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Discovery potential of light sterile neutrinos with displaced vertices

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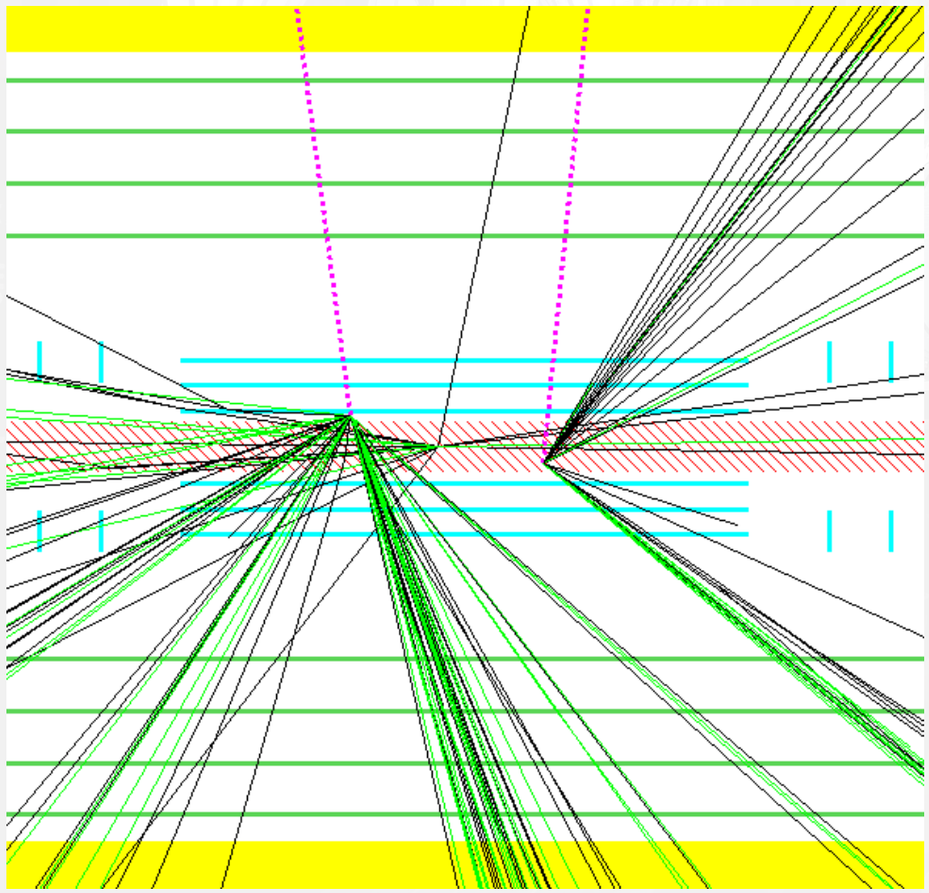
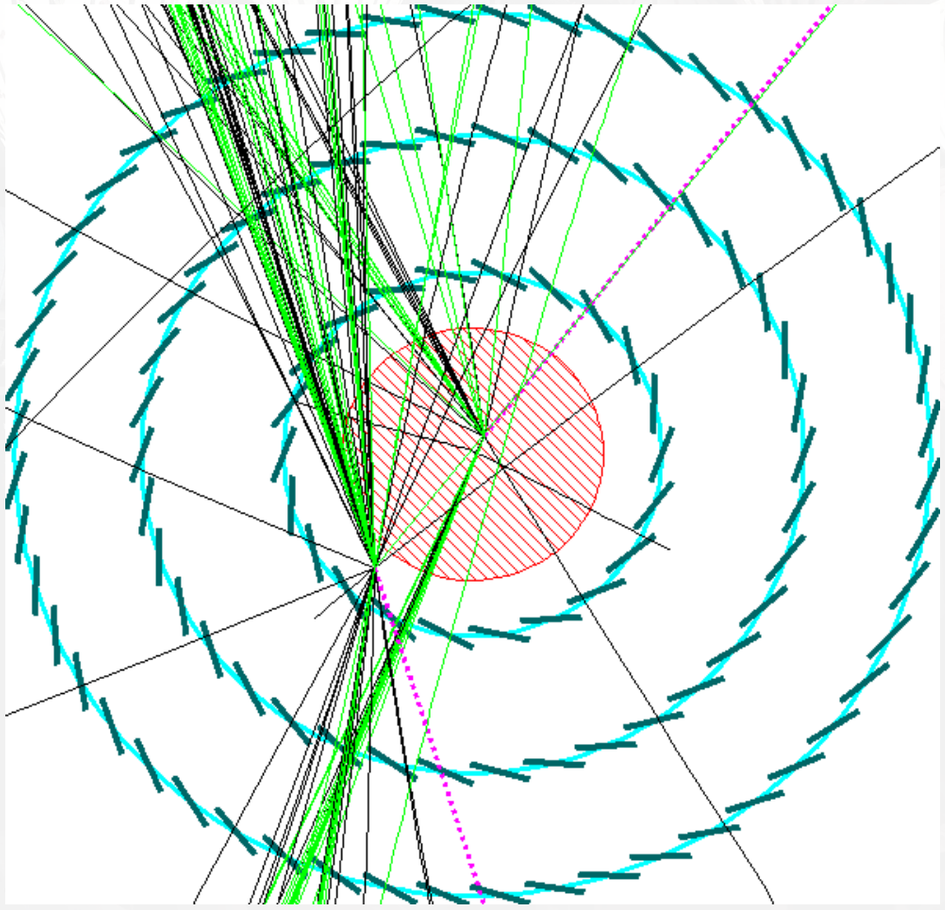
ICHEP 2018, Seoul, Korea

