



# Latest Results from FASER at the LHC

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on behalf of the FASER Collaboration

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**HEISING-SIMONS**  
FOUNDATION

**SIM**  
FOUNDATION

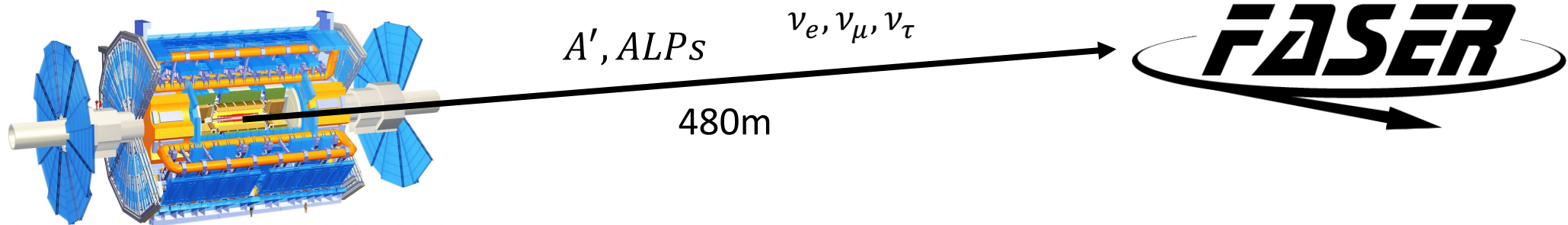
**NS**

**科研費**  
KAKENHI



# FASER physics

ATLAS Interaction Point(IP)



FASER's target: Light and weakly-interacting particles at LHC

- New long-lived particles(LLPs)
  - Dark photons
  - Axion-like particles (ALPs)
- $e, \mu, \tau$  (anti-)neutrino in TeV energies

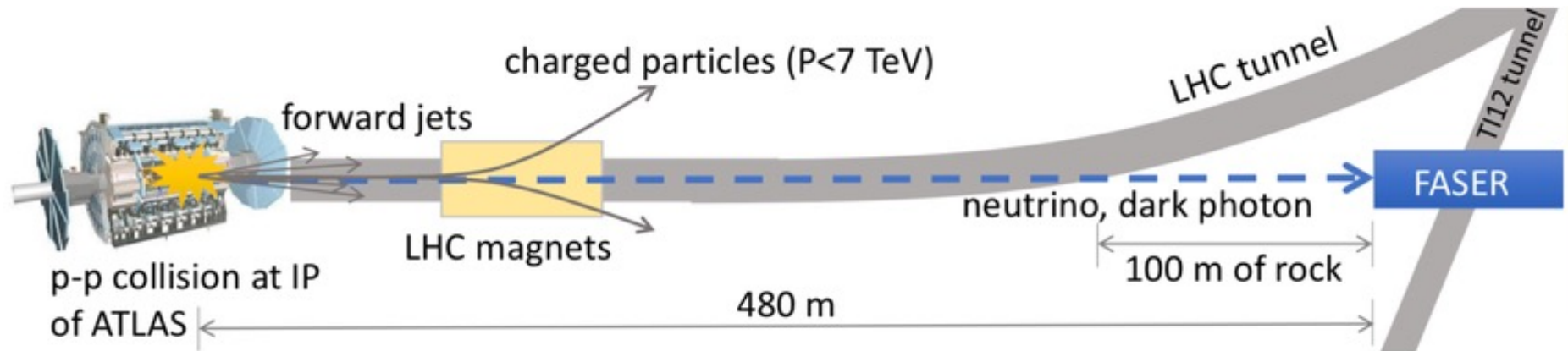
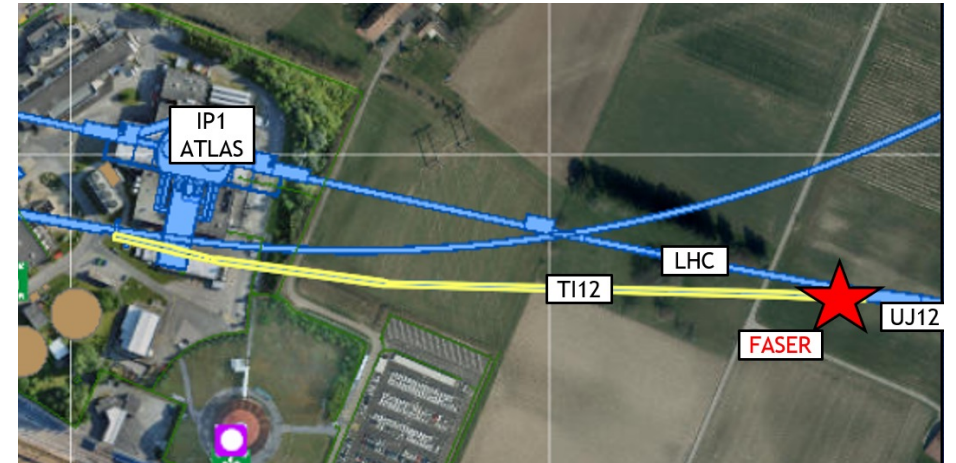
These particles are emitted in very forward direction ( $\theta \sim mrad$ )

# ForwArd Search ExpeRiment (FASER)

480m downstream from ATLAS IP

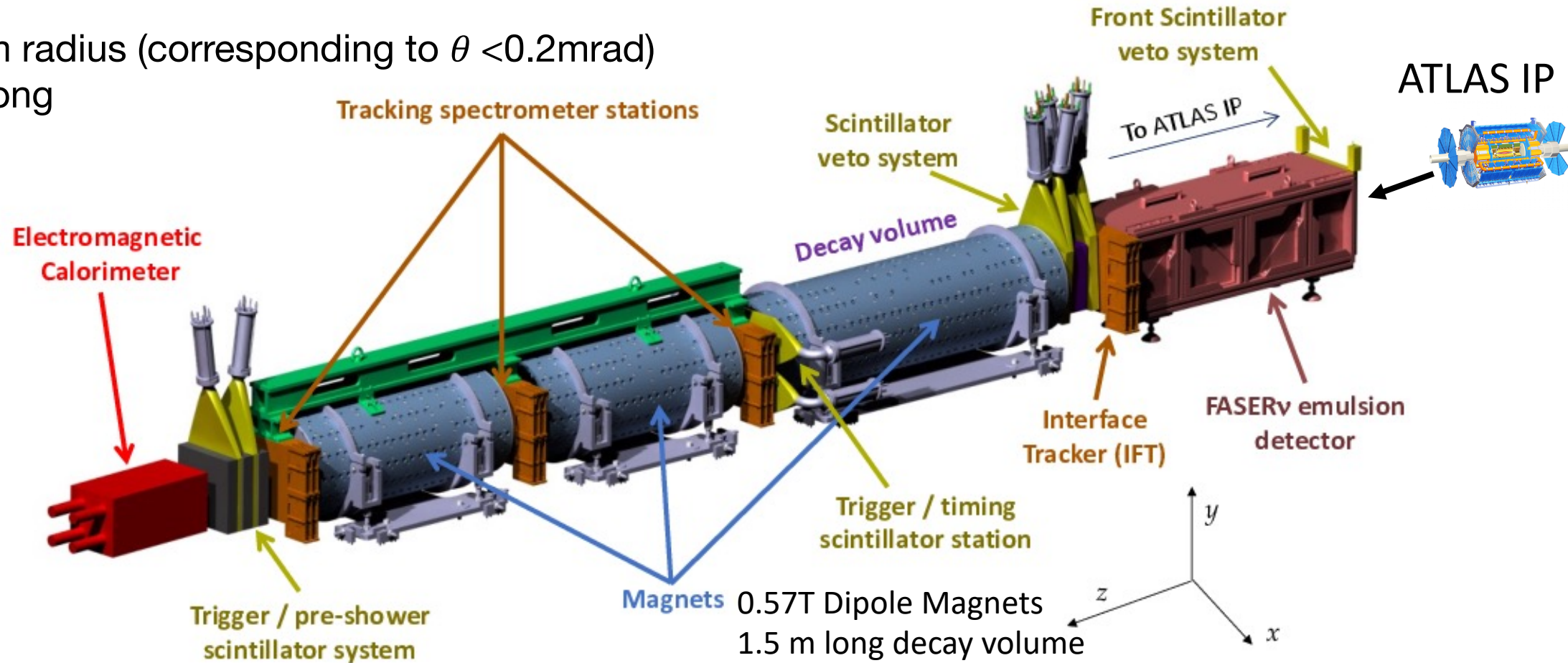
- New LLPs (e.g. Dark photons, ALPs)
  - Three flavours Neutrinos
  - High Energy Muons
- are expected to be reached to FASER detector

