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Technical Note

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Test run for the HRMT-15 (RPINST) experiment

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Abstract

The present document discusses the results of the measurements carried out during the test run performed before the main beam time of the HRMT-15 (RPINST) experiment in the HiRadMat facility, which is planned for October 2012. A prototype detector, specifically designed for measuring pulsed neutron fields, was employed in different positions in order to evaluate the stray neutron field conditions in the TA7 tunnel of HiRadMat. Critical points to be taken into account for the main experiment in October are presented, along with solutions to overcome them.

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1. Introduction

The main run of the HRMT-15 (RPINST) experiment is scheduled in week 41 (8-12 October 2012) in the HiRadMat [1] facility. The experiment includes the intercomparison of radiation protection instruments in the pulsed field generated in the TA7 tunnel by the interaction of a pulsed proton beam impinging on the beam dump [2]. In order to evaluate the experimental procedure and examine the uniformity of the stray neutron field, a test run was carried out during weeks 30 and 34 (July-August) of 2012.

The aim of the test run was to:

- Evaluate and qualify the uniformity of the stray field in the TA7 tunnel. A uniform stray field would allow more instruments to be tested simultaneously.
- Verify the time structure of the neutron field, to estimate and experimentally test at which level the detector electronics are stressed, in terms of possible saturation.

Moreover, since the access procedure in the underground areas must follow specific safety rules and be coordinated by RP and the CCC, a careful plan of accesses has to be foreseen for the main experiment. Another purpose that the test run served was to plan these accesses.

2. Experimental set-up

The test measurements were carried out employing a prototype neutron detector called LUPIN [3] (Long interval, Ultra-wide dynamic, Pile-up free, Neutron rem counter), which is specifically designed to work in pulsed neutron fields. Measurements were carried out with the detector placed in three selected positions in the TA7 tunnel of the HiRadMat area:

- position 1 and 2, before the ventilation door (VD) (Figure 1);
- position 3, after the VD (Figure 2).

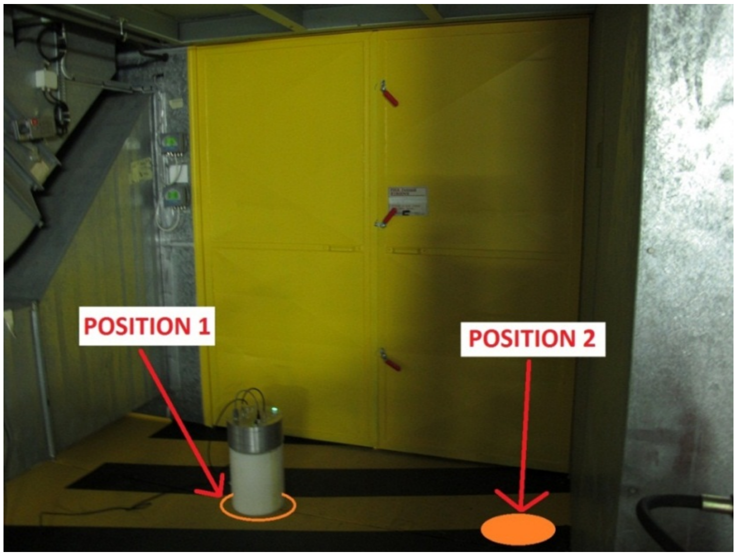

Figure 1 – The LUPIN placed in position 1 before the ventilation door.

Figure 2 – The LUPIN placed in position 3, after the ventilation door.

The VD is installed 7 meters downstream of the entrance of the TA7 tunnel (see Figure 3 for a plan of the area). The purpose of the VD is to maintain an underpressure of the air of the TNC (1) tunnel (in Figure 3 the acronym is in French, i.e. TCN), in order to avoid possible leakage of radioactive air. The planning of personnel access beyond the VD after an irradiation can be quite complicated, since the safety regulations require a complete flushing of the air and renewal with fresh one. On the contrary, the access before the VD is easier since no activation of the air flowing in this area is expected, except in case of very high integrated beam fluxes.

3. Instrumentation and cabling

The output signal of the detector is transmitted via a BNC cable to the control room, where it is acquired by a PC oscilloscope. The cable is connected into a special rack located in the area (in the TJ7 tunnel) from which structured cabling guides the output to the surface control room (Figure 4). Since the VD is closed during beam operation, a special intervention was performed in order to pass the cable from a tray located on the tunnel wall, specifically serving this purpose (Figure 5).

