Latest results from NEMO-3 and status of SuperNEMO

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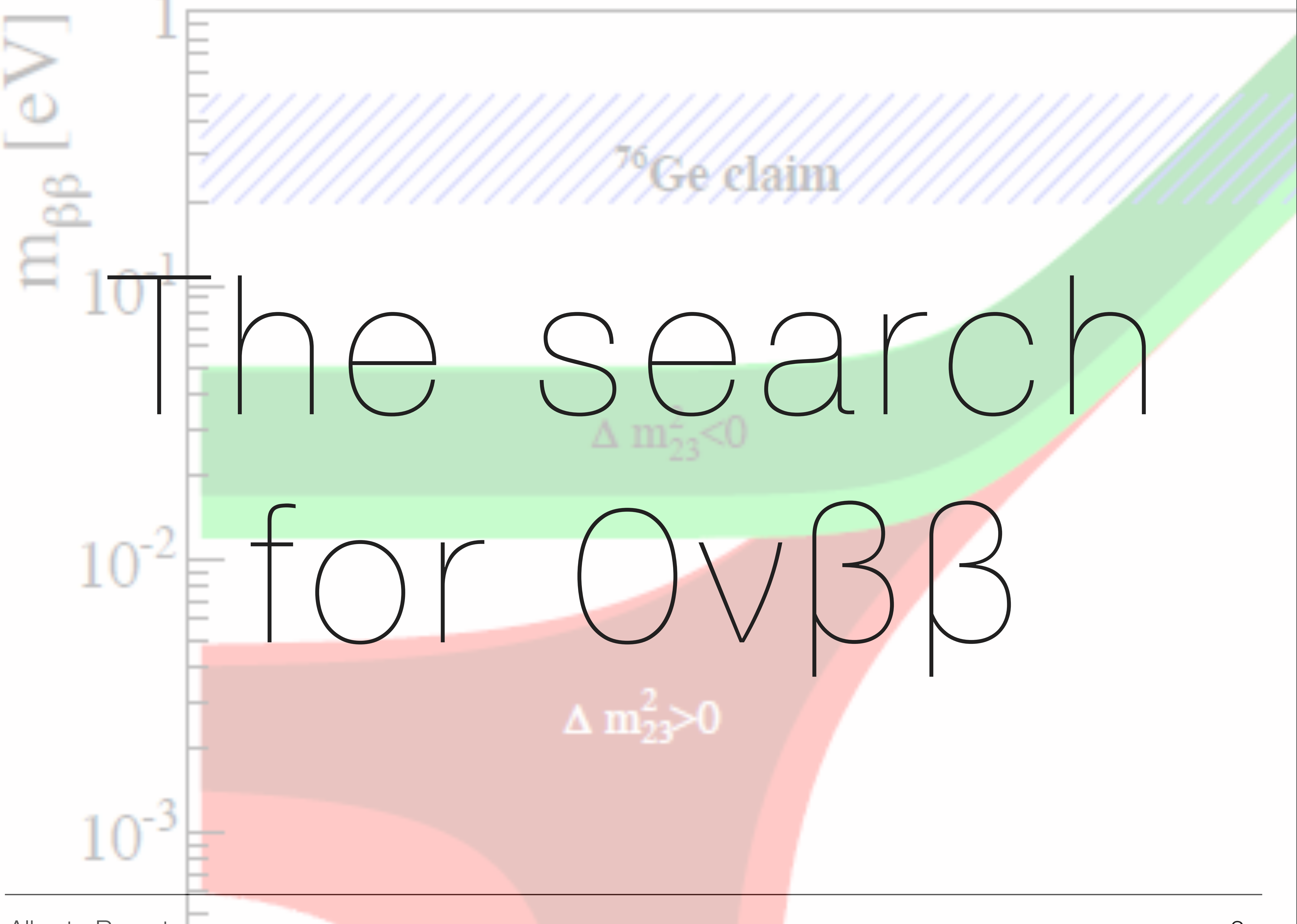
What is on the menu?

- Searching $0\nu\beta\beta$ decay
- Looking for $\beta\beta$ events with a tracker & calorimeter
- Recent results from NEMO-3
- Toward the new generation with SuperNEMO

The search for $0\nu\beta\beta$

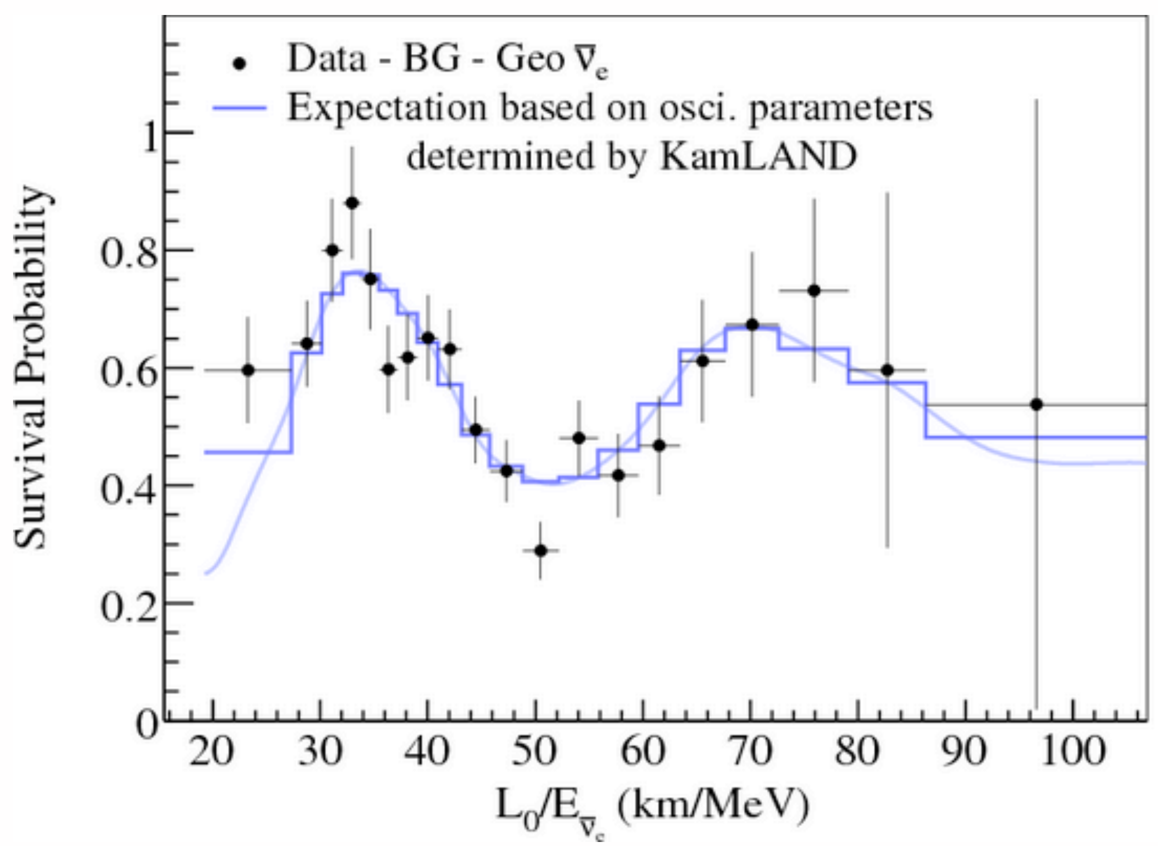


Once upon a time…

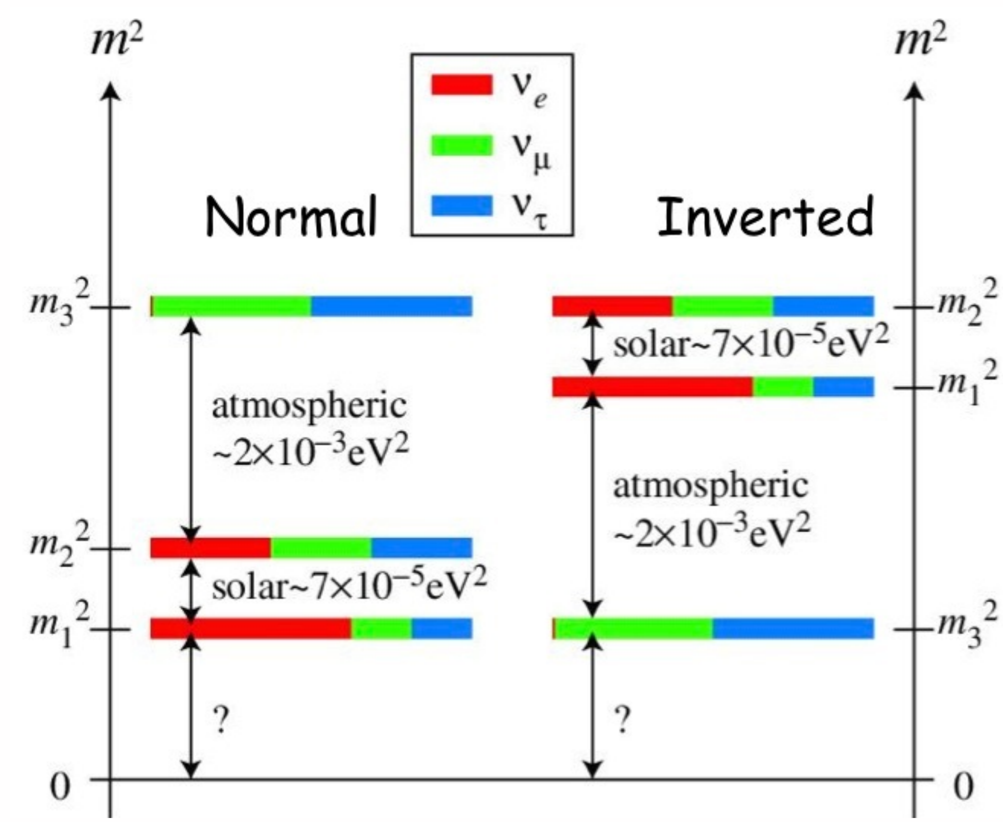
1936 — E. Majorana proposes a *real* wave to describe massive & electrically neutral fermion

1957 — B. Pontecorvo set the basis for the neutrino flavour oscillation

Last 20 years: Huge effort to confirm neutrino oscillation and measure parameters



PRL, 100:221803, 2008



We know a lot about neutrino oscillation but not everything yet: mass hierarchy, δ_{CP}, θ_{23} octant

Is the neutrino a Majorana particle?

We know that neutrino is:

1) fermion
2) electrically neutral
3) massive

→ **It could be a Majorana particle**

Search for 0νββ decay is the only practical way to test Dirac/Majorana nature of neutrinos

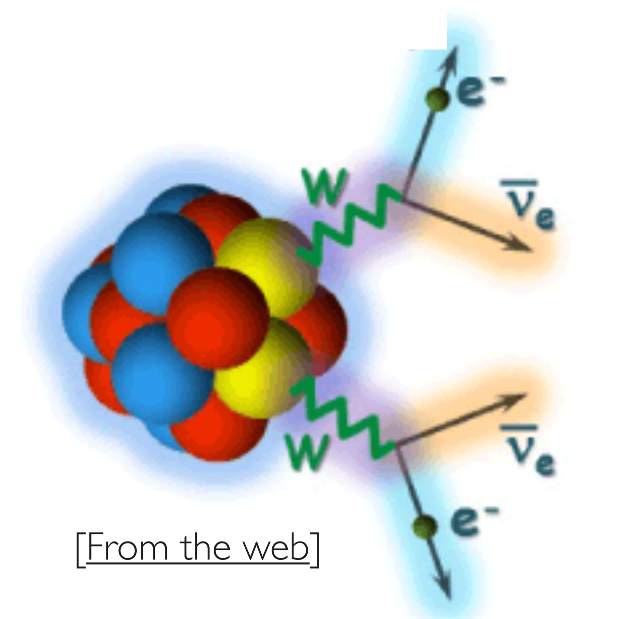
If Majorana particle exists, there are interesting implications for particle physics:

- Lepton number violation must occur: $\nu \equiv \nu^c \rightarrow |\Delta L| = 2$
- GUT, Leptogenesis model, See-Saw mechanism

Double beta decay in a nutshell

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

- 2nd order process allowed in the SM
- Single β decay forbidden (energy & angular momentum)
- 11 isotopes have been experimentally observed undergoing 2vββ decay



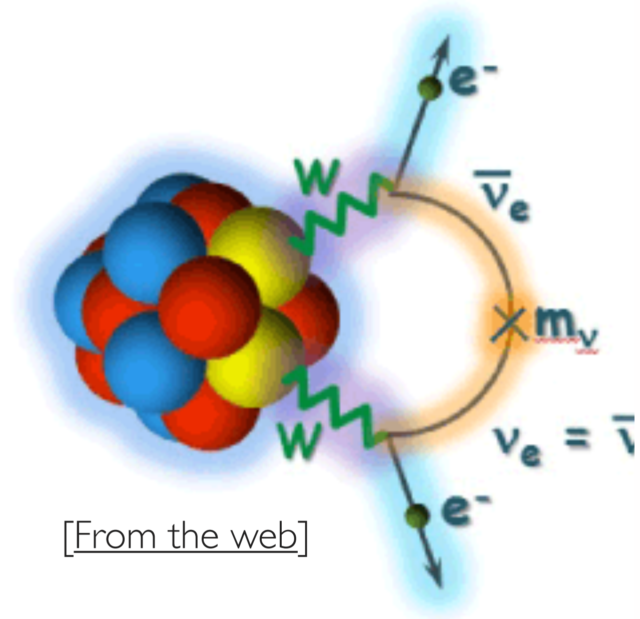
[From the web]

$$(T_{1/2}^{2\nu})^{-1} = G_{2\nu}(Q_{\beta\beta}, Z)|M_{2\nu}|^2$$

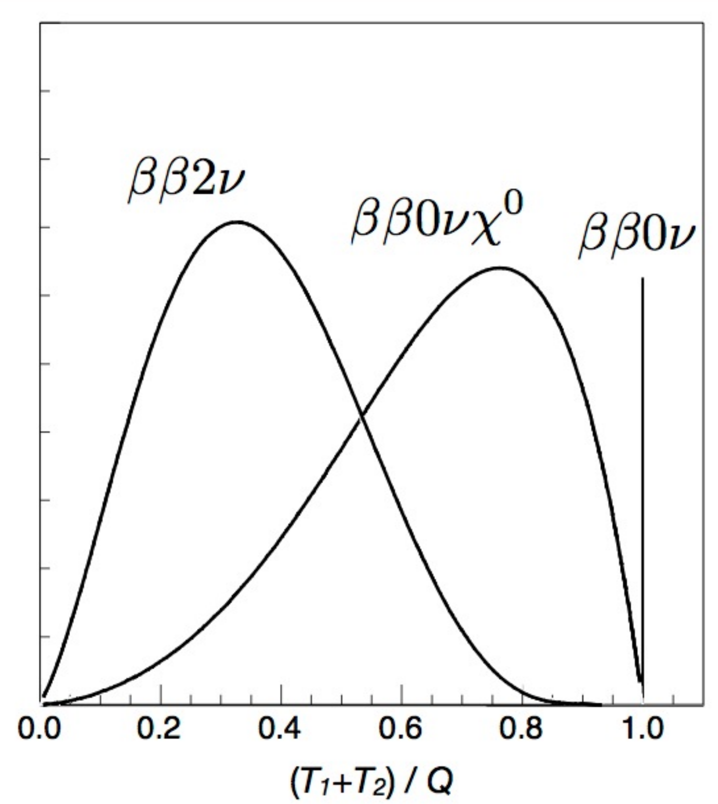
Neutrino-less double beta decay in a nutshell

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

- Process forbidden in the SM
- Half-life strongly suppressed



[From the web]



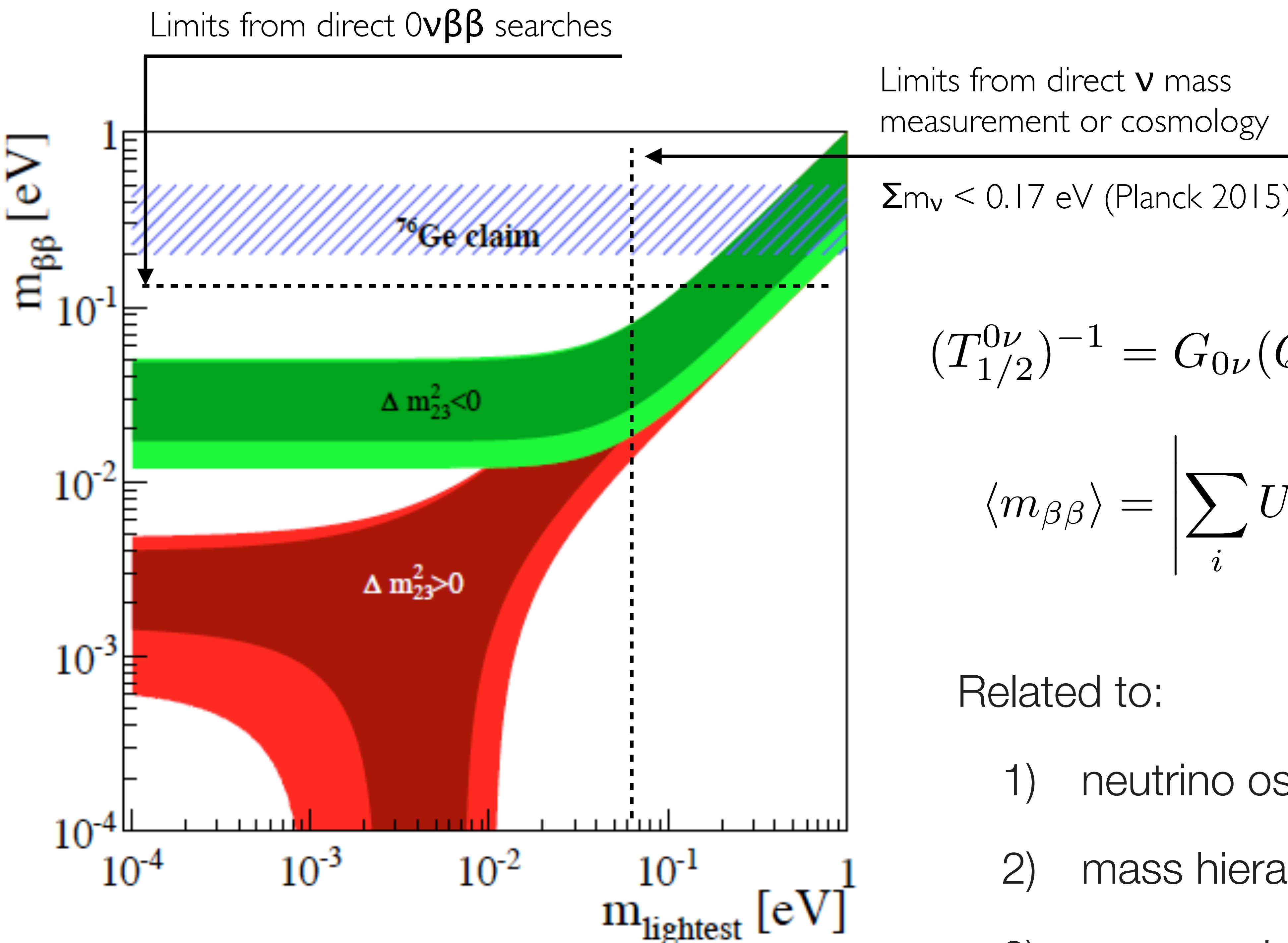
$$(T^{0\nu}_{1/2})^{-1} = G_{0\nu}(Q_{\beta\beta}, Z)|M_{0\nu}|^2\eta^2$$

Few different mechanisms may induce 0νββ

- Light Majorana neutrino exchange
- Right-handed current (V+A), SUSY, Majoron(s), etc.

Different topology in the final state!

Sensitivity to the light Majorana neutrino



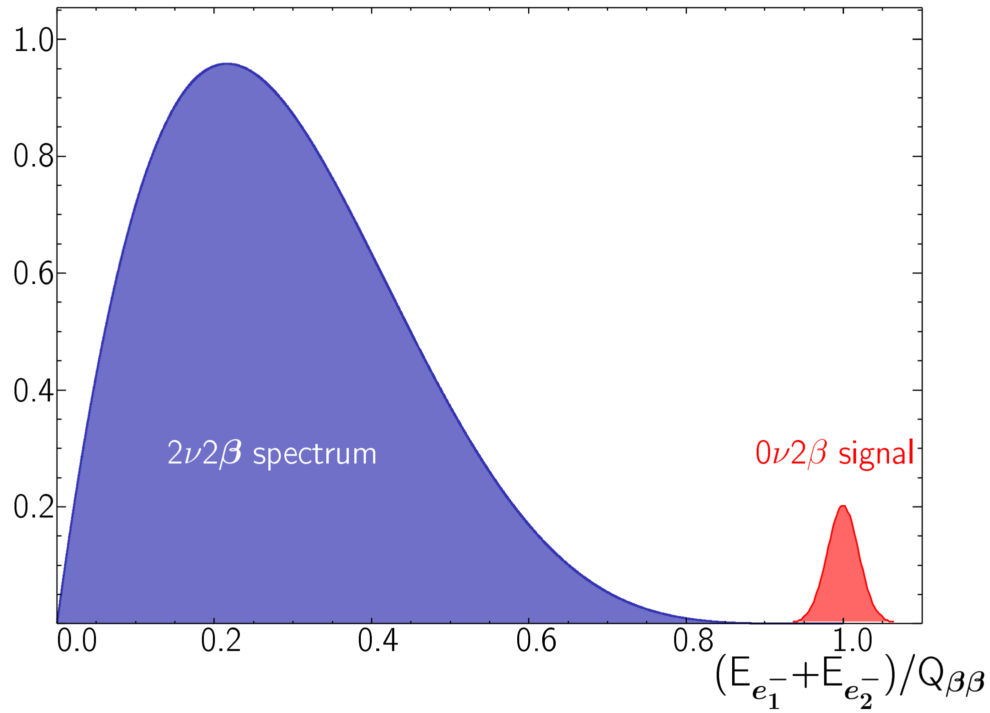
$$(T^{0\nu}_{1/2})^{-1} = G_{0\nu}(Q_{\beta\beta}, Z)|M_{0\nu}|^2 \frac{\langle m_{\beta\beta}\rangle^2}{m_e^2}$$

$$\langle m_{\beta\beta}\rangle = \left|\sum_i U^2_{ei} m_i\right|$$

Related to:

1) neutrino oscillation
2) mass hierarchy
3) mass scale

0νββ searches in practice



Measure the 2 e⁻ energy spectrum

- 2νββ signature → Broad spectrum
- 0νββ signal signature → Peak @ $Q_{\beta\beta}$

If no signal → set a limit on half life

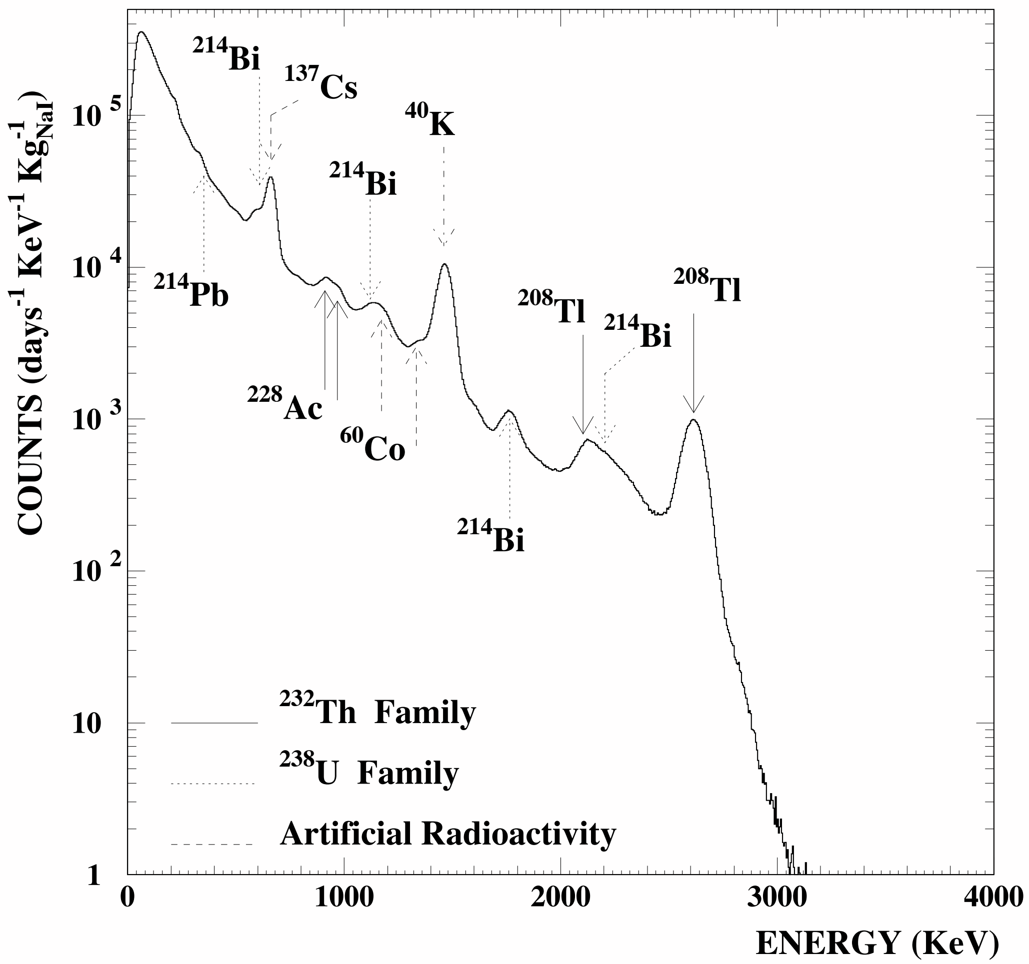
$$T_{1/2}^{0\nu} > \frac{N_A \ln 2}{n_\sigma} \times \frac{\epsilon}{A} \times \sqrt{\frac{M \times t}{B \times \Delta E}}$$

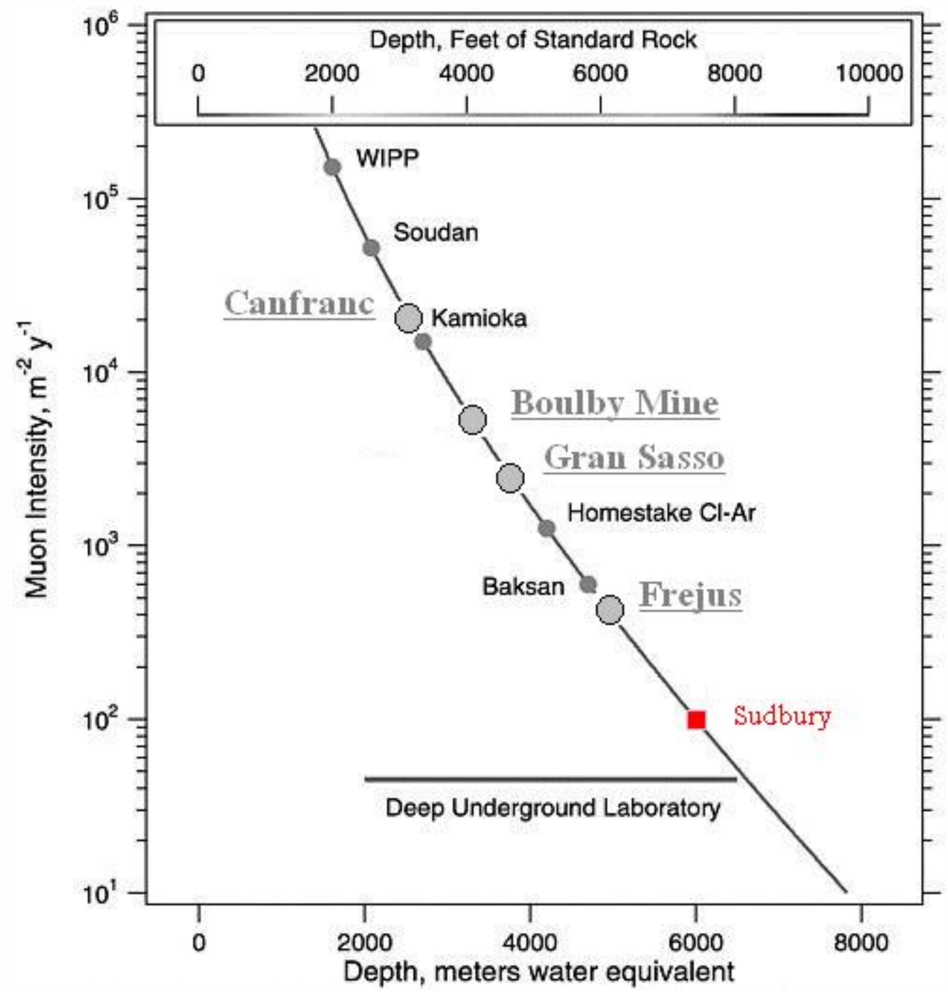
- Detection efficiency → ϵ
- ββ emitter mass → M
- Exposure time → t
- E res. @ Qββ → ΔE
- Excluded events at a given C.L. → n_σ
- Atomic mass → A
- Bkg. index → B

Few important aspects…

Low energy process ($Q_{\beta\beta} \lesssim 5$ MeV):

- Natural radioactivity is an issue (^{238}U , ^{232}Th)
- Cosmic muons are an issue



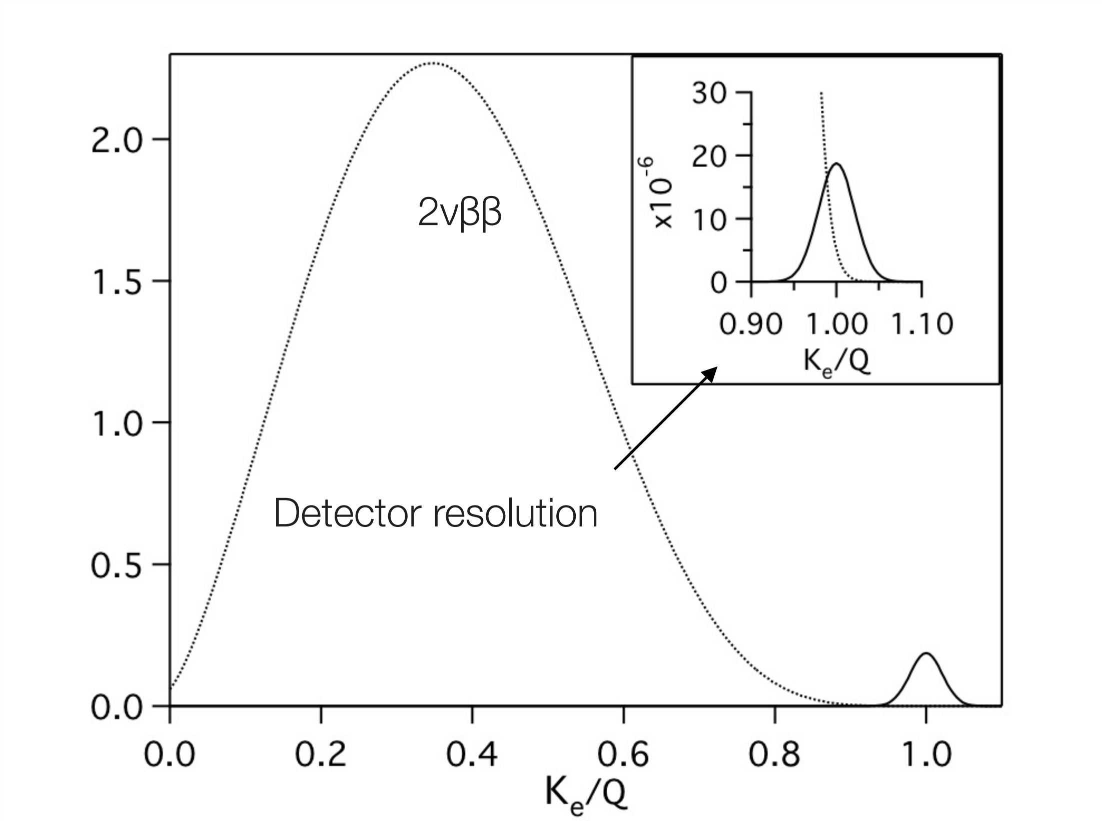


Few important aspects…

Distinguish 0ν from 2ν mode → irreducible background

- Good detector energy resolution

Few available isotopes → multiply experimental efforts



Isotope	$Q_{\beta\beta}$ [keV]	Nat. abund. (enrich.) [%]
$^{48}Ca \rightarrow {}^{48}Tl$	4270	0.187 (73)
$^{76}Ge \rightarrow {}^{76}Se$	2039	7.8 (86)
$^{82}Se \rightarrow {}^{82}Kr$	2995	8.7 (97)
$^{96}Zr \rightarrow {}^{96}Mo$	3350	2.8 (57)
$^{100}Mo \rightarrow {}^{100}Ru$	3034	9.6 (99)
$^{110}Pd \rightarrow {}^{110}Cd$	2018	7.5
$^{116}Cd \rightarrow {}^{116}Sn$	2802	7.5 (93)
$^{130}Te \rightarrow {}^{130}Xe$	2527	34.5 (90)
$^{136}Xe \rightarrow {}^{136}Ba$	2480	8.9 (80)
$^{150}Nd \rightarrow {}^{150}Sm$	3367	5.6 (91)

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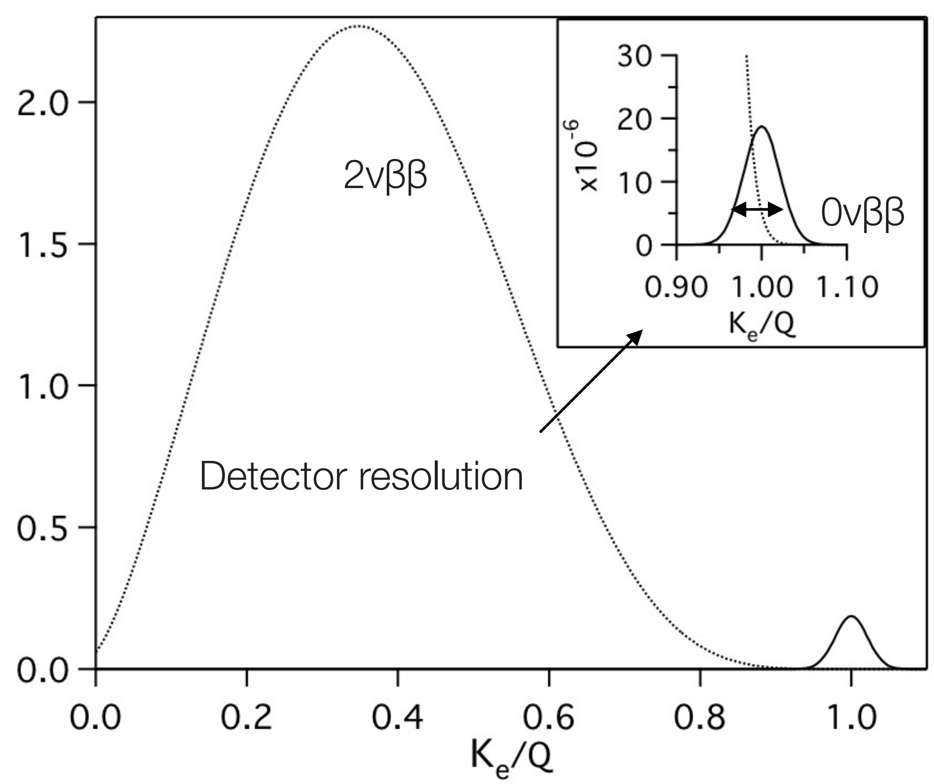

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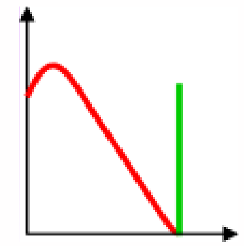
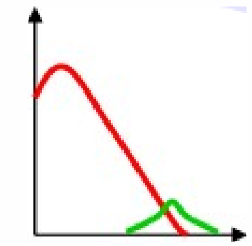
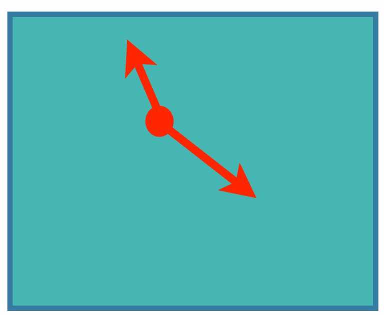
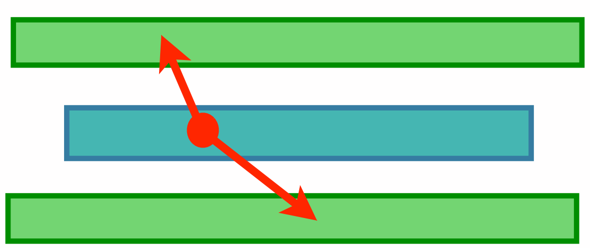
Which technology?

