Heavy Neutral Leptons at Belle II?

Michele Tammaro

'Anomalies and Precision in the Belle II Era', 07/09/2021

Preliminary work with

S. Dreyer, T. Ferber & S. Longo (DESY), J. Zupan & P. Ilten (U. Cincinnati)

Jožef Stefan Institute

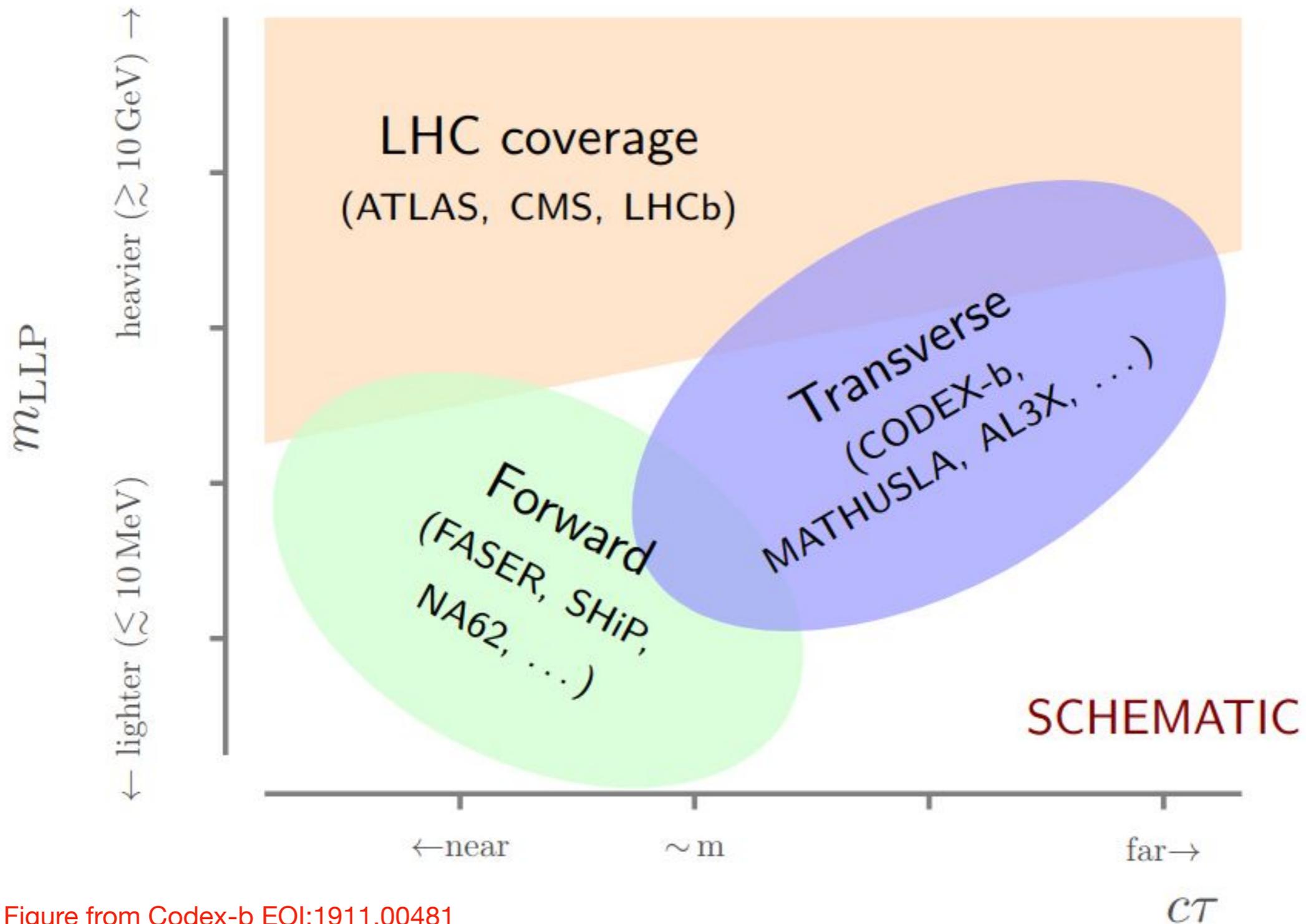# The search for Long Lived Particles (LLP)

