Status of PSB B-train

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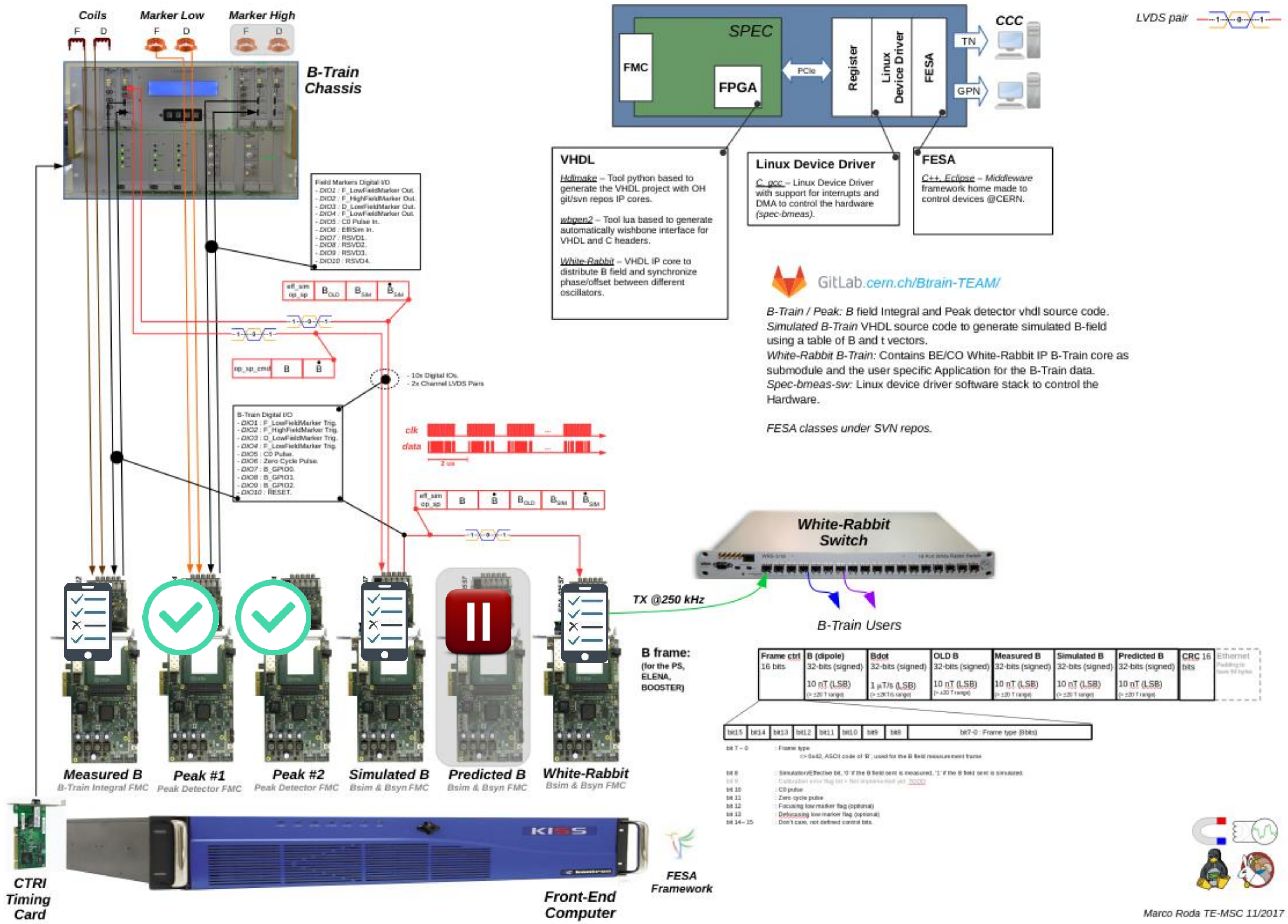
TE/MSC/MM

1. **Status of the B-train consolidation project**
2. **Commissioning of the PSB test system (b. 361)**
3. **Plans for the PSB Upgrade (b. 245)**
4. **Summary**

1. Status of the B-train consolidation project
2. Commissioning of the PSB test system (b. 361)
3. Plans for the PSB Upgrade (b. 245)



Coils
F D
Marker Low
F D
Marker High
F D
B-Train Chassis
Field Markers Digital I/O
- DIO1 : F_LowFieldMarker Out.
- DIO2 : F_HighFieldMarker Out.
- DIO3 : D_LowFieldMarker Out.
- DIO4 : F_LowFieldMarker Out.
- DIO5 : C0 Pulse In.
- DIO6 : EffSim In.
- DIO7 : RSVD1.
- DIO8 : RSVD2.
- DIO9 : RSVD3.
- DIO10 : RSVD4.
eff_sim op_sp
B_{OLD}
B_{SIM}
$\dot{B}_{SIM}$
op_sp_cmd
B
$\dot{B}$
- 10x Digital IOs.
- 2x Channel LVDS Pairs
B-Train Digital I/O
- DIO1 : F_LowFieldMarker Trig.
- DIO2 : F_HighFieldMarker Trig.
- DIO3 : D_LowFieldMarker Trig.
- DIO4 : F_LowFieldMarker Trig.
- DIO5 : C0 Pulse.
- DIO6 : Zero Cycle Pulse.
- DIO7 : B_GPIO0.
- DIO8 : B_GPIO1.
- DIO9 : B_GPIO2.
- DIO10 : RESET.
clk
data
2 us
eff_sim op_sp
B
$\dot{B}$
B_{OLD}
B_{SIM}
$\dot{B}_{SIM}$
SPEC
FMC
FPGA
PCIe
Register
Linux Device Driver
FESA
TN
GPN
CCC
LVDS pair
VHDL
Hdlmake – Tool python based to generate the VHDL project with OH git/svn repos IP cores.
wbgen2 – Tool lua based to generate automatically wishbone interface for VHDL and C headers.
White-Rabbit – VHDL IP core to distribute B field and synchronize phase/offset between different oscillators.
Linux Device Driver
C, gcc – Linux Device Driver with support for interrupts and DMA to control the hardware (spec-bmeas).
FESA
C++, Eclipse – Middleware framework home made to control devices @CERN.
GitLab.cern.ch/Btrain-TEAM/
B-Train / Peak: B field Integral and Peak detector vhdl source code.
Simulated B-Train VHDL source code to generate simulated B-field using a table of B and t vectors.
White-Rabbit B-Train: Contains BE/CO White-Rabbit IP B-Train core as submodule and the user specific Application for the B-Train data.
Spec-bmeas-sw: Linux device driver software stack to control the Hardware.
FESA classes under SVN repos.
White-Rabbit Switch
TX @250 kHz
B-Train Users
B frame:
(for the PS, ELENA, BOOSTER)
Frame ctrl 16 bits
B (dipole) 32-bits (signed) 10 nT (LSB)
Bdot 32-bits (signed) 1 µT/s (LSB)
OLD B 32-bits (signed) 10 nT (LSB)
Measured B 32-bits (signed) 10 nT (LSB)
Simulated B 32-bits (signed) 10 nT (LSB)
Predicted B 32-bits (signed) 10 nT (LSB)
CRC 16 bits
Ethernet
bit15 bit14 bit13 bit12 bit11 bit10 bit9 bit8
bit7-0 : Frame type (8bits)
bit 7 – 0 : Frame type
bit 10 : C0 pulse
bit 11 : Zero cycle pulse
bit 12 : Focusing low marker flag (optional)
bit 13 : Defocusing low marker flag (optional)
bit 14 – 15 : Don't care, not defined control bits.
Measured B
B-Train Integral FMC
Peak #1
Peak Detector FMC
Peak #2
Peak Detector FMC
Simulated B
Bsim & Bsyn FMC
Predicted B
Bsim & Bsyn FMC
White-Rabbit
Bsim & Bsyn FMC
CTRI Timing Card
Front-End Computer
FESA Framework
Marco Roda TE-MSC 11/2017

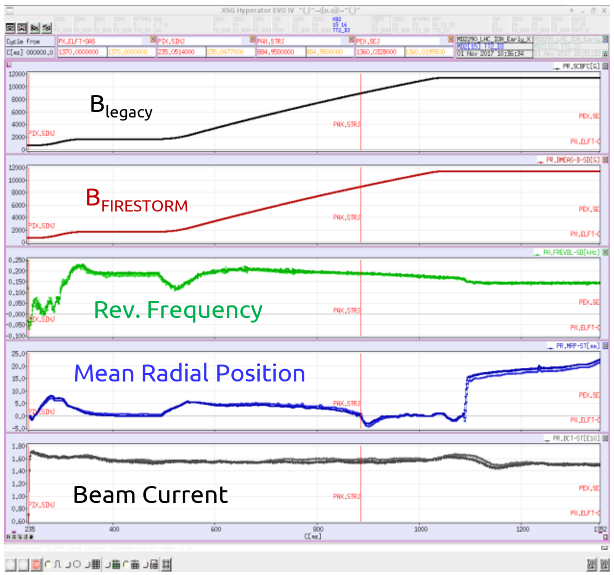
FIRESTORM deployment overview

Machine	Room	Chain	Rack	FEC	FESA classes	FPGA gateware				
						WR	SIM	INT	PEAK	PRED
LEIR	150-R-031	ch. 1	MY-L001	cfc-150-mleibtop	Btrain 3.2.2	*2018*	*2018*	2.4	1.0	*LS2*
		ch. 2	MY-L002	cfc-150-mleibtsp	Btrain 3.2.2			2.4	1.0	
PS	355-R-012	ch. 1	RR 24 (WRS)	cfc-355-mbtrainop	BmeasPS 6.1.4	*2018*	*2018*	2.0	1.0	*LS2*
		ch. 2		cfc-355-mbtrainsp	BmeasPS 6.1.4			2.0	1.0	
		ch. 3		cfc-355-mpsbtsp	FSBT_xxx 0.2.1	1.0	0.6	2.6	1.0	
PSB	361-1-012	ch. 1	R 373	cfc-361-mpsbbtdev	Btrain 3.3.0	*2018*	*2018*	2.3	1.0	
PSB-U	245-S-403	ch. 1	RYAAU05	*LS2*	*LS2*	*LS2*				
		ch. 2	RYAAU06							
		ch. 3	RYAAU07							
		ch. 4	RYAAU08							
SPS	870-R-018	ch. 1	*tba*	*YETS 17*	*YETS 17*	*YETS 17*				*LS2*
		ch. 2								
ELENA	193-R-407	ch. 1	RAK 298	cfc-193-melenaop	Btrain 3.3.0	*2018*	*2018*	2.4.1	1.0	*LS2*
		ch. 2	RAK 299	cfc-193-melenasp	Btrain 3.3.0			2.4.1	1.0	
AD	193-R-005	ch. 1	RA-J-007	*2018*	*2018*	*2018*	*2018*			*LS2*
		ch. 2	RA-J-007							
bldg. 30	30-3-003	dev. 1	M.1	cfc-30-mbtraindev	Btrain 3.2.2	2.4.1	-	2.4.1		*LS2*
		dev. 2	M.1	cfc-30-cmagma	Btrain 3.2.2	-	-	-		

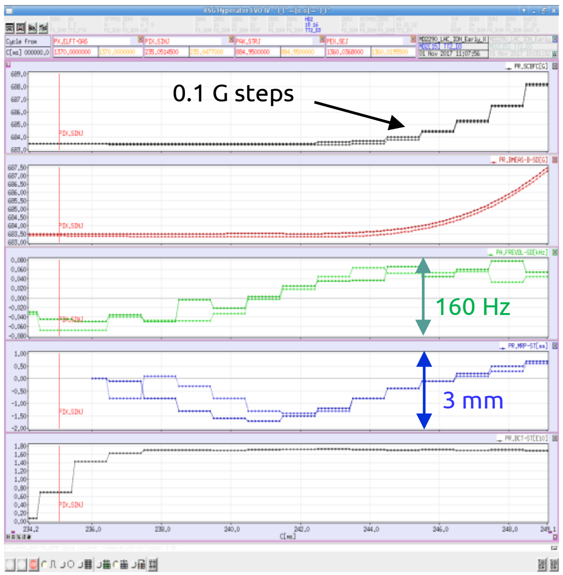
- All electronic components procured/in stock
- Installed and working in LEIR, PS, PSB , ELENA with prototype FPGA gateware
- Production gateware (Integrator, White Rabbit, Simulated) + FSBT_* FESA classes currently under tested in the PS (DEV chain)
- Deployed across all systems in 2018
- New magnetic sensors planned for LEIR (YETS17), SPS (2018) and PS (LS2)

Status of PS system – MD results

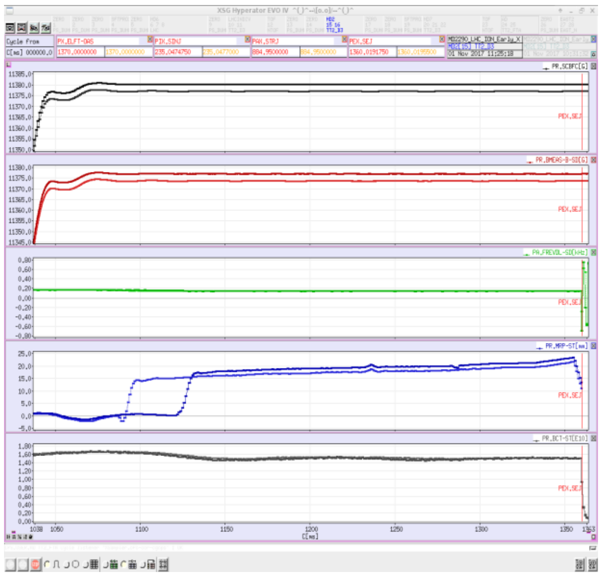
- 3 chains (OP/SP/DEV), 1y+ of operation with old B_{up}/B_{down} distributed via White Rabbit
  (FMR markers in F/D half; calibrated to best match (on average) the legacy measurement @ injection)
- beam successfully accelerated/extracted on all cycle types (minor adjustments only): LHC_INDIV, LHC25, MTE, TOF, EAST, AD, LHC_ION_Xenon
- repeatability ~ **0.02 G**, difference w.r.t legacy: **< 0.2 G @ injection**, **< 4 G @ extraction**
  (well within the radial RF loop correction capabilities)
- effective resolution ~**0.02 G**
  - White Rabbit resolution = 10 nT, effective resolution $\geq f_{WR}\, dB/dt = 9\ \mu T$ (0.09 G) on acceleration ramps
  - example of benefit: elimination of 27 Hz ripple on POPS current, due to non-linear control (0.1 G quantization of B_{up}/B_{down})
- MRP differences at extraction are below typical fluctuations (19 ± 8 mm)
- Since November: operation by default with new system, continuing throughout 2018



