ON THE POSSIBILITY TO INCREASE A NEUTRON BEAM FLUX OF IREN

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Abstract

A system of the neutron generating IREN target circled with beryllium cylinder of 11 - 41 cm thickness is considered. A sizeable (n,2n) cross section for beryllium, which has a value about 0.6 b at 4 –10 MeV neutrons energies, can increase a neutron flux of IREN experimental beams, if real neutron spectrum from source has essential part of fast neutrons. Using GEANT and FLUKA codes the neutron yield and time distribution of neutron in W-Be source were estimated.

There is a paradox, which appear on application of the electron accelerator with a neutron-produced target for time-of-flight neutron spectrometry: if the energy of the accelerated electrons reaches or exceeds 30 MeV, the neutron intensity becomes proportional to the electron beam power. In this case it is possible to double the intensity at the facility like IREN due to ones more accelerating section only. And the additional section must duplicate all the parameters of functioning one, what practically demands the funds redoubling. That is why we were interested in the possibility to increase the neutron source intensity for the time-of-flight investigations without using the additional accelerator equipment.

The influence of a beryllium block, which is situated around the tungsten (or uranium-238) bremsstrahlung target, on the neutron source characteristics is considered below. Beryllium has a visible cross section of reaction (n,2n) for fast neutrons and slight scattering cross section at negligible capture.

Using the well-known programs GEANT and FLUKA for different configurations of the target and beryllium block relative position the calculations were made to evaluate a change of neutron yield from the combined source and a flux of resonance neutrons at a required flight path. The cross sections of (n,2n) reaction and of the elastic scattering for Be are presented in Fig.1.

The effect of increasing the number of neutrons after their passing through Be layer with the thickness L can be counted up as:

$$N = N_0 + N_0 \int_0^L [\exp(-n\sigma_t x) n\sigma_t dx] \frac{\sigma_{n,2n}}{\sigma_t} \quad \Rightarrow \quad N_0(1+\mu),$$

$$\mu = \frac{\sigma_{n,2n}}{\sigma_t}[1 - \exp(-n\sigma_t L)]$$

In a case of $L > 10$ cm of Be $\mu \approx \dfrac{\sigma_{n,2n}}{\sigma_t}$, and for neutron energies more than 4 MeV $\mu \approx 1/2$.

