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EFFICIENCY OF A TUNGSTEN DUMP FOR THE SPARC BEAM

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Abstract

In order to fully characterize and set the electron beam for the FEL SPARC experiment, many tests and machine setup tests are needed. To avoid irradiation of the wiggler (UNDULATOR) by the 150 MeV electron beam, a protecting tungsten target is provided. Here the target shielding effect is evaluated through Montecarlo computation by the FLUKA code.

Work performed in the frame of the the FLUKA collaboration and SPARC activity

1 INTRODUCTION

SPARC commissioning is well underway.

150 MeV, 1.1 nC electron beam carries about 1.65 W power (at 10 Hz repetition rate) and this power, if continuously released on the permanent magnet of the wiggler poles, can endanger their magnetization. In order to avoid wiggler damagement, during the settings of the accelerator, a beam dump should be provided. Because of dimensional constraints the only thickness available for the target can be 17 or 25 mm, 45° tilted. Tungsten will be used because of its high efficiency in stopping electromagnetic showers (radiation length of 3.5 mm). In Fig. 1 a view of the wiggler entrance is shown.

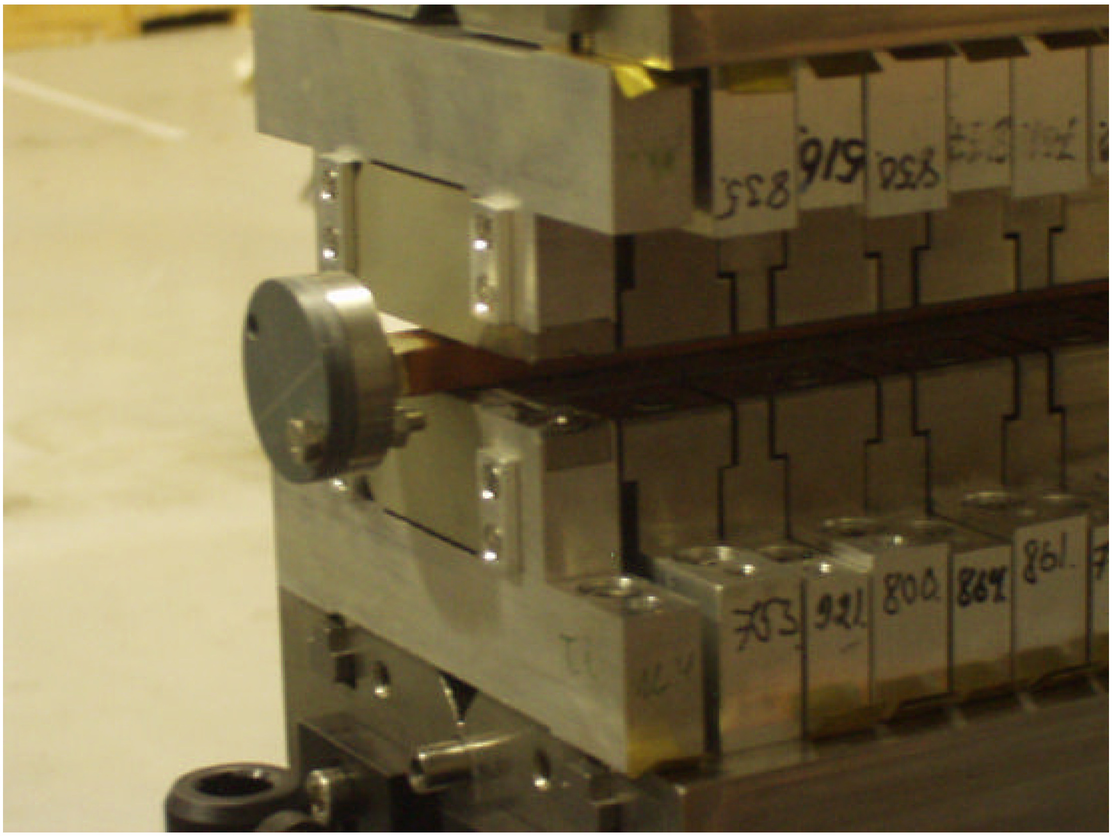

Fig. 1. Entrance of the SPARC wiggler.

A computation of the efficiency of the W dumps has been performed with the FLUKA code (Ref. 1,2).

2 150 MeV ELECTRON BEAM ON TUNGSTEN

As a first run, while waiting for the actual dimension of the tungsten screen a preliminary computation of the energy deposition of a 150 MeV electron beam into 10 and 5 cm tungsten has been done. In Fig. 2 results as from 10 independent, 1000 particles each, FLUKA run are shown.

