Status of PSB B-train system upgrade

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Status of new PS B-train

- Basis for all other B-train upgrades
- Prototype PS system deployed in 2014, now measuring in parallel with the old system
- Sensors: 2×FMR markers in F/D + one spare, spare flux loops in F/D, additional harmonic coils and Hall probes
- Two FESA classes to control basic properties + display some 10 kHz signals (FMR output, Bdot, Bmeas) being tested
- Successful tests of OP/SPARE with WR feedback to RF with and w/o beam, protons or ions
- Calibrated to be as close as possible to old B-train (selected cycles only, for the moment)
- Ongoing work: finalization of the FPGA firmware and FESA classes, sensor improvement, test and calibration in all relevant cycling conditions
- Foreseen to be switched on-line for long-term testing mid 2017, old system dismissed after LS2

2× AnaPico 20 GHz signal generators for F,D FMR
(local/frequency setting only)

B-train chassis including: 8-page multi-function display, analog and digital I/O, RF amplifier, power supplies

SPEC FMC 2-ch. integrator card
- "classic" integration reset at \( c_0 \) + weighted sum of F/D integrals
- basic offset correction
- software-configured ADC/preamp calibration with internal voltage reference, automatically done during zero cycles (NB yearly offline calibration still necessary)

SPEC FMC 2-ch. marker card
- trigger generation with high-Q FMR
- trigger generation with NMR (tested in MedAustron)

Commercial White Rabbit switch

Switching chassis
- simulated/measured B-train (based on POIPS being on/off)
- OP/SPARE B-train (HW signal from CCC)

Front End industrial PC

New high quality PFW/I8 DCCT out

Courtesy O. Michels
## PSB B-train upgrade – specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Max. magnetic field $B$</td>
<td>1.2</td>
<td>T</td>
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<tr>
<td>Min. magnetic field $B$</td>
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<tr>
<td>Max. $\frac{dB}{dt}$</td>
<td>6 (-9)</td>
<td>T/s</td>
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<td>Measurement uncertainty</td>
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<td>Measurement resolution</td>
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<td>ramp-up and flat-top</td>
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<td>(ramp-down)</td>
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<tr>
<td>Cycle duration</td>
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<tr>
<td>Field broadcast rate</td>
<td>600</td>
<td>kHz</td>
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(see: PSB Upgrade TDR, talk at LIU-PSB WG of 16/10/2014)
• Electronic components (and spares) for all approved systems in production: (early 2016) B-train chassis, integrator and marker FMC carrier and mezzanine cards, power supplies etc.
• Linux Front-Ends and CTRi timing cards: 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 with control and diagnostic parameters, OASIS diagnostic signals
Open questions to the WG (from last presentation)

- **Overall architecture**: where to put SPARE sensors / use SPARE as OP?
  Top/bottom asymmetry < 2 \(\cdot 10^{-4}\) → hot-spare duplicated sensors possible, can be added in the bottom rings at little additional cost

- **NMR frequency programming**: how is it done now, who will do it in operation?
  CCC via FESA parameters

- **3 full-height racks** needed for the production system (as close as possible to the ref magnet)
  can we fill in free space in the B-train racks now?
  Yes (needed for component tests in the immediate future)

- **2 \(\times I_{MPS}\) (\(+ 4 \times I_{trim}\)** broadcast via White Rabbit: in parallel or merged?
  Still to be discussed, depends on White Rabbit latency and its impact on operation

- **define signals, variable and alarms** to be exchanged with the CCC
  Still to be discussed

- **what about the synthetic B-train?** Define uses and tolerances
  Common new architecture being defined for all machines (was not included in the TDR)

- **are there any other users?** NO

- Internal drift/gain correction may generate **steps in the distributed B-train**.
  Maximum acceptable step size (→ need to smooth out over a certain time)
  Must be tested, can be changed at any time
Synthetic B-train

- Artificial $B_{up}/B_{down}$ corresponding to a cycle type (user) selected by the CR, triggered in synch with standard timing, transmitted along the measured B-train channels. Aim:
  - RF cavity tuning w/o beam, typically on each restart
  - Run the beam in lieu of the measured B-train, e.g. in case of faults or for testing purposes

