# The NEMO experiment. Present and Future.

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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

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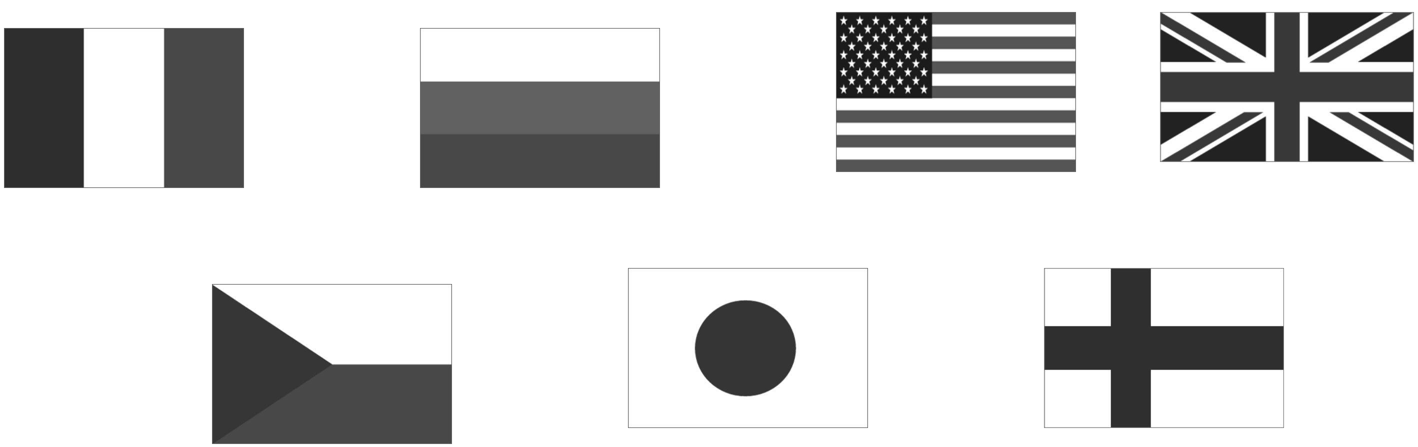
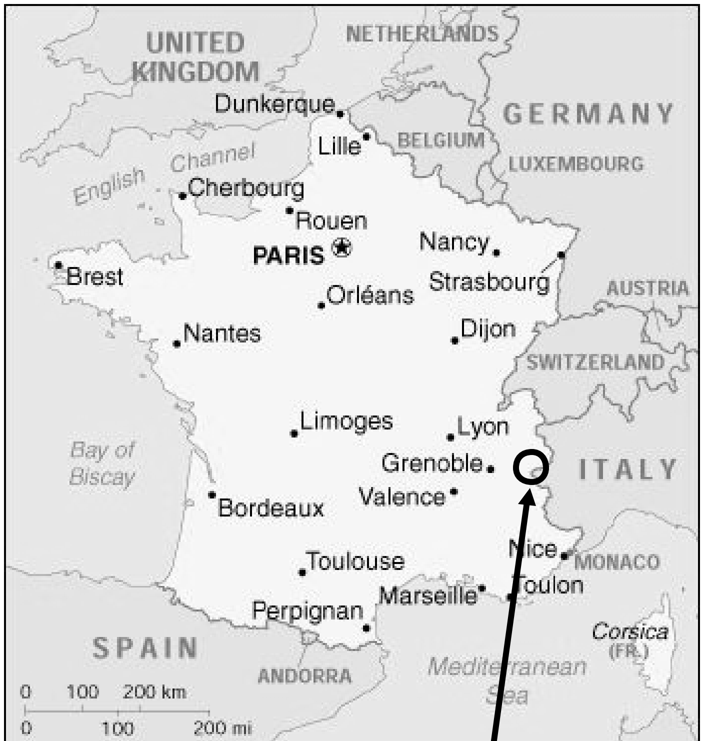
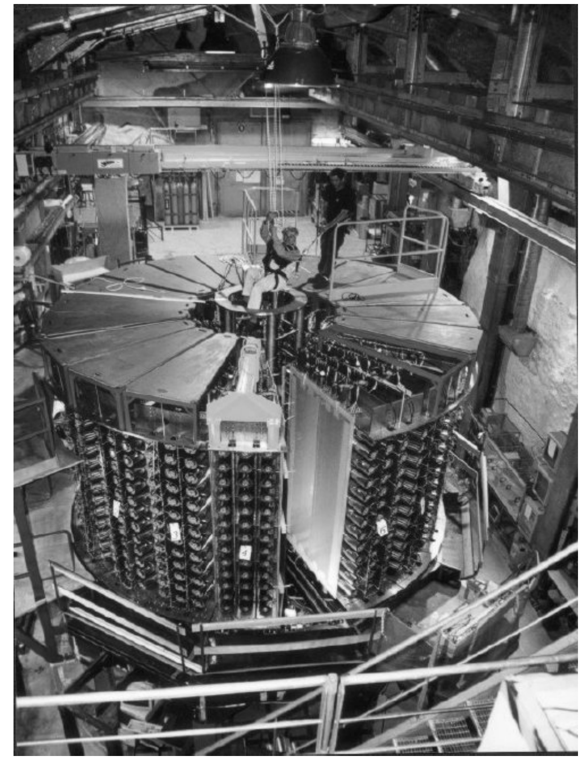
7 Countries



