# Minutes PSB Upgrade WG Meeting 5th November 2015

**Participants:** M. Buzio, R. Chritrin, J. Coupard, J. Devine, G.P. Di Giovanni, A. Findlay, R. Froeschl, D. Grenier, G. Guidoboni, M. Haase, K. Hanke, J. Hansen, D. Hay, B. Mikulec, S. Moccia, M. Morgenstern, A. Newborough, M. Paoluzzi, S. Pittet, W. Weterings.

Agenda (https://indico.cern.ch/event/458040/):



## 1. Approval of Minutes

- The minutes of the last LIU-PSB WG meeting #161, available here, have been approved.

## 2. Communications

- **Management News:**
  - K. Hanke will take over S. Gilardoni as project leader for the LIU-PS starting from the 1st December 2015.

- **Party for the End of the Year:**
  - The tentative date is the 10th December 2015 at around 16:00.
  - More details about the exact location and time will be sent later.

- **LIU-PSB Meeting Time Slot:**
  - The new proposed time slot for the meeting is on Tuesday from 16:00.
  - The LIU-PSB WG meeting will be alternated with the LIU-PS WG meeting on a tentative bi-weekly basis.

- **Consolidation:**
  - The LIU-PSB project has been requested to provide a list of the **essential consolidation requests**, with a precise description of the necessary consolidation items, location, budget and reason for each request.
  - An email has been circulated to the WP-holders.
  - Based on the input received, K. Hanke and B. Mikulec prepared a **preliminary summary, see here.**
  - **Several items are still missing. The WP-holders are requested to send the information to K. Hanke and B. Mikulec**

- **LIU-PSB Spending:**
  - The LIU-PSB project has been requested to **update the budget to reflect the real expenditures until the end of the year**. The table to fill is available here.
  - **The WP-holders are requested to send the information to K. Hanke and B. Mikulec**
  - **The deadline has been set to the 10th November 2015.**

- **Some inconsistencies were found while comparing the budget with the data extracted from CET in the last weeks**:
  - The level of spending (including the pipeline) has dropped down from 53% to 45% from the data of 30th September 2015 and 14th October 2015.
  - The main explanation for the **spending decrease comes from BC 99238 (new MPS)**, because the sum that was in the pipeline was drastically cut. F. Boattini confirms that the changes for 99238 originate from moving the adjudication of the contract for the power converters (IT 4094) and of the storage capacitors (IT-3990).
  - During the process the LIU-PSB **payment budget for 2015 has suddenly decreased by 215 kCHF**. This could mainly be explained by the change in **3 budget codes, 65732, 65735, 65740 (PSB injection)**. For these ABT budget codes, it turns out that a budget adjustment has been done within TE.
  - If third parties manipulate the data directly in CET, and without informing the management, the tracking of the budget codes becomes very complicated.
  - An additional point to be clarified is that apparently parts of the material budget were used to finance manpower, which should not be the official policy.

- **Space Reservation (SSR):**
  - J. Coupard reported that several SRRs are expected from the PSB:
    - **New absorber/scraper in period 8 (Contacts: F-X Nuiry/D. Grenier).**
    - **New pick-up in 3L1 (Contact: M. Gasior).**
    - **Finemet cavity C16 in 5L1 (Contact: M. Paoluzzi).**
    - **New BLMs (Contact: C. Zamantzas).**
    - The responsible experts have been additionally contacted by B. Mikulec.

- **Alignment Issues in the BI Line:**
  - The issue is that **T. Dobers cannot align a few elements (magnets and BPM) between the end of the BI line and at the beginning of the BT line.**
  - A meeting was organized among experts of CV, RP and Survey Groups to define the best strategy to follow.
  - **Pipes used for CV are blocking the access to the alignment screws at the basis of the elements on the side outside the PSB ring.** A. Newborough commented that since the problematic magnets are going to be replaced, one could envision a different alignment system. B. Mikulec added that unfortunately this issue also affects some BPMs.
  - An access was already performed to investigate the area concerned.
  - **Major work would be needed to re-route these pipes.** All steps should be taken to try to access the screws in other manners before considering a re-routing of the pipes.
  - **It was agreed that a walkway should be installed for T. Dobers to access the magnets on the internal side of the PSB rings. If the alignment can be performed from this side, the problem would be solved.**
  - During the investigations it was observed that **2 pipes of cooling water (open circuit) are not used anymore** and during LS1 already the valves were closed and nobody complained since. These 2 pipes run along the BI/BT lines, and along the ring and further to the PS tunnel through the shielding wall.
  - **OP asked CV to start a cleanup campaign. This will not solve the alignment issues, but will free space besides the beam lines and ease access to the cables installed**

**below. The details of this intervention have to be discussed with the RP Group.** A. Newborough proposed to take the occasion to assess which are the water cooled elements in the BI line. S. Moccia will make sure that during the YETS 2015/2016 the CV drawings of the CV infrastructure in the machine will be updated.

