

Imperial College
London

Forward physics & beam dump experiments

PPAP community meeting, Birmingham

Mark Smith + many others

17 July 2026

Foreword

May 2026: [\[European strategy update\]](#)

- *“The exploration of the neutrino sector, searches for dark sector particles, precision measurements in the flavour sector and tests of fundamental symmetries are crucial elements of particle physics. Major progress in these areas is expected in the next decade with the realisation of a broad programme of experiments. . . ”*

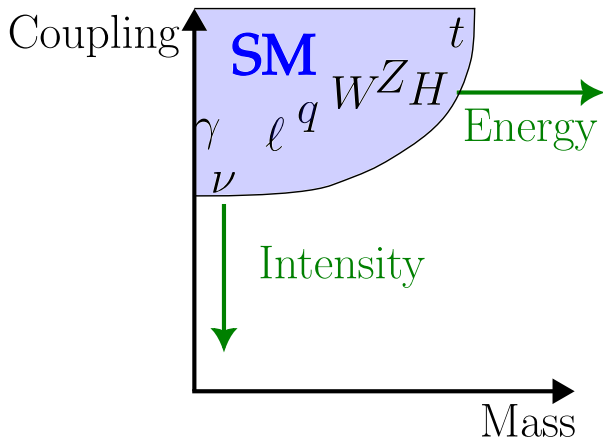
June 2026: [\[Roadmap for non-collider physics at CERN\]](#)

- *“in the course of one year, with intermediate check- and reporting-points, prepare and deliver a long- term roadmap proposal that is sufficiently mature to inform and support the 2027 Medium-Term Plan exercise.”*
- Launch accompanied by a set of training lectures [\[1\]](#), [\[2\]](#), [\[3\]](#)
- Workshop at [\[CERN in December\]](#)

May 2026: [\[Mark Thomson\]](#):

- *“NA-CONS is a necessary high-priority project for CERN - the main challenge is the significant resource required”*

Motivation



- No sign of NP at the energy frontier
 - How massive is NP?
- Intensity frontier relatively unexplored
 - NP is comparatively light but **feebly coupled**

Motivation

NP models can solve problems of the SM



Heavy neutral leptons

- Right-handed neutrinos (spin $\frac{1}{2}$) explain the light neutrino mass
- Candidates for dark matter, explanation of baryon asymmetry



Axion-like particles

- Light pseudoscalar particles with small couplings to SM
- Excellent dark matter candidates



Dark Higgs portal

- Scalar portal to an extended hidden sector



Dark photons

- An extra (broken) $U(1)$ gauge group
- Same Lagrangian structure as SM photon - mixes
- Vector portal to an extended hidden sector



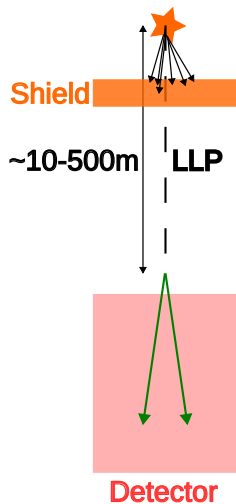
Motivation

NP models can solve problems of the SM

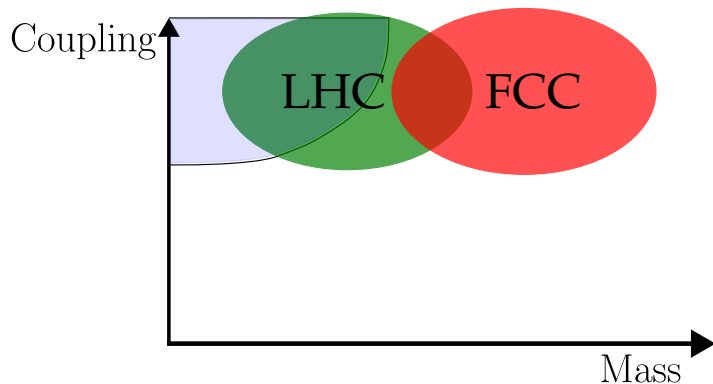
- ⊗ Heavy neutral leptons
 - Right-handed neutrinos (spin $\frac{1}{2}$) explain the light neutrino mass
 - Candidates for dark matter, explanation of baryon asymmetry
- ⊗ Axion-like particles
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 - Excellent dark matter candidates
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 - Scalar portal to an extended hidden sector
- ⊗ Dark photons
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⋮

