The NEMO experiment. Present and Future.

Ruben Saakyan
UCL
28 January 2004
IOP meeting on double beta decay
Sussex

Neutrino Ettore Majorana Observatory

50 physicists and engineers

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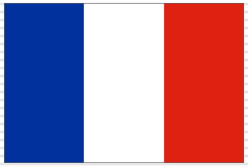
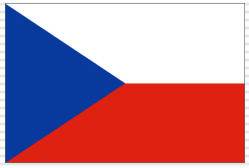
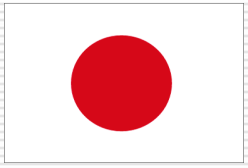
13 Laboratories/Universities

•

7 Countries






NEMO-III in Frejus

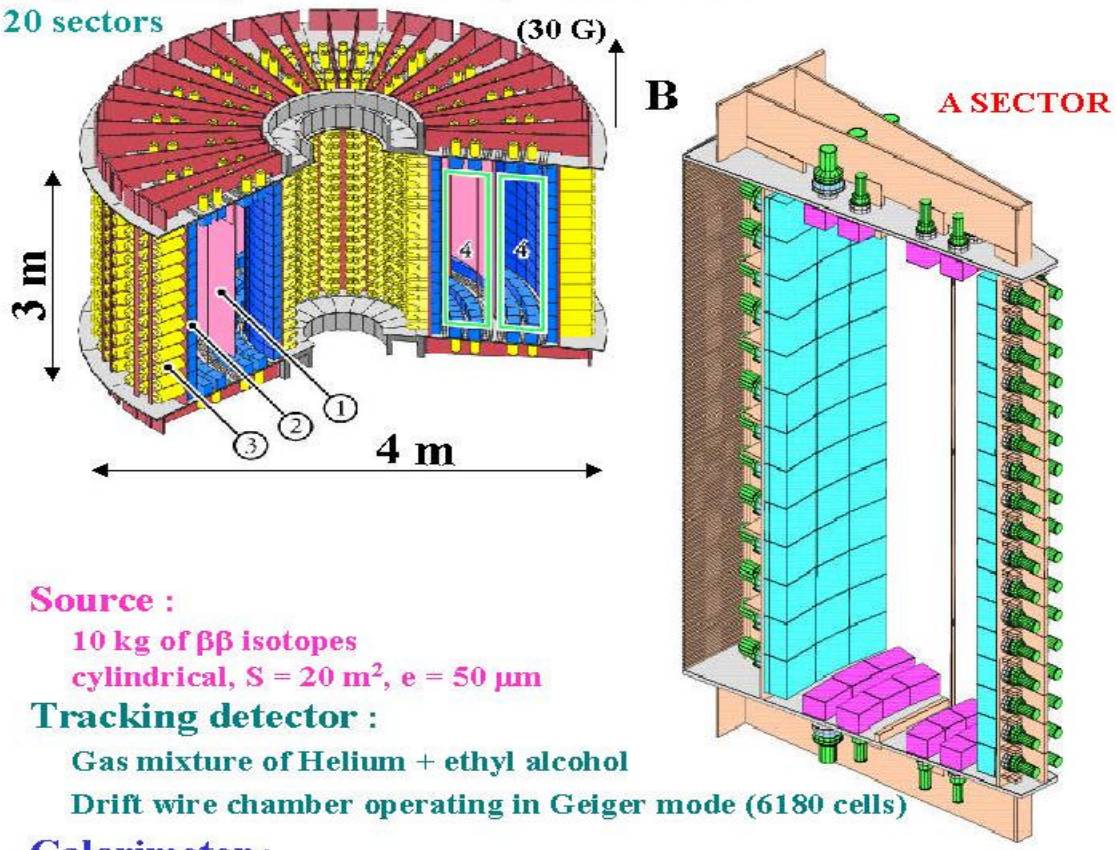
Frejus

NEMO-III and CUORICINO to determine ββ sensitivity until 2008-10

The NEMO3 detector

Fréjus Undergroud Laboratory : 4800 m.w.e.

20 sectors



Source :

10 kg of ββ isotopes

cylindrical, S = 20 m², e = 50 μm

Tracking detector :

Gas mixture of Helium + ethyl alcohol

Drift wire chamber operating in Geiger mode (6180 cells)

Calorimeter :

1940 plastic scintillators coupled to low radioactivity PMs ;

σ(E)/E at 3 MeV ~ 3.5%

+ Magnetic field + Iron shielding + Neutron shielding

Identification : e^-, e^+, γ, n and delayed-α

→ ββ events detection

→ Measurement of source radiopurity

→ Background rejection

- From scintil detector:
  σ_τ = 250 ps
- From tracker:
  $\sigma_{||}$ = 1cm $\sigma_\perp$ = 0.45mm
  (using timing information on plasma propagation)

Calibration:

- Laser survey
- neutron Am/Be for $\sigma_{||}$, $\sigma_\perp$, e^+ signature
- e^- ^{207}Bi, ^{90}Sr for energy calibration
- γ ^{60}Co for time alignment

Trigger:

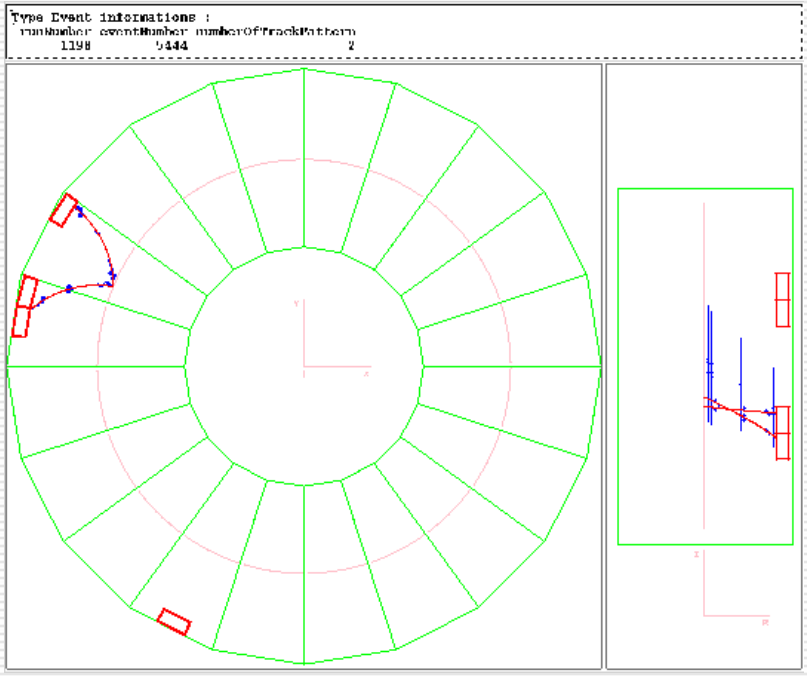
1 scintillator hit > 150 keV

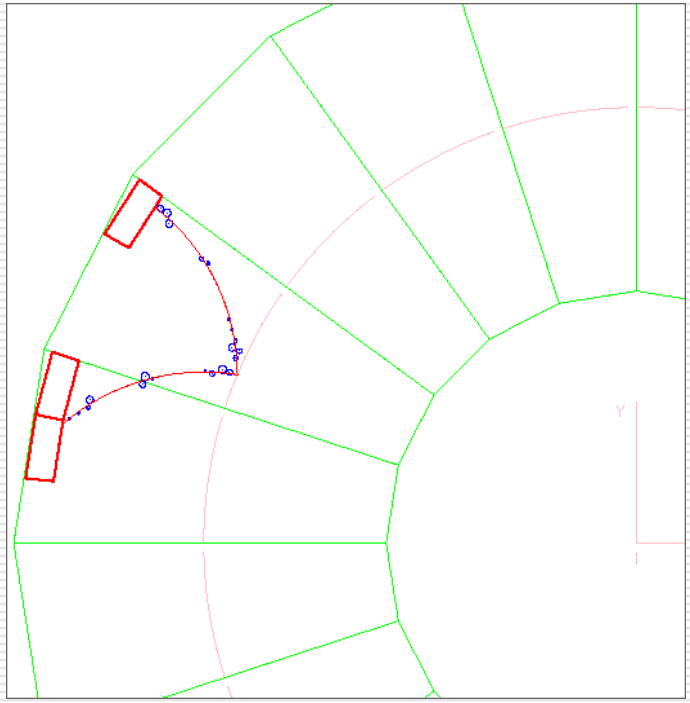
+

1 track: few Geiger planes

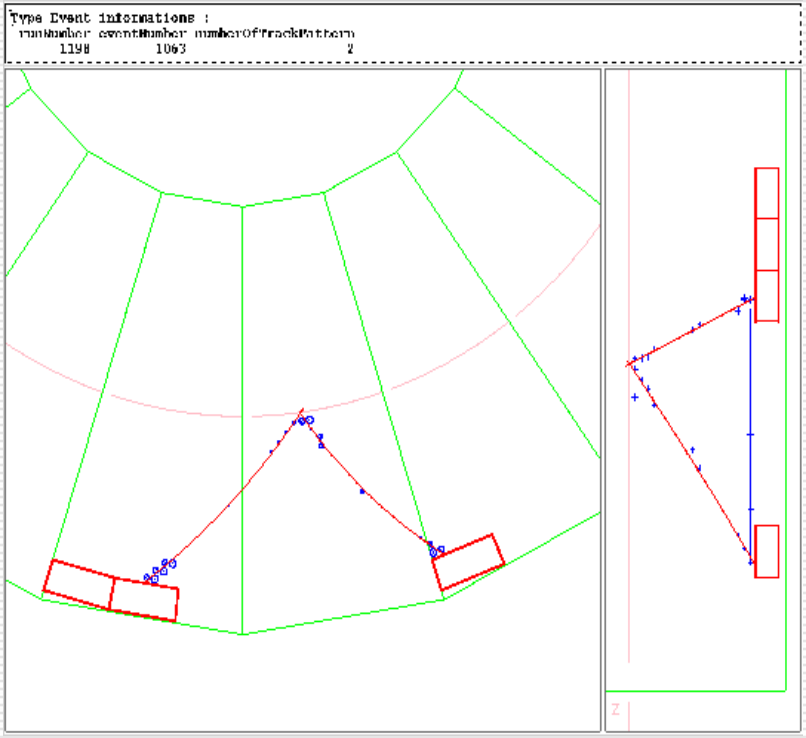
(flexible → 3 – 7 Hz)

