Radiation damage of plastic scintillation counter

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We studied radiation damage of a plastic scintillation counter in an isospin diffusion experiment (NP0709-RIBF42-01) using the BigRIPS separator[1)] of RIKEN RIBF. Heavy-ion cocktail beams (^{108}Sn,^{107}In,^{106}Cd) with high intensity (0.7∼1 MHz) were produced by projectile fragmentation of a ^{124}Xe beam at an energy of 345MeV/nucleon.

Figure 1 shows the experimental setup of the scintillation counter at F3 of the BigRIPS separator[1)]. To change the position of the scintillation counter after radiation damage, the movable ladder stage was designed to be remotely operated during the experiment. The EJ-212 scintillation counter[2)] was used in an isospin diffusion experiment with a high-intensity beam, and the position of the scintillation counter was changed after 50% damage, which was identified by checking the relative peak position of the light output.

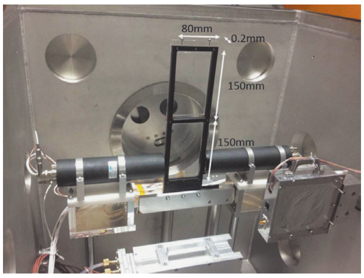

Fig. 1. Experimental setup of the scintillation counter

The radiation damage was reported with respect to the absorbed dose. The radiation absorbed dose was calculated using Eq. 1. A dose of one Gray is equivalent to a unit of energy [J] deposited in a kilogram of a substance.

$$Dose[Gy] = \frac{N_{beam} \cdot \Delta E \cdot R_{beam}}{volume \cdot density}, \qquad (1)$$

where N_{beam} denotes beam intensity, ΔE is the energy loss of isotopes at the scintillation counter, and R_{beam} is the ratio of the number of events taking place in an exposed volume to the total number of events taking place at the scintillation counter. The volume is defined as $10{\times}6{\times}0.2\ mm^3$ after checking the beam spot size by the beam profile, and the density of the EJ-212 scintillator[2)] is 1.023 g/cc.

To define the exposed area, the concentrated irradiation region of the scintillation counter was determined using the beam profile shown in Fig. 2. Fig. 2(a) shows a scatter plot of beam profile and (b) and (c) show the x and y distributions of the beam, respectively. The black square box in Fig. 2(a) indicates the defined exposed area, which is the concentrated irradiation region with 96.3% isotopes. The energy loss of isotopes at the scintillation counter was calculated with the ratio of the cocktail beams as ^{108}Sn:^{107}In:^{106}Cd = 2.51%: 74.0%: 22.86%. It is noteworthy that the ratio of isotopes rarely influences the energy loss calculation because the difference of energy loss between isotopes is only in the range of 2-3%.

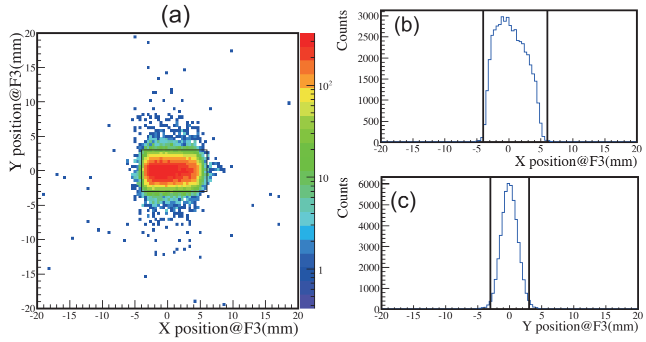

Fig. 2. Beam profile: (a) scatter plot of beam profile and (b), (c) shows x and y distribution of beam, respectively.

Figure 3 shows the results of a relative light output as a function of the accumulated dose. The relative light output is defined as the relative peak position of the light output before and after irradiation. It is clearly seen that the light output decreases with the increase in the accumulated radiation dose at all the different positions, and a similar decreasing tendency is found at all the positions. The results indicate that about 50% radiation damage of the EJ-212 scintillation counter occurs at an accumulated dose of $12{\times}10^3$ Gy.

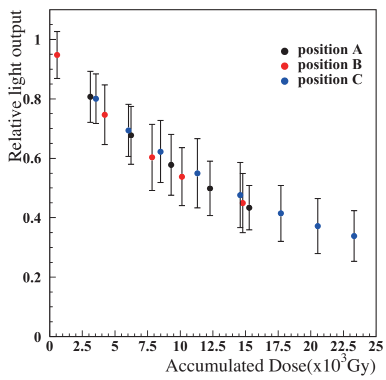

Fig. 3. Relative light output as a function of the accumulated dose: The different colors indicate different positions on the scintillation counter.

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References

1) T. Kubo et al.: Prog. Theor. Exp. Phys. **2012**, 03C003
2) http://www.eljentechnology.com/