70th Meeting of the Machine Protection Panel

Participants: A. Bertarelli, F. Burkart, F. Carra, S. Dos Santos, D. Grenier, I. Efthymiopoulos, M. Hempel, E.B. Holzer, C. Kurfuerst, L. Lari, N. Mariani, E. Nebot, R. Schmidt, J. Wenninger, D. Wollmann, M. Zerlauth

1 Presentations

The slides of all presentations can be found on the website of the LHC and SPS Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

1.1 First results of the HiRadMat experiment on Hydrodynamic Tunneling of the SPS High Intensity Proton Beam in a copper target - (J. Blanco)

- The objective of the HiRadMat experiment was to understand the damage potential of high-density proton beams. Simulations predicted hydrodynamic tunneling. The experiment was performed to validate the simulations.
- The simulations were performed combining FLUKA and a hydrodynamic code with the help of Nahem Tahir from GSI, Germany. These simulations gave a prediction, how far the beam would drill a hole into the copper target.
- The tunneling experiment was performed in CERN's HiRadMat facility. The target consisted of three 1.5m long copper targets. These targets were made from 15 10cm long copper cylinders with a diameter of 5cm.
- To measure the dynamic behavior during the experiment 3 diamond detectors, 3 SEMs, 8 temperature sensors and 4 strain gauges were installed at and around the targets. The presentation focuses on the analysis of the data recorded with the diamond detectors.
- The electrical model of the diamond detector is equivalent to a current source in parallel to a capacity.
    - A. Bertarelli asks, what the typical size of the diamonds is. Juan answers that these were diamonds with a thickness of 100um and a diameter of 3mm. These were developed in collaboration with

Civitec with the goal to operate them in high particle fluencies without breaking.

- The experiment was performed in two phases. Phase one with low intensity beam to check the setup and instrumentation.
- During phase two high intensity beam was put into the three targets:
    - Target 1: 144b a 1.9e11 with 2mm beam size. Melting of the material expected, but no tunneling.
    - Target 2: 108b a 1.9e11 with 0.2mm beam size. Tunneling expected.
    - Target 3: 144b a 1.9e11 with 0.2mm beam size. Tunneling expected.
- The diamond detectors where placed following the simulation results along the 4th, the 5th and the 12th cylinder to measure the changing particle shower distribution due to the tunneling of the beam into the material.
- Raw-signals of the diamond detectors show a decrease in peak voltage over 144b. This is caused by a voltage drop of the supply capacitor due to the high particle fluencies. This voltage decrease was about 15%. The effect of this capacitor discharge was corrected in the data taken for target 2 and 3 with the help of the results from target 1.
    - Ilias comments that there is also a second effect visible in the data: the increase of the base line. This maybe due to the creation of ions, i.e. holes. Juan answers that this effect cannot be caused by the holes, as in diamonds these are faster than the electrons. The baseline change stays constant after three bunches (~15ns). For the analysis these three bunches were ignored.
    - Markus asks, if we can be sure that there was no tunneling in target 1, as otherwise the analysis would be compromised.
- Results from the irradiation of target 3: Corrected signal from diamond1 decrease during the irradiation by 16.3%. The corrected signal from diamond 2 increased by 5.7%, the one from diamond 3 increased by 15.8%

- Results from the irradiation of target 2: The corrected signal from diamonds 1 decreased by 10.8 %, the signal from diamond 2 increases by 2.7% and the signal from diamond 3 increased by 17%
- For target 2 and 3 diamond 1 shows qualitatively the predicted behavior. Diamonds 2 and 3 showing the opposite behavior than expected. Note that the geometry for target 2 and 3 are not completely the same, as there are SEMs and a crane mushrooms installed on target 2, which gives an additional shielding to the diamonds during the irradiation of target 2.
- To improve the correction additional measurements are currently ongoing:
    - Lab measurements to get the charge collection distance of the diamonds.
    - In addition two diamonds will be installed to align the crystal HiRadMat experiment, which will hopefully allow to calibrate the diamond signals to FLUKA simulations.
- In addition a post mortem analysis it is planned to open the experiment and to see how far the tunneling proceeded.
    - Nicola comments that one could also use x-ray tomography as in the LHC during the post mortem analysis. This would probably allow for better analysis results with much lower dose rates.
    - Alessandro asks if there is already a plan in which lab the post mortem analysis will be performed. Juan answers that the first visual inspection is planned in situ in the HiRadMat cool-down area.
- In additional it is planned to measure the profile of the activation of the target and compare this to the expectations from the simulations.
- The experimental verification of the simulations is important for the further understanding of the damage limits in high intensity proton beam machines.