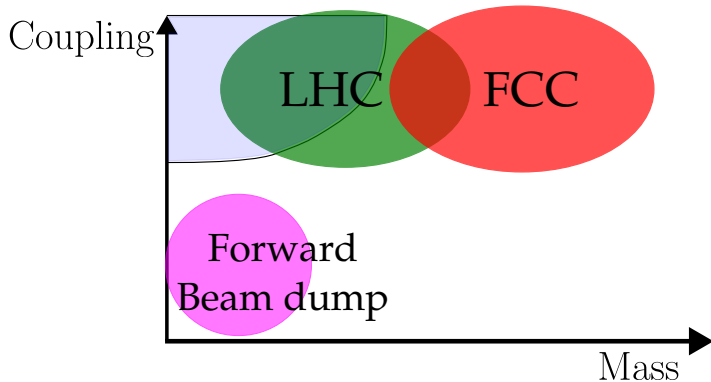
feeble couplings → long lifetimes



Experimental landscape

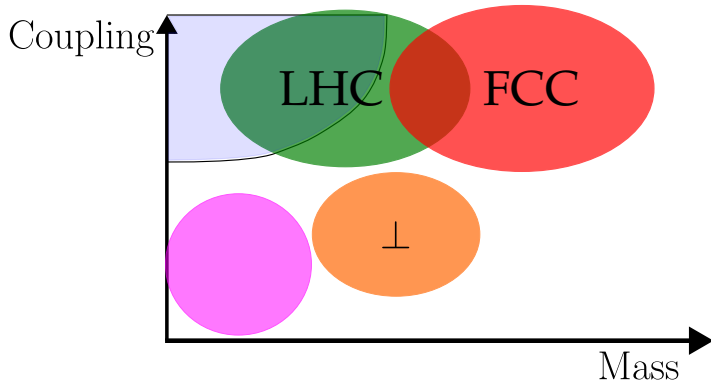


Experimental landscape



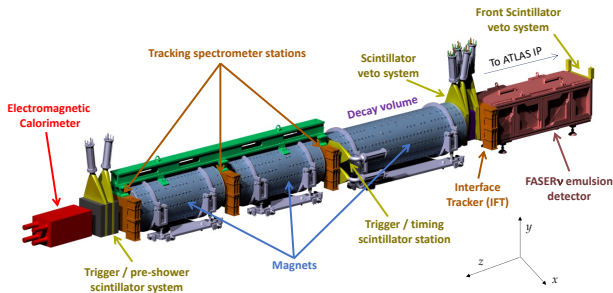
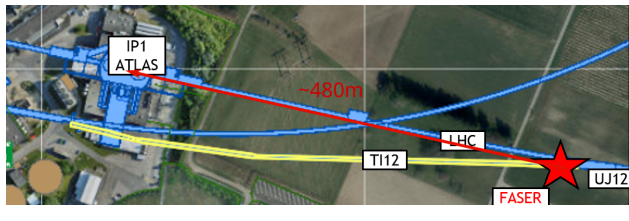
- Forward and beam dumps:
 - SND@LHC and FASER
 - SHiP
 - Includes neutrino physics

Experimental landscape



- Forward and beam dumps:
 - SND@LHC and FASER
 - SHiP
 - Includes neutrino physics
- Perpendicular LLP detectors
 - ANUBIS, CODEX-B, MOEDAL
 - Heavier NP

FASER



- NP searches
 - FIPs in MeV to GeV range
- Collider neutrinos
 - All flavours at TeV scales

Successful data-taking since 2022

- 311 fb^{-1} , 207 fb^{-1} with emulsion

To look forward to

- 95% of emulsion data to be analysed
- Exploration of Run 4 upgrade possibilities [[arXiv:2503.19775](https://arxiv.org/abs/2503.19775)]

