Japan-US seminar on

Double Beta Decay and Neutrinos

Status of the **DCBA** Experiment

DCBA: **D**rift **C**hamber **B**eta-ray **A**nalyzer

Nobu ISHIHARA (KEK)

for the DCBA collaboration

Contents

1. Introduction to DCBA
2. DCBA-T2 in engineering run
3. DCBA-T3 under construction
4. Future prospect of DCBA/MTD

Introduction to DCBA

Momentum analyzers to study

- Majorana nature by searching for $0\nu\beta\beta$
- Effective neutrino mass by measuring $T_{1/2}^{0\nu}$

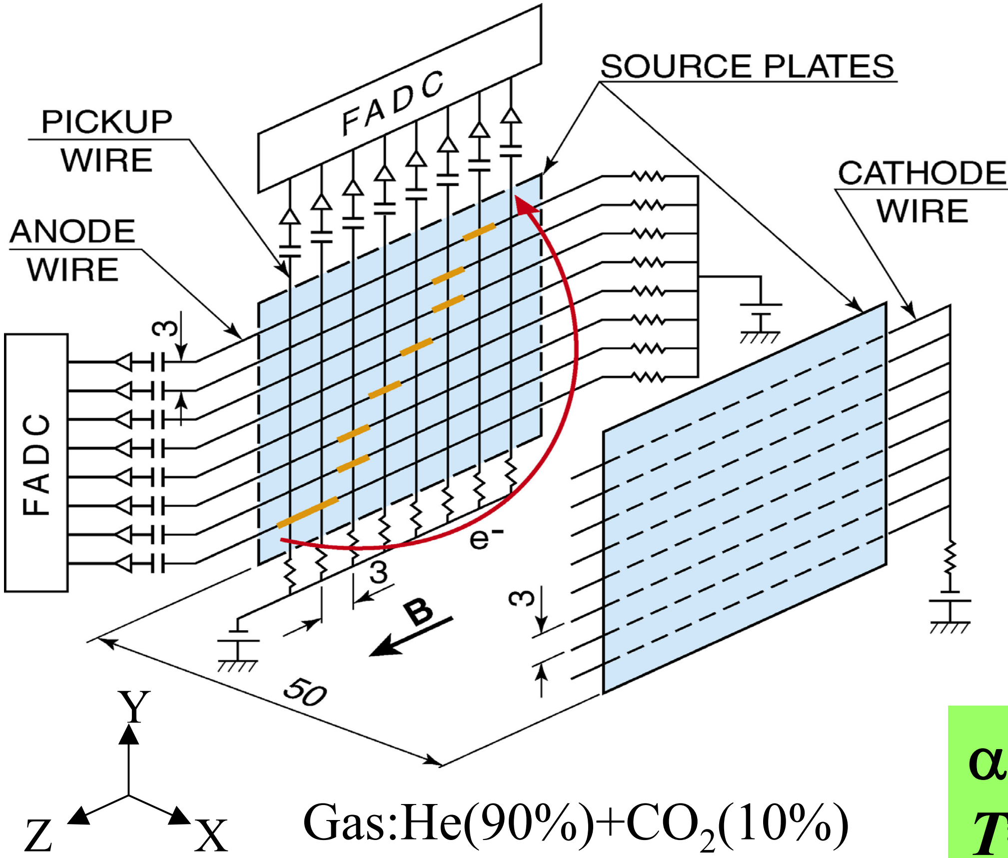
Advantage of DCBA

- Background elimination by particle ID
- Characteristic pattern of $\beta\beta$ in a magnetic field
- Decay vertex determination
- Energy measurement of individual β (e^-)
- Angular correlation between $\beta\beta$

Disadvantage

- Energy resolution (FWHM≈100 keV) worse than Ge and Te calorimeter
- Low detection efficiency (≈30%)
- Large space for decay source installation

Principle of electron detection in DCBA



Gas:He(90%)+CO_2(10%)

Momentum Acceptance

$\boldsymbol{p}$(MeV/c)=0.3$\boldsymbol{r}$(cm)$\boldsymbol{B}$(kG)

$\boldsymbol{B}\approx 2$ kG

2 cm < $\boldsymbol{r}$ < 5 cm

$\Downarrow$

1.2 MeV/c < $\boldsymbol{p}$ < 3 MeV/c

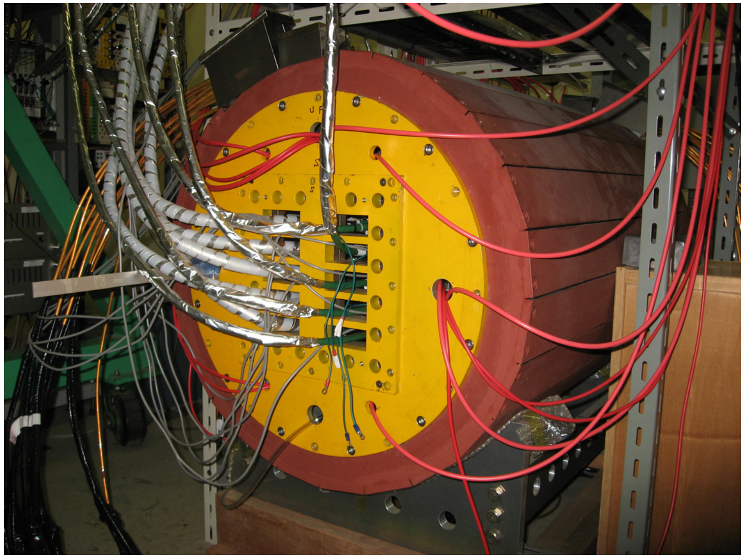
Energy Acceptance for e^-

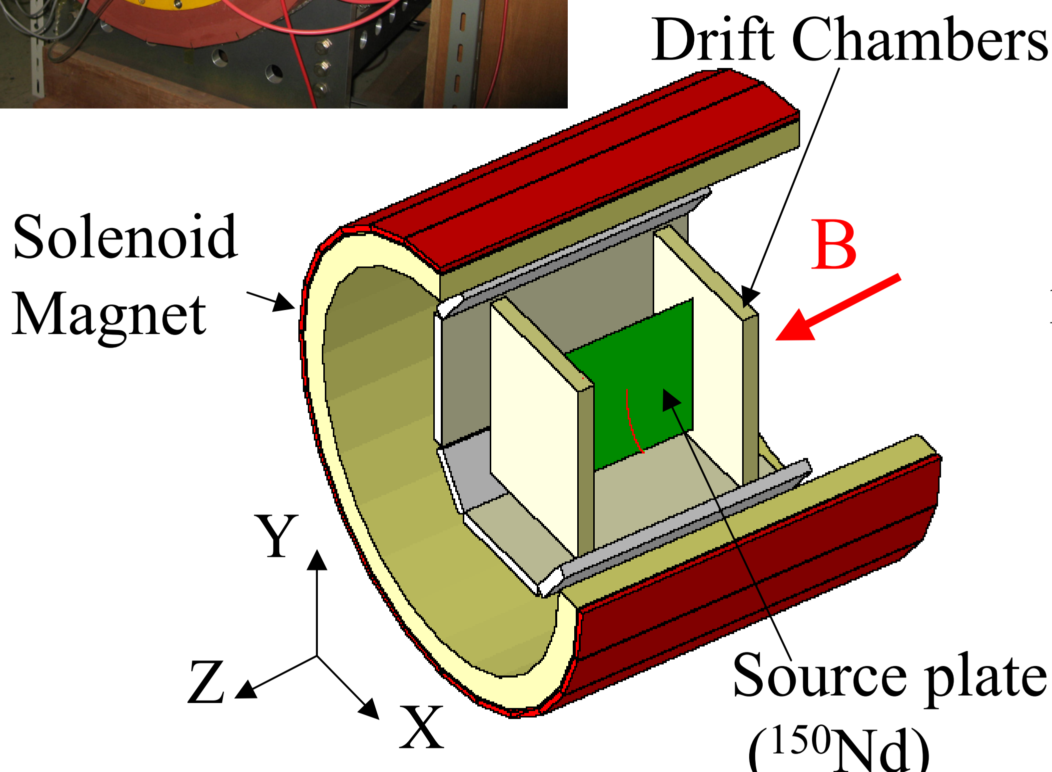
0.8 MeV < $\boldsymbol{T}$ < 2.5 MeV

α is automatically rejected

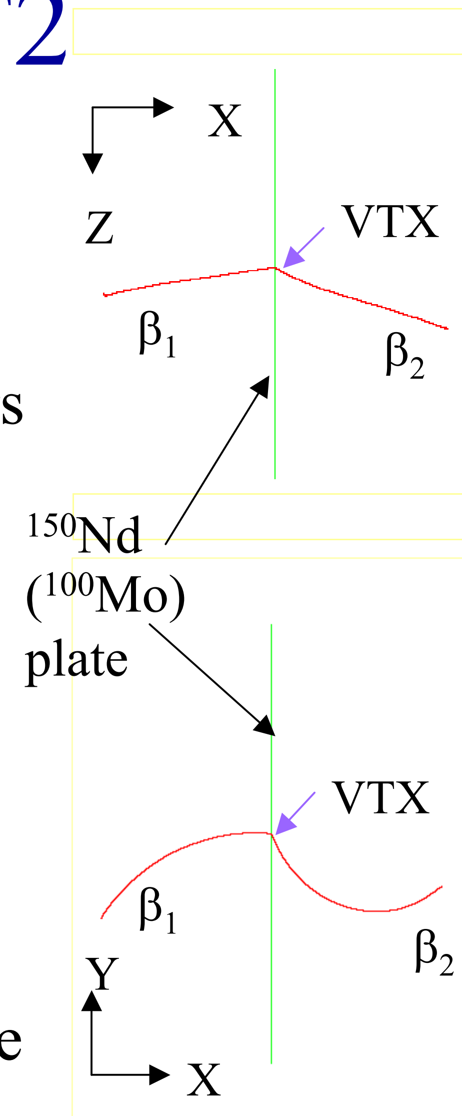
$\boldsymbol{T}$=1 MeV $\rightarrow$ $\boldsymbol{p}\approx$ 87 MeV/c

DCBA-T2



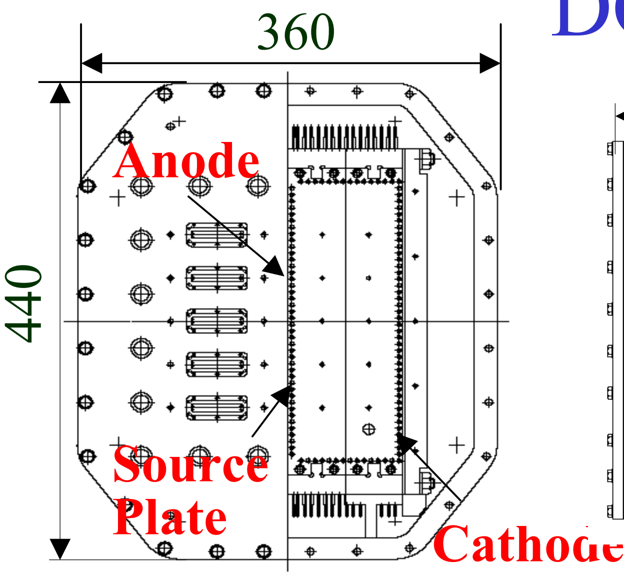


Drift Chambers
Solenoid Magnet
B
Y
Z
X
Source plate (^{150}Nd)

