CERN

Performance of the Collimation System During 2016 – Hardware Perspective

A. Mereghetti, on behalf of the LHC Collimation Team

Disclaimer:

In the past this talk was usually given by G. Valentino, who is now back to Malta. The content has been split among the presentation by D. Mirarchi (yesterday) and the present one, which collects the work of many people.

Table of Contents

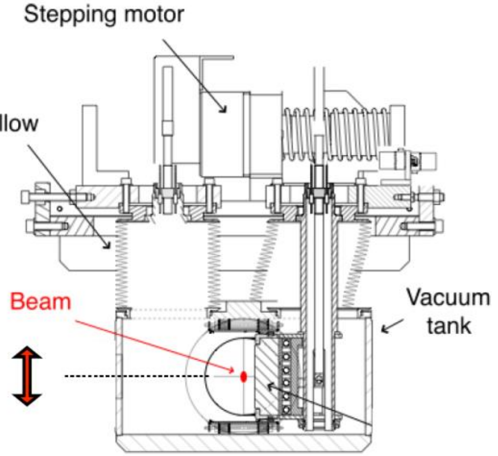
- Hardware Changes during YETS 2015;
- System Availability;
- Hardware Performance (including BPMs);
- Validation;
- Hardware Changes during EYETS 2016;

Table of Contents

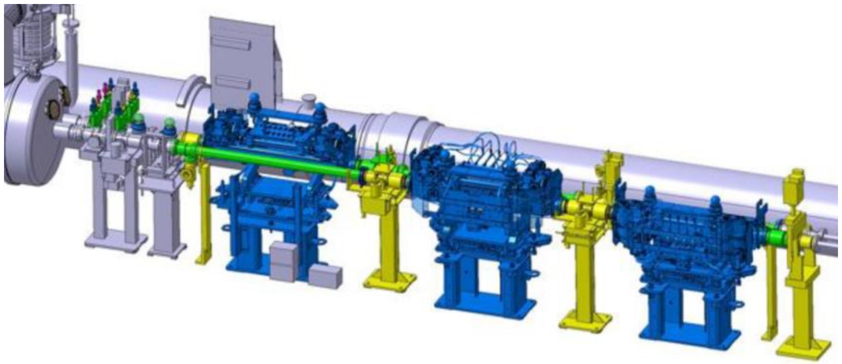
- Hardware Changes during YETS 2015;
- System Availability;
- Hardware Performance (including BPMs);
- Validation;
- Hardware Changes during EYETS 2016;

Hardware Changes during YETS 2015

- No hardware upgrades relevant for OP during YETS2015;
  - → mainly 5th axis (A.Rossi, S.Redaelli);



- "5th motor axis" functionality: moving transversally the whole tank by ±10mm to offer "fresh surface" in case of beam impacts;
- Hardware intervention on TCTs and TCL4: complicated area for intervention;



LHC-TC-EC-0004 (EDMS 1522993), A. Rossi (HSS section meeting, 2016-02-10)

- Satisfactory installation in spite of many small problems found along the way:
  - Functionality fully recovered for TCTPHs/TCLs;
  - Half movement (inwards) for TCTPVs;
- Thanks to all involved teams! (BE/ABP, EN/STI, TE/VSC, EN/ACE)
- no impact on machine availability;
- nowadays less stringent thanks to safer MKD-TCT phase advance;

Table of Contents

System Availability (Preliminary Analysis)

- 12 faults involving collimators (as from PM database data browser):
  - 2 during ramp;
  - 1 at FT;
  - 3 during SBs;

  → Dumps by collimators due to UFOs not considered here → see talk by A. Lechner;
- Causes:
  - 2 due to collimator temperature sensors (1 during ramp);
  - 2 due to wrong collimator set-up:
    - after 66kV fault stop, after ~2h of SB;
    - after VdM, during ramp;
  - 3 involving IR3 collimators (1 right after SB declared, 1 after >3h of SB) → related to IR3 flooding;
  - 5 during manual operations (eg: MDs, optics measurements, … 1 at FT);

