Measuring the neutrino mass

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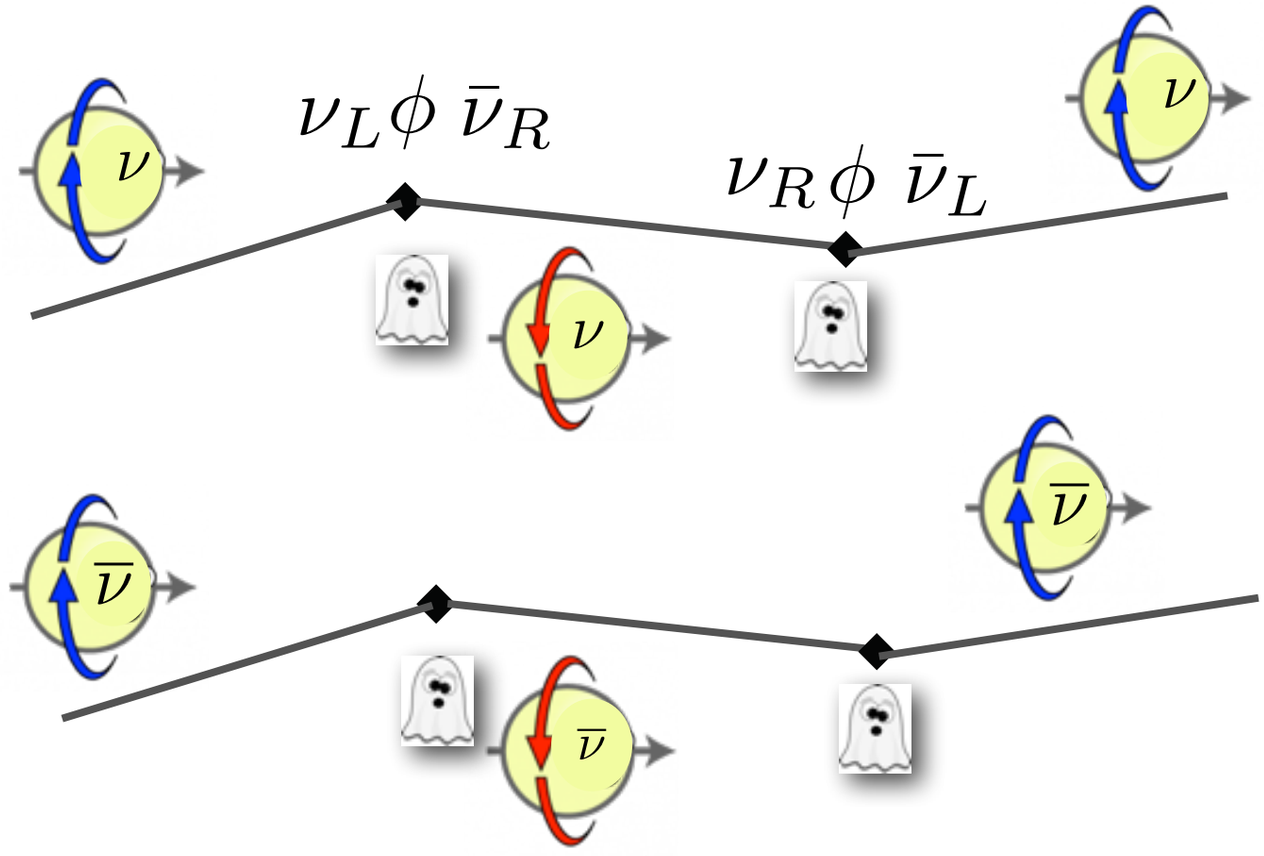
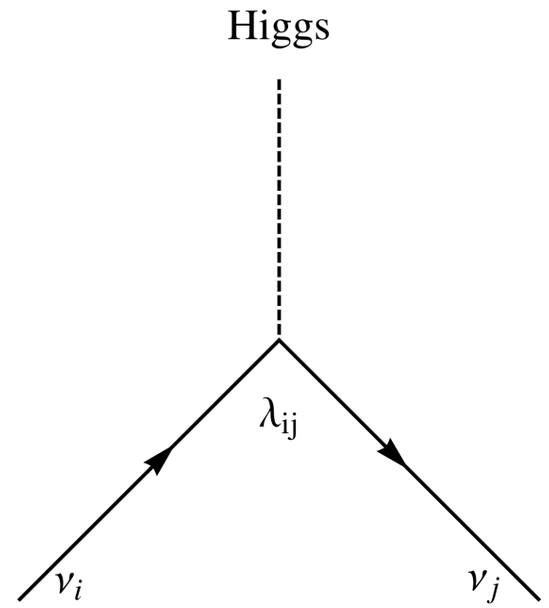
Lecture 2

