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HiRadMat High Intensity Beam Commissioning

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Summary

On Wednesday 14 September and Monday 19 September 2011, high intensity proton beam was sent for the first time down the HiRadMat primary beam line (thereafter TT66), onto the beam dump located in the HiRadMat experimental cavern. This high intensity beam commissioning followed a first period of low intensity beam commissioning which took place in June 2011. During the low intensity beam commissioning, it was checked that all beam line equipment operated as specified. Energy matching and beam steering were performed; optics checks did not reveal any optical errors. Aperture measurements confirmed that there were no bottlenecks. Radiation protection monitoring worked as expected and the measurements were within expectation [1].
With the completion of the HiRadMat ventilation system, the high intensity beam commissioning could successfully continue in September 2011. The main outcome is reported in this note.

1. Introduction

The High Radiation to Materials facility - hereafter HiRadMat - was designed for testing accelerator components, in particular those of the LHC and its injectors, with the impact of high-intensity pulsed beams [2]. The HiRadMat irradiation facility will provide high power LHC type proton and lead ion beams with the maximum SPS energy of 450 GeV (baseline operation is 440 GeV) and 177.4 GeV per nucleon (baseline operation is 173.46 GeV), respectively. Beam intensities of up to $5 \cdot 10^{13}$ protons and $3.6 \cdot 10^{9}$ ions will be available. The detailed beam specifications can be found in [3].

Two beam commissioning periods took place, the first one from Wednesday 22 June to 28 June 2011 with low intensity beam [1]. The second period took place on Wednesday 14 September and Monday 19 September 2011, with high intensity beam. An integrated intensity of $4.46 \cdot 10^{13}$ protons was sent onto the HiRadMat beam dump.

2. High intensity beam commissioning

A special feature of the HiRadMat beam line is its optics flexibility. It can provide beams with beam radii between σ=0.1 mm and 2.0 mm, at different focal point locations. For the different beam sizes and focal points different optics must be loaded. For the purpose of high intensity commissioning, the optics used was F1-1_00-1_00-2011v1 (σ=1 mm in both planes). It is recalled that the corrector RIBH.610337 has to be of positive polarity for the HRM cycle (while for the LHC it has negative polarity).

Pilot bunches were sent down the beam line to check the trajectory and re-establish the low-intensity commissioning reference. No correction was required; the trajectory was similar to the June reference recorded during the low intensity beam commissioning [Fig.1].

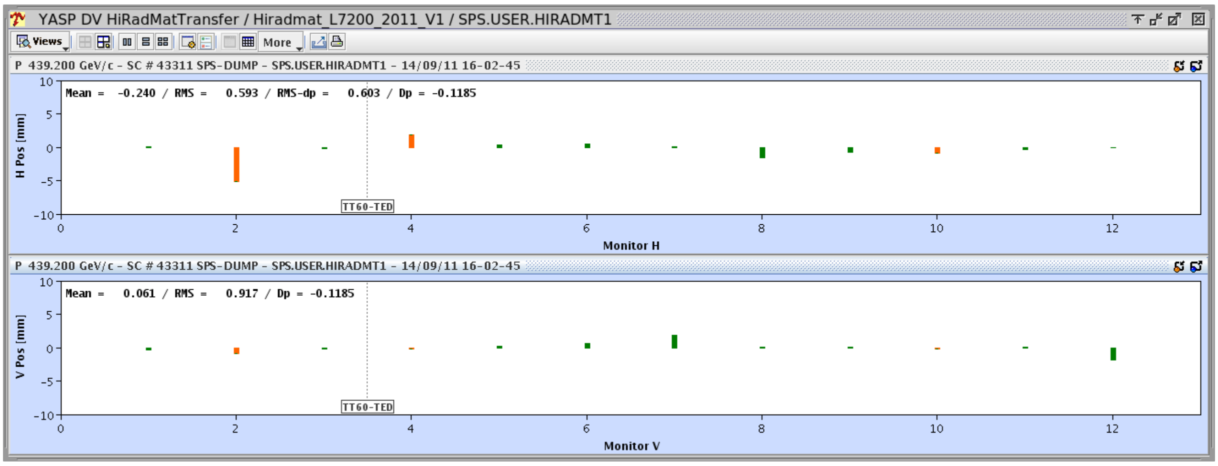

Figure 1 Pilot trajectory difference wrt June reference

The positioning of the 12 bunches on the MKE kick waveform flat top was then checked before extracting into the beam line [Fig.2].

