Superallowed $0^+ \rightarrow 0^+$ Beta Decay: the Cases of ^{22}Mg and ^{30}S

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Superallowed $0^+ \rightarrow 0^+$ nuclear beta decays provide both the best test of the Conserved Vector Current (CVC) hypothesis and, together with the muon lifetime, the most accurate value for the up-down quark-mixing matrix element, V_{ud}, of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. This matrix should be unitary, and experimental verification of that expectation constitutes an important test of the Standard Model. With current world data for $0^+ \rightarrow 0^+$ nuclear beta decay [1] used to obtain a value for V_{ud}, and standard values [2] taken for the other required elements of the CKM matrix, the unitarity test from the sum of the squares of the elements in the first row fails to meet unity by more than twice the estimated uncertainty. This result is tantalizingly close to establishing a definitive disagreement with the Standard Model, and motivates this experimental program, which is aimed at firmly establishing (or eliminating) the discrepancy with unitarity.

A recent re-examination [1] of the calculated radiative and isospin symmetry-breaking corrections applied to the nuclear data reveals no evident defects that could cause the apparent non-unitarity, but suspicion continues to fall on the latter, δ_C, which depends sensitively on the details of nuclear structure. To establish the accuracy of the calculated δ_C corrections once and for all, we have mounted an experimental program to measure the *ft*-values (to a precision approaching ±0.1%) of T_z = -1 superallowed emitters with 18 ≤ A ≤ 38.

The first cases to be studied, ^{22}Mg and ^{30}S, were chosen [3] because the calculated δ_C value for the superallowed transition from ^{22}Mg is very low, 0.35%, while that for ^{30}S is 1.2%, about a factor of two higher than for any case currently known. If the measured *ft*-values support this "large" calculated difference between the two cases, then the theoretical uncertainties associated with all calculated isospin symmetry-breaking corrections in this mass region can be reduced considerably.

Our first major data-taking experiment – to determine branching ratios in the decay of ^{22}Mg via its β-delayed γ-rays – took place in February. To reach the required level of precision, we had previously built up specialized experimental equipment, with our own dedicated electronics and data-acquisition system [4,5]. Over many months, we had taken (and have continued to take since) great pains to characterize the efficiency [6] and stability of our HPGe detector in a laboratory well removed from the cyclotron target area. For the experiment, the detector, electronics and data-acquisition computer were wheeled intact to the target area, where the entire system remained electrically isolated from the beam-line, the ^{22}Mg samples being delivered via the tape-transport system to a precisely measured and well shielded position in front of the HPGe detector. Thus we ensured, insofar as possible, that the calibration conditions were unchanged during the actual measurement; we confirmed this by additional *in situ* calibrations.

During the experiment, a 28 *A* MeV ^{23}Na beam from the K500 cyclotron was directed into a cooled hydrogen-gas target, producing ^{22}Mg via the reaction p(^{23}Na, 2n)^{22}Mg. Unwanted reaction products were then separated away by

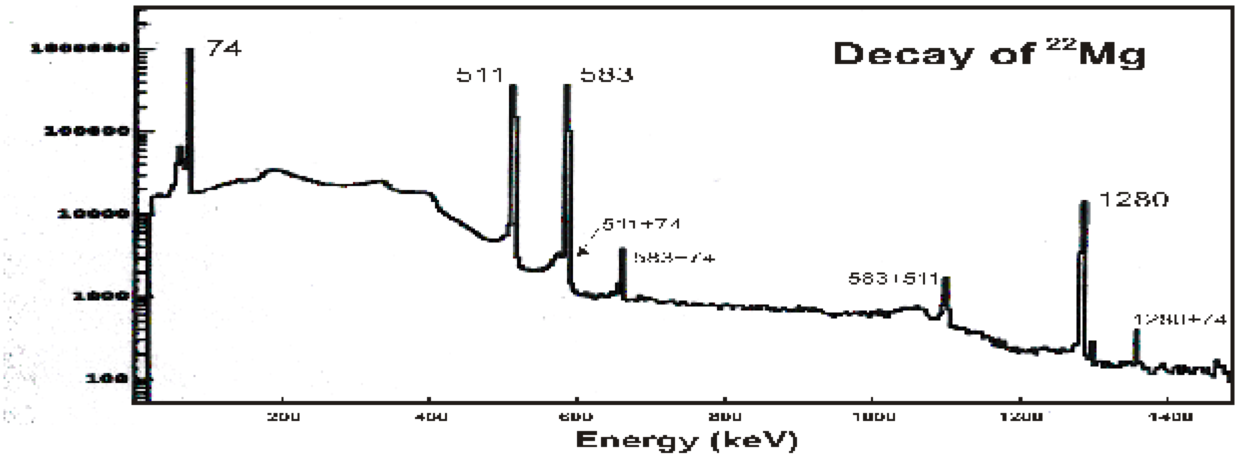

Figure 1: Spectrum of β-delayed γ-rays observed following the β-decay of ^{22}Mg. Peaks are labeled with their energy in keV.

the MARS recoil spectrometer, leaving at the spectrometer exit a ~5,000-atoms/s beam of 25 *A* MeV ^{22}Mg with a measured purity of 99.8%. This beam exited the vacuum system through a 50 μm kapton window, then passed through a 0.3-mm-thick BC-404 scintillator disk mounted on a R329P Hamamatsu phototube, next through a set of aluminum degrader-foils and finally stopped in the 76-μm-thick aluminized mylar tape of our tape-transport system. The ^{22}Mg nuclei ($t_{1/2}$ = 3.86 s) were collected on the stationary tape for 5 s, after which the cyclotron beam was interrupted and the collection-spot on the tape moved to the shielded counting station ~90 cm away. The move took 180 ms, and was followed by a 5-s counting period. When the counting period had been concluded, the cyclotron beam restarted and a new collection began. This sequence was repeated until more than 10^6 counts were obtained in each of the photo-peaks of interest.

At the counting station, the tape was positioned between the HPGe γ-ray detector and a 1-mm-thick BC-404 scintillator disk used to detect β^+-particles from the decay of ^{22}Mg. Coincidence data were recorded event-by-event, four parameters being stored for each event: γ-ray energy, β energy, β-γ relative time, and time elapsed since the last tape move. The data stream was made up of such events recorded during the counting periods, interspersed with heavy-ion events recorded at the MARS exit during the collection period. Thus, the size of each ^{22}Mg sample was precisely known and could easily be correlated with the corresponding decay data. Singles γ-ray spectra were also recorded in separate runs.

A coincident γ-ray spectrum recorded with a source-detector distance of 15.0 cm is shown in Fig. 1. Analysis of the data is in progress.

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