

Run 2 Overview of LHC Beam Instrumentation

Michal Krupa for the BI Group

31/01/2019

9th LHC Operations Evian Workshop



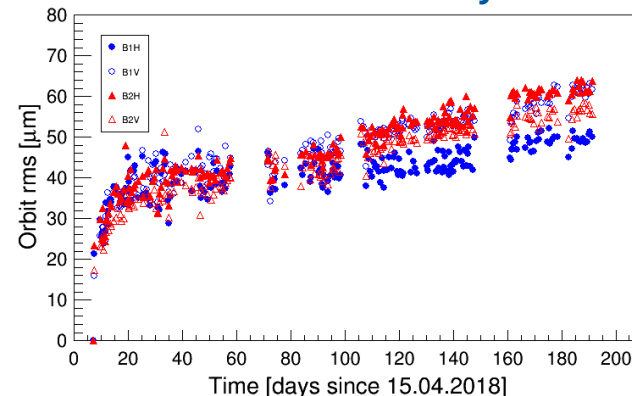
Outline

- Run 2 improvements, operational experience, performance of major BI system:
 - **BPM** (orbit, interlock, DOROS), **BLMs** (main, diamond), **BCTs** (DC, fast), **feedbacks**, **BBQ**, **Schottky**, **instability**, **special** diagnostics
 - For emittance measurements – see G. Trad's talk
- Overview of BI availability
- Outlook for LS2 / Run 3

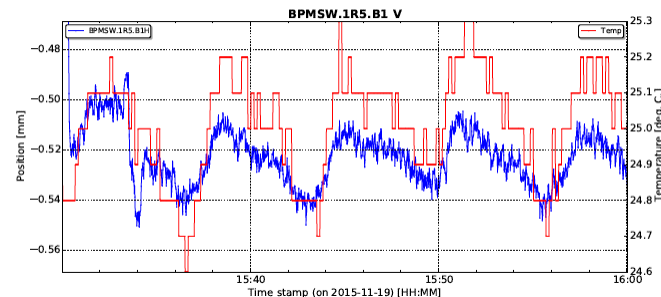
Orbit BPMs

- Around 1100 BPMs in orbit FB
 - Orbit measurement resolution: $\sim 1 \mu\text{m}$
 - Long-term reproducibility: $\sim 50 \mu\text{m}$
 - Smooth Run 2 commissioning
- Analogue electronics with limitations
 - Bunch pattern: calibration ($< 50 \mu\text{m}$)
 - Temperature: thermalised racks ($< 50 \mu\text{m}$)
 - “Dancing” BPMs: in reality multiple issues, solved

LHC orbit stability



Rack temperature vs beam position



Orbit BPMs

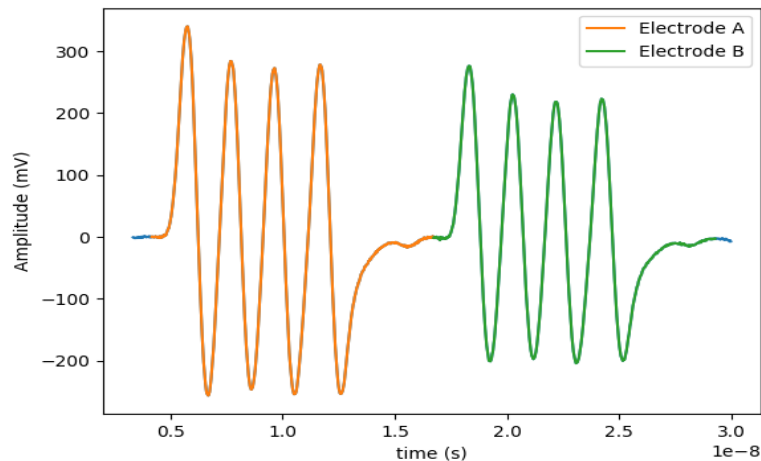
- Some development during Run 2
 - Multiple FW upgrades: bug fixes, more stability and maintainability
 - “Synchronous orbit”: for p/Pb run
 - Automatic adjustment (with the bunch pattern) of orbit filter BW: reduced noise
 - Testbed: dry runs before commissioning, ongoing
- No major intervention in LS2
 - FW upgrades
 - Consolidation planned for LS3

