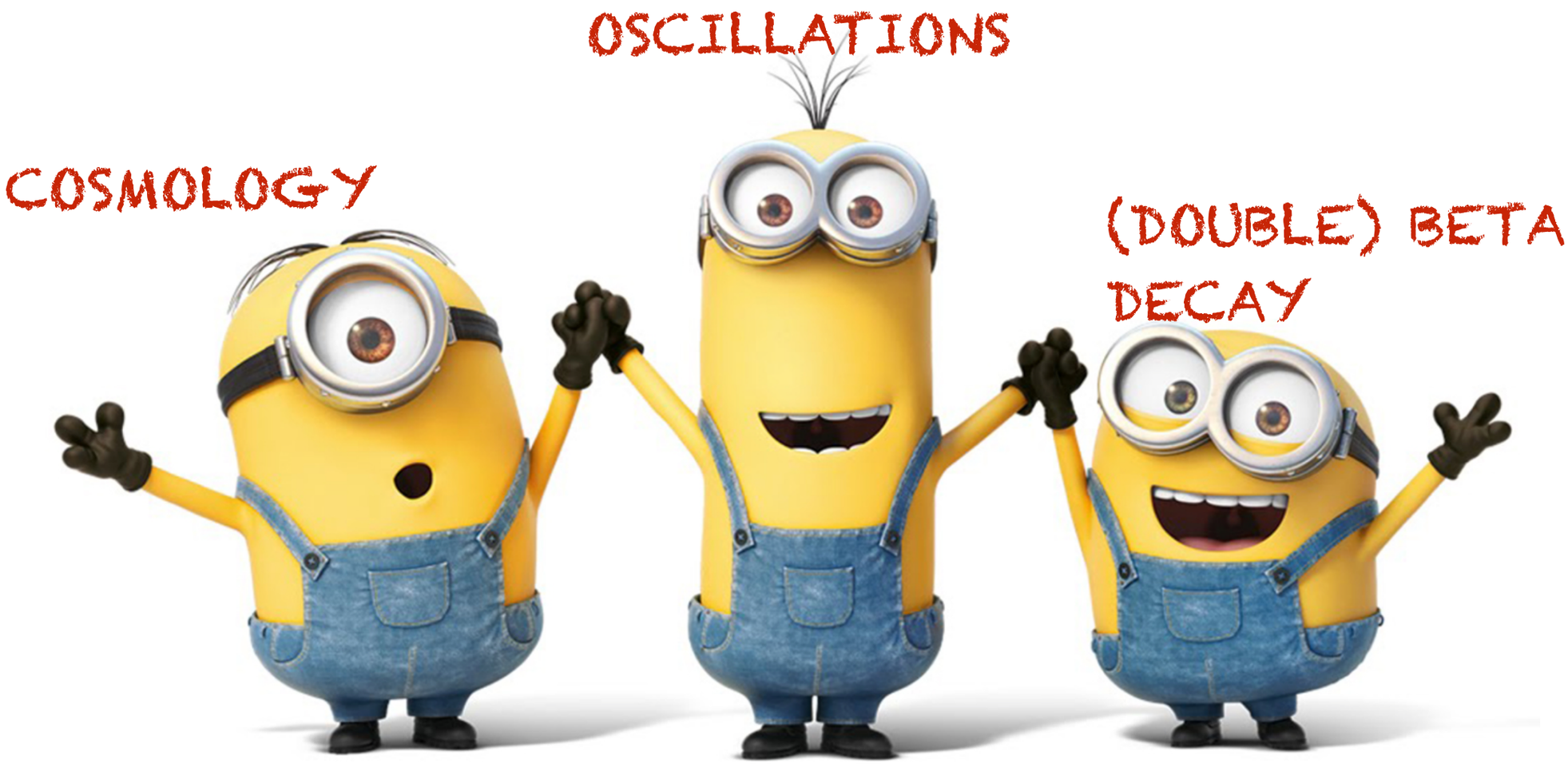
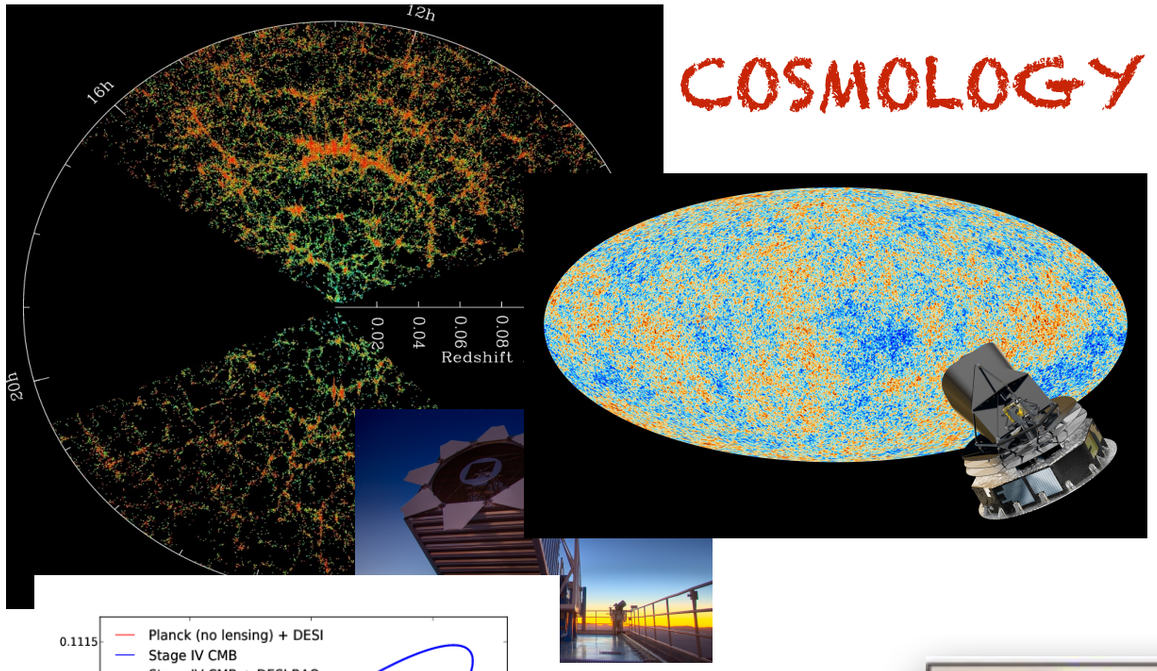
Complementarity between cosmology and lab searches of neutrino properties

Topics in Cosmic Neutrinos
Fermilab, 10 October 2019

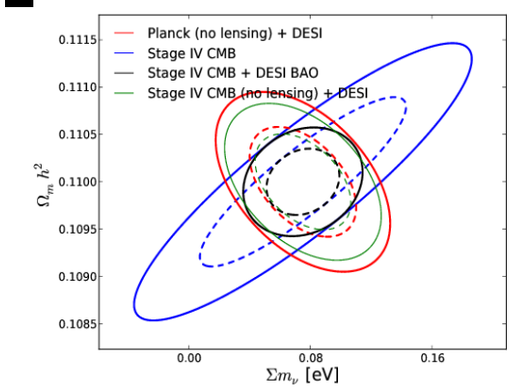


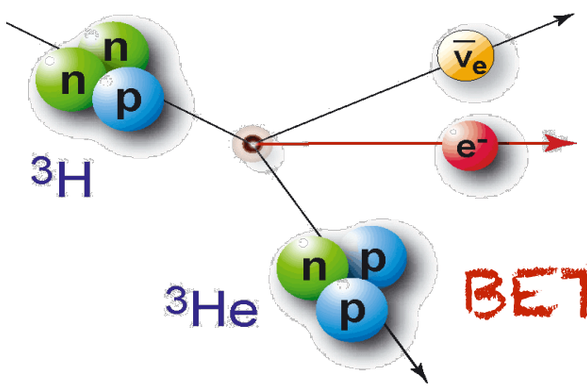
Martina Gerbino
Argonne National Laboratory