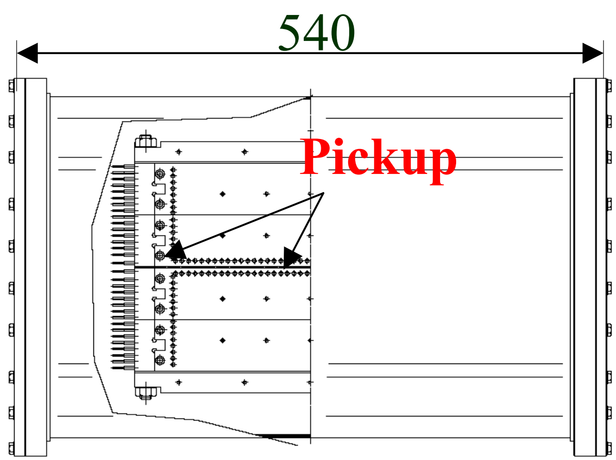


X
Z
VTX
β_1
β_2
^{150}Nd (^{100}Mo) plate
VTX
β_1
β_2
Y
X

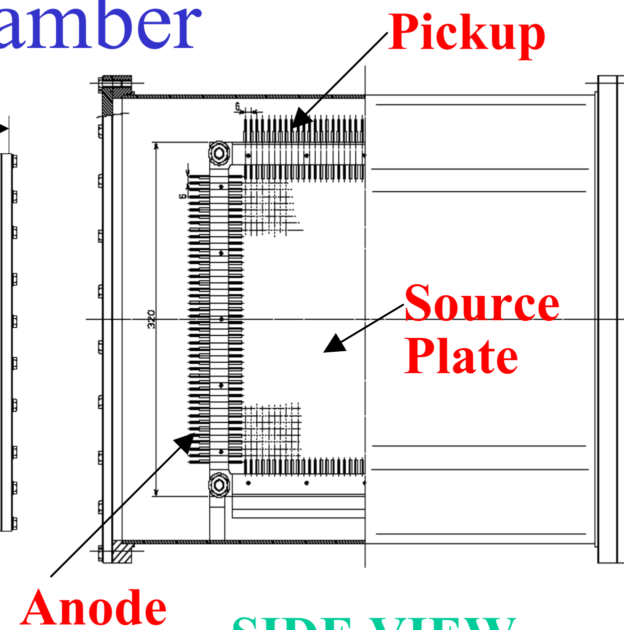
DCBA-T2 drift chamber



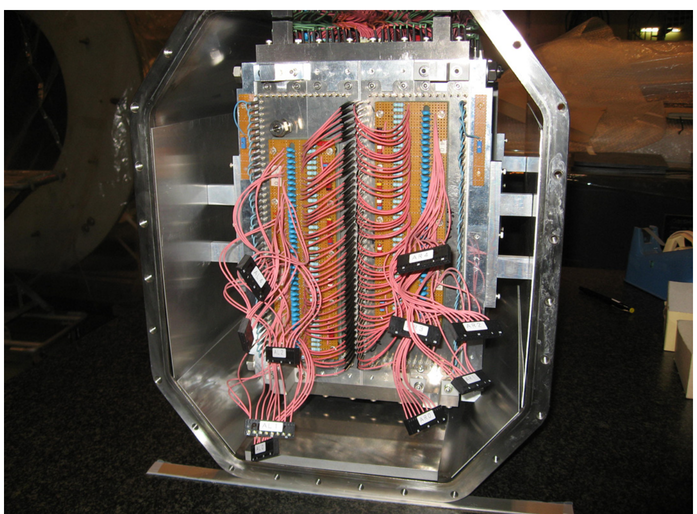
FRONT VIEW



TOP VIEW

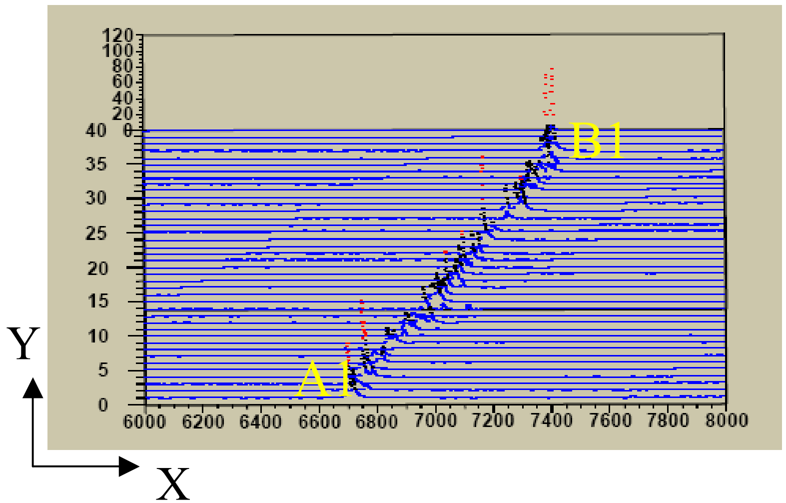


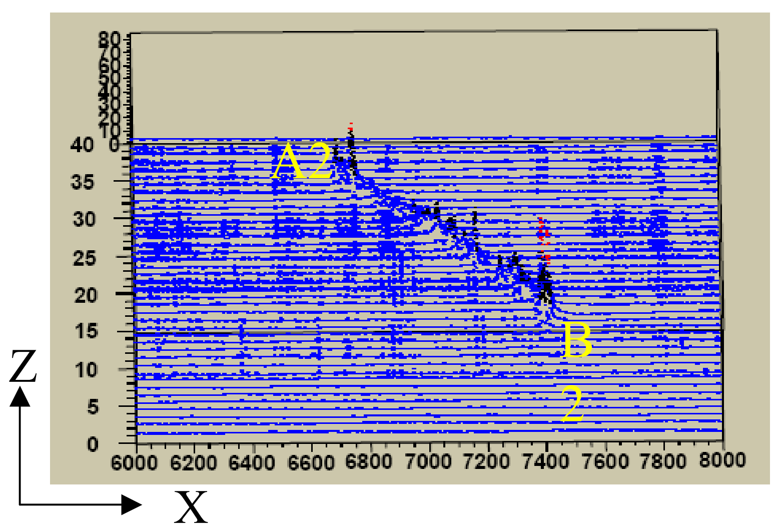
SIDE VIEW

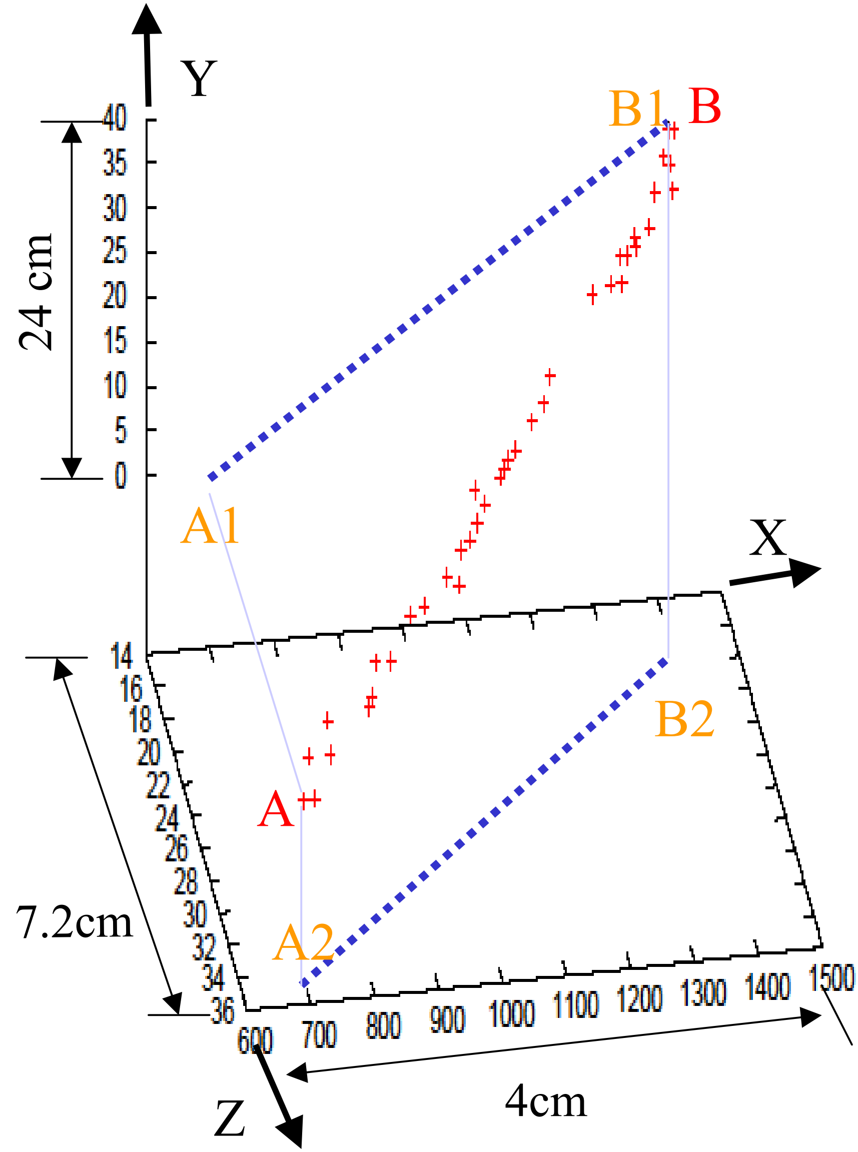


Sensitive vol.	:	18(x) × 24(y) × 24(z) [cm^3]
Gas	:	He (90%) + CO_2(10%)
Magnet	:	solenoid magnet 0.6 - 0.8 [kG]

