24th US-LARP Collaboration Meeting - CM24
May 11th-13th, 2015
Fermi National Accelerator Laboratory, Batavia, IL, USA

Update on HL-LHC collimation layouts

Stefano Redaelli, CERN, BE-ABP
on behalf of the LHC collimation project and HL-WP5

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

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- Introduction
- LHC collimation in Run II
- Upgrade baseline and options
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- Conclusions

LHC collimation - main roles

- **Halo cleaning** versus quench limits
  Main design driver of the system - 362MJ vs ~20mW/cm³
- Passive **machine protection**
  First line of defense in case of accidental failures.
- **Cleaning of physics debris**
  Avoid magnet quenches in the high-luminosity points
- Optimize **background** in the experiments
  Minimize the impact of halo losses on quality of experimental data
- **Reduce total doses** to accelerator equipment and **concentration of beam losses** in dedicated warm areas
  Provide local protection to equipment and easy maintenance
- Beam tail/halo **scraping**, **halo diagnostics**
  Control and probe the transverse or longitudinal shape of the beam

Collimation system for LHC RunII

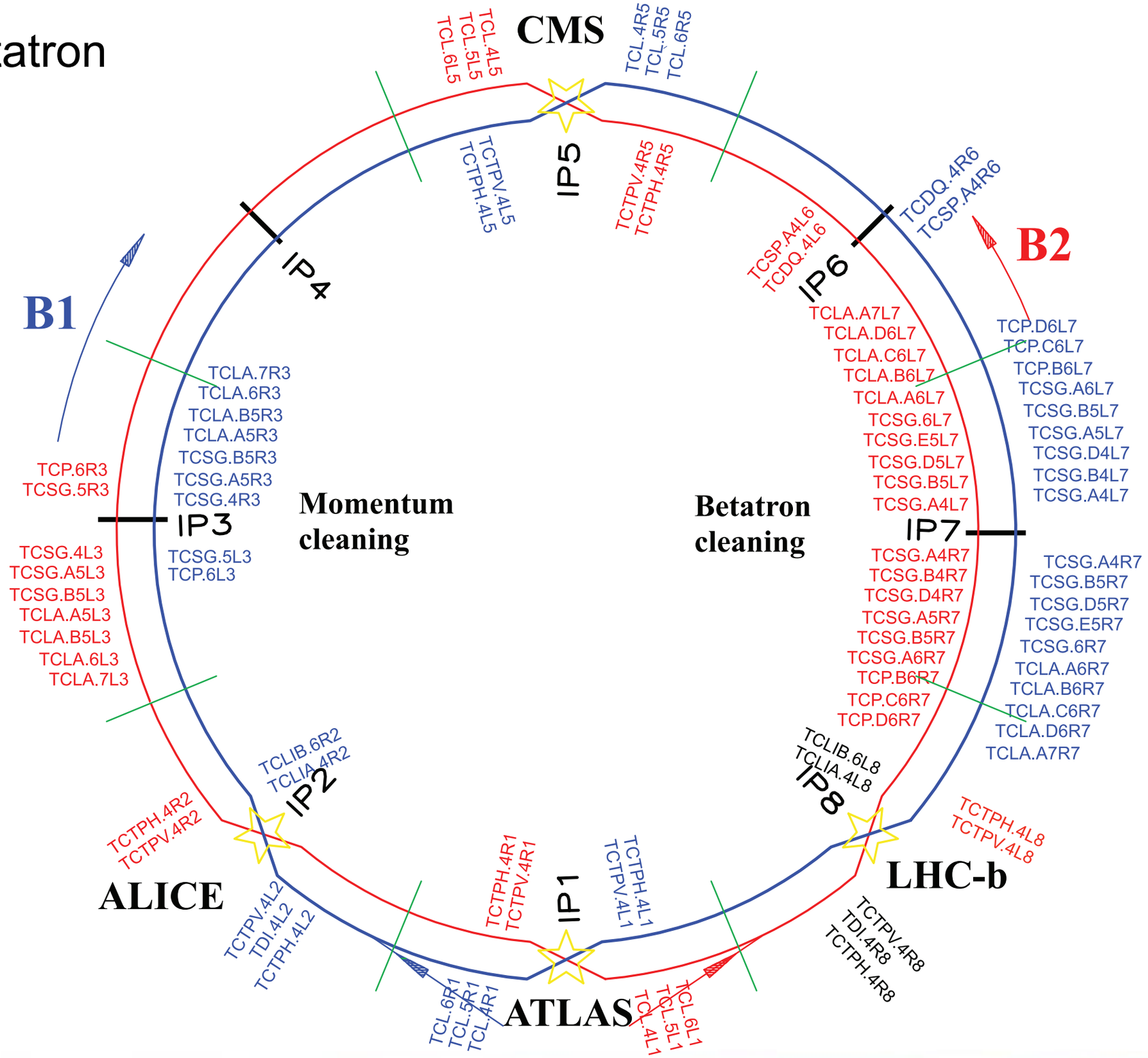
Dedicated insertions for betatron (IR7) and momentum (IR3) cleaning systems.

Cleaning of incoming beam in all experiments.

Physics debris collimation in the high-lumi IR1/5.

32 collimators in the machine, i.e. 30% of the system!

Total of 118 [was 108] **collimators (108** [was 100] **movable).**



Collimation upgrades in LS1

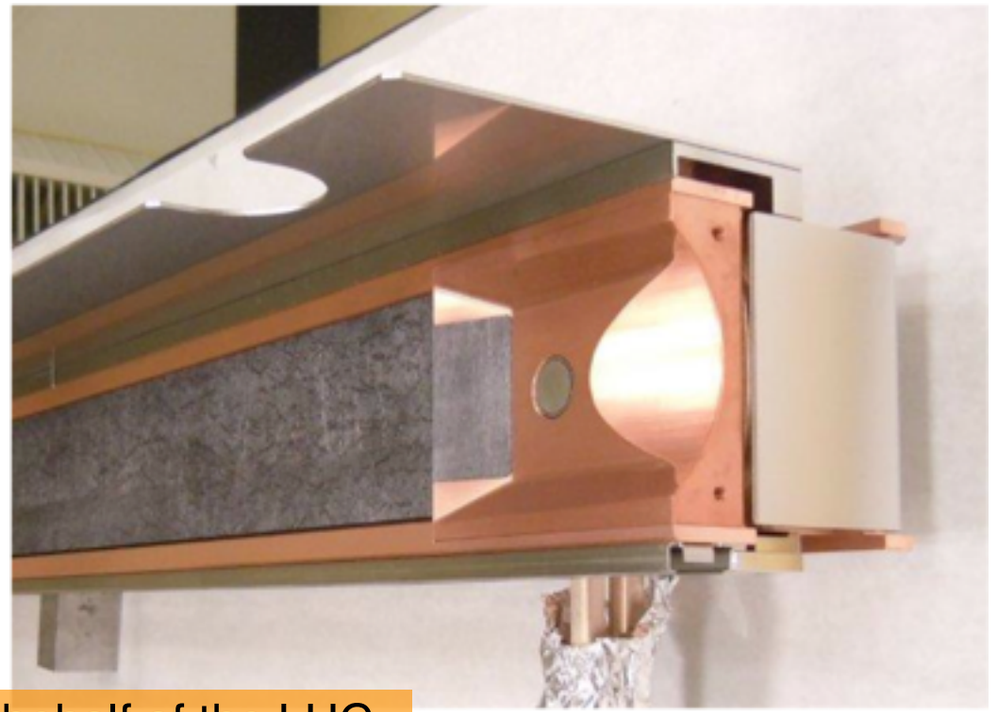
First important upgrades of the system started in the first LHC Long Shutdown (LS1):

1) **Collimators with in-jaw BPMs for experiments + dump regions (18 units).**
2) **New layout for physics debris collimation in ATLAS/CMS**.
3) Improved warm magnet shielding in the momentum cleaning (IR3).
4) Survey/maintenance.

