

# Neutrino results at TeV-energies from the LHC-FASER experiment

H. Rokujo (Kyushu Univ.)  
on behalf of FASER collaboration





CMU 2t

CMU 2t

WE ARE GOING TO DIS

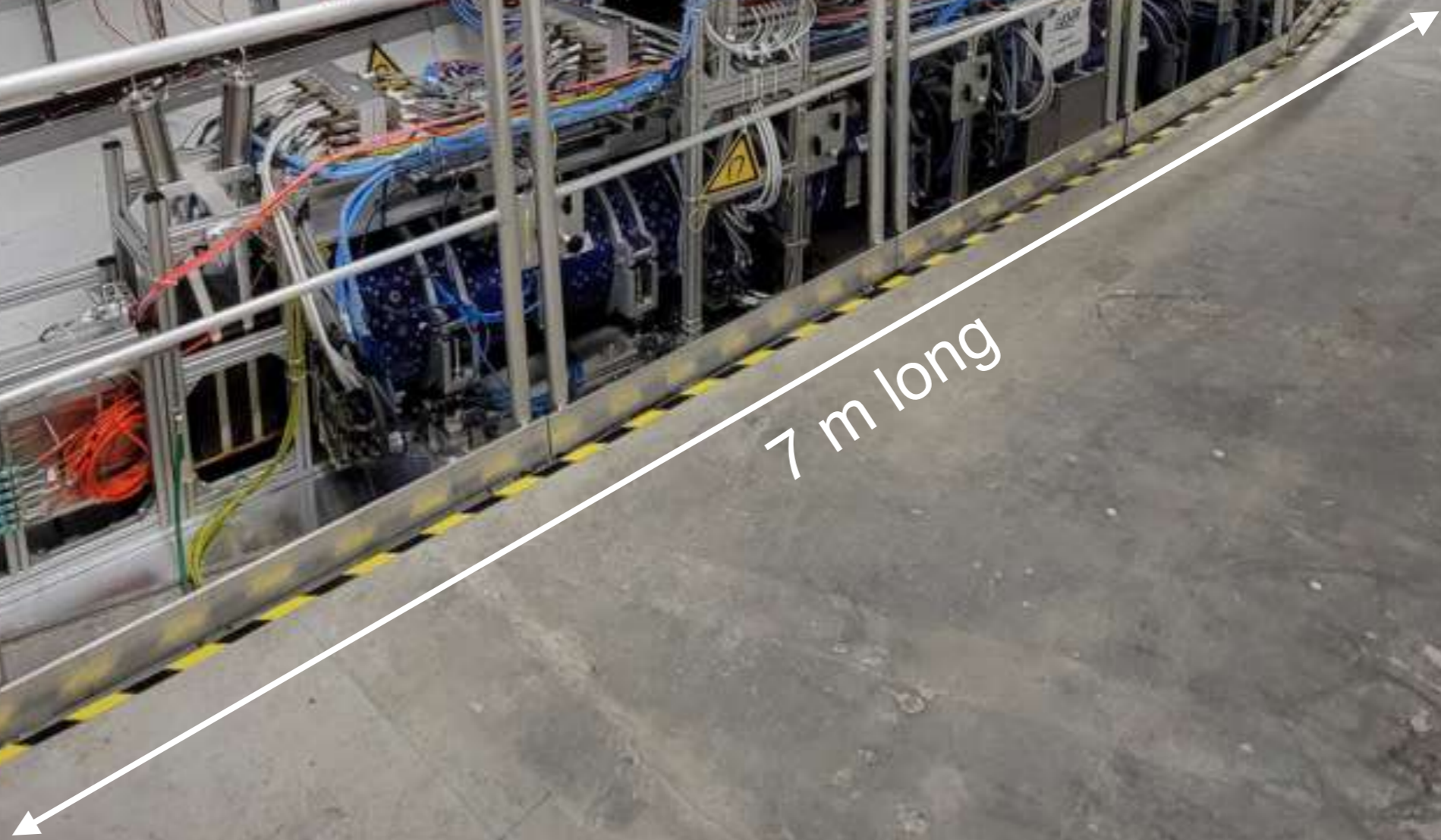


CMU 2t

CMU 2t

2t

7 m long



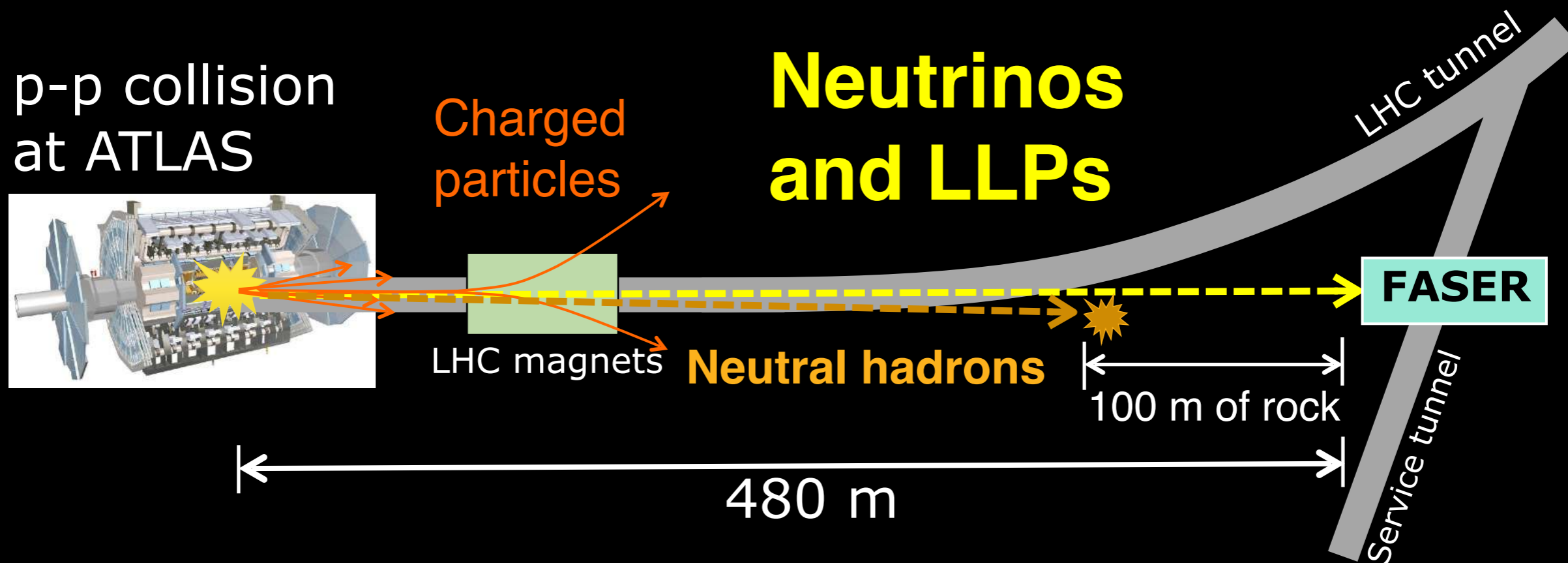
FORWARD SEARCH EXPERIMENT AT THE LHC

# FASER experiment at LHC

FASER TP [arXiv:1812.09139](https://arxiv.org/abs/1812.09139),

FASER $\nu$  [Eur. Phys. J. C \(2020\) 80: 61](https://doi.org/10.1007/s00037-020-00000-0)

FASER web page: <https://faser.web.cern.ch/>



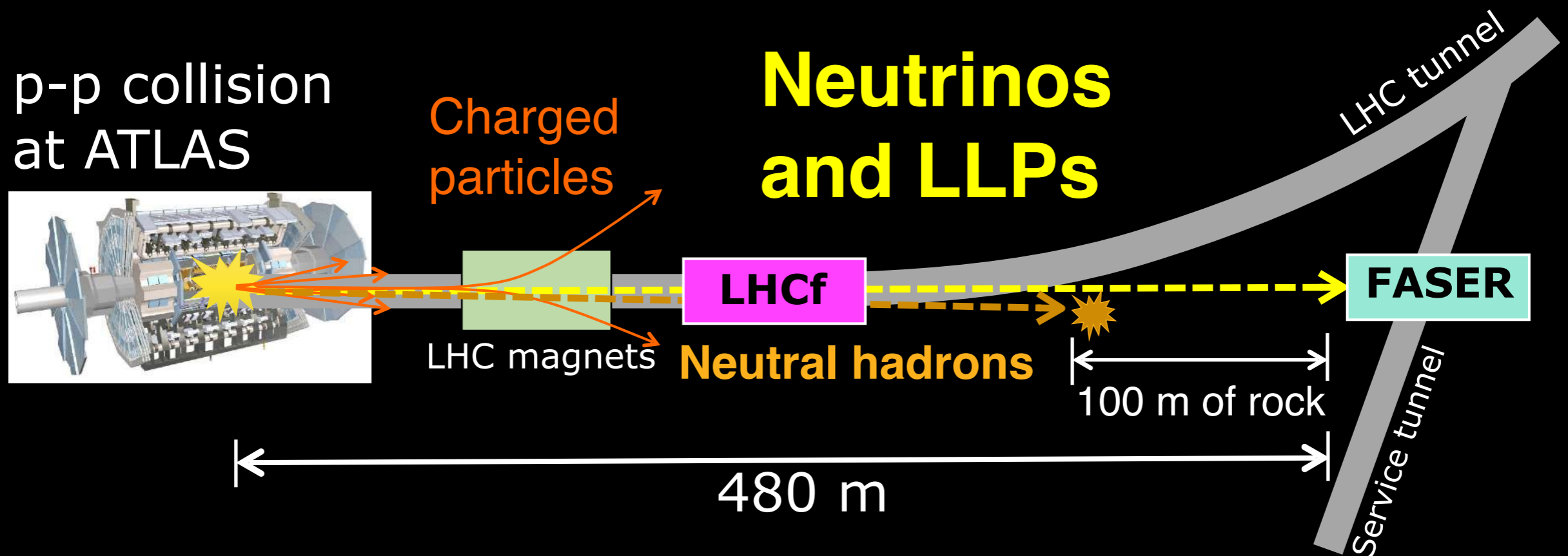
- Located 480 m downstream of ATLAS interaction point
- Targets are **long-lived BSM particles** (e.g.  $A'$ , ALPs) and **SM neutrinos** (and  $\mu$ )

