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An updated calculation of neutron fluence in the CNGS first muon pit

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Abstract

An updated Monte Carlo calculation of particle fluence in the dump of the CNGS neutrino beam is presented. The neutron background level in the first muon pit is expected to be well below the muon signal.

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1 Introduction

The Monte Carlo simulation of the CNGS neutrino beam was updated in order to better describe the particle flow in the beam-dump region and evaluate the neutron flux in the first muon pit. A particular attention was devoted to the geometrical description of the cave, of its concrete walls and platform and of the iron and graphite absorbers. The obtained particle fluxes were compared to those relative a modified set-up were the empty space between the cave wall and the iron absober is filled with concrete.

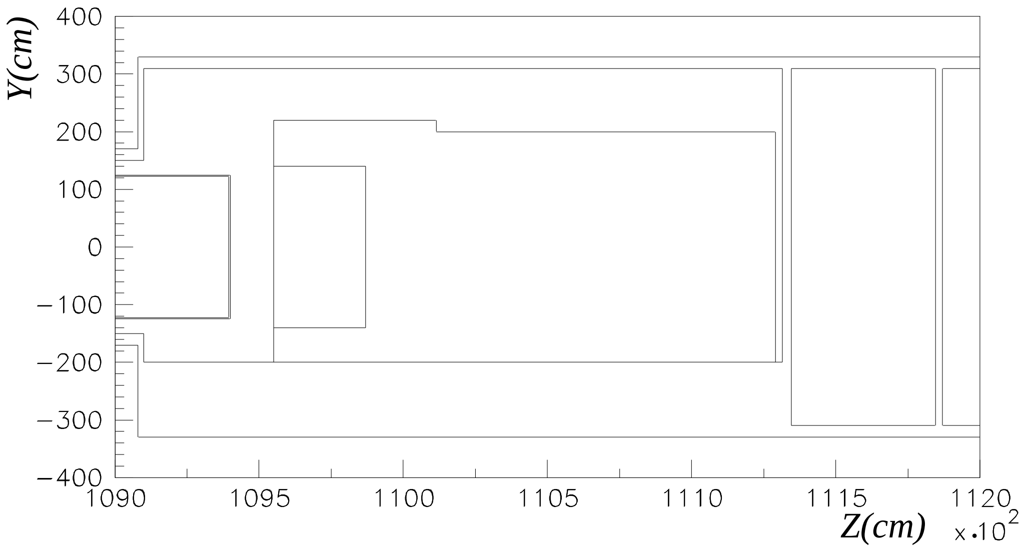

Figure 1: Lateral $z - y$ view of the dump region.

