

Comparing the Shielding Properties of Lead and Tungsten for Shielding of 11 GeV Electrons

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Abstract

In this report detailed studies of the physical consequences and shielding properties of lead and tungsten are performed for the 11 GeV electrons. Effects of the shielding are calculated for the shielding thicknesses of 30 cm. The type, the energy distributions and the rates of some of the secondary particles are computed. The results will help to understand the consequences of the background produced by the shielding.

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I. Introduction

The scope of this report is to estimate the effects of the electron shielding on the surrounding detectors and compare lead to tungsten as a shielding material. Any desired or undesired effects are function of the background rates produced at the shielding. Studying the shielding properties as a separate problem reduces the amount of the simulation needed to optimize the entire experiment. This report could be used as the initial step in the shielding design.

Propagation of particles through the shielding material, their range, the associate production of secondary particles and energy deposition was obtained using a simulation tool called FLUKA [FERRARI 2005, BATTISTONI 2007], a fully integrated particle physics Monte Carlo simulation package with many applications in high energy experimental physics and engineering, shielding, detectors and telescopes design, cosmic ray studies, dosimetry, medical physics and radio-biology. Once the incoming particles are generated and the properties of the material are known, it is straight forward to simulate the shielding capabilities. The physical mechanisms implemented in today's simulation software are very accurate and the differences between the simulated and measured results are in the most cases negligible.

In this report detailed study of the shielding properties are done for 11 GeV electrons. Effects of the shielding are calculated for the shielding thicknesses 30 cm.

II. Results for 30 cm thick shielding

In this section we study the effects of electrons impinging on a 20 cm x 20 cm x 30 cm tungsten and lead blocks. In addition to the total deposited energy in the blocks, the fluences of neutrons, electrons and photons are also calculated in units of number of particles per cm^2 normalized to number of incoming particles per cm^2 . With such a choice of units one only needs to multiply shown fluences with primary particles rates (which can be calculated separately) to get the fluences expected in the experiment. In the simulation the cutoff energy threshold for all the particles was 10^{-5} GeV, except for the neutrons where the cutoff threshold was 10^{-8} GeV.

The total deposited energy is shown in Figure 1 and 2 in units of MeV/cm. The average deposited energy for both tungsten and lead blocks was 10.94 GeV or 99.5 % of the energy of the incoming electron. The fluences integrated over all the secondary particles energies are shown in Figures 3-5 and Figures 6-8.

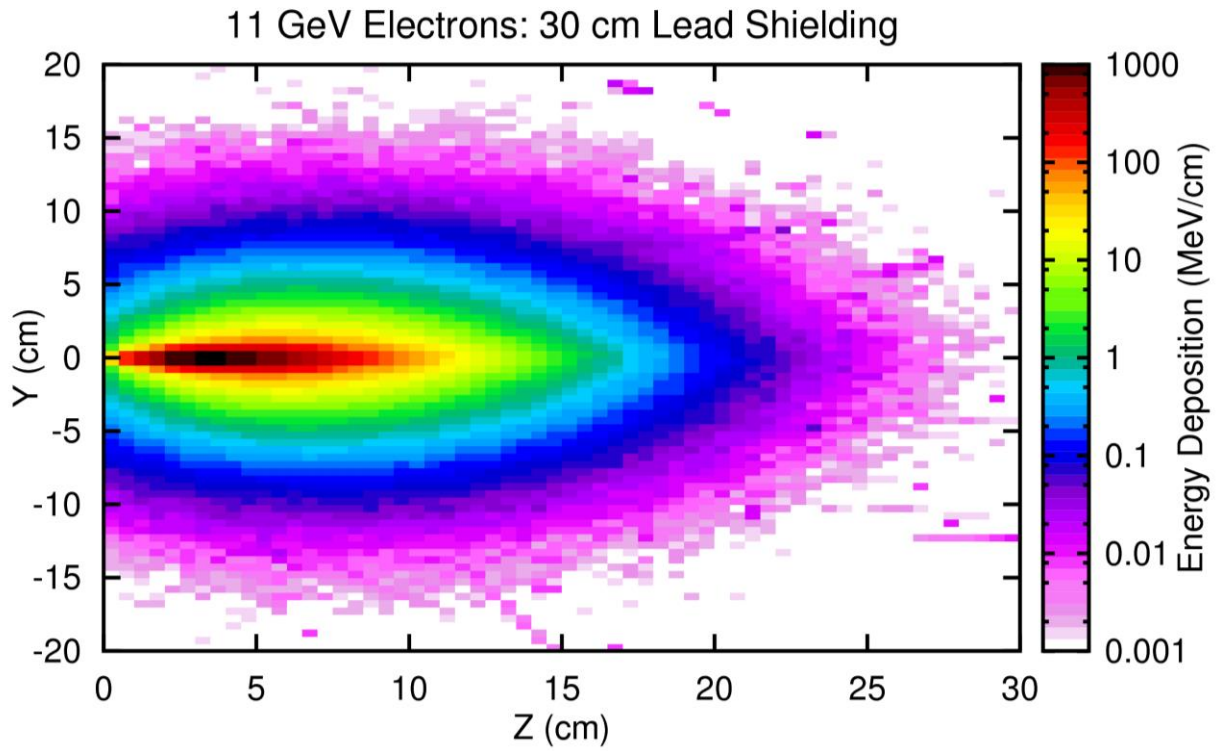
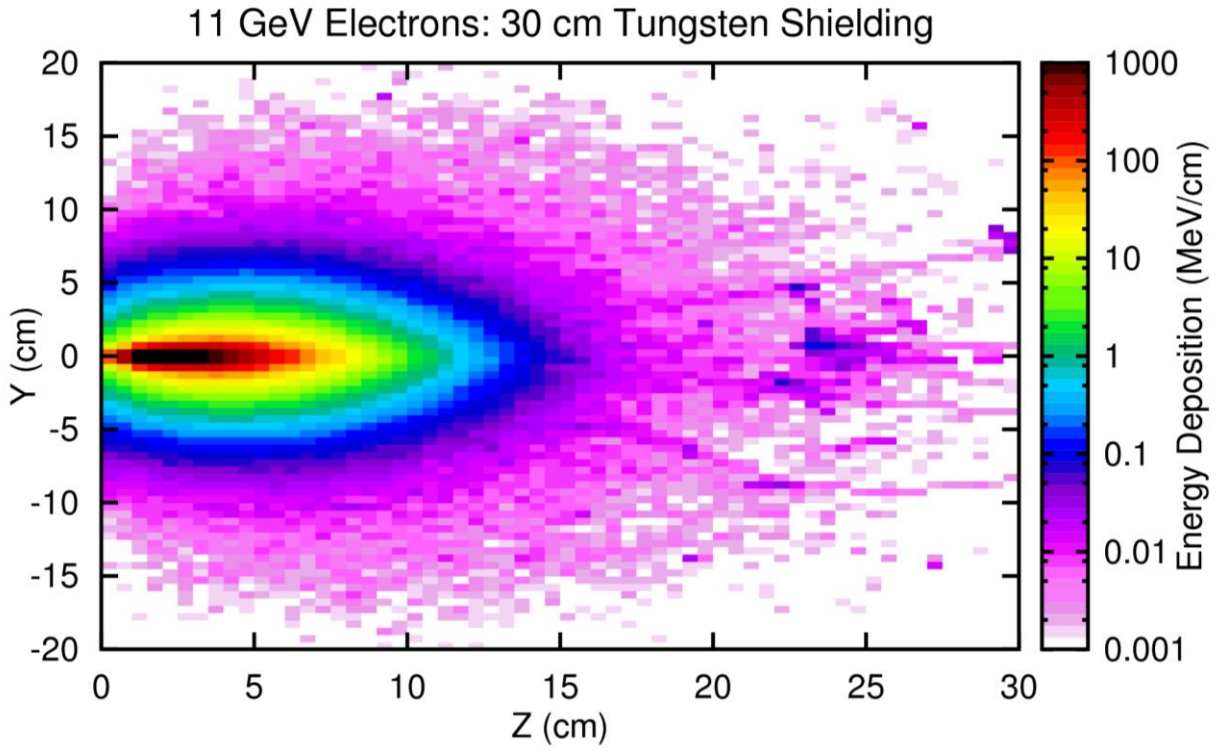


