Present status of DCBA experiment

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- Motivation for Neutrinoless DBD
- Introduction to DCBA
- Recent results from DCBA-T2
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Neutrinoless DBD, Seesaw mechanism and Leptogenesis

Seesaw mechanism (1979, Yanagida, Gell-Mann et al.)

$$m_\nu \approx m_D^2 / M_N ,$$

m_D : mass of charged Dirac particle

M_N : mass of heavy Majorana neutrino N_R

Majorana neutrino permits **lepton number violation process**

→ **Neutrinoless D**ouble **B**eta **D**ecay.

→ **Leptogenesis** (1986, Fukugita, Yanagada) →Baryogenesis

$$\mathrm{BR}(N_R \to \ell_L + \overline{\phi}) \neq \mathrm{BR}(N_R \to \overline{\ell_L} + \phi),$$

ϕ: Higgs particle

Prediction from **Leptogenesis**: 0.001 eV < **$\langle m_\nu \rangle$** <0.1 eV

[W. Bachmuller, R. D. Peccei and T. Yanagida, Annu. Rev. Nucl. Part. Sci. 2005, 55: 311-355]

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

R&D for Future **MTD** (**M**agnetic **T**racking **D**etector)

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Principle of **DCBA** (**D**rift **C**hamber **B**eta-ray **A**nalyzer)

$^{150}Nd \rightarrow ^{150}Sm + 2e^-$

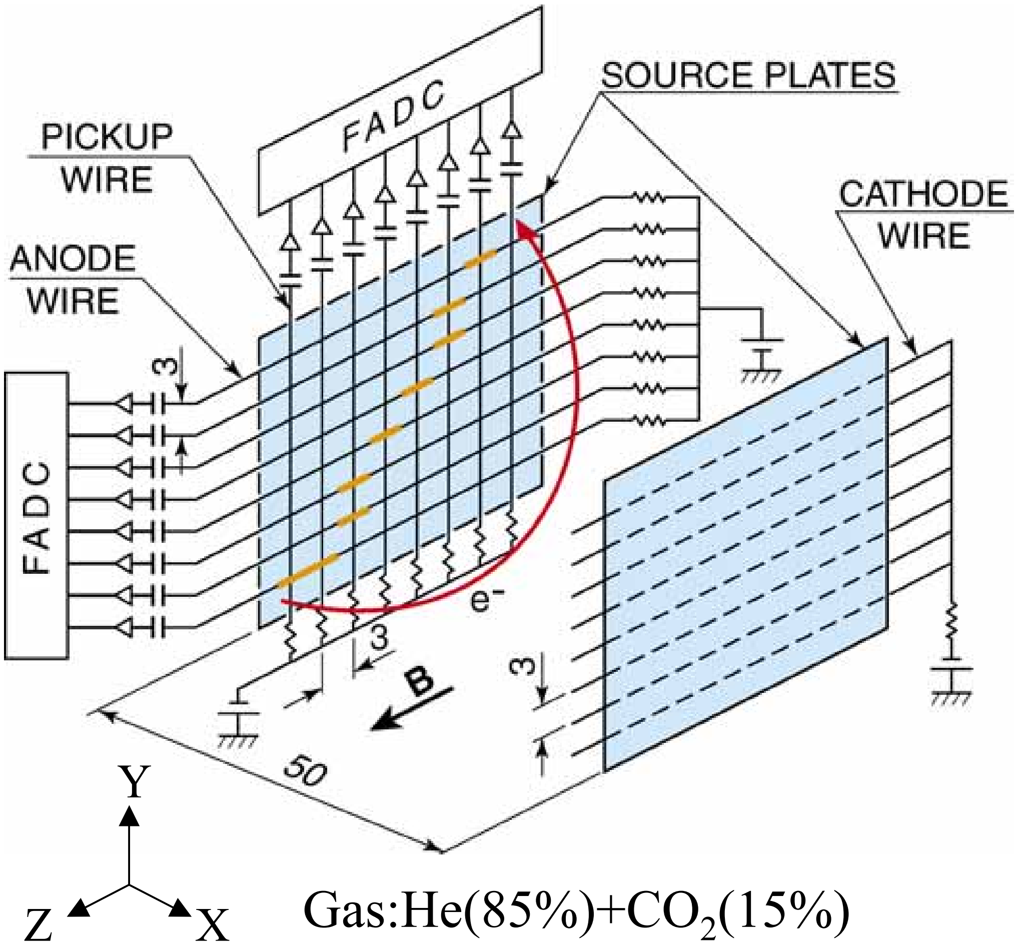
$$p\cos\lambda = 0.3rB,$$

$$T = (p^2 + m_e^2)^{1/2} - m_e$$

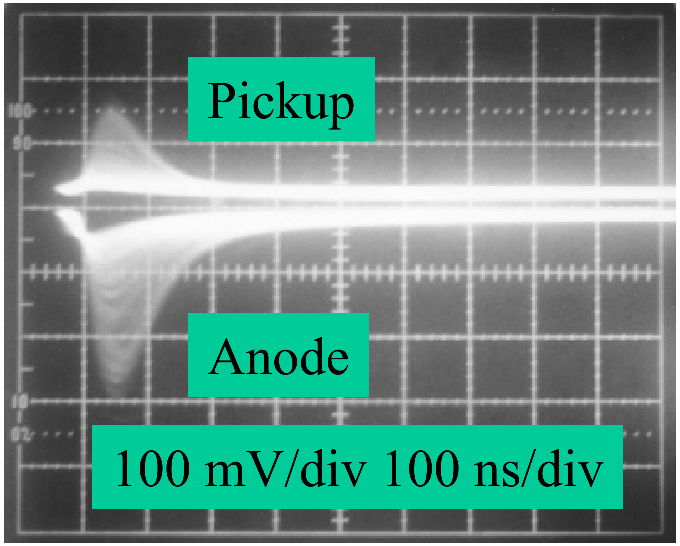
p (MeV/c): momentum, r (cm): radius,

λ: pitch angle, B (kG): magnetic field,

m_e (MeV/c^2): electron mass



Gas:He(85%)+CO_2(15%)

