

# Jornadas científicas

LIP PARTÍCULAS & TECNOLOGIA

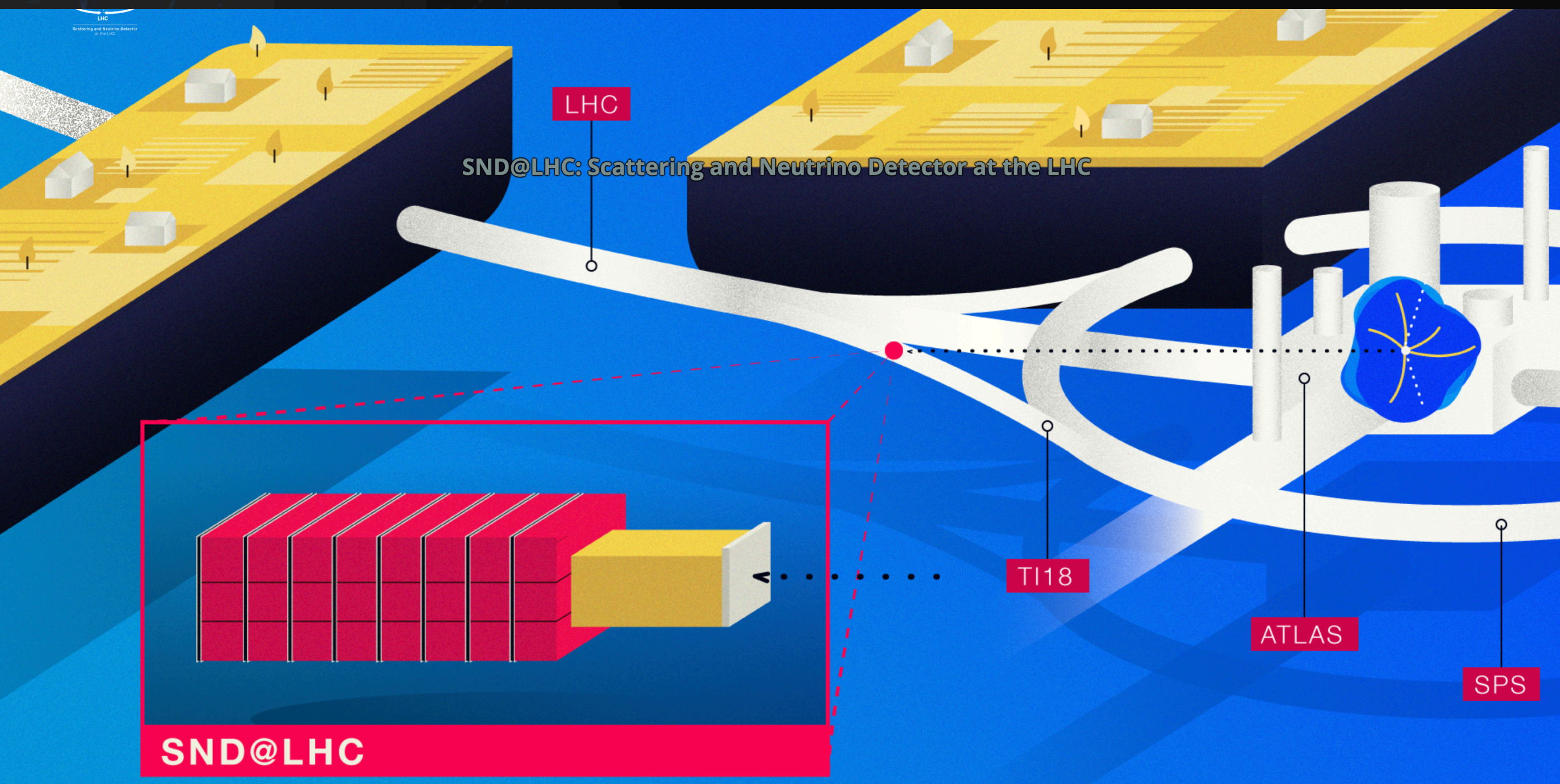
## SHiP&SND@LHC

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Coimbra, 8.7.2022



LABORATÓRIO DE INSTRUMENTAÇÃO  
E FÍSICA EXPERIMENTAL DE PARTÍCULAS  
*partículas e tecnologia*



**SND@LHC**



# The SHiP & SND@LHC Group at LIP

A.Blanco, P.Bordalo, P.Fonte, N.Leonardo, L.Lopes, S.Ramos, J.Saraiva, G.Souares

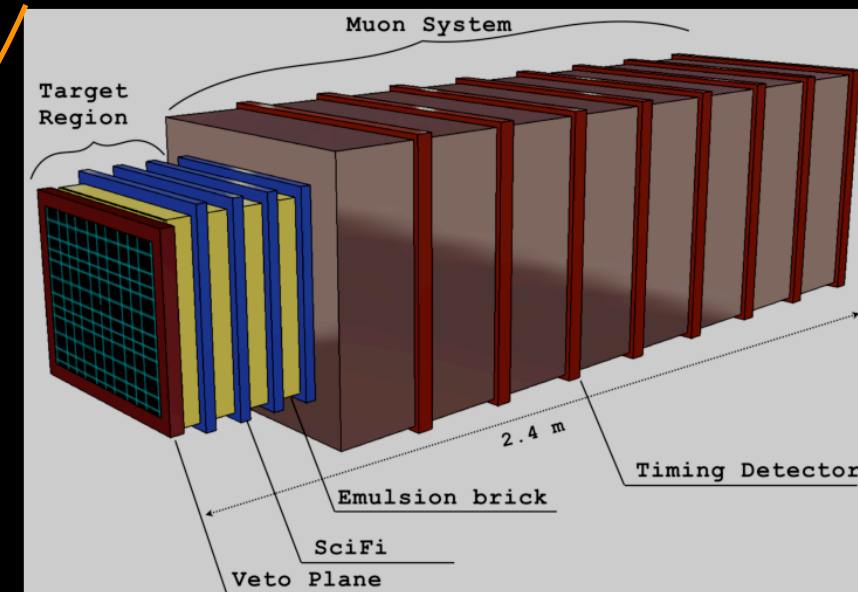
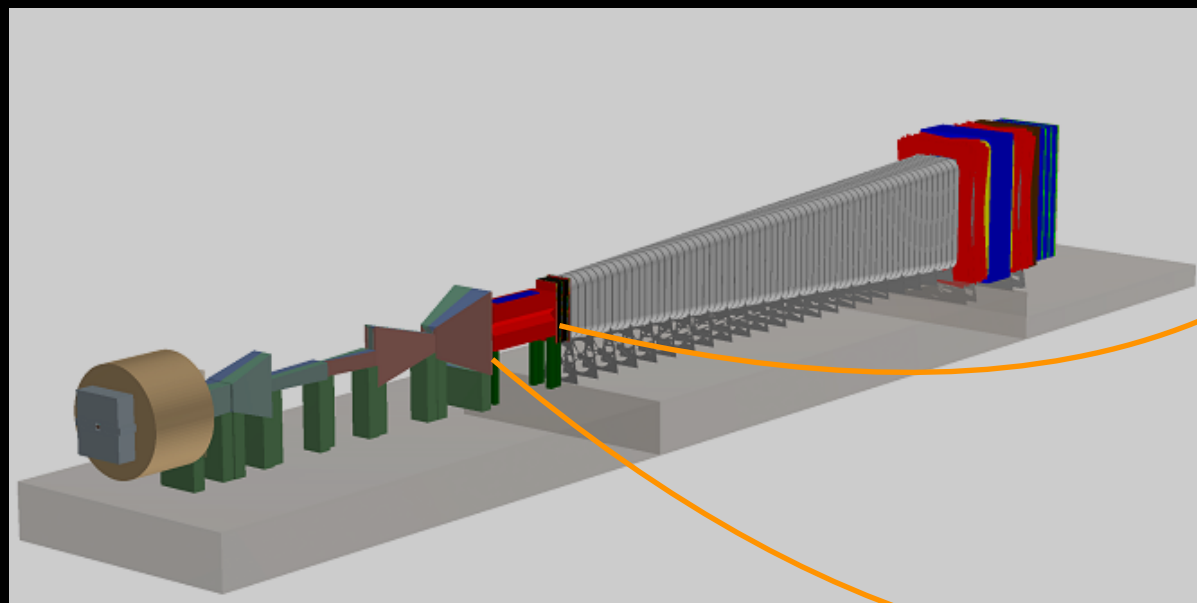
Interns: A.Branco, P.Figueiredo, F.Safara, H.Santos, R.Santos, R.N.Santos



CERN/FIS-INS/0028/2021

from SPS

to LHC



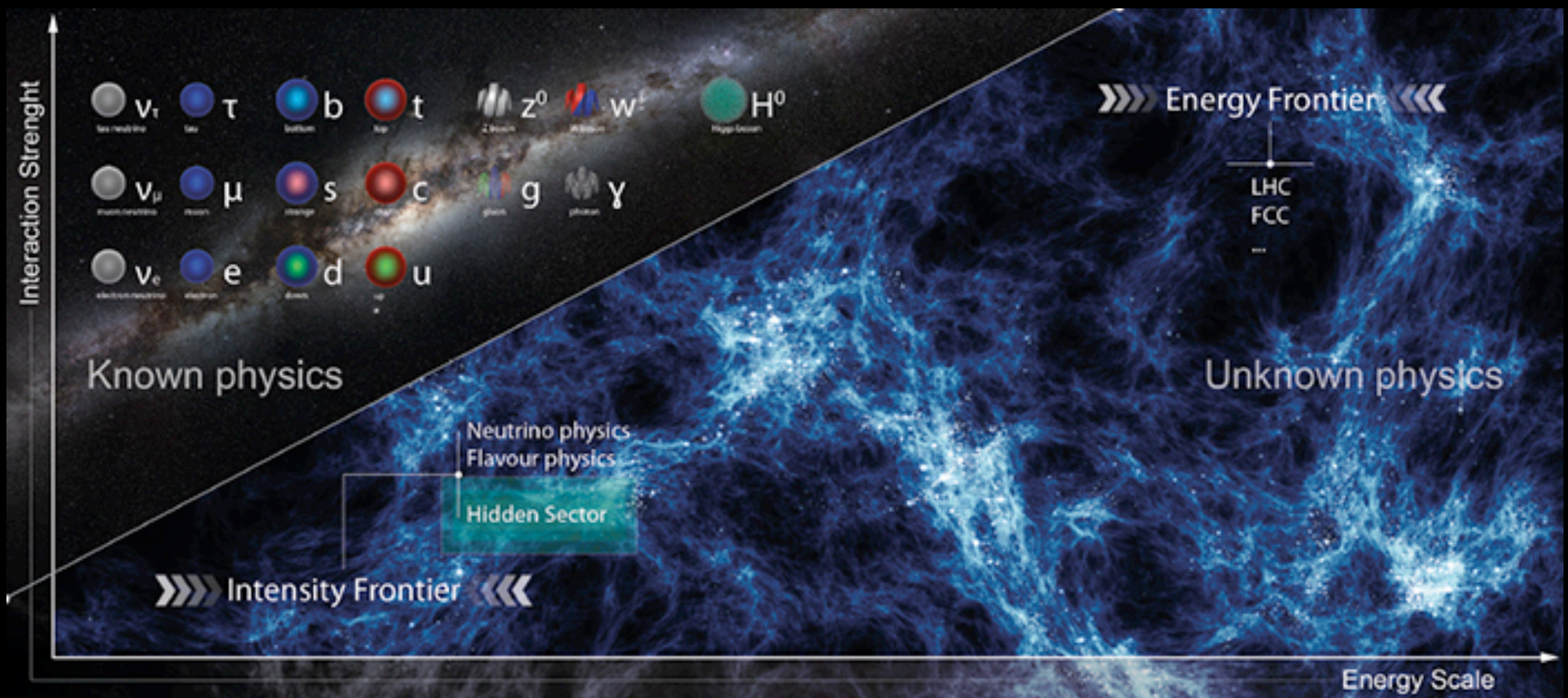
## SHiP

- **Next-generation experiment**
- LIP involved in Timing + Veto detectors
- TDR phase delayed after ESPPU'2020
- Due to BDF cost, despite leading sensitivity
- **Redesigned for new location at SPS**
- Reduce cost, keep physics potential
- Decision before next ESPPU

