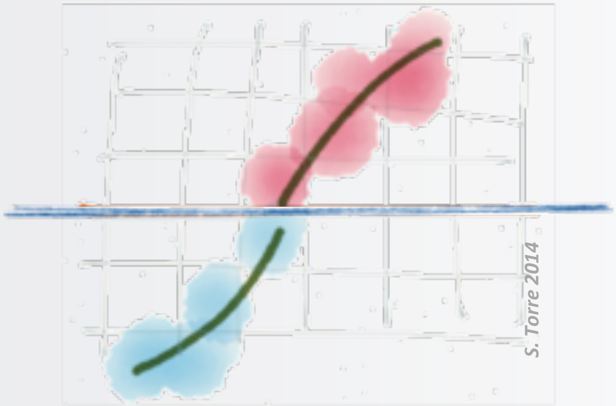
SuperNEMO

A unique tracking approach for DBD studies



GDR Neutrino - Bordeaux

Christine Marquet

29th October 2019

2β0ν mechanisms

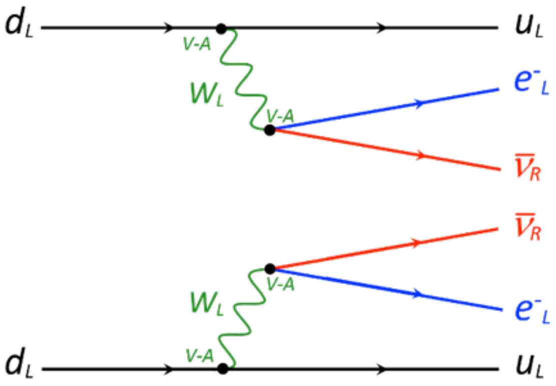
« ***Neutrinoless double beta decay*** » *Erik Minter, USA*

2β(2ν) and 2β(0ν)

2β2ν

$$(A,Z) \rightarrow (A, Z+2) + 2e^- + 2\bar{\nu}_e$$

Allowed by the Standard Model $T^{2\nu}_{1/2} \sim 10^{18-24}$ ans



2β0ν

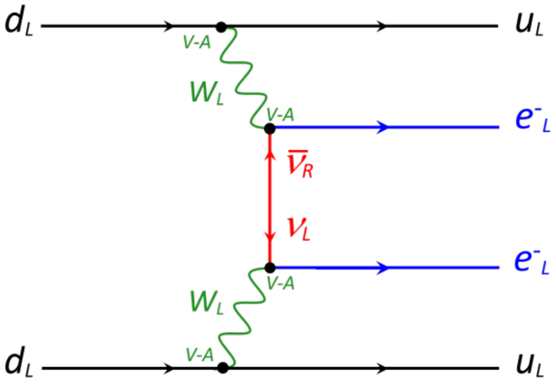
$$(A,Z) \rightarrow (A, Z+2) + 2e^-$$

ν Majorana $m_\nu \neq 0$ $\Delta L=2$ $\Delta(B-L)=2$

Beyond the Standard Model

If light neutrino exchange : $T_{1/2} = f(m_{\beta\beta}^2) > 10^{25-26}$ ans

$$m_{\beta\beta} = |\Sigma U_{ei} m_i|$$

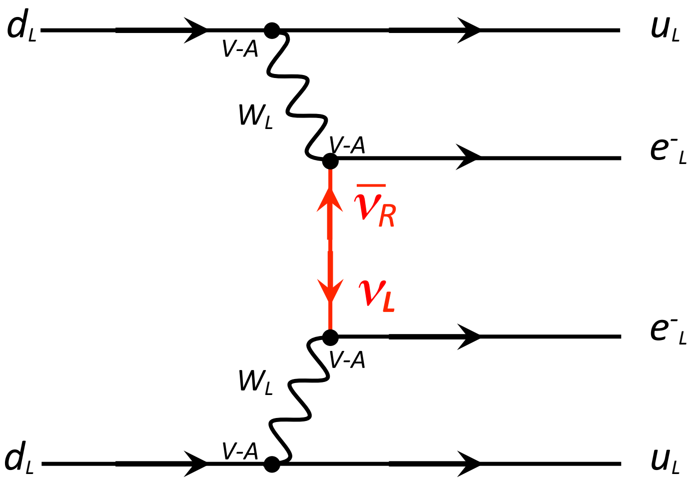


Which New Physics ?

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^-$$

Mechanism i

Light neutrino V-A



Parameter ε_i

$m_{\beta\beta}$

$$T^{-1}_{1/2} = (g_A{}^{\text{eff}}_{i})^4 \; G^{0\nu}_{i} \; |M^{0\nu}_{i}|^2 \; \varepsilon^2_{i}$$

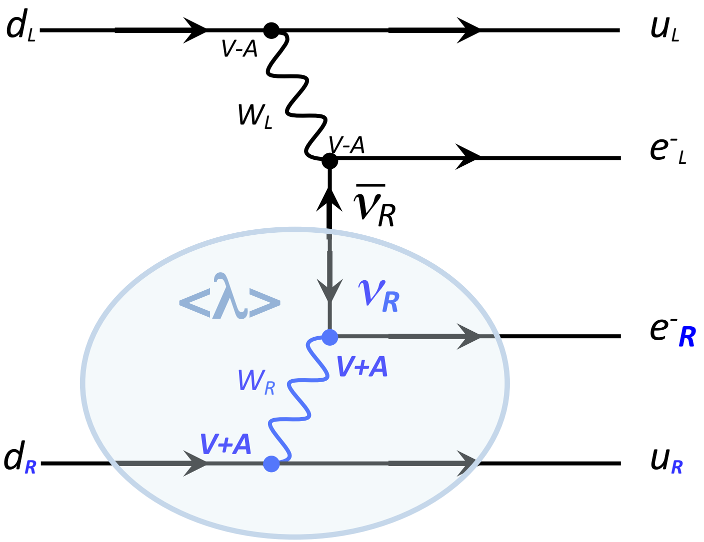
Which New Physics ?

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^-$$

Mechanism i

Light neutrino V-A

V+A

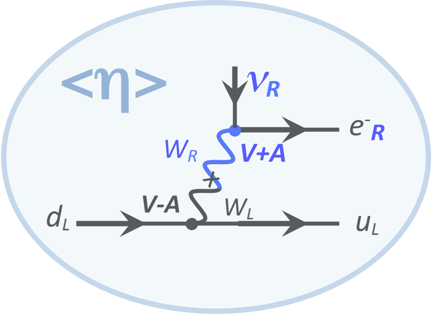


Parameter ε_i

$m_{\beta\beta}$

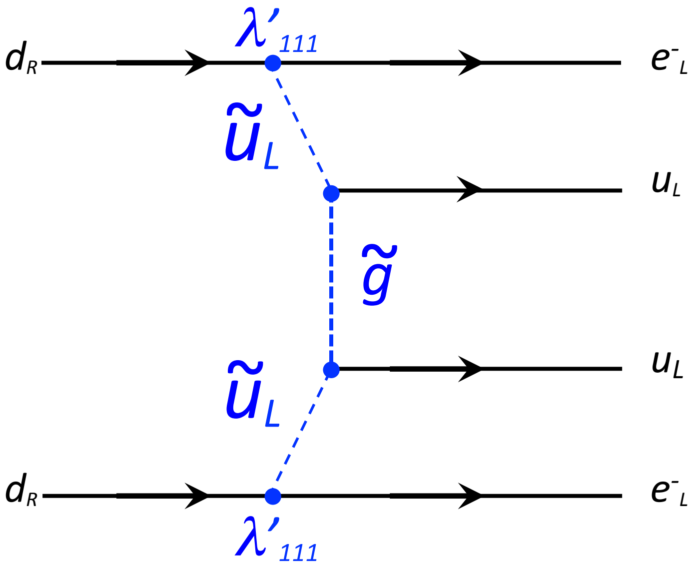
$\langle\lambda\rangle\langle\eta\rangle$

$$T_{1/2}^{-1} = (g_A^{\mathrm{eff}}{}_i)^4 \; G^{0\nu}_i \; |M^{0\nu}_i|^2 \; \varepsilon_i^2$$



Which New Physics ?

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^-$$



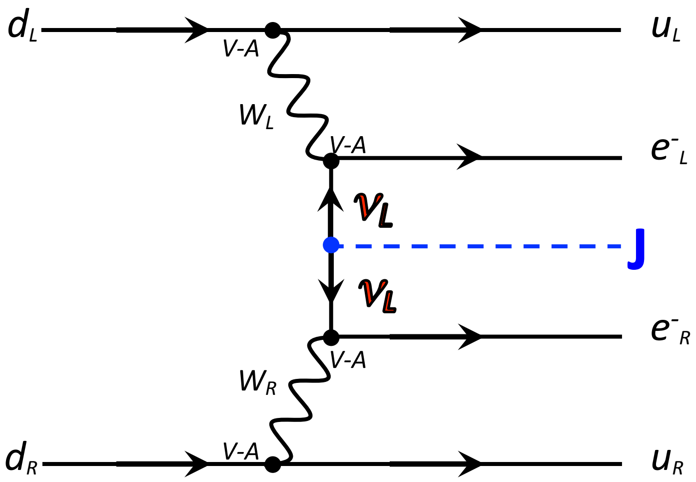
Mechanism i	**Parameter ε_i**
Light neutrino V-A	$m_{\beta\beta}$
V+A	$\langle\lambda\rangle\langle\eta\rangle$
SUSY $R\!\!\!/_p$	$\lambda^{2\prime}_{111}$

$$\boxed{T^{-1}_{1/2} = (g_A^{\text{eff}}{}_i)^4\ G^{0\nu}_i\ |M^{0\nu}_i|^2\ \varepsilon_i^2}$$

Which New Physics ?

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^- + J$$

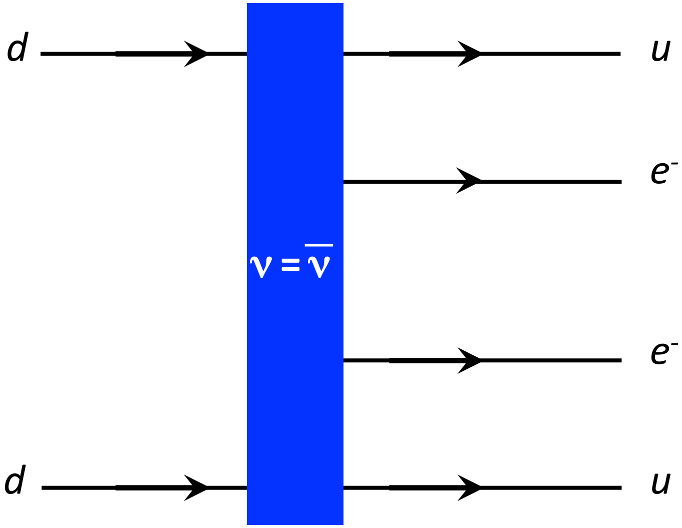
Mechanism i	Parameter ε_i
Light neutrino V-A	$m_{\beta\beta}$
V+A	$\langle\lambda\rangle\langle\eta\rangle$
SUSY $\not{R}_p$	$\lambda^{2\prime}_{111}$
Majoron J	$\langle g_J\rangle$



$$T^{-1}_{1/2} = (g_{A\,i}^{eff})^4\; G^{0\nu}_i\; |M^{0\nu}_i|^2\; \varepsilon^2_i$$

Which New Physics ?

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^- \;(+J,\gamma)$$



Mechanism i	Parameter ε_i
Light neutrino V-A	$m_{\beta\beta}$
V+A	$\langle\lambda\rangle\langle\eta\rangle$
SUSY R$\not{p}$	$\lambda^{2\prime}_{111}$
Majoron J	$\langle g_J\rangle$
Excited states	

$$T^{-1}_{1/2} = (g_{A\,i}^{\mathrm{eff}})^4 \; G^{0\nu}_i \; |M^{0\nu}_i|^2 \; \varepsilon_i^2$$

Which New Physics ? Which isotope ?

Mechanism i

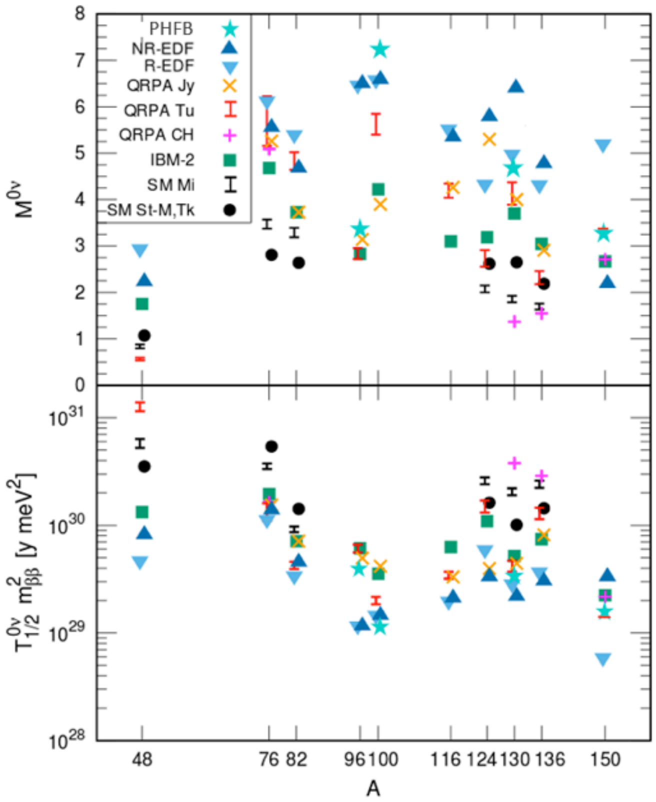
Light neutrino V-A

V+A

SUSY $\cancel{Rp}$

Majoron J

Excited states



$$T^{-1}_{1/2} = (g_A{}^{eff}_{i})^4 \; G^{0\nu}_{i} \; |M^{0\nu}_{i}|^2 \; \varepsilon^2_{i}$$

Parameter ε_i

$m_{\beta\beta}$

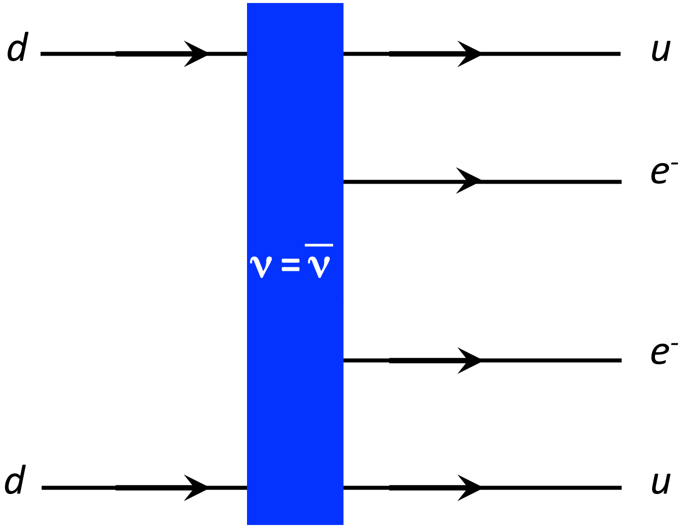
$<\lambda><\eta>$

$\lambda^{2\prime}_{111}$

$<g_J>$

Which New Physics ?