Figure 1. Total deposited energy in the 30 cm thick tungsten and lead blocks per incoming 11 GeV electron.

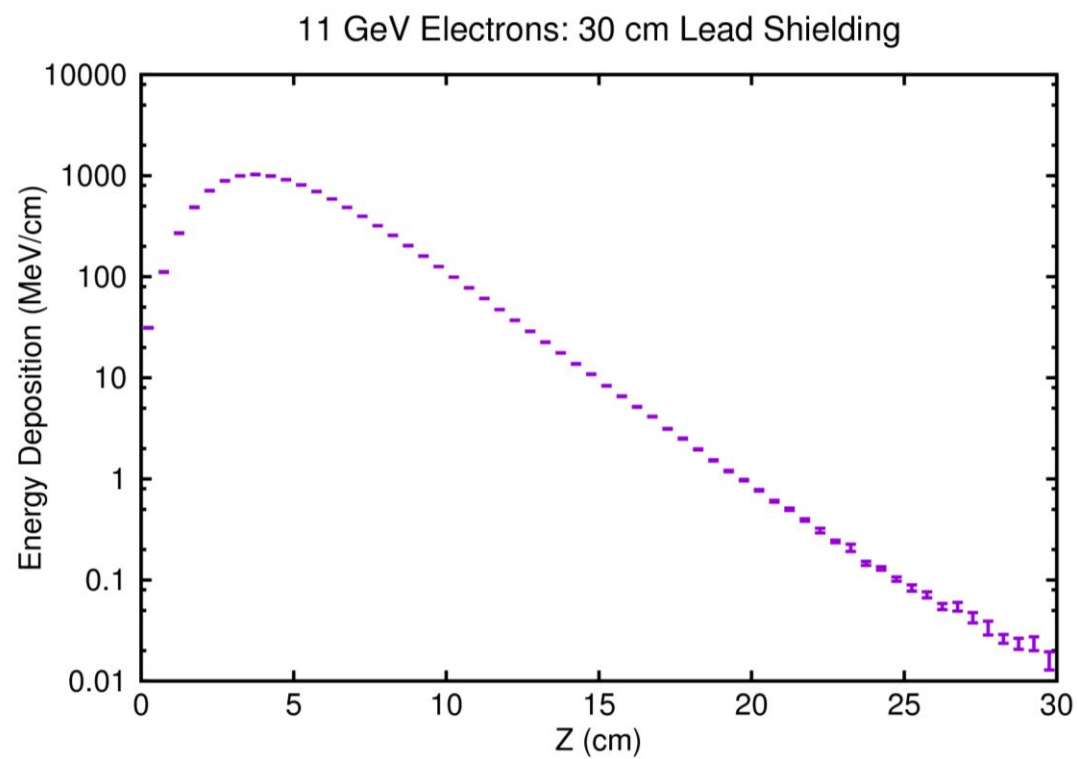
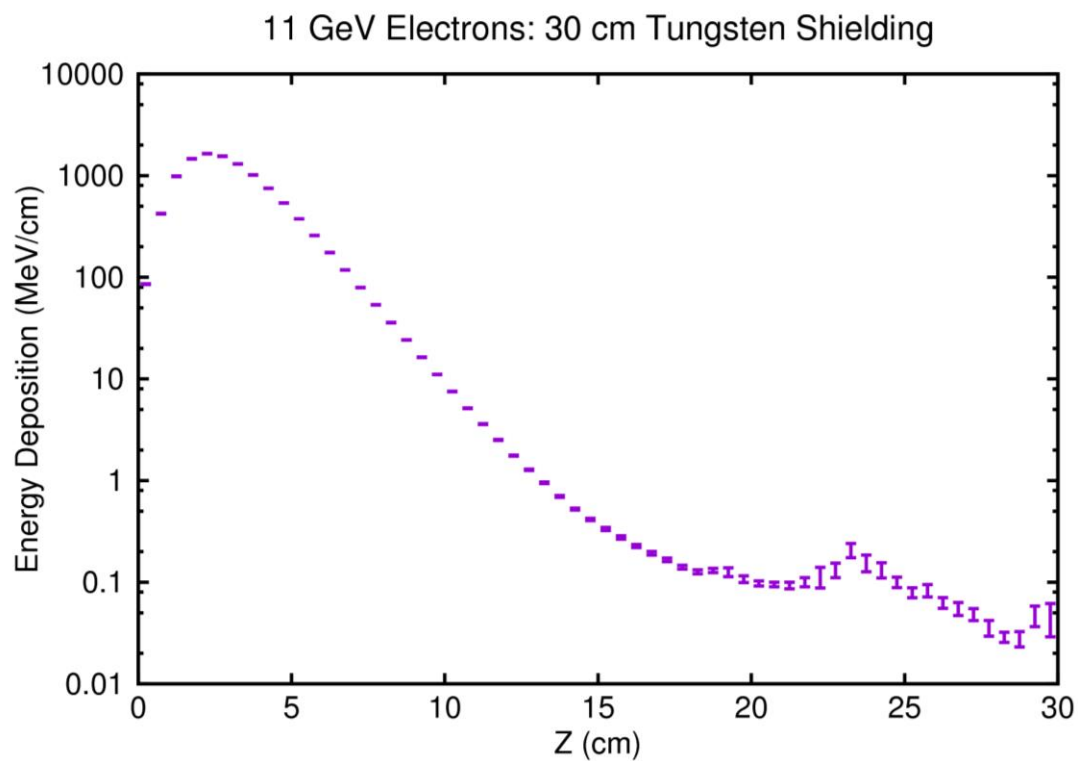


Figure 2. Total deposited energy in the 30 cm thick tungsten and lead blocks per incoming 11 GeV electron.