## SND@LHC

- **The most recent LHC experiment**
- Approved & constructed in 2021
- **LIP is a founding member**
- LIP involved in Muon system
- Detector design and construction
- **Full detector commissioning ongoing**
- Experiment installed in time for Run3

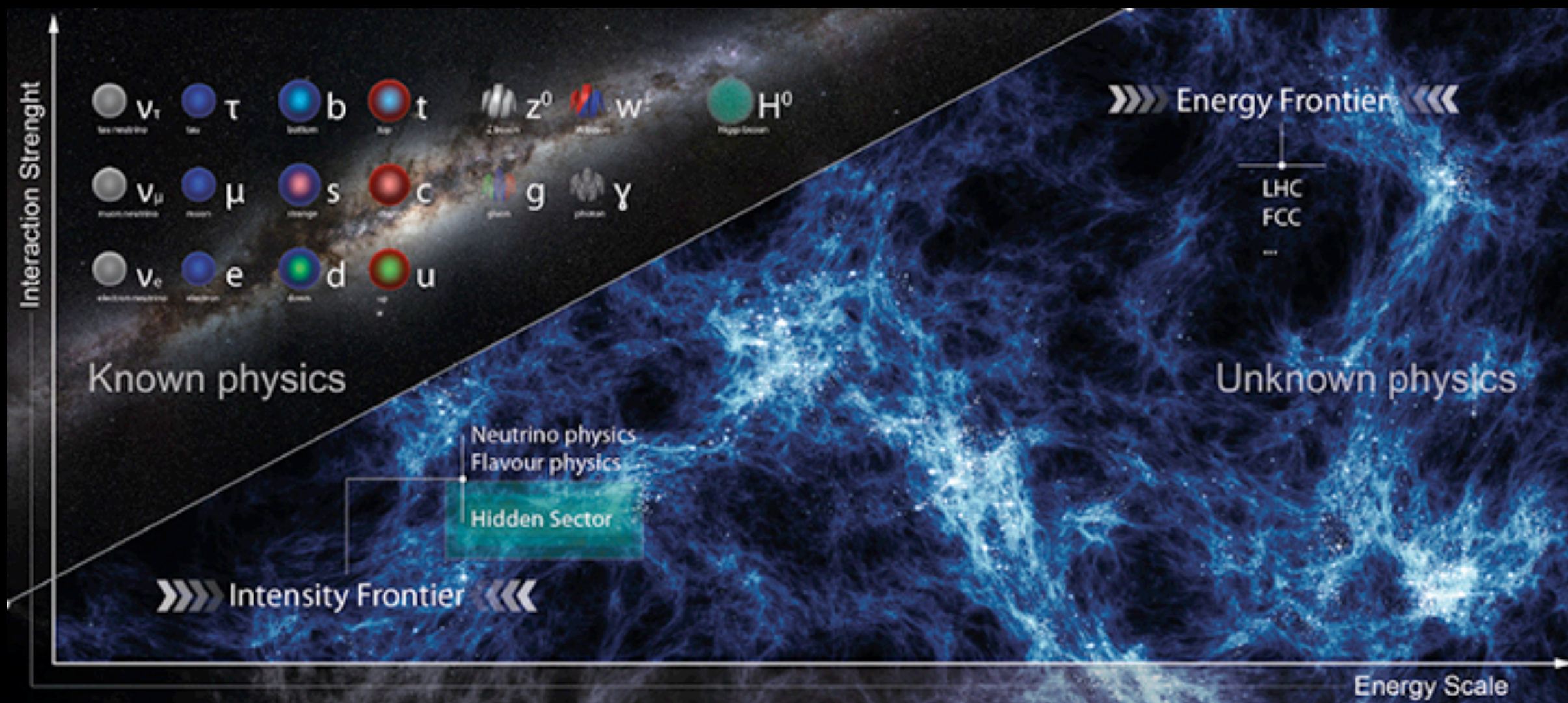






# Goals

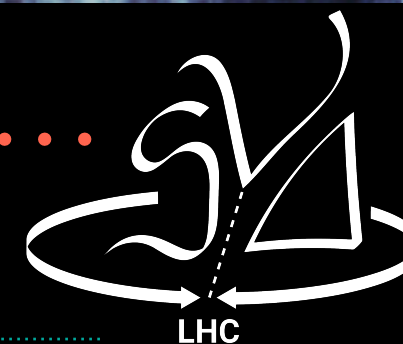
Explore the intensity frontier of particle physics  
 Contribute novel detector systems  
 Extend the LHC physics reach



Neutrinos

Flavour

Hidden Particles

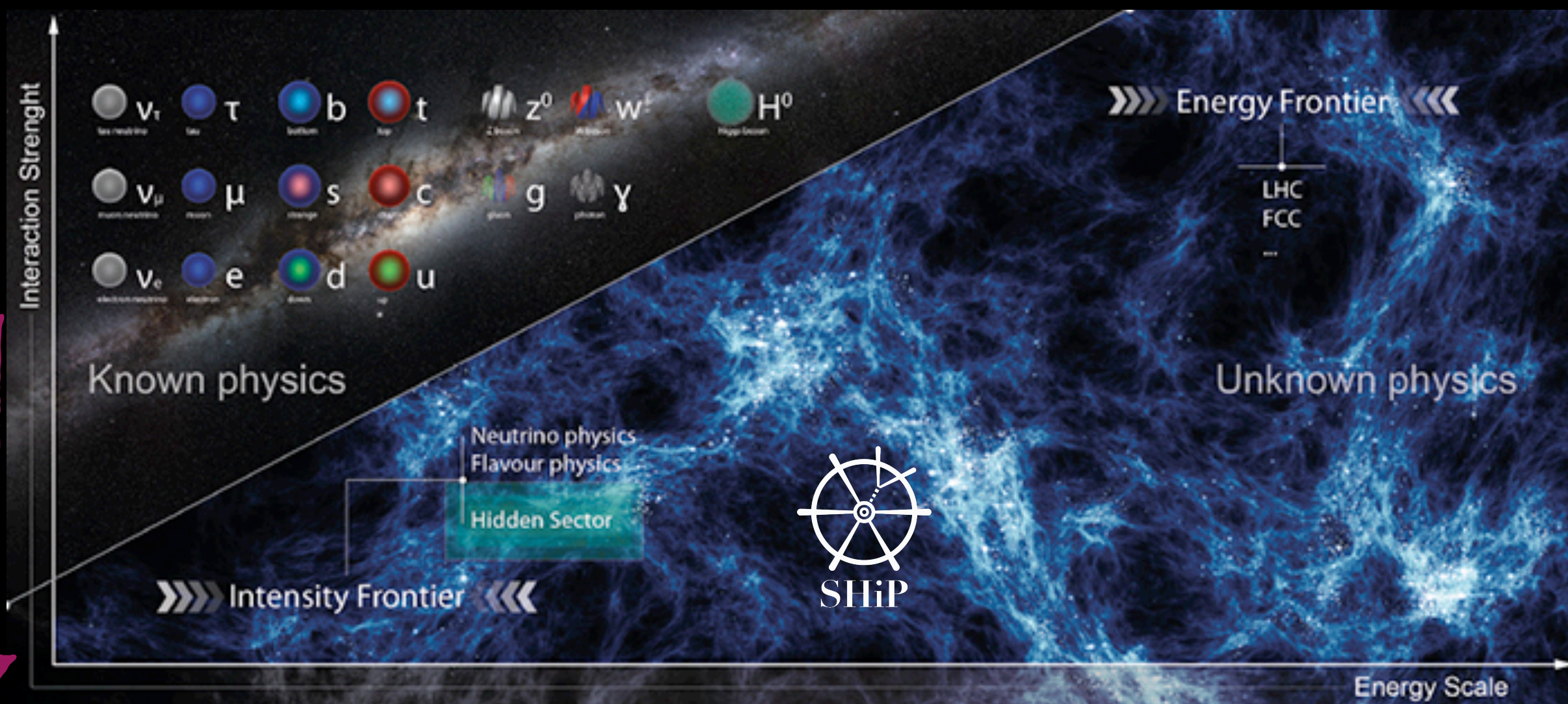


Scattering and Neutrino Detector  
at the LHC



energy frontier →

intensity frontier ↓

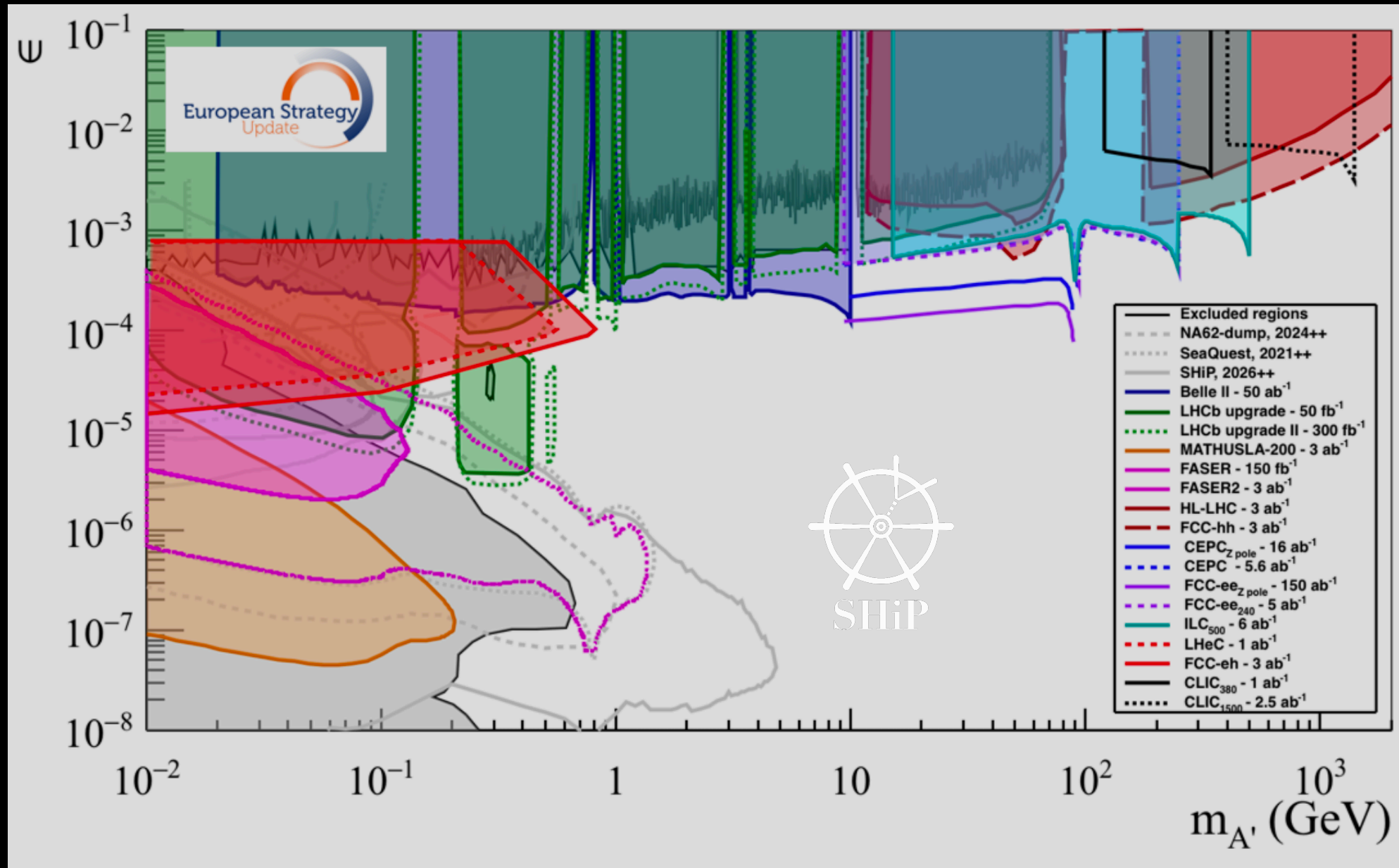




# Search for **F**eebly **I**nteracting **P**articles

energy frontier →

LHC  
FCC



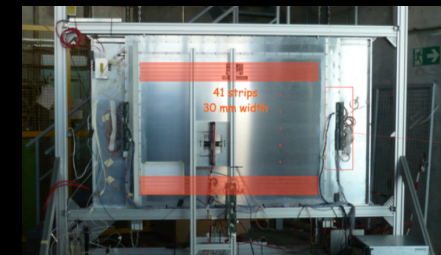
intensity frontier ↓



# SHiP — Search for Hidden Particles



RPC detector prototype  
tested at CERN and FAIR



Timing Detector - MRPC's

Target/Hadron absorber

Muon Shield

Vacuum decay vessel (1 mbar)