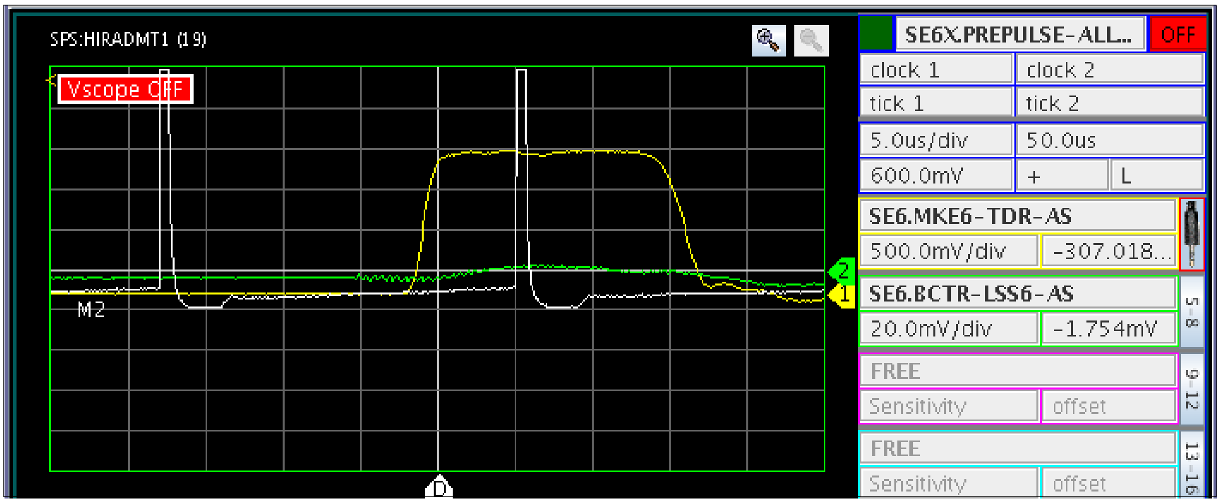

Figure 2 BCT versus MKE waveform for 12 bunches

The difference trajectory of the first batch of 12 bunches measured in the line is shown in Figure 3. The corresponding losses are shown in Fig.4. The trajectory was very similar to the one with pilot beam and the losses measured occurred actually after the end window of the proton beam line, on the BLMs catching the losses on the beam dump. The threshold values will be updated at these locations.

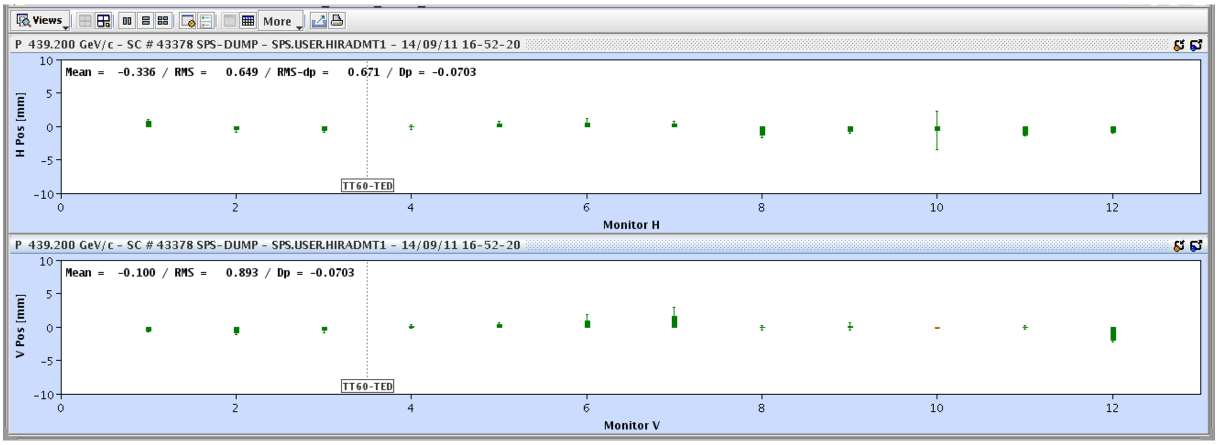

Figure 3 Difference trajectory (w.r.t. reference) with the first batch of 12 bunches

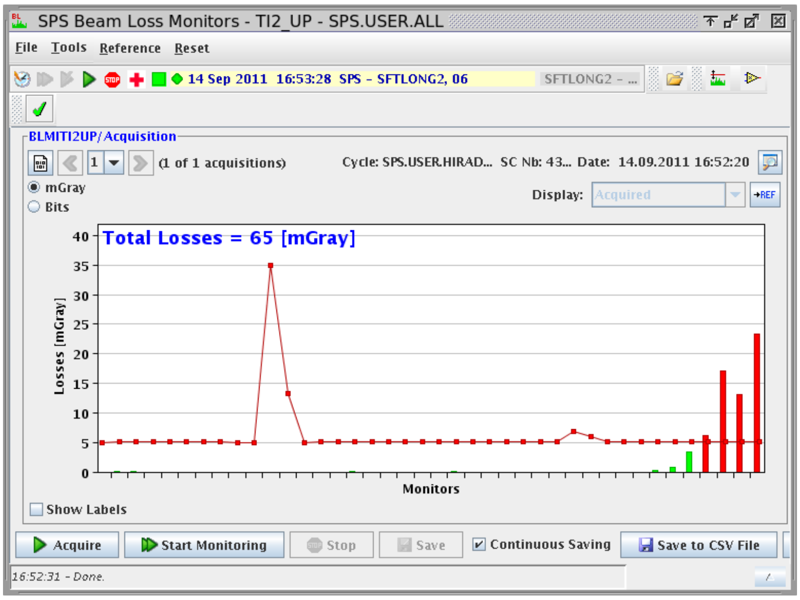

Figure 4 Losses at the BLMs along the TT66 beam line, with the first batch of 12 bunches

The high intensity commissioning continued on Monday 19 September, this time with batches of 36 bunches. One up to four batches were first extracted on the TT60 TED in order to check the correct extraction timing [Figure 5 and Figure 6].