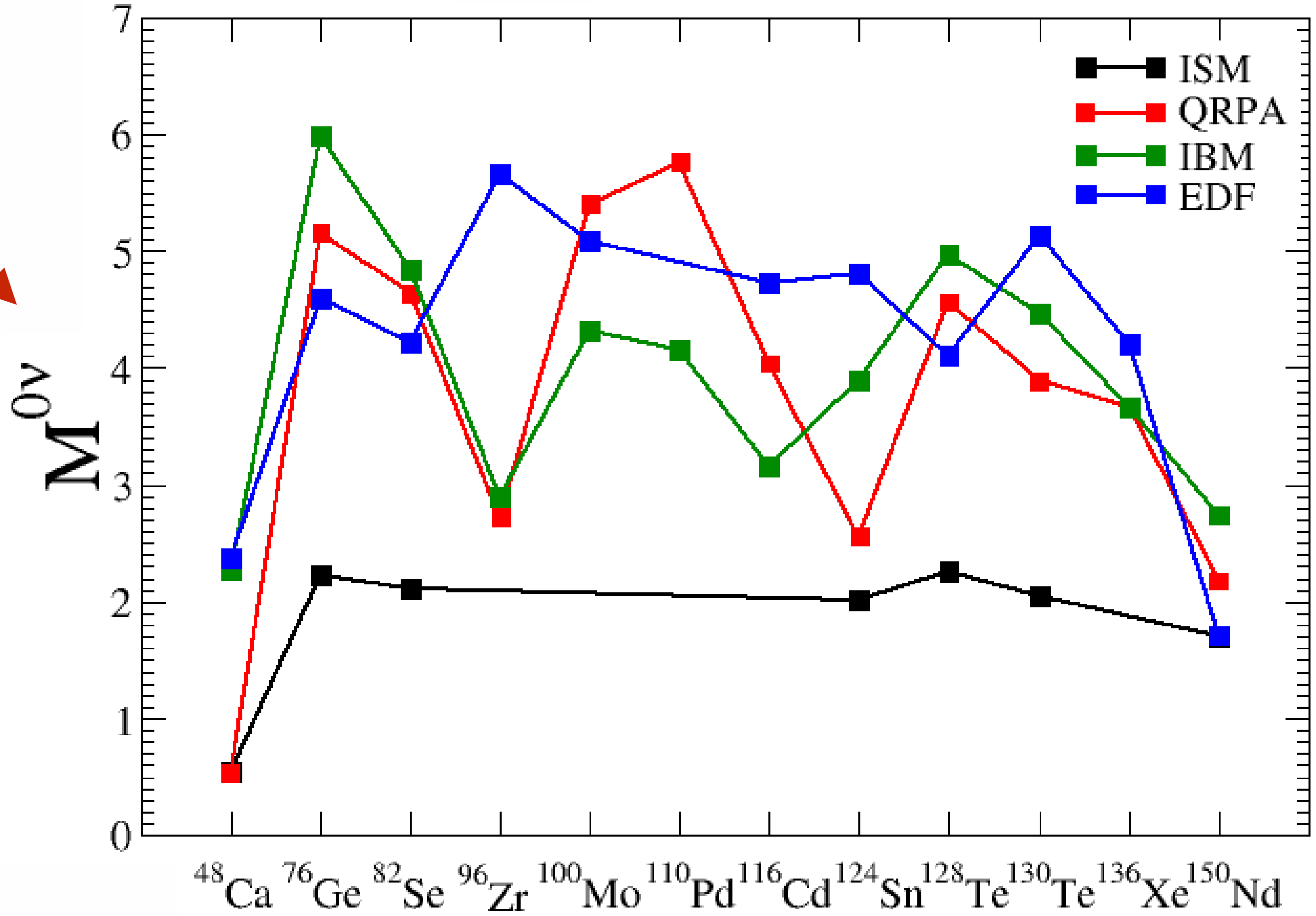
Technique \ En. resolution	< 1 % 	> 1 % 
Calorimeter  **Detector = Source**	Diodes ^{76}Ge	Liquid scintillators ^{136}Xe, ^{150}Nd, ^{48}Ca, ^{100}Mo
	Bolometers ^{130}Te, ^{82}Se, ^{100}Mo	Liquid/Gas TPC ^{136}Xe
Electron Tracking  **Source** **Detector**		Tracking + Calorimetry ^{82}Se, ^{150}Nd, ^{48}Ca, ...
		Pixelized Scintillator ^{116}Cd

Watch out for the NME…

$$(T^{0\nu}_{1/2})^{-1} = G_{0\nu}(Q_{\beta\beta}, Z)|M_{0\nu}|^2\eta^2$$

- Contain nuclear structure effects
- Many approximation methods
- Different among isotopes
- Measuring NME in 2νββ does not help

Compiled by F. Simkovic (2014) g_A =1.25(7)

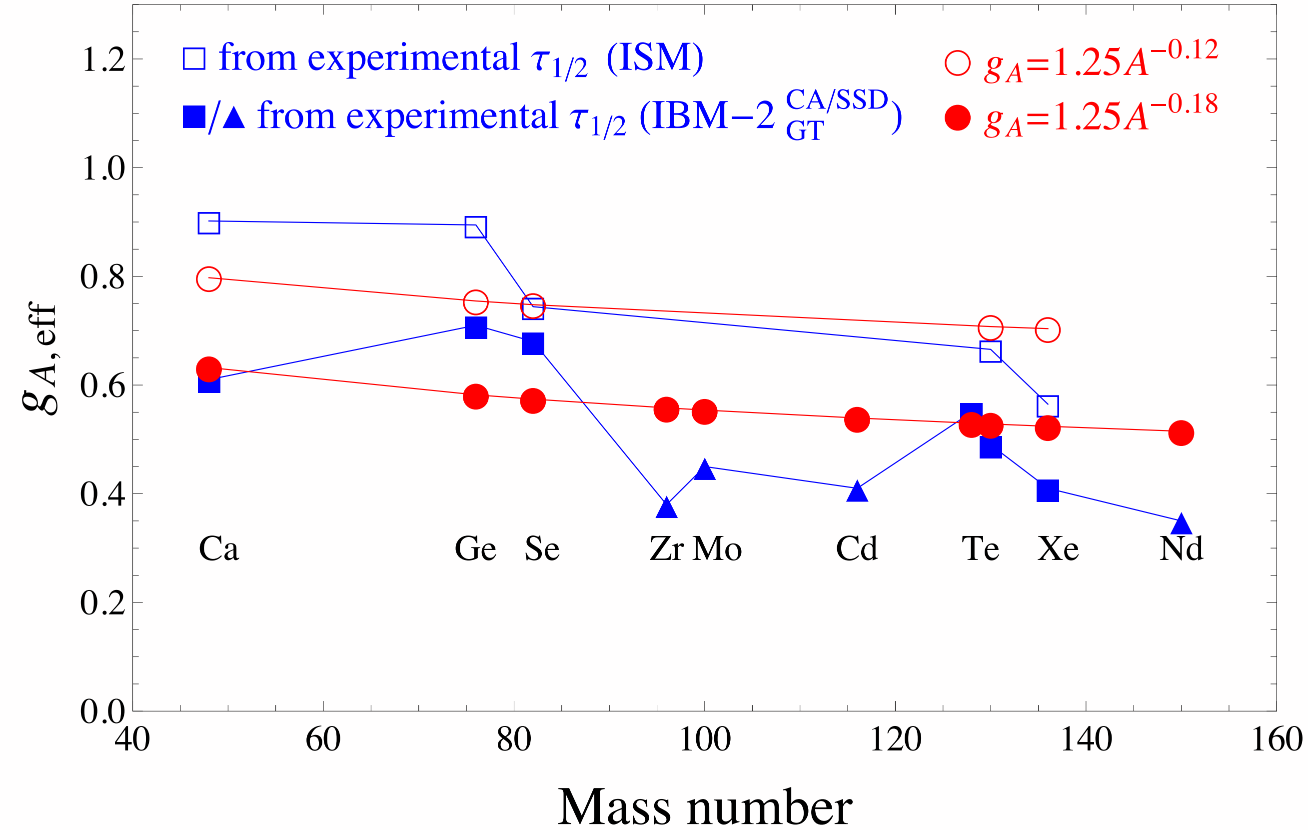


Main limitation in interpreting results & comparing among different isotopes

…but also the axial coupling constant

[Phys. Rev. C 87, 014315 (2013)]

- g_A is know to be quenched in β and ββ decay
- An effective constant is extracted from experimental measurement
- Quenching factor ~0.8 — 0.5
- g_A quenched in 0vββ as much as in 2vββ?



g_A appear at the 4th power in $T_{1/2}$ calculation
→ it may impact ⟨$m_{\beta\beta}$⟩ sensitivity up to x6–34

What is the status?

1993 - 2000

HdM (35.5 kg x y) & **IGEX**, ^{76}Ge

- $T^{0\nu}_{1/2} > 1.9 \times 10^{25}$ y @ 90% C.L.

HdM claim: $\langle m_\nu \rangle = 0.32 \pm 0.03$ eV

2000 - 2010

Cuoricino (19.75 kg x y): TeO_2 bolometer

- ^{130}Te: $T^{0\nu}_{1/2} > 2.8 \times 10^{24}$ y @ 90% C.L.

NEMO3 (34.7 kg x y with Mo): track + calo.

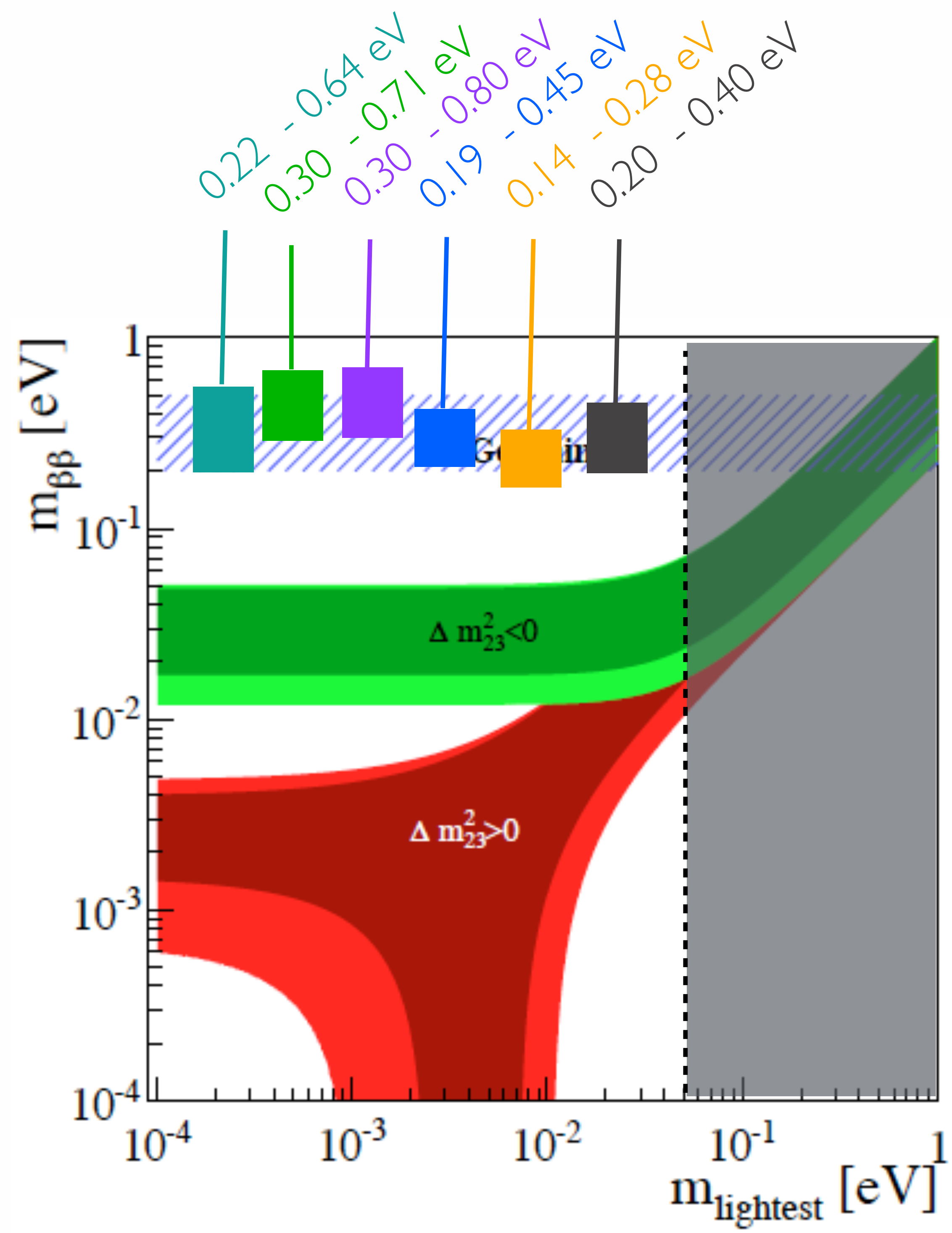
- ^{100}Mo: $T^{0\nu}_{1/2} > 1.1 \times 10^{24}$ y @ 90% C.L.

Since 2011

EXO200 (> 95 kg x y): Liquid Xe TPC

Kamland-ZEN (190 kg x y): Liquid Scintillator

GERDA Phase 1 (>20 kg x y): Ge diodes



Future projects

CUORE, Gerda, Majorana, Lucifer, AMORE, NEXT, COBRA, EXO, SNO+, KamLAND-Zen, CANDLES, SuperNEMO, DCBA, ...

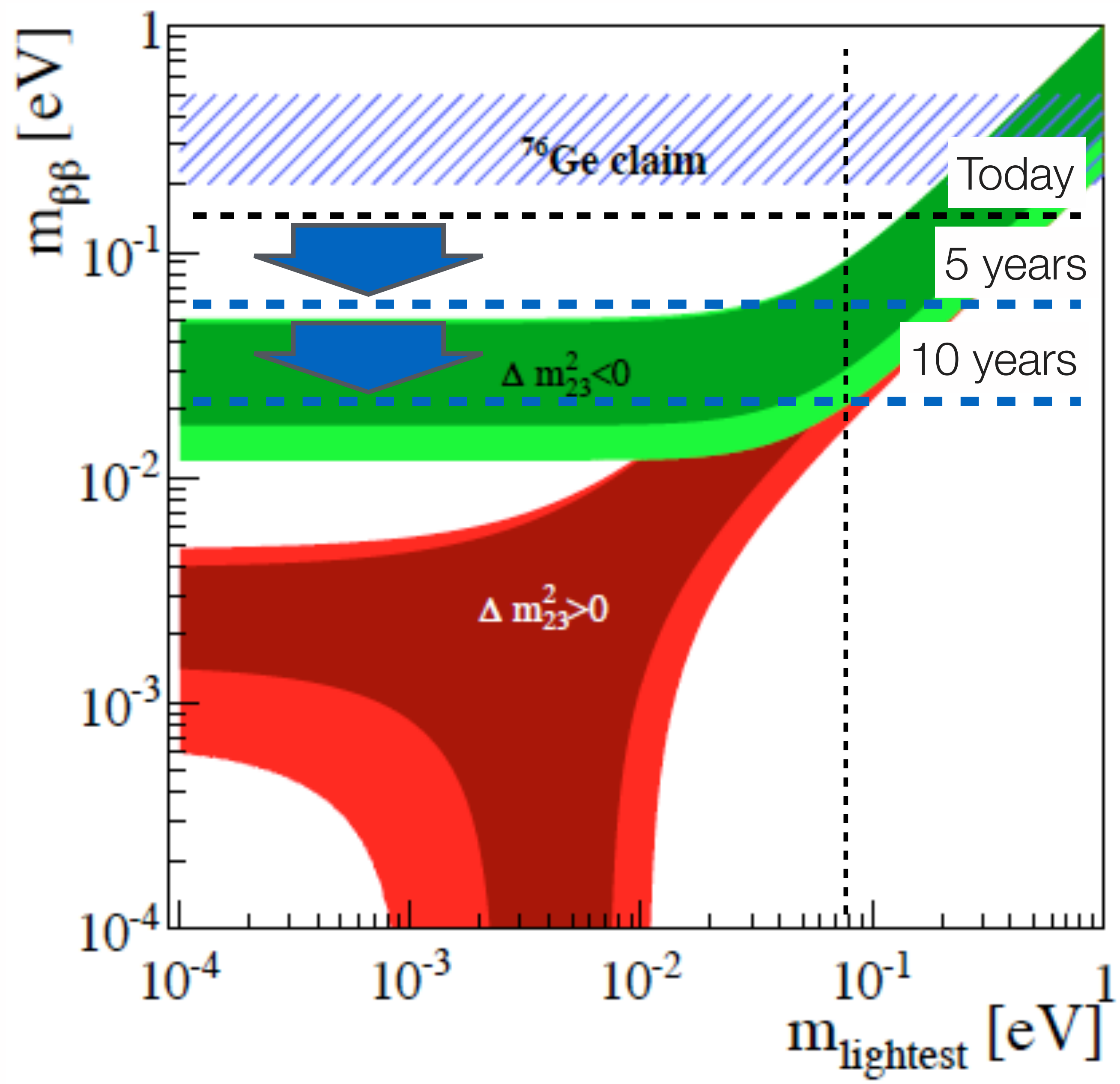
5 years time scale:

- M ~ 10 - 50 kg of ββ isotope
- Background level 10^{-3} cts. /(keV kg y)
- Explore quasi-degenerate region

10 years time scale:

- M ~ 100 kg - 1t of ββ isotope
- Background level 10^{-4} cts. /(keV kg y)
- Approach Inverse Hierarchy region

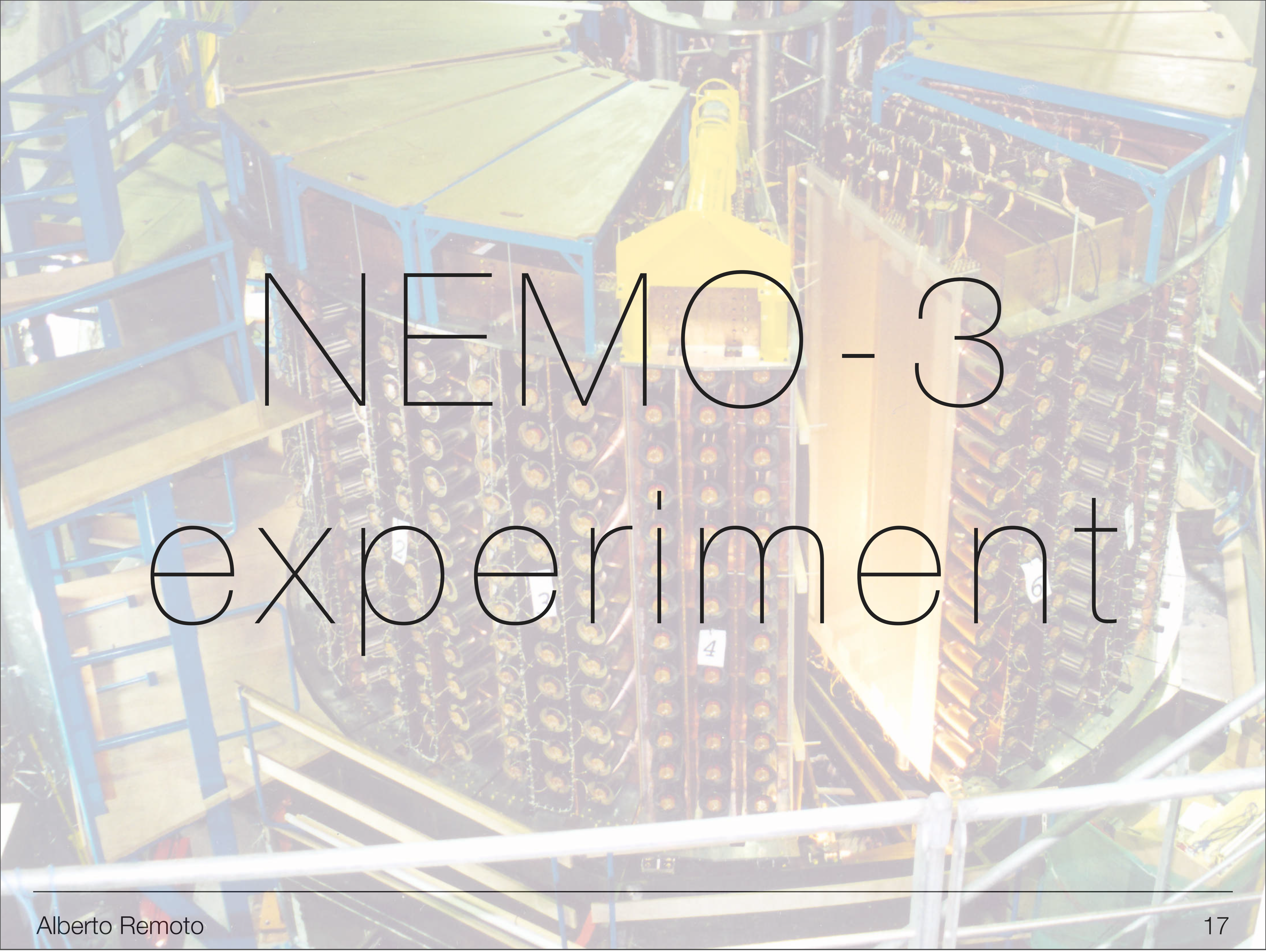
$$T^{0\nu}_{1/2} > \frac{N_A \ln 2}{n_\sigma} \times \frac{\epsilon}{A} \times \sqrt{\frac{M \times t}{B \times \Delta E}}$$



Extended R&D: Energy resolution, particle ID, radio-purity

Multi-phase approach: demonstrate scalability and background levels

NEMO-3 experiment

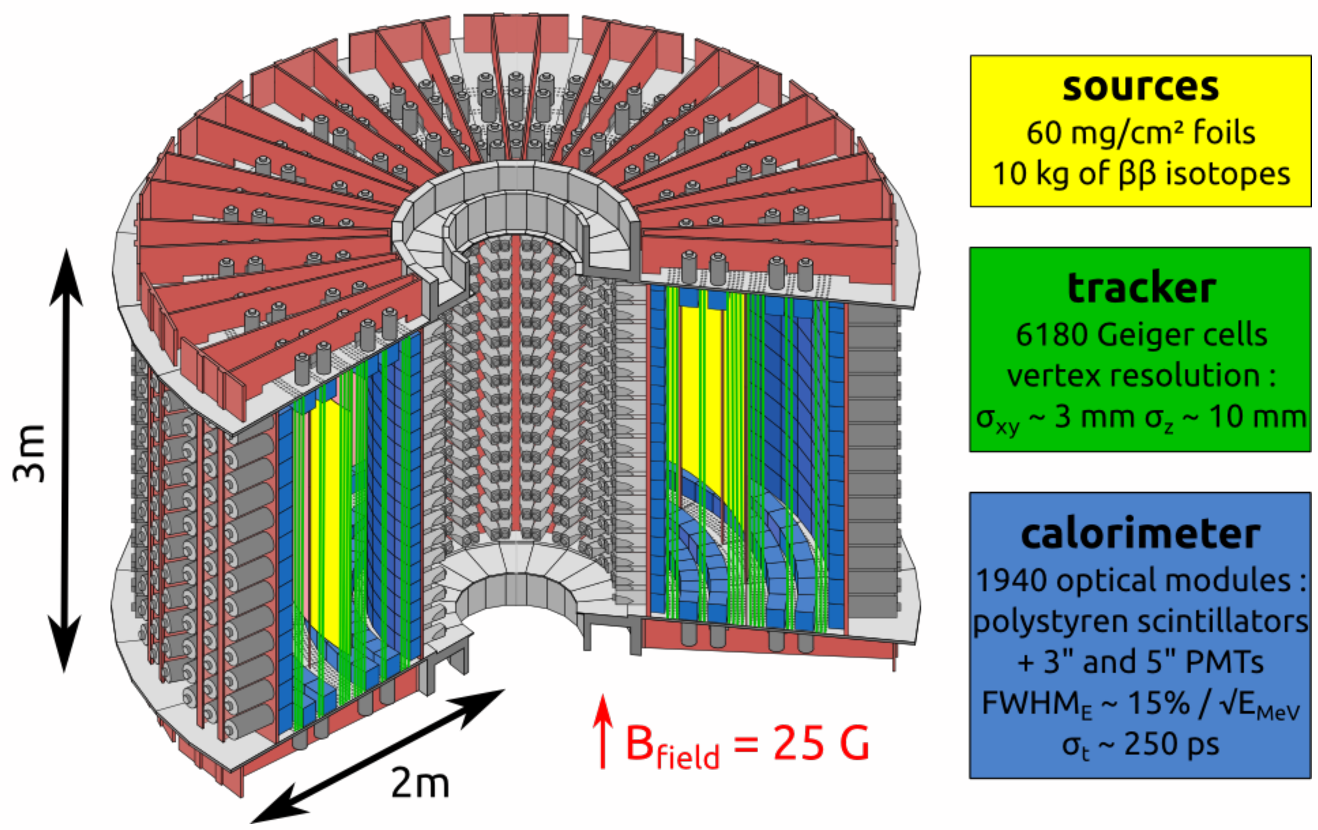


NEMO-3

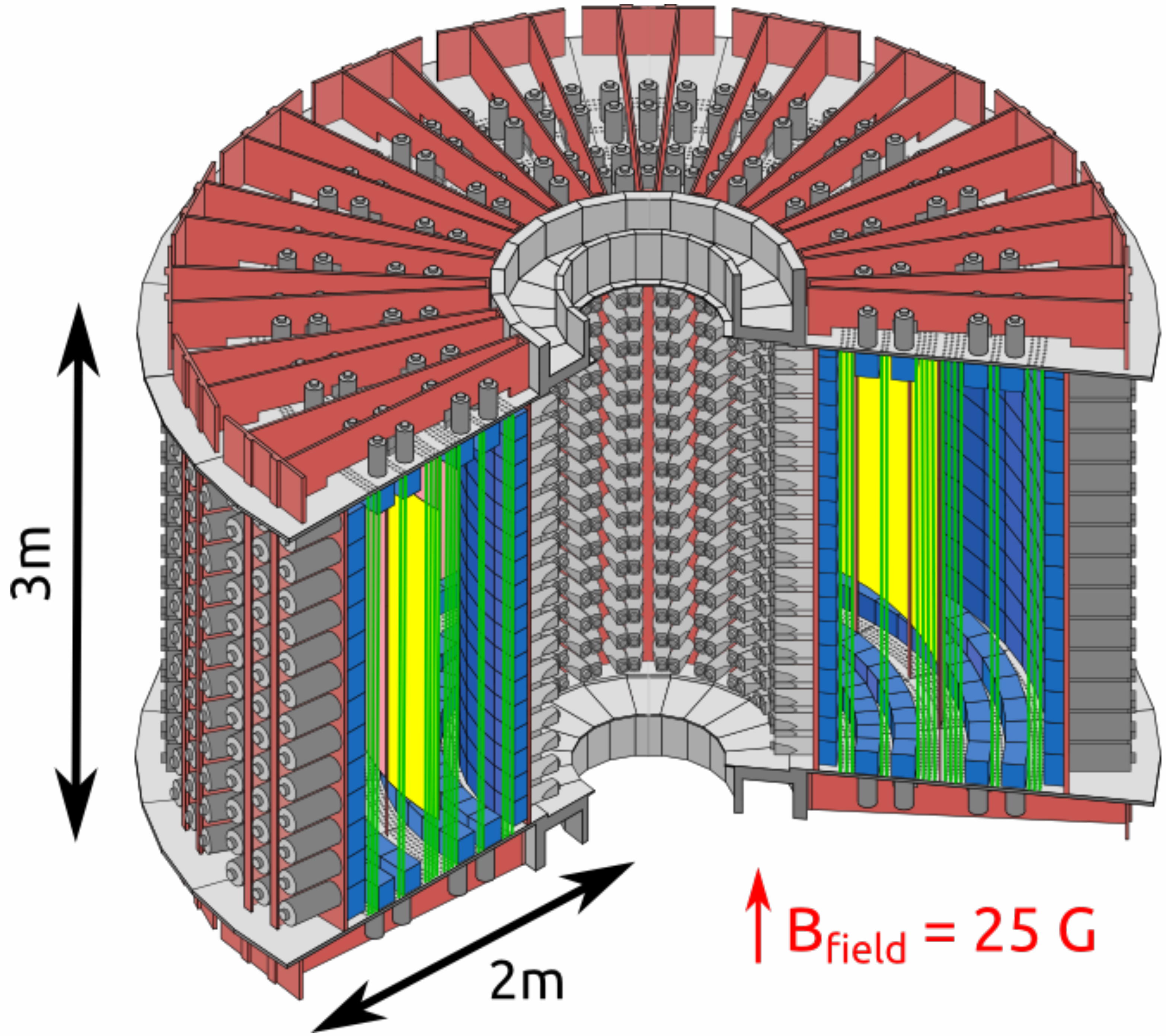
ββ decay experiment combining tracker and calorimetric measurement

Located at the Modane underground laboratory (~4800 m.w.e.)