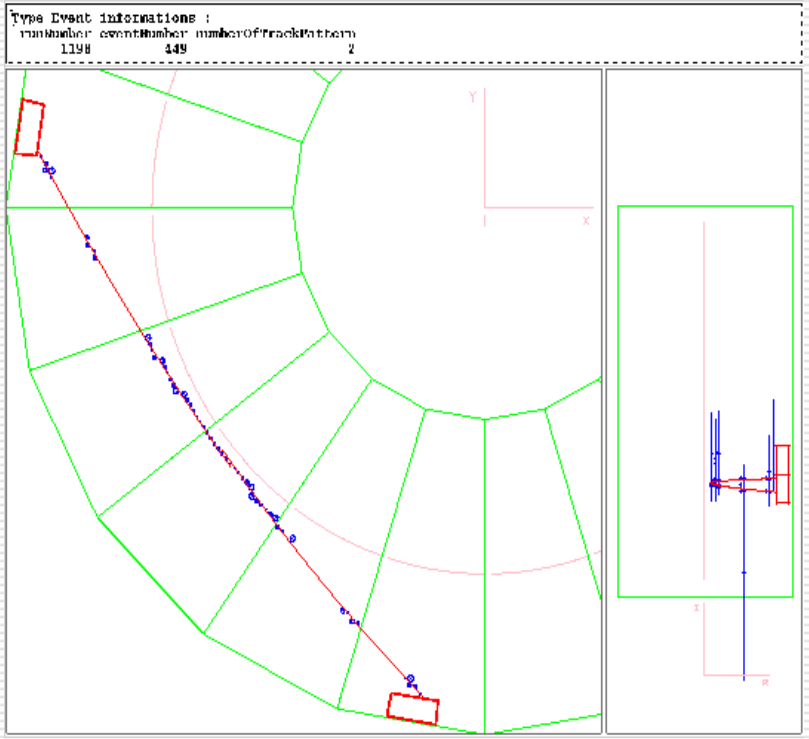
NEMO ββ events





NEMO background events

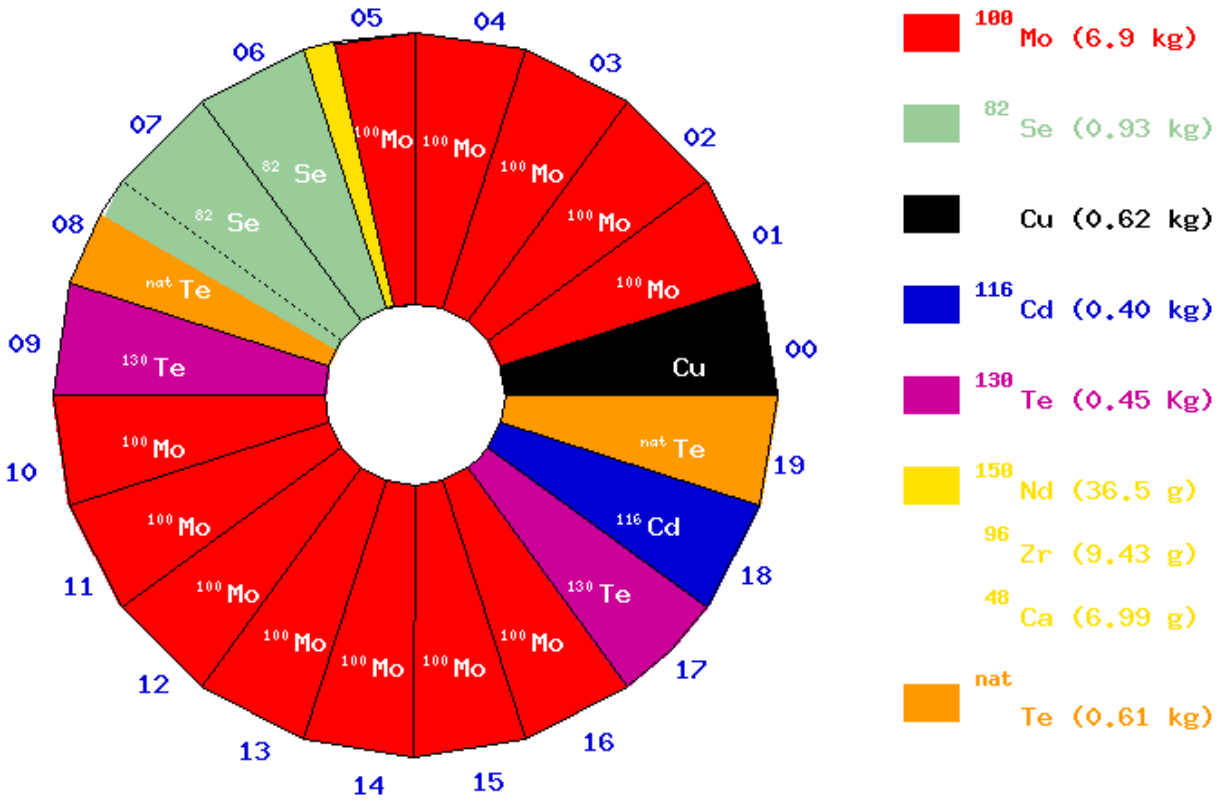


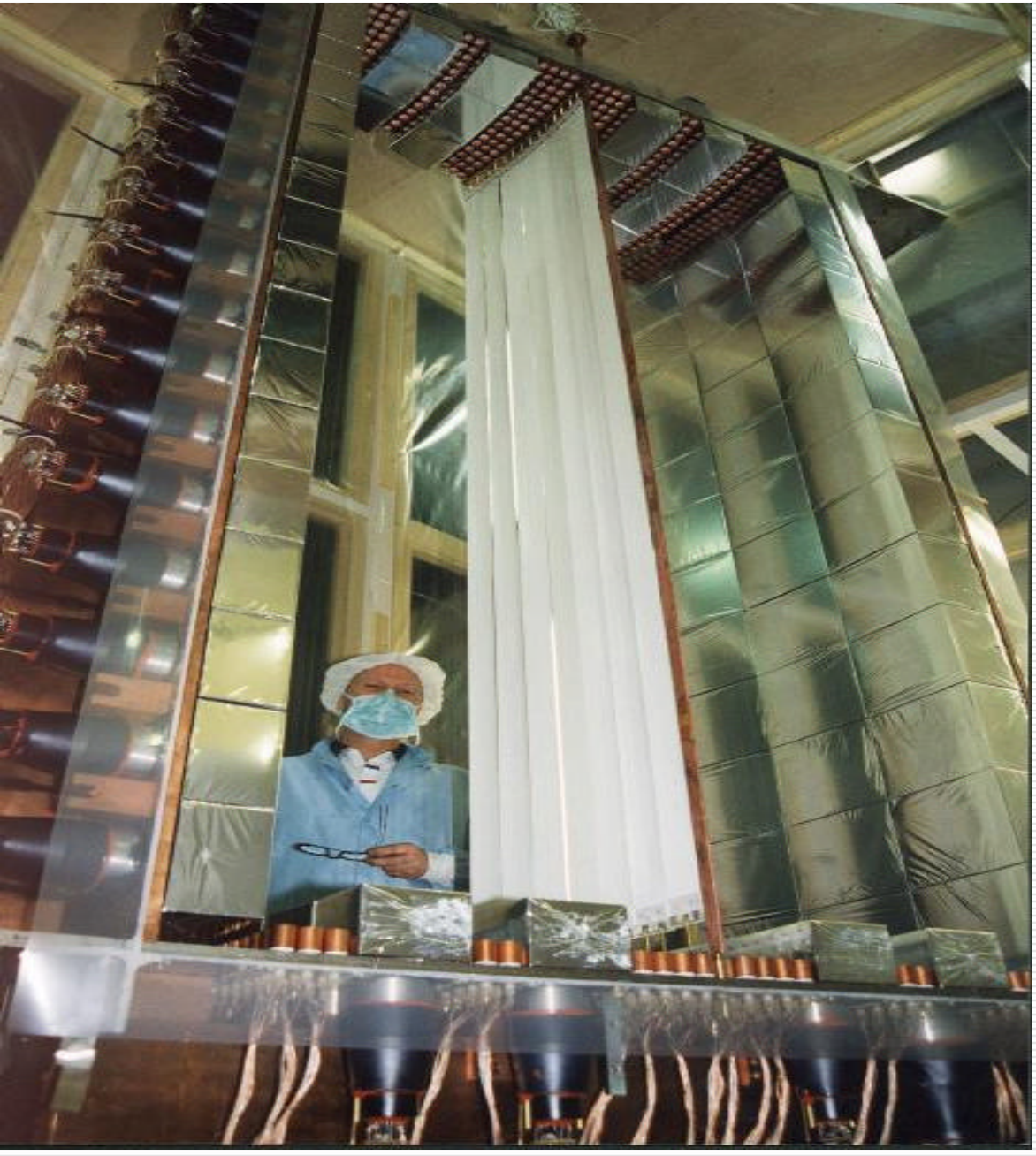


$\gamma \rightarrow e^+e^-$

e^- (~7 MeV) from $n\gamma$

SOURCE DISTRIBUTION in NEMO 3





