The Preparation and Use of ^{48}Cr and ^{120m}Sb as Calibration Sources

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A key requirement of our program to test CKM unitarity via high-precision measurements of superallowed β-decay [1] is to know the efficiency calibration of our 70% HPGe detector to a precision of ~0.1%. In order to obtain this very precise calibration, we have made careful high-statistics measurements of various sources, with the results being combined with Monte Carlo calculations for the exact dimensions and composition of our detector [2].

We identified two sources of particular interest – ^{48}Cr and ^{120m}Sb – which could be produced with K500 cyclotron beams. Both sources provided γ-rays in the region of 100-keV as members of pure γ-ray cascades (no side-feeding) in their β-decay daughters. The ^{48}Cr decay yields a pair of γ-rays at 112.4 and 308.3 keV, while ^{120m}Sb yields four at 89.8, 197.3, 1023.1 and 1171.3 keV. Since the β-decay of ^{22}Mg leads to several γ-rays, including one at 74.0-keV [3], the measurement of its branching to the superallowed transition depends crucially on the precision of our efficiency calibration in that energy region. In the cases of ^{48}Cr and ^{120m}Sb, internal conversion does not play a dominant role, so their decays yield precise relative efficiencies (± 0.1-0.2%) that connect the 100-keV region with higher energies.

We prepared ^{48}Cr ($t_{1/2}$ = 22 h) sources using a 37 *A*MeV ^{50}Cr beam from the cyclotron incident on a cooled hydrogen gas target in the MARS target chamber. Products from the reaction p (^{50}Cr,p2n) ^{48}Cr were separated in MARS, producing a ^{48}Cr beam of ~31.4 *A*MeV. The ions passed through a plastic scintillator and a series of degraders before stopping in a piece of aluminized mylar tape, 76 μm thick. Once the degrader thickness had been optimized, over 90% of the ^{48}Cr ions were stopped in the tape. Signals from the plastic scintillator were counted to give an approximate measure of the total number of ions deposited in the tape. Three ^{48}Cr sources were prepared, with strengths between 1.7 and 3.8 kBq, and each was placed in our standard counting position 15.1 cm from the front surface of the HPGe detector. Combined, the spectra from the measurements of the three sources had $>2\times10^6$ in both the 112- and 308-keV peaks, sufficient to yield statistical uncertainties below 0.1%. A spectrum appears in Figure 1. Analysis of the data followed our usual methods [4], which incorporate careful corrections for coincidence summing.

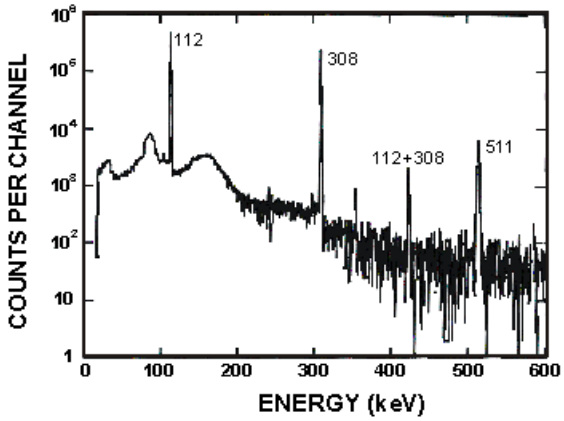

Figure 1: Gamma-ray energy spectrum observed following the beta-decay of ^{48}Cr.

We used a proton beam from the cyclotron, degraded to 10 MeV, to produce a source of ^{120m}Sb ($t_{1/2}$ = 5.8 d) from the reaction ^{120}Sn (p,n) ^{120m}Sb. The target was a 1.7 mg/cm^2 foil enriched to 99.4% in ^{120}Sn, mounted on an aluminum frame. The beam was collimated to a

1-cm-diameter spot to ensure that only the target itself was activated. The total proton flux was determined via a Faraday cup placed behind the target. The ^{120}Sn foil was activated for a total of 12.5 hours, with an accumulated proton charge of 7.5 mC. The source produced had an initial activity of ~12 kBq.

Initial inspection of the γ-ray spectrum from the source indicated five impurities were present: ^{56}Mn ($t_{1/2}$ = 2.6 h), ^{117}Sb (2.8 h), ^{118m}Sb (5 h), ^{24}Na (15 h) and ^{122}Sb (2.7 d). The first three of these impurities have very short half-lives and quickly decayed away. Neither of the other two,

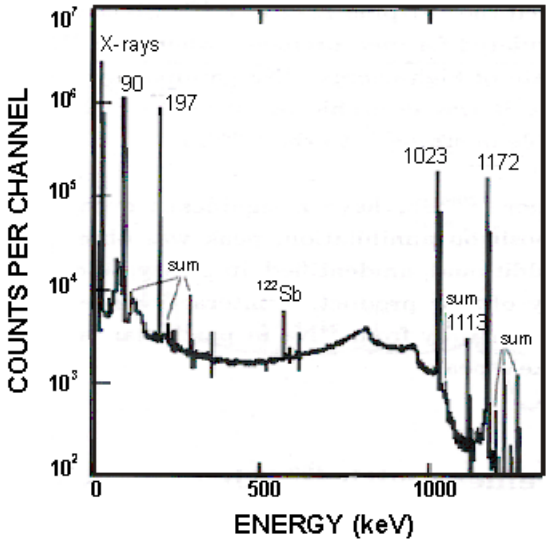

Figure 2: Gamma-ray energy spectrum observed following the beta-decay of ^{120m}Sb. This spectrum was recorded after the aluminum frame had been removed. The only impurity peak visible is the ^{122}Sb peak at 564-keV.

^{24}Na and ^{122}Sb, emit γ-rays close to any of the main ^{120m}Sb peaks, so they were not of serious concern. However, the 1369-keV peak from ^{24}Na obscured the (197 + 1172) keV ^{120m}Sb sum peak; and the presence of high-energy γ-rays from ^{24}Na increased the background for the ^{120m}Sb peaks. Several measurements were made while the ^{24}Na decayed over a two-day period; and then the target foil was removed from the aluminum frame entirely, which reduced the ^{24}Na activity still further. The spectrum in Figure 2 was acquired at this time. Analysis proceeded as before.

The resulting efficiencies determined from these two sources have now been incorporated into our overall efficiency curve [2], where they have been instrumental in improving the precision of our detector efficiency below 200-keV to 0.15%.

References

[1] J. C. Hardy *et al., Progress in Research*, Cyclotron Institute, Texas A&M University (2001-2002), p. I-21.

[2] J. C. Hardy *et al., Progress in Research*, Cyclotron Institute, Texas A&M University (2001-2002), p. V-14.

[3] M. Sanchez-Vega *et al., Progress in Research*, Cyclotron Institute, Texas A&M University (2001-2002), p. I-24.

[4] J. C. Hardy *et al.*, Applied Radiation & Isotopes **56,** 65 (2002).