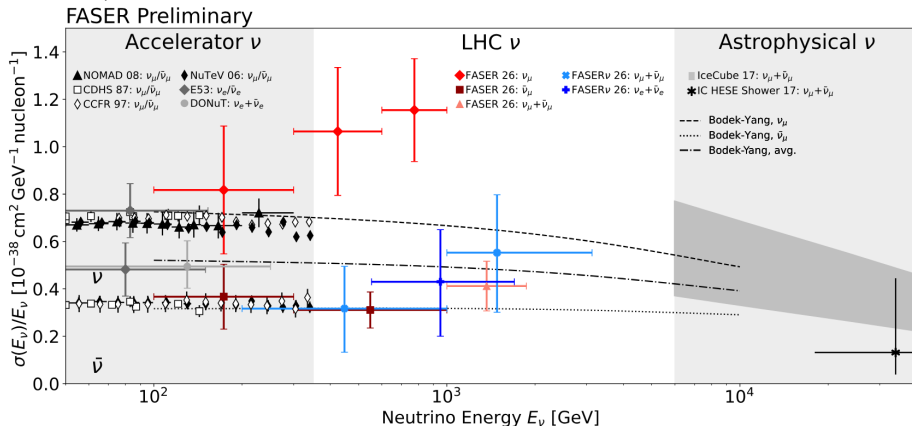
FASER recent highlights

Several recent neutrino measurements:

- First observation of ν_e in ECAL
- TeV-scale CC interaction cross-section for ν_e and ν_μ

[CERN-FASER-CONF-2026-002]
[CERN-FASER-CONF-2026-003]
[CERN-FASER-CONF-2026-004]
[CERN-FASER-CONF-2026-005]

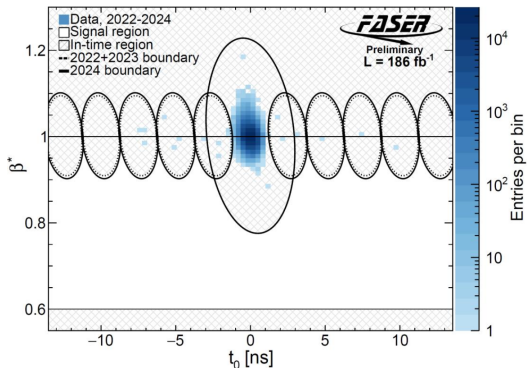
- Double-differential ν_μ flux
- First search for ν with associated charm



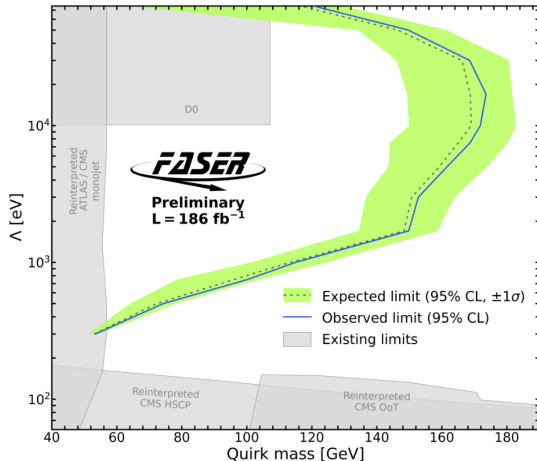
FASER recent highlights

First search for quirks:

- SM charges + $SU(N_{IC})$ “infracolour”
- $m_Q \gg \Lambda \rightarrow$ propagate as a pair
- Long-lived, double charge, slow



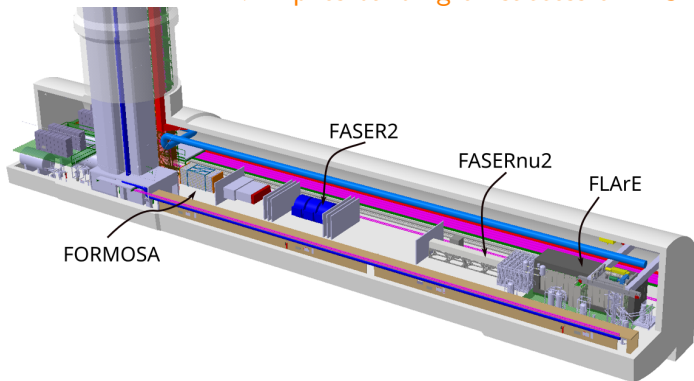
[Arash Jofrehei at LLP]



