

Standard Model

**Energy Frontier** 

**Coupling Frontier** 

Mass

(HL LHC, FCC ~ €50 Billion)

### Neutrino experiments at CERN (SPS & LHC)

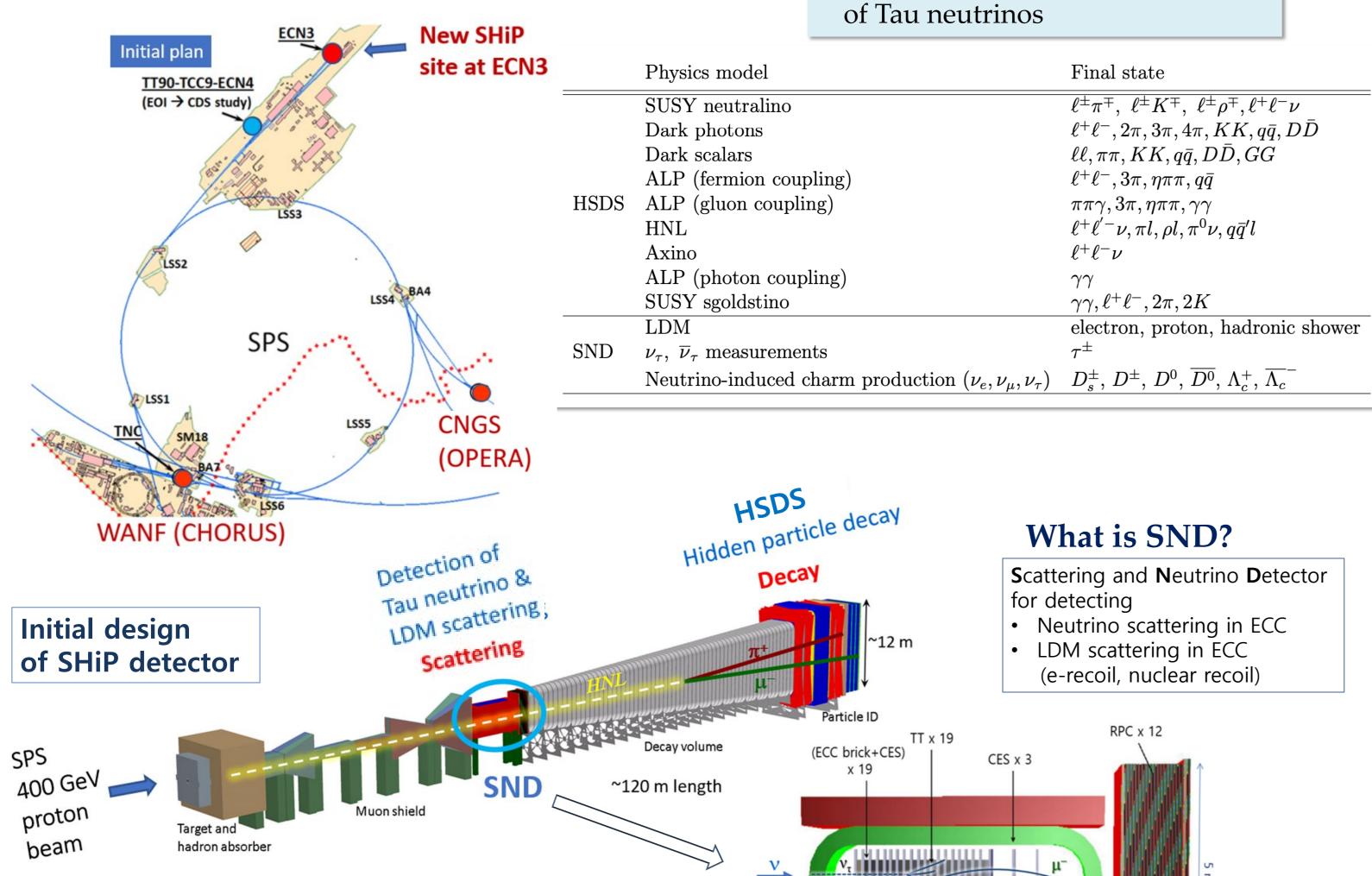
## **Scattering and Neutrino Detector**

at the LHC

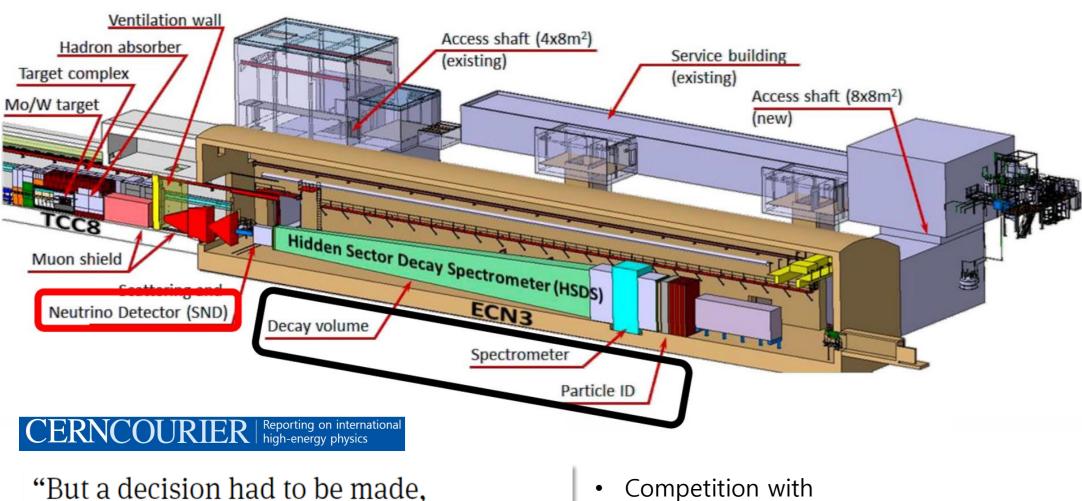
#### **SHiP**

#### **Explore the unexplored parameter space**

- New physics is either too heavy or interacts very feebly, i.e. much weaker than neutrino.
- The SHiP is a new experiment at the **intensity** frontier aimed at exploring the hidden sector (low mass, very small coupling).
  - Search for a broad range of FIPs:
  - HNLs (Heavy Neutral Leptons)
  - Dark photons
  - Dark Scalar Higgs-like particles
  - ALPs (Axion-like particles)
  - Unprecedented measurements



#### SHiP at ECN3 was approved **SHiP detector at ECN3** by CERN RB on 6 Mar 2024.



 Competition with HIKE (Successor of NA62) & SHADOWS (FIPs)