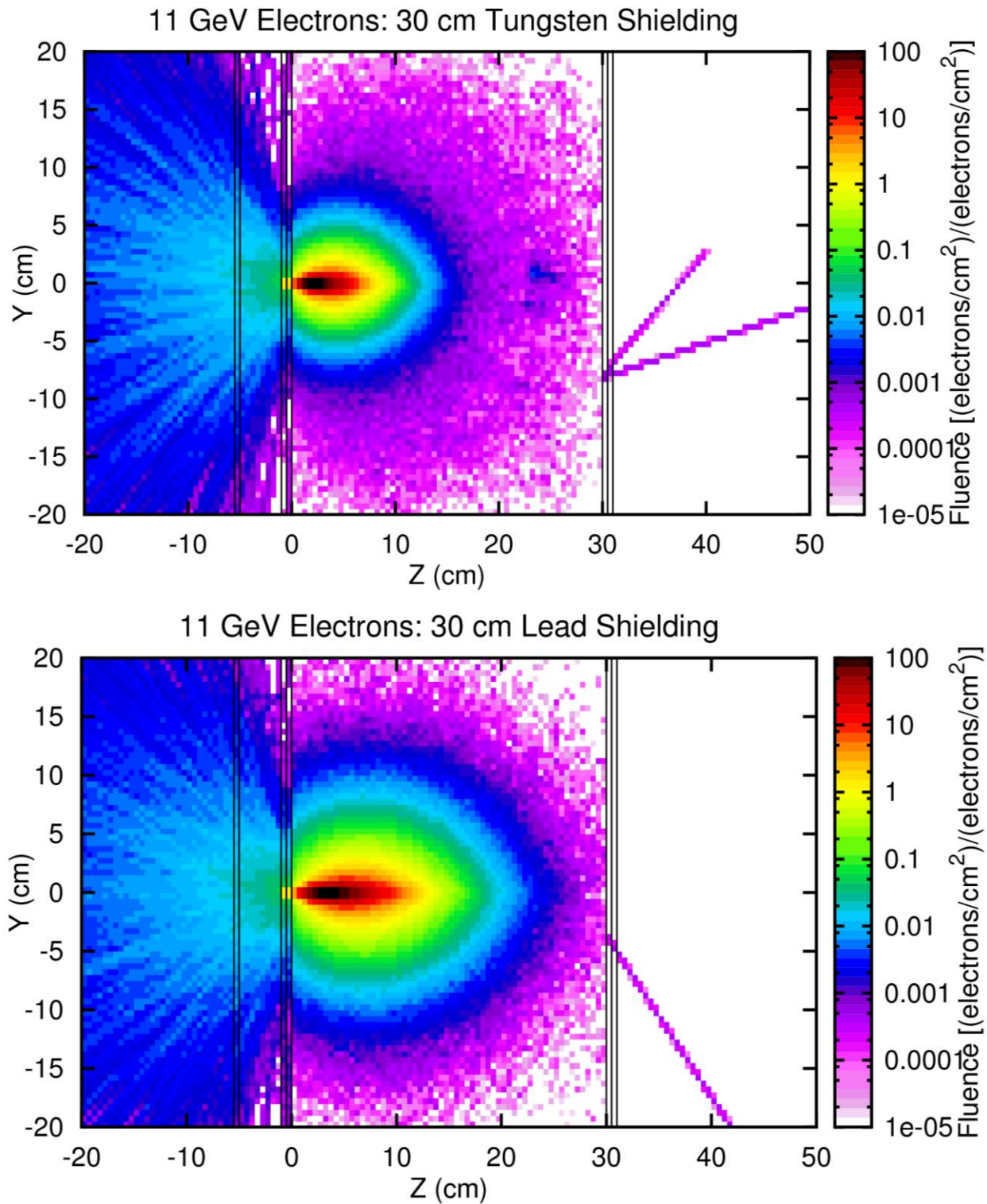


Figure 3. Electron fluence in the case of the 30 cm thick tungsten and lead blocks per incoming 11 GeV electron.

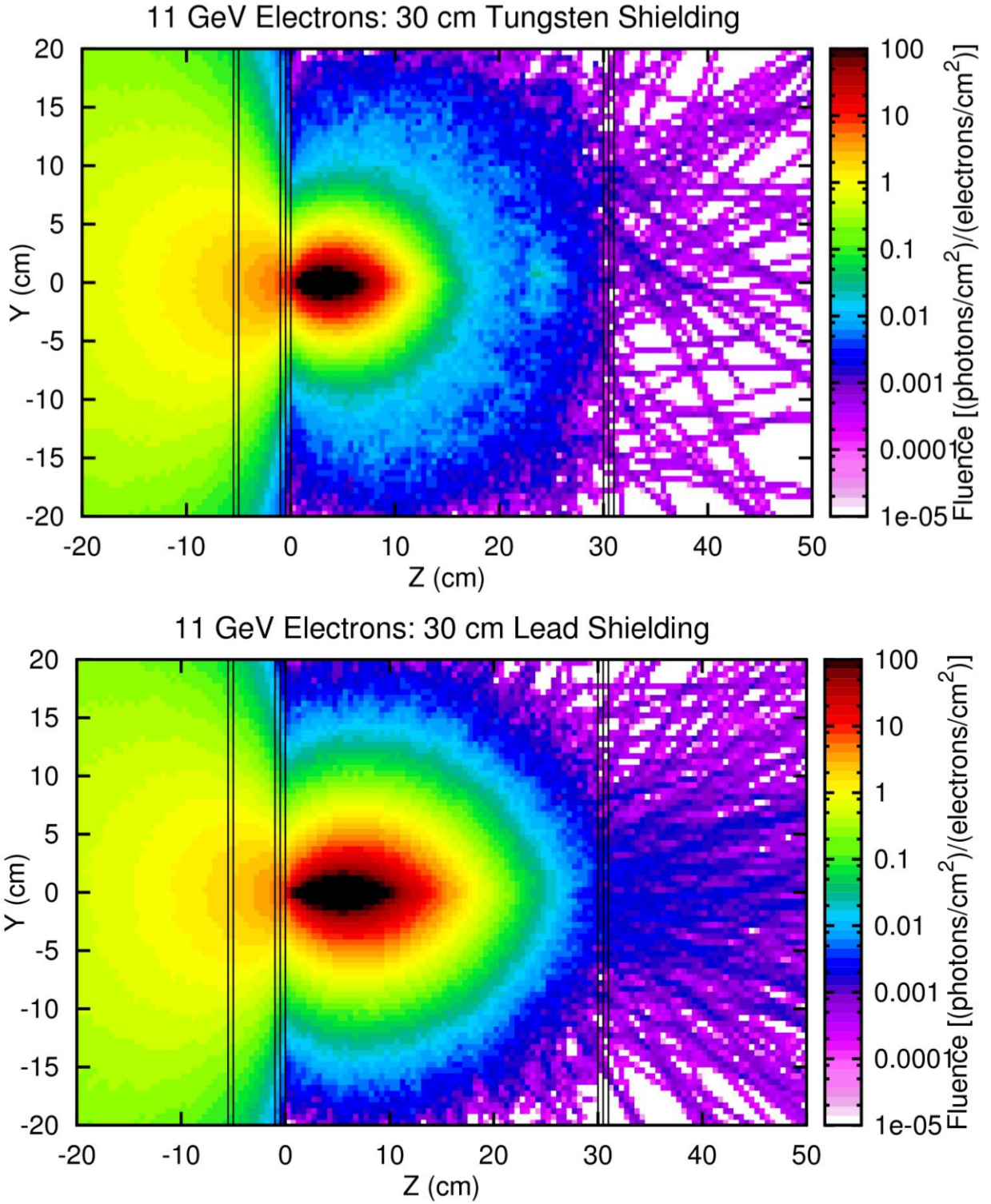


Figure 4. Photon fluence in the case of the 30 cm thick tungsten and lead blocks per incoming 11 GeV electron.