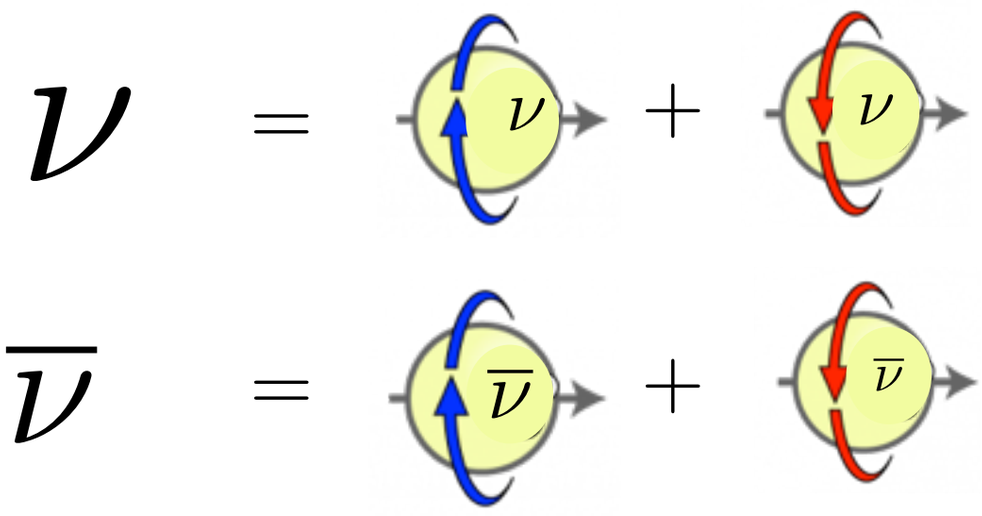
ββ0ν decays

Dirac neutrinos





$$-\mathcal{L}_{\text{Dirac}} = \bar{\nu}_L m_\nu \nu_R + h.c.$$
$$m_\nu = \lambda_\nu v$$



