5th Joint HiLumi LHC-LARP Annual Meeting
October 26th-30th, 2015
CERN, Geneva, CH

Collimation Status and Recent Baseline Changes

Stefano Redaelli, CERN, BE-ABP
on behalf of 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.

Contributions

CERN :

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R.B. Appleby, J. Molson, M. Serluca, S. Tygier

SLAC : T. Markiewicz

FNAL: G. Stancari, A. Valishev

BNL: N. Simos

Other important contributions / collaborations

Kurchatov

EuCARD2

FP7-WP5 deputy coordinator

FP7-HiLumi-WP5

WP5.1: Coordination & Communication

WP5.2: IR Simulations of Halo Loss

– Assess locations and magnitudes of halo loss in the IR's for various upgrade scenarios (includes crab cavities, ATS, ...).

– Assess impact of imperfections.

WP5.3: IR Simulations of Energy Deposition

– Assess locations and magnitudes of energy deposition in the IR's for various upgrade scenarios.

– Assess impact of imperfections.

WP5.4: Design of IR Collimation

– Study required collimation to keep losses at the same level or below before the upgrade.

– Integration of collimators, new layout and optics.

– Feed-forward to simulation WP's.

Focus: collimation in interaction points; scope extended to dispersion suppressor collimators around IR7

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Upgraded collimation system for Run II

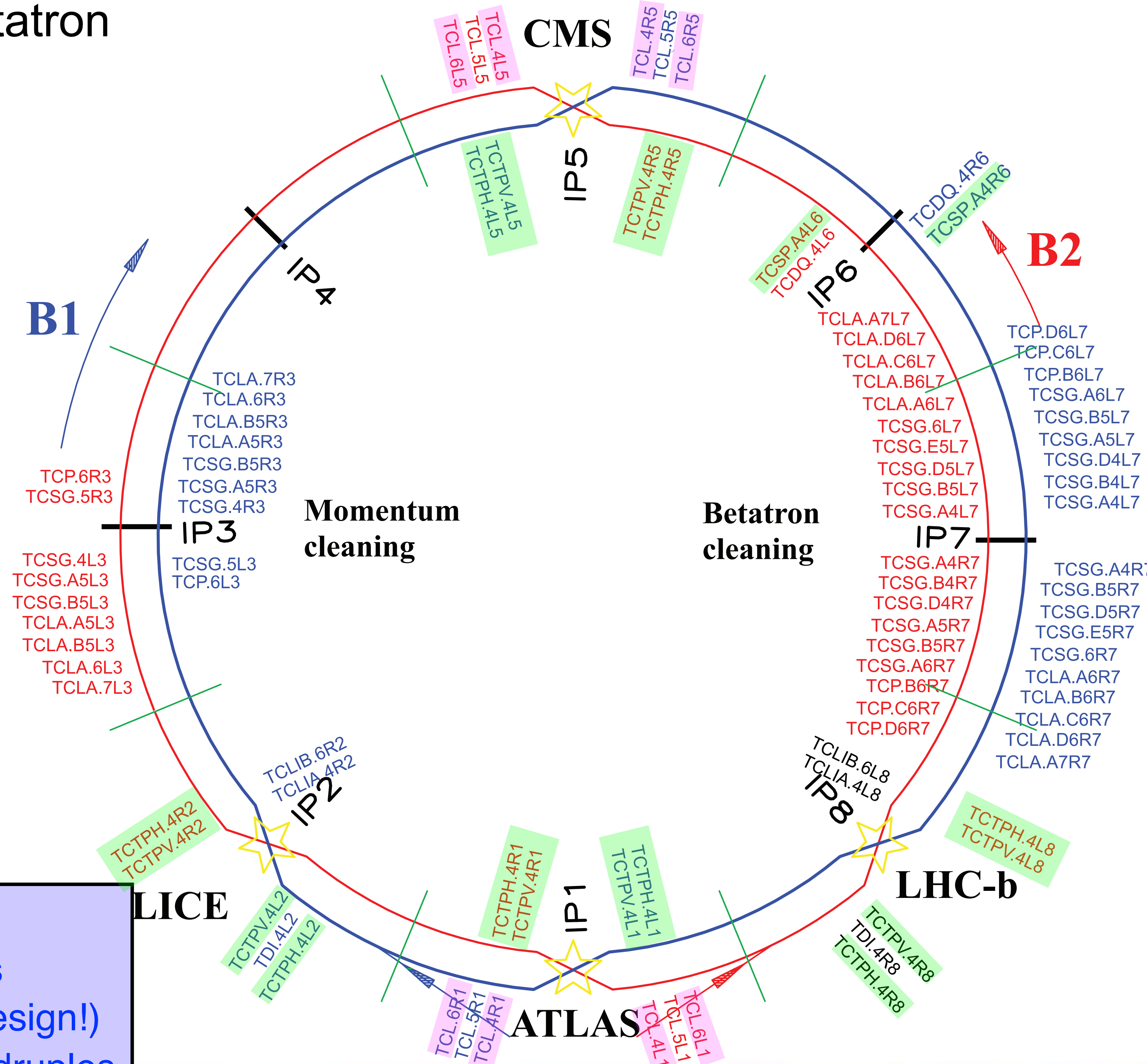
Dedicated insertions for betatron (IR7) and momentum (IR3) cleaning systems.

