Results from the HiRadMat Primary Beam Line Commissioning


Abstract

The High Radiation to Materials facility (HiRadMat) is a new experimental area at CERN, for studies of the impact of high-intensity pulsed beams on accelerator components and materials. The beam is delivered from the SPS by a new primary beam line, which has been constructed during the 2010/11 winter technical stop. The paper summarizes the construction phase and describes the results from the beam line commissioning in spring 2011. Beam parameter and aperture measurements are presented, as well as steering tests. A special emphasis has been put on the handling of the exceptionally flexible beam line optics in the control system.
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INTRODUCTION
The High Radiation to Materials facility (HiRadMat) is a new irradiation facility at CERN designed for testing accelerator components and materials with the impact of high-intensity pulsed beams. This facility is capable to provide high-power LHC type proton and lead ion beams with energies of 440 GeV and 173.5 GeV per nucleon, and with pulse intensities of up to $5 \times 10^{13}$ protons and $3.6 \times 10^9$ ions, respectively. Due to these unique beam properties the facility is ideally suited for testing equipment for the LHC and other high-intensity accelerators. The detailed beam specifications can be found in [1].

HiRadMat primary beam line
The HiRadMat facility is located in the cavern of the former West Area Neutrino Facility [2], in front of the former neutrino production target. It shares the same extraction channel with the LHC beam 1, the latter being transported through the TI 2 transfer line down to the LHC: the HiRadMat beam is extracted from the SPS and sent down the existing TT60 transfer line, from which the new HiRadMat primary beam line (TT66) branches off after ~200 m (Fig. 1). The switching is performed by 8 powerful dipole magnets. The beam is then transported another ~200 m to the experimental area, where five quadrupoles provide the required focussing onto the test objects. The primary beam line design has been described in detail in [3].

HiRadMat experimental area
The HiRadMat experimental area is equipped with three test stands, which can either house small test objects or can be combined for testing up to 9 m long objects (Fig. 2). To be able to serve all three test stands with focused beams the focal point position is adjustable between positions (1) and (3) in Fig. 2. The beam size at the focal point can be varied between $\sigma=0.1$ mm and $\sigma=2.0$ mm. For focal point positions near the beam line exit window or the beam dump entrance window (1 and 3), the minimum beam radius is limited to 0.5 mm to protect the windows against damage. For practical reasons exists a set of 18 predefined optics for the three focal points (1) to (3) and six different beam sizes.

Figure 2: Layout of the HiRadMat experimental area. The focal point is adjustable between positions (1) and (3), with beam radii ranging from 0.1 mm to 2.0 mm.

A detailed description of the HiRadMat experimental area can be found in [4]. This paper focuses on the construction and the commissioning of the primary beam line.

BEAM LINE CONSTRUCTION
The HiRadMat primary beam line has been constructed during the years 2010 and 2011. Due to its vicinity to the TI 2 injection line to the LHC, the installation schedule was strongly influenced by the LHC operation schedule. While the installation work of the main subsystems has been carried out during the 2010/11 winter technical stop,
which lasted several weeks, also the regular 4-day LHC technical stops every 6 weeks have been used for preparation and installation work. Furthermore, work was carried out within short accesses of a few hours between LHC fillings, where no beam is present in TI2 and the area is accessible.

During this period 25 magnets [5], 17 beam instrumentation elements and 200 m of new vacuum system have been installed. Furthermore, 460 new cables with a total length of 4000 m and 14 new or refurbished power converters [6] have been installed. Prior to the installation work, extensive dismantling work of old equipment of former beam lines to the CERN West Area has been carried out at the installation site [7].

The installation work required the temporary dismounting of four magnets in the TI2 transfer line and part of its vacuum system. An additional beam stopper has been installed in TI2 after the switch to ensure the accessibility of the downstream part of TI2 and LHC during HiRadMat operation. Furthermore, the beam interlock system has been adapted for HiRadMat [8].

**BEAM COMMISSIONING**

The first beam has been sent to HiRadMat on 22 June 2011, followed by a period of a few days for validating the beam line design and testing the correct functioning of the beam line equipment. During this period only low-intensity LHC type “probe” single bunches with ~8×10^9 protons per bunch were used. Tests with high intensity beams will follow. The detailed description of the tests and the results can be found in [9].

**Beam line steering**

The first beam sent to HiRadMat reached directly the end of the beam line. The corresponding uncorrected trajectory is shown in Fig. 3. After matching the energy to 439.2 GeV and correcting the trajectory, the trajectory shown in Fig. 4 has been obtained, which is well within the specification of the beam line aperture.

**Beam instrumentation tests**

In TT66 various beam instrumentation elements are installed, which were tested during the beam commissioning: Beam position monitors (BPM), screens (BTV), beam loss monitors (BLM) and a fast current transformer (FBCT).

It was verified with kick response measurements that the signal polarity of all BPMs is correct. The transverse beam profile was measured with the BTV screens. From this measurement reasonable values of the normalized emittance around 2 µm were calculated using the screen matching application.

The beam intensity measured with the FBCT in TT66 was in good agreement with that measured with the upstream FBCT in TT60 and the absolute accuracy will improve considerably as the bunch/total intensity is increased.

The beam loss monitors in the primary beam-line are connected to the beam interlock system in order to disable the extraction of the beam from the SPS in case of beam losses exceeding operational thresholds. During the low-intensity beam commissioning, most of the time no beam losses were detected, as expected for these intensities. Only towards the end of the commissioning period one BLM showed losses above the noise level. This was due to a steering setting which produced high beam excursions. During high-intensity beam operation a resolution of a few 10^-4 Gy is expected.

**Beam line aperture**

Aperture measurements were performed using a typical beam with a 1σ radius of 0.5 mm at focal point 1. While observing the signal of two fast current transformers, located in TT60 and at the end of TT66 respectively, orbit oscillations were induced for both horizontal and vertical planes using corrector magnets at the start of TT60 and recorded with beam position monitors. These oscillations were induced for different phases in 30° steps and different amplitudes of up to 10σ to cover as much as possible of the beam line. As an example, measured and simulated beam position values for two oscillations in the horizontal and vertical plane are shown as a function of the BPM position in Fig. 5.

No significant intensity decrease has been observed between the two fast current transformers and no beam losses above background have been detected with the
The tests showed that for each optics tested during the low-intensity beam commissioning period with high-intensity beams. No serious problems were discovered. The second beam commissioning period with high-intensity beams is scheduled for September and the first experiment is foreseen to take place in autumn this year.

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**REFERENCES**