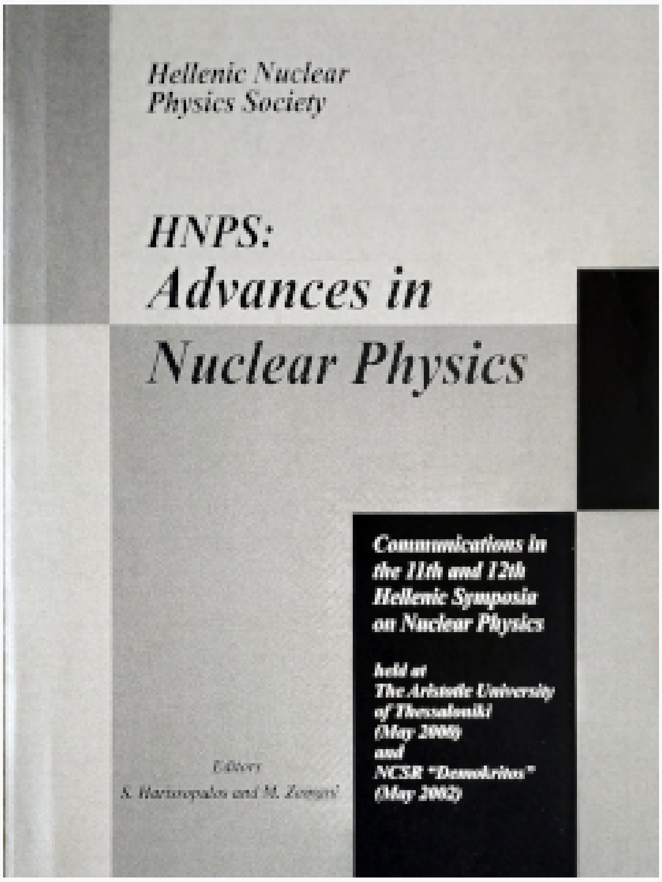
HNPS Advances in Nuclear Physics

Vol 11 (2002)

HNPS2000 and HNPS2002



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doi: 10.12681/hnps.2204

Spallation Neutron Production in the Dubna Transmutation Assembly

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Abstract

A large lead target with a U blanket was irradiated by 1.5 GeV protons at the Dubna Nuclotron accelerator. Spatial distributions of neutron fluxes were determined by Solid State Nuclear Track Detectors in the new experimental transmutation assembly. Slow and fast neutron components were studied inside sections of the setup and on the U blanket surface. Neutron distributions after Cd and polyethylene shielding were also investigated. The results show that the new arrangement is efficient mainly to transmutation experiments by fission and (n,xn) reactions as well as by (n,γ) reactions.

Keywords: Subcritical assembly, Neutron detection, Transmutation

1. Introduction

A new subcritical Lead-Uranium assembly is designed in Dubna experiments by the motivation to perform experiments on increasing safety nuclear power engineering and transmutation of radioactive waste. Such experiments have been performed in Dubna during last decade by a large cylindrical lead target (Wan et al., 1998; Adloff et al.,1999). Proton and Carbon beams at GeVs range were used for irradiations on Uranium and Lead plus Uranium targets. The design of this setup includes a parafine moderator to shift spallation neutron spectrum to lower energies. The part of the neutron spectrum at the resonance region is very important for (n,γ) reactions due to the high cross sections. In addition fast neutrons can be used to transmutation experiments via (n,xn) and fission reactions. To favorize fast neutron production a composite target is more preferment as it is concluded from the previous

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experiments (Adam et al., 2002). A new setup on this basis is designed as a model for a core of an electronuclear reactor (Krivopustov et al., 2001). First experiments with 1.5 GeV proton beams were run last two years. The measured neutron distributions by Solid State Track detectors (SSNTDs) are presented in this work.

2. Experimentals

The installation consists from a cylindrical lead target of 52 cm in length and 8 cm in diameter. Around the lead target U rods are placed in hexagon form. Each U rod is a cylinder with 10.4 cm in length and 3.6 cm in diameter. Four sections were needed to cover the target. For the shielding 1mm Cd and about 10 cm of granulated polyethylene were used. Experiments were performed at Nuclotron accelerator (High Energy Laboratory) in Dubna. Proton beam at 1.5 GeV was run at 10^{11} for SSNTDs.

