COLLIMATION AND MATERIAL SCIENCE STUDIES (ColMat) AT GSI*

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Abstract

Within the frame of the EuCARD [1] program, the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt is performing accelerator R&D in workpackage 8: ColMat. The coordinated effort is focussed on materials aspects important for building the FAIR accelerator facility [2] at GSI and the LHC upgrade at CERN. Accelerator components and especially protection devices have to be operated in high dose environments. The radiation hazard occurs either by the primary proton and ion beams or the secondary radiation after initial beam loss. Detailed numerical simulations have been carried out to study the damage caused to solid targets by the full impact of the LHC beam as well as the SPS beam. Tungsten, copper and graphite as possible collimator materials have been studied. Experimental an theoretical studies on radiation damage on materials used for the LHC upgrade and the FAIR accelerators are performed at the present GSI experimental facilities. Technical decisions based on these results will have an impact on the FAIR component specifications. A cryogenic ion-catcher prototype will be constructed and tested. The ion-catcher is essential for reaching highest heavy ion beam intensities in SIS100 [3]. The prototype will be setup at GSI to perform measurements with heavy ion beams of synchrotron SIS18.

INTRODUCTION

EuCARD contains all EU FP7 accelerator R&D workpackages. The GSI activities within this framework are contained in EuCARD workpackage 8 (ColMat). The goals of ColMat are the identification and characterization of new materials to be used generally in accelerators and especially for collimators and other components exposed to high-dose radiation for LHC and FAIR. The ColMat R&D activities at GSI include simulations, irradiation tests and actual prototyping of collimators.

We present an administrative overview and scientific summary of the combined R&D at GSI for the ColMat workpackage.

COLMAT ACTIVITIES AT GSI

The different investigations are performed within the Sychrotrons, Material Research, Plasma Physics and Accelerator Theory departments of GSI.

Simulation of Beam-Material Interaction

Simulations are performed to estimate the damage in collimators, beam stoppers or magnets have to suffer due to accidental loss of a part or full beam of SPS and LHC [4]. The SPS delivers protons with 450 GeV to LHC where they are further accelerated to 7 TeV. Simulations have been performed for protons at these two energies interacting with copper, tungsten, and graphite targets. The simulations are performed in two steps. First, the energy loss of the protons is calculated with the FLUKA code. The resulting energy loss data is used as input for the SD hydrocode BIG2 simulating the thermodynamic and hydrodynamic response of the target (see Figure 1). The penetration depth of the projectiles is much longer than predicted with a static model: LHC protons penetrate up to 35 m in copper and 10 m in graphite. Both the SPS and LHC beam generate severe damage to the targets.

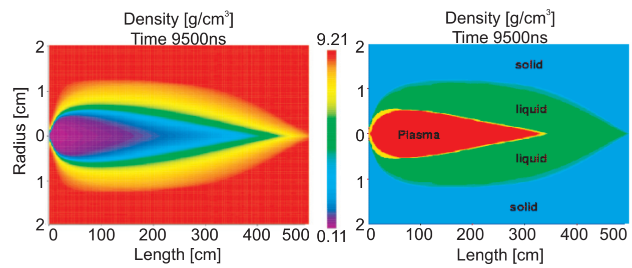

Figure 1: Simulation of a 7 TeV proton beam at the LHC in a graphite target. The maximum penetration depth for a LHC beam in this simulations was 35 m in copper and 10 m in graphite. The right picture show the distribution of the different phases corresponding to the density plot on the left.

Another focus of the ColMat project at GSI is the design of the collimation system of the halo collimation in SIS100. This work has started in 2010. Studies of ion beam dynamics and halo formation will be included. A two stage collimation system for protons is under consideration. The protons will be scattered in the first stage collimator and are stopped in the second stage collimator downstream. SIS 100 will be operated with ions of intermediate charge state (e.g. U^{28+}). Due to the immediate loss of electrons on impact to any material, heavy ions cannot be collimated with the same two stage approach foreseen for protons. A separate halo collimation system for heavy ions has to be developed to remove the beam halo in a single collimator approach.