**SHIP SND** 

**ECC target :** ~ 8 tons

2 x 2 bricks x 19 walls

**RPC**: Muon ID, charge

 $(80 \times 80 \text{ cm}^2/\text{ wall})$ 

# Hidden Sector proposals in CERN North Area

electron-recoil

v DIS interaction

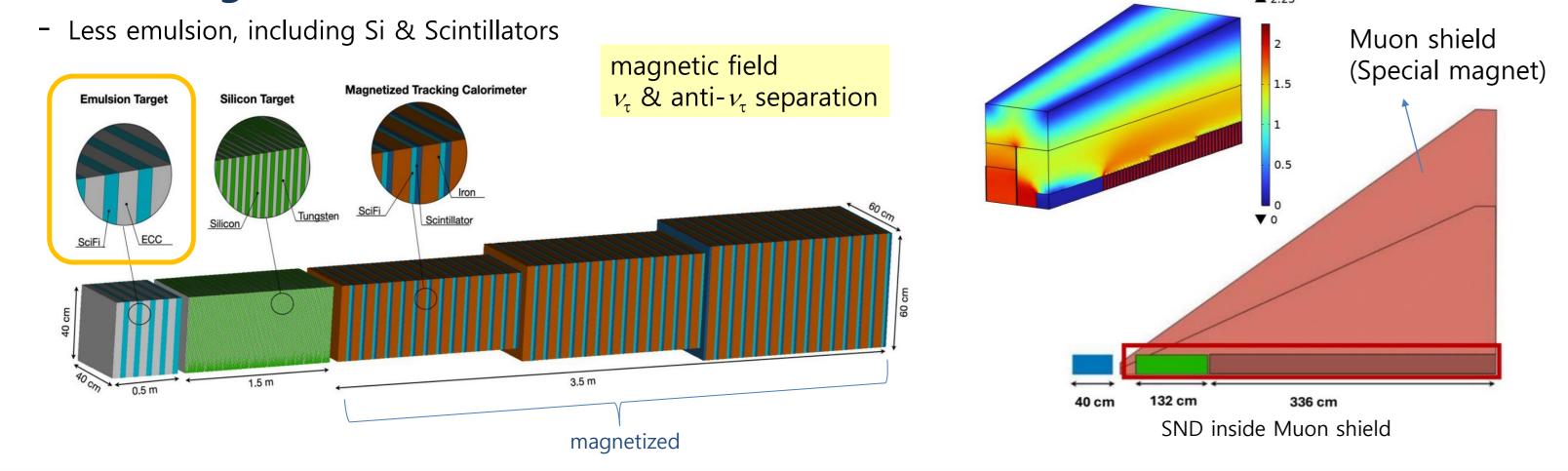
 Existing infrastructure at ECN3 Currently hosting NA62 (~150m)

#### New design of SHiP SND

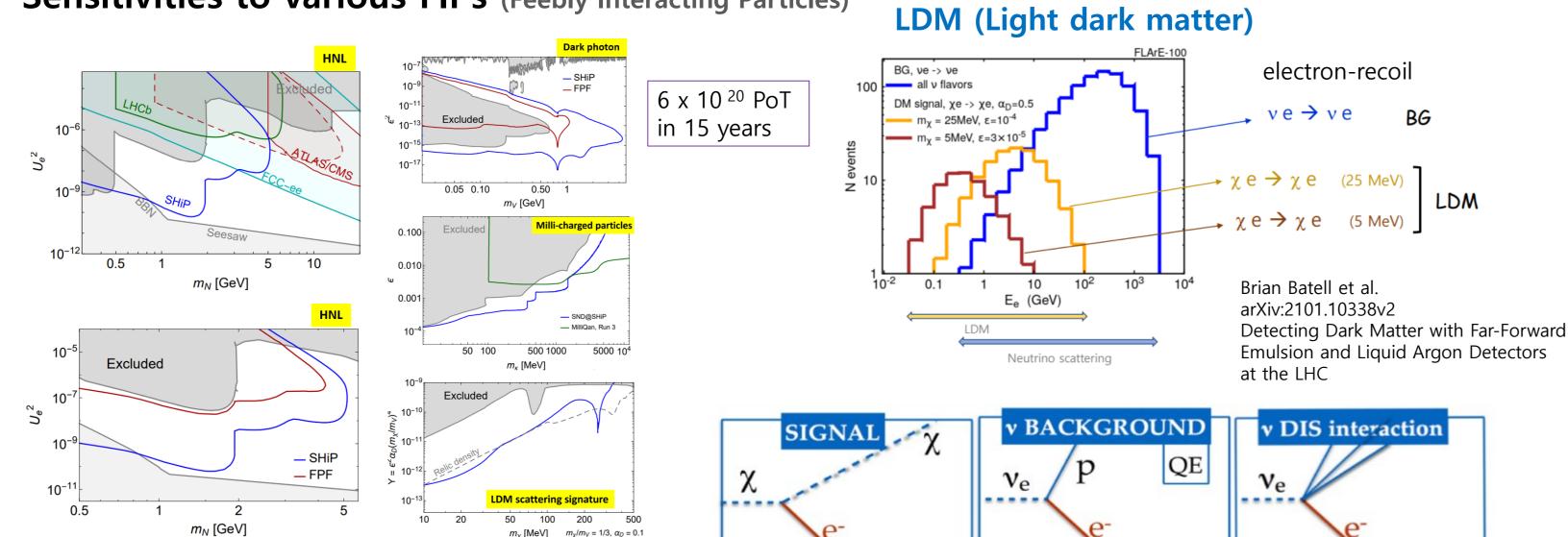
and SHiP was a strategic choice for CERN."