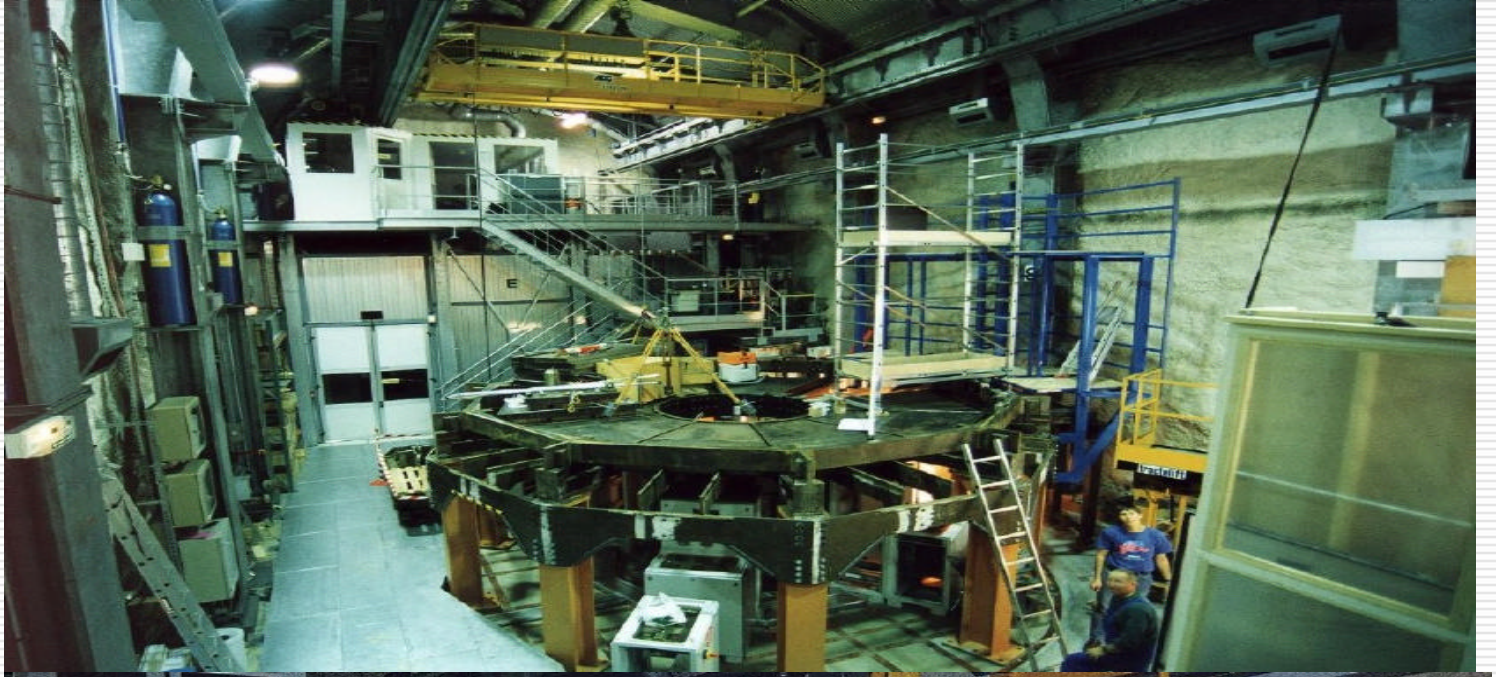
Pure materials:

Source foils
measured with the
NEMO-3 detector

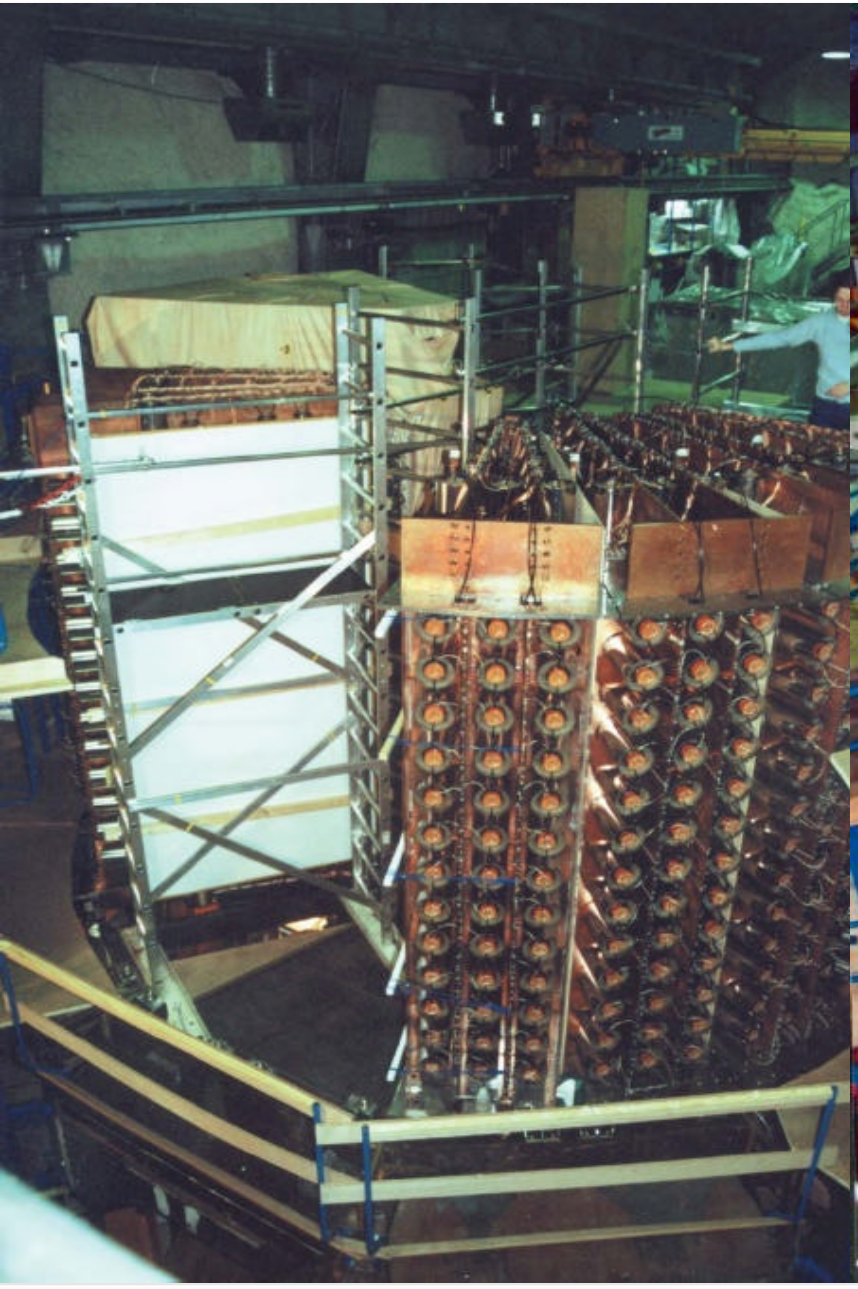
- ^{208}Tl < 2 μBq/kg
- ^{214}Bi < 2 μBq/kg
- neutrons < 10^{-9} n $cm^{-2}s^{-1}$

