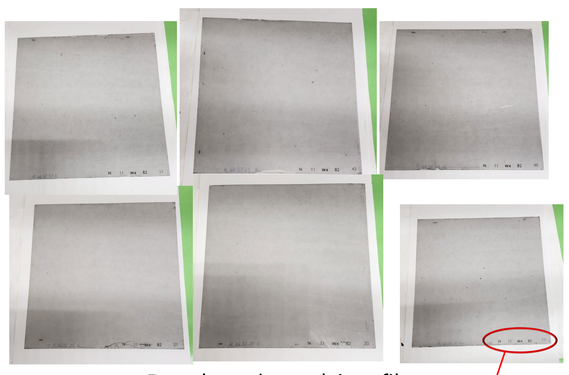
Develop → Stop → Fix → Wash → Dry → Glycerine





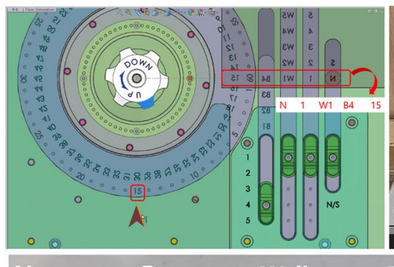
Emulsion development facility at CERN

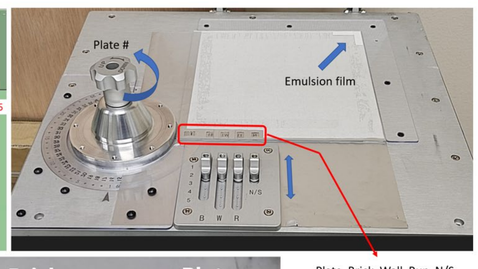
Assembled ECC targets



Developed emulsion films

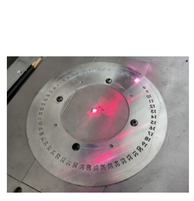
Labeling machine (Em Run #, Wall #, Brick #, Plate #)

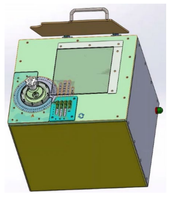


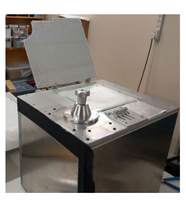


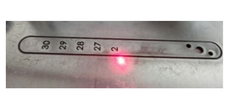
Nagoya	Run	Wall	Brick	Plate
N	13	W2	B3	29
Slavichi	1~20	1~5	1~4	1~60

Plate Brick Wall Run N/S



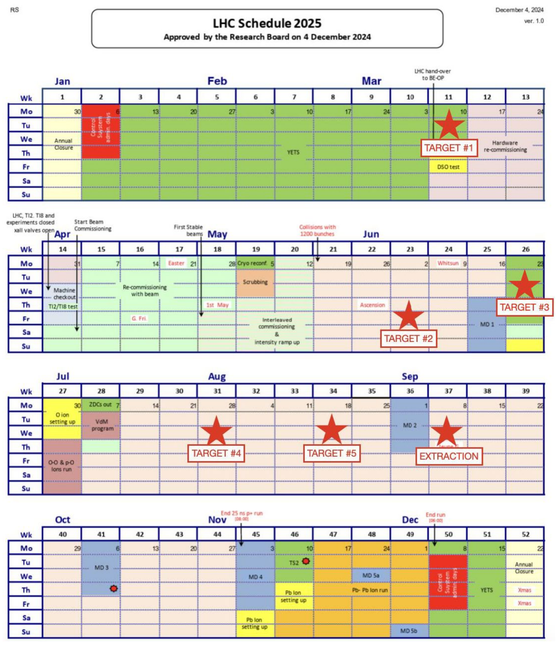






Laser cutting

Emulsion scanning at CERN



Concept of Emulsion Scanning

3D image detector → Precision tracker

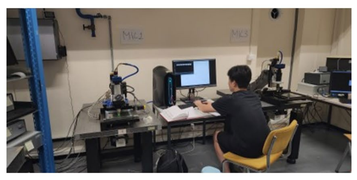
observation of event or tracks by microscope

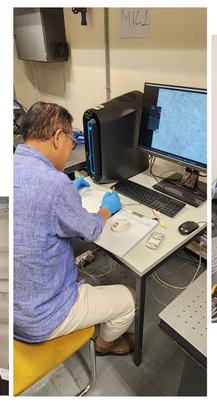
Full automatic record of all grains (raw data)

