Latest results of the FASER Experiment

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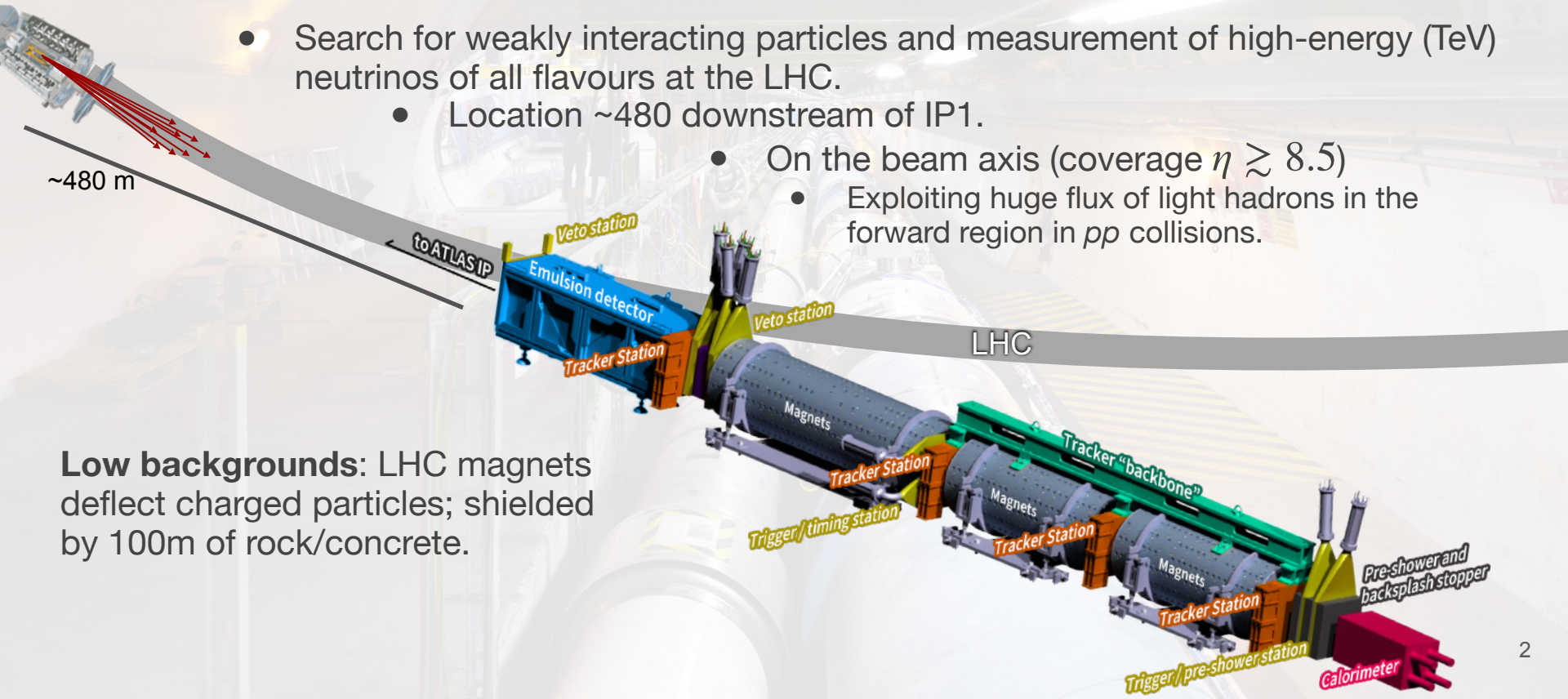
On behalf of the FASER Collaboration

60th Rencontres de Moriond - Electroweak
15th-22nd March, 2026
La Thuile, Italy

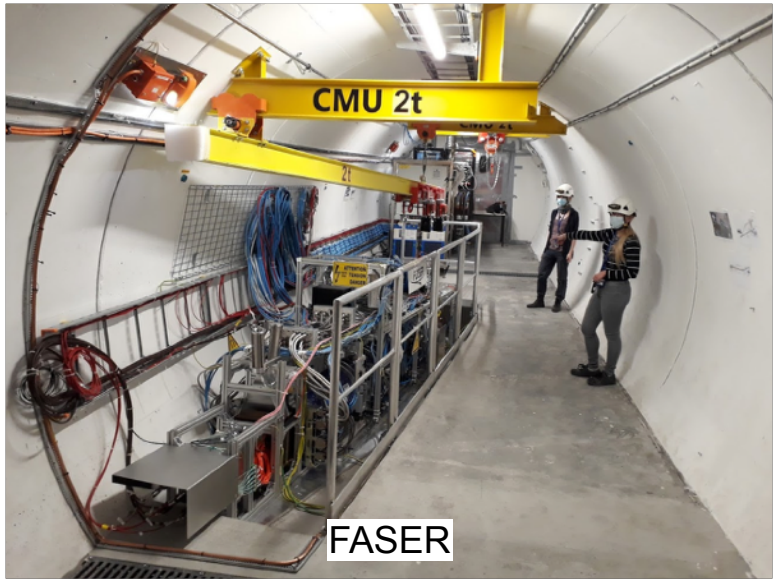
ForwArd Search ExpeRiment (FASER)

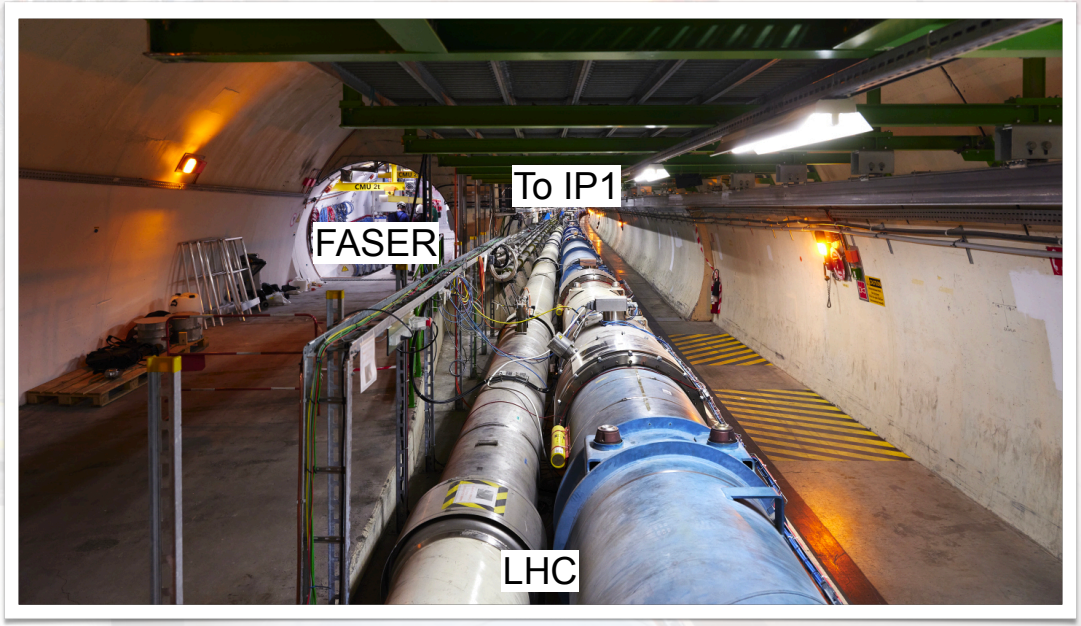
- Search for weakly interacting particles and measurement of high-energy (TeV) neutrinos of all flavours at the LHC.
  - Location ~480 downstream of IP1.
    - On the beam axis (coverage $\eta \gtrsim 8.5$)
      - Exploiting huge flux of light hadrons in the forward region in *pp* collisions.



Low backgrounds: LHC magnets deflect charged particles; shielded by 100m of rock/concrete.

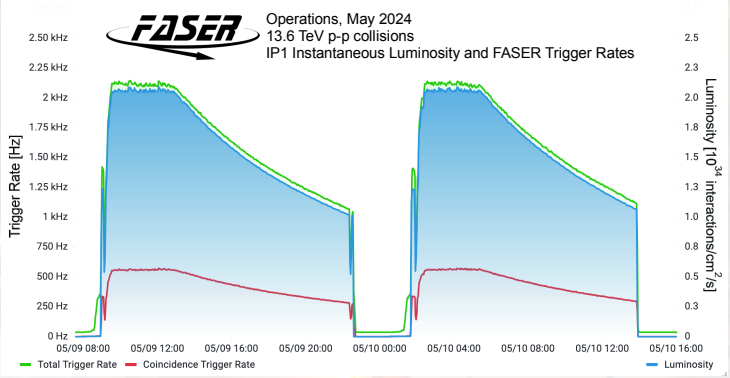
ForwArd Search ExpeRiment (FASER)

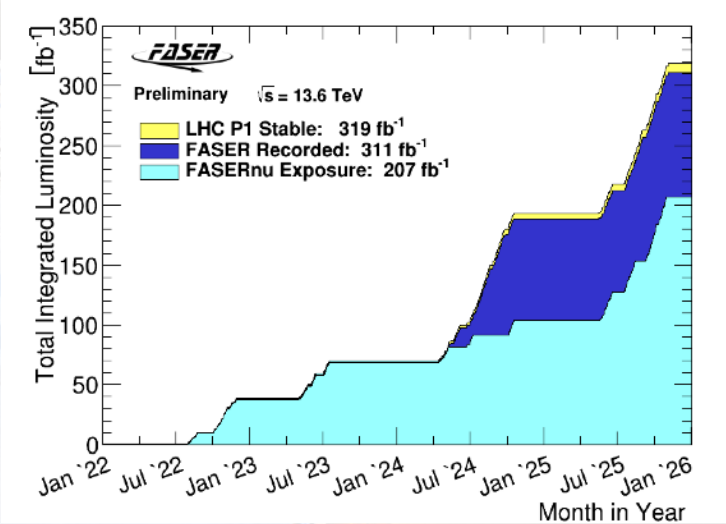




FASER Operations

- Taking data since 2022.
- Successfully recorded >97% of data.
- 311 fb^{-1} total recorded (2022-2025)
  - 207 fb^{-1} with emulsion detector
- New results today correspond to
  - 9.5 fb^{-1} of 2022 emulsion data
  - 2022-2024 electronic data



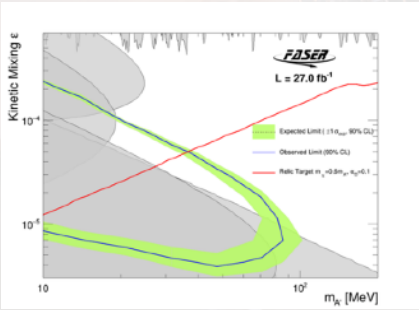


Luminosity from ATLAS

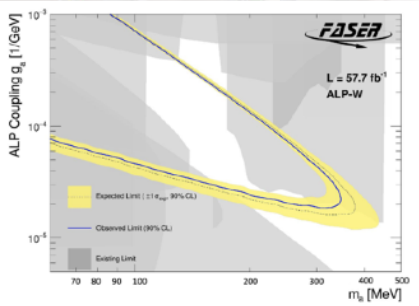
FASER Physics

Searches beyond the SM:

- **Weakly interacting** particles the
  ~ MeV to GeV range e.g.
  - Dark photons
  - Axion like particles (ALPs)



Phys.Lett.B 848 (2024)

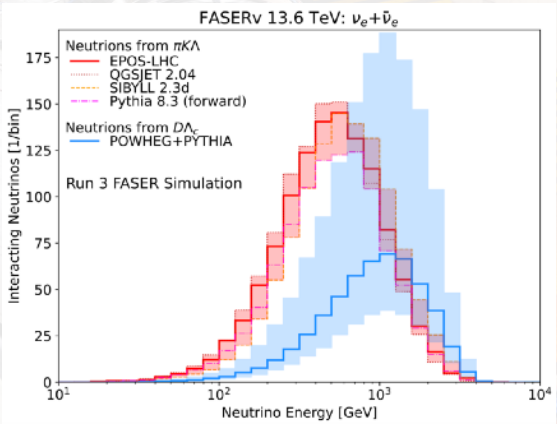


JHEP 01 (2025)

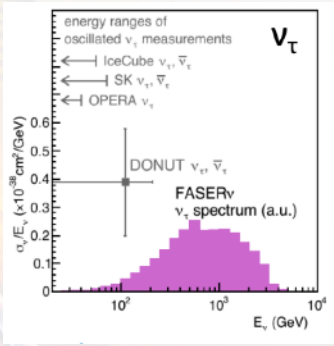
Collider neutrinos:

- High energy neutrino interactions of **all flavours**
  - Cross sections at unexplored TeV scales, LFV, and QCD
- Probe **forward hadron** production
  - Cosmic ray shower modelling

Phys.Rev.D 110 (2024)



FASERν at Run 3 (250 fb^{-1})		
$\nu_e + \bar{\nu}_e$	$\nu_\mu + \bar{\nu}_\mu$	$\nu_\tau + \bar{\nu}_\tau$
1675^{+911}_{-372}	8507^{+992}_{-962}	28^{+48}_{-12}



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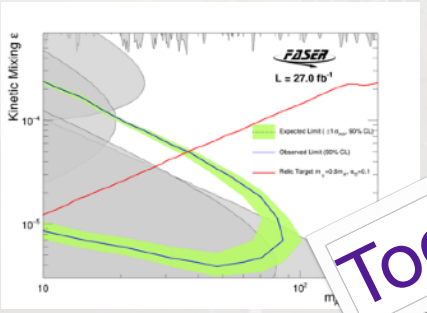
  - Cross se… …xplored TeV sca… …d QCD
- P… …**d hadron** production
  …ic ray shower modelling

Today: hot-off-the-press new results!



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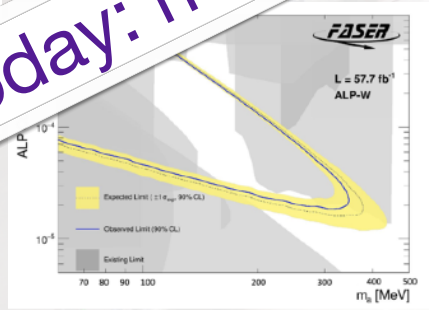
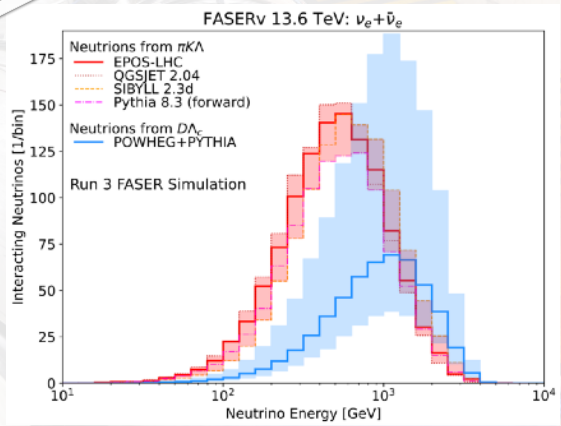


JHEP 01 (2025)

Phys.Rev.D 110 (2024)



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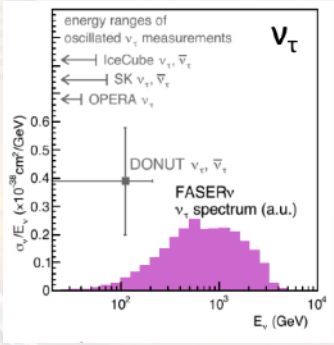


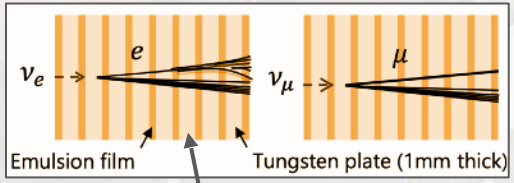
Neutrinos

Neutrinos at FASER

Two ways to detect collider neutrinos, independent (so far).