### 3. Follow-up of Open Actions

- 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." → An MD is foreseen on Monday 9th November 2015.

- D. Grenier on "Report about the status of the beam stopper certification for the 160 MeV/2 GeV operations." → A new fellow just started working on it. The deadline was moved to June 2016.

### 4. Measurements on the PSB Dipole Magnet and the Proposed Trim Circuits

- R. Chritin presented the results of the measurement campaign on the PSB main and injection dipole magnets, see here.

**SUMMARY:**

- A measurement campaign was carried over in order to assess the magnetic properties of the field in the PSB main and injection dipole magnets.
- It was observed that the **new laminated sides plates installed only on the outer apertures provide the most optimal configuration** to:
    - Reduce integrated differences between outer apertures at 2 GeV.
    - Reduce the disparity between main and injection magnets at high currents.
    - **Reduce the current requirements for power converters and subsequently reduce the requirements for the Q-trims.**

Hide Detailed Description

- **PSB Main Dipole Magnets:**
    - Measurement Setup:
        - Two 6 kA power converters: one for the measurements in the inner apertures and one for outer apertures.
        - All measurements were taken in pulsed mode with 2.5 meters long coil plus ADC acquisition.
        - 3 different side plates configurations were tested: **All 4 rings equipped with the original side plates**, **all 4 rings equipped with the new (laminated) side plates**, **only the 2 outer rings equipped with the original side plates (mixed configuration)**.
    - **The first measurement campaign aimed at determining the currents needed by the two converters to achieve the same integrated field level in both inner and outer gaps for 1.4 and 2.0 GeV and define the requirements for the Q-trims:**
        - It was measured that the difference in current between inner and outer aperture to reach the same integrated field at 2.0 GeV is:
            - 188 A (3.44%) for the original side plates.
            - 74 A (1.38%) for the new side plates installed in all 4 rings.

        - 67 A (1.25%) with the mixed configuration: old side plates in the inner rings (more saturation), and new side plates in the outer rings (less saturation).
    - Similar trend was observed for the measurements at 1.4 GeV.
    - The mixed configuration provides the best performance in reducing the current to reach the same integrated field in all 4 apertures.
  - **The second measurement campaign aimed at determining the equivalent magnetic length of the four apertures for the different configurations:**
    - The balance of the magnetic lengths for the 4 rings is improved at 2.0 GeV with the mixed configuration, while it is slightly worsen at 1.4 GeV.
    - A slight increase of the equivalent length was observed with the mixed side plates if compared to the original ones.
  - **Excitation Curves of the Center and Integrated Field (Bdl):**
    - The saturation is measured to be higher in the outer apertures.
    - The saturation was measured to be higher in the integral field due to saturation effects at the end of the magnets.
    - Measurement of the dynamic excitation curves with the original plates and the mixed side plates configuration showed a clear improvement in reducing Eddy current effects with the use of the laminated plates, mostly for the outer apertures.
  - **Eddy Current Effects:**
    - The comparison was done between the mixed configuration and the one with the new plates installed on all 4 apertures.
    - These values are not directly comparable to those reported in 2011 due to different test conditions.
    - The new plates reduce the amplitude of the eddy currents, while the time constant is not significantly affected both at 1.4 and 2.0 GeV.
- **PSB Injection Dipole Magnet:**
  - Similar measurements were performed on the PSB injection dipole magnet with the default configuration and compared to results on the PSB main dipole magnets with different side plates configurations.
  - The injection dipole magnet has a smaller current difference between apertures than measured in the main dipole with the original side plates (128 A versus 188 A).
  - Integrated field difference between the two outer apertures and the two inner apertures is at the per mill level, and it is improved with the mixed configuration for the side plates. It could possible to trim the difference between the two inners and two outers with extra shims.
  - The difference in integrated field between outer and inner apertures was found to increase at 2.0 GeV with respect to the 1.4 GeV case.
  - The measurement of the excitation curves showed similar expected trend as for the main PSB dipole magnet, but more saturation effects are measured on the PSB main dipole magnet.
  - The measurement of the integrated field quality showed an homogeneity better than +/- 1 per mill on +/- 80 mm.
  - The measured Eddy current effects were comparable to the ones measured in the PSB main dipole magnet.
  - The profile of the integrated field along the longitudinal direction was compared to simulation:
    - Very good agreement was observed between data and simulation.