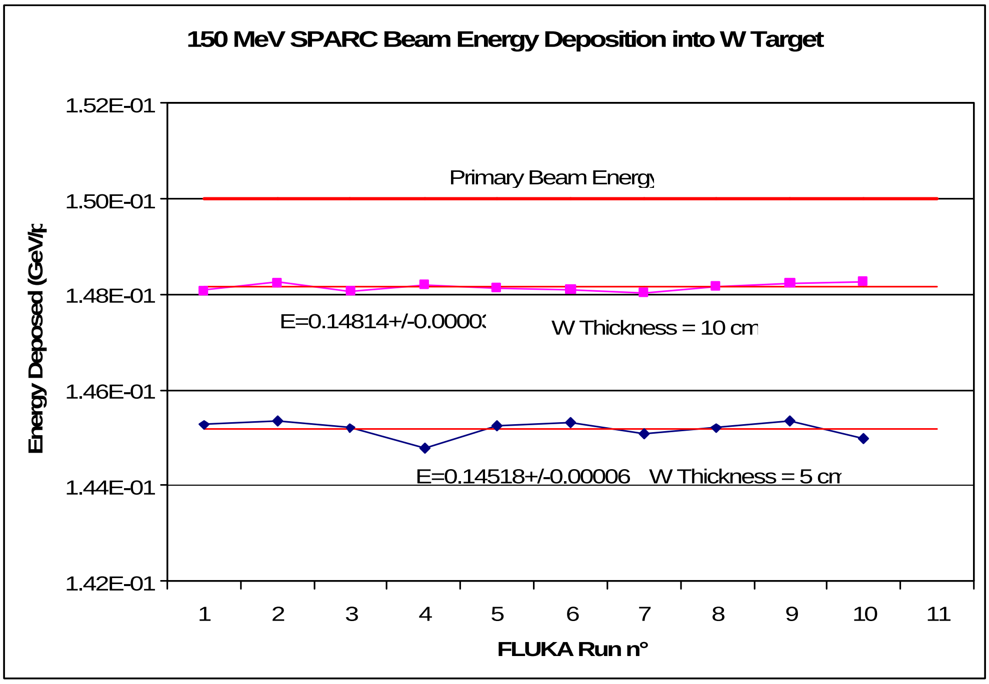

Fig. 2. Absorption of the SPARC beam in W , 10 FLUKA runs.

In the case of 10 cm thickness the absorbed energy is 148.14 MeV/(primary particle) while for 5 cm it is 145.18 MeV/(primary particle) with an absorption efficiency of about 99% e 97 % respectively.

In Fig. 3 the absorption profile i.e. the energy density deposition versus the target depth is shown. The effective length of the actual W target, 45° tilted, is shown too.

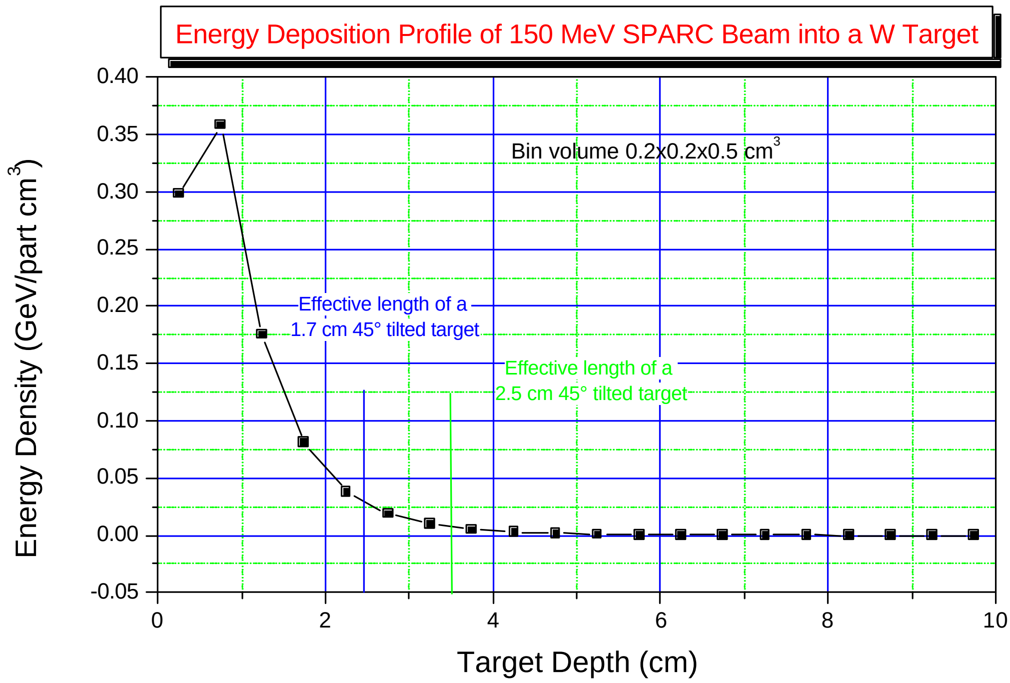

Fig. 3. Energy deposition vs. target depth.