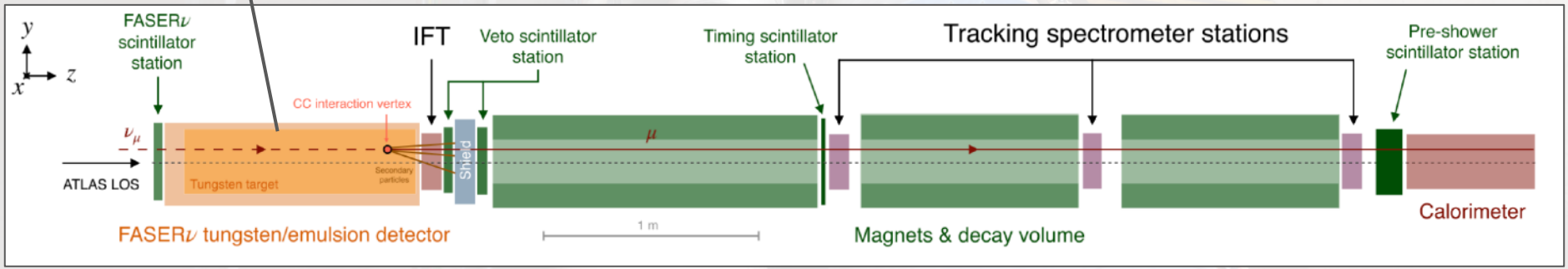
1) Emulsion detector:

- detect **all neutrino flavours**
- excellent spatial resolution (0.3 μm)
- slow (each film must be scanned, digitised, and processed)



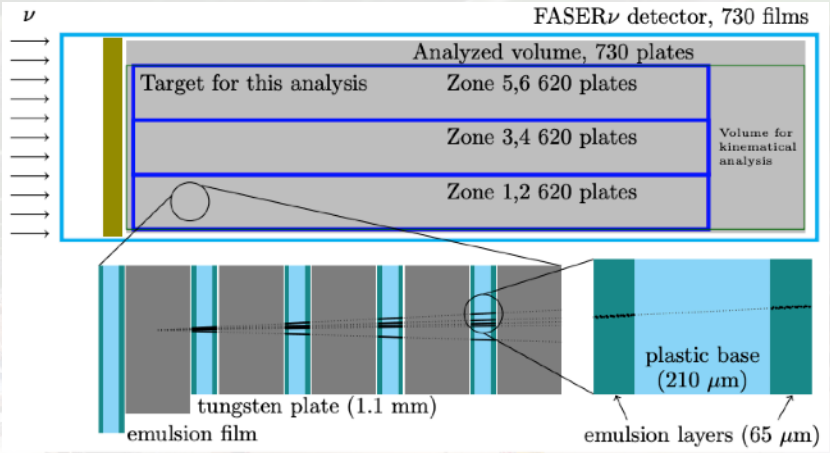
2) Electronic spectrometer:

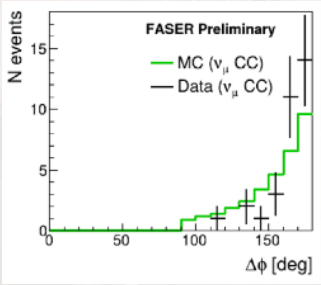
- fast analysis (only using electronic components of detector)
- separate anti-neutrino/neutrino (muon charge)
- can study only **CC muon neutrino** interactions (so far)

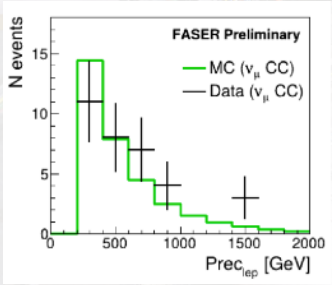


FASERν analysis

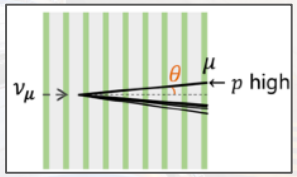
- **New** results corresponding to **681 kg** target mass and 9.5 fb^{-1} of data.
  - Factor 2x increase in statistics!
- Small background from neutral hadrons.

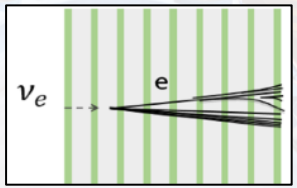


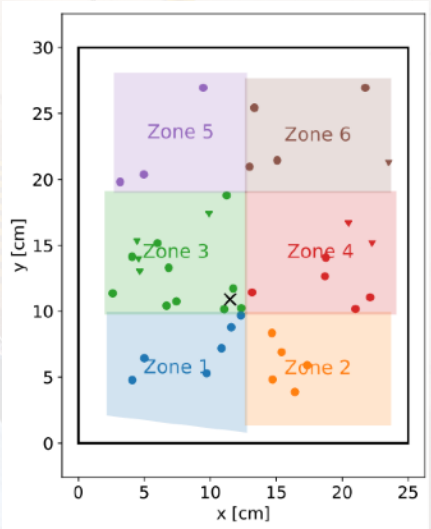




	ν_e CC	ν_μ CC
Expected signal	$7.7^{+6.3}_{-2.5}$	$40.0^{+14.5}_{-9.7}$
Expected background	$0.13^{+0.08}_{-0.05}$	$1.17^{+0.62}_{-0.40}$
Observed events	7	33





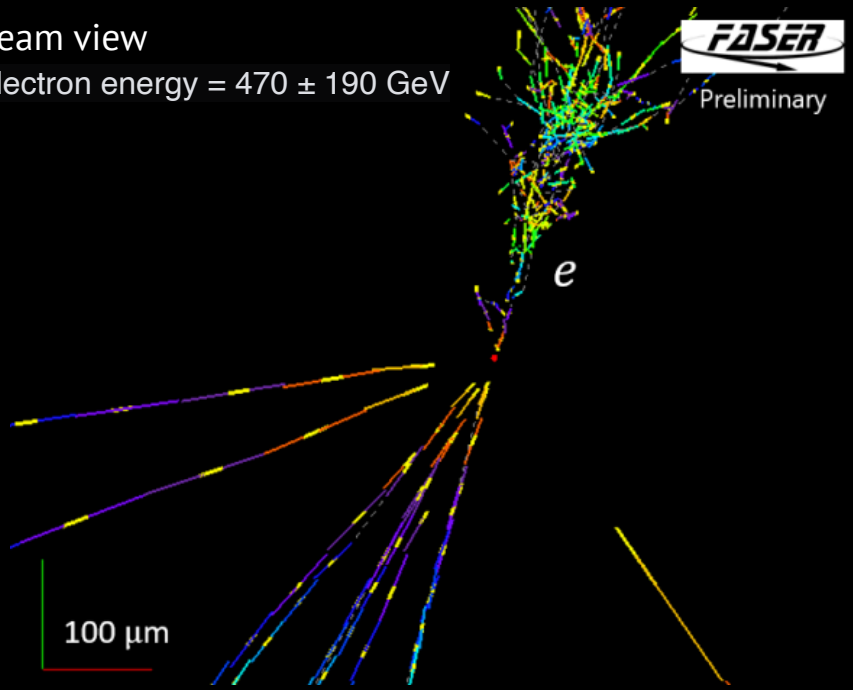


FASERν analysis

ν_e

Beam view

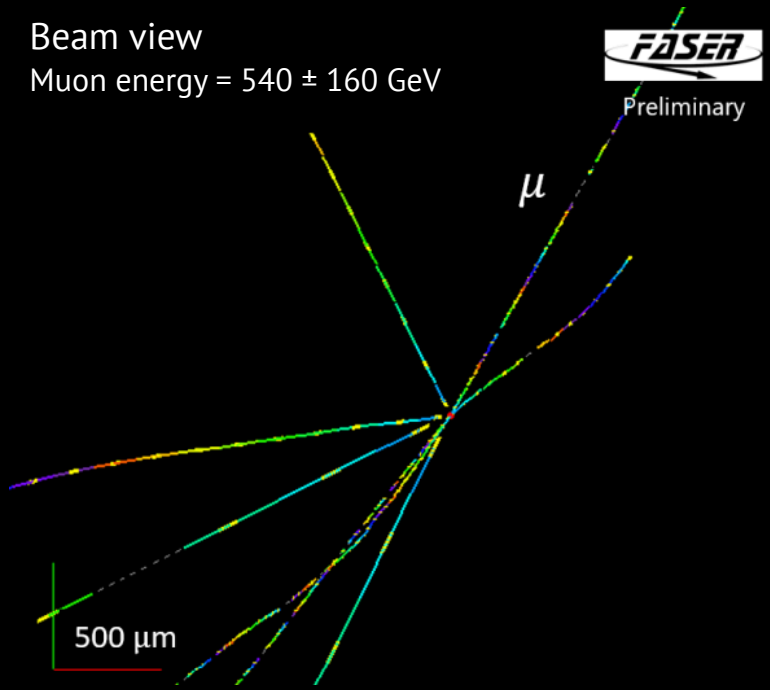
Electron energy = 470 ± 190 GeV



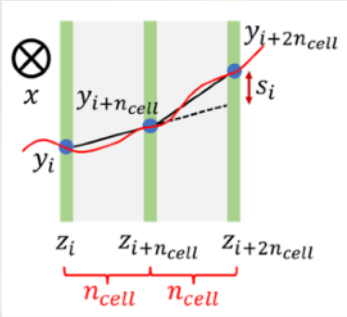
ν_μ

Beam view

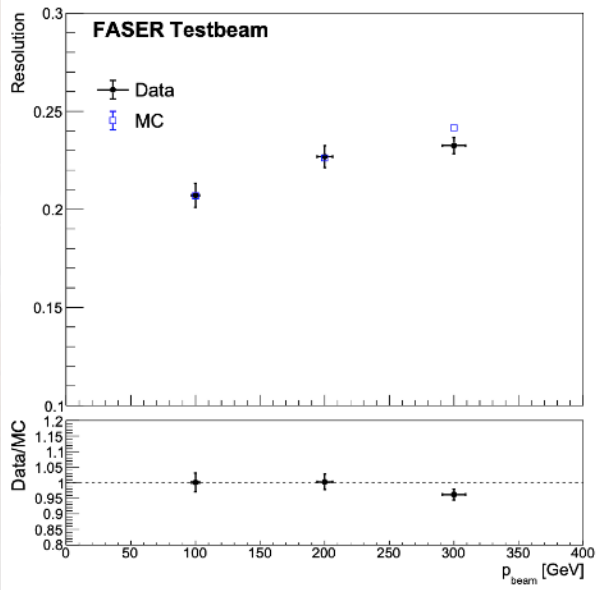
Muon energy = 540 ± 160 GeV



Neutrino energy reconstruction

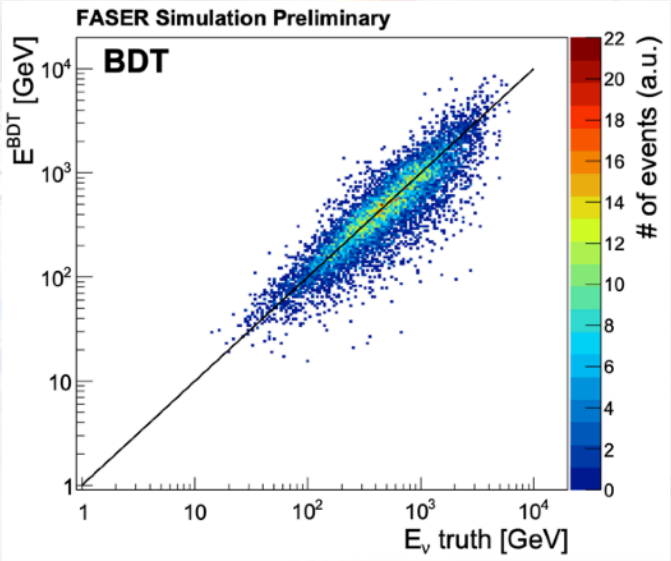


arxiv:2602.17575



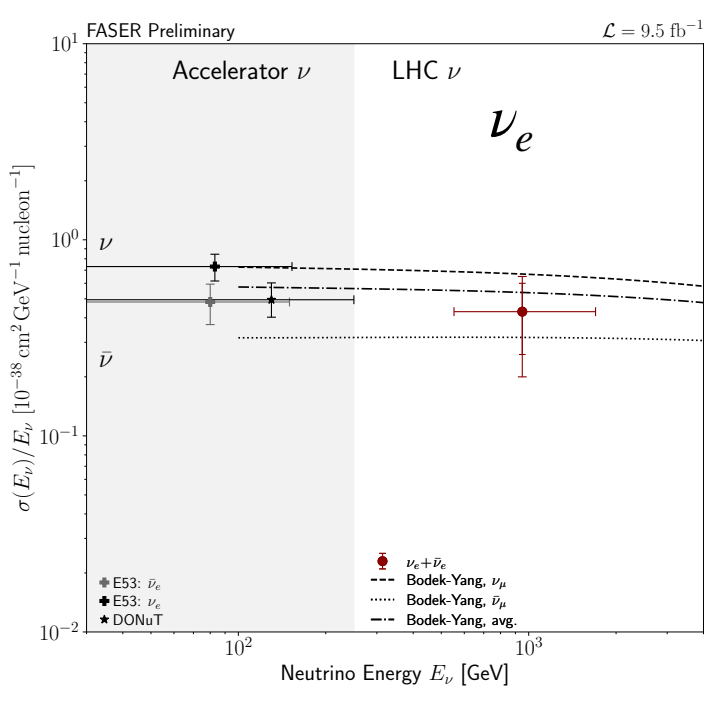
- Muon momentum measured exploiting multiple coulomb scattering.
  - **20-23%** resolution, validated in testbeam

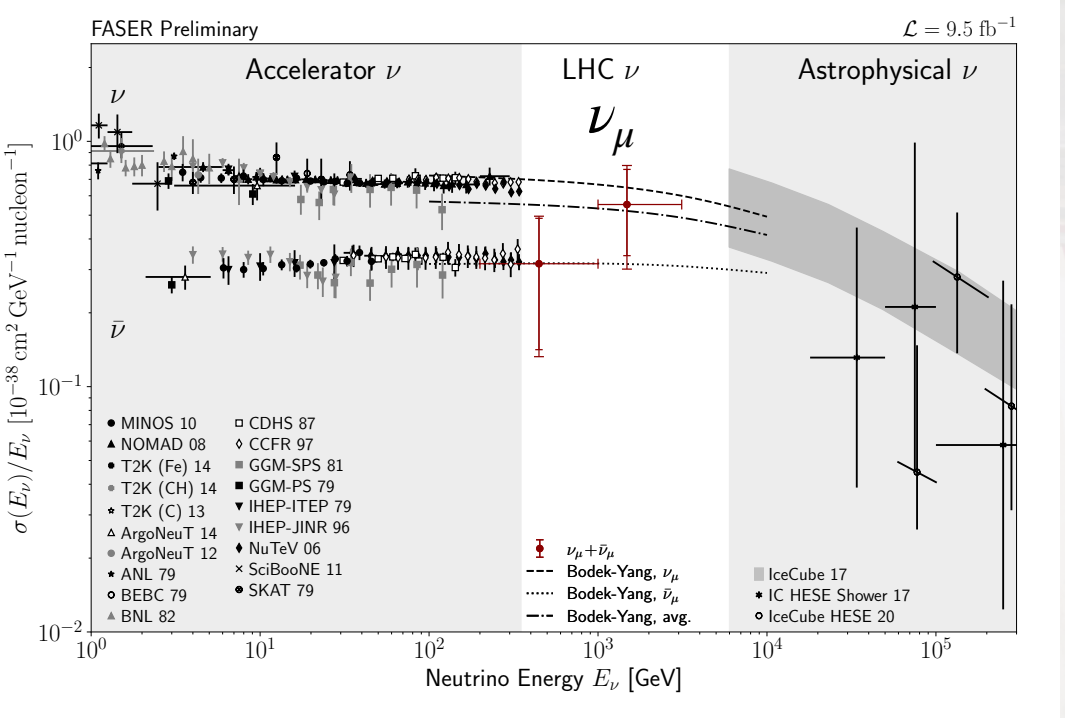
- Neutrino (ν_μ) energy reconstructed with a regression BDT for ν_μ CC.
  - Inputs: p_μ, $1/\theta_\mu$, and $\sum p_{\text{had}}^{\text{ch}}$



CERN-FASER-CONF-2026-002

Differential cross section

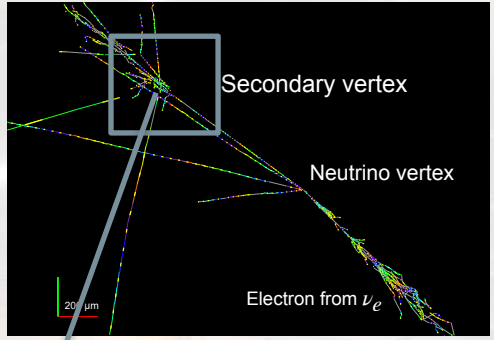


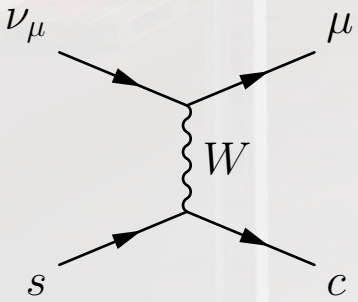


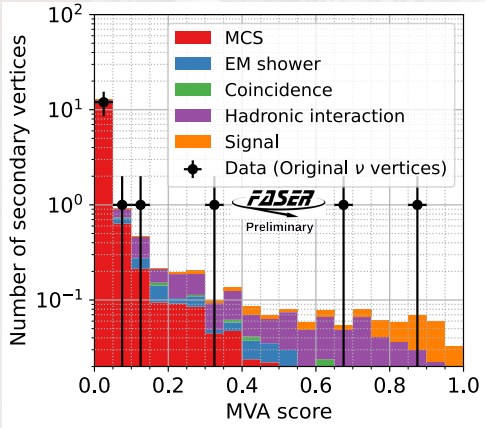
Cross section obtained by scaling the theory expectation by the observed number of events.
ν_e energy bins: 68% range expected from neutrinos in simulation, ν_μ energy bins: 95% range expected from neutrinos in simulation.