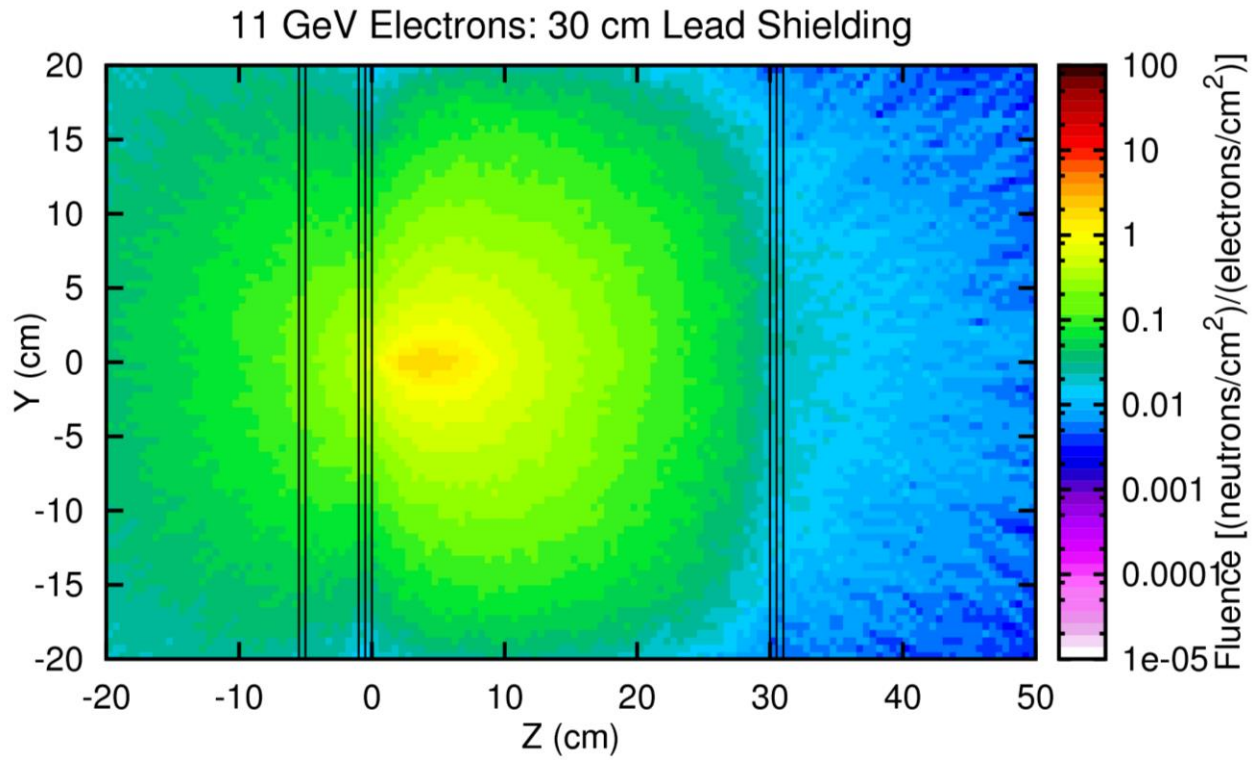
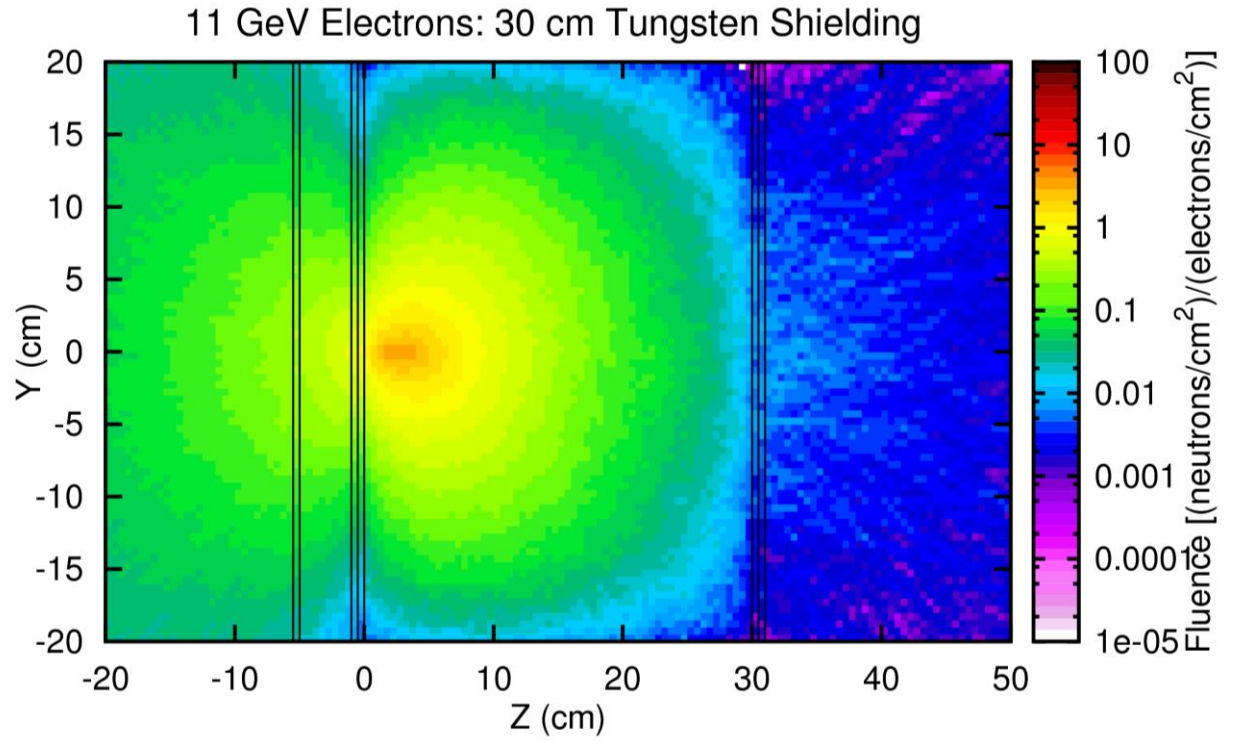


Figure 5. Neutron fluence in the case of the 30 cm thick tungsten and lead blocks per incoming 11 GeV electron.