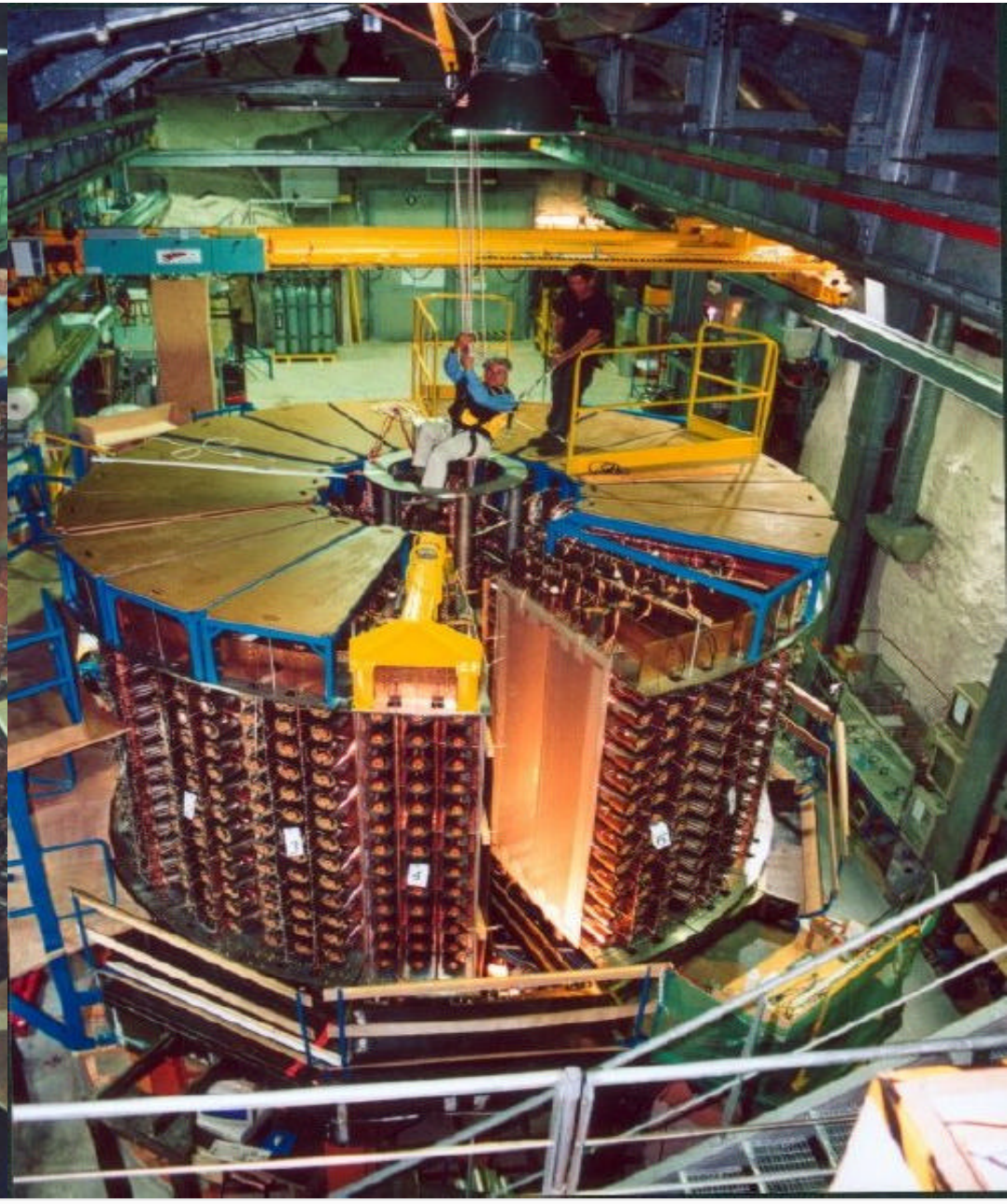
Radon in the detector
- ^{222}Rn ~ 20 mBq/m^3
- ^{220}Rn ~ 1.6 mBq/m^3

to be improved with new anti-radon shielding




E

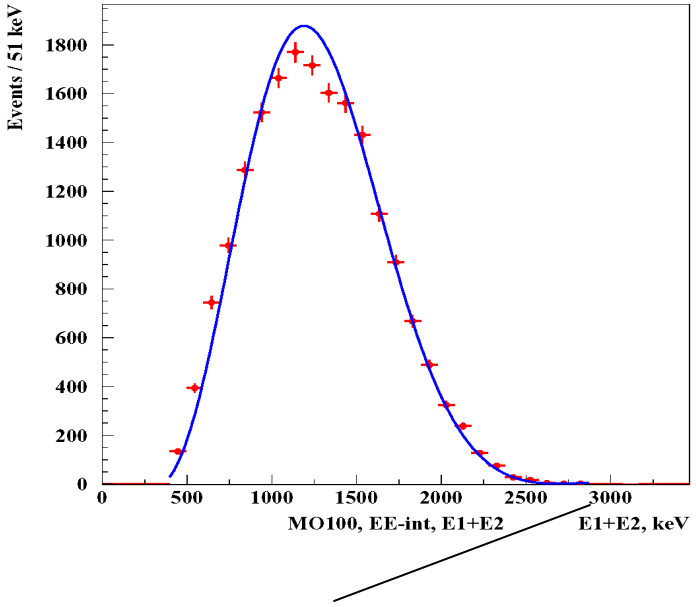




Data taking

- June 2002: start with all 20 sectors, iron shielding, neutron shielding but…
- …still a lot of debugging (both tracking detector and calorimeter)
- 14 February 2003: start of routine data taking

NEMO-3 First Results
^{100}Mo



2.8-3.2 MeV is used for 0ν analysis

2ν 1200 h:

$T_{1/2} = [7.4 \pm 0.05(stat) \pm 0.8(sys)] \times 10^{18}$ yr

(19000 events; S/B ≈ 50)

0ν:

Preliminary from 3800 h:

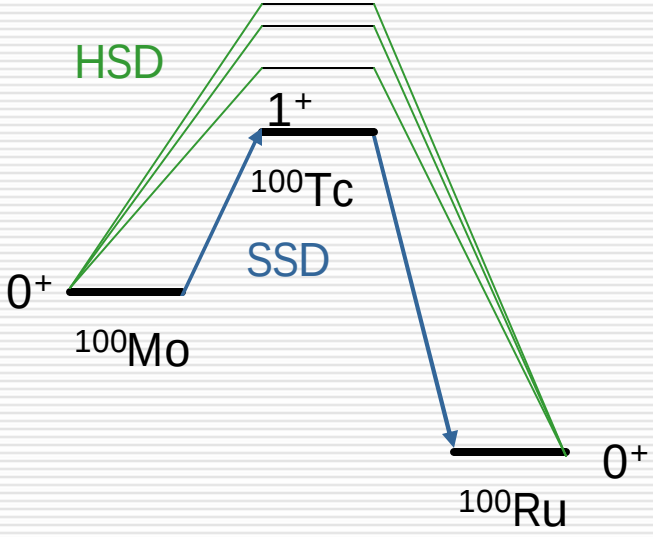
$T_{1/2} > 2.3 \times 10^{23}$ yr (90% CL)