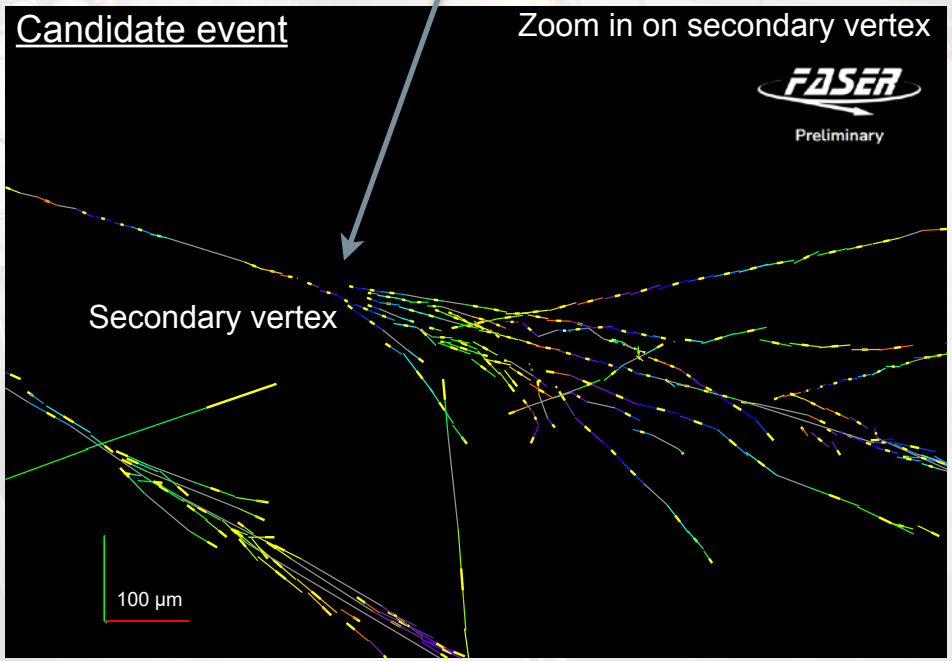
Search for associated charm production

- Search for **charm** hadrons produced in association with ν_e or ν_μ interactions.
- **Displaced vertex** reconstruction
- Important benchmark for ν_τ reconstruction.



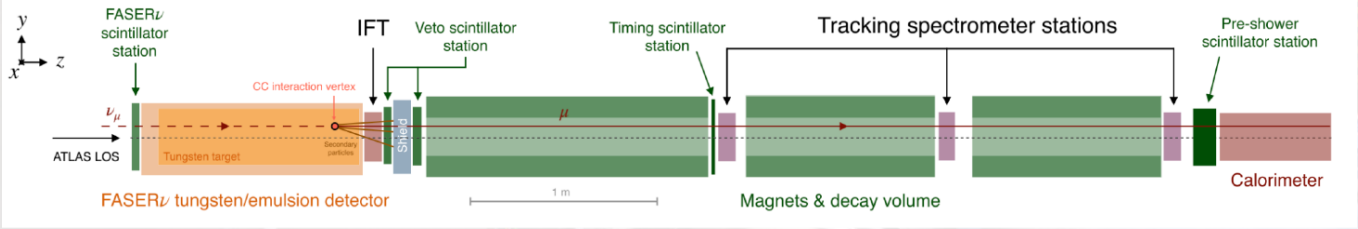


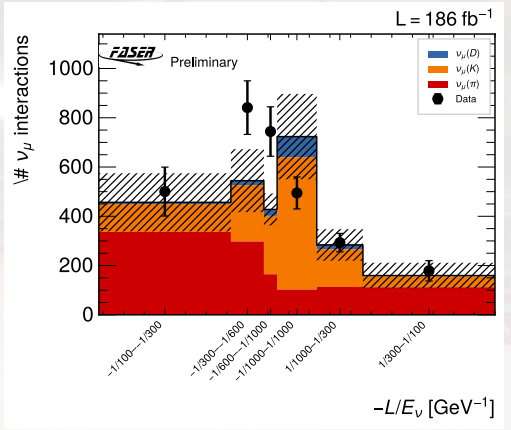


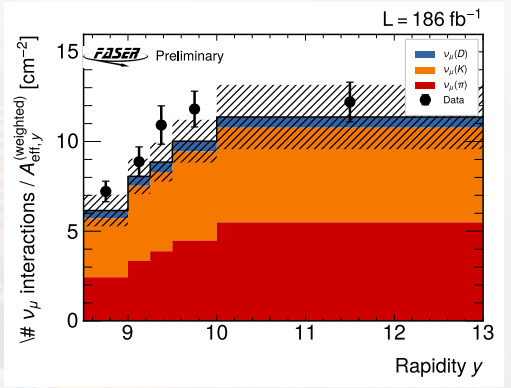


ν_μ differential measurement

- ν_μ CC: muon appearance signature in electronic spectrometer (using FASERν as tungsten target).
- Updated with 2022-2024 data (2.8x increase in statistics)
- Low backgrounds: 0.03 ± 0.1 from muons that miss the veto scintillators
- Unfold to 1D bins of neutrino energy or rapidity, and (for the first time) in 2D.

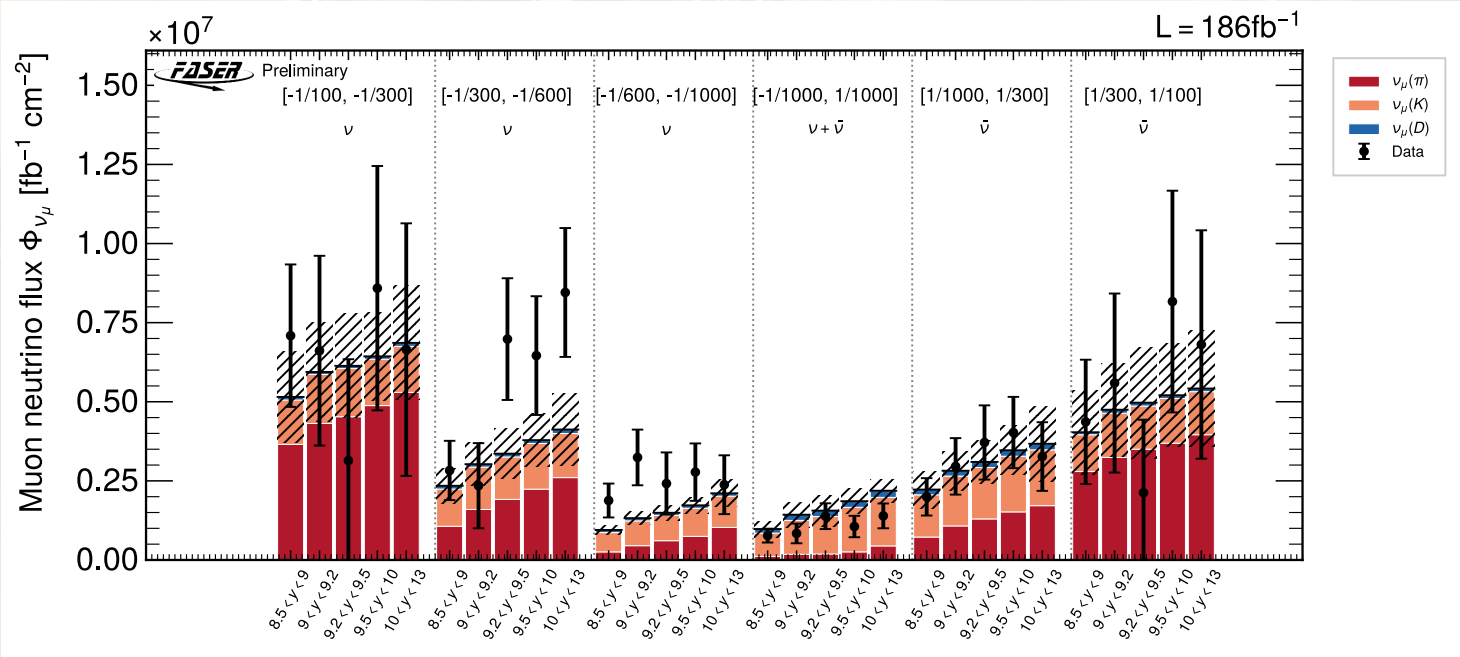




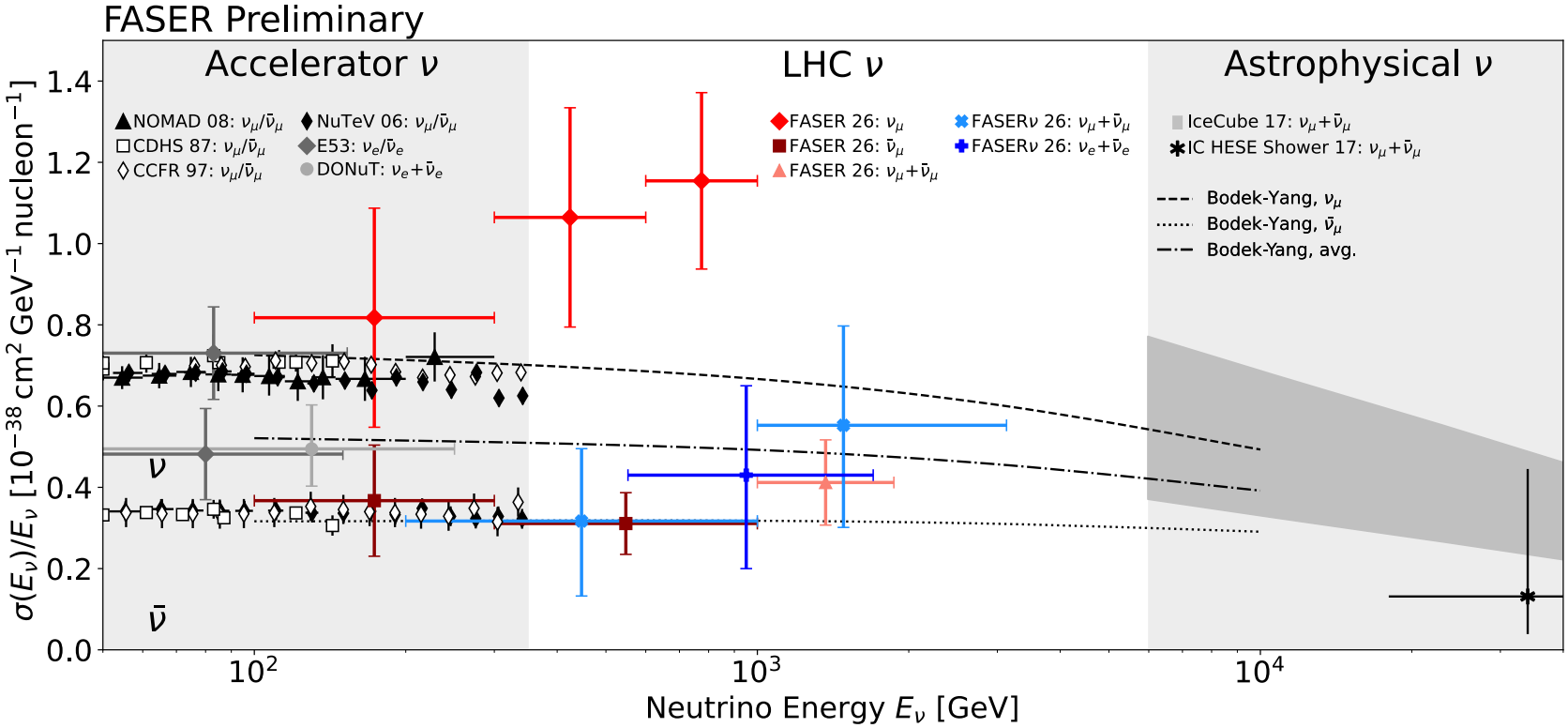


ν_μ differential measurement

- Measure cross-section (assuming flux) or flux (assuming cross section).
- Probe of models relevant to cosmic ray showers with higher precision.



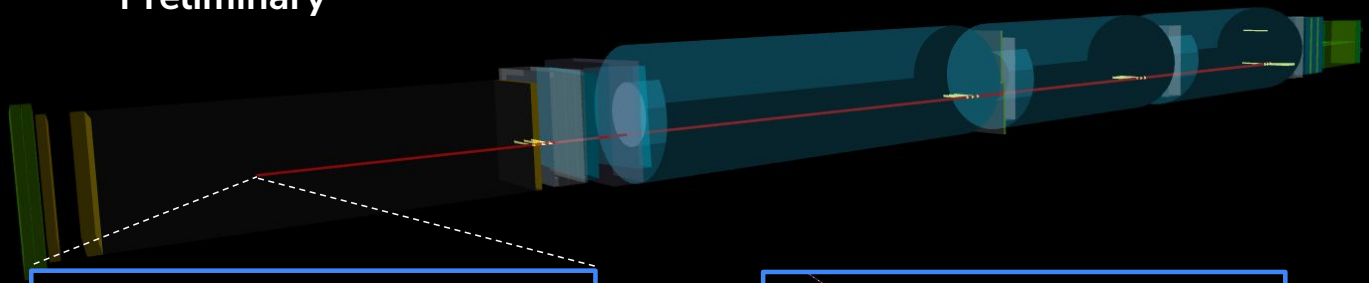
Differential cross section

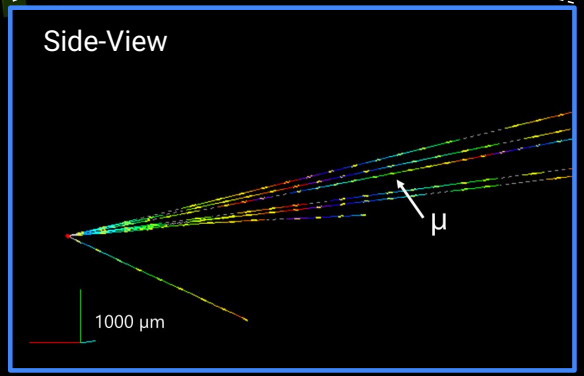


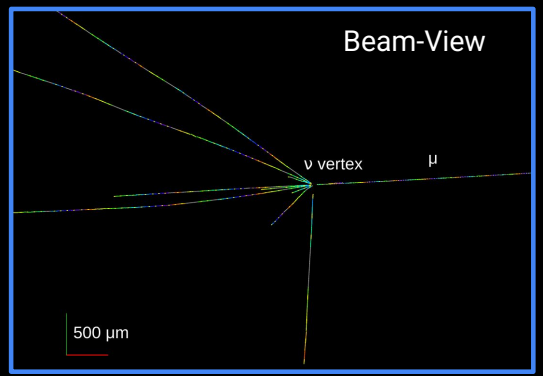
Emulsion-spectrometer matching

Preliminary

Run: 8336 - Event: 25655346
Tuesday, 23 August 2022 06:26:30
Negative charged track

