Neutrino and hidden sector physics at CERN:

ongoing ν program and the SHiP experiment

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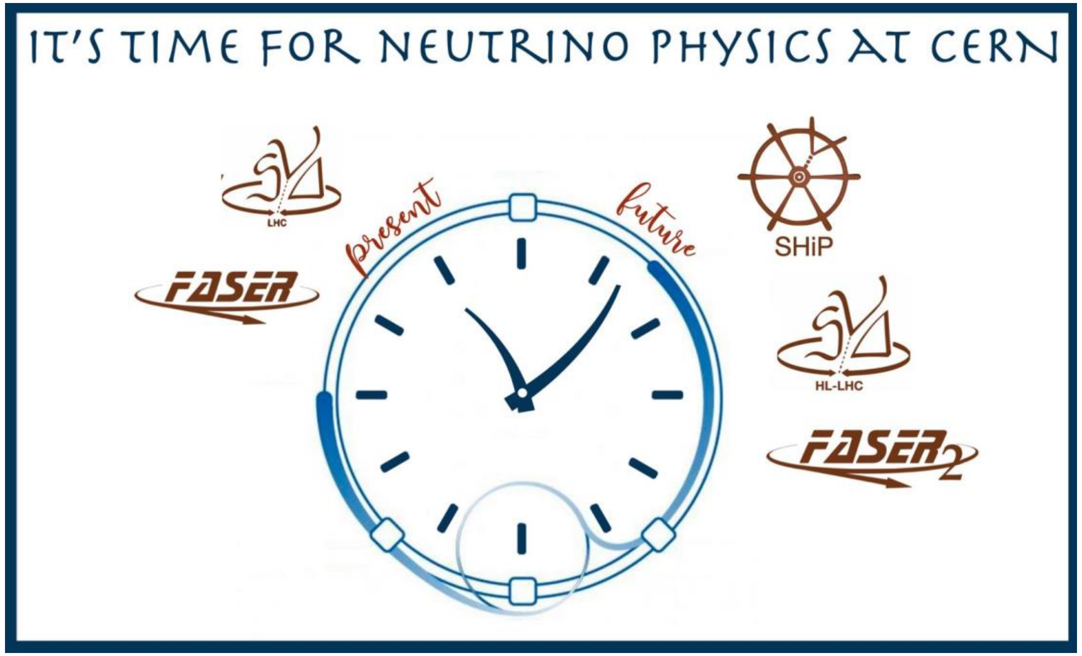


- *SND@LHC: taking data and studying neutrinos at the LHC*
- *The Beam Dump Facility and the SHiP experiment at the SPS*

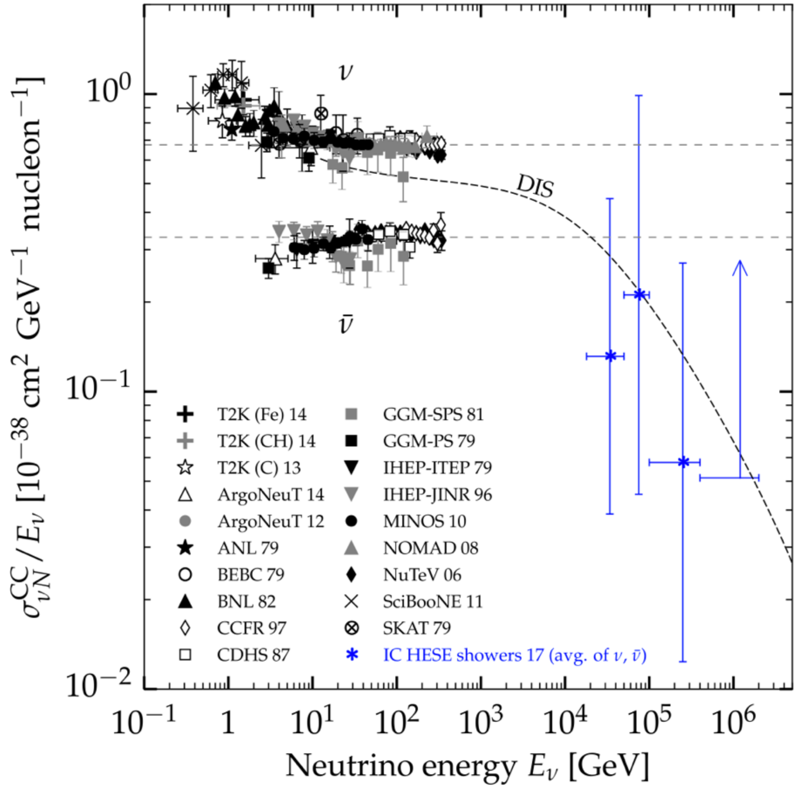
Flavour changing and conserving processes, Anacapri, October 1st 2025

Neutrino physics at the LHC: motivation

- A. De Rujula and R. Ruckl, Neutrino and muon physics in the collider mode of future accelerators, CERN-TH-3892/84
- Klaus Winter, 1990, observing tau neutrinos at the LHC
- F. Vannucci, 1993, neutrino physics at the LHC
- http://arxiv.org/abs/1804.04413 April 12th 2018, First paper on feasibility of studying neutrinos at LHC

LHC
Scattering and Neutrino Detector at the LHC

PRL 122 (2019) 041101



OPEN ACCESS
IOP Publishing
Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. **46** (2019) 115008 (19pp)
https://doi.org/10.1088/1361-6471/ab3f7c

Physics potential of an experiment using LHC neutrinos

N Beni[1], M Brucoli[2], S Buontempo[5], V Cafaro[4], G M Dallavalle[4,8], S Danzeca[2], G De Lellis[2,3,5], A Di Crescenzo[3,5], V Giordano[4], C Guandalini[4], D Lazic[6], S Lo Meo[7], F L Navarria[4] and Z Szillasi[1,2]

Eur. Phys. J. C (2020) 80:61
https://doi.org/10.1140/epjc/s10052-020-7631-5
THE EUROPEAN PHYSICAL JOURNAL C
Check for updates
Regular Article - Experimental Physics

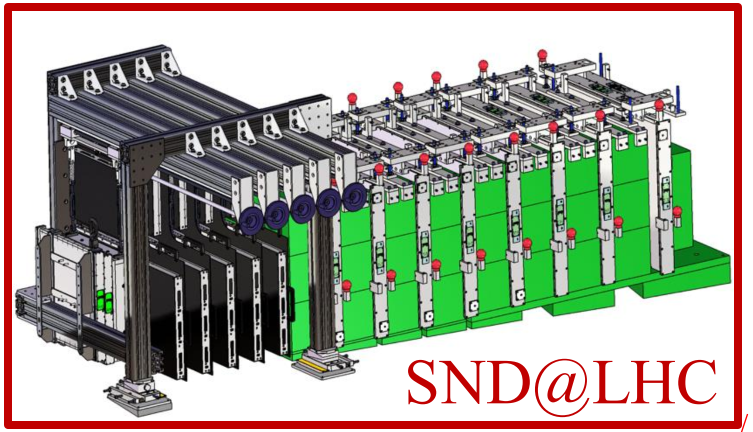
Detecting and studying high-energy collider neutrinos with FASER at the LHC

FASER Collaboration

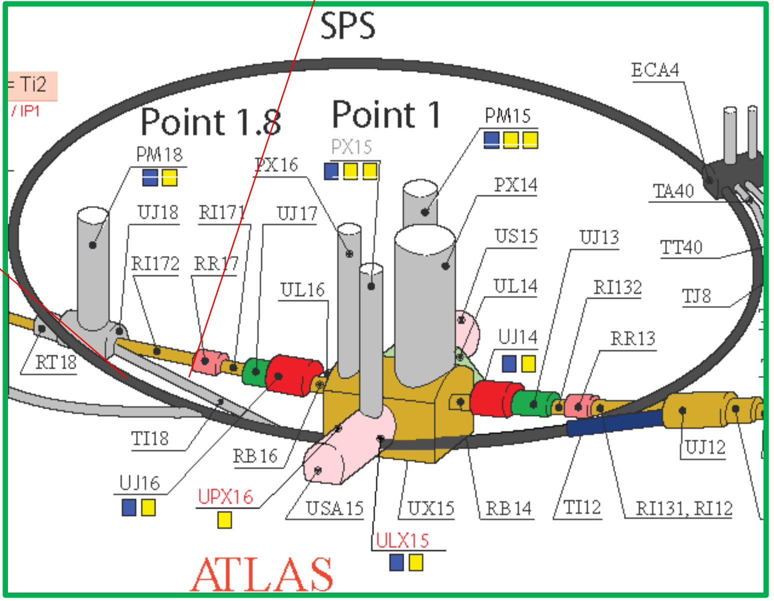
CERN is unique in providing energetic **ν** (from LHC) and measure pp → **ν**X in an unexplored domain

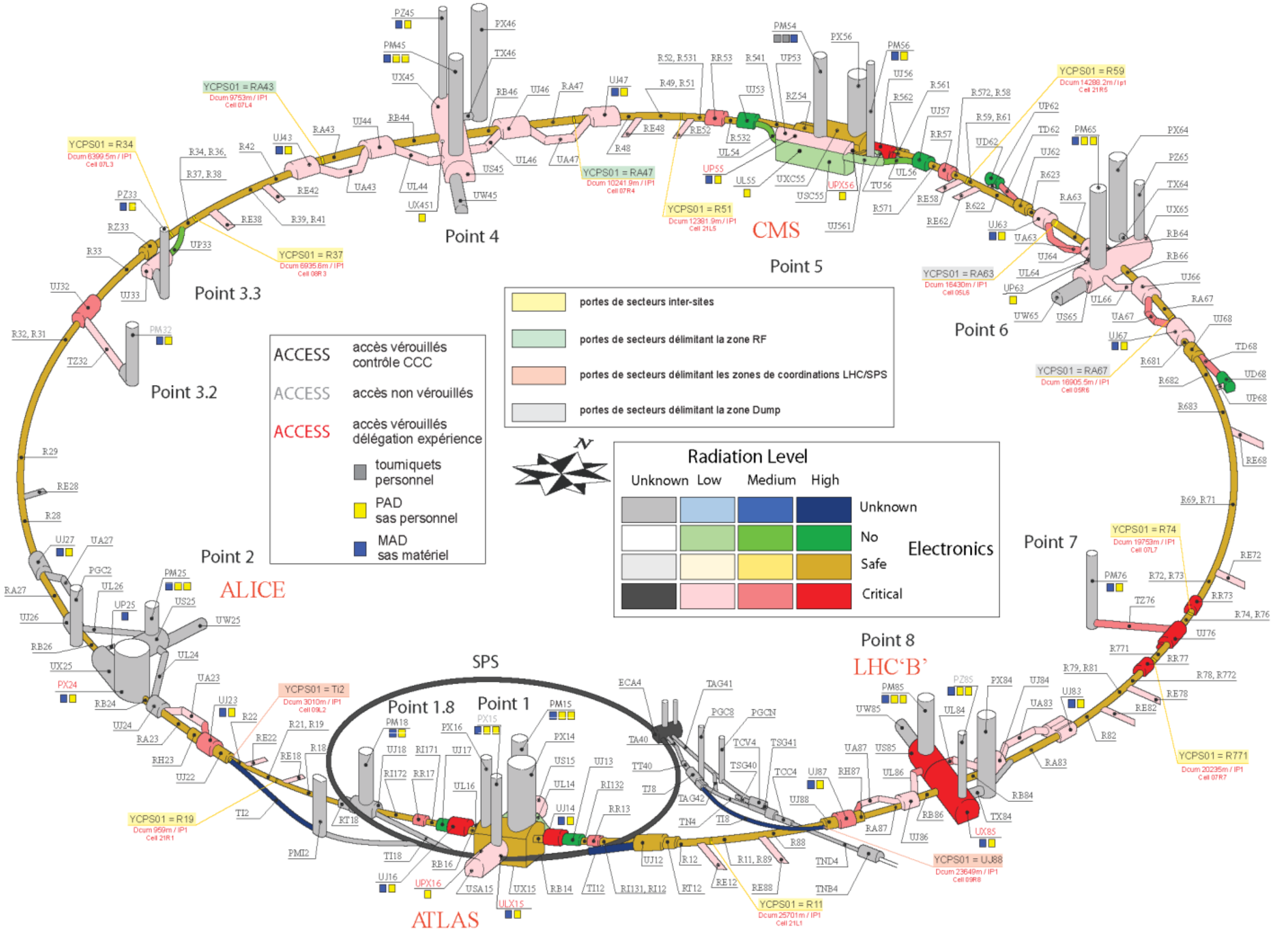
Location at CERN

- 480 m away from the ATLAS IP
- Charged particles deflected by LHC magnets
- Shielding from the IP provided by 100 m rock



Former transfer tunnels connecting SPS to LEP





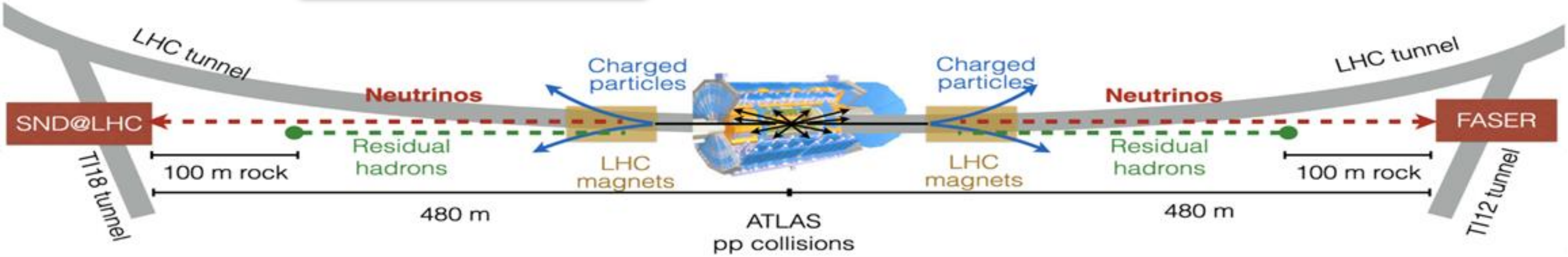
Injection tunnels used at LEP

LHC
Scattering and Neutrino Detector at the LHC

E.g. the TI18 tunnel in 2020

The LHC seen from the TI18 tunnel

Detector ready for the LHC Run 3 in March 2022

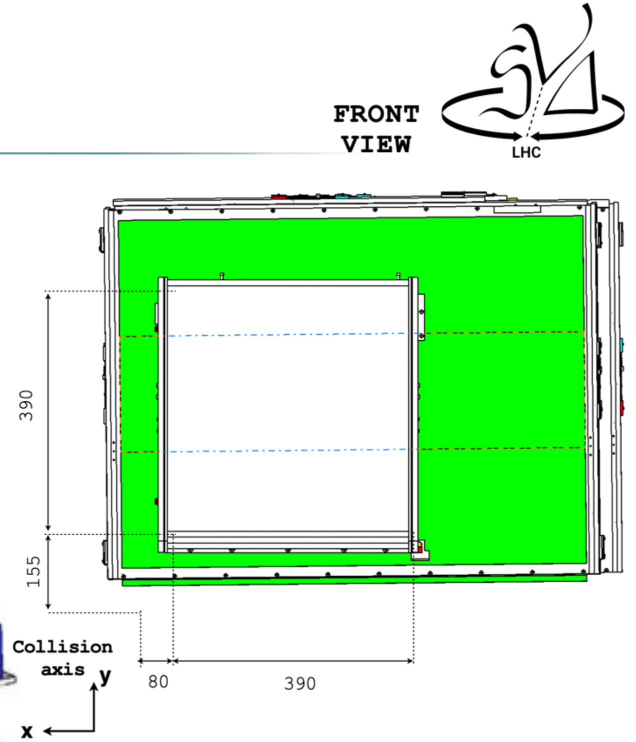


SND@LHC detector

Veto system
Two 1 cm thick scintillator planes.

Target, vertex detector and ECal
830 kg tungsten target.
Five walls x 59 emulsion layers
+ five scintillating fibre stations.
84 X_0, 3 λ_{int}

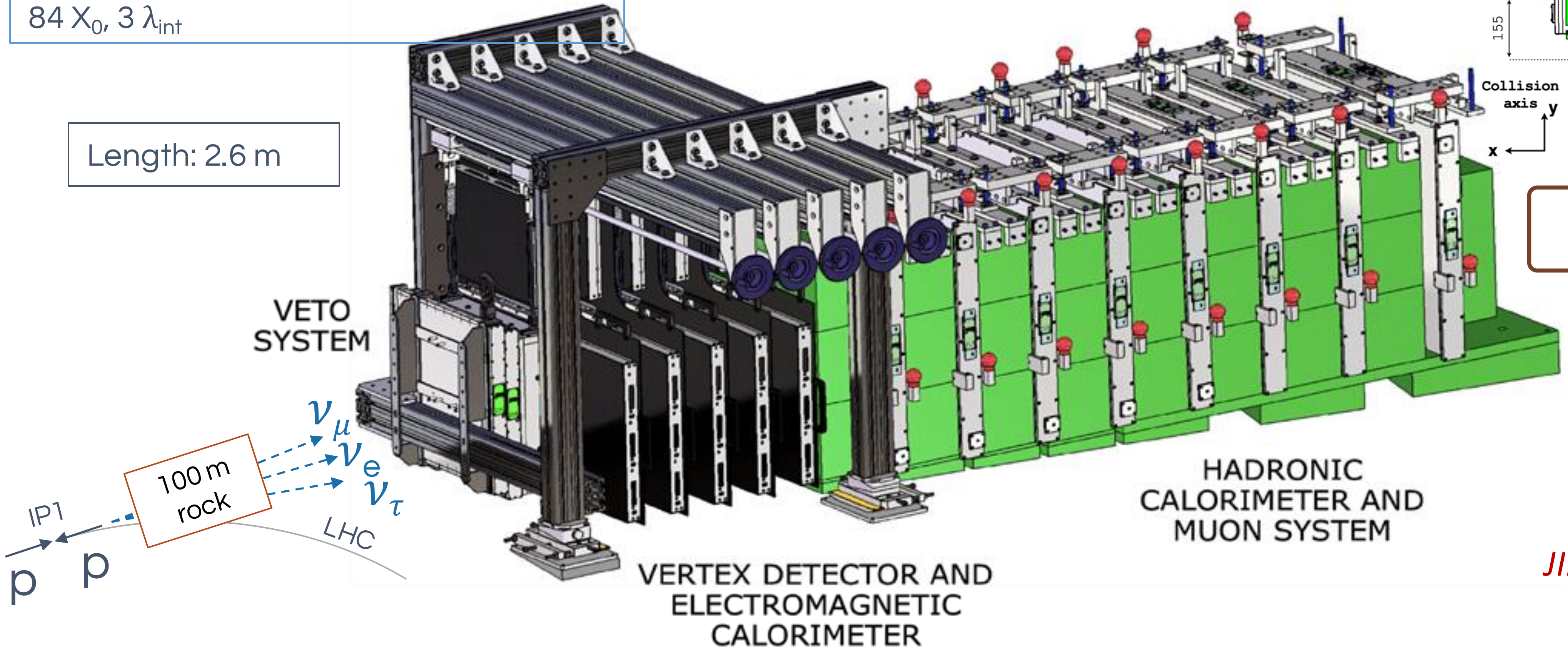
HCal and muon system
Eight 20 cm Fe blocks
+ scintillator planes.
Last 3 planes have finer
granularity to track muons.
9.5 λ_{int}



Off axis location

$7.2 < \eta < 8.4$

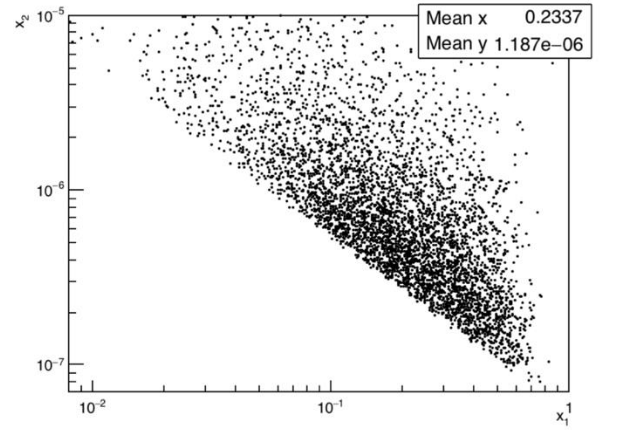
Length: 2.6 m

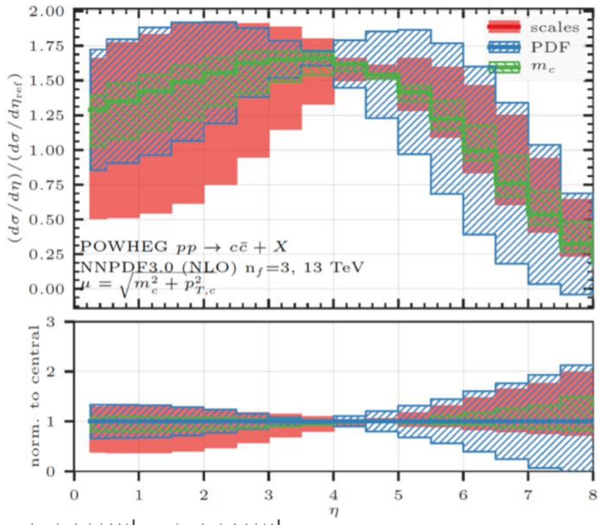


JINST 19 (2024) 05, P05067

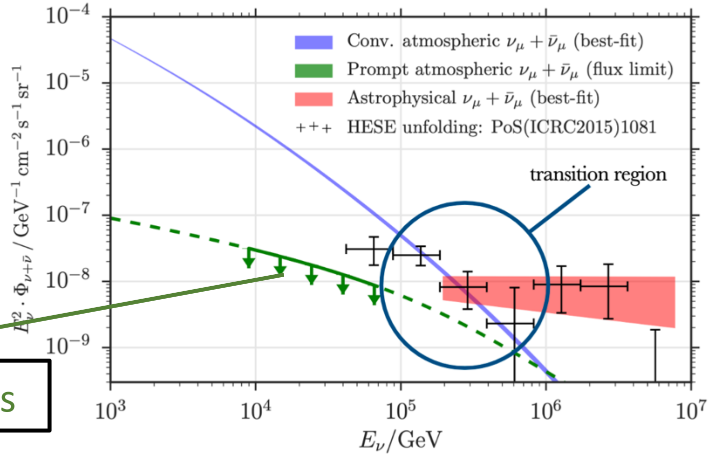
Physics goals

- Study neutrino interactions (cross-section, LFU, ..) in a new energy domain
- Lepton flavour universality tests with ν interactions with $R_{e\mu}$ and $R_{e\tau}$
- Use νs as probes of their parent, e.g. in some angular region ν_e production dominated by charm decays → measuring charm production in pp collisions in the forward region
- Manyfold interest for the charm measurement in pp collision at high η
- Prediction of very high-energy neutrinos produced in cosmic-ray interactions → experiments also acting as a bridge between accelerator and astroparticle physics





IceCube Collaboration, six years data, Astrophysics J. 833 (2016) 3, https://iopscience.iop.org/article/10.3847/0004-637X/833/1/3/pdf

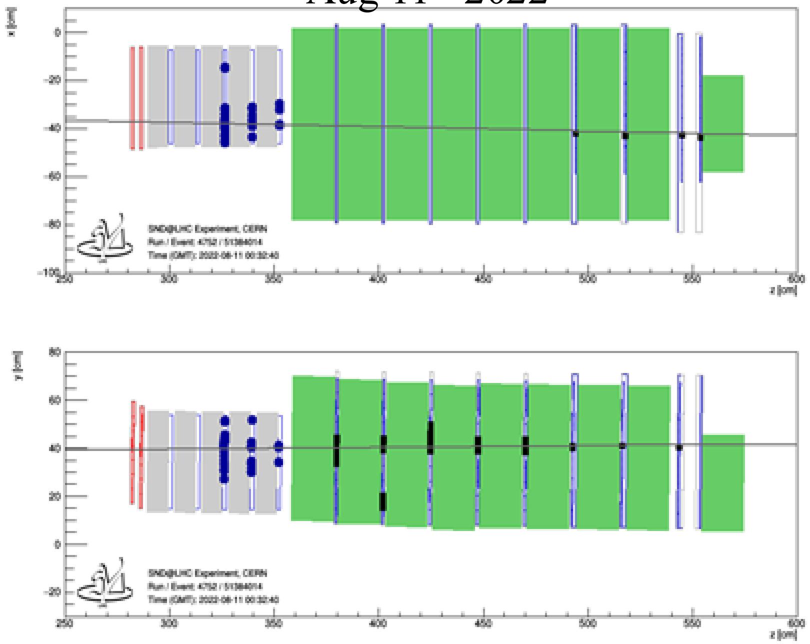


7+7 TeV *p-p* collisions correspond to 100 PeV proton interaction for a fixed target

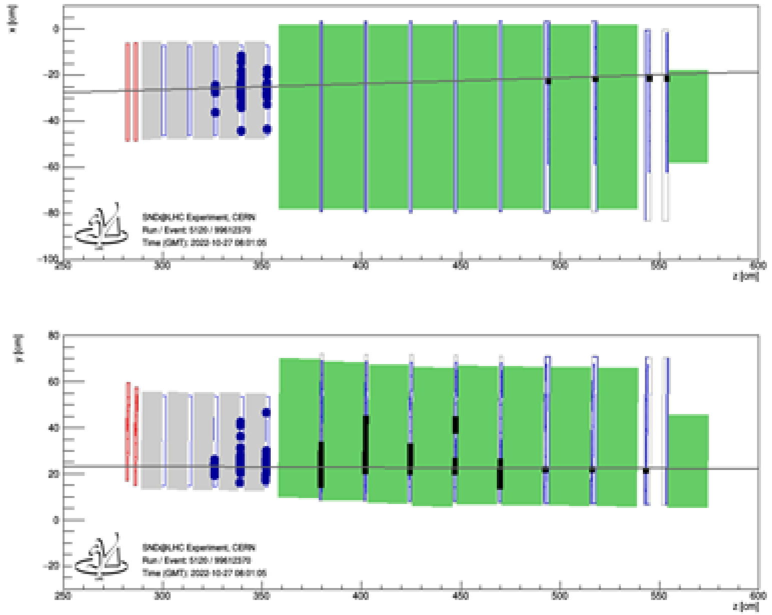
prompt atmospheric neutrinos

Observation of collider muon neutrinos with 2022 data

Aug 11th 2022



Oct 27th 2022

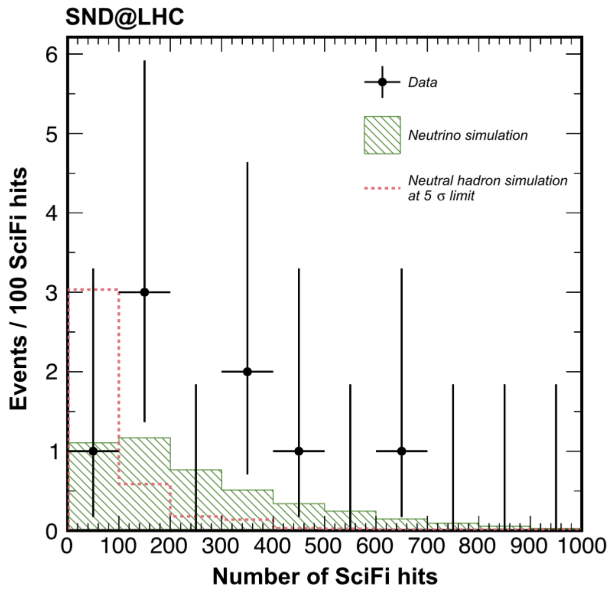


Editors' Suggestion

Observation of Collider Muon Neutrinos with the SND@LHC Experiment

R. Albanese *et al.* (SND@LHC Collaboration)

Phys. Rev. Lett. **131**, 031802 (2023) – Published 19 July 2023



Distribution of SciFi hits for ν_μ candidates with the MC expectation for ν events and background (augmented to the 5-sigma level)

8 observed events and an expected background of

$$(8.6 \pm 3.8) \times 10^{-2}$$

Background only hypothesis probability:

$$P = 7.15 \times 10^{-12}$$

6.8 σ observation

https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.131.031802

Observation of 0μ (ν_e CC and ν NC) events with 2022-23 data

PHYSICAL REVIEW LETTERS **134,** 231802 (2025)
https://journals.aps.org/prl/abstract/10.1103/r2qy-9hft

Neutral hadron background

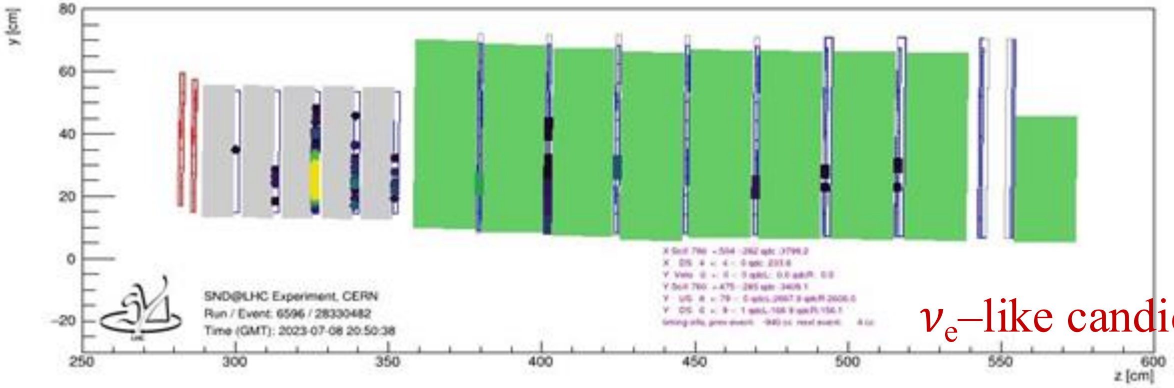
- Define background-dominated control region.
- Scale the background prediction to the number of observed events in the control region.
- Events **expected in signal region**: **0.01**