Cleaning of incoming beam in all experiments.

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

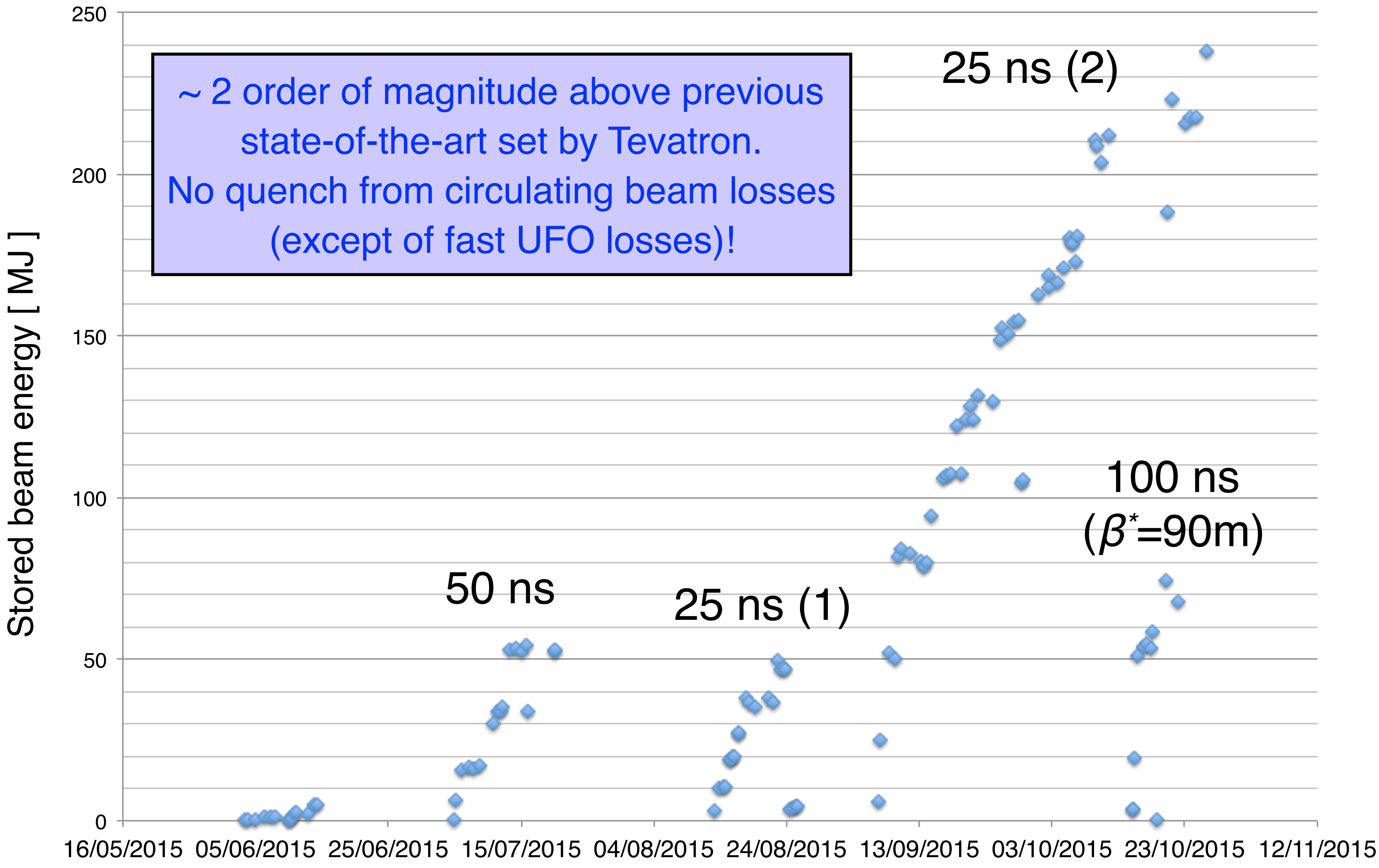
32 collimators in the machine, i.e. 30% of the system!