Forward Physics Facility

"The full exploitation of the physics potential of the LHC and HL-LHC and the completion of the high-luminosity upgrade remain the highest priorities of European particle physics"

→ implies building on success of FASER and SND@LHC



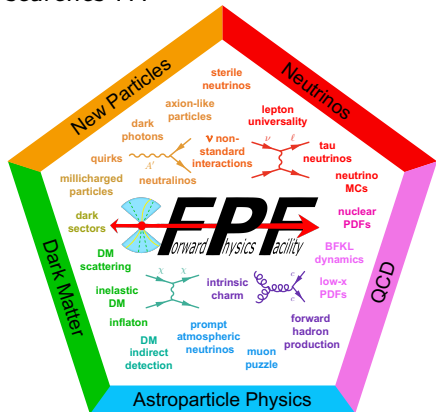
Proposal for the FPF:

- March 2025 EPPSU input
[\[arXiv:2503.19010\]](#)
- August 2025 LoI
[\[arXiv:2510.26260\]](#)
 - Physics case
 - Facility design
 - Cost and timeline
- March 2026
[\[FPF9 meeting\]](#)

Forward Physics Facility

[Jacob Steenis at FPF9]
[arXiv:2510.26260]

Broad physics potential:
 ~ 1 million TeV neutrinos, NP
searches ...



FORMOSA demonstrator installed in Run 3



The collaboration is working with RNCP group at CERN to define the decision timeline for the facility

ANUBIS

[NIM 1091 (2026) 171687]

[NIM 1086 (2026) 171501]

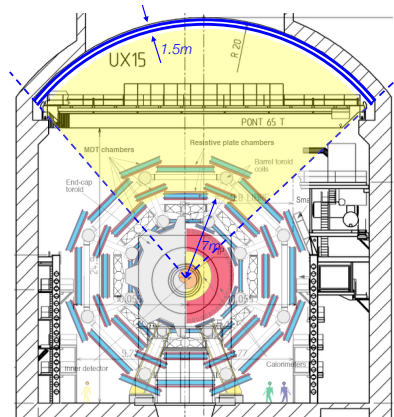
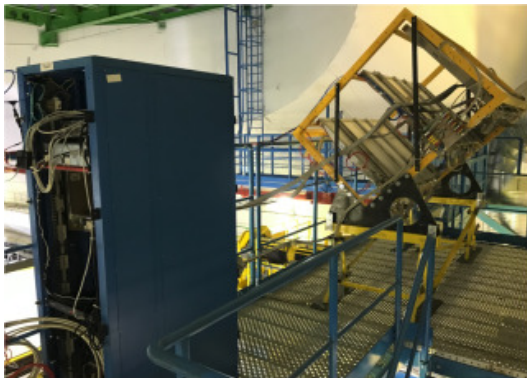
[arXiv:2510.26932]

Proposed instrumentation of ATLAS cavern ceiling



Proof-of-concept demonstrator proANUBIS

- 3 layers of $0.99\text{m} \times 1.78\text{m}$
- 176fb^{-1} of pp data in 2024 and 2025

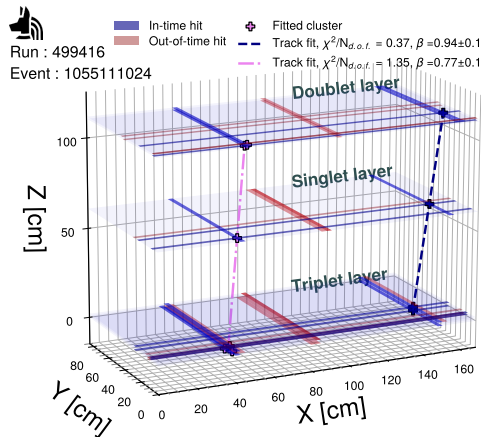
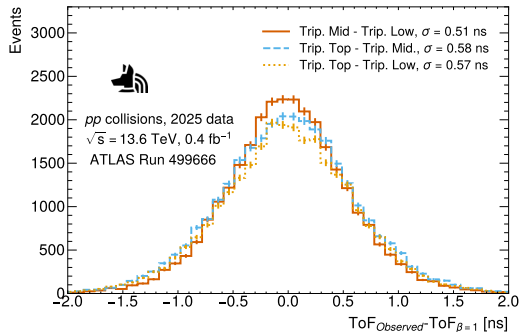