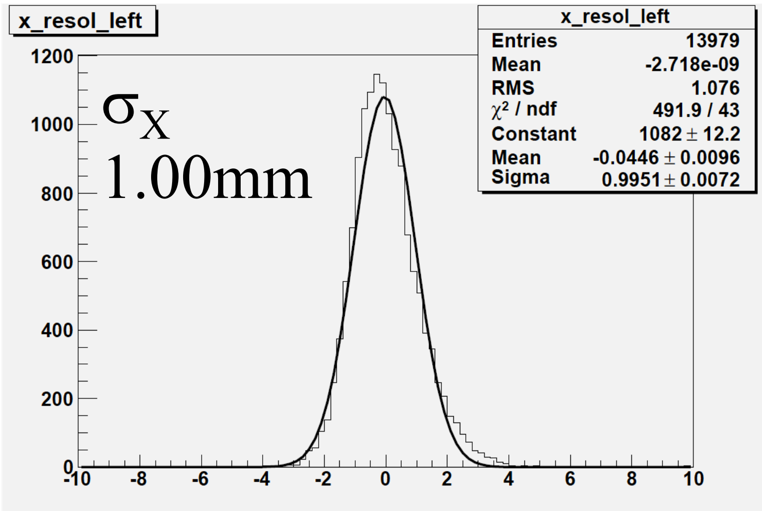
Straight track of a cosmic ray

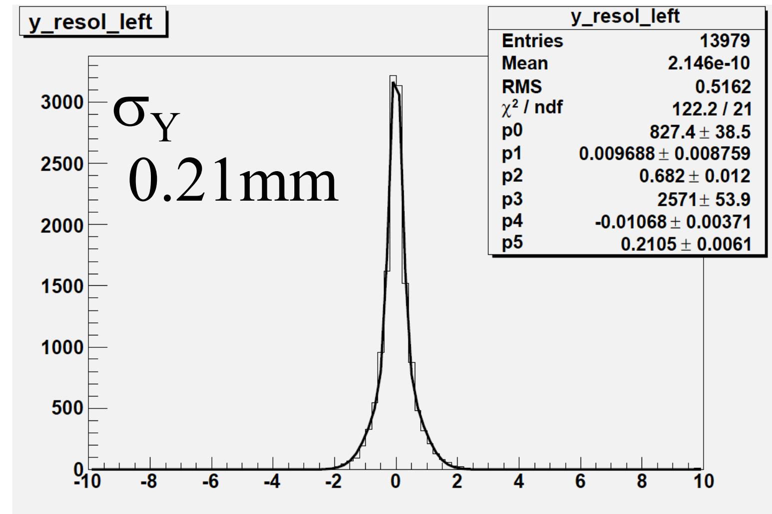


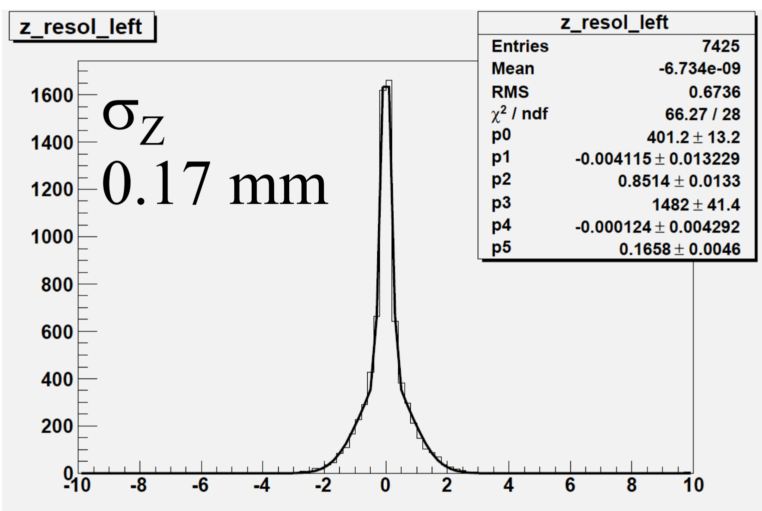


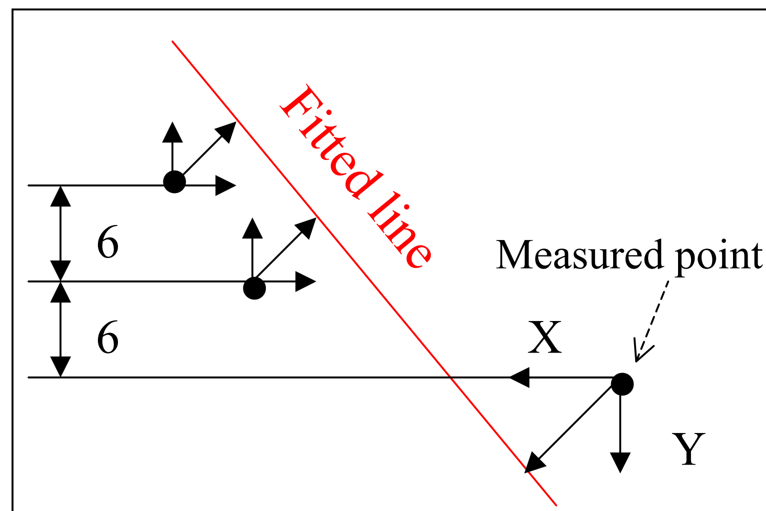


Position resolution of DCBA-T2

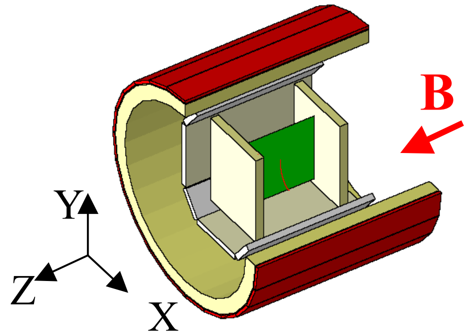


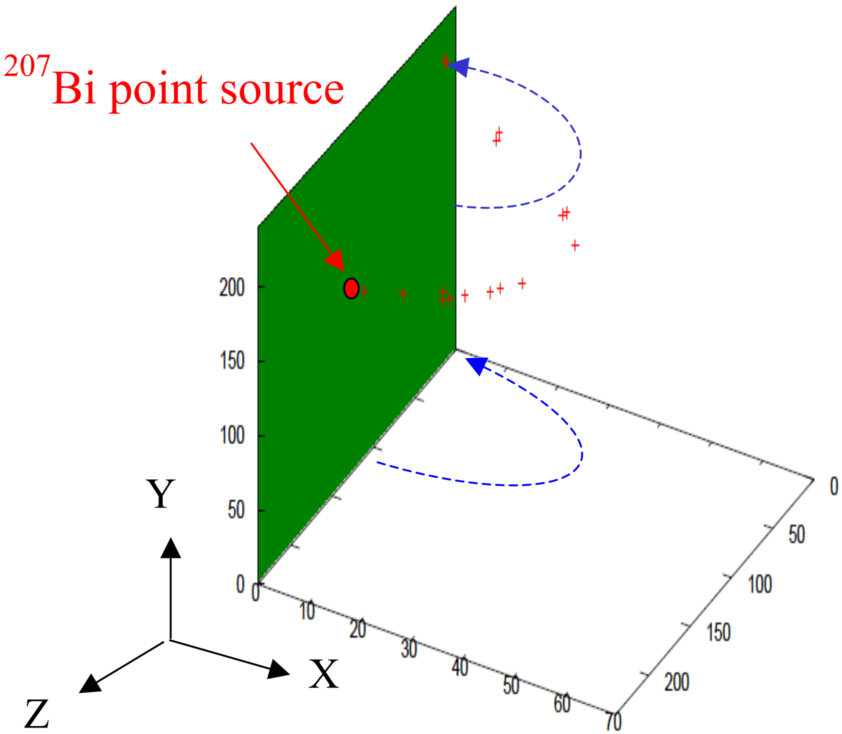




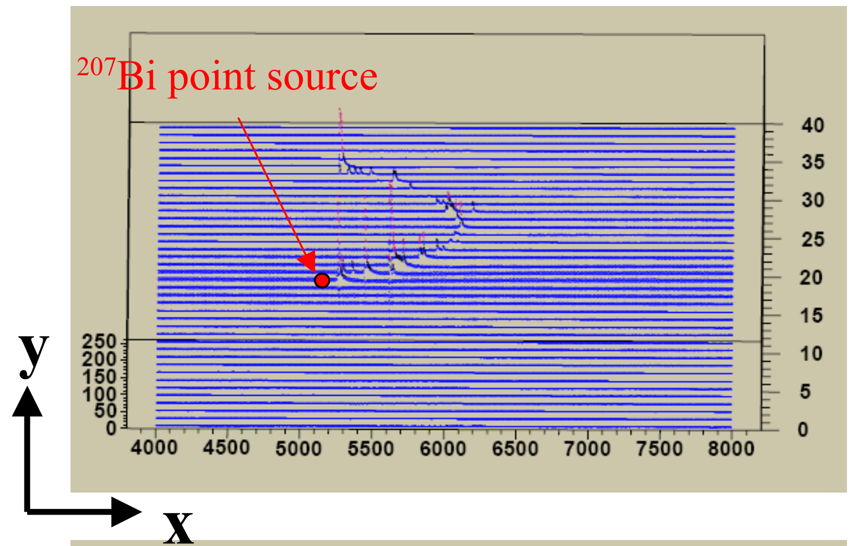


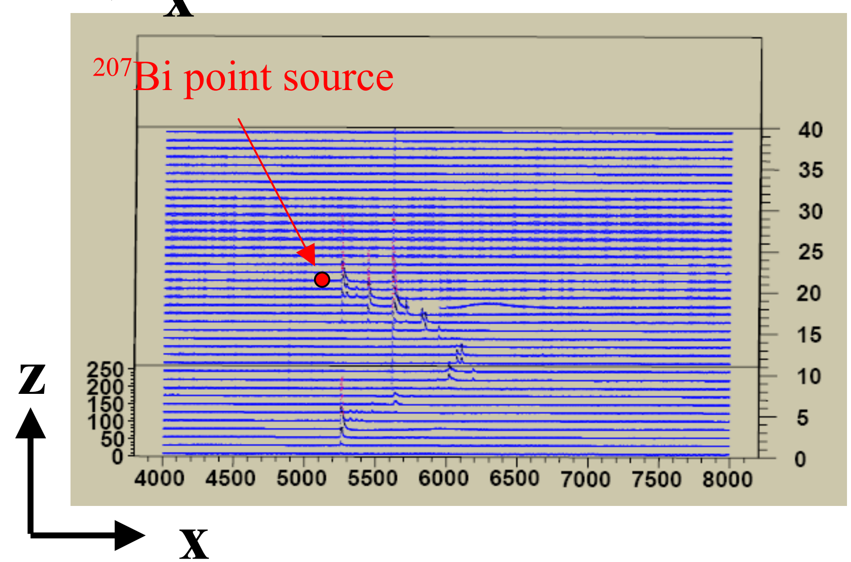
Energy measurement of an I. C. electron from ^{207}Bi