Neutrino background

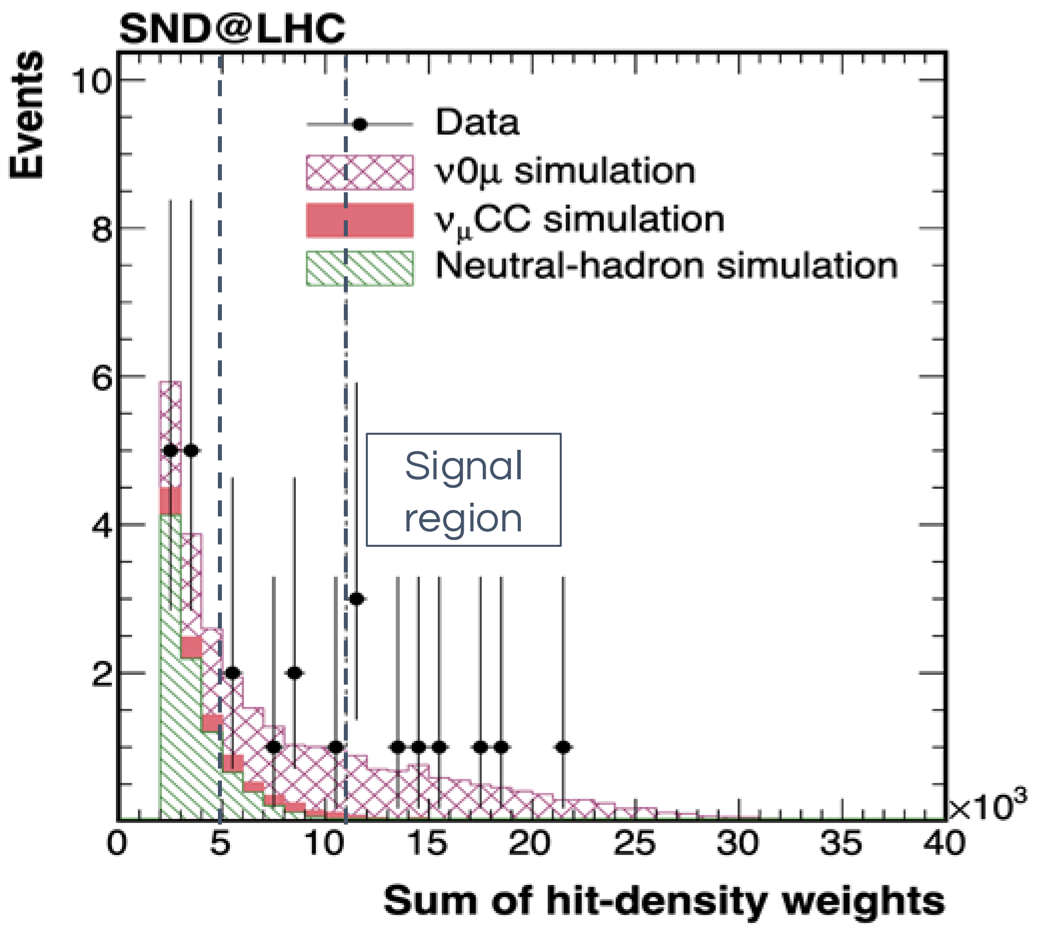
- ν_μ CC interactions are the dominant background, with **0.30** expected events
- ν_τ CC1μ interactions expected: 0.002

0μ observation significance

- **Total expected background: 0.32 ± 0.06 events**
- **Expected signal: 7.2 events**
  - 4.9 ν_eCC, 2.2 NC, 0.1 ν_τCC
- **Expected significance: 5.5 σ**



ν_e–like candidate



Number of events observed: 9
Observation significance: 6.4 σ

Updated ν_μ results (2022-2023 data) with electronic detector

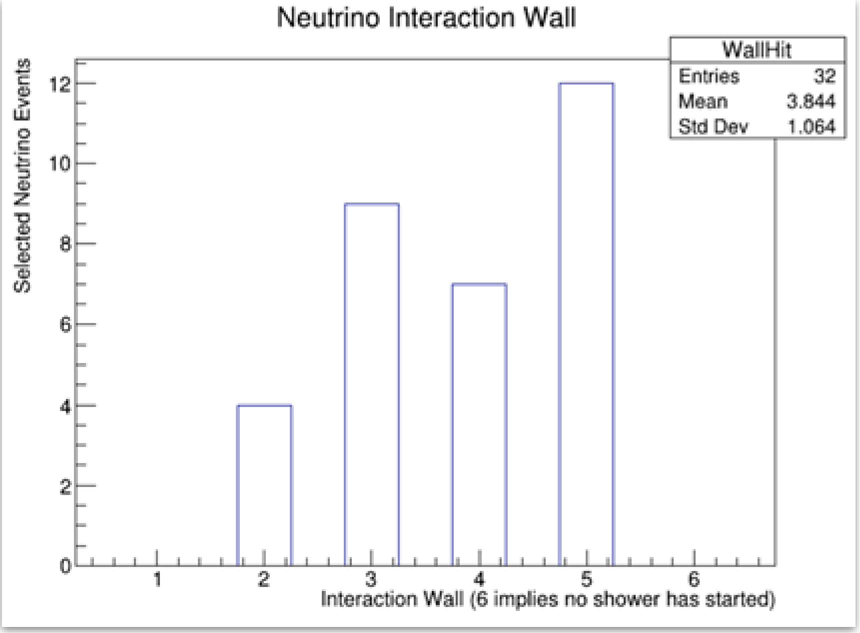
Period		Luminosity	Survival Rate	Inefficiency		μ Background
				Veto	SciFi	
2022	1	1.21 fb^{-1}	4.13×10^{-3}	3.03×10^{-4}	2.50×10^{-4}	7.88×10^{-2}
	2	14.00 fb^{-1}	5.57×10^{-3}	7.00×10^{-4}	1.06×10^{-4}	1.18
	3	7.12 fb^{-1}	6.21×10^{-3}	3.03×10^{-4}		2.75×10^{-1}
	4	1.58 fb^{-1}	6.41×10^{-3}	1.04×10^{-5}		2.08×10^{-3}
	5	5.72 fb^{-1}	5.07×10^{-3}	3.98×10^{-7}		2.89×10^{-4}
	6	9.01 fb^{-1}	5.50×10^{-3}	4.40×10^{-7}		5.28×10^{-4}
2023	1	11.60 fb^{-1}	4.02×10^{-4}	4.40×10^{-5}	1.18×10^{-4}	8.96×10^{-5}
	2	9.68 fb^{-1}	4.30×10^{-3}	4.05×10^{-7}		4.73×10^{-4}
	3	10.50 fb^{-1}	2.81×10^{-3}	9.00×10^{-8}		1.18×10^{-4}
Total		70.43 fb^{-1}	-	-	-	1.53

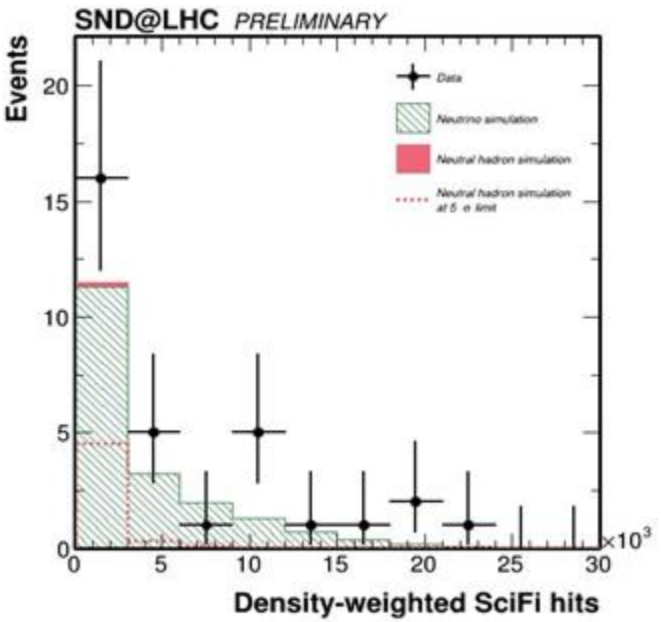
Events expected in 68.6 fb^{-1}

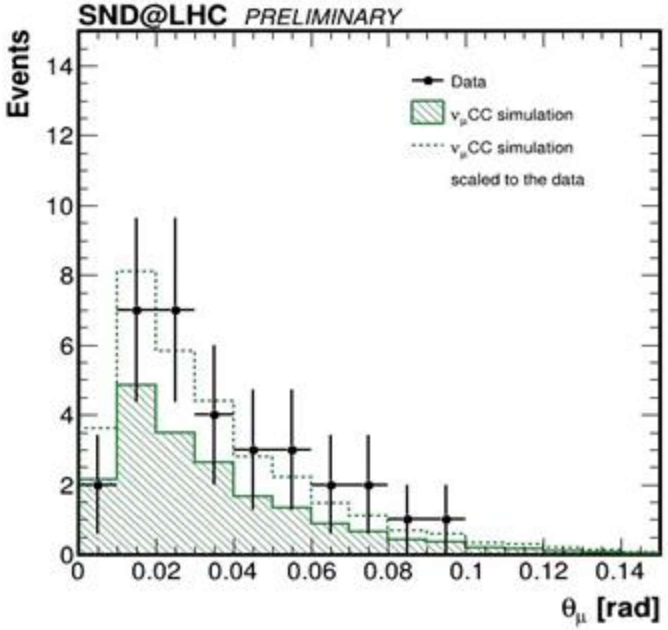
- Signal: 19.1± 4.1
- Neutral hadrons: 0.25 ± 0.06
- Unidentified muons: 1.5±0.3

29 events observed

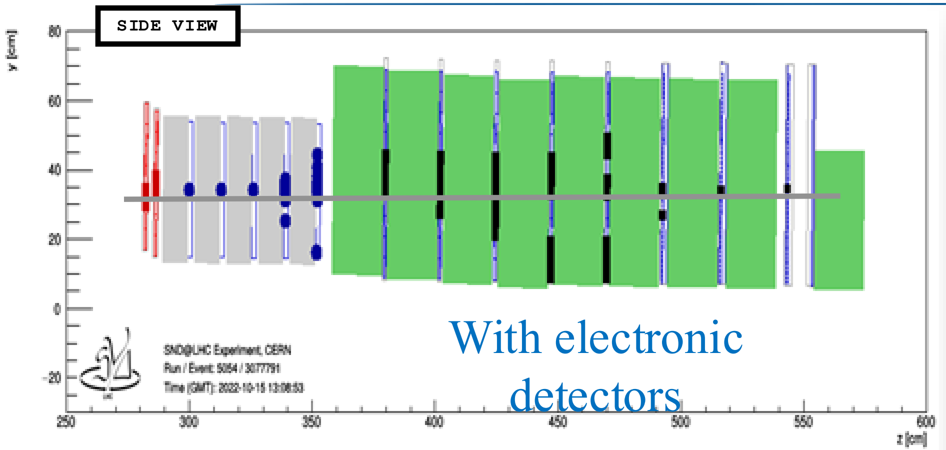
Expected ν_μ: 19.1 ± 4.1(production sys)+1.6 (selection sys)



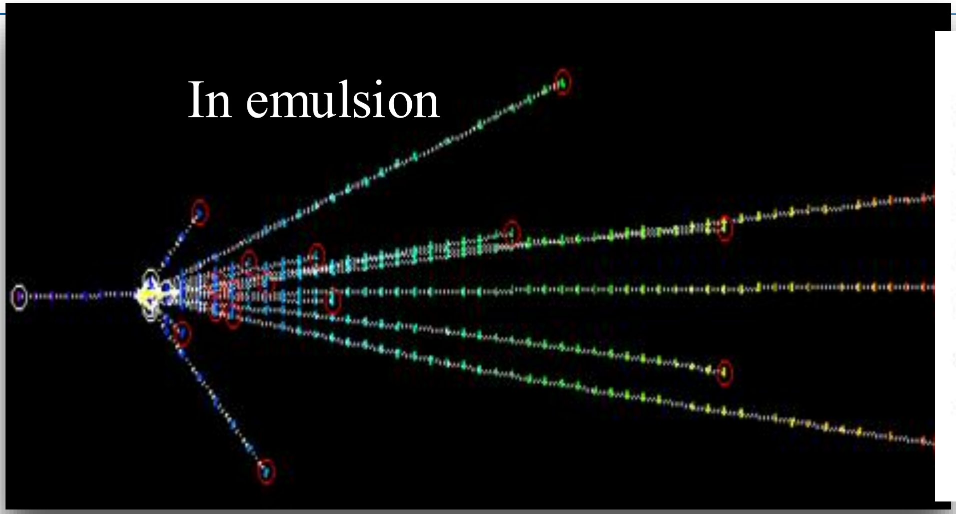




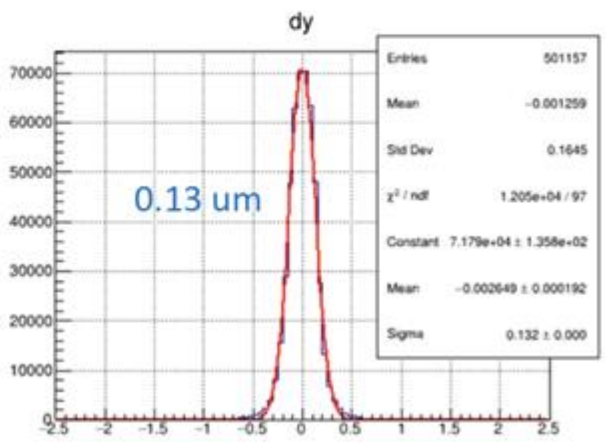
Study of muon Deep Inelastic Scattering



With electronic detectors



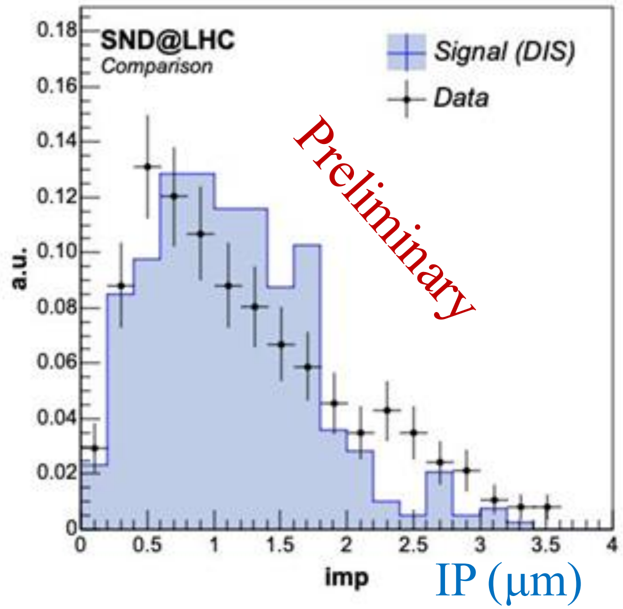
In emulsion



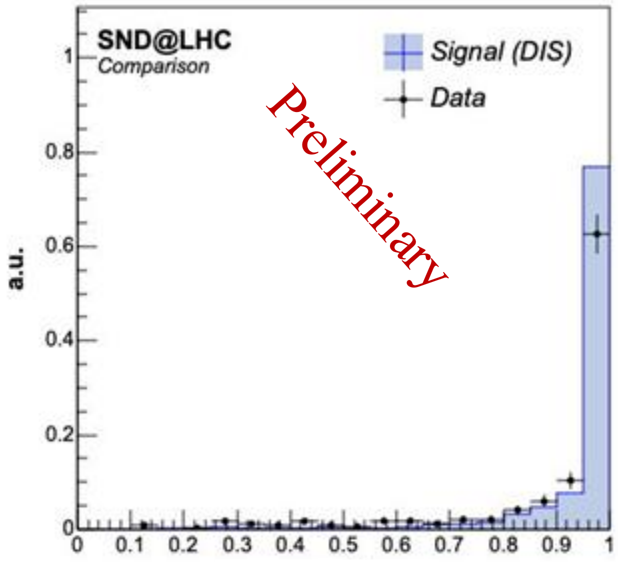
0.13 um

Expected signal: 870
Background: 1030±360

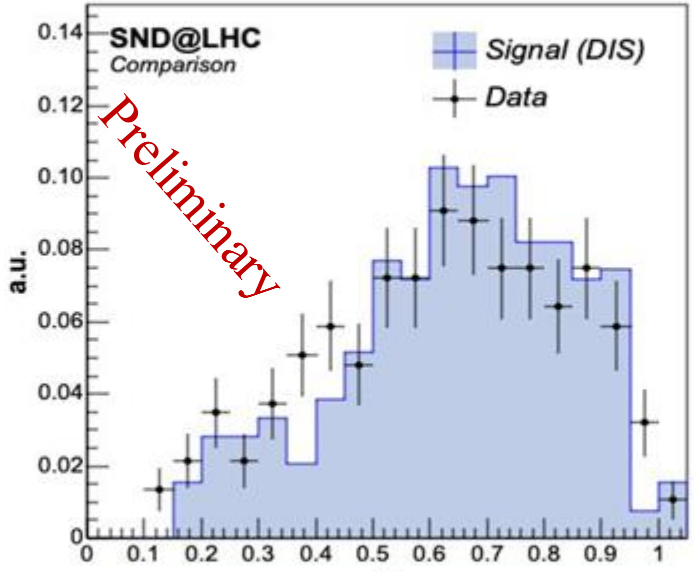
Observed events : 1741
Expected events : 1900 ± 360



IP (μm)



VTX prob



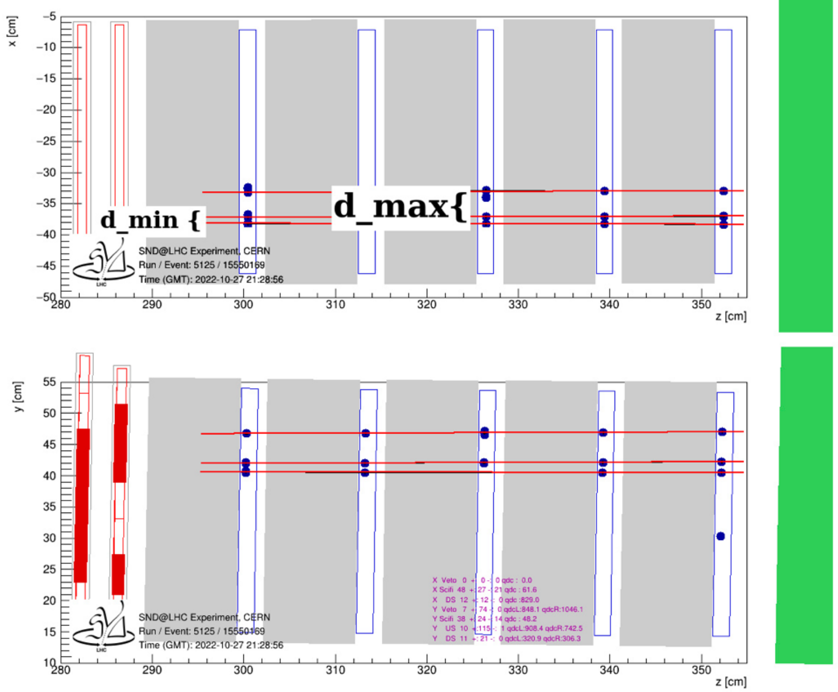
Relative length of the track in the brick

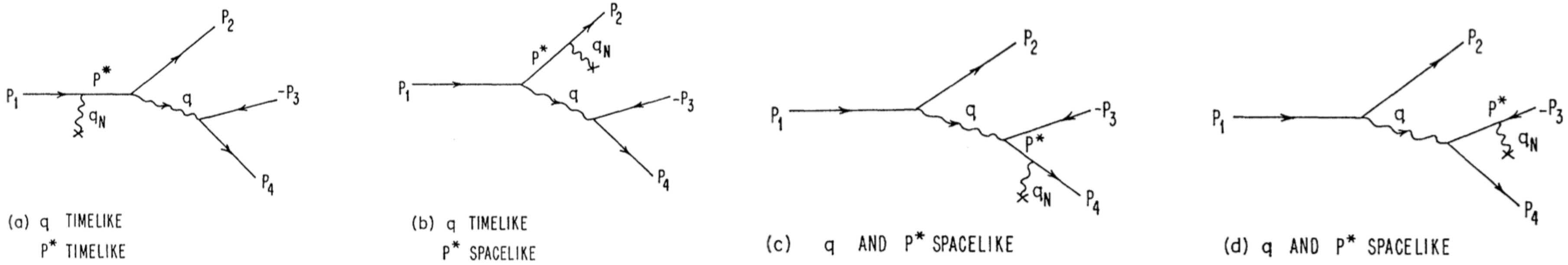
Trident process in the surrounding rock

- $\mu^{\pm} + N \rightarrow \mu^{+}\mu^{-}\mu^{\pm} + N$
  - Studied in the 60's and 70's, Muon Tridents, J.D. Bjorken(SLAC), M.C. Chen, Observation of Muon Trident Production in Lead and the Statistics of the Muon
  - Due to identical muons, sensitive to Fermi statistics
  - With 10 GeV muon beam, measured 60 nb per lead nucleon
- "Background": bremsstrahlung followed by γ-conversion

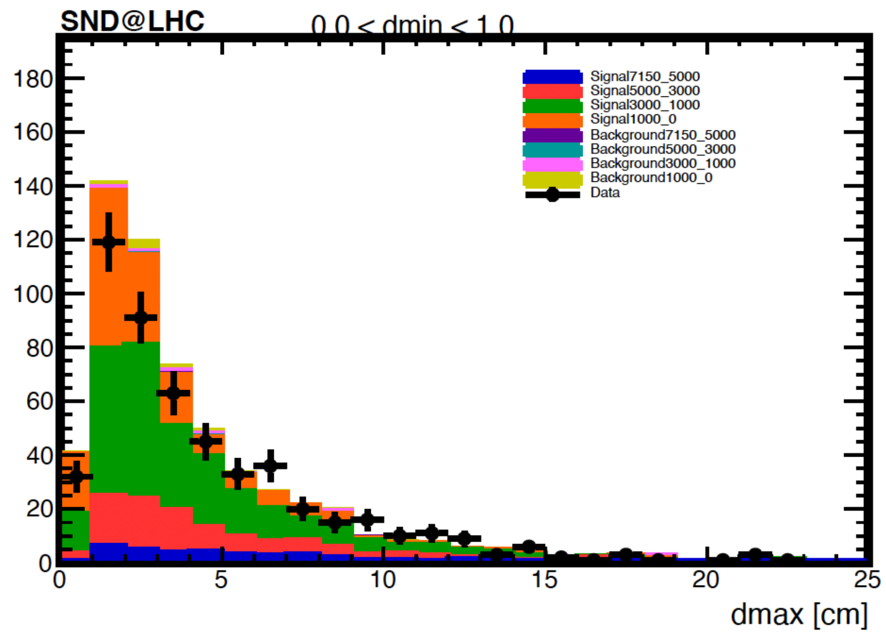
$$\mu^{\pm} + N \rightarrow \mu^{\pm} + N + \gamma, \gamma + N \rightarrow N + \mu^{+}\mu^{-}$$

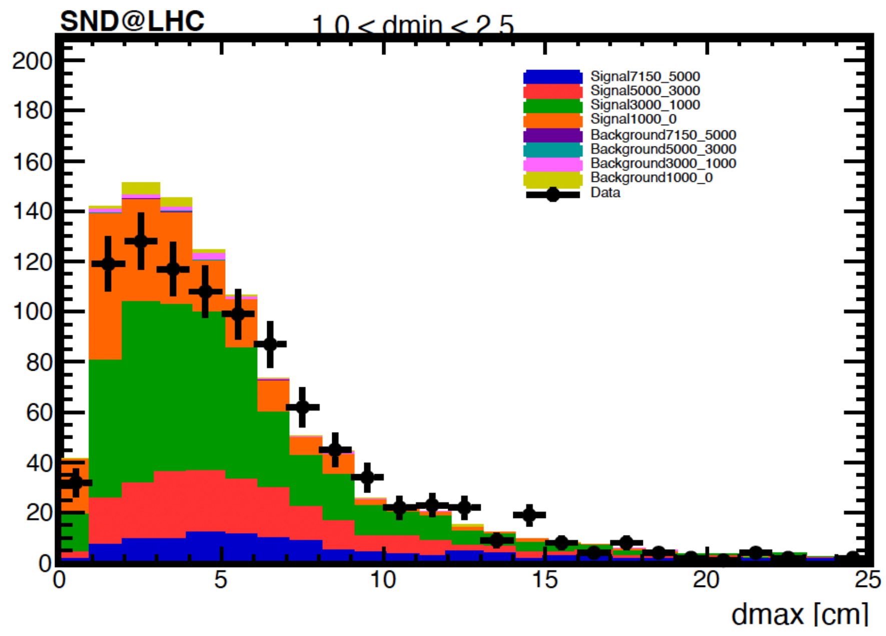
- Process introduced in GEANT4 in 2022
- Rate inconsistent with coincidence muons (already with 2 muons)



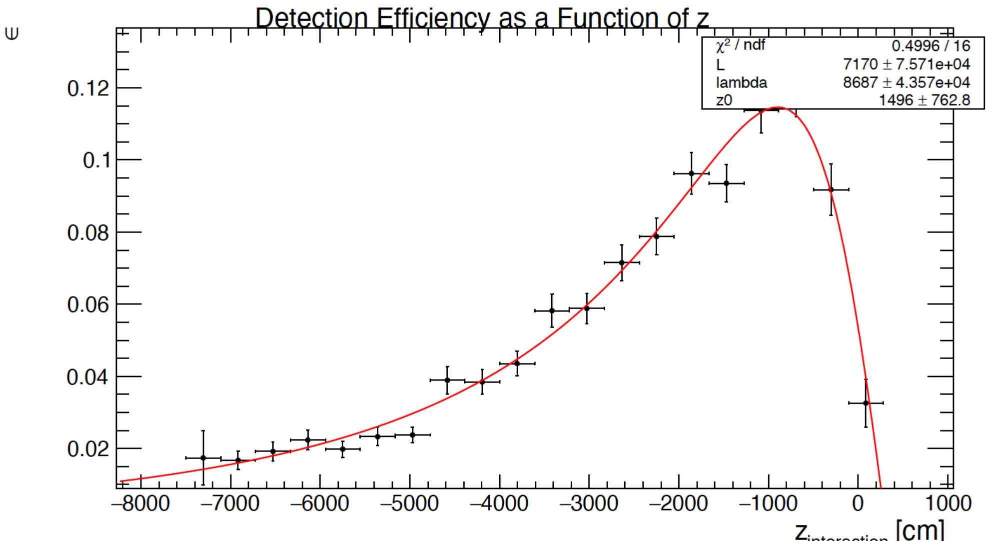


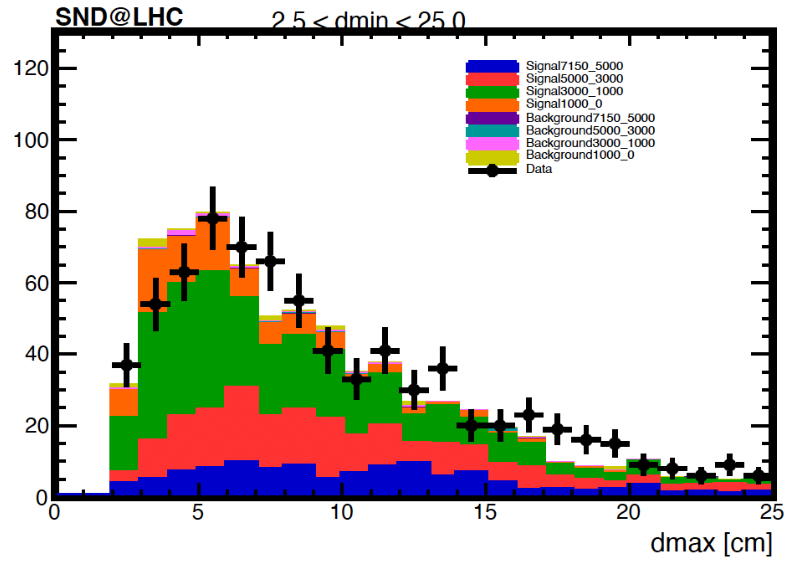
Preliminary results on the muon trident





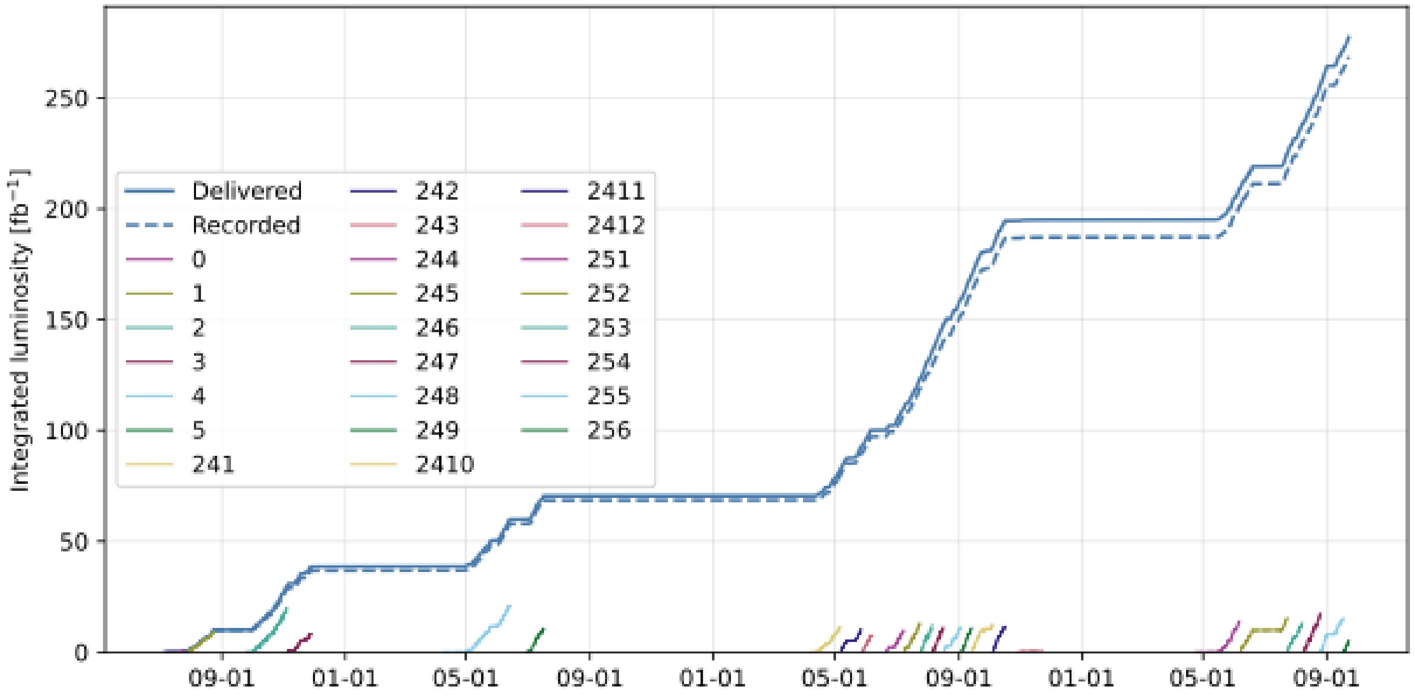
σ = 127 ±29 nb

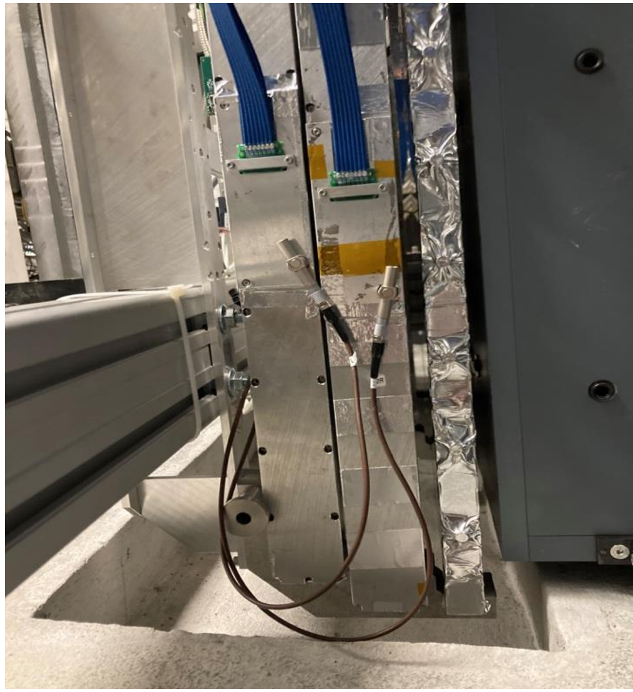




(Much) more data coming…

Integrated luminosity above 250 fb^{-1}!





