Precise half-life measurement for ^{29}P

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The most precise value for the up-down quark mixing element V_{ud} in the Cabbibo-Kobayashi-Maskawa (CKM) matrix, comes from superallowed $0^+ \rightarrow 0^+$ beta decays [1]. An independent test of its value can be obtained from ft-values measured on T=1/2 nuclear mirror transitions [2], particularly from 5 cases: ^{19}Ne, ^{21}Na, ^{29}P, ^{35}Ar and ^{37}K. When compared to the superallowed decays, there is an added difficulty in extracting V_{ud} from these transitions: being mixed Fermi and Gamow-Teller decays, they require an additional measurement of the relative contribution of the vector and axial vector components.

In this context we report here a precise measurement of the half-life of ^{29}P. The radioactive beam was produced in the ^{30}Si(H,^{29}P) reaction. Using the Magnetic Achromat Recoil Spectrometer (MARS), a better than 99% beam purity was achieved in spectrograph's focal plane (see Fig. 1). The radioactive beam at 22 *A* MeV was extracted in air, passed through a 0.3mm thick BC404 plastic scintillator, a series of Al degraders, eventually being implanted in a 76 mm-thick Mylar tape of our fast tape transport system. The scintillator-degrader combination further refined the beam purity. When compared to MARS's focal plane, the tape-retained activity contained only traces of ^{30}P and ^{26}Si, at levels of 10^{-4} relative to ^{29}P. Fig. 2 details the status of the impurities retained in the Mylar tape. Note that we have set the centroid of the ^{29}P implantation closer to the back side of the Mylar tape (beam's perspective); this ensures that the dominant impurity at MARS's focal plane ^{27}Si punches through the Mylar tape, leading to its complete elimination in the tape-retained activity. To ensure a high data quality, a mandatory requirement in high precision experiments, the beam purity was checked daily over the duration of the experiment.

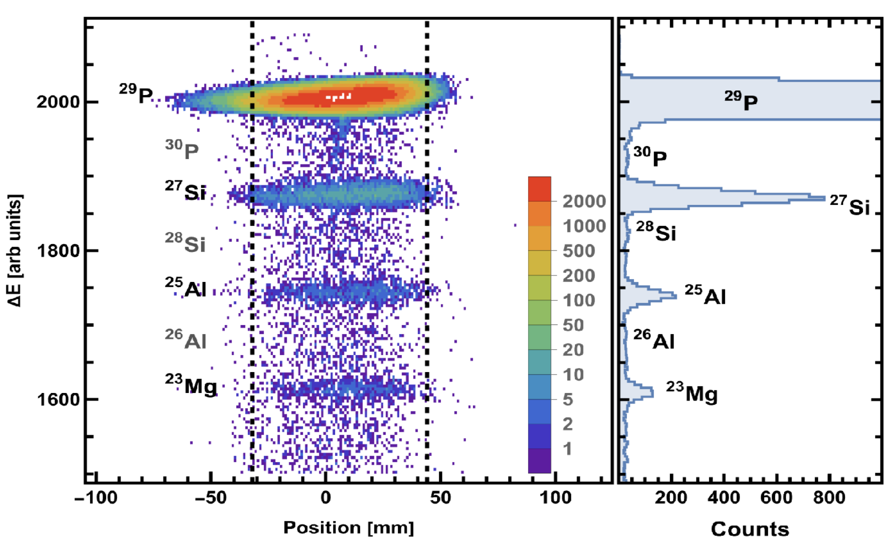

Fig. 1. Radioactive beam purity as observed in MARS's focal plane.

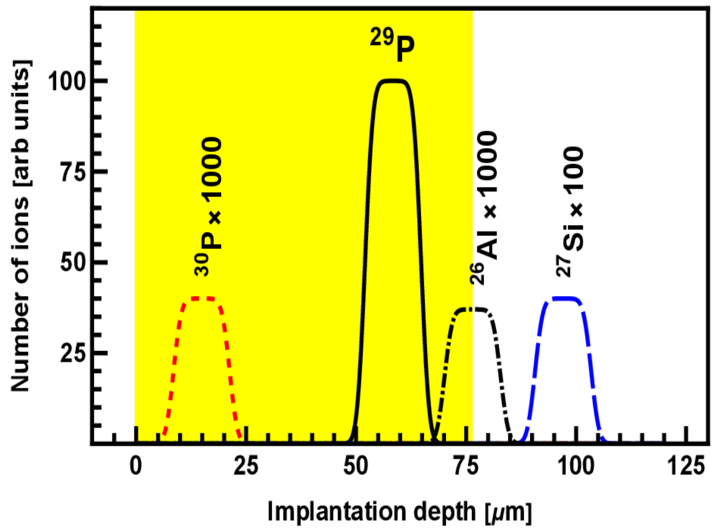

Fig. 2. Depth distribution of implanted ions. The yellow region indicates the 76mm-thick tape. The implanted beam enters the left side.

