

SHIP

Carl Gwilliam

21st May 2026

HEP Annual Meeting



UNIVERSITY OF
LIVERPOOL

Motivation

- We know SM can't be complete e.g. dark matter (DM), dark energy, BAU, ...
 - But there are no significant signs of new physics (NP) at the energy frontier
- On the other hand, many BSM theories predict new light, feebly interacting particles (FIPs)
 - Hidden sector (HS): DM is part of a more complex NP sector, interacting with SM via mediator/portal

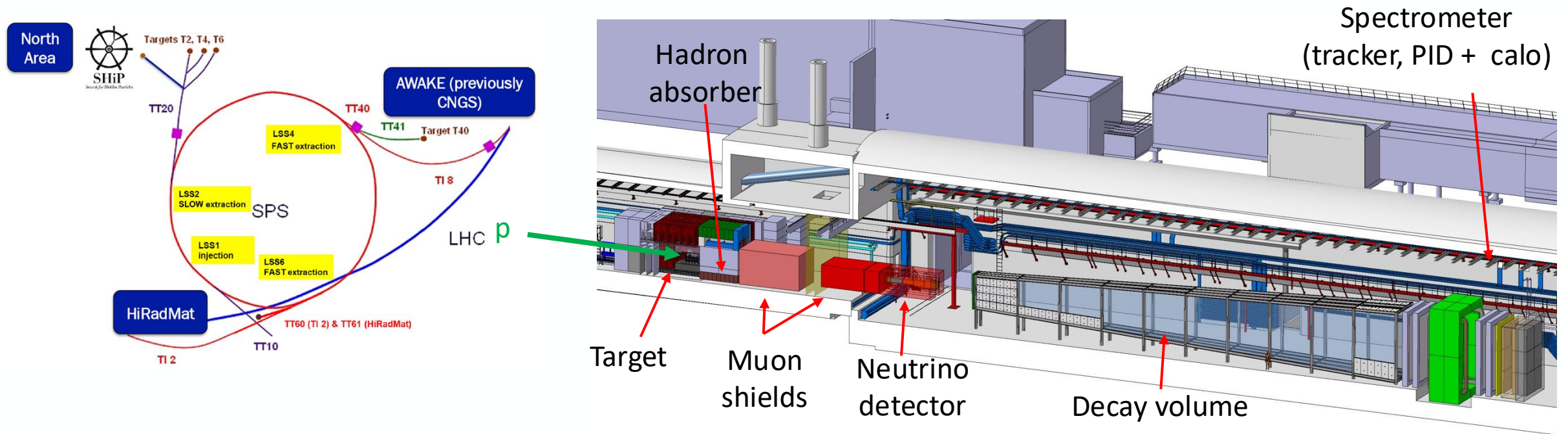


- Vector Portal e.g. dark γ
- Scalar Portal e.g. dark H
- Pseudoscalars Portal e.g. ALPs
- Fermion Portal e.g. HNLs

- Such feeble coupling tends to lead to long lifetimes
 - Giving rise to long-lived particles (LLPs) that may evade GPDs
- Efficiently exploring the FIPs phase space needs dedicated experiments
 - Transverse or forward of colliders, such as FASER at the LHC
 - At proton beam dumps, such as the Search for Hidden Sector Particles (SHiP) at the SPS ...

Experiment

- SHiP is an approved experiment at the upgraded ECN3 facility in the SPS North Area
 - Liverpool officially joined in July 2026 with small fractions of several people
 - Carl (TL), Themis, Christos Joe, Saskia, Eduardo, Dave S, John C,

