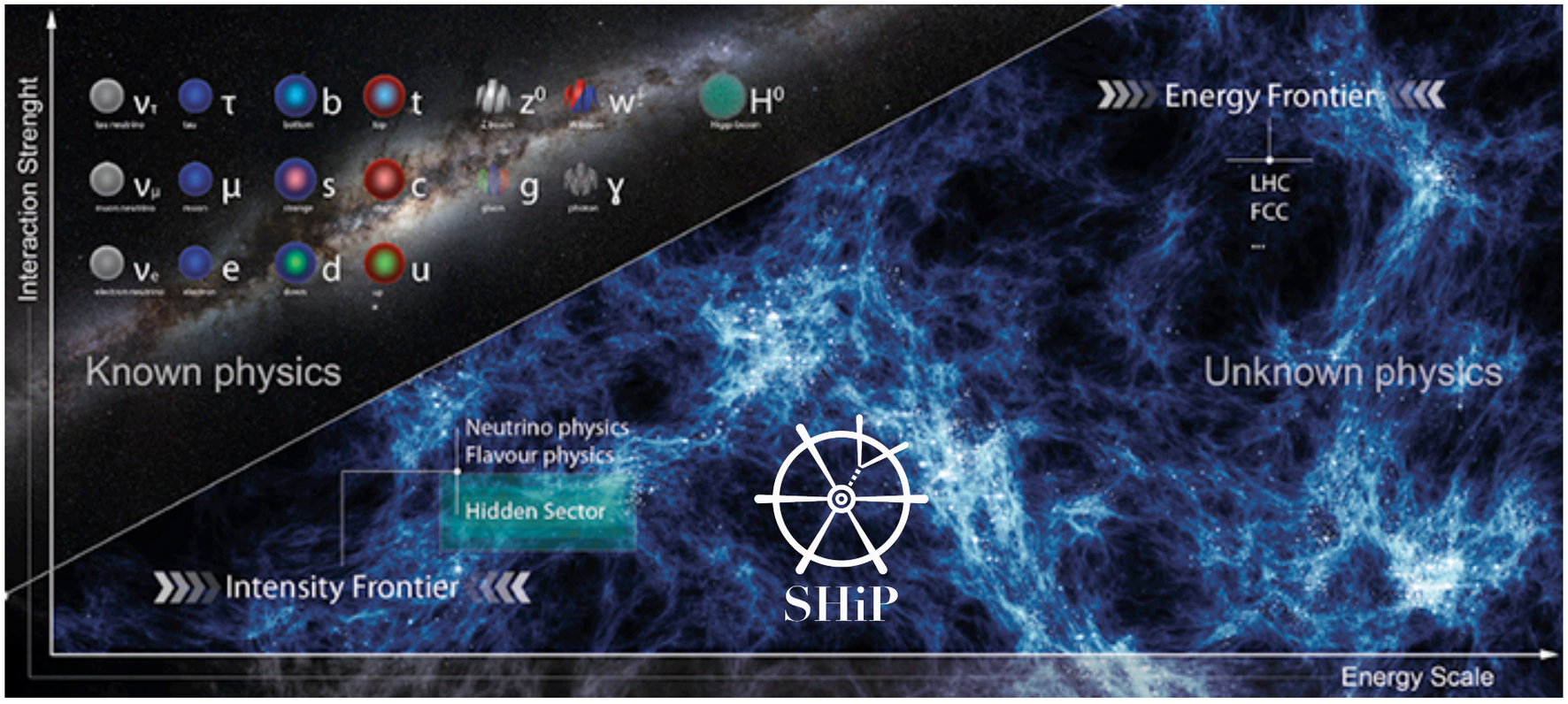
Explore the Hidden Sector of Particle Physics

