Studying neutrinos at the high energy frontier with FASERν at the LHC

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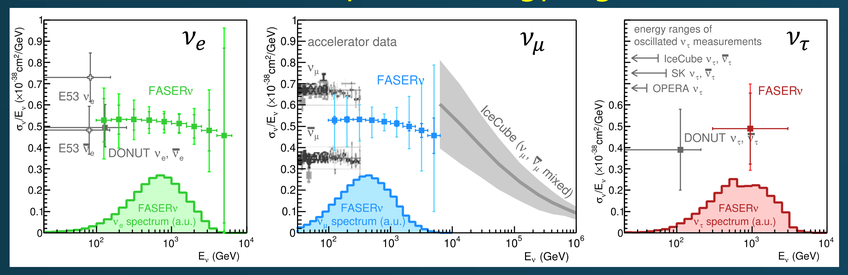
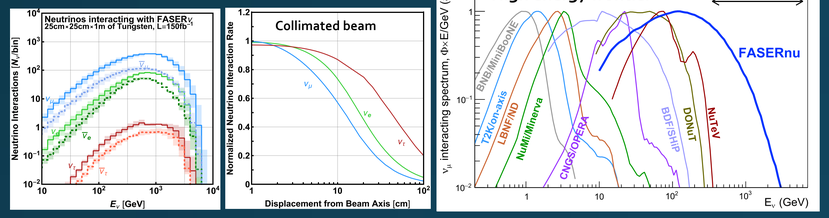
High energy frontier of man-made neutrinos

Studies of neutrino production, propagation, and interaction in an unexplored energy regime



Interacting energy spectra and FASERν cross section reach in Run 3 (2021-2024)

Fluxes were computed with the hadron interaction generators: Epos-LHC, QGSJet, Sibyll, Pythia 8 (Monash, minimum bias A2-tune).



Production

- Prompt neutrino production at 100 PeV in fixed target ($\sqrt{s} \sim 10$ TeV) → Input for neutrino telescopes
- QCD (charm/gluon PDF, intrinsic charm)

Propagation

- Unique energy and baseline, $L/E \sim 10^{-3}$ m/MeV
- Neutrino oscillation at $\Delta m^2 \sim 100$ eV^2

Interaction

- 3 flavor neutrino cross sections in unexplored energy range
- Neutrino induced heavy quark productions
- New physics effects

Schedule and milestones

Data taking in LHC Run 3 (150 fb^{-1}) — HL-LHC (3000 fb^{-1})

2020 Preparation, Pilot run analysis
2021 Installation
2022 Data taking & analysis
2023 ν_μ, ν_e cross sections
2024 ν_μ, ν_e induced charm production
2025 ν_τ cross section, other physics analyses
2026 2027 2028 …

FASERν2 with larger detector and higher luminosity is under discussion

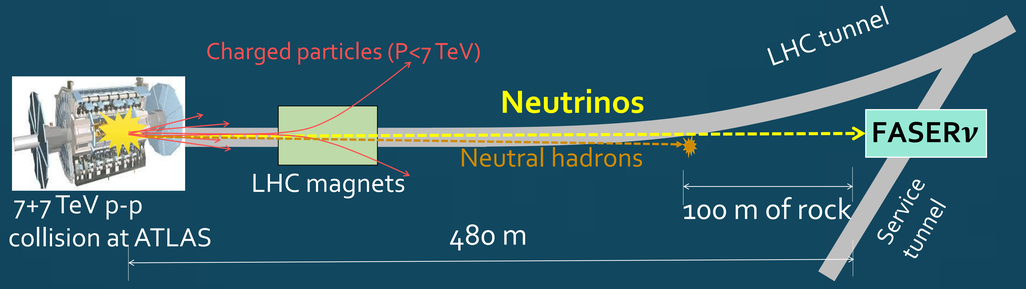
	# of CC int. (FASER original)	# of CC int. (FLUKA-based)	Mean interacting energy
$\nu_e, \bar{\nu}_e$	810, 460	3000, 1300	830 GeV
$\nu_\mu, \bar{\nu}_\mu$	4500, 1400	8400, 2700	840 GeV
$\nu_\tau, \bar{\nu}_\tau$	15, 7	110, 55	970 GeV

Expected # of interactions in Run 3 (2021-2024) with 7+7 TeV, 150 fb^{-1}, detector mass 1.2 ton

References

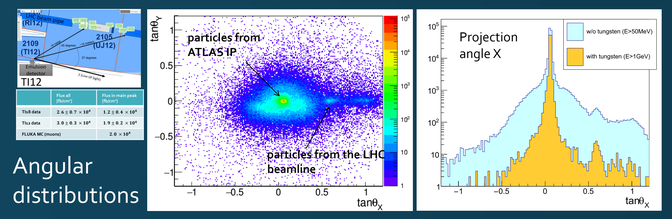
FASERν physics paper (LOI to CERN) : 10.1140/epjc/s10052-020-7631-5
FASERν Technical Proposal : arXiv:2001.03073
General info about FASER: https://faser.web.cern.ch/ Twitter :

LHC forward neutrino beam setup, allowing the first studies with "Collider neutrinos"