3 FLUKA MODEL

A 150 MeV electron beam with 0.03% energy spread and 0.017 mm·mrad emittance, with a spot radius of 0.2 mm start to propagate from the origin (here are the FLUKA cards defining the beam)

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BEAM        -0.15    0.0003    -0.017      0.02       0.0
1.0ELECTRON
BEAMPOS       0.0       0.0       0.0.
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At z=30 cm there is the W target (a square parallelepiped of 10x10x25 cm^3, or 10x10x17 cm^3) 45° tilted respect to the XY plane; downstream a 1 cm thick screen, collecting the energy passing through the target is located at 39 cm.

The collecting screen has been set at first of lead, then, in order to avoid backscattering, a material with infinite absorption coefficient has been used (Black Hole, in FLUKA terminology).

A more refined model has been then implemented by defining a rough wiggler entry geometry instead of just a screen, in order to evaluate the amount of energy that effectively hits the magnet and the one that is transmitted downstream in the beam pipe along the wiggler. The vacuum beam pipe is neglected. The bin volume is 0.50x0.50x0.45 cm^3.

4 RESULTS

Here the results from the FLUKA computations are reported. The first paragraph refers to the integral values, i.e. the total energy deposition in the different regions (target and wiggler model), while in the next paragraph the peak value of the energy density deposition are reported.

4.1 Integral values

The total energy deposed in the target and in the screen is summarized in Table 1, for screen material lead, blackhole and for the rough wiggler geometry.

Table 1. Energy deposition in the W target and in the dump after the tungsten.
The two numbers of the wiggler case refer to the upper (u) and lower (l) pole.

	W Target thickness = 25 mm		**W Target thickness = 17 mm**	
Screen material	Energy in the W target (MeV/part)	Energy in the screen/wiggler (MeV/part)	Energy in the W target (MeV/part)	Energy in the screen/wiggler (MeV/part)
Black Hole	134.50±0.11	12.28±0.11	-	-
Lead	134.63±0.11	6.02±0.05	119.03±0.19	141.9±0.15
“Wiggler” (AISI)	134.56±0.11	6.03±0.08 (u) 2.72±0.04 (l)	119.13±0.18	13.14±0.18 (u) 7.413±0.14 (l)

For the case with a wiggler model the peak energy deposition (Fig. 4 and 5) and electron, positron photon and neutron fluence (Fig.6-13) plots are shown. The fluence is the trajectory length in the considered bin volume (so it is measured in cm^{-2}).