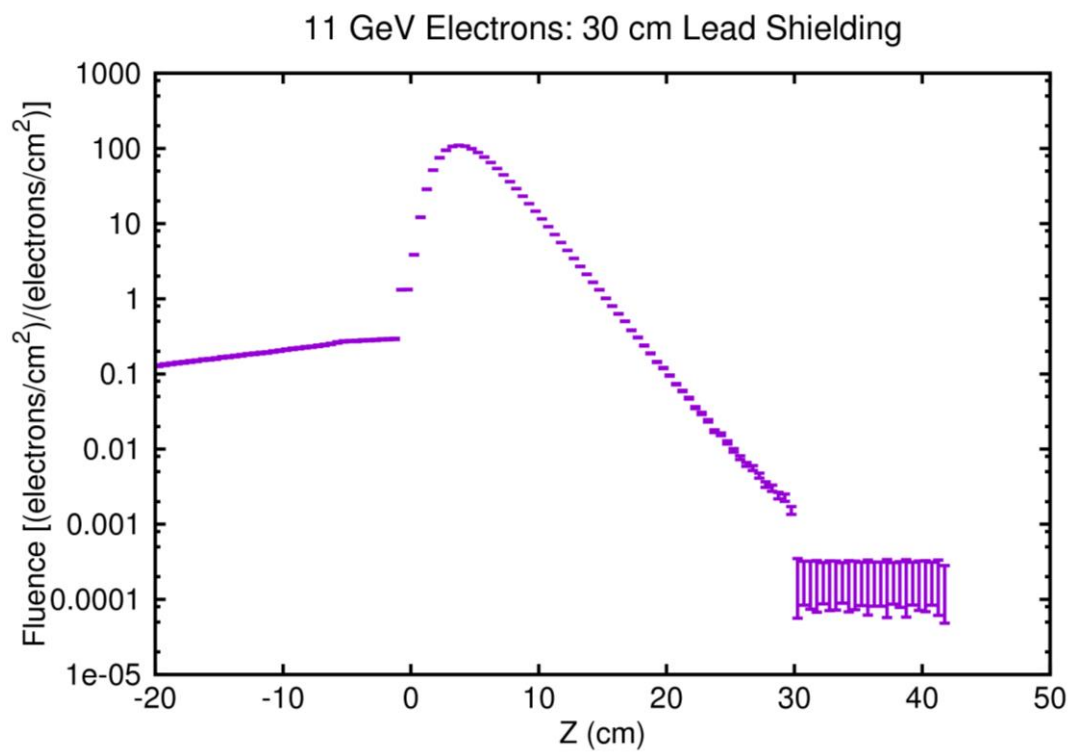
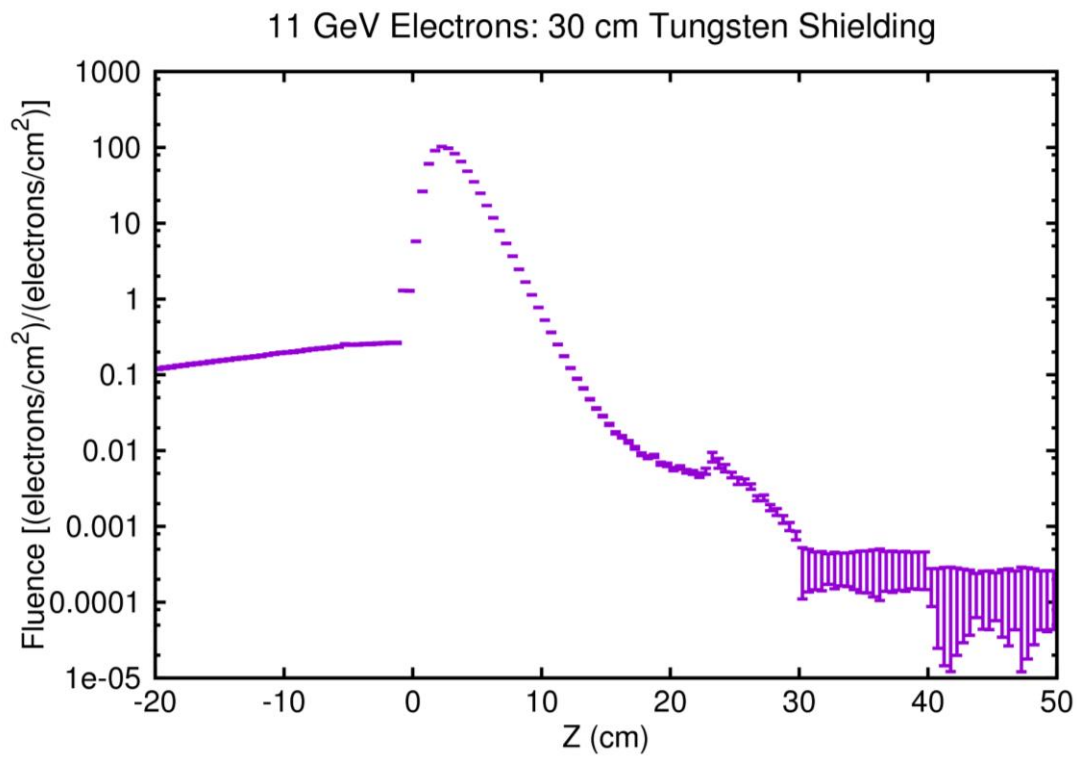


Figure 6. Energy integrated electron fluences as a function of position.