COSMOLOGY

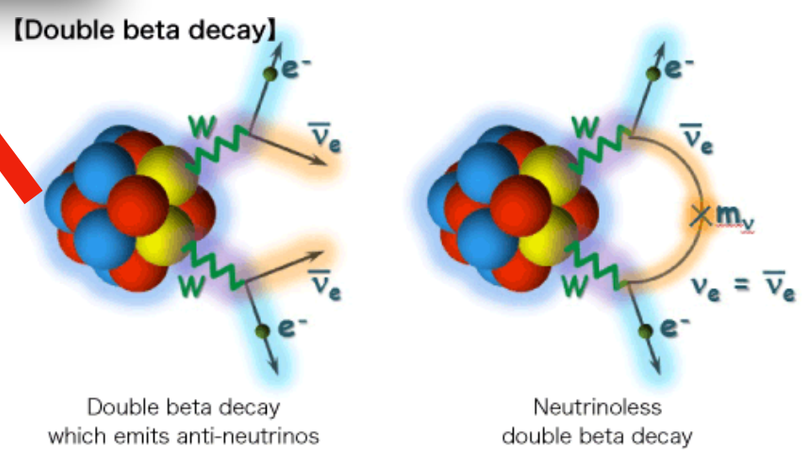
OSCILLATIONS





BETA DECAY

DOUBLE BETA DECAY



Complementarity

Examples of complementarity:

- absolute mass scale
- mass ordering
- nature (Dirac vs Majorana)

Additional examples (not covered in this talk)

- additional (light) species (Gariazzo+2019, Berryman2019,J.M.Cline2019,...)
- neutrino non-standard interactions (Forastieri+2019,Kreisch+2019,Blinov+2019,Barenboim+2019, ...)

The absolute mass scale can be measured through:

- tritium beta decay

$$m_\beta \equiv \left[\sum |U_{ei}|^2 m_i^2\right]^{1/2} < 1.1 \text{ eV @ 90\%CL}$$ (KATRIN)

- neutrinoless double beta decay

$$m_{\beta\beta} \equiv \left|\sum U_{ei}^2 m_i\right| < 0.06 - 0.16 \text{ eV @ 90\%CL}$$

(Kamland-Zen)

- cosmological observations

$$\sum m_\nu \equiv \sum_i m_i < 0.12 - 0.24 \text{ eV @ 95\%CL}$$

(Planck+…)

The mass ordering can be measured through:

- oscillation experiments

mild preference for NH

Esteban+2018,deSalas+2018,Capozzi+2017

- cosmological observations (indirectly)

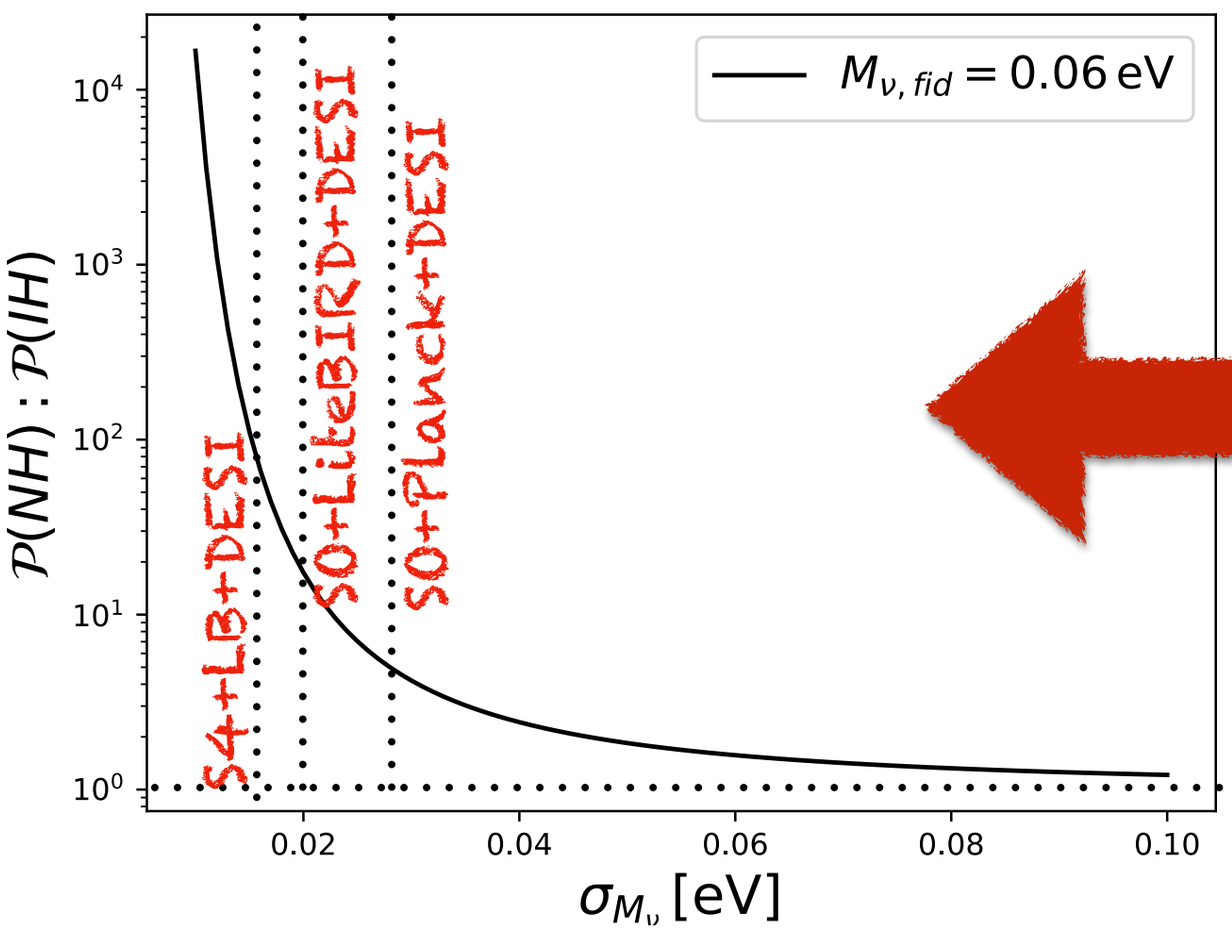
mild preference fro NH

MG+2017,Vagnozzi+2017,Gariazzo+2018,Mahony+2019

- neutrinoless double beta decay, beta decay (indirectly)