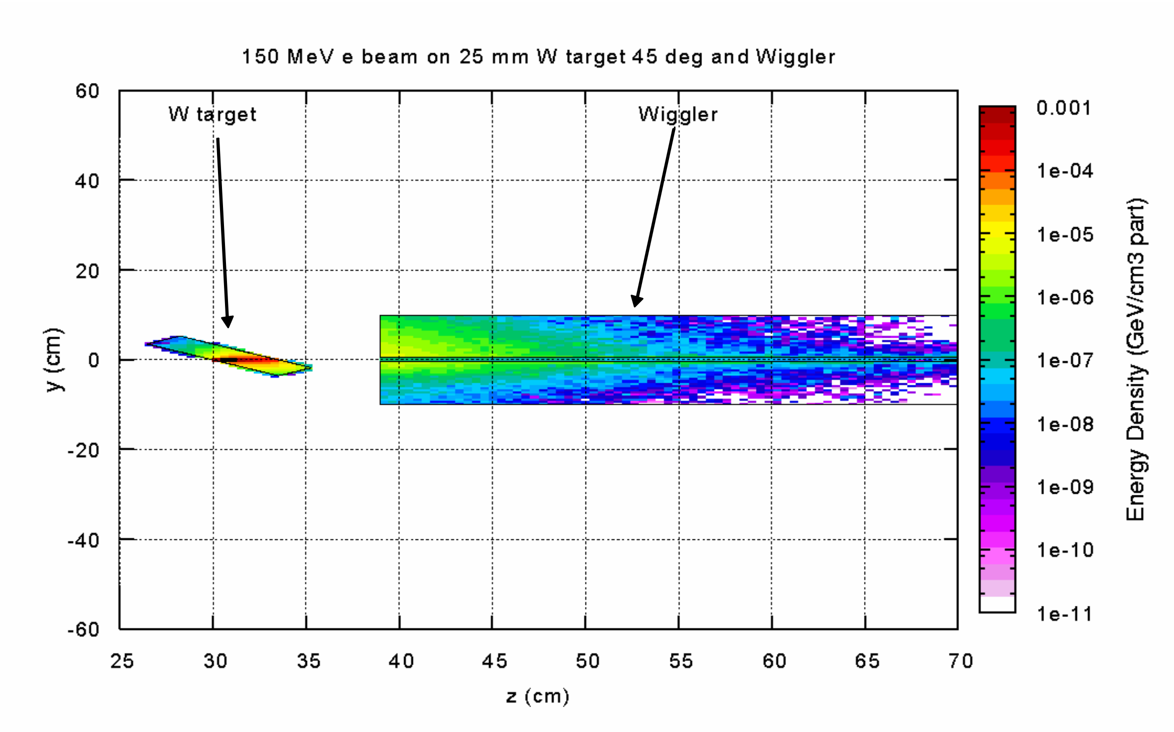

Fig. 4. Energy density deposition in the 25 mm W target and in the wiggler.

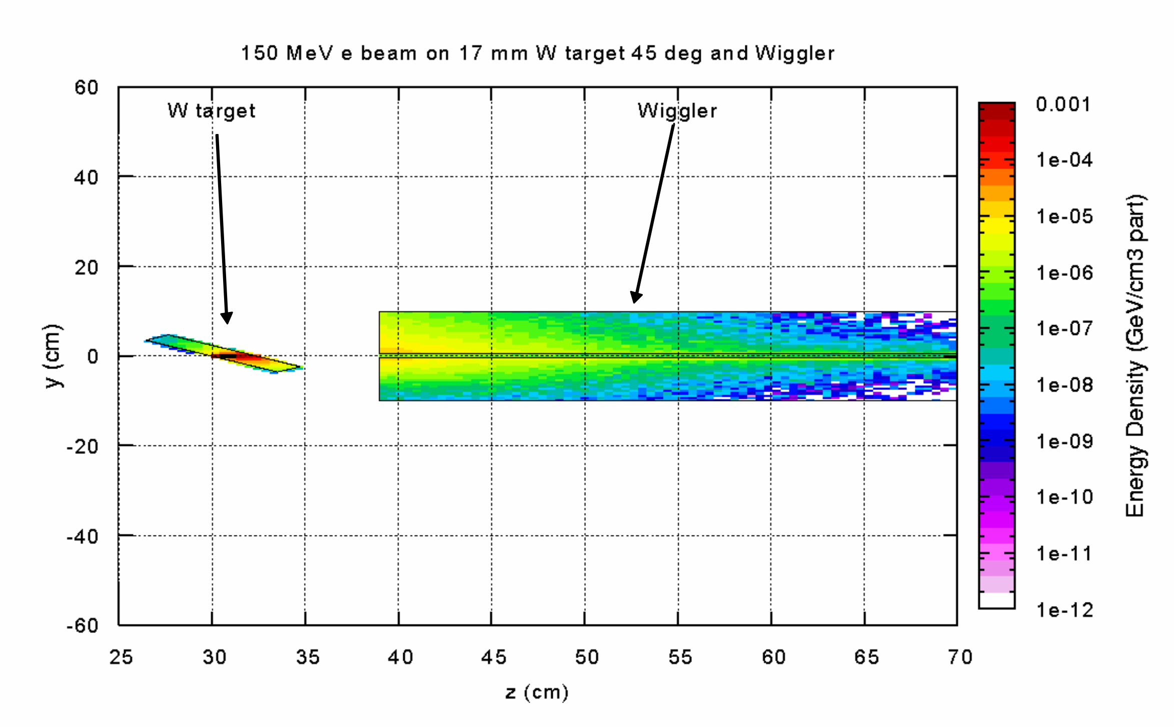

Fig. 5. Energy density deposition in the 17 mm W target and in the wiggler.

In Fig. 6 and 7 the fluence (the trajectory length in the bin/bin volume) of the electron for tungsten target of 25 and 17 mm respectively is shown.