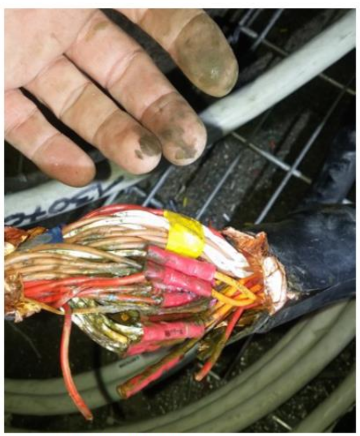
IR3 Flooding

- 21st June 2016: water flood in IR3, which involved also the false floor of UJ33 (E.Bravin, 269th LMC, 29th June 2016);

→ Water on Collimator Cables, affecting TCSG.4R3.B1, TCLA.A5R3.B1, TCSG.A5L3.B2, TCLA.A5L3.B2 (E.Bravin, LHC MM, 23rd June 2016);

Water on collimator cables in P3

Faults on collimators TCSG.4R3.B1 and TCLA.A5R3.B1 detected (that share the same controls units together with TCSG.4L3.B2) during the access, could not be solved by replacing drivers.
At ~17h30 this was traced to a problem in a cable junctions, cause by water flood.
Fixed by EN/STI with an access between 20h-24h.
Problems occurred again in the recovery after beam dump ~5h00
Planned EN/EL intervention this morning. No beam before end of the morning.



A. Masi for the STI team: Christophe, Mario, Salvatore

S. Redaelli, LHC meeting, 21-06-2016

LMC Summary - J. Wenninger, W. Hofle

06/07/2016

S. Redaeilli, LHC MM, 22nd June 2016

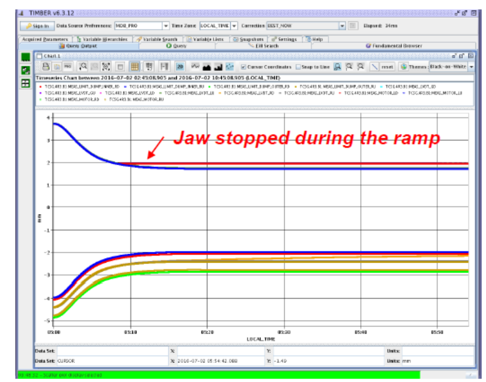
Collimator Drive / LVDT Fault

- Fill 5068 was dumped on Saturday morning 9:40 by a LVDT interlock on a TCGS in IR3. The LVDT signal was drifting and finally reached the interlock limit. The LVDT was disabled.
- Fault on driver re-appeared in ramp 5075 (dumped in early part of ramp)
  - *The other jaw of the same collimator stopped moving during the ramp, but fortunately remained within the limits – driver faulty. Ok after restart of the motor driver.*

TCSG.4R3.B1

Drifting LVDT in orange

Access at next occasion



15

J. Wenninger, LMC, 6th July 2016

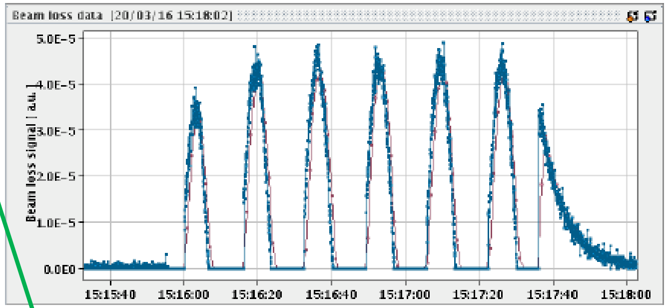
3rd dump took place on 13th Aug 2016, triggered by LVDT drifting on TCLA.A5L3.B2;

Table of Contents

Commissioning: Collimation Software

- Java applications:
  - ➡ Changes to several APIs (LSA, BIS, CALS etc) incorporated in new release.
  - ➡ New AFP devices included in COLLS LSA table + Java application: 

  - ➡ Change in crystal goniometer device names (pending change in FESA)
- LHCCollAlign FESA class:
  - ➡ BLM data rate increased from 12.5 Hz to 100 Hz (thanks to Stephen & Christos!)
  - ➡ Max coll trigger rate (and therefore alignment feedback loop): 50 Hz
  - ➡ 100 Hz still logged for offline analysis (now published every second as 2D array, should be easier for TIMBER).
  - ➡ FEC appears to be stable and can handle additional future FESA class (off-momentum loss maps)



BLM data published for display purposes @ 25 Hz

Essential in the speed-up of alignment time achieved in 2016!