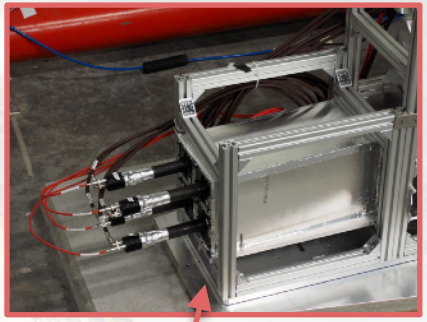


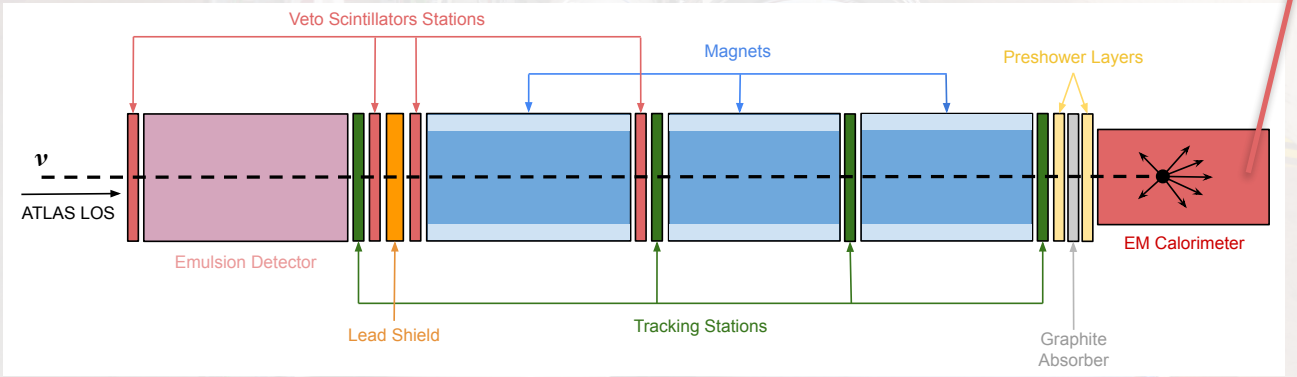




ν_e in the EM calorimeter

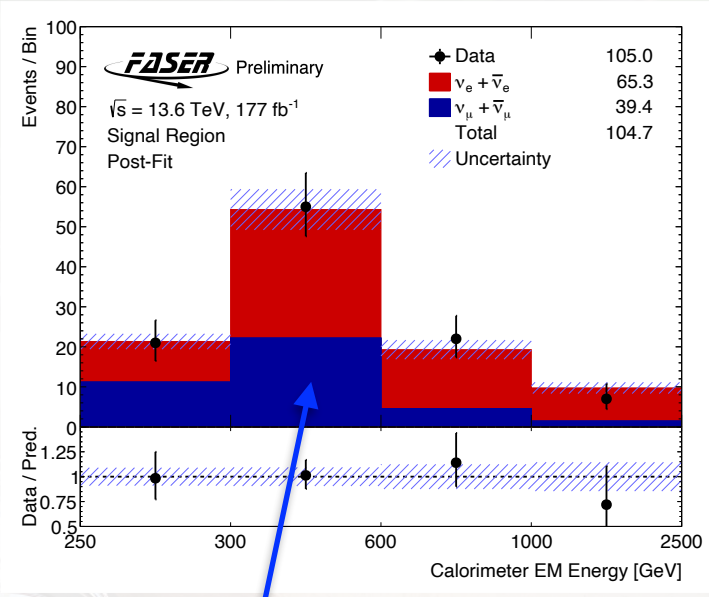
- Measurement of electron neutrinos interacting in the calorimeter.
  - Spare LHCb outer ECAL modules, interleaved lead and scintillator
- Probe of forward (charm) hadron production, background in BSM searches, step towards differential measurements for ν_e.

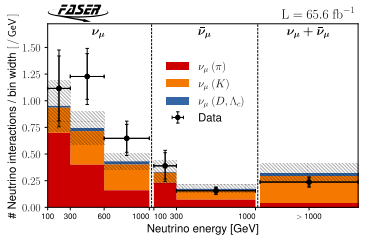




ν_e in the EM calorimeter

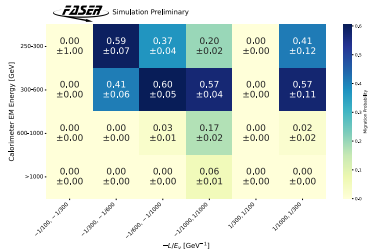
- Main background: muon neutrinos, constrained using data.
- **Observation** (5.5σ) of electron neutrinos (CC + NC ν_e) in the EM calorimeter.
- Observed: 105 events
- Expected: 81 ± 29 events ($39 \pm 9\ \nu_\mu$)
- Highest energy event **E = 2.1 TeV**





ν_μ CC interactions in bins of neutrino energy

×

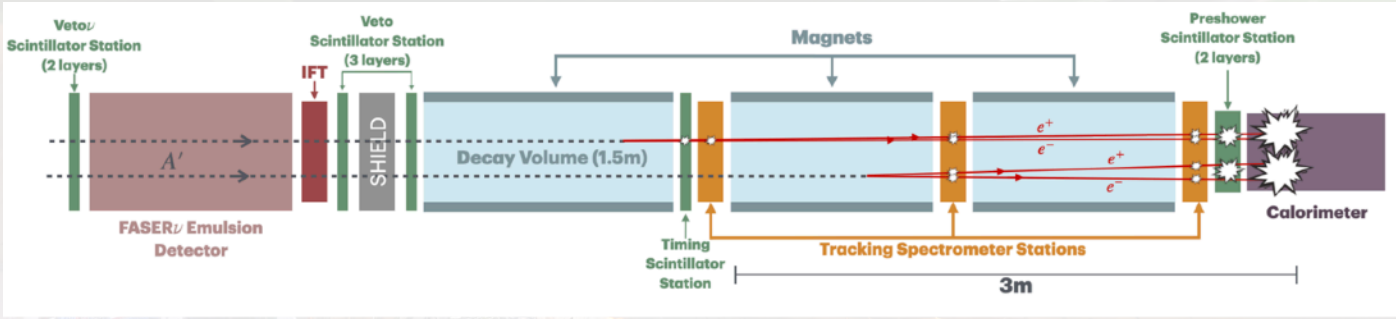


Migration matrix: neutrino energy to calorimeter energy

Background prediction of ν_μ

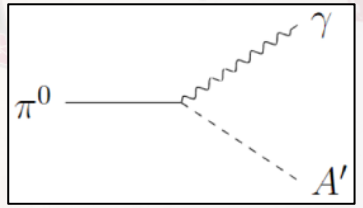
Beyond the SM

Dark Photons

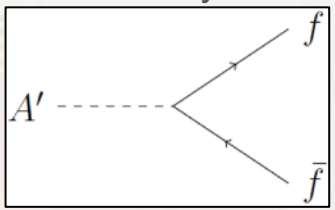


- Search for dark photons decaying into e^+e^- using 2022-2024 data.
  - First update since Moriond 2023, with 6.5x more data.
- No veto signal and E(calo) > 500 GeV.
- New signal regions:
  - **One track** and **track segment** SRs (2.5x higher signal efficiency).
- Small background from neutrinos:
  - One-track SR: 0.05 ± 0.04 events
  - Track segment SR: 0.027 ± 0.014 events

Production

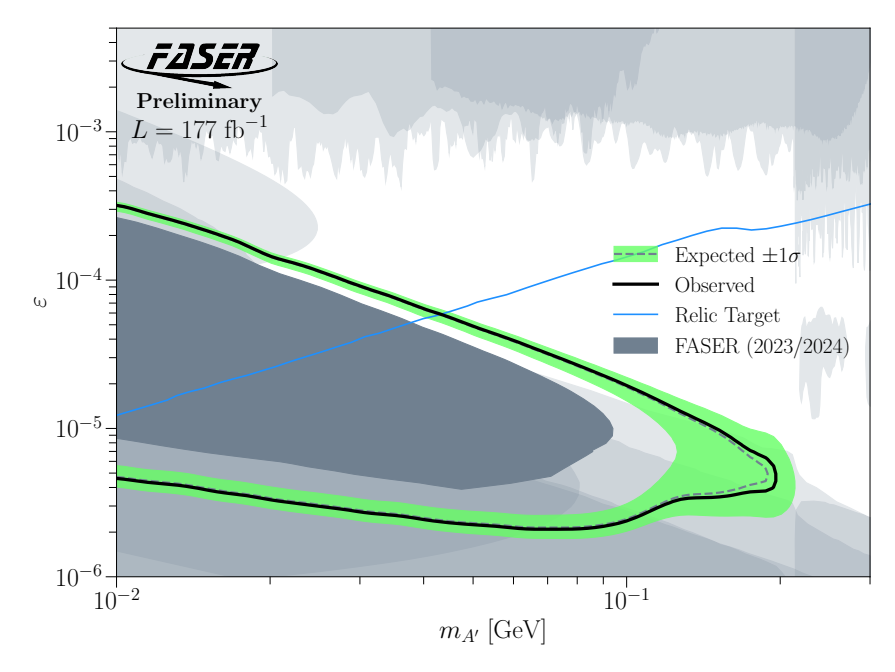


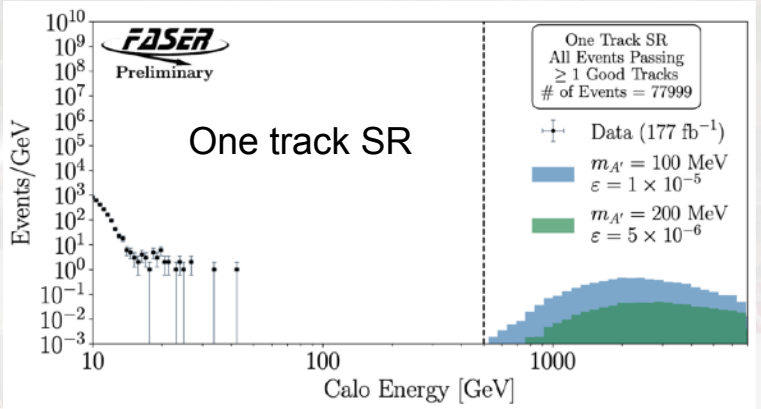
Decay

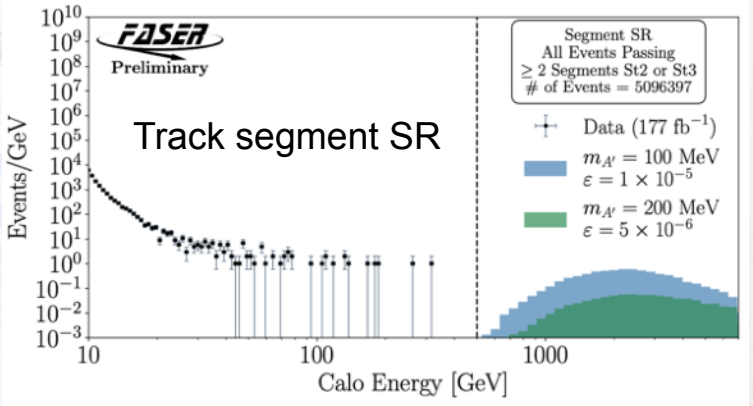


Dark Photons

- **0 events** observed in all SRs
- New world-leading constraints on dark photons with mass ~ 10 MeV-150 MeV and $\epsilon \sim 10^{-5} - 10^{-4}$

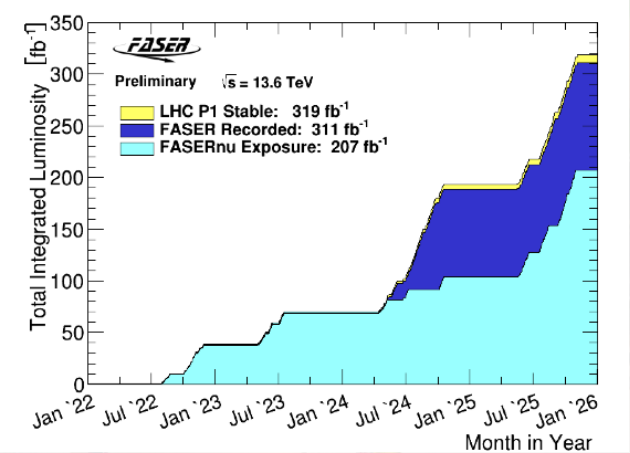






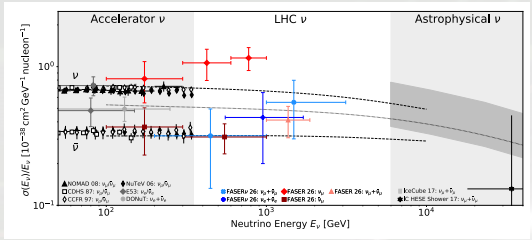
Lots to look forward to

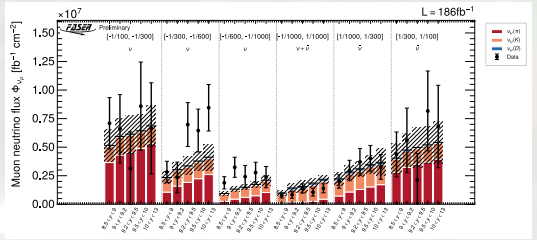
- New signatures and analysis techniques.
- More data from 2025 and 2026.
  - Upgraded preshower from 2025 onwards.
- 95% of emulsion data to be analysed.
- New neutrino detectors for HL-LHC Run-4:
  - Investigating emulsion and electronic neutrino detection technologies (arXiv:2503.19775).
  - Prototype off-axis neutrino detectors installed in tunnel for 2026 data taking:
    - AHCAL (prototype CEPC hadronic calorimeter)
    - FASERCal (based on T2K SuperFGD scintillating cubes)

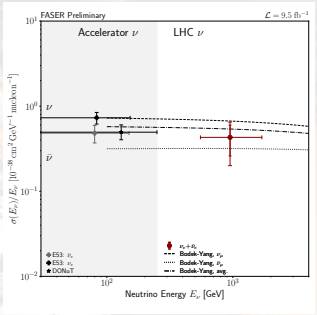


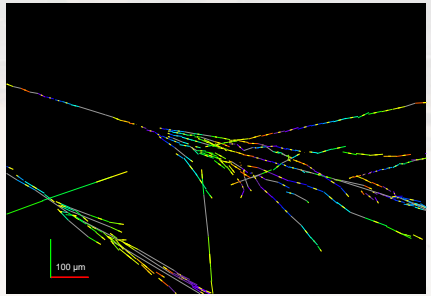
Summary & Outlook

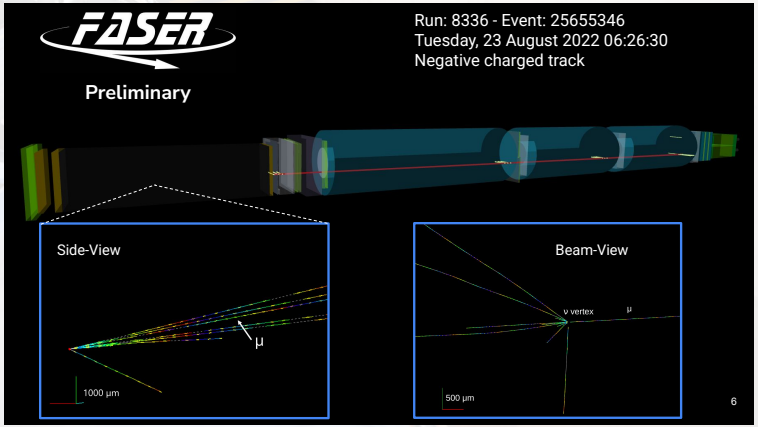
- Presented hot-off-the-press new results covering FASER's neutrino and BSM programmes.
- Represents significant advance since FASER started taking data in 2022.
- Still huge amount of data to be exploited, and exploring upgraded detectors for Run-4.