Hidden sector particle

Scattering and  
Neutrino detector

Decay product

Straw Trackers

Muon ID

Decay Spectrometer  
with particle ID

Photon Track  
(ECAL)



## Optimization of the Selection of Hidden Particles in the SHiP Experiment

Guilherme Machado Santos Soares

CERN-THESIS-2021-038

## Search for dark matter and supersymmetry using machine learning at SHiP

Francisco Safara<sup>1,a</sup> and Raúl Santos<sup>2,b</sup>

<sup>1</sup>Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal

<sup>2</sup>Instituto Superior Técnico, Lisboa, Portugal

Project supervisors: N. Leonardo, G. Soares

October 2020

LIP-STUDENTS-20-17

**Abstract.** SHiP is an Intensity Frontier experiment designed to search for new physics particles, low masses and interactions, specifically dark matter and supersymmetry. The experiment is designed to search for the *hidden sector* of particles, specifically dark matter and supersymmetry. The experiment is designed to search for the *hidden sector* of particles, specifically dark matter and supersymmetry. The experiment is designed to search for the *hidden sector* of particles, specifically dark matter and supersymmetry.

KEYWORDS: Hidden Sector, Dark Photons, Heavy Neutral Leptons, Neutralinos, Deep Neural Networks, Intensity Frontier

## Distinguishing Hidden Sector Particles with Machine Learning at SHiP

Henrique Santos<sup>1,a</sup> and André Branco<sup>1,b</sup>

<sup>1</sup>Instituto Superior Técnico, Lisboa, Portugal

Project supervisors: N. Leonardo, G. Soares

October 2021

### Abstract.

Given the plausible existence of new physics particles and interactions, the SHiP experiment at CERN aims to explore the Intensity Frontier in search for the so called Hidden Sector particles with exceedingly feeble couplings and thus distinctively rare decays. Three theoretical particles are studied consisting of Dark Photons (DP), Heavy Neutral Leptons (HNL) and Neutralinos. Using previously Monte Carlo simulated data sets in conjunction with sundry machine learning methods it is possible to classify those three different hypothetical particles from several decays (into Pion-muon and Muon-muon pairs) yielded from the input information culminating in efficiencies over 74% for all results and over 99% for the foremost ones.

KEYWORDS: Hidden Sector, Dark Photons, Heavy Neutral Leptons, Neutralinos, Deep Neural Networks, Intensity Frontier

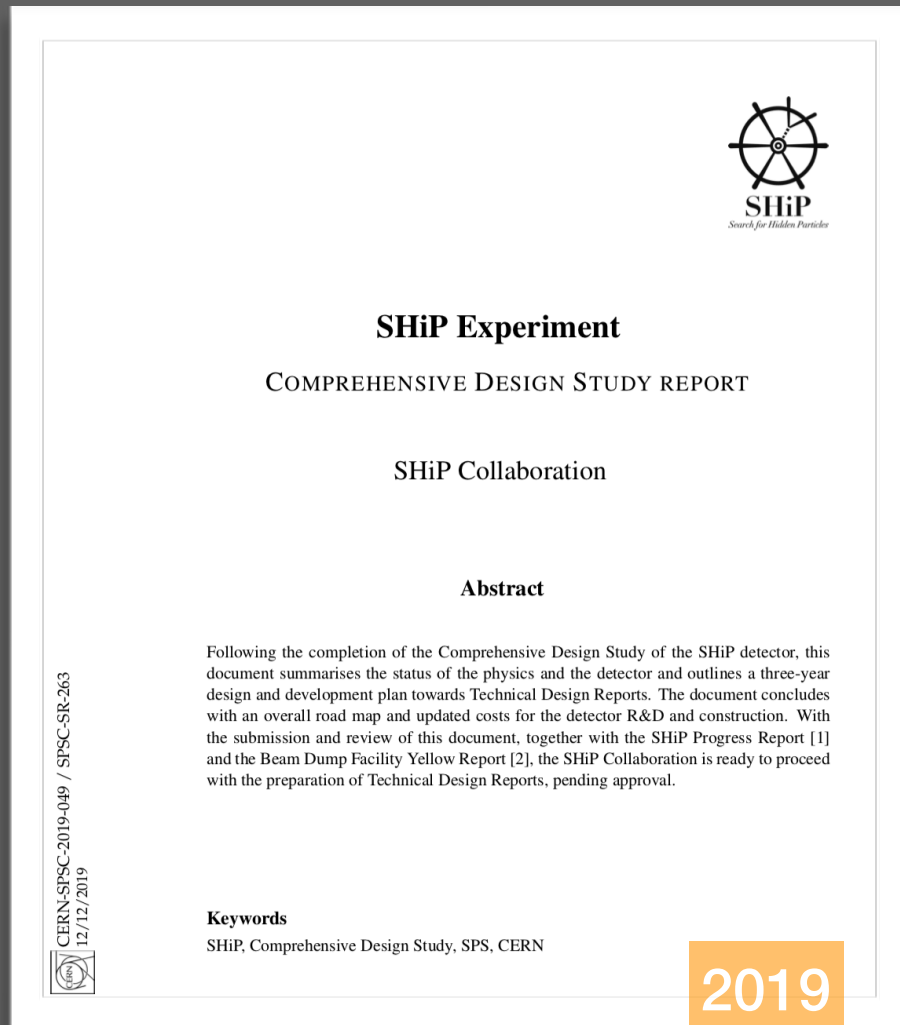
LIP-STUDENTS-21-06



# Literature

Group strongly involved in preparation of SHiP

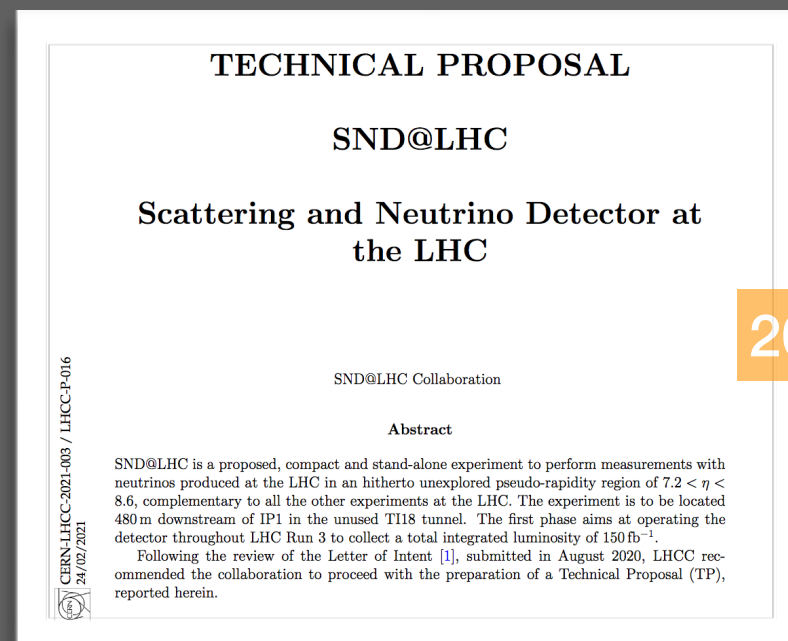
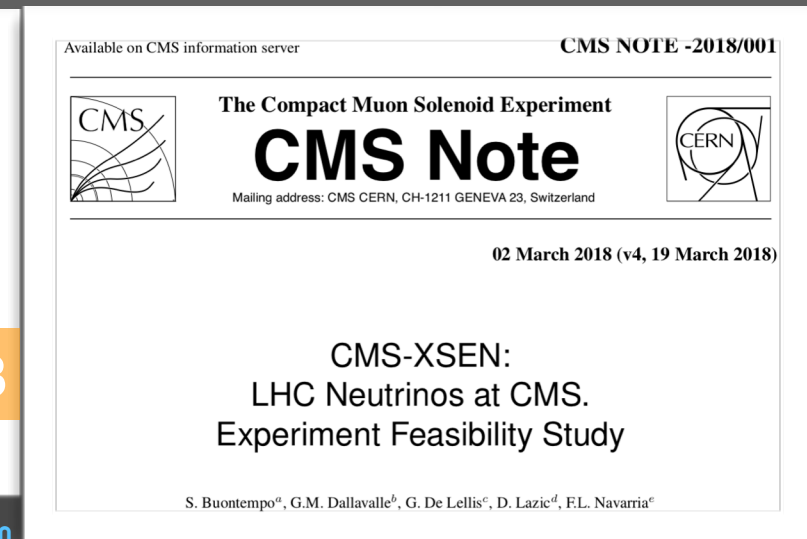
Proposals for neutrino physics at the LHC have a long history



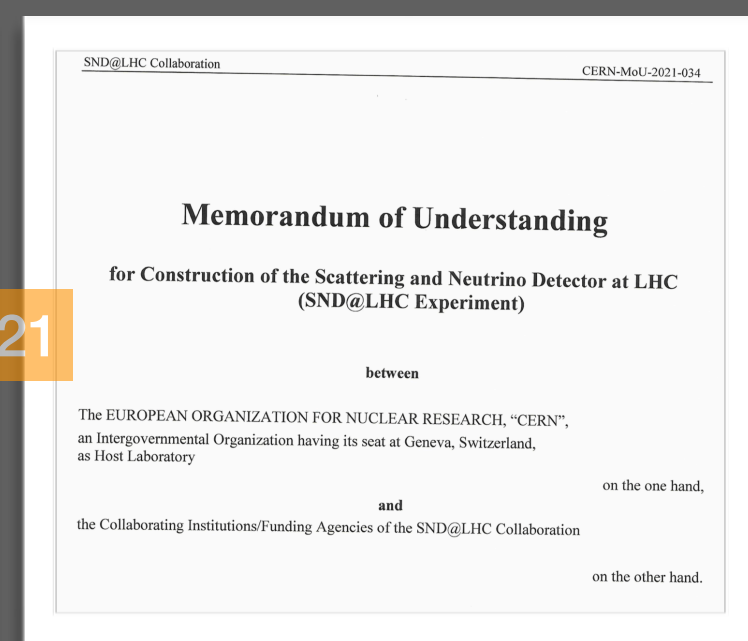
<https://cds.cern.ch/record/2704147/>



<https://www.sciencedirect.com/science/article/abs/pii/0550321393904270>



<https://cds.cern.ch/record/2750060> <https://arxiv.org/abs/2002.08722>



Journal of Instrumentation

2020

## The SHiP timing detector based on MRPC

A. Blanco<sup>1</sup>, F. Clemencio<sup>2</sup>, P. Fonte<sup>1,3</sup>, C. Franco<sup>1</sup>, N. Leonardo<sup>1</sup>, L. Lopes<sup>1</sup>, C. Loureiro<sup>4</sup>, J. Saraiva<sup>1</sup> and G. Soares<sup>1</sup>