$$\nu = \nu_L + \nu_R$$

$$\nu^C = (\nu_L)^C + (\nu_R)^C$$

Majorana neutrinos

$$\nu = \nu + \nu$$

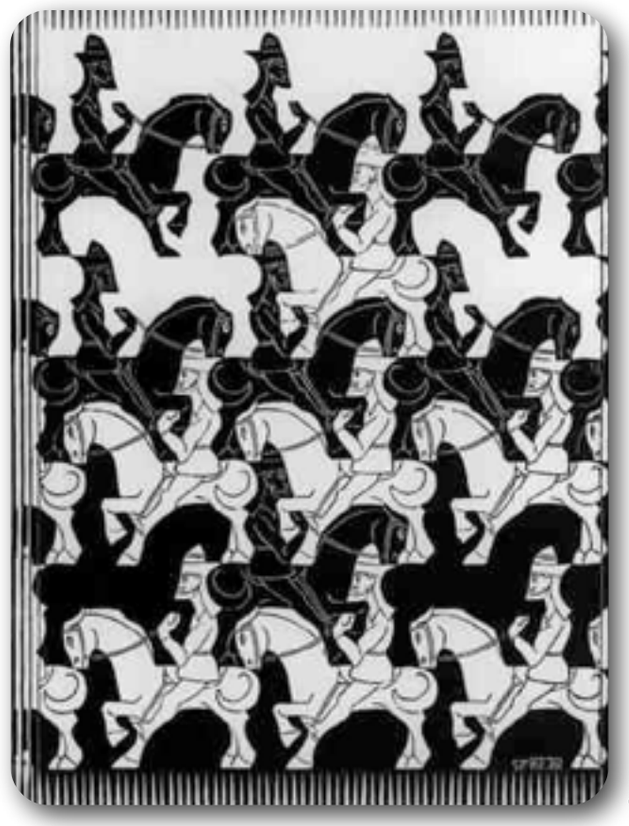
$$\nu = \nu_L + \nu_R$$

$$\overline{\nu} + \overline{\nu}$$

$$\nu^C = (\nu_L)^C + (\nu_R)^C$$

$$\nu = \nu_L + \nu_L^C \qquad \nu^c = \nu$$

$$\nu = \bar{\nu}$$

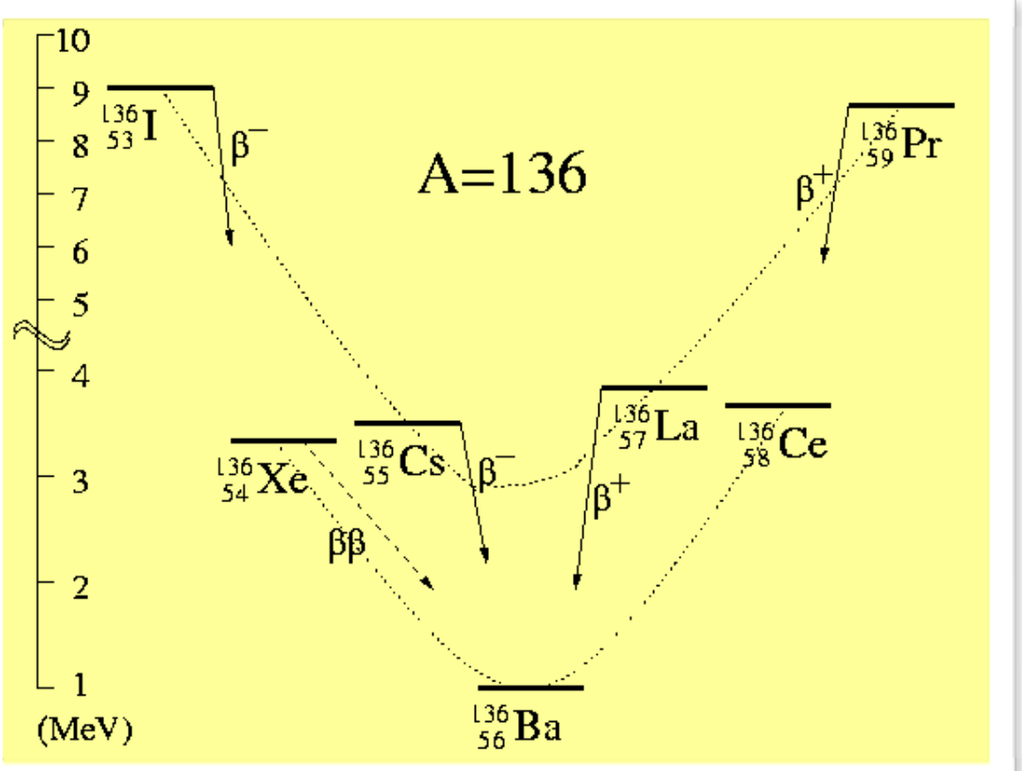


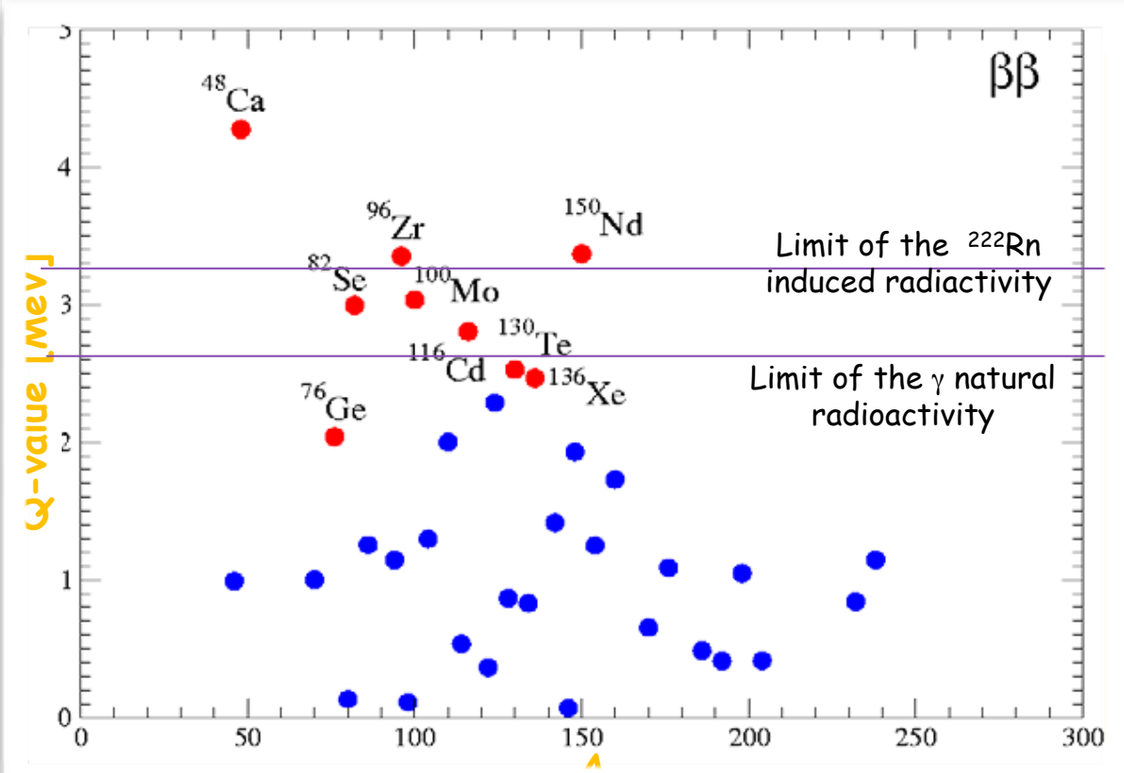
Experimental approach

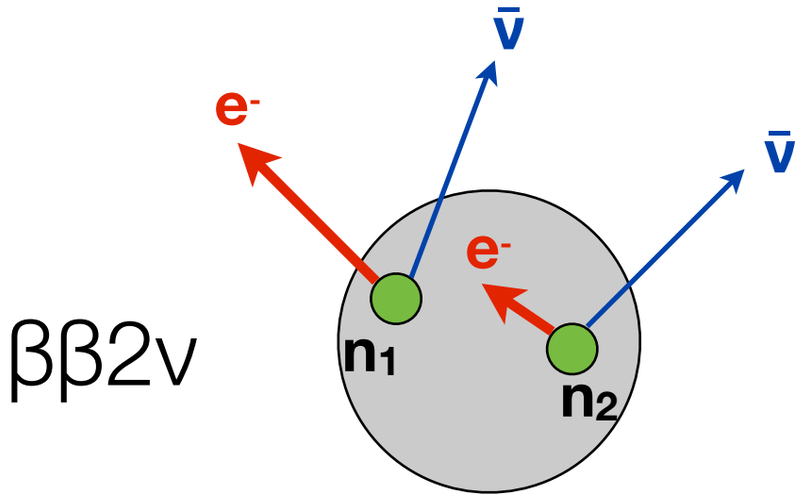
?

