The NEMO-3 and SuperNEMO experiments

M. Cascella
(for the NEMO-3 and SuperNEMO collaborations)

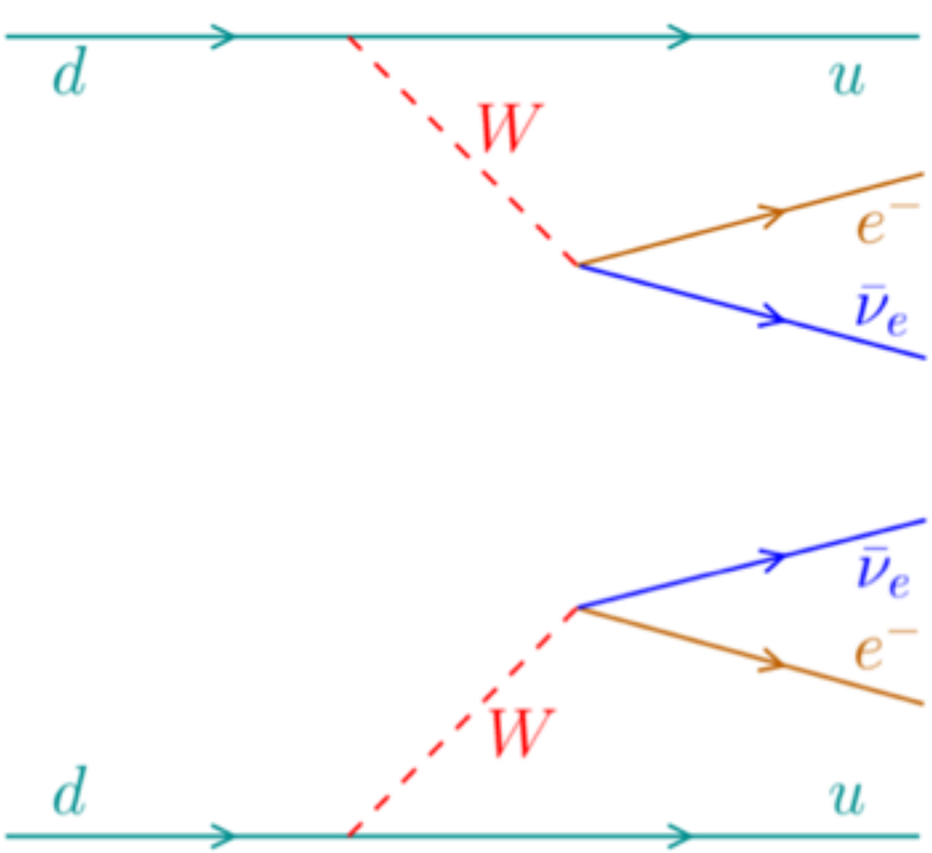
22/05/2017 TIPP2017

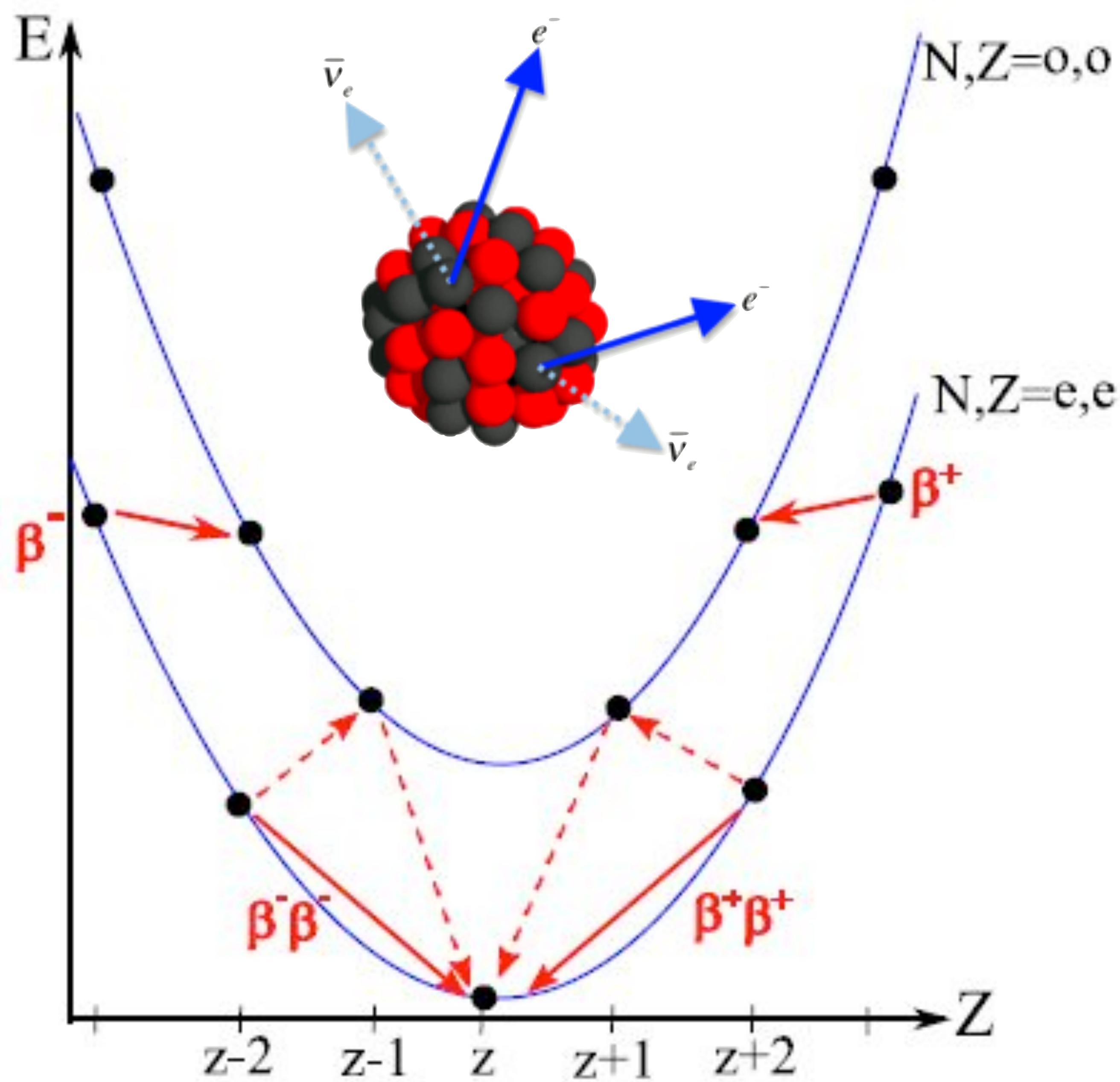
Introduction

- Double beta and neutrinoless double beta decay
- NEMO-3 results
- SuperNEMO demonstrator module

Double β decay

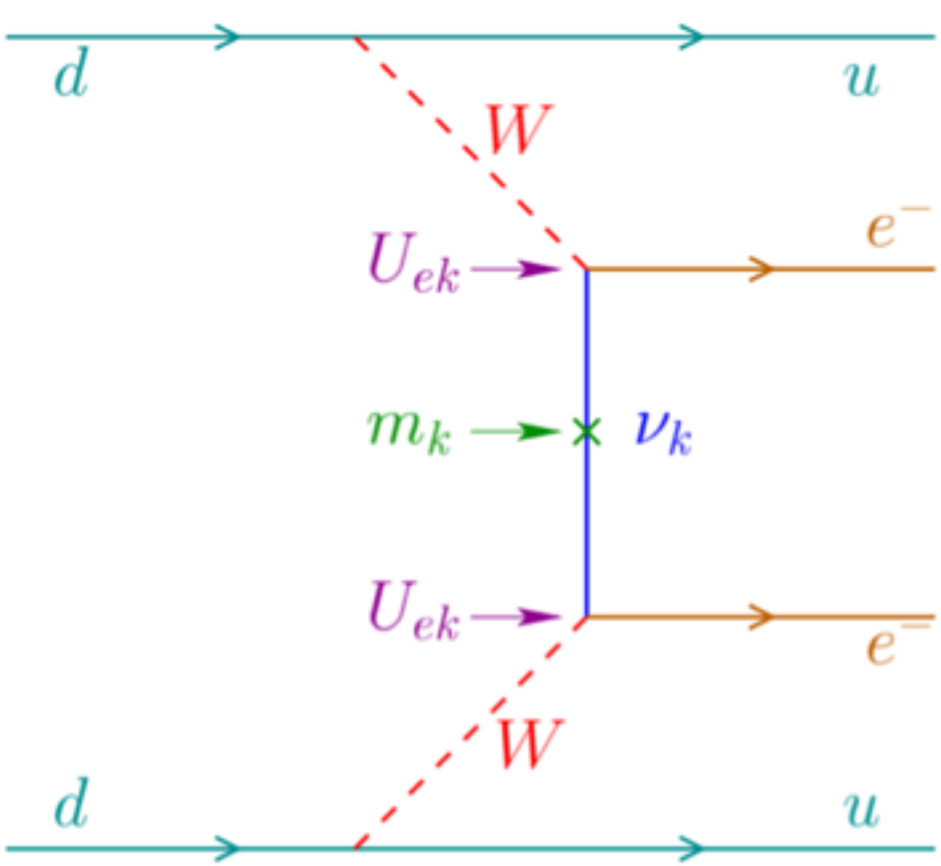
Analogue to β decay, for cases where the Z±1 is forbidden (heavier nucleus) but Z±2 is allowed.

