

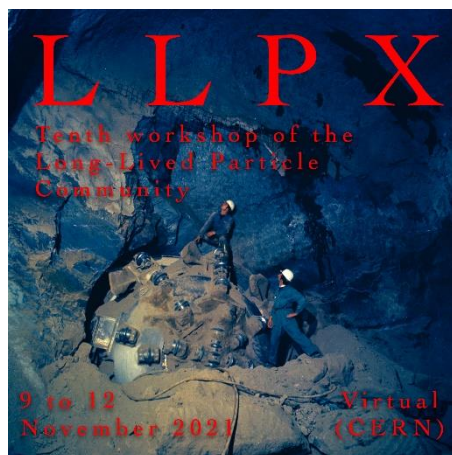


Scattering and Neutrino Detector
at the LHC

Status of SND@LHC

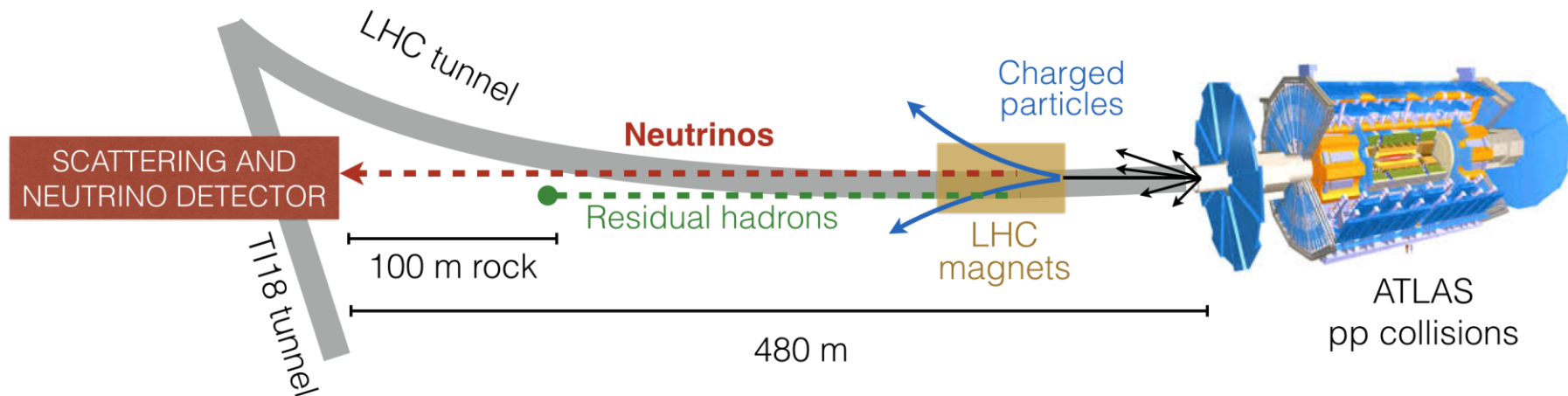
The Scattering and Neutrino Detector at the LHC

Eric van Herwijnen (MISiS)
On behalf of the SND@LHC Collaboration
9 October 2021



Searching for long-lived particles at the LHC and beyond: 10th workshop of the LLP community

