Proton-Induced Polonium Production in Massive Lead-Bismuth Target Irradiated by 660 MeV Protons

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Abstract

The paper presents study of polonium production in bismuth foils placed in a lead target. Proton–induced production of residual nuclei ^{206}Po, ^{207}Po, ^{208}Po, ^{209}Po, ^{210}Po in ^{209}Bi foils placed in lead target irradiated by 660 MeV protons was calculated. A comparison with the calculated spatial distribution of polonium production using an MCNPX code and experimental results has been performed. The results of calculation will be useful for designing the target of SAD (Subcritical Assembly in Dubna).

1. Introduction

Data for residual nuclei production by proton induced reactions on heavy target elements at medium energies are strongly interested in Accelerator Driven System (ADS). As a step in the studies of characteristics of ADS, a combination of 660 MeV proton phasotron available at JINR and a subcritical assembly with MOX fuel have been proposed [1], [2], [3]. The proposed ADS facility consists of the 660 MeV proton accelerators, beam bending magnets, a removable lead and tungsten target, a subcritical core based on MOX fuel elements, lead reflectors, concrete shielding, control and auxiliary systems.

2. Experiments

A series of experiments on the lead target have been performed in Dubna using a 660 MeV proton beam [4], [5], [6]. The experimental target was assembled from the cylinders of natural lead. The geometry of the target is presented on Fig.1.

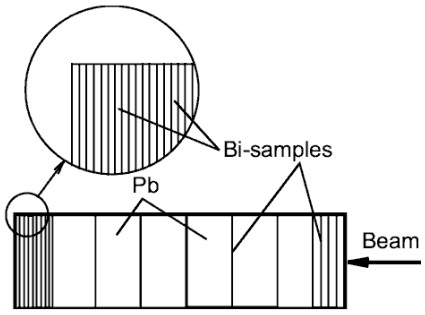

Fig. 1: Structure of the target (diameter 80 mm, length 308 mm)

The target was built of several pieces of 5 cm and 1 cm thick cylindrical parts of 8 cm in diameter. The target was enclosed in a 1.5 mm thick stainless steel cylinder. Samples were placed along the lead target in such a way that it best reproduces the spatial distribution of proton induced activity. In the experiment was used 31 pieces of 1 mm thick lead and bismuth samples. All parts of the target were irradiated and then the samples were counted with the use of HPGe coaxial detector. For quantitative evaluation some nuclides

were selected from ones with the identified lines in the measured y-spectra and for which axial distributions inside the lead target were obtained. Paper [7] gives experimental and calculated data of spatial distribution of bismuth produced in the massive lead target irradiated by 660 MeV protons. In this paper we present results of calculation of spatial distribution of polonium produced in bismuth samples placed in the lead target.

3. Calculations

We calculated the production of the following isotopes: Po-206, Po-207, Po-208, Po-209 and Po-210. Different methods were applied in calculations of the induced activity. We calculated isotopes production by two ways, by calculations of spatial-energy proton distributions in the target and by using experimental cross sections. The second way is using a cascade-evaporation model for simulation of the isotopes production. The results of calculations for Po-206 and Po-207 are presented on Fig.2 and Fig.3.

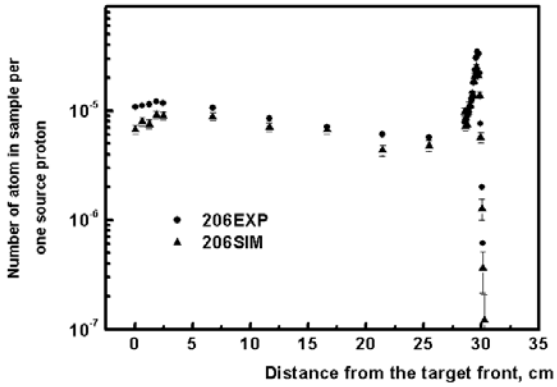

Fig. 2: Distribution of the Po-206 radionuclide production along the target irradiated with 660 MeV protons

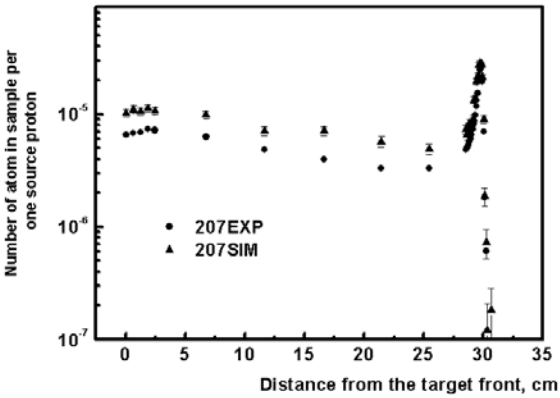

Fig. 3: Distribution of the Po-207 radionuclide production along the target irradiated with 660 MeV protons

One can observe the results of simulation (SIM) MCNPX code in good agreement with the results obtained using experimental cross sections (EXP).

The activity of Po isotopes inside the target shows a peak near the end of the proton range. It results from the changing proton energy spectrum in the end of the lead target to energy less than 50 MeV. As we can see from Fig.4, the maximum cross sections are for energy less than 50 MeV.

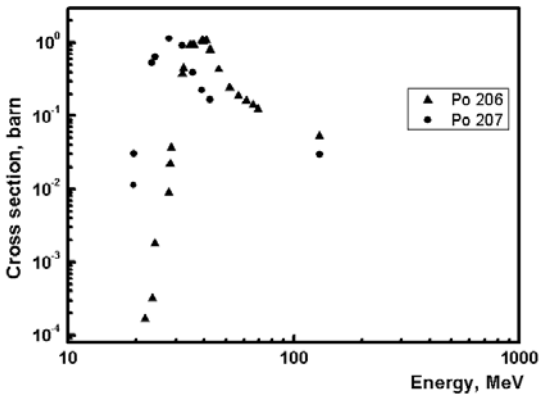

Fig. 4: Experimental excitation functions for the production of Po-206 and Po-207 in Bi-209 taken from EXFOR

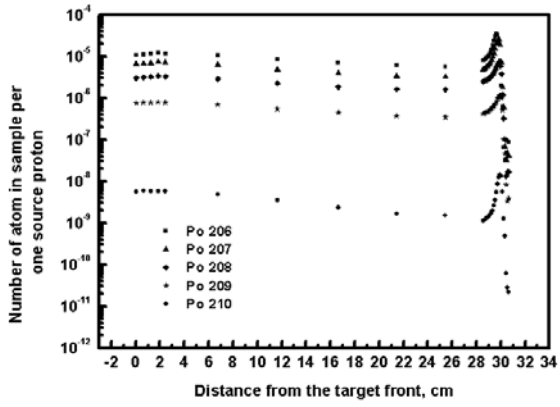

Fig. 5: Distribution of the Polonium radionuclide production along the target irradiated with 660 MeV protons

The spatial distribution of production of Po isotopes (206,207,208,209,210) in Bi-209 samples placed in lead target is presented on Fig.5.

As we can see from Fig.5, the production of Polonium isotopes increases with decreasing the atomic number of isotopes. The maximum activity induced by protons is observed on the end of the range of 660 MeV protons in lead.

Conclusion

The maximum of production polonium isotopes by protons in the lead-bismuth target is for energy of protons less than 100 MeV. This production we observe on the end of the range of protons in a massive target. High energy protons produce secondary neutrons and therefore at the beginning of the target we observe production of isotopes by neutrons.

References

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