Minutes PSB Upgrade WG Meeting 12th November 2015

Participants: J. Abelleira, S. Albright, F. Boattini, L. De Mallac, A. Findlay, G.M. Georgiev, G.P. Di Giovanni, G. Guidoboni, B. Gutierrez Hernandez, M. Haase, K. Hanke, M. Kowalska, B. Jones, L. Jorat, B. Mikulec, S. Moccia, M. Morgenstern, A. Newborough, R. Noulibos, S. Pittet, J.Tan, W. Weterings

Agenda (https://indico.cern.ch/event/460775/):

1. Approval of Minutes

- The minutes of the last LIU-PSB WG meeting #162, available here, have been approved.
  - **F. Boattini commented that the proposed scenario for the MPS to be able to provide 6 kA to the PSB dipole magnets is unrealistic.**
  - **The EPC group is currently working on documenting the maximum operational current for each power supplies.** → Open Action.

Assigned to	Due date	Description
F.Boattini	2016-01-31	Provide the specifications for the maximum operational current of the power converters of the upgraded MPS.

2. Communications

- **Party for the End of the Year:**
  - The tentative date is the 10th December 2015 at lunch time, to be confirmed.
  - The currently proposed location is 37-R-022.

3. Follow-up of Open Actions

- J.M. Lacroix on "Complete integration of PSB-PS transfer line" → J.M. Lacroix implemented the beam envelope from the MADX simulation of the BT-BTM line provided by J. Abelleira. A few critical areas were found where the beam envelope is expected to be larger than the available aperture in the vacuum pipes. In more detail, the elements concerned are BT3.DVT30, BT3.QNO20, BT2.QNO20 and the line between BT2.BPM20 and BT2.DVT40. J. Abelleira is following up this issue: mismatch is expected between the aperture model in MADX and the drawings. **J. Abelleira will report at the next meeting about these issues.**

- F. Roncarolo on "Prepare a document for approval about the specifications for the H0/H- current monitor electronics." → Some details about the timing are currently under

discussion, but the document should be ready for approval in the next two weeks. The BI group received the components for the prototype card and the electronics design office should be able to make the assembly by December 2015: The hope is to be able to test it in January 2016.

- J. Tan on "Demonstrate 200 µm resolution for low intensity beam for the turn-by-turn measurement system. Demonstrate reliable operation with new firmware/software. Electronics to be ready for deployment in EYETS 16-17." → Several problems were fixed by J. Belleman in the last days and data could be collected during an MD session performed on Monday 9th November 2015. If possible, some additional tests will be performed before the proton beam is stopped in the PSB.

- D.Aguglia on "Approve document with the functional specifications of the power converters for BSW magnets for both the LIU-PSB and the Half-Sector Test in Linac4 addressing the open issues from v0.2" → Currently the document has been rejected by Y. Muttoni and J. Borburgh. By talking with T. Birtwistle a proposed strategy is for D. Aguglia to prepare a new version addressing all the comments to be first circulated among the people who comments. If the new version is accepted, then Y. Muttoni and J. Borburgh will modify their comment and the document could be released.

4. Injection Tests with Carbon Foils in ISIS

- B. Jones presented the results of the recent injection tests with stripping carbon foils in ISIS, see here.

SUMMARY:

- Several **tests on carbon foils** instead of the standard Al_2O_3 foils have been performed in ISIS.
- **The Al_2O_3 foils cover the full vertical aperture, while for the tests with carbon foils only half-length foils were used:**
    - The idea was to try to avoid hitting the foil in the bottom section during recirculation.
- Similar result from all the test:
    - **Significant foil deformation of the corner not attached to the frame were observed after 5-6 hours of 50 Hz beam operations (T ≈ 500K).**
    - **Single test using supporting fibres (as done in J-Parc) turned out to be unsuccessful.** The fibres were found to be detached from the frame. It is not clear if it was due to the beam or it happened during the mounting operation.
- **Generally the operators were very happy with foils:**
    - Easier to mount/install.
    - The fibres installation turned to be more problematic.
    - The RP group in ISIS reviewed the installation procedure and recommended **a contamination hood rather than a respirator. It was easier for the operator to perform the foil installation with this new configuration, but the new outfit reduces the capability to hear external voices.**
    - Additionally a new foil preparation area was built with a **plastic box separating the operators from the foil. The new setup is electrically earthed which helped reducing the damages to the foils during the mounting onto the frames.**