Interlocked BPMs

- 8 dedicated BPMs in IR6
 - Real time, bunch by bunch, fail-safe
- Existing system with limitations
 - Obsolete analogue electronics (WBTN)
 - Sensitivity selection, signal reflections (mitigated), no doublets
- Upgrade under development
 - Modern digital signal processing (VFC)
 - Single gain, doublets
 - $< 200 \mu\text{m}$ resolution
 - Vertical slice test in Run 3

Time	PHY	Comment
21:17	BI	Summary BPM interlock problem It is very probable that the problem was the pilot intensity, that in the first cases it was just at the limit of the low sensitivity (used for nominals). To be confirmed offline. <i>created by lhcop on CWO-CCC-D4LC</i>

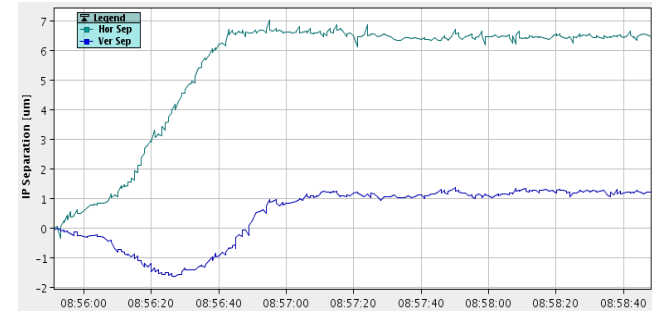
New interlock BPM signal processing



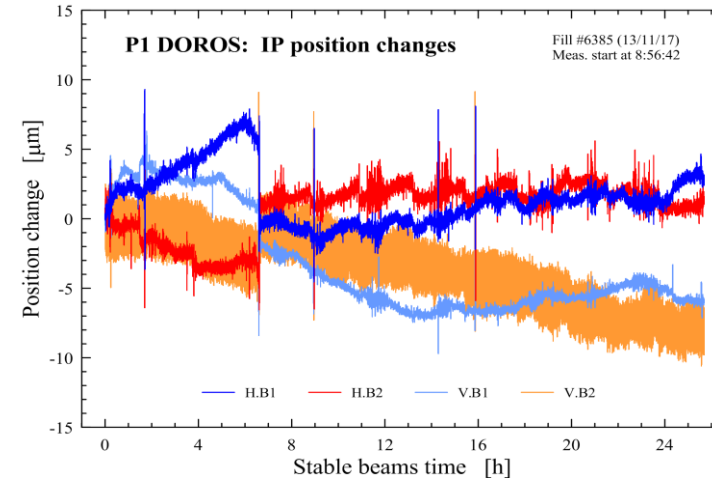
DOROS BPMs - orbit

- Alternative acquisition electronics
 - Installed on 40 standard BPMs
- Good performance, some limitations
 - Intensity dependence: correction ($\sim 30 \mu\text{m}$)
 - 2 HW R2E faults: component identified
- Planned upgrades during LS2
 - Further correction of intensity dependence
 - R2E mitigation by HW changes
 - Orbit FB compatibility for a possible future addition
 - Real-time orbit spectra for Q2s in IP1

IP8 separation in μm

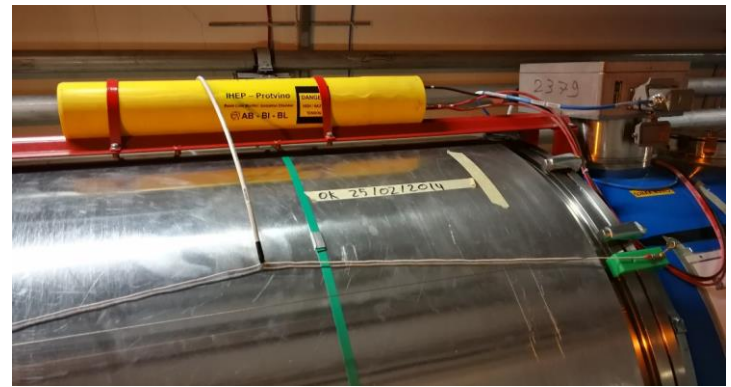


DOROS beam intensity sensitivity



Main BLMs

- Very large interlocked system
 - ~ 4000 ionisation chambers
- Generally good performance
 - No known protection critical issues
 - Diligent fault analysis
 - Availability improvement due to LS1 interventions
- DISMAC and related interventions
 - Estimated ~ 1600 BLM channels to be removed and re-installed
 - Requires full check-out and irradiation