LHC_ION_Xenon cycle



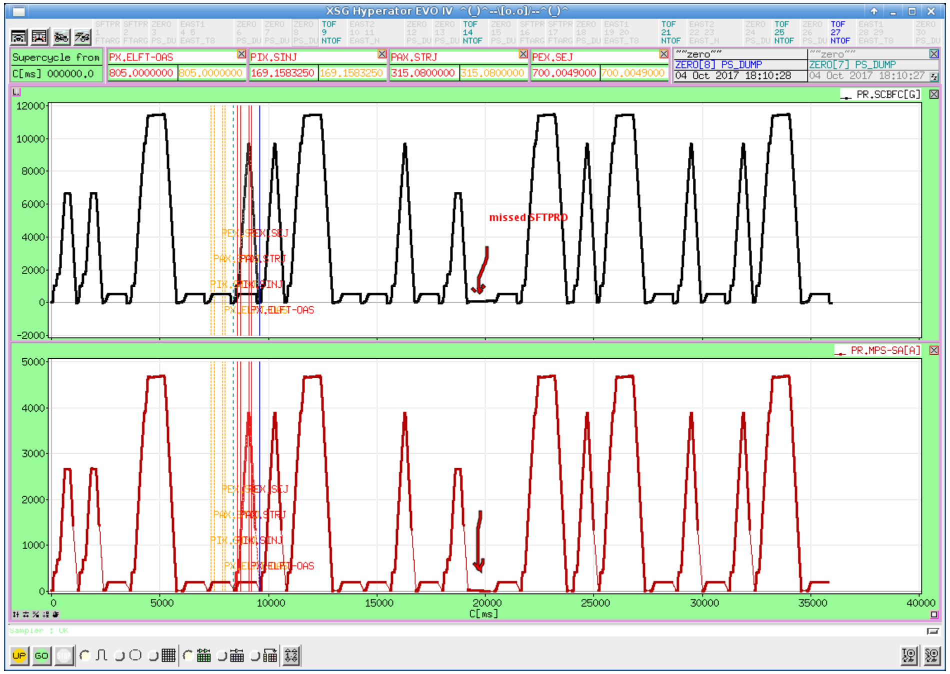
zoom in @ injection



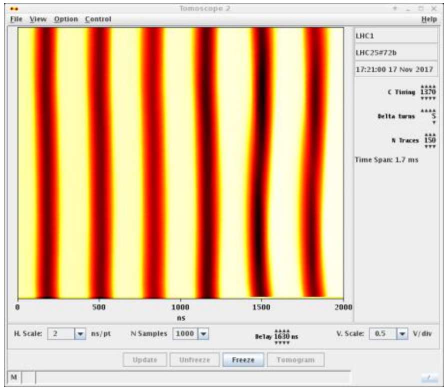
zoom in @ extraction

Problems reported by OP in Oct/Nov:

- Random B_{up}/B_{down} pulses before the 49.8 G preset
  POPS fails its internal check for B = 0 at c_{20} ⇒ **sporadic aborted cycles**.
  Noise source not clear (it's there even if the pulses are distributed via WR) but
  <u>the problem is solved by switching over to the new continuous measurement</u>
- **Higher rate of POPS trips** at c_0 after switching over to FIRESTORM.
  Problem traced to <u>PBL/PAL cards communication in the FGC2 crate</u> (F. Boattini)
- **Beam oscillation :** injection field level has to be adjusted slightly on certain beams
  (energy matching remains to be done)

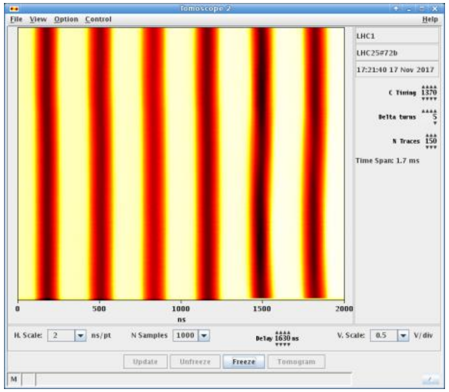


Lost cycle on Oct 4 due to B≠0 @ c_{20}



Before adjustment

after adjustment

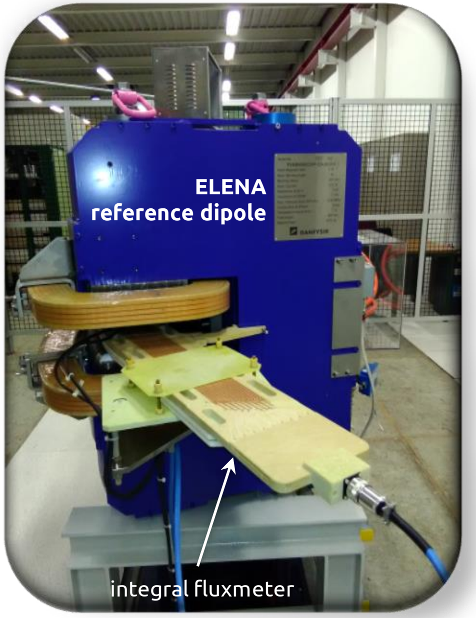


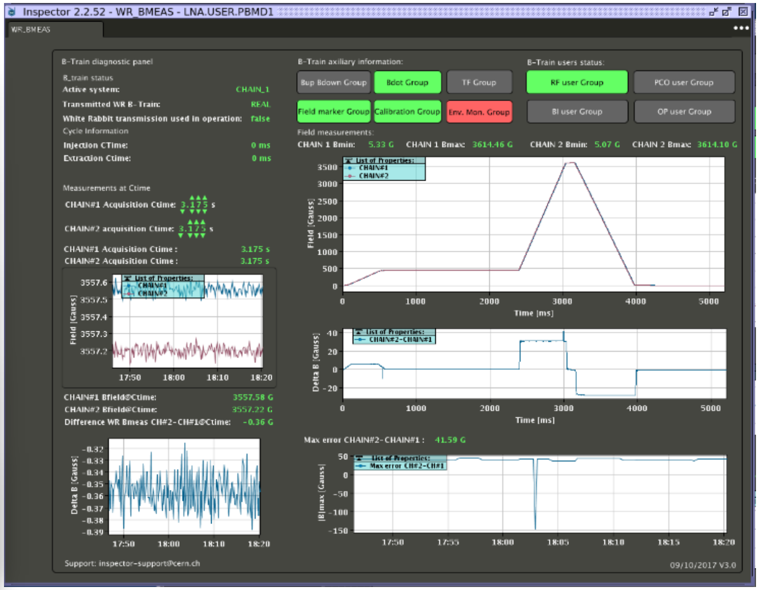
http://elogbook.cern.ch/eLogbook/event_viewer.jsp?eventId=2483170

Status of ELENA system

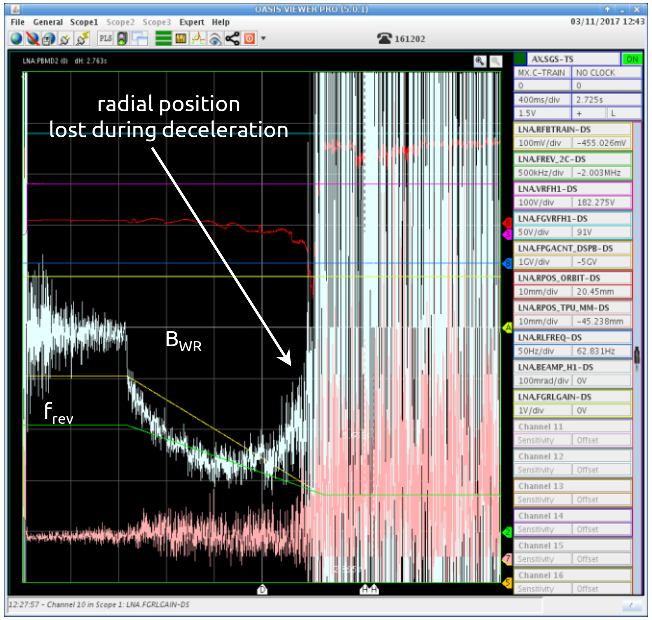
- New system in use since Nov 2016 for ring commissioning and as a testbed for debugging
- **pbar beams successfully captured at 5.3 MeV and decelerated to ~0.7 MeV**
  (effectiveness of the radial loop limited by the low intensity – improvements expected after installation of the e-cooler)
- **Metrological performance**:
  - Effective NMR marker repeatability: 0.09 G (@ 450 G) **0.03 G (@ 3400 G)**
  - Integrator drift: **0.02 ± 0.01 G/s**
  - Reproducibility @ injection: **0.04 G (OP)** 0.7 G (SP) *(under investigation)*
  - Difference OP-SP: -0.7 ± 0.7 G ($3 \cdot 10^{-4}$)

  (for comparison: magnet's transfer function repeatability = $3.5 \cdot 10^{-5}$ (-))





Inspector diagnostic interface



Absolute ELENA B-train calibration

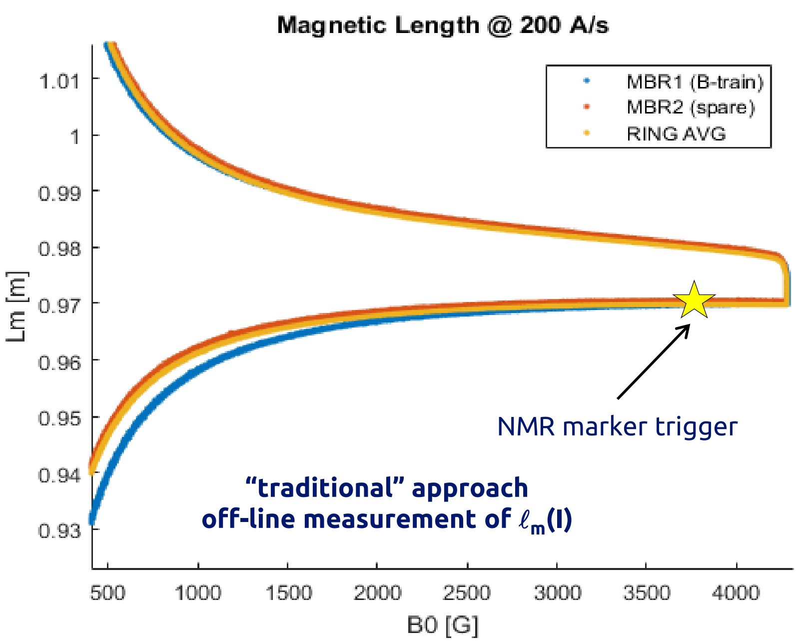
- Aim: provide rigorous uncertainty estimation = error bounds for subsequent adjustments
- Novel approach, will allow absolute energy matching (data analysis in progress, implemented on restart)

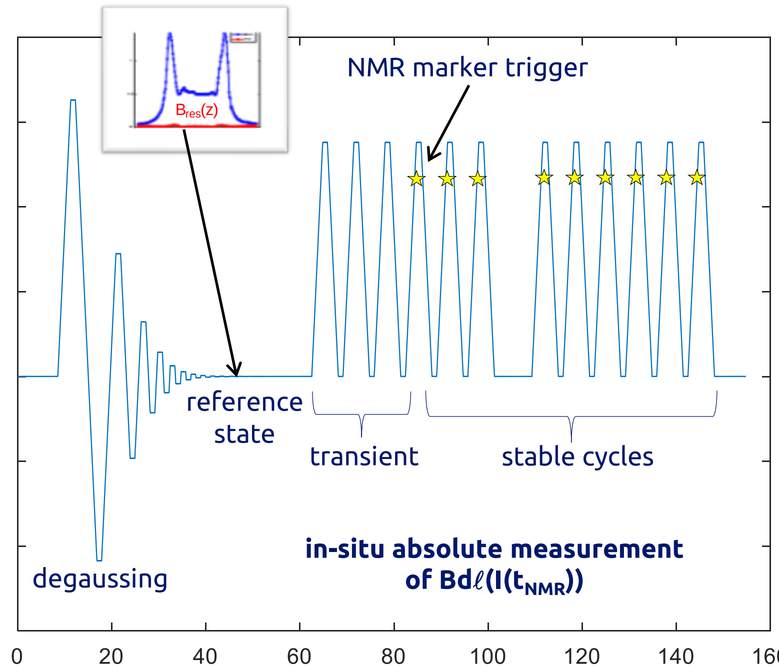
$$V_c = \frac{1}{1-\frac{R_c}{R_{in}}}(V_{meas} - V_0),$$

- V_c: coil voltage
- V_0: voltage offset (source of integrator drift)
- $\frac{R_c}{R_{in}}$: resistance ratio coil to integrator input

$$\bar{B}(t) = \frac{1}{l_0}\frac{Bd\ell_{ring}}{N_D Bd\ell_{ref}}\left(B_{marker} l_m + \frac{1+\varepsilon}{w_{eff}}\int_{t_{marker}}^{t} V_c\, dt\right)$$

