Minutes PSB Upgrade WG Meeting 24th September 2015

Participants: J. Abelleira, W. Bartmann, O. Berrig, J. Betz, T. Birtwistle, J. Borburgh, J. Coupard, G.P. Di Giovanni, V. Forte, R. Froeschl, G.M. Georgiev, S. Gilardoni, B. Goddard, D. Grenier, M. Haase, K. Hanke, J. Hansen, D. Hay, J.M. Lacroix, B. Mikulec, S. Moccia, M. Morgenstern, A. Newborough, M. Paoluzzi, S. Pittet, G. Rumolo, R. Steerenberg, J. Tan, W. Weterings.

Agenda (https://indico.cern.ch/event/447764/):

1. Approval of Minutes

- The minutes of the last LIU-PSB WG meeting #158, available here, have been approved.

2. Communications

- **RF Bypasses:**
  - W. Hofle accepted the responsibility within the BE-RF group to perform the installation (except for the injection region which will be done by W. Weterings) and the yearly measurements of the RF bypasses.
- **Finemet Review:**
  - A first draft of the reviewers' comments have been received. The document is circulating only among few people and, only when approved, it will be circulated to the rest of the group.
  - M. Paoluzzi will present it at the IEFC for formal approval.
- **2 GeV Upgrade ISOLDE:**
  - The IEFC has decided that this cannot be implemented for LS2.

3. Follow-up of Open Actions

- D. Hay on "Prepare and submit an ECR to describe the proposed new rack layout in BRF2/BAT" → D. Hay was not present at the time the open actions were reviewed. He will be contacted via email.
- D. Hay on "Define the rack layout for the interlock system" and B. Puccio on "Submit the DICs for the interlock system" → Both actions are correlated with each other. G.M. Georgiev confirmed that both actions can be closed. → **BOTH ACTIONS CLOSED**.

4. Review of the Optics of the PSB Extraction Lines

Previous Presentations:

- 2014/11/06: Aperture Study on the PSB Extraction and Recombination Lines.
- 2014/05/08: New Optics of the PSB measurement line (BTM).
- 2013/10/10: PSB Ejection Lines.

- 2013/06/27: BTM Optics Studies.
- 2012/05/03: BT.BHZ10 Upgrade.
- 2011/10/06: Study to Replace the BT.BHZ10 and on New Optics of the PSB Extraction Line.

- This review is an update of the design presented in October 2013, see here.
- The aim of this review is to revisit the ejection line design after iterations on integration, magnet design and optics.
- Two talks have been presented:
    - J. Abelleira presented slides discussing the geometry, optics and integration, see here.
    - W. Bartman presented slides discussing the stability studies performed to assess the robustness of the chosen design for the PSB-PS extraction line, see here.

Geometry, Optics, Integration

- **New Geometry for the BT Line:**
    - The new geometry of the BT line has been already discussed in November 2014, see here:
    - Longer septa will have to be installed to cope with the 2 GeV beam energy. Therefore the angles of the beam at the entrance and/or exit of the septa would slightly change. Nevertheless **the BT line has been rematched such that the identical geometry is kept at the exit of the septa BT.SMV10 and BT.SMV20**. The trajectories are different between the entrance of the preceding bending magnets and the exit of the septa. The corresponding angles of septa and bending magnets have been changed.

- **New Optics for the BT-BTM line:**
    - In October 2013, it was reported that the **bottleneck of the measurement line was the BTM.BHZ10**, in particular for the optics to send the beam to the dump.
    - A new set of optics for the dump, for the horizontal emittance measurement both with small and large horizontal dispersion and for the vertical emittance measurement has been prepared and reviewed at the LIU-PSB WG meeting in October 2014, see here.
    - The aim of this new set of optics was to reduce the beam size at BTM.BHZ10 and to **provide higher resolution for the emittance measurements**.
    - The optics have been successfully tried in the control room with beam and proven to work. On the other hand, a thorough analysis of the data is being performed.

- **PSB-PS Optics, BT-BTP:**
    - Two main changes with respect to the review in 2013.
    - The quadrupoles **BT.QNO40 & BT.QNO50 have been moved back to their present location**. At the time of the review in 2013 it was not clear if the deflection center of BT.BHZ10 could be kept as of today. Finally **it was checked with integration that the new BT.BHZ10, which is longer, could be extended in both directions. Keeping the deflection center has been preferred, as the geometry of the BTP line would not change after BT.BHZ10. Therefore, there is no need to displace the BT.QNO40 and BT.QNO50**. This would also preserve the tunability of the line, as the distance between these two quadrupoles can be preserved.
    - For these updated studies the **4 independent models of the BT lines have been used**.
    - Three sets of BTP optics have been investigated:

        - Fixed target, **matched to the PS with the magnet insertions**.
        - LHC, **fully matched to the PS**
        - LHC, **with the same values at PS injection as we have today (mismatched optics, which would allow an emittance blow up in case the beam brightness from the PSB would be excessive for the PS)**.
    - By comparing the betatron function there are changes with respect to the previous results due to the new magnet position.
    - Additionally **there is a significant spread in the horizontal betratron function at the PS injection resulting from the difference in the weak focusing of the vertical dipoles. Generally the difference is more important for the matched optics**.
    - **A spread is also observed in the vertical betatron function.**
    - Finally, **the most relevant effect is visible in the vertical dispersion function: For the LHC matched optics it is about 1 m difference between ring 1 and ring 4**. While it is always possible to match one line to the PS, it is not possible to match all the lines together.
        - K. Hanke asked which ring is used for the matching. J. Abelleira replied that it is **ring 4**. **K. Hanke recommended to perform the matching using ring 3. J. Abelleira mentioned that as a next step he will try to match all the 4 lines together, aiming to minimize the overall spread in dispersion/betatron functions.**
    - **Quadrupole Gradient and Good Field Region (GFR):**
        - For the evaluation of the gradient and the GFR the beam size definition as given in slide 14 has been used and assuming in all cases a factor 3 in the betatron beam size contribution.
        - **The estimations indicate that both gradient and GFR are fine within the maxim specification gradients assuming the scenario of 2 GeV.**
        - Generally there are some slight changes due to the new quadrupole magnets positions and to the betatron and dispersion spreads.
        - The only relevant change is for **BTP.QNO20 for the fixed target optics, where there is an increase of about 20% with respect to the previous estimations**. A. Newborough commented that this looks to be at the limit. W. Bartmann replied that given all the conservative assumptions done, it should be still fine and the requests can be considered to be within the given specifications.
    - **Integration:**
        - Several new input received:
            - Envelopes for the BT.QNO40, BT.QNO50, BTP.QNO20, BTP.QNO30, BTP.QNO35, BTP.QNO50, BTP.QNO55 and BTP.QNO60. The engineering specification for these magnets are being prepared.
            - 3D model for the bending magnets BT.BHZ10 & BTM.BHZ10. The engineering specification for these magnets are being prepared.
                - **BT.BHZ10 will be longer, but the deflection centre will be kept as of today.**
                - **BTM.BHZ10 will be longer. There seems to be just enough space for the magnet to be installed. To be checked and in case a small part of the shielding should be removed. To be agreed with the RP group. → Open Action**
            - There is an open question about the **beam stopper design for the 2 GeV upgrade. It is not yet clear if it will be the same or a new one.**
        - **As BT.QNO40 and BT.QNO50 are kept in the same position as of today there is an integration issue:**

        - First of all it was noted by J.-M. Lacroix that the **vacuum chamber of BT.QNO50 should be replaced as its present diameter is excessive (199 mm).**
        - There is a **collision between BT.QNO40 and BT.DVT60 as well as a collision between BT.QNO40 and the support of BT.BPM40.**
        - O. Berrig suggested to move the BT.BPM40 downstream of BT.QNO50. In this way, one could make sure to align the beam after both quadrupoles BT.QNO40 and BT.QNO50 and before injecting in BT.BHZ10. The mis-alignment could be checked by changing the strength of the quadrupole and checking if the beam remains (or not) in the same position. This change could make the checking of the line more effective. BT.DVT60 should be kept in the same position as of today, maybe shifting a bit BT.QNO40.
        - J. Abelleira and W. Bartmann said that it would be preferable to keep the BT.BPM40 in the same position as of today for better commissioning of the line as the new positions could be compared with the ones currently reported. Moroever the movement of the BT.BPM40 downstream of BT.QNO50 will imply moving the centre of the quadrupole and the optics will have to be changed again. So also the quadrupole centre should not be changed.
        - S. Gilardoni mentioned that the phase advance at the BPM is changed anyway so moving the BPMs should not be a fundamental issue.
        - **K. Hanke said that any change should be carefully evaluated if it has an impact on the schedule of the project.**
        - **These space conflicts should be investigated by JM Lacroix with the integration model to check for possible design solutions.**
        - Given the new quadrupole design, **BTP.QNO20 would collide with the current shielding of the wall. Part of the shielding has to be removed/modified.**
            - The input from the RP group is needed. R. Froeschl mentioned that he would need the scale of the amount of shielding to be removed. → **Open Action**
            - S. Gilardoni asked for the reason of having a wall separating the PSB and the PS complex. R. Steerenberg mentioned that the reason is to allow the access to the PS while operating the beam from the PSB to ISOLDE.
    - **Beam Instrumentation:**
        - The position of the wide-band pick-up in the BTP line is decided, see here.
        - **The complete integration of model of all the BPMs is anyway needed.**
        - New positions for the BLMs have been proposed.
        - BT.BTV30 has been moved outside of the tank of the septum BT2.SMV20, see here.