(1) The abbreviation "TNC" of this tunnel originates from the old WANF facility that existed at the underground location that now hosts HiRadMat. The acronym stands for "Tunnel Neutrino Cave" with reference to the old neutrino beam facility. For more information on the WANF area and the experiments hosted there, more information can be found in the reports CERN-ESP-95-14 and CERN Yellow Report 83-06.

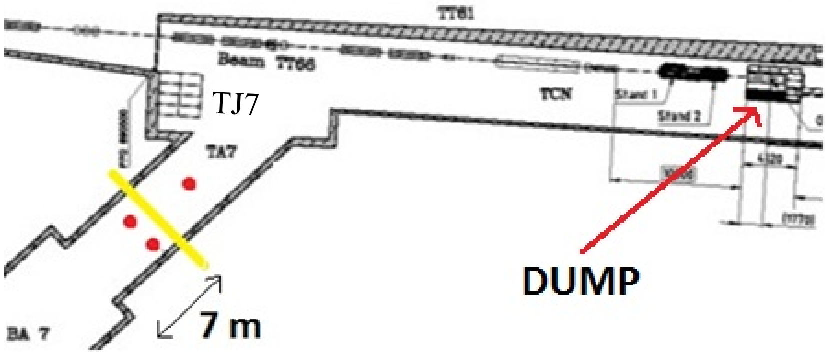

Figure 3 – Layout of the tunnels of the HiRadMat area. The ventilation door (VD) is indicated by the yellow line, the three reference positions by the red marks. The distance between the dump and the measurement positions is around 40 m.

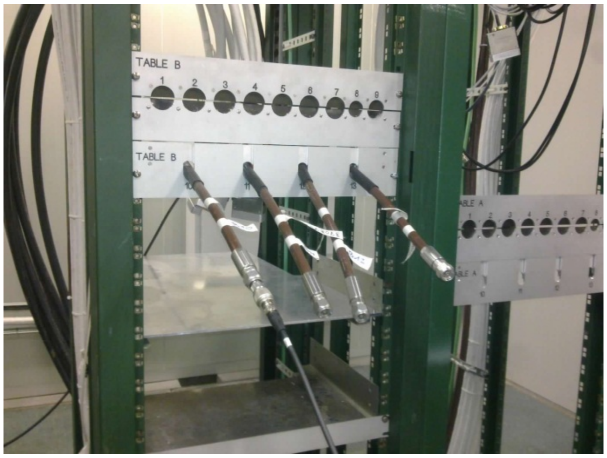

Figure 4 – The rack located in the HiRadMat control room on ground level.

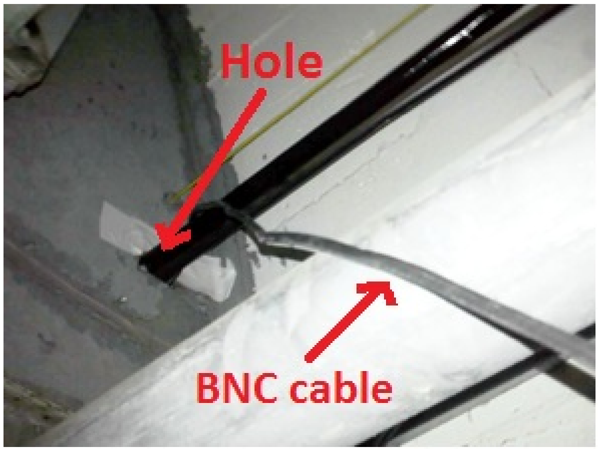

Figure 5 – The tray located on the side of the ventilation door, used for the passage of the BNC cable.

4. Measurements

For each one of the three measurement positions, the detector response was acquired for 8 of the 14 beam settings foreseen for the main run (Table 1). The only quantity of interest for the present experiment is the total number of protons per pulse impinging on the dump, since neither the beam size nor the number of bunches per single pulse is correlated with the specificity of the produced stray field. The length of each pulse was around 1.7 ns.

Table 1 – Beam settings used during the test run.

