SuperNEMO

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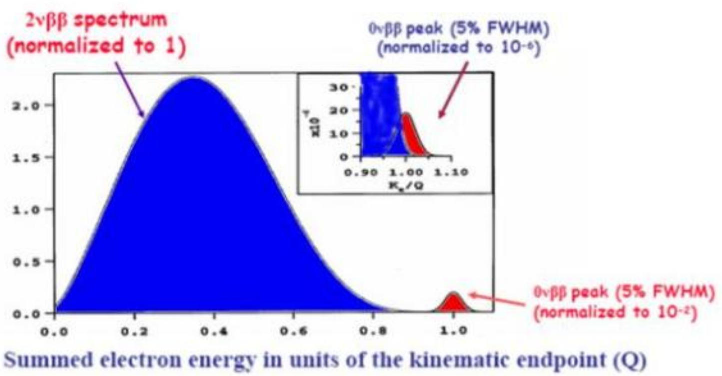
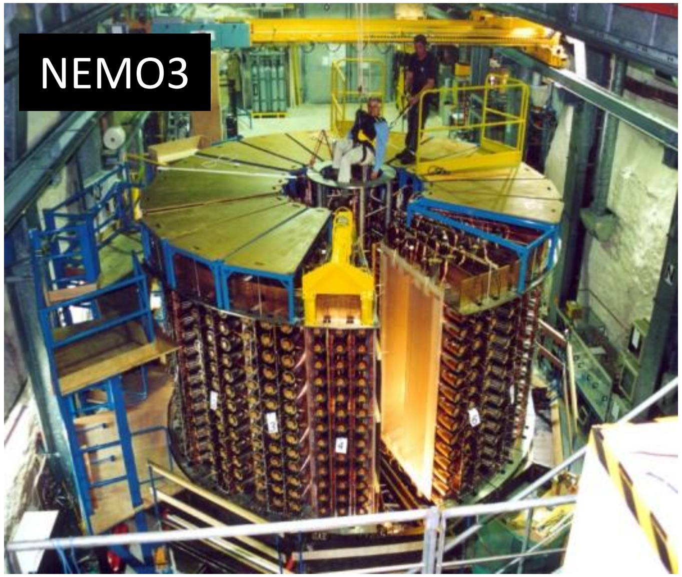
Double beta decay: physics case

- Leptonic number violation
- Nature of neutrino : Dirac ($\nu \neq \bar{\nu}$) or Majorana ($\nu = \bar{\nu}$)
- Absolute neutrino mass and neutrino mass hierarchy
- Right-handed current interaction
- CP violation in leptonic sector
- Search of Supersymmetry and new particles

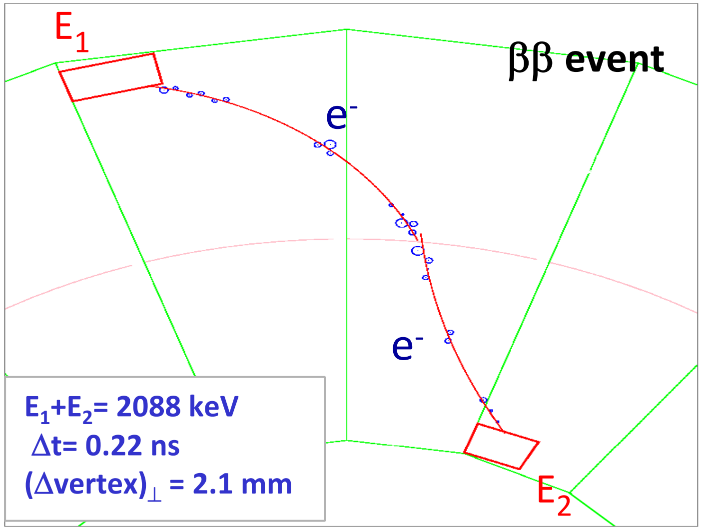
NEMO : tracko-calo technique

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





Unique feature: measurement of all kinematic parameters: individual energies and angular distribution



