Performance of New Designs Deployed in Run II and Plans for Run III

A.Mereghetti, on behalf of the LHC Collimation Team

2019 International Review of the HL-LHC Collimation System
CERN (CH) – 11-12 Feb 2019

Outline

- Introduction and highlights of IR7 Upgraded designs
- Upgraded prototypes in the LHC
- Collimator Beam Position Monitors and alignment
- Layout in Run III
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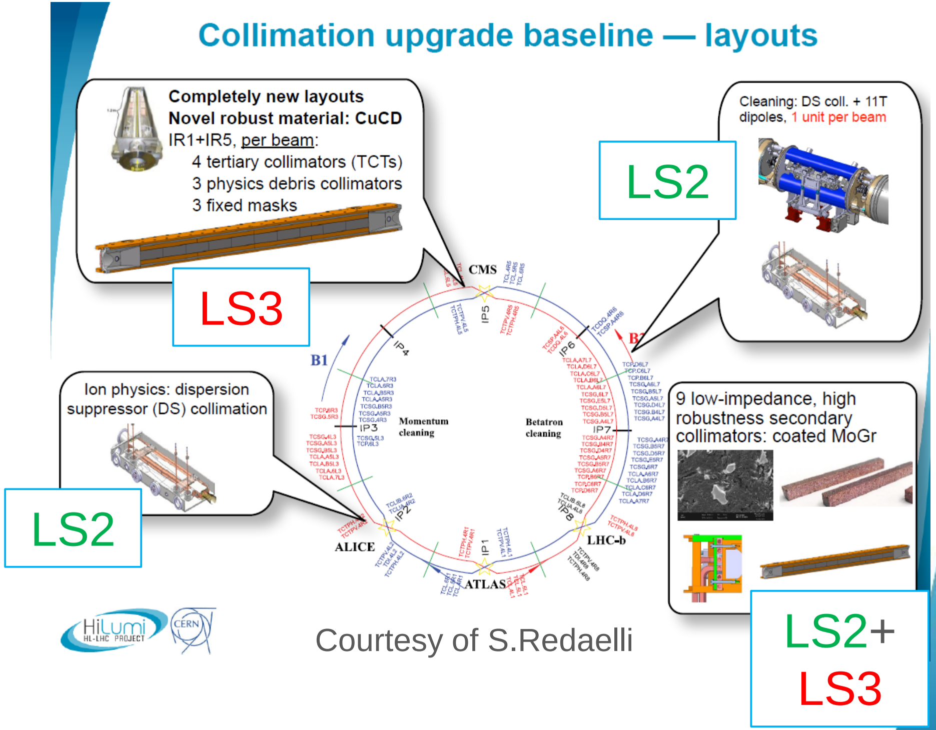
IR7 Collimation Upgrade in view of HL-LHC

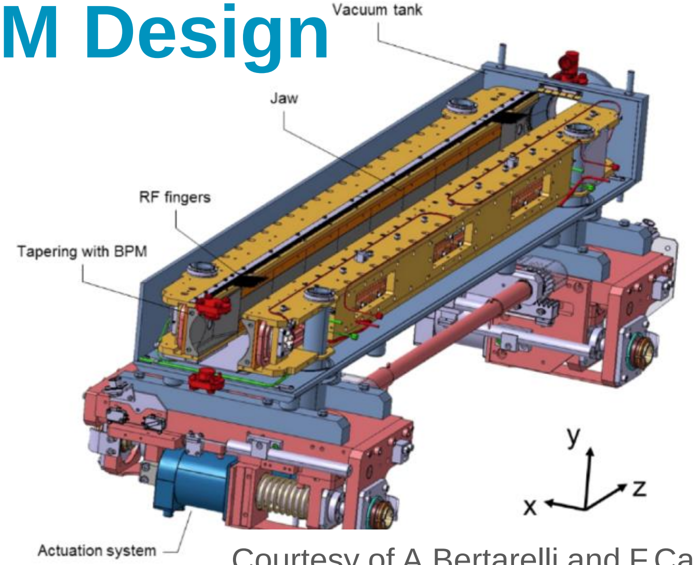
- In the framework of the HL-LHC project, it is foreseen to increase (with respect to Nominal LHC figures):
  - Beam brightness, by a factor of ~3;
  - Beam current, by a factor ~2;
- Challenges on the collimation system in terms of:
  - Cleaning inefficiency, i.e. leakage to cold magnets;
  - Robustness and thermo-mechanical response of collimator jaws;
  - Impedance contribution from collimators;
- Baseline upgrade in IR7:
  - Upgraded primary collimators TCPPM:
    - 2 per beam, installed in LS2 (Consolidation);
  - Upgraded secondary collimators TCSPM:
    - 4 per beam in LS2;
    - 5 per beam in LS3;
  - New collimators in dispersion suppressor between 11T dipoles TCLD:
    - 1 per beam in LS2;



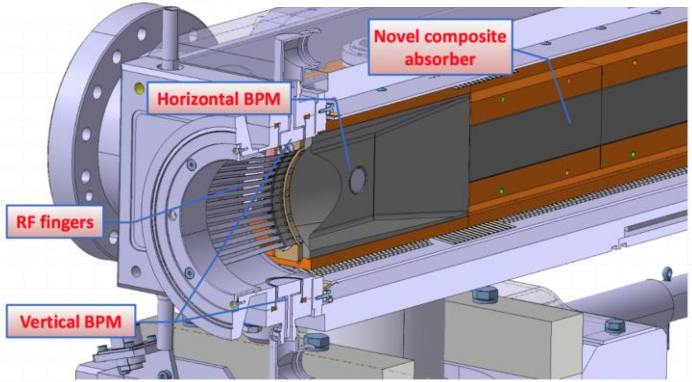
Highlights of TCSPM Design

- TCSPM (upgraded secondary collimator):
  - 1m active length (as LHC secondary collimators);
  - Mo-coated MoGr jaws:
    - MoGr (bulk material):
      - robustness similar to CFC but better electrical resistivity:
      - Better Mo adhesion with respect to CFC;
    - Mo (coating):
      - further decrease of contribution to impedance;
  - in-jaw Beam Position Monitors (BPMs), for faster alignment and monitoring of beam position on collimation plane;
  - 3rd BPM embedded in tank, for monitoring of beam position on plane orthogonal to that of collimation;
  - 5th axis capability:
    - Possibility to move the collimator on the plane orthogonal to that of collimation;
    - To expose a fresh (undamaged) surface after failure accidents at injection or flat top;
- TCPPM (upgraded primary collimator):
  - very similar design to that of TCSPM;
  - 60cm active length (as LHC primary collimators);
  - No coating;

More details in presentations by A.Bertarelli and F.Carra

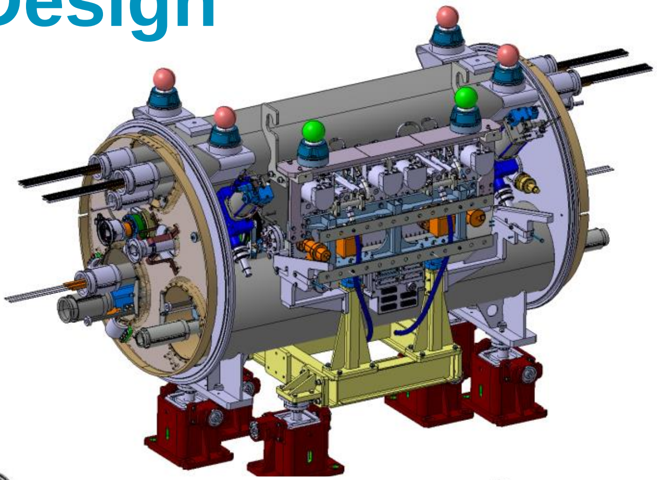


Courtesy of A.Bertarelli and F.Carra

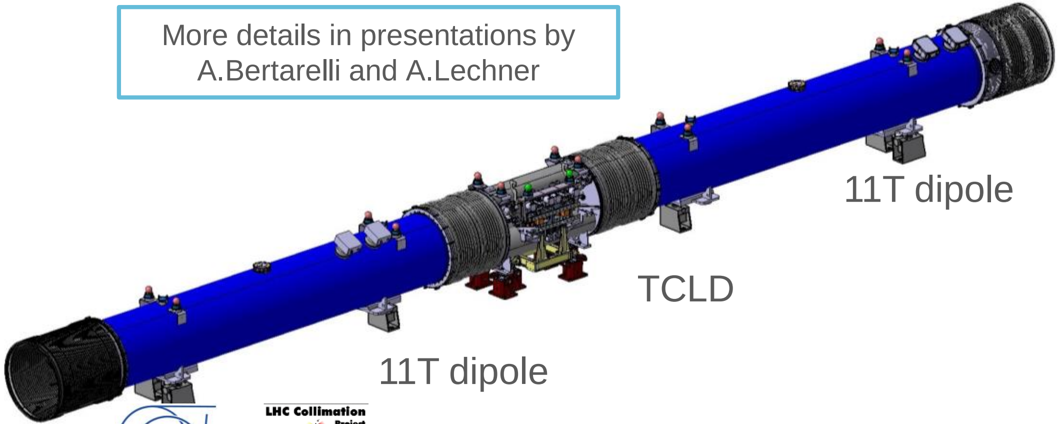


Highlights of TCLD Design

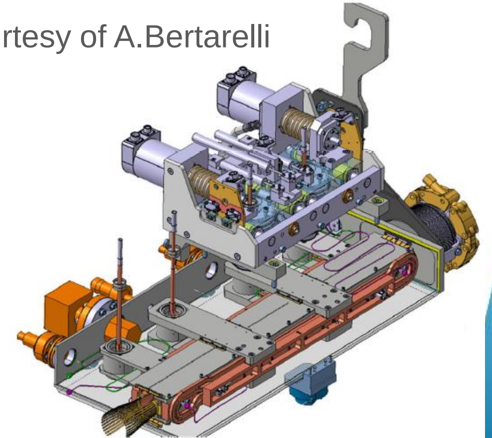
- TCLD (new collimator in IR7 dispersion suppressor):
  - Fitted between adjacent 11T dipoles: complex integration design!
  - 60cm active length;
  - Jaws made of tungsten alloy:
    - To minimize leakage from jaws;
  - in-jaw BPMs, for fast alignment and monitoring of beam position on collimation plane;



More details in presentations by A.Bertarelli and A.Lechner



Courtesy of A.Bertarelli



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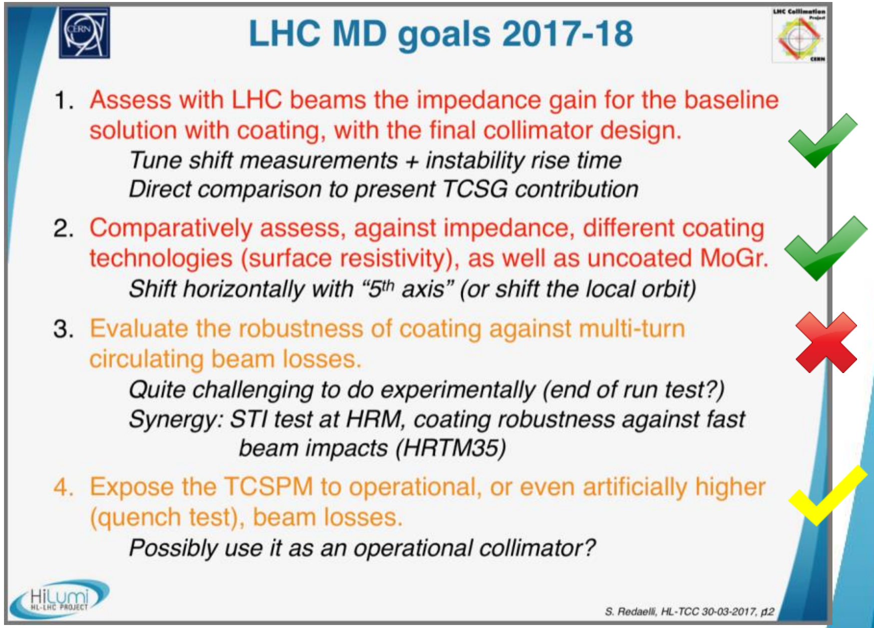
Upgraded Hardware for Tests in the LHC

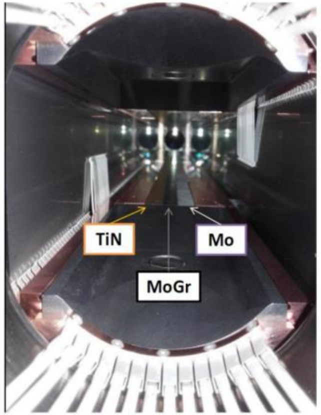
- Given the challenges and extension of the upgrade effort, it is important to validate with circulating beams key aspects of the new design before going into series production;
- Prototypes of upgrade hardware installed in EYETS2016 to test with beam new design:
  - *Exchange* of the LHC horizontal primary collimator on B1 with upgrade design (LHC-TC-EC-0005):
    - TCP.C6L7.B1;
    - In-jaw BPMs;
    - CFC jaw (no material change);
    - Operational in 2017 and 2018;
  - *Addition* of a vertical upgraded secondary collimator on B2 (LHC-TC-EC-0006):
    - TCSPM.D4R7.B2;
    - In-jaw BPMs + 3rd BPM (tank);
    - MoGr jaw with 3 stripes;
    - Operational in 2018;

