# Offline measurement of mass and correlated decay properties using radioactive $^{224}$Ra source via MRTOF+$\alpha$-TOF detector

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Recently, we newly developed a detector called the "$\alpha$-TOF" detector[1] for the measurement of mass and correlated decay properties by using a multi-reflection time-of-flight mass spectrograph (MRTOF-MS).[2] We performed realistic performance tests using a $^{224}$Ra source. The source, produced by a chemical separation from a $^{228}$Th source,[3] was placed in a cryogenic gas cell.

Ions of $^{220}$Rn and $^{216}$Po produced by the decay of $^{224}$Ra were thermalized in the gas cell and extracted using an RF carpet, transported to the MRTOF-MS preparation traps, and injected into the MRTOF-MS for the correlated measurement of the time of flight (ToF) and $\alpha$-decay. $^{220}$Rn and $^{216}$Po have half-lives of 55.6 s and 145 ms with characteristic $\alpha$-particle energies of 6.29 MeV and 6.78 MeV, respectively. During this measurement, the MRTOF was operated for only 2 laps inside the MRTOF reflection chamber. This was sufficient to unambiguously determine the $A/q$ value with a mass resolving power of $R_m \approx 1500$ with a wide mass bandwidth.

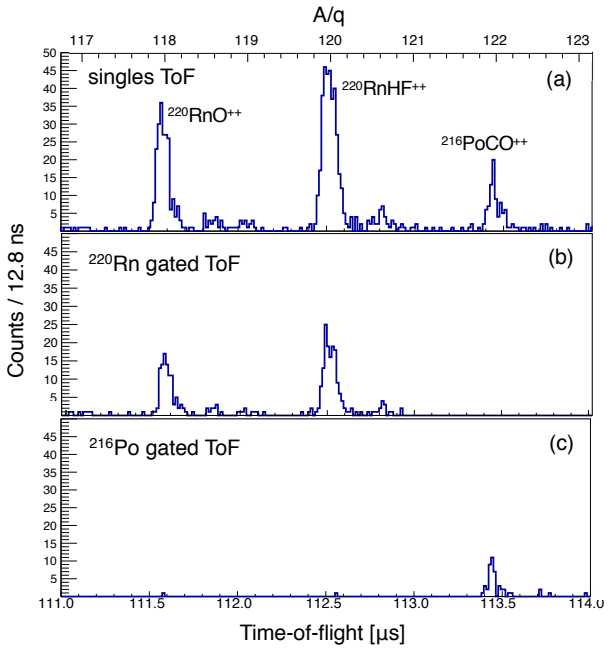


Fig. 1. (a) Singles ToF spectrum. (b) ToF spectrum in coincidence with $^{220}$Rn $\alpha$-decays obtained using a time gate of $T_c = 180$ s. (c) ToF spectrum in coincidence with $^{216}$Po decays with $T_c = 450$ ms.

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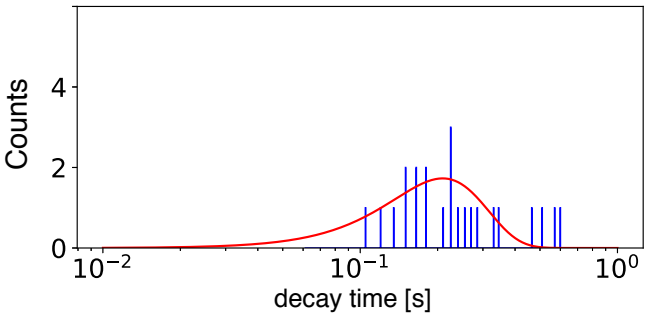


Fig. 2. Distribution of decay time of $^{216}$PoCO$^{++}$. The solid line indicates a distribution curve drawn with values obtained from the literature.

Figure 1 shows the ToF spectrum of $^{220}$Rn and $^{216}$Po. ToF and $\alpha$-decay signals were recorded event by event with absolute time stamps. Figure 1(a) shows the singles ToF spectrum. By using a coincidence time gate ($T_c$) prior to the detection of an $\alpha$-decay signal, it is possible to discriminate between ToF events corresponding to $^{220}$Rn and $^{216}$Po, as shown in Fig. 1(b) and (c), respectively. To identify the peak of $^{216}$Po, a $\pm$150 keV energy gate was used for the $\alpha$-decay signal at approximately 6.78 MeV with $T_c = 450$ ms corresponding to three half-life periods. To identify the peak of $^{220}$Rn, a similar gate was made on the 6.29 MeV $\alpha$-decay signal with $T_c = 180$ s.

Using the $\alpha$-decay correlated ToF event, we determined that the ToF peak occurs at $A/q = 118$ and 120 from $^{220}$Rn events and $A/q = 122$ from $^{216}$Po events. The limited mass resolution of the wide mass bandwidth measurement precluded precise molecular identification. However, based on past experience, we have tentatively assigned the $A/q = 118$, 120 and 122 peaks to $^{220}$RnO$^{++}$, $^{220}$RnHF$^{++}$ and $^{216}$PoCO$^{++}$, respectively. In addition, by defining the decay time as the time interval between the $\alpha$-signal and the ToF event, we demonstrated the ability to measure half-lives with the $\alpha$-TOF detector. Figure 2 shows a plot of the measured decay time of $^{216}$PoCO$^{++}$ ions along with the expected decay time distribution function based on the value reported in the literature. We evaluated the half-life of $^{216}$Po as $T_{1/2} = 123(22)$ ms, which is in good agreement with the literature value of 145(2) ms.

References

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