A displaced vertex signature can occur when a long-lived particle* decays inside a particle detector's acceptance

(lifetime ~ picoseconds-nanoseconds)





Source: G. Cottin

*long-lived particle = *"BSM particle that dies (gives up all its energy or decays to SM) somewhere in the detector acceptance"*. J.Beachman @ LHC-LLP workshop, CERN

Using Displaced Vertices @ LHC to shed light on New Physics

Two studies in this talk motivated by Neutrinos:

1. Reinterpreting current displaced searches in the context of a left-right symmetric model with a long-lived sterile neutrino. **Proposing a displaced strategy with optimized cuts**
   Phys. Rev. D 97, 055025 (2018) [arXiv:1801.02734] G. Cottin, J.C. Helo, M. Hirsch

2. Same displaced strategy used in **constraining sterile neutrino mixing.** Strategy shows no competition with other searches and proposed experiments [arXiv:1806.05191] G. Cottin, J.C. Helo, M. Hirsch

Source: nobelprize.org

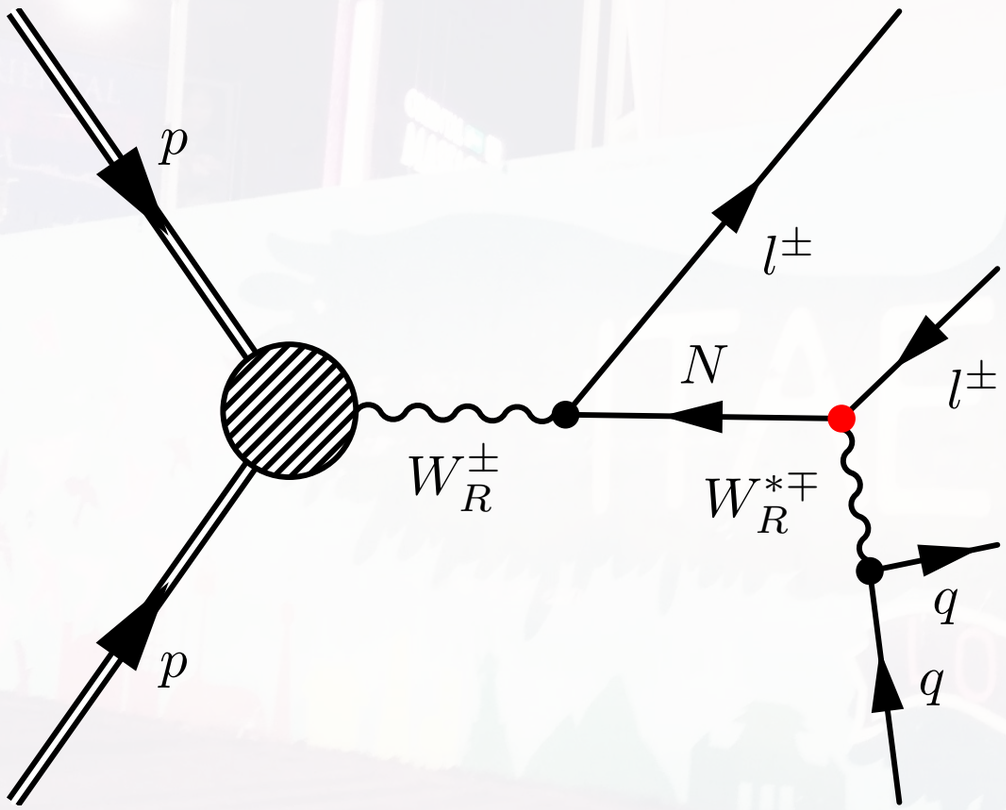
Looking for a light, long-lived sterile neutrino from Left-Right symmetric model

Phys. Rev. D 97, 055025 (2018) [arXiv:1801.02734] G. Cottin, J.C. Helo, M. Hirsch

$$SU(2)_L \times SU(2)_R \times U(1)_{B-L}$$

LR model:

J. C. Pati and A. Salam, Phys. Rev. D10, 275 (1974)
R. N. Mohapatra and J. C. Pati, Phys. Rev. D11, 2558 (1975)
R. N. Mohapatra and G. Senjanovic, Phys. Rev. D23, 165 (1981)