# NEMO-III in Frejus




Frejus

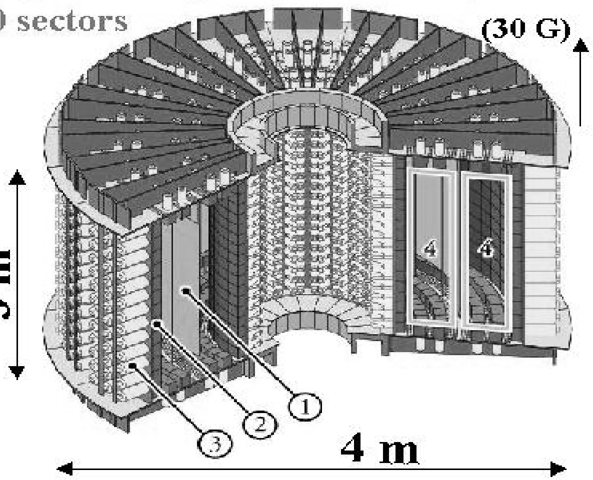


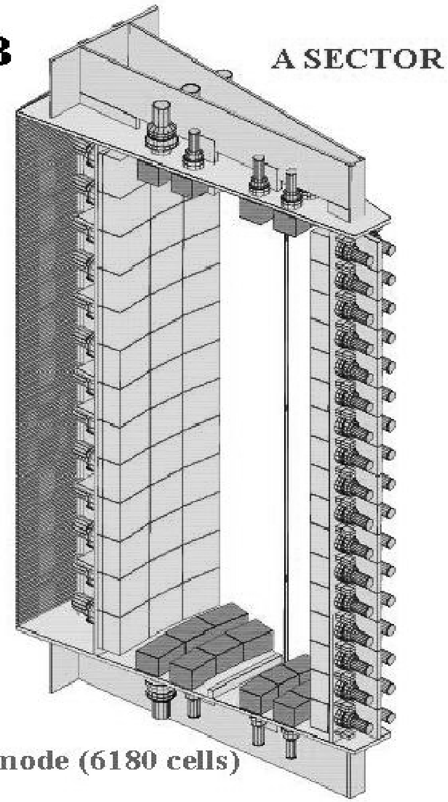
NEMO-III and CUORICINO to determine ββ sensitivity until 2008-10

# 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 ;
$\sigma(E)/E$ at 3 MeV ~ 3.5%

**+ Magnetic field + Iron shielding + Neutron shielding**

**Identification : $e^-$, $e^+$, $\gamma$, n and delayed-$\alpha$**

→ ββ events detection

→ Measurement of source radiopurity

→ Background rejection

- From scintil detector:
  $\sigma_\tau$ = 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
- $\gamma$ $^{60}$Co for time alignment

Trigger:

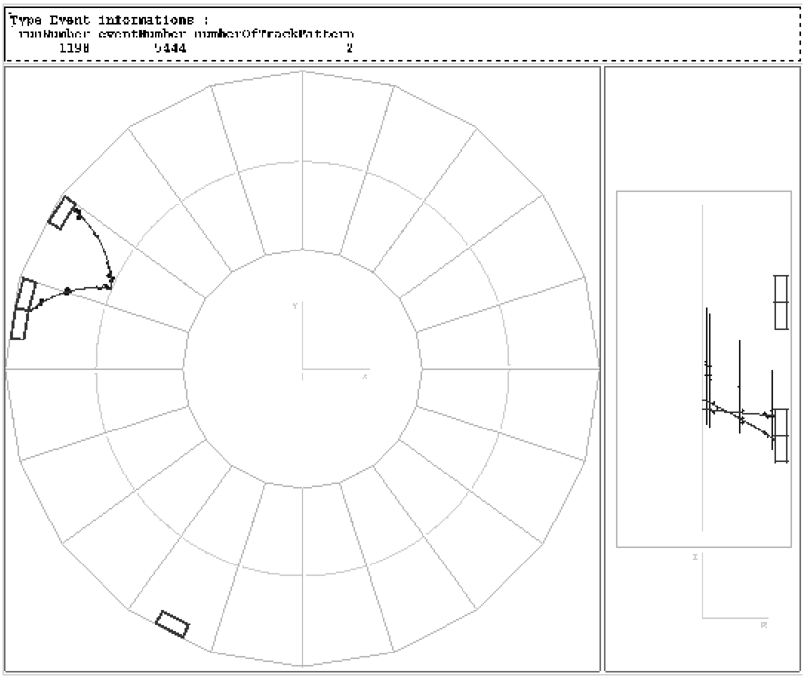
1 scintillator hit > 150 keV

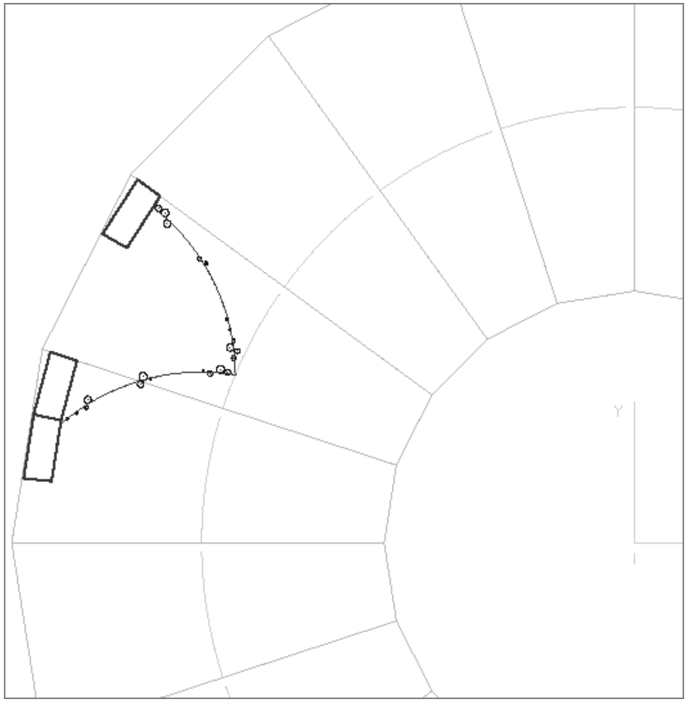
\+

1 track: few Geiger planes

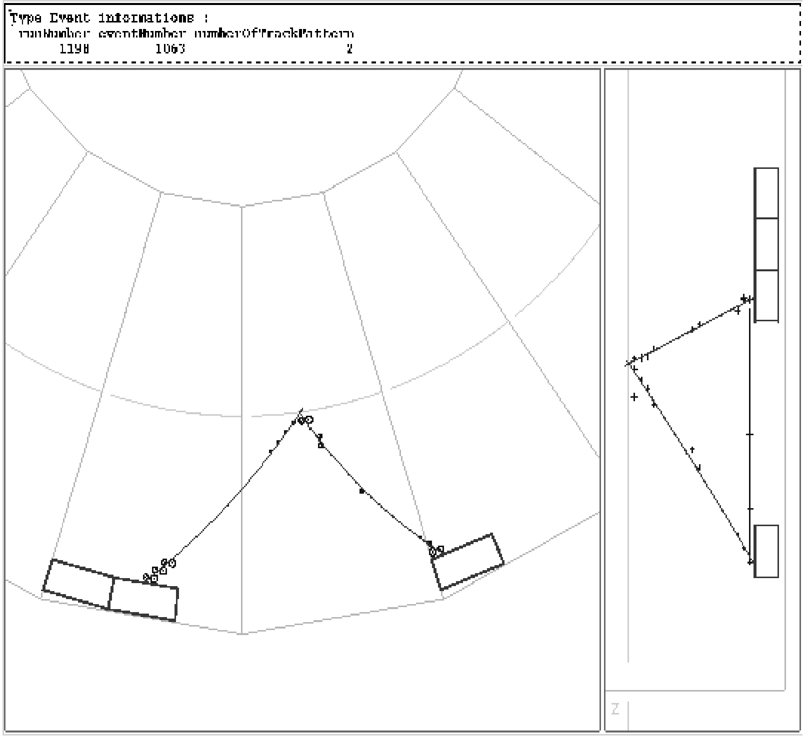
(flexible → 3 – 7 Hz)

