Minutes PSB Upgrade WG Meeting 8th March 2016

Participants: S. Albright, M.E. Angoletta, E. Benedetto, F. Boattini, J. Devine, G.P. Di Giovanni, T. Dobers, V. Forte, R. Froeschl, G.M. Georgiev, G. Guidoboni, M. Haase, M. Migliorati, B. Mikulec, S. Moccia, M.M. Morgenstern, A. Newborough, S. Pittet, D. Quartullo, J. Tan.

Agenda (https://indico.cern.ch/event/504432/):

1. Approval of Minutes

- The minutes of the last LIU-PSB WG meeting #168, available here, have been approved.

2. Communications

- **EN-EL Activities:**
  - The last LIU Project Team meeting was dedicated to the review of the outcome of the LIU meeting with the EN-EL Group.

- **EN-CV Activities:**
  - A review was held the 7th March to review the activities to be carried out by EN/CV in the framework of LIU.
  - Minutes are available here.
  - As a result, few actions have been opened, see below.

Assigned to	Due date	Description
M.Haase	2016-03-31	Confirm the requirement for CV about the new RF system and in particular about the C16-RF cavity, which was originally foreseen to run on drinking water for ferrite cavities.

Assigned to	Due date	Description
F.Boattini	2016-03-31	Confirm the requirements for CV of B245 specified in the EDMS documents 1327071and 1573184.

Assigned to	Due date	Description
F.Boattini	2016-06-01	Update the schedule of the powering tests foreseen in B245 for the commissioning.

Assigned to	Due date	Description
S.Moccia	2016-05-15	Prepare a document containing the requests received for the demineralized water cooling system.

- **ECR/SRR Needed for EYETS:**
  - J. Coupard prepared a list of the ECR and SRR needed for the scheduled work to be done during EYETS (2016/2017).
  - The complete list is available here.
  - The relevant contact people have been informed and requested to provide the necessary feedback.

3. Follow-up of Open Actions

- W. Weterings on "Define a set of requirements for CV needed for the foil exchange procedure." → Measurements of the air flow were performed during the last YETS 2015/2016 in the area where the foil exchange procedure should take place with and without ventilation active. No measurable difference in the airflow could be detected. W. Weterings added that the foil exchange procedure will be performed under a glass box to protect the foil. **Action closed**

- S. Moccia on "Verify the feasibility of W. Weterings' requirements for CV for the foil exchange procedure." → See above. **Action closed**

4. Review of the Present Issues in the Alignment the PSB Equipment

- G.P Di Giovanni presented the alignment changes during YETS 2015/2016 in the BI line and PSB rings, see here.
- **BI Line:**
  - **Align BI.QNO40 and BI.QNO50 in the horizontal plane** in order to lie on smooth the line connecting BI.QNO30 and BI.QNO60.
  - **BI.BPM40 was realigned in both horizontal and vertical planes** to have a zero offset with respect to the neighbor quadrupole magnets.
  - **BI.BPM50 could not be realigned.**
- **PSB Rings:**
  - **BR.QFO72** had to be replaced because of a vacuum leak and offered the occasion to realign it: Move horizontally the exit point to zero.
  - The replacement of BR.QFO72 also provided the possibility to test of the main dipole realignment on **BR.BHZ72**: Realign horizontally entry and exit points to zero.
  - Due to a vacuum leak on BR.BHZ62, **both BR.QFO62 and BR.BHZ62** had to be taken out:

        - Align horizontally entry and exit points for both elements.
        - Align vertically entry and exit points of BR.QFO62 to 1.5 mm.
        - Align vertically entry and exit points of BR.BHZ62 to 1.4 mm.
    - **The alignment of BR.QFO151, BR.QDE15 and BR.BPM15L3 could not be performed because of issues with a screw in BR.QFO151:**
        - The alignment of these elements is a long standing issue.
        - G. Dumont from the RP Group presented the RP survey and one of the hottest area is between Sections 15 and 16.
        - **E. Benedetto, using YASP, tracked back the current vertical orbit distortion measured in the PSB rings to the mis-alignment of the QDE15 quadrupole.**

