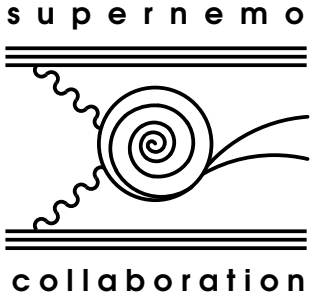
Status of the SuperNEMO experiment



Pawel Guzowski

University of Manchester

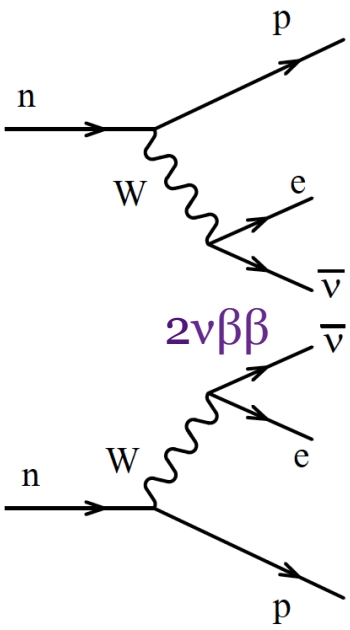
On behalf of the NEMO collaboration

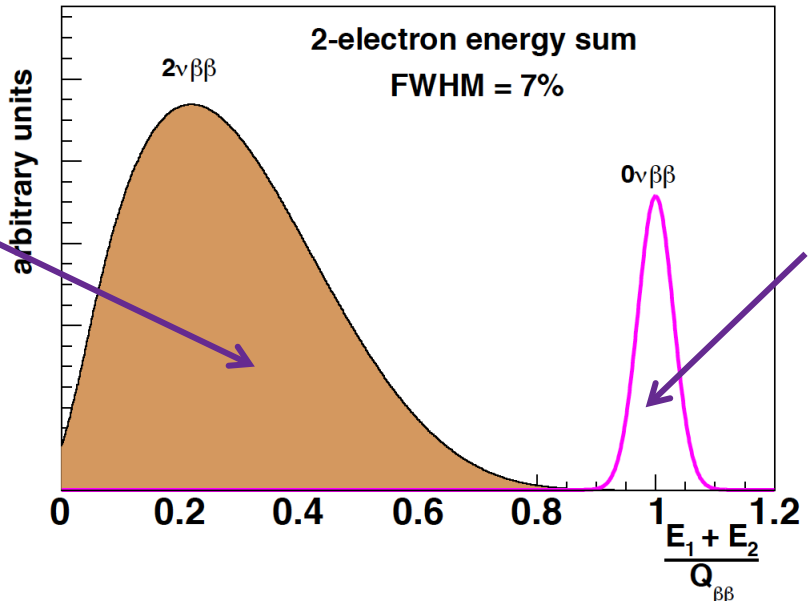
Outline

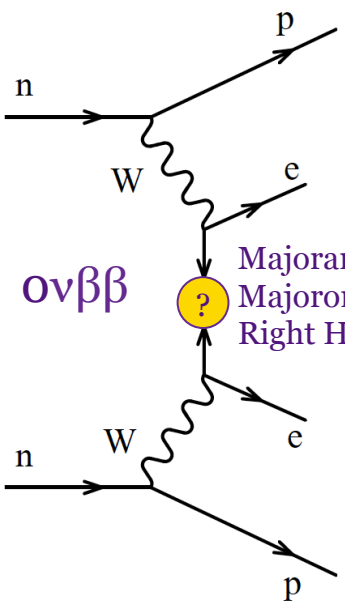
- Neutrinoless double β decay phenomenology
- The SuperNEMO experimental technique
- Current status of the detector production

- See also talks by Stefano Torre (NEMO-3 results) and Guillaume Eurin (^{96}Zr NEMO-3 analysis & low-radioactivity measurements for SuperNEMO)