not there yet

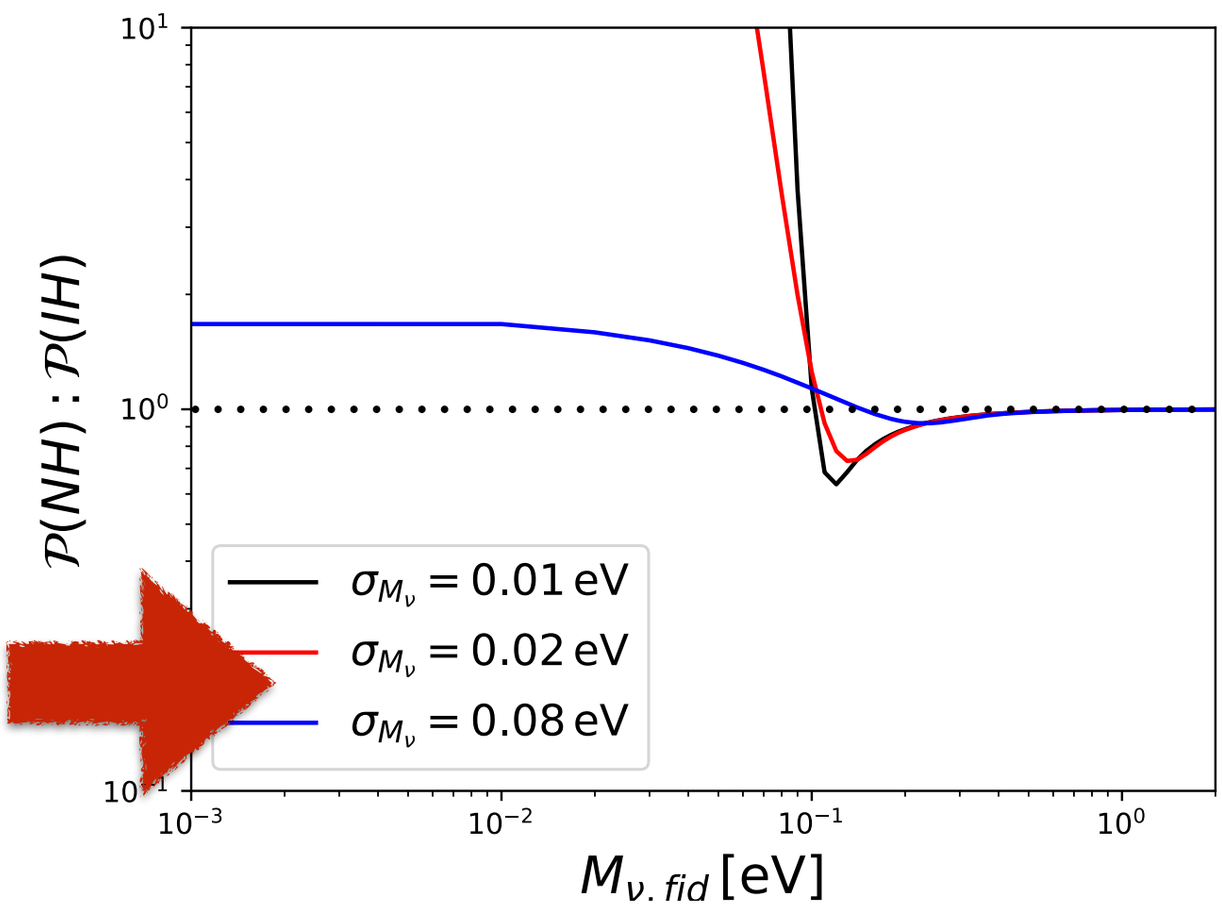
Sensitivity to the hierarchy



MG, Lattanzi, Mena&Freese 2017
Adapted from TeVPA2017
see also talk by C.Mahony

Fixed fiducial
As sigma increases, NH is as likely as IH

Fixed sigma
NH favoured for Mnu<0.1eV, IH favoured for Mnu~0.1eV, no preference for Mnu>0.1eV

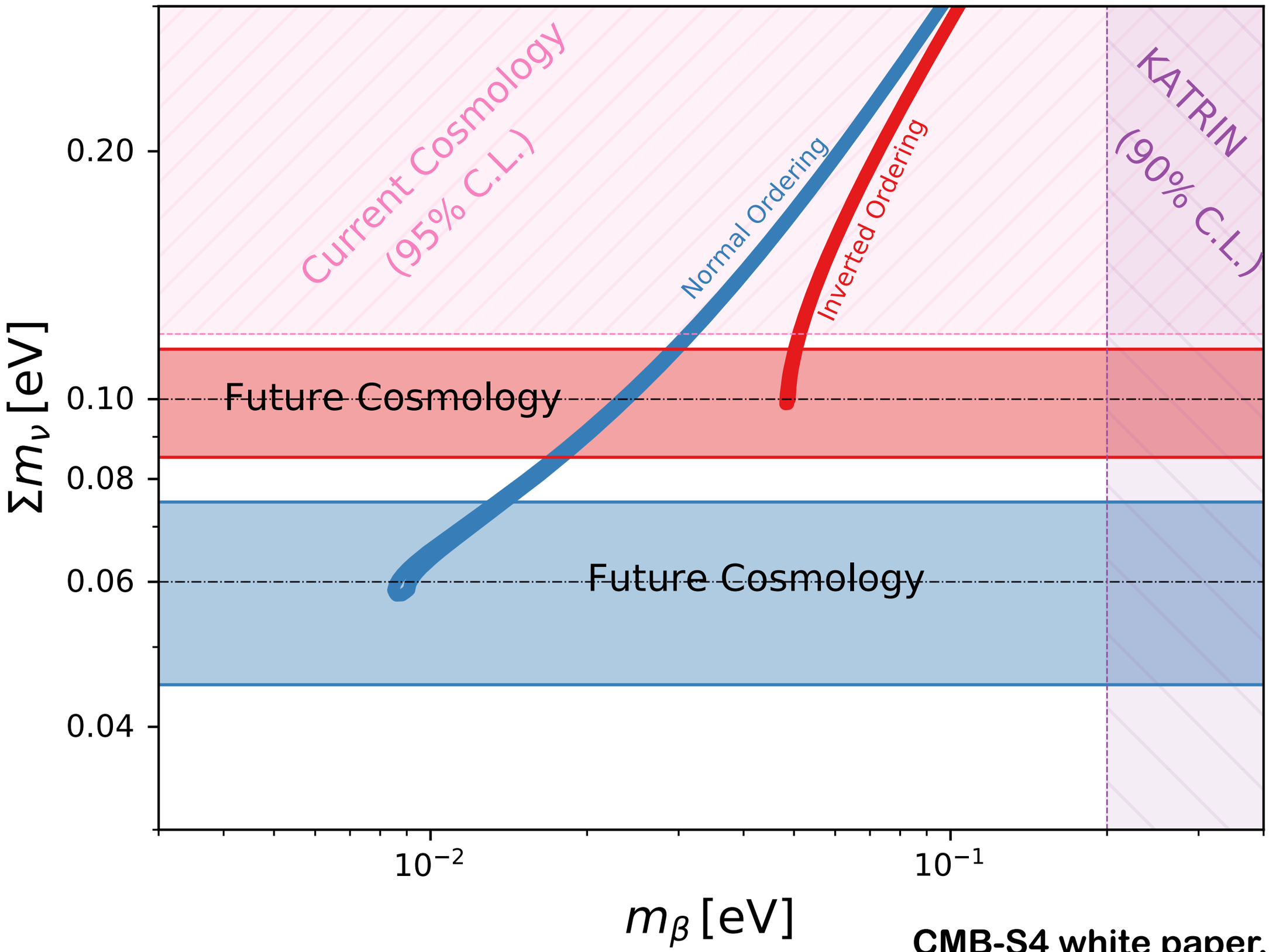


The neutrino nature can be measured through:

- neutrinoless double beta decay

not there yet

- combination with other probes of the mass scale can help



CMB-S4 white paper, 2019

Detection scenarios

IF…THEN…ELSE…

Concordant signals from both cosmology and 0nu2b. Neutrinos are Majorana. Hierarchy might be determined or not.