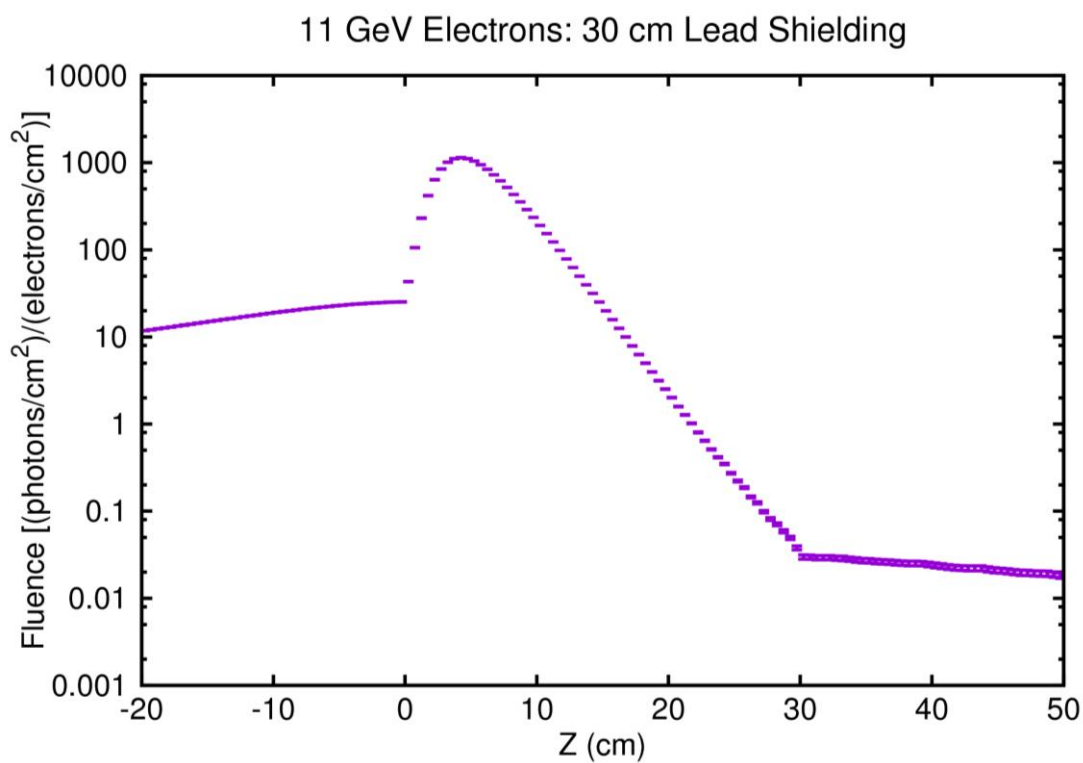
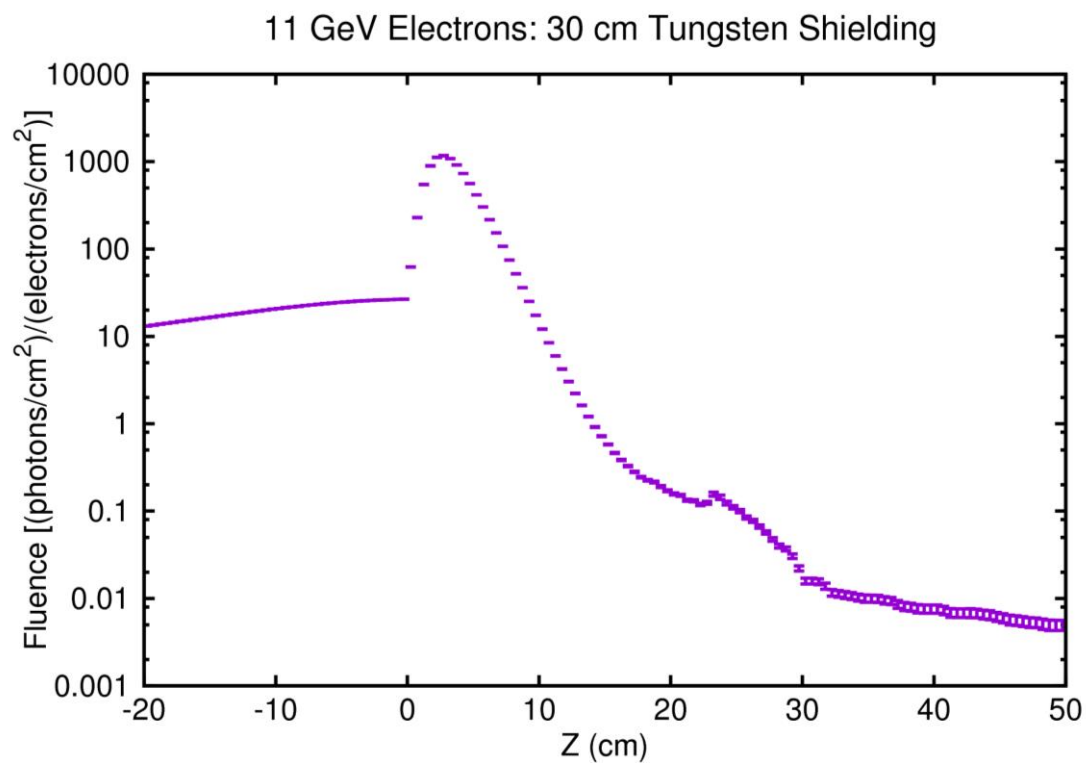


Figure 7. Energy integrated photon fluences as a function of position.

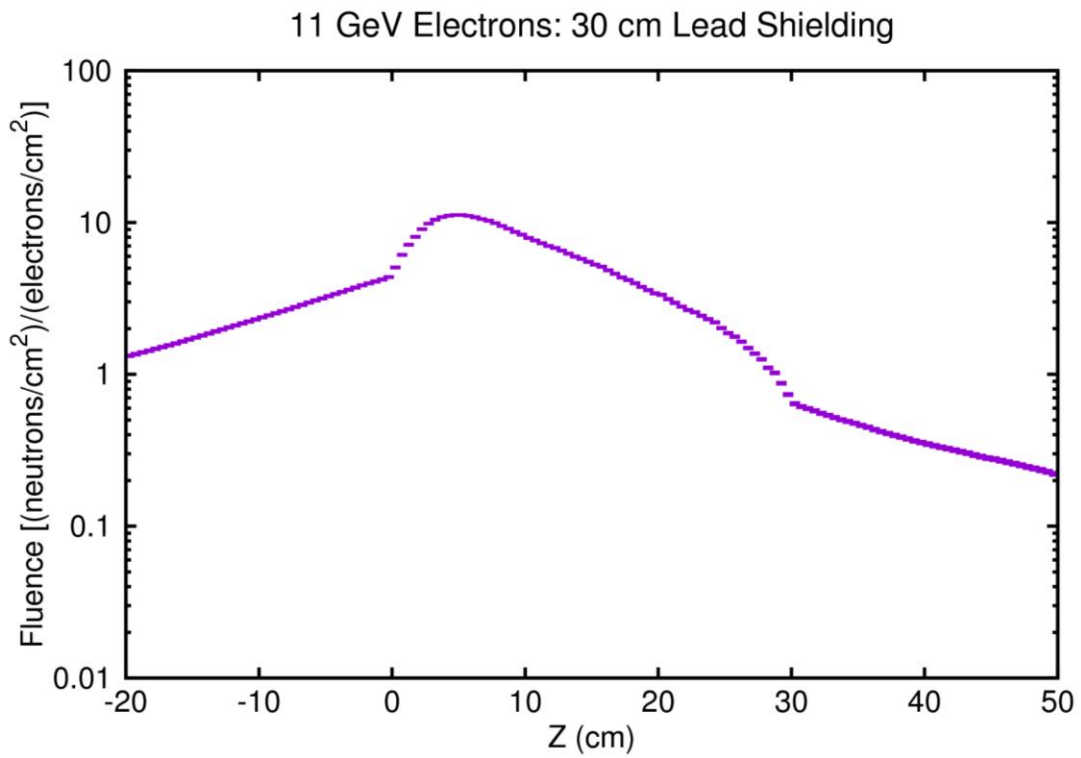
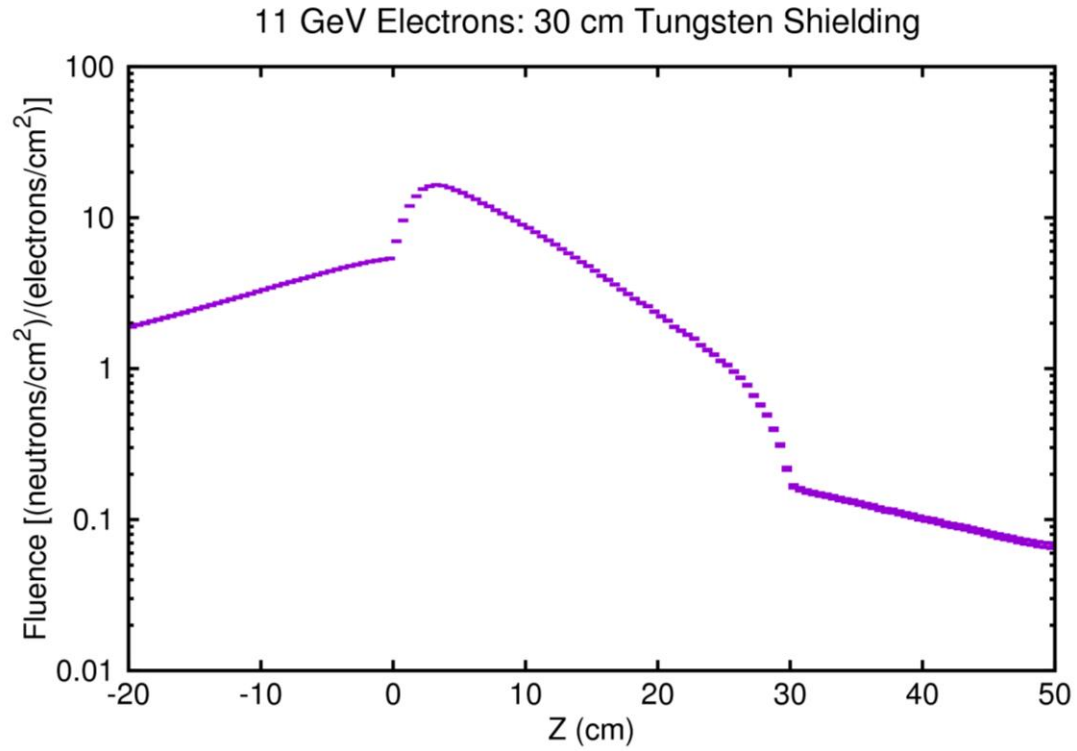