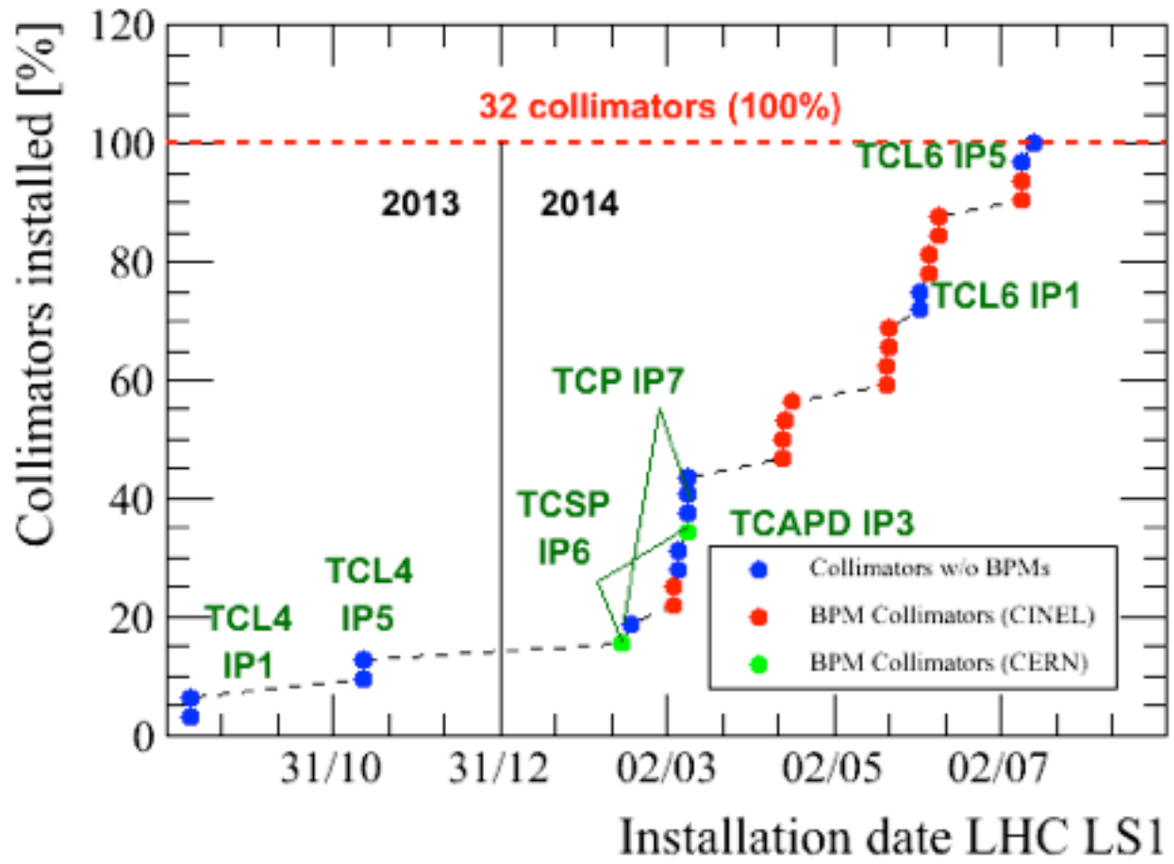
Work relevant for the future upgrades:

5) Preparation of layout slots for future upgrades (low-impedance).
6) Installation of a **crystal collimation** test stand in IR7.
7) Preparation for the installation of the SLAC rotatable collimator in the SPS (planned in June).

BPM collimators (i)



On behalf of the LHC collimation project team



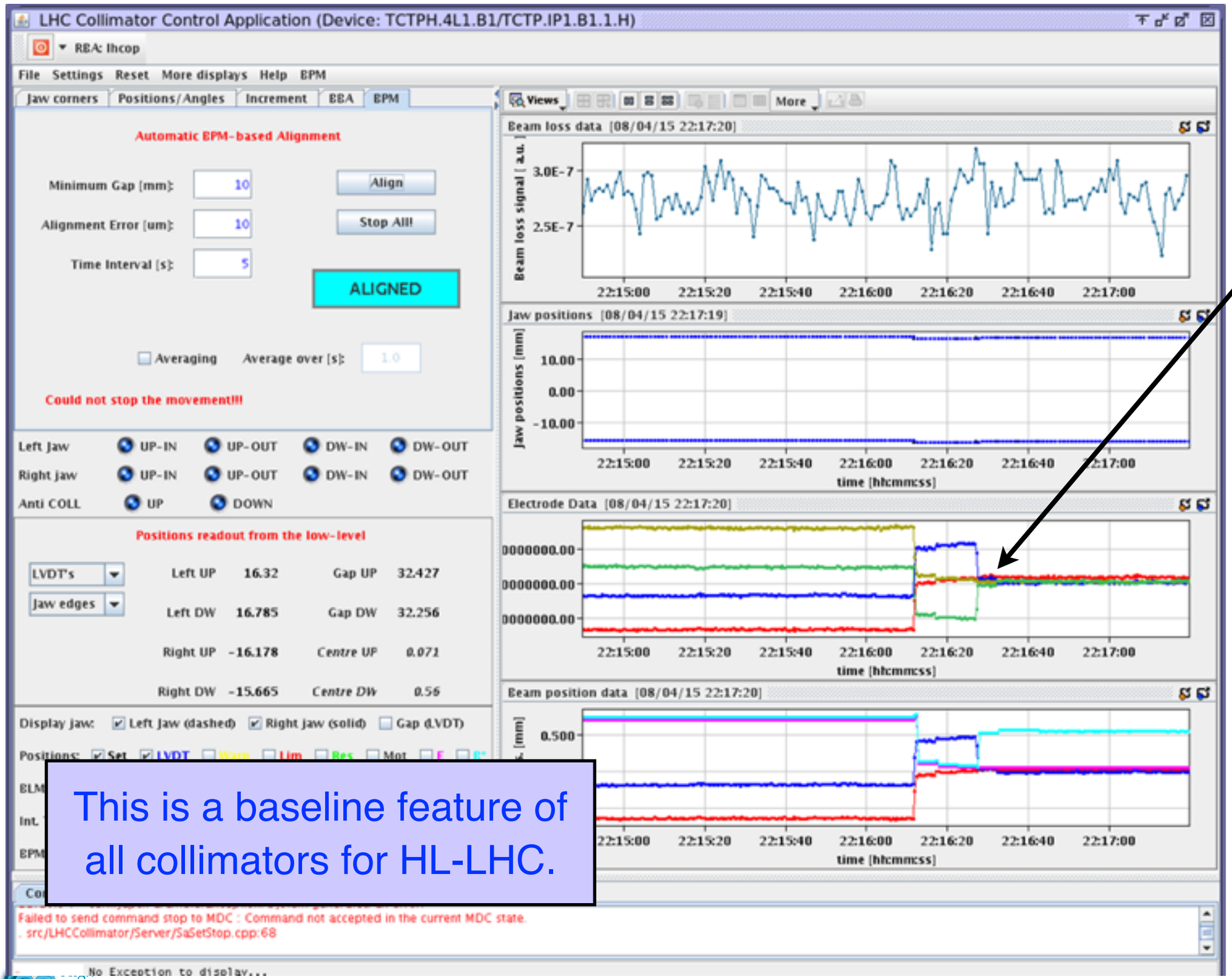
The production was a great success as all the units were installed.

A hiccup: one TCT in IR8 replaced by a spare (torque problem).

Unfortunately, we have <u>delays</u> with the production of the BPM electronics units so only IP1 is equipped.

Full system expected to be ready in June for the first tech. stop.

BPM collimators (ii)



This is a baseline feature of all collimators for HL-LHC.

Equalized electrode signals, then cross checked against standard BLM-based alignment.

Looks OK: LHC collimator aligned in 10s!

