INVESTIGATION OF THE LIFETIME OF ELECTRONICS AND FIBER OPTICS INSIDE THE NICHE AND THE TUNNEL IN THE SLOW EXTRACTION AREA OF SIS100

A. Plotnikov*, E. Mustafin, N. Pyka, P.Spiller, GSI, Darmstadt, Germany

Abstract

The loss of ions in the slow extraction area of the SIS100 accelerator planned for FAIR project can be dangerous for the electronic equipment and fiber optics situated inside the tunnel and niches around. During slow extraction the lost ions irradiate the yoke of the quadrupole magnets and the collimator and produce neutron flux, which can damage the electronic devices or trigger single event upset (SEU). Moreover, fiber optic cores fade under the action of irradiation. In the present work an investigation of the dose distribution and neutron fluxes, as well as a calculation of lifetime of the electronics and fiber optics in different places of the tunnel has been done. By using these results the design of the niches and shielding is planned.

MOTIVATION

The Facility for Antiproton and Ion Research (FAIR) is planned to be finished in 2015 (fig.1). In the frame of the project two synchrotrons will be built: SIS100 and SIS300. The features of those machines are high intensity and energy of the proton and heavy ion beams. For SIS100 the energy is going to be 2.7 GeV/u for U^{+28}, and bunch compression to ~60 ns for $5{\cdot}10^{11}$ U ions. For SIS300 - 34 GeV/u for U^{+92} and slow extraction of ~$3{\cdot}10^{11}$ U-ions per sec [1].

The prospective beam loss during slow extraction is $1.5{\cdot}10^{10}$ particles per second (here and below only uranium ions are considered). Thus, the slow extraction area is the region with the highest dose rate in the whole ring (fig. 2).

At the present stage of SIS100/300 facility design, it is very important to plan the tunnel construction so that the infrastructure and measuring instruments situated in the immediate proximity to the accelerator line are properly shielded.

SIMULATION SETUP

To investigate this problem part of the SIS100 and SIS300 line has been modeled by the use of FLUKA code [2-3]. The original design of the SIS100 slow extraction area and surrounding facilities were taken into account to set up the FLUKA geometry (fig. 2). As an initial beam the U beam with 2.7 GeV/u was used. $1.5{\cdot}10^{10}$ uranium ions per second, stripped on the Electrostatic Septum wires from U^{+28} to U^{+92} simulated the lost beam in the model. After passing the Electrostatic Septum these stripped particles are mainly lost in the collimators, specially installed to intercept them. But the flux of charged particles and neutrons, produced during this process, creates a dangerous dose rate for nearby situated equipment, fiber-optic cables, sanitary water tube and electronics. Their models have been implemented also in the FLUKA model of the slow extraction area.

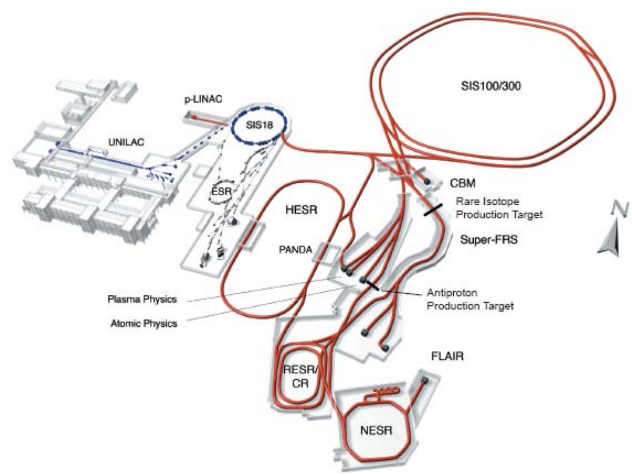

Figure 1: Schematic view on the existing GSI facility: UNILAC, SIS18, ESR (blue line) - and the planned FAIR facility on the right: the superconducting synchrotrons SIS100, SIS300, the collector ring CR, the accumulator ring RESR, the new experimental storage ring NESR, the rare isotope production target, the superconducting fragment separator Super-FRS, the proton linac, the antiproton production target, and the high energy antiproton storage ring HESR. Also shown are the experimental stations for plasma physics, relativistic nuclear collisions (CBM), radioactive ion beams (Super-FRS), atomic physics, and low-energy antiproton and ion physics (FLAIR).

RESULTS

In FLUKA simulation the whole slow extraction area have been investigated (fig. 3)

Neutron Field in the Niche

The niche in the wall of the tunnel is one of the points of interest because of electronics which will be installed there. Niche volume is shielded by a concrete wall of 1.5 m thickness.