Taking data since LHC Run3 (2022)



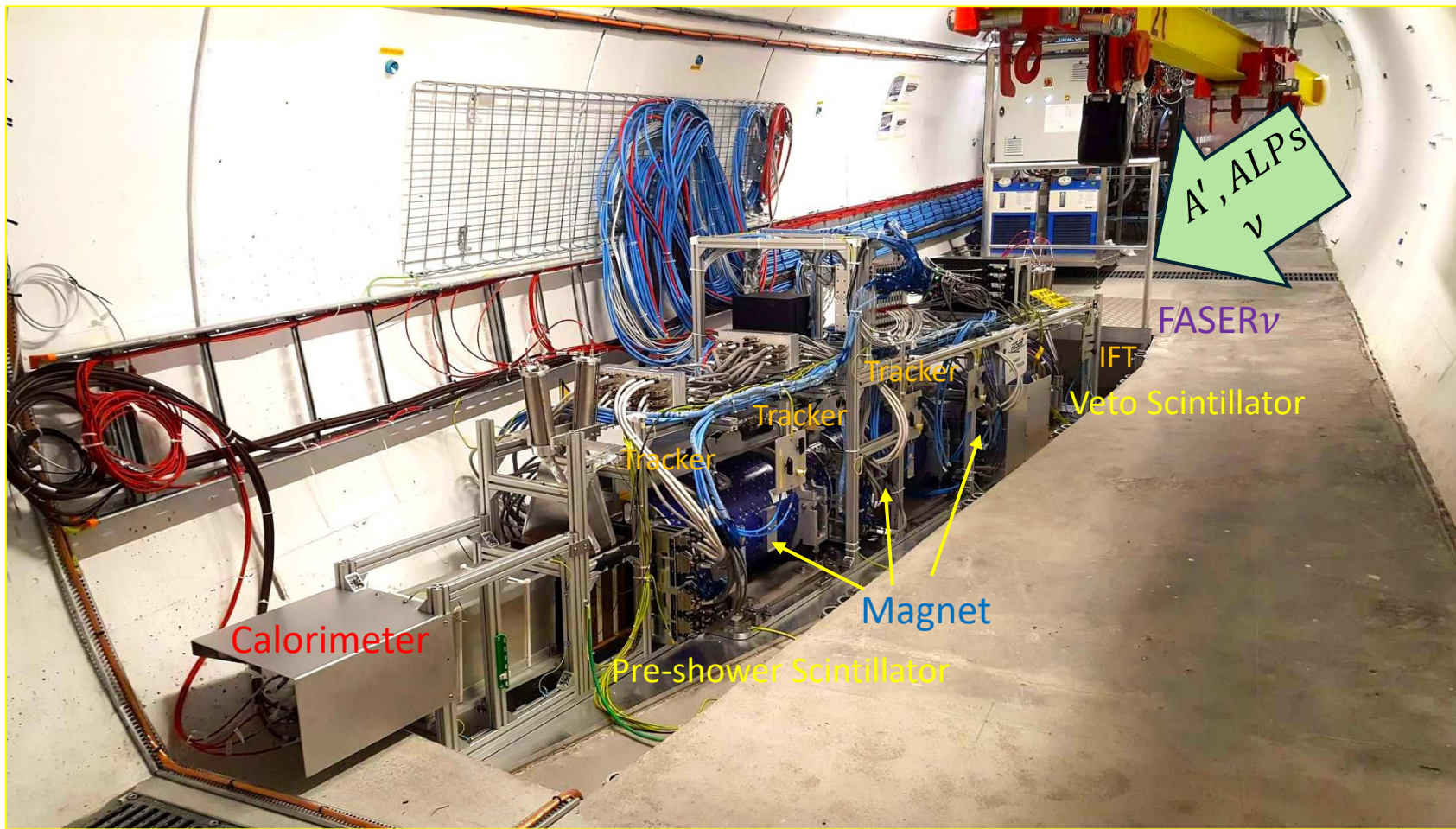
# FASER detector

- 10cm radius (corresponding to  $\theta < 0.2\text{mrad}$ )
- 7m long





# FASER detector



# Results from FASER

## BSM

2023 Mar.

Search for **Dark Photons**

with 2022 data

2024 Mar.

Search for **Axion-Like Particles (ALPs)**

with 2022+2023 data

## SM

2023 Jul.

First Direct **Observation** of Collider Neutrino

with 2022 data

2024 Mar.

Measurement of the

**$\nu_e$  and  $\nu_\mu$  Interaction Cross Sections**

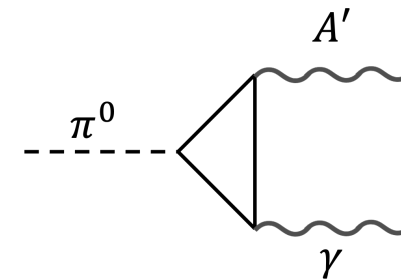
with 2022 data

from FASER $\nu$  emulsion detector

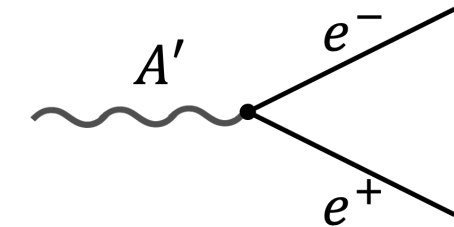
# Dark photons Search in FASER

[Phys. Let B, 848, 138378](#)

- Dominant source is neutral pion decay
- Mostly decay to electron and positron
- expected to be sensitive to the region where  $m_{A'} \sim 100\text{MeV}$  and  $\epsilon \sim 10^{-5}$