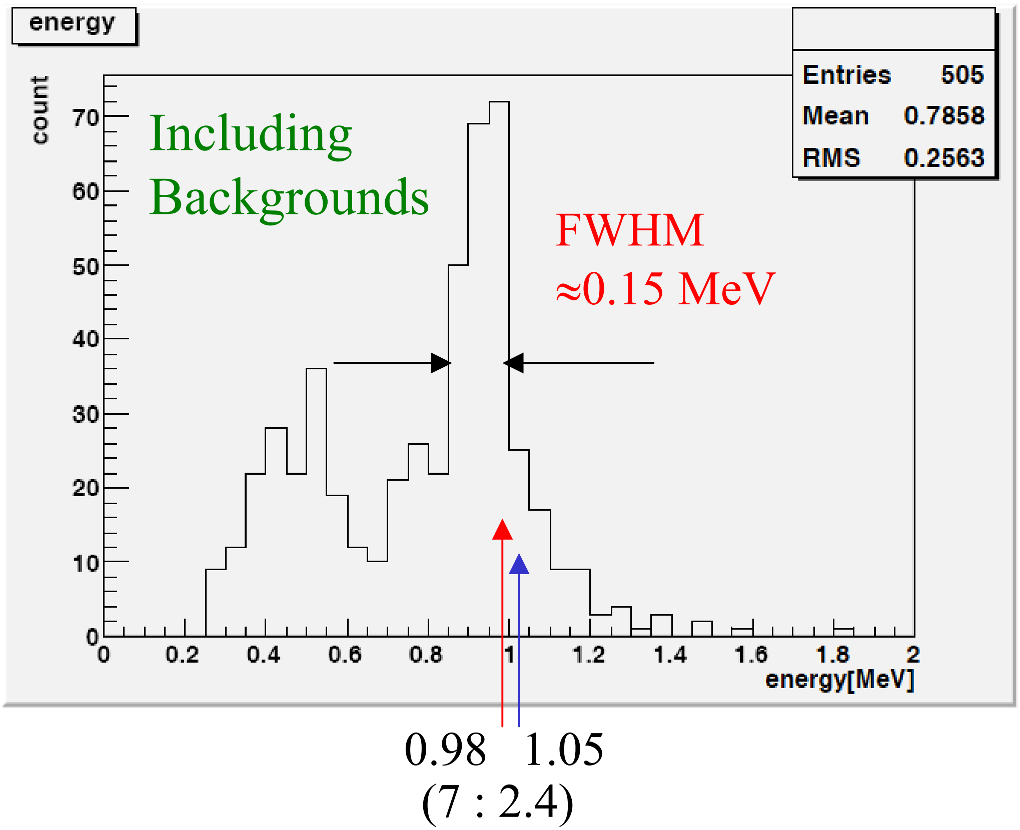
Energy = 1073keV

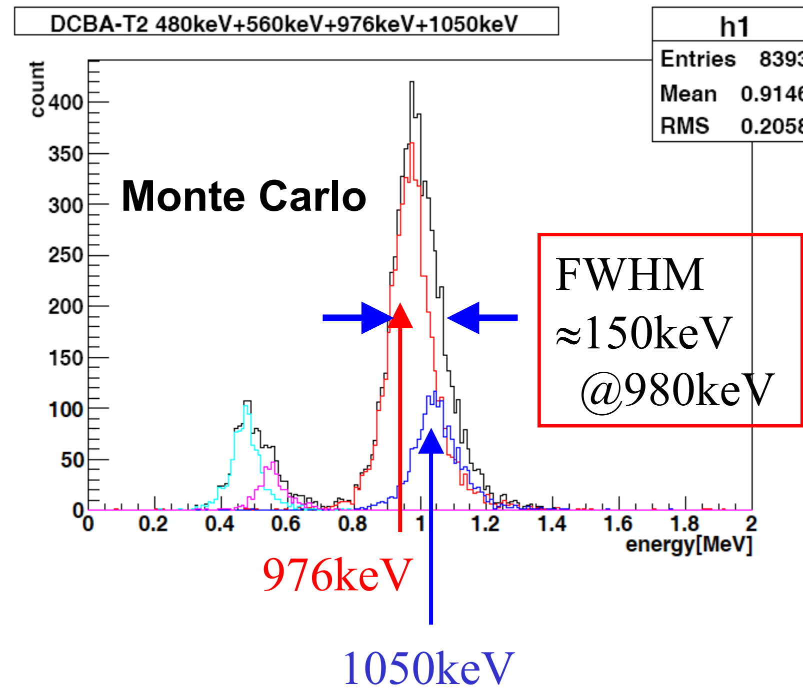




Energy resolution of DCBA-T2

Energy spectra of internal conversion electrons from ^{207}Bi

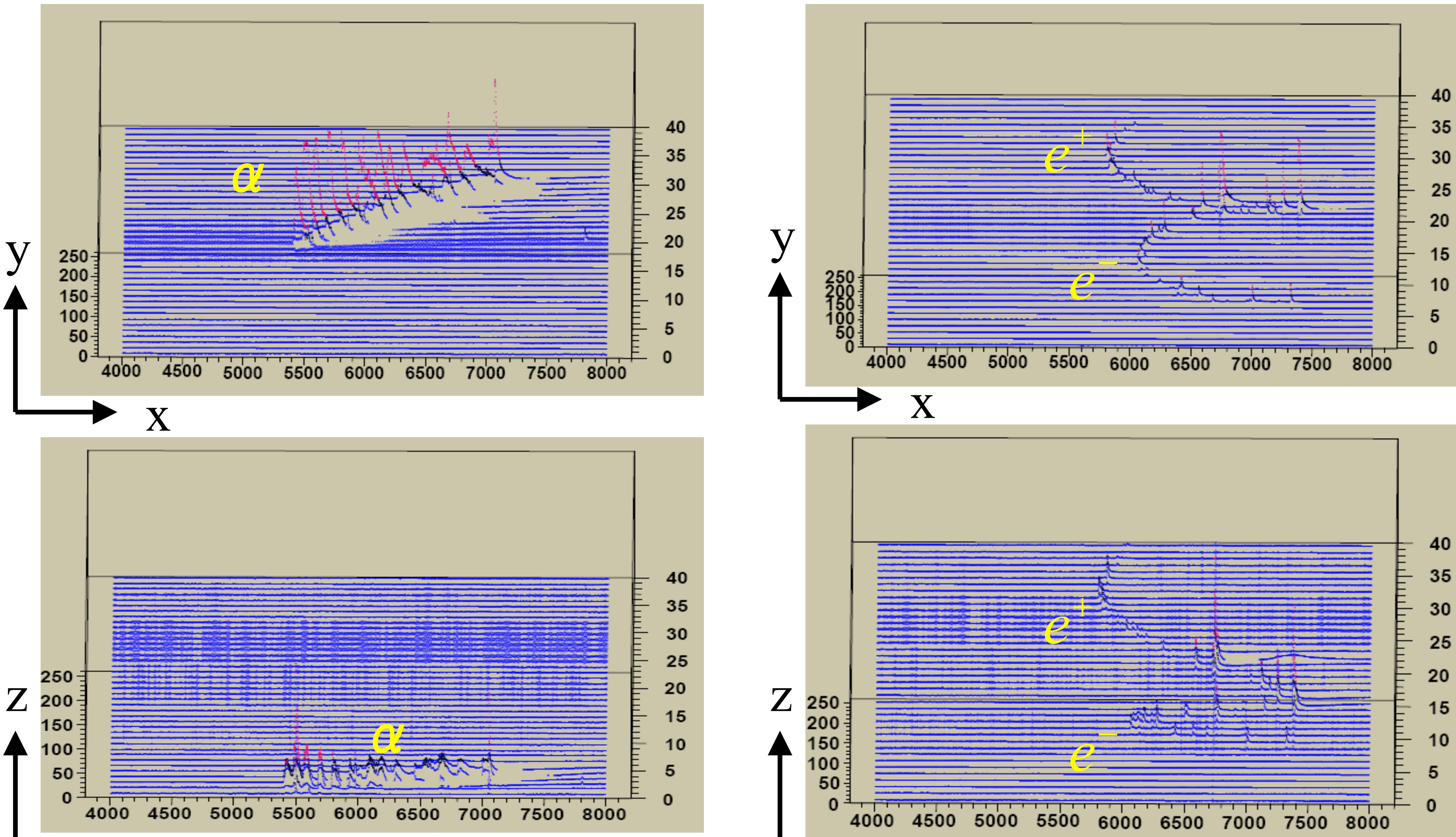




Expected ΔE/E at Q = 6.3% (FWHM) for ^{150}Nd

Chamber conditions
He(90%)+CO_2(10%) 1atm
B=0.8 kG
Wire pitch=6 mm

Other BGD events (1)



Alpha-ray **pair creation**

Double Buffer FADC against Background Events

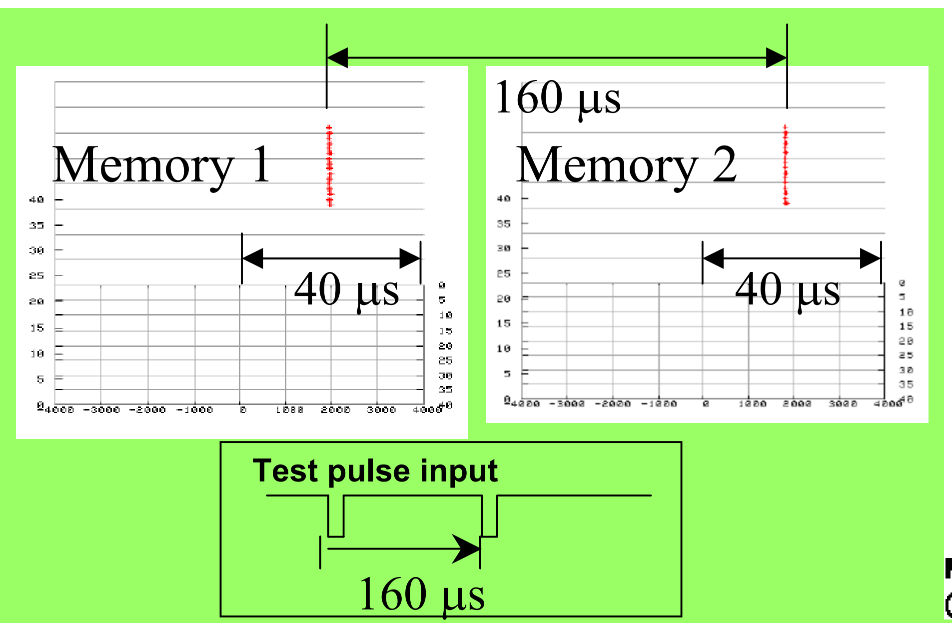
$2e^-$ Background

$$ {}^{214}_{83}\mathrm{Bi} \rightarrow {}^{214}_{84}\mathrm{Po} + \underline{\underline{\beta^-}} + \bar{\nu} $$

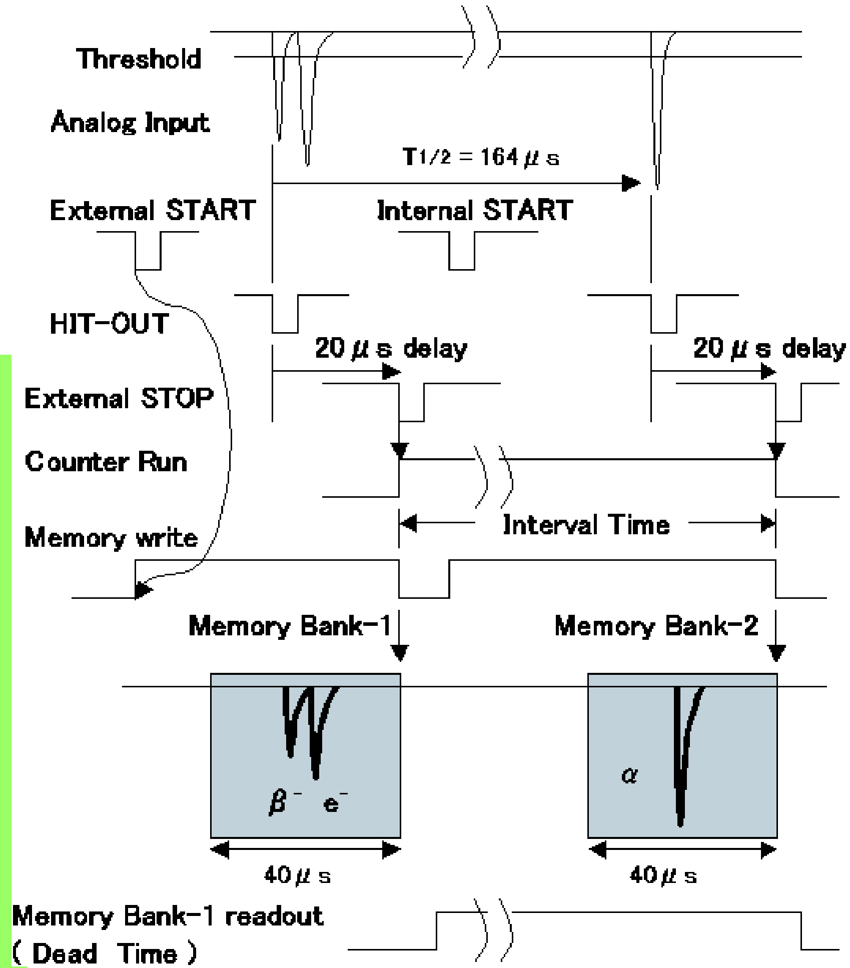
(Q=3.28MeV) $\downarrow\rightarrow$ $\underline{\underline{\text{conv. } e^-}}$