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^- \;(+J, \gamma)$$

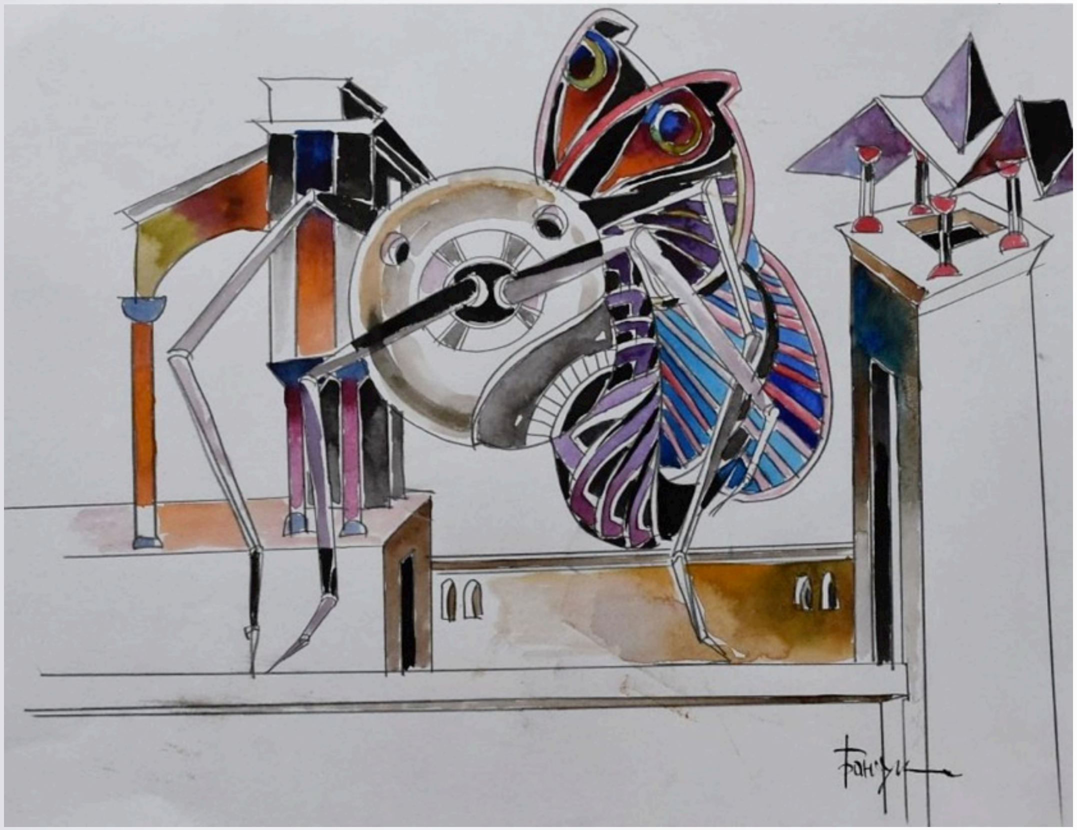


Mechanism i	**Parameter** ε_i
Light neutrino V-A	$m_{\beta\beta}$
V+A	$\langle\lambda\rangle\langle\eta\rangle$
SUSY $\cancel{Rp}$	$\lambda^{2\prime}_{111}$
Majoron J	$\langle g_J\rangle$
Excited states	

$$T^{-1}_{1/2} = (g_{A\,i}^{\mathrm{eff}})^4 \; G^{0\nu}_i \; |M^{0\nu}_i|^2 \; \varepsilon_i^2$$

Which mechanism ? Which isotope ? Quenched gA ?

Experimental approaches

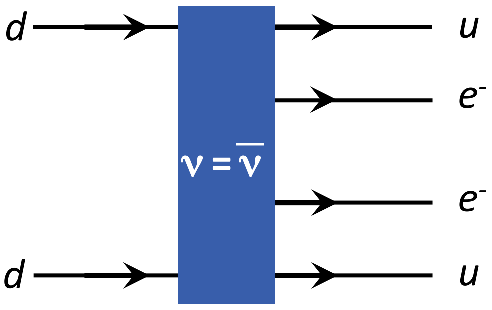


*« **Triumph Neutrino** » Roman Bonchuk, Ukraine 2018*

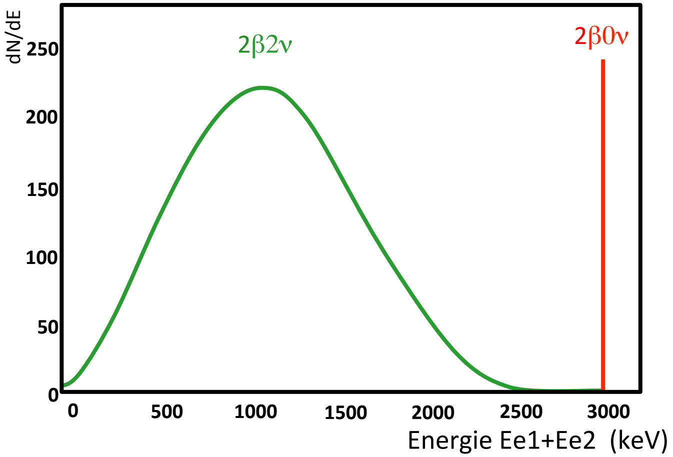
Observables

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^- \;(+\; J,\gamma)$$

$$\boxed{T^{-1}_{1/2} = g_{A\,i}^{\,eff}\; G^{0\nu}_{i}\; |M^{0\nu}_{i}|^{2}\; \varepsilon^{2}_{i}}$$



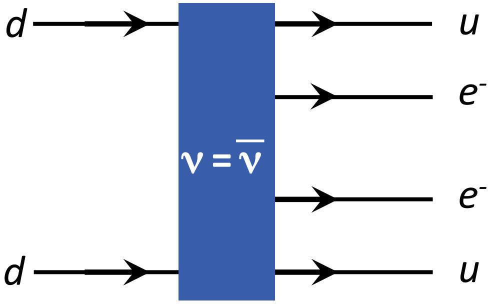
Mechanism i	**Observables** → **Parameter ε_i**	
Light neutrino V-A	$E_{e1}+E_{e2}$	$m_{\beta\beta}$
V+A	$E_{e1}+E_{e2}$	$<\lambda><\eta>$
SUSY $R\cancel{p}$	$E_{e1}+E_{e2}$	$\lambda^{2\prime}_{111}$
Majoron J	$E_{e1}+E_{e2}$	$<g_J>$
Excited states	$E_{e1}+E_{e2}$	



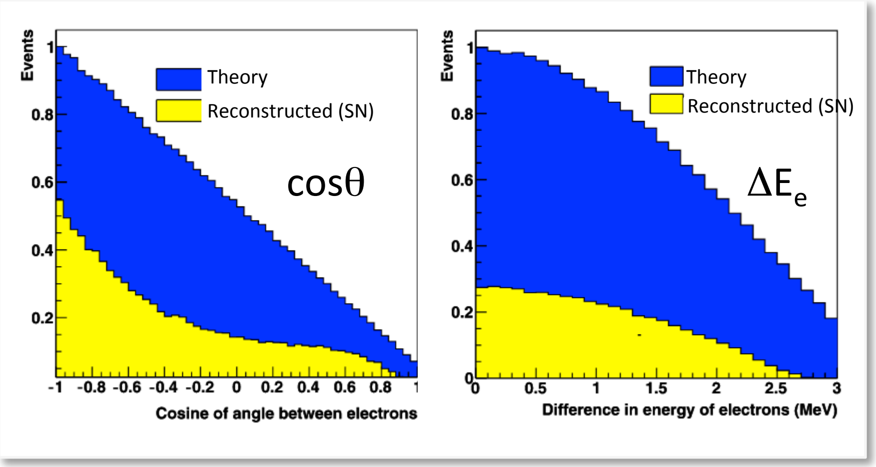
Observables

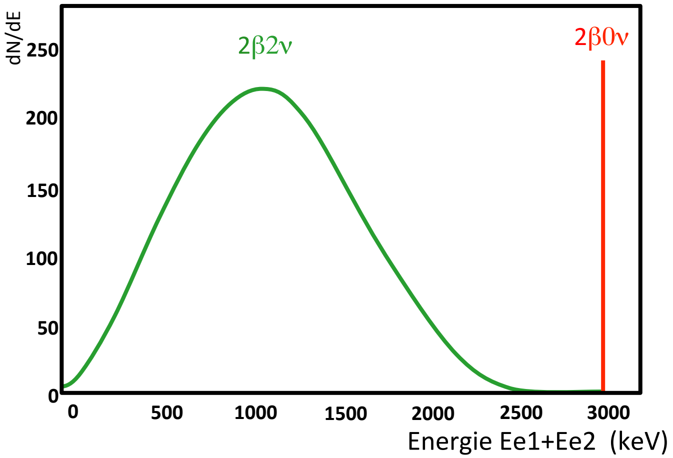
$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^- \ (+\ J,\gamma)$$

$$T^{-1}_{1/2} = g_{A\,i}^{\mathrm{eff}}\ G^{0\nu}_{i}\ |M^{0\nu}_{i}|^2\ \varepsilon^2_i$$



Mechanism i	**Observables** → **Parameter** ε_i	
Light neutrino V-A	$E_{e1}+E_{e2}$, E_{e1}, E_{e2}, θ	$m_{\beta\beta}$
V+A	$E_{e1}+E_{e2}$	$<\lambda><\eta>$
SUSY $R\cancel{p}$	$E_{e1}+E_{e2}$	$\lambda^{2'}_{111}$
Majoron J	$E_{e1}+E_{e2}$	$<g_J>$
Excited states	$E_{e1}+E_{e2}$	



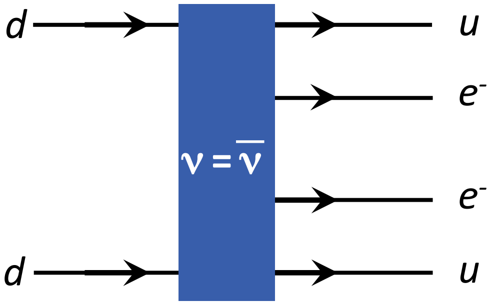


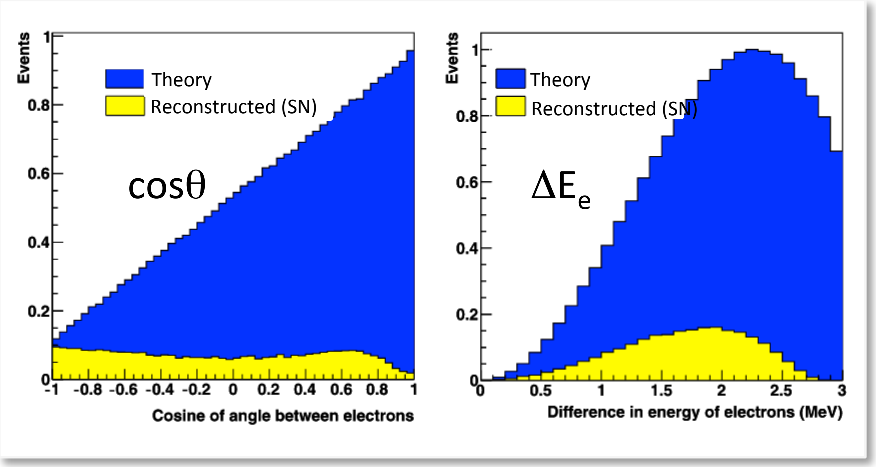
Observables

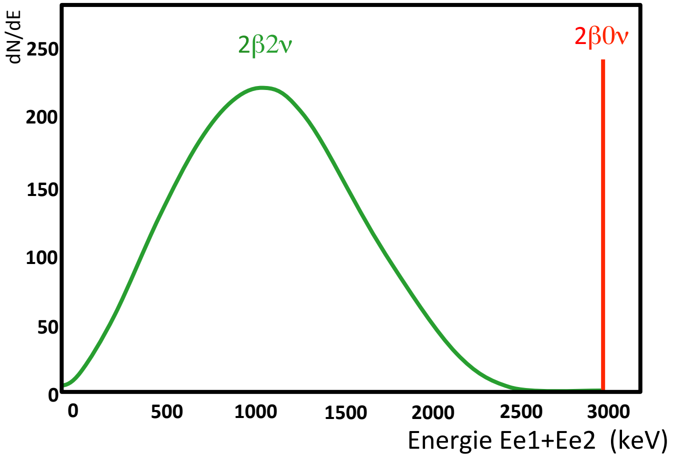
$(A,Z) \longrightarrow (A,Z+2) + 2\,e^-\ (+\ J,\gamma)$

$$T^{-1}_{1/2} = g_{A\,i}^{eff}\ G^{0\nu}_{i}\ |M^{0\nu}_{i}|^{2}\ \varepsilon^{2}_{i}$$

Mechanism i	**Observables** →	**Parameter** ε_i
Light neutrino V-A	$E_{e1}+E_{e2}$, E_{e1}, E_{e2}, θ	$m_{\beta\beta}$
V+A	**$E_{e1}+E_{e2}$, E_{e1}, E_{e2}, θ**	$<\lambda><\eta>$
SUSY R$\cancel{p}$	$E_{e1}+E_{e2}$	$\lambda^{2\prime}_{111}$
Majoron J	$E_{e1}+E_{e2}$	$<g_J>$
Excited states	$E_{e1}+E_{e2}$	



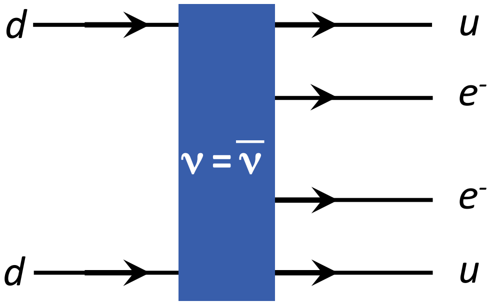




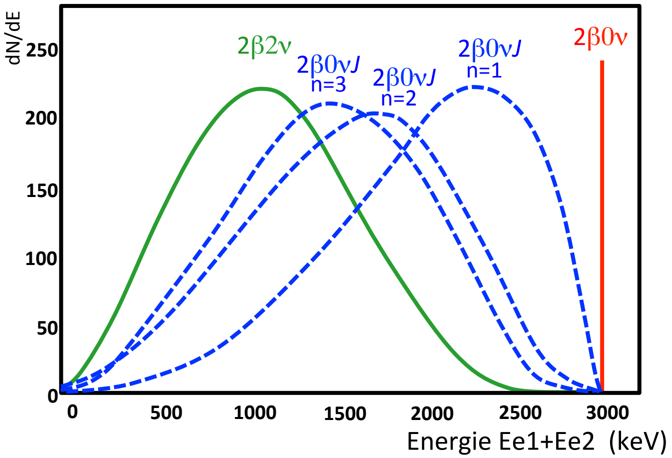
Observables

$$(A,Z) \longrightarrow (A,Z+2) + 2\,e^- \;(+\; J,\gamma)$$

$$T^{-1}_{1/2} = g_{A\,i}^{\,eff}\; G^{0\nu}_{i}\; |M^{0\nu}_{i}|^2\; \varepsilon^2_{i}$$



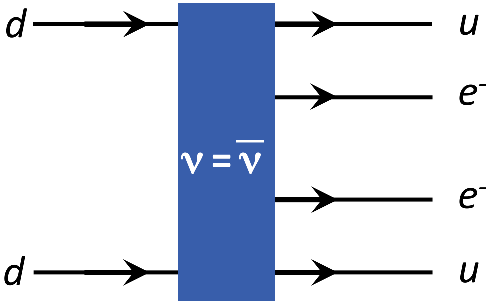
Mechanism i	**Observables** →	**Parameter** ε_i
Light neutrino V-A	$E_{e1}+E_{e2}$, E_{e1}, E_{e2}, θ	$m_{\beta\beta}$
V+A	$E_{e1}+E_{e2}$, E_{e1}, E_{e2}, θ	$\langle\lambda\rangle\langle\eta\rangle$
SUSY $R_{\cancel{p}}$	$E_{e1}+E_{e2}$	λ'^{2}_{111}
Majoron J	$E_{e1}+E_{e2}$	$\langle g_J\rangle$
Excited states	$E_{e1}+E_{e2}$	



