NEUTRONS PRODUCTION IN HEAVY SPALATION TARGETS BY ELECTRONS BEAMS

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OUTLINE

MOTIVATION

ABSTRACT

RESULTS OF CALCULATIONS USING MCNPX AND FLUKA CODES

CONCLUSIONS

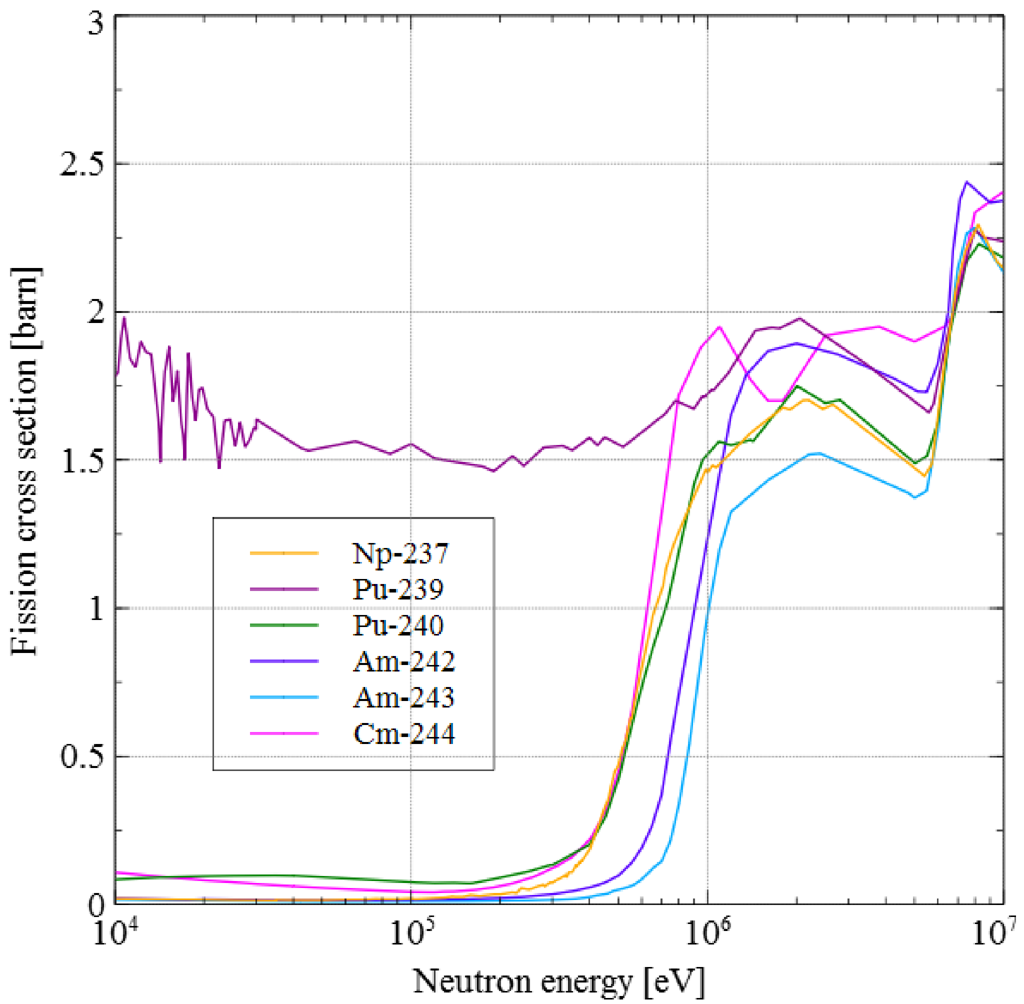
Motivation

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.

Abstract

We compare the results of our calculation of energy spectra of the neutrons produced in heavy spallation targets performed as Pb and W rods by electrons from 200 MeV to 1 GeV with similar distributions of neutrons generated by 1 GeV protons in the same targets. All calculations are performed by using MCNPX and FLUKA codes.

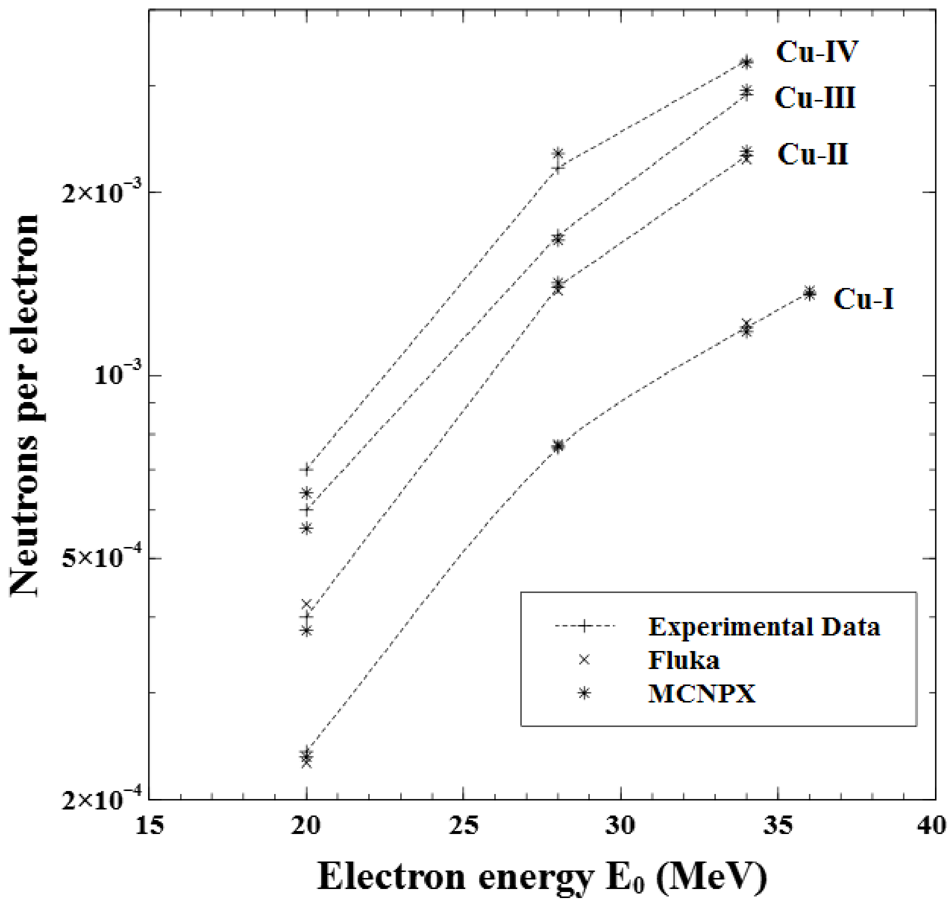
Main results have been published in ***Progress in Nuclear Energy****, Volume 78, January 2015, Pages 1–9.*