$$ \downarrow\rightarrow {}^{210}_{82}\mathrm{Pb} + \alpha $$

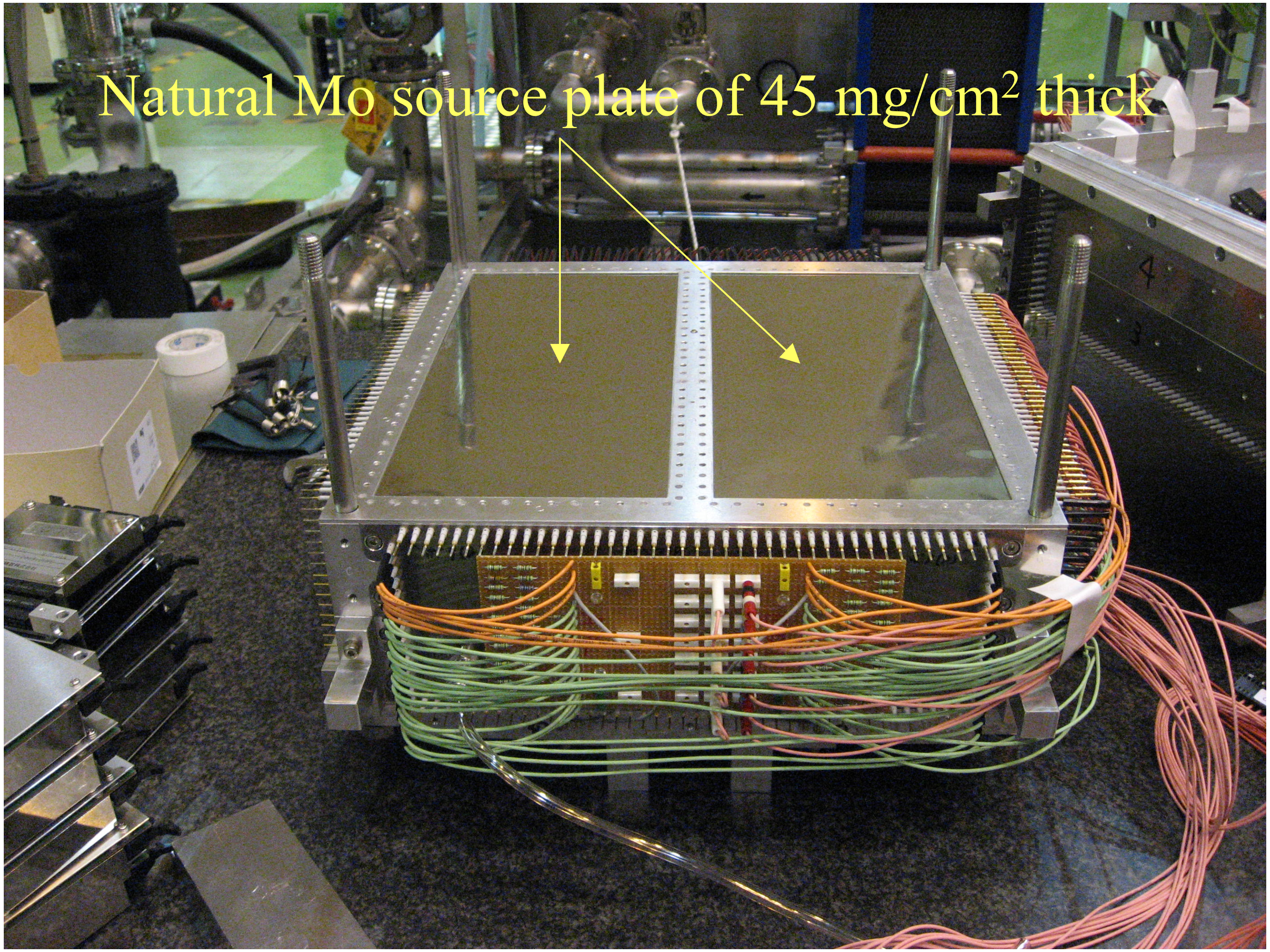
$$ (T_{1/2} = 164\ \mu\,\mathrm{sec}) $$