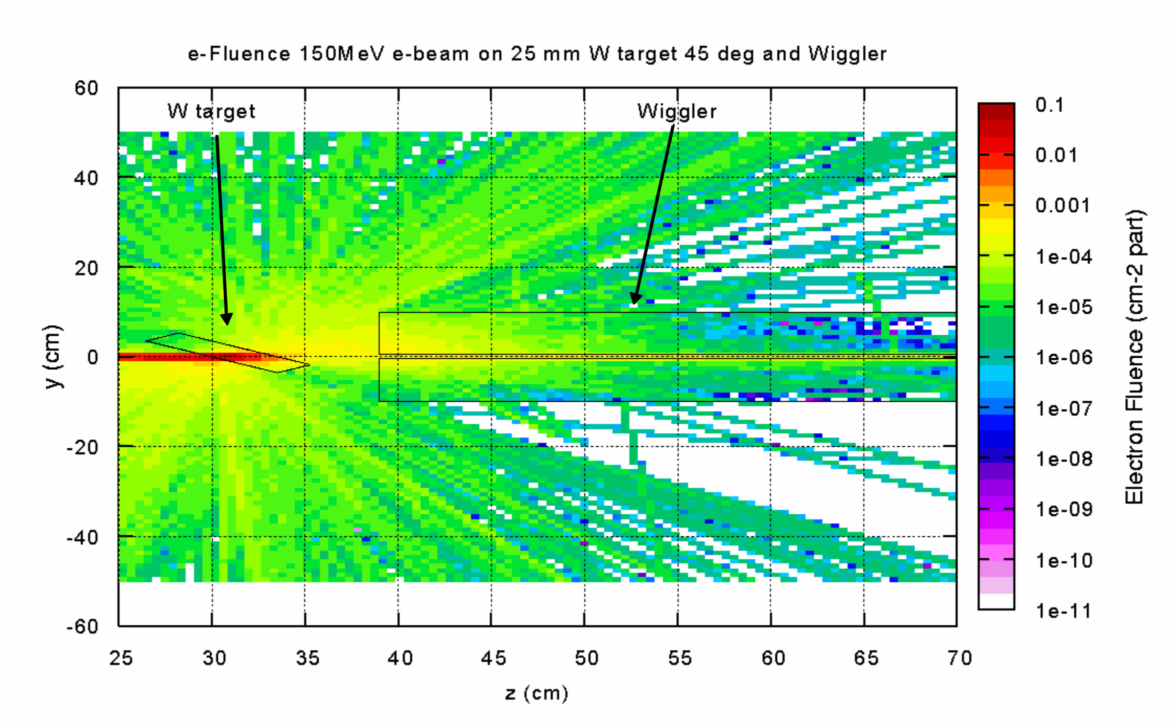

Fig. 6. Electron fluence in the case of 25 mm W target.

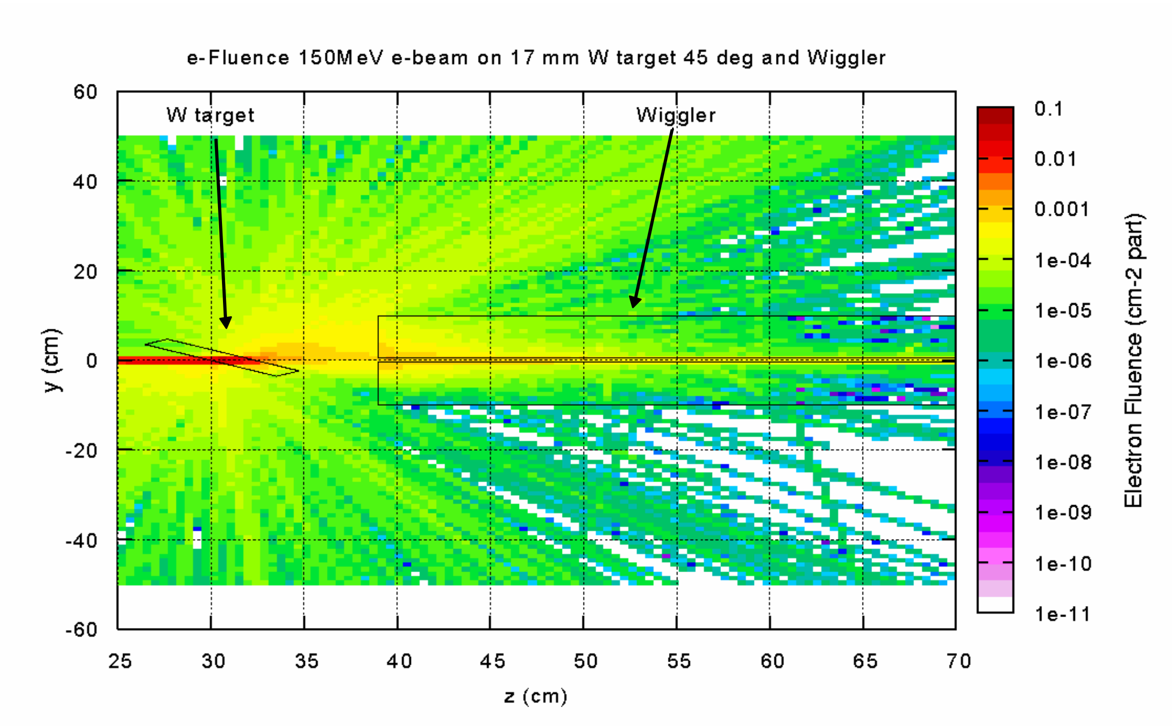

Fig. 7. Electron fluence in the case of 17 mm W target.