NEMO 3 calorimeter

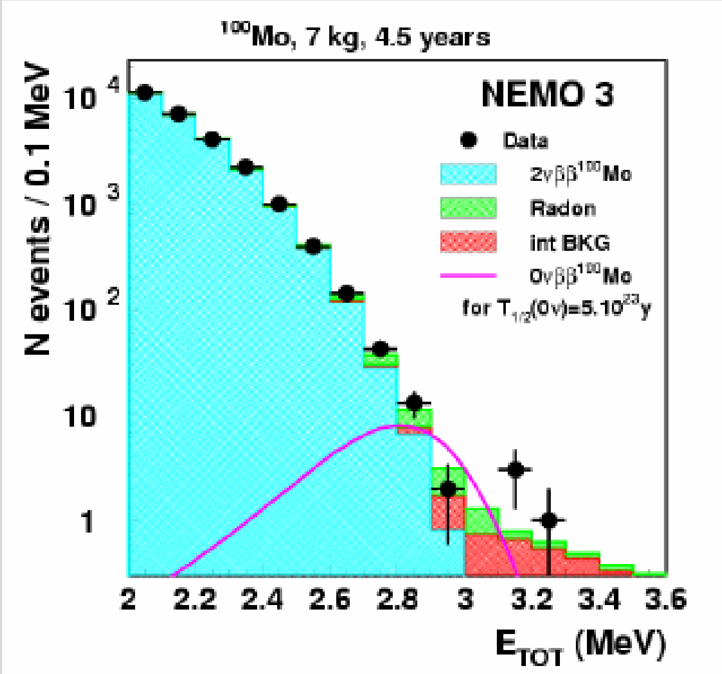
1940 plastic scintillators +PMT

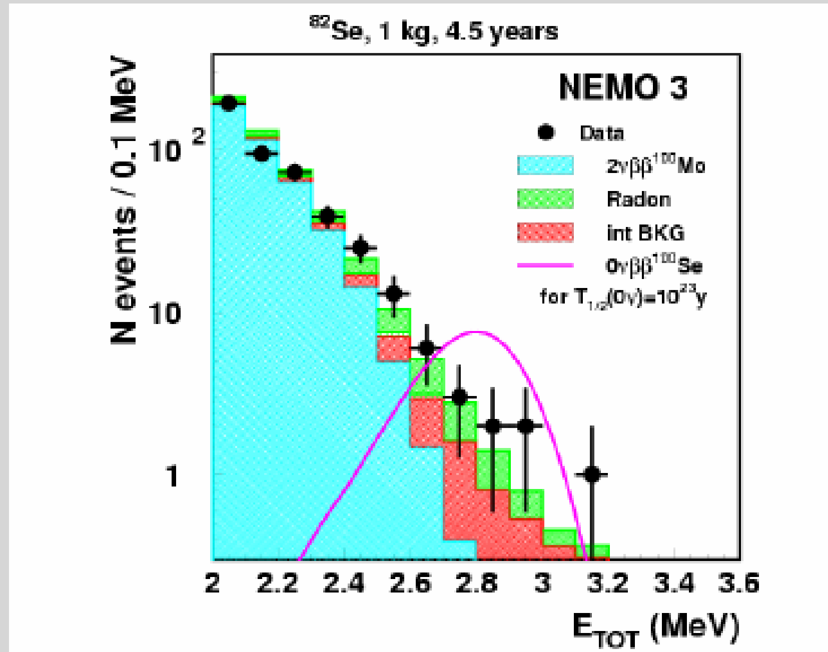
(Low radioactive glass)

