SHIP

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HEP Annual Meeting

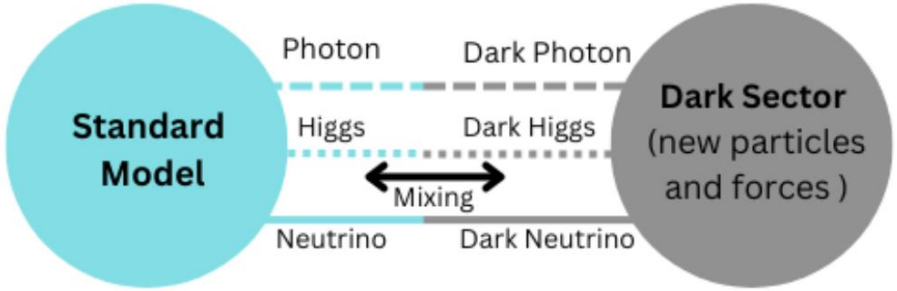
SHiP

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



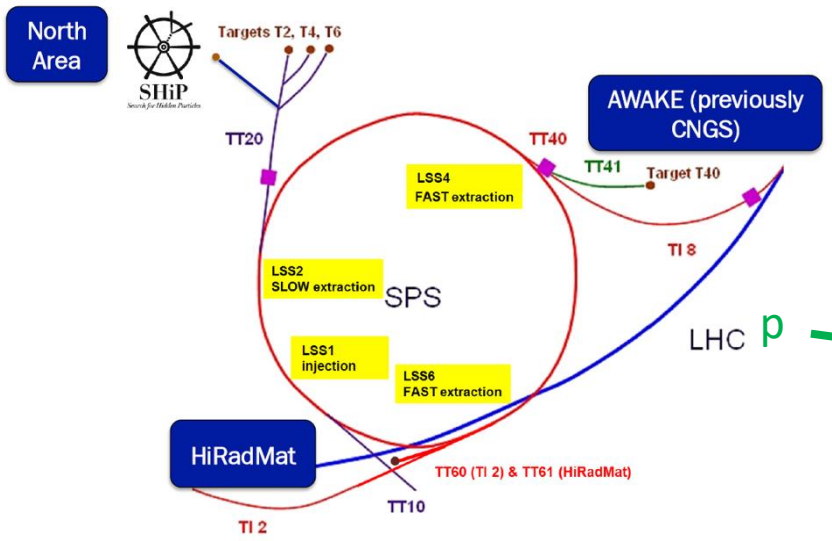
- Vector Portal e.g dark γ
- Scalar Portal e.g. dark H
- Pseudoscalars Portal e.g. ALPs
- Fermion Portal e.g HNLs

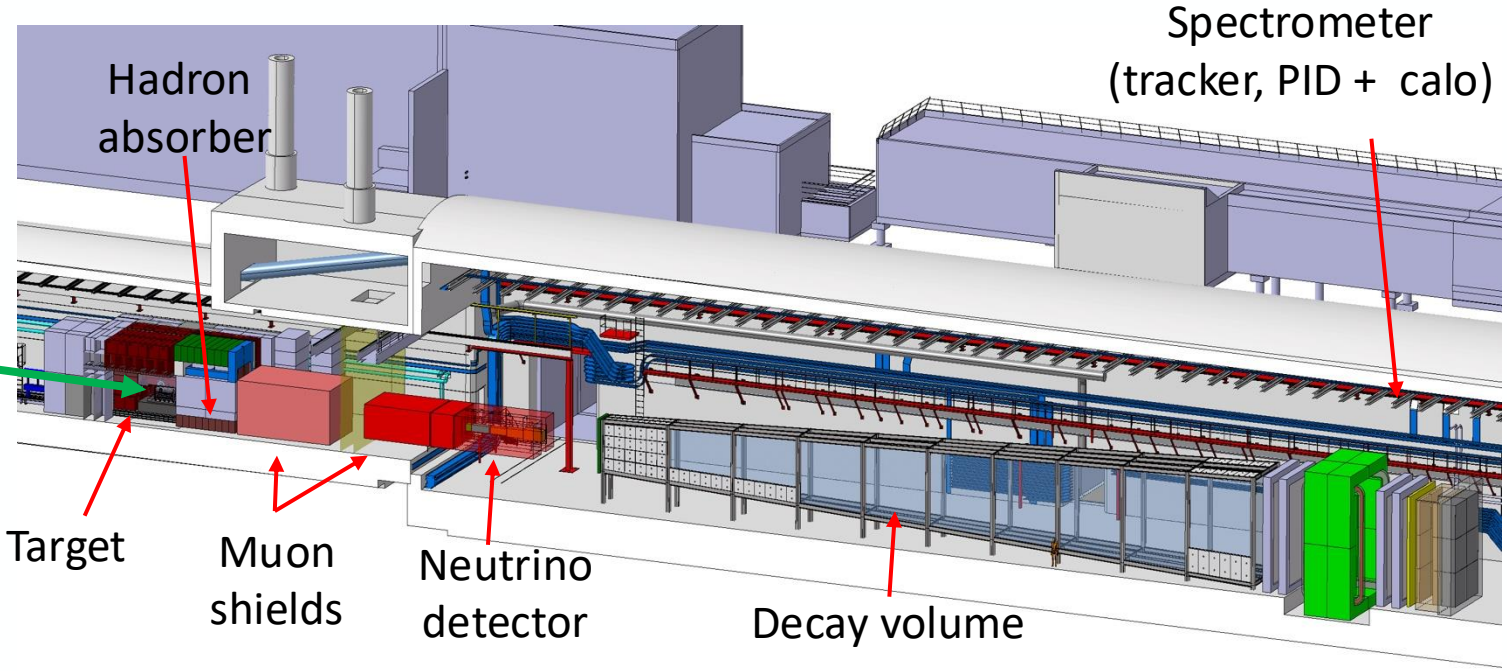
- Such feeble coupling tends to lead to long lifetimes
  - Giving rise to long-lived particles (LLPs) that may evade GPDs