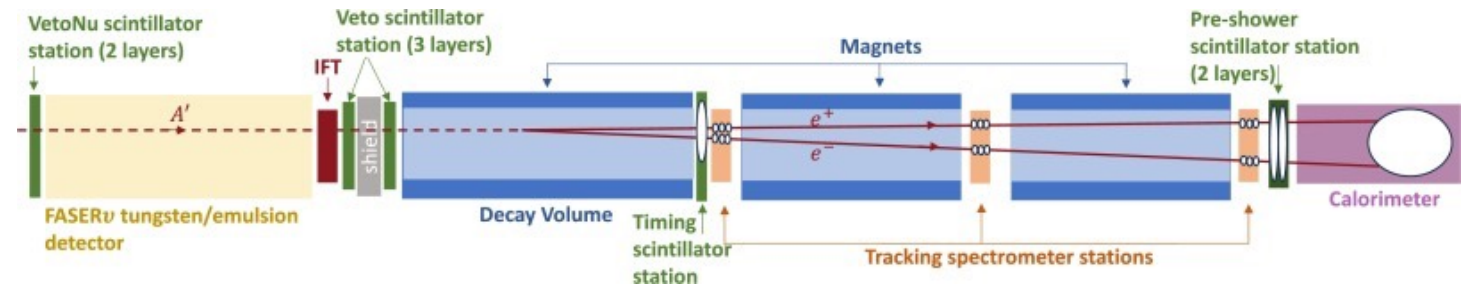
production



Decay

## Signal

- No signals in veto scintillators
- Signal in Pre-shower scintillator
- Two reconstructed tracks
- (total calorimeter energy) $>500\text{GeV}$

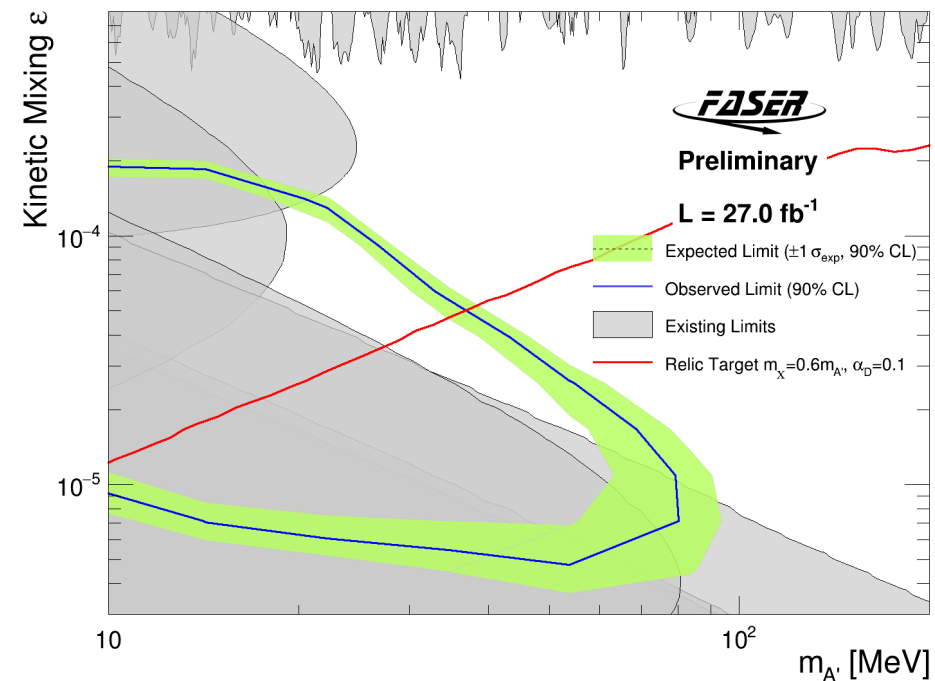
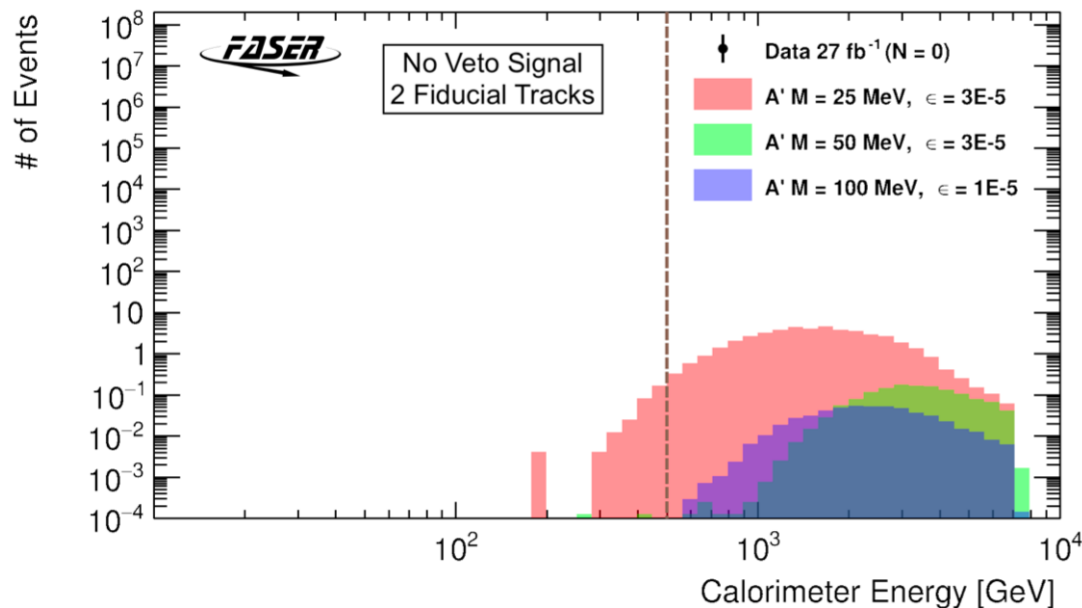


# Latest results about Dark photons Search

Phys. Let B, 848, 138378

27.0 fb<sup>-1</sup> of collision data in 2022 was used.

- $(2.7 \pm 2.7) \times 10^{-3}$  events was expected as background in total.
- **No event** was found in signal region.

