FJPPL-Nu_2-WP3

R&D of detectors for future high statistics, high precision experiment

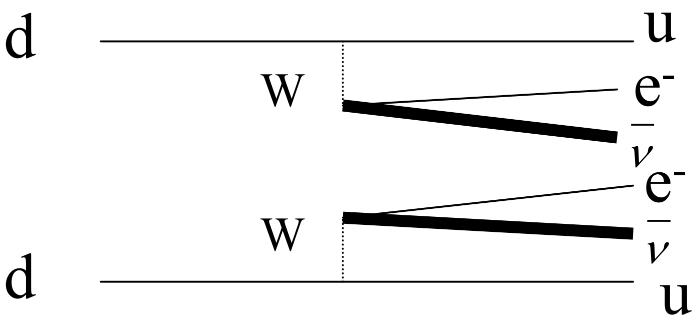
R&D for neutrinoless Double Beta Decay experiments

Nobuhiro ISHIHARA (KEK)

Contents

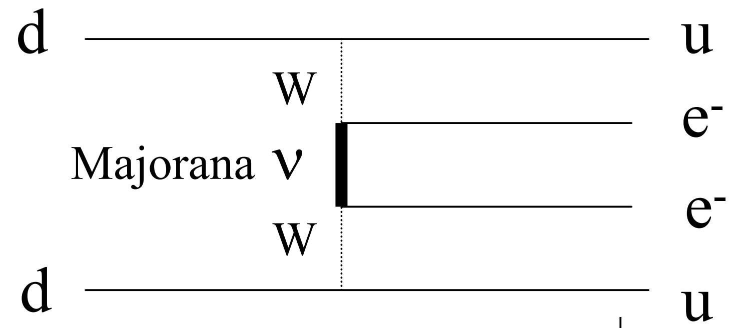
Double Beta Decay

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



0νββ: $(Z,A) \rightarrow (Z+2,A) + 2e^-$

Lepton number violation process

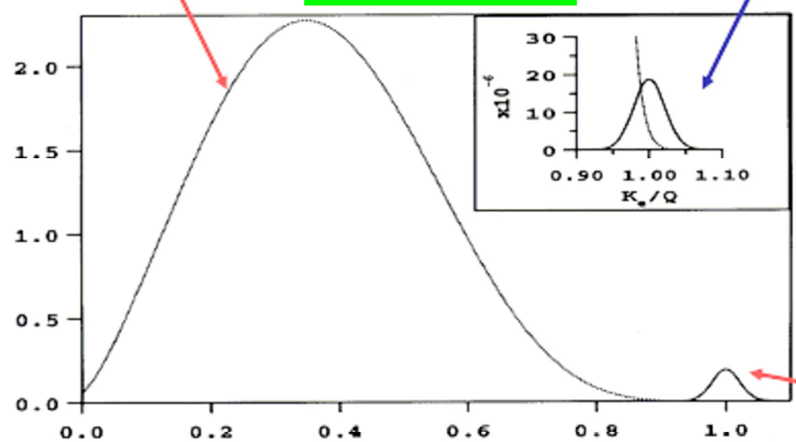


2νββ spectrum (normalized to 1)

$T_{1/2}^{2\nu} \approx 10^{19}$ y

0νββ peak (5% FWHM) (normalized to 10-6)

$T_{1/2}^{0\nu} \approx 10^{25}$ y



Summed electron energy in units of the kinematic endpoint (Q)

F. Piquemql

KEK, April 6, 2009

$T_{1/2}^{0\nu} \approx 10^{21}$ y

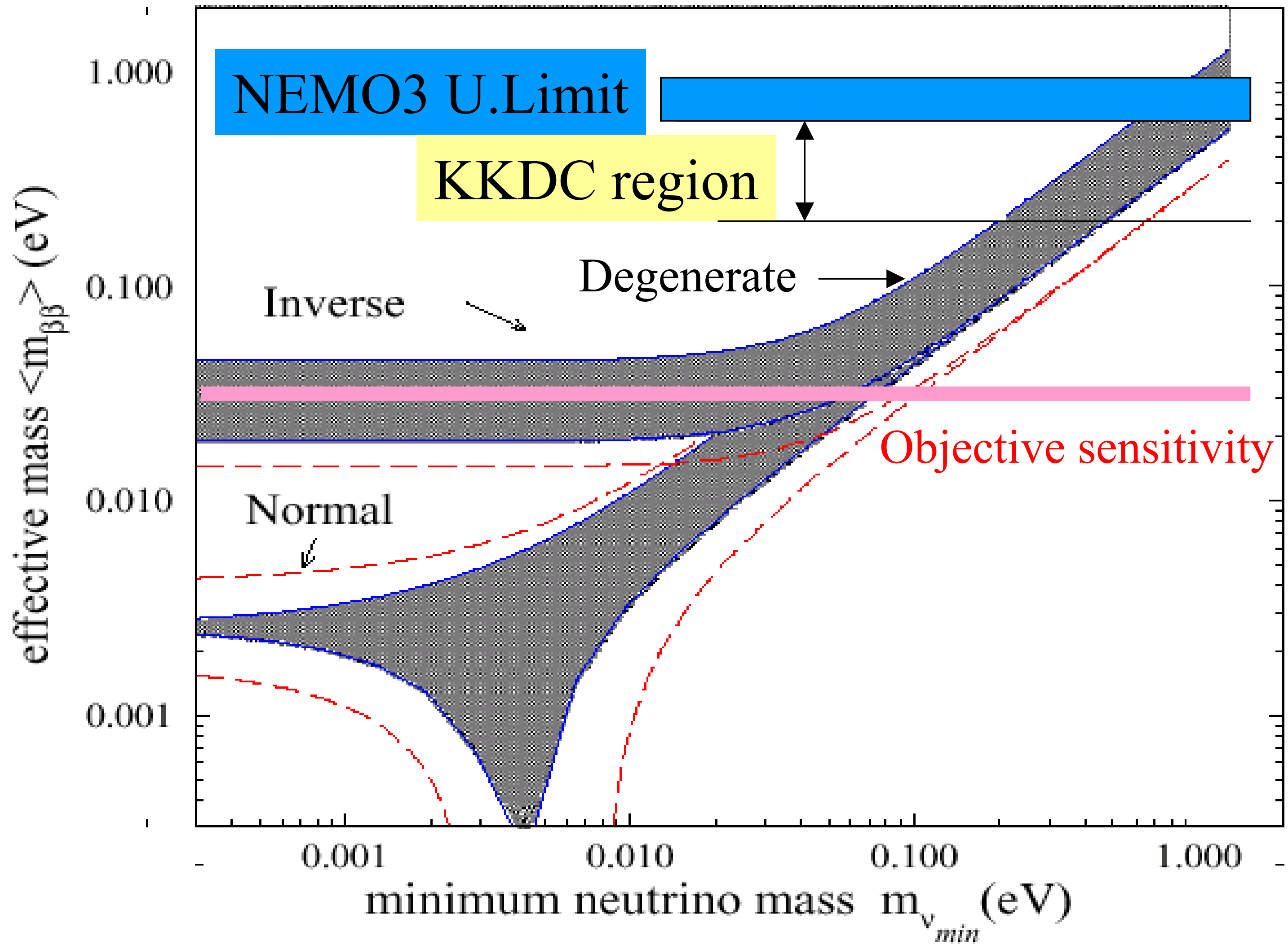
0νββ peak (5% FWHM) (normalized to 10-2)

$$(T_{1/2}^{0\nu})^{-1} = G^{0\nu} \left|M^{0\nu}\right|^2 < m_{\beta\beta} >^2$$