- 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 2025 with small fractions of several people
    - Carl (TL), Themis, Christos Joe, Saskia, Eduardo, Dave S, John C, Tim J



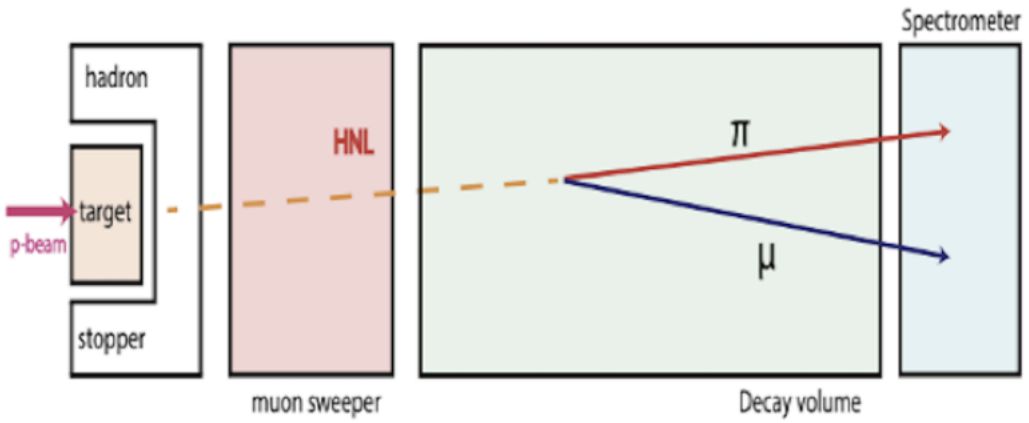


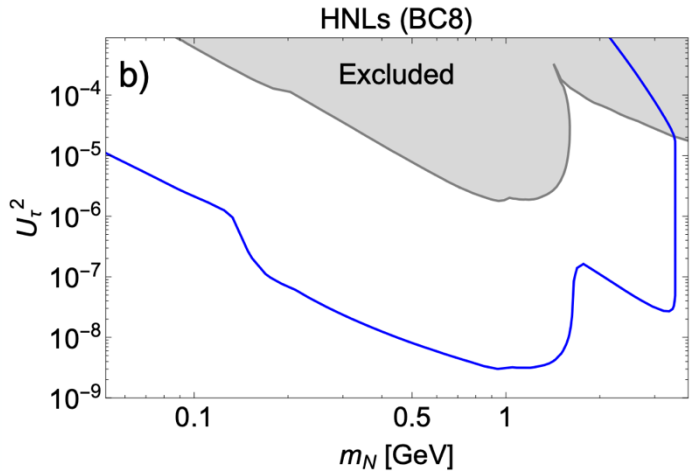
- Plan to start operation in last year of run 4 (2032) before upgrades over LS4 for run 5 (2036-41)
  - Aiming to collect 6 x 10^{20} protons on target at 400 GeV with near zero background.