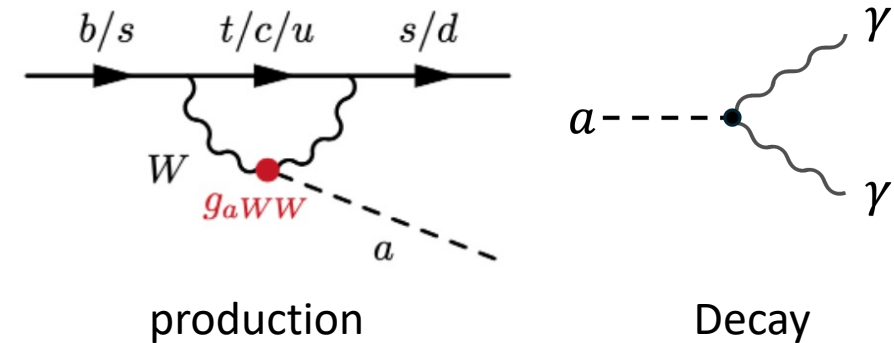




# ALPs Search in FASER

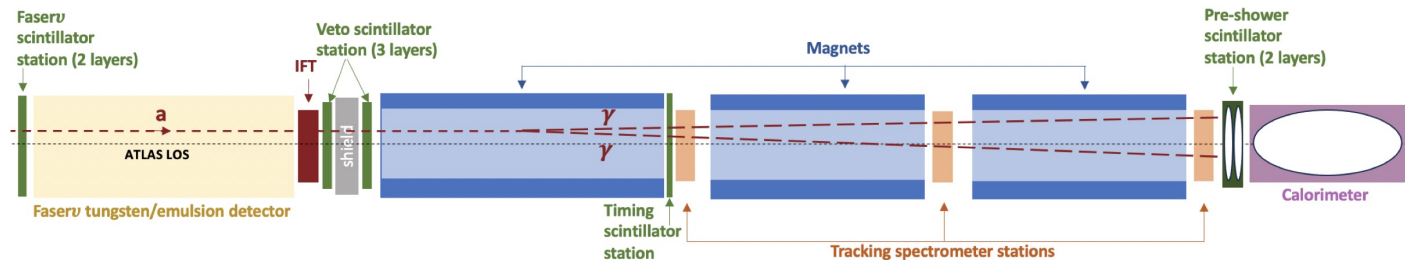
CERN-FASER-CONF-2024-001

- Dominant source is b(s)-flavoured hadrons decay
- decay to pair of photons
- expected to be sensitive to the region where  $m_a \sim 60 - 400$  MeV and  $g_{aWW} \sim 10^{-5} - 10^{-3} \text{GeV}^{-1}$



## Signal

- No signals for veto scintillators
- Pre-shower scintillator had a signal from EM shower by photons.
- (total calorimeter energy) > 1.5 TeV

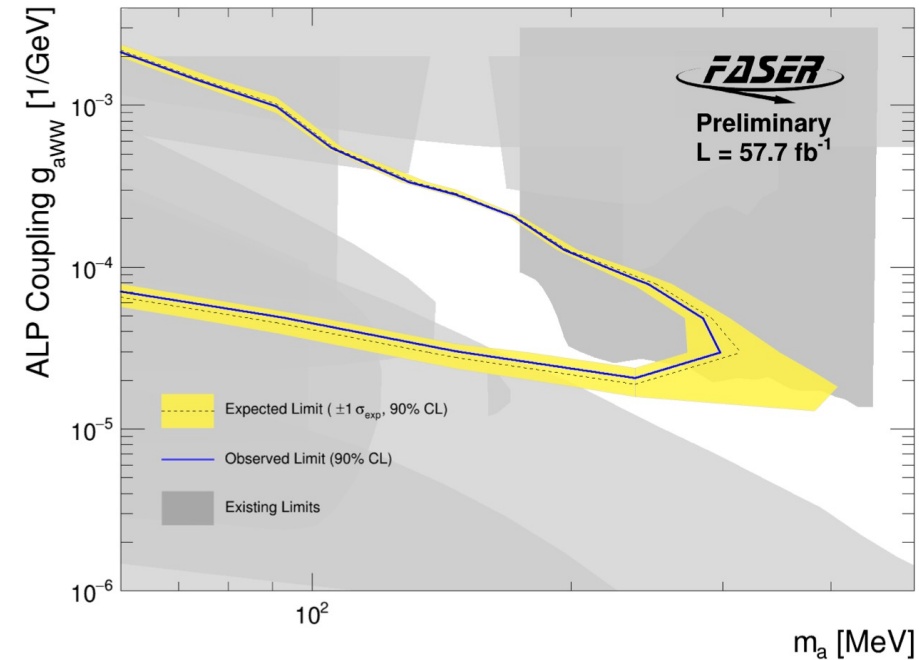
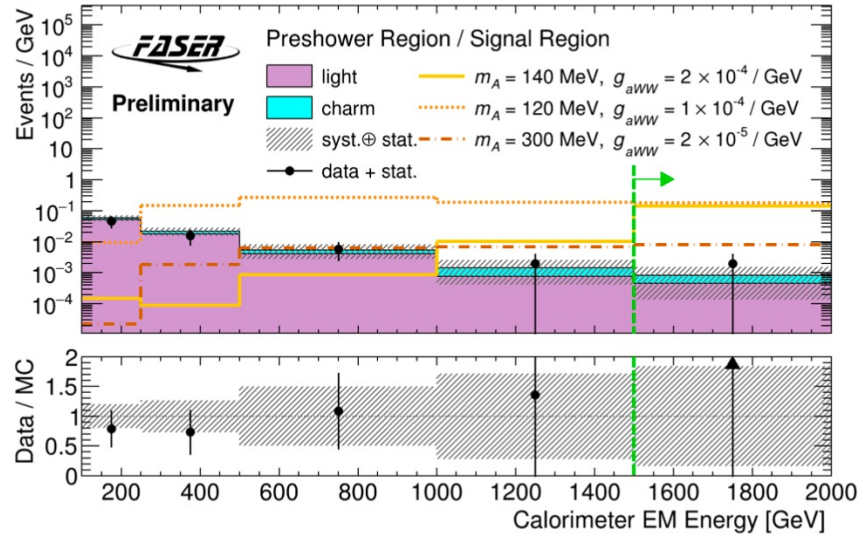


# Latest results about ALPs Search

CERN-FASER-CONF-2024-001

57.7 fb<sup>-1</sup> of collision data was collected in 2022 and 2023.

- $0.42 \pm 0.38$  events was expected as background in total.  
Main background source is neutrino interacting in the pre-shower scintillator.
- **One event** was found in signal region.