$\Delta E/E$: 15% **(FWHM) @ 1 MeV**

Running at Modane laboratory since 2003

ββ(0ν) results





[2.8-3.2] MeV: DATA = 18; MC = 16.4±1.4

$T_{1/2}(0\nu) > 1.0\times10^{24}$ yr at 90%CL

$\langle m_\nu \rangle < (0.47 - 0.96)$ eV

[2.6-3.2] MeV: DATA = 14; MC = 10.9±1.3

$T_{1/2}(0\nu) > 3.2\times10^{23}$ yr at 90%CL

$\langle m_\nu \rangle < (0.94 - 2.5)$ eV

V+A: $T_{1/2}(0\nu) > 5.4\times10^{23}$ yr at 90%CL

Majoron: $T_{1/2}(0\nu) > 2.1\times10^{22}$ yr at 90%CL

$\lambda < 1.4\times10^{-6}$

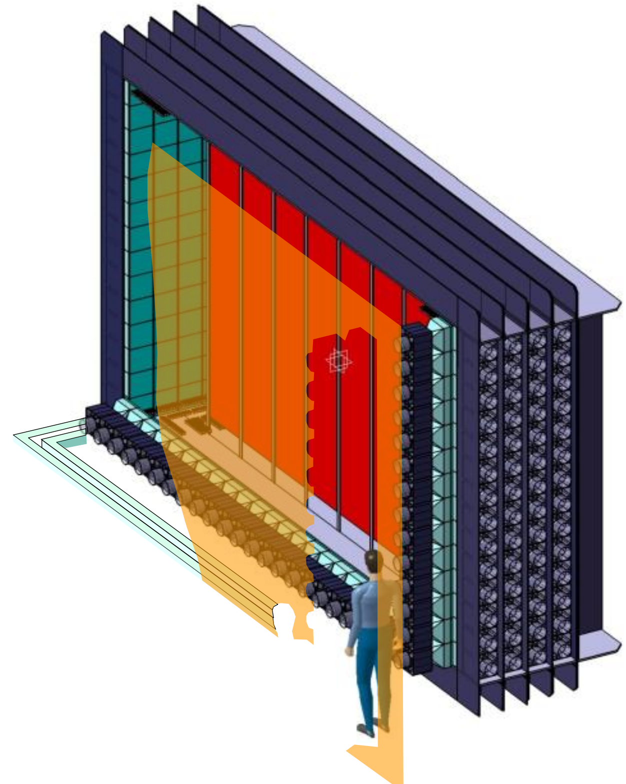
$g_{ee} < 0.5\times10^{-4}$ World's best result!

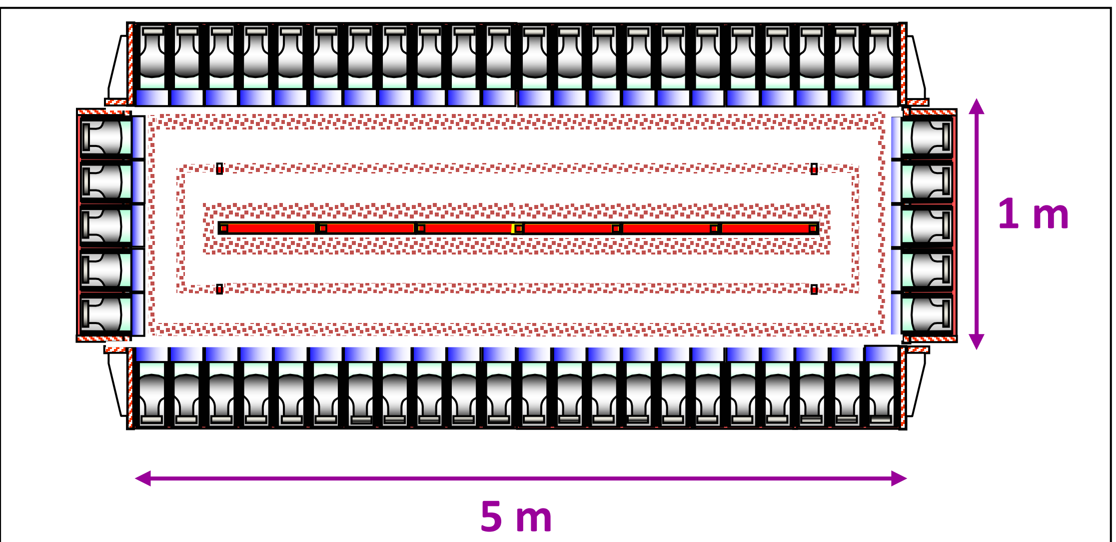
SuperNEMO conceptual design

20 modules for 100 kg

Source (40 mg/cm^2) 12m^2
Tracking (~4000 Geiger cells).
Calorimeter (500 channels)

Total:~ 40 000 – 60 000 geiger cells channels
~ 8 - 10 000 PMT





Top view

100 kg of ^{82}Se:
$<m_\nu>$ < 50 – 100 meV

Module 0 : 7 kg of ^{82}Se

$<m_\nu>$ < 0.2 – 0.5 eV (1 year of data)