=

Double beta decay



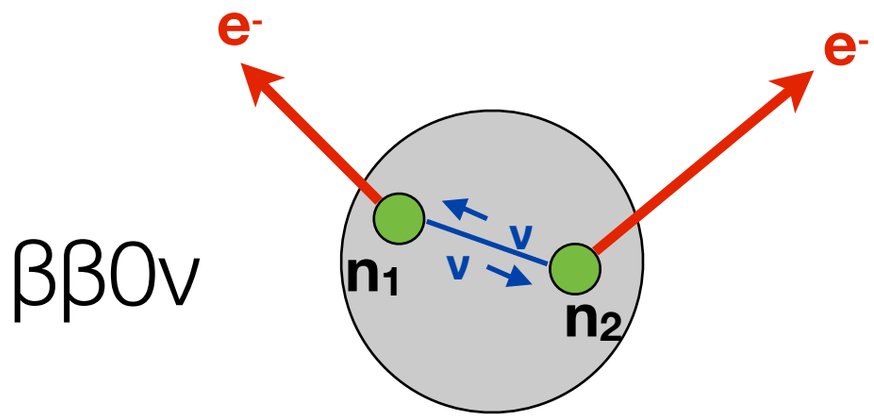




Two neutrino mode

- Observed in several nuclei
- 10^{19}-10^{21} yr half-lives
- Standard Model allowed

Neutrinoless double beta decay



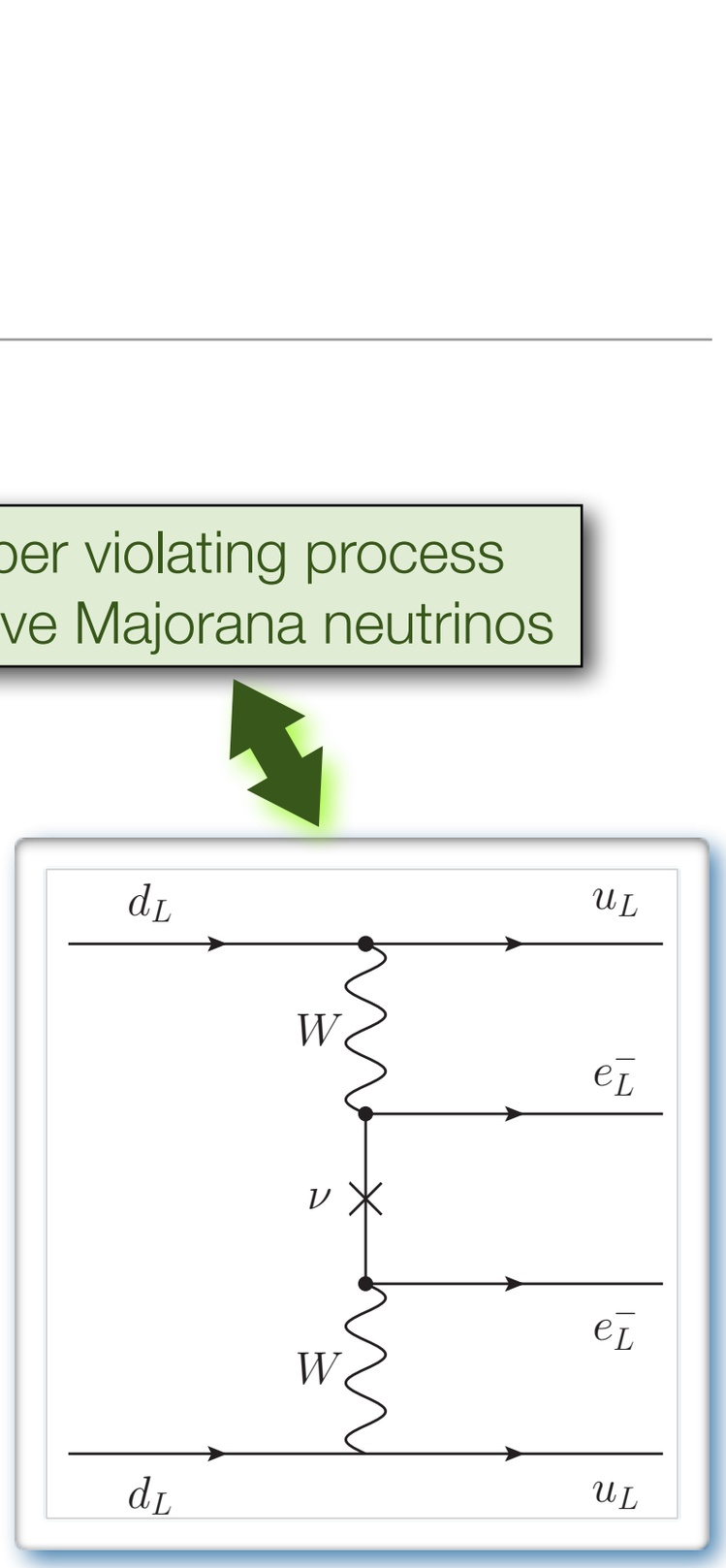
ββ0ν

Neutrinoless mode

- Requires Majorana neutrinos
- Not observed yet in Nature
- >10^{25} yr half-lives
- Would signal Beyond-SM physics

