Status of
PSB B-train system upgrade

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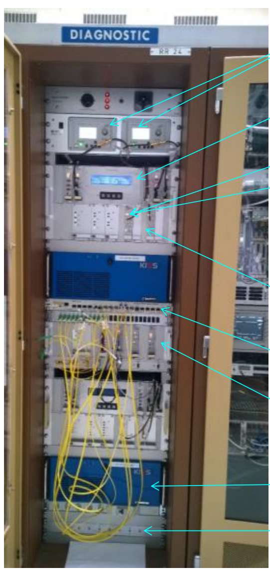
Contents

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
- <u>Successful tests of OP/SPARE with WR feedback to RF with and w/o beam</u>, 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/preampli calibration with internal voltage reference, automatically done during zero cycles
(NB yearly offline calibration still necessary)

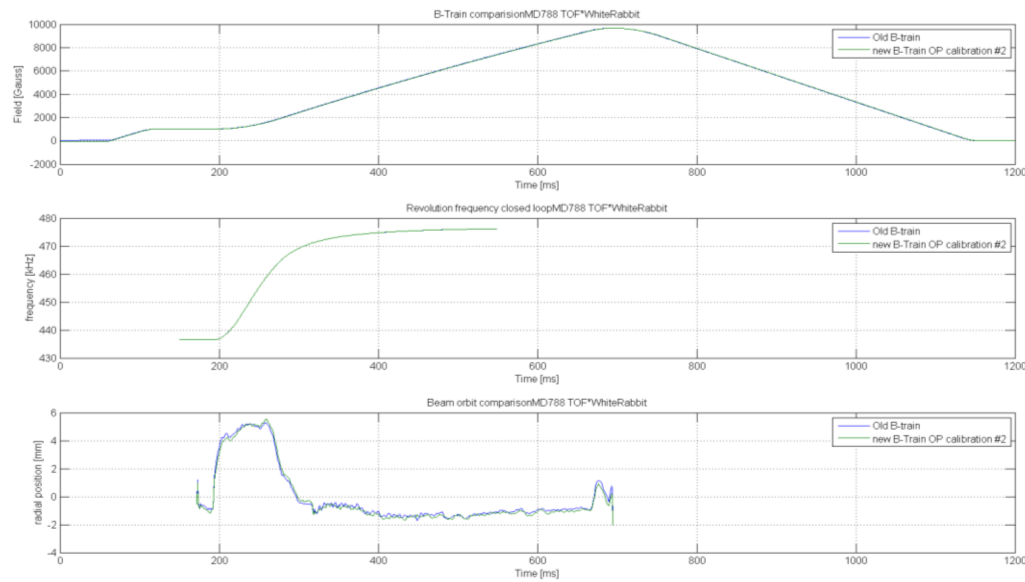
SPEC FMC 2-ch. marker card
- trigger generation with high-Q FMR
- trigger generation with NMR (tested in MedAustron)