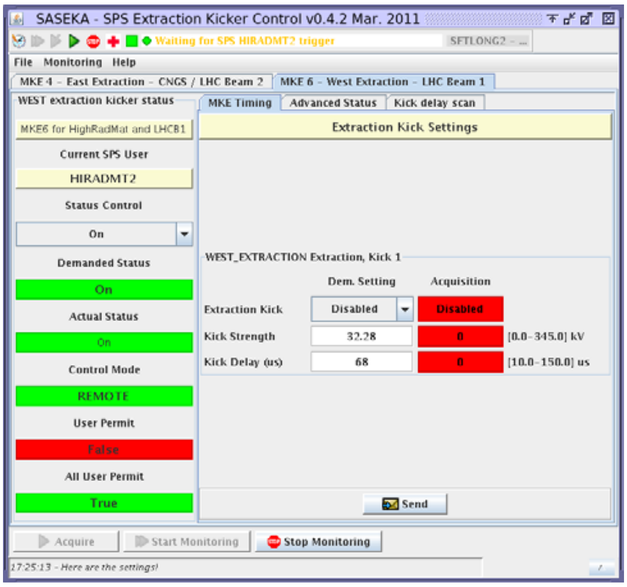

Figure 5 Correct settings of the SPS extraction kicker

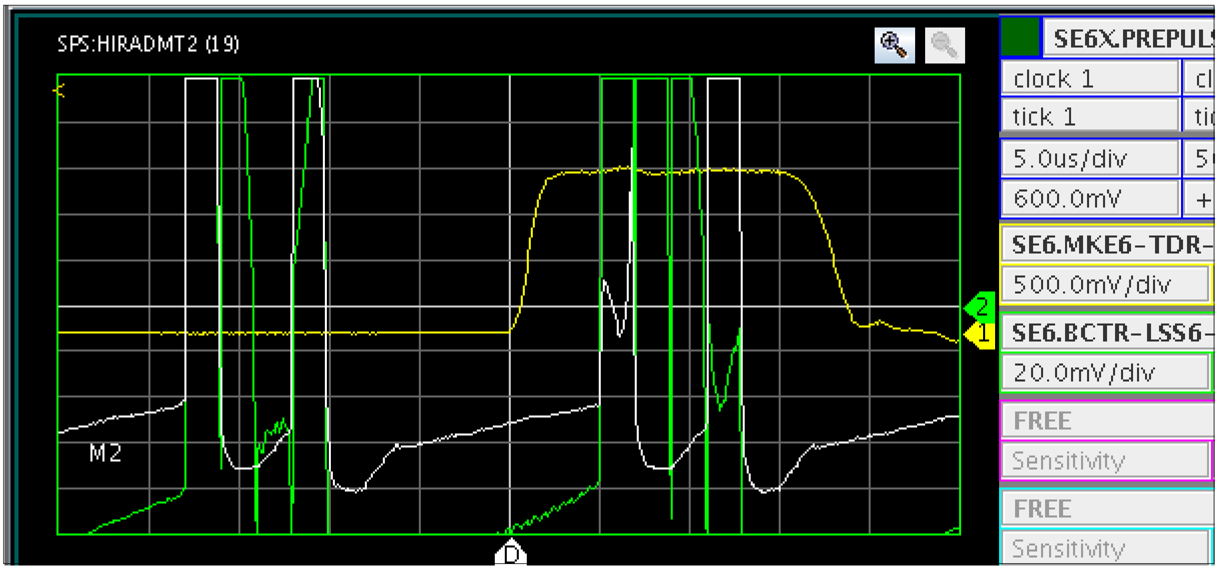

Figure 6 BCT versus MKE waveform for 4 batches of 36 bunches

The trajectory was measured for each step (1 to 4 batches of 36 bunches extracted) and was found to be very stable without any noticeable deviation from the reference trajectory (Figure 7).