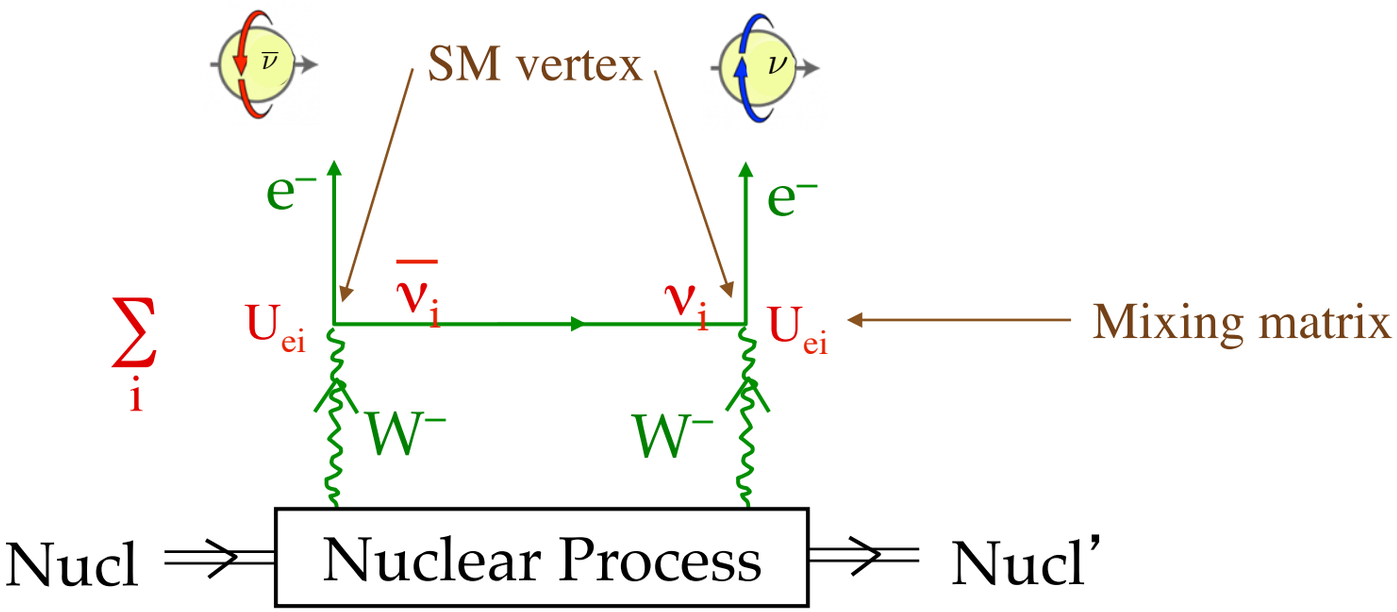
Lepton number violating process
implying massive Majorana neutrinos

