Results of the Monte Carlo Simulation of the Neutron and Gamma Background in a Second Experimental Area for Fission Measurements at nTOF

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Introduction

The suitability, in terms of neutron and neutron-induced gamma background, of a design [1] for the second experimental area for fission measurements has been investigated by means of Monte Carlo simulations with MCNPX [2]. This short note reports on the results of the simulations performed.

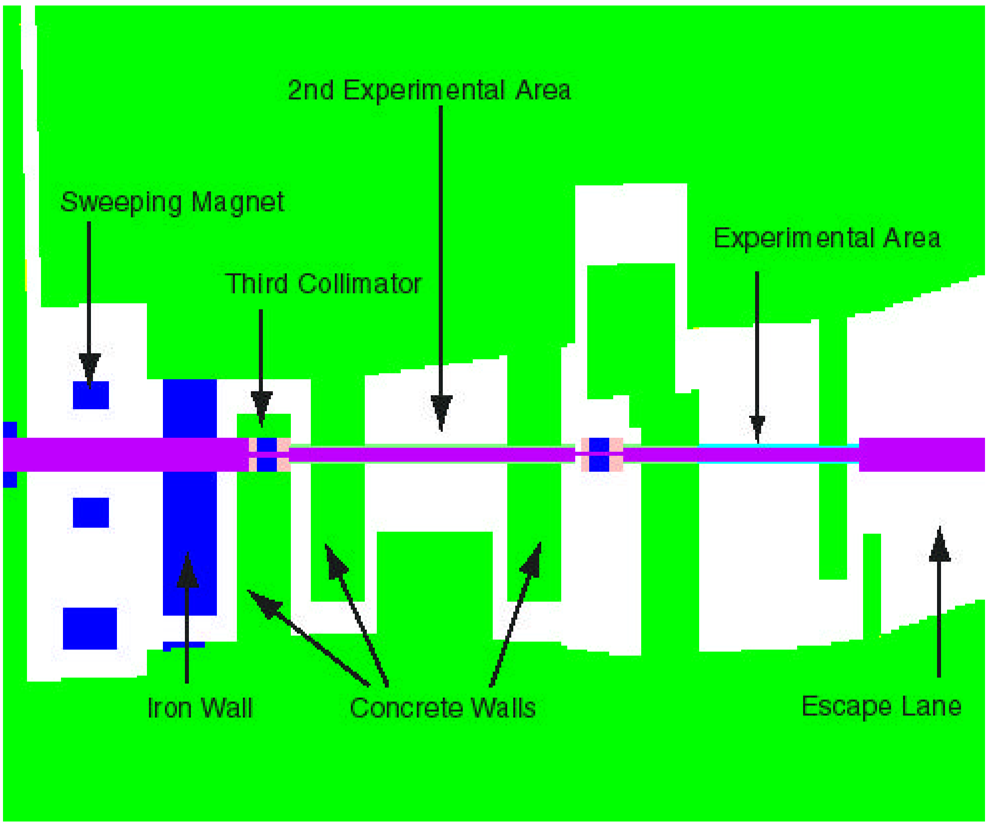

Figure 1. View of the geometry of the proposed 2nd experimental area and main experimental area as defined for MCNPX. Notice that the vertical (x) and horizontal (z) axes are not in the same scale.

A fully detailed geometry of the complete nTOF tunnel, from the spallation target up to the escape lane, has been modelled for MCNPX. It also includes the design proposed for the second area for fission measurements located at 165 m TOF. The relevant part of the geometry is shown in Fig.1. It includes a third collimator of 5 cm inner radius with the same material design as the 2nd collimator currently in use [3,4]: 50 cm of borated polyethylene, 125 cm of Fe and 75 cm of borated polyethylene.

Results of the Simulations

Due to the excessively time consuming simulation of the complete spallation process, a realistic neutron source (with the correct spatial and energy distributions) was modelled alternatively. A total number of $6.3 \cdot 10^6$ primary events were generated during 1 processor-week of CPU time on CIEMAT´s SGI ORIGIN-3800 (160 processors). It has been verified in parallel that the contribution of the spallation process to the secondary area in terms of neutron and neutron-induced gamma background can be neglected with the improved version of the shielding existing since spring 2002. The background produced by the interaction of charged particles coming from the Pb-target was not considered and should be the subject of a separate study.