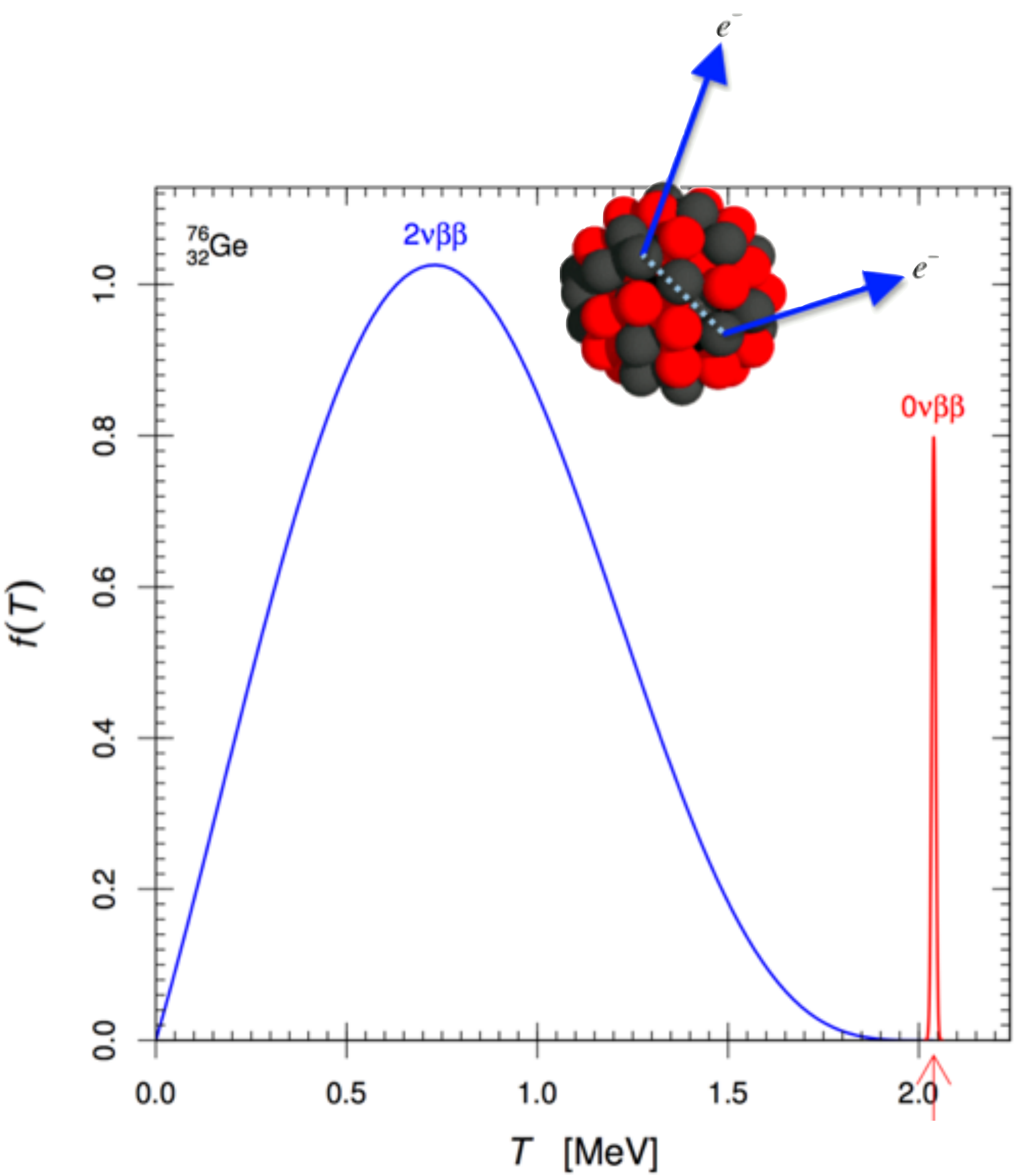




Neutrinoless double β decay

- If neutrinos are Majorana fermions 0v2β is allowed
- electrons~few MeV

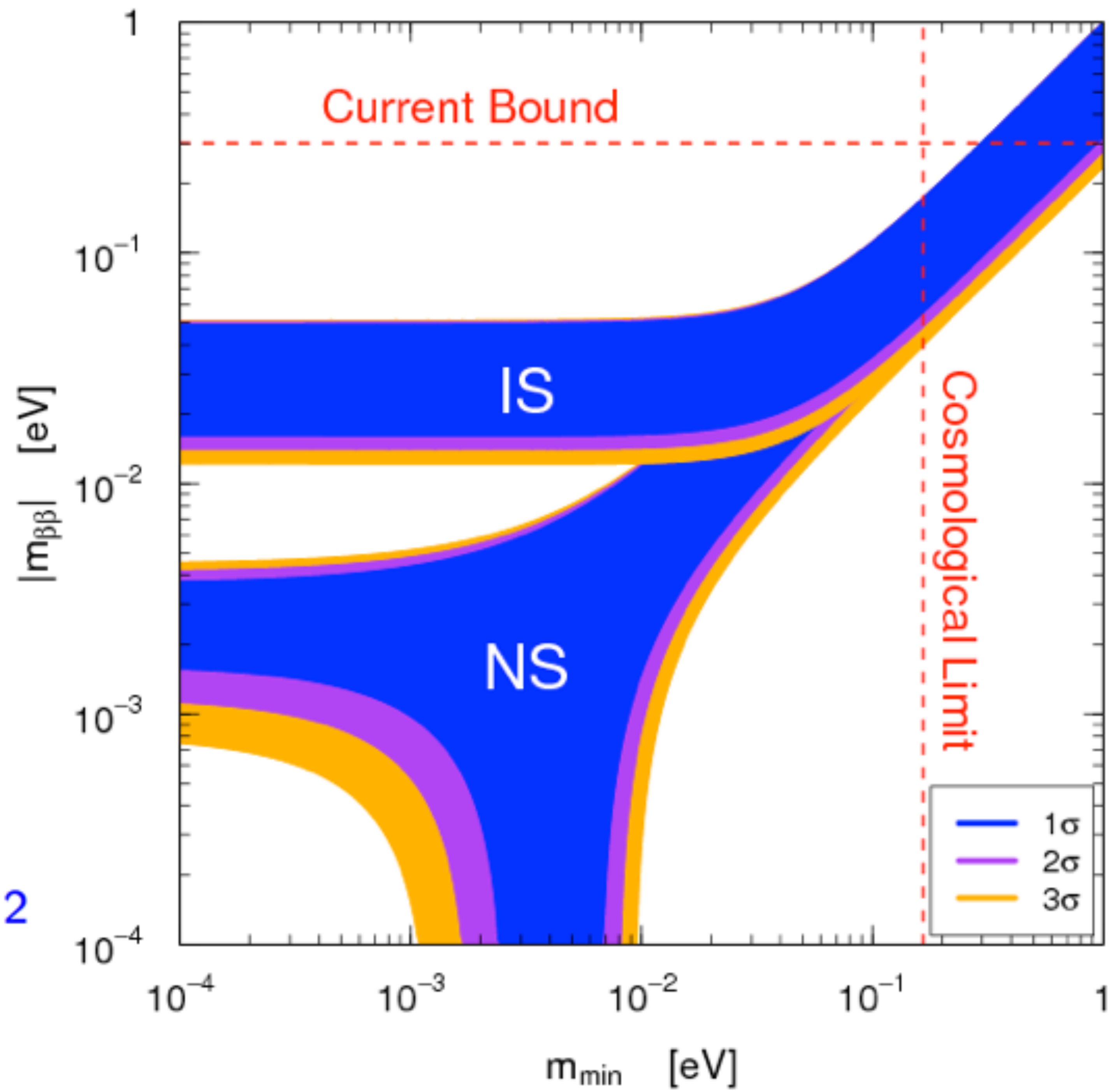




Why is 0ν2β interesting?

- Lepton number violation
- New physics
- Neutrino mass and mass ordering

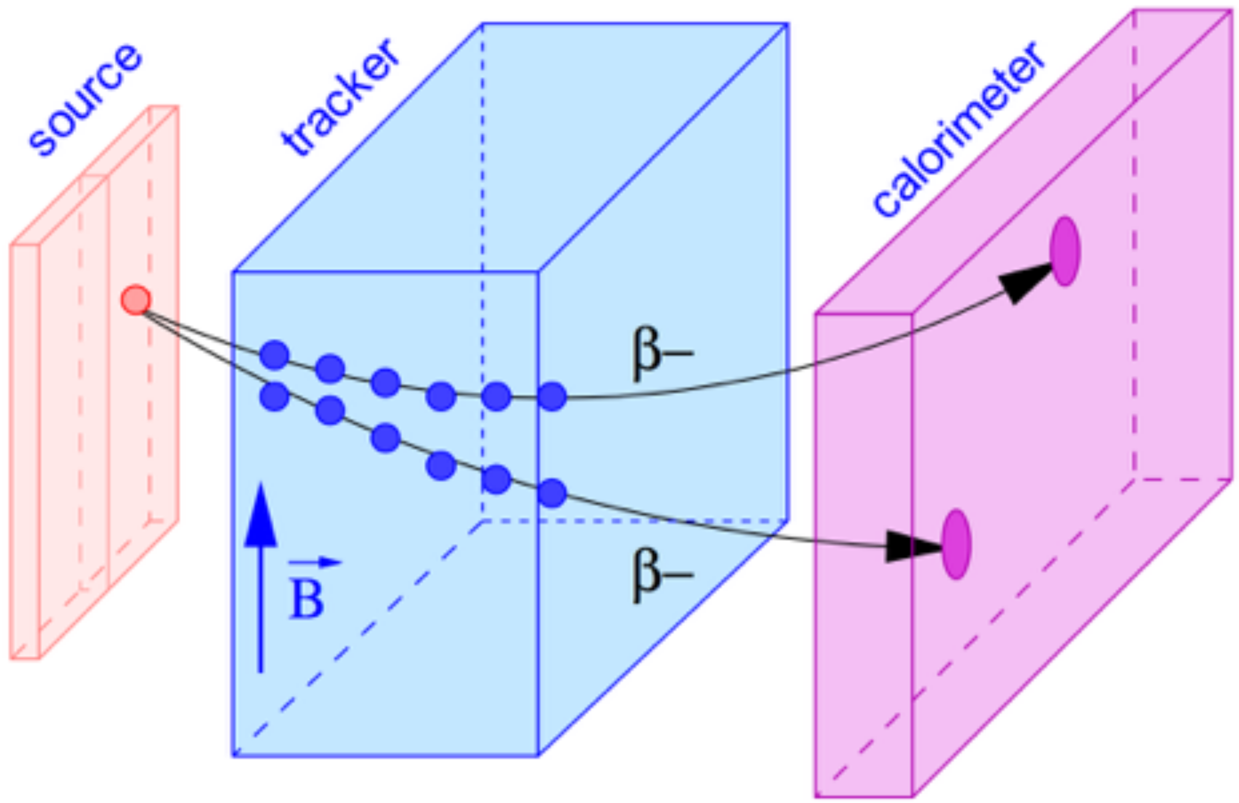
$$(T^{0\nu}_{1/2})^{-1} = G_{0\nu}\,|\mathcal{M}_{0\nu}|^2\,|m_{\beta\beta}|^2$$

