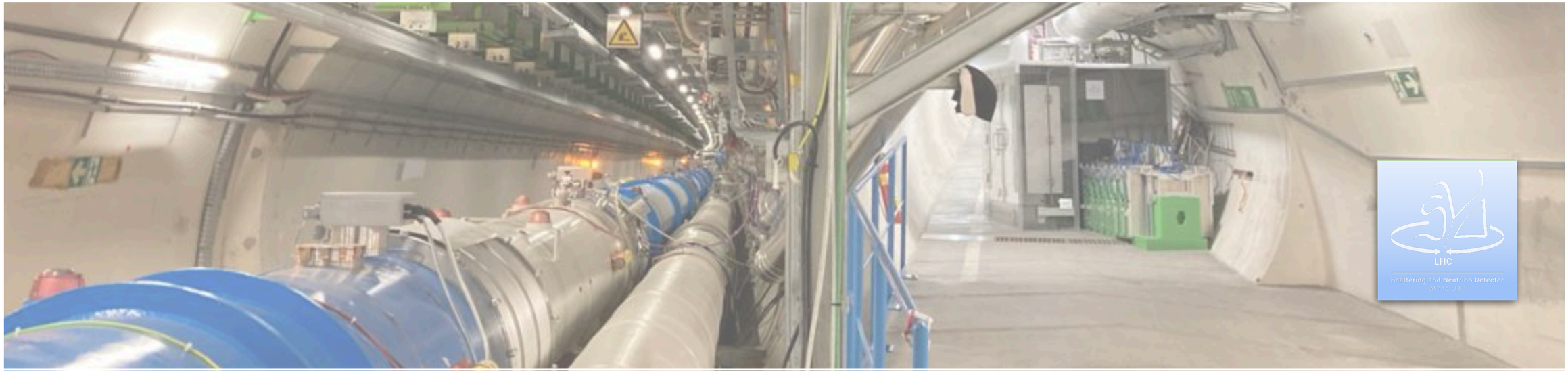
SHiP/SND@LHC

Recent Highlights

Approved 2024

Approved 2021, 1st physics results 2023



Fundação para a Ciência e a Tecnologia
CERN/FIS-INS/0028/2021

The LIP SHiP/SND@LHC Group

A.Blanco, P.Bordalo, T.Camporesi, P.Fonte, N.Leonardo, L.Lopes, S.Ramos, J.Saraiva, H.Santos, G.Soares, C.Vilela

Interns: B.Candeias, P.Figueiredo, A.Mendonça, B.Semião, P.Teigão

LIP Advisory Committee

Lisbon, April 19th 2024

(contact: nuno@cern.ch)

Physics

Physics — VIEWPOINT

The Dawn of Collider Neutrino Physics

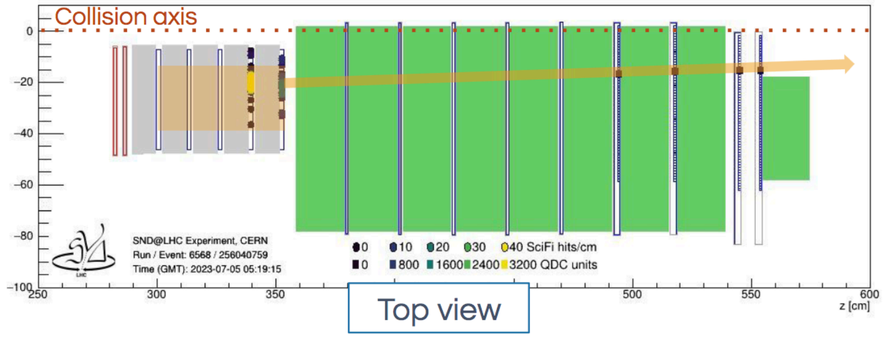
Editors' Suggestion | Open Access

PRL'2023 observation

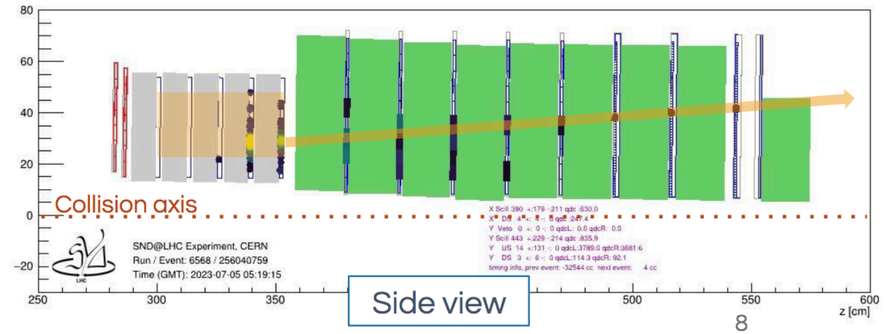
Observation of Collider Muon Neutrinos with the SND@LHC Experiment

R. Albanese *et al.* (SND@LHC Collaboration)
Phys. Rev. Lett. **131**, 031802 – Published 19 July 2023

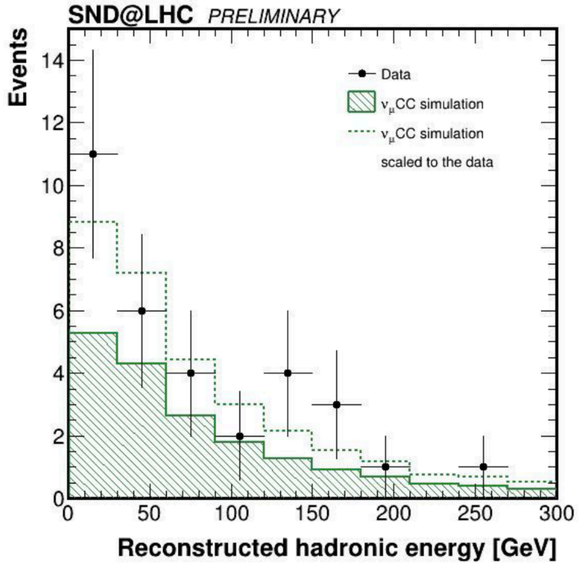
C.Vilela: the paper's corresponding author;
appointed (2023) Deputy **Physics Coordinator**



Top view



Side view



Updated ν_μ CC analysis

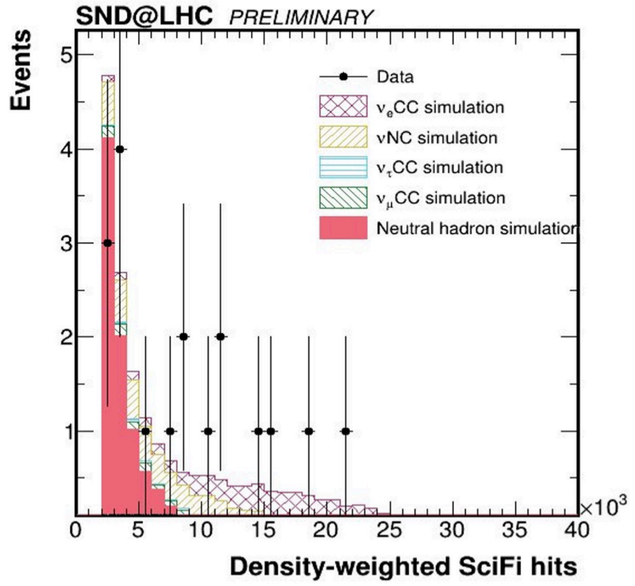
- 2022 + 2023 data
- increased fiducial region
- **hadronic energy measurement**