# Measurements for CR physics

FASER TP [arXiv:1812.09139](https://arxiv.org/abs/1812.09139),

FASER $\nu$  [Eur. Phys. J. C \(2020\) 80: 61](https://doi.org/10.1007/s00037-020-00000-0)

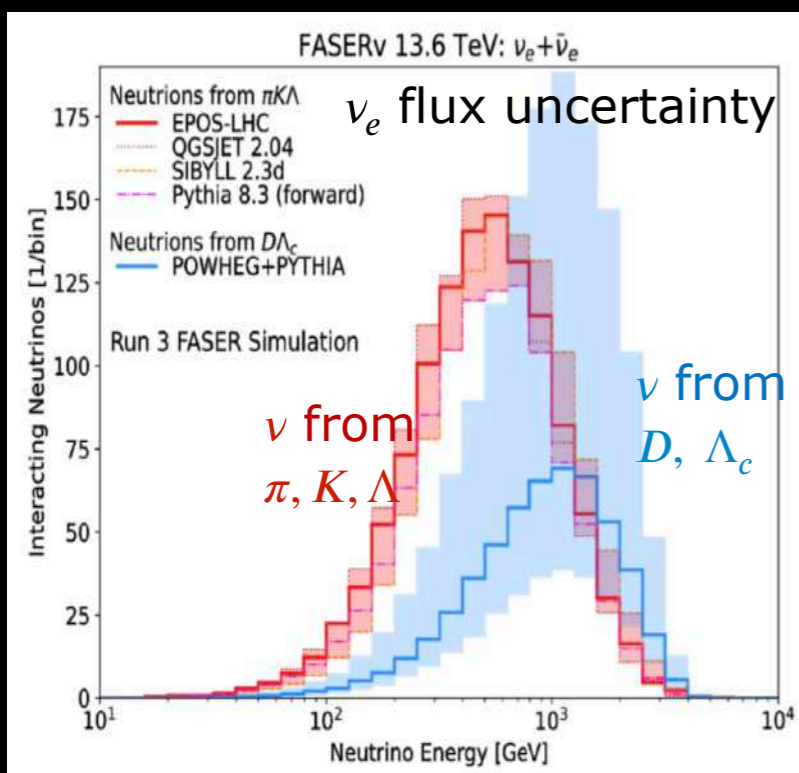
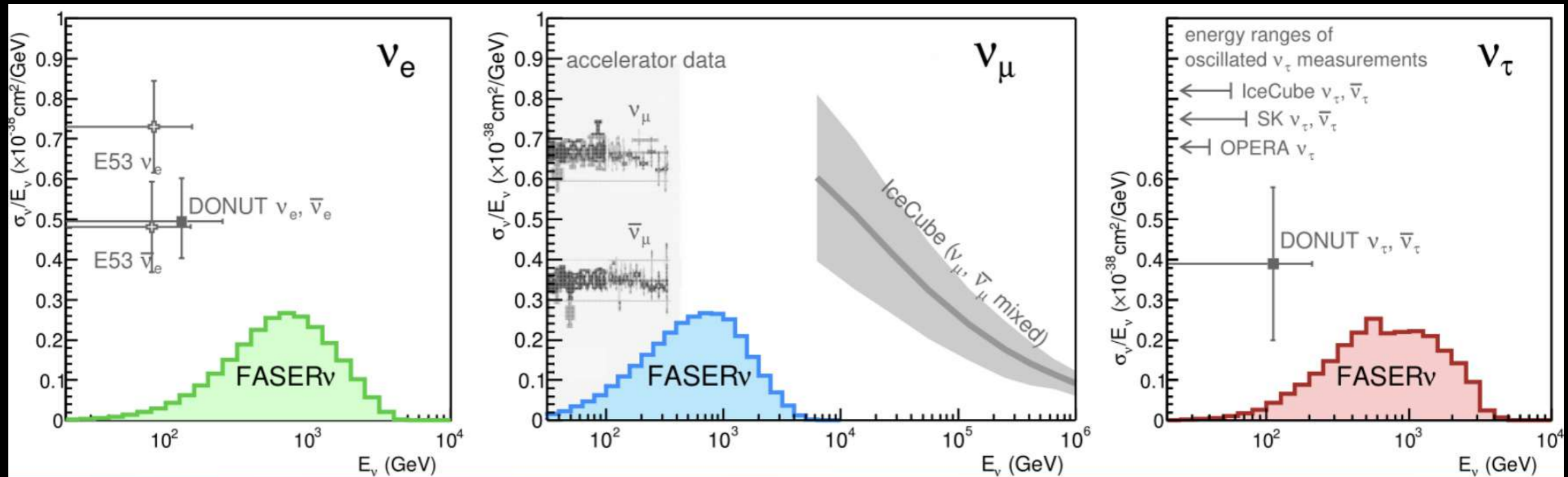
FASER web page: <https://faser.web.cern.ch/>



- LHCf measured  $\pi^0$ ,  $\gamma$ ,  $n$  at forward region and input them to the post-LHC had. prod. models.
- FASER measurements ( $\nu_e$ ,  $\nu_\mu$ ) bring information of  $\pi^\pm$ , K, D mesons production.
  - Dedicated talk will be presented by K.Ohashi
- **This talk focuses on the latest results of TeV-neutrinos cross section measurement.**

# Neutrino studies in FASER

*Eur.Phys.J. C80 (2020) no.1, 61*



- Neutrino cross sections at unexplored TeV energies
- Highest energy man-made
- Lepton Flavor Universality in neutrino scattering
- Heavy quark flavors channels

**In LHC Run 3, expect:**

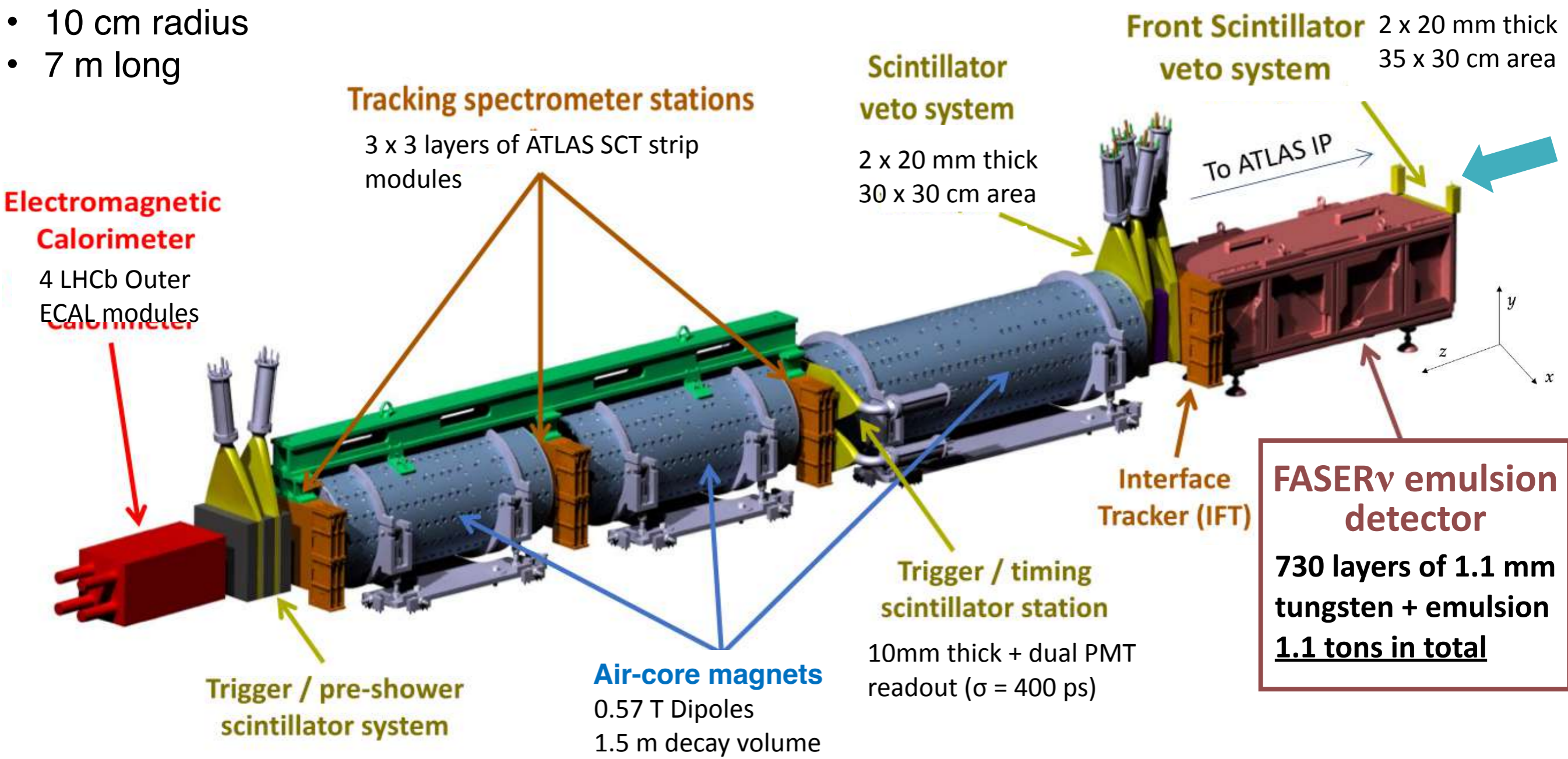
$\approx 1700 \nu_e$  interactions  
 $\approx 8500 \nu_\mu$  in FASERv  
 $\approx 30 \nu_\tau$   
 (MC expectations for 250 fb<sup>-1</sup>)