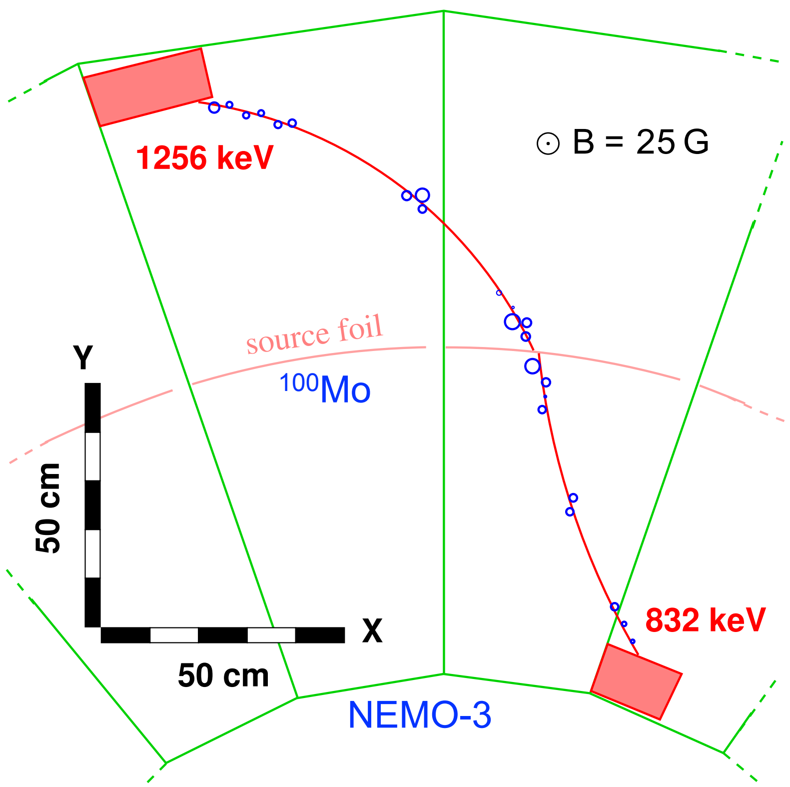


NEMO-3

NEMO design principles

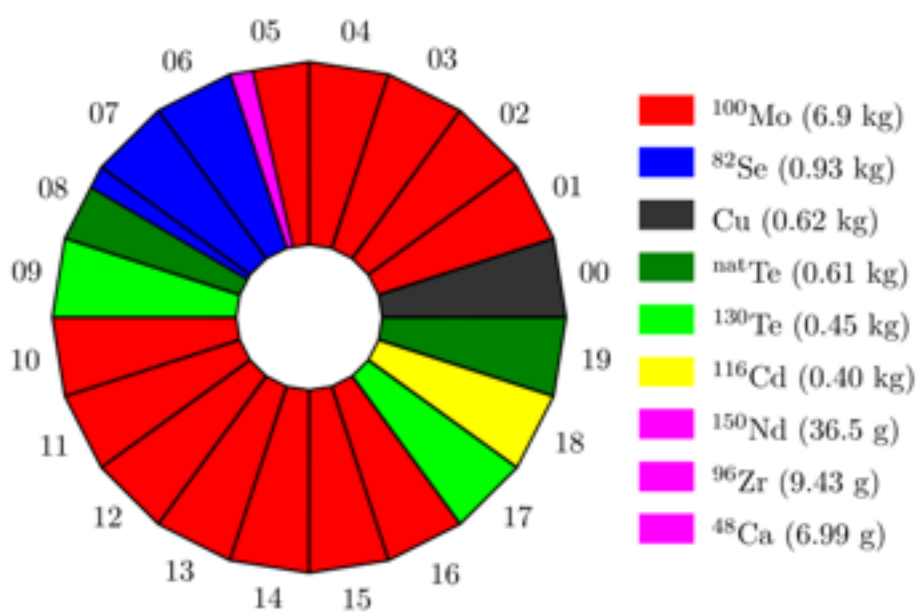
- Source independent from detector
- Compromise between calorimeter resolution / tracking
- Topological information, timing and particle tagging
    - Background suppression and BSM decays





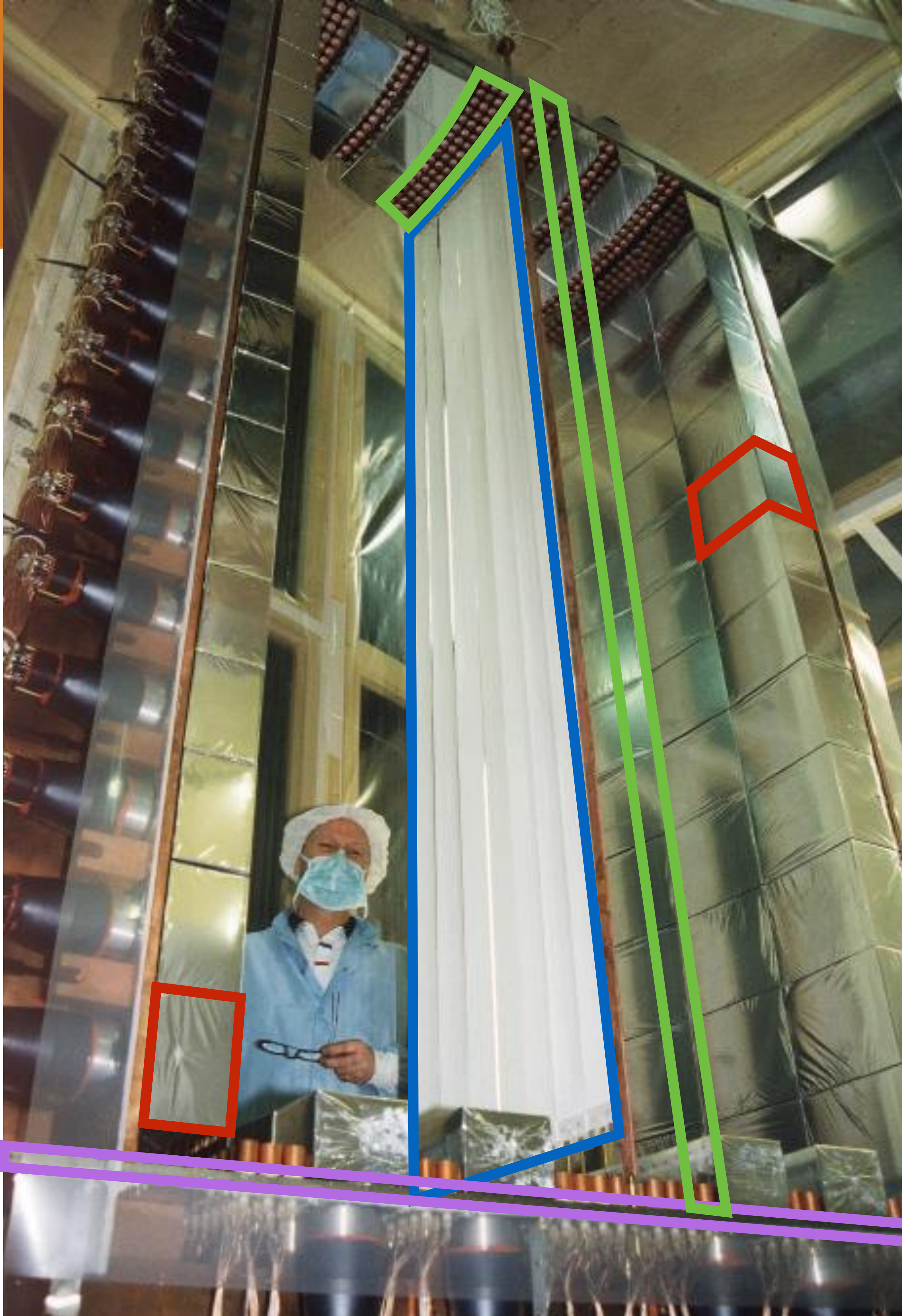
NEMO-3

- Active from 2003 to 2011
- Hosted in Frejus tunnel (1700m, 4800 w.e.m. 10^{-6}x cosmics)
- 7x 2β and several calibration sources