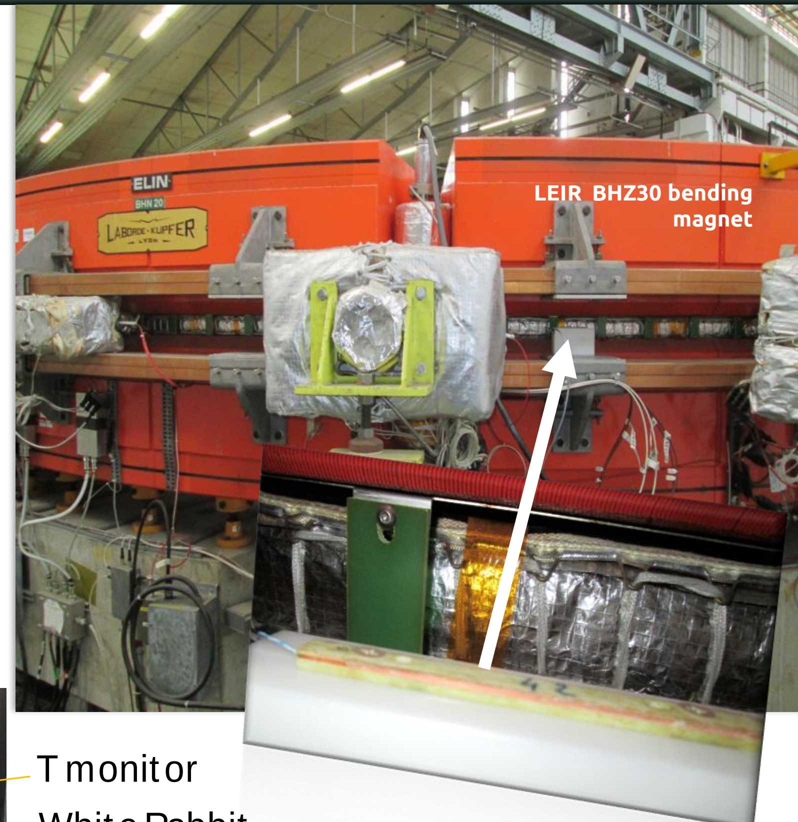
- $\bar{B}(t)$: average bending field in the ring
- l_0: reference magnetic length
- $\frac{Bd\ell_{ring}}{N_D Bd\ell_{ref}}$: field integral ratio between average of the ring and reference magnet
- $B_{marker} l_m$: integration constant = f(I, dI/dt, I(τ≤t), x_c)
- ε: coil correction factor = f(I, dI/dt, I(τ≤t), x_c)
- w_{eff}: effective coil width



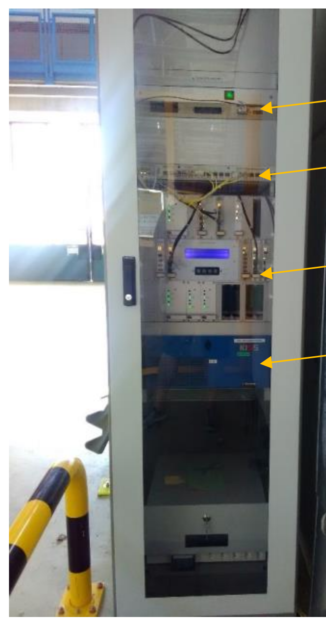


Status of LEIR system

- 2× new racks installed in 150-R-031 (available location closest to the ring)
- New (temporary) coils in the fringe field of BHZ20/30, to be replaced by final ones + new FMR markers
- Known issues:
  - temperature variations (~20˚C seasonal drifts expected, sensors will be T-controlled, electronics may need air-conditioning)
  - long cabling from the sensors in the ring, EMI interference observed



100 × 12 mm
0.6 m^2 induction coil



T monitor

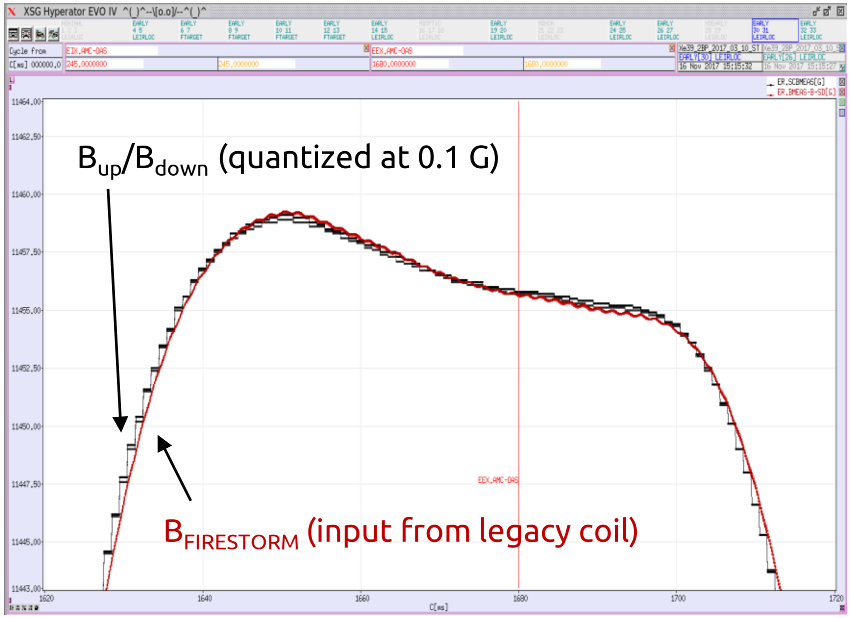
White Rabbit optical switch

B-train chassis

Linux FEC (integrators, marker…)

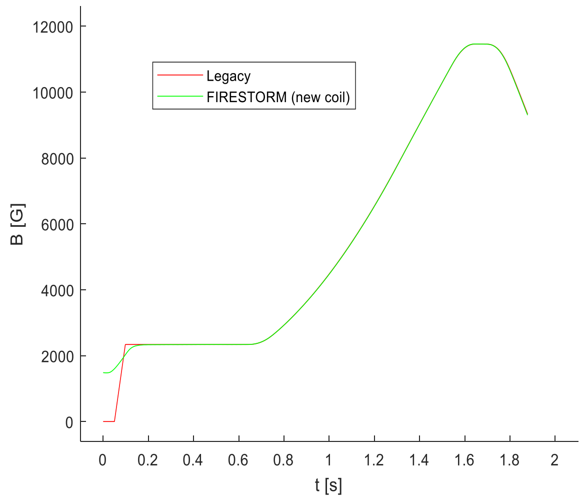
FIRESTORM input from legacy coil

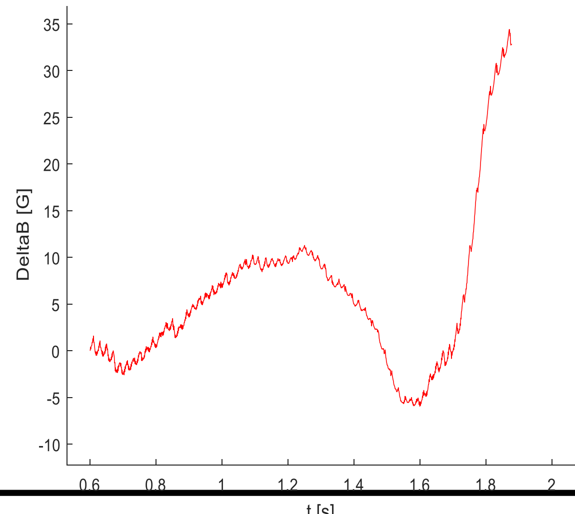
- **EARLY beam successfully accelerated an extracted**

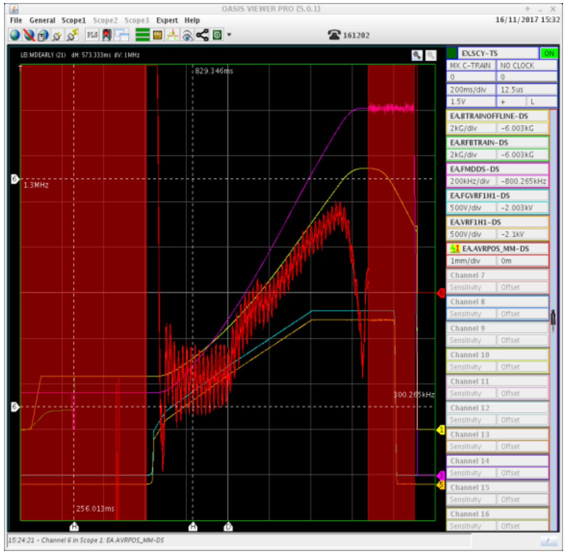


FIRESTORM input from new fringe-field coil

- Measured field: error w.r.t. $B_{up}/B_{down} \approx 15$ G p-p
- MRP oscillations due to 50 Hz EMI on coil destabilizing the radial loop
- Very encouraging results in view of consolidation – compelling argument to forget new coils inside the magnet gap
- Actions: investigate and shield against the EMI source, repeat MDs with longer cycles







Other systems

AD

- new simulated B-train hardware under test at the PS (Dev chain)
- successful generation of interpolated WR stream from locally stored cycle data
- update of the FESA class to get LSA cycles under way (with BE/CO support)
- to be tested and extended to other machines in 2018

SPS

- installation of two electronic racks + cabling to be completed during YETS
- tests using legacy sensors (coils/markers) planned upon restart

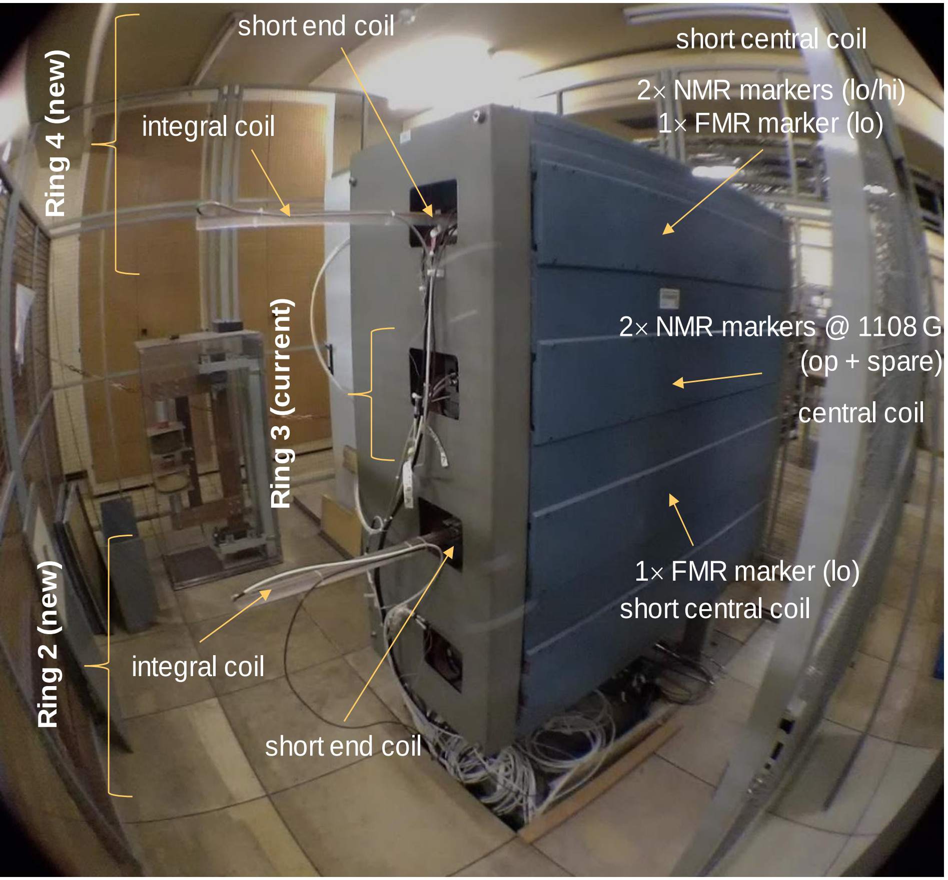
(NB legacy system will still work after LS2; simultaneous WR/$B_{up/down}$ operation will be possible)

1. Status of the B-train consolidation project

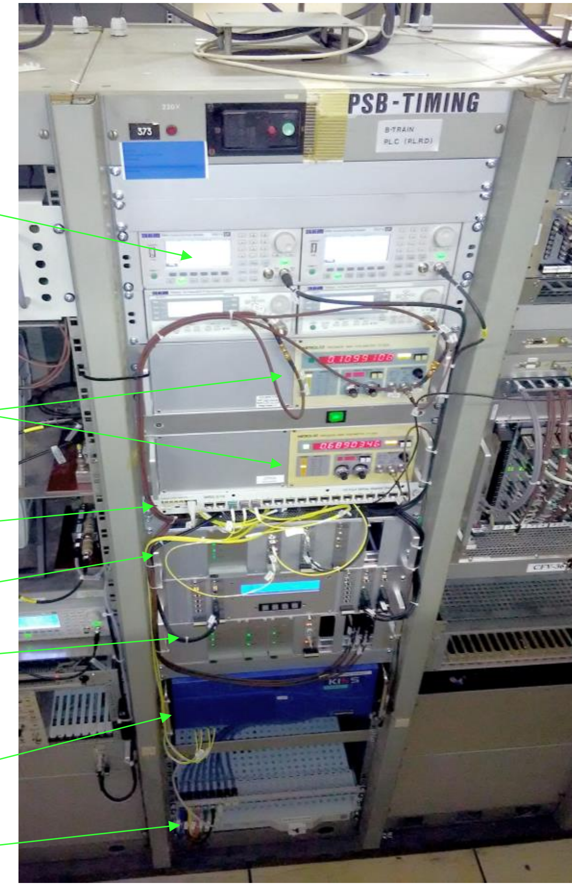
2. **Commissioning of the PSB test system (b. 361)**