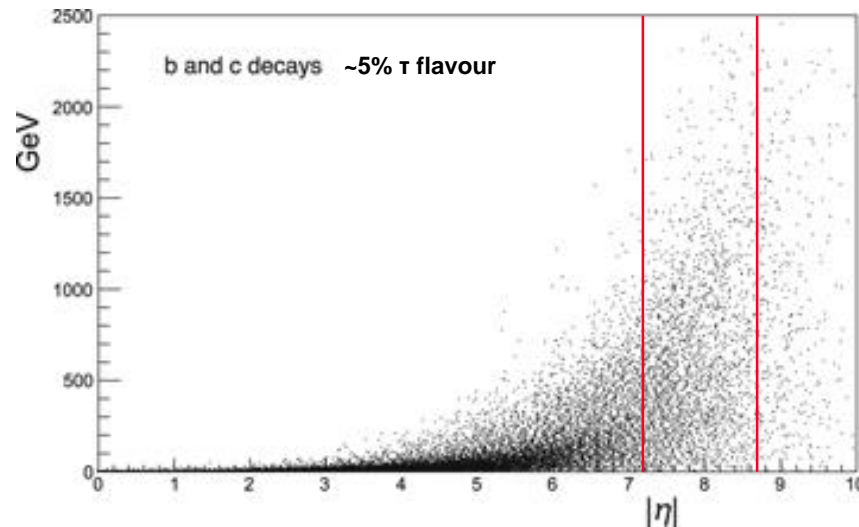
Scattering and Neutrino Detector @ LHC



Stand-alone experiment 480m downstream of IP1 in TI18 to do measurements on neutrinos in the pseudorapidity region $7.2 < \eta < 8.7$

**Approved by the CERN Research Board on 17 March 2021
<https://snd-lhc.web.cern.ch/>**

- ◆ Large expected ν flux in forward direction
- ◆ High ν energies: relatively large ν cross sections
 - $7.2 < \eta < 8.7$: large nb high energy ν from heavy flavour
 - $\sqrt{s}=14$ TeV corresponds to cosmic ray neutrino energy of 10^5 TeV



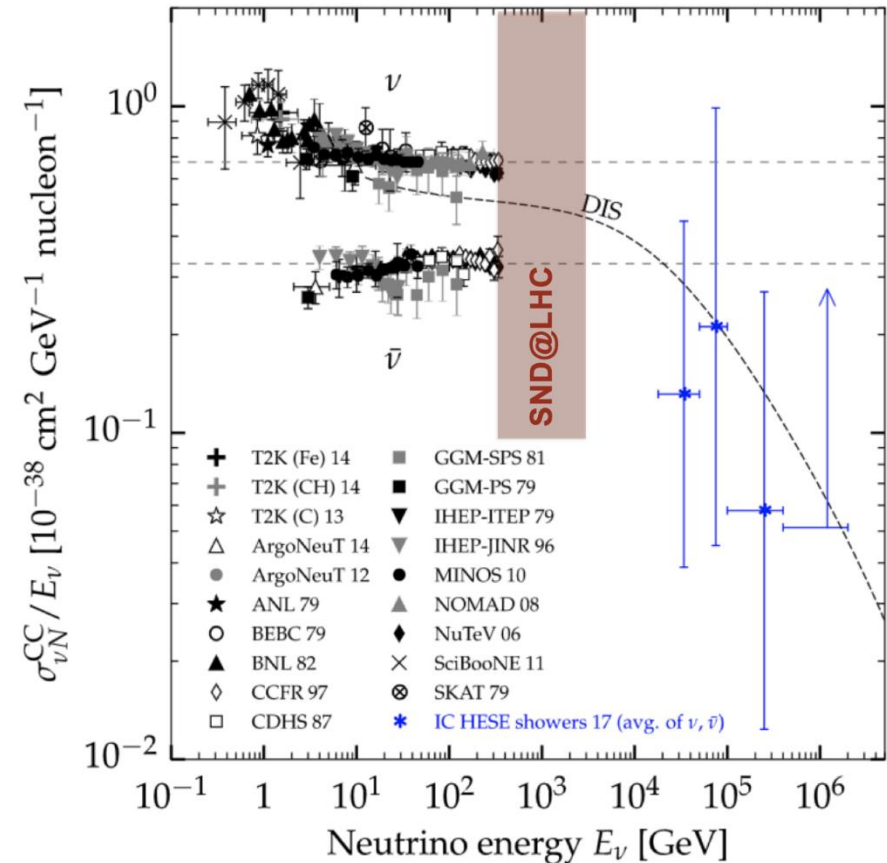
N. Beni et al., “Physics Potential of an Experiment using LHC Neutrinos”, J. Phys. G: Nucl. Part. Phys. 46 (2019) 115008, doi:10.1088/1361-6471/ab3f7c [arXiv:1903.06564]