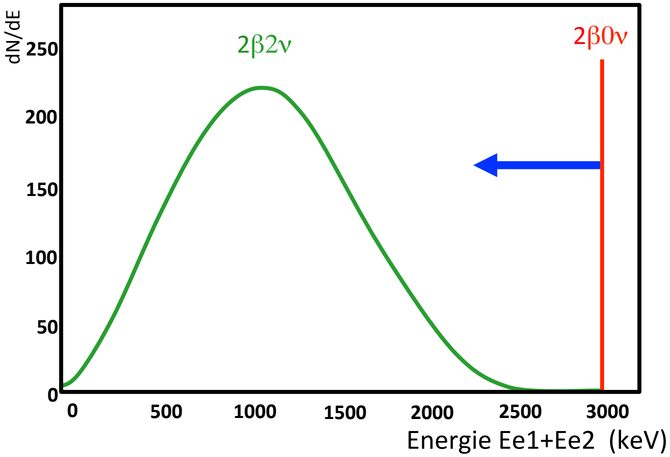
Observables

$(A,Z) \longrightarrow (A,Z+2) + 2\,e^-\ (+\ J,\gamma)$

$$T^{-1}_{1/2} = g_{A\,i}^{\,eff}\ G^{0\nu}_i\ |M^{0\nu}_i|^2\ \varepsilon^2_i$$



Mechanism i	**Observables** →	**Parameter** ε_i
Light neutrino V-A	$E_{e1}+E_{e2}$, E_{e1}, E_{e2}, θ	$m_{\beta\beta}$
V+A	$E_{e1}+E_{e2}$, E_{e1}, E_{e2}, θ	$<\lambda><\eta>$
SUSY $R\cancel{p}$	$E_{e1}+E_{e2}$	$\lambda^{2\prime}_{111}$
Majoron J	$E_{e1}+E_{e2}$	$<g_J>$
Excited states	$E_{e1}+E_{e2}$, $E_{\gamma1}$, $E_{\gamma2}$…	



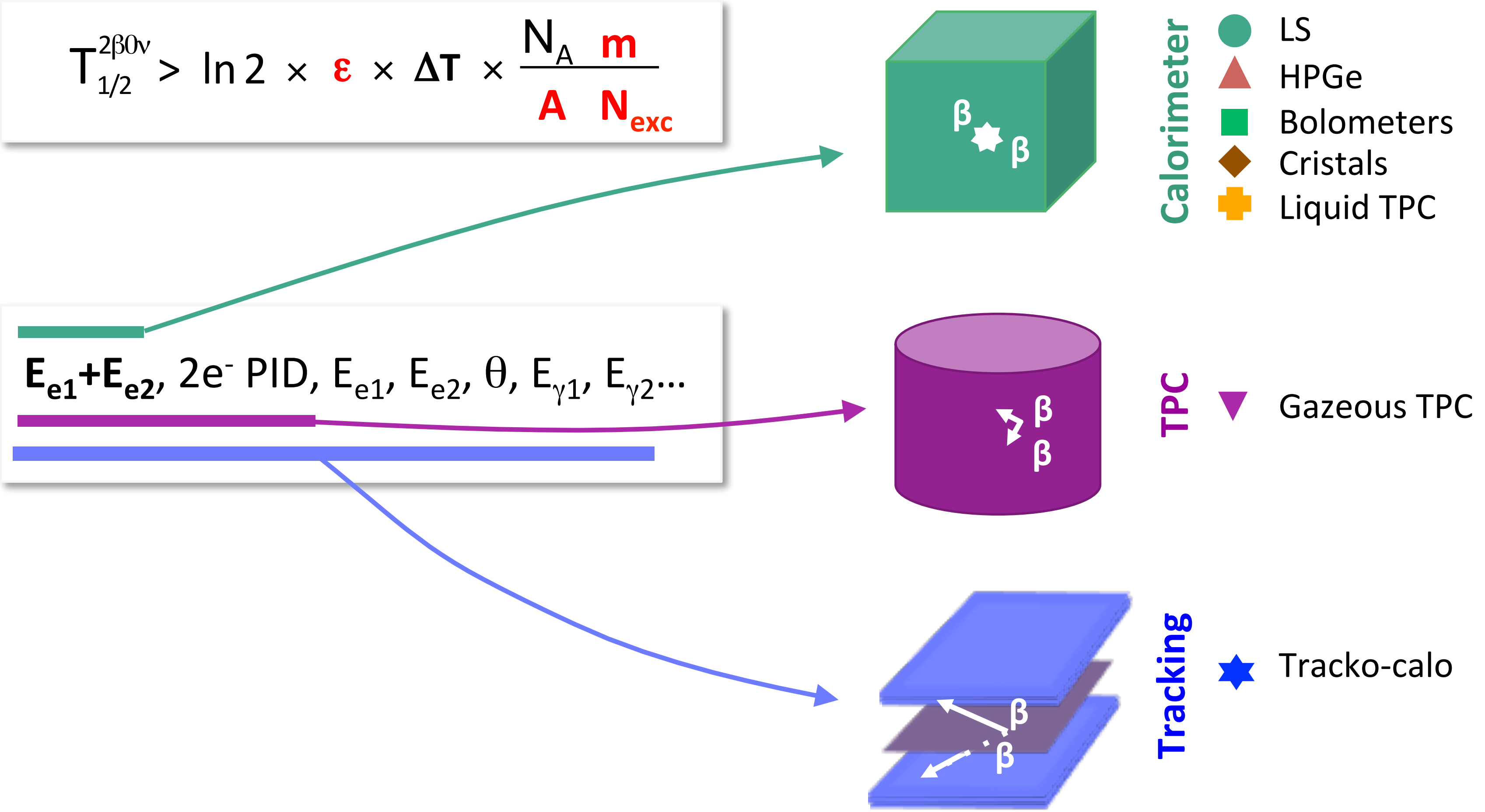
Sensitivity

$$T_{1/2}^{2\beta 0\nu} > \ln 2 \times \varepsilon \times \Delta T \times \frac{N_A \; m}{A \; N_{exc}}$$

Sensitivity

$$T_{1/2}^{2\beta0\nu} > \ln 2 \times \varepsilon \times \Delta T \times \frac{N_A\ m}{A\ N_{exc}}$$

$E_{e1}+E_{e2}$, 2e^- PID, E_{e1}, E_{e2}, θ, $E_{\gamma1}$, $E_{\gamma2}$…



Calorimeter

- ● LS
- ▲ HPGe
- ■ Bolometers
- ◆ Cristals
- ✚ Liquid TPC

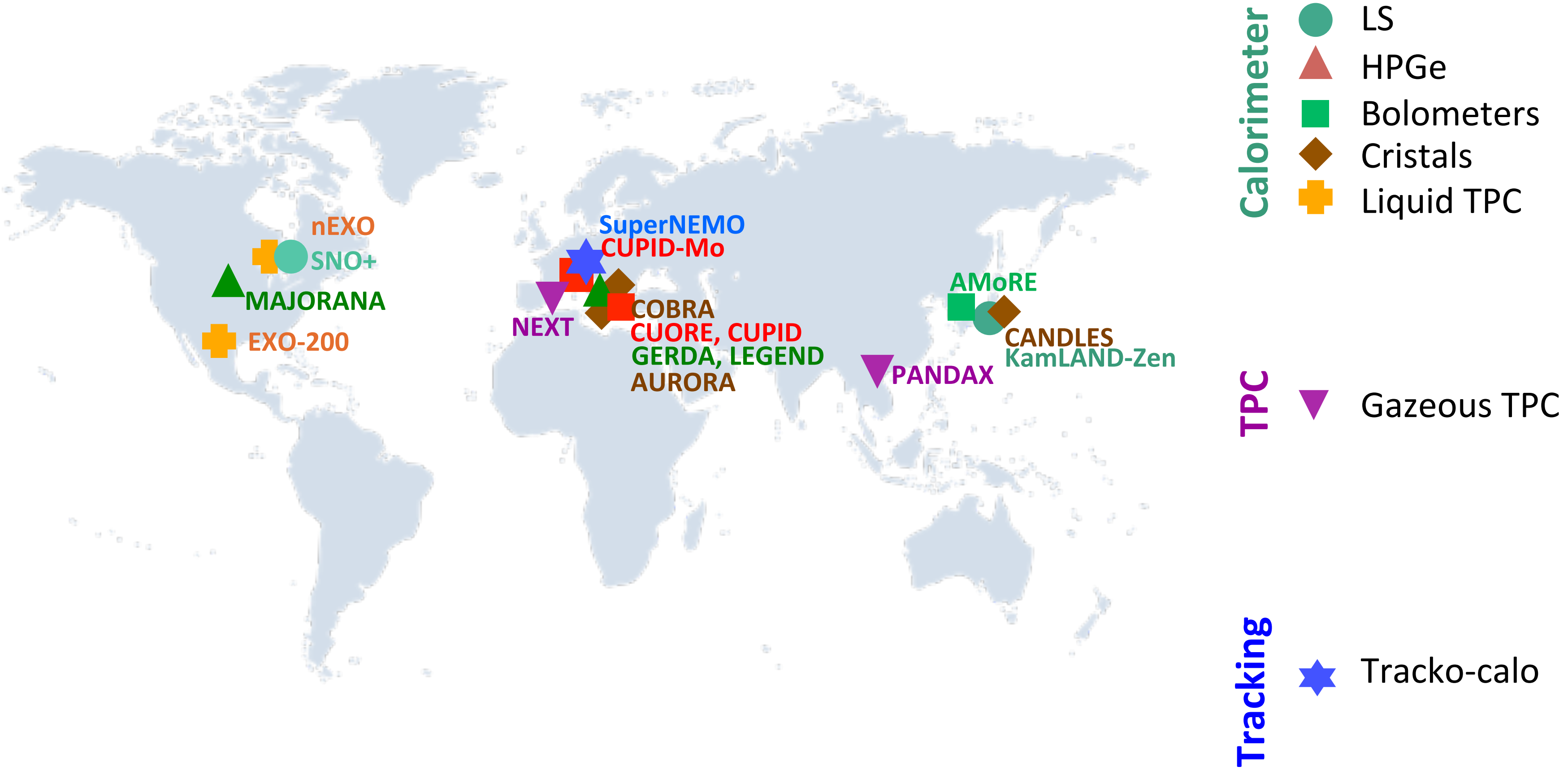
TPC

- ▼ Gazeous TPC

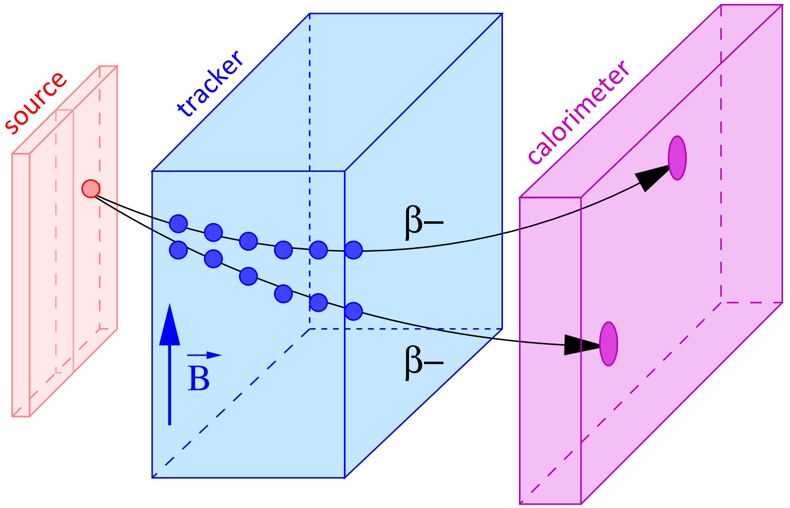
Tracking

- ✡ Tracko-calo

Expériences 2β0ν



Tracking calorimeter technique



- Particle ($e^{\pm}$, γ, α) identification
- Kinematic : $E_{individual}$, θ, tof

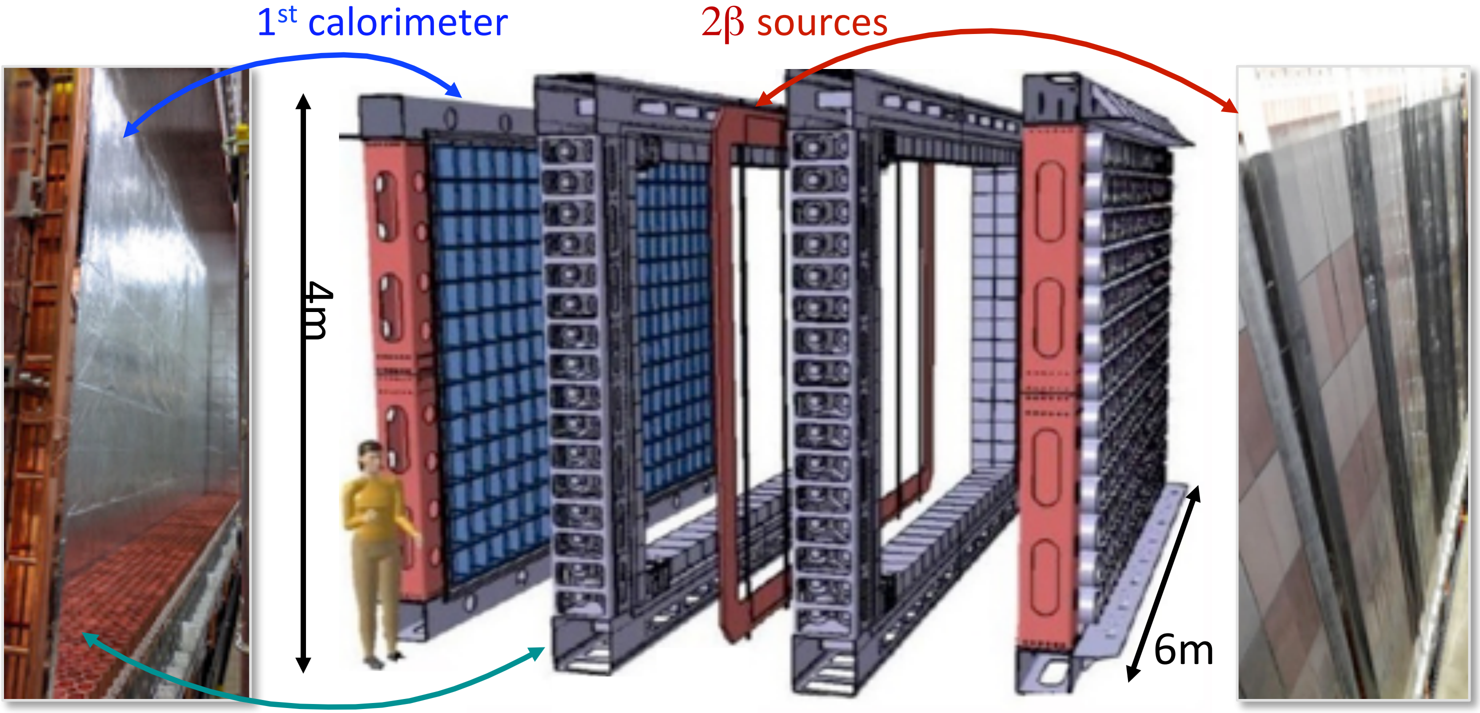
→ **Event topology**

- ➢ **« Golden event »** 2e
- ➢ Background modelisation
- ➢ **2β0ν mechanisms**
- ➢ 2β2ν precise measurements