Figure from Codex-b EOI:1911.00481

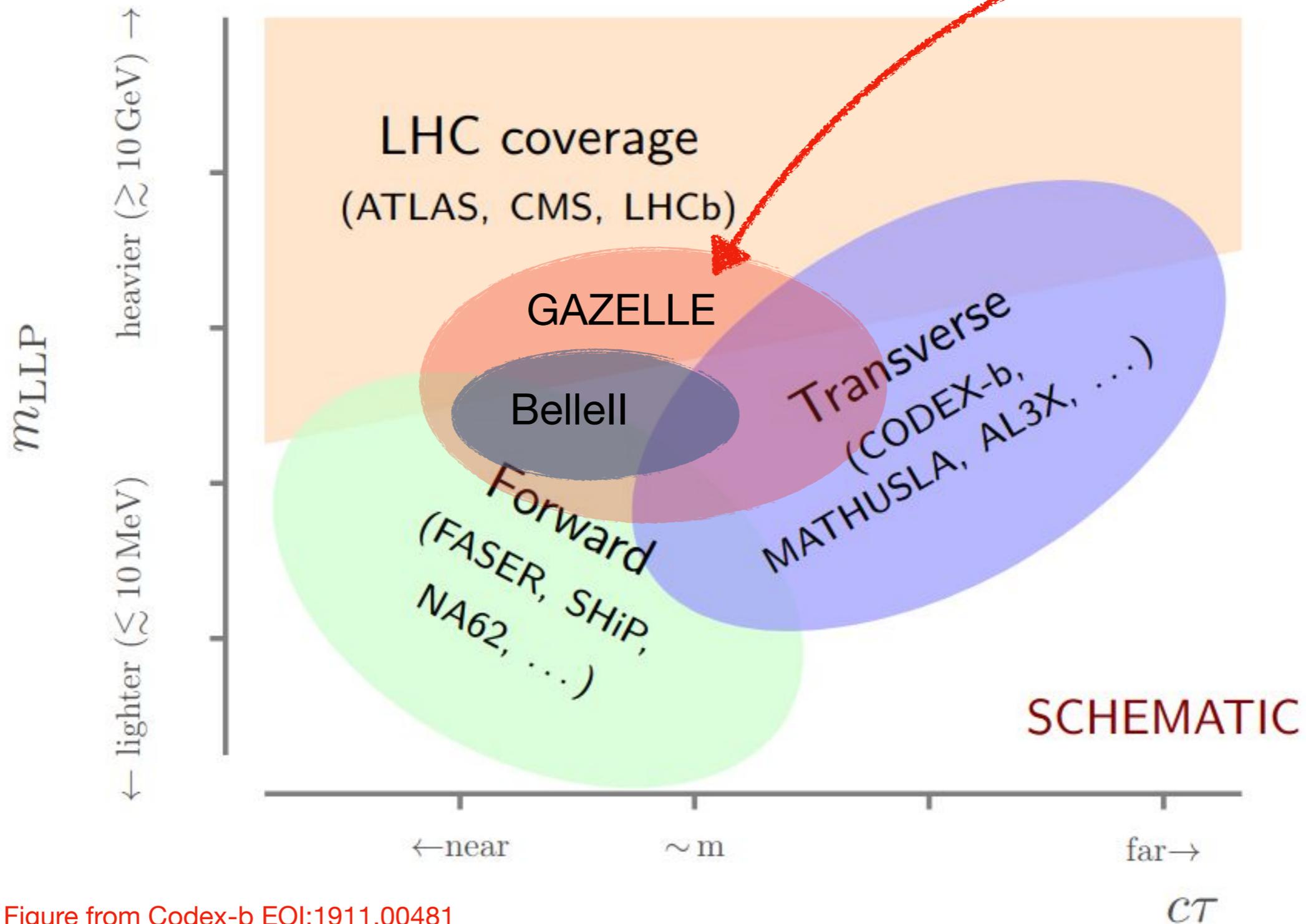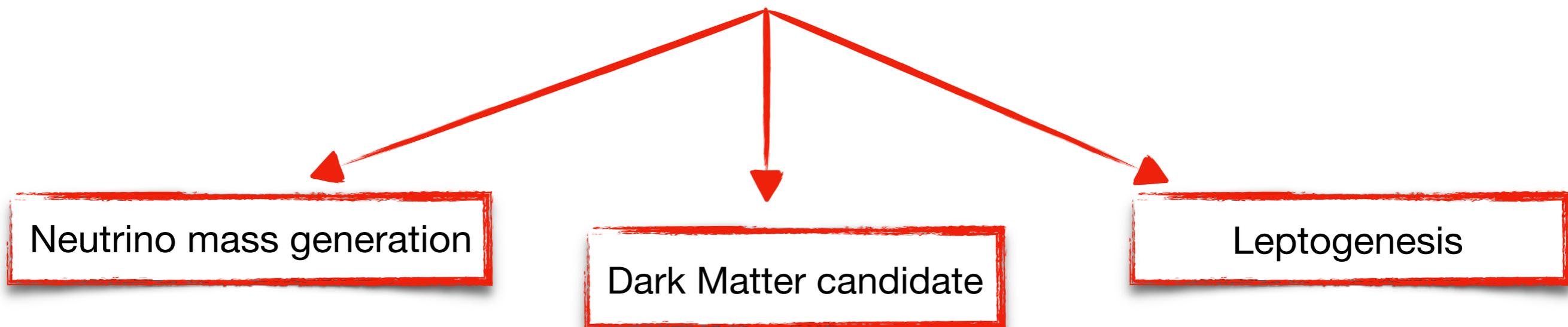# The search for Long Lived Particles (LLP)

