

Results From TeV Neutrinos at The FASER Experiment

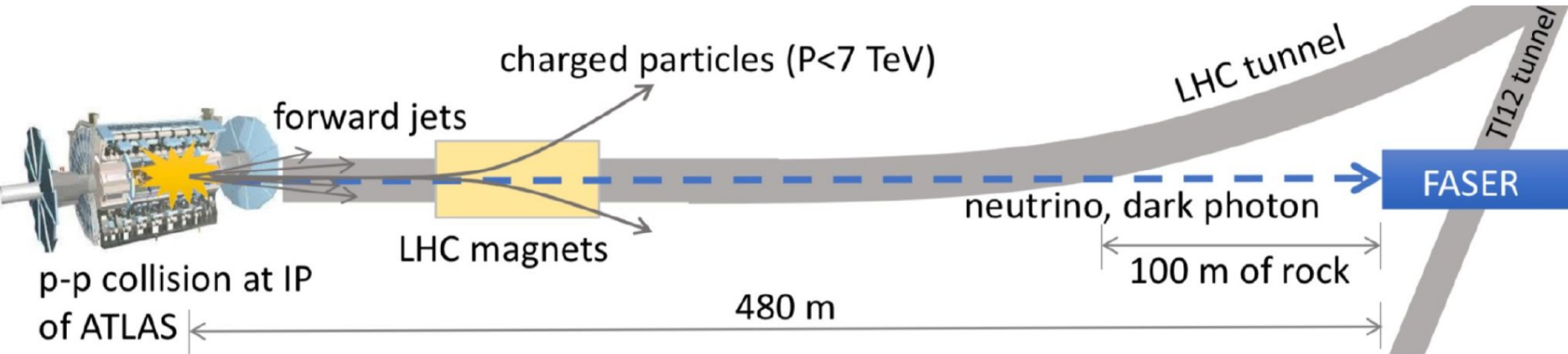


Ali Garabaglu on behalf of
FASER Collaboration
May 14th, 2024
DPF-PHENO 2024



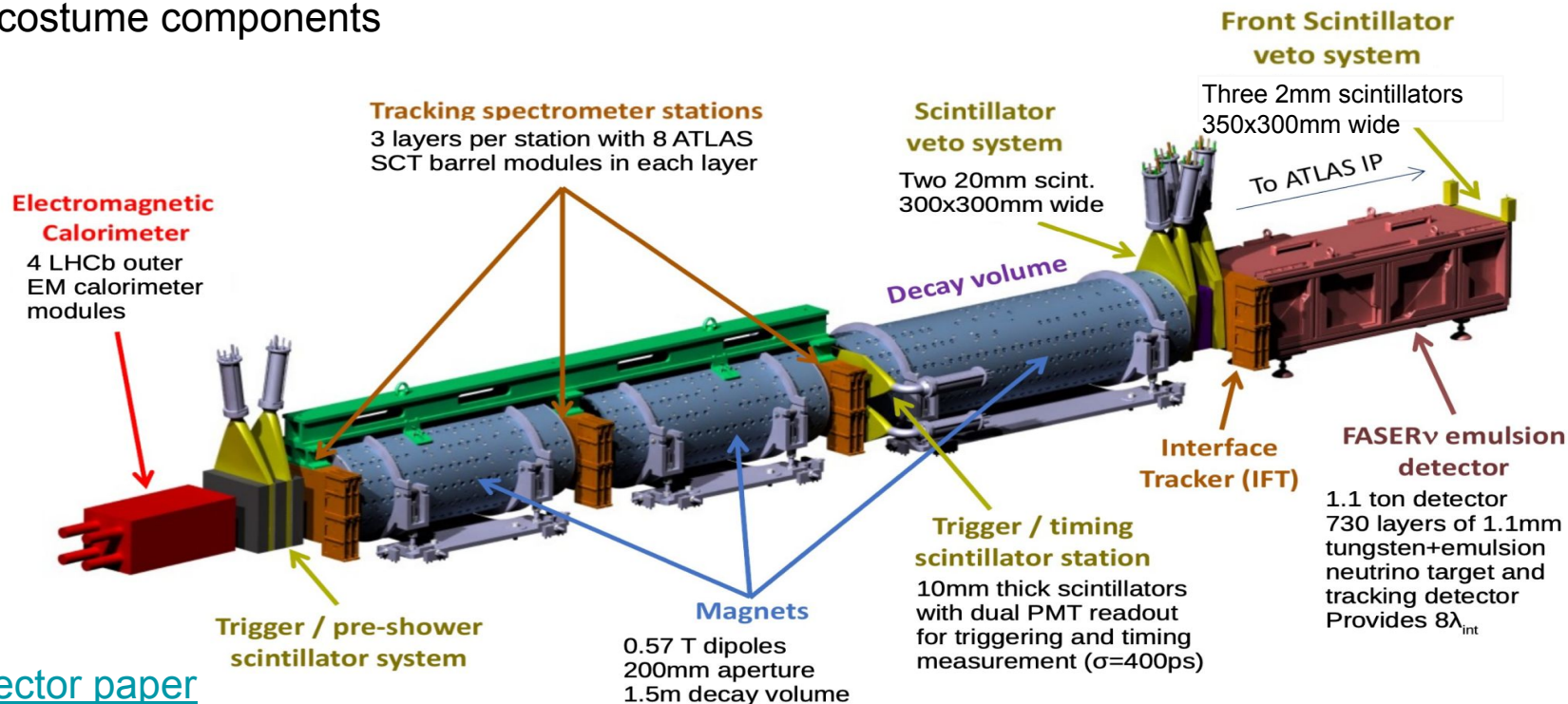
ForwArd Search ExpeRiment (FASER) At The LHC