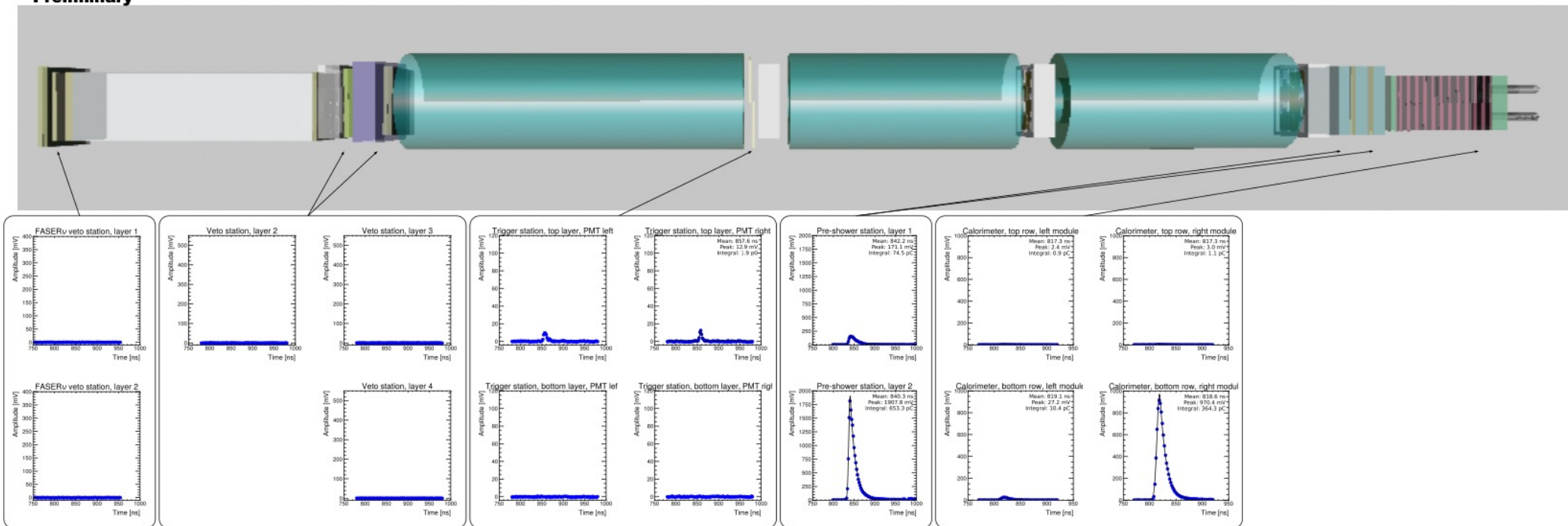


# Event display of 1 selected event

CERN-FASER-CONF-2024-001



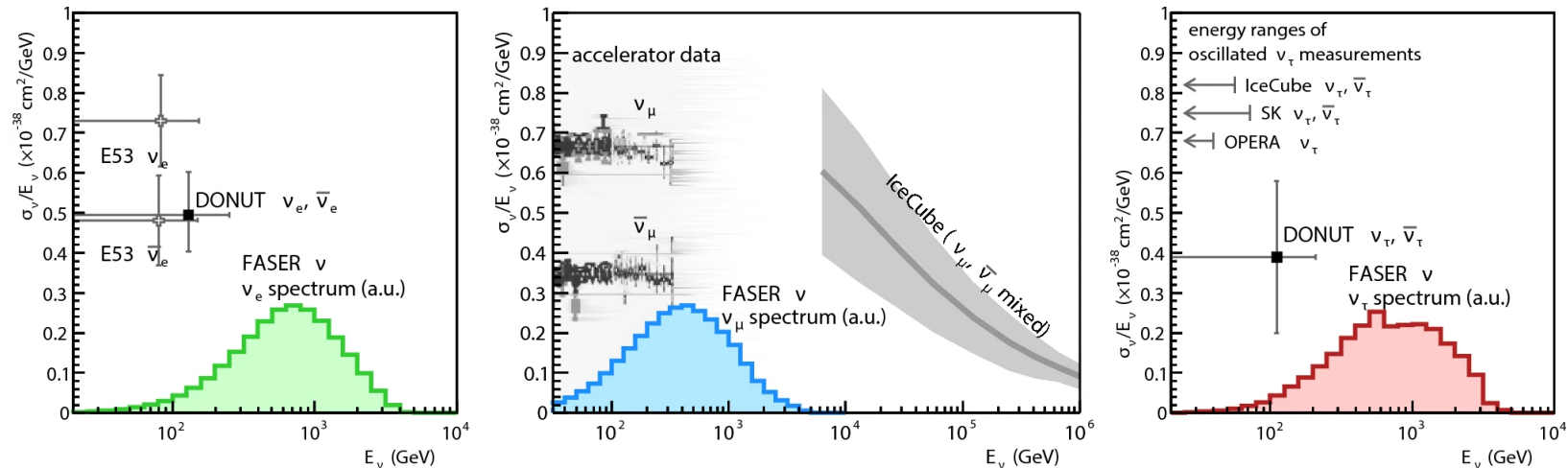
Run 8834  
Event 44421456  
2022-10-13 16:09:44



This is also consistent with a signal of neutrino interaction (background) event.

# Neutrino studies in FASER

- **Neutrinos and anti-neutrinos of all flavors** are produced at particle colliders.  
→ 1700  $\nu_e$ , 8500  $\nu_\mu$  and 30  $\nu_\tau$  are expected to interact in FASER $\nu$  detector  
for an integrated luminosity of 250 fb<sup>-1</sup>.
- These neutrinos are typically in TeV energies which is an unexplored region.





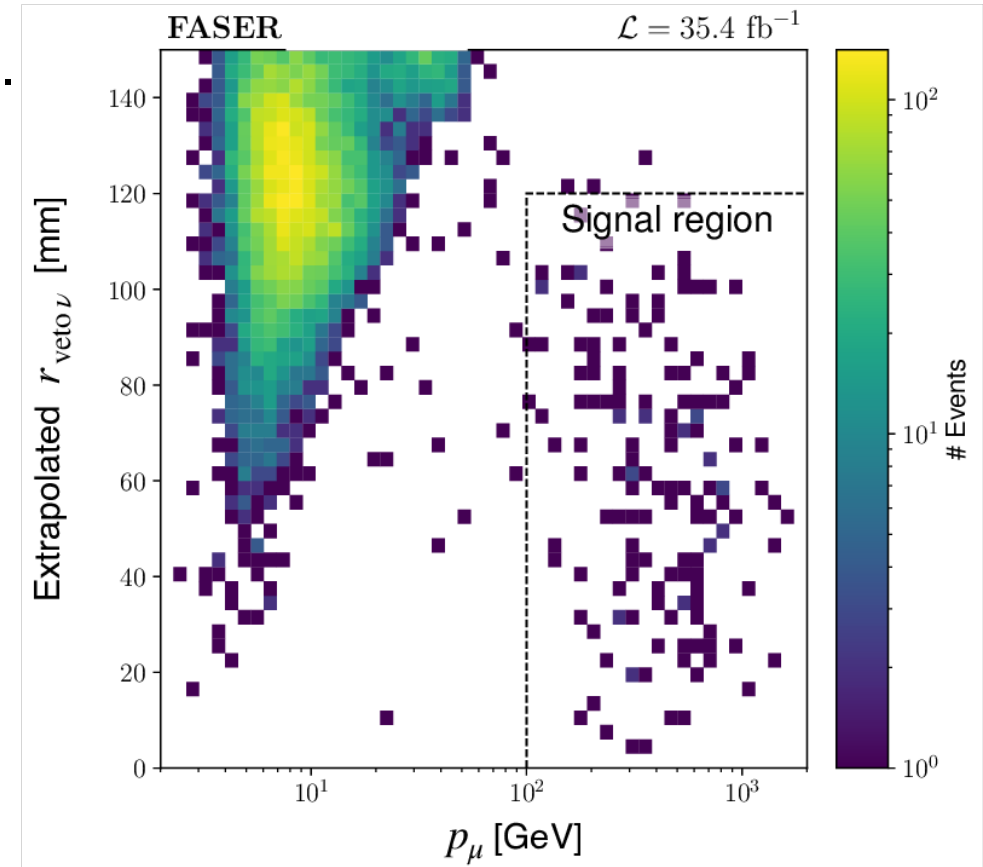
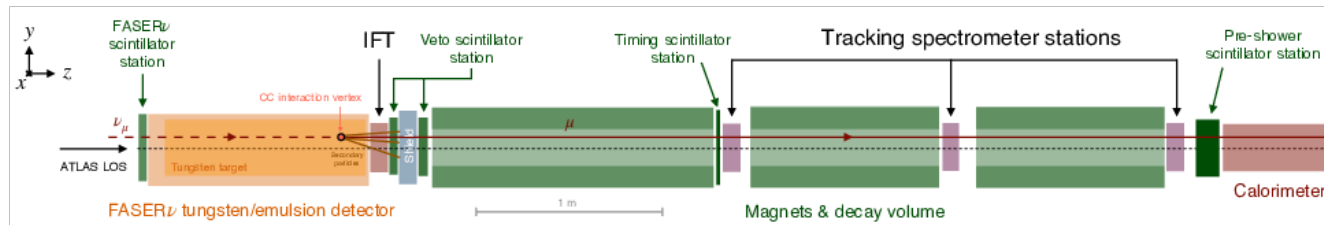
# First detection of Collider Neutrino

- 35.4 fb<sup>-1</sup> of collision data in 2022 was used.
- Only electronic components of the detector was used.

