FASER and the Forward Physics Facility

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for the FASER Collaboration

28 March, 2024
Future of HEP: A New Generation, a New Vision
Aspen Center for Physics
• Use massive rate of forward mesons to search for light long-lived weakly interacting particles
• Exploit huge rate in collimated beam
  ▪ Inelastic pp cross-section: $\sim 100$ mb, $N \sim 10^{16}$ at Run3
  ▪ Very forward production: $\theta \sim \Lambda_{\text{qcd}} / E \sim \text{mRad}$
  ▪ Decay length: $\sim 100$ m for $m \sim 10$-100 MeV, $\epsilon \sim 10^{-5}$
• Put small detector on line-of-sight collision axis, probe unexplored territory!

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Letter of Intent: [CERN-LHCC-2018-030](https://cern.ch/)

28 March 2024
• FASER is 480m away from IP1 on the collision axis
  ▪ 100m of rock shielding before detector
• Designed for a variety of long-lived, weakly interacting particles
  ▪ New physics: Dark Photons, Axion-like particles, …
  ▪ Neutrinos: $\nu_e$, $\nu_\mu$, $\nu_\tau$
  ▪ Also observe SM muons
• Demonstrates small and cheap experiment
  ▪ Proposed in 2017, installed and taking data in 2021!
  ▪ Currently 96 members, 26 institutions, 10 countries

Tech Proposal: [CERN-LHCC-2018-036](http://example.com)
• Detector design constrained by **cost, space, and time**
• Scintillators w/ PMT readout for veto, trigger, and preshower (particle ID)
• 96 ATLAS SCT modules + 0.6T dipole magnets, \( r = 10 \text{ cm aperture} \)
• 4 LHCb calorimeter modules
• 1.1 Ton Tungsten-emulsion target for additional neutrino sensitivity
Installed in TI12 tunnel

• 4 years from idea to realization
• Installed and commissioned in time for Run3 startup
• Have recorded Run3 data with 97% efficiency
Muons

- ≈250 Hz of muons from IP1 through r=10 cm dipole aperture (total trigger rate ≈1 kHz)
- Rate highly correlated with luminosity (i.e. collisions)
- Important for tracker alignment/performance, calorimeter stability, veto station efficiency measurements, overall monitoring
FASER BSM Results
• U(1) gauge boson, could provide portal to dark sector
  ▪ Produced mainly by light mesons ($\pi^0, \eta$) via kinetic mixing

• Observed as $A \rightarrow e^+e^-$ pair appearing from ‘nothing’ with $\sim$TeV of energy
  ▪ Must decay in 1.5m decay volume - defines acceptance
• Selection
  ▪ 2 opposite-sign tracks within fiducial $r < 95$ mm
  ▪ $> 500$ GeV in calorimeter
  ▪ Nothing in all 5 veto counters
  ▪ Something in downstream scintillators
  ▪ In time with LHC collision

• Backgrounds Considered
  ▪ Veto inefficiency
  ▪ Neutrino interactions
  ▪ Neutral hadrons
  ▪ Large-angle muons
  ▪ Non-collision / cosmics

All backgrounds found to be very small
• Observed no events in 27 fb\(^{-1}\) from 2022, \((2.3 \pm 2.3) \times 10^{-3}\) background expected \(\rightarrow\) place limits

  - Dark photon and B-L gauge boson models

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**Dark Photon**

**B-L Gauge Boson**

• Same dataset as shown last year, updated and published: [PLB 848 (2024) 138378](https://link.springer.com/article/10.1007/s11005-024-04002-3)
• Observed no events in 27 fb\(^{-1}\) from 2022, 
\((2.3 \pm 2.3) \times 10^{-3}\) background expected → place limits
  - Dark photon and B-L gauge boson models

• New NA62 result! [arXiv:2312.12055](https://arxiv.org/abs/2312.12055)
Axion-like Particles - NEW!

