PREPARATION OF THE IRRADIATION TEST AT CAVE HHD OF GSI DARMSTADT

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Abstract

In the frame of the FAIR project in spring 2008 an irradiation test of superconducting magnet components was done at GSI Darmstadt. Cave HHD with the beam dump of SIS18 synchrotron was taken as the test area. The beam dump was reequipped to meet the irradiation test requirements. Thereby the first stage of preparation for the irradiation test was to investigate the radiation field around the reconstructed beam dump from the point of view of radiation safety. FLUKA simulations were performed to estimate the dose rate inside and immediate outside of the cave during the irradiation. The simulations showed safe level of the radiation field, and it was later confirmed by the measurements provided by the radiation safety group of GSI.

MOTIVATION

The Facility for Antiproton and Ion Research (FAIR) is planned to be finished in 2015 (Fig. 1). In the frame of the project among other accelerators 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. Thus, the slow extraction area is the region with the highest beam loss rate in the whole tunnel, accommodating the two synchrotrons.

At the present stage of SIS100/300 facility design, it is very important to investigate the lifetime of the materials which will be used in magnets and other equipment of the new facility. Since the superconducting magnets are the most important component of the synchrotrons, it is necessary to know as precisely as possible the radiation hardness of the most radiation fragile material used in the magnets – the insulators.

THE RADIATION TEST SET-UP

The significance of the presented irradiation test consists in the unique setup of the target. Main aim of the experiment was to reproduce the real beam-loss conditions during the operation of the synchrotron. All test samples were shielded by stainless steel plate which represented the wall of the vacuum chamber. Beams hit the surface of this plate at a tiny angle to reproduce the charge exchange losses and losses in the slow extraction area [2].

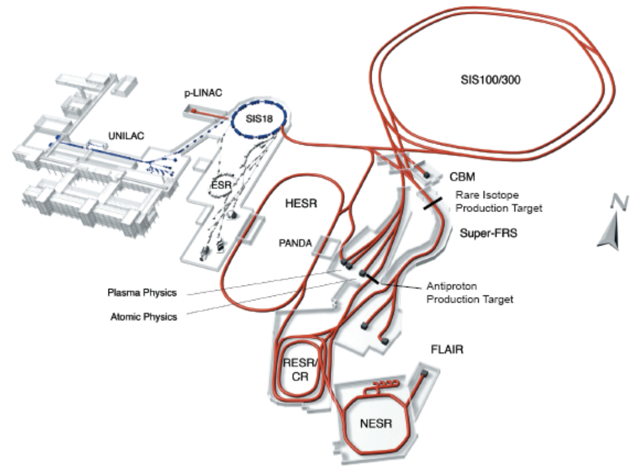

Figure 1: Schematic view on the existing GSI facility: UNILAC, SIS18, ESR (blue line) - and the planned FAIR facility on the right: the superconducting synchrotrons SIS100, SIS300, the collector ring CR, the accumulator ring RESR, the new experimental storage ring NESR, the rare isotope production target, 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).

HHD Cave

Facility of the SIS18 contains a beam dump for the emergency dump of the high energy ion beam (Fig. 2). The beam dump is situated in the HHD cave. It is a massive iron cube with a cavity to accept the beam. This place was taken for the needs of the experiment. Part of the vacuum line 1.5 m long was removed to let us install a special transporter. This mechanism allowed moving the target in two horizontal dimensions of freedom. Thus one can remotely drive the target left-right in order to centre it relatively to the beam axis and also push-pull it in order to get the target inside the beam dump cavity or get it outside.