SuperNEMO calorimeter requirements

- Energy measurement (plastic scintillator + Photomultipliers) < 8% (FWHM) at 1 MeV
  4% @ 3 MeV
- ToF measurement < 250 ps at 1 MeV (σ) (time difference between 2 counters)
- Low Z scintillator for electron backscattering (plastic scintillator)
- γ–rays tagging
- Measurement of γ-rays from excited states
- Radiopurity (Background, counting rate, Radon emanation)
- Stability and aging: running for 10-15 years
- Calibration and gain control better than 1% over a period of one month (between to period of absolute calibrations)
- Linearity from 30 keV to 4 MeV

Calorimeter R&D

2 electron spectrometer at CENBG (Sr source)

β beam: 0.4 – 2 MeV

Beam : $\Delta E/E$ < 1%

Automatization of test bench:
Mesure of linearity, resolution vs energy,
Response uniformity vs impact point

Energy resolution

SMES ID = 617 **Runs ID = 1 - 5** **Date :** ________________ **Operator :** ________________

Comment : ____

SCINTILLATOR

EJ-204 RAW II (sc_156)

Wrapping

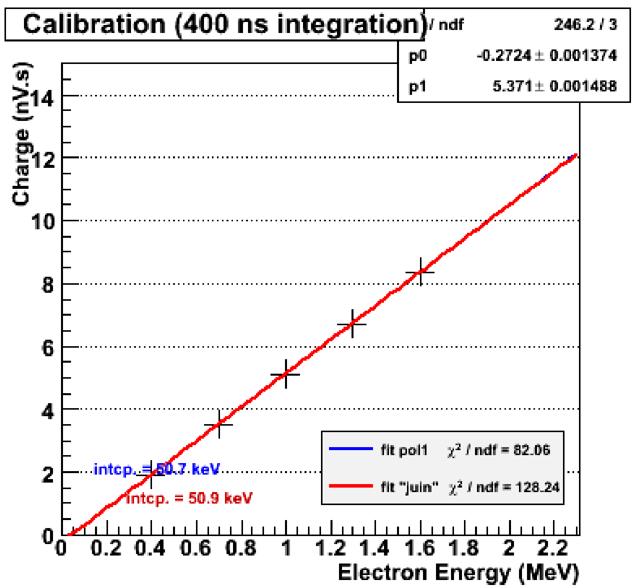
- front : __________
- sides : __________
- back : __________

