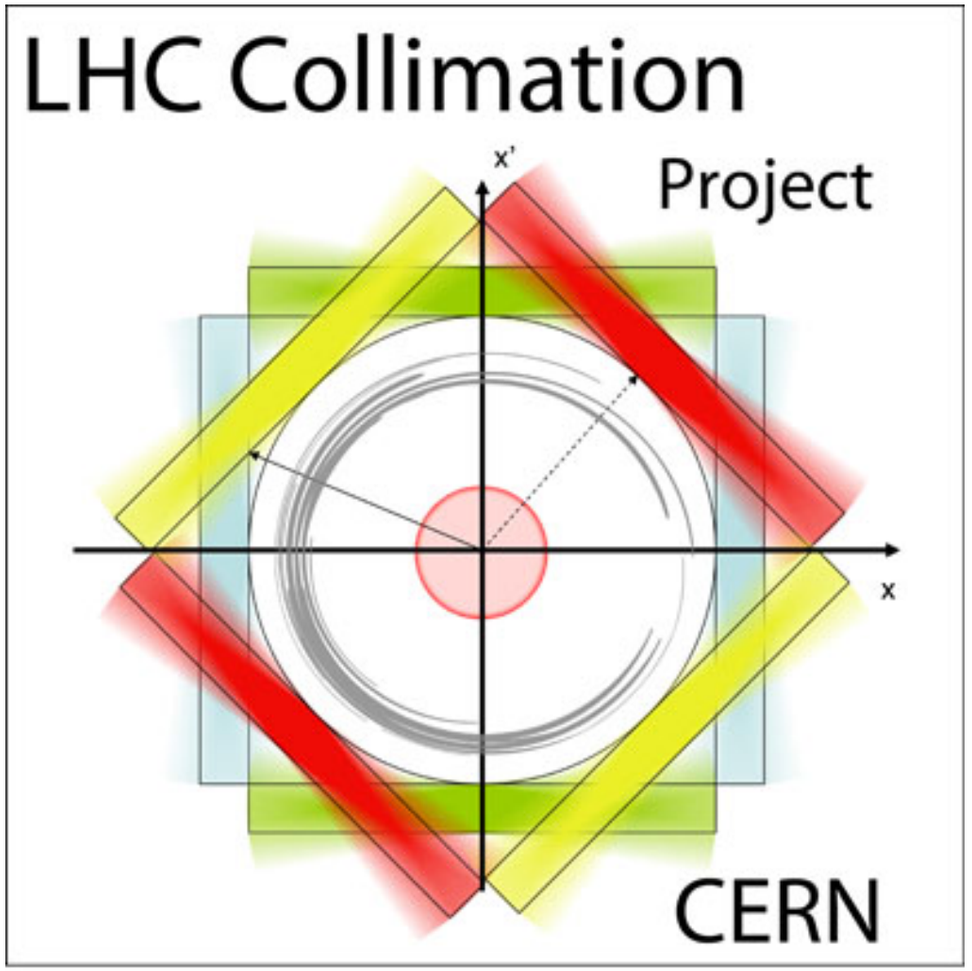
Collimation system post-LS1: status and commissioning

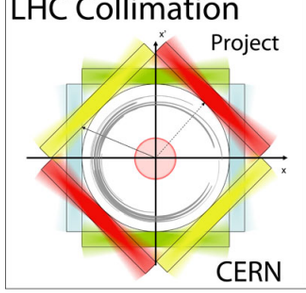


G. Valentino, R. Bruce, S. Redaelli, B. Salvachua

on behalf of the ABP Collimation Team: A. Marsili, D. Mirarchi, E. Quaranta, A. Rossi, R. Rossi

Special thanks to:

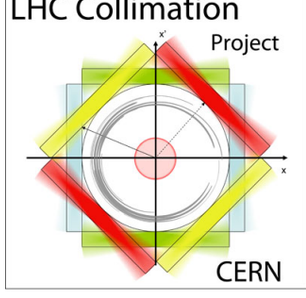
O. Aberle, J. Albertone, S. Athanasiadis, V. Baglin, A. Bertarelli, C. Boccard, F. Carra, G. Cattenoz, F. Cerutti, J. Coupard, S. Chemli, C. Derrez, L. Esposito, R. Folch, I. Garcia, M. Gasior, S. Jackson, L. Jensen, J. Lendaro, R. Losito, A. Masi, E. Skordis, J. Wenninger, D. Wollmann



Outline

- **Introduction**
- **Post-LS1 collimation system**
  - Expected gains from upgrades
- **System readiness**
  - Installation status
  - Upgrades of collimation controls + software
- **Commissioning**
  - Sector Test
  - Commissioning without/with beam
  - Intensity required for alignments and loss maps
- **Early measurements**
- **Conclusions**

Introduction



Important collimation upgrade program during LS1 with 30% of the system changed. All IRs with collimators are affected.

- **New collimators with embedded BPMs (IR1, IR2, IR5, IR8 and IR6).**
- **Improved TCL layouts in IR1 and IR5.**
- **Installation of additional passive absorbers in IR3.**
- **Improved IR8 layout: replacement of 2-in-1 beam collimators by 1 beam collimators.**
- **Removal and re-installation of 3 primary collimations TCP in IR7 due to the ventilation work and replacement of 1 primary collimator IR7 due to heating problems during Run I.**
- **Software upgrades to profit from the new embedded BPM collimators**

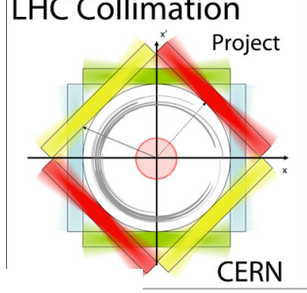
Engineering Change Requests (ECRs)

EDMS Doc.	Description
1251162	New BPM collimators in IR1/2/5/6
1251173	New BPM collimators in IR8
1273450	New passive absorber in IR3
1283867	Infrastructure preparation for TCL6
1329235	Crystal collimation experiment in IR7
1357736	TCL6 installation

Close collaboration with:

O. Aberle, F. Cerutti, C. Derrez, R. Folch,
I. Garcia, J. Lendaro, R. Losito, A. Masi EN/STI
A. Bertarelli, F. Carra EN/MME
J. Coupard, S. Chemli EN/MEF
V. Baglin, G. Cattenoz TE/VSC
J. Albertone, C. Boccard BE/BI
S. Redaelli, B. Salvachua BE/ABP