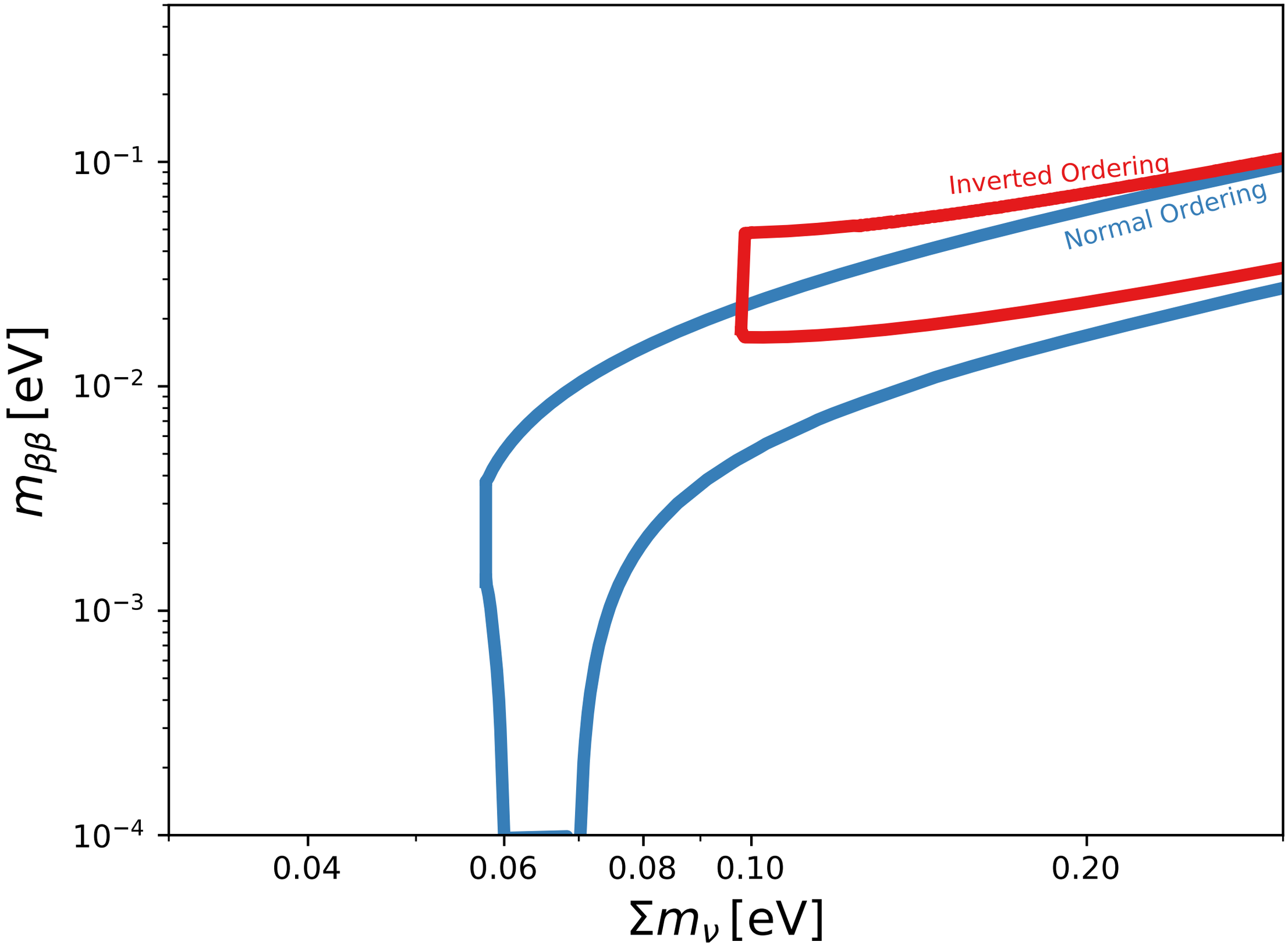
Signal from cosmology with Mnu<0.1 eV, no signal from 0nu2b. Hierarchy is normal. Majorana/Dirac undetermined.

Signal from cosmology with Mnu > 0.1 eV, no signal from 0nu2b. Neutrinos are Dirac. Hierarchy is undetermined.

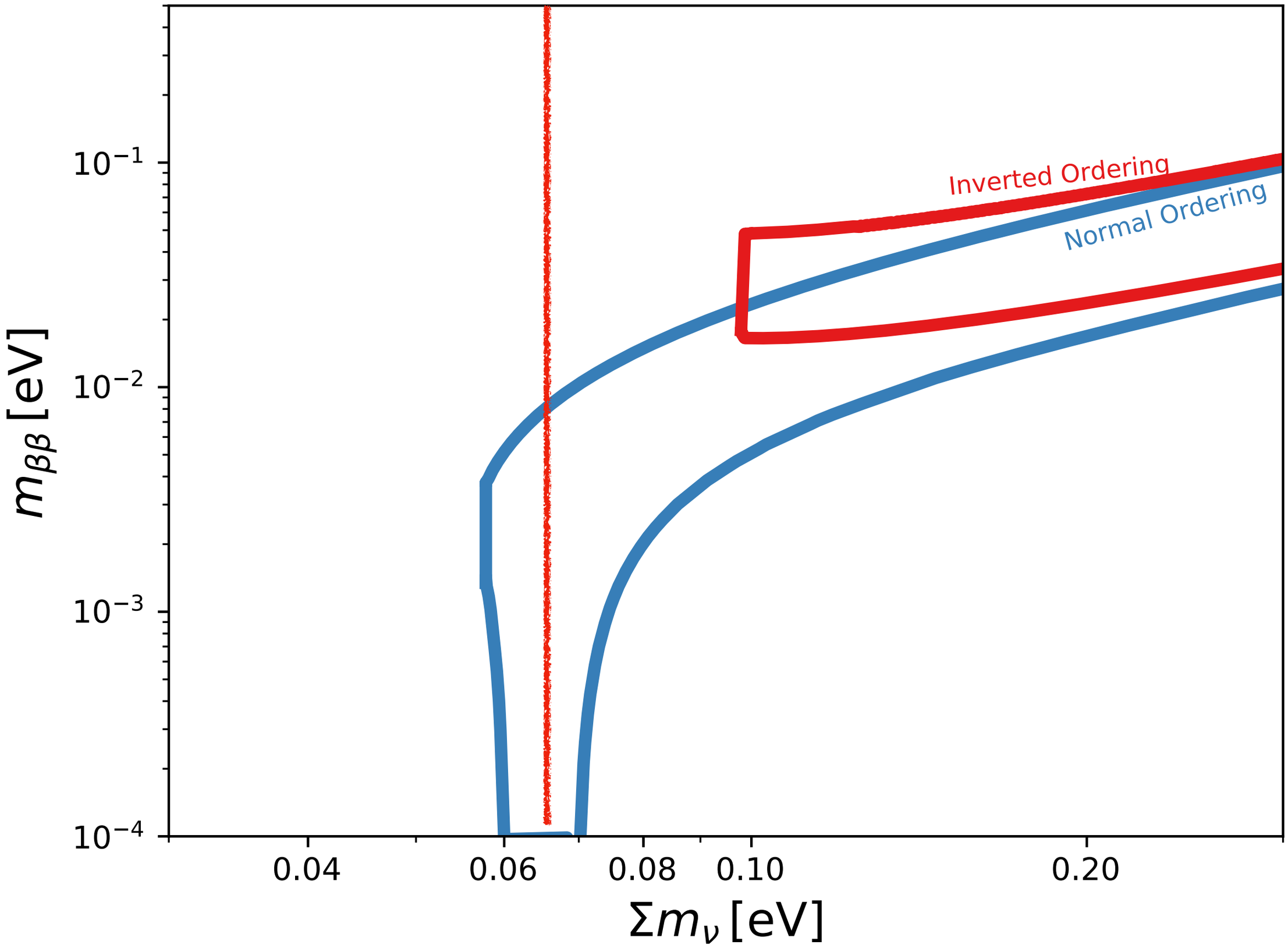
No signal from cosmology, signal from 0nu2b. OR we see discordant signals. Neutrinos are Majorana. New physics? E.g. BSM neutrino interactions?