- Identity
- Mass scale
- Mass ordering
- Mixing
- Species



- **See Boris Kayser lectures**

Neutrinoless double beta decay and the neutrino mass

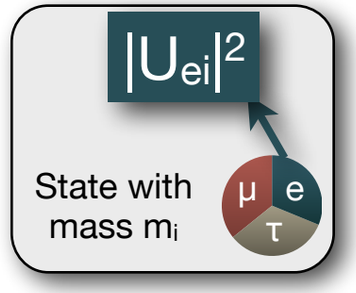


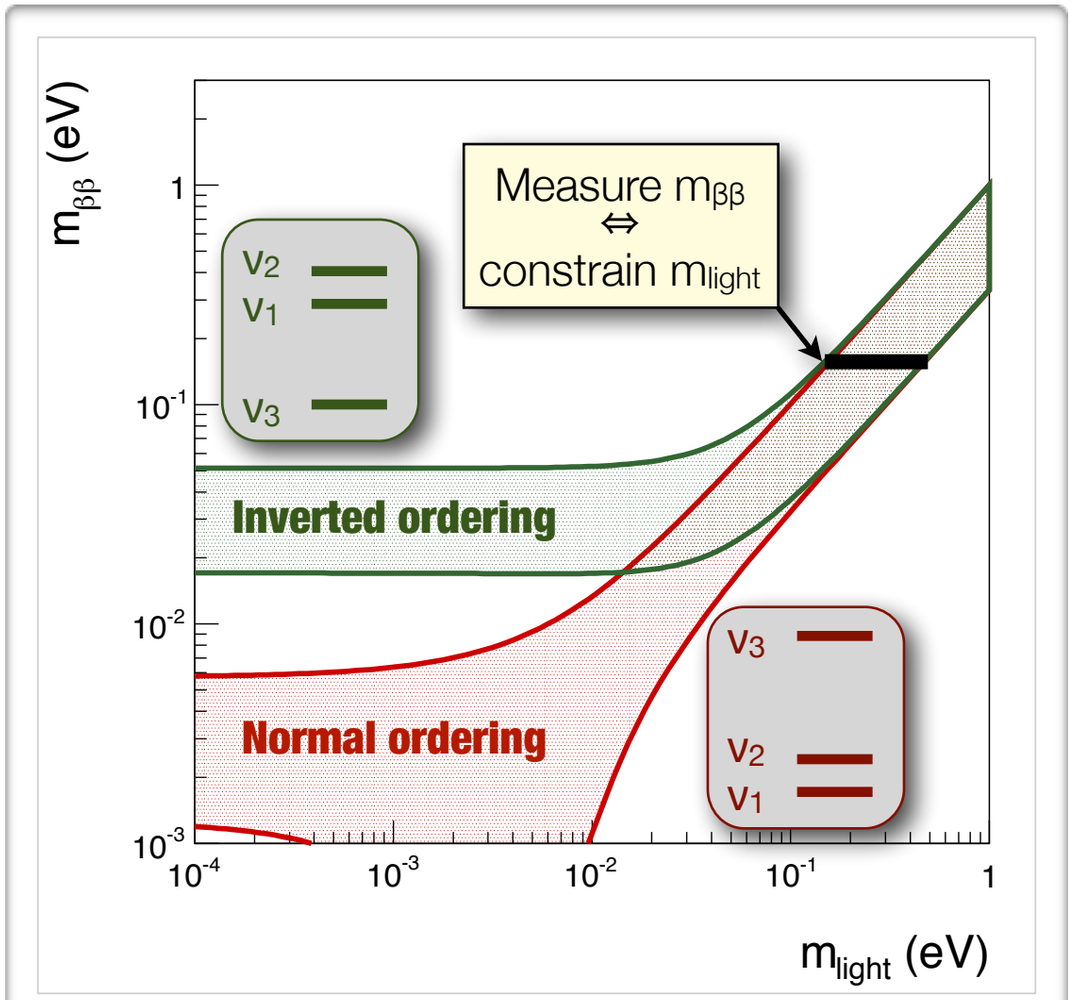
$$\longrightarrow \quad \text{helicity flip} \quad \propto \frac{m_i}{E}$$