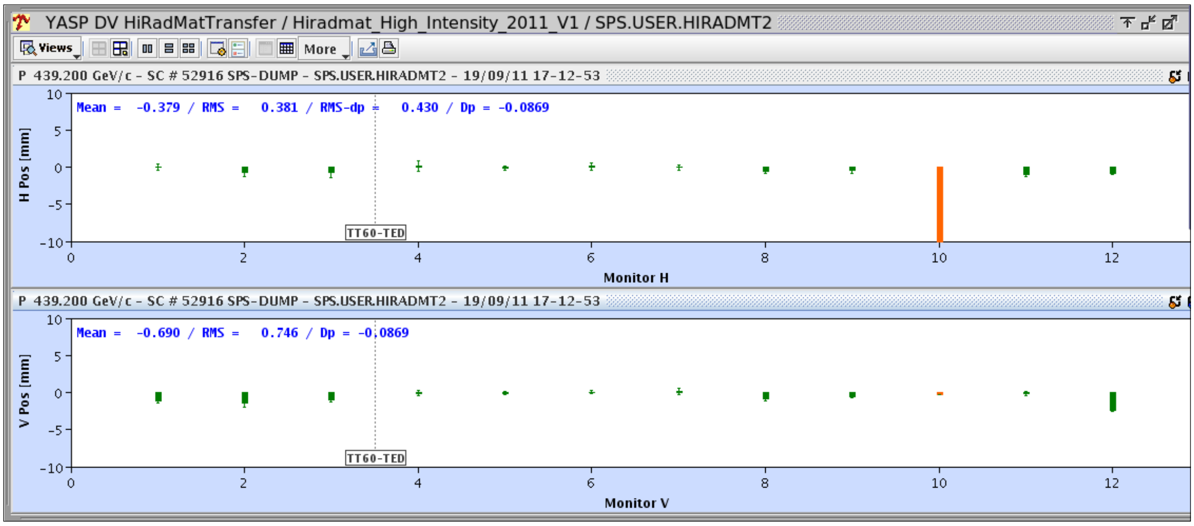

Figure 7 Difference trajectory for 4 batches of 36 bunches

No BLM loss was recorded along the TT66 beam line. The higher values to the right on Figure 8 are again for the BLM measuring the beam losses on the HiRadMat beam dump.

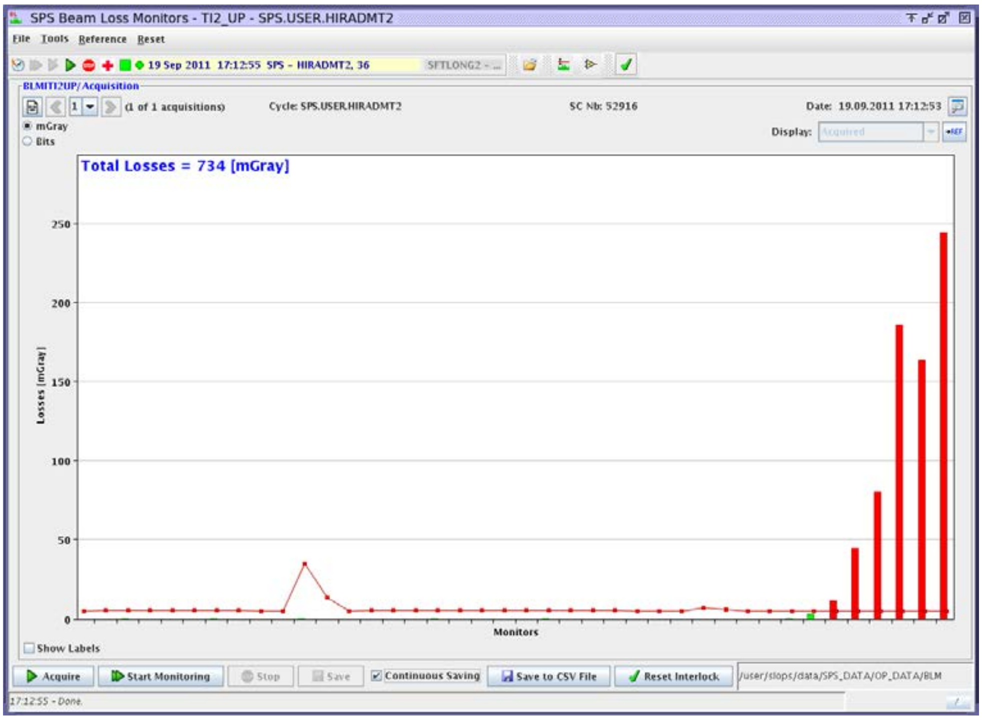

Figure 8 Losses at the BLMs along the TT66 beam line, with 4 batches of 36 bunches

3. Radiation protection observations

The position of the RAMSES radiation detectors in that region is displayed in Figure 9 and Figure 10. The monitors used to obtain the dose rate and the air activation results presented in the subsequent figures are highlighted by circles.

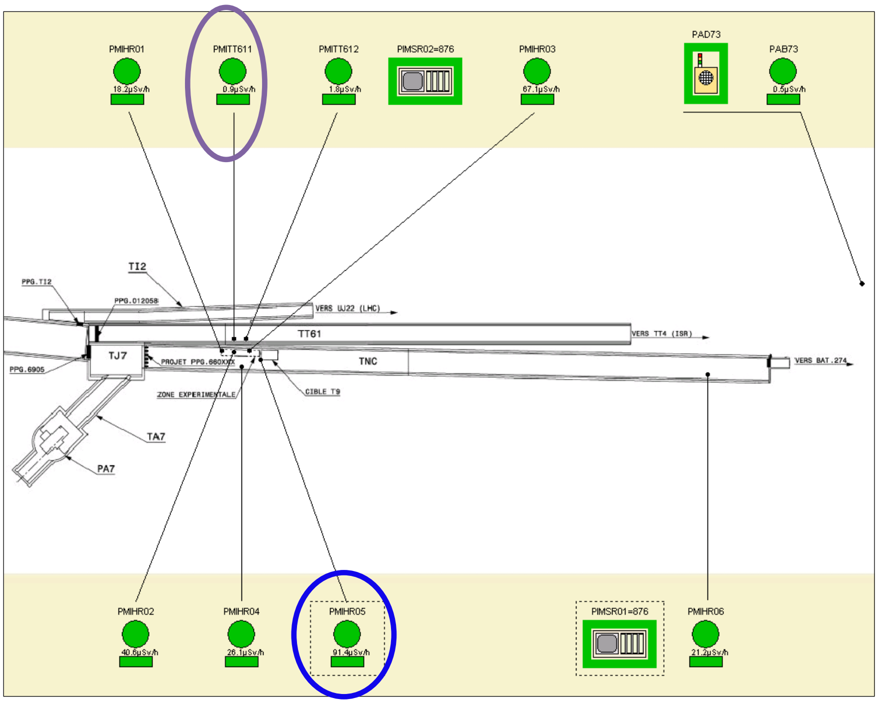

Figure 9 Schematic view of the position of the relevant RAMSES monitors in the underground area of HiRadMat