Nuno Leonardo (nuno@cern.ch) for SHiP/SND LIP Group

Jornadas da Engenharia Física, NFIST, March 9th 2022

energy frontier



interaction strength

intensity frontier

energy scale

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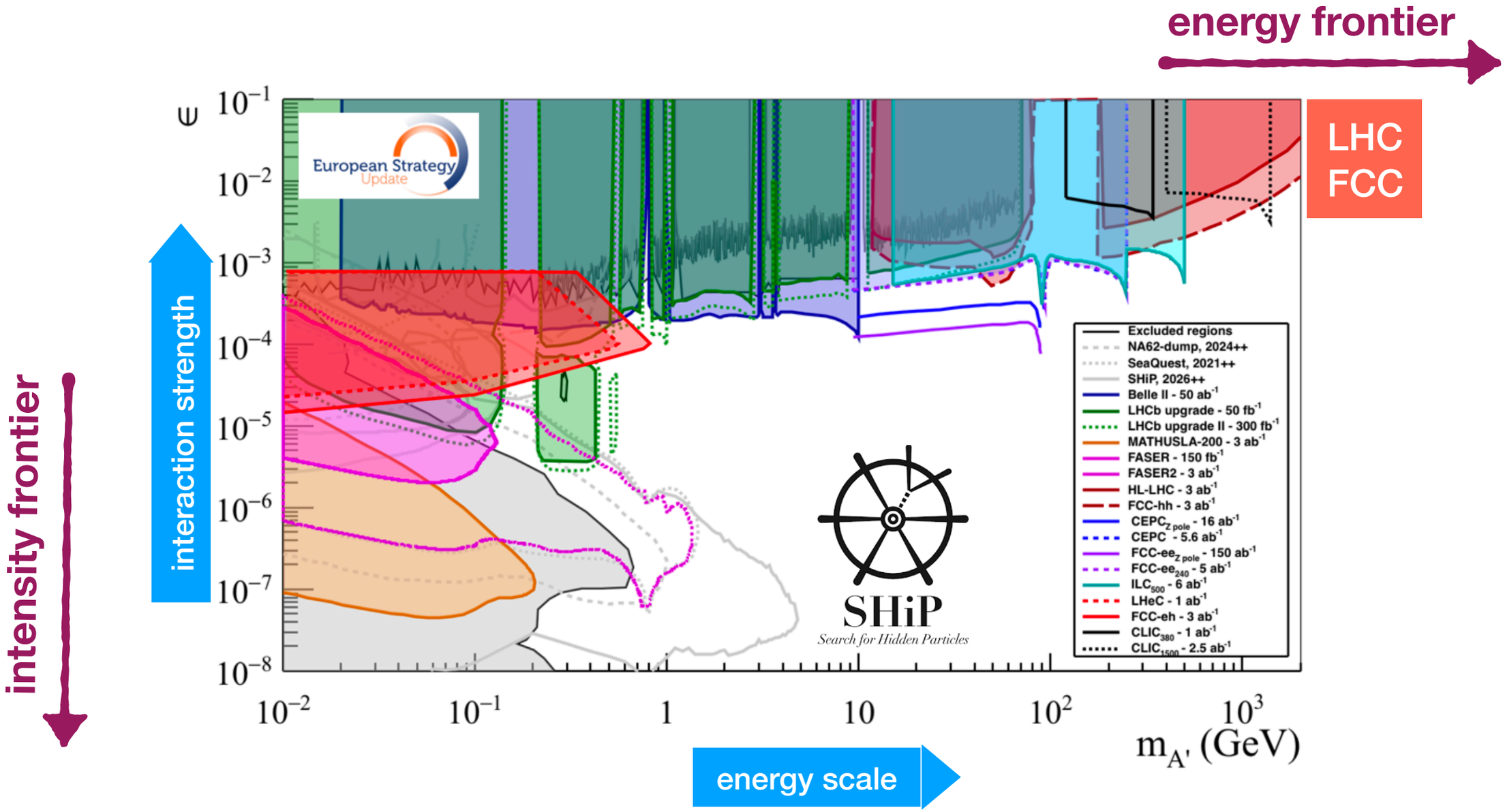
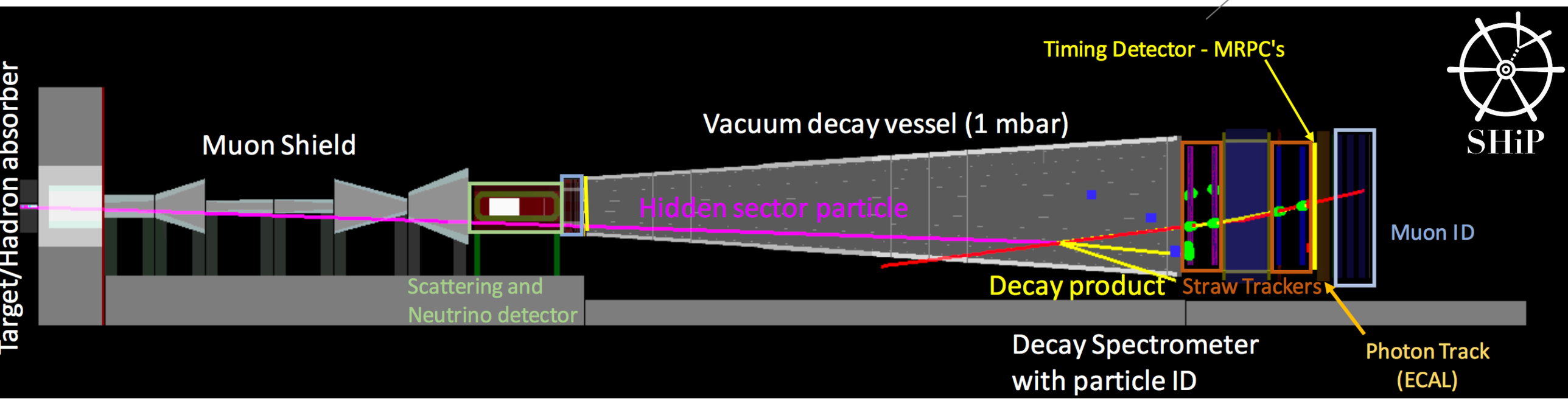


