Collider neutrinos

Portuguese Discussion on the European Strategy for Particle Physics

Lisbon, January 20 2025

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

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Neutrinos at the Large Hadron Collider

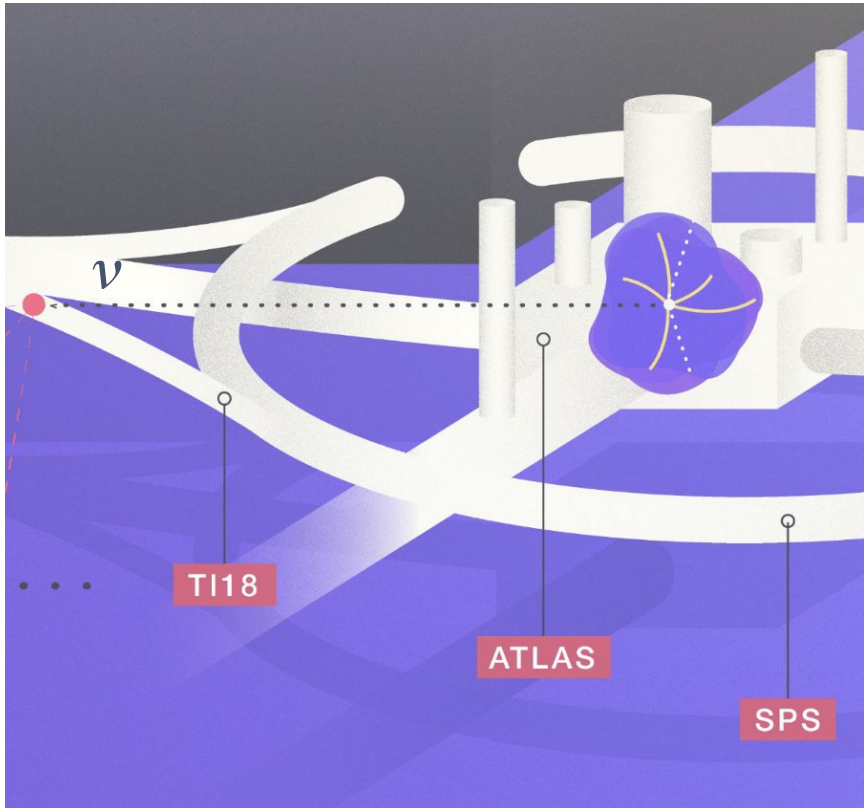
- Initial studies on **neutrino detection at the LHC** date back to the 80s.
  CERN-1984-010-V-2.571; Nucl. Phys. B405, 80; LPNHE-93-03
  - Back then, seen as an opportunity to discover the ν_τ.
  - Also to search for new particles.
    Phys.Lett.B 153 (1985) 183

- **Large flux** of neutrinos in the forward region.
- Very **high neutrino energy** ($\sigma_\nu \propto E_\nu$).

⇒ A small-scale LHC experiment can observe neutrinos of all **three types** .