G: Phase volume,

M: Nuclear matrix element

Effective neutrino mass $<m_{\beta\beta}>$



FJPPL PROGRAM : Nu_2-WP3

R&D of detectors for future high statistics, high precision experiment

R&D for neutrinoless Double Beta Decay experiments

France NEMO3 & Super NEMO
NEMO: Neutrino Ettore Majorana Observatory
Leader F. Piquemal

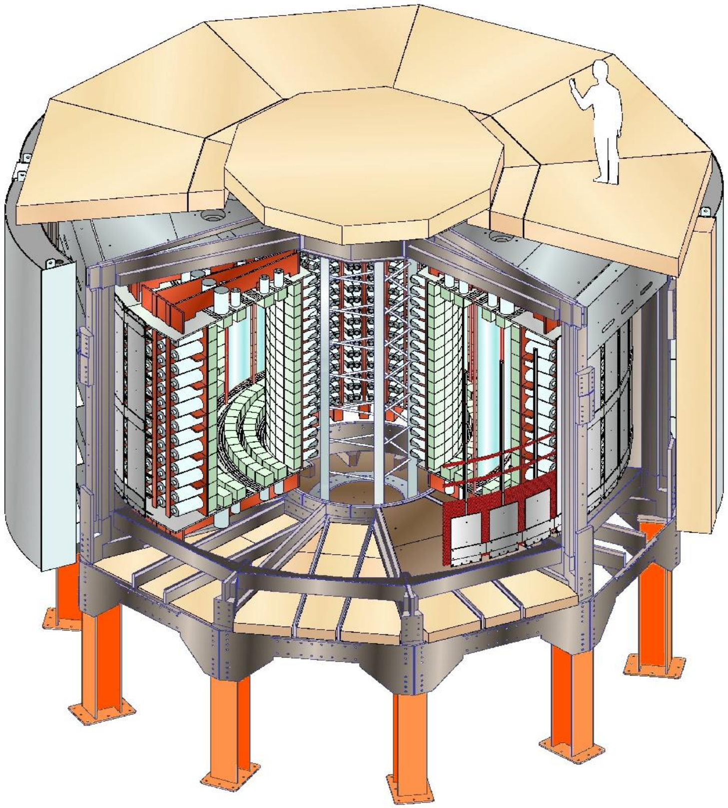
Japan DCBA & MTD
DCBA: Drift Chamber Beta-ray Analyzer
MTD: Magnetic Tracking Detector (temporary)
Leader Y. Yamada, Sub-leader N. Ishihara

The NEMO3 detector

F. Piquemql

April 6, 2009

Fréjus Underground Laboratory : 4800 m.w.e.



Source: 10 kg of ββ isotopes
cylindrical, S = 20 m², 60 mg/cm²

Tracking detector:
drift wire chamber operating in Geiger mode (6180 cells)
Gas: He + 4% ethyl alcohol + 1% Ar + 0.1% H_2O

Calorimeter:
1940 plastic scintillators coupled to low radioactivity PMTs

Magnetic field: 25 Gauss
Gamma shield: Pure Iron (18 cm)
Neutron shield: borated water + Wood

Background: natural radioactivity, mainly ^{214}Bi et ^{208}Tl (γ 2.6 MeV)Radon, neutrons (n,γ), muons, ββ(2ν)

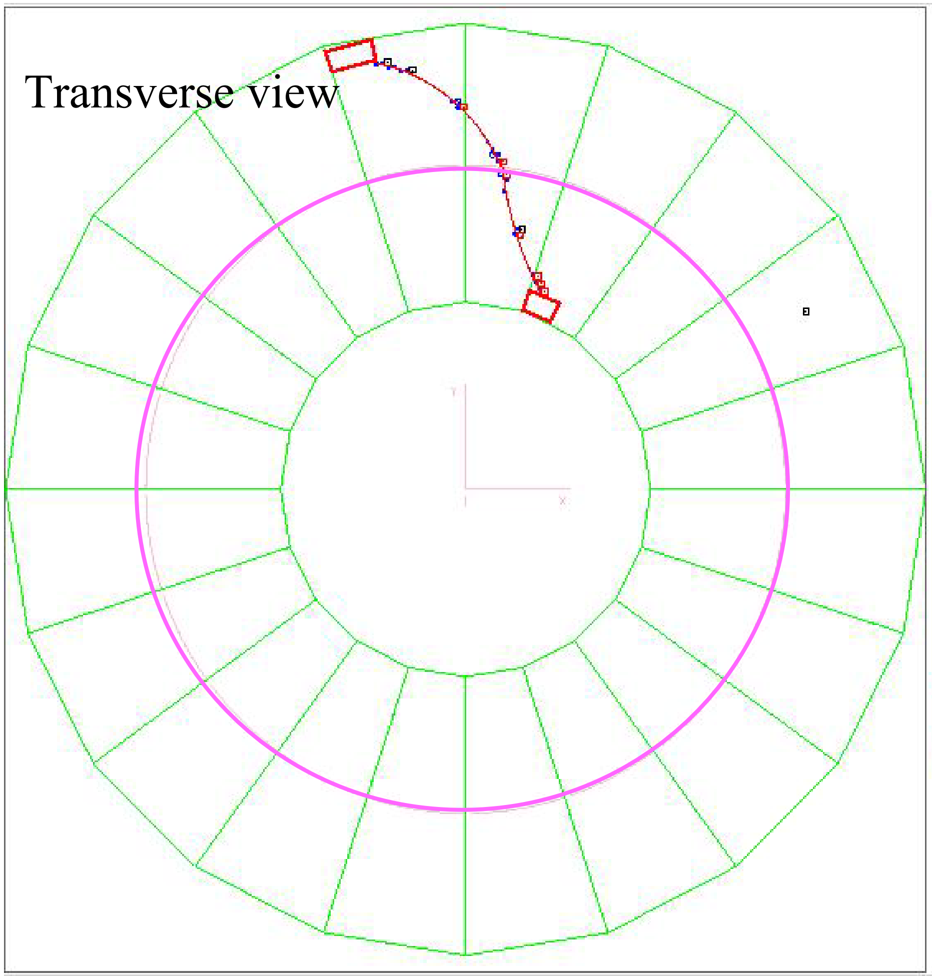
→ **Able to identify e^-, e^+, γ and α**

