The possibility of the neutron beams formation on base of cyclotron C18

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Abstract. It is performed the investigation of the possibility of obtaining neutron beams under external proton beams of cyclotron C18. The intensity and neutron spectra of neutron beams have been investigated in the view of using them for investigation of the processes in nucleosynthesis and of the radiation resistance of the electronics.

It is suggested on the external beam of cyclotron C18 with proton energy 18 MeV and current 100 μA obtaining the monoenergetic neutron beam. A neutron source is considered monoenergetic when the energy spectrum consists of a single line with an energy width which is much less than the energy itself. In accelerator based sources this width is mainly determined by the target thickness. In practical applications it is usually of little importance to have a narrow energy width of the line. So the "thick target yield" of a source is of interest, rather than the differential one.

Therefore the monochromaticity of a source must be viewed at with an eye on the application. Basically there are three types of applications:

- a) scientific ones (physics)
- b) technical ones and
- c) medical ones.

In each case the demands on a monoenergetic source can differ greatly.

The yield of neutrons of the desired energy from an accelerator based monoenergetic source depends on [1]:

- the charged particle beam intensity,
- the target thickness,
- the differential cross section of the reaction
- the specific energy loss in the target material.

For instance, high-Z targets can be used to produce spallation neutrons. However, there is a recent interest in the use of a 7Li target, which, when bombarded with protons, can produce a relatively high yield of quasimonoenergetic neutrons in the forward direction via the 7Li(p, n)7Be reaction. The quasimonoenergetic and broad neutron sources are needed for research in different areas in nuclear science and technology, e.g. Accelerator Transmutation of Waste (ATW), radiation damage studies, medical isotope production, and physics cross section experiments. In order to assess the feasibility of using lithium target to produce neutrons, accurate evaluated cross section data are needed. These data can be used to predict the neutron yield, as well as the neutron energy and angular dependencies, from both thin and thick targets. (Thin targets allow the possibility of producing quasimonoenergetic neutron sources, whereas thicker targets produce broad-spectrum neutron sources.).

Neutron production in the MeV range by the 7Li(p, n)7Be reaction is attractive for two reasons:

- emission of neutrons only into a narrow forward cone and
- the neutron production cross section is very high, especially at lower energies.
On the figure 1 is shown the cross section of the reaction $^7\text{Li}(p, n)^7\text{Be}$ in dependence of proton beam energy [2, 3]. The cross section of reaction $^7\text{Li}(p, n)^7\text{Be}$ has the peak in the region of $E_p = 5-7$ MeV, the value of the peak is about 250 mb. Consequently, to obtain the high yield of neutrons on the external proton beam of cyclotron C18 necessary to use degrader for decrease proton beam energy up to 5 MeV.

![Cross section of reaction $^7\text{Li}(p, n)^7\text{Be}$ in dependence of incident proton energy](image1)

**Figure 1.** The cross section of reaction $^7\text{Li}(p, n)^7\text{Be}$ in dependence of incident proton energy [3].

The neutron spectra in the case of incident proton energy 5 MeV calculated by code TALYS 1.4 [4] is presented on the figure 2.

Usually only neutron emission at an angle of 0° with respect to the charged particle beam is considered.

![Neutron spectra at angle 0° in case of incident proton energy 5 MeV, calculated by TALYS 1.4](image2)

**Figure 2.** Neutron spectra at angle 0° in case of incident proton energy 5 MeV, calculated by TALYS 1.4.
The angular distribution of emitted neutrons $^7\text{Li}(p,n)^7\text{Be}$ via neutron energy calculated by code DROSG2000 [5] is presented on the figure 3.

From the figure 3 is seen, that placing the sample at $0^\circ$ has the following advantages:

- The neutron yield is usually forward peaked;
- Neutrons emitted at $0^\circ$ have the highest energy.

![Figure 3. The dependence emitted neutrons energy via neutron angle, calculated by DROSG2000 [5].](image1)

The yield of neutrons from reaction $^7\text{Li}(p, n)^7\text{Be}$ under protons beam in the protons energy region 2-5.5 MeV was investigated in [6]. With the increase of the energy of the incident proton, the neutron yield increases. The neutron yield behavior in dependence of the energy of the protons is shown in figure 4.

![Figure 4. Neutron yield from a 5mm thick natural Lithium target for proton energies from 2.5 to 5.5 MeV.](image2)

- [6]
- [7]
- [8]
The integral yield of neutrons at incident protons energy 5.5 MeV is $6 \times 10^8$ n/100nA, or $6 \times 10^9$ n/\(\mu\)A. In the same [5] work the angular distribution of the emitted neutrons is presented also (figure 3). From this figure the neutrons yield in the angle region 0-20\(^\circ\) is estimated, $1.43 \times 10^9$ n/\(\mu\)A.

![Figure 5. Angular distribution of neutron yield from thick Lithium target from 5.5 and 4.5 MeV proton energies [5]. Circles - 5.5 MeV, triangles - 4.5 MeV.](image)

Thus, the carried out preliminary studies show that it is possible to obtain neutron beams on the extracted proton beam of the cyclotron C18 with intensity about $10^{11}$ n/\(\mu\)A which sufficient for performing research on the study of the astrophysical reactions and application problems connected with the radiation resistance of the components of spacecraft electronics.

References

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