Discussion:

- Ruediger asks, what would need to be done to improve the diamonds with more capacitors. Juan answers that this maybe limited by the space in the casing. To be studied with CIVITEC, i.e. Erich Griessmayer.
- Ruediger and Juan mention that in principle one could replace diamond by sapphire or silica, which are less efficient than diamonds, but could be a solution for experiments with high particle fluencies. Ilias comments that the difficulty with silica is the bonding of these materials. These detectors would clearly only work with high fluencies.
- Markus asks about the signals recorded from the other detectors (SEMs, PT100, strain gauges). Juan answers that the signals from the SEMs do not make sense for the moment. These were quite noisy. The analysis of the other sensor signals is still ongoing. Unfortunately some of the temperature sensors died during the experiment. Eduardo mentions that BI sees similar noise (with a lower amplitude) in the SEMs.
- Ilias comments that the opening of the experiment will probably be not before the end of January. Any real activity should be planned after the end of LHC beam operation (~12th of February).
- **Action:** Markus mentions that we should have another presentation on the results, once the target has been opened.

1.2 Study of the response of Ionization Chambers in HiRadMat (E. Nebot)

- Experiments were performed in HiRadMat to study the behavior of different ionization chambers - linearity and response against high voltage changes:
    - Standard LHC type ionization chamber (gas pressure: 1.1bar).
    - Little ionization chamber (LIC, gas pressure: 1.1bar).
    - Little ionization chamber as installed in the LHC injection regions (LIC, gas pressure: 0.4bar).
    - Flat ionization chamber (FIC, gas pressure: 1.1 bar).
- The BLMs were installed close to the dump of the HiRadMat facility.
- Observations:
    - High frequency noise during a few 100ns.

- The FIC and the LIC (1.1 bar) showed negative signals. As reason for this behavior a wrong arrangement of the capacitor and resistor on the supply side of the ionization chambers was identified in the lab after the experiment.
- For the other two ionization chambers the total collected signal is measured well within 8μs.
  - Ruediger comments that the noise seems to be beam dependent. Daniel adds that this noise was also observed in the signals from the diamond detectors, which were also tested during this experiment.
  - Barbara asks if this noise was also observed in Juans experiment. Daniel explains that as the diamond detectors were placed much closer to the beam axis during Juan's experiment, the signal to noise ratio was much better also for back scattering from the dump (shots on the dump). Juan comments that low noise was visible during his experiment.
- The integrated signal of the functioning LIC (0.4 bar) showed linear dependency on intensity.

- Further measurements were performed in the PSB dump line (1.4GeV, 1e10 p/bunch, 60ns, 1mm beam size) after the repair of the FIC and LIC.
  - The measured signals were (after the repair) as expected.
  - The different integration windows show good linearity also for the shortest integration window (1us).
  - For 80μs integrated charges the FIC and LIC showed again good linearity. Simulations are ongoing to reproduce the measured charges.
  - HV scans (integrated signals over 80μs per primary proton) showed a relatively flat response between 800 and 1600V. An outlayer at 1500V can be explained by hysteresis effect, due to changes of the voltage during the experiment.

  - This measurement confirms the adjustment of the SIS-HV interlock, which was performed earlier in this year for the BLMs in IR7.
- The BLM team requests to replace two SEMs at the TDIs (Pt 2) by a LIC (1.1bar) and a FIC.
- In theory the lower pressure in the 0.4bar LICs should protect against the development of secondary electrons (from electron avalanches) due to high particle fluencies. This was unfortunately not observed during the performed experiments.
- Therefore it is recommended to replace the 0.4bar LICs by 1.1bar LICs.

Discussion:

- Markus asks if the chambers are already available to exchange the TDI SEMs. Eduardo answers that they first need to be de-install from the PS, but then the replacement should be quick (~1h).
- Ruediger comments that for the long term it would be nice to measure injection losses with fast detectors like diamonds. Is the installation of these detectors foreseen / could the installed diamonds be introduced into the IQC? Markus and Jorg comment that the LICs and diamond detectors would be complementary. The LICs are for protection and the diamonds for diagnostics.
- Maria comments that the diamonds are currently not operationally used although the data could be very useful.
- **Action**: Discuss with Stephan Bart Pedersen on post-mortem data of BLMs during injection (diamonds) (Markus, Daniel).
- MPP recommends the installation of the two LICs in replacement of the SEMs at the TDIs as soon as possible.