$$\mathcal{A} \propto m_i \quad \text{for each} \quad \nu_i$$

$(\text{Rate})_{\beta\beta0\nu} \propto m_{\beta\beta}^2$

Majorana ν mass:
$m_{\beta\beta} \equiv \left| \sum_i m_i U_{ei}^2 \right|$

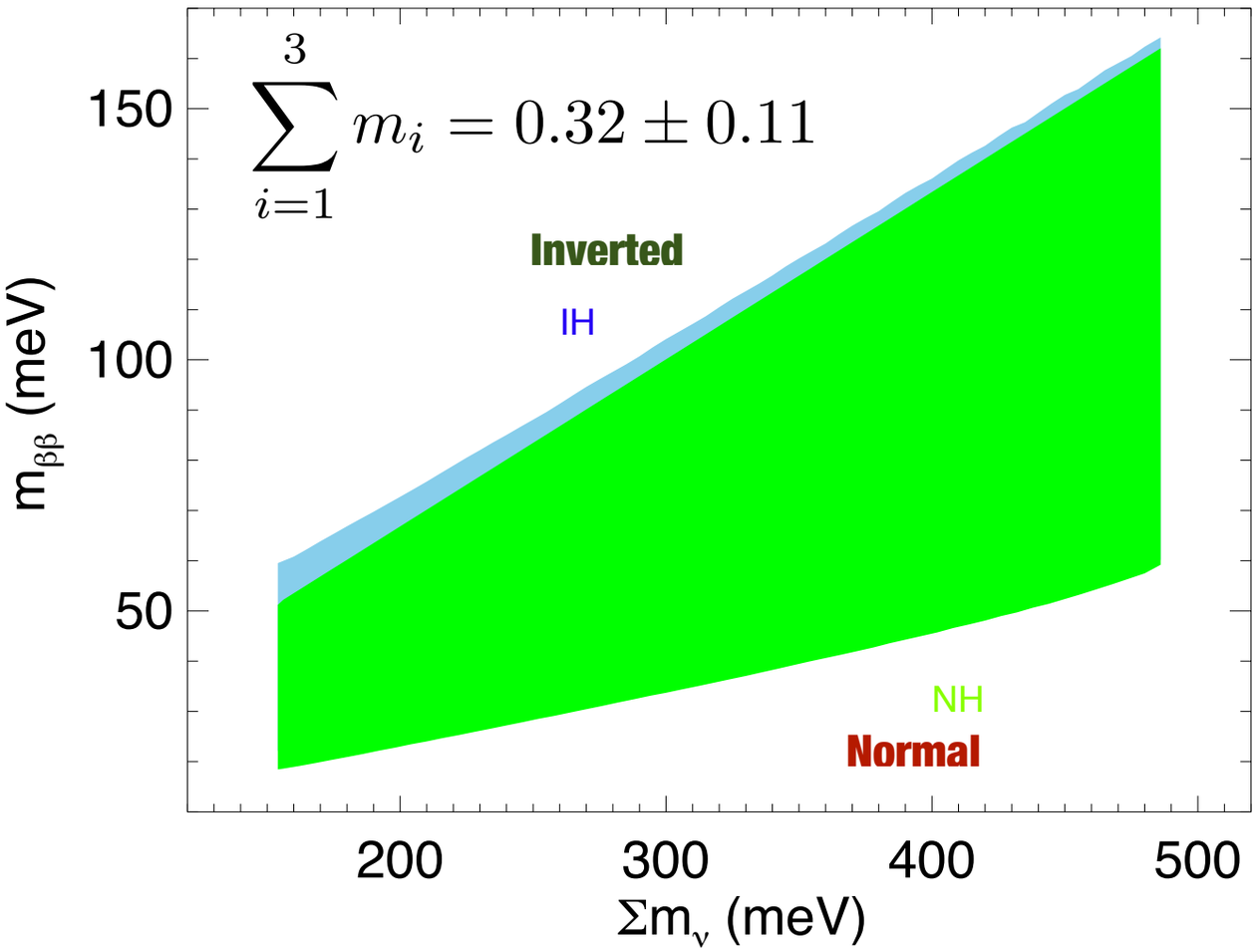


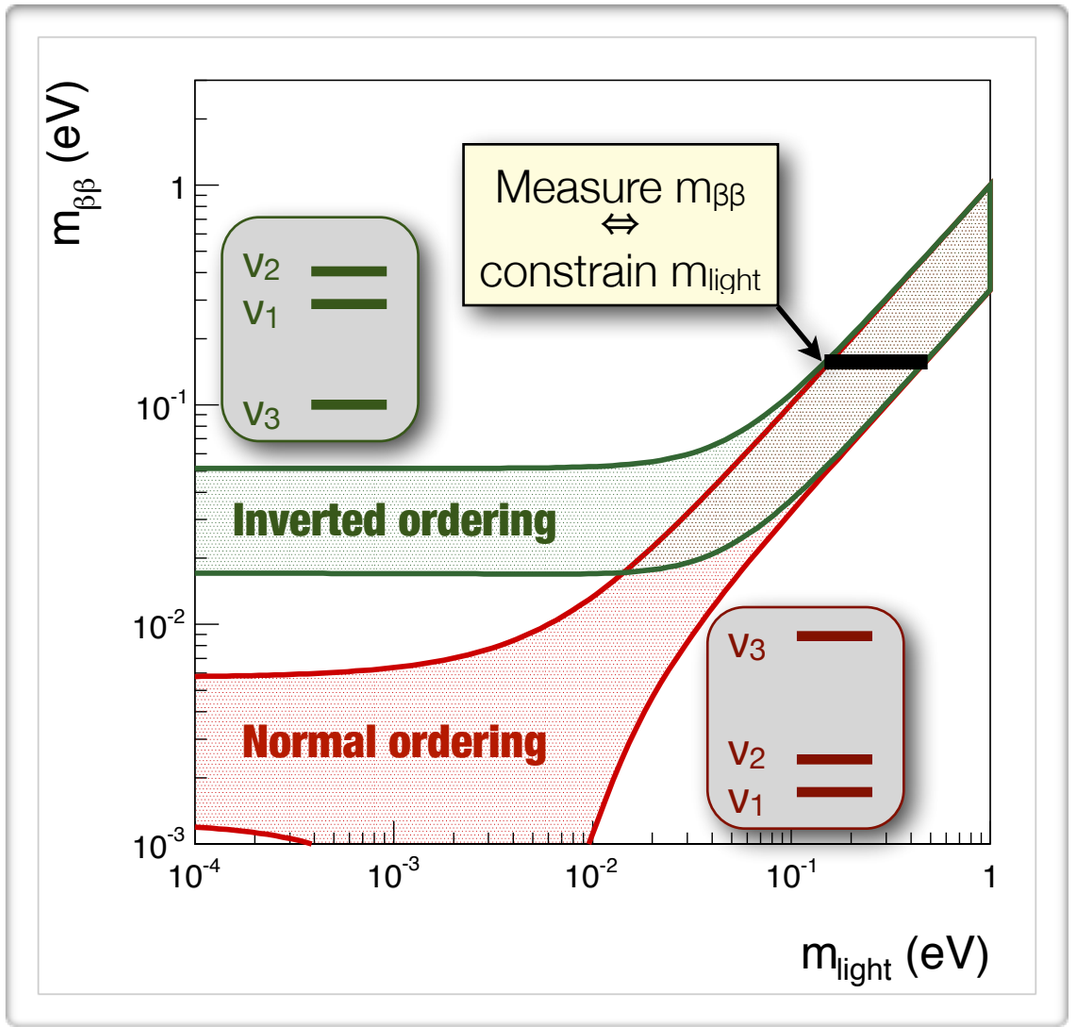


Exploring Majorana landscape

Evidence for Massive Neutrinos from Cosmic Microwave Background and Lensing Observations