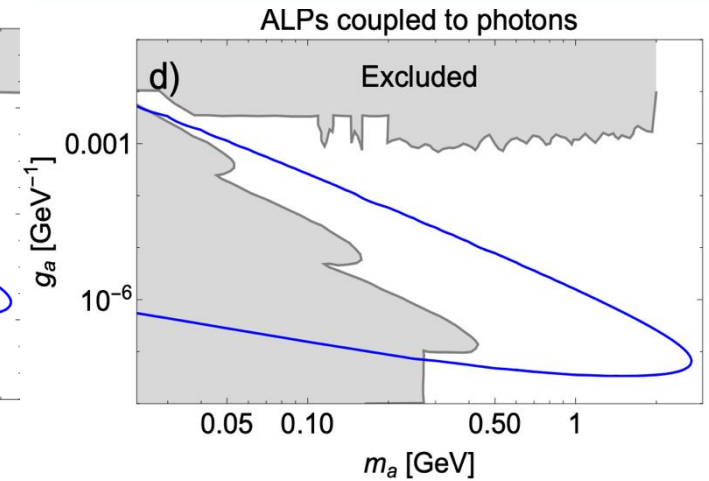
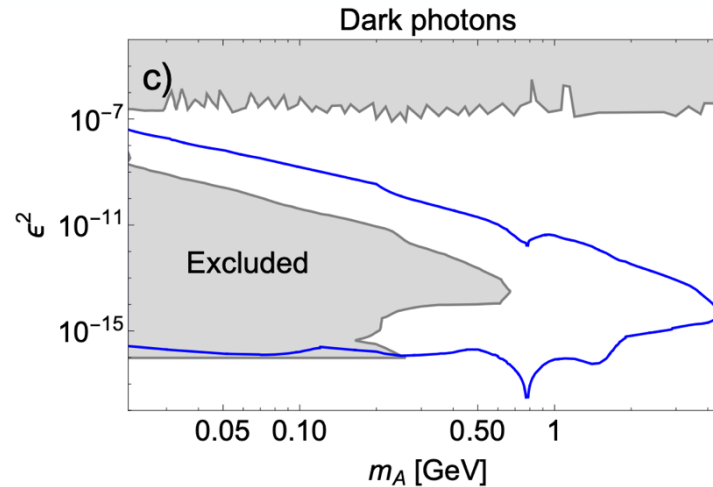
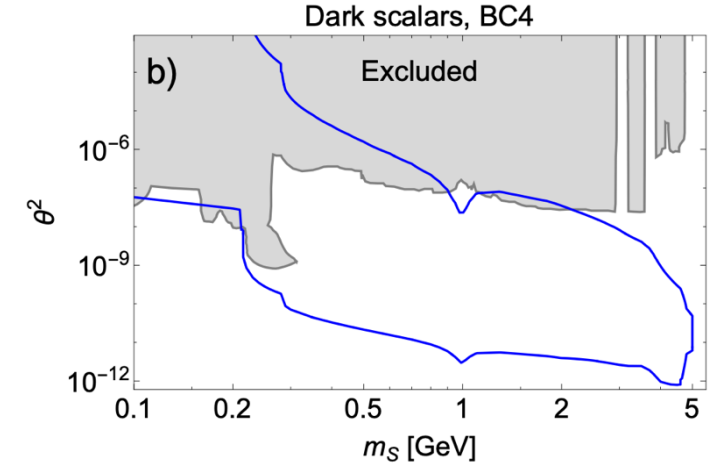
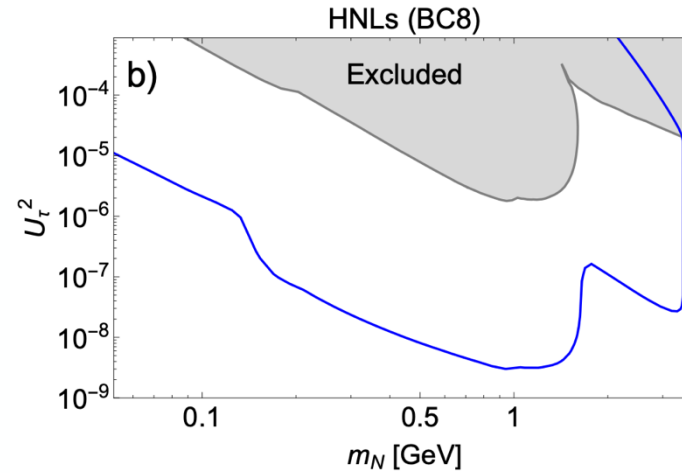
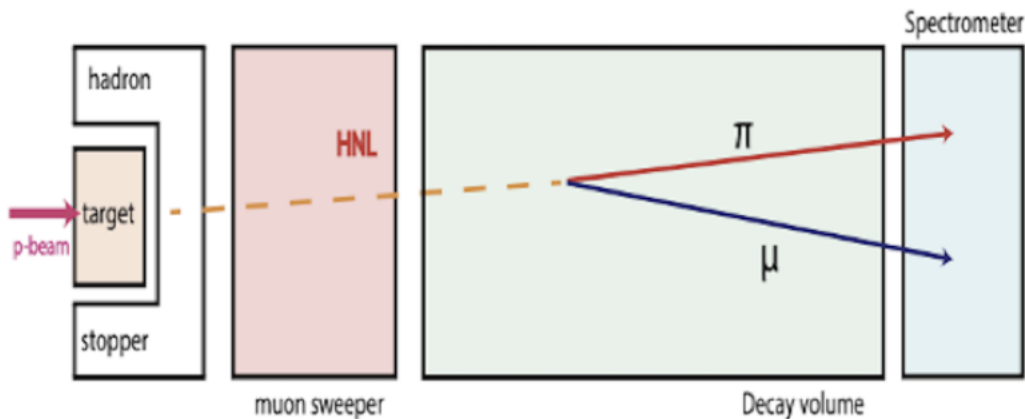