0νββ phenomenology

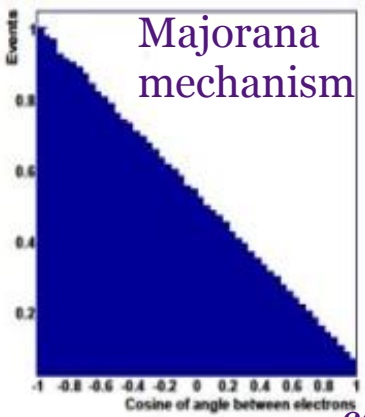


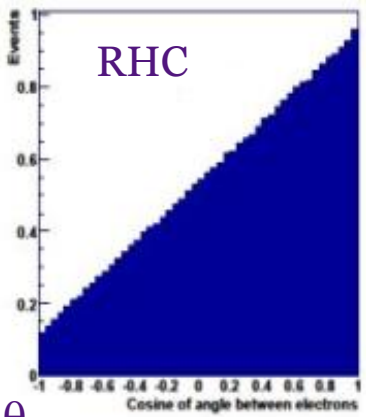




0νββ mechanisms have different kinematic signatures

- Individual electron energy spectra
- Angles between electrons





cos θ

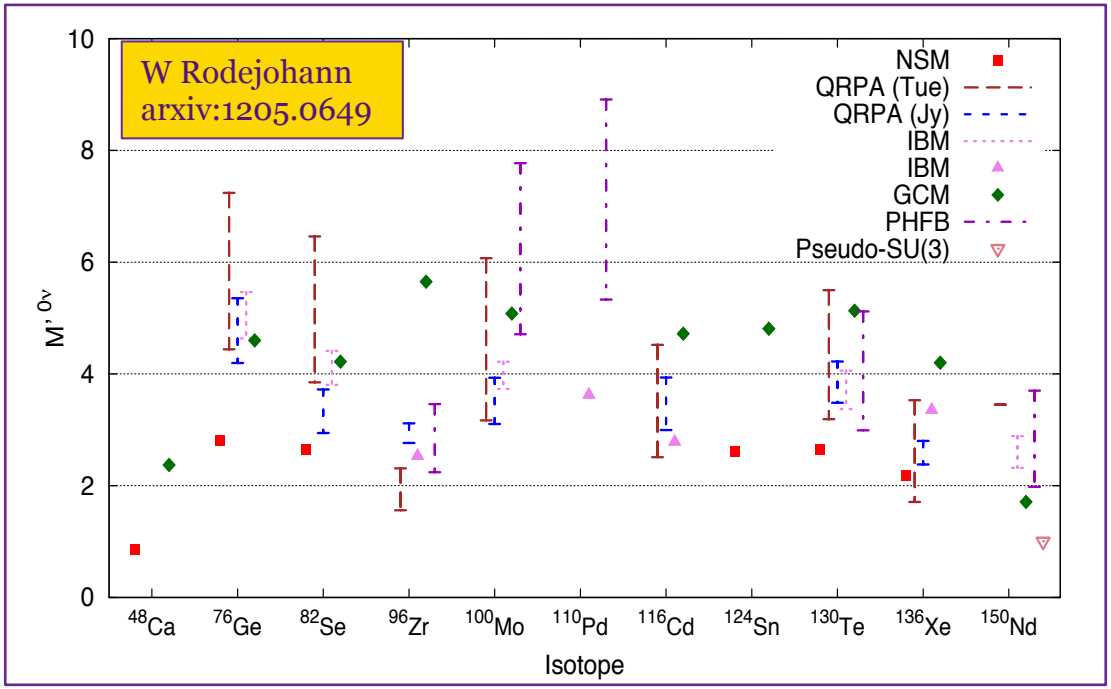
ovββ phenomenology

- $\langle m_\nu \rangle$ – effective ν_e mass
- $G_{0\nu}$ – phase space factor, well known
- Nuclear matrix elements $M_{0\nu}$ currently biggest source of theoretical uncertainty
  - Large variations between nuclear models
- For best sensitivity, want large G & M
- Want large Q for better background rejection
- NEMO allows mixing & matching sources

$$\frac{1}{T_{1/2}^{0\nu}} = G_{0\nu}(Q_{\beta\beta}^5, Z)\left|M_{0\nu}\right|^2 \frac{\langle m_\nu \rangle^2}{m_e^2}$$

(Majorana mechanism)

Isotope	Abundance (%)	$Q_{\beta\beta}$ (MeV)	$G_{0\nu}$ (10^{-14} y^{-1})
^{48}Ca	0.19	4.274	6.35
^{76}Ge	7.8	2.039	0.62
^{82}Se	9.2	2.996	2.70
^{96}Zr	2.8	3.348	5.63
^{100}Mo	9.6	3.035	4.36
^{116}Cd	7.6	2.809	4.62
^{130}Te	34.5	2.530	4.09
^{136}Xe	8.9	2.462	4.31
^{150}Nd	5.6	3.367	19.2



SuperNEMO Physics Goals

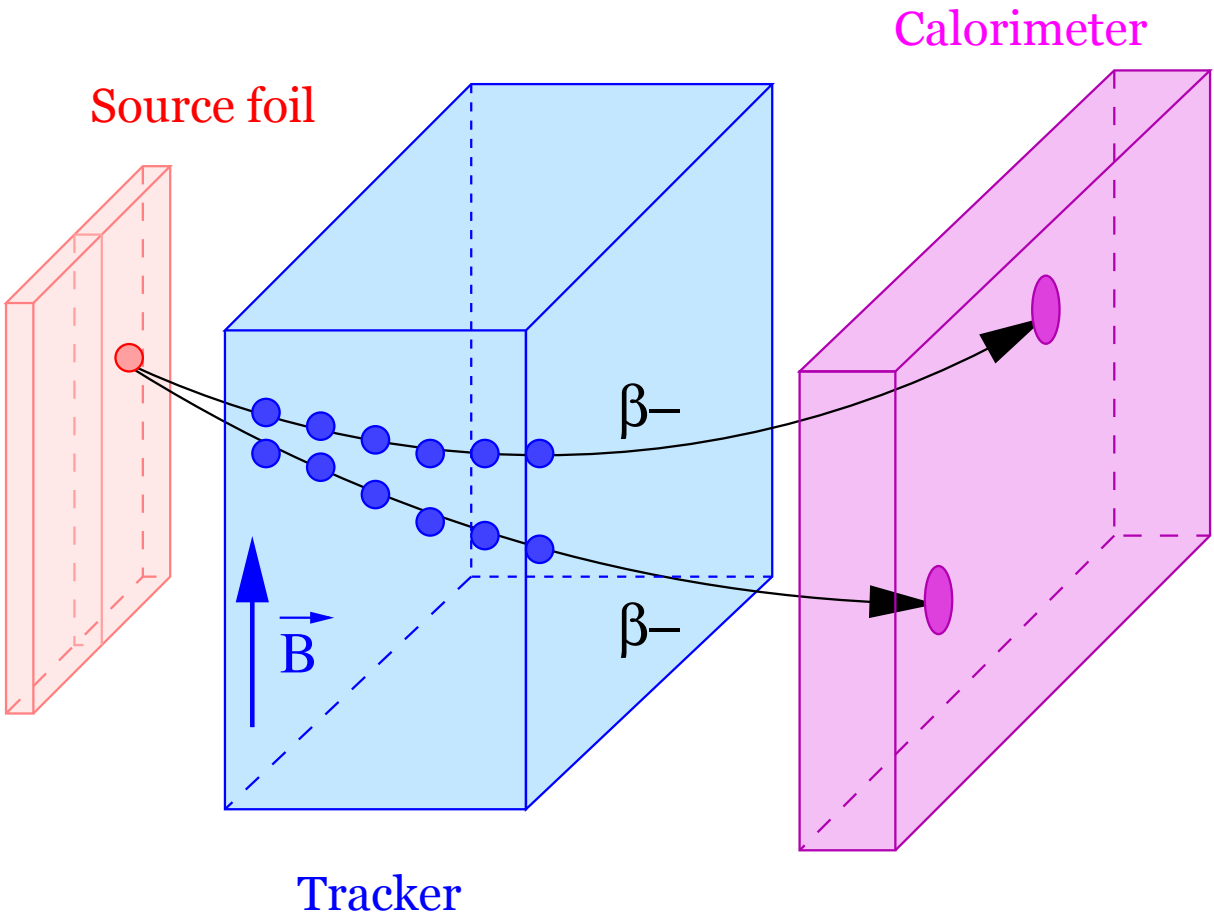
- Latest generation of NEMO experiments
  - More than an order of magnitude lower backgrounds than the predecessor NEMO-3
- Demonstrator module under construction, data taking from 2015
  - Prove that zero background is achievable
  - A further 19 modules to be made later
- Extremely low background environment is needed in construction
  - ~1 billion times less activity per unit mass than a brazil nut