In Fig. 8 and 9 the fluence of the photons for tungsten target of 25 and 17 mm respectively is shown.

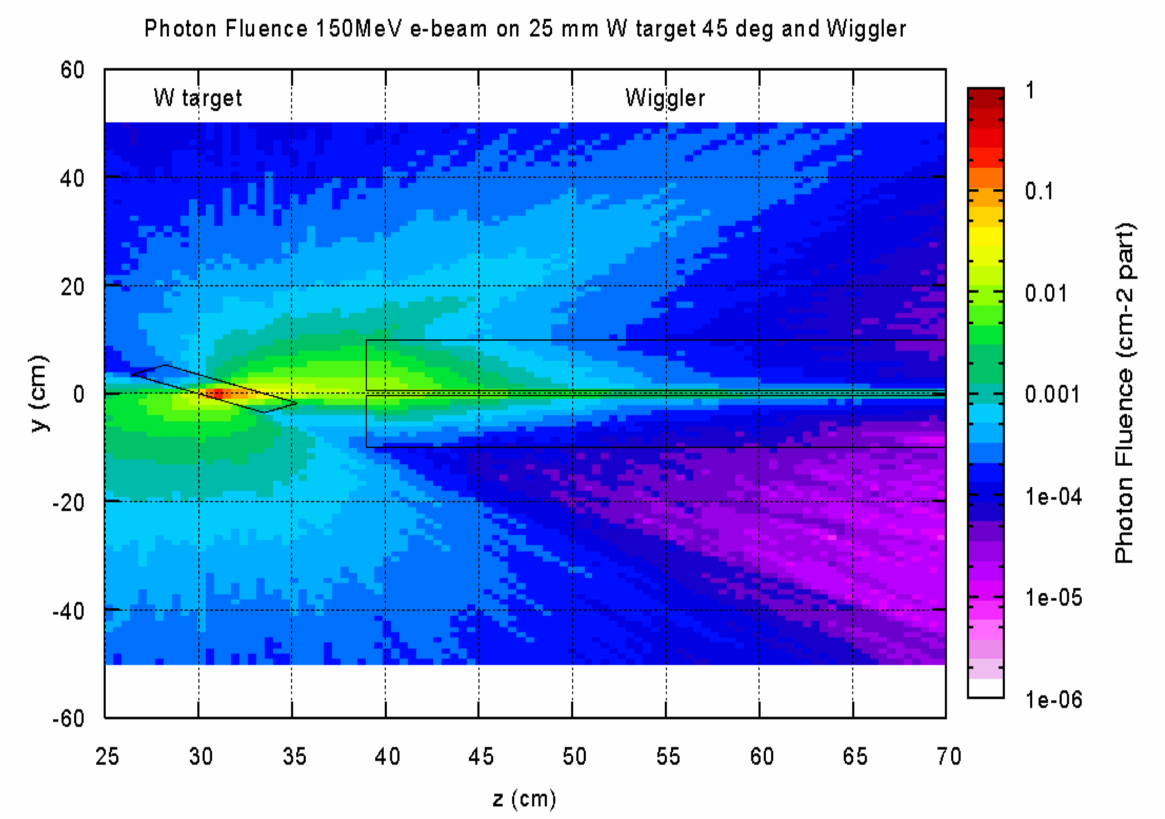

Fig. 8. Photon fluence in the case 25 mm W target.