Courtesy of M.Lattanzi
MG, Lattanzi, Mena&Freese 2017
See also CMB-S4 white paper 2019
Dvorkin, MG+2019

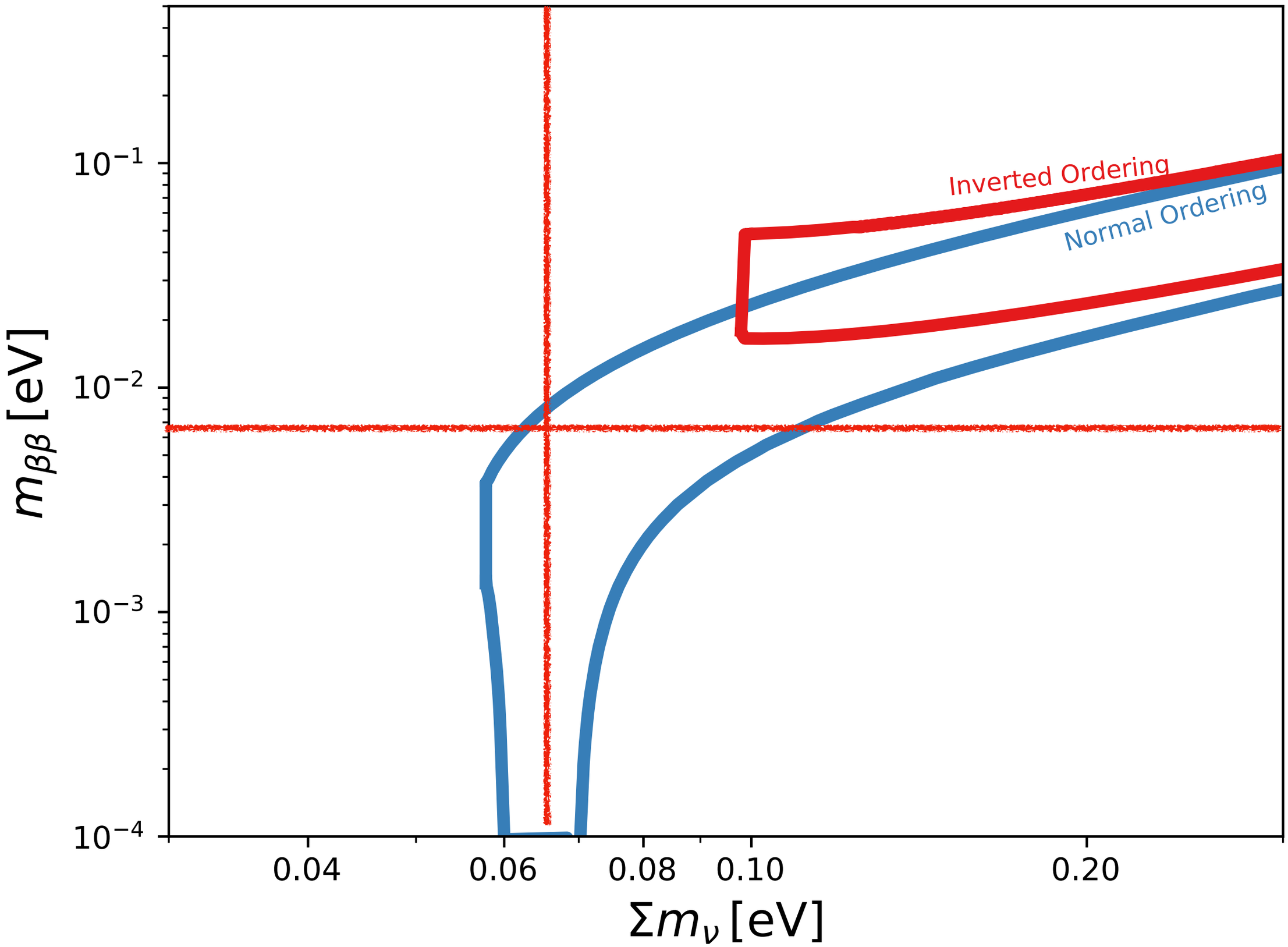
95%CL regions from NuFit
Courtesy of C.Gonzales-Garcia