CERN
CH-1211 Geneva 23
Switzerland



LHC

EDMS NO.	REV.	VALIDITY
896394	3.4	DRAFT

REFERENCE

LHC-OP-MPS-0009

Date: 2018-03-04

MPS COMMISSIONING PROCEDURE

MPS Aspects of the Beam Loss Monitoring System Commissioning

ABSTRACT:

This document describes the set of tests, which will be carried-out to validate for operation the machine protection aspects of the **LHC Beam Loss Monitoring system**. The area concerned by these tests extends over the whole LHC machine for each of the two LHC beams.

These tests include hardware commissioning, machine check-out and tests with beam.

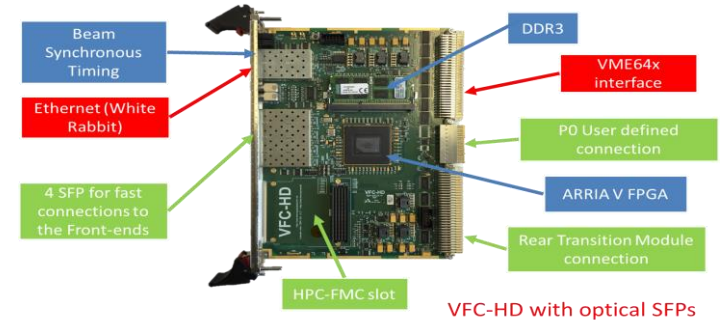
Main BLMs

- Ongoing developments
 - Implemented logging in NXCALS, data migration done
 - 700 new processing modules in production, vertical slice test in Run 3
 - Improved irradiation source trolley
 - Radiation source with TIM by EN/SMM
- Run 3 commissioning
 - 11 hardware and 3 system tests
 - Major SW (FESA 3) and FW (VME comms upgrade) changes to be validated

TIM-based irradiation station



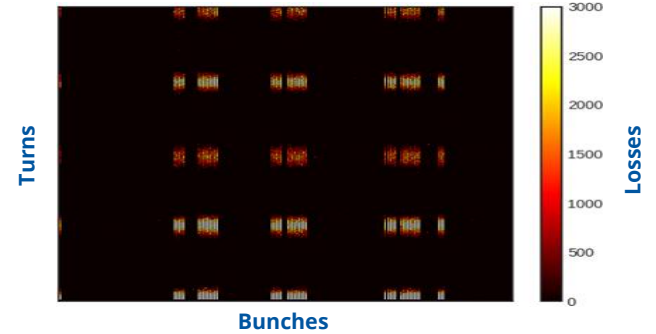
VFC-based processing module



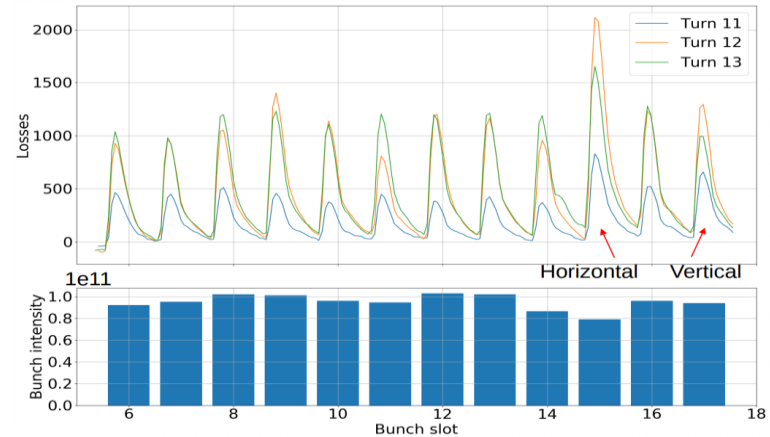
Diamond BLMs

- System developed during Run 2
 - 10 BLMs: P2,8 (inj), P6 (extr), P7 (TCPs, crystal)
- New read-out deployed in 2018
 - VFC + FMC / FESA – better integration
 - Archiving in NXCALS for IP7
- Used for beam studies
 - On-board UFO trigger
 - Scraping studies
 - 10 Hz oscillation

10 Hz beam oscillation



Bunch losses during UFO event



DCCTs – beam intensity

- Very stable system
 - Smooth commissioning
- Run 2 developments:
 - 24 bit ADC: single sensitivity, simplified VdM preparation
 - Noise reduction
 - Software / FESA upgrade
 - Resolution: 1e9
- No major development in LS2
 - Vacuum sector bake-out...