Commercial White Rabbit switch

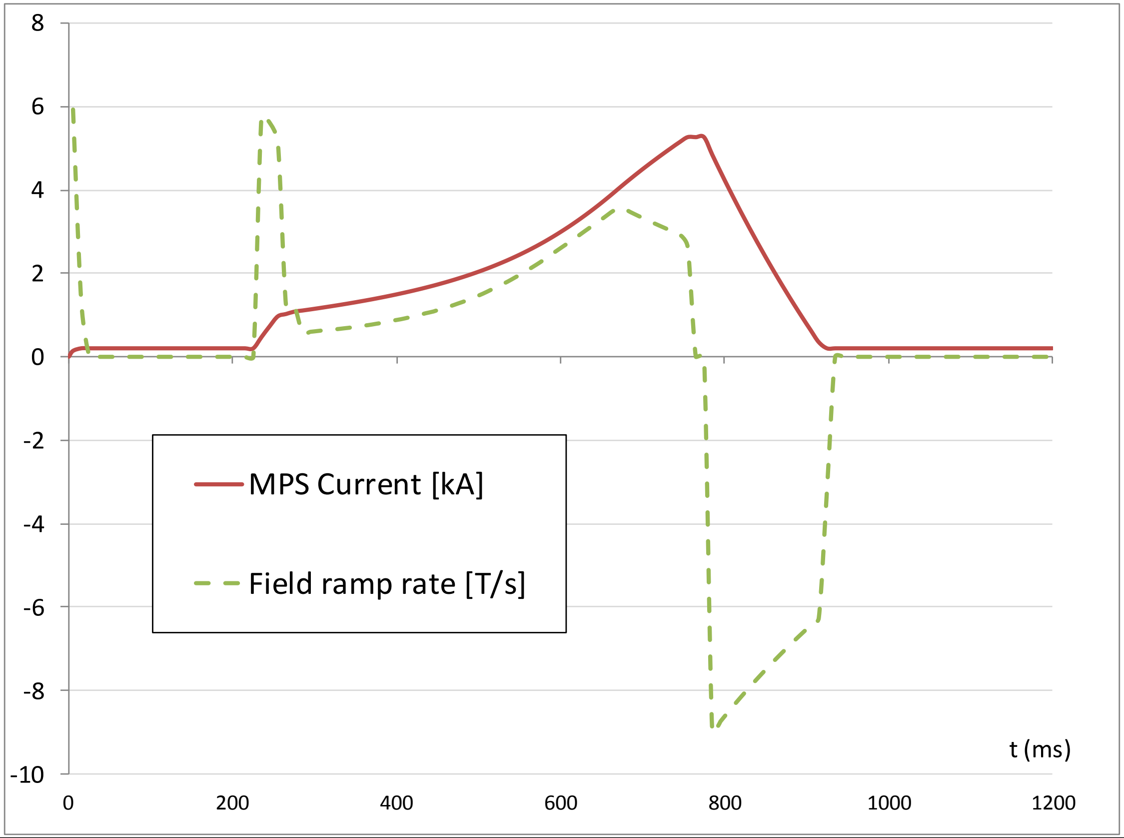
Switching chassis
- simulated/measured B-train (based on POPS being on/off)
- OP/SPARE B-train (HW signal from CCC)

