

Other non-collider experiments and facilities

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ECFA-UK Kick-off meeting



UNIVERSITY OF
LIVERPOOL

MANCHESTER
1824

Introduction

Principally using high intensity proton beams with forward detectors for

BSM Searches: light DM, LQs, HNLs, ALPs, dark photons, Z' , monopoles ...

CP-violation: EDMs, QCD-axion

SM Studies : QCD, ν interactions (e.g. with large ν_τ samples), ...

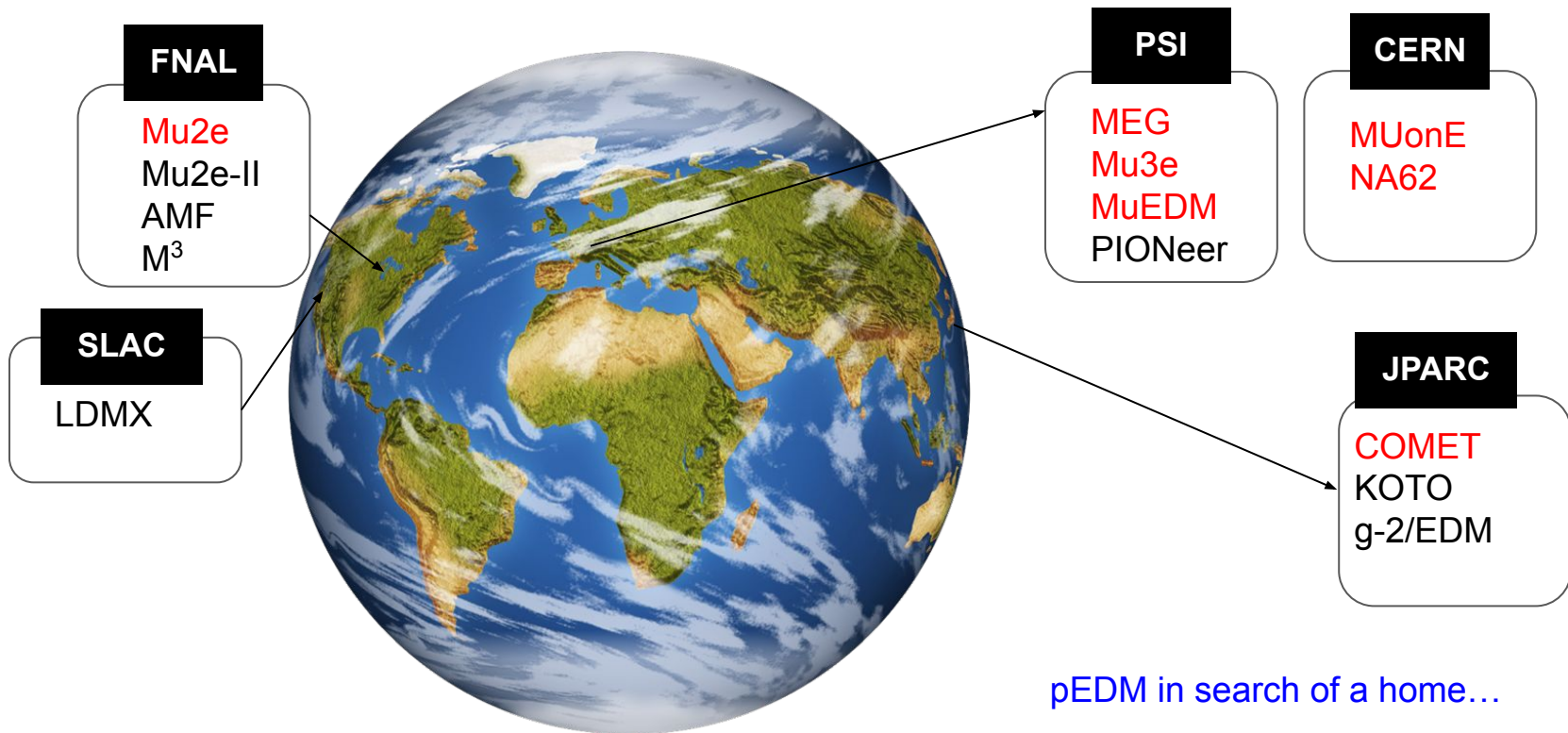
e.g. Mu2e: 4×10^{21} POT, SHiP: 6×10^{20} , KoTO: 3×10^{20}

Rare Flavour & EDM Searches: muon, kaon experiments e.g. Mu2e, COMET, MEG-II, Mu3e, NA62, KoTO, MuEDM

Feebly Interacting Particle Searches (FIPs) e.g. SHiP, FASER, FLArE, CODEXb, MoEDAL, AdvSND, FORMOSA,