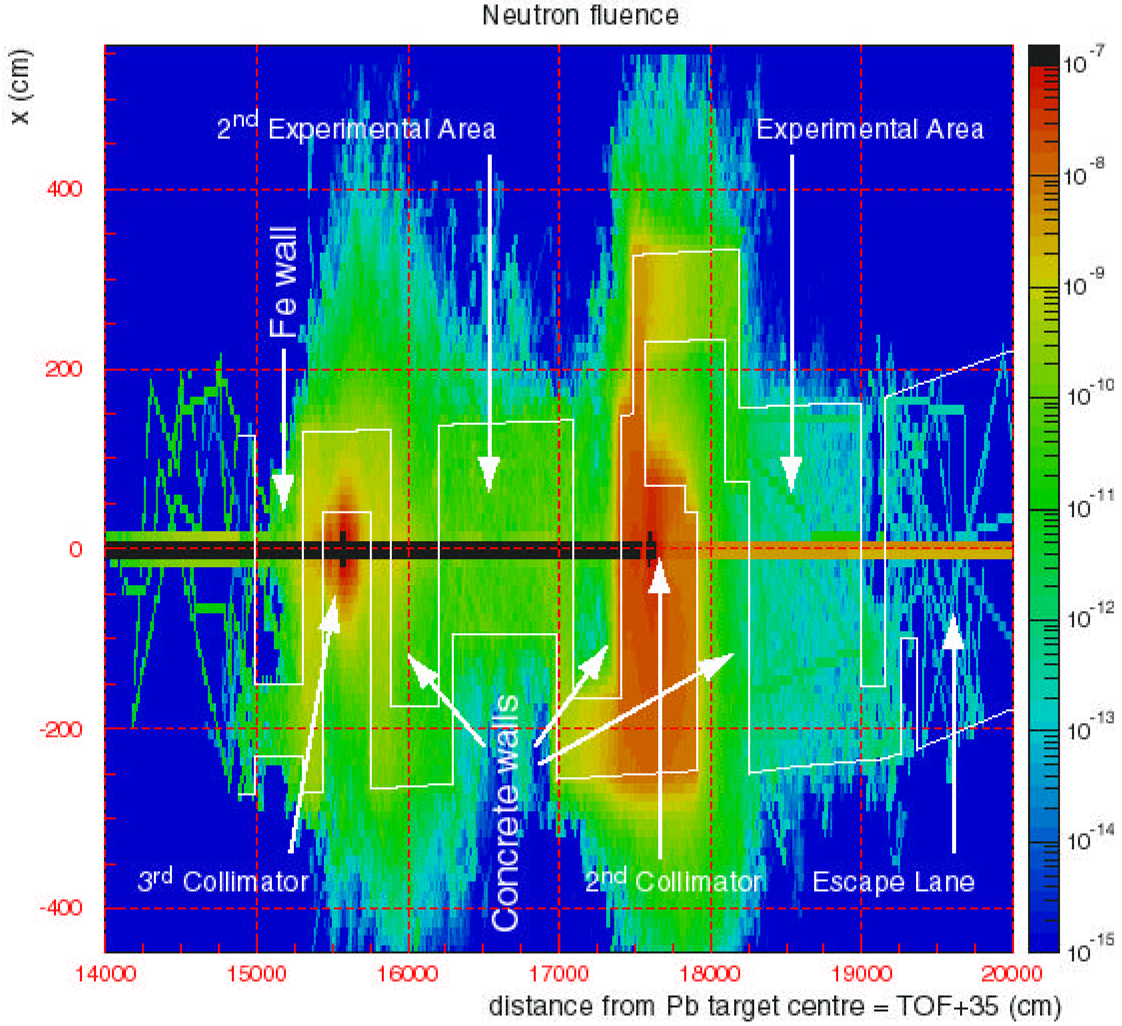

Figure 2. Neutron fluence distribution along the last 60 metres of the tunnel. The figure represents a bird's-eye view of the nTOF tunnel. Both horizontal (beam axis) and vertical (horizontal tunnel x-axis) axes have been divided in 10 cm substeps. The perpendicular axis (not seen in the plot) corresponds to one single bin between –500 and 500 cm which includes the floor and ceiling of the nTOF tunnel.