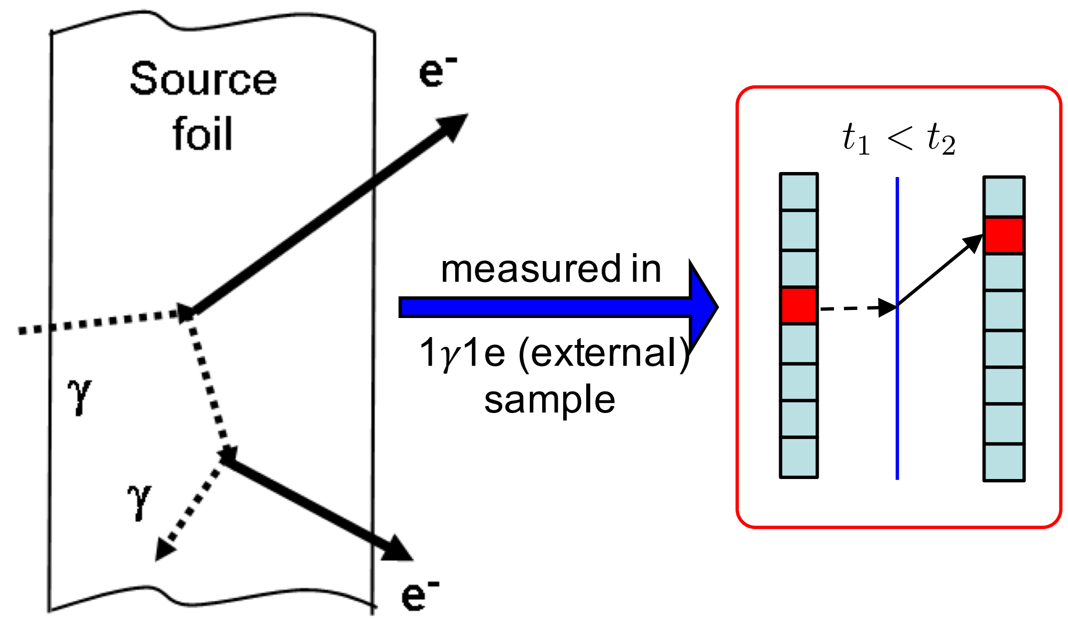
NEMO-3 structure

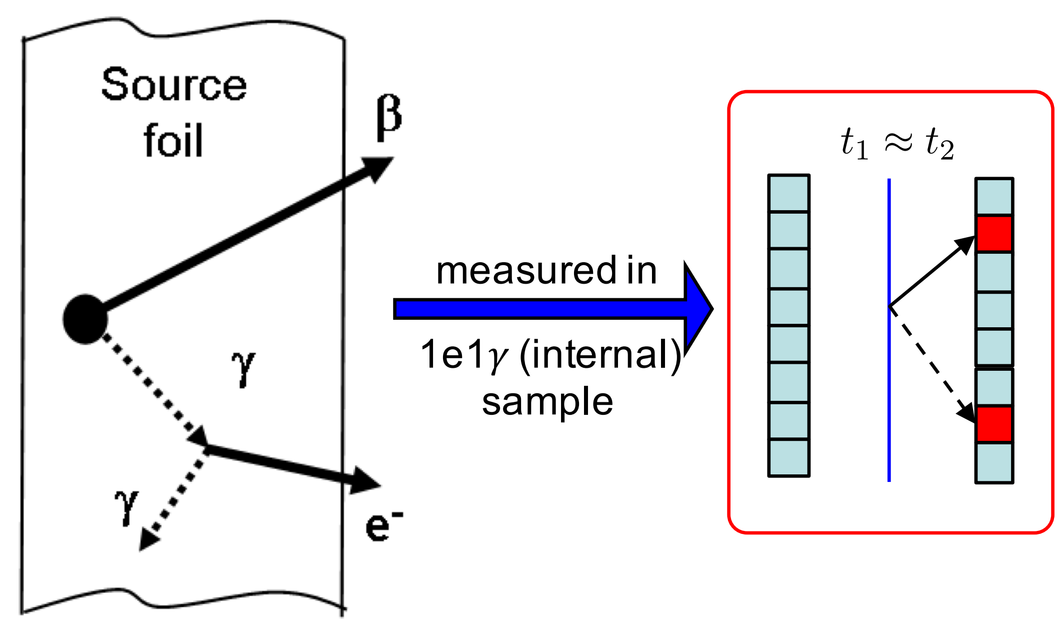
1. Source strips
2. 3D tracking multi-wire Geiger cells
3. PS scintillator with low activity PMTs
4. Cu/Fe frame

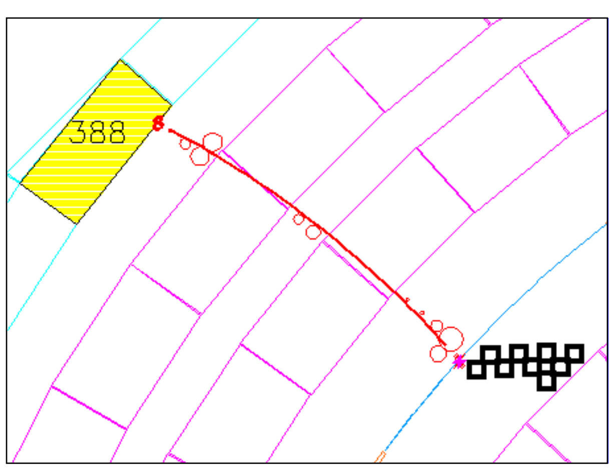


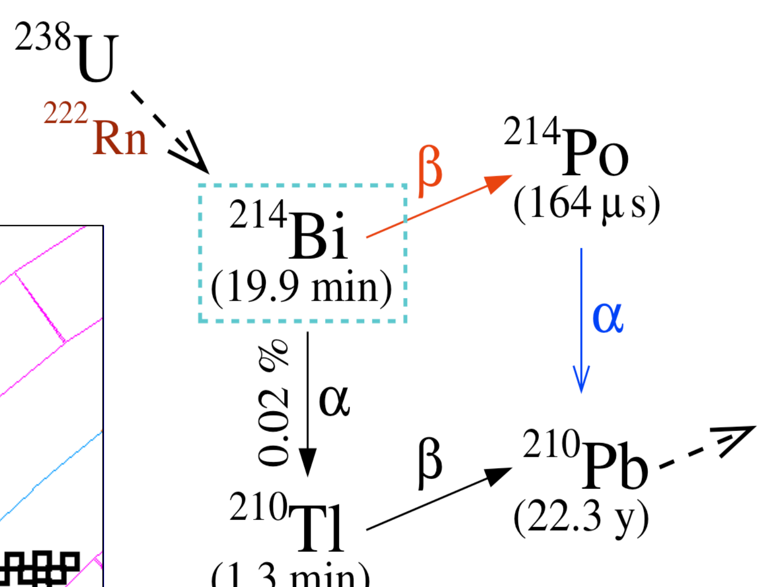
Bismuth and Radon

- Tracker essential in rejecting background
- Internal contaminations
- External radiation
- ^{214}Bi (Q_β = 3.3 MeV)
  - α tagging