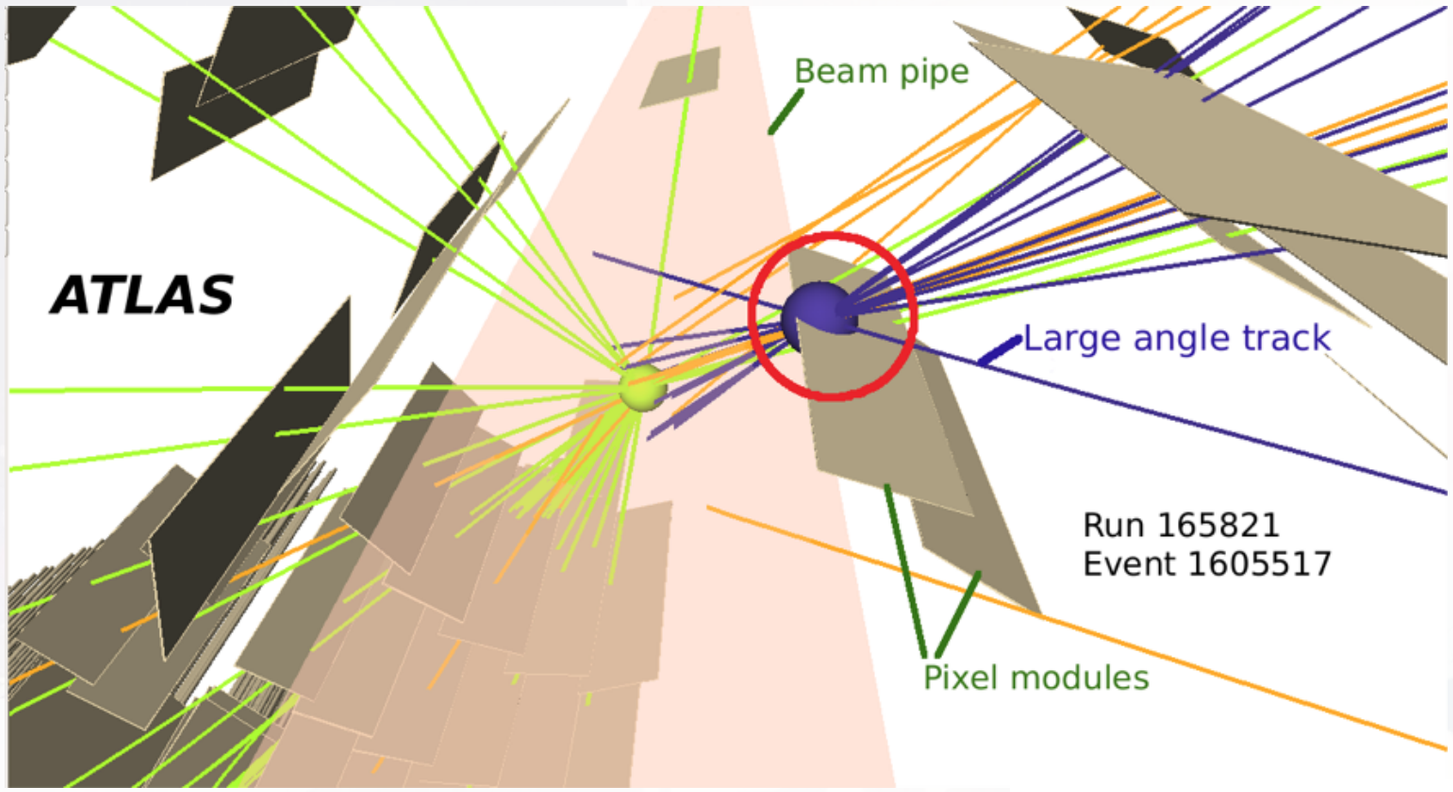


$$c\tau_N \sim 0.12 \left(\frac{10 \text{ GeV}}{m_N} \right)^5 \left(\frac{m_{W_R}}{1000 \text{ GeV}} \right)^4 \text{ [mm]}$$

Production and decay of the sterile neutrino depends on the unknown mass of the new, heavy right-handed gauge boson

Other displaced LR strategies in:
M. Nemevsek, F. Nesti, and G. Popara, arXiv:1801.05813
J. C. Helo, M. Hirsch, and S. Kovalenko, Phys. Rev. D89 (2014)

ATLAS Multitrack DV 13 TeV inspired search [arXiv:1710.04901]