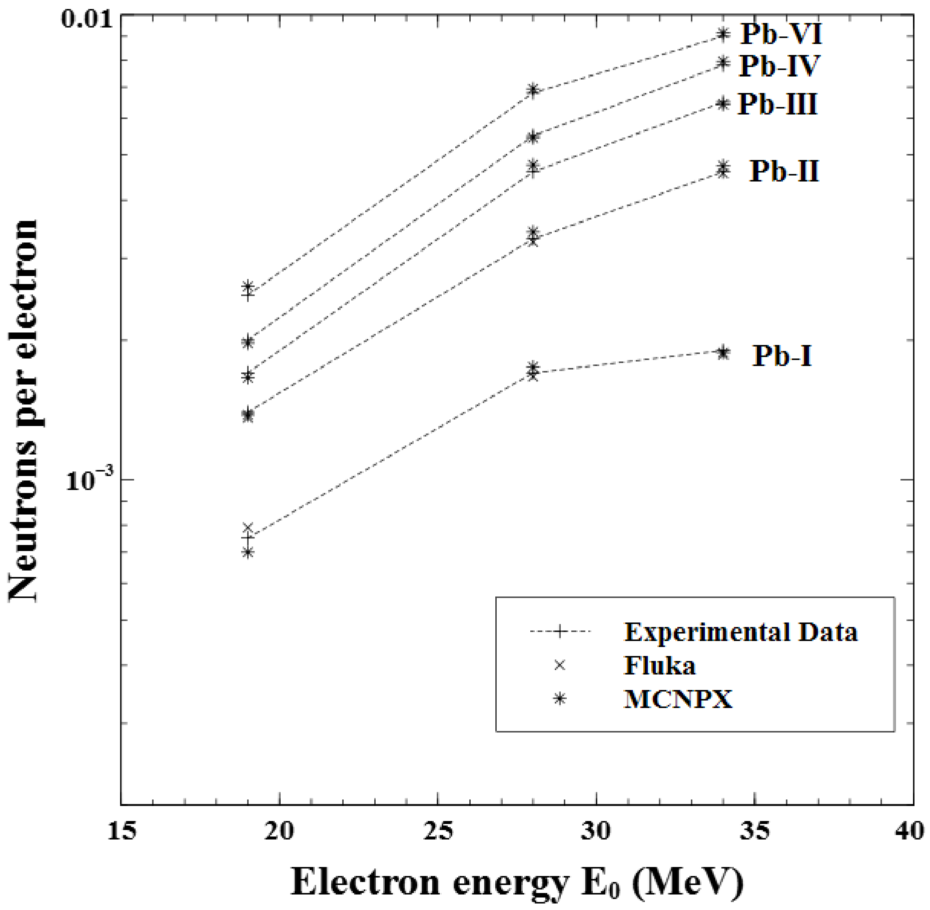


Fission cross section of selected isotopes

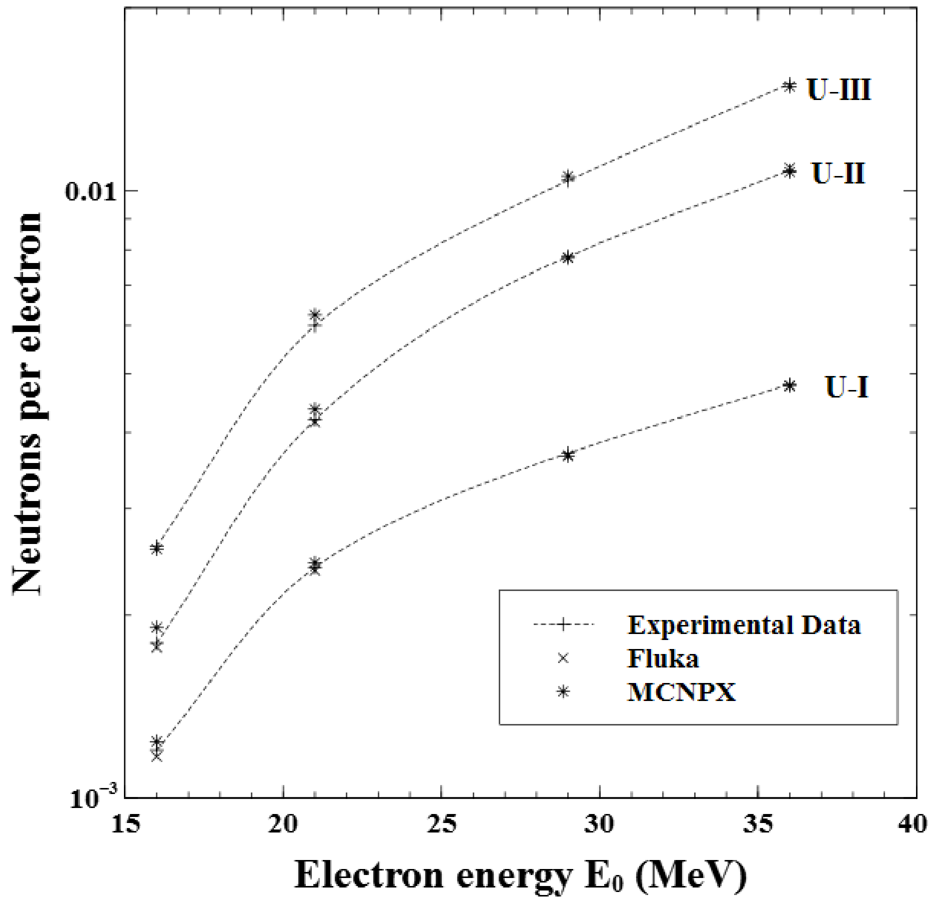
Checking of the MCNPX and FLUKA

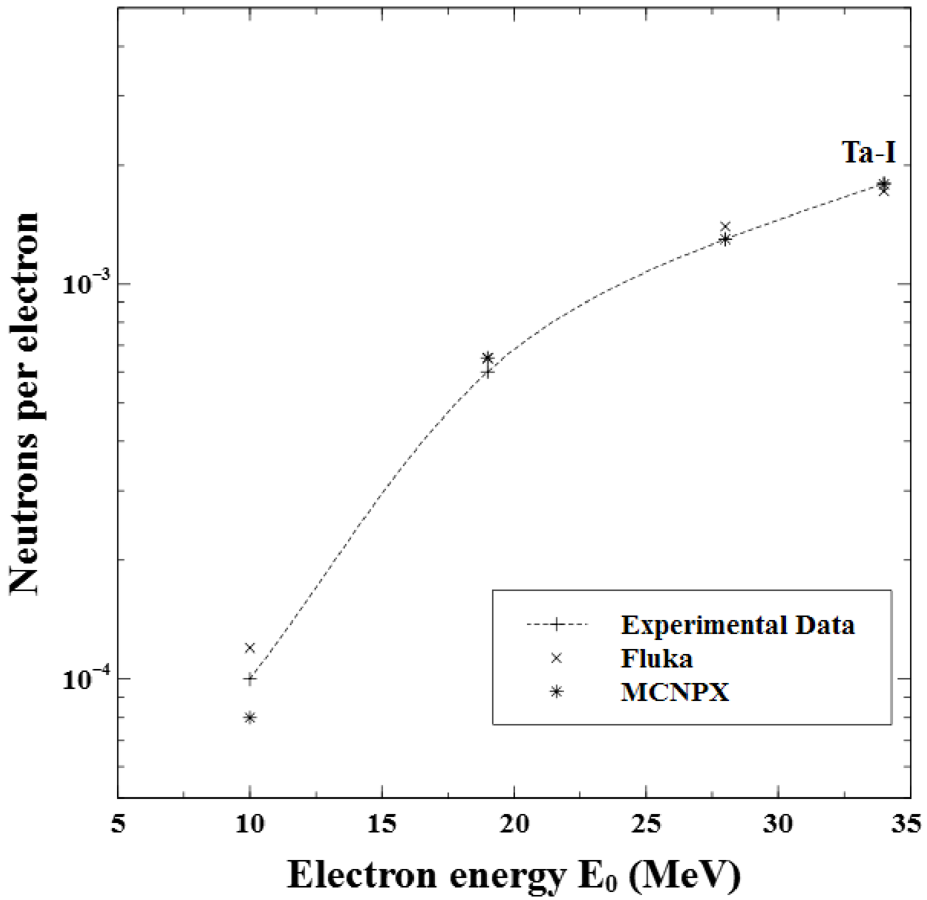
Energy spectra of neutrons induced by 20-40 MeV electrons and leaving Cu (left) and Pb (right) targets of various thicknesses





Energy spectra of neutrons induced by 20-40 MeV electrons and leaving U (left) and Ta (right) targets of various thicknesses



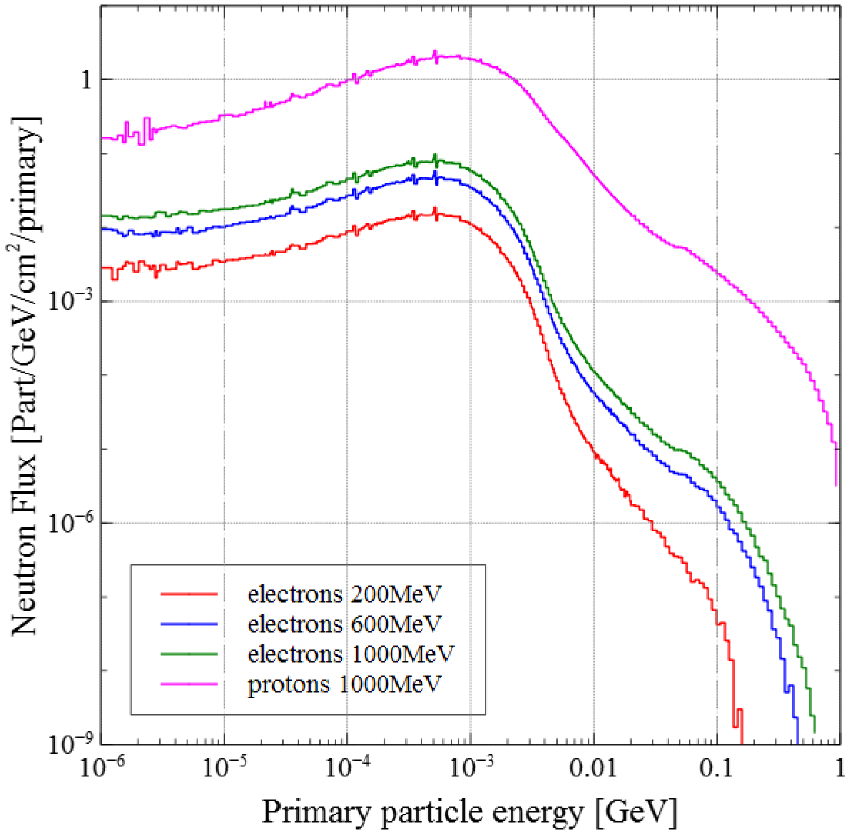


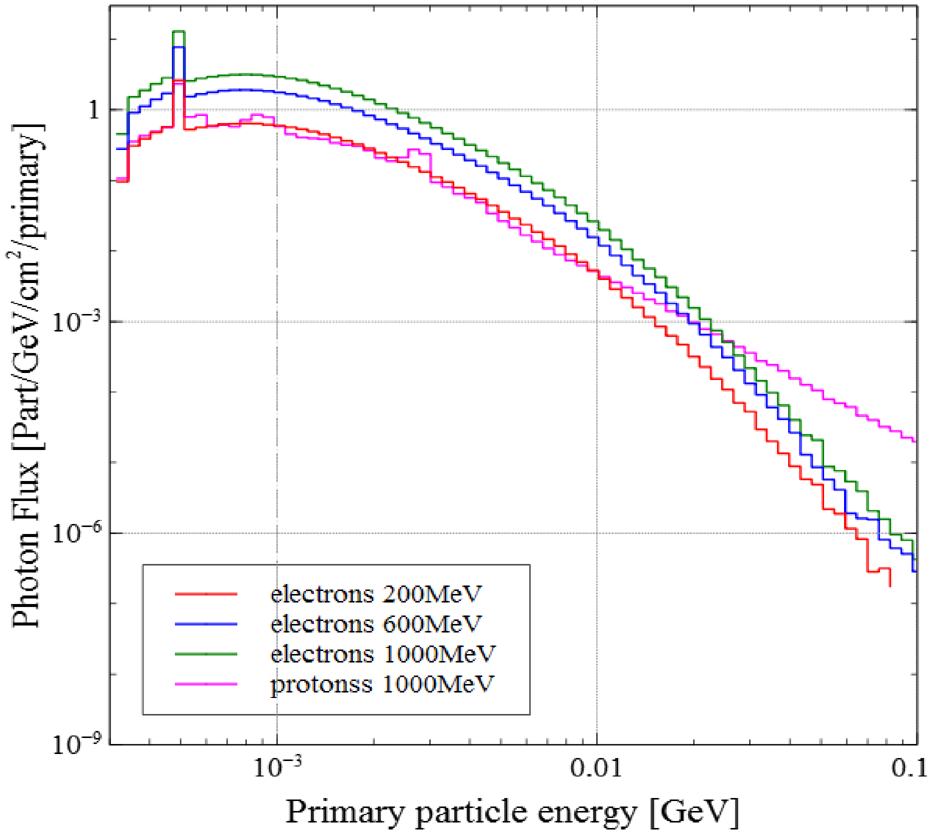
Thicknesses of targets used in experiment [1] and our calculations. All targets contained isotopes in their naturally-occurring proportions.