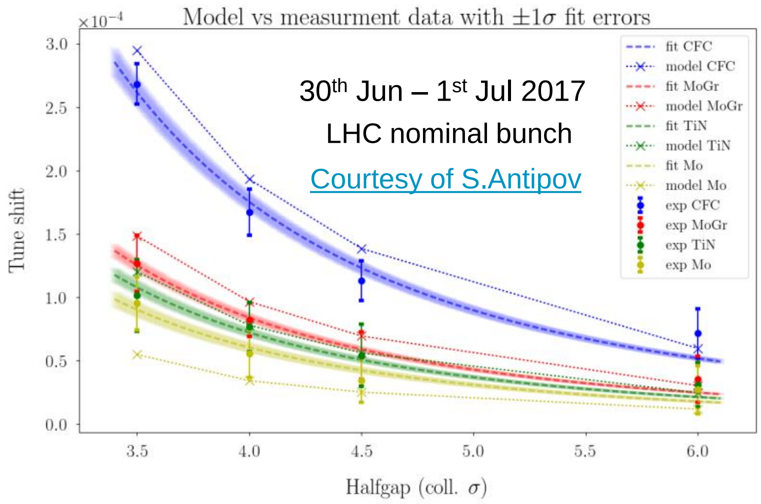


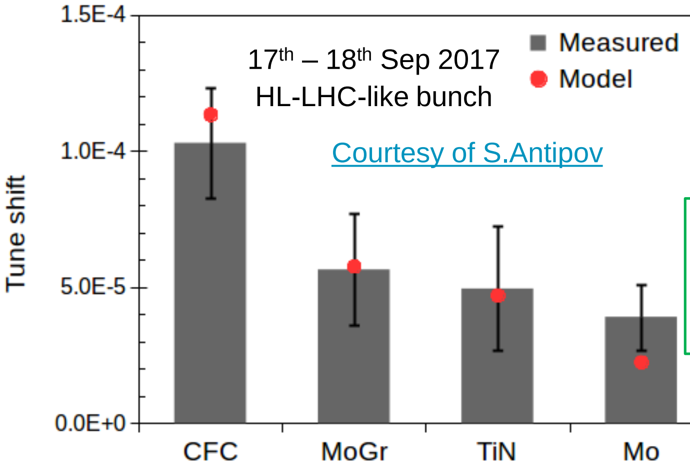
S.Redaelli, TCC Meeting, 30th March 2017, CERN, Geneva, Switzerland;

Experience with Prototype of Upgraded Secondary Collimator – 2017

- Prototype of upgraded secondary collimator TCSPM installed in slot D4R7.B2:
  - A vertical secondary collimator (CFC) already in slot immediately upstream for direct comparisons;
  - Smallest beam σ among secondary collimators → ideal for impedance measurements;
  - Three stripes of different materials, to assess effect of coating on impedance;
- Extensive MD campaign of impedance measurements in 2017, to benchmark expectations from impedance models:
  - measure the beam tune-shift while cycling collimator jaws between operational and fully open position;







Challenging measurements, with sensitivity of ΔQ ~2 10^{-5}!

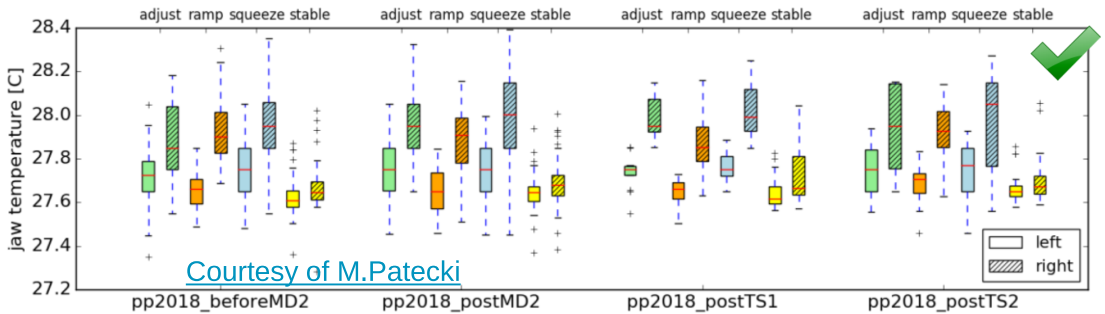
Discrepancy of measurements with respect to predictions allowed to refine requirements on coating

More details in presentation by E.Metral

Experience with Prototype of Upgraded Secondary Collimator – 2018

- After one year in the machine with no hardware issue, prototype of upgraded secondary collimator TCSPM deployed in operation throughout 2018;
- Cycled in every LHC physics fill as the upstream secondary collimator (TCSG.D4R7.B2);

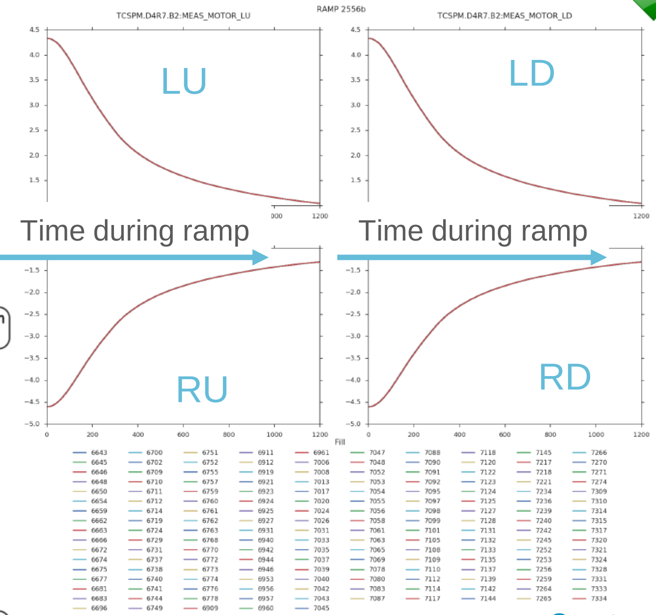
A smooth operation in 2018 with no hardware faults!



Courtesy of M.Patecki

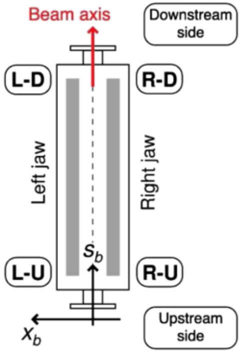
Jaw temperatures – All 2018 pp physics fills – no outliers

Motor positions – All pp physics fills of 2018

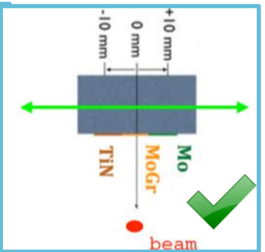


Excellent reproducibility

Courtesy of M.Patecki



5[th] axis functionality thoroughly deployed for impedance measurements with no issues

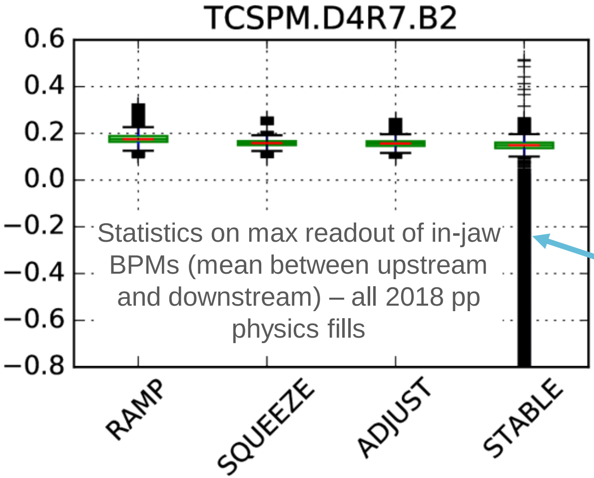


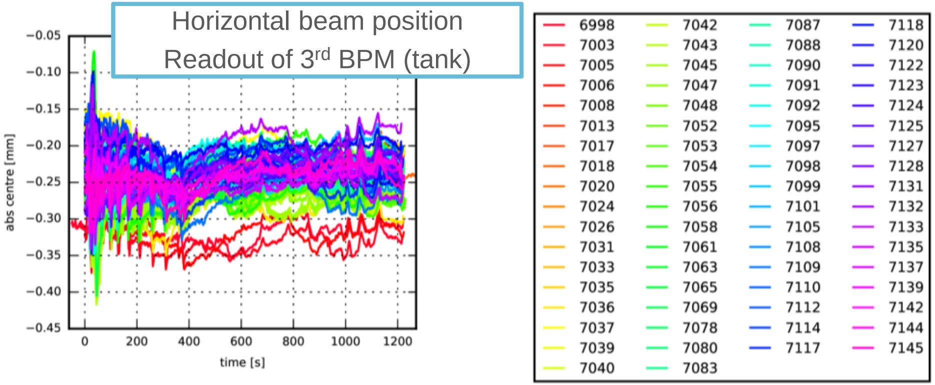
Performance from a vacuum perspective in presentation by G.Bregliozzi

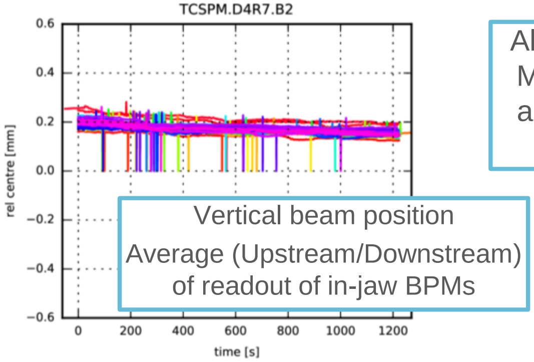
Experience with Prototype of Upgraded Secondary Collimator – 2018 (II)

- The prototype of upgraded secondary collimator TCSPM is equipped with in-jaw BPMs and a 3rd BPM on the tank, which allow to monitor:
  - beam position;
  - fill-to-fill reproducibility;
  - slow orbit drifts throughout the year;

…on both collimation plane and the orthogonal one!







All 2018 pp physics fills between Machine Development block #2 and Technical Stop #2 – RAMP beam process

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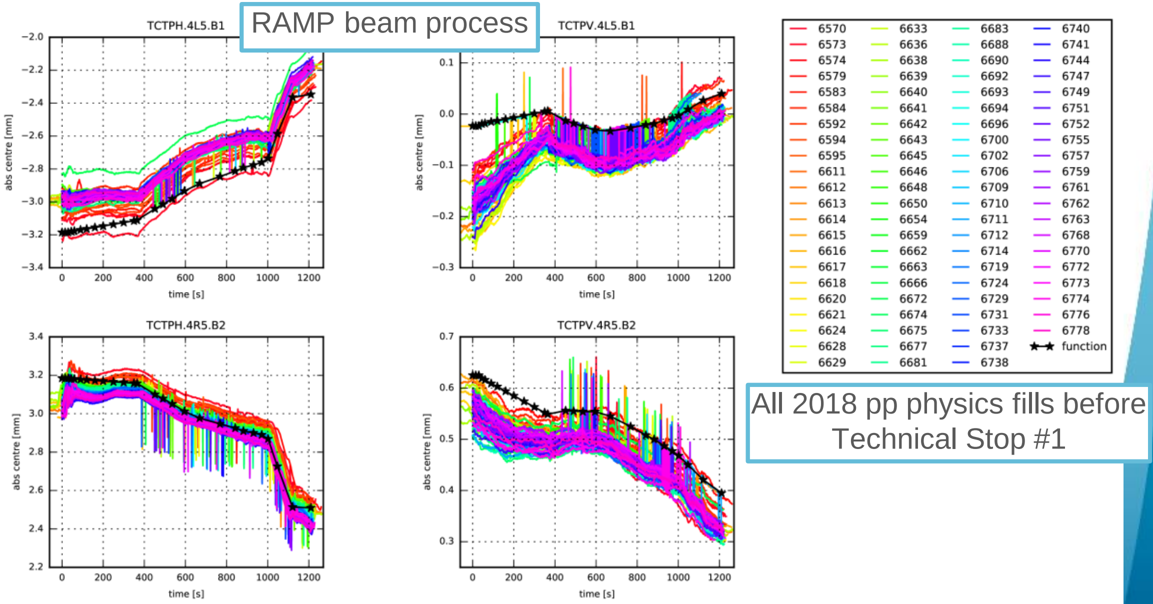
Beam Position Monitors and Interlocks

- During the Long Shutdown #1, tertiary collimators (TCTs) and IR6 secondary collimators (TCSPs) have been equipped with in-jaw BPMs, with various advantages:
  - Fast alignment of collimators, with following ease of accommodating changes in crossing conditions;
  - Possibility of monitoring optimum collimator centering throughout the year;
  - Possibility to detect potentially dangerous distortions on the closed orbit → interlocks on orbit position!