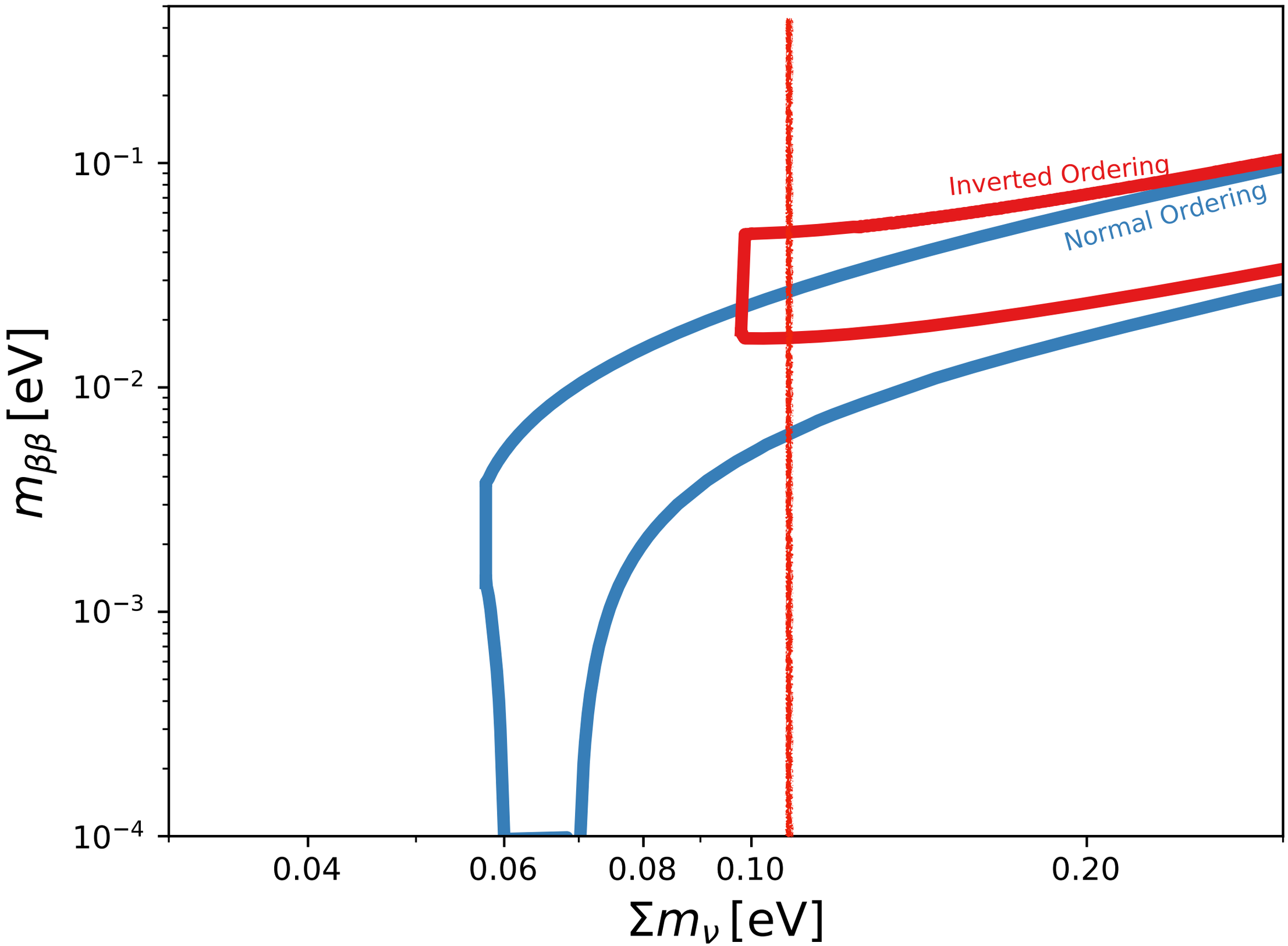
Hierarchy: normal; Nature: undetermined



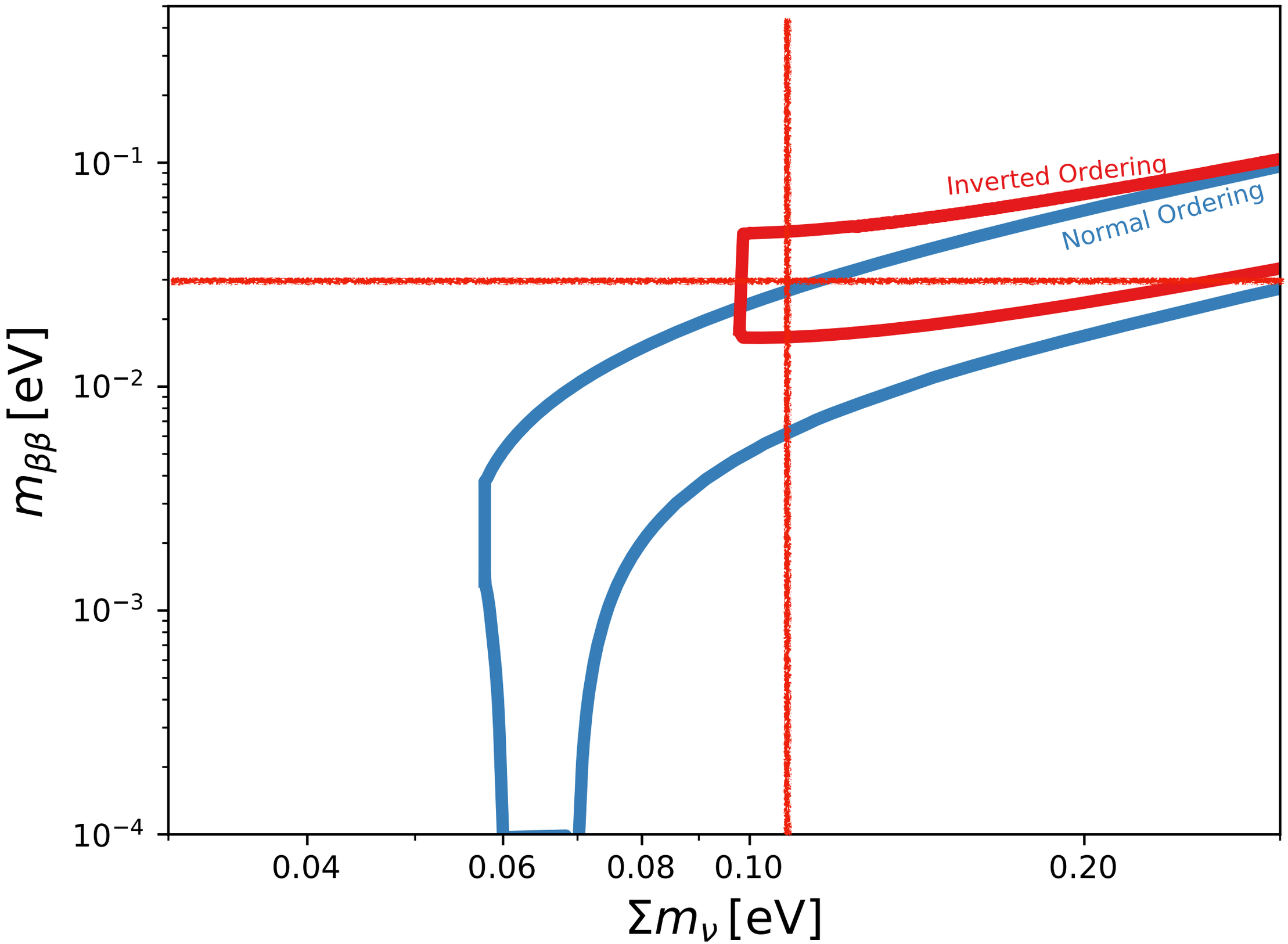
Hierarchy: normal; Nature: Majorana



Hierarchy: undetermined; Nature: Dirac?

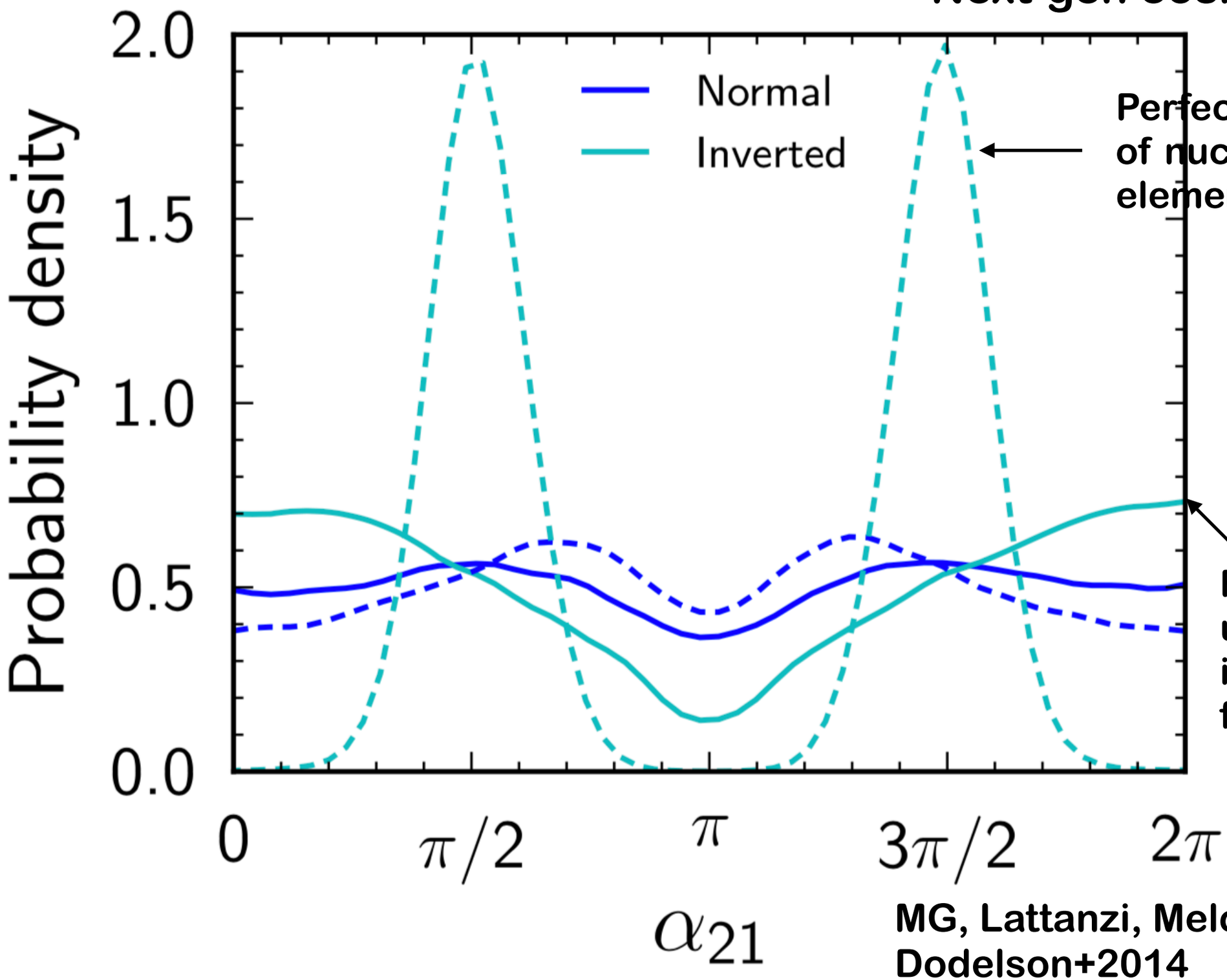


Hierarchy: undetermined?; Nature: Majorana



Measuring the Majorana phases?