Rare Flavour & EDM Searches

Flavour : 2026-2036



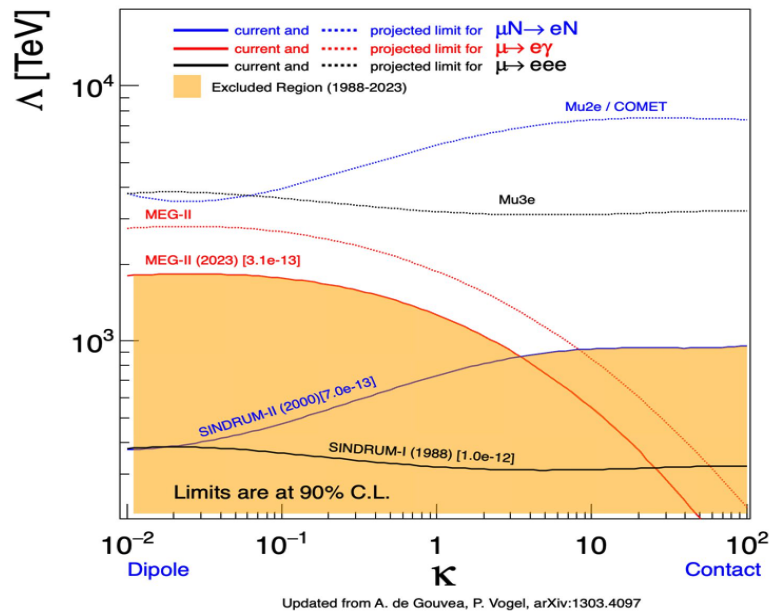
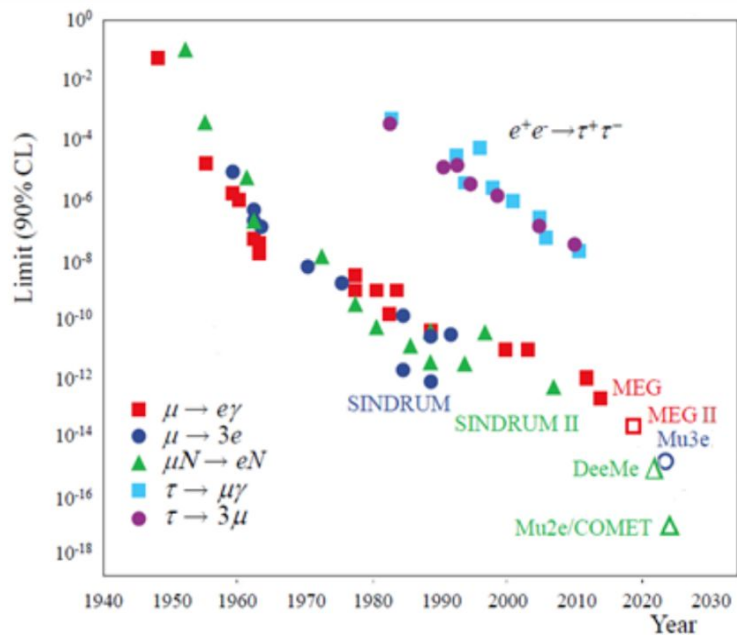
UK: Birmingham, Bristol, Glasgow, Imperial, Lancaster, Liverpool, Manchester, Oxford, Sussex, UCL
Also LHCb, ATLAS, CMS doing CLFV (particularly τ) & LFU

Rare Flavour & EDMs

Looking for a deviation from precise SM prediction e.g. rare Kaon decay, LFU

Looking for a signal that is essentially zero in the SM

e.g. muon electric dipole moment (EDM) or charged lepton flavour violation (CLFV)



Current generation

MEG-II has begun data taking : will conclude 2026. Needs new ideas/detectors to improve.

COMET, Mu3e, Mu2e all coming online 2025-2027 and will extend sensitivity by $\times 10^4$.
Conclude ~ 2033 when systematics limited \rightarrow new ideas/detectors

Mu3e benefits from HIMB PSI upgrade (ready 2029/30) as does MuEDM.

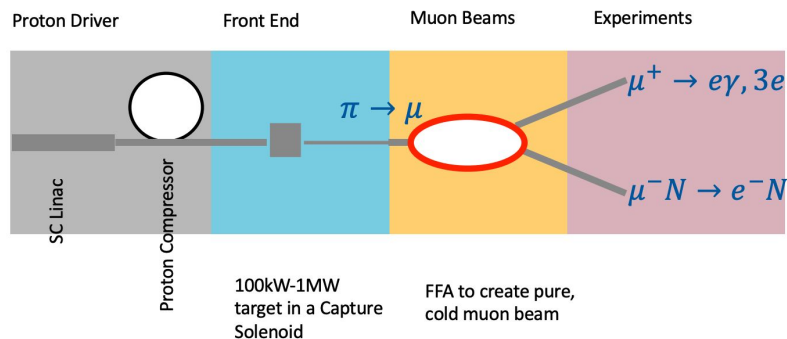
Plenty of BSM ideas out there but the actual measurements don't need much theory since SM prediction is 30 orders of magnitude below experimental sensitivity ...

Flavour : Muon CLFV

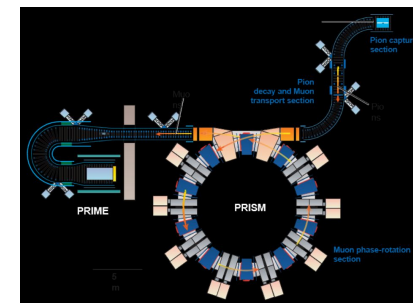
Next generation: construction 2033+, physics: 2040s !

- Mu2e-II (2035-2040) can get x10 with same beam & better detectors
- Further improvement needs new facility e.g. AMF at FNAL or PRISM at JPARC : likely only one.

