INVISIBLES24

Neutrino masses and $0\nu\beta\beta$ decays in leptoquark models

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Motivation

- Neutrinos are massive and oscillate → Evidence of physics Beyond Standard Model (BSM)
- Neutrino masses are described by the Weinberg operator:

$$\mathcal{L}^{d=5} = \frac{C_{ij}^{(5)}}{\Lambda}(\overline{L_i^C}\tilde{H}^*)(\tilde{H}^\dagger L_j) + h.c.$$

→ Majorana neutrino masses

→ Lepton Number (L) is broken

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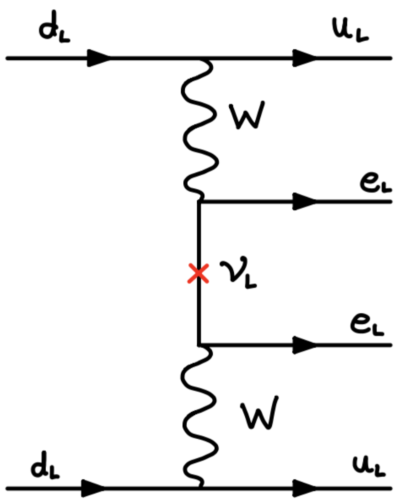
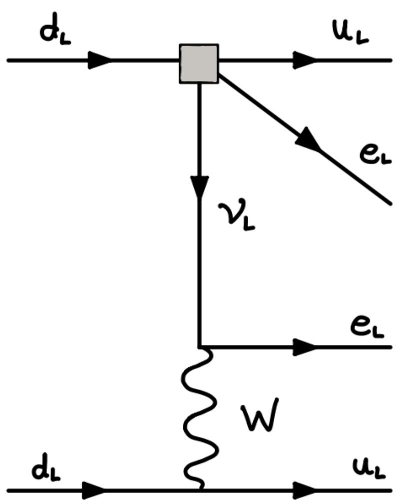
- ❖ Neutrinoless double beta decays are a clean prediction :

(d = 5)



$(\propto m_\nu)$ +

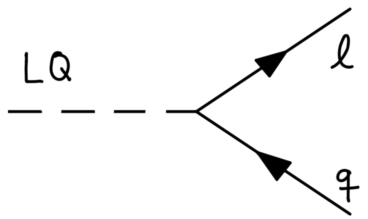
(d > 5)



⟹ However, concrete BSM models for neutrino masses induce additional contributions to $0\nu\beta\beta$

This Talk: **We** explore this effects in a minimal leptoquark (LQ) model

Our Framework

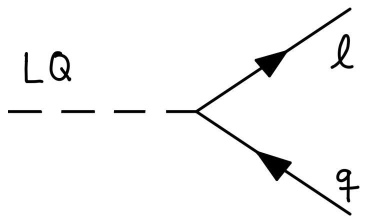


- Leptoquarks: colored particles that couple to quarks and leptons
- Example: $S_3 \sim (\bar{\mathbf{3}}, \mathbf{3}, 1/3)$ and $\widetilde{R}_2 \sim (\mathbf{3}, \mathbf{2}, 1/6)$

$$\mathcal{L}_{\widetilde{R}_2 \& S_3} \supset y_{3L}^{ij} \overline{Q_i^C} i\tau_2 (\tau^a S_3^a) L_j - y_{2L}^{ij} \bar{d}_{Ri} \widetilde{R}_2 i\tau_2 L_j - \lambda_3 \widetilde{R}_2^\dagger (\tau^a S_3^a)^\dagger H + \text{h.c.}\,,$$

Mixing induces
Lepton Number Violation

Our Framework



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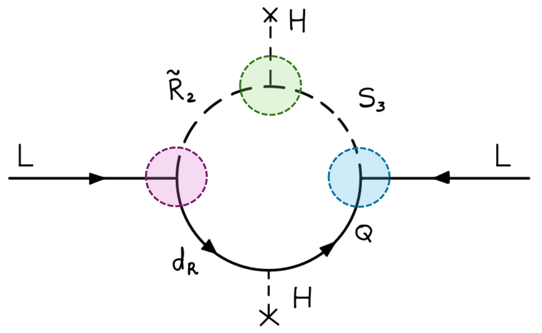
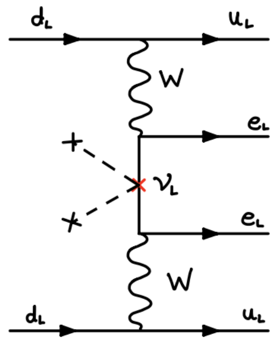
Neutrino Masses

