Status of the B-train for the PSB Upgrade

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TE/MSC

1. B-train consolidation project status
   (including recent PS tests)

2. PSB test system (b. 361)

3. PSB Upgrade system (b. 245)
B-train consolidation project Status
**ELENA**
- new system being commissioned, White Rabbit provided to new LLRF for H⁺ injection at ~500 G
- repeatability of NMR marker about 0.15 G at both low and high field
- issues being worked on: cross-calibration of the two chains (consistency of high-field markers for gain calibration), drift control on minute-long plateaux, stability when reversing the polarity

**PS**
- tests started in 2014, currently $B_{up}/B_{down}$ distributed via White Rabbit
- four new CERN/EPFL FMR resonators/oscillators being tested at 497 G, (OP/SPARE in F, D); up to ~2100 G possible
- first tests with simultaneous feedback of new measurement to RF + POPS (newly implemented PPM) carried out successfully, more planned next months
- operation with new measurement by default in 2018
- gradual upgrade to production hardware, new coils in LS2

**PSB**
- new sensors + prototype B-train chain installed in b. 361, tests ongoing
- fully new system (incl. reference magnet) to be installed in 245 during LS2

**LEIR**
- electronics and new sensors installed
- major decision (opening of a dipole to install new coils) pending, according to upcoming test results

**SPS**
- survey of available sensors done, 5 NMR probes found still alive, coil signals usable
- electronic racks assembled in the lab, preparations for installation ongoing

**AD**
- only synthetic B-train needed
- prototype hardware ready to be tested, missing general FESA class go get cycles from LSA
PS system tests (1/5) – Normal operation

oscillation ±0.2 G @ 27 Hz

source not clear, appears when regulating on B_{up}/B_{down}

(irrespective of distribution mode)

B(t) measured by old B-train (B_{up}/B_{down} pulses), distributed via White Rabbit (WROLDB_BTRAIN)

POPS keeps it \equiv reference within its original resolution 0.1 G

|B_{up}/B_{down} – FIRESTORM| \leq 0.5 G, \quad FIRESTORM |OP–SPARE| \leq 0.2 G
PS system test (2/5): clone of LHC_INDIV

- **MD2290**: 31 May tests w/o beam, 14 June tests with beam on LHC_INDIV
- **POPS PPM works as intended**, no impact on following cycle (for the tested S.C.)
- B(t) measured by FIRESTORM B-train feedback to both RF and POPS in PPM
- with FIRESTORM: **27 Hz ripple disappears**, field resolution from 0.1 to < 0.02 G, frequency resolution from 8 to 1 Hz

http://elogbook.cern.ch/eLogbook/event_viewer.jsp?eventId=2371101

http://elogbook.cern.ch/eLogbook/event_viewer.jsp?eventId=2371081

**Feedback from B<sub>up</sub>/B<sub>down</sub>**

**Feedback from FIRESTORM B(t)**
MD2290 June 21: tests with beam on EAST (w/o nTOF bunch)

- B(t) measured by FIRESTORM B-train feedback to both RF and POPS in PPM
- FIRESTORM measurement stable within 0.1 G at injection, no apparent oscillations
- measurements differ by ≤ 0.5 G
- MRP differs by < 1 mm, no BCT/BLM difference

http://elogbook.cern.ch/eLogbook/event_viewer.jsp?eventId=2378979
PS system tests (4/5) – ION Xe

- **MD2290 June 21**: tests with beam on ION Xenon
- B(t) measured by FIRESTORM B-train feedback to both RF and POPS in PPM
- FIRESTORM measurement stable within 0.02 G on intermediate flat-top; 27 Hz oscillations appear on $B_{UP}/B_{DOWN}$
- measurements differ by $\leq 0.8$ G
- RMS MRP with FIRESTORM smaller by several mm

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http://elogbook.cern.ch/eLogbook/event_viewer.jsp?eventId=2379039

beam MRP [mm] feedback from $B_{UP}/B_{DOWN}$

beam MRP [mm] feedback from FIRESTORM B(t)
• **MD2290 LHCINDIV_WR 28 June** (courtesy of Heiko Damerau)
• both radial and longitudinal RF loops switched off immediately after injection at constant and known energy from the PSB
• Comparing results between the two measurements → absolute $|\Delta B| \leq 0.2$ G

http://elogbook.cern.ch/eLogbook/event_viewer.jsp?eventId=2383271
PSB test system (b. 361)
New sensors in the Reference Magnet

- **Integral coil (2.75 m long, 1.6 m²)**
  - Left-right symmetric (not shown)

- **End and central coils (100 mm long, 0.3 m²)**

- **Old coil set removed during EYETS**
  - Supports for new integral coils, NMR and FMR ready (YETS 17/18)

**Aim:**
- Feed independent signals to the new FIRESTORM prototype B-train chain
- Get currently missing information (full integral including fringe field, end and central eddy currents in both an inner and an outer ring)
New sensors in the Reference Magnet

- **High- and low-field NMR probes**
  - (field marker)

- **Central induction coil**
  - (measurement of the magnetic length)

- **End induction coil**
  - (measurement of local eddy current effects)

- **Integral induction coil**
  - (measurement of the entire magnetic field swing)
• output signals found adequate for magnetic measurements and B-train commissioning
• minor issues (noise on small coils, abnormally low level of integral coil) → replacement when possible
• are OASIS channels wanted to monitor raw signals in the CCC?
• Preliminary magnetic measurements in line with test bench results
• Acquisition of raw NMR output to correct integrator drift (ongoing)
• **Online** measurement of hysteresis-dependent and eddy current effects (advantage wrt existing system: high-field NMR marker, inner and outer ring, central and fringe field coil)
4x signal generators for low- and high-field NMR

