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CLHCP 2023

First Observation of Collider Neutrinos with FASER

Jinfeng Liu (Tsinghua University)

FASER collaboration

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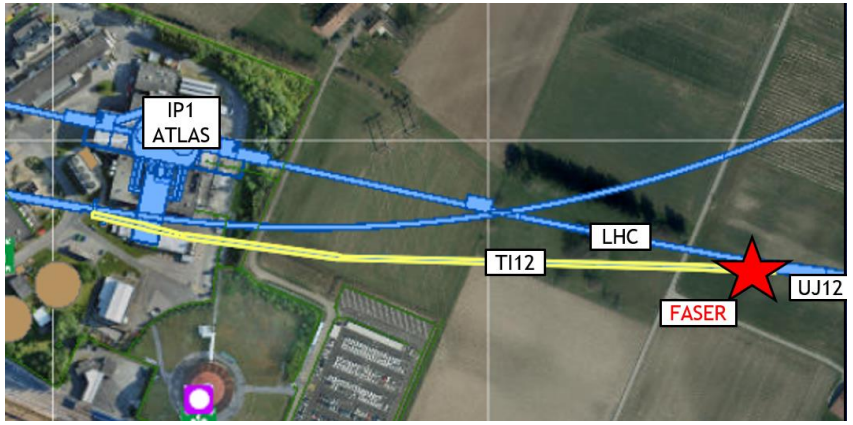
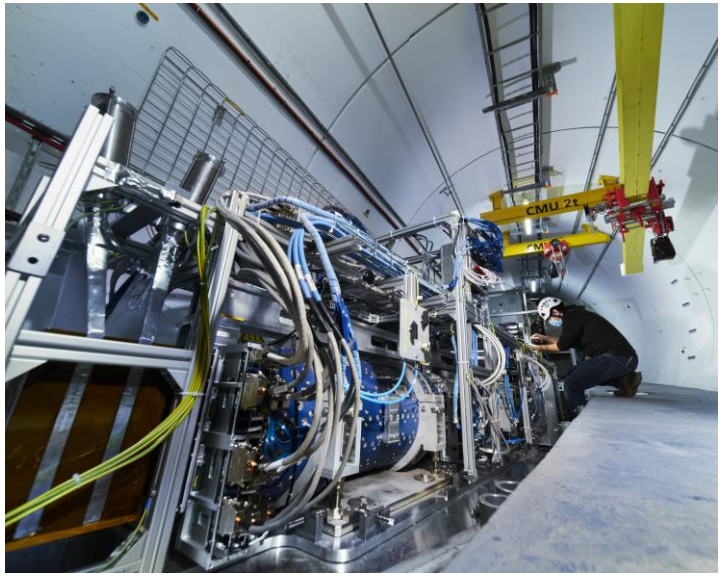
- **FASER (The ForwArd Search ExpeRiment) is a new experiment at LHC (in operation since 2022)**
- **The target of FASER includes dark matter and collider neutrino (FASERν)**
- **An introduction has been given last year:**
  - Tomohiro: Looking forward to New Physics and Neutrinos with FASER at LHC
- **We report the latest physics results from FASER:**
  - Dark photon search, Hao Pang: 9:50, 18th Nov
  - **Collider neutrino search: This report**





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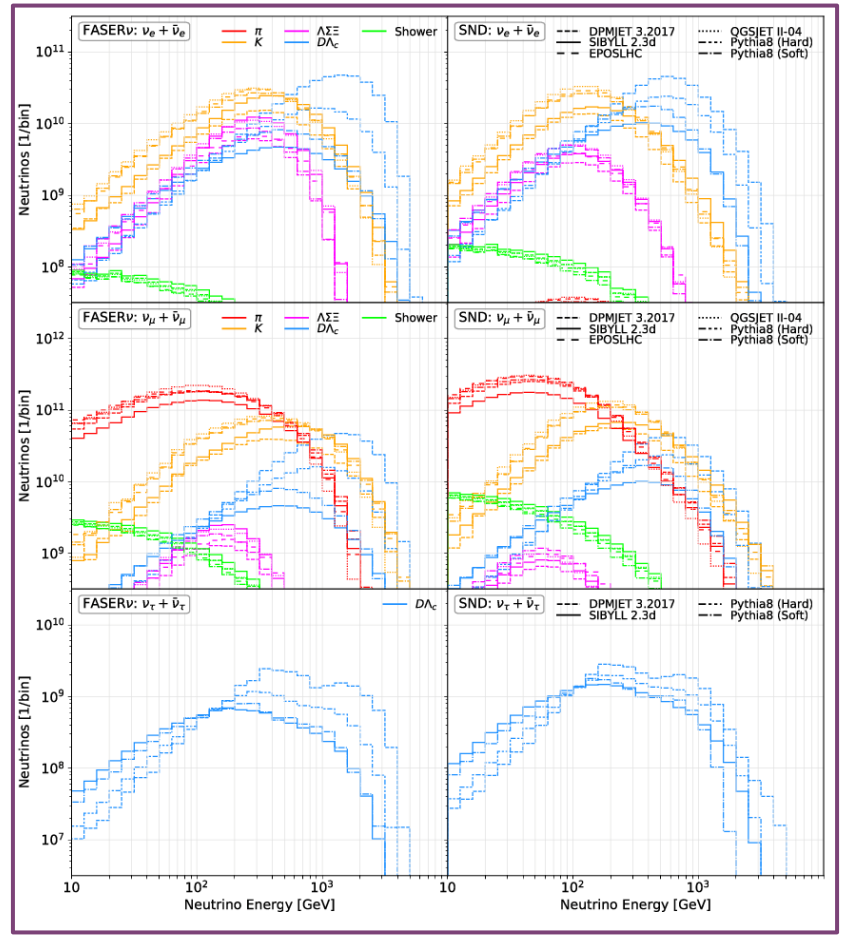
- **Neutrinos are copiously produced at collider, but they have never been directly detected**
  - Small cross section, high background, forward produced …
- **Collider neutrinos have exciting features compared with other neutrino sources**
  - Compared to cosmic neutrino, collider neutrino can be **largely produced**
  - Compared to reactor and beam dump neutrino, collider neutrino has much **higher energy**
  - The source of collier neutrino can be **charm/bottom decay**
  - Neutrinos with **all flavors** can be produced from collider (not from oscillation)