ββ events selection in NEMO-3

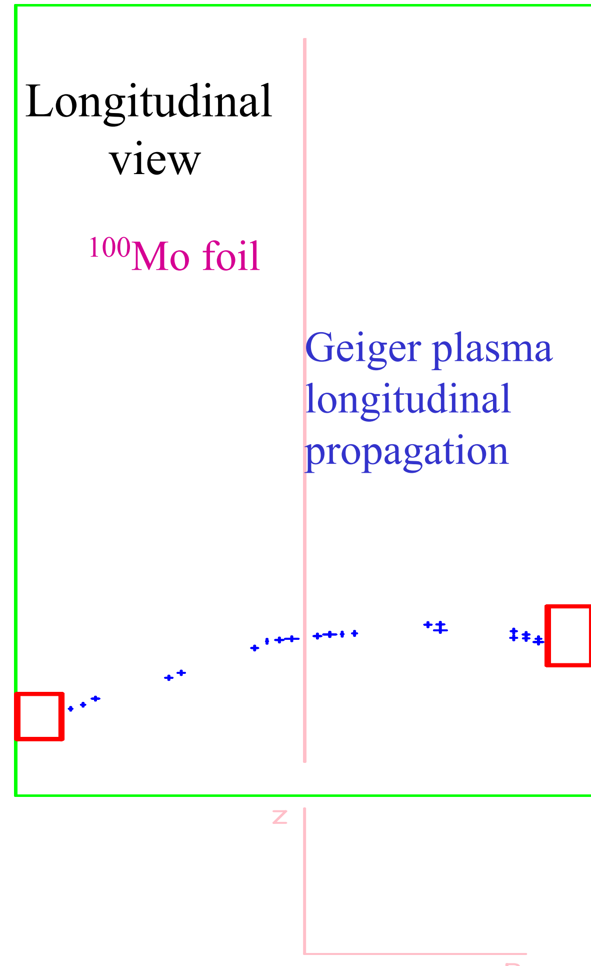
F. Piquemql

April 6, 2009

Typical ββ2ν event observed from ^{100}Mo

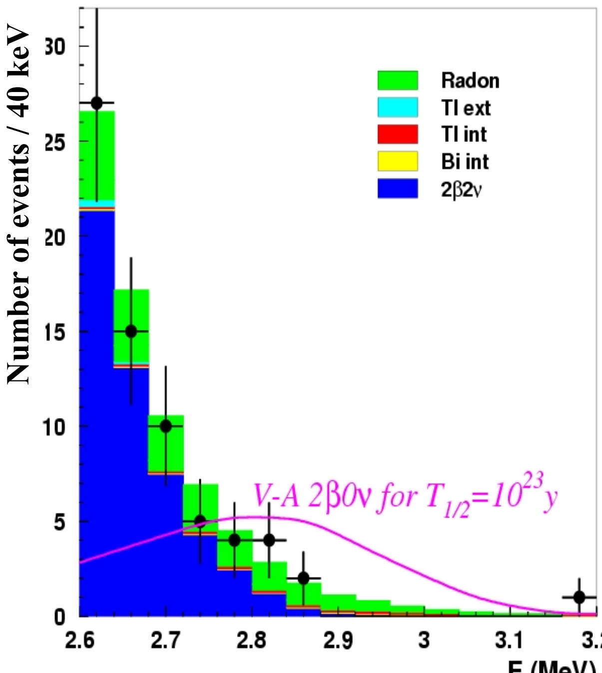


Top view



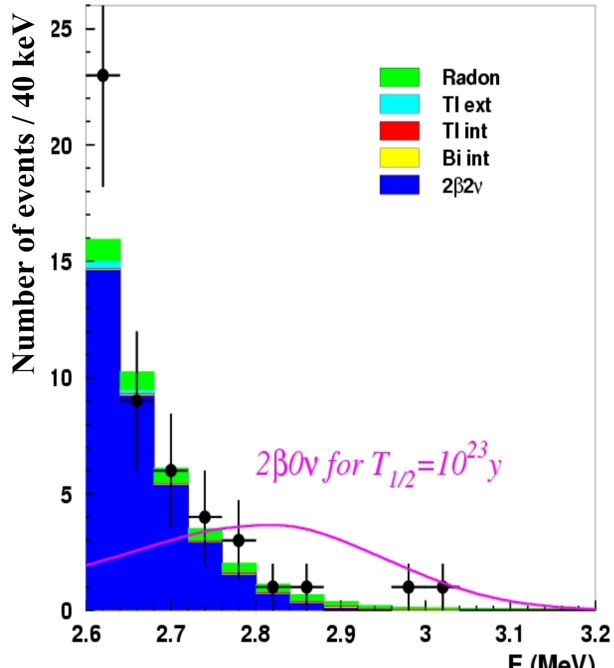
NEMO 3: ^{100}Mo ββ0ν results

Phase I, High radon
7.6 kg.yr



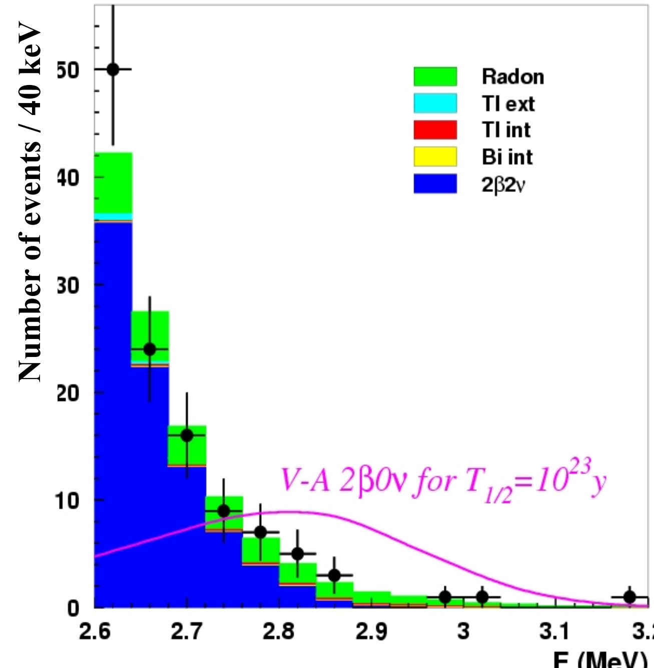
[2.8-3.2] MeV: ε(ββ0ν) = 8 %
Expected bkg = 8.1 events
$N_{observed}$ = 7 events

