Neutrinos at FASER - Cross-section Measurements and Neutrino Energy Reconstruction

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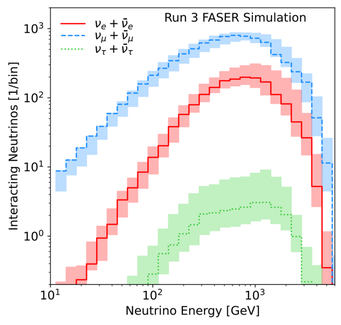
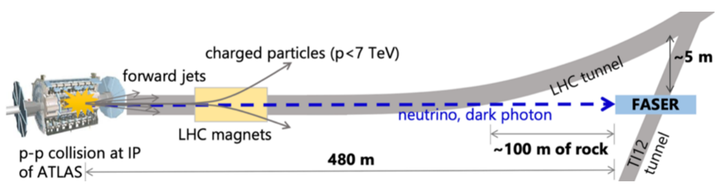
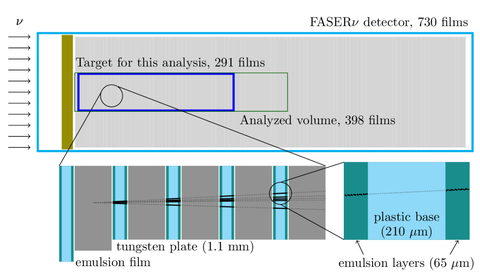
The ForwArd Search ExpeRiment

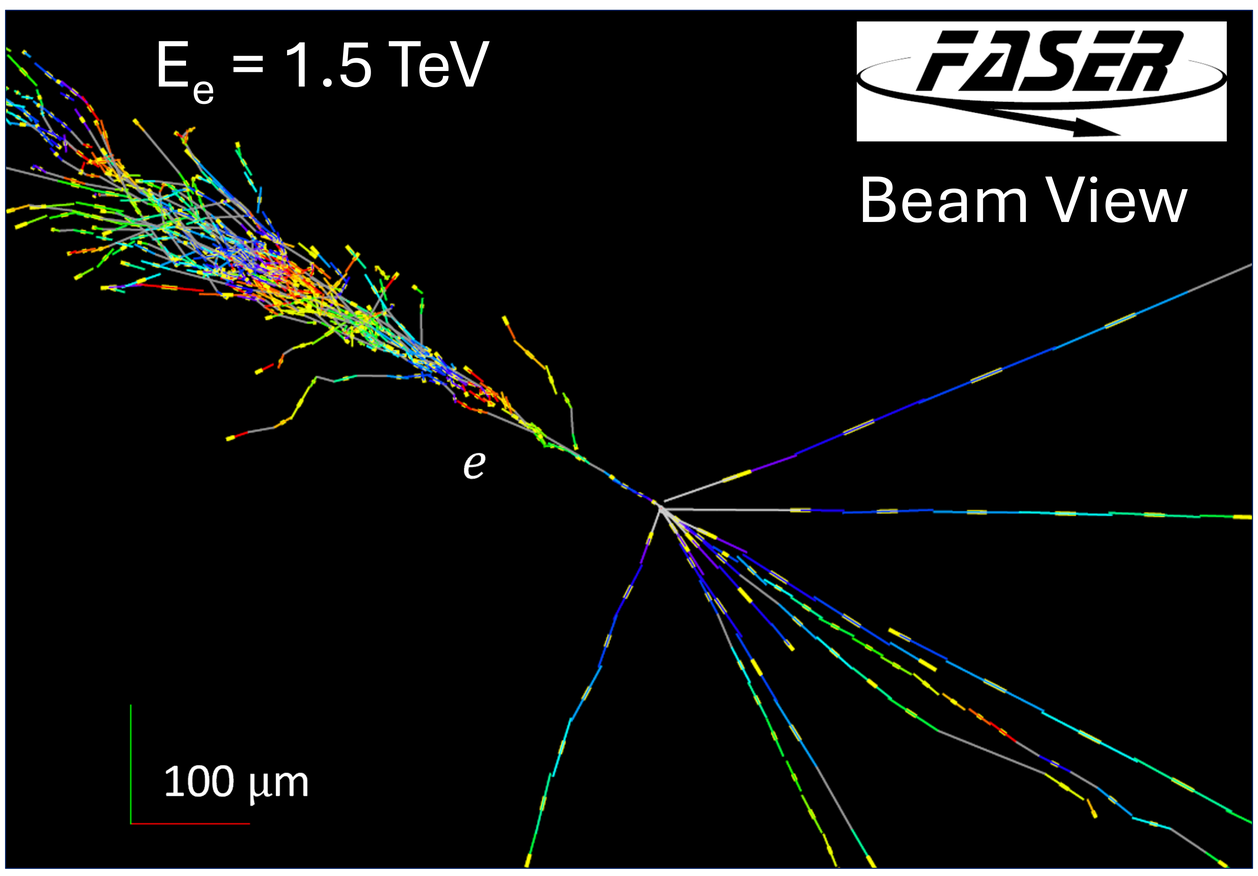
- **Goal**: to investigate light, long-lived, weakly-interacting particles and **TeV-scale neutrinos** produced in the far-forward region of collisions at the ATLAS interaction point (IP1) $\sqrt{s} = 13.6$ TeV.
- High-energy neutrinos of all 3 flavours can be flavour-tagged and investigated.



- **FASERν detector**: 730 interleaved emulsion films and tungsten plates, resulting in a 1.1 tonne target mass.
- Number of expected events for 250 fb^{-1}: ν_e ~1700, ν_μ ~8500, ν_τ ~30 (**Phys. Rev. D 110, 012009**).