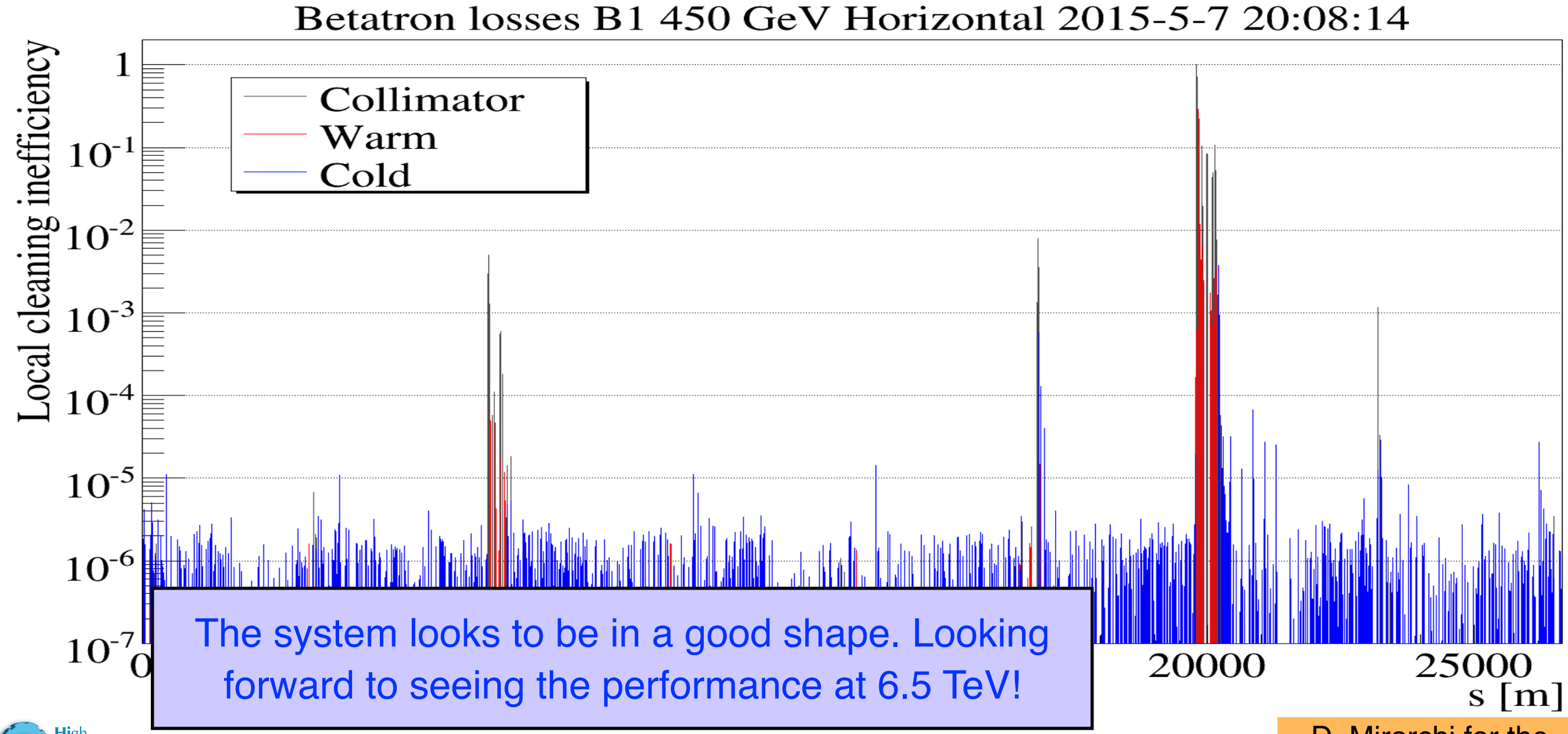
G. Valentino + LHC BI

Status of beam commissioning

Completed alignment of the system at injection and validated.

"Coarse" collimation setup at 6.5TeV during beam commissioning.

First 6.5TeV alignment scheduled for this week!



The system looks to be in a good shape. Looking forward to seeing the performance at 6.5 TeV!

CERN plans for the SLAC RC

Timeline

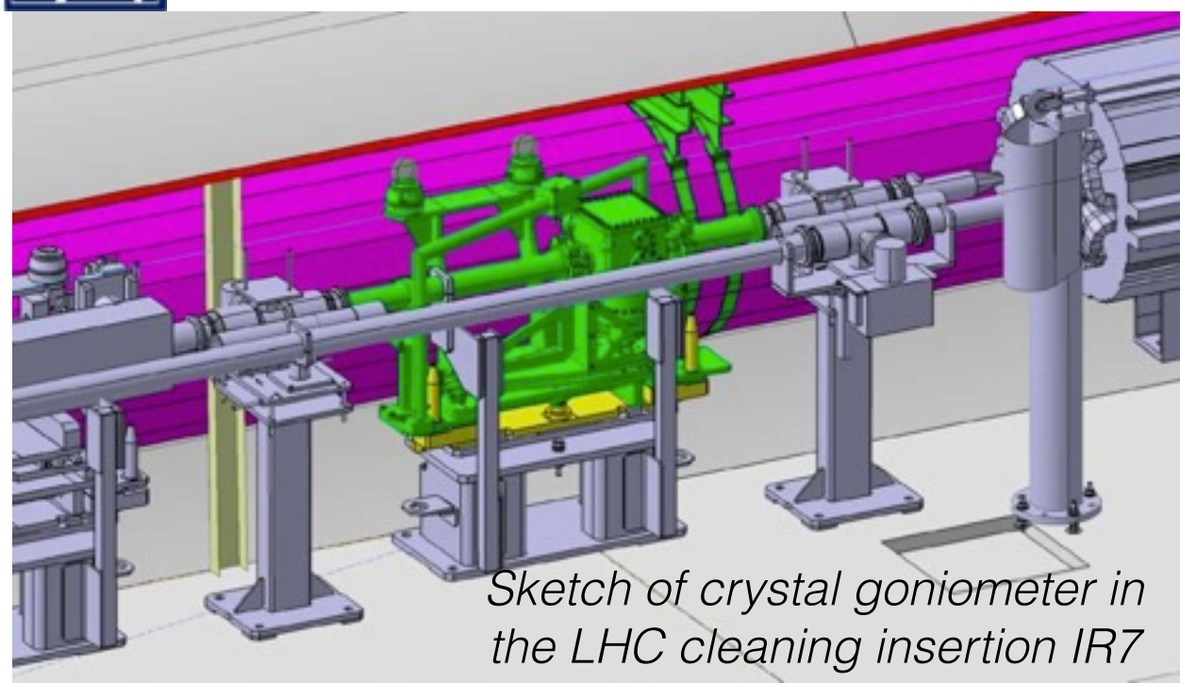
15th Sep 2014 Third and final set of jaw movement tests
15th Aug 2014 End of bakeout, incl. jaw movement tests under vacuum
22nd Jul 2014 Start of vacuum bakeout
22nd Apr 2014 Controls tests (torque measurements, LVDT calibration, rotation
20th Mar 2014 Start of wire impedance tests
11th Mar 2014 First jaw movement tests made
05th Mar 2014 SLAC collimator passed first leakage test
12th Feb 2014 SLAC collimator tank opened
27th Nov 2013 Arrival of SLAC rotatable collimator at CERN!

The rotatable collimator prototype was tested at CERN against our standard criteria for machine readiness.

Vacuum ok for LHC and SPS. Mechanical system works as expected.
Impedance compatible with operation SPS in 2015, before upgrades.

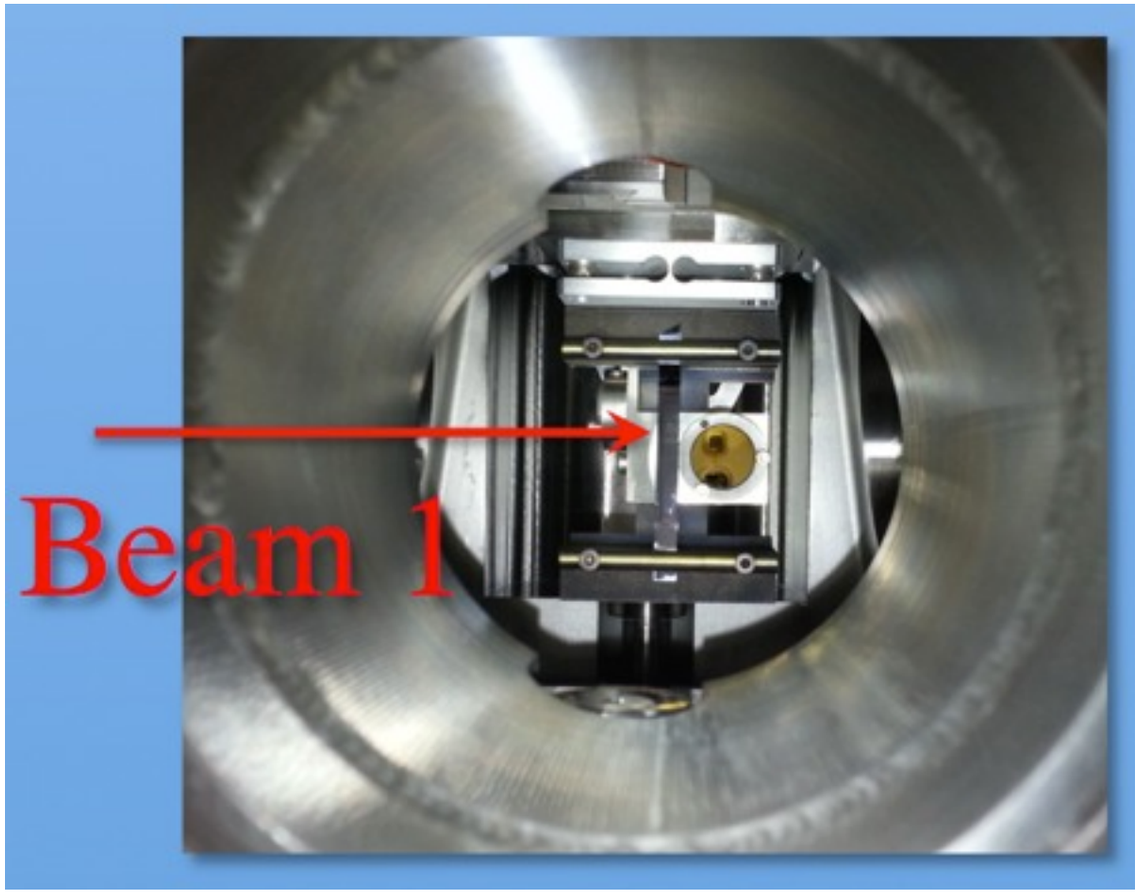
Beam test strategy: SPS beam tests in 2015 (as of June)
"Destructive" HiRadMat experiment in 2016

Crystal collimation test stand in IR7



Sketch of crystal goniometer in the LHC cleaning insertion IR7

Two bent crystal installed in IR7 for horizontal and vertical collimation tests.
Requested beam time in 2015 for first test at low intensity!



