LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

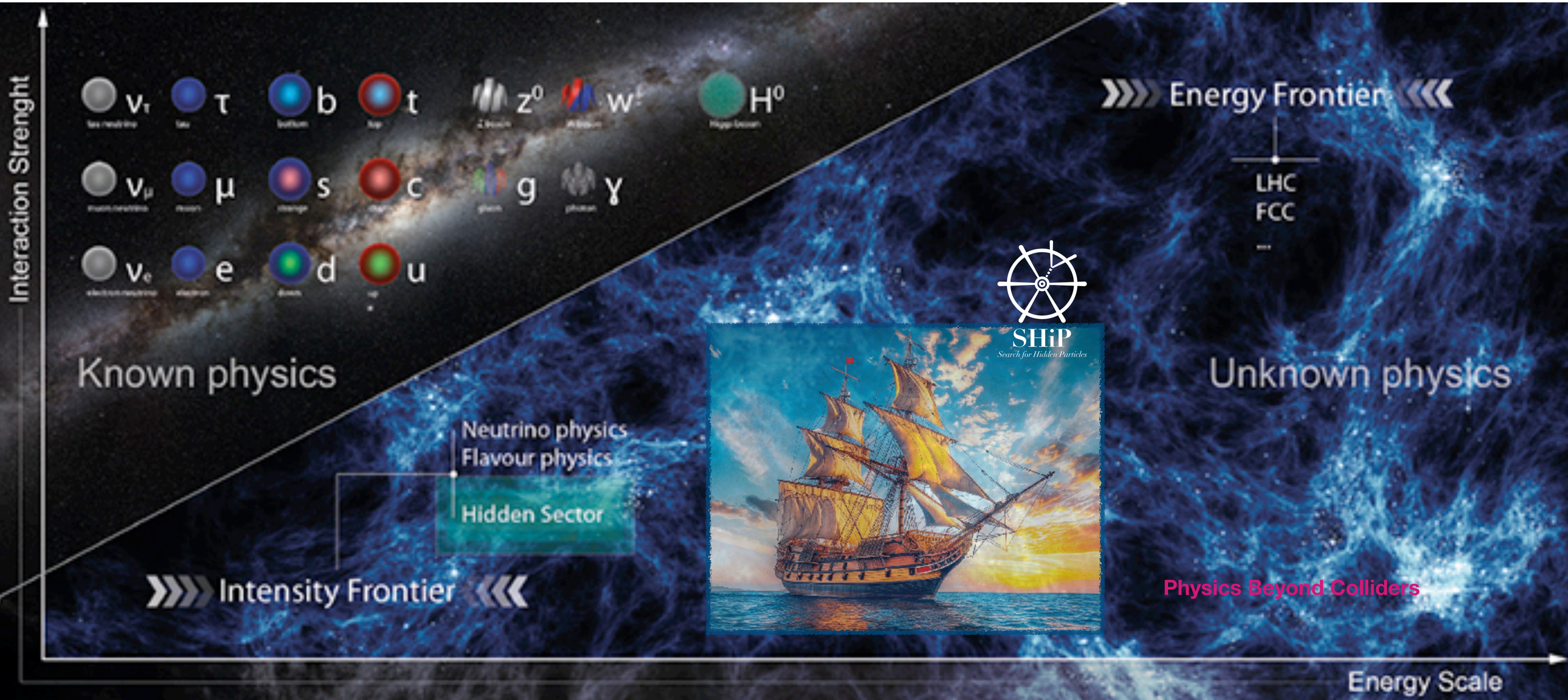
Fundação
para a Ciência
e a Tecnologia

# Search for Hidden Particles

N. Leonardo, SHiP/SND@LHC LIP Group

Portuguese Discussion European Strategy Particle Physics, 20/1/2025

European Strategy Update



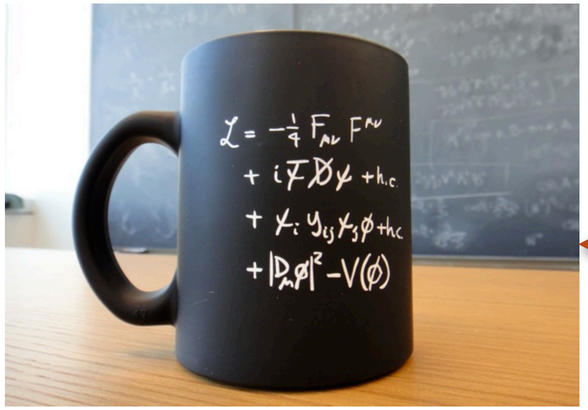
# Exploring the **hidden sector** of particle physics