- FASER is designed to search for long lived BSM particles and **neutrinos**.
- Located 480m from ATLAS interaction point



FASER Detector

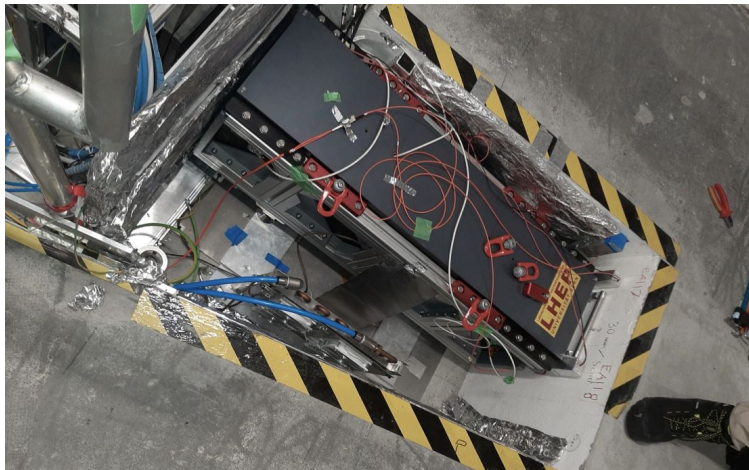
- Low cost modular detectors built with both existing and some costume components



[detector paper](#)

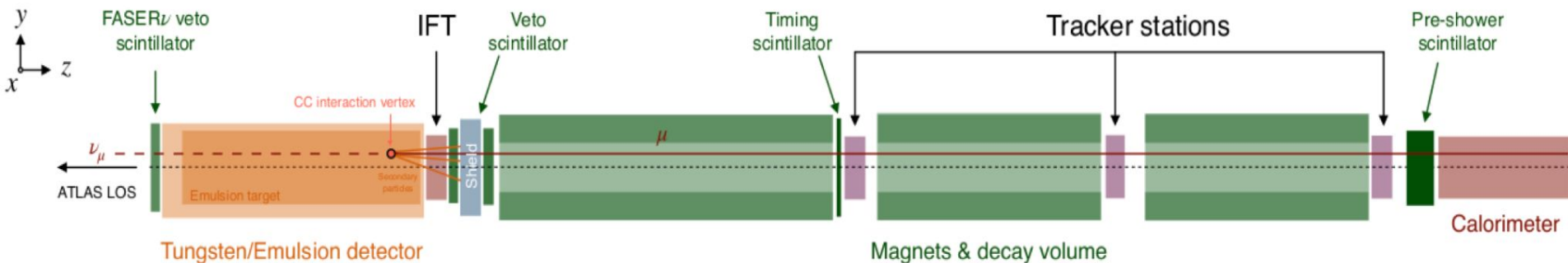
FASER ν Detector

- 730 emulsion films and 1.1 mm thick tungsten plates. 1.05 m long with area of 25 x 30 cm². Target mass 1.1 tonnes.
- Emulsion sub-detector is in place for about 2 months. Up to $O(10^6)$ tracks/cm², with $O(10^7)$ tracks in the spectrometer triggered while one emulsion detector is in place.