        - Field attenuation on the magnet side was measured with respect to the simulation because of the injection beam pipe which goes across the yoke causing more saturation in this area.

- B. Mikulec asked if it is understood why more saturation is observed in the PSB main dipole magnets with respect to the injection ones. A. Newbourough replied that the reason has not been investigated yet.

- A. Newborough presented a status of the design of the PSB dipole magnets and required trims, see here.

**SUMMARY:**

- **The proposal is to install the laminated side plates on the outer gaps of the 30 normal magnets.**
- Two new special magnets with additional isolated trim circuits will be produced and the existing magnets will be fitted with new coils including the trims to act as dedicated spares.
- **The requirements for the trim circuits to compensate for the differences between the magnet design and steel properties have been discussed with EPC and a solution is almost set.**
- **Open issue: The required margin for the QF and QD trim converters needs to be determined. An option for sizing them to the 6 kA of the MPC with the possibility of 5 % 'tunability' of the gradients has been presented but this has to be followed up with the EPC group, who already stated that most likely the limit is 5.5 kA.**
- Tests on the new steel are needed to better determine the margin on the MPS and TRIM currents.
- **Design of the new INJECTION/EXTRACTION bending magnets well underway: steel has been ordered, coil design well advanced. → A document with the specification will be circulated by the end of the year.**

Hide Detailed Description

- The presentation is based on the results from the measurement campaign applied to the 2.0 GeV cycle.
- The configuration for the LIU-PSB main magnets is to be split and powered by two MPC:
    - BHZ Outer (30 x BHZ 1+4, 1 x BHZ INJ 1+4, 1 x BHZ EXT 1+4) and 32 QF all in series
    - BHZ Inner (30 x BHZ 2+3, 1 x BHZ INJ 2+3, 1 x BHZ EXT 2+3) and 16 QD all in series.
- The MPC will drive the currents in the main bending to correct field compensating the differences between BHZ Outer (1+4) and BHZ Inner (2+3) due mainly to saturation.
- Parallel trim converters act on the QF and QD magnets to achieve the correct gradients, while isolated trim converters will compensate for differences between the two BHZ INJ & EXT magnets.
- The BDL and QSTRIP trim converters compensate for differences between rings.
- The evolution of the requirement on the trims is:

| Magnet Circuit | First Extrapolated Trims (+) | Trims from the Measurement Campaign (orig. side-plates) | Trims from the Measurement Campaign (mixed config.) |
|---|---|---|---|
| Bending Outer | 5268 A | 5470 A | 5350 A |

| | | | |
|---|---|---|---|
| Bending Inner | 5268 A | 5282 A | 5280 A |
| QF | -365 A | -567 A (++) | -446 A |
| QD | -365 A | -292 A | -290 A |
| INJ/EXT Outer | -268 A | +18 to -45 A (+++) | +75 A |
| INJ/EXT Inner | -268 A | +16 A | +18 A |

(+) Courtesy of J.L. Sanchez-Alvarez who extrapolated the trims from the proposed magnetic cycle. The extrapolation does not take into account separate powering of the inner and outer gaps and saturation.
(++) Because the outer gaps have higher saturation the QF which are connected in series need higher current.
(+++) Since the INJ/EXT magnets have less saturation with respect to the main bending magnets the current goes from +18 A to -45 A to compensate for the difference.

- **The introduction of the laminated side plates on the outer gaps will minimise the differences between the inner and outer rings as well as minimise the QF trim requirement.**
- **All these results do NOT assume any margin.**
- A. Newborough contacted E. Benedetto who proposed that a 2/3% margin should be fine.
- In order to have an idea of a few percent tunability, **the MPC trim has been scaled to the maximum of 6 kA provided by the MPS for the outer bending magnets. Assuming for 5% margin, the QF(QD) would need -802(-580) A. The margin would be on the MPS current and not on the TRIM current**. This does not mean that either the MPS or the magnets can achieve or operate at this value. The margin has to be discussed with the EPC Group. A meeting will take place to refine the values soon.*