Physics beyond-SM **needed**:

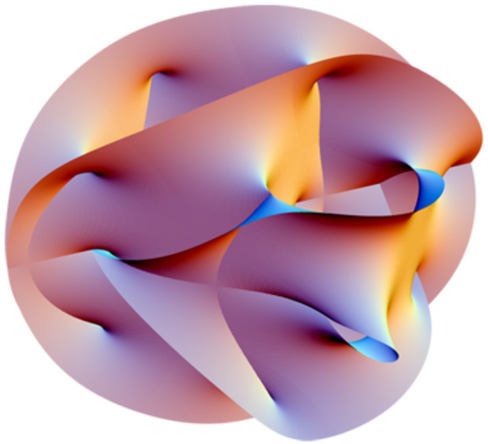
- dark matter
- neutrino masses
- baryon asymmetry

No clear guidance towards BSM:

- from theory or experiment
- no prejudice on mass, spin, coupling

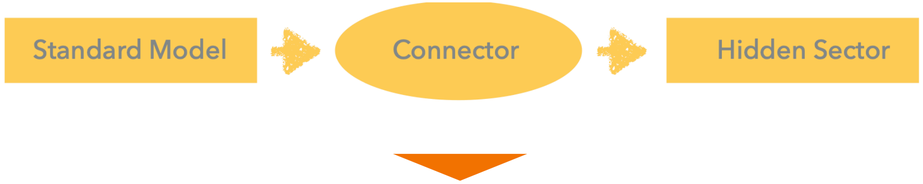


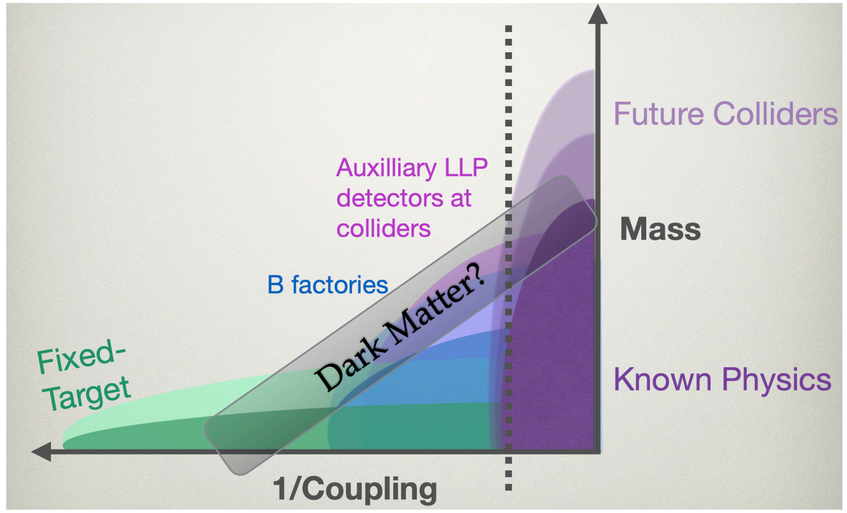
$$\mathcal{L} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{Mediator}} + \mathcal{L}_{\text{HS}}$$



New particles **not** yet **found** as:

1. too **heavy** for the available √s ↪ energy frontier, *or*
2. very **feebly** interacting with SM ↪ **intensity frontier**