3. Plans for the PSB Upgrade (b. 245)

PSB prototype FIRESTORM B-train



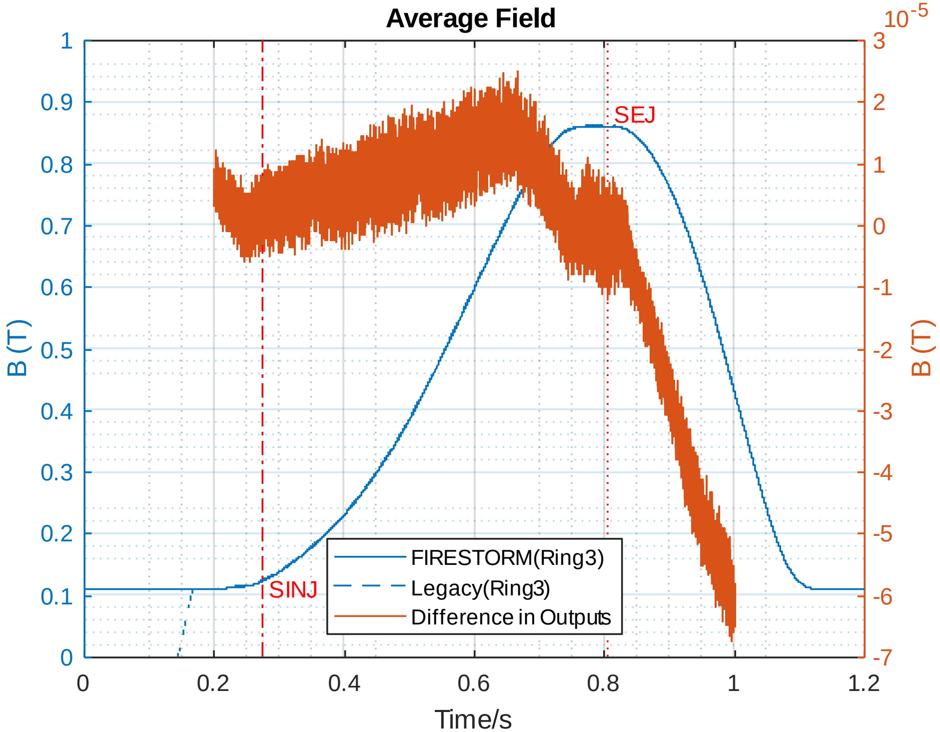
new magnetic sensor setup
in the PSB reference bending dipole

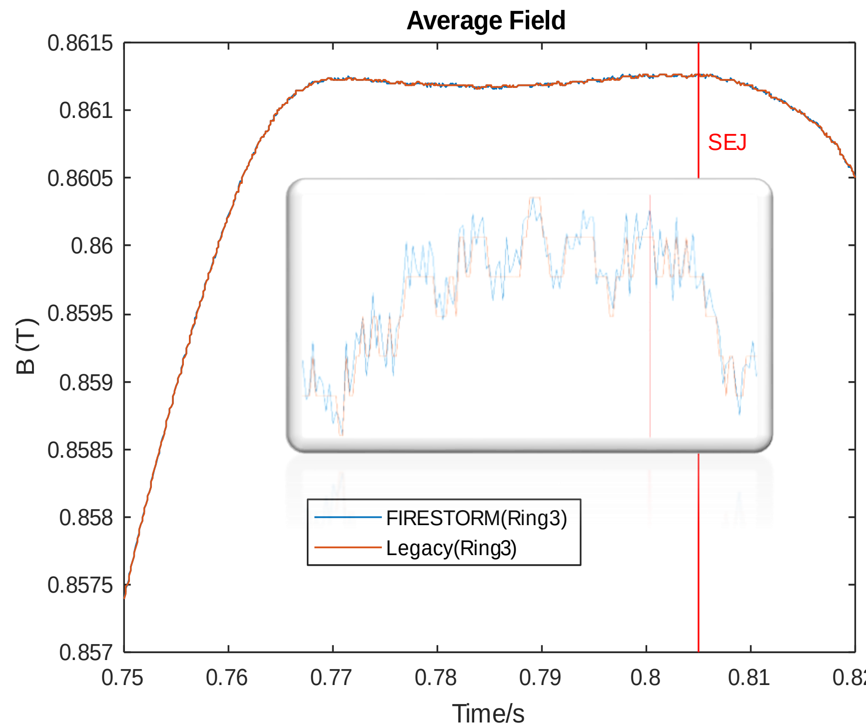


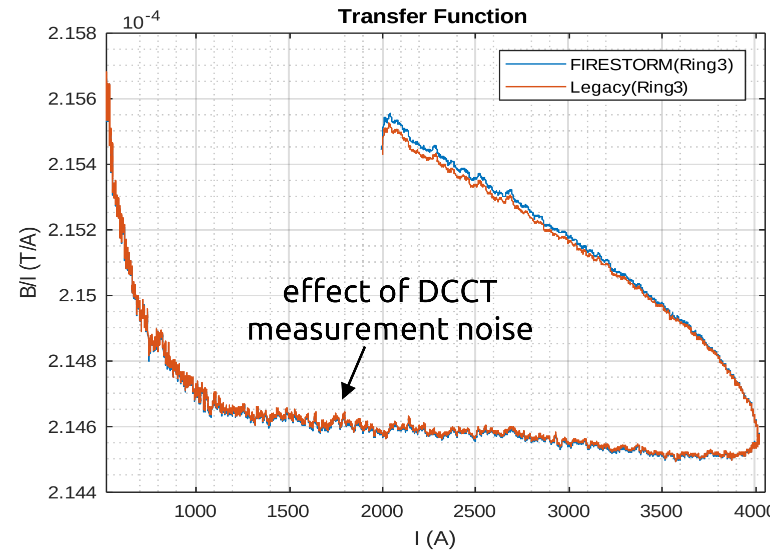
new FIRESTORM electronics
next to legacy B-train

- Electronics hardware of one new FIRESTORM B-train chain fully installed in b. 361
- Installation of new sensors in Ring 2 & 3 of the reference dipole completed in Sept.
- YETS17: new FMR sensors in Ring 4, final WR cabling to RF/BI

Offline tests – FIRESTORM taking input from Ring 3

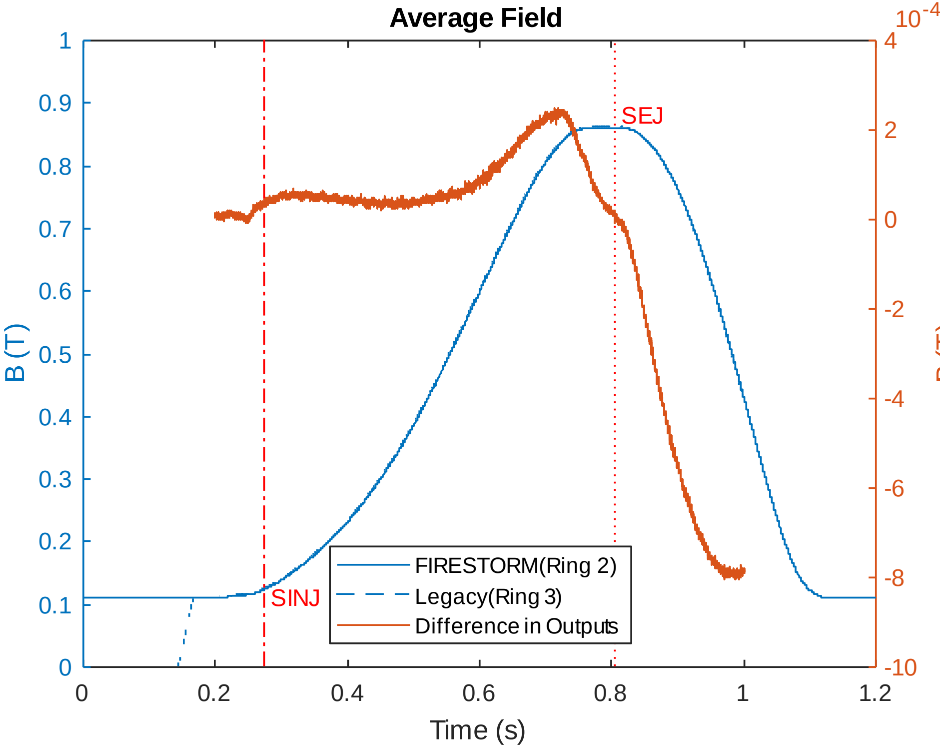


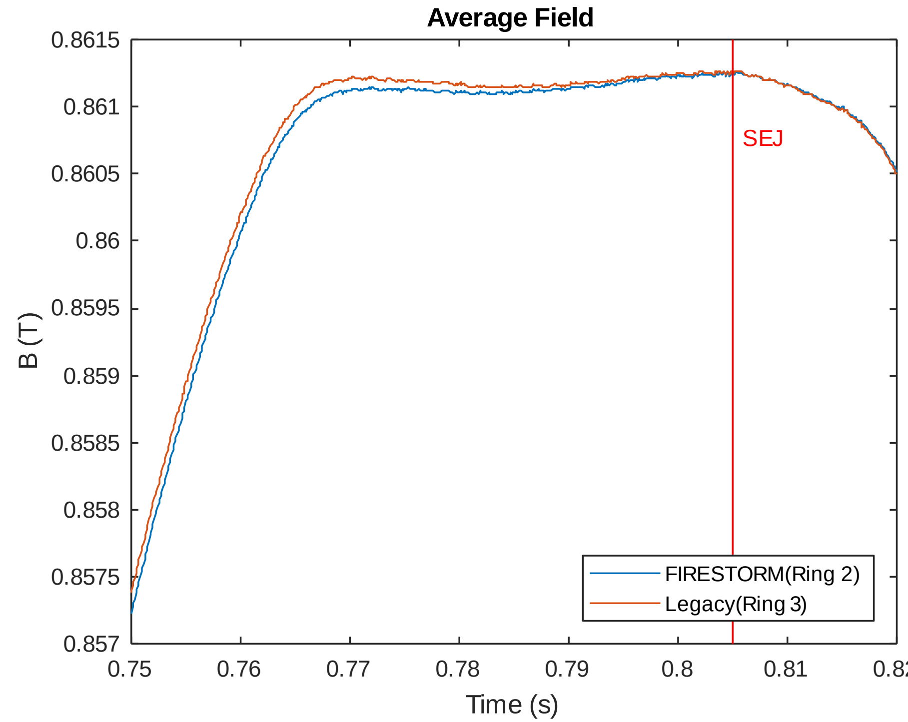




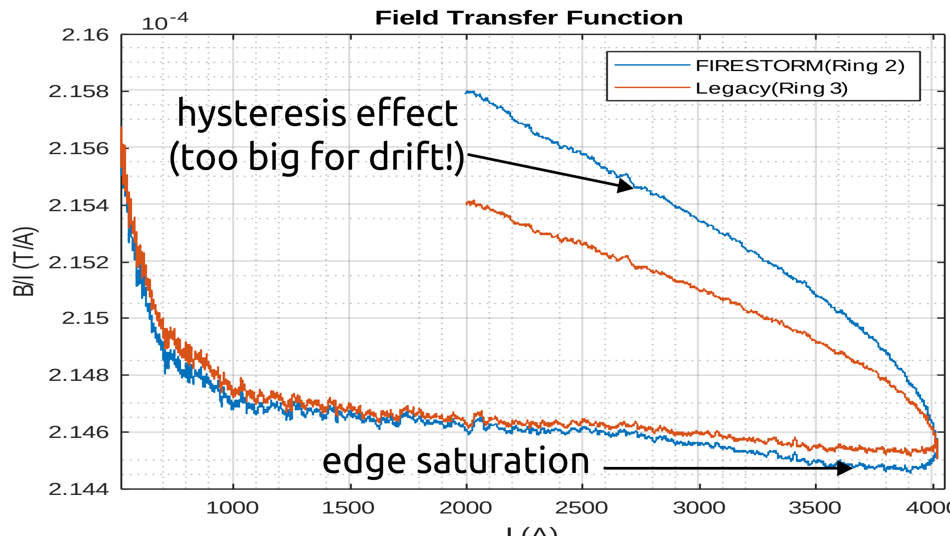
- legacy Ring 3 coil/NMR marker output split up and fed at the same time to both B-trains
- Relative RMS difference across 30 sequential cycles $(B_{FIRESTORM} - B_{legacy}) \approx 2.5 \cdot 10^{-5}$
  (as expected from gain differences in the two acquisition chains)
- Strong indication that the new system can replace the old (general consolidation goal)