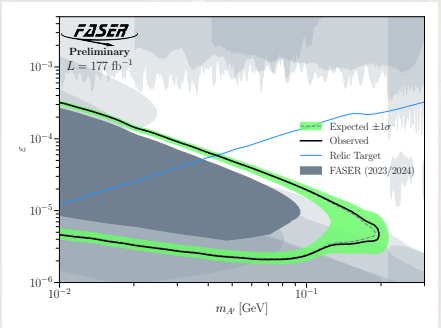


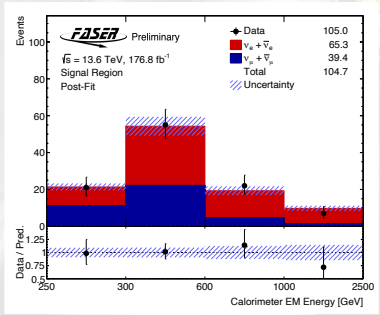












Acknowledgements

FASER is supported by:

We also thank:
– LHC for the excellent performance
– ATLAS Collaboration for providing luminosity information
– ATLAS SCT Collaboration for spare tracker modules
– ATLAS for the use of their ATHENA software framework
– LHCb Collaboration for spare ECAL modules
– CERN FLUKA team for the background simulation
– CERN PBC and technical infrastructure groups for the excellent support

Backup

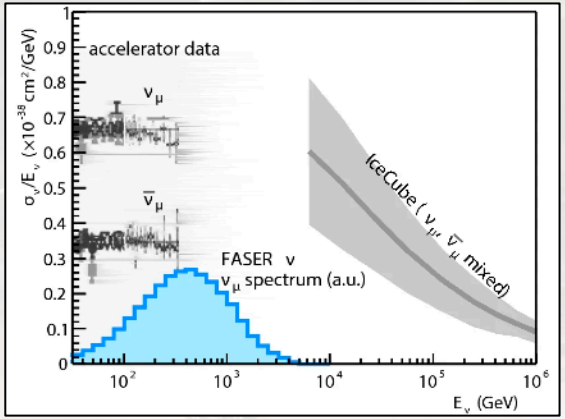
Why study collider neutrinos?

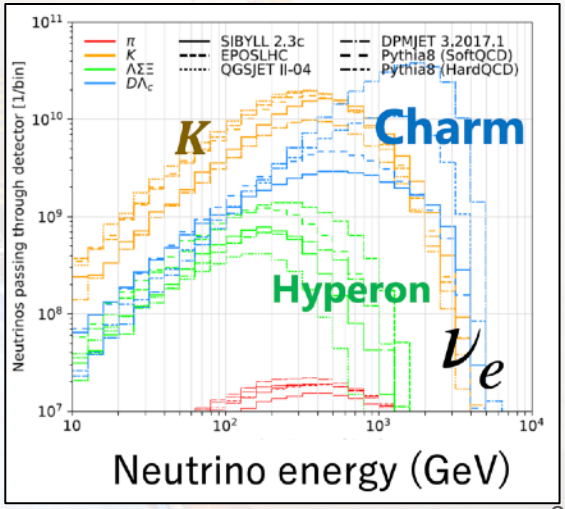
1. Neutrino interactions (all flavours) at **unexplored TeV energies**

2. Probe of **forward hadron production**, novel inputs for:
   - QCD (gluon PDFs at low-x, intrinsic charm)
   - Astroparticle physics (collider counterpart of high-energy cosmic rays interactions: cosmic ray muon puzzle)

3. Probe of **hadron structure** (proton/nuclear PDFs)

4. Background to BSM searches





JINST 19 (2024) P05066

Aperture: 20 cm
Length: 7 m

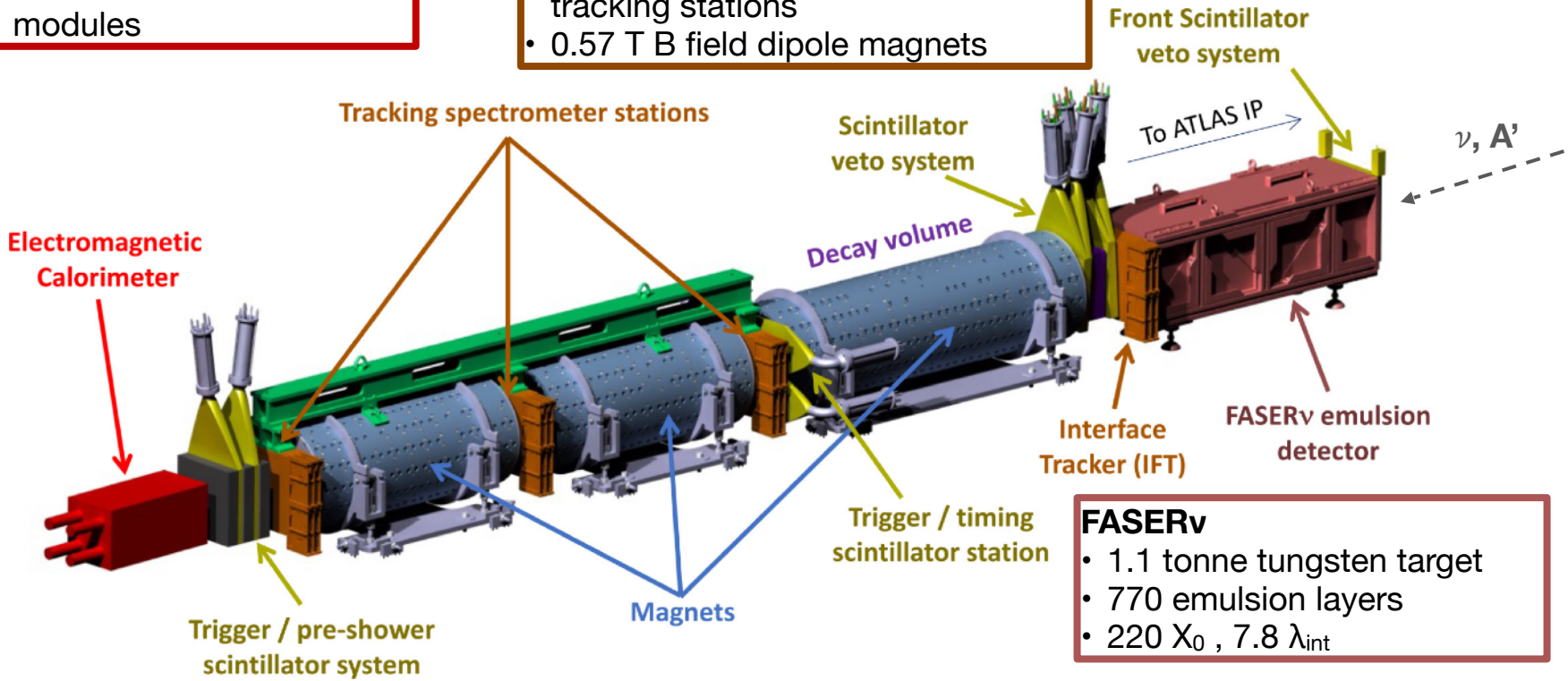
Linked with LHC clock, luminosity from ATLAS

The FASER detector

EM calorimeter
- 4x LHCb outer EM modules

Spectrometer
- 3x silicon strip (ATLAS SCT) tracking stations
- 0.57 T B field dipole magnets

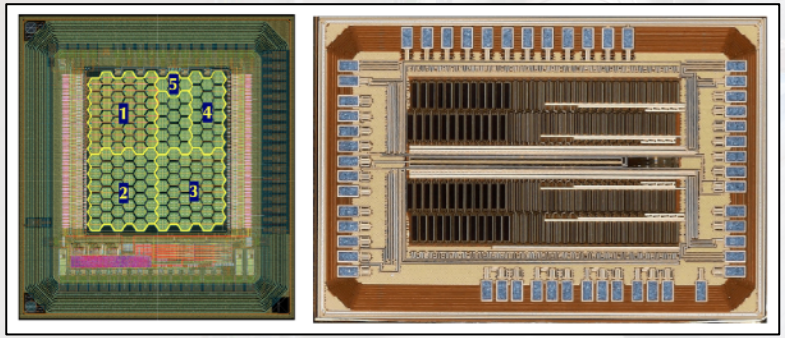
Veto system
- 2x2cm scintillator planes

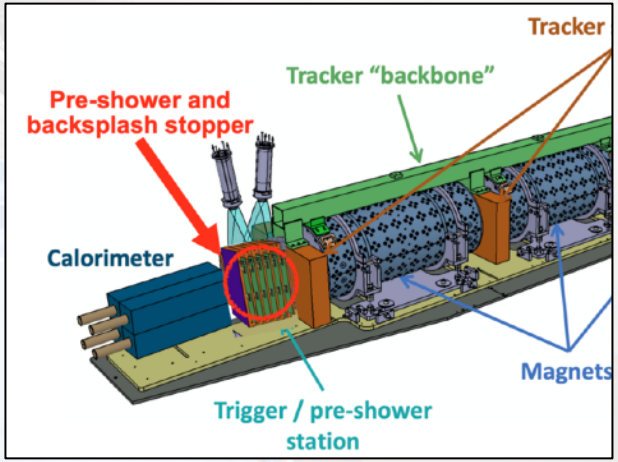


FASERν
- 1.1 tonne tungsten target
- 770 emulsion layers
- 220 X_0 , 7.8 λ_{int}

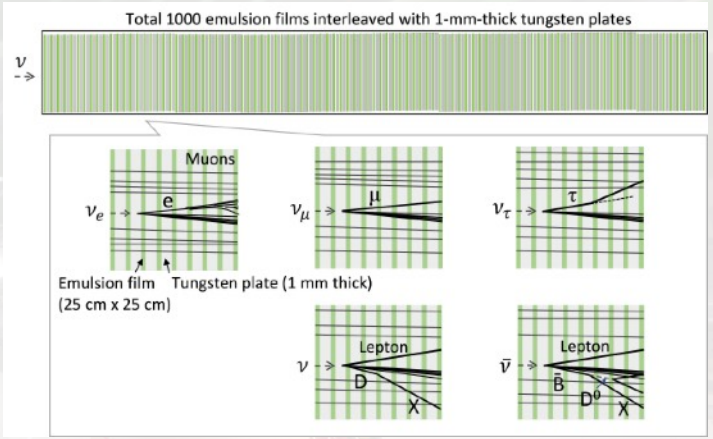
Preshower upgrade

- ALPs decays to 2 photons generally separated by < 1 mm
  → cannot be resolved in current detector.
- **Preshower upgrade:**
  - Layers of monolithic silicon pixel detectors (high-granularity hexagonal pixels) with tungsten absorber
  - Identify photons separated by ~200 μm
  - Installed in February 2025

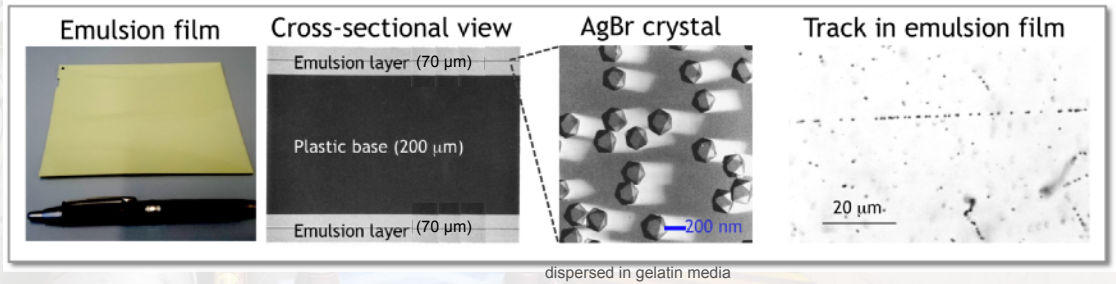


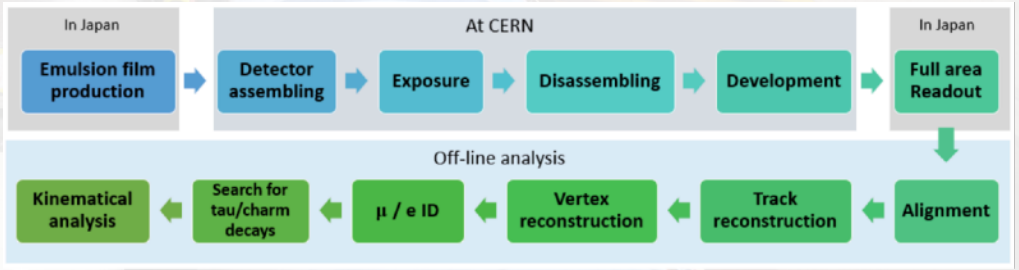


FASERν detector



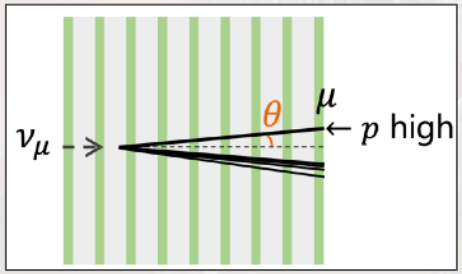
- FASERν: tungsten emulsion detector
  - 3D tracking detector, 50 nm precision, no timing
    - Total mass 1.2 tons, 285 X_0, 10.1 λ_{int}
- Needs to be exchanged every ~3 months (during technical stops) to control track density $\lesssim 1 \times 10^6$ tracks/cm^3
  - 10 emulsion detectors in total needed for 2021-2024 data

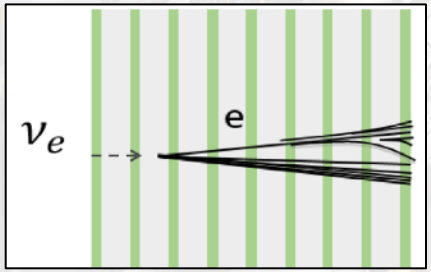


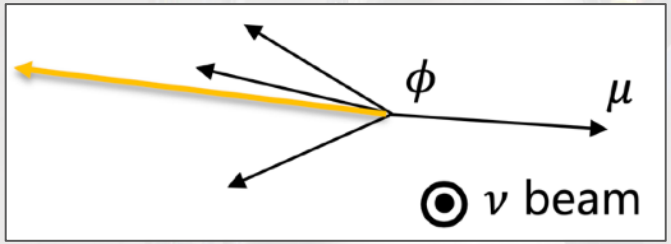


FASERν analysis

- CC neutrino candidates selected from vertices with at least 5 tracks:
  - **Electrons:** short track, EM shower
  - **Muons**: long track, no secondary particles
- Large angular separation between lepton and CC remnants.