Published 14 October 2020 • © 2020 IOP Publishing Ltd and Sissa Medialab

[Journal of Instrumentation](#), Volume 15, October 2020

[XV Workshop on Resistive Plate Chambers and Related Detectors \(RPC2020\)](#)

Citation A. Blanco *et al* 2020 *JINST* 15 C10017

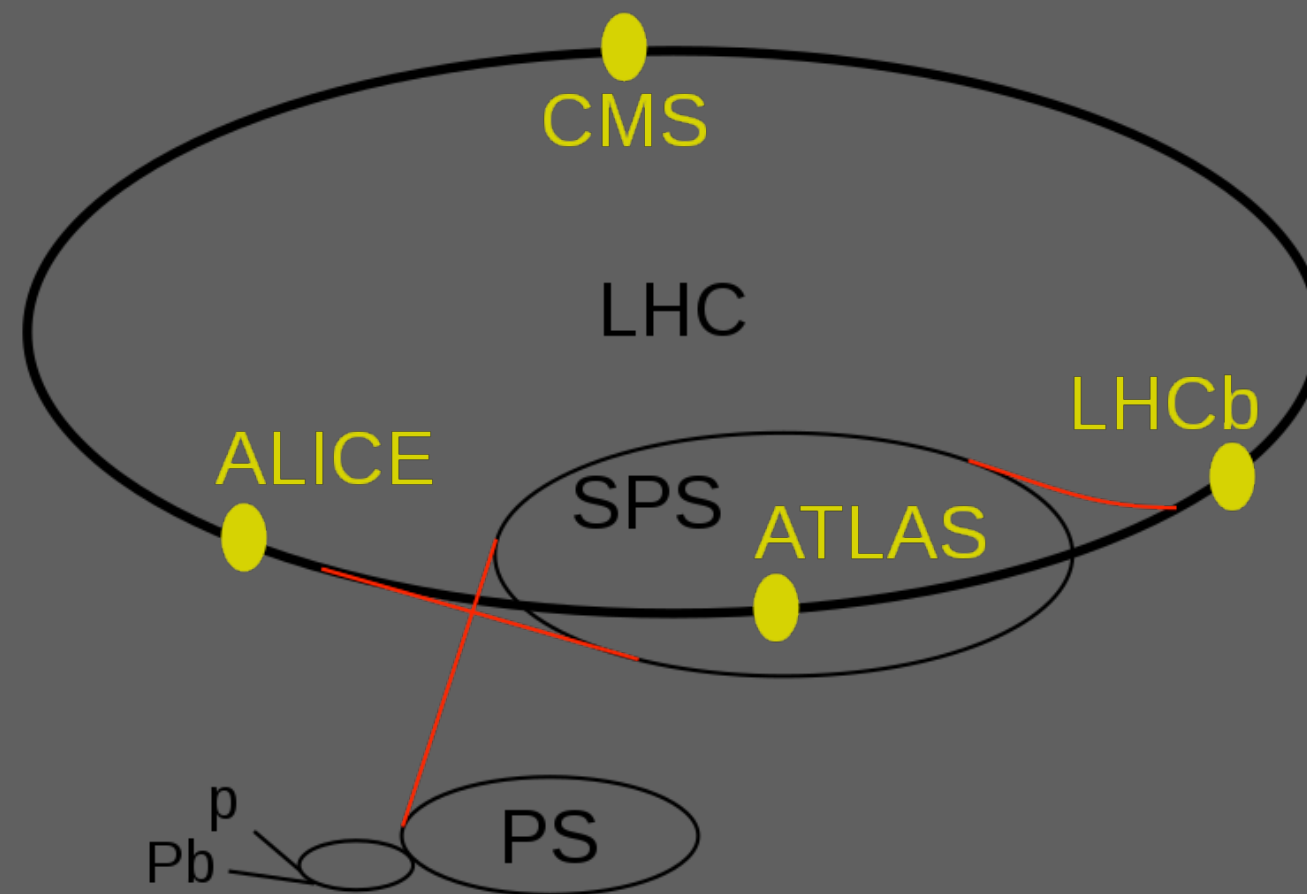
<https://iopscience.iop.org/article/10.1088/1748-0221/15/10/C10017>