Offline tests – FIRESTORM taking input from Ring 2

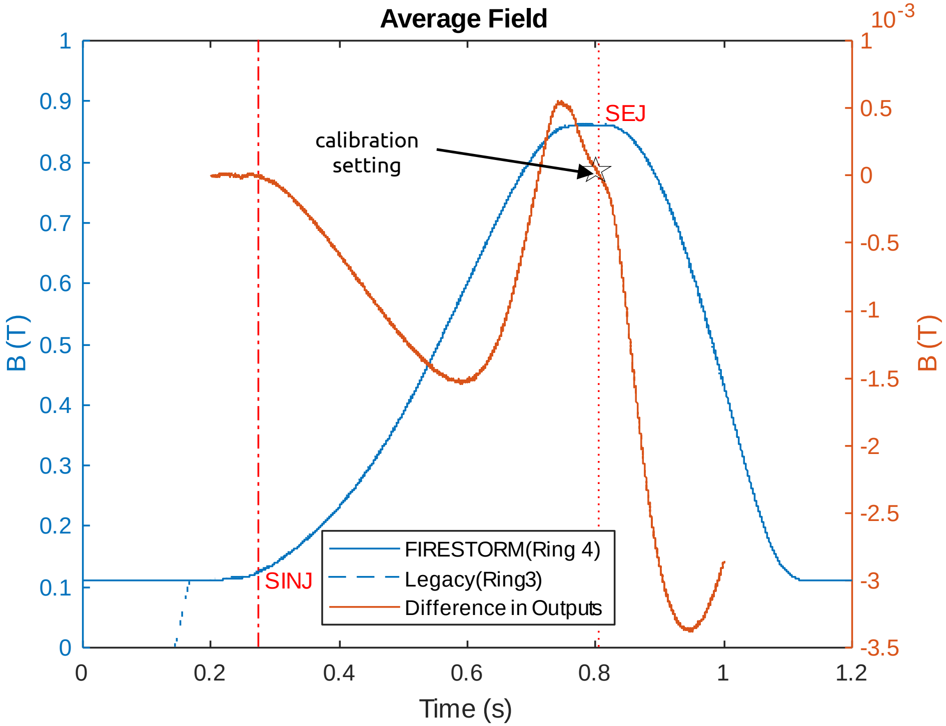


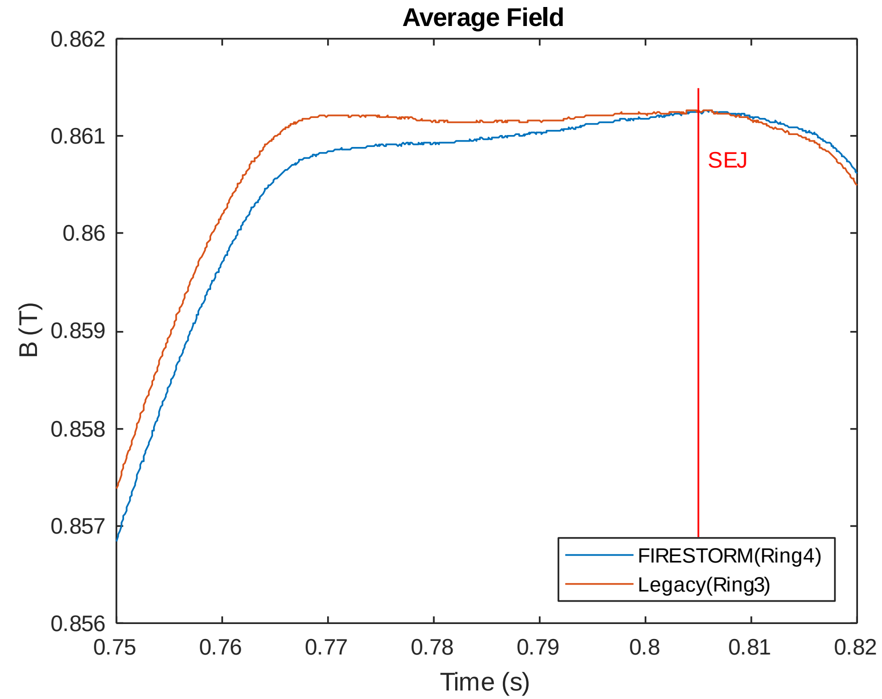


- FIRESTORM input from Ring 2 (same field in principle as Ring 3)
- the integral coil in Ring 2 sees a bit more saturation (edge effect)
- difference from injection to extraction **$(B_{FIRESTORM} - B_{legacy}) \approx \pm 1.4$ G $(1.6 \cdot 10^{-4})$**

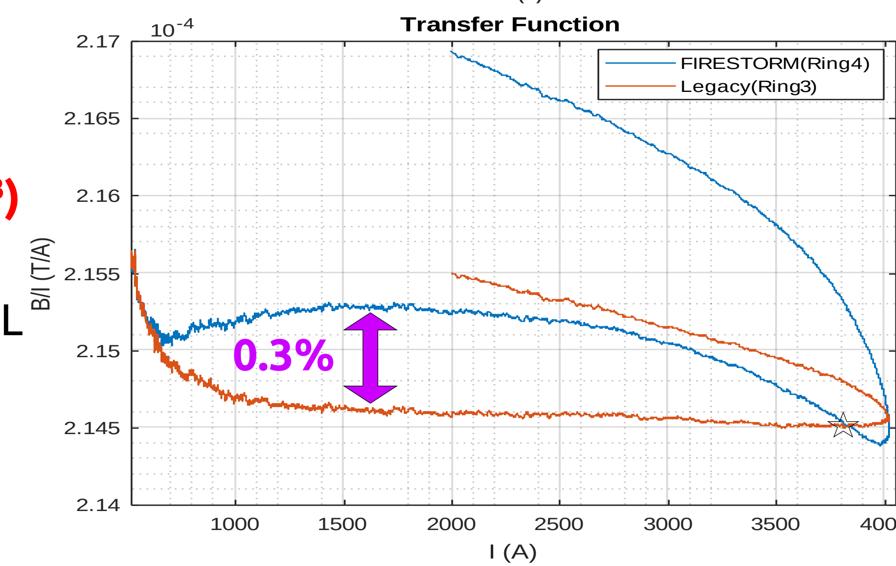


Offline tests – FIRESTORM taking input from Ring 4



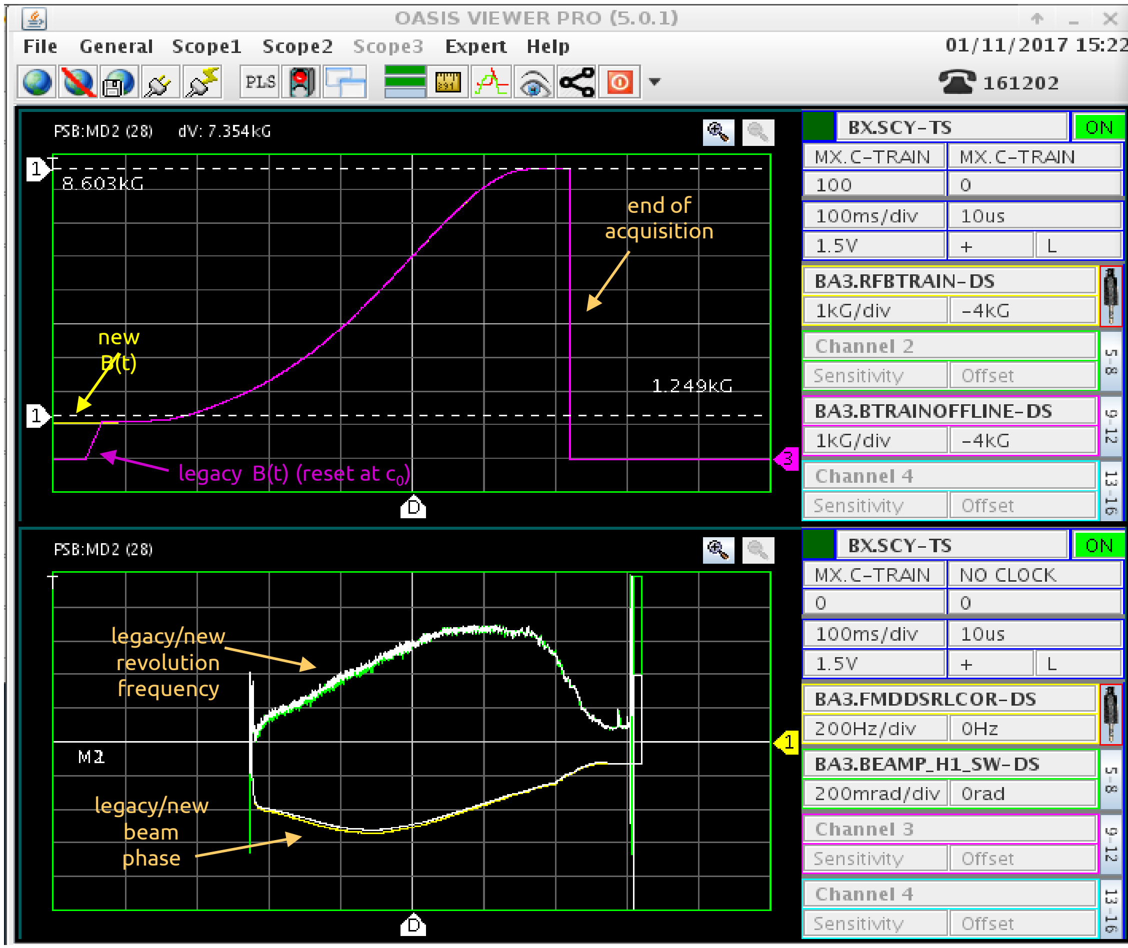


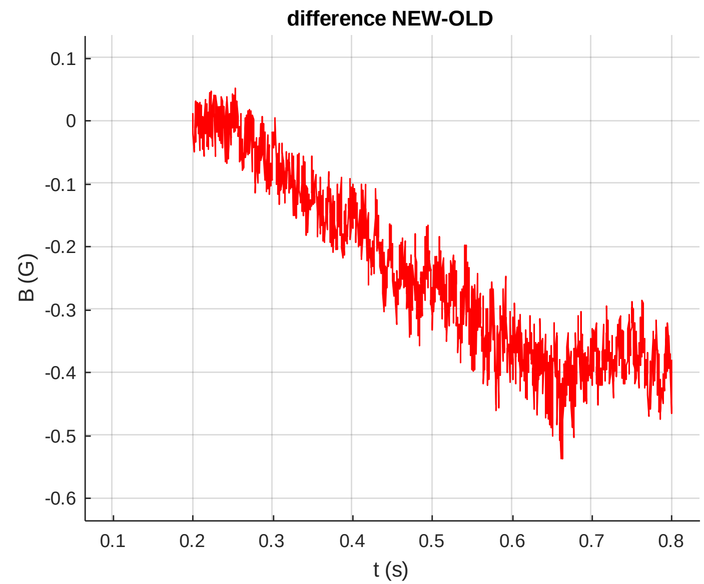
- FIRESTORM taking input from Ring 4 integral coil (with Ring 2 NMR)
- difference **($B_{FIRESTORM} - B_{legacy}$) ≈ ±10 G ($1.1 \cdot 10^{-3}$)**
- apparent **ΔTF ≈ 0.3% between R4 and R3** – needs to be confirmed by adding in trim and BdL currents
- possibility of improving the equalization of B in the rings – is that needed ?

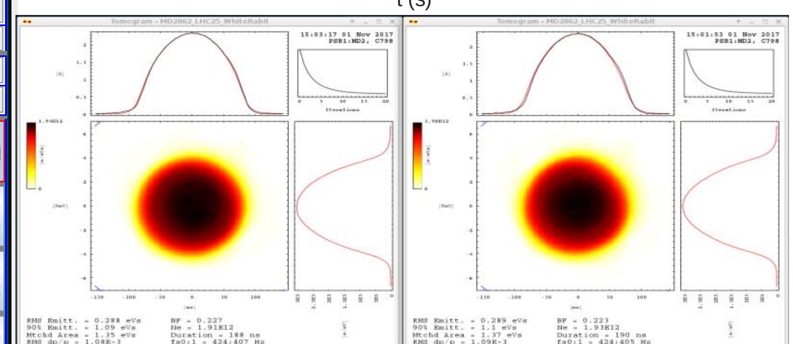


PSB – B-train MD on Nov 01

- Beam accelerated for the first time with the new FIRESTORM measurement distributed via WR
- New LLRF on all four rings tested with input from legacy magnetic sensors (coil/NMR) in Ring 3
- less than ~0.5 G field difference with initial calibration, no measurable impact on beam