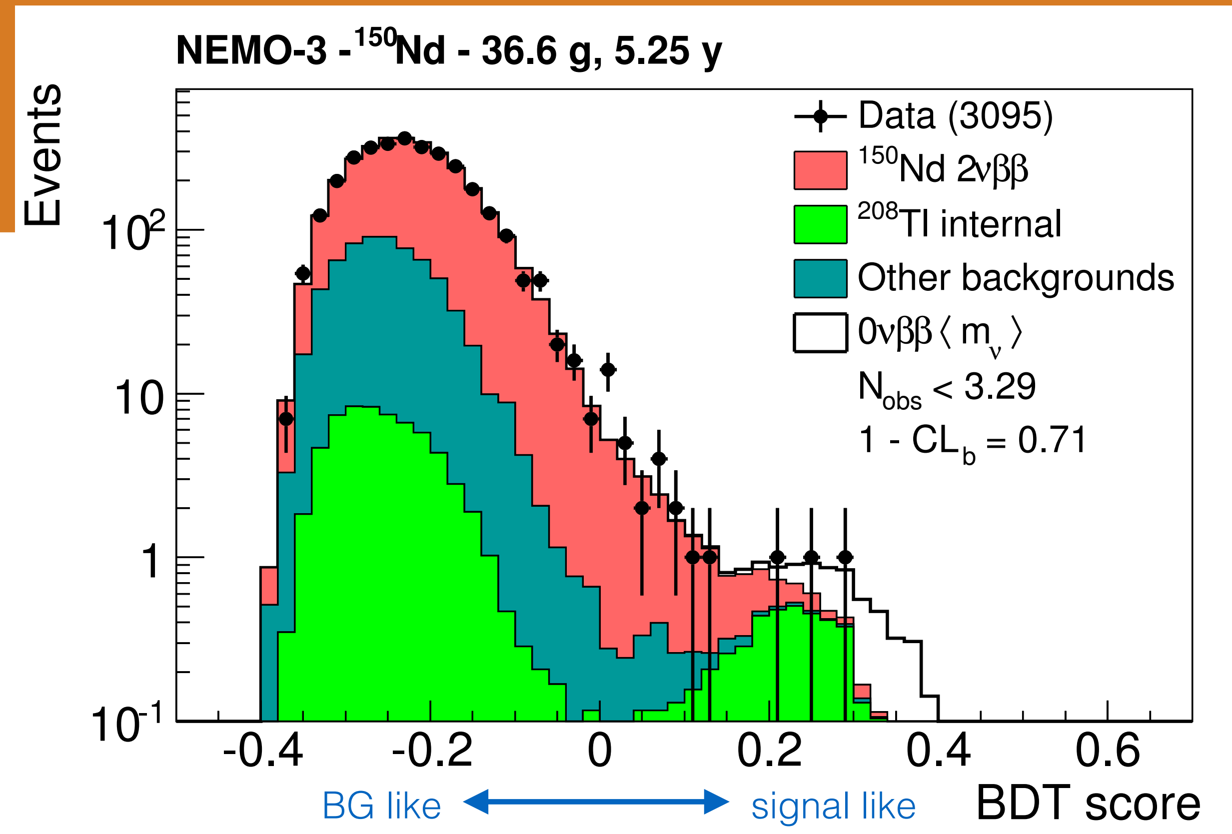
^{150}Nd

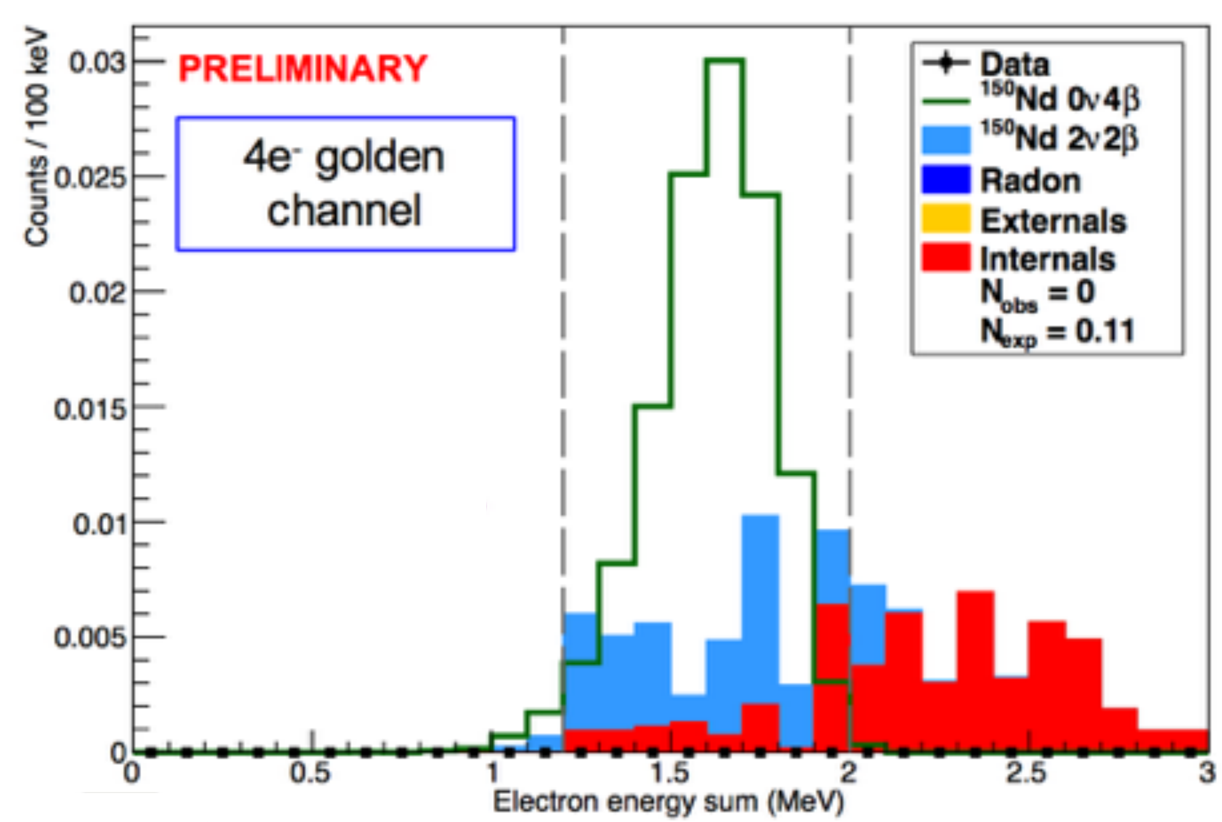
- Large $Q_{\beta\beta}$ = 3.4 MeV and phase space (36.6 g of isotope)
- BDT using 10 kinematic variables
- Quadruple beta decay search

$$T_{1/2}^{0\nu\beta\beta} > 2.0 \times 10^{22}\,\mathrm{yr}\,(90\%\,\mathrm{C.L.})$$

$$T_{1/2}^{2\nu} = [9.34 \pm 0.22\,(\mathrm{stat.})\,^{+0.62}_{-0.60}(\mathrm{syst.})] \times 10^{18}\,\mathrm{yr}$$

- Phys. Rev. D 94 072003



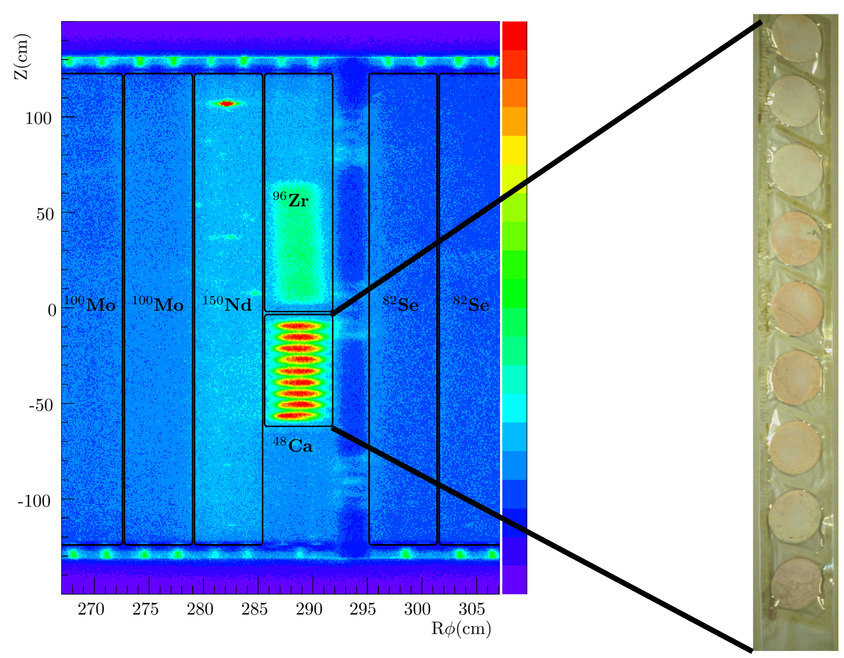


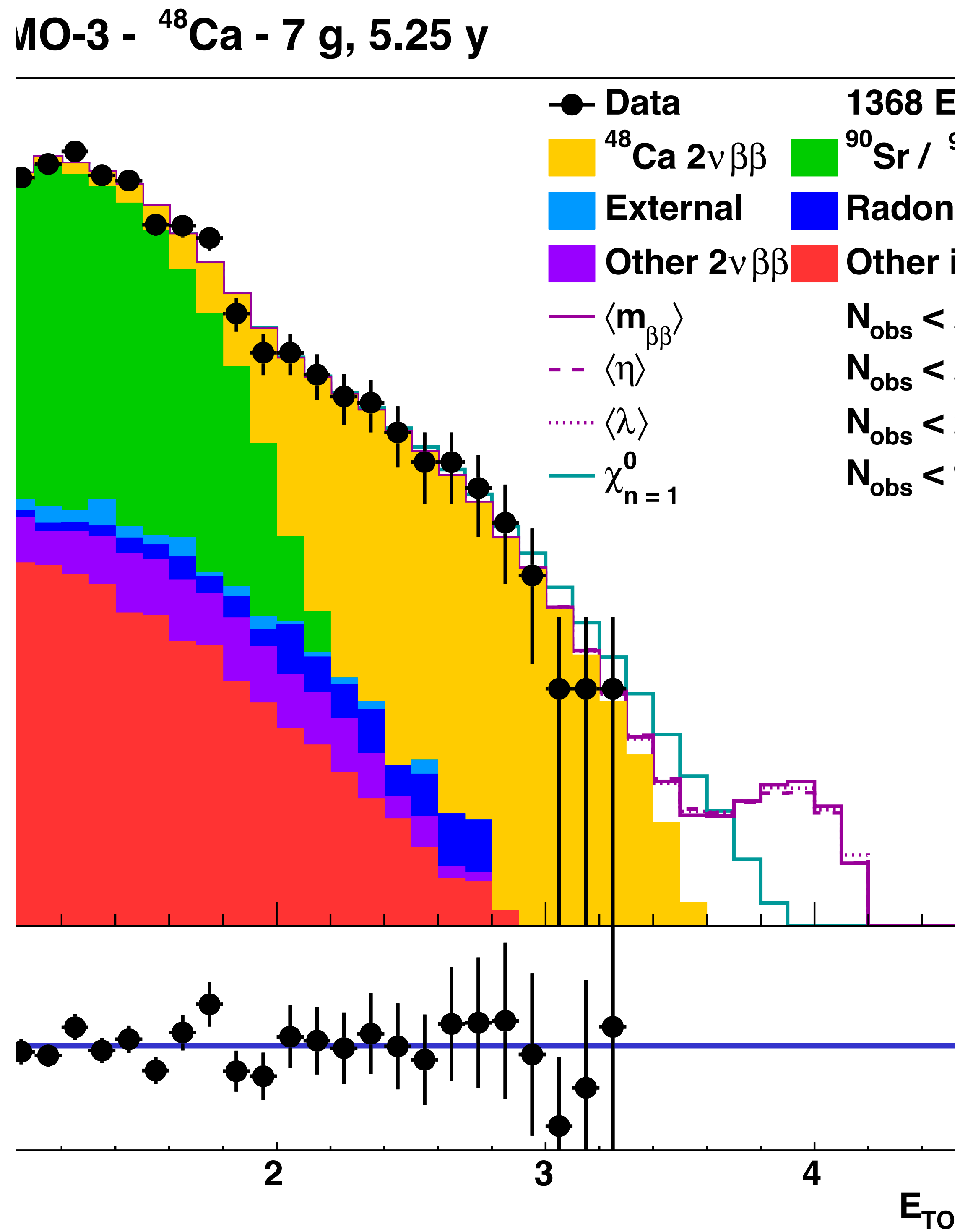
^{48}Ca

- highest $Q_{\beta\beta}$ = 4.3 MeV
- 7g of isotope
  (~300 2v2β events)

$$T^{2\nu}_{1/2} = [6.4\,^{+0.7}_{-0.6}(\mathrm{stat.})\,^{+1.2}_{-0.9}(\mathrm{syst.})] \times 10^{19}\ \mathrm{yr}$$