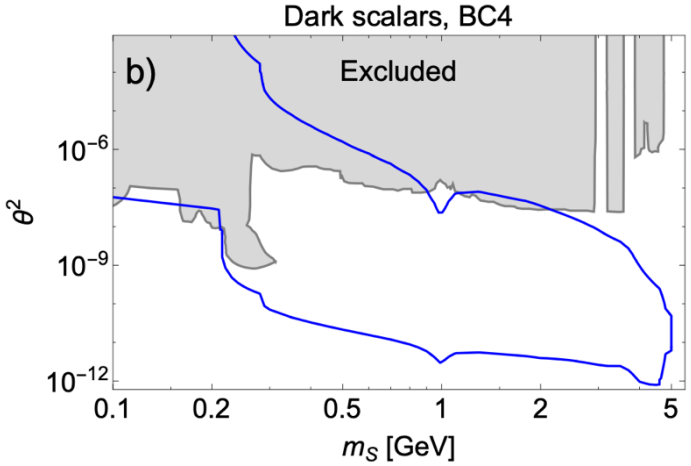
Physics: Decay Spectrometer

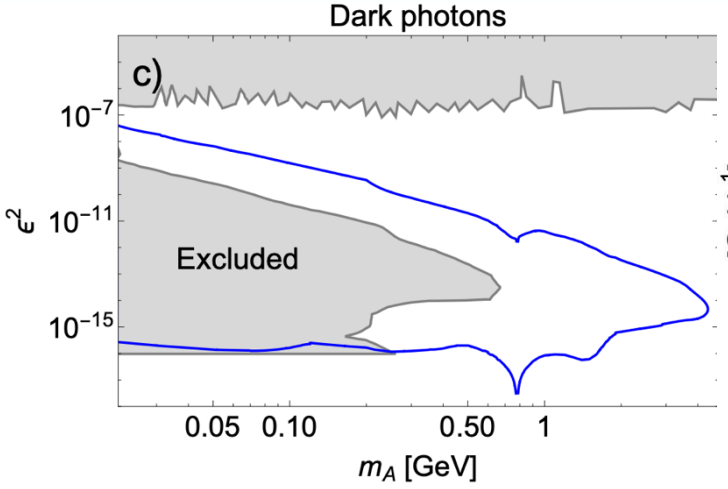
- Slamming 400 GeV protons into target produces copious D/B mesons
  - These could decay immediately into FIPs in narrow solid angle, which are reco'd via their decay back to SM particles

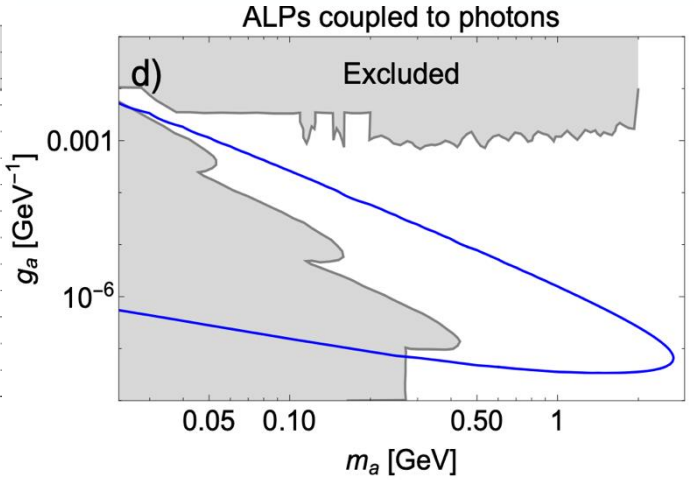
	Physics model	Final state
HSDS	SUSY neutralino	$\ell^{\pm}\pi^{\mp},\ \ell^{\pm}K^{\mp},\ \ell^{\pm}\rho^{\mp},\ell^{+}\ell^{-}\nu$
	Dark photons	$\ell^{+}\ell^{-},2\pi,3\pi,4\pi,KK,q\bar{q},D\bar{D}$
	Dark scalars	$\ell\ell,\pi\pi,KK,q\bar{q},D\bar{D},GG$
	ALP (fermion coupling)	$\ell^{+}\ell^{-},3\pi,\eta\pi\pi,q\bar{q}$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