Test-beam campaign (fall 2023)
↪ allowed **energy calibration**

Moriond'2024 updates

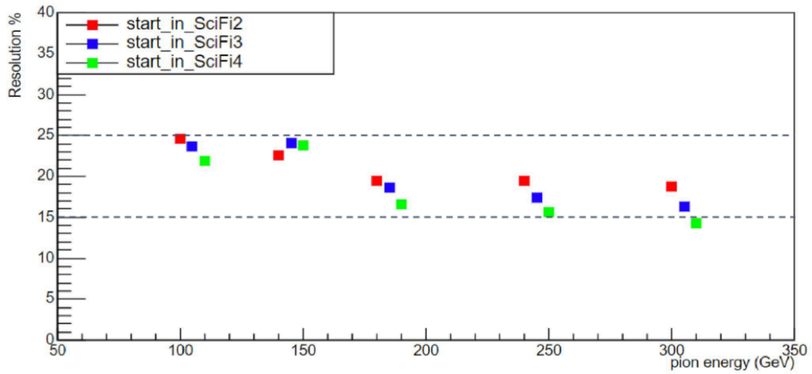
Search for shower-like neutrino events

(signal = ν_e CC + NC)



Number of events observed: 6
Observation significance: 5σ

Operations & sRPC installation @LHC



↪ LIP involved in building **test-beam** apparatus, data taking, and energy calibration analysis

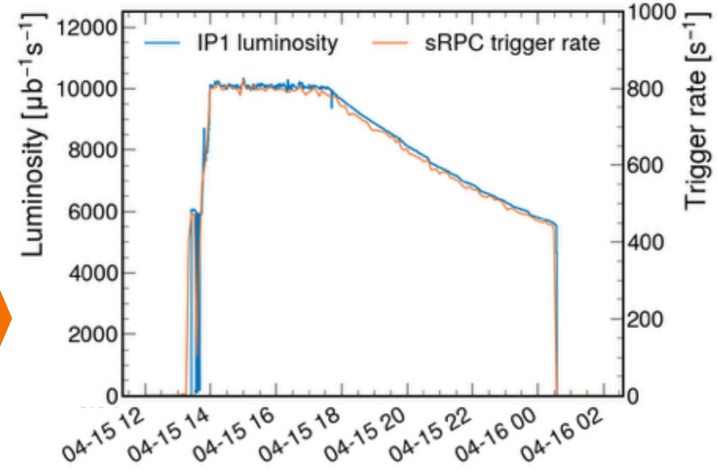
Test beam for HCAL calibration (Summer 2023)

- produced exact replica of hadron calorimeter
- very successful calibration campaign
- calibrated calorimeter response

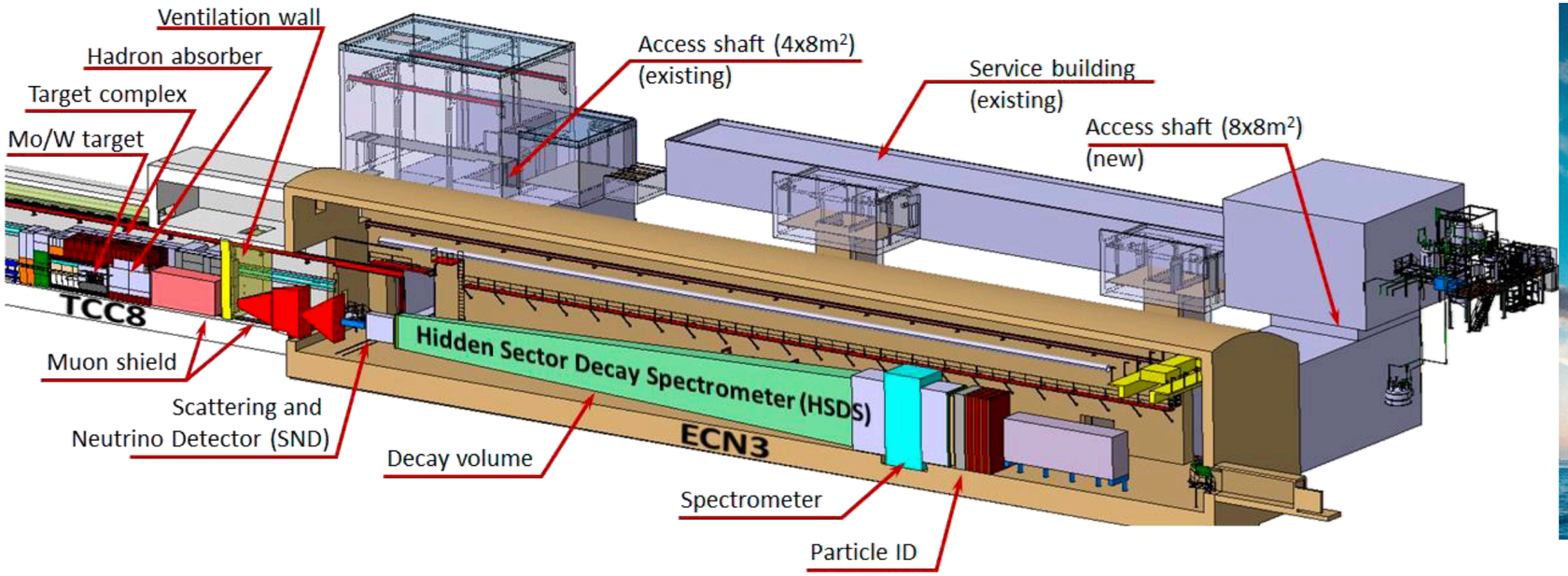
Installation of sealed-RPC telescope (Spring 2024)

- detector based on novel, LIP-designed technology
- deployed in front of SND@LHC: measure muon flux
- demonstrate new technology in LHC environment

↪ new LIP detector ***sees*** first 2024 LHC collisions!



SHiP experiment approved (2024)