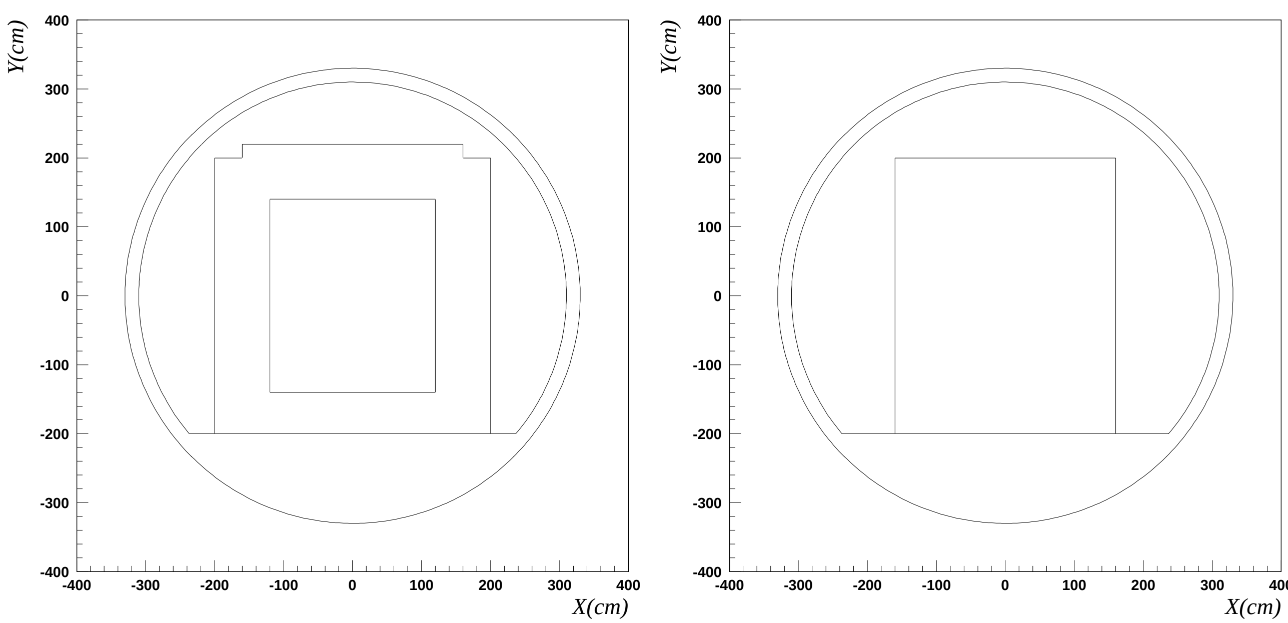

Figure 2: Transversal section of the dump cave at $z = 1097.5$ m (left) and $z = 1112.5$ m (right) from the target.

2 Beam-dump description in the CNGS beam simulation

The calculations described here are based on the FLUKA[1] code and on the tools already developed for all the CNGS beam simulations. The secondary beam optics corresponds to the design described in