Phase II, Low radon
5.7 kg.yr



[2.8-3.2] MeV: ε(ββ0ν) = 8 %
Expected bkg = 3.0 events
$N_{observed}$ = 4 events

Phase I + II
13.3 kg.yr



[2.8-3.2] MeV: ε(ββ0ν) = 8 %
Expected bkg = 11.1 events
$N_{observed}$ = 11 events

Phases I + II $T_{1/2}(\beta\beta0\nu) > 5.8\ 10^{23}$ yr (90 % C.L.) $<m_\nu> < 0.6 – 1.3$ eV

Expected in 2010 $T_{1/2}(\beta\beta0\nu) > 2.\ 10^{24}$ yr (90 % CL) $<m_\nu> < 0.3 –0.7$ eV

From NEMO-3 to SuperNEMO… challenges

$$T_{1/2}(\beta\beta0\nu) > \ln 2 \times \frac{\mathcal{N}_A}{A} \times \frac{M \times \varepsilon \times T_{obs}}{N_{90}}$$

F. Piquemql

April 6, 2009

NEMO-3		SuperNEMO
^{100}Mo	isotope	^{150}Nd or ^{82}Se
	isotope mass M	
8 %	efficiency ε	~ 30 %
^{208}Tl: < 20 μBq/kg ^{214}Bi: < 300 μBq/kg	internal contaminations ^{208}Tl and ^{214}Bi in the ββ foil	^{208}Tl < 2 μBq/kg *if ^{82}Se*: ^{214}Bi < 10 μBq/kg
8% @ 3MeV	energy resolution (FWHM)	4% @ 3 MeV

NEMO-3	SuperNEMO
$T_{1/2}(\beta\beta0\nu) > 2 \times 10^{24}$ y $\langle m_\nu \rangle < 0.3 – 1.3$ eV	$T_{1/2}(\beta\beta0\nu) > 2 \times 10^{26}$ y $\langle m_\nu \rangle < 50$ meV

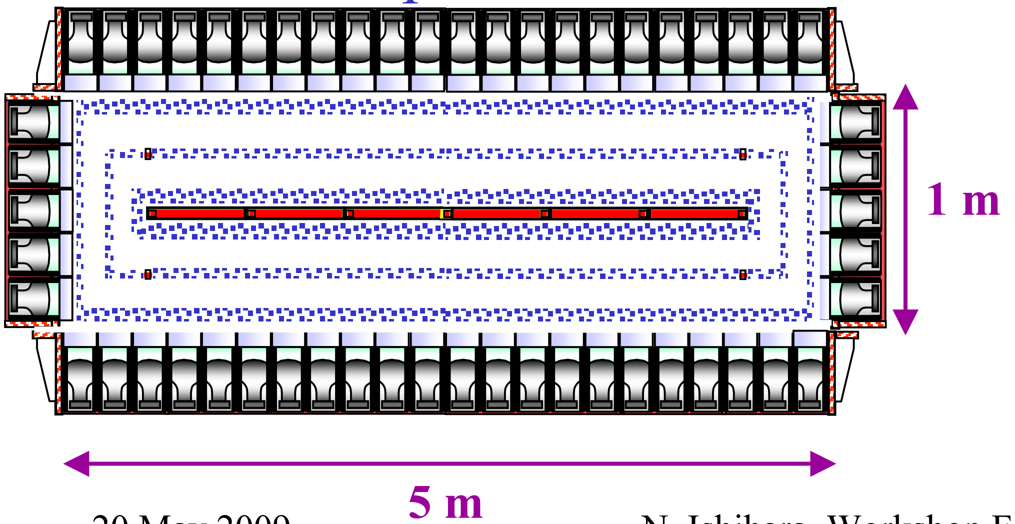
SuperNEMO conceptual design

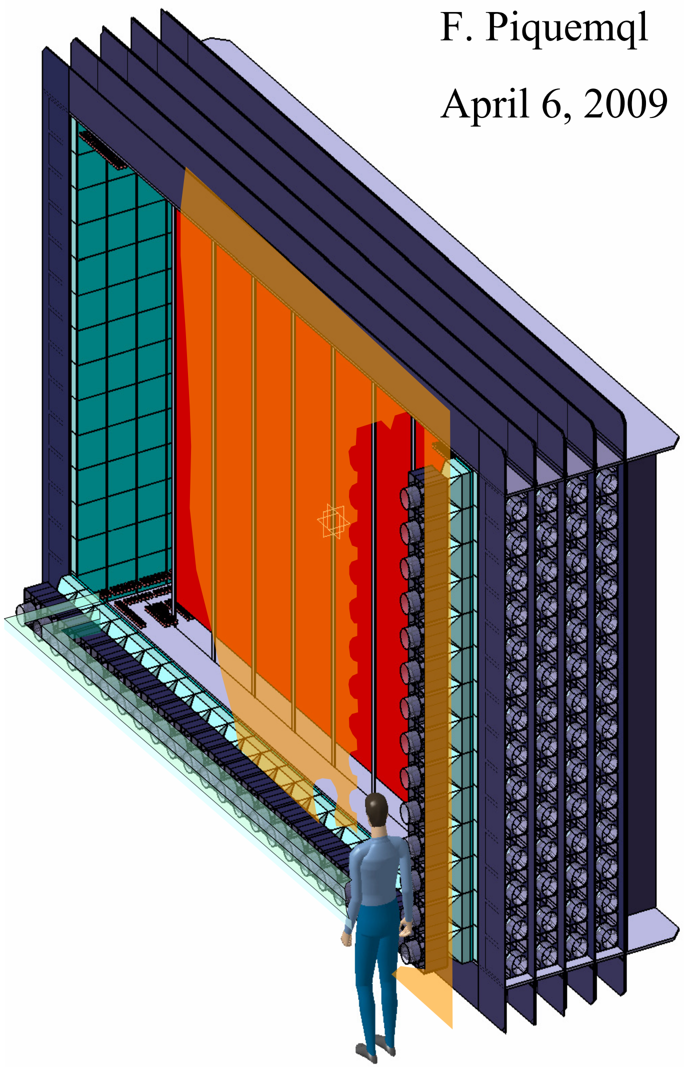
20 modules for 100 kg

Source (40 mg/cm^2) 12m^2
Tracking (~2-3000 Geiger cells).
Calorimeter (600 channels)