SHiP — Search for Hidden Particles

aka FIPs: Feebly Interacting Particles

by LIP



TÉCNICO LISBOA

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[1,a] and Raúl Santos[2,b]

[1] *Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal*
[2] *Instituto Superior Técnico, Lisboa, Portugal*

Project supervisors: N. Leonardo, G. Soares — *October 2020*

LIP-STUDENTS-20-17

Abstract. SHiP is an Int
actions, low masses and
of the *hidden sector* of p
particles, specifically da
and tested several mach
taining a high signal effi
regression and classifica

Keywords: Hidden Sec

LIP-STUDENTS-21-06

Distinguishing Hidden Sector Particles with Machine Learning at SHiP

Henrique Santos[1,a] and André Branco[1,b]

[1] *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

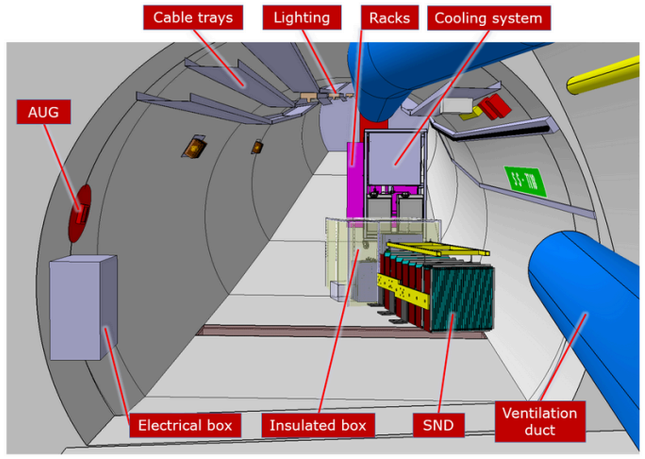
Neutrinos at the LHC?

LIP involved in construction, and commissioning of the new experiment at CERN
☛ data taking starting soon!

Neutrinos@LHC

LIP-ECO/N. Leonardo | 04 Setembro, 2020

"O protótipo de um detector de neutrinos desenvolvido para a experiência SHiP está preparado para ser instalado no LHC antes do próximo run. A proposta, subscrita pelo LIP, foi recentemente submetida ao CERN. "