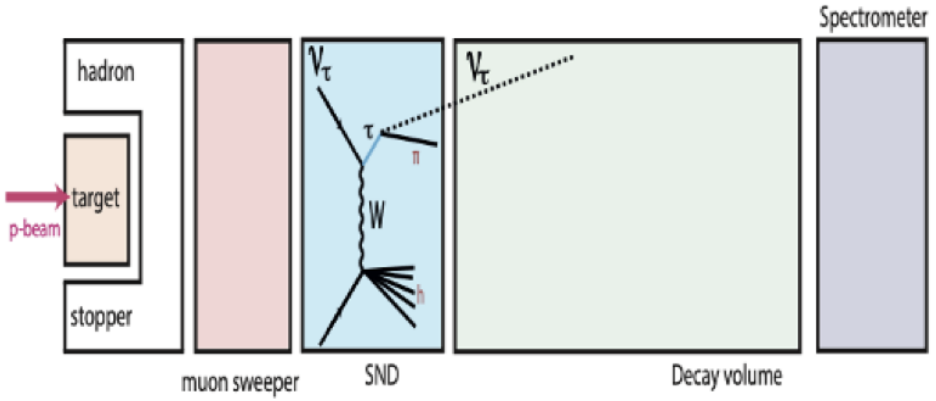




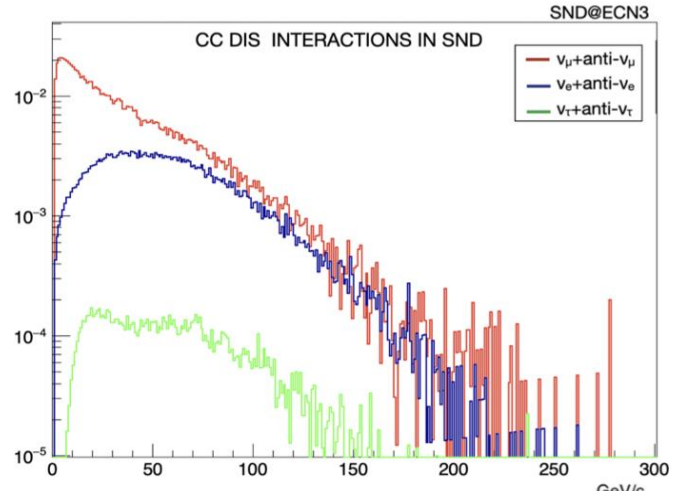
- Significant new coverage in wide variety of HS models for m < 5 GeV (assuming can achieve 0 background)

Physics Reach: Neutrino detector

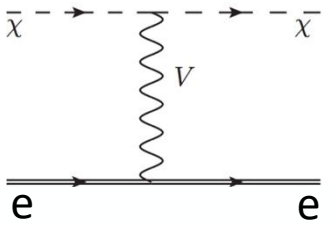
- Protons interactions in target also produce copious number of multi-GeV energy neutrinos
  - Detected via dedicated scattering neutrino detector (SND) upstream of decay volume
  - Allows in depth studies such as ν-induced charm production + detailed ν_τ measurements

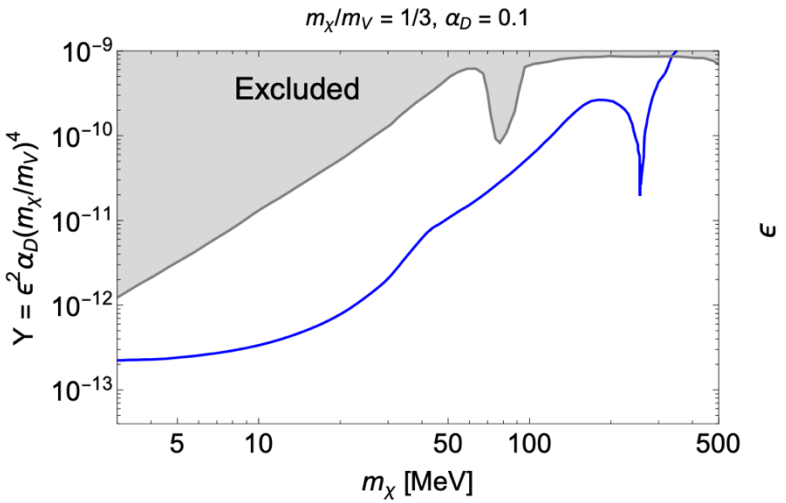


	<E> [GeV]	CC DIS interactions
N_{ν_μ}	40	8.0×10^6
$N_{\overline{\nu}_\mu}$	33	1.8×10^6
N_{ν_e}	63	2.8×10^6
$N_{\overline{\nu}_e}$	49	5.9×10^5
N_{ν_τ}	54	8.8×10^4
$N_{\overline{\nu}_\tau}$	74	6.1×10^4