- **More Details about the PSB INJECTION/EXTRACTION Dipole Magnets:**
  - Two new magnets are to be built, one for each of the INJ & EXT regions.
  - The new magnets will include new coils with trim windings to compensate for differences already seen at 1.4 GeV which will become worse at 2 GeV.
  - The existing magnets once removed will be fitted with the new coils to act as dedicated spares.
  - The magnets are to be powered with pairs of apertures connected in series: INJ 1+4, INJ 2+3, EXT 1+4, EXT 2+3.
  - **Margin:**
    - A factor of 12/10 for difference between # turns on main and trim coils.
    - A margin of 250% (requested by MSC) due the difference in performance of the steel and field given by MPS. To be determined and discussed in case.
    - The following assumptions would lead to a requirement of 230 (60) A for the INJECTION/EXTRACTION outer (inner) bending magnets.
    - **If the full MPS of 6 kA was applied there may or may not be enough margin. It depends on the performance of the steel, which is not yet**

**available for testing. A sample of the old steel has been used for chemical analysis.**

- The design of the coil is well advanced and the requirement for the converters have been defined.
- There are few constraints on the coupled voltage due to the particular variation of the ramp at injection and between 600 ms and 800 ms. These are being discussed with the EPC Group.

- S. Pittet commented that it will be not possible to reach a current of 6 kA especially trying to keep the request of a 10% margin on the RMS current requested by MSC. It is more likely that the upper limit is about 5.5 kA.
- K. Hanke commented that another hard constraint on increasing the current could come from the cooling needs to operate at high current.
- A. Newborough replied that A. Blas also presented a cycle long 900 ms which reduces the requested magnet performance almost to the current ones at 1.4 GeV.
- J. Hansen asked which type of magnets would be the one installed in case of an early Linac4 connection in 2016 as the Vacuum Group is working on the chambers and support for the coils of the new magnets. A. Newborough replied that the injection magnet would be one of the existing spare, but the installation of the new coils is foreseen for the beginning of 2018. Generally, the early Linac4 connection in 2016 is the worse case scenario for the MSC as also the magnet in Section 11, BR.BHZ11, will have to replaced using the second spare. But at that point one of the radioactive magnet will have to be used as reference magnet and this is not an optimal working scenario.

## 5. Booster B-train System Upgrade

- M. Buzio reported about the status of the B-train system upgrade, see here.

**Summary:**

- The new PSB B-train system will be based on the PS B-train upgraded system which is currently being tested with positive results. **The goal would be to switch to the new B-train on-line for long-term testing sometime mid 2017.**
- The old system is to be dismissed after LS2.
- The PSB B-train will consist of two independent system installed in ring 3 and 4 and two independent system to act as a spare installed in ring 1 and 2.
- The procurement of the electronics is well underway as well as the definition of many of its details.
- **On the other hand, it is very unlikely to be able to test the system with beam before LS2, but certainly all the possible online and offline tests will be performed before LS2.**
- **The synthetic B-train was not originally not included in the project. The idea is to first understand the implementation in the current system and present a proposal which should be the standard implementation for all the accelerator complex.**
- If the old MPC has to be used because of problems with POPS-B, three scenarios are possible:
  - Use the existing B-train and reference magnet kept “as is” with the **risk of unmaintained(-able) components. → Current default**
  - Use the new B-train system with the old power supply, either
    - **By connecting the new reference magnet to the old power supplies and pulling 6 kA cables. → Recommended by M. Buzio**

        - By using the existing reference magnet and pulling sensor cables from the existing to the new reference magnet (may add noise) or bring the electronics racks of the new system to the existing reference magnet and adapt it.