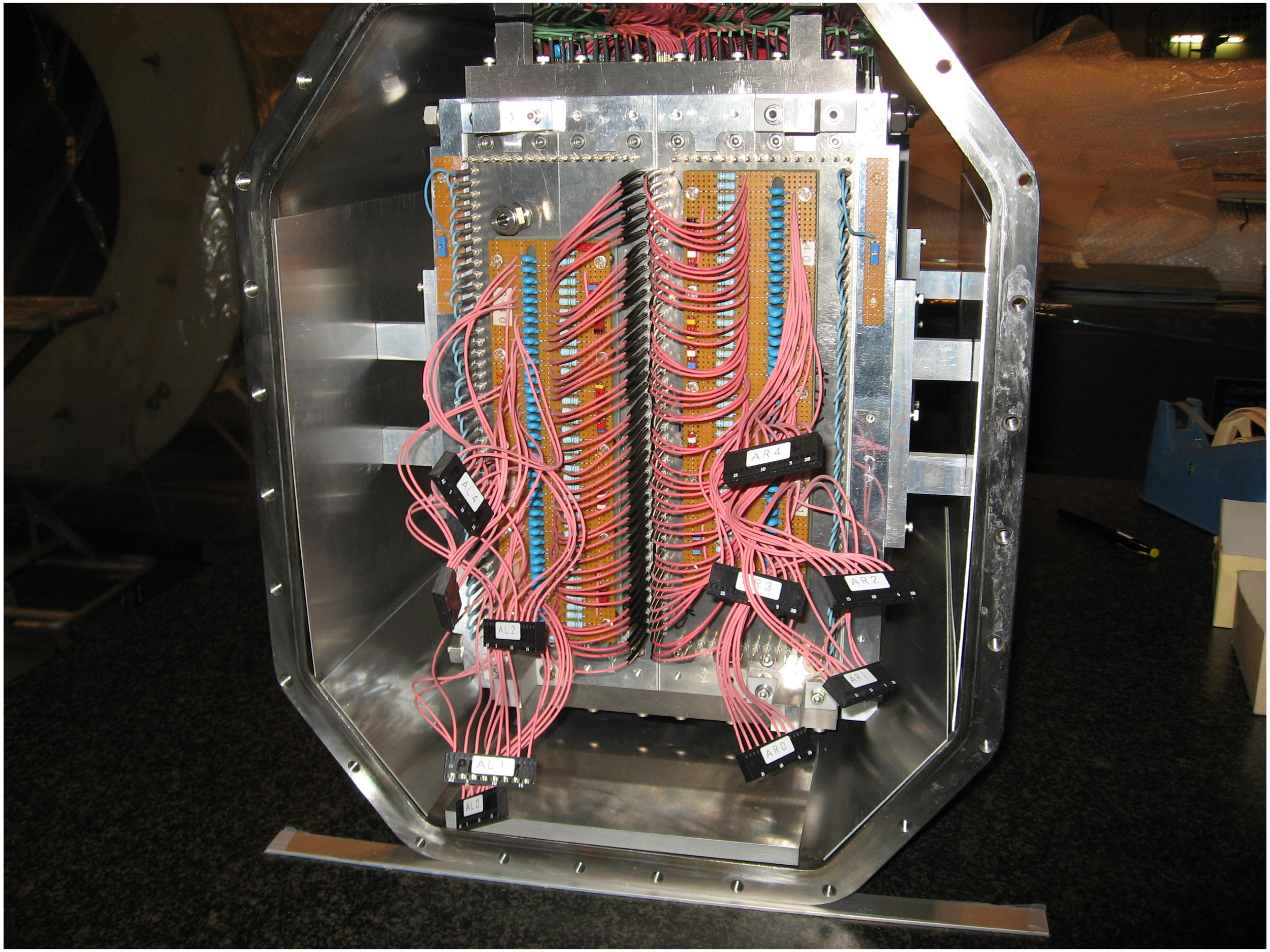
Double buffer FADC



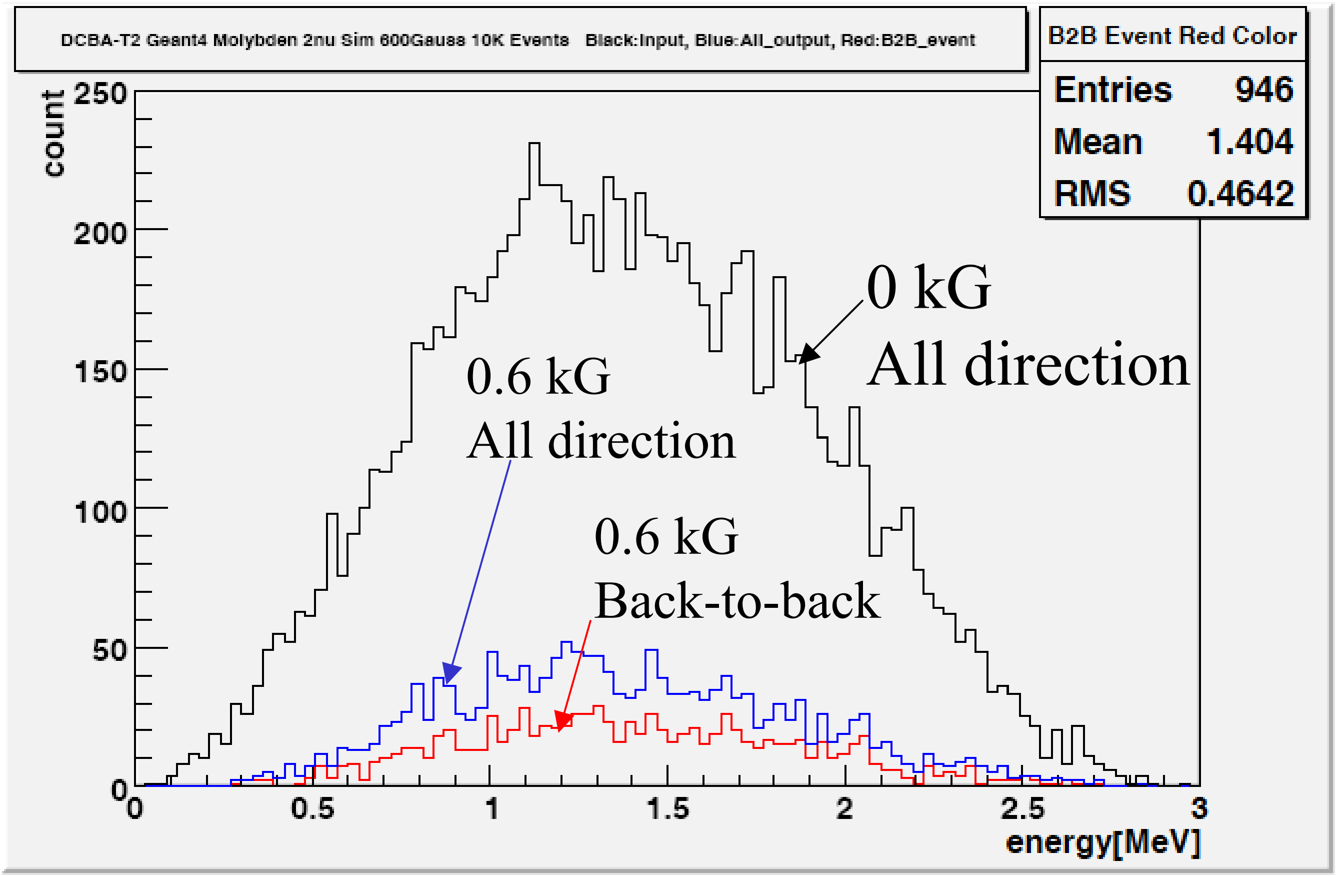
Engineering run of DCBA-T2 using



DCBA-T2 after installing Mo



Detection Efficiency for 2νββ in DCBA-T2

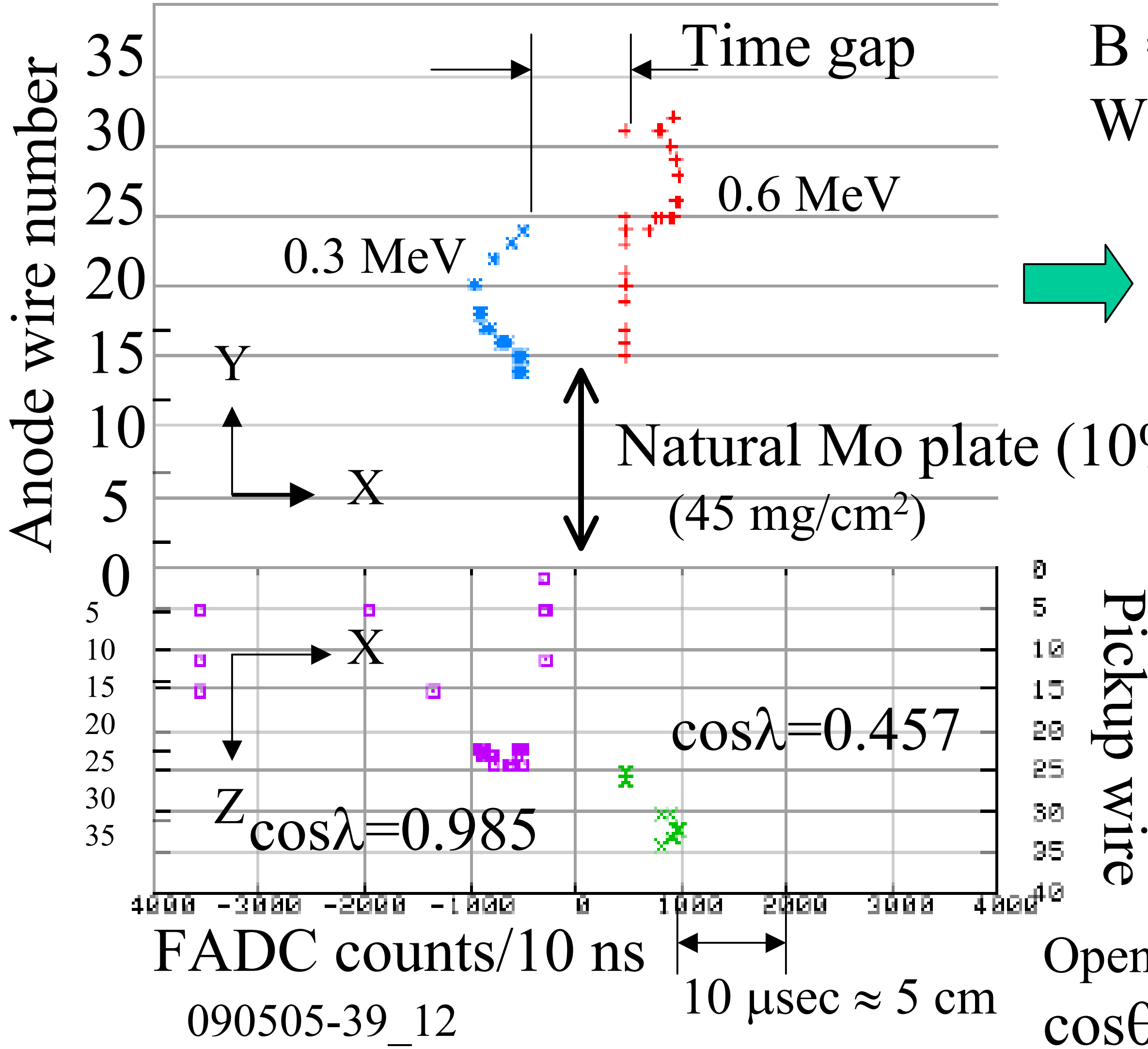


Nat. Mo
(10% ^{100}Mo)
45 mg/cm^2

B=0.6 kG
Back-to-back

ε = 9.5%

Back-to-back event of DCBA-T2 (Candidate of $2\nu\beta\beta$)