**A new experiment, at the LHC?**

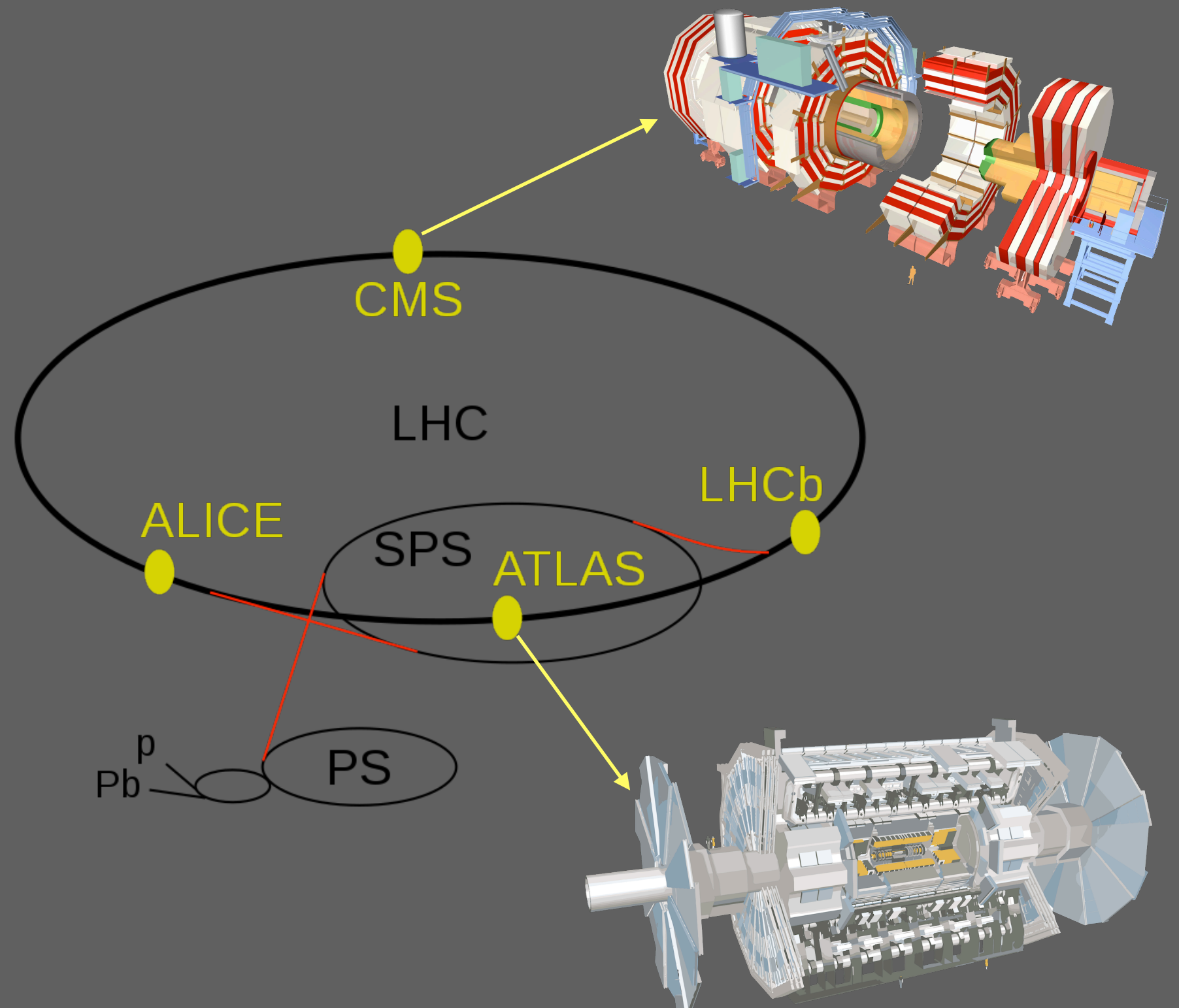


# A new experiment, at the LHC?



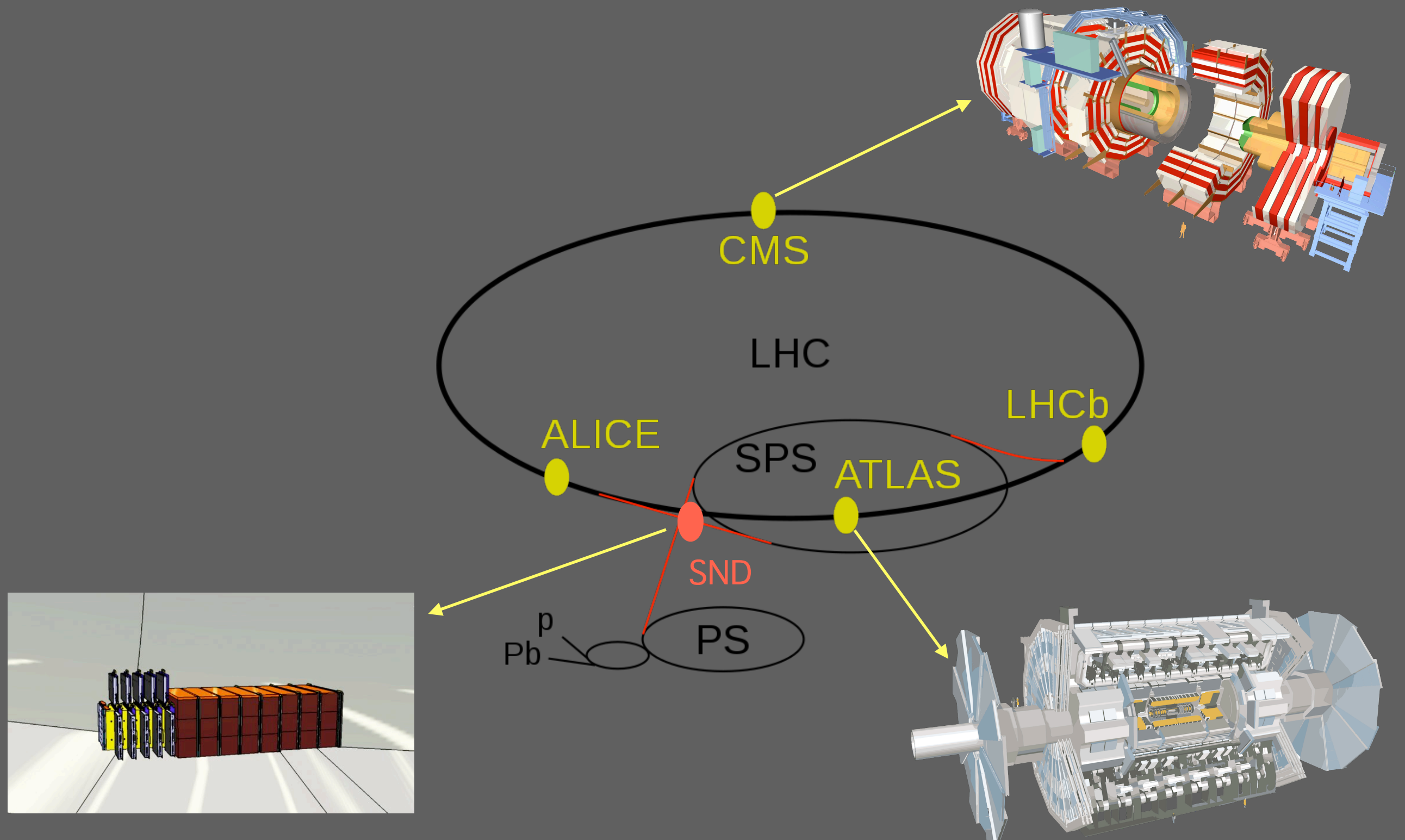


# A new experiment, at the LHC?



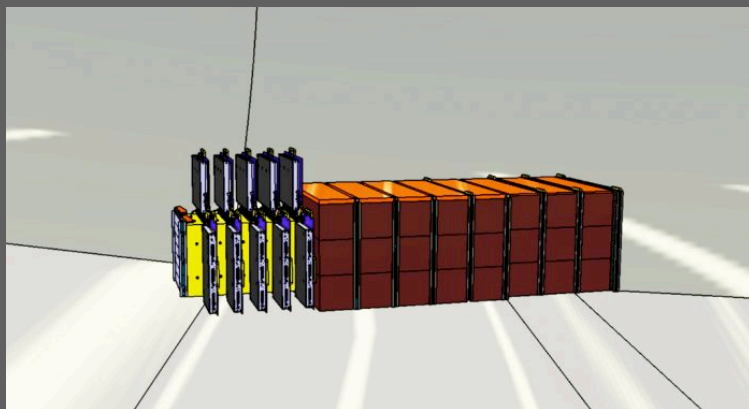
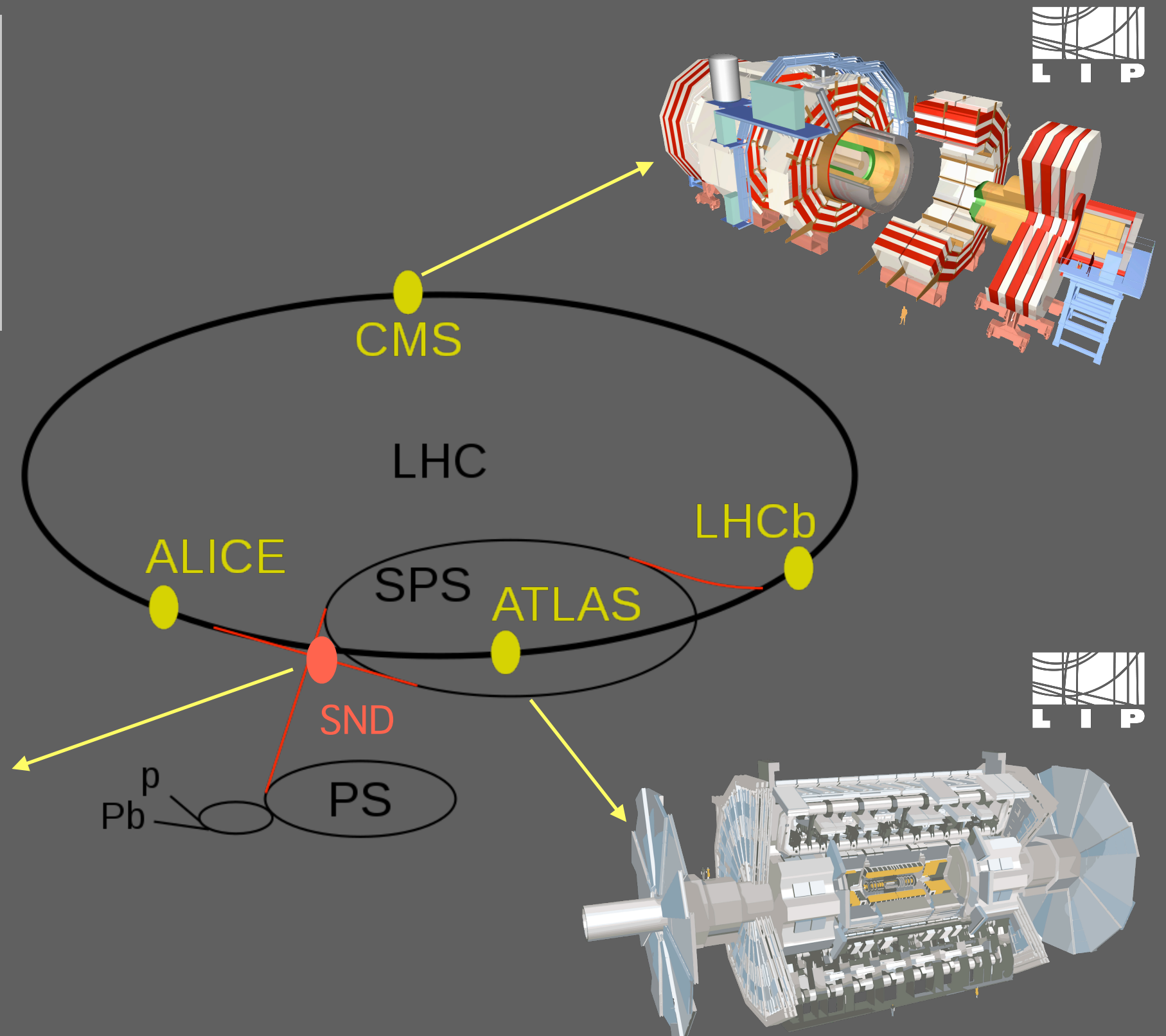
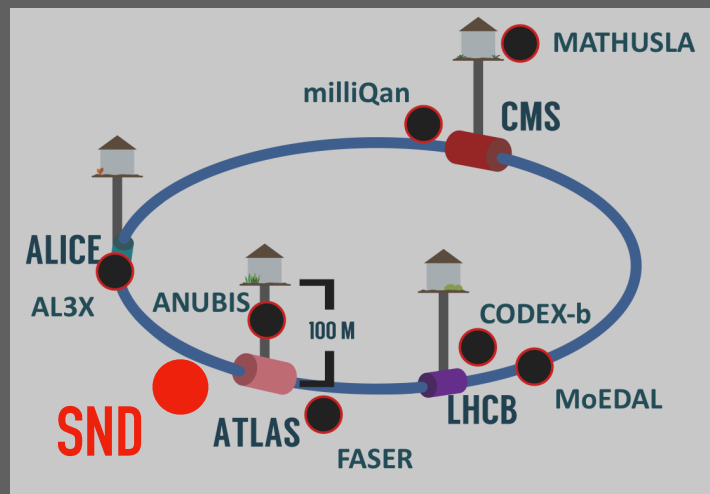


# A new experiment, at the LHC?





# A new experiment, at the LHC?

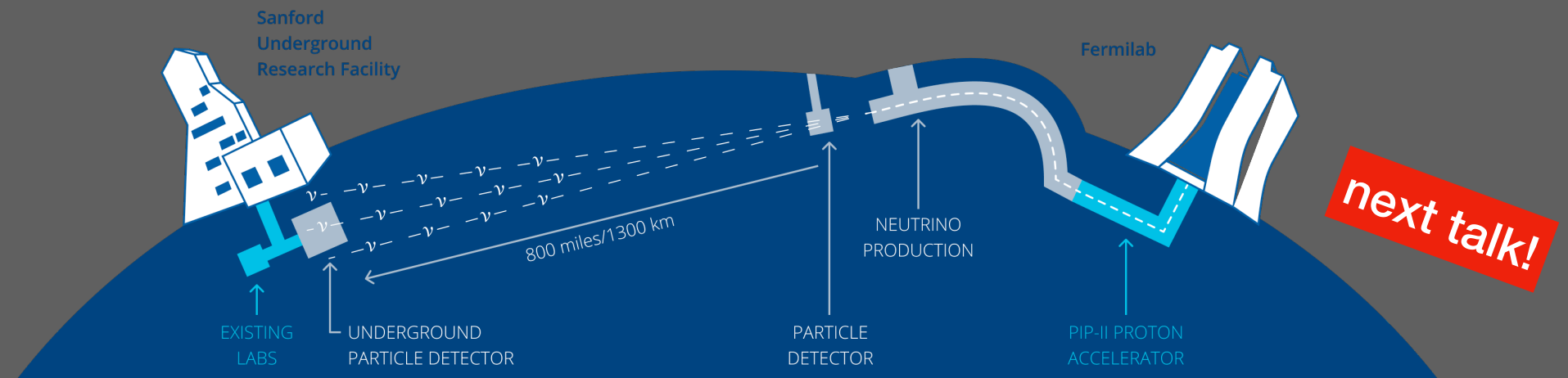


# Neutrinos, at the LHC?



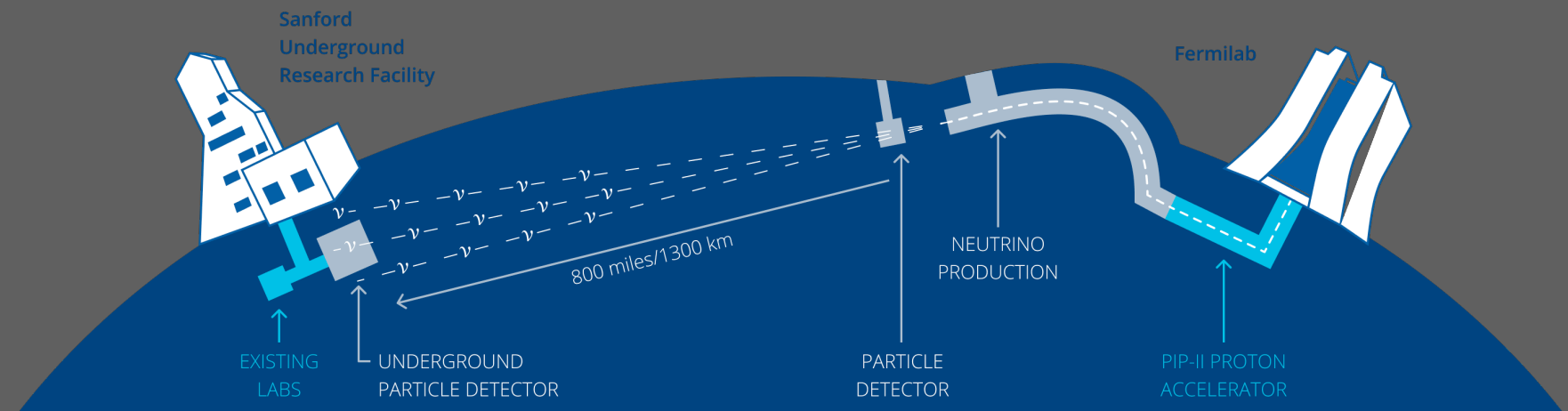
# Neutrinos, at the LHC?