The neutron and neutron-induced gamma background have been tallied at several regions of interest along the tunnel. The absolute magnitude (i.e. normalisation) of the neutron and gamma fluences is not defined since the neutrons from the Pb-target have been generated within a very small solid angle. Only the relative values (i.e. ratios) with respect to the neutron beam fluences shown in Fig. 6 should be taken into account.

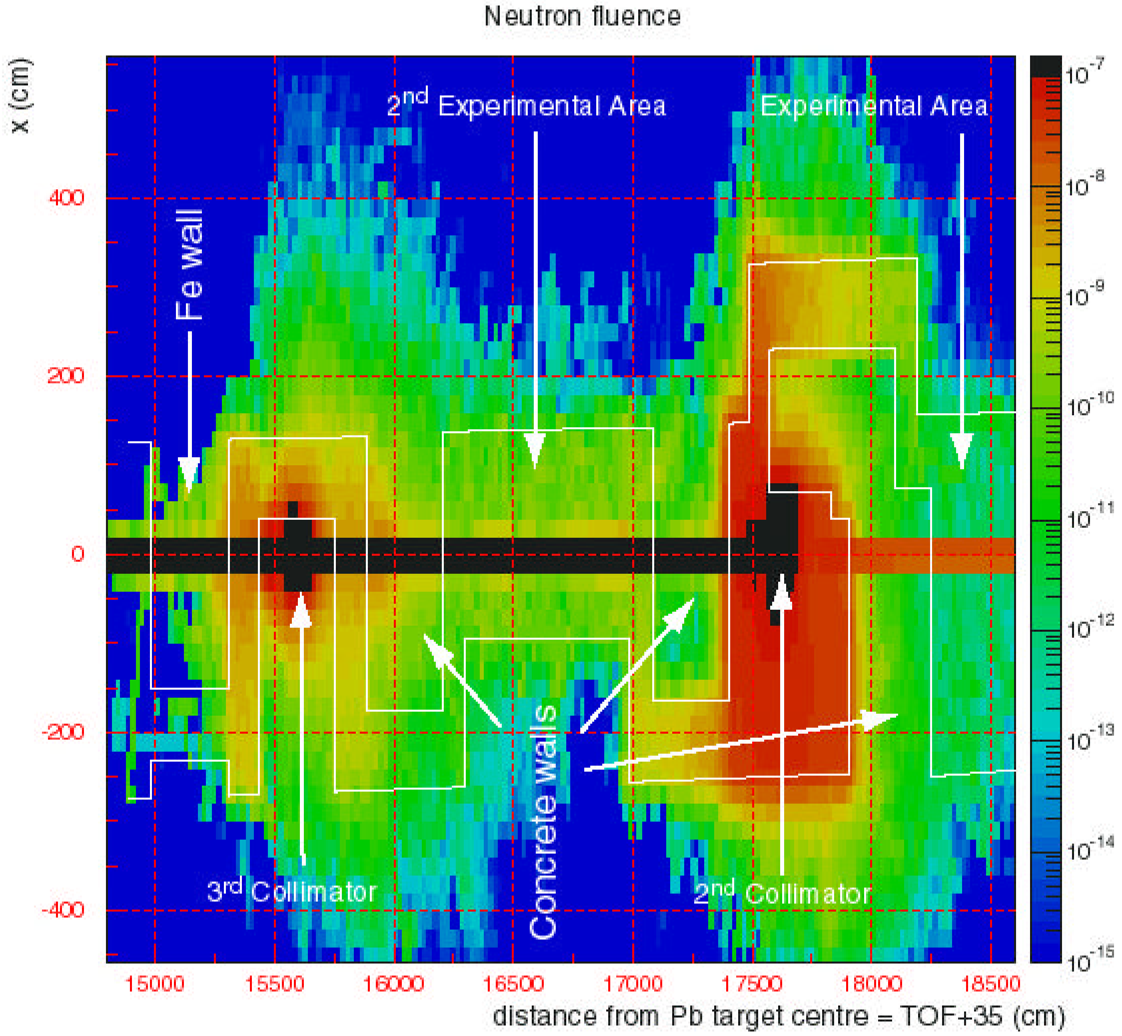

Figure 3. Neutron fluence distribution between 140 and 186 metres from the centre of the Pb target. The distribution corresponds to a cut on the vertical axis above and below the nTOF tube which neither includes the floor nor the ceiling.