Stability Studies:

- Two set of errors have been considered in the study:
    - **Correctable Errors:**

        - These are errors like magnet misalignment, magnet systematic errors (due to different laminations, steel, etc, etc), magnets random errors, long term drifts due to temperature, humidity, etc, etc.
        - All these errors lead to trajectory variations that can be corrected, but since the transfer function is considered correctable a **direct relationship between the current error and the magnetic field error has been assumed ΔI/I = ΔB/B**
    - **Uncorrectable Errors:**
        - Typical errors of such kind would be shot-to-shot stability, in particular in view of ppm operation between 1.4 and 2.0 GeV, systematic errors such as power converter ripple, kicker waveforms.

- For the **correctable errors**, the feasibility of the correction was **already checked in 2013, so this assumption is still considered to be fine.**
- As a next step, the machine is assumed to be free of correctable errors and each dynamic error is treated separately to identify the main contributors to the final imprecision.
- **The error are treated as distributed as a Gaussian and using 2 σ width**
- The **emittance growth is evaluated in the normalized phase space as the square of the radius divided by the geometric emittance.**
- B. Goddard commented that for the tolerance of ΔI/I one should generally quote it based on I_{max} instead of the $I_{nominal}$. So the values assumed for the study are more conservative than needed.
- G.P. Di Giovanni asked the source of the random error associated with the PSB orbit (currently assumed to be +/- 0.15/0.10 mm, h/v). W. Bartmann replied that it was obtained from the RMS of the peak-to-peak PSB orbit variation on several shots.
- **Most of the random error on the tolerances are of the order of 10^{-4}, but for the systematic effect on the KFA10 and KFA20 that are of the order of 10-3.**
- **The biggest contribution comes from the tolerance in the switching dipole, BT.BHZ10, and the systematic effect of the recombination kickers for the horizontal and vertical plane, respectively.**
- While calculating the delivery precision of position and angle at PS injection the aperture have been checked for losses and radiation):
    - **Even after including all dynamic errors, the contributions to trajectory variation are within the defined aperture.**
- Beta-beating from uncorrectable quadrupole errors is in the regime of a few percent (**while a 20% assumed in the calculation of the GFR**) and therefore negligible compared to the systematic optics differences between the four lines.
- **S. Gilardoni asked what is the effect of a tilt in the alignment in the recombination kicker which could couple the effect in both planes.** W. Bartmann mentioned that this is considered to be **negligible for the current studies. To be discussed in case it is required to be included in future reviews.**

Conclusion:

- **The emittance growth from steering error is found to be relatively small compared to the unavoidable contribution of emittance growth from optics and dispersion mismatch for LHC-type and high intensity beams**
- A further optimization to improve the current situation would be to attempt to minimize the overall betatron and dispersion mismatches instead of exactly matching only one ring.

- **Particle losses due to emittance growth:**

- Relevant for HI beams. The worse case scenario was considered: a proton beam with kinetic energy of 1.4 GeV.
- Aperture bottleneck at PS injection when bump is fully on. It was found that 4.2 σ of HI beam could be fit in horizontal plane.
- **The imminent effect of increase due to steering error is found negligible.**
- The beam size changes by 0.8% due to optics mismatch after filamentation has taken place (slower effect)
- **The conclusion is that no additional losses due to emittance growth are expected.**

- S. Gilardoni asked which is the tunability of the line. W. Bartmann replied that the **PSB-PS extraction line is quite flexible**, as 3 very different optics have been designed and all fit within the required specifications.
- S. Gilardoni also remarked that while the study is thorough, **an emittance growth of the order of 10% is not currently observed in the BT-BTP line as the study seems to indicate for the upgraded line. B. Goddard underlined that these are all pessimistic assumptions anyway. W. Bartmann agreed that the analytical calculations lead to an overestimate of the emittance growth which was also seen dedicated measurements in the PS. The growth values should be used rather used to estimate the growth from different effects with respect to each other than absolute values**.
- G.P. Di Giovanni asked if the code is mature enough to add the code on a repository. J. Abelleira and W. Bartmann will consider this option.

Assigned to	Due date	Description
R.Froeschl	2015-11-30	Evaluate the possibility to remove part of the shielding to allow the installation of the new magnets BTM.BHZ10 and BTP.QNO20 for the upgrade of the BT/BTM/BTP lines.

5. AOB

- The next meeting is tentatively scheduled for the 8th October 2015.