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Radiation-induced degradation of materials

The Materials Research group at GSI has long experience in exposing materials to energetic heavy ions and characterizing the resulting damage. To study radiation-induced degradation of thermo-mechanical properties, graphite and AC 150 carbon-carbon composite samples were irradiated with heavy and light ions. The irradiation experiments were performed at various target stations using UNILAC beams of maximum 11.4 MeV/u (M-branch, XO). Exposure to higher energies (several hundred MeV/u Uranium ions) available at SIS18 was performed. Furthermore, some samples were placed at the beam dump of SIS18 for high dose tests.

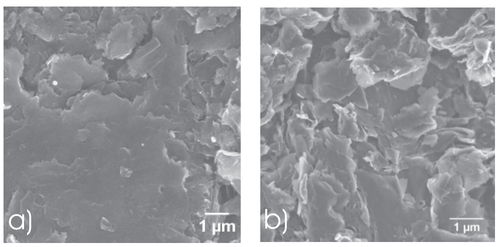

Figure 2: Low magnification SEM images of polycrystalline graphite sample (a) before and (b) after irradiatiation with $5 \cdot 10^{12}$ U ions/cm^2 reveals surface corrugation

At present, structural changes and hardening of irradiated graphite samples are under investigation. Depending on the specific modifications and functional properties, the most suitable material will be selected for the construction of collimators to be used for FAIR and LHC upgrade.

Construction of a "Cryo Catcher" Prototype For FAIR

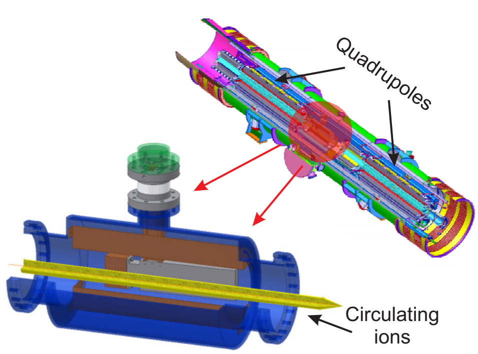

Figure 3: Sketch of the cryocollimator prototype for FAIR. The cryo catcher will be placed in between the two main quadrupoles in the arc sections of SIS100. The catcher will catch uranium ions which lost electrons due to interaction with residual gas.

FAIR's main synchrotron SIS100 will be operated with ions of intermediate charge state. The design ion is U^{28+}. A main issue at operation with highest beam intensities is to maintain ultra high vacuum conditions during the complete machine cycle. Interaction of the beam with residual gas atoms will cause ions to loose electrons and consequently lead to beam loss. Ions hitting uncontrolled on the walls of the vacuum vessel will desorb loosely bound atoms and molecules. The beam will interact with the released gas causing more beam loss which in turn creates even more gas desorption. This dynamic vacuum behavior is studied with the STRAHLSIM code developed at GSI [5].

To control the beam loss caused by charge-exchange, a special charge separator lattice with a peaked loss distribution has been developed for SIS100 [6, 2]. Dedicated ion catchers will be placed at the loss positions. A prototype ion catcher is being developed at GSI [7]. The cryo catcher is placed within the cold arcs of SIS100 between the main quadrupoles. The lost ions impact a block of dedicated low desorption material. The desorbed gas is removed by pumping cold surfaces surrounding the catcher. This setup keeps the influence of the lost ions and the desorbed gases to the circulating beam minimal.

The prototype construction will be finished in 2010 and the first tests with beam are foreseen in 2011 with ions from the existing GSI facility.

SUMMARY

The present and future high energy, high power accelerators are demanding advanced materials used in collimation and machine protection devices. The R & D activities within the EuCARD workpackage 8, ColMat help to form collaborations between European research laboratories meeting these demands. GSI activities in this framework are progressing well and first results have been obtained.

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