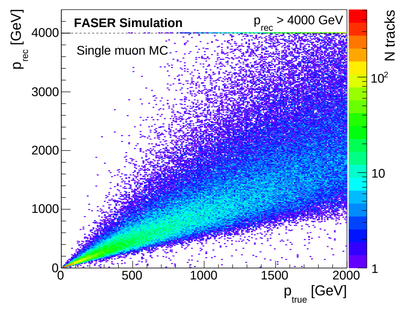


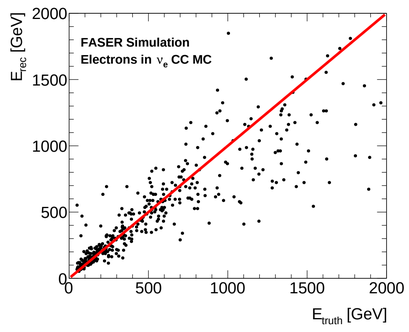


Results from FASERν: ν_μ and ν_e at the LHC

Kinematics performance

- 300 nm position resolution has been achieved, leading to 0.04 mrad angular resolution for a 1 cm track.

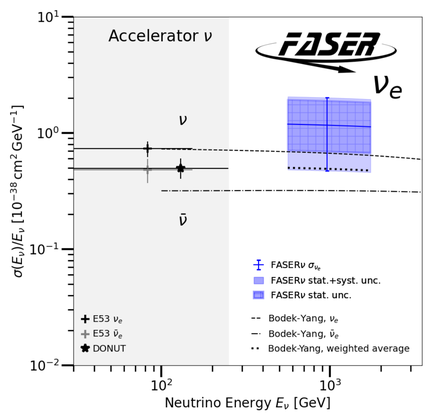


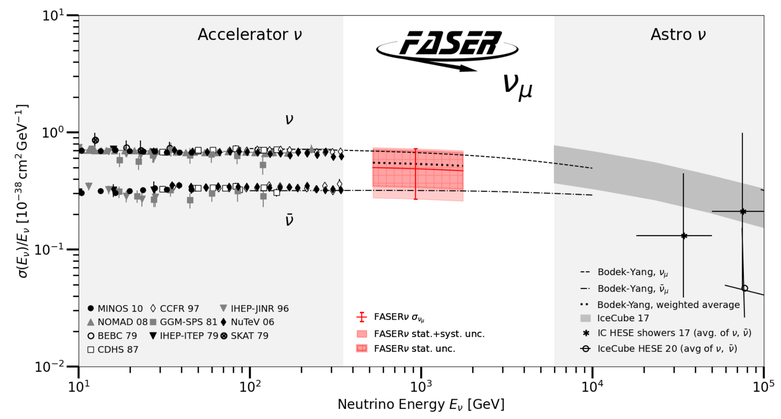


- Momentum measurement from Multiple Coulomb Scattering (MCS): $\Delta P/P$ at 200 GeV ~ 0.30, performance validated with testbeam.
- EM shower energy found using segment multiplicity in core of EM shower: $\Delta E/E$ at 200 GeV ~ 0.25.

Cross-section measurement (Phys. Rev. Lett. 133, 021802)

- Dataset: sub-volume of the 2nd 2022 module, target mass = 128.6 kg, equivalent to 9.5 fb^{-1}, $\sim 1.7\%$ of the data collected to date.
- Selection criteria:
  - Vertex reconstruction: $N_{charged} \geq 5$; $N_{\tan\theta \leq 0.1} \geq 4$.
  - Lepton requirements: E_e or $p_\mu > 200$ GeV; $\tan\theta_e$ or $\tan\theta_\mu > 0.005$.
  - Back-to-back topology: $\Delta\phi > 90°$.
- **First ν_e observation at the LHC** - highest ν_e energy ever observed.
- 4 ν_e and 8 ν_μ CC events were observed, corresponding to a significance of 5.2σ and 5.7σ respectively.
- **First neutrino cross-section measurement in the TeV range, compatible with SM prediction.**





Development of Neutrino Energy Reconstruction

- Future cross-section measurements should be performed as a function of neutrino energy - neutrino energy reconstruction is needed.
- Dataset: FASER GENIE simulation of ν_μ CC interactions at truth level with smearing to emulate the effect of MCS in 100 emulsion films and tungsten plates.
- ΣP_{vis}: total momentum of all charged particles scaled by $\langle\alpha\rangle = \langle E_\nu^{truth} / \Sigma P_{vis}^{truth}\rangle \approx 1.34$.
- TMVA Boosted Decision Tree (BDT) and k-Nearest Neighbour (KNN) Regression methods investigated.
- Input variables chosen correlate with E_ν^{truth} and are stable across PYTHIA6 hadronisation tunes: $P_{smeared}^{lep}$, $\Sigma P_{smeared}^{ChargedHadrons}$ and $1/\tan\theta_{smeared}^{lep}$.
- Energy resolution found in the 100 GeV - 1 TeV range as the $r.m.s.(\frac{E^{reco} - E_\nu^{truth}}{E_\nu^{truth}})$ for all methods.
- **Preliminary application of TMVA methods improves resolution across the range to $\sim$ 0.4.**
- Improving the resolution to $\sim$ 0.3 in the range of 100 GeV - 6 TeV would allow the muon neutrino cross-section to be measured in 9 neutrino energy bins.
- Next steps: add in more variables, including related to EM showers, and investigate different methods to improve the energy reconstruction performance.