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Collimation challenges at HL-LHC

- ☑ Increased beam stored energy: 362MJ → 700MJ at 7 TeV

  Collimation cleaning *versus quench limits of superconducting magnets.*

  Protection constraints from ***beam tails*** *(7 MJ above 3 sigmas for a Gaussian!)*

- ☑ Larger bunch intensity (lb=2.3x10^{11}p) in smaller emittance (2.0 μm)

  Collimation impedance *versus beam stability.*

  Collimator robustness *against beam failures at injection and top energy.*

- ☑ Larger p-p luminosity (1.0 x 10^{34}cm^{-2}s^{-1} → 5.0-7.5 x 10^{34}cm^{-2}s^{-1})

  More challenging ***collimation of physics debris****.*

- ☑ Much smaller β^* in the collision points (55 cm → 15 cm)

  Cleaning *and* ***protection*** *of high-luminosity insertions; experiment* ***background****.*

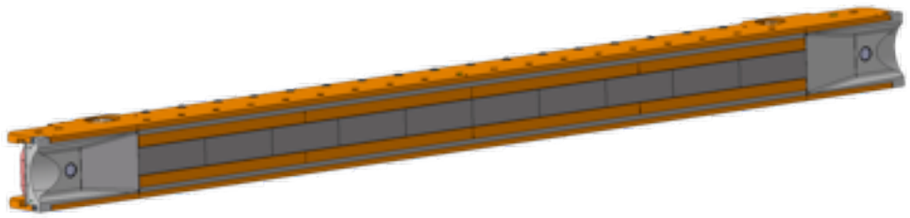
- ☑ Operational efficiency is critical for HL-LHC!

  Collimators: high precision devices that must work in high radiation environment.

- ☑ Upgraded ion performance (6 x 10^{27}cm^{-2}s^{-1}, i.e. 6 x nominal)

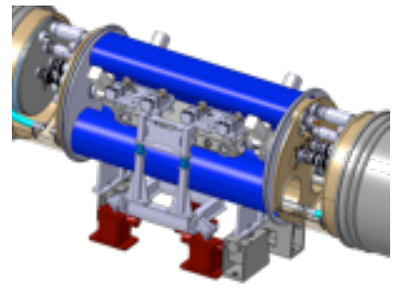
Baseline upgrades

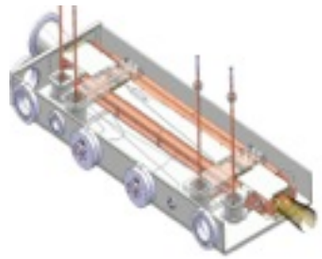
IR1+IR5:
4 tertiary collimators per beam
3 physics debris absorbers
Completely new layouts!
Novel collimator materials.

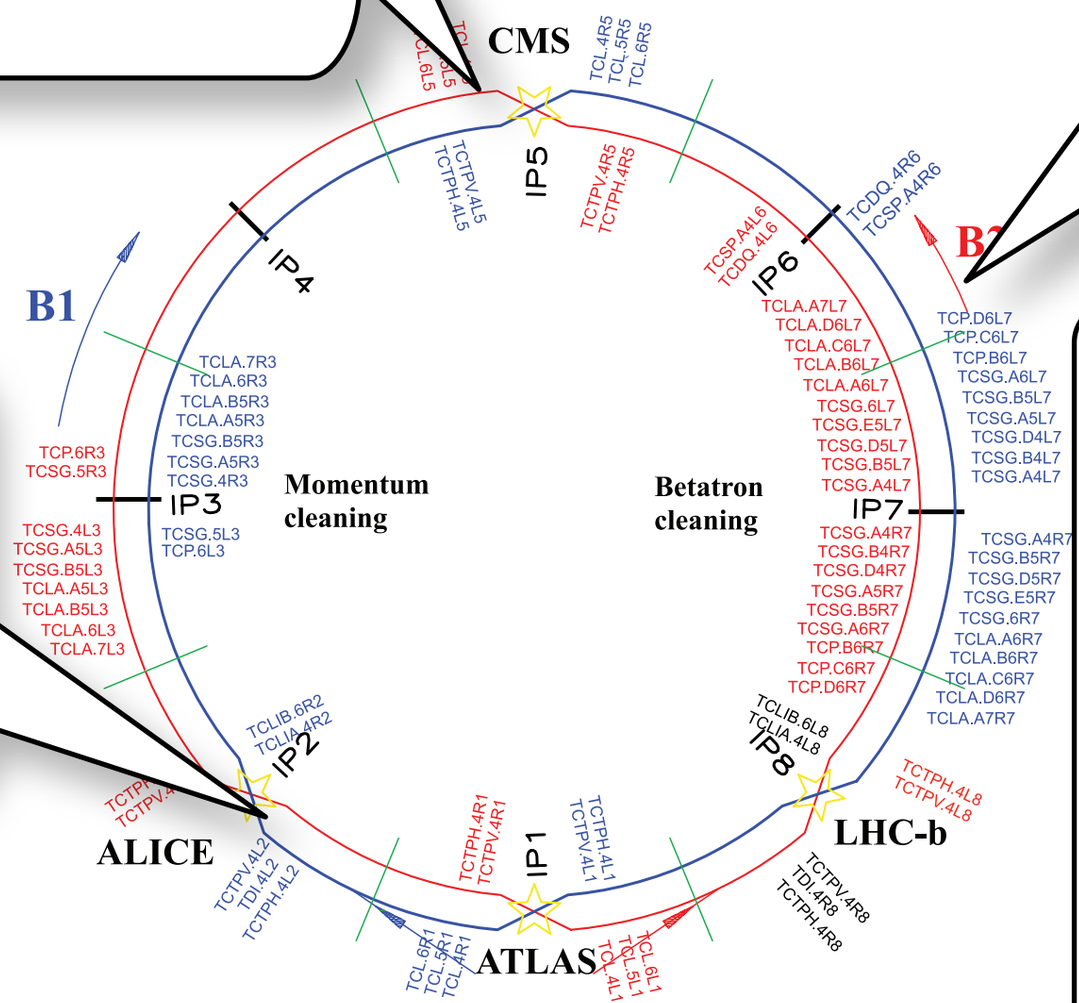


Final decision on installation to be taken based on Run 2 experience

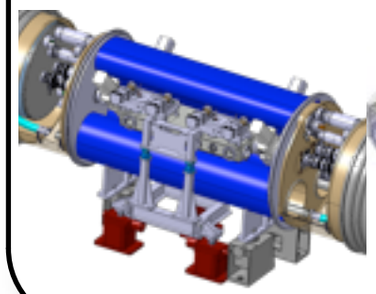
Cleaning: DS coll. + 11T dipoles, 2 units per beam

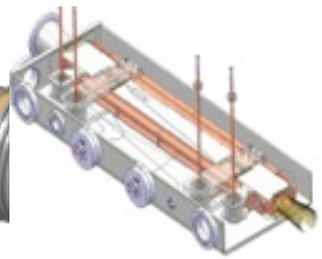




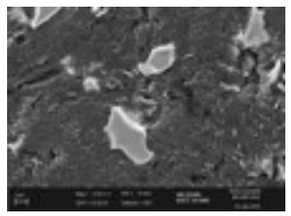


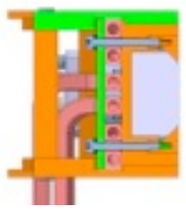
Ion physics debris:
DS coll. + 11T dipoles