Figure 2 shows the neutron fluence distribution in the last 60 metres of the nTOF tunnel, including both second and main experimental areas. The horizontal (beam axis) and vertical (horizontal tunnel axis) axes of the figure have been segmented in 10 cm bins. However, one single bin was defined along the perpendicular axis of the tunnel including also the floor and the celing. Therefore, Fig.2 does not show the real neutron fluence observed by the fission detectors placed in beam at 165 m, since it also accounts for the extra fluence of neutrons hitting the floor and the ceiling of the tunnel. It only illustrates which are the strongest sources of background near the possible new fission station.

The real neutron background fluence observed by a fission detector is shown in Fig.3, which corresponds to the neutron fluence inside a region 20 cm above and 80 cm below the pipe and including the neutron beam. The neutron background outside the beam pipe, expressed in terms of fluence, was found to be 5 orders of magnitude below the neutron beam value. Half of the background neutrons appear at times of flight smaller than 10 µs, while the rest contribute at times of flight larger than 1 ms (eV region). Within the available statistics, the energy distribution of the background neutrons outside the pipe can not be resolved. However, neutrons ranging from thermal energies up to 10 GeV have been observed.

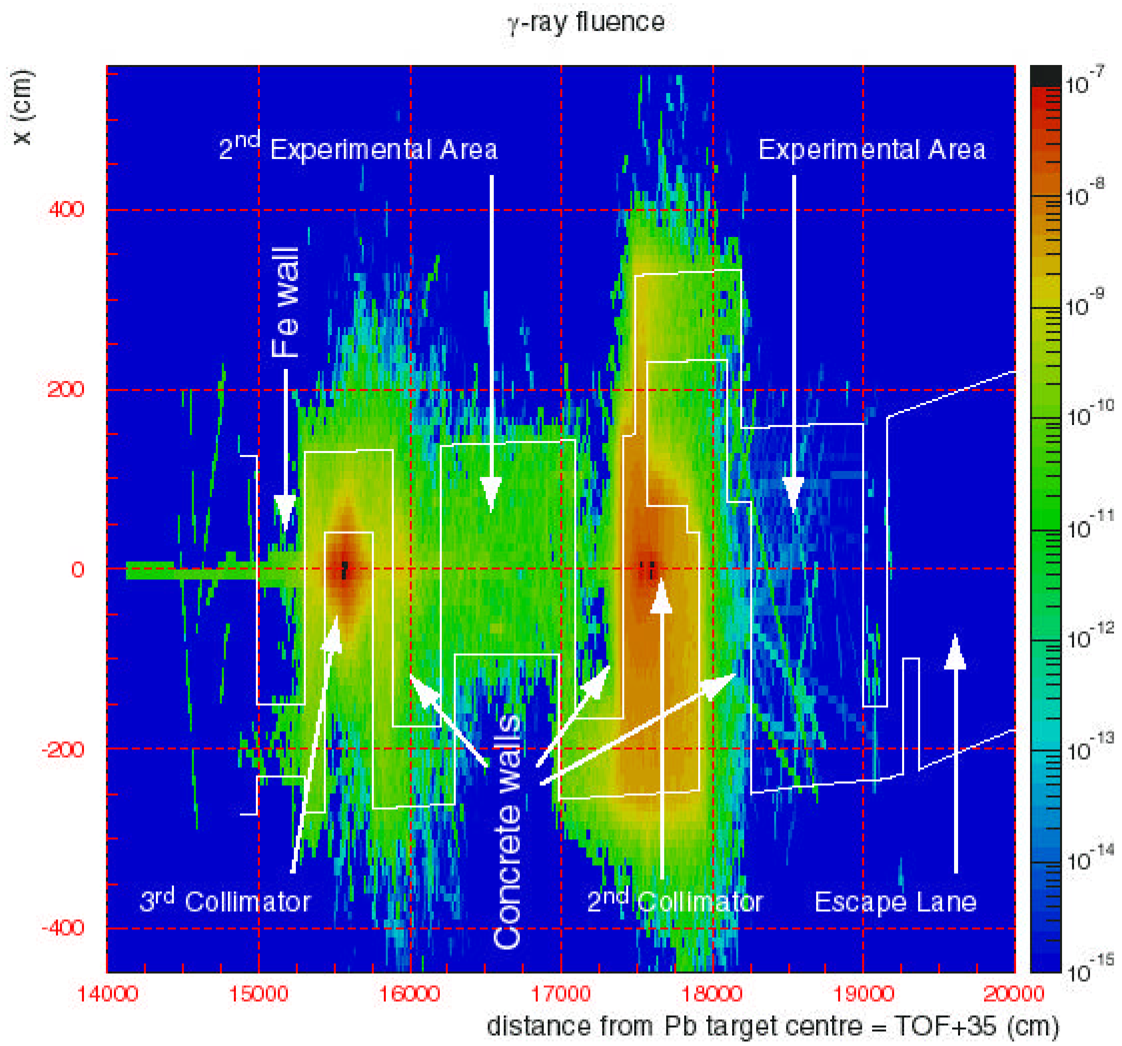