Hide Detailed Description

- The new PSB B-train system will be based on the PS B-train upgraded system:
    - A prototype PS system has been deployed in 2014, now measuring in parallel with the old system and giving feedback to the RF system via the WhiteRabbit communication system.
    - It was tested with both protons and ions. The initial tests are encouraging.
    - The system is calibrated to be as close as possible to old B-train and for the moment works only on few selected cycles.
    - The ongoing work include finalization of the FPGA firmware and FESA classes, sensor improvement, test and calibration in all relevant cycling conditions.
    - The goal is to switch on-line for long-term testing sometime mid 2017, such that the old system could be dismissed after LS2.
- Concerning the dB/dt of the 2.0 GeV PSB cycle, which is the main parameter for the B-train, the major constraints come from the ramp up at injection (6 T/s) and the ramp down after extraction (-9 T/s). It is important to take into account the ramp down as the long term goal is to have a **continuous integration in order to abstract the B-train system from the timing** of the machine which is a source of error during the operations.
- In order to have a resolution of 0.1 Gauss, the measurement have to be streamed out at 600 kHz (within the theoretical peak of the WhiteRabbit, 1 MHz).
- Layout:
    - **Two independent system installed in ring 3 and 4. Two independent system to act as a spare installed in ring 1 and 2.**
    - Electronic components (and spares) for all approved systems are in production (early 2016).
    - Linux Front-Ends and CTRi timing cards are available as stock components.
    - NMR components already at CERN (or available rapidly).
    - **Still being defined: integral PCB fluxmeters (4-10 months to procure), sensor supports, cabling, FESA classes and OASIS diagnostic signals.**
- Open issues from last LIU-PSB WG meeting (here):
    - Since the top/bottom asymmetry in the rings is measured to be less than 2E-4, hot-spare duplicated sensors can be added in the bottom rings at little additional cost.
    - The NMR frequency programming would be done via FESA classes (controlled in the CCC).
    - Three full-height racks are needed and will be placed as close as possible to the reference magnet (communicated to D. Hay and included in the plan).
    - In order to perform real time diagnostic and check if there are differences between the apertures or the spares the operational sensors, it will be possible to read back the current coming from the DCCTs. The development is ongoing.
    - The continuous integration provides a more robust system, but it is not yet implemented. The next few months will be dedicated to implement it.
    - Synthetic B-train:
        - **Originally not included in the project.**
        - It is needed for the RF cavity tuning w/o beam, typically on each restart.
        - It may be needed to run the beam in place of the measured B-train, e.g. in case of faults or for testing purpose.

        - The system is implemented in slightly different ways depending on the accelerator complex. The goal would be to standardize the implementation.
        - The setup is done via FESA software.
        - **A proposal is being prepared which foresees a system based on an additional FMC card able to get in input current (either in real time or a preset waveform) and apply a magnetic model to derive the field.**
        - **A. Findlay commented that up to now the beam could not be accelerated with the synthetic B-train, but recently there have been few developments and the acceleration process would be tested again.**
    - Planning:
        - Currently the planning is still rough as there are problems with the resource allocated.
        - **The current resources are sufficient for the work on the PSB, PS and ELENA, but for instance not for the work on the synthetic B-train.**
        - Concerning the PSB, the plan is to keep performing offline tests (as the measurements shown by R. Chritrin today) until the end of 2016. The following step would be to work on the installation and test until LS2, in order to be ready to perform tests with real beam sometime in the end of LS2. **B. Mikulec asked if there is any chance to test the beam before LS2. M. Buzio replied that it is very unlikely to be able to test the system with beam before LS2, but certainly all the possible online and offline tests will be be performed before.**
    - An additional concern is that some of the component in the existing B-train are going to be phased out by the end of LS2:
        - The maintenance of the front-end of the measurement system of the synthetic B-train and some accessory cards is being dismissed by the BE-CO group after LS2.
        - If the new B-train system is proven to be working by June 2017 the handover will be done to the TE/MSC Group as the old system could be dismissed.
        - There could be implications in case the old MPC has to be used if there are problems with POPS-B. Three scenarios are possible:
            - **Use the existing B-train and reference magnet kept "as is" with the risk of unmaintained(-able) components. → baseline scenario**
            - Use the new B-train system with the old power supply. Some details about the DCCT beta normalization are still being discussed with L. Soby and P. Odier but they are not a showstopper. The scenarios are two:
                - **Connect the new reference magnet to the old power supplies, which implies pulling 6 kA cables. In this case it would be enough to take a subset of the measurements (from ring 3 instead of all 4 rings) and give them to RF and BI equipment. → Recommended by M. Buzio.** B. Mikulec mentioned that it could be difficult to pull out power cables.
                - Use the existing reference magnet. This implies pulling sensor cables from the existing to the new reference magnet (may add noise) or bring the electronics racks of the new system to the existing reference magnet and adapt it.

- Planned Activities:
    - Get a complete "snapshot" of the current system in terms of available documentation, spares and details of the synthetic B-train generation software.
    - Whenever possible split up sensor output for measurements in parallel with a separate acquisition system, so that one could also use the new electronics.
    - Clean up the system by removing old or disconnected sensors inside the existing reference magnet.
    - Define the needed FESA classes and OASIS signals.
    - Keep working on offline magnetic tests in B867. Several open questions to address, for instance if using NMR or FMR as field markers, or perform a full characterization of new reference magnet.
    - Test the new B-train system with both the existing and new reference magnet and whenever available with the POPS-B.
    - Partial installation of new B-train in B361, use existing sensors and/or add new ones in the free gaps and attempt to run in parallel with existing B-train providing feedback to RF.

**6. AOB**

- The next meeting is tentatively scheduled for the 12th November 2015.