G. Azzopardi takes over the collimation software!

- TODO: dry-runs of alignment + collimator scans for BPM non-linearities tomorrow.

G.Valentino, R.Bruce, S.Redaelli, B.Salvachua, CWG 21st March 2016

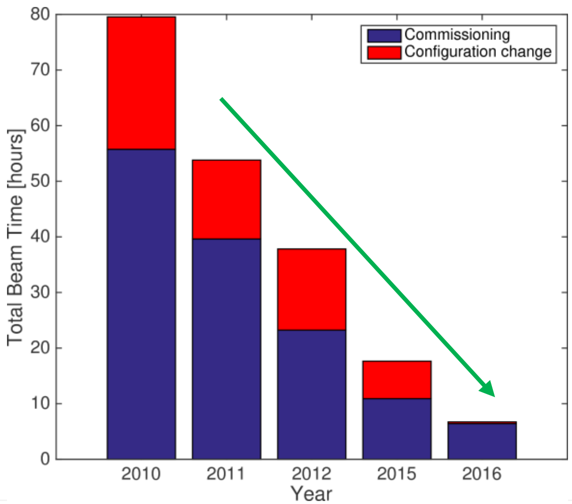
Commissioning: Alignment

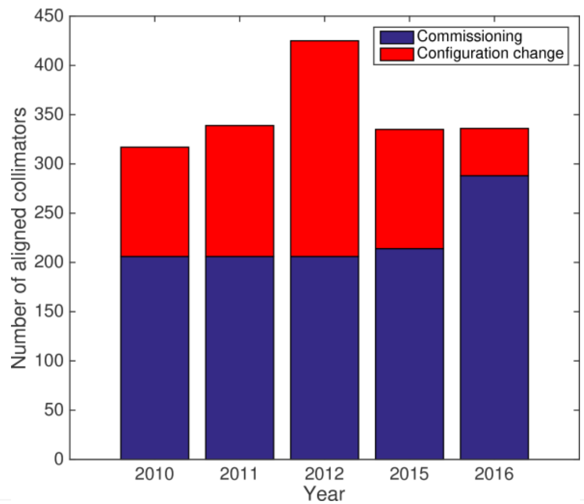
- **Injection:** 80 collimators incl. inj. prot -> 02/04/2016
- **Flat top:** 76 collimators -> 06/04/2016
- **End of squeeze:** 16 TCTs -> 10/04/2016
- **Collisions:** 16 x 3 TCTs + 12 TCLs -> 10/04/2016 (wo IR1 bump) + 19/04/2016 (w IR1 bump)

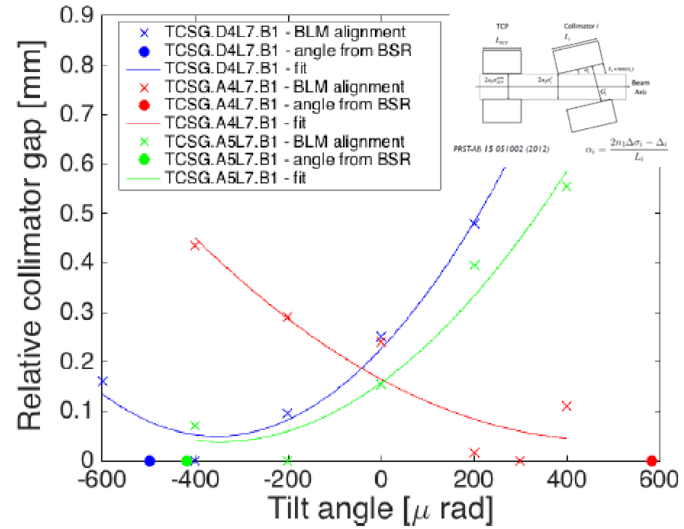
G.Valentino, CWG 25th April 2016

Alignment of full system in 1hr 45min!

- Deployment of alignment feedback @ 50 Hz was successful, except for some delays observed in sending the alignment command (due to removed rotatable collimator from control system).







Angular scans on selected IR7 TCSGs allowed to spot misalignment angles!