- **Review of the Present Issues in the Alignment the PSB Equipment by T. Dobers:**
    - **Issue with BI.BPM50:**
        - T. Dobers could access the triangular area between the PSB rings, the BT and lines, but finally there was a **piece of black material, likely carbon, which blocked the access to the screws to BI.BPM50**. The block is fixed on the frame of a quadrupole and the mentioned BPM.
        - B. Mikulec asked if it would it be possible to identify the material.
        - After the meeting T. Dobers sent a **photo, to be circulated to the working-group to help the identification of the block.** → **Action postponed to end of the year.**
    - **Issue with BR.QFO151:**
        - In this case the screws could be accessed, but one of them was blocked. Adding greasing on it did not help.
        - **The problem seems connected to the jacks themselves. A proposal for the next EYETS is to use auxiliary jacks to lift the magnet and turn (or even change) the screw without the load of the magnet.**
        - J. A. Ferreira Somoza mentioned that the lifting should be as minimal as possible to not misplace pipes, bellows, etc, etc. T. Dobers confirmed that he is aware of these issues and the operation would be done with the proper care.
    - **Test on the SPS jacks:**
        - **The alignment of the two bending magnets BR.BHZ62 and BR.BHZ72 was performed using the current old jacks, i.e. there was no need to test the SPS jacks.**
        - **T. Dobers added he is confident that using the SPS jacks, if needed, will not be an issue.** → **Action closed.**
        - B. Mikulec asked if by using the SPS jack there could be additional delay in the realignment operation. T. Dobers replied it should not be the case.
    - **Tilt measurement tool:**
        - The tool will be designed and fabricated at CERN. It should anyway be a modified version of the existing tool.
        - **The input about the design of the quadrupole magnets is needed. A. Newborough mentioned that the design of these quadrupole magnets should be finalized within the next few weeks.**
        - B. Mikulec suggested to test the tilt measurement tool on the current quadrupole magnets to validate it.

- G.P. Di Giovanni asked if there are other known elements which are difficult to align. T. Dobers confirmed that, to his knowledge, only BI.BPM50 and BR.QFO151 are the elements which pose problems with their alignment.

5. Longitudinal Dynamic Simulations of PSB Beams in the LINAC4 Scenario

- D. Quartullo presented slides about the longitudinal dynamic simulations of the PSB beams for the LIU, see here.

SUMMARY:

- The motivation behind the presented studies is to assess the longitudinal beam dynamics for the PSB beams after LS2:
    - The injection kinetic energy will increase from 50 MeV to 160 MeV.
    - The extraction kinetic energy will be 1.4 GeV for ISOLDE-type beams, or 2 GeV for HL-LHC beams.
    - The simulation code is called BLonD, acronym of Beam Longitudinal Dynamics, and it is developed at CERN by the BE/RF Group for synchrotron accelerators:
        - Code and documentation are available at http://blond.web.cern.ch/.
    - The code has been successfully benchmarked against pyOrbit, a PIC (particle-in-cell) code developed at SNS.
    - The impedance model has been updated and revisited for the PSB:
        - Accurate results for the **space-charge impedance at injection** obtained via the LSC code developed at SLAC and using inputs from the most updated simulations and measurements. The average impedance was estimated to be **633.14 Ω**
        - **The space-charge impedance along the cycle was obtained rescaling from the value of the space charge at injection. There is a factor 8 change during cycle, but the space-charge effect is reduced less due to bunch length reduction.**
        - Other sources of impedance are the extraction kickers, extraction kicker cables, KSW magnets, resistive wall, beam pipe discontinuities and Finemet cavities.
        - **The Finemet real part impedance dominates all the other contributions which can be considered as a perturbation which is slightly dependent on beam energy.**
            - **Three possible configurations for Finemet cavities: Short circuited gap off, gap on with open loop, gap on with closed loop.**
                - The short circuited impedance is a small contribution.
                - **The dominant contribution comes from the gap with open loop.**
                - **The importance of the gap with closed loop is to reduce the impedance at specific longitudinal harmonics, from 1 to 8 and in case even more.**
    - One turn wake **excludes the relevance of Robinson instability mechanisms.**
    - **Loss of Landau damping in single RF for both HL-LHC and ISOLDE beams ISOLDE.**
    - **Simulation results:**
        - **Single RF:**
            - ISOLDE-type beam was simulated with a voltage of 15 kV and an intensity of 1.6e13 ppp per ring.