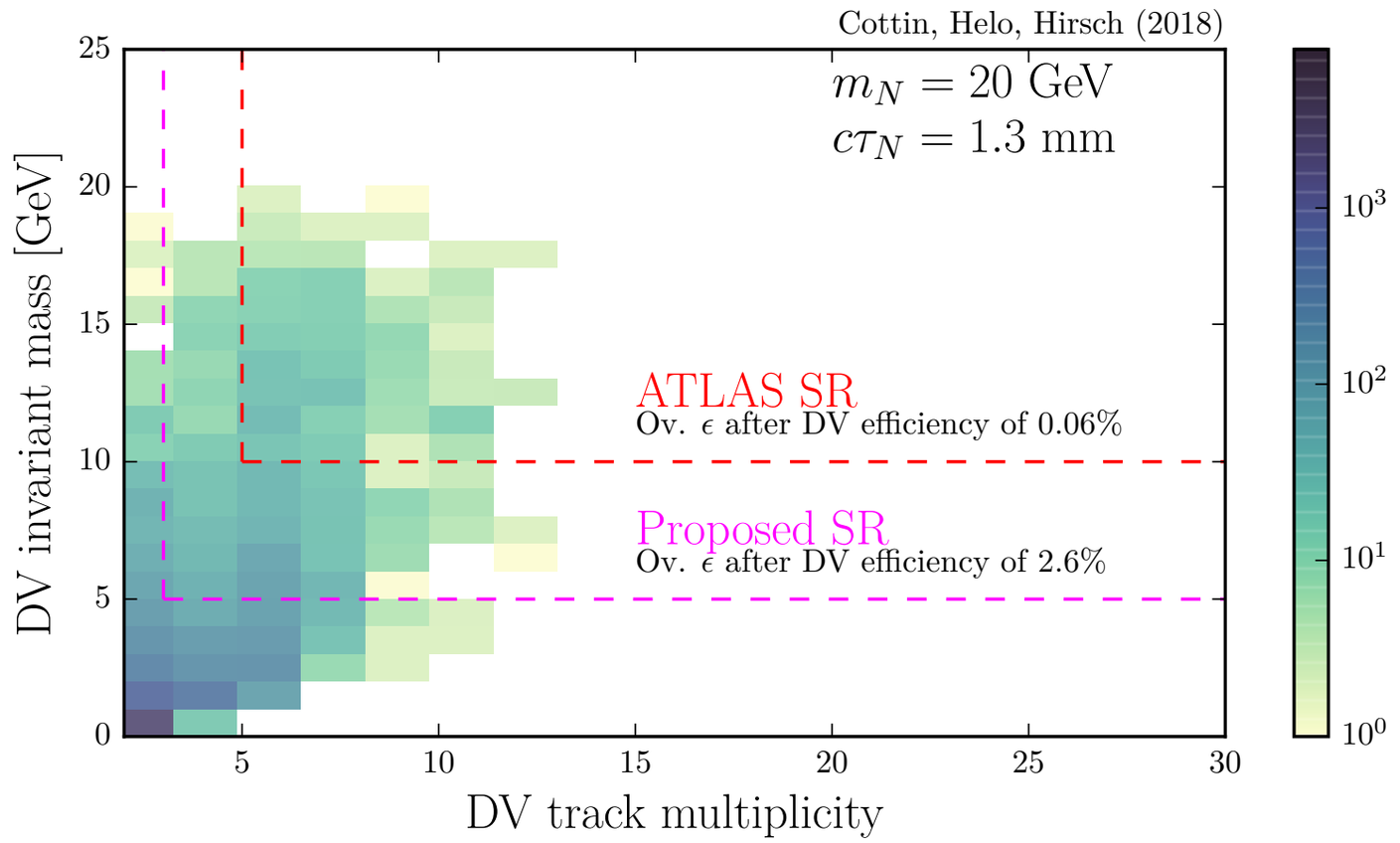
Source: ATLAS Event Display arXiv:1109.2242

Signatures inside inner tracker

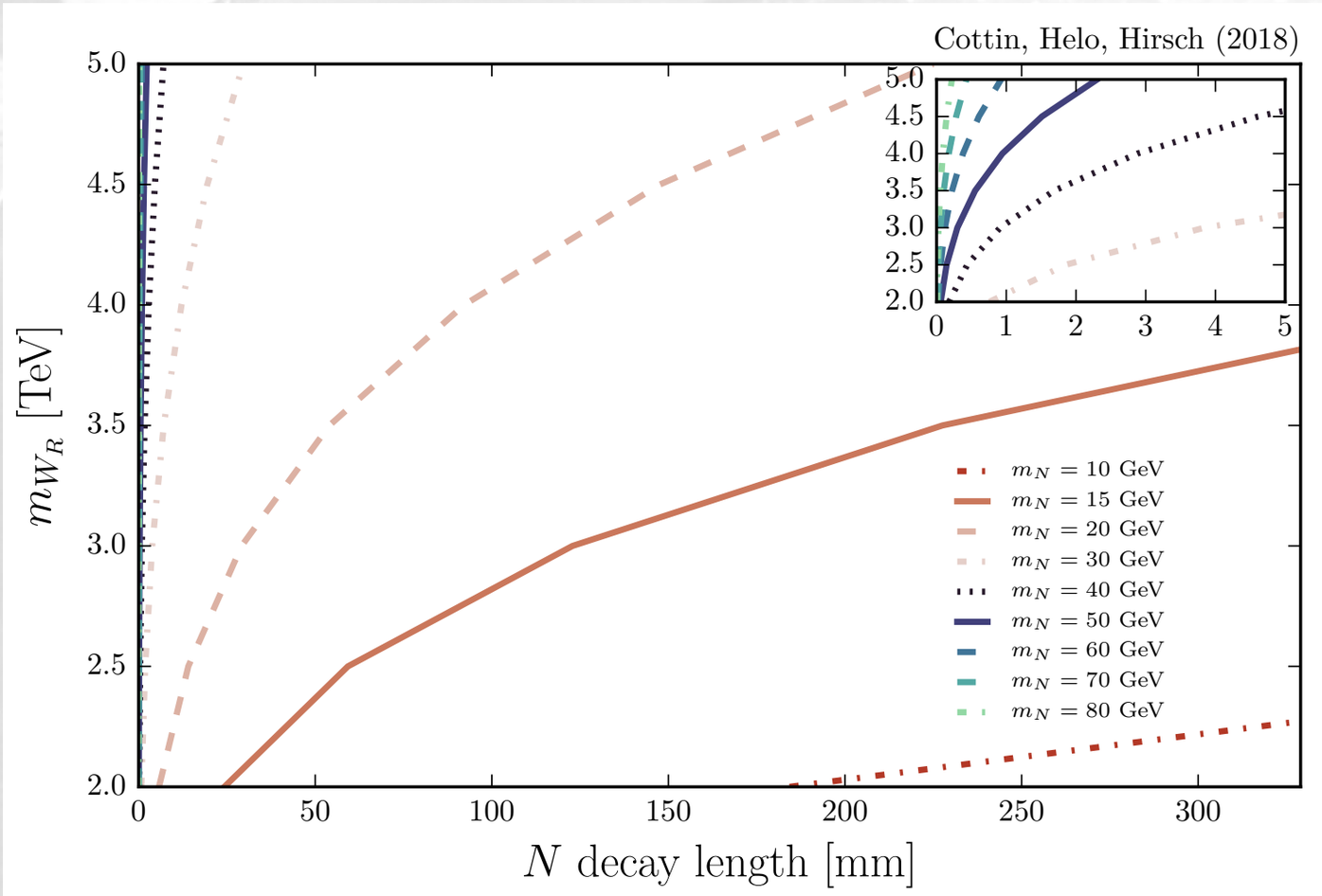
Analysis triggers on MET. We use prompt lepton.