A. Filimonova's talk

Figure from Codex-b EOI:1911.00481

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Heavy Neutral Leptons

Massive neutrinos + Standard Model $---\!>$ New Particles [Ma ('98)]

Heavy Neutral Leptons (HNL) aka Sterile Neutrinos

$$\mathcal{L}_{int} = \sum_{\alpha, I} c_{\alpha, I} (\bar{L}_\alpha H) N'_I \qquad \xrightarrow{\text{EWSB}} \qquad \nu'_\alpha \simeq \nu_\alpha + U_\alpha N$$

Neutrino mass generation

Dark Matter candidate

Leptogenesis

Heavy Neutral Leptons

Massive neutrinos + Standard Model $———>$ New Particles [Ma ('98)]

For practical purposes, focus on one flavoured HNL

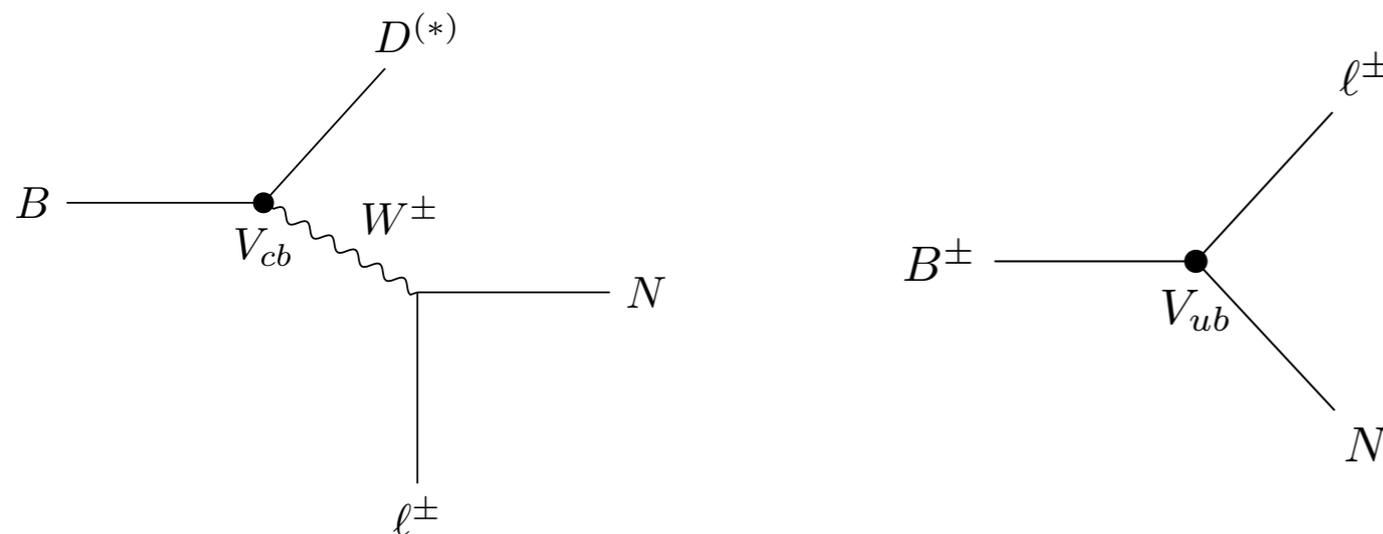$$\mathcal{L}_{int} = c_\alpha \left(\bar{L}_\alpha H \right) N'$$

EWSB

$\alpha = e, \mu, \tau$
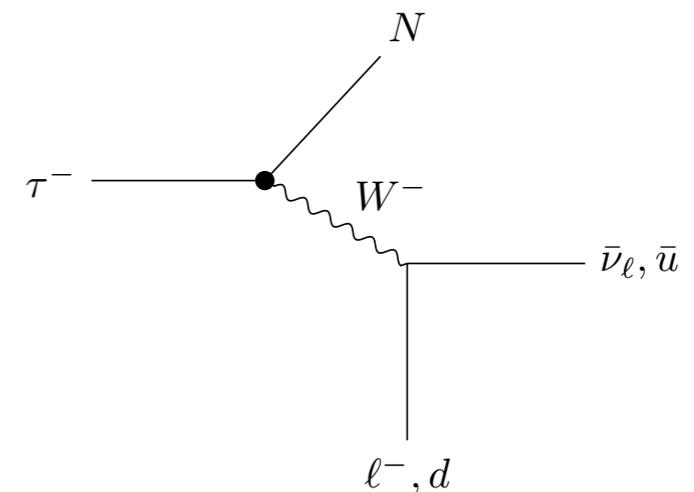
$$\nu'_\alpha \simeq \nu_\alpha + U_\alpha N$$

PRODUCTION

[K. Bondarenko et al:1805.08567]

$m_N < m_\tau$

B meson decay

Tau lepton decay

Heavy Neutral Leptons

Massive neutrinos + Standard Model ———> New Particles [Ma ('98)]