Hide Detailed Description

- ISIS is situated in the Rutherford Appleton Laboratory (RAL) in UK.
- ISIS is a spallation neutron source where protons are fired into fixed tungsten targets in order to produce neutron beams. The neutron beams are used for a wide range of condensed matter research over length scales of several orders of magnitude from atoms to long molecular chains.
- H^- ions are generated by a source with a peak current of 50 mA accelerated through an RFQ at 665 keV and finally accelerated by a 4 tank drift tube linac up to 70 MeV.
- The synchrotron has a circumference of 160 m and accelerates the beam up to 800 MeV. The intensity is of the order of 3E13 ppp.
- The complex operates in 4 cycles of 40 days per year for the users. Machine development tests could be carried between cycles.
- ISIS H^- injection:
    - Four dipoles are powered in series to create an orbit bump of 65 mm at the stripping foil, which is made of ~200 μg/cm^2 Aluminum-Oxide, Al_2O_3.
    - The beam is painted transversally in both planes to minimize the space-charge effect:
        - Vertically, the painting is done with a programmable dipole (sweeper) in the injection line.
        - Horizontally, the painting is achieved by movement of the closed orbit. The foil covers the full vertical aperture, so the foil is hit about 30 times during recirculation in the injection process.
- **The Al_2O_3 stripping foils have been produced in-house for the last 30 years:**
    - They are very fragile and the installation is rather challenging.
    - There is an additional complication: **Once the foil is installed, one of the corners is sliced with a scalpel to allow more flexibility during beam loading (empirical finding during operations).**
- The option to try **carbon foils** looked appealing:
    - **Much more robust than Al_2O_3.**
    - **Commercially available.**
    - In use at J-Parc and SNS. Also planned for CSNS and CERN PSB in the framework of the LIU project.
- Ten 100 μg/cm^2 carbon foils of the size of 50x65 mm have been ordered in ISIS:
    - Five made of hybrid Boron-Carbon (like the ones used in J-Parc).
    - Five made of Diamond-like Carbon.
    - The frames with clamps at the top and bottom were manufactured at RAL.
    - **The foils covered half the size of the vertical aperture (while the current operational foils cover the full vertical aperture). The idea was to try to avoid hitting the foil in the bottom section during recirculation.**
- A new mounting bench has been installed with plastic separating the operator from the foil
    - **The mounting bench is electrically earthed which was found to reduce the risk of foil breakages while handing them.**
    - **An ion gun is used to further reduce static on the foil.**
- The first carbon foil was successfully installed on the 25th July 2015 without major problems:
    - The RP group reviewed the foil installation process and tested a new contamination hood for the operators. It was indeed found to be easier for the operator to perform the foil installation with this new configuration, rather than only using a respirator as it is generally complicated to find a good fit for different people. On the other hand, the full contamination hood reduces the capability to hear external voices, etc.