Scattering and Neutrino Detector
at the LHC

Physics program

- ◆ $\sigma_{pp \rightarrow \nu \chi}$ in $7.2 < \eta < 8.7$ range
- ◆ ν_e as a probe of charm quark production
- ◆ Lepton universality test: ν_τ/ν_e and ν_μ/ν_e
- ◆ Measurement of the NC/CC ratio
- ◆ Direct search for feebly interacting particles through their scattering

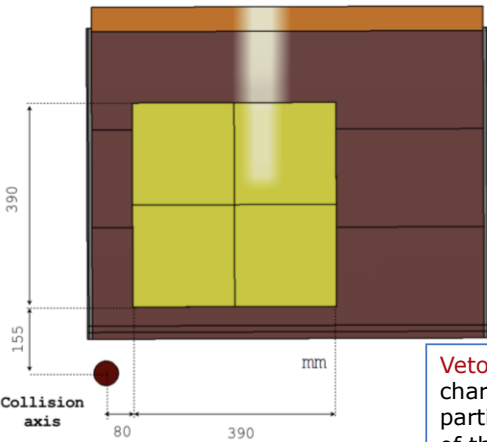




Scattering and Neutrino Detector
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Detector concept

FRONT
VIEW



Electromagnetic calorimeter
 $\sim 40 X_0$

Hadronic calorimeter
 $\sim 10 \lambda$

Emulsion Cloud Chamber, emulsion and W absorbers for micrometric accuracy in the detection of τ and FIPs, EM shower energy measurement.

SciFi with timing, provide time stamp to emulsion, records TOF information of events in the target region, track matching with ECCs. EM shower measurement as sampling calorimeter every $\sim 10 X_0$.

Muon system - hadronic calorimeter 8λ , sampling every λ , with target region $\sim 10 \lambda$.

Timing upstream for the muon filtering

Timing downstream, double X-Y planes with higher granularity for muon-hadron separation

Veto plane for charged particles in front of the target region

x5 SciFi electronics

x5 SciFi modules

x5 Upstream Scintillator planes

x3 Downstream Scintillator planes

x5 Emulsion/Tungsten bricks

x1 Scintillator plane

x8 Iron blocks

SIDE
VIEW

Floor

Line of sight

Floor

Off axis location
Angular acceptance:
 $7.2 < \eta < 8.7$
Target material: Tungsten
Target mass: 830 kg
Surface: $390 \times 390 \text{ mm}^2$

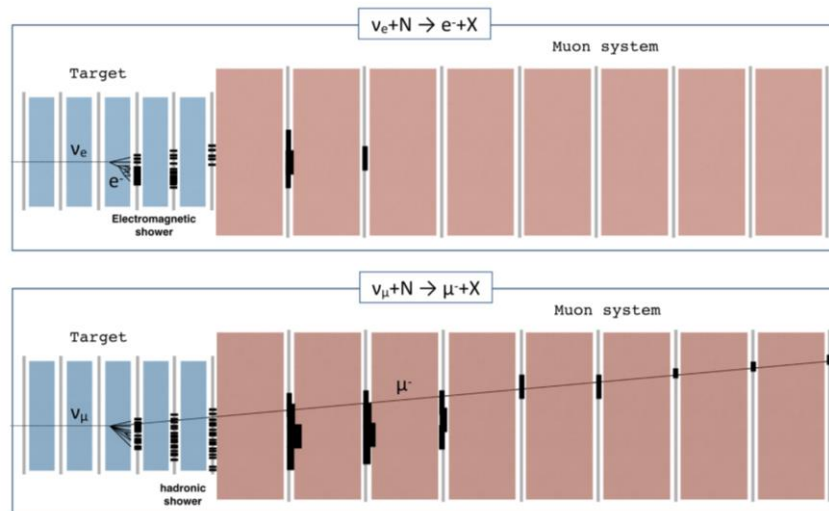


Scattering and Neutrino Detector
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Event reconstruction