Time	P H Y	Comment
		Shift Summary
		Started the shift with a fill (72bpi) for checks at injection.
14:59	2 1	Then precycled and prepared for vdM scans: (...) - DCCT fixed to range 3 (total intensity should not exceed 4.0-4.1e12 p/ring).

created by lhcop on CWO-CCC-D9LS

Interlocks pour l'étuvage des chambres à vide des BCTs

1. Température. BCT < 60 °C
2. Contact Eletta fermé (c'à d. circuit d'eau de refroidissement ouvert)



Ne pas débiter l'étuvage sans la présence d'un responsable BI !

Responsables: [D.Belohrad](#) AB/BI, tél. 76318 163455

[P.Odier](#) AB/BI, tél. 73817

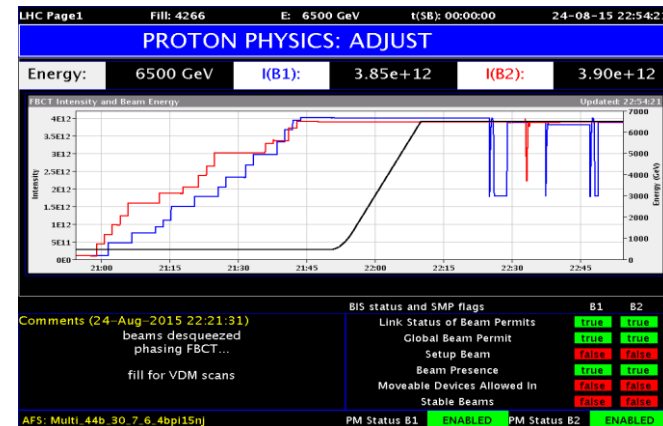
[S.Thoulet](#) AB/BI, tél. 72584

[S.Longo](#) AB/BI, tél. 74560

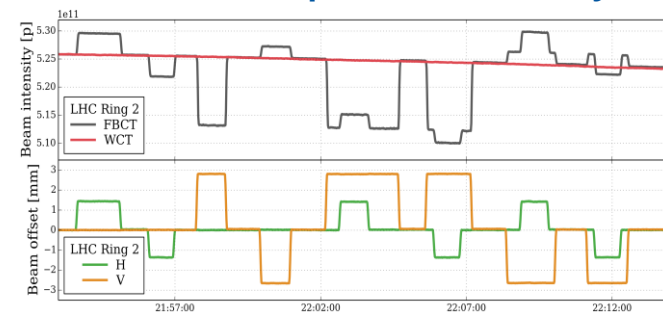
FBCTs – bunch intensity

- Complete overhaul during Run 2
 - New BCTW sensors: better signal, no beam position dependence
 - New acquisition electronics: modern digital integration, no phasing required
 - New software / FESA
 - Resolution: $1e8$
- Some development ongoing
 - Absolute calibration