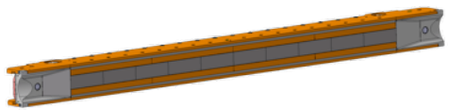




Advanced materials:
Better TCT robustness
Better impedance in IR7

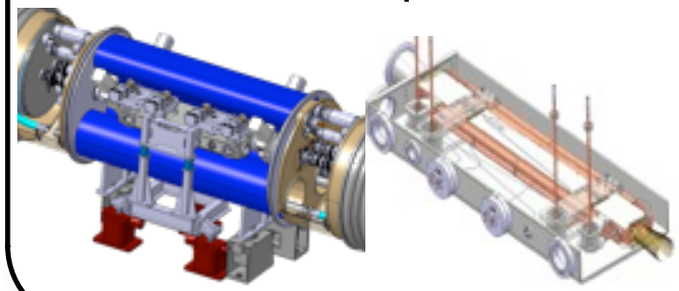




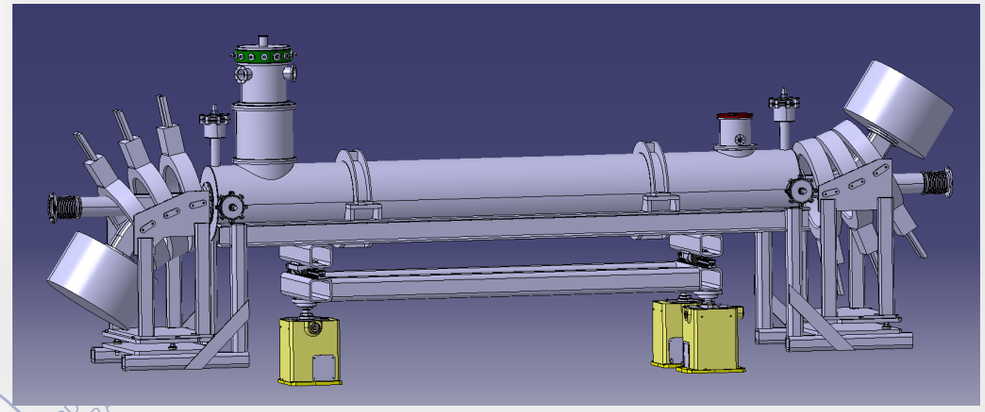


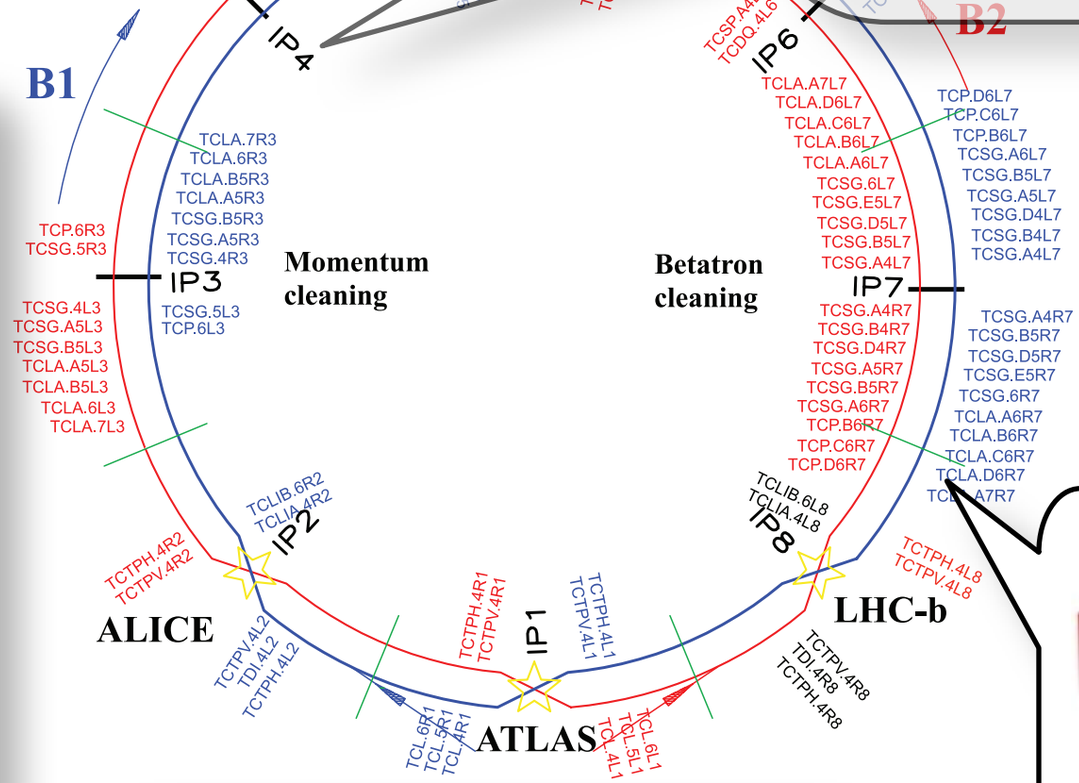
Non-baseline upgrades

ATLAS/CMS physics debris:
DS coll. + 11T dipoles

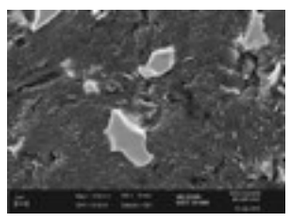


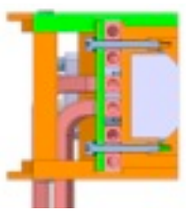
Hollow e-lenses for cleaning

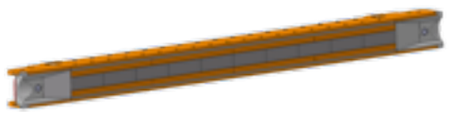




Advanced materials in IR3:
low-impedance secondaries

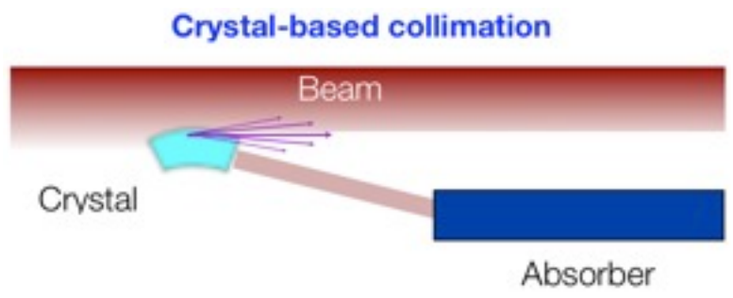




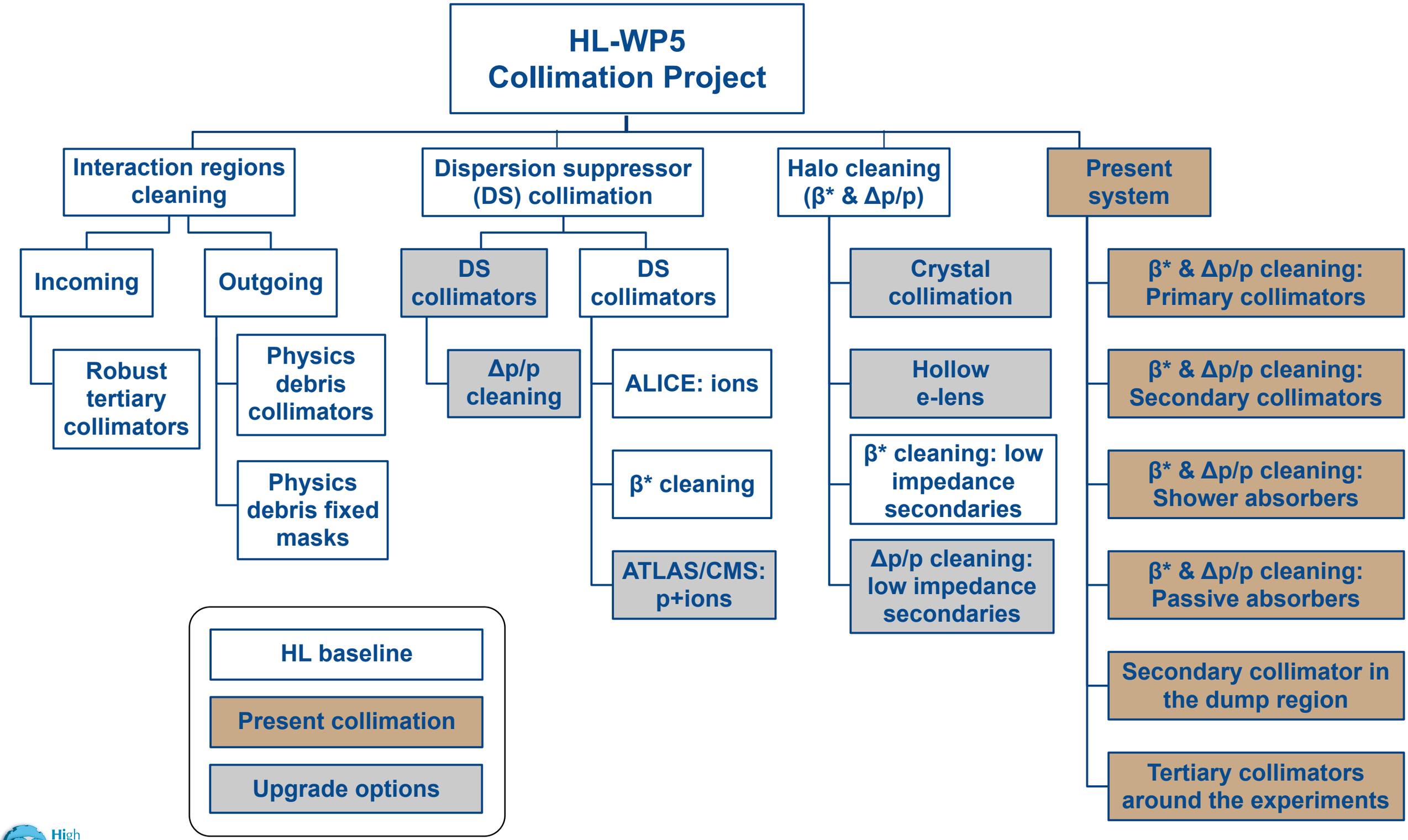


Advanced materials more robust tertiary collimators in low-luminosity points 2 / 8.

R&D fully funded, actual implementation not baseline



Project upgrade structure



Conceptual Functional Specifications

Draft Conceptual Functional Specifications for the HL-LHC collimation upgrade

We collect here the working drafts of the **functional specification documents** for the collimation upgrades within HL-LHC.

Dispersion suppressor collimators: TCLD collimators around IR2	DOCX	PDF	official EDMS link (Doc. 1366517)
Dispersion suppressor collimators: TCLD collimators around IR7	DOCX	PDF	official EDMS link (Doc. 1366519)
Dispersion suppressor collimators: TCLD collimators around IR1/5	DOCX	PDF	official EDMS link (Doc. 1366520)
Improved secondary collimators in cleaning insertions: TCSPM collimators in IR3/7	DOCX	PDF	official EDMS link (Doc. 1393878)
Improved tertiary collimators in experiment insertions: TCTPM collimators in IR1/2/5/8	DOCX	PDF	official EDMS link (Doc. 1393893)
Physics debris collimation: TCL collimators in IR1/5	DOCX	PDF	official EDMS link (Doc. 1366522)
Physics debris collimation: TCLM masks in IR1/5	DOCX	PDF	official EDMS link (Doc. 1393868)
Hollow electron lenses for active halo cleaning	DOCX	PDF	official EDMS link (Doc. 1366525)
Crystal collimation MD at the LHC	DOCX	PDF	official EDMS link (Doc. 1366524)

LHC primary collimators in IR3 and IR7 (TCP, TCPP)	DOCX	PDF	official EDMS link (Doc. xxx)
LHC secondary collimators in IR3 and IR7 (TCSG)	DOCX	PDF	official EDMS link (Doc. xxx)
LHC shower absorber collimators in IR3 and IR7 (TCLA)	DOCX	PDF	official EDMS link (Doc. xxx)
LHC passive absorbers collimators in IR3 and IR7 (TCAP)	DOCX	PDF	official EDMS link (Doc. xxx)
LHC secondary collimators with pick-up buttons in I			