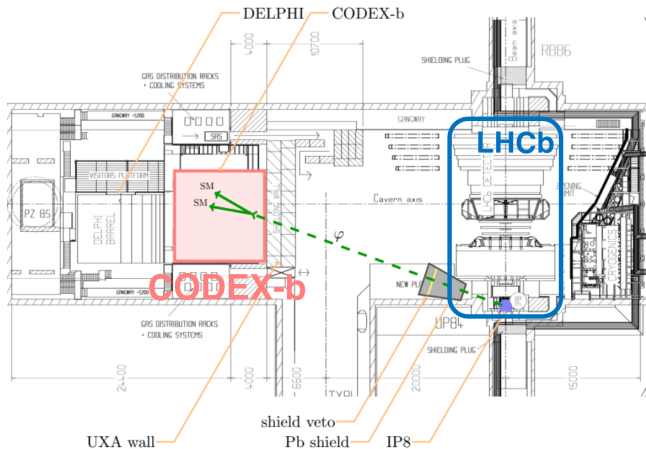
UNIVERSITY OF
CAMBRIDGE



Prototype performance studied

-  High hit efficiency in RPC layers
-  Excellent time resolution
 - Ability to discern low β particles
-  More analysis in progress





Proposed LLP detector in DELPHI cavern

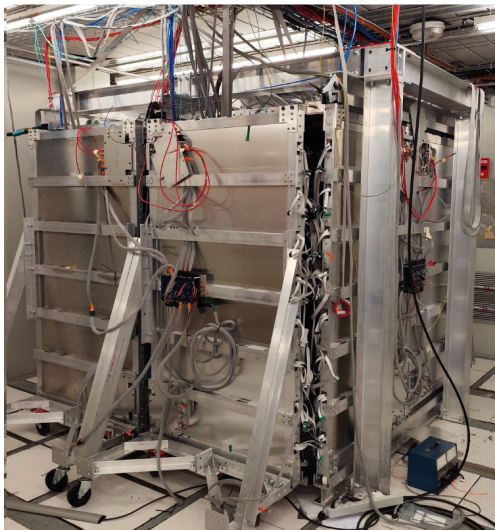
- 10m×10m×10m cube of RPCs

Small CODEX- β demonstrator installed!

- 2m×2m×2m
- Integrated with LHCb run control
- Data taken!



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BIRMINGHAM



LHCb: TOP

System: LHCb State: **RUNNING** Auto Pilot: **ON** Tue 12-May-2026 16:24:26

Sub-System State

Sub-System	State
DCS	READY
DAI	READY
DAQ	RUNNING
RunInfo	RUNNING
TFC	RUNNING
EB+HLT1	RUNNING
Monitoring	NOT_ALLOCATED

Run Info

Run Number: 346742 Activity: NotPhysics Settings...

Run Start Time: 12-May-2026 16:11:56 Trigger Config: hlt1_pp_2026 Settings... Defer HLT

Run Duration: 000:12:29 Time Alignment: TAE half window

Nr. Events: 9410/057491 Max Nr. Events: Run limited to 0 Events

Step Nr: 0 To Go: 0 Automated Run with Steps: Start at: 0 Steps

Input Rates: TFC: 12.61 MHz HLT1 Rates: IN: 3.44 MHz Dead Time: 100% Incompl. Evs: 100%
EB: 17.44 MHz OUT: 0.00 KHz 0.00% 0.00%

Data Destination: Local Data Type: CALIBRATION26 Automatic File: hlt1 Run DB

Alignment & Calibration: CurrVs Velo Tracker Rich1 Rich2 Muon Calo

HLT2 Buffer Usage: Runs/Files: 1267 / 5221615 Rate In/Out: 882.93 / 227.23 KHz Farm Node Status: 15%