Target	Thickness (radiation lengths)
Cu-I	1.04
Cu-II	2.08
Cu-III	3.13
Cu-IV	4.17
Pb-I	1.01
Pb-II	1.97
Pb-III	2.98
Pb-IV	3.94
Pb-VI	5.93
U-I	1.14
U-II	2.30
U-III	3.46
Ta-I	0.98

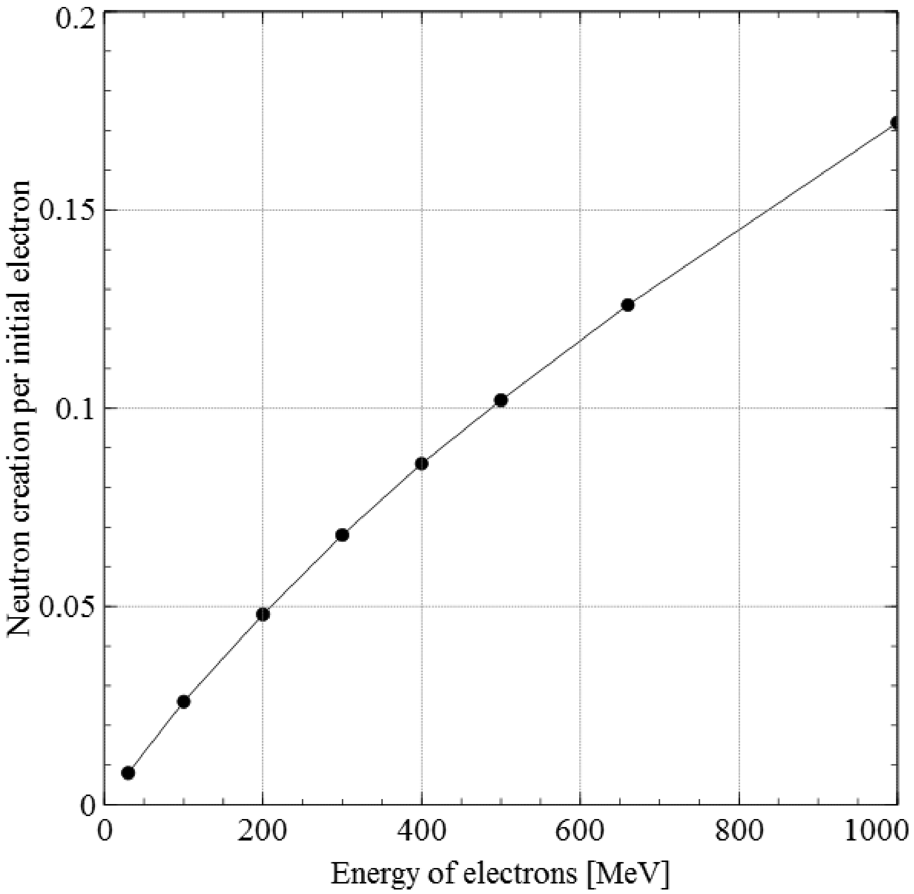
Our results of neutrons and photons energy spectra calculation

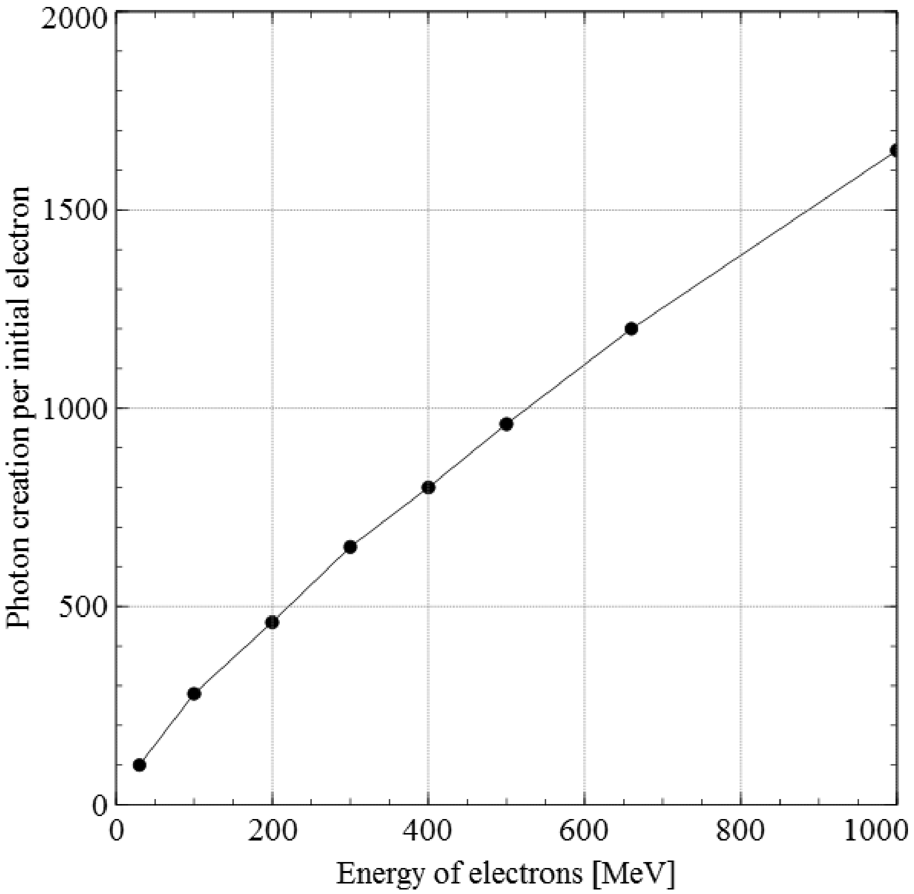
Energy spectra of neutrons and photons produced in a lead target by electrons and protons at different energies



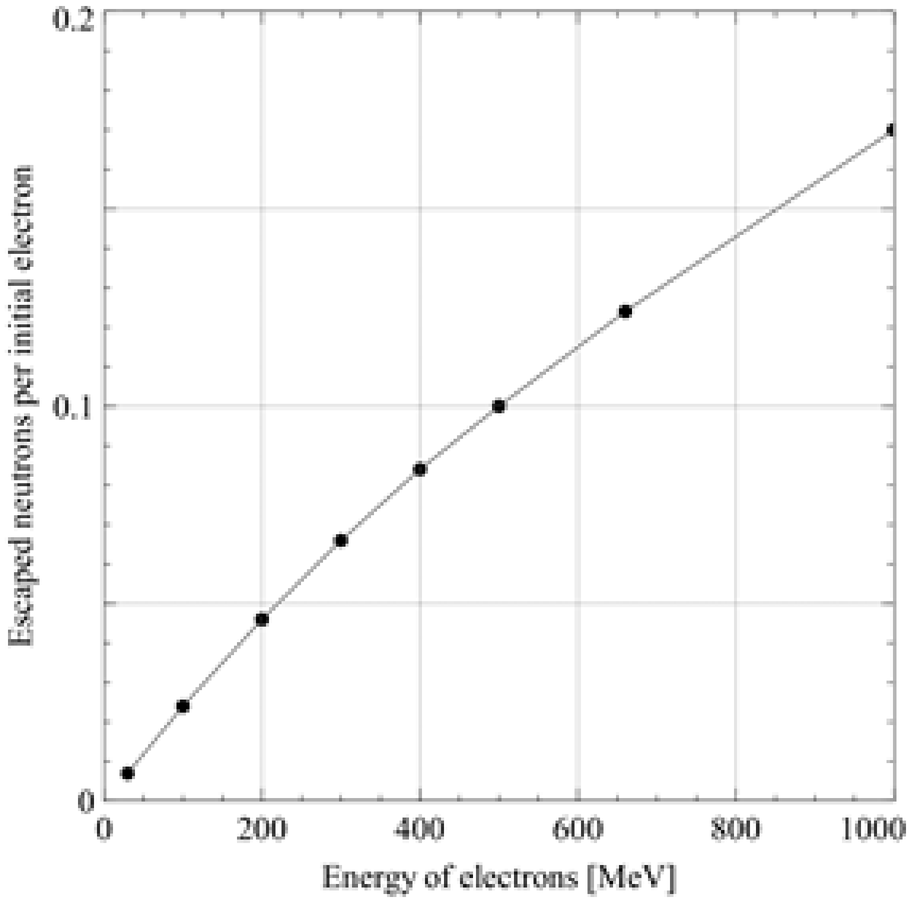


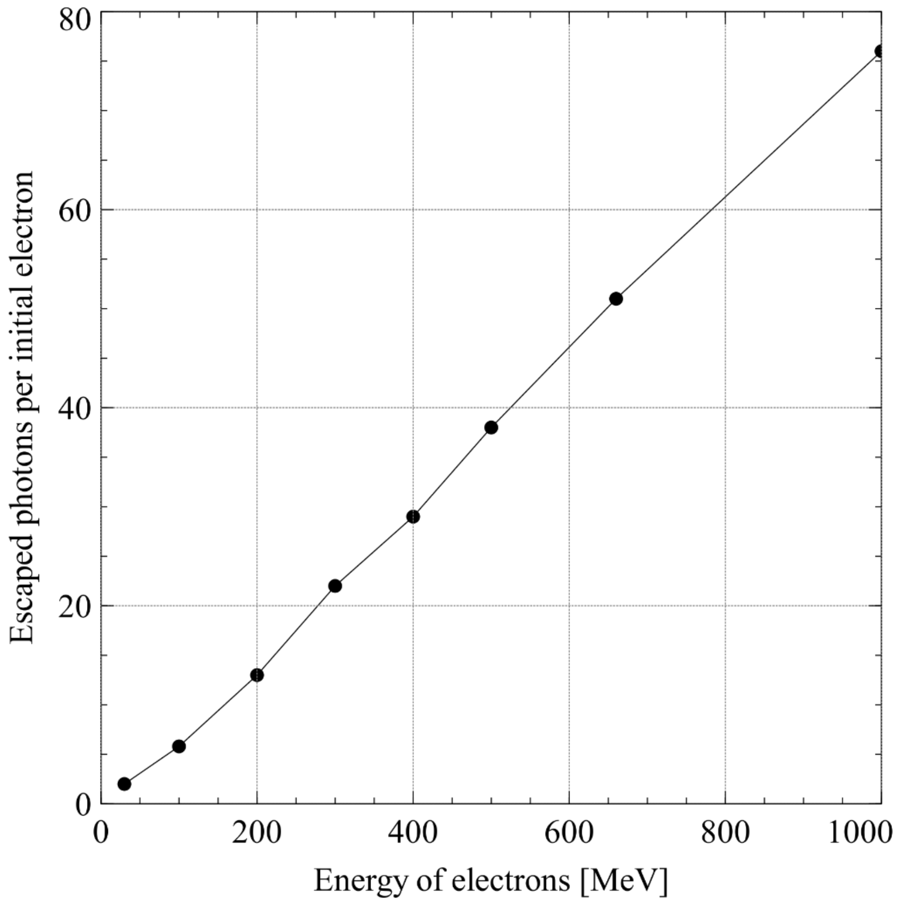
Intensity of neutrons (left) and photons (right) created in a cylindrical lead target of 3.34 cm long and 3.34 cm in radius by electrons of energy from 30 MeV to 1000 MeV (calculated by using MCNPX)