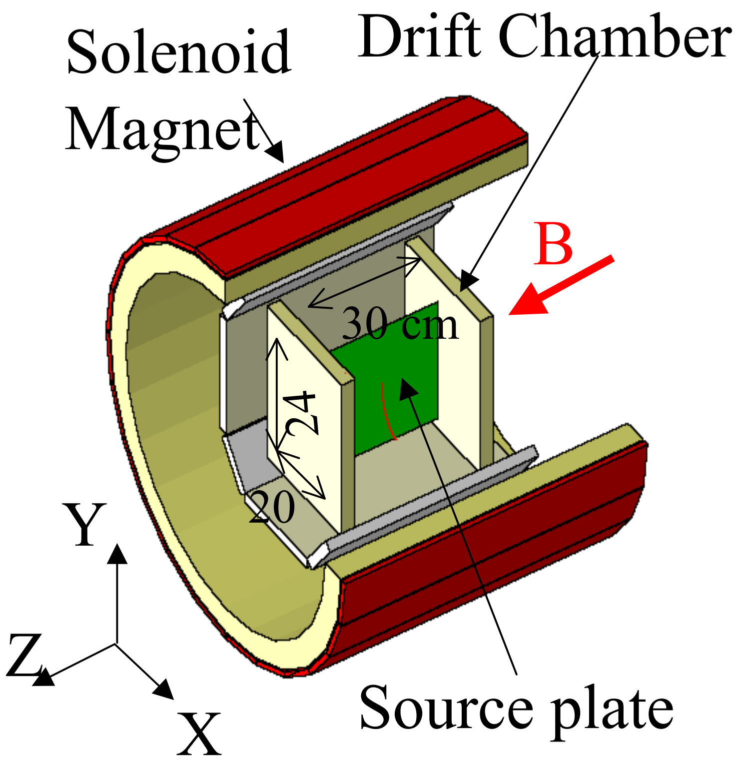
Total:~ 40 000 - 60 000 geiger cells
~ 12 000 PM

Top view



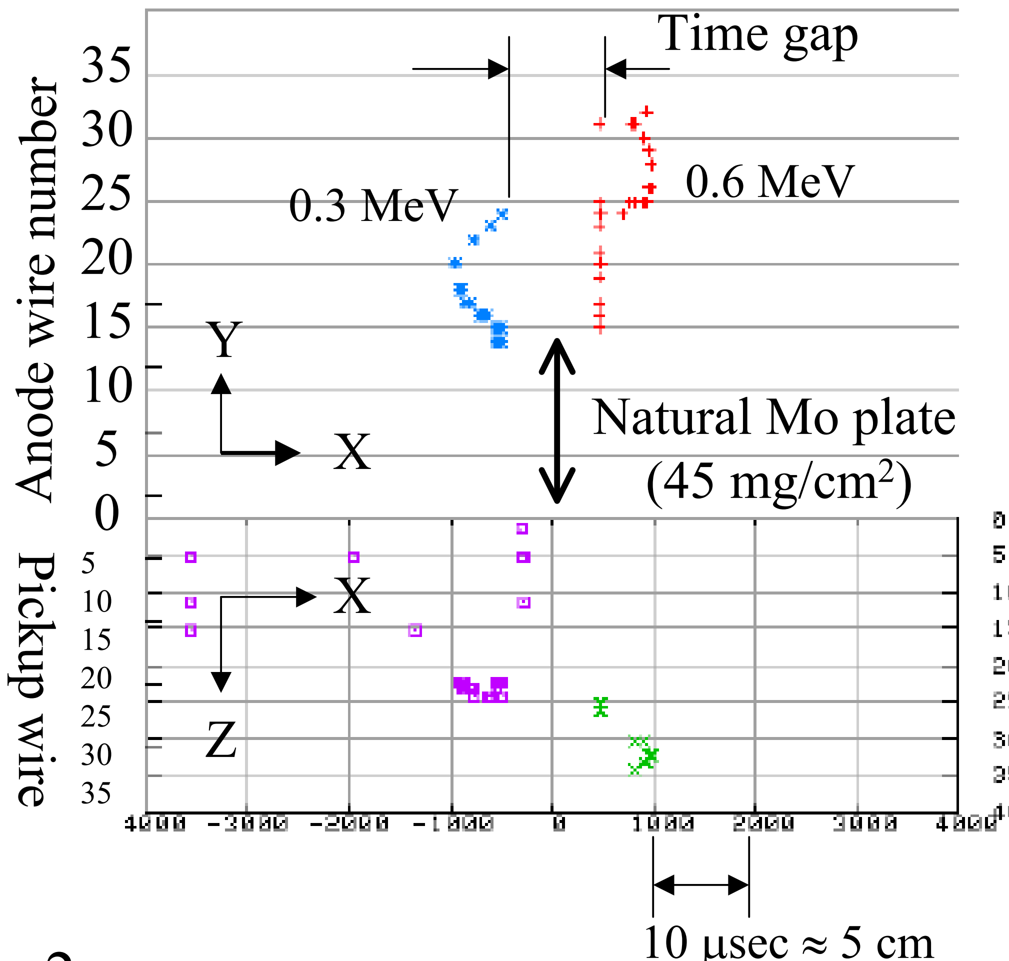


DCBA-T2



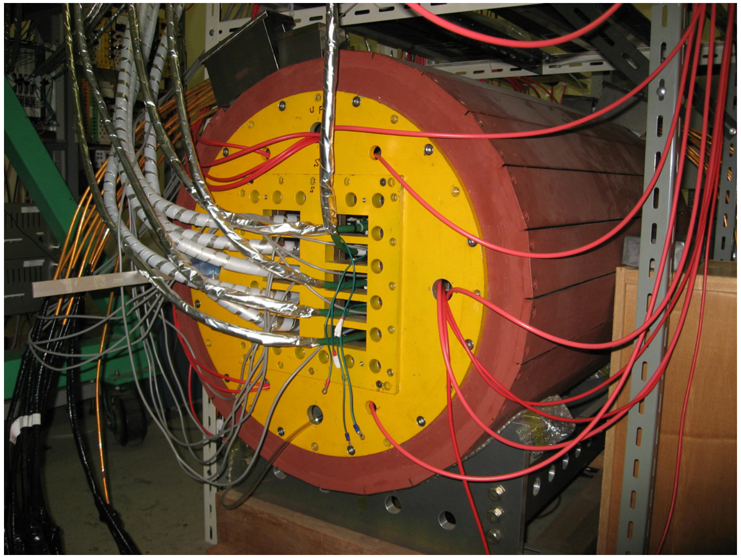
Sensitive volume
(X×Y×Z) = (10×24×30)cm^3 ×2