The data was acquired in cycles. Each cycle started with activity collection: ^{29}P nuclei were implanted for up to two half-lives in the Mylar tape. Then, with the beam turned off, the activity was moved in the center of our 4p proportional counter, where the decays were measured for 20 half-lives. Cycles were repeated until the desired statistics was achieved. In a seven day experiment we collected more than 100 million ^{29}P decays.

The signal processing began with a high-gain amplification aiming at preserving the time information. The amplified signals were then sent to a leading-edge discriminator, whose output was then passed to two non-retriggering gate generators, that inserted two independent major non-extending dead-times. These two parallel event streams were then multiscaled and recorded for each cycle.

The experiment was split in sub-runs, differing from one another by critical acquisition parameters: detector bias (from 2350 to 2650 V, in steps of 50 V), discrimination threshold (150-, 200-, and 250-mV), and dominant dead-times (4-, 6-, and 8-ms). More experimental details can be found in the report [3].

We performed half-life fits on pre-sorted dead-time corrected data: We carefully analyzed each cycle, and accepted it in the fit only if:

(1) the implantation beam provided more than 5000 ^{29}P nuclei,

(2) the ratio of detected betas to implanted nuclei was at least 90% of the expected value, and

(3) the cycle c^2 was below an upper limit set such that the probability for higher values is less than 10^{-4}.

Each sub-run was subject to a maximum likelihood fit as described in [4]. To test for possible abnormalities in the reduced half-life, we grouped the sub-runs based on detector bias and discriminating threshold. The results (see Fig. 3) show no inconsistencies between the bias and discriminator sub-groups. Similarly, we see no dead-time effects in the extracted half-life: Almost no difference is observed between corresponding results from the two parallel streams differing only in the inserted dominant dead-time.

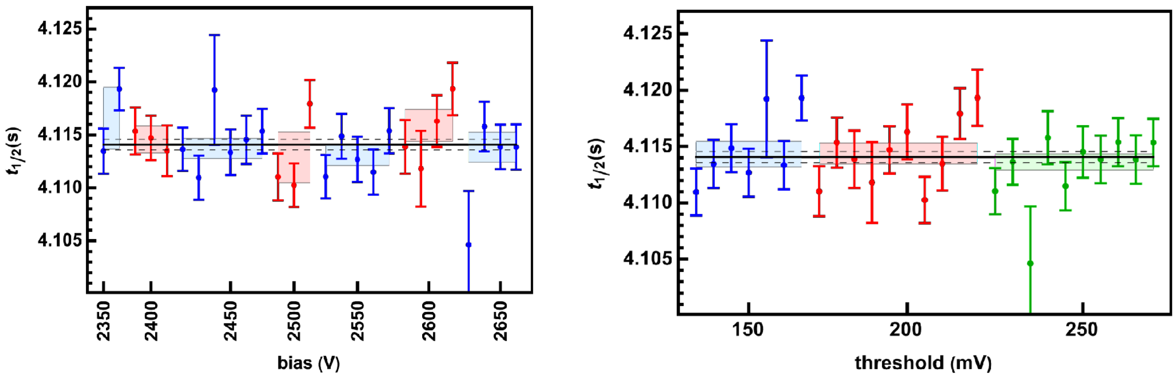

Fig. 3. Test for ^{29}P half-life dependencies on major acquisition parameters. Left panel: extracted half-life from runs with common detector bias. Right panel: extracted half-life from runs with common discrimination threshold.

We couldn't identify abnormalities neither in the data, nor in the extracted half-life. Our preliminary result is 4.1140(8) s. This value is more precise but above the recent result of J.Long *et al.* [5], the only published measurement with a precision close to 0.1%. Their result is 4.1055(44) s; however, they estimate the radioactive impurities from the fit, which we believe is the cause of the discrepancy with our result.

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