- Source separated from detector → (almost) **all isotopes**

- Poorer efficiency & energy resolution than “homogeneous” detectors

SuperNEMO demonstrator



1st calorimeter

2β sources

4m

6m

1st tracker

2d tracker

2d calorimeter

Located in Modane underground Laboratory (LSM) at ~4800 m.w.e

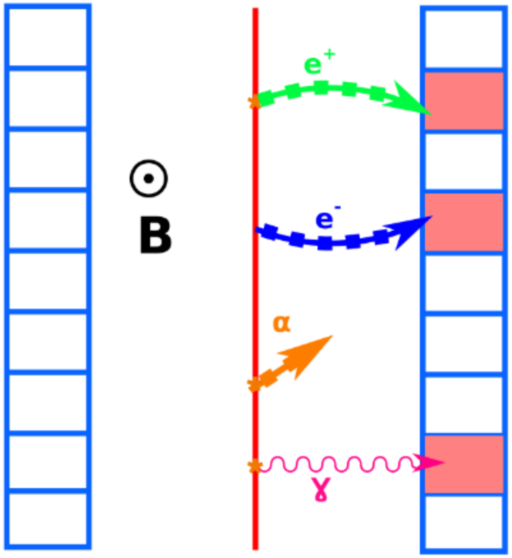
21 Laboratories

CENBG (Bordeaux), CPPM (Marseille), Charles U. (Prague), Comenius U. (Bratislava), CTU (Prague), INL (Idaho Falls), Imperial College (London), ITEP (Moscow), JINR (Dubna), LSM (Modane), LPC (Caen), LAL (Orsay), LAPP (Annecy), INR (Kiev), Osaka U. (Osaka), Manchester U. (Manchester), Texas U. (Austin), UCL (London), Jyväskylä U. (Jyväskylä), Warwick U. (Warwick), Werc (Fukui)

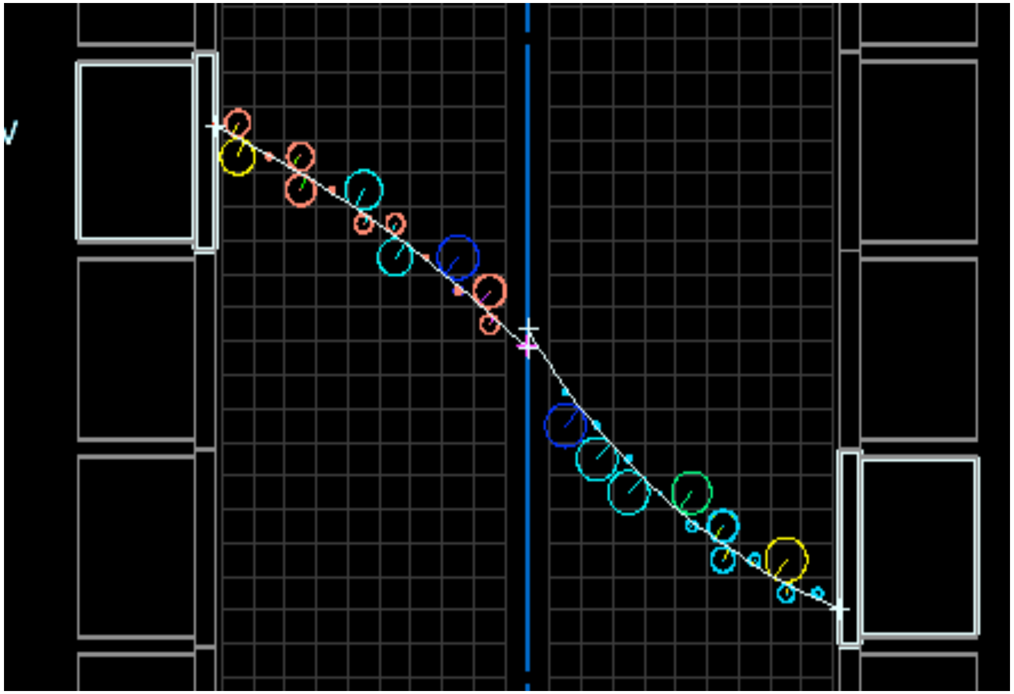
SuperNEMO

in LSM

Event topology



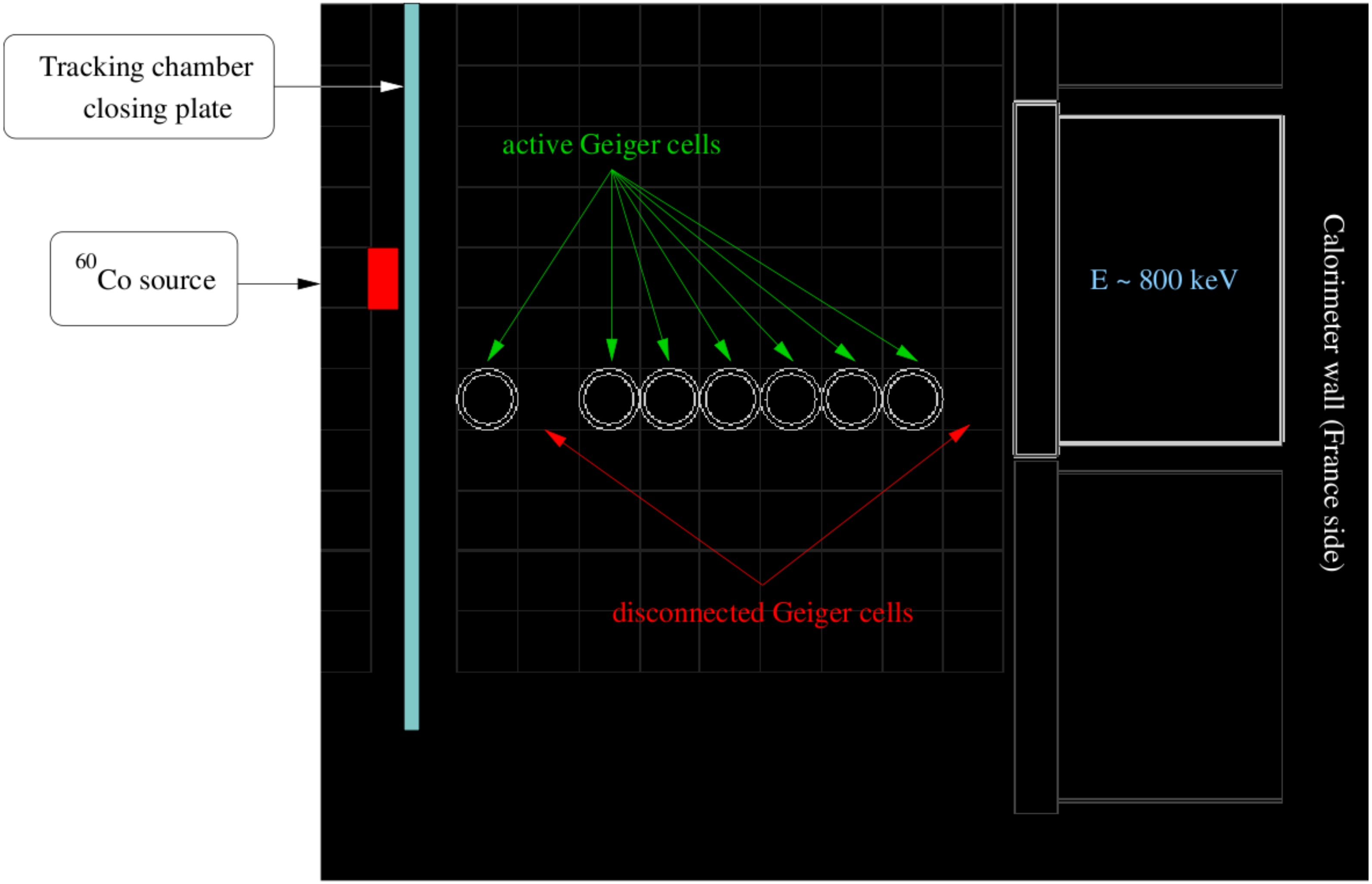
Particle identification



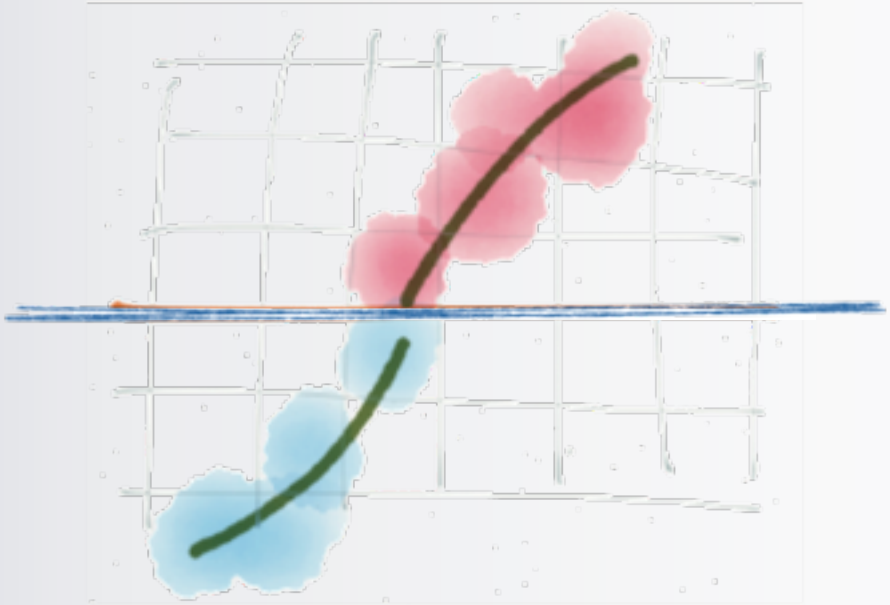
Simulated ββ event in SuperNEMO

Event topology

First measured track (half-detector commissioning)



NEMO physics potential



« Stefano Torre, UCL 2014

$2\beta0\nu$ sensitivity

$$T_{1/2}^{2\beta0\nu} > \ln 2 \times \varepsilon \times \Delta T \times \frac{N_A\ \mathbf{m}}{\mathbf{A}\ \ N_{exc}}$$

	NEMO-3	**SuperNEMO**
Isotope	^{100}Mo	^{82}Se (^{150}Nd, ^{96}Zr, ^{48}Ca)
Mass (kg)	7	~ 100
Efficiency ROI (%)	8,5	15
BKG(evts/(keV.kg.y))	1,1 x 10^{-3}	8,5 x 10^{-5}
Energy resolution (%) FWHM à 1 MeV	13,4-19,8	8
^{208}**Tl sources** (μBq/kg)	$90^{m} - 130^{c}$	< 2
^{214}**Bi sources** (μBq/kg)	$60^{m} - 310^{c}$	< 10
^{222}**Rn gas** (mBq/m^3)	6,5	< 0,15
$T_{1/2}^{2\beta0\nu}$ 90%CL (y)	> 1,1 x 10^{24}	> 10^{26}
$m_{\beta\beta}$ 90%CL (eV)	< 0,33 – 0,62	< 0,05

m : métallique, c : composite

$2\beta0\nu$ sensitivity

$$T^{2\beta0\nu}_{1/2} > \ln 2 \times \varepsilon \times \Delta T \times \frac{N_A \;\; m}{A \;\; N_{exc}}$$

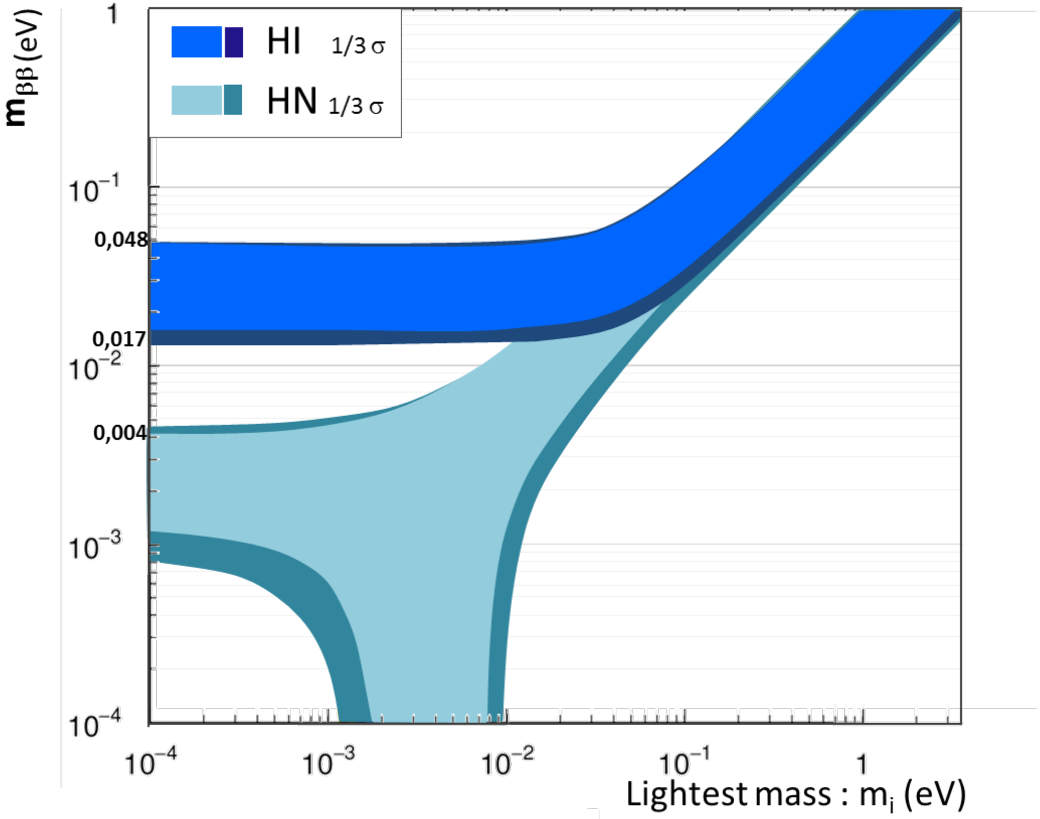
See Cloé's talk

	NEMO-3	**SuperNEMO -demo**		
Isotope	**^{100}Mo**	**^{82}Se** **(^{150}Nd, ^{96}Zr, ^{48}Ca)**	**^{82}Se**	✓
Mass (kg)	**7**	**~ 100**	**6,3**	✓
Efficiency ROI (%)	**8,5**	**15**	**15**	✓
BKG(evts/(keV.kg.y))	**$1,1 \times 10^{-3}$**	**$8,5 \times 10^{-5}$**	$8,5 \times 10^{-5}$	
Energy resolution (%) FWHM à 1 MeV	**13,4-19,8**	**8**	**8**	✓
^{208}Tl sources (µBq/kg)	**$90^{m} – 130^{c}$**	**< 2**	< 2	20
^{214}Bi sources (µBq/kg)	**$60^{m} – 310^{c}$**	**< 10**	< 10	<300
^{222}Rn gas (mBq/m³)	**6,5**	**< 0,15**	< 0,15	0,16 *tracker*
$T^{2\beta0\nu}_{1/2}$ 90%CL (y)	**$> 1,1 \times 10^{24}$**	**$> 10^{26}$**	$> 5,7 \times 10^{24}$	
$m_{\beta\beta}$ 90%CL (eV)	**< 0,33 – 0,62**	**< 0,05**	<0,25-0,50	

m : métallique, c : composite

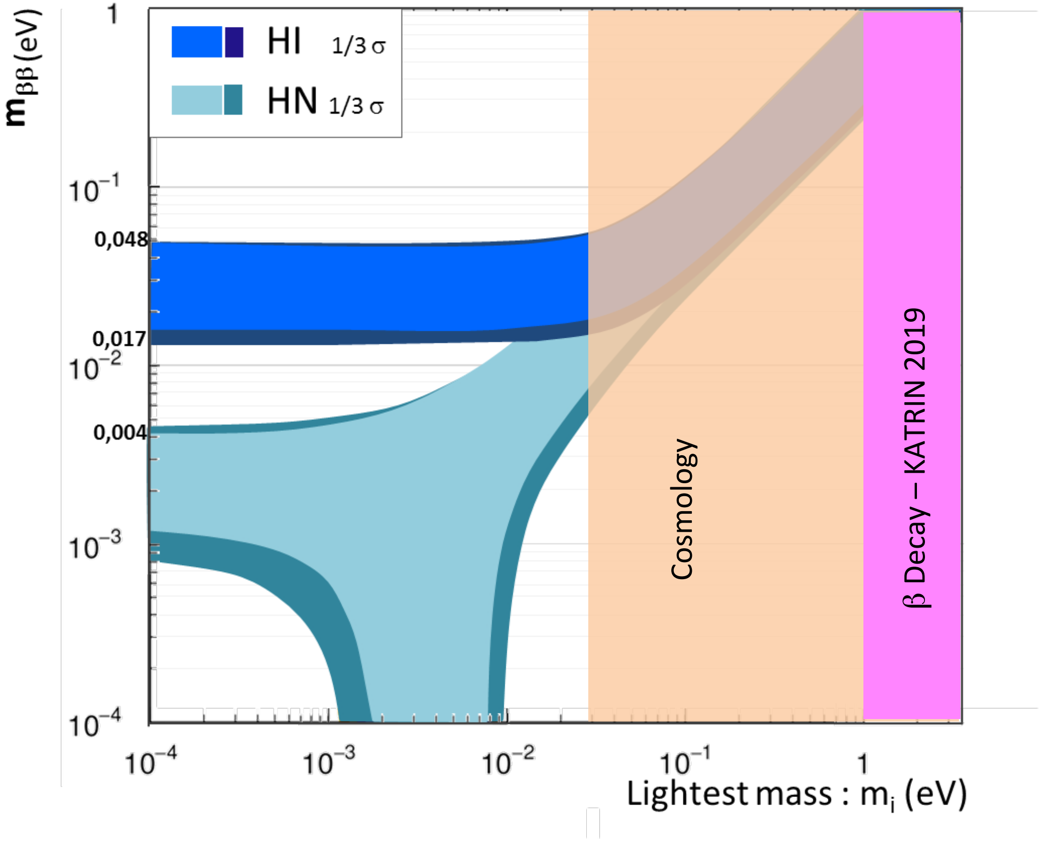
Light neutrino exchange sensitivity

$$m_{\beta\beta} = |\, m_1 |U_{e1}|^2 + m_2 |U_{e2}|^2 e^{2i\alpha_2} + m_3 |U_{e3}|^2 e^{2i\alpha_3} \,|$$