Upgraded veto system at the end of 2023

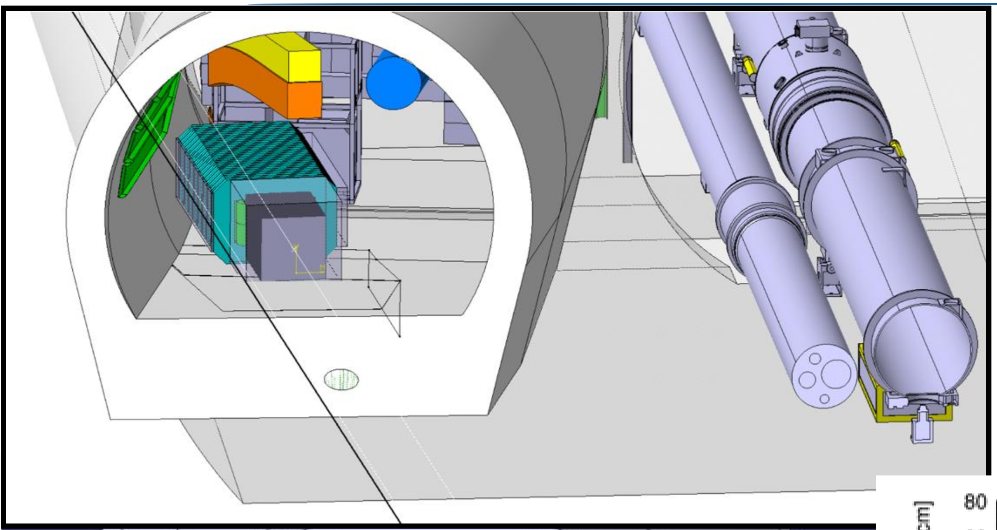
Recorded/delivered luminosity: 269/277 fb-1, 97% overall
In 2025: 81/82 fb-1, 98.8% efficiency

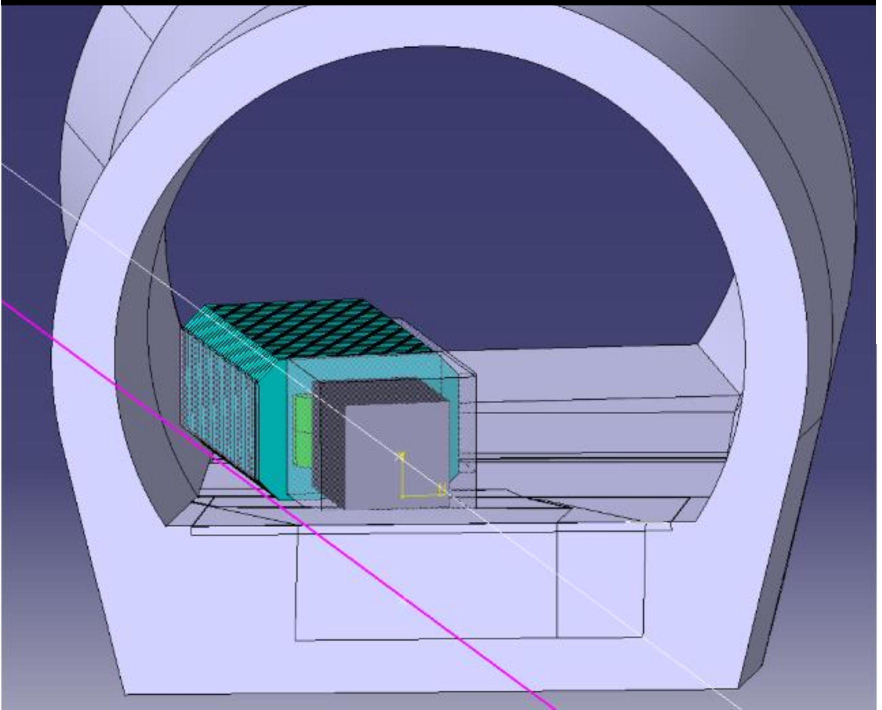
Current analyses based on 60 fb^{-1}, large statistical improvement thanks to the good LHC run in 2024-25 and to the upgrade of the detector (increase the acceptance by a factor of ~2)

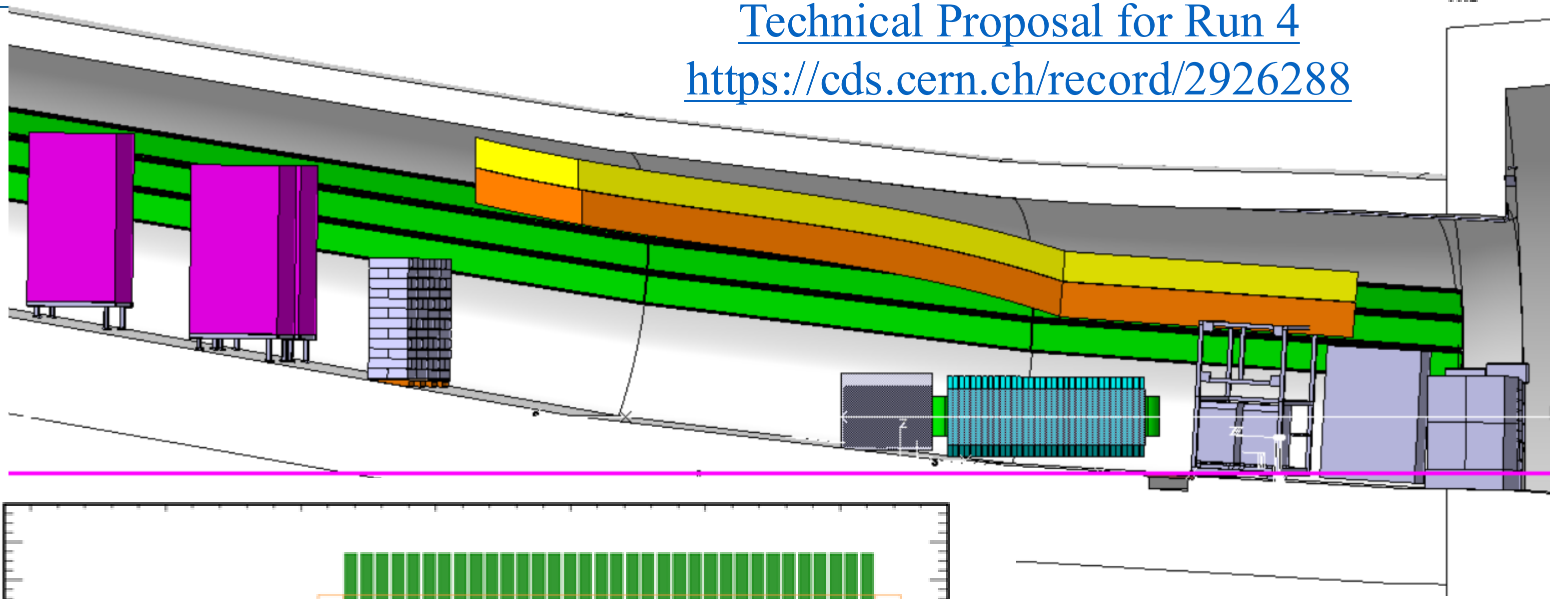
SND@LHC UPGRADE FOR HL-LHC

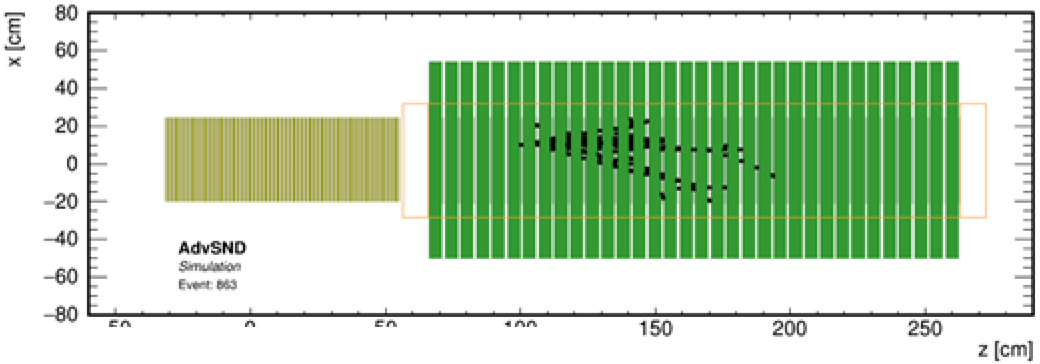
Detector for the High Luminosity Runs

[Technical Proposal for Run 4](https://cds.cern.ch/record/2926288)
https://cds.cern.ch/record/2926288



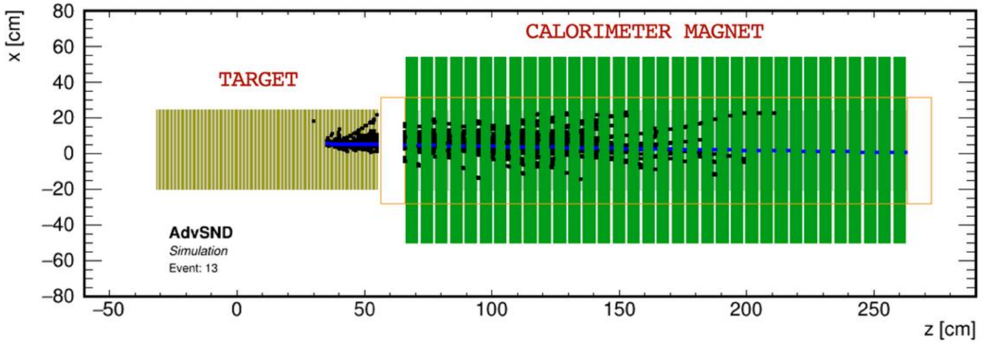






Approved in June 2025

Flavour	CC DIS DPMJET π/K	CC DIS DPMJET charm	CC DIS POWHEG+P8 charm
ν_μ	9.6×10^3	1.4×10^3	1.5×10^3
$\bar{\nu}_\mu$	3.1×10^3	9.9×10^2	6.8×10^2
ν_e	5.0×10^2	1.6×10^3	1.5×10^3
$\bar{\nu}_e$	2.0×10^2	1.1×10^3	6.9×10^2
ν_τ	—	2.2×10^2	9.3×10^1
$\bar{\nu}_\tau$	—	5.7×10^1	5.0×10^1
Tot	1.3×10^4	5.4×10^3	4.5×10^3



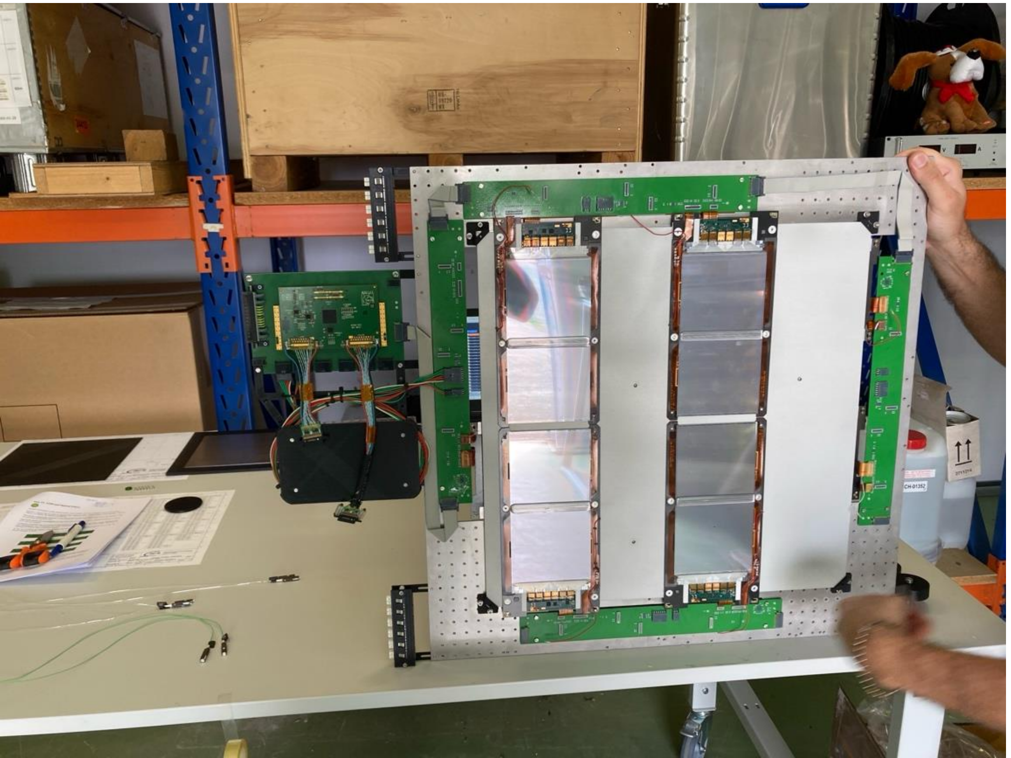
Station design and first prototype

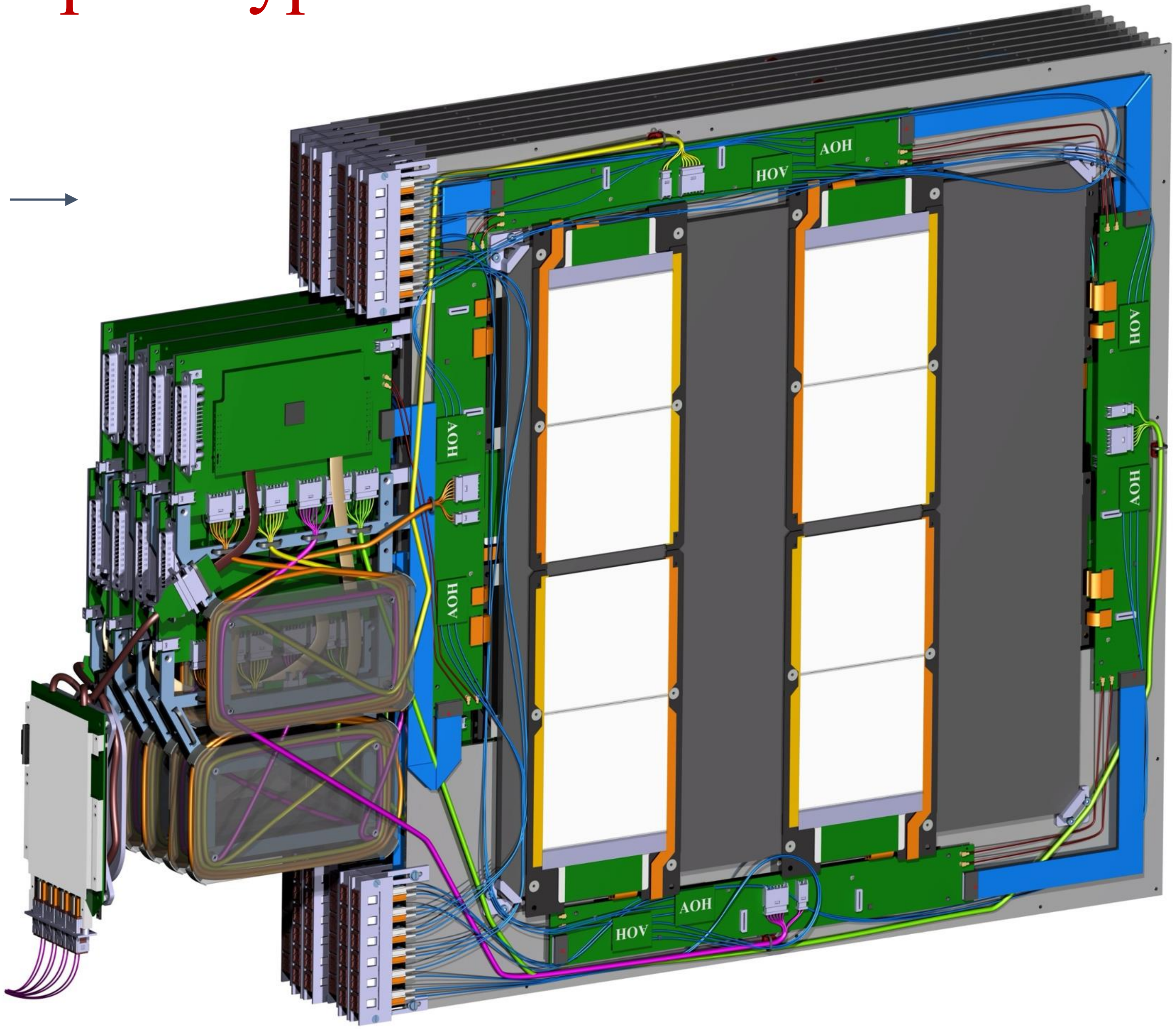
Pitch of 15 mm

7 mm W, with 8 mm gap to host silicon modules

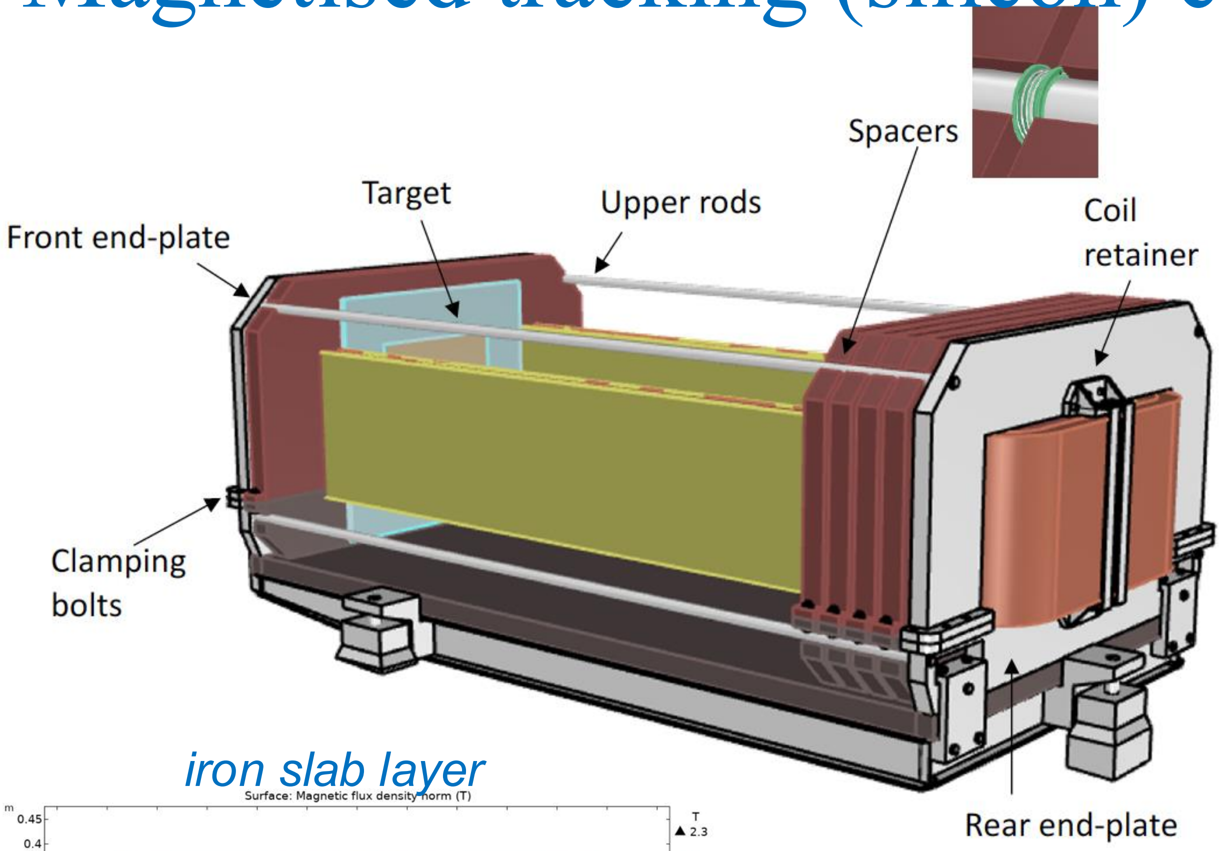
A block of 8-10 consecutive stations is controlled by a Digital OptoHybrid Module

Mechanical assembly verified in July

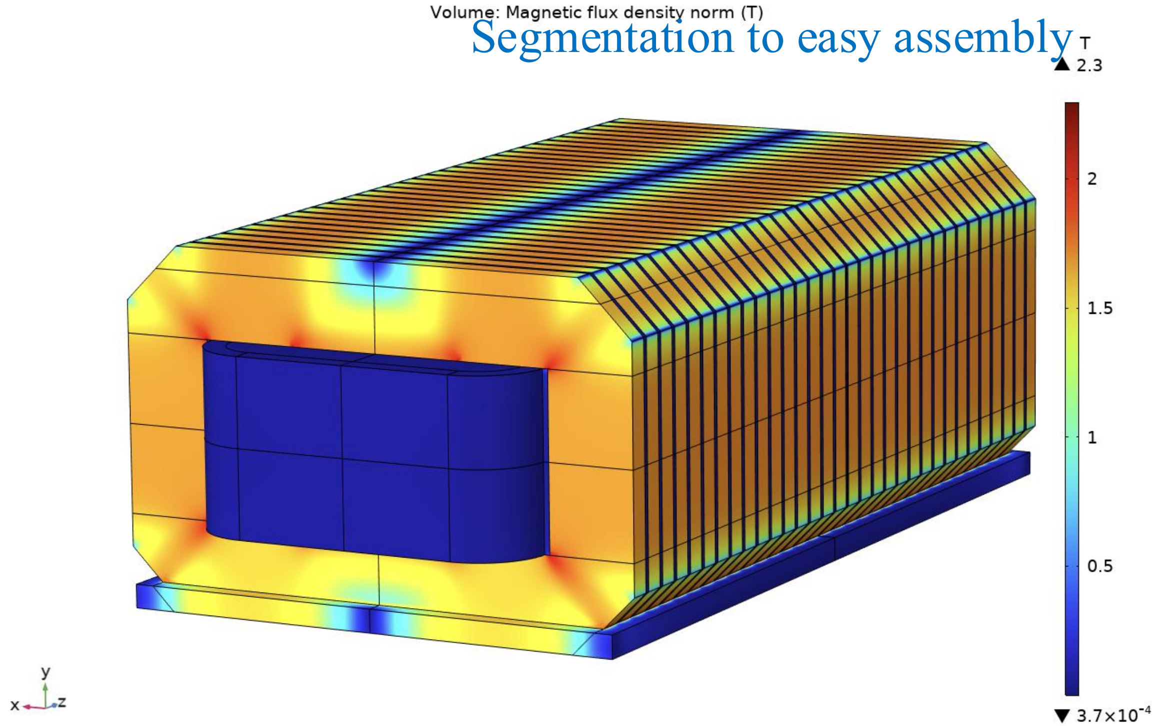




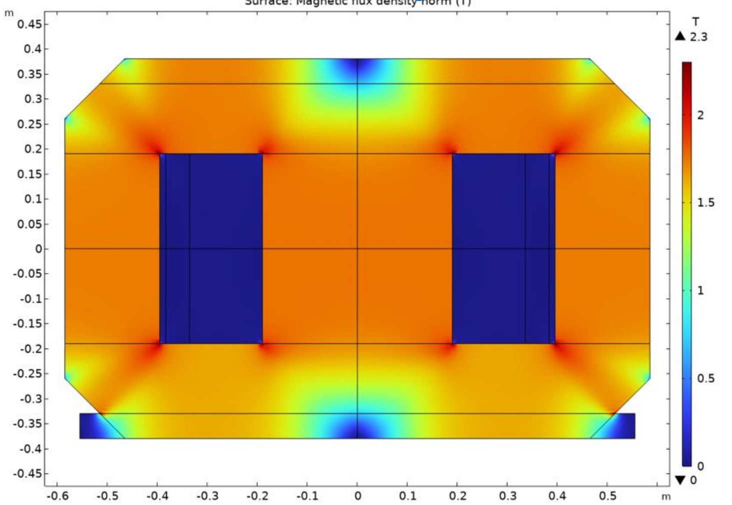
Magnetised tracking (silicon) calorimeter