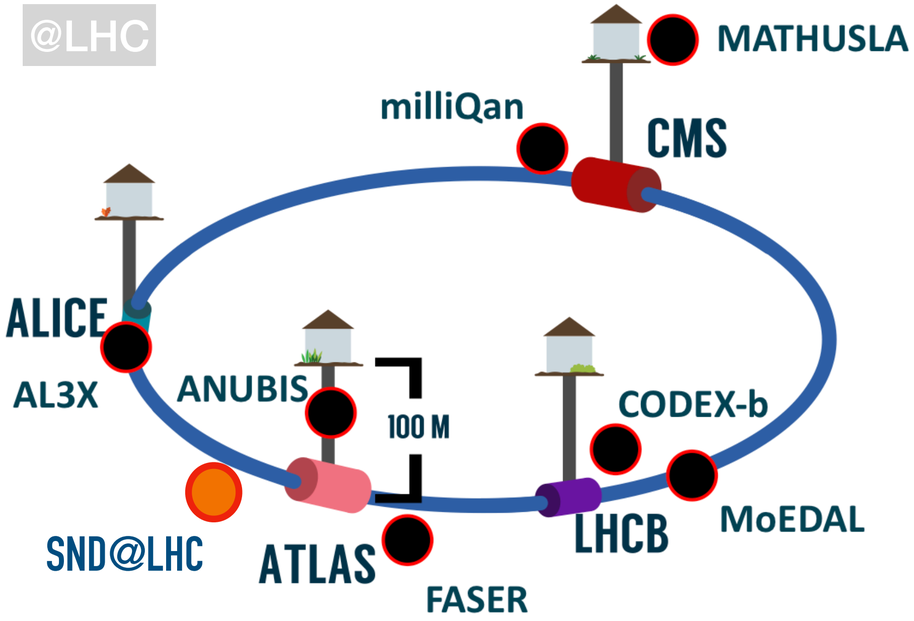



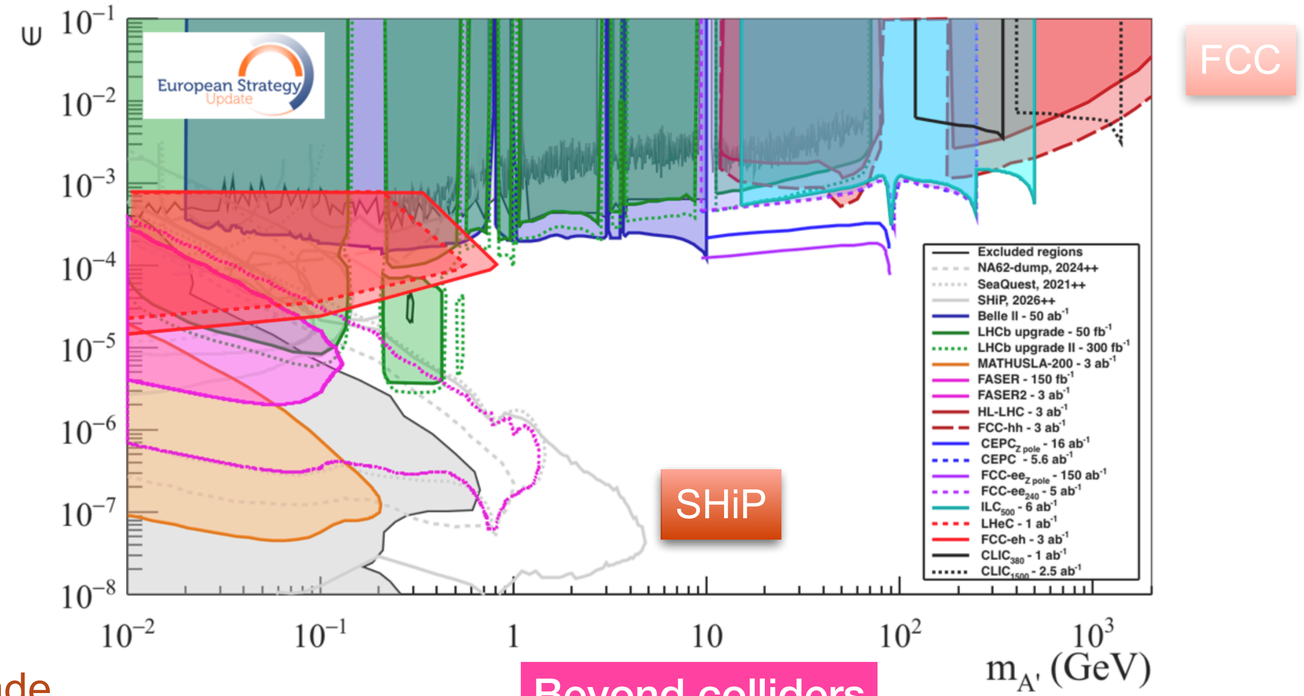

Hidden / **dark sector** accessible via portals:

- scalar portal: dark scalars, **dark Higgs**
- pseudo-scalar portal: axion-like particle, **ALPs**
- vector portal: e.g. **dark photon**, DP
- fermion portal: e.g. heavy neutral leptons, **HNLs**

Weakly-coupled new physics ↪ lead to **long-lived** signatures

# Searching for FIPs: Feebly Interacting Particles



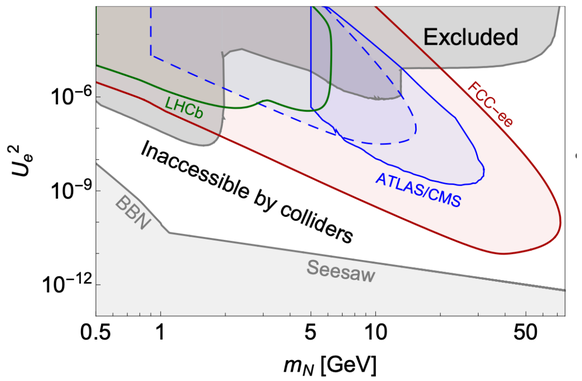



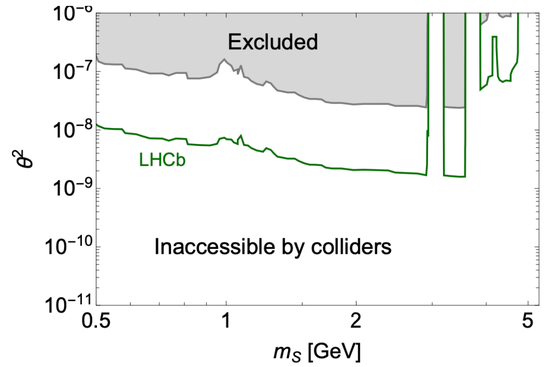

Beyond colliders

Enormous increase in interest in FIP searches over last decade
↪ following nulls results from direct BSM searches at LHC

Multiple FIP-dedicated projects being prototyped, proposed
↪ at LHC (incl. dedicated FPF) and beyond

SHiP's recent approval facilitates framework for collaboration
↪ allows not only to detect FIPs but measure their properties

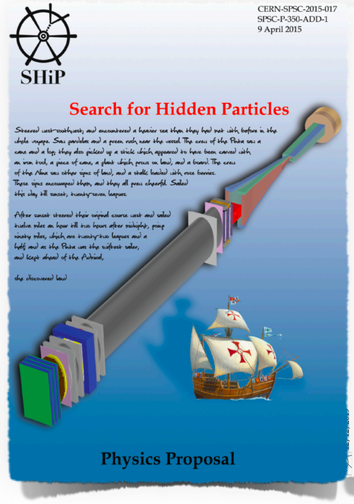


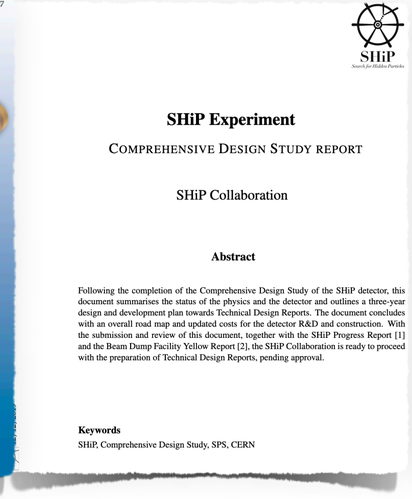



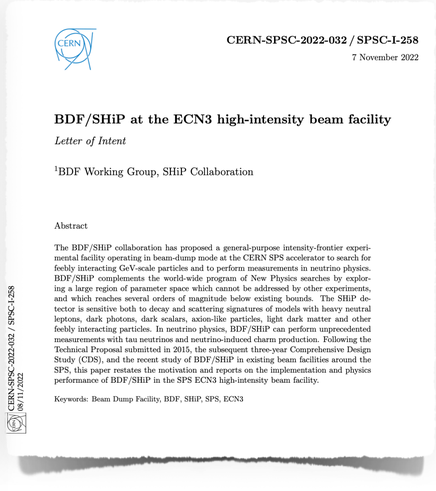
# SHiP, approval history

- 2013: Letter of Intent, 1310.1762
- 2015: Technical + Physics proposals, 1504.04956/CERN-SPSC-2015-040
- 2019: CDS report, CERN-SPSC-2019-049
- 2021: SND@LHC approved, SHiP neutrino detector prototype
- 2023: BDF/SHiP at ECN3, CERN-SPSC-2023-033
- 2023: CERN approves high-intensity upgrade of ECN3
- 2024: CERN approves SHiP for exploring ECN3 facility
- 2026: TDR (ongoing)