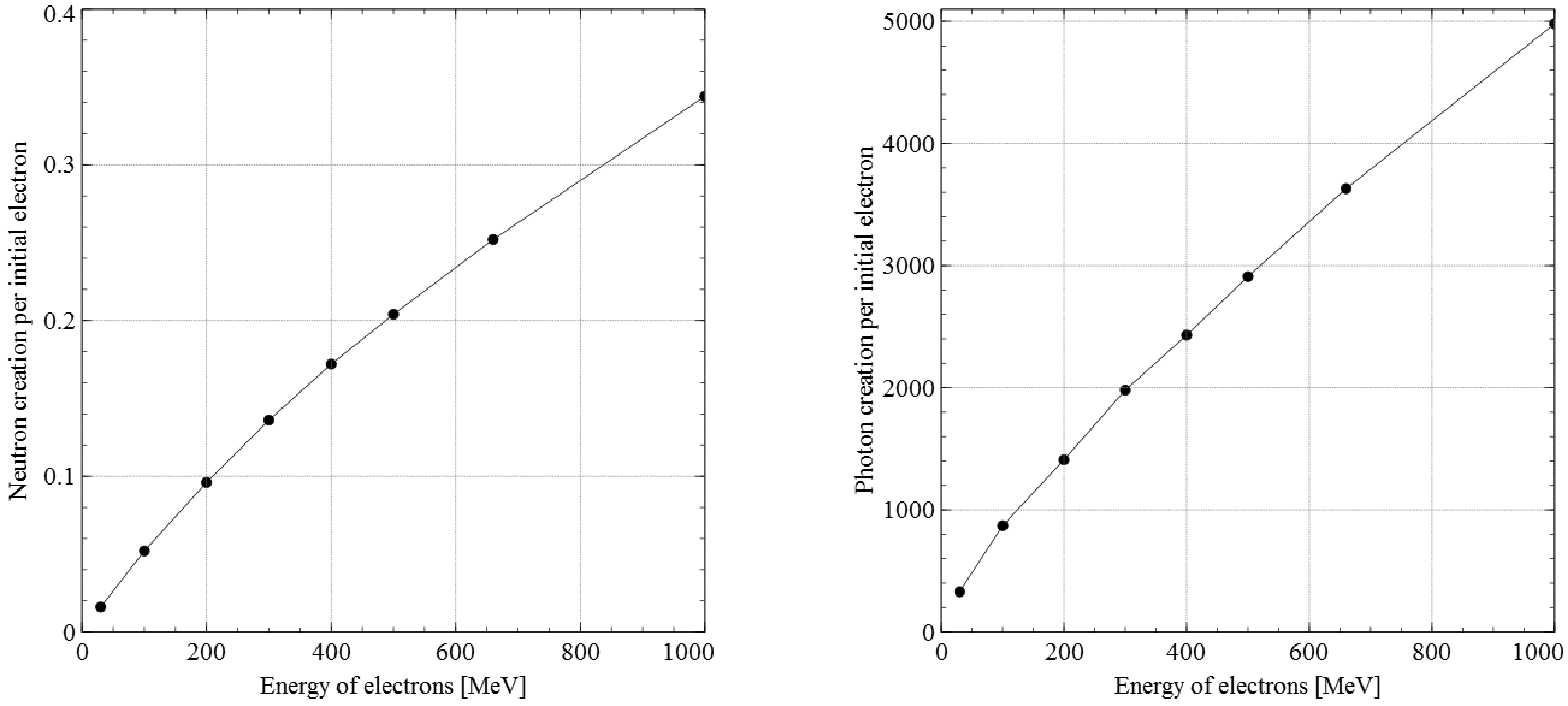


Intensity of neutrons (left) and photons (right) escaping from a cylindrical lead target of 3.34 cm long and 3.34 cm in radius by electrons of energy from 30 MeV to 1000 MeV (calculated by using MCNPX)

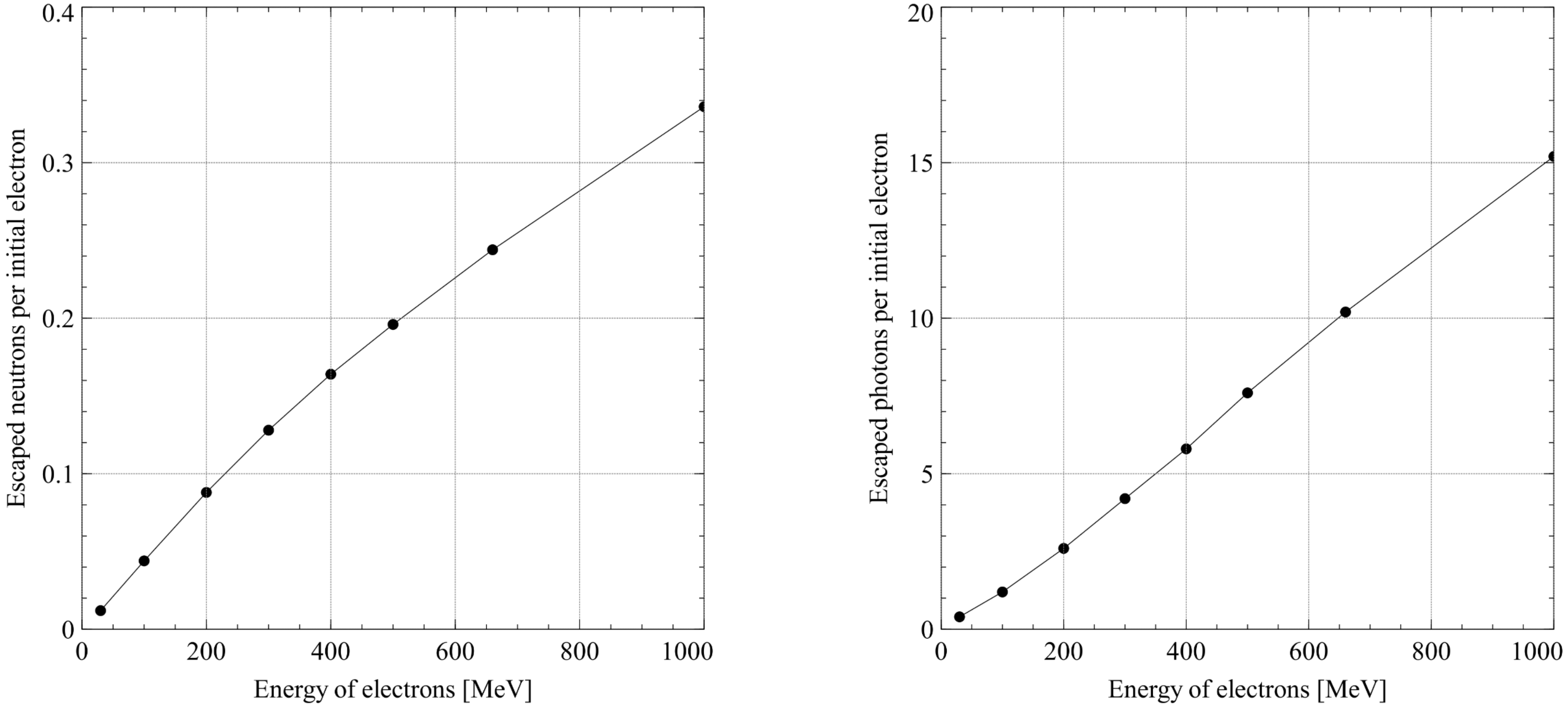




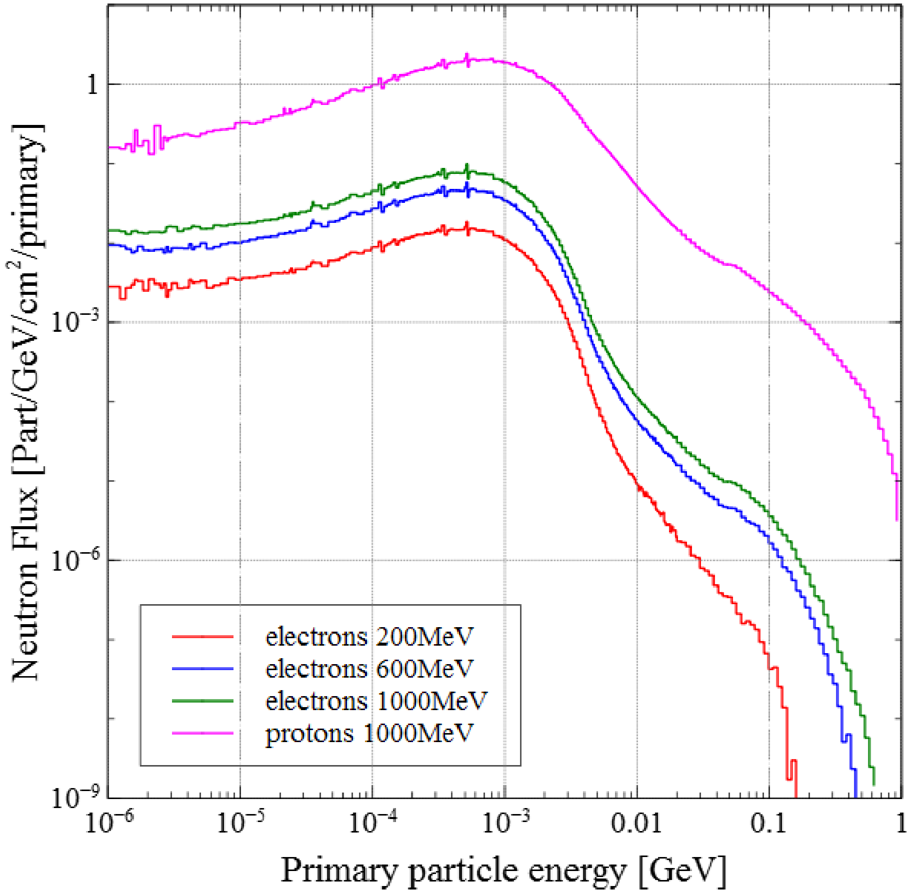
Yields of neutrons (left) and photons (right) created inside the cylindrical lead target of 70 cm long and 9 cm in radius by electrons of energy from 30 MeV to 1000 MeV calculated by using MCNPX.