Efficiency EB Rates TFC Control TELL40s LHCb Elog

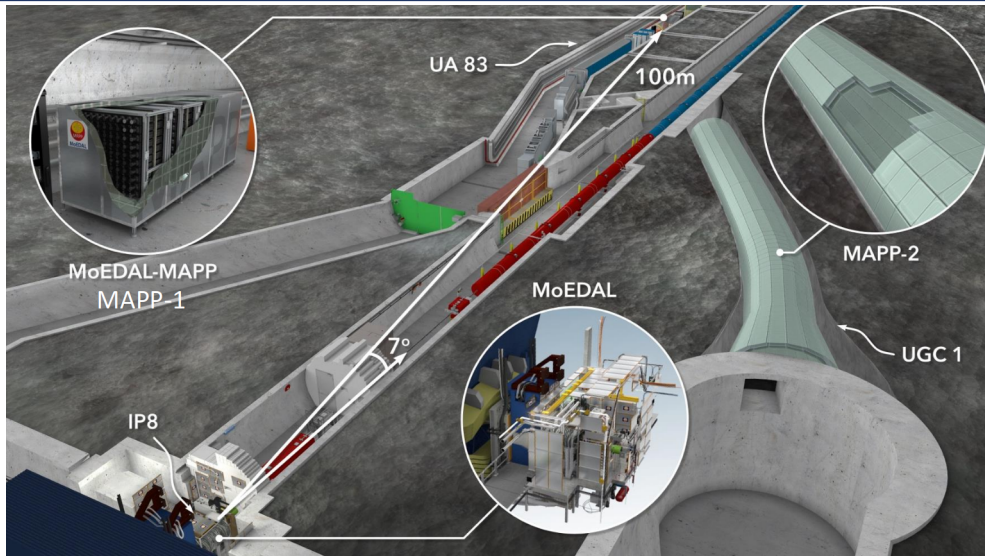
Sub-Detectors:

Sub-Detector	State
VELOA	ERROR
VELOC	ERROR
UTA	RUNNING
UTC	RUNNING
SFA	RUNNING
SFC	RUNNING
RICH1	RUNNING
RICH2	RUNNING
ECAL	RUNNING
HCAL	RUNNING
MUONA	RUNNING
MUONC	RUNNING
PLUME	RUNNING
CODEXB	RUNNING

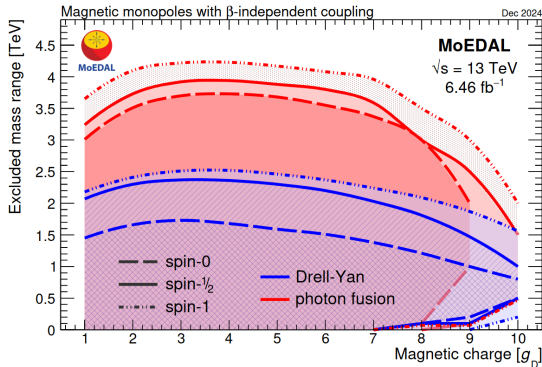
Messages:

12-May-2026 16:11:57 - LHCb_TFC executing action START_TRIGGER
12-May-2026 16:11:58 - LHCb in state RUNNING
12-May-2026 16:13:03 - *** WARNING - Output Rate Too Low, please check...

Close



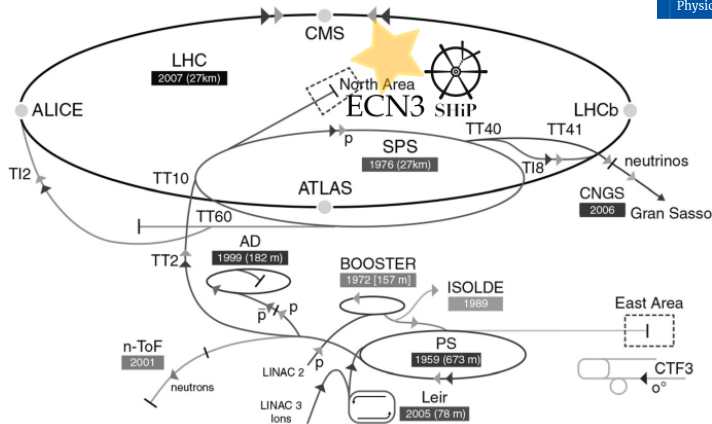
- Run 2 MoEDAL
 - Set best limits on HIPs
- Run 3 MoEDAL
 - Track and trapping detectors to be scanned
 - MAPP-1 upgrade currently being commissioned
- Run 4 MoEDAL
 - Lol for data-taking to be submitted this year
 - Proposal for MAPP-1 outrigger
 - Proposal for MAPP-2