NEMO-3		SuperNEMO
^{100}Mo, ^{82}Se (^{150}Nd, ^{130}Te, ^{116}Cd, ^{96}Zr, ^{48}Ca)	**Isotopes**	^{82}Se (^{150}Nd, ^{48}Ca)
10	**Mass (kg)**	100—200 (*demo: 7*)
^{208}Tl: ~100 ^{214}Bi: <300	**Source contamination (μBq/kg)**	^{208}Tl: <2 ^{214}Bi: <10
5	**Radon level (mBq/m^3)**	<0.15
8%	**Energy resolution (FWHM at 3MeV)**	4%
1	**$T_{1/2}$ sensitivity (10^{24} y)**	100 (*demo: 6.6*)
300—900	**$\langle m_\nu \rangle$ sensitivity (meV)**	40—100 (*demo: 200—400*)

Experimental technique

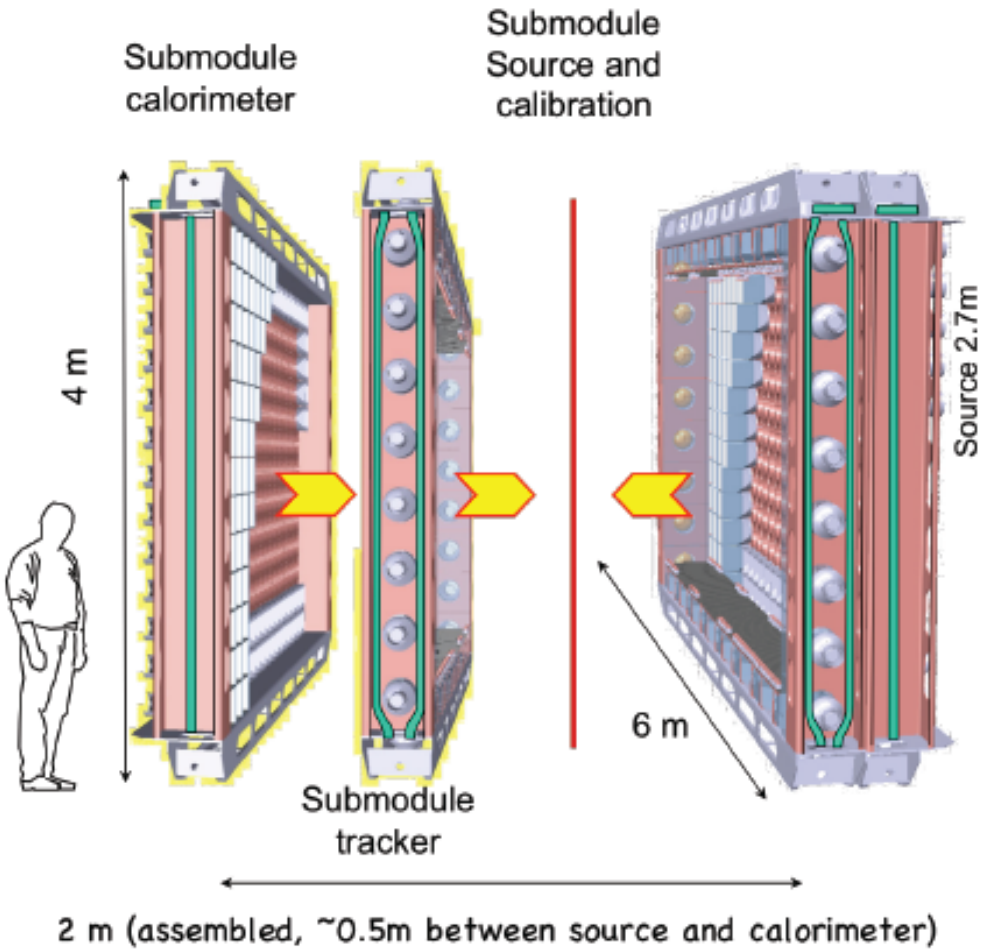
- Calorimeters provide E, t measurements
- Tracker for vertexing, charge ID, angles
- PID: e^-, γ, e^+, α

- Knowledge of full event topology allows disentangling decay mechanisms
- All backgrounds determined experimentally in situ