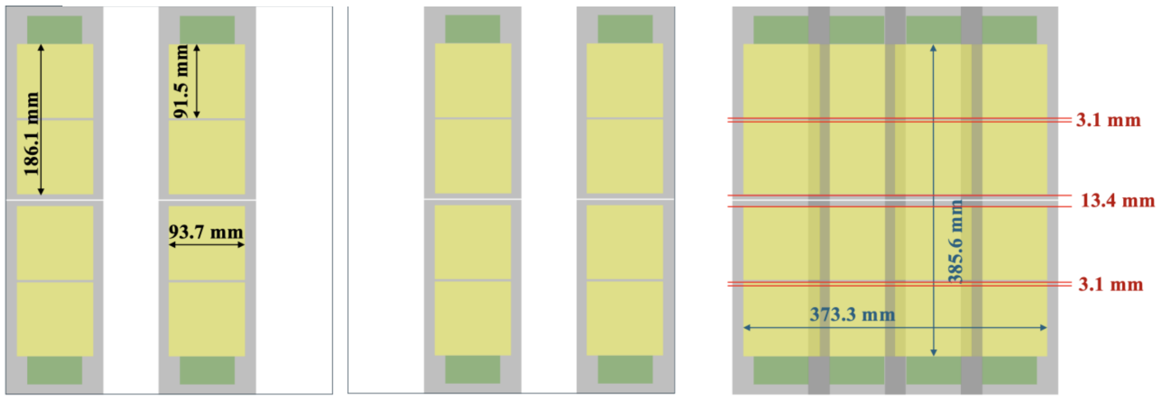
Segmentation to easy assembly



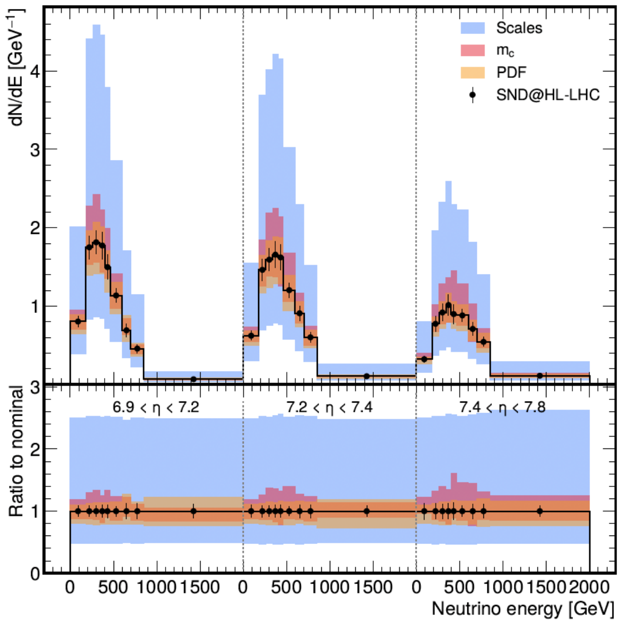
iron slab layer

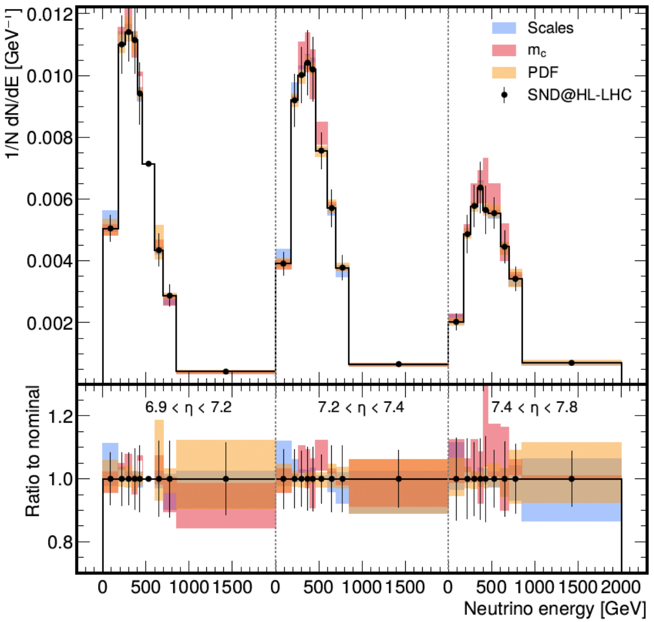


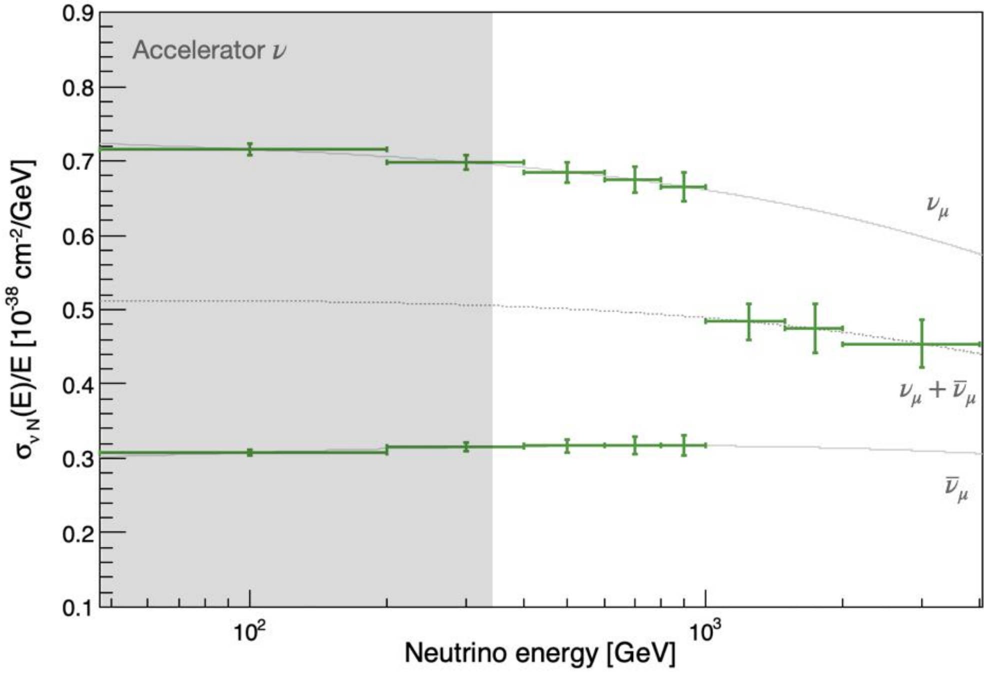
Front Back Active layer



Physics case in the High-Luminosity era in a nutshell







- *Energy and η distribution of (charm-induced) νe CC interactions*
- *Left: event yield. Right: normalized to an arbitrarily chosen reference bin*

Run3

Measurement	Uncertainty Stat.	Sys.	Uncertainty Stat.	Sys.
Gluon PDF	5%	35%	2%	5%
ν_e/ν_τ ratio for LFU test	30%	22%	6%	10%
ν_e/ν_μ ratio for LFU test	10%	10%	2%	5%
Charm-tagged ν_e/ν_μ ratio for LFU test	-	-	10%	< 5%
ν_μ and $\bar{\nu}_\mu$ cross-section	-	-	1%	5%

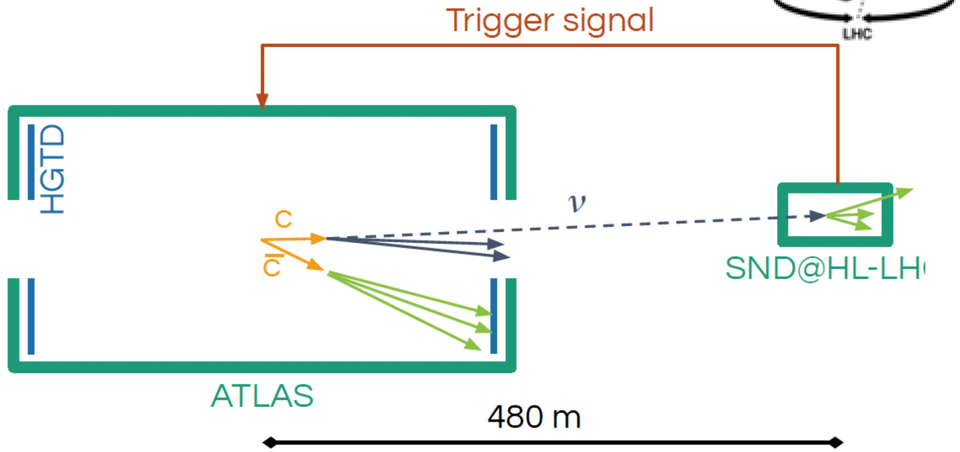
HL

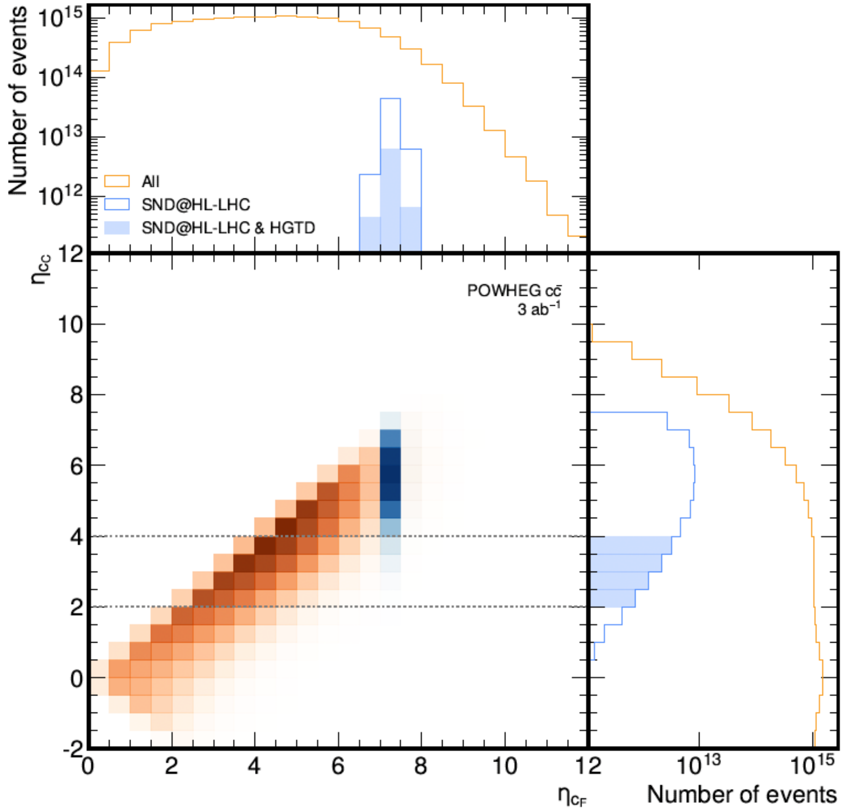
Extending ν cross-section measurements to a few TeV

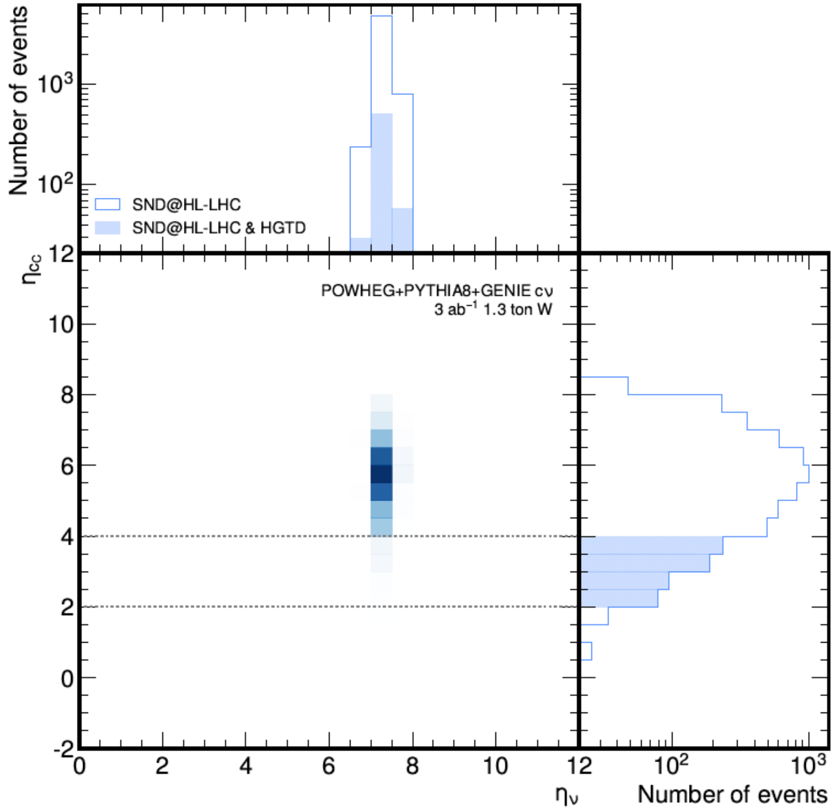
Technical Proposal for Run 4
https://cds.cern.ch/record/2926288

ν tagging: triggering ATLAS with ν events

- Forward charm producing a neutrino
- Less-forward charm being detected in ATLAS
- In ~ 10÷15% of ν events, the partner charm is in the ATLAS acceptance ($2 < \eta < 4$)







- Number of events in 3 ab^{-1}: ~1000

SHiP
Search for Hidden Particles

The SHiP (Search for Hidden Sector) experiment at CERN

http://cds.cern.ch/record/2007512/files/SPSC-P-350.pdf Technical Proposal in 2015

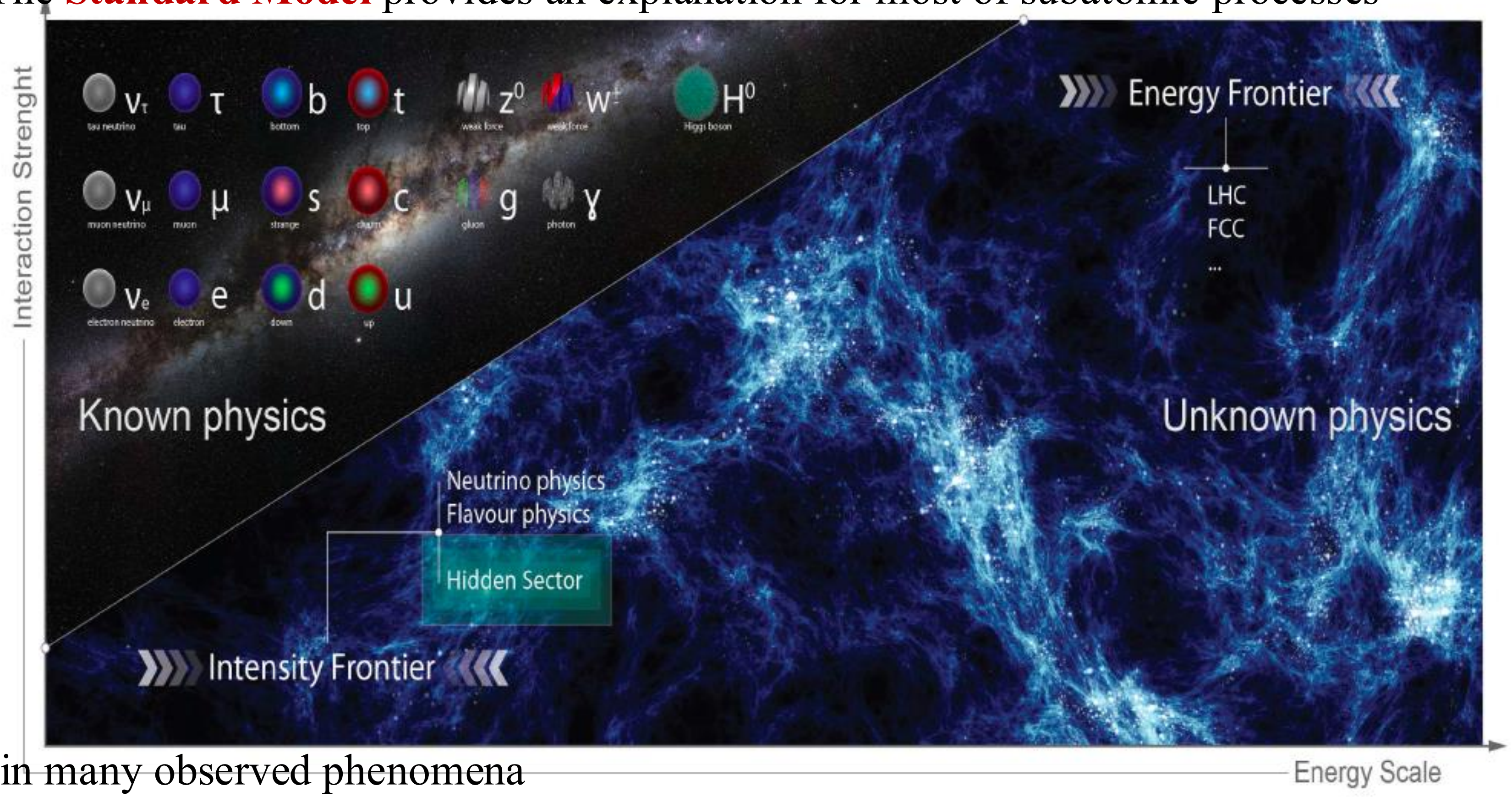
EPJC (2022) 82:486

Collaboration of 38 Institutes from 15 Countries and CERN

Collaboration meeting in April 2024

Motivation

- The **Standard Model** provides an explanation for most of subatomic processes



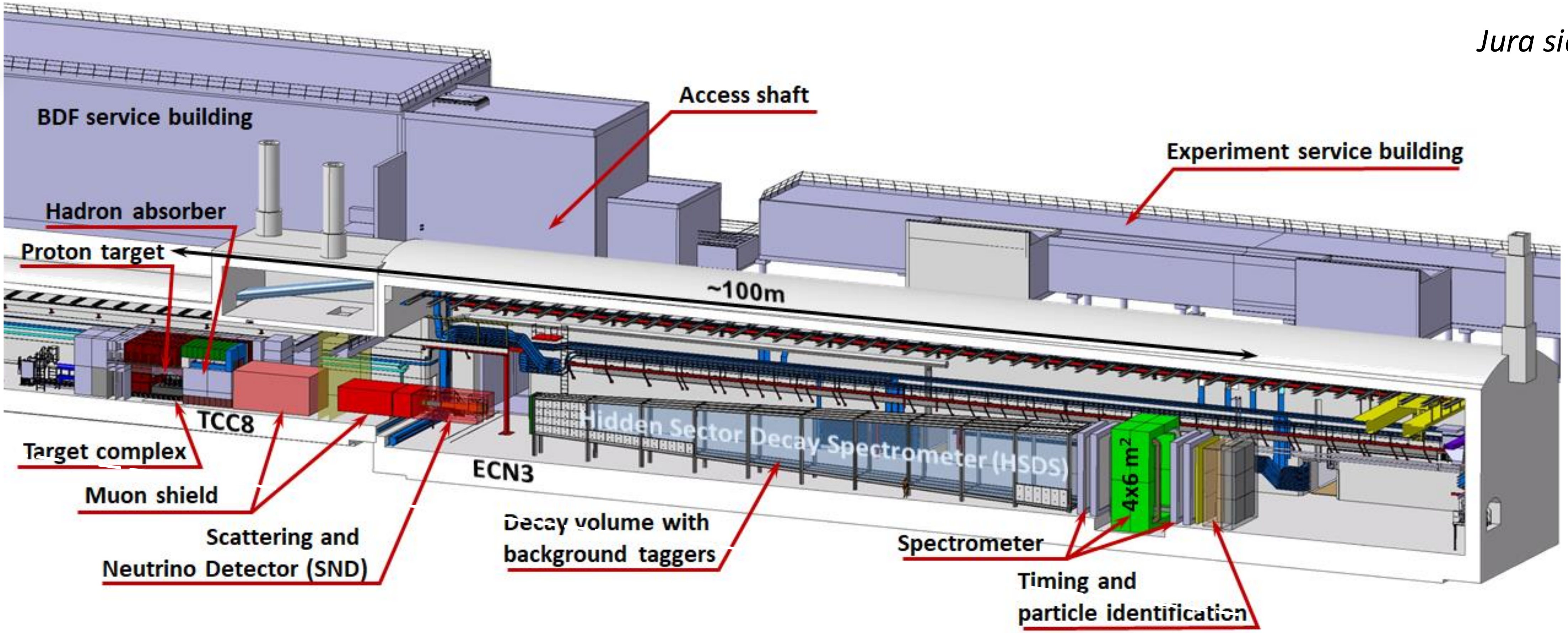
- It fails to explain many observed phenomena
  - **Dark Matter**
  - **Neutrino Oscillation and masses**
  - **Matter/antimatter asymmetry in the Universe**

- A **Hidden Sector (HS)** of weakly-interacting BSM particles as an explanation

Energy Frontier:
Heavy particles → high energy collisions

Intensity Frontier:
Very weakly interacting particles → high intensity beam

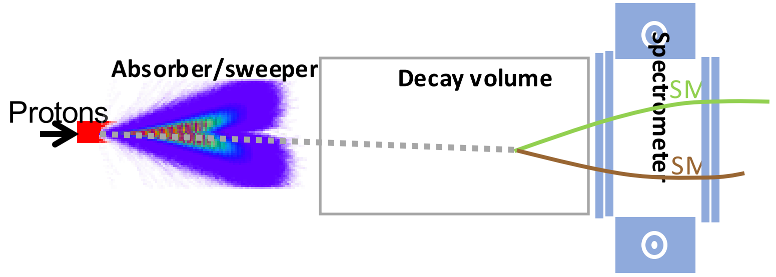
SHiP detector in more detail



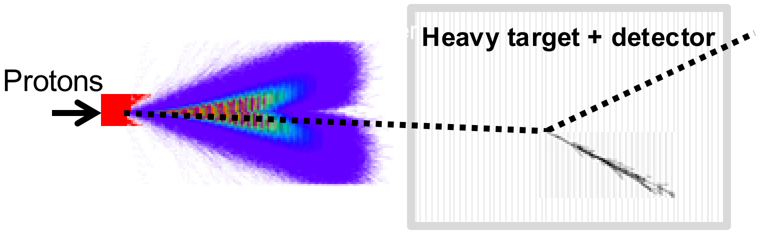
BDF/SHiP experimental techniques

➔ Explore Light Dark Matter, and associated mediators - generically domain of FIPs - and ν mass generation through:

Decay signatures



Scattering signatures



Neutrino interaction physics with all flavours

- Acceptance optimisation of both techniques described in arXiv:2304.02511, *EPJC* 83 (2023) 12

- Exhaustive search by aiming at model-independent detector setup
  - Full reconstruction and identification of both fully and partially reconstructible modes
    - ➔ Sensitivity to partially reconstructed modes also proxy for the unknown
  - In case of discovery ➔ precise measurements to discriminate between models / test compatibility with hypothetical signal

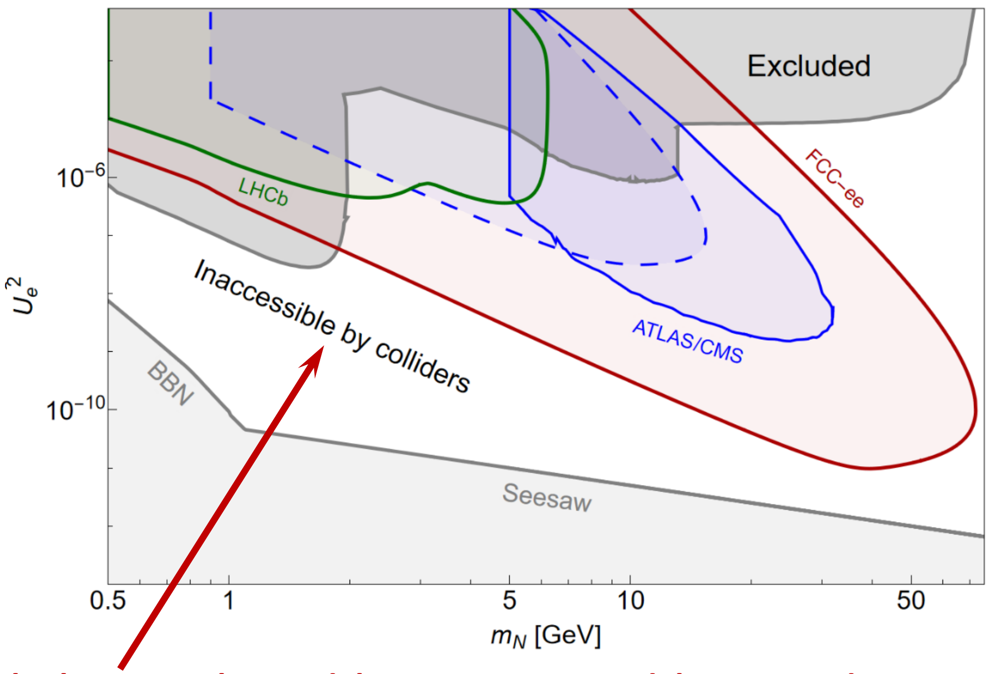
➔FIP decay signature search in background-free environment and LDM scattering
➔Rich neutrino interaction physics with access to tau neutrino

SHiP strategy

- Full exploitation of physics potential of SPS available since CNGS (*Rep. Prog. Phys.* **79** (2016) 124201)
- Rich and relevant physics programme with the injectors at CERN going beyond LHC, bridging gap to next collider

➔SPS suitability to explore *Light Dark Matter and associated mediators, and* ν *mass generation* – FIPs generically

E.g. Heavy Neutral Leptons



Similar behaviour $\tau_{FIP} \propto \frac{1}{\epsilon_{FIP}^{x} m_{FIP}^{y}}$

for all types of FIPs

➔Region that can *only* be explored by optimised beam-dump experiment

➔Production modes in limited forward cone – large lifetime acceptance

➔SPS energy and intensity provide huge production of charm, beauty and electromagnetic processes

➔Unique *direct discovery potential in the world in the heavy flavour region,* capable of reaching "physical floor/background floor"

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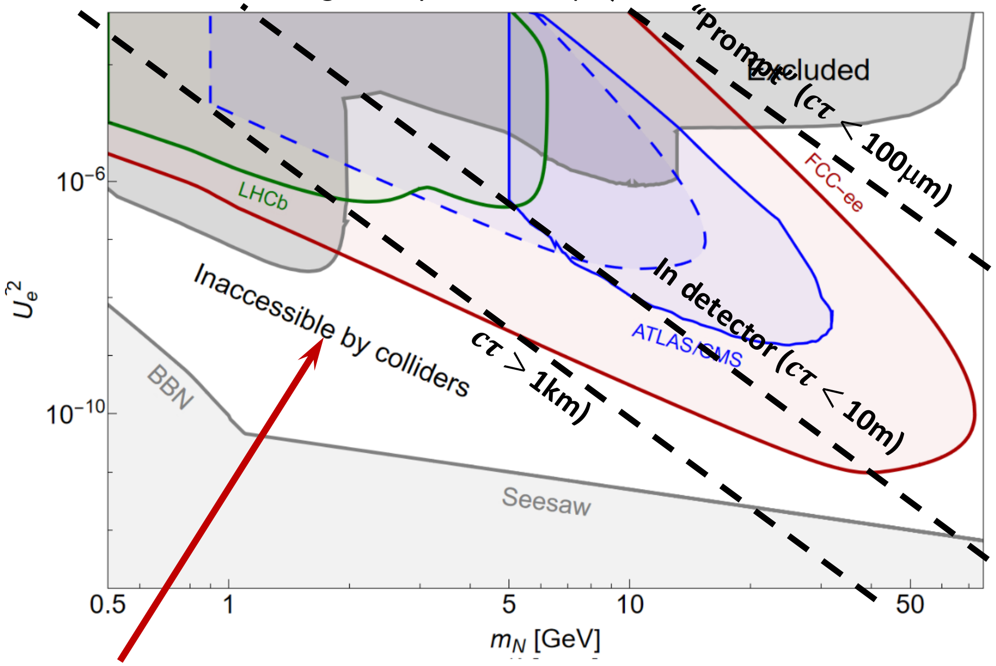

Similar behaviour $\tau_{FIP} \propto \frac{1}{\epsilon_{FIP}^x m_{FIP}^y}$ for all types of FIPs

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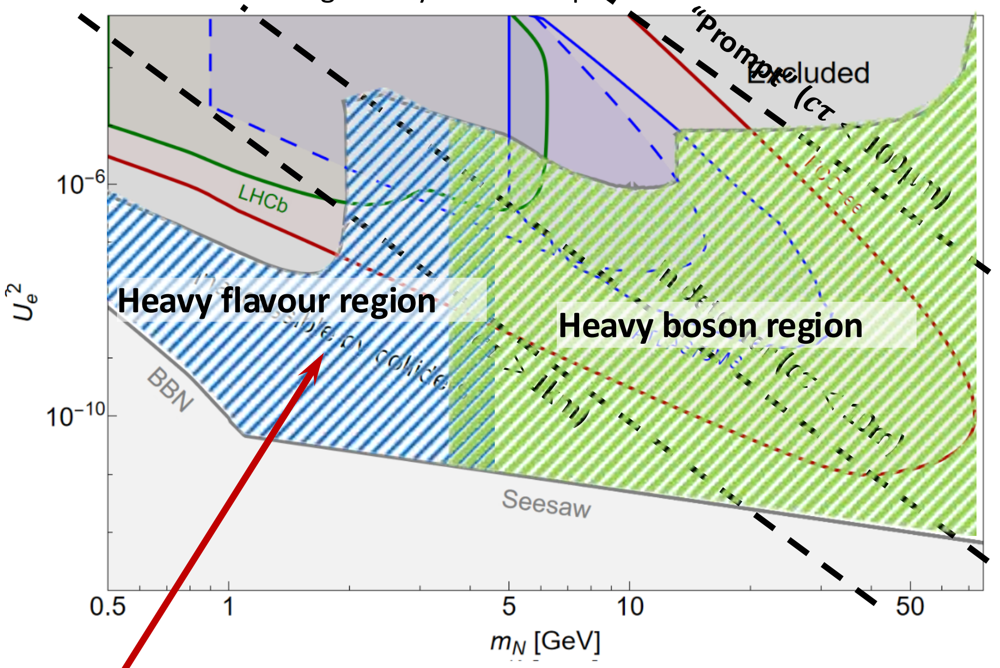

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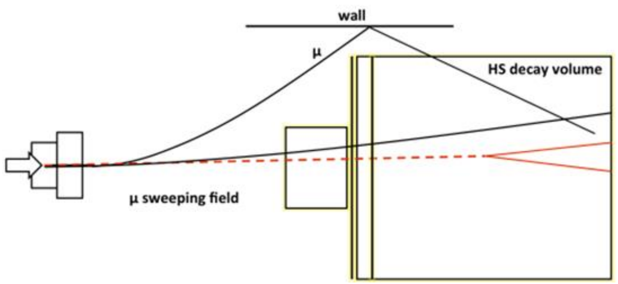
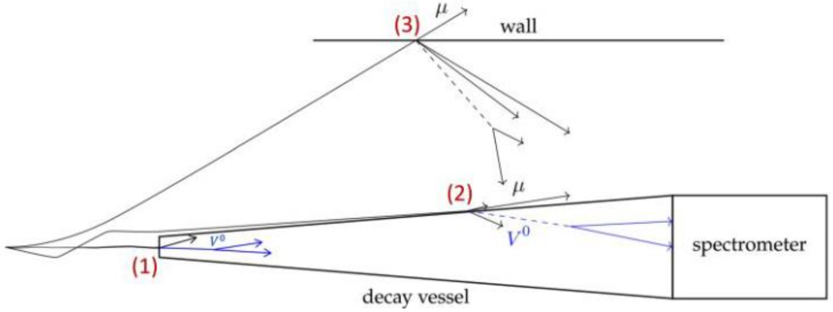
HSDS: FIP decay search background evaluation