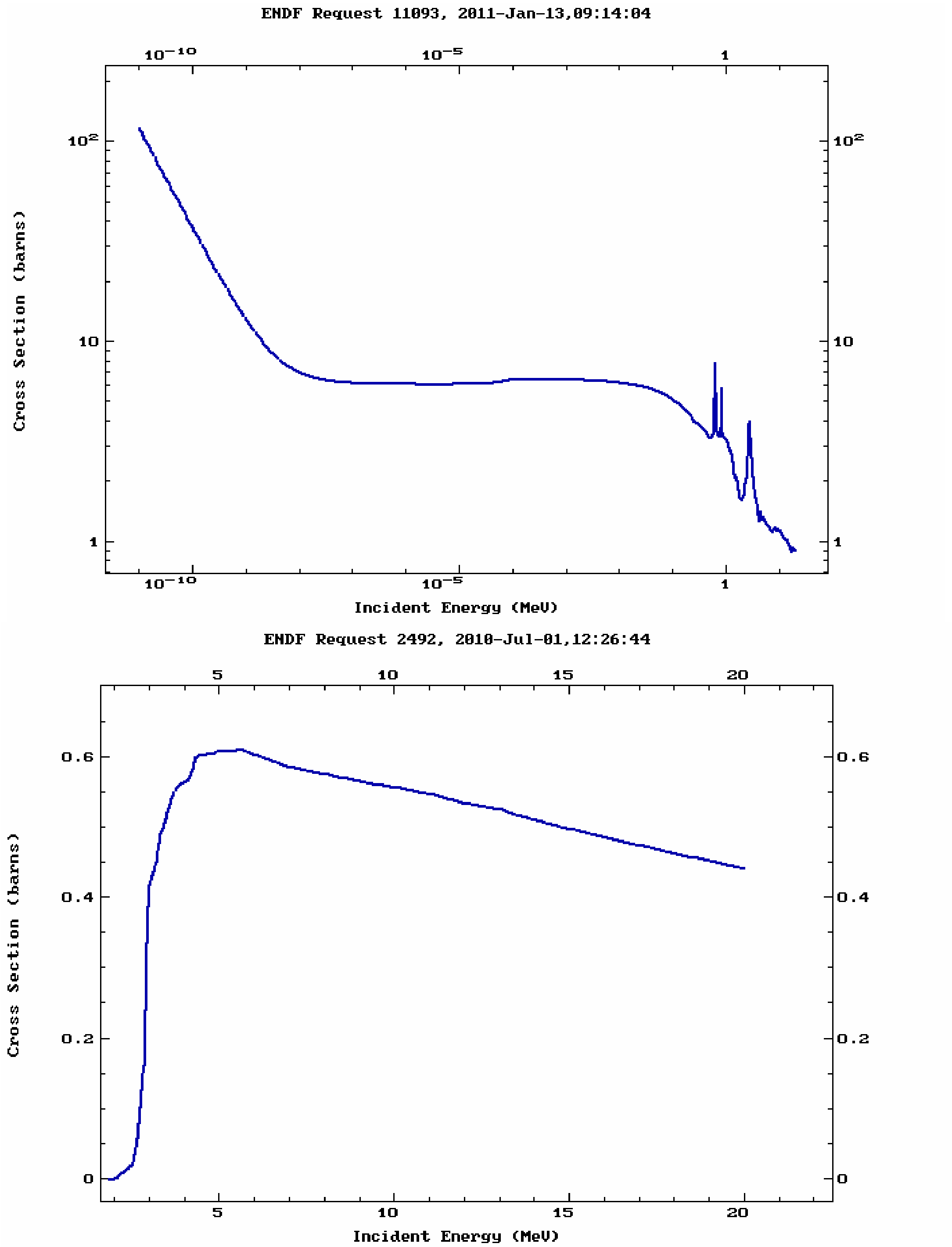

Fig.1. The cross sections of (n,2n) reaction (upper picture)and of the elastic scattering for Be(lower picture).

Thus, one can expect the neutron intensity increase in 1.5 times. The calculations with a Be ball with point neutron source in the center of 5 MeV energy is demonstrated in Fig.2 and shows that there is the 1.5 multiple neutron intensity increasing if the diameter of Be ball is 20 cm.

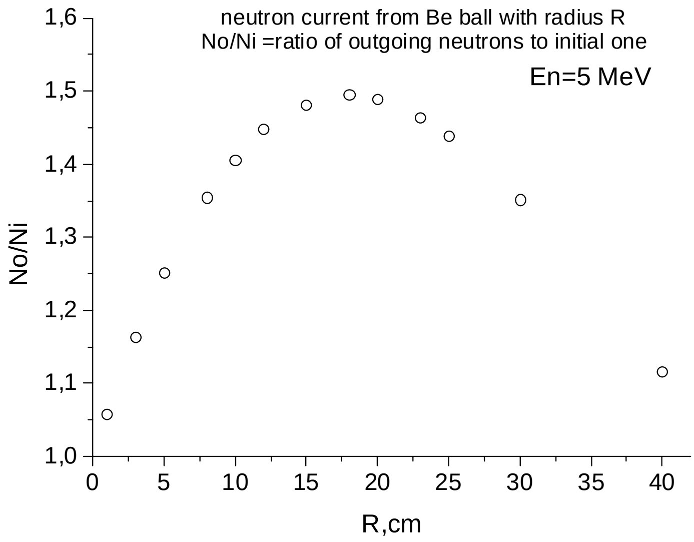

Fig.2. FLUKA calculations of dependency of the neutron yield per incident neutron with energy 5 MeV from the Be ball radius.

For our task solving it is important to know the neutron spectrum from the bremsstrahlung target. The postirradiation neutrons spectra calculated by FLUKA и GEANT programs at electron energies 30 and 50 MeV are presented in Fig. 3.