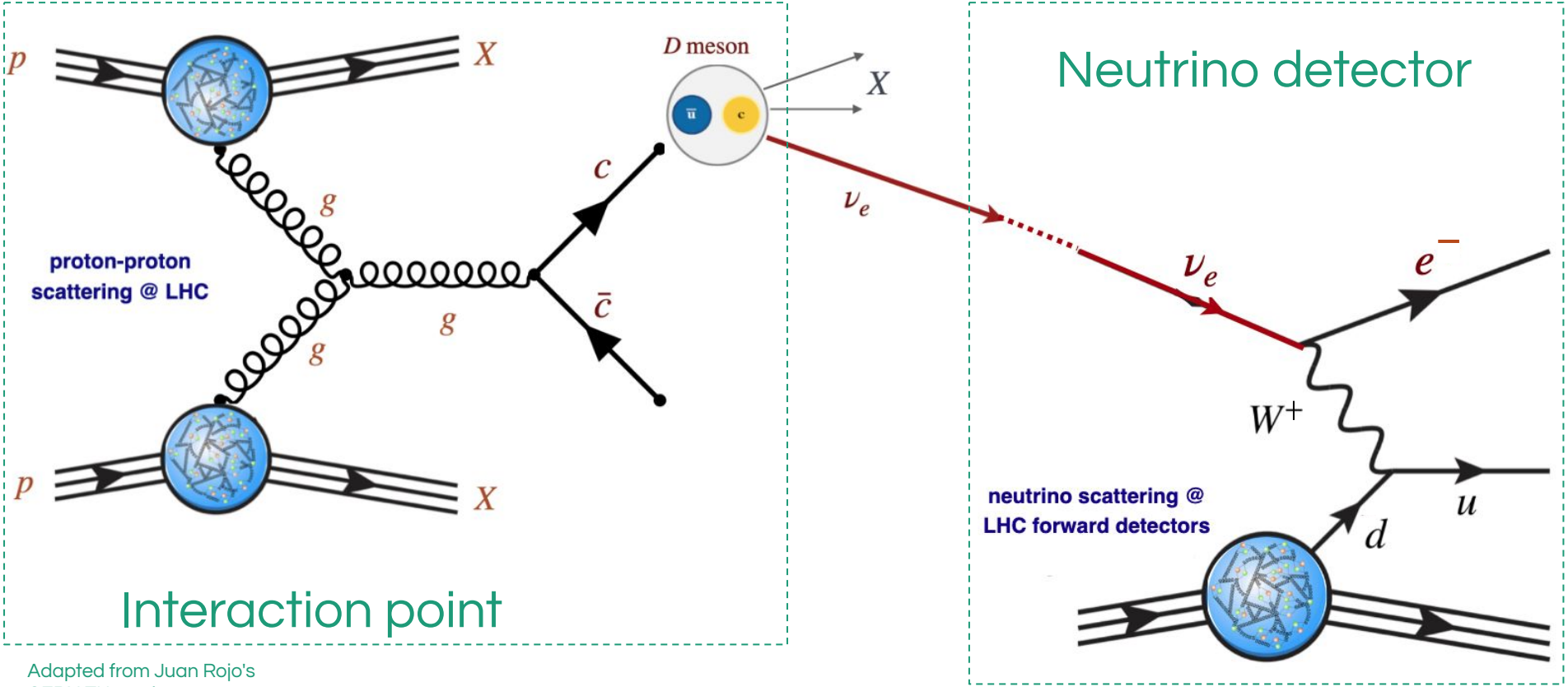
  - Highest energy human-made neutrinos!

- Two neutrino experiments in operation at the ATLAS interaction point since June 2022:
  SND@LHC and **FASERν**