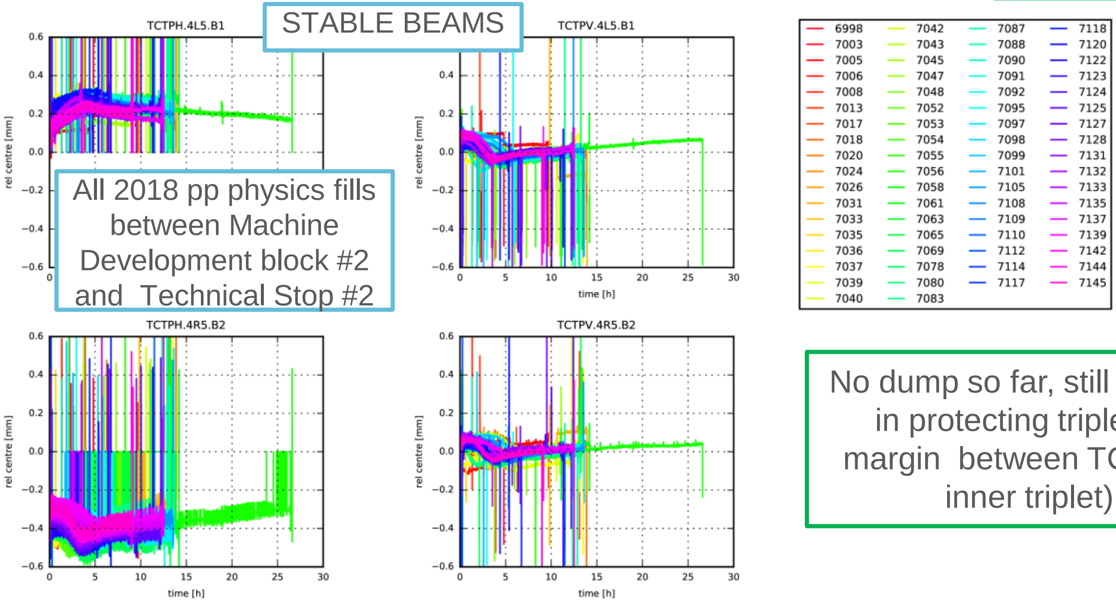
- Interlocks on beam position during regular physics fills relies on optimum centering of collimators throughout the physics fill;
- Centering ensured by programmed functions, describing changes in collimator centers during the various phases of the LHC cycle;
- Centre functions generated combining alignment data at matched points and MADX predictions of the closed orbit during beam processes;

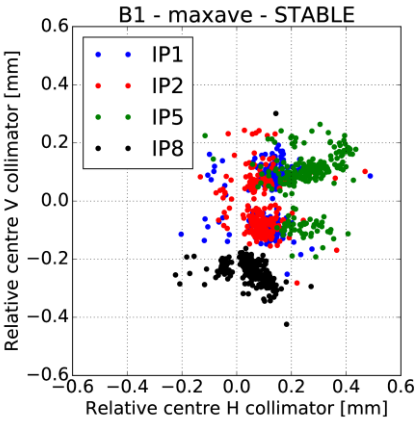


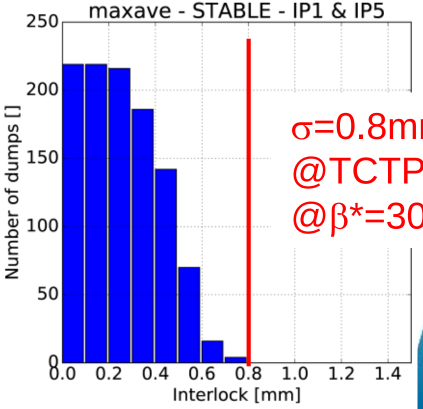
Beam Position Monitors and Interlocks (II)

- Interlocks on beam position have been applied to in-jaw BPMs at tertiary collimators and at IR6 secondary collimators:
  - Tested in 2017 and deployed for the final part of data taking, as requirement for pushing β* to 30cm (from 40cm);
  - Used throughout 2018 physics fills;
- Settings of interlocks such that:
  - Fill-to-fill reproducibility is easily accommodated;
  - Slow drifts over the year can be tolerated;

2018 Interlock settings (@FT)
- ✓ IR1/5: 1σ
- ✓ IR8: 2.5σ
- ✓ IR6: 1.5σ





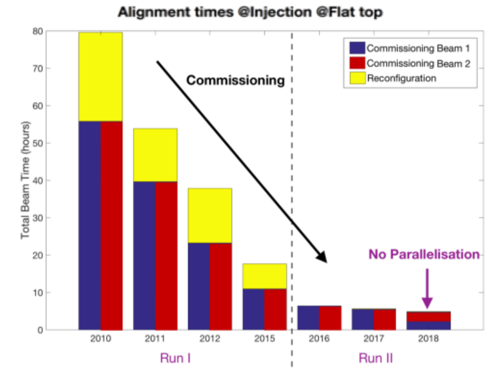


σ=0.8mm @TCTPV @β*=30cm

No dump so far, still effective in protecting triplet (1σ margin between TCTs and inner triplet);

Collimator Alignment

- Alignment is a key commissioning activity to ensure optimum performance of the collimation system:
  - BLM-based alignment: for each collimator, jaws are moved until they touch the beam envelop, with a spike detected by the downstream BLM;
  - The procedure ensures collimator centering;
  - For alignment with beam angle, the procedure must be repeated many times with different jaw angles;
  - LHC collimation system is complex, with >50 collimators per beam → lengthy operation;
  - Semi-automatic alignment: feedback loop from BLM signal to jaw movement;
  - Relevant improvements throughout Run I and Run II;
- BPM collimators firstly introduced mainly at TCTs in LS1:
  - Non-invasive: jaws centered equalizing the signal from the BPM buttons;
  - Having an upstream and a downstream BPM, alignment procedures aligns the jaws to the local beam angle;
  - BPM-based alignment tested in 2015;
  - Fully deployed started from 2016: time for reconfigurations (TCTs) became negligible;



Collimation milestones over the years:

Run 1 - 2010: Semi-automatic alignment
- 2012: 12 Hz data available

Run 2 - 2015: BPMs introduced
- 2016: 100 Hz data available
- 2018: Fully-automatic alignment

G.Azzopardi, N.Fuster Martinez, B.M.Salvachua Ferrando, G.Valentino
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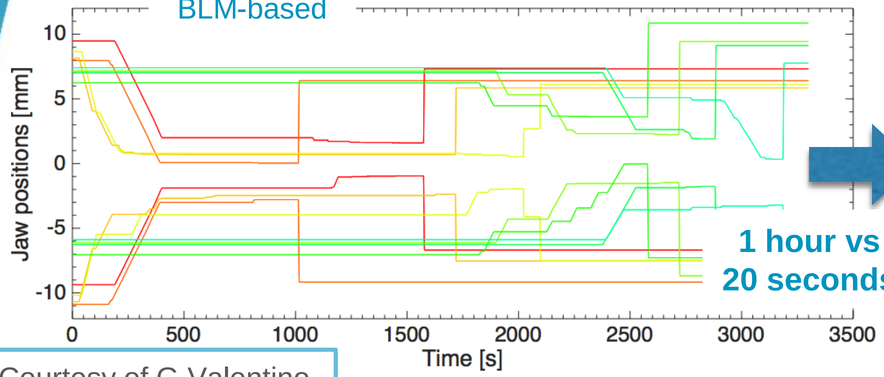
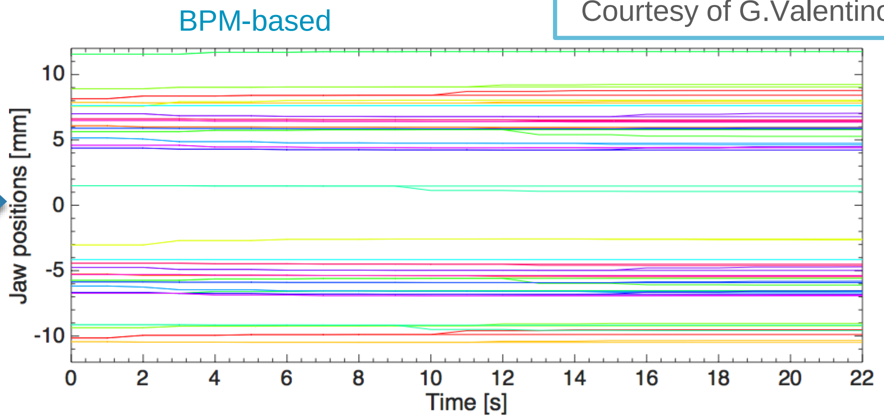
BLM-based vs BPM-based Alignment



Courtesy of G.Valentino

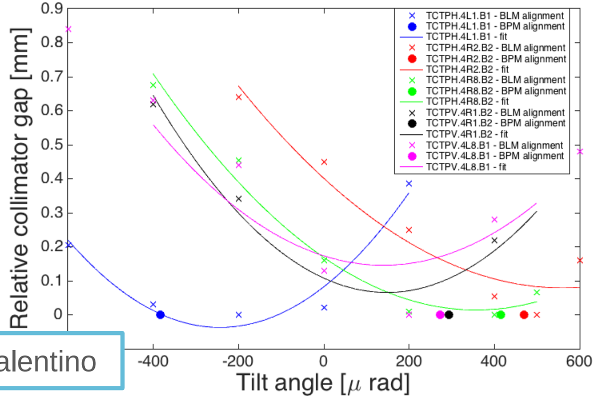
1 hour vs 20 seconds



Courtesy of G.Valentino

- BLM-based:
  - collimators are closed until each jaw touches the beam halo;
  - One collimator per beam at a time (cross-talk on BLM signal);
- BPM-based:
  - done at large gaps:
    - improved safety, as jaws are far from circulating beams;
    - any beam intensity can be deployed;
  - Many collimators can be aligned in parallel

Example of angular alignment: 1 point with BPMs vs many points with BLMs + fit



Courtesy of G.Valentino

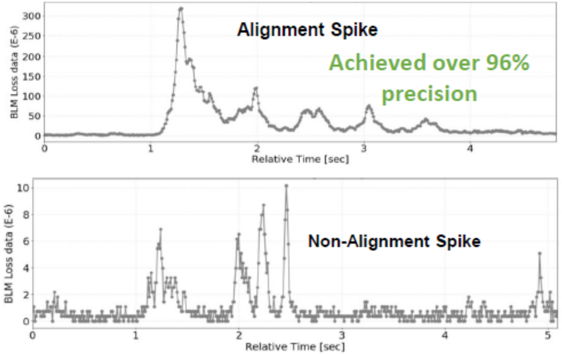
Fully-Automatic Alignment

Important R&D activity in Run II!!

Fully-automatic alignment implementation

First time used in 2018 fully-automatic

- ❑ Automatic Threshold Selection
- ❑ Machine Learning for Spike Detection

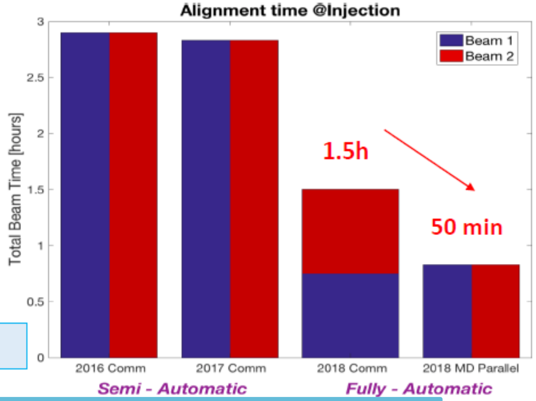


- ❑ Crosstalk analysis of BLM signals performed from real data for parallel auto selection of collimators.

Fully-automatic parallel alignment validated during an MD.

Fully-Automatic Alignment procedure:

- AUTO Select collimator
- AUTO Select BLM threshold
- AUTO Start alignment
  - Collimator moves to beam
  - Collimator stops at threshold
- AUTO Check if collimator aligned



Algorithm controls sequence of alignment steps

→ collimator expert only needed for supervision;

Spike recognition via Machine Learning

Algorithm takes into account also cross-talk from other collimators on the other beam

G.Azzoparti, N.Fuster Martinez, B.M.Salvachua Ferrando, G.Valentino
9th LHC Operations Evian Workshop

Angular Alignment

Important R&D activity in Run II!!

Angular auto-alignment implementation

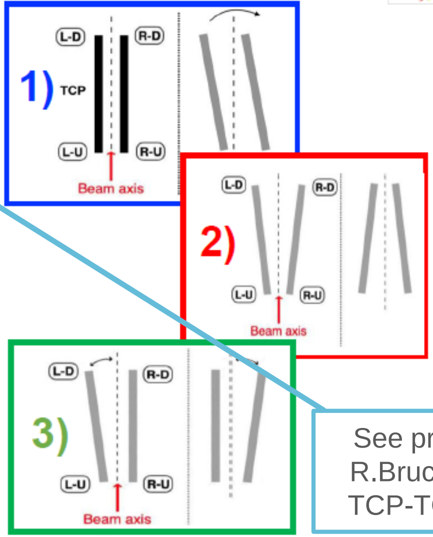
*Slides by **G. Azzopardi**, B. Salvachua, G. Valentino*

- Collimators have always been aligned with a zero tilt angle w.r.t the beam.

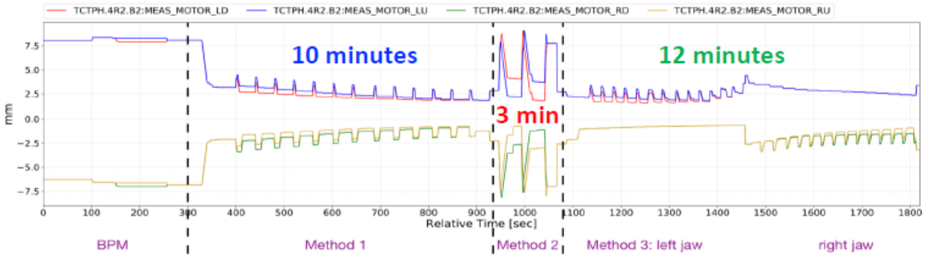
Angular alignment is a key element if we want to tighten more the TCP-TCSG retraction margins.