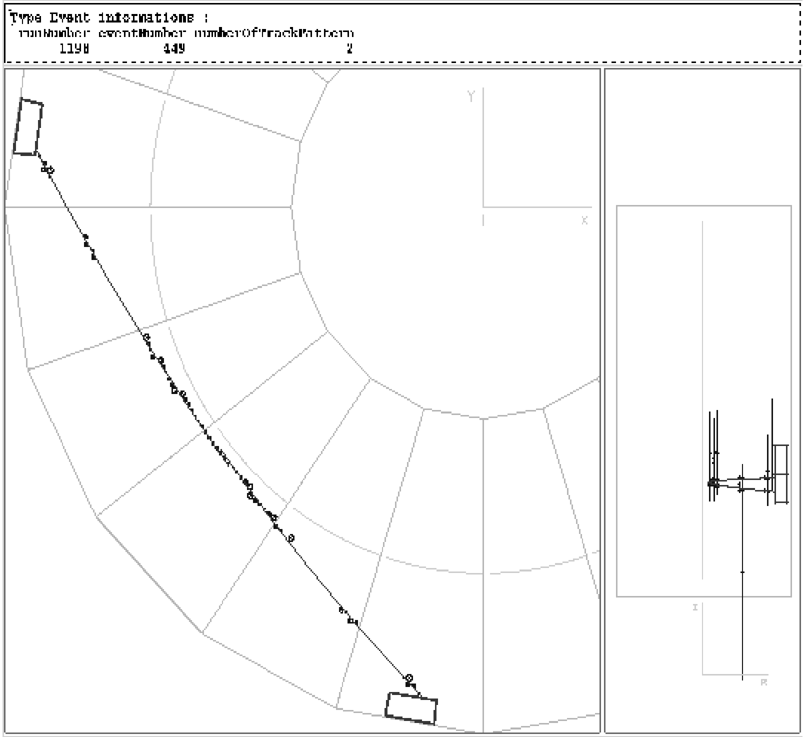
# NEMO ββ events



# NEMO background events

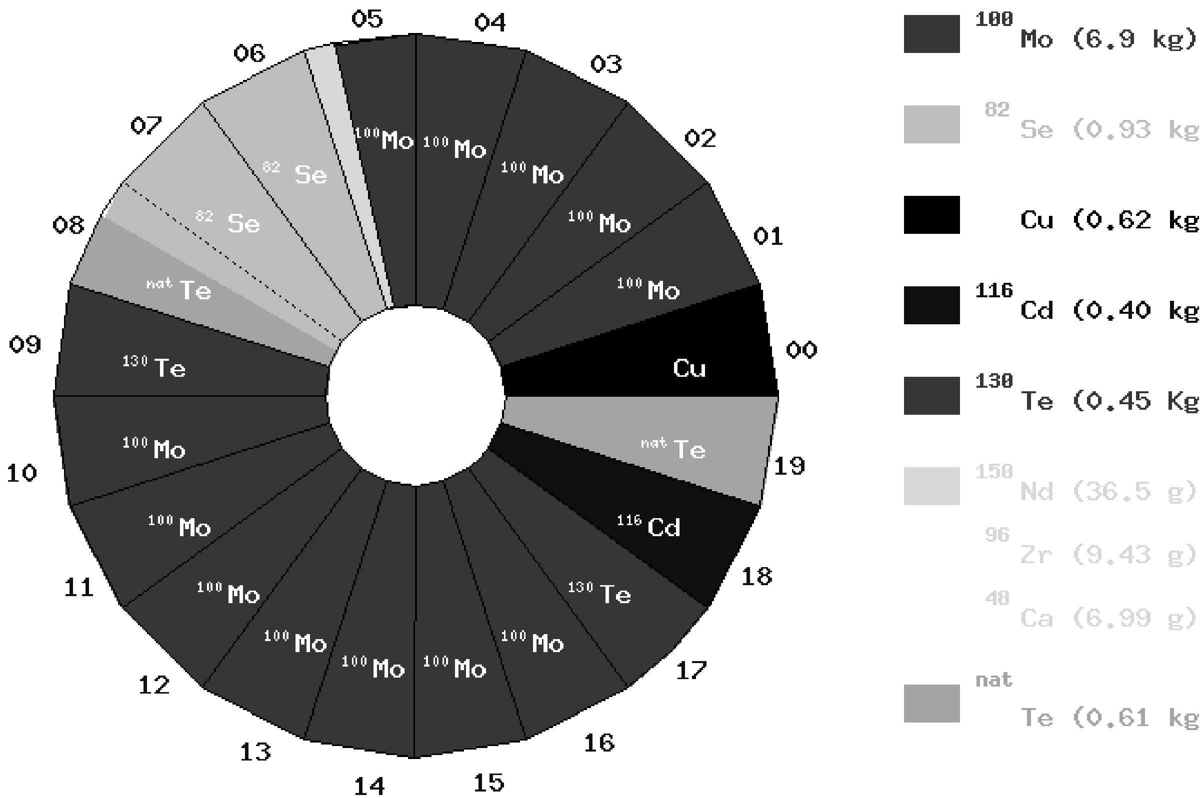



$\gamma \rightarrow e^+e^-$