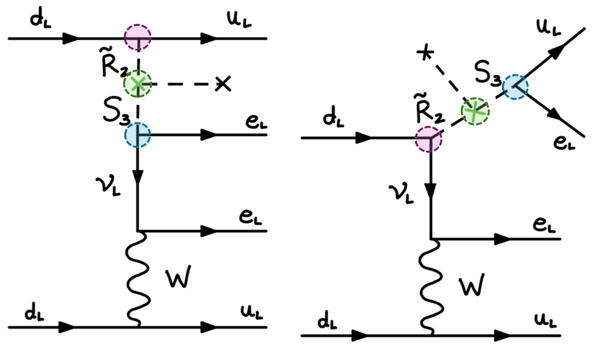


$0\nu\beta\beta$

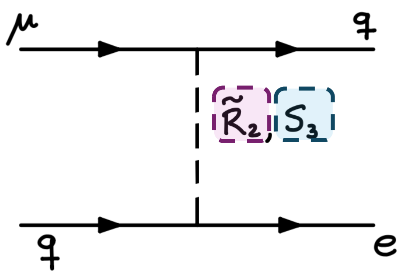
d = 5 contribution
(loop - level)



d = 7 operators
(tree - level)



Flavor Physics
tree - level
(d = 6)

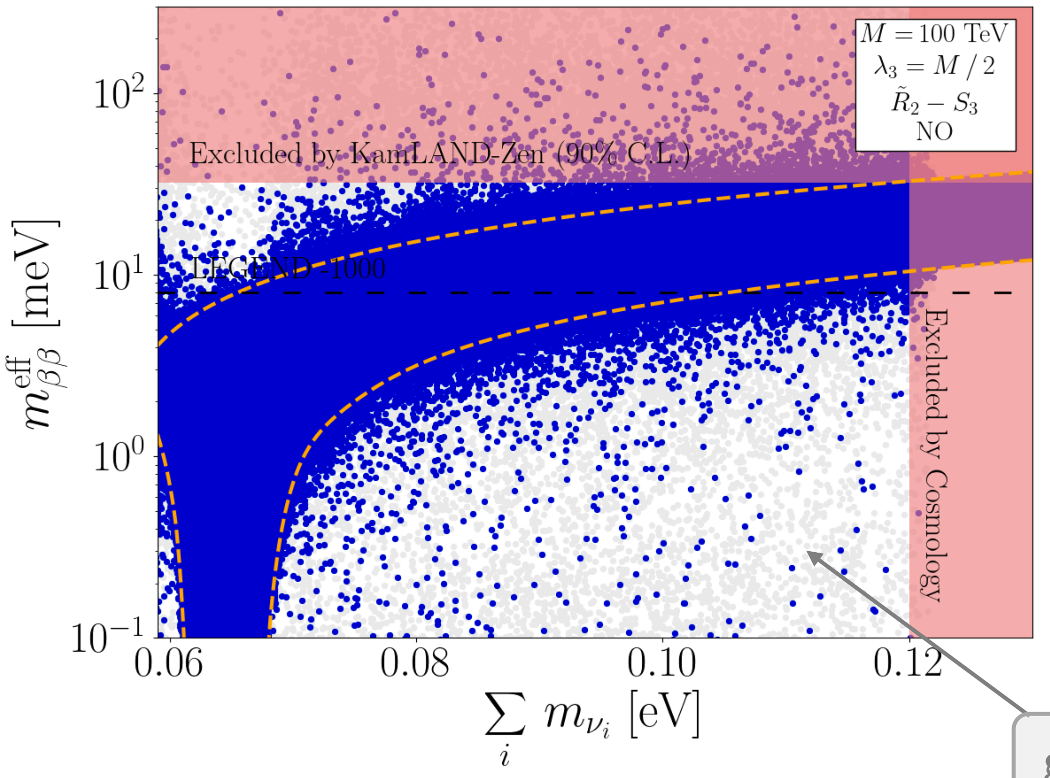


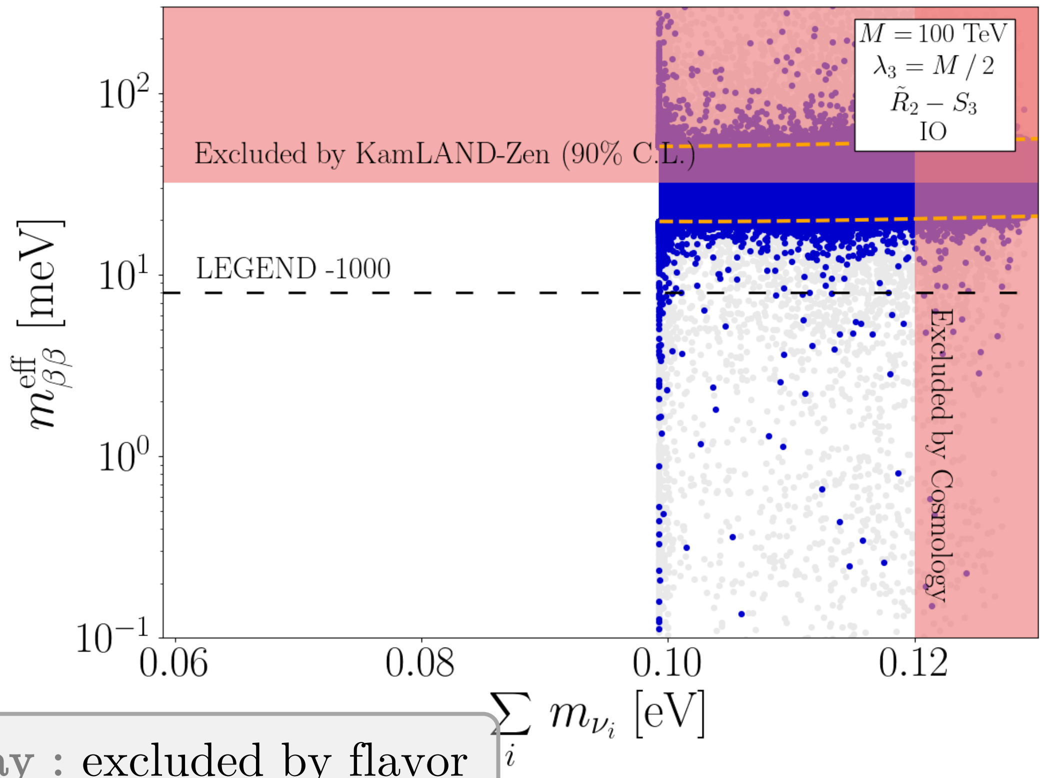
- LQ contributions to $0\nu\beta\beta$ are chirality enhanced ($\propto E/m_{\nu_i}$, $E \simeq 100\,\text{MeV}$)
  $\Longrightarrow$ breaking of naive power counting

Predictions

$$\left(m_{\beta\beta}^{\text{eff}}\right)^2 \equiv m_{\beta\beta}^2 + \delta m_{\beta\beta}^{2\,(\text{int})} + \delta m_{\beta\beta}^{2\,(\text{LQ})} \;;\; m_{\beta\beta} = \sum_i U_{ei}^2 m_{\nu_i}$$

- Benchmark: $m_{\tilde{R}_2} = m_{S_3} = M = 100\,\text{TeV}$
- LQ Yukawas fixed to explain neutrino masses for both neutrino orderings





gray : excluded by flavor

$\Rightarrow$ Ambiguity between normal and inverted ordering (more information needed)

Predictions

$$\left(m_{\beta\beta}^{\text{eff}}\right)^2 \equiv m_{\beta\beta}^2 + \delta m_{\beta\beta}^{2\,(\text{int})} + \delta m_{\beta\beta}^{2\,(\text{LQ})} \;;\; m_{\beta\beta} = \sum_i U_{ei}^2 m_{\nu_i}$$