FBCT phasing

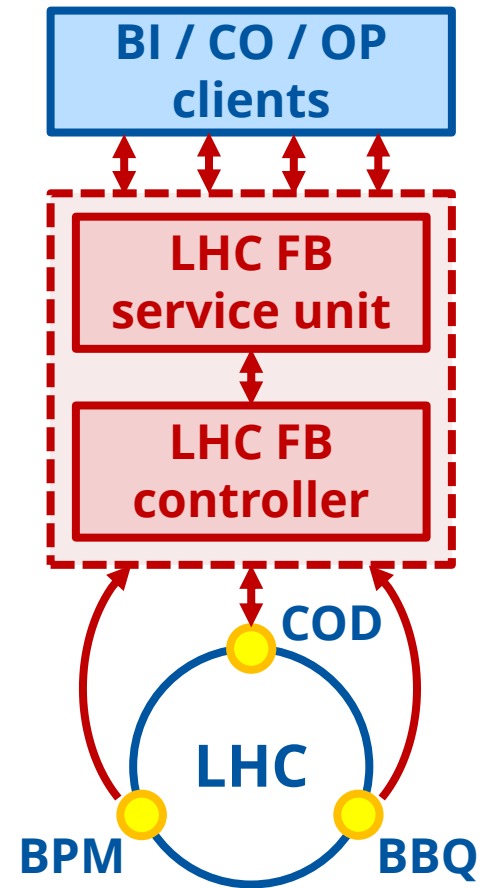


FBCT beam position sensitivity



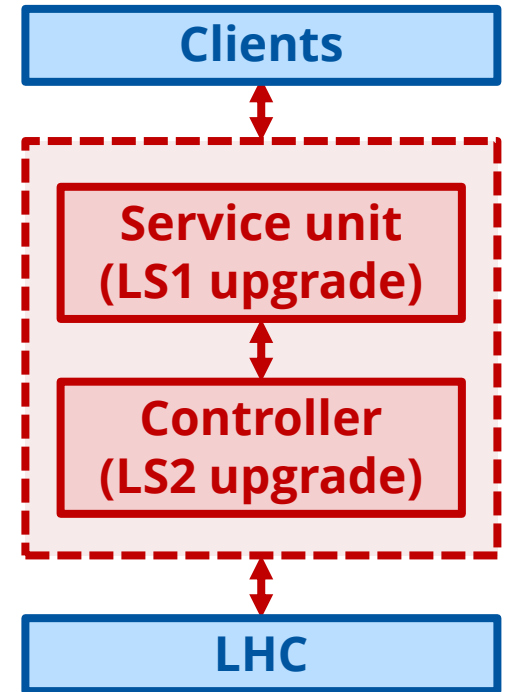
Feedbacks (orbit + tune)

- Large and stable system
 - 80k+ lines of code
 - Smooth Run 2 commissioning
- Major upgrade in LS1
 - Ported to new hardware
 - Service unit: ported to FESA
 - Controller: documented, improved trigger and logging
 - Testbed: dry runs before commissioning, issue investigation



Feedbacks (orbit + tune)

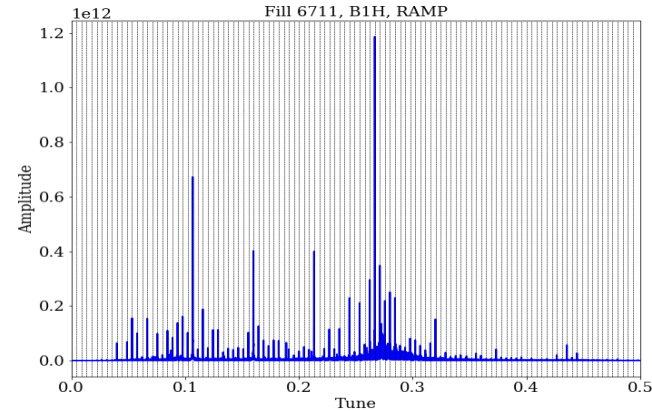
- Major upgrade in LS2
 - Controller: re-engineering, standardisation, ported to FESA
 - Pre-commissioning test campaign: validation with testbed
 - No issues expected for Run 3 commissioning



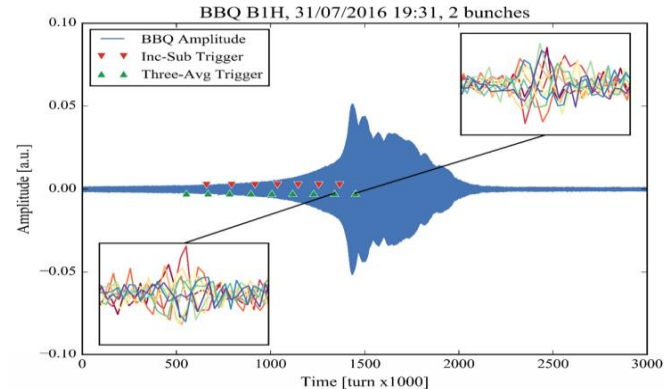
BBQ - tune

- Very stable system
 - No major issues observed
 - Added instability trigger and BTF features in Run 2
- Some limitations remain
 - Incompatibility with damper, gated BBQ
 - Multiples of 50 Hz on the beam, under study
- Development during LS2
 - Consolidation of acquisition to VFC
 - Software upgrade to FESA3