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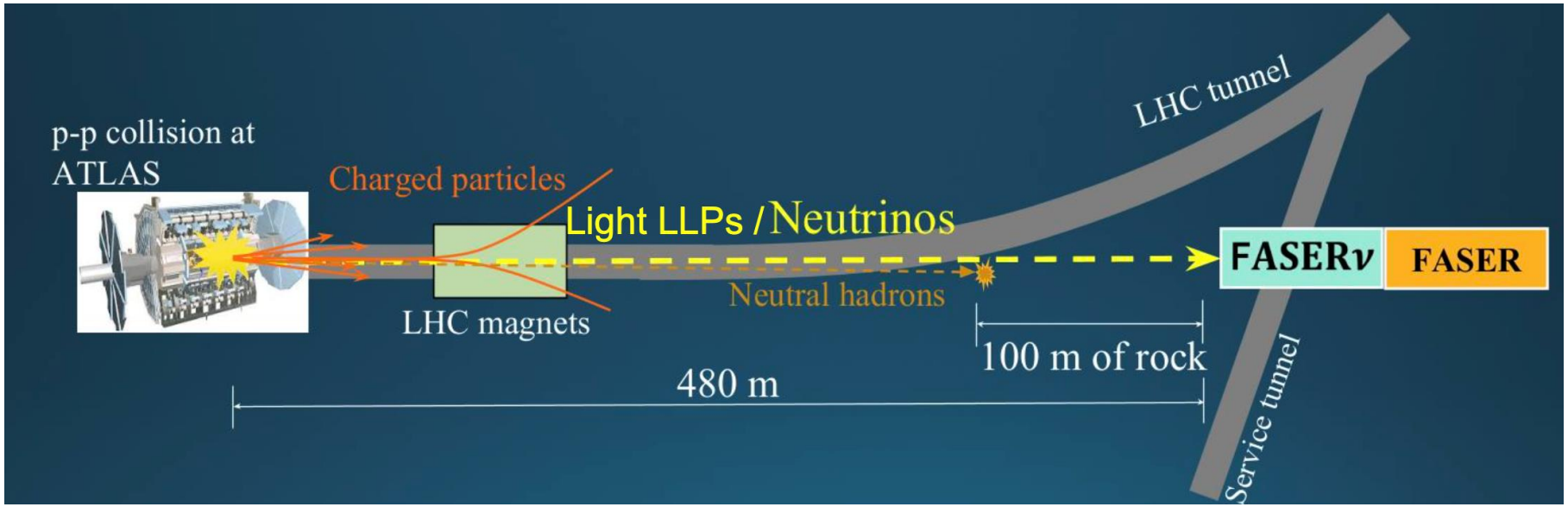
- FASER is an experiment aims to detect light, long-lived particles produced at the LHC collisions. These particles tend to fly in a very forward direction, which is the blind area for traditional spectrometers
- FASER is located at the beam axis line-of-sight (LOS) from the ATLAS collision point (IP1)
- Installation started by 2021. Data taking started by 2022, will run during the Run3



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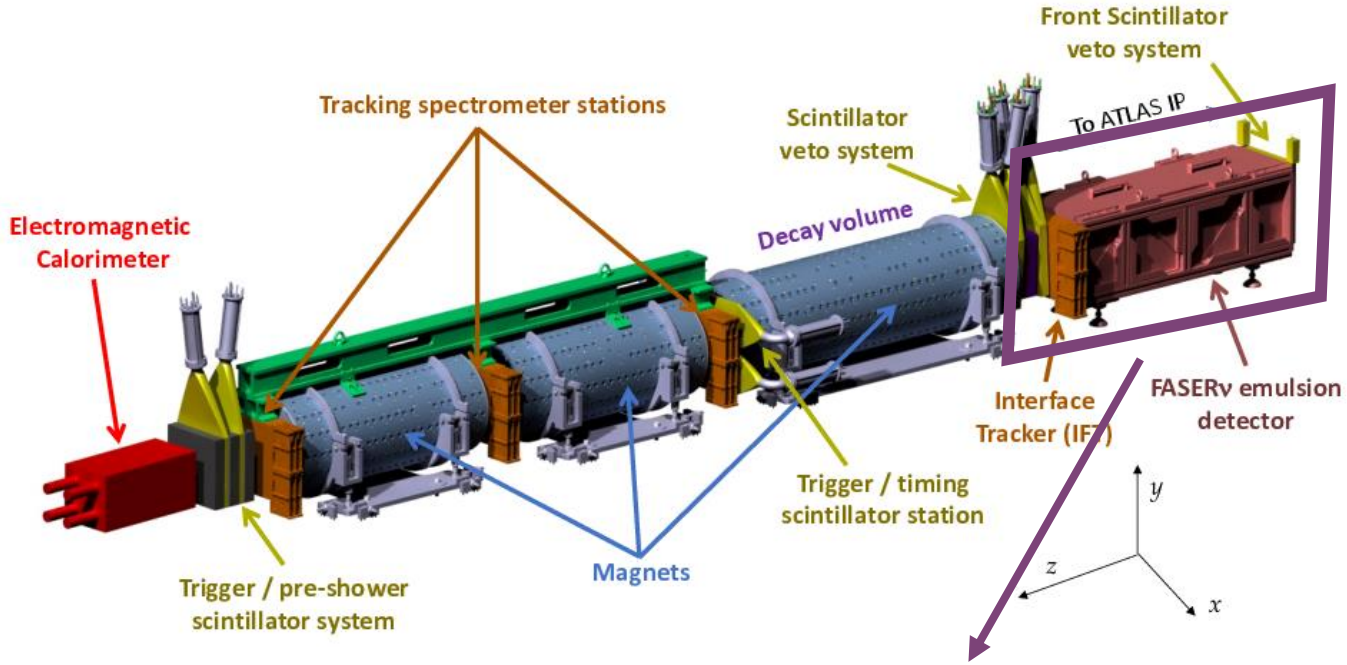
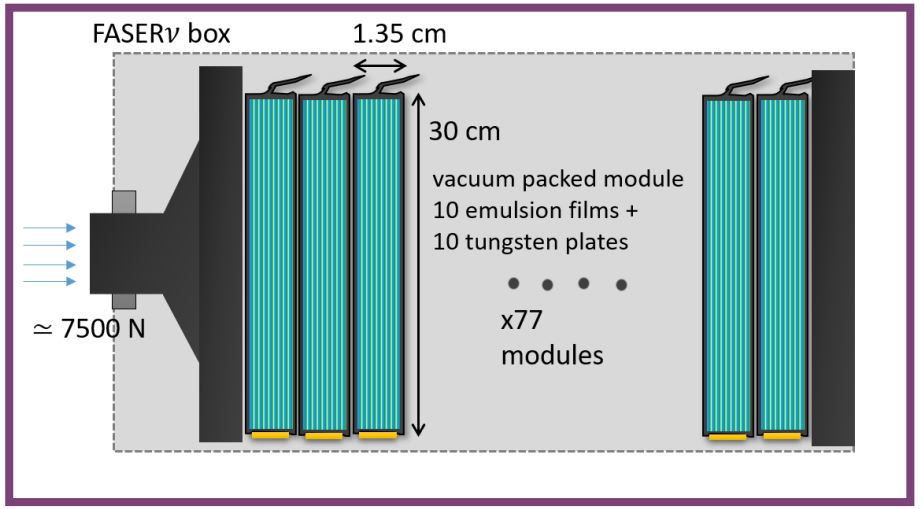
- FASER is a light weight detector (7m long, 20cm diameter)
- Comprised of an emulsion (with tungsten), scintillators, tracking stations and an electromagnetic calorimeter
- Main detecting volume in 0.6T magnetic filed
- The major part of FASERν includes 730 alternate layers of emulsion film and tungsten plate
  - Act as the target of neutrino interaction and vertex tracker