10 kg of different ββ isotopes taking data from February 2003 to January 2011



NEMO-3



sources
60 mg/cm² foils
10 kg of ββ isotopes

tracker
6180 Geiger cells
vertex resolution :
$\sigma_{xy} \sim 3$ mm $\sigma_z \sim 10$ mm

calorimeter
1940 optical modules :
polystyren scintillators
+ 3" and 5" PMTs
$FWHM_E \sim 15\% / \sqrt{E_{MeV}}$
$\sigma_t \sim 250$ ps

Laboratoire Souterain de Modane

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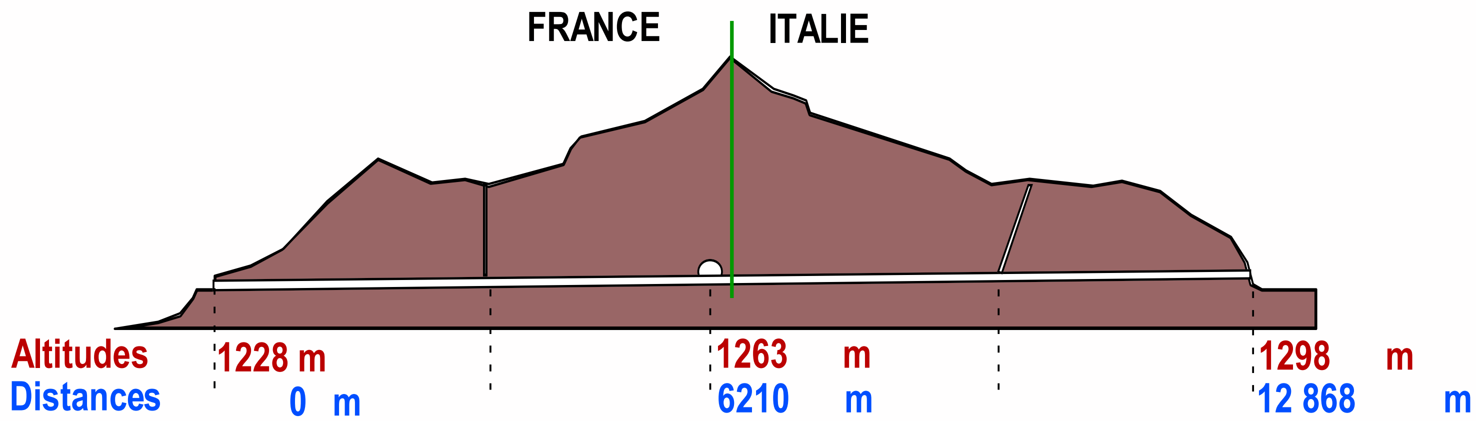
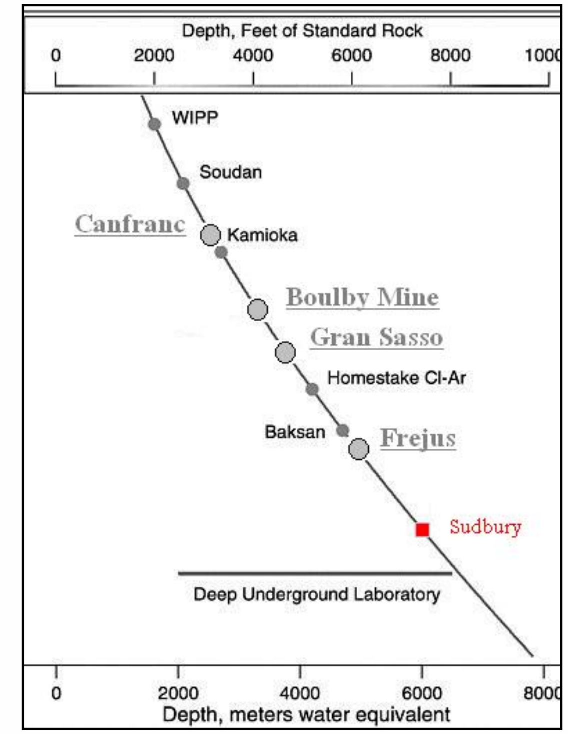
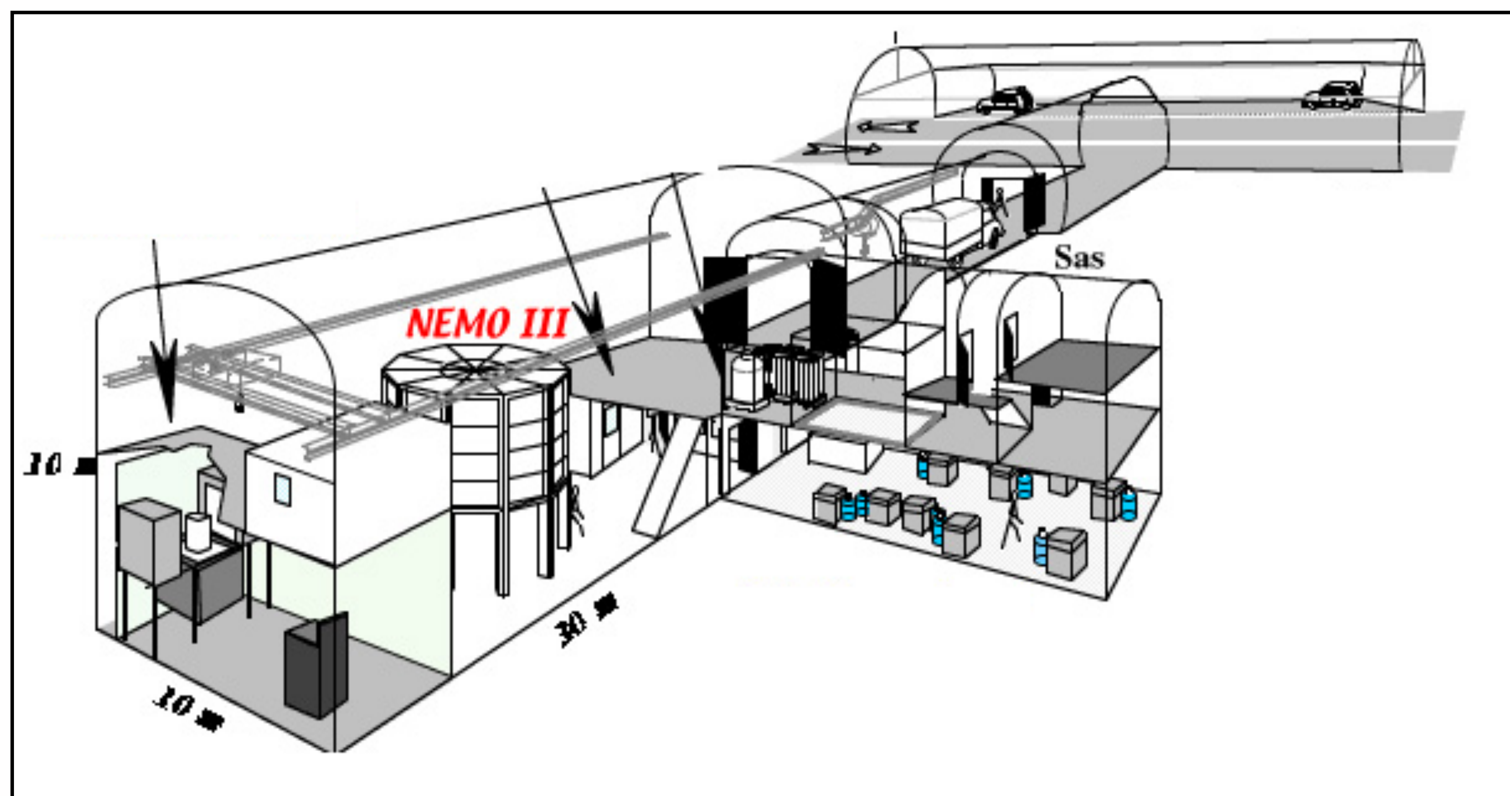


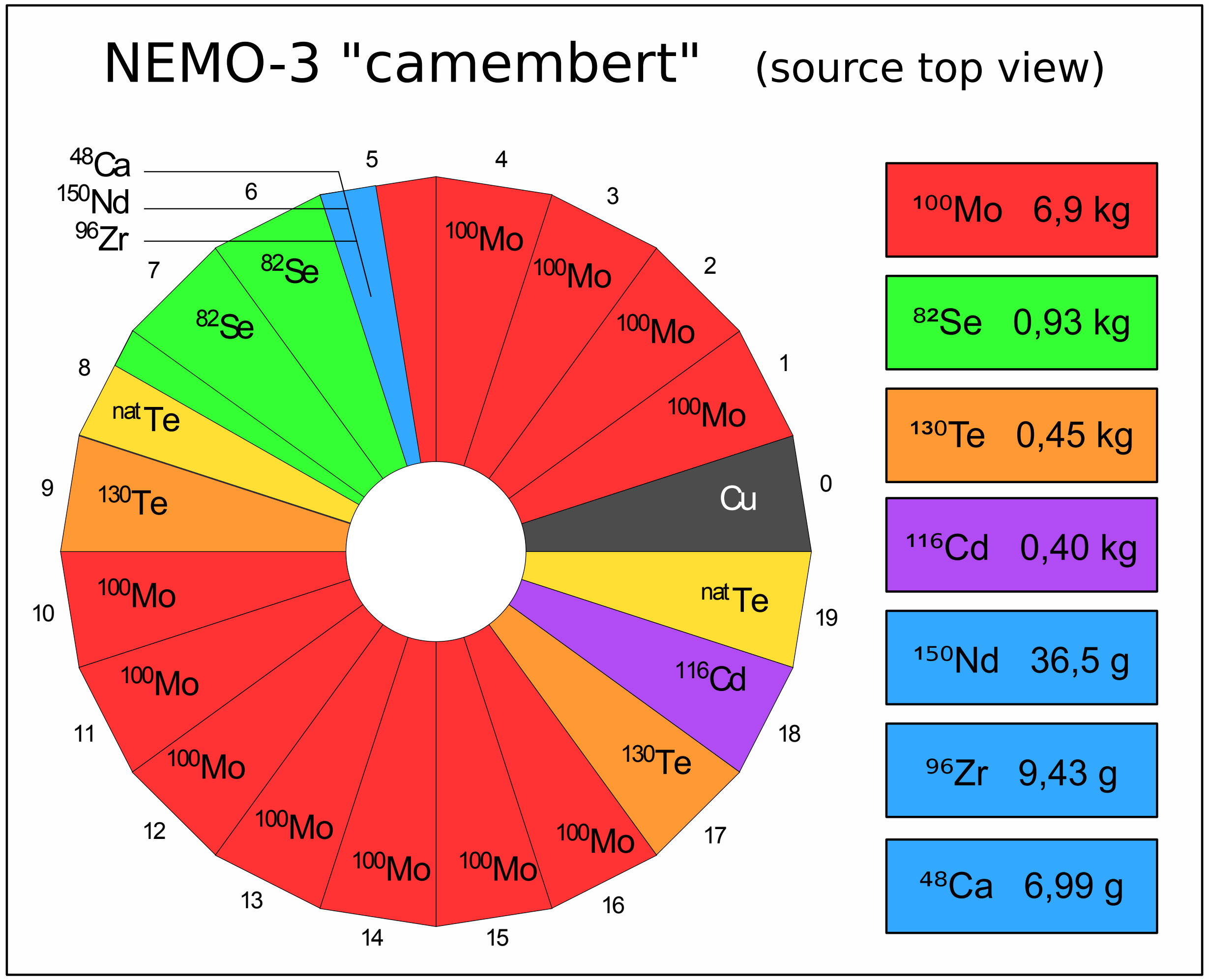


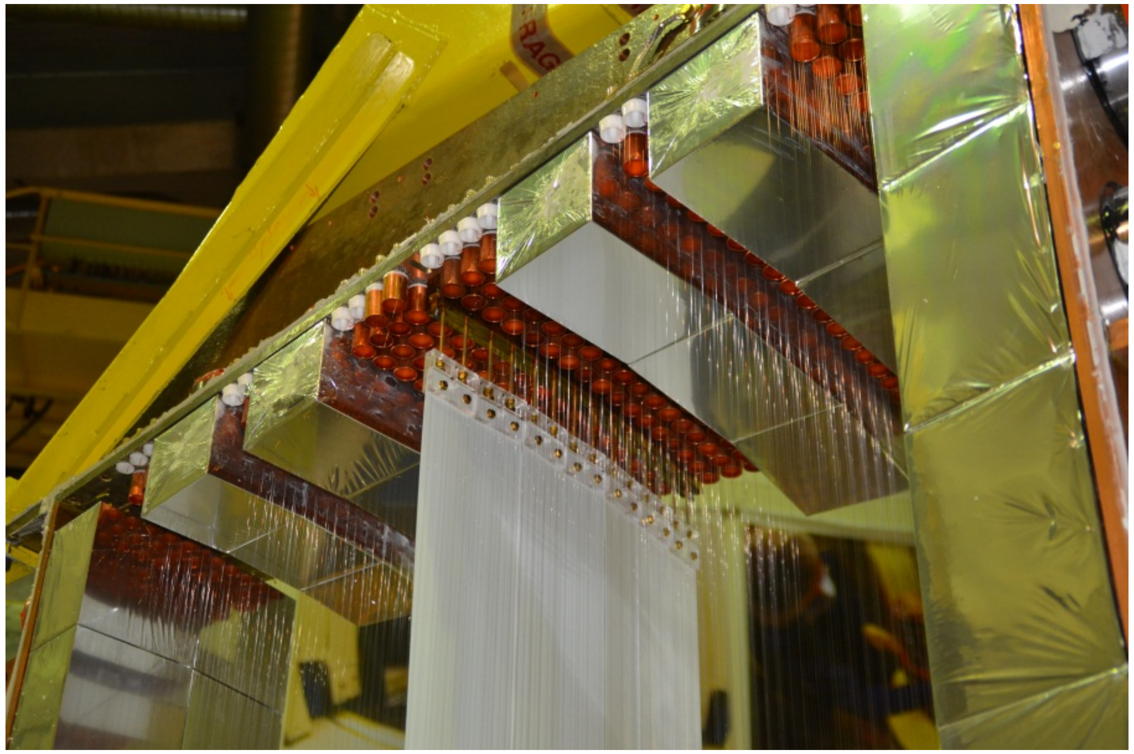


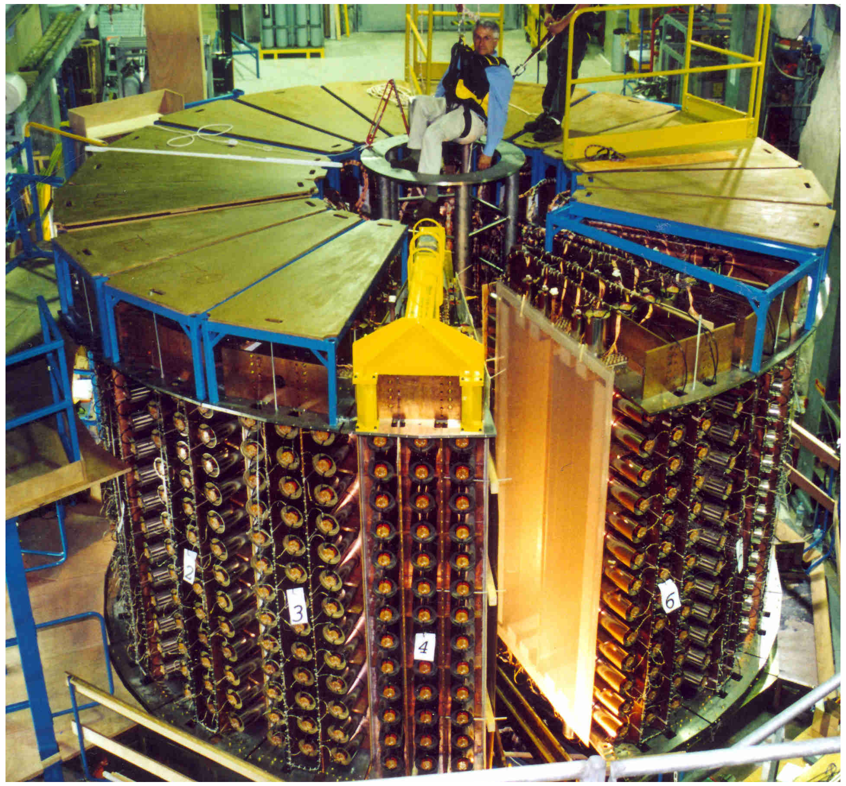
Monday, 23 March 15

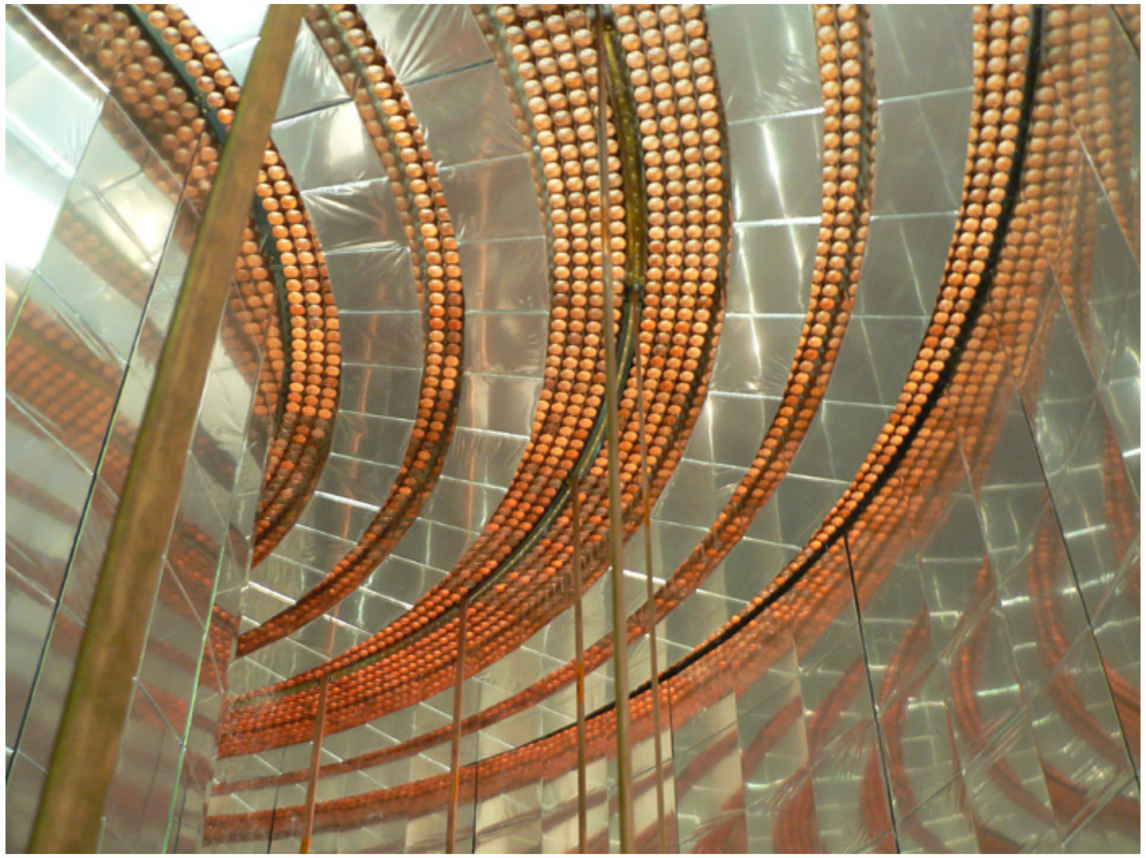
NEMO-3 : The ββ source

- Mainly ^{100}Mo (7 kg) & ^{82}Se (1 kg) + smaller quantities of others isotopes
- Blank foils to cross-check background measurements (Cu & ^{Nat}Te)










NEMO 3

NEMO-3

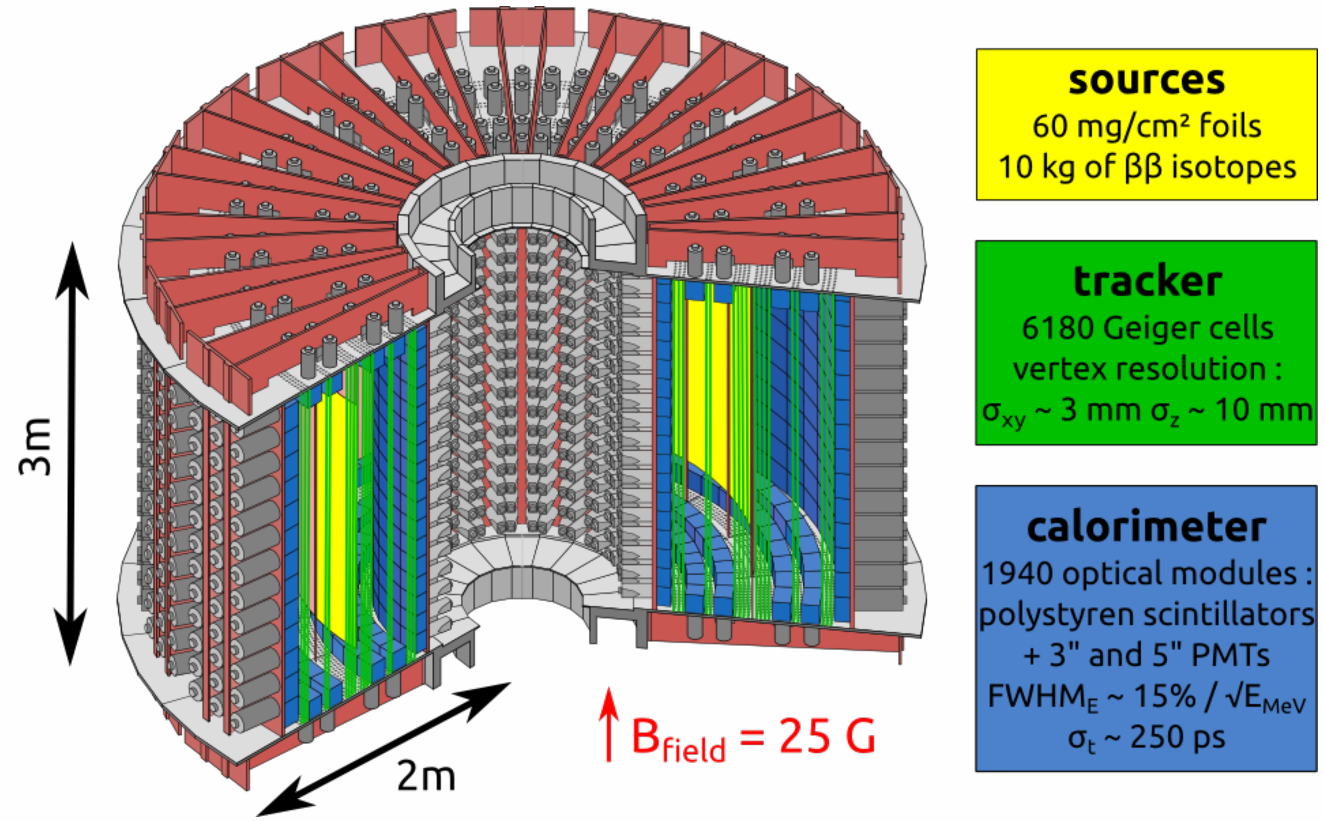
Full reconstruction of $2e^-$ kinematics: unique!

- Individual e^- energy, arrival time, track curvature, emission vertex and angle

Excellent background rejection

- Identification e^-, e^+, γ, α, Internal/External

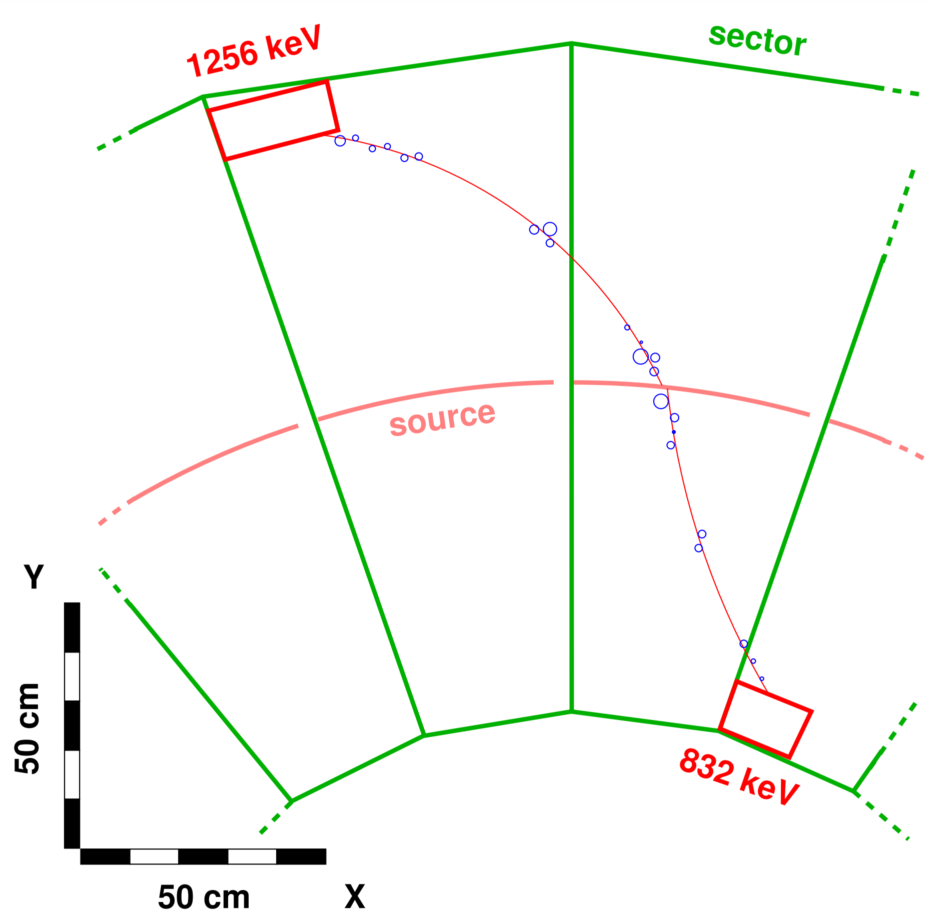
Low energy resolution: [14 - 17] % / Sqrt(E)



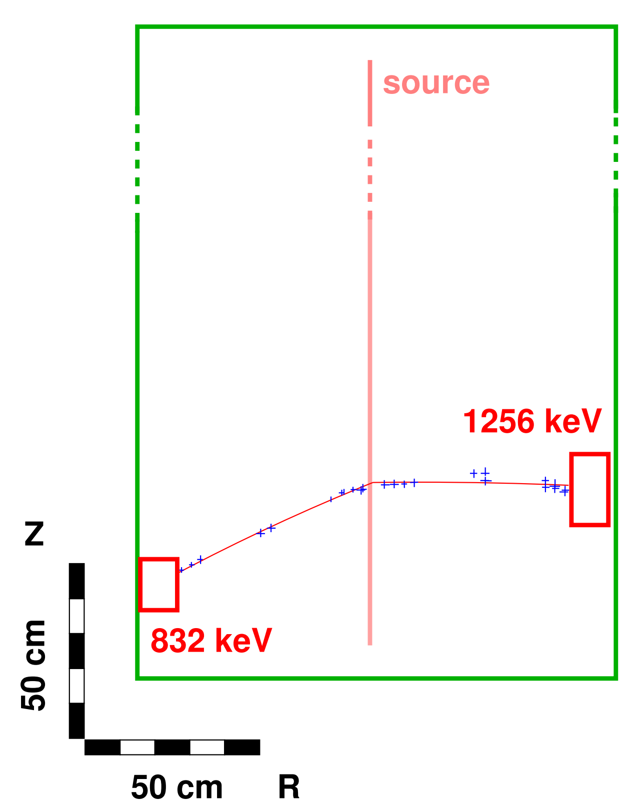
Sensitivity equivalent to best calorimetric experiment