→ Their compensation allowed to cure IR7 hierarchy breakage seen in 2015 and 2016 MDs when reducing operational margins!

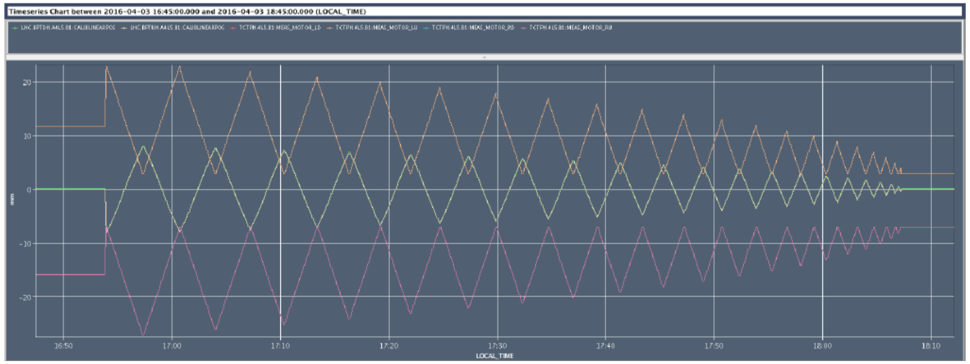
Next improvements (G. Azzopardi):

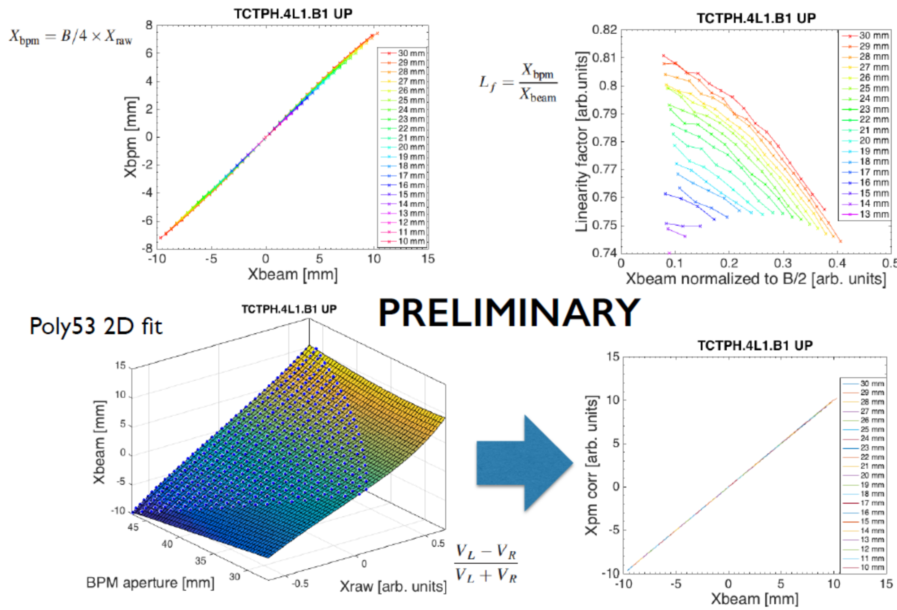
- New automated procedure for angular alignments;
- New FESA class to handle coordination of alignment of collimators in parallel (presently done by the Java application);

Collimator BPMs

- Exhaustive collimator BPMs commissioning before alignment campaigns to profit as much as possible, including detailed determination of non-linear coefficients;
  → BPMs available from the very beginning!, being up and running the whole time (flags);
- DOROS-FESA system very reliable since TS1;
- Extensive use of BPMs for alignment (fully automated and done in parallel), TCT centre function generation and monitoring;

- Non-linearity collimator scans:
  - Make cut with TCP IR7 H &V @ 4 sigma
  - Define margins of 4 sigma beyond which jaws will not move (to avoid touching beam)
  - Using automatic routine, scan from gap of ~30 mm to 8 sigma, changing the offset by 500 um and pausing for 5 seconds to collect data
  - Once a full cycle is performed, reduce gap by 1 mm and repeat.
  - All collimators scanned in parallel at inj. and ft in ~1.5 hours.