Next-gen cosmo+0nu2b

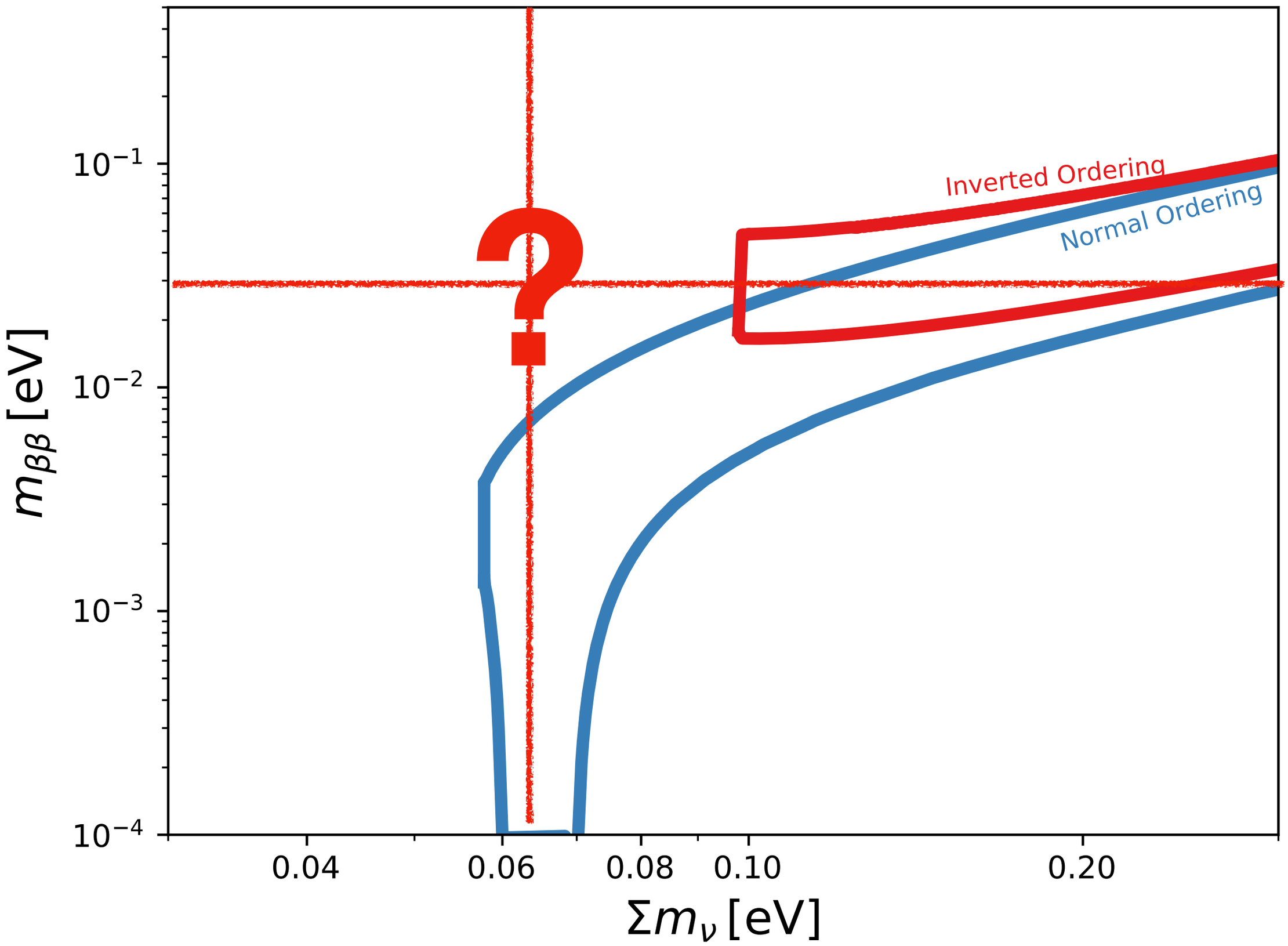


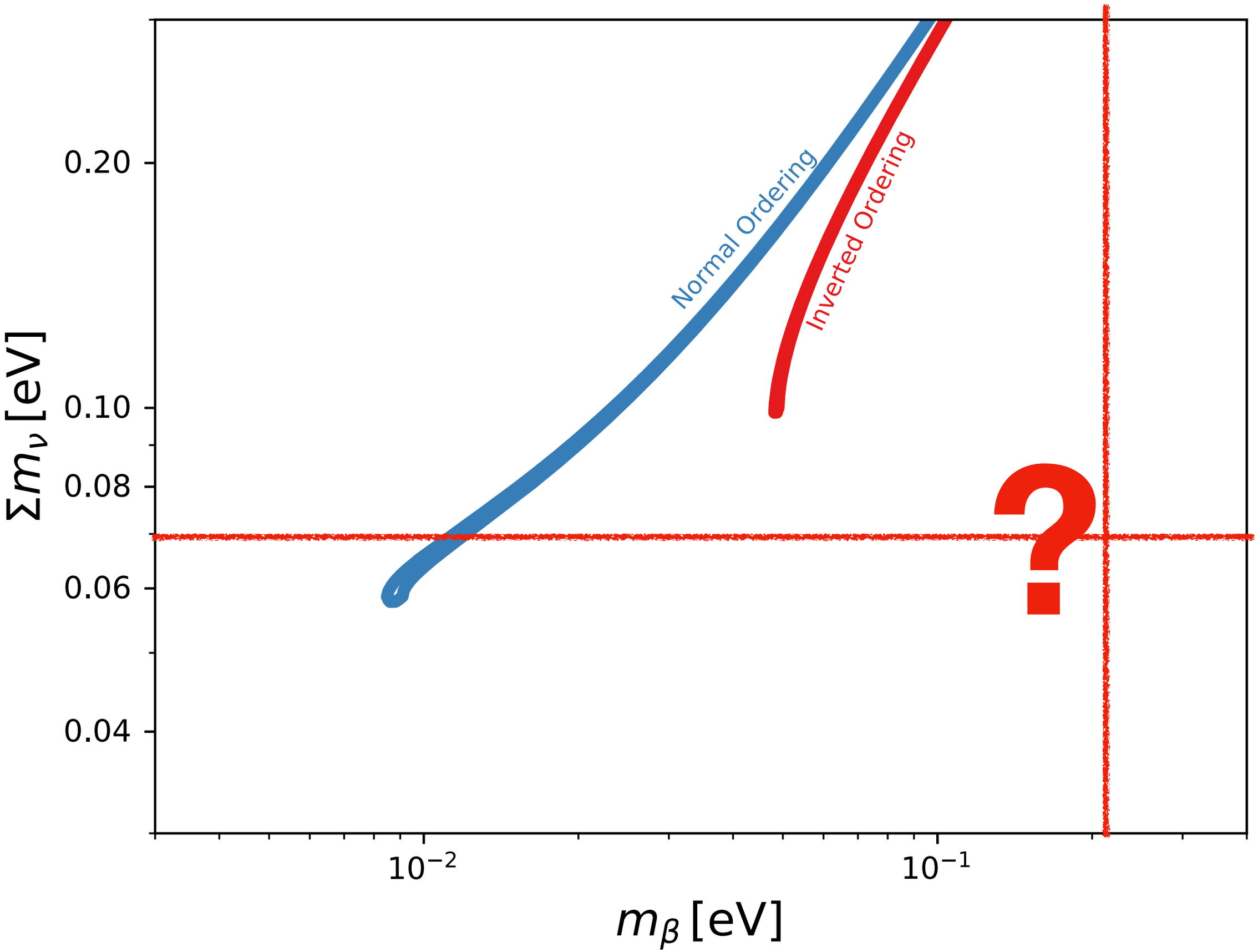
Perfect knowledge of nuclear matrix elements