* a.b.plotnikov@gsi.de

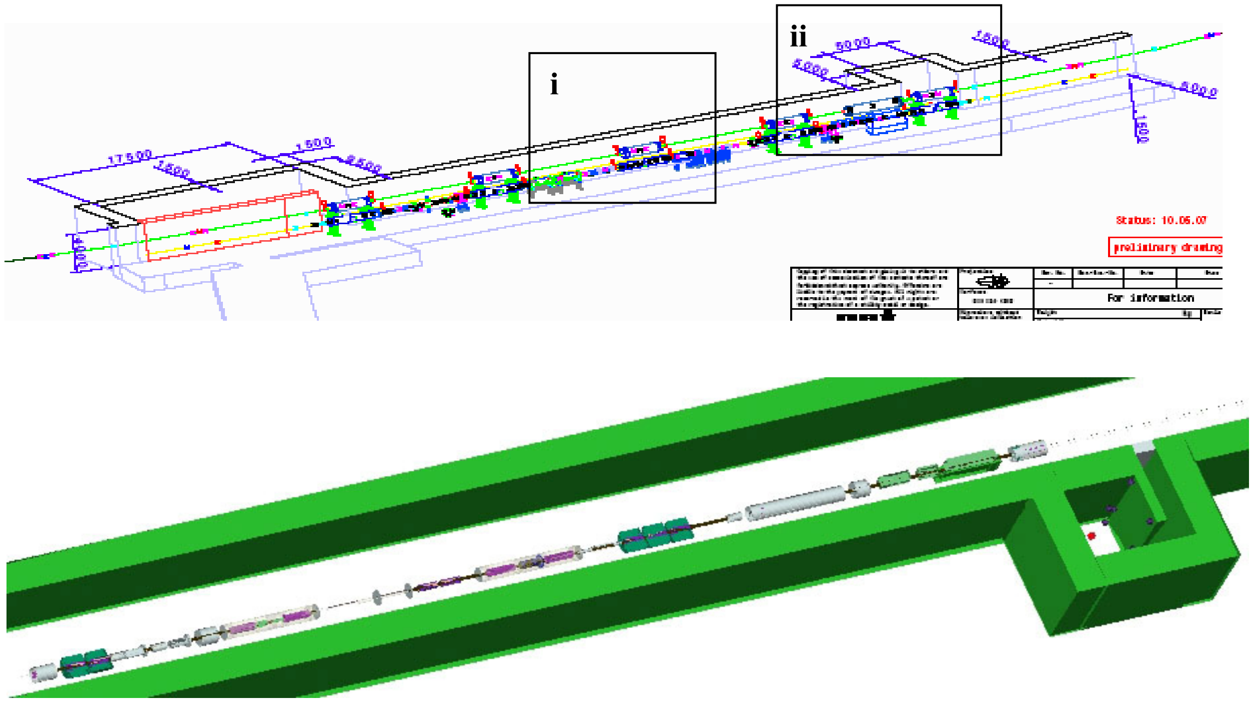

Figure 2: on the top - Original design of the Slow Extraction: i – part of the SIS100 line which contains two blocks of the Electrostatic Septum, and Duplet with two quadruples and collimator inside; ii – area with beam dump and niche for electronic equipment; in the bottom - Model of the original geometry in FLUKA code, visualisation has been done by using Simple Geo code. [4]

For a chip or microprocessor there exists a probability of a SEU. It depends on the energy of the interacting neutrons. Several Fluka detectors have been installed in the niche volume to score the flux of the neutrons.

Using the data from Fluka simulation and SEU probability [5] it is possible to calculate the number of the SEU per year M.

$$M = \sum_{\Delta E} F(E) \times N_{prim.particle.} \times T \times P(E)$$

where F(E) is the flux of the neutrons depending on energy, $N_{pirm.particle}$ - number of the primary particles, T – time of the irradiation per year, here 6700 hours of slow extraction operation were taken, P(E) – probability of the SEU.

In this case the maximal number of SEU per year of operation was 0.2.

Doses in the Niche

The doses deposited in targets inside the niche have been calculated. The average dose from neutrons was 1.3±0.2 Gy per year, and the total dose from all particles and gammas was 260±30 Gy per year. The lifetime dose for the electronics is 10kGy.

The full flux of neutrons in the niche in the simulation was 9.4×10^{11} particles per year.