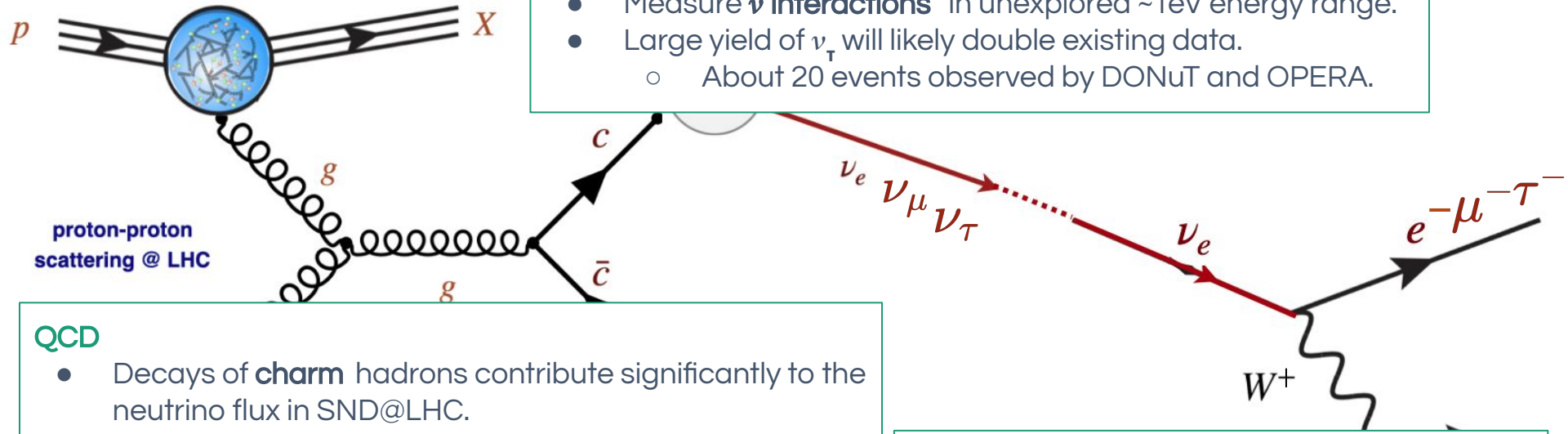

LIP-μ detector

Hadron collider neutrino physics



Adapted from Juan Rojo's CERN TH seminar

Hadron collider neutrino physics



Neutrino interactions

- Measure **ν interactions** in unexplored ~TeV energy range.
- Large yield of ν_τ will likely double existing data.
  - About 20 events observed by DONuT and OPERA.

QCD

- Decays of **charm** hadrons contribute significantly to the neutrino flux in SND@LHC.
  ⇒ Measure **forward charm production** with ν_es.
  ⇒ Constrain **gluon PDF** at very **small x**.

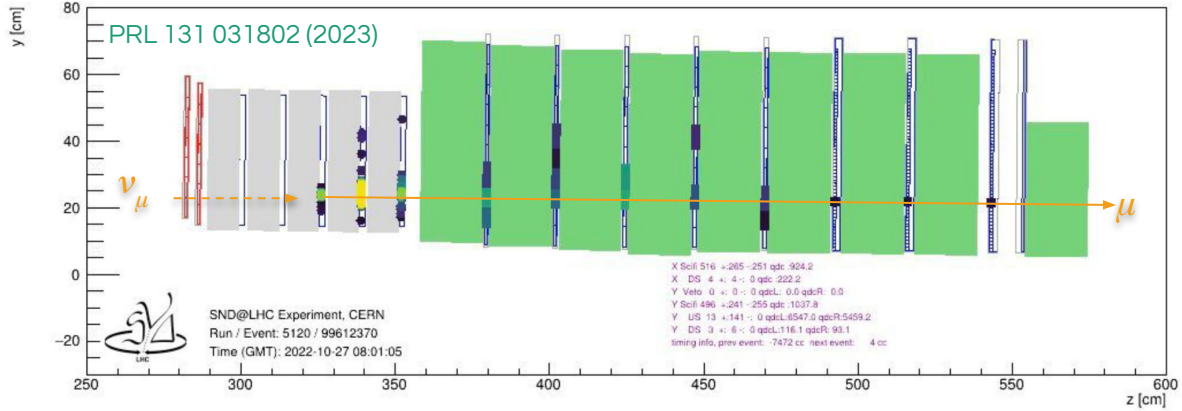
Beyond the Standard Model

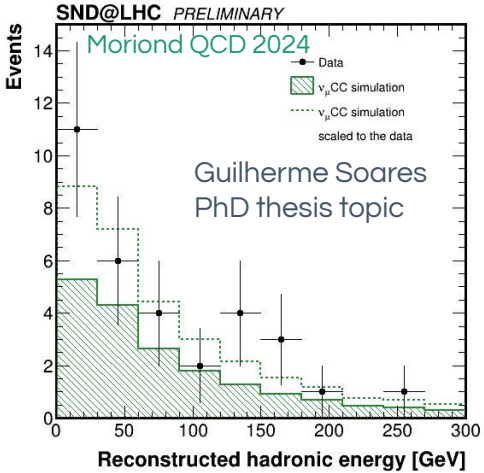
- Search for **new**, feebly interacting, **particles decaying** within the detector or **scattering** off the target.