- Phys. Rev. D 93, 112008



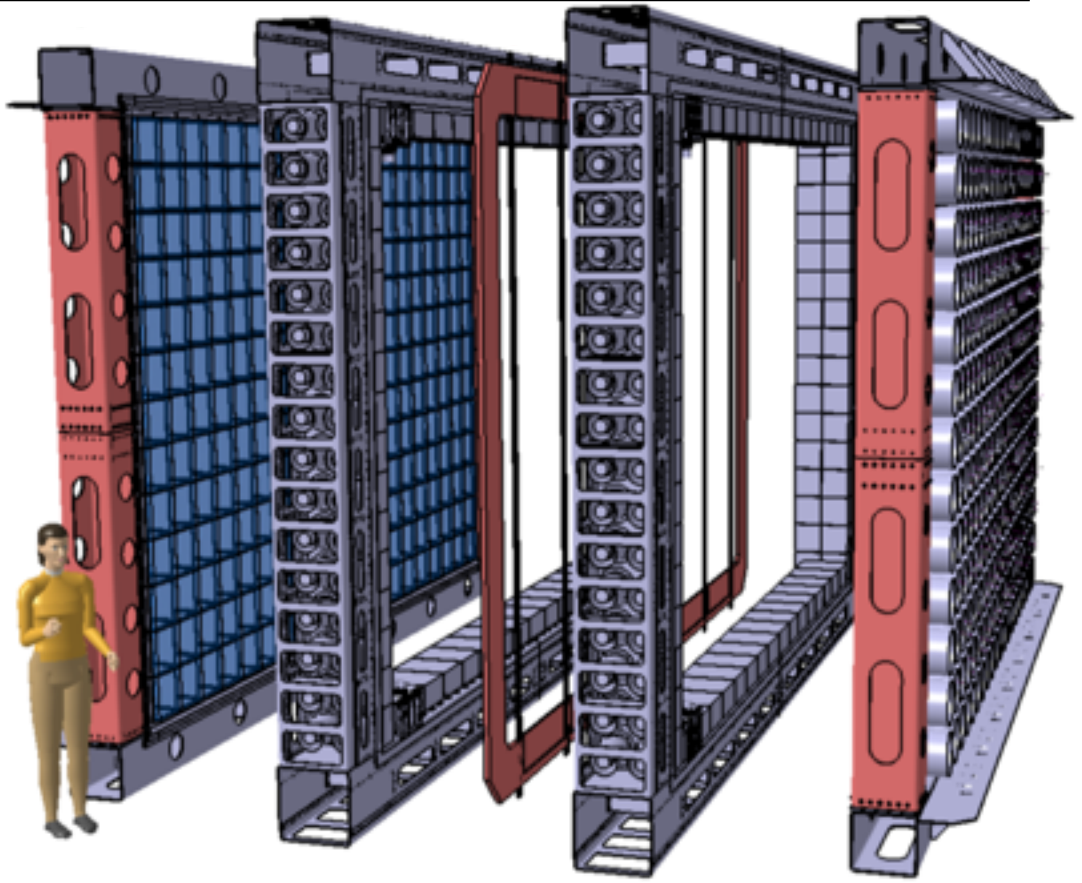


SuperNEMO

SuperNEMO

NEMO-3		SuperNEMO
^{100}Mo	isotope	^{82}Se (or ^{150}Nd)
7 kg	isotope mass	7 (demonstrator) ➔ 100 kg
5 mBq/m^3	radon	0.15 mBq/m^3
^{208}Tl: 100 µBq/kg ^{214}Bi: 300 µBq/kg	internal contamination	^{208}Tl ≤ 2 µBq/kg ^{214}Bi ≤ 10 µBq/kg
14% @ 1 MeV	Calorimeter	8% @ 1 MeV

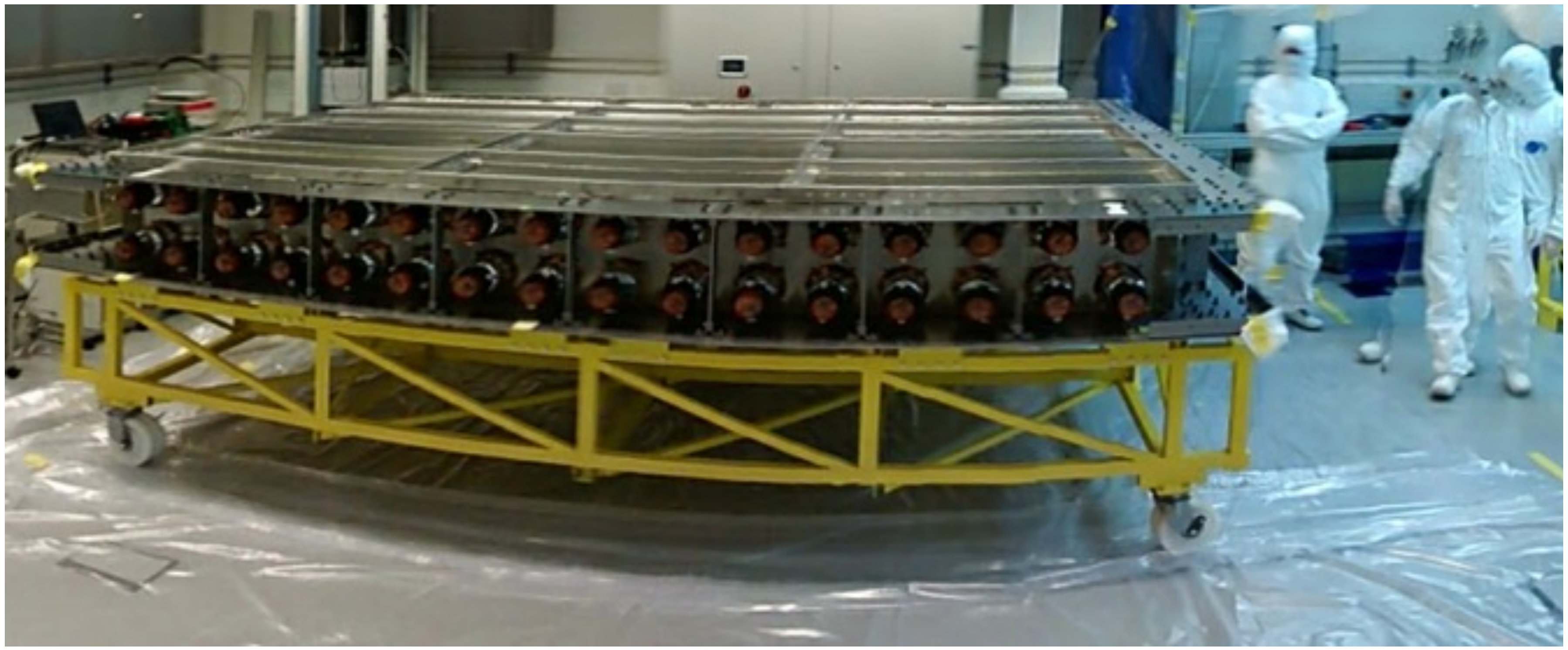
- Next gen demonstrator
- Modular design
- Better hermeticity



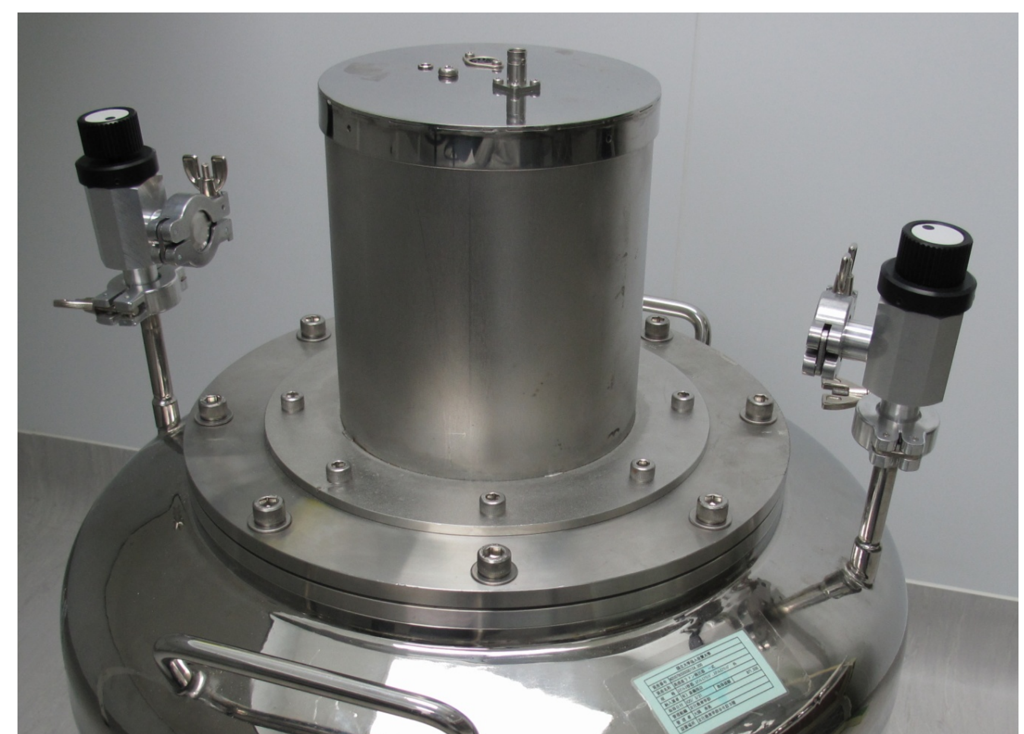
The SuperNEMO tracker

- Restricted materials: copper, steel, duracon. HPGe and Rn tested
- Robotic construction of 2034 cells (~45Km of wires)
- Controlled construction, assembly and testing conditions.