- Currently sensitive to axion-like particles (ALPs) coupling to SU(2)$_L$ gauge bosons
  - Mainly produced in B meson decays in our sensitivity range

- Observed as $a \rightarrow \gamma \gamma$ appearing from ‘nothing’ with $\sim$TeV of EM energy (can’t separate photons)
  - Can decay anywhere in FASER spectrometer volume
ALPs Selection

- Significant backgrounds from neutrinos interacting near the calorimeter
  - Require > 1.5 TeV in calorimeter
  - Use control regions to validate neutrino modeling

"Magnet" Region, $E_{\text{calo}} > 100$ GeV
ALPs Results

- Observed 1 event in 58 fb$^{-1}$ after unblinding
- Expecting $0.4 \pm 0.4$ from CC $\nu$ interactions

Unblinded Signal region

First preliminary result on Axion-like Particles

Documentation here next week:

https://faser.web.cern.ch/physics/publications
FASER Neutrino Results
• Copious production of neutrinos in forward region
• All species produced at ~TeV energy range
• Allows first direct observation of ν from collider

<table>
<thead>
<tr>
<th>R3: 250 fb⁻¹</th>
<th>$V_\mu$</th>
<th>$V_e$</th>
<th>$V_\tau$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Source</td>
<td>Pions</td>
<td>Kaons/Charm</td>
<td>Charm</td>
</tr>
<tr>
<td>Traversing FASER</td>
<td>$\sim 10^{12}$</td>
<td>$\sim 10^{11}$</td>
<td>$\sim 10^9$</td>
</tr>
<tr>
<td>Interacting in FASERnu</td>
<td>8,500</td>
<td>1,700</td>
<td>30</td>
</tr>
</tbody>
</table>

Neutrinos are Interesting

- Measure cross-section in uncovered TeV energy range
  - Highest man-made source, currently unconstrained
- Production rate measures forward hadron production
  - Novel input for PDFs, charm ($\nu_e$) poorly constrained

Considerable interest for Neutrino telescopes, cosmic ray observatories, QCD, and measuring neutrino properties

**Spectrum of interacting $\nu$**

**Measured $\sigma_\nu$**

$v$ from $\pi/K$  
$v$ from charm

Detecting Neutrinos

• Emulsion detector - FASERnu
  ▪ Sensitive to all 3 species, no charge information
  ▪ 1.1 Ton Tungsten target w/ 730 emulsion planes
  ▪ Exquisite ~300 nm hit resolution

• Electronic detector - FASER
  ▪ Sensitive to muon neutrinos, can separate $\nu_\mu$ from $\bar{\nu}_\mu$
CC Neutrino Observation

- Small background from neutral hadrons and large-angle muons

\[ n_\nu = 153^{+12}_{-13} \text{(stat)} +^{2}_{-2} \text{(bkg)} = 153^{+12}_{-13} \text{(tot)} \]

(35.4 fb^{-1})

PRL 131, 031801 (2023)

Stay tuned for update!
• Analyzed fraction of 1 exposure in 2022 (9.5 fb⁻¹)
• Candidate vertices reconstructed and selected from scanning emulsion films (slow)
  ▪ Energy (e) from shower multiplicity
  ▪ Momentum (µ) from multiple scattering RMS
• Backgrounds primarily from neutral hadrons produced in muon interactions is surrounding rock, NC background also evaluated (small)
After all vertex selection requirements:

<table>
<thead>
<tr>
<th></th>
<th>Obs</th>
<th>Exp</th>
<th>Bgd</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\nu_e$</td>
<td>4</td>
<td>1.1-3.3</td>
<td>0.025 ± 0.012</td>
<td>5.2 $\sigma$</td>
</tr>
<tr>
<td>$\nu_\mu$</td>
<td>8</td>
<td>6.5-12.4</td>
<td>0.22 ± 0.08</td>
<td>5.7 $\sigma$</td>
</tr>
</tbody>
</table>

1.5 TeV!

New! arXiv:2403.12520
Figure 12: Event displays of one of the $\mu$ CC candidate events (top) and one of the $e$ CC candidate events (bottom). In each panel, the right-handed coordinate axes are shown in the bottom left, with red, green, and blue axes indicating the $x$ (horizontal), $y$ (vertical), and $z$ (beam) directions, respectively. The right panels show views transverse to the beam direction, and so the blue axes are not visible. The left panels are slightly rotated views, with the blue axes barely visible, to show the longitudinal development of the event. Yellow line segments show the trajectories of charged particles in the emulsion films. The other coloured lines are interpolations, with the colours indicating the longitudinal depth in the detector.

The NC background. The prior distribution, $\pi$, is flat and assumed to be 1 except for unphysical values of the parameters where it is 0.