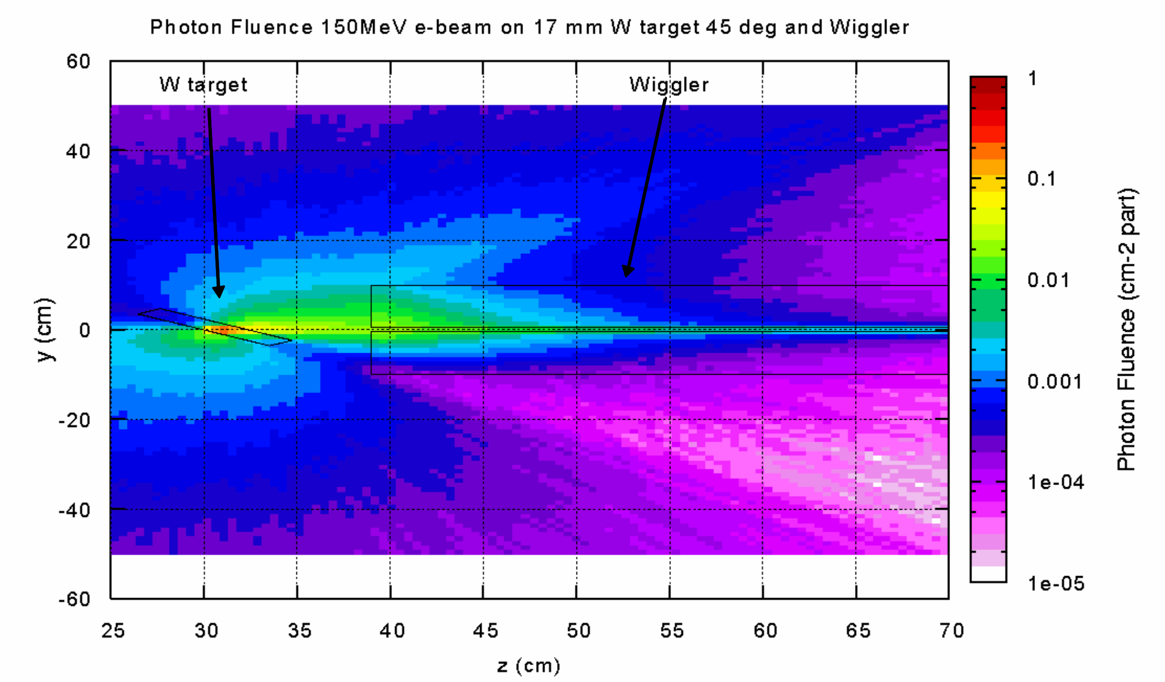

Fig. 9. Photon fluence in the case 17 mm W target.

In Fig. 10 and 11 the fluence of the neutrons for tungsten target of 25 and 17 mm respectively is shown.

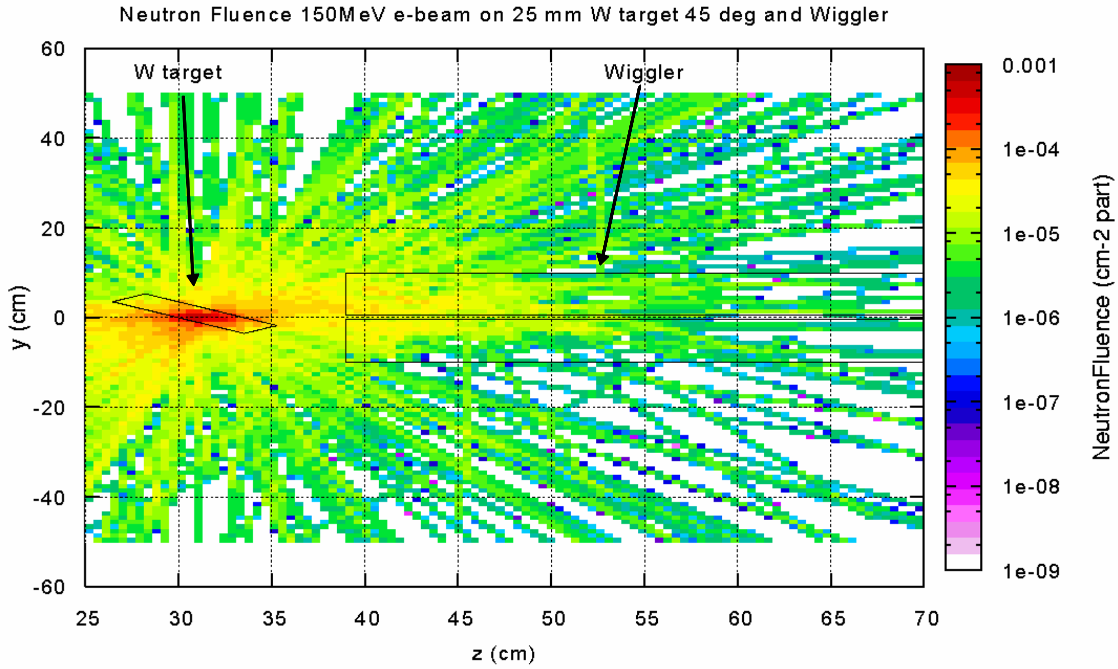

Fig. 10. Neutron fluence in the case 25 mm W target.