Radon measurements

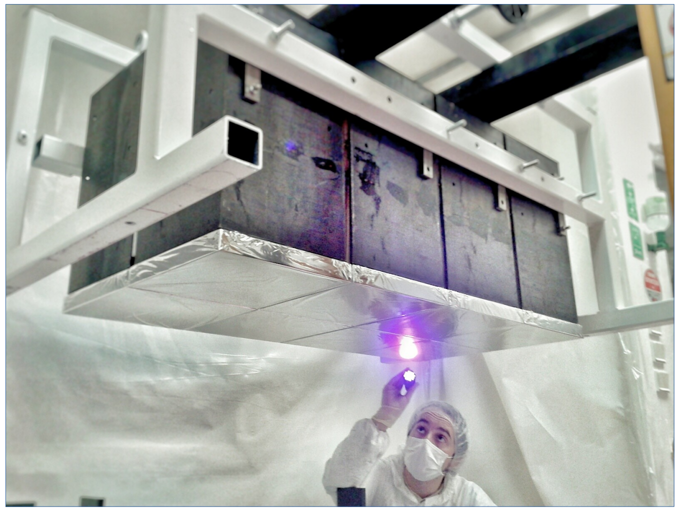


1. Purge for several $T^{1/2}$
2. Flow through cooled carbon trap
3. Release into electrostatic detector
4. Rn: 41.3 ± 4.7mBq (→150μBq/m^3 with flushing)



SuperNEMO calorimeter

- 520 x 8'' + 192 x 5'' high q.e. PM
- 8% FWHM, σ_t = 400 ps @ 1 MeV (1% stability)



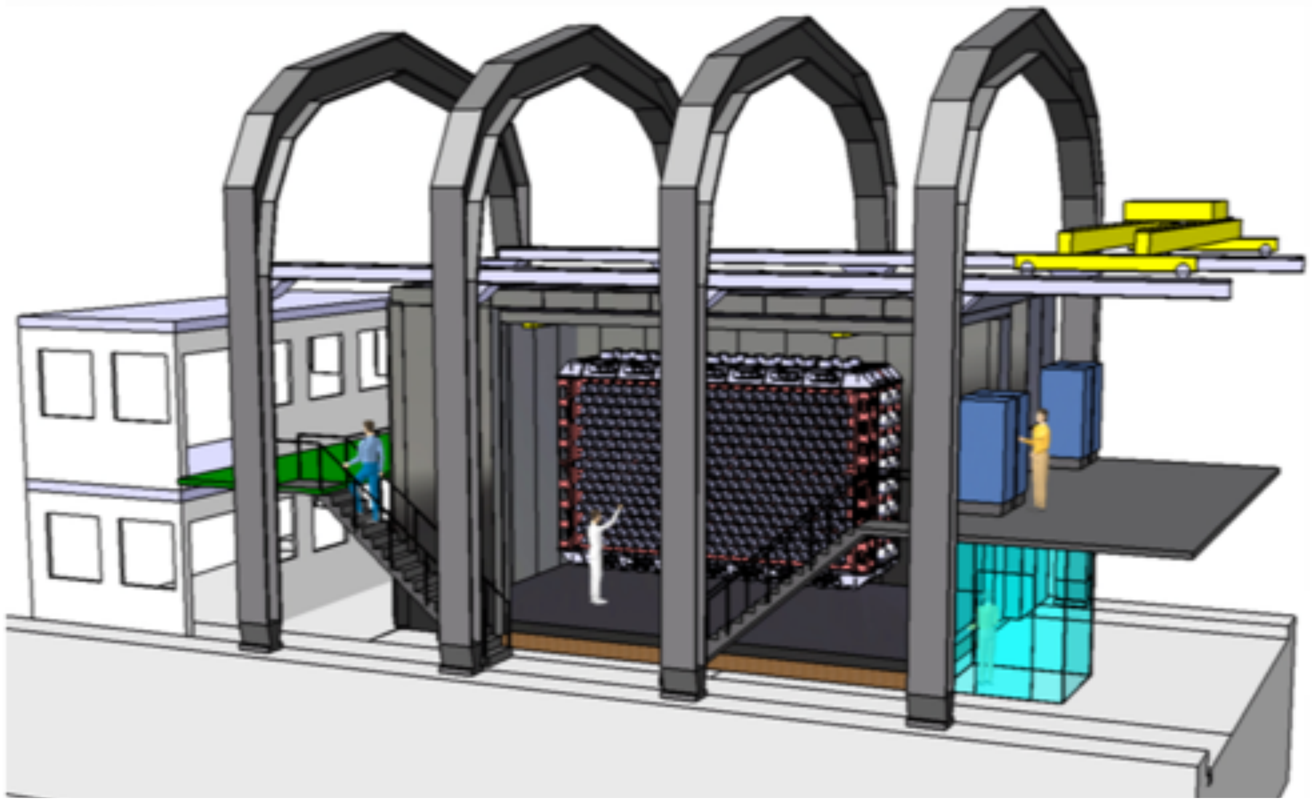
SuperNEMO source foil

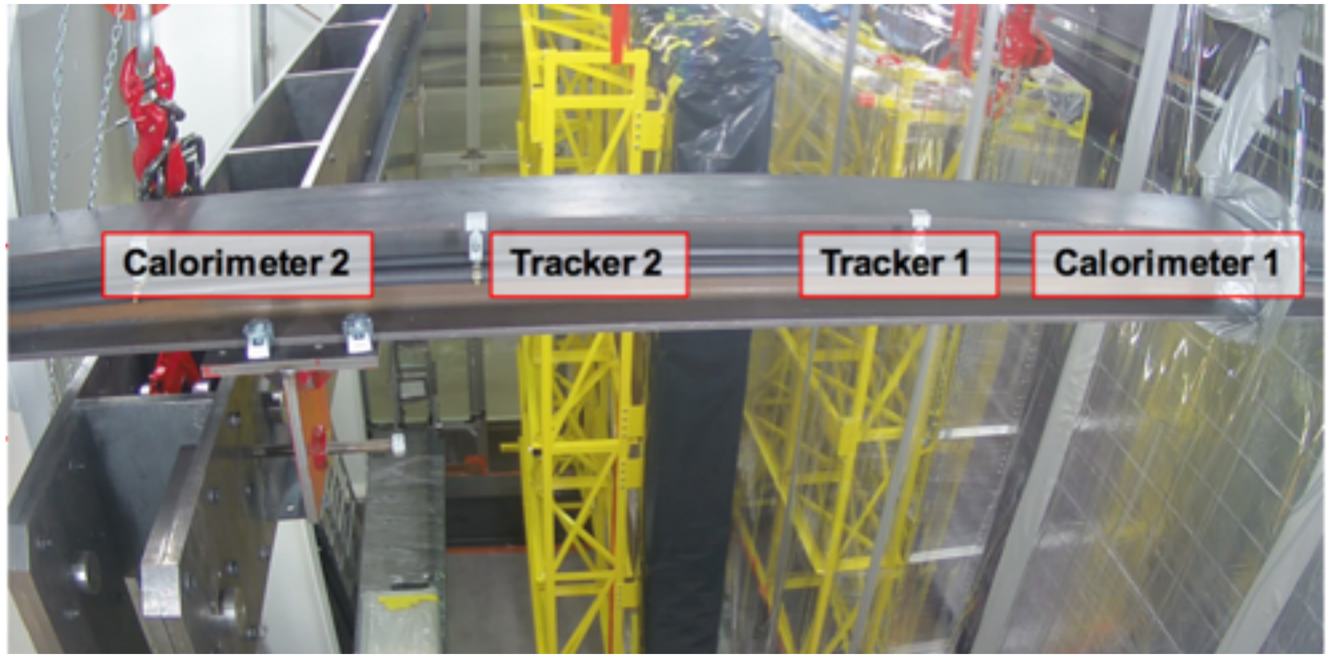
- Purification methods tested: distillation, chromatography, chemical precipitation

- All foils checked with “BiPo” to measure contamination at few μBq/kg level

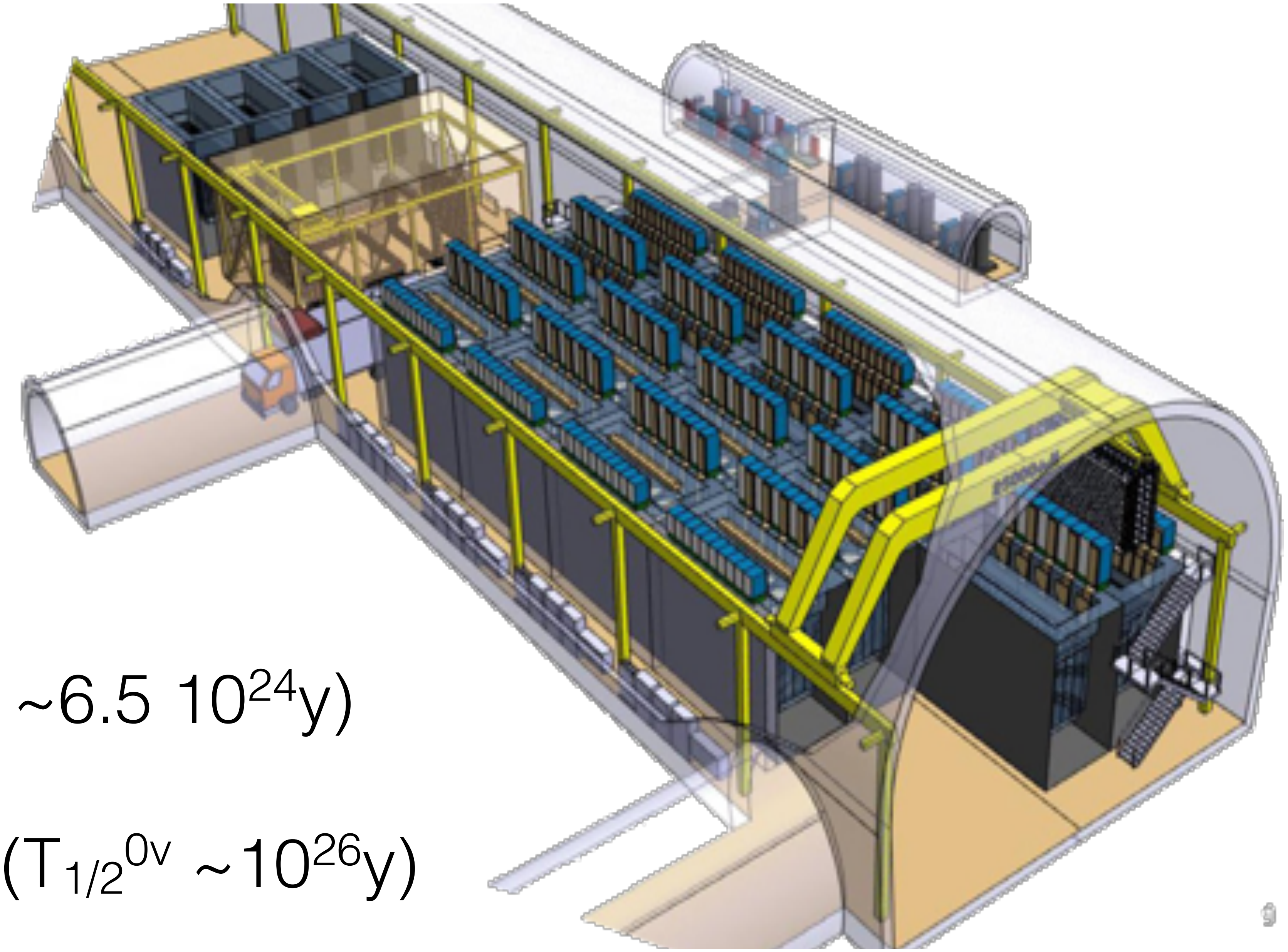
Current detector status

- Calorimeter and tracker delivered
- Source frame arriving next month
- Demonstrator running by end of year





