Precise Half-Life of the Superallowed β^+ Emitter ^{34}Ar

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As part of our program of precise measurements aimed at testing the Standard Model *via* the unitarity of the Cabibbo-Kobayashi-Maskawa(CKM) matrix, we have determined the half-life of the superallowed $0^+ \rightarrow 0^+$ β^+ emitter ^{34}Ar. This is a particularly difficult case since the daughter of this decay, ^{34}Cl, is itself radioactive with a half-life only about a factor of two longer than that of ^{34}Ar. Since we measure decay positrons, we are unable to distinguish between the parent and daughter activities, and the composite activity decays with what is very nearly a single component, a component that exhibits the half-life of the daughter! As a result, our first attempt to measure the ^{34}Ar half-life [1] yielded the value 847.0(37) ms, a result quoted with a precision of only 0.43%.

For a measurement to be meaningful in the context of a CKM unitarity test, it must achieve a precision of better than 0.1%. We therefore took considerable pains to refine our methods and last year we reported the development of a new technique that yields higher precision for such parent-daughter decays [2]. We report here a new measurement of the ^{34}Ar half-life, which preliminarily quotes a precision of ~0.1% and is expected to be improved still further in final analysis.

In the experiments analyzed with the novel technique, a high-purity (>99.3%) radioactive beam of ^{34}Ar was produced *via* the ^{1}H(^{35}Cl,2n)^{34}Ar reaction on an LN$_2$-cooled hydrogen gas target, and separated in the MARS spectrometer. The ^{34}Ar ions were collected in the 76μm-thick mylar tape of our fast tape-transport system, having passed first through a plastic scintillator (to measure the production rate) and a stack of aluminum degraders. The ^{34}Ar activity was collected for either 0.7s or 1s. At the end of this collection time the beam was switched off and the collected activity was moved 90 cm in 180 ms by the tape-transport system to a 4π proportional gas counter located in a low background region. The counter signals were then multiscaled for a period of 12s, yielding a 500-channel decay spectrum.

We collected about 400 million decay events, from both ^{34}Ar and its ^{34}Cl daughter. The experimental data were split into 64 separate runs, differing only in their detection parameters: dominant dead-time (ranging from 3 to 12 μs), detector bias (ranging from 2400 to 2700V) and discrimination threshold (150 or 200mV). The separate analysis of these individual runs allowed us to assess the uncertainty on the final result. Fig. 1 presents the half-life results run-by-run, with the various detector biases and discrimination thresholds identified for each. No systematic trend appears.

The constrained fitting method introduced and described in Ref. [2] takes account of the complete history of the decaying nuclei, including the initial production rate of the radioactive sample. In our case, the use of a cooled gas target with a pulsed accelerator beam led to a slight non-uniformity in the measured production rate at the beginning of each collection period (see Fig. 2). The characteristic shape of the production-profile requires a numerical integration for every collect-move-detect cycle in order to determine correctly the ratio of the ^{34}Ar to ^{34}Cl nuclei at the beginning of the detection time.

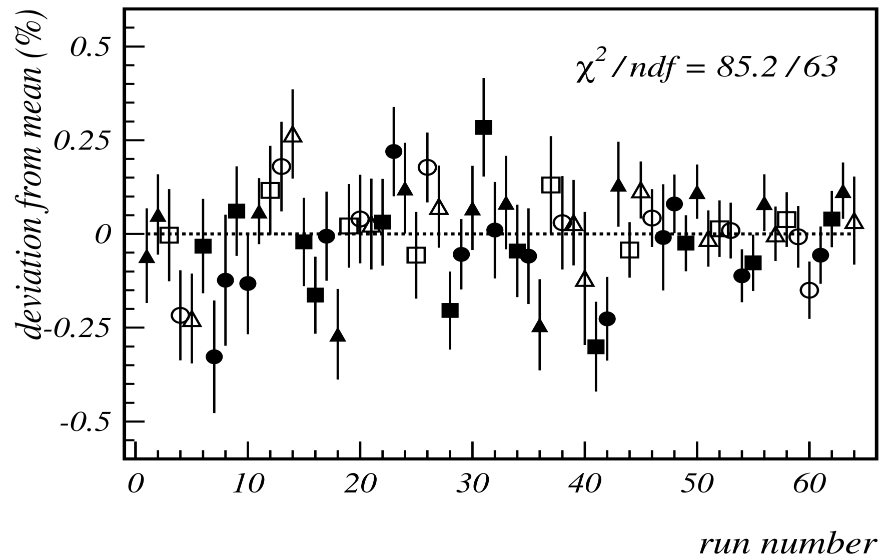

Figure 1. Values for the ^{34}Ar half-life obtained from each run, coded to indicate the specific acquisition parameters – discriminator threshold or detector bias – pertaining to each. Full/open symbols represent the two 150mV/200mV discriminator settings; circles/squares/triangles represent respectively the detection biases 2400V/2550V/2700V. The first 40 runs contain about 180 million events while the last 24 runs contain about 220 million events.

Our preliminary result for the ^{34}Ar half-life is 843.8(9) ms; we anticipate that the final analysis will drop the uncertainty significantly below 0.1%. The reported uncertainty contains the statistical error,

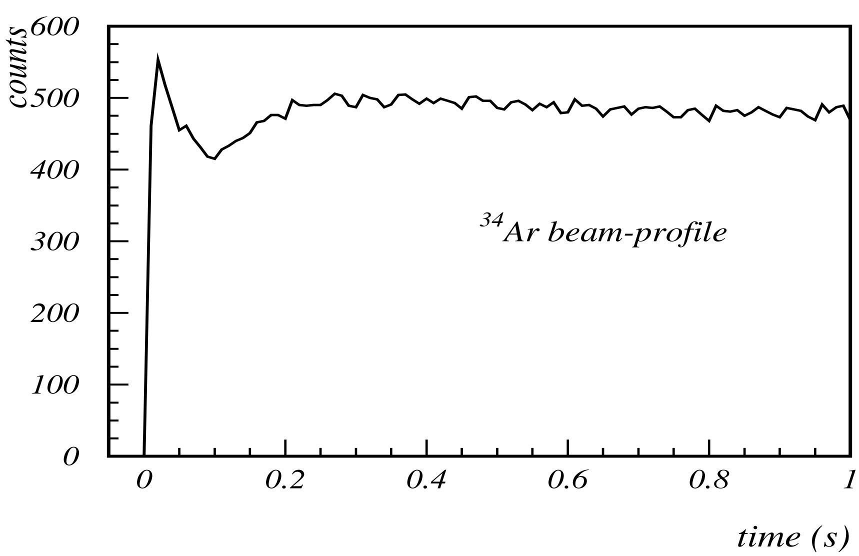

Figure 2. Typical radioactive-beam production-rate profile. The initial drop in production rate is generated by the lowering of the gas density along the beam path as the primary beam heats up the gas. A fan located inside the gas-target helps equalize the heat rapidly, leading to the plateau evident after 0.2 s.

the uncertainty in the half life of the daughter nucleus ^{34}Cl, the scatter associated with the dead-time corrections, the uncertainty in the impurity levels, the uncertainty due to the beam profile, the scatter associated with the discriminator thresholds, and the scatter in the results obtained from the various experiments. The result agrees with, but is four times more precise than, the currently accepted value [3], which was obtained more than 30 years ago.

[1] V.E. Mayes *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2000-2001), p. I-28.

[2] V. E. Iacob, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2004-2005), p. I-21.

[3] J.C. Hardy, H. Schmeing, J.S. Geiger, and R.L. Graham, Nucl. Phys. **A223**, 157 (1974).