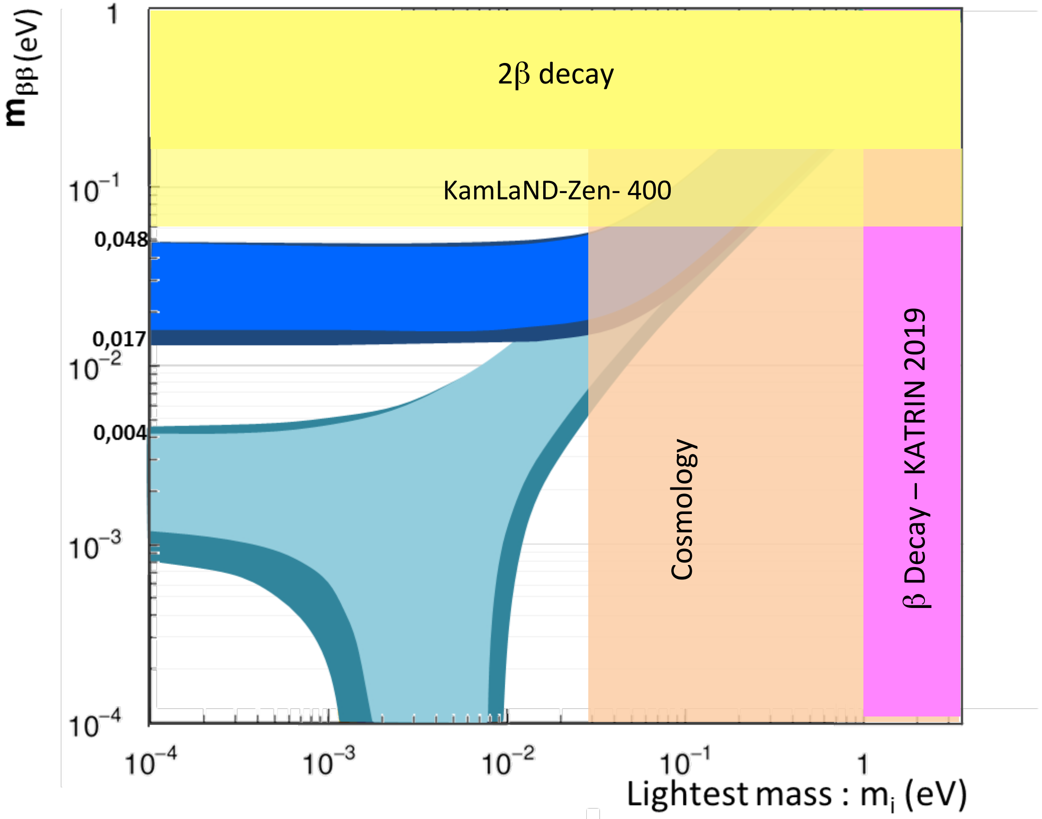
Light neutrino exchange sensitivity

$$m_{\beta\beta} = |\, m_1 |U_{e1}|^2 + m_2 |U_{e2}|^2 e^{2i\alpha_2} + m_3 |U_{e3}|^2 e^{2i\alpha_3}\, |$$



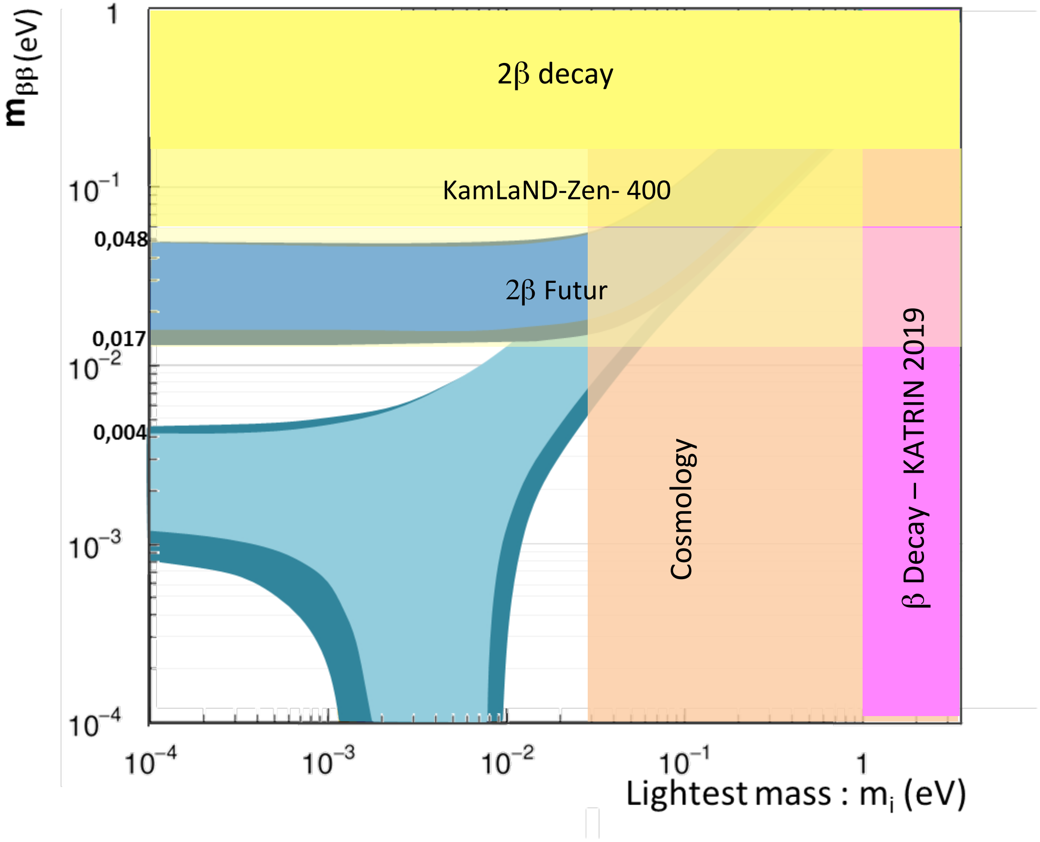
Light neutrino exchange sensitivity

$$m_{\beta\beta} = \left|\, m_1 |U_{e1}|^2 + m_2 |U_{e2}|^2 e^{2i\alpha_2} + m_3 |U_{e3}|^2 e^{2i\alpha_3} \,\right|$$

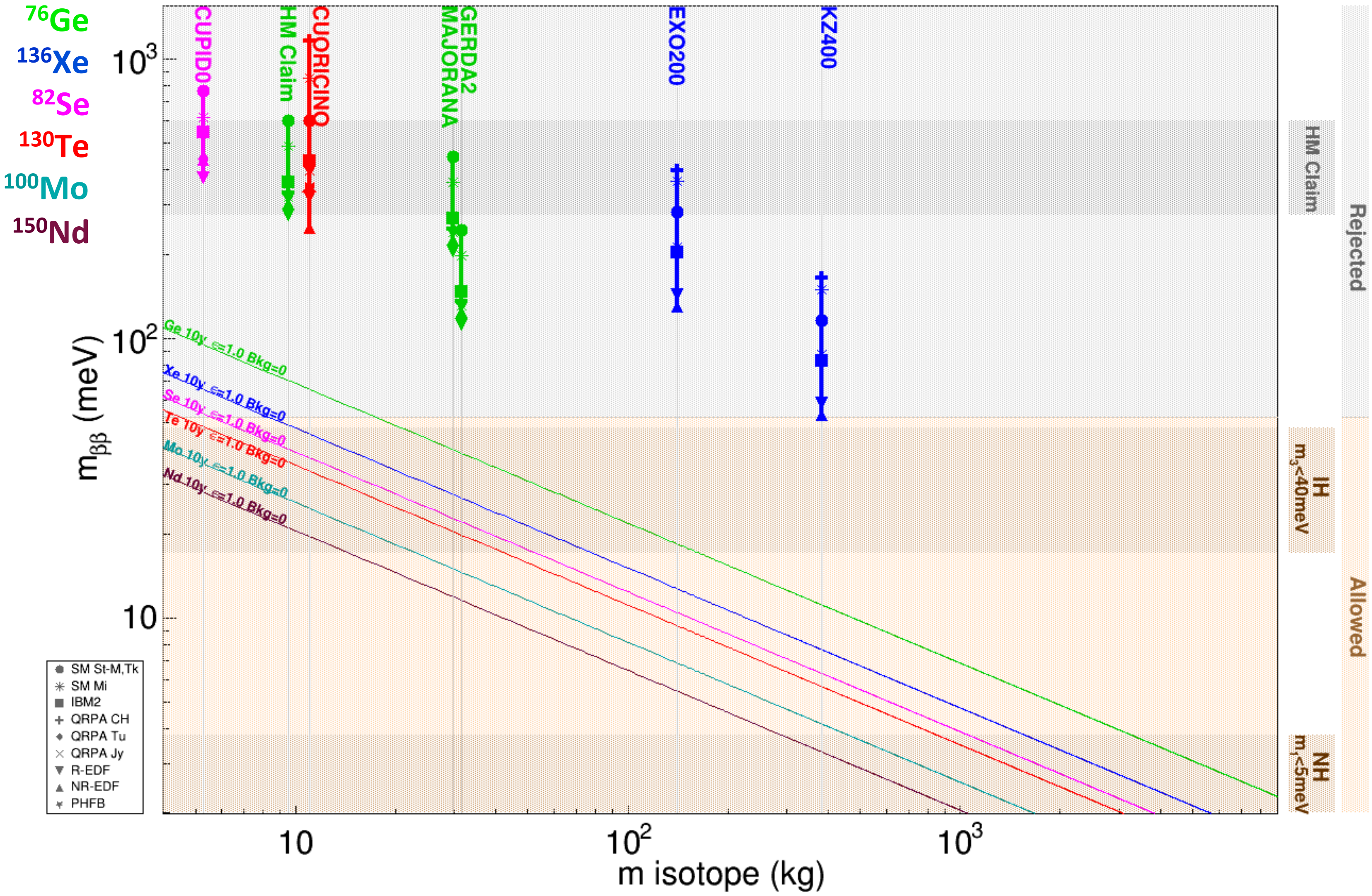


Light neutrino exchange sensitivity

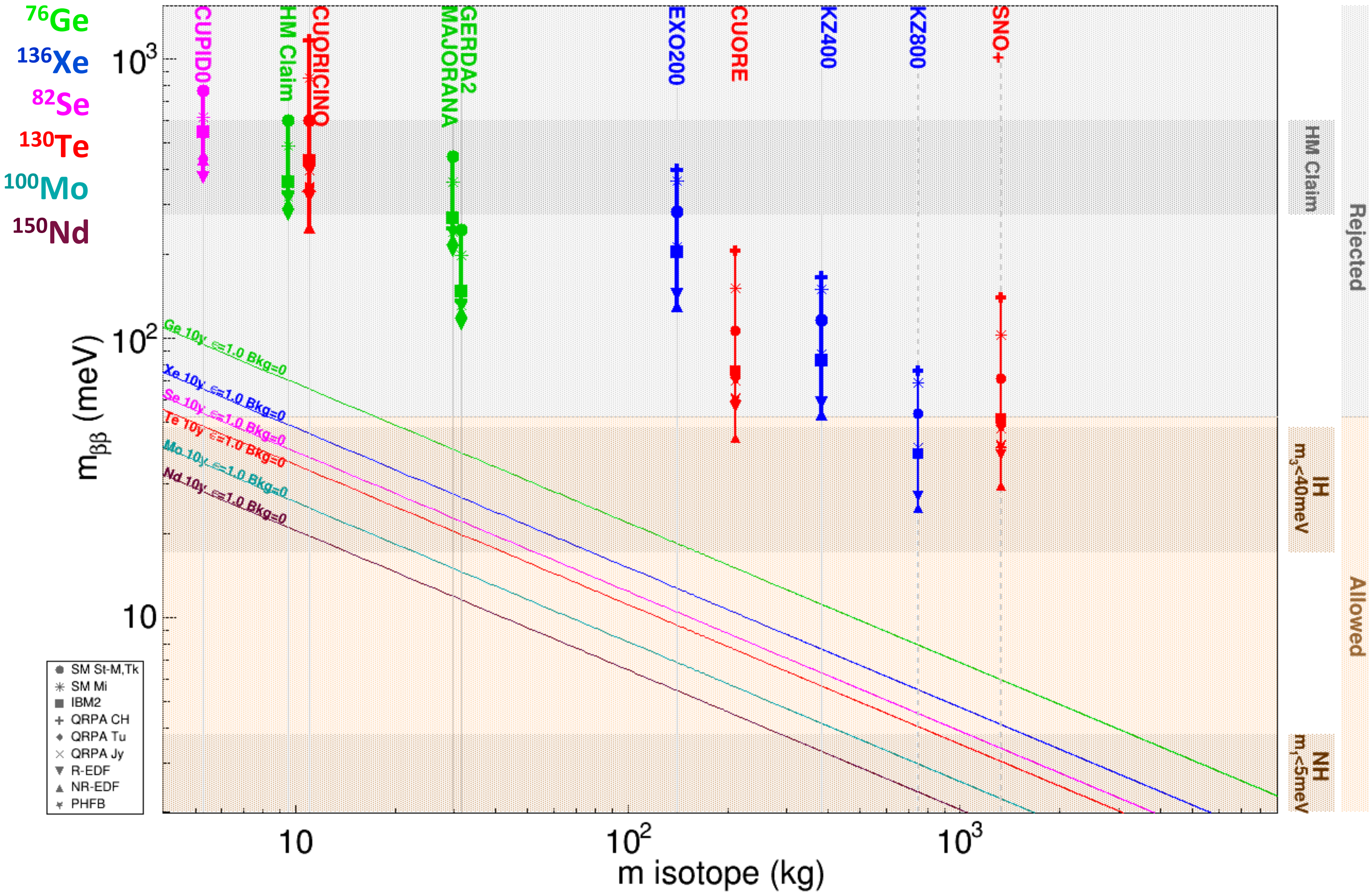
$$m_{\beta\beta} = |\, m_1 |U_{e1}|^2 + m_2 |U_{e2}|^2 e^{2i\alpha_2} + m_3 |U_{e3}|^2 e^{2i\alpha_3} \,|$$



