Decay of ^{180m}Hf as a (-ray Calibration Source

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A key requirement of our program to test CKM unitarity via high precision measurements of superallowed $\exists$-decay [1] is to know the efficiency calibration of our 70% HPGe detector to a precision of about $\pm$ 0.1%. In order to obtain this very precise efficiency calibration we have made careful high-statistics measurements of various sources, and the results have been combined with Monte Carlo calculations for the exact dimensions and composition of our HPGe detector [2]. In particular we have used the decay of the isomer ^{180m}Hf($t_{1/2}$ = 5.5 h) to obtain rather precise data for efficiencies in the energy range from 90 to 330 keV. This range is important for the study of ^{22}Mg decay, which requires (-ray efficiencies down to 74 keV. The decay of ^{180m}Hf to the ^{180}Hf ground state includes a cascade of three consecutive E2 (-ray transitions of energies 332.3, 215.4 and 93.3 keV with no other feeding of the intermediate states (see figure 1). Thus, the relative (-ray intensities depend only on the calculated E2 conversion coefficients.

We produced ^{180m}Hf by irradiating a 0.91 mg sample of HfO_2, isotopically enriched to 87% in ^{179}Hf, at the TRIGA reactor in the Texas A&M University Nuclear Science Center. The thermal neutron cross section for ^{179}Hf (n,() ^{180m}Hf is 0.4 b. Irradiation in a neutron flux of N=7•10^{12} neutrons/cm^2•s for 26 minutes produced 10 :Ci of activity, principally ^{180m}Hf. In order to minimize the self-absorption of (-rays in Hf we needed to produce a thin source. Following a procedure developed by Kellog & Norman [3], the activated HfO_2 sample was dissolved in 0.50 ml of hot 48% HF acid. The

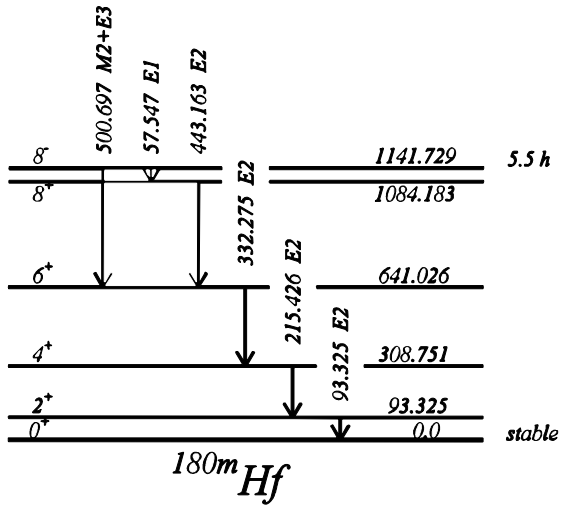

Figure 1: The decay of ^{180m}Hf to the ^{180}Hf ground state includes a cascade of three consecutive E2 (-ray transitions of energies 332.3, 215.4 and 93.3 keV with no other feeding of the intermediate states.

solution was stirred for 20 minutes while being maintained at 70-80^{o}C. The HfO_2 reacted with the HF to produce HfF_4, which remained in solution. A 0.03-0.04 ml drop of the solution was deposited on a 50 mg/cm^2 carbon foil, which had been coated with insulin and pre-mounted on a 0.08-mm-thick Mylar foil backing. For about 20 minutes the HF acid was evaporated under gentle heat, leaving the HfF_4 salt residue stuck in small crystals (< 5 :m thick) to the carbon foil. Finally, we placed another 0.08-mm-thick Mylar foil on top of the source, sealing it with tape at the edges. Figure 2 shows the (-ray spectrum recorded for 4.2 hours with our 70% HPGe detector at 15 cm from the ^{180m}Hf source.

The measurements on the decay of ^{180m}Hf were performed at source-detector distances of 10 cm and 15 cm. Summing

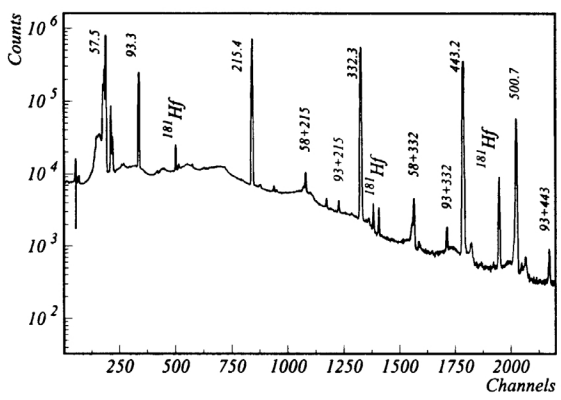

Figure 2: Gamma-ray spectrum of ^{180m}Hf recorded with a 70% Ge detector at 15 cm for 4.2 h.

corrections, including the effects of angular correlations, were included in the analysis. The peak areas of interest were determined with 0.1% precision or better. The calculated E2 internal conversion coefficients were taken from Ref. [4] and assumed to bear a 1% uncertainty. The results axe shown in figure 3. The circles and triangles show the detector efficiency measured with ^{133}Ba and ^{180m}Hf, respectively, expressed as their percentage difference from the efficiencies obtained with preliminary Monte Carlo calculations that used only nominal detector dimensions. These results played an important role in refining the Monte Carlo calculations, which now agree very closely with the data, as shown in [2].

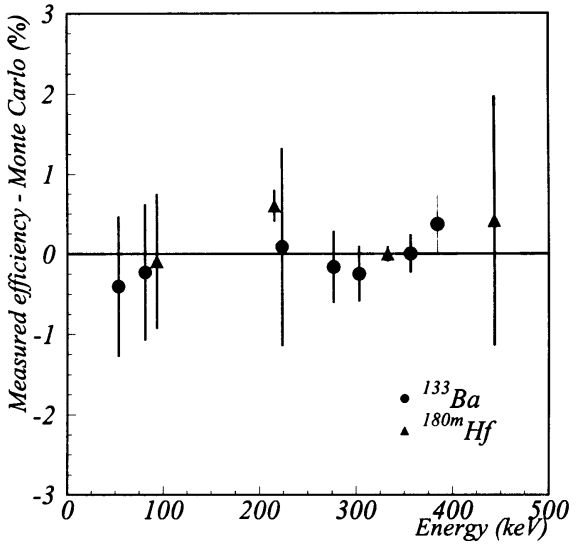

Figure 3: Percentage difference between the detector efficiency measured with ^{133}Ba and ^{180m}Hf, and the calculated efficiency obtained from preliminary Monte Carlo calculations.

References

[1] J. C. Hardy *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2000-2001), p. I-24.

[2] J. C. Hardy *et al., Progress in Research*, Cyclotron Institute, Texas A&M University (2000-2001), p. V-24; and Applied Radiation and Isotopes, to be published.

[3] S. E. Kellog and E. B. Norman, Phys. Rev. C **31,** 1505 (1985); Phys. Rev. C **46**, 1115 (1992).

[4] Program HSICC v.11.13.a 08-Feb-99, Brookhaven National Laboratory and references therein.