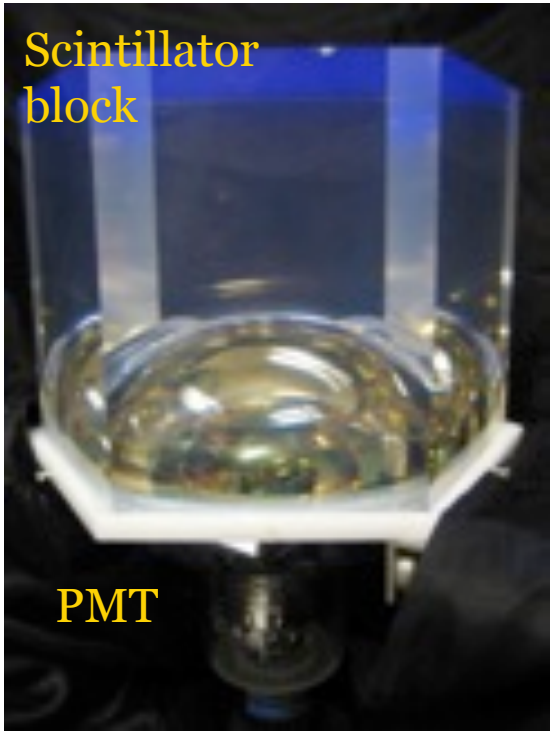
SuperNEMO module

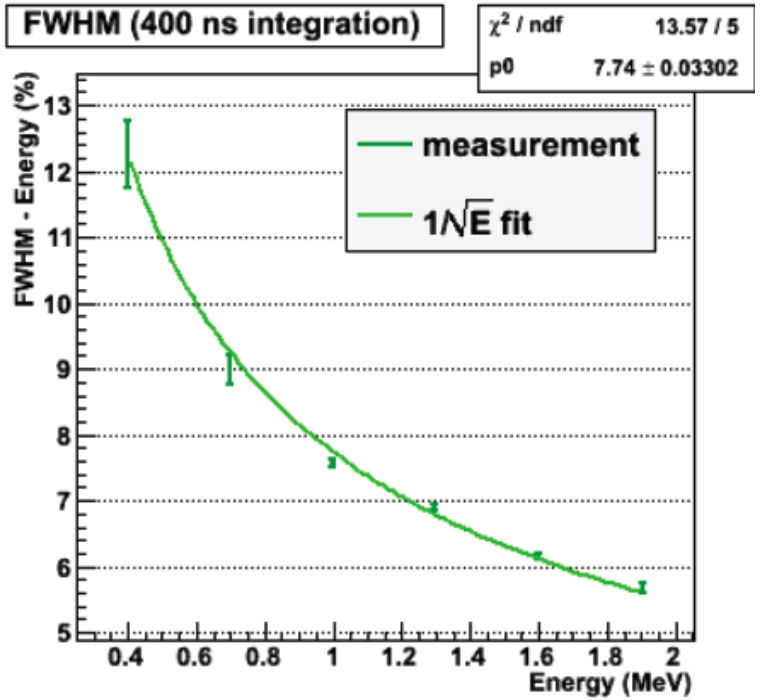
- 4 x 3.7 m² source foil (~40 mg/cm²)
  - Guillaume Eurin's talk
- ~500 calorimeter modules
- ~2000 tracker cells
- 20 tons
- Background less than 10^{-4} counts/keV/kg/year
  - order of magnitude lower than planned competitors



