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I. 7 Production of the Long-Lived Isotope ^{163}Ho for the Study of the Mass of Electron Neutrino

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The neutrinos are the most elusive among the known elementary particles and only upper limits of their rest masses were determined experimentally. Recently an experimental estimate of the mass of the electron anti-neutrino has been published[1)] to be $14\ eV \leq m_{\bar{\nu}_e} \leq 46\ eV$ using the β^- decay of ^3H, and it is highly desirable to check this value because the mass of the neutrino or anti-neutrino has a profound significance in our understanding of the universe as well as in the theory of elementary particles. Recently a new method of determining the mass of the electron neutrino m_{ν_e} has been proposed[2)], which utilizes the internal bremsstrahlung (I.B.) accompanying electron-capture decay of some long-lived radioisotopes, especially, that of ^{163}Ho. Another method[3)] which has been also proposed recently makes use of a precision measurement of the characteristic x-rays in the decay of ^{163}Ho. A project of such a study is going on as a collaboration of National Laboratory for High Energy Physics (KEK) and this university, in which ^{163}Ho is produced using the CYRIC cyclotron and I.B. and other radiations measured at KEK.

The radioactivity of ^{163}Ho was produced by the $^{164}Dy(p,2n)$ reaction at $E_p \sim$ 20 MeV. Since the half-life of ^{163}Ho should be very long, e.g.[4)] $T_{1/2} = 33 \pm 23$ y, and the beam intensity at the RI production courses [1] and [2] in target room no. 1 ($I_p \leq 20\ \mu A$) is insufficient, an internal irradiation of the target inside the vacuum chamber of the cyclotron up to a beam intensity of $I_p \sim 100\ \mu A$ was planned. For the sake of economy of time and cost the main probe of the cyclotron was utilized for this purpose.

The most important task in the present high-intensity irradiation is the cooling of the target, necessitating the resolution of the following problems: i) modification of the cooling block of copper of the main probe on the basis of a thermal design[5)] of water cooling, ii) addition of a safety facility to suppress water leakage into the cyclotron in case of melting of the block due to over-heating, iii) preparation of a metal target in the form of a thin plate from enriched $^{164}Dy_2O_3$, and iv) bonding of the target plate onto the cooling block using a high-temperature brazing, and disbonding the target after irradiation. These problems have been resolved and an irradiation of a ^{164}Dy target by a proton beam of $100\ \mu A \times 24$ h has been carried out successfully at an irradiation position of R = 645 mm which is inner than the effective extraction radius of 675 mm. The target assembly is illustrated in fig. 1 and the design parameters are shown in table 1.

For the preparation of ^{164}Dy metal plate $^{164}Dy_2O_3$ from ORNL was first fluorinated into $^{164}DyF_3$, which then was reduced into metal by a calcium reduction method in a tantalum crucible, followed by pressing and rolling. The reduction and the bonding and dis-bonding mentioned above were performed in an induction furnace under argon atmosphere.

From the irradiated target silver and copper due to the brazing metal were removed by a precipitation method, and then the holmium fraction was separated from the target dysprosium by an ion-exchange method using cation-exchange resin of AG 50W-X8 and eluting agent of α-hydroxy-isobutyrate buffer solution. The ^{163}Ho activity was electroplated onto a nickel foil by a small-volume electrolysis using a dilute ammonium lactate solution.

The x-ray spectrum from ^{163}Ho is being studied at this center using a Si(Li) detector and a proportional counter. Figure 2 shows the MX-ray spectrum from the decay of ^{163}Ho taken with the Si(Li) detector. A detailed study of the radiations from ^{163}Ho is planned at KEK using a double-pass cylindrical-mirror electron analyser and a position-sensitive crystal x-ray spectrometer.

References

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Table 1. Design parameters of target assembly[a)]

Proton beam	21 MeV × 100 μA over 10 × 5 mm^2 (min.)
Beam grazing angle	7.0 degrees
Dy metal target	30 × 10 × 0.15 mm^3
Brazing filler metal	BAg-8 0.1 mm thick
Cross section of Cu Block	32 × 30 mm^2
Conduction layer of Cu	8.0 mm thick
Cooling channel	22.5 × 4 × 25 mm^3
Cooling water	5.3 ℓ/min at 30°C, 4 ata
Estimated temp. at Dy surface	872°C (max.)

a) Some of these were modified in the actual irradiations.

