Summary of the LIU-PSB/PS Meeting 1

Held on Tuesday 3rd May 2016

Agenda (https://indico.cern.ch/event/522580/***)***

1. Communications

2. Complementary Measurements on the Main Dipole for the Booster B-Train System (A. Beaumont)

3. B-Train System (M. Buzio)

4. AOB

PRESENT: S. Albright, M.E. Angoletta, A. Beaumont, Y. Beraud, J. Betz, F. Boattini, J. Borburgh, M. Buzio, J. Coupard, H. Damerau, S. Deleval, L. De Mallac, G.P. Di Giovanni, V. Forte, M.A. Fraser, R. Froeschl, G.M. Georgiev, M. Gouber-Pace, A. Guerrero Ollacarizqueta, G. Guidoboni, M. Haase, D. Hay, P. Lelong, B. Mikulec, A. Newborough, D. Perrelet, G. Rumolo, R. Steerenberg, G. Sterbini, J. Tan, W. Weterings.

1. Communications

The meeting was chaired by **B. Mikulec** and **H. Damerau**. The communication for the different machines will be discussed in the respective LIU meetings.

2. Complementary Measurements on the Main Dipole for the Booster B-Train System (Annex 1)

The aim of the talk is to describe the measurements done on one of the main dipoles of the PSB to study the effect of the magnetic history and define the design of the B-Train coil and finalize the field markers choice.

The test bench was composed by the magnet with 4 apertures, one per ring, equipped with two coils, in one of the inner and outer rings.

The effect of the magnetic history was based on 3 identical stabilization cycles, followed by a cycle where the change was implemented and finally the cycle where the measurements were performed.

Two coils of different lengths (2.0 m and 2.5 m) were tested. Additionally a Hall probe was placed in the middle of the bending magnet.

A study of the absolute field marker sensor was performed using as a figure of merit the transfer function (TF), defined as the Bdl normalized by the current.

- Similar behaviour in the inner and outer aperture with respect to the magnetic history effect, for the TF and the magnetic length, was observed.

- An effect of the order of 0.2% was measured due to the magnetic history at low field, i.e. at the beginning of ramp-up and at the end of the ramp down.
- When the previous cycle is saturated (below saturation) an effect of 0.03% (0.005%) is measured.
- The measurements were found to be compatible for the 2.0 and 2.5 m coils at injection energy of 50 and 160 MeV, as well as the extraction energy of 1.4/2.0 GeV. The maximum difference between the two coils was measured to be 0.06%.
- Additionally a curved coil following the ideal particle trajectory was installed and the maximum difference with respect to a straight coil was found to be 0.04%.
- A possible layout of a Printed Circuit Board (PCB) fluxmeter was presented.

In conclusion:

- Coils length under discussion due to PCB standard manufacturing up to 2.2 m. For an extension to 2.5 m wired coils have to be used.
- Straight coils will be used to reduce the complexity of the manufacturing.

Concerning the field markers, the current proposal for LIU-PSB is:

- For low field (< ~0.1 T) and low field ramp rate (< 1.5 T/s) one could use a Nuclear Magnetic Resonance (NMR) probe. This is what is currently employed as B-train marker for the PSB.
- NMR offers the best precision, for an operation with dB/dt < 1.5 T/s.
- For medium to high field (> ~0.1 T) the proposal is to use a Ferro-Magnetic Resonance (FMR) probe, currently under testing in the PS B-Train.
    - These probes operate with dB/dt > 1.5 T/s. **To be produced for the PSB requirements.**
- Another option are Electron Paramagnetic Resonance (EPR) probes, but this is currently only in a R&D stage.
- The field markers will likely be done with NMR and/or FMR probes.

B. Mikulec asked at which point the NMR markers are placed in the PSB, as the ramp can have values of dB/dt > 1.5 T/s. **A. Beaumont** replied that the probe is placed where the ramp is about 1 T/s. It could be investigated if one could implement more markers.