LHC terticary collimators with pickup buttons in the			

As of February 2015.
Being updated to reflect recent changes of baseline.

https://lhc-collimation-upgrade-spec.web.cern.ch/lhc-collimation-upgrade-spec/Documents.php

Recent changes of baseline

Three main baseline changes proposed before the C&S review.
Items now as 'options':

1) TCLD dispersion suppressor collimators in IR1/5

Keep in baseline IR2 (ion collision debris) and IR7 (betatron cleaning)

2) Low-impedance collimators in the momentum cleaning

Keep in the baseline all secondary collimators in IR7

3) New, more robust tertiary collimators in IR2/8

Keep in the baseline, obviously, collimators for new IR1/5 layouts

Proposals under discussion:

4) Hollow e-lenses for collimation as part of baseline

5) Reviewing timeline and alternatives for 11T dipoles in IR2

Focus here on the items more relevant for LARP.

Advanced collimator materials

Status of collimator material irradiation at BNL	*Simos NICK*	
One East, Fermilab - Wilson Hall		15:30 - 16:00
Post Irradiation Analysis of collimator sample	*Paola NOCERA*	
One East, Fermilab - Wilson Hall		16:00 - 16:30
Update on DPA calculations	*Dr. Sergei STRIGANOV*	
One East, Fermilab - Wilson Hall		16:30 - 17:00
Status of collimator activities within EuCARD2	*Adriana ROSSI*	
One East, Fermilab - Wilson Hall		17:00 - 17:30
Report on advanced collimator materials	*Alessandro BERTARELLI*	
One East, Fermilab - Wilson Hall		17:30 - 18:00

See details at the dedicated session yesterday.
Emphasis on excellent results from BNL irradiation campaign.
Can simulation effort at FNAL be supported?

LHC hollow e-lenses

- We are studying the possibility to include **hollow e-lenses for collimation** as a HL-LHC baseline item.

  Goal: *sort this out by the technical design report at the end of this year. Technical justifications are there, consistently recommended by reviews. Important to trigger infrastructure preparation.*

- Synergy within CERN: the long-range compensation studies

  See talk by H. Schmickler on the setup of an e-beam test facility at CERN.

- My ambitious aim is to install a prototype e-lens in the LHC in LS2.

  Status of technical design discussed later: technically feasible!

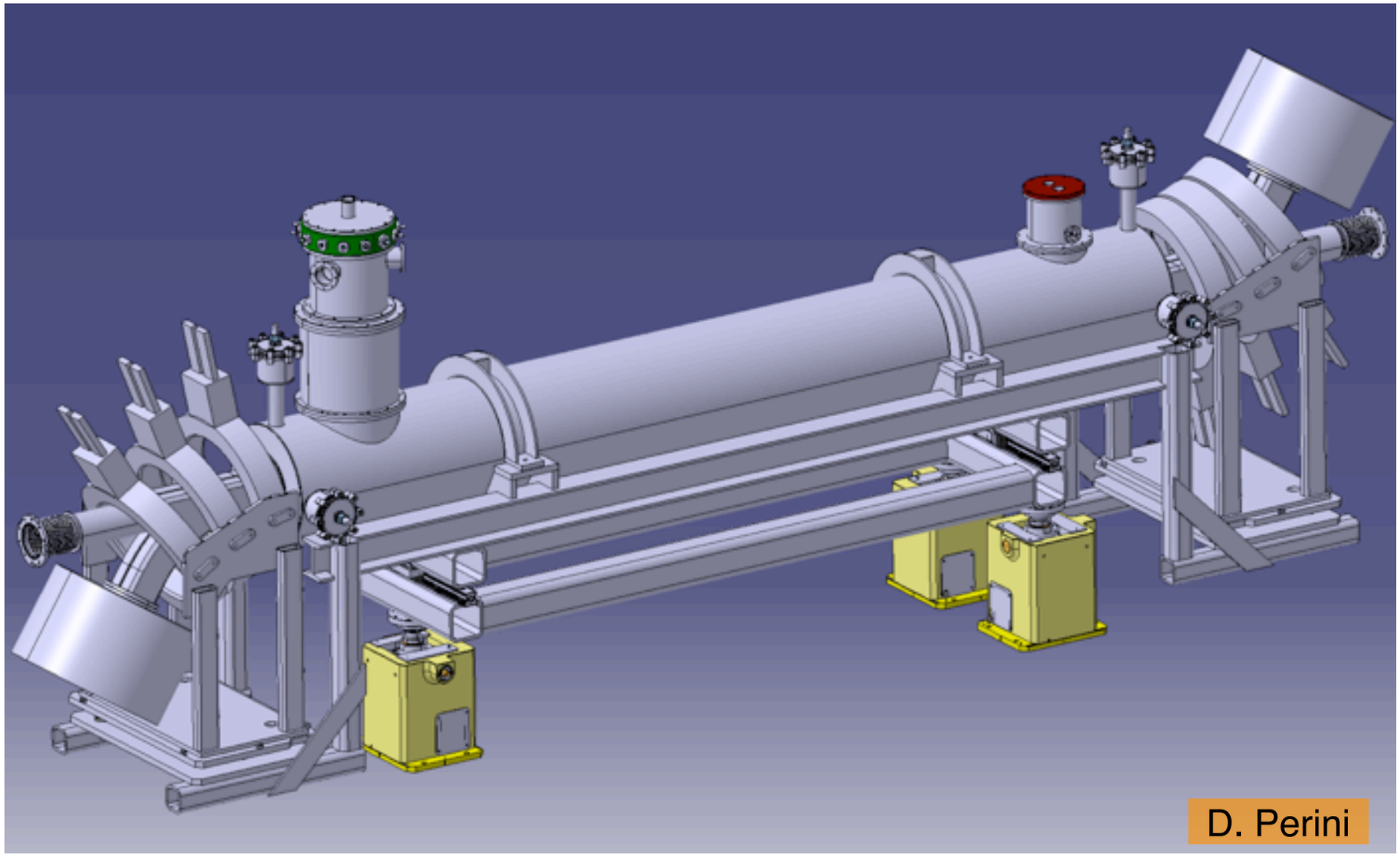
- We will monitor the LHC beams at 6.5 TeV to establish a proper deployment strategy after enough operational experience.