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

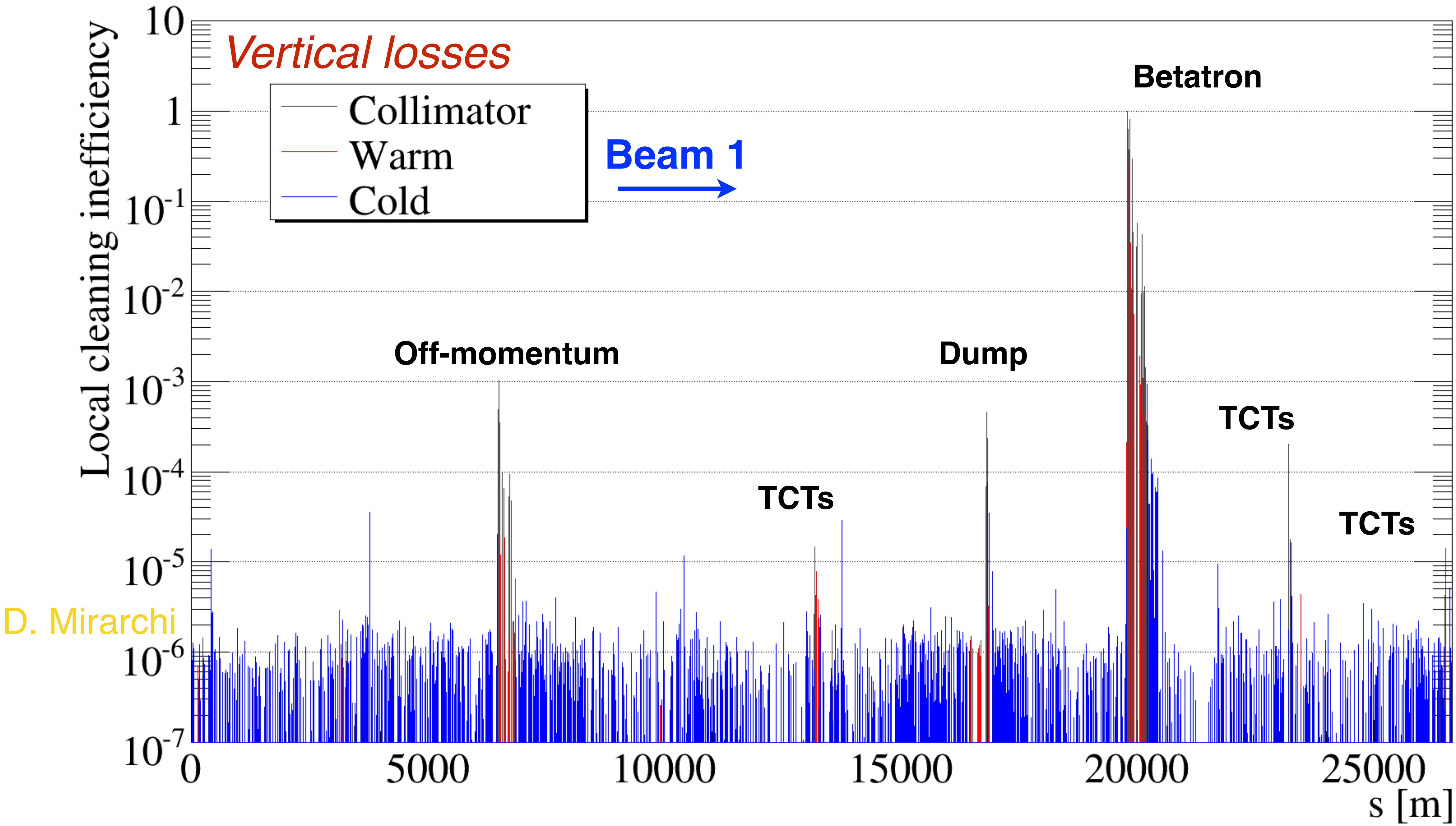


Important activities relevant for HL:
- Physics debris layout with 3 TCLs
- BPM collimators (new baseline design!)
- Improved protection of warm quadruples