        - **Some dipole and quadrupole oscillations observed at the end of the ramp, but no losses.**
    - HL-LHC-type beam was simulated with a voltage of 8 kV and an intensity of 3.6e12 ppp per ring.
        - **No dipole and quadrupole oscillations along the cycle (the Bdot is different from the ISOLDE-type beam and the intensity is lower). Also no losses.**
- **Double RF:**
    - The second voltage starts to decrease linearly at C705.
    - ISOLDE-type beam was simulated with a voltage of 12 kV +6 kV and an intensity of 1.6e13 ppp per ring.
        - **As for the single RF, dipole and quadrupole oscillations observed at the end of the ramp, but no losses.**
        - **Phase for bunch lengthening mode simulated without considering intensity effects.**
        - **Some filamentation at the end of the cycle.**
    - HL-LHC-type beam was simulated with a voltage of 8 kV + 4 kV and an intensity of 3.6e12 ppp per ring.
        - **No dipole and quadrupole oscillations along the cycle and no losses.**
        - **Phase for bunch lengthening mode simulated without considering intensity effects.**
        - **Phase of second RF in bunch lengthening mode creating high peaks in line density towards the end of the ramp leading to strong filamentation (also because of high deceleration).**
        - Tried several other voltage combinations: **Bunch splitting and merging for the 8+6 and 8+8 cases. Bunch emittance too small.**
        - The bucket and bunch areas increase as the second harmonic voltage goes up.

- **To add in the simulation:** Phase-loop, study of effect of noise in momentum program, double RF operation in particular phase optimisation through cycle taking into account intensity effects and study of controlled emittance blow-up.

- E. Chapochnikova remarked the importance of optimizing the double RF process:
    - So far the difficulty is that **the phase between the RF cavities is not known well enough**. Somehow the phase of the emittance blowup is arbitrary.
    - It was asked if the LLRF group could think about means to measure it.
- **B. Mikulec mentioned that the longitudinal emittance requirement for LIU-PSB is 2.4 eVs for LHC-type beams:**
    - So far only an emittance of 1.8 eVs was reached.
    - A. Findaly and S. Hancock plan to look at the blow up and understand if the current limit can be overcome.
    - **This is a crucial input for LIU because if the required emittance could not be reached then the parameters will have to be updated.**

Detailed Description

- The motivation behind the presented studies is to assess the longitudinal beam dynamics for the PSB beams after LS2:

    - The injection kinetic energy will increase from 50 MeV to 160 MeV.
    - The extraction kinetic energy will be 1.4 GeV for ISOLDE-type beams, or 2 GeV for HL-LHC beams.
    - The Longitudinal beam dynamics simulations is meant to predict beam stability based on:
        - A realistic impedance model (cavities, ...).
        - Reliable estimation of space charge-dominant impedance source.

- The simulation code is called BLonD, acronym of Beam Longitudinal Dynamics, and it is developed at CERN by the BE/RF Group for synchrotron accelerators:
    - The code is supposed to replace ESME, developed at Fermilab.
    - Code and documentation are available at http://blond.web.cern.ch/.
    - The code is written in Python and C++.
    - It allows simulation of single and multi-bunches, while simulating acceleration, multiple RF systems, multiple RF stations, etc, etc
    - The collective effects can be treated in frequency and time domain.
    - The code includes low-level RF options (phase noise, phase loop, feedbacks...).
    - **A treatment of the low-beta case (introduced for PSB).**

- The code is currently used to describe the RF gymnastic performed at CERN in the accelerator chain:
    - PS-to-SPS bunch splitting and rotation.
    - LHC emittance blow up, achieved injection controlled noise in the RF phase to blow-up the core while maintaining the tail in a certain area.