Front End industrial PC

New high quality PFW/I8 DCCT out
Courtesy O. Michels

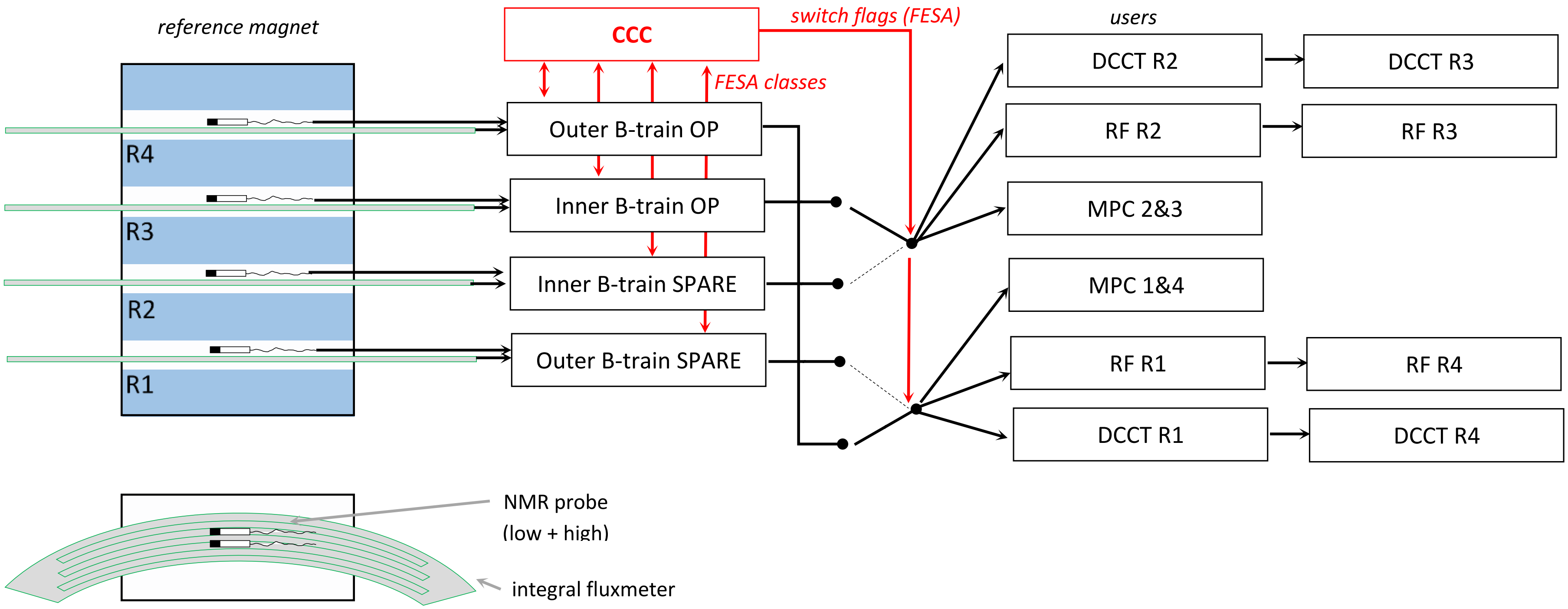


Parameter	Value	Unit
Max. magnetic field B	1.2	T
Min. magnetic field B	0.1	T
Max. dB/dt	6 (-9)	T/s
Measurement uncertainty	30	µT
Measurement resolution ramp-up and flat-top (ramp-down)	10 (15)	µT
Cycle duration	1.2	s
Field broadcast rate	600	kHz



(see: PSB Upgrade TDR,
talk at LIU-PSB WG of 16/10/2014)

PSB B-train upgrade – layout and status



- 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 < $2 \cdot 10^{-4} \rightarrow$ 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 ($\rightarrow$ need to smooth out over a certain time)
  Must be tested, can be changed at any time