- **Three novel angular algorithms** were introduced to identify the best angle:
  1) **Using a reference collimator** - Check for offset in tank
  2) **At maximum angles** - Quickly calculate upstream and downstream centers
  3) **Using a jaw as reference** - Check for asymmetries within the collimator itself
- The algorithms were implemented in **FESA** using the **fully-automatic BBA**.

G. Azzopardi, et al., "Automatic angular alignment of LHC collimators," ICALEPCS'17



See presentation by R.Bruce on reducing TCP-TCS retractions



Angular Auto-Alignments (in MD)
1 collimator at 41 angles for
3 methods @Injection: 28 minutes

13

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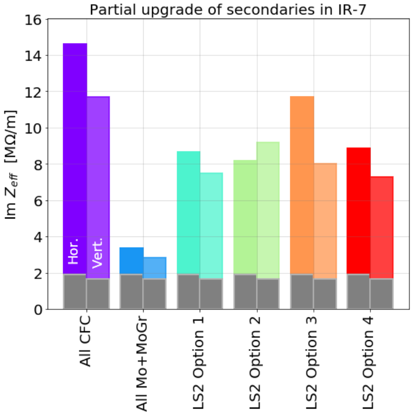
Installation Slots of Upgraded Secondary Collimators

- Slots of installation of the 4 TCSPMs chosen among a pool of 4 possible ones (CERN-ACC-2019-0001):
  1. Reduce impedance as much as possible – collimators with largest contribution;
  2. Avoid first two skew collimators – most exposed to steady-state losses;
  3. Avoid H and V secondary collimators – ABD + inj. failures;
  4. Avoid H secondary collimators only – ABD;

Chosen one: option 2

		1	2	3	4
TCSG.A6L7.B1					
TCSG.B5L7.B1					
TCSG.A5L7.B1					
TCSG.D4L7.B1	V				
TCSG.B4L7.B1	H				
TCSG.A4L7.B1					
TCSG.A4R7.B1					
TCSG.B5R7.B1					
TCSG.D5R7.B1					
TCSG.E5R7.B1					
TCSG.6R7.B1	H				



Courtesy of S.Antipov

- 50% of the expected impedance reduction can be achieved exchanging only 4 collimators;
- Option 2 favored over the others since no TCSPM installed in most loaded location, giving time to further optimize design, and it minimizes octupole current on H plane;
- Cleaning performance evaluated for each option, but no major differences found (A.Mereghetti, HL-LHC Annual Meeting, 2017);

B1	B2	
TCSG.D4L7	TCSG.D4R7	*exchange*
TCSPM.B4L7	TCSPM.B4R7	*addition*
TCSPM.E5R7	TCSPM.E5L7	*addition*
TCSPM.6R7	TCSPM.6L7	*addition*

Present TCSG exchanged, since test equipment already present in downstream slot

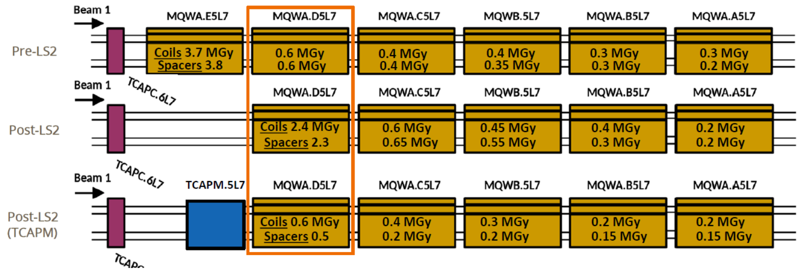
Changes in IR7 in LS2 and Layout in Run III

Hardware installation in IR7 during LS2 (per beam):

- Replacement of 2 out of 3 LHC primary collimators with upgraded ones (LHC-TC-EC-0016);
- Addition of 3 upgraded secondary collimators and replacement of the vertical LHC secondary collimator with the upgraded one (LHC-TC-EC-0014);
- Replacement of MQWA.E5x7 with appropriate shielding (LHC-TCAP-EC-0001):
  - Magnet will refurbish spares;
  - Shielding required to keep unchanged dose levels in downstream MQWA module;
  - Optics re-matched (R.Bruce, HSS section meeting, 6th Dec 2017);
- Installation of a DS collimator between 2 11T dipoles at the place of MBA.9 (LHC-TC-EC-0013);

B1	B2	
TCSG.D4L7	TCSG.D4R7	*exchange*
TCSPM.B4L7	TCSPM.B4R7	*addition*
TCSPM.E5R7	TCSPM.E5L7	*addition*
TCSPM.6R7	TCSPM.6L7	*addition*

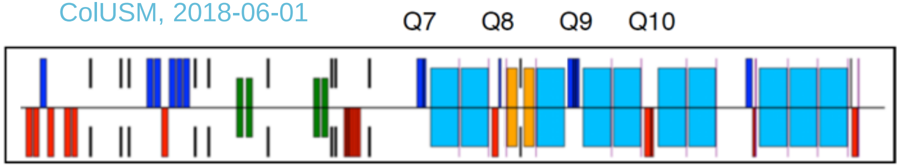
Total peak dose accumulated by the end of HL-LHC



Assuming 8.4 x 10^{16} protons lost in IR7 for the whole HL-LHC nominal operation

R. Garcia Alia, 7th HL-LHC Collaboration Meeting, 15/11/17

Courtesy of C. Bahamonde, ColUSM, 2018-06-01



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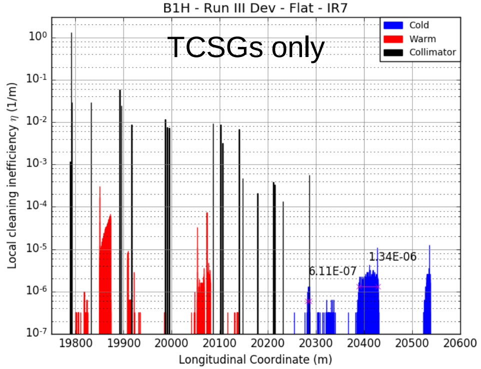
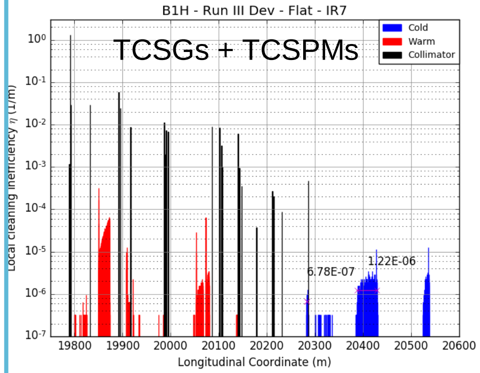
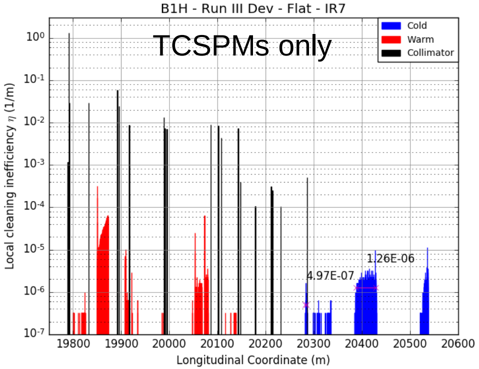


- Possibility to run with hybrid scenarios, where LHC secondary collimators and upgraded ones are used at the same time;
- Hybrid scenarios would allow to gain experience with new hardware;
- Limited effect on cleaning seen in simulations (Fluka-SixTrack coupling, candidate Run III flat collision optics, OP-2018-like collimator settings);





A.Mereghetti, HL-LHC Annual Meeting, 2018

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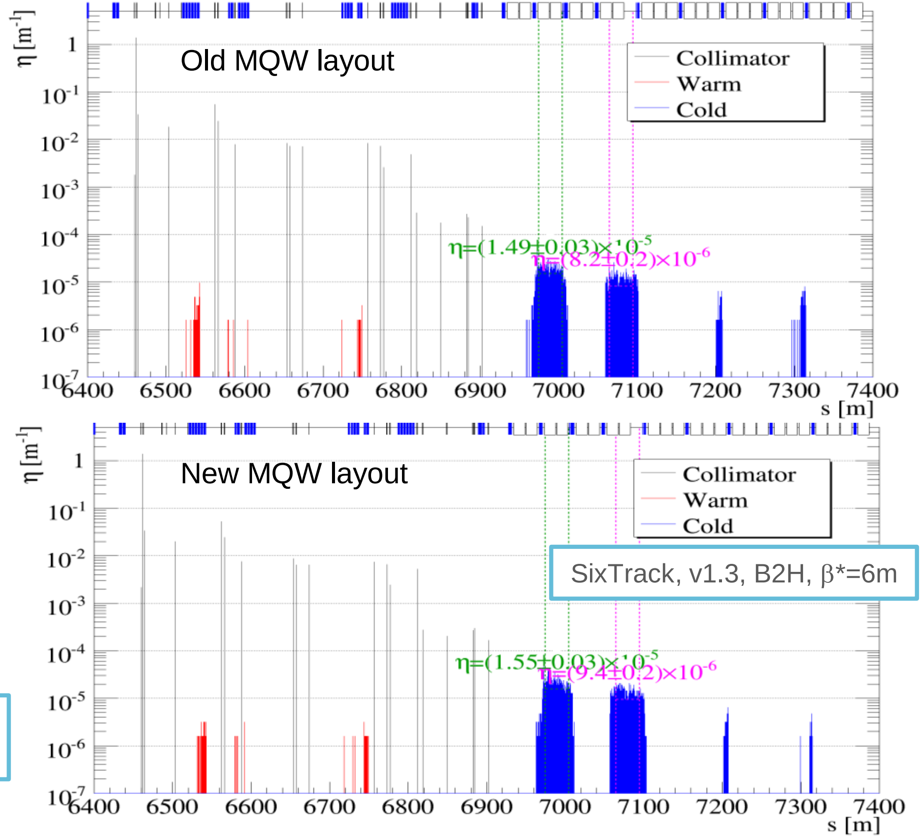
- Replacement of 2 out of 3 LHC primary collimators with upgraded ones (LHC-TC-EC-0016);
- Addition of 3 upgraded secondary collimators and replacement of the vertical LHC secondary collimator with the upgraded one (LHC-TC-EC-0014);
- Replacement of MQWA.E5x7 with appropriate shielding (LHC-TCAP-EC-0001):
  - Magnet will refurbish spares;
  - Shielding required to keep unchanged dose levels in downstream MQWA module;
  - Optics re-matched (R.Bruce, HSS section meeting, 6th Dec 2017);
- Installation of a DS collimator between 2 11T dipoles at the place of MBA.9 (LHC-TC-EC-0013);

Slight worsening of cleaning performance, but acceptable



R.Bruce, D.Mirarchi, HSS section meeting, 6th Dec 2017

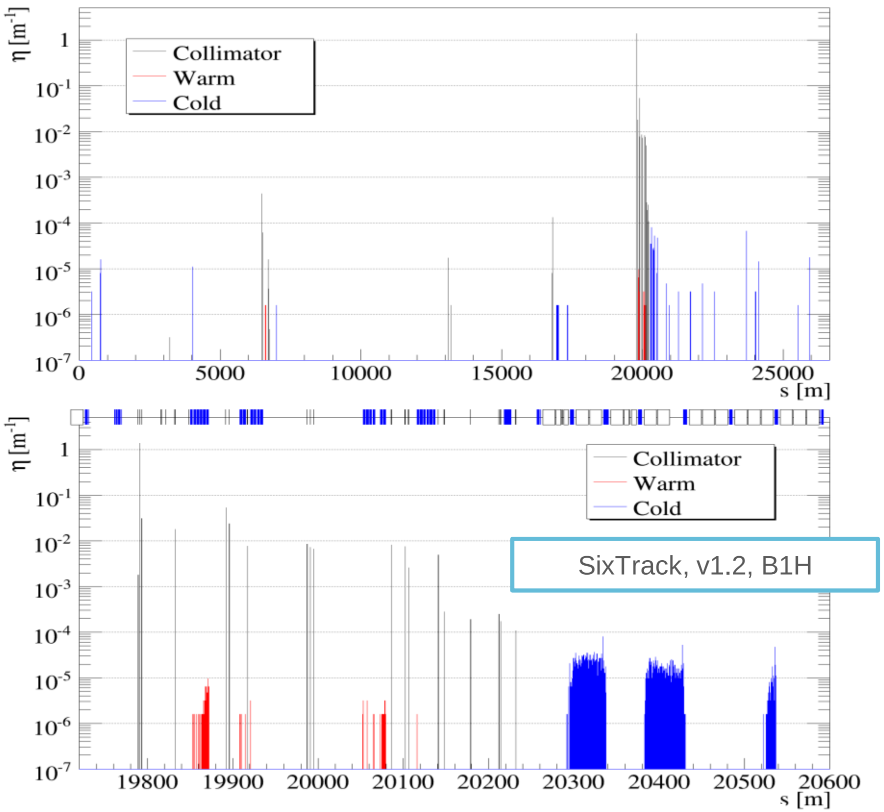
Changes in IR7 in LS2 and Layout in Run III

Hardware installation in IR7 during LS2 (per beam):