NEMO-3: ββ event topology

Top view



Lateral view

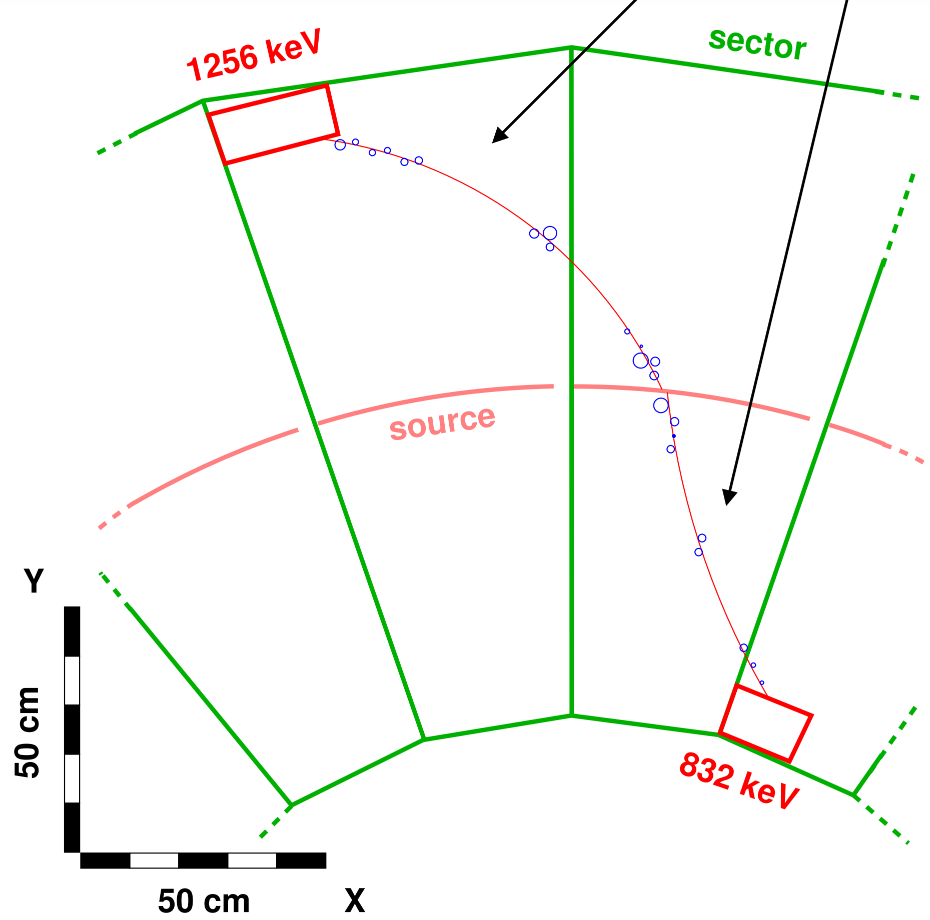


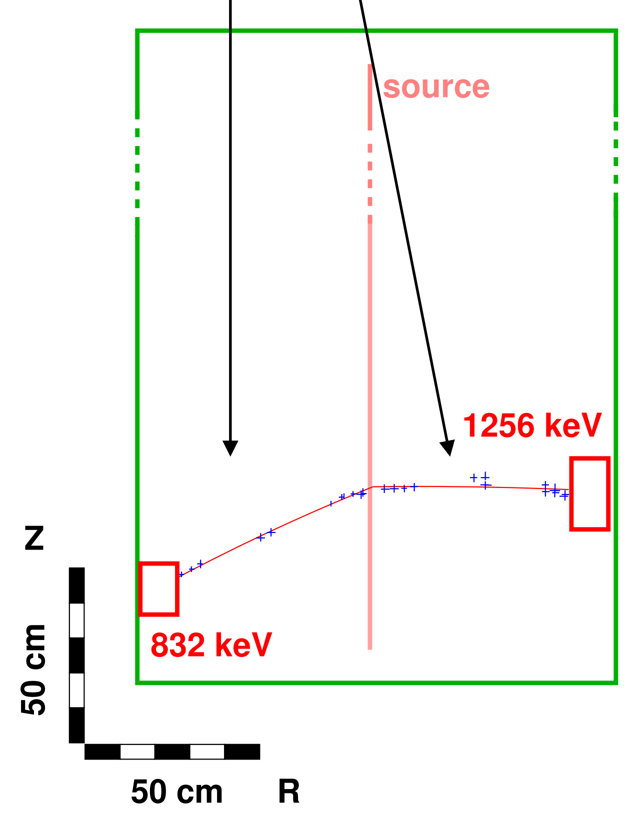
NEMO-3: ββ event topology

2 tracks with negative charge

Top view

Lateral view

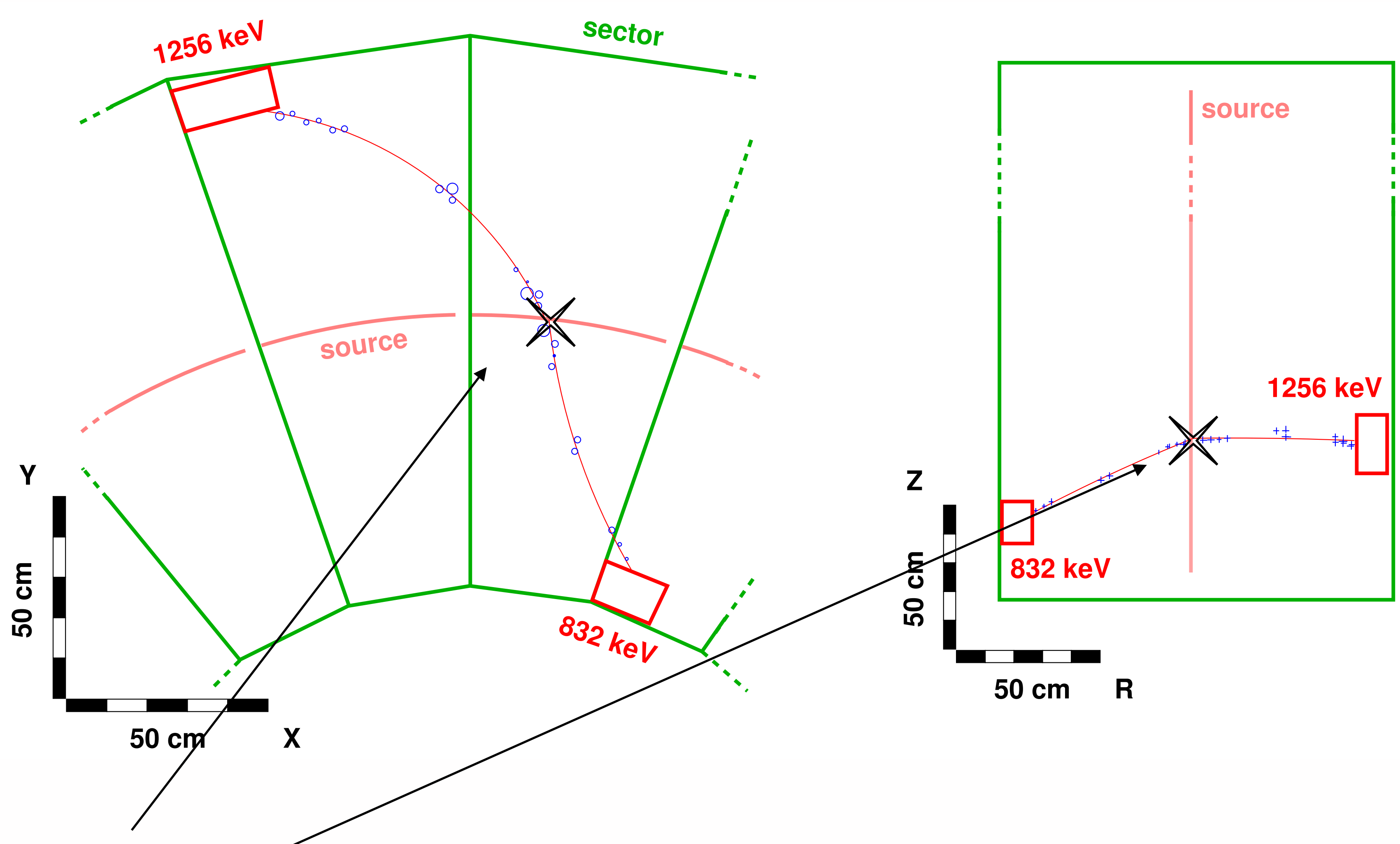




NEMO-3: ββ event topology

Top view

Lateral view

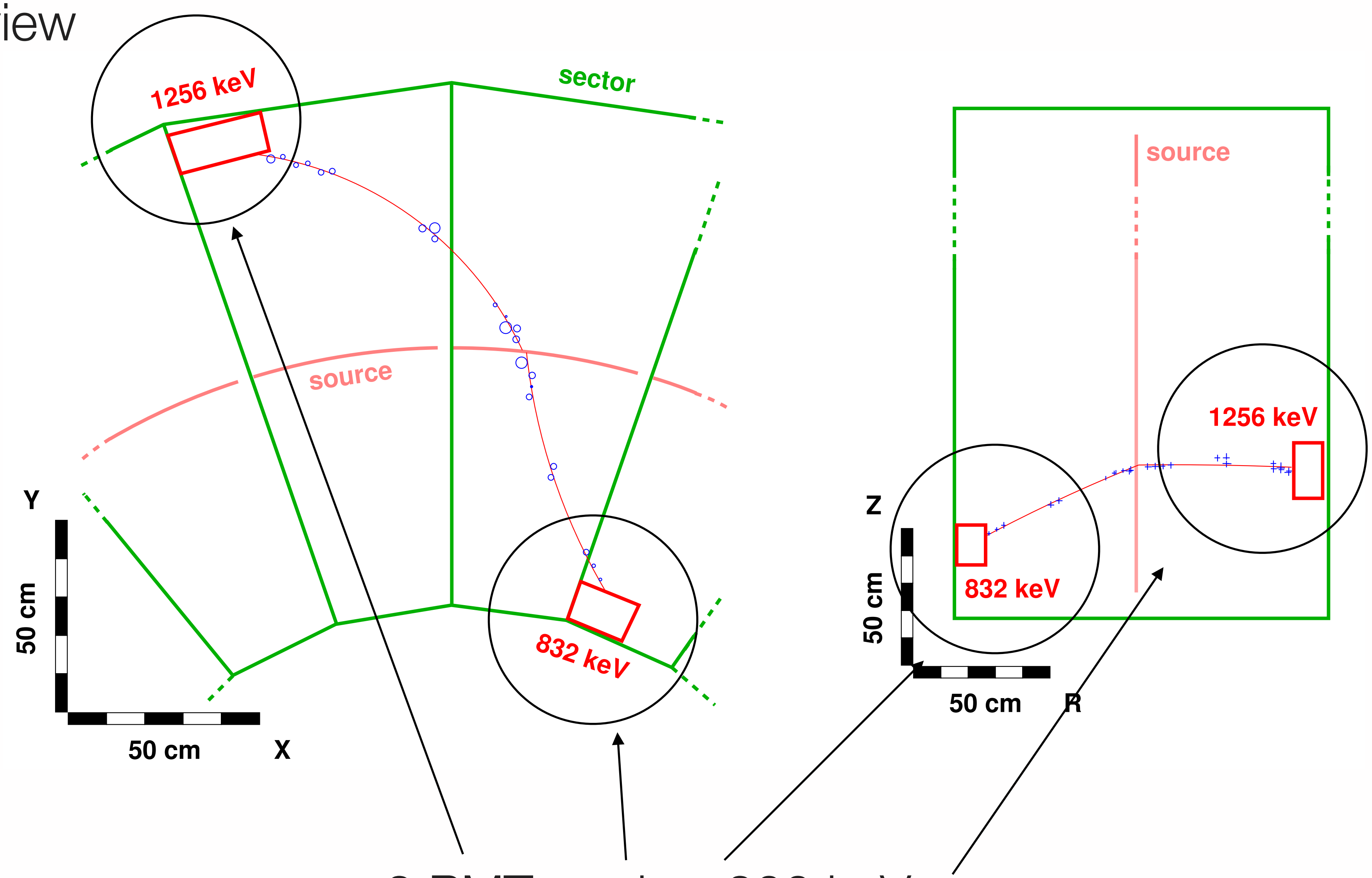


Common vertex

NEMO-3: ββ event topology

Top view

Lateral view

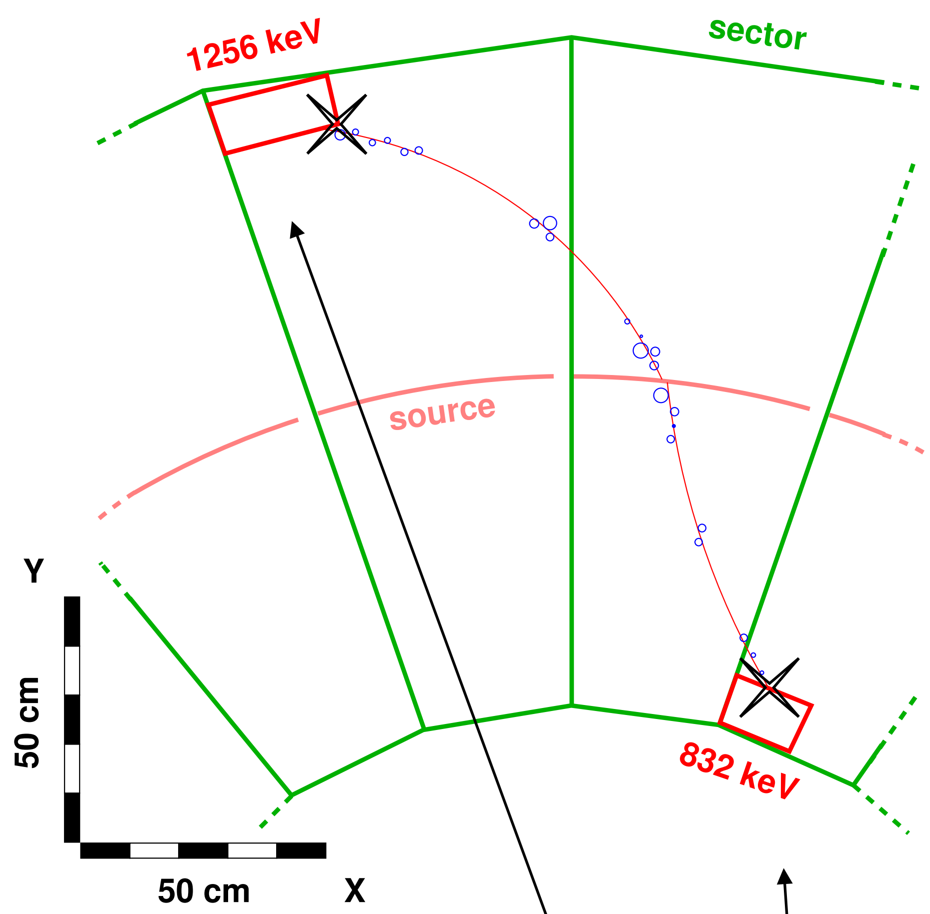


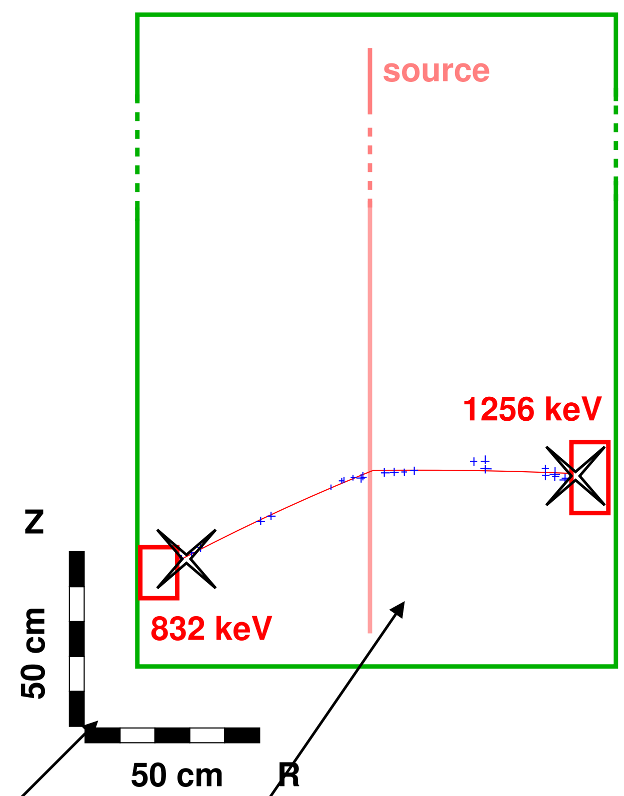
2 PMT, each > 200 keV

NEMO-3: ββ event topology

Top view

Lateral view

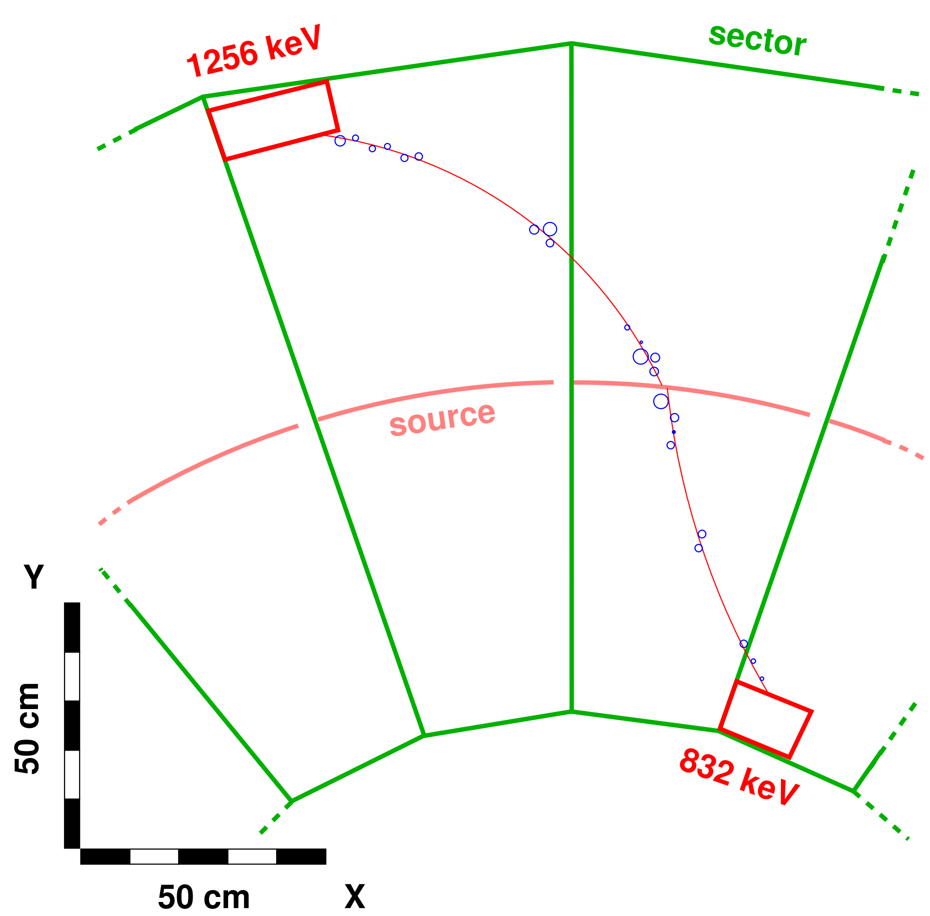




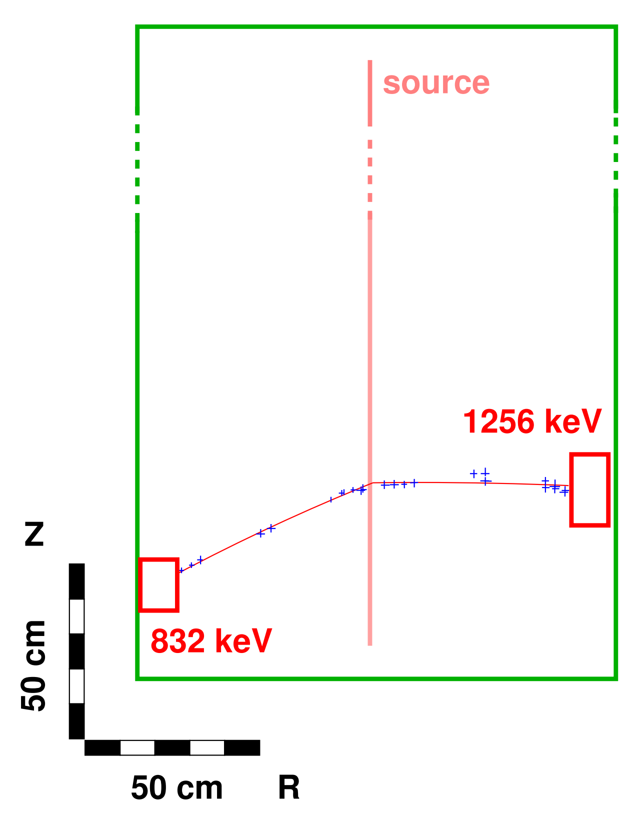
PMT-Track association

NEMO-3: ββ event topology

Top view



Lateral view

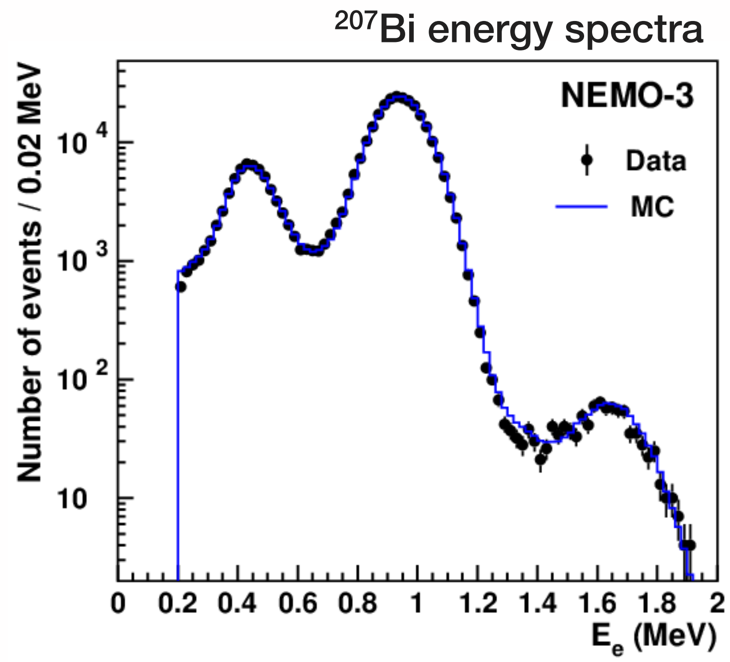


Selection efficiency for E_{2e} > 2.0 MeV is 11.3 % (MC)

NEMO-3: energy calibration

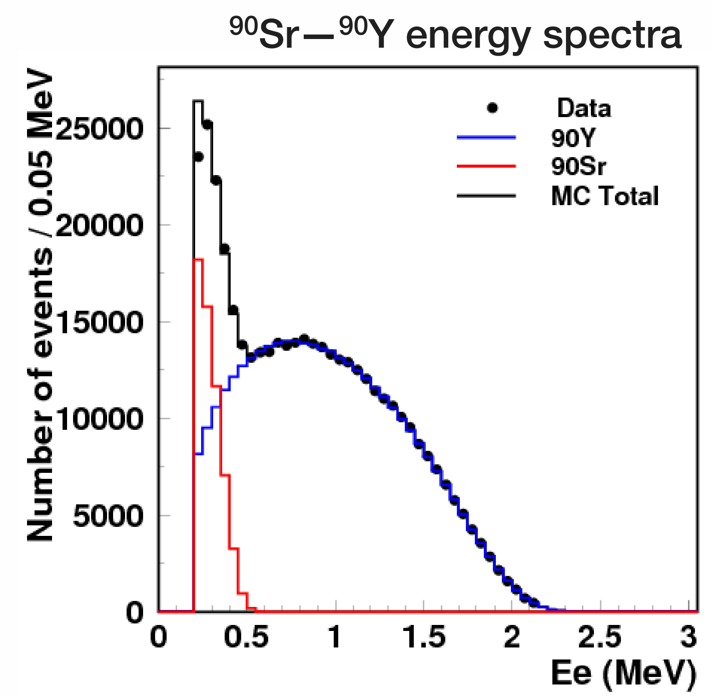
Radioactive sources:

- ^{207}Bi: 482 keV and 976 keV conversion electron
- ^{90}Sr — ^{90}Y: β-decay end point Q_β = 2280 keV
- ^{207}Bi: 1682 keV conversion electron to test energy scale: 99% PMTs Data/MC < 0.2%



Laser inter-calibration system:

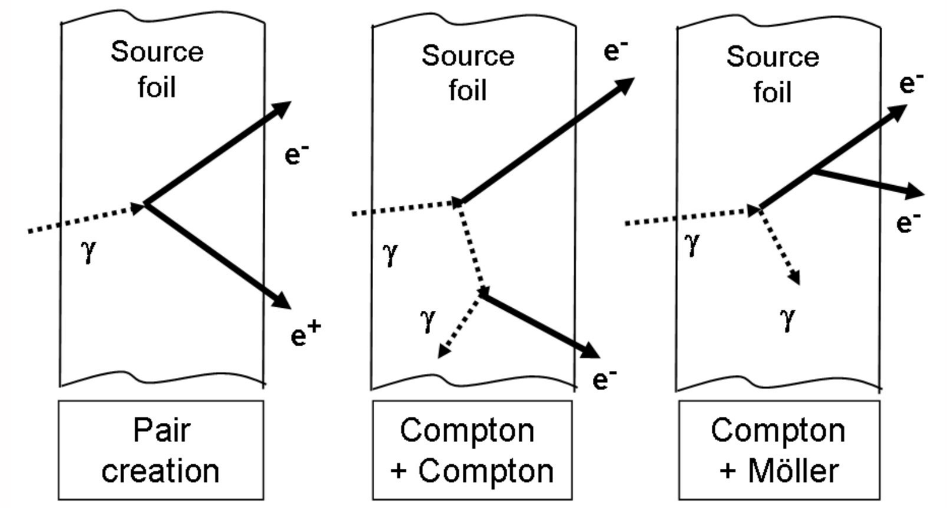
- Gain and time survey twice a day PMTs linearity < 1% for E < 4 MeV
- 82% of PMTs stable < 5% over the whole data taking



NEMO-3: backgrounds

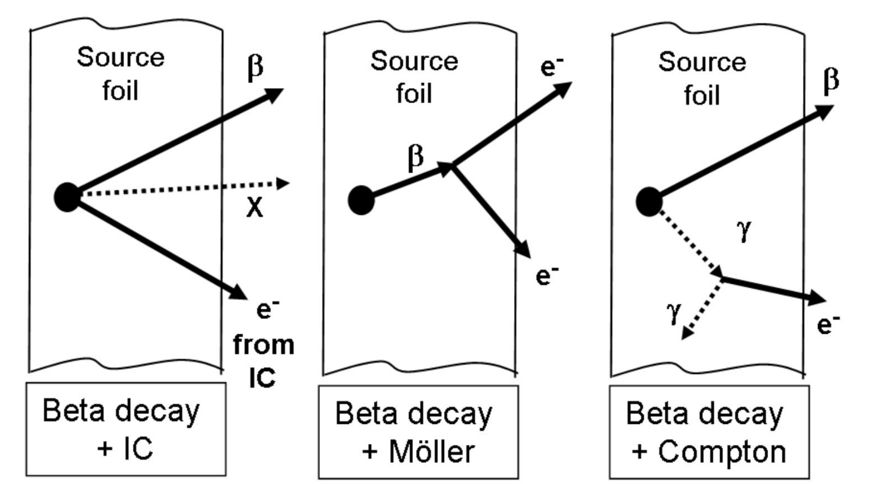
Radio-impurities in material, γ from (n,γ) and μ bremsstrahlung

- γ from ^{208}Tl at 2.6 MeV
- (n,γ) up to 10 MeV



^{208}Tl (from ^{232}Th) and ^{214}Bi (from ^{238}U) contamination in foil source and ^{214}Bi from Rn decay in tracker volume

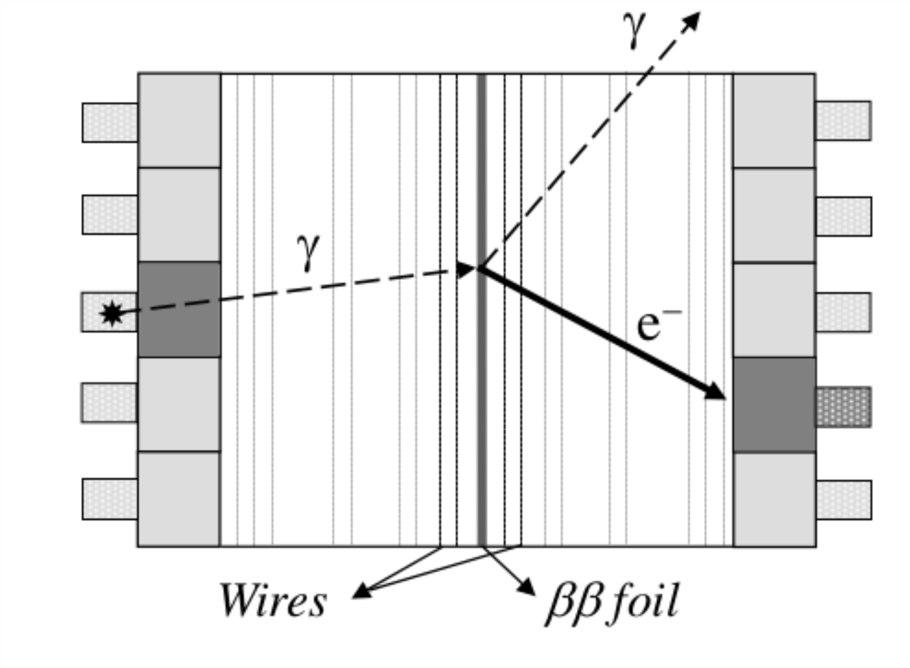
- ^{208}Tl Q_β at 5 MeV
- ^{214}Bi Q_β at 3.27 MeV

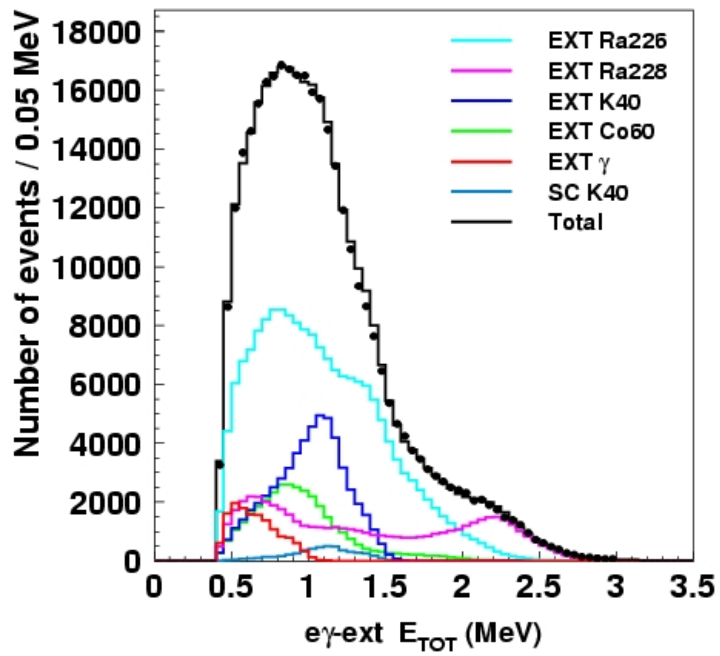


NEMO-3: external backgrounds

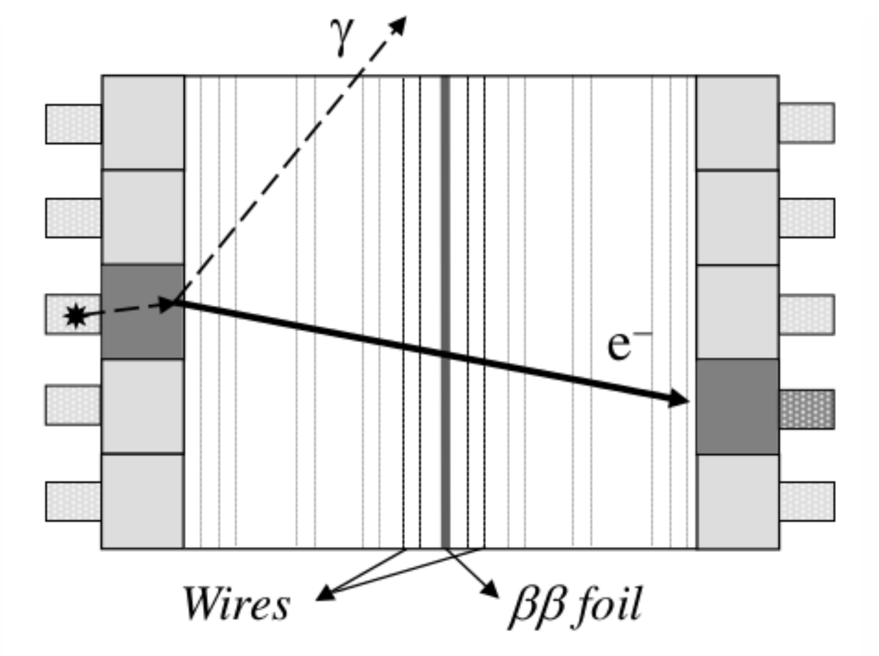
Take advantage of PID capabilities of NEMO-3: e^-, e^+, γ, α and TOF measurement

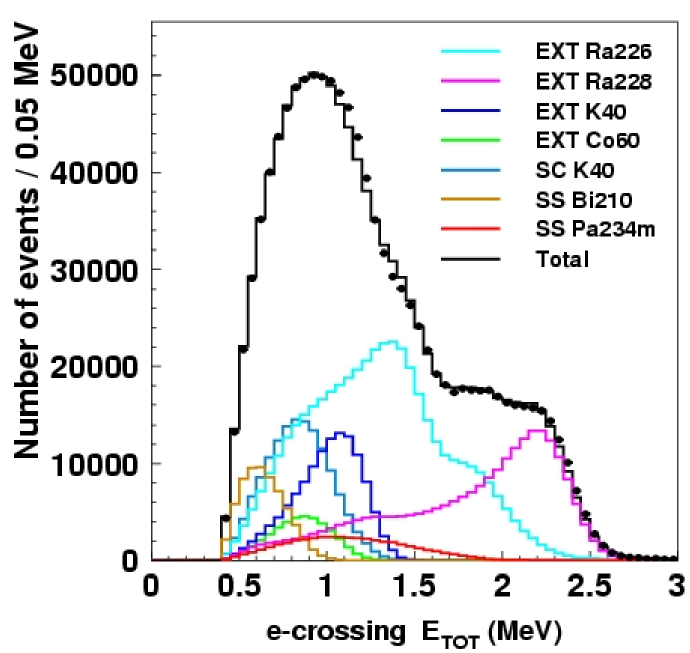
$(\gamma e^-)_{ext.}$ channel





Crossing e^- channel



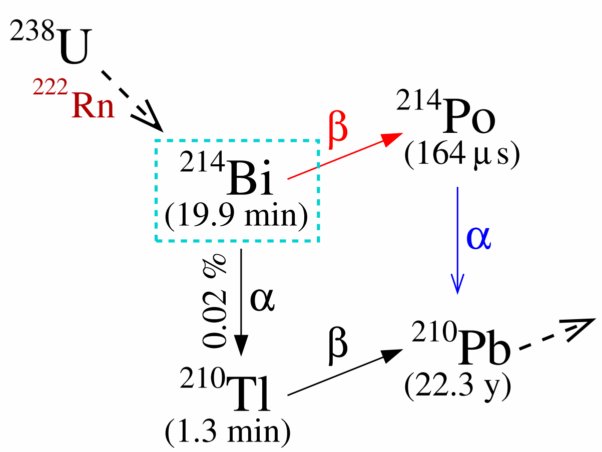


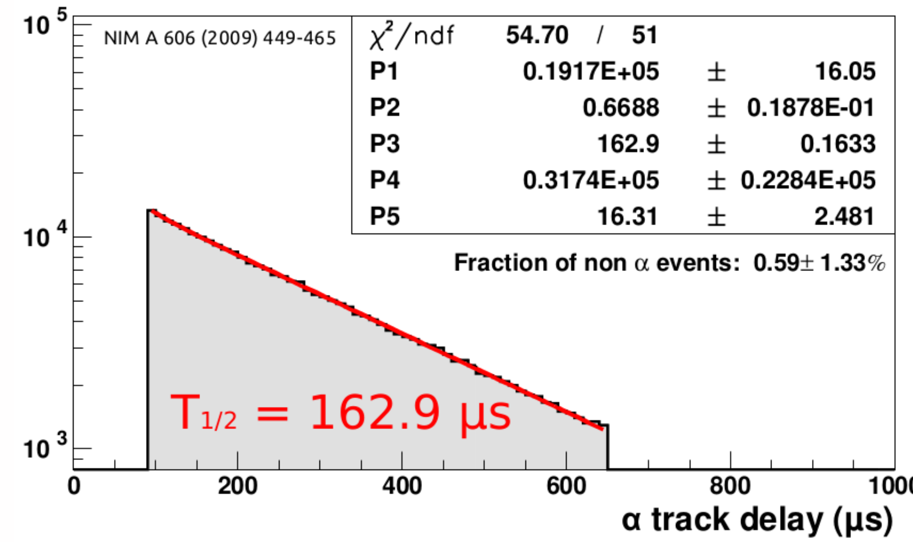
Monday, 23 March 15

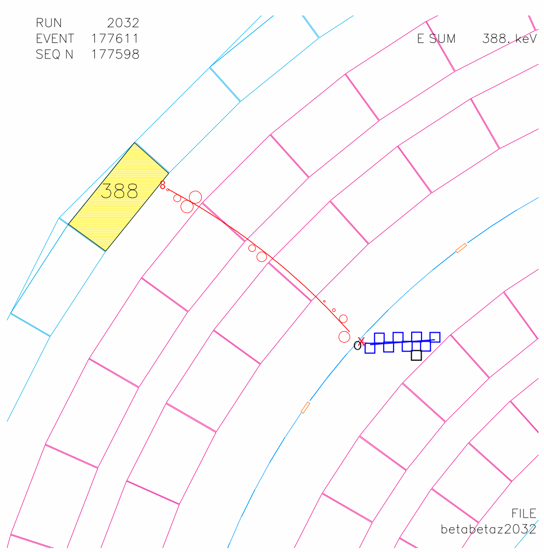
NEMO-3: internal backgrounds

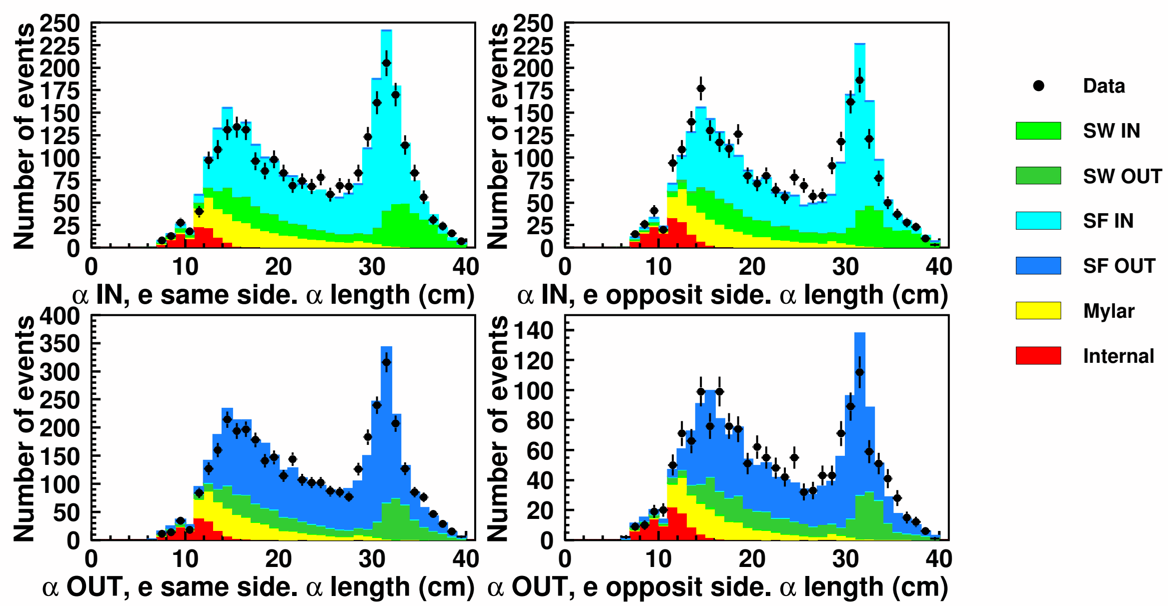
Take advantage of PID capabilities of NEMO-3: e$^-$, e$^+$, γ, α and TOF measurement