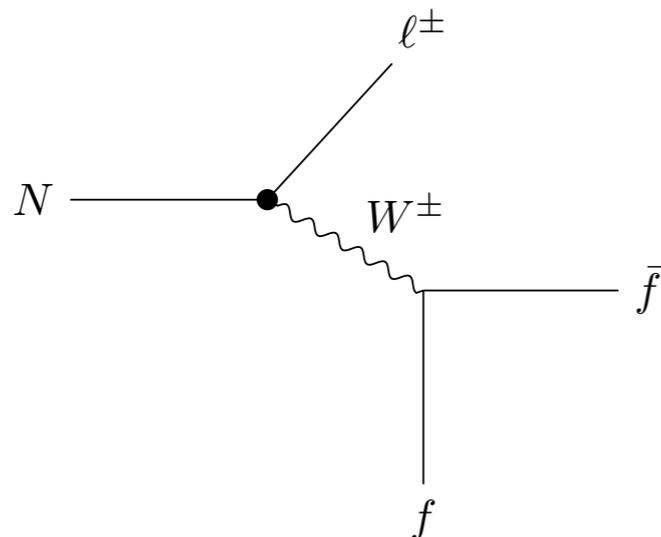For practical purposes, focus on one flavoured HNL

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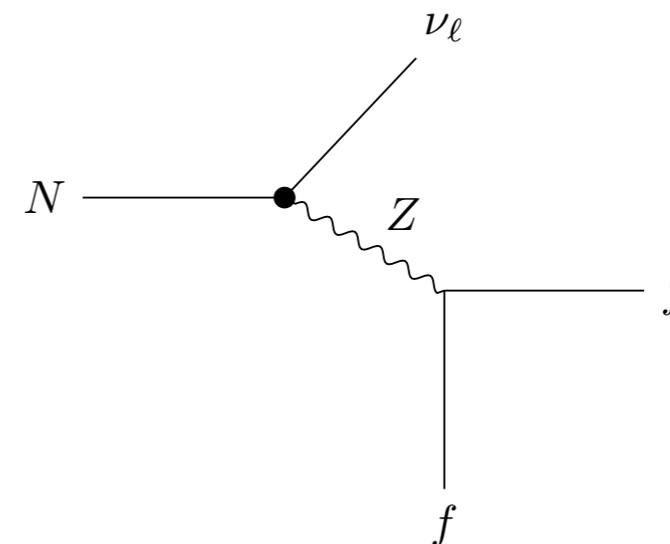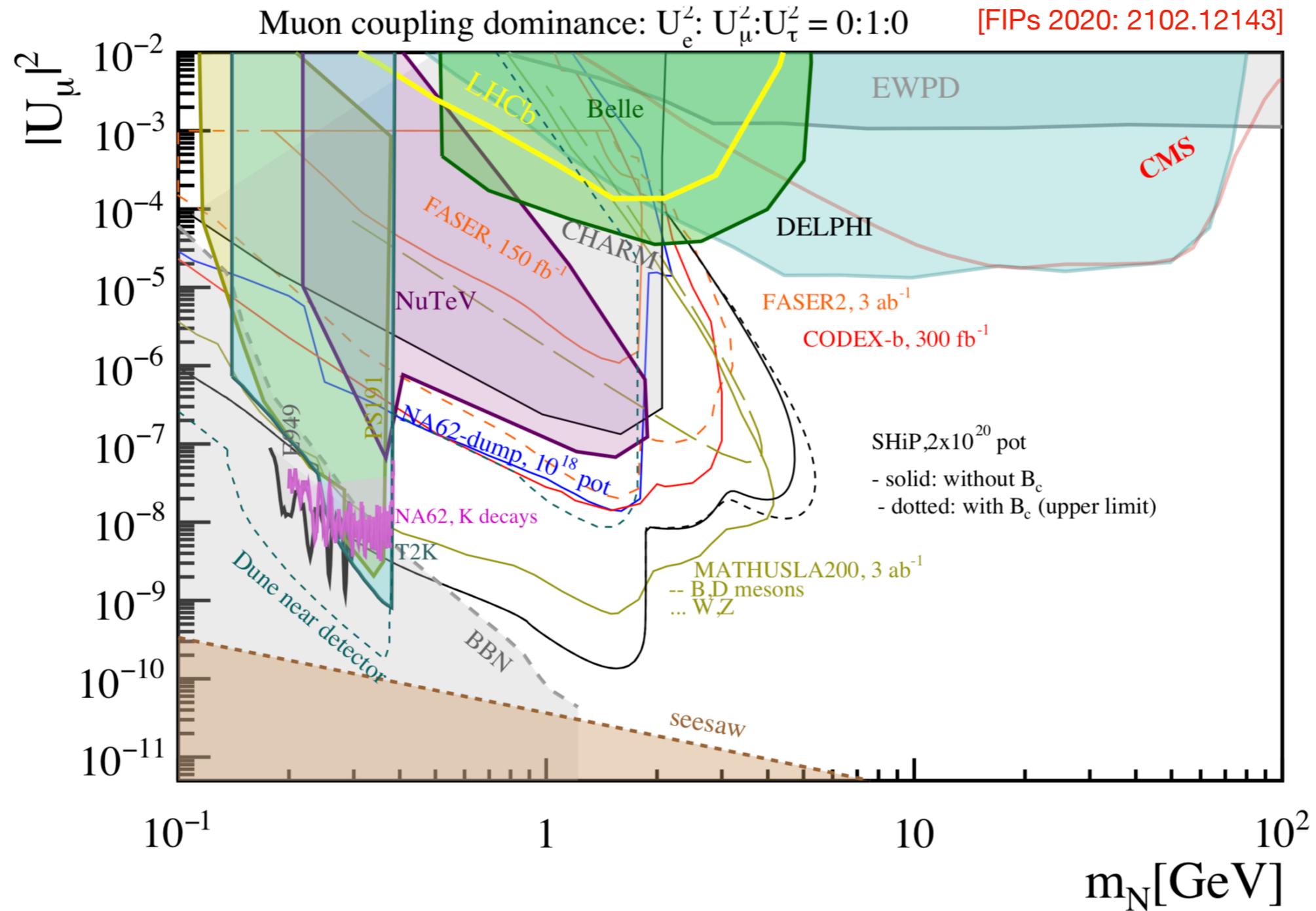
DECAY