◆ First phase: electronic detectors

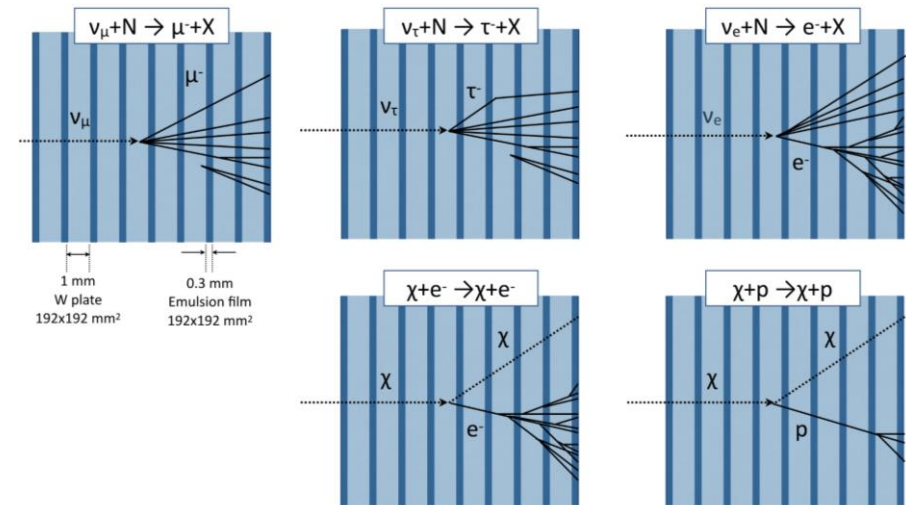
- ν candidates
- μ 's
- em showers (SciFi)
- ν energy (SciFi+Muon)



ν_e (top) and ν_μ (bottom) CC interactions
9 November 2021

◆ Second phase: nuclear emulsion

- em showers
- ν vertex reconstruction
- match with candidates from electronic detectors



Reconstructible signal topologies in emulsion



Scattering and Neutrino Detector
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Commissioning

Commissioning of 5 muon stations in H8 testbeam:



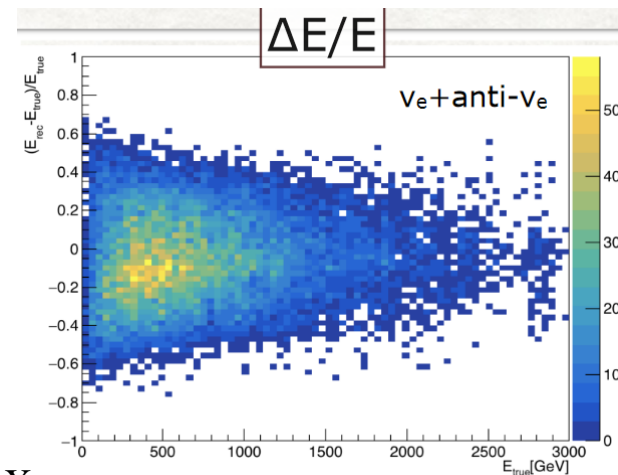
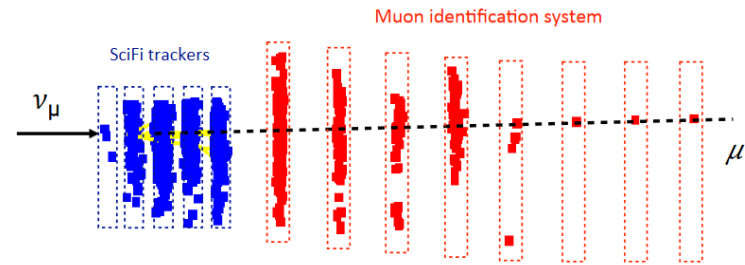