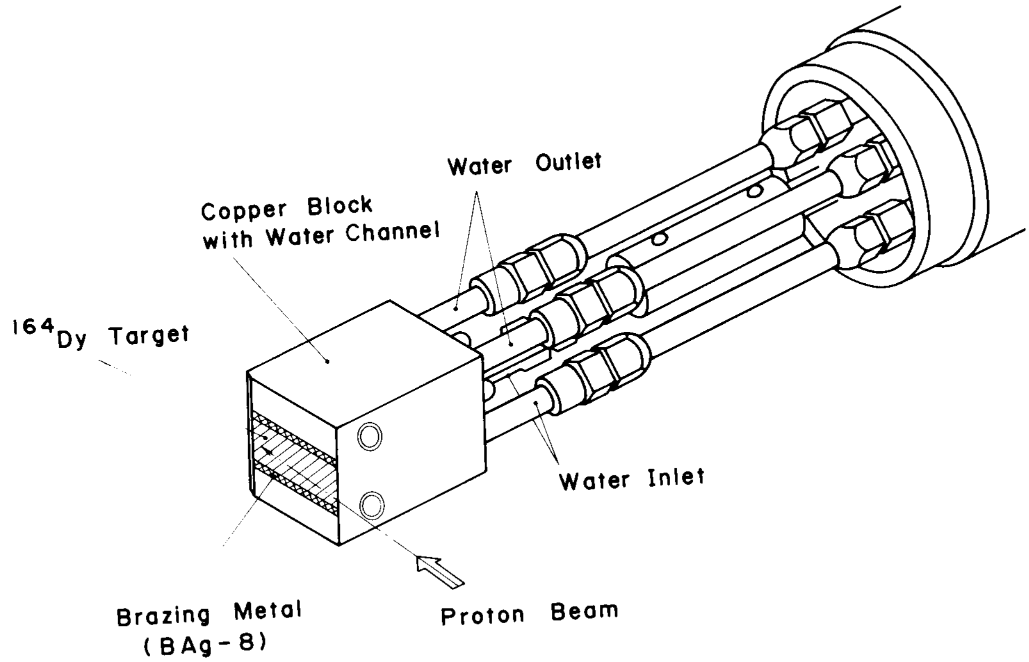

Fig. 1. Target assembly consisting of Dy target, brazing metal and cooling block of copper with water channel.

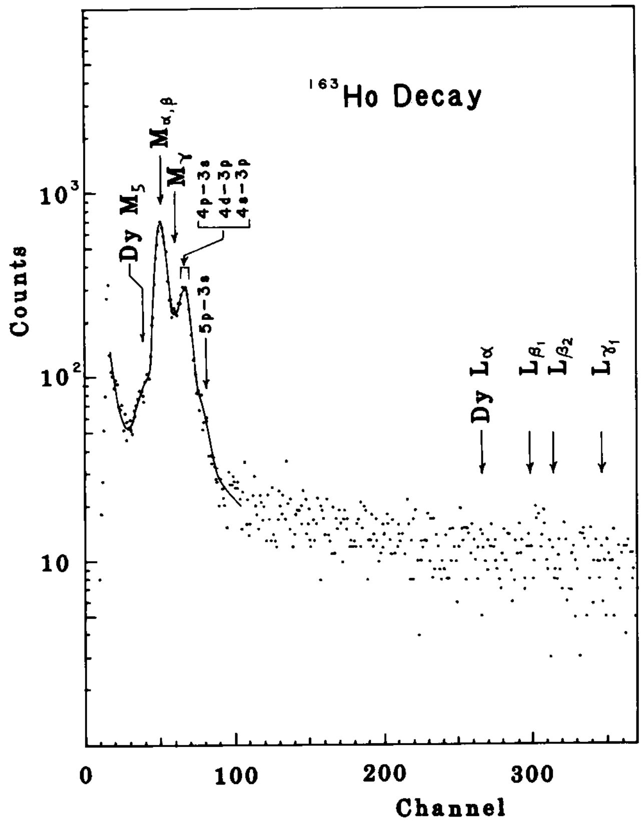

Fig. 2. MX-ray spectrum of a source of ^{163}Ho taken with a Si(Li) detector. Note the absence of Dy LX-rays.