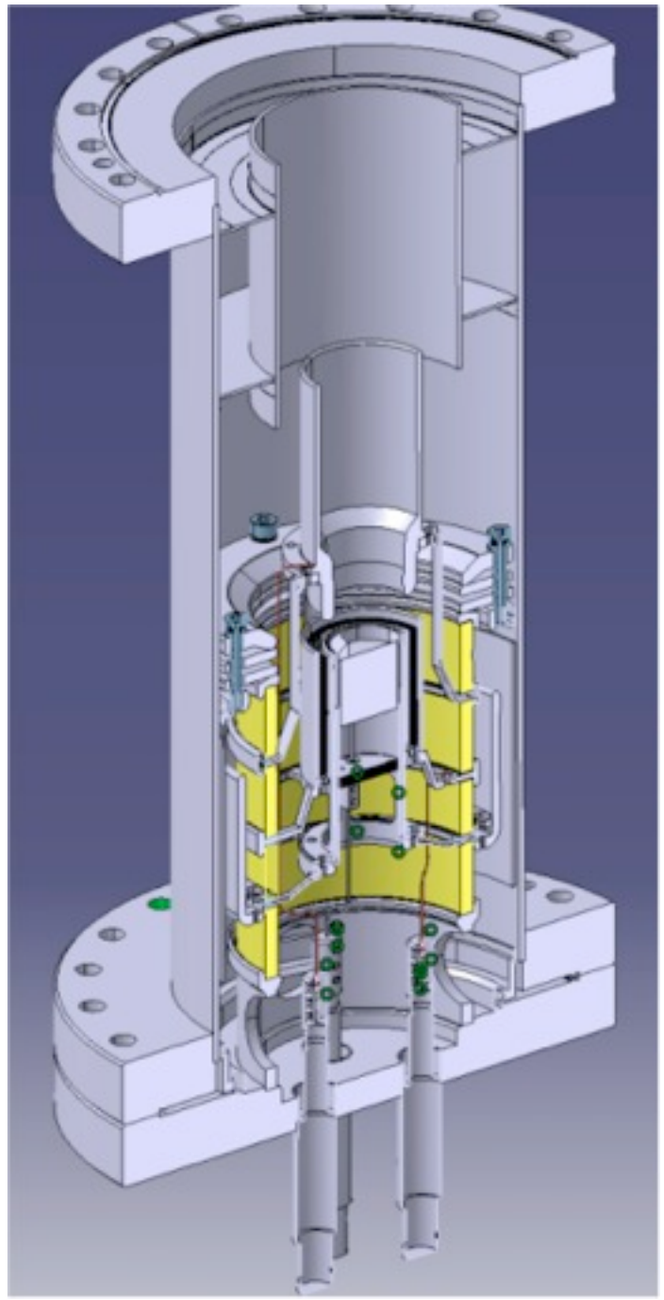
  Beam tests in 2015: halo population studies. Quench limits and lifetime.
  Studying alternative halo control methods: tune ripple + narrow band excitations.

- Looking for international partners

- Contribution from the collaboration with FNAL remains vital.

R&D - LHC hollow e-lenses (ii)





Details in talks by A. Rossi

Recent progress:
- Published CDR as joint FNAL/CERN report.
- Detailed technical design evolving rapidly.
- Launching the production of a hollow gun to be tested at FNAL before the end of 2015! RHIC?

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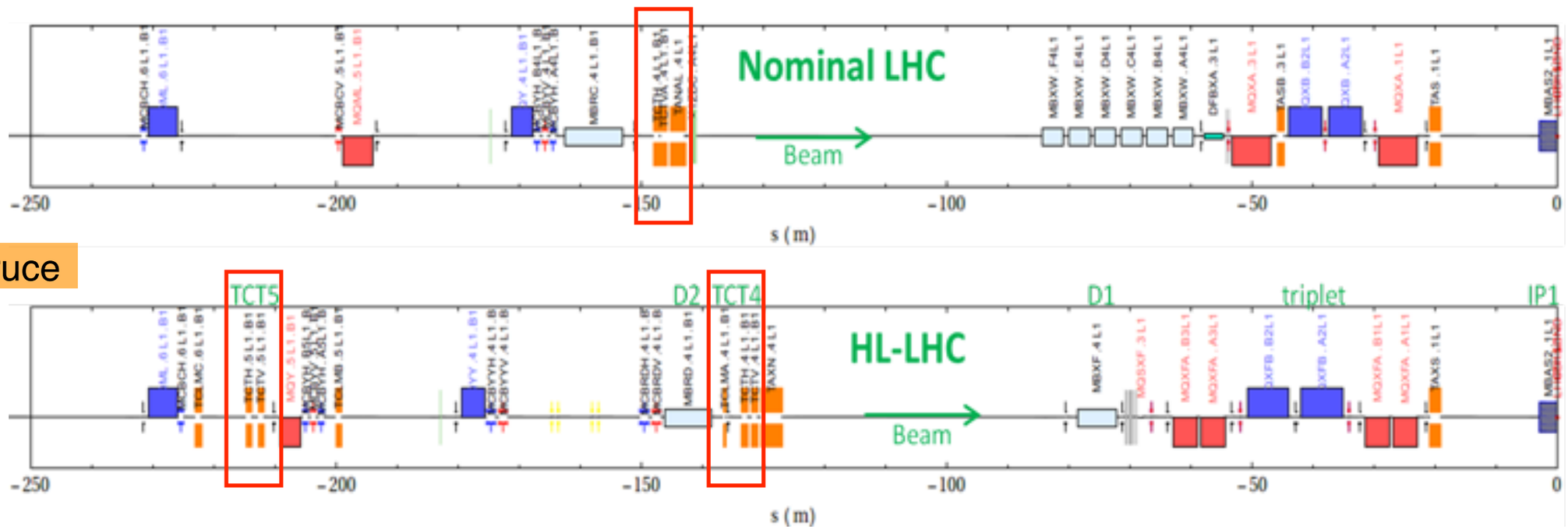
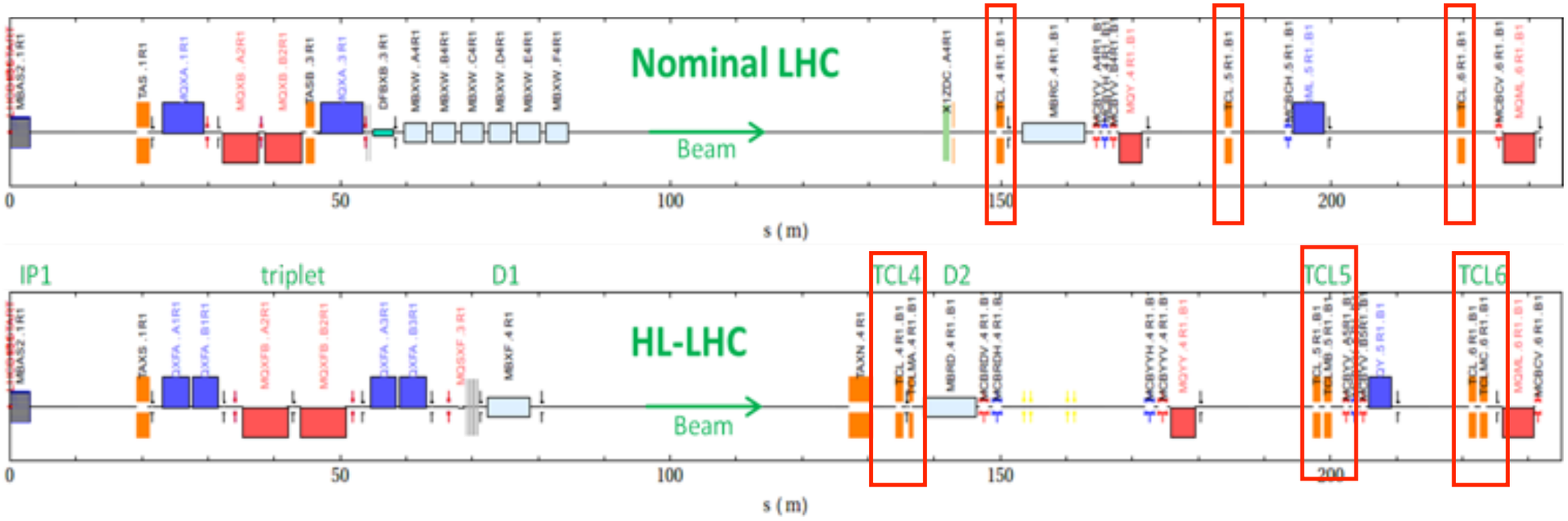
Layouts as of HiLumi@KEK

R. Bruce



*Additional H/V tertiary collimators protect the Q5 aperture from **incoming beam** losses.*



*Standard TCL layout complemented by fixed mask for **outgoing beam** cleaning.*

Improved layout

- The conceptual layout that we proposed at the last annual meeting had known integration issues in the **D2-TAN** region.