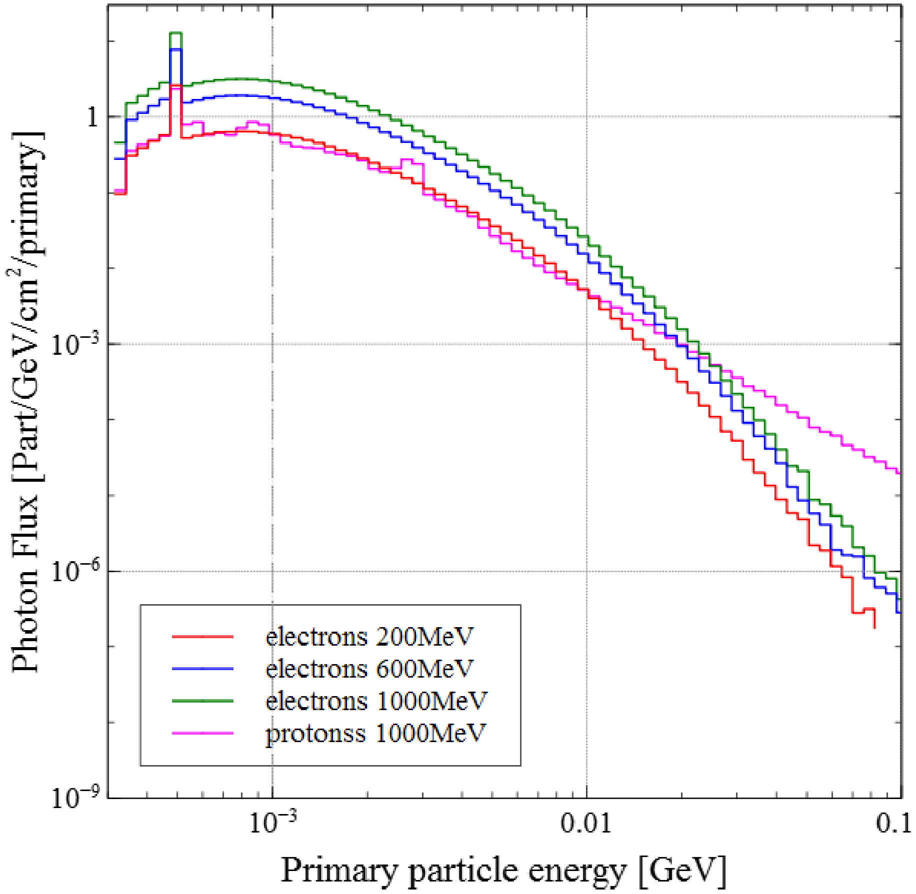


Yields of neutrons (left) and photons (right) escaping from the the cylindrical lead target of 70 cm long and 9 cm in radius by electrons of energy from 30 MeV to 1000 MeV calculated by using MCNPX.

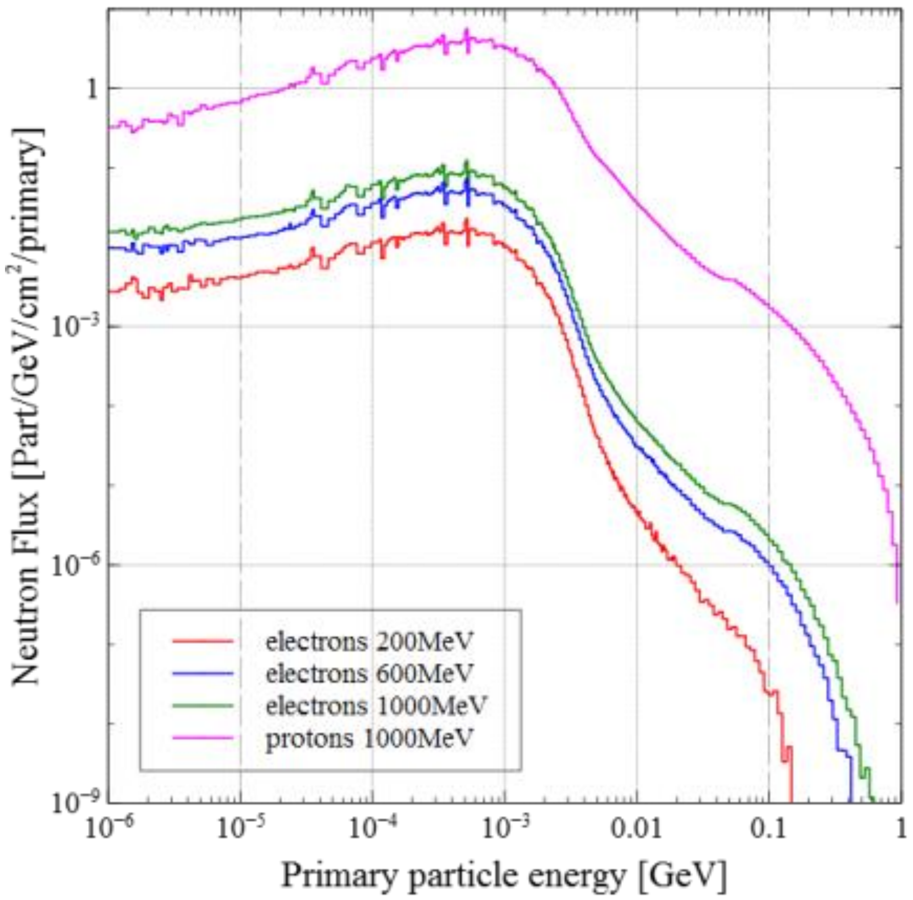


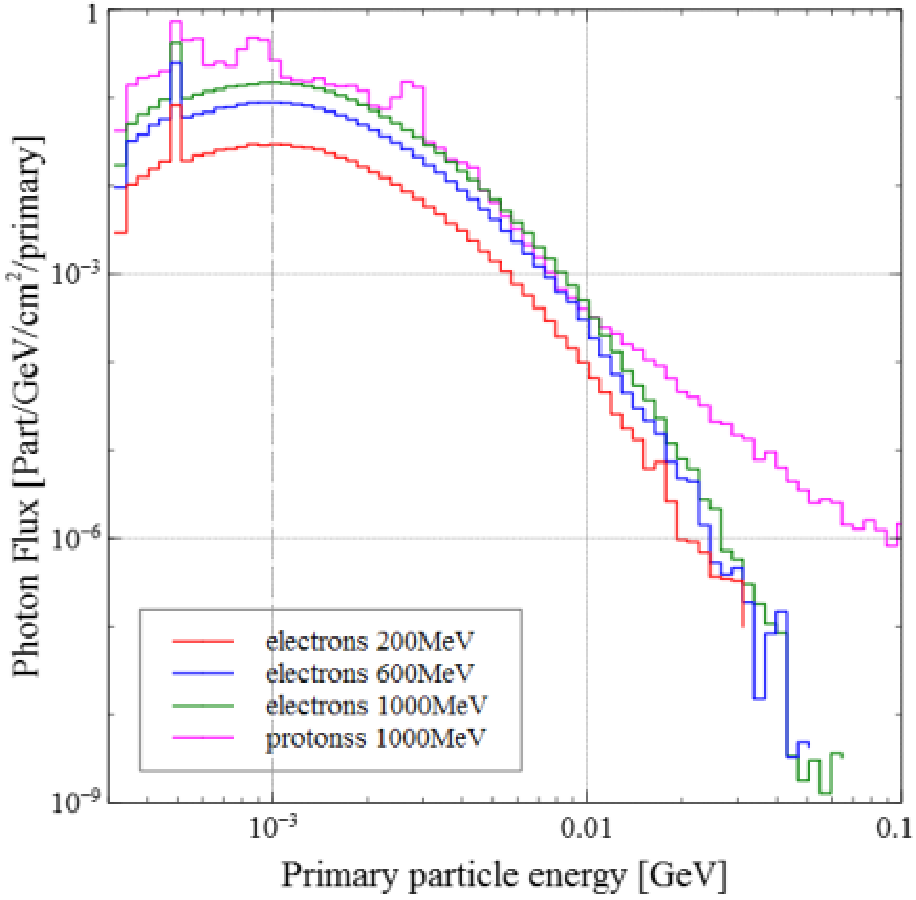
Energy spectra of neutrons (left) and photons (right) produced by electrons of energy 200, 600 and 1000 MeV and protons at 1000 MeV in a cylindrical lead target of 3.34 cm long and 3.34 cm in radius and escaping from it. Calculated by means of FLUKA.