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


SOURCE DISTRIBUTION in NEMO 3



## Pure materials:

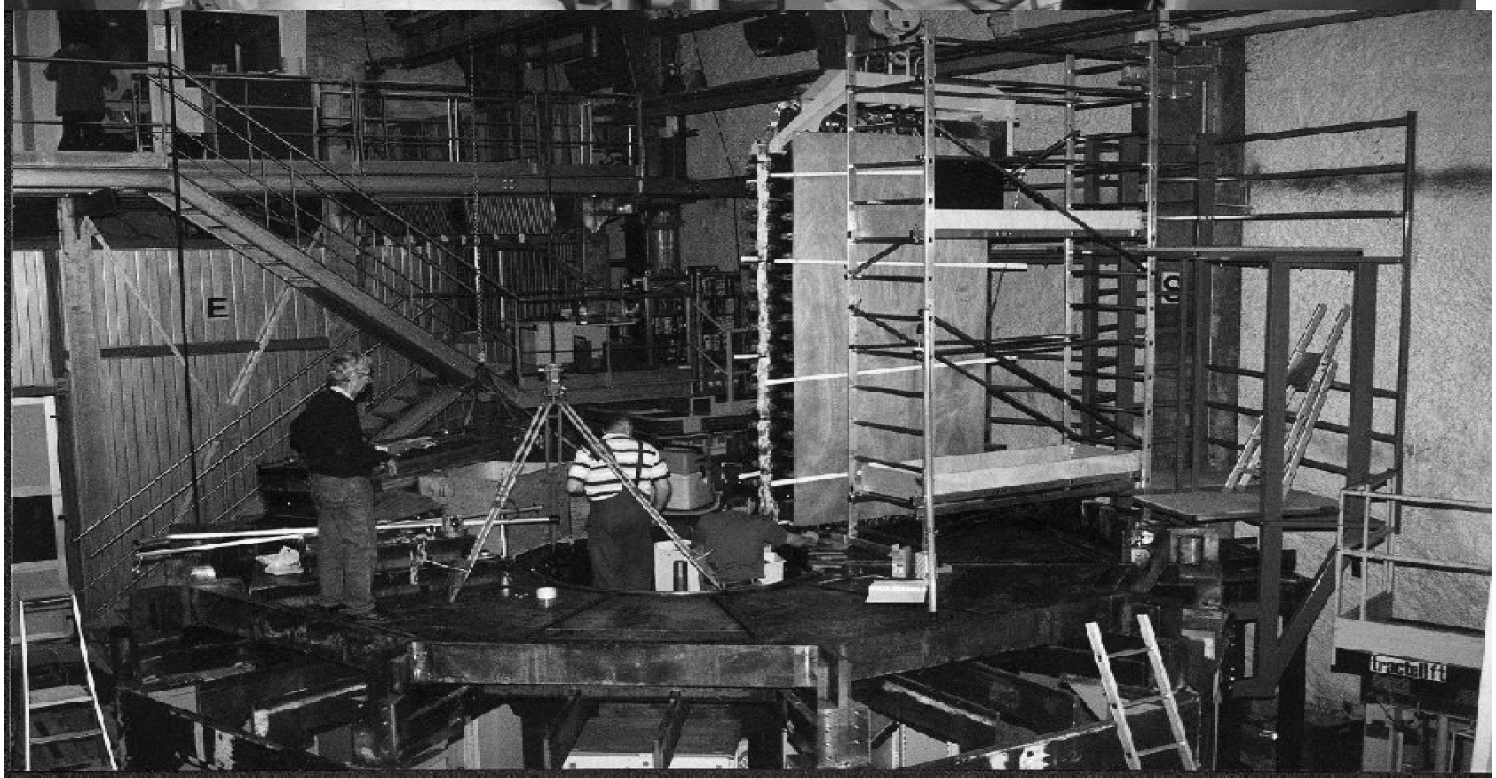
Source foils measured with the NEMO-3 detector