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Muon ID, $\Delta E/E$

- ◆ ν_μ CC interactions identified by muons
- ◆ μ -ID at ν vertex crucial to identify charmed hadron production, background to ν_τ detection
- ◆ Sampling calorimeter
- ◆ Average resolution on ν_e energy: 22%

	% evts CC-DIS	% evts NC-DIS
0 μ	31.1	99.6
1 μ	67.6	0.27
2 μ	1.1	0.06

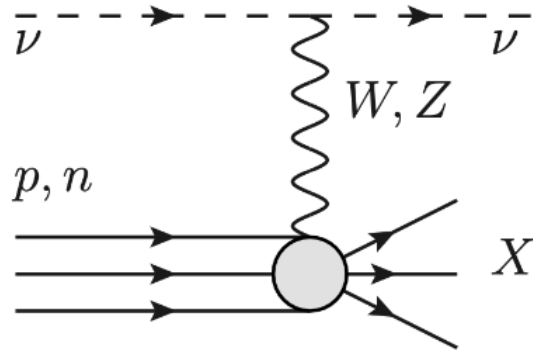




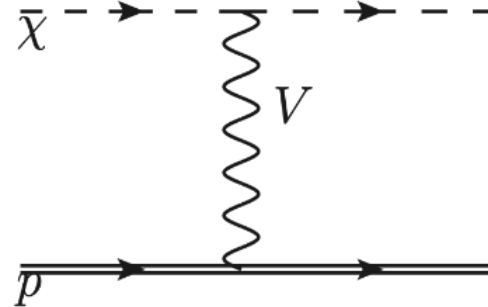
Search for new particles

Scattering and Neutrino Detector
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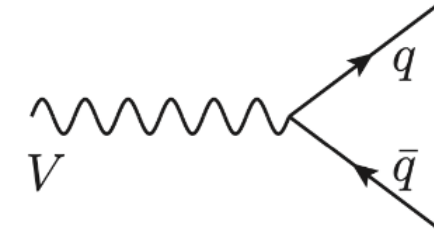
SM NC interactions



DM scattering



Mediator decay



1. Scattering inside the target $pp \rightarrow V + X, V \rightarrow \chi\chi$

- Elastic: signature one charged track $\chi + p/e \rightarrow \chi + p/e$
- Inelastic: $\chi + p/n \rightarrow \chi + X$ similar to ν NC (exploit kinematics, look for excess in NC events)
- Exploit time of flight (IP 480 m)

2. Visible mediator decay inside detector

- Look for isolated decay vertex
- Exploit time of flight (IP 480 m)



Scattering and Neutrino Detector
at the LHC

Dark photon (150 fb^{-1})

◆ Vector portal with minimal SM extension:

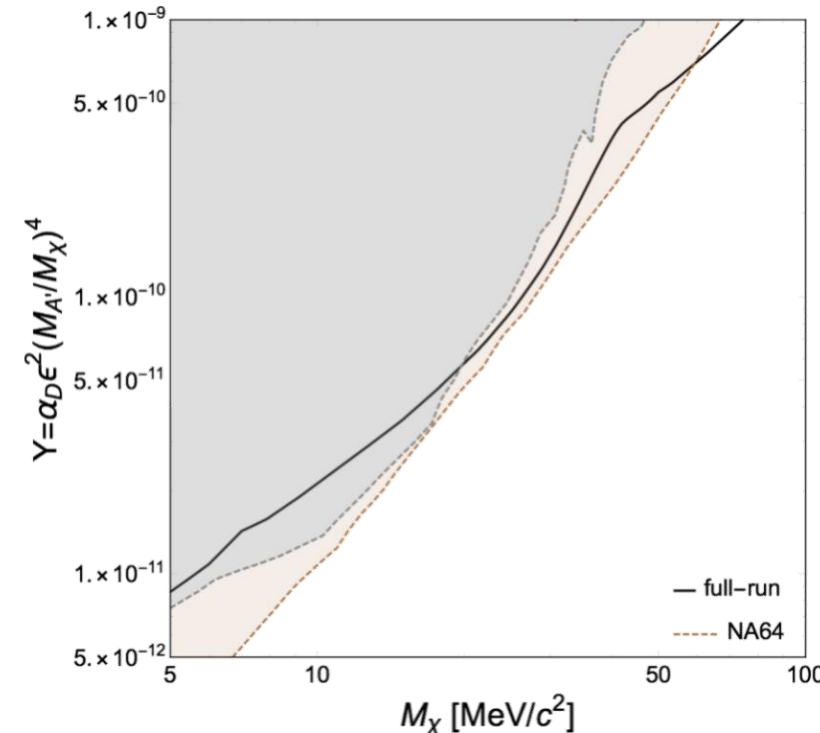
$$\mathcal{L}_{\mathcal{A}'} = -\frac{1}{4}F'_{\mu\nu}F'^{\mu\nu} + \frac{m_{\mathcal{A}'}^2}{2}A'^{\mu}A'_{\mu} - \frac{1}{2}\epsilon F'_{\mu\nu}F^{\mu\nu} \quad (1)$$