Largest **background** to charged-current (CC)  $\nu_\mu$  is NC  $\nu_\mu$  and CC  $\nu_e$

# FASER detector

10.1088/1748-0221/19/05/P05066

- 10 cm radius
- 7 m long



**FASER $\nu$  emulsion detector** is target and tracker for neutrino measurements.

# Data taking in LHC-Run 3 (2022-)

2018

2019

2020

2021

2022

2023

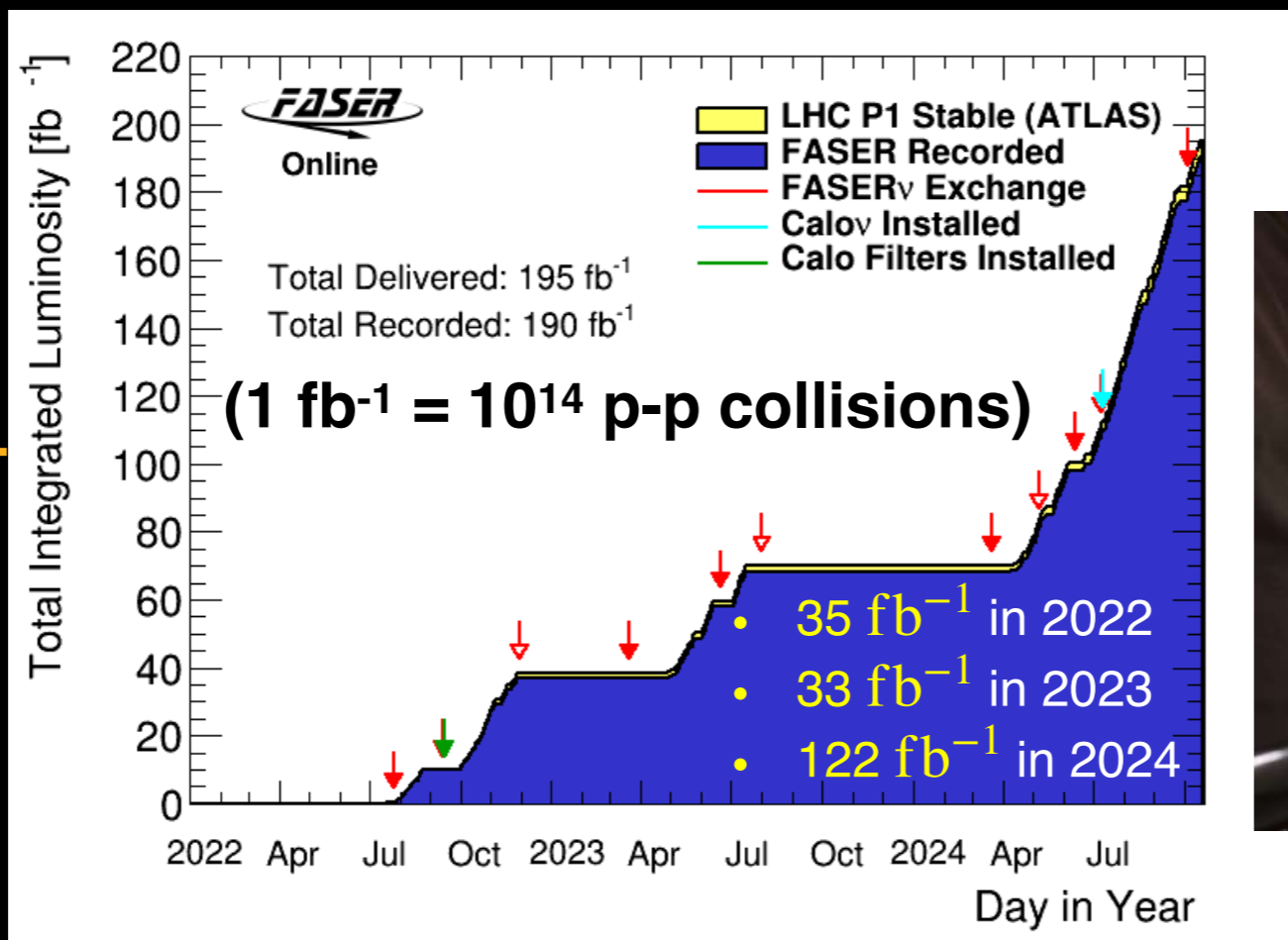
2024

2025

Run 2

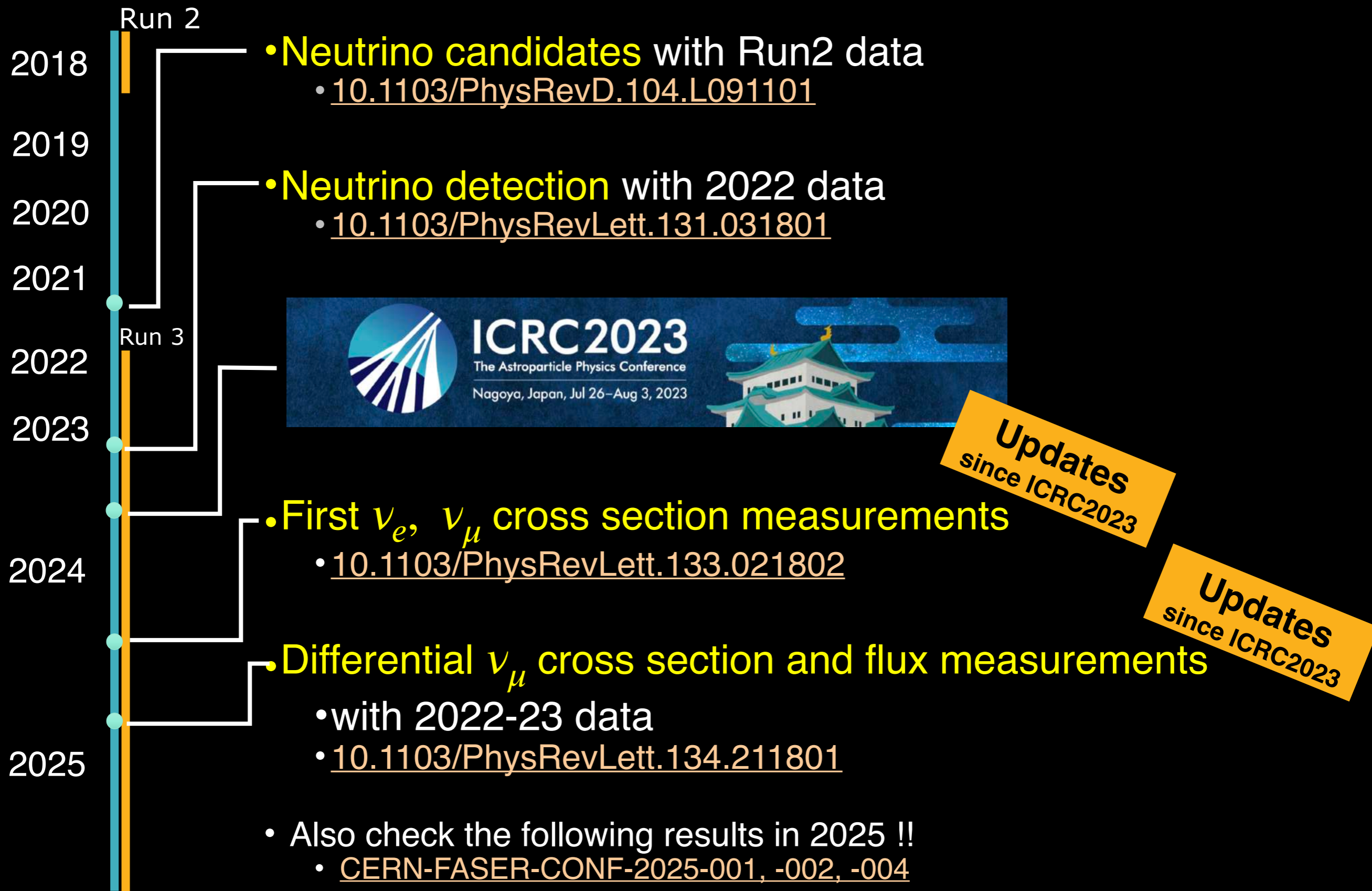
Run 3

- **Neutrino candidates** with Run2 data
- [10.1103/PhysRevD.104.L091101](https://arxiv.org/abs/10.1103/PhysRevD.104.L091101)



- Data taking is ongoing
  - Physics trigger rates are on average 1 kHz
  - >97% data taking efficiency since startup
- 7 FASERv emulsion detector has been exposed
  - Receiving **~105 fb<sup>-1</sup>** of data

# Neutrino Results from FASER



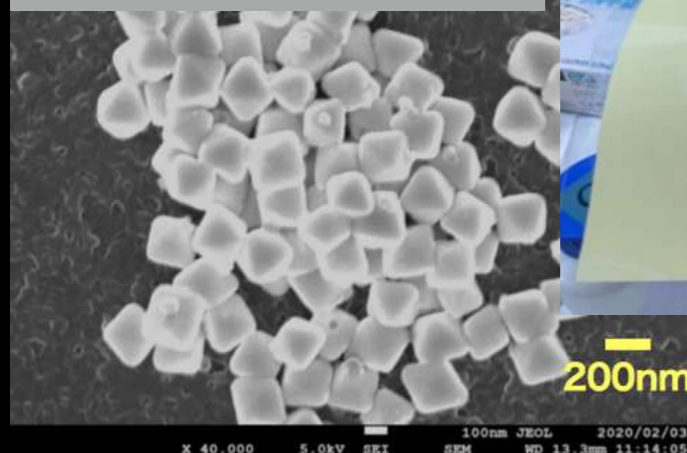
# FASER $\nu$ detector

- Emulsion/tungsten neutrino detector
  - 730 emulsion films
    - ~ an **exa-channel** detector
  - Target mass of **1.1 tons** ( $8 \lambda_{int}$ ,  $220 X_0$ )