[K. Bondarenko et al:1805.08567]

Charged current

Neutral current

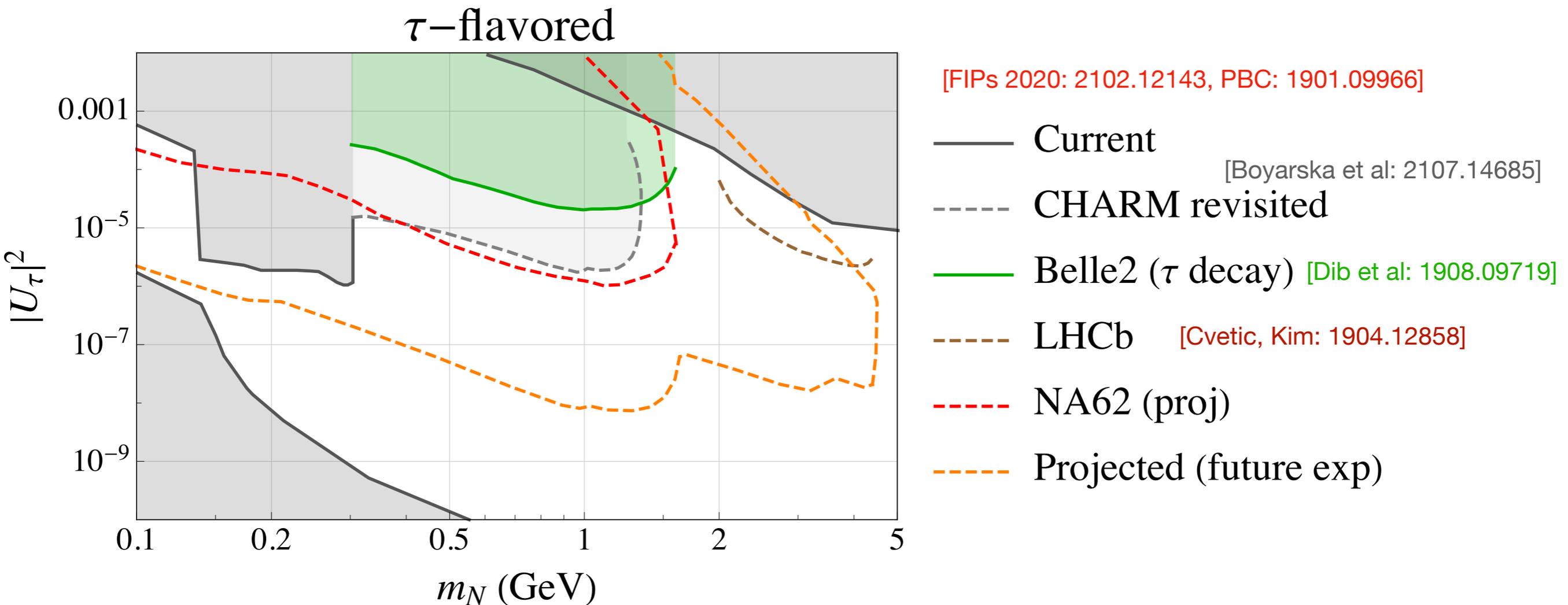# Heavy Neutral Lepths

Muon-flavoured case

Muon coupling dominance: $U_e^2 : U_\mu^2 : U_\tau^2 = 0:1:0$ [FIPs 2020: 2102.12143]

Heavy Neutral Leptons

Tau-flavoured case, mostly unexplored

Can we explore more space with B mesons at Belle II?