◆ $\mathcal{A}' \rightarrow \chi\chi$ with $\chi + e \rightarrow \chi + e$ in the target

◆ Simulation: 0 SM background

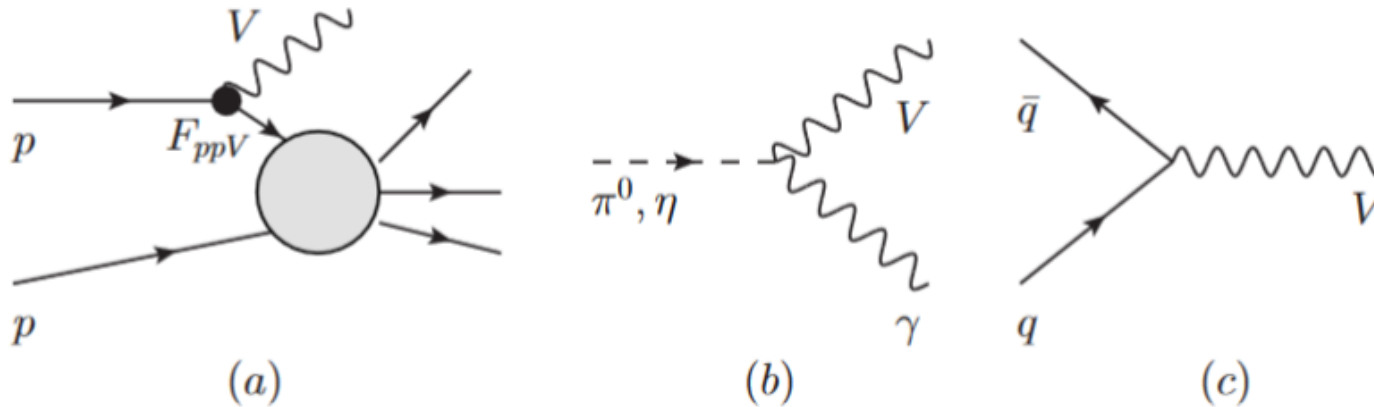
◆ Sensitivity dominated by small couplings:

- DM scattering acquires and additional ϵ^2 in the yield
- SND@LHC is an ϵ^4 experiment
- NA64 is an ϵ^2 experiment and has better sensitivity



Leptophobic portal

$$\mathcal{L}_{\text{leptophob}} = -g_B V^\mu J_\mu^B + g_B V^\mu (\partial_\mu \chi^\dagger \chi + \chi^\dagger \partial_\mu \chi), \quad J_\mu^B = \frac{1}{3} \sum_q \bar{q} \gamma_\mu q$$