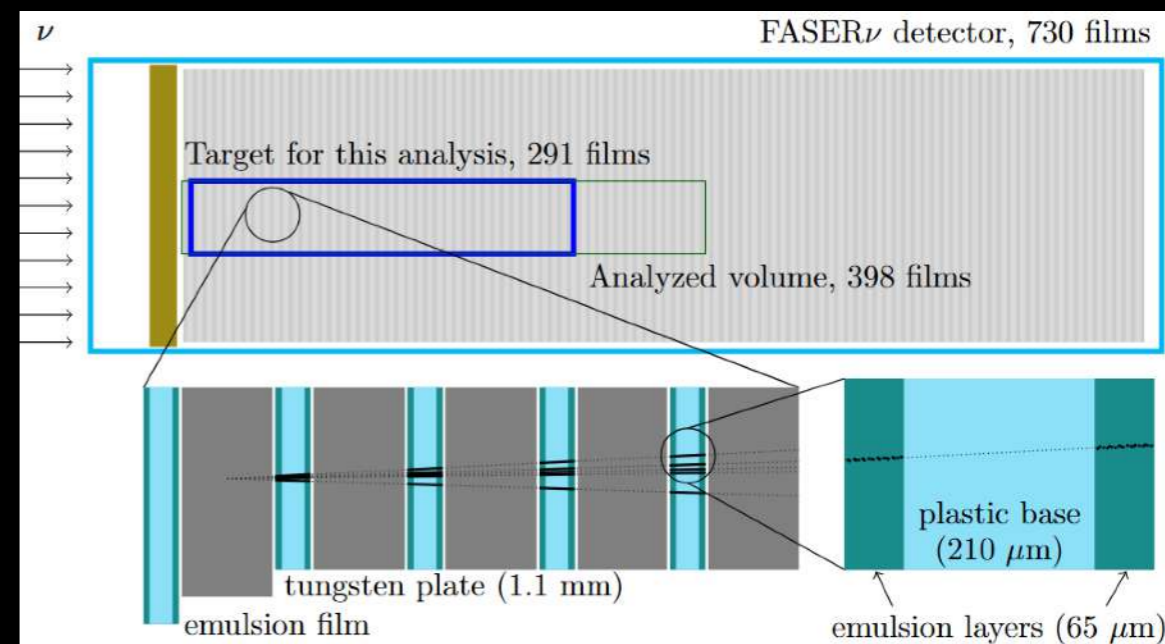
## Emulsion films

Silver bromide crystals

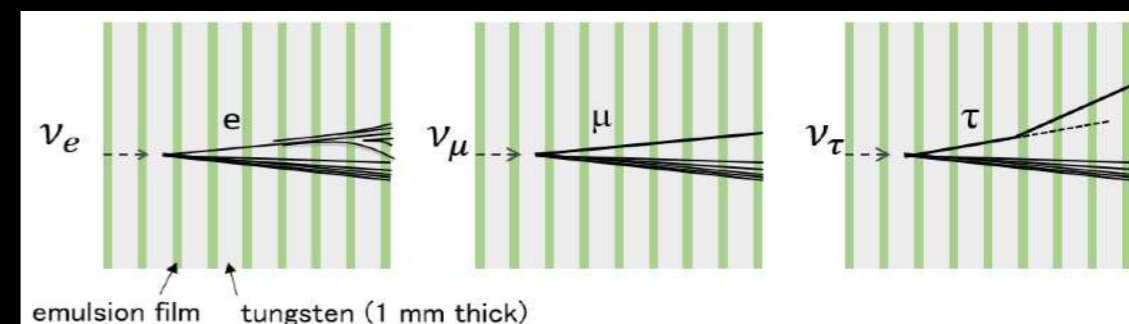


produced in Japan

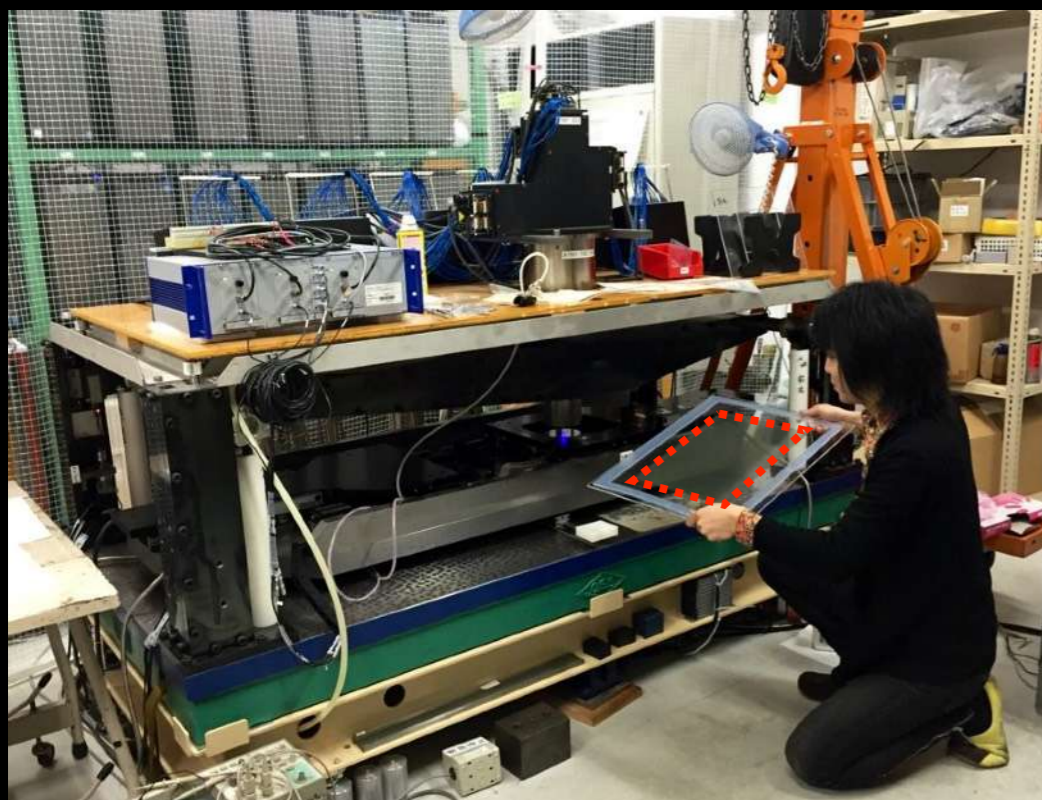
- **Silver bromide crystals** ~ 200 nm, position sensors for charged particles
- Super large number of detection channels ~  $8 \times 10^{14}$  **detection channels / film** (30 x 25 cm<sup>2</sup> in FASER $\nu$ )
- 3D tracking device with 50 nm intrinsic resolution