- ❖ Benchmark: $m_{\tilde{R}_2} = m_{S_3} = M$
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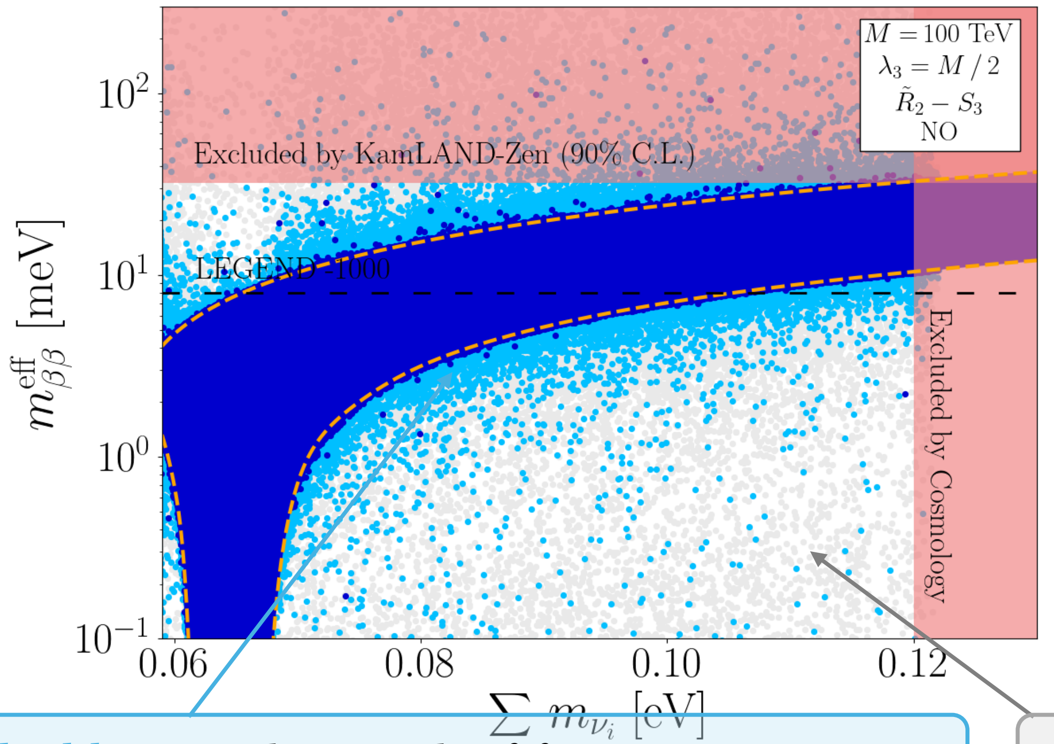
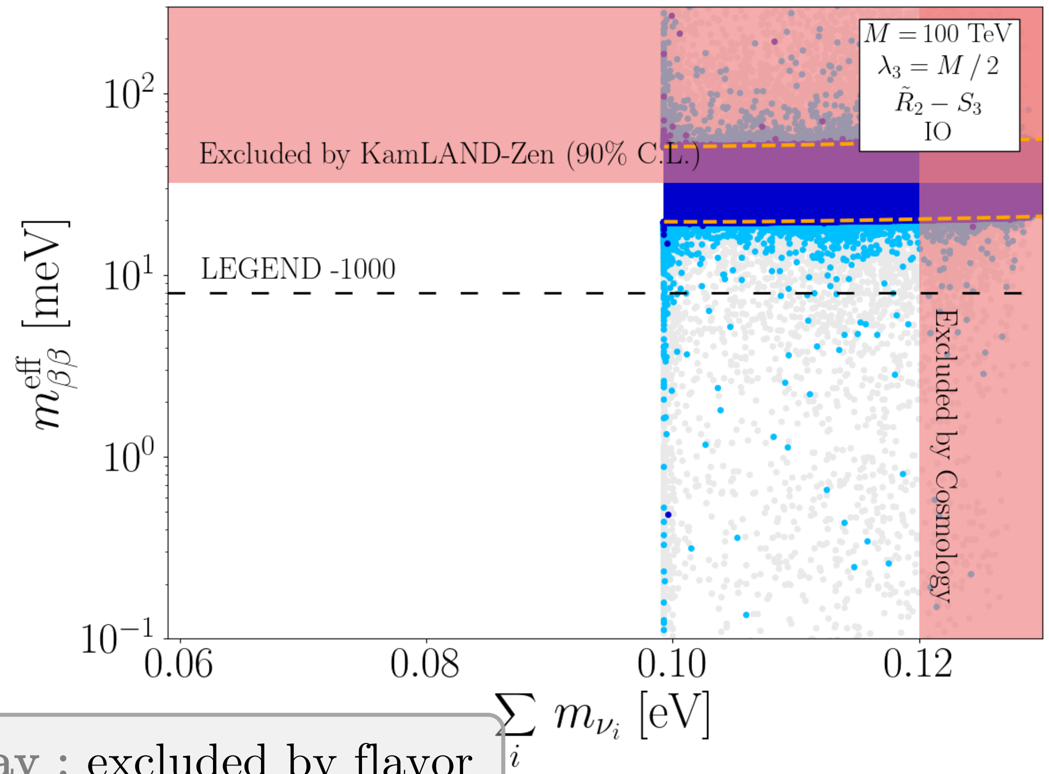