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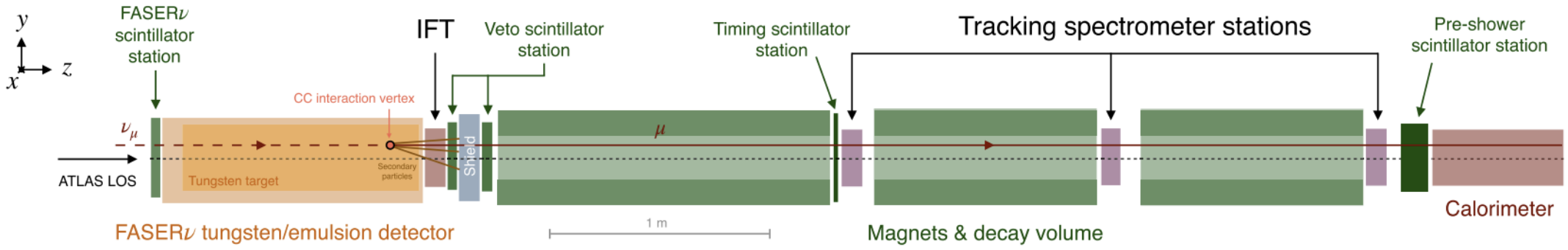
Observation of Collider Neutrinos with Electronic Detector



- The result about collider neutrino search based on electronic detectors of FASER has been published [PhysRevLett.131.031801]
- The information from the emulsion is not utilized
- Track propagating through the entire length of the FASER detector is served as candidate (consistent with υ_μ CC interaction)
- Dataset collected between 2022.7-11 ($35.4fb^{-1}$) is used, with collision energy 13.6TeV
- Expected number of events is: $\mathbf{151 \pm 41}$

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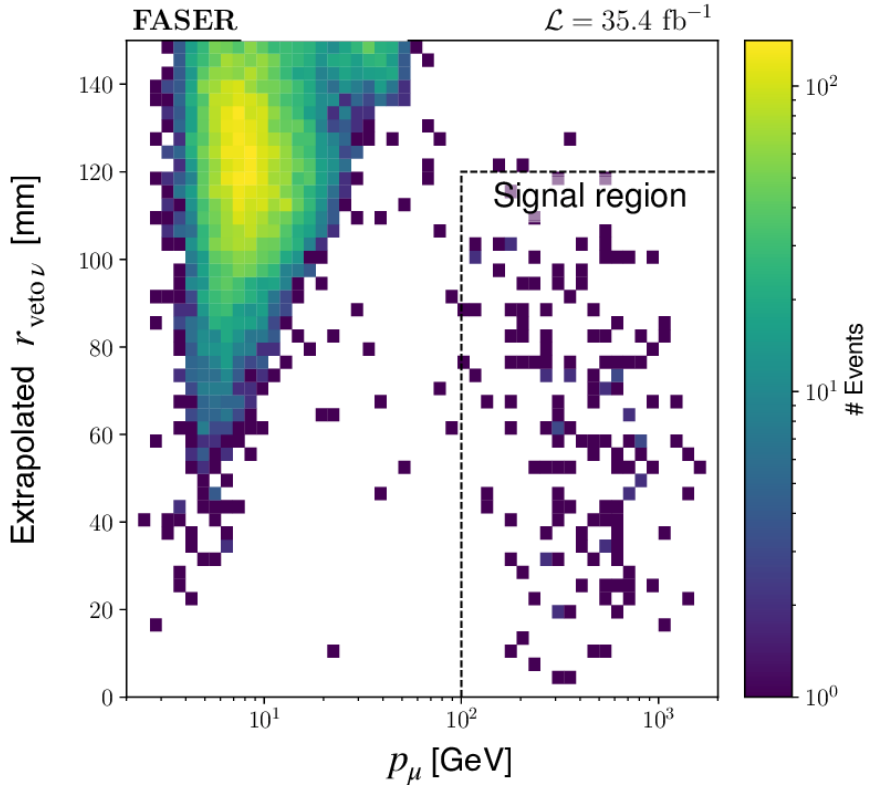
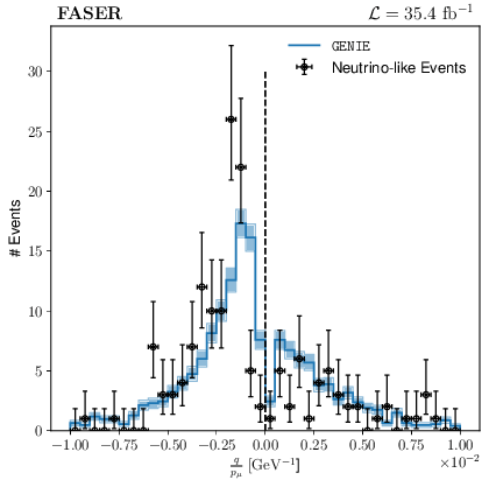
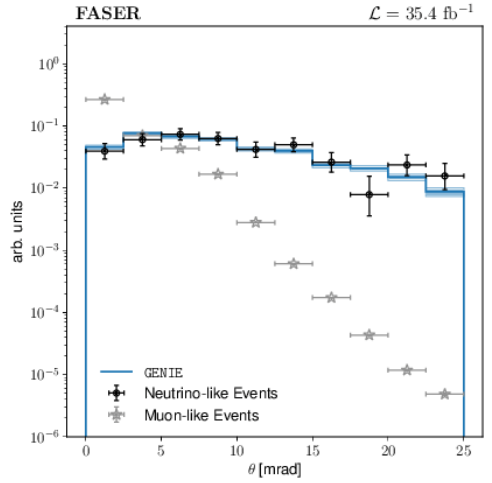
- **Signal is selected with high momentum μ** ($p > 100$GeV) **and passing through the center of veto scintillator** (r<120 mm)
- **Several backgrounds are investigated**
  - High momentum μ: vetoed by scintillator
  - Neutral hadrons: estimated by simulation
  - Geometric backgrounds: estimated by sideband
- **153^{+12}_{-13} neutrino events after unblinding**
  - 99% originate from **ν_μ CC interaction**
  - 40 events with **positively charged** track
    → **$\overline{\nu_\mu}$** observed!