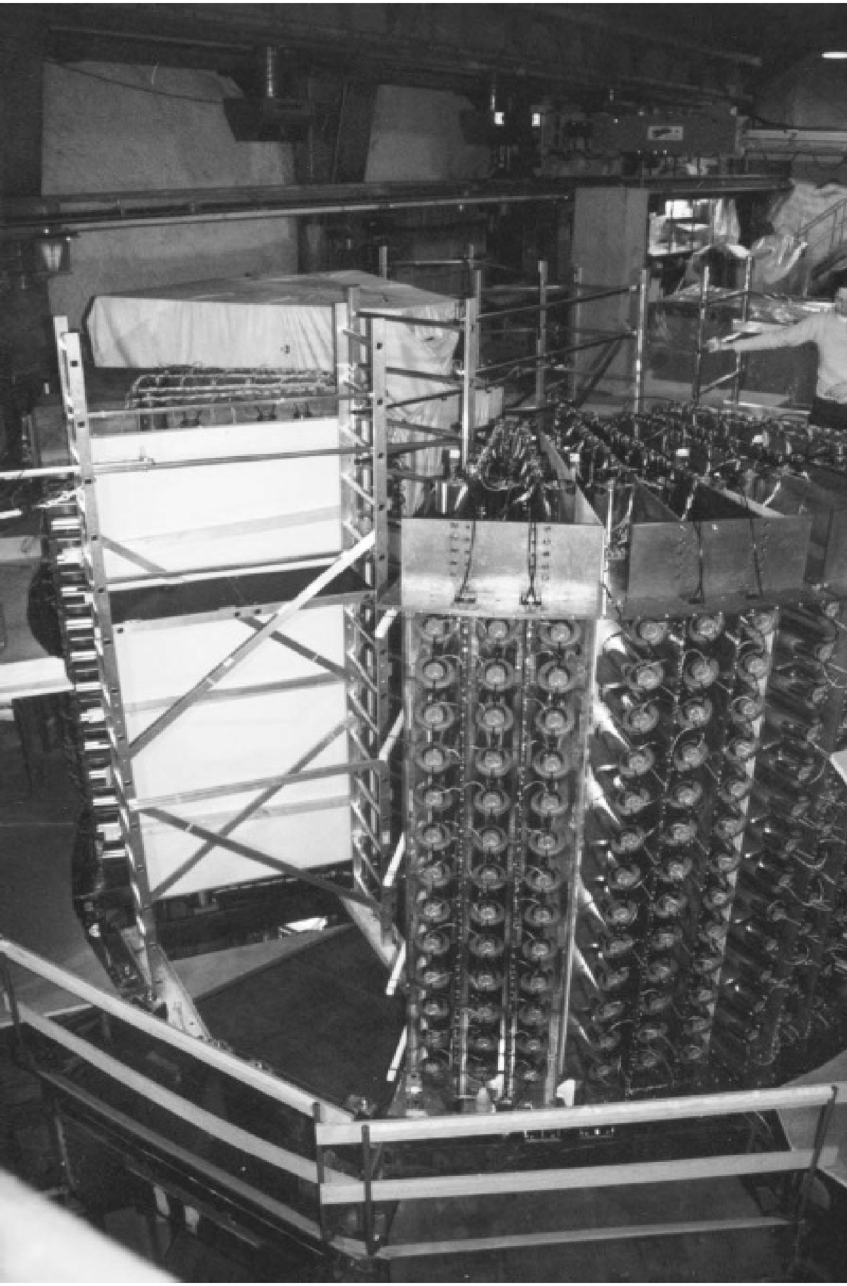
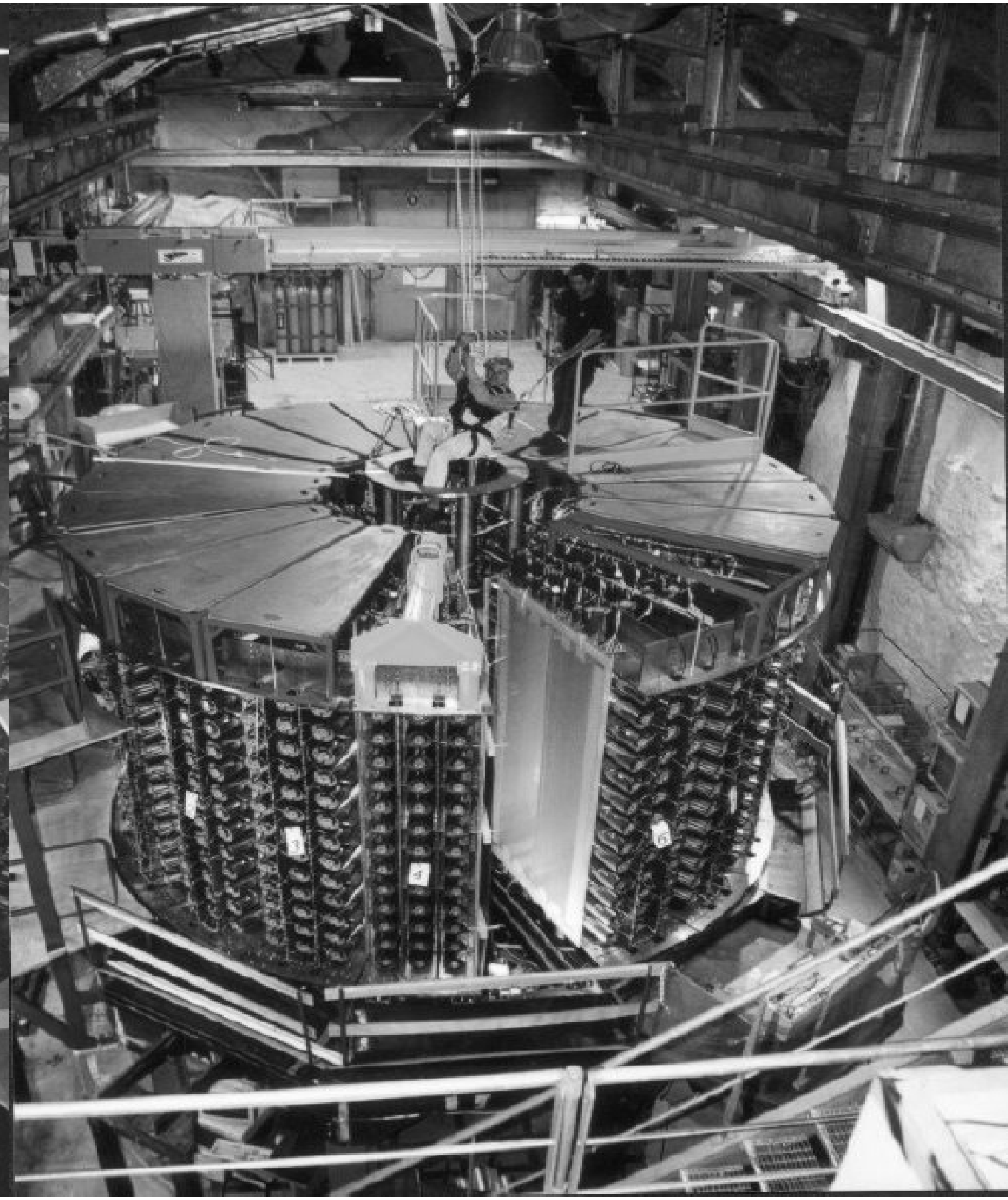
- $^{208}$Tl < 2 μBq/kg
- $^{214}$Bi < 2 μBq/kg
- neutrons < $10^{-9}$ n $cm^{-2}s^{-1}$

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

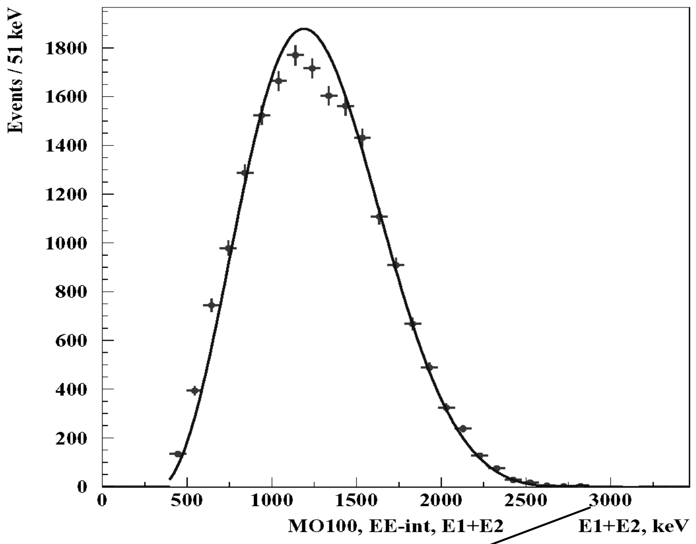



# Data taking

- 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±0.05(stat)±0.8(sys)]×$10^{18}$yr
(19000 events; S/B ≈ 50)

