HiRadMat: A NEW IRRADIATION FACILITY FOR MATERIAL TESTING AT CERN

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Abstract

HiRadMat (High Irradiation to Materials) is a new facility under construction at CERN designed to provide high-intensity pulsed beams to an irradiation area where material samples as well as accelerator component assemblies can be tested. The facility uses a 440 GeV proton beam extracted from the CERN SPS with a pulse length of 7.2μs, to a maximum pulse energy of 3.4 MJ. In addition to protons, ion beams with an energy of 173.5 GeV/nucleon and a total pulse energy of 21 kJ can be used. The facility is expected to become operational in autumn 2011. The first tests will include candidate materials and prototype assemblies of LHC collimators foreseen to operate at the ultimate LHC beam powers. Experiments on beam windows and high-power target material options, such as tungsten powder, are also planned. The paper will describe the layout and design parameters for the facility and the way experiments can be operated. Ideas on online and post-irradiation tests and instrumentation will be outlined.

INTRODUCTION

In the new generation of accelerators like LHC, the circulating beam has sufficient power that can reach deposited energy density of interaction with accelerator components well above the damage thresholds of the most robust materials. For the near beam components of LHC like collimators, lot of effort has been put in the material choice and overall design, however their robustness at beam impact with the nominal beam intensity or even fractions of it is difficult to predict even using the most advanced multi-physics simulation tools available today. To avoid destructive incidents during operations, any new potentially beam intercepting device must be tested prior to its installation for sufficient robustness to as realistic as possible conditions to the future operation, to at least ensure that possible and unavoidable damage can be locally constrained and not be catastrophic (e.g. causing damage to nearby components, water leaks into vacuum from the cooling system, spread of sputtered materials and vacuum quality deterioration over long distances).

Past tests of robustness and damage effects on LHC collimators and materials were performed in ad-hoc installations in the TT40 transfer beam line to LHC and CNGS in 2004 and 2006 [1]. The difficulty in performing such important tests on temporary installations and the potential impact on operating transfer lines were the main motivations for the decision to build a new dedicated facility, called **HiRadMat - High Radiation to Materials**, designed to study beam shock impacts on materials and accelerator components, primarily LHC collimators.

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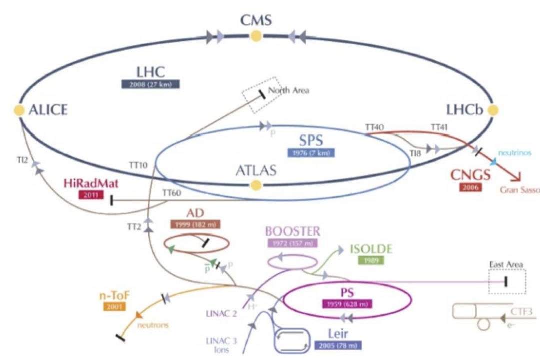

Figure 1: The CERN accelerator complex indicating the location of HiRadMat.

HiRadMat will use an extracted primary proton or ion beam from SPS (see Fig. 1) of LHC type. The main beam parameters are listed in Table 1 and in [2]. The beam spot size at the focal point at the experiment can be varied from 0.5 to 2 mm^2 which together with the variable beam intensity offer sufficient flexibility to test materials at different deposited energy densities.

Table 1: Key Parameters for the HiRadMat Beam

	Protons	Ions(Pb^{82+})
Energy	440 GeV	173.5 GeV/u
Bunch int. (max)	1.7×10^{11} prot.	7×10^{9} ions
No of bunches	1 to 288	52
Pulse int. (max)	4.9×10^{13} prot.	3.6×10^{9} ions
Pulse energy (max)	3.4 MJ	21 kJ
Bunch length	11.24 cm	11.24 cm
Bunch spacing	25,50,75,150 ns	100 ns
Pulse length	7.2 μs	5.2 μs

Beyond the needs of LHC, HiRadMat will be, like all CERN beam facilities, open to other users and is also included in the EUCARD FP7 European Project as transnational access to facilitate its use by European teams. Experiments in HiRadMat will contribute to the understanding of the behavior of materials under beam impact, thus providing important feedback for tuning of mechanical multi-physics simulation codes thus enhancing their predictive power and impact on the design of the new high-power accelerators and spallation target stations considered these days. The construction of the facility is basically completed, and the commissioning with beam started [3]. The facility will become operational later in Autumn 2011.