B = 0.8 kG

Wire pitch = 6 mm

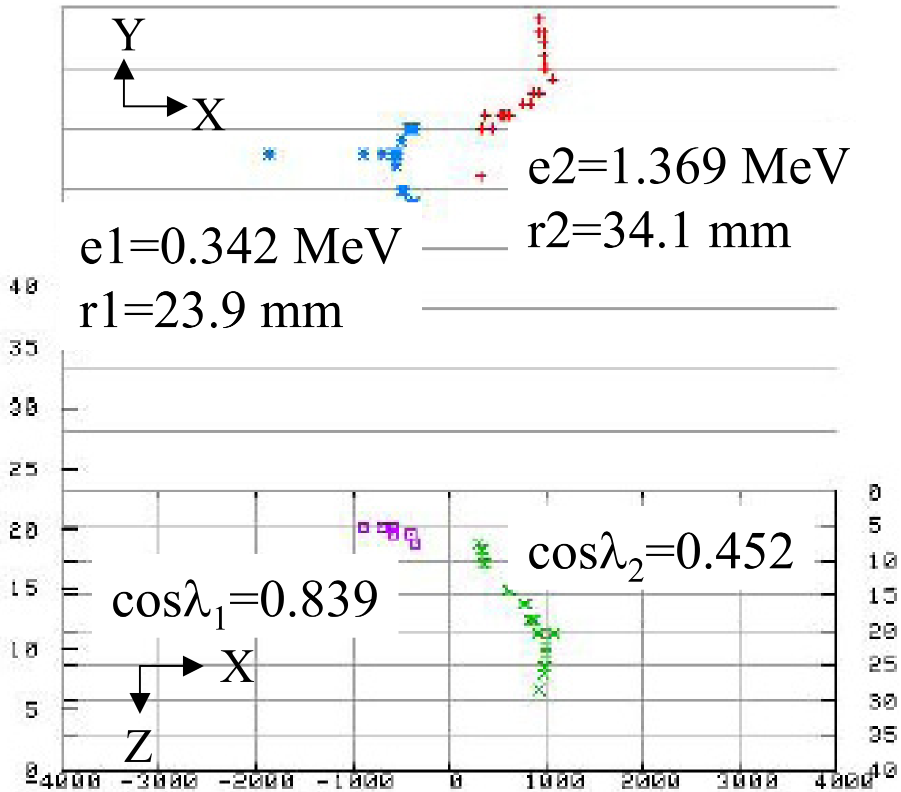
→ Helical Radius: r
Azimuth Angle: φ

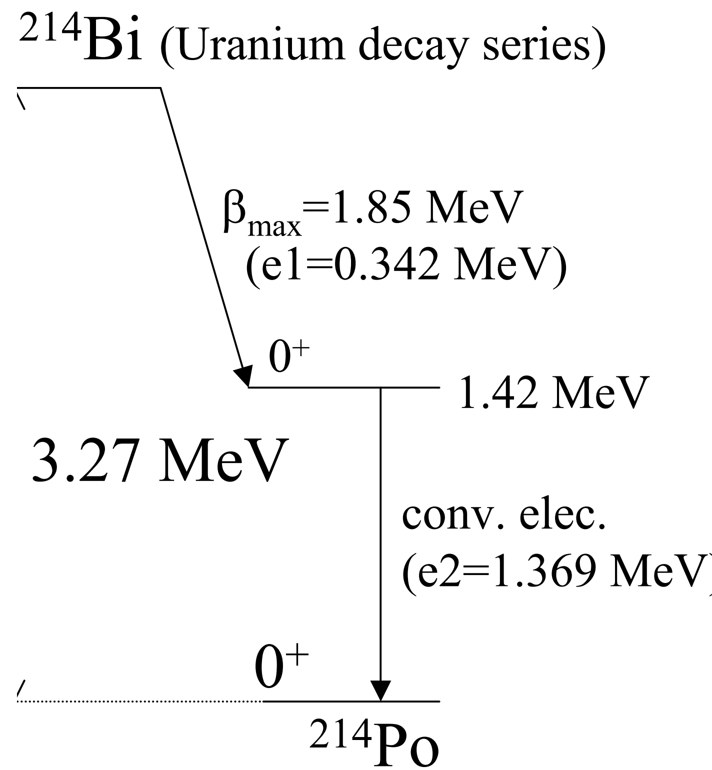
→ Pitch Angle: λ

Opening angle θ≈120 deg

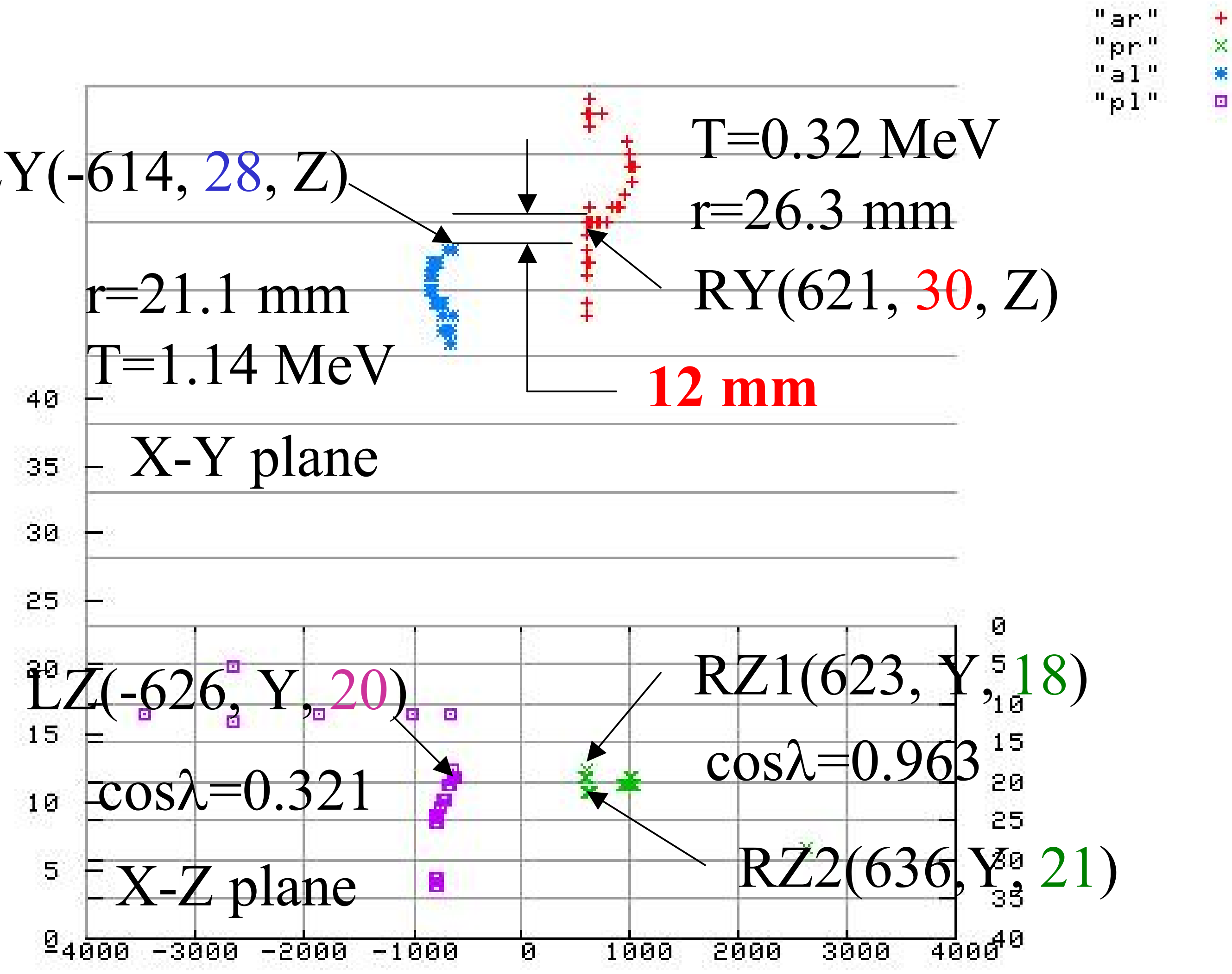
cosθ=−0.5

Back-to-back event probably coming from ^{214}Bi





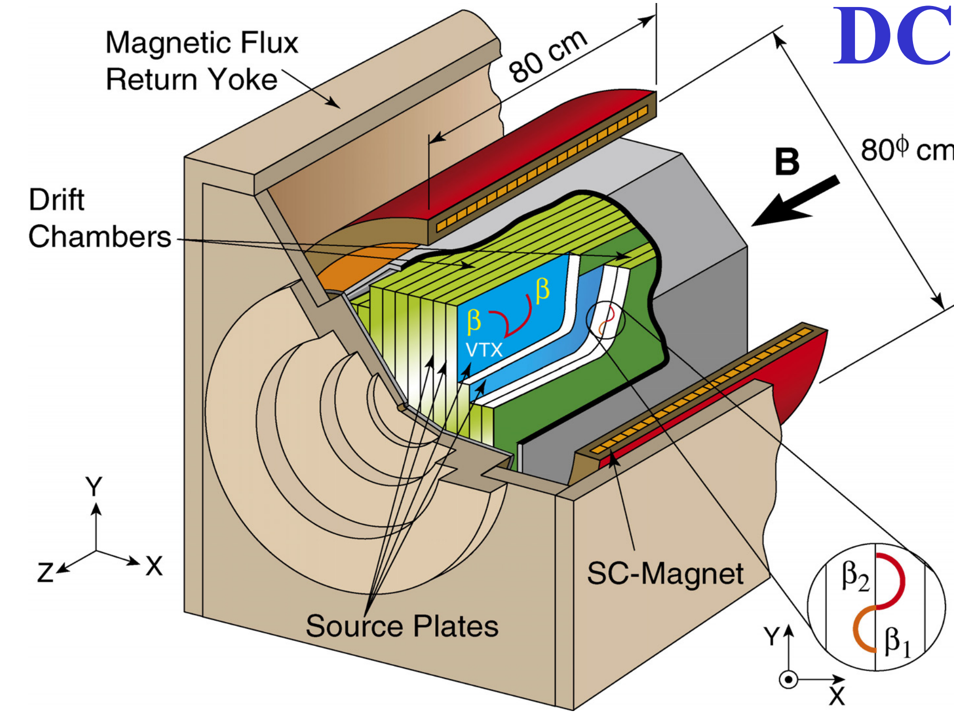
Background Event / Double Compton?

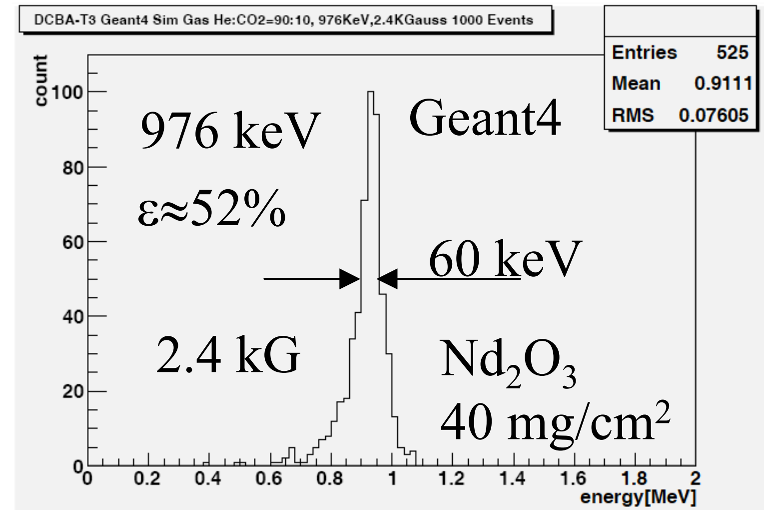


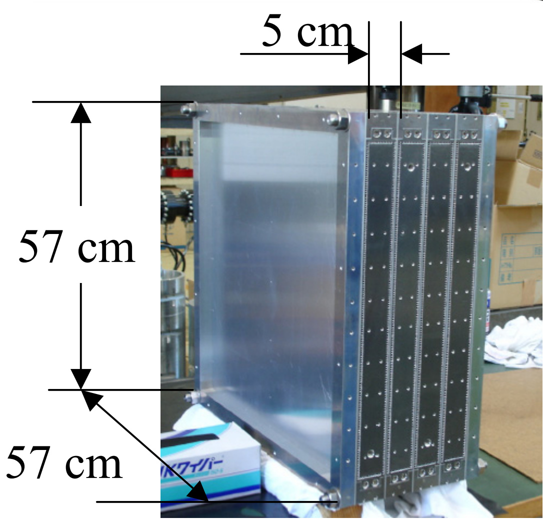
10FADC counts ≈ 0.5 mm

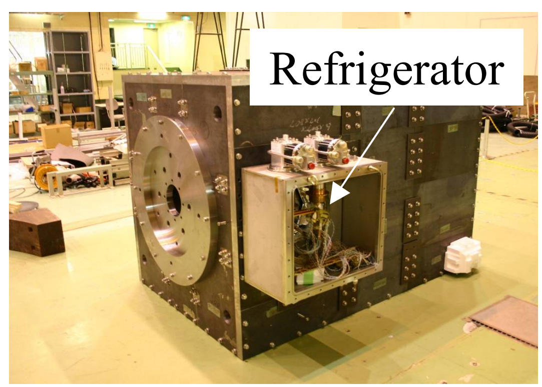
090505-52_14

DCBA-T3 (under construction)

