Precise half-life measurement for ^{29}P

V.E. Iacob, D.G. Melconian, N.Nica, D. McClain, M. Nasser, G. Chubarian, V. Kolhinen,
B. Roeder, and A. Saastamoinen

Precision measurements for *ft*-values for positron emitters are providing a precise value for the up-down quark mixing element V_{ud} in the Cabbibo-Kobayashi-Maskawa (CKM) matrix, a pillar of the standard model. This allows for a very demanding test: the unitarity in the upper row of the CKM matrix. While superallowed decays provide to date the most precise value for V_{ud}, five mixed Fermi and Gamow-Teller decays between T=1/2 mirror nuclei (^{19}Ne, ^{21}Na, ^{29}P and ^{37}K) have been identified to have a high potential to add to the experimental body of data [1]. However, as both vector and axial vector components contribute in these decays, the *ft*-value needs to be complemented by one of the angular correlation coefficiens.

We measured the half-life of ^{29}P in a seven-day experiment. The radioactive beam was produced by bombarding with ^{30}Si at 24 *A* MeV a hydrogen gas target kept at liquid nitrogen temperature and a pressure of 2 atm. The ejectiles were sorted with the Magnetic Achromat Recoil Spectrometer (MARS). The average beam intensity was 10,000 ions/s, and the beam purity (MARS focal plane) was 99%. We tested the beam composition once a day during this experiment.

With an energy of 22 A MeV, the radioactive beam passed through a 51 mm thick Kapton window, then through a 0.3 mm-thick BC404 plastic scintillator, a series of aluminum degraders, eventually being stopped in a 76 mm-thick Mylar tape. The degraders were adjusted to place the implanted ^{29}P ions close to the back side of the tape. We chose this position to get the best possible further purification of the beam: Less than 0.1% radioactive impurities were retained in the Mylar tape.

Keeping the beam on for up to 8 s (about two half-lives) we collected a radioactive sample and scaled the implanted ions with the plastic scintillator. Then we turned the beam off, moved the radioactivity within ~0.15 s in the center of a 4π proportional counter where it was multiscaled for 84 s (about twenty half-lives). We repeated such collect-move-detect cycles until we obtained the desired statistics.

The 4π proportional counter signals were sent to a fast preamplifier followed by fast timing amplifier; the amplifier's signals were clipped with a Schottky diode, to speed-up the base-line recovery. The amplifier's output was passed to a leading-edge discriminator, then split and sent to two non-retriggering gate generators, that inserted in the event-stream major non-extending dead-times. The two dead-time-distorted streams were eventually passed to two multichannel scalers

During this experiment we collected more than 100 million events. The total decay spectrum is presented in Fig.1. Note the low relative background rate: We could follow the decay for almost four decades. This is what enables us to claim a precision that significantly exceeds 0.1%.

To allow for stability-tests of the result, we split the experiment in sub-runs, with statistics ranging between 4 and 5 million events. We changed from a sub-run to another the acquisition parameters that could affect the result: discrimination threshold (150-, 200-, and 250-mV), major dead-times (4-, 6-, and 8-ms) and bias used to polarize the 4p detector (from 2350 to 2600 V, in steps of 50 V). To test for the possible presence of a long-lived unidentified impurity, in one of the sub-runs, the beam-move-collect cycling was set to 30-0.15-300 s.

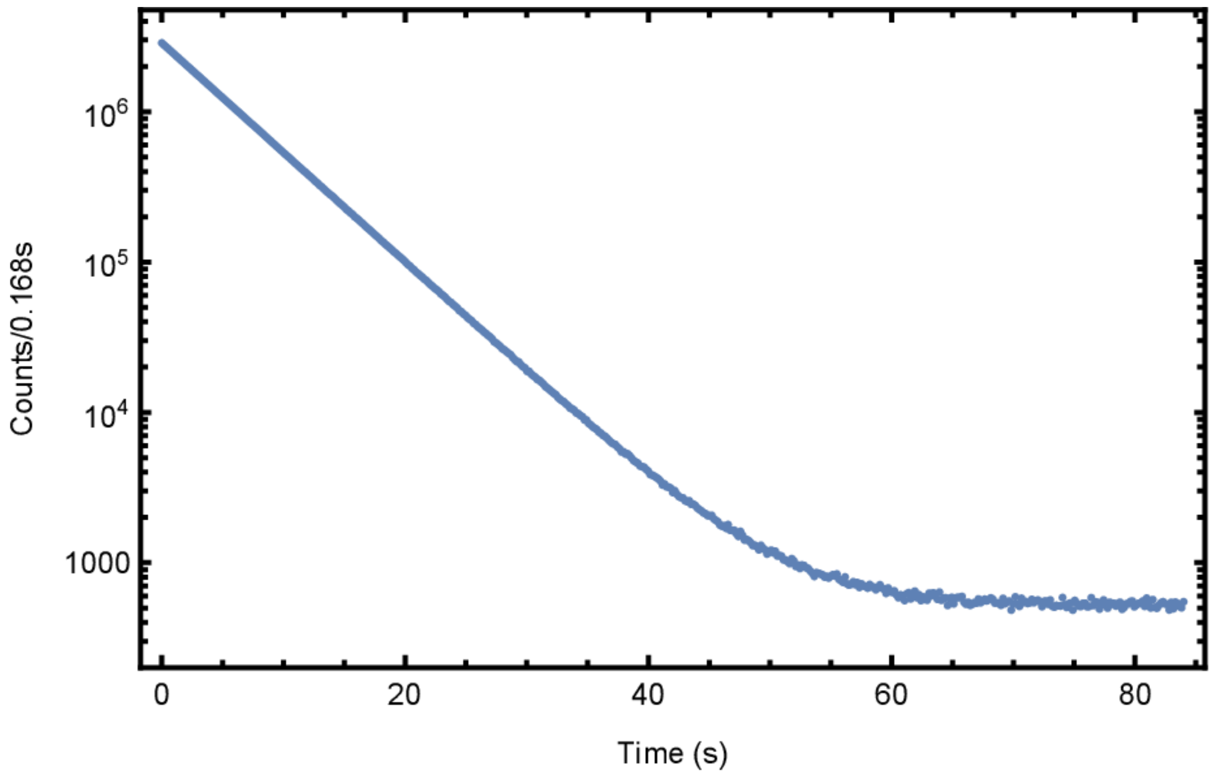

Fig. 1. Selected total decay spectrum observed in the decay of ^{29}P. The decay events are distributed in 500 channels, each 0.168 s wide.

We performed maximum likelihood fits on pre-sorted the 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 χ^2 was below an upper limit set such that the probability for higher values is less than 10^{-4}.

We couldn't identify any abnormality in the data: The sub-run fit results were fully consistent with one another. Our preliminary result is 4.1144(8) s. This value is more precise but above the recent result of J. Long *et. al.* [2], the only published measurement with a precision close to 0.1%. Their result is 4.1055(44) s; we assume it was probably contaminated by unknown impurities.

[1] O. Naviliat-Cuncic and N. Severijns, Phys. Rev. Lett. **102**, 142302 (2009).

[2] J. Long *et al.*, Phys. Rev. C **101**, 015501 (2020).