PROCEEDINGS OF SCIENCE

Neutrons production in heavy spallation targets by electron beams

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In the work we compare the results of our calculation of energy spectra of the neutrons produced in heavy spallation targets as Pb and W rods by electrons from 200 MeV to 1 GeV with analogous distributions of neutrons generated by 1 GeV protons in the same targets. All calculations are performed by using MCNPX and FLUKA codes. In more detail the results have been published in [1].

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1. INTRODUCTION

One of the main problems of present and future nuclear power is safe and rational management of radioactive wastes from nuclear plants, in particular, by means of transmutation and incineration in appropriate neutrons fields. Although it is commonly accepted that for this purpose optimal are ~1 GeV protons producing neutrons in heavy spallation targets like Pb, W and U, but accelerators of such beams are expensive and not available in many laboratories. Therefore, the keen interest for neutrons generation has also displayed in electronuclear reactions initiating by electrons because the relevant accelerators are much cheaper and sufficiently popular.

In the work we compare the results of our calculation of energy spectra of the neutrons produced in heavy spallation targets as Pb and W rods by electrons from 200 MeV to 1 GeV with analogous distributions of neutrons generated by 1 GeV protons in the same targets. All calculations are performed by using MCNPX and FLUKA codes. In more detail the results have been published in [1].

2. PRODUCTION OF NEUTRONS AND PHOTONS BY ELECTRONS FROM 30 MeV TO 1000 MeV IN DIFERENT TARGETS

The fundamental problem facing a spallation source is its production ability mainly of neutrons and other particles. In the case of a cylindrical lead target 3.34x3.34 cm2 irradiated with a beam of electrons of energy between 30 MeV and 1000 MeV the neutrons and photons yield dependencies on electrons energy are depicted in Fig. 1.

It should be mentioned that photons are created in the investigated spallation target predominantly via bremsstahlung and pair-annihilation processes. Moreover, the modeling code MCNPX used in calculation includes X-ray creation and fluorescence radiation. A small amount of photons is produced as well in secondary interactions of neutrons and photons with atomic nuclei. Low energy photons are absorbed in the target via interactions with electrons (photoelectric effect). High energy photons produce neutrons mainly as a result of photo-nuclear reaction.

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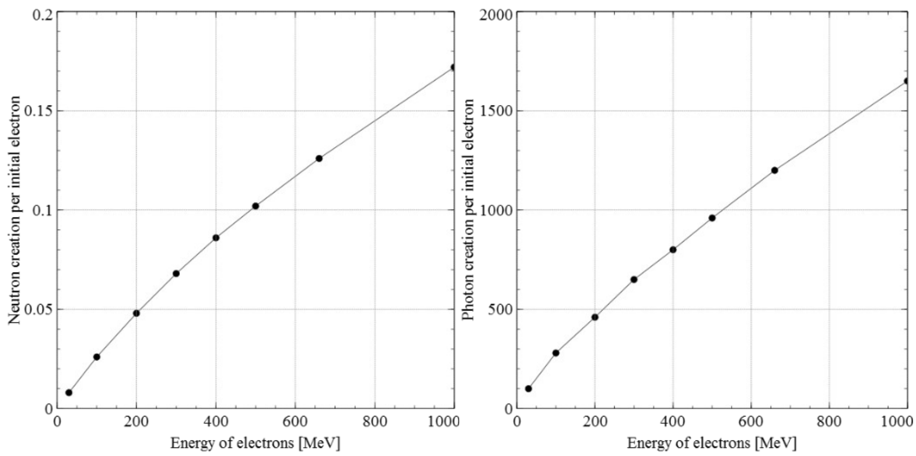

Fig.1. Intensity of neutrons (left) and photons (right) created in a cylindrical lead target of 3.34 cm long and 3.34 cm in radius by electrons of energy from 30 MeV to 1000 MeV (calculated by using MCNPX).

3. PRODUCTION OF NEUTRONS BY ELECTRON AND PROTON BEAMS IN TARGETS OF SUBCRITICAL NUCLEAR REACTOR

In the work the modeling of neutron flux and energy generation have been performed for the subcritical fast neutron reactor cooled with gas and based on MOX fuel. We emphasize that one of the benefits of subcritical reactor is its practical insensitiveness to fuel impurities as compared to typical fast reactors, where above a certain threshold rate of fission products created the reactor should be shut down and fuel elements have to be replaced often enough.

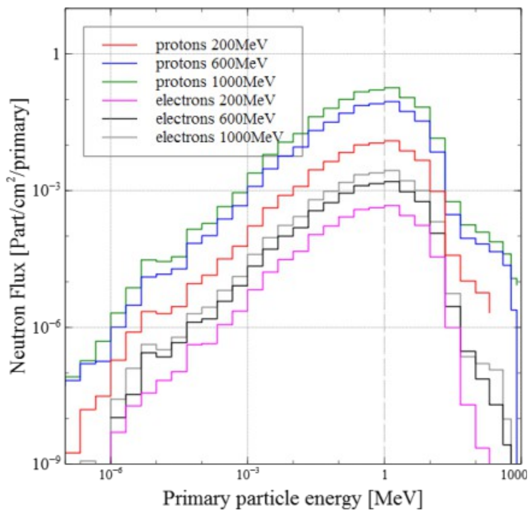

Fig.2. Energy spectra of neutrons produced in one of experimental channels by electrons of energy 200, 600 and 1000 MeV, and protons of energy 600 and 1000 MeV.