1e$^-$ (single β emitters), e$^-$Nγ (^{208}Tl) , e$^-$α (^{214}Bi) channels channels





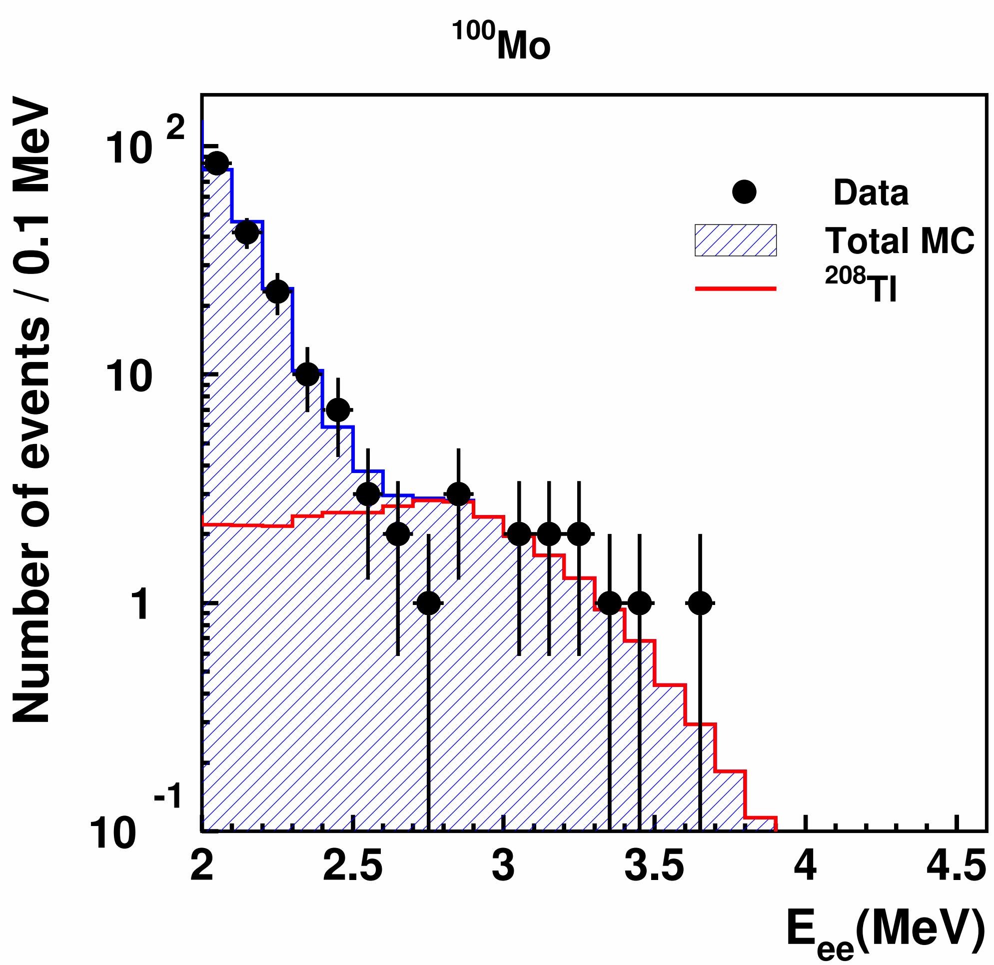




NEMO-3: Check internal ^{208}Tl and ^{214}Bi background measurements

^{208}Tl activity checked with ^{232}U sources → 10% systematics w.r.t. HPGe measurement

^{214}Bi activity compared in two different channel → e-Nγ, e-α: 10% systematics



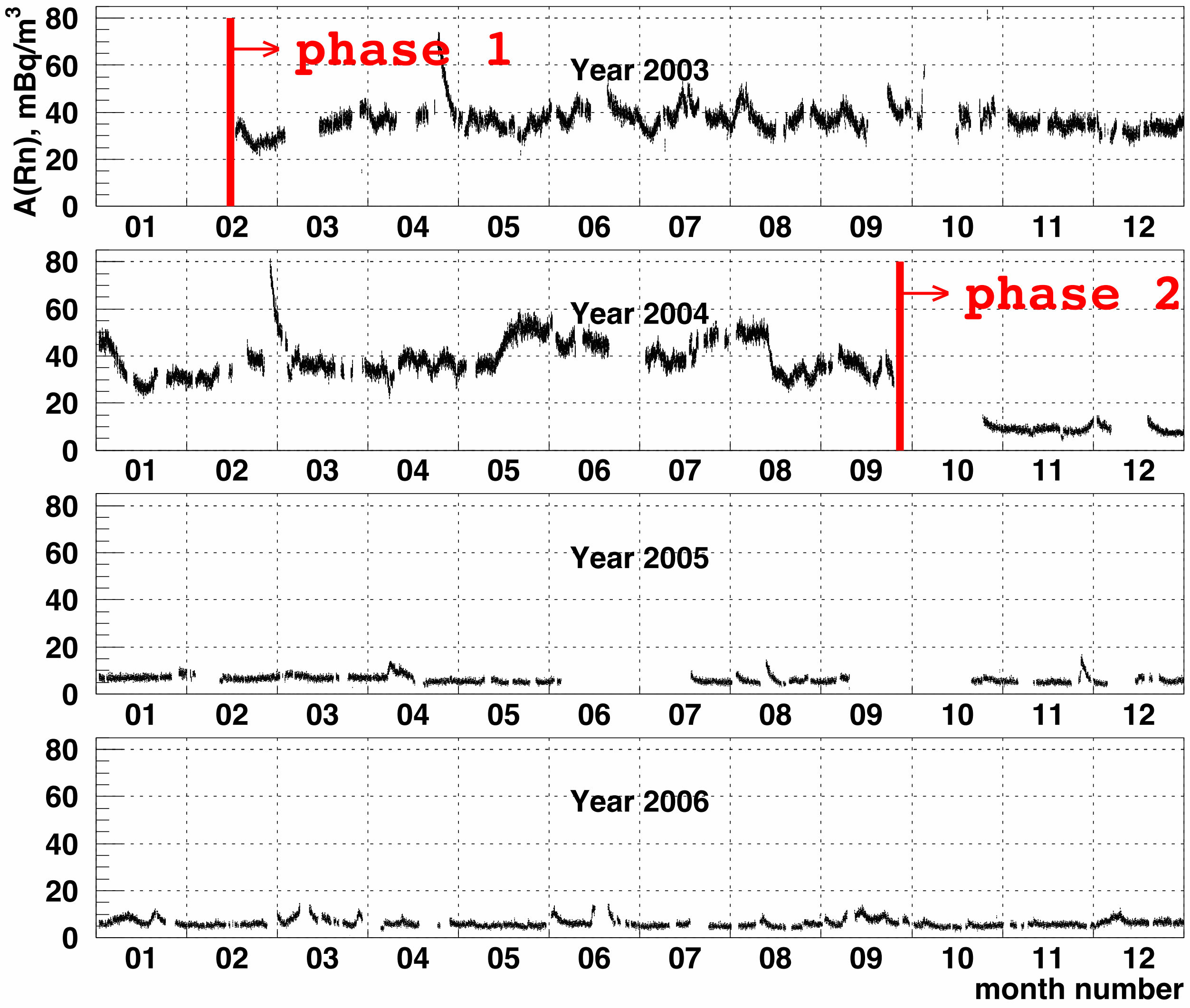
Background checked in 2e⁻Nγ (^{208}Tl) and 2e⁻α (^{214}Bi) channels

- ^{208}Tl: 7 events, 8.8 expected
- ^{214}Bi Phase 1: 3 events, 6.5 ± 0.4 expected
- ^{214}Bi Phase 2: 3 events, 2.9 ± 0.2 expected

NEMO-3: ^{222}Rn background

^{222}Rn in the gas of the tracking chamber monitored through the 1e1α channel

Strongly suppressed upon flushing Rn-free air into a dedicated tent surrounding the detector

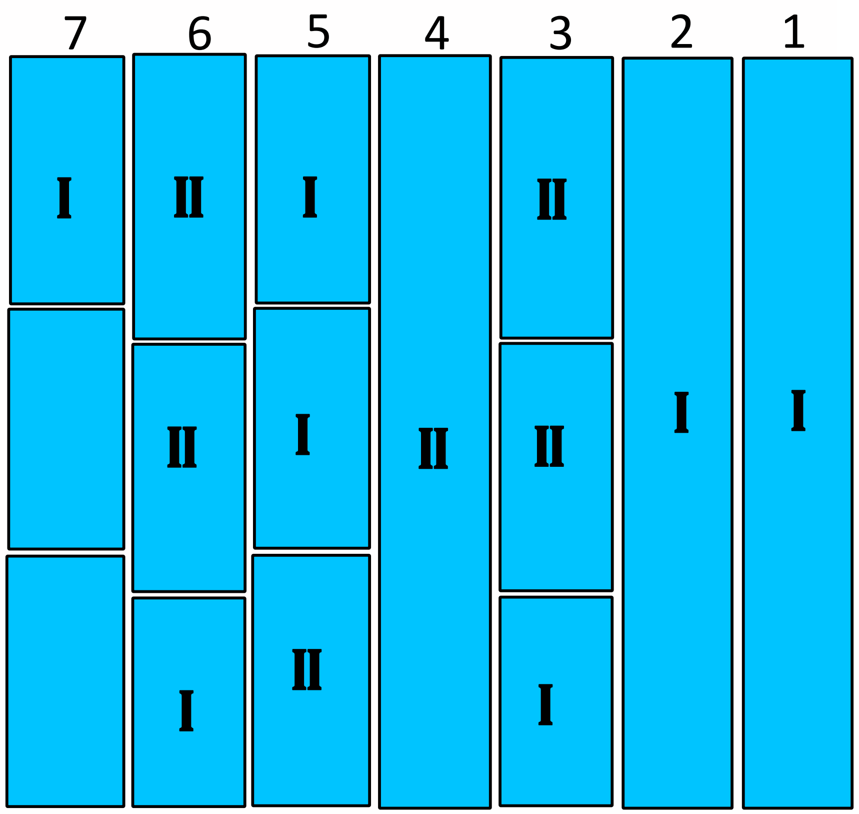


Phase 1: 37.7±0.1 mBq/m^3

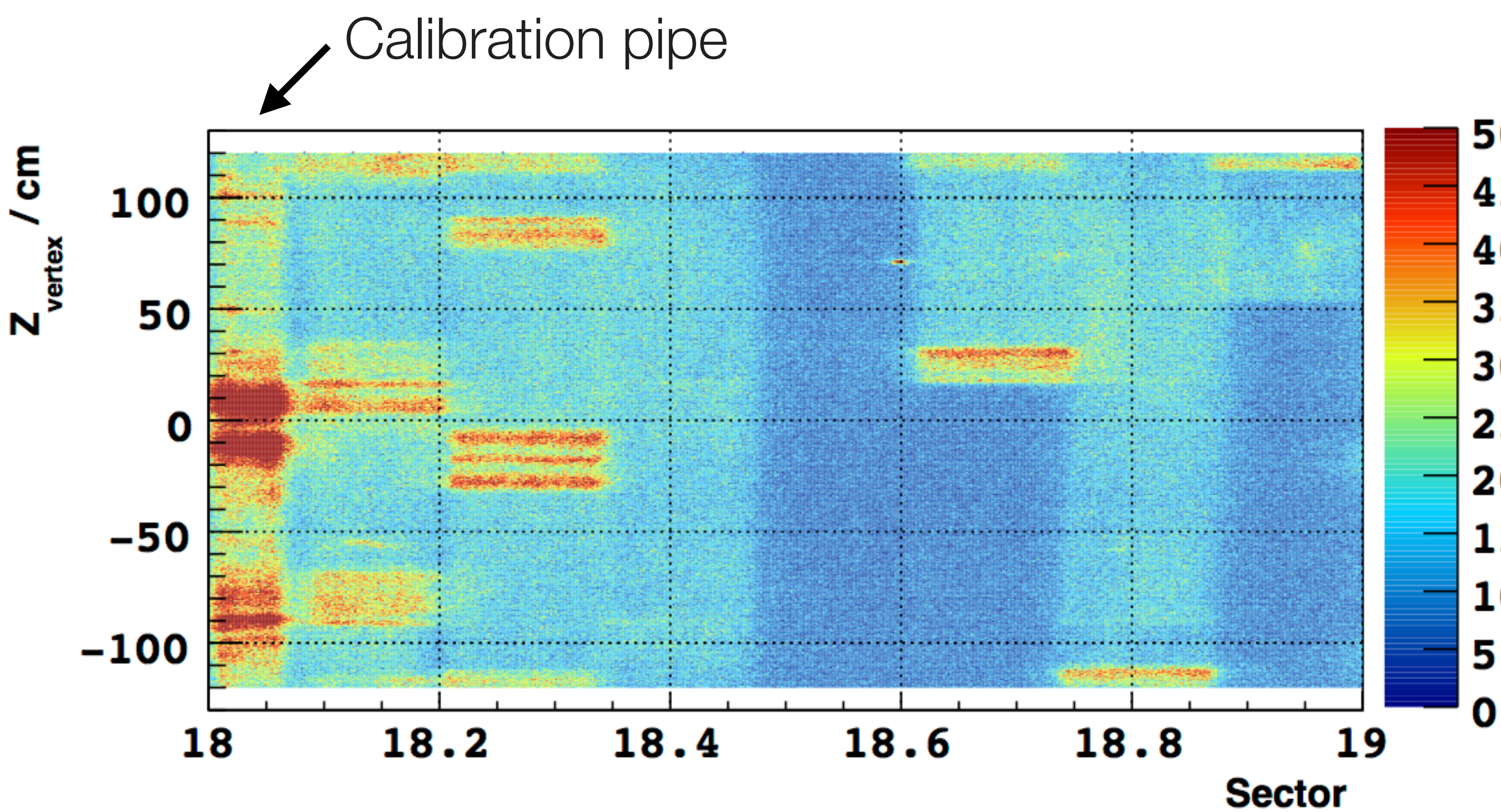
Phase 2: 6.46±0.02 mBq/m^3

NEMO-3: hot spots identification

Vertex reconstruction capabilities: $\sigma_z = 0.6$ cm and $\sigma_r = 1.0$ cm



^{116}Cd foil production parts



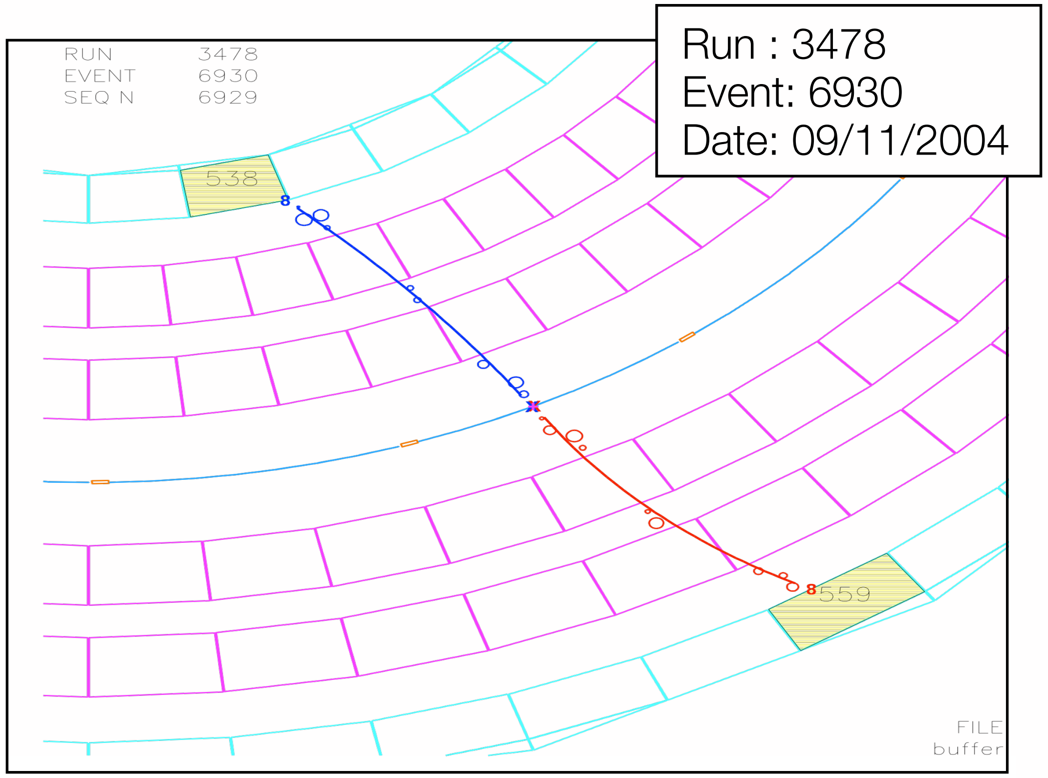
1e channel vertexes in ^{116}Cd sector

Able to reduce backgrounds removing activity hot spots from the foils surface

Monday, 23 March 15

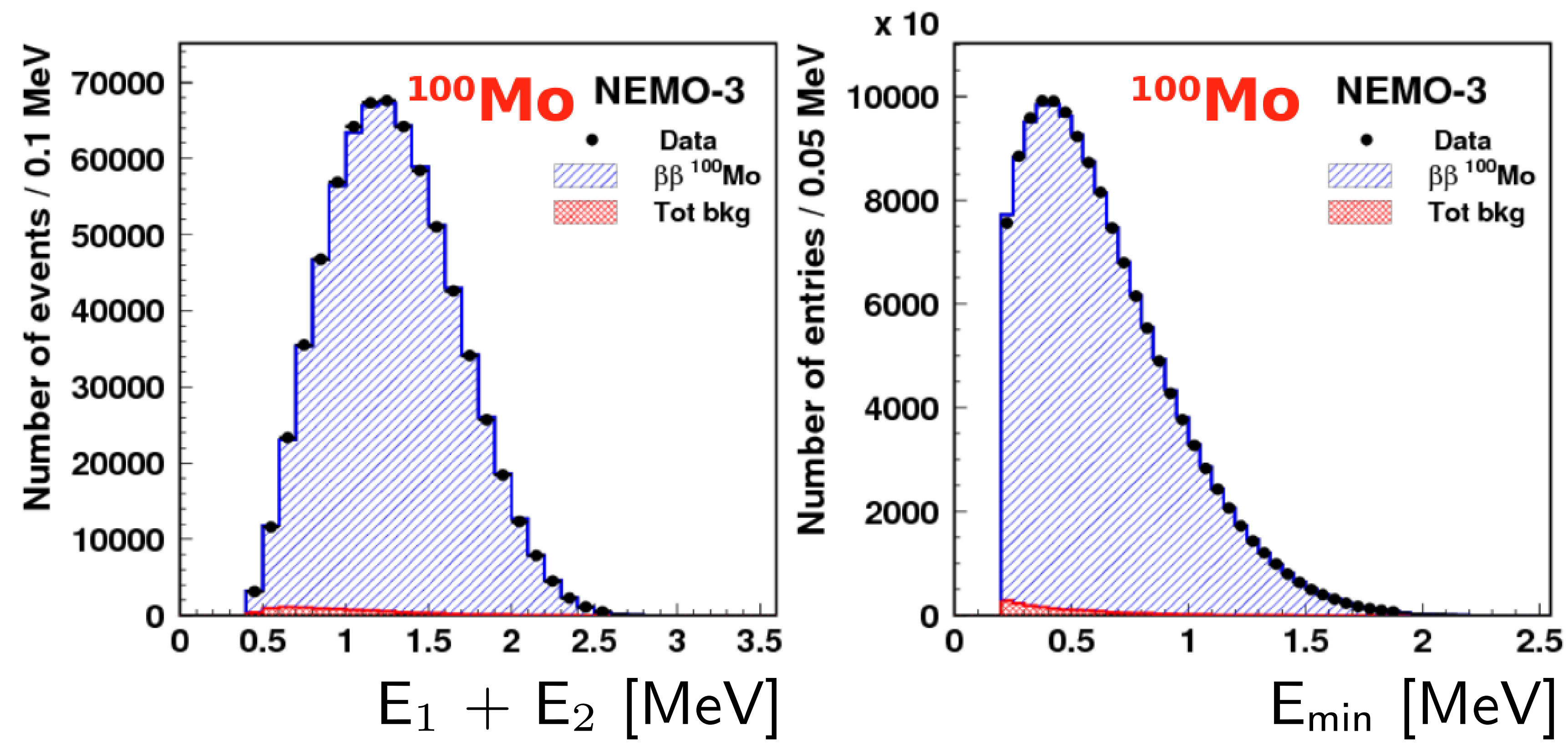
NEMO-3: ^{100}Mo 2νββ results

- About 700 000 2νββ events
- Detection efficiency = 4.3 ± 0.7 %
- Signal over Background ratio = 76



$T^{2\nu}_{1/2}$ = [7.16 ± 0.01 (stat) ± 0.54 (syst)]×10^{18} y

Consistent with previously published [PRL 95 (2005) 182302]

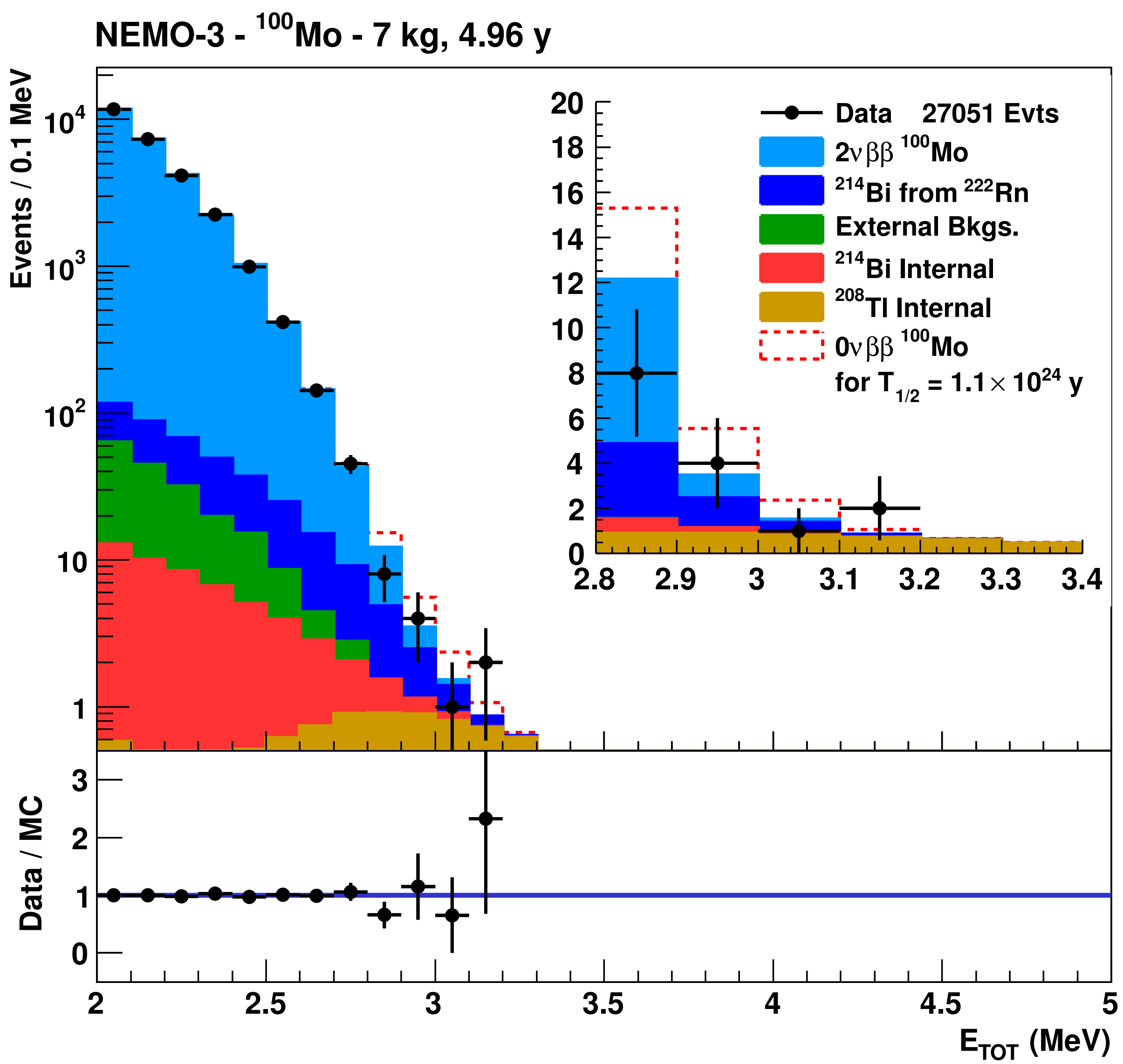


[Phys. Rev. D. 89.111101 (2014)]

Detailed paper to be published in the following weeks

NEMO-3: ^{100}Mo 0νββ result

- No event excess after 34.3 kg×y exposure
- $T^{0\nu}_{1/2} > 1.1\times10^{24}$ y (90 % C.L.) → $\langle m_\nu \rangle < 0.3 - 0.9$ eV



Expected background in [2.8 - 3.2] MeV

2νββ	8.45 ± 0.05
^{214}Bi from radon	5.2 ± 0.5
^{208}Tl internal	3.3 ± 0.3
^{214}Bi internal	1.0 ± 0.1
External	< 0.2
Total	18.0 ± 0.3
Data	15

Total background: 1.3×10^{-3} cts / (keV×kg×y)

[Phys. Rev. D. 89.111101 (2014)]

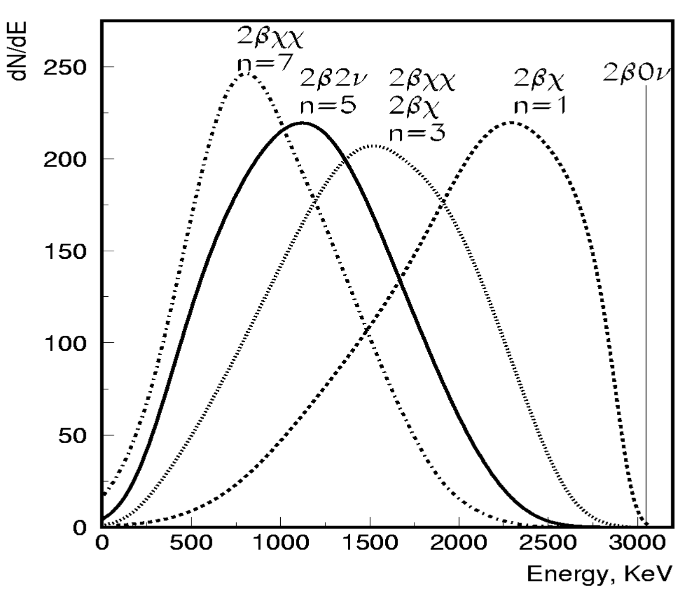
NEMO-3: ^{100}Mo 0νββ result

Detailed paper to be published in the following weeks

- $T^{0\nu}_{1/2}$ limit set with a modified frequentist analysis [N.I.M. A 434 (1999) 435]
- Using full information in E_{Tot} = [2.0; 3.2] MeV
- Detection efficiency: 11.3 ± 0.8 %
- Account for statistical and systematic uncertainties and their correlation

Systematics

2νββ events in window	0.7%
0νββ detection efficinecy	7.0%
^{214}Bi contamination	10.0%
^{208}Tl contamination	10.0%

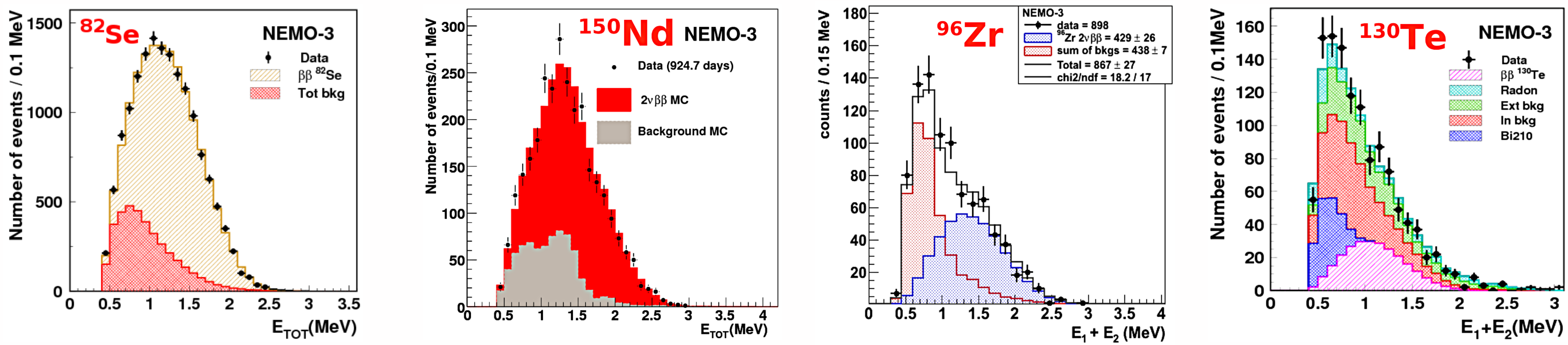


Limits at 90% C.L. in units of 10^{24} y

Process	Stat. Only	Stat. + Syst.	Expected
Mass mechanism	1.1	1.1	1.0 [0.7; 1.4]
RH Current ⟨λ⟩ ($q_{r.h.}$ — $l_{r.h.}$)	0.7	0.6	0.5 [0.4; 0.8]
RH Current ⟨η⟩ ($q_{l.h.}$ — $l_{r.h.}$)	1.0	1.0	0.9 [0.6; 1.3]
Majoron (n=1)	0.050	0.044	0.039 [0.027; 0.059]

NEMO-3: other results

Other isotopes: only partial exposure has been published



Isotope	Mass [g]	Exposure [days]	$T_{1/2}(2\nu)$ [x 10^{19} y]	$T_{1/2}(0\nu)$ [y] @ 90% C.L.	$\langle m_\nu \rangle$ [eV] @ 90% C.L.	Reference
^{82}Se	932	389	9.6 ± 1.0	> 1.0 x 10^{23}	< 1.7 - 4.9	Phys.Rev.Lett. 95 (2005) 182302
^{150}Nd	37	925	0.90 ± 0.07	> 1.8 x 10^{22}	< 4.0 - 6.3	Phys. Rev. C 80, 032501 (2009)
^{96}Zr	9.4	1221	2.35 ± 0.21			Nucl.Phys.A 847(2010) 168
^{130}Te	454	1275	70 ± 14			Phys. Rev. Lett. 107, 062504 (2011)

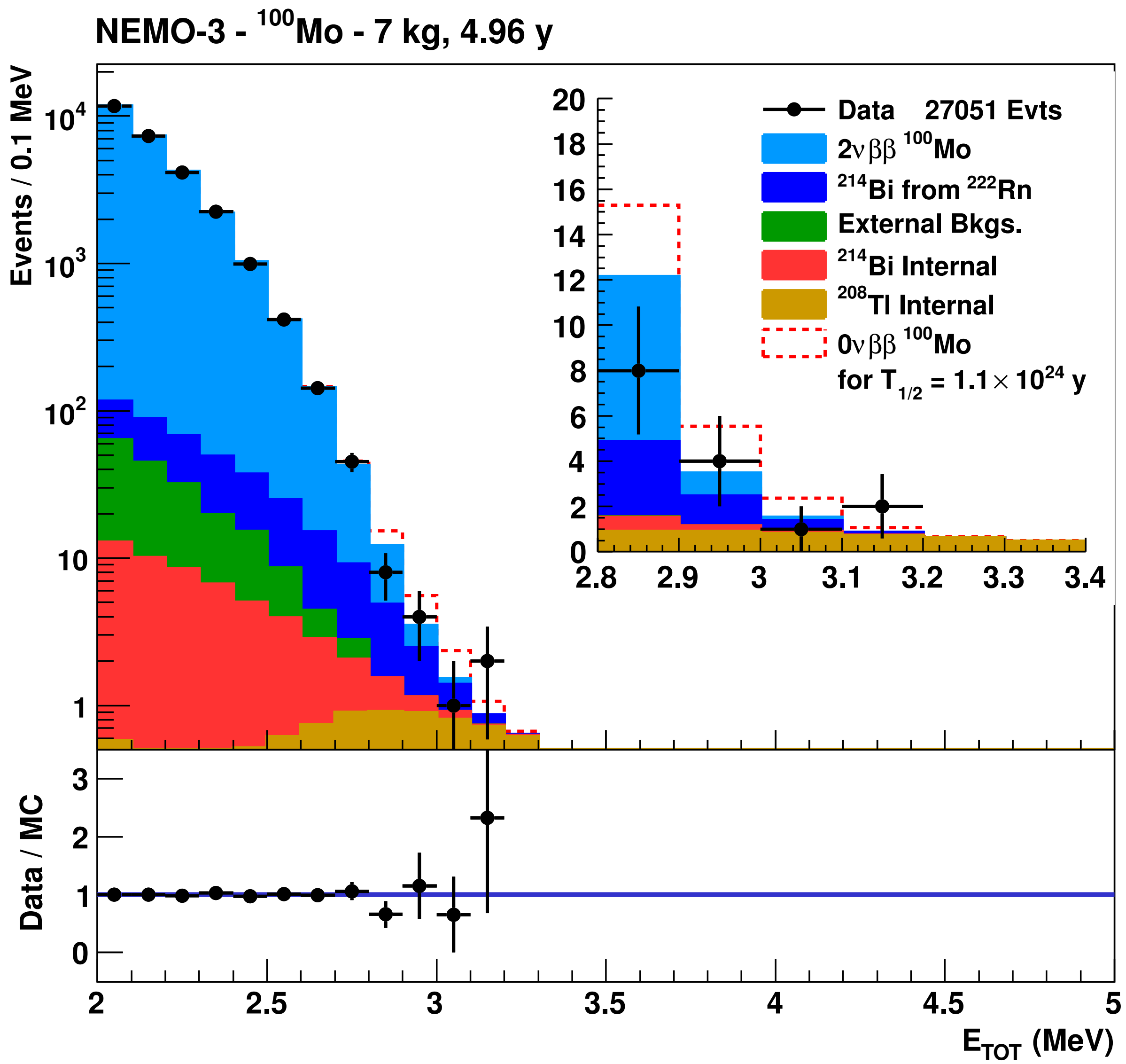
Analysis of whole statistics ongoing (^{82}Se, ^{48}Ca, ^{96}Zr, ^{116}Cd, ^{150}Nd)…stay tuned!