- Replacement of 2 out of 3 LHC primary collimators with upgraded ones (LHC-TC-EC-0016);
- Addition of 3 upgraded secondary collimators and replacement of the vertical LHC secondary collimator with the upgraded one (LHC-TC-EC-0014);
- Replacement of MQWA.E5x7 with appropriate shielding (LHC-TCAP-EC-0001):
  - Magnet will refurbish spares;
  - Shielding required to keep unchanged dose levels in downstream MQWA module;
  - Optics re-matched (R.Bruce, HSS section meeting, 6th Dec 2017);
- Installation of a DS collimator between 2 11T dipoles at the place of MBA.9 (LHC-TC-EC-0013);

Assessment of energy deposition in 11T magnet in presentation by A.Lechner

No TCLD



SixTrack, v1.2, B1H

D.Mirarchi, ColUSM meeting, 29th Sep 2017

Changes in IR7 in LS2 and Layout in Run III

Hardware installation in IR7 during LS2 (per beam):

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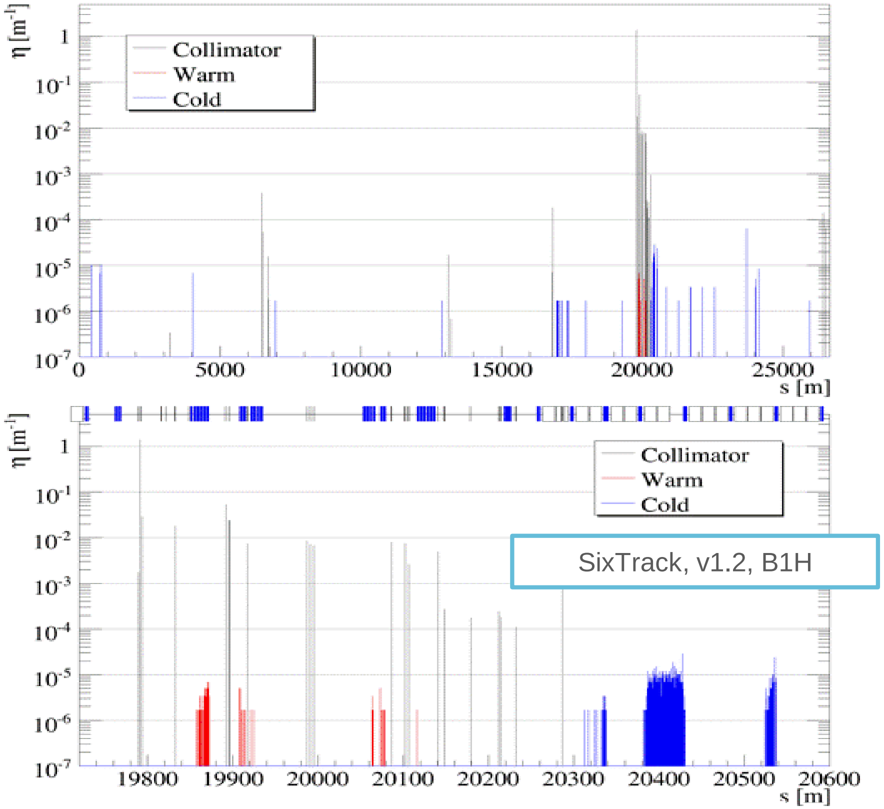
- Addition of 3 upgraded secondary collimators and replacement of the vertical LHC secondary collimator with the upgraded one (LHC-TC-EC-0014);
- Replacement of MQWA.E5x7 with appropriate shielding (LHC-TCAP-EC-0001):
  - Magnet will refurbish spares;
  - Shielding required to keep unchanged dose levels in downstream MQWA module;
  - Optics re-matched (R.Bruce, HSS section meeting, 6th Dec 2017);
- Installation of a DS collimator between 2 11T dipoles at the place of MBA.9 (LHC-TC-EC-0013);

Assessment of energy deposition in 11T magnet in presentation by A.Lechner

TCLD in MB.B8



SixTrack, v1.2, B1H

D.Mirarchi, ColUSM meeting, 29th Sep 2017

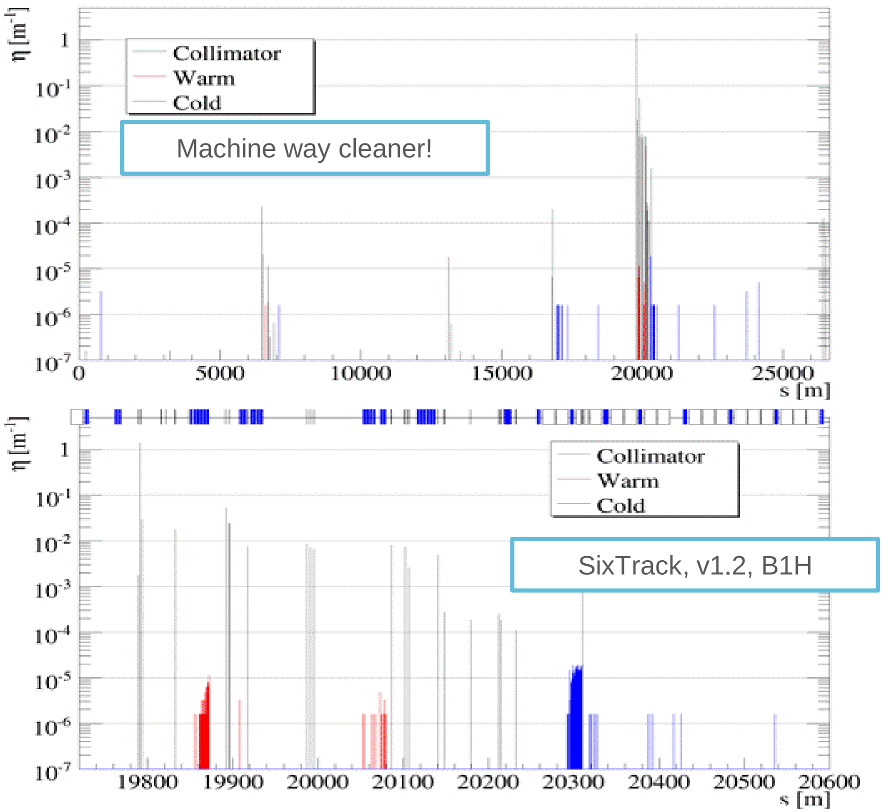
Changes in IR7 in LS2 and Layout in Run III

Hardware installation in IR7 during LS2 (per beam):

- Replacement of 2 out of 3 LHC primary collimators with upgraded ones (LHC-TC-EC-0016);
- Addition of 3 upgraded secondary collimators and replacement of the vertical LHC secondary collimator with the upgraded one (LHC-TC-EC-0014);
- Replacement of MQWA.E5x7 with appropriate shielding (LHC-TCAP-EC-0001):
  - Magnet will refurbish spares;
  - Shielding required to keep unchanged dose levels in downstream MQWA module;
  - Optics re-matched (R.Bruce, HSS section meeting, 6th Dec 2017);
- Installation of a DS collimator between 2 11T dipoles at the place of MBA.9 (LHC-TC-EC-0013);

Assessment of energy deposition in 11T magnet in presentation by A.Lechner

TCLD in MB.A9



D.Mirarchi, ColUSM meeting, 29th Sep 2017

Outline

- Introduction and highlights of IR7 Upgraded designs
- Upgraded prototypes in the LHC
- Collimator Beam Position Monitors and alignment
- Layout in Run III
- Conclusions

Conclusions

- Very good performance of upgraded hardware installed in the LHC during Run II;
  - It was important to verify with beam validity of new designs;
  - Confidence on expected good performance of upgraded designs;
- Collimator BPMs are a valuable tool for collimator alignment, orbit monitoring and beam position interlocks for machine protection;
  - Impressive improvements in alignment procedure, still BPMs offer more functionalities and an almost negligible alignment time;
- A good fraction of the upgraded hardware will be available already during Run III;
  - A start-up with hybrid settings will give opportunity to get acquainted to new hardware;
  - Relevant changes in IR7 addressed with simulations, though final assessment of performance requires stable versions of Run III optics (currently in production);

HiLumi HL-LHC PROJECT

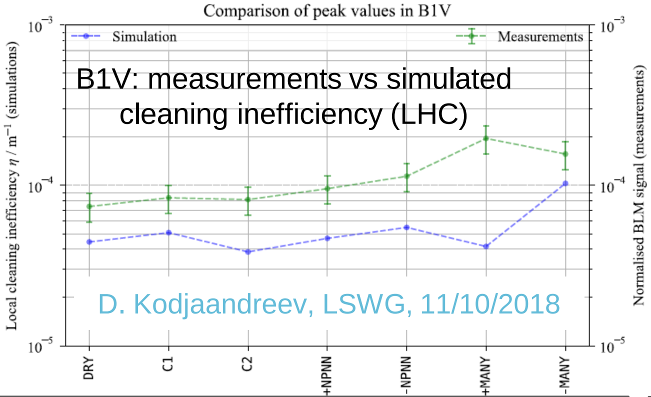
Thanks a lot!

CERN

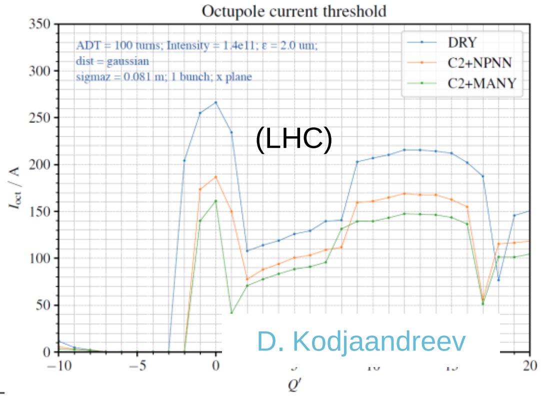
LHC Collimation Project CERN

Asymmetric Collimator Settings

- Impedance of collimation system is comfortably under control in Run III (N. Mounet, 5th Run III Config .WG meeting:
  - Partial IR7 collimator upgrade (4 TCSPMs/beam) introduces already 50% of gain from full upgrade (11 TCSPMs/beam);
  - CRDS with tele-index of ~2.5 enhances the octupole effectiveness;
  - Ok for pushed settings (as in 2018-OP) with beam brightnesses foreseen for Run III;
- In 2018, asymmetric collimator settings explored in simulations and MDs as a mean to further decrease collimator impedance at the expenses of limited worsening of cleaning inefficiency;



Measured inefficiency reasonably match expectations for B1, whereas discrepancies are found on B2;
→ To be understood;



Estimation of impedance reduction based on resistive wall term, dominant for LHC collimators;
→ To be refined, in view of Run III and (especially) HL-LHC, for having a final word;

- Considered asymmetric configurations (IR7):
  - TCPs (C1/C2);
  - The 4 TCSGs of the LS2 upgrade (NPNN/ANTI-);
  - Almost all IR7 TCSGs (MANY/ANTI-);

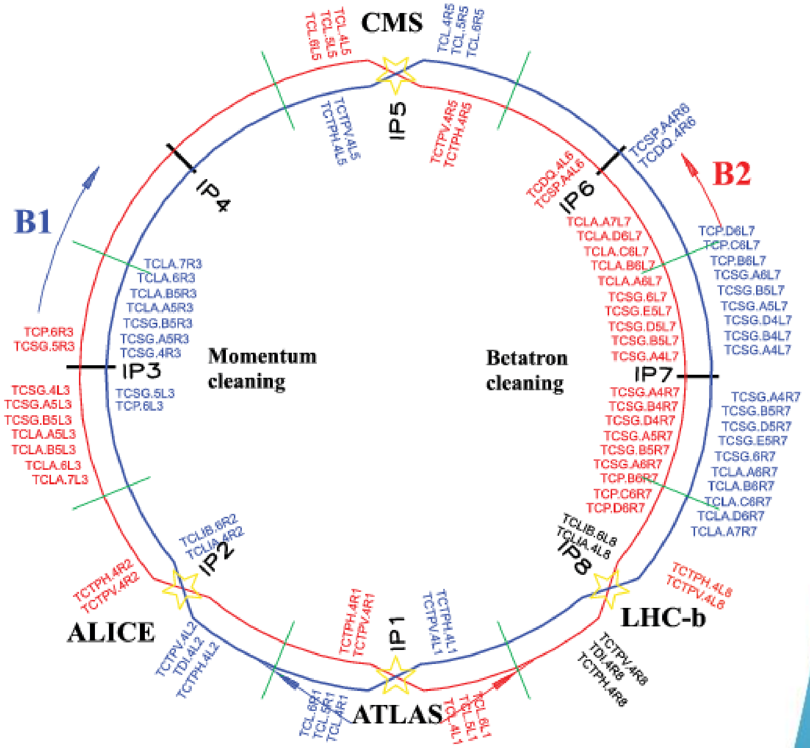
Overview of the Upgrade of the LHC Collimation System

- Partial HL-LHC Upgrade* (during LS2):
  - Exchange of 2 IR7 TCPs (60cm): from CFC to MoGr;
  - Addition/Exchange of 4 IR7 TCSs (1m): from CFC to Mo-coated MoGr;
  - A single module MBH(11T)+TCLD+MBH(11T) in IR7 (p+ions) and a single TCLD in IR2 (ions only);
  - Exchange MQWA.E5[L,R]7 with shielding (reduce dose to MQW coils and spacers);

- Run III

- Full HL-LHC Upgrade* (during LS3):
  - Exchange remaining TCSGs (7);
  - IR1/IR5 TCTPs (1m):
    - Cell 4: from Inermet180 to CuCD (4);
    - Cell 6: TCTPHs in CuCD (2) + re-use TCTPVs in Inermet180 (2);
  - New TCLs (6);

New design of TCTPH.4 and TCL.4, with two beams in same tank!