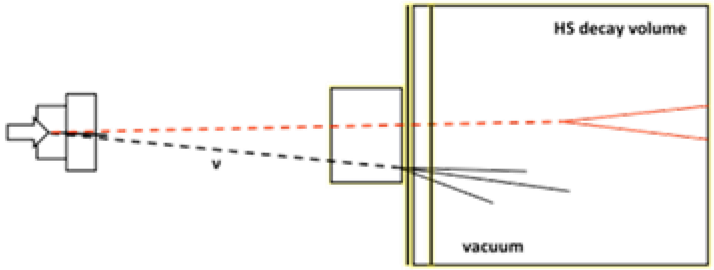
Three categories of background from residual muons and neutrinos

Muon combinatorial



Muon DIS





- Backgrounds from μ and ν DIS dominated by random combinations of secondaries, not by V^0s

➔Very simple and common selection for both fully and partially reconstructed events – model independence

➔Possibility to measure background with data, relaxing veto and selection cuts, muon shield, decay volume

Selection

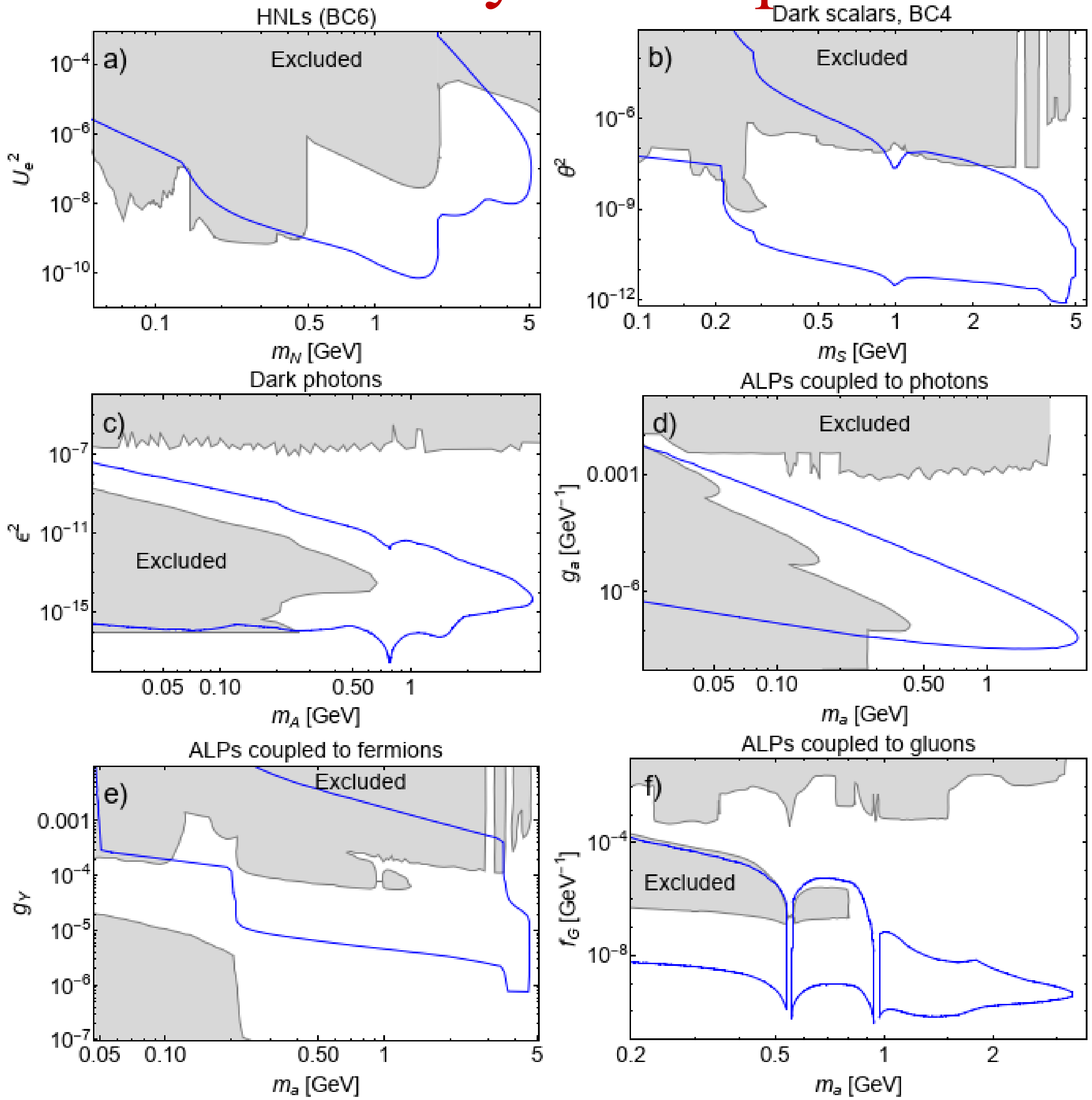
Criterion	Requirement
Track momentum (and track quality)	> 1.0 GeV/c
Vertex quality (distance of closest approach)	< 1 cm
Track pair vertex position in decay volume	> 5 cm from inner wall
	> 100 cm from entrance (partially)
Impact parameter w.r.t. target (fully reconstructed)	< 10 cm
Impact parameter w.r.t. target (partially reconstructed)	< 250 cm

+ Time coincidence + UBT/SBT

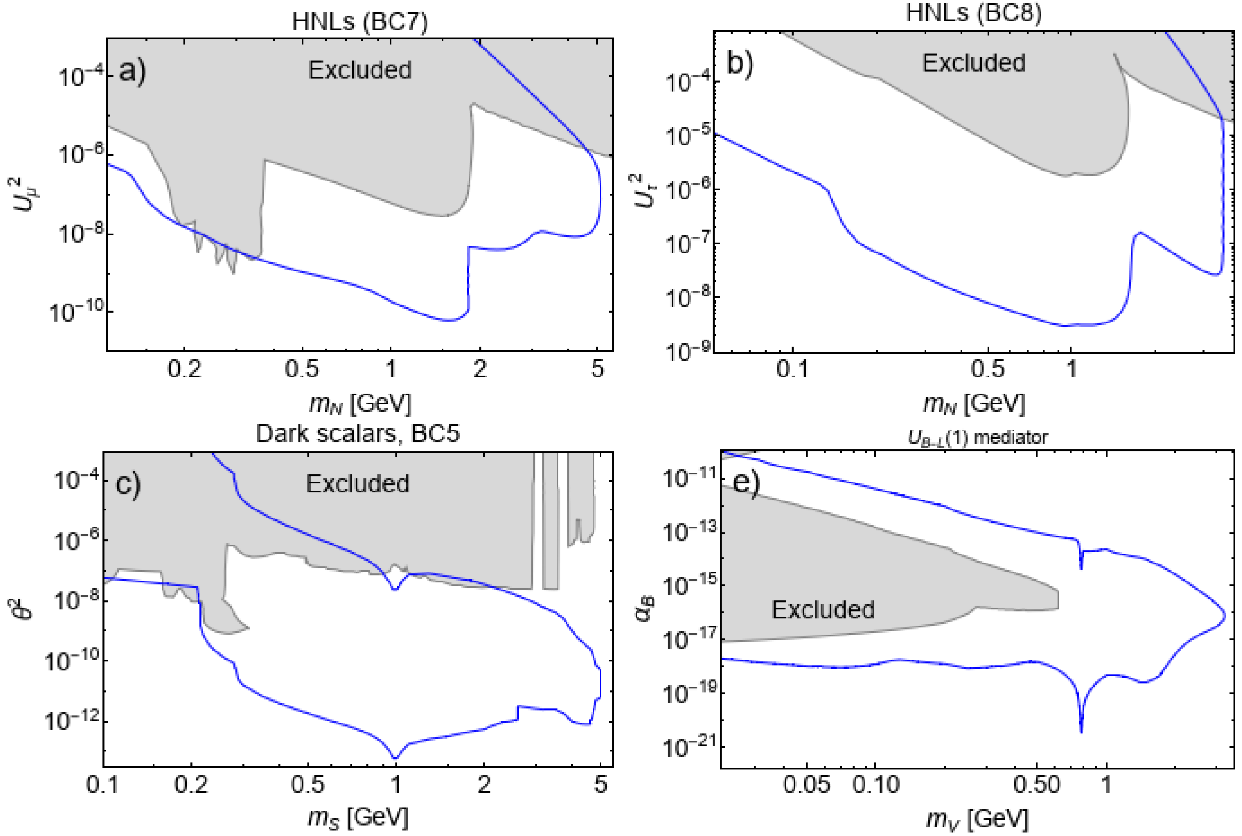
Expected background is <1 event for 6×10^{20} pot (15 years of operation)

Background source	Expected events
Neutrino DIS	< 0.1 (fully)/$<$ 0.3(partially)
Muon DIS (factorisation)*	$< 5 \times 10^{-3}$ (fully) / $<$ 0.2(partially)
Muon combinatorial	$(1.3 \pm 2.1) \times 10^{-4}$

HSDS: FIP decay search performance, all benchmark models



SHiP sensitivity not limited by backgrounds in 6 x 10^{20} PoT

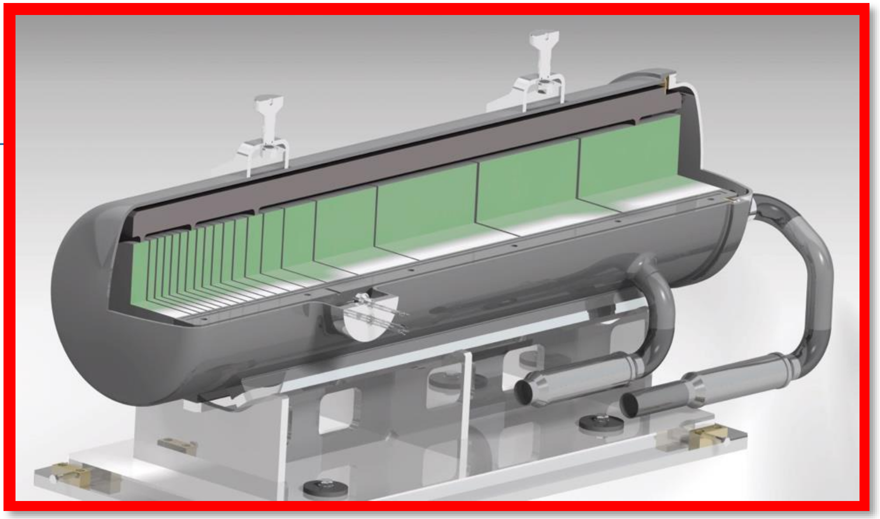


+ also SUSY-related benchmarks

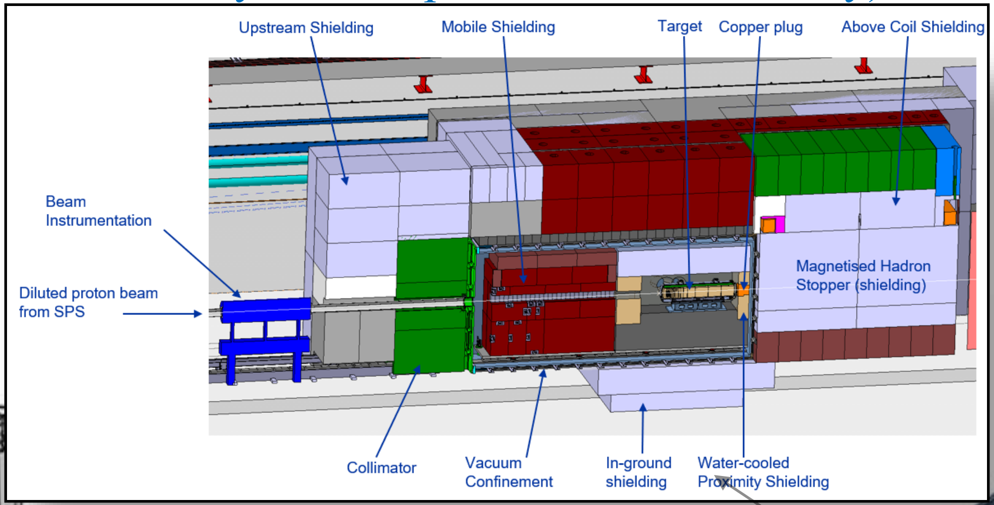
Exploration of (2-5 ⊗ 1-2) orders of magnitude (coupling^2 ⊗ mass) beyond current experiments in all benchmark models

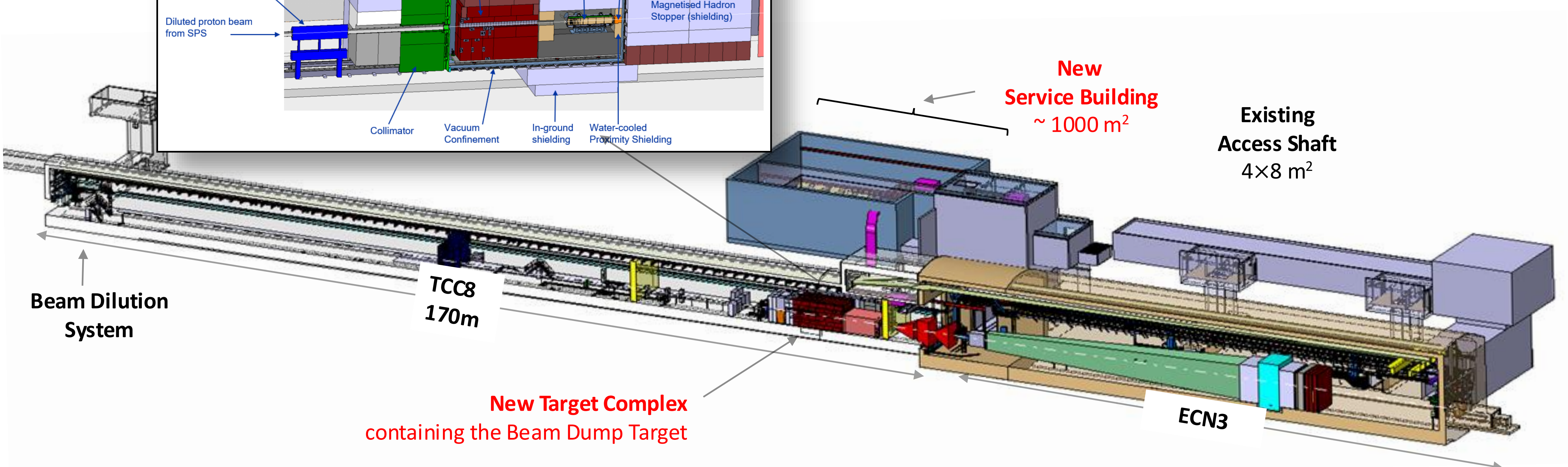
BDF/SHiP target complex

- BDF will host the highest activation equipment CERN has ever had
- Target design to be a **replaceable component** (5 y operation as target compared with 15+ years of operation for the facility)



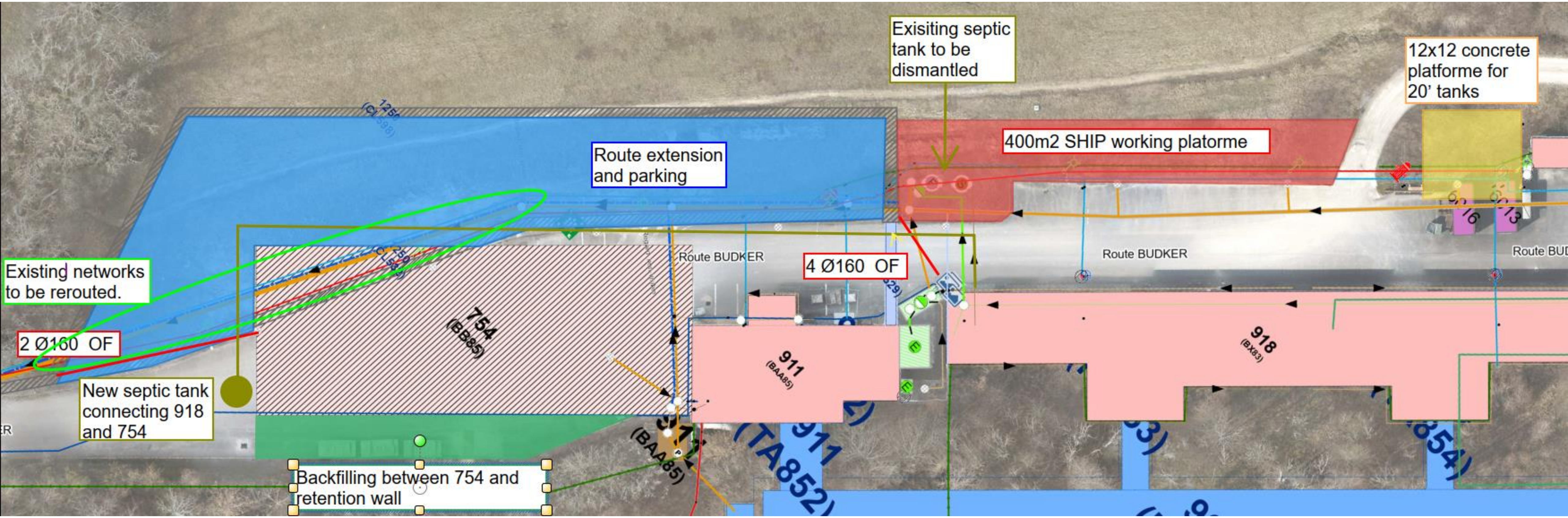
1.5m Tungsten Target



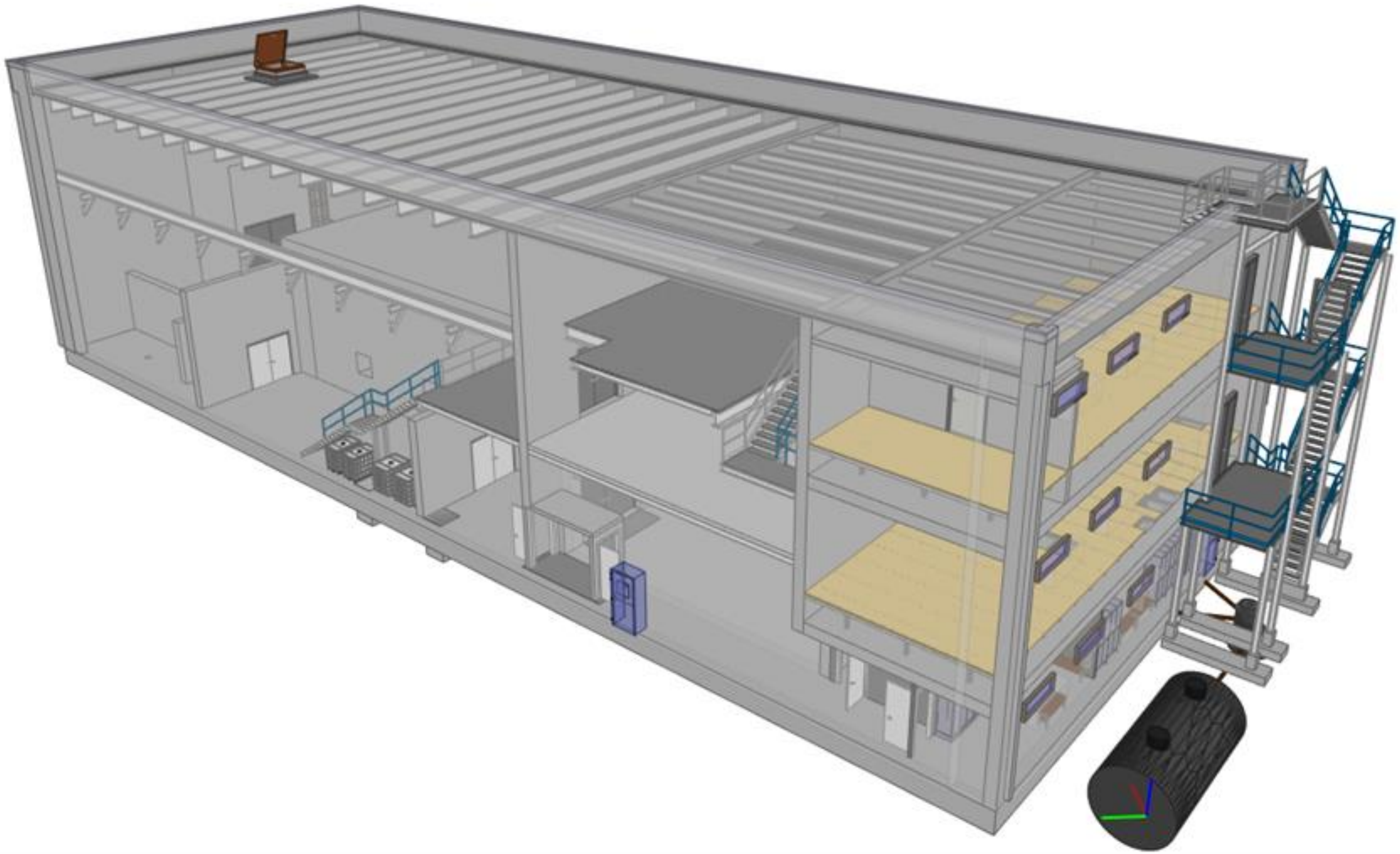


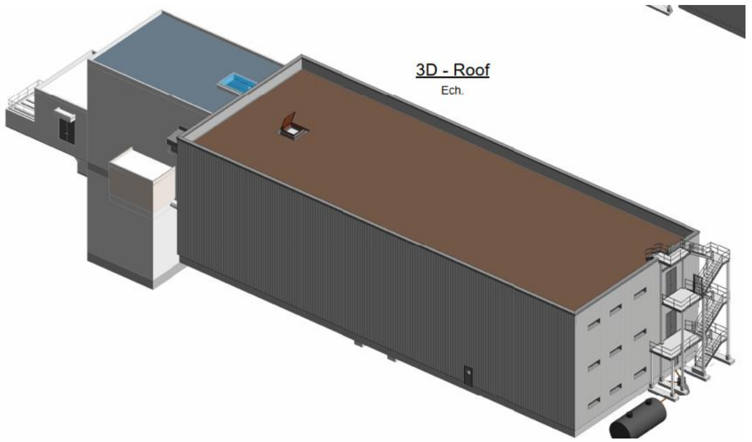
Civil engineering scope

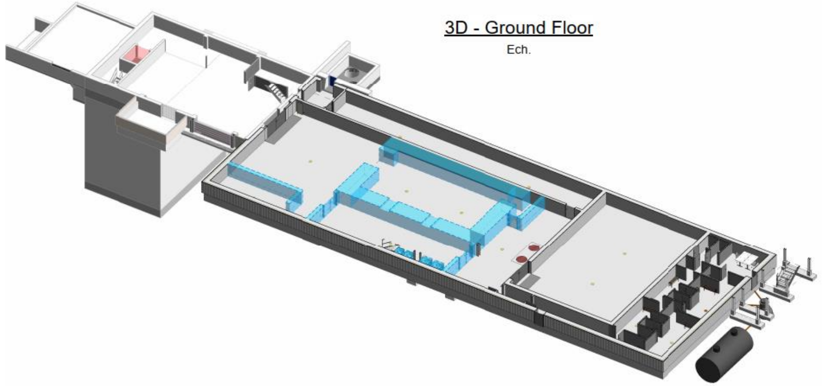
- Civil Engineering Procurement for HI-ECN3 starting soon
  - **Scope:** new surface building for BDF target complex (B754), underground excavation and renovation of B911, B912 and B918