50 Hz "noise" lines



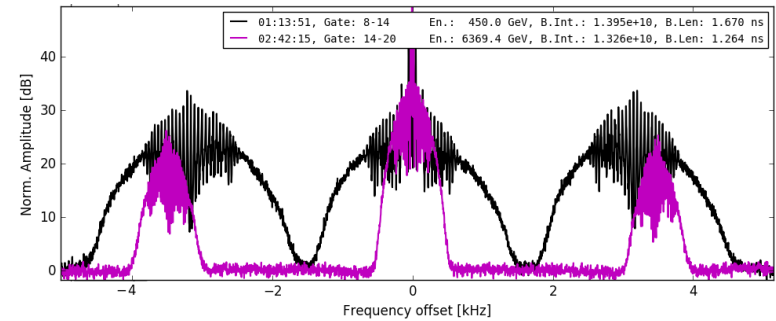
BBQ instability growth trigger



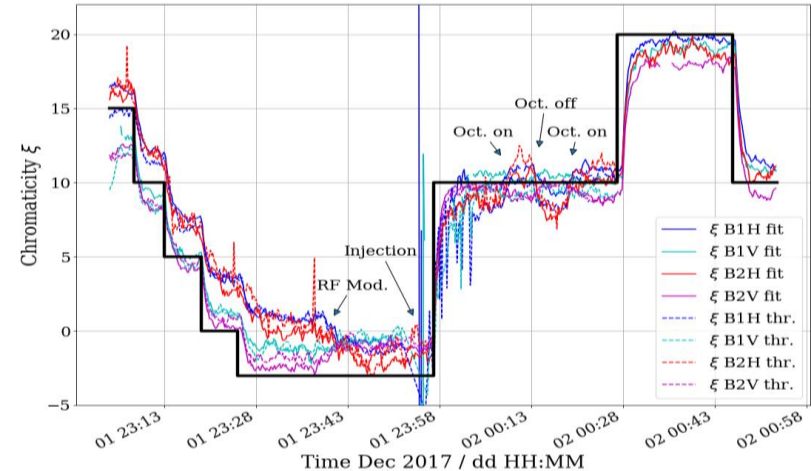
Schottky diagnostics

- Chromaticity, Q , f_s , emittance...
- Operational / expert system
 - Tweaking for non-standard beams
 - Turn-key for injection
 - ξ , Q logged online, fixed screen
- Overhaul during Run 2
 - State-of-the-art hardware
- No development in LS2
 - Benchmarking with other systems and data analysis toolkit needed

Ion Schottky signals before and after ramp



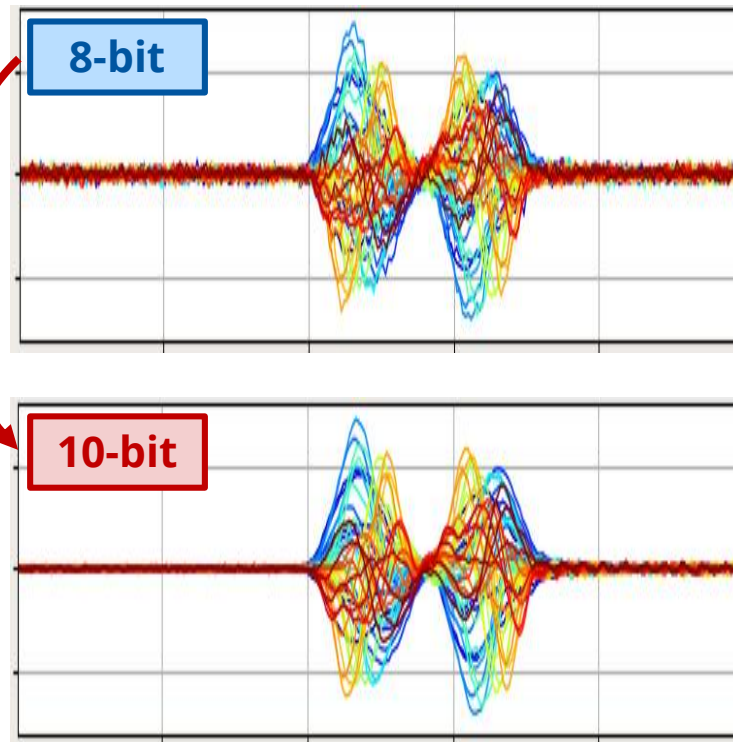
Chromaticity measurement



Instability diagnostics

- Head-Tail Monitor used extensively
 - Triggering from the BBQ via the LIST network operational since 2016
 - Trigger at beam-dump for 16L2 diagnostics implemented in 2017
- Acquisition upgraded in YETS17/18
 - Higher resolution and longer acquisition time
- Multi-Band Instability Monitor
 - Real-time diagnostics
 - Promising first results
 - Full deployment planned for LS2