Post-LS1 Collimation System

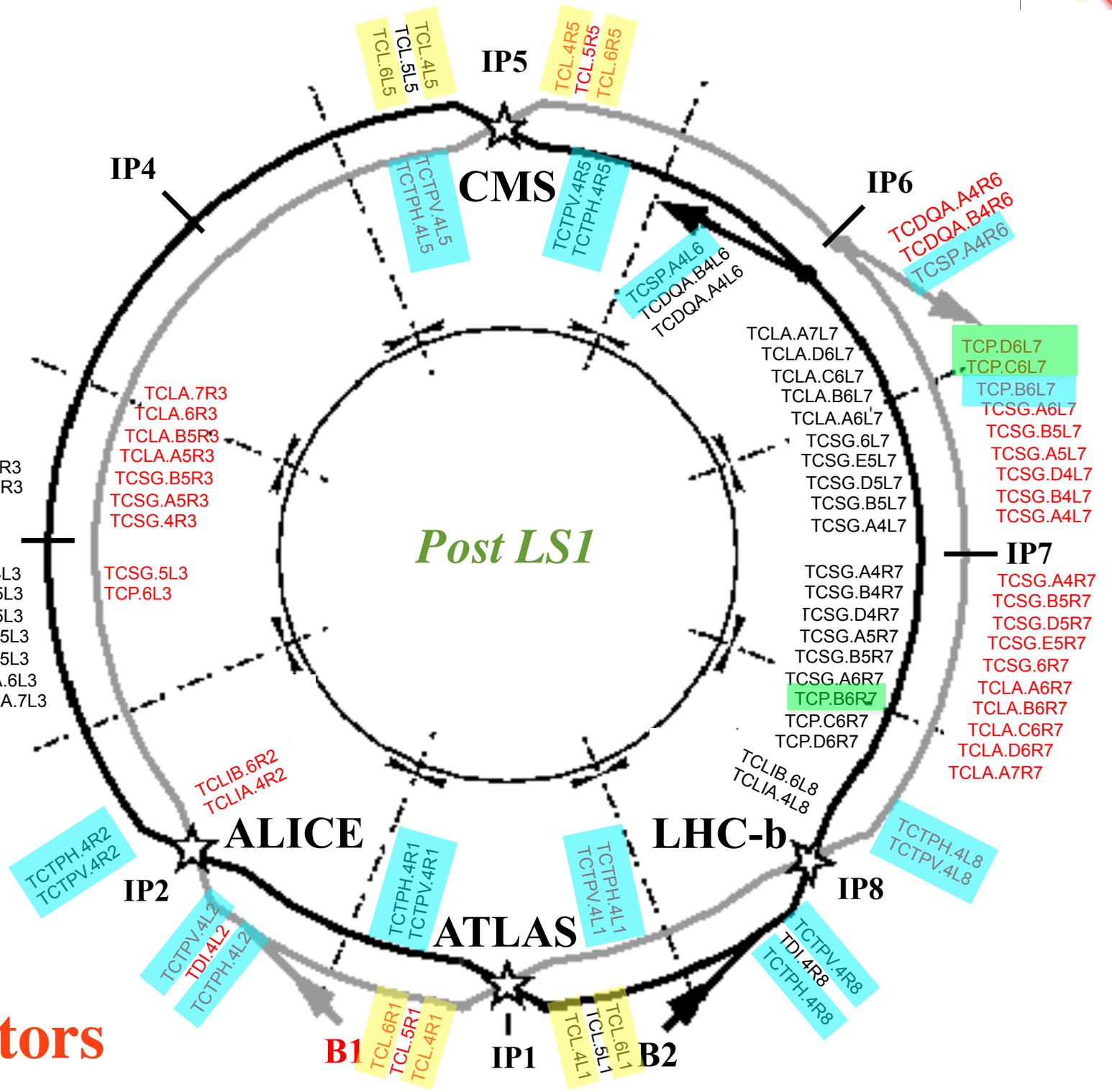


New

Replaced

Taken out + put back

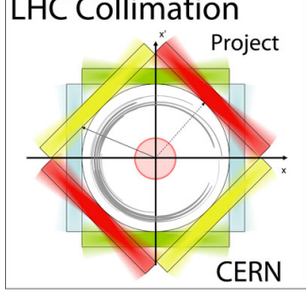
- **Upgrades:**
  - 16 TCTs + 2 TCSGs
  - 8 TCLs
- **Consolidation:**
  - 1 TCP
  - 3 TCPs



Post LS1: 118 collimators

Movable 100 → 108

Collimators with BPMs



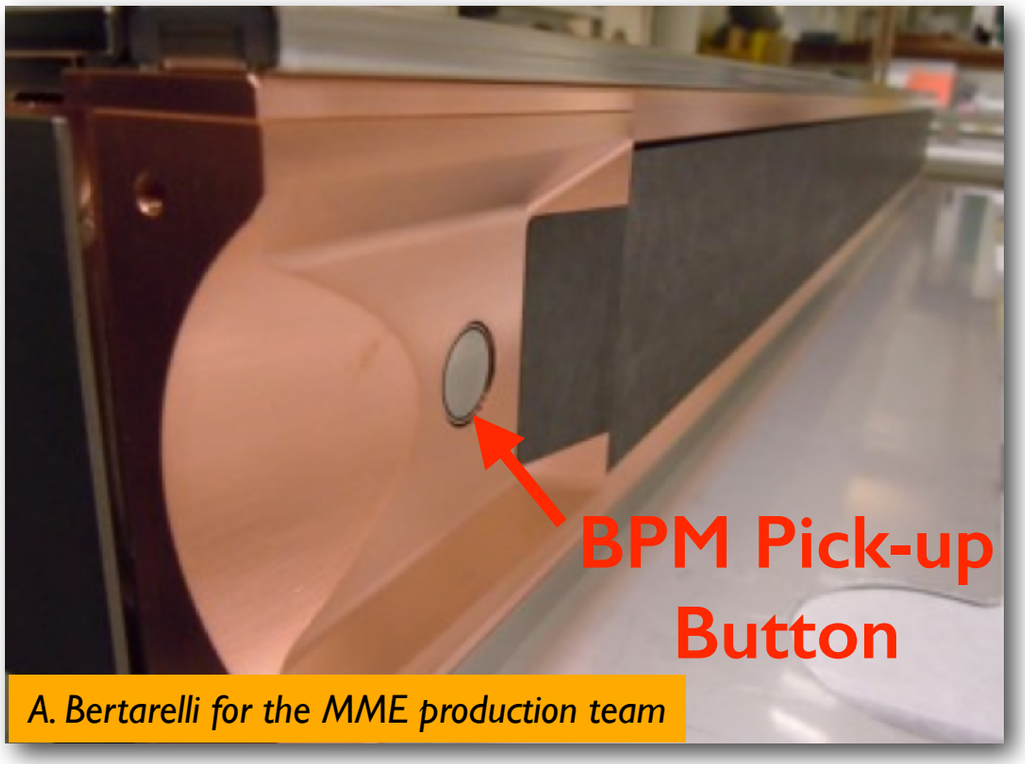
16 *Tungsten* TCTs in all IRs and **2** *Carbon* TCSGs in IR6 will be replaced by new collimators with integrated BPMs.

→ *Direct measurement of the beam orbit at the collimator*

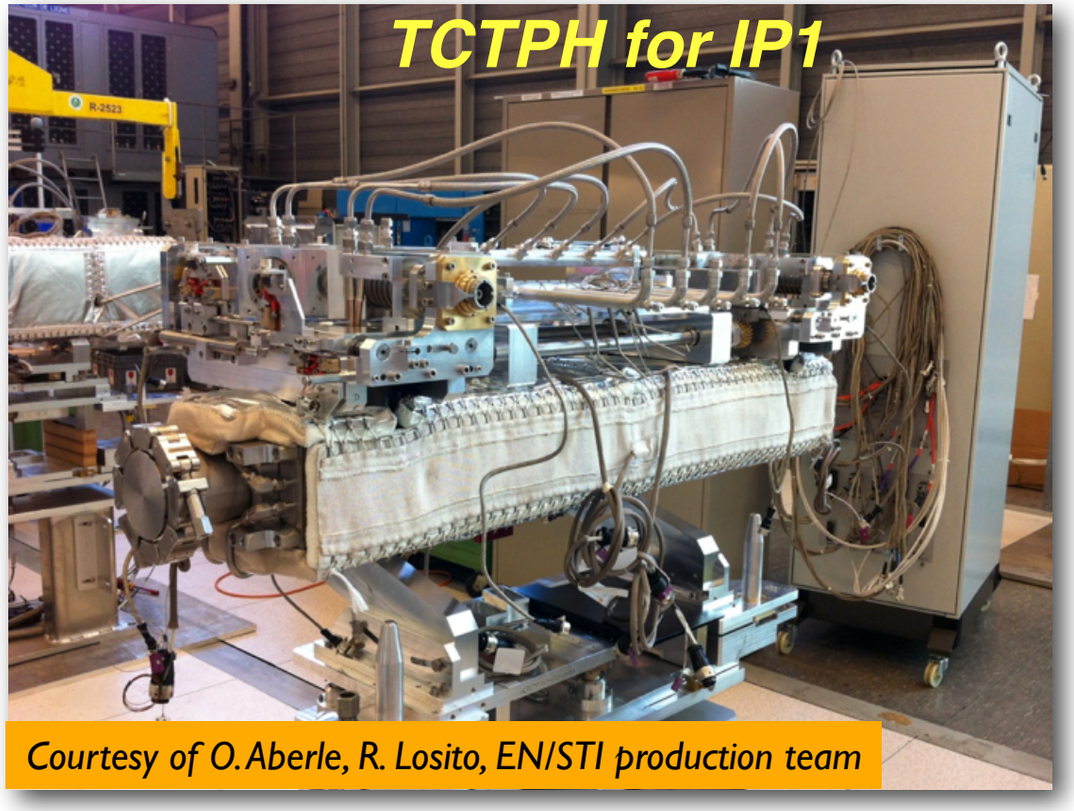
Motivation for the change:

- Faster alignment → more flexibility for the IR configuration
- Reduce orbit margins in IR6 TCSG-TCT hierarchy: more room to squeeze