**0ν:**

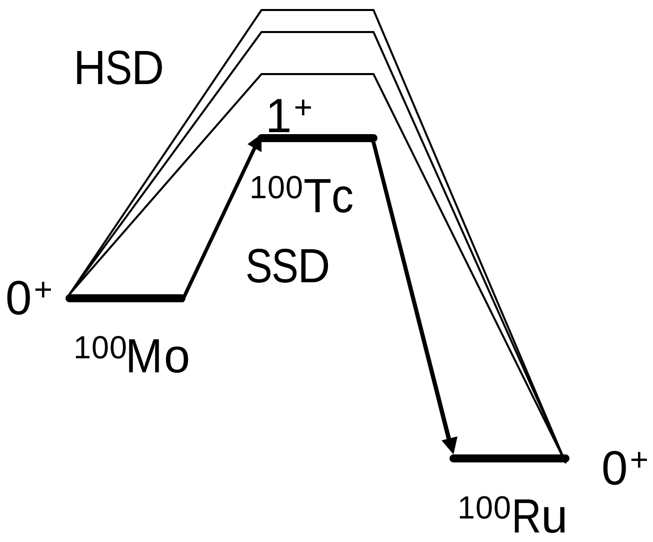
Preliminary from 3800 h:

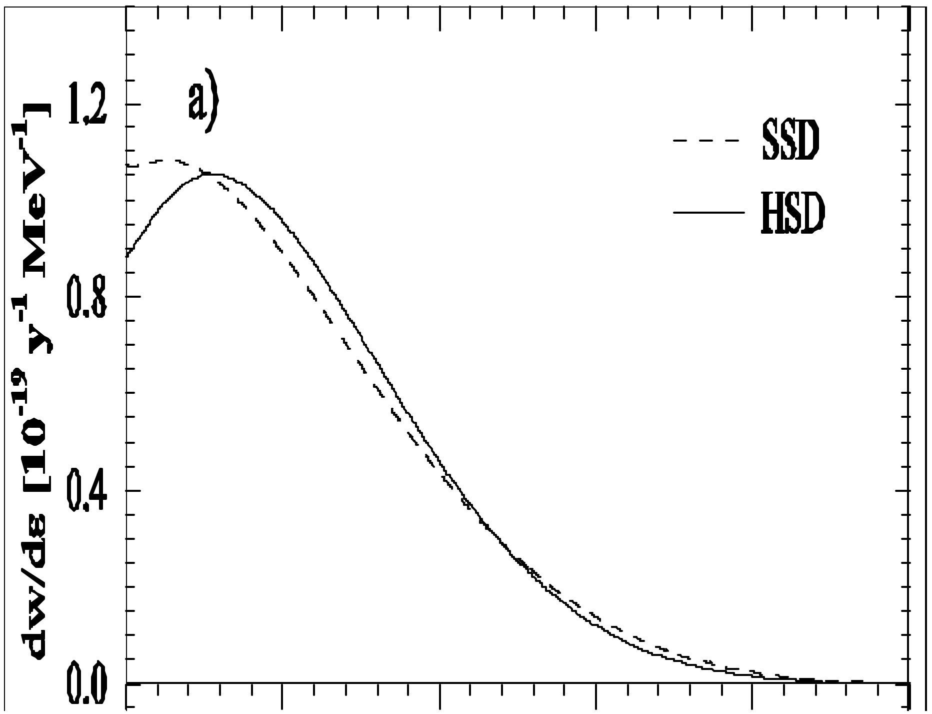
**$T_{1/2} > 2.3 \times 10^{23}$ yr (90% CL)**
**$\langle m_\nu \rangle$ < 0.6 eV – 1.3 eV**

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

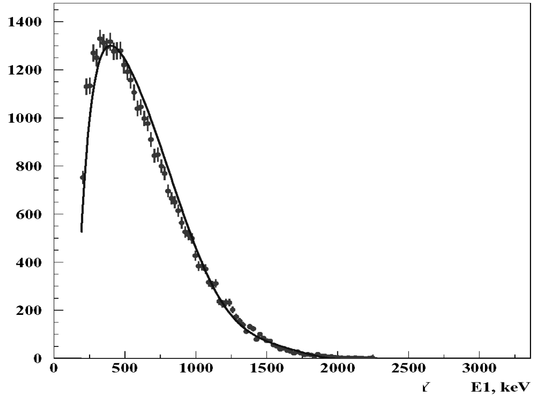


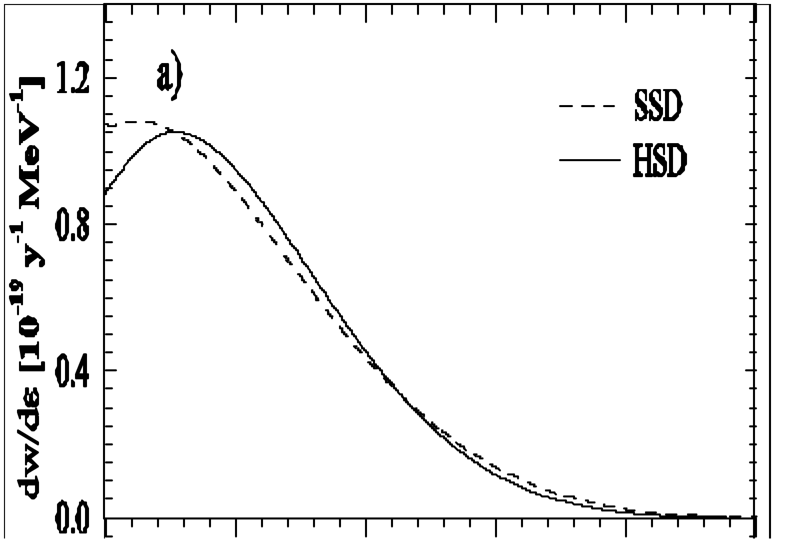



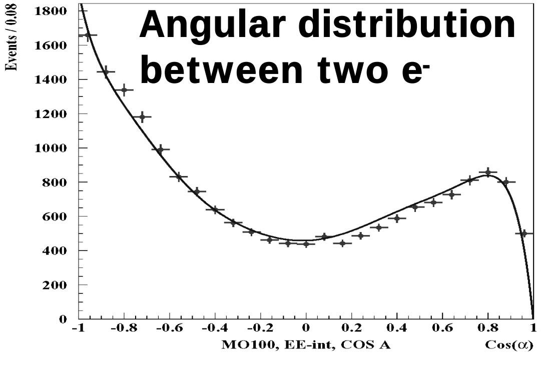

$^{100}$Mo + NEMO-like detector can test it experimentally !