LHC stored energy in 2015

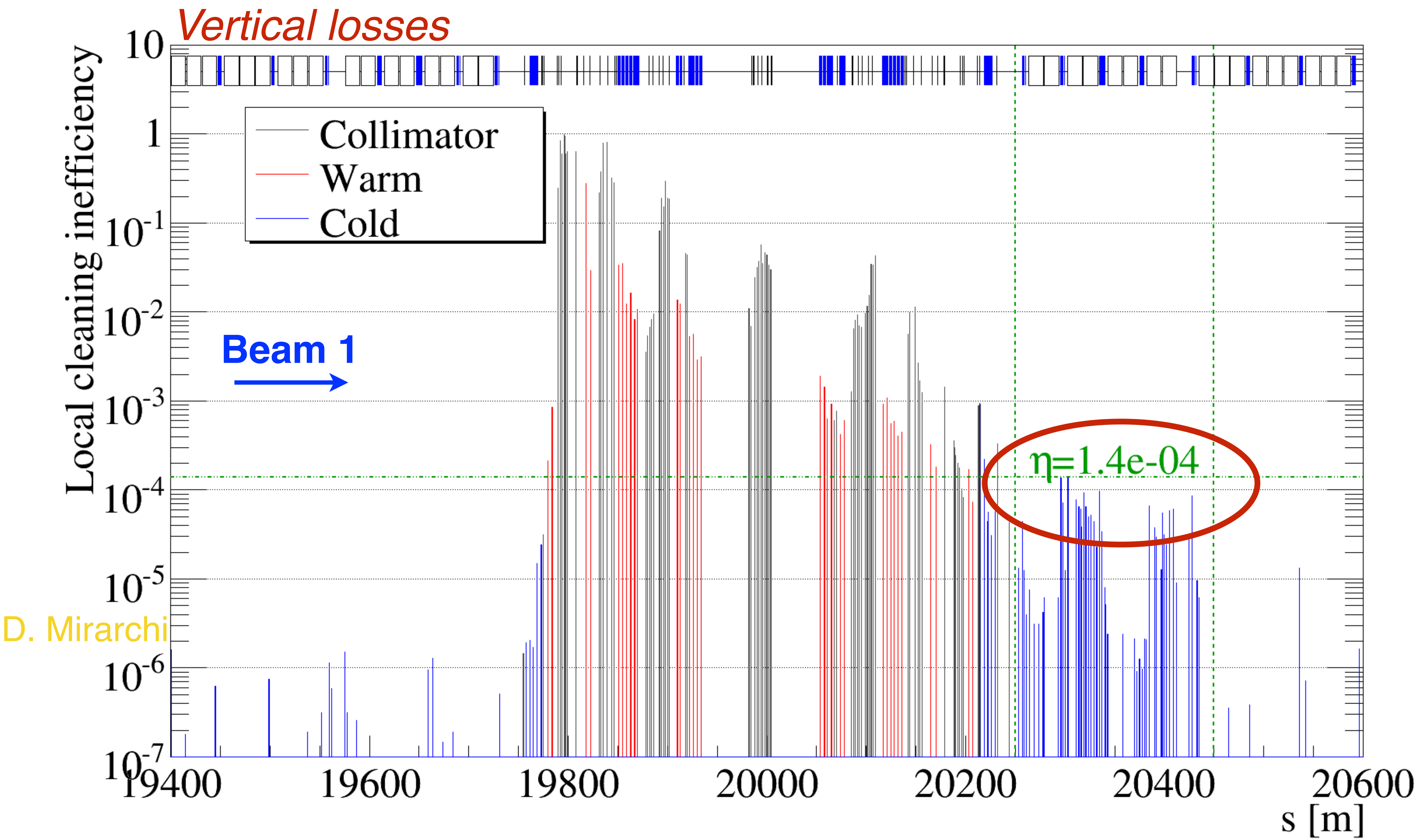


Collimation cleaning: 6.5 TeV, β^*=80cm



"Relaxed" settings as in 2012 (limited by impedance): cleaning = 1-5 x 10^{-4}

Collimation cleaning - IR7 (B1-V)



Confirmed limiting locations at the dispersion suppressors.

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High Luminosity LHC

Pillars of HL collimation upgrade

Collimation upgrades are needed for HL to

☑ **Improve the collimator impedance**

Present carbon-based secondary collimators not compatible with stability requirements of HL beams

☑ **Improve the cleaning in dispersion suppressors**

Present system not capable to intercept "dispersive" losses for proton and ion beams (IR's + cleaning insertions)
Improve operational efficiency (like: BPM design)

☑ **Find new solutions for upgraded layouts in high-luminosity experiments ("IR collimation")**

Incoming beam protection: new tertiary collimators

Physics debris collimation.

☑ **Control tail population and loss rates**

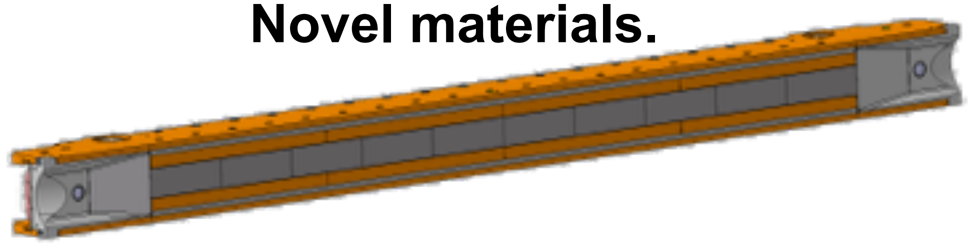
Crucial synergy with CONS: successful LHC upgrade relies on collimators not replaced within HL

Beam brightness
Beam intensity
Damage potential
Peak luminosity
Machine availability

Baseline upgrades

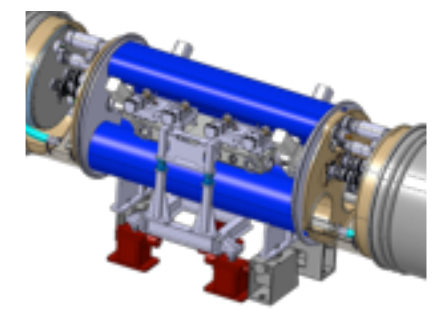
IR1+IR5, per beam:
- 4 tertiary collimators
- 3 physics debris collimators
- fixed masks

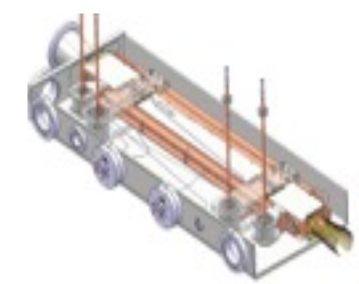
Completely new layouts
Novel materials.