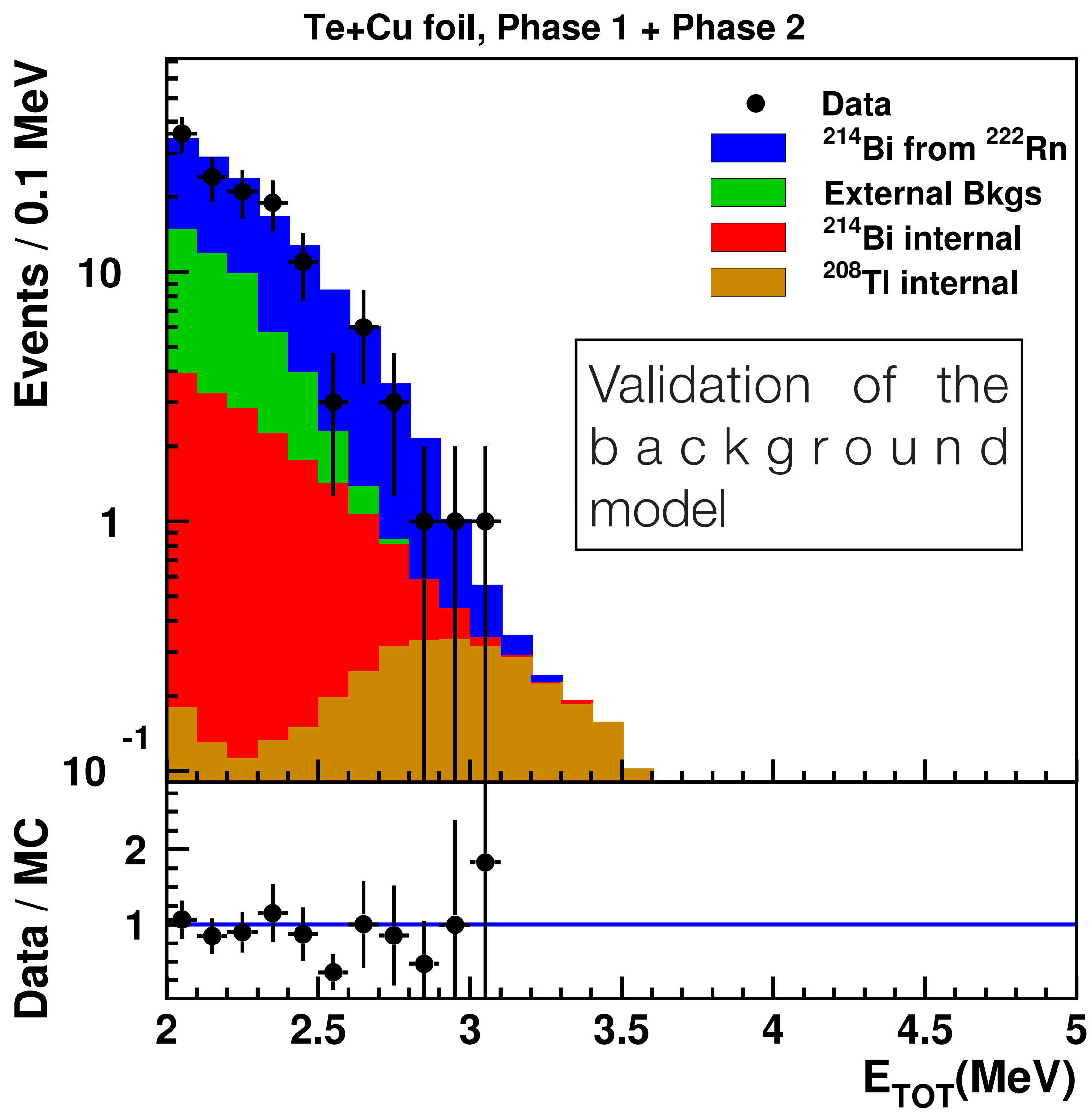
^{100}Mo 0νββ decay to the ^{100}Ru excited states [Nuclear Physics A781 (2007) 209-226]

NEMO-3: high energy background

No events in ^{100}Mo foils after 34.3 kg×y > 3.2 MeV

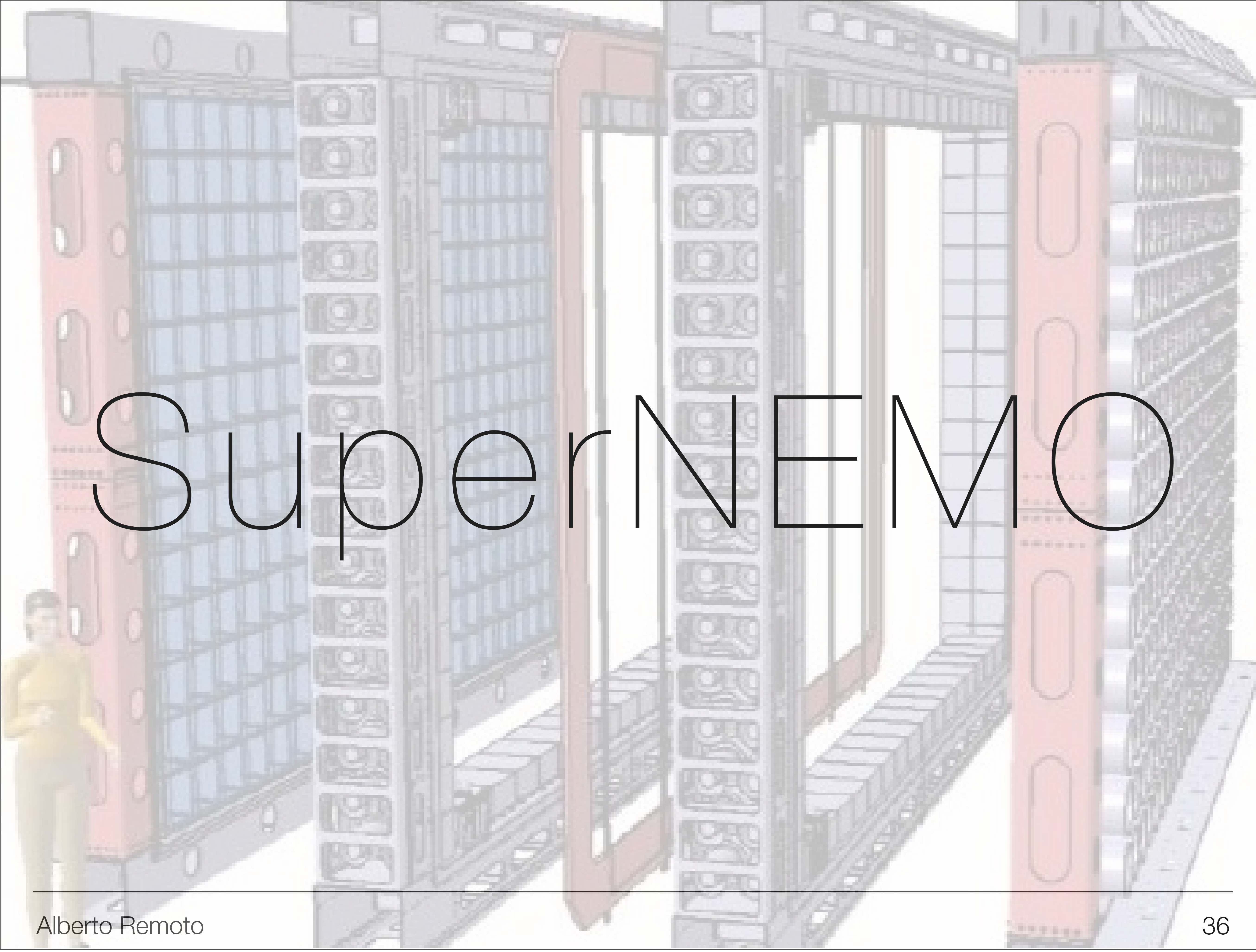
No events in Cu & Te foils after 13.5 kg×y > 3.1 MeV





Promising background free technique for high $Q_{\beta\beta}$ isotopes

^{48}Ca (4.272 MeV), ^{150}Nd (3.368 MeV) or ^{96}Zr (3.350 MeV)



SuperNEMO

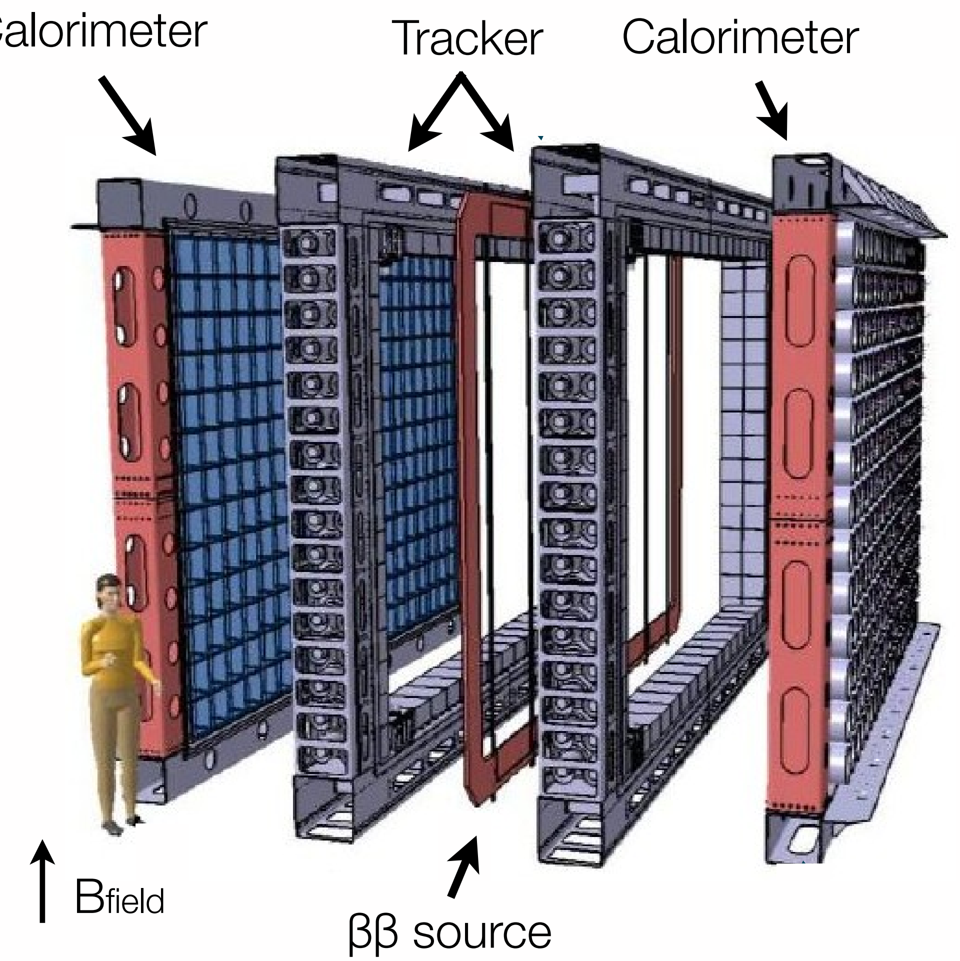
[Eur. Phys. J. C70: 927-943,2010]

SuperNEMO: toward the new generation

Extrapolate a well known technique:

- 100 kg of ββ emitter in 20 detection module
- Approach Inverted Hierarchy region

	NEMO-3	SuperNEMO
Efficiency	18%	~30%
Isotope	7 kg ^{100}Mo	~100 kg ^{82}Se (^{150}Nd, ^{48}Ca)
Exposure	35 kg y	~500 kg y
Energy res.	8% @ 3 MeV	4% @ 3 MeV
^{208}Tl (source)	~100 μBq/kg	< 2 μBq/kg
^{214}Bi (source)	~ 300 μBq/kg	< 10 μBq/kg
Rn (in tracker)	5 mBq/m^3	0.15 mBq/m^3
$T_{1/2}$	10^{24} y	10^{26} y
$\langle m_\nu \rangle$	0.3 - 0.9 eV	0.04 - 0.1 eV



A challenge in many aspects:

- R&D program in the past years almost completed!
- Next step: Demonstrator module

[Eur. Phys. J. C70: 927-943,2010]

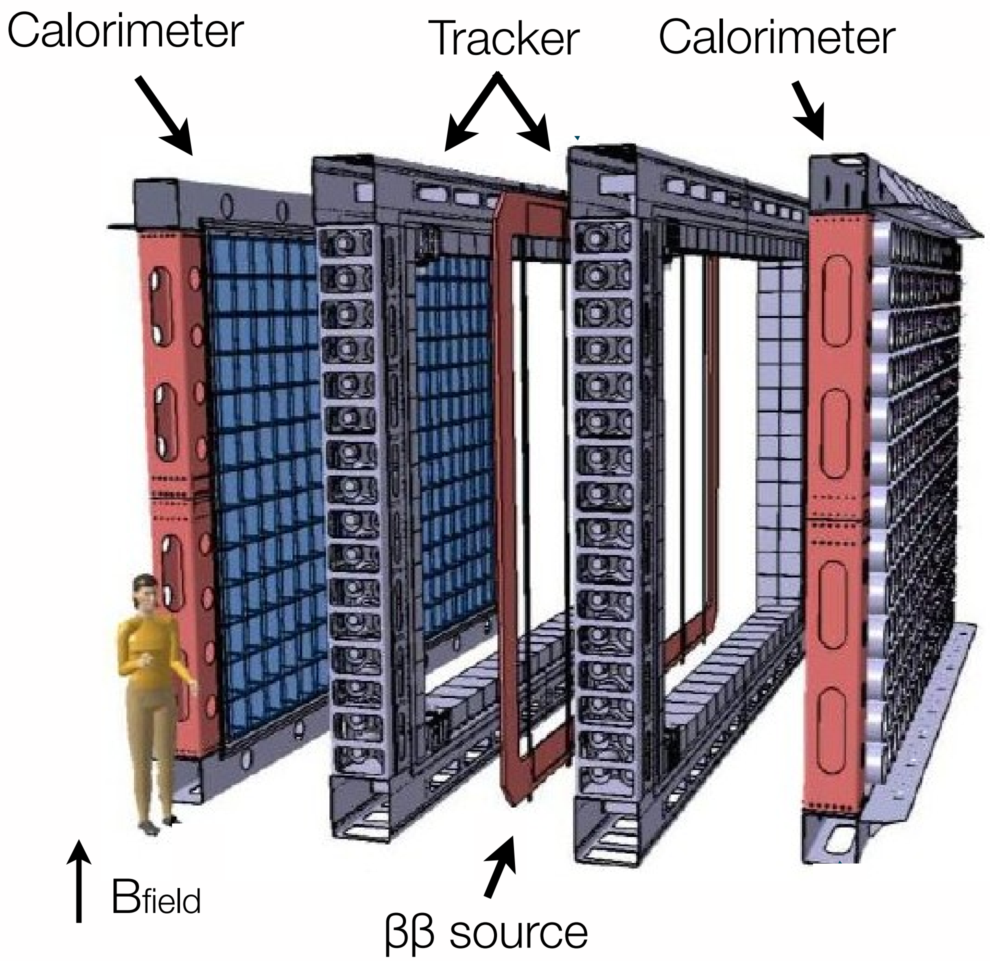
SuperNEMO: the demonstrator module

One SuperNEMO module → 7 kg ^{82}Se running ~2.5 y

- To be installed @ LSM (replacing NEMO-3)
- Match SuperNEMO requirements

Reach NEMO-3 (^{100}Mo) sensitivity in 4.5 months

- Sensitivity: $\langle m_\nu \rangle$ ~ 0.20 - 0.40 eV

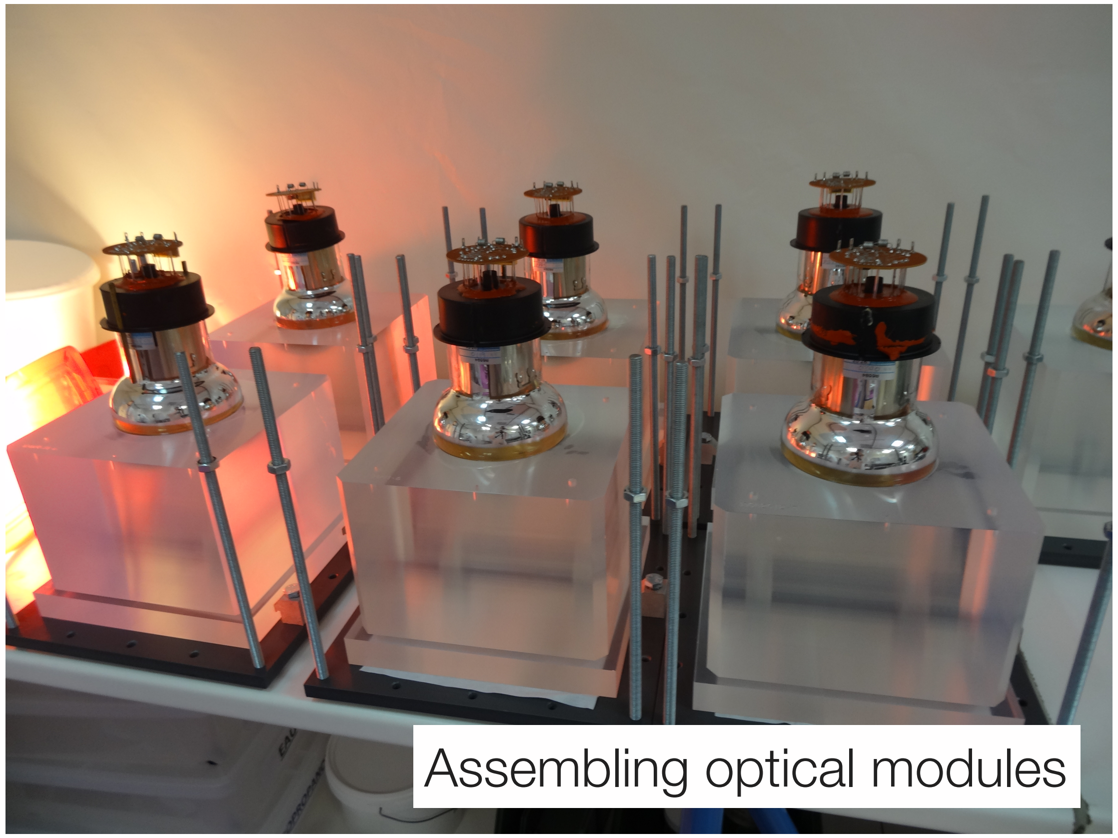


Schedule:

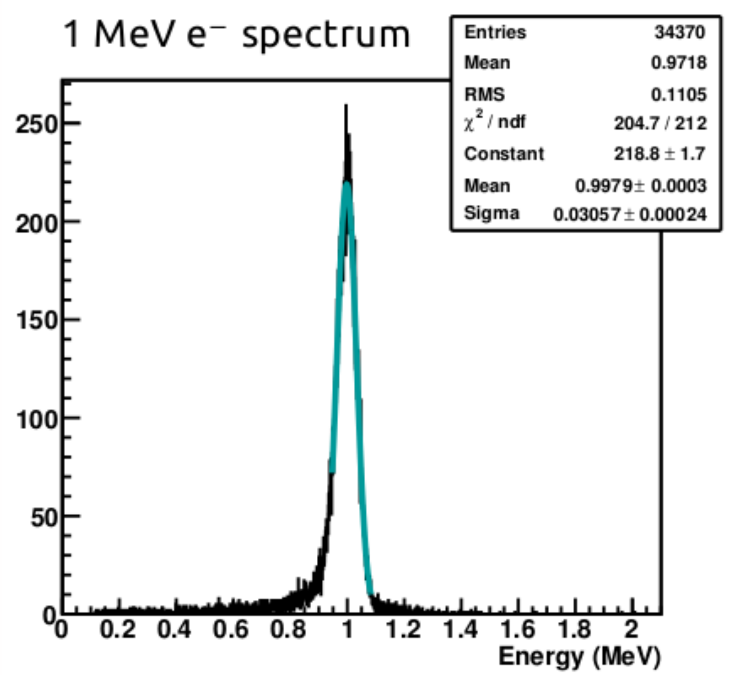
- Calorimeter & tracker under production
- Installation starting in 2015
- Commissioning & First data by 2016

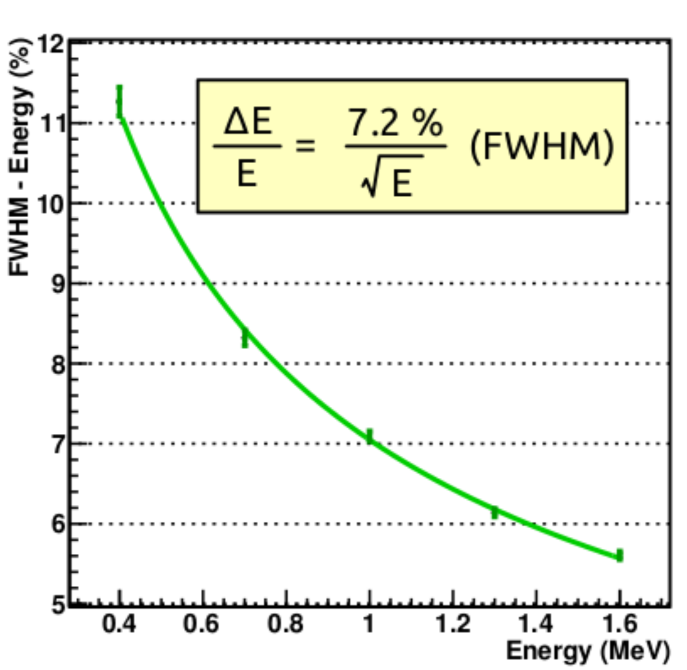
SuperNEMO: the calorimeter

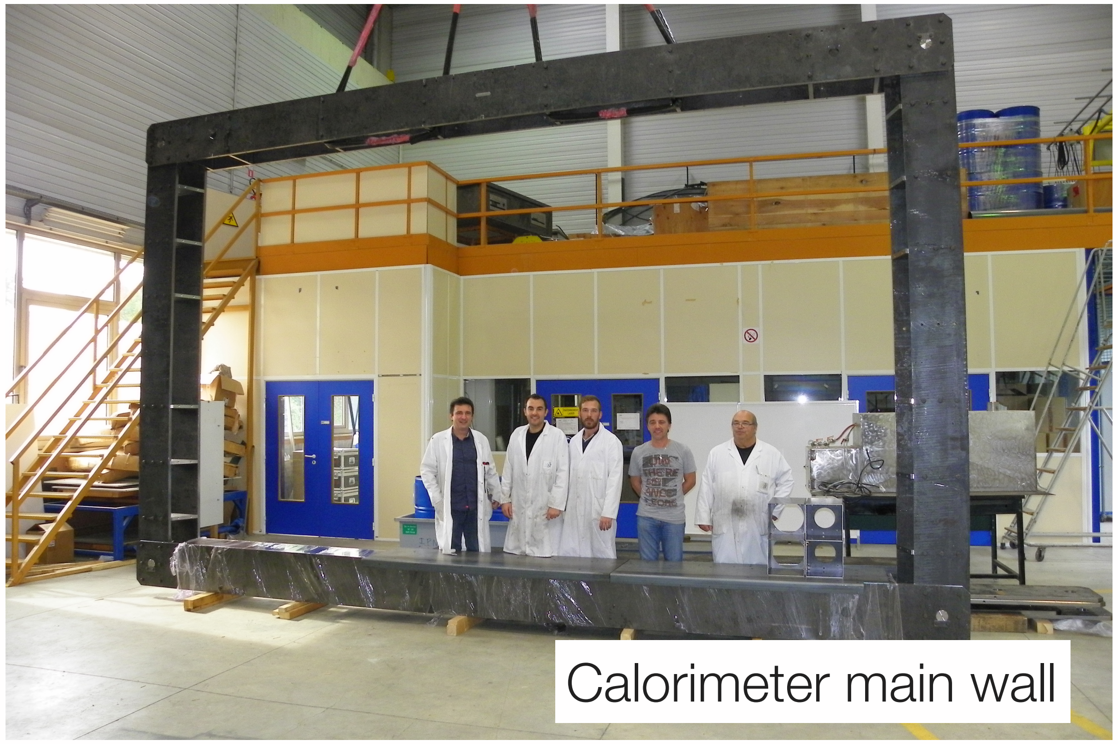
- 5” and 8” high quantum efficiency PMT directly coupled to a scintillator block with optimised geometry
- Energy resolution: 7.2 % FWHM @ 1 MeV
- Electronics, optical modules, shield, mechanical structure under production



Assembling optical modules



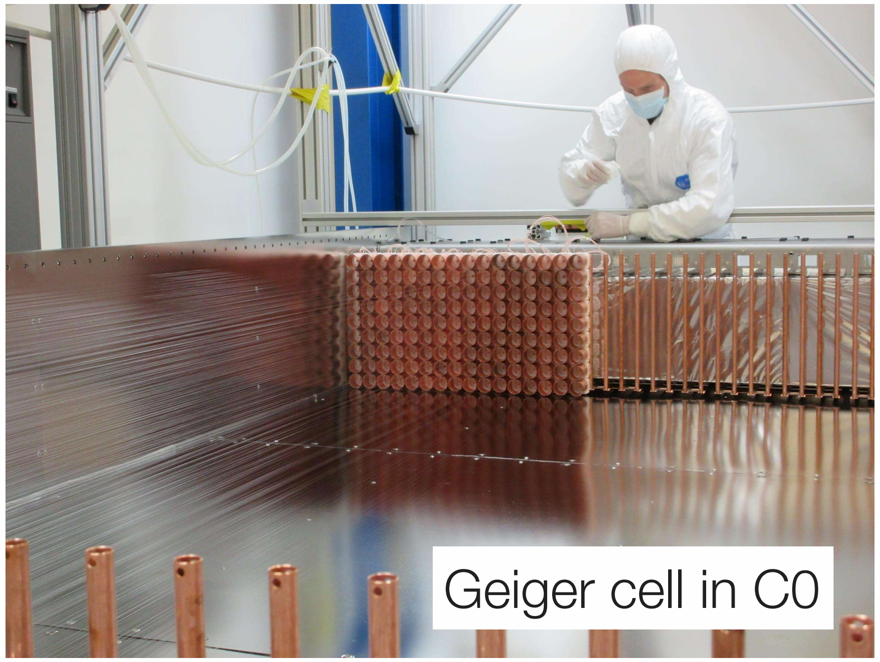


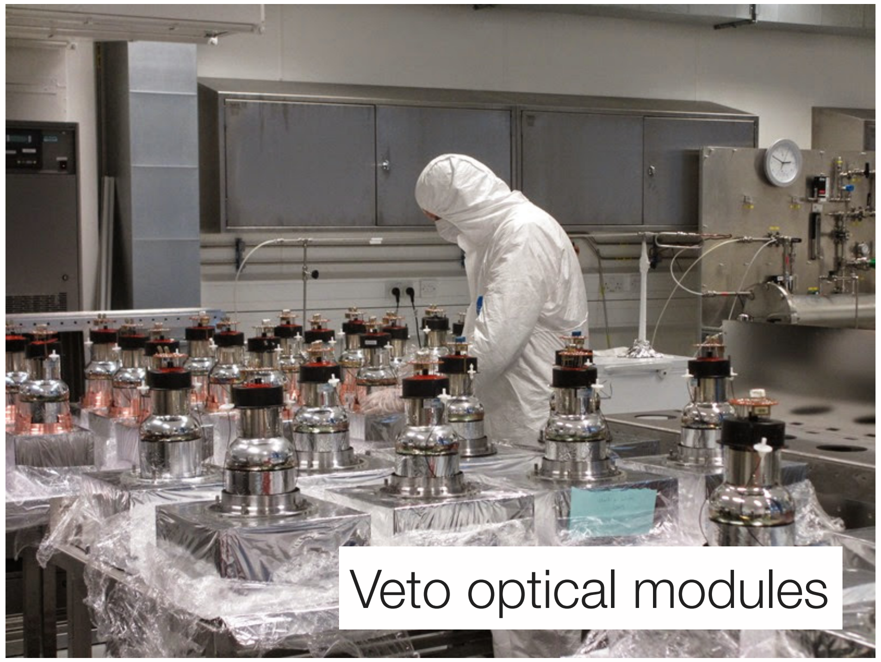


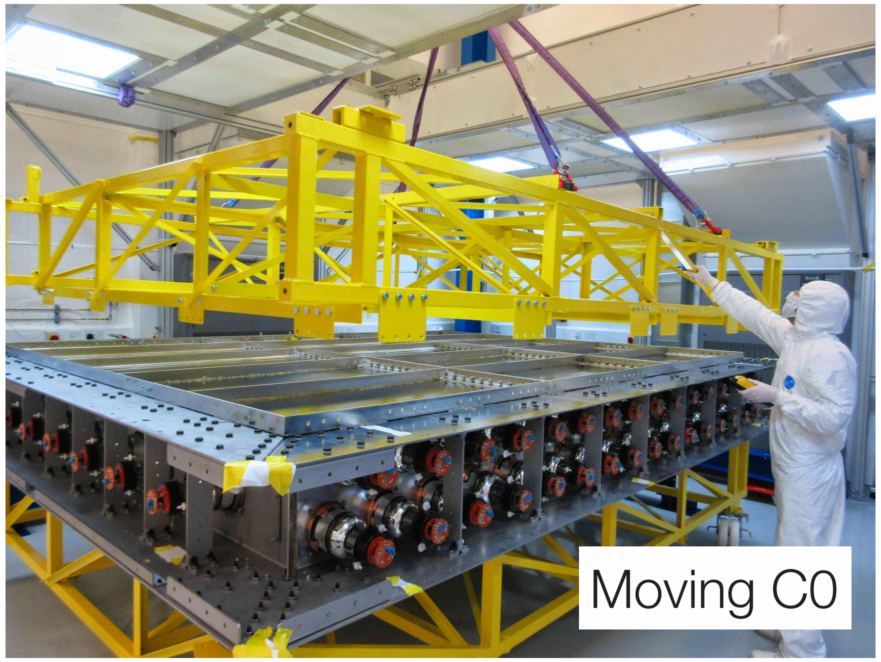
Calorimeter main wall

SuperNEMO: the tracker

- 2034 Geiger cells in a Rn-tight chamber surrounded by optical modules for veto
- Drift cells under production whit automatic wiring robot
- Tracker assembled in 1/4 @ MSSL (UK) then moved to LSM for integration
- Commissioning of C0 ongoing at sea level, C1 under construction