Simulating decays

Implementation of heavy
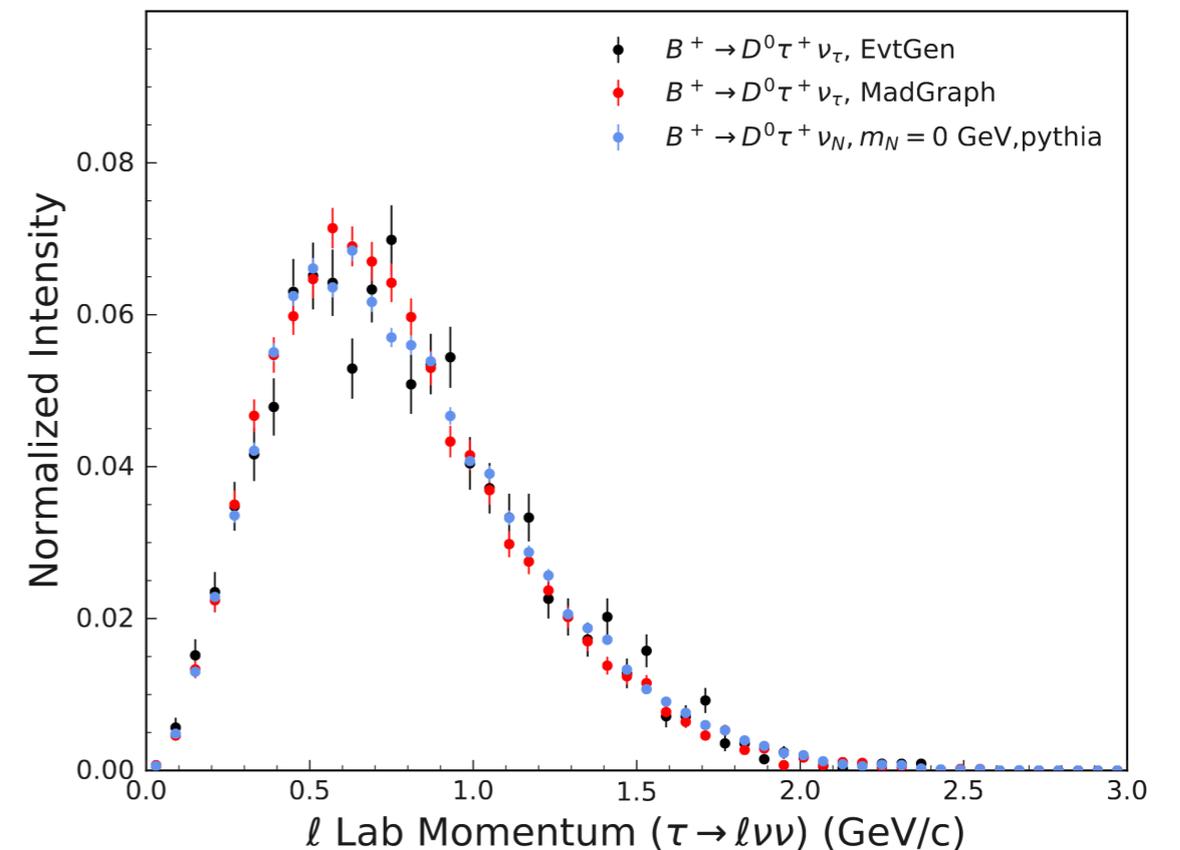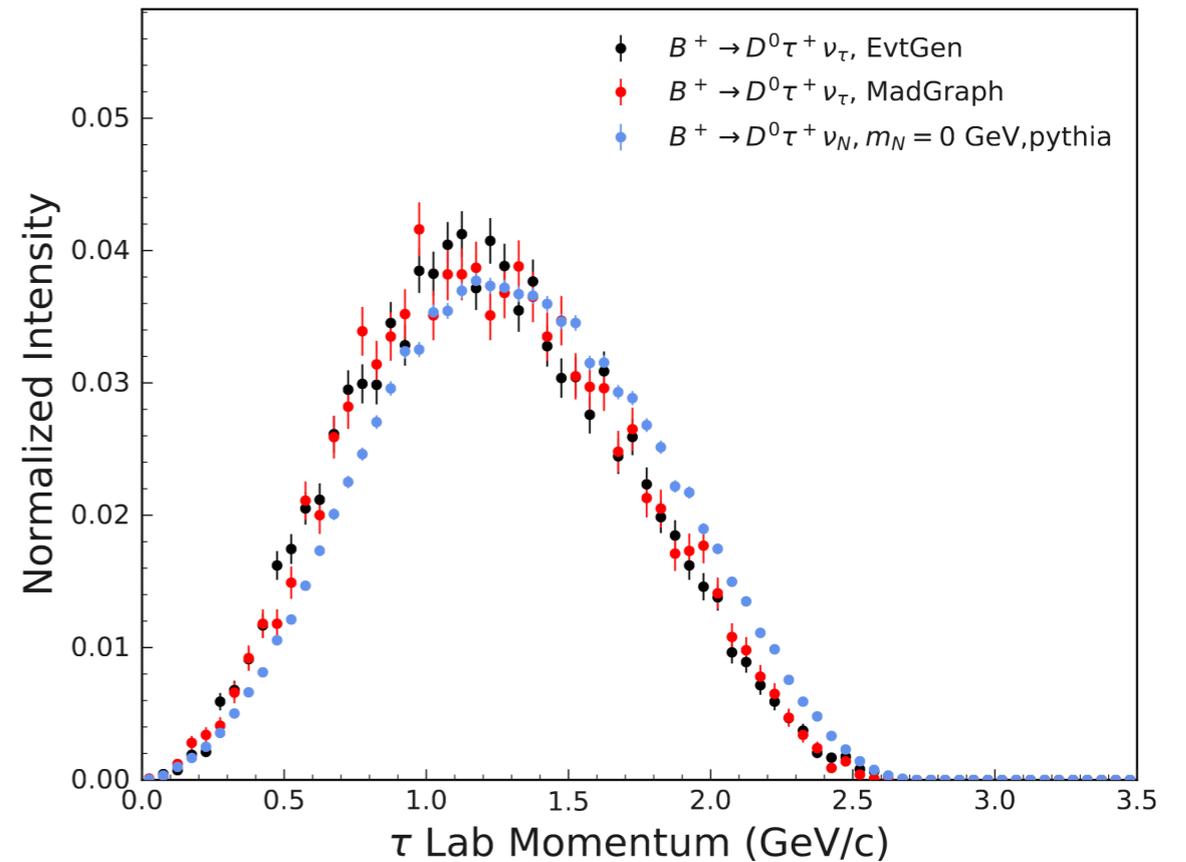meson decays