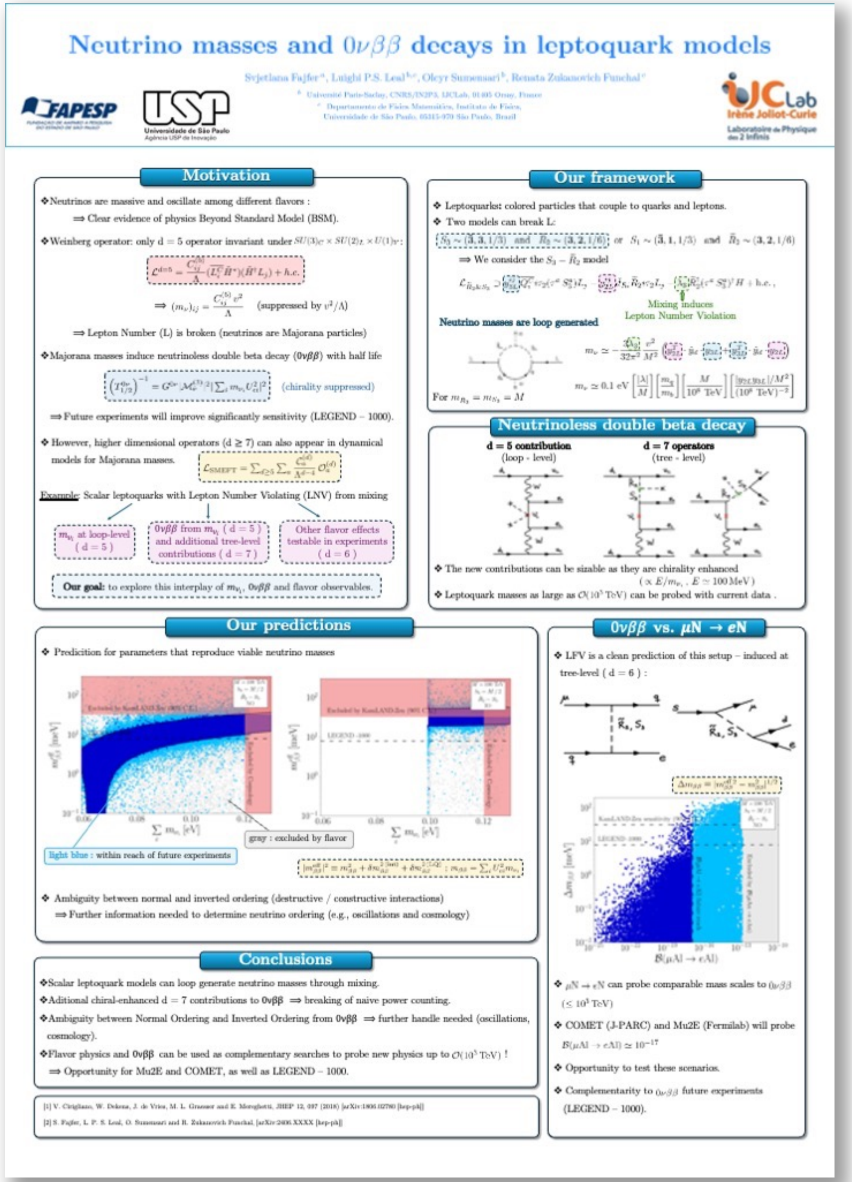


light blue : within reach of future experiments

gray : excluded by flavor

Flavor physics and $0\nu\beta\beta$ are complementary to probe new physics up to $\mathcal{O}(10^3\,\text{TeV})$

