FLUKA studies of the Radiation Environment for Plasma Physics Experiments

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The future plasma physics program at FAIR foresees a general-purpose target chamber for a variety of experiments. FLUKA simulations have been performed to assess the radiation level, prompt and residual, due to the interaction of an intense ion beam with a target. The aim was manifold: to optimize the position of the electronic equipment within and near the chamber in order to minimize the risk of component failures due to radiation damage, to estimate the residual dose rates in the vicinity of the chamber, and to determine the cooling times for interventions in order to minimize the exposure of personnel. Furthermore, the induced radioactivity and the complete inventory of radionuclides in each of the components, including the airborne activity, were studied for different safety scenarios.

To obtain realistic radiation fields, the complete geometry of the target chamber, of the beam line with the dump, and of the APPA cave with the surrounding concrete shielding had to be modelled in detail (Fig.1.)

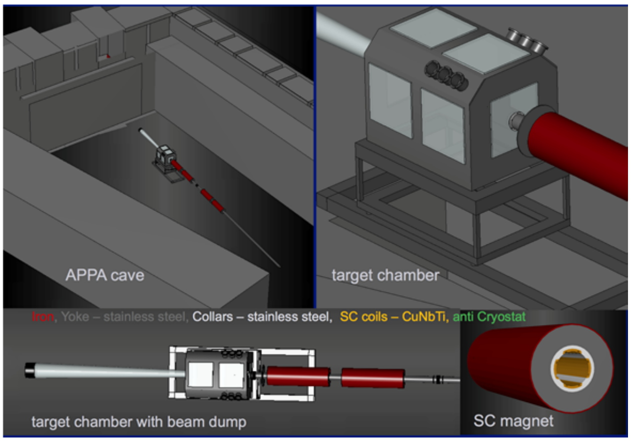

Figure 1: FLUKA geometry of the APPA cave with the beam line, the target chamber and the dump.

The results are based on a focussed uranium beam of maximum intensity (5×10^{11} particles per pulse) at 1 GeV/u, while for the target both extreme situations were considered: a thick lead target which stops the ion beam completely (length 27 mm), and a 100 μm thin aluminium foil with the ion beam mostly deposited in the carbon beam dump. The simulation assume four experimental campaigns per year with 1 shot per 10 minutes for 10 days, and with 80 days between the runs, implying altogether 5760 shots per year.

The study of the energy deposition within the Pb target showed that, although the target is much longer than the range of the primary ions, a high fraction of about 11% of the ion beam energy, i.e. 12 MJ for 5760 shots, is not deposited in the target, but escapes in the form of secondaries which create the radiation field in the cave.

To assess the risk to electronic equipment, three different physics quantities (physical dose, 1MeV-equivalent neutron- and hadron fluence) responsible for the radiation damage were evaluated. The dose was found to exceed 1Gy per experimental shot for equipment in the immediate vicinity of the target (at 10cm distance) and still had a high value of 10 mGy per shot for equipment outside the chamber. A detailed composition of the background radiation in terms of energy spectra of different contributions was determined and will be used to estimate the background for each detector system once the precise location, type and response to different particles is known.

The target material and the chamber with all installations contained will be activated to a level that prohibits immediate access during or directly after an experiment. The target will be evaporated by the ion beam and a new target is used for each shot. The peaked residual dose rate in the chamber (Fig.2) is correct if the activated material can be confined to a small volume around the target

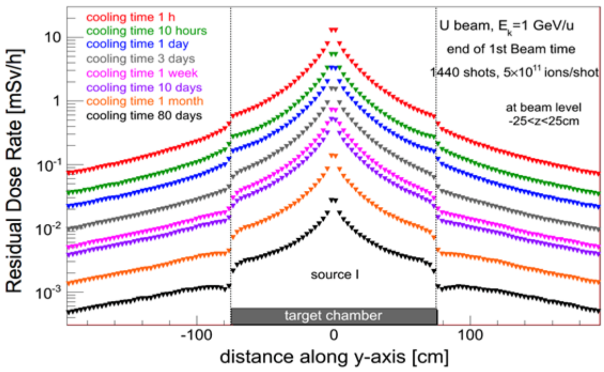

Figure 2: Time dependence of the residual dose rates along a line perpendicular to the beam axis.

position. In this case the dose rate outside of the chamber is determined to 70% by the activated target material and to 30% by the activation of the chamber. In the other extreme case of complete distribution of the activated target over the chamber walls the dose rate outside of the chamber is dominated by the chamber activation.

The residual dose rates for cooling times between 1h and 80 days were almost the same after the end of the 1st and 4th beam time period (not shown). The original layout of the chamber was using a steel frame with aluminium flanges. It was found that replacing the steel by an aluminium frame results in the same residual dose after few hours but leads to a drop of the activity after few days that is ten times faster than in the original design.

Waste disposal planning and safety issues connected with fire scenarios were also studied, assessing the induced radioactivity and complete inventory of radionuclide for each of the components.

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