Identify all the flavors from the topology at the vertex

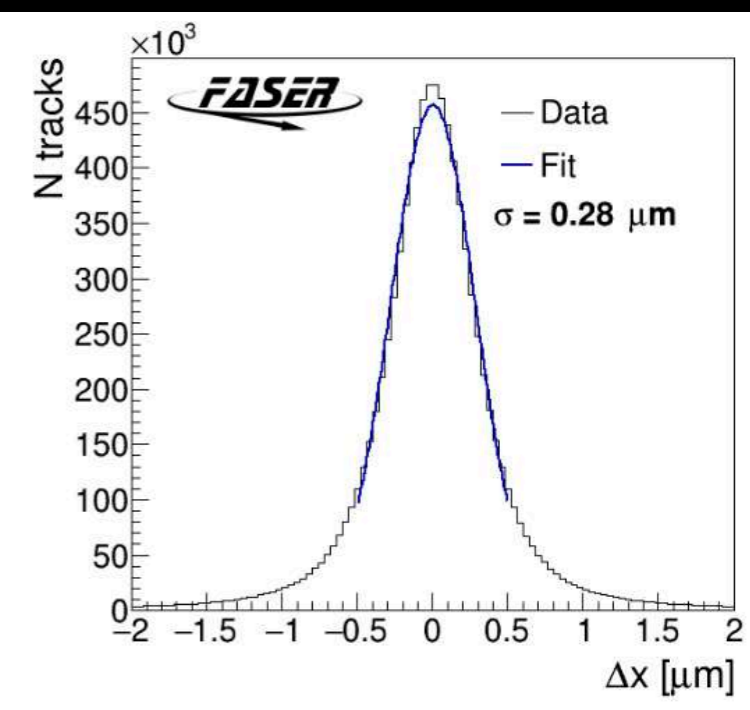
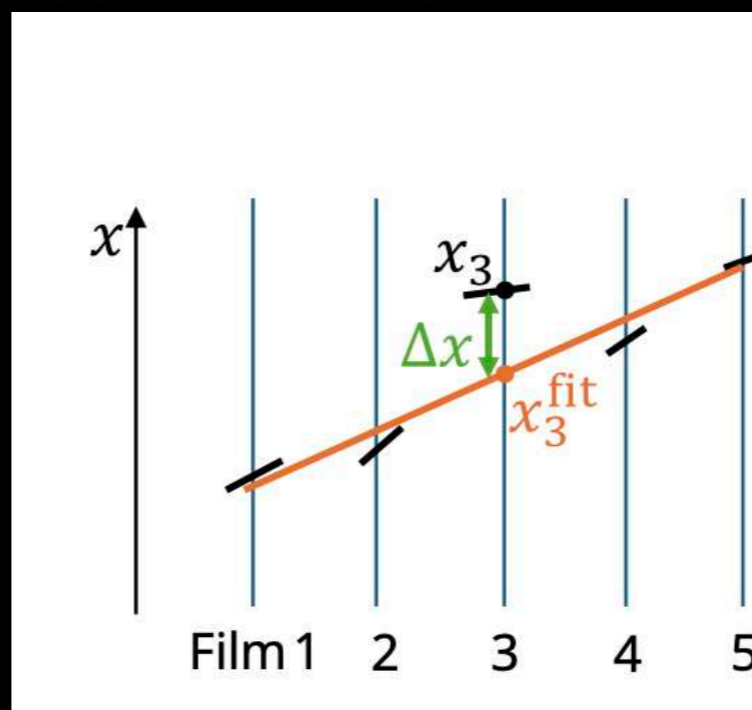
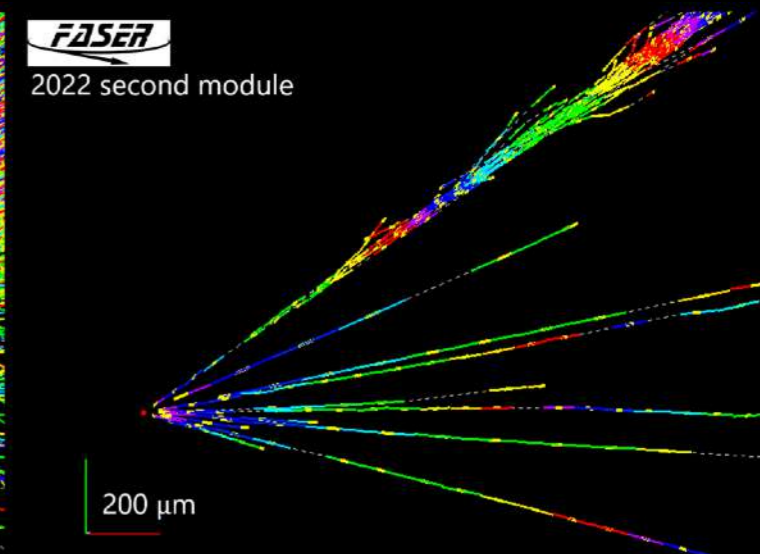
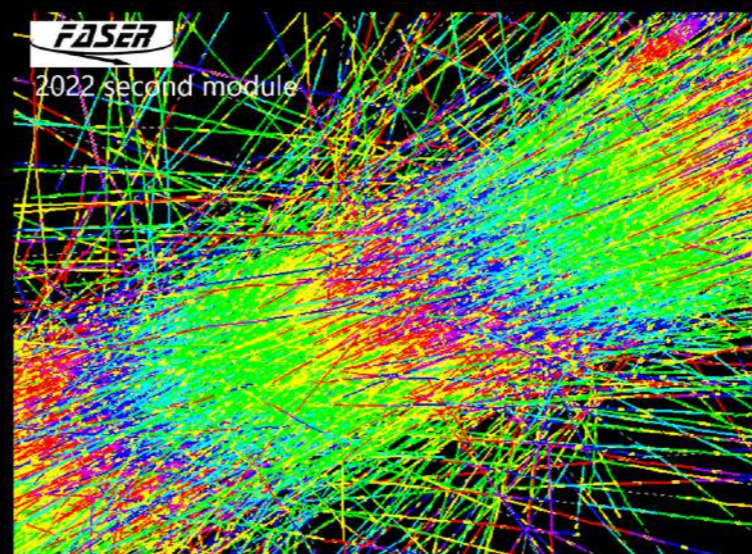


# Emulsion Data Acquisition & Vertex Reconstruction



Data acquisition in Japan

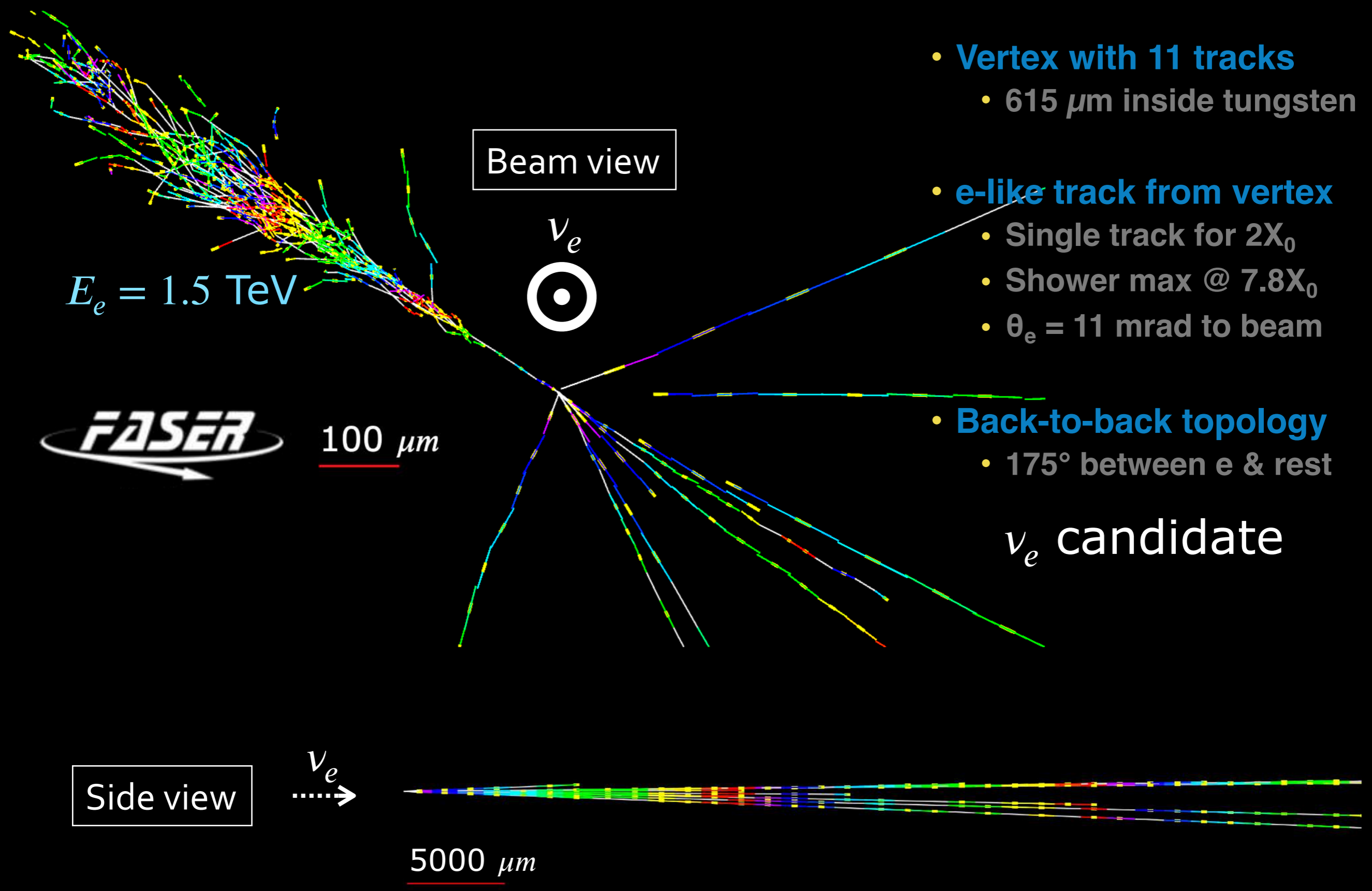
Converted analog tracks of emulsion into digital data w/ world's fastest scanning machines (HTS and HTS2)