## Signals

- No FASER<sub>ν</sub> veto scintillator signal.
- The track which is consistent with a  $\nu_\mu$  CC interaction
- $p_\mu > 100\text{GeV}$
- **153<sup>+12</sup><sub>-13</sub> events** were observed.  
→ significance of 16 standard deviations

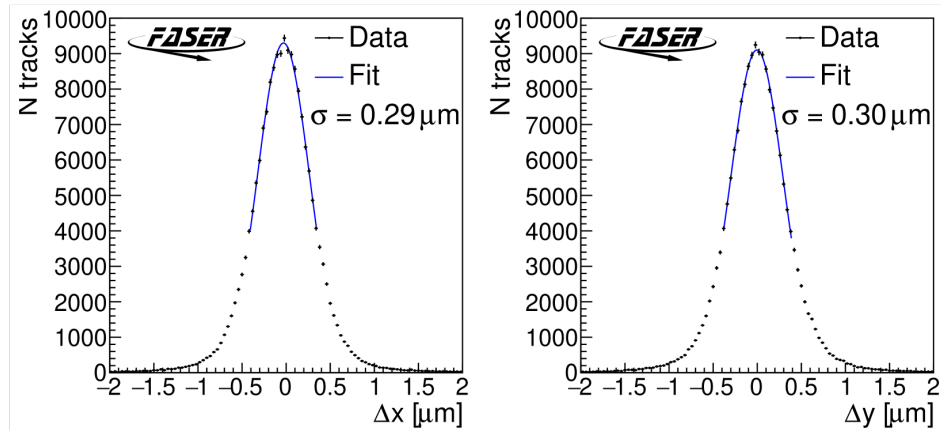
[Phys. Rev. Lett. 131, 031801](#)



# FASER $\nu$ detector

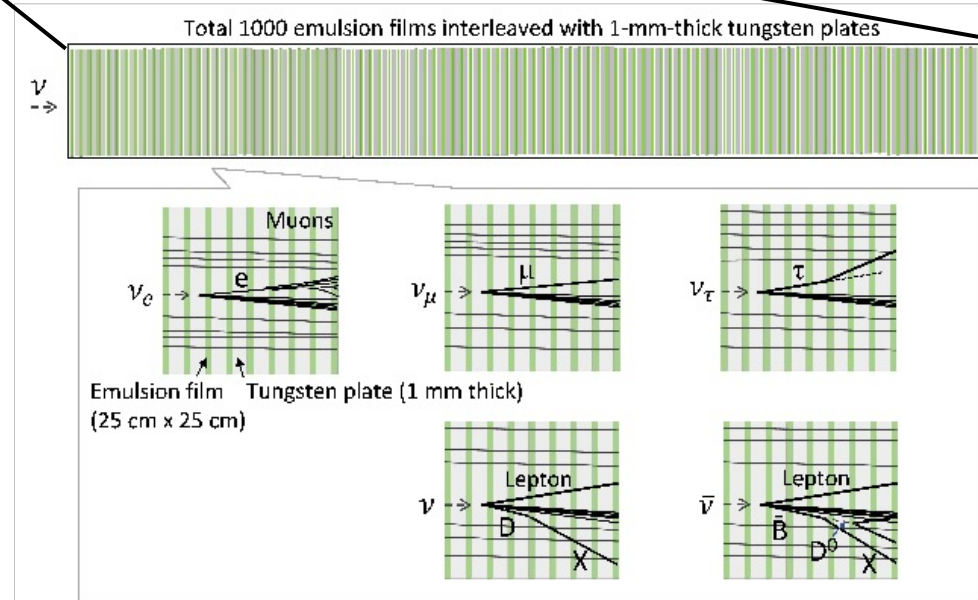
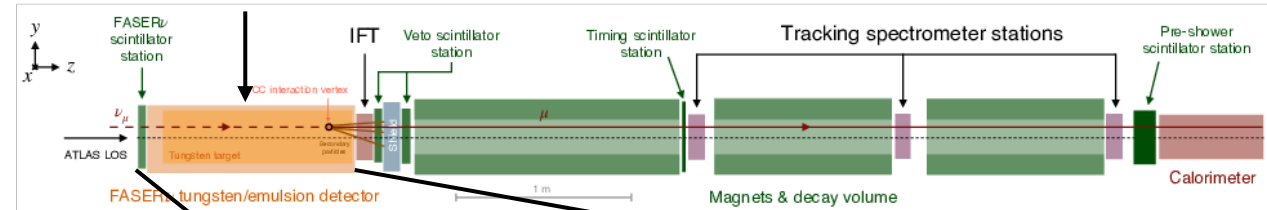
- Emulsion detector with 730 layers of tungsten plates and emulsion films
- 1.1 tonnes target mass
- 1.05m long
- 0.3 $\mu$ m of position resolution

9.5 fb<sup>-1</sup> data in 2022 Jul.-Sep. was analyzed so far.