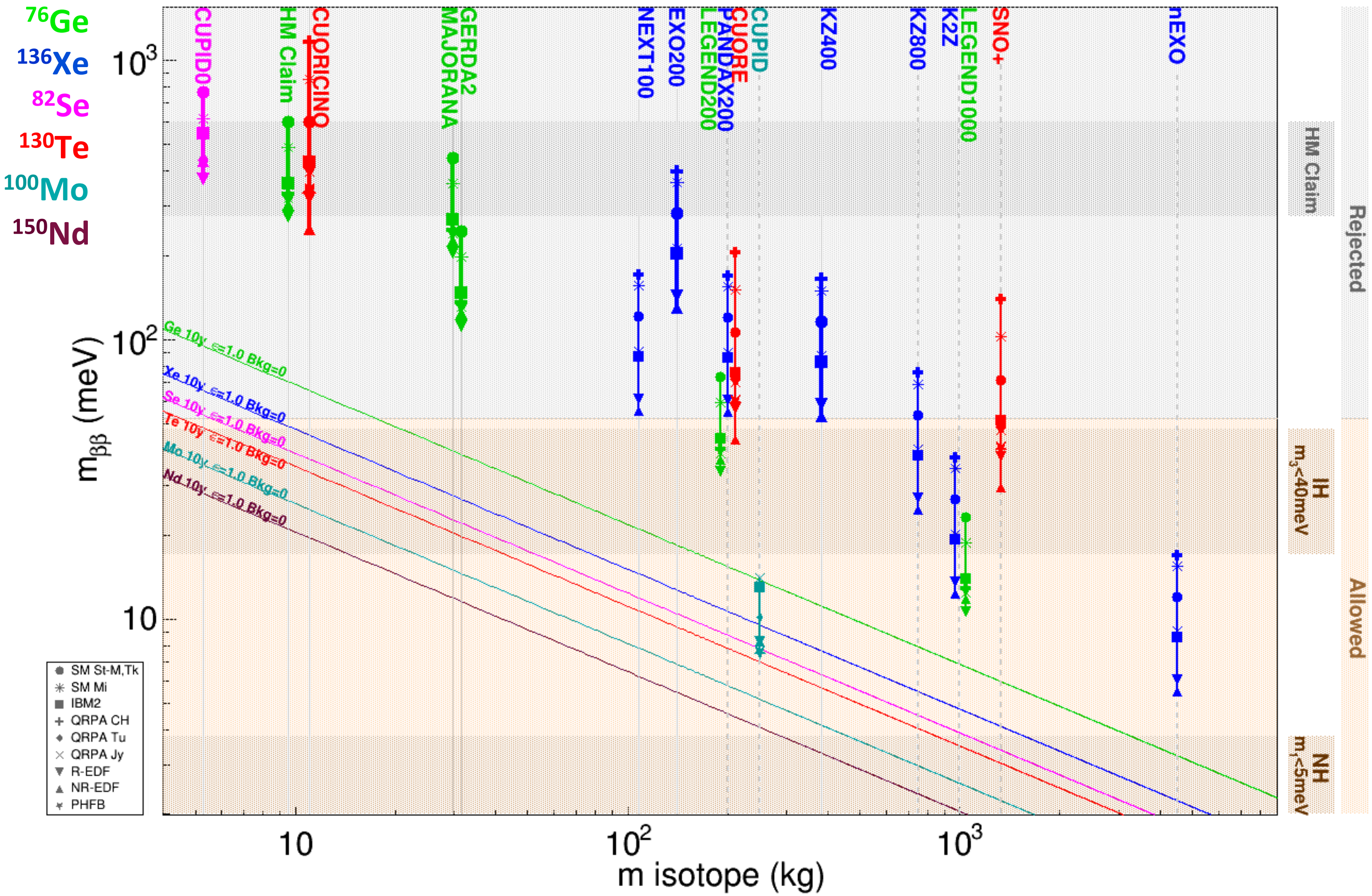
Light neutrino exchange sensitivity



Light neutrino exchange sensitivity

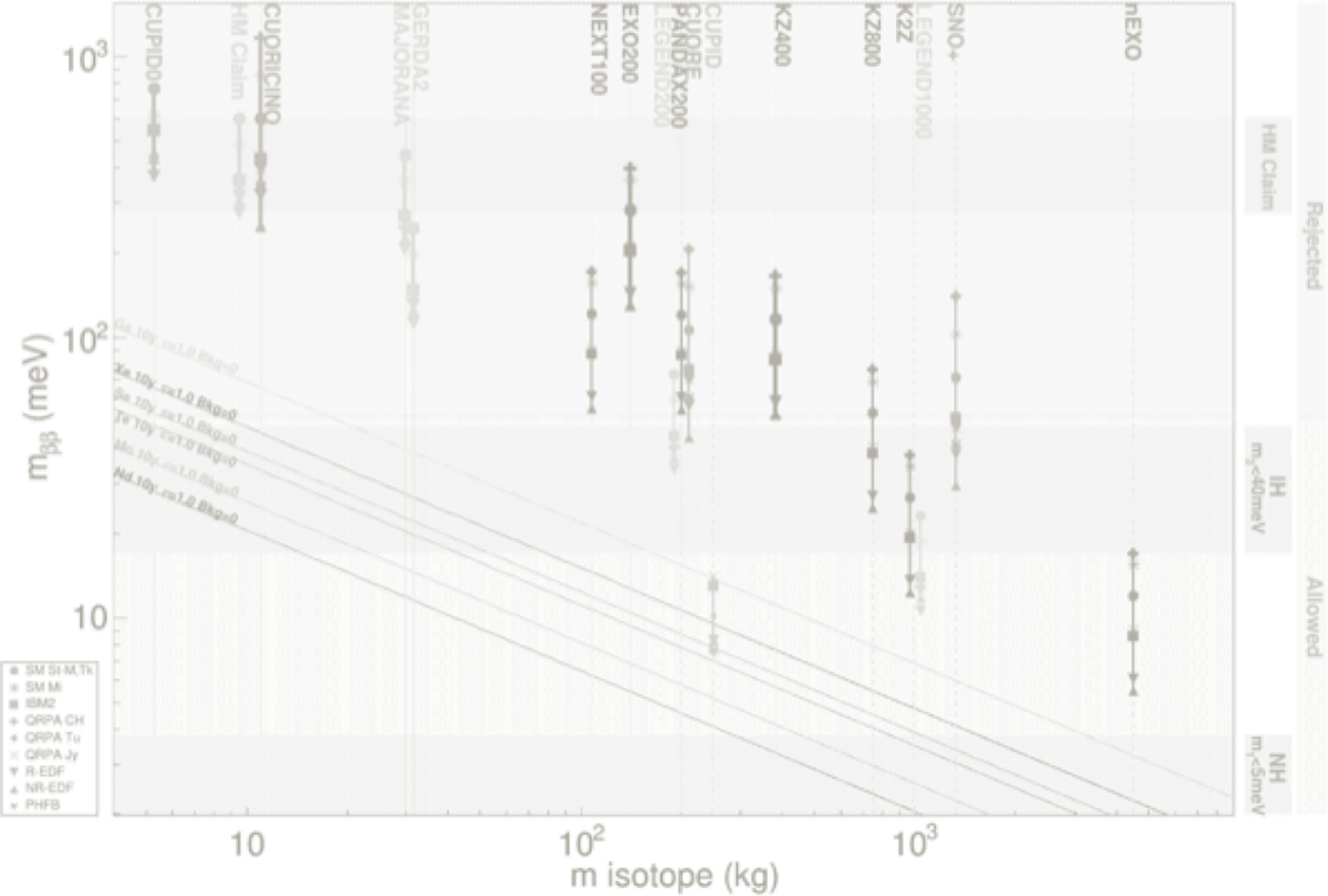


Light neutrino exchange sensitivity



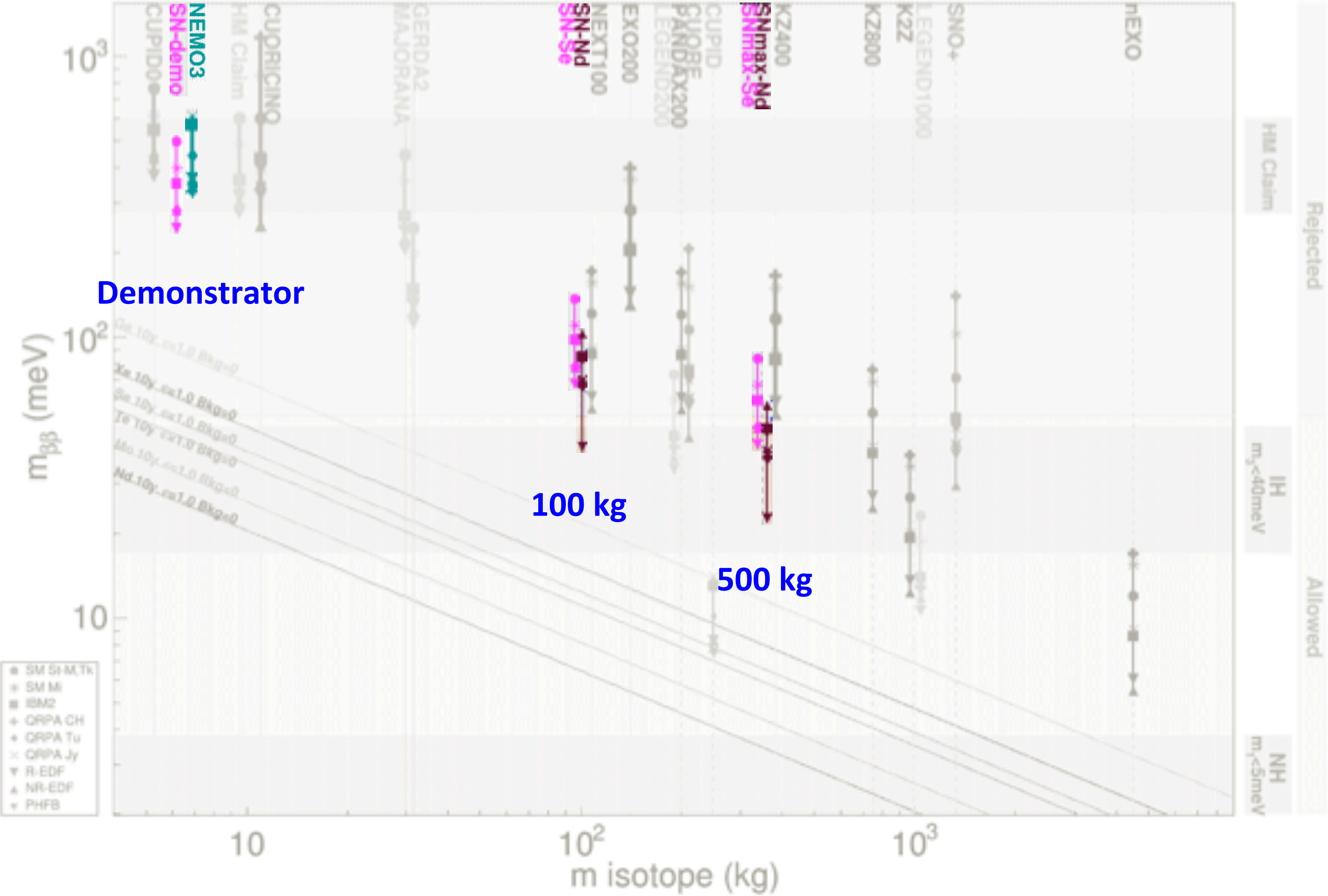
Light neutrino exchange sensitivity

SuperNEMO sensitivity



Light neutrino exchange sensitivity

SuperNEMO sensitivity

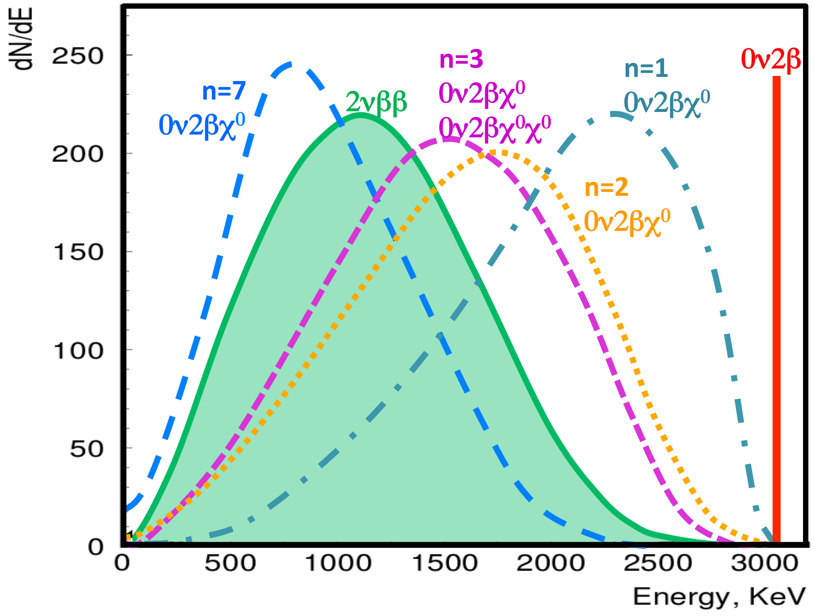


Demonstrator

100 kg

500 kg

Other 2β0ν modes: Majoron



Mode n=1, 2β0νJ

Isotope	$\langle g_J \rangle$ (10^{-5}) 90% C.L.	Expérience	
^{76}Ge	3,4 - 8,7	GERDA	
^{82}Se	3,2 - 8,5	NEMO3	
^{100}Mo	1,6 - 3,0	NEMO3	*7kg !*
^{116}Cd	4,6 - 8,1	SOLOTVINA	
^{130}Te	6 - 16	NEMO3	
^{136}Xe	0,8 - 1,6	KamLAND-zen	*380 kg*
^{150}Nd	3,8 - 14,4	NEMO3	

Phys. Rev. D 92 (2015) 072011

Other modes:

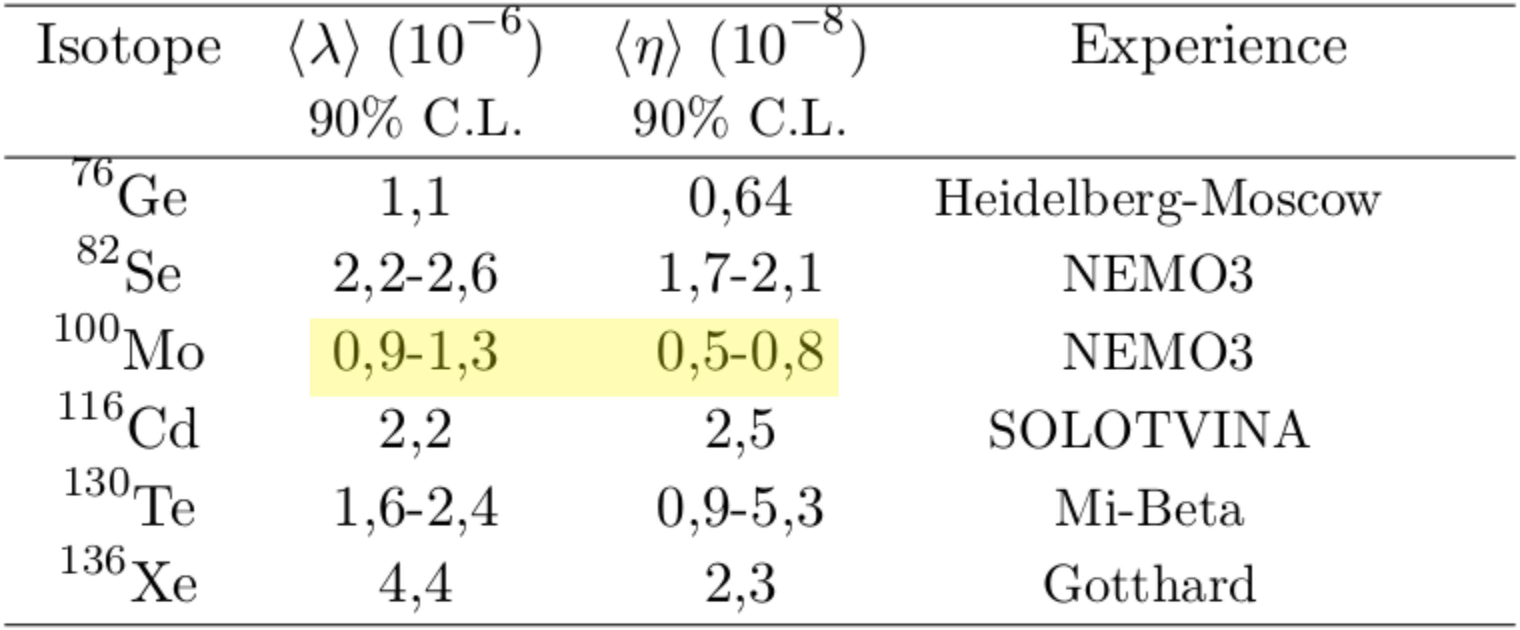
		NEMO3	EXO-200	GERDA
n	Mode	^{100}Mo	^{136}Xe	^{76}Ge
$n = 3$	χ^0	0.013–0.035	0.06	0.047
$n = 3$	$\chi^0\chi^0$	0.59–5.9	0.6–5.5	0.7–6.6
$n = 7$	$\chi^0\chi^0$	0.48–4.8	0.4–4.7	0.8–7.1