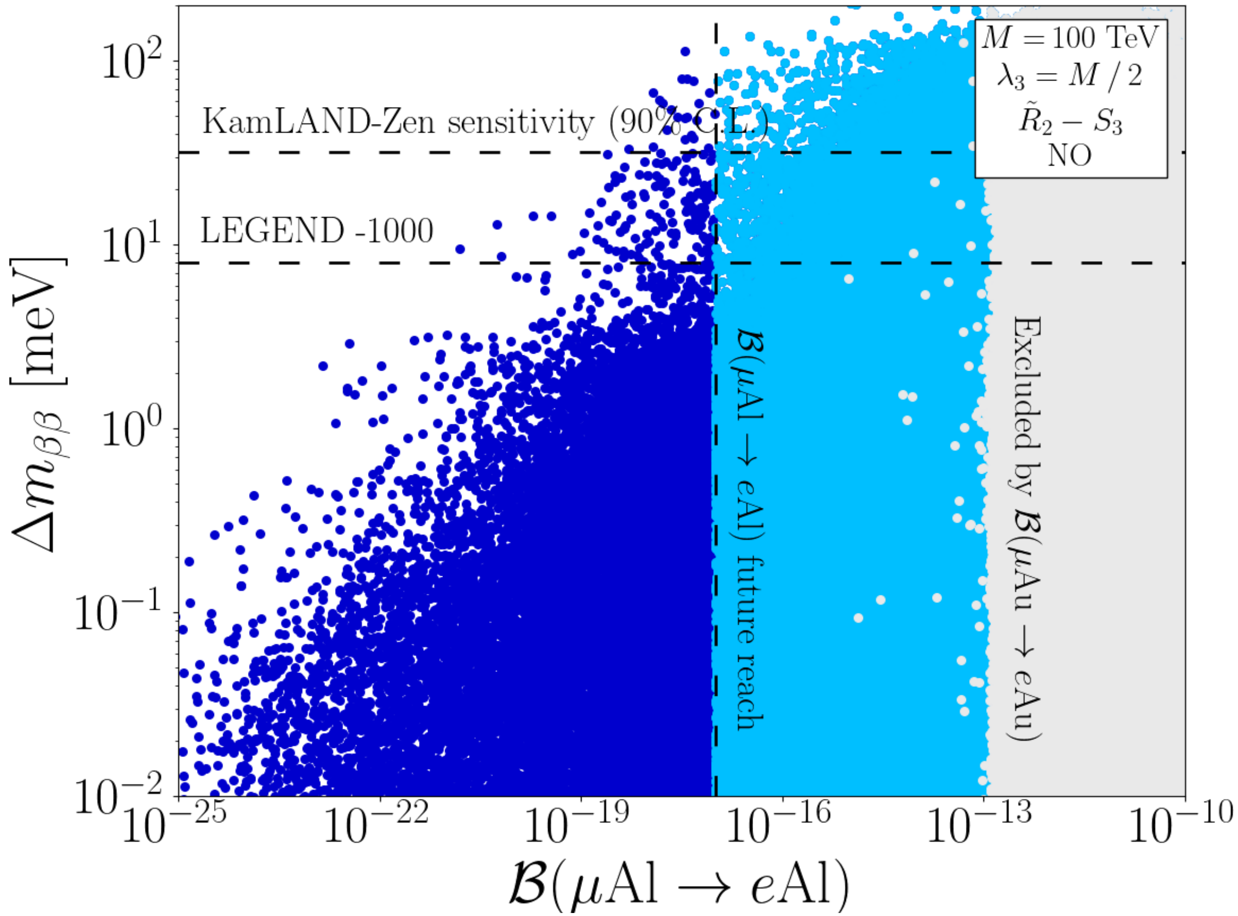
Thank you!