- 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′

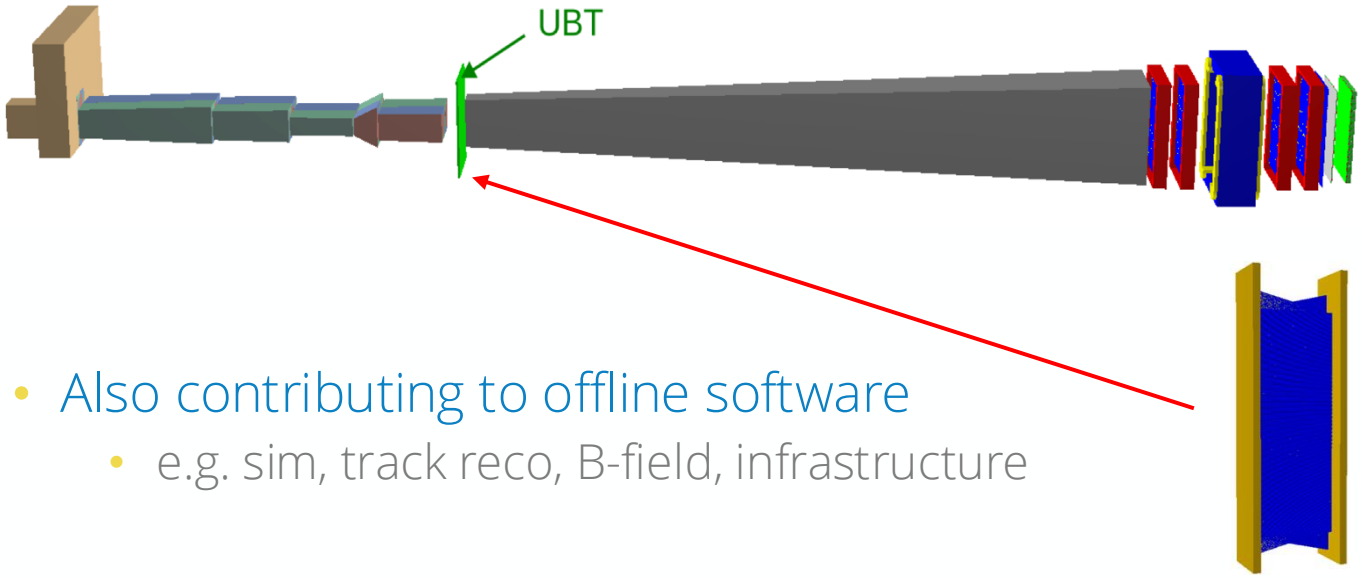


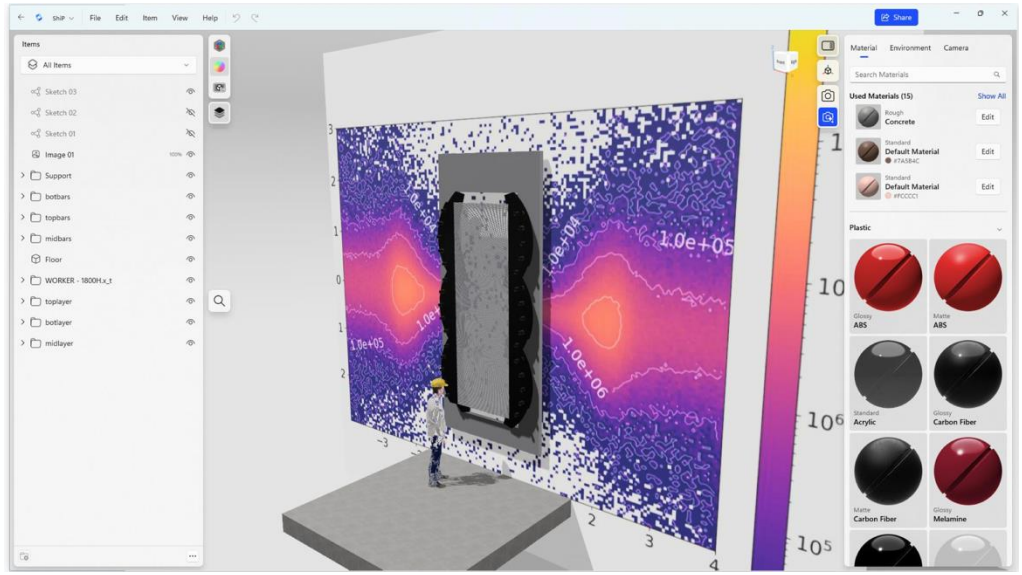


- Further details in updated SHiP proposal
  - CERN-SPSC-2023-033

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