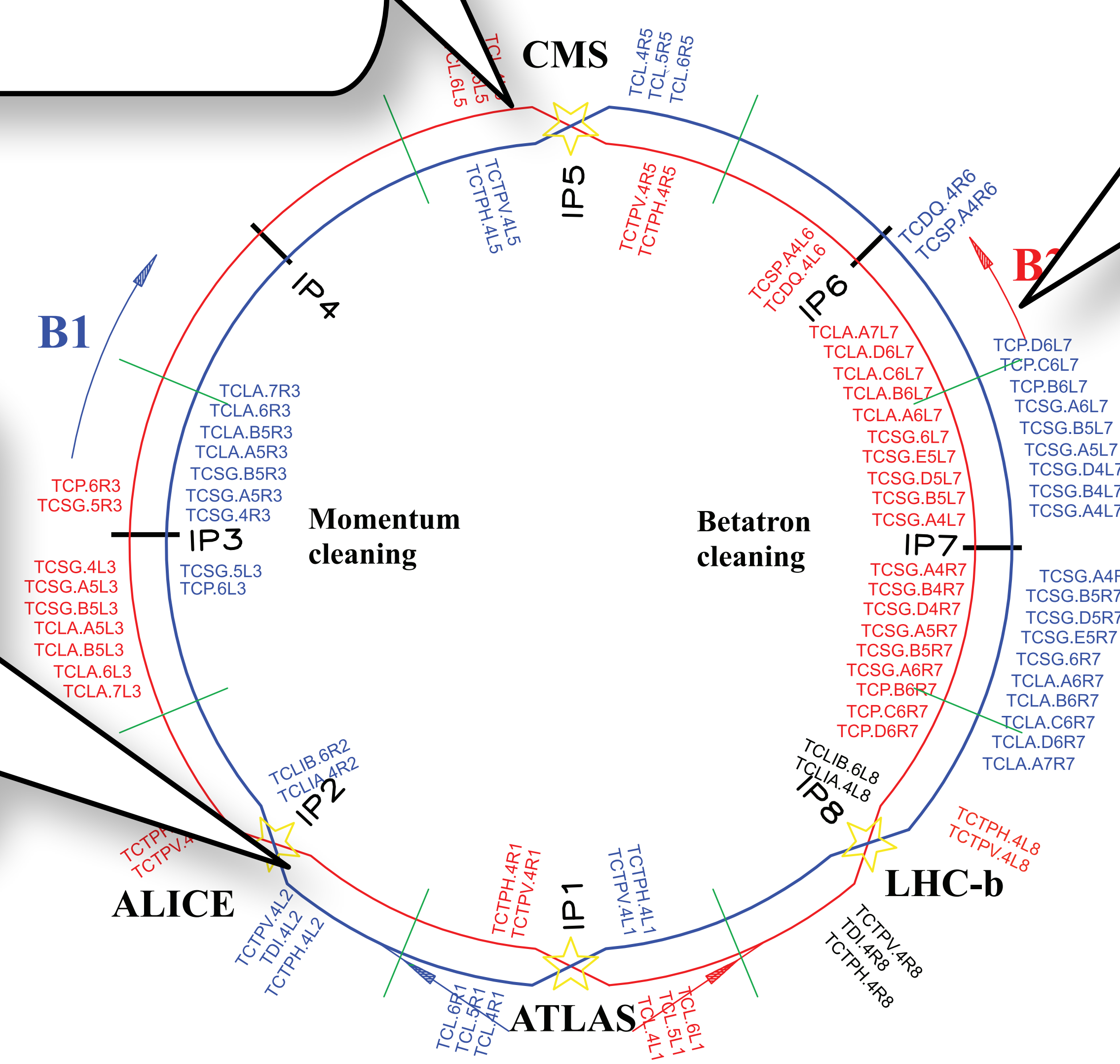


Final decision on installation to be taken based on Run 2 experience

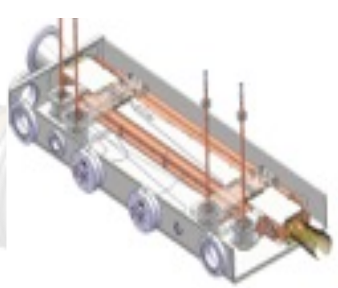
Cleaning: DS coll. + 11T dipoles, 2 units per beam



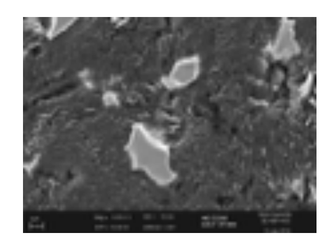


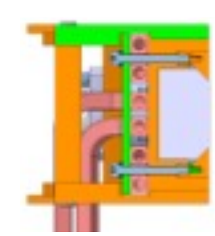


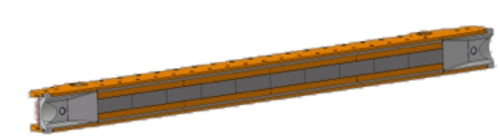
Ion physics debris:
DS coll. + 11T dipoles



