3D tracking at SND@LHC

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SND@LHC *collaboration*

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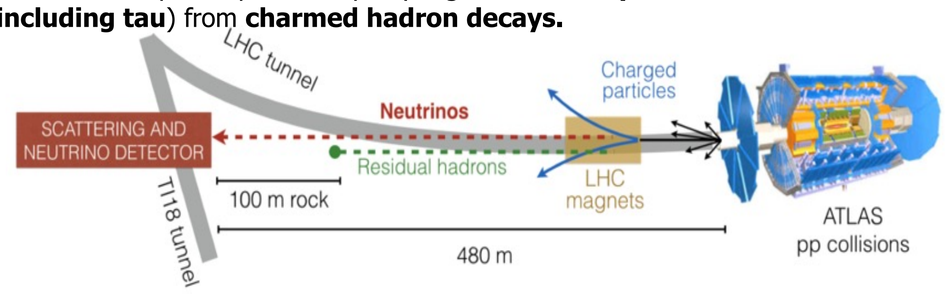
Introduction

SND@LHC (Scattering & Neutrino Detector) is a compact and stand-alone experiment measuring neutrinos produced at the LHC [1].
Built & commissioned in less than one year, it has successfully collected 117 fb^{-1} data during LHC Run 3!

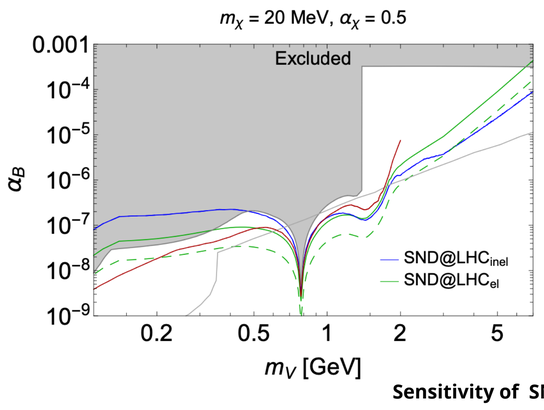
Overview:

- Located in **TI18**, 480 m downstream of the **ATLAS IP1 (forward direction) –** large flux of **high energy neutrinos (100 GeV – few TeV).**
- Off-axis – unexplored pseudo-rapidity region of **7.2 < η < 8.4** – all three neutrino flavours (**including tau**) from **charmed hadron decays.**



Physics programme

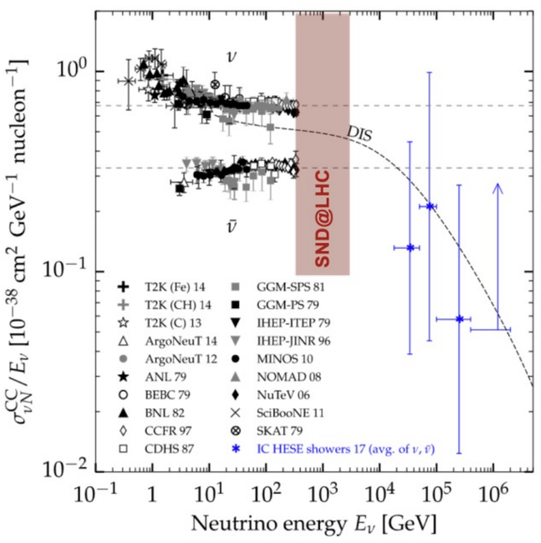
- Measurement of the $\mathbf{pp \rightarrow \nu_X X}$ **cross section** (including the least studied tau neutrinos $\boldsymbol{\nu_\tau}$).
- **Heavy-flavour production** in pp collisions.
- **Lepton flavour universality test** in neutrino interactions.
- Direct search for **feebly interacting particles (FIPs)** through their scattering.



Sensitivity of SND@LHC to the leptophobic portal – FIP search [2].

Run 3: 250 fb^{-1}

Flavour	Neutrinos in acceptance ⟨E⟩ [GeV]	Yield	CC neutrino interactions ⟨E⟩ [GeV]	Yield
ν_μ	130	3.0×10^{12}	452	910
$\bar{\nu}_\mu$	133	2.6×10^{12}	485	360
ν_e	339	3.4×10^{11}	760	250
$\bar{\nu}_e$	363	3.8×10^{11}	680	140
ν_τ	415	2.4×10^{10}	740	20
$\bar{\nu}_\tau$	380	2.7×10^{10}	740	10
TOT		4.0×10^{12}		1690