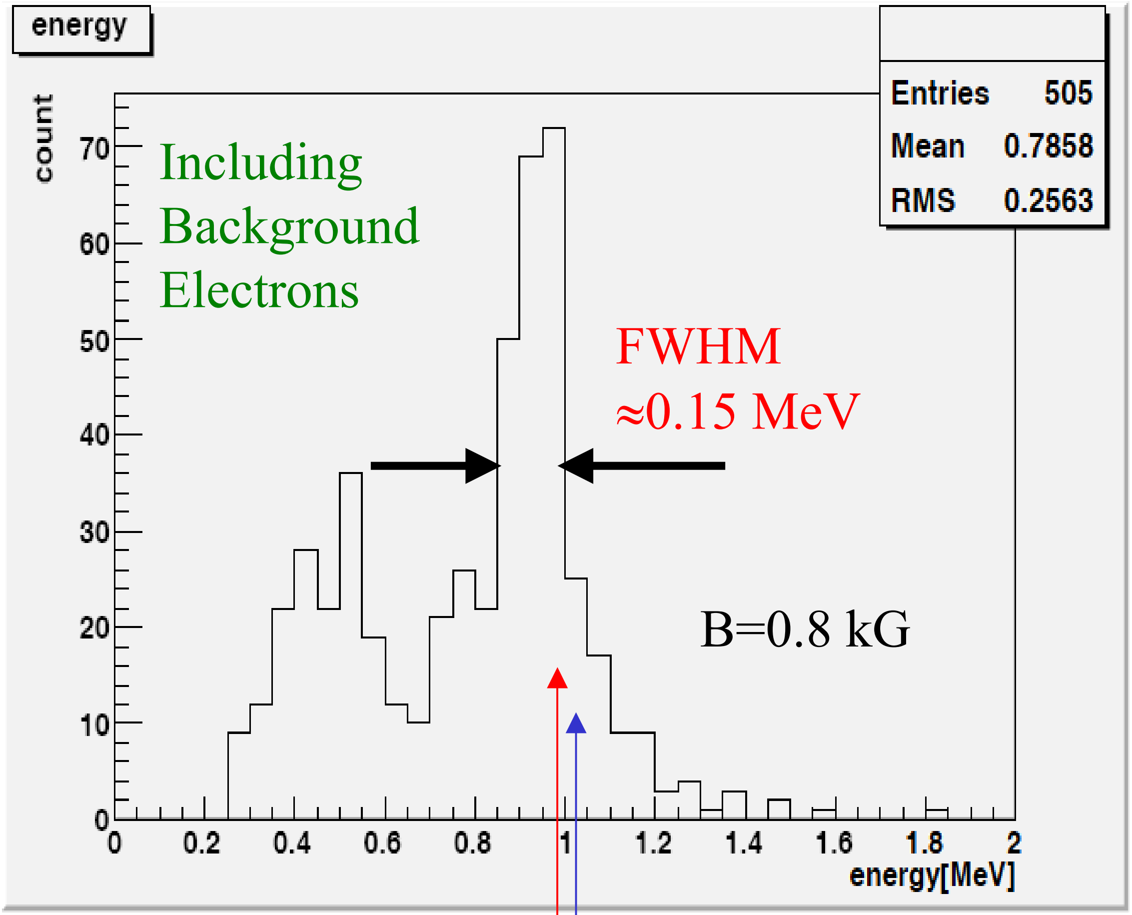
Back-to-back event (Candidate of 2νββ)