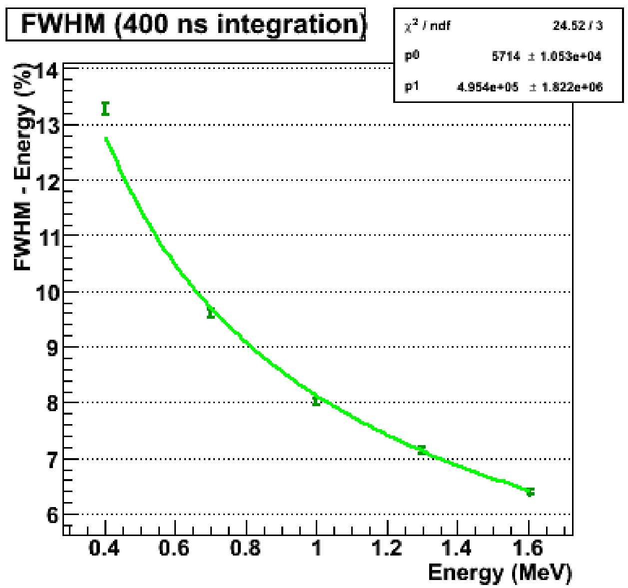
PMT

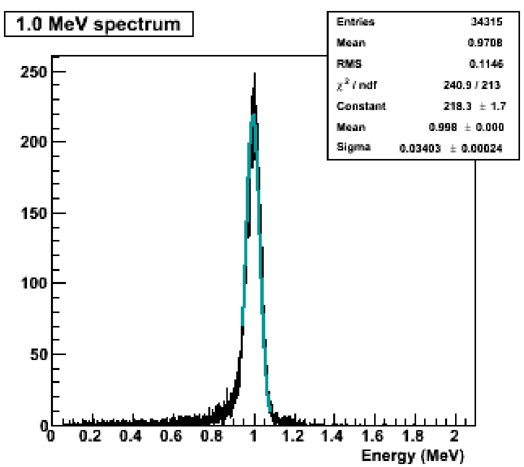
R5912MOD_ZQ0068

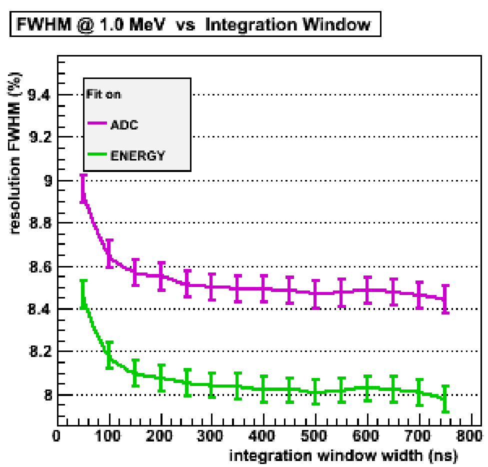
High Voltage =1650 V

Voltage Divider #4









*** * * 1 MeV RESULT (400 ns integration) * * ***

Pedestal = 0.2693 ± 0.0153 mV [χ^2=2.47]
Amplitude = 331.4 ± 17.7 mV
Gain @ 1 MeV = 5.371 nV.s / MeV

T_{RISE} = 4.2 ± 0.2 ns
T_{FWHM} = 12.3 ± 0.6 ns
T_{FALL} = 19.1 ± 1.0 ns

ADC = 5.088 ± 0.001 nV.s
FWHM - ADC = 8.49 ± 0.06 %

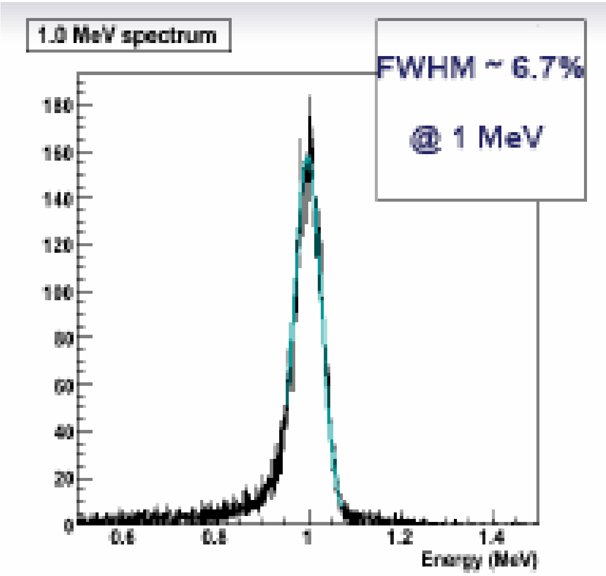
Energy = 0.9979 ± 0.0003 MeV
FWHM - Energy = 8.02 ± 0.06 %
FWHM - Energy - Stable = 8.12 %

Energy resolution

Requirement: ΔE/E < 8% FWHM at 1 MeV (<4% @ $Q_{\beta\beta}$)

Hexagonal PVT scintillator block
EJ 204
28 cm large 10 cm thick
8'' Photonis PMT (QE > 40%)