***Since last ESPPU (2020)**, significant cost reduction achieved by adopting existing ECN3 cavern instead of building new ECN4 BDF facility*

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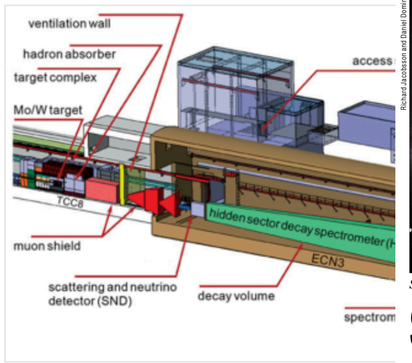
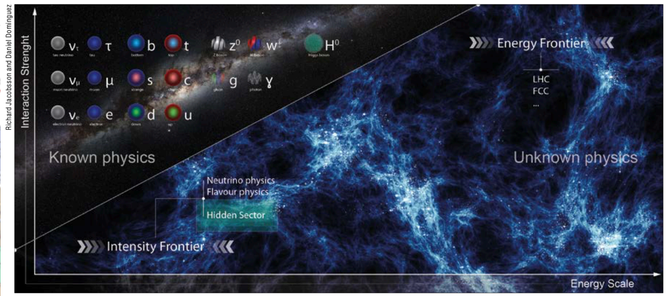
## SHiP to chart hidden sector

3 May 2024




**Full speed ahead** Layout of the SHiP experiment the ECN3 hall. Credit: SHiP collab.




*SHiP is a new experiment at the intensity frontier aimed at exploring the hidden sector.*

## SHiP sets a new course in intensity-frontier exploration

SHiP (Search for Hidden Particles) is a newly proposed experiment for CERN's Super Proton ... challenging

have now observed all the particles of the Standard Model, however it is clear that it is not the ultimate theory. Some yet unknown particles or interactions are required to explain a number of observed phenomena in particle physics, astrophysics and cosmology, the so-called beyond-the-Standard Model (BSM) problems, such as dark matter, neutrino masses and oscillations, baryon asymmetry, ion of the universe.
phenomena are well-established observationally, dication about the energy scale of the new physics. of new LHC data collected at √=13 TeV will soon probed the TeV scale for new particles with cou- level. The experimental effort in flavour physics, and

## SHiP sets sail to explore the hidden sector

The experiment is designed to detect very feebly interacting parti... candidate dark-matter particles

19 APRIL, 2024 | By Corinne Pra...

## Green light to build revolutionary new experiment at CERN to search for unknown particles

30 April 2024

...of preparations, CERN has approved a groundbreaking new experiment

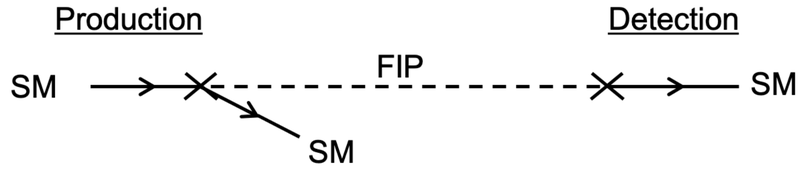
## SHiP collaboration sets course on New Physics