DCBA-T2

Energy spectra of conversion electrons from ^{207}Bi

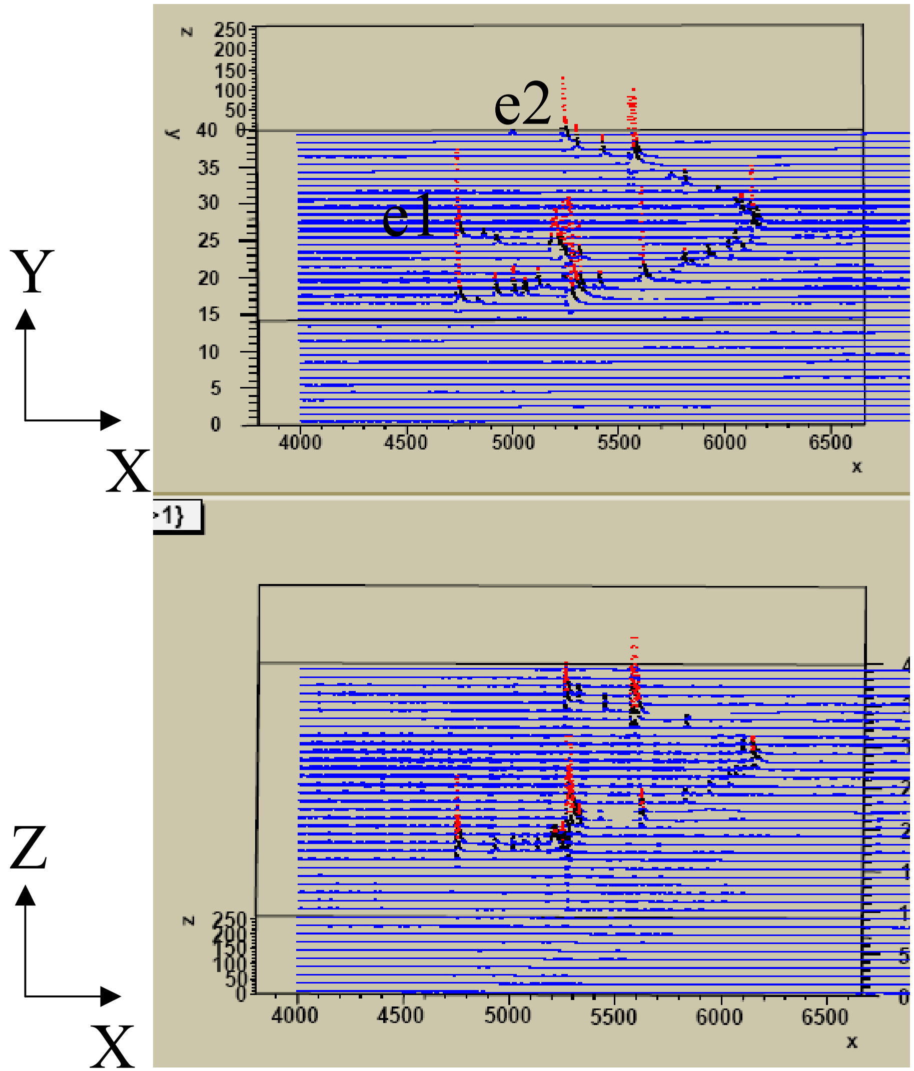


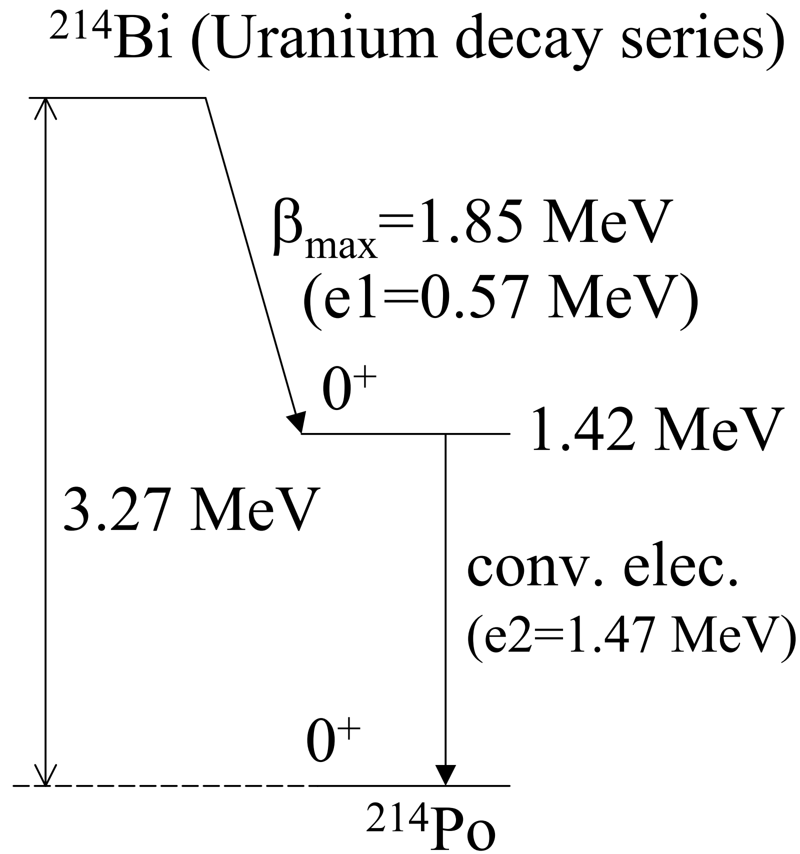


Resolution corresponding to the sum energy of two β's.

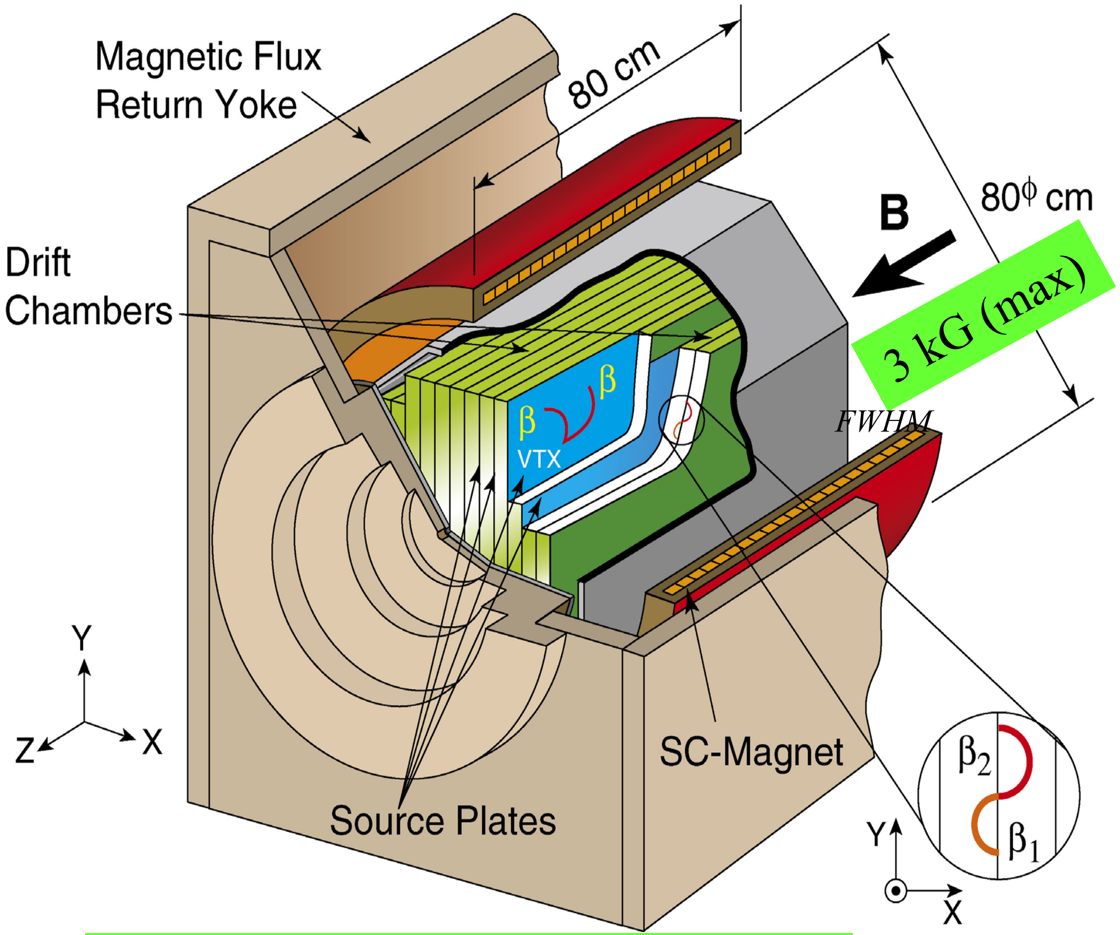
$$\frac{\mathrm{FWHM}(E_{sum})}{Q_{^{150}Nd}(3.37\ \mathrm{MeV})} \approx 6.2\%$$

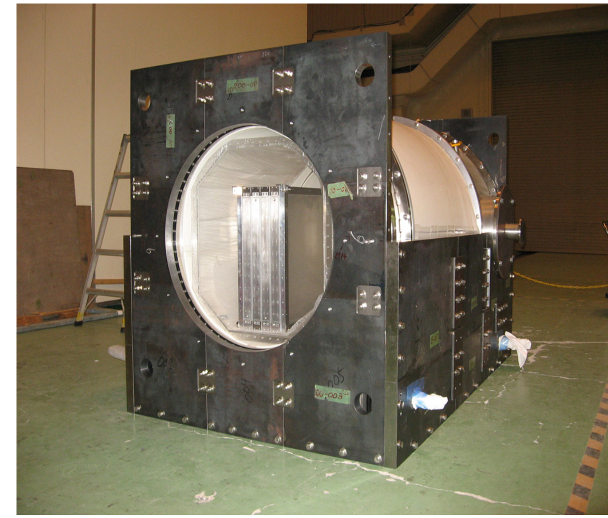
Background 2-electron event

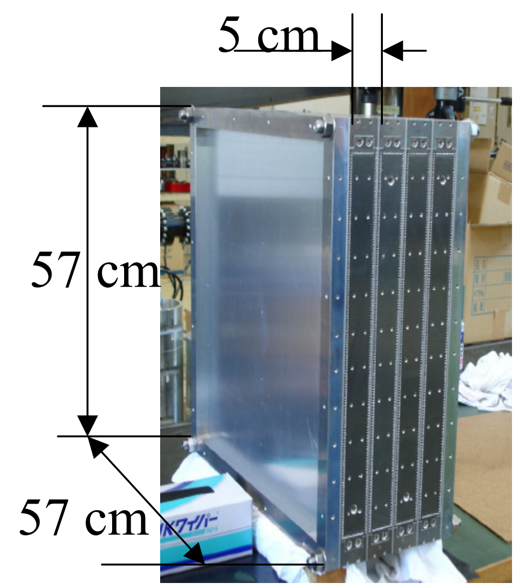




DCBA-T3
(under construction)