- 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

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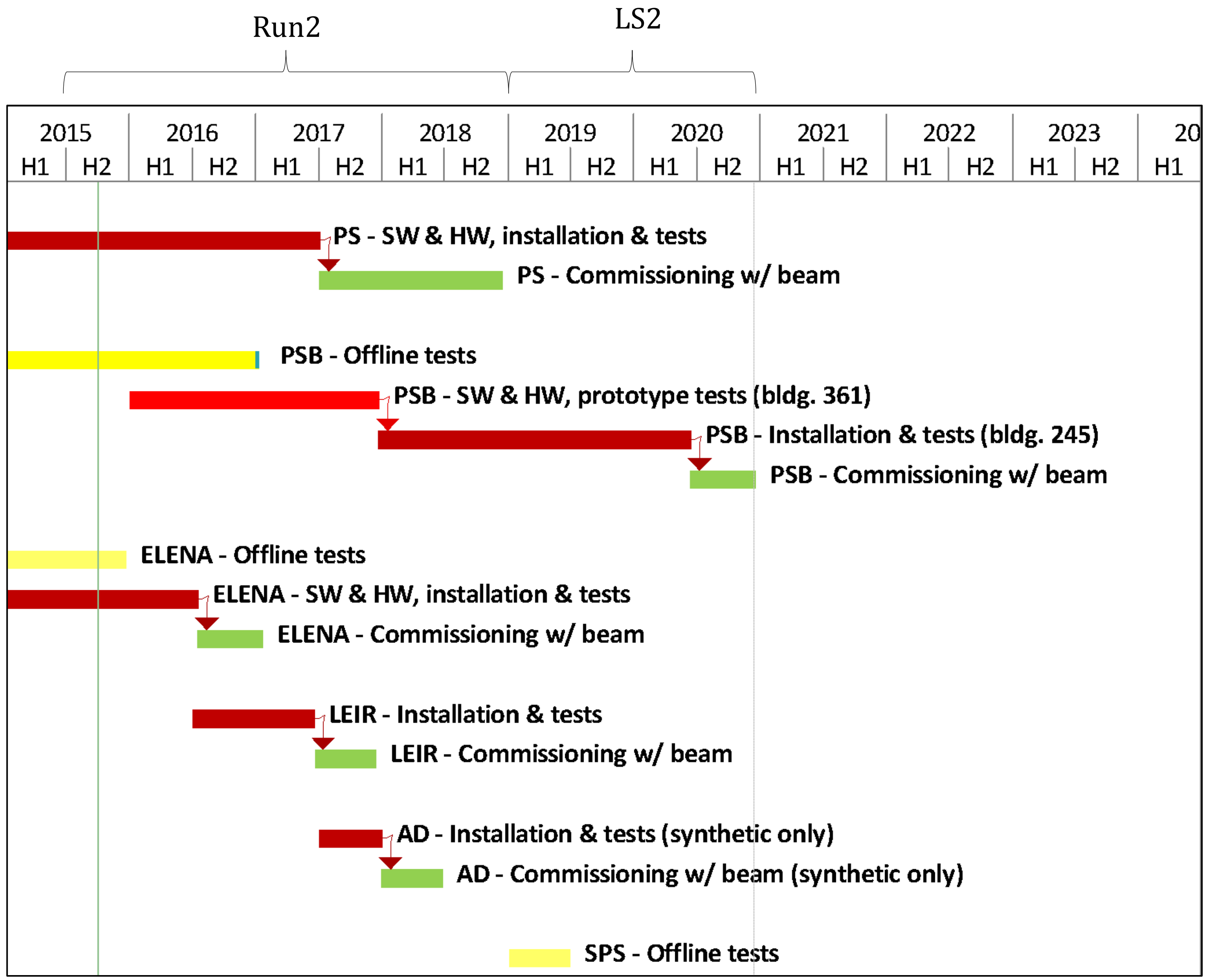
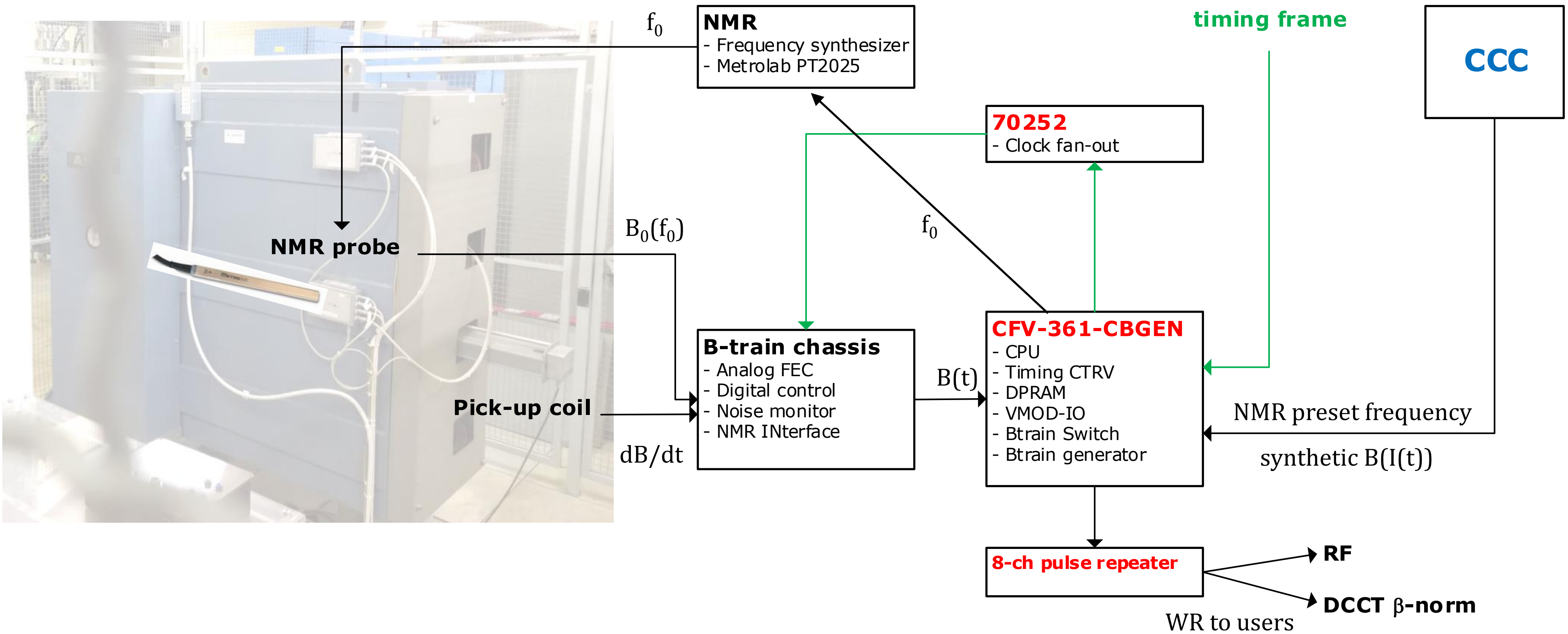
Deployment schedule (DRAFT)



Existing PSB B-train



Responsibility accepted by TE in 2008

Responsibility of BE/CO

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

Fallback to MPS after LS2 – three scenarios

0) Existing B-train and reference magnet kept "as is"
Risk: unmaintained(-able) components

<u>Recommended alternative</u>: 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 possibile 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