The posterior is obtained with a Markov chain MC with the Metropolis-Hastings algorithm ($40 \times 10^{5}$). The calculation was repeated for $2 \times 10^{5}$ steps, where the first 3000 steps are considered as the initialization stage and are not used for the final result.

The parameter is measured to be $2.4^{+1.8}_{-1.3}$ and $0.9^{+0.5}_{-0.3}$ for $e$ and $\mu$, respectively. The energy-independent part of the interaction cross sections per nucleon, $\sigma_{\text{obs}}/E_{\nu}$, is measured to be $(1.22^{+0.8}_{-0.7}) \times 10^{-38}$ cm$^2$/GeV for $e$ and $(0.5^{+2.2}_{-0.2}) \times 10^{-38}$ cm$^2$/GeV over the energy range of 560–1740 GeV for $e$ and $\mu$.

Figure 13 shows the measured cross sections, together with those obtained by other experiments: E53 (41), DONuT (42), MINOS (43), NOMAD (44), T2K (45); 46, 47), ArgoNeut (48; 49), ANL (50), BEBC (51; 52), BNL (53), CDHS (54), CCFR (55), Gargamelle (56; 57), IHEP (58; 59), NuTeV (60), SciBoone (61), SKAT (62), and IceCube (63; 64; 65). The measured value of $\sigma_{\text{obs}}$ is shown as the blue curved line for $e$ and the red curved line for $\mu$.

The weighted average of the GENIE-predicted cross section is also shown, assuming the ratio of the incoming neutrino to antineutrino fluxes to be 1.03 for $e$ and 0.62 for $\mu$.

8. Conclusions

First results from the search for high-energy electron and muon neutrino interactions in the FASER tungsten/emulsion detector of the FASER experiment have been presented. The analysis uses a subset of the FASER volume, corresponding to a target mass of 128.6 kg, exposed to 9.5 fb$^{-1}$ of LHC pp collisions during the summer of 2022. Selections are applied to retain reconstructed vertices consistent with high-energy $e$ and $\mu$ CC interactions, while minimizing the background from neutral-hadron interactions. Four electron neutrino interaction candidate events are observed, with an expected background of $0.025^{+0.015}_{-0.010}$, leading to a statistical significance for the electron neutrino signal of 5.2 standard deviations. This represents the first direct observation of electron neutrinos produced at a particle collider. Eight muon neutrino interaction candidate events are also found, with an expected background of $0.22^{+0.09}_{-0.07}$, leading to a statistical significance for the muon neutrino signal of 5.7 standard deviations. The interaction cross section $\sigma(E_{\nu}) = 1.5$ TeV $e^{-1}$ and $360$ GeV $\mu^{-1}$.
Future Plans
Near Future Plans

- FASER Preshower upgrade
  - 6 layers of high-granularity Si pixels with W absorber
  - Separate photons at ~200 μm
  - Installed before 2025 (Run3)
- Improve ability to identify 2γ, reject ν backgrounds
- FASER approved for Run4
  - Will record large dataset with upgraded FASER at HL-LHC

Preshower: [CERN-LHCC-2022-006](#)
Run4: [CERN-LHCC-2023-009](#)
Forward Physics Facility

- FPF is a planned project at CERN to build a cavern to house experiments at HL-LHC
- Physics Goals similar to FASER but much improved reach and varied detectors
- Currently Proposed Detectors
  - FASER2 / FASERnu2
  - AdvancedSND - off-axis \( \nu \)
  - FLArE - LAr TPC for \( \nu \)
  - FORMOSA - millicharge det.

- Community
  - Supported by CERN Physics Beyond Collider group, latest PBC Workshop this week
  - fpf.web.cern.ch, latest meeting Feb: 7th FPF Meeting
Dedicated ~65m cavern, 620m from IP1, on the French side

Construction and access possible during HL-LHC operation
FASER2 Baseline detector: Details

**Magnet**
- Large aperture
- 3m wide X 1m gap
- Superconducting technology
- Magnetic Field: $2 - 4 \ Tm$
- Based on the SAMURAI magnet

**Calorimeter**
- Based on dual-readout calorimetry
- Spatial resolution: $1 - 10 \ mm$

**Tracker**
- Based on LHCb's SciFi tracker
- SiPM and scintillating fiber design
- Detector resolution: $\sim 100 \ \mu m$