Dose Distribution in Electronics, Glassfiber-Optics Along the Line

Several test cables have been implemented in the Fluka model to investigate the irradiation damage in fiber optics and electronics inside the tunnel in the slow extraction area. The ditch and the two niches in the floor of the tunnel serve as a shelter for electronics and fiber-optic cables.

The maximum dose for a fiber-optic cable was 70kGy in the closest point to the epicentre of beam loss. In the other scoring points the loss was less.

Dose Rate for Sanitary Infrastructure

Over the main tunnel for SIS100/300 an auxiliary tunnel is situated. It is shielded by 1.5 m thick concrete roof. Some sanitary infrastructure is going to be installed therein. In the present model three water tubes have been placed in the niche above the main tunnel.

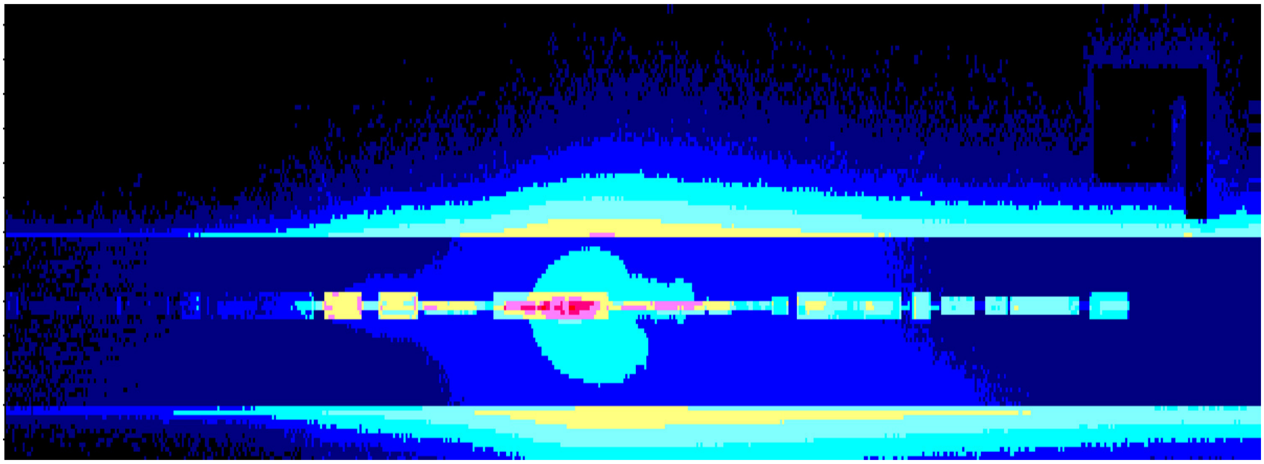

Figure 3: Dose rate map (relative units) of the tunnel of the Slow Extraction area.

Results of the simulation show what the maximum dose rate spot in water tubes is situated exactly above the collimator and is equal to 2.5 mSv/h.

Conclusions

As the result of this work we have estimated the life time for electronics and the fiber-optic cables situated in the slow extraction area.

For the electronics in the niche in the left wall, covered by 1.5 m concrete wall and situated almost 25m far from the point of the lost beam impact, simulation showed that the number of SEU varies from 0.06 to 0.2 cases per year. It gives us 1 accident per 5 years.

If one takes the CERN criterion for the radiation tolerance of 10^{12} $n{\cdot}cm^{-2}$ for fast neutron fluence and 200 Gy for the lifetime integrated dose, then the equipment in the niche needs additional shielding in order to reduce the neutron flux and the deposited dose [6].

Calculation of the dose rate inside the accelerator tunnel shows that it is not possible to put any electronics around the collimator without shielding.

On the other hand, the doses for the fiber-optic cables are under the one-year-lifetime limit even in the most dangerous position. Here we used the 80kGy lifetime criterion, which was taken from [7].

The dose rate in the water tubes brings up the question of the tube cross-section and the speed of the flow. In case of motionless water the dose rates are intolerable. But for the speed of the flow of around 1 m^3/s, the activation of the water will be within the limit of tolerance, because the part of the tunnel with dose rate above 1μSv/h is only 30 m long.

PLANS FOR FUTURE

Although the results still need to be cross-checked with calculations by other particle transport codes, we have now reliable estimates of the radiation damage for the construction elements of the equipment situated in or around the main tunnel of SIS100/300. At the beginning of May 2008 an irradiation test was performed at GSI with the aim to determine the dose tolerance for particular materials which will be used in future accelerator equipment. Results of this experiment are going to help us to estimate the life time of this equipment and find a solution to protect it against the radiation damage produced by beam loss during the slow extraction.

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