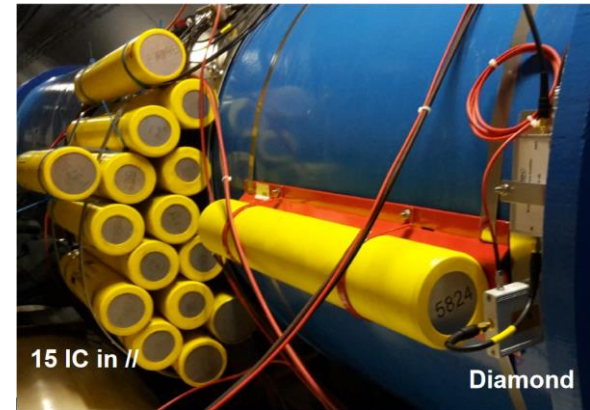
Head-Tail upgrade



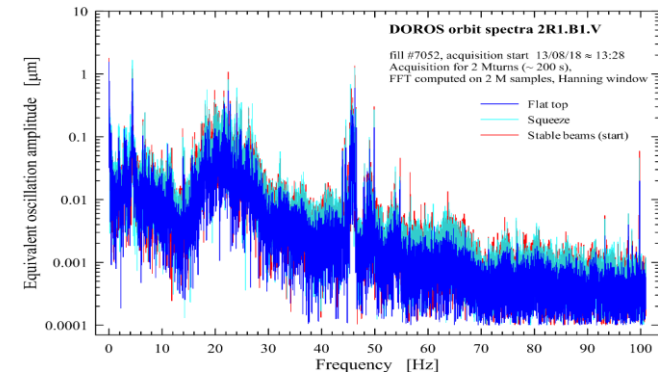
Special diagnostics

- Ad-hoc developments to address unforeseen LHC issues
 - BLM assembly for 16L2: improved SNR
 - DOROS for ground motion
 - BPM phase measurements for electron cloud