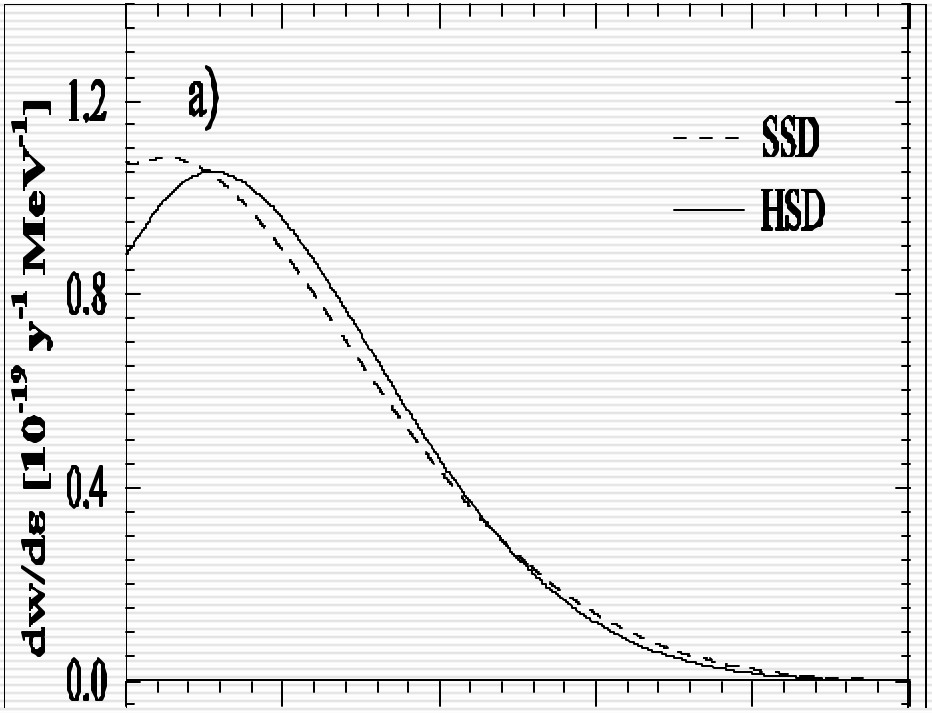
$< m_n > < 0.6$ eV – 1.3 eV

World's best result for ^{100}Mo

Single State Dominance (SSD) VS Higher order State Dominance (HSD)

Simkovic, Domin, Semenov
nucl-th/0006084, Phys. Rev. C

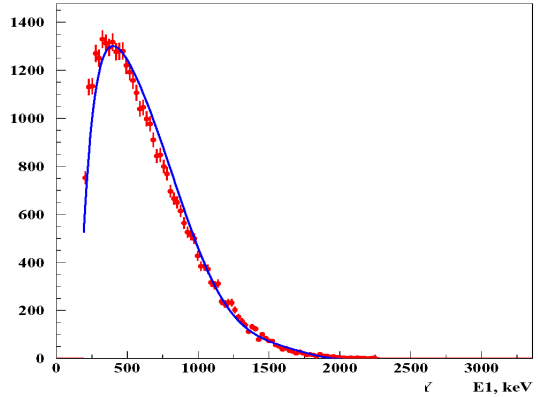


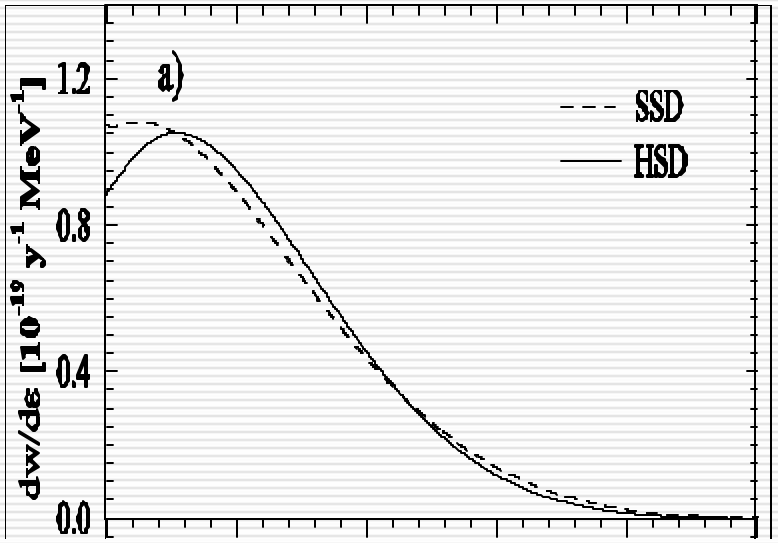


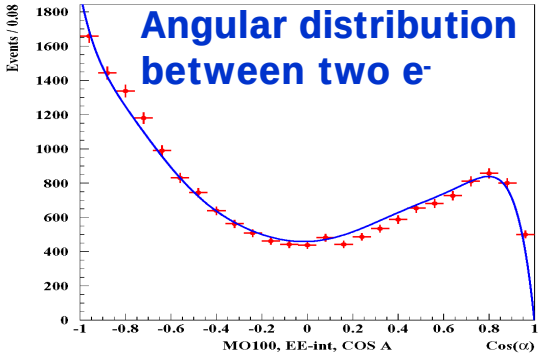
^{100}Mo + NEMO-like detector can test it experimentally !