ΔE/E = (6.7 ± 0.1) %



Results with R5912 MOD_ZQ0068

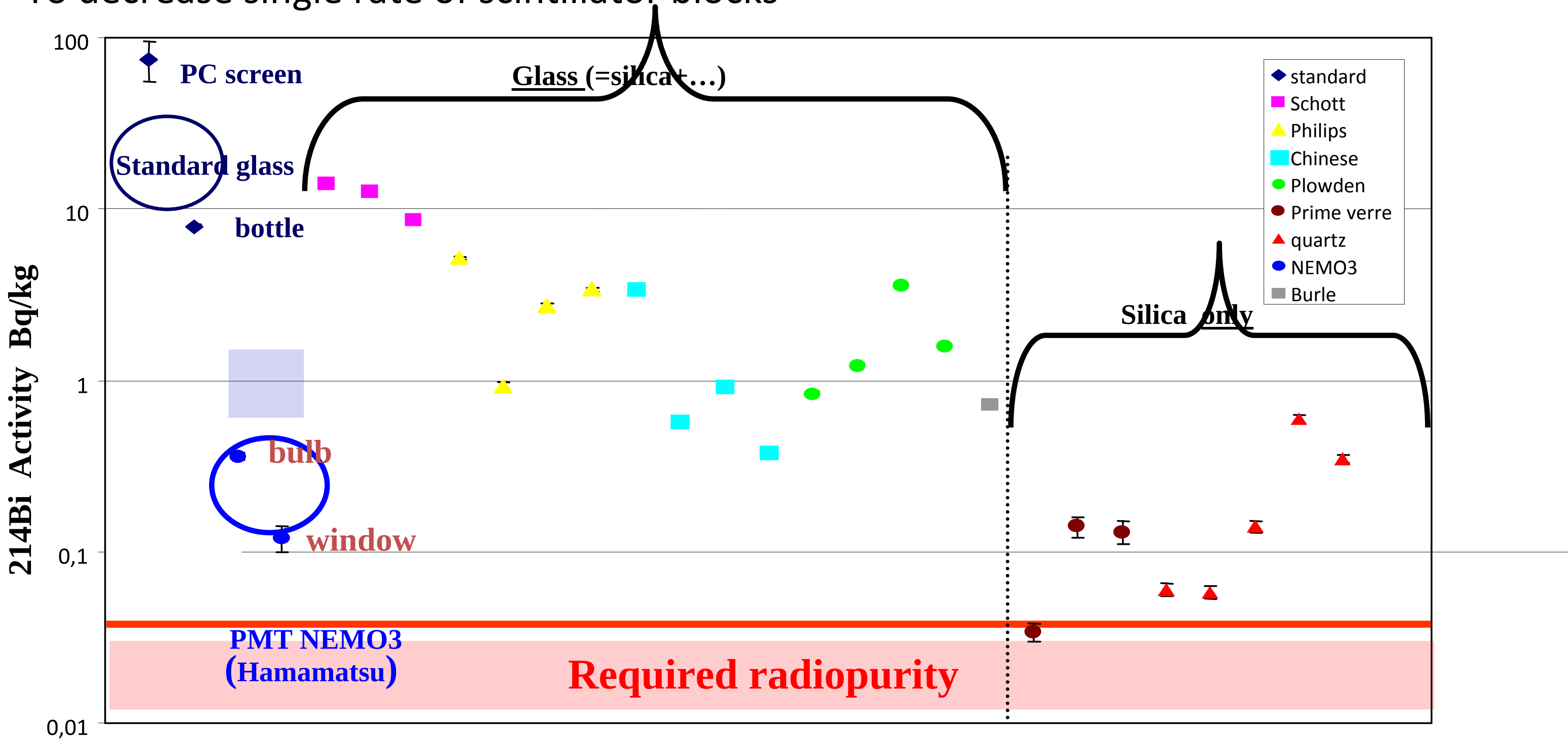
Bloc	Cubic 308 mm	Cubic 256 mm	Hexa 276, 0°	Hexa 276, 6°
PS Evinet (raw) PS Evinet (polished)	9.9 9.8	8.7	9.5 8.7	8.7 8.7
PVT EJ 200 (raw) PVT EJ 200 (poli.)	9.0 8.6	8.1 8.2		
PVT EJ 204 (raw) PVT EJ 204 (poli.)	8.1		7.5	

Energy resolution

Gamma-rays from PMT, not a problem for $\beta\beta(0\nu)$ of ^{82}Se, ^{100}Mo, ^{150}Nd, ^{96}Zr, ^{48}Ca

Main problem could be radon emanation (not a problem for ^{150}Nd and ^{48}Ca).
Startegies to protect tracker from radon emanation

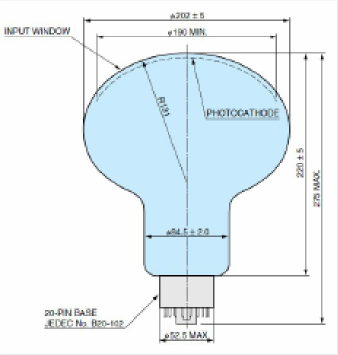
To decrease single rate of scintillator blocks



To improve by a factor 10 the radiopurity of glass compare to NEMO3

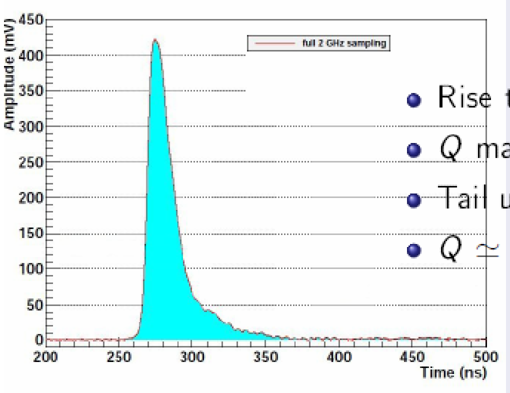
Calorimeter electronics requirements

Typical candidate : Hamamatsu R5912MOD (8")



