Measurement of β end point energies with LEPS detector

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Introduction

The experimental determination of Q_β values providing information on one of the most fundamental quantities, viz., atomic mass, requires the knowledge on the beta ray maximum energy and the level scheme of the daughter nuclei. The information on beta decay maximum energy has also been very important for the identification of the nuclear isomeric states when determined in coincidence with the gamma rays de-exciting the excited levels of the daughter nucleus [1].

The detection of beta particles has been explored since many years using a variety of detector systems having a wide range of efficiency and resolution, viz., magnetic spectrometer, plastic scintillators, silicon and germanium solid state detectors. The planar Hyper Pure Germanium (HPGe) detectors having a thin Be window have already been demonstrated to be quite efficient in this purpose [2,3]. Moreover these detectors provide a very good energy resolution as well as can be calibrated up to very high energy using appropriate gamma ray sources. However, the high atomic number of Ge gives rise to high backscattering and bremsstrahlung production probability making a distortion at the low energy part of the spectrum. The coincidence measurement with an appropriate gamma detector becomes unique for determining the end point energies related to even very weakly populated levels of the daughter nuclei. Very few studies are known that have employed the beta gamma coincidence technique involving germanium detectors in order to measure the end point energies. Specially, in most of the cases, the measurements have been made with nuclei having simple decay structures in order to avoid the contamination from the gamma response of the Ge detector. However, it is important to see the use of such technique using Ge detector with complicated level spectra of the daughter nuclei as the very high efficiency of Ge detector is the only choice to measure the weak beta branches and high energy beta decays.

In this work, we have reported the success of the beta gamma coincidence technique utilizing the beta response of thin window Ge LEPS detector for the measurement of endpoint energies, even for very weak beta branching.

Experimental Techniques and Results

The β endpoint energies for several known and unknown branches of ^{106}Rh and the known branches of ^{22}Na, ^{181}Hf decay have been measured using a coincidence setup consisting of a 11mm thick Ge Planar segmented LEPS (Low Energy Photon Spectrometer) detector and a 10% efficient coaxial HPGe detector. The LEPS detector has a 300 μm thick Be window which is completely stops only beta particle with energy up to 223 keV and the 10% Ge detector has response to only very high energy beta particles for its thick entrance window. The front face of the 10% detector was covered with 11 mm thick aluminium plate in order to ensure that no beta particle enters this detector. The open sources with high specific activity with insignificant solid content were prepared which was dried on an electro-polished stainless steel surface of 0.5 mm thickness. The detectors were kept at a distance of 2.9 cm from each other and the source was kept at a distance of 0.9 cm from, and the front side facing, the LEPS detector. As the LEPS detector has response for both beta and gamma radiations it is expected that a coincidence spectrum in the LEPS detector, made by gating a gamma ray, decaying from the level of interest in daughter nucleus, in 10% HPGe detector, will have contribution from the (i.) respective beta decay branch populating the level of interest, (ii.) gamma rays (photopeak and Compton) in coincidence which are decaying from the lower lying states, (iii.) gamma rays (photopeak and Compton) in coincidence, de-exciting to the level of interest from the higher lying states and (iv.) the beta branch decaying to these higher lying states. Hence, it is important to properly delineate and subtract all other contributions and to extract the required beta spectrum. For this purpose the coincidence measurements were taken in two configurations, viz., (i.) the open source facing the LEPS and putting no absorber other than the factory made Be window in front of LEPS and (ii.) the open source facing the 10% Ge detector and keeping a 8 mm thick Ta block in front of the LEPS detector. Gamma ray gate was put in the 10% detector and the corresponding spectra were projected in four segments of the LEPS detector. The spectrum from measurement (i) consists of the response both from beta and gamma radiations whereas the spectrum from measurement (ii) consists of that only from gamma. The spectra were normalized at the most intense photopeak in coincidence and the second spectrum was subtracted from the first one in order to arrive at the required beta spectrum. The contribution from the unwanted low energy beta branches were subtracted by appropriately subtracting the two different gamma gates. However, many a times it is difficult to subtract the contribution from the Compton profile of the detected gamma rays and the lower energy part of the spectrum becomes different than expected. Experimentally, the spectra have been obtained for the known beta branches of energy 3050 keV, 2400 keV and 2000 keV, in one segment of the LEPS detector, by putting gates on the corresponding gamma rays, viz. 511 keV, 621 keV and 1049 keV respectively, in the 10% HPGe detector and correcting for the unwanted events as described above. The results for the ^{106}Rh decay [4] have been shown in Fig. 1, where they have also been compared with the response obtained using the simulation code GEANT3 [5]. The observed mismatch in the lower energy side is due to the finite thickness of the source as well as the improper subtraction of Compton profile. However, the higher energy part matches quite well except at very high energy. This may be due to the contribution of summing of the gamma ray with the beta profile. From a preliminary analysis, the end point energies to these known beta decays have been measured with an reasonable accuracy, considering the attenuation at the Be window of LEPS, as shown in Fig. 2. The end point energies comes out to be 2916$\pm$60 keV, 2227$\pm$28 keV and 1850$\pm$13 keV for the three known beta branches of 106Rh decay. The endpoint energies for some of the unknown weak beta branches of ^{106}Rh decay have been measured and will be presented.

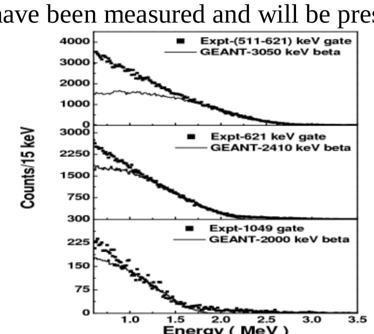

Figure 1: The beta spectrum obtained for ^{106}Rh decay from the LEPS detector and compared with the GEANT simulation

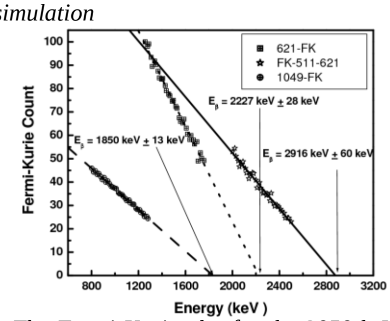

Figure 2: The Fermi-Kurie plot for the 3050 keV and 2410 keV β decay of ^{106}Rh

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