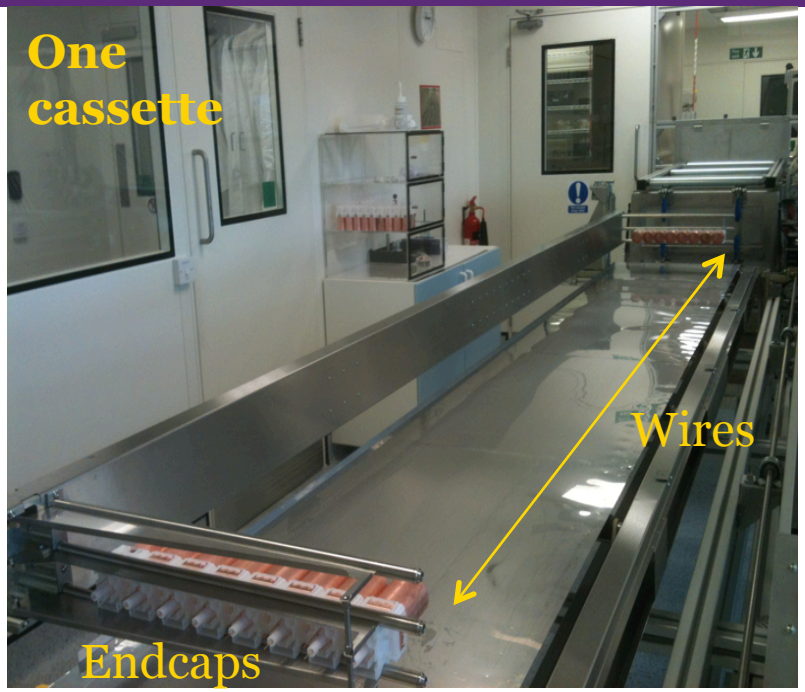
Calorimetry

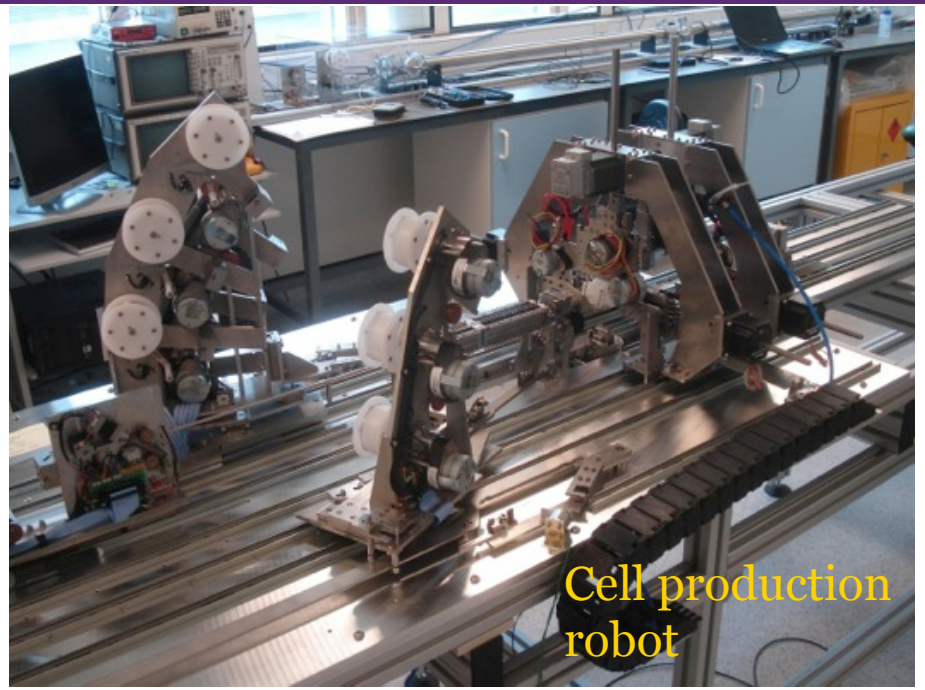
- Demonstrated $\Delta E/E < 8\%$ for 1 MeV electrons (equivalent to 4% at Q=3MeV)
- Final design: Hamamatsu 8” PMTs, 256 x 256 x 150 mm^3 scintillator blocks
- 60 / 500 now delivered to France



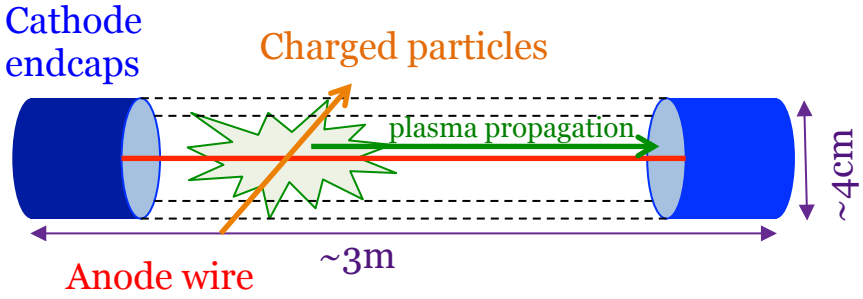


Tracker production





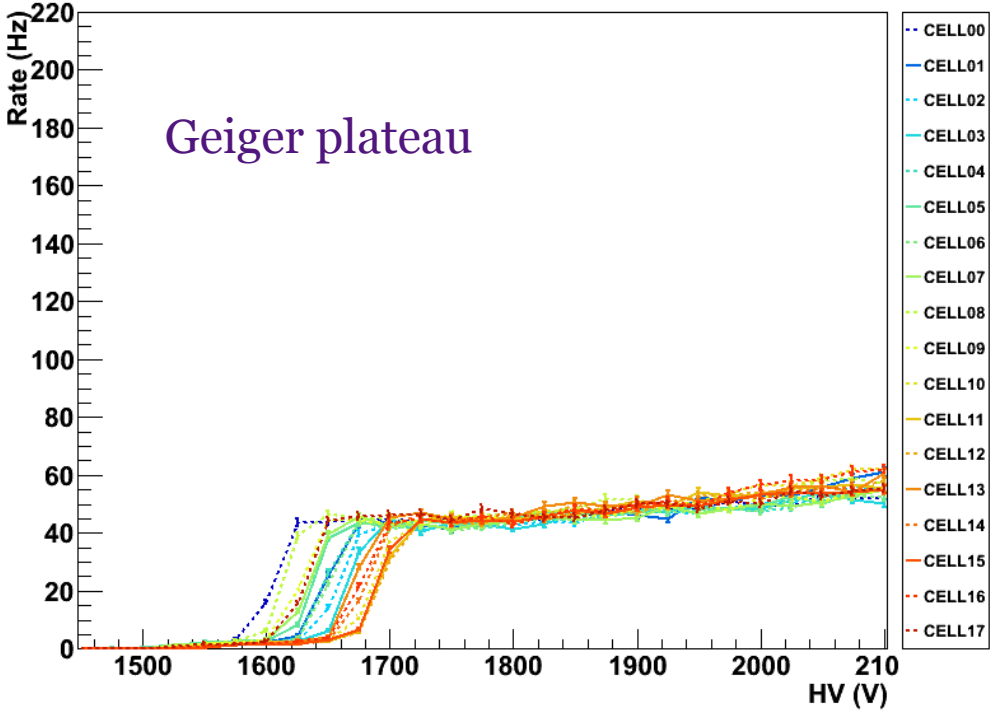
- Tracker construction well under way
  - Cassettes of 18 Geiger cells
  - Goal: 2-3 cassettes / week