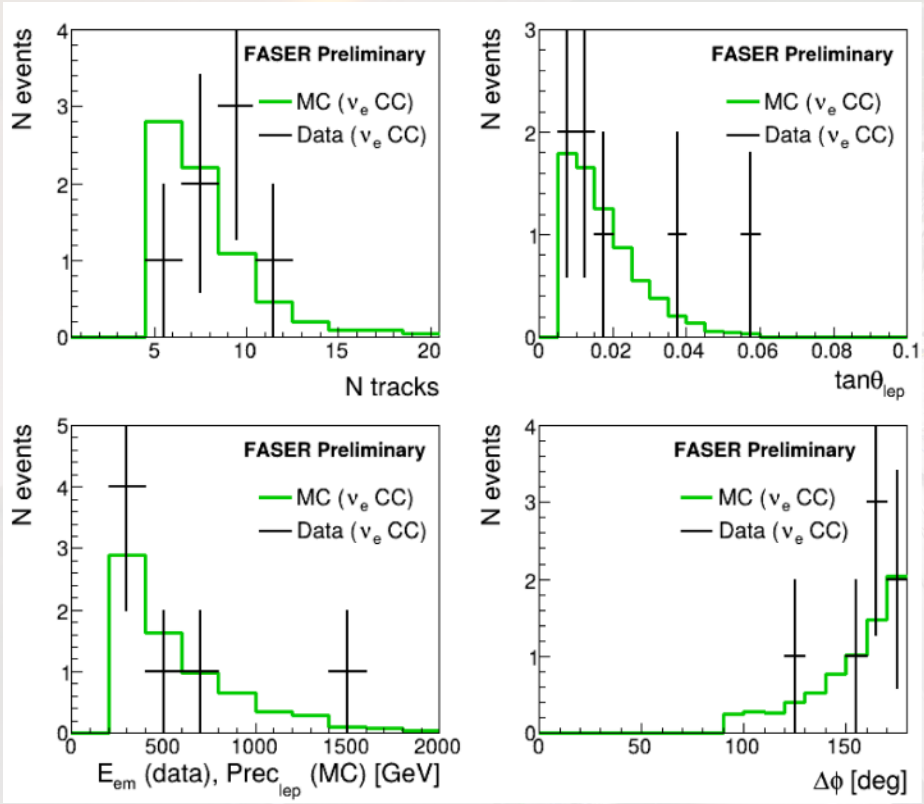


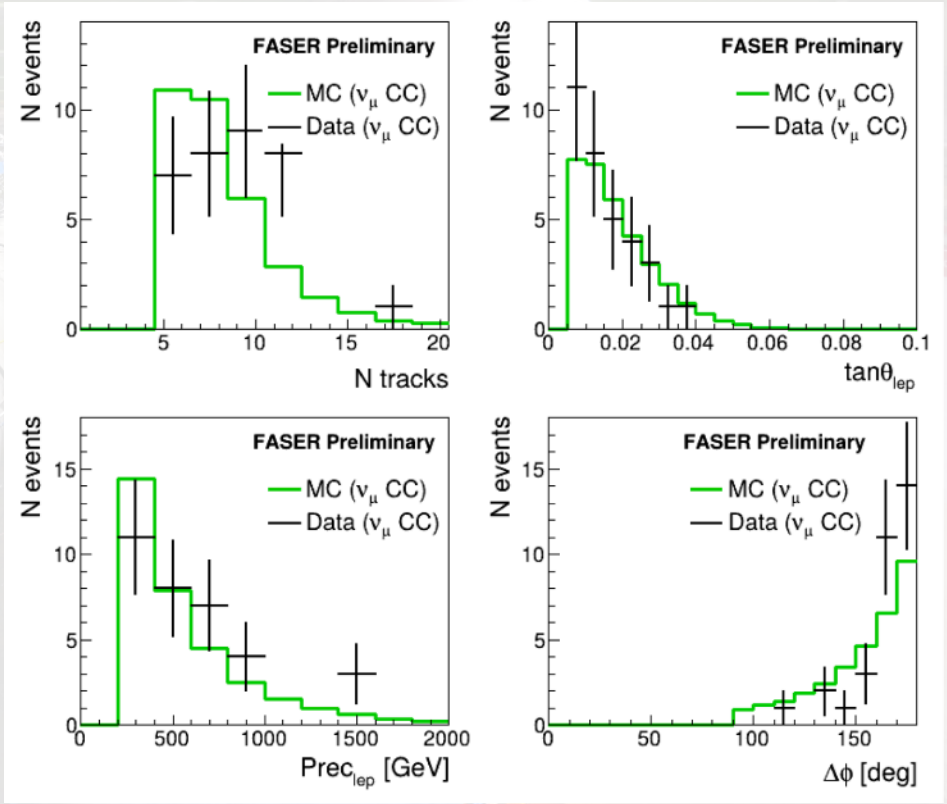




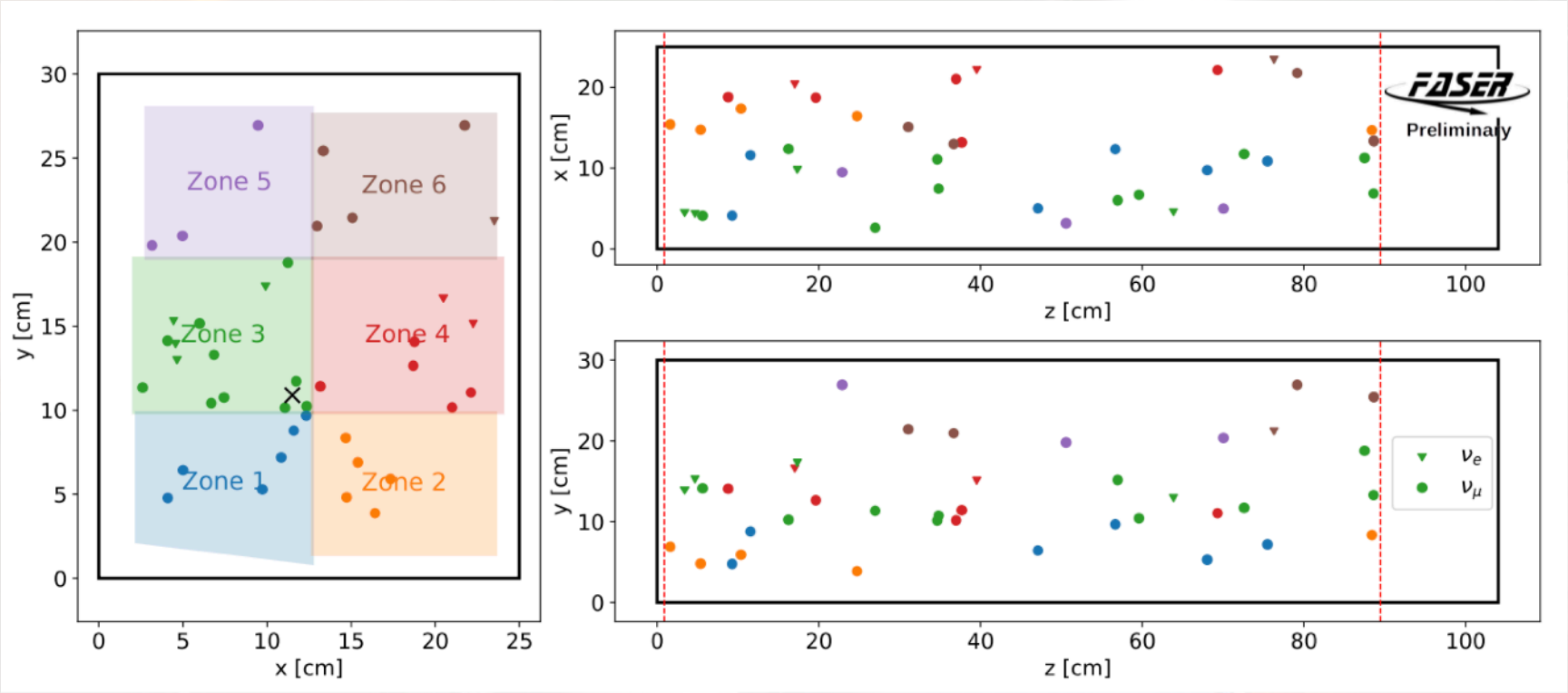
High purity selection
Vertex reconstruction ($N_{\text{track}} \geq 5$, $N_{\text{track}}(\tan\theta \leq 0.1) \geq 4$)
E_e or p_μ >200 GeV
$\tan\theta_e$ or $\tan\theta_\mu$ >0.005
ϕ>90°

FASERν analysis



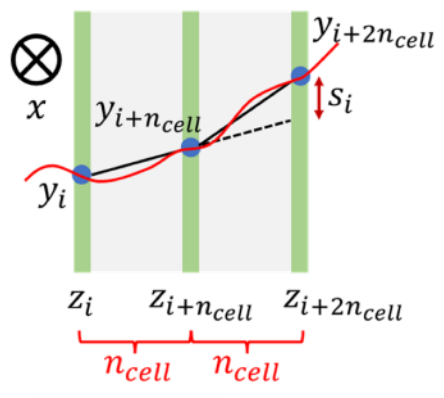


FASERν analysis

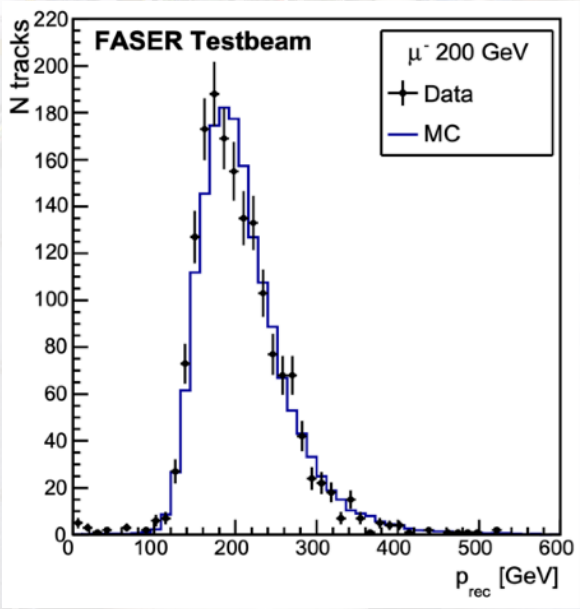


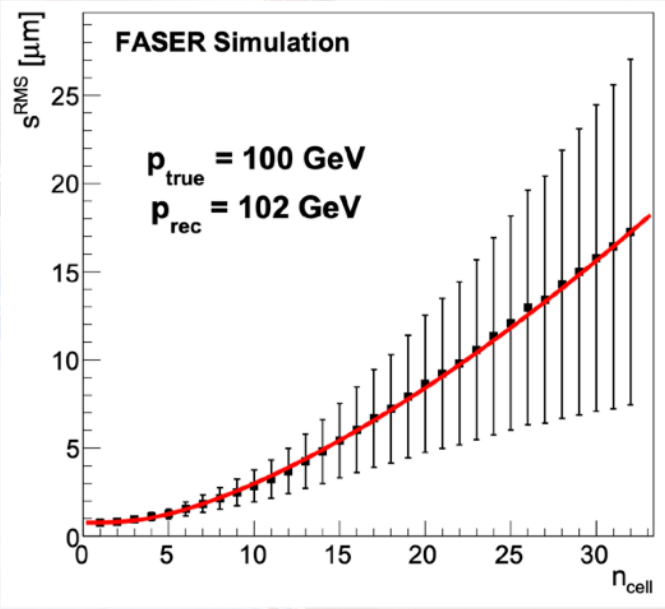
arxiv:2602.17575

FASERν muon momentum reconstruction

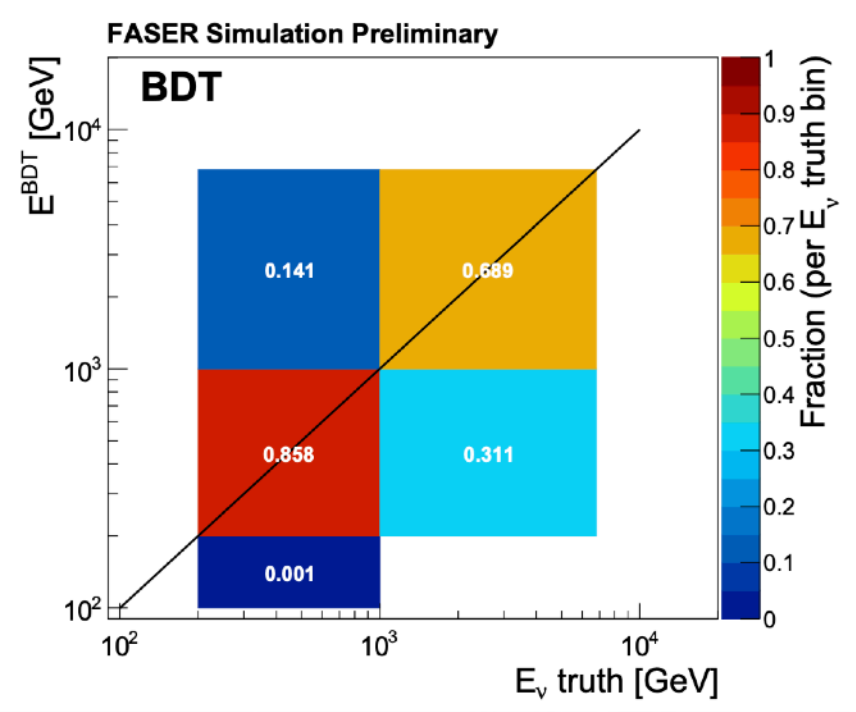


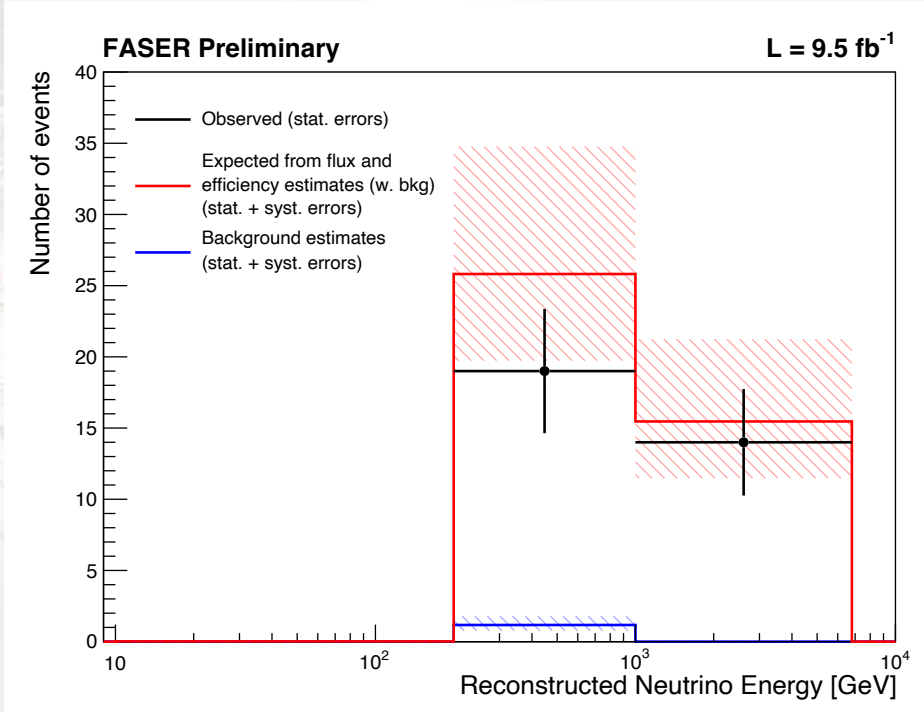
$$\theta_{\text{plane}}^{\text{RMS}} = \frac{0.0136\ \text{GeV}}{\beta pc}\sqrt{\frac{z}{X_0}}\left\{1 + 0.038\ln\left(\frac{z}{X_0\beta^2}\right)\right\}$$