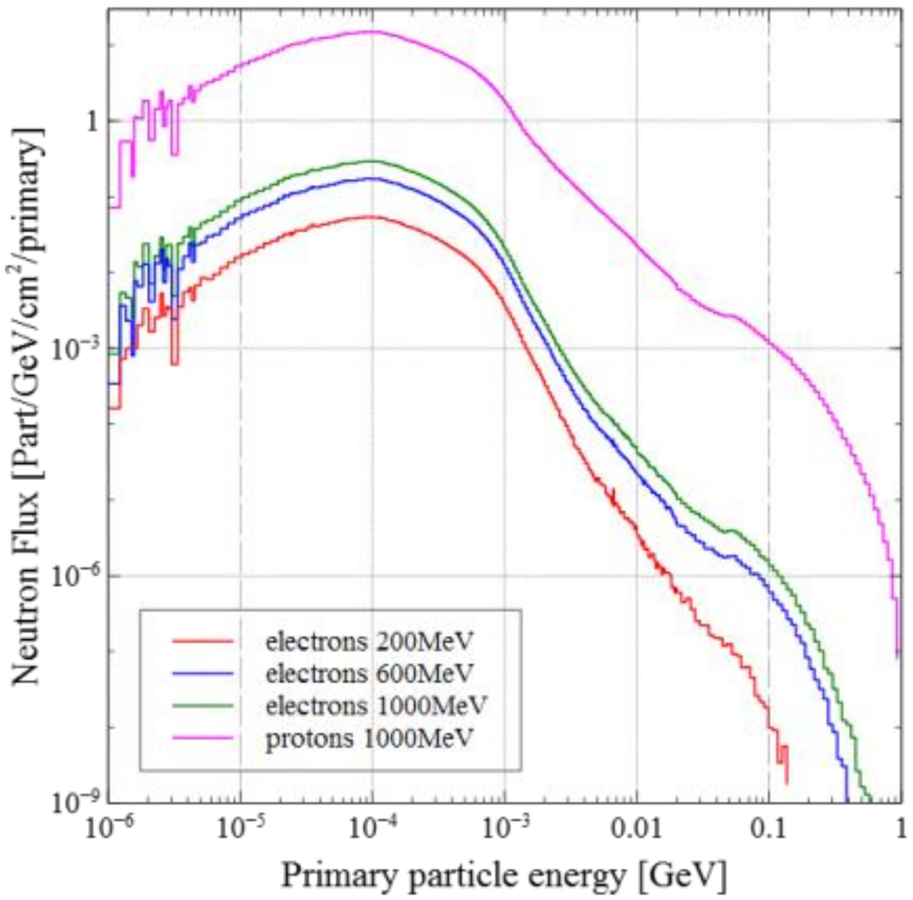


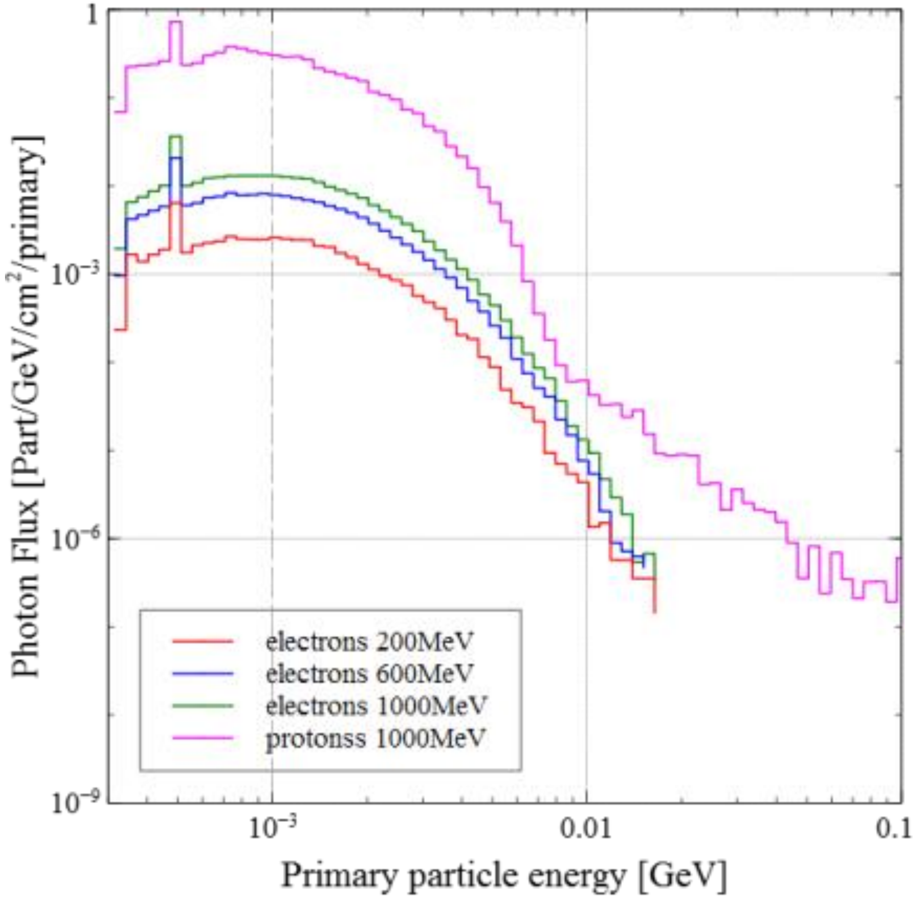
Energy spectra of neutrons (left) and photons (right) produced by electrons of energy 200, 600 and 1000 MeV and protons at 1000 MeV in a cylindrical lead target of 70 cm long and 9 cm in radius and escaping from it. Calculated by means of FLUKA.



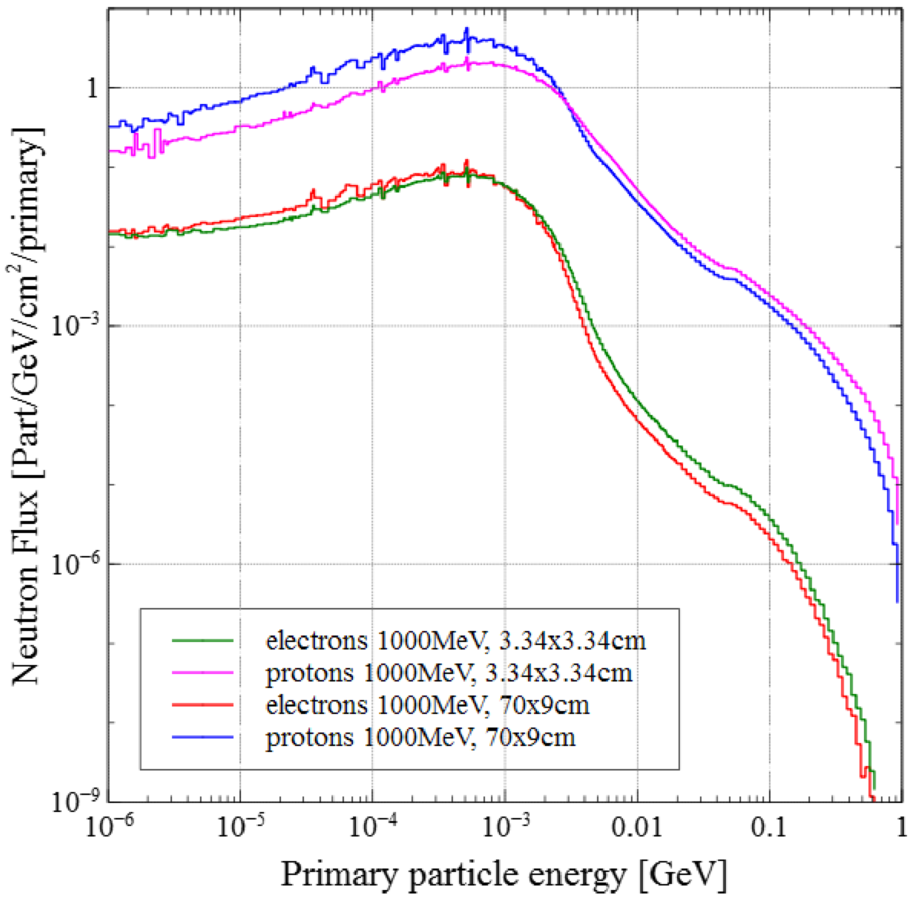


Energy spectra of neutrons (left) and photons (right) produced by electrons of energy 200, 600 and 1000 MeV and protons at 1000 MeV in a cylindrical tungsten target of 70 cm long and 9 cm in radius and escaping from it. Calculated by means of FLUKA.