BLMs for 16L2

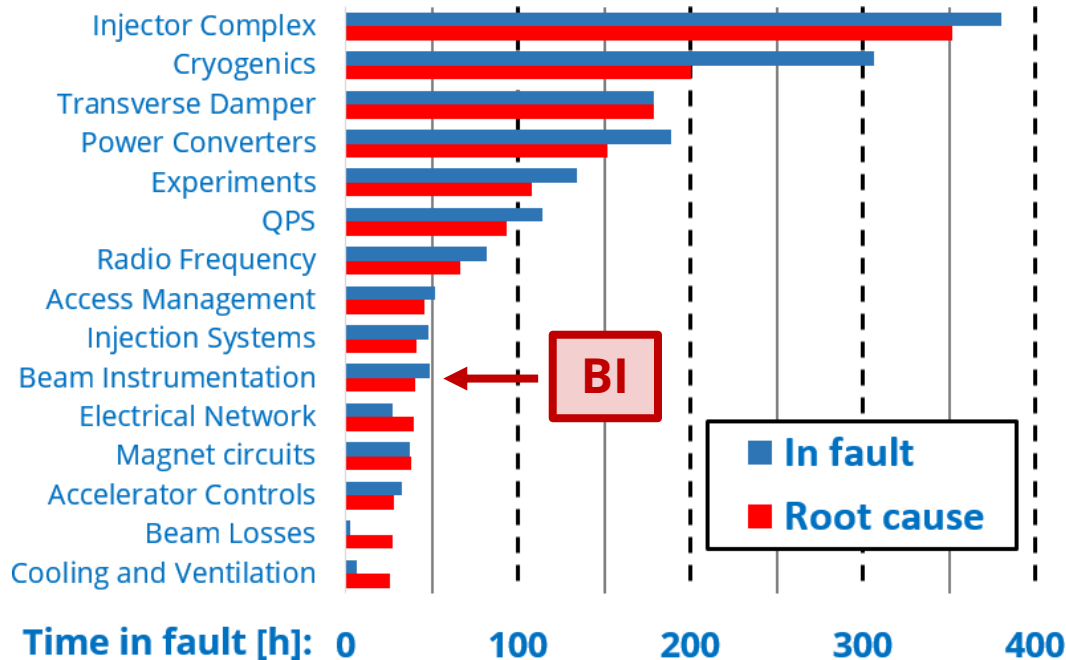


DOROS for ground motion



2018 LHC BI availability

- 47 BI faults in 2018 = 49 h of LHC downtime



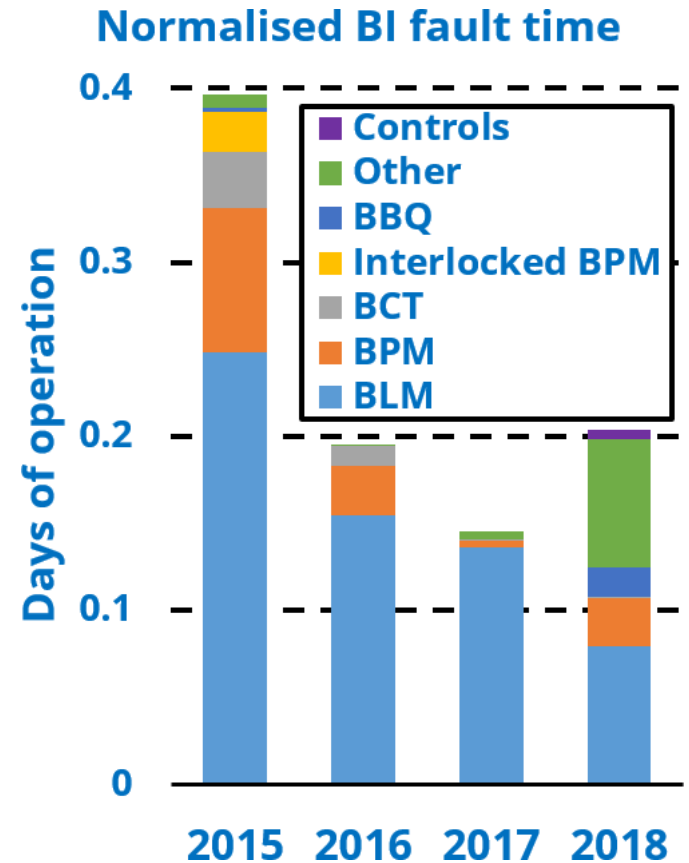
Longest blocking BI faults:

- BTV screen stuck: 4 h 42 min (maintenance in LS2)
- BLM sanity check: 3 h 38 min
- BLM connectivity: 3 h 36 min
- B1H WS PSU: 2 h 24 min
- BLM card fail: 2 h 10 min

In total 33 hours of blocking BI faults

Run 2 LHC BI availability

- Decreasing trend until 2018
 - Spike mainly due to “Other” (WS: 54%, BTV: 29%, BSRA: 17%)
 - Best BLM performance ever
 - Increased availability due to actions taken in LS1
- Since 2018 tracking of “Controls”
 - Mostly software faults reassigned to BI after analysis
- AFT could be a good tool for internal BI fault tracking and analysis



Conclusions

- Major LHC BI systems are fully operational
 - Used daily by OP, available for MDs
 - No major outstanding / blocking issues
 - Availability constantly improving, AFT analysis
 - Testbeds developed for dry runs and issue analysis
- Performance improved with ongoing developments
 - All non-interlocked systems upgraded during Run 2

Conclusions

- Major LHC BI systems are ready for Run 3 parameters
 - $1.8e11$ ppb within dynamic range
 - For emittance see G. Trad's talk
- LS2 mostly for house-keeping
 - Maintenance, inspections, protection
 - Major SW / FW upgrades, LHC Feedback upgrade, CO changes
 - Testbeds validation
- Focused on avoiding issues during Run 3 commissioning
 - As after LS1, dedicated BI commissioning time needed
 - Detailed commissioning plan to be done later

Thank you for your attention

Run 2 Beam Instrumentation Overview

Michal Krupa for the BI Group

31/01/2019

9th LHC Operations Evian Workshop

Special acknowledgements:

D. Alves, A. Boccardi, I. Degl'Innocenti, M. Gasior, J. Kral, T. Levens, P. Odier, V. Schramm, M. Wendt, J. Wenninger, C. Zamantzas