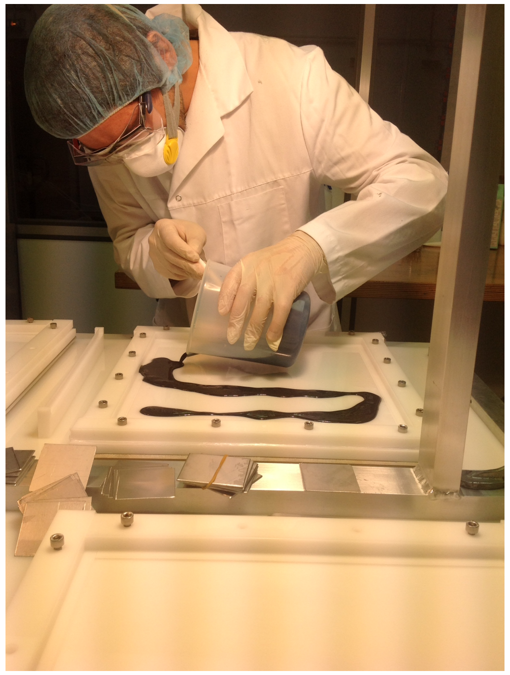

Geiger cell in C0


Veto optical modules

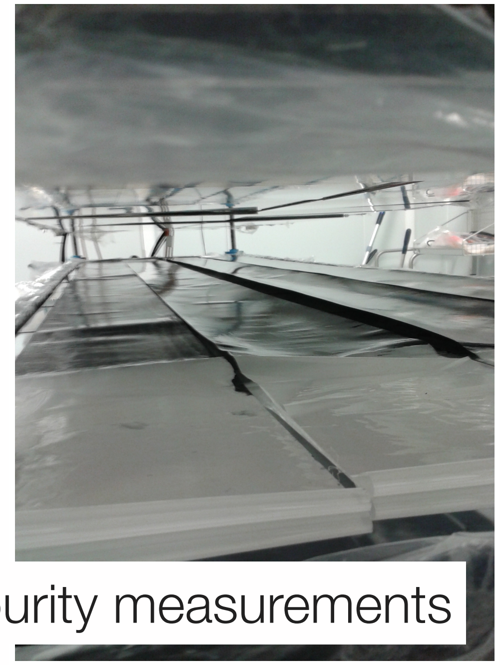

Moving C0

SuperNEMO: the source foil

- About 37 foils installed on the source frame in the detector center
- ^{82}Se powder mixed with PVA glue + mylar or nylon mechanical support
- Limits on foil contamination in ^{208}Tl (2 µBq/kg) and ^{214}Bi (10 µBq/kg) are challenging
- Purification technique under investigation: chemical chromatography, distillation, etc.
- LAPP is in charge for the production of 1/2 of the source for the Demonstrator



Training foil production technique



^{82}Se foils radio-purity measurements

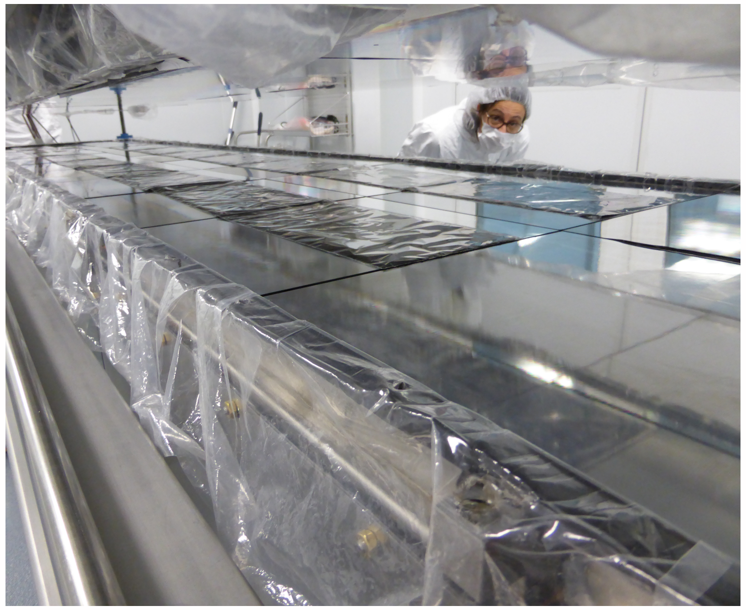
SuperNEMO: radio-purity measurements

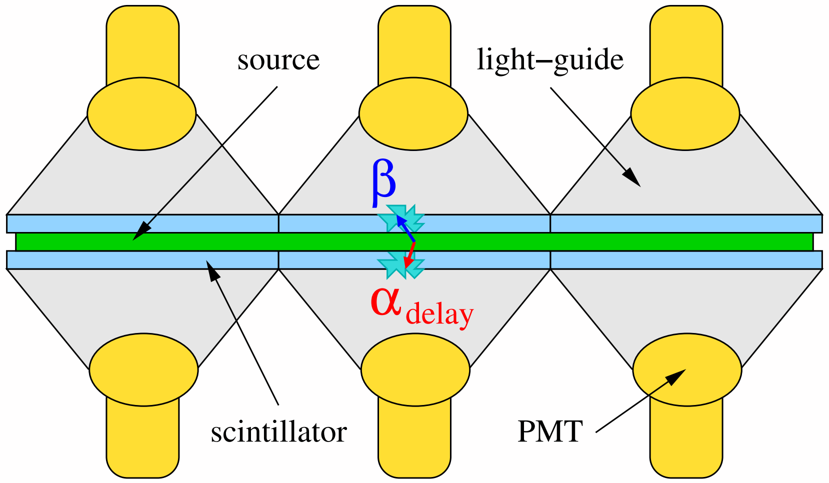
Detector radio-purity budget:

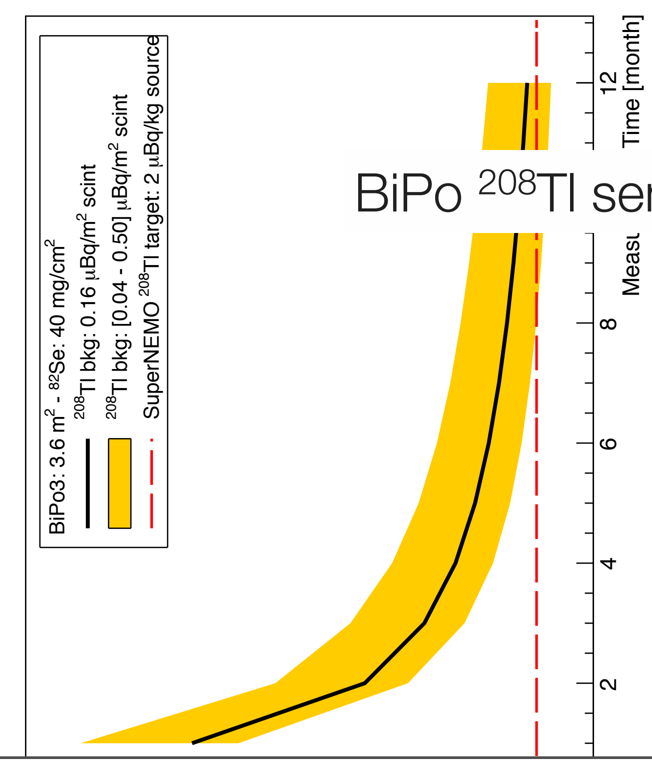
- Materials validation with HPGe detectors (sensitivity ~ mBq)

Source foils:

- HPGe not sensitive enough for SuperNEMO requirement: dedicated setup @ LSC (Canfranc) BiPo
- Detecting delayed β—α coincidence from Bi—Po chain
- First two ^{82}Se foils currently under measurement



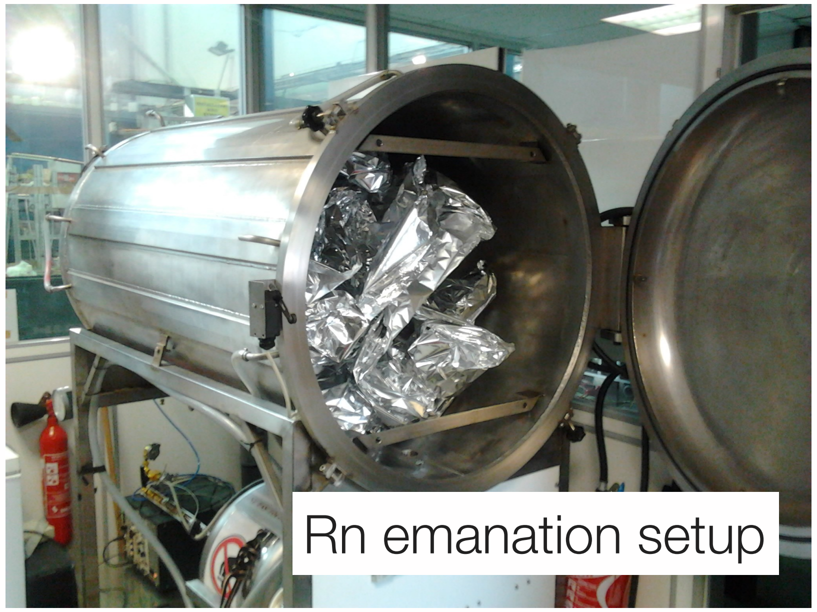


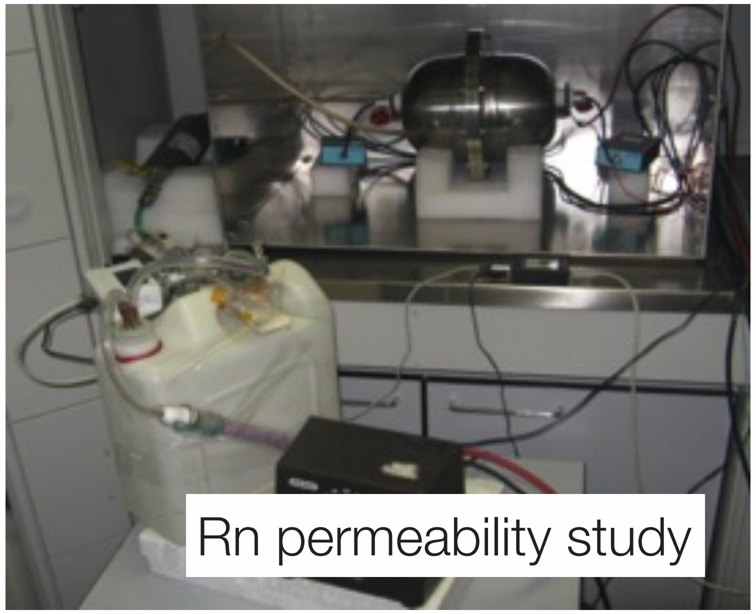


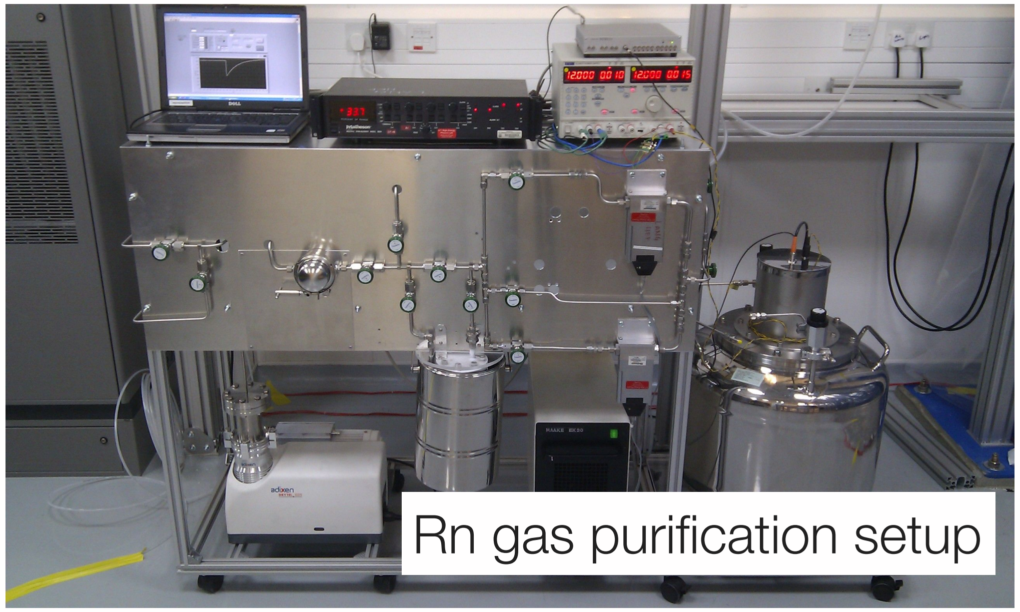
BiPo ^{208}Tl sensitivity

SuperNEMO: Radon measurements

- The Rn gas in the tracker volume was the dominant background in NEMO-3
- Reduce Rn contamination to 0.15 mBq/m^3
- Control the Radon emanation of the materials
- Radon purification/absorption with dedicated setup
- Preliminary radon emanation of C0 = 0.236 ± 0.035 mBq/m^3 — limit is close!


Rn emanation setup


Rn permeability study


Rn gas purification setup


Esher - Ascending and descending (1960)

Summary

Summary & conclusions

Tracking + Calo. technique

- Unique: allowing direct reconstruction of the $2e^-$
- Full signature of $0\nu\beta\beta$ events and powerful background rejection
- Background-free technique for high energy $Q_{\beta\beta}$ isotopes

Latest NEMO-3 results

- Total ^{100}Mo exposure of 34.3 kg×y shows no event excess
- $T^{0\nu}_{1/2} > 1.1\times10^{24}$ y → $\langle m_\nu \rangle < 0.3 - 0.9$ eV @ (90 % C.L.)
- Other isotopes: re-analysis of full statistics ongoing

SuperNEMO demonstrator

- Under construction: commissioning by 2016
- Foresee to run for 2.5 years with 7 kg of ^{82}Se
- $T^{0\nu}_{1/2} > 6.5\times10^{24}$ y → $\langle m_\nu \rangle < 0.20 - 0.40$ eV @ (90 % C.L.)

Future: Full SuperNEMO

- 20 demonstrator-like modules: 100 kg of ^{82}Se for 5 years
- $T^{0\nu}_{1/2} > 1\times10^{26}$ y → $\langle m_\nu \rangle < 0.04 - 0.10$ eV @ (90 % C.L.)
- ^{48}Ca, ^{150}Nd or ^{96}Zr are also possible candidates

Esher - Ascending and descending (1960)

Backup

Which isotope?

Isotopes enrichment and $T^{2\nu}_{1/2}$ from respective experiment

Isotope	$Q_{\beta\beta}$ [keV]	Nat. abund. (enrich.) [%]	$G_{0\nu}$ [10^{-14} y^{-1}]$^{(*)}$	$T^{2\nu}_{1/2}$ [10^{19} y]	Experiment
^{48}Ca	4270	0.187 (73)	6	$4.2^{+2.1}_{-1.0}$	NEMO3
^{76}Ge	2039	7.8 (86)	1	150±10	GERDA
^{82}Se	2995	8.7 (97)	3	9.0±0.7	NEMO3
^{96}Zr	3350	2.8 (57)	6	2.0±0.3	NEMO3
^{100}Mo	3034	9.6 (99)	4	0.71±0.04	NEMO3
^{116}Cd	2802	7.5 (93)	5	3.0±0.2	NEMO3
^{130}Te	2527	34.5 (90)	4	70±10	NEMO3
^{136}Xe	2480	8.9 (80)	4	238±14	KamlandZEN
^{150}Nd	3367	5.6 (91)	19	0.78±0.7	NEMO3

What is the status?

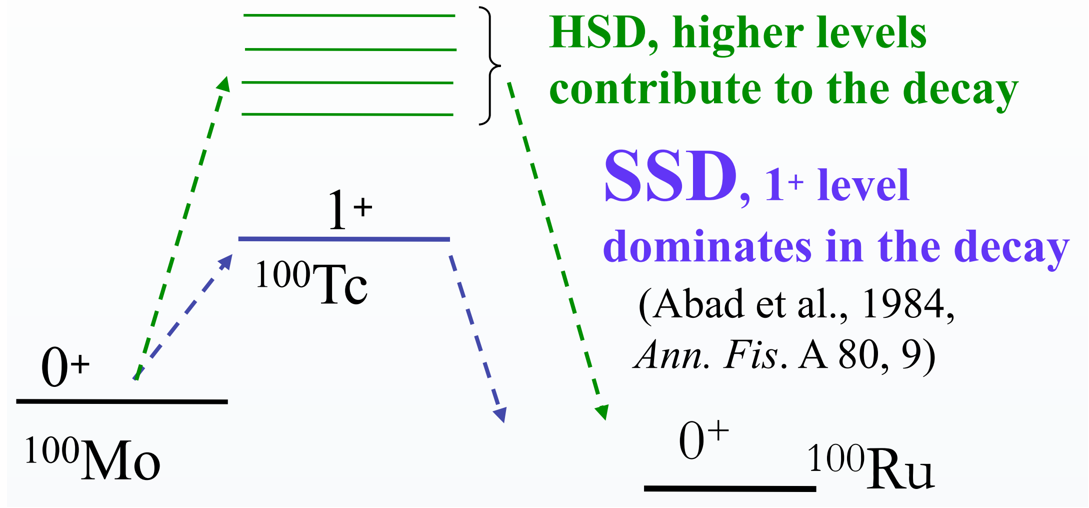
		Light Majorana neutrino exchange		Right handed current		SUSY: neutralino or gluino exchange	Majoron emission
Isotope	Exposure (kg·y)	Half life (10^{25} y) published	$\langle m_\nu \rangle$ (eV) published	$\langle \lambda \rangle$ (10^{-6}) published	$\langle \eta \rangle$ (10^{-8}) published	λ'_{111}/f (10^{-2}) published	$\langle g_{ee} \rangle$ (10^{-5}) published
^{100}Mo [1] (NEMO-3)	34.7	0.1	0.33 - 0.87	0.9 - 1.3	0.5 - 0.8	4.4 - 6.0	2 - 5
^{130}Te [2][3] (CUORICINO)	19.75	0.3	0.31 - 0.71	1.6 - 2.4	0.9 - 5.3		17 - 33
^{136}Xe [4][5] (KamLAND-Zen)	89.5	1.9	0.14 - 0.34				
^{136}Xe [9] (KamLAND-Zen)	109.4 + 89.5	2.6	0.14 - 0.28				
^{136}Xe [6] (EXO-200)	99.8	1.1	0.19 - 0.45				
^{76}Ge [7][8] (GERDA)	21.6	2.1	0.2 - 0.4				3.4 - 8.7
^{76}Ge [9] (HdM)	35.5	1.9	0.4	1.1	0.6		8.1

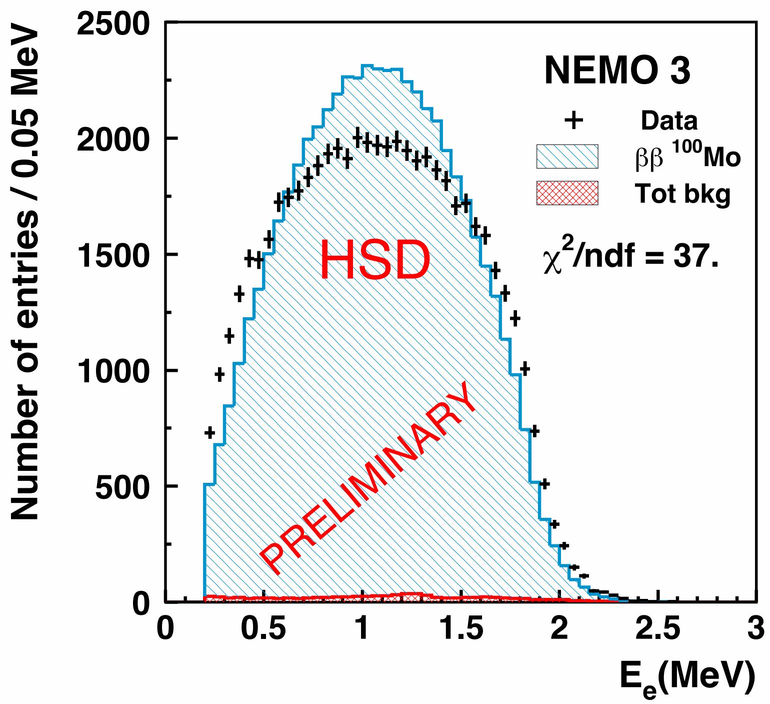
NEMO-3: 2νββ of ^{100}Mo SSD/HSD

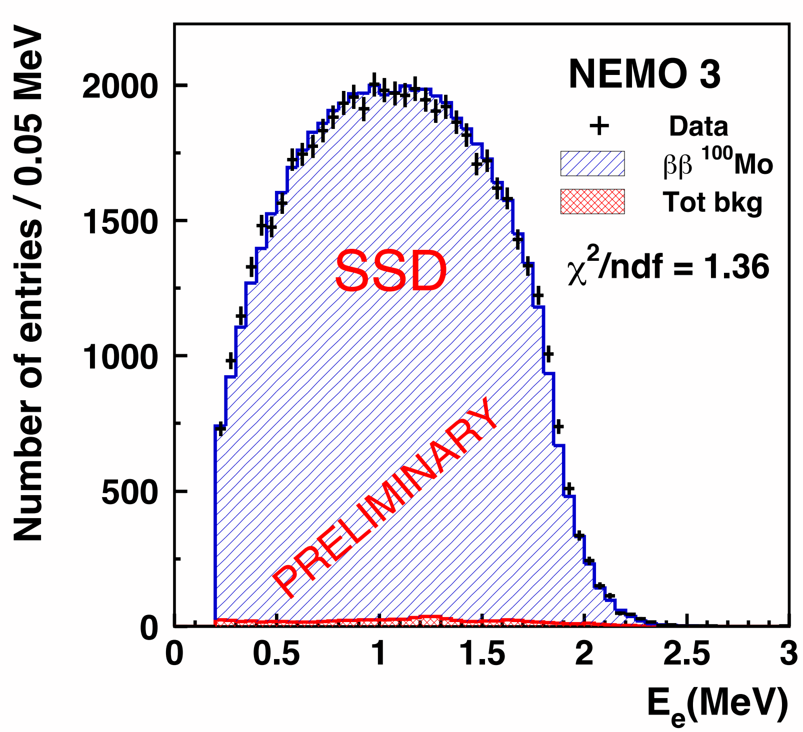
If the intermediate nucleus is a J^{π}=1+ state, the NME could be dominated by GT transitions through this state.

If the SSD hypothesis is confirmed

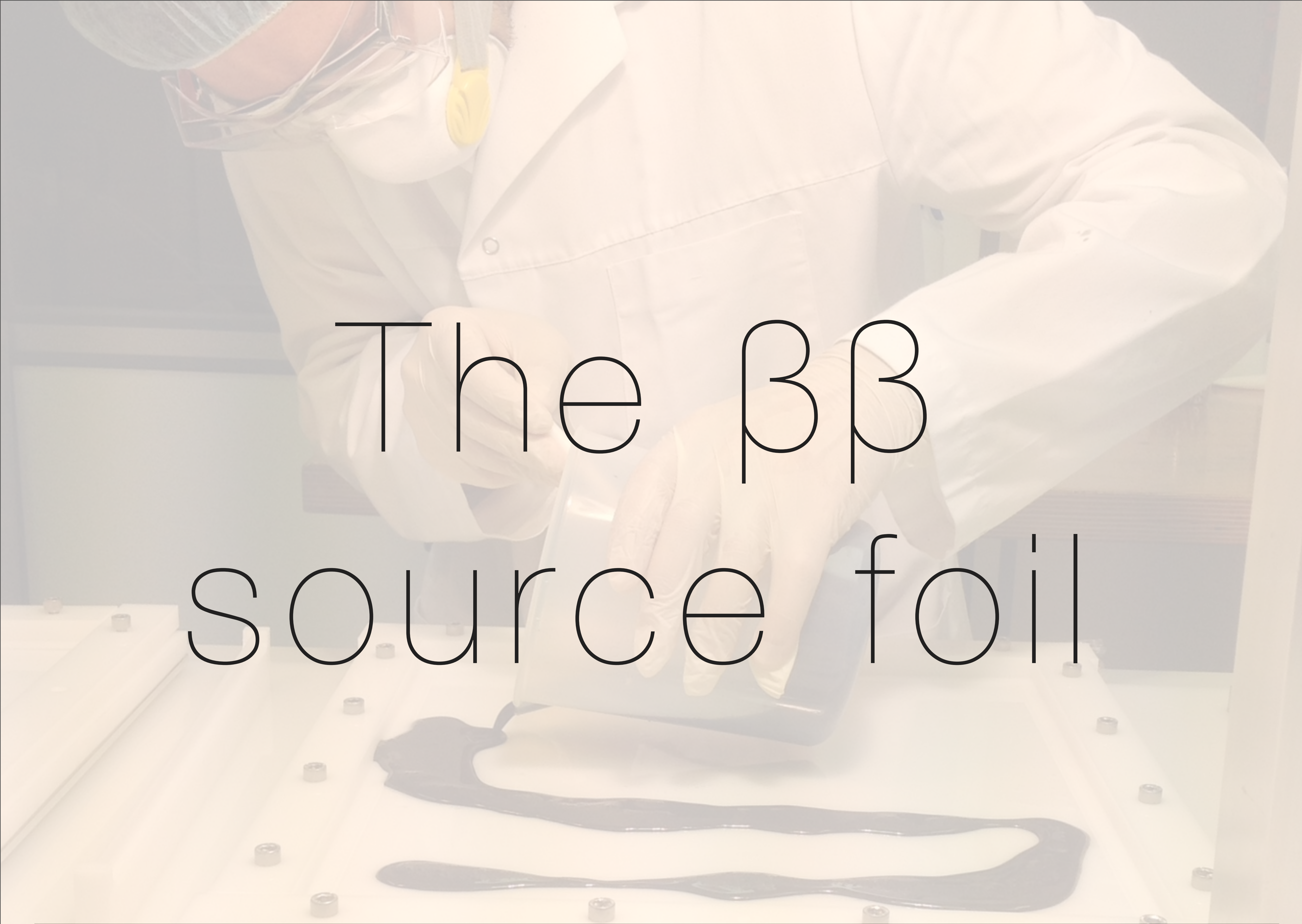
- 2νββ half-life could be determined from single-β and electron capture (EC) measurements.
- simplification in the theoretical description of the intermediate nucleus







Electron energy distribution in 2νββ decay of ^{100}Mo is in favour of SSD



The ββ source foil

Foil source design

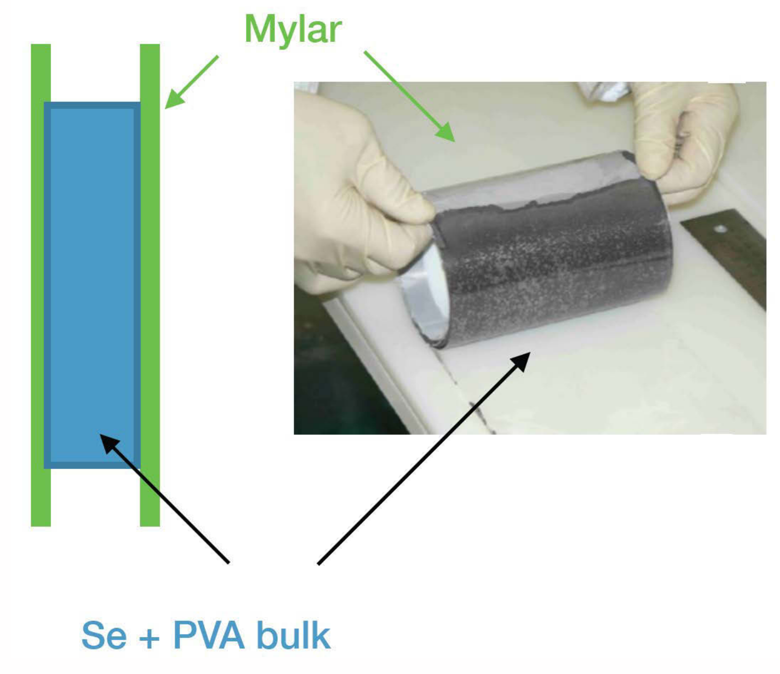
A. Remoto, D. Duchesneau, J.M. Dubois, A. Jeremie, T. Le Noblet

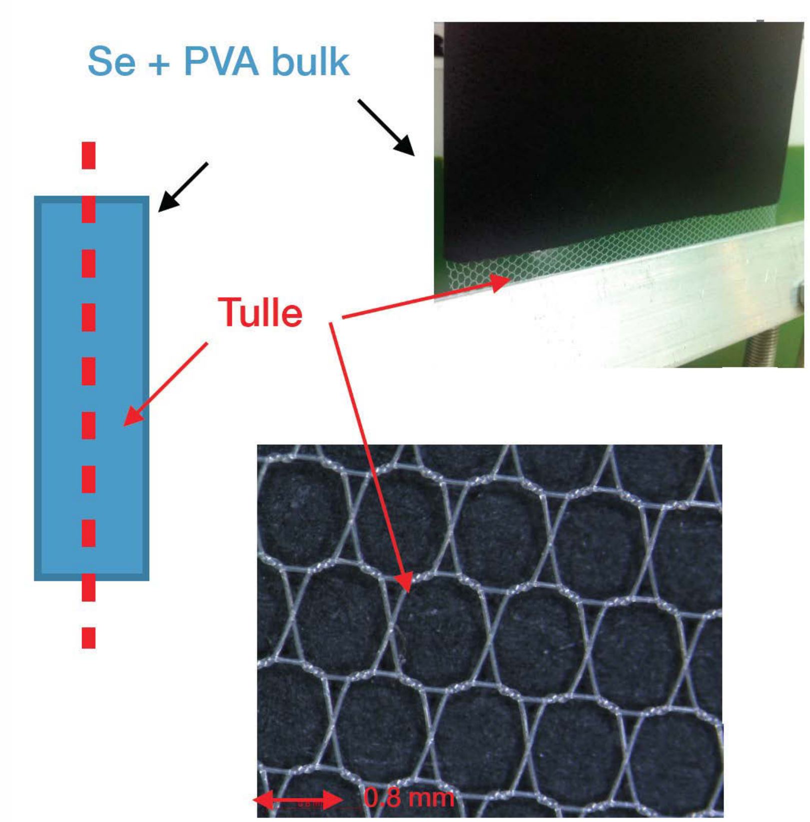
The ββ emitter is shaped in thin foil (150–200 um) mixing ^{82}Se powder with PVA glue — very fragile!