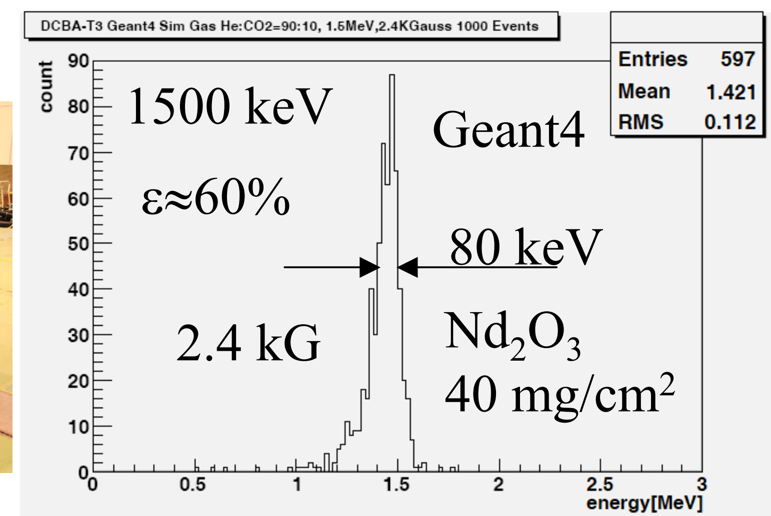








SC-magnet



Differences between DCBA-T3 and T2

• Drift chamber Mini-jet chambers with multi-particle separation capability

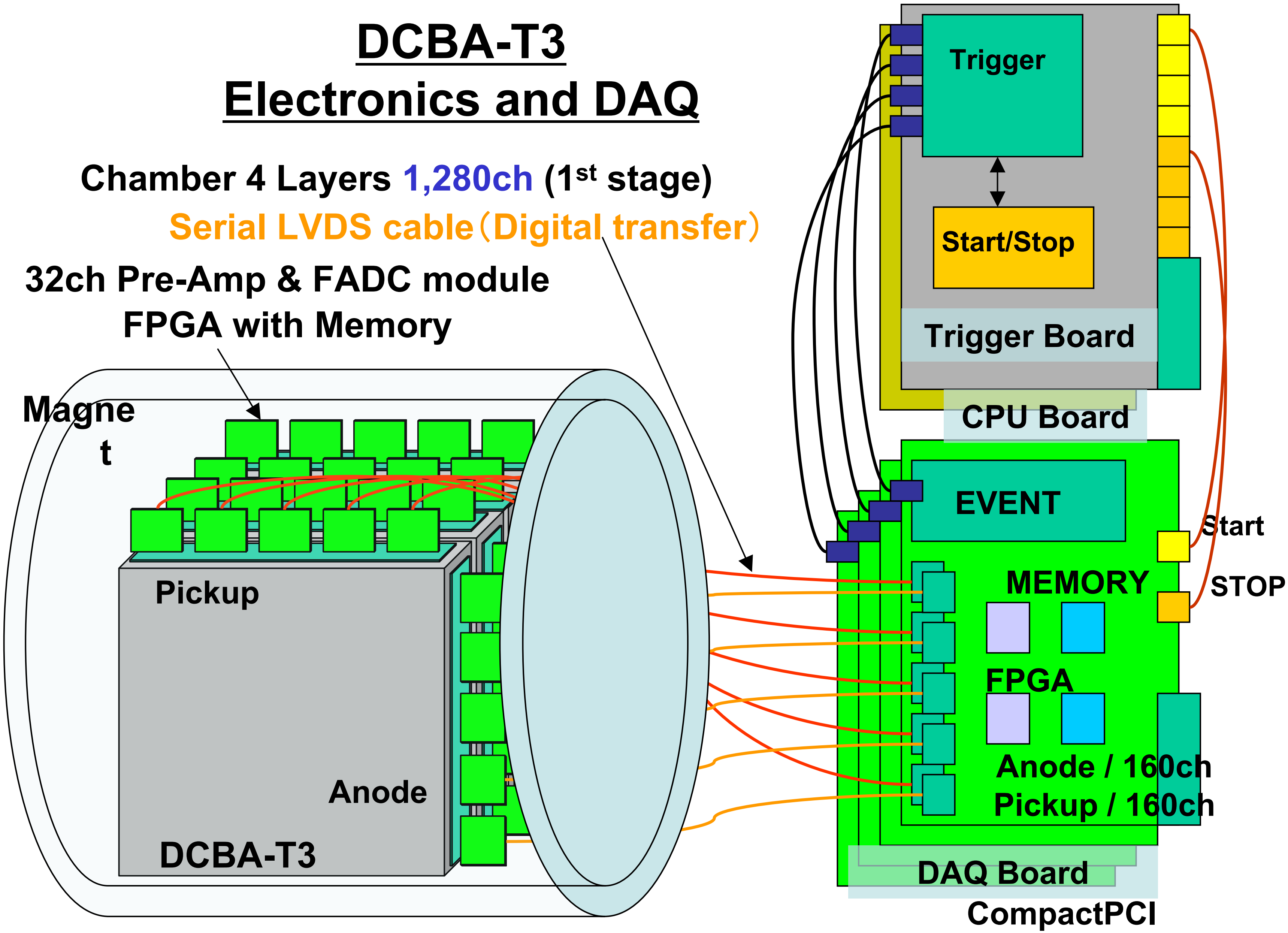
	DCBA-T3	DCBA-T2
Source	Nd_2O_3 (40 mg/cm^2 ×13,760 cm^2 = 550 g : ^{150}Nd = 0.18 mol)	Nd_2O_3 ^{150}Nd = 0.008 (Natul. Mo:32g ^{100}Mo=0.03 mol)
Sensitive vol.	8 × (4(X) × 44(Y) × 44(Z)) cm^3 4 × (4(X) × 20(Y) × 44(Z)) cm^3	9(X) × 26(Y) × 26(Z) cm^3
Anode pitch	3 mm	6 mm
Pickup pitch	3 mm	6 mm
Signal readout	Flash ADC	Flash ADC
X-position	Drift vel. × time : $\sigma_X \approx 0.5$ mm	$\sigma_X \approx 1$ mm
Y-position	Anode position : $\sigma_Y \approx 0.2$ mm	$\sigma_Y \approx 0.2$ mm
Z-position	Pickup position : $\sigma_Z \approx 0.2$ mm	$\sigma_Z \approx 0.2$ mm
• Magnet	SC-solenoid + F.R.Y.	Normal-sol.+ F.R.Y.
Magnetic field	3.0 kG (Max.)	0.8 kG (Max)
Uniform Vol.	80 dia. x 60 cm^3 $\delta B/B_0 < 1\%$	40 dia. x 60 cm^3 $\delta B/B_0 < 1\%$
ΔE/E expected at Q	< 5% (FWHM)	6.3% (FWHM)
Power consumption	1 kW (refri.)+10 W (power supply)	9 kW (Power supply)

DCBA-T3
Electronics and DAQ

Chamber 4 Layers 1,280ch (1st stage)

Serial LVDS cable（Digital transfer）

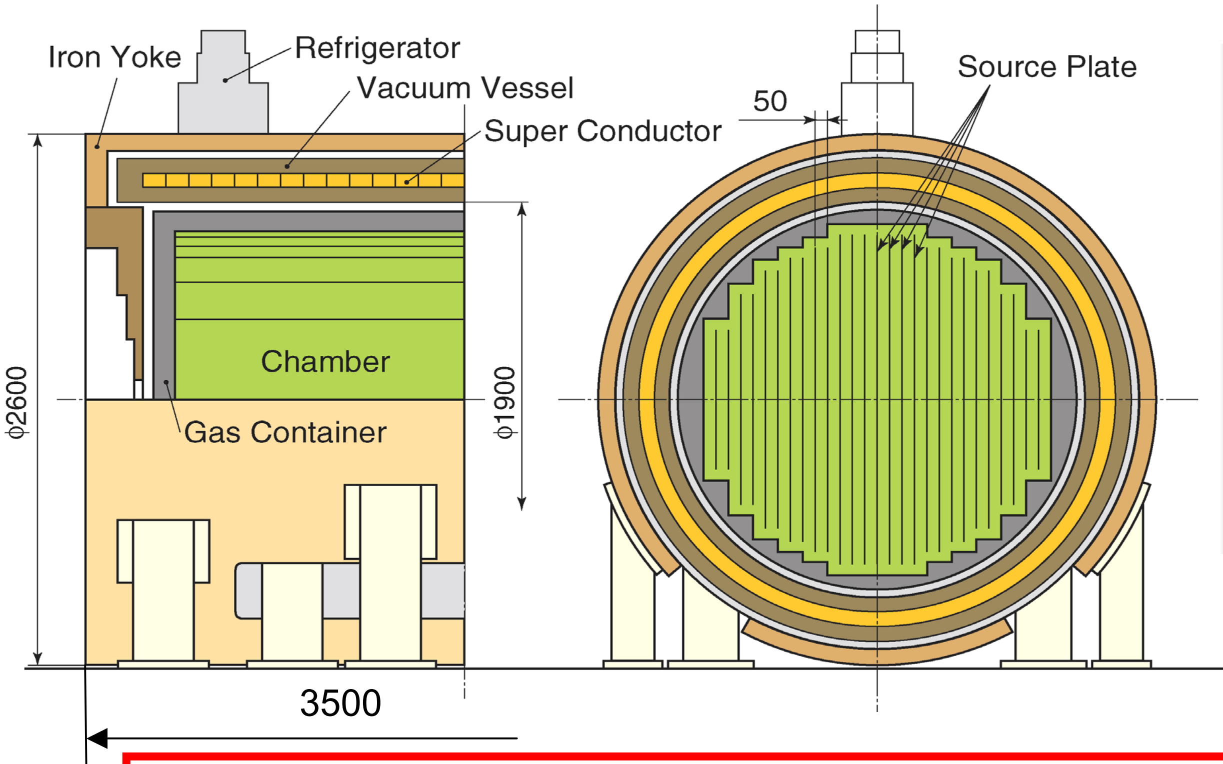
32ch Pre-Amp & FADC module
FPGA with Memory

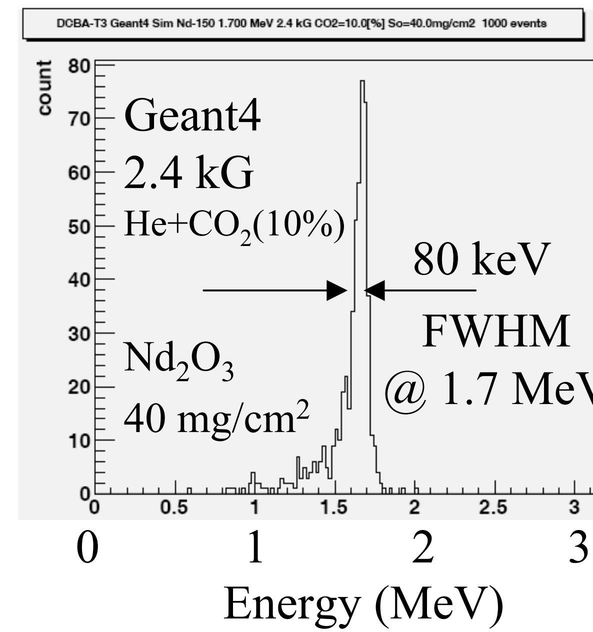


MTD (Magnetic Tracking Detector: temporary name) module after DCBA

Chamber cell : the same as DCBA-T3, Source plate: 80 m^2/module

Thickness: 40 mg/cm^2, Source weight: 32 kg/module





Expected Energy Resolution $$\frac{\mathrm{FWHM}(E_{sum}) = \sqrt{2}\times 80\mathrm{keV}}{Q_{\mathrm{Nd\text{-}150}}(3370\mathrm{keV})} \approx 3.4\%$$

Expected event rate in MTD

Conditions

- Assumed effective mass $< m_{\beta\beta} >$ is 50 meV.
- Used $T_{1/2}^{0\nu}$ are from Faessler *et al*. presented at TAUP2009 and A. Staudt *et al*. in Europhys. Lett. 13 (1) (1990) 31.
- 50 modules of MTD are operated.
- Source thickness is 40 mg/cm^2: thus 30 kg/mod × 50 mod = 1500 kg.
- Event rate is obtained by $n = \varepsilon N_0 \ln 2 / T_{1/2}^{0\nu}$ where ε is the detection efficiency (=0.3) and N_0 the number of nuclei.

Item \ Source	Natural Nd (5.6% ^{150}Nd)	^{150}Nd (60% enr.)	^{100}Mo (90% enr.)	^{82}Se (90% enr.)	^{76}Ge (90% enr.)
Amount (mol)	560	6000	13500	16460	17760
Faessler $T_{1/2}^{0\nu}$ (y)	3.55×10^{25}	3.55×10^{25}	3.33×10^{26}	3.50×10^{26}	1.10×10^{27}
Event rate (y^{-1})	2	21	5	8	2
Staudt $T_{1/2}^{0\nu}$ (y)	1.35×10^{25}	1.35×10^{25}	5.08×10^{26}	2.41×10^{26}	9.32×10^{26}
Event rate (y^{-1})	5	55	3	9	2

DCBA collaboration

N. Ishihara[1], G. Iwai[1], H. Iwase[1], Y. Kato[1], M. Kawai[1], Y. Kondou, T. Haruyama[1], T. Inagaki[1], Y. Makida[1], T. Ohama[1], K. Takahashi[1], S. Takeda[1], Y. Yamada[1], H. Igarashi[2], T. Ishikawa[2], T. Sumiyoshi[2], E.Tashiro[3], T. Ishizuka[3], S. Kitamura[4], Y. Teramoto[5], I.Nakano[6], Y. Sakamoto[7], Y. Nagasaka[8], N. Tamura[9], K. Tanaka[10], R. Ito[11],

[1]KEK, [2]TMU, [3]Shizuoka Univ., [4]NMS, [5]OCU, [6]Okayama Univ., [7]TGU, [8]HIT, [9]Niigata Univ., [10]SSI, [11]Futurescope

(26 persons from 11 Institutes)

Conclusions

1. DCBA is momentum analyzers for studying neutrinoless double beta decay.
2. DCBA-T2 has taken DBD candidates from natural Mo source plates of 45 mg/cm^2 thickness, which include 10% ^{100}Mo.
3. DCBA-T3 is now under construction at KEK, being expected to have the energy resolution of less than 100 keV (FWHM) for each electron in the energy range of 1 – 2 MeV.
4. Magnetic Tracking Detector (MTD: named temporarily) is the future project based on DCBA. The energy resolution of MTD is expected to be less than 4% (FWHM) at the Q-value of ^{150}Nd (3.37 MeV). MTD of 50 modules will make it possible to investigate the effective neutrino mass down to 50 meV.