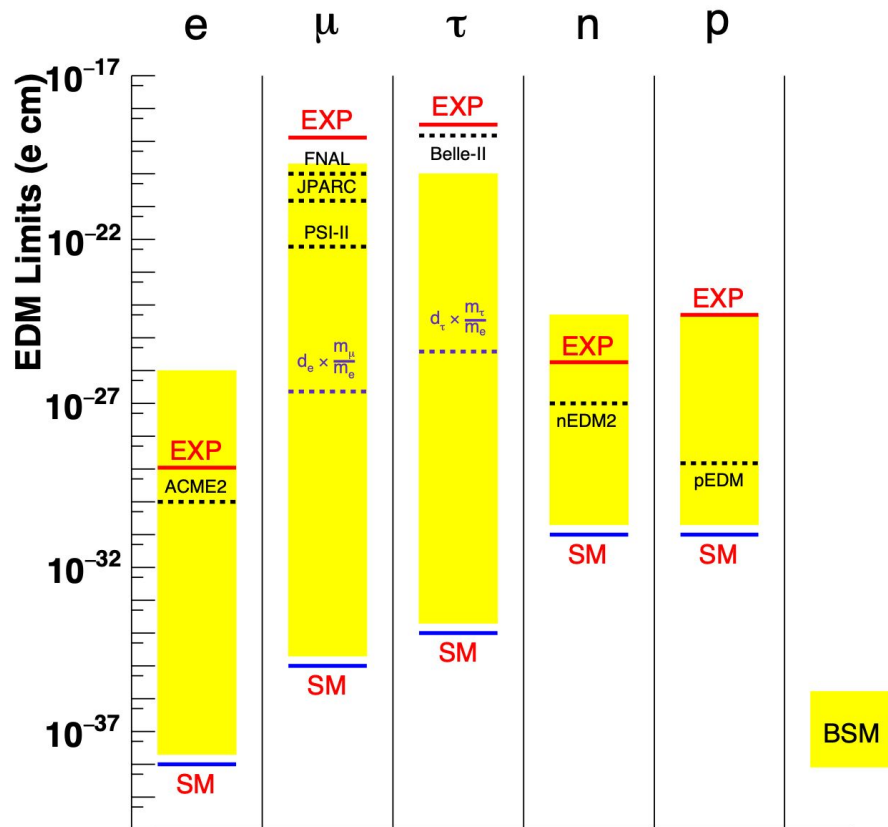
Challenges: target (1MW beam); cooling (FFAGs); proton rebunching; low- X_0 detectors
→ synergy with Muon collider (NuStorm) & DRD detectors.



All 3 CLFV modes at one facility/experiment
x 100 in $\mu \rightarrow e\gamma, \mu \rightarrow eee$
x 1000 in $\mu N \rightarrow eN$
 $\mu^+ e^-$ (muonium) oscillations



Flavour: EDMs



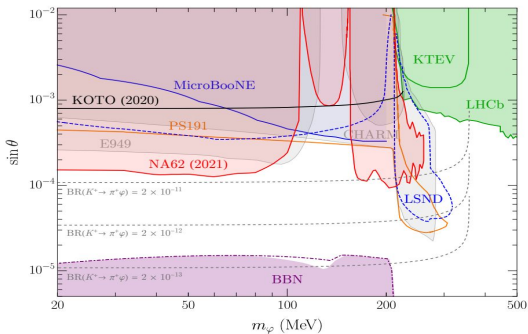
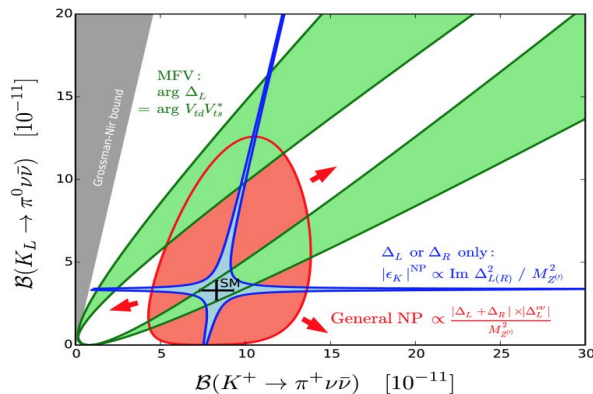
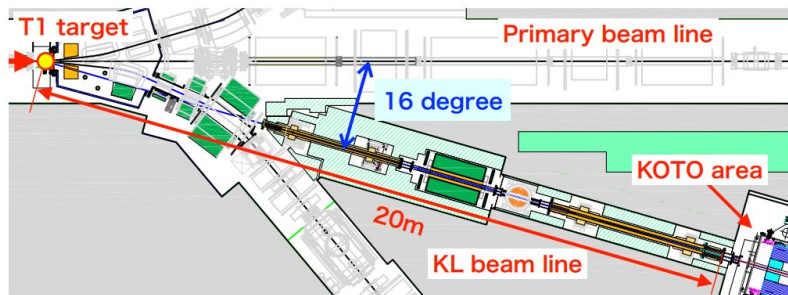
UK involvement in nEDM2, MuEDM : both at PSI & plans for a pEDM prototype.

MuEDM: proof of frozen-spin technique 2026-2028. 6×10^{-23} measurement after HIMB upgrade : 2030.

Post P5: pEDM requires a home. First stage proof of principle: 5 MV/m quadrupoles, low X_0 Si polarimeter : 2030s project...

Flavour : Kaons

NA62 will run to LS3 and expect 5σ observation of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ (SM BR $\sim 9 \times 10^{-11}$)
 KOTO (JPARC) sensitivity to $\sim 2 \times \text{SM}$ in 2026 of $K^0 \rightarrow \pi^0 \nu \bar{\nu}$ (SM BR $\sim 3 \times 10^{-11}$)
 KOTO2: 5σ sensitivity with higher power, new (extended) beamline/detectors in 2030s.