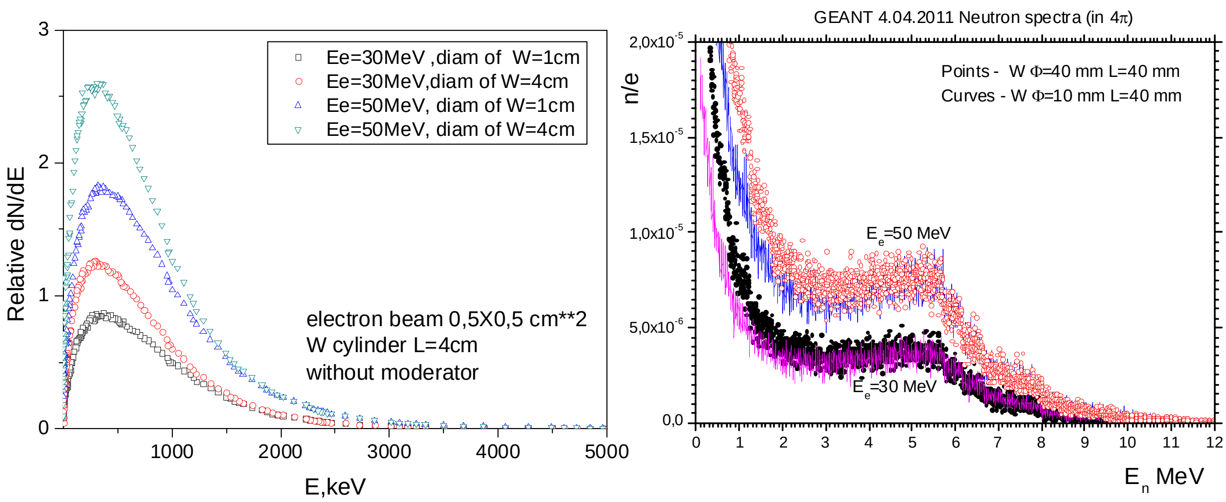

Fig.3. Neutron spectrums in W target calculated by FLUKA (left picture) and GEANT (right picture).

Unfortunately, these two programs bring out not the same spectra, and the results of completed calculations are different. Namely, FLUKA calculations does not give an increase of neutron yield when W target is surrounded by Be, whereas GEANT does it. In Table 1 there are the results of GEANT calculations for the compound W-Be target, which is shown in Fig.4.

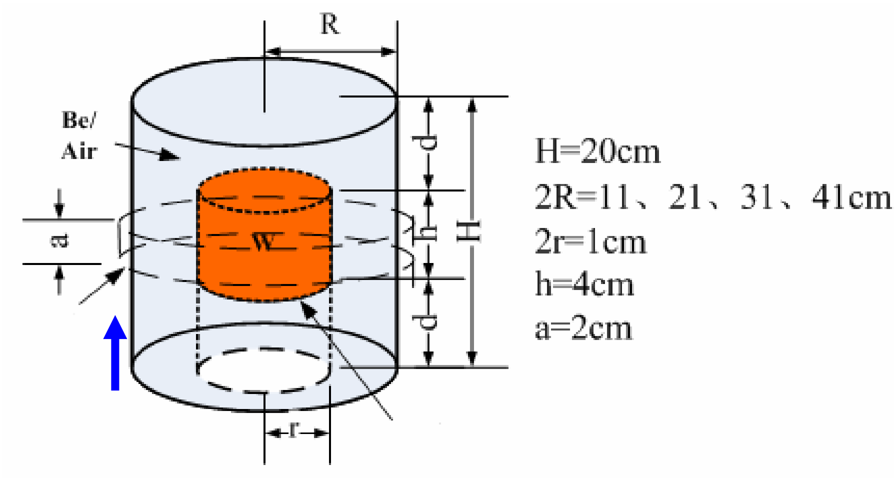

Fig.4. The source construction for demonstrated calculations.

