Precise Branching Ratio Measurement of the Superallowed $\exists^+$-decay of ^{22}Mg

M. Sanchez-Vega, J. C. Hardy, V. E. Iacob, A. Azhari, C. A. Gagliardi, J. Giovanazzo[a], E. V. Mayes, P. G. Neilson, L. Trache, R. E. Tribble, D. Willis and Y. Xiao

[a] *Centre d'Etudes Nucléaires de Bordeaux-Gradignan, IN2P3/CNRS, France*

Our principal focus for the past year has been a study of the $\exists^+$-decay of ^{22}Mg ($t_{1/2}$ = 3.86 s) in order to measure with high precision the superallowed $0^+ \rightarrow 0^+$ branching ratio to the 657.0 keV level in 22 Na. This work is part of our experimental program (see [1]) to measure the *ft*-values for superallowed $0^+ \rightarrow 0^+$ decays of nuclei with 22 $\leq$ A $\leq$ 34 to a precision approaching ± 0.1%. We have begun with ^{22}Mg because the calculated charge correction, δ_C, for the superallowed transition in ^{22}Mg is very low, 0.26%. The experimental input to any *ft*-value comprises the branching ratio and decay energy of the particular transition, together with the half-life of the parent nucleus. We report here on our measurement of the branching ratios for $\exists$ transitions from ^{22}Mg. The following report [2] describes our half-life measurement.

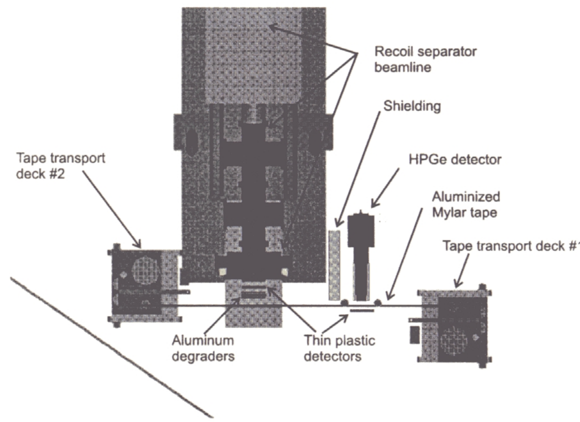

Figure 1: Plan drawing of the focal plane of the MARS spectrometer, tape-transport system and detectors. Note the plastic detector at the end of MARS, which is used to observe the 22Mg ions destined for collection on the tape. Another plastic detector is used at the counting location, where we record $\exists$-(coincidences.

The experimental arrangement is shown in Fig. 1. We produced ^{22}Mg using a 28A MeV ^{23}Na beam from the K500 cyclotron to initiate the ^{1}H(^{23}Na, 2n)^{22}Mg reaction on a cooled hydrogen gas target. The recoil products entered the MARS spectrometer where the ^{23}Na beam and other impurities were separated away, leaving a >99.6% pure ^{22}Mg beam at the MARS focal plane. This beam, containing approximately 10,000 atoms/s at 23A MeV, then exited the vacuum system through a 50-:m-thick Kapton window, passed successively through a 0.3-mm-thick BC-404 scintillator and a stack of aluminum degraders, finally stopping in the 75-:m -thick aluminized mylar tape of the tape-transport system [3]. The impurities, having different ranges from ^{22}Mg, were not collected on the tape. We determined experimentally that >99.8% of the exiting ^{22}Mg beam stopped in the tape. Furthermore, we were unable to detect any evidence of collected impurities and therefore we conclude that any remaining impurities in the collected sample must be substantially less than 0.1% of the 22mg content.