High mass and track multiplicity DVs. We relax these cuts (still zero background)

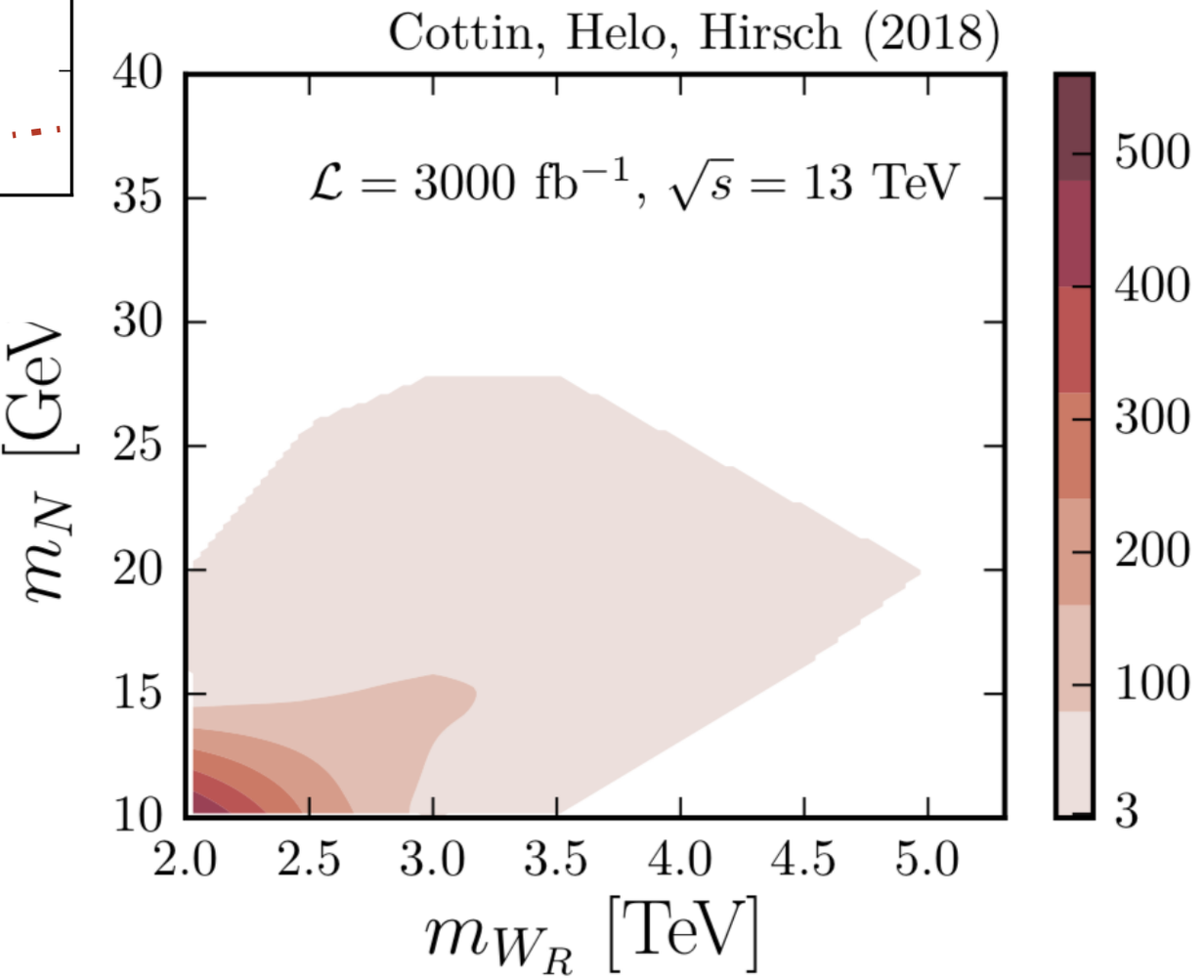
Analysis provides efficiency maps depending on DV mass, tracks and decay distance (within 4 and 300 mm). We use them to model detector response to DVs