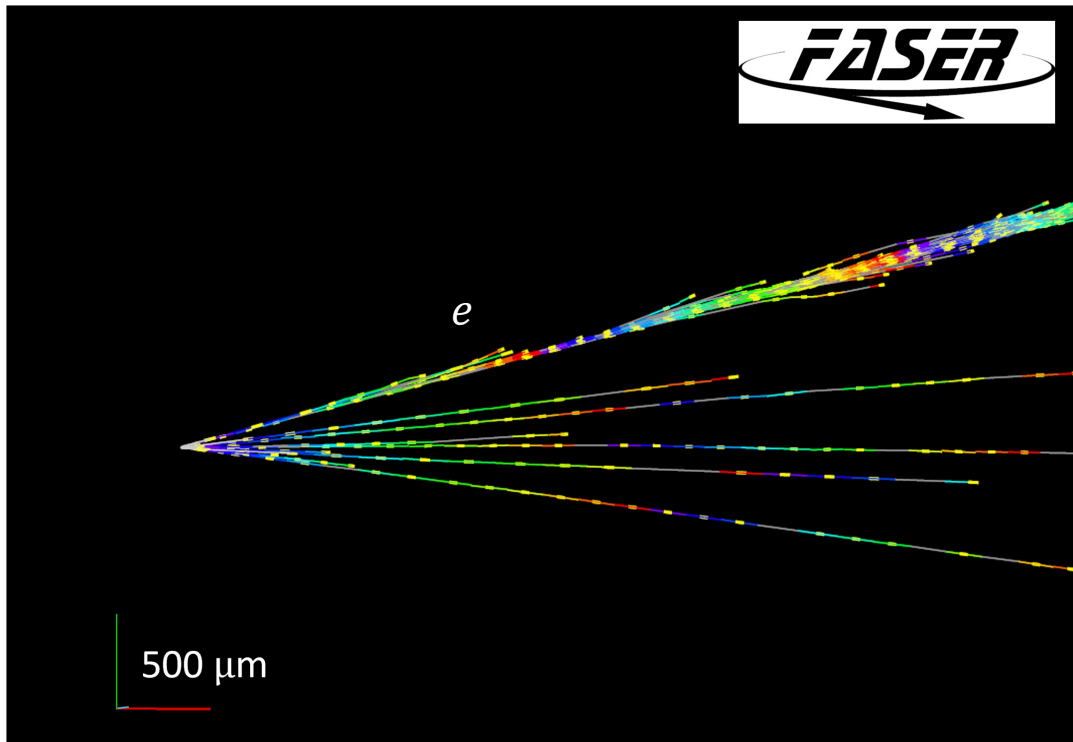
FASER $\nu$  detector

[arxiv: 2403.12520](https://arxiv.org/abs/2403.12520)

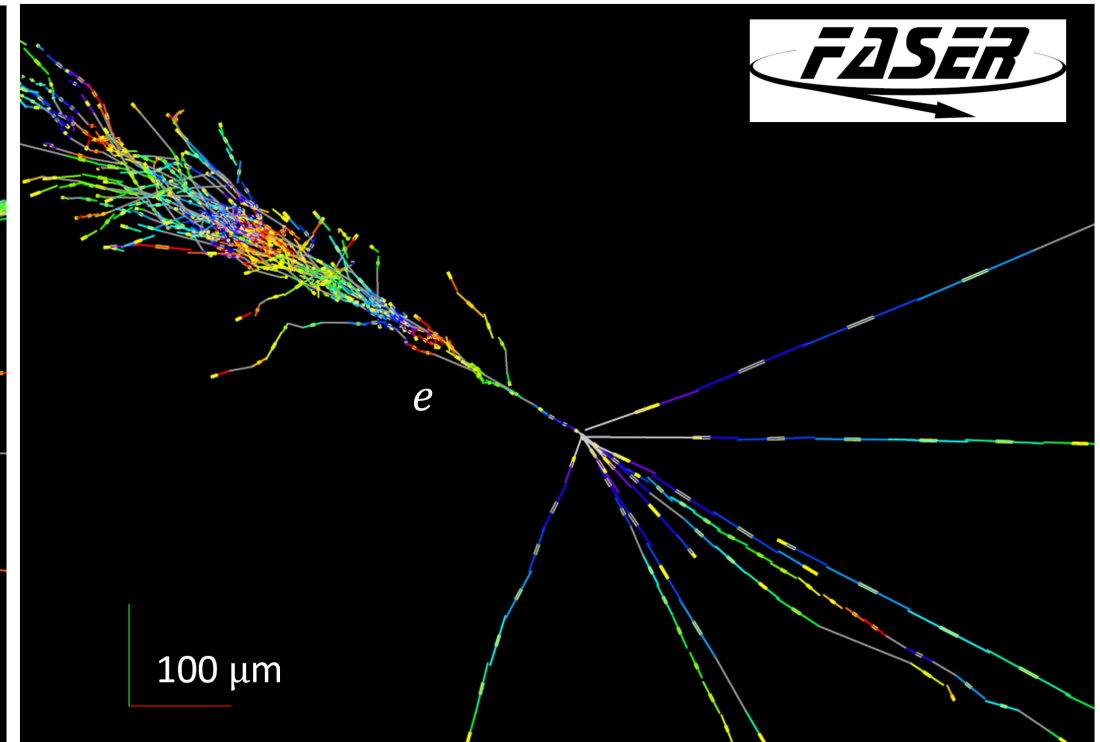


# $\nu_e$ CC interaction in FASER $\nu$ detector

[arxiv: 2403.12520](https://arxiv.org/abs/2403.12520)