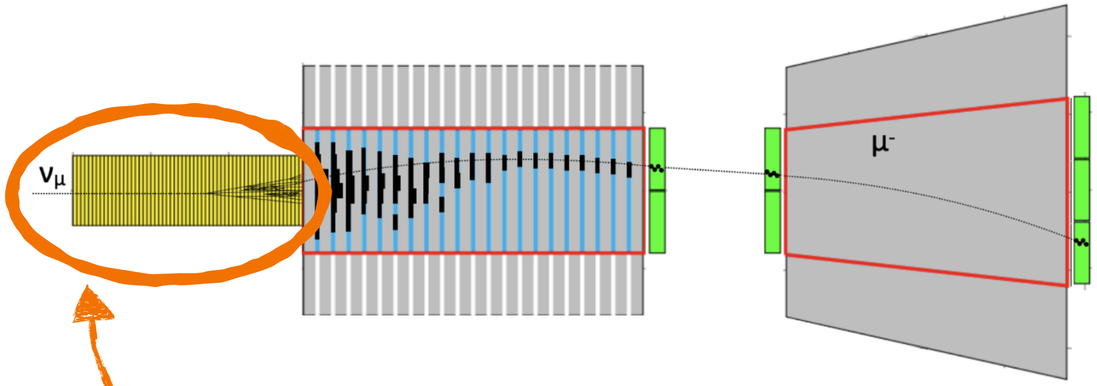
SHiP
Search for Hidden Particles

SHiP Collaboration Meeting (this week at CERN) — 28th meeting — 1st of TDR phase

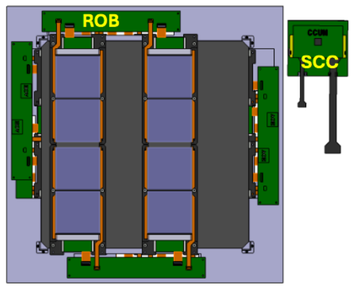
Upgrades: AdvSND & SHiP

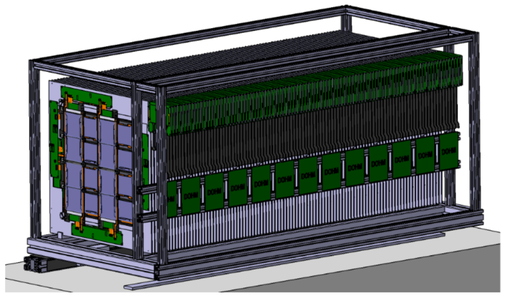
- AdvSND LoI just submitted
- SHiP experiment just approved

AdvSND proposal for HL-LHC just submitted (LoI)

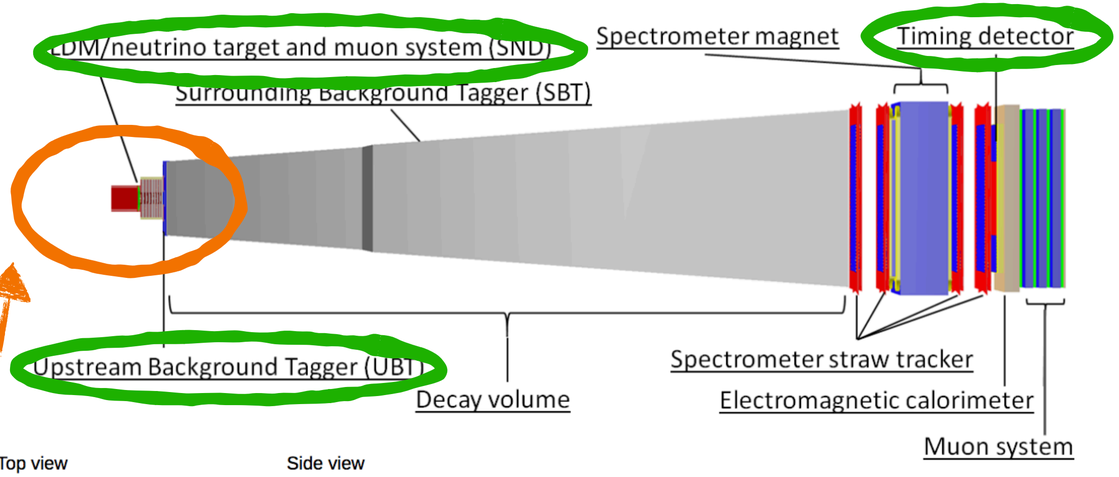


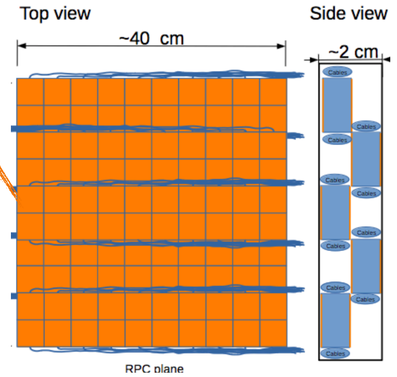
Target tracker

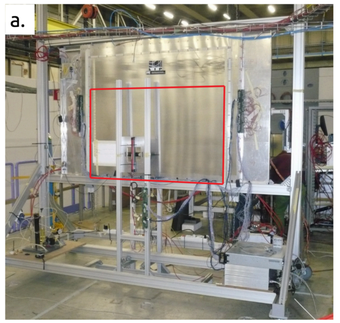




The SHiP experiment has been just approved (LoI)







Precision timing RPCs

A. Blanco et al
JINST 15 (2020) C10017

Silicon-based target tracker

- to replace emulsion-based tracker at HL-LHC
- repurpose current CMS TOB modules
- R&D starting for **AdvSND**, later **SHiP**

Precision-timing RPCs

- for timing/trigger, embedded in Silicon tracker, for **AdvSND**
- for background vetoing (and timing), for **SHiP**
- built-up from SHiP timing prototype + sRPC at SND@LHC

S.W.O.T. & long-term planning

Strengths

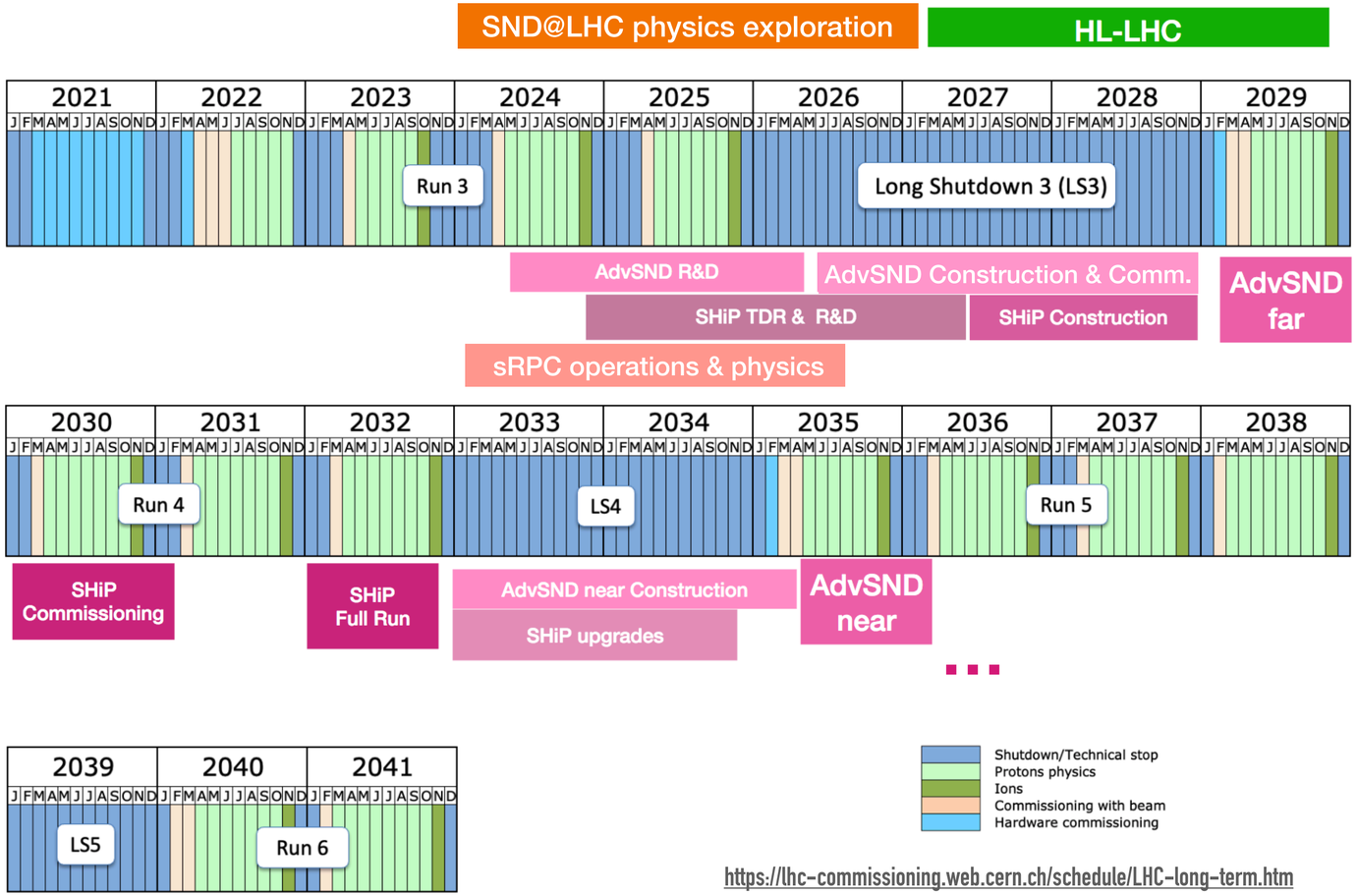
- team formed of **consolidated researchers**
- strongly integrated in the collaboration
- leadership roles in **Detector** *and* **Physics**
- projects are attractive *also* to students