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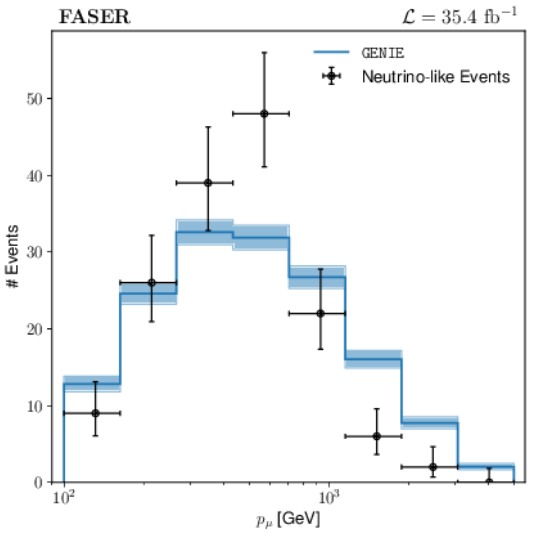
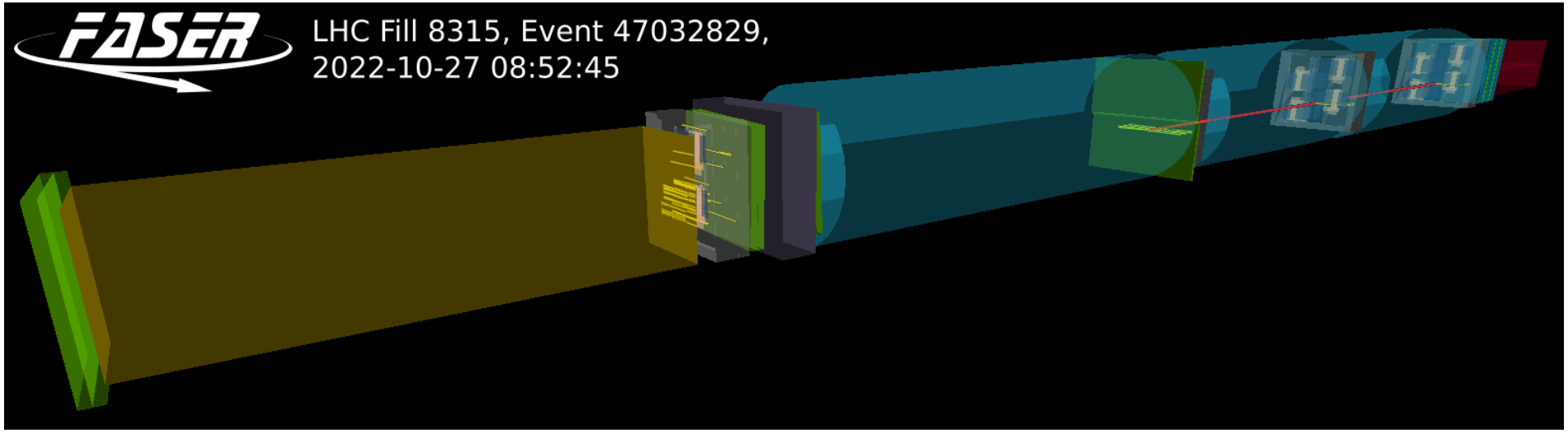
- **The first direct observation of collider neutrinos!**
  - 16σ deviations above the background-only hypothesis
- **Expected to be the most energetic neutrino ever detected from an artificial source!**
  - Estimated energy significantly above 200GeV
- **Published at PRL** [PhysRevLett.131.031801]





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Observation of Collider Neutrinos with Emulsion Detector