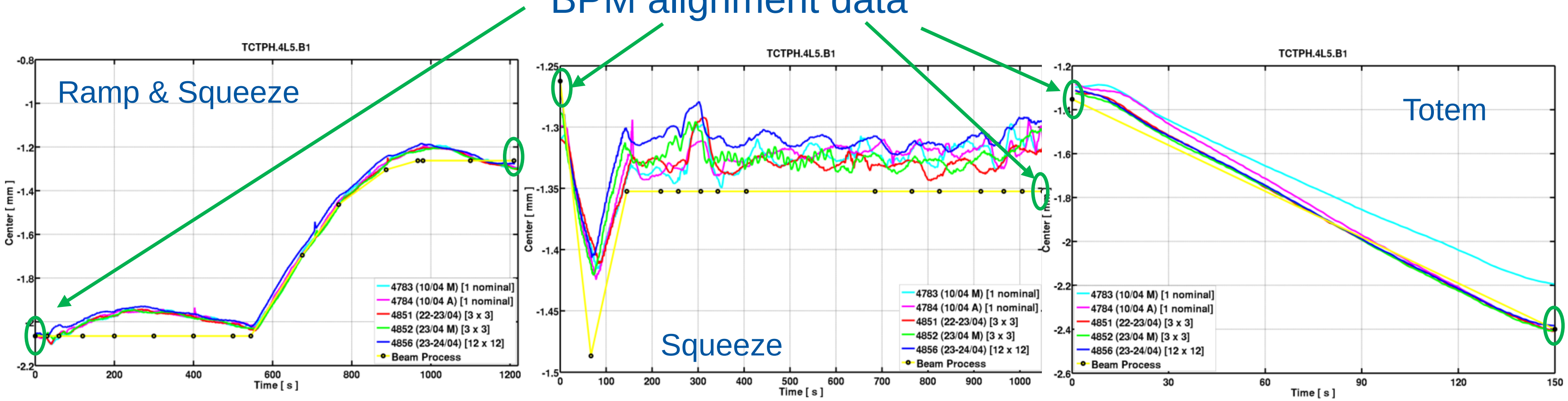


G.Valentino, CWG 25th April 2016

TCT Centre Functions

- TCT BPMs allow for a fast and reliable alignment of TCTs in different phases of the LHC hypercycle → it is relatively easy to accommodate in functions changes in the CO@TCTs following beam manipulations at the IPs;
- TCT centre functions:
  - MADX predictions of CO@TCTs for each machine configuration (time profile);
  - BPM-based alignment results to scale MADX predictions;
- Extensive deployment of TCT centre functions generated on the basis of BPM alignments:
  - All TCTs;
  - All 2016 OP beam processes: RaS, Squeeze, Totem, 2 adjusts;
  - All 2016 special runs (R&De, DeSqueeze) and MDs (ATS);