Weaknesses/Threats

- past funding *vs* achievement/responsibilities
- executed a first FCT project (40k€, 2022-2024), was important ***seed*** for establishing the new group
- responsibilities undertaken by the group require **increased funding**: pay collaboration dues; detector construction & operations & upgrade R&D; support researcher's missions; award studentships

Opportunities

- Collecting unique datasets, **extend LHC physics** reach;
- Dawn of **new era: neutrino physics** at particle colliders;
- **HL-LHC upgrade** offers exciting opportunities for LIP;
- "*SHiP/ECN3, ~~if approved,~~ will be a **major player** in experimental particle physics. Physics case drawing an **explosion of interest**, potential to bring significant **breakthroughs** to the field.*" (updated, from the report)



LIP Research Line Strategy Discussion: Dark Matter & Neutrino
Nov. 20th, 2023, https://indico.lip.pt/event/1640/

Outreach

latest all

New LIP detector installed at the LHC / 2024-03-19

A muon telescope based on the novel sealed RPC technology has been installed in front of the target of the SND@LHC experiment at CERN

READ MORE >

Coordinating the analysis of SND@LHC data / 2023-12-22

Cristóvão Vilela, member of the LIP group in SND@LHC, has just been appointed "Deputy Physics Coordinator" of the experiment, which has been analysing data since 2022 at CERN.

READ MORE >

SND@LHC: beam test at CERN / 2023-08-30

From 2 to 16 August, the SND@LHC collaboration was at CERN's North Area calibrating the detector, and the LIP team had a central role. This is a fundamental step towards measuring the energy of the first neutrinos detected at the LHC.

READ MORE >

SND@LHC published the first observation of neutrinos produced in particle collisions at an accelerator / 2023-07-27

The SND@LHC and FASER collaborations just published in Physical Review Letters their first results, from which emerges the first observation of high-energy muonic neutrinos produced at the LHC. SND@LHC has a strong involvement of LIP, who led the data analysis.

READ MORE >

LIP News

News from the March CERN Council Session

27 March, 2024

By Fabiola Gianotti

Fabiola Gianotti is the Director-General of CERN.

During presentations of the scientific programme, the Council delegates were informed that **the SHiP experiment,** which will search for feebly interacting particles, **has been chosen to run in the North Area's ECN3 hall** using high-intensity proton beams from the SPS. This decision concluded a **process that took more than a year**, involving the Physics Beyond Colliders study group and the SPS and PS Experiments Committee (SPSC).

LIP will be hosting the 2024 SND@LHC Collaboration Week in June, 11-14, in Lisbon

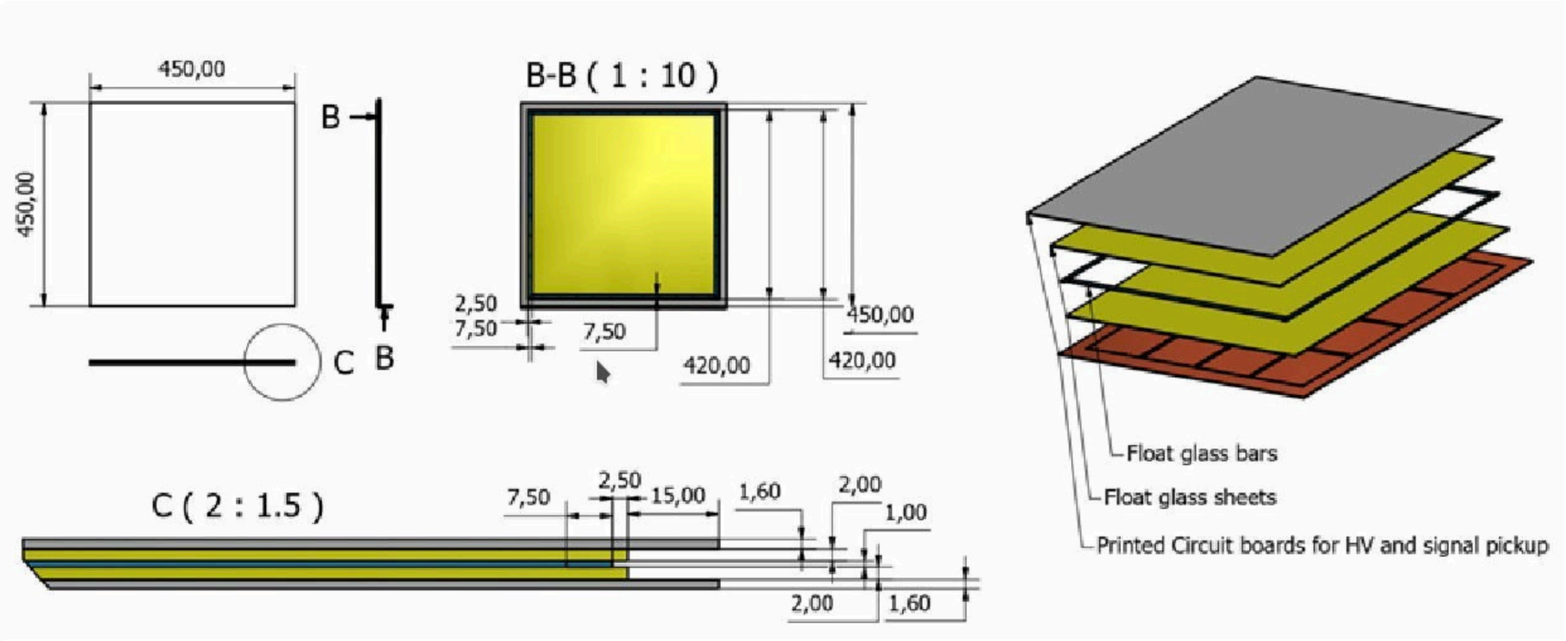
LIP event page

Thank you.