A good fraction of the HL-LHC collimation hardware already available in Run-III, for gaining experience with LIU Beams!

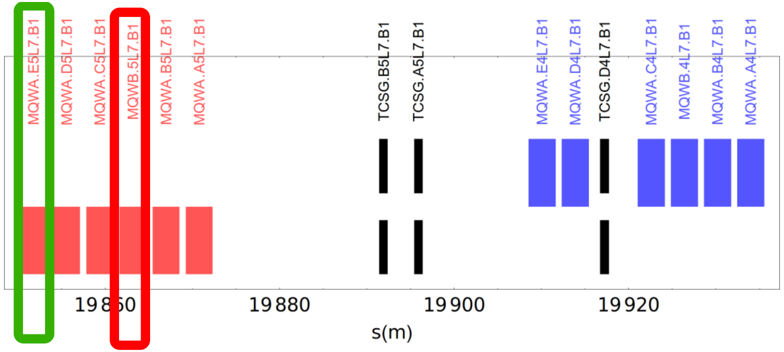
* Units are given ***per beam***.

Removal of MQWA.E5[L,R]7 and Installation of Shielding

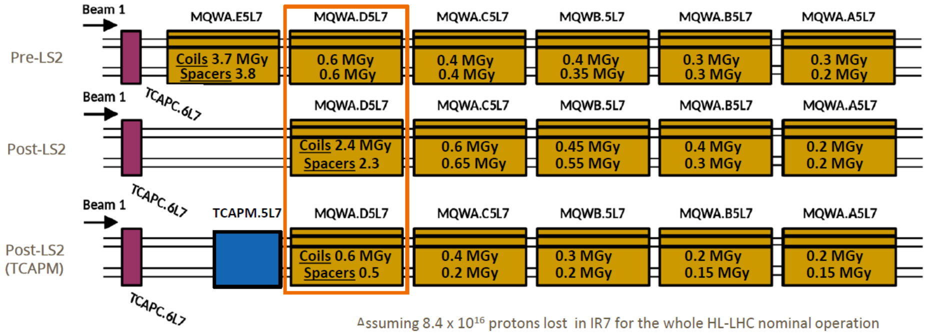
- Removal of MQWA.E5[L,R]7:
  - Module subject to highest load from IR7 losses (integrated dose);
  - Measurements and simulation campaign to estimate loads for present LHC and for HL-LHC (F.Cerutti and P.Fessia, HL-LHC TCC #14);
  - Proposal (P.Fessia et al): remove the module and propose solution to limit load on following module;
- New IR7 optics by R. Bruce (HSS Section Meeting, 12th Dec 2017):
  - MQWB.5 reconfigured as MQWA, in addition to MQWA module removal
  - Re-matching to arc optics;
  - Verification of cleaning performance (D. Mirarchi);

- Large simulation campaign (C.Bahamonde et al.), to propose shielding solutions – currently: tungsten masks at each magnet + iron shielding (2m);
- Final design presented by L. Gentini, ColUSM 31/08/2018;

Courtesy of R. Bruce, HSS section meeting (2017-12-06)



Total peak dose accumulated by the end of HL-LHC



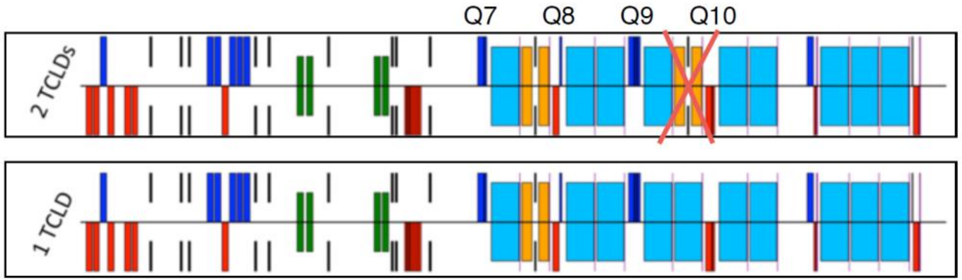
Assuming 8.4 x 10^{16} protons lost in IR7 for the whole HL-LHC nominal operation

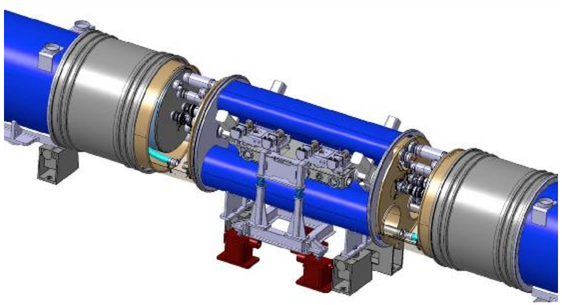
R. Garcia Alia, 7th HL-LHC Collaboration Meeting, 15/11/17

Courtesy of C. Bahamonde, ColUSM, 2018-06-01

TCLDs

- During LS2, it is planned to install a single module MBH(11T) + TCLD(Inermet180) + MBH(11T) in DS downstream of IR7 (protons / ions) per IR7 side:
  - Position currently considered: MB.B8x7 → Second unit (Q10) initially foreseen removed with 2016 re-baselining;
  - In IR2, only TCLD collimator in connection cryostat;





- Large simulation campaign (D.Mirarchi, P.D.Hermes, C.Bahamonde et al.), for optimizing position of TCLD package:
  - Cleaning performace (SixTrack);
  - Endep in magnets downstream of TCLD collimators (FLUKA):
    - Quench limit due to peak endep in SC coil;
    - Total endep in coils and cold bore tube (specific to 11T dipole);
    - Total power on cryogenics;

Input relevant for evaluations of cryogenics performance and adequacy to loss scenarios

Expected Performance in Run III – 2017

- Expected performance of IR7 in Run III already presented in HL-LHC annual meeting in 2017:
  - Comparative assessment of IR7 cleaning inefficiency for the four possible post-LS2 configurations considered for installation;
  - IR7 settings: 2σ-retraction (i.e. TCPs@5.7σ, TCSGs@7.7σ);
  - Optics: v1p3:
    - β*=15cm, no TCLD installed → max η(s) at IR7 DS1;
    - β*=6m, TCLD installed + removal of MQWA.E5[R,L]7 → max η(s) at IR7 DS2;

Simulated Scenario	None $[10^{-6}]$	C–1 $[10^{-6}]$	C–2 $[10^{-6}]$	C–3 $[10^{-6}]$	C–4 $[10^{-6}]$	post–LS3 $[10^{-6}]$
β^* =15 cm, B1H	6.19	5.77	6.38	6.11	5.73	6.23
β^* =15 cm, B1V	5.33	5.12	5.17	5.32	5.07	5.34
β^* =6 m, B1H	2.47	2.41	2.45	2.34	2.35	2.25
β^* =6 m, B1V	3.73	3.52	3.55	3.70	3.58	3.84

6.07±4%
5.23±2%
DS1

2.38±3%
3.65±3%
DS2

Very little impact on cleaning inefficiency from TCSPM installation layout for the same settings (as expected)

Expected Performance in Run III – 2018

- Present TCSPM installation foresees to actually replace only 1 TCSG (.D4[L,R]7) out of 4;
- The other 3 TCSPMs are added immediately downstream of respective TCSGs;
- It would be possible to run with TCSGs and installed TCSPMs at the same time or separately;

B1	B2	
TCSG.D4L7	TCSG.D4R7	*exchange*
TCSPM.B4L7	TCSPM.B4R7	*addition*
TCSPM.E5R7	TCSPM.E5L7	*addition*
TCSPM.6R7	TCSPM.6L7	*addition*

- Set of simulations aimed at assessing variations in cleaning performance if TCSPMs and/or TCSGs are used:
  - Studies focused on a first version of possible Run III optics, developed in the framework of the Run III Configuration WG;
  - Flat optics (50cm/15cm) considered – in MDs, found to be more challenging in terms of aperture margins;
  - 2018-like collimator settings (pushed performance) vs HL-LHC-like settings (more relaxed settings, especially on impedance);
  - CRDS beam process, i.e. telescope with tele-index at ~2.5 → increased effectiveness of octupoles in stabilizing the beam;
- Run III optics does not incorporate the new one of IR7;
  - Quick look also at HL-LHC v1p4, to focus mainly on new IR7 optics;

Simulation Settings

- optics:
  - Run III Flat (β*=50cm/15cm);
  - HL-LHC v1p4 (β*=15cm, with IR7 optics);
- 7 TeV, B1H / B1V only, 0.04σ halo;
- 2018 OP-like settings vs HL-LHC baseline;

New: aperture and offset directly from MADX when generating fort.2!
→ Preliminary results!

IR	Coll Family	HL-LHC [ε=2.5μm]	HL-LHC [ε=3.5μm]	2018 OP-like [ε=2.5μm]	2018 OP-like [ε=3.5μm]
IR7	TCP/TCS/TCLA/TCLD	6.7/9.1/12.7/16.6	5.7/7.7/10.7/14	5.9/7.7/11.8/16.6	5/6.5/10/14
IR3	TCP/TCS/TCLA	17.7/21.3/23.7	15/18/20	17.7/21.3/23.7	15/18/20
IR6	TCDQ/TCSP	10.1/10.1	8.5/8.5	8.6/8.6	7.3/7.3
IR1/5	TCT/TCL	10.4/14.2	8.8/12	9.5/17.7	8/15
IR2	TCT	43.8	37	35.5	30
IR8	TCT	17.7	15	35.5	30

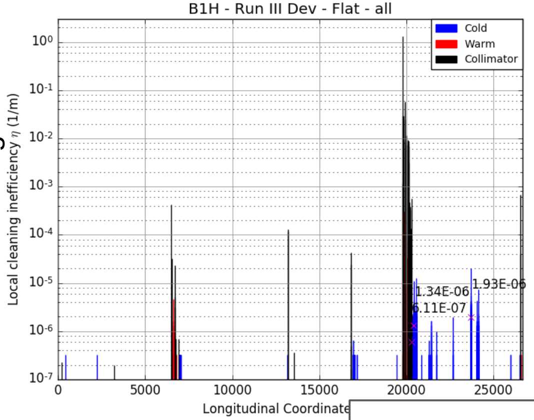
In 2018 operation we actually had: 8.5σ@30cm, 7.8σ@25cm

In 2018 operation we actually had: 37σ@IR2, 15σ@IR8

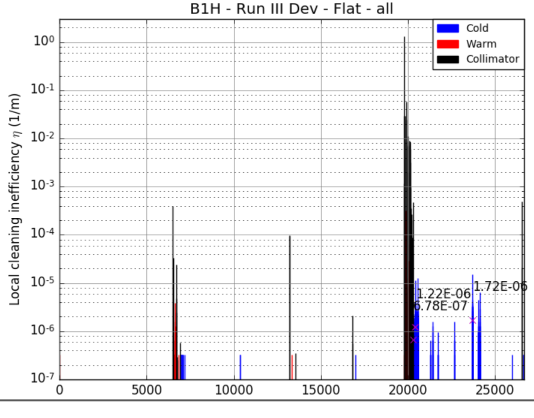
Results – LMs – Run III Flat, OP-2018 Like Settings, B1H

Entire ring

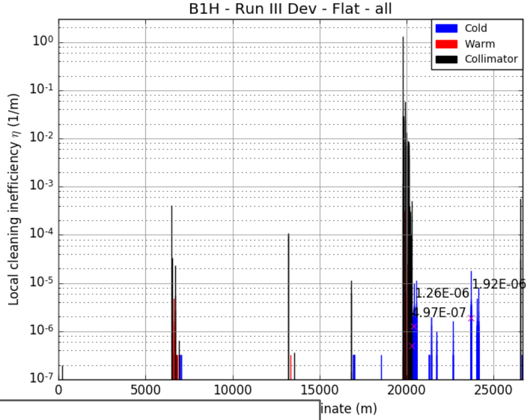
TCSGs only



TCSGs + TCSPMs

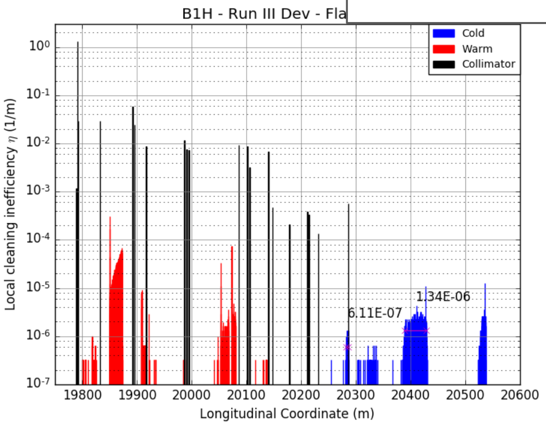


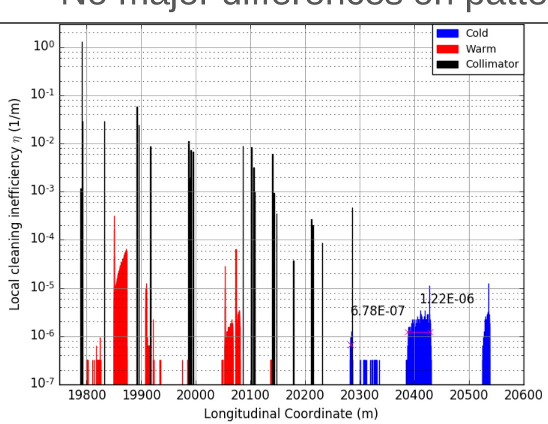
TCSPMs only

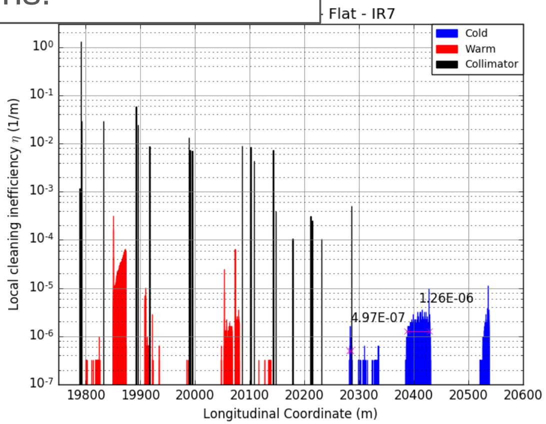


No major differences on patterns!