Figure 8. Energy integrated neutron fluences as a function of position.

The fluences shown in Figures 3-8 are integrated over all the secondary particles energies and can be used to calculate the background rates, but, to fully understand the background, it is also important to know the secondary particles energy spectra. In Figures 9-11 the isolethargic spectra are shown for the secondary particles produced by the shielding in forward and backward directions. The reason for using isolethargic spectra is that the dynamic range of the energies of the secondary particles requires a logarithmic energy scale. For such a scale the area under the isolethargic spectrum curve is proportional to the number of particles in a particular energy interval.

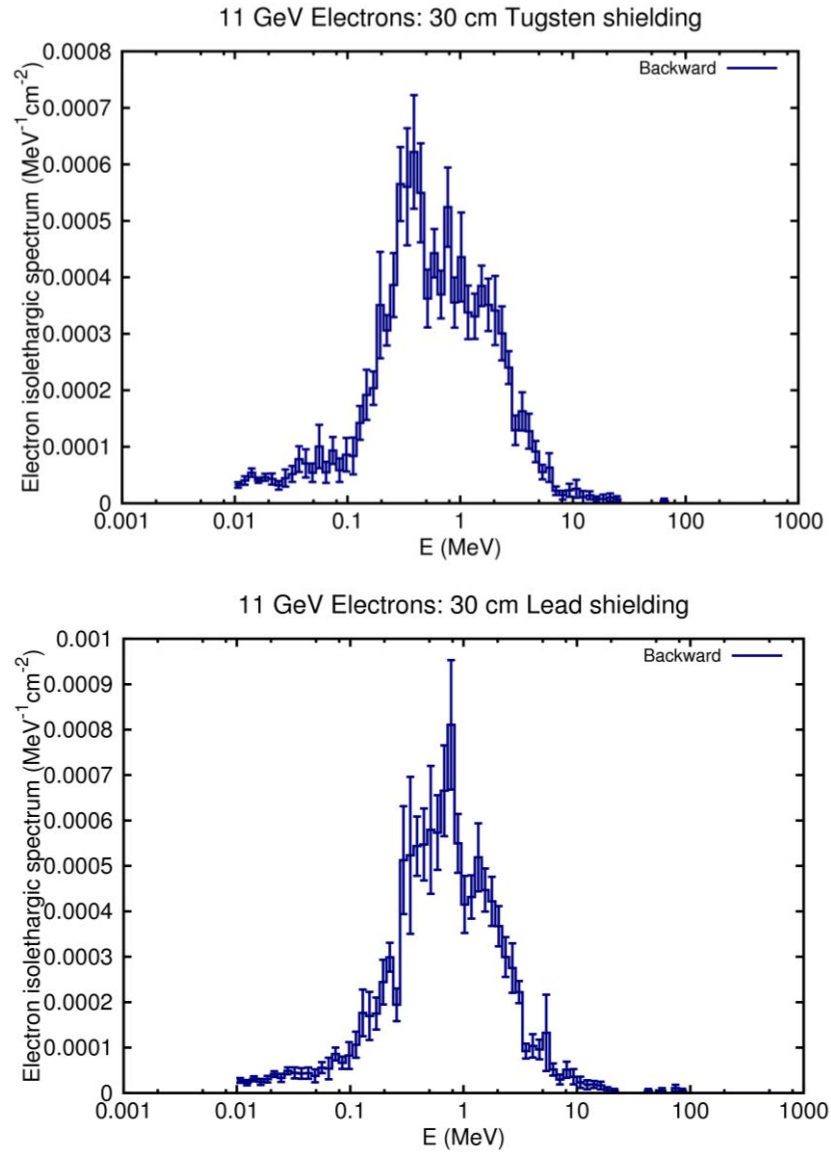


Figure 9. Electron isolethargic spectrum for backward produced electrons in 30 cm thick tungsten and lead shielding.