•  $6 \times 10^{20}$  protons in 15 years

• ~ $10^6$  neutrinos (~ $5 \times 10^4 v_{\tau}$ )

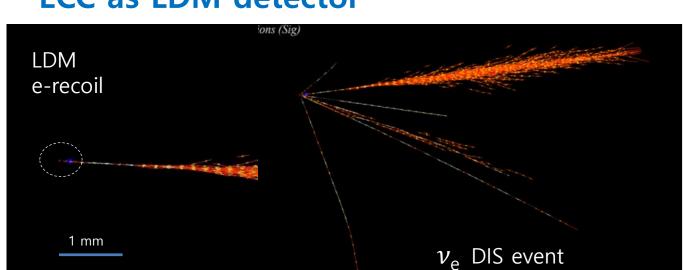


#### Sensitivities to various FIPs (Feebly Interacting Particles)



 $m_{\chi} \, [\text{MeV}]$   $m_{\chi}/m_{V} = 1/3, \, \alpha_{D} = 0.1$ 

#### **ECC** as LDM detector



Single electron produced by an LDM particle scattering: In the background suppression against  $v_e$  interactions, the most powerful handle is the isolation criterion: No extra-activity

#### Ground-breaking for HI-ECN3 (BDF/SHiP) 13th May 2025



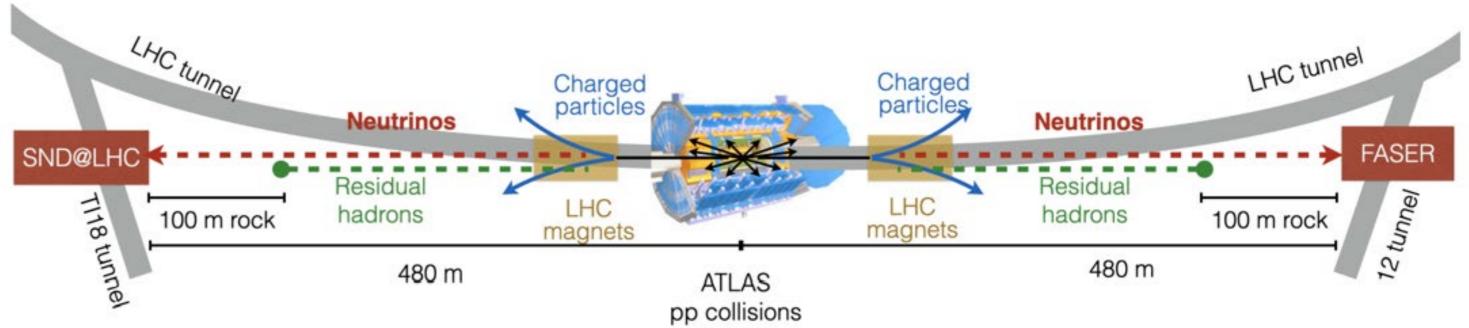
#### **SHiP Schedule** 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | Accelerator schedule LHC Run 3 SPS (North Area) Production / Construction / Installation BDF / SHiP Milestones BDF PRR TDR studies TDR studies Milestones SHiP PRR Facility Approval for TDR **Experiment TDRs**