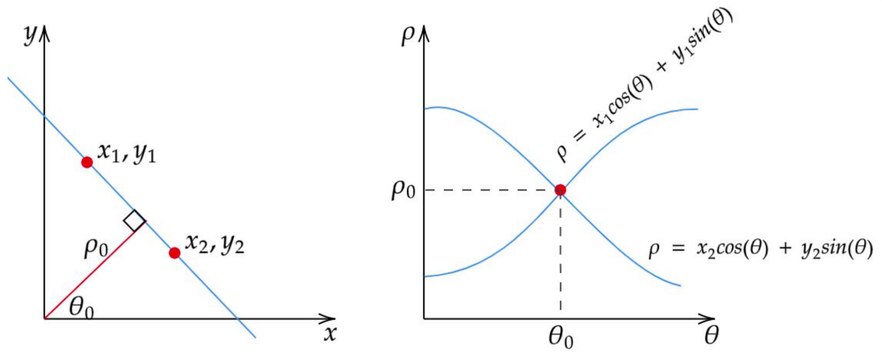
Available cross-section measurements. SND@LHC lies in the unexplored energy range.

Hough transform

Track fitting performed in two consecutive steps — **detect lines with Hough transform** and line fitting with Kalman filter.

First step — Hough transform:

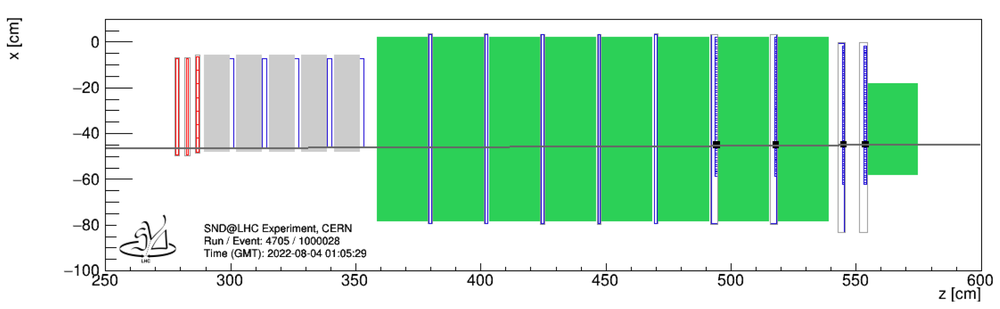
- Transforms points (x, y) in Cartesian space into **sinusoidal curves in parameter space** (θ, ρ)
- **Intersection points of curves** in parameter space gives slope and intercept of line along the corresponding points in Cartesian space

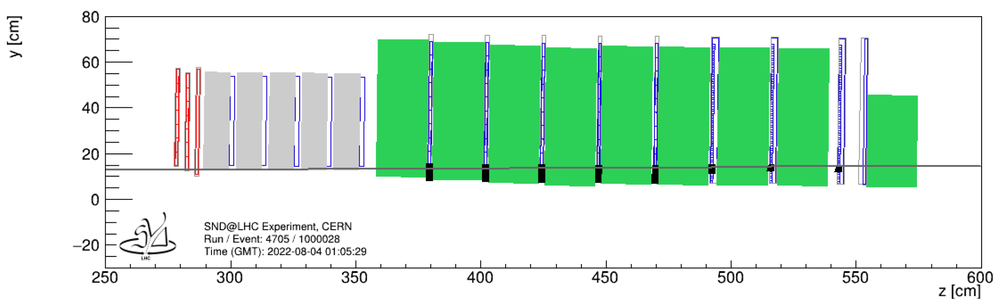


Cartesian and parameter space representation of two points along a line [3].