Factor~2 uncertainty in NME folded in

MG, Lattanzi, Melchiorri 2017
Dodelson+2014
CMB-S4 Science Book 2016

Beyond-standard-model physics?




Normal Ordering
Inverted Ordering
?
0.20
0.10
0.08
0.06
0.04
Σm_ν [eV]
10^{-2}
10^{-1}
m_β [eV]

Beyond-standard-model physics?

Discordant signals could hint to new physics:

- non-standard neutrino interactions
- non-standard cosmological model
- additional (sterile) species
- ...

We can test these scenarios with future facilities

Synergy is the key!

Conclusions

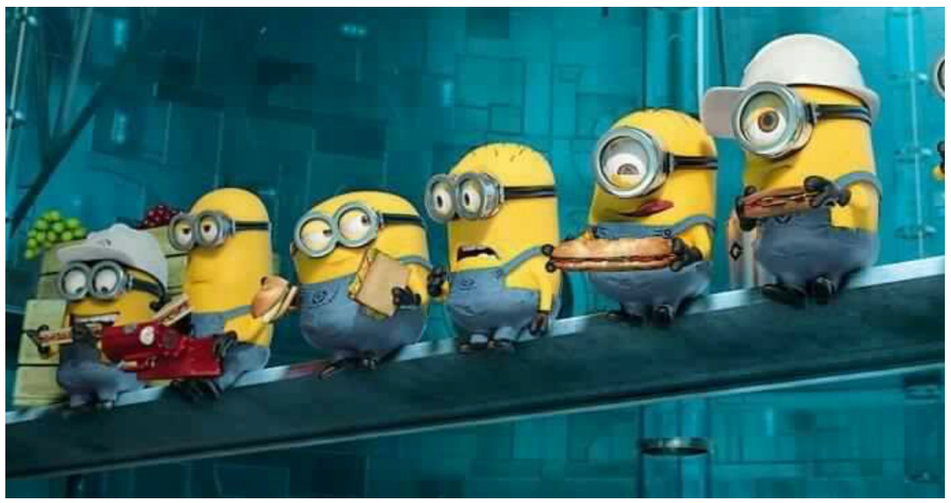
Terrestrial facilities and cosmological surveys are complementary probes of neutrino physics

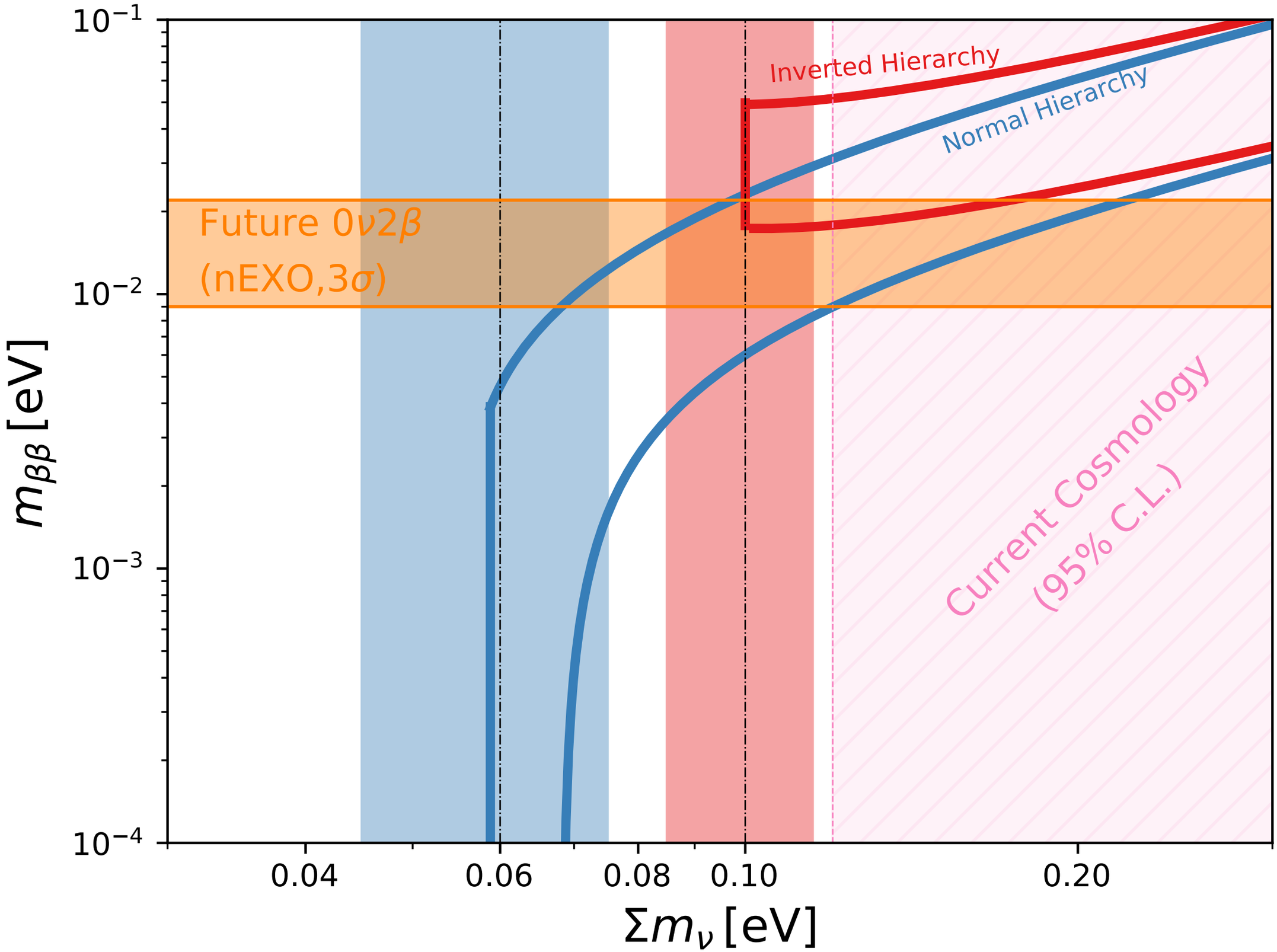
They are (or will be) competitive in sensitivity

A synergic approach can strengthen constraints on neutrino properties

Or can unveil hints to new physics in the neutrino sector

...and now let's have coffee!




Inverted Hierarchy
Normal Hierarchy
Future 0ν2β
(nEXO,3σ)
Current Cosmology
(95% C.L.)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$m_{\beta\beta}$ [eV]
0.04
0.06
0.08
0.10
0.20
Σm_ν [eV]