IR7 only



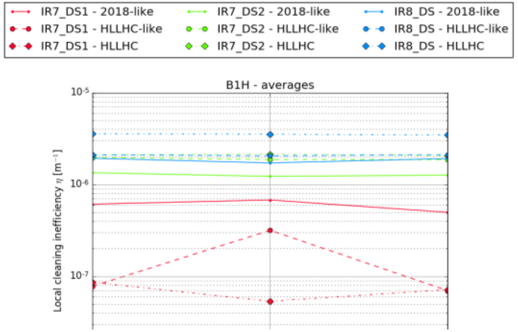




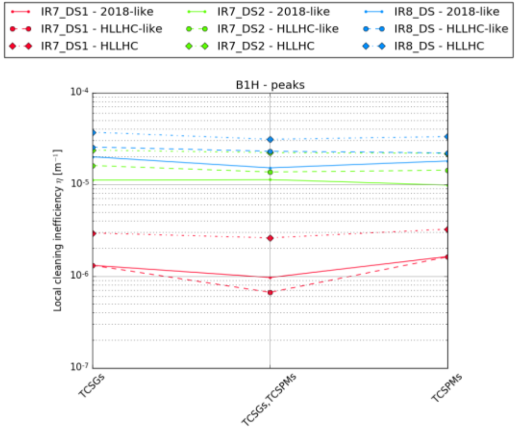
Results – Cleaning Inefficiencies

B1H

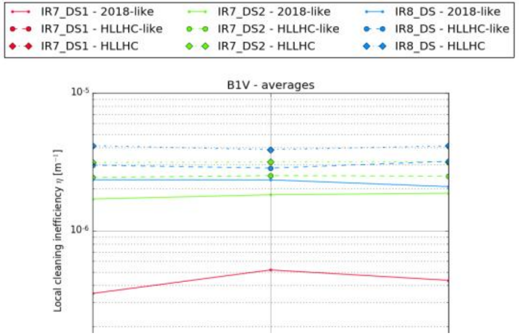
averages

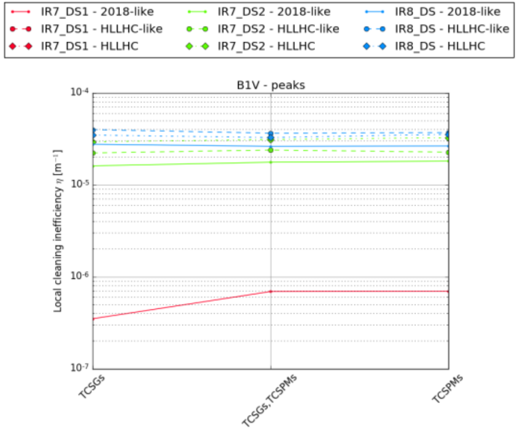


peaks



B1V





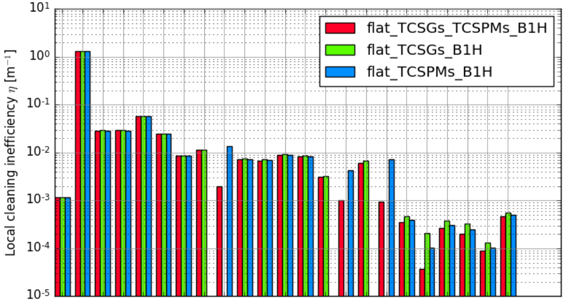
B1	B2	
TCSG.D4L7	TCSG.D4R7	*exchange*
TCSPM.B4L7	TCSPM.B4R7	*addition*
TCSPM.E5R7	TCSPM.E5L7	*addition*
TCSPM.6R7	TCSPM.6L7	*addition*

- 18 simulated cases:
  - TCSGs and TCSPMs vs only TCSGs vs only TCSPMs;
  - 2018-OP like settings vs HL-LHC settings;
  - B1H / B1V;
  - Run III Flat vs HL-LHC v1p4;
- Little variation in cleaning inefficiency when choosing between TCSGs and TCSPMs (as expected);
- Worse cleaning inefficiency with HL-LHC settings than with 2018-like settings (as expected);

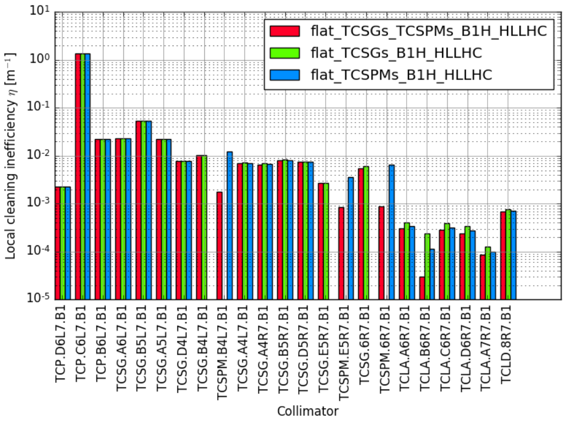
Results – Collimator Losses – B1H

Run III Flat optics

2018-OP like settings

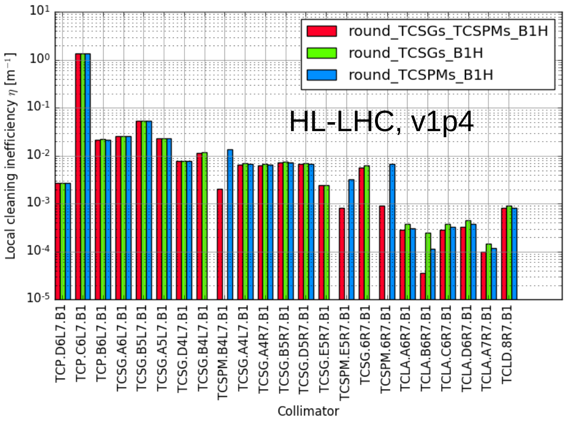


HL-LHC settings



B1	B2	
TCSG.D4L7	TCSG.D4R7	*exchange*
TCSPM.B4L7	TCSPM.B4R7	*addition*
TCSPM.E5R7	TCSPM.E5L7	*addition*
TCSPM.6R7	TCSPM.6L7	*addition*

- 18 simulated cases:
  - TCSGs and TCSPMs vs only TCSGs vs only TCSPMs;
  - 2018-OP like settings vs HL-LHC settings;
  - B1H / B1V;
  - Run III Flat vs HL-LHC v1p4;

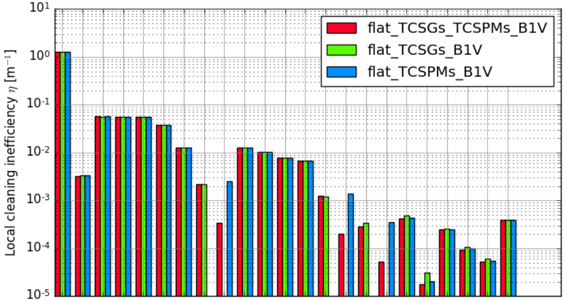


- TCSGs + TCSPMs:
  - TCSPMs in shadow of upstream TCSG;
  - Least load on TCLAs and TCLD;
- TCSGs only:
  - Highest load on TCLAs and TCLD;
- No major differences in patterns between 2018-OP-like and HL-LHC settings, or between Run III flat and HL-LHC v1p4;

Results – Collimator Losses – B1V

Run III Flat optics

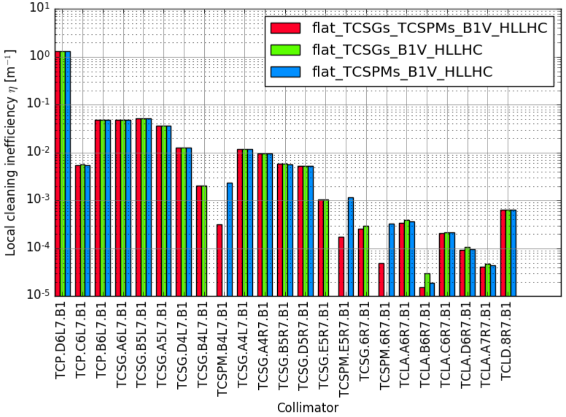
2018-OP like settings

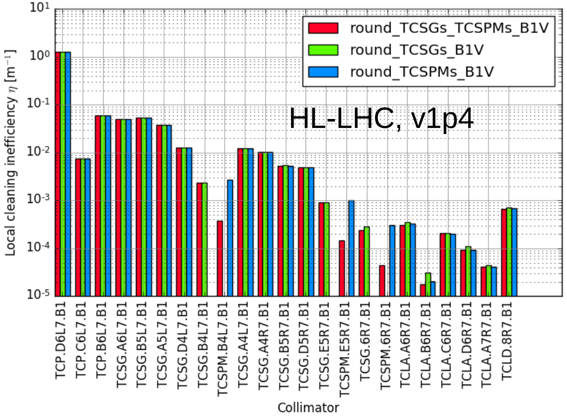


B1	B2	
TCSG.D4L7	TCSG.D4R7	*exchange*
TCSPM.B4L7	TCSPM.B4R7	*addition*
TCSPM.E5R7	TCSPM.E5L7	*addition*
TCSPM.6R7	TCSPM.6L7	*addition*

- 18 simulated cases:
  - TCSGs and TCSPMs vs only TCSGs vs only TCSPMs;
  - 2018-OP like settings vs HL-LHC settings;
  - B1H / B1V;
  - Run III Flat vs HL-LHC v1p4;

HL-LHC settings



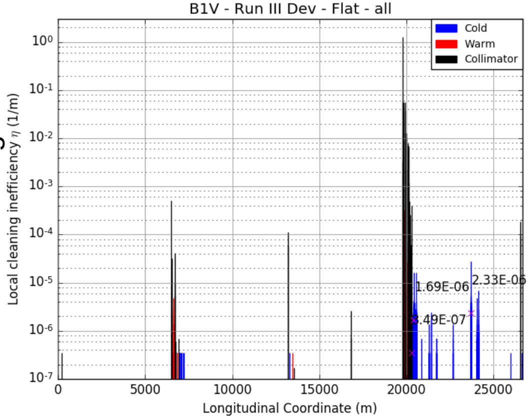


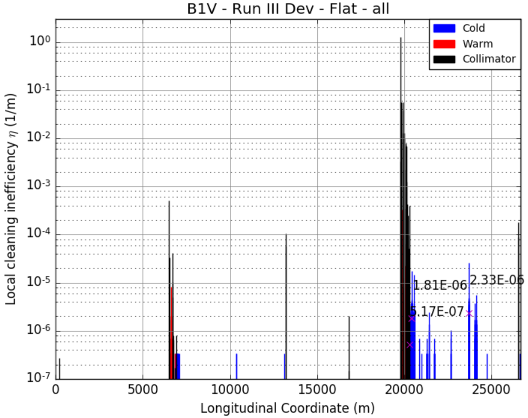
- TCSGs + TCSPMs:
  - TCSPMs in shadow of upstream TCSG;
  - Least load on TCLAs and TCLD;
- TCSGs only:
  - Highest load on TCLAs and TCLD;
- No major differences in patterns between 2018-OP-like and HL-LHC settings, or between Run III flat and HL-LHC v1p4;

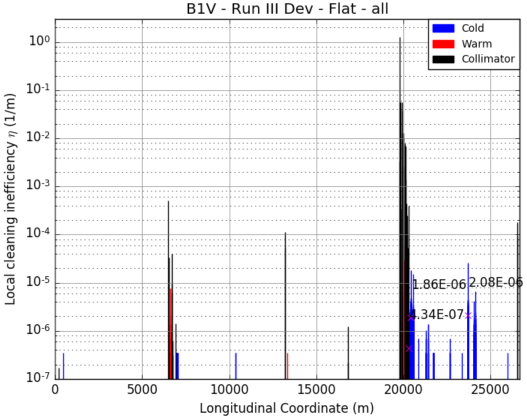
Results – LMs – Run III Flat, OP-2018 Like Settings, B1V