- Plastic scintillator + PMT : ≃100(collected p.e for 1 MeV electron
- QE≃ 30%
- Gain ≃ 10^{5-6}
- Q ≃ 100 pC @ 1 MeV (NEMO-3 : 500 pC @ 4 MeV)
- Range for physics : 50-100 keV ↔ 5-10 MeV
- Pedestal background (using MATACQ) : < 2 mV

Signal characteristics (from MATACQ @ CENBG)



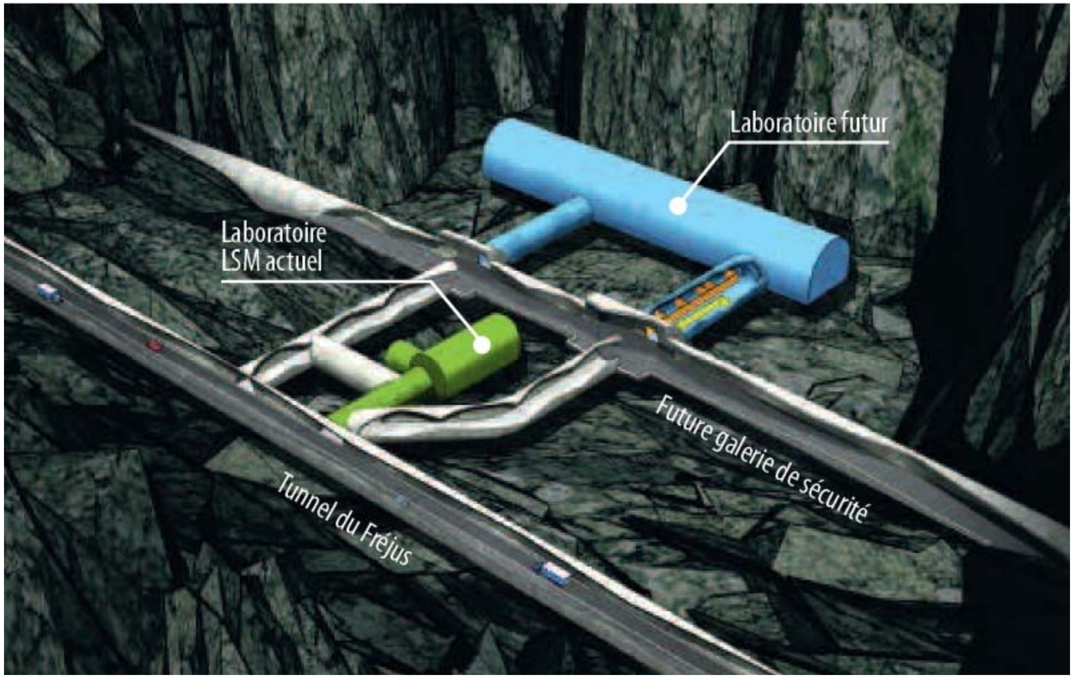
- Rise time : ≃ 5 ns
- Q main integration window : ≃ 50 ns
- Tail up to ≃ 400 ns
- Q ≃ 2.5 nV.s @ 1 MeV

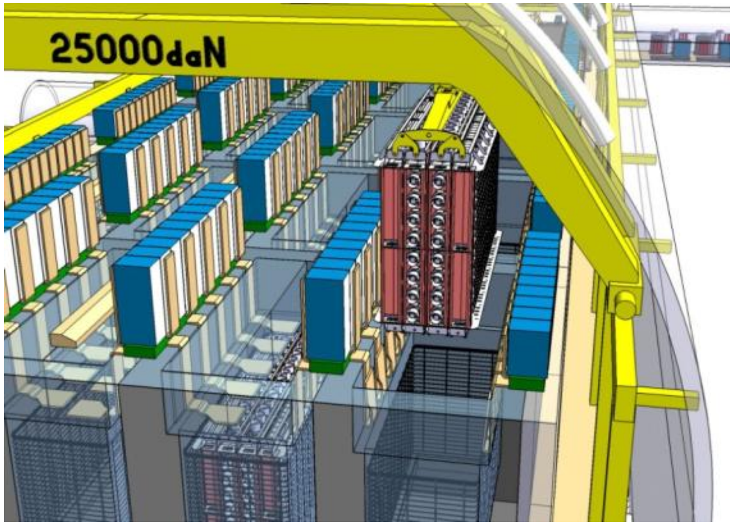
Requirements for the calorimeter front-end electronics