Recent Physics Results

- Search for Dark Photons with FASER, see Ansh's [talk](#). ([PLB 848, 2024, 138378](#)).
- First observation of collider neutrinos with FASER With 153 events at 16σ ([PRL.131.031801](#))
- And in this talk I will focus on first measurement of muon and electron neutrino cross sections at the LHC ([Submitted to PRL](#))

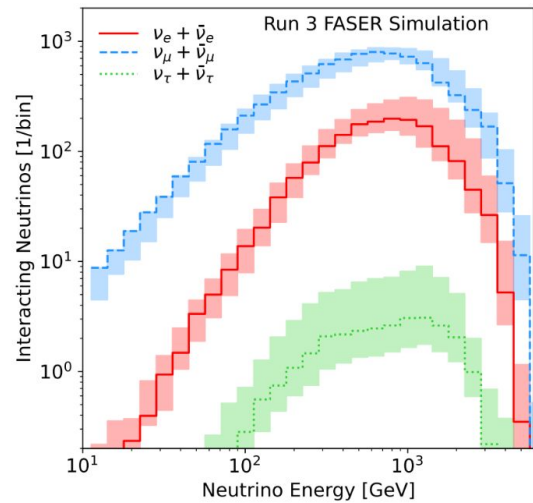
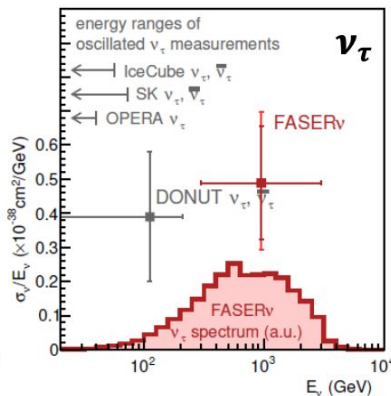
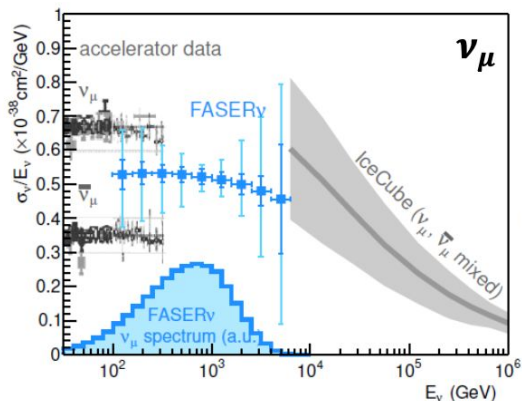
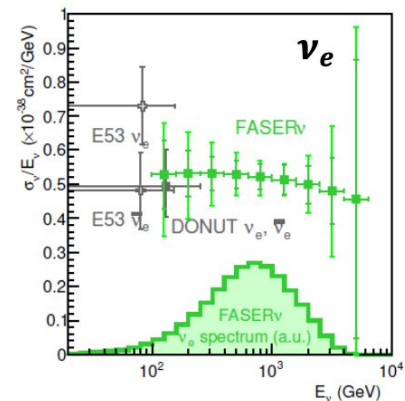


Neutrinos In FASER

- FASER ν can probe neutrino cross section measurements in TeV energy range.
- Expect $\mathcal{O}(1000)$ electron and muon neutrino events.
- Expected energy spectra of **electron**, **muon**, and **tau** neutrinos are shown in colored histograms.