BPM alignment data



A. Mereghetti and A. Valloni, CWG 25th April 2016

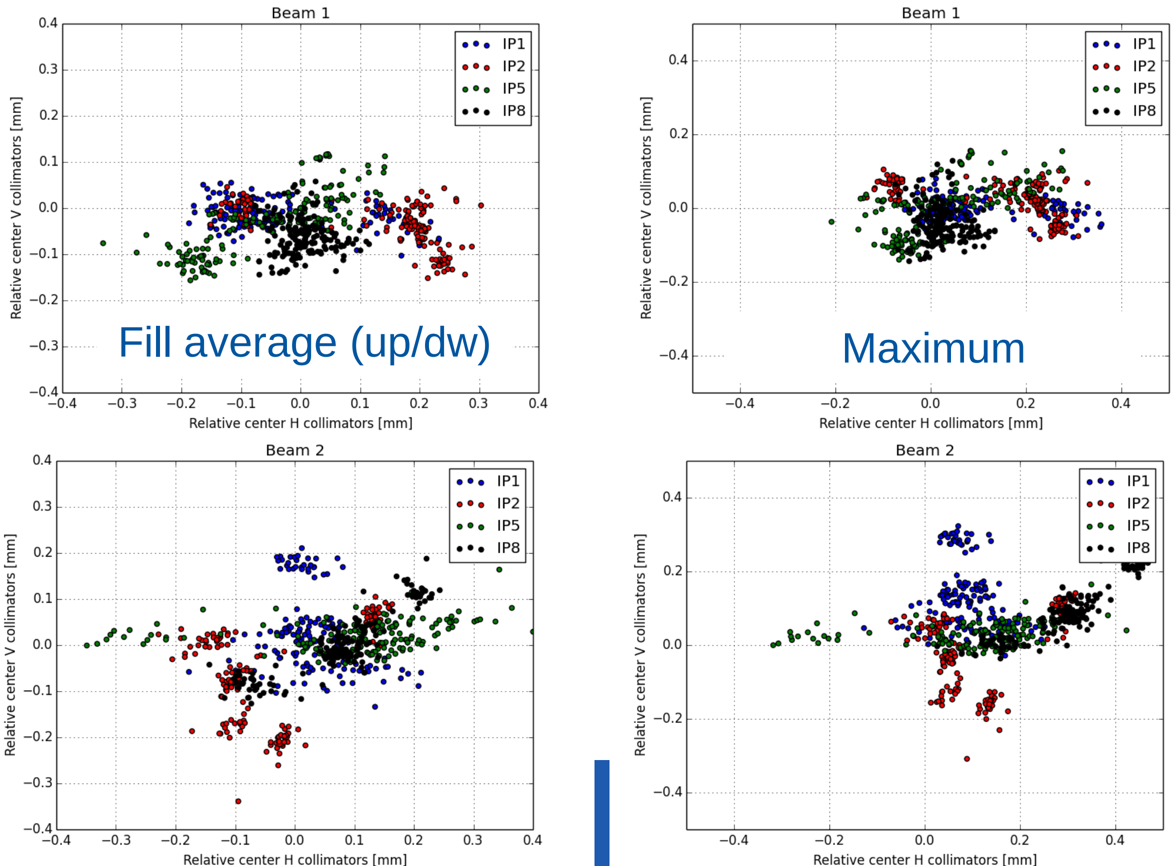
Orbit Stability at TCTs

- Orbit stability at TCTs and IR6 TCSPs throughout the year monitored and analysed by G. Valentino (Coll WG meeting, 5th Dec 2016);
- Analysis of 155 fills (2016pp), for different machine configurations (ramp, squeeze, collisions, SBs);
- Observable: beam excursion wrt TCT centre (function);

Example: analysis over SBs

B1

B2



Proposal of SIS Interlock Based on TCT BPM Readouts

Given the good orbit stability, a SIS interlock on BPM readouts at TCTs (and IR6 TCSP) can be proposed;

Current SIS implementation:

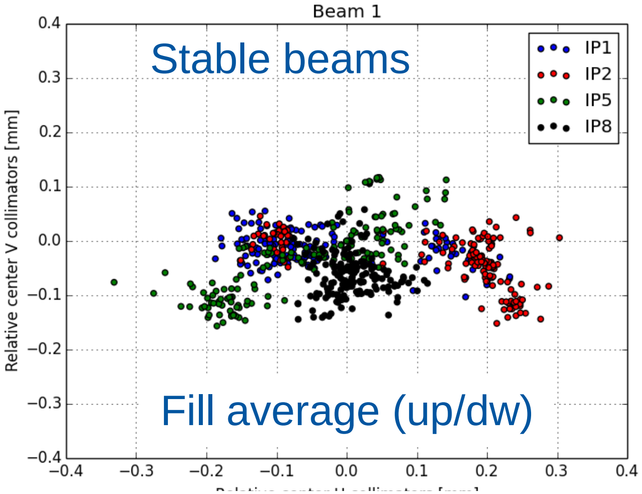
- All collimator BPM interlocks are running reliably (at least on the SIS side).
- All interlocks are in the interlock tree, but are currently masked.
- The interlock limits are currently set to 4σ except for:
  - *1σ in IR1 and IR5 at β*= 40 cm,*
  - *1.5σ in IR6 at β*= 40 cm (linked to IR5 β*),*
  - *2.5σ in IR8 at β*= 3 m.*

J.Wenninger, 127th MPP meeting

Analysis:

- Set a threshold for the beam excursion wrt TCT centres (functions);
- Count number of dumps for a given threshold;

→ 600 μm seems a reasonable number!