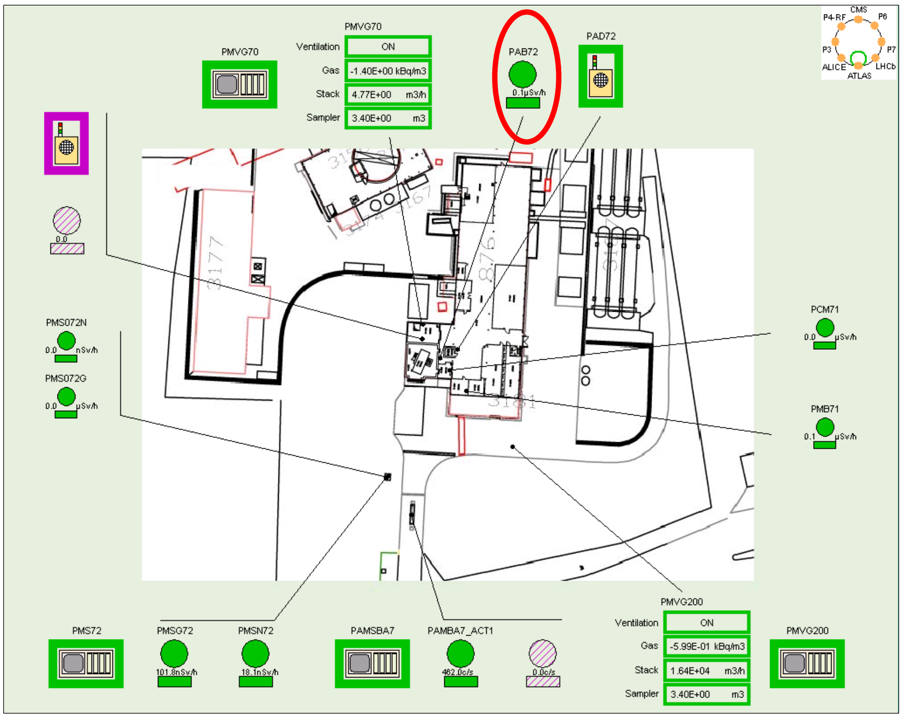

Figure 10 Schematic view of the position of the relevant RAMSES monitors in the surface building BA7

Observations on 14 September 2011 (Figure 11): Shots with pilot beam into HiRadMat ($8 \cdot 10^9$ protons): Radiation is clearly visible in the experimental HiRadMat area (blue line) and in the neighbouring TT61 tunnel at the location parallel to the HiRadMat focus points (purple line). However, the radiation at the accessible areas, which can be found at the end of the TT61 (yellow line) and at the surface level of BA7 (red line), remains at the background level.

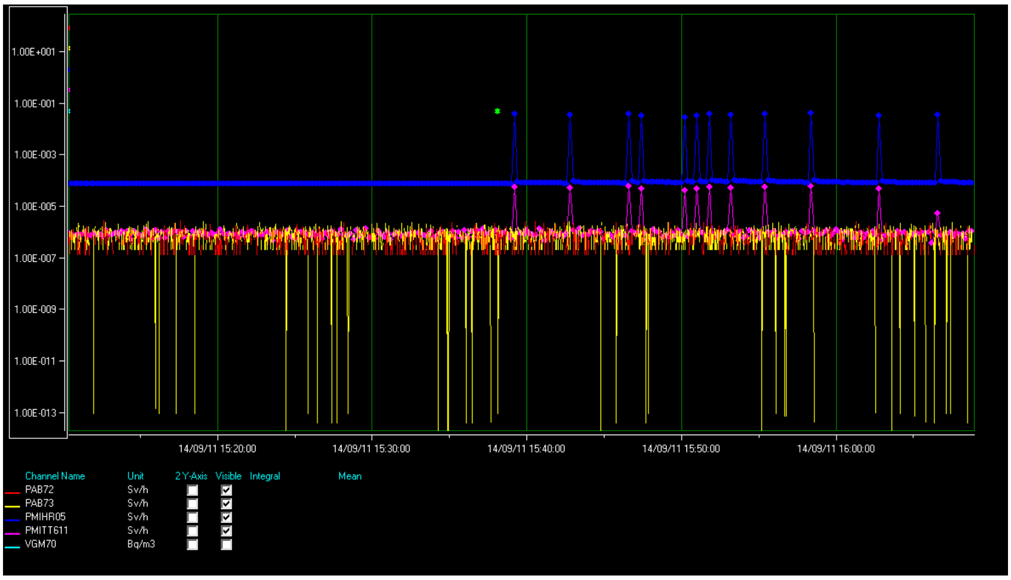

Figure 11 Readings of the RAMSES monitors in the experimental area as well as in BA7 during the commissioning on 14 September

Observations on 14 September 2011 (Figure 12): Shots with 12 bunches of LHC nominal intensity through HiRadMat ($12x1.3 \cdot 10^{11}$ protons): At 170 times higher beam intensity than in the previous test, no radiation was visible in accessible areas. As PMI monitors are in recombination/saturation, they do not show the factor of 170 in dose rate increase.