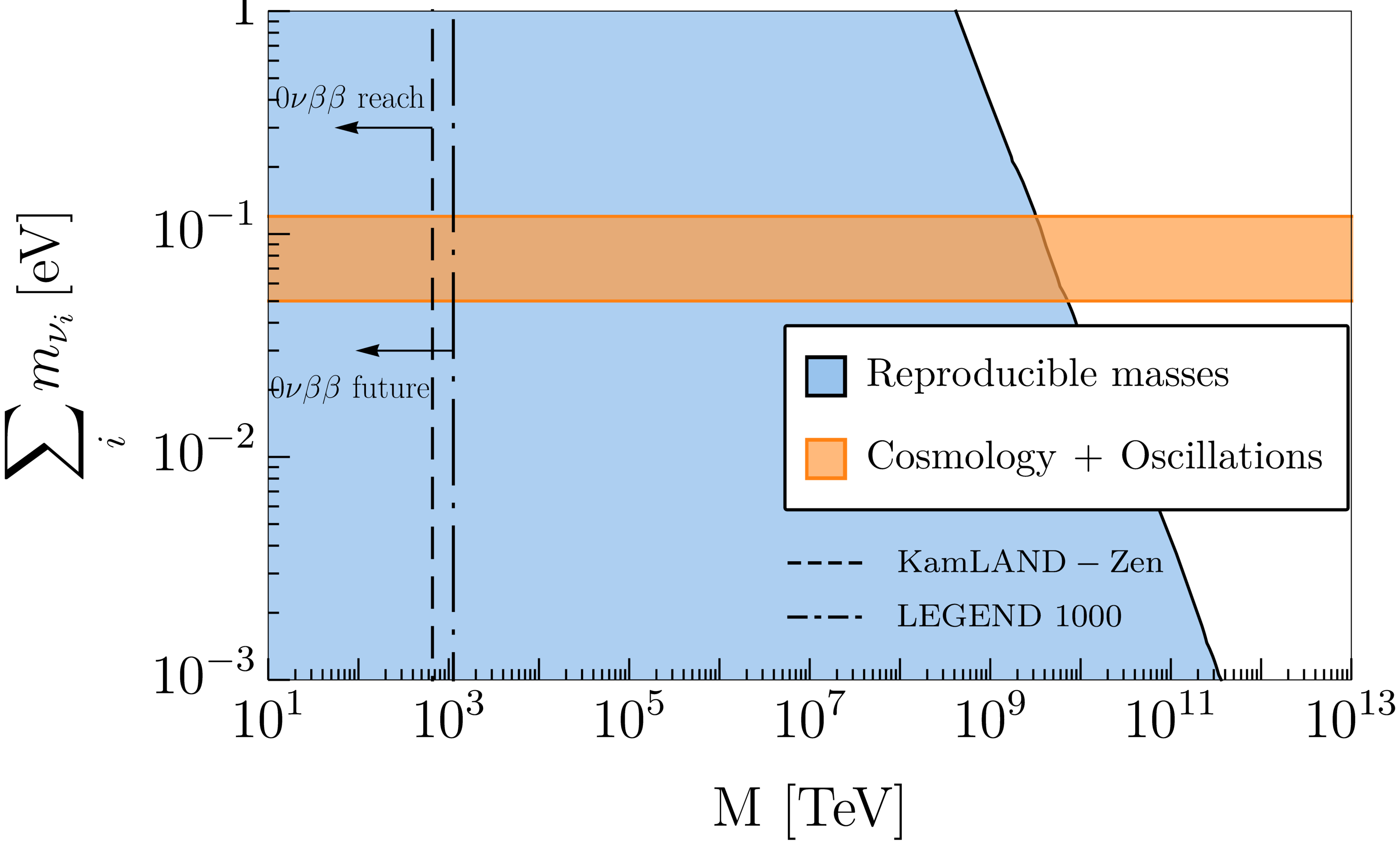

Neutrino masses and $0\nu\beta\beta$ decays in leptoquark models
Motivation
Our framework
Neutrinoless double beta decay
Our predictions
$0\nu\beta\beta$ vs. $\mu N \to eN$
Conclusions

Backup

$\Delta m_{\beta\beta} \equiv |m_{\beta\beta}^{\mathrm{eff}\,2} - m_{\beta\beta}^2|^{1/2}$

Future sensitivity: $\mathcal{B}(\mu\mathrm{Al} \to e\mathrm{Al}) \simeq 10^{-17}$





$\sum_i m_{\nu_i}$ [eV]
M [TeV]
$0\nu\beta\beta$ reach
$0\nu\beta\beta$ future
Reproducible masses
Cosmology + Oscillations
KamLAND – Zen
LEGEND 1000