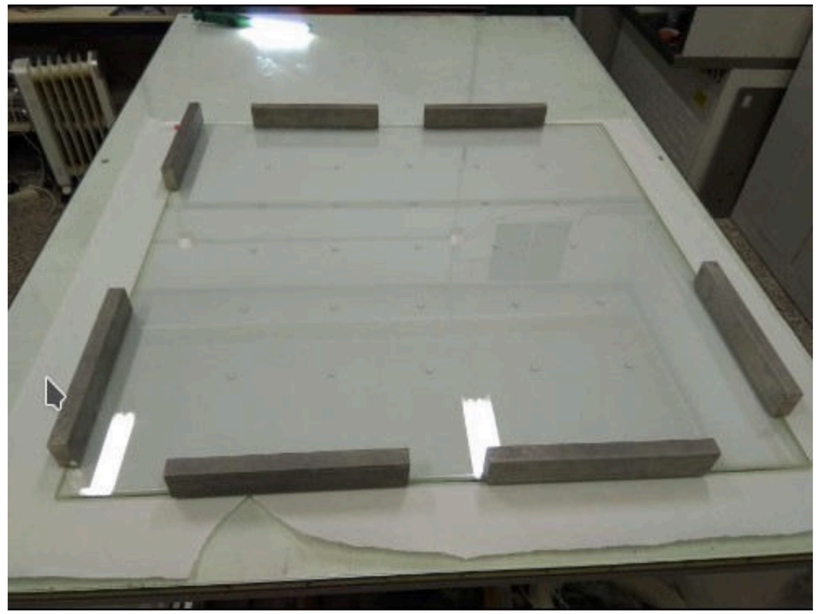
Detector Technology. Sealed RPCs (sRPCs)

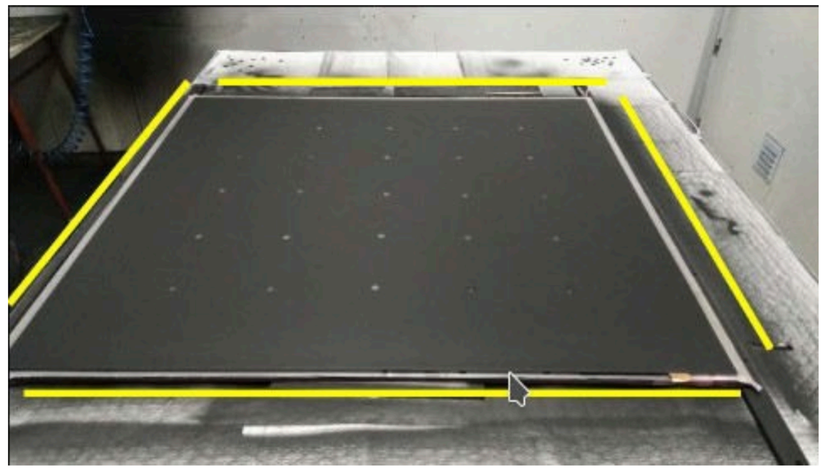
Multi-gap RPC (2x1mm gap) with permanently sealed gaps

- **There is no gas flux on the detector !!!**
- It is just filled and sealed < 100 gr/m²



Schematic design





Real device 1x1 m²

L. Lopes et al 2020 JINST 15 C11009

10.1088/1748-0221/15/11/C11009

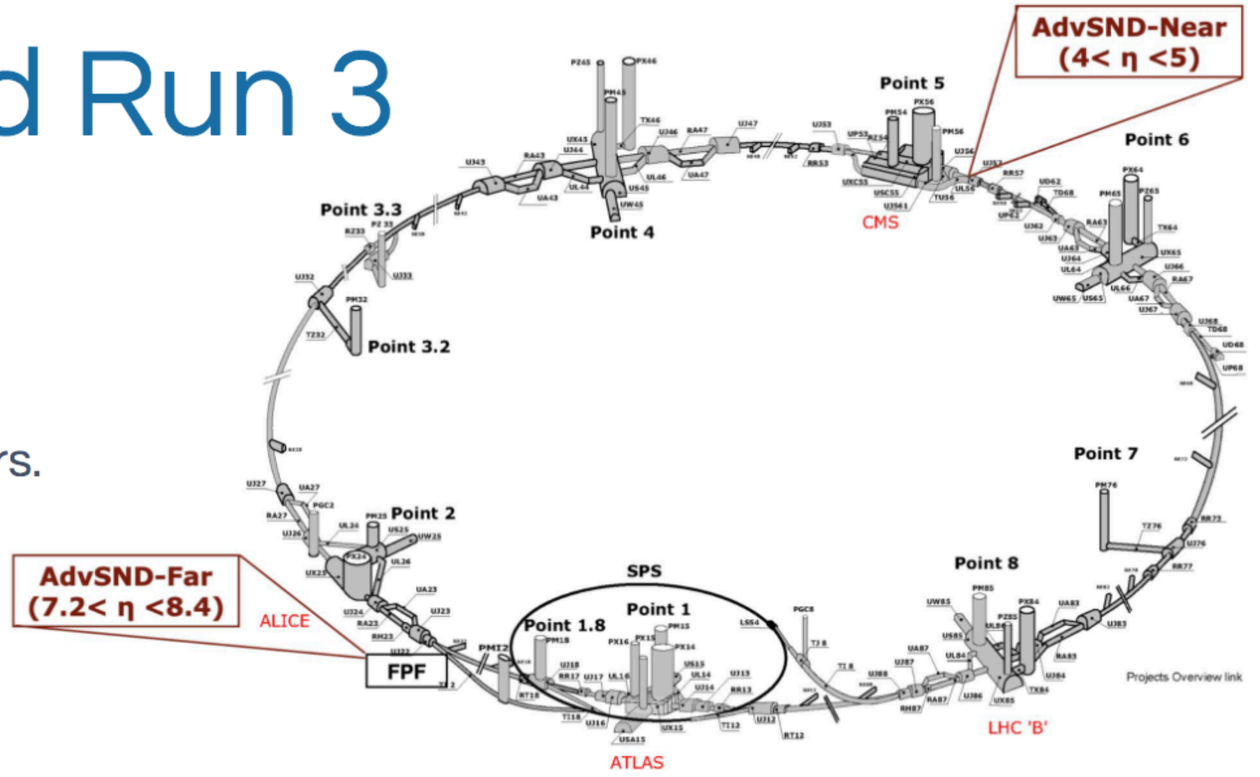
Upgrades beyond Run 3

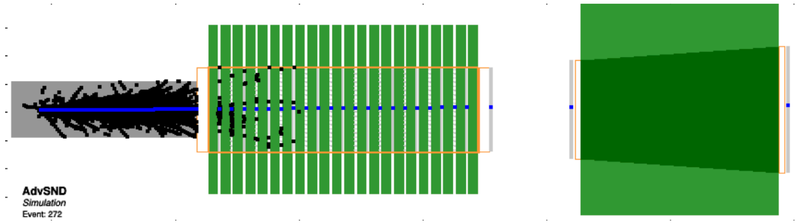
Run 4

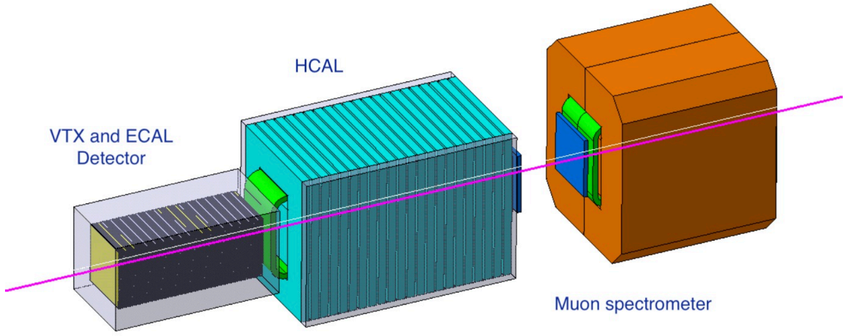
- Electronic **vertex detector**.
  - Si options under consideration.
- Iron-core **muon spectrometer**.
- Improved **hadron calorimeter** and **timing** detectors.

