NUMERICAL STUDY FOR CONCEPTUAL DESIGN OF ^{8}LI RADIOACTIVE ISOTOPE BEAM APPARATUS

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Conceptual design work for ^{8}Li radioactive isotope beam (RIB) apparatus is conducted in this study. The present ^{8}Li RIB system is driven by a proton accelerator with ^{9}Be(p,2p)^{8}Li reaction. A production rate of ^{8}Li is designed as 10^{6} particles per second (pps) when 1 μA of the 100-MeV proton beam irradiated on a beryllium oxide (BeO) target. Also, a surface ionization source is adopted, because it allows selective ionization. Several design parameters of the target and ion source determined by results of numerical study will be presented.

I. INTRODUCTION AND OBJECTIVES: ^{8}LI RIB APPARATUS DRIVEN BY PROTON ACCELERATOR

^{8}Li is representative radioactive and rare isotope utilized in beta-detected nuclear magnetic resonance (β-NMR) technique which is a powerful tool to research material science. However, limited time and opportunity are served to related scientists because the routinely operated β-NMR facility such as Isotope Separator and Accelerator (ISAC) at TRIUMF (Canada) does not satisfy the demand. Thus there are many β-NMR facilities planned, designed or constructed in worldwide. Also, this study conceptually designs ^{8}Li beam production system driven by the proton accelerator. The numerical study is mainly conducted to deduce the design parameters. The detail description and results of the numerical study will be presented in the next sections.

II. NUMERICAL STUDY FOR CONCEPTUAL DESIGN OF ^{8}LI RIB APPARATUS

This work adopts ^{9}Be(p,2p)^{8}Li reaction to generate ^{8}Li with 100-MeV proton accelerator. Then, in order to determine an optimal thickness of the beryllium oxide target, Monte Carlo simulation is conducted. In addition, an ionization efficiency of Li and other by-products in the surface ion source is calculated.

II.A. Monte Carlo Simulation Result

FLUKA code is utilized to conduct the Monte Carlo simulation. ^{8}Li production rates are calculated with the various BeO target thickness. The ^{8}Li and neutron production rates are depicted in figure 1. The ^{8}Li production rate is increased and saturated according to the target thickness. In contrast, the neutron production is steadily increased. Thus, there is the optimal thickness which secures enough ^{8}Li generation and avoids unnecessary neutron production. The optimal thickness is 24 mm. With this thickness, the ^{8}Li yield is estimated approximately 10^{10} particles per 1 μA of the 100-MeV proton beam.

II.B. Ionization Probability of ^{8}Li in Surface Ion Source

According to FLUKA simulation result, there are various isotopes produced by the interaction between BeO and the proton. Helium, beryllium, boron and carbon isotopes are generated. Thus, in order to increase a purity of Li beam, the ion source should be ionize the products selectively. The ionization probabilities of these products are calculated for candidate materials of the surface ion source. The surface ionization probability is obtained by the Langmuir-Saha equation

$$P_i = \frac{n_i}{n_0+n_i} = \left[1 + \frac{g_0}{g_i} exp\{e(\varphi_i - W)/kT\}\right]^{-1}, \quad (1)$$

where g_i and g_0 are statistical weights of the ion and atom, φ_i is the ionization potential of the atom, W and T are the work function and the temperature of the surface ion source material, respectively. The ionization probabilities are presented in Table 1. The rhenium ion source shows superior ionization characteristics. The ionization probability of the lithium is extremely larger than other species.

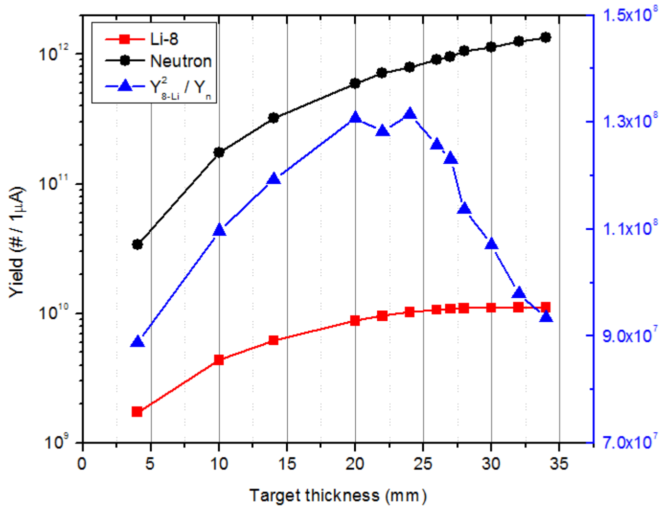

Fig.1. ^{8}Li and neutron production rates obtained by the FLUKA simulation with various BeO target thickness

TABLE I. Surface ionization probabilities with various ion source conditions

Ion source temperature (K)	Ion source material	Species				
		He	Li	Be	B	C
500	Ta	7.0E-207	5.0E-14	4.7E-53	2.5E-43	1.2E-72
	W	2.4E-202	1.7E-9	1.6E-48	8.7E-39	4.1E-68
	Re	3.3E-198	2.3E-5	2.2E-44	1.2E-34	5.6E-64
1000	Ta	1.2E-103	1.6E-7	9.7E-27	3.6E-22	1.5E-36
	W	2.2E-101	2.9E-5	1.8E-24	6.6E-20	2.9E-34
	Re	2.6E-99	3.4E-3	2.1E-22	7.7E-18	3.3E-32
1500	Ta	3.0E-69	2.3E-5	5.7E-18	4.0E-15	1.7E-24
	W	9.9E-68	7.5E-4	1.9.E-16	1.3E-13	5.5E-23
	Re	2.4E-66	1.8E-2	4.4E-15	3.1E-12	1.3E-21
2000	Ta	4.9E-52	2.8E-4	1.4E-13	1.3E-11	1.8E-18
	W	6.6E-51	3.8E-3	1.9E-12	1.8E-10	2.4E-17
	Re	7.2E-50	4.0E-2	2.1E-11	2.0E-9	2.6E-16

III. CONCLUSIONS

The conceptual design work for ^{8}Li RIB apparatus is conducted in this study. ^{8}Li RIB system is planned to utilize the 100-MeV proton accelerator with the beryllium oxide target. The thickness of the target will be ~ 24 mm which is the optimum thickness determined by FLUKA simulation. This thickness can secure the sufficient ^{8}Li products rate (~ 10^{10} pps). Also, the rhenium surface ion source is adopted to enhance the selective ionization effect. This work is very fundamental work. Therefore, more detail research should be conducted to develop ^{8}Li RIB apparatus.

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