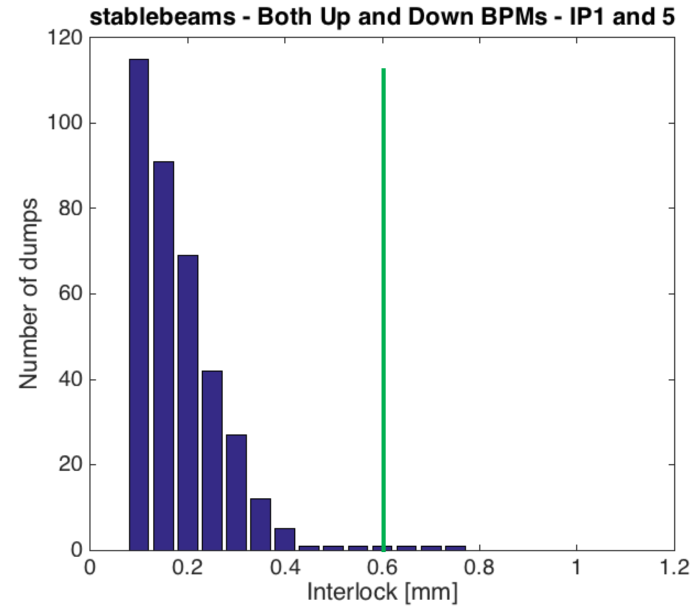


Table of Contents

- Hardware Changes during YETS 2015;
- System Availability;
- Hardware Performance (including BPMs);
- Validation;
- Hardware Changes during EYETS 2016;

Loss Maps

- LM campaigns carried out after relevant hardware interventions or long periods without beam (e.g. TSs);
- Large number of LMs performed and analysed in 2016:
  - it reflects the complexity of LHC hypercycle, with many beam processes;
  - Symplifying the LHC hypercycle would imply less LMs to be performed;
  - LMs always performed with final collimator functions in;
- Limited impact in terms of number of fills required, thanks to development of FESA class for off-momentum LMs (feedback to RF trim) – used some MD time (MD1690) for verification;

After YETS

LM	450 GeV		Ramp& Squ.	6.5 TeV						
	Inj. Prot. IN	Inj. Prot. OUT		FT	Squ.	EoS	TOTEM	Coll. I	Coll. II	XRP
B1H	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B1V	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B2H	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B2V	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
+δp/p	✓	✓	–	✓	–	✓	✓	–	–	✓
-δp/p	✓	✓	–	✓	–	✓	✓	–	–	✓

After TS1

LM	450 GeV		Ramp& Squ.	6.5 TeV						
	Inj. Prot. IN	Inj. Prot. OUT		FT	Squ.	EoS	TOTEM	Coll. I	Coll. II	XRP
B1H	✓	✓	–	✓	–	–	✓	–	–	✓
B1V	✓	✓	–	✓	–	–	✓	–	–	✓
B2H	✓	✓	–	✓	–	–	✓	–	–	✓
B2V	✓	✓	–	✓	–	–	✓	–	–	✓
+δp/p	✓	–	–	–	–	–	–	–	–	–
-δp/p	✓	–	–	–	–	–	–	–	–	✓

After TS2

LM	450 GeV		Ramp& Squ.	6.5 TeV						
	Inj. Prot. IN	Inj. Prot. OUT		FT	Squ.	EoS	TOTEM + Xing	Coll. I	Coll. II	XRP
B1H	✓	✓	–	✓	–	✓	✓	–	–	✓
B1V	✓	✓	–	✓	–	✓	✓	–	–	✓
B2H	✓	✓	–	✓	–	✓	✓	–	–	✓
B2V	✓	✓	–	✓	–	✓	✓	–	–	✓
+δp/p	✓	–	–	–	–	–	–	–	–	✓
-δp/p	✓	–	–	–	–	–	✓	–	–	✓