- Plan to start operation in last year of run 4 (2032) before upgrades over LS4 for run 5 (2036-41)
 - Aiming to collect 6×10^{20} protons on target at 400 GeV with near zero background.

Physics: Decay Spectrometer

- Slamming 400 GeV protons into target produces copious number D/B mesons
 - These could decay immediately into FIPs in narrow solid angle, which are reco'd via their decay back to SM particles

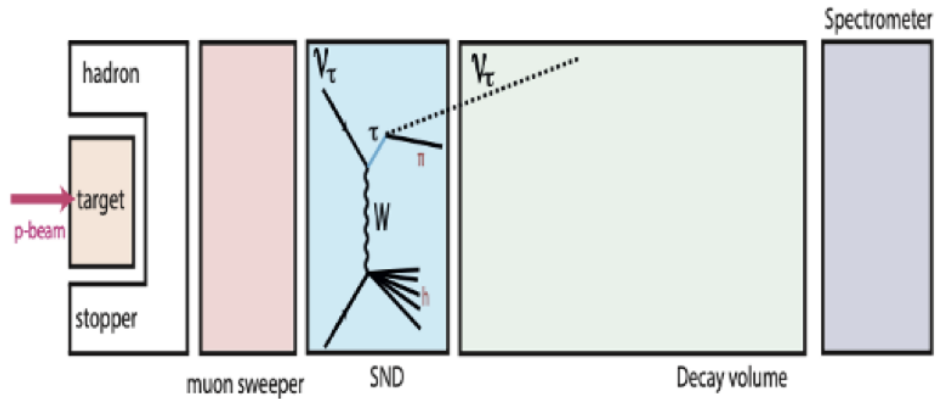
Physics model	Final state
SUSY neutralino	$\ell^\pm \pi^\mp, \ell^\pm K^\mp, \ell^\pm \rho^\mp, \ell^+ \ell^- \nu$
Dark photons	$\ell^+ \ell^-, 2\pi, 3\pi, 4\pi, KK, q\bar{q}, D\bar{D}$
Dark scalars	$\ell\ell, \pi\pi, KK, q\bar{q}, D\bar{D}, GG$
ALP (fermion coupling)	$\ell^+ \ell^-, 3\pi, \eta\pi\pi, q\bar{q}$
HS DS 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	$\gamma\gamma, \ell^+ \ell^-, 2\pi, 2K$



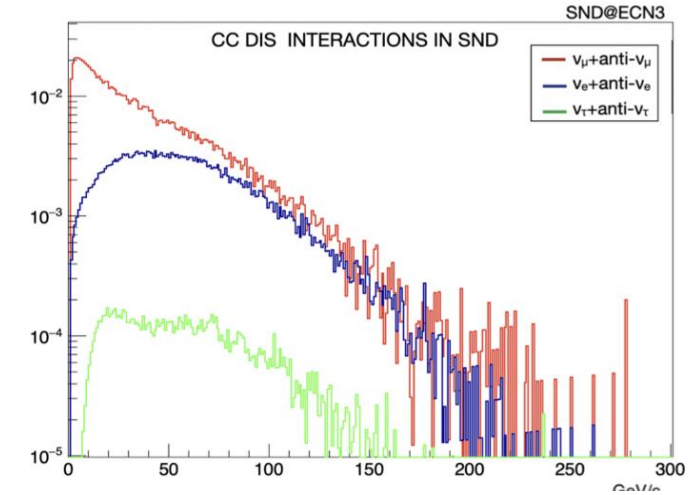
- Significant new coverage in wide variety of HS models for $m < 5$ GeV (assuming can achieve 0 background)