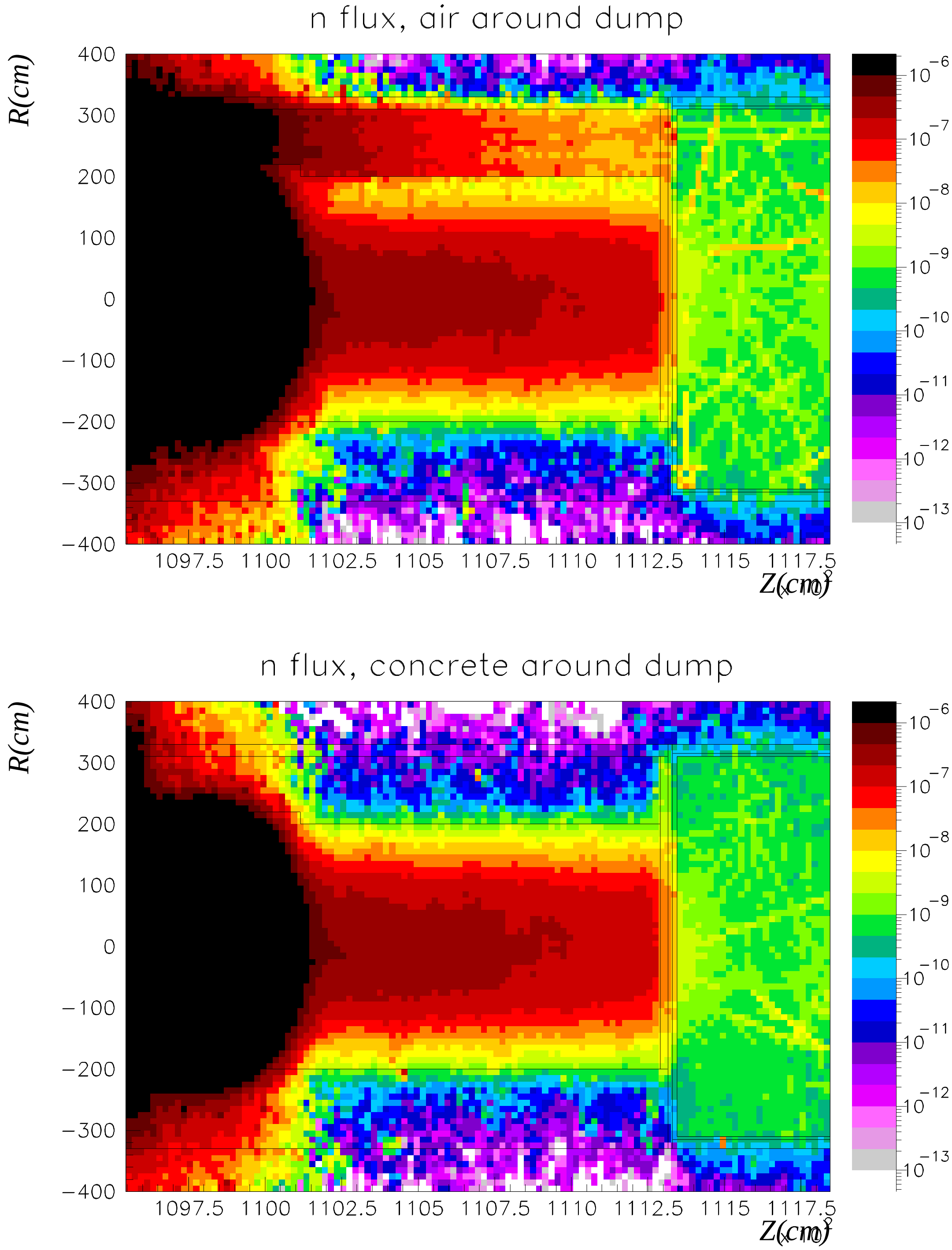

Figure 3: Neutron flux in a vertical section of the dump cavern, in the present layout (top) and in the old layout (all space filled with concrete).

[3]. The CNGS target and target assembly geometry follows the conceptual design as available from the CNGS target working group [4]. The geometrical description of the beam-dump region was included in the Monte Carlo code according to the latest technical drawings [5]. In fig. 1, one can recognize the end of the decay tube, separated by 1.5 m of air from the beam-dump which is posed on a flat concrete platform. The dump material is iron with a 5% carbon content, for a density of 7.2 g/cm^3. It has a total

length of 17.4 m[1], and its first 3.2 m include a 2.40×2.80 m graphite insertion ($\rho = 1.75$ g/cm^3) (see fig. 2). At the end of the dump cave there is a concrete wall, 30 cm thick. This wall is composed by concrete blocks having a relatively low density (2.1 g/cm^3), and by a concrete door. In the simulations the wall is supposed to be homogeneous, without holes or cracks in between blocks or near the door. Immediately after this wall comes the first muon pit, having a length of 5 m.

Particle transport and interactions have been performed down to a threshold of 1 MeV for muons and thermal energy for neutrons, while charged hadrons were cut at 2 GeV. Electrons and photons have been generated in interactions but not transported, in order to save CPU time.

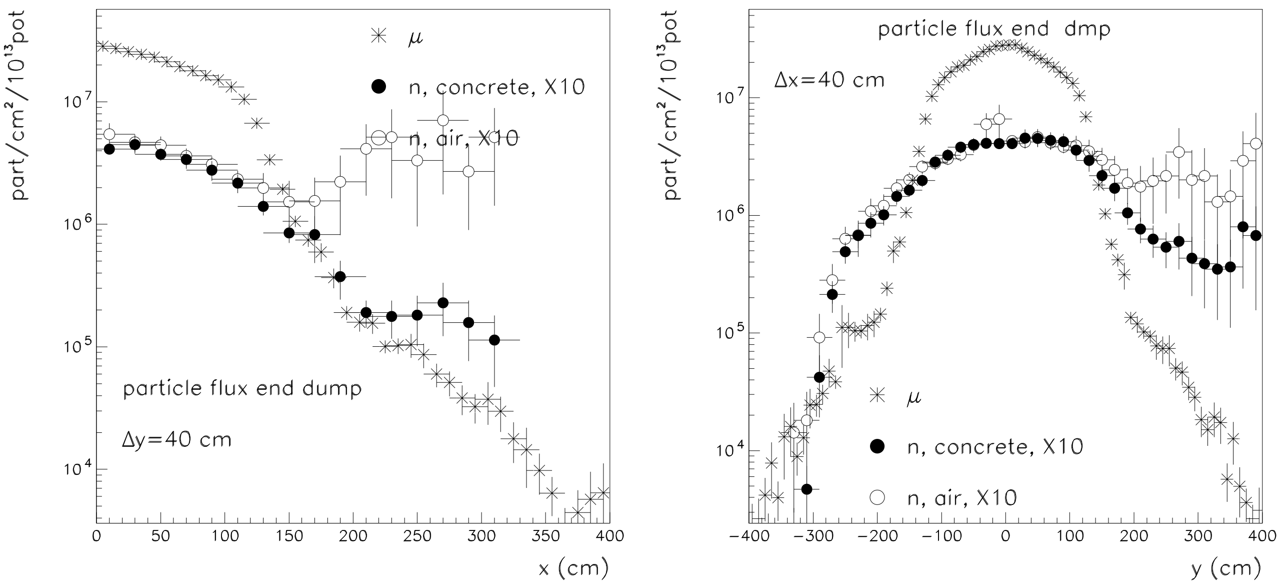

Figure 4: Muon and neutron fluxes at the end of the beam-dump cave, in the the horizontal (x, right) and vertical(y, left) plane, calculated in the standard dump configuration (air) and with the space between iron absorber and cavern wall filled with concrete (concrete). Fluxes are averaged over ± 20 cm in y (resp. x). Neutron fluxes are multiplied by 10.