H. Damerau mentioned that a second marker in the PS would be too late to implement any correction. **A. Beaumont** replied that the second marker would be used for the next cycle. The first marker is at injection. **H. Damerau** asked if a cycle-to-cycle correction exists. **M. Buzio** replied that this is not yet implemented but under investigation.

3. B-Train System (Annex 2)

M. Buzio presented the status and planning of the PSB/PS B-Train system upgrade.

Component R&D:

- The design of the 100T Flux Magnetic Coil (FMC) Integrator has been frozen and 26 units have been ordered.
- The logic will be implemented in the FPGA via network with minimal disruption. Every update may require few hours and tests beforehand.
- Plan to rewrite the VHDL code in collaboration with BE-CO and upgrade the WhiteRabbit (WR) core to the latest version 3.
- Advanced functions to be implemented (one year timescale to implement):
    - On-the-fly correction of drift and gain with two markers.
        - As of today the B-train stops-restarts every cycle to avoid errors of 2/3 Gauss
        - The goal is to integrate the field continuously and apply corrections on the fly to deduce drift and gain errors and provide an error associated to a measurement.
    - Use a standard DC field measurements (e.g. from NMR teslameter or Hall probe) as a variable-level field marker.
    - Field-dependent gating of marker triggers to reject spurious resonances.
    - Field-, current- and history-dependent calibration parameters such as the magnetic length.

Resolution:

- **The resolution of the current system is 0.1 G.**
- The magnetic field resolution ΔB of the new B-TRAIN is a function of many parameters and changes continuously during a cycle.
- A resolution of ΔB = 10 nT comes from last significant bit of a 32-bit value.
- The theoretical resolution of the integrator function of the attached coil is typically < 1 nT.
- The WR frame processing and distribution is estimated to be 3 μT (0.03 G) for the PS, 6 μT for PSB for a frequency of 250 kHz. Theoretically 1 MHz is possible with the WR, but not yet tested.
- **The main limitation is from measurement noise: It must be measured on the final setup, but it is expected to be in the range 1 to 50 μT (max of 0.5 G).**
- Similar performances are expected for all machines.

Synthetic and simulated B-Train:

- The functions of the system are technically very different. One can distinguish two main cases:
    1) Provide a reference B(t) or dB/dt to check the RF system or for testing the power converters faults. **No beam is present in the machine and can be provided without current in the main circuit. The aim is to provide a conformity to the reference.**
    2) Estimated B(t) or dB/dt to be used in special cases as a replacement for the measurement. **To be used in operation in case of problems. The aim is accuracy.**
- Functions in 1) can be covered by what is commonly called simulated B-train, taking the information from the programmed B-field stored in a LSA database.

- Functions in 2) should be covered by the SYNTHETIC B-Train, where a complete mathematical model should be constructed and based on the input currents and provide the correct magnetic model up to a precision of 5E-4.
- The new synthetic/simulated B-Train will cover both functions. **The synthetic/simulated B-Train was not originally foreseen in the project. B. Mikulec** asked about the use case of the simulated B-Train. **M. Buzio** explained that in case of unavailability of the main power supply, one could consider to test the RF devices using the simulated B-Train.

WhiteRabbit distribution:

- Advancing well. Successful transmission at the PS to RF (latency of 10 μs at 250 kHz) and tx/rx from POPS (latency of 5.6 μs at 1 kHz).
- Strong support by BE/CO.
- A new frame for the WR protocol was proposed and tested.
    - To also incorporate permanently the previous B_up/B_down protocol for compatibility purpose.
    - Fields containing multipole slots were dropped, as not needed in real time and, if needed in the future, a separate WR connection could be used.
    - Introduce the synthetic B-train.
- The frame will contain the history and current field, the synthetic and simulated field for comparison as well.
    - Depending on a switch from the CCC, the chosen field will become the active one and its dB/dt will be also provided.
- Concerning the field markers:
    - Studies are ongoing with the Hall probe for the multipole measurements.
    - The NMR will be used for ELENA
    - The FMR (and their peak detection algorithm) will be used for PSB and PS. Custom made PCB prototypes are being developed (EPFL collaboration). The new FMR will mark the field also during ramp-down. The system has the flexibility to optimize the marker field during the commissioning of the system.
- A prototype FESA class is now available and is accessed for tests using the FESA navigator. Iterations with the FESA experts are ongoing. **B. Mikulec** asked when the new FESA class will be released for the initial tests for the PSB. **M. Buzio** answered that a first stable version of the class will be available for the summer. The TE-MSC mandate does not include the development of an application for the machine operation. **B. Mikulec** commented that off-line discussions on the interface and tools to put in operation the new B-Train have to be organized.
- Dedicated test benches have been set up to debug the new B-Train as much as possible without asking for MD time.
- PS B-Train status and planning

- The MU101 is equipped with two FMRS and uses the spare flux coils to produce (and test) the new B-Train in parallel with the old system (used in operation).
- In Nov 2015 the new B-Train was used by the RF to accelerate different beams.
- In Dec 2015 preliminary tests (without beam) were done for the B-Train and POPS (LHC and SFTPRO cycles)
- In May 2015, the beam was first accelerated (RF only) using the magnetic field of the old B-train system, but distributed via WR.
- The new B-Train is expected to become operational (without the final hardware) in 2017.

- PSB deliverables
  - After the finalization of the B-Train coil geometry, most of the tests are planned in B245.
  - No change of planning with respect to the one presented in Nov 2015 is expected (all possible tests will be carried out before LS2, but very unlikely with the beam).
  - The new B-Train will be in operation after LS2
- Budget
  - PSB and ELENA B-Train budget is included in the LIU baseline.
  - The PS, LEIR and AD are in the CONS.
  - The SPS is not budgeted.

H. Damerau commented if the switching between the measured/synthetic/simulated B-Train will be transparent for the users. **M. Buzio** answered that it will be transparent.

H. Damerau asked if next year the PS B-Train will work using 2 or 4 markers. **M. Buzio** answered that it will use 2 markers. **M. Buzio** explained that in this direction a dedicated MD with POPS will be organized when POPS will be repaired and available. **M. Buzio** commented that the rotating machine has to be equipped for receiving the WR to be compatible to the new B-Train. **F. Boattini** informed that he will transfer the information to the TE-EPC group. **F. Boattini** added that the layout of the POPS-B is getting finalized so asked **M. Buzio** to provide the input for the B-Train hardware. → Action for M. Buzio: "Provide input to F. Boattini concerning the B-Train hardware to be installed in the B245". Deadline 30/06/2016.

R. Steerenberg asked when the interface for the new B-Train has to be prepared. **M. Buzio** answered that an iteration in this direction has to be done after having agreed on the functional specifications of the new B-Train.

R. Steerenberg commented that a precision of 0.5 Gs is 5 times larger that the present theoretical precision.

R. Steerenberg asked if the continuous calibration of the B-Train can be disabled in the FESA class. **M. Buzio** answered positively.

H. Damerau and **M.-E. Angoletta** commented that the effect of 20 μs latency of the B-Train has to be checked in the different machines. **R. Steerenberg** suggested that this could be tested in the PSB with the present B-Train.

M.-E. Angoletta commented that AD will be ready to switch to the new B-Train only after LS2.

G. Sterbini asked if the new B-Train can measure up to the octupole component. **M. Buzio** answered positively commenting that with higher multipole order the calibration becomes critical.

G. Sterbini asked if the new B-Train can deliver, differently from the present one, the measure B-field during the whole cycle. **M. Buzio** answered positively.

4. AOB

There was no AOB.

Minutes reported by G.P. Di Giovanni/G. Sterbini the 11th May