Panos Charitos 26th Jun 2023

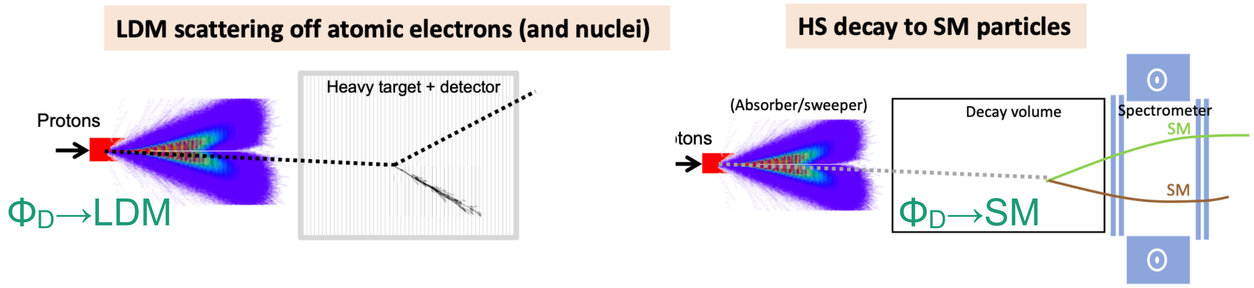
# SHiP, specs

- general-purpose **intensity-frontier** experiment facilitating comprehensive investigation of **hidden sector** of particle physics in the GeV scale, to explore the high-intensity SPS beams of 400 GeV protons in dump mode
  - $4 \times 10^{19}$ protons-on-target (PoT) per year; full physics program 15 years running will yield $6 \times$ **$10^{20}$ PoT**
  - integrated **luminosity** *per year*: SPS > $4 \times 10^{45}$ cm$^{-2}$ *vs* HL-LHC = $10^{42}$ cm$^{-2}$
  - each year: ~$10^{17}$ charm hadrons, ~$10^{12}$ beauty hadrons, ~$10^{5}$ tau leptons, ~$10^{20}$ photons >100 MeV, tau neutrinos
- wide physics program: probe new **FIP** particles, small couplings, GeV scale masses, long lifetimes (cτ: 50-100m), through decay or scattering, along with precision **neutrino** measurements