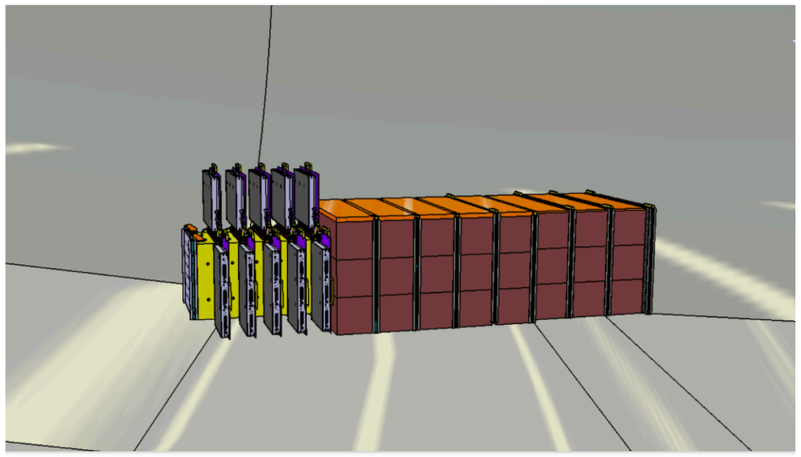


SND@LHC
the most recent
LHC experiment

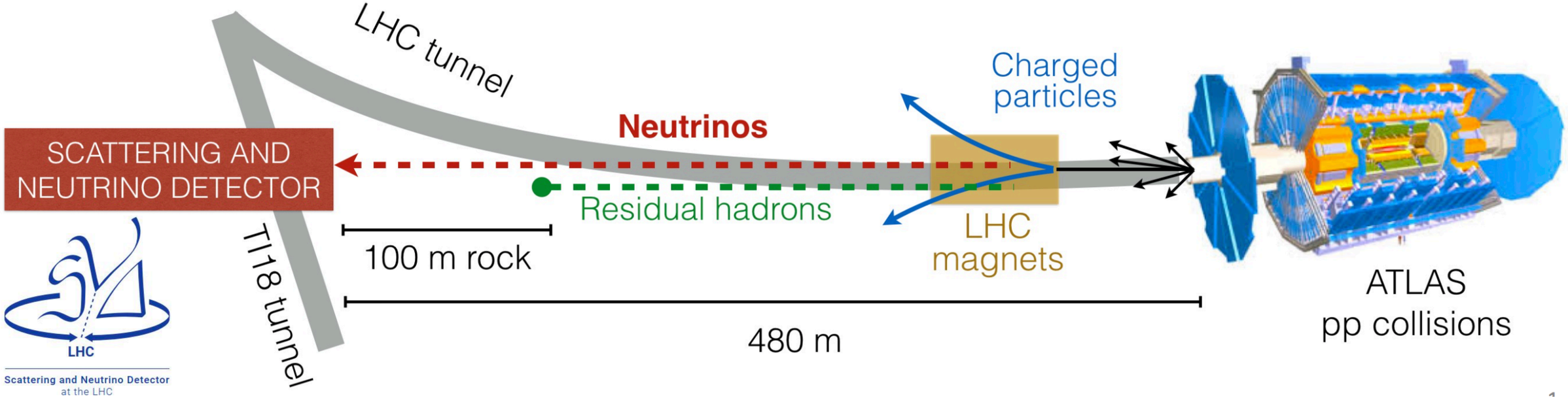
CERN approves new LHC experiment

SND@LHC, or Scattering and Neutrino Detector at the LHC, will be the facility's ninth experiment