  Tricky: 2 TCT on incoming beam; 1 TCL on outgoing; a mask.

- We now have worked out a solution for the optics version 1.1

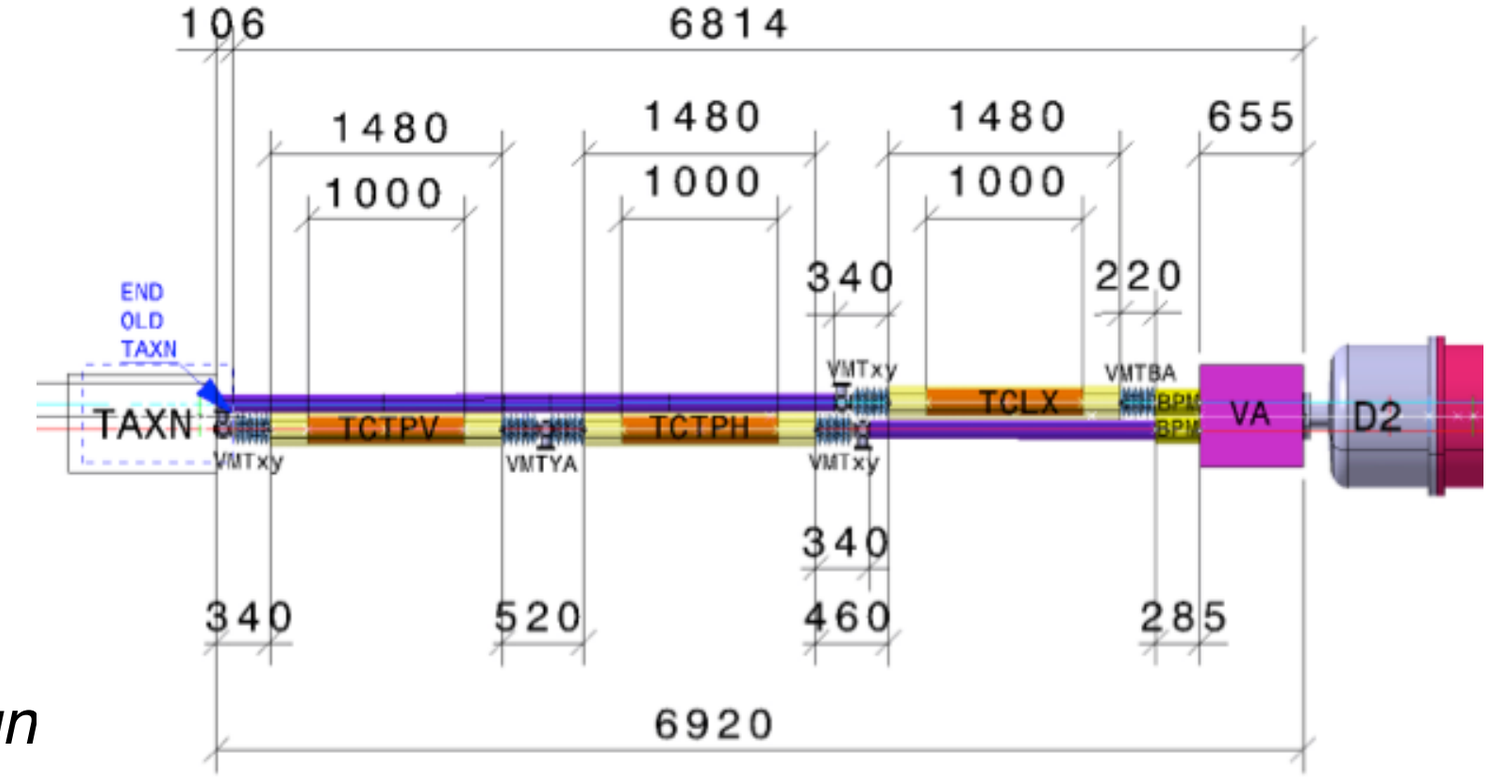
  Subject of a recent WP5 EU deliverable document.

- Key changes:

  - Improved performance for round and flat beams;
  - removed fixed mask on D2;
  - new, "thicker" TCLX jaw;
  - finalized longitudinal layout.

- Work ahead

  - Need new designs:
  - Completely new TCL
  - Small updates of TCT design
  - Complete simulations will be ready by fall 2015.



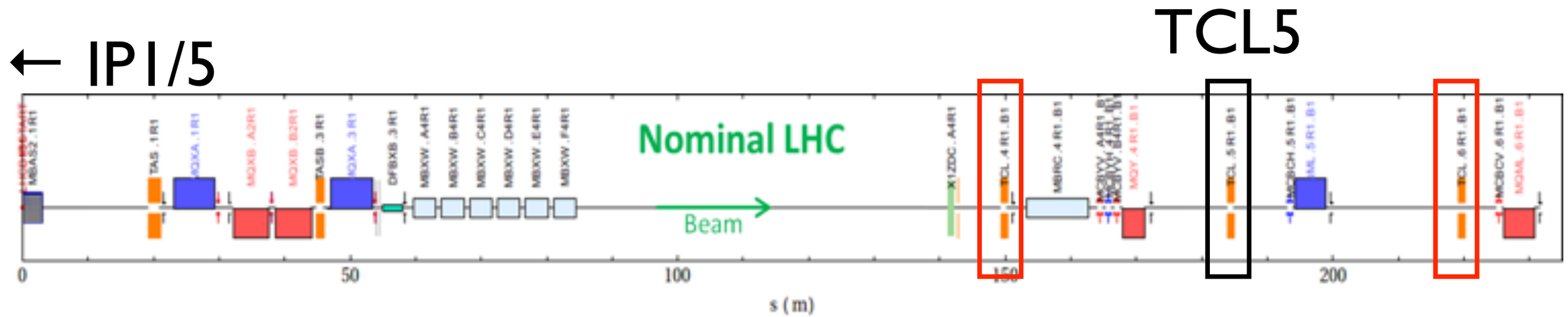
P. Fessia *et al.*

Conclusions

- **The collimation system for the LHC Run II was reviewed.**
  Important upgrades started already in LS1!
- **The collimation challenges for HL-LHC were recalled.**
  Doubling the energy in smaller emittances and increasing the peak luminosity pose obvious collimator constraints.
- **HL-LHC baseline and option upgrades were introduced.**
  Focused here on recent changes compared to the status report at the HiLumi annual meeting in Japan.
  *Dedicated session yesterday covered **new material studies**.*
- **We have converged to a solid baseline, with a few items still pending a final agreement**
  Changes of number of units of 11T dipoles and low-impedance collimators.
  Work proceeded well on hollow e-lenses, we hopefully see it as baseline!
- **We are very happy of the progress of the US collaborators**
  Excellent work on collimator materials, continued support for hollow e-lens.
  We must find a way to continue these activities.

Reserve slides

Upgraded IR layouts



8 additional physics debris collimators (TCL's) in IR1/5 in preparation for the operation at higher peak luminosities.

Strong synergy with HL studies as this layout is also adopted as a baseline for HL (with obvious adaptations to new IR geometry)!

IR2 ion debris cleaning (i)

Alternative solution?

- There is a *possibility* that we can combine bumps and an alternative location of the TCLD
  - No 11 T magnets
  - Different but simpler integration

J. Jowett, Collimation Upgrade Specification meeting (ColUSM), 01/08/2014

TCLD in connection cryostat