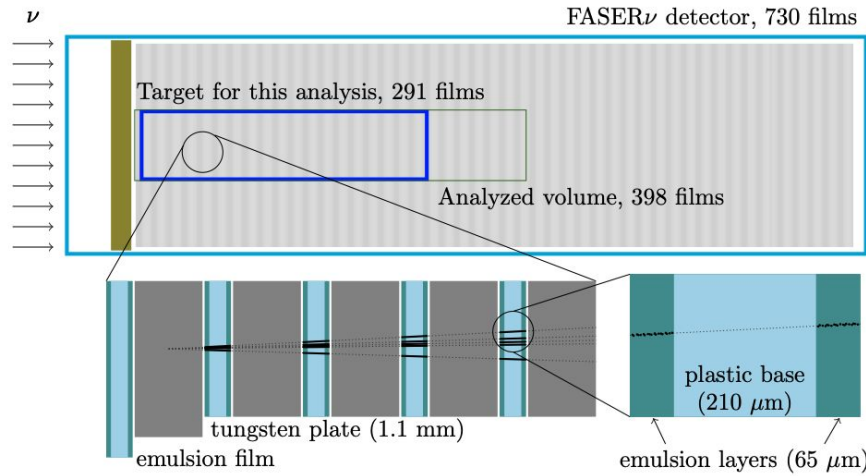
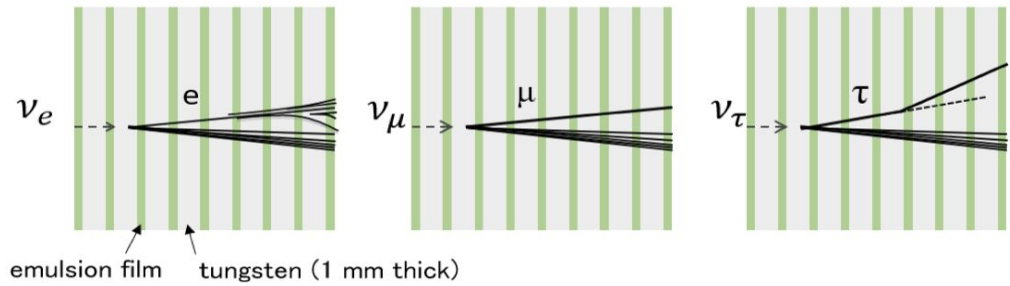
Run 3 (250 fb $^{-1}$)	ν_e	ν_μ	ν_τ
expected CC events in FASER ν	~1700	~8500	~30

arXiv:2402.13318



Emulsion Detector

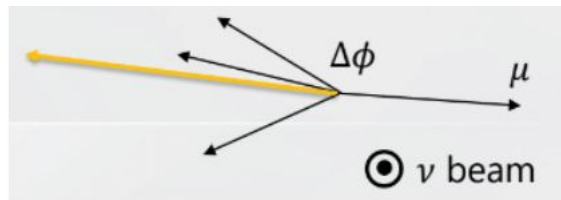
- Current analysis:
 - 9.5 fb^{-1} from 2022 run
 - Analyzed target mass of 128.6 kg. $\sim 1.7\%$ of data collected so far.
 - $23.4 \text{ cm} \times 9.0 \text{ cm}$ is analysed, and in the longitudinal direction, 41.5 cm
- Neutrino events can be flavour tagged using topological and kinematical variables.



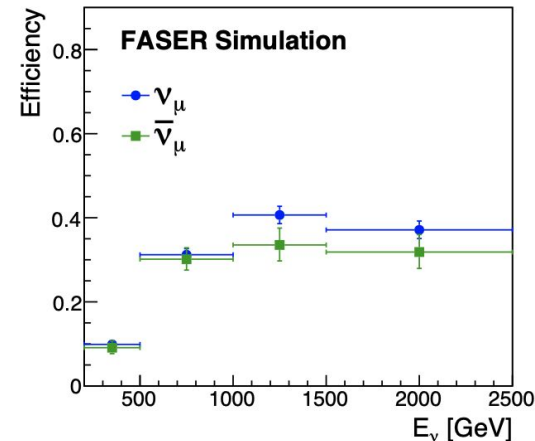
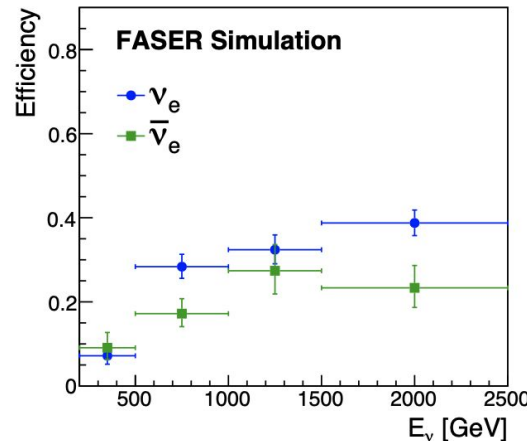
Emulsion Physics Analysis