Physics Reach: Neutrino detector

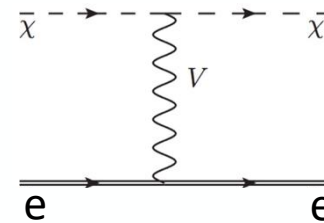
- Protons interactions in target also produce copious number of multi-GeV energy neutrinos
 - Detected via dedicated scattering neutrino detector (SND) upstream of decay volume
 - Allows in depth studies such as ν -induced charm production + detailed ν_τ measurements



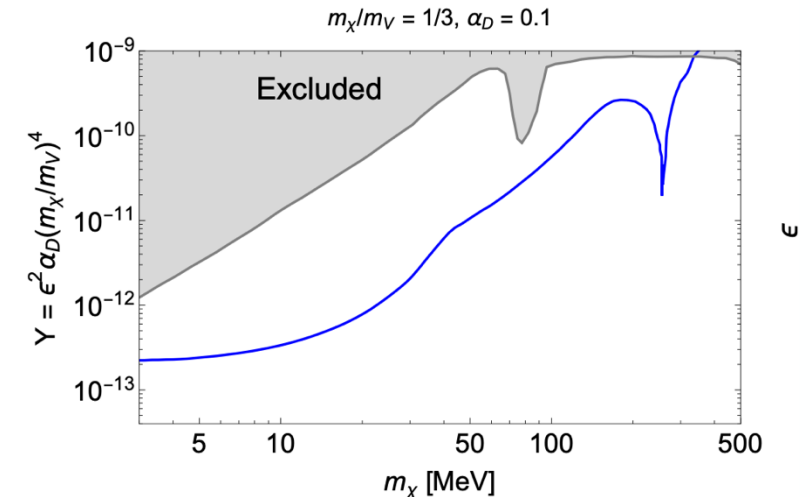
	$\langle E \rangle$ [GeV]	CC DIS interactions
N_{ν_μ}	40	8.0×10^6
$N_{\bar{\nu}_\mu}$	33	1.8×10^6
N_{ν_e}	63	2.8×10^6
$N_{\bar{\nu}_e}$	49	5.9×10^5
N_{ν_τ}	54	8.8×10^4
$N_{\bar{\nu}_\tau}$	74	6.1×10^4



- Also acts as target for light (sub-GeV) DM searches
 - Scatters of nucleon or electron via mediator
 - E.g. DM scattering off electron via A'