NEMO-3 First Results
^{100}Mo 1200 h

single e$^-$ spectrum

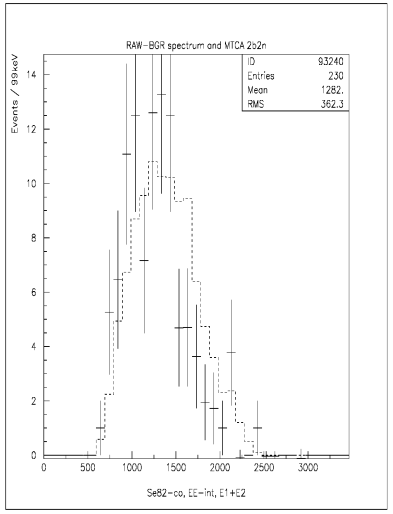






Preliminary:
SSD is preferred

NEMO-3 First Results
Other Isotopes

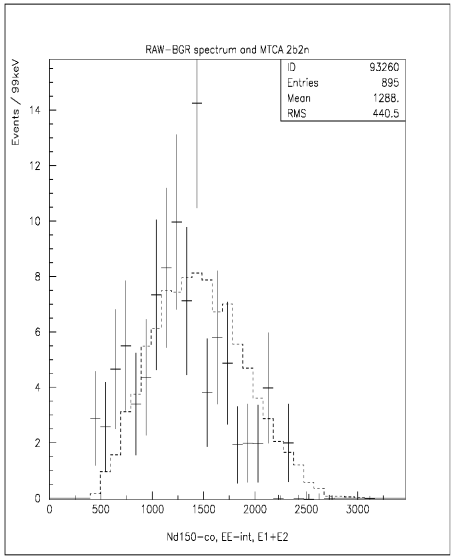


^{82}Se

$T_{1/2} = [8.2 \pm 0.4(stat) \pm 0.8(sys)] \times 10^{19}$

$T_{1/2} > 4 \times 10^{22}$ y 90% CL

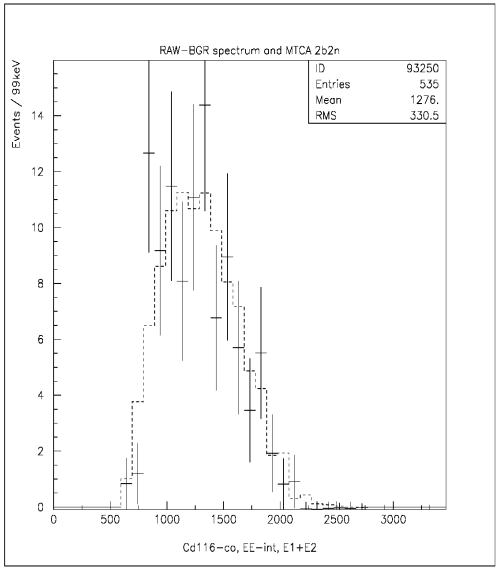
World's best result !



^{150}Nd

$T_{1/2} = [7.0 \pm 0.7(stat) \pm 0.7(sys)] \times 10^{18}$

$T_{1/2} > 7.7 \times 10^{20}$ y 90% CL



^{116}Cd

$T_{1/2} = [3.9 \pm 0.3(stat) \pm 0.4(sys)] \times 10^{19}$

$T_{1/2} > 1.0 \times 10^{22}$ y 90% CL

NEMO-3 $0\nu\beta\beta$ sensitivity 5 years

E = 2.8 – 3.2 MeV

^{100}Mo

7 kg $Q_{\beta\beta}$ =3.034 MeV

External BG: 0

Internal BG:

radioactivity < 0.04 event/y/kg

$2\nu\beta\beta$ = 0.11 event/y/kg

⇓

$T_{1/2} > 3 \times 10^{24}$ yr

⇓

$\langle m_\nu \rangle < 0.2 – 0.5$ eV

^{82}Se

1 kg $Q_{\beta\beta}$ =2.995 MeV

External BG: 0

Internal BG:

radioactivity < 0.01 event/y/kg

$2\nu\beta\beta$ = 0.01 event/y/kg

⇓

$T_{1/2} > 1 \times 10^{24}$ yr

⇓

$\langle m_\nu \rangle < 0.6 – 1.2$ eV

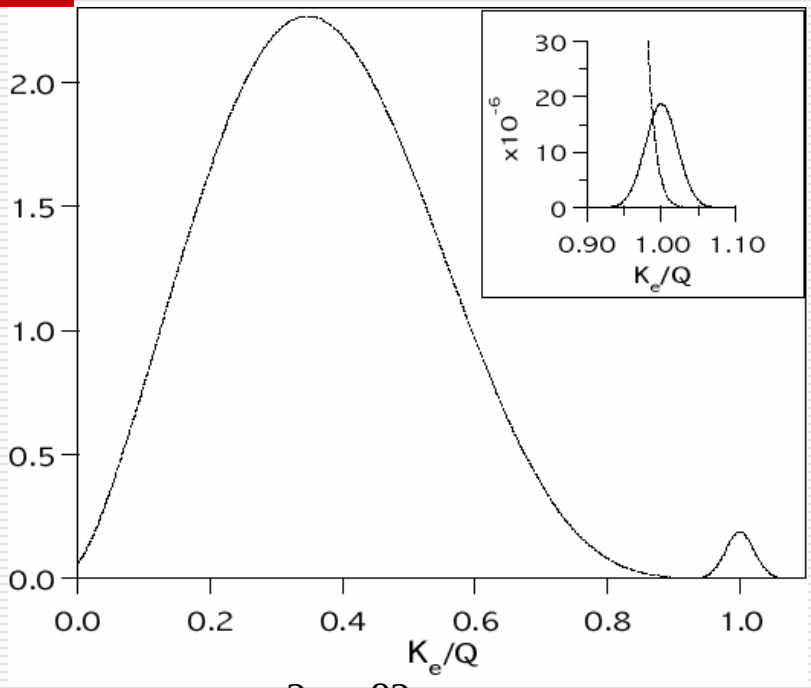
In case of full load of ^{82}Se (~14kg) $\langle m_n \rangle < 0.15 – 0.3$ eV

From NEMO-III to SuperNEMO

- Very well known and working technology (15 yr of R&D experience)
- Successful detector operation and physics results with NEMO-II and NEMO-III
- Modest amount of isotope needed (100kg of ^{82}Se)
  - Current enrichment capabilities – 30 kg/yr max
- Short time scale and modest price
  - 40-50 meV by 2014
  - 20-25 MEuros
- 3-5 December 1st SuperNEMO meeting in Orsay. EOI to national funding agencies in preparation

Which Isotope?