3 Particle flux at the end of beam-dump and in the first pit

Neutrons that are produced by hadronic interactions and decays in the first meters of the beam-dump are attenuated by the dump itself, and stream partially through the air gaps around the dump. Neutrons are also produced all along the dump by muon photonuclear interactions. Indeed, the neutron flux decreases very slowly in the last ten meters of the dump, as shown in fig. 3.

The calculated neutron flux at the end of the Beam-dump results largely suppressed with respect to the muon flux, up to a factor ~ 60 in the central area $|x, y| \leq 150$ cm (fig. 4, standard case “air”). As expected the neutron fluence increases with the distance from the center of the dump because of the free space around the iron absorber (see fig. 2) and it is dominating in the lateral and upper part for $|x| > 250$ cm and $y > 250$ cm.

However these low energy neutrons are strongly absorbed by the last transversal wall of 30 cm tickness which separate the dump from the first pit. At the muon monitors position, the neutron flux is lower by a factor 100 with respect to the muon flux (fig. 5 full line). In the central part of the pit a neutron to muon suppression by 2000 is determined (see fig. 6, standard case “air”). The average energy is 14.9 GeV for μ and 25 MeV for neutrons. In fig. 7 the neutron spectra at the end of the dump and at

[1]The absorber has been shortened by 80 cm (one iron block) with respect to the TDR design, in order to gain space for mounting.

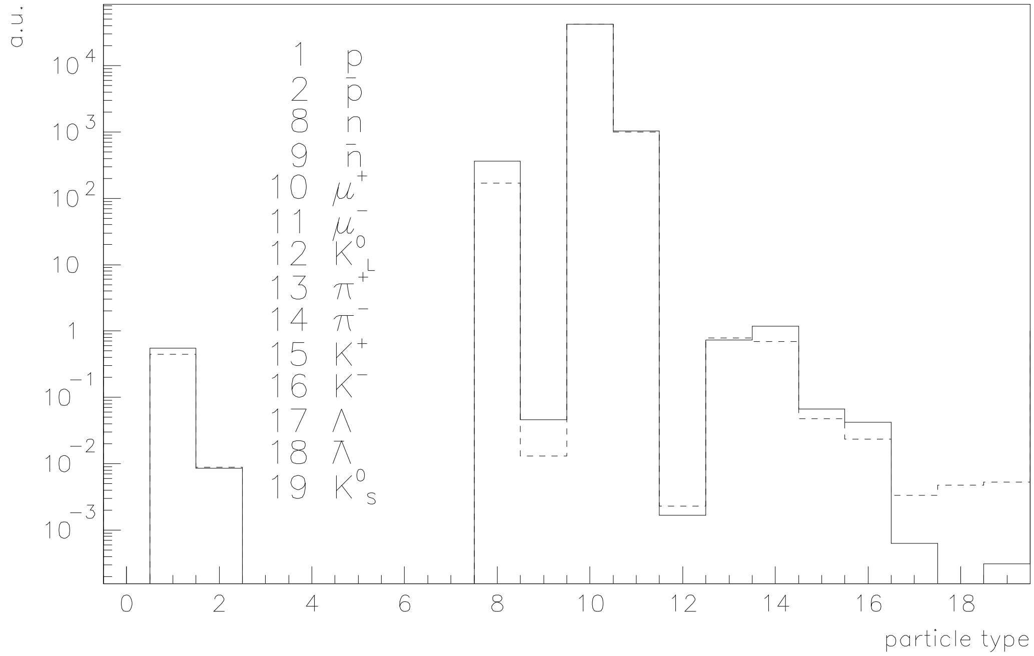

Figure 5: Particle spectrum at the first pit: standard case “air” (full line) compared to “concrete” case (dashed line).