Sensitivity with “prompt lepton + loose DV multitrack”



Optimized cuts in ATLAS DV multitrack inspired search needed to cover more parameter space in LR model



Strategy’s accesible region

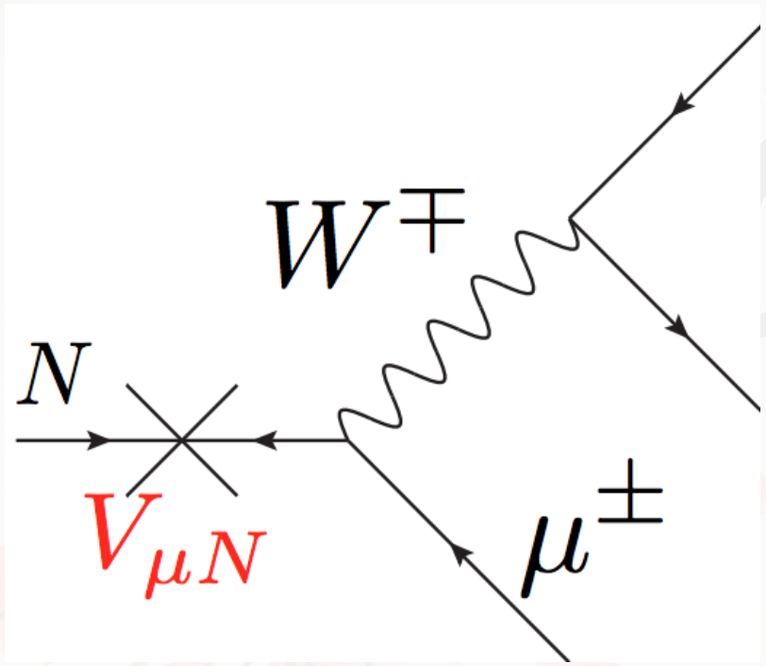
$$10 \text{ GeV} < m_N < 40 \text{ GeV}$$

$$2 \text{ TeV} < m_{W_R} < 5 \text{ TeV}$$

Left-Right

Standard Model + N

Still looking for a light, long-lived sterile neutrino in Standard Model + N [arXiv:1806.05191] G. Cottin, J.C. Helo, M. Hirsch



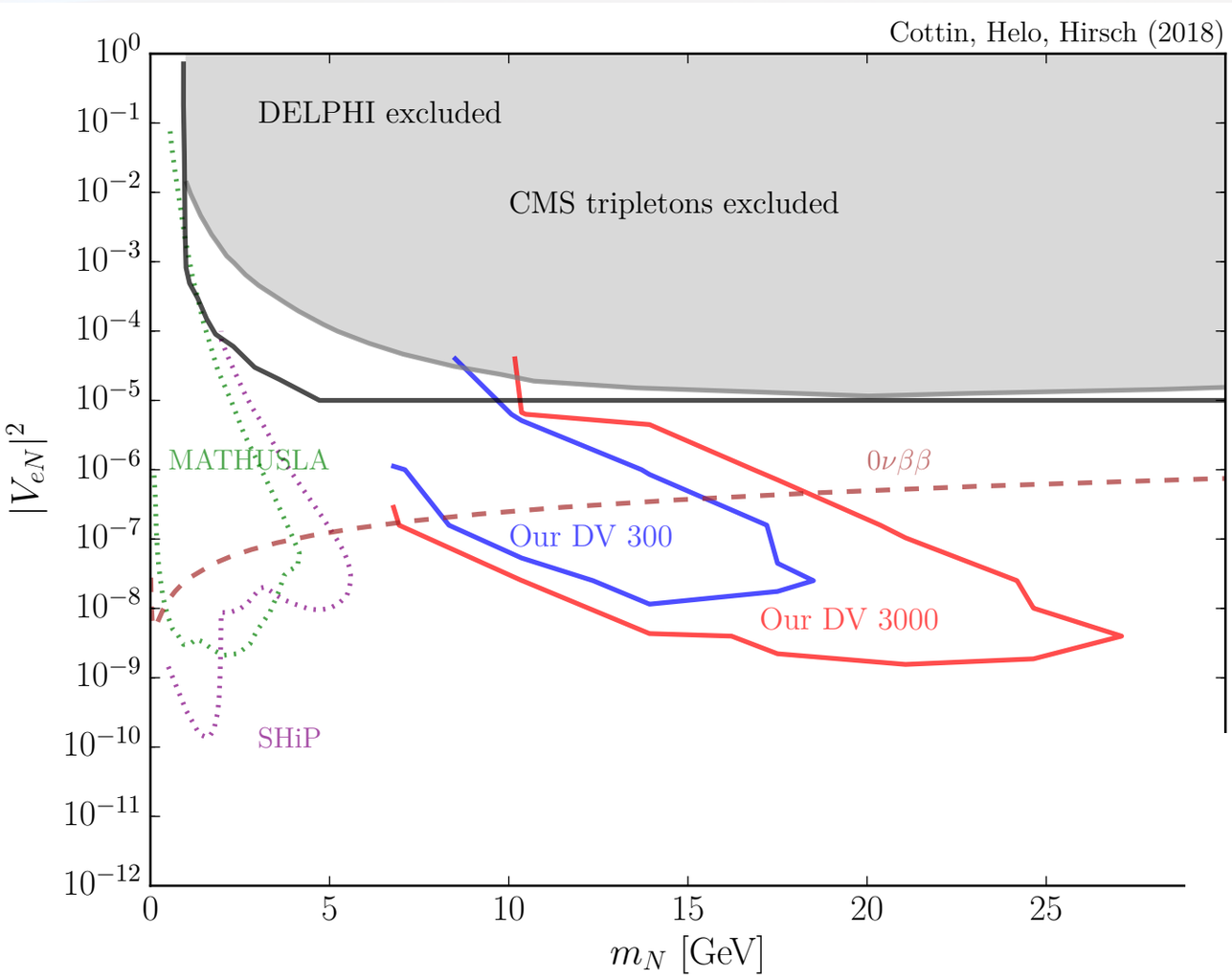
Seesaw:
P. Minkowski, Phys. Lett. 67B (1977)
R. N. Mohapatra and G. Senjanovic, Phys. Rev. Lett. 44 (1980)
J. Schechter and J. W. F. Valle, Phys. Rev. D22, 2227 (1980)