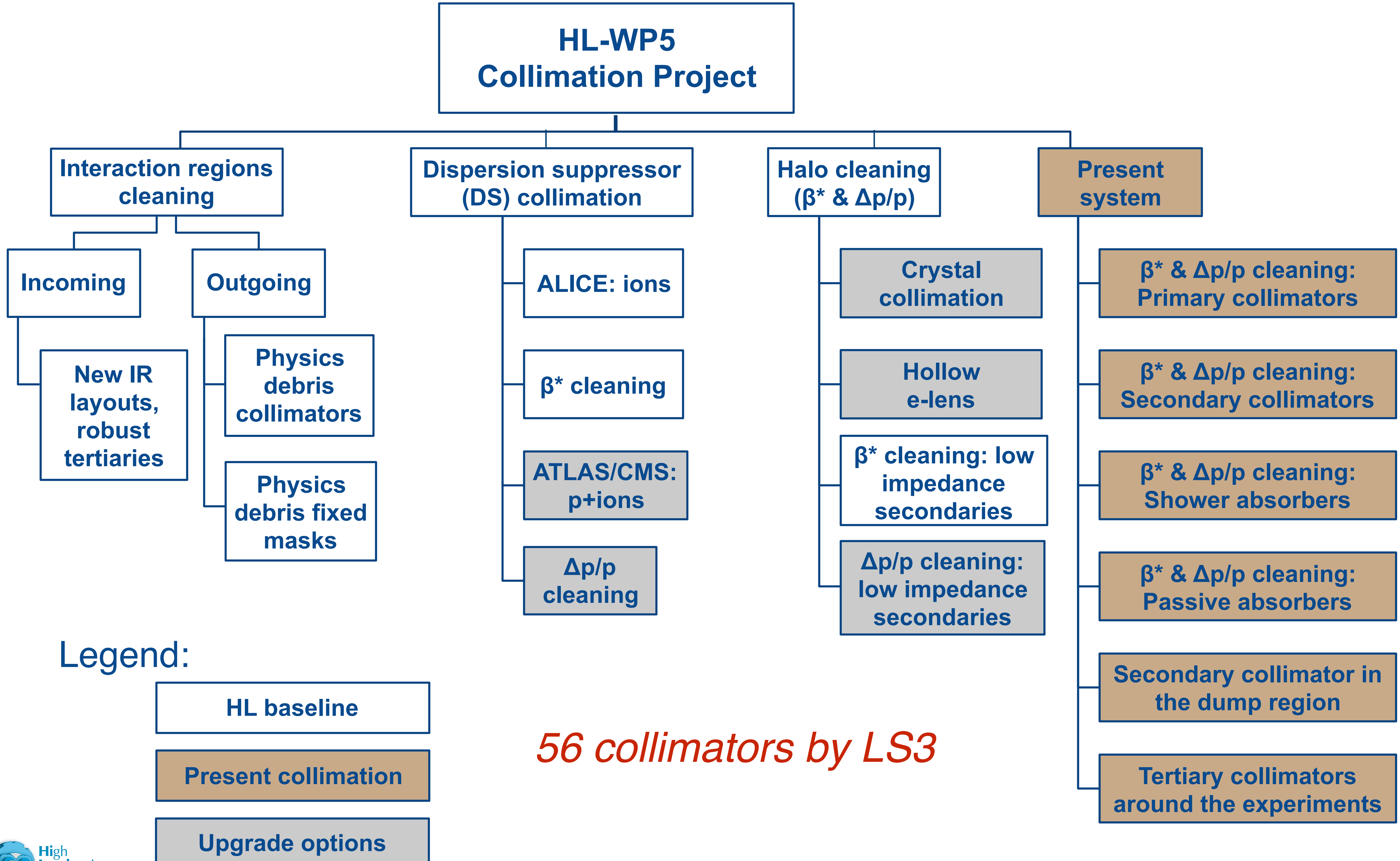
Low-impedance, high robustness secondary collimators







Project upgrade structure



Main production lines and timeline

LS2

2 DS collimators (TCLD) + spare for IR2

If ready: low-impedance collimators for IR7: 8-10 TCSPW units

4 more robust tertiary collimators (HL design, CONS funding)

LS3 (Final HL)

Complete low-impedance solution in IR7 (12-14 TCSPW units)

New tertiary collimators in IR1/5: (16 TCTPW units)

New physics debris absorbers and masks (12 TCL units)

Up to 4 TCLD units in IR7

Until LS2 (prototyping phase)

Prototype low-impedance collimator for LHC beam tests

Four collimators with wires for beam-beam long range compensation

Interventions on crystal collimation test stand - new goniometers

Heavy involvements with beam tests outside LHC (SPS, HiRadMat, etc.)