FASER2 Spectrometer - 2-4 Tm field, 3m² aperture

FASERnu2 10-20 tons

AdvSND

FLArE

FORMOSA design in FPF paper

Not to scale...
FPF Detectors

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Tracker:
• Based on LHCb’s SciFi tracker
• SiPM and scintillating fiber design
• Detector resolution: ~ 100 µm

FASER2 Spectrometer - 2-4 Tm field, 3m² aperture

Orders of Magnitude improvement
• x10 in integrated luminosity @ HL-LHC
• x10 in target mass (neutrinos)
• x 1000 in decay volume (searches)

Short-baseline neutrino facility at TeV energy
Expect to detect 1000 neutrinos per day!

Not to scale…

28 March 2024
Can investigate many interesting BSM neutrino signatures too …

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Figure 3.1: Projected discovery sensitivities for various FASER2 scenarios in the dark photon (left) and dark Higgs boson (right) models.

The system will be scintillator-based, similar to FASER. The significantly increased area of the active volume makes it impractical to use silicon tracker technology. A SiPM and scintillating fibre tracker technology, such as LHCb's SciFi detector [74], is a strong candidate to replace the ATLAS SCT modules used in FASER. In addition, Monitored Drift Tube (MDT) technology, similar to that used in the ATLAS New Small Wheel [75], is also being considered, although this option requires the use of gases in the LHC tunnel that could be problematic for the UJ12 alcoves scenario.

For the magnets, superconducting technology would be required to maintain sufficient field strength across the much larger aperture. Suitable technology for this already exists and can be built for FASER2. There are several possibilities for the cooling of such magnets; the use of cryocoolers and the possibility to share a single cryostat across several magnets are being considered. The calorimeter needs to have sufficient spatial resolution to be able to identify particles at \(\sim 10^{-1}\) mm separation; good energy resolution; improved longitudinal separation with respect to FASER; and the capability to perform particle identification, separating, for example, electron and pions. Dual readout calorimetry [76, 77] is a good candidate to satisfy all these requirements. Finally, the ability to identify separately electrons and muons would be very important for signal characterisation, background suppression, and for the interface with FASER [\(\nu\)] (see Sec. 3.2) and other detectors.

To achieve this, a mass of iron will be placed after the calorimeter, with sufficient depth to absorb pions and other hadrons, followed by a detector for muon identification.
• CERN is very serious about FPF
  ▪ Conceptual design ongoing
• Construction doesn’t interfere with HL-LHC operations
• Cavern could be ready for experiments by 2031 (mid-Run4)
• FPF Snowmass report: arXiv:2203.05090
  - ~200 authors, > 400 pages, 18 working groups
• P5 report did not recommend FPF per-se, but…
  # Can be considered as part of ASTAE (small expt program) with reduced scope
• Most expensive detector is FLArE
  - Investigating cheaper options, could be built by non-U.S.
• We believe small experiments are important
  - Need discussion with US agencies, ASTAE does not exist yet

Figure 2 – Construction in Various Budget Scenarios

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Less</th>
<th>Baseline</th>
<th>More</th>
<th>Neutrinos</th>
<th>Higgs Boson</th>
<th>Dark Matter</th>
<th>Cosmic Evolution</th>
<th>Evidence Imprints</th>
<th>Science Drivers</th>
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<tbody>
<tr>
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<td>N</td>
<td>N</td>
<td>P</td>
<td>S</td>
<td>P</td>
<td>P</td>
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<tr>
<td>$60–100M</td>
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<td>FPF #</td>
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  # Can be considered as part of ASTAE (small expt program)

5.1.5  – 20-Year Vision & Future Opportunities

The program described in this section consists of a combination of large and small projects and holds great promise for discovery. By the end of this 20-year period we will have ultimate LHC results from the general purpose experiments and a constellation of agile auxiliary experiments. We will also be in the final stages of construction of a Higgs

FPF experiments aim to be part of this future!