Neutron measurements concern the region inside sections, the upper surface of the U blanket and the top of the shielding. Inside sections 12 sets of CR39 detectors were placed along the diameter of the target. On the surface of the U blanket 4 sets of CR39 were positioned in a vertical direction relative to the axis of the cylindrical lead target. At the same positions on the top of the shielding 4 sets of CR39 were placed for the dose control of the setup. Each set of CR39 detectors contain CR39 detectors in contact with Kodak LR115 Type 2B partially covered by 1 mm Cd. So each set was used to detect thermal-epithermal neutrons and intermediate-fast neutrons. A free CR39 foil was also used to detect proton recoils and give supplementary information about fast neutrons namely in the neutron energy range of $0.3<E_n<3$ MeV (Zamani et al., 1996, Harvey et al., 1998). Sets of SSNTDs as fission detectors with ^{nat}U were placed on the U blanket in the middle sections.

3. Results and discussion

Neutron distributions (neutrons/cm^2/p) between sections can be seen in figure 1 as a function of the distance from the center of the Pb target. In all cases the neutron production is very high in the target center and drops towards U blanket surface. Although at small distances the points correspond to Pb target and at lagre distances to those produced in U target the neutron distribution is fitted by an exponential law as $y=Ax^{-B}$. Parameters a and b varies from the first to the last gap between sections and are given in table 1.

Table 1. Fitting parameters describing the drop of neutron distributions in the gaps inside sections.

Distance along the target (cm)	Fitting model (R-squared)	Parameter A ($n.cm^{-3}$ per p)	Parameter B
10.5	$Y = A.x^B$ (98%)	1.26 (±0.19)	-1.61 (±0.09)
21	$Y = A.x^B$ (98%)	0.71 (±0.08)	-1.33 (±0.07)
31.5	$Y = A.x^B$ (88%)	0.09 (±0.01)	-0.61 (±0.08)

At the first two sections neutron number falls rather sharply than at the last section. Also the neutron production at the central region of the target is reduced in the last gap. Both behaviours can be explained by the interaction length of protons in lead target which at the energy of 1.5 GeV is about 18 cm. Above this distance only neutrons produced by secondary reactions are detected.

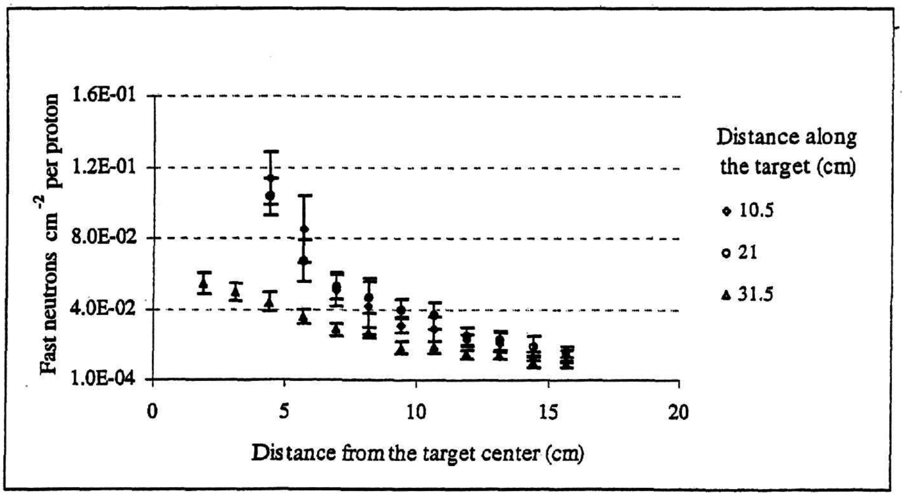

Figure 1. Fast neutron distribution inside target sections

At large distances from the target center neutron fluxes coincide with measurements on the upper surface of the U blanket. Between the four sets placed on each section significant variations were not observed. So the results given in figure 2 represent a mean value of four independent measurements at the same position.

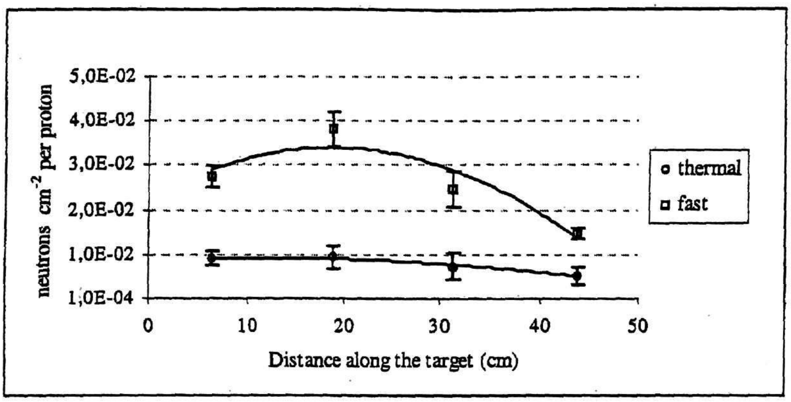

Figure 2. Thermal and fast neutron distribution at the surface of the U blanket. Each point corresponds to successive sections of the set up.

