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Estimation of neutron and γ-rays flux at the MAGNEX facility via FLUKA simulations

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Abstract. Simulations for estimating the neutron and γ-rays radiation background in the forthcoming NUMEN experiments at the upgraded MAGNEX facility were performed with the simulation package FLUKA. Three main radiation sources were considered in our simulations namely, the beam-target interaction, the moderation of the beam particles inside the beam dump and a hypothetical 10W loss in the beam intensity during the beam transport. In the present contribution, the results of this preliminary analysis are presented and discussed.

1 Introduction

The upgrade of the K800 Superconducting Cyclotron at the Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud (INFN-LNS) is still in progress. This improvement was driven by the NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) project [1], which aims to study Double Charge Exchange (DCE) reactions, characterized by low cross-sections, as a mean to shed some light on the determination of the Nuclear Matrix Elements (NMEs) of the $0\nu\beta\beta$ decay [2–4]. Once the Cyclotron upgrade is completed, in the case of NUMEN experiments, the use of ^{18}O and ^{20}Ne ion beams with an intensity of (1-10)kW is foreseen. The interaction of such high intensity beams with the target may yield a substantial increase in the radiation level inside the MAGNEX [5] experimental hall. Furthermore, one should keep in mind that the beam particles must be stopped into a shielded area, like a beam dump. The moderation of the beam particles will trigger a large production of neutrons and gamma rays. This is an important aspect to take into account during the R&D of the electronic devices as well as of the detectors in the new Focal Plane Detector (FPD) of the MAGNEX spectrometer [6, 7]. Taking into consideration all the above, Monte Carlo simulations for the neutrons and γ-rays induced radiation background at the MAGNEX facility were performed using the FLUKA code [8].

2 The simulation

The simulation was performed following the prescription of [9] using a schematic geometry which appears in Figure 1. In more details, a $^{20}Ne^{10+}$ beam at the energy of 60 *A*MeV with a flux of 1.05x10^{13} pps was impinged into a ^{76}Ge target 214 μg/cm^2 thick, followed by a 2 μm ^{12}C layer [10, 11]. The simulated neutron and γ-ray energy spectra, measured at the FPD (see Figure 1), are presented in Figures 2 and 3, respectively, with the dashed green-line. Further on, a loss of 10 W during the transport of the beam towards the beam dump was also considered in the simulations. In this case, a substantial increase in the radiation level in the vicinity of the FPD is inferred. In the last part of our simulations, the $^{20}Ne^{10+}$ beam was moderated onto a thick Ag target located inside the beam dump. The beam dump is confined into a (5x5x3)m^3 portland concrete box, providing thus a shield against neutron and gamma radiation.

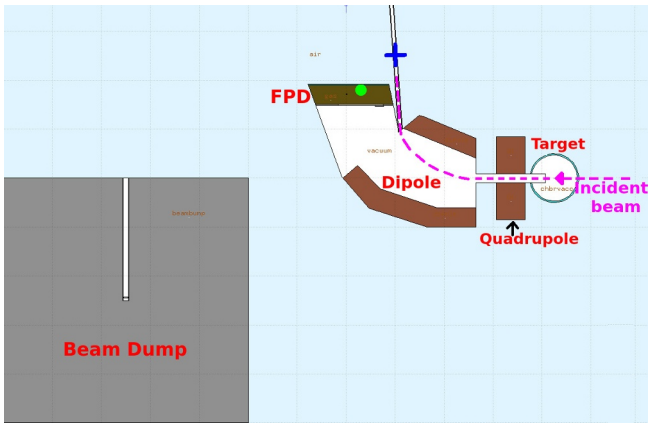

Figure 1. A schematic representation of the expected geometry, after the facility upgrade, at the MAGNEX experimental apparatus considered in the FLUKA simulations. The detector used in the simulation is indicated by a filled green circle, while the position where the 10W loss occurs is denoted with the blue cross (see text for details).

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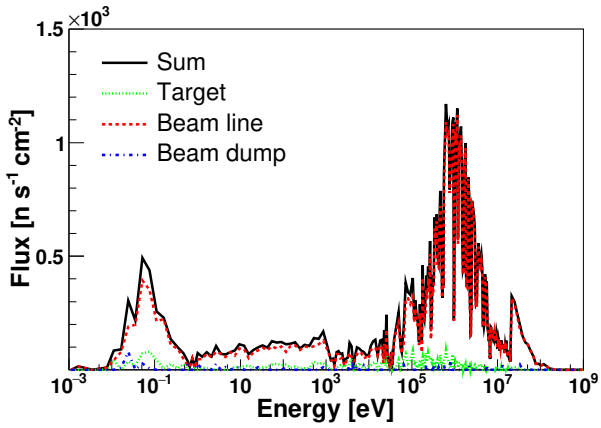

Figure 2. The simulated neutron energy spectra at the MAGNEX FPD region. The spectrum corresponding to neutrons emerging from the beam-target interaction, the beam dump and the hypothetical 10W loss are denoted with the dotted green, dotted-dashed blue and dashed red lines, respectively.The sum of the three contributions is presented with the solid black line. Figure from Ref. [7].

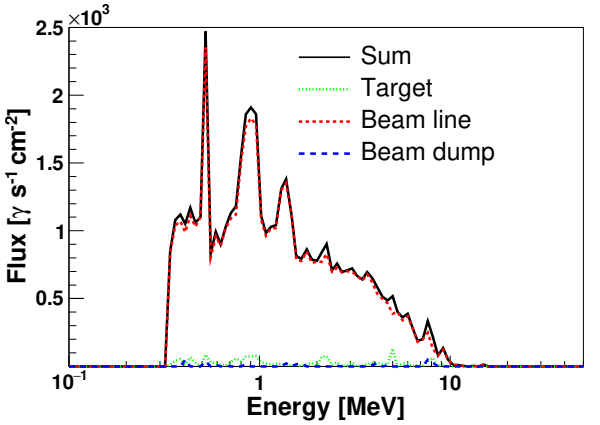

Figure 3. Same as in Figure 2, but for the simulated γ-rays energy spectrum.

3 Results and discussion

Taking into consideration the radiation sources presented above, the simulated energy distribution of the neutron flux at the FPD region is presented in Figure 2. The total integrated neutron flux at the FPD region is 7.2x10^4 n s^{-1} cm^{-2}, dominated by fast neutrons above 100 keV. These results are also reported in a recent publication of the NUMEN collaboration [7]. The simulated γ-ray energy distribution is presented in Figure 3 corresponding to an integrated yield at the FPD zone of about 4.8x10^4 γ s^{-1} cm^{-2}.

Both Figures 2 and 3 show that the main sources of neutrons and γ-rays in the FPD region come from the possible scattering of the beam into the beam pipe close to the FPD. Therefore, a detailed study of the beam transport is in progress in order to quantify the beam losses in the FPD region and reduce them to tolerable values. Moreover, a significant reduction of radiation level is expected by the introduction of proper shields to the detectors and electronics, which are also currently under study.

4 Summary

Systematic simulations for the neutron and γ-rays induced radiation background were performed with the simulation code FLUKA. Three different radiation sources were considered in our simulations namely, the beam-target interaction, the moderation of the beam particles inside the beam dump and a hypothetical 10W loss in the beam intensity during the beam transport. It was found that the bulk of the produced neutron and γ-rays is originated from the possible beam scattering into the pipe close to the FPD. The introduction of shielding materials around the FPD and their effect on the simulated energy spectra is currently under study. In the near future, we also intend to implement a more realistic geometry of the MAGNEX FPD in our simulations.

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