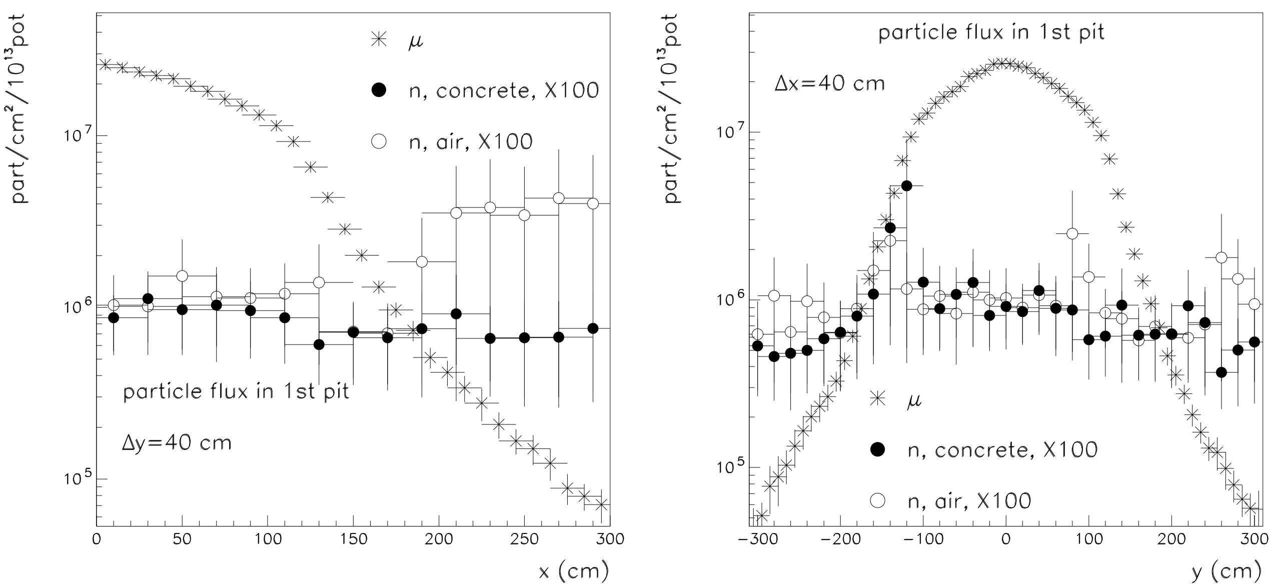

Figure 6: Muon and neutron fluxes at the entrance of the 1st muon pit. As in fig. 4, but neutron fluxes are multiplied by 100.

the muon pit are shown. The concrete wall is specially effective in reducing the low energy part of the spectrum, up to a few MeV, while the small high energy component is less affected. The profile of the radially integrated neutron flux inside the concrete wall is shown in fig.8. Despite the large error bars, it is clear that the design 30 cm are sufficient only in the ideal case of no holes, no cracks, well known density. A few (equivalent) centimeters less could suddenly increase the neutron flux. Therefore, the addition of 10 cm of concrete is highly recommended for safety and to reduce the impact of geometrical uncertanties on the calculated neutron flux.

It has to be mentioned that the simple calculation of fluxes does not allow to evaluate the induced count rate in the muon detectors. The counter sensitivity to neutrons should be either experimentally