◉ FIPs produced promptly and form decay of heavy flavour ➥



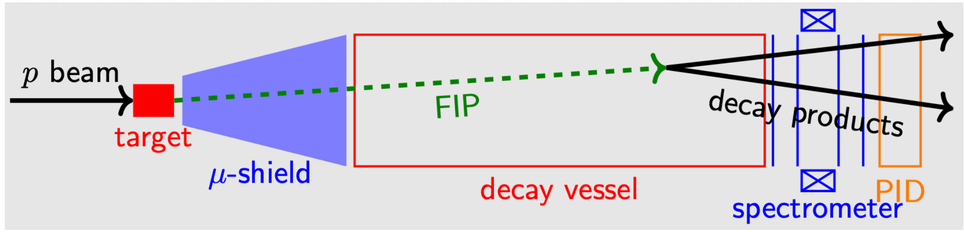

*Two FIP direct-search techniques*

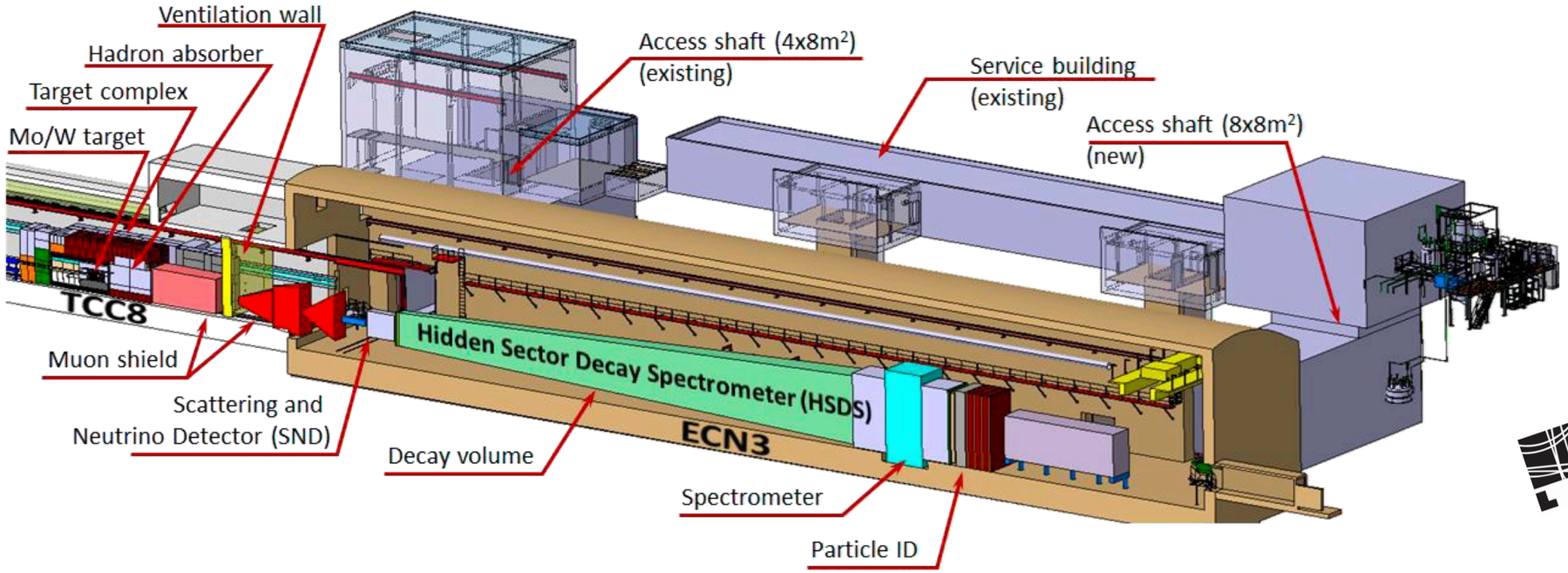


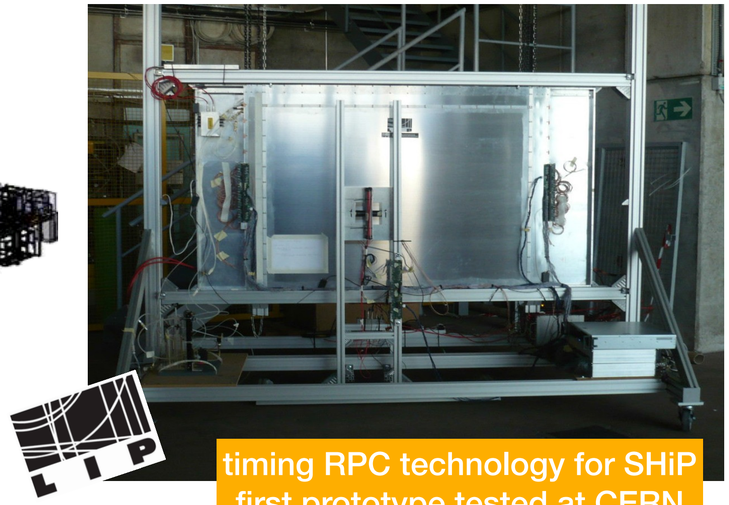

SHiP: dual-platform experiment that combines both

| | Physics model | Final state |
|---|---|---|
| HSDS | HNL, SUSY neutralino | $\ell^{\pm}\pi^{\mp}$, $\ell^{\pm}K^{\mp}$, $\ell^{\pm}\rho^{\mp}(\rho^{\mp} \rightarrow \pi^{\mp}\pi^{0})$ |
| | DP, DS, ALP (fermion coupling), SUSY sgoldstino | $\ell^{+}\ell^{-}$ |
| | DP, DS, ALP (gluon coupling), SUSY sgoldstino | $\pi^{+}\pi^{-}$, $K^{+}K^{-}$ |
| | HNL, SUSY neutralino, axino | $\ell^{+}\ell^{-}\nu$ |
| | ALP (photon coupling), SUSY sgoldstino | $\gamma\gamma$ |
| | SUSY sgoldstino | $\pi^{0}\pi^{0}$ |
| | LDM | Electron, proton, hadronic shower |
| SND | $\nu_\tau$, $\overline{\nu}_\tau$ measurements | $\tau^{\pm}$ |
| | Neutrino-induced charm production ($\nu_e$, $\nu_\mu$, $\nu_\tau$) | $D_s^{\pm}$, $D^{\pm}$, $D^{0}$, $\overline{D^{0}}$, $\Lambda_c^{+}$, $\overline{\Lambda_c}^{-}$ |