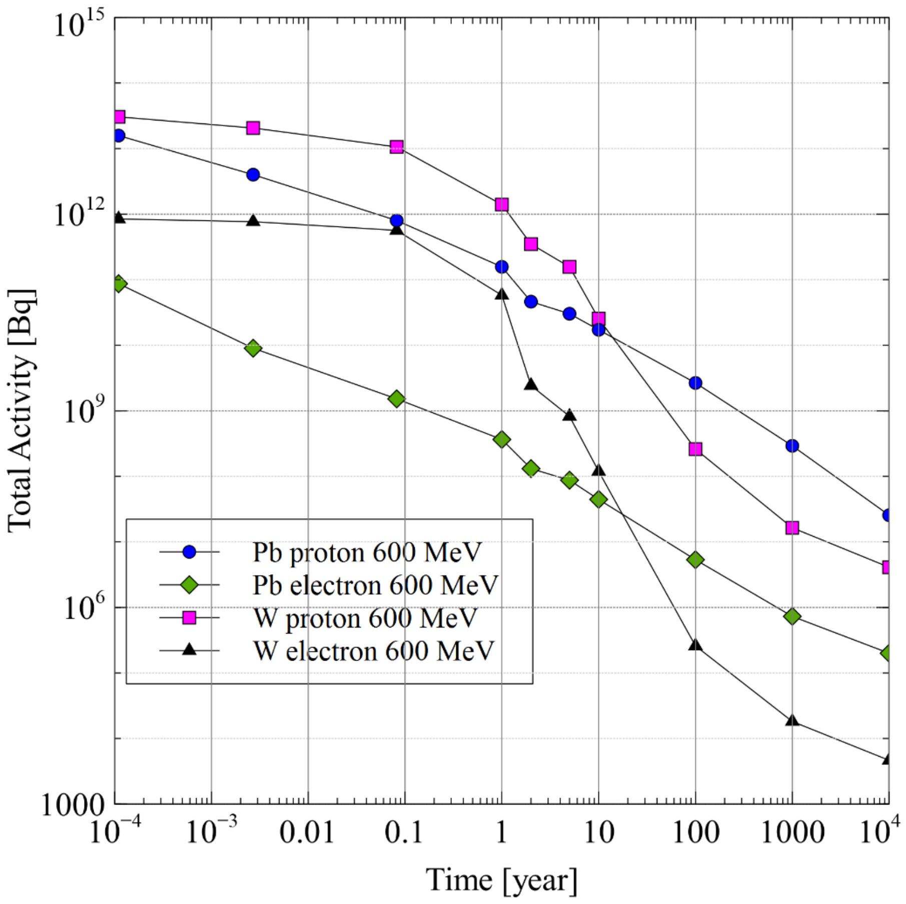




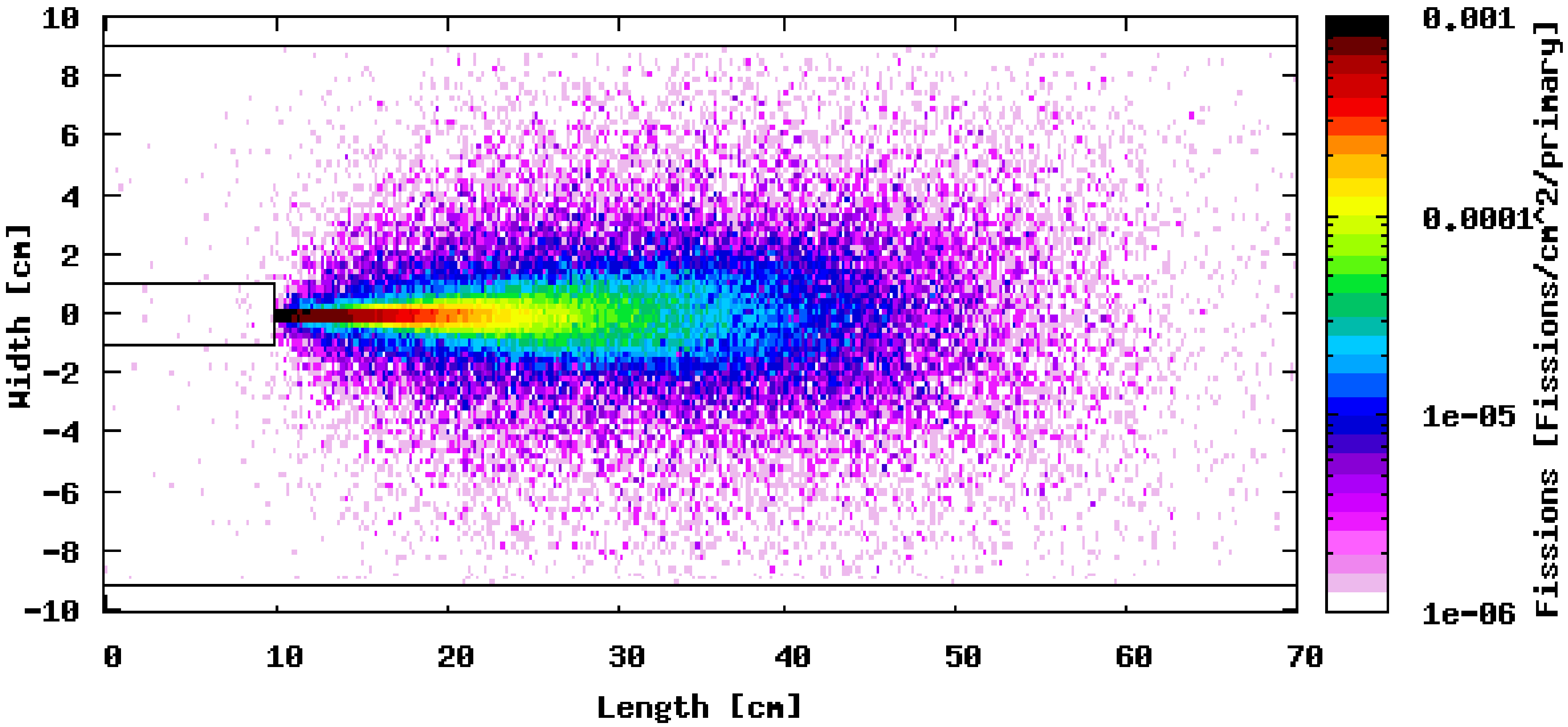
Energy spectra of neutrons produced by electrons and protons of energy 1000 MeV in cylindrical lead targets of 3.34 cm long and 3.34 cm in radius and a 70 cm long and 9 cm in radius



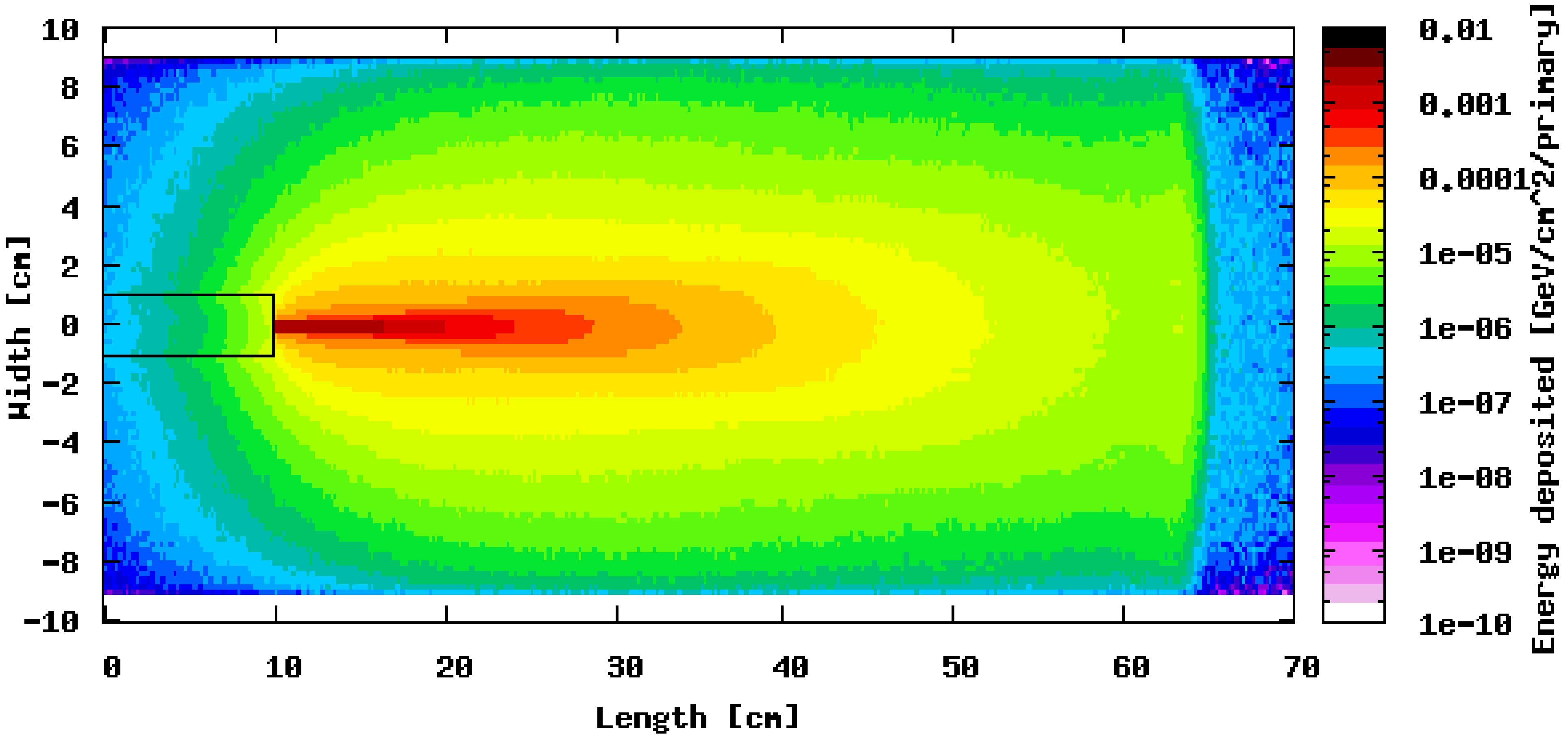
Total radioactivity evolution of the lead (natural) and tungsten (natural) targets irradiated by the 600 MeV electron and proton beams



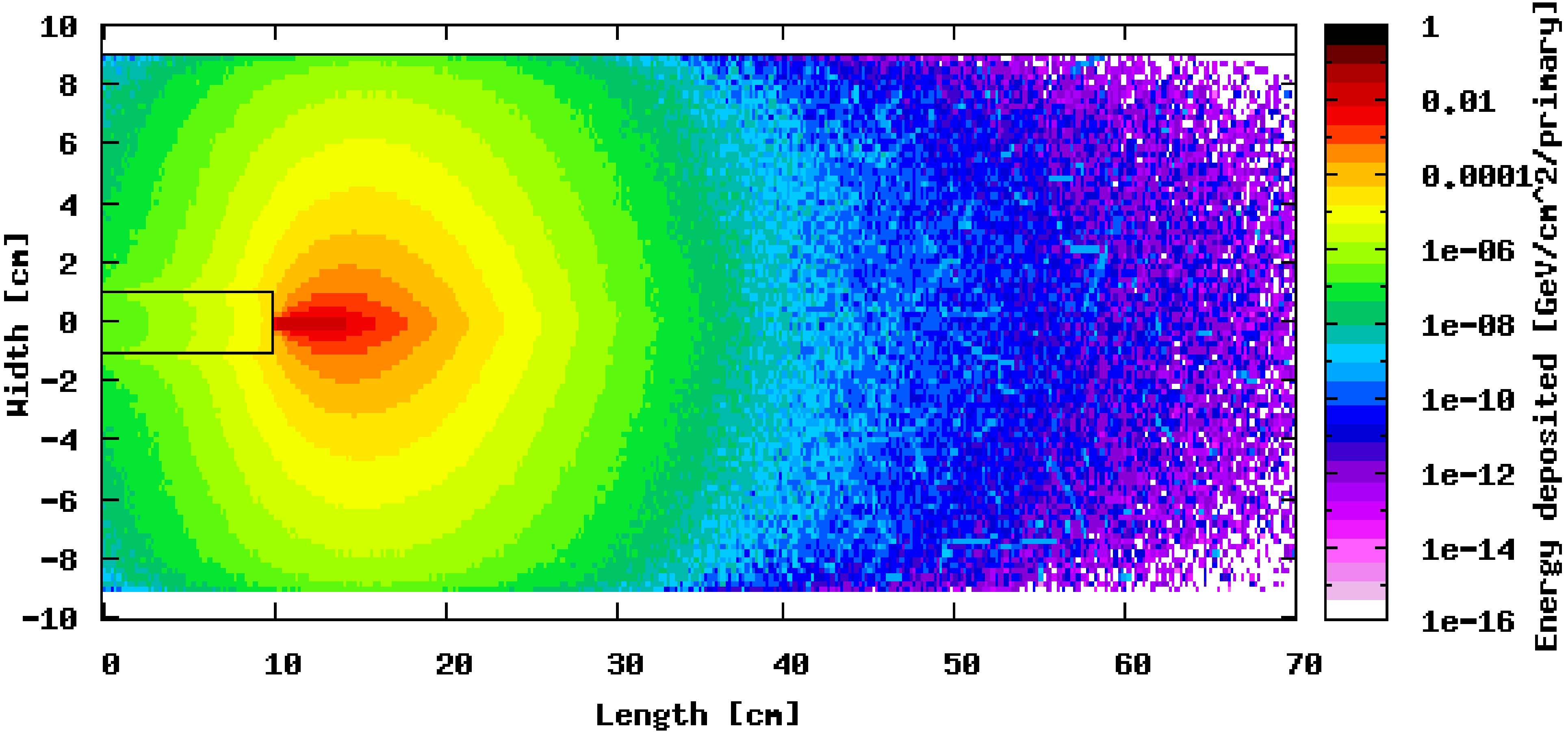
Localizations of fissions leading to residual nuclei production in a cylindrical target of 70 cm long and 9 cm in radius irradiated by protons of energy 1 GeV.