- The simulation based on ORBIT showed no expected change in injection efficiency (~99%) with the carbon foils and a slight reduction in emittance growth and losses due to the insertion of half of the foil which avoids losses due to beam recirculation.
- During the first test with a 10% diluted beam (~3E12 ppp) an efficiency of 40% was observed:
    - The lower efficiency was tracked down to an injected beam position which was 9 mm lower than expected and could not be previously noticed with foils covering the full vertical aperture.
    - Additionally the closed orbits was re-adjusted for the new injection position.
    - The beam spot shape was tuned with HEDS (injection line) quadrupole magnets.
    - After all the corrections, the efficiency performance was recovered and tests could be run for almost **4 hours using a 180 µA beam.**
    - Few tests were carried, including stopping and restarting the beam to thermally shock the foil with no observable losses of performance.
    - **During the shift the losses slowly increased with time and it was necessary to keep inserting the foil further in:**
        - The visual inspection of the foil the following day showed that the edge which was not attached to the frame curled in, explaining why the losses had increased and inserting the foil further in helped.
        - W. Weterings asked how many additional mm the foil had to be inserted in. B. Jones replied about 2 mm.
        - Foil deformations were already observed at J-Parc (https://accelconf.web.cern.ch/accelconf/IPAC10/papers/thpeb020.pdf) where the deformations were observed to stabilize after about 7E20 injected particles (which corresponds to about 3 days of 50 Hz beam in ISIS).
    - **The foil was removed the 10th August and it survived the hoovering system in ISIS which is used to vacuum clean the foil from the frame.**
- The following test aimed at running for few days with a new foil mounted, but the test was cancelled due to major issues with the UPS of the main bending magnets.
- A third test was then planned for the 16th October 2015:
    - **The aim was to run for long time, but the injection losses appeared after 5.5 hours of 50 Hz beam. The foil was found to be curled in, again.**
- **Another attempt was tried by supporting the foil with carbon fibres on both front and rear side of the foil. The fibres were pulled across the frame and glued with Aquadag:**
    - **Again, after about 6 hours of full-power beam the injection losses became too high to keep running the test. The fibres were found to be detached from frame.** It is not clear if the fibres were detached because of the beam or it happened at the time of the installation.
- The next steps are:
    - Improve the fibres mounting procedure.
    - Test a foil covering the full vertical aperture. There is the possibility for one more test before the winter break.
    - Review holder design and mounting method.
    - Perform off-line tests on the foil, like heating test where the foil is hit with a laser or a lamp and investigate the foil reaction.
    - One of the current issue is also about the radiation the operators accumulate when performing all these foil exchanges required for testing.
- Recently a new American company started to produce graphene circular foils for nano-technology applications, see http://science.energy.gov/~/media/np/pdf/sbir%20sttr/presentations/2011/Pavlovsky_Graphene_Stripper_Foils.pdf:

    - The foil are one order of magnitude more expensive that the carbon foils, 2500 $ with respect to about 250 $ per carbon foil.
    - The 100 μg/cm^2 graphene foils have a diameter of 13 cm and are 0.6 μm thick. They could spin thousands of RPMs and a 2-2.5 cm foil could stand 1 Kg weight. So the foil looks quite robust and could solve several of the installation issues.

- A. Findlay asked if the vacuum pump had any influence on the foil, for instance to cause the curling at the edge. B. Jones replied that this was not explicitly checked. As a side note, B. Jones reported that in J-Parc they claim to be able to measure the outgassing with the foil, but it could not be measured in ISIS.
- A. Findlay asked which is the successful foil rate in ISIS. B. Jones said that **one could count to use 1 foil out of 25**. Several foils are already destroyed at the time of the production. Moreover the foils have a shelf life, so once one foil is installed and working well it lasts for one user cycle and the ones in the shelves start degrading and generally end up being thrown away.
- W. Weterings commented that concerning the 20 μm fibers, B. Goddard and C. Bracco did not like the idea in particular for LHC-type beams, as they are afraid that there could be losses due to the beam hitting the fibres.
- W. Weterings asked if the clamping was done with glue or screws. B. Jones replied that it was done with screws and a gluing process has not been tried out yet. W. Weterings added that gluing looks a robust enough solution for the graphite foils probed at CERN. On the other hand the graphite foils mounted at CERN have not been hit with beam.
- W. Weterings reported that the RP group performed simulation on the radiation received after inhaling the foil and it is estimated to be about 20 mSv, so it is important to establish a correct foil removal procedure. **Additionally some laboratory try to keep the used foils to investigate them afterwards and this could be another constraint.** B. Jones said that the used foils are not kept in ISIS.

5. AOB

- The next meeting is tentatively scheduled for the 26th November 2015.
- **R. Noulibos and W. Weterings reported about the BTV interlock test. So far 2 foils were installed in the test stand and 1 broke during the test.**
- J. Abelleira reported that he is completing the re-matching of the BTP line for minimal beta functions and dispersions average.
- **A. Findlay reported that in the last days the RF group tried to replace the C16 with the Finemet for LHC25-type and with LHCINDIV-type beams and the MD tests were rather successful. The full outcome will be discussed during the meeting of the 10th December 2015.**