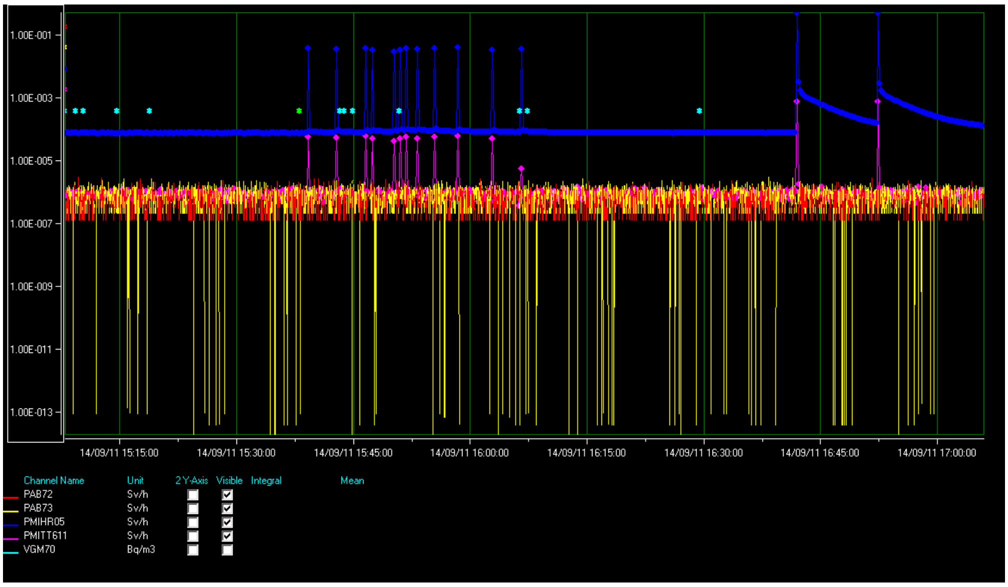

Figure 12 Readings of the RAMSES monitors in the experimental area as well as in BA7 during the commissioning on the 14th of September

Observation made on Tuesday 19 September 2011 (Figure 13) – Few shots with 1 batch of 6 bunches were first sent into HIRADMAT for preliminary checks. Then 36 up to 144 bunches of LHC nominal ($1.3 \cdot 10^{11}$ protons) were used: In Fig.15, the residual dose rate monitor PMIHR05 (blue), which is located next to the HiRadMat dump, nicely shows the beam pattern throughout the commissioning. The beam pattern is also reflected by the detector PMITT611 (magenta) which is located in the adjacent TT61 tunnel. In addition this monitor also shows when the beam was sent onto the TED between about 16:45 and 16:55. During the whole period no significant readings that could be correlated to the beam pattern were observed on the surface monitor PAB72 (red), which is located right outside the shielded access shaft. As can be seen from Figure 14, the high intensity shots with up to 144 bunches did show a clear signal in the reading of the ventilation station monitor. A peak in the concentration of airborne radionuclides released to the environment could be observed at about 17:50. Considering that the last high intensity shot with 144 bunches was sent into HiRadMat at about 17:12 suggests that the air requires of the order of about 40 minutes from the experimental area to the release point, at a flow rate of 2600 m^3/h which was set for the commissioning by Cooling and Ventilation experts.