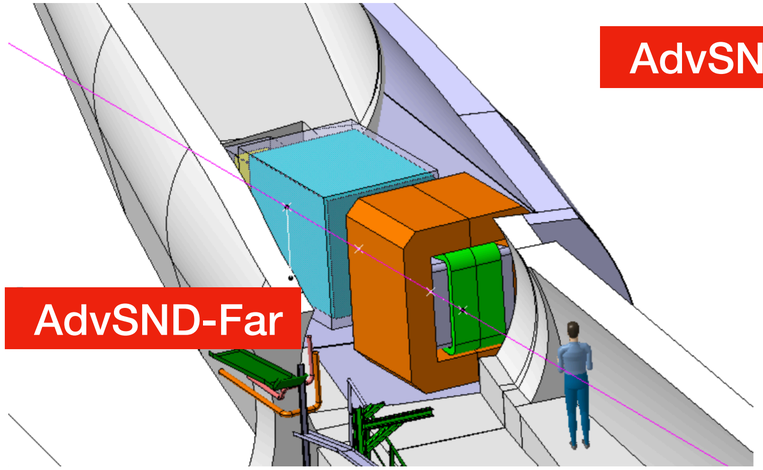
Beyond run 4

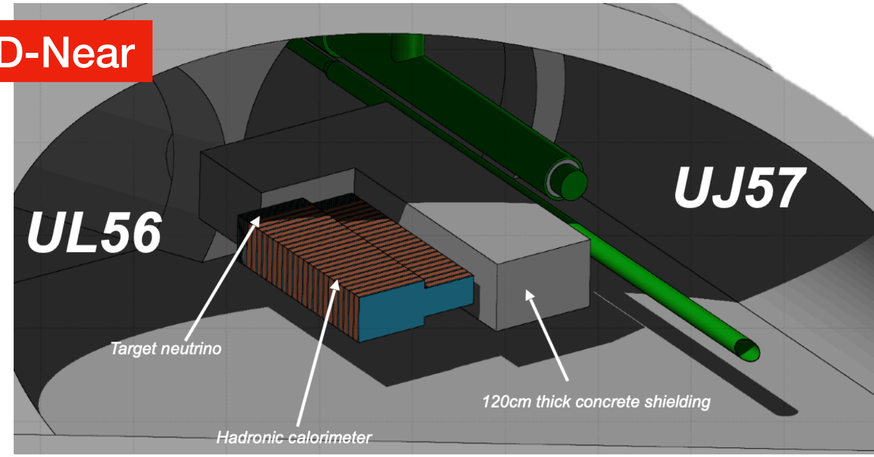
- **Near detector** at lower η to constrain systematic uncertainties in addition to **far detector** in the same η range as the current detector.