Beam setting	Protons per bunch
Setting 1	$5{\cdot}10^{9}$
Setting 2	10^{10}
Setting 3	$2{\cdot}10^{10}$
Setting 4	$4{\cdot}10^{10}$
Setting 5	$7.5{\cdot}10^{10}$
Setting 6	10^{11}
Setting 7	$2{\cdot}10^{11}$
Setting 8	$4{\cdot}10^{11}$

5. Results

Screenshots of the acquisition program of the LUPIN for the measurements carried out in position 2 and 3 are shown in Figures 6 and 7, respectively. The data analysis showed that almost 80% of the burst intensity was acquired in the first 2 ms after the start of the triggered signal. The recorded signal after these first 2 ms can be attributed to scattered neutrons that diffuse and get thermalized in the moderator at a later time. The most delayed neutrons encountered multiple scattering events in the tunnel. Therefore the stray field cannot be considered as completely pulsed, since the signal is partially broadened over a few tens of ms.

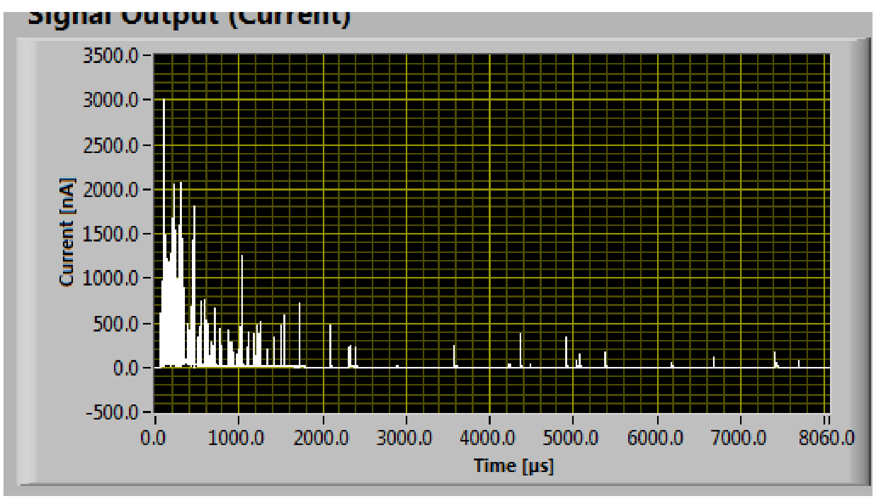

Figure 6 – Screenshot of the acquisition program of the LUPIN taken in position 2.

In order to check the uniformity of the stray field in positions 1 and 2, the ratio between the measured H*(10) and the number of protons impinging on the dump was calculated. The results for positions 1 and 2 are shown in Figures 8 and 9, respectively, along with the corresponding statistical uncertainties (depicted in the figures as y-error bars). For the lower burst intensities, the uncertainty is much higher due to the reduced number of counts measured by the detector. In Figures 8 and 9 the H*(10) is depicted as a function of increasing bunch intensity. The data points tend to an asymptotic value on the right-end side. The value of H*(10)/10^{10} protons foreseen by FLUKA [4,5] Monte Carlo simulations [2] was around 10 nSv/10^{10} protons.

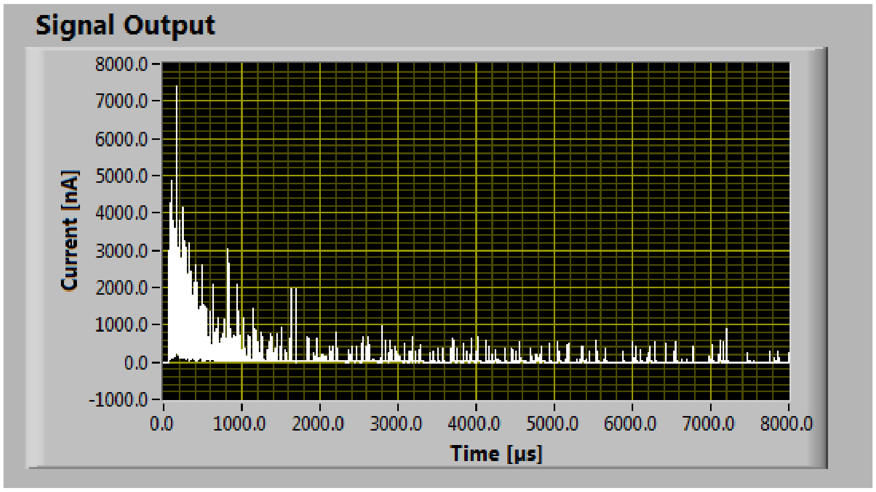

Figure 7 – Screenshot of the acquisition program of the LUPIN taken in position 3.