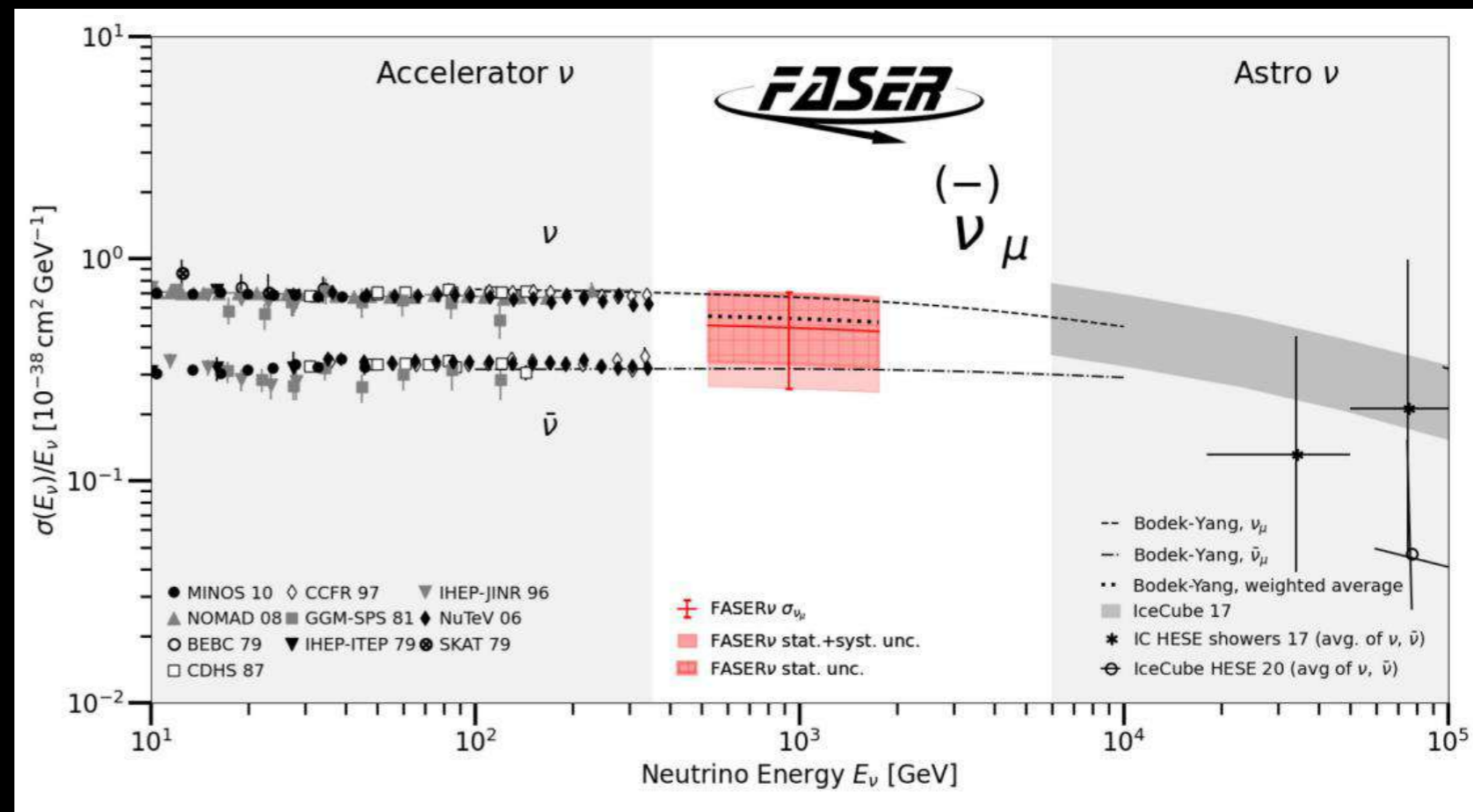
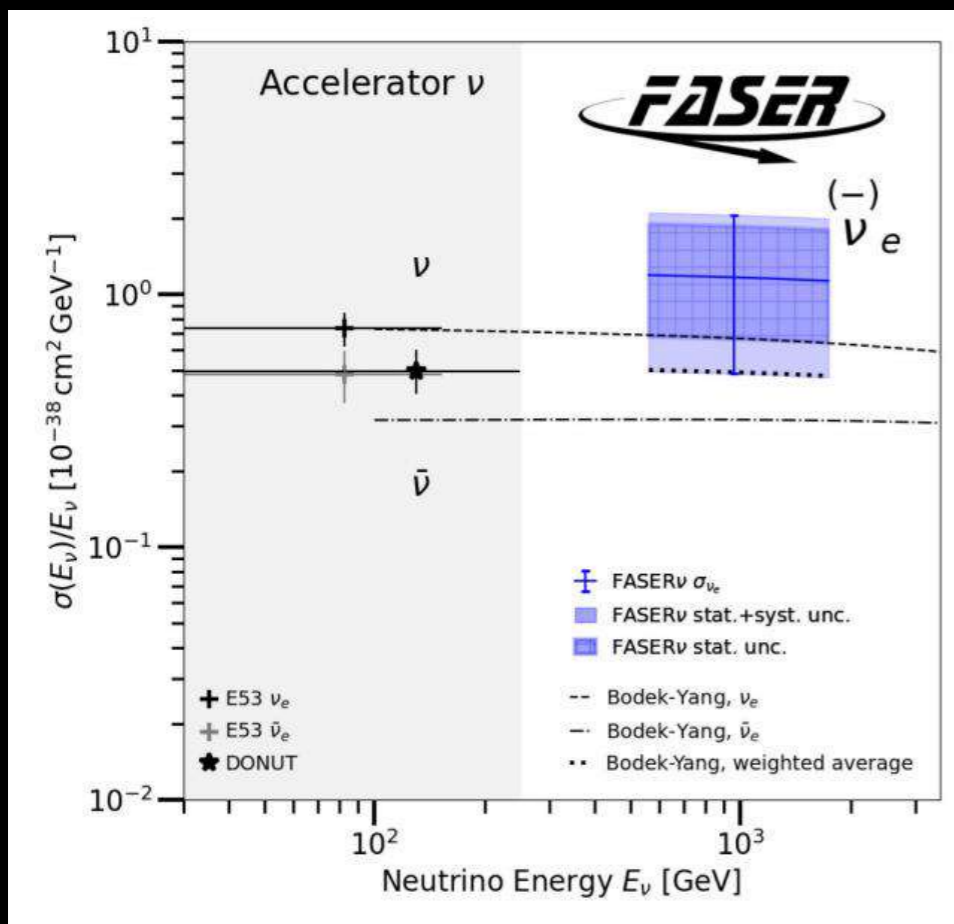
- Analyzed data set for the published result:
  - **~1.7%** of data collected by the end of 2023
  - **9.5 fb<sup>-1</sup>** in 2022 run, target mass of **128.6 kg**

[arXiv:2504.13008](https://arxiv.org/abs/2504.13008)

# Electron neutrino observation in FASERv



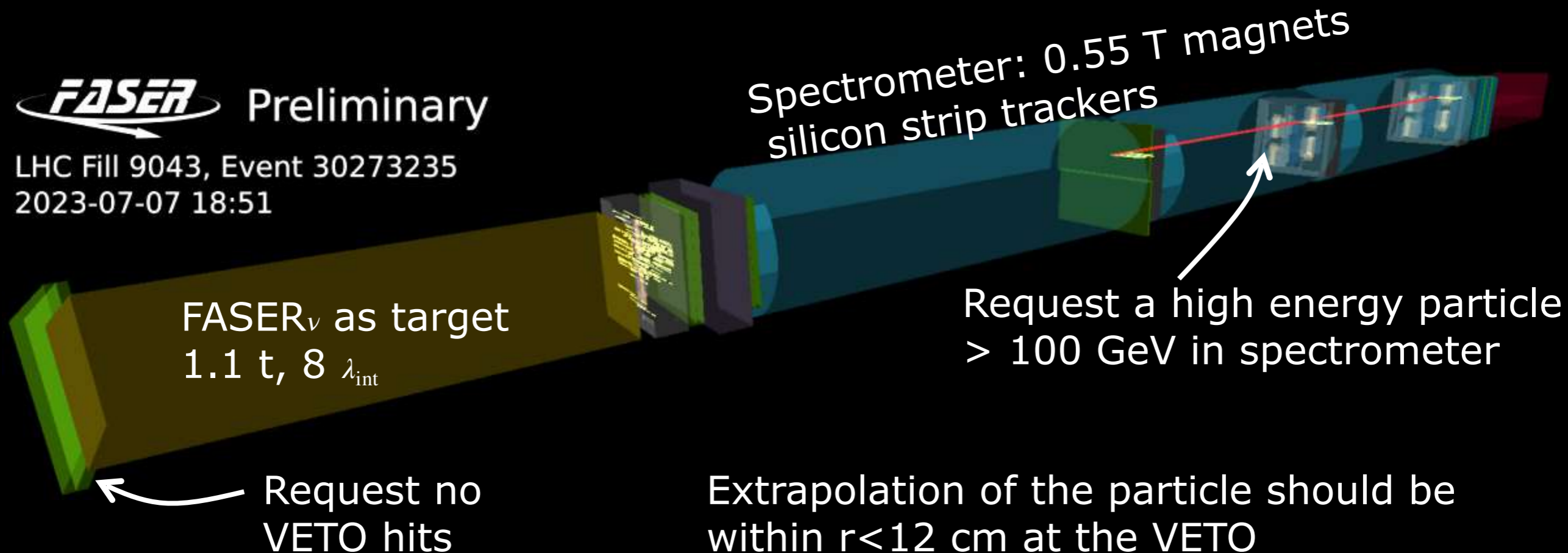
# Neutrino cross section measurements



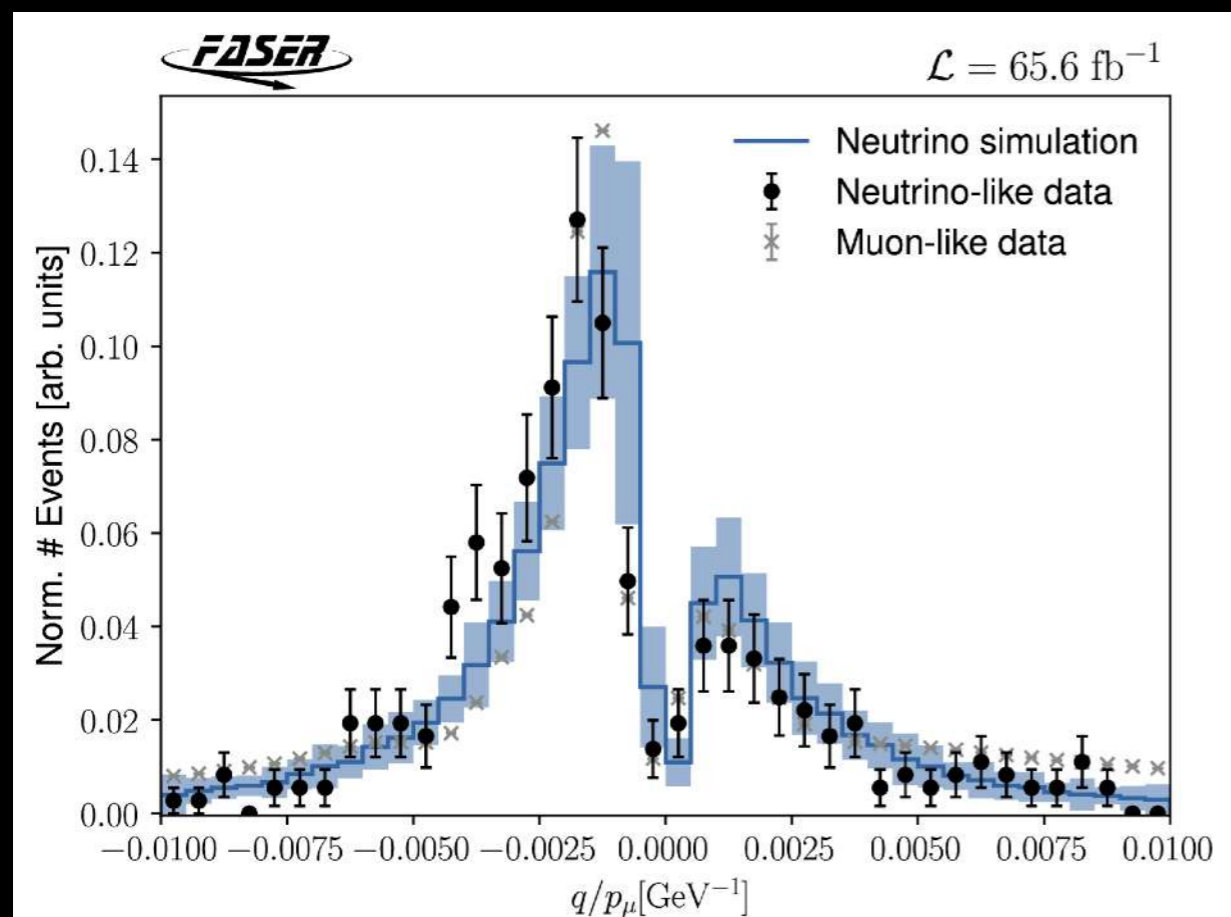
- First measurement of  $\nu_e$  and  $\nu_\mu$  cross sections in TeV energy region
- Working on a differential cross section measurement with the full 1.1 tons detector volume for  $9.5 \text{ fb}^{-1}$  data [CERN-FASER-CONF-2025-002](https://cds.cern.ch/record/2854447)