- **Code benchmarking:**
    - The code was benchmarked against measurements of the full-width-at-half-maximum (FWHM) bunch length at PSB extraction for various intensities, full ramp. The agreement is less than 10 ns, with a slightly more blow-up in the measurements.
    - The simulation was compared to PyOrbit simulation for the injection energy at 160 MeV in double RF, with and without space-charge, and the simulation results are nearly identical.
    - Finally the synchrotron frequency distribution for a matched parabolic bunch with space-charge below transition was compared between BLonD and PyOrbit to give a perfect agreement.

- **Space-charge impedance estimation at 160 MeV (injection):**
    - Several estimation were done, based on formulae valid for round uniform beam in a circular potential or based on tomoscope measurements, which gave a wide range of results.
    - A more accurate results was obtained via the LSC code developed at SLAC and using input from the most updated simulations and measurements. The average impedance was estimated to be **633.14 Ω**

- **Space charge impedance during the cycle:**
    - Obtained scaling from the value of the space charge at injection.
    - Factor 8 change during cycle, but the space-charge effect is reduced less due to bunch length reduction.
    - E. Benedetto asked if the value of the space-charge impedance has been compared with the results from C. Zanini. D. Quartullo replied that this check was not yet done.

- **PSB impedance model:**
  - Other sources of impedance are the extraction kickers, extraction kicker cables, KSW magnets, resistive wall, beam pipe discontinuities and
  - Finemet Cavities:
    - This is the second most important contribution to the impedance model.
    - Three Finemet cavities (36 gaps) will be installed in each ring for total V of 24 kV.
    - Three possible configurations: Short circuited gap off, gap on with open loop, gap on with closed loop.
    - The short circuited impedance is a small contribution.
    - **No dependency on the beam energy, but only revolution frequency.**
    - The dominant contribution comes from the gap with open loop.
    - **The importance of the gap with closed loop is to reduce the impedance at specific longitudinal harmonics, from 1 to 8 and in case even more.**
      - With the closed loop the impedance contribution remains comparable to the other contributions from resistive wall, extraction kicker and kicker cables and KSW magnets. This is the case for both real and imaginary component.
      - The current limit in the simulation is a frequency of 100 MHz determined by available Finemet impedance measurements.
  - The Finemet real part impedance dominates all the other contributions which can be considered as a perturbation which slightly dependent on beam energy.
  - For the imaginary part impedance, at injection and extraction energies the space charge impedance dominates all the other components above ~1 MHz and ~4 MHz respectively.

- **PSB longitudinal wake:**
  - One turn wake unlike the case with ferrite cavities where the wake was lasting > 100 turns, exclude the relevance of Robinson instability mechanisms.

- **Simulation:**
  - For ISOLDE-type beam simulation with an extraction kinetic energy of 1.4 GeV the current operational cycle was assumed. The intensity was set to 1.6e13 ppp.
  - For HL-LHC-type beam simulation with an extraction kinetic energy of 2.0 GeV the new operational cycle was assumed. The intensity was set to 3.6e12 ppp.
    - The new designed cycle has a faster acceleration than the current operational cycle (and faster deceleration at the end). The derivative of the B-field at injection is greater than 0.
  - Other assumptions made:
    - No longitudinal painting at injection in simulations.
    - Bunch emittance of 1 eVs after filamentation.
    - Costant voltages along the ramp.

- Landau damping:
  - **Loss of Landau damping in single RF for both HL-LHC and ISOLDE beams ISOLDE.**
  - Landau damping in a single RF is lost for the whole cycle above ~3e12 ppp.
  - Simulations at 15 kV using a kick show showed that Landau damping is lost between 1e12 ppp and 2e12 ppp:
    - Good agreement with analytical prediction, and the oscillations will be damped by the phase loop, not yet simulated.