D. Mirarchi, S. Redaelli, B. Salvachua, G. Valentino

Table of Contents

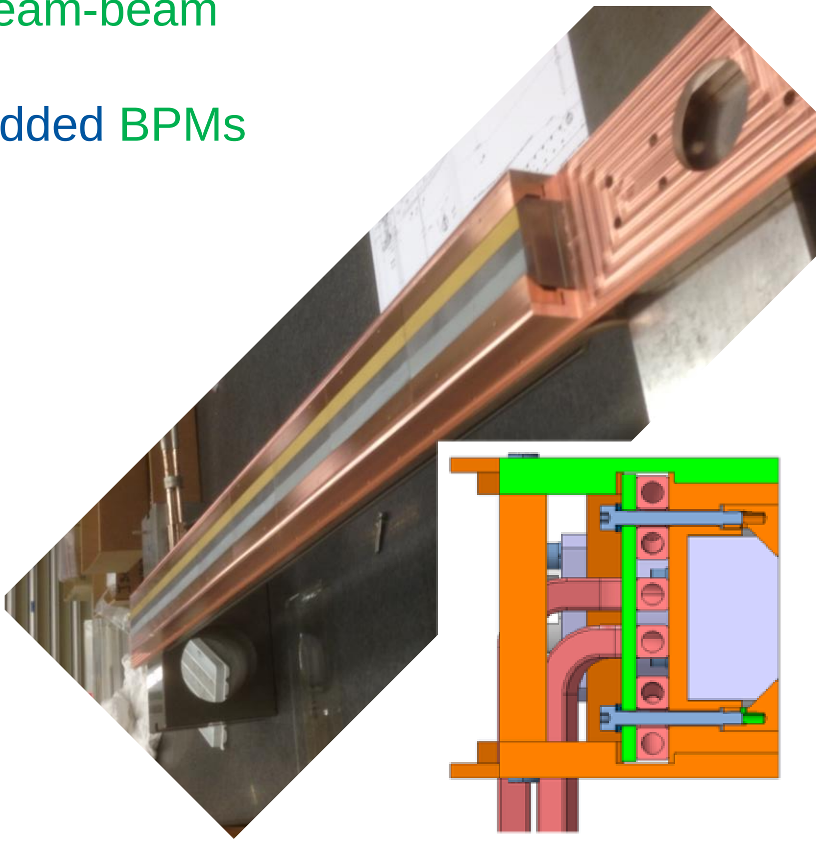
- Hardware Changes during YETS2015;
- System Availability;
- Hardware Performance (including BPMs);
- Validation;
- Hardware Changes during EYETS 2016;
- Conclusions;

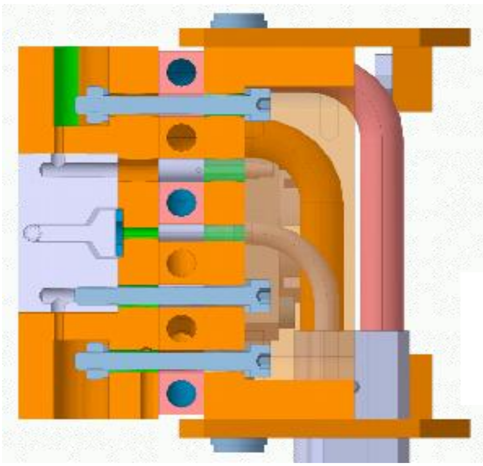
Hardware Updates During EYETS 2016

1. Low-impedance collimator prototype for HL-LHC (TCSPM);
2. Two collimators with wire for long-range beam-beam compensation studies (TCTPW);
3. Consolidated design of TCP collimators: added BPMs (TCPP);
4. 2 crystals on B2;

Collaboration with EN/STI and EN/MME.

TCSPM: MoGr jaw with surfaces for impedance beam tests (MoGr, Mo and ceramic)





TCTPW for beam-beam compensation studies

Tertiary collimator with embedded wire for LRBB MDs;
→ Hardware for MD activities; nevertheless, ~0.5 shift required during commissioning time;

Table of Contents

Conclusions

- Limited hardware and software upgrades of collimation system during YETS 2015;
  → Nevertheless, relevant for speeding up commissioning / set up activities – e.g. RF trim for off-momentum LMs, 100 Hz BLM logging and BPMs for fast alignment;
- Reliability / reproducibility at the heart of system performance;
  → Up to proposal of SIS interlock on BPM readouts at TCTs;
- Installation of new hardware during EYETS 2016, especially meant for MD activities (HL-LHC perspective);

Thanks for Your Attention!