In those positions thermal and fast neutrons were detected. Both neutron distributions show a decreasing behaviour along the complex target. At the last section neutron flux reach about 40% of its initial value. About half of the produced neutrons in the lead target are shifted to thermal-epithermal energy range. By fission detectors fast neutrons measured at the surface of the second and third section give $(7.4\text{-}7.6)10^{-3}$ n/cm^2/p and is in agreement within experimental errors with results obtained by proton recoils of CR39.

Concerning neutrons escaping by the shielding in figure 3 distributions of thermal and fast neutrons are presented. The position is an indication of the CR39 set in a vertical direction relative to the lead target axis and corresponds to the U sections. The neutrons escaping the shielding are equally fast and thermal. Their number is at least an order of magnitude less than in the surface of U blanket.

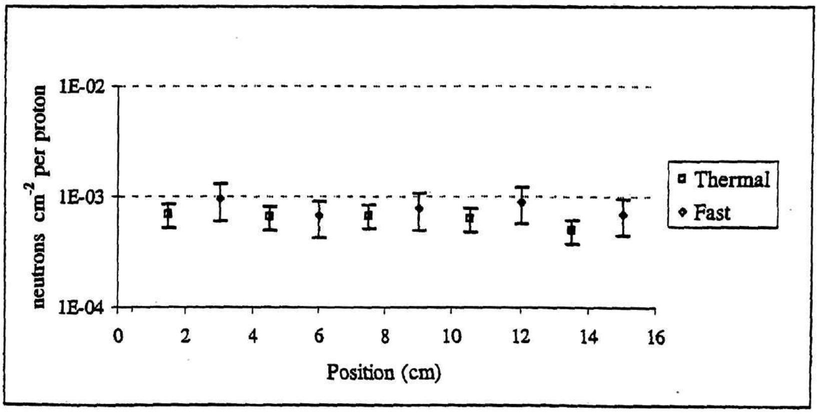

Figure 3. Thermal and fast neutron distributions at the top of the shielding

4. Conclusion

An experimental transmutation assembly is designed to give high neutron fluxes. The measured neutron fluxes on the surface of the composite target show a contribution of thermal and fast neutrons of the order 10^{-2} neutrons/cm^2/p. These rates are almost constant along the target. The assembly can be used for transmutation experiments by (n,γ), (n,xn) reactions and by fissions too. The shielding of the assembly decreases by an order of magnitude neutron fluxes comparing with those produced in the target.

References

Adam J. et al., 2002. Transmutation of ^{239}Pu and other Nuclides using Spallation Neutrons produced by Relativistic Protons reacting with Massive U and Pb targets. Radiochim. Acta **90**, 431-442

Adloff J. C., R. Brandt, M. Debeauvais, F. Fernandez, M. I. Krivopustov, B. A. Kulakov, A. N. Sosnin, and M. Zamani, 1999. Secondary Neutron Production from Thick Pb Target by Light Particle Irradiation, Radiat. Meas. **31**, 551-554

Harvey J. R., Tanner, R. J., Arberts, W.G., Barttlet, D.T., Presch, E.K., Schaube, H., 1998. The contribution of Eurados and CENDOS to etched track neutron dosimetry. Radiat. Prot. Dos. **77**, 267-304.

Krivopustov M.I., et al., 2001. Experimental Studies of Electronuclear Method of Energy Production and Transmutation of Radioactive Wastes using Relativistic Beams from JINR (Dubna) Syncrophasotron/Nuclotron in: A. M. Baldin, V.V.Burov and A. I. Malakhof, Proceedings of the XV International Seminar on High Energy Physics Problems, Vol II, p.3, Dubna

Wan, J.-S.et al.: 1998. Transmutation of Radioactive Waste by means of Relativistic Heavy Ions, Kerntechnik **63**, 167-177

Zamani M., Sampsonidis, D., Savvidis E., 1996. An individual neutron Dosemeter with (n,a) and (n,p) converter. Radiat. Meas. **26**, 87-92.