TCSGs only | TCSGs + TCSPMs | TCSPMs only

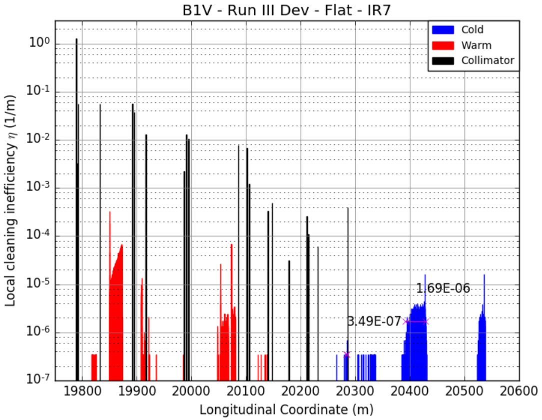
Entire ring

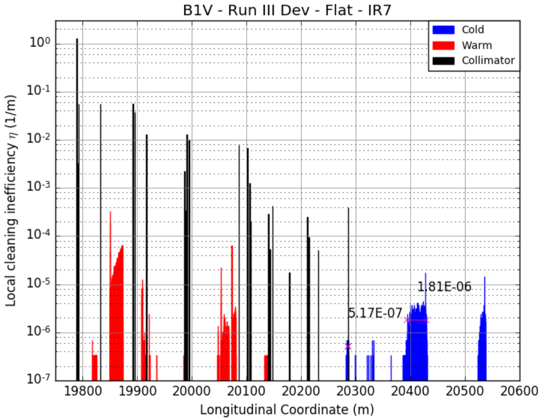


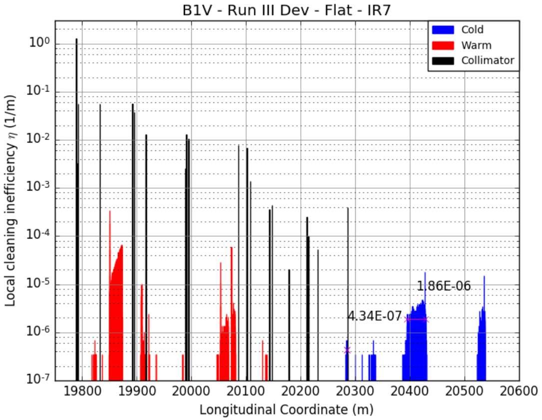




IR7 only

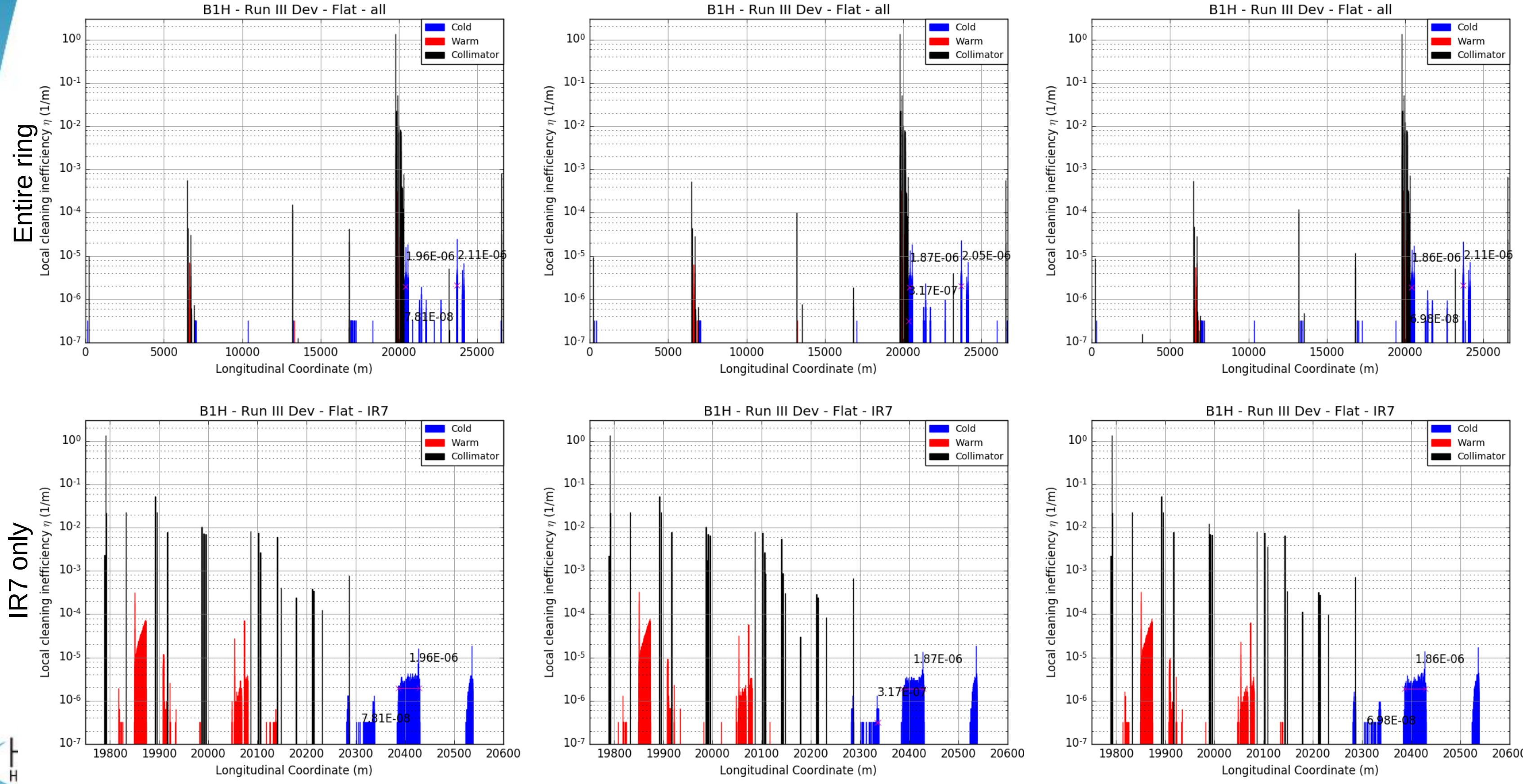




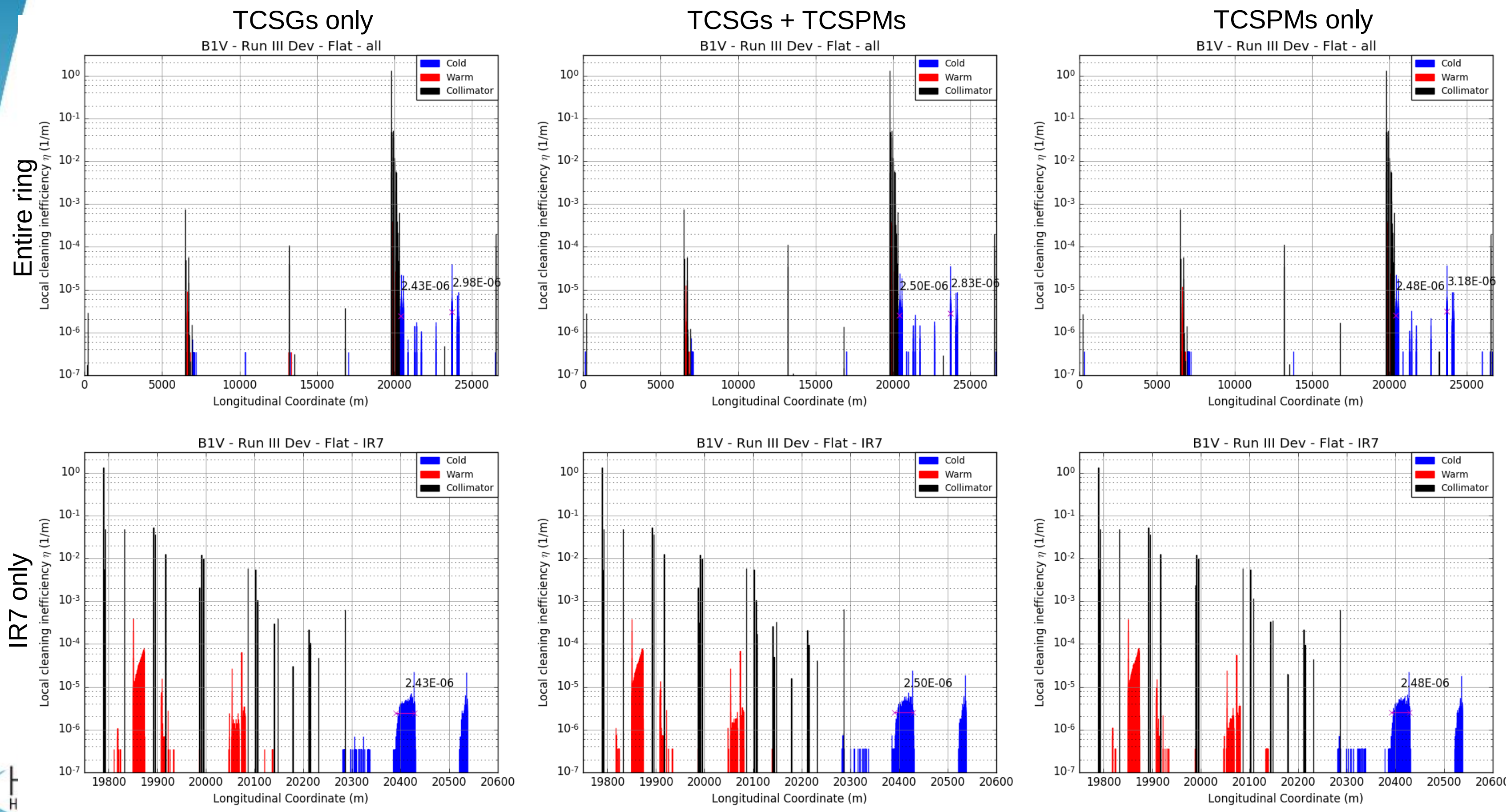


Results – LMs – Run III Flat, HL-LHC Settings, B1H

TCSGs only | TCSGs + TCSPMs | TCSPMs only



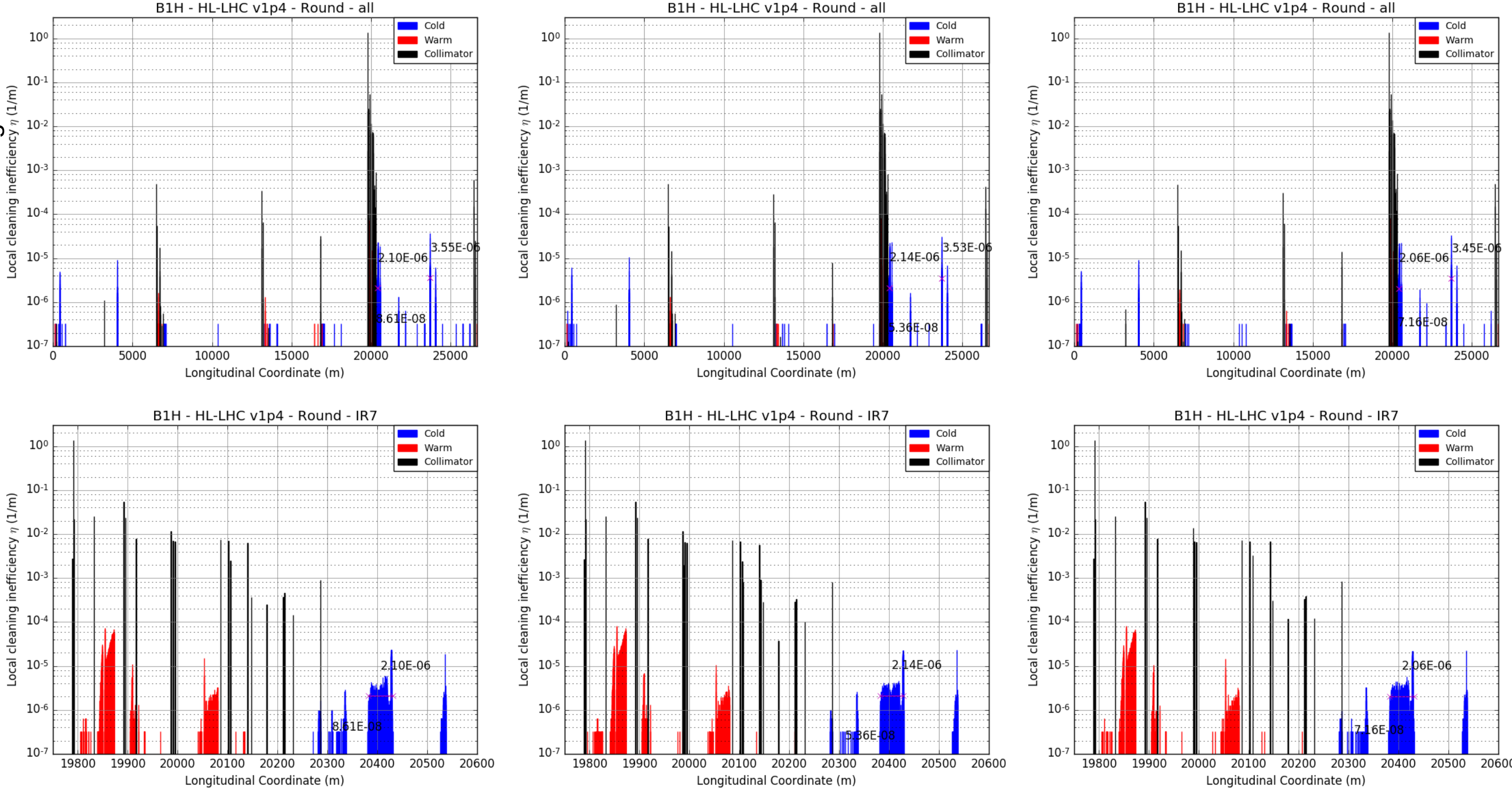
Results – LMs – Run III Flat, HL-LHC Settings, B1V



Results – LMs – HL-LHC v1p4, B1H

TCSGs only | TCSGs + TCSPMs | TCSPMs only

Entire ring / IR7 only



Results – LMs – HL-LHC v1p4, B1V