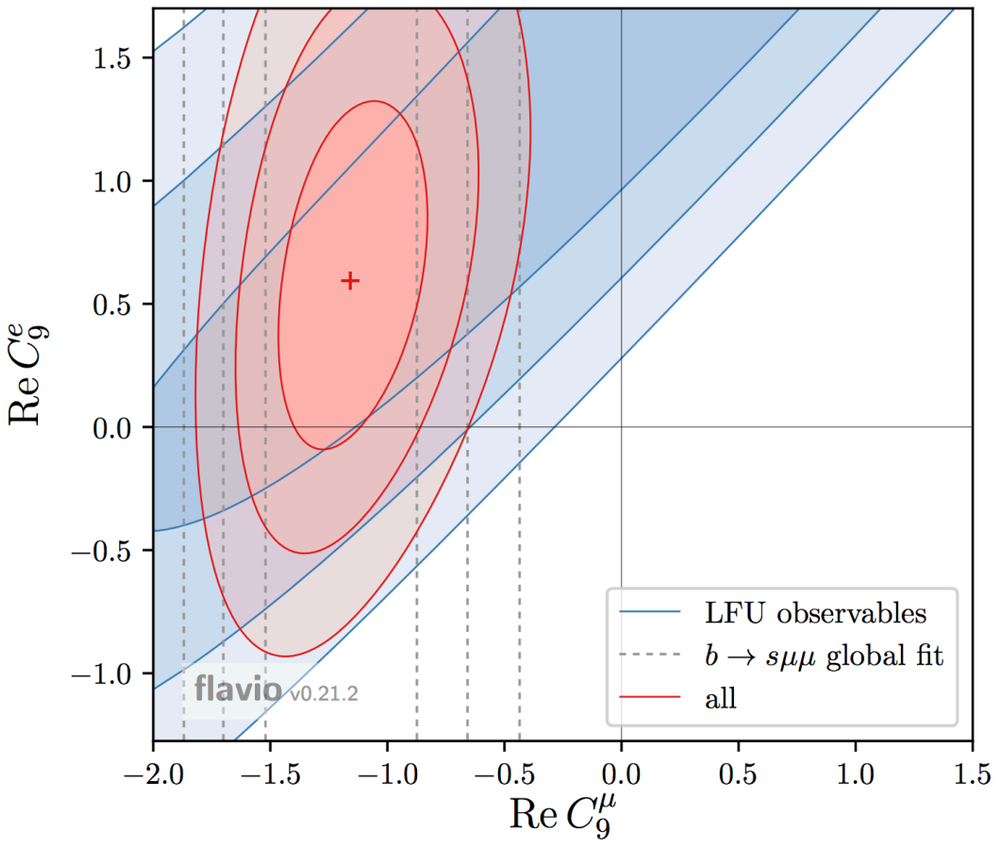
27 AVRIL, 2021 | Par Ana Lopes



The SND@LHC experiment consists of an emulsion/tungsten target for neutrinos (yellow) interleaved with electronic tracking devices (grey), followed downstream by a detector (brown) to identify muons and measure the energy of the neutrinos. (Image: Antonio Crupano/SND@LHC)



LFU — Lepton Flavour Universality violation?

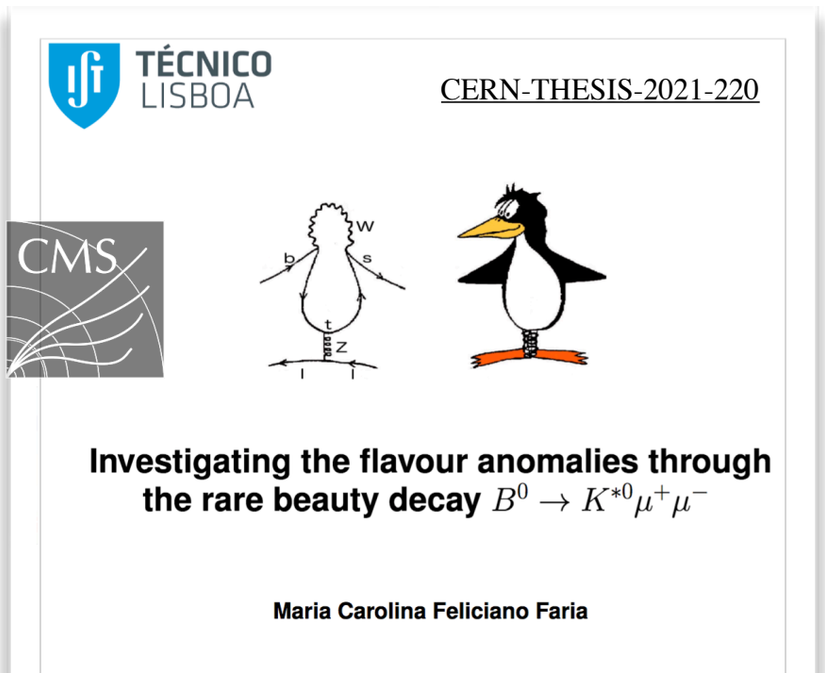


SND@LHC shall:

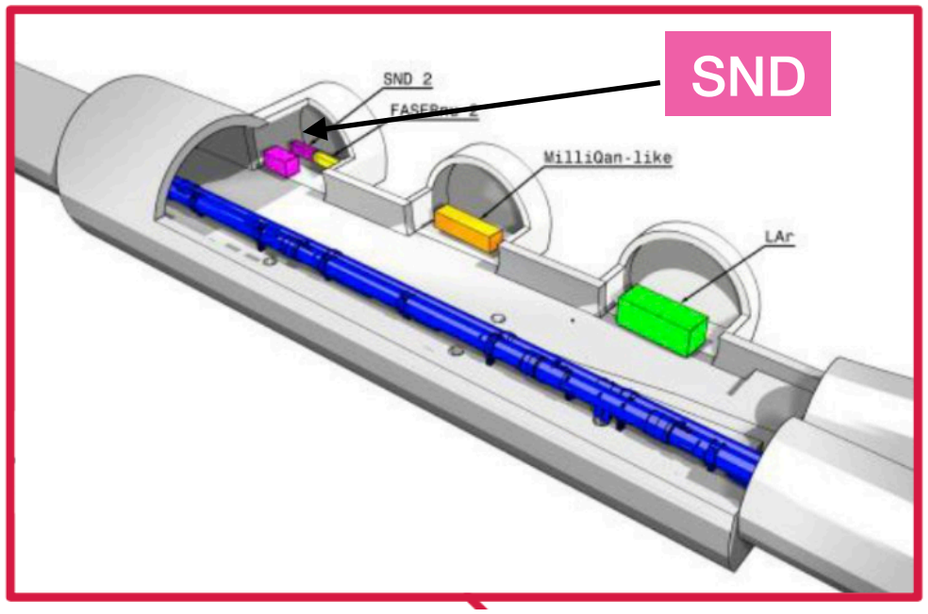
- measure **first** collider neutrinos!
- in unexplored energy range yet
- study least known SM particle: ν_τ

⇔

- test **LFU** violation: $R_{12} = \frac{\nu_e}{\nu_\mu}$, $R_{13} = \frac{\nu_e}{\nu_\tau}$
- search for **FIPs**



Future: SND2 at FPF for **HL-LHC**



LIP Internship Program

- from few weeks to two months, from July to September
- carry out a **research project** as a member of international research team
- learn about particle physics, detector design, machine learning (tutorials)
- present results to peers at workshop, possibility to write scientific paper

https://www.lip.pt/training/internship-program/

LIP-STUDENTS-19-08

B mesons as novel probes of QGP

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[2] *Faculdade de Ciências, Lisboa, Portugal*

Project supervisors: N. Leonardo, J. Silva — *October 2019*

Abstract. In this work we study B mesons as novel probes of the quark gluon plasma (QGP). We used PbPb data collected by the CMS experiment at the LHC in November 2018. The B^+ and B_s production differential cross-sections in PbPb collisions are measured. The cross sections of the two mesons and their ratios provide unique information about the properties of the QGP and how the hot and dense QCD medium affects the hadronization of the b quark. The B_s meson is observed for the first time in heavy ion collisions.

KEYWORDS: LHC, QGP, heavy flavour, production cross section, quark fragmentation, strangeness enhancement

LIP-STUDENTS-20-17

Contents

Search for dark matter and supersymmetry using machine learning at SHiP

Francisco Safara[1,a] and Raúl Santos[2,b]
[1] *Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal*
[2] *Instituto Superior Técnico, Lisboa, Portugal*

Project supervisors: N. Leonardo, G. Soares — *October 2020*

Abstract. SHiP is an Intensity Frontier experiment aimed at the search for particles with extremely feeble interactions, low masses and long lifespan. Such particles are predicted in a number of recently elaborated scenarios of the *hidden sector* of particle physics. In this project we used the SHiP software framework to simulate hidden particles, specifically dark photons and neutralinos, and study their kinematic properties. We have implemented and tested several machine learning techniques, with the aim of rejecting the neutrino background while maintaining a high signal efficiency. We were able to achieve, exploring neural networks with feature pre-processing, regression and classification, nil backgrounds and signal efficiencies above 95%.

KEYWORDS: Hidden Sector, Dark Photons, Neutralinos, Neural Networks

1 Introduction

The Standard Model (SM) of particle physics aims to describe the most fundamental properties of matter, it was developed during the second half of the 20th century, in a global initiative based on the ideas of unification and symmetries. It has provided a consistent description of Nature's fundamental constituents and interactions.

However, it fails to explain a number of observed phenomena in particle physics, astrophysics and cosmology such as the matter–antimatter asymmetry, the nature of dark matter and dark energy. To explain this phenomena, newer particles and/or interactions would be needed, but until this moment no direct experimental evidence exists.

Figure 1: Theory landscape of dark matter candidates [2].