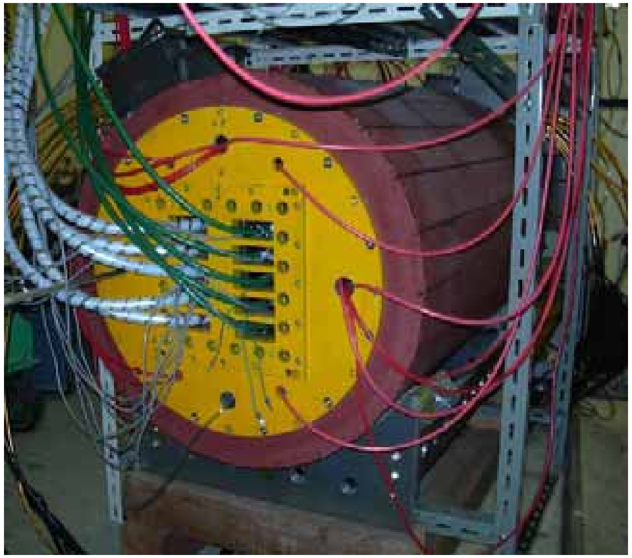


DCBA-T2

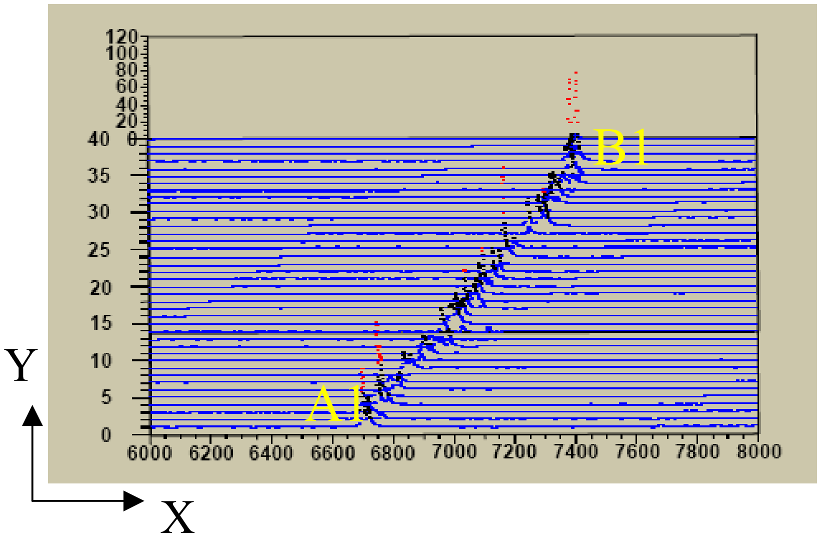
- Drift chamber — Multi-track capability
  - Source — Nd_2O_3 (40 mg/cm^2) (^{150}Nd =0.008 mol)
  - Sensitive vol. — (9(X) × 26(Y) × 26(Z)) × 2 cm^3
  - Signal readout — Flash ADC
  - X-position — Drift velocity × Drift time ($\sigma_X \sim 1$ mm)
  - Y-position — Anode wire position (6 mm pitch) ($\sigma_Y \sim 0.2$ mm)
  - Z-position — Pickup wire position (6 mm pitch) ($\sigma_Z \sim 0.2$ mm)

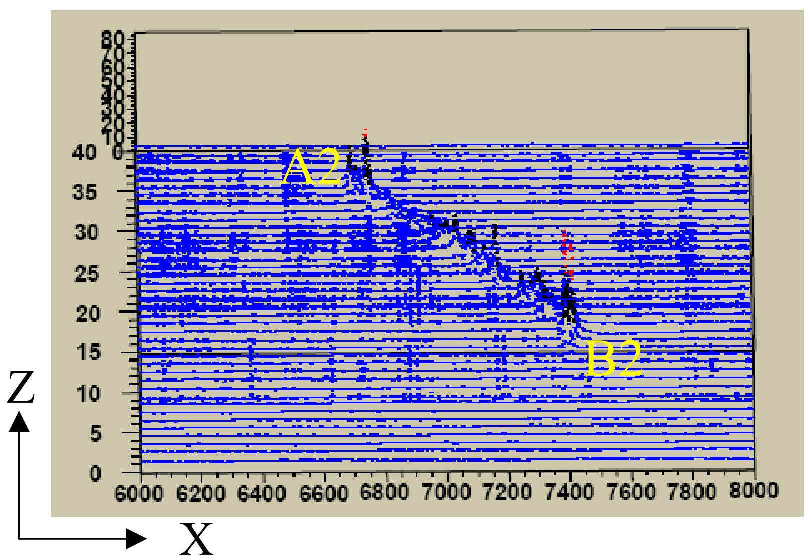
- Magnet — Solenoid coil (normal cond.) + Flux return yoke
  - Magnetic field — 0.8 kG (Max.)
  - Uniform Vol. — 40 dia. × 70 cm^3 ($\delta B/B_0 < 1\%$)

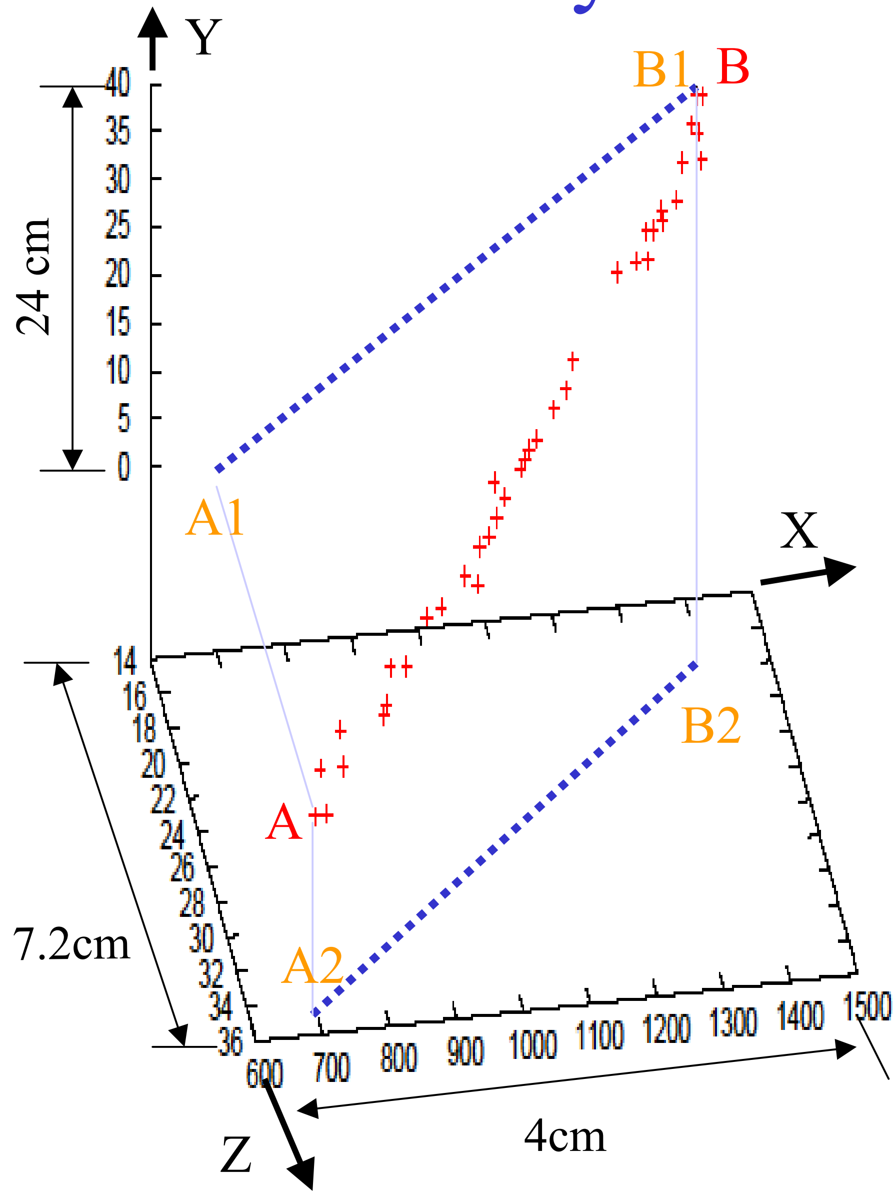
- Veto-counters — Scintillation counters



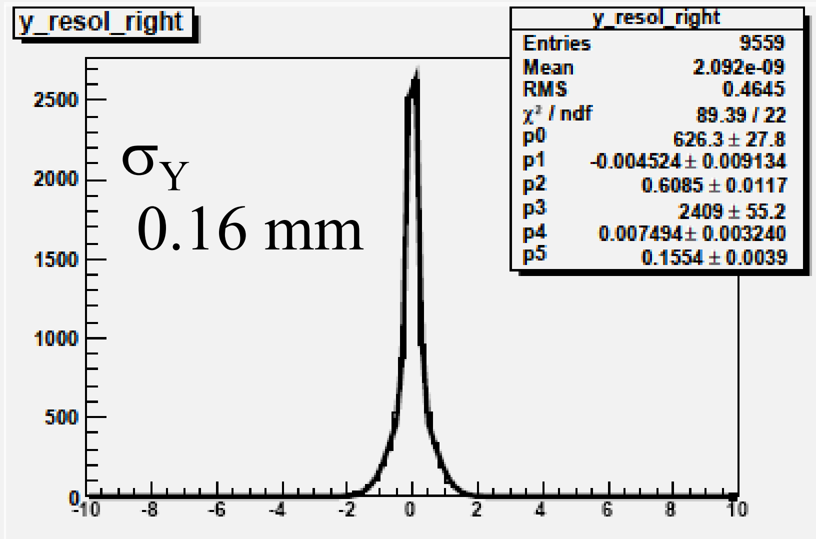
3-D raw data plot of cosmic ray

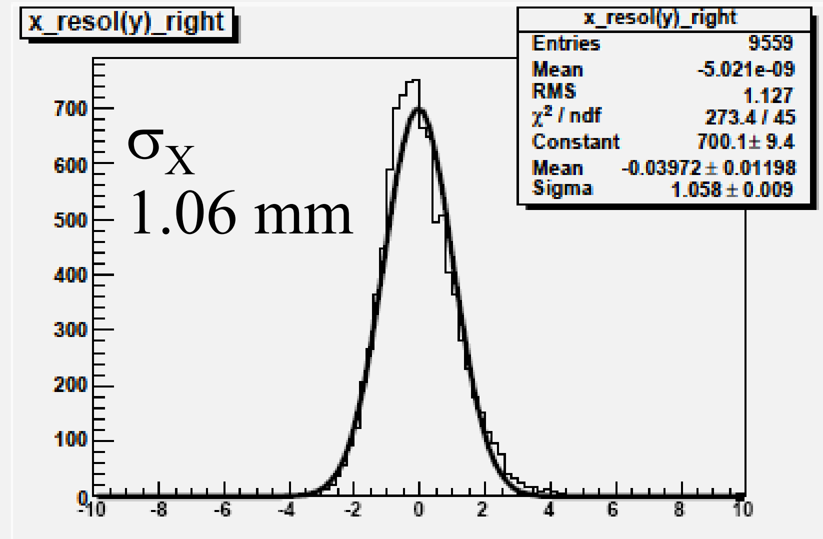


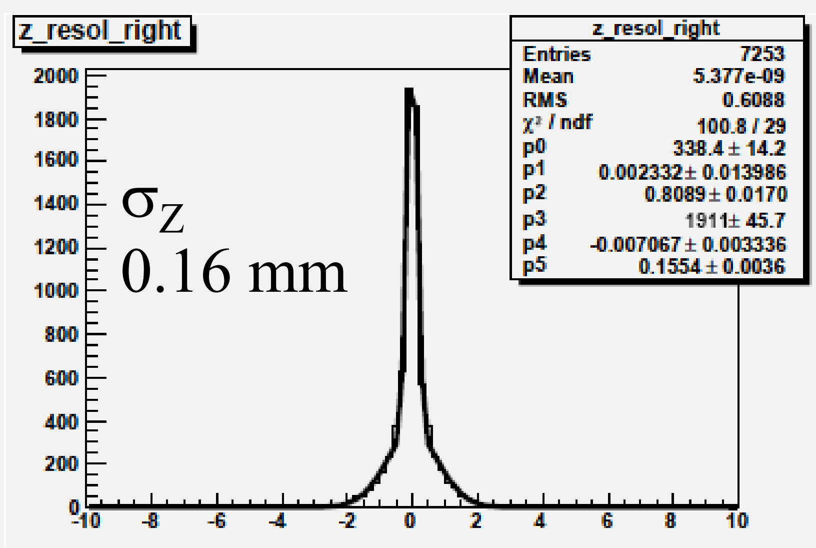


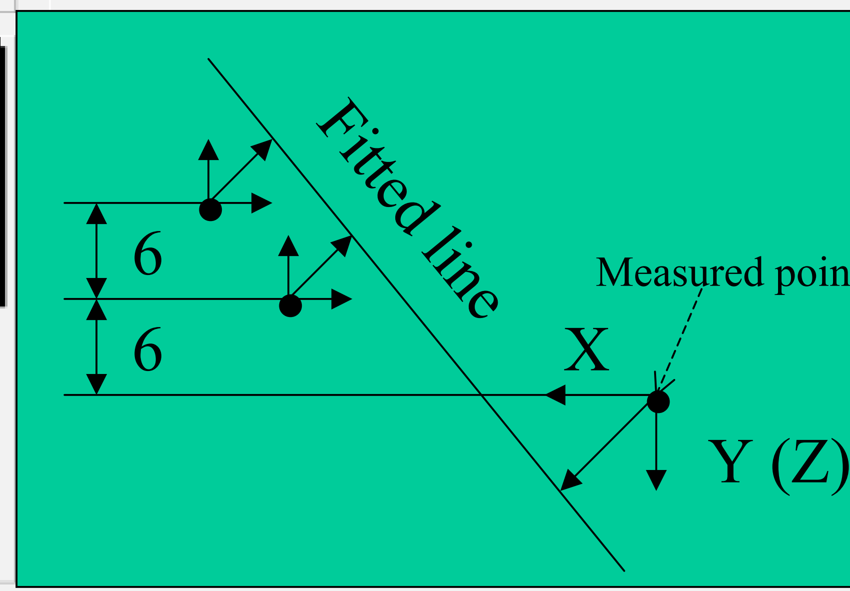


Position residual with cosmic straight tracks

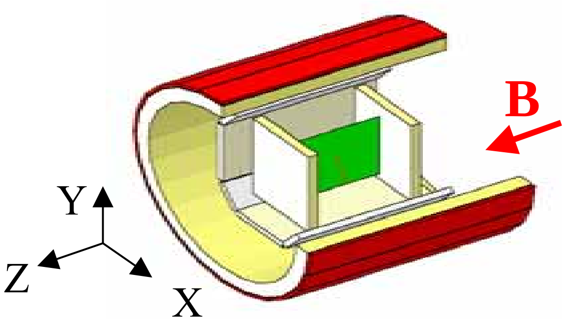


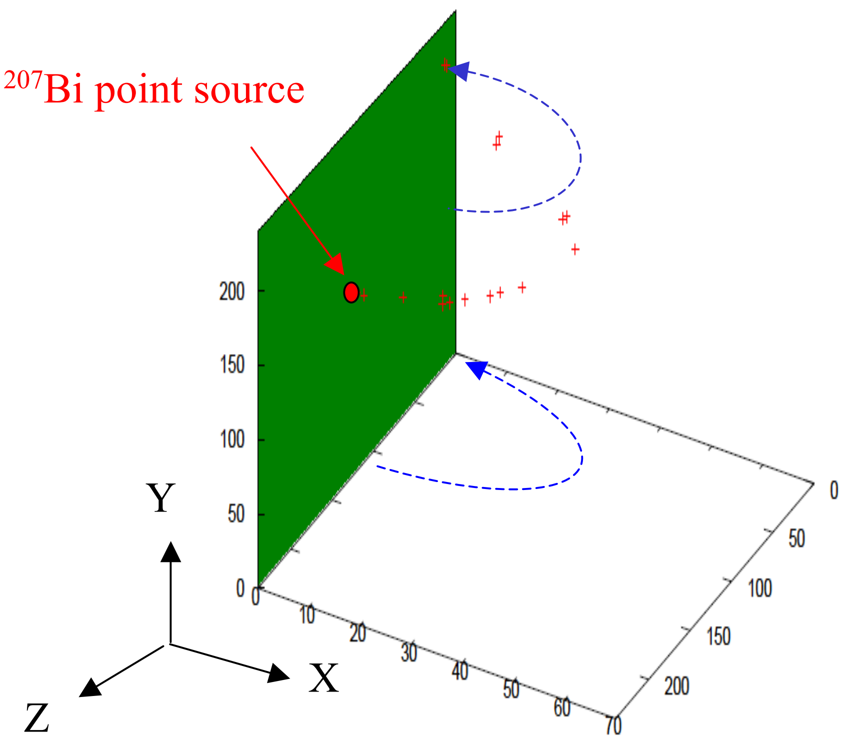


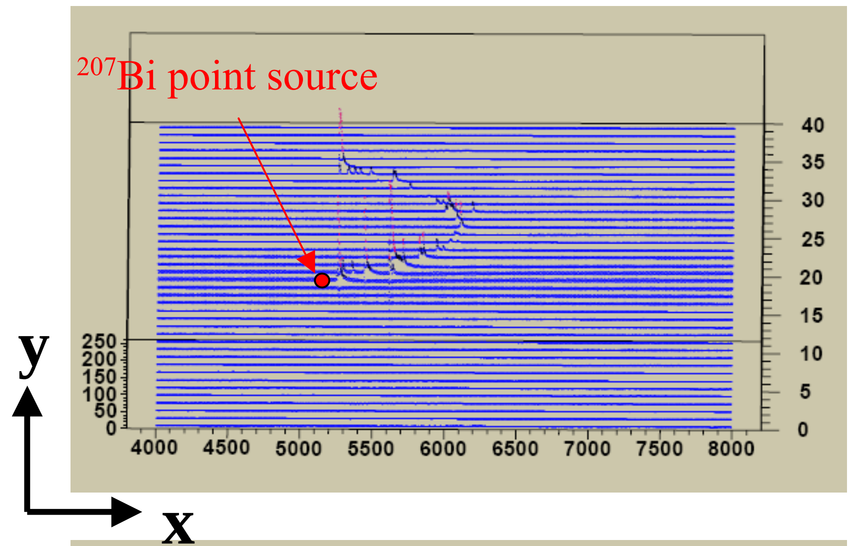


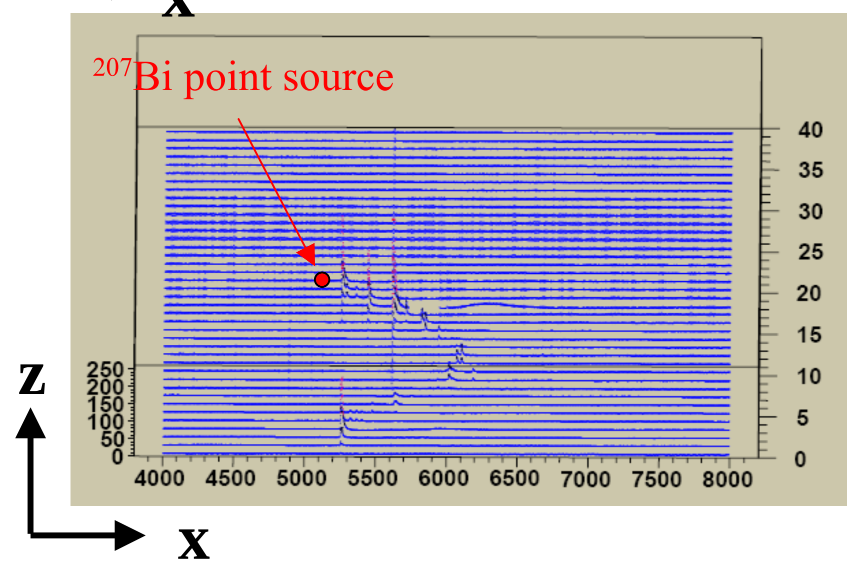


Energy measurement of an I. C. electron from ^{207}Bi



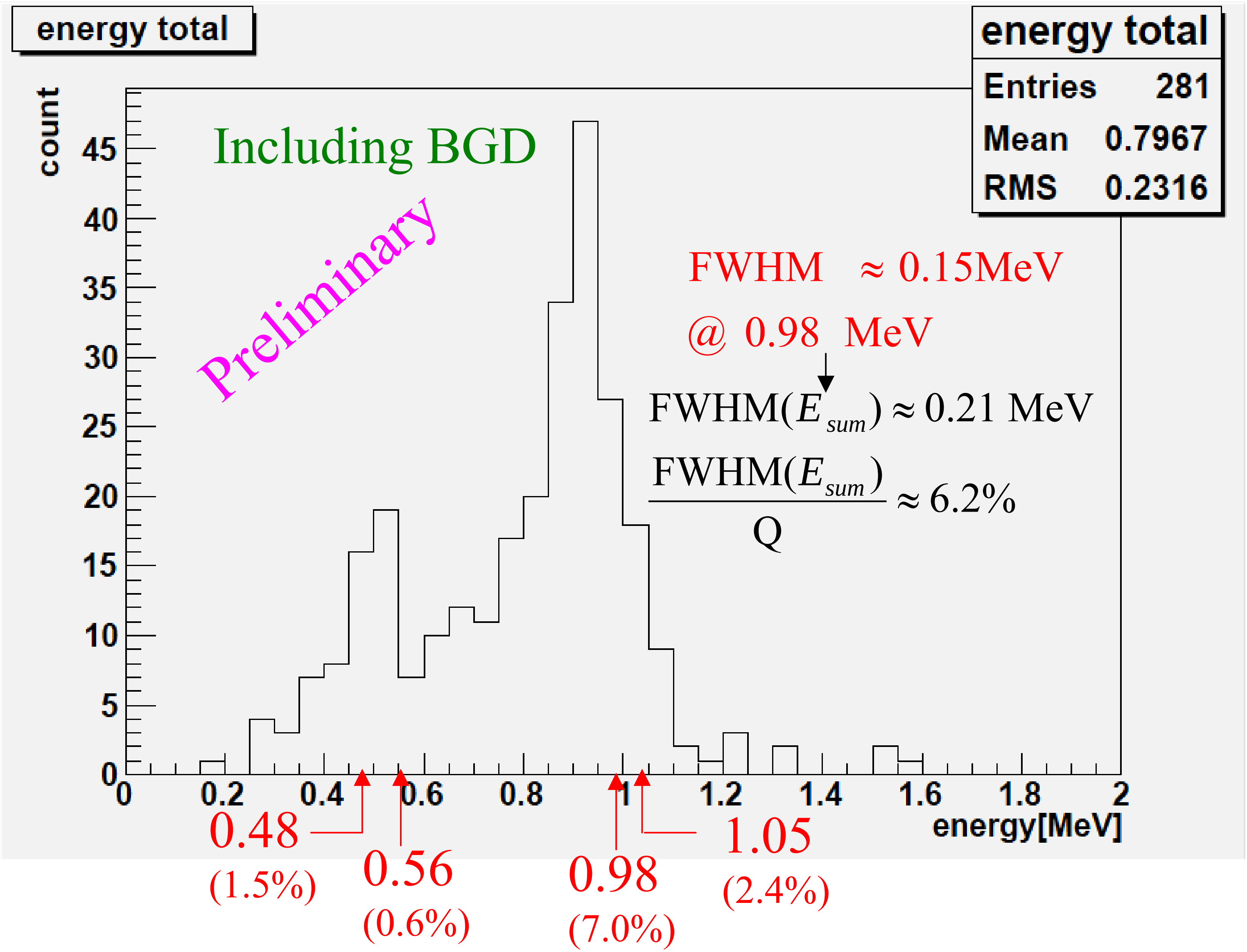






Energy = 1073keV

Energy Resolution of **DCBA-T2**



Estimation of energy resolution at Q-value

$$\mathrm{FWHM}(E_\beta) \approx 0.15\ \mathrm{MeV} \approx 2.35\sigma(E_\beta)$$

$$\sigma(E_{\beta 1}) = \sigma(E_{\beta 2}) = \sigma(E_\beta) \approx 0.064\,\mathrm{MeV}$$

$$E_{Sum} = E_{\beta 1} + E_{\beta 2}\ \left(= Q \quad for\ \ 0\nu\beta\beta\right)$$

$$\sigma^2(E_{Sum}) = \sigma^2(E_{\beta 1}) + \sigma^2(E_{\beta 2}) = 2\sigma^2(E_\beta),\ \ \sigma(E_{Sum}) = \sqrt{2}\sigma(E_\beta)$$

$$\mathrm{FWHM}(E_{Sum}) \approx 2.35\sigma(E_{Sum}) = 2.35\sqrt{2}\sigma(E_\beta) \approx \sqrt{2}\mathrm{FWHM}(E_\beta)$$

$$\mathrm{FWHM}(E_{Sum}) \approx 0.21\,\mathrm{MeV}$$

$$\frac{\mathrm{FWHM}(E_{Sum})}{Q} \approx \frac{0.21}{3.37} \approx 0.062 \Rightarrow 6.2\%$$

DCBA-T2
(equal to plastic scinti.)

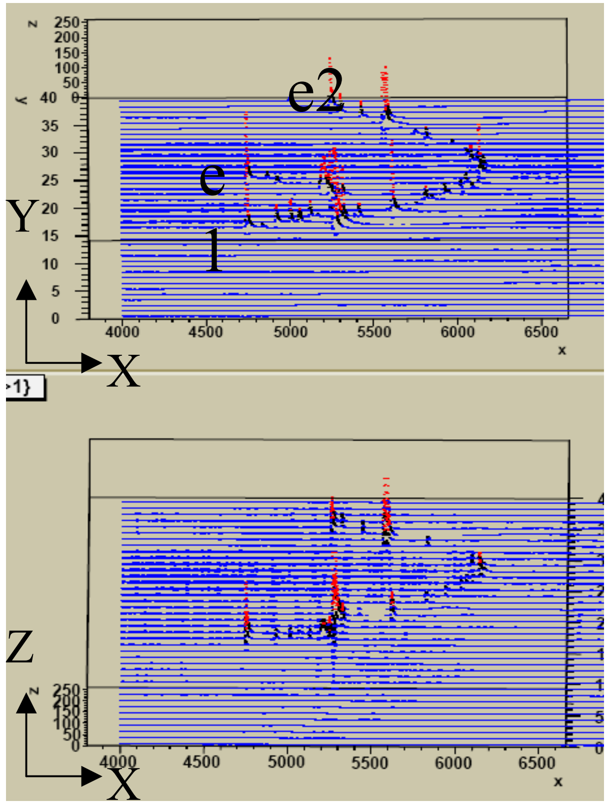
$$\mathrm{FWHM}(E_\beta) \approx \underset{(0.08)}{0.1}\ \mathrm{MeV} \rightarrow \mathrm{FWHM}(E_{Sum}) \approx \underset{(0.11)}{0.14}\ \mathrm{MeV}$$

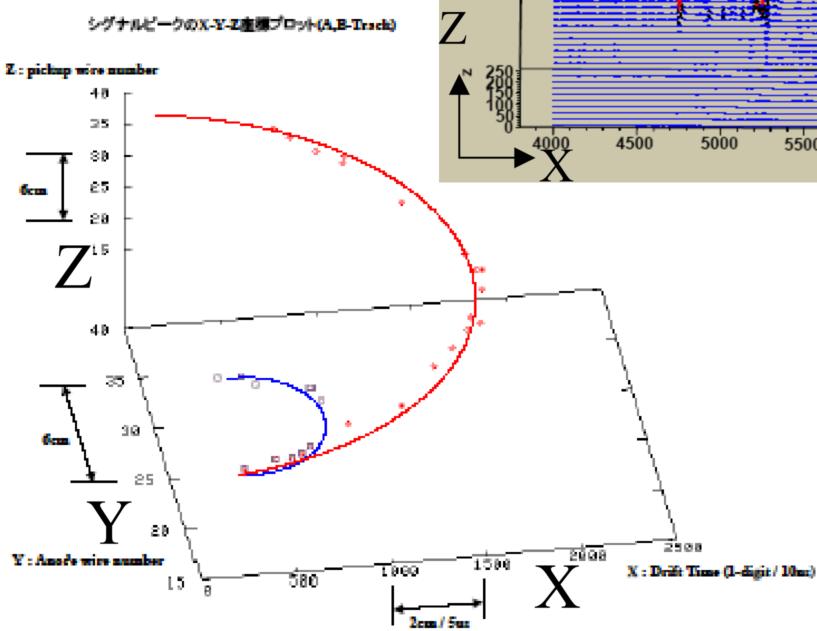
$$\frac{\mathrm{FWHM}(E_{Sum})}{Q} \approx \frac{0.14\,(0.11)}{3.37} \approx \underset{(0.033)}{0.042} \Rightarrow \underset{(3.3)}{4.2\%}$$

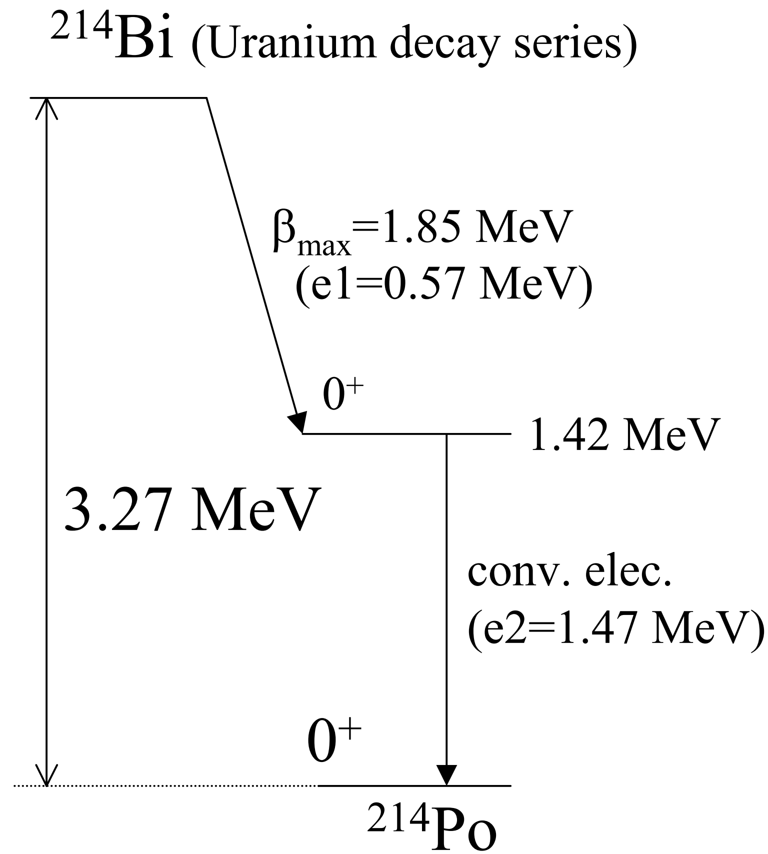
DCBA-T3

BGD event

2-electron event

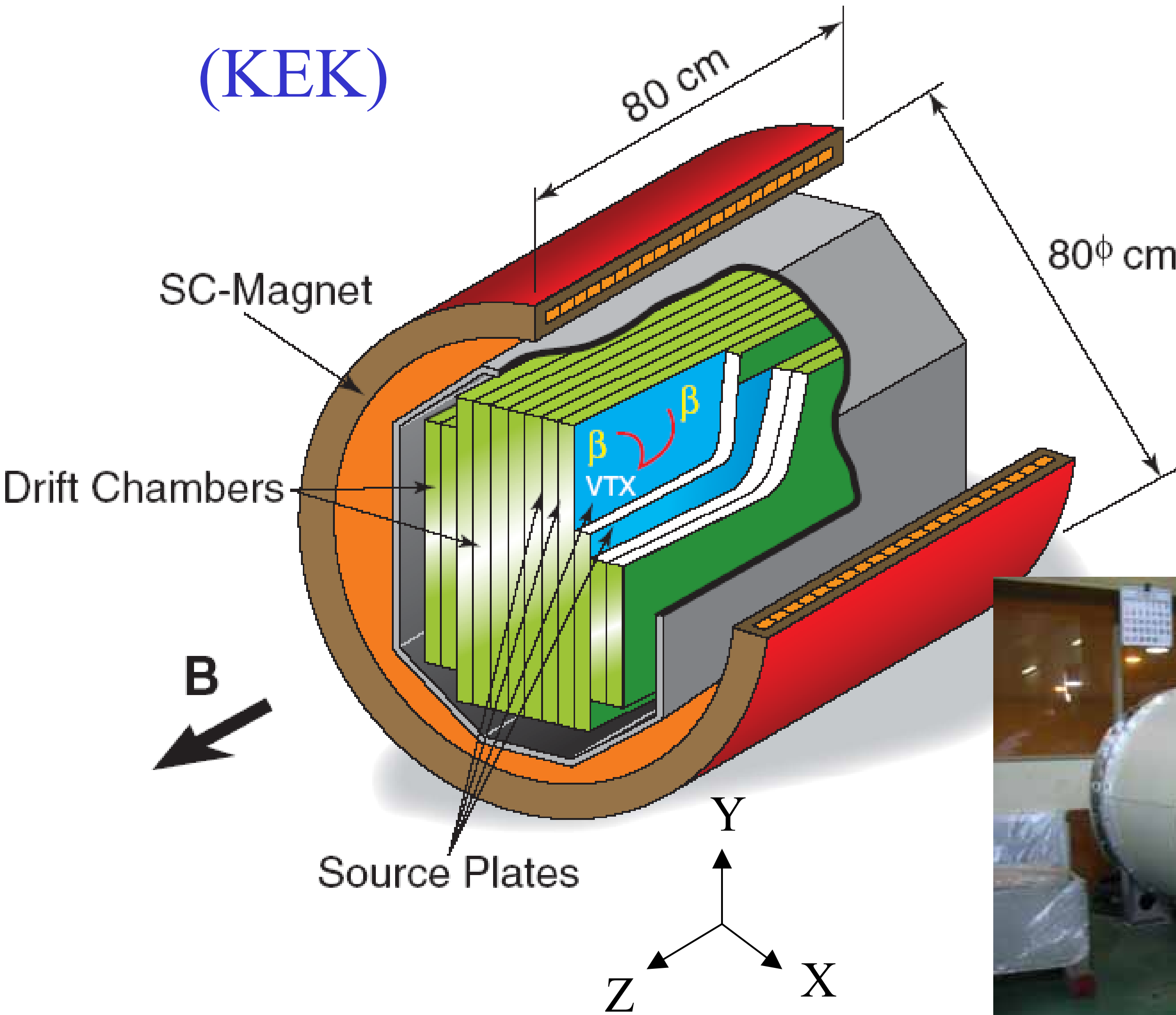






DCBA-T3 (Drift Chamber Beta-ray Analyzer)

(KEK)



DCBA-T3

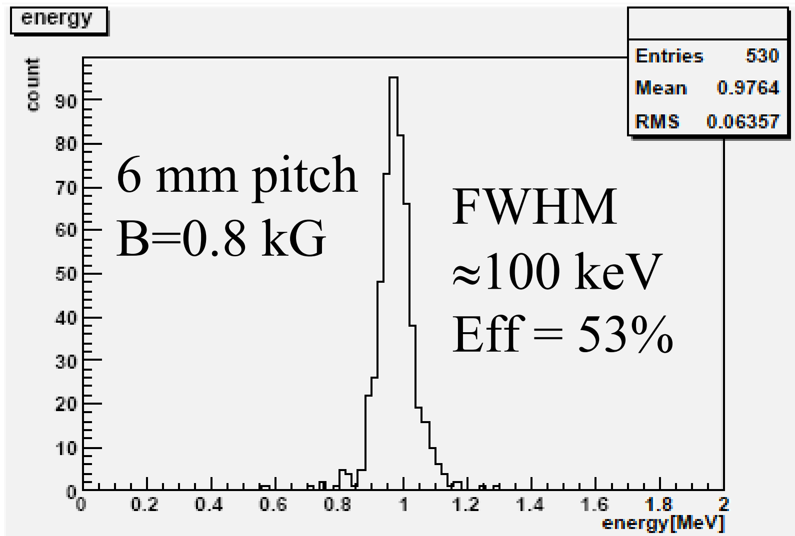
• Drift chamber	Multi-track capability
Source	Nd_2O_3 (40 mg/cm^2 ×13,760 cm2 = 550 g) (^{150}Nd = 0.18 mol)
Sensitive vol.	4(X) × 44(Y) × 44(Z) cm^3/chamber: 8 chamber 4(X) × 20(Y) × 44(Z) cm^3/chamber: 4 chamber
Anode wire pitch	3 mm
Pickup wire pitch	3 mm
Signal readout	Flash ADC
X-position	Drift velocity × Drift time ($\sigma_X \approx 0.5$ mm)
Y-position	Anode wire position ($\sigma_Y \approx 0.2$ mm)
Z-position	Pickup wire position ($\sigma_Z \approx 0.2$ mm)

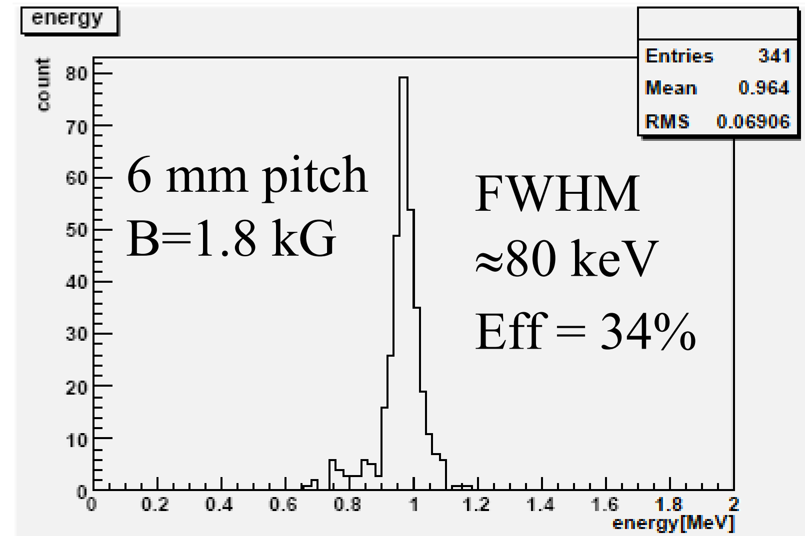
• Magnet	Superconducting Solenoid + Flux return yoke
Magnetic field	2.0 kG (Max.)
Uniform Vol.	80 dia. x 80 cm^3 ($\delta B/B_0 < 1\%$)