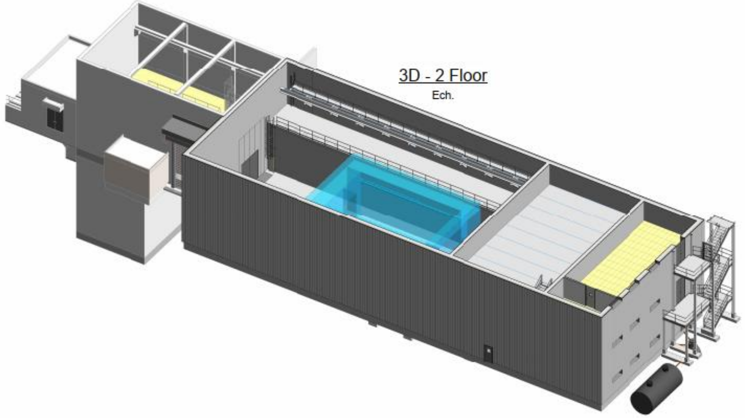


Civil Engineering: B754

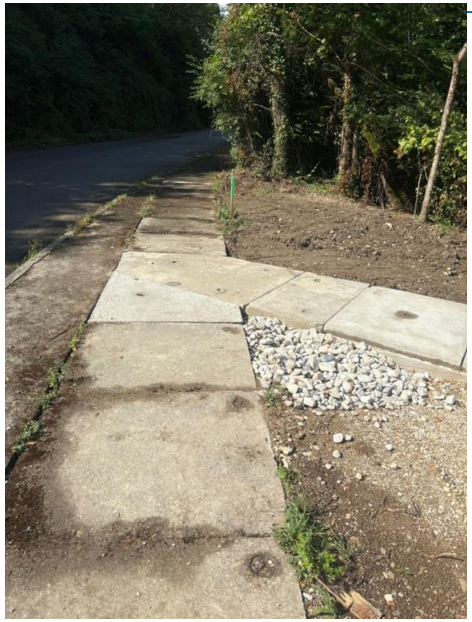






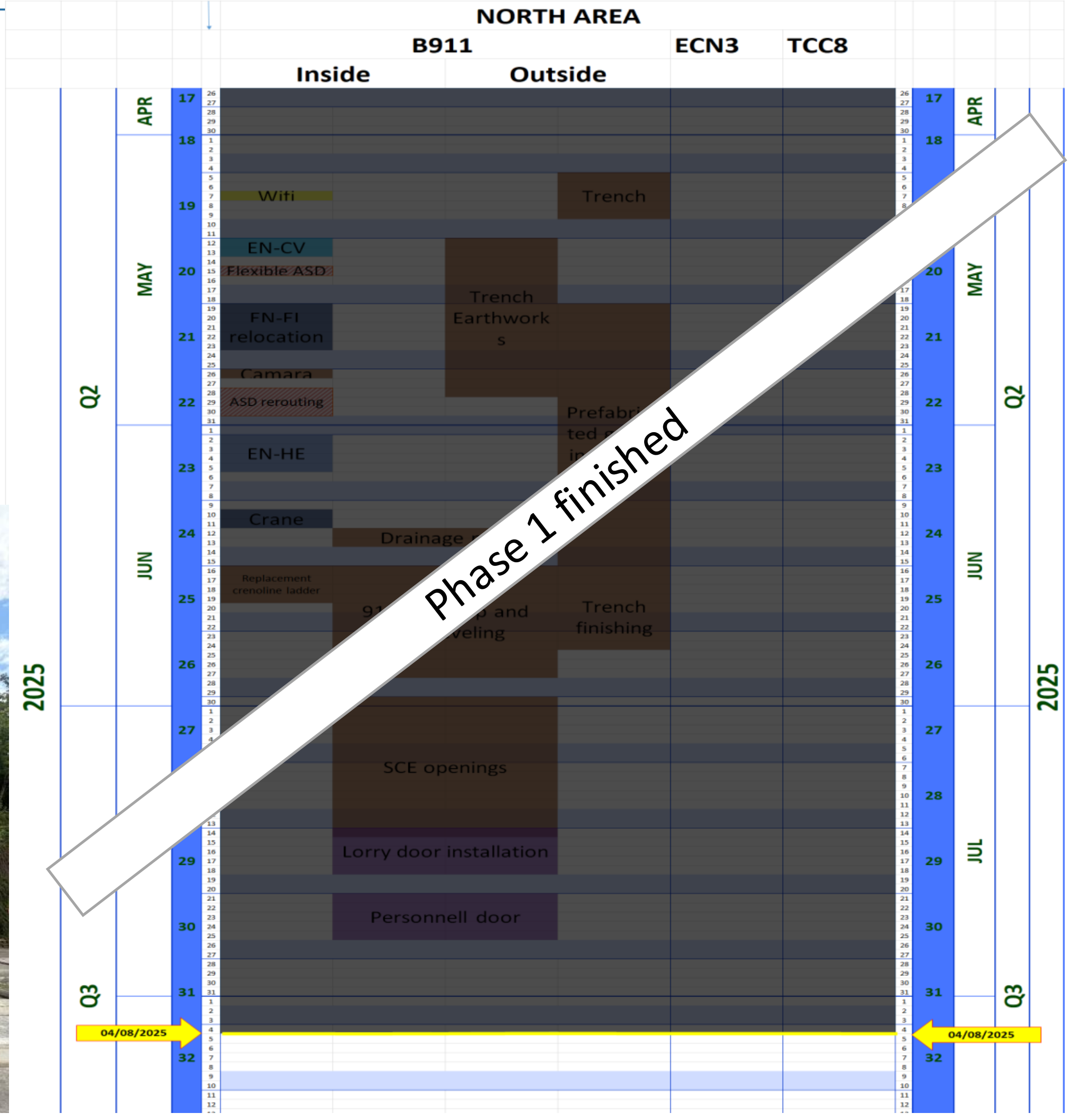


Ready to construct B754



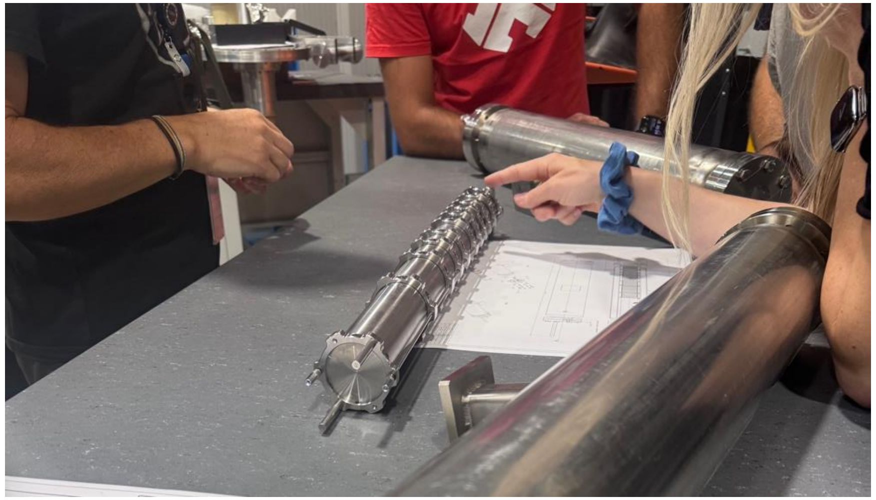
Trench

New B911 doors

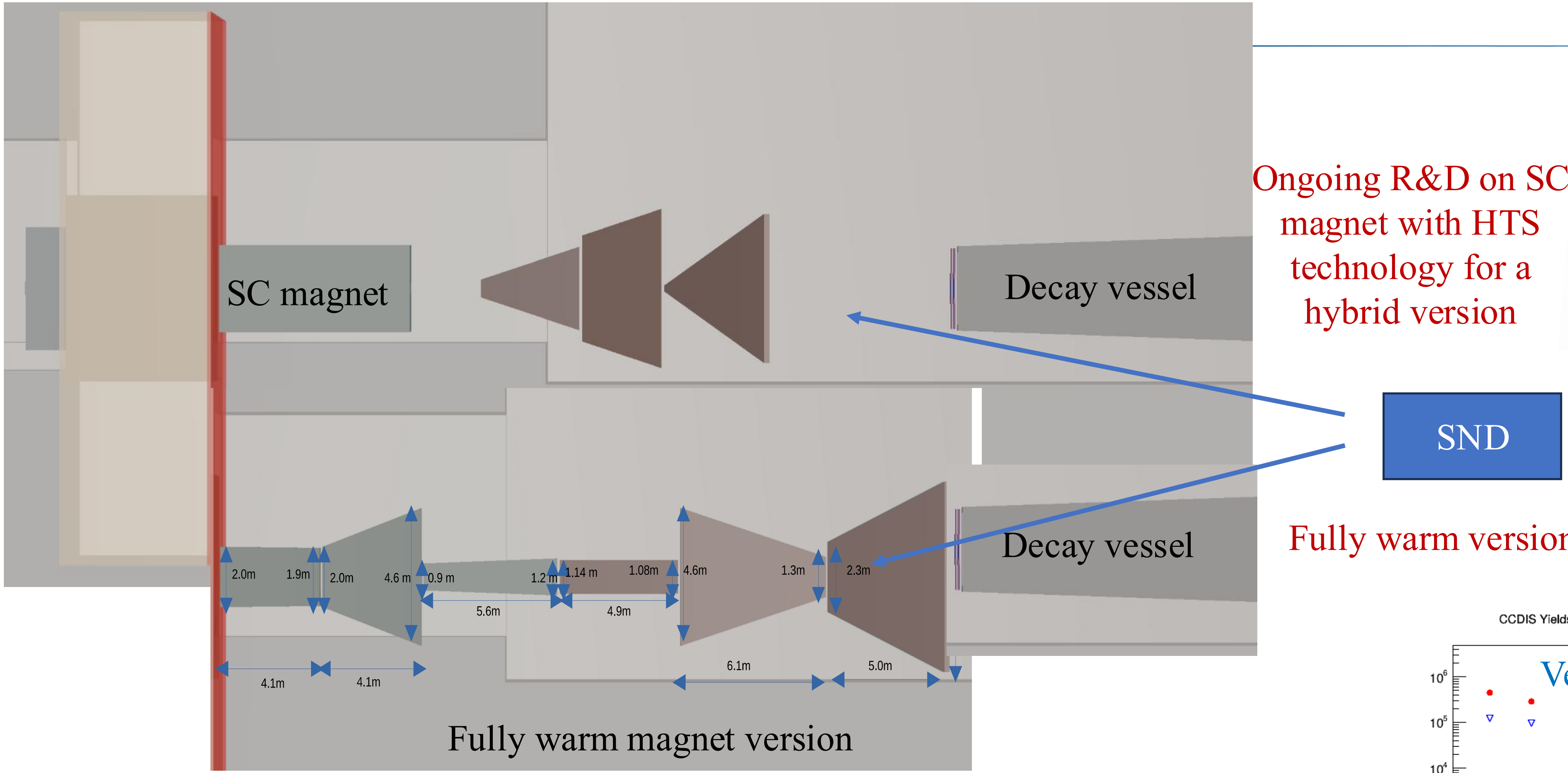


BDF target R&D

- BDF He-cooled prototype target tests going ahead:
  - **Static test (no active cooling) in 2025:** installed in TCC2 last Wednesday 10th September 2025
  - **Dynamic test (helium-cooled system) in 2026:** He compressor under procurement, installation integrated in planning for **YETS25/26** thanks to BE-EA and NA-CONS

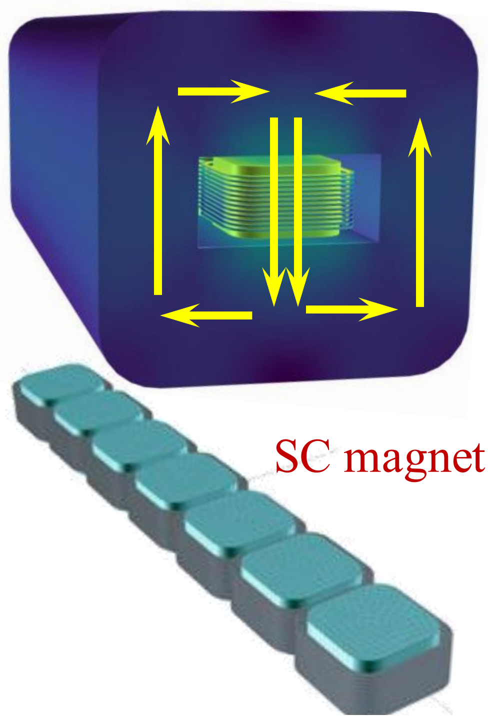


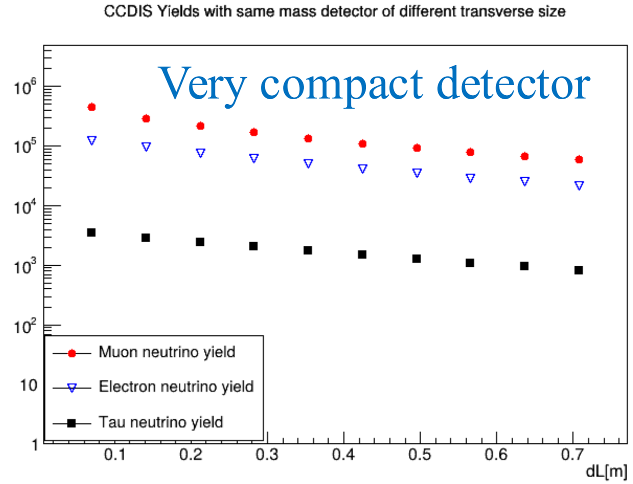

SND detector embedded in the muon shield



Ongoing R&D on SC magnet with HTS technology for a hybrid version

Fully warm version





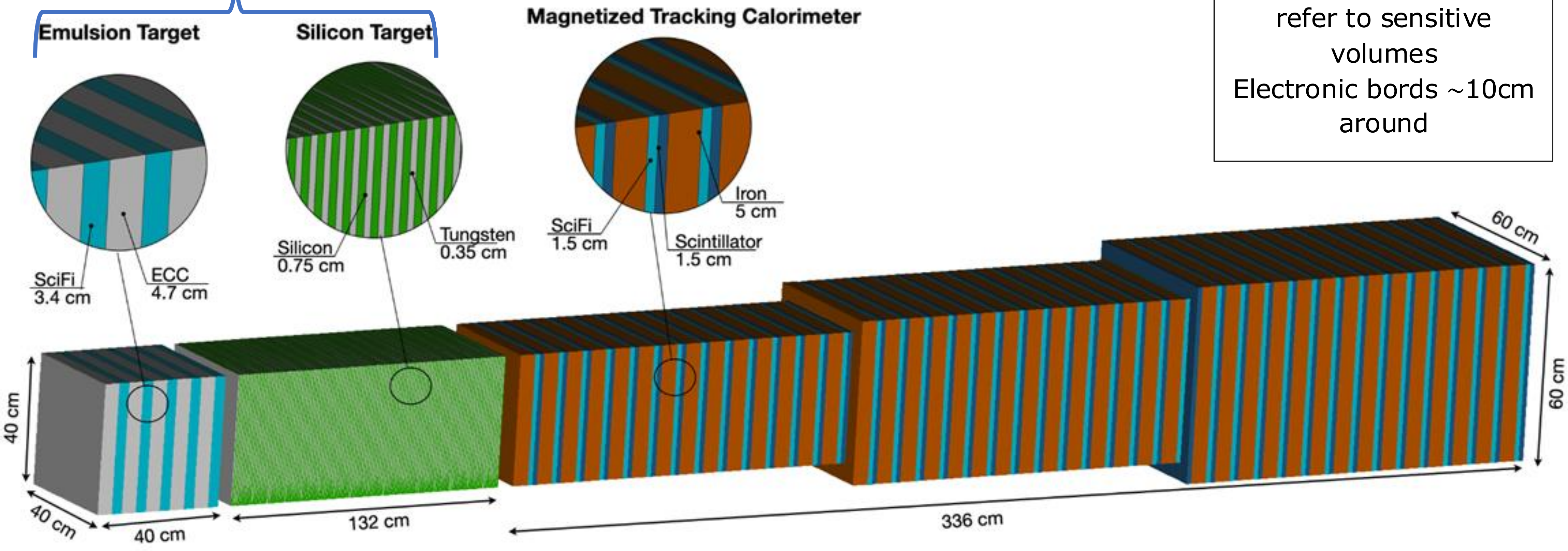
SND requires a muon spectrometer (magnet) → embed it within the magnetised iron of the muon shield

SND@SHiP: neutrino detector concept a là SND@LHC

High-precision VTX detector
ν_τ, charm and LDM

Magnetised tracking calorimeter (MTC)

quoted dimensions refer to sensitive volumes
Electronic bords ~10cm around



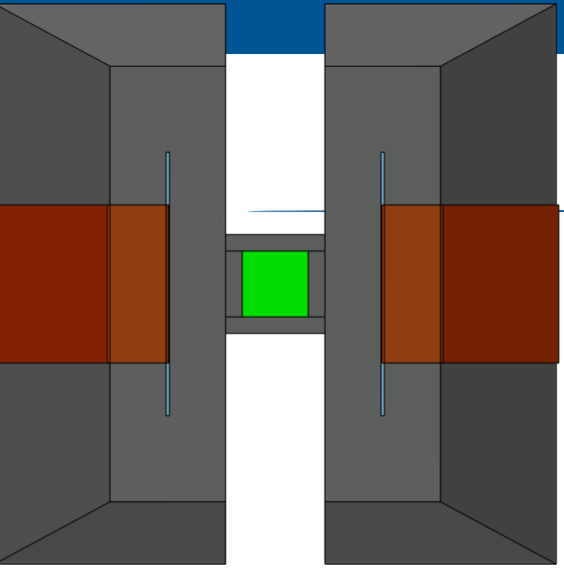
EMULSION TARGET			
ECC	5	Tungsten	180
		Emulsion	180
SciFi	5		
Weight	0.5 ton		

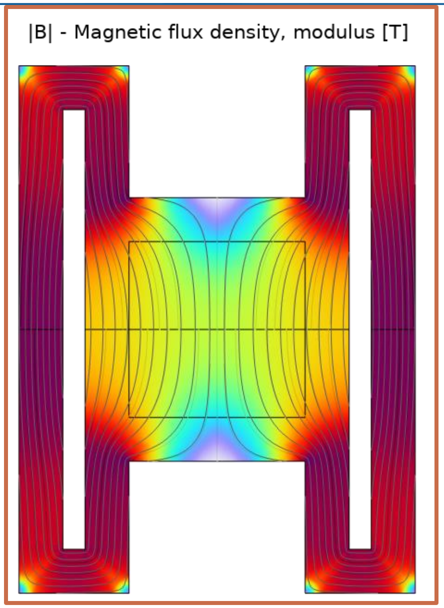
SILICON TARGET	
Tungsten	120
Silicon	120
Weight	1.2 ton

MAGNETIZED TRACKING CAL	
Iron	42
Scintillator	42
SciFi	42
Weight	2.5 ton

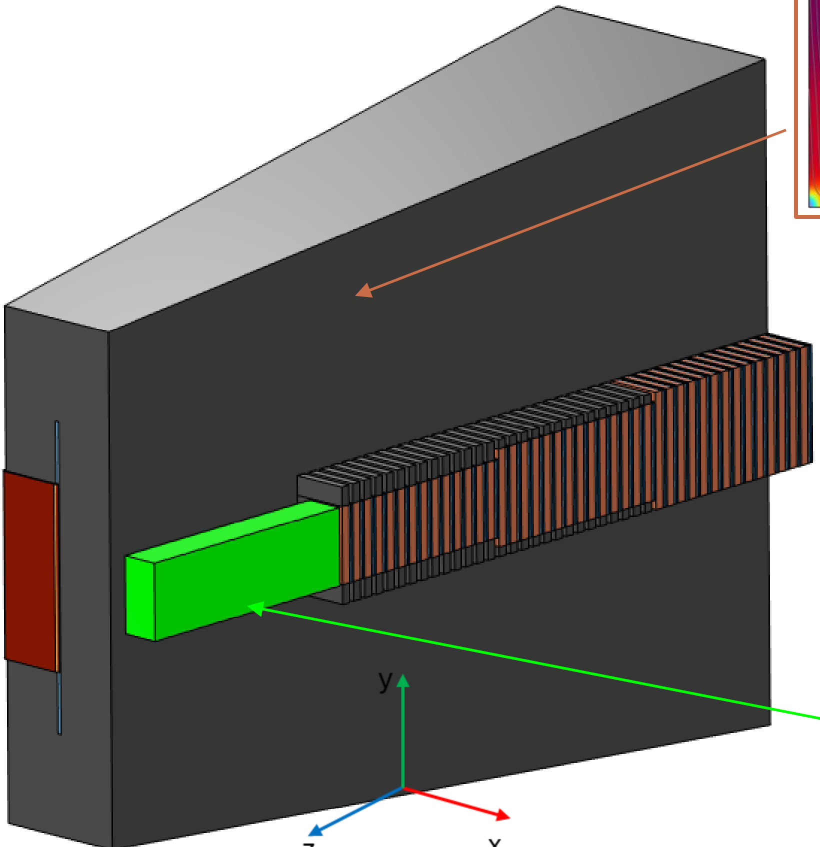
42 slabs, 5 cm each
~ 10 λ

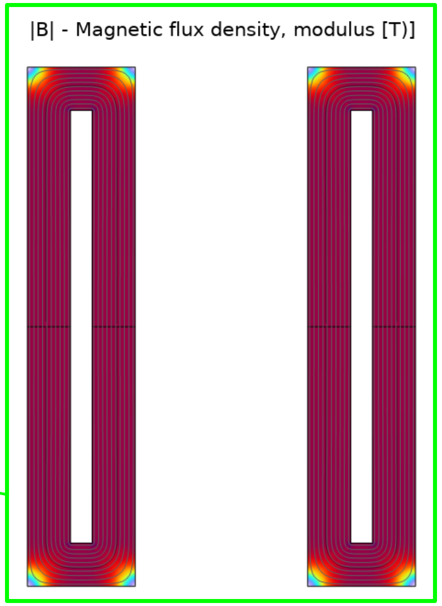
Two different options to embed the SND in the last magnet

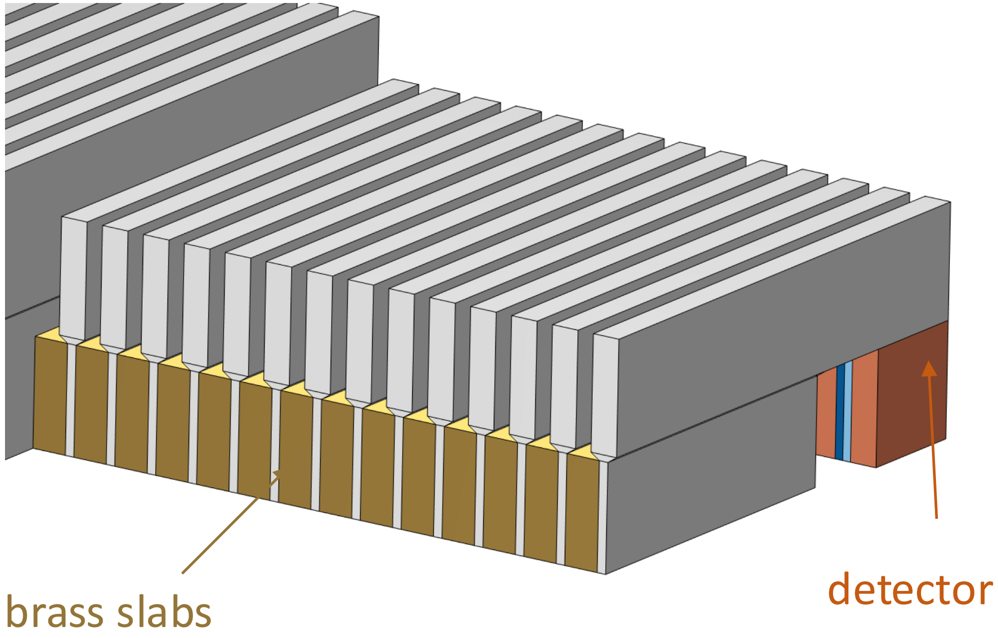


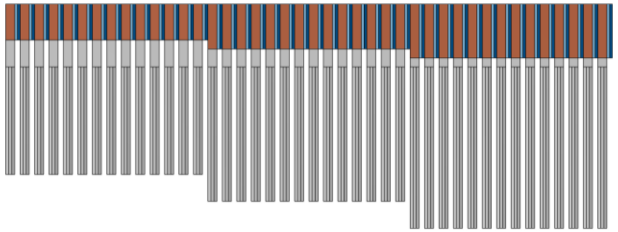


Field inside the HCAL region (core AND wings)

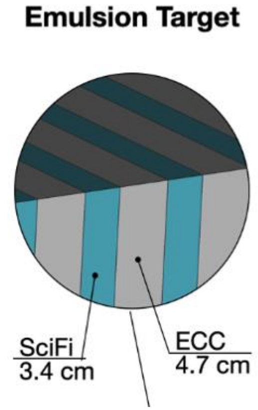




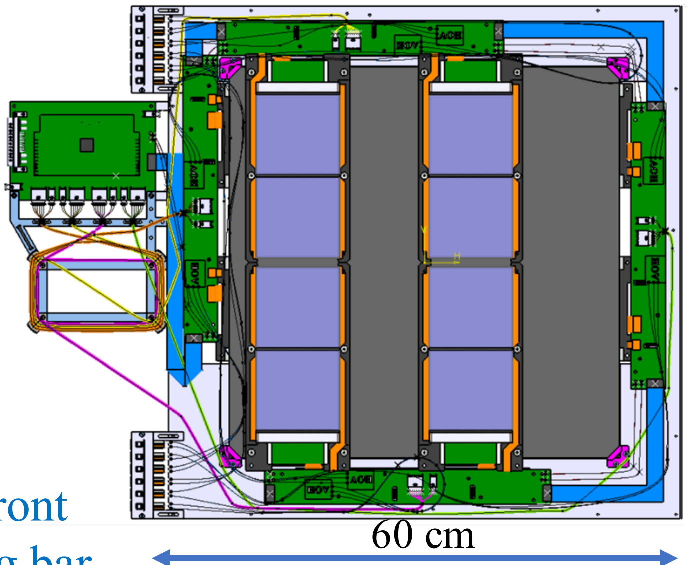


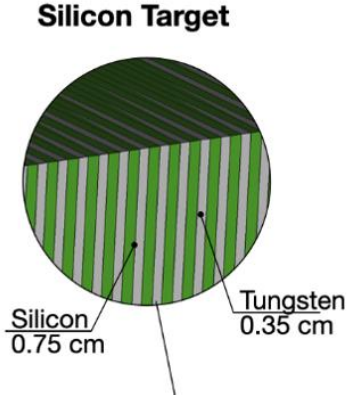


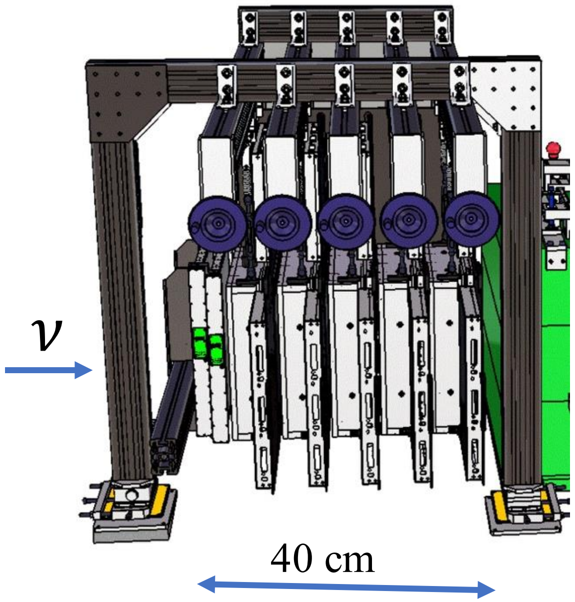
Detector components: high-precision vertex



Exact position will depend on the muon rate

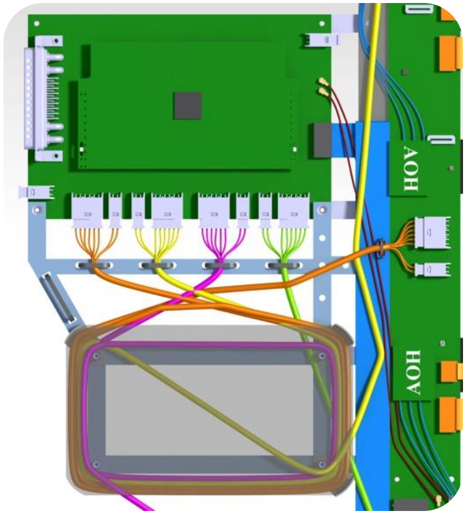


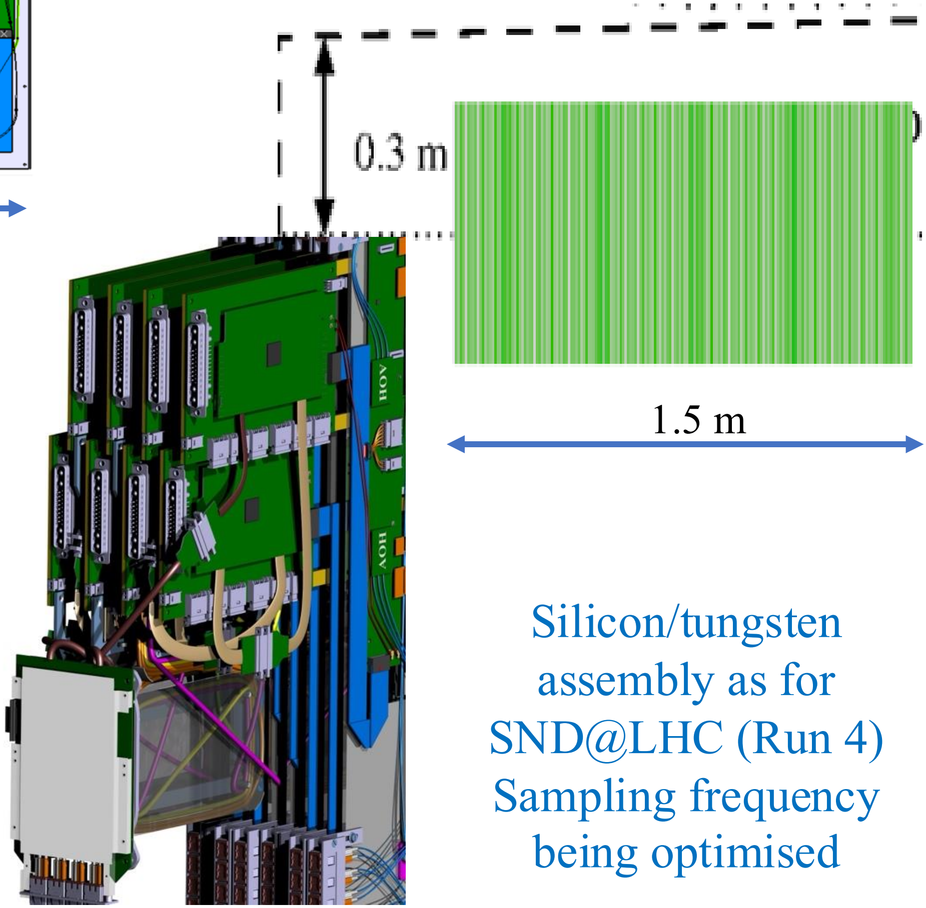




Similar implementation as in SND@LHC, ECC walls interleaved with SciFi stations

Veto station in front with 3 scintillating bar planes



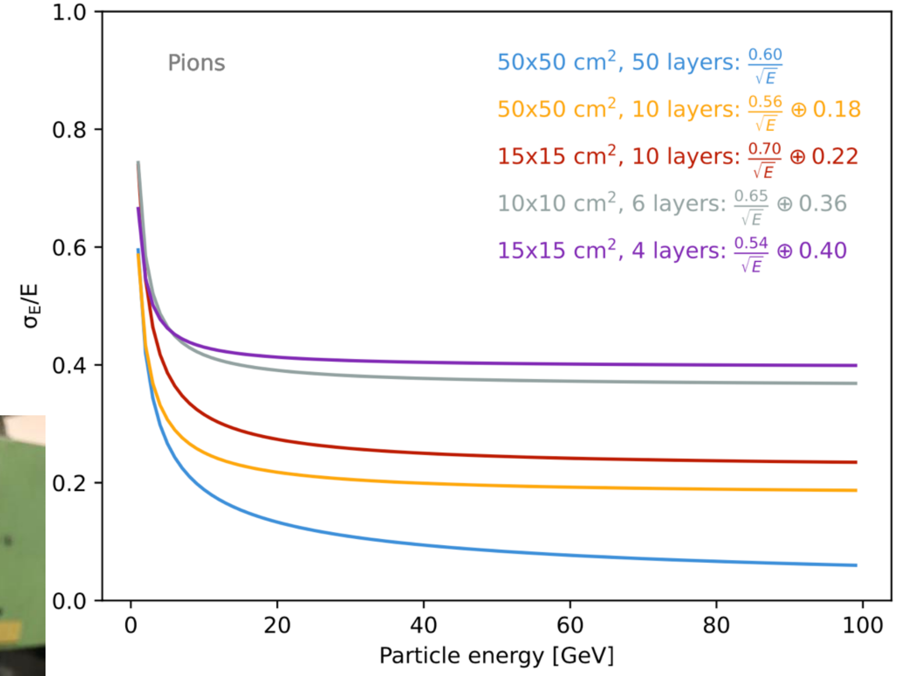


Silicon/tungsten assembly as for SND@LHC (Run 4)
Sampling frequency being optimised

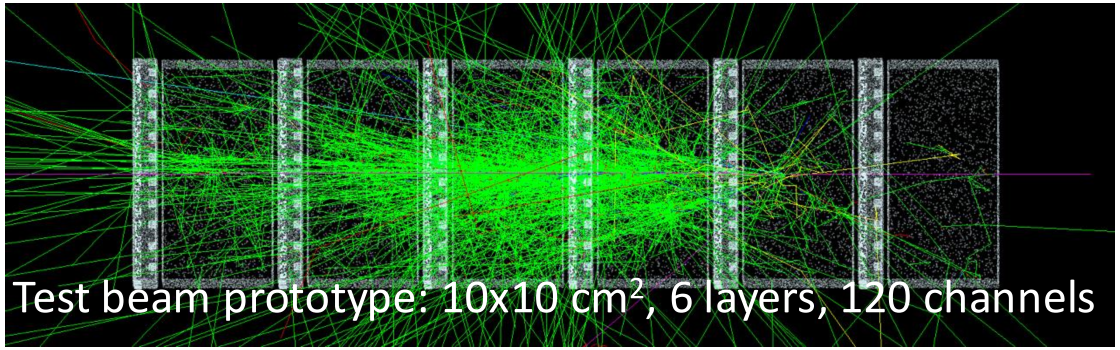
Scintillating pads: energy resolution and tests

Full-sized detector: expect 0.6/sqrt(E) for π and 0.31/sqrt(E) for electrons, dominated by statistical fluctuations

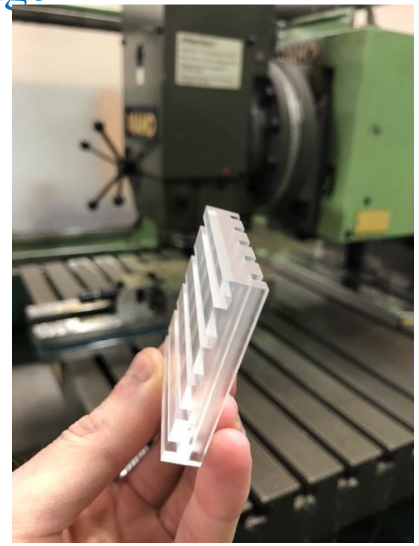
- π resolution limited by the constant term due to significant shower leakage (lateral and longitudinal)
- sufficient containment of EM showers over the full energy range