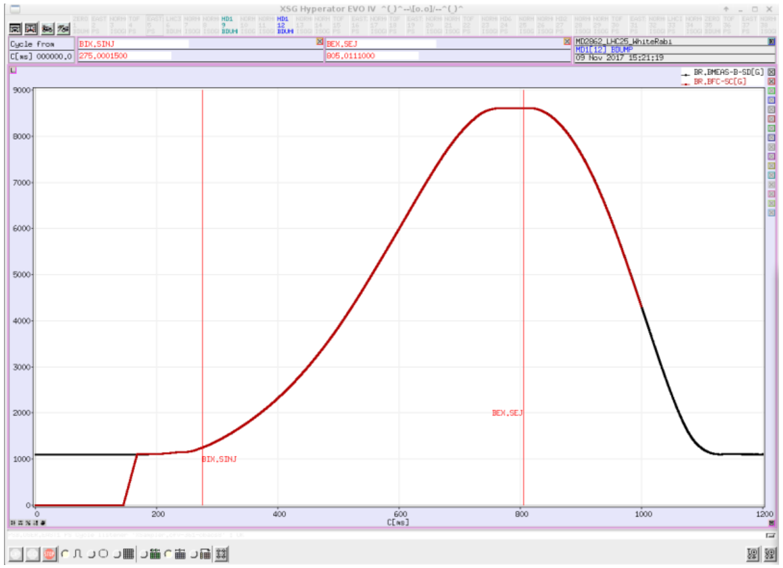


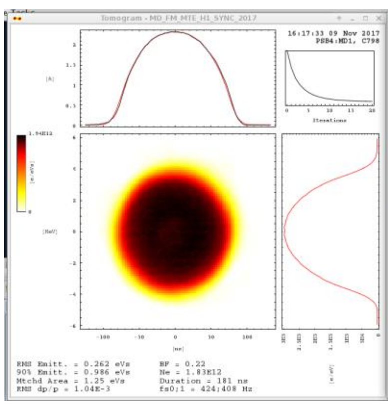


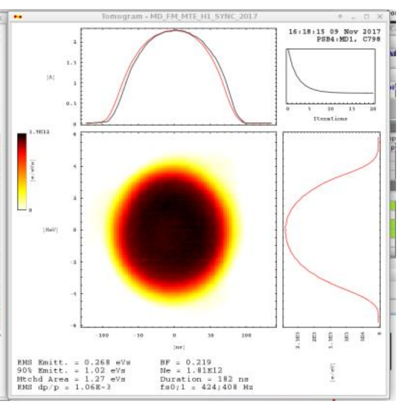


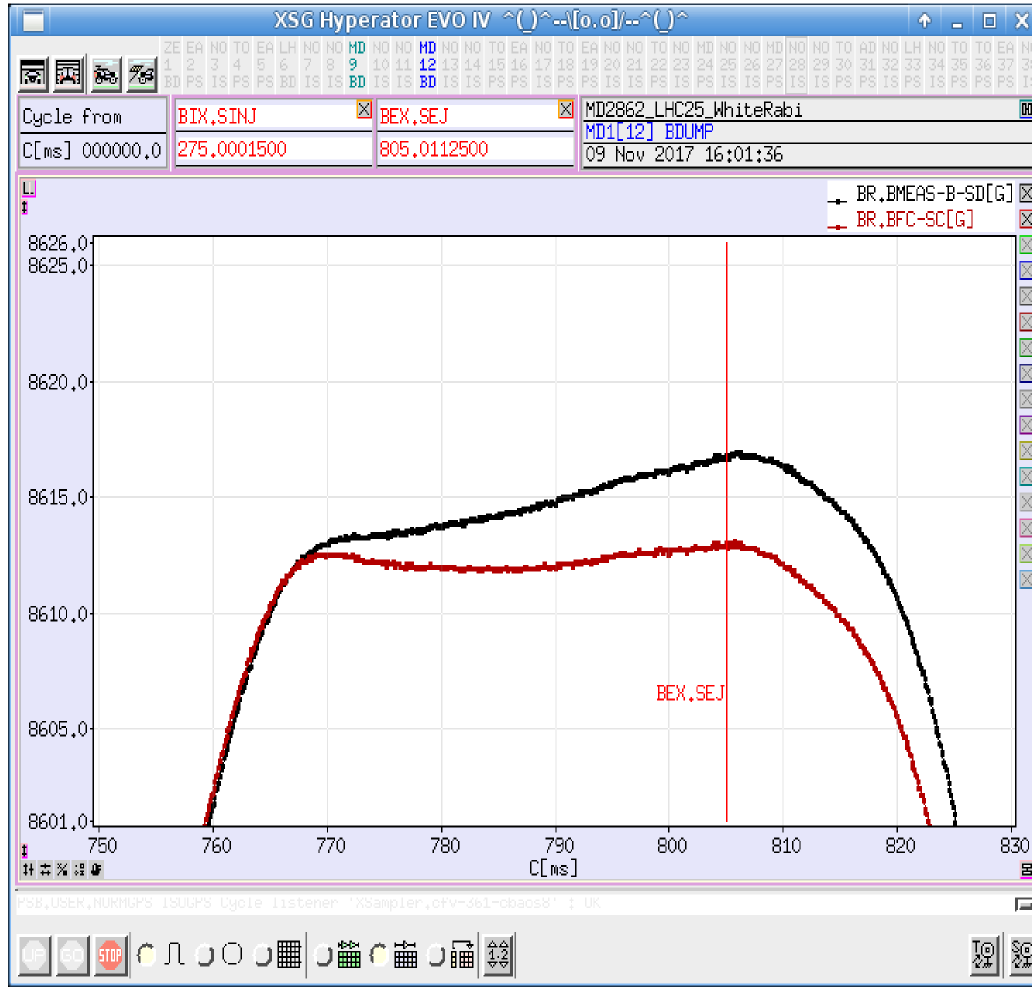
beam tomography with legacy (left) and new (right) B-train

- LHC25 beam accelerated with the new FIRESTORM measurement taking input from the new magnetic sensors (integral coil/NMR) in Ring 2 fed to LLRF R2/R4
- ~4 G field difference at high field

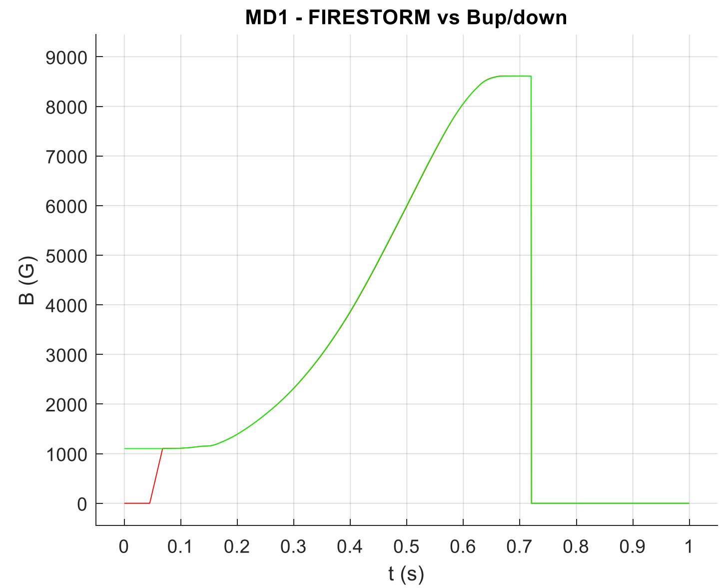


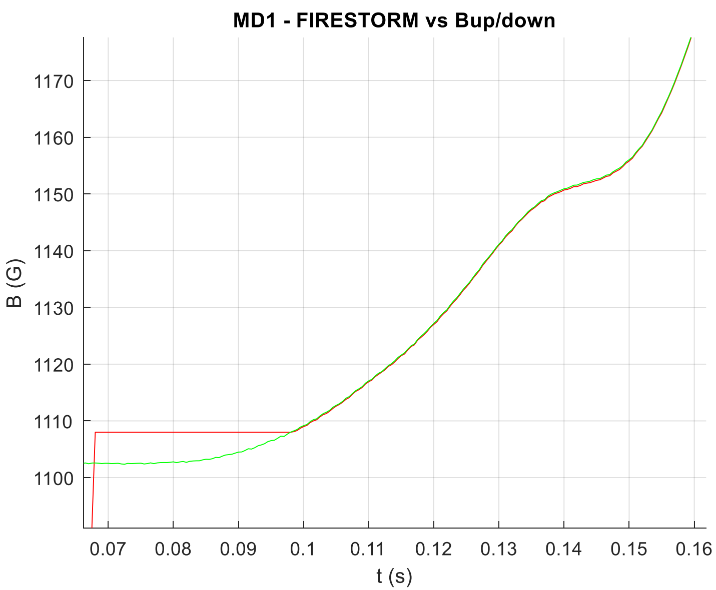


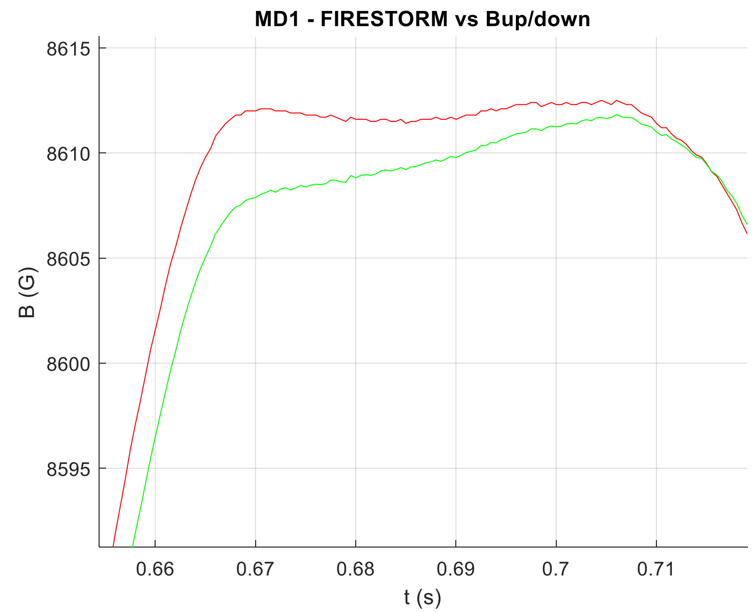




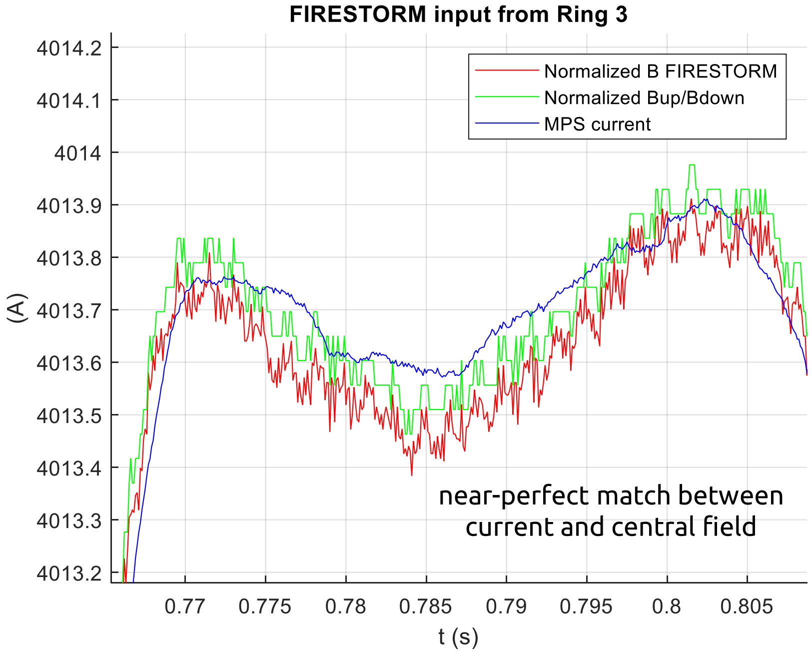
- beam accelerated with the new FIRESTORM measurement taking input from the new magnetic sensors: integral coil in Ring 4, NMR in Ring 2
- ~5 G field difference at high field (after gain correction)

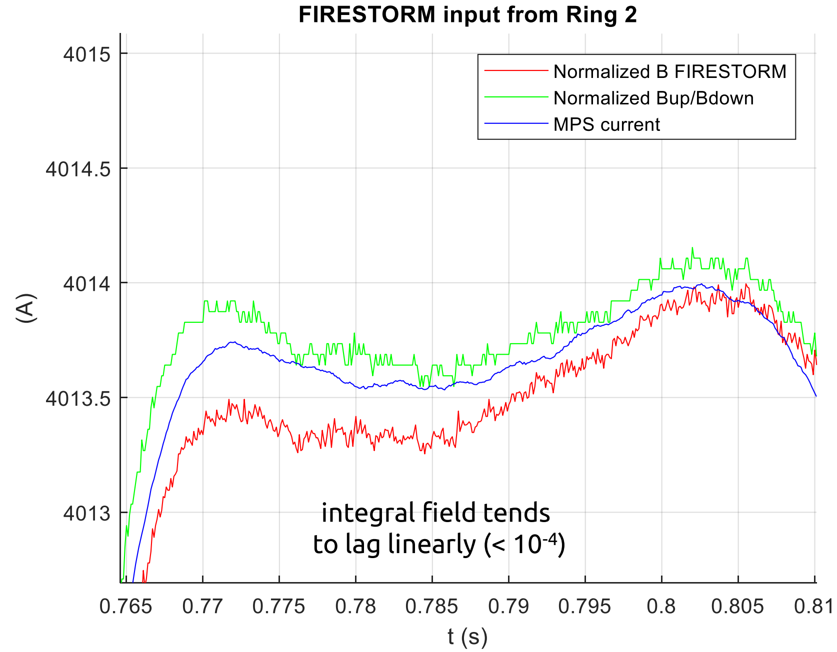


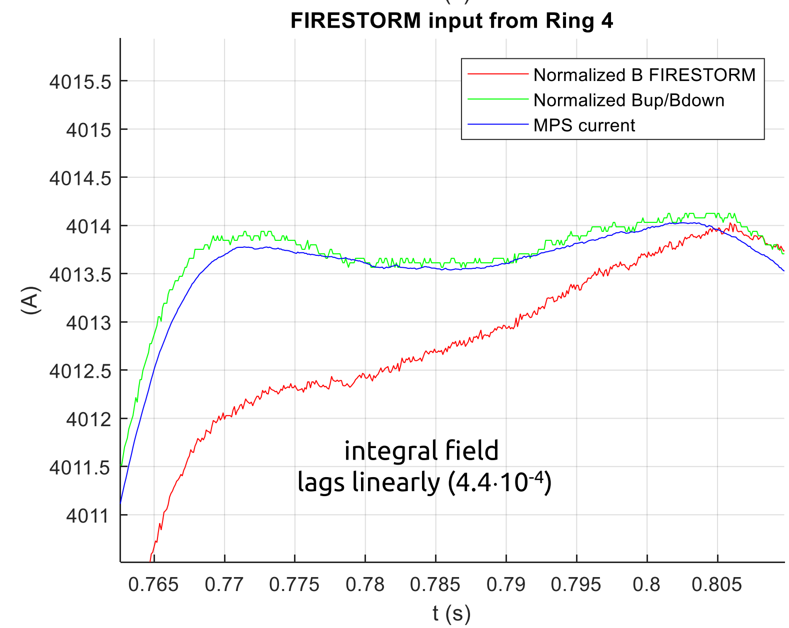




Eddy current effects







- Eddy current analysis: normalize the field to match current at end of flat-top, look for signature exponential decay
- linear decay observed for R2 (small) and R4 (large)
- no clear evidence for eddy current effects
- confounding factors: rounding-off and oscillations of the current, trim/BdL current missing from the analysis

Planned actions

YETS 17/18

- Replacement of faulty power supply for the OP NMR interface in the legacy B-train
- commissioning of new FMR markers in Ring 2 & 4
- install and cable new OASIS chassis
- replacement of temporary WR fiber to RF (BOR R708 in 361-1-009) and BCT (BOR 757 in 361-1-011) + new fiber to b. 30 (cabling demand launched)