Changes of baseline - March 2015

Three main baseline changes proposed and presented to the C&S review. Items now as ‘options’:

1) TCLD collimators and 11 T dipoles in IR1/5

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

2) Low-impedance collimators in the momentum cleaning (IR3)

Keep in the baseline all secondary collimators in IR7

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

Keep in the baseline the devices for the new IR1/5 layouts

Presented at the Cost&Schedule review and at the HiLumi/US-LARP spring meeting

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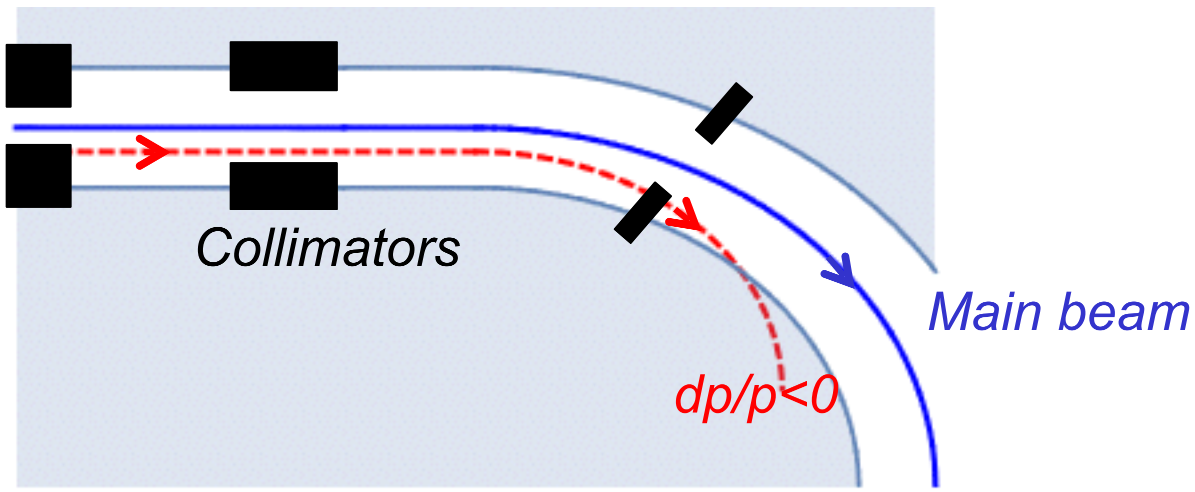
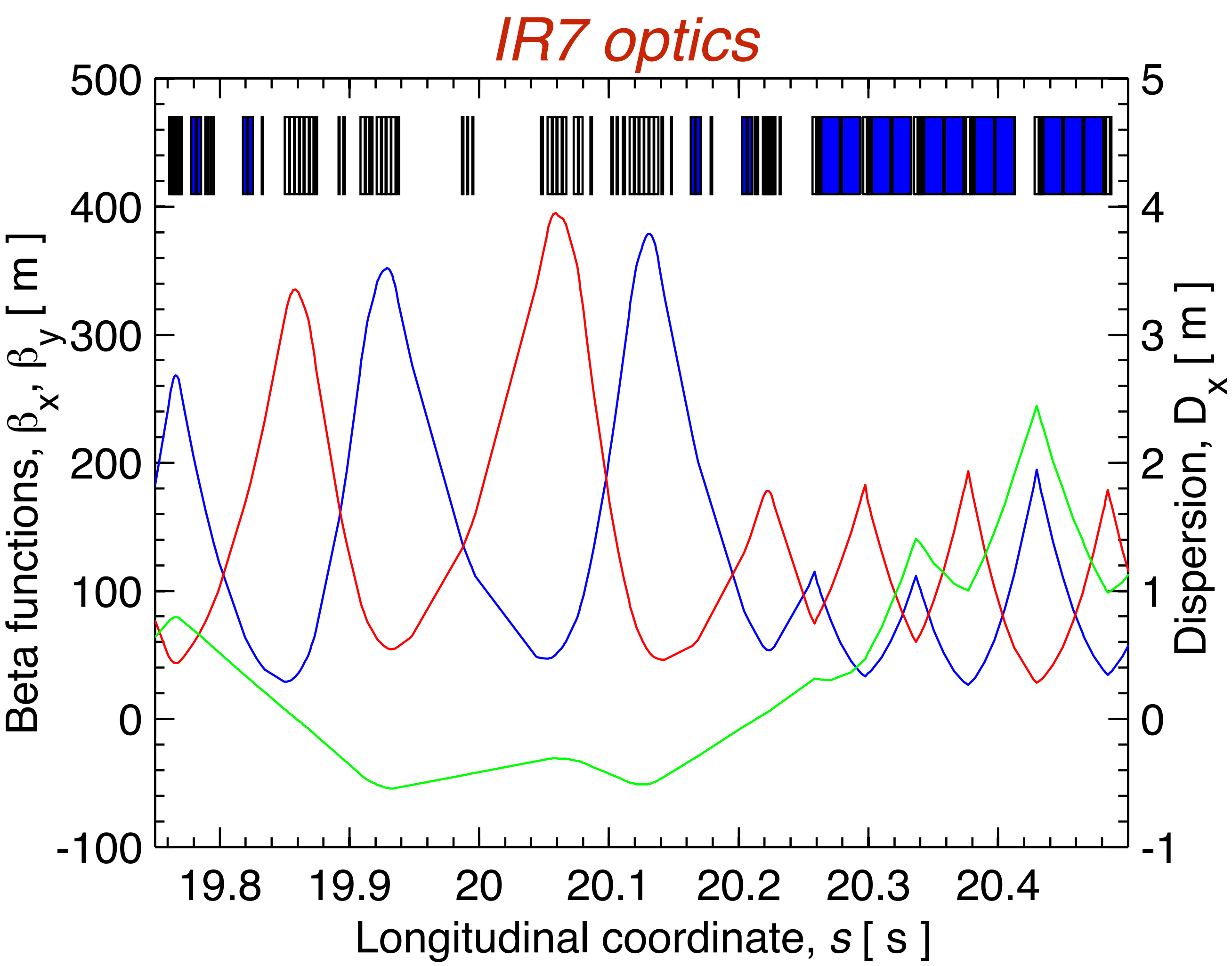
- Introduction
- Collimation upgrade baseline
- **Status of baseline items**
    - **DS collimation**
    - **IR layouts**
    - **Update on materials**
- News on upgrade options
- Conclusions