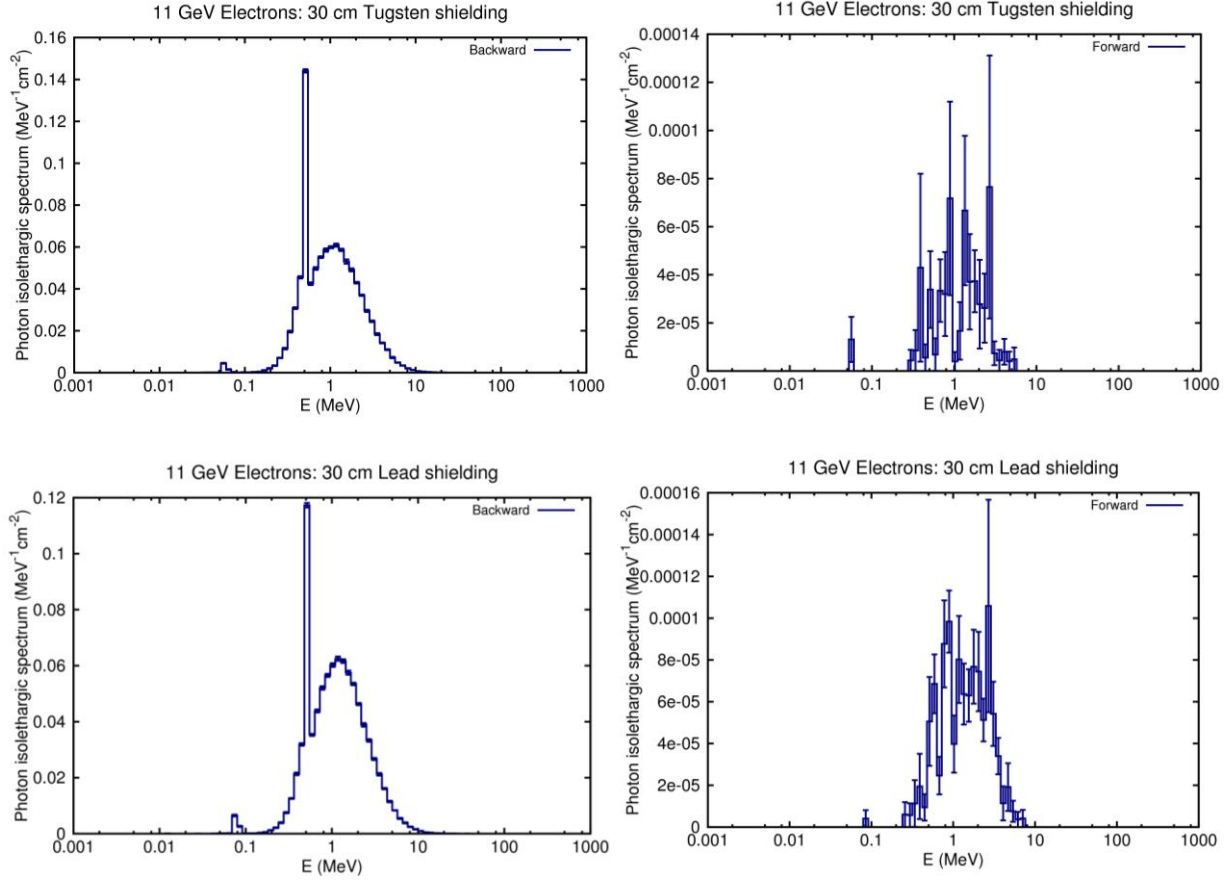


Figure 10. Photon islethargic spectrum for backward and forward produced photons in 30 cm thick tungsten and lead shielding.

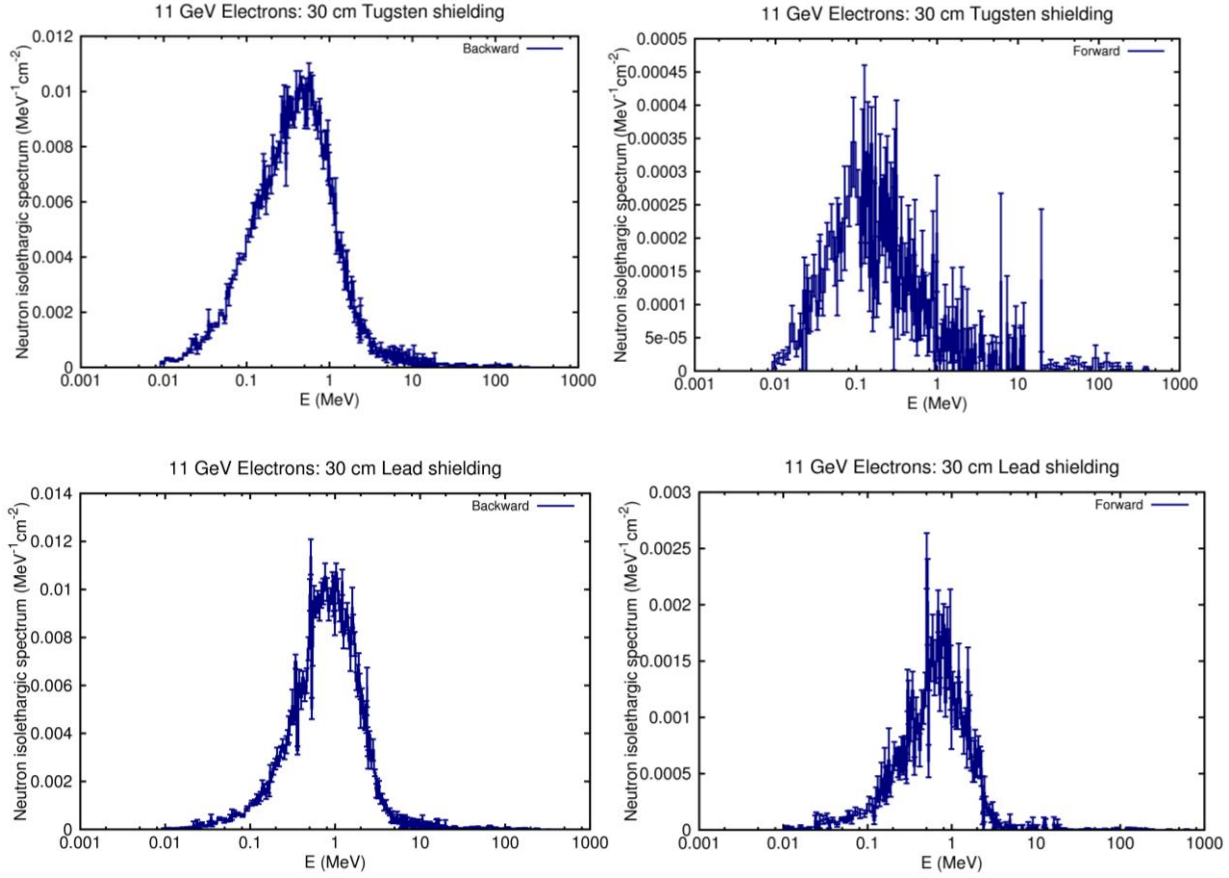


Figure 11. Neutron islethargic spectrum for backward and forward produced neutrons in 30 cm thick tungsten and lead shielding.

III Summary

The following table shows the types and the rates of the secondary particles produced by the 11 GeV electrons in 30 cm thick tungsten and lead shielding in the forward and backward directions. The secondary particles rates are obtained assuming the electrons rate of 1 GHz/cm^2 .

		Electrons (1 GHz/cm^2)			
		Secondary Particles Backward		Secondary Particles Forward	
Shielding:		30 cm Tungsten	30 cm Lead	30 cm Tungsten	30 cm Lead
n	Rate (GHz/cm^2)	5.3	4.1	0.16	0.62
e ⁻	Rate (GHz/cm^2)	0.26	0.3	$2.4 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$
γ	Rate (GHz/cm^2)	26.7	25.8	$1.6 \cdot 10^{-2}$	$2.9 \cdot 10^{-2}$

Table 1. Rates for electron produced secondary particles for tungsten and lead shielding normalized to 1 GHz incoming electrons.

IV Conclusion

In this report detailed studies of the shielding properties of 30 cm thick tungsten and lead shield are performed for the electron energy of 11 GeV. The type, the energy distributions and the rates of some of the secondary particles are computed. The most significant difference between two shielding materials is the reduction of the neutron production in forward direction by a factor of 4. From Figures 1-8 it is also possible to estimate the effects of the reduction of shielding thickness on the rates of the produced secondary particles. In addition to help optimize the thickness of the shielding, the results will help to understand the consequences of the background produced by the shielding and, therefore, help in the design of the detectors.

References

[BATTISTONI 2007] G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fasso', J. Ranft, "The FLUKA code: Description and benchmarking", Proceedings of the Hadronic Shower Simulation Workshop 2006, Fermilab 6--8 September 2006, M. Albrow, R. Raja eds., AIP Conference Proceeding 896, 31-49, (2007)

[FERRARI 2005] A. Ferrari, P.R. Sala, A. Fasso', and J. Ranft, "FLUKA: a multi-particle transport code" CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773