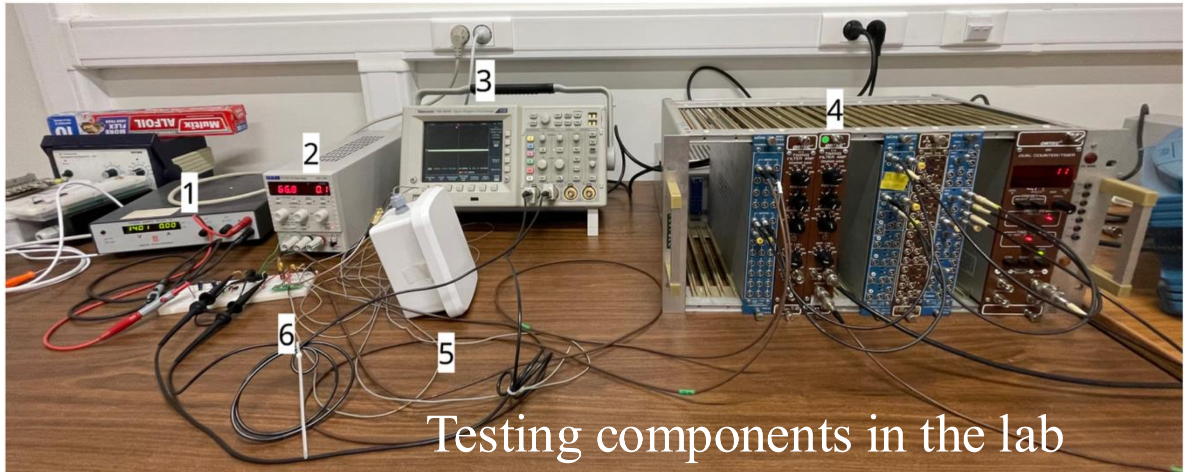


Test beam foreseen in Spring 2026 at PS and SPS



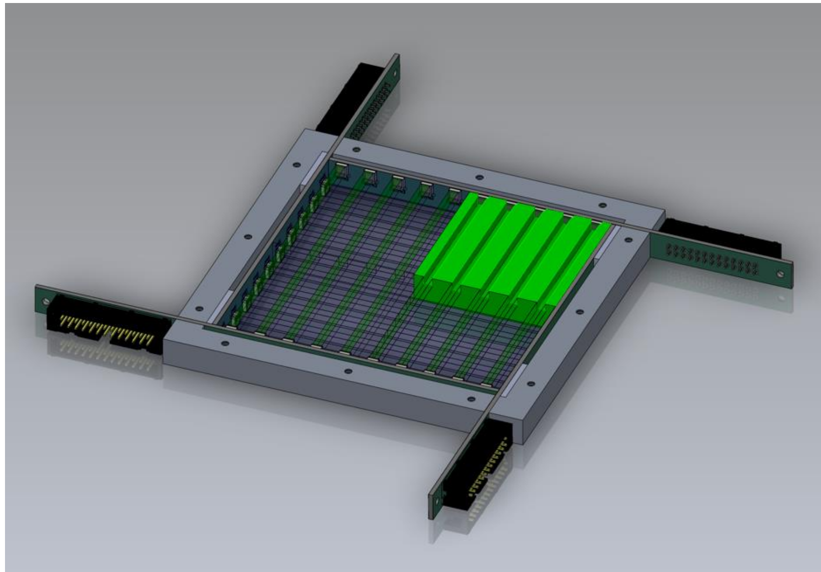
Test beam prototype: 10x10 cm^2, 6 layers, 120 channels



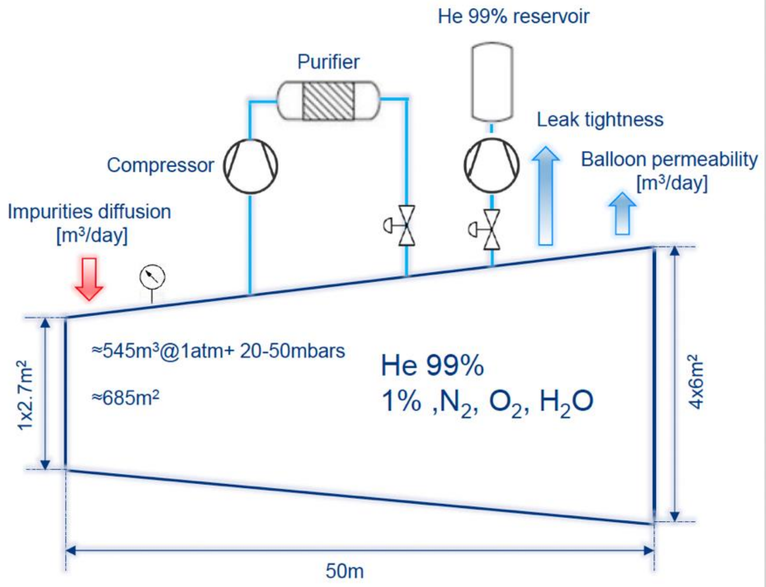


Testing components in the lab

- Wrap the whole scintillator plane in reflective material (Mylar)
- Improve light transmission from one tile to another using optical grease (EJ-552)



Decay vessel and the surrounding veto system

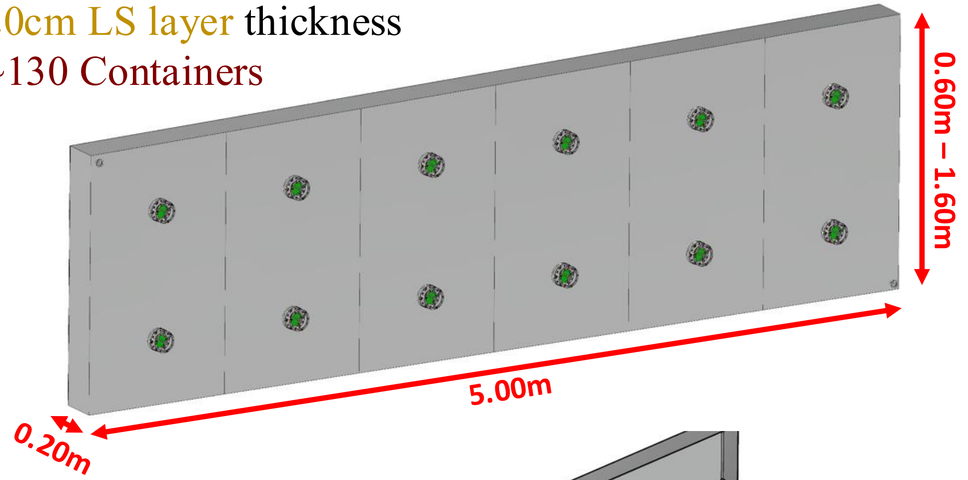


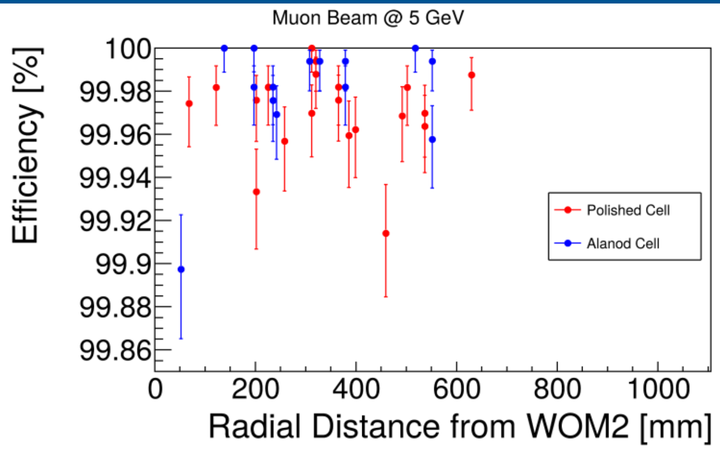
6 Interconnected liquid scintillator filled cells

Welded from large sheets of polished AW 5083 (AlMg4.5)

20cm LS layer thickness

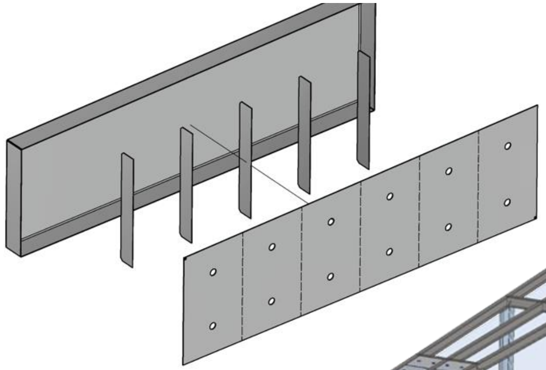
~130 Containers

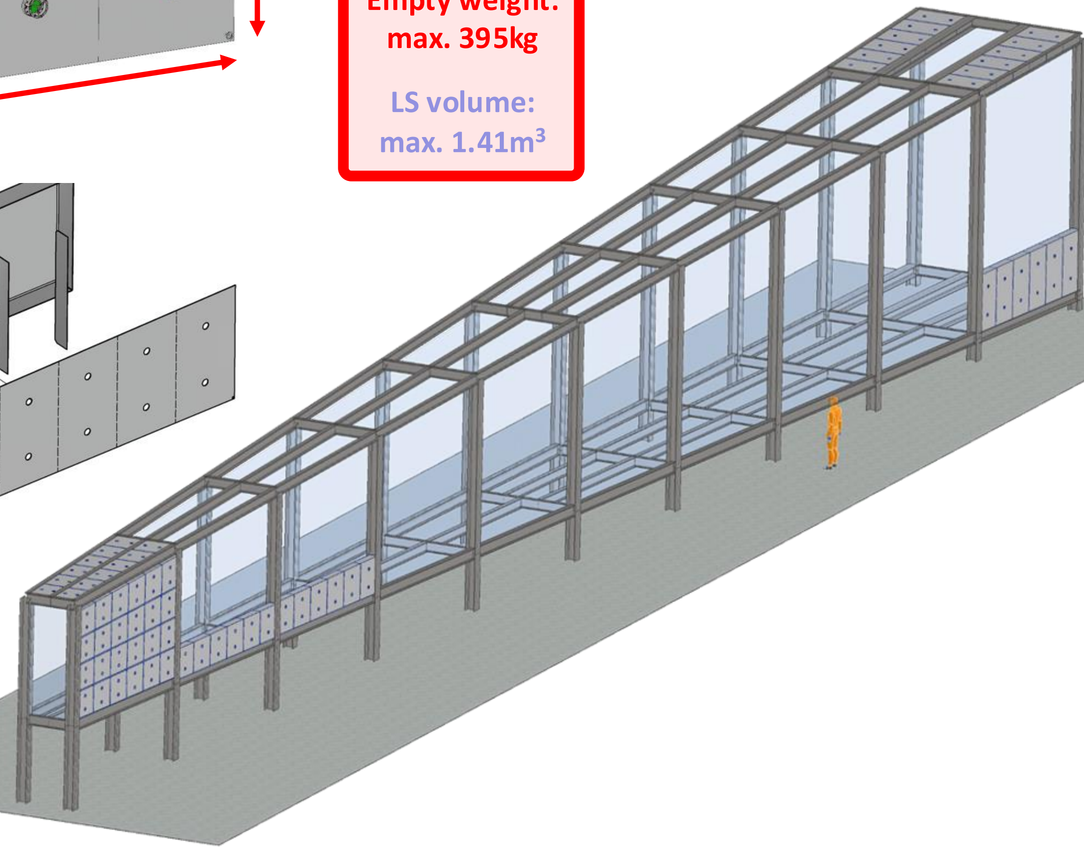




Empty weight: max. 395kg

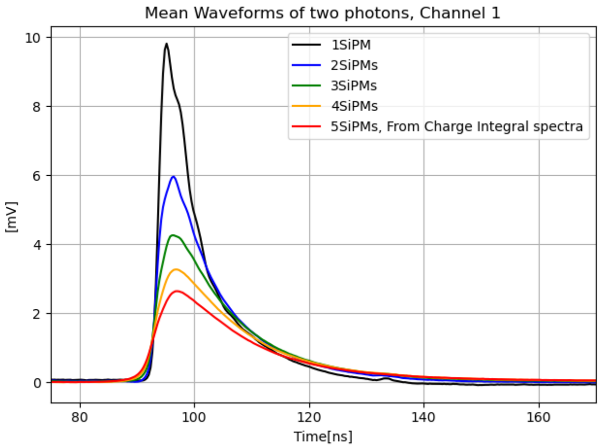
LS volume: max. 1.41m^3





0.3-0.4 mm thick

Waveforms by 2 photons, for one channel



Spectrometer magnet with HTS technology

Proof-of-Principle

Magnet based on MgB_2 cable (wire same as HL-LHC SC Link)

Indirect cooling – Cryocooler+Cryofan – GHe ~20K

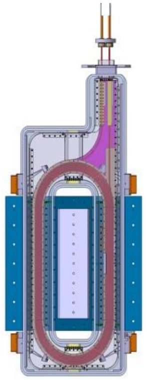
EESD1: coil pack concept validated

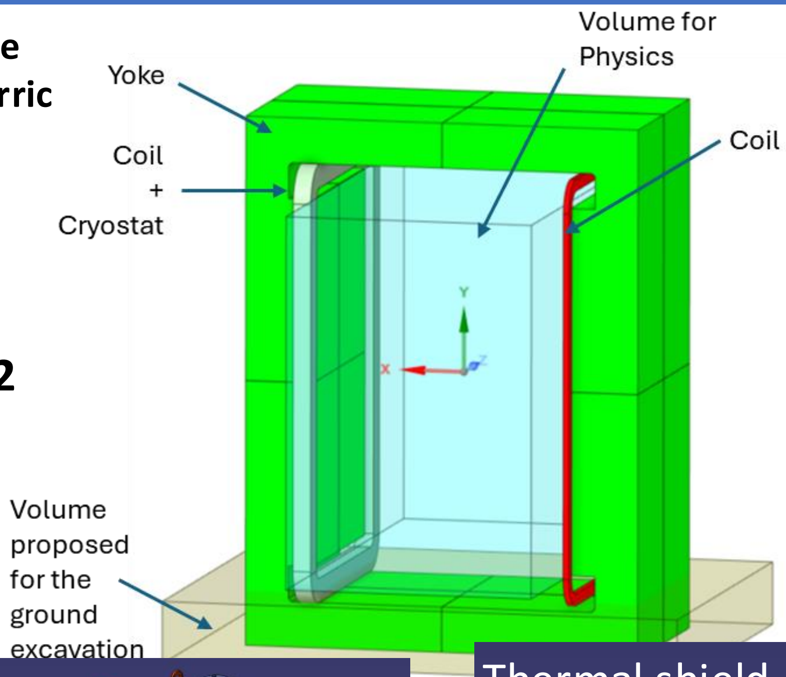
ESSD2: Validate cooling concept + operation with current leads

From Proof-of-Principle

Energy-Efficient Superferric Dipole

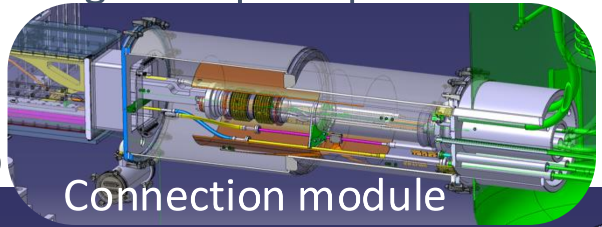
~ 1m

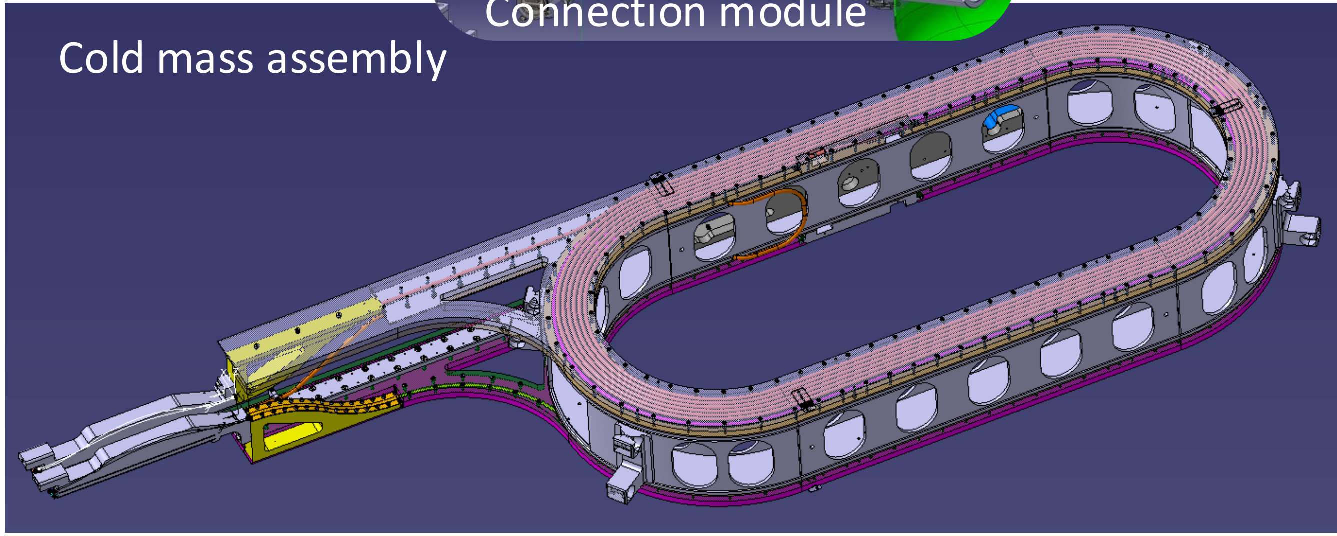


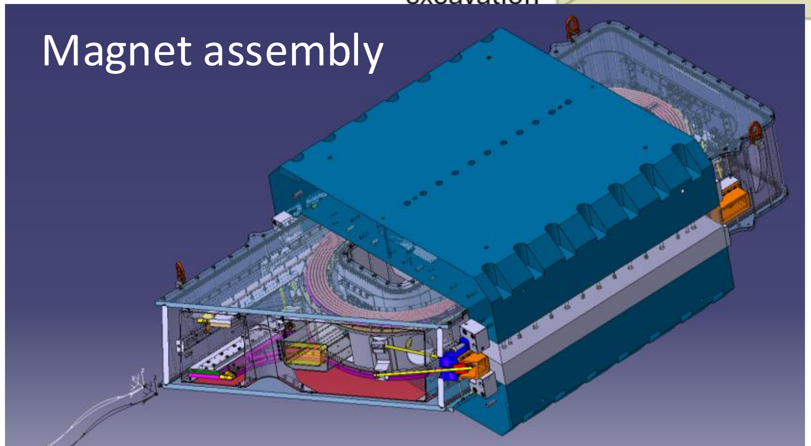


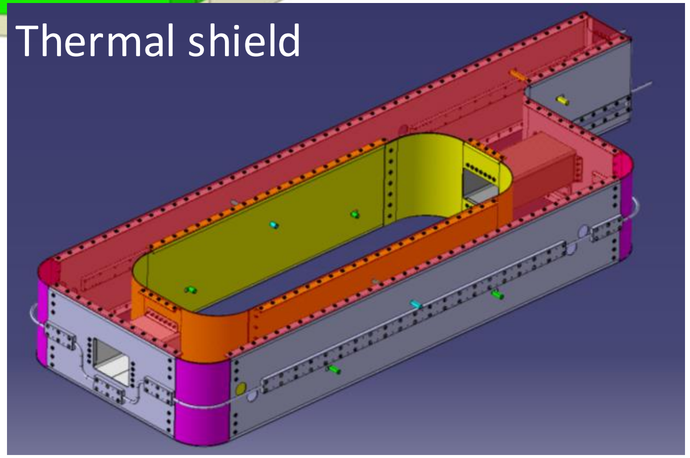
To Full-Scale Magnet

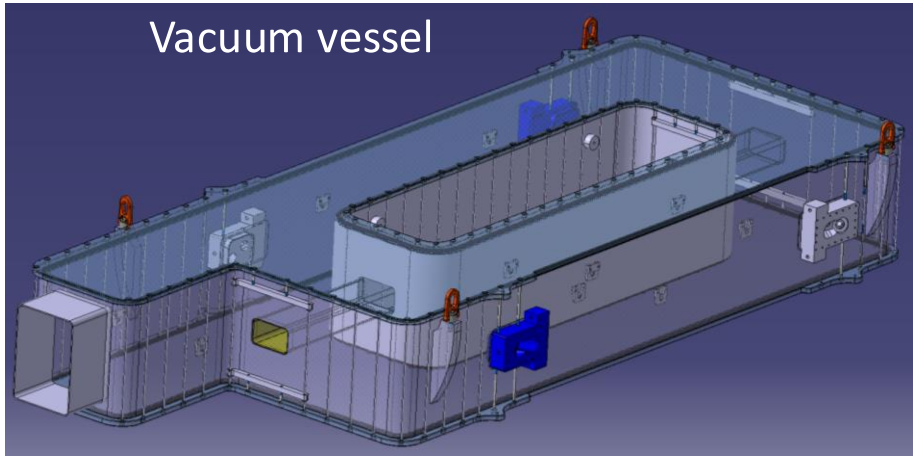
~ 5m (Z) x ~ 7.5m (Y)



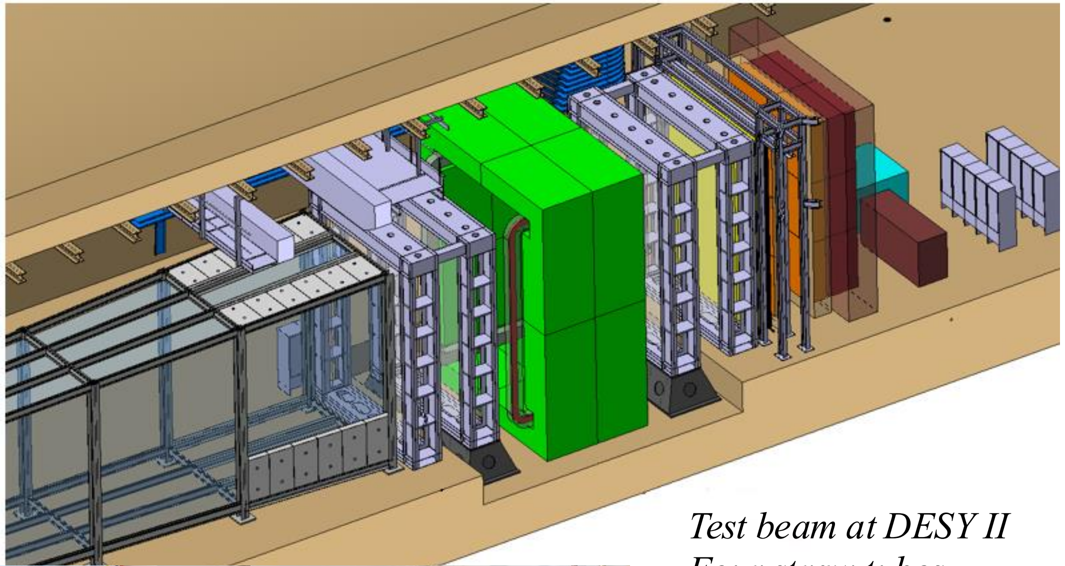




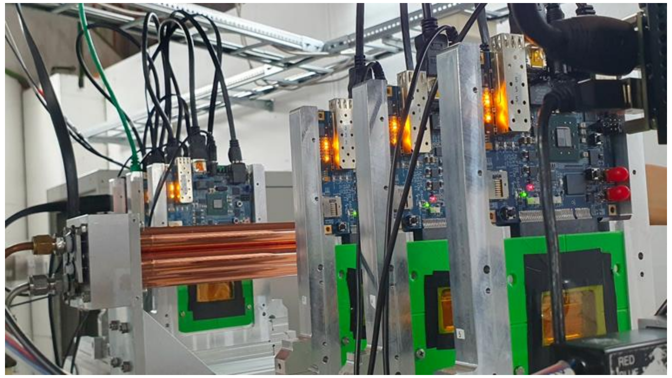


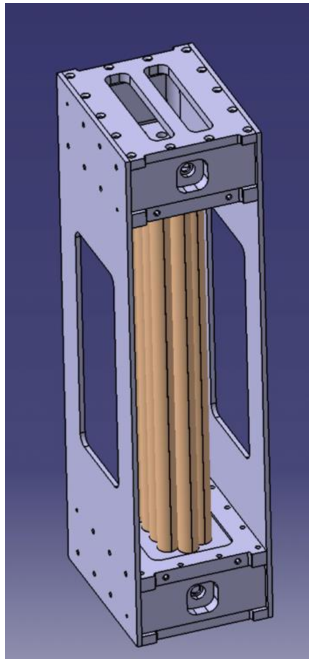


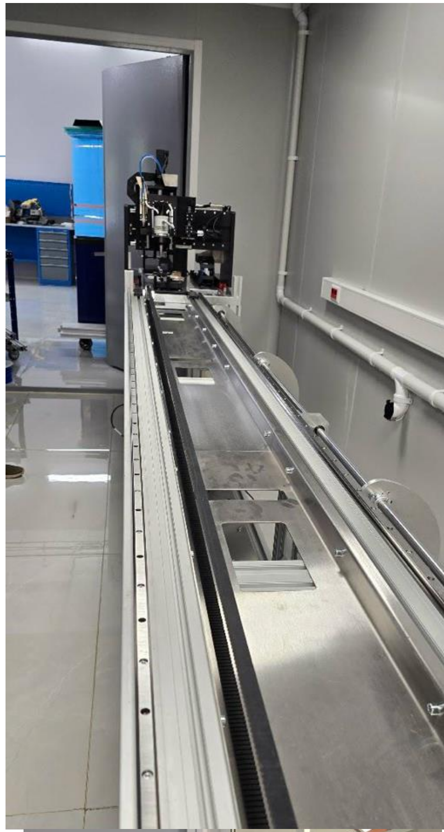
Straw tracker developments for the spectrometer



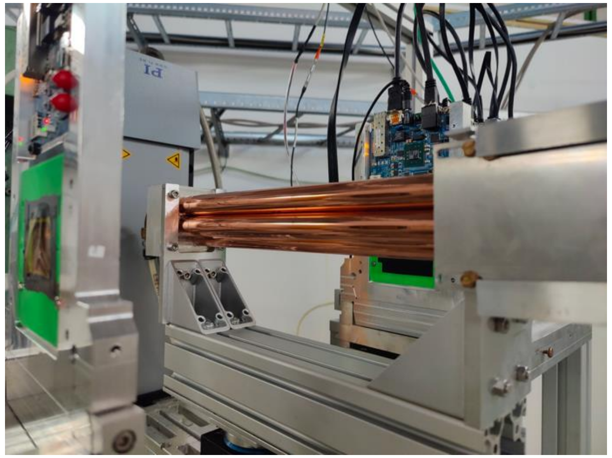
Four identical stations, aperture of 4m x 6m
300 tubes on top, 8 layers per station
2400 straws per station → almost 10000 channels
Modules of 2 x16 straws (32 cm high)





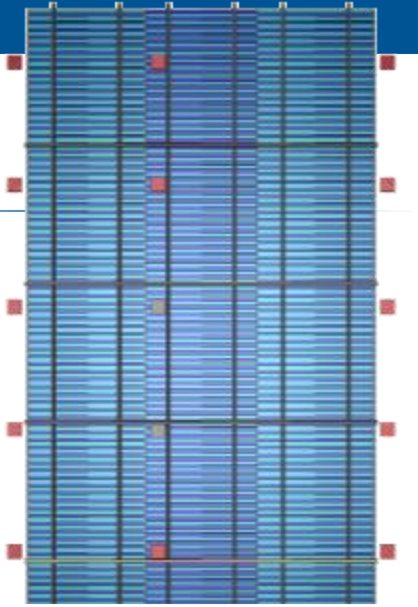


Test beam at DESY II
Four straw tubes
30 cm long, 2cm diameter
30 μm wire
80/20 Ar/CO2
at ambient pressure
Readout with SAMPIC

