# 2 - 20 α-decay Studies of $^{220}$Pa Using Digital Pulse Processing Technique

Huang Tianheng, Sun Mingdao, Liu Zhong, Zhang Wenqiang, Liu Xiaoyu, Ding Bing and Lu Hongyang

The α-decay of neutron-deficient heavy nuclei far from β stability is an indispensable spectroscopic tool to study their low-energy structure. $^{220}$Pa, a trans-lead isotope near the shell closure $N$=126, its decay properties are still not well established, though it was studied in two α-decay experiments 30 years ago[1, 2]. Recently, we applied successfully the modern digital pulse processing (DPP) technique[3, 4] to the decay spectroscopy in the $Z\geq91$ and $N$=128~131 region[5] and the decay chain of $^{220}$Pa was established at the first time.

The isotope $^{220}$Pa was produced in the $^{187}$Re($^{40}$Ar, $\alpha$3n) reaction channel with isotopically enriched (98.6%) $^{187}$Re targets. The $^{40}$Ar beam was accelerated to 188 MeV by the Sector-Focusing Cyclotron (SFC) of the Heavy Ion Research Facility in Lanzhou (HIRFL). The evaporation residues (ERs) emitted in the beam direction were separated in flight from the primary beam by the gas-filled recoil separator SHANS[6] and implanted into a double-sided silicon strip detector (DSSD) with 48 horizontal and 128 vertical strips of 1 mm wide. The digital signal processing technique has been implemented in the data acquisition system consisting of 27 14-bit flash ADCs from CAEN S.p.A[7]. The shapes of the pre-amplifier signals from all the detectors were independently recorded in 15 μs-long traces with a sampling rate of 100 MHz.

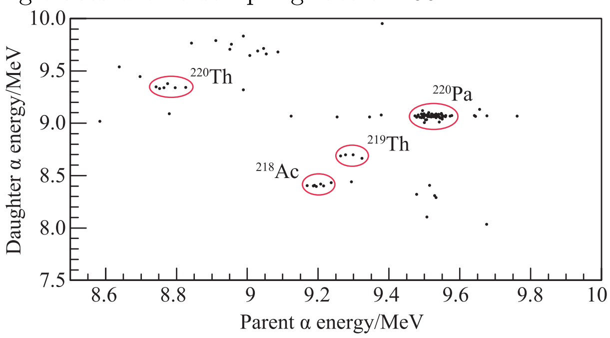


Fig. 1 Correlations between the α-particle energies of mother and daughter nuclei. The time window is set as 1 ms for ER → $\alpha_1$, the first generation decay, and 500 ms for $\alpha_1 \to \alpha_2$, the second generation decay.

The short-lived implanted ERs were identified based on the mother-daughter decay correlations as shown in Fig. 1. In the most intense activity, a half-life of 0.36(7) ms and $E_\alpha = 9.069(3)$ MeV (see Fig. 2) were deduced for α decay of the daughter nucleus, in good agreement with the literature value of $^{216}$Ac[8]. Therefore the mother nucleus was identified to be $^{220}$Pa unambiguously.

71 ER($^{220}$Pa)-α($^{220}$Pa)-α($^{216}$Ac) decay chains were attributed to the implantation and α decay of $^{220}$Pa produced in the α3n channel. An α energy of $E_\alpha$ = 9.520(16) MeV and a half-life of $T_{1/2} = 0.90(13)$ μs were deduced for $^{220}$Pa(see Fig. 2). One two-pulse trace is plotted in Fig. 3 as an example to show the pileup of ER and its decay.