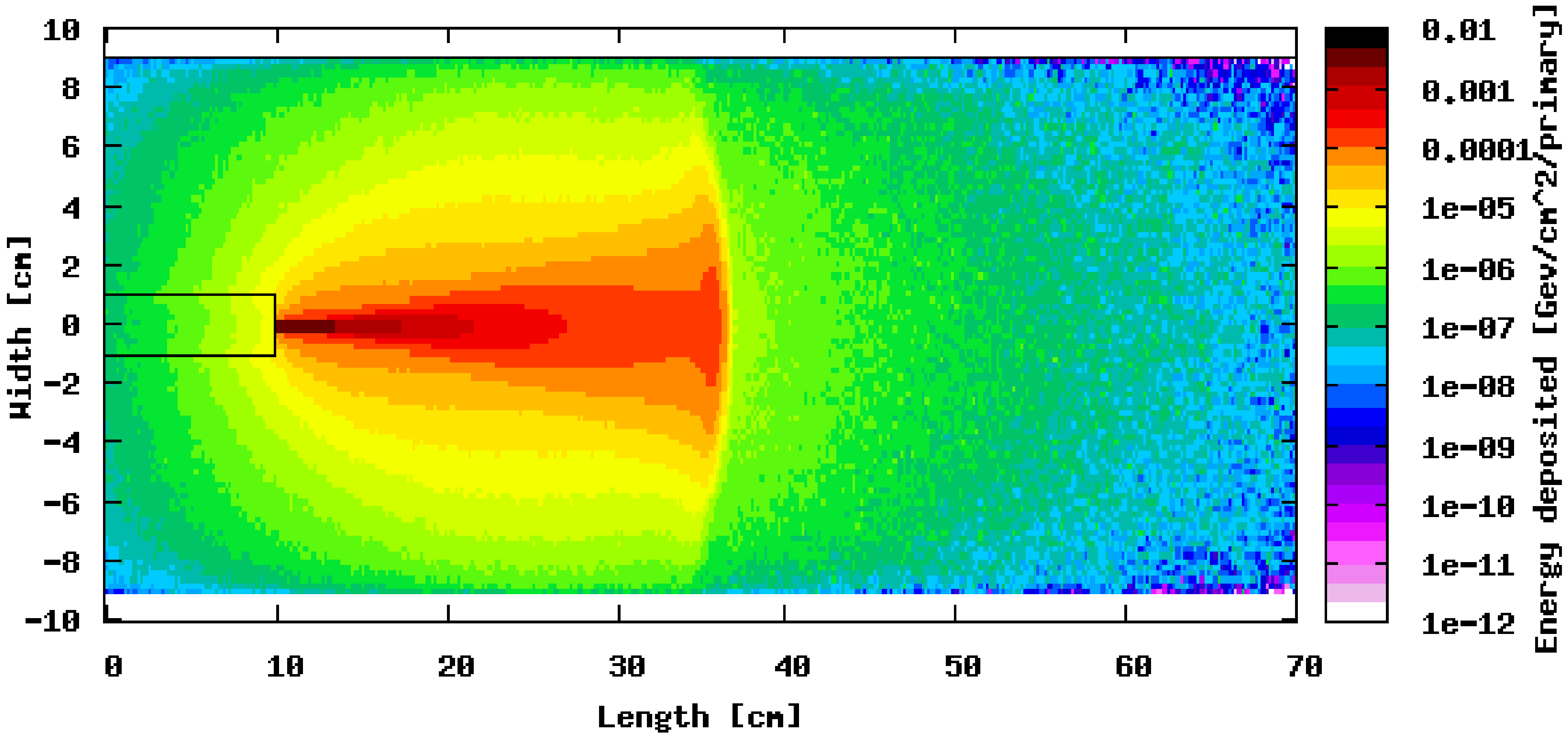
Energy deposition in a cylindrical lead target of 70 cm long and 9 cm in radius target irradiated by 1 GeV protons



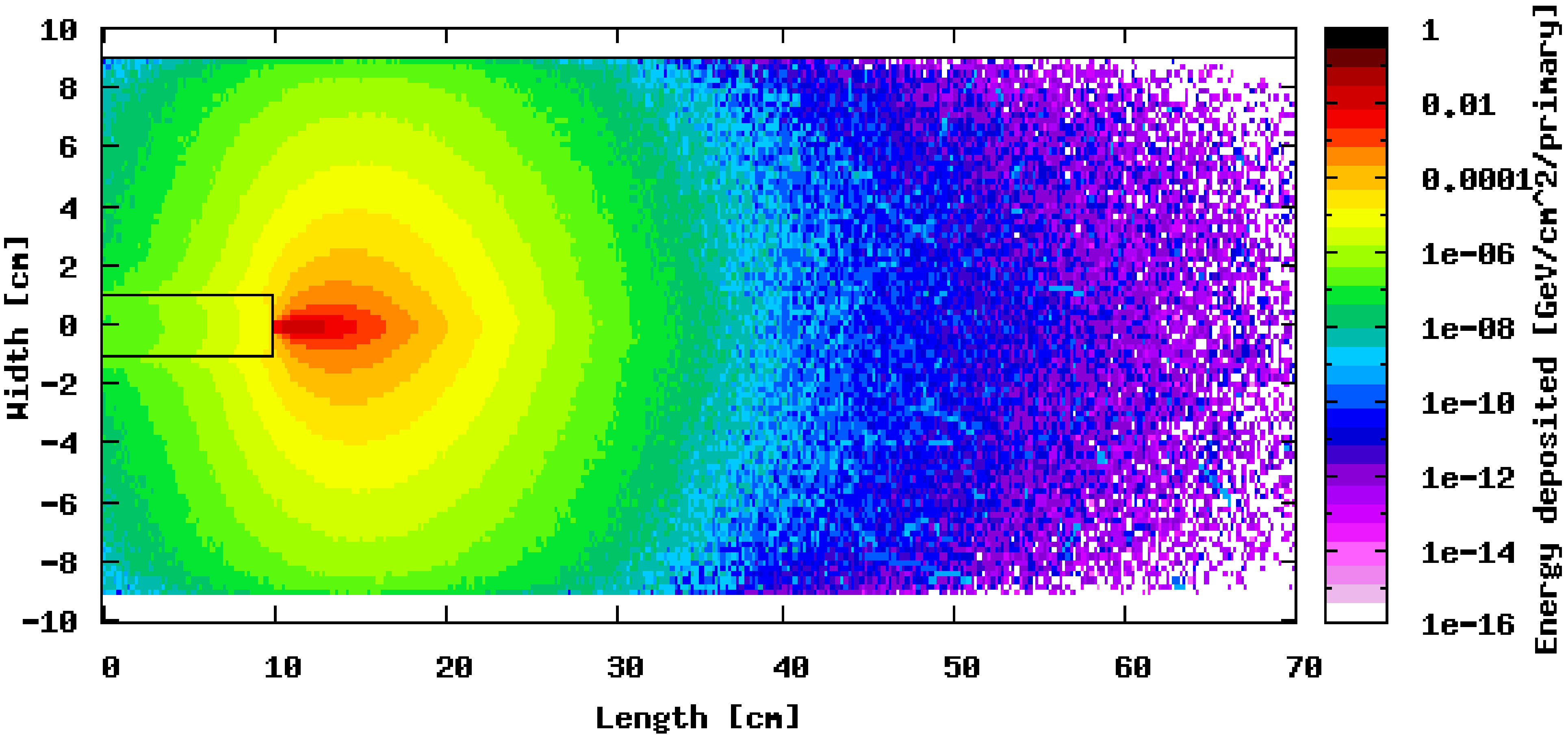
Energy deposition in a cylindrical lead target of 70 cm long and 9 cm in radius target irradiated by 1 GeV electrons



Energy deposition in a cylindrical lead target of 70 cm long and 9 cm in radius target irradiated by 600 MeV protons



Energy deposition in a cylindrical lead target of 70 cm long and 9 cm in radius target irradiated by 600 MeV electrons



Summary and conclusion

The shape of neutrons energy spectra created by both 1GeV protons and electrons are acceptably comparable below ~1 MeV .

Above ~1 MeV 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.

The main/detailed results are summarized as follows:

1. The energy spectra of neutrons produced both by electrons and protons have similar shape in the range of lower energies (i.e. $\lesssim$10 MeV) and significantly differ at higher electrons energies (i.e. $\gtrsim$10 MeV).
2. The yield of neutrons generated by electrons is about two orders of magnitude lower as compared to their production by protons.
3. The radioactivity of the target in the case of protons beams is greater than after its electrons irradiation by about three orders of magnitude during all the irradiation time up to one year.
4. For 1 GeV protons the ***optimal area of a lead target*** for neutrons production is a cylinder of about 65 cm in depth and about 8 cm in radius.
5. The highest temperature is generated along the first 10 cm of the beam of 1 GeV protons impinging on a target and the beam energy is practically dissipated within the target cylindrical area of 60 cm in depth and 8 cm in radius both of Pb and W targets whilst in the case of irradiation with 1 GeV electrons the energy dissipation regime is achieved at much shorter depths (less than 30 cm) in these targets.

As a general conclusion one can infer that electrons beams of high enough energy can be used for transmutation and incineration of spent nuclear waste, at least for experimental elaboration of technical parameters of the relevant ADS-type multipurpose device.

Thank you for attention