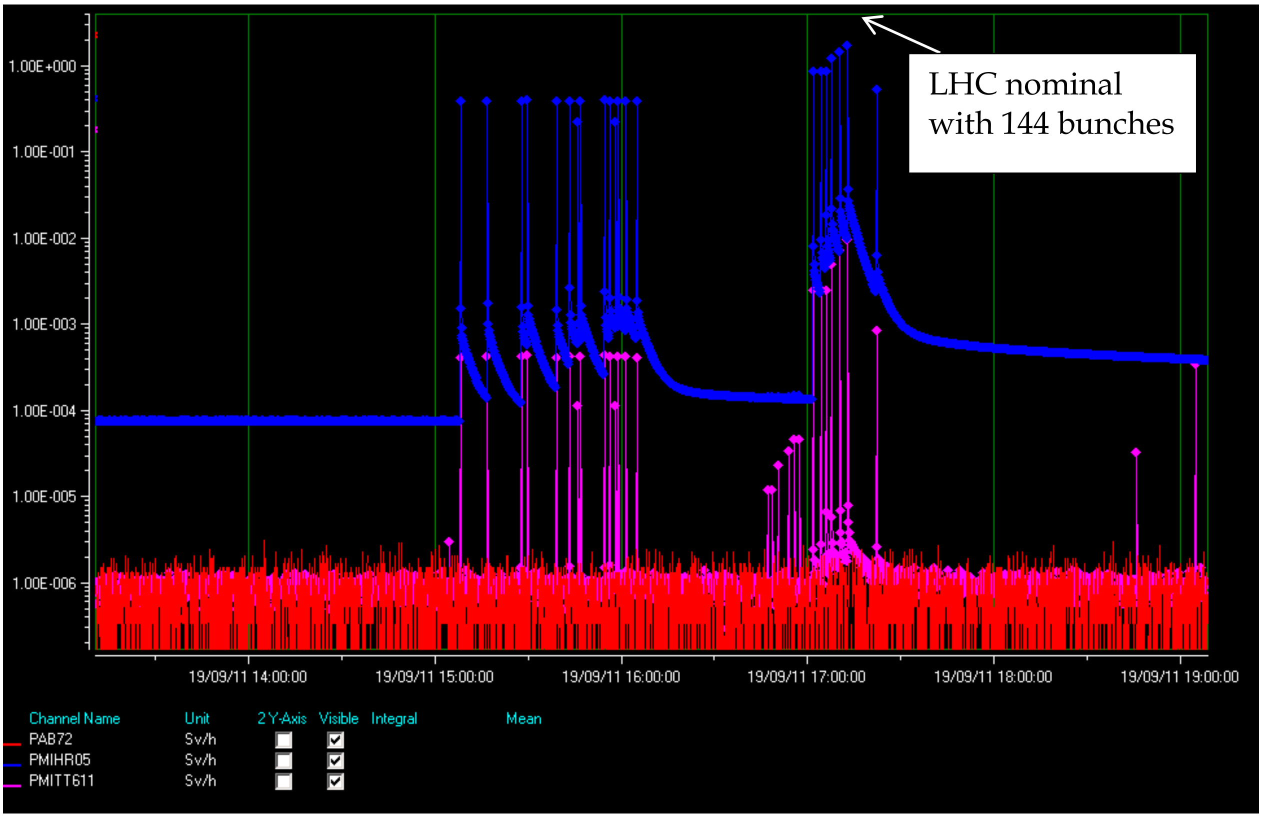

Figure 13 Readings of the RAMSES monitors in the experimental area as well as in BA7 during the commissioning on 19 September

According to a FLUKA simulation conducted for the design of HiRadMat [4], a peak reading of up to ~2 μSv/h could be expected on PAB72 during one extraction of 144 bunches onto an optimum target (99 % interaction probability) located at the most upstream experimental test stand 1. The lack of this signal comes from the fact that the whole beam was sent to the downstream dump instead of a target, as it will be the case during regular operation. It should also be noted that, as shown in [4], the average dose rate is expected to be compliant with a non-designated area also for operation with an optimum target. The compliance with the area classification will be closely monitored throughout each future experiment. In case the limit is exceeded an alarm will be raised in RAMSES as well as the LASER system to notify both RP and the control room.

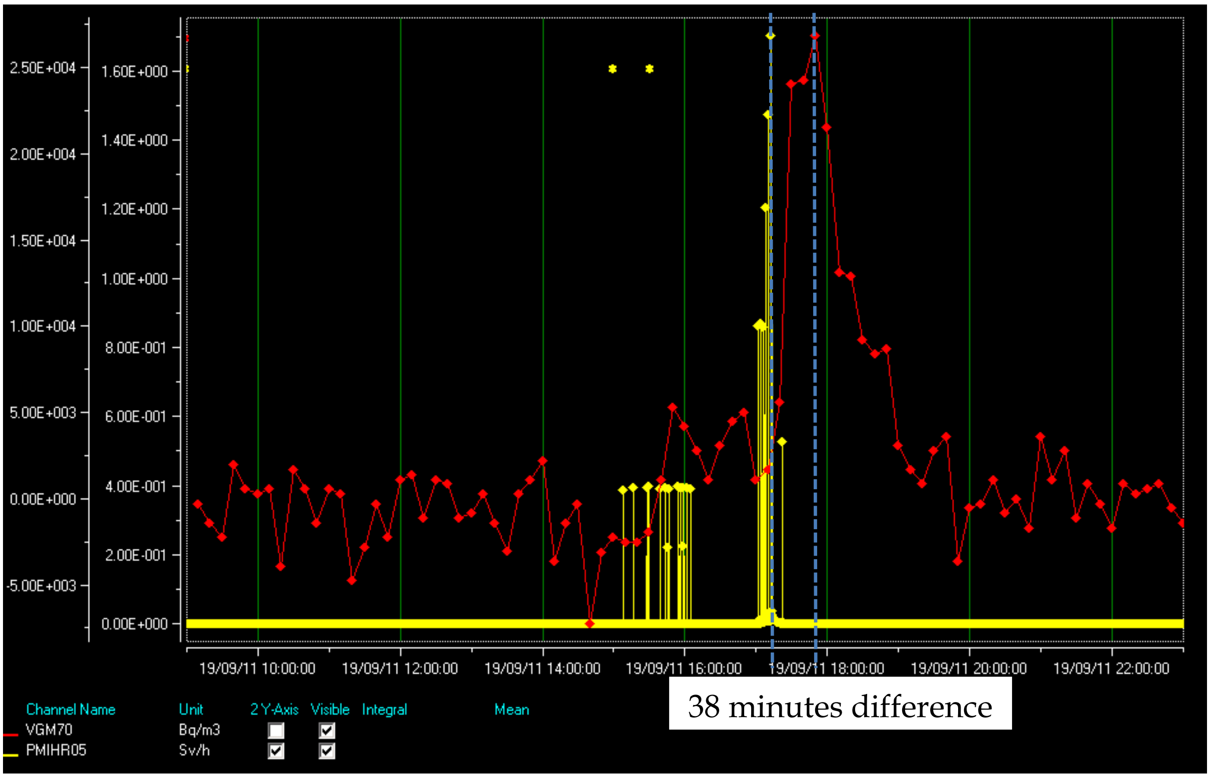

Figure 14 Readings of the ventilation station monitor VGM70 (red) connected to HiRadMat's ventilation system and the PMIHR05 monitor (yellow) which shows the beam impact pattern