An embedded mechanical support is necessary to provide mechanical strength over the foil length

Different designs of the mechanical support are under consideration:

- NEMO-3 like design (ITEP): ^{82}Se+PVA within mylar backing film
- New design (LAPP): ^{82}Se+PVA with light nylon fabric support
- New design (LAPP): standalone ^{82}Se+PVA foil with clean mylar film welded to offer a protective layer

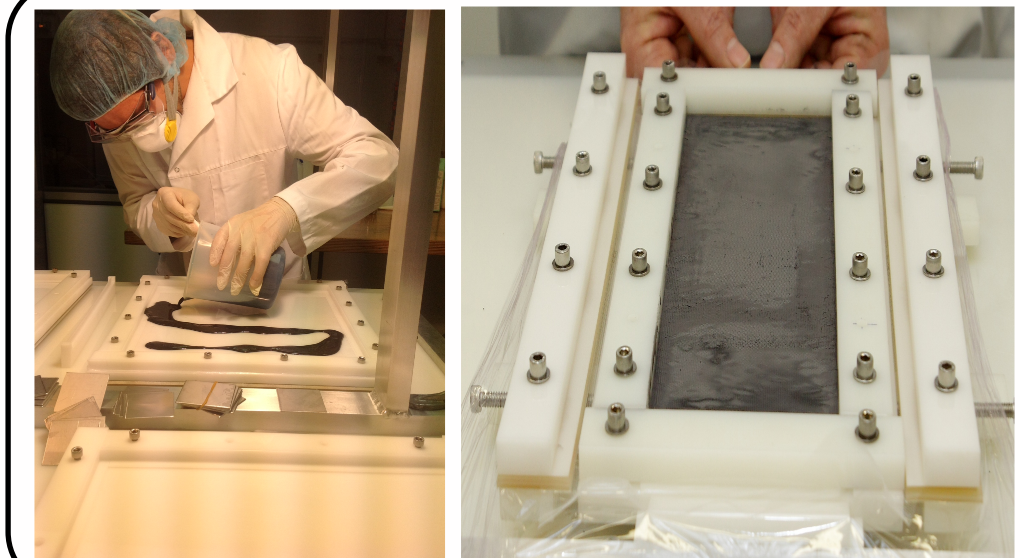




Foil source production

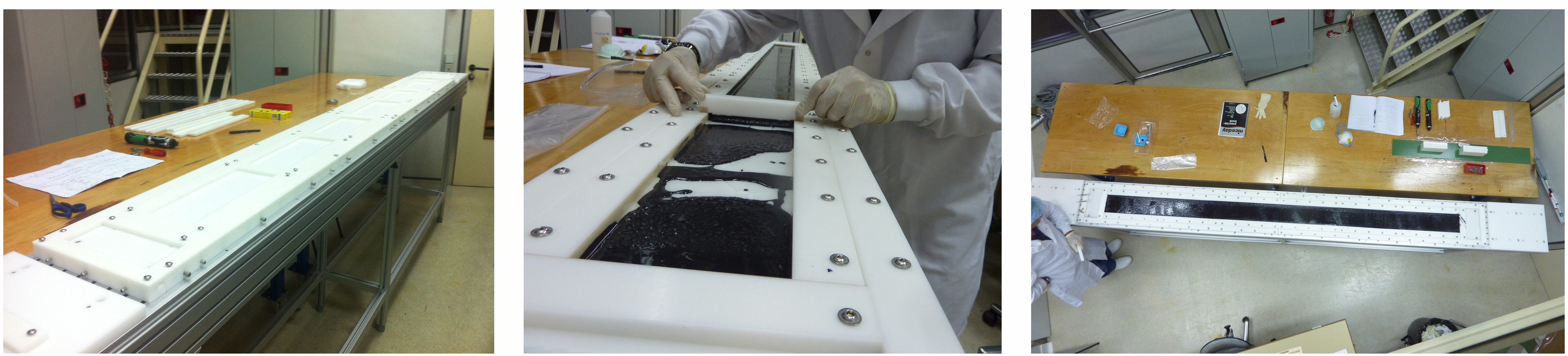
A. Remoto, D. Duchesneau, J.M. Dubois, A. Jeremie, T. Le Noblet

- Foil production protocol is defined. All the tools are ready! Improving the technique with practice…
- All materials to be used in foil production have been defined.
- Radio-purity measurements have been performed (collaboration with LSM, LAL and LSC - Canfranc)



Where we were last year

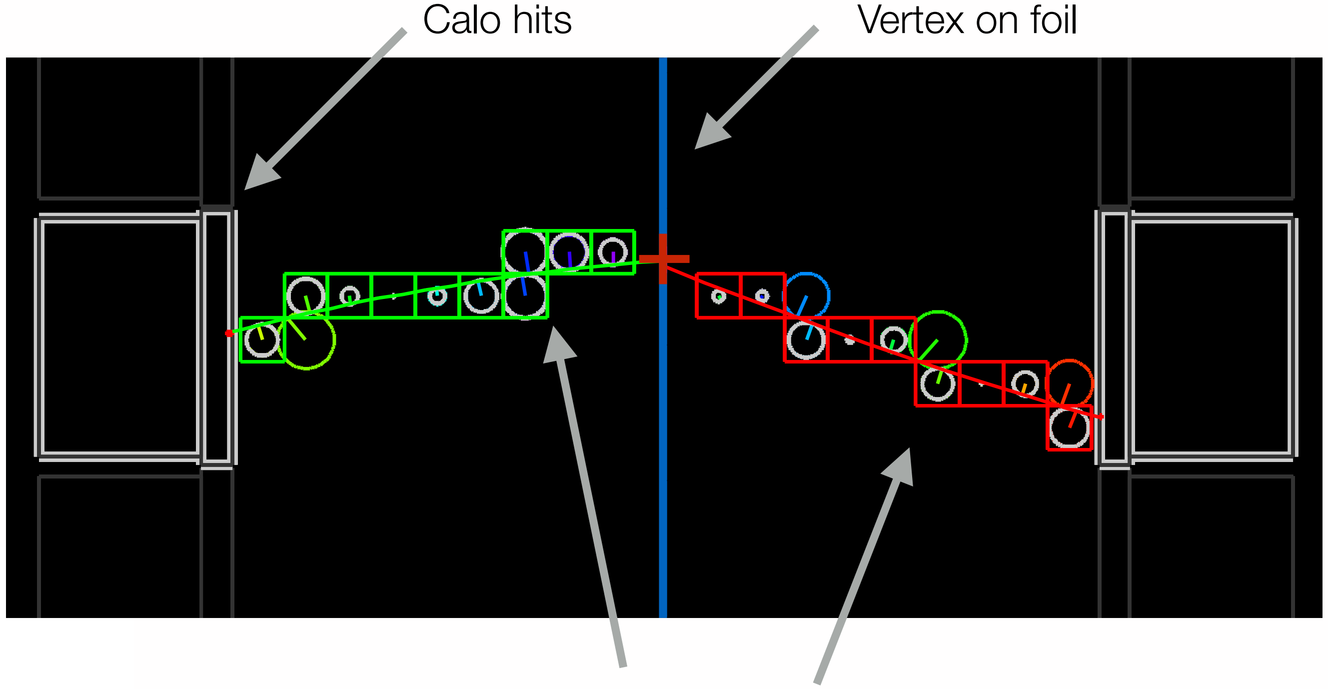
Where we are now

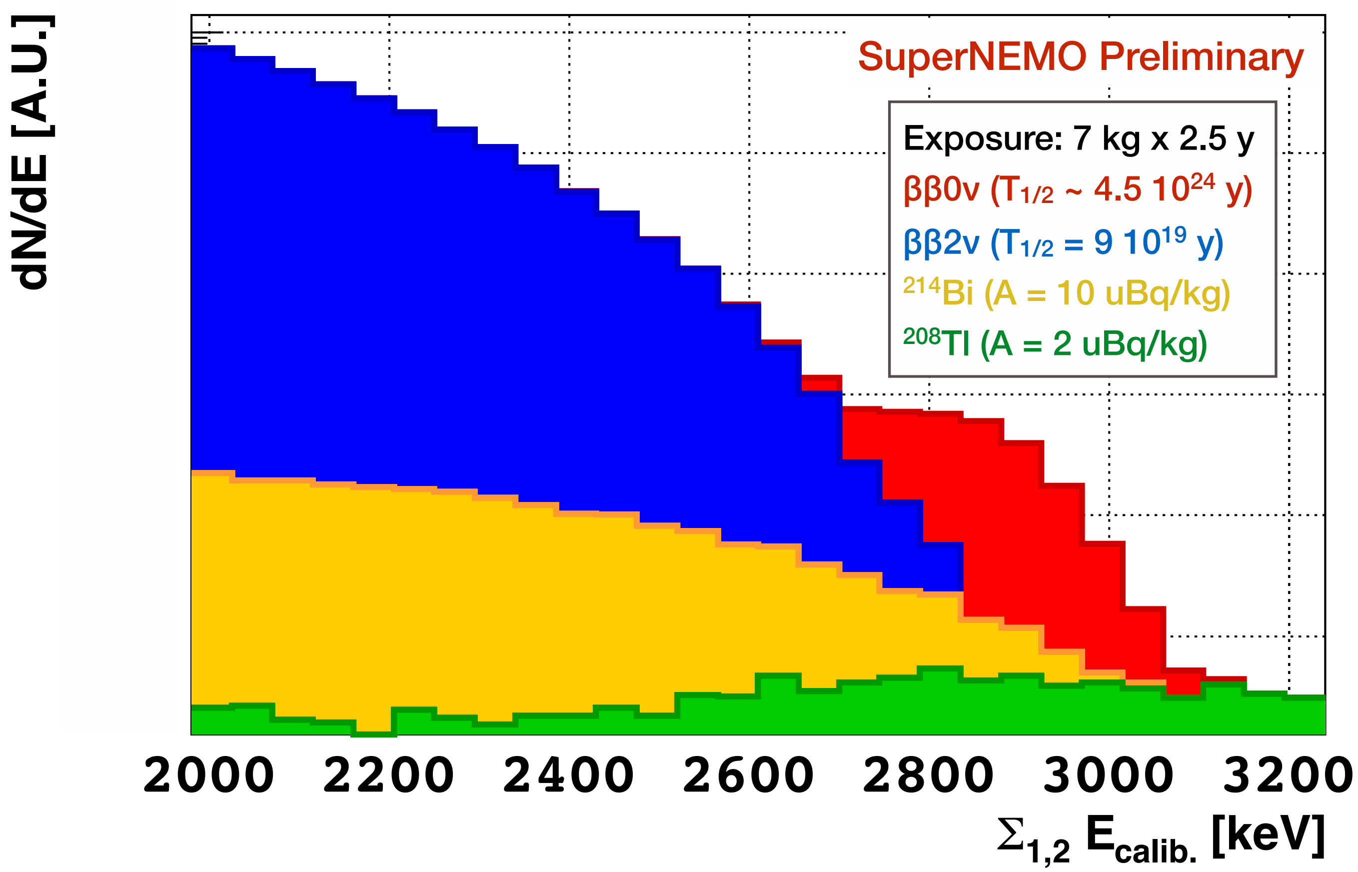


Sensitivity studies

T. Le Noblet, A. Remoto

- Study ββ0ν sensitivity w.r.t. foil design
- Check the foil design doesn't alter physics performance and results
- Generating signal, background and detector response





$$T^{0\nu}_{1/2} > \frac{N_A \ln 2}{W} \times \frac{\epsilon \times M \times T}{\mathcal{S}(b)}$$

- ε : Signal selection efficiency
- S(b) : Average upper limit on the number of signal events (Feldman & Cousins)

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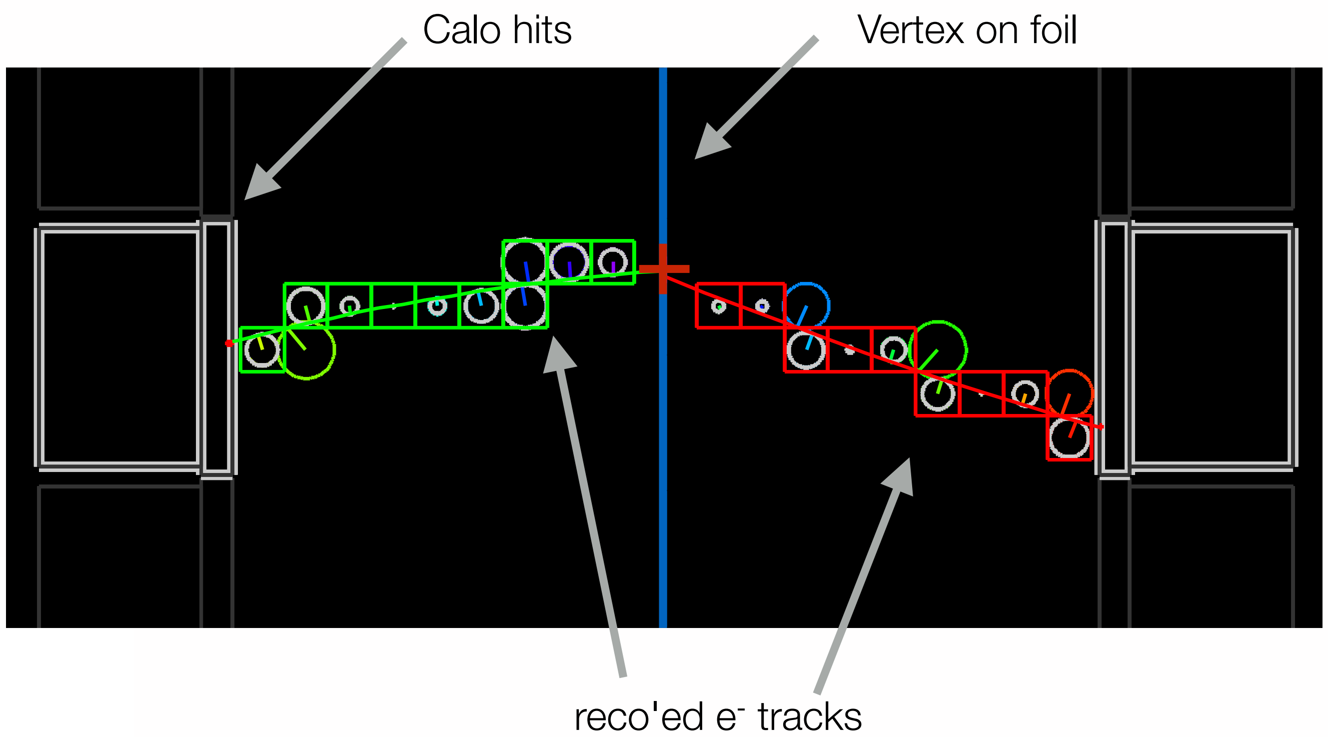

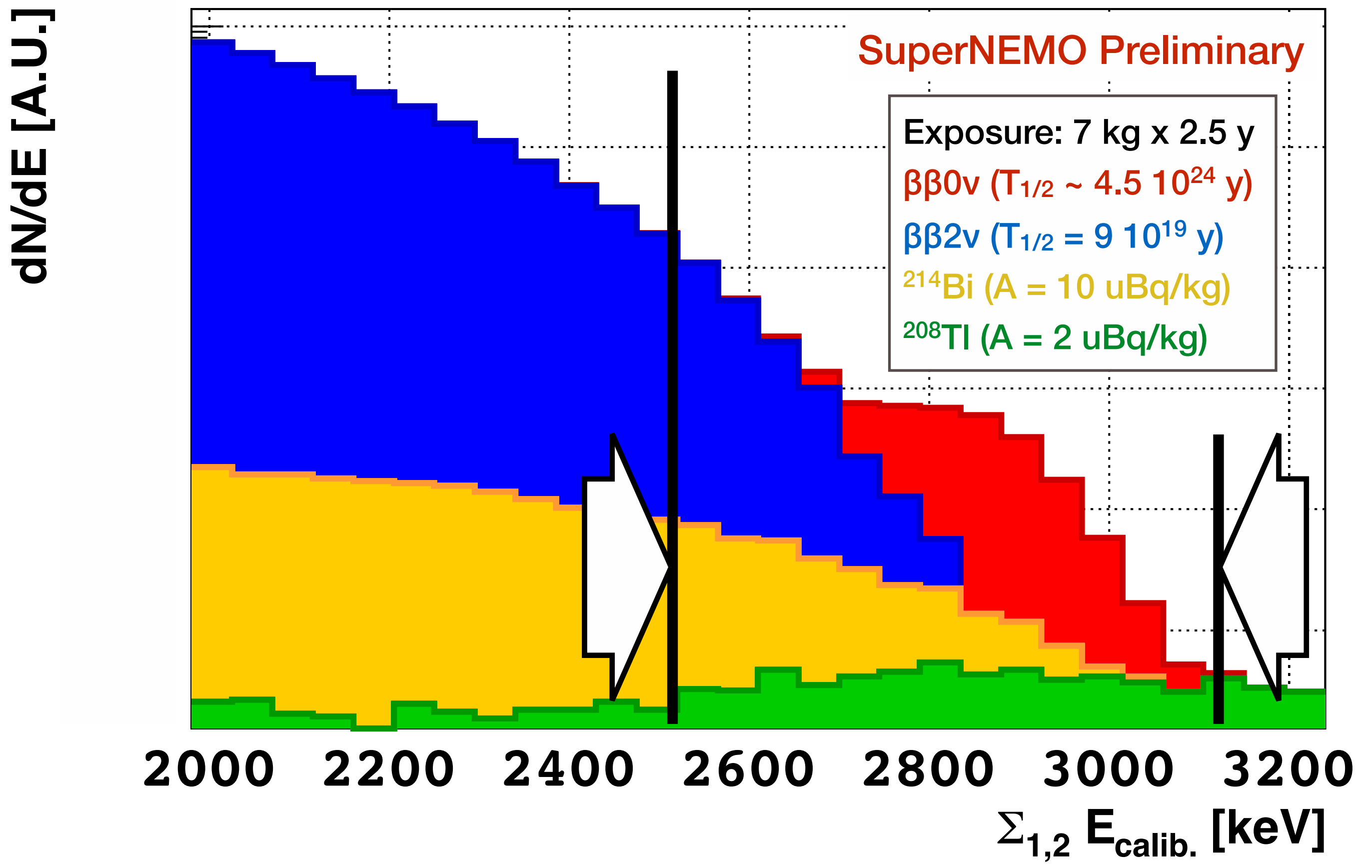

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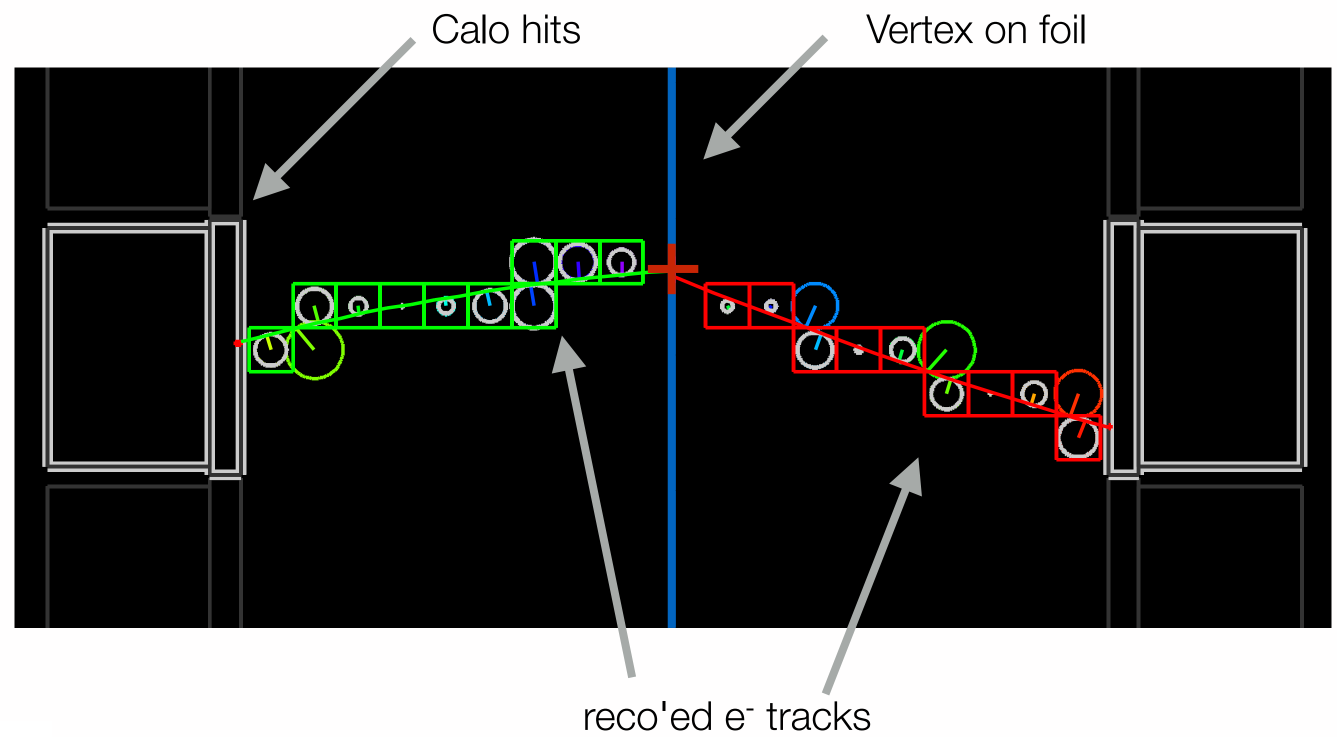

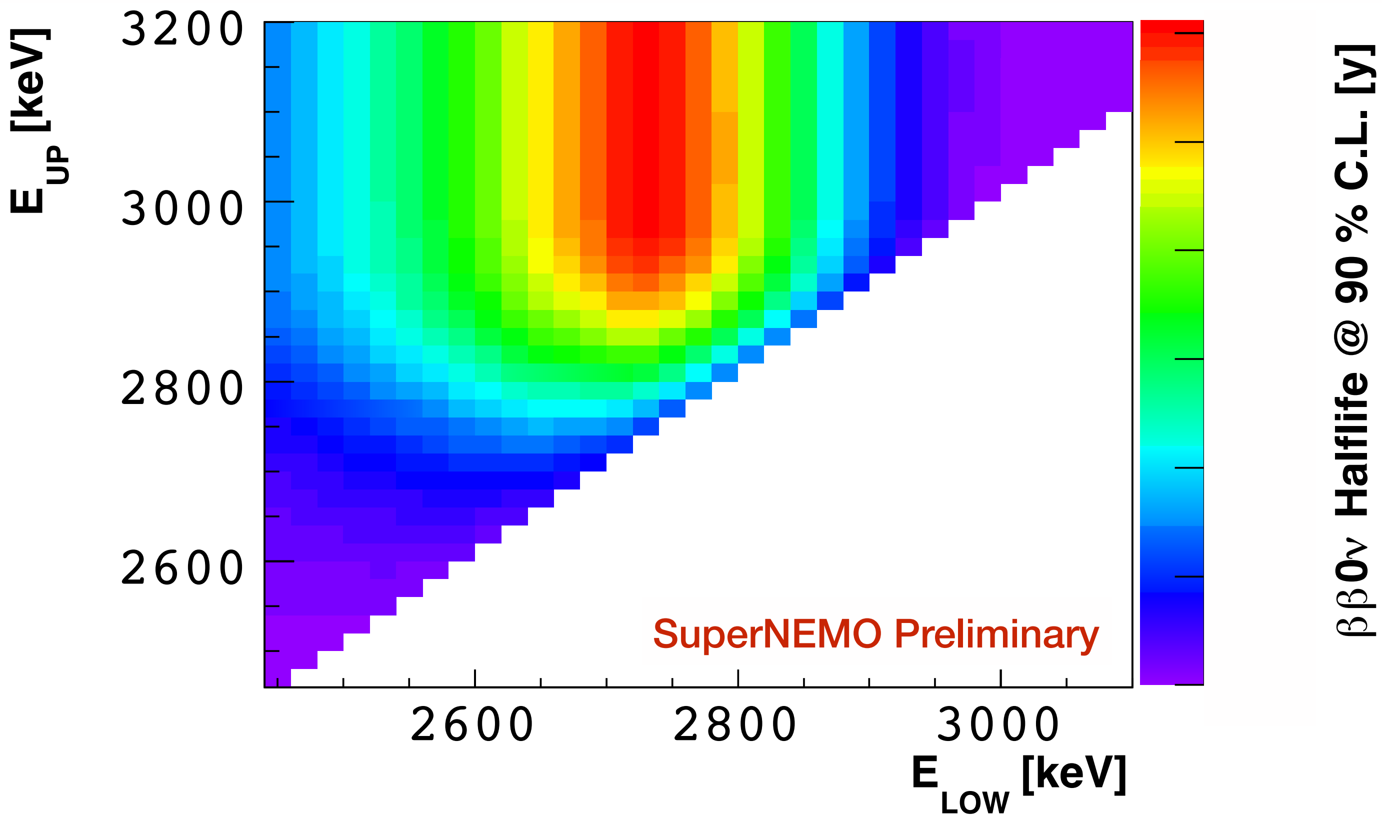

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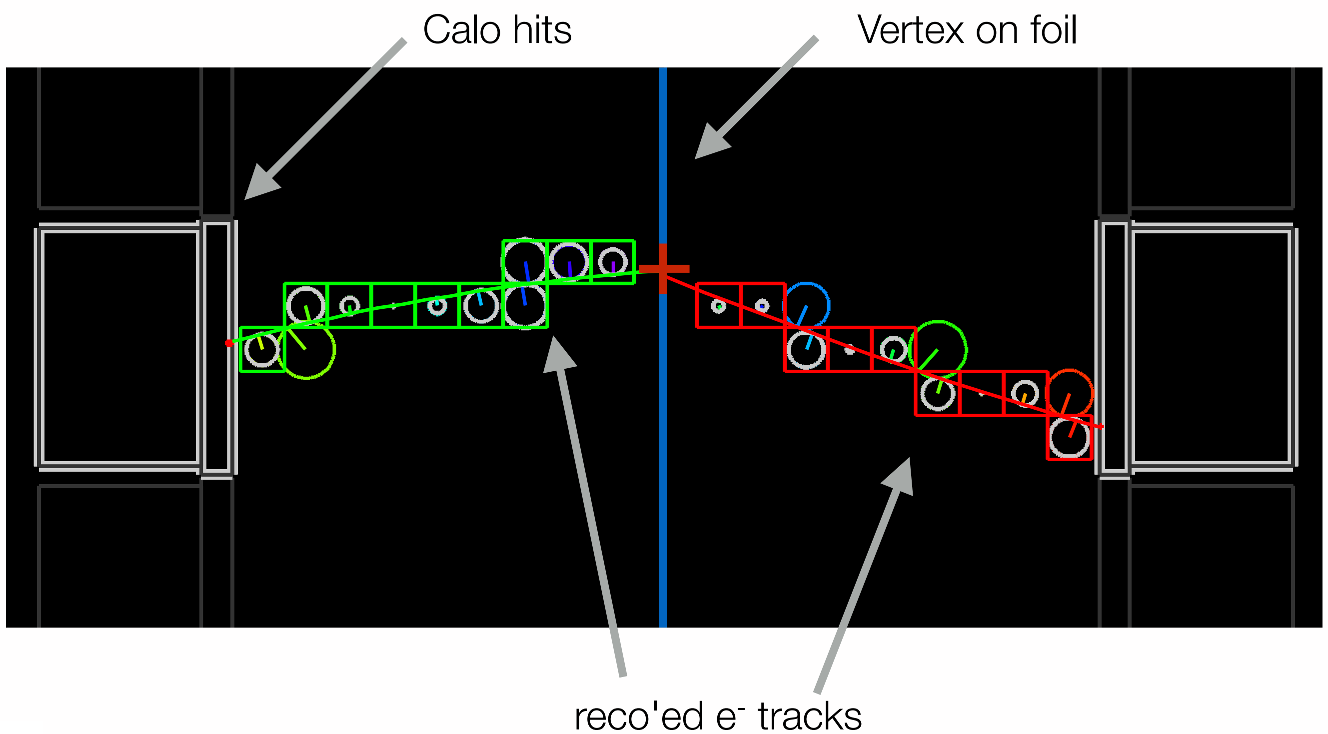

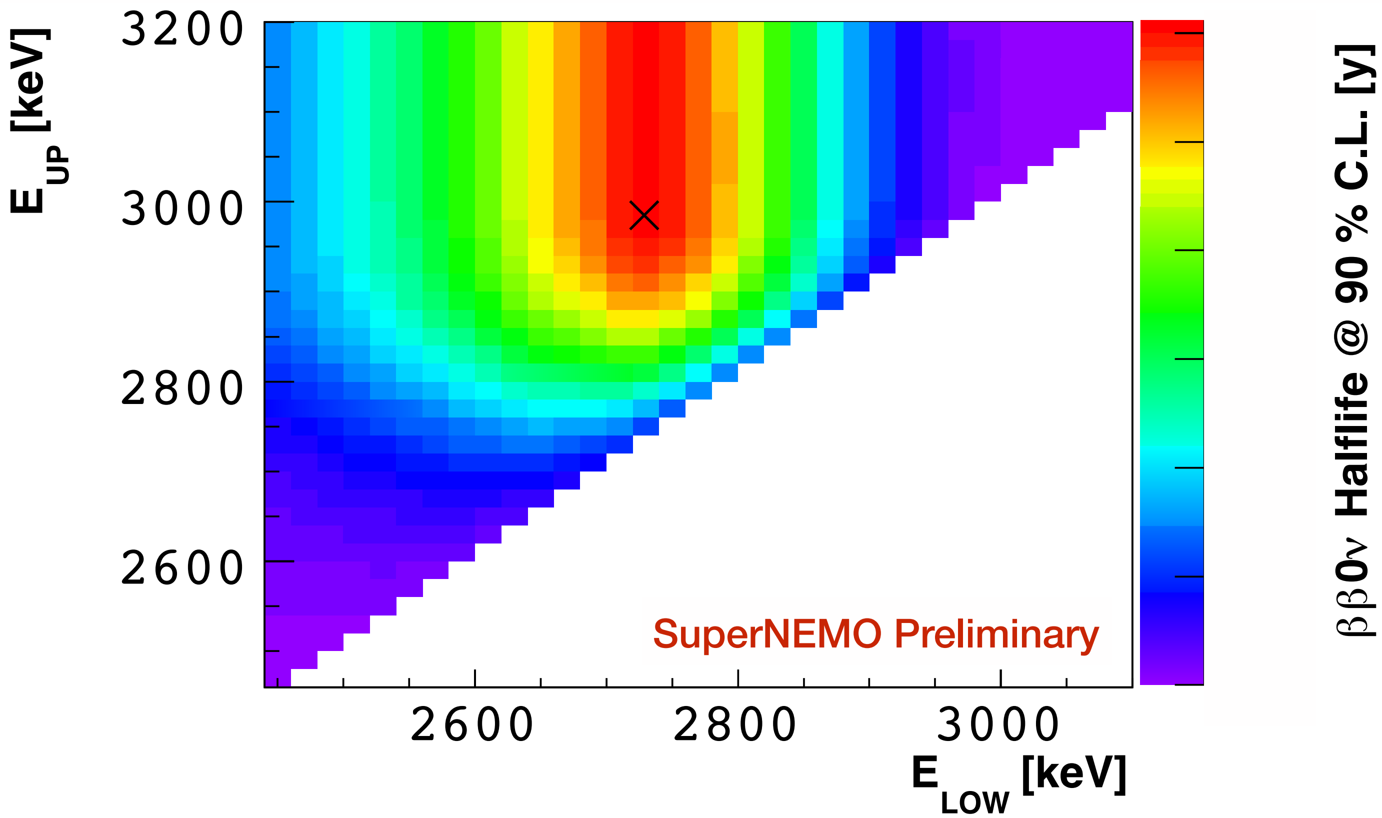

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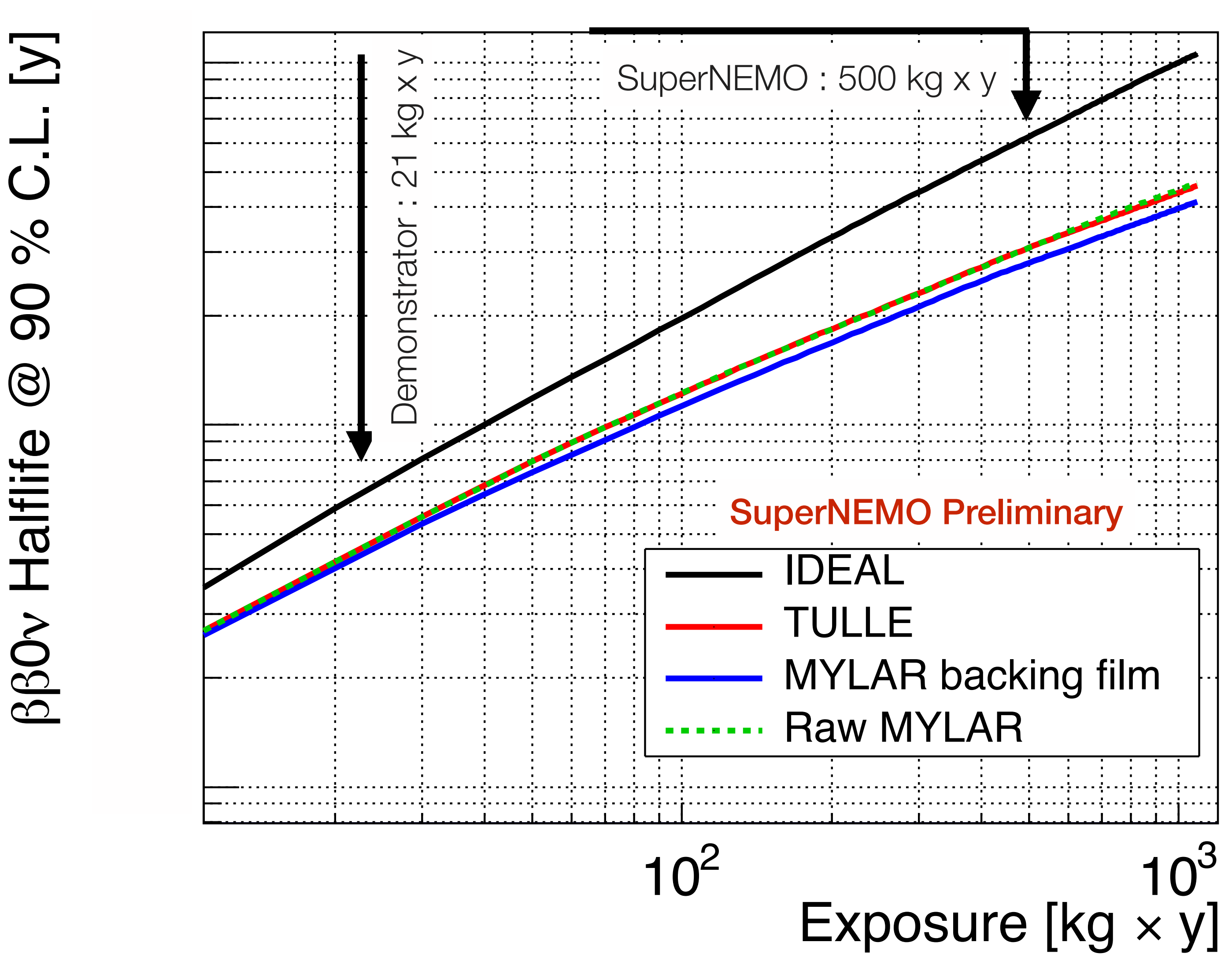

- Compare different design of the foil
- Recent radio-purity measurements are taken into account
- Currently limited by the PVA glue (x5 times the limit in ^{214}Bi)
- PVA purification procedure under R&D