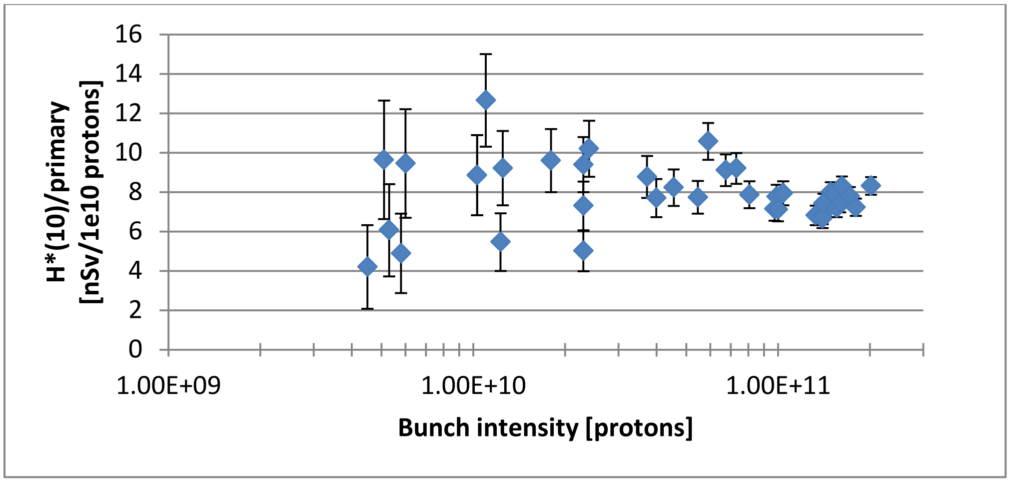

Figure 8 – Graph of the H*(10)/10^{10} primaries with the related uncertainties for position 1. The data are plotted against the burst intensity.

Figures 8 and 9 show that the stray field is not uniform in positions 1 and 2. The asymptotic value in the two positions is 6.2 and 8.1 nSv/10^{10} protons, respectively. This difference of about 30% is not acceptable for accurate simultaneous measurements of more than one detector, since for intermediate values of H*(10) per burst 30% is the typical underestimation of conventional rem counters [3].

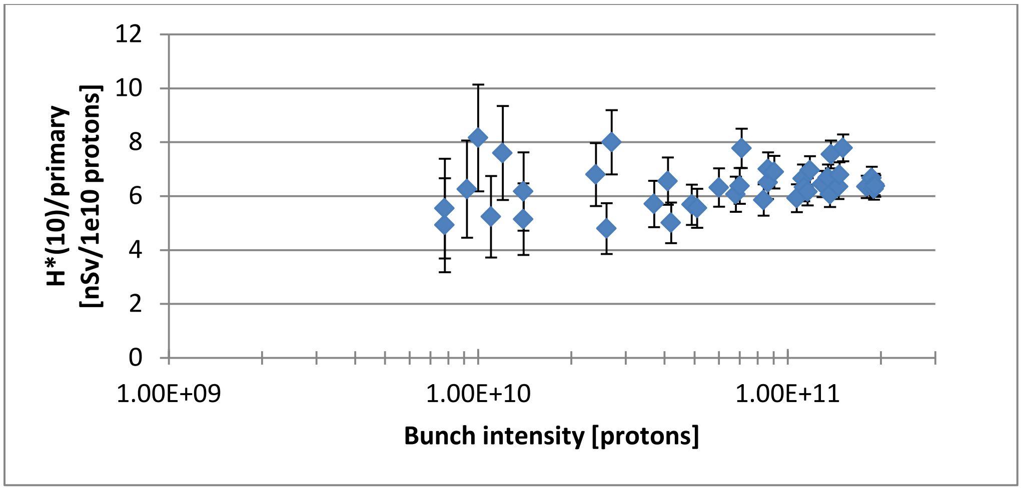

Figure 9 – Graph of the H*(10)/10^{10} primaries with the related uncertainties for position 2.