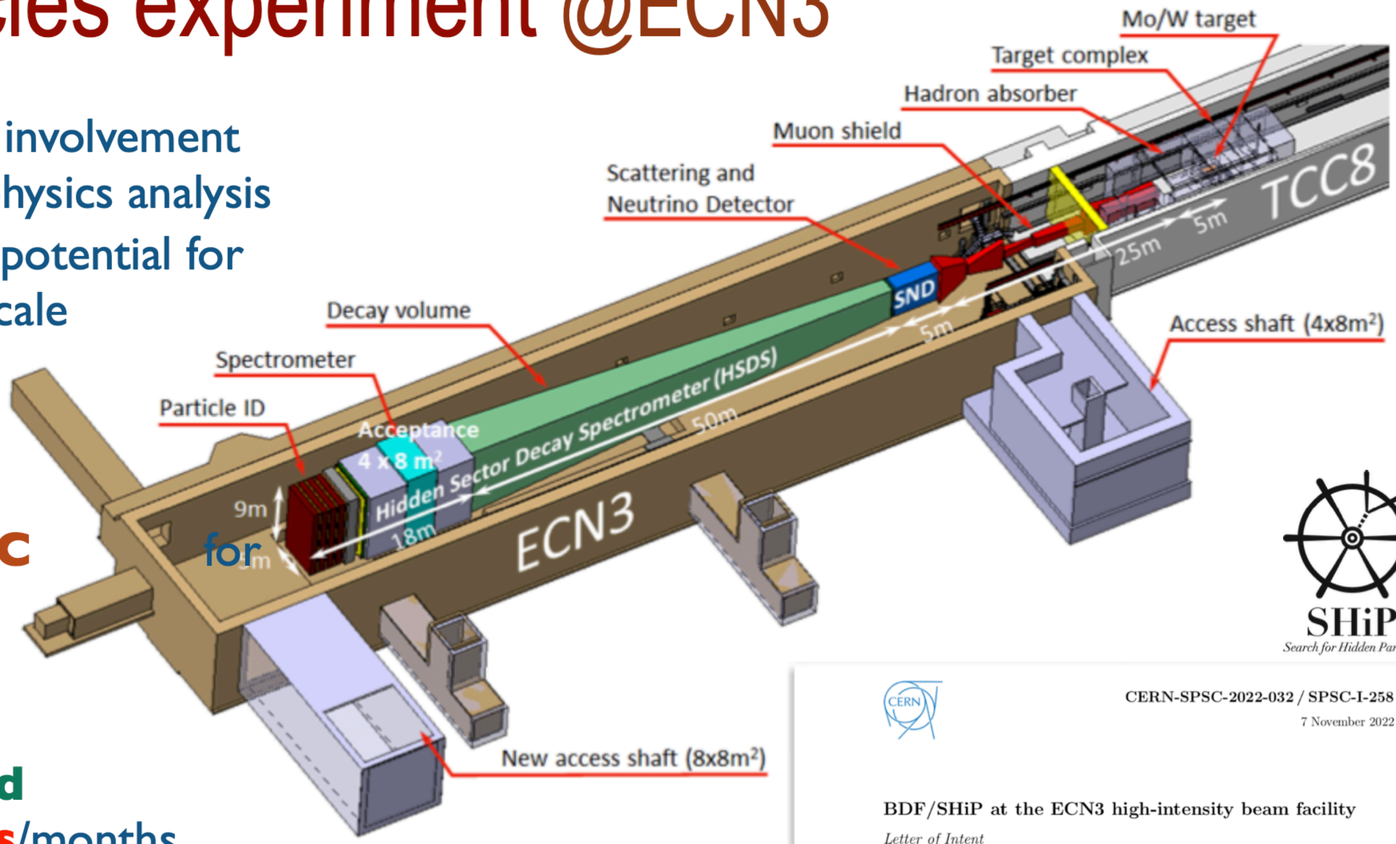




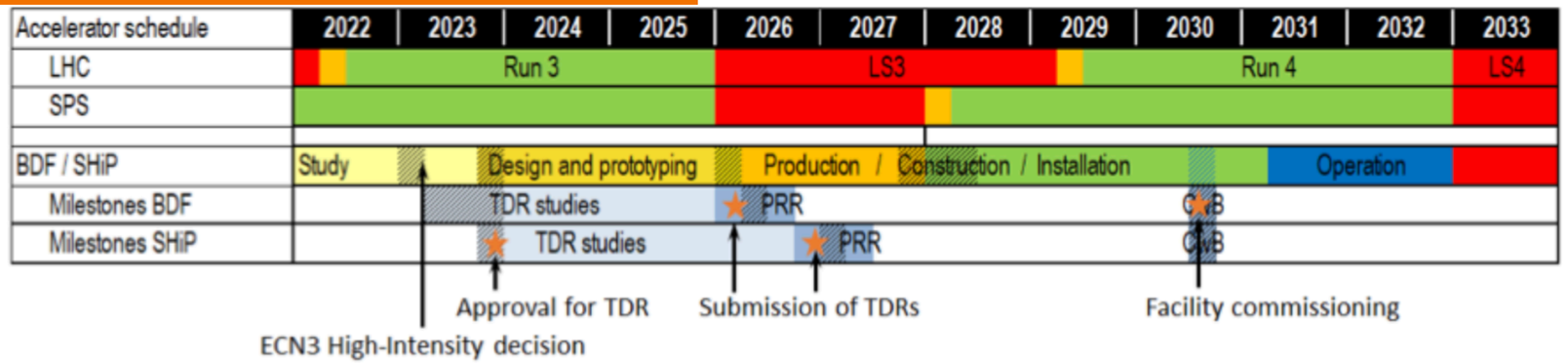
Search for Hidden Particles experiment @ECN3

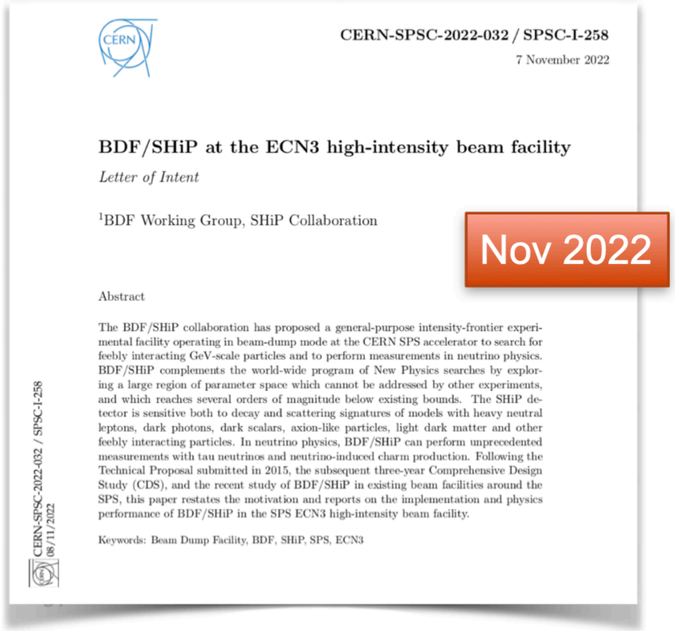
- **LIP is a proponent of SHiP**, with direct involvement in the **Timing + Veto detectors** and in physics analysis
- it shows **leading sensitivity** and discover potential for broad hidden sector scenarios in GeV mass scale
- **Detector re-optimised for ECN3** existing location at SPS at CERN
- Reducing cost, maintaining physics potential
- **Favourable recommendation by SPSC** for the intensity upgrade at ECN3 **(March 2023)**
- SHiP/BDF along with SHADOWS+HiKE submitted proposals for installation at ECN3
- **Currently proposals being scrutinised** and iterated towards a decision **next weeks**/months