The calculations were carried out using GEANT for tungsten target (in version of cylinder with 1 cm diameter and height L=4cm) inside of beryllium cylinder of different diameters and 20 cm height and for two energies of incident electrons. Two variants of the calculations were carried out: for air-filled cylinder and for beryllium cylinder of the same sizes.

Table 1.
Neutron yields per 1 electron obtained by GEANT.

		Cylinder diameter			
		11 cm	**21 cm**	**31 cm**	**41 cm**
Electron energy 30 MeV					
Yield in 4π	Air	0.00648	0.00642 0.0064*	0.00647 0.0063*	0.00640 0.0062*
	Be	0.00728	0.00760	0.00779	0.00767
	Ratio Be/Air	1.12	1.18	1.20	1.20
Yield from cylinder side	Air	0.00575	0.00452	0.00362	0.00289
	Be	0.00662	0.00514	0.00343	0.00200
	Ratio Be/Air	1.15	1.14	0.95	0.69
Electron energy 50 MeV					
Yield in 4π	Air	0.0139	0.0139 0.0128*	0.0139	0.0139
	Be	0.0159	0.0166	0.0167	0.0167
	Ratio Be/Air	1.14	1.19	1.20	1.20
Yield from cylinder side	Air	0.0123	0.00983	0.00776	0.00631
	Be	0.0145	0.0112	0.00738	0.00440
	Ratio Be/Air	1.18	1.14	0.95	0.70

* - *earmarked values were obtained by FLUKA program*

It is significant, that there are little experimental data about photoneutron spectra in the literature. There is information that maximums of photoneutron spectra for wide nuclei diapason are located at the same energies 1 – 3 MeV. There are also experimental data measured at 30 MeV electron accelerator in Toronto [1], where photoneutron spectrum for Pb have a maximum at 2 MeV and sizeable tail of fast neutrons up to 6 MeV. And there is an experience of forming the medical beams of fast neutrons too [2].

Thus, our expectations of increasing the neutron yield from source by placing the target inside of Be block did not find an undoubted confirmation. To clear up this question it is necessary to carry out measurements at the target of IREN facility putting it into Be block.

The calculations presented in Fig.5 shows that apprehensions about possible time delay of neutrons because of their moving through beryllium (and as a result essential broadening of produced neutron pulse) can be found unfounded, as calculated broadening of pulse is not more than 200 ns.

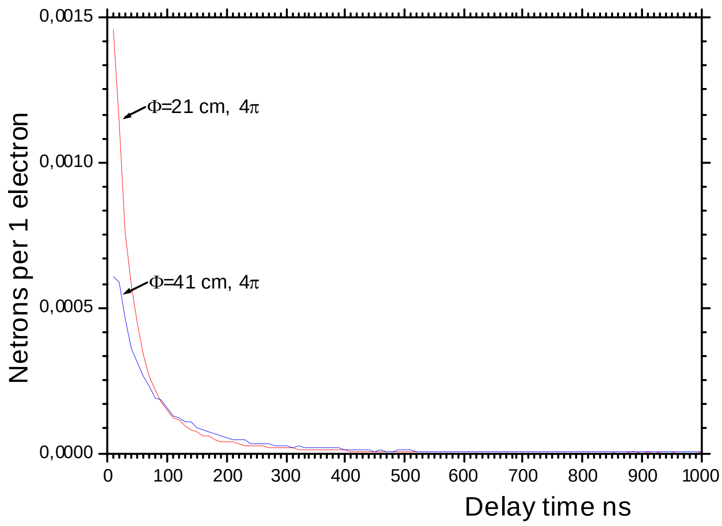

Fig.5. Time delay distribution for neutron moved in beryllium (diameters of Be cylinder are 21 and 41 cm).

In conclusion we wonder to note two important aspects, which follow from our executed calculations: 1) making the W target length longer than 4cm does not increase neutron yield; 2) extension of target cylinder diameter from 1 cm to 4 cm (diameter of incident electron beam is less than 1 cm) augments the neutron yield ~ 1.5 times for electron energies 30 and 50 MeV alike. First result corresponds to conclusion of [3], and the second one contradicts to deductions of this paper.

References.

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