Figure 10 shows the same graph for position 3. Due to the higher intensity of the stray field (expected, since position 3 is closer to the beam dump as seen in Figure 3), the values of H*(10) are also substantially higher. For high burst intensities (close to 10^{11} protons/pulse) the detector seems to saturate. This saturation prevents the accurate calculation of the asymptotic value. Saturation can be deduced by the fact that the last data points can be fitted by a straight line with negative slope. The mean value of the data is 35 nSv/10^{10} protons, i.e. around a factor of 5 higher than the corresponding value in positions 1 and 2. This is not the optimal location where measurements can be carried out, since the value of H*(10)/proton is too high to investigate with accuracy the dose per burst at which the detector starts to saturate.

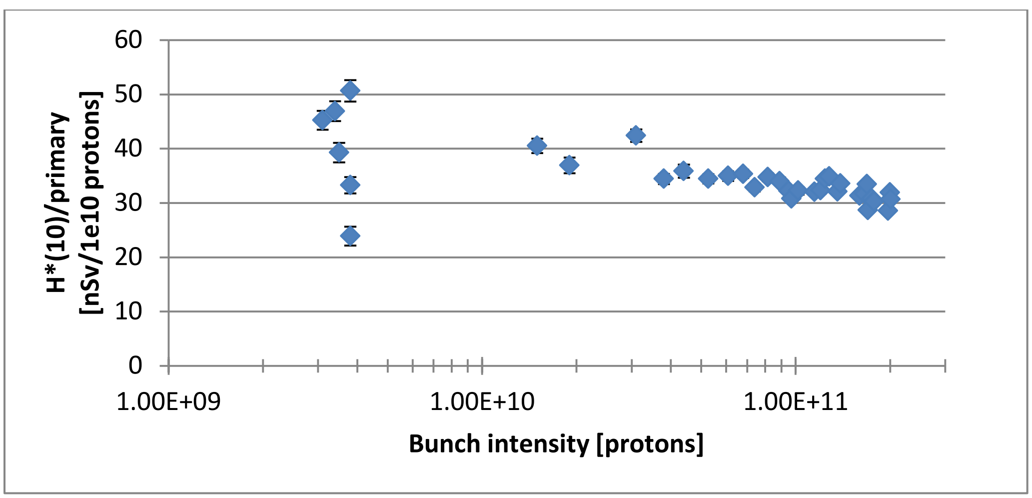

Figure 10 - Graph of the H*(10)/10^{10} primaries with the related uncertainty for position 3.

4. Conclusions

The Monte Carlo simulations correctly predicted the intensity of the stray neutron field in the region before the VD to well within a factor of 2. Nonetheless, the measured 30% difference on the field intensity between reference positions 1 and 2 does not allow considering the stray field in the two positions as exactly the same. Therefore it is not possible to simultaneously measure with several detectors placed in positions a few metres apart. Two solutions can be deployed in order to overcome this problem:

- test of one detector at the time in the same position;
- design and installation of a dedicated rotating platform, remotely controlled, that would allow the exchange of the detectors between positions without manual intervention.

Both solutions imply a repetition of the 14 beam settings for a number of times equal to the number of the detectors to be tested. The first solution requires a large number of accesses because the exchange of the detectors would be done manually. The second solution requires the design and the implementation of a rotating platform with appropriate measures to be put in place to avoid problems with detectors stability and cabling, but would substantially reduce the number of accesses.

The high intensity of the stray field measured in position 3 causes the saturation of the detector with the first settings, and therefore, it would prohibit the complete understanding of the performance of the instruments in their whole dynamic range.

The stray neutron field can be considered as “partially pulsed”: 80% of the burst is detected in the first 2 ms after the triggered acquisition. The last part of the signal is spread over a few tens of ms. This aspect must be taken into consideration during the future analysis of the performances of the detectors.

The access procedure is easier if the measurements are performed before the VD, due to less strict safety measures that govern access to the underground area. The average waiting time starting from the end of the irradiation until access is granted is 20 minutes. The procedure is more complicated if access is required beyond the VD, with a waiting time that can go up to 45 minutes. Therefore, concerning the experiment in October, it is planned to perform the detector tests before the VD using a movable platform presently under construction, and to plan a limited number of accesses beyond the VD for the other parts of the experiment. Nevertheless, for precautionary measures, if the total integrated fluence of primary protons exceeds 10^{13} protons on the dump in a limited amount of time, a partial procedure of air flushing must be put in place, and in that case the access time is around 35 minutes.

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