TCSP jaw

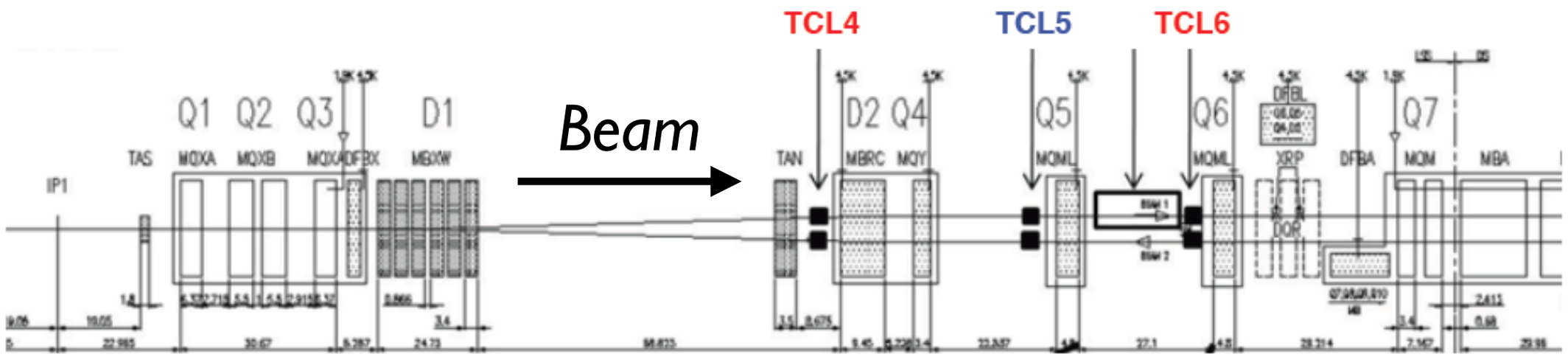


A. Bertarelli for the MME production team



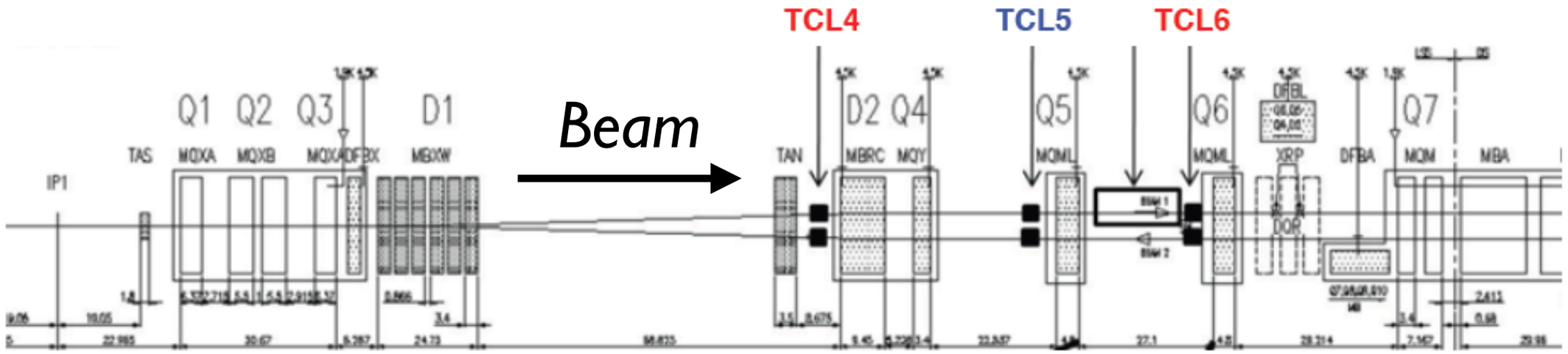
Courtesy of O. Aberle, R. Losito, EN/STI production team

TCL physics debris collimators



- **TCL5: already installed and used in 2012**
- **TCL4: already produced but not installed in Run 1**
  - only required at design lumi + space needed for RP147 station
  - **Gains:** up to factor 10 better cleaning than single TCL5, and allows operation of forward physics detectors by opening the TCL5 in high-intensity fills
- **TCL6: recycled from previously-installed tungsten TCTs**
  - **Gains:** reduces losses in DS by factor 100 + provide flexibility for future upgrades of forward physics programme.
  - **Disadvantages**: radiation to RRs and contribution to impedance increase if used at tight settings (e.g. 10 σ). Still evaluating which settings should be used (e.g. asymmetric, 15-20 σ).

TCL physics debris collimators



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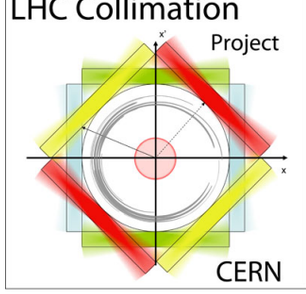
FLUKA simulations presented in several CWG meetings

Passive absorbers

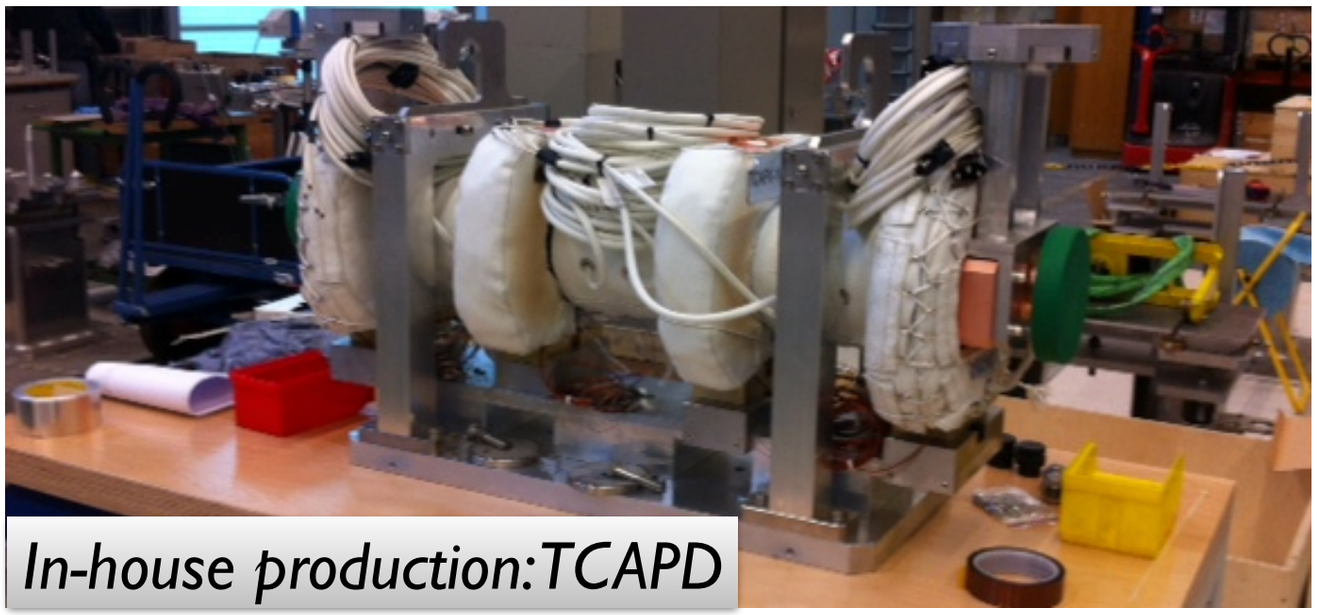


- **Run 1 → to reduce the dose in the warm magnets and increase their lifetime:**
  - In IR7: 3 passive absorbers per beam were added to protect D3 and Q5
  - In IR3: only 1 passive absorber per beam to protect D3

- **Doses measured 2011-2012 showed that the flexibility of the collimators settings (IR3/ IR7 loss sharing) could be compromised without protecting IR3 Q5.**

- **FLUKA simulations indicate an improvement by a factor 2-5 in Q5.**

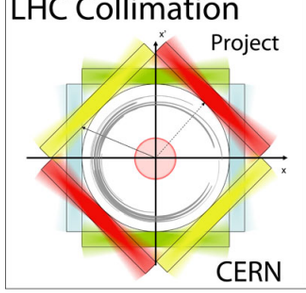
- **Therefore, the installation of 1 additional absorber per beam in IR3 in front of Q5 to reduce the dose from off-momentum losses was proposed.**