Figure 4. Neutron-induced gamma ray fluence distribution along the last 60 metres of the tunnel. The figure represents a bird's-eye view of the nTOF tunnel. Both horizontal (beam axis) and vertical (horizontal tunnel x-axis) axes have been divided in 10 cm substeps. The perpendicular axis (not seen in the plot) corresponds to one single bin between –500 and 500 cm which includes the floor and ceiling of the nTOF tunnel.

Fig.4 and Fig.5 are similar to Fig.2 and Fig.3, respectively, but showing the neutron-induced gamma ray fluence distribution in the last part of the nTOF tunnel. It can be observed that the two major background sources are the 2nd and 3rd collimators. Its level, expressed in terms of fluence, is the same as the neutron background outside the pipe, i.e. 5 orders of magnitude lower than the neutron beam fluence. Such a result should not affect the fission measurements since the fission detectors to be used are nearly insensitive to gamma rays. However, its 2 orders of magnitude larger value with respect to the neutron-induced gamma ray background in the main experimental area should be subject of a careful study on the suitability of cross section measurements in which gamma ray detectors are involved.

The neutron induced gamma ray-background level at the experimental area is not affected by the by the 2nd experimental area and remains 6-7 orders of magnitude with respect to the neutron beam fluence. With the current statistics, no information about the time structure of the gamma ray background can be extracted.