Scanning system saves tomographic images of all tracks

- Micro-track
- Base-track
- Volume-track
- Event

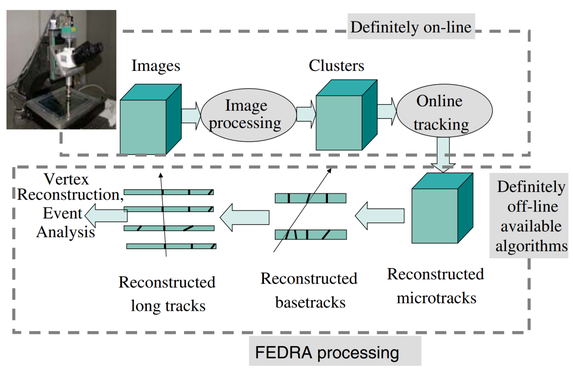
Off-line analysis reconstruction of tracks and events

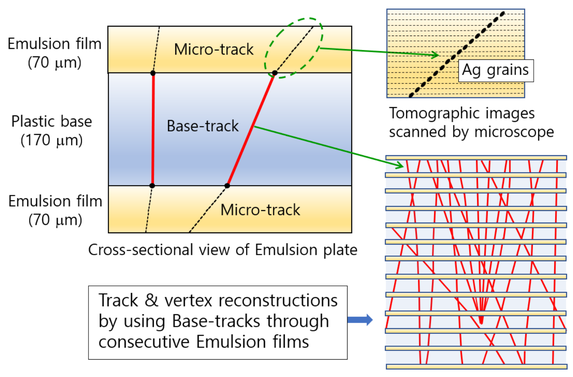




Emulsion Scanning room at CERN

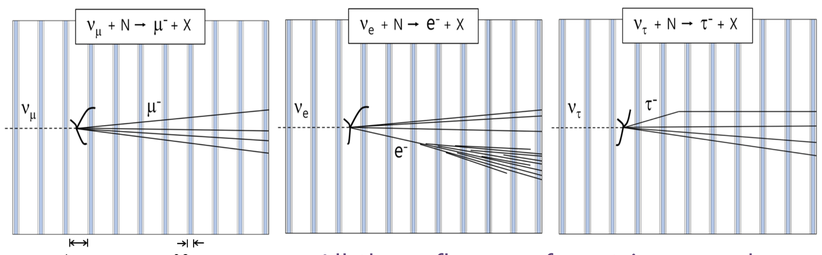
Off-line analysis - Reconstructions of Tracks and Neutrino vertices





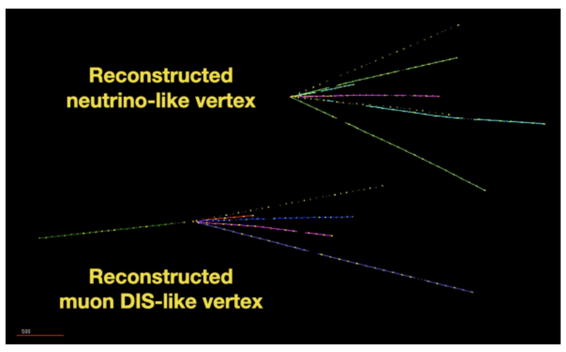
Neutrino event in emulsion

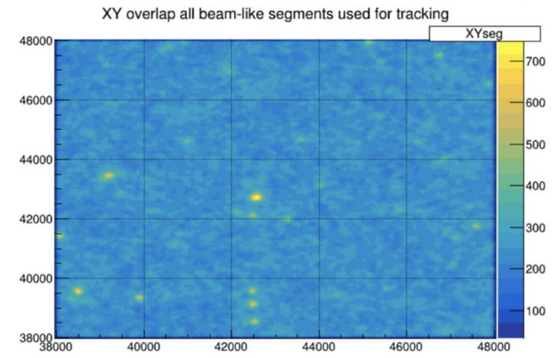
Neutrino event in ECC

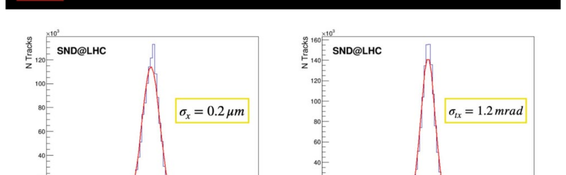


All three flavors of neutrinos can be identified in the ECC.