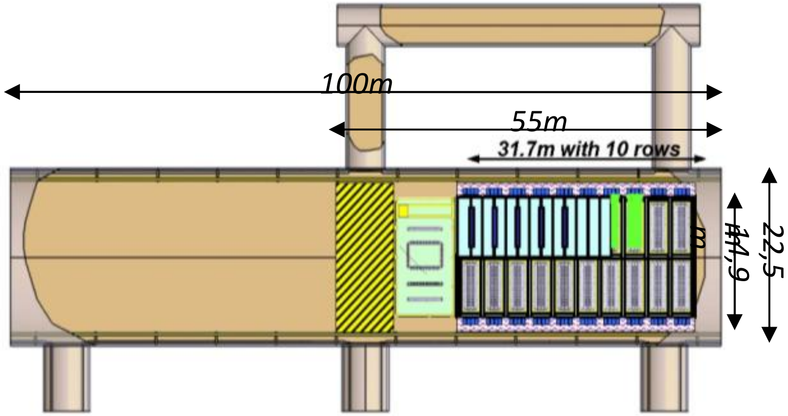
- Charge (Q) measurement : high dynamics ≃ 5-500 pC
- Time (T) measurement for TOF analysis :
  - absolute time-stamping @ ≃200ps within one module (200-5000 keV)
  - absolute time-stamping @ 1 ns between any two modules
- Pedestal measurements
- PSA :
  - detection of pre-pulses, fast pile-up, signal shape anomaly
  - charge/amplitude ratio survey

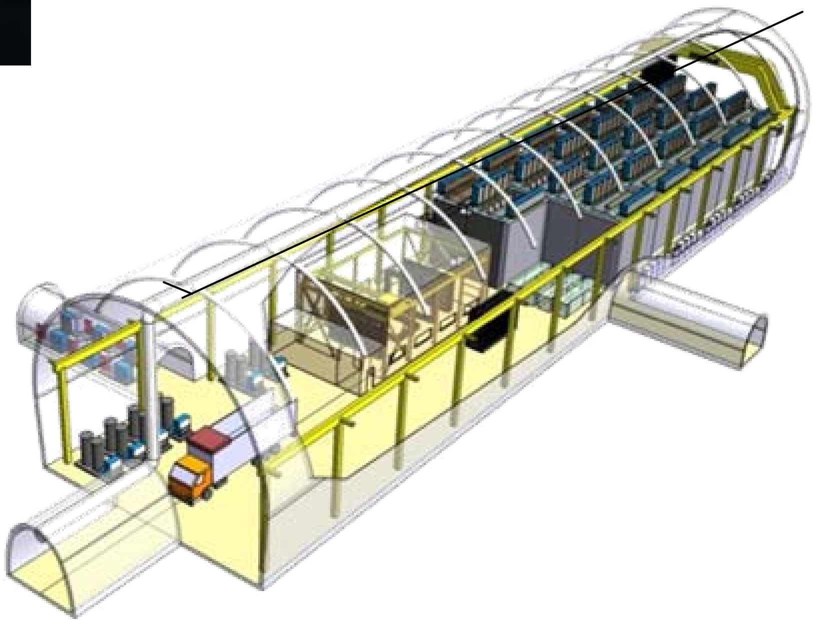
Development of ASIC and board by LAL Orsay and LPC Caen (France) in progress

Location: LSM extension









Schedule

Requirement $\Delta E/E < 8$ % @ 1 MeV (4% @ $Q_{\beta\beta}$) reached

Demonstrator module (installed in present LSM or in the extension):

Construction 2011 – 2012 → PMT (8'', 100 in 2011, 400 in 2012)

Commissioning and running 2013 -2014

Full detector (20 modules):

Construction 2014 – 2016 → ~8 000 PMT (increasing of scintillator blocks)

Commissioning : 2015 – 2016

Running : 2015 – 2020 (possibilities to use several sources)