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

single $e^-$ spectrum

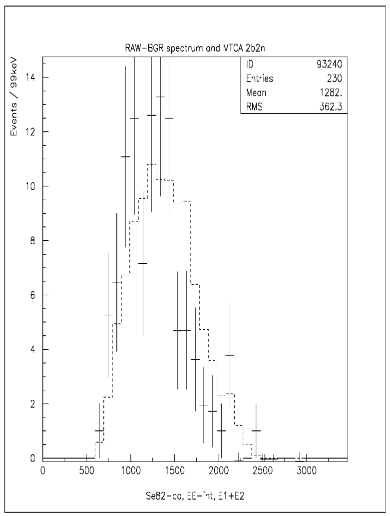



Preliminary:
SSD is preferred

# NEMO-3 First Results
# Other Isotopes

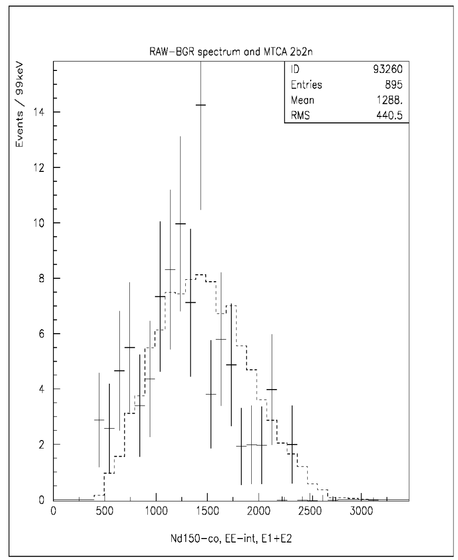



$^{82}Se$

$T_{1/2}=[8.2\pm0.4(stat)\pm0.8(sys)]\times10^{19}$

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

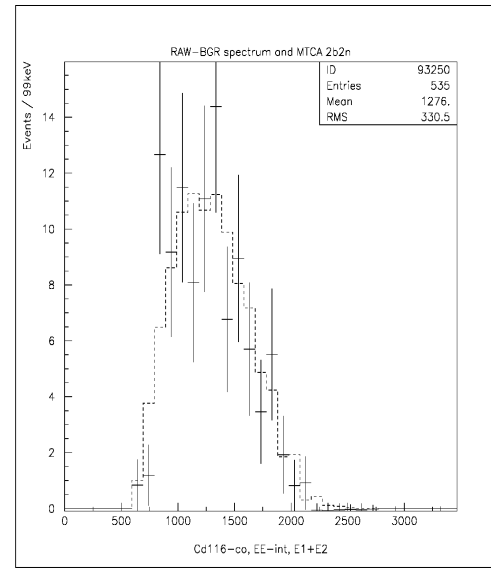
World's best result !




$^{150}Nd$

$T_{1/2}=[7.0\pm0.7(stat)\pm0.7(sys)]\times10^{18}$

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




$^{116}Cd$

$T_{1/2}=[3.9\pm0.3(stat)\pm0.4(sys)]\times10^{19}$

$T_{1/2} > 1.0 \times 10^{22}$ 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

$\Downarrow$

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

$\Downarrow$

$\langle m_\nu \rangle < 0.2 - 0.5$ 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

$\Downarrow$

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

$\Downarrow$

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

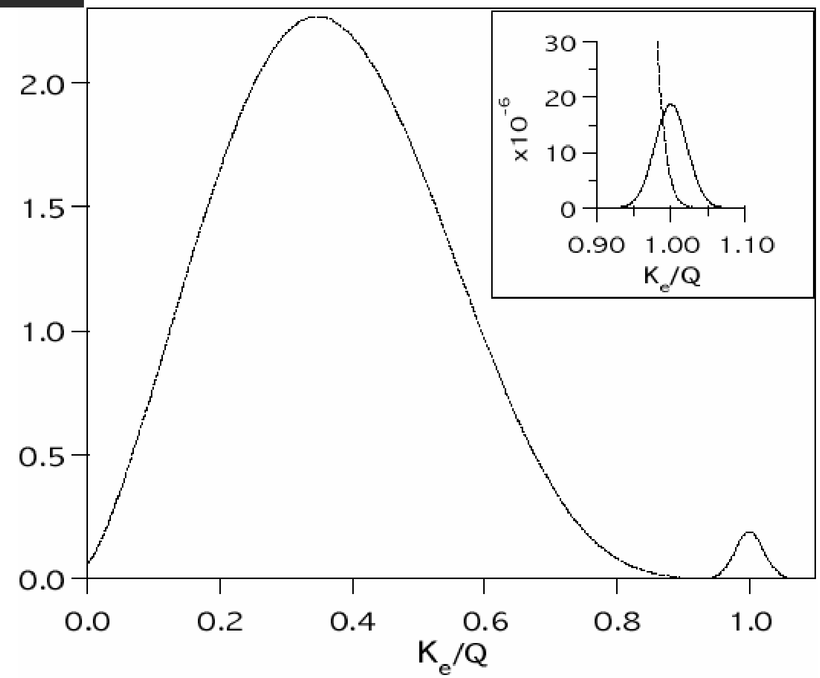
**In case of full load of $^{82}Se$ (~14kg) $\langle m_n \rangle < 0.15 - 0.3$ eV**