V target

All components of the target were installed on the so-called V-target (Fig. 3a). Each of the two arms of the V-target was a plate of stainless steel. All the samples under investigation were situated behind those plates, grouped

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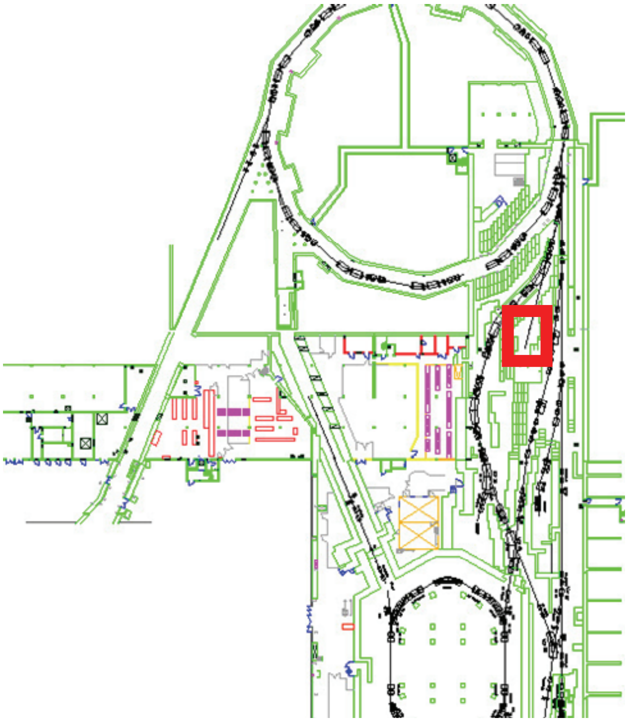

Figure 2: AutoCAD plot of the SIS18. The experimental area, cave HHD, is marked by red square.

in five identical modules (Fig. 3b). Last sixth module was empty. It was used for calibration of the ion flux. The beam of U^{28+}, 1 GeV/u passed the collimator and irradiated the surface of stainless steel plates. By using the method of scanning radiation treatment each single module absorbed different flux.

Samples

For the test the following samples of the equipment and materials were taken: S1 – stack of polyimide foils for thermal, mechanical, electrical tests and measurements by optical spectroscopy; S2 - kapton insulated wire; S3 – nuclotron cable; S4 - SIS300 cable; S5 – corrector conductor; S6 – SuperFRS conductor; S7 – voltage breaker; S8 – G11 rod for mechanical test in compression mode; S9 – G11 "dog bones" for tensile test; S10 – polyimide foils glued with Pixeo; S11 – G11 "sticks" for thermal conductivity test; S12 – G11 plate for high voltage tests; S13 – temperature sensors (Fig. 3b).

All of the samples were installed in the special holders and situated directly behind the stainless steel plates.

Radiation Safety in HHD

The beam dump was specially constructed to intercept safely high intensity heavy ion beams. The arbitrary changes of the beam dump set-up were not allowed according to the rules of radiation safety of the accelerator facility. Reconstruction of the beam line for the aims of the irradiation test dramatically changed geometry of the beam dump, thus the estimates of the dose rates in the cave and around it was necessary.