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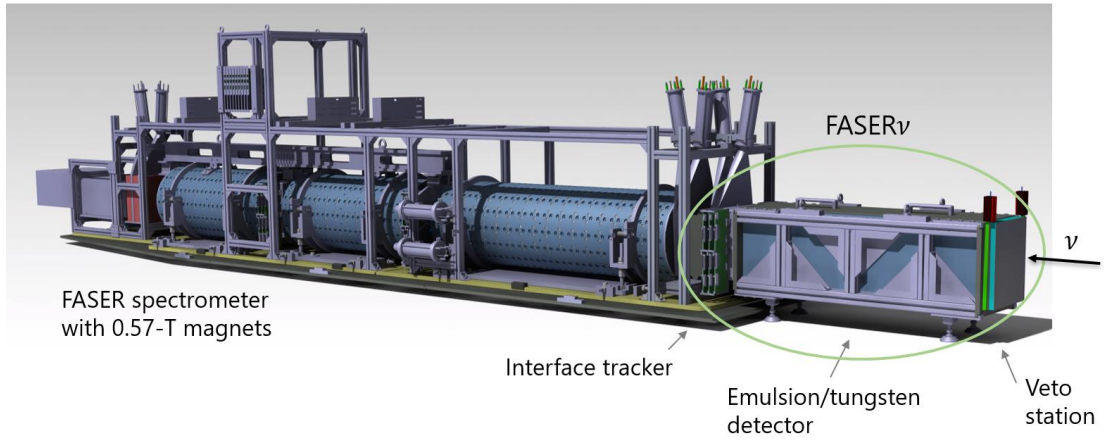
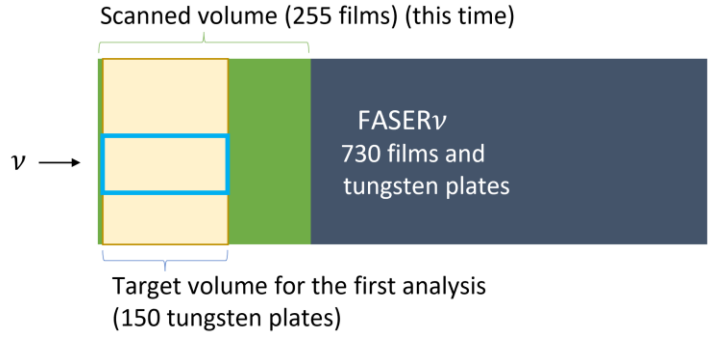
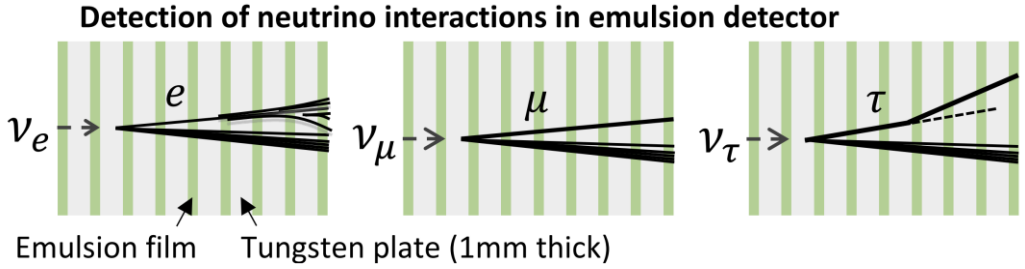
- Although with slower workflow, emulsion of serves not only the target of neutrino interaction but also a tracker with excellent position resolution
  - Three neutrino flavors can be identified
- A investigation has been conducted with a subset of the emulsion
- Not matched with tracks from electronic detector
- Dataset collected between 2022.7-9 $(9.5fb^{-1})$ is used, with collision energy 13.6TeV







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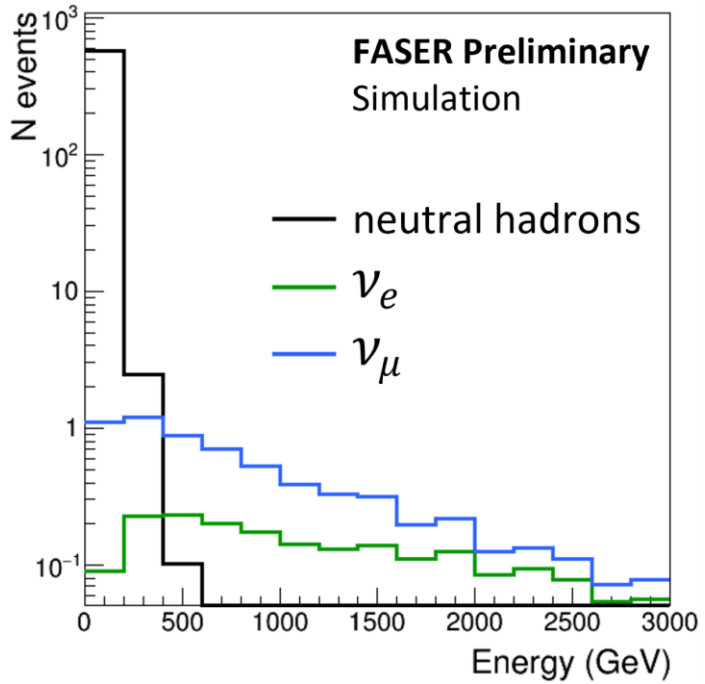
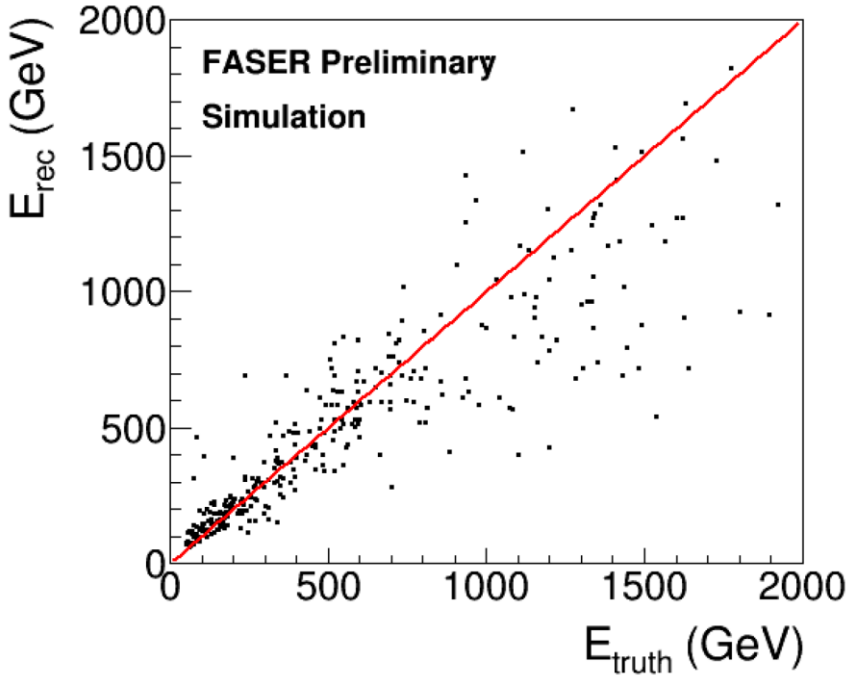
- **Main background arises from neutral hadrons produced by μ from the collision**
  - Estimated by simulation
  - 0.51±0.27 for υ_μ, 0.002±0.003 for υ_e
- **Energy of neutrinos can also be estimated by emulsion tracks**
  - Resolution: ~20% for E_e and ~25% for P_μ

- **4 vertexes υ_μ and 3 vertexes for υ_e are observed**
  - With energy and azimuthal angle requirements