Eur. Phys. J. C 79, 440 (2019)

Best sensitivity in all modes
(with only 7 kg)

SuperNEMO:
Improve the limits by 1 order of magnitude

Other 2β0ν modes: V+A

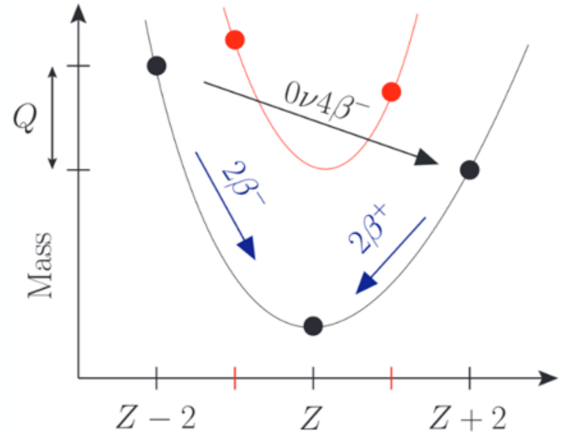


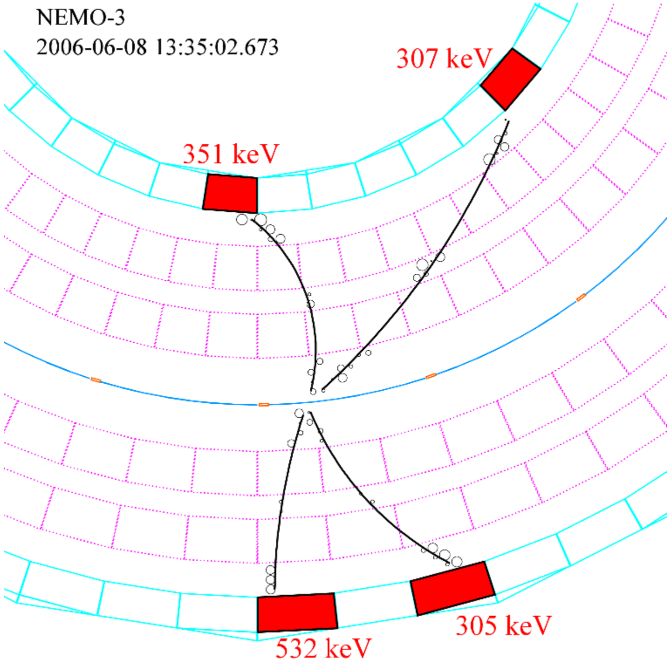
Isotope	$\langle\lambda\rangle$ (10^{-6}) 90% C.L.	$\langle\eta\rangle$ (10^{-8}) 90% C.L.	Experience
^{76}Ge	1,1	0,64	Heidelberg-Moscow
^{82}Se	2,2-2,6	1,7-2,1	NEMO3
^{100}Mo	0,9-1,3	0,5-0,8	NEMO3
^{116}Cd	2,2	2,5	SOLOTVINA
^{130}Te	1,6-2,4	0,9-5,3	Mi-Beta
^{136}Xe	4,4	2,3	Gotthard

Exotic modes: 4β0ν

Neutrinoless quadruple beta decay

- Proposed by Heeck and Rodejohann
  Europhys. Lett. 103, (2013) 32001
- Lepton number violating process
- Dirac neutrinos & 0ν2β forbidden
- Best candidate: ^{150}Nd →^{150}Gd + 4e
  $Q_{4\beta}$=2.079 MeV





NEMO3

$T_{1/2}^{0\nu4\beta}$ > (1.1 – 3.2) 10^{21} y

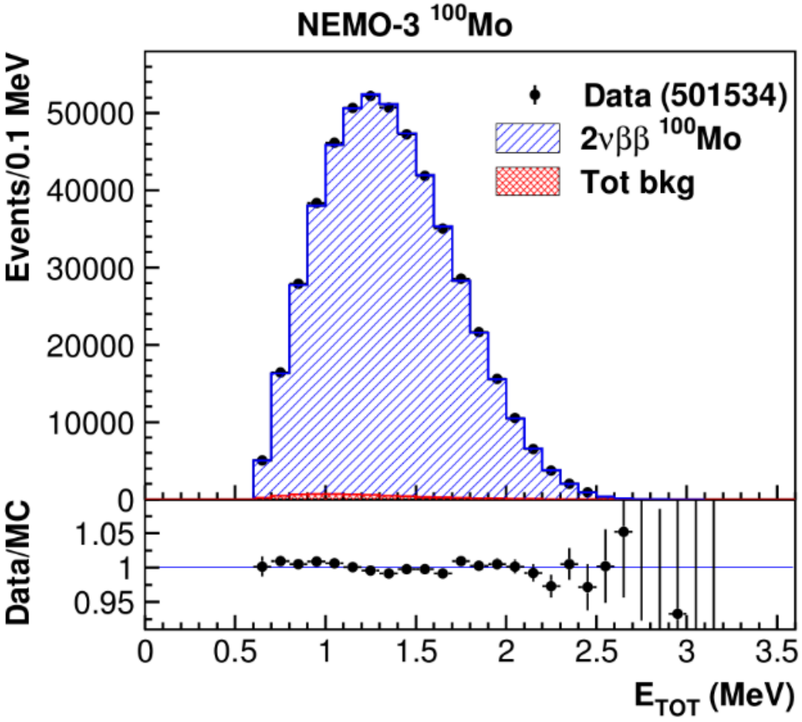
World's first limit

Phys. Rev. Lett. 119 (2017) 041801

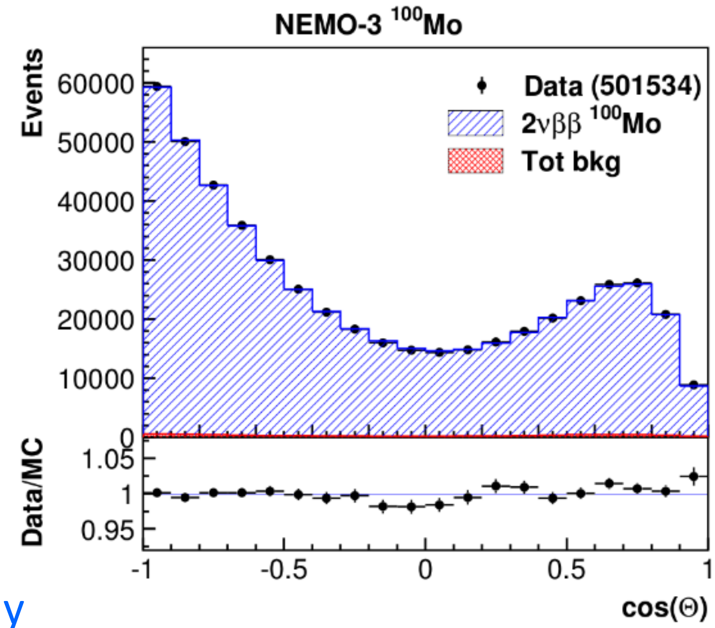
2β2ν precision measurements

NEMO3 : **5 10^5** 2β2ν events (34.3 kg.y of ^{100}Mo)

S/B=79



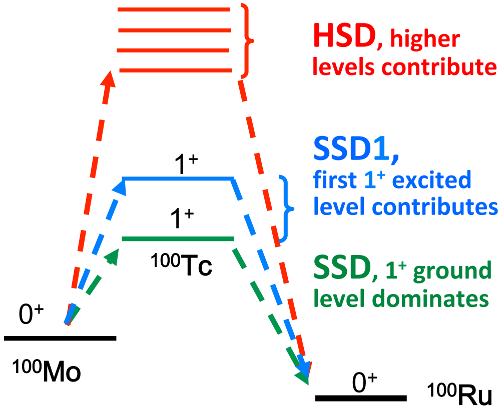
T1/2 = (6.81 ± 0.01(stat) ± 0.46(syst)) x 10^{18} y



First precise measurement of the angular distribution

Eur. Phys. J. C 79, 440 (2019)

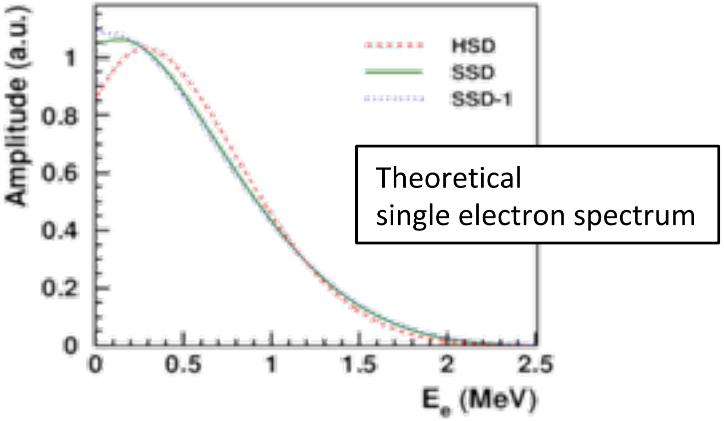
$2\beta2\nu$ precision measurements: SSD/HSD



HSD, higher levels contribute

SSD1, first 1^+ excited level contributes

SSD, 1^+ ground level dominates

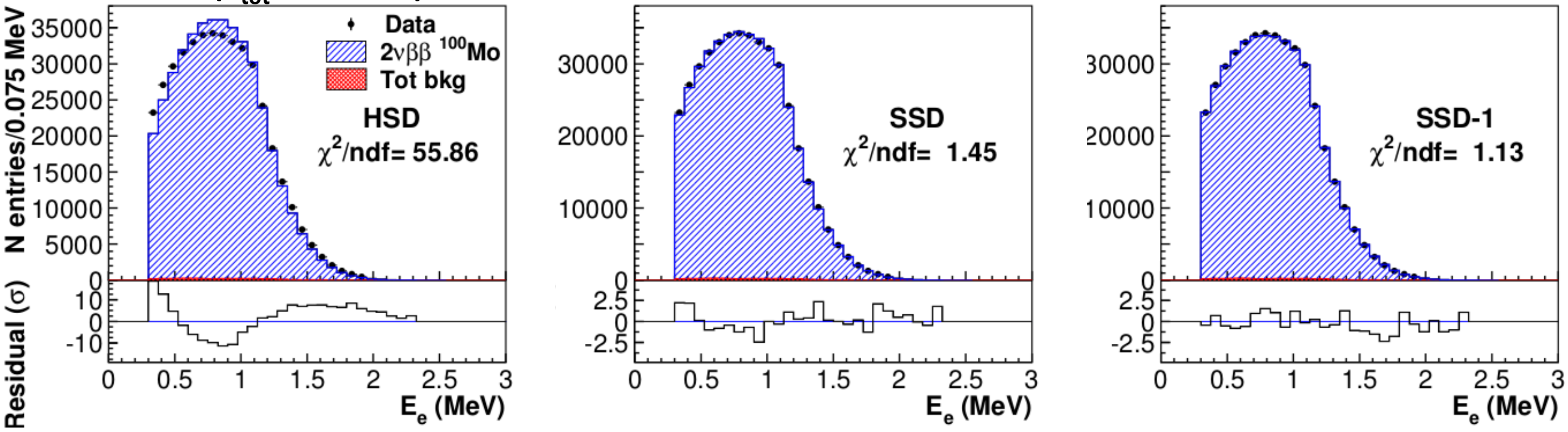


Theoretical single electron spectrum

HSD mechanism rejected from ^{100}Mo single e^- spectra

Eur. Phys. J. C 79, 440 (2019)

NEMO3 data (E_{tot}>1.4 MeV)



$2\beta 2\nu$ precision measurements: Constraints on gA^{eff} ?

$$T^{-1}_{1/2} = (g_{A\,i}^{\,eff})^4 \; G^{0\nu}_i \; |M^{0\nu}_i|^2 \; \varepsilon^2_i$$

Quenching value of gA for $2\beta 0\nu$?

g_A =1	Pure leptonic : muon decay
g_A =1.27	Free nucleon (from neutron decay)
g_A < 1.27	**Nucleus g_A~0.6-0.9 for β decay**

- $2\beta 0\nu$ Historically NME calculations are made with g_A=1.27 (or 1) !

Can we constrain g_A^{eff} value for $2\beta 0\nu$?