➥ SHiP selected by CERN, March 2024



SHiP
Search for Hidden Particles





CERN-SPSC-2022-032 / SPSC-I-258
7 November 2022

BDF/SHiP at the ECN3 high-intensity beam facility

Letter of Intent

[1]BDF Working Group, SHiP Collaboration

Nov 2022

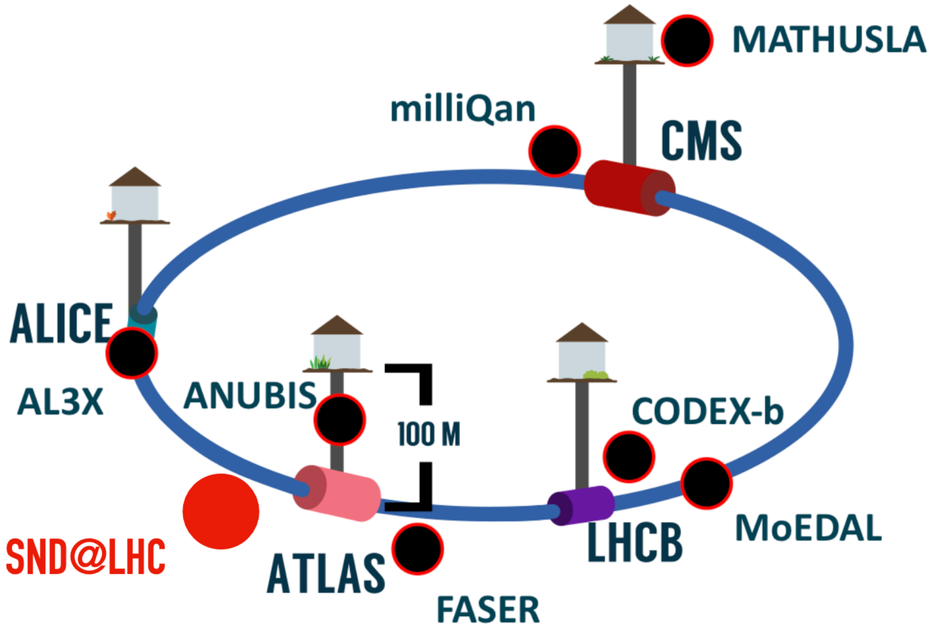
Abstract

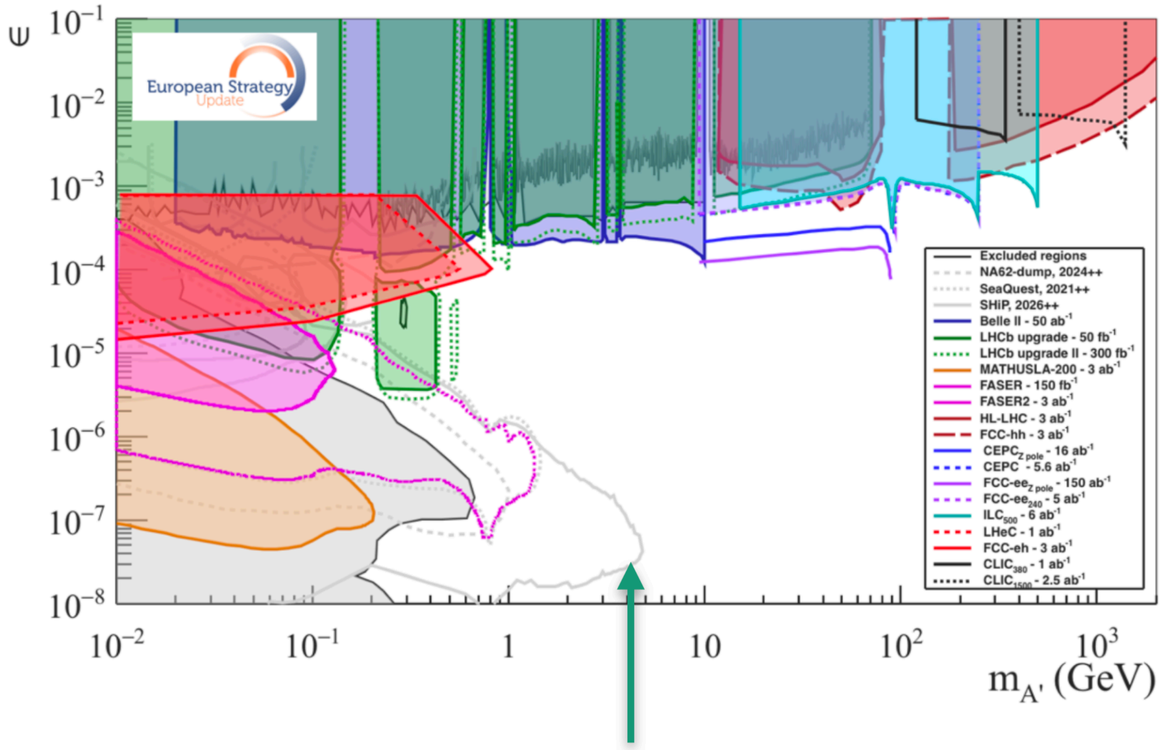
The BDF/SHiP collaboration has proposed a general-purpose intensity-frontier experimental facility operating in beam-dump mode at the CERN SPS accelerator to search for feebly interacting GeV-scale particles and to perform measurements in neutrino physics. BDF/SHiP complements the world-wide program of New Physics searches by exploring a large region of parameter space which cannot be addressed by other experiments, and which reaches several orders of magnitude below existing bounds. The SHiP detector is sensitive both to decay and scattering signatures of models with heavy neutral leptons, dark photons, dark scalars, axion-like particles, light dark matter and other feebly interacting particles. In neutrino physics, BDF/SHiP can perform unprecedented measurements with tau neutrinos and neutrino-induced charm production. Following the Technical Proposal submitted in 2015, the subsequent three-year Comprehensive Design Study (CDS), and the recent study of BDF/SHiP in existing beam facilities around the SPS, this paper restates the motivation and reports on the implementation and physics performance of BDF/SHiP in the SPS ECN3 high-intensity beam facility.

Keywords: Beam Dump Facility, BDF, SHiP, SPS, ECN3

CERN-SPSC-2022-032 / SPSC-I-258
08/11/2022

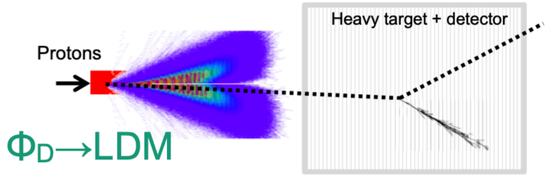
Searching for FIPs : Feebly Interacting Particles



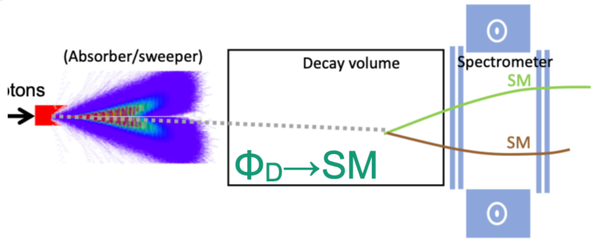


Two FIP direct-search techniques

LDM scattering off atomic electrons (and nuclei)



HS decay to SM particles



SHiP: dual-platform experiment that combines both

- **SHiP is a next-generation experiment** for **FIP** searches and ν_τ measurements at **SPS**
- general-purpose **intensity-frontier** experiment facilitating comprehensive investigation of the **hidden sector** of particle physics in GeV scale

Neutrinos & FIPs

SND @LHC

AdvSND-far @HL-LHC

AdvSND-near @HL-LHC

SHiP

SND@LHC (DPMJET+FLUKA)

Flavour	ν in acceptance All	ν in acceptance hardQCD: $c\bar{c}$	CC DIS All	CC DIS hardQCD: $c\bar{c}$
$\nu_\mu + \bar{\nu}_\mu$	5.6×10^{12}	5.6×10^{11}	1270	360
$\nu_e + \bar{\nu}_e$	7.2×10^{11}	5.2×10^{11}	390	350
$\nu_\tau + \bar{\nu}_\tau$	5.1×10^{10}	5.1×10^{10}	30	30
Tot	6.4×10^{12}	1.1×10^{12}	1690	740

AdvSND-Far (DPMJET+FLUKA)

Flavour	ν in acceptance All	ν in acceptance hardQCD: $c\bar{c}$	CC DIS All	CC DIS hardQCD: $c\bar{c}$
$\nu_\mu + \bar{\nu}_\mu$	1.3×10^{14}	1.4×10^{13}	73.5×10^{3}	21.4×10^{3}
$\nu_e + \bar{\nu}_e$	2.0×10^{13}	1.4×10^{13}	25.2×10^{3}	21.5×10^{3}
$\nu_\tau + \bar{\nu}_\tau$	1.4×10^{12}	1.4×10^{12}	1.1×10^{3}	1.1×10^{3}
Tot	1.5×10^{14}	2.9×10^{13}	1.0×10^{5}	4.4×10^{4}

AdvSND-Near (PYTHIA8)

Flavour	ν in acceptance hardQCD: $c\bar{c}$	ν in acceptance hardQCD: $b\bar{b}$	CC DIS hardQCD: $c\bar{c}$	CC DIS hardQCD: $b\bar{b}$
$\nu_\mu + \bar{\nu}_\mu$	1.1×10^{13}	1.7×10^{12}	1150	230
$\nu_e + \bar{\nu}_e$	1.2×10^{13}	1.8×10^{12}	1200	230
$\nu_\tau + \bar{\nu}_\tau$	1.5×10^{12}	6.2×10^{11}	90	45
Tot	2.9×10^{13}		2.9×10^{3}	

	CC DIS interactions	CC DIS w. charm prod.
N_{ν_e}	8.6×10^{5}	5.1×10^{4}
N_{ν_μ}	2.4×10^{6}	1.1×10^{5}
N_{ν_τ}	2.8×10^{4}	1.5×10^{3}
$N_{\bar{\nu}_e}$	1.9×10^{5}	9.8×10^{3}
$N_{\bar{\nu}_\mu}$	5.5×10^{5}	2.2×10^{4}
$N_{\bar{\nu}_\tau}$	1.9×10^{4}	1.1×10^{3}