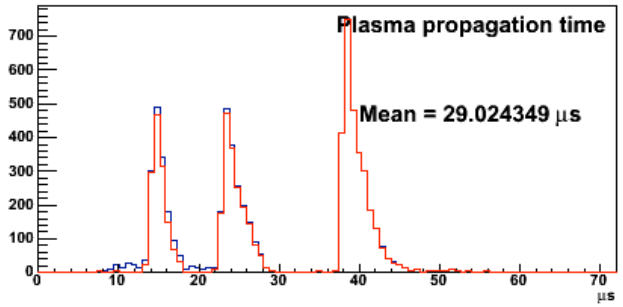
He/Ar/ethanol gas

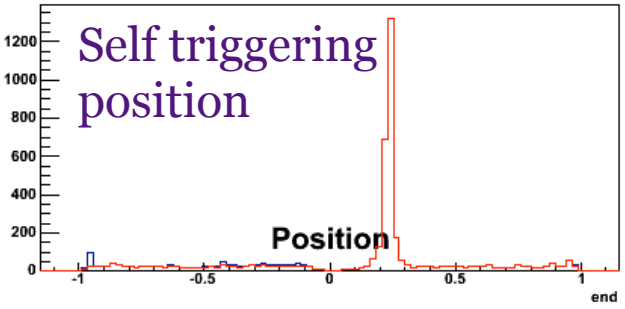
Cassette testing

- Testing at University of Manchester
- Use cosmic ray events for testing the tracker cells
- Reject cells with:
  - Poor Geiger plateaus
  - Dust that blocks plasma propagation
  - Self trigger points
- Only ~2% of cells rejected so far (and likely to decrease)

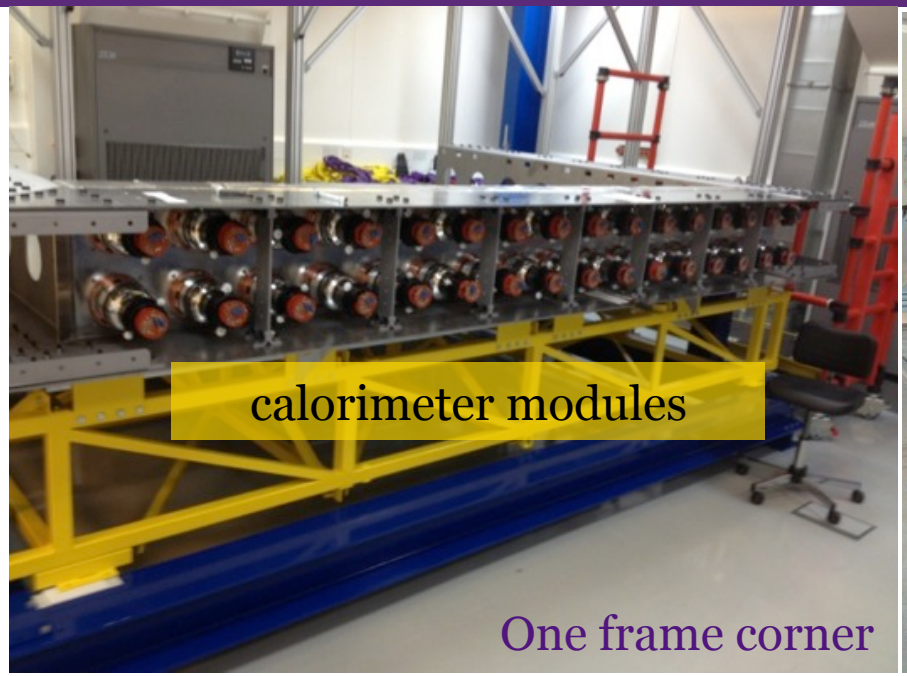


Plasma blocking point





Frame production



- Frame being produced at the Mullard Space Science Laboratory
- One out of the four corners of the frame has been built
  - Optical modules have been attached
  - Cassettes are ready to be inserted
  - 12 / 113 cassettes produced so far

SuperNEMO schedule

2013	2014	2015	2016	2017	2018	2019	2020	2021

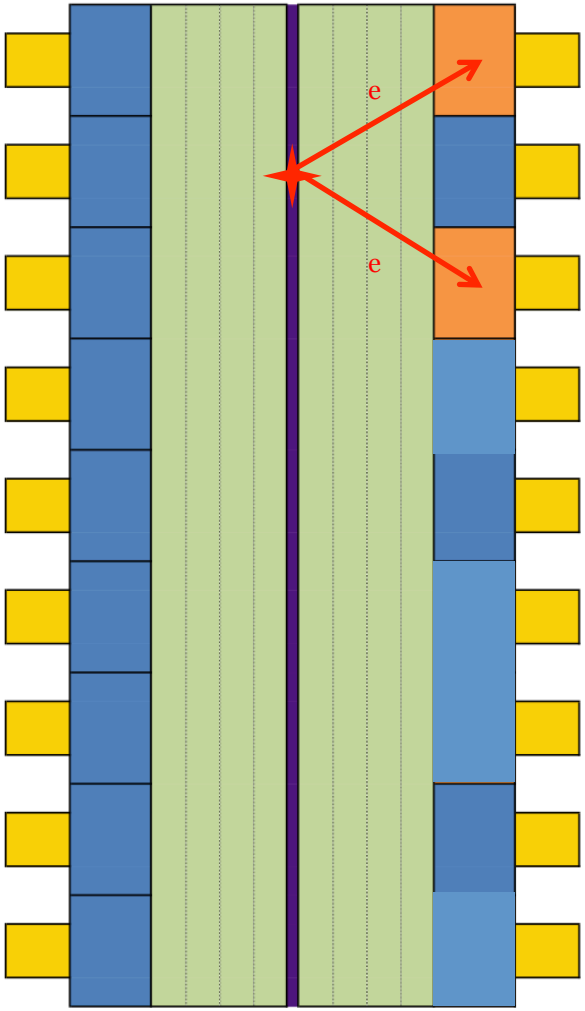
Demonstrator module construction and commissioning
Demonstrator operation: Prove low background is achievable $T_{1/2}$ sensitivity ~ 6.6 x 10^{24} years
Construction & operation of remaining 19 modules $T_{1/2}$ sensitivity ~ 10^{26} years (100 kg, 5 years)