<table>
<thead>
<tr>
<th>Science Drivers</th>
<th>P</th>
<th>P</th>
<th>P</th>
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</thead>
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$60–100M$

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<td>N</td>
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</table>

P5 Report
The FASER Collaboration has 96 members from 26 institutes in 10 countries

http://faser.web.cern.ch/
The FASER Collaboration gratefully acknowledges our funding agencies for their support:

Along with the tremendous institutional support from
Conclusions

• FASER was installed in time for Run3

• First results on LLP (dark photons, ALPs)

• First cross-section measurement for $\nu_e$ and $\nu_\mu$

• More physics to come in Run3, including upgrades

• FASER will continue into Run4, pathfinder for future small forward-physics experiments

Believe future is bright with CERN support of FPF
Opportunities for new people to get involved!
Backup

Spring 2021
FASER Trigger Rates

Operations, Oct 2022
13.6 TeV p-p collisions
IP1 Instantaneous Luminosity and FASER Trigger Rates

Trigger Rate [Hz]
1.75 kHz
1.50 kHz
1.25 kHz
1 kHz
750 Hz
500 Hz
250 Hz
0 Hz
0 0.5 1.0 1.5 2.0 2.5
Luminosity [10^34 cm^-2 s^-1]
0 Hz 08:00 16:00 00:00 08:00 16:00 00:00 08:00
10/22 10/22 10/23 10/23 10/23 10/23 10/24 10/24
Total Trigger Rate Coincidence Trigger Rate Luminosity
• Need to identify nearby, pair-produced tracks
• 4 tracking planes in 4 stations (12 planes in total)
• Use 96 spare ATLAS SCT modules, 8 per layer
  ▪ 80 µm pitch, 40 mRad stereo angle, 24 cm x 24 cm area
  ▪ 17 µm precision in bending (vertical) plane

Tracker Station

Single Layer

Thanks ATLAS!
Preshower

- Layers of scintillator, tungsten, and porous graphite
- Provides shower depth information
  - Useful for identifying particles
Dark Photon Properties

- Produced in meson decays, e.g.:

\[ B(\pi^0 \rightarrow A'\gamma) = 2\epsilon^2 \left(1 - \frac{m_{A'}^2}{m_{\pi^0}^2}\right)^3 B(\pi^0 \rightarrow \gamma\gamma) \]

- Other production modes possible

- Long decay length, large boost in forward direction

\[ \bar{d} = c \frac{1}{\Gamma_{A'}} \gamma_{A'} \beta_{A'} \approx (80 \text{ m}) \ B_e \left[ \frac{10^{-5}}{\epsilon} \right]^2 \left[ \frac{E_{A'}}{\text{TeV}} \right] \]
Dark Photon Limit

- Expected Limit ($\pm 1\sigma_{exp}$, 90% CL)
- Observed Limit (90% CL)
- Relic Target $m_x = 0.6m_A$, $\alpha_0 = 0.1$
- Relic Target $m_x = 0.6m_A$, $\alpha_0 = 1$
- Relic Target $m_x = 0.6m_A$, $0.01 < \alpha_0 < 1$

FASER

$L = 27.0$ fb$^{-1}$

Kinetic Mixing $\varepsilon$ vs. $m_A$ [MeV]

- $10^{-5}$
- $10^{-4}$
- $10^{2}$
- $10^{0}$

28 March 2024
$L = 27.0 \text{ fb}^{-1}$

- Expected Limit
- $(\pm 1 \sigma_{\text{exp}}, 90\% \text{ CL})$
- Observed Limit (90\% CL)
- NA62 (ee) Limit
- BaBar Limit
- KLOE Limit
- LHCb Limit
- NA48 Limit
- NA64 Limit
- E141 Limit
- Orsay Limit
- NuCal Limit
- E137 Limit
- CHARM Limit
- Relic Target $m_x=0.6m_A$, $\alpha_D=0.1$
Axion-Like Particles

- Produced from photons scattering off TAN
- Observe di-photon final state
ALPs control regions

Preshower Layer 1 nMIP

Magnet Region

“Other” Region

Preshower Region / Signal Region

Calorimeter Region

Preshower Ratio

Simulation

Calorimeter Region
Calo. energy > 100 GeV

Station 1
Station 2
Station 3

Magnet

Calo.