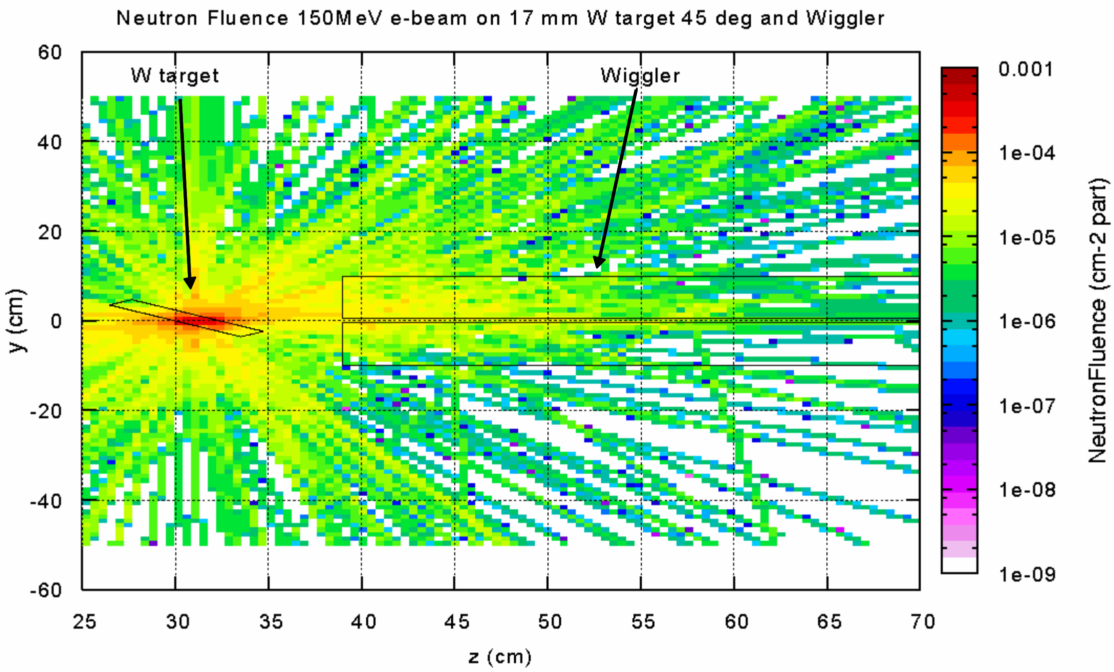

Fig. 11. Neutron fluence in the case 17 mm W target.

4.1 Peak values

The peak energy density depostion occurs, of course, in the tungsten target. We are interested in the energy deposed into the wiggler poles, in order to avoid any deterioration of the magnetic characteristics of the wiggler magnet.

The maximum peak energy deposition occurs in the upper pole of the wiggler, as can be seen from Figs. 4 and 5; their values are :

$E_{pole\text{-}wigg} = 0.104 \pm 0.032$ MeV/cm^3 part for 25 mm W target
$E_{pole\text{-}wigg} = 0.239 \pm 0.032$ MeV/cm^3 part for 17 mm W target

With a bin dimension of 0.5 x 0.5 x 0.45 cm^3

By assuming an adiabatic heat absorption with the SPARC parameters (1.1 nC with 10 Hz maximum beam repetition rate) the maximum local temperature increase is negligible.

5 CONCLUSIONS

The efficiency of a W target in shielding the SPARC wiggler is demonstrated.

As a matter of fact the W target absorbs about 90 % of the 150 beam energy for a 25 mm target thickness and about 80 % for 17 mm.

The remaining energy is spreaded out around the target and 6% or 14% goes into the wiggler poles for tungsten target thickness of 25 mm and 17 mm respectively.

Because of the 45° tilting in the W target the fraction of the energy deposed into the upper poles is 4% or 9% of the beam energy for the two thickness considered.

The beam pipe and the details of the vacuum ancillary components around the beam pipe and the wiggler entrance are not taken into account but can absorbe some of the energy, so the foreseen tungsten thickness is efficient in shielding the SPARC wiggler.

6 REFERENCES

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

(2) A.Fasso`, A.Ferrari, S.Roesler, P.R.Sala, G.Battistoni, F.Cerutti, E.Gadioli, M.V.Garzelli, F.Ballarini, A.Ottolenghi, A..Empl and J.Ranft, "The physics models of FLUKA: status and recent developments", Computing in High Energy and Nuclear Physics 2003 Conference (CHEP2003), La Jolla, CA, USA, March 24-28, 2003, (paper MOMT005), eConf C0303241 (2003), arXiv:hep-ph/0306267.