Dispersion suppressor losses



R. Bruce



Out-scattered off-energy protons have different bending radius than main beam

Qualitatively similar behaviour in collimation insertion and experiments.

Start deviating significantly only in first bends, downstream of collimators

Idea: Install new collimators (TCLD) in front of exposed magnets, where there is already separation from main beam.

Need two jaws: ion beams; better shower absorption; more precise alignment.

Plans for DS collimation

Present baseline:

1) 4 TCLD units in IR7 with 11 T dipoles

2) 2 TCLD units in IR2 with bumps, possibly without 11 T dipoles

See outcome of 2013 review and report at last Annual meeting.

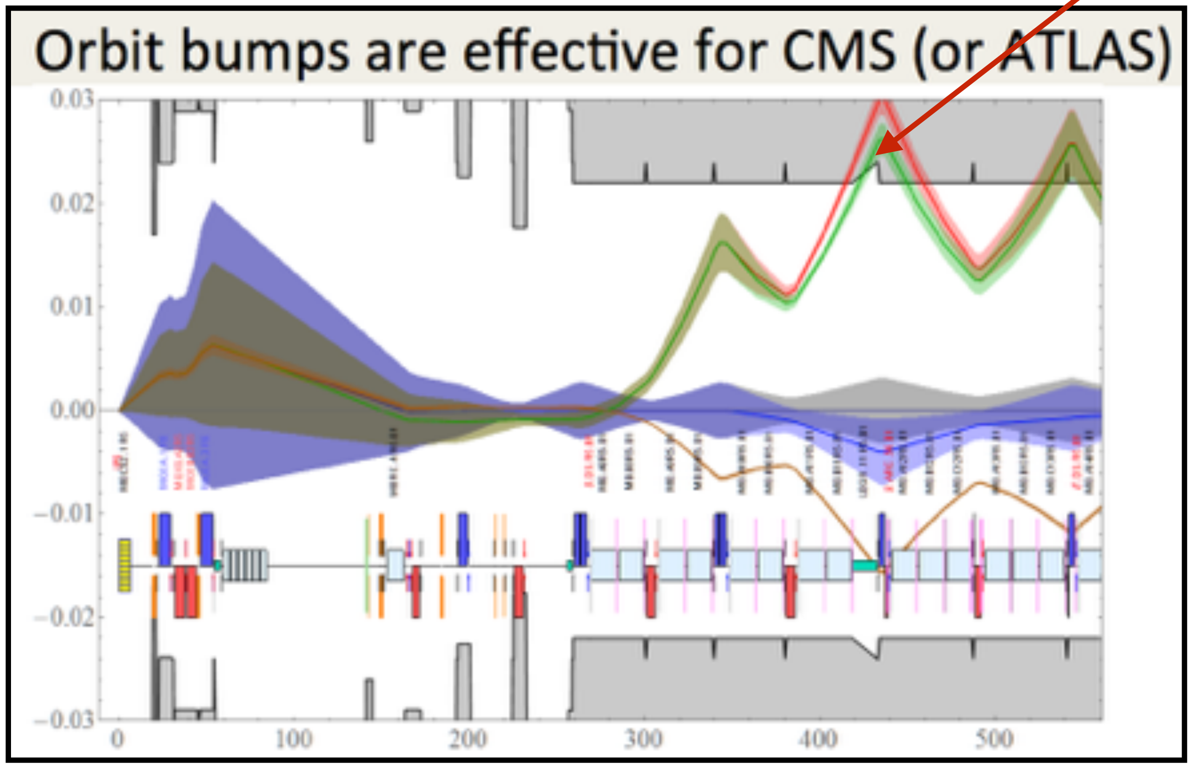
Report here on following topics:

