Magnetic tracking detector **DCBA/MTD**
for neutrinoless double beta decay experiments

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**DCBA**: Drift Chamber Beta-ray Analyzer
**MTD**: Magnetic Tracking Detector (temporary)

Nobuhiro ISHIHARA (KEK) for the DCBA collaboration
Introduction

- DCBA: R&D program for neutrinoless DBD experiments
- DCBA-T2
  (i) 2 drift chambers with 6mm wire pitch
  (ii) Decay source: $^{100}\text{Mo}$ in natural Mo commercially available
  (iii) Conventional solenoid magnet of 0.8 kG maximum
- DCBA-T3
  (i) 12 drift chambers with 3 mm wire pitch
  (ii) Decay source: $^{150}\text{Nd}$ in nat. Nd$_2$O$_3$ plates developed at KEK
  (iii) Superconducting solenoid magnet of 3 kG maximum
- MTD (temporary name)
  (i) Future plan technically based on DCBA
  (ii) Decay source: $^{150}\text{Nd}$ of 10(nat.)-200(enr.) mol in 1 module
  (iii) Permanent name will be given by a new collaboration.
Magnetic Tracking Detector

Principle of electron detection

PICKUP WIRE
ANODE WIRE
FADC
CATHODE WIRE

Source Plates

Gas: He(90%) + CO$_2$(10%)

**Momentum Acceptance**

\[ p(\text{MeV/c}) = 0.3r(\text{cm})B(\text{kG}) \]

\[ B \approx 2\ \text{kG} \]

\[ 2\ \text{cm} < r < 5\ \text{cm} \]

\[ 1.2\ \text{MeV/c} < p < 3\ \text{MeV/c} \]

**Energy Acceptance for e\(^{-}\)**

\[ 0.8\ \text{MeV} < T < 2.5\ \text{MeV} \]

\( \alpha \) is automatically rejected

\[ T = 1\ \text{MeV} \rightarrow p \approx 87\ \text{MeV/c} \]
DCBA-T2 with natural Mo source

9.6% $^{100}\text{Mo}$

45 mg/cm$^2$ thick plate

0.03 mol $^{100}\text{Mo}$

Natural Mo source plate
Energy resolution of DCBA-T2

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

Including Backgrounds

FWHM $\approx 0.15$ MeV

0.98 1.05 (7 : 2.4)

Monte Carlo

FWHM $\approx 150$ keV @980 keV

976 keV

1050 keV

Chamber conditions
He(90%) + CO$_2$(10%) 1 atm
B=0.8 kG
Wire pitch=6 mm
Example of $2\nu\beta\beta$ candidates from $^{100}\text{Mo}$

Source plate

B=600G (Z-direction)

$\beta_1$ (0.99 MeV)

$\beta_2$ (0.65 MeV)

VTX

FADC time counts

Energy spectra

Energy sum of two electrons

Single electron energy

Preliminary

Preliminary

Sep. 7, 2001 N. Ishihara at TAUP2011, Munich
Decay time distribution of $^{214}$Po obtained by detecting a two- or single-electron event followed by an alpha ray.

Example of a two-electron event:

Source plate: Mo

$^{214}$Bi $\beta$ decay to $^{214}$Po + Compton $e^-$

$\alpha$ Decay of $^{214}$Po at the same VTX

$^{214}$Bi $\beta$ decay to $^{214}$Po + Compton $e^-$
DCBA-T3 (under construction)

- **Magnetic Flux Return Yoke**
- **Drift Chambers**
- **Source Plates**
- **SC-Magnet**
- **Refrigerator**

**Dimensions:**
- **5 cm**
- **57 cm**

**Materials:**
- **Nd$_2$O$_3$$^{40}$ mg/cm$^2$**

**Energy Levels:**
- **976 keV**
- **60 keV**
- **1500 keV**
- **80 keV**

**Efficiency:**
- **$\varepsilon \approx 52\%$**
- **$\varepsilon \approx 60\%$**

**Geant4**

N. Ishihara at TAUP2011, Munich
Magnetic Field Uniformity of DCBA-T3

Detector Region in Z

Error of Flux Density

+0.5%

-0.5%
DCBA-T2.5
T2 Chamber + T3 Superconducting Solenoid Magnet

2νββ event candidate from $^{100}$Mo (9.6%)

DCBA-T2 Chamber installed into the DCBA-T3 SC-Magnet

Left

Right

B = 0.8 kG

VTX

$0.82 \text{ MeV}$

$0.67 \text{ MeV}$
MTD (Magnetic Tracking Detector: temporary name) module after DCBA

Chamber cell: the same as DCBA-T3,  Source plate: 80 m²/module
Thickness: 40 mg/cm²,  Source weight: 32 kg/module

Expected Energy Resolution

\[
\frac{\text{FWHM}(E_{\text{sum}})}{Q_{\text{Nd-150}}(3370\text{keV})} = \sqrt{2 \times 80\text{keV}} \approx 3.4\%
\]
Conclusions

1. Magnetic tracking detector is a momentum analyzer for studying neutrinoless double beta decay.

2. DCBA is the R&D project followed by a future plan MTD.

3. DCBA-T2 has taken 2νββ candidates from natural Mo source plates. DCBA-T2.5 consisting of the T2 chamber and T3 magnet is in operation at KEK.

4. DCBA-T3 chamber accommodating natural Nd is under construction for improving energy resolution.

5. Several ten modules of MTD will make it possible to investigate the effective neutrino mass down to 50 meV.

6. We have applied funds to JSPS Grant-in-Aid for a MTD module.