Pythia
(done but not embedded yet)

MadGraph
(no B -> D* yet)

Simple but helpful codes for
BR and widths
(Python and Mathematica)

https://gitlab.com/hnls

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Expected Yield

Require charged final states

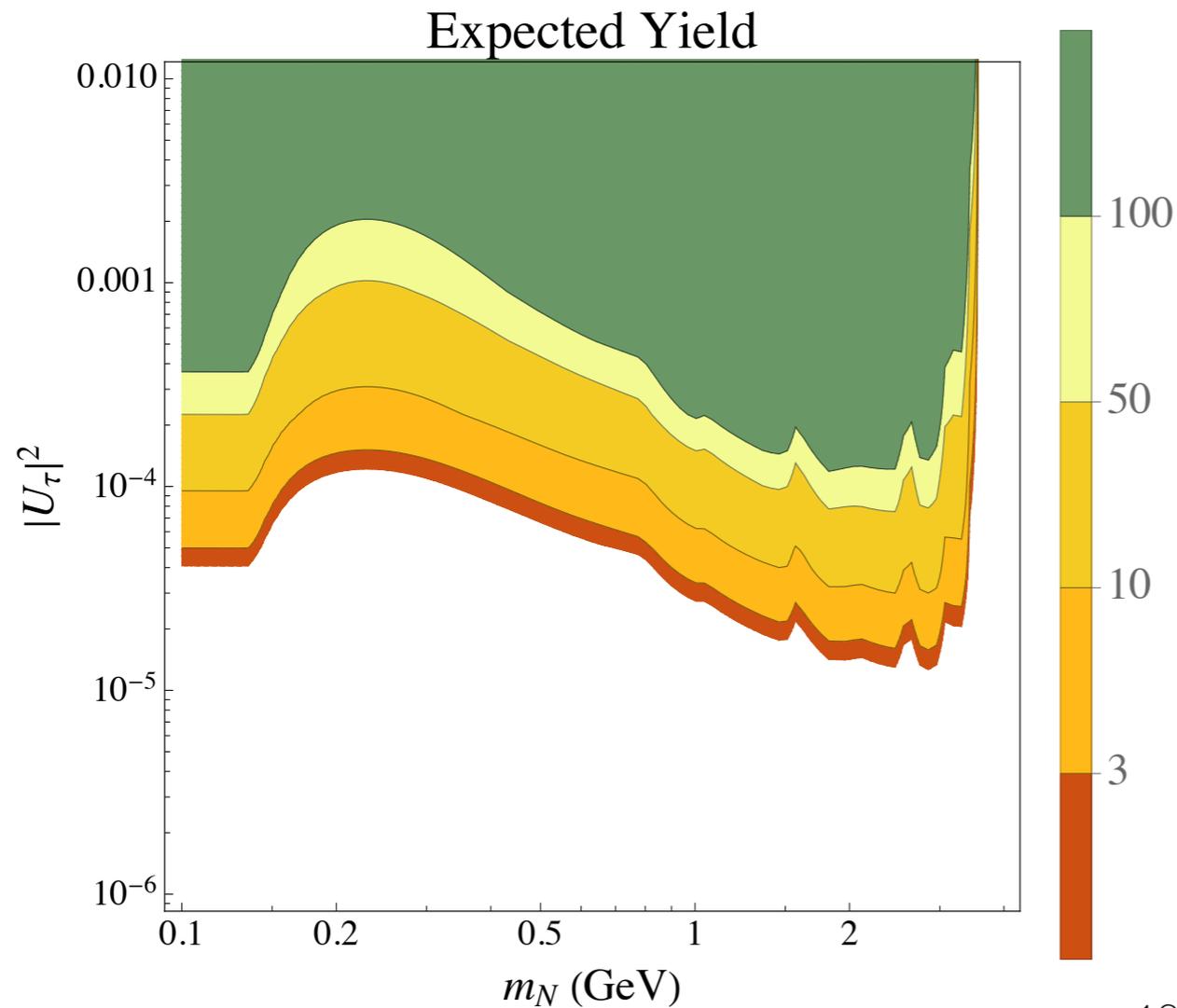$$N_N = N_{B\bar{B}} \times \mathcal{B}(B \to NX) \times \mathcal{B}(N \to \nu_\tau f^+ f^-) \times \mathcal{A}$$
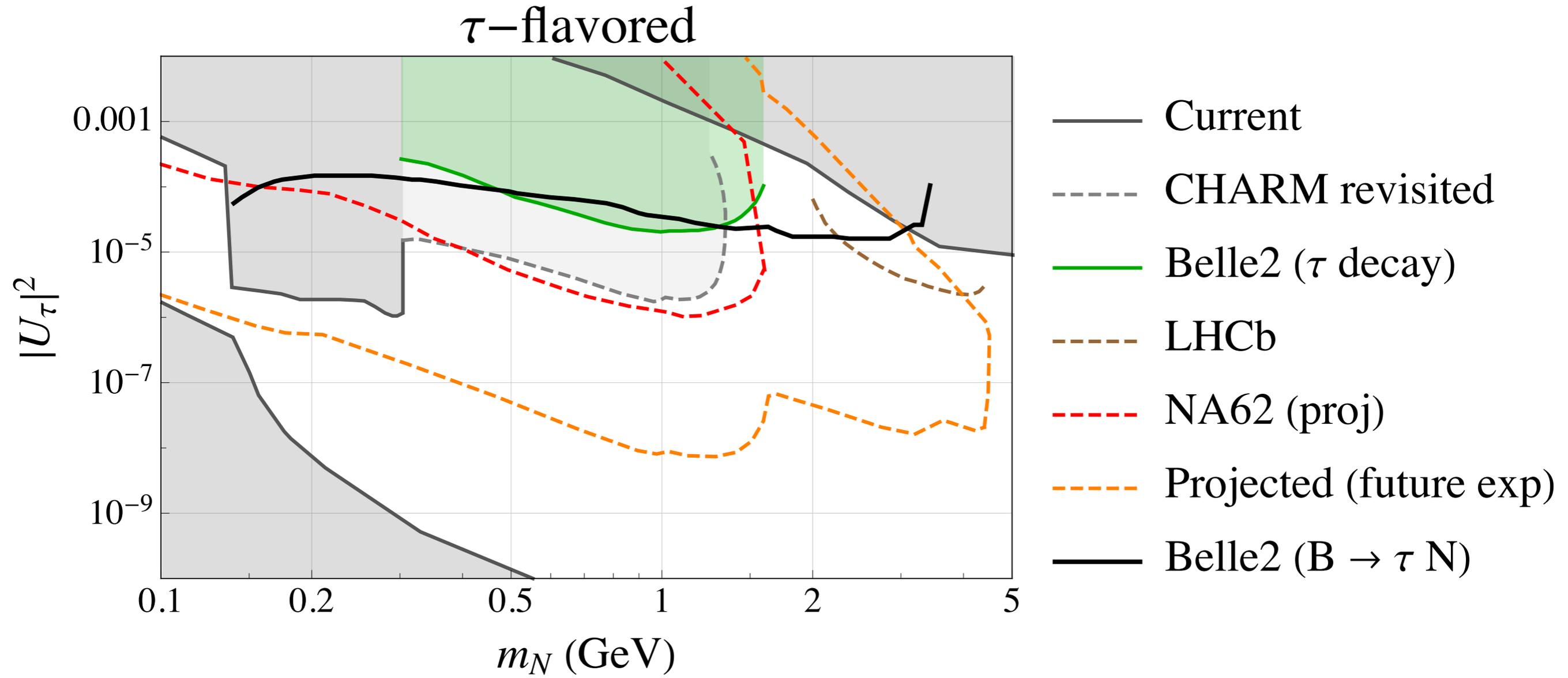
N decays in tracking volume

$$0.5 < r_T < 80 \text{ cm}$$
$$0.3 < \theta_{lab} < 2.6 \text{ rad}$$

Cut on final state momenta

$$p_f > 0.1 \text{ GeV}$$

Expected Yield

$B \to \tau N$

Expected Yield

$\tau-$flavored

Legend:
- Current
- CHARM revisited
- Belle2 (τ decay)
- LHCb
- NA62 (proj)
- Projected (future exp)
- Belle2 ($B \to \tau N$)

Axis labels: $|U_\tau|^2$ versus m_N (GeV)

Still ideal case

Take home message

- User-friendly simulations frameworks for meson decays are (almost) ready

https://gitlab.com/hnls

- Searches for HNLs at Belle 2 are still limited by statistics