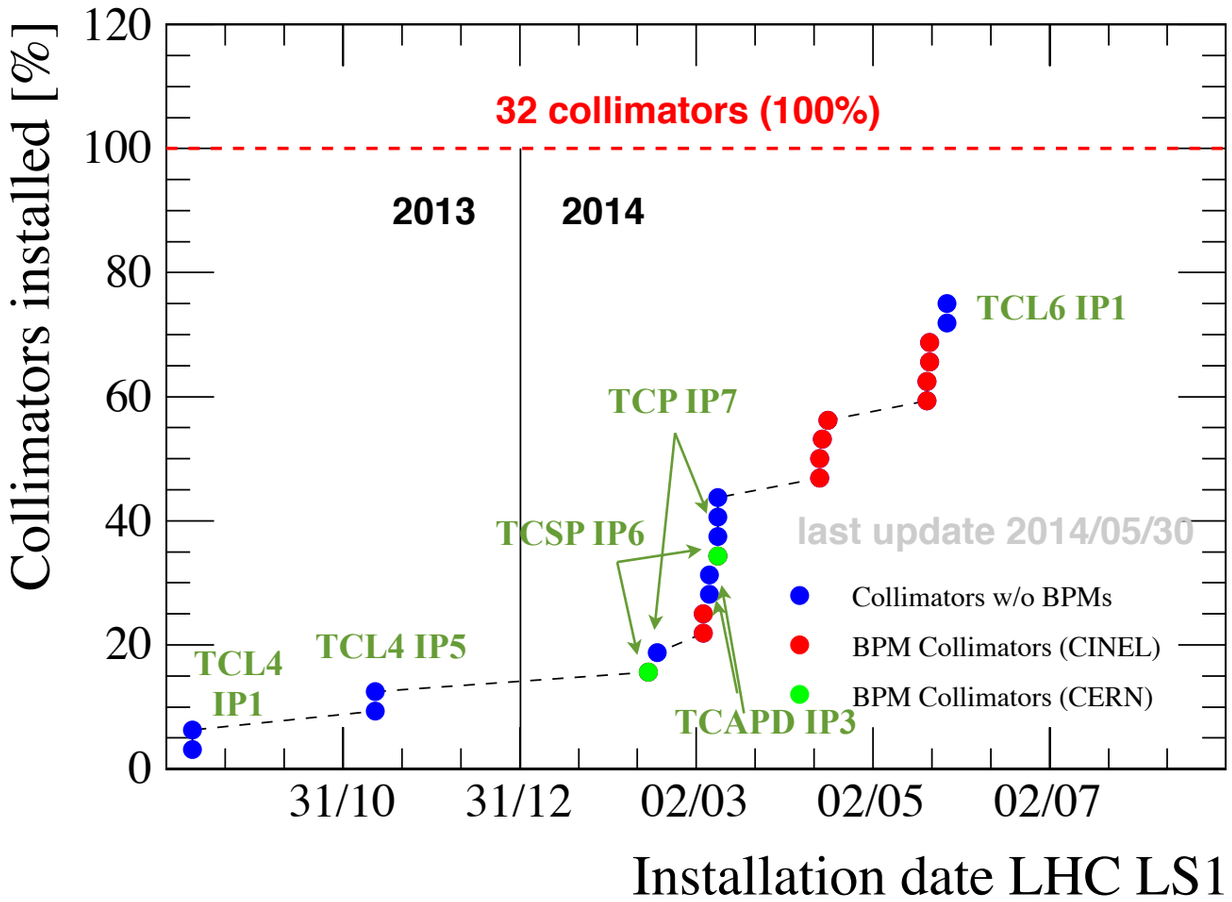


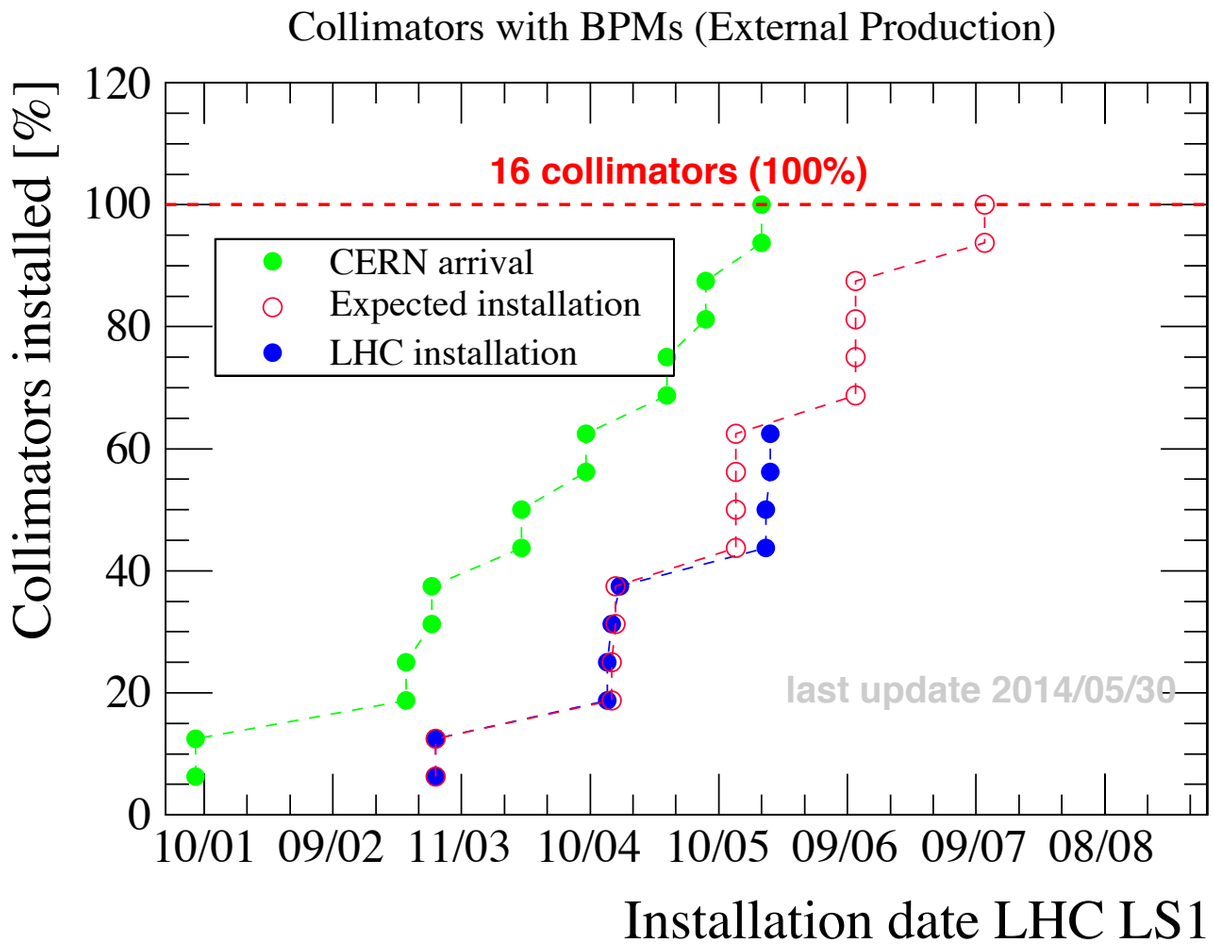
In-house production: TCAPD

Component	New distance from IP3 (m)	Length (m)
TCAPD.6L3.B1	-153.058	1
TCAPD.6R3.B2	153.051	1

