DCBA experiment for searching for neutrinoless double beta decay (I)

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Abstract. A magnetic tracking detector called DCBA (Drift Chamber Beta-ray Analyzer) is being developed at KEK in order to search for neutrinoless double beta decay. Kinetic energy of each beta ray is obtained from its momentum, which is measured with a drift chamber installed in a uniform magnetic field. Energy resolution has been studied using a test prototype DCBA-T2. The study results are briefly described together with the structure and the principle of DCBA detector.

1. Introduction

The existence of neutrino mass was confirmed by the neutrino oscillation experiments. Next important issues are both the absolute mass scale and the Majorana nature of neutrinos. Neutrinoless double beta decay \((0\nu\beta\beta)\) experiment is only the realistic method to investigate the issues, because \(0\nu\beta\beta\) takes place when neutrinos are Majorana particles, and the effective neutrino mass \(<m_\nu>\) is obtained from the decay life. Though Klapdor et al. insist that they measured the \(0\nu\beta\beta\) half-life of \(^{76}\text{Ge}\) [1], their results elicited a number of critical replies [2]. Therefore other experiments are now strongly desired to decide that their results are valid or not.

DCBA (Drift Chamber Beta-ray Analyzer) consists of gas drift chambers and a solenoid magnet [3]. Since the drift chamber is sensitive to only charged particles, gamma ray backgrounds are automatically rejected. DCBA also can easily separate the \(0\nu\beta\beta\) events from background events such as single electrons, alpha particles and electron-positron pair creations. However, the energy resolution of DCBA was not well known so far. The results of energy resolution study using a test prototype DCBA-T2 are discussed below together with the detector structure and its operational principle.
2. DCBA-T2
A test prototype DCBA-T2 shown in figure 1 has been constructed and operated at KEK.

![Diagram of DCBA-T2](image)

**Figure 1. Illustration of DCBA-T2.**

DCBA-T2 consists of a source plate, two drift chambers, a gas container and a solenoid magnet. Source plate is made of natural Nd₂O₃ including 5.6% ¹⁵⁰Nd. Two drift chambers are located at both the sides of the source plate. Each chamber has wire planes of anode, pickup and cathode. A wire pitch is 6 mm for every wire. An anode wire is gold-plated tungsten of 20 µm diameter, and other wires are aluminum of 80 µm diameter. The anode wires are horizontally strung with 4 mm apart from the source plate. The pickup wires are vertical with a gap of 2 mm from anode wires. The volume of 90 mm between the pickup wire plane and the cathode one is sensitive to the trajectory of charged particle. The chambers are filled with the premixed gas of 85% He and 15% CO₂.

2.1. Operational principle
In figure 1, X, Y and Z-coordinates are defined as well as magnetic field direction B. Suppose ⁰νββ takes place at the vertex point (VTX) back-to-back, each beta ray makes ionization along its track in the chamber gas. Produced ionization electrons drift to anode wires along lines of electric force, and reach to anode wires. The coming electron is accelerated by strong electric field near the anode wire, and makes the so-called electron avalanche on the wire surface. While huge number of electrons produced in the avalanche is immediately absorbed in the anode wire, ions leave the anode wire for other electrodes such as pickup wires and the source plate of ground potential. An anode signal is induced by the leaving ions, and a pickup signal is done by the coming ions. Completely same timing of both the anode and pickup signals is useful to determine X, Y and Z-coordinates of a track point. The X-coordinate is the product for the velocity and the drift time of the drift electron. The Y and Z-coordinates corresponding X are the positions of anode and pickup wires, respectively. In figure 1, tracks named β₁ and β₂ are shown in three projected planes after making the three dimensional reconstruction of positions. The measurement of helical radius and pitch angle of each track enables us to obtain its momentum (p) and kinetic energy (T) from equations shown in figure 1.

2.2. Actual tracks of charged particles
Figure 2, 3 and 4 show actual tracks of an electron, alpha and electron-positron pair creation, respectively. In the figures, X-Y planes show anode wire signals and X-Z planes show pickup wire signals. We can make three-dimensional reconstruction from these tracks.

2.3. Energy resolution
In order to study the energy resolution of DCBA-T2, a point source of $^{207}$Bi has been installed at the central part of the source plate. Figure 5 shows the energy spectra of $^{207}$Bi including background events. Most intensive electron energy is 0.98 MeV. The energy resolution at 0.98 MeV is about 150 keV (FWHM). If same resolution is obtained for every beta ray, the resolution of sum-energy of two betas becomes about 210 keV (FWHM). This means that the relative energy resolution is about 6.2% (FWHM) at the Q-value of $^{150}$Nd. Since the energy resolution depends on the multiple scattering and the energy loss of a beta ray in the chamber gas, it is very useful to make the track length short in a stronger magnetic field in order to improve the energy resolution.

3. Conclusions
DCBA-T2 has a possibility of 6.2% FWHM energy resolution at Q value of $^{150}$Nd. More improvement is expected by using a stronger magnetic field in order to investigate the effective neutrino mass down to 30 meV [4].

References
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