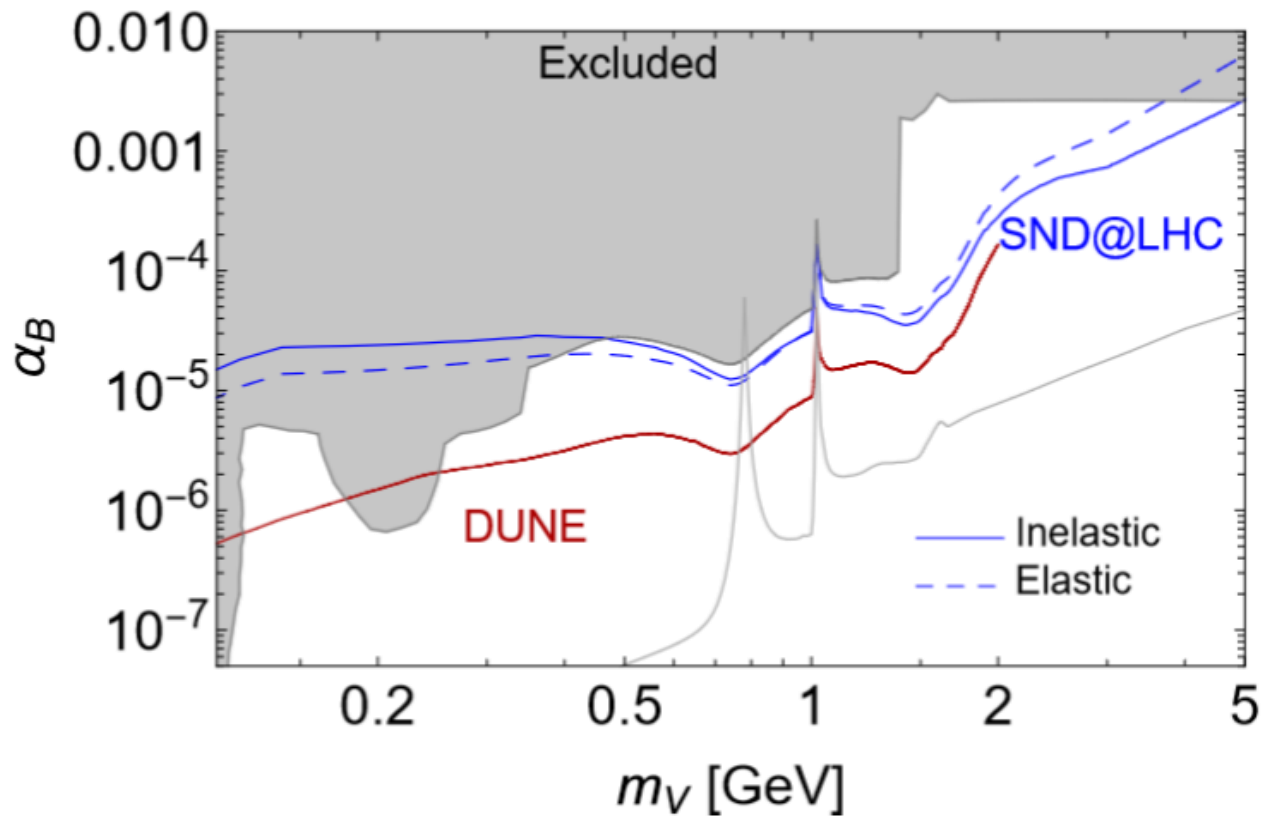
◆ Like dark photon, mediator is produced:

- a) By proton bremsstrahlung
- b) In decays of unflavored mesons
- c) By Drell-Yan