FACILITY LAYOUT

HiRadMat will be located in the TNC tunnel in the SPS BA7 area, used in the past by the West Area Neutrino Facility (WANF). A large scale decommissioning was performed to clean-up and convert the former WANF tunnel and target area to the needs of the new facility [4]. The beam will be delivered from the SPS to HiRadMat using the existing TT60 transfer line via a new transfer line, named TT66. The experimental area covers the last 10 m of the TT66 line where three test stands of 2.2 m long each are foreseen (see Fig. 2) upstream of the former WANF target now converted to a beam dump. Details on the beam design and first performance results from its commissioning can be found in [3].

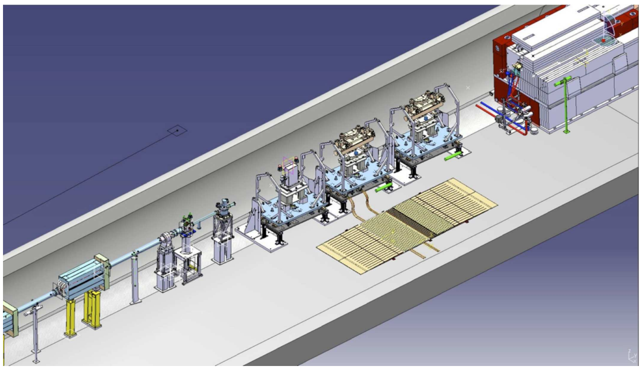

Figure 2: 3D view of the HiRadMat experimental area.

EXPERIMENTS IN HIRADMAT

HiRadMat is not an irradiation facility where large doses on equipment can be accumulated. It is rather a test area designed to perform single experiments to evaluate the effect of high-intensity pulsed beams on materials or accelerator component assemblies in a controlled environment. The facility is designed for a 10^{16} maximum number of protons per year, distributed among 10 experiments, each having a total of 10^{15} protons or about 100 high-intensity pulses. This limit allows reasonable cool-down times for the irradiated objects (few months to a year) before they can be analyzed in a specialized lab.

Experiments in HiRadMat must comply with strict safety requirements according to the CERN rules and regulations, Access in the experimental area will be controlled at all times. To minimize the dose taken for the installation and exchange of experiments, a simple interface with a support plate is defined as shown in Fig. 3. The support plate with its lifting structure defines a volume of 2 m(L)$\times$0.7 m(W)$\times$1.5 m(H) for the experiments and can support a total weight of 2 t. It can be remotely manipulated with the overhead crane of the facility and positioned using fixed mechanical references within 0.1 mm.

Services like water cooling, electrical power and signal cables are delivered via plug-in connectors such that the experiments can be installed with minimal intervention in the area. A simple or double confinement of the test material must be provided to avoid any spray of melted (or sublimated or evaporated) material in the test area and provide an inert gas or vacuum environment for the test material. Longer setups can be possible by combining more support tables within the capabilities of the overhead crane. The experiments won't be connected to the primary beam line vacuum to avoid pollution of the TT66 and adjacent TI2 beam lines. Special beam windows carefully placed to avoid rupture by the beam can be used for the experimental containment.

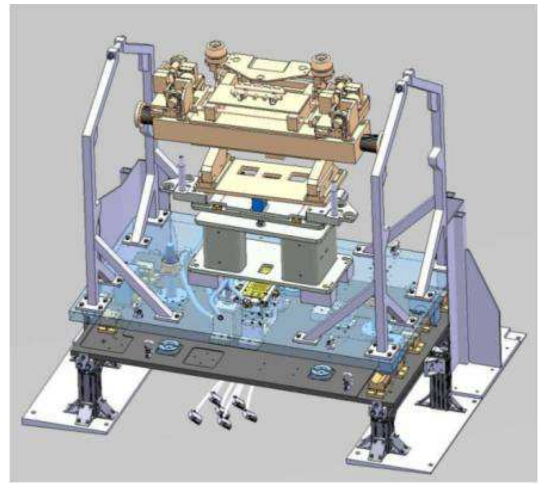

Figure 3: 3D view of a test stand: the fixed base (in black) the lifting support plate (blue) and the experimental test stand - in this example of an LHC collimator.

