Off-line activation cross-section calculation for varying beam current

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Introduction

The off-line activation method [1] of cross-section determination in nuclear reaction experiments has theoretical as well as experimental simplicity. The simplest, thus most preferred, scenario in the activation and all other methods consists of constant beam current or flux during the irradiation time as the calculations are highly simplified. However, besides the difficulty of accurate measurements of beam flux, the constant beam flux for longer irradiation, as is required in the measurement of the production cross section of long-lived radioisotopes, is difficult to achieve technically [2]. Besides, there are unavoidable natural and statistical fluctuations in accelerator physics [3]. Different methods are employed for beam current measurements—Faraday cups, beam current transformers, calorimetric intensity measurements, secondary electron monitors, ionization chambers. Variation in the beam current is generally monitored by recording the time-varying charge on the target via the multi-channel scaling mode of an analog-to-digital converter. The integrated current can also be recorded after very short time intervals to reveal the beam current variation.

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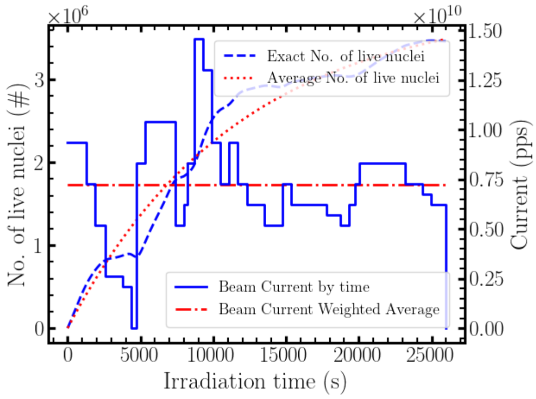

FIG. 1: The variation of live number of ^{186}Pt ($t_{1/2}$ = 2.2 h) nuclei populated via the emission of three neutrons in ^{14}N + ^{175}Lu system at energy 67.41 ± 1.10 MeV during irradiation for the averaged beam current and the actual varying current.

Varying Beam Current

The changing beam current during irradiation time makes the cross-section determination difficult. The general assumption for simplification is to use the average beam flux for the calculations by measuring the total charge deposited at the end of irradiation. However, using the average beam current (or flux) will result in erroneous values of the deduced cross-sections. Overestimation of as large as 20% is reported by Gyürky *et al.* [4, 5] as a result of using the average current instead of the varying flux (continuously decreasing to be precise). In the work to be presented, the credibility of such an act has been exam-

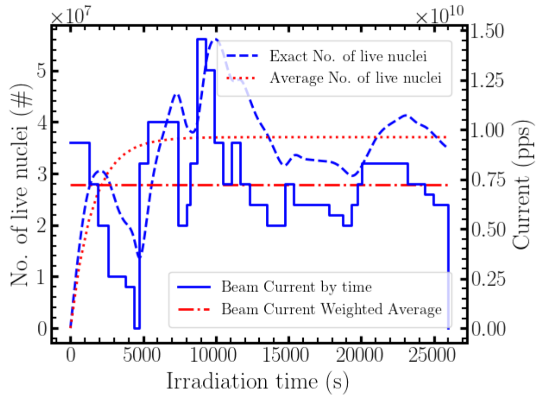

FIG. 2: The variation of live number of ^{184}Pt ($t_{1/2}$ = 17.3 min) nuclei populated via the emission of five neutrons in ^{14}N + ^{175}Lu system at energy 85.03 ± 0.97 MeV during irradiation for the averaged beam current and the actual varying current.

ined systematically in depth. The mathematical framework of the cross-section calculations when the beam current varies during irradiation will also be presented. Besides, the dependence of the magnitude of the error introduced in the cross-section calculation as a result of using the average beam current on the half-life of the residue will also be examined critically. The variation of the number of live nuclei of two different radioisotopes of considerably different half-lives during irradiation are shown in Fig.1 and Fig.2. The live number of nuclei of the radioisotope ^{186}Pt and ^{184}Pt with half-lives equal to 2.2 hours and 17.3 minutes populated by the emission of three neutrons and five neutrons in ^{14}N + ^{175}Lu system [6] at energies 67.41 ± 1.10 MeV and 85.03 ± 0.97 MeV are plotted and shown in Fig.1 and Fig.2, respectively. As can be seen from the figures, the difference between the actual number of nuclei and the ones obtained using the average beam current nuclei number is different for the two isotopes owing to their different half-lives. The difference is more for shorter half-life residue as compared to that of the residue with half-life larger or comparable to the irradiation time. In the activation method [1] the number of live nuclei at the end of the irradiation are equated with the number obtained using the decay curve of the corresponding residue and directly gives the cross-section. Any error in the number of the live number of residual nuclei is, therefore, propagated to the obtained cross-section. Further details will be presented.

Conclusion

The importance of recording the beam current for off-line cross-section calculation is very important for obtaining correct experimental cross-sections. If the average beam current is used for calculating the cross-section instead, the evaluated cross-sections are not the correct ones. The cross-sections of the residues with half-lives much smaller than the irradiation time is more off than that of the residues with half-lives roughly same as the irradiation time or more.

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