@ long  
baseline



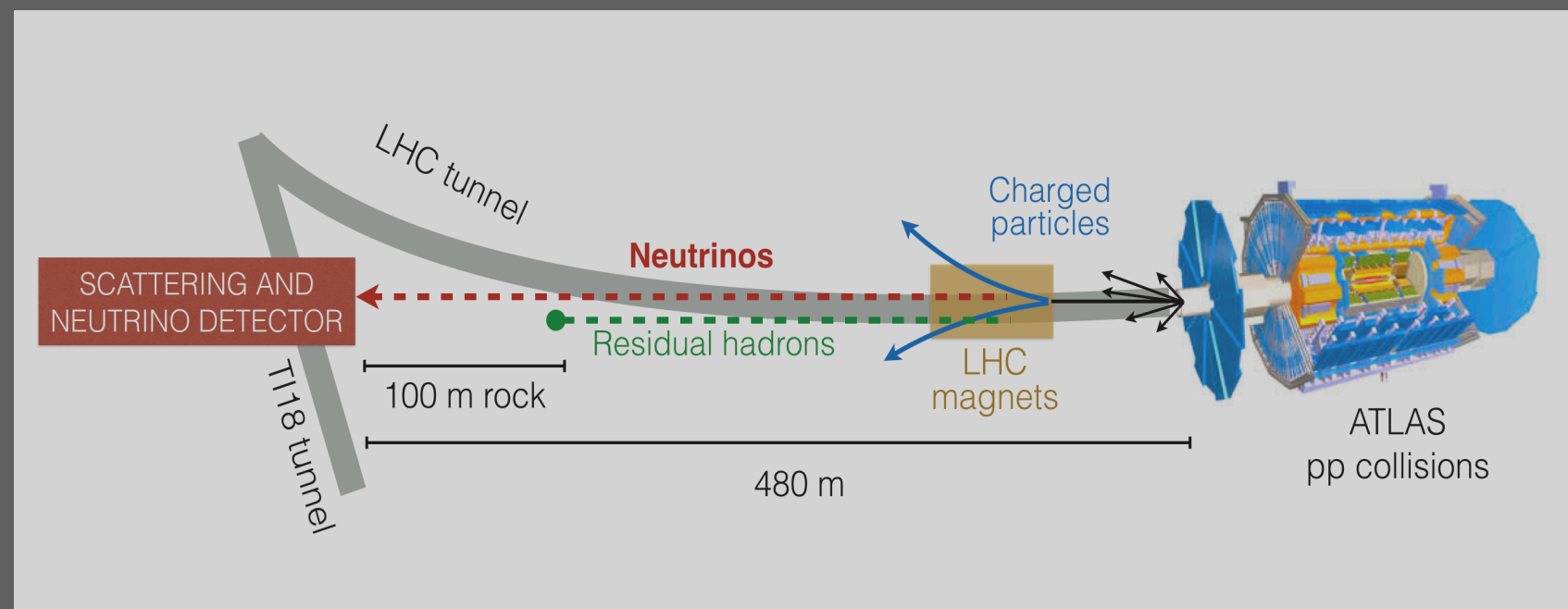
# Neutrinos, at the LHC?

@ long  
baseline



↕ complementary

@ particle  
collider !



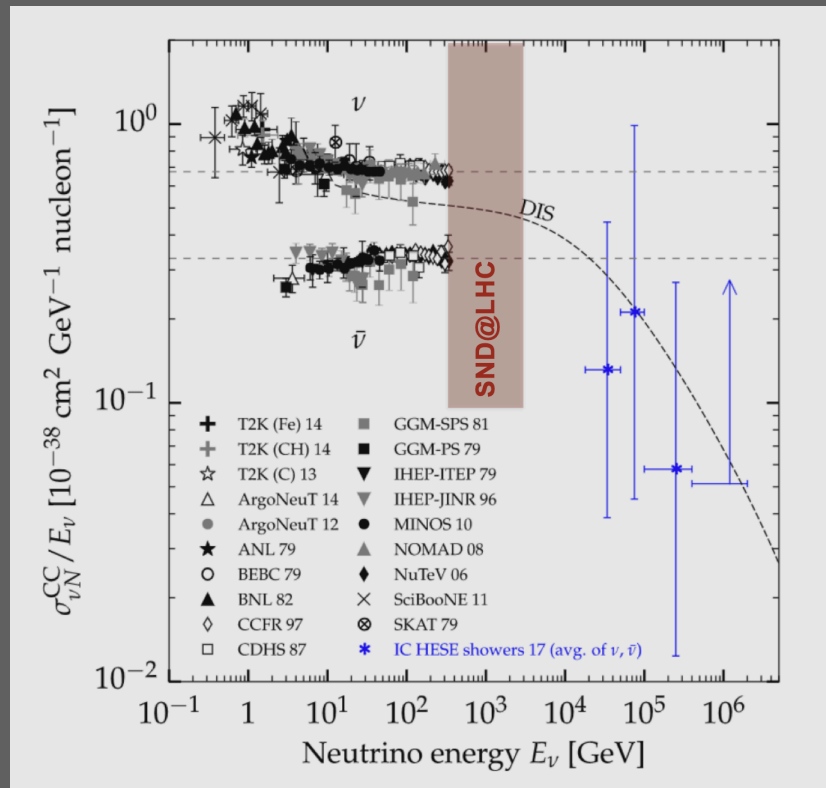


# Detector installation





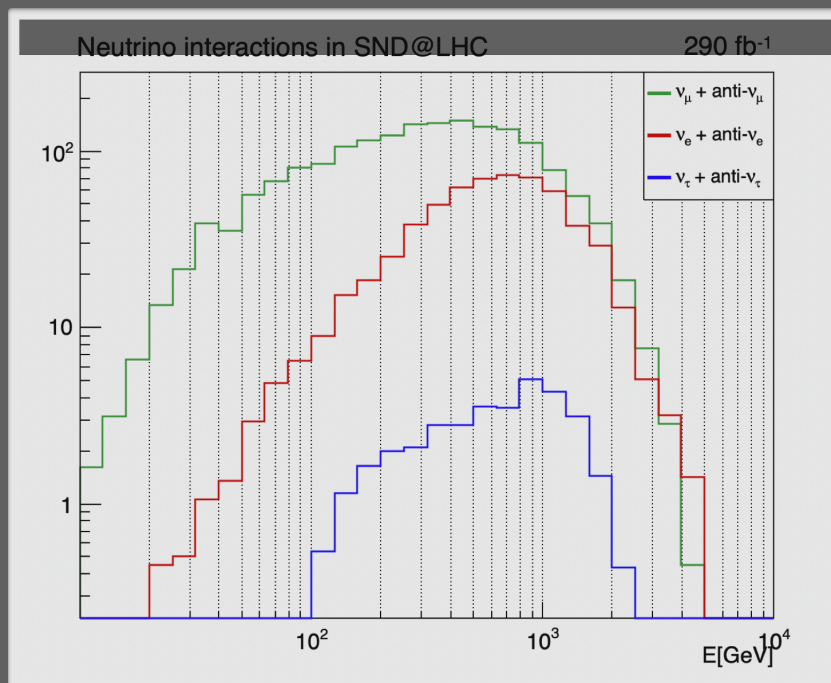
# Neutrinos et al with SND@LHC



- **high  $\nu$  energies** (large  $\nu N$  cross-section)
- **large  $\nu$  flux** (forward region,  $7.2 < \eta < 8.4$ )
- **all  $\nu$  flavours** (from heavy quark decays)

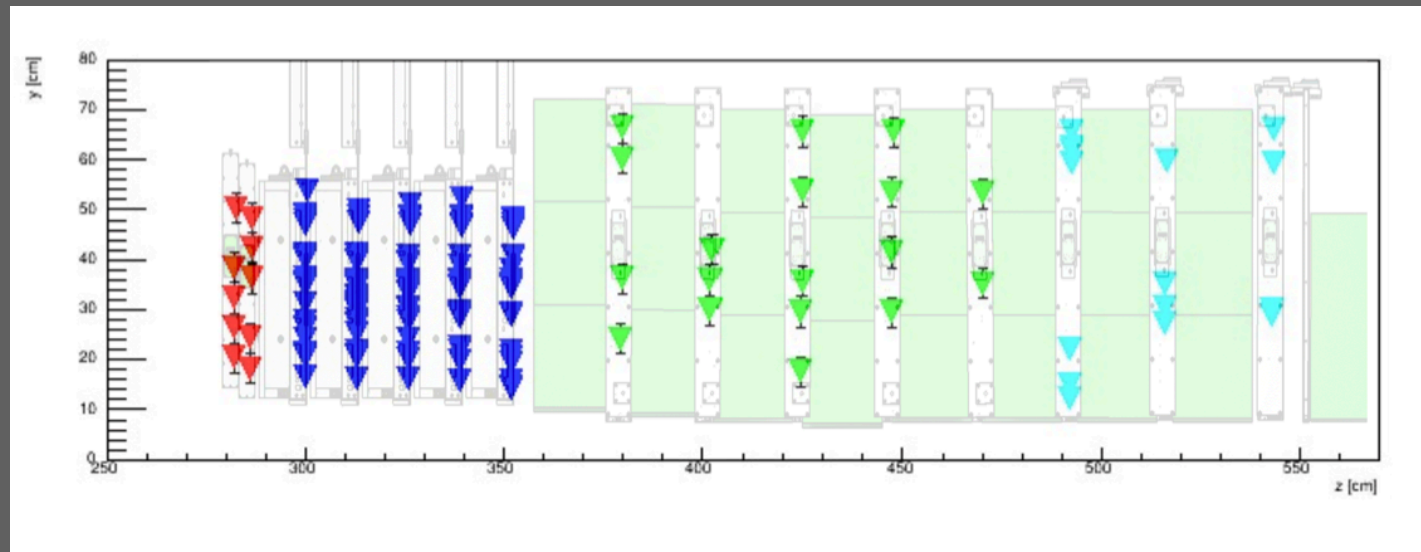
**SND @ LHC** physics goals:

- **observe first collider neutrinos**
- measure backgrounds
- measure  $pp \rightarrow \nu X$  cross sections
- heavy flavour production in pp collisions
- **probe lepton flavour universality (LFU)**
- measure least known SM particle ( $\nu_\tau$ )
- **direct search for new particles (FIPs)**





# First events, from cosmics & LHC

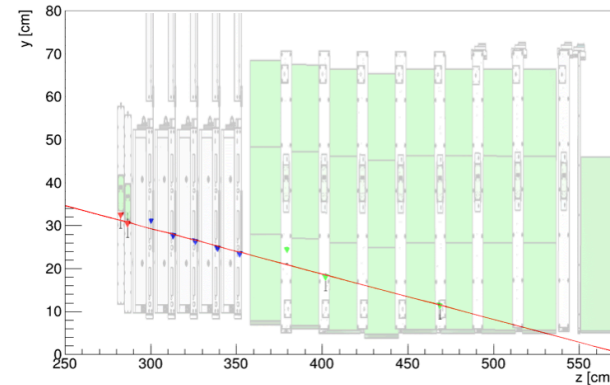
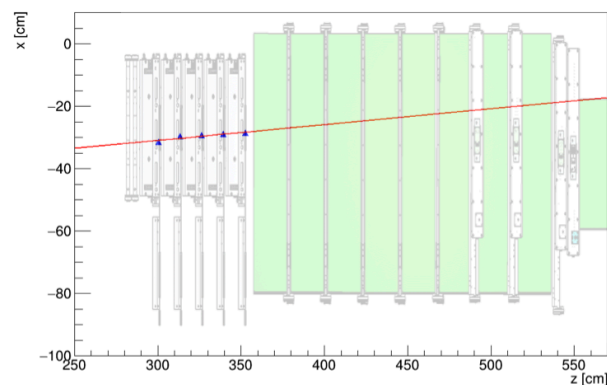


cosmic rays

TOP VIEW

EV 215120

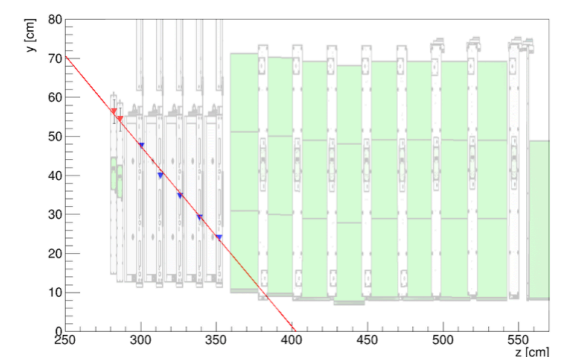
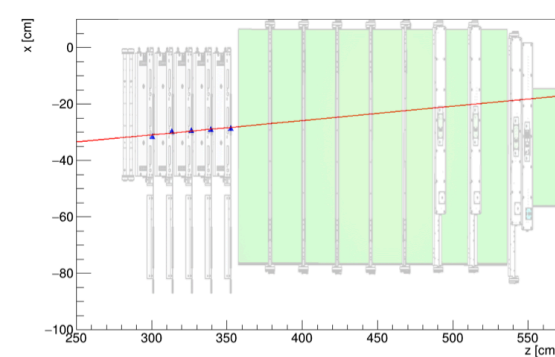
SIDE VIEW