Figure 4: Photo of a support interface plate being positioned in the experimental area.

Interested experimental teams will have to fill an application form requesting a slot in the HiRadMat planning, providing a brief scientific justification for the experiment, a technical description and a beam pulse list with intensity and beam properties. Proposals have to reach the HiRadMat management by Autumn for the planning of the next year, which for SPS is typically from April to November.

A User Selection Panel will review the proposals and give an initial approval and time slot for the experiments which will be validated once a full technical and safety review of the proposed experiment is completed.

HiRadMat will operate as one of the SPS users. Low intensity beams (up to 72 bunches) can be scheduled with minimal disturbance to other users of SPS while high-intensity pulses will have to be explicitly scheduled. Experiments in HiRadMat will be single-pulse mode, with a beam request submitted each time via the SPS control system. The time between two pulses would depend on the requested configuration and can be long if a reconfiguration of of the SPS and the upstream injector chain would be required.

The steps in the lifetime of an experiment in HiRadMat is outlined in Fig. 5. The experimental setup is first prepared, aligned and tested on a support plate in a surface lab where a test stand identical to those in the experimental area is installed. Then the whole setup is lowered via the access shaft in the underground areas. Underground, it is

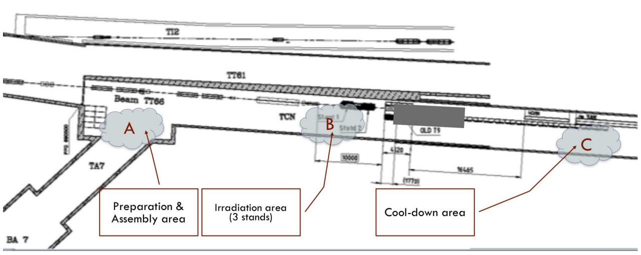

Figure 5: The different stages in the lifetime of an experiment in HiRadMat as explained in the text.

first placed in a non controlled area (position A in Fig. 5) for a final check, and is cabled with the final long cables to the control room at the surface. Then the setup is taken with the overhead crane and installed using the plug-in system in one of the three test positions in the experimental area (position B in Fig. 5). Limited access to the experimental area may be authorized (depending on the radiation levels and the time since the last beam in the area) to install auxiliary equipment, like gas lines, not technically possible via the plug-in connectors. The experiment is then ready to start its physics program with beam. Once completed, is taken remotely with the overhead crane and moved to a downstream area (position C in Fig. 5) for cool-down. The cool-down time would depend on the irradiated material and the amount of beam used for the test. Radiation monitors remotely read are placed in all areas, which allow for careful planning of all operations with minimal human intervention.

Depending on the scientific scope of each experiment online or offline (post -irradiation) analysis will be required. Although rather challenging, online measurements are very interesting as thy provide informaiton on the dynamic of the beam impact on the test material. HiRadMat management will provide scientific and technical support to the users, based on past experience [5]. Online measurements can include: secondary particle flux measurement using pCVD diamond or ACEM detectors to probe density losses in the material, laser vibrometry to measure instantaneous deformations, fast cameras (few kHz frame rate) to visualize the beam impact, accelerometers to measure the propagation of shock waves, local and remote temperature measurements, and acoustic measurements which is a new and very promising technique to measure deformations and the dynamic response of materials. The use of any of these techniques in each experiment must be integrated in its design. The preparation phase as well as the data-taking and analysis efforts must not be underestimated.

SUMMARY AND OUTLOOK

HiRadMat will be a unique facility and test place for accelerator R&D on materials and near beam components. The facility offers a powerful and flexible beam that can be easily adjusted to simulate the beam impact to materials in the present and future accelerators. The design of the experimental area is optimized to support the experiments with remote handling and possibilities for specialized online diagnostic systems. From the first call, 12 proposals for experiments have been received so far that cover a wide spectrum of studies, which will provide important feedback on the damage process of materials under beam impact. In the future, HiRadMat should be completed with a surface lab where simple, non-destructive analysis of the radioactive samples from the experiments can be performed.

ACKNOWLEDGMENTS

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