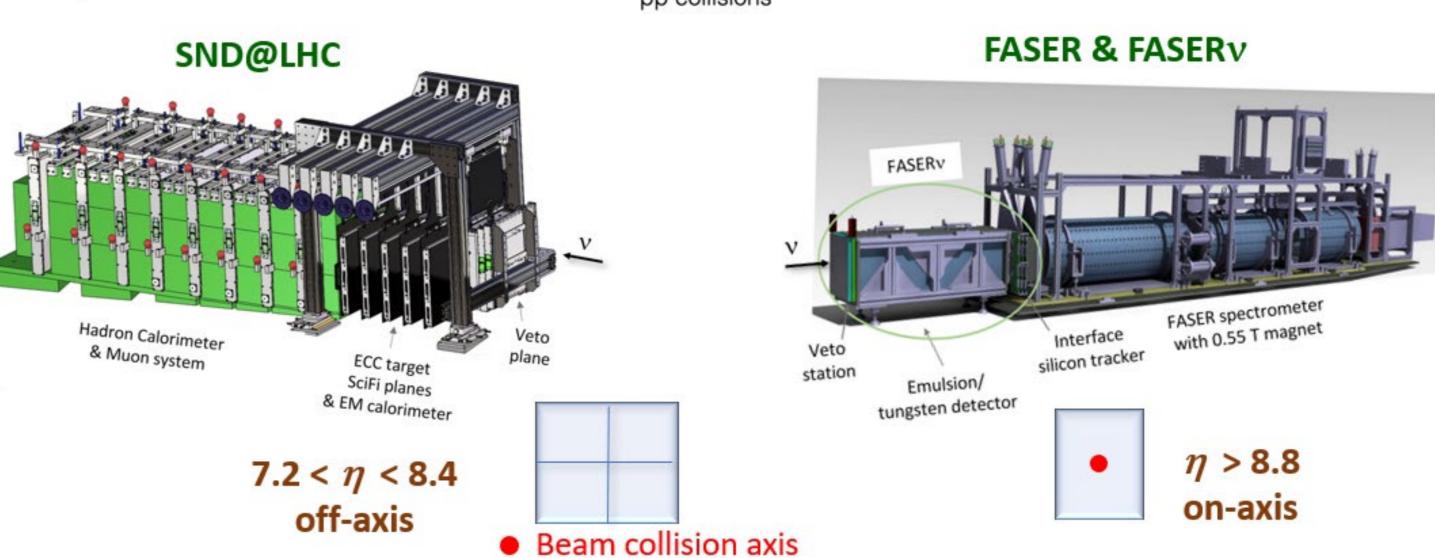
 $6.9 < \eta < 7.7$ 

#### SND@LHC

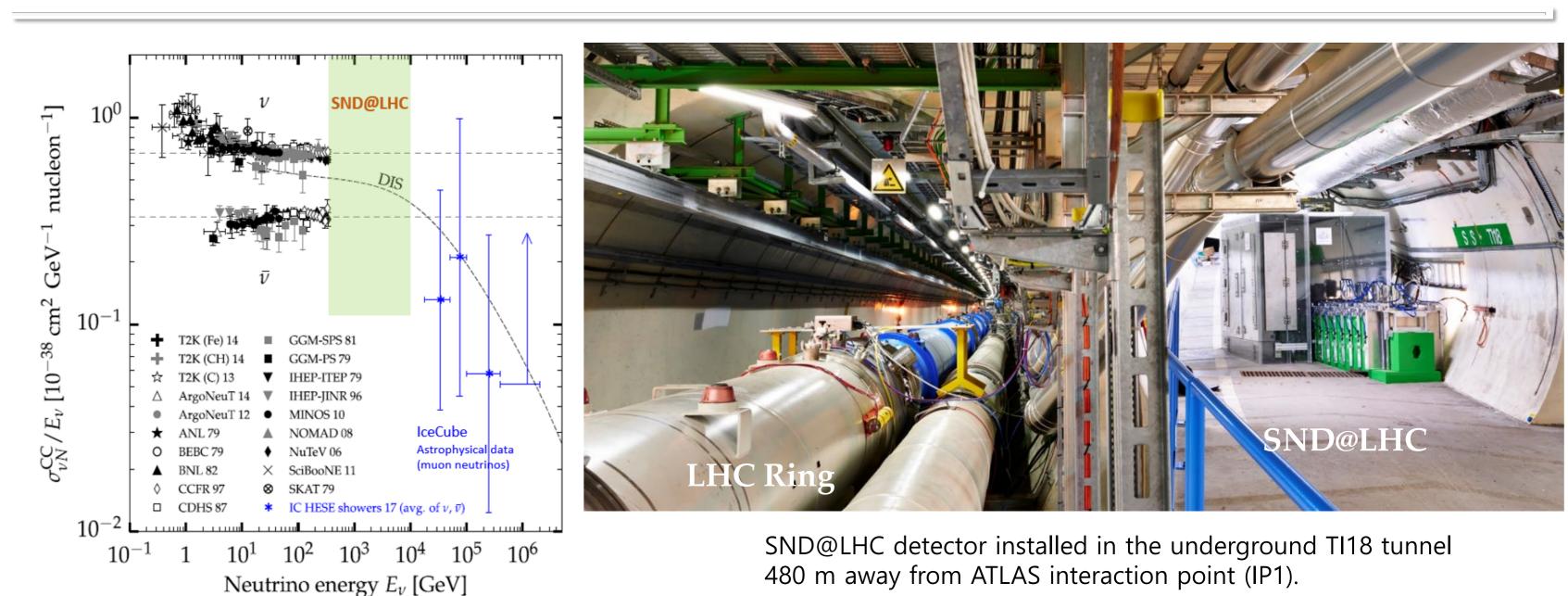
#### SND@LHC and FASER

Suitable experimental environment Symmetric - 480 m away from ATLAS IP LHC magnet - deflect charged particles **Complementarity** - different η range 100 m rock - absorb residual hadrons





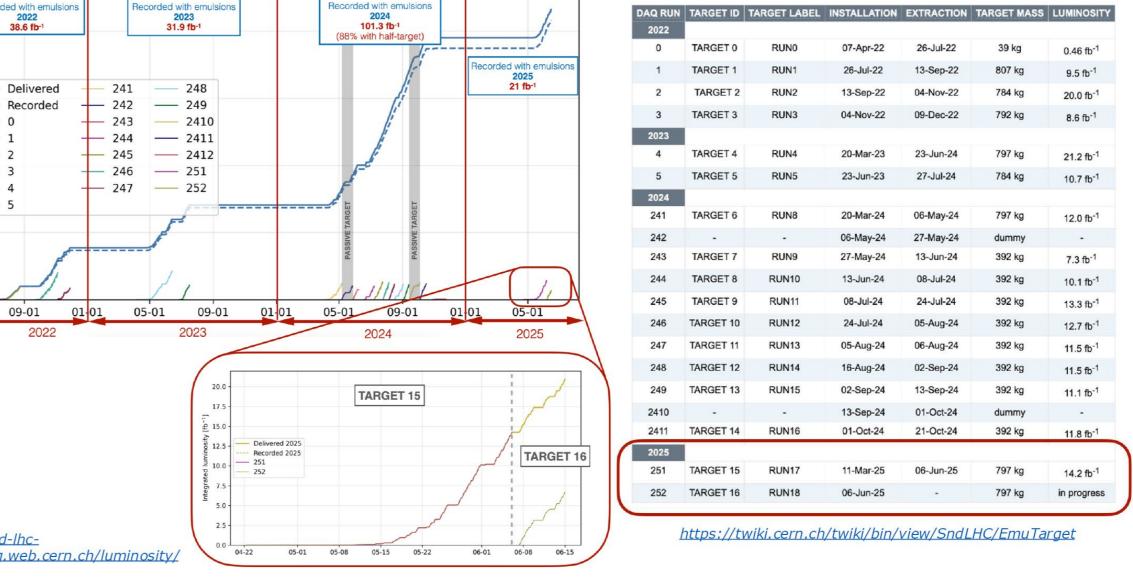
- The LHC experiments (CMS, ATLAS, LHCb) focused high P<sub>T</sub> and low cross section events (~ fb to pb)
- → No new physics yet.
- Most of highest energy particles are in the forward region and low  $P_T$  (~ 100 mb).
- → No detectors in the forward direction (beam pipe).
- The SND@LHC experiment is newly proposed to study the forward produced particles in the unexplored regions of energy (100 GeV - TeV) and pseudo-rapidity.