2018

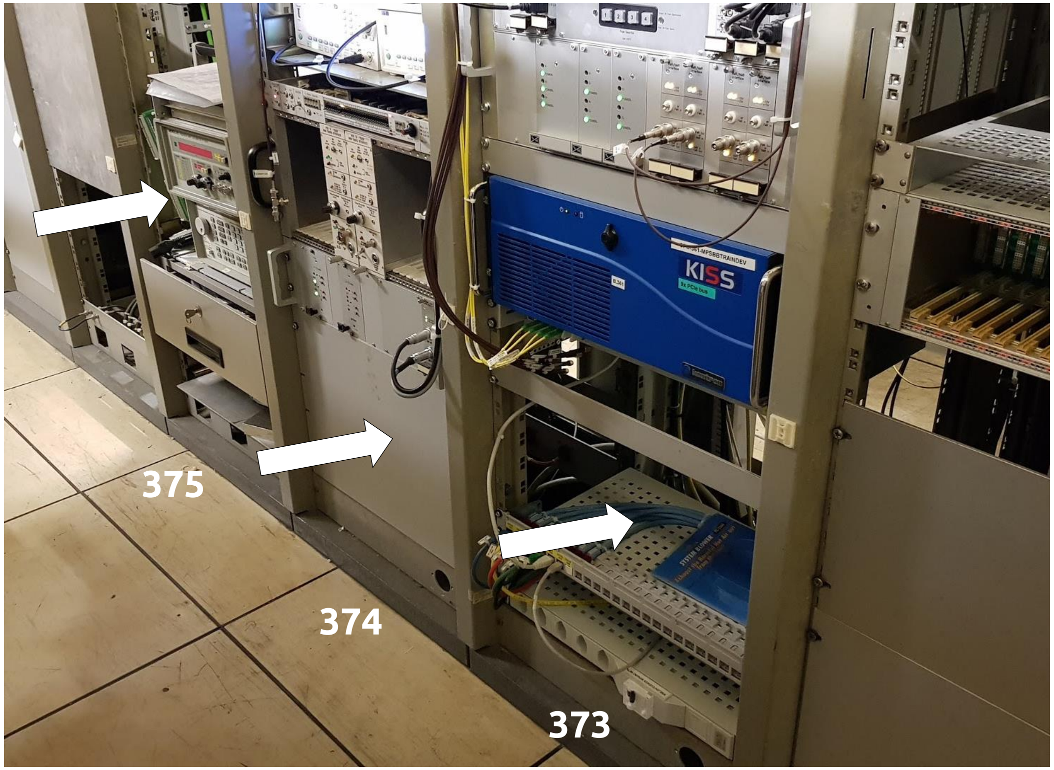
- update VHDL/FESA, check calibration with new FMR (offline)
- dedicated MD(s) to find optimal configuration with beam
- reliability run (2 weeks) to gather stats and OK phasing out VME FEC
- if all the above OK: switch over to regular operation

LS2

- Baseline in case of fallback to MPS: power the new reference magnetic in b. 245 with old MPS
- Recover NMRs / scopes / OASIS crate from b. 361 → b. 245, dismantle the rest

New OASIS crate

- new OASIS crate with 16×2 diff. channels, 16-bit, 200 kHz (~ 12 kCHF on 99284)
  (overlapping bandwidth with existing crates is not recommended)
- adequate for all legacy and new sensors
- temporary installation in b. 361 during YETS17, to be moved to b. 245 during LS2
- possible emplacements: BCR 368/367/373/374/375 in 361-1-012 (TBD with B. Ninet)
- triggers locally generated as PX.SCYDEL-FMR, clock synchronized as PX.CLK-FMR

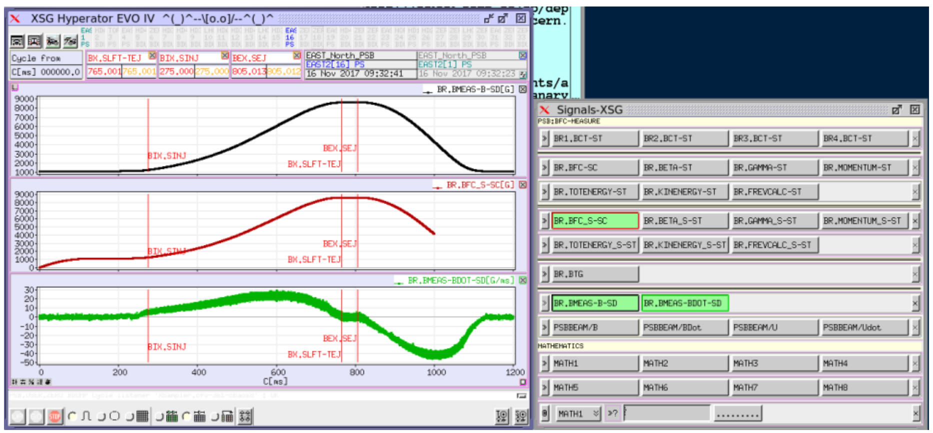


New OASIS/Sampler B-train Signals

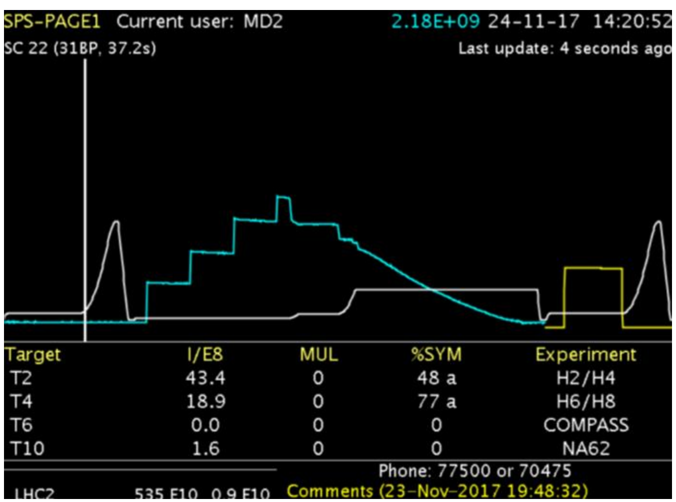
MAIN USERS	BUDGET CODE	DEPARTMENT	SIGNAL NAME	DESCRIPTION
PSB OP	99392	TE/MSC/MM	BR2.LONGCOIL-AS	integral coil Ring2
PSB OP	99392	TE/MSC/MM	BR2.SHORTCOIL_1-AS	end coil Ring2
PSB OP	99392	TE/MSC/MM	BR2.SHORTCOIL_2-AS	central coil Ring2
PSB OP	99392	TE/MSC/MM	BR2.FMR_LOW-AS	FMR marker low Ring 2
PSB OP	99392	TE/MSC/MM	BR2.NMR_LOW-AS	NMR marker low Ring 2
PSB OP	99392	TE/MSC/MM	BR2.NMR_HIGH-AS	NMR marker high Ring 2
PSB OP	99392	TE/MSC/MM	BR3.SHORTCOIL_CENTER_OP-AS	operational coil for old B-train
PSB OP	99392	TE/MSC/MM	BR3.SHORTCOIL_CENTER_SP-AS	spare coil 1 for old B-train
PSB OP	99392	TE/MSC/MM	BR3.SHORTCOIL_EDGE-AS	spare coil 2 for old B-train
PSB OP	99392	TE/MSC/MM	BR3.NMR_LOW_OP-AS	operational marker for old B-train
PSB OP	99392	TE/MSC/MM	BR3.NMR_LOW_SP-AS	spare marker for old B-train
PSB OP	99392	TE/MSC/MM	BR3.NMR_HIGH-AS	legacy marker (high) for old B-trair
PSB OP	99392	TE/MSC/MM	BR4.LONGCOIL-AS	integral coil Ring4
PSB OP	99392	TE/MSC/MM	BR4.SHORTCOIL_1-AS	end coil Ring 4
PSB OP	99392	TE/MSC/MM	BR4.SHORTCOIL_2-AS	central coil Ring 4
PSB OP	99392	TE/MSC/MM	BR4.FMR_LOW-AS	FMR marker low Ring 4
PSB OP	99392	TE/MSC/MM	BR4.NMR_LOW-AS	NMR marker low Ring 4
PSB OP	99392	TE/MSC/MM	BR4.NMR_HIGH-AS	NMR marker high Ring 4

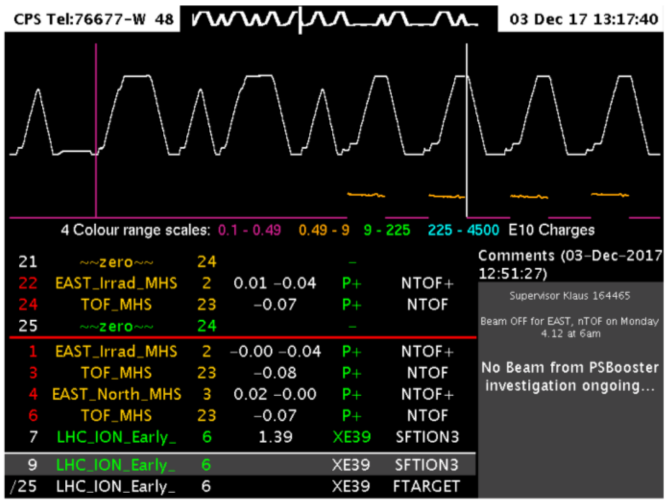
TIMBER Variable Name	
BR.BFC-SC:SAMPLES	old B-train
BR.BMEAS-B-SD:SAMPLES	new B-train
BR.BMEAS-BDOT-SD:SAMPLES	(B and Bdot)
FSBT_PSB_CV:M1MarkerSignal	operational field markers
FSBT_PSB_CV:M2MarkerSignal	(NMR or FMR)
BR1.BCT-ST:SAMPLES	
BR2.BCT-ST:SAMPLES	
BR3.BCT-ST:SAMPLES	beam current in the 4 rings
BR4.BCT-ST:SAMPLES	
BR.MPS-SA:SAMPLES	
BA1.FREV-SD:SAMPLES	
BA2.FREV-SD:SAMPLES	
BA3.FREV-SD:SAMPLES	revolution frequency
BA4.FREV-SD:SAMPLES	programmed & measured
BA1.FREQPROG-SD:SAMPLES	
BA2.FREQPROG-SD:SAMPLES	
BA3.FREQPROG-SD:SAMPLES	
BA4.FREQPROG-SD:SAMPLES	
BA1.RPOS-COR-SD:SAMPLES	radial position
BA2.RPOS-COR-SD:SAMPLES	
BA3.RPOS-COR-SD:SAMPLES	
BA4.RPOS-COR-SD:SAMPLES	

- Requests for new signals in OASIS and TIMBER have been made
- NB: due to the input impedance being as low as 800 kΩ , <u>operational sensors will need additional buffering</u>



- Objective: **new Fixed Displays** showing measured B field + other relevant data (simulated field, OP/SP comparison, markers …) in real-time (refresh ≤ 100 ms)
- Existing published FESA signals not adequate ⇒ new development needed
(currently: vector properties published at the end of every cycle i.e. every 1.2 s up to ~120 s)
- Proposed solution: **dedicated FEC** , receiving WR input on standard FMC carriers, publishing it via a **new FESA class** at the required rate
- main advantage: show signals as received by users
- possible synergy: high level, real-time quality assessemnt, diagnostics and alarms
- Proof-of-concept in 2018 (support of BE/CO/APS):
PS B-train chain 3 → analog output on FMC_INT → OASIS digitizer → new Fixed Display.
- Final deployment during LS2; detailed definition and customization by BE/OP
Attention to the risk of confusion between $B_{measured}/B_{simulated}/B_{predicted}$ …



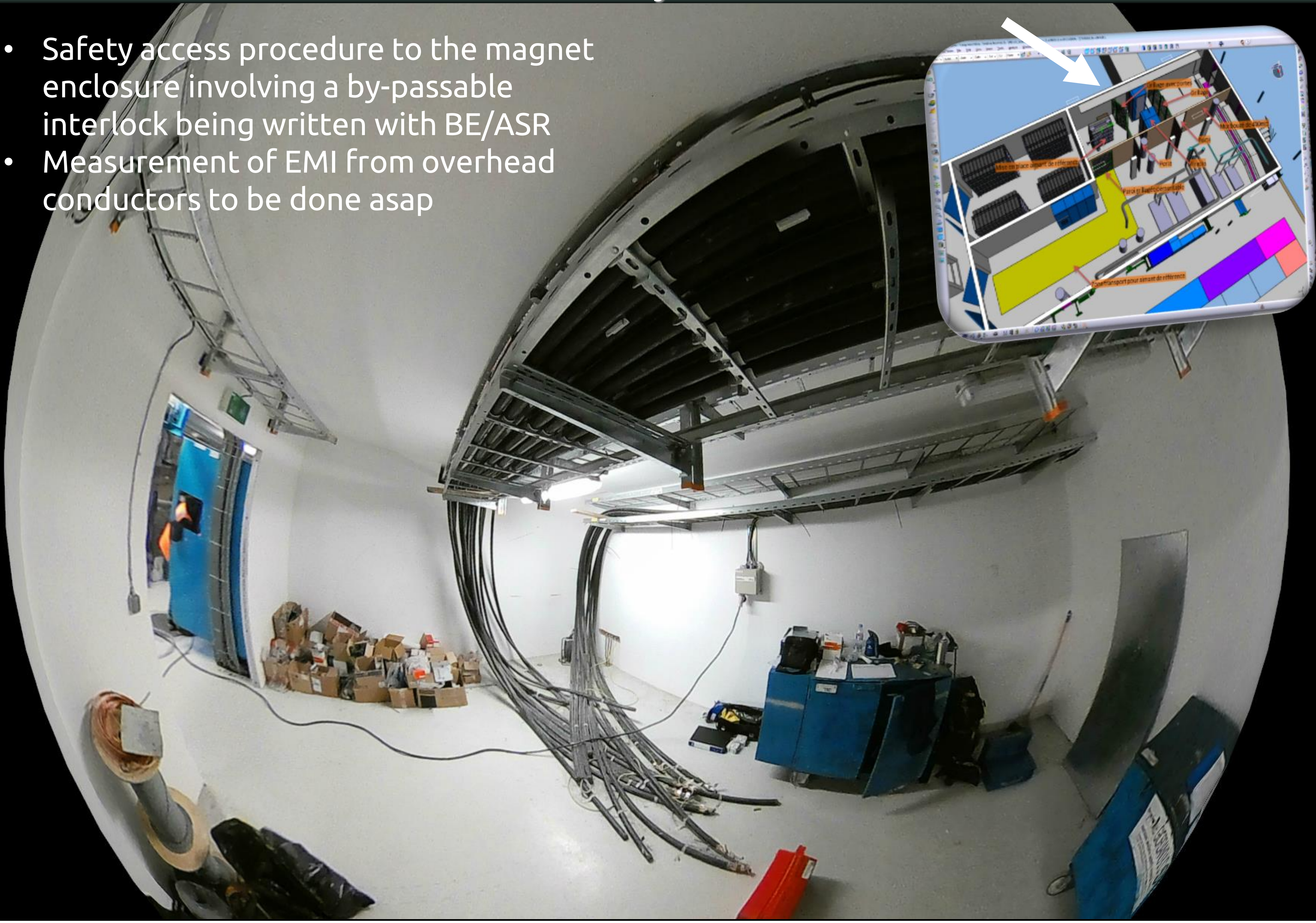


Fixed vs. scrolling cursor – can we make the same choice for all systems ?