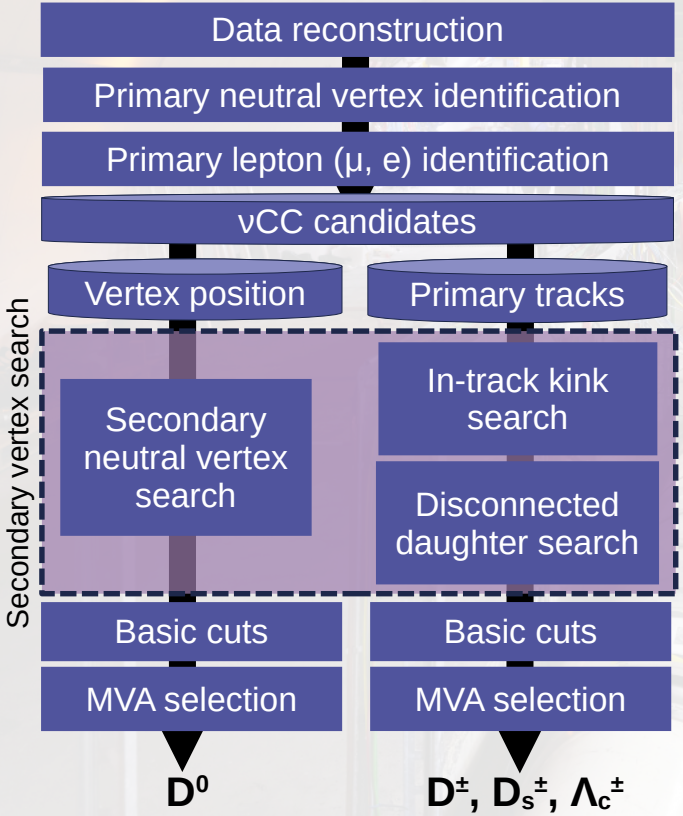


FASERν differential cross section

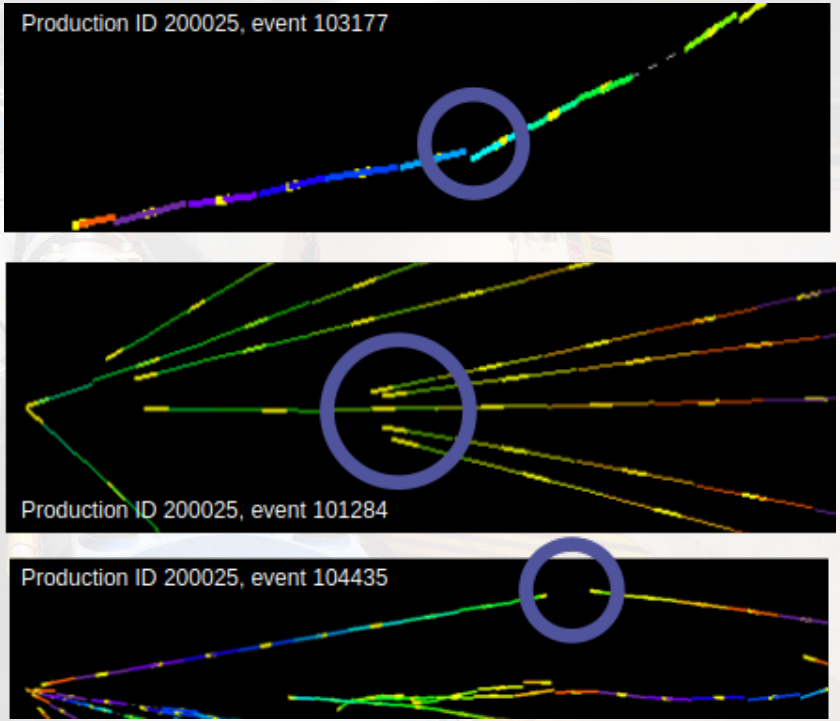




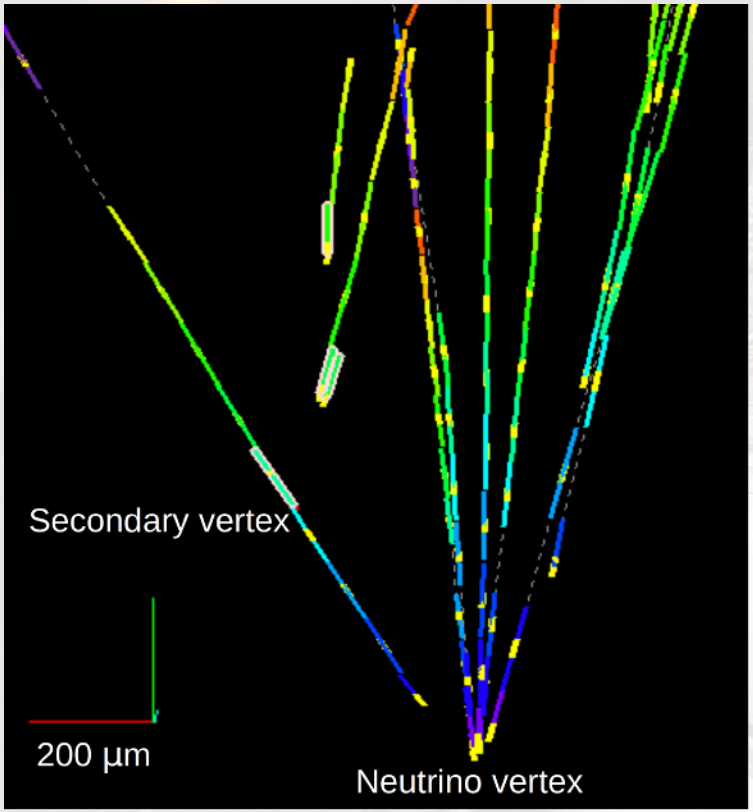
Search for associated charm production

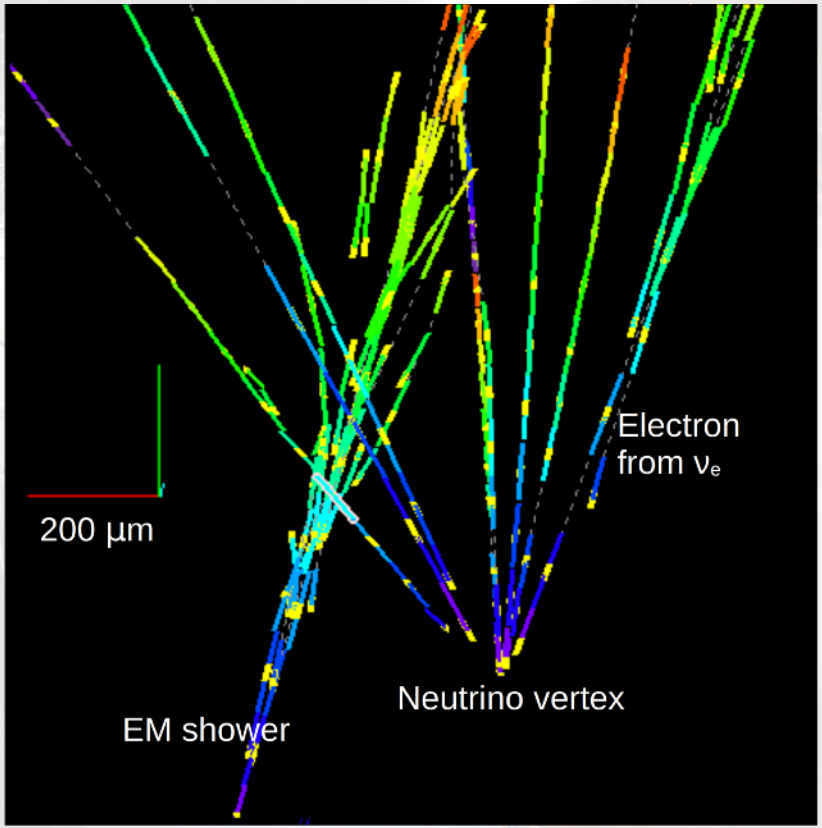


Simulation

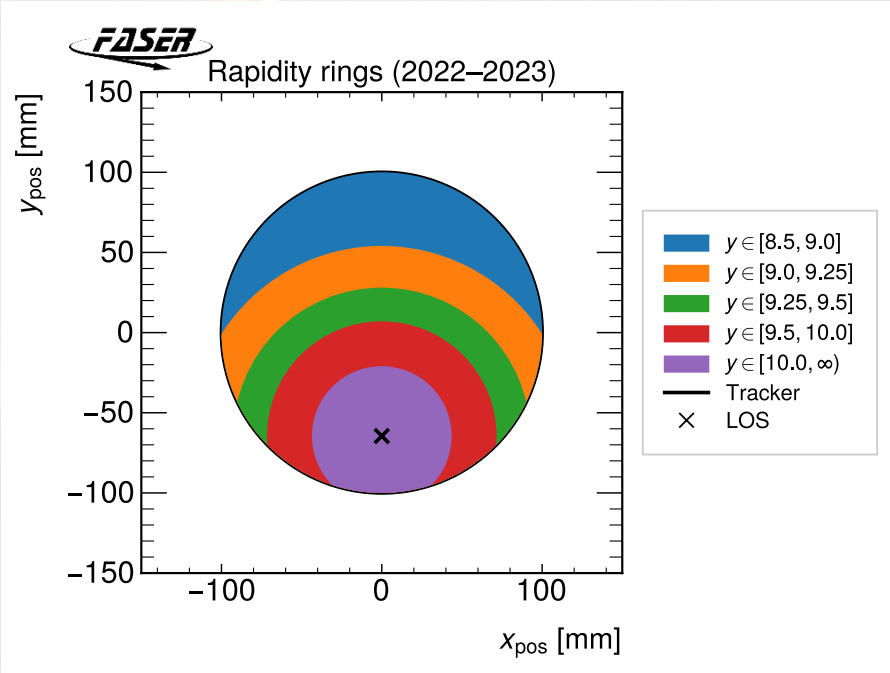


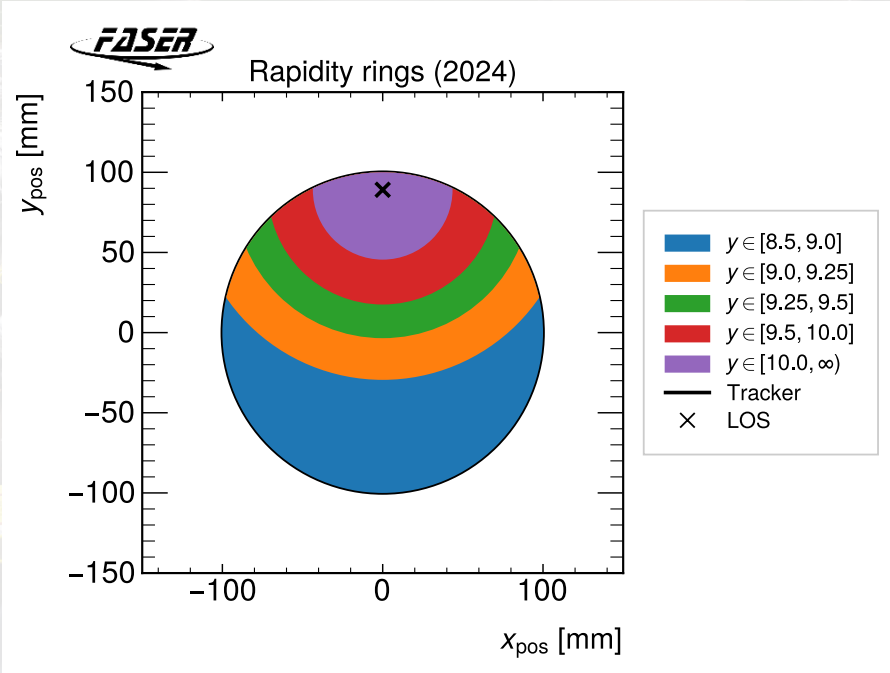
Search for associated charm production



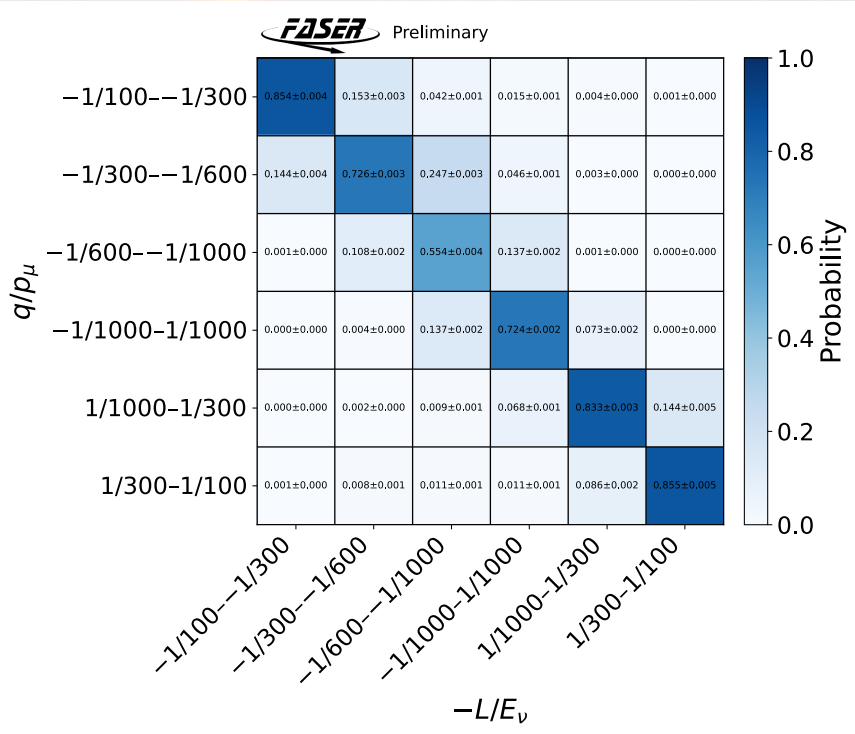


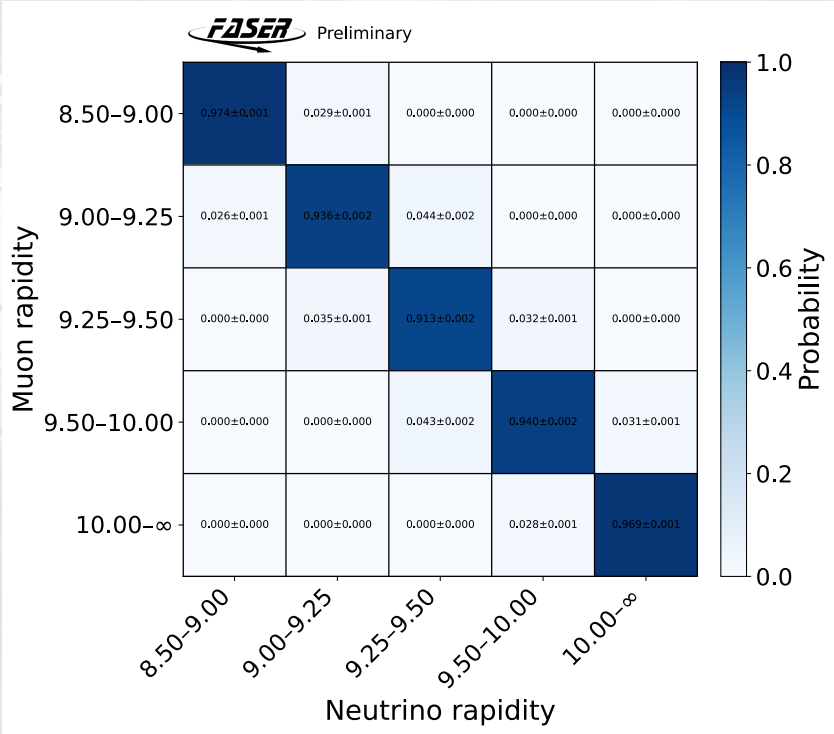
ν_μ differential measurement



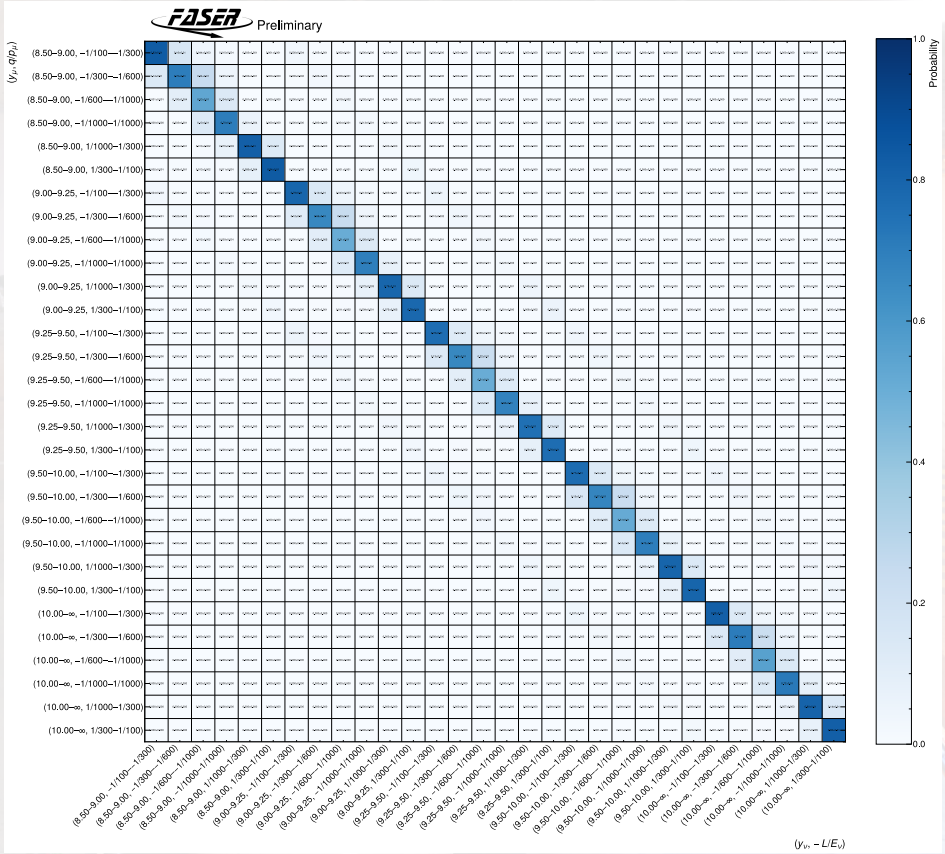


ν_μ differential measurement

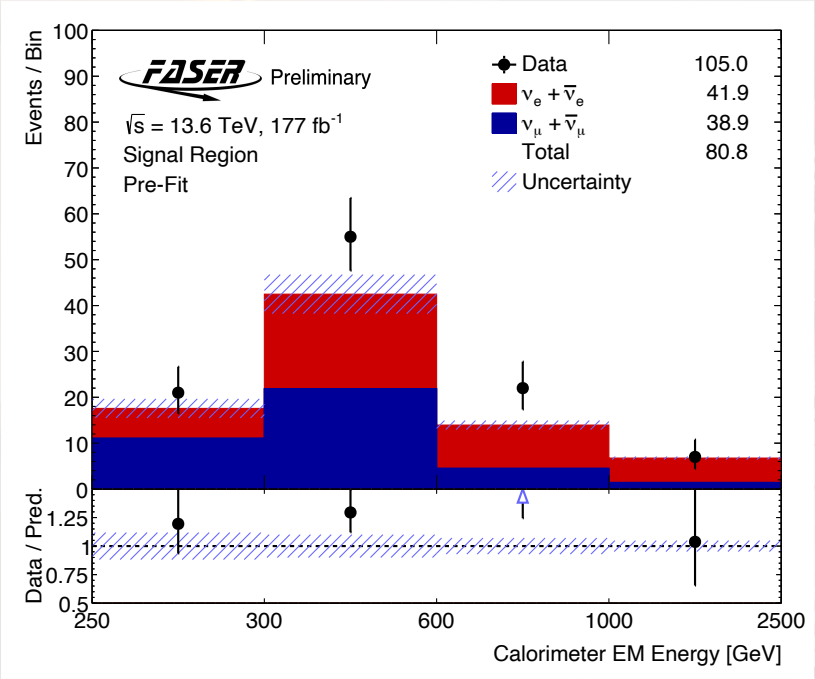


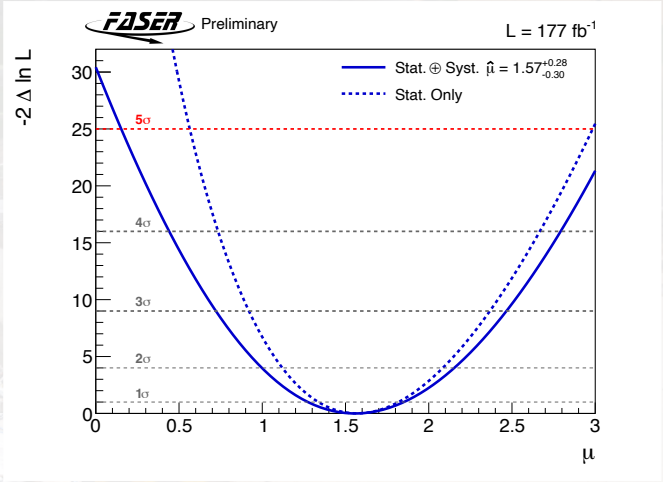


ν_μ differential measurement



Calorimeter electron neutrinos

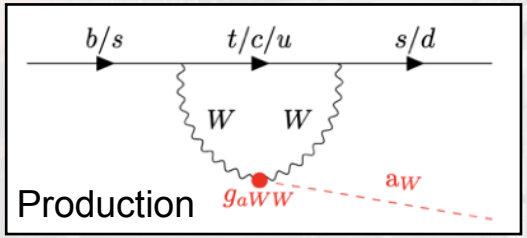


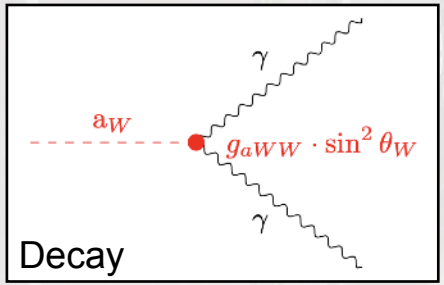


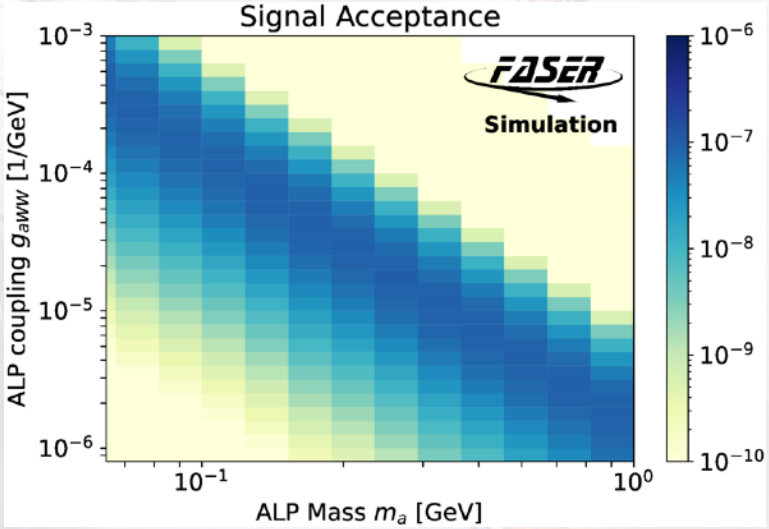
E_{Calo} [GeV]	[250-300]	[300-600]	[600-1000]	[+1000]	Total
$\nu_e + \bar{\nu}_e$	6.52 ± 3.32	20.62 ± 12.59	9.44 ± 7.01	5.32 ± 4.40	41.90 ± 27.32
$(\nu_\mu + \bar{\nu}_\mu)$ FV	9.85 ± 2.76	19.52 ± 4.97	3.94 ± 1.02	1.26 ± 0.32	34.57 ± 9.07
$(\nu_\mu + \bar{\nu}_\mu)$ Out-FV	1.11 ± 0.30	2.12 ± 0.54	0.52 ± 0.12	0.14 ± 0.03	3.89 ± 0.99
$\nu_\tau + \bar{\nu}_\tau$	0.10 ± 0.18	0.22 ± 0.37	0.04 ± 0.09	0.03 ± 0.04	0.40 ± 0.67
Signal $(\nu_e + \bar{\nu}_e)$	6.52 ± 3.32	20.62 ± 12.59	9.44 ± 7.01	5.32 ± 4.40	41.90 ± 27.32
Background	11.06 ± 2.78	21.87 ± 5.01	4.50 ± 1.03	1.43 ± 0.32	38.86 ± 9.15
Expected	17.58 ± 4.33	42.49 ± 13.55	13.94 ± 7.09	6.75 ± 4.41	80.76 ± 29.38
Observed	**21**	**55**	**22**	**7**	**105**