From the RP point of view the second phase of HiRadMat high-intensity beam commissioning went as expected without any bad surprises. There was no significant dose rate measured in the accessible areas.

Following the high-intensity beam commissioning, the RAMSES monitors connected to the ventilation system was checked. According to the readings (Figure 15) the flushing did not release any additional radioactivity. Given the timeframe and the commissioning intensities this is perfectly in line with Radiation Protection expectations.

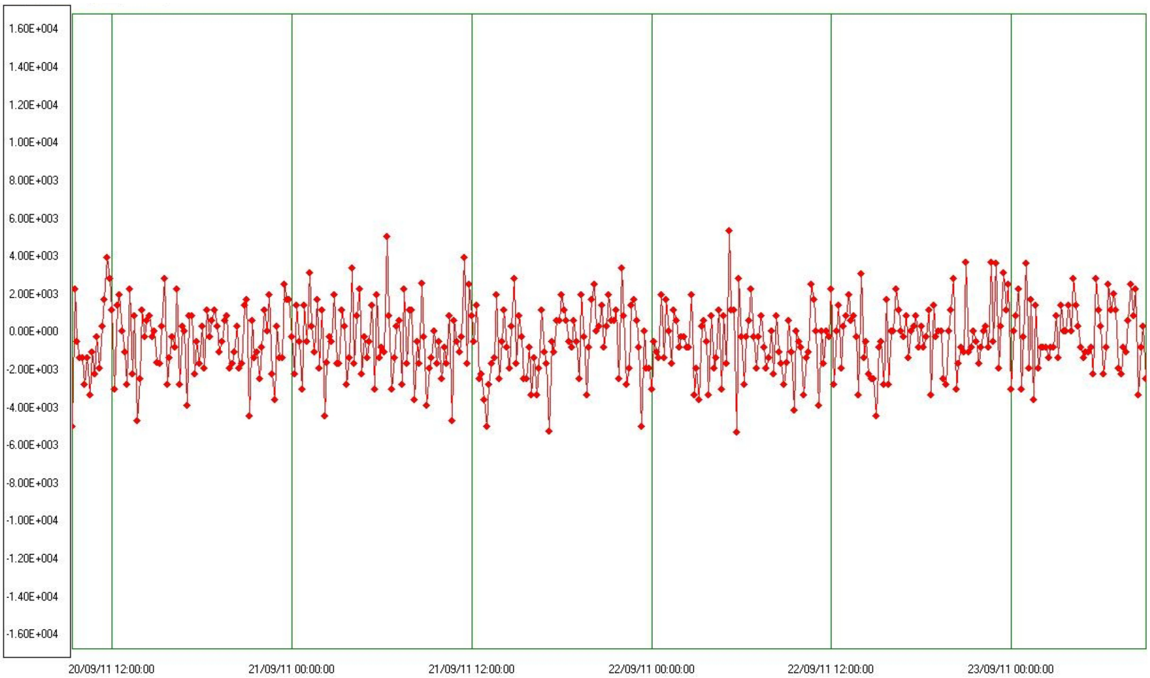

Figure 15 No additional radioactivity measured by the ventilation system Ramses monitors

4. Summary

The high intensity beam commissioning of the HiRadMat primary beam line took place on Wednesday 14 September and Tuesday 19 September 2011. Up to 4 batches of 36 bunches were sent through TT66. The trajectory was checked and found to be very similar to the reference trajectory recorded during the low intensity beam commissioning. The signal from the BLM monitors did not reveal any anomalies. The second phase of the HiRadMat high intensity beam commissioning went as expected by the Radiation Protection experts. No discernible dose rate was measured in the accessible areas.

The HiradMat primary beam line is declared operational, ready for the first experiments.

5. Acknowledgements

All the members of the primary beam line working groups and the teams involved are sincerely thanked for their dedicated work during the whole life cycle of the HiRadMat project.

The operation crews are thanked for their assistance during all the HiRadMat accesses, the preparation of the beam commissioning and the beam line commissioning.

6. References

[1] Web page: 'The HiRadMat facility at CERN SPS', https://espace.cern.ch/hiradmat-sps/

[2] C. Hessler, 'HiRadMat Beam Parameters', EDMS document #1054880.

[3] J. Blanco Sancho et al, 'HiRadMat Low Intensity Beam Commissioning', CERN-ATS-Note-2011-055 PERF.

[4] C. Theis et al, 'Prompt, Activation and Background radiation studies for the HiRadMat facility of CERN/SPS', EDMS document 1144976.