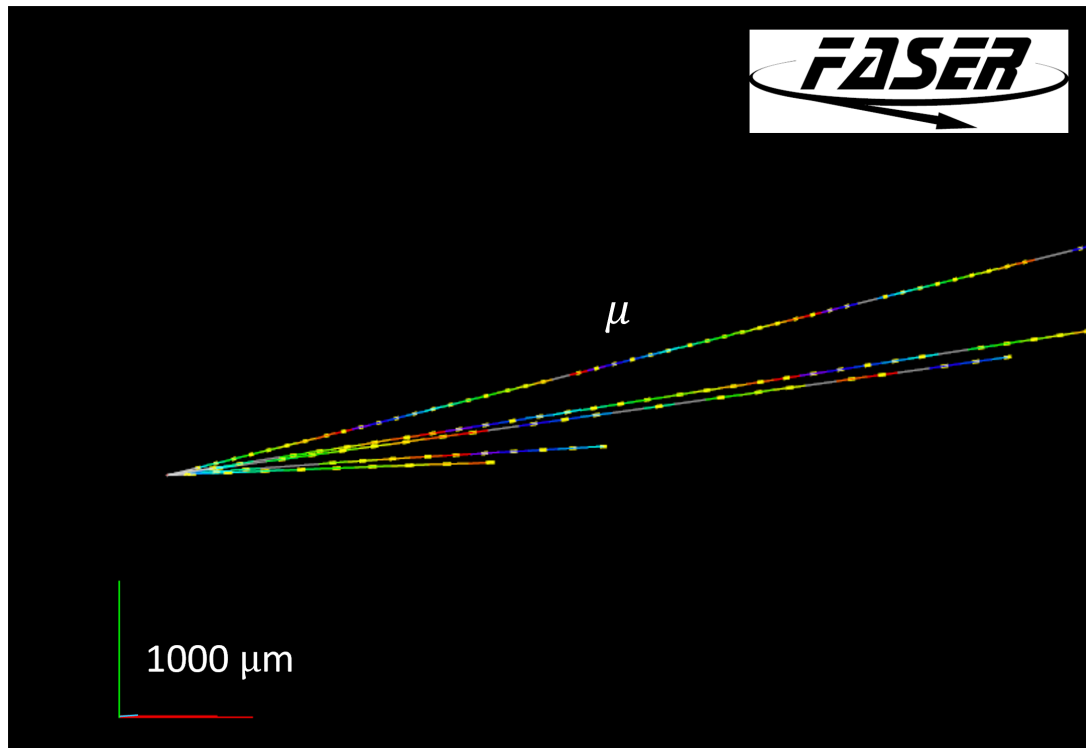
Rotated view



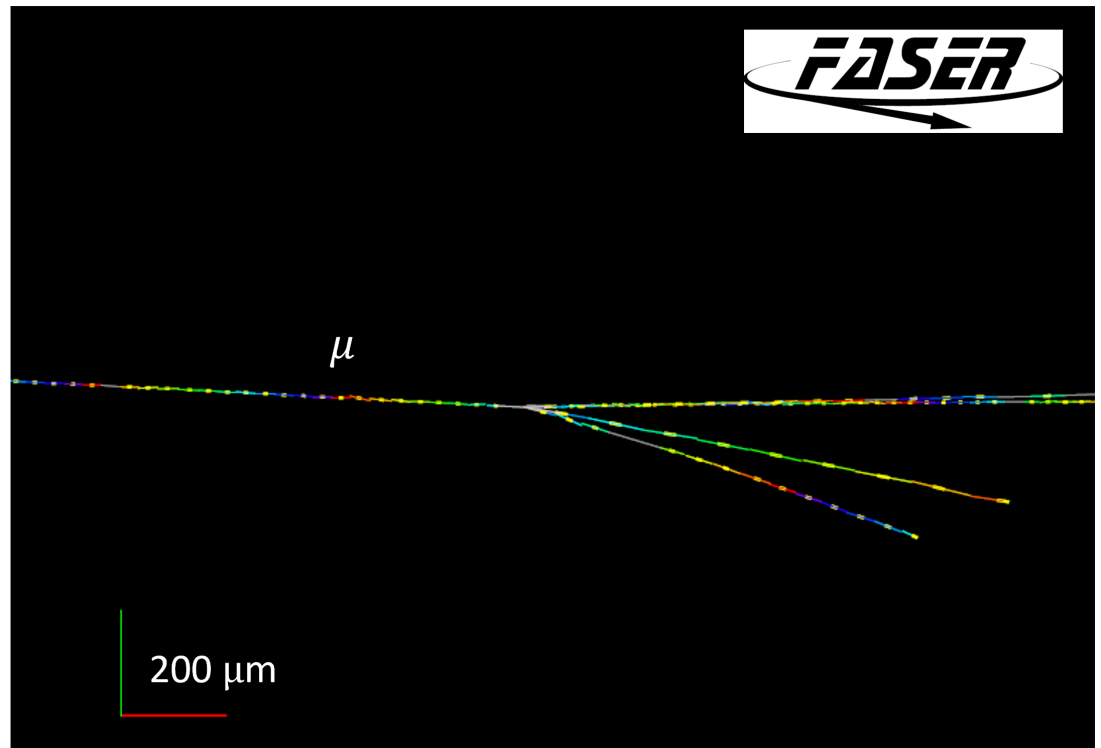
transverse to the beam view

# $\nu_\mu$ CC interaction in FASER $\nu$ detector

[arxiv: 2403.12520](https://arxiv.org/abs/2403.12520)



Rotated view



transverse to the beam view



# Cross section measurements of Neutrino

[arxiv: 2403.12520](https://arxiv.org/abs/2403.12520)

Candidate events were required

- Reconstructed vertex with  $>4$  tracks and  $>3$  of them are  $\tan \theta < 0.1$
- EM shower with  $>200\text{GeV}$  energy for  $\nu_e$  or  $>200\text{GeV}$  momentum muon track for  $\nu_\mu$
- The lepton emit to the direction with  $\tan \theta > 0.005$ ,  $\Delta\phi > \pi/2$

Expected Background

- $0.025^{+0.015}_{-0.010}$  event for  $\nu_e$
- $0.22^{+0.09}_{-0.07}$  event for  $\nu_\mu$

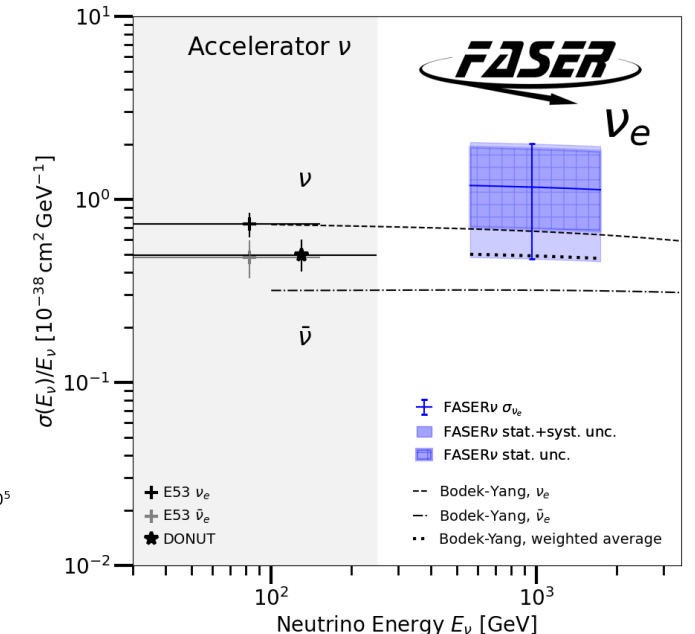
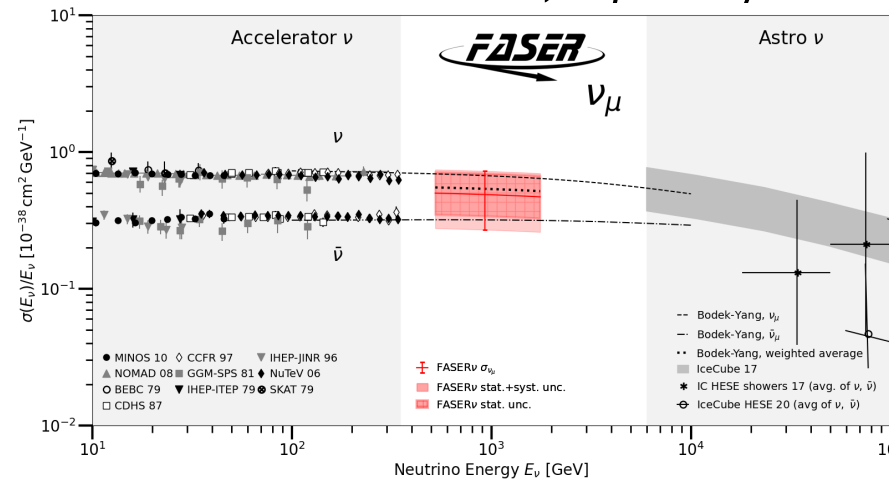
Selected candidate events

- 4 events for  $\nu_e$
- 8 events for  $\nu_\mu$

Cross Sections

- $(1.2^{+0.8}_{-0.7}) \times 10^{-38} \text{ cm}^2 \text{ GeV}^{-1}$  (560-1740GeV) for  $\nu_e$
- $(0.5 \pm 0.2) \times 10^{-38} \text{ cm}^2 \text{ GeV}^{-1}$  (520-1760GeV) for  $\nu_\mu$

→ Consistent with Standard Model predictions.



Cross Sections are derived by scaling the theory curve by the measured neutrino rate.

# Summary

FASER collected  $\sim 100 \text{ fb}^{-1}$  collision data since 2022.

## FASER

- limited parameter space for Dark Photons
- limited parameter space for ALPs
- directly observed collider neutrinos
- measured  $\nu_e$  and  $\nu_\mu$  cross section in TeV energies.

Expect  $150 \text{ fb}^{-1}$  more data until the end of LHC Run3.