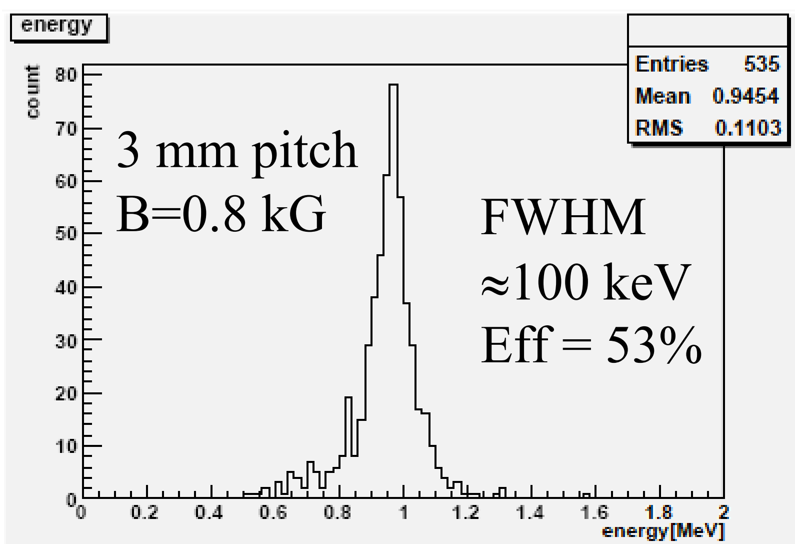
• Veto-counters	Scintillation counters

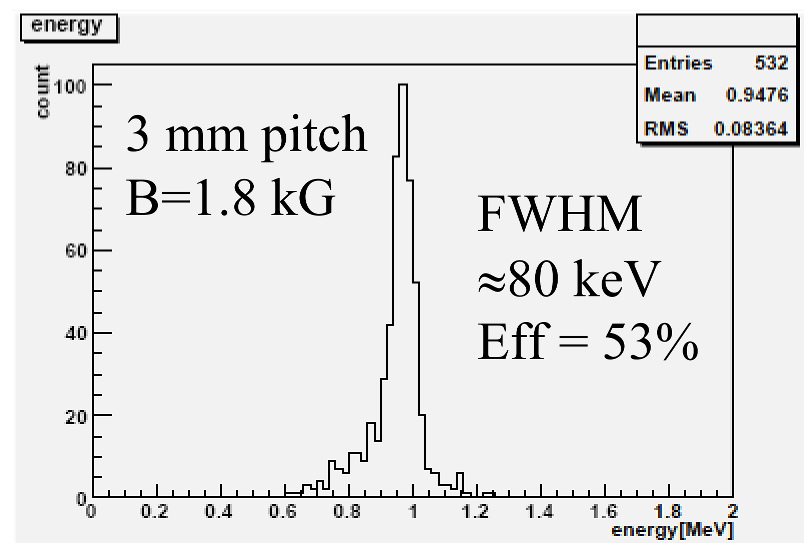
Geant4 studies on energy resolution

E(single) = 976 keV, Chamber gas: He + CO_2(15%), 1 atm



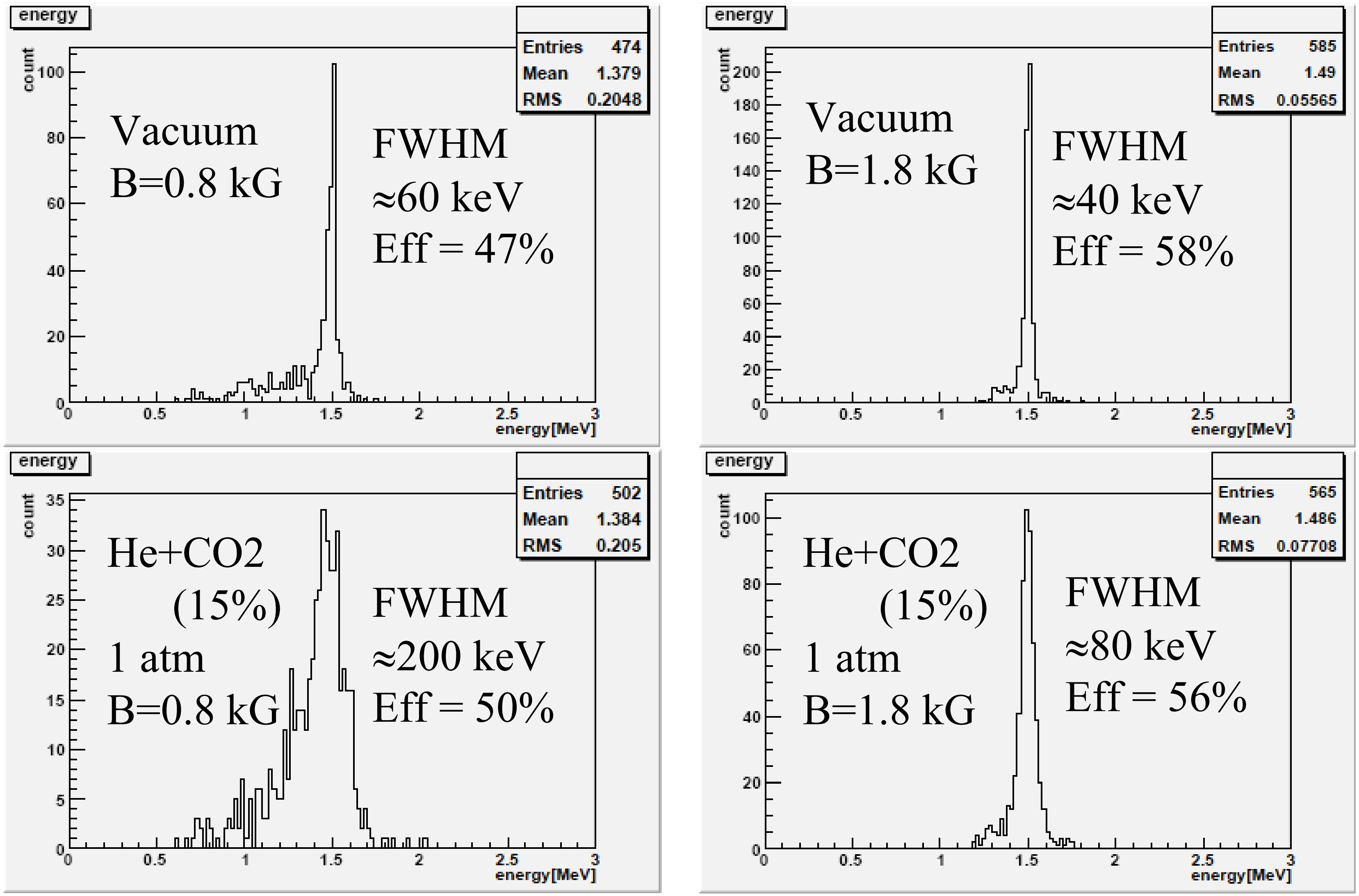






Geant4 studies on energy resolution

E(single) = 1500 keV, Wire pitch = 3 mm

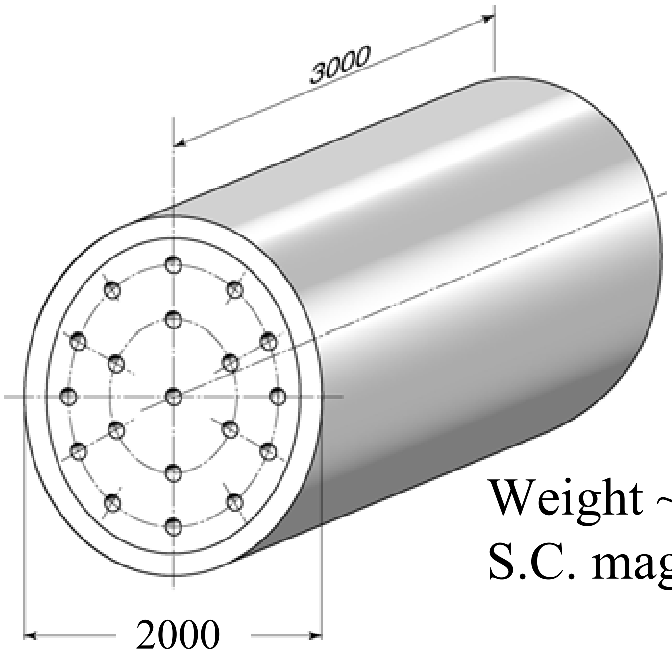


Future plan MTD (tentative)