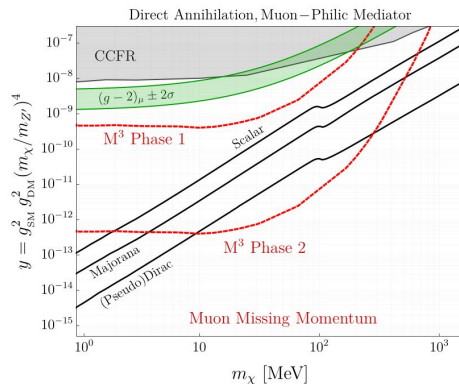
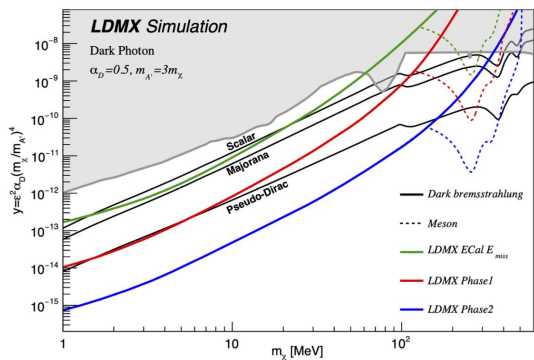
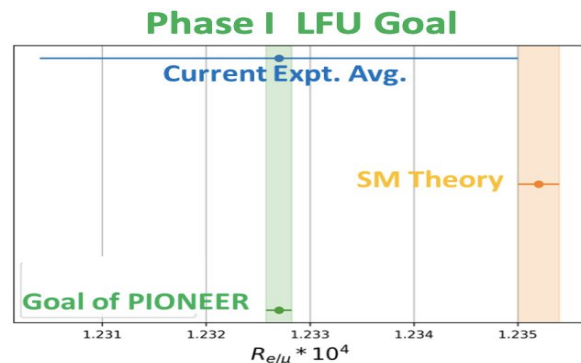
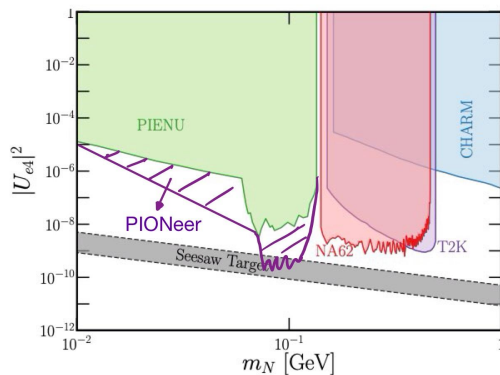
HIKE not approved.

Looking now to extend the KOTO2 physics reach / case
 Synergy with DRD detector goals
 Will be Kaon theory input into ESPPU

Flavour : presently no UK role

PIONeer : online ~ 2030 at PSI.
 HNL: 1-120 MeV; 0.005% on LFU,
 clean V_{ud} at 0.02%

LDMX : online ~ 2030 at SLAC.



Potentially a muon variant at FNAL : **M³**
 ~ similar timescale

Contacts

COMET: Yoshi Uchida

Mu2e: Mark Lancaster

MuEDM: Gavin Hesketh

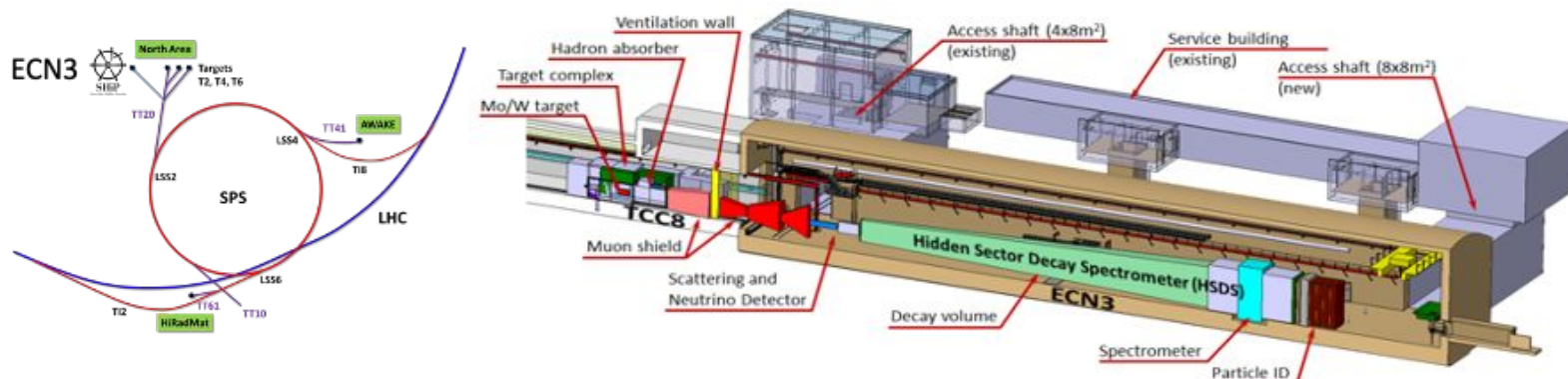
Mu3e: Joost Vossebeld

nEDM2: Philip Harris

pEDM: Themis Bowcock / Alex Keshavarzi

FIPs (including neutrinos)