TOP VIEW

EV 261930

SIDE VIEW



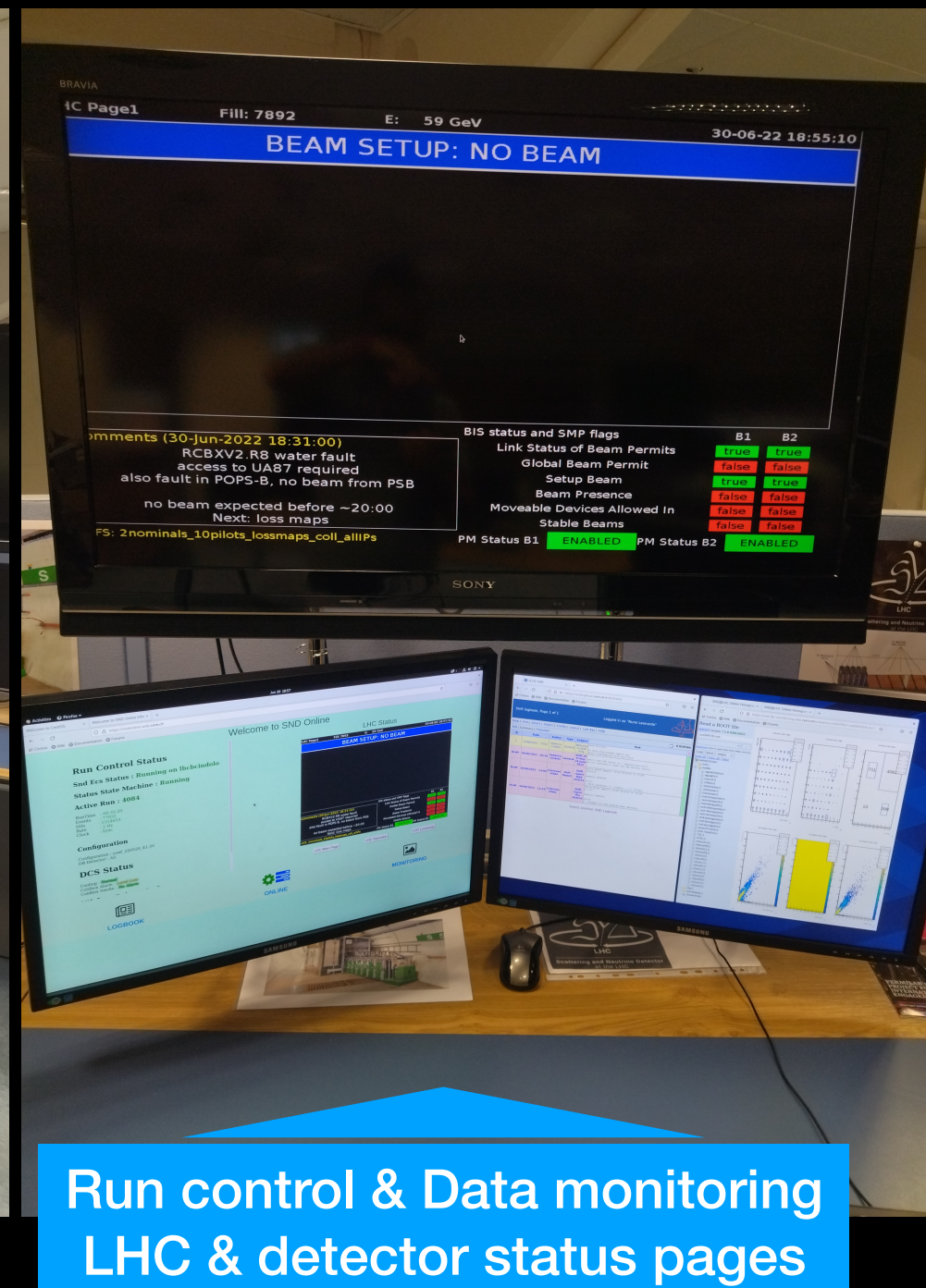
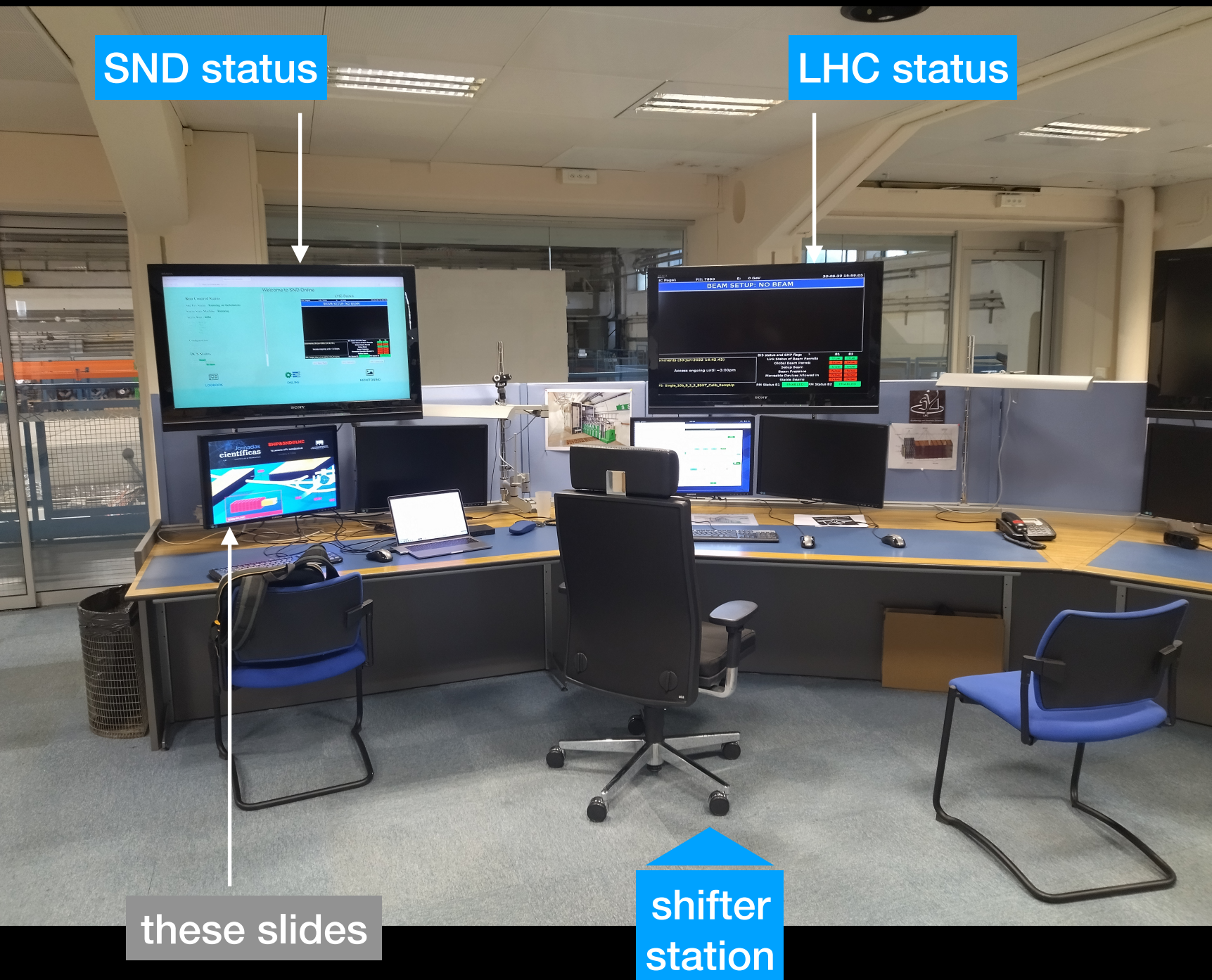


# Control Room @CERN

I've set it up last week — in time for start of stable data taking.  
Installed in a section of the CMS Center in CERN's Meyrin site.

**Team members actively involved in data taking & shifts at CERN.**

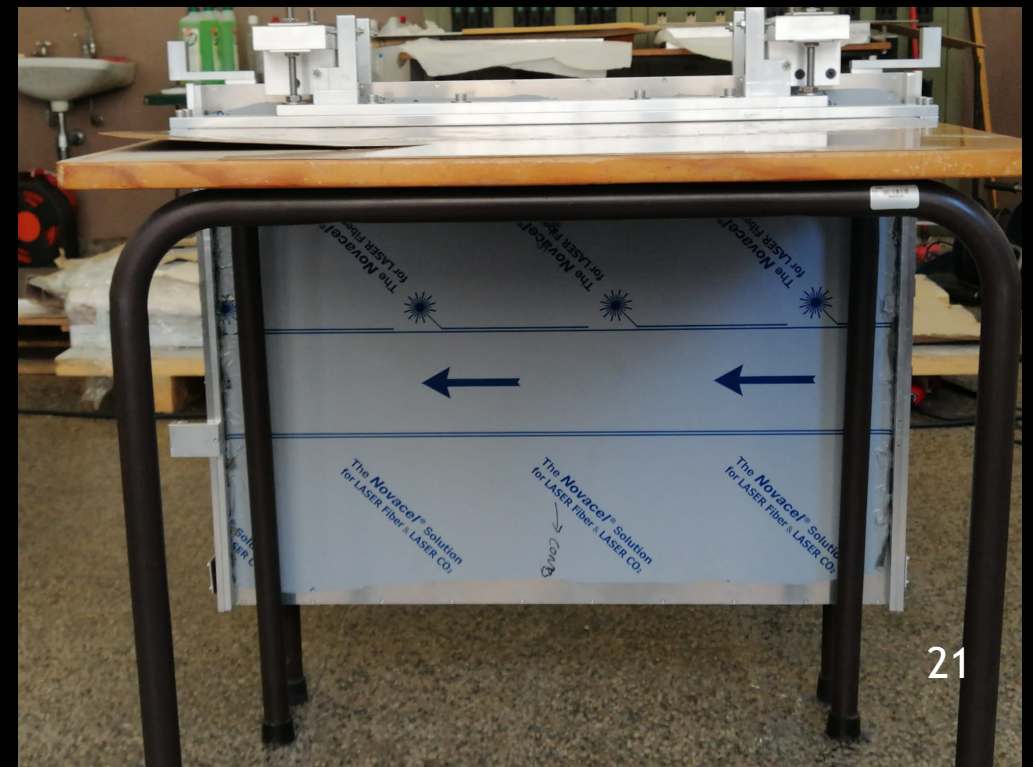
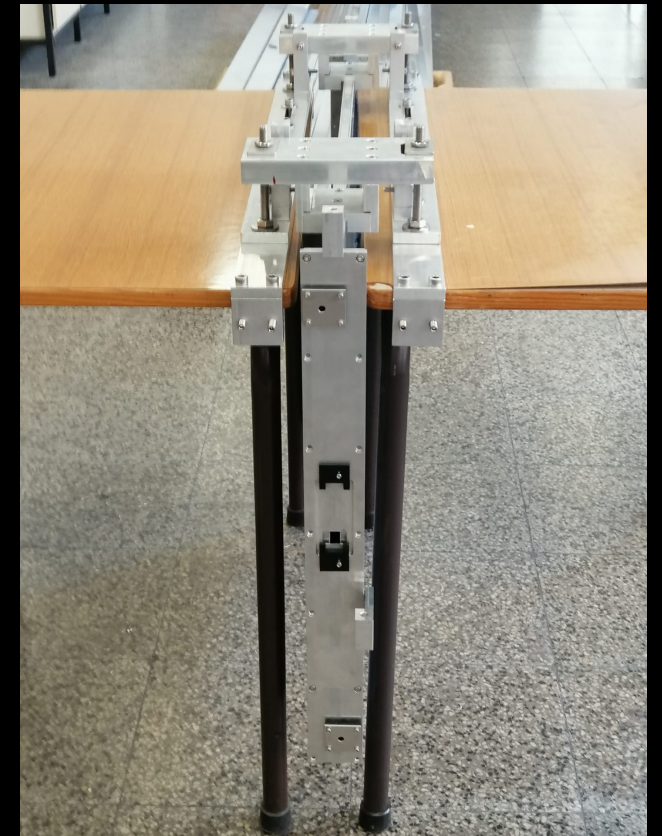
**LHC Run 3 data  
taking just started**