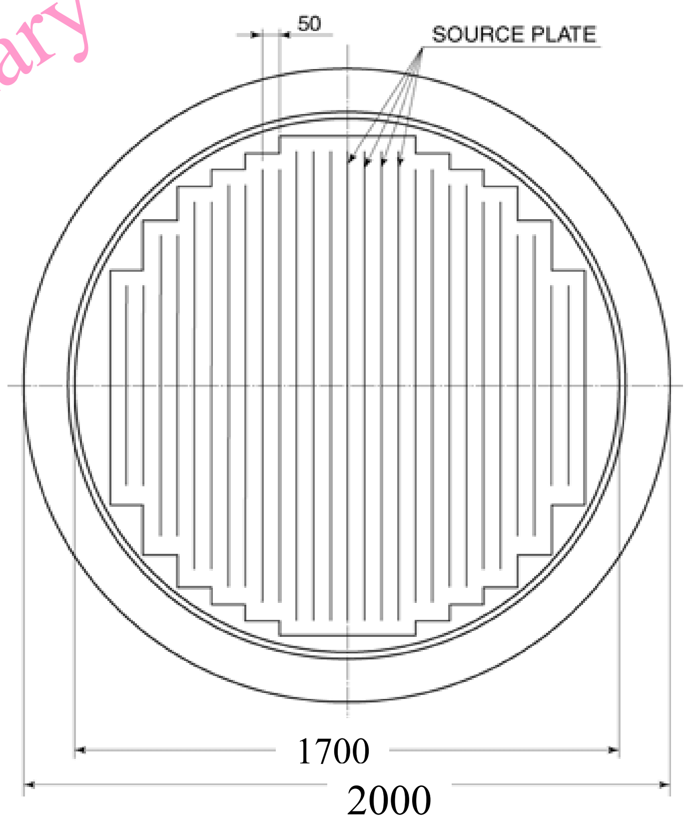
Source plate: 84 m^2/module
Thickness: 15 (40) mg/cm^2
Weight: 12.6 (33.6) kg/module

Anode wire: 10600/module
Pickup wire: 26200/module

Preliminary



Weight ~ 30 t
S.C. magnet



$< m_\nu > \approx 0.8\,\text{eV}\ (0.5\,\text{eV})$ for natural Nd/mod.yr

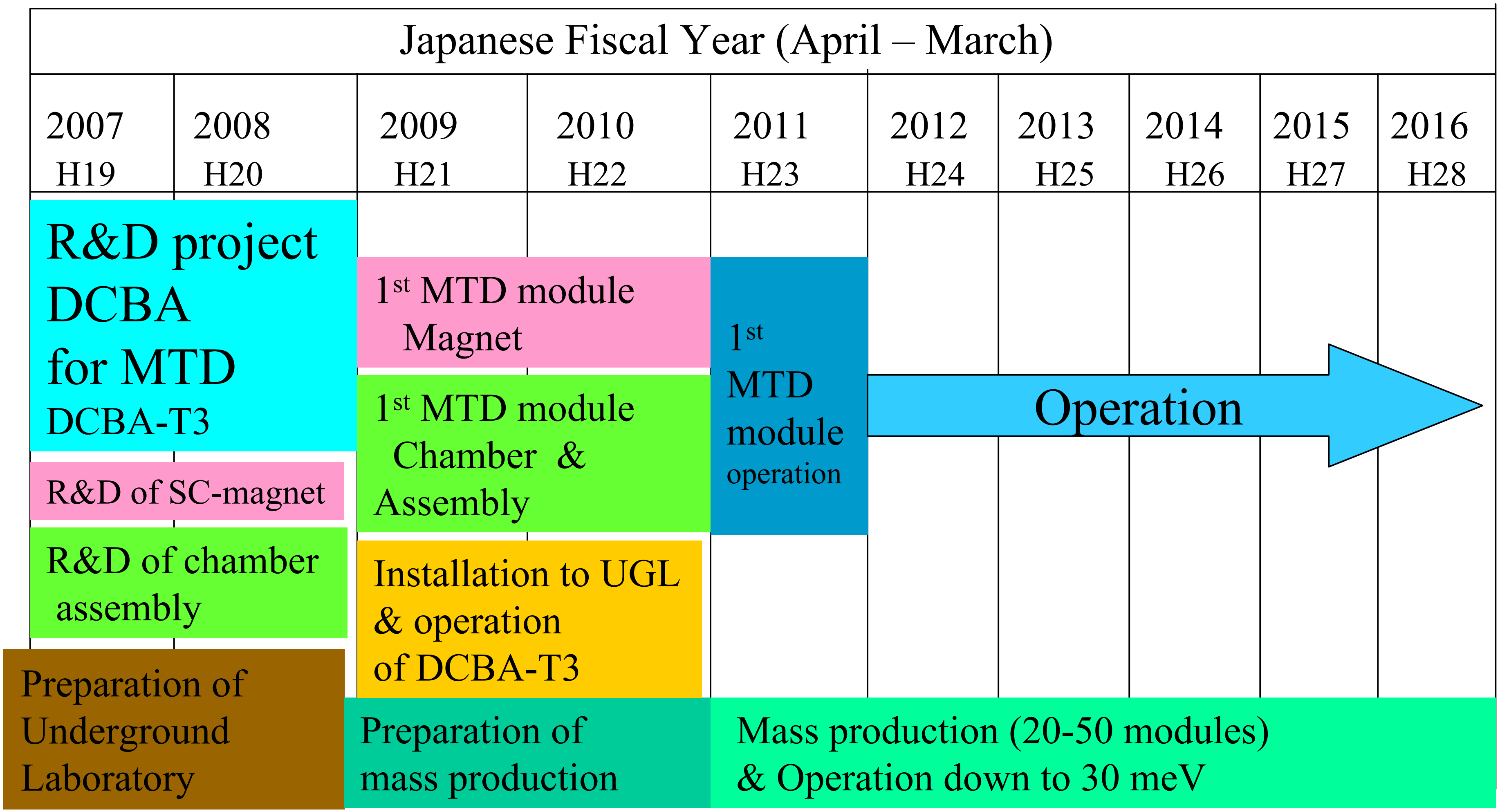
$< m_\nu > \approx 0.2\,\text{eV}\ (0.1\,\text{eV})$ for 60% ^{150}Nd/mod.yr

Half-life and Effective Mass Sensitivities of MTD for ^{150}Nd, ^{100}Mo and ^{82}Se (Tentative)

	Natural Nd (5.6% ^{150}Nd)	^{150}Nd (80% enr.)	^{100}Mo (90% enr.)	^{82}Se (90% enr.)
MTD Amount (mol) (600 kg : 50 modules of 15 mg/cm^2)	190	2700	5400	6600
$T^{1/2}_{0\nu}$ sens. (yr)	9×10^{24}	1×10^{26}	2×10^{26}	3×10^{26}
$<m_\nu>$sens. (eV)	0.06	0.02	0.07	0.04

Nucl. Matrix Element: A. Staudt et al. Europhys. Lett. 13 (1) (1990) 31

Optimistic Schedule of DCBA/MTD
(depending on financial support)



Summary

♦ Leptogenesis predicts the effective neutrino mass being between 0.001 eV and 0.1 eV.

♦ DCBA (Drift Chamber Beta-ray Analyzer) is an R&D project for constructing Future MTD (Magnetic Tracking Detector).
The test apparatus of DCBA (DCBA-T2) have shown that the energy resolution is better than 150 keV (FWHM) at 970 keV, and background events are clearly identified.

♦ DCBA-T3 is scheduled to be constructed in 2007 and operated in 2008. Target energy resolution is less than 100 keV at 976 keV.

♦ New international collaboration of MTD will be able to investigate the effective neutrino mass down to around 0.05 eV.