• CERN's LHC is a unique facility which can create huge numbers of high-energy neutrinos.

Even small neutrino detector will be effective since neutrino cross section increases with its energy 2 ton @ 1 TeV ~ 200 ton @ 10 GeV

#### LHC beam exposure (2022-2026)



Operation in Run 3 (5 years) to collect  $\sim 300 \text{ fb}^{-1}$ 

Integrated luminosity:

Delivered 217 fb<sup>-1</sup> Recorded 209 fb<sup>-1</sup> (96.3%)

ECC target #16 (July 2025)

#### SND@HL-LHC in Run 4

- SND@HL-LHC expects a high event rate of all 3 neutrino flavors LFU (Lepton Flavour Universality) test
- High-energy  $v_e$  from charm decays enable studies of forward charm production in pp collisions - probing the gluon PDF at Bjorken x below  $10^{-5}$ .
- High-statistics cross-section measurements.

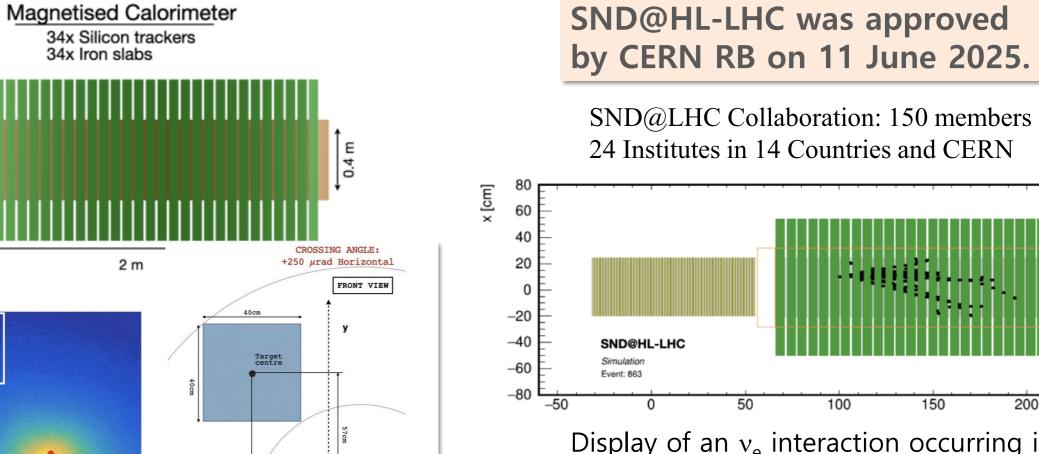
34x Iron slabs

Neutrino Target

58x Silicon trackers

58x Tungsten layers

3x Scintillator trackers



Display of an  $v_e$  interaction occurring in the HCAL.

	SND@LHC	SND@HL-LHC	SHiP
$\nu_{\mu}$	~ 1800	$\sim 2.4 \times 10^4$	$\sim 7 \times 10^5$
$v_{e}$	~ 625	$\sim 5.5\times 10^3$	$\sim 2 \times 10^5$
$\nu_{ au}$	~ 30	$\sim 4.5 \times 10^2$	$\sim 5 \times 10^4 \text{ ($\sim$3500/yr)}$
	$\sim 300 \text{ fb}^{-1}$ (7.2 < n < 8.4)	$\sim 3000 \text{ fb}^{-1}$ (6.9 < n < 7.7)	6 × 10 <sup>20</sup> pot (15 yrs)