Isotope	Q, MeV
^{100}Mo	3.033
^{82}Se	2.995
^{116}Cd	2.802
^{130}Te	2.529



Factor of 10 lower BG for ^{82}Se

$$\frac{T_{1/2}^{2n}(^{82}Se)}{T_{1/2}^{2n}(^{100}Mo)} \sim 10$$

Can be produced in centrifuge - $30K-$50K/kg

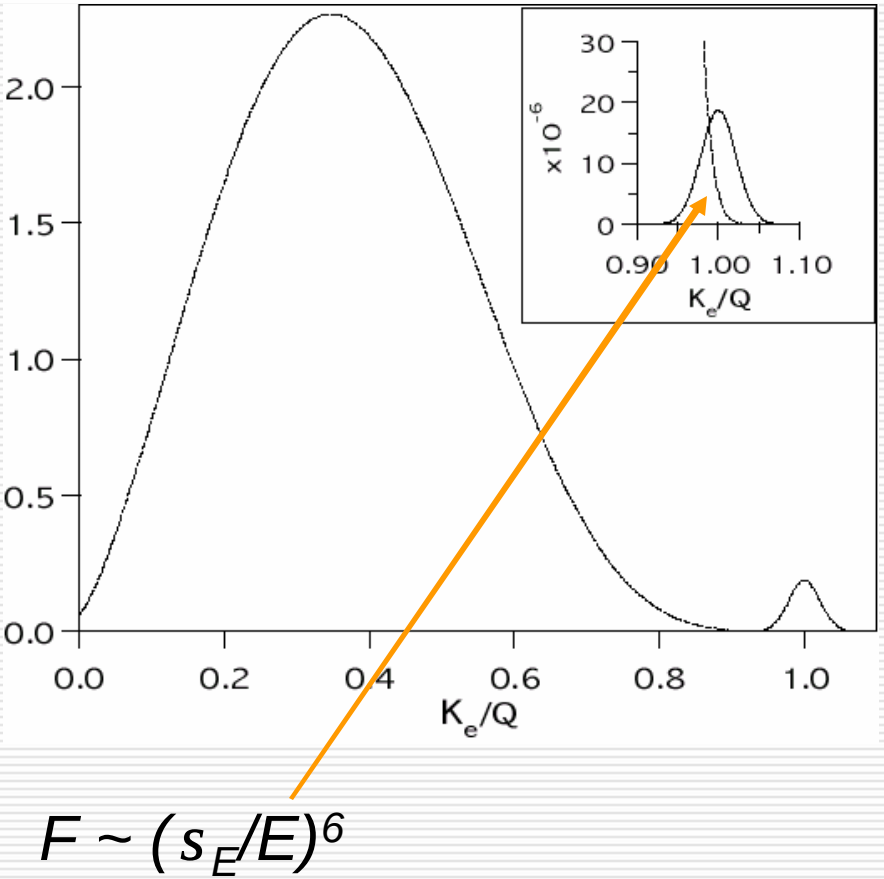
Energy Resolution and Sensitivity

Discovery potential for
$\langle m_n \rangle$ = 0.05 eV (mass scale from Δm^2_{atm})

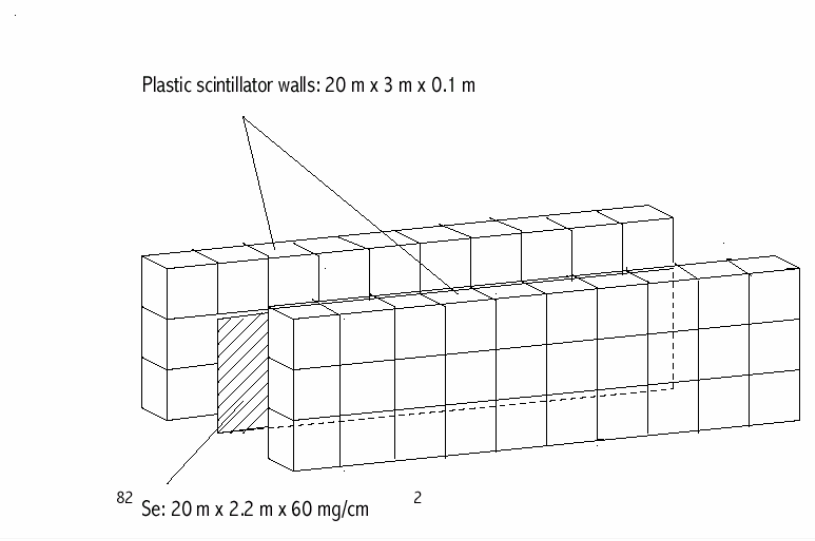
In 5 yr:

$\Delta E/E = 14\%/\sqrt{E}$ (NEMO-III)
SIGNAL = 5 events
BG = 15 events

$\Delta E/E = 8\%/\sqrt{E}$ (R&D goal)
SIGNAL = 5 events
BG = 0.6 events



SuperNEMO



4 supermodules, planar geometry

100 kg ^{82}Se (Q_{bb} ~ 3 MeV, long $T_{1/2}^{2n}$)

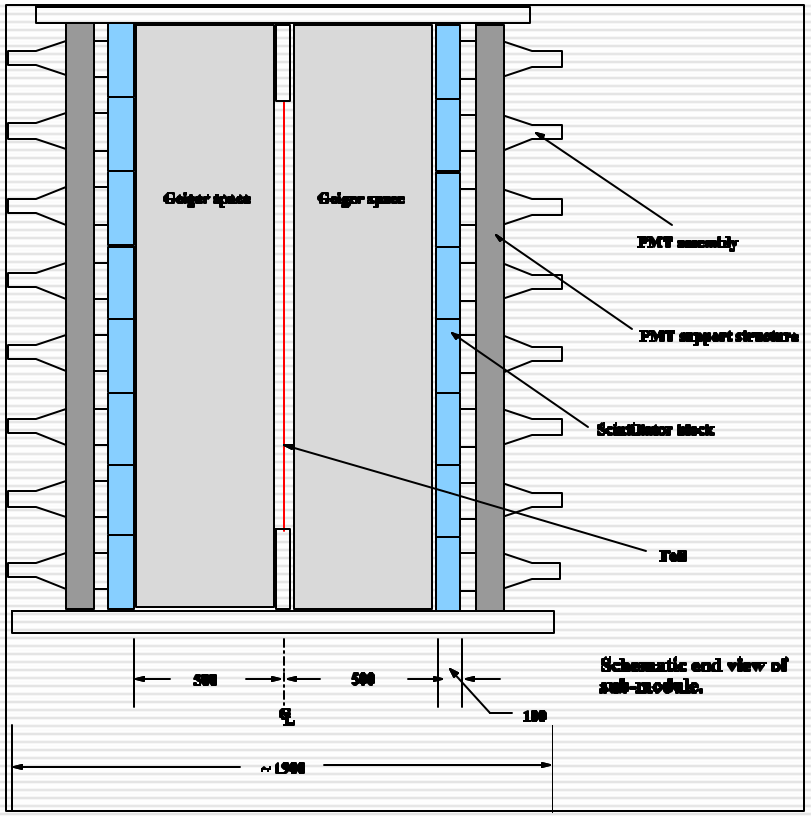
Boulby mine is the most attractive experimental site

Sensitivity ~0.04 eV in 5 yr
Feasible if Zero BG experiment:

1) No BG from radioactivity the only possible BG from 2n tail (NEMO-III)
2) Improve ΔE/E from existing (14%-16%)/√E to (8%-10%)/√E
R&D in UK and Dubna

SuperNEMO. Time Scale.

- 2004 – 2005: scintillator R&D
- 2006-2007: Development and characterization of 1st submodule
- 2007-2008: Start SuperNEMO installation (Boulby..?)
- 2009-2010: Start taking data
- 2014: planned sensitivity ~0.04 eV
- Excellent chance to be the first to reach 40-50 meV



Summary

- First anniversary of NEMO-III data taking approaching.
- So far: $\langle m_\nu \rangle < 0.6$ eV, precise 2ν measurements for *several* isotopes
- $\langle m_\nu \rangle < 0.2$ eV by 2009
- Experimental proof that BG(radioact)=0 reachable
- SuperNEMO is well positioned to reach 40-50 meV on a very competitive time scale