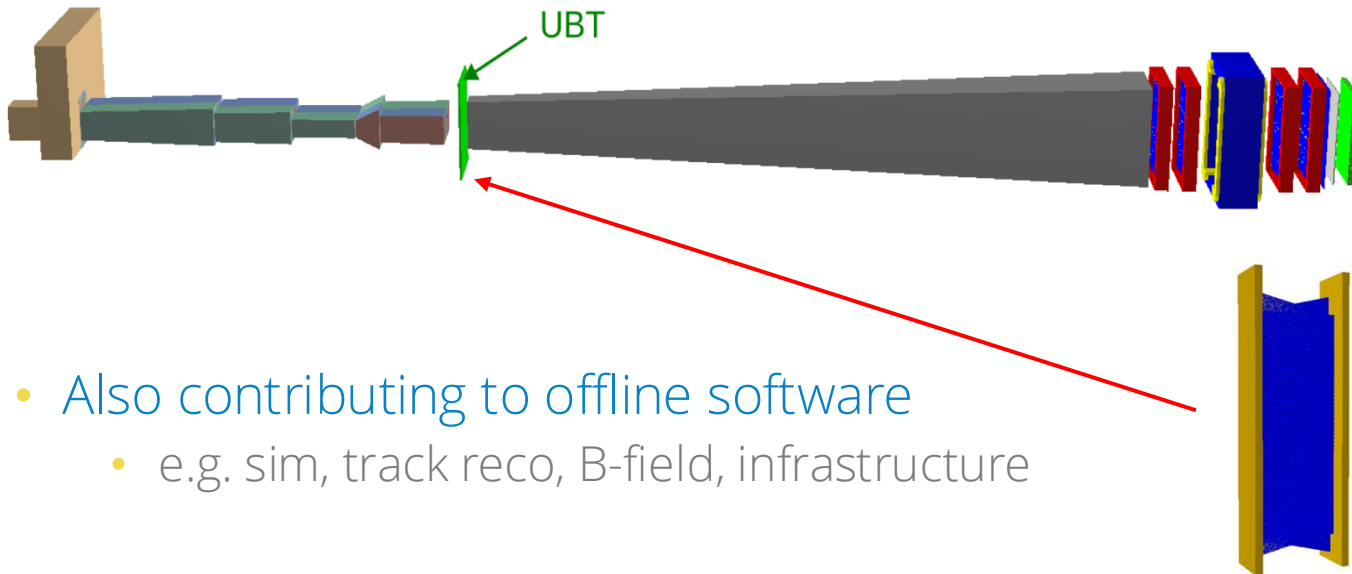


- Further details in updated SHiP proposal
 - [CERN-SPSC-2023-033](https://cds.cern.ch/record/2811033)

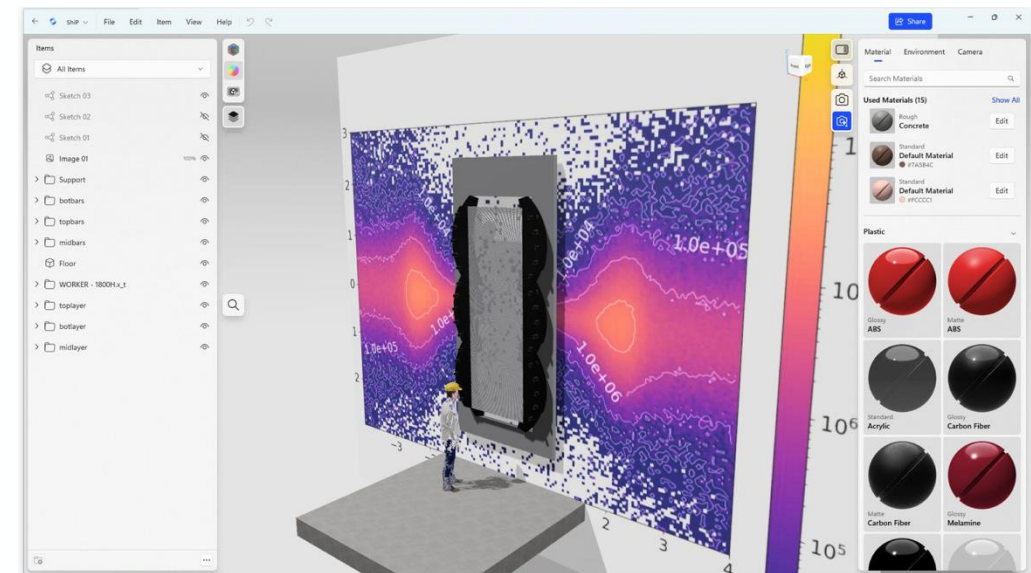


Liverpool Involvement

- SHiP design being simplified to reduce complexity and save money
 - He rather than vacuum in decay volume → harder to veto background
 - Replace emulsion SND with electronic detector → more space upstream
- Liverpool have proposed Upstream Background Tracker (UBT) as part of veto system
 - Straw tracker utilising on our experience from g-2



- Also contributing to offline software
 - e.g. sim, track reco, B-field, infrastructure
- Longer term interest mostly in FIPs searches
 - But potentially also in neutrino measurements



Summary

- Liverpool joined SHiP experiment to search for FIPs
 - And potentially measure neutrinos
- Investigating potential upstream straw veto tracker
 - Dependent on (non-STFC) funding
- Timeline is tight, with TDRs needed by next year
 - Aim to contribute here, utilising project students