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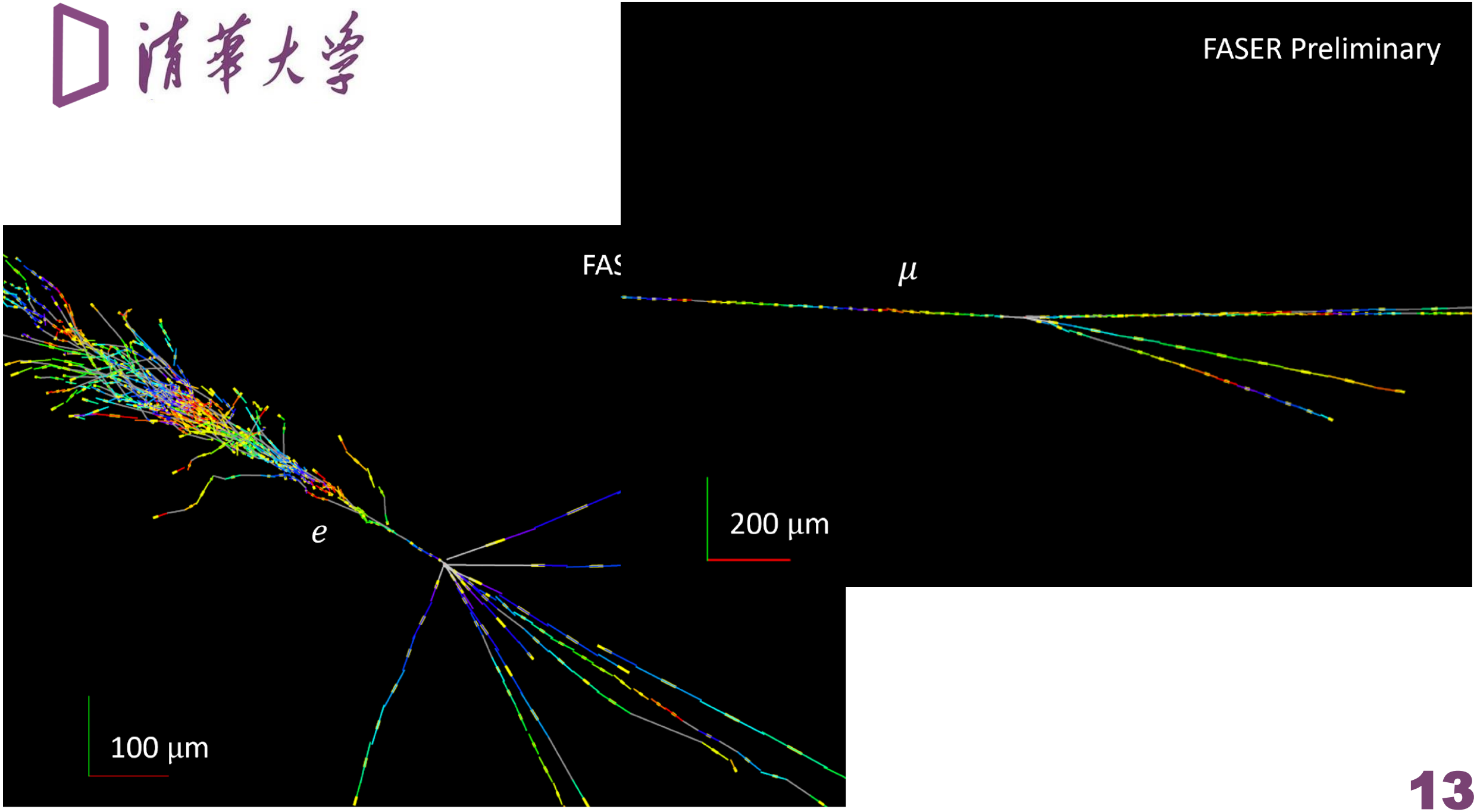

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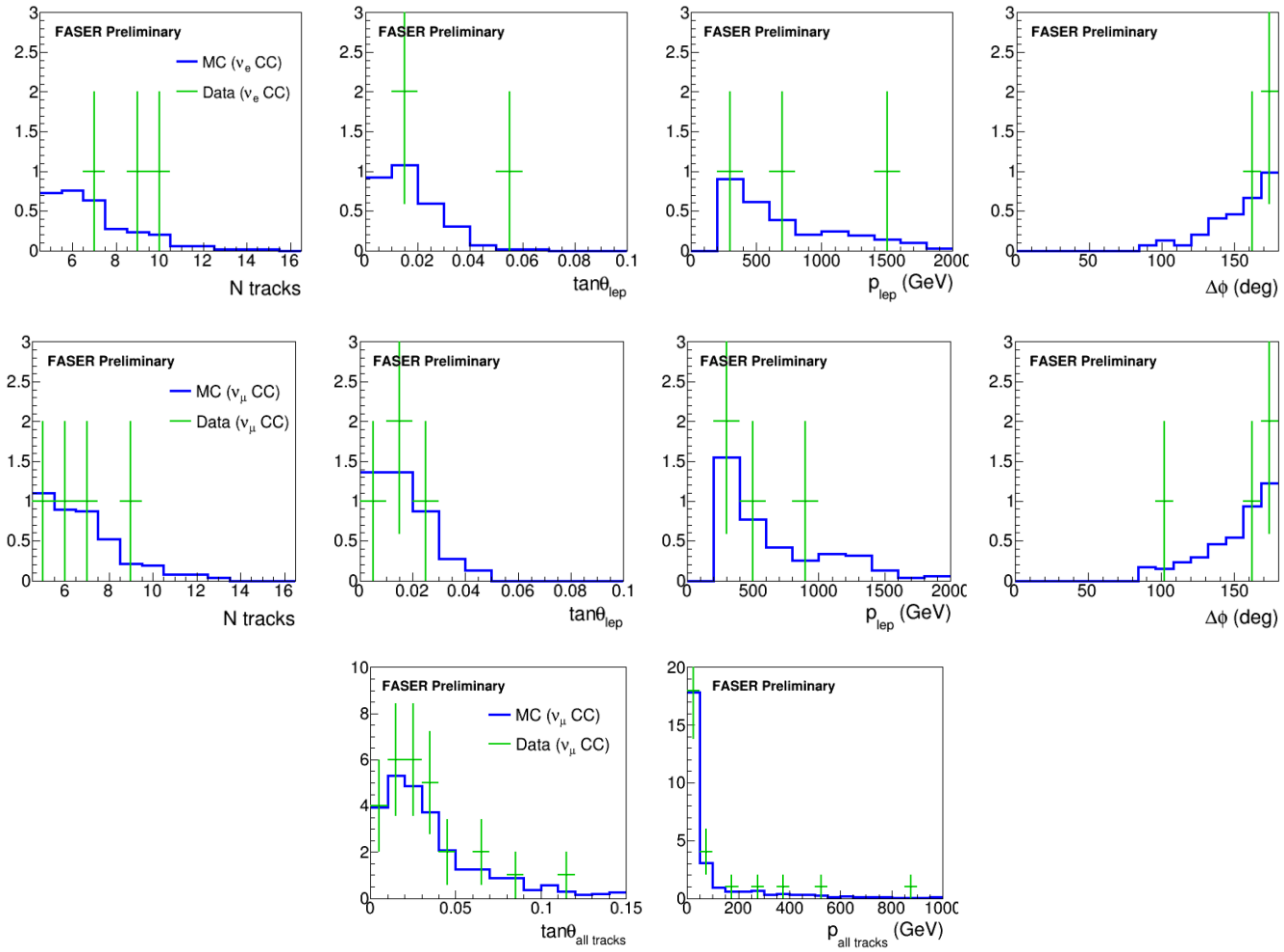
- **First preliminary result with the FASERν emulsion detector** (CERN-FASER-CONF-2023-002)
- **First observation of collider electron neutrino**
  - 5σ for υ_e, 2.5σ for υ_μ
- **Demonstrate the ability to carry out neutrino studies with the FASERν emulsion detector**
  - Will be improved with longer range used