The calculated energy spectra of neutrons produced in different experimental channels both by electrons of 200 MeV, 600 MeV and 1000 MeV and protons of 200 MeV, 600 MeV and 1000 MeV energy are depicted in Fig.2.

4. TARGET RADIOACTIVITY

The radioactivity of a target set-up induced in the course of longtime irradiation is its important feature from practical and safety viewpoint. Fig.3 shows the radioactivity evolution of the lead and tungsten targets irradiated by 600 MeV electrons and protons beams during one year of irradiation. The results have been obtained using FLUKA code. One can see that the radioactivity of the target in the case of protons beams is greater than after electrons irradiation by about three orders of magnitude for lead target and two orders of magnitude for tungsten target during all irradiation time. So, the less target radioactivity produced by electrons is a great advantage of the Accelerator Driven System (ADS) operating in transmutation mode. It has also been shown that for tungsten target the overall radioactivity is higher till ~10 years after irradiation as compared to the lead target.

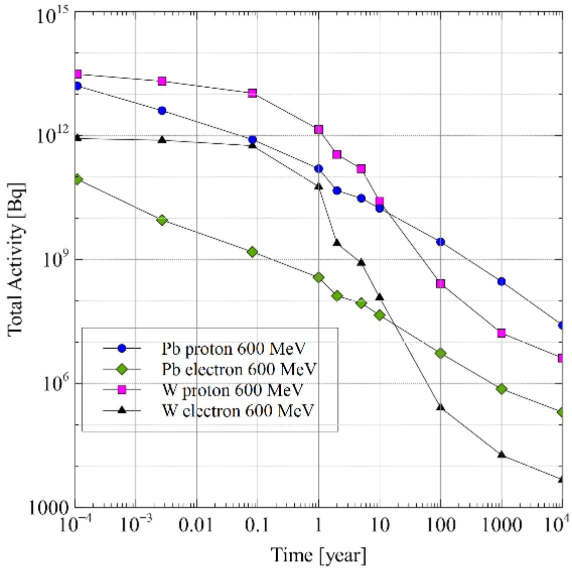

Fig.3. Total radioactivity evolution of the lead (natural) and tungsten (natural) targets irradiated by the 600 MeV electron and proton beams. The dimensions of the targets considered: radius 9cm, thickness 70cm. Calculation results from FLUKA code for irradiation time – 1 year with statistics of the order of 107 histories. The beams parameters: 9.45*1012particles/s (1kW).

The highest concentration of residual nuclei is the area where the highest energy gets deposited (Fig.4). Fission density follows the beam entry axis closely and lowers rapidly with perpendicular direction. When comparing the activity of electron and proton beams of the same, for example 600 MeV energy, the electron beam produces around 3 orders of magnitude less activity than a proton one during the whole time (Fig. 3) making it a better choice when target longevity is of concern.

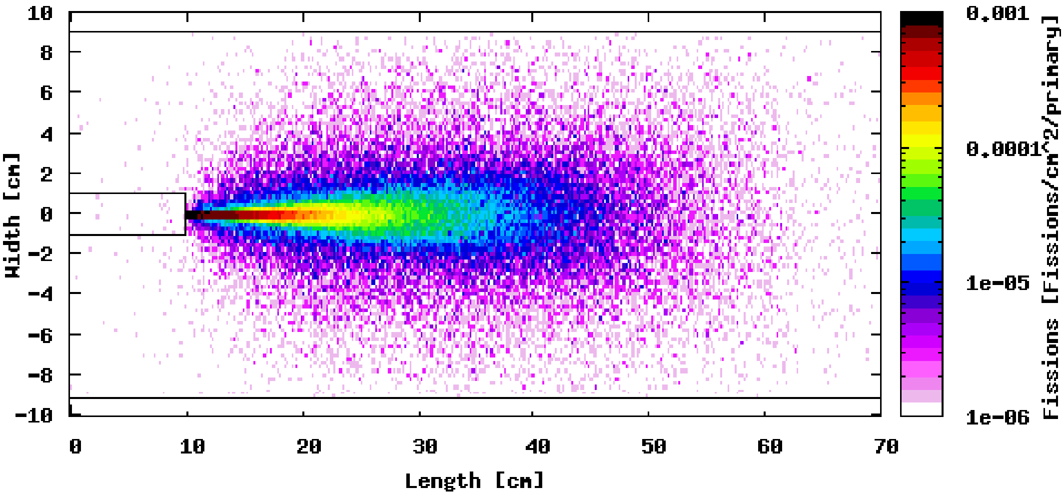

Fig.4. Localizations of fissions leading to residual nuclei production in a cylindrical target of 70 cm long and 9 cm in radius irradiated by protons of energy 1 GeV.

5. CONCLUSION

The shape of neutrons energy spectra created by both 1GeV protons and electrons are acceptably comparable below ~1 MeV whilst above this value electronuclear neutrons are numerous enough to be used as a spallation neutron source for several aims like transmutation and incineration at least at the experimental level. Additionally, the heat release and remnant radioactivity of the investigated targets have also been estimated. In more detail our results have been published in [1].

References

[1] A.Polański, B.Słowiński, T.Jackowski, A.Pacan, *Neutrons production in heavy extended targets by electrons of energy from 15 to 1000 MeV,* Progress in Nuclear Energy, Vol 78, January 2015, pages 1-9. http://dx.doi.org/10.1016/j.pnucene.2014.07.009