Summary

- Full production of the SuperNEMO demonstrator module is well under way
  - Prove the low background requirements are achievable
- Demonstrator module will have a $0\nu\beta\beta$ half-life sensitivity for ^{82}Se of ~ 6.6 x 10^{24} years
- Complete experiment will be sensitive to $T_{1/2} \sim 10^{26}$ years

EXTRA SLIDES

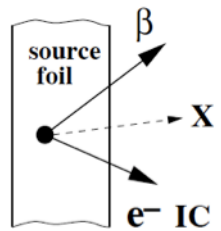
Backgrounds



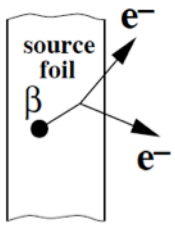
Internal background

Due to impurities in the source foil
Main culprits ^{208}Tl (Q=5MeV), ^{214}Bi (Q=3.2MeV)

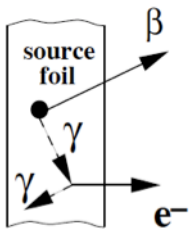
Produce two electron topologies due to Internal Conversion of daughter isotope, Moller scattering of beta, or Compton scattering of daughter deexcitation photon



beta + IC

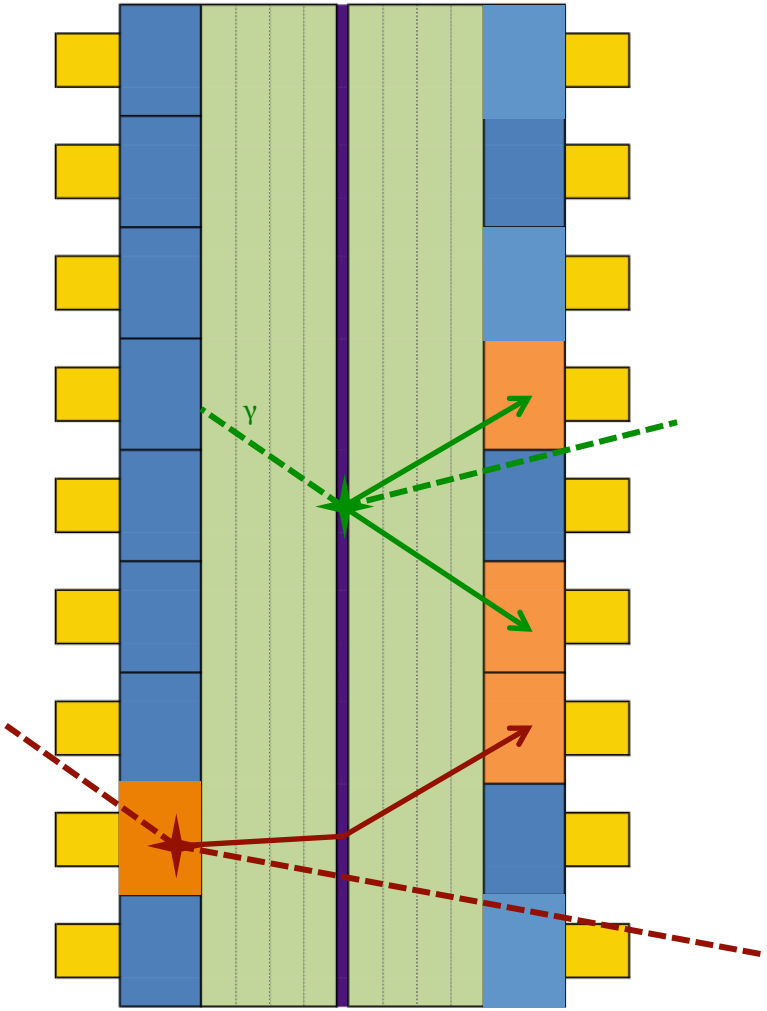


beta + Möller



beta + Compton

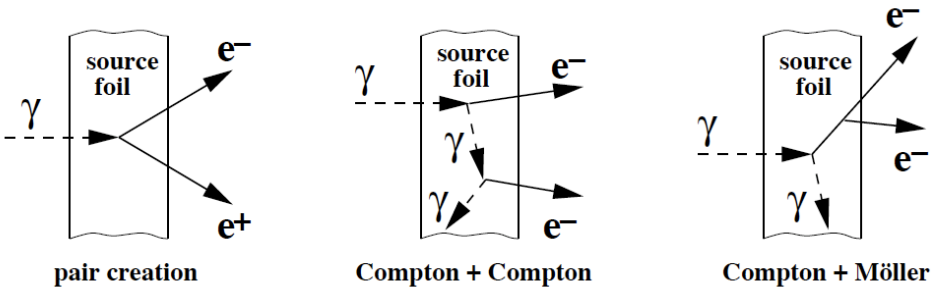
Backgrounds



External γ background

Due to impurities in the detector materials, also gamma flux from outside detector (e.g. uranium in cavern)

