

## Half-life of the superallowed beta emitter, $^{30}\text{S}$

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The superallowed  $0^+ \rightarrow 0^+$   $\beta$ -decay branch from  $^{30}\text{S}$  is not one of the fourteen  $0^+ \rightarrow 0^+$  transitions that have been measured to  $\pm 0.1\%$  precision or better. The most recent survey of world data [1] gives  $ft = 3005(41)$  s and  $\mathcal{F}t = 3016(41)$  s for the  $^{30}\text{S}$  transition, a precision of  $\pm 1.35\%$ , which is more than a factor of 10 too large for it to contribute to fundamental tests of the weak interaction or of isospin symmetry breaking [2]. The predominant contribution ( $\pm 1.34\%$ ) to the large uncertainty is from the branching ratio, which is based on a single 1963 measurement. Though the half-life is known much more precisely, it is still not adequate since its world-average value [1] is quoted to  $\pm 0.14\%$  and that is based on two measurements, only one of which has  $0.14\%$  precision. Alone among the three required experimental quantities, the  $Q_{\text{EC}}$  value can be considered to be measured with sufficient precision: Its contribution to the  $ft$ -value uncertainty is merely  $\pm 0.03\%$ .

The  $^{30}\text{S}$  case is an interesting one because its calculated nuclear-structure-dependent correction term is unusually large: *viz.*  $\delta_{\text{C}} - \delta_{\text{NS}} = 1.040(32)\%$ . We argue that such a case offers a good test of the correction terms themselves: If the measured  $ft$  value for such a transition yields a corrected  $\mathcal{F}t$  value that is consistent with the other well-known cases, then this serves to verify the calculations' reliability for the existing cases, which have smaller corrections [2].

We have chosen to begin with a measurement of the half-life of  $^{30}\text{S}$ . Quite apart from its ultimate benefit in contributing to a usefully precise  $ft$  value, the measurement also offers an excellent opportunity to compare results from the various techniques we now have available to measure half-lives. Unlike most  $T_{\text{Z}} = -1$  superallowed  $\beta$  emitters,  $^{30}\text{S}$  does not feed a second  $0^+ \rightarrow 0^+$   $\beta$  transition from its daughter. The  $0^+$ ,  $T=1$  state populated in  $^{30}\text{P}$  decays electromagnetically to the ground state, which proceeds by ordinary allowed  $\beta$  decay to  $^{30}\text{Si}$  with a half-life of  $2.498(4)$  min. Thus there is a very clean separation between the  $^{30}\text{S}$  half-life of  $1.18$  s and that of its daughter, which is more than a factor of 100 longer. Because we detect the positrons from both decays simultaneously in the same detector, this separation between parent and daughter half-lives makes it possible in principle to achieve much higher precision on the parent half-life than is possible when both activities have very similar half-lives. This makes possible a very demanding comparison of the results based on different experimental techniques.

We produced a  $^{30}\text{S}$  radioactive beam via the  $p(^{31}\text{P}, 2n)^{30}\text{S}$  reaction, with a  $30$  A-MeV  $^{31}\text{P}$  primary beam impinging on a  $\text{H}_2$  cryogenic gas-target kept at a pressure of  $2$  atm and at liquid-nitrogen temperature. A high purity  $^{30}\text{S}$  beam was then selected with the Momentum Achromat Recoil Separator (MARS), extracted into air, where it passed through a thin plastic scintillator, a series of Al degraders, and eventually implanted in the  $76\text{-}\mu\text{m}$ -thick Mylar tape of our fast tape-transport system. The thickness of the Al degraders was experimentally tuned to optimize the implantation and purity of the  $^{30}\text{S}$  beam.

Data were collected in cycles: After  $^{30}\text{S}$  nuclei had been implanted for a pre-selected time interval (of the same order as the  $^{30}\text{S}$  half-life), the beam was turned off and the tape-transport system moved the sample in  $\sim 175$  ms to a well-shielded location  $90$  cm away, stopping it in the center of a  $4\pi$  proportional gas counter. The decay positrons were then detected for twenty half-lives ( $24$  s). These collect-move-

detect cycles were computer controlled and their timing was continuously monitored on-line. They were repeated, with a separate decay spectrum recorded for each, until the desired overall statistics had been achieved. In its shielded location, the gas counter had a background rate of about 0.5 counts/s, which was 3-4 orders of magnitude lower than the initial count rate for each collected sample.

The total measurement took 6 days, with the first half dedicated to our digital system. In that case, the signal from the gas proportional counter was amplified by two cascaded fast amplifiers with total gain of 1000, before being sent to a high-speed digitizer (NI-5154) for digitizing and pulse capture. The second half of the measurement we replaced the digital system with our standard analogue electronics (see, for example, [3]) and, in parallel, our TDC-based system [4]. Thus we have two sets of independent data, one processed via digital pulse analysis, and the other via either multiscaler spectra or event-by-event time stamps. The analysis is nearly complete.

[1] J.C. Hardy and I.S. Towner, *Phys. Rev. C* **91**, 025501 (2015).

[2] J.C. Hardy *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2016-2017), p. I-1.

[3] H.I. Park *et al.*, *Phys. Rev. C* **85**, 035501 (2012).

[4] V. Horvat and J.C. Hardy, *Progress in Research*, Cyclotron Institute, Texas A&M University (2010-2011), p. V-51.