Phys. Rev. Lett. 112, 051303 (2014)





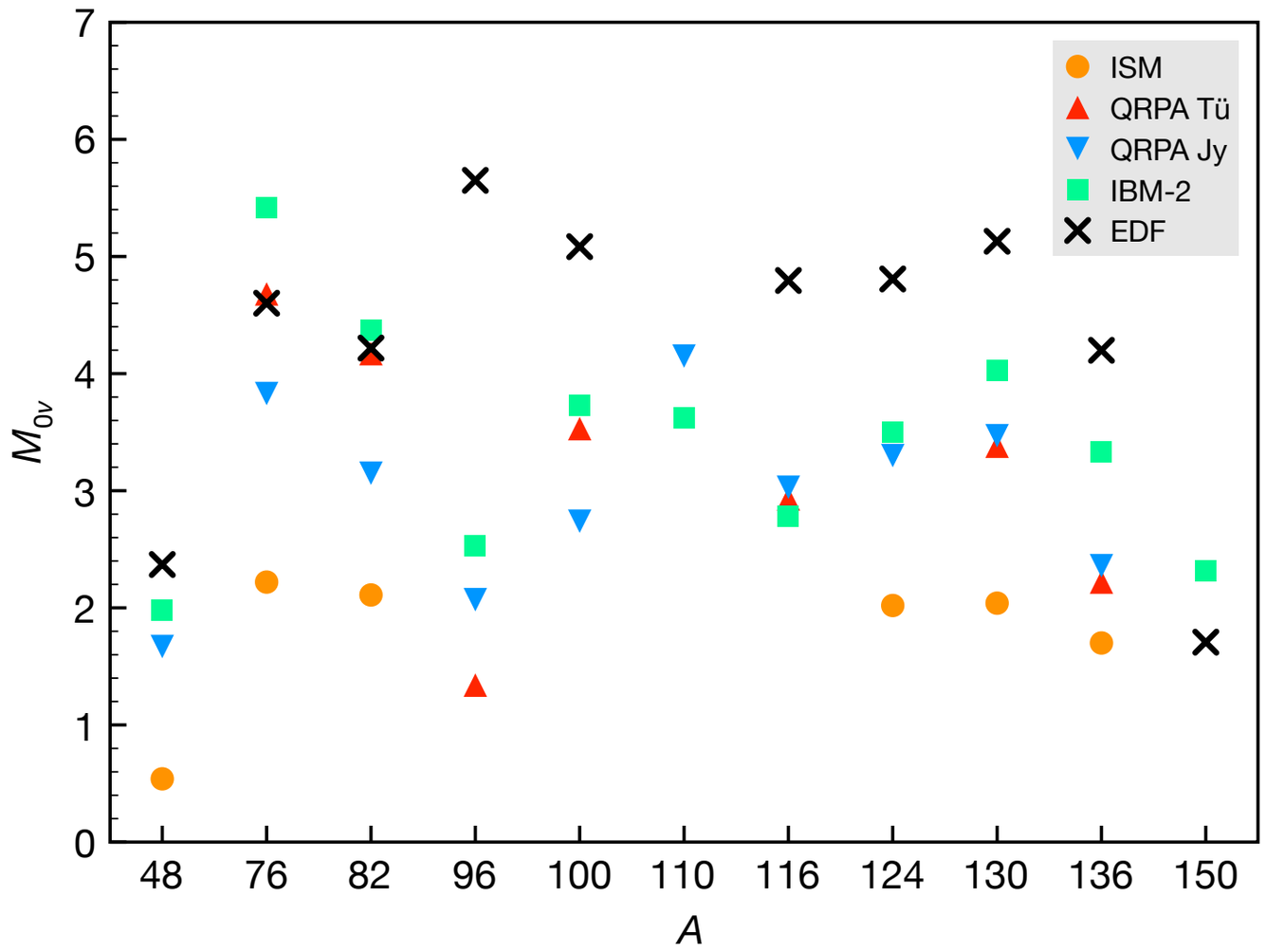
Discovery potential of xenon-based neutrinoless double beta decay experiments in light of small angular scale CMB observations

JCAP 1303 (2013) 043

- **Degenerated: mββ~50 meV**
- **Inverse: mββ~20 meV**
- **Normal: mββ~2 meV**

The NME

$$(T^{0\nu}_{1/2})^{-1} = G^{0\nu}(Q,Z)\ |M^{0\nu}|^2\ m^2_{\beta\beta}$$



- **Difference between models can be up to a factor 3 in M →factor 10 in mββ**
- **The discrepancy in NME is a major source of uncertainty (in particular if no discovery is made)**