Preparation of 169Yb Calibration Sources for the Measurement of Electron Anti-Neutrino Mass

I. 9   Preparation of ^{169}Yb Calibration Sources for the Measurement of
        Electron Anti-Neutrino Mass

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     Recently, whether the neutrino has a finite rest mass or not is of great
interest, especially, in the field of elementary particle physics and
cosmology, and the experimental studies of neutrino masses are competitively
proceeding by many groups over the world.   Also in Japan,   our group
(collaboration   of   Univ. of Tokyo/Tohoku Univ./Tokyo Metropol. Univ./Tokyo
Inst. of Tech./Jissen Women's Univ./KEK) is preparing for a measurement of the
electron anti-neutrino mass.   The principle of our measurement using the INS
iron-free β-ray spectrometer is to find the mass effect on the continuous β-
spectrum of ^{3}H in the end-point energy region (18.6 keV).   This year's
preparatory work has greatly progressed and as the result, it has pushed us to
the final stage of preparation.   This year's progress is briefly reported in
reference 1.

     Two of the important preparatory experiments are the understanding of the
response function of the spectrometer, and the absolute energy calibration of
the measurement. ^{169}Yb is suitable for this purpose.   This isotope[2] emits
M_I(18.437 keV), M_{II}(18.654 keV) and M_{III}(18.859 keV) conversion lines from the
20.744 keV transition of ^{169}Tm. ^{169}Yb was prepared as follows.

     To obtain an enough amount of ^{169}Yb for manufacturing the source, an Er
target was bombarded at the AVF cyclotron of CYRIC with a high intensity α-
beam.   The method of bombardment was described in ref. 3.   After the
bombardment, the target was transported to INS and ^{169}Yb was chemically
separated from the target.[3] However, it had been not always the case to
obtain a source of high resolution because of some impurities in the separated
sample.   The sample of a cold run was qualitatively analyzed by means of an
electron-probe X-ray microanalyzer; as a result, Al, Ca and Si were detected
as impurities.   Therefore, an additional separation was done as follows.
First, the coprecipitation of Yb with $Fe(OH)_3$ was performed to eliminate
alkaline and alkaline earth elements, which were soluble in this solution.
Secondly, the anion exchange method with mixed solvent of ethanol, HCl and

water was carried out to separate Yb from Al and Si. The Yb fraction eluted from the anion exchange column was evaporated and the resultant material was served for the preparation of calibration sources by vacuum evaporation.

As the method of source deposition, the vacuum evaporation is superier to electrical deposition in our case of the wide extended non-equipotential source.[4] The use of a continuous conductive plate as the source backing and the requirement of a large source (2 cm × 10 cm or 4 cm × 5 cm) and good uniformity of 90 % was easily achieved with the vacuum evaporation technique. ^{169}Yb was mounted on a Ta boat as HCl solution. First, evaporation in the air changed Yb to $YbCl_3 \cdot 6(H_2O)$. Secondly, evacuation and pre-heating changed the $YbCl_3 \cdot 6(H_2O)$ to $YbCl_3$ and then to Yb metal. ^{169}Yb was then vacuum-evaporated in a few seconds at 1000°C. About 10 % of the whole activity, however, remained on the boat, perhaps in the form of Yb_2O_3. The backing, a resistive plate of 4 cm × 5 cm area, was rotating at 50 cps for good uniformity. The distribution of the activity on the source backing was measured with auto-radiograph and photometrical technique, and agreed with the calculated distribution. Its uniformity was 90 %. The conversion lines from this source was measured at the INS β-spectrometer, from which we knew that the quality of the source was good.

The L_I conversion lines of the 109.78 keV and the 20.744 keV transitions were measured with the non-equipotential method. Spectra obtained are shown in Fig. 1 and Fig. 2. Momentum resolutions measured were 0.019 % and 0.038 %, respectively. These are well consistent with the spectra which are calculated by convolution of a Monte-Carlo simulated optical resolution of 0.016 % with a Lorentian shape of 5 eV natural width. For the ^{3}H β-spectrum, the momentum resolution of 0.016 % corresponds to an energy resolution of 6 eV. This resolution is about 4 times better than that of the ITEP experiment.[5]