Progress in vertex reconstruction







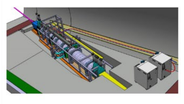
Excellent tracking resolution achieved

Search for "hot spots" consistent with EM showers

Summary

First direct observation of Collider Neutrinos !

- ν_μ candidates (1μ): **32 events**
- ν_e or NC candidates (0μ): **9 events**

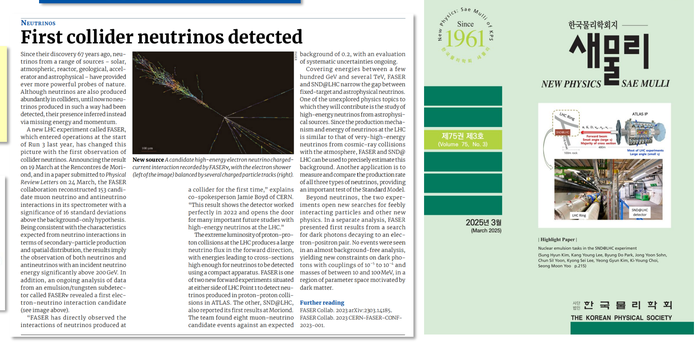


PHYSICS NEWS AND COMMENTARY

The Dawn of Collider Neutrino Physics

July 19, 2023

The first observation of neutrinos produced at a particle collider opens a new field of study and offers ways to test the limits of the standard model.



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NEUTRINOS

First collider neutrinos detected

Since their discovery 67 years ago, neutrinos from a range of sources – solar, atmospheric, reactor, geological, accelerator and astrophysical – have provided ever more powerful probes of nature. Although neutrinos are also produced abundantly in colliders, until now nonetheless produced in such a way had been detected, their presence inferred instead via missing energy and momentum.

A new LHC experiment called FASER, which entered operations at the start of Run 3 last year, has changed this picture with the first observation of collider neutrinos. Announcing the result on 19 March at the Rencontres de Moriond, and in a paper submitted to *Physical Review Letters* on 24 March, the FASER collaboration reconstructed 153 candidate muon neutrino and antineutrino interactions in its spectrometer with a significance of 16 standard deviations above the background-only hypothesis. Being consistent with the characteristics expected from neutrino interactions in terms of secondary-particle production and spatial distribution, the results imply the observation of both neutrinos and antineutrinos with an incident neutrino energy significantly above 200 GeV. In addition, an ongoing analysis of data from an emulsion/tungsten subdetector called FASERν revealed a first electron–neutrino interaction candidate (see image above).

"FASER has directly observed the interactions of neutrinos produced at a collider for the first time," explains co-spokesperson Jamie Boyd of CERN. "This result shows the detector worked perfectly in 2022 and opens the door for many important future studies with high-energy neutrinos at the LHC."

The extreme luminosity of proton–proton collisions at the LHC produces a large neutrino flux in the forward direction, with energies leading to cross-sections high enough for neutrinos to be detected using a compact apparatus. FASER is one of two new forward experiments situated at either side of LHC Point 1 to detect neutrinos produced in proton–proton collisions in ATLAS. The other, SND@LHC, also reported its first results at Moriond. The team found eight muon–neutrino candidate events against an expected background of 0.2, with an evaluation of systematic uncertainties ongoing.

Covering energies between a few hundred GeV and several TeV, FASER and SND@LHC narrow the gap between fixed-target and astrophysical neutrinos. One of the unexplored physics topics to which they will contribute is the study of high-energy neutrinos from astrophysical sources. Since the production mechanism and energy of neutrinos at the LHC is similar to that of very-high-energy neutrinos from cosmic-ray collisions with the atmosphere, FASER and SND@LHC can be used to precisely estimate this background. Another application is to measure and compare the production rate of all three types of neutrinos, providing an important test of the Standard Model.

Beyond neutrinos, the two experiments open new searches for feebly interacting particles and other new physics. In a separate analysis, FASER presented first results from a search for dark photons decaying to an electron–positron pair. No events were seen in an almost background-free analysis, yielding new constraints on dark photons with couplings of 10^{-5} to 10^{-3} and masses of between 30 and 100 MeV, in a region of parameter space not visited by dark matter.

New source *A candidate high-energy electron neutrino charged-current interaction recorded by FASERν, with the electron shower (left of the image) balanced by several charged particle tracks (right).*

Further reading

FASER Collab. 2023 arXiv 2303.14185.
FASER Collab. 2023 CERN-FASER-CONF-2023-001.