Station 1
Station 2
Station 3

Preshower Region / Signal Region
Calo. energy > 100 GeV

Simulation

28 March 2024
ALPs limits

Preliminary
$L = 57.7 \text{ fb}^{-1}$

- Expected Limit ($\pm 1 \sigma_{\text{exp}}$, 90% CL)
- Observed Limit (90% CL)
- BaBar Limit
- SN1987 Limit
- E137 Limit
- LEP Limit
- E949 Limit
- KOTO Limit
- KTEV Limit
- NA62 + NA48/2 Limit
- CDF Limit
- NA62 Limit

28 March 2024
Upgrade ALPs projections

Realistic analysis
Run3 - 2025

Ideal detector
HL-LHC
Emulsion Processing

Emulsion film (340 μm) → $\nu_e$ → e

Tungsten plate (1.1 mm) → $\nu_\mu$ → $\mu$

$\nu_\tau$ → $\tau$

HTS

The total image transfer rate is 48 Gbytes/s

Under operating for:
- NINJA (J-PARC)
- NA65/DsTau (CERN)
- FASER$\nu$ (CERN)
- GRAINE (Balloon)
- Radiography
Neutrino Energy

\[ \text{dE/E} \approx 25\% \text{ at } 200 \text{ GeV, up to } 40\% \text{ at higher } E \]
Multiple Coulomb Scattering

\[ dE/E \sim 30\% \text{ at } 200\text{ GeV, up to } 50\% \text{ at higher } p \]
neutrino flux as a function of energy for \( e^\nu \) (left), \( \mu^\nu \) (middle), and \( t^\nu \) (right), with expected precision of FPF measurements (statistical uncertainties only). 

Feng et al., J.Phys. G 50:030501, 2023

Can investigate many interesting BSM neutrino signatures too…

Chapter 3. Experiments

Figure 3.1: Projected discovery sensitivities for various FASER2 scenarios in the dark photon (left) and dark Higgs boson (right) models.

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To achieve this, a mass of iron will be placed after the calorimeter, with sufficient depth to absorb pions and other hadrons, followed by a detector for muon identification.
FPF Neutrino Statistics

Numbers from 2 generators shown (SIBYLL / DPMJET), typically span the range of other generators.

<table>
<thead>
<tr>
<th>Detector</th>
<th>Name</th>
<th>Mass</th>
<th>Coverage</th>
<th>Luminosity</th>
<th>( \nu_e + \bar{\nu}_e )</th>
<th>( \nu_\mu + \bar{\nu}_\mu )</th>
<th>( \nu_\tau + \bar{\nu}_\tau )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FASER(\nu)</td>
<td>1 ton</td>
<td>( \eta \gtrsim 8.5 )</td>
<td>150 fb(^{-1})</td>
<td>901 / 3.4k</td>
<td>4.7k / 7.1k</td>
<td>15 / 97</td>
</tr>
<tr>
<td></td>
<td>SND@LHC</td>
<td>800kg</td>
<td>( 7 &lt; \eta &lt; 8.5 )</td>
<td>150 fb(^{-1})</td>
<td>137 / 395</td>
<td>790 / 1.0k</td>
<td>7.6 / 18.6</td>
</tr>
<tr>
<td></td>
<td>FASER(\nu2)</td>
<td>20 tons</td>
<td>( \eta \gtrsim 8.5 )</td>
<td>3 ab(^{-1})</td>
<td>178k / 668k</td>
<td>943k / 1.4M</td>
<td>2.3k / 20k</td>
</tr>
<tr>
<td></td>
<td>FLArE</td>
<td>10 tons</td>
<td>( \eta \gtrsim 7.5 )</td>
<td>3 ab(^{-1})</td>
<td>36k / 113k</td>
<td>203k / 268k</td>
<td>1.5k / 4k</td>
</tr>
<tr>
<td></td>
<td>AdvSND</td>
<td>2 tons</td>
<td>( 7.2 \lesssim \eta \lesssim 9.2 )</td>
<td>3 ab(^{-1})</td>
<td>6.5k / 20k</td>
<td>41k / 53k</td>
<td>190 / 754</td>
</tr>
</tbody>
</table>

Huge increase in number of neutrinos detected with FPF.
Enables broad physics programme.
FPF studied in context of PBC for last 3 years
- Strong physics case built up covering searches for new particles, and physics with high energy neutrinos
- New facility allows x10 bigger neutrino detectors, allowing detection of $10^5 \nu_e$, $10^6 \nu_\mu$, $10^4 \nu_\tau$ at highest energies
- Ultimate exploitation of LHC neutrino beam