Leptophobic sensitivity

Excluded: by CDF, BES, E949 and BNL

$$m_\chi = m_\nu/3, \alpha_\chi = \alpha_B$$



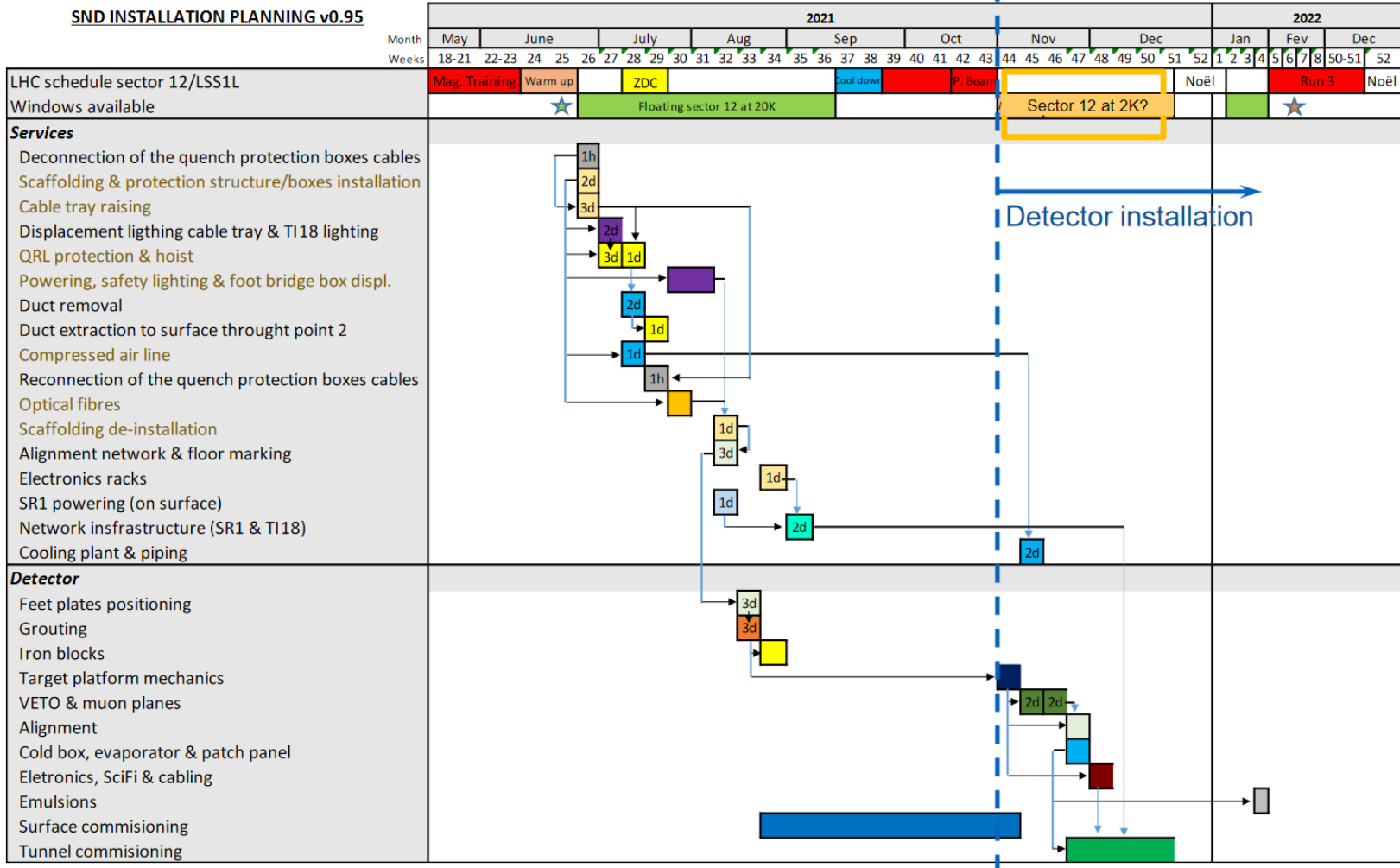


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Timeline



SND INSTALLATION PLANNING v0.95





Scattering and Neutrino Detector
at the LHC

Integration in T118



Conclusions

- ◆ **SND@LHC is on schedule and advancing with detector construction and installation**
- ◆ **Timeline is tight, commissioning ongoing**
- ◆ **Physics studies for SM and NP searches ongoing**
- ◆ **For more on sensitivity estimates for FIPs see [arxiv:2104.09688](https://arxiv.org/abs/2104.09688)**