Axion Like Particles (ALPs)

- Search for a light pseudoscalar particle decaying to a pair of photons.
- ALPs reaching FASER have momentum up to TeVs.
- Using 58 fb^{-1} of 2022 + 2023 data.

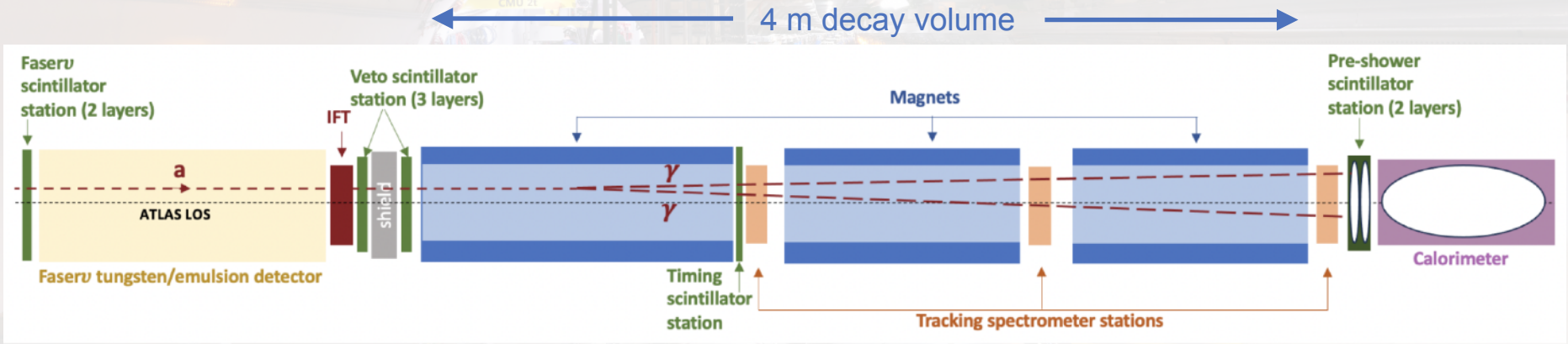






arXiv:2410.10363

Axion Like Particles (ALPs)



No charge deposited in scintillators

Decays to pair of photons

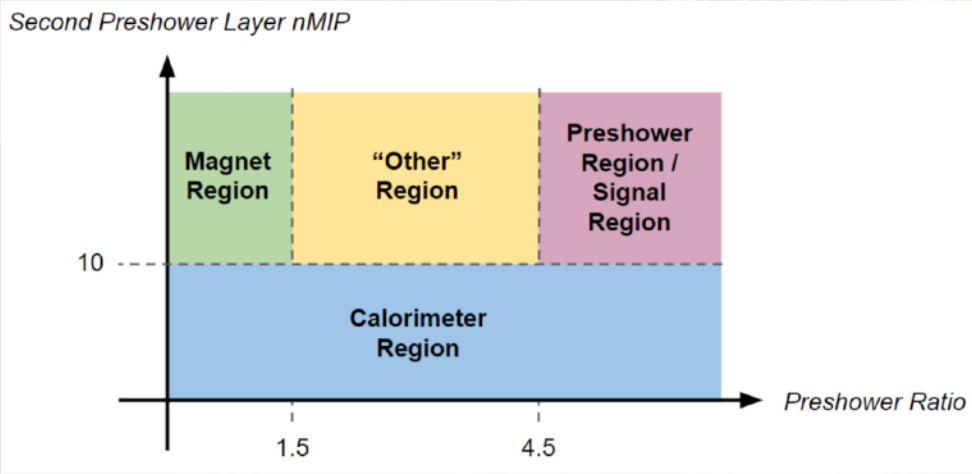
Preshower charge > 10 MIPs, ratio > 4.5

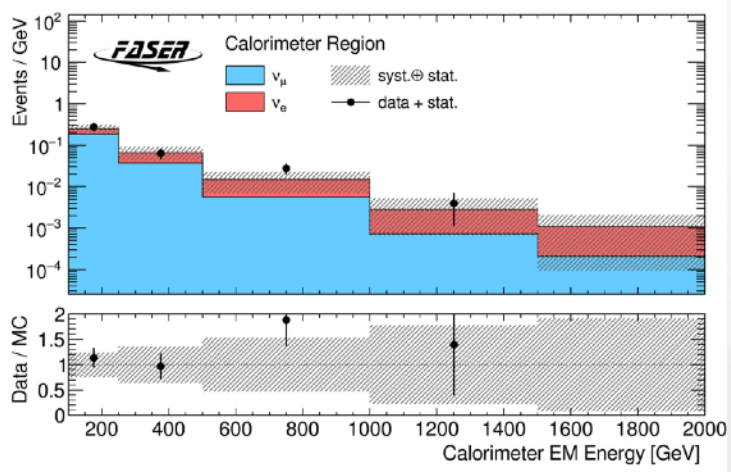
Calorimeter energy > 1.5 TeV

arXiv:2410.10363

Axion Like Particles (ALPs)

- Dominant background: neutrino interactions → 0.4 ± 0.4 events
- Negligible backgrounds from other sources:
  neutral hadrons, large-angle muons, non-collision/cosmic
- Backgrounds validated in control regions

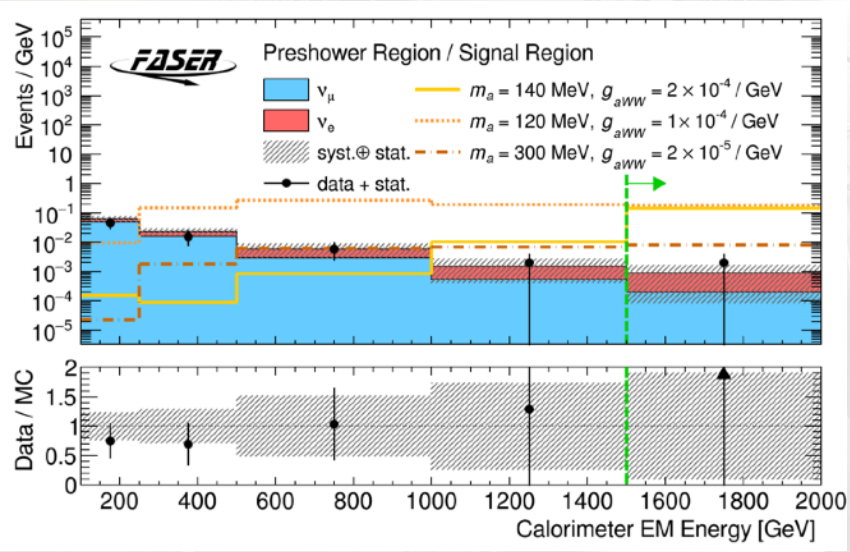


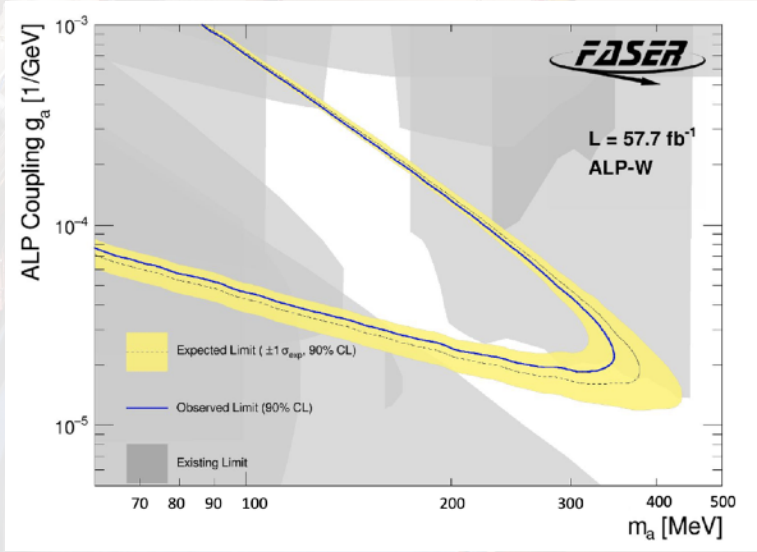


arXiv:2410.10363

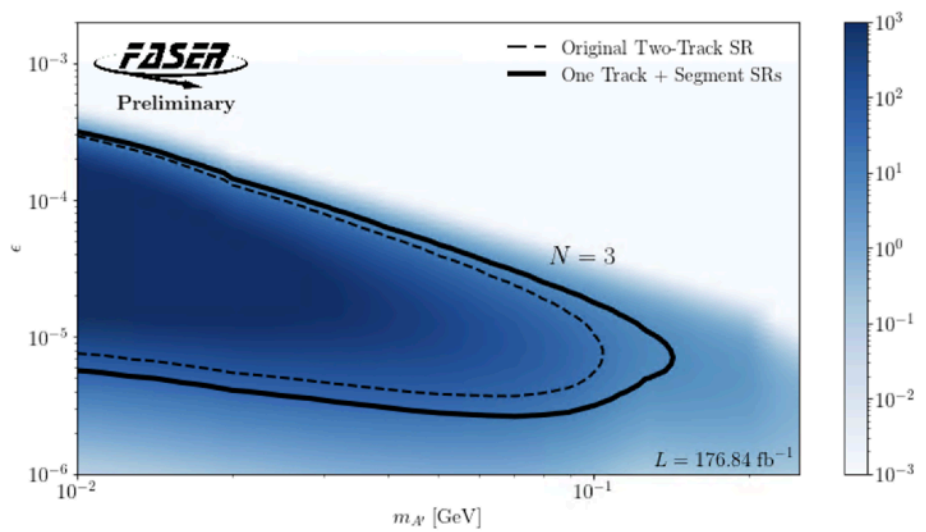
Axion Like Particles (ALPs)

- Expect 0.4 ± 0.4 from ν interactions
- 1 observed event
- Exclude uncovered parameter space significantly





Dark Photons



Source	Value	Effect on Signal Yield
Theory, Statistics and Luminosity		
Dark Photon Generation (from mesons)	15%	15% ± 13% (8%)
Dark Photon Generation (from dark Bremsstrahlung)	22%	22% ± 30% (40%)
Luminosity	1.9%	1.9%
Tracking: One Track		
Momentum Scale	5%	<0.5%
Momentum Resolution	5%	<0.5%
Single Track Efficiency	1.22%	1.22%
Tracking: Segment		
Segment Efficiency	6.07%	6.07%
Preshower		
Preshower Ratio	3.6%	3% ± 3% (10%)
Calorimeter		
Calo E Scale	5.46%	3% ± 3% (11%)