- **Main Event Selection Criteria:**

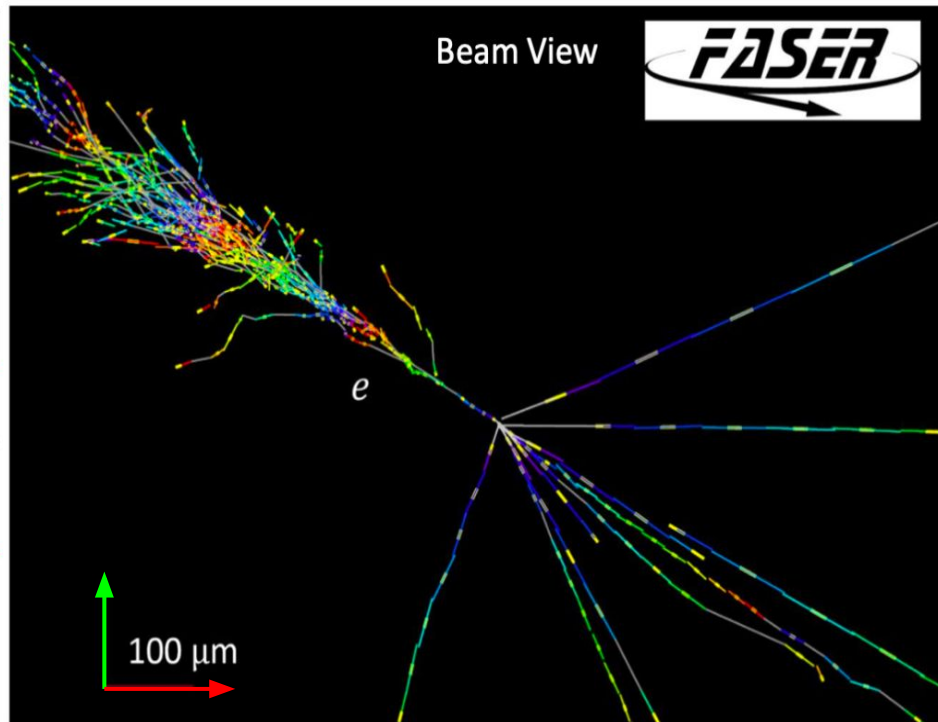
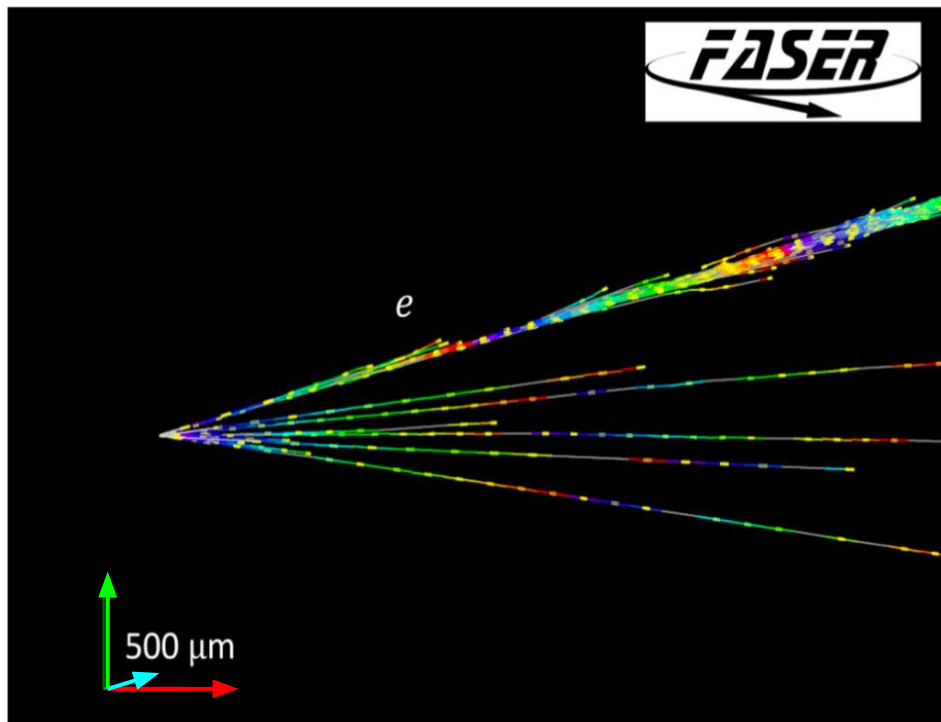
- Vertex reconstruction:
 - $N_{\text{tracks}} (\tan\theta \leq 0.5) \geq 4$
 - $N_{\text{tracks}} (\tan\theta \leq 0.1) \geq 3$
- Lepton requirements
 - E_e or $p_\mu > 200$ GeV
 - $\tan\theta_e$ or $\tan\theta_\mu > 0.005$
- Back-to-back topology: $\Delta\phi > 90^\circ$



- **The main background:** neutral hadrons interacting in the detector or concrete.
 - Mostly lower in energy.
 - Can be suppressed with topological and kinematic cuts



Electron Neutrino Candidate



- Coordinate system: red, green, and blue axes indicating the **x (horizontal)**, **y (vertical)**, and **z (beam)** direction
- The highest reconstructed electron energy from neutrino interaction, with energy of 1.5 TeV, was observed.

Muon Neutrino Candidate

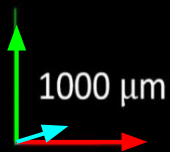


Beam View



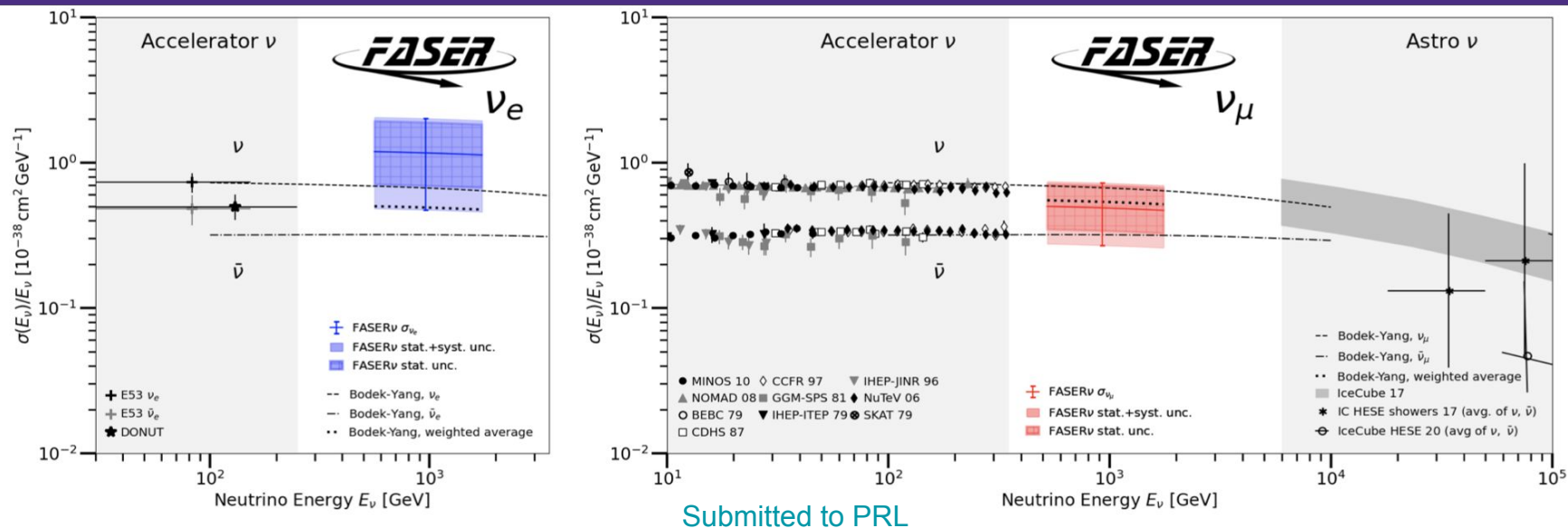
μ

μ



- Coordinate system: red, green, and blue axes indicating the **x (horizontal)**, **y (vertical)**, and **z (beam)** direction
- Muon neutrino candidate

Cross Section Measurement



- First measurement of TeV scale neutrino cross sections at an accelerator.
- Both measurements are consistent with the Standard Model

	ν_e	ν_μ
Bkg	0.03 ± 0.01	0.22 ± 0.08
Exp	1.1 – 3.3	6.5 – 12.4
Obs	4	8
Sig	5.2σ	5.7σ