# Results with Electronic detectors

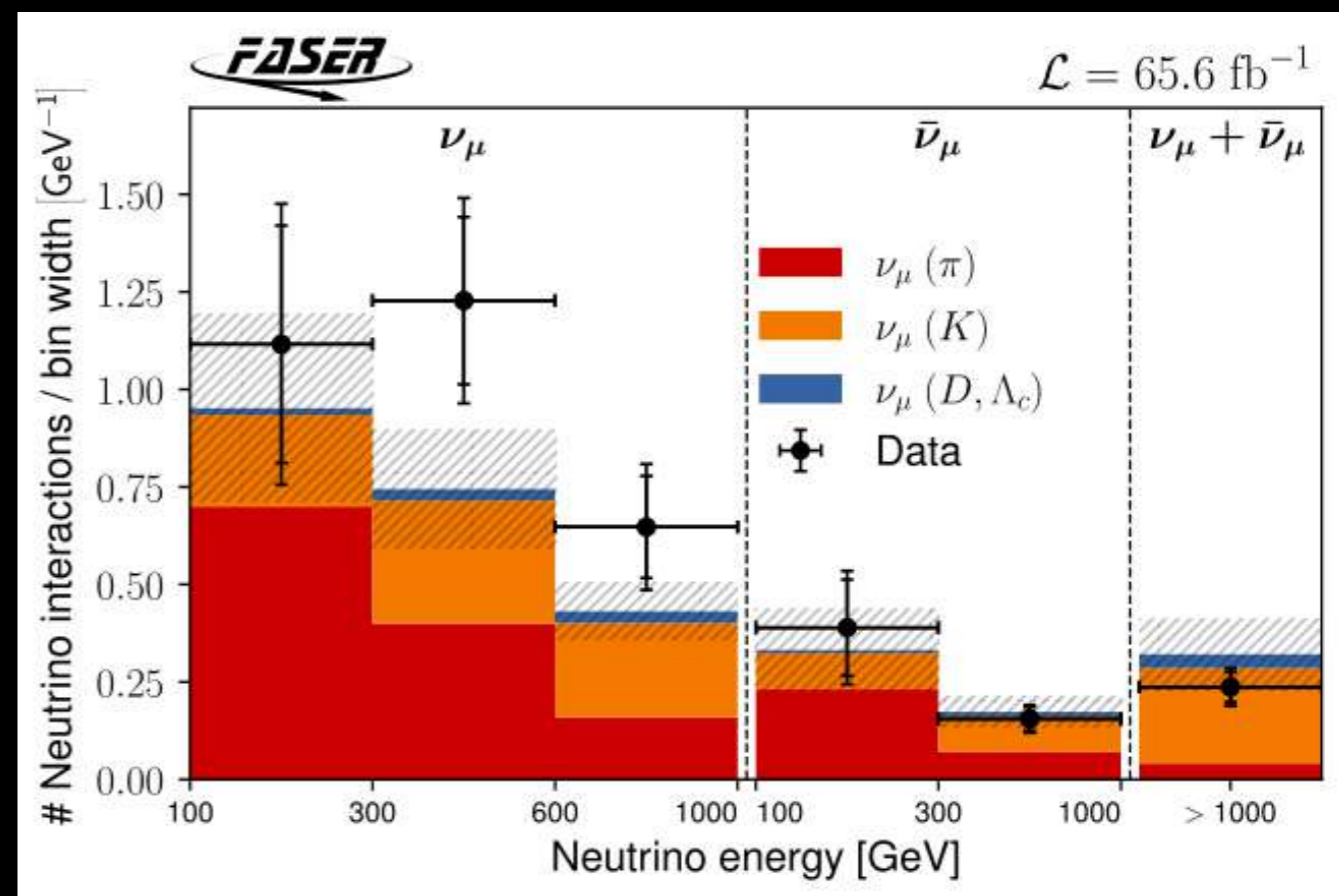
- First detection of neutrinos at the LHC was done by electronic detectors [10.1103/PhysRevLett.131.031801](https://arxiv.org/abs/10.1103/PhysRevLett.131.031801)
- Result of  $\nu_{\mu}$  measurement as a function of energy in 2024, using data set of 2022-2023 ( $65.6 \text{ fb}^{-1}$ ) [10.1103/PhysRevLett.134.211801](https://arxiv.org/abs/10.1103/PhysRevLett.134.211801)



# Observed events and kinematics



362 observed,  $322 \pm 51$   $\nu_\mu$  CC expected  
 + 24 non- $\nu_\mu$  CC BG

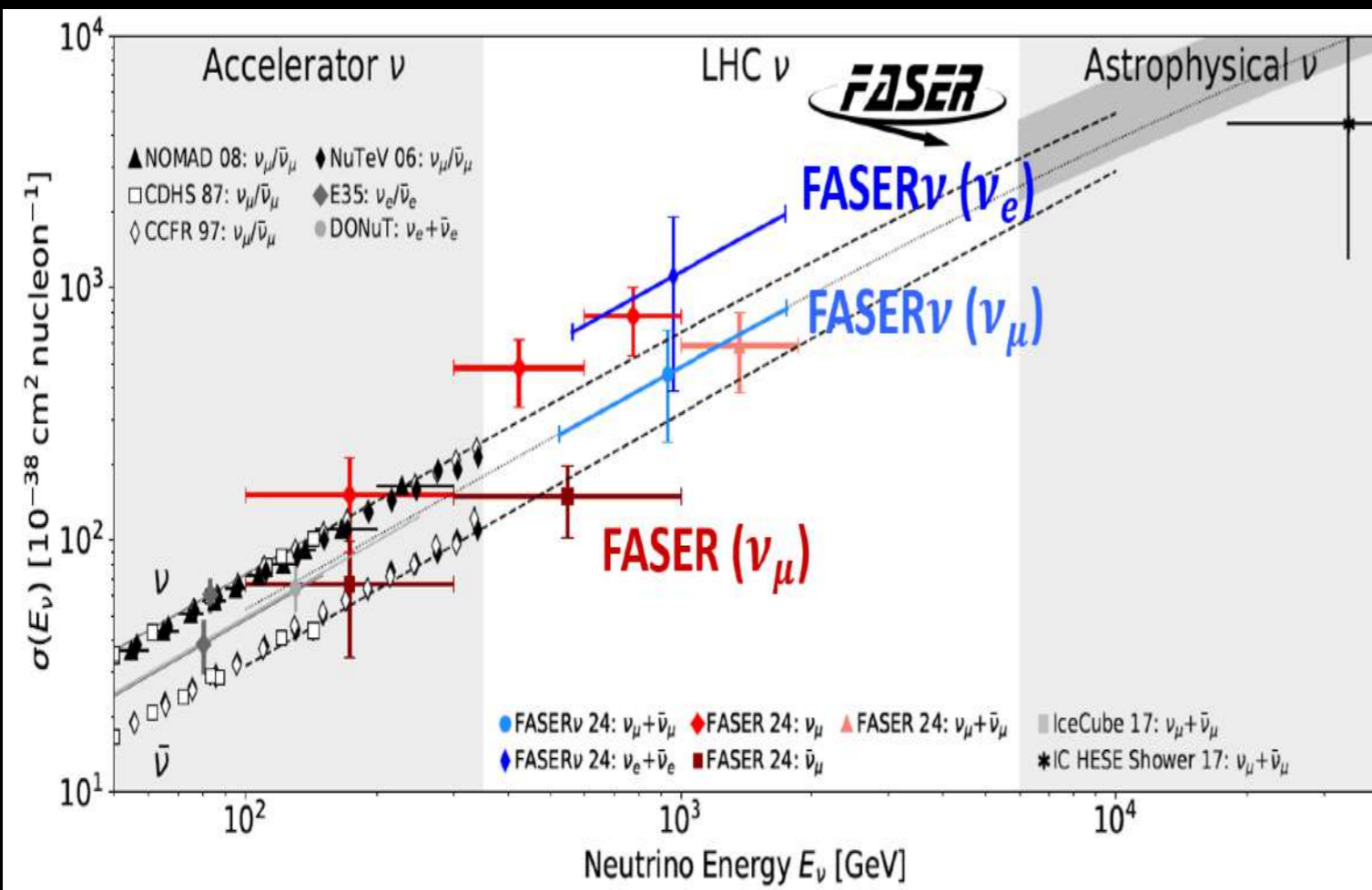
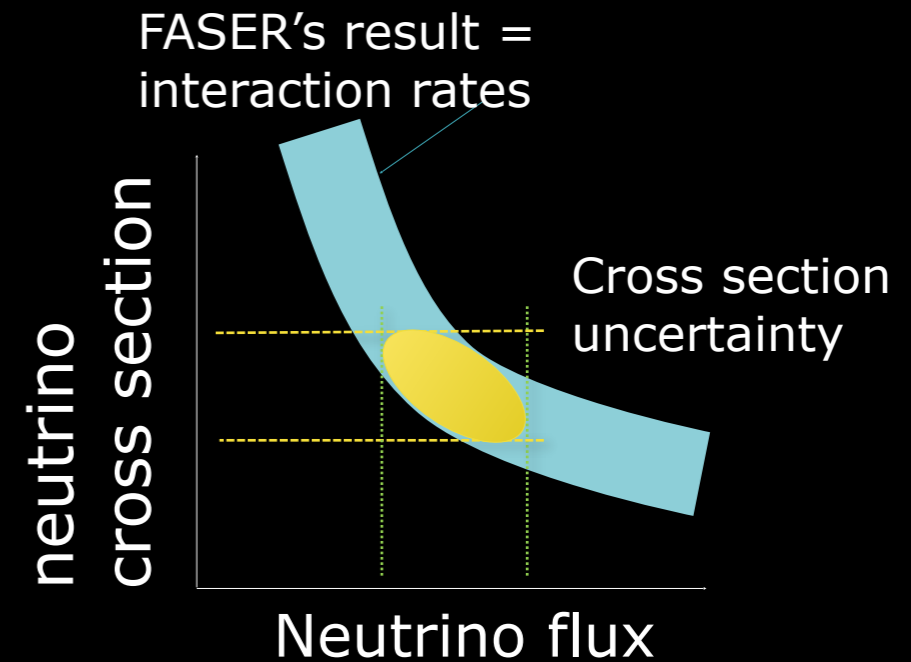