System Readiness

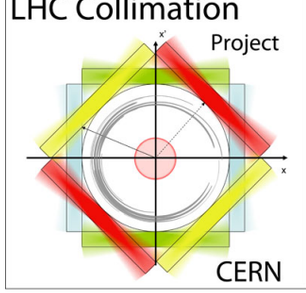




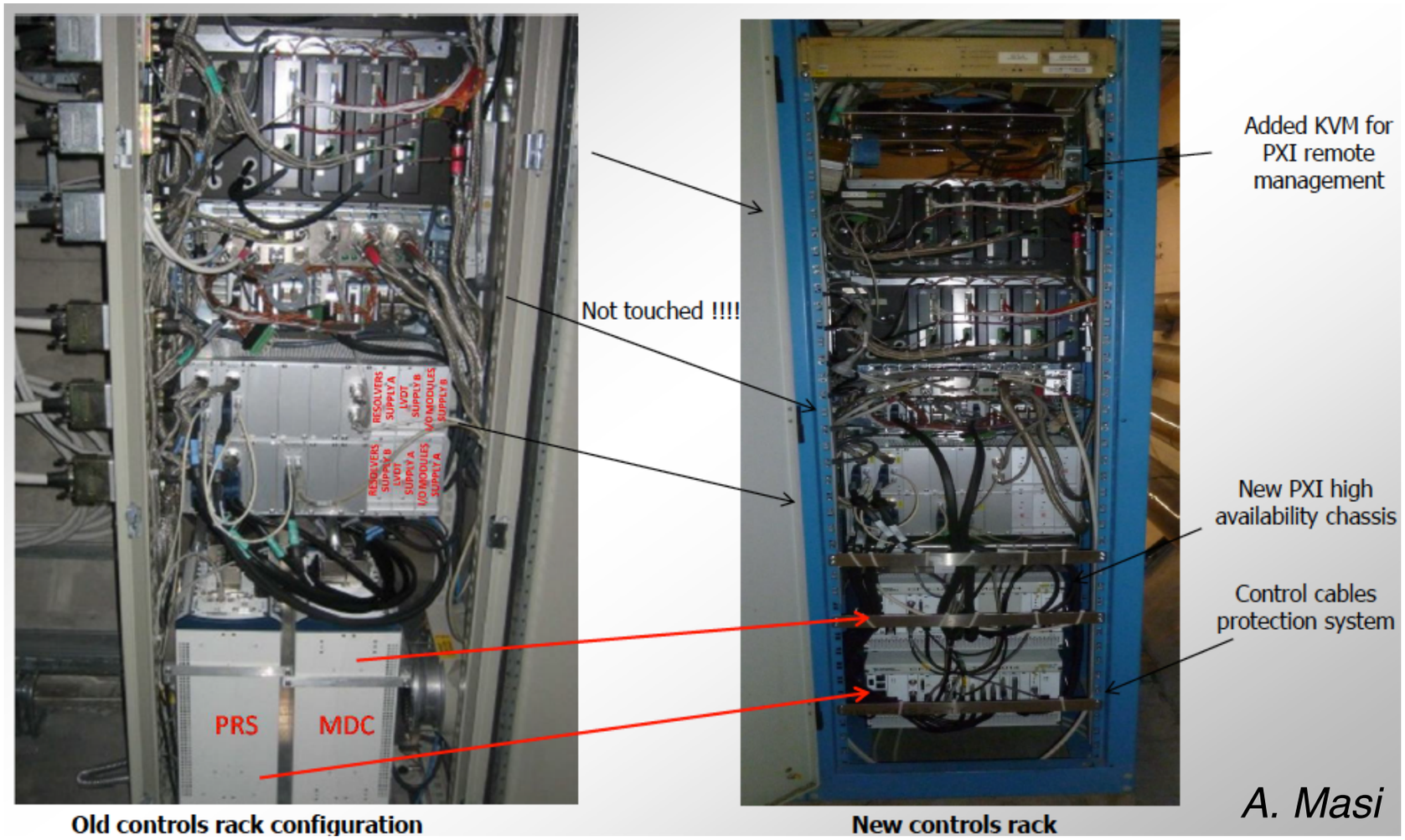


- **80% of the foreseen new collimators are installed.**
- **IR1, IR2, IR3, IR6 and IR7 installations have been completed!**
- **On track to complete TCTP installation by mid-July 2014.**
- **Commissioning in the tunnel has started, and we plan to start remote commissioning as the collimators become available.**
- **By the time of the Sector Test (November) we plan to have ALL collimators commissioned.**

Collimation Software Upgrades

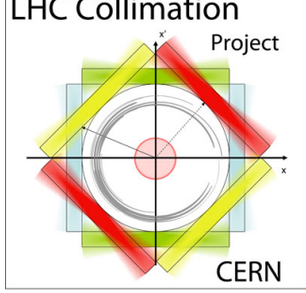


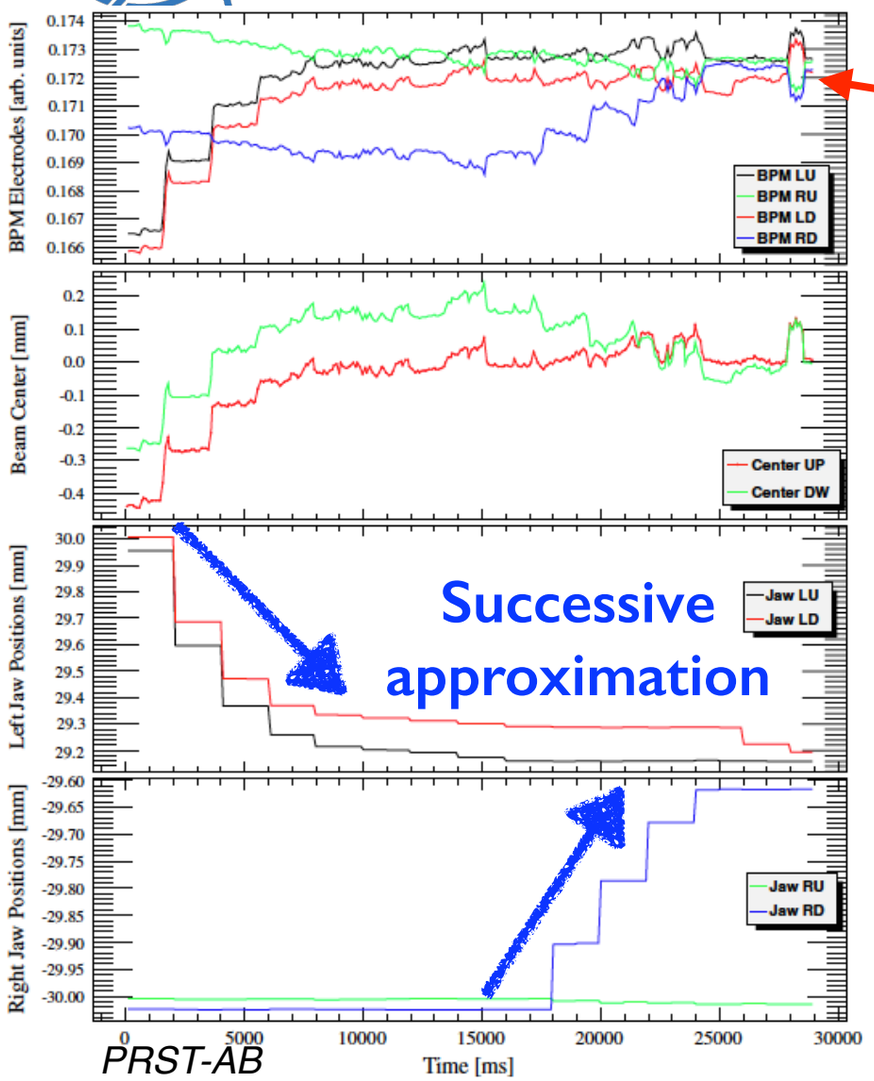
- **The low-level controls have been upgraded and improved (EN/STI).**



- **Upgrade to FESA v3 (framework upgrades discussed by D. Jacquet).**
- **12 LVDTs will be replaced with a new design (I2PS) unaffected by EM fields.**
  - drifts of up to 200 μm for one IR3 collimator

Collimation Software Upgrades



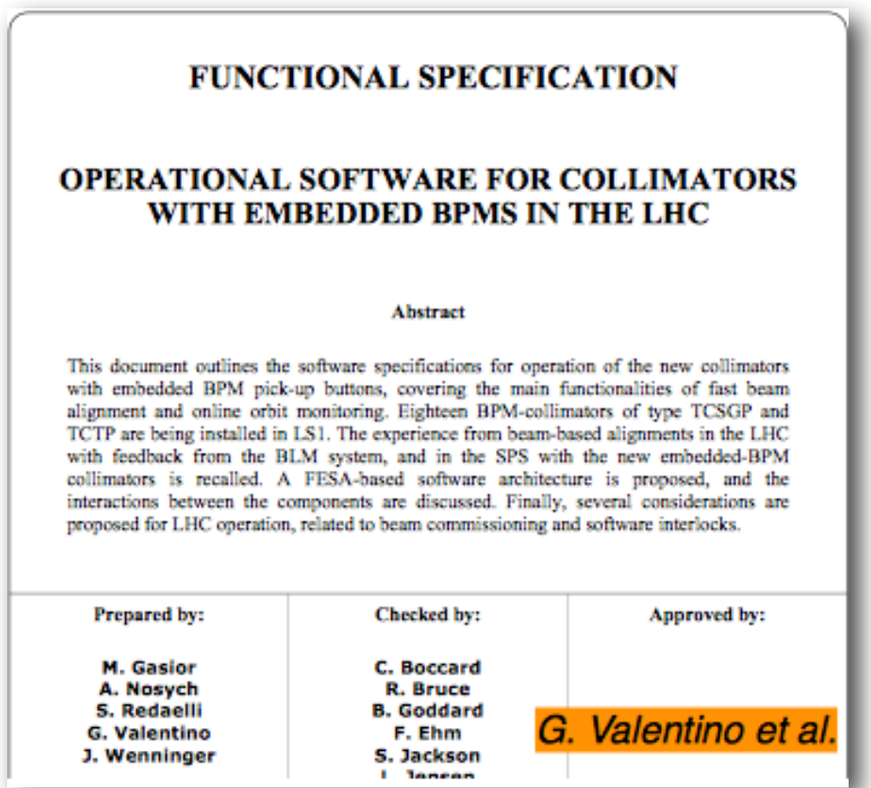


PRST-AB

Jaws aligned when BPM signals are equalized!