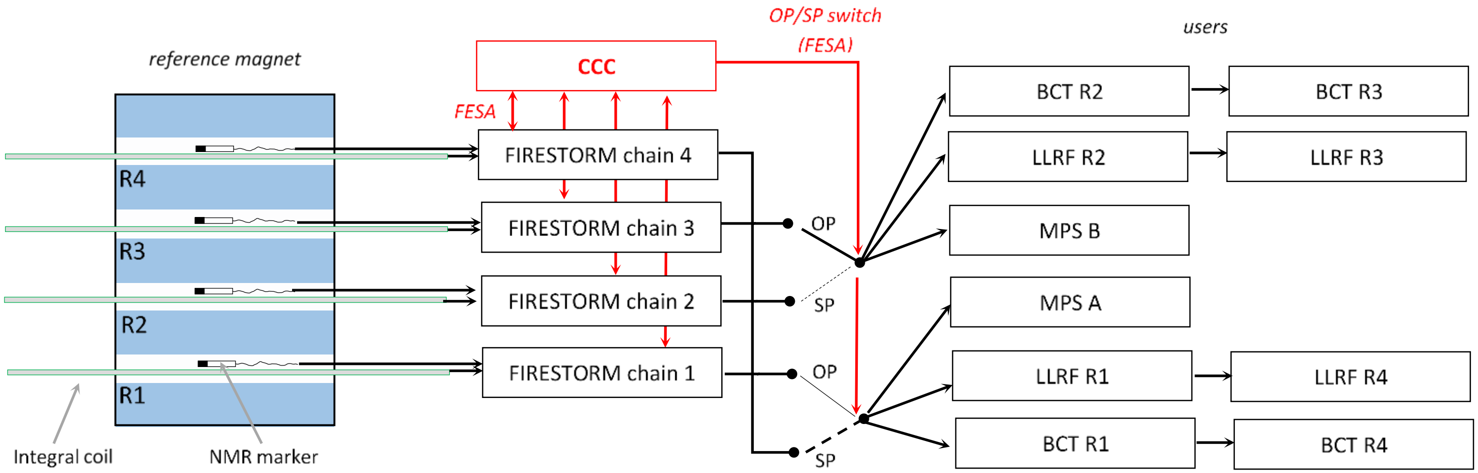
1. Status of the B-train consolidation project
2. Commissioning of the PSB test system (b. 361)
3. **Plans for the PSB Upgrade (b. 245)**

B-train facility in 245-S-403

- Safety access procedure to the magnet enclosure involving a by-passable interlock being written with BE/ASR
- Measurement of EMI from overhead conductors to be done asap



- **Baseline layout**: assume top/bottom symmetry (to be remeasured on final reference magnet)
- B-train chains switched as a whole: chain 2 = hot spare of 3, chain 1 = hot spare of 4
  (NB: sensor failure much less probable than electronics)
- Simultaneous failure of R2/R3 or R1/R4 chains not covered
  (requires expert intervention and rewiring/repair)



Selection made by CCC via 2× settable boolean FESA properties

Selection bit 1	1	1	0	0
Selection bit 2	1	0	1	0
FIRESTORM chain 4 →	MPS A, LLRF 1/4, BCT 1/4	–	MPS A, LLRF 1/4, BCT 1/4	–
FIRESTORM chain 3 →	MPS B, LLRF 2/3, BCT 2/3	MPS B, LLRF 2/3, BCT 2/3	–	–
FIRESTORM chain 2 →	–	–	MPS B, LLRF 2/3, BCT 2/3	MPS B, LLRF 2/3, BCT 2/3
FIRESTORM chain 1 →	–	MPS A, LLRF 1/4, BCT 1/4	–	MPS A, LLRF 1/4, BCT 1/4

- Problem: LLRF/BCT could profit from feedback from individual rings
- Solution: more complex switching matrix requiring four-tier switching, capable of recovering from all single-point and some double-point failures
- Simultaneous failure of inner or outer chains still not covered
- **Benefits should be weighted carefully against extra complexity ….**

	Default operation	single chain failure			
Selection bit 1	1	0	1	1	1
Selection bit 2	1	1	0	1	1
Selection bit 3	1	1	1	0	1
Selection bit 4	1	1	1	1	0
FIRESTORM chain 4 →	MPS A, LLRF 4, BCT 4	–	MPS A, LLRF 4, BCT 4	MPS A, LLRF 4, BCT 4	MPS A, LLRF 1/4, BCT 1/4
FIRESTORM chain 3 →	MPS B, LLRF 3, BCT 3	MPS B, LLRF 3, BCT 3	–	MPS B, LLRF 2/3, BCT 2/3	MPS B, LLRF 3, BCT 3
FIRESTORM chain 2 →	LLRF 2, BCT 2	LLRF 2, BCT 2	MPS B, LLRF 2/3, BCT 2/3	–	LLRF 2, BCT 2
FIRESTORM chain 1 →	LLRF 1, BCT 1	MPS A, LLRF 1/4, BCT 1/4	LLRF 1, BCT 1	LLRF 1, BCT 1	–

…

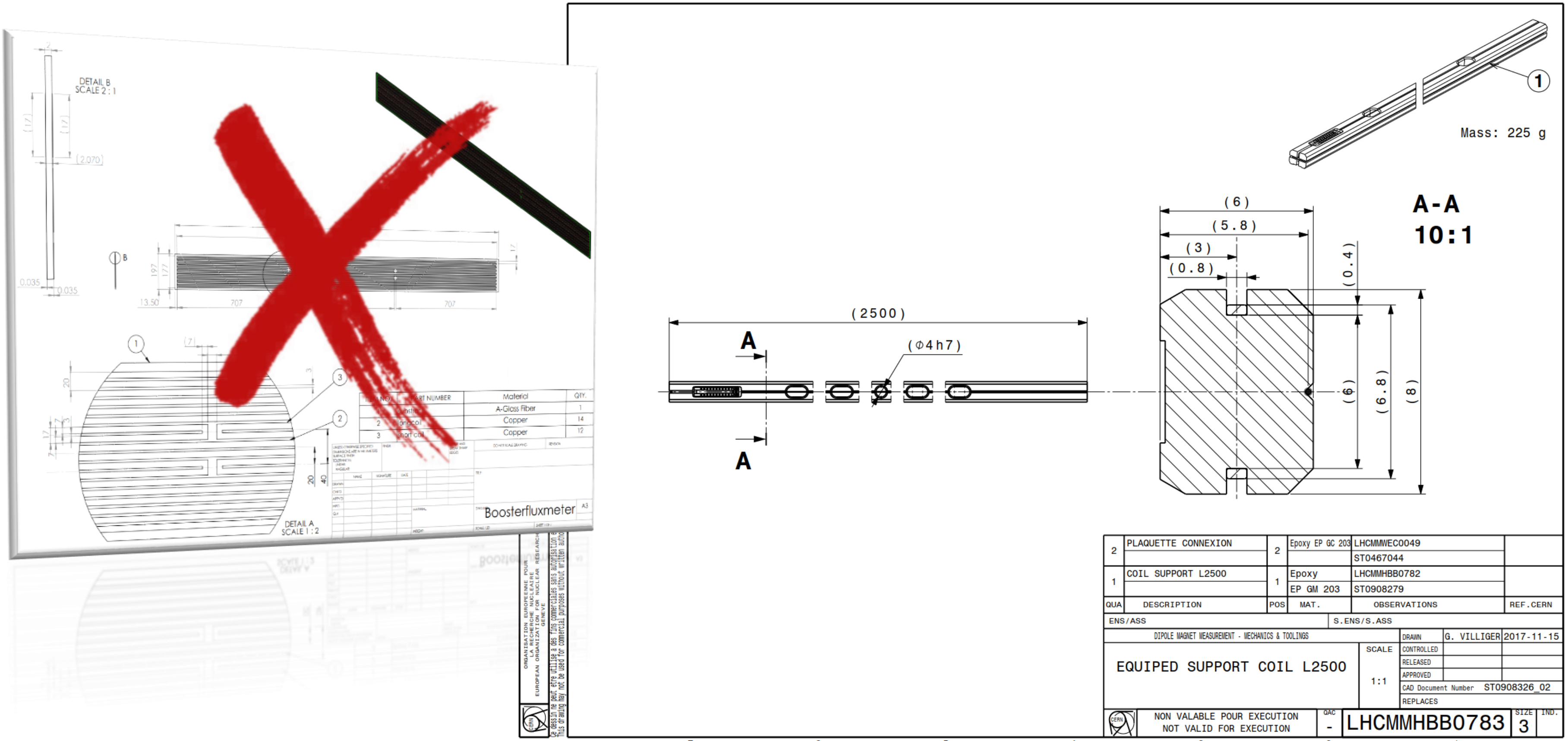
double chain failure

0	0	1	1
0	1	0	1
1	0	1	0
1	1	0	0
–	–	MPS A, LLRF 1/4, BCT 1/4	MPS A, LLRF 1/4, BCT 1/4
–	MPS B, LLRF 2/3, BCT 2/3	–	MPS B, LLRF 2/3, BCT 2/3
MPS B, LLRF 2/3, BCT 2/3	–	MPS B, LLRF 2/3, BCT 2/3	–
MPS A, LLRF 1/4, BCT 1/4	MPS A, LLRF 1/4, BCT 1/4	–	–

…

- Yet another possibility, closer to the physics of the object being controlled:
  - feedback the average of inner/outer rings to POPS-B A and B
  - feedback individual rings to RF/BI
- **major disadvantages**: extremely more complex, more integrator FMCs, more WR switches (and one more rack necessary), distributed field is different for different users …

New integral dipole coils



- **PCB fluxmeter**: recent failures with both external and CERN manufacturing of the ELENA unit → <u>too risky to continue</u> (esp. considering that field harmonics are <u>not</u> required)
- plan B: switch to traditional solution (**multi-filament wire wound on a G10 form**)
  (same as integral coils being used now in bldg. 361)
- absolute calibration possible in 867-R-H29, no need for strict surface equality between rings
- order being prepared, foreseen ready for installation H2 2018

Summary

- A number of **important milestones** has been reached, proving that the new FIRESTORM B-train is **capable to accelerate and extract** a wide variety of beams in **ELENA, LEIR, PSB and PS**
- Under many operating conditions, performance **far exceeds** the old system in terms of resolution and stability
- No major obstacle identified that prevents phasing out legacy VME FECs at the end of LS2, however:
- **Simulated B-train** still to be completed; substantial **VHDL and FESA development** foreseen in 2018 and beyond
- We rely on the continuing support by BE/CO and BE/OP, as well as on functioning control infrastructure during LS2

Additional slides

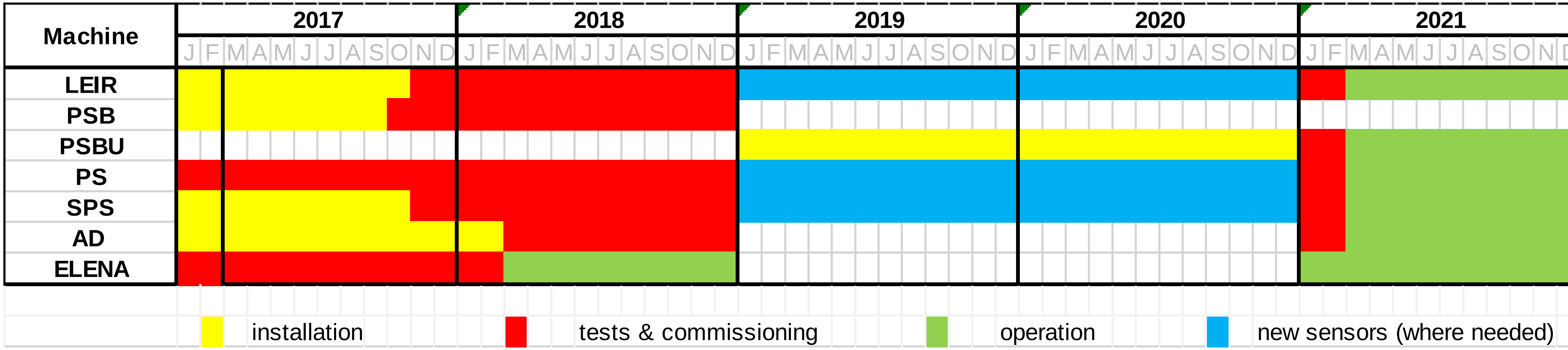
CRITICAL ITEMS – ALL SYSTEMS (2018)

- simulated B-train
  - get next B/Bdot/I cycles from LSA and prepare for real-time interpolation at next cycle
  - differences between machines to be coded in FESA and tested
- complete and propagate debugged version
  - 2.4% round-off error in B and Bdot gain
  - coil calibration coefficient limited to [0,2]
  - two cycles published via FESA instead of one (linked to absence of end-of-cycle timing event in ELENA, PSB, LEIR)
- update of VHDL & FESA classes to final modular WR hardware
- Add PPM FESA properties to adapt calibration constants on a per-cycle/type basis
- metrological characterization of the new chain under the full range of operating conditions (in particular, supercycle composition)

FURTHER IMPROVEMENTS

- new magnetic sensors for the PS, LEIR and SPS
- additional VHDL/FESA functionality
  - continuous estimation and subtraction of integrator voltage offset (→ reduced need of ZERO cycles for internal calibration)
  - enable marker triggers based on current field level rather than fixed time window (→ simpler, more robust calibration)
  - dynamic calibration constants as function of field level (→ simpler, more flexible than PPM properties)

All changes to be tested in the shadow of normal operations on (SP/DEV) chains – fully reversible in a few hours



alignment of production version
VHDL (gateware) / FESA
on all systems

Reliability Run 2018

Accumulated statistics (thanks to having the same components everywhere)

- ELENA: all year
- PS: all year
- LEIR: 2 weeks in May
- PSB: TBD
- AD: TBD
- SPS: TBD

need to agree on acceptance criteria
to phase out legacy VME FECs after LS2