# SHiP Detector @ECN3



timing RPC technology for SHiP
first prototype tested at CERN

## Portuguese group responsibilities & involvement:

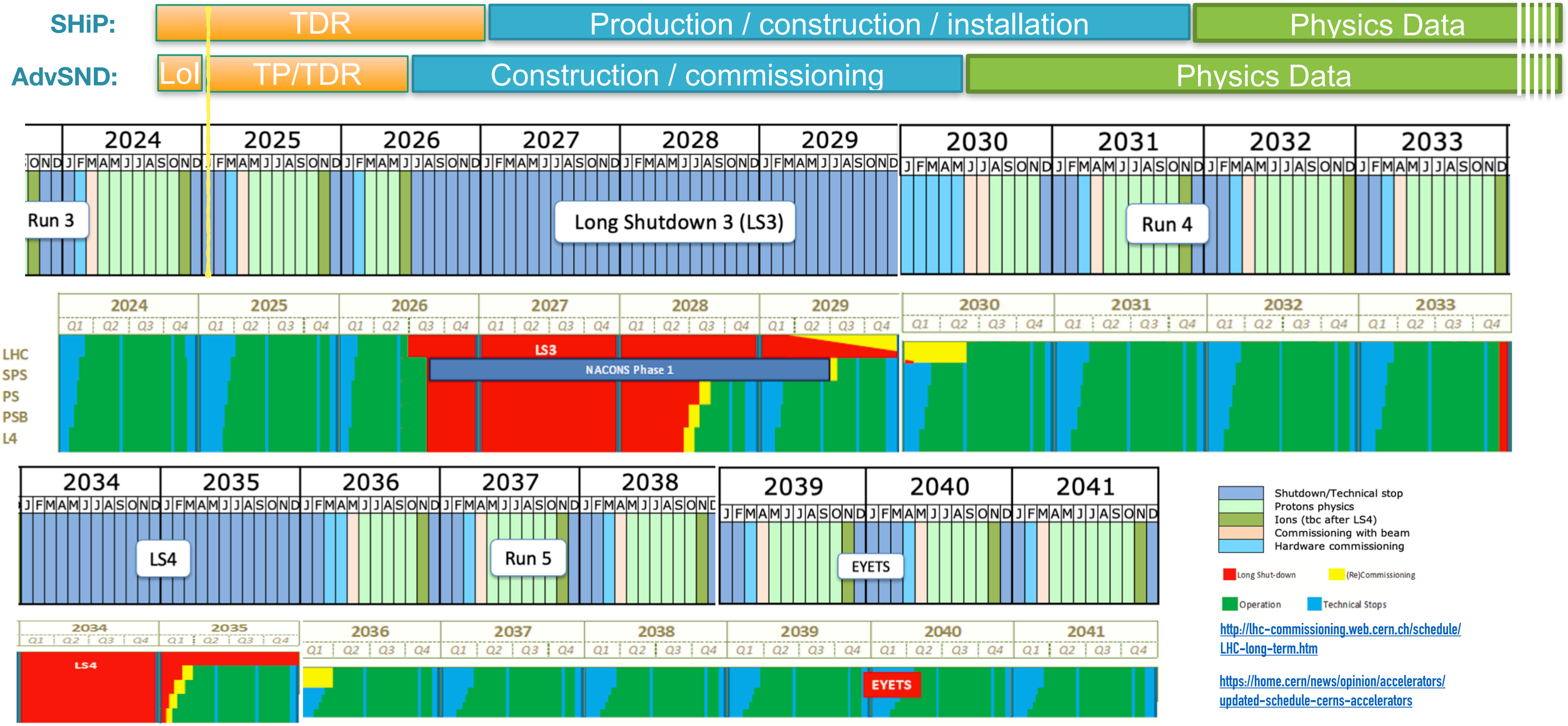
- veto detector (UBT; group responsibility in the SHiP proposal)
- timing detector option with RPC technology
- neutrino detector (SND) option with Silicon technology

➡ R&D in full synergy with SND@LHC upgrade for HL-LHC

sealed RPC chambers operating @LHC

# CERN: long-term schedule

2022-2026 LHC Run3 ATLAS/CMS phase1, SND
2030-2041 HL-LHC ATLAS/CMS phase2, AdvSND
2032-2045 SHiP
2045-2060 (?) FCCee
2070-2095 (?) FCChh




http://lhc-commissioning.web.cern.ch/schedule/LHC-long-term.htm

https://home.cern/news/opinion/accelerators/updated-schedule-cerns-accelerators