- **Successive approximation algorithm** needed due to BPM non-linearities
- **Fast, parallelized alignment:** < 20 s for all BPM collimators (reduction by **2 orders of magnitude**)
- Can align at large gaps (> 50 mm) with < 10 μm accuracy **without touching the beam**
- Individual jaw corner alignment (not possible with BLMs)

- We are preparing a test stand on surface for controls tests
- Complemented with more beam tests at the SPS in Oct/Nov 2014
- A **functional specification** has been circulated and agreed upon by BE/ABP, BE/BI, BE/OP and EN/STI



FUNCTIONAL SPECIFICATION

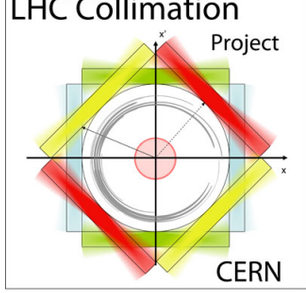
OPERATIONAL SOFTWARE FOR COLLIMATORS WITH EMBEDDED BPMS IN THE LHC

Abstract

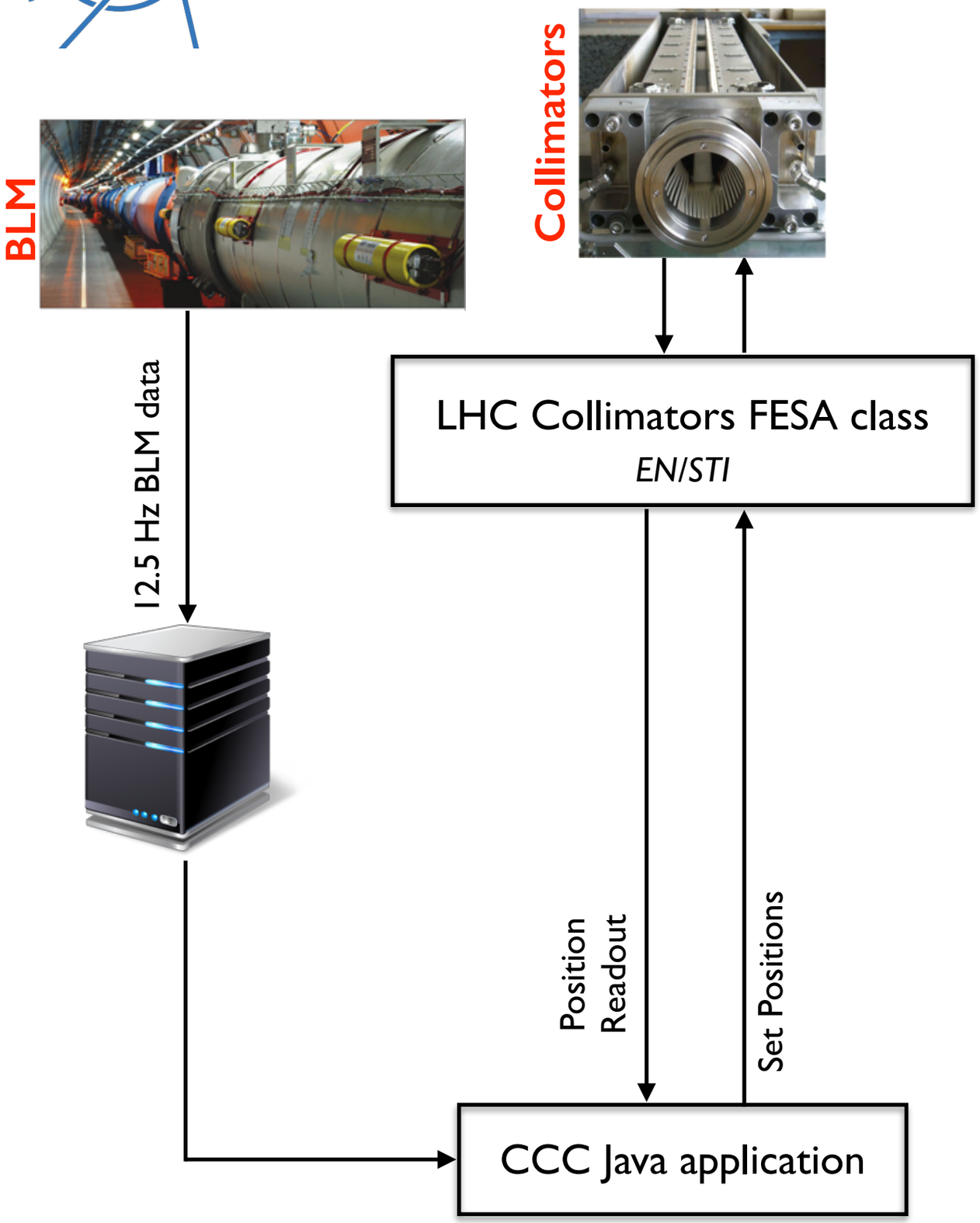
This document outlines the software specifications for operation of the new collimators with embedded BPM pick-up buttons, covering the main functionalities of fast beam alignment and online orbit monitoring. Eighteen BPM-collimators of type TCSGP and TCTP are being installed in LS1. The experience from beam-based alignments in the LHC with feedback from the BLM system, and in the SPS with the new embedded-BPM collimators is recalled. A FESA-based software architecture is proposed, and the interactions between the components are discussed. Finally, several considerations are proposed for LHC operation, related to beam commissioning and software interlocks.

Prepared by:	Checked by:	Approved by:
M. Gasior A. Nosych S. Redaelli G. Valentino J. Wenninger	C. Boccard R. Bruce B. Goddard F. Ehm S. Jackson L. Jensen	G. Valentino et al.