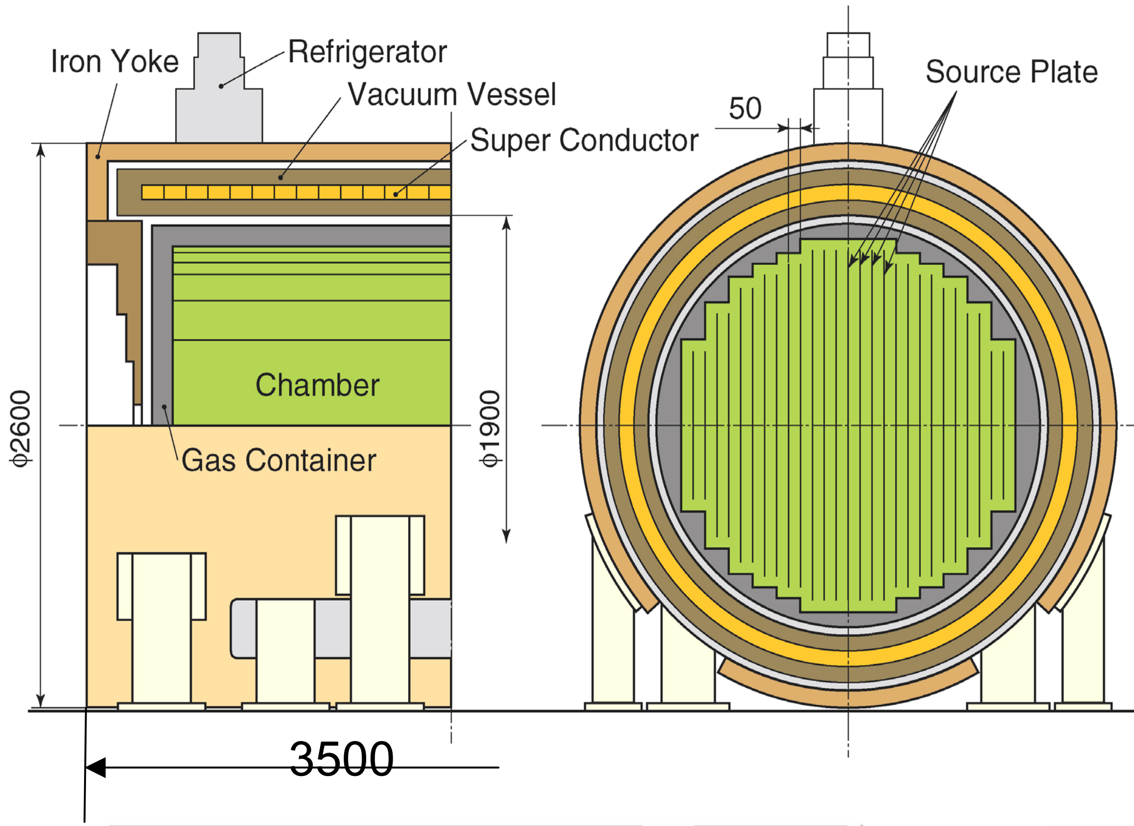






FWHM ≤ 100 keV around 2 MeV

Wire pitch = 3 mm



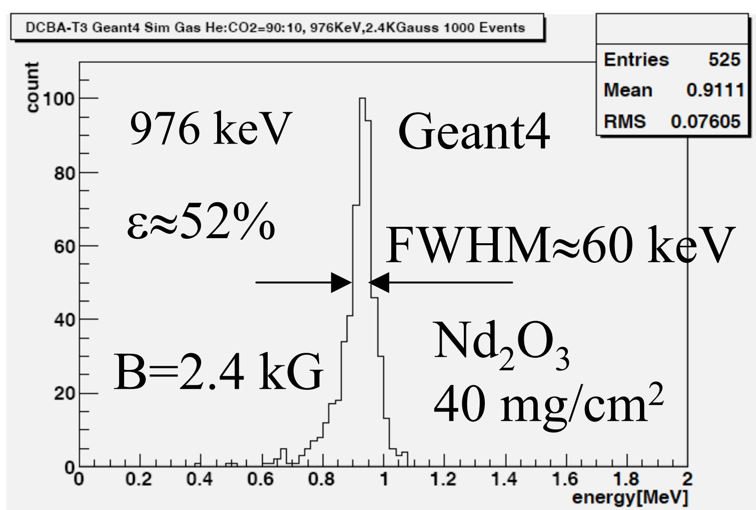
MTD

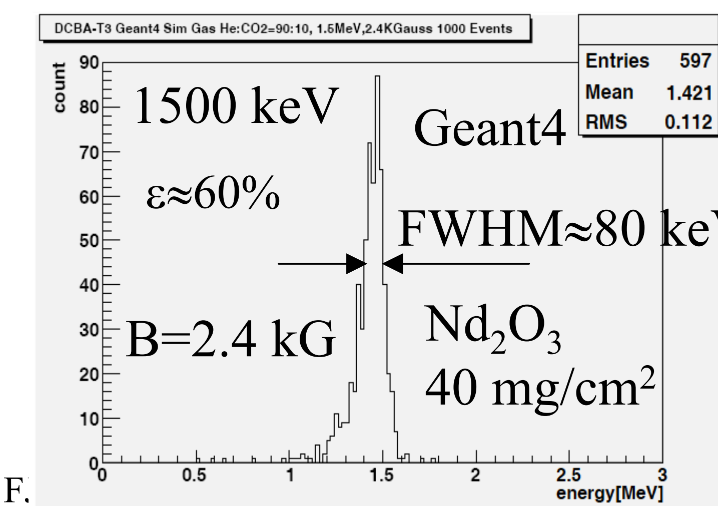
Magnetic **T**racking **D**etector
(based on **DCBA-T3**)

Expected Energy Resolution

$$\frac{\mathrm{FWHM}\,(E_{sum})}{Q_{^{150}\mathrm{Nd}}\,(3.37\,\mathrm{MeV})} \leq 5\%$$

Source area: 80 m^2/module
40 mg/cm^2 → 32 kg/module





Vorkshop F.

Concluding remarks

1. If neutrinos are Majorana particles, neutrinoless double beta decay (0νββ) takes place.
2. The half-life of 0νββ gives us the absolute mass scale of neutrino.
3. The R&D's with NEMO3 and DCBA are aiming at the constructions of future detectors SuperNEMO and MTD (temporary name), respectively, which will have the sensitivity of effective neutrino mass $<m_{\beta\beta}>$ down to 30 meV.
4. Both detectors have tracking devices, which are very useful to eliminate background events.
5. The information of tracking and background elimination will be actively exchanged between two groups in FJPPL.