SHiP experiment at CERN

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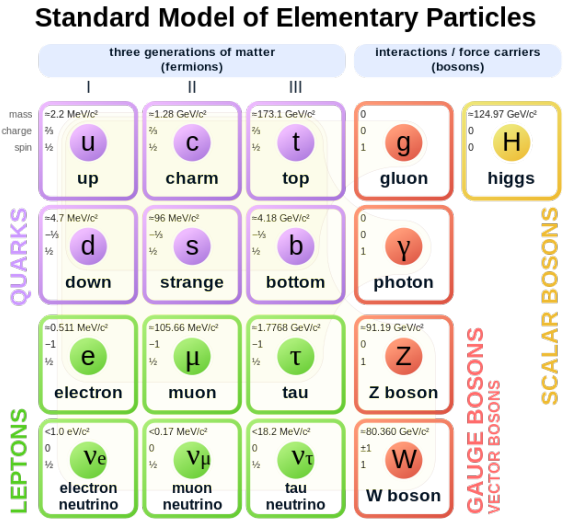
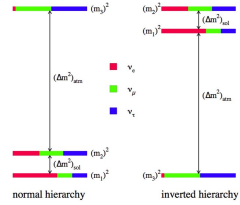
Beyond the Standard Model



Still missing:

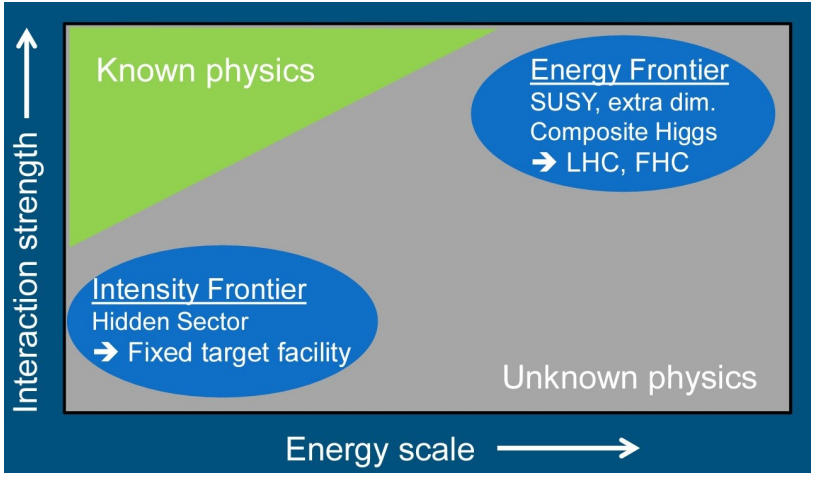
Dark matter

Baryon asymmetry



Neutrino masses

Frontiers in particle physics



New particles may be light but feebly coupled - **feebly interacting particles** (FIPs)

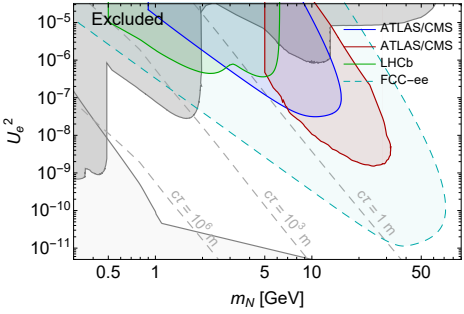
- Scalar portal
- Fermion portal (HNLs)
- Vector portal (Dark photon)
- Axion portal (ALPs)

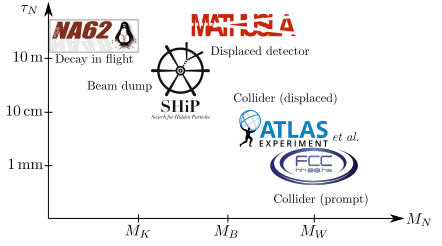
Rich phenomenology!