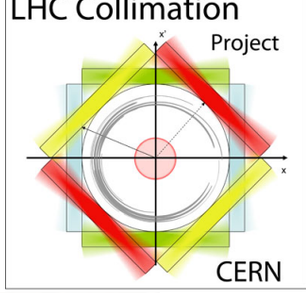
Collimation Software Upgrades



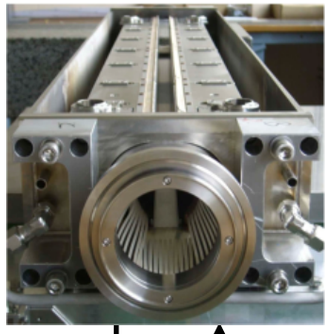
—— Run I



Collimation Software Upgrades

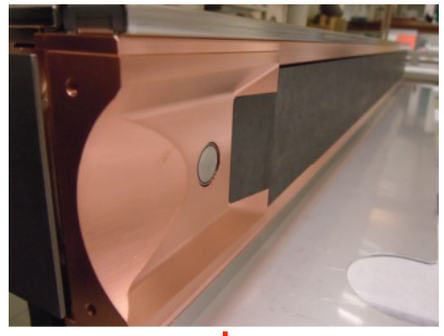


BLM



Collimators

Run I
Run II



Collimator BPMs

LHC Collimators FESA class
EN/STI

BPM pick-up signals

Alignment FESA class
BE/ABP

Collimator Gaps

Beam Positions

BPM FESA class
BE/BI

Position Readout

Start/Stop Alignment

Beam Positions

Beam Positions

Beam Positions

CCC Java application

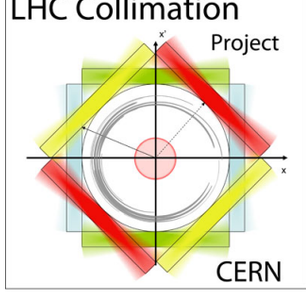
Beam Position Fixed Display

Orbit Feedback Controller*

Software Interlock System*

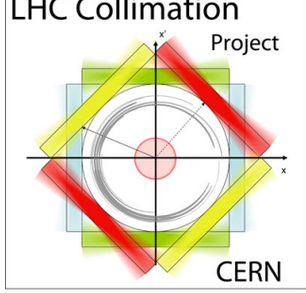
*after experience gained with new BPMs

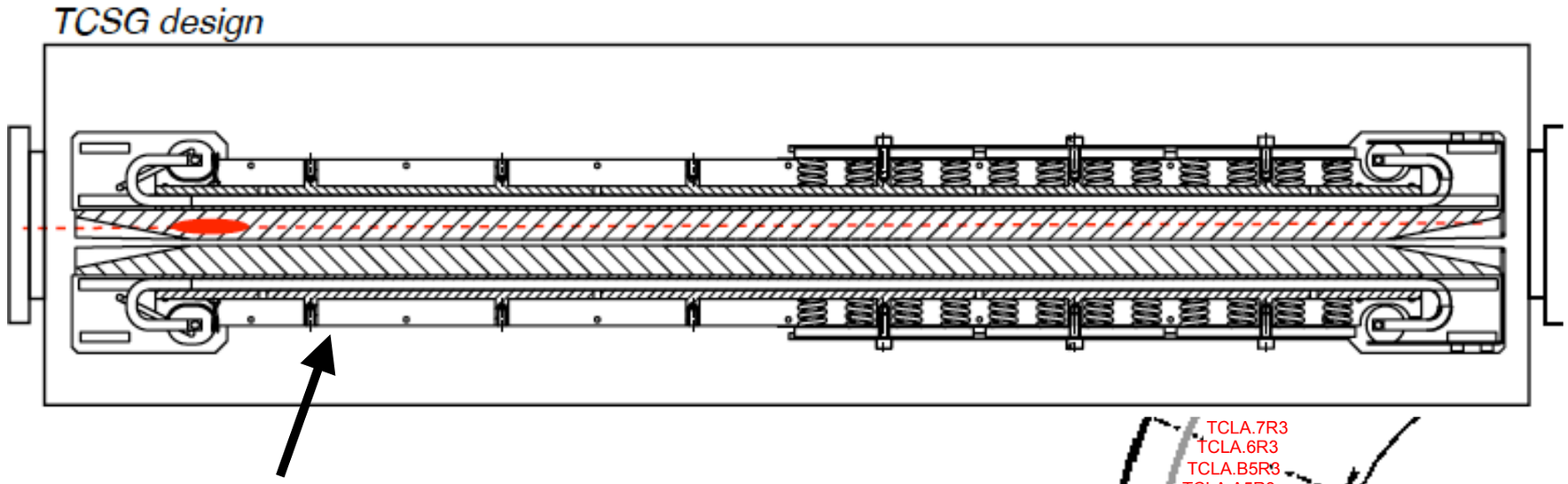
Follow-up from MP Workshop



- **Actions from MP Workshop being followed up (see talk by D. Wollmann)**
  - Discussed in joint inj/dump + collimation meeting
- **Validation of collimator settings:**
  - Avoid issues encountered in 2012 with wrong settings (not caught by loss maps!)
  - CCC application to verify that settings measured during alignment = settings put in the machine
- **Collimation Vistar improvement:**
  - Clearer machine-mode dependent colour-coding: e.g. inj. prot. collimator statuses should not turn red at > 450 GeV (when gaps are opened and prevent injection)
  - Ensure that “red” only indicates an issue for operation
- **Beam-beam separation limits for TCTs**
  - No robust calculation, decision taken to rely on embedded BPMs.
  - Risk of TCLs (no BPMs) not moving considered acceptable

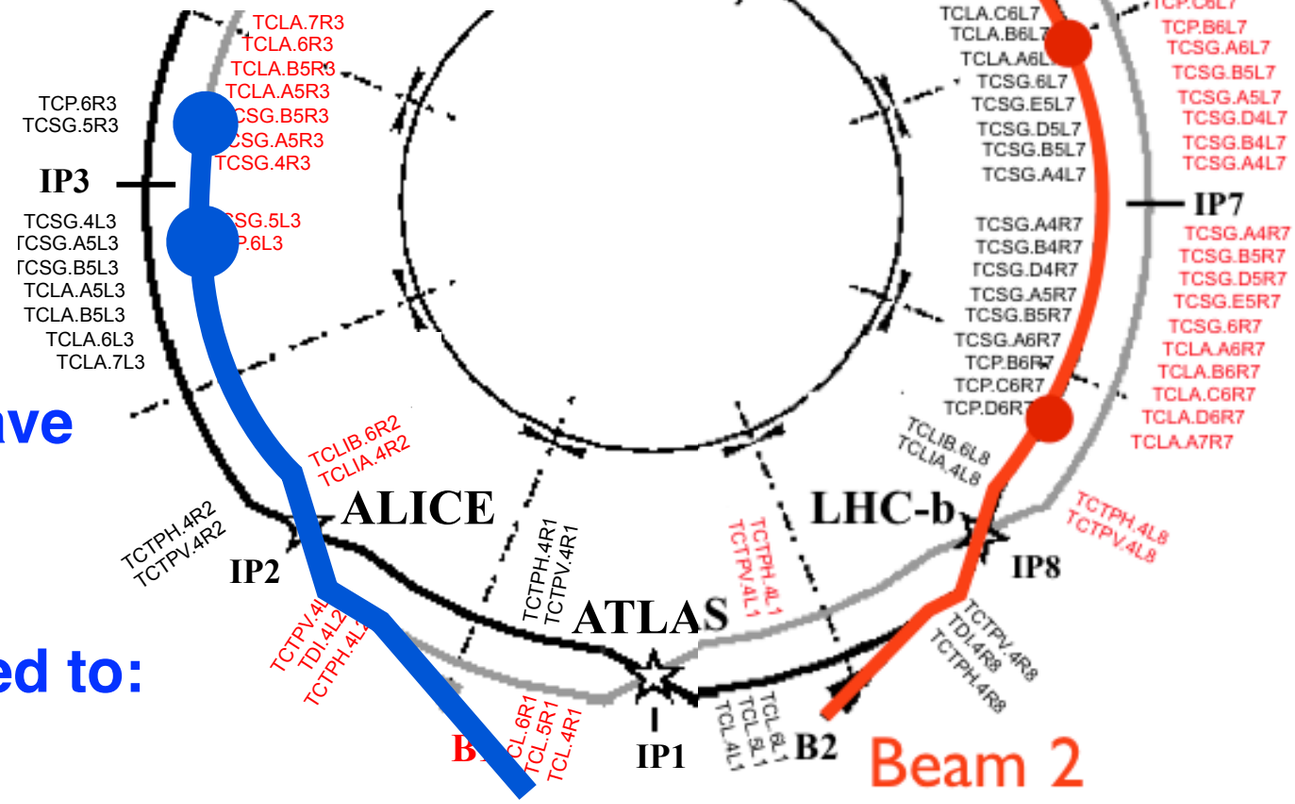
Preparation of sector tests





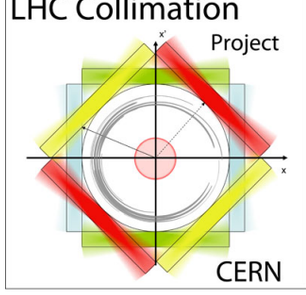
Collimator on anti-collision switches

- **Similar to 2008 Sector Tests**
- **Before Sector Test, collimators should have been commissioned without beam and regularly included in dry-runs.**
- **During Sector Test collimators will be used to:**
  - Stop beam in IR3, IR7 & IR6
  - Re-validate BLM dump signals with different collimator settings in collaboration with BLM team (C. Zamantzas)



= beam stopped by collimator

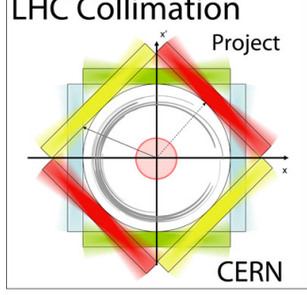
First ideas on Commissioning



- Initial commissioning **without** and **with beam** will be very similar to previous commissioning.
  - Remember that just 18 out of 108 collimators have BPMs

    Expect the first alignment of all collimators to take same time as in 2012 (7 hours)
  - The benefit from BPMs at the collimators will come a bit later:
    - *Improving β* reach: We do not expect to rely on the new functionality from day 1, expect a learning curve (see R. Bruce talk)*
    - *Fast IR configuration: We could benefit quite early thanks to the experience in the SPS*
    - *Interlocks: Validation is needed, evaluate stability of the signals, etc.*
  - Detail commissioning plan including adequate testing of the BPMs is progressing in collaboration with BI.
- As soon as the new FESA classes are ready we can test a subset of collimators as they become available.

Required intensity for commissioning with beam

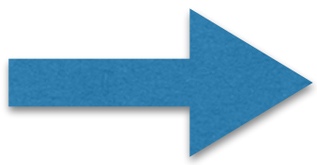


- **Minimum intensity for alignment:**
  - full BLM-based alignment intensity consumption: **7E10 - 1E11 p**
  - minimum for embedded BPMs: **5E9 p**

- **Minimum intensity for loss maps:**
  - defined by the minimum BLM signal needed to measure the leakage to Q8 in IR7

$$\mathrm{BLM}^{\mathrm{Q8}} = \eta_c \times \mathrm{BLM}^{\mathrm{TCP}}_{\mathrm{min}} > \mathrm{BLM}^{\mathrm{noise}}$$

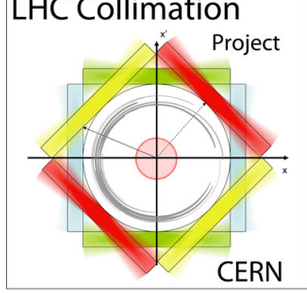
$$\mathrm{BLM}^{\mathrm{TCP}}_{\mathrm{min}} > \frac{3 \cdot 10^{-7}[\mathrm{Gy/s}]}{5 \cdot 10^{-5}} = 6 \cdot 10^{-3}[\mathrm{Gy/s}]$$



> 8E9 p (at 4 TeV) per plane

- **For alignments and loss map validation, we need a stable beam orbit**
  - **bottle-neck:** need 2 nominal bunches to establish and optimize collisions!