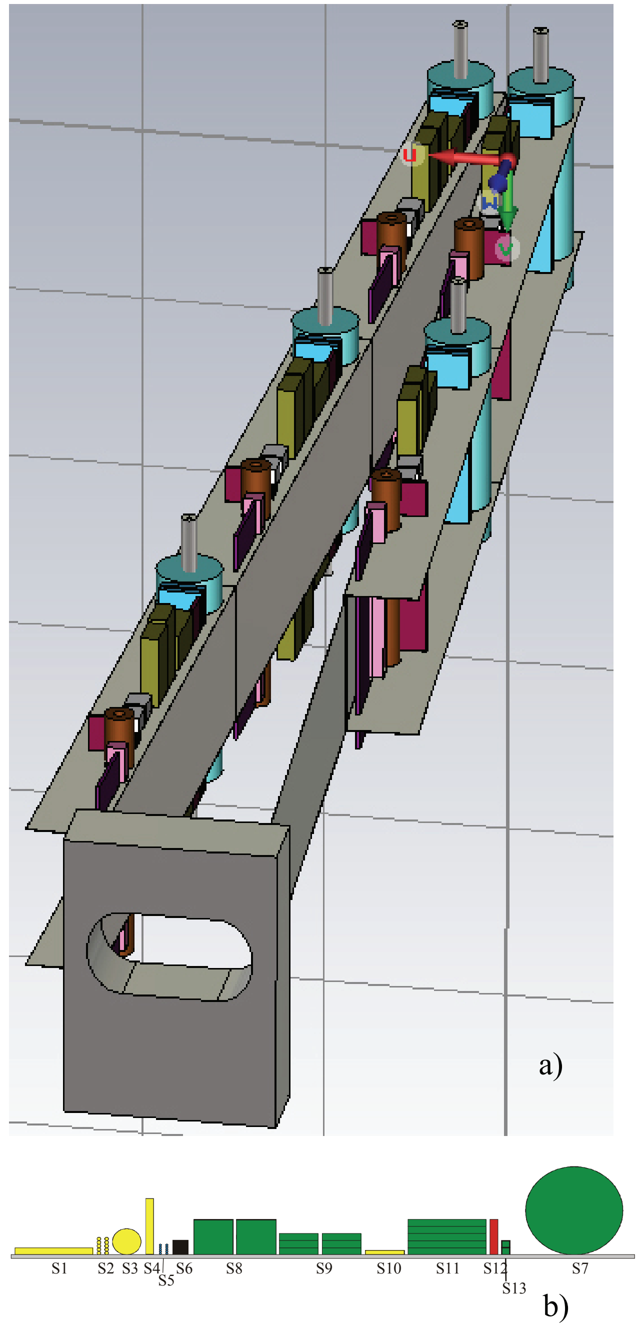

Figure 3: a) 3D virtual model of the V-target with the collimator and all samples installed; b) order and numbers of the samples in one single module of the V-target [3].

Originally the dumped heavy ion beams passed through the transportation channel from SIS18 to the 700 mm deep beam dump cavity. The cavity was directly connected to the vacuum pipe of the transport line.

New setup required the following changes: the vacuum chamber of the beam transport line were interrupted 1.5 m before the beam dump and was closed by a stainless steel vacuum window; the space between this vacuum window and the beam dump as well as the space inside the cavity of the beam dump were used to accommodate the rails of the target set-up, the collimator, the sample holder, video-cameras and scintillating light targets.

In the reconstructed set-up of the beam dump the heavy ion beam would not hit the beam dump directly, but it would first pass through the target set-up with the irradiation samples. This would definitely increase the dose rate inside the cave. The aim of our simulation was to show how much the dose rate would increase outside the cave, and would that dose rate be below the safe level.

COMPUTER SIMULATION OF THE IRRADIATION TEST

To investigate this problem the FLUKA code was used. FLUKA is a general purpose tool for calculations of particle transport and interactions with matter, covering an extended range of applications spanning from proton and electron accelerator shielding to target design, calorimetry, activation, dosimetry, detector design, Accelerator Driven Systems, cosmic rays, neutrino physics, radiotherapy, etc. [4-6].

Simulation Setup

The entire HHD cave was simulated with the help of FLUKA, including beam dump details, shape and thickness of the concrete walls and geometry of the labyrinth. To obtain the high statistics without increasing the CPU time so-called BIASing was used. This feature of FLUKA allows multiplying the amount of particles on a border between regions with different BIAS coefficients.

The aim of the simulation was to get the level of the dose rates above the roof of the HHD cave, where the uncontrolled access area starts, and at the entrance to the HHD cave where the sluice is situated and controlled access area starts. Both places were the most problematic zones in sense of radiation safety.

Results of Numerical Estimation of the Dose Rate in the HHD Cave

Simulation with the help of the FLUKA code gave the results which allowed us to evaluate the dose rate in the whole volume of the HHD cave and in the surrounding area. The dose rate level in the spots of considerations is represented in Fig. 4.

This picture shows the dose rate in horizontal cross section of the cave at the 2 m height. Beam came from the top and absorbed in the beam dump (red flash in the centre of the picture). The left picture corresponds to the original construction of the beam dump and the right one shows the situation for the reconstructed cave.

For example, the dose rate near the entrance of the cave HHD (light blue area at the bottom of the plots on Fig. 4) is from 1 to 10 μSv/h. This level meets the requirements of the radiation safety.