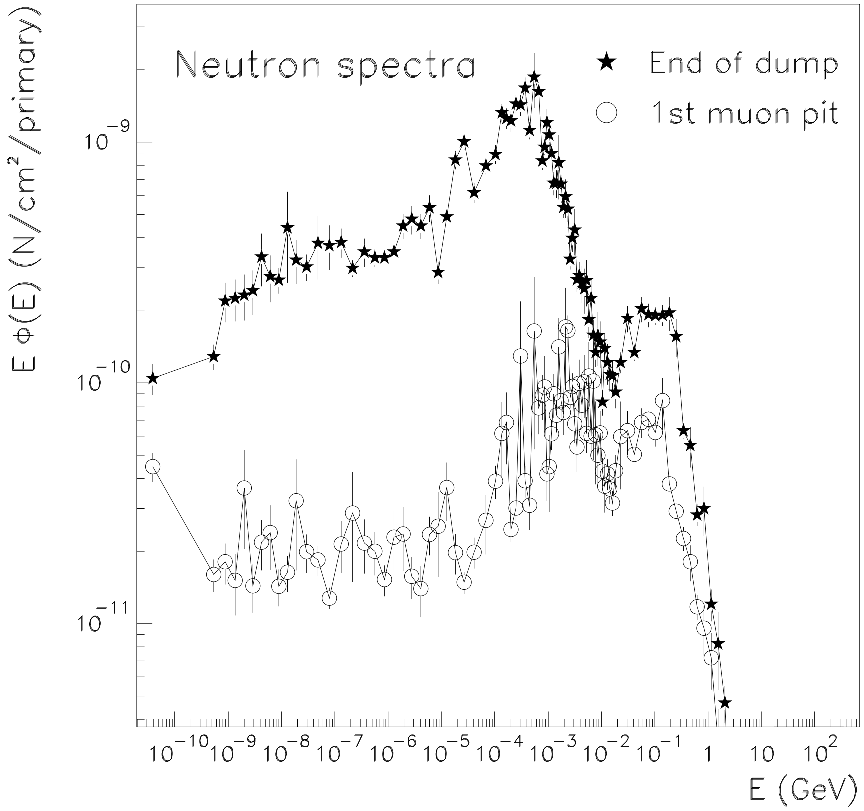

Figure 7: Lethargy neutron spectra at the end of dump and in the 1st muon pit.

determined or calculated.

The possibility to fill the empty space between the iron absorber and the cave wall with the concrete was also considered in the simulation. In this case the neutron fluence detected at the end of the dump in the external part, $|X| \geq 150$ cm and $Y \geq 250$ cm are reduced with respect to the previously considered standard configuration (fig. 4, "concrete" case vs. standard case "air"). However due to the low energy of these neutrons, no large difference is detected in the first pit, due to the presence of the 30 cm concrete wall which separates the dump form the pit (see fig. 6, "concrete" case vs. standard case "air").

4 Conclusions and recommendations

The description of the beam-dump in the CNGS Monte Carlo code has been improved according to the last drawings of the cave and of absorbers. The calculation of the resulting particle fluence indicated that a negligible neutron background in the first muon pit is expected with respect to the muon flux. No significant variations were found in the muon pit if the space between the iron absorber and the cave wall is filled with concrete. However the confidence in the muon signal exploitation can be improved by increasing by 10 cm the concrete thickness of the tranversal wall between the absorbers and the first pit.

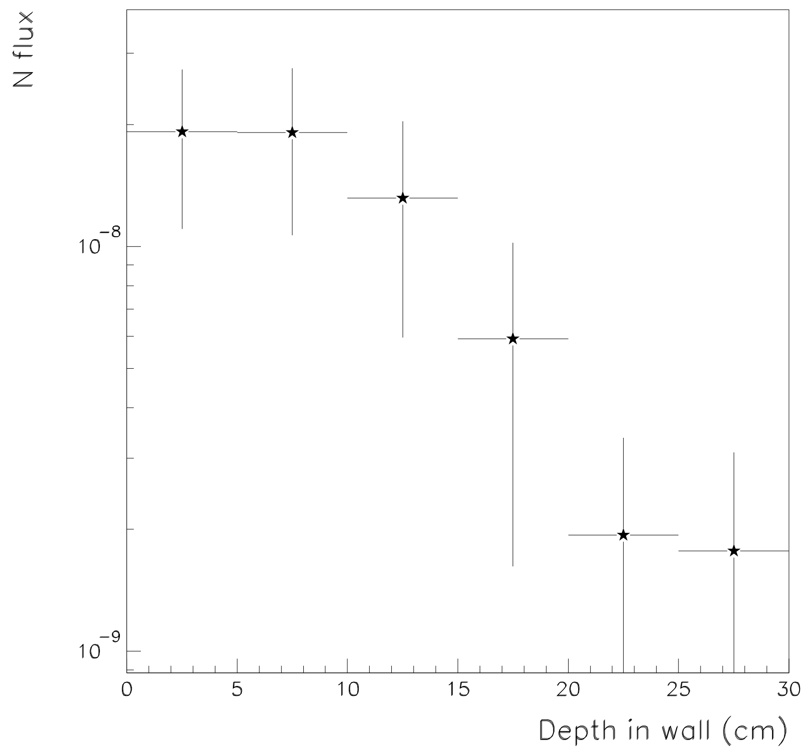

Figure 8: Longitudinal profile of neutron flux inside the concrete wall that separates dump and pit. Flux is integrated over energy and transversal dimensions.

References

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[2] G. Acquistapace et al. “The CERN neutrino beam to Gran Sasso (NGS)”, Conceptual Technical Design, CERN 98-02 and INFN/AE-98/05 (1998).

[3] A.E. Ball et al., “CNGS: Update on secondary beam layout ” CERN SL-Note-2000-063 DI (2000).

[4] L. Bruno, private communication.

[5] EDMS drawing 364662 and K. Elsener, private communication.