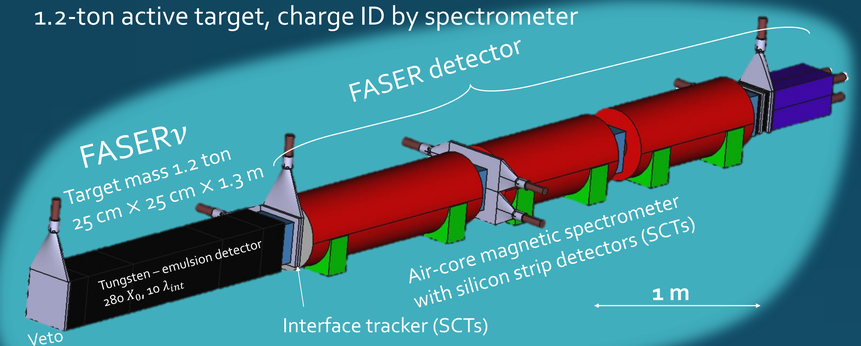
In-situ measurement of background in 2018

Emulsion detectors installed in the TI18, TI12 tunnels. The measured flux in TI12 = $\mathbf{3.0 \times 10^4}$ tracks fb/cm^2 in all angular space, $\mathbf{1.9 \times 10^4}$ tracks fb/cm^2 in the main peak, consistent with the FLUKA prediction of $\mathbf{2 \times 10^4}$ fb/cm^2. The background is sufficiently low to carry out neutrino studies.



FASERν + FASER hybrid detector

1.2-ton active target, charge ID by spectrometer

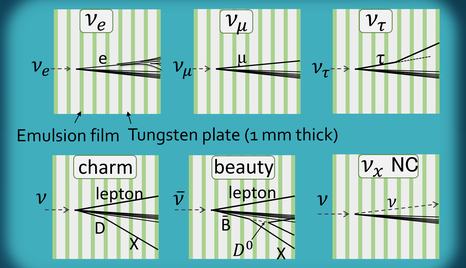


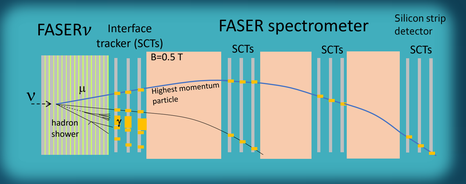
FASERν detector

- 1.2-ton target mass, 1000 each of 1-mm tungsten, emulsion films
- Spatial resolution of 0.4 μm
- Angular resolution of ~ 0.1 mrad
- 280 X_0 → EM shower reco.
  → Mom. reco. by the MCS
- 10 λ_{int} → Muon identification
- Energy resolution $\Delta E/E \simeq 30\%$
- Exchange films 10 times during Run 3

FASER spectrometer complements the charge ID for muons → Measurement of ν_μ / $\bar{\nu}_\mu$ separately

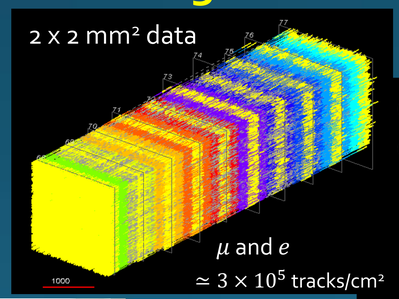
Emulsion-based detector, sensitive to 3 flavors ν_e, ν_μ, ν_τ and heavy quarks (charm, beauty)

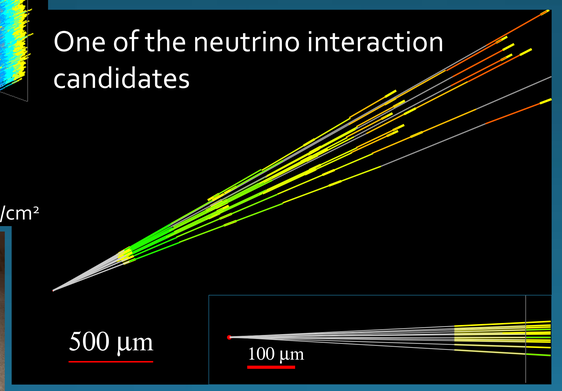




Pilot run in 2018: First demonstration of detecting neutrinos from the LHC

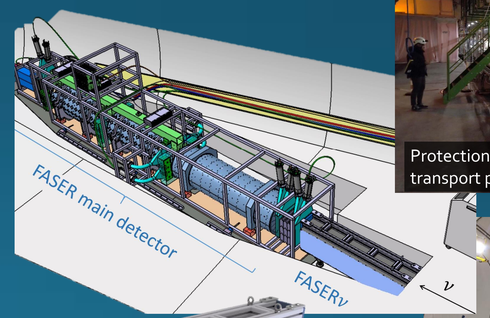
30 kg target, 12.5 fb^{-1} of data





30 kg neutrino detector was placed in the TI18 tunnel, which corrected 12.5 fb-1 of data. A handful of neutrino interaction candidates have been selected. The preliminary significance w.r.t. zero neutrino hypothesis is 2.7 σ.

Infrastructures




Protection for the LHC beam pipe under the transport path of the FASERν detector

The FASER site in March 2020. The civil engineering work has mostly been completed.