Muon momentum is unfolded into neutrino energy (3 bins),  
 anti-neutrino energy (2 bins), and a high energy bin for nu + nu-bar

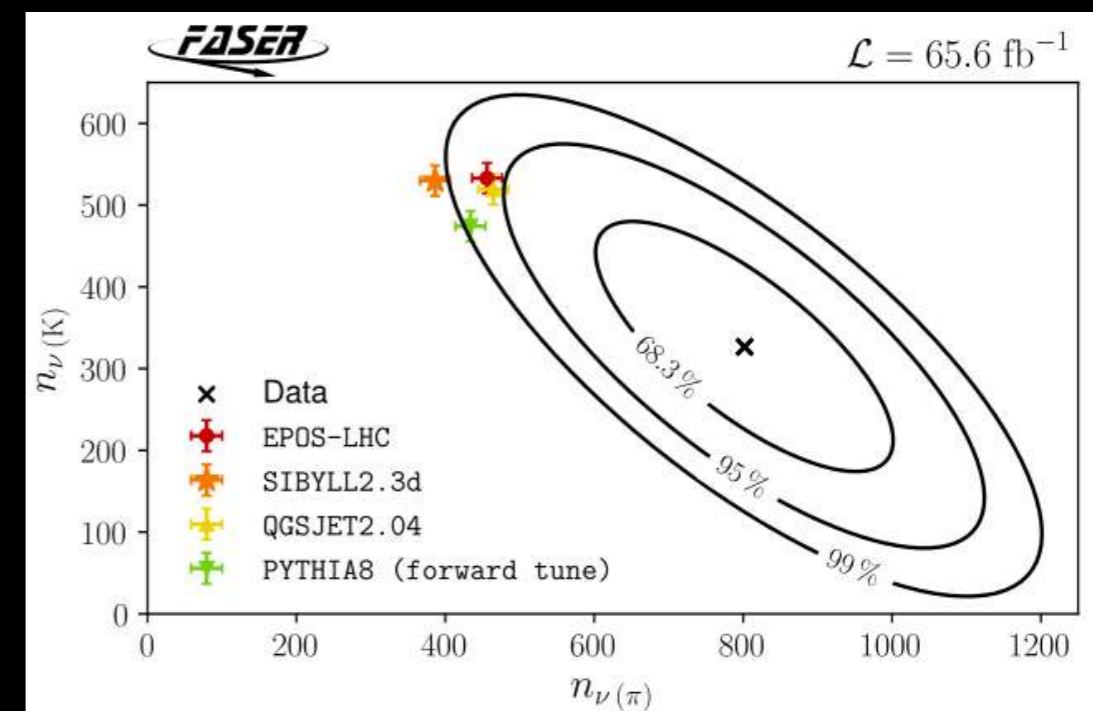
Pseudorapidity distributions are also updated in [CERN-FASER-CONF-2025-001](#)

# Interpretations of $\nu_\mu$ interaction rate

- FASER's result can be interpreted in two ways
  - Neutrino cross sections
  - Flux measurement  $\rightarrow$  hadron production model study

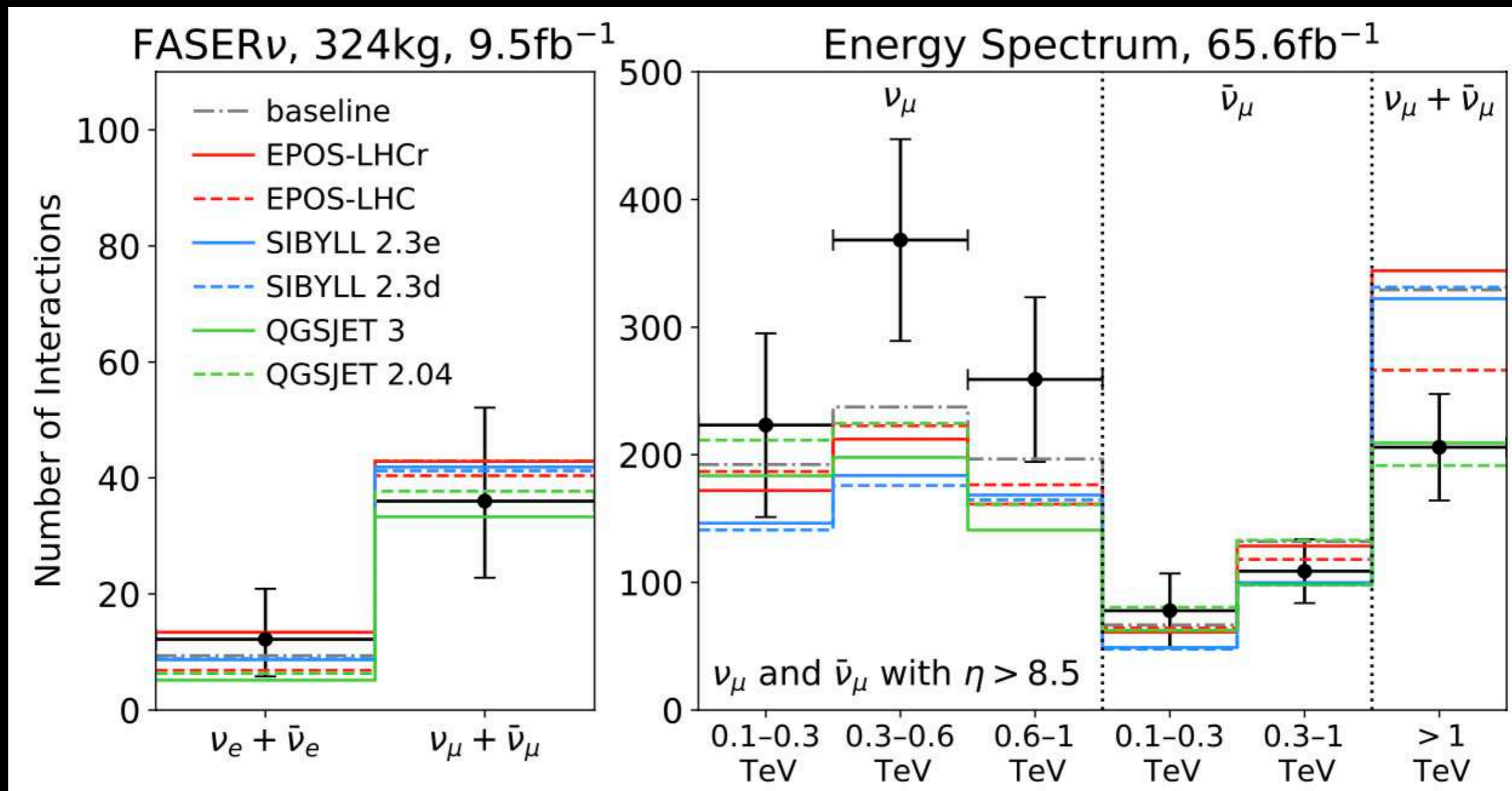


Analysis in  $\pi/K$  production ratio at  $p$ - $p$  collisions



# Comparison of Cosmic Ray Monte Carlos to FASER data

Dedicated talk by K. Ohashi



- Towards more precise measurements [CERN-FASER-CONF-2025-004](https://cds.cern.ch/record/2874444/files/CERN-FASER-CONF-2025-004)
- FASER at Run4 (2030-2033) (approved)
- FASER2 and FASERv2 at Forward Physics Facility (FPF)

# Summary & Prospects

- **Targets of FASER experiment**
  - **long-lived BSM particles and SM neutrinos**
- **Latest results of TeV-neutrinos measurement.**
  - **First measurement of  $\nu_e$  and  $\nu_\mu$  cross sections in TeV energy region**
  - **Result of  $\nu_\mu$  measurement as a function of energy**
  - **Comparison of Cosmic Ray Monte Carlos to FASER data**
- **Discussing extended physics programs**
  - **FASER at Run4 (2030-2033) (approved)**
  - **FASER2 and FASERv2 at Forward Physics Facility (FPF)**