2β2ν precision measurements: Constraints on gA^{eff} ?

$$\boxed{T^{-1}_{1/2} = (g_{A}{}^{eff}_{i})^4 \; G^{0\nu}_{i} \; |M^{0\nu}_{i}|^2 \; \varepsilon^2_{i}}$$

2018: 2β2ν half-life developement proposed by F. Simkovic *Phys. Rev. C 97, 034315 (2018)*

$$(T^{2\nu}_{1/2})^{-1} \simeq (g_A^{eff,2\nu})^4 \; |(M^{2\nu}_{GT})^2 G^{2\nu} + \overbrace{M^{2\nu}_{GT} \, \underbrace{M^{2\nu}_{GT-3}}_{\textit{More robust calculation}} \, G^{2\nu}_2}^{\text{Sensitive to the lower energy intermediate states}} |$$

2β2ν precision measurements: Constraints on gA$^{\mathrm{eff}}$?

$$T^{-1}_{1/2} = (g_{A\,i}^{\mathrm{eff}})^4 \; G^{0\nu}_{i} \; |M^{0\nu}_{i}|^2 \; \varepsilon^2_{i}$$

2018: 2β2ν half-life developement proposed by F. Simkovic *Phys. Rev. C 97, 034315 (2018)*

$$\left(T^{2\nu}_{1/2}\right)^{-1} \simeq (g_A^{eff,2\nu})^4 \; |(M^{2\nu}_{GT})^2 G^{2\nu} + \overbrace{M^{2\nu}_{GT} M^{2\nu}_{GT-3} G^{2\nu}_2}^{\text{Sensitive to the lower energy intermediate states}}|$$

More robust calculation

$$= (g_A^{eff,2\nu})^4 \; |M^{2\nu}_{GT-3}|^2 \; \frac{1}{|\xi^{2\nu}_{31}|^2} \; |G^{2\nu} + \xi^{2\nu}_{31} \, G^{2\nu}_2|$$

$$\xi^{2\nu}_{31} = \frac{M^{2\nu}_{GT-3}}{M^{2\nu}_{GT}}$$

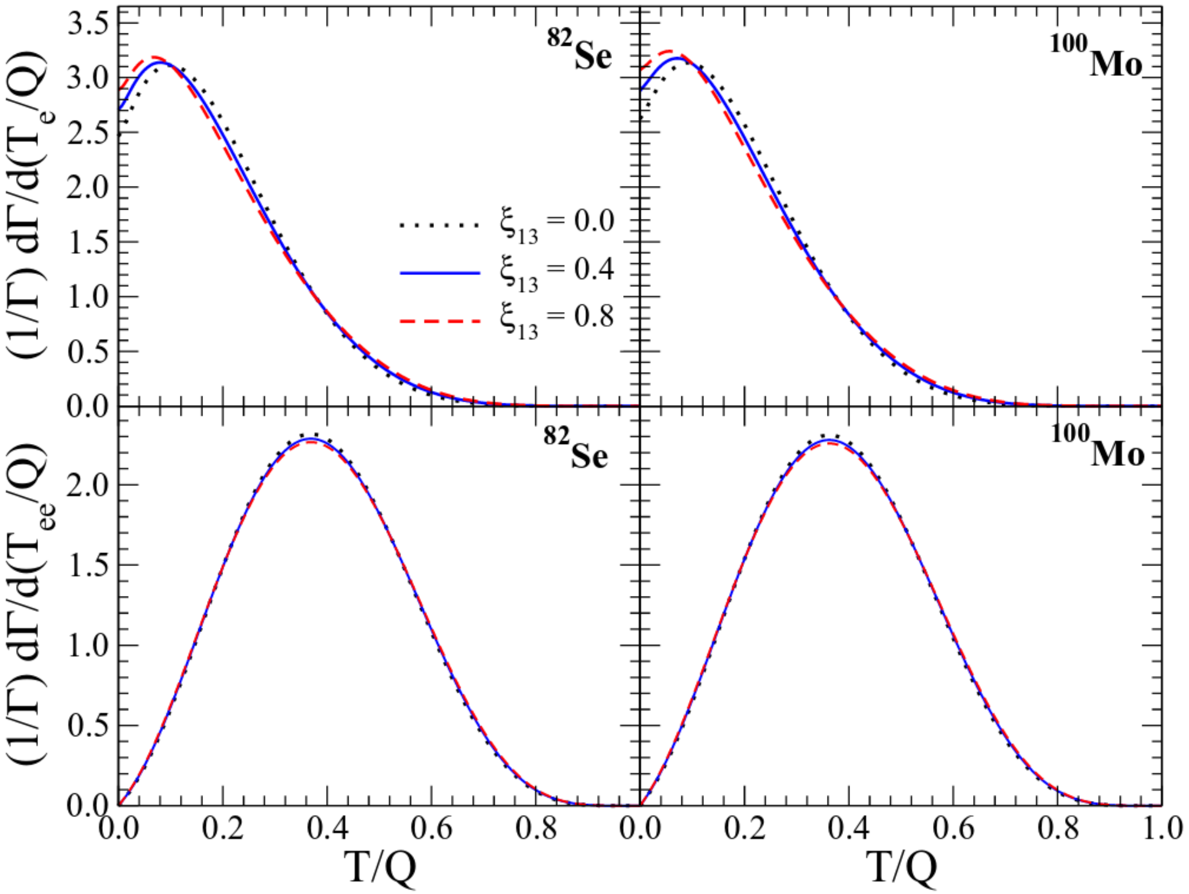
New parameter sensitive to the lightest states of the intermediate nucleus

=> Experimentally accessible by the electron energy distribution !

2β2ν precision measurements: Constraints on gA^{eff} ?

E$_{ind}$

E$_{tot}$



Phys. Rev. C 97, 034315 (2018)

$2\beta2\nu$ precision measurements: Constraints on gA$^{\text{eff}}$?

$$T_{1/2}^{-1} = (g_{A\,i}^{\text{eff}})^4 \; G_i^{0\nu} \; |M_i^{0\nu}|^2 \; \varepsilon_i^2$$

2018: $2\beta2\nu$ half-life developement proposed by F. Simkovic *Phys. Rev. C 97, 034315 (2018)*

$$\begin{aligned}(T_{1/2}^{2\nu})^{-1} &\simeq (g_A^{eff,2\nu})^4 \; |(M_{GT}^{2\nu})^2 G^{2\nu} + M_{GT}^{2\nu} M_{GT-3}^{2\nu} G_2^{2\nu}| \\ &= (g_A^{eff,2\nu})^4 \; |M_{GT-3}^{2\nu}|^2 \; \frac{1}{|\xi_{31}^{2\nu}|^2} \; |G^{2\nu} + \xi_{31}^{2\nu} G_2^{2\nu}|\end{aligned}$$

Observables

$2\beta2\nu$ precision measurements: Constraints on gA^{eff} ?

$$T^{-1}_{1/2} = (g_{A}{}^{\text{eff}}_{i})^4\ G^{0\nu}_{i}\ |M^{0\nu}_{i}|^2\ \varepsilon^2_{i}$$

2018: $2\beta2\nu$ half-life developement proposed by F. Simkovic *Phys. Rev. C 97, 034315 (2018)*

$$(T^{2\nu}_{1/2})^{-1} \simeq (g_A^{eff,2\nu})^4\ |(M^{2\nu}_{GT})^2 G^{2\nu} + M^{2\nu}_{GT}\ M^{2\nu}_{GT-3} G^{2\nu}_2|$$

$$(T^{2\nu}_{1/2})^{-1} = \boxed{(g_A^{eff,2\nu})^4}\ |M^{2\nu}_{GT-3}|^2\ \frac{1}{|\xi^{2\nu}_{31}|^2}\ |G^{2\nu} + \xi^{2\nu}_{31}\ G^{2\nu}_2|$$

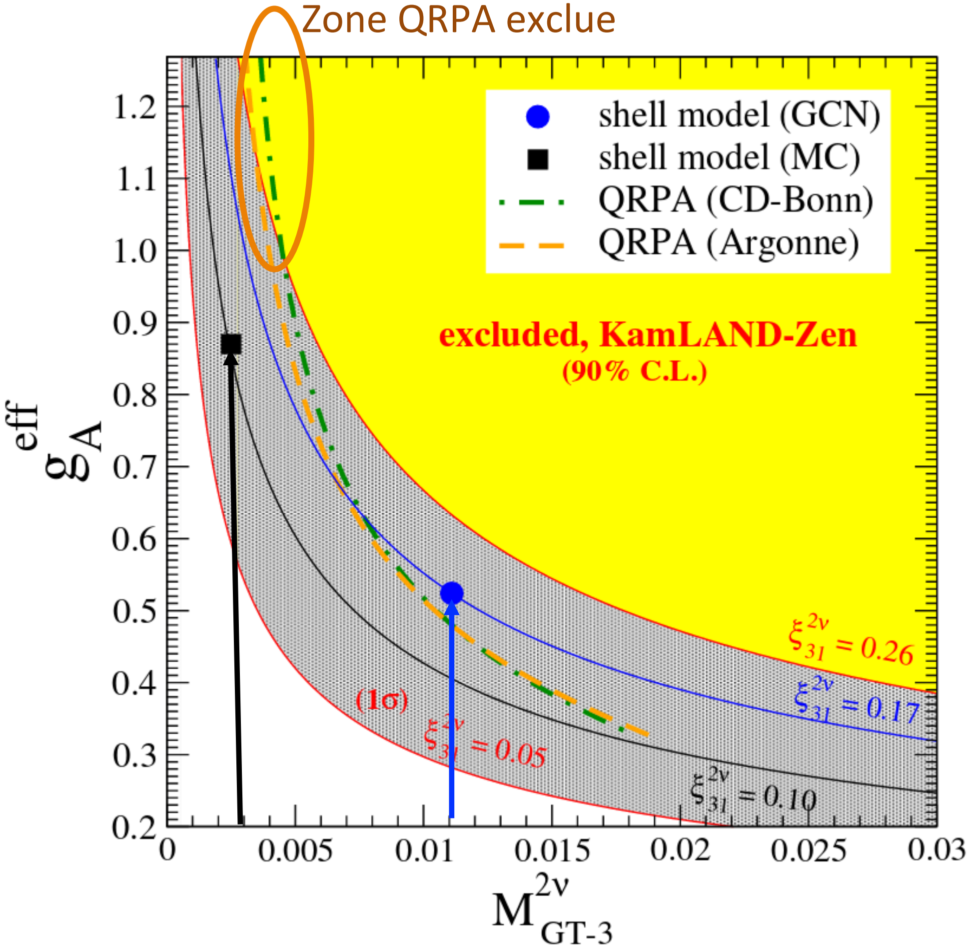
🟩 **Calculations OK**

🟥 **Observables**

$$g_A^{eff,2\nu} = f(\xi^{2\nu}_{31}, T^{2\nu}_{1/2}, \frac{1}{\sqrt{M^{2\nu}_{GT-3}}})$$

2β2ν precision measurements: Constraints on g_A^{eff} ?

KamLAND-Zen study


Zone QRPA exclue

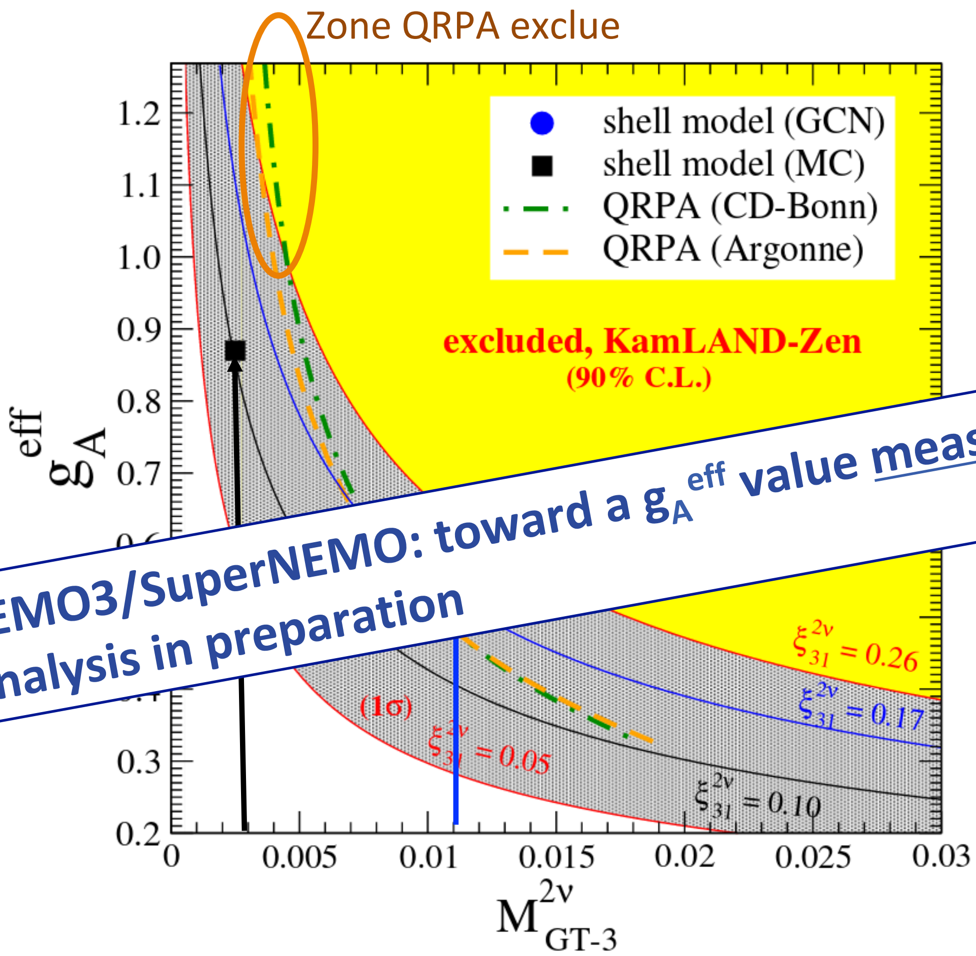
$\xi_{31}^{2\nu}$ < **0,26** (90% CL)

KamLAND-Zen

$2\beta2\nu$ precision measurements: Constraints on gA^{eff} ?

KamLAND-Zen study

Zone QRPA exclue



NEMO3/SuperNEMO: toward a g_A^{eff} value measurement

Analysis in preparation

$\xi_{31}^{2\nu}$ < **0,26** (90% CL)

KamLAND-Zen

Advantages of NEMO3/SuperNEMO:

- ✓ Individual energy + angular correlation
- ✓ SSD Isotopes (higher ξ contribution)

SuperNEMO Strategy

SuperNEMO Phase 1: 6kg ^{82}Se (2020-2022)

2019: End of construction and commissionning

- Test the detector performances (background : 1 year)

^{82}Se 17.5 kg.y **$T_{1/2}(0\nu) > 5\ 10^{24}$ y** **$<m_\nu> < 0.26\text{-}0.51$ eV**

NEMO3 ^{82}Se: $T_{1/2}(0\nu) > 0.25\ 10^{24}$ y $<m_\nu> < 1.2\text{-}2.3$ eV

SuperNEMO Phase 2: Other isotope ? ^{96}Zr, ^{150}Nd ?

Enrichment under progress in Russia : new centrifugation method

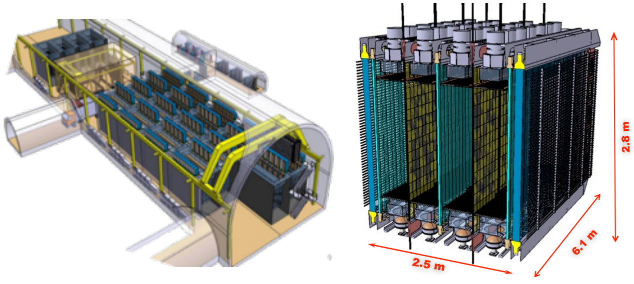
Sensitivity of 6kg ^{150}Nd ~ 12 kg ^{82}Se

SuperNEMO Phase 3 : Can the technique be extended to a 100 kg scale ?

Best technique for exploring a signal !

R&D on the compactness (cost, efficiency…)

Feedback from the demonstrator construction & running



CONCLUSIONS

SuperNEMO : a unique tracker-calorimeter experiment

- 2 electron **visualisation**: DBD « smoking gun » evidence
- Unique sensitivity on the identification of the **DBD mechanism:** light neutrino, V+A, SUSY, Majoron, excited states…
- $2\beta2\nu$ **precision measurement & exotic process**: HSD/SSD, gA, bosonic neutrinos, excited states, 4β

^{100}Mo	**0ν**	**V+A**	**J**	**SUSY**	**2ν**	**0/2ν***
^{82}Se	0ν	**V+A**	**J**	SUSY	**2ν**	0/**2ν***
^{130}Te	0ν	V+A	**J**	SUSY	2ν	
^{116}Cd	0ν	V+A	**J**	SUSY	2ν	
^{150}Nd	**0ν**	**V+A**	**J**	**SUSY**	**2ν**	**4β0ν**
^{96}Zr	**0ν**	**V+A**	**J**	**SUSY**	**2ν**	
^{48}Ca	0ν	**V+A**	**J**	SUSY	**2ν**	
	$m_{\beta\beta}$	**$\langle\lambda\rangle$ $\langle\eta\rangle$**	**$\langle g_J\rangle$**	**λ'_{111}**	*World's Best*	

20 publications, 20(/55) citations PDG2018

SuperNEMO demonstrator : final commissioning

See Cloe's talk

- Most precise study of ^{82}**Se** (6kg)
- New isotopes like ^{150}**Nd,** ^{96}**Zr** are considered
- Can the technique be extended **to confirm a signal anywhere in the IH region ?** R&D and isotope developments can point the way

SuperNEMO R&D results in new technical improvements. For example:

- **Radiopurity control** : BiPo detector, HPGe, Radon set-up (emanantion, concentration, diffusion)
- **Source** enrichment, purification methods
- Development of **new material** : radiopure glass, PS scintillators