Intensity frontier at LHC/FCC

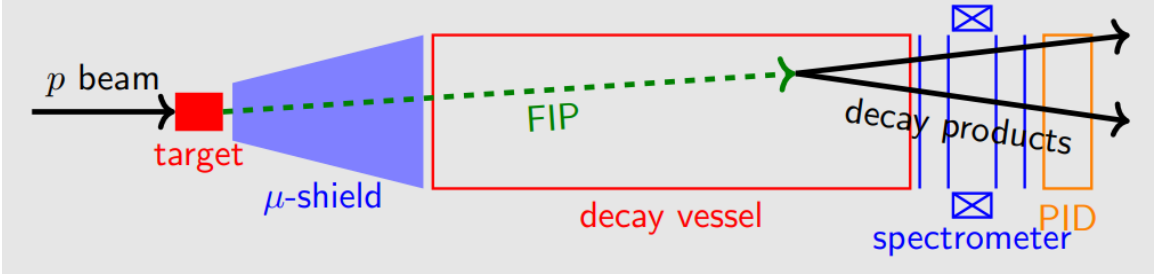
- *Feebly* interacting particles — large intensity of the experiments
- LHC during high luminosity phase and FCC will collect large integrated luminosity – can probe intensity frontier below ~ 100 GeV
- However, FIPs lifetime $\sim 1/m_{\rm FIP}^n$ ($n = 1 - 5$, depending on portal), so light ~ 1 GeV FIPs may have macroscopic decay length and escape the detectors

- LHC/FCC are not suitable for probing NP at GeV scale

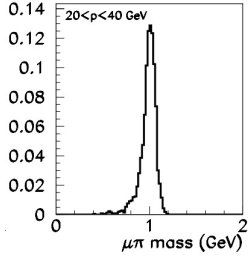




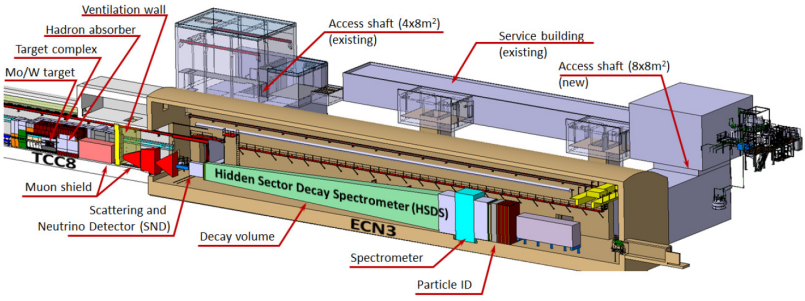
Dedicated intensity frontier experiment: Beam dump facility



1. Beam dump facility (BDF) experiments may search for all new particles regardless of their nature
2. BDF experiments may measure the properties of new particles - mass, spin, their being portal particles or particles from more complicated models
3. $\rightarrow$ potentially we can not only find FIPs, but also **probe their connection to BSM problems**!



The SHiP experiment at CERN



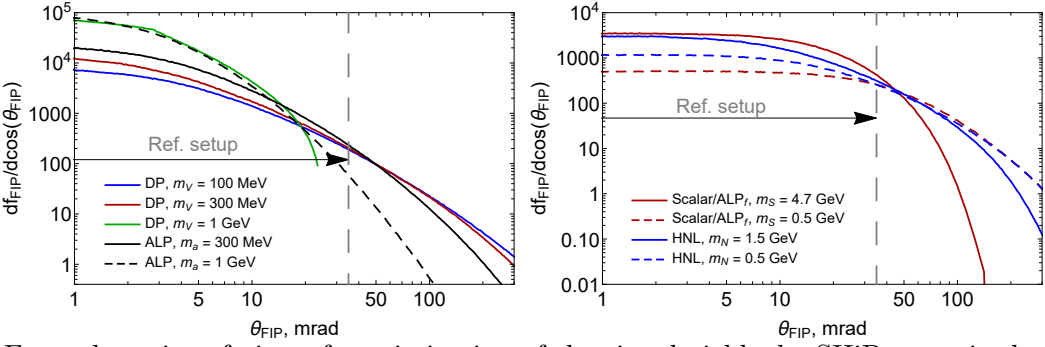
E_p	400 GeV
N_p	$6 \cdot 10^{20}$
N_D	$3 \cdot 10^{18}$
N_B	$2.1 \cdot 10^{14}$
N_τ	$3 \cdot 10^{16}$
$N_{\gamma, E>100\,\mathrm{MeV}}$	$O(10^{21})$

Requirement	Value
Track momentum	$> 1.0\,\mathrm{GeV}/c$
Track pair distance of closest approach	< 1 cm
Track pair vertex position in decay volume	> 5 cm from inner wall
Impact parameter w.r.t. target (fully reconstructed)	< 10 cm
Impact parameter w.r.t. target (partially reconstructed)	< 250 cm

Background source	Expected events
Neutrino DIS	< 0.1 (fully) / < 0.3 (partially)
Muon DIS (factorisation)	$< 6 \times 10^{-4}$
Muon combinatorial	1.2×10^{-2}