- Recently approved beam-dump experiment at SPS HI-ENC3 facility
 - Originally proposed by UK and now led by UK spokesperson
 - Currently 4 UK institutes: involved in muon shield and PID detectors



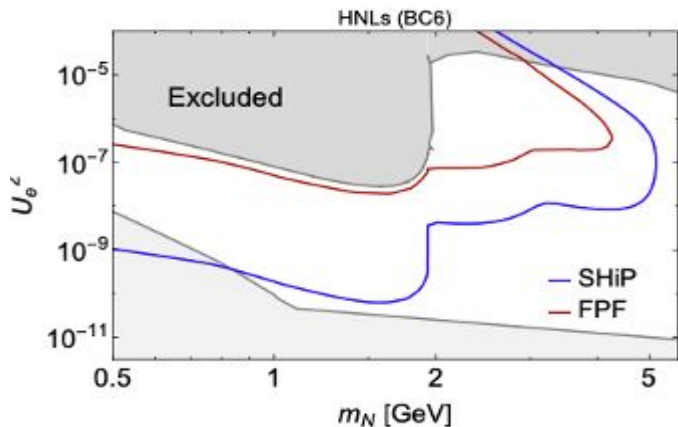
- Will take data from latter half of run-4, collecting 6×10^{20} POT over 15 years

Accelerator schedule	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
LHC	Run 3	Run 3	Run 3	Run 3	LS3	LS3	LS3	Run 4	Run 4	Run 4	Run 4	LS4
SPS (North Area)	Run 3	Run 3	Run 3	Run 3	Run 3	Run 3	Run 3	Run 3	Run 3	Run 3	Run 3	Run 3
BDF / SHiP	Study	Design and prototyping	Design and prototyping	Design and prototyping	Production / Construction / Installation	Production / Construction / Installation	Production / Construction / Installation	Production / Construction / Installation	Production / Construction / Installation	Operation	Operation	Operation
Milestones BDF		TDR studies	TDR studies	TDR studies	PRR	PRR	PRR	PRR	PRR	PRR	PRR	PRR
Milestones SHiP		TDR studies	TDR studies	TDR studies	PRR	PRR	PRR	PRR	PRR	PRR	PRR	PRR

Approval for TDR
Submission of TDRs
Facility commissioning

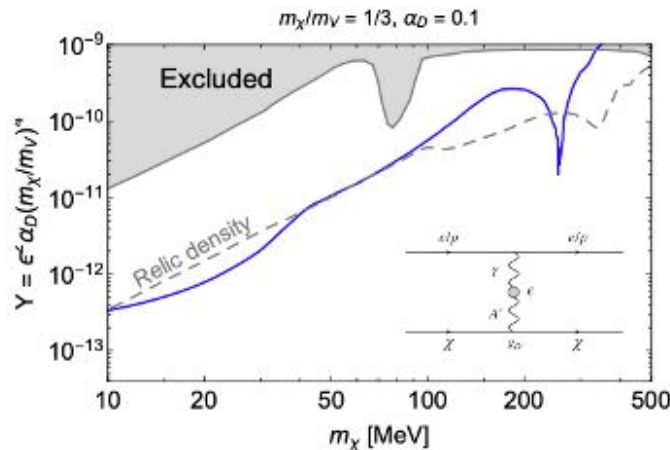
- World-leading sensitivity to a wide range of Hidden sector models
- Decay signature

- Dark scalars, dark photons, **HNLs (N)**, ALPs



- Scattering signature

- E.g. **Light dark matter** interacting via vector portal (V)



- In addition, large sample of ν up to ~ 100 GeV

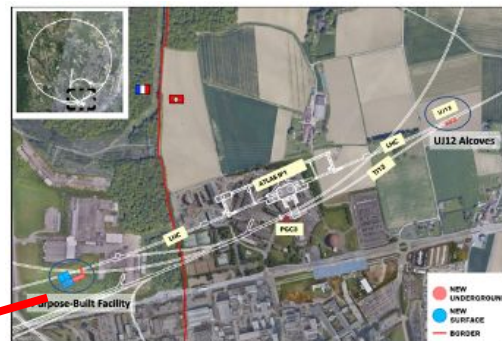
- Especially ν_T from $D_S \rightarrow \nu T$
- Measure x-sects for oscillation expts.

	$\langle E \rangle$ [GeV]	Beam dump	$\langle E \rangle$ [GeV]	CC DIS interactions
N_{ν_e}	6.3	4.1×10^{17}	63	2.8×10^6
N_{ν_μ}	2.6	5.4×10^{18}	40	8.0×10^6
N_{ν_τ}	9.0	2.6×10^{16}	54	8.8×10^4
$N_{\bar{\nu}_e}$	6.6	3.6×10^{17}	49	5.9×10^5
$N_{\bar{\nu}_\mu}$	2.8	3.4×10^{18}	33	1.8×10^6
$N_{\bar{\nu}_\tau}$	9.6	2.7×10^{16}	74	6.1×10^4

- Now ramping up physics studies towards TDR for 2026
 - With several high-priority tasks needing to be done already this year
 1. Deciding on He vs vacuum for decay volume → converging on He
 2. Optimisation of muon shield → main UK effort
 3. Advanced veto
 4. Configuration of SND → could be integrated into muon shield
 5. Individual signal selection
 6. Comprehensive physics case → including new signatures
- UK aiming to submit Sol to Science Board in next year or so
- Lots of opportunities and room to contribute
 - Get in touch with Andrei Golutvin (Spokesperson) or Mitesh Patel (UK SHiP liaison) if interested