In Fig. 5 the dose rate above the roof of the cave is shown. This is a horizontal cross section at the 0.5m distance above the roof of the HHD cave. The left plot corresponds to the original geometry, the right one to the new one. Most dangerous area lies exactly over the beam dump (the yellow spot at the bottom of the plots)

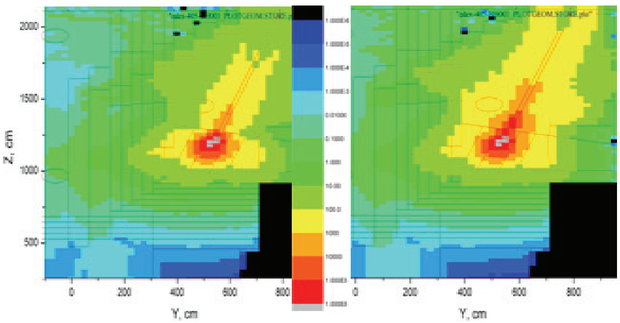

Figure 4: Dose rate map in the HHD cave (horizontal cross section): left – original geometry of the beam dump, right – after reconstruction. It the middle scale of the dose is situated, range in mSv/h.

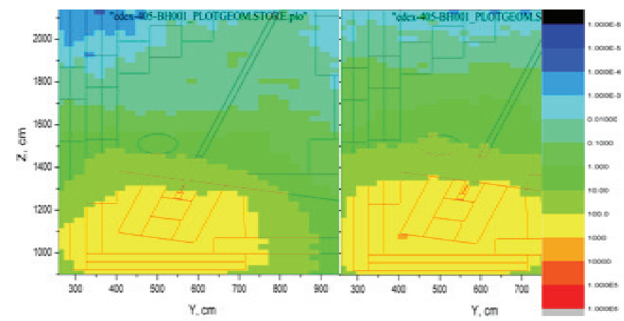

Figure 5: Dose rate map on the roof above HHD cave (horizontal cross section): left – original geometry of the beam dump, right – after reconstruction. At the right side scale of the dose is situated, range in mSv/h.

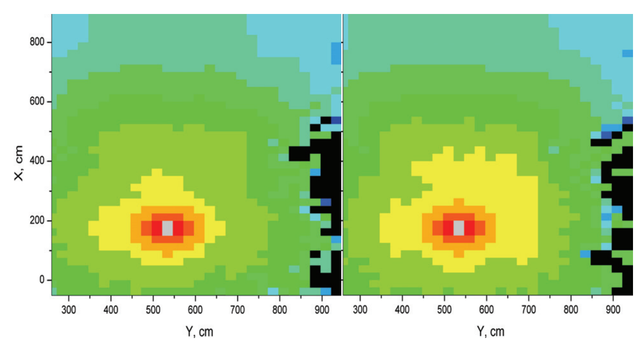

Figure 6: Dose rate map in the HHD cave (vertical cross section along the front of the beam dump): left – the original geometry of the beam dump, right – after reconstruction. The scale of the dose is the same as in Fig. 4 and 5.

Thus we obtained the dose rate level on the roof of the cave of 10 – 30 μSv/h in both cases in the hottest point. One may conclude, the changes to the cave introduced with the experimental setup inside the cave did not change the dose rate above the test site.

At last in Fig. 6 one can see the dose rate in vertical cross section of the HHD cave which is perpendicular to the vacuum tube and lies on the front surface of the beam dump. The left plot shows the dose distribution in the original cave configuration, the right one shows the same after the reconstruction. Those plots demonstrate that dose rate inside the cave is higher when the new experimental setup installed, but the doses outside the concrete walls are the same in both cases.

CONCLUSIONS

The experimental setup which was installed in the cave HHD for the purpose of the irradiation test changed the dose distribution inside the cave and in the area around this cave volume. The numerical estimation has been done by using the FLUKA code. Results showed that the average dose rates expected during the irradiation test become larger inside the cave. But the dose rates outside the HHD cave are the same as the dose rates one can expect from the original beam dump configuration. Thus all the safety requirements were preserved, and the experiment has got the permission. The measurements of the dose rates performed by the radiation safety group during the experiment (6.05.08 – 14.05.08) gave a good agreement with numerical estimations.

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