$$c\tau_N \sim 3.7 \left(\frac{1\,\text{GeV}}{m_N}\right)^5 \left(\frac{0.1}{|V_{lN}|^2}\right) \text{ [mm]}$$

Sterile N mixes with SM neutrino. Large lifetime due to off-shell decay

Other displaced N strategies in:
E. Izaguirre and B. Shuve, Phys. Rev. D91 (2015) (lepton-jets 1)
S. Dube, D. Gadkari, and A. M. Thalapillil, Phys. Rev. D96 (2017) (lepton-jets 2)
J. C. Helo, M. Hirsch, and S. Kovalenko, Phys. Rev. D89 (2014)

For constraints on mixing, see:
G. Cvetic, A. Das, J. Zamora-Saa, arXiv:1805.00070
A.Das, N. Okada, arXiv:1702.04668



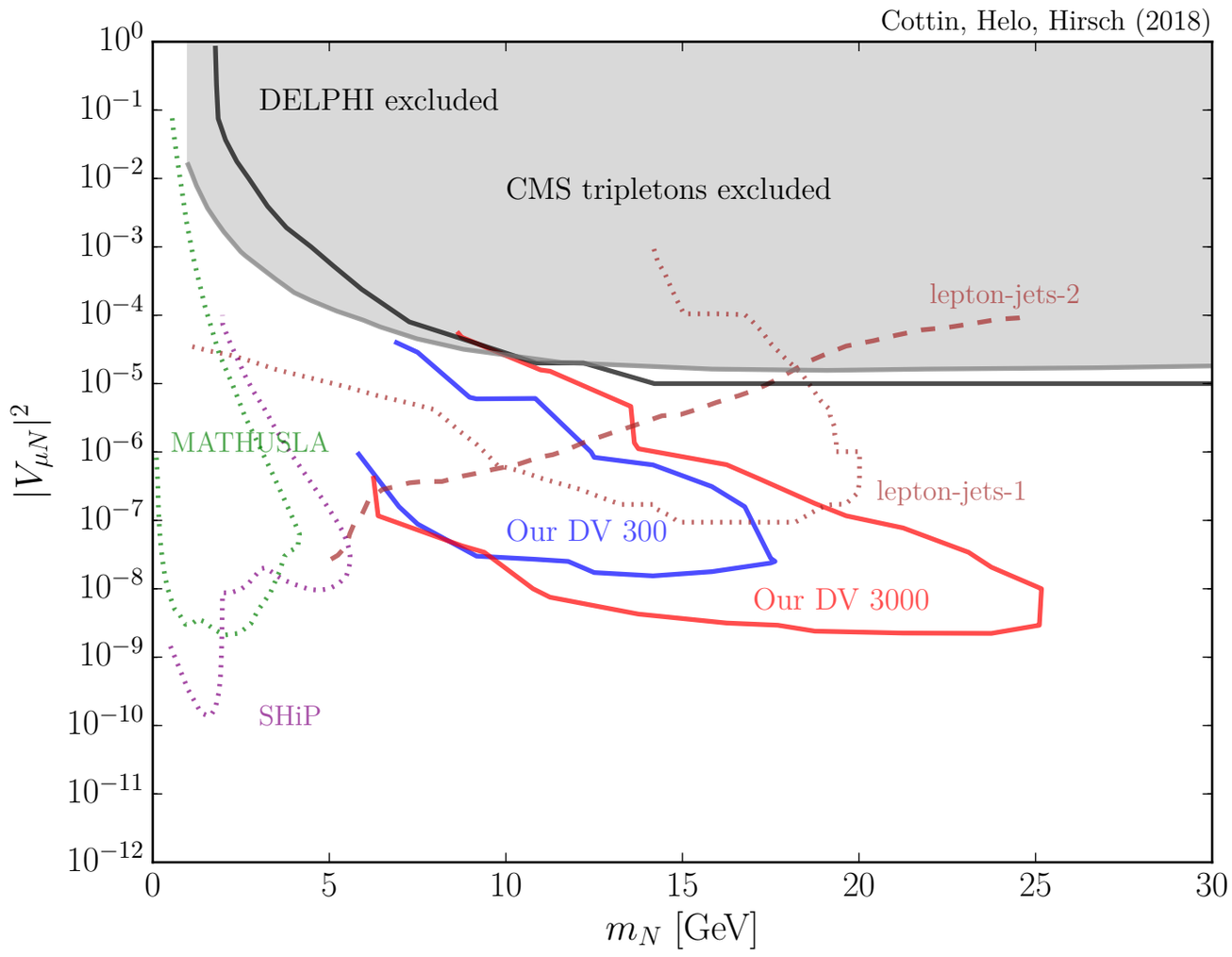
$$pp \to W^{\pm} \to N l^{\pm}$$