- Same system in PSB, AD, LEIR: VME FEC + BTG (B-train Generator) cards that simulate directly the $B_{up}/B_{down}$ pulse trains based on a simple field model $B(I,dI/dt) = B_0 + kI + k'dI/dt$.
  Setup done by FESA software (last inheritor: J. M. Nonglaton)

- Today not TE/MSC responsibility; logically part of the B-train system; standardization is a goal

- Upgrade proposal: system based on an additional FMC card able to operate in two modes:

  Real-time (default) measured $I$ received in real time via WR, $B(I)$ computed on-the-fly
  Considerable scope for improvements with modern mathematical models, (e.g. Jiles-Atherton coupled with eddy current circuits): the model is a basis for real-time diagnostic comparison with the measured B-trains, and it could provide operational flexibility and robustness by replacing the measured B-train in a wider range of cases

  Preset (equivalent to BTG today) when no measured $I$ is available, the card receives a preset $I(t)$ waveform, computes $B(I(t))$ and plays it in synch with timing
Deployment schedule (DRAFT)

Run2

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LS2

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- **PS - SW & HW, installation & tests**
- **PS - Commissioning w/ beam**
- **PSB - Offline tests**
- **PSB - SW & HW, prototype tests (bldg. 361)**
- **PSB - Installation & tests (bldg. 245)**
- **PSB - Commissioning w/ beam**
- **ELENA - Offline tests**
- **ELENA - SW & HW, installation & tests**
- **ELENA - Commissioning w/ beam**
- **LEIR - Installation & tests**
- **LEIR - Commissioning w/ beam**
- **AD - Installation & tests (synthetic only)**
- **AD - Commissioning w/ beam (synthetic only)**
- **SPS - Offline tests**
Responsibility accepted by TE in 2008

Obsolete hardware and software (in particular measured and synthetic VME FEC, CTRV and PLS-SU timing cards, FESA2 classes), maintenance hard to ensure after LS2 handover to TE/MSC or switchover to new system to be decided in June 2017
0) Existing B-train and reference magnet kept “as is”
   Risk: unmaintained(-able) components

**Recommended alternative:** existing B-train electronics should be dismantled after the new system has been successfully commissioned with beam.

- $B_{up}/B_{down}$ no longer useful since MPS does not require feedback
- RF is compatible with White Rabbit already today

*(what about DCCT beta-normalization? will this require $B_{up}/B_{down}$?)*

1) New reference magnet connected in series to MPS
   *(power cables to be pulled, trim circuit to be added?)*
   New B-train system unchanged
   White Rabbit signal representing the field in Ring 3 is transmitted to RF/BI

2) New B-train system modified to use sensors inside existing reference magnet
   *(long signal cables to be pulled or electronics to be moved to 361, new calibration necessary)*
   White Rabbit signal representing the field in Ring 3 is transmitted to RF/BI
Planned activities

- Fully detailed snapshot of existing system:
  - roundup of old documentation
  - detailed list of spares
  - details of the synthetic B-train generation software
  - split up sensor output for measurements in parallel with a separate acquisition system
  - identification and removal of old/disconnected sensors inside the existing reference magnet

- Definition of FESA classes and OASYS signals
  (e.g. NMR output in the CCC, alarms based on difference between OP/SPARE chains, etc. etc.)

- Offline magnetic tests in bldg. 867:
  - NMR/FMR as field markers with the faster cycles
  - magnetic coupling between ring 1/4 and 2/3 possible impact on the MPS control system
  - possibility/need of a high field marker (used in the past, then dropped)
  - impact of dynamics and hysteresis effects on the calibration of the new B-train
  - full characterization of new reference/spare bending
  - test of quadrupoles (field quality, dynamics, hysteresis)

- No beam tests with new system before end LS2 → test in advance as much as possible
  - test new B-train system in 867 with existing/new reference magnet
  - (partial) install of new B-train in 361, use existing sensors/add new ones in the free gaps to run in parallel with existing B-train (feedback to RF possible)
  - when new reference magnet in 245, test whole system with new POPS/another power converter