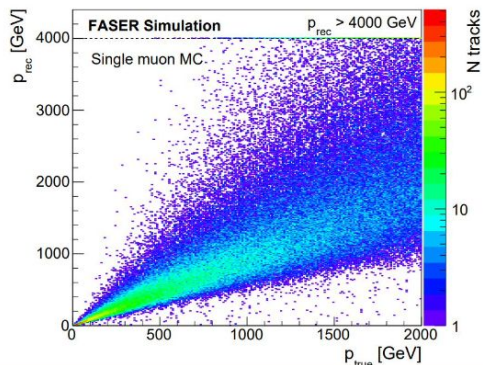
Summary

- FASER and FASER ν have **successfully taken data** and produced great results, including measurements of **neutrino cross section** at previously **unexplored energy** scales.
- The findings from FASER ν showcase the capability of conducting neutrino measurements using **emulsion-based detectors** under the demanding conditions present at the LHC.
- There is still **more data** to be reconstructed and analysed by FASER ν . And more data to be taken by FASER in current run.
- **Future Outlook:**
 - FASER approved for Run 4.
 - The Forward Physics Facility (FPF) at CERN is a planned project aimed at constructing a new experimental cavern during the HL-LHC era to enhance the physics program, which will include FASER2 and FASER ν 2. See talks by [Jonathan Lee Feng](#) and [Shih-Chieh Hsu](#)

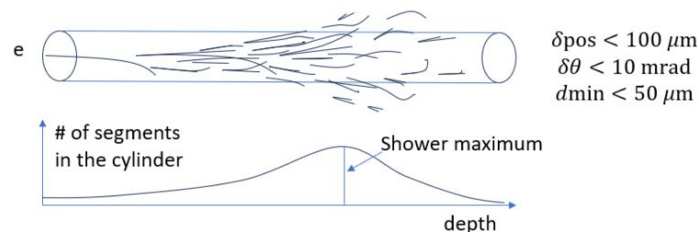
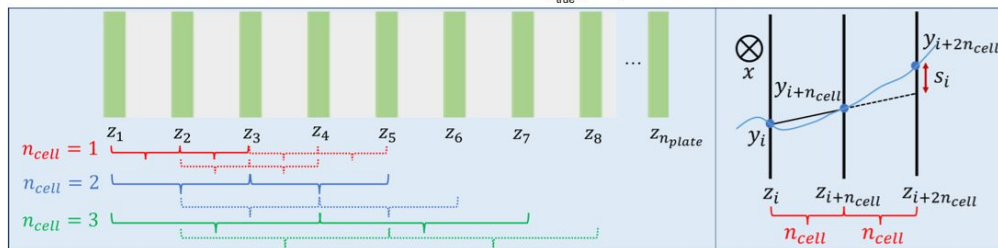
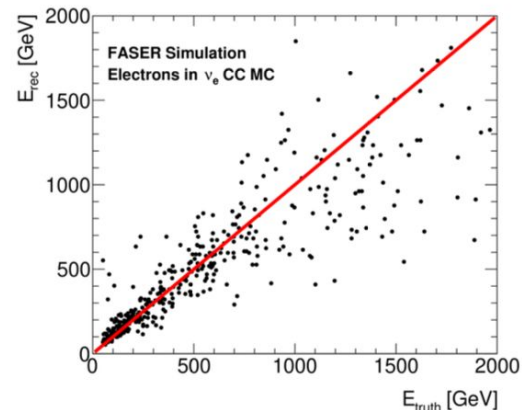
BackUp

FASER ν Kinematic Measurements

- Particle momenta calculated using Multiple Coulomb Scattering (MCS) via the Coordinate Method (works well even > 1 TeV).
- Muon momentum: $\Delta P^{\text{RMS}}/P \approx 0.3$ at 200 GeV.



- EM shower energy found using track multiplicity.
- Reconstructed electron energy: $\Delta E/E \approx 0.25$ at 200 GeV.



FASER ν Performance

- Position resolution is determined using the position displacement between a hit and the linear fit of a track.
- Hit resolution ~ 300 nm after dedicated film alignment using high-momentum muon tracks ($\mathcal{O}(10^5)$ tracks/cm 2).
- Angular resolution for track of length ~ 1 cm is ~ 0.04 mrad.
- Angular spread of muon peaks ~ 0.4 mrad.