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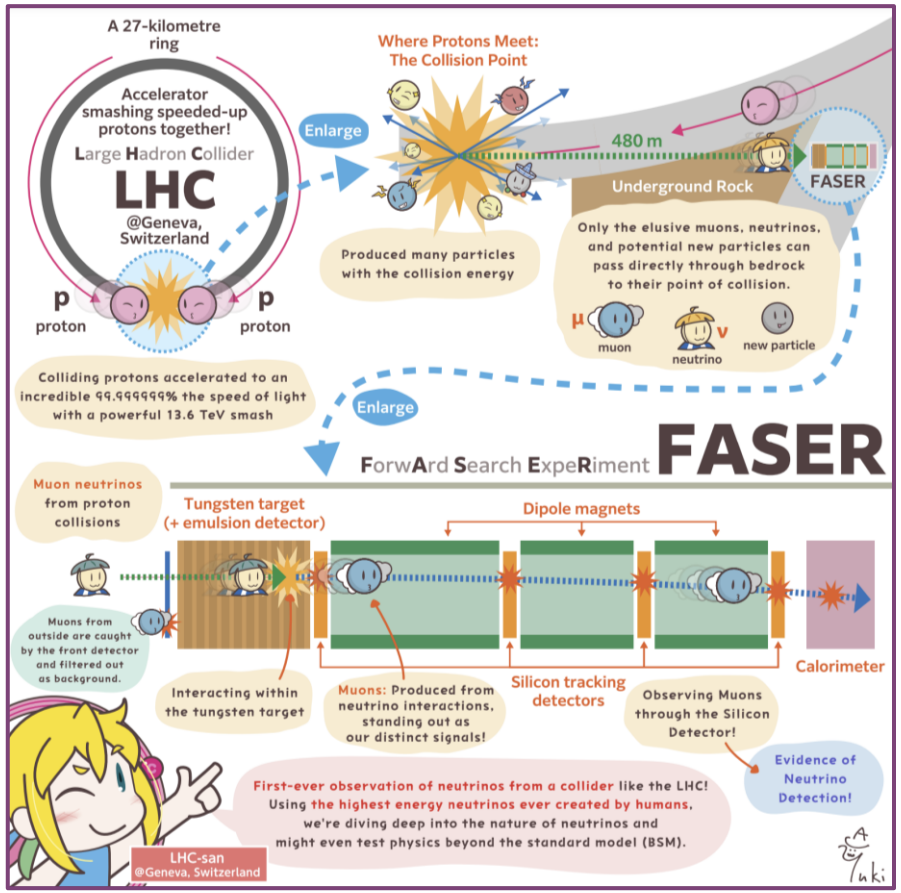
• Summary



- FASER is a young forward experiment at LHC
- FASER aims to search for light, long-lived particles, including possible new particles and collider neutrinos
- With electronic detector, FASER made the first observation of collider neutrinos with relatively high energy
- With emulsion detector, FASERν achieved the first observation of collider electron neutrinos
- Better performance is expected with more emulsion films analyzed, matching emulsion and electronic detector, upgrading analysis method…

FASER

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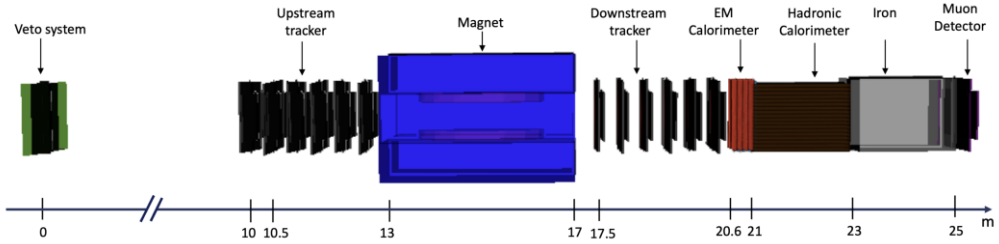
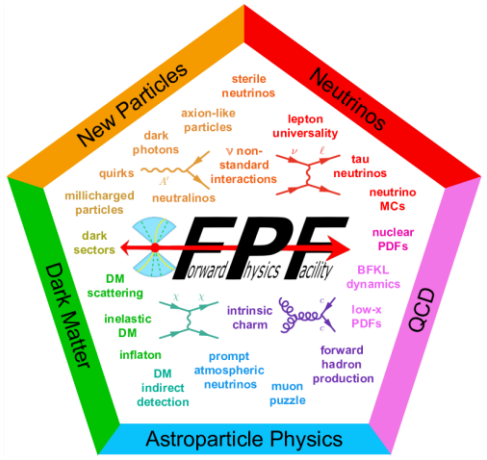
- A totally new physics domain has been presented, and we just only the first page…
  - FASER experiment
    - Main Page, publication and presentation
    - You may also have a virtual tour
  - FASER will be upgraded to a more powerful version: FASER2
  - A greater plan is under discussion: FPF (Forward Physics Facility)





Thank You!