SEARCHES FOR NEW PHYSICS | NEWS

SHiP to chart hidden sector

3 May 2024



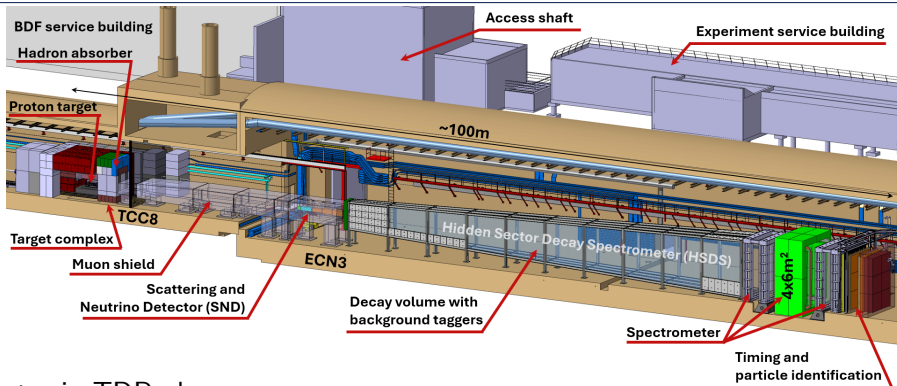
- ⚙ Approved in 2024
- ⚙ To operate at the new SPS beam dump facility at ECN3
- ⚙ Expecting 15 years of operation
 - ⚙ 4×10^{19} PoT per year
 - 6×10^{20} PoT total

CERN is committed:

- ⊗ Finance allocated for HI-ECN3 and SHiP in [\[MTP\]](#)
- ⊗ Initial civil engineering started in 2025
- ⊗ Target prototypes in test beams



SHiP - detector



Detector in TDR phase

- Subdetector designs and requirements being laid out
- Significant UK work on the UBT, muon shield, computing

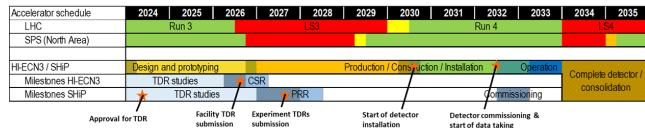


Design of facility close to final

- Target station
- Studies of beam backgrounds ongoing

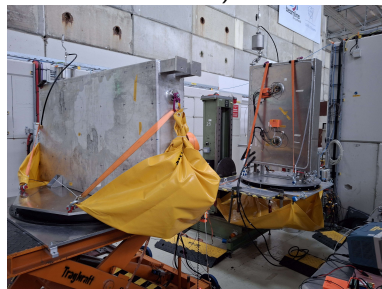
SHiP plan

2026-04-29



- ⚙ Commission in 2032, data-taking in 2033
 - Data from Run 4
- ⚙ Will achieve unprecedented power for hidden sector searches
- ⚙ Technical design reports for second half of next year
 - Studies for detector design and optimisation are well-advanced

SBT and UBT test beam (this week)



Conclusion

UK involvement in a panoply of projects

- Various stages of development
 - Taking data now
 - Confirmed and in preparation for Run 4
 - Prototyping and proof-of-concept

Broad physics programme covered

- Enormous array of NP signatures
 - Challenge many well-motivated NP models
 - Complementary to LHC direct searches
- TeV collider neutrinos
 - Unique energy range
 - NP measurements (LFU)
 - Input for HL-LHC measurements

Model building
HNLs, ALPs,
dark Higgs



Experiment



Adapted from
Alex Lenz

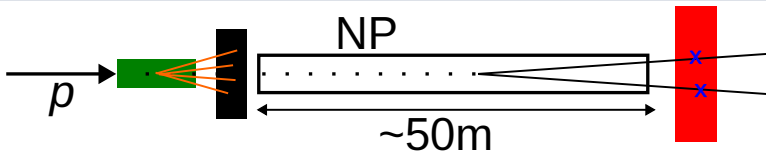
The End

Thanks

Thanks to:

Nigel Watson, Dan Johnson, Anne-Marie Magnan, Matthew Fraser, Arttu Rajantie, Oleg Brandt, Michaela Queitsch-Maitland, Alan Barr, Konstantinos Petridis, Mitesh Patel, Mario Campanelli. . .