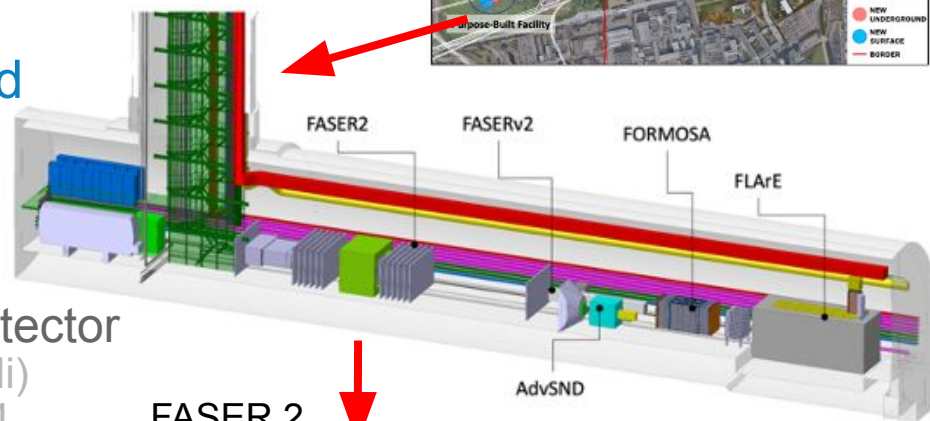


- Proposed forward-physics facility at the HL-LHC
 - Again, aiming for data-taking from latter half of run 4
 - Many civil engineering studies already undertaken
 - Can be built in parallel to HL-LHC operation

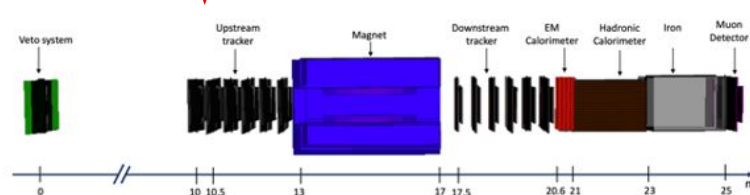


- 5 experiments currently envisaged

- FASER2: LLP spectrometer
 - 5 UK institutes
 - Leading tracker, magnet, (calo)
- FASERv2: W+emulsion ν det.
- AdvSND: Electronic off-axis ν detector
 - 1 UK institute (Mario Campanelli)
 - Recently submitted [LoI](#) for run-4 upgrade in current T118 location
- FLArE: LAr TPC for ν and DM
 - 1 UK institute: LAr optical readout
- FORMOSA: W+scintillator for mCP



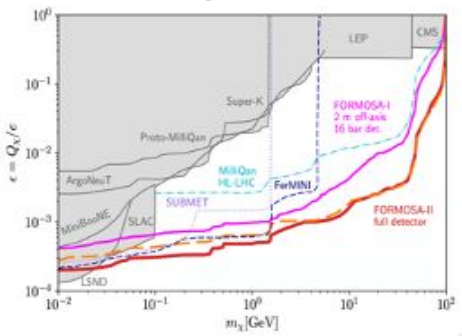
FASER 2



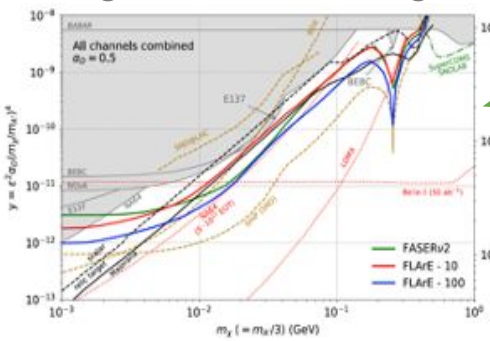
FPF Physics

- Very broad physics program bring together many areas for modest cost

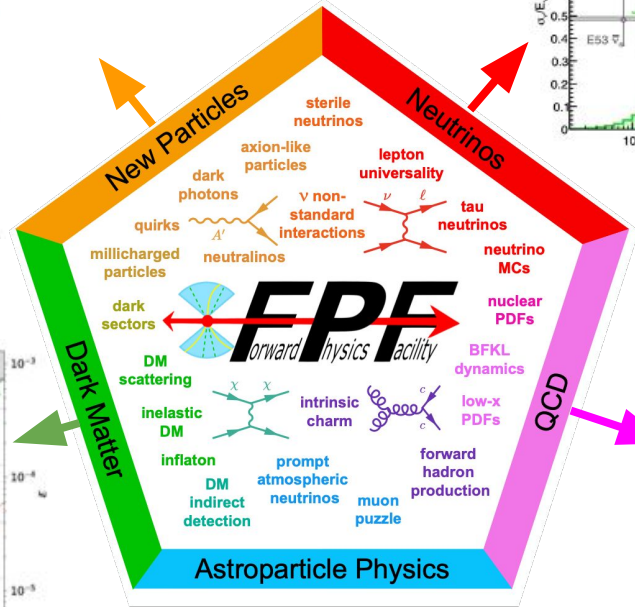
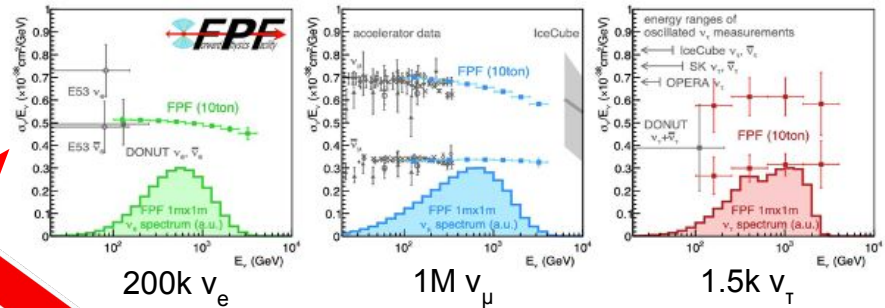
Millicharged particles