- **Simulation results:**
  - **Single RF:**
    - ISOLDE-type beam was simulated with a voltage of 15 kV and an intensity of 1.6e13 ppp per ring.
      - **Some dipole and quadrupole oscillations observed at the end of the ramp, but no losses.**
    - HL-LHC-type beam was simulated with a voltage of 8 kV and an intensity of 3.6e12 ppp per ring.
      - *No dipole and quadrupole oscillations along the cycle (keep in mind the Bdot is different from the ISOLDE-type beam and the intensity is lower). Also no losses.
  - **Double RF:**
    - The second voltage starts to decrease linearly at C705.
    - ISOLDE-type beam was simulated with a voltage of 12 kV +6 kV and an intensity of 1.6e13 ppp per ring.
      - **As for the single RF, dipole and quadrupole oscillations observed at the end of the ramp, but no losses.**
      - **Phase for bunch lengthening mode simulated without considering intensity effects.**
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    - HL-LHC-type beam was simulated with a voltage of 8 kV + 4 kV and an intensity of 3.6e12 ppp per ring.
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      - Tried several other voltage combinations: **Bunch splitting and merging for the 8+6 and 8+8 cases. Bunch emittance too small.**
      - The bucket and bunch areas increase as the second harmonic voltage goes up.

- **To add in the simulation:**
  - Phase-loop in simulations.
  - Study of effect of noise in momentum program.
  - Double RF operation:
    - Phase optimisation through cycle taking into account intensity effects.
  - Study of controlled emittance blow-up.

- E. Chapochnikova remarked the importance of optimizing the double RF process:
  - So far the difficulty is that the phase is not known well enough.
  - Somehow the phase of the emittance blowup is arbitrary.
  - It was asked if the LLRF group could think about means to measure it.
  - M.E. Angoletta mentioned that the phase between C02 and C04 cavities depends on the synchrotron frequency in bunch lengthening mode. E. Chapochnikova replied it should not be the case.
- B. Mikulec mentioned that the longitudinal emittance requirement for LIU-PSB is 2.4 eVs for LHC-type beams:
  - So far only an emittance of 1.8 eVs was reached.

    - A. Findaly and S. Hancock plan to look at the blow up and understand if the current limit can be overcome.
    - This is a crucial input for LIU because if the required emittance could not be reached then the parameters will have to be updated.
- S. Albright wondered about the possibility of changing the Bdot since the filamentation observed in the LHC-type beam seems to depend on the strong variations at the end of the cycle.

6. AOB

- The next meeting is planned for the 22nd March 2016.
- G.M. Georgiev reported about the request of the EN-EL Group to install some additional containment (1 extra 300mm ladder in most parts of the PSB):
    - These **ladders were previously designated as 'future space reservations' however, it turned to be significantly easier to install them now before the cables are pulled.**
    - The works will take **an extra 2 weeks and should be completed by the 18th March 2016.**
    - The motivation for similar extension is to be able to offer definitive power supplies to any users who need it from the EN-EL new distribution infrastructure, and before the end of year shutdown (EYETS + 1 week) this year.
    - **If the work is delayed the EN-EL Group will not be in a position to energise the new infrastructure for at least the start of EYETS + 3 (minimum) weeks. Moreover during this activity will have to be carried out in parallel with the decabling campaign.**
    - **B. Mikulec agreed on the work extension under the following conditions:**
        - **K. Hanke should agree.**
        - **Extreme care should be taken by the contractors to avoid damage of installed equipment, in particular of parts sticking out from the racks (like connectors, cables). There was an instance with a card for the B-Train being broken during one of the previous containment installation.**
        - **M. Haase mentioned that they have originally been asked that material for these interventions to be stocked in the BRF2. It seems that now this room (which has sensitive operational high-voltage equipment inside) has also been used to do works like cutting pieces with machines. Such work producing metallic dust going over the crates has to be performed outside.**
- R. Froeschl reported that a meeting was held with A. Perillo Marcone and J. Hansen to discuss about the material choice for the window at the exit of the BTM line. The material choice is titanium which seems to be adequate from an RP point of view and acceptable from the TE-VSC Group. The choice will be formalized in a presentation at the LIU-PSB WG meeting.