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BACK UP

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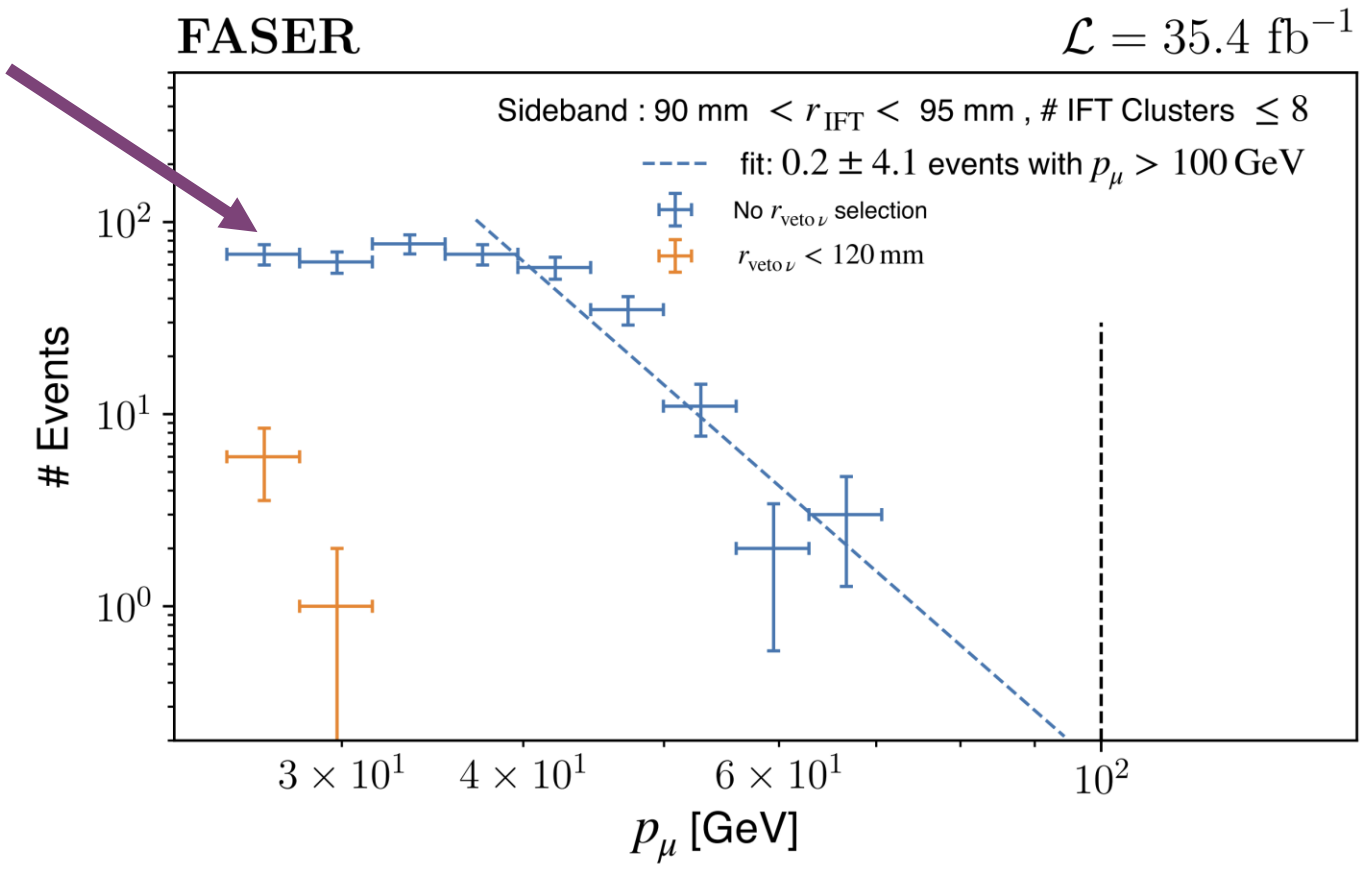
- Geometric background estimation

Side band candidate



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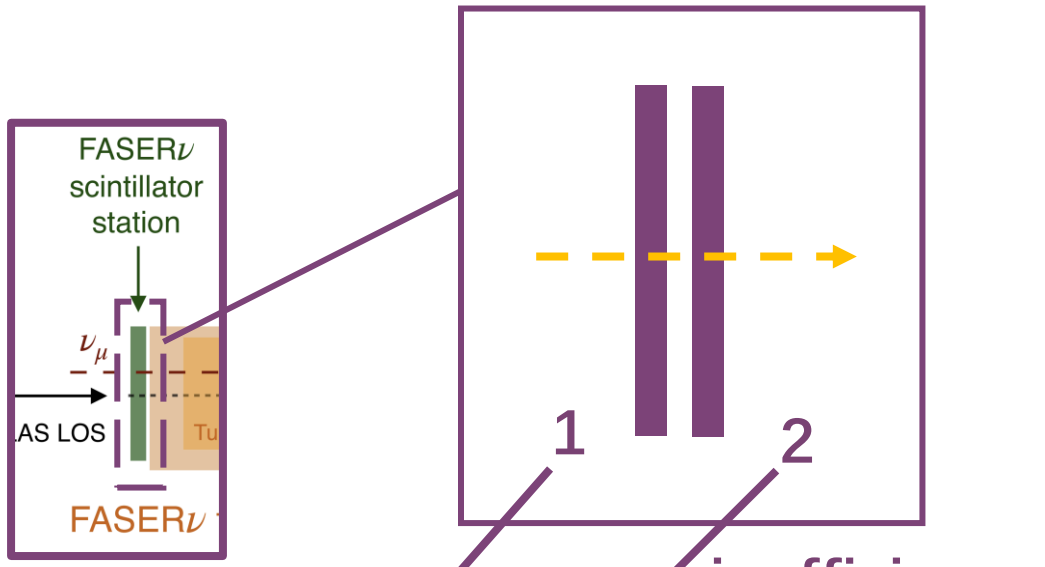
- Muon background estimation



Category	Events	Expectation
Signal	153	$n_\nu + n_b \cdot p_1 \cdot p_2 + n_{\text{had}} + n_{\text{geo}} \cdot f_{\text{geo}}$
n_{10}	4	$n_b \cdot (1 - p_1) \cdot p_2$
n_{01}	6	$n_b \cdot p_1 \cdot (1 - p_2)$
n_2	64 014 695	$n_b \cdot (1 - p_1) \cdot (1 - p_2)$