2x Metrolab NMR teslameters for Ring 4 (expensive! Ring 2 will be equipped with 2 further units only if necessary)

White Rabbit switch

Power supplies

B-train chassis with status display

FMR/NMR signal conditioning

Linux FEC

Fiber optic patch panel

Calibration (setting gains and offsets as FESA properties) still pending
Planned actions

2017
- Commissioning of new FIRESTORM B-train chain
- Feedback to new LLRF in PPM possible to test with beam (non need for dedicated MDs)
- Tests as done in the PS: a) distributing $B_{up}/B_{down}$ wia WR and b) new measurement using R3 and R4 sensors as input

YETS 17/18
- Replacement of coils in Ring3 + new sensors in Ring2
- replacement of temporary WR fibre to RF (BOR R708 in 261-1-009) with a permanent one + new fibre to building 30 (demand discussed with EN/EL)

2018
- systematic beam tests using old sensors in R3 or new ones in R2/4
- Main goal: validate the new B-train to drive PSB

After LS2
The system remains in place as a fallback in case of return to MPS (FEC in the old B-train will not work anymore)
PSB Upgrade system (b. 245)
B-train installation in 245-S-402

- “New” reference magnet currently in our test hall in b. 867.
- Refurbishment to the final configuration (thicker outer ring side plates) foreseen by September 2017, detailed test campaign to follow Pre-DIC for LS2 transmitted to EN/EL

- All B-train electronics on stock or procured (except for marker frequency generators)
- Safety access procedure to the magnet enclosure involving a bypassable interlock being written with BE/ASR
Planned actions

2017
- Finalization of DIC with missing details
- Launch procurement of PCB fluxmeters with CERN PCB Service
- Tests on finalized reference magnet in b. 867 ((harmonic field quality, calibration of new PCB coils when available, cross-talk effects between the two coupled powering circuits, choice of NMR vs FMR marker)

2018/19
- Measure ambient field perturbations esp. from nearby 6kA cabling as soon as power available
- Install electronics as soon as racks available
- Install sensors in magnet as soon as available
- Test and commission new system w/o beam as soon as POPS-B connected

Open points
- Do we want to feedback RF from all rings in parallel?
- NMR vs FMR markers for high-Bdot cycles
• switching dipole on the extraction line to ISOLDE/PS
• first unit expected at CERN around 03/2018 (vacuum chamber before then)
• to be tested in new bldg. 311 for reproducibility choose between open/ closed loop
• closed loop solution: basic design in preparation, prototype development to start in September (also motivated by other applications)
• spare unit will remain available for tests indefinitely (degree of sameness will be measured)
Conclusions
Summary

• PS tests show that **the beam can be correctly injected, accelerated and extracted with the new measurement**

• Measurement resolution **far exceeds** the old system

• Systematic differences **well below 1 G** (calibration still being worked on)

• Stability and reproducibility need to be assessed statistically (tests in parallel on multiple machines are foreseen before LS2)

• The system (electronics + sensors) installed in b. 261 will be used to **validate the new measurement for the PSB** before LS2
Additional slides
**Project documents**

- B-train renovation first discussed at the LEIR coordination meeting on 12.10.2015 (see attached *.ppt)
- Renovation of PS, SPS, LEIR and AD B-trains approved in 07.2016 as a CONS Work Unit (~1.5 MCHF)
- **ELENA, PSBU** budgeted separately
- ECR formally approved at the 192th IEFC (20.01.2017)
- Activities declared in PLAN (no impact on tunnel activities)
### Acquisition and processing system

- All essential hardware components procured or in stock at CERN
- The production version requires additional hardware plug-ins (FPGA mezzanine cards)
- Current work mainly focused on software (FESA) and firmware (FPGA) finalization

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<td>SPEC PCIe carrier board</td>
<td>(developed with BE/CO, under test)</td>
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<td>FESA</td>
<td>- compatible with production VHDL</td>
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<td>(PS, ELENA in operation; PSB, LEIR deployed and under test)</td>
<td>- high-level diagnostics, alarms, logging</td>
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<td>Inspector tool</td>
<td>- synthetic and simulated facilities</td>
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**SPEC, SPEXI = Simple PCIe/PXIe FMC carrier, FMC = FPGA Mezzanine Card (daughter board with custom analog front end, ADCs etc)**

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**Notes:**
- **FIRESTORM prototype (2014-2017):**
  - Linux FEC
  - SPEC PCIe carrier board
  - Ancillary components (interfaces, diagnostics, patch panels)
  - FMC integrator
  - FMC marker trigger generator

- **FIRESTORM production (2018-2020):**
  - FMC White Rabbit interface (developed with BE/CO, under test)
  - FMC synthetic (prototype ready to be tested)
  - FMC simulated (yet to be developed)

- **Hardware:**
  - **Frozen & already installed or procured:**
    - SPEC PCIe carrier board
    - Ancillary components (interfaces, diagnostics, patch panels)
    - FMC integrator
    - FMC marker trigger generator
  - **New plug-in hardware:**
    - FMC White Rabbit interface (developed with BE/CO, under test)
    - FMC synthetic (prototype ready to be tested)
    - FMC simulated (yet to be developed)

- **Software firmware:**
  - **Work ongoing:**
    - VHDL
      - basic drift correction, integrator includes WR interface
    - FESA
      - (PS, ELENA in operation; PSB, LEIR deployed and under test)
    - Inspector tool (PS, ELENA in operation)
    - extend to all machines