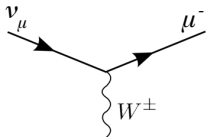
Flavour

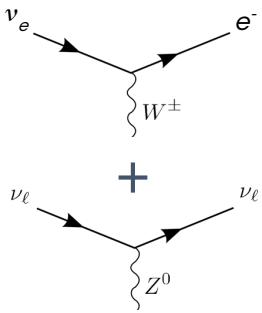
- Detection of all **three types of neutrinos** allows for tests of **lepton flavour universality** .
  - Charm parentage leads to partial cancelation of flux uncertainties

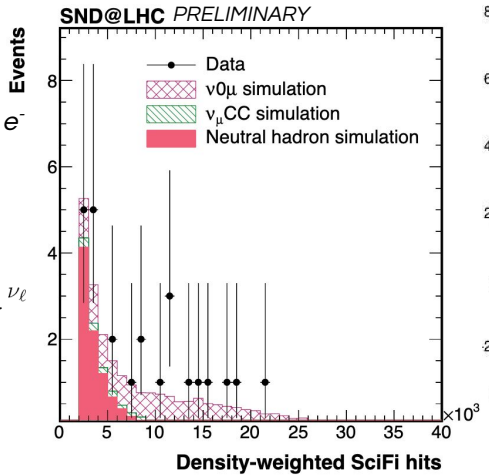
SND@LHC first neutrino measurements

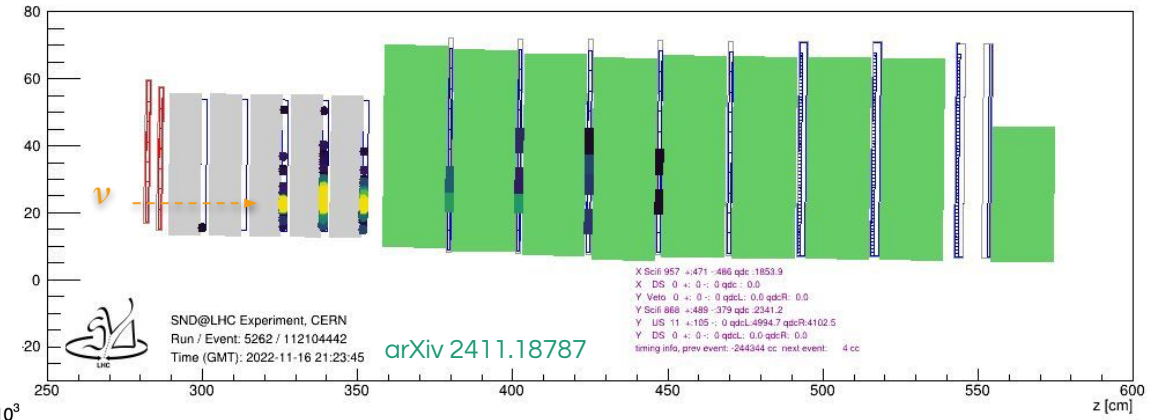






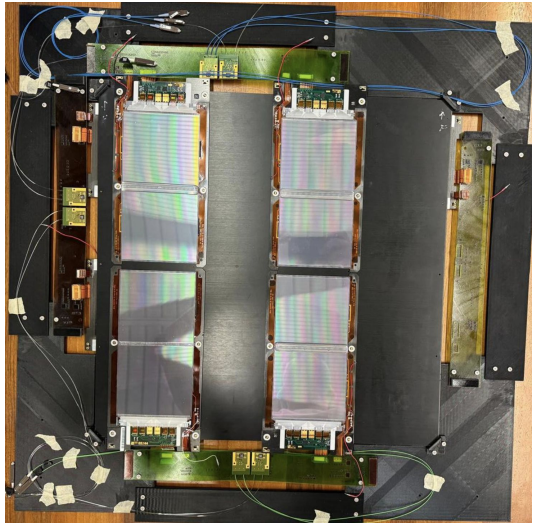




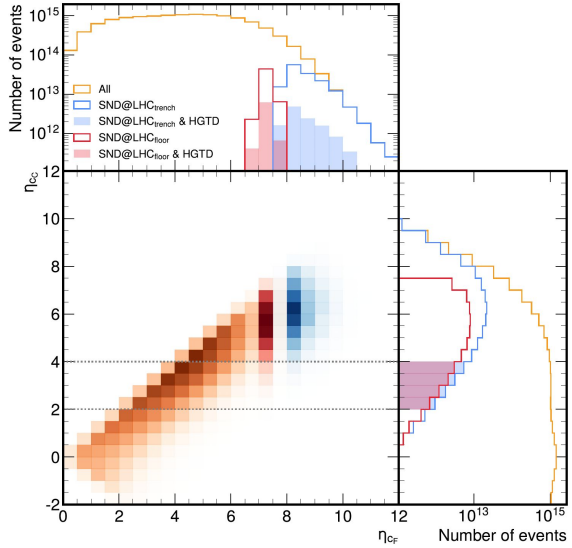


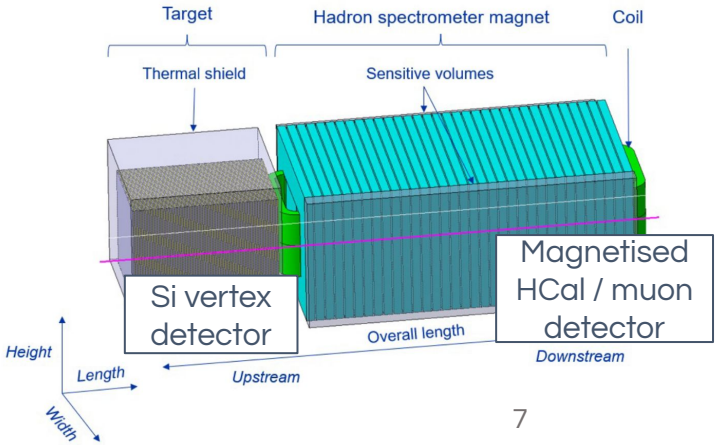
SND@HL-LHC

- Order-of-magnitude increase in event yield in HL-LHC.
  - Emulsion technology is not viable in this context.
- Experiment will take ownership of CMS tracker outer barrel modules to instrument neutrino target.
  - First use of silicon for neutrino vertex detection.
  - Retain tau neutrino identification capability.
    - Opportunity to discover the tau antineutrino!
- Opportunity to detect neutrinos in coincidence with activity in ATLAS (over 1000 events).



Flavour	SND@LHC$_{\text{trench}}$ light parent	SND@LHC$_{\text{trench}}$ charm parent
$\nu_\mu + \bar{\nu}_\mu$	6.5×10^4	7.9×10^3
$\nu_e + \bar{\nu}_e$	4.0×10^3	8.5×10^3
$\nu_\tau + \bar{\nu}_\tau$	—	3.9×10^2
Total	1.1×10^5	1.7×10^4





Portuguese roles and strategy

Roles within the collaboration

- Physics coordination
- Upgrade coordination
- Editorial board membership

Hardware responsibilities

- Upgrade:
  - Silicon vertex detector power cables.
  - RPC fast timing detectors
- Current detector:
  - Sealed-RPC muon telescope
  - HCal / muon system mechanical structure

Portuguese group strategy

- Exploitation of Run-3 data:
  - Maintain / enhance leadership in neutrino and BSM analyses.
    - Most physics results still to come!
- High-luminosity upgrade:
  - Maintain / enhance central role in project management.
  - Pursue major detector responsibilities.
    - Highly synergistic with SND@SHiP.

European strategy priority: exploitation of the HL-LHC to its fullest extent.