Looking for FIPs



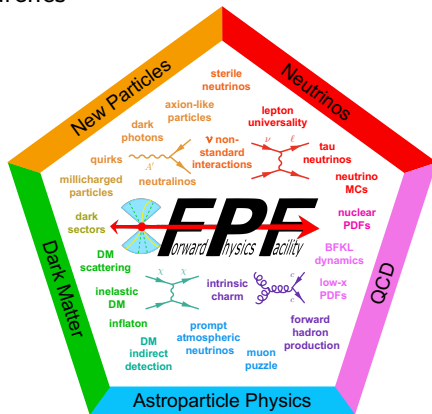
	Physics model	Final state
HSDS	SUSY neutralino	$\ell^\pm \pi^\mp, \ell^\pm K^\mp, \ell^\pm \rho^\mp, \ell^+ \ell^- \nu$
	Dark photons	$\ell^+ \ell^-, 2\pi, 3\pi, 4\pi, KK, q\bar{q}, D\bar{D}$
	Dark scalars	$\ell\ell, \pi\pi, KK, q\bar{q}, D\bar{D}, GG$
	ALP (fermion coupling)	$\ell^+ \ell^-, 3\pi, \eta\pi\pi, q\bar{q}$
	ALP (gluon coupling)	$\pi\pi\gamma, 3\pi, \eta\pi\pi, \gamma\gamma$
	HNL	$\ell^+ \ell'^- \nu, \pi l, \rho l, \pi^0 \nu, q\bar{q}' l$
	Axino	$\ell^+ \ell^- \nu$
	ALP (photon coupling)	$\gamma\gamma$
	SUSY sgoldstino	$\gamma\gamma, \ell^+ \ell^-, 2\pi, 2K$
SND	LDM	electron, proton, hadronic shower
	$\nu_\tau, \bar{\nu}_\tau$ measurements	$\tau^\pm$
	Neutrino-induced charm production (ν_e, ν_μ, ν_τ)	$D_s^\pm, D^\pm, D^0, \bar{D}^0, \Lambda_c^+, \bar{\Lambda}_c^-$

Forward Physics Facility

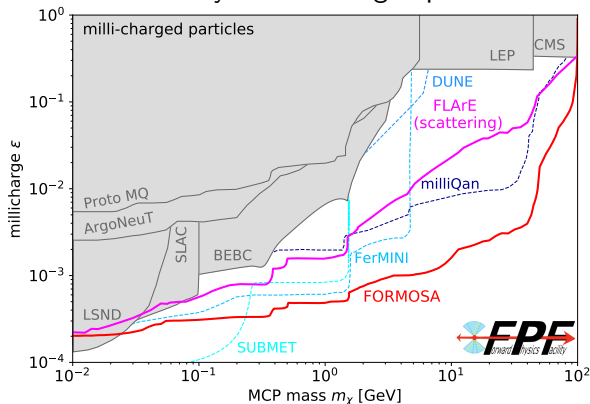
[arXiv:2510.26260]

Broad physics potential:

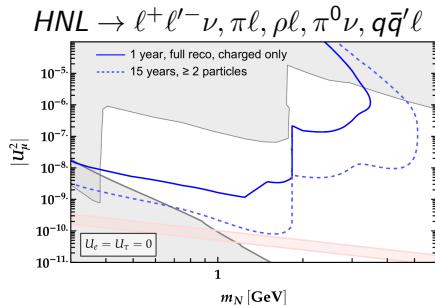
~ 1 million TeV neutrinos, NP searches



i.e. sensitivity to millicharged particles:



SHiP physics sensitivity



- ⊗ Several orders of magnitude improvement in sensitivity for a range of NP models
- ⊗ Expect $\mathcal{O}(10^4)$ $\nu_\tau \bar{\nu}_\tau$ neutrinos
- ⊗ Unprecedented LDM sensitivity