# 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**

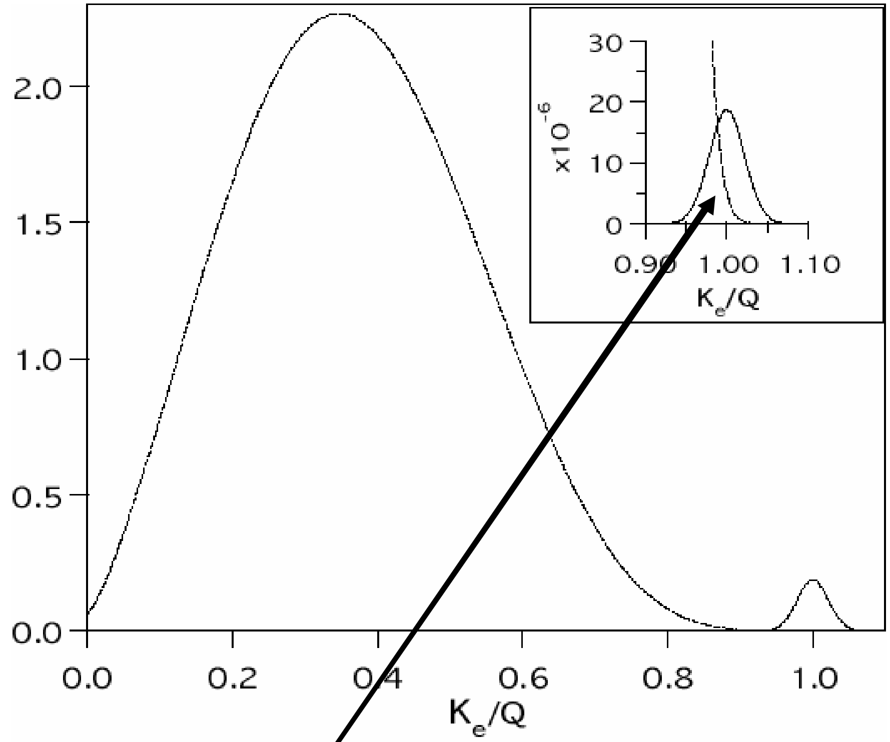
# Energy Resolution and Sensitivity

**Discovery potential for**
**$<m_n>$ = 0.05 eV (mass scale**
**from D$m^2_{atm}$)**

**In 5 yr:**

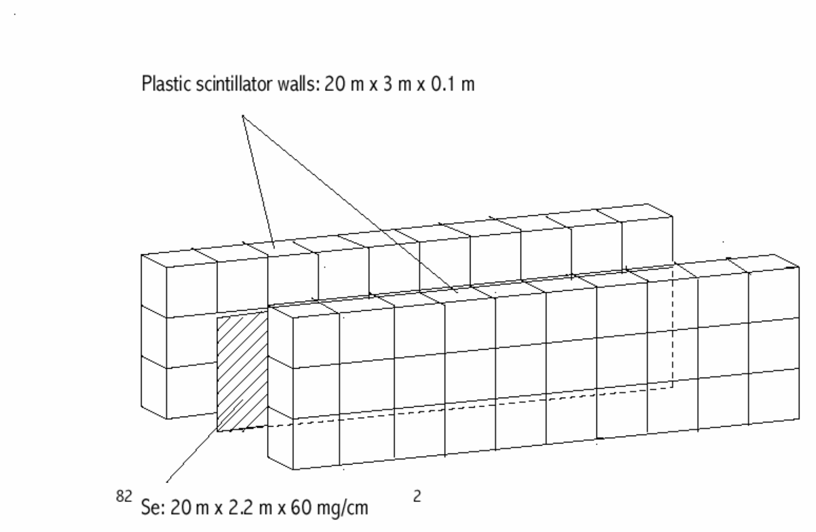
<u>D**E / E = 14% /**ÖE</u> **(NEMO-III)**
**SIGNAL = 5 events**
**BG = 15 events**

<u>D**E / E = 8% /**ÖE</u> **(R&D goal)**
**SIGNAL = 5 events**
**BG = 0.6 events**




$F \sim (s_E/E)^6$

# SuperNEMO




**4 supermodules, planar geometry**

**100 kg $^{82}$Se ($Q_{\beta\beta}$ ~ 3 MeV, long $T_{1/2}^{2\nu}$)**

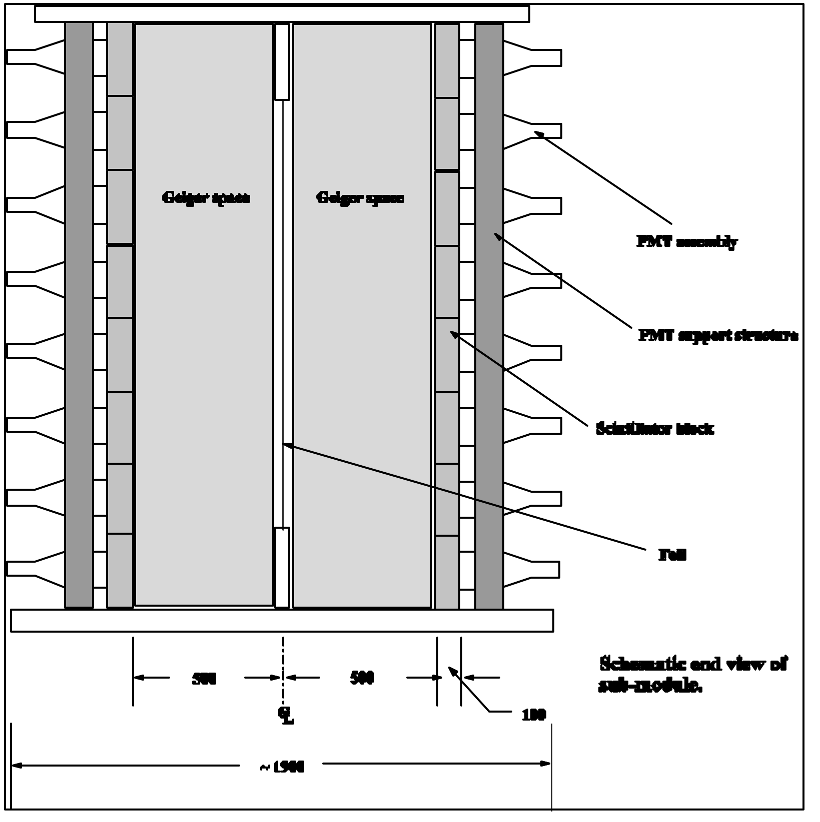
**Boulby mine is the most attractive experimental site**

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

**1) No BG from radioactivity the only possible BG from $2\nu$ tail (NEMO-III)**
**2) Improve $\Delta E/E$ from existing (14%-16%)/$\sqrt{E}$ to (8%-10%)/$\sqrt{E}$**
**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: $<m_\nu> < 0.6$ eV, precise 2ν measurements for *several* isotopes
- $<m_\nu> < 0.2$ 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