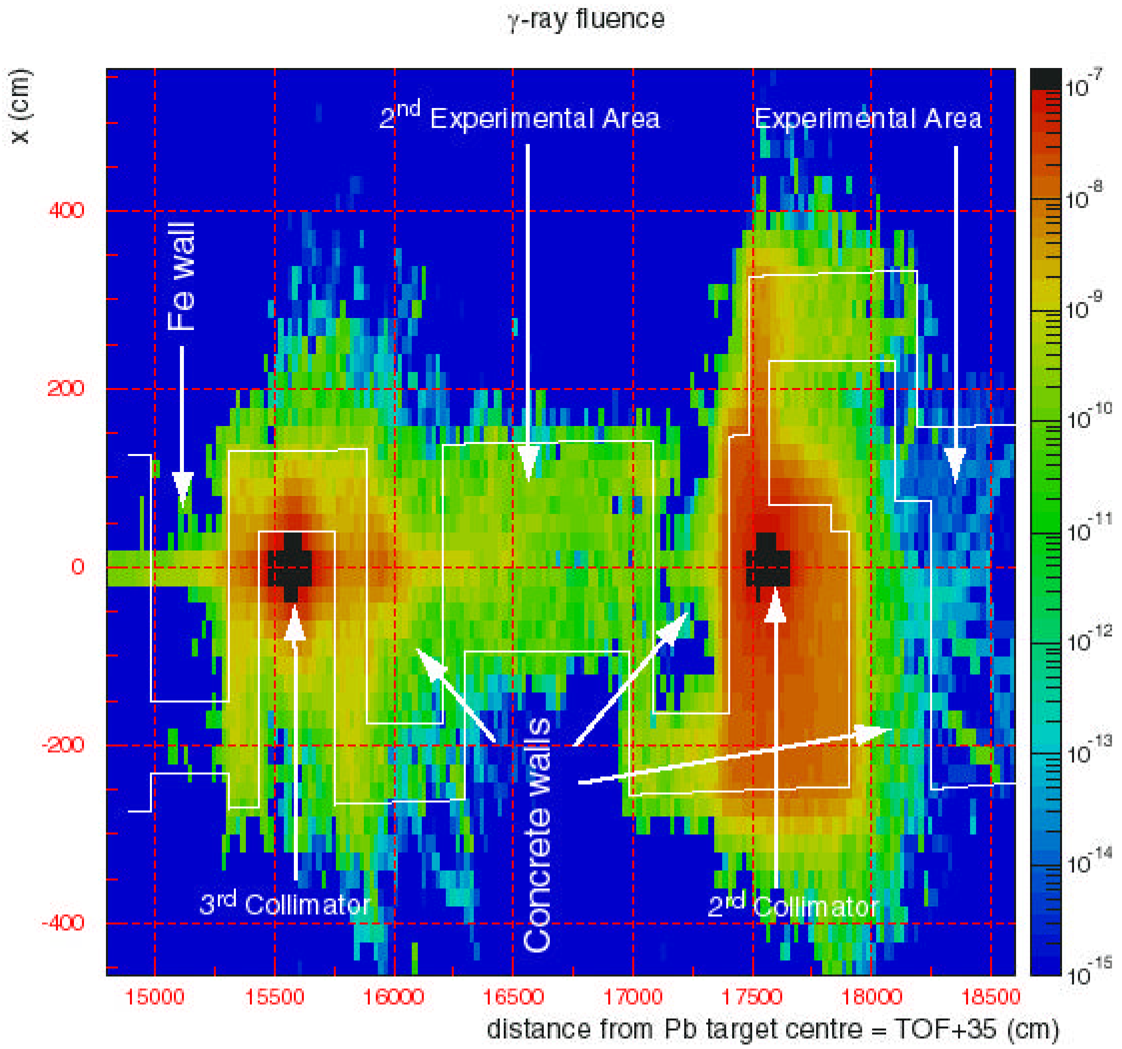

Figure 5. Neutron-induced gamma ray fluence distribution between 140 and 186 metres from the centre of the Pb target. The distribution corresponds to a cut on the vertical axis above and below the nTOF tube which neither includes the floor nor the ceiling.

Fig. 6 shows the neutron beam radial profiles at the second area (black curve) and the main experimental area (red curve). It can be seen that the neutron background in the main experimental area remains, after the insertion of the extra shielding, at 6-7 orders of magnitude below the neutron beam there. It is also shown that the neutron background at the second experimental area is 5 orders of magnitude below the neutron beam fluence. Such a value could be furtherly lowered by the insertion of borated polyethylene plates placed adequately.

