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Nuclear Instruments and Methods in Physics Research A 562 (2006) 741–742
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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Transmutation studies with GAMMA-2 setup using relativistic proton beams of the JINR Nuclotron

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Available online 28 February 2006

Abstract

A spallation neutron source consisting of an extended lead target surrounded with a paraffin moderator irradiated by 1, 1.5, and 2.0 GeV protons is used to study neutron capture and transmutation reaction rates in ^{139}La, ^{129}I and ^{237}Np samples in secondary neutron fluences. Reaction rates are obtained by activation analysis using HPGe detectors. The results are compared with calculations using a cascade-evaporation model.

PACS: 28.41.Kw; 28.90.+i

Keywords: Spallation neutron source; Transmutation; Nuclear waste incineration

GAMMA-2 extended setup consisted of an 8 cm in diameter 50 cm long lead target surrounded with a 6 cm thick paraffin moderator was irradiated by 1, 1.5 and 2 GeV Nuclotron accelerator proton beam for the purpose of study of spallation neutron production in thick targets and radioactive waste transmutation rates. The integral proton beam fluence was about 3×10^{13} protons. The other conditions and the beam monitoring technique were similar to those described in Ref. [1], where a shorter lead target was used, and the incident proton energy range was up to 4 GeV.

The 15 mm in diameter plastic vials containing about 1 g of ^{139}La in the form of $LaCl_3 \times 7H_2O$ each were placed onto the outer surface of the moderator along the beam direction with 5 cm gaps between them (see Fig. 1). Radioactive waste samples of ^{129}I and ^{237}Np isotopes about 1 g in weight weld-sealed in aluminum containers were placed onto the outer mantle of the moderator.

Induced γ-activity of $^{139}La(n,\gamma)^{140}La$, $^{129}I(n,\gamma)^{130}I$ and $^{237}NP(n,\gamma)^{238}NP$ reaction products was measured using a set of HPGe detectors, and the γ-spectra were analyzed employing software applying the methods similar to those described in Ref. [2].

Dependence of the (n,γ) reaction rates on the incident proton energy as well as distance from the beam entrance point are shown in Fig. 2. The results allow determining the position (10–15 cm from the front) with the maximum fluence of the thermal neutrons for placement of the transmutation samples and threshold detectors, and prove the decrease in the grows of fluence in the region from 1 to

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doi:10.1016/j.nima.2006.02.036

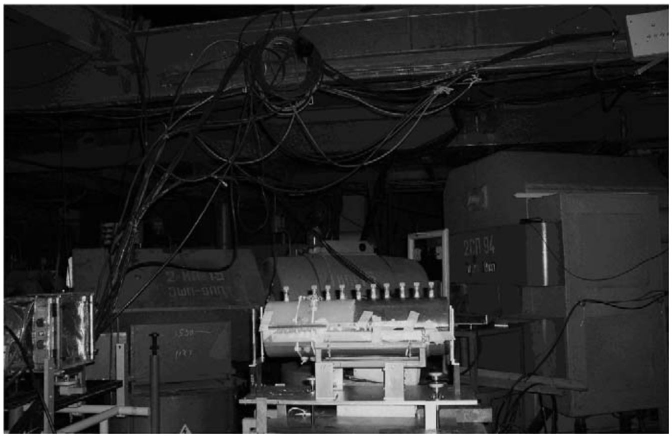

Fig. 1. GAMMA-2 setup in the configuration used in this work at the F3N focus of the Nuclotron.

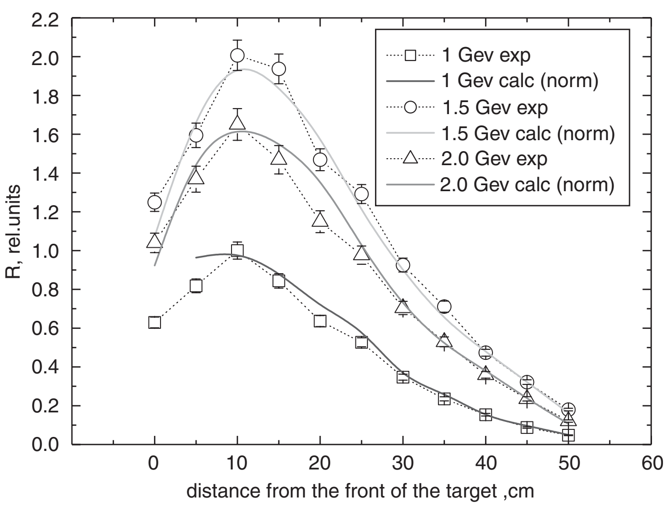

Fig. 2. Reaction rates in the ^{139}La samples.

2 GeV, which complies with our previous results obtained with the shorter target.

Dependence of the measured transmutation rates per GeV initial proton energy on its energy is given in Fig. 3. This value can be understood as a "transmutation

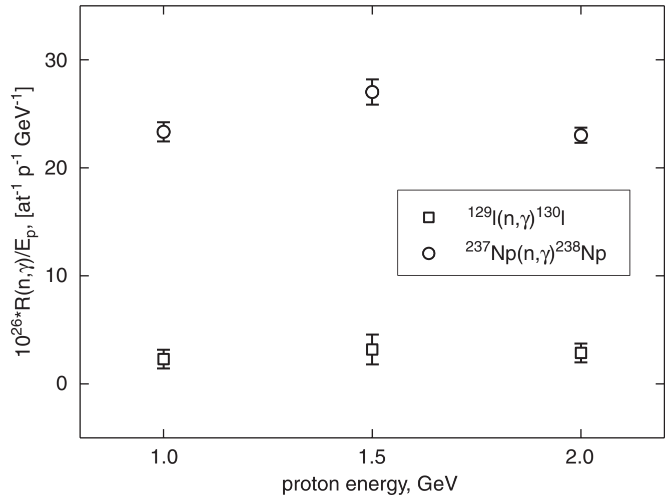

Fig. 3. Reaction rates in the transmutation samples.

efficiency" for the radioactive isotopes under study and for current configuration of the setup.

The results show that within the energy range under study transmutation rates are almost constant. This observation also does not contradict to our previous results obtained with the shorter target. Calculations performed using a cascade-evaporation-transport model implemented in the LAHET code showed a reasonable agreement with the experimental data.

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