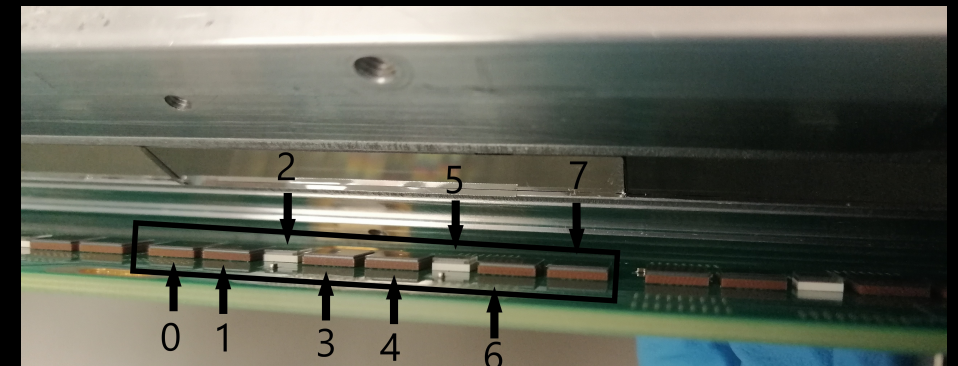
# Building the Muon System

- Detector assembly: July - October 2021
- Frames produced by LIP in Coimbra





# Building the Muon System





# Test Beams at H8 (SPS)

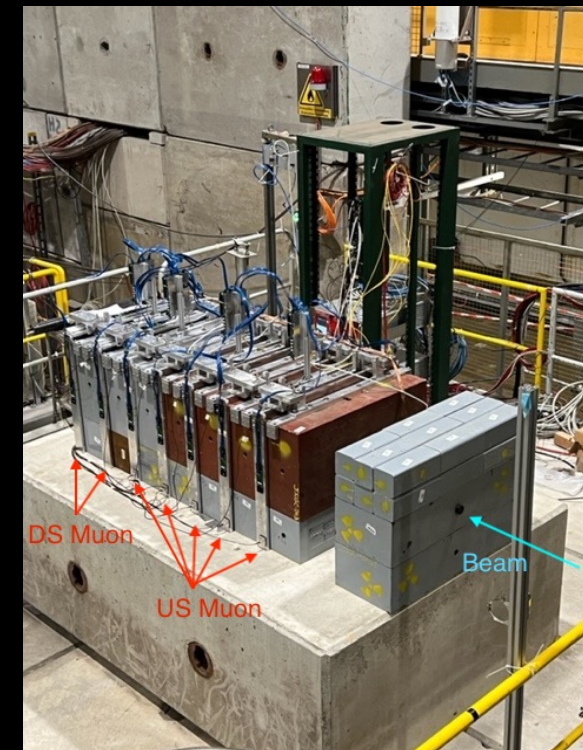
## 1. 1 - 5 September:

1<sup>st</sup> Time detector was turned on  
No useful data for commissioning



## 2. 29 September - 6 October:

Pion beams  
4 different energies  
Varied luminosity  
Different FEE calibrations  
Most data currently used for  
commissioning

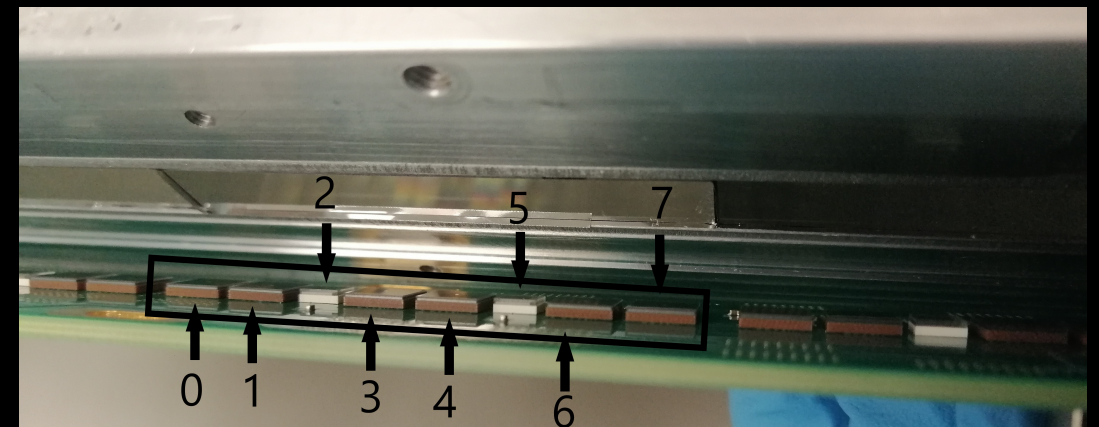


# Timing Calibration

— bad SiPM timing coincidence

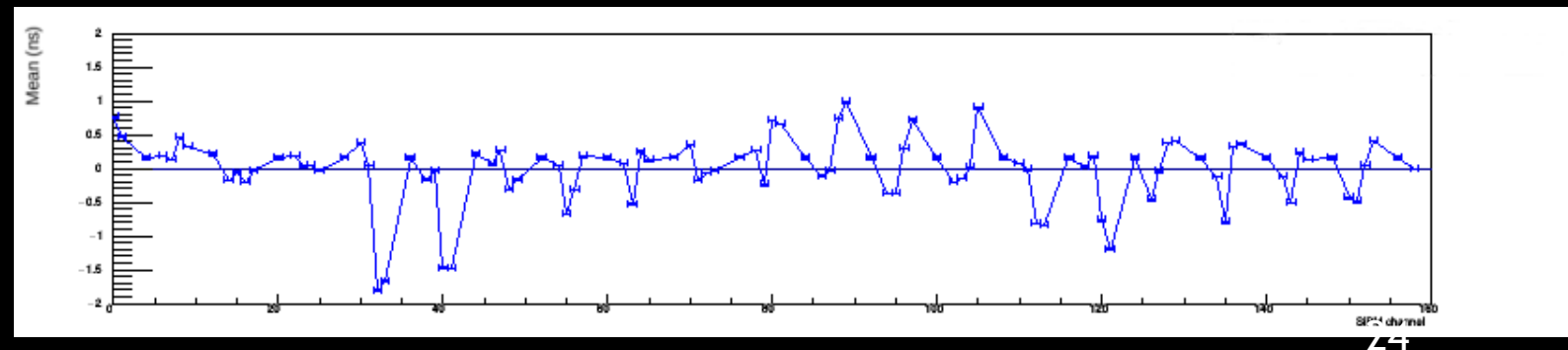
## Goals:

- Check timing difference distributions
- Infer corrections
- Define easily repeatable and automated process that can be applied retroactively and to Run 3 data



## Process:

- Fit distributions
- Find the mean
- Refine fitting criteria
- Get accurate description
- Correct channels





# Timing Calibration

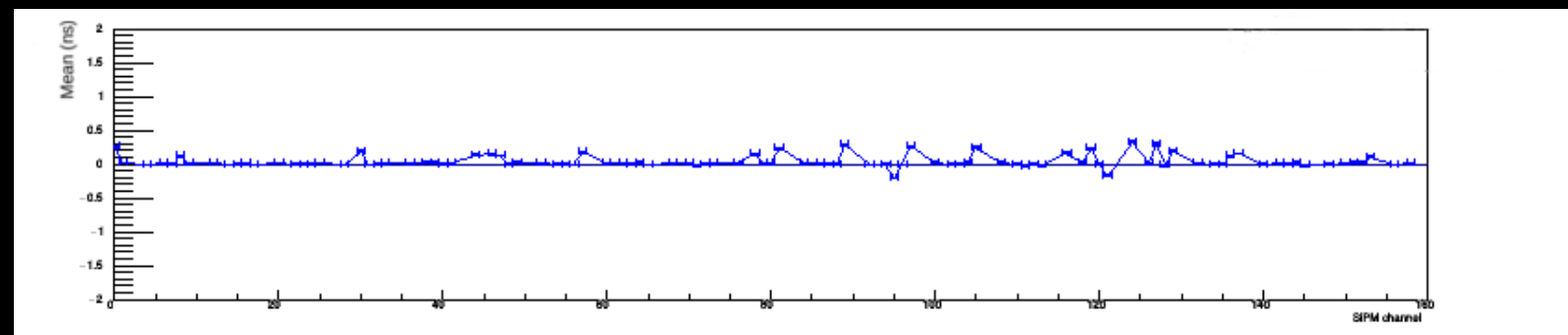
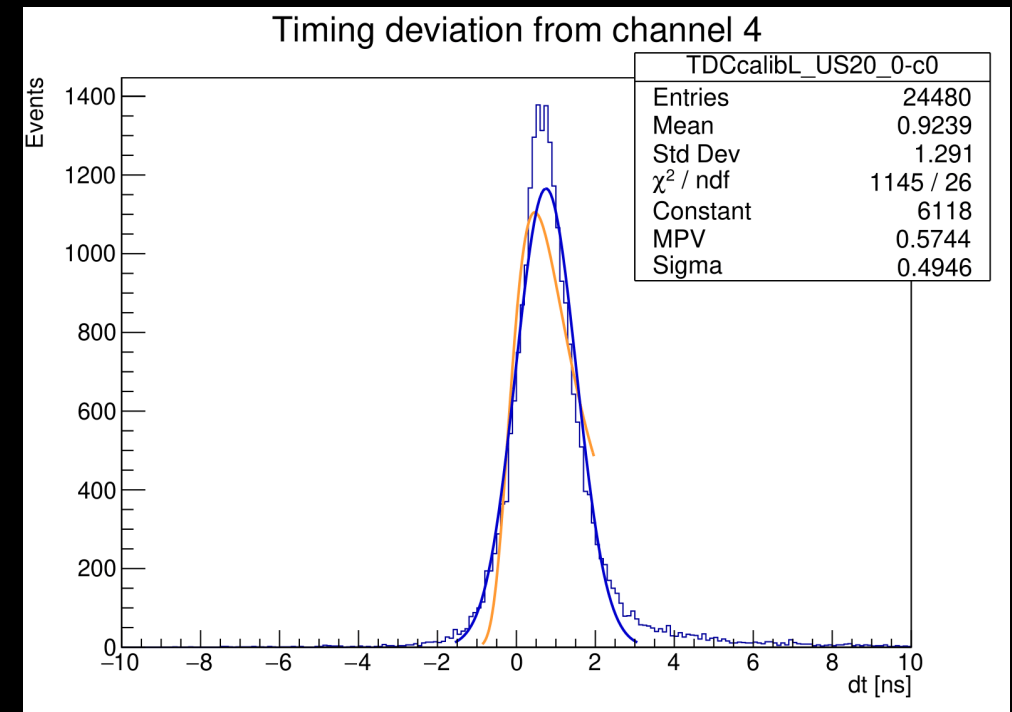
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- Correct channels



# Summary

- **SND@LHC is a novel experiment at the LHC**
- aim at measuring neutrinos at LHC and search for BSM physics
- approved, constructed, installed in 2021 — just started taking data
- LIP involved in construction, commissioning, data taking and analysis
- **SHiP proposed as a next-generation experiment**
- large sensitivity in search for feebly interacting particles
- LIP involved in detector design, prototype, analysis sensitivity
- FIPs are enjoying explosion of interest in the community
- **era of neutrino exploration at the LHC is starting**