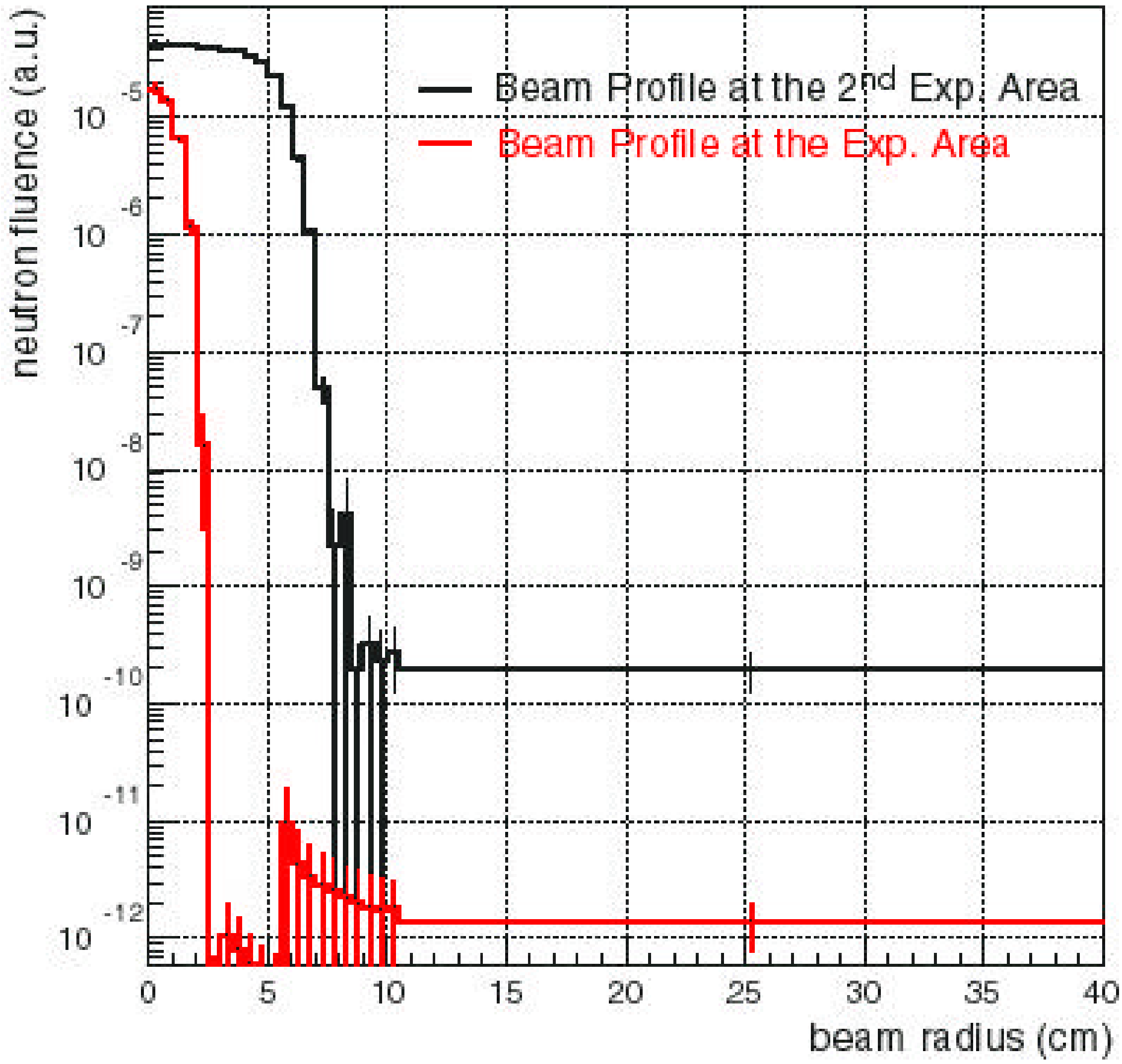

Figure 6. Radial beam profile distributions at the the 2nd experimental area (in black) and main experimental area (in red).

Summary and Conclusions

- A fully detailed and realistic geometry of the nTOF tunnel has been modelled for the MCNPX Monte Carlo code.
- A simulation for calculating the neutron and neutron-induced gamma background in a possible second experimental area for fission has been performed.
- The background produced by the charged particles has not been evaluated.
- The results for $6.3 \cdot 10^6$ primary neutron events have been presented.
- The neutron background fluence at the second experimental area is 5 orders of magnitude lower than the neutron beam fluence at the same place.
- Half of the background neutrons appear at short times of flight below 10 μs, while the rest contribute at large times of flight above 1 ms.

- Within the available statistics, the energy distribution of the background neutrons outside the pipe can not be resolved. However, neutrons ranging from thermal energies up to 10 GeV have been observed.
- The neutron background fluence at the main experimental area stays by 6-7 orders of magnitude below the neutron beam fluence at the same place.
- The neutron background at the 2nd experimental area is 100 times larger than the neutron background at the main experimental area.
- The neutron induced gamma-ray background fluence at the second experimental area is 5 orders of magnitude lower than the neutron beam fluence at the same place.
- The neutron induced gamma ray background fluence at the main experimental area stays by 6-7 orders of magnitude below the neutron beam fluence at the same place.
- The neutron induced gamma ray background at the 2nd experimental area is 100 times larger than the neutron background at the main experimental area.

References

[1] I. Durán, C. Stephan. Private Communication.
[2] H.G. Hughes, R.E. Prael and R.C. Little, MCNPX – The LAHET/MCNP Code Merger, XTM-RN(U)97-012, LA-UR-97-4891, Los Alamos National Laboratory (April 1997)
[3] D. Cano-Ott, M. Embid, E. González and D. Villamarín, Design of a Collimator for the Neutron Time of Flight (TOF) Facility at CERN by means of FLUKA/MCNP4B Monte Carlo Simulation, DFN/TR-07/II-99
[4] D. Cano-Ott and E. González, Proposal for a two-step cylindrical collimation system for the n_TOF facility, DFN/TR-04/II-00