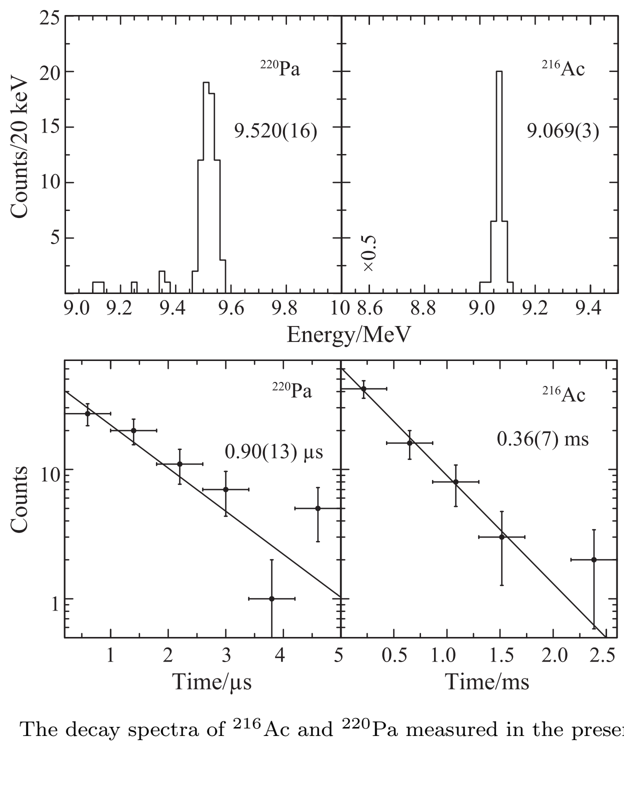


Fig. 2 The decay spectra of $^{216}$Ac and $^{220}$Pa measured in the present work.

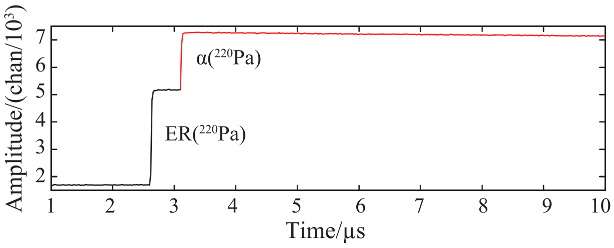


Fig. 3 (color online) An example of pileup trace where $^{220}$Pa was registered.

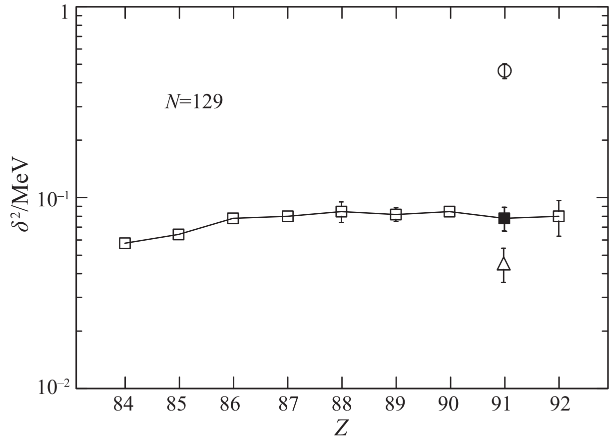


Fig. 4 (color online) The reduced α-decay widths for the g.s. to g.s. decay of neutron deficient $N$=129 isotones. The new data(solid symbol) of $^{220}$Pa is compared with those extracted from Faestermann's experimental results(triangle)[1] and the RIKEN results(cycle)[2].

The transmission efficiency of SHANS was estimated to be 11(3)% using the experimental cross-sections for the $^{40}$Ar + $^{175}$Lu reaction[9]. The production cross section for $^{220}$Pa was determined to be $7.82^{+0.53}_{-0.46}$ nb in the $^{187}$Re($^{40}$Ar, $\alpha$3n)$^{220}$Pa at the 188 MeV beam energy. The error bars represent statistical errors only and were calculated according to the method described in Ref. [10].

The reduced α-decay widths for $N$=129 isotones are shown in Fig. 4 as a function of proton number[11] assuming no angular momentum is carried by the α particle($\triangle L=0$) for the ground state to ground state decays. The value of 77(13)keV deduced from the new data of $^{220}$Pa is much closer to those of the even-even neighbors for the ground state to ground state decays(~80 keV), while the value obtained from T.Faestermann's experimental results[1] seems to be too small to fit into the systematicness while the other one[2] is too high. This result also shows that the α decay of $^{220}$Pa is unhindered and the spin-parity is most probably $1^-$, the same as the other odd-$Z$ isotones from astatine to actinium.

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