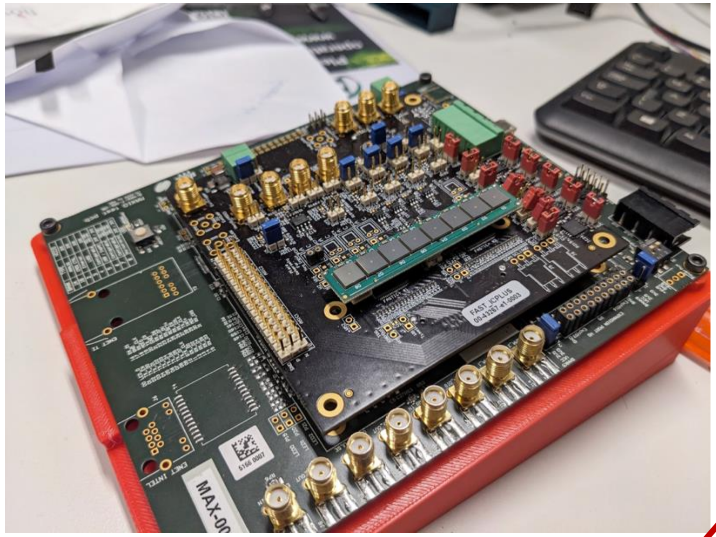


Timing detector

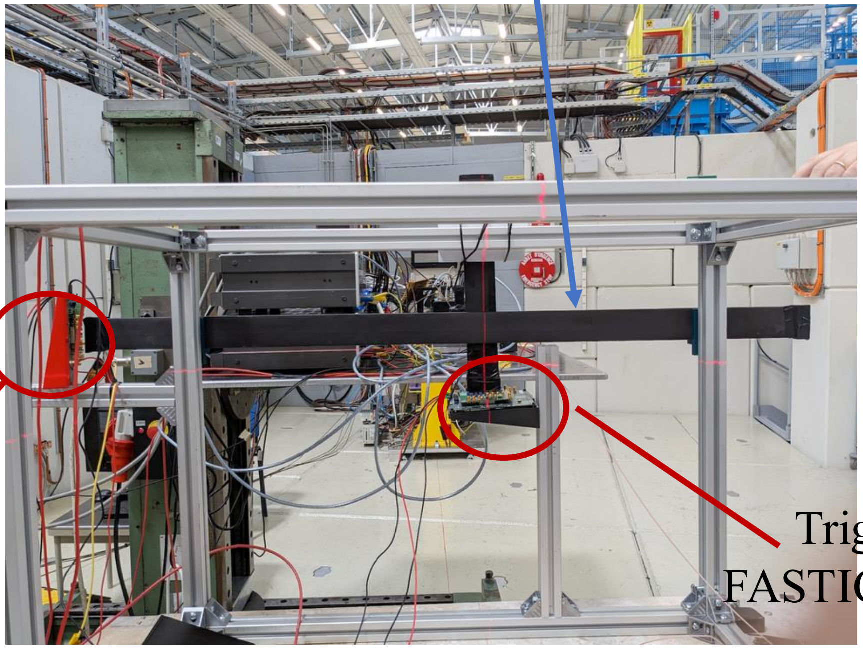
- Provide precise timing (<100 ps) of each track to reject combinatorial background
- Plastic scintillator characteristics
  - Three-column setup with EJ200 plastic bars of 140cm × 6cm × 1cm, providing 0.5cm overlap
  - Readout on both ends by array of eight 6×6 mm^2 SiPMs, 8 signals are summed
  - 330 bars and 660 channels



FASTIC with 25ps TDC embedded

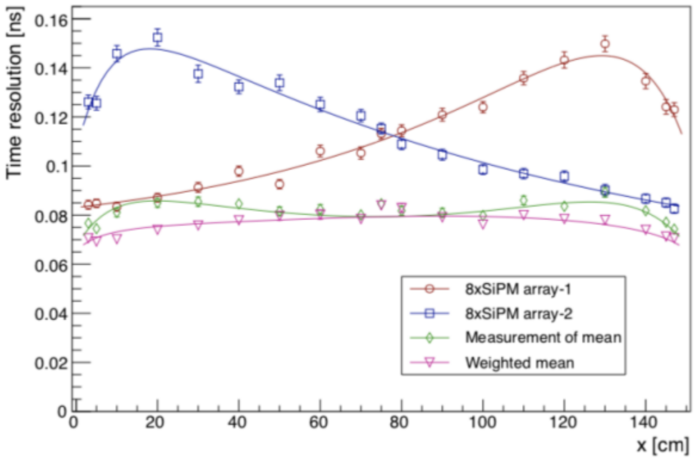


Test beam in Sep 2025 at CERN T10



Trigger IN
Beam Counter

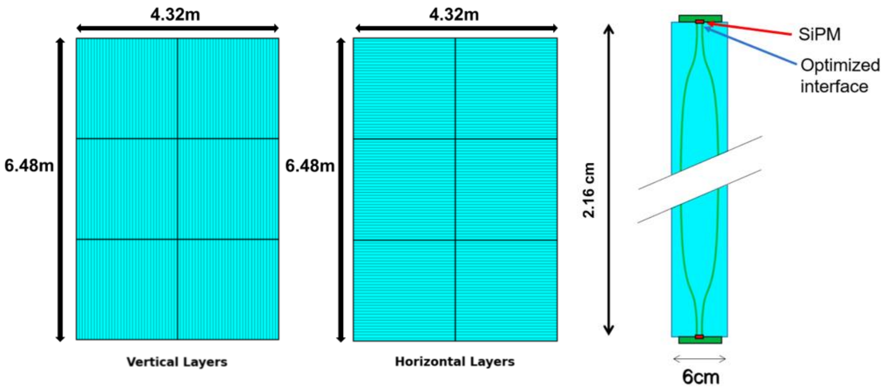
Trigger IN
FASTIC- Fast OR

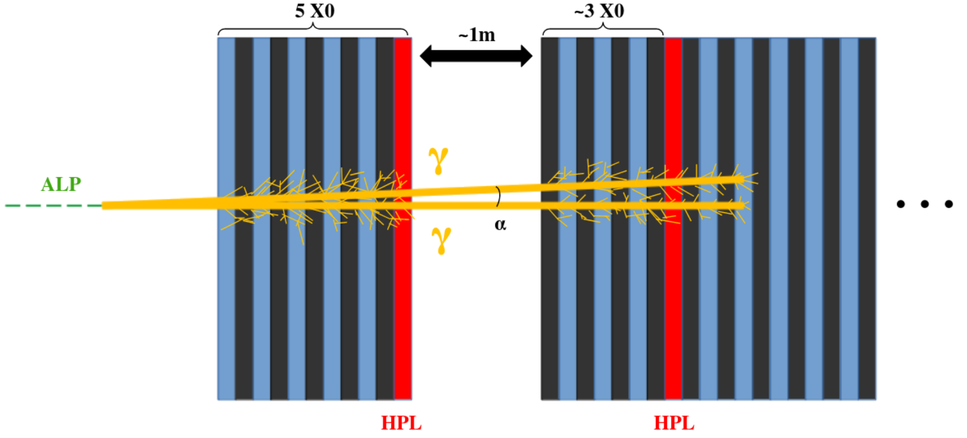


NIM A 979 (2020) 164398

Calorimeter and Particle ID system

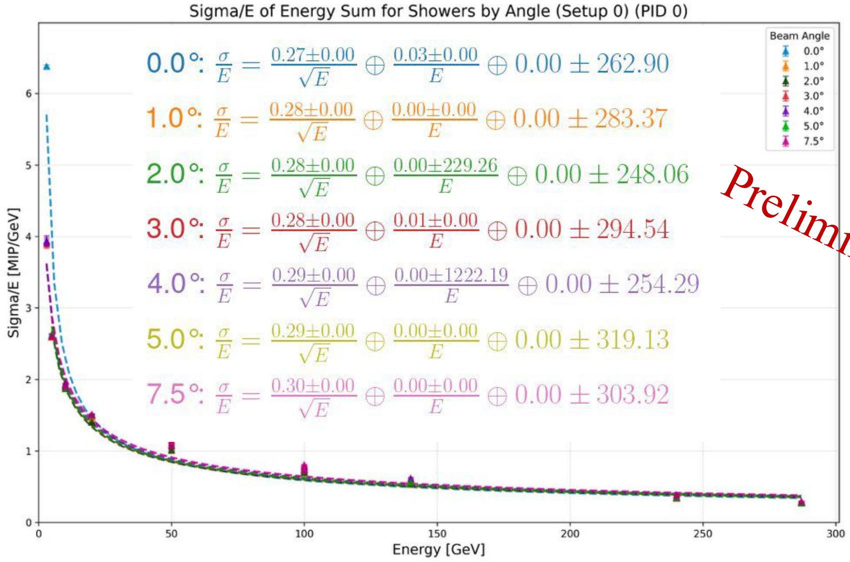
- *PID composed of sampling ECAL and HCAL based on scintillators readout by SiPMs*
- *ECAL based on the SplitCal concept to reconstruct neutral (γγ) final states*
- *Thin scintillator bars*
- *GEMs (High Precision Layers)*
- *Detector built in 6 hexants for modularity*
- *Needs to reconstruct MIPs and large showers*

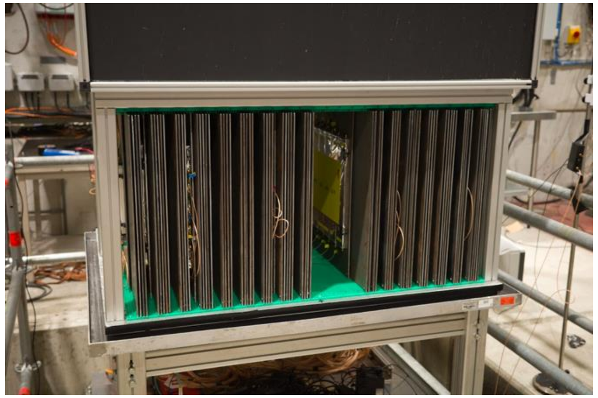


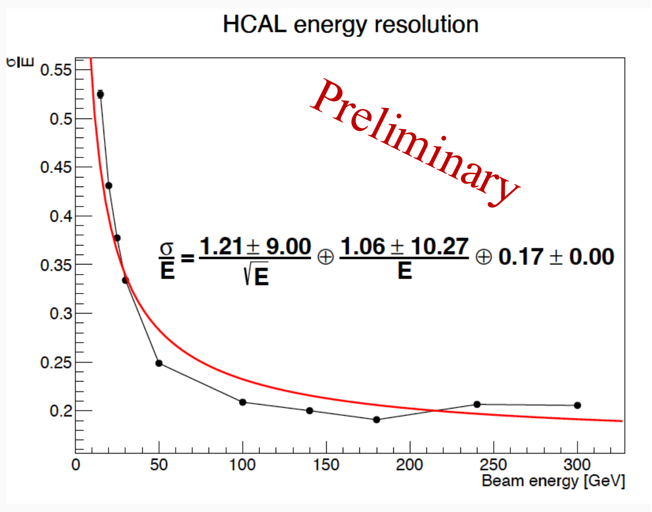


Test beam in May 2025 at SPS

- *ECAL prototype: 17 active layers, 20 X0, 112 cm total depth with central 20 cm split*
- *Prototype included thin and wide scintillator bars*

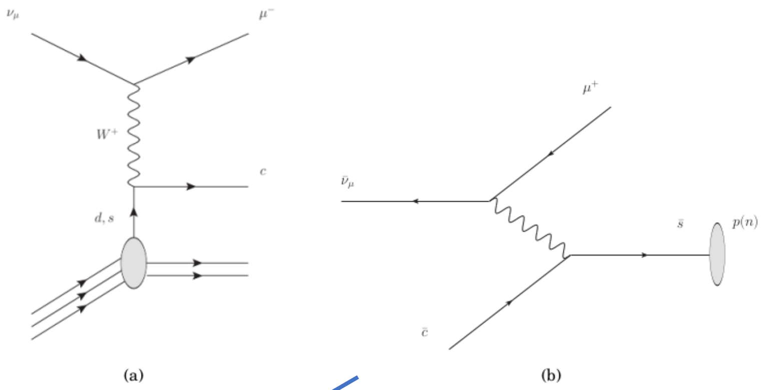






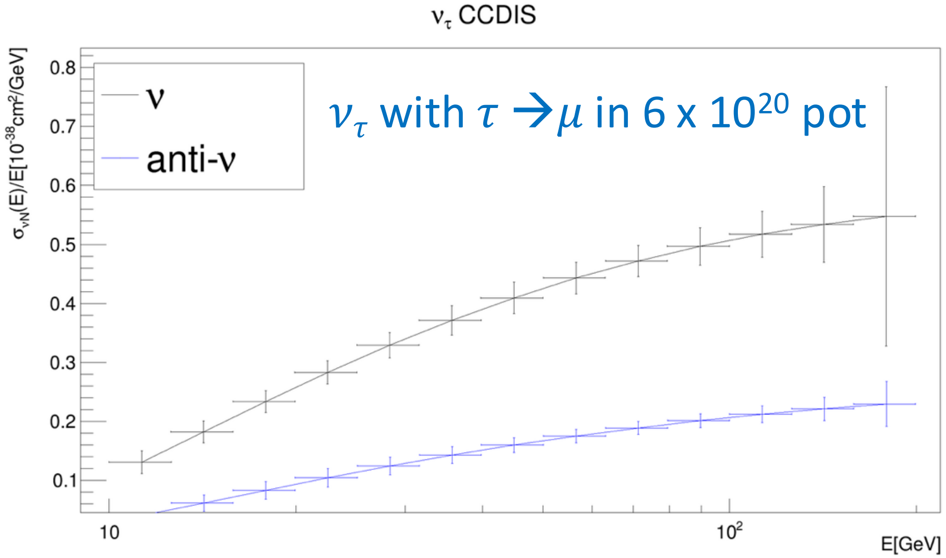
The ν origin in the (Mo/W) target and neutrino samples

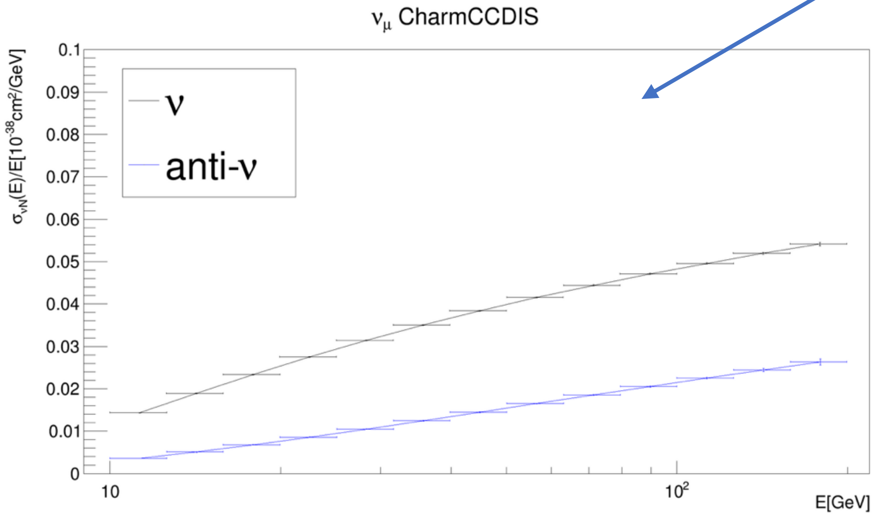
	Charmed hadron decay [%]	Pion/kaon/other decay [%]
$N_{\nu_e+\bar{\nu}_e}$		
Produced at SHiP target	47.3%	52.7%
In acceptance at SND position	71.5%	28.5
Interacting (CCDIS)	92.4%	7.6%
$N_{\nu_\mu+\bar{\nu}_\mu}$		
Produced at SHiP target	4.1%	95.9%
In acceptance at SND position	8.0%	92.0%
Interacting (CCDIS)	31.7%	68.3%



This is relevant for lepton flavour conservation studies with neutrino interactions!

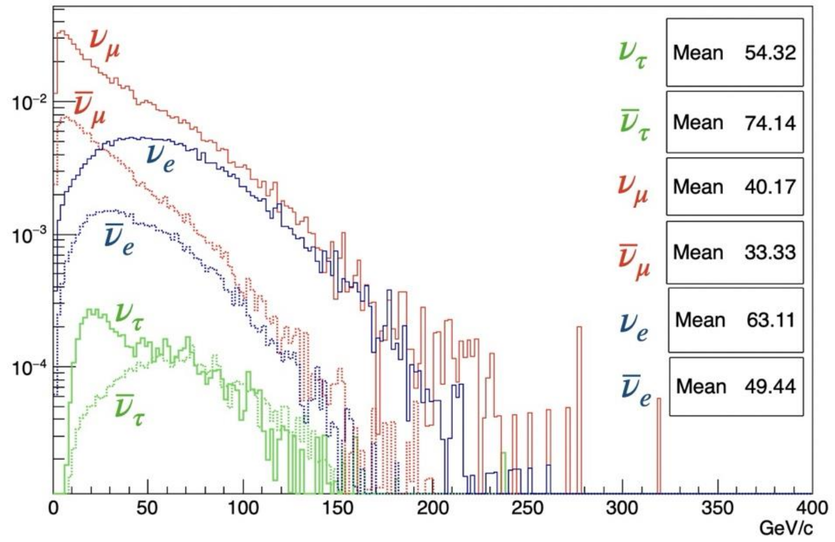
It will further improve with the new concept of full W target





ν_τ cross-section, ν-induced charm, structure functions, …

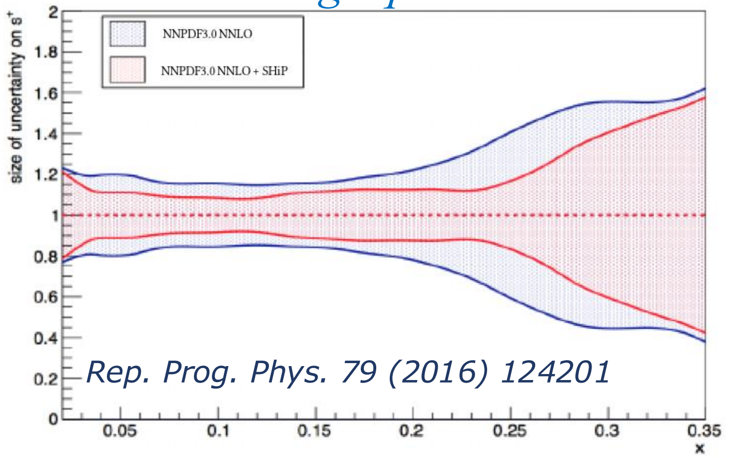
Decay channel	ν_τ	$\overline{\nu}_\tau$
$\tau \to \mu$	4×10^3	3×10^3
$\tau \to h$	27×10^3	
$\tau \to 3h$	11×10^3	
$\tau \to e$	8×10^3	
total	53×10^3	



Complementary energy region to the LHC measurements

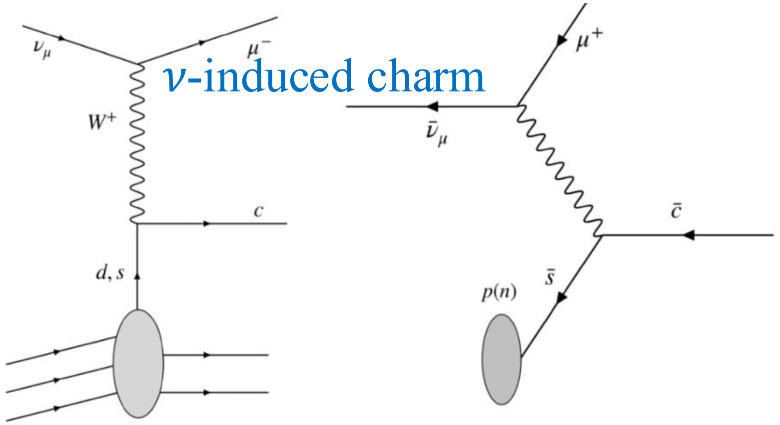
	<E> [GeV]	CC DIS interactions
N_{ν_e}	63	2.8×10^6
N_{ν_μ}	40	8.0×10^6
N_{ν_τ}	54	8.8×10^4
$N_{\overline{\nu}_e}$	49	5.9×10^5
$N_{\overline{\nu}_\mu}$	33	1.8×10^6
$N_{\overline{\nu}_\tau}$	74	6.1×10^4

Strange quark distribution



Rep. Prog. Phys. 79 (2016) 124201

ν-induced charm



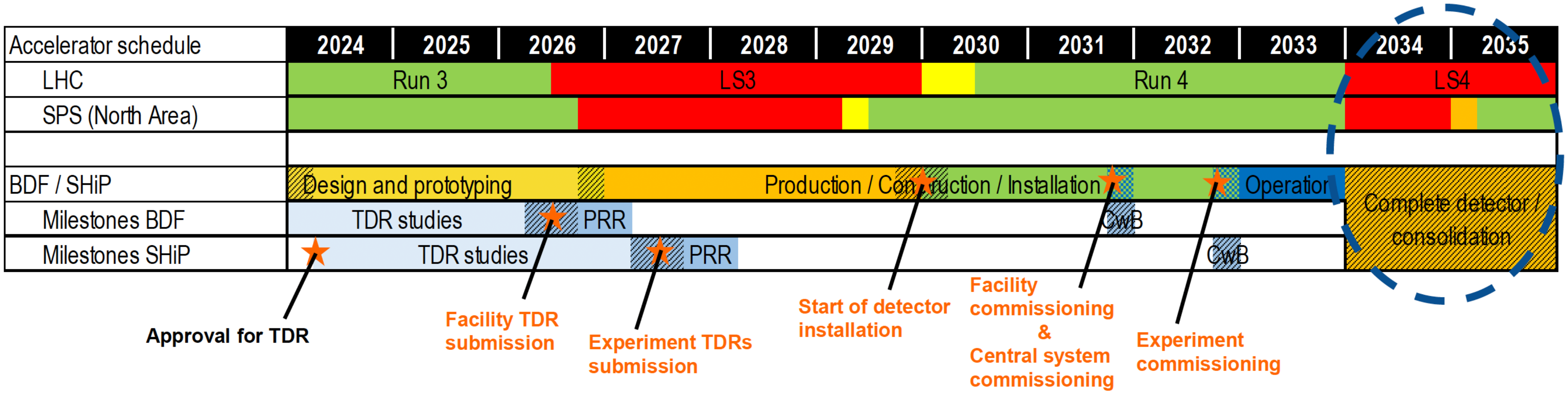
	(GeV)	with charm prod
N_{ν_μ}	57	3.5×10^5
N_{ν_e}	71	1.7×10^5
$N_{\overline{\nu}_\mu}$	50	0.7×10^5
$N_{\overline{\nu}_e}$	60	0.3×10^5
total		6.2×10^5

F4, F5 structure functions

$$\frac{d^2\sigma^{\nu(\overline{\nu})}}{dxdy} = \frac{G_F^2 M E_\nu}{\pi(1+Q^2/M_W^2)^2}\Bigg((y^2x + \frac{m_\tau^2 y}{2E_\nu M})F_1 + \left[(1-\frac{m_\tau^2}{4E_\nu^2}) - (1+\frac{Mx}{2E_\nu})\right]F_2 \pm \left[xy(1-\frac{y}{2}) - \frac{m_\tau^2 y}{4E_\nu M}\right]F_3 + \frac{m_\tau^2(m_\tau^2+Q^2)}{4E_\nu^2 M^2 x}F_4 - \frac{m_\tau^2}{E_\nu M}F_5\Bigg),$$

At LO $F_4 = 0$, $2xF_5 = F_2$
At NLO $F_4 \sim 1\%$ at 10 GeV

BDF/SHiP schedule: 15 years of data taking



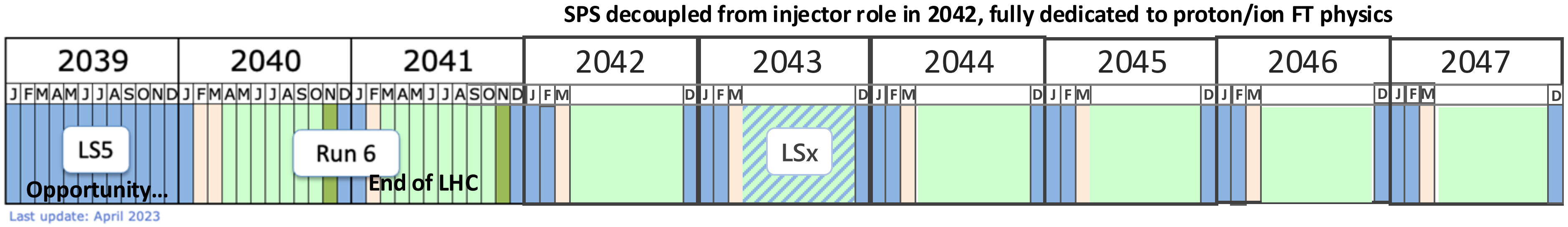
Construction / installation of facility and detector is decoupled from NA operation

Important to start data taking >1 year before LS4

Several upgrades/extensions of the BDF/SHiP in consideration over the operational life

SPS decoupled from injector role in 2042, fully dedicated to proton/ion FT physics

Operation till 2047



Reach ν physics program and most sensitive FIB searches at CERN

https://home.cern/news/news/physics/new-lhc-experiments-enter-uncharted-territory

New LHC experiments enter uncharted territory

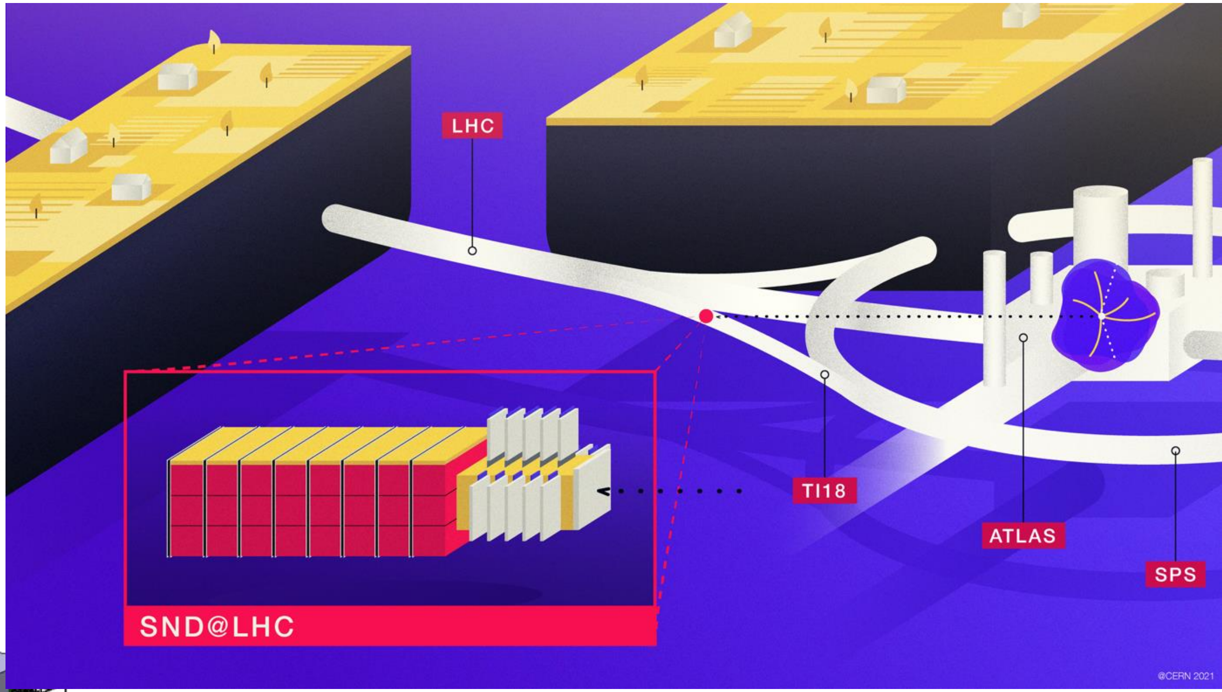
NEUTRINOS | NEWS

Collider neutrinos on the horizon

2 June 2021

https://cerncourier.com/a/collider-neutrinos-on-the-horizon/

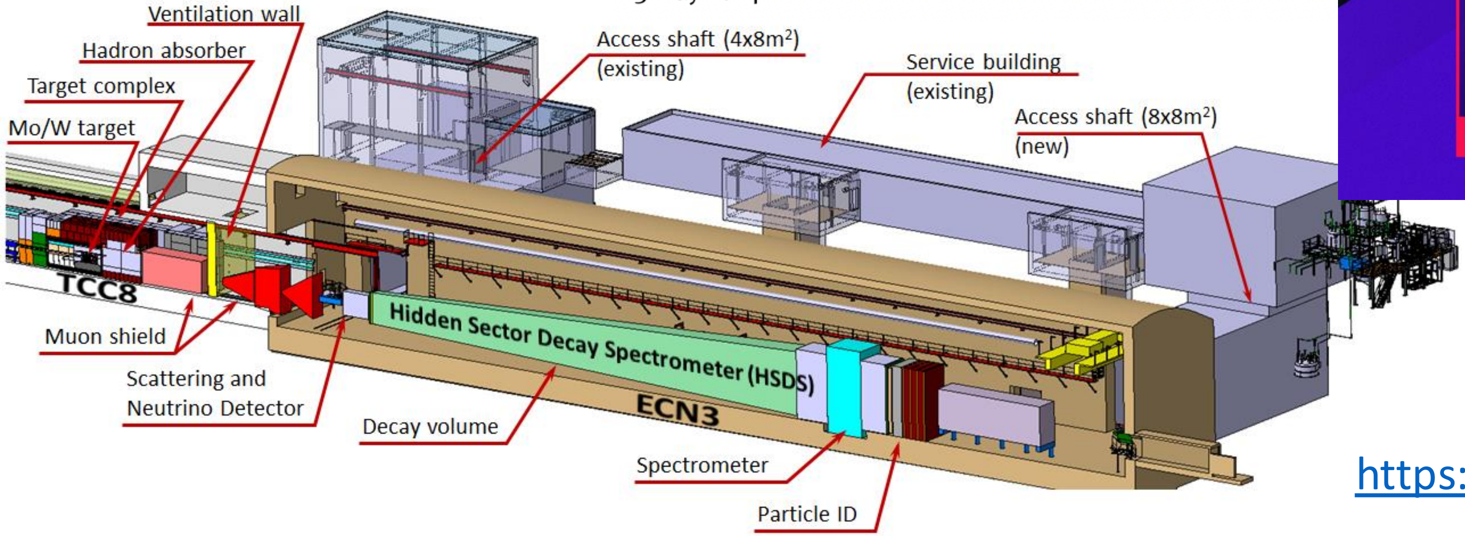
CERNCOURIER | Reporting on international high-energy physics



SEARCHES FOR NEW PHYSICS | NEWS

SHiP to chart hidden sector

3 May 2024



Stay tuned!

https://cerncourier.com/a/ship-to-chart-hidden-sector/