In a typical measurement, we collected ^{22}Mg on the tape for 5 s, then interrupted the accelerator beam and moved the sample to the shielded counting location 90 cm away in 180 ms; there data were recorded for a further 5 s while the beam remained off. This cycle was clock-controlled and was repeated continuously. At the counting location, the sample was positioned between a 70% HPGe (-ray detector and a 1-mm-thick BC404 plastic scintillator that was used to detect $\exists^+$ particles. Time-tagged

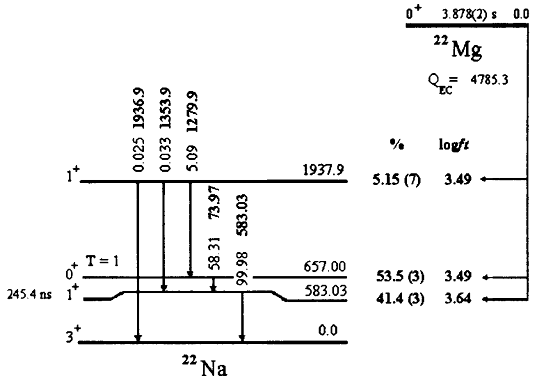

Figure 2: Preliminary results for the ∃+-decay of ^{22}Mg.

coincidence data were stored event by event with our fast PC- and CAMAC-based acquisition system with KmaxNT software [4]. In separate runs, we recorded ∃-(coincidence data with the (-ray detector placed at 10 and at 15 cm from the sample. We also recorded a singles (-ray spectrum.

The decay of ^{22}Mg has the important property (see Fig. 2) that the transition to the ^{22}Na ground state, being second forbidden unique, is suppressed by ten orders of magnitude or more, and can be neglected. Thus, since all significant ∃ branches are followed by (-rays, we need only measure the relative intensities of these (-rays to obtain the ∃ branching ratios. This also has an important impact on our future studies because the (-ray data on ^{22}Mg yield a value for our system's overall counting efficiency relative to the number of ^{22}Mg ions detected at the exit of MARS. Since we record these ions as a function of time during the collection period, we know precisely the number of ^{22}Mg nuclei present in our collected sample at the beginning of the counting period. This provides an *in situ* calibration of our absolute (-ray detection efficiency. This will be very important for future measurements of branching ratios of other decays in which there is direct ground-state ∃ feeding.

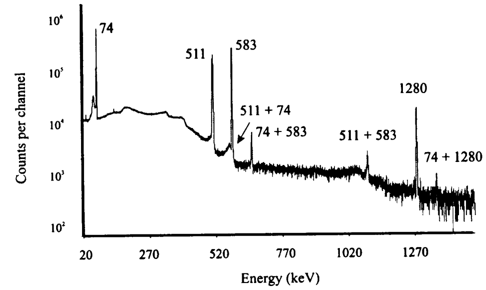

Figure 3: Spectrum of (-rays with energies less than 1.3 MeV observed following the ∃+-decay of ^{22}Mg. It was recorded at 15cm with a 70% HPGe detector. Each peak is marked with its energy in keV; sum peaks are also indicated.

The preliminary results that we present here were obtained in two experiments, one that took place in February 2000 and the other in March 2001. The experimental conditions were identical except that the coincidence ∃-(time window was larger in the latter experiment (1 :s instead of 500 ns). This modification was needed because the 583-keV level has a half-life of 245 ns. In order to reduce our uncertainties, we chose to minimize the correction to the area of the 583-keV peak required as a result of (-rays delayed beyond our time window. A coincident (-ray spectrum recorded with a source-detector distance of 15.0 cm is shown in Fig. 3.

Our HPGe detector has been meticulously calibrated with radioactive sources and Monte Carlo calculations [5]. This calibration currently yields relative (-ray intensities to 0.2% for energies above 200 keV and 0.4% for energies below that energy; further improvements will be forth-coming soon, as additional calibration sources are prepared and measured. Summing corrections incorporating the effects of (-(angular correlations were included both in our calibration data and in the analysis of our ^{22}Mg measurements. The preliminary results are presented in Fig. 2. In particular, the branching ratio for the $0^+ \rightarrow 0^+$ transition is 53.5(3)%. Ultimately, we expect to reach a precision approaching 0.1%.

References

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