References

1) INS Annual Repport 1984.
2) Shirley V. S., Nuclear Data Sheets 36 (1982) 443.
3) CYRIC Annual Report 1983, p. 54.
4) Bergkvist K. E., Ark. Fyz. 27 (1964) 383.
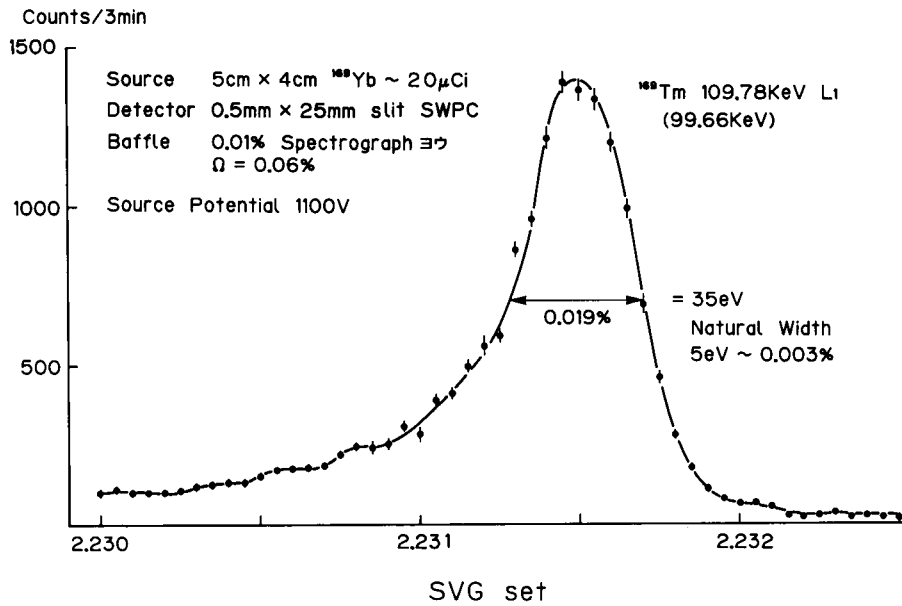5) Boris S. et al., submitted paper to EPS-HEP83, Brighton, 20-27 July 1983.

Counts/3min

1500

Source   5cm × 4cm ¹⁶⁹Yb ∼ 20μCi
Detector 0.5mm × 25mm slit SWPC
Baffle   0.01% Spectrograph ∃ぅ
          Ω = 0.06%

Source Potential 1100V

1000

                                            ¹⁶⁹Tm 109.78KeV Lı
                                            (99.66KeV)

                              0.019%   = 35eV
                                        Natural Width
500   5eV ∼ 0.003%

        2.230   2.231   2.232

                        SVG set

Fig. 1.   Spectrum of the 99.66 keV conversion line   (^{169}Tm
          109.78 keV-L_I fed from the decay of ^{169}Yb)   taken
          by the field-scanning method.   The horizontal axis,
          SVG, is proportional to the magnetic field of the
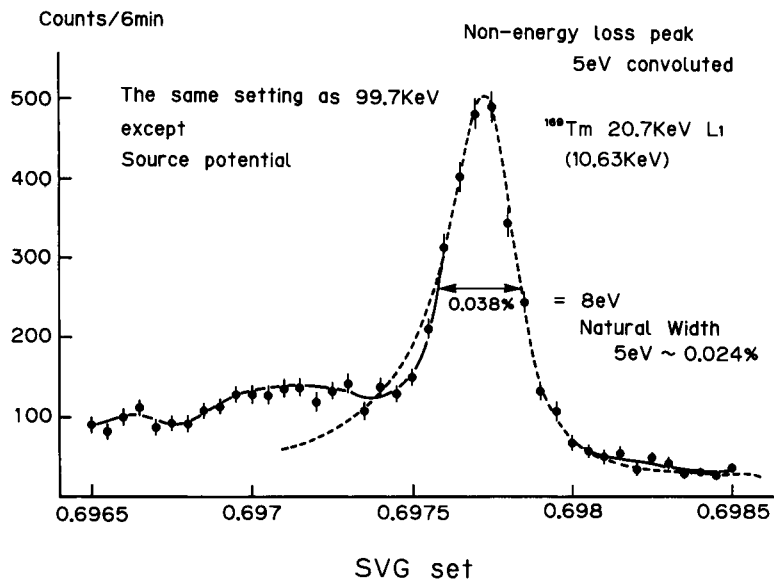   spectrometer.

Counts/6min
                                    Non-energy loss peak
                                      5eV convoluted
500   The same setting as 99.7KeV
           except   ¹⁶⁹Tm 20.7KeV Lı
           Source potential   (10.63KeV)
400

300

                              0.038%   = 8eV
                                       Natural Width
200   5eV ∼ 0.024%

100

     0.6965   0.697   0.6975   0.698   0.6985

                        SVG set

Fig. 2.   Spectrum of the 10.63 keV conversion line   (^{169}Tm
          20.74 keV-L_I) measured by the field-scanning method.
          The broken line is the spectrum obtained by convolu-
          tion of the 99.66 keV line (Fig. 1) with a Lorentzian
          shape of 0.021 % momentum width.   The Lorentzian of
          0.021 % corresponds to the difference of the effects
          of the 5 eV natural width to the 99.66 keV line (0.003
          %) and the 10.63 keV line (0.024 %).