2112.01487

SHiP geometry



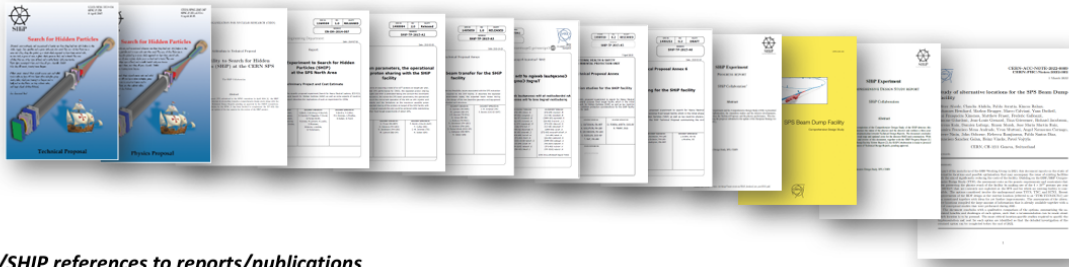
– From the point of view of maximization of the signal yield, the SHiP setup is close to optimal:

- On-axis placement
- Projective decay volume, neither too long nor too short
- Not too far placed

2304.02511

SHiP collaboration

on behalf of the SHiP Collaboration of 38 institutes from 15 countries and CERN



BDF/SHIP references to reports/publications

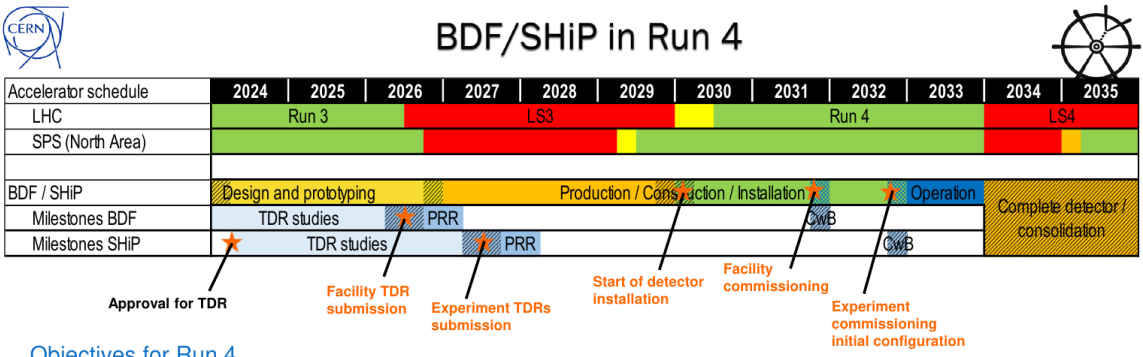
- *17 submitted to SPSC and ESPPSU2020*
- *26 on the facility development*
- *37 on the detector development*
- *11 on physics studies*
- *20 on theory developments dedicated to SHiP*
- *20 PhD thesis, a few more in pipeline*

BDF/SHiP approved by the CERN RB in March 2024

Recent documents:

- ✓ ***Proposal, BDF/SHiP at the ECN3 high-intensity beam facility, CERN-SPSC-2023-033***
- ✓ ***Letter of Intent, BDF/SHiP at the ECN3 high-intensity beam facility, CERN-SPSC-2022-032***

Current status and timeline



Objectives for Run 4

1. Facility commissioning - performance of beam and target systems (low/high intensity)
2. Muon shield commissioning – performance (low/high intensity)
3. Detector commissioning – time/space alignment, performance (low intensity)
4. Background measurements with muon shield off & decay volume under air, including reconstruction performance, tune simulation (low intensity)
5. Physics run (high intensity and nominal spill rate)

Relations to CERN

- The SHiP experiment was approved by CERN in spring 2024
- CERN allocated the first 60 million euro for the development of BDF
- Will be constructed in CERN North area and use SPS as source of protons
- Already working neutrino experiment SND at CERN supported by the SHiP collaboration tests emulsion technologies for the neutrino detector SND@SHiP

General comments to PP strategy document

- **The era of guaranteed discoveries in particle physics is over** – we need to search everywhere within our technological reach
- The beam dump experiments like SHiP form not a narrow research direction but a whole **frontier**. It is relatively simple (comparing to LHC/FCC), but it covers important parameter space that would not be probed by any other experiment
- The fact that SHiP was approved by CERN shows understanding of these points by a larger community

Example statement for the PP strategy document

The recently approved intensity frontier experiment SHiP at CERN has unique capabilities to probe a wide range of models of feebly interacting particles in phenomenologically interesting parameter space which is complementary to collider physics reach and has not been explored before.

Back-up

Sensitivities