Light DM scattering

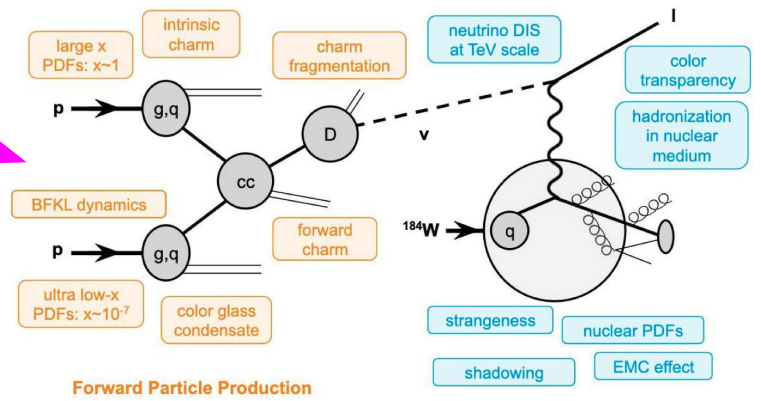


Large rate of all ν flavours with \sim TeV energy




Probing background to astrophysical neutrinos


Allowing many probes of QCD



Forward Particle Production

FPF Plans

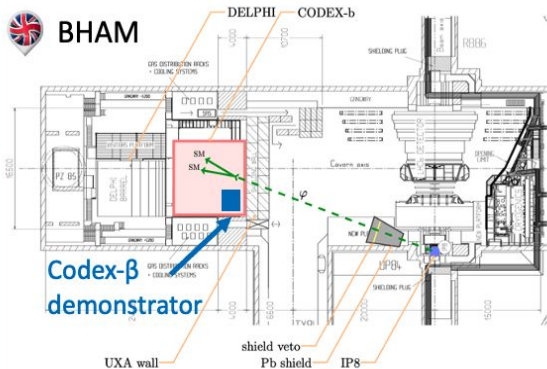
- Aiming for LOI early 2025, followed shortly by TDR
 - Plenty of scope for more detailed studies and influencing detector design
- Many interesting FPF areas needing work e.g.
 - FIPs sensitivity beyond simple hidden sectors
 - Possibilities for alternative neutrino detectors
 - Measuring PDFs independent of new-physics
 - Constraining forward charm production

Contact relevant FPF [WG conveners](#)
- In addition to FASER2 detector studies e.g.
 - Addition of silicon precision layer
 - Finalisation of magnet specifications
 - Use as μ spectrometer for neutrino detectors
 - Medium-term test bed for new technology

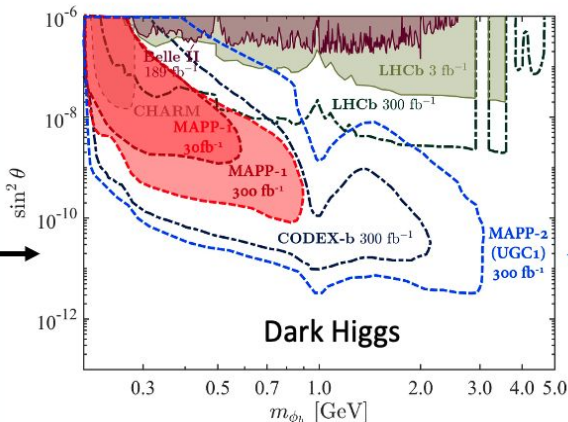
Contact Alan Barr and Josh McFayden as FASER 2 conveners

Other FIPs Proposals with UK Involvement

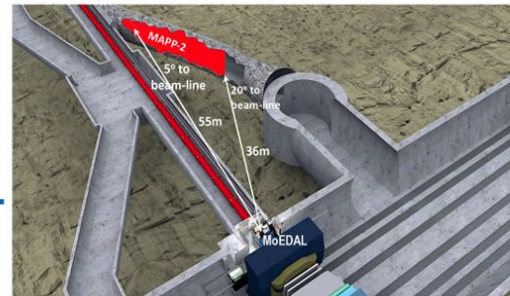
- **CODEXb**: 25m away (transverse)
 - RPC for Run 4 (β prototype now)



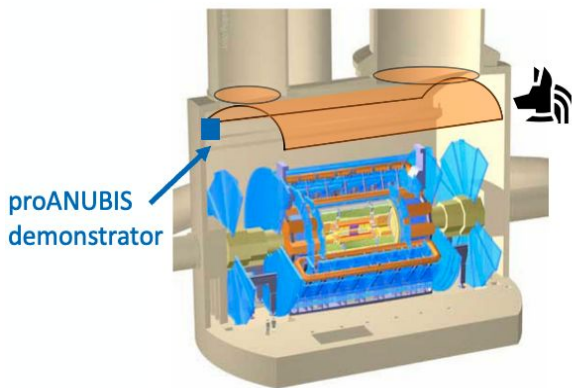
LHCb (IP8)