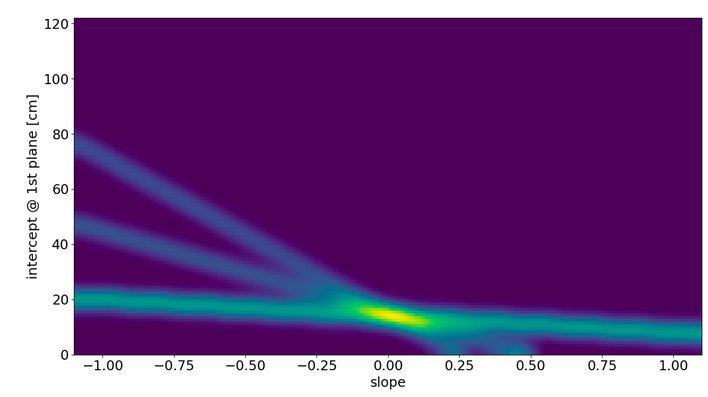
Results

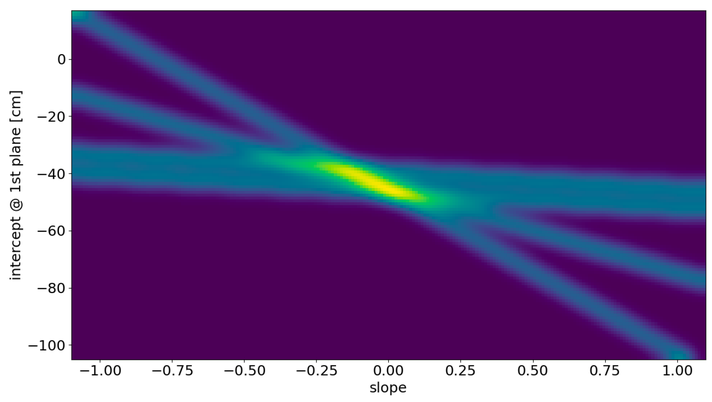
- For now: modify x coordinate acquisition and perform **Hough transform only — pattern recognition done**, track fitting pending
- Next step: **adapt Kalman fitter**
- Finally: **compare with previous 2D tracks**





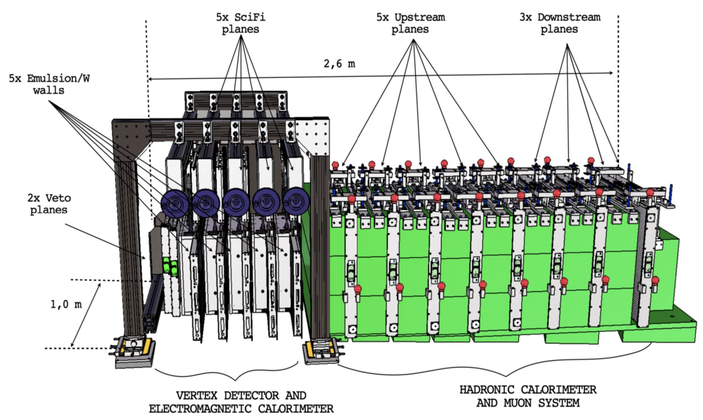
Downstream 3D track projection in two planes.





Hough space for the two projections of the same track.

Detector concept



Hybrid detector needed to identify **all neutrino flavours** and detect **FIPs:**

- Veto System
- Vertex detector & electromagnetic calorimeter — Emulsion Cloud Chamber (interleaved **tungsten** neutrino target + emulsion) + electronic trackers (**Sci-Fi**)
- Hadronic calorimeter (**HCAL**) & Muon system

Muon tracking and project goal

Current tracking state:

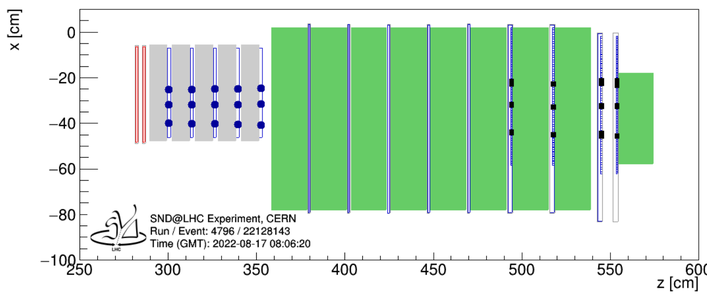
- **Two 2D tracks** in horizontal yz and vertical xz plane based on two different sets of hits

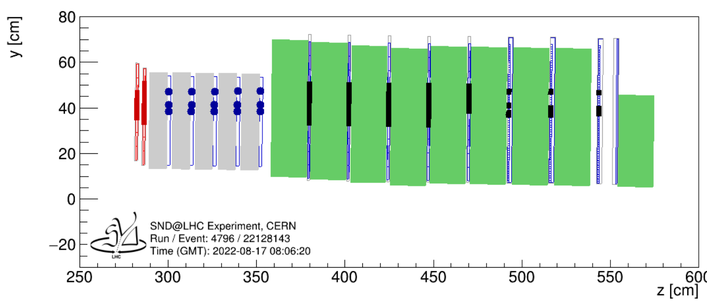
Project goal — **3D tracking**:

- Consider horizontal yz hits only and infer x position from the **time of flight** of the photons in the scintillating detector bar
- Perform track reconstruction in xz and yz planes again, but now with the **same set of hits**

Applications

- Inherently **3D tracks** — remove ambiguity from combination of 2D hits
- Would allow to reconstruct **multi-muon events in 3D** — for now it is not possible to match vertical and horizontal tracks when there are many of them per plane.





Multi-muon event display.

References

[1] SND@LHC Collaboration. (2024). SND@ LHC: the Scattering and Neutrino Detector at the LHC (*JINST* 19 P05067)..
[2] Boyarsky, A., Mikulenko, O., Ovchynnikov, M., & Shchutska, L. (2022). Searches for new physics at SND@ LHC. Journal of High Energy Physics, 2022(3), 1-30.
[3] Lee S. (2020). Lines Detection with Hough Transform — An algorithm to find lines in images. Towards Data Science.

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