Conclusions



- NEMO-3
  - World leading 0ν and 2νββ measurements
  - Unique new physics searches
- SuperNEMO demonstrator ($T_{1/2}^{0\nu}$ ~6.5 10^{24}y)
- Scales to 500 kg·yr ($T_{1/2}^{0\nu}$ ~10^{26}y)
- Tracker-calorimeter technique powerful ββ physics probe

Thank you

Questions?

Majorana and Dirac models

Two models to give neutrinos their masses

Dirac

$$\begin{bmatrix} \nu_L \\ \nu_R \\ \overline{\nu}_L \\ \overline{\nu}_R \end{bmatrix}$$

ν_R and $\bar{\nu}_L$ exists, even if we (currently) have no way to detect them

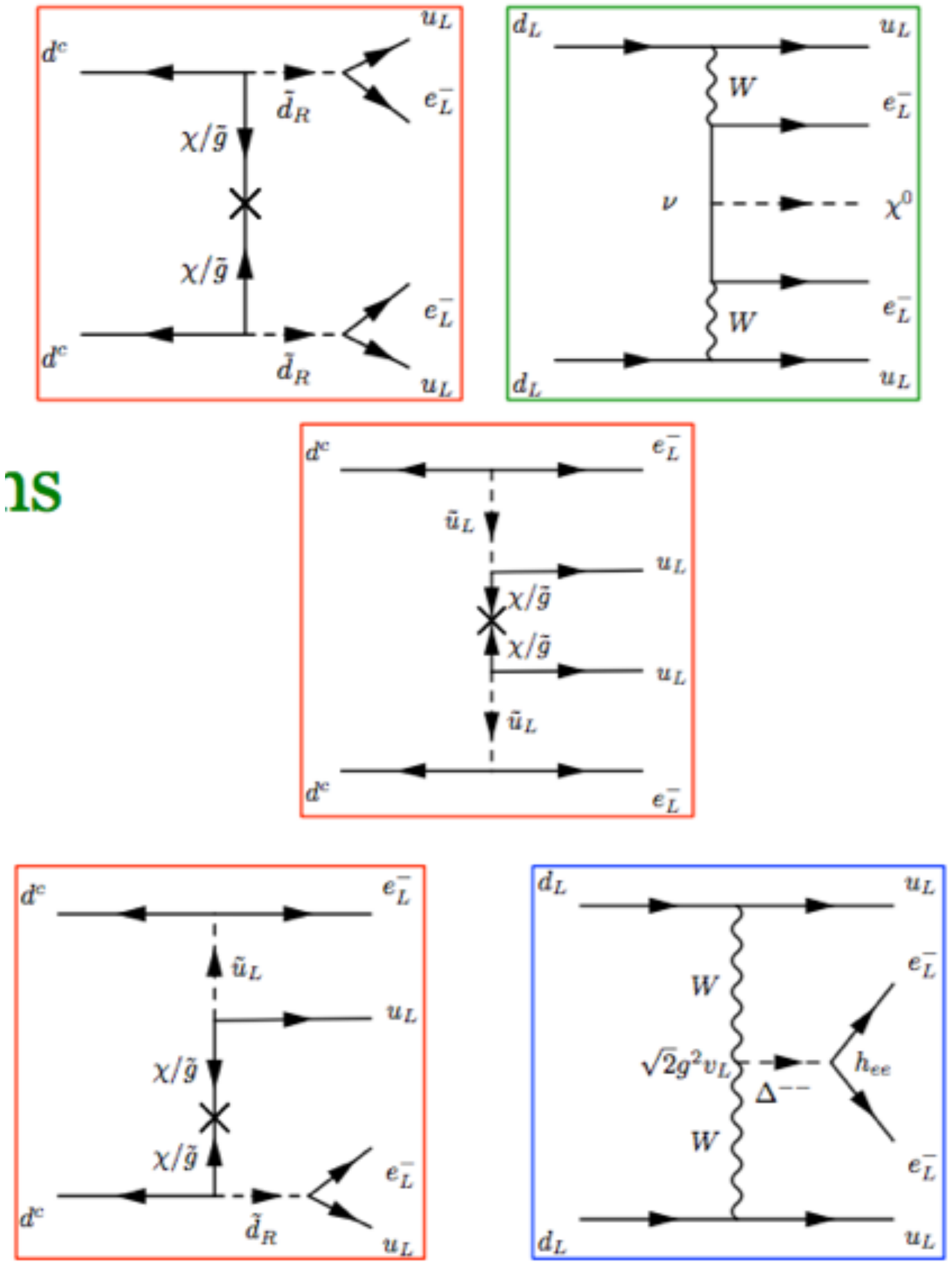
Majorana

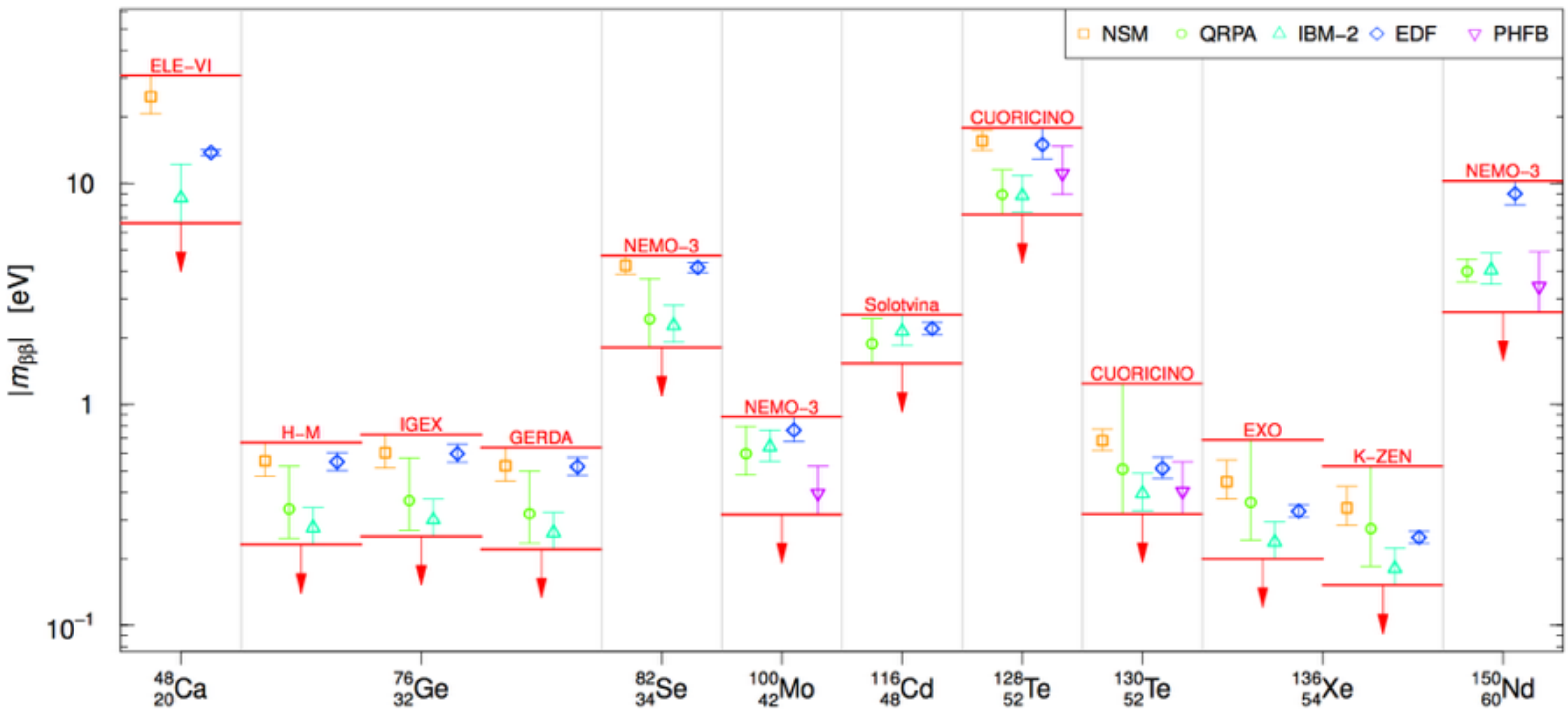
$$\begin{bmatrix} \nu_L \\ \overline{\nu}_R \end{bmatrix}$$

ν are their own antiparticle!

Why is 0ν2β interesting

- Window into new physics
  - Supersymmetry
  - Right handed weak currents
  - Majorons
  - Doubly-charged Higgs bosons
  - Heavy neutral leptons
  - Light Majorana neutrino exchange





$$(T^{0\nu}_{1/2})^{-1} = G_{0\nu}\,|\mathcal{M}_{0\nu}|^2\,|m_{\beta\beta}|^2$$

$$m_{\beta\beta} = \sum_k U^2_{ek}\, m_k$$