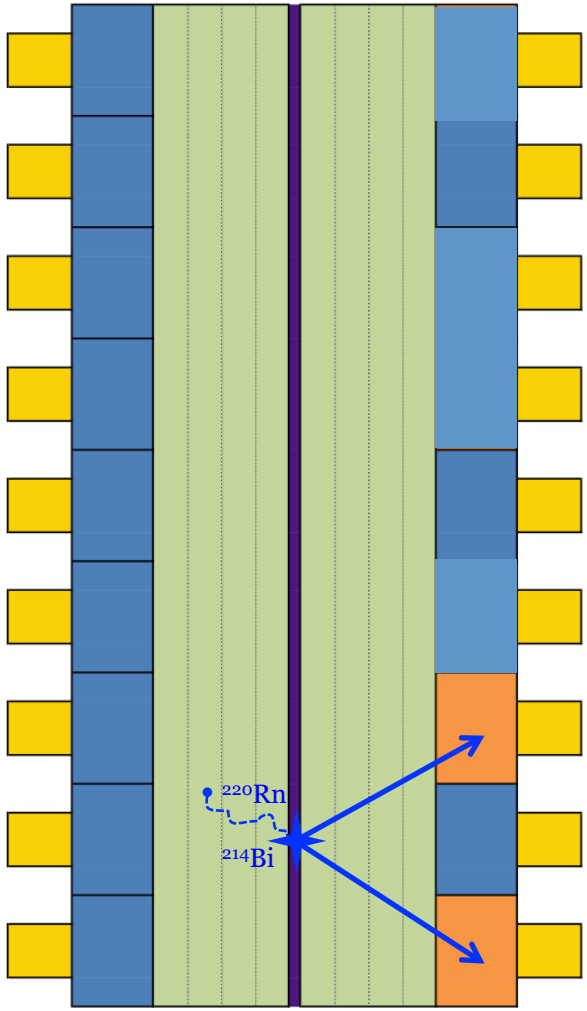
Produce two electron topologies due to pair production, Compton and Moller scattering



Also can produce crossing electrons; use time of flight analysis to discriminate

Backgrounds

supernemo collaboration

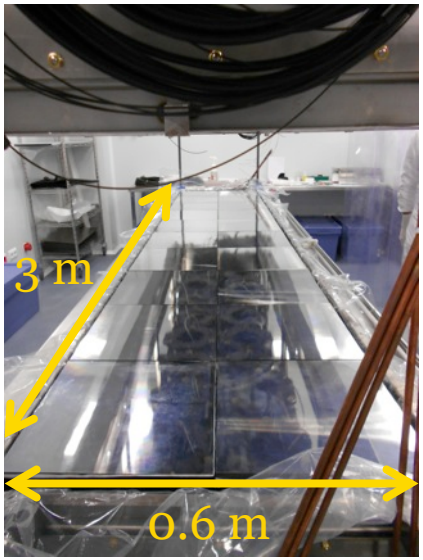
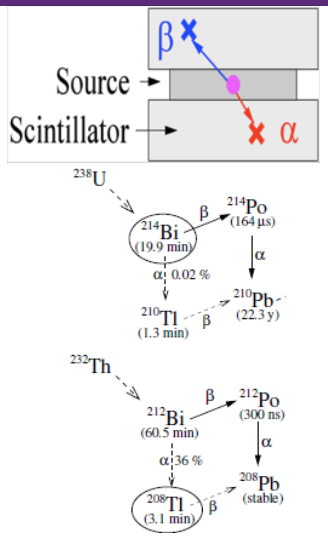
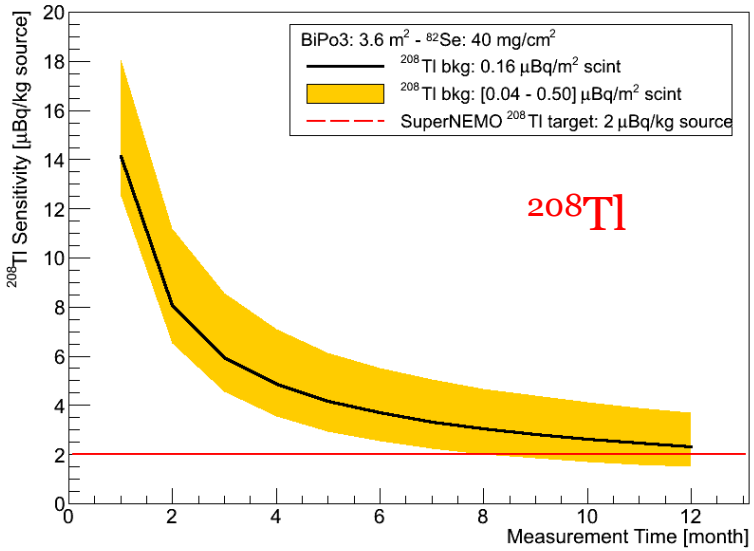
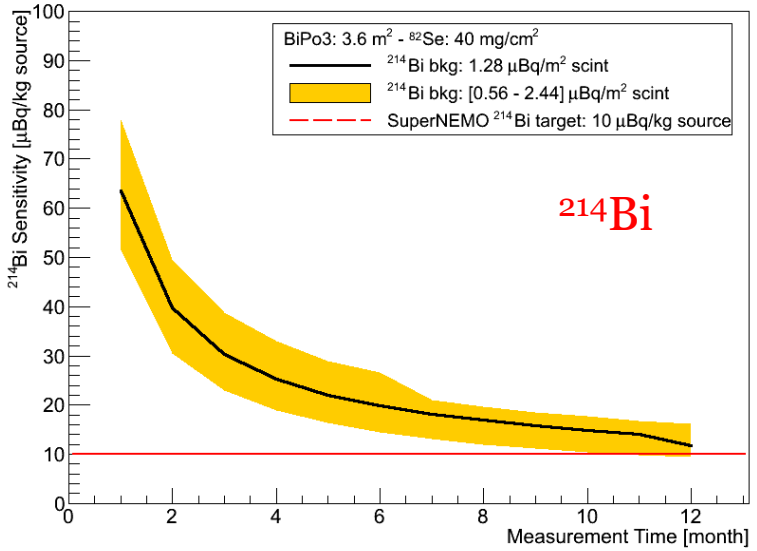


Radon

Leaves deposits of ^{214}Bi, ^{208}Tl on the surfaces of the detector

Installation of charcoal trap & radon tent to reduce the amount of radon entering the detector volume

Source production

supernemo collaboration

- 5.5 kg ^{82}Se produced
- 'BiPo' detector operating at Canfranc lab, measuring ^{214}Bi and ^{208}Tl contamination levels in the source foil
  - β-α delayed coincidence