$$N \to l^{\pm} q \bar{q}$$

$$N \to l'^{\mp} l^{\pm} \nu_l$$

Constraints on electron and muon mixing

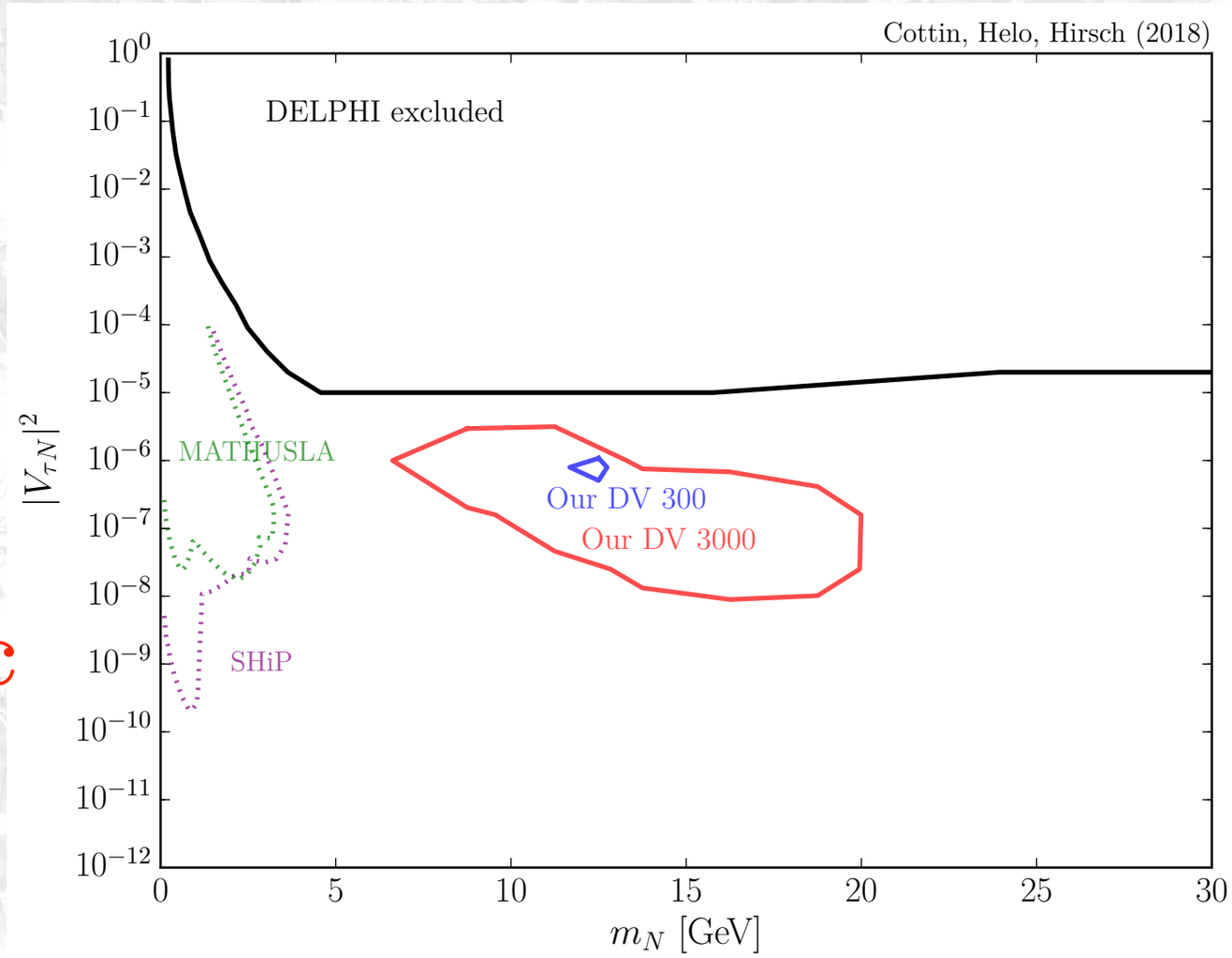
Complementarity with future experiments



Can also access tau mixing with a multitrack DV strategy !

$$pp \to W^{\pm} \to N l^{\pm}$$

$$N \to \nu_l q \bar{q}$$



We avoid a problematic tau coming from the DV. Complementarity with future experiments

Displaced vertex signatures are well motivated. Can be present in most BSM frameworks. Interesting phenomenology at the LHC.

We can have a clear collider test of models for neutrino mass generation