Required intensity for commissioning with beam



- Assuming **2-3 fills per machine mode** for alignment + qualification:

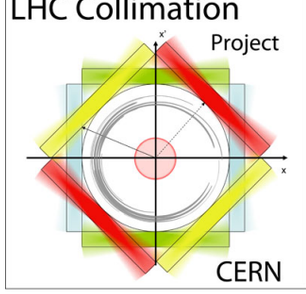
Same fill → Same fill

	Alignment		Betatron Loss Maps		Momentum loss maps*	
Machine Mode	**Intensity (E11)**	**Bunch Config**	**Intensity (E11)**	**Bunch Config**	**Intensity (E11)**	**Bunch Config**
Injection	2	2 nominal	2	2 nominal (H/V)	2	2 nominal
Flat Top	2	2 nominal	2	2 nominal (H/V)	2	2 nominal
After Squeeze	2	2 nominal	2	2 nominal (H/V)	2	2 nominal
Collisions	2.2	2 nominal	2.2	2 nominal + 2 non-coll probes (H/V)	2.2	2 nominal + 2 non-coll probes

***will probably need +1 for off-momentum (+ 1 for async dump)**

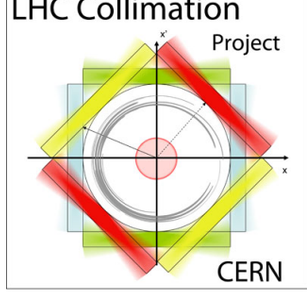
- Fits in with the proposed **"restricted SBF"** of 2 nominal + pilots (see talk by L. Ponce)
- Would still prefer 3 nominal bunches as done in previous years for **operational margin**..
- For eventual frequent configuration changes which require alignments and loss maps, we can have **1 fill for squeeze + colliding (as in 2012)**, and inject 2.5E11 p directly from the start.
- Once experience is gained with embedded BPMs in TCTs, alignment in squeeze + collisions won't consume any intensity.

Early measurements



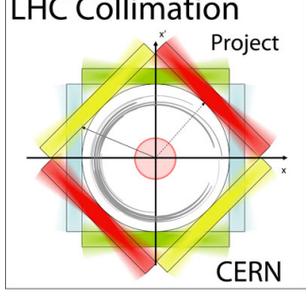
- **Operation with embedded BPMs**
  - parasitically test the BPM acquisition from the very first fill.
  - need to perform collimator scans to measure the BPM non-linearity coefficients for more accurate beam monitoring.
  - compare alignment with both BLM-based and BPM-based techniques at 7 TeV.
- **Controlled off-momentum loss maps**
  - evaluate the minimal RF trim for the right trade-off between loss map quality & operational efficiency.
- **Tests of collimator settings**
  - need to test several sets of settings before taking the final decision (see talk by S. Redaelli).
  - done via loss maps as in collimation quench test.
- **TCL settings for operation and eventual forward physics runs**
  - Validation of simulations done for cleaning, impedance and R2E studies for different RP and TCL settings.

Ideas for MDs



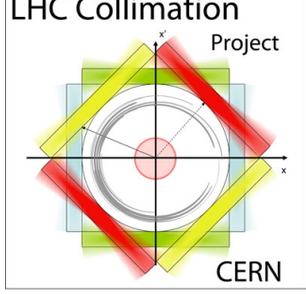
- **Halo measurements + characterization**
  - Beam scraping with collimators
- **Active halo population control**
  - Induced tune ripple + ADT blow-up to check limitations from loss spikes
  - Measurements needed to evaluate e-lens installation in LHC
- **Tighter collimator settings**
  - Evaluate cleaning, impedance, machine stability (as done in the past)
- **Crystal collimation**
  - Installed in IR7 during LS1
- **Detailed MD list to come later on..**

Conclusions

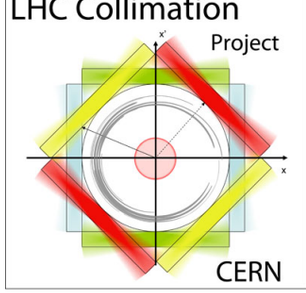


- LHC collimation system has performed very well during Run I: **no quenches** and cleaning efficiency ≈ design value
- **Several HW + SW upgrades** ongoing during LS1 to prepare the system for Run II as we approach nominal beam parameters:
  - 18 collimators with embedded BPMs
  - 8 physics debris collimators
  - 2 passive absorbers
  - 1 replaced TCP in IR7
  - upgrade of collimator controls from CCC-level down to low-level
- **Upgrades and HW commissioning** on track and will be ready for sector test in November
- First plans for **beam commissioning** of the collimation system presented

Reserve Slides



LHC collimation: Post LS1



Insertion Region	Collimator name	Acronyms	Functionality	Material	End of Run 1	Post LS1	New in LS1
IR7: Betatron cleaning	Primary collimator	TCP	Primary betatron cut	CFC	6	6	0
	Secondary collimator - Graphite	TCSG	Secondary betatron cut	CFC	22	22	0
	Shower absorber	TCLA	Absorber of larger-amplitude showers	W	10	10	0
	Secondary collimator - Metallic	TCSM	Sceondary betatron cut	MoGr?	0	0	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
	Passive absorber	TCAP	Reduce total doses in warm magnets	W	6	6	0
IR3: Momentum cleaning	Primary collimator	TCP	Primary momentum cut	CFC	2	2	0
	Secondary collimator - Graphite	TCSG	Secondary momentum cut	CFC	8	8	0
	Shower absorber	TCLA	Absorber of large-amplitude showers	W	8	8	0
	Secondary collimator - Metallic	TCSM	Secondary momentum cut	MoGr?	0	0	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
	Passive absorbers	TCAP	Reduce total doses in warm magnets	W	2	4	2
IR6: Dump protection	Primary dump protection	TCSG	Aperture definition for dump protection	CFC	2	0	-2
	Primary dump protection with BPM	TCSP	Aperture definition for dump protection	CFC	0	2	2
	Secondary dump protection	TCDQ	Dump absorption block (one-sided)	C	2	2	0
	Shower absorber	TCLA	Shower absorbers for Q4 and Q5	W	0	0	0
IR1/IR5: High lumi experiments	Tertiary collimator	TCTH/V	Local triplet protection	W	8	0	-8
	Tertiary collimator with BPM	TCTPH/V	Local triplet protection	W	0	8	8
	Physics debris absorber	TCL	Clean matching section and DS from debris	Cu (W)	4	12	8
	Tertiary collimators with BPM for MS	TCTPH/V	Additional protection for D2/Q4/Q5	W	0	0	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
IR2: ALICE and B1 injection	Tertiary collimator	TCTH/V	Local triplet protection	W	4	0	-4
	Tertiary collimator with BPM	TCTPH/V	Local triplet protection	W	0	4	4
	Absorbers fro injection protection	TCLIA/B	Auxiliary injection protection devices	C	2	2	0
	Primary injection protection aperture	TDI	Injection protection absorption block	C	1	1	0
	Injection protection mask	TCDD	Movable D1 mask	C?	1	1	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
IR8: LHCb and B2 injection	Tertiary collimator	TCTH	Local triplet protection	W	2	0	-2
	Tertiary collimator (2-in-1 design)	TCTVB	Local triplet protection	W	2	0	-2
	Tertiary collimator with BPM	TCTPH/V	Local triplet protection	W	0	4	4
	Absobert for injection protection	TCLIA/B	Auxiliary injection protection devices	C	2	2	0
	Primary injection protection aperture	TDI	Injection protection absorption block	C	1	1	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
	Physics debris absorber	TCL	Clean matching section and DS from debris	Cu (W)	0	0	0
TI2/TI8	Injection protection collimators	TCDIH/V	Injection protection in the transfer lines	Gr	13	13	0
				TOTAL	108	118	28
				Movable	100	108	26

Replacement

Addition

Replacement

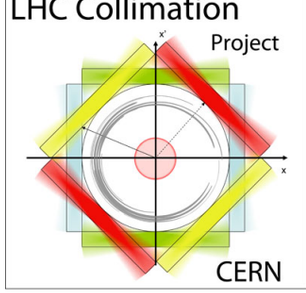
Replacement and addition

Replacement

Replacement

Courtesy of S.Redaelli

LHC collimation: Post LS1



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	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
	Passive absorbers	TCAP	Reduce total doses in warm magnets	W	2	4	2
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	Tertiary collimator with BPM	TCTPH/V	Local triplet protection	W	0	8	8
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	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
IR2: ALICE and B1 injection	Tertiary collimator	TCTH/V	Local triplet protection	W	4	0	-4
	Tertiary collimator with BPM	TCTPH/V	Local triplet protection	W	0	4	4
	Absorbers fro injection protection	TCLIA/B	Auxiliary injection protection devices	C	2	2	0
	Primary injection protection aperture	TDI	Injection protection absorption block	C	1	1	0
	Injection protection mask	TCDD	Movable D1 mask	C?	1	1	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
	Tertiary collimator	TCTH	Local triplet protection	W	2	0	-2
				W	2	0	-2
				W	0	4	4
				C	2	2	0
				C	1	1	0
				W?	0	0	0
				(W)	0	0	0
					13	13	0
				TOTAL	108	118	28
				Movable	100	108	26

Replacement

Addition

Replacement

Replacement and addition

Replacement

Replacement

Installation of 28 collimators

Post LS1: 118 collimators

Movable: 100 → 108

Availability of information

- ECRs for installation
- Online availability of status of production/installation
- MTF filled with results of all qualification tests for installation
- Acceptance for installation
- Updated LSA database
- Commissioning procedures