- **MoEDAL-MAPP**: 55m away (forwards)
 - Scintillator + PMT for HL-LHC

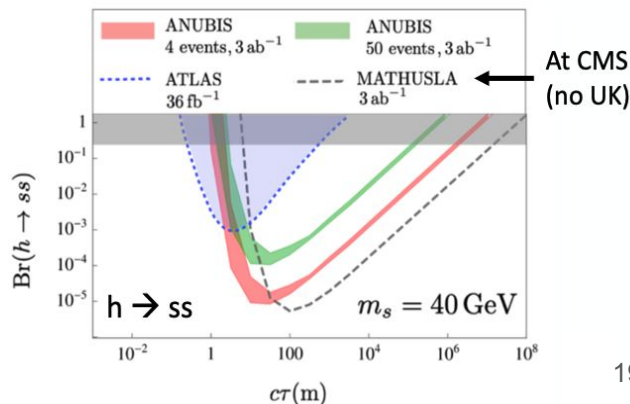


Bristol, Imperial, KCL, QMUL



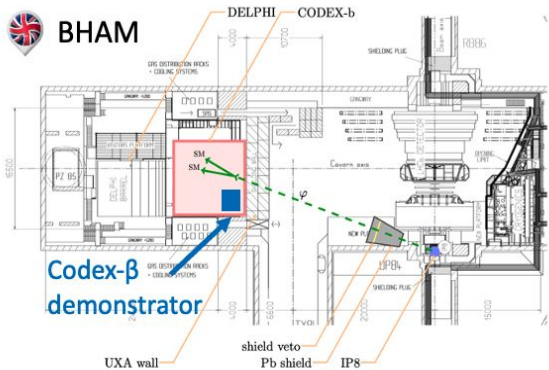
- **ANUBIS**: 25m from ATLAS (transverse)
 - RPC for HL-LHC
 - proAnubis demo.

CAM, Durham

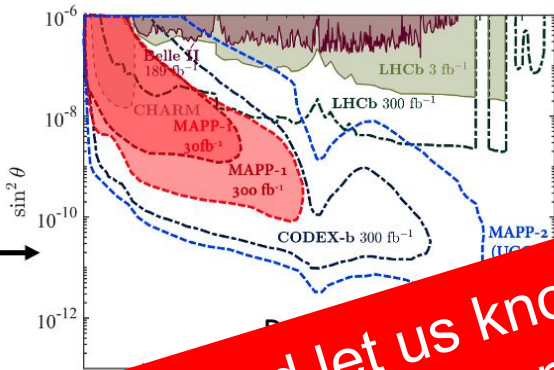


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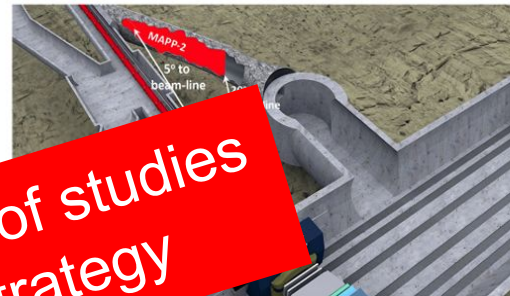
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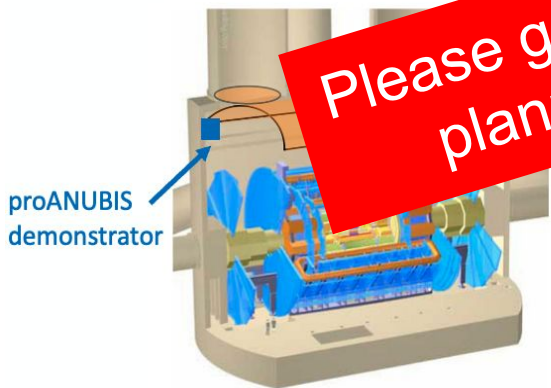


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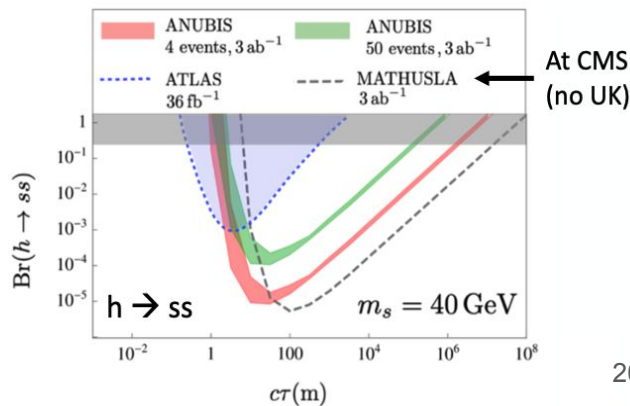
Please get in touch and let us know of studies planned as input to European Strategy



ANUBIS: 25m from ATLAS (transverse)

- RPC for HL-LHC
- proAnubis demo.

CAM, Durham



Summary

- Wide theme, primarily focused around 2 areas: muons and FIPs
 - Apologies for any areas/studies we might have missed
 - Please let us know and we can add them for September
- Many opportunities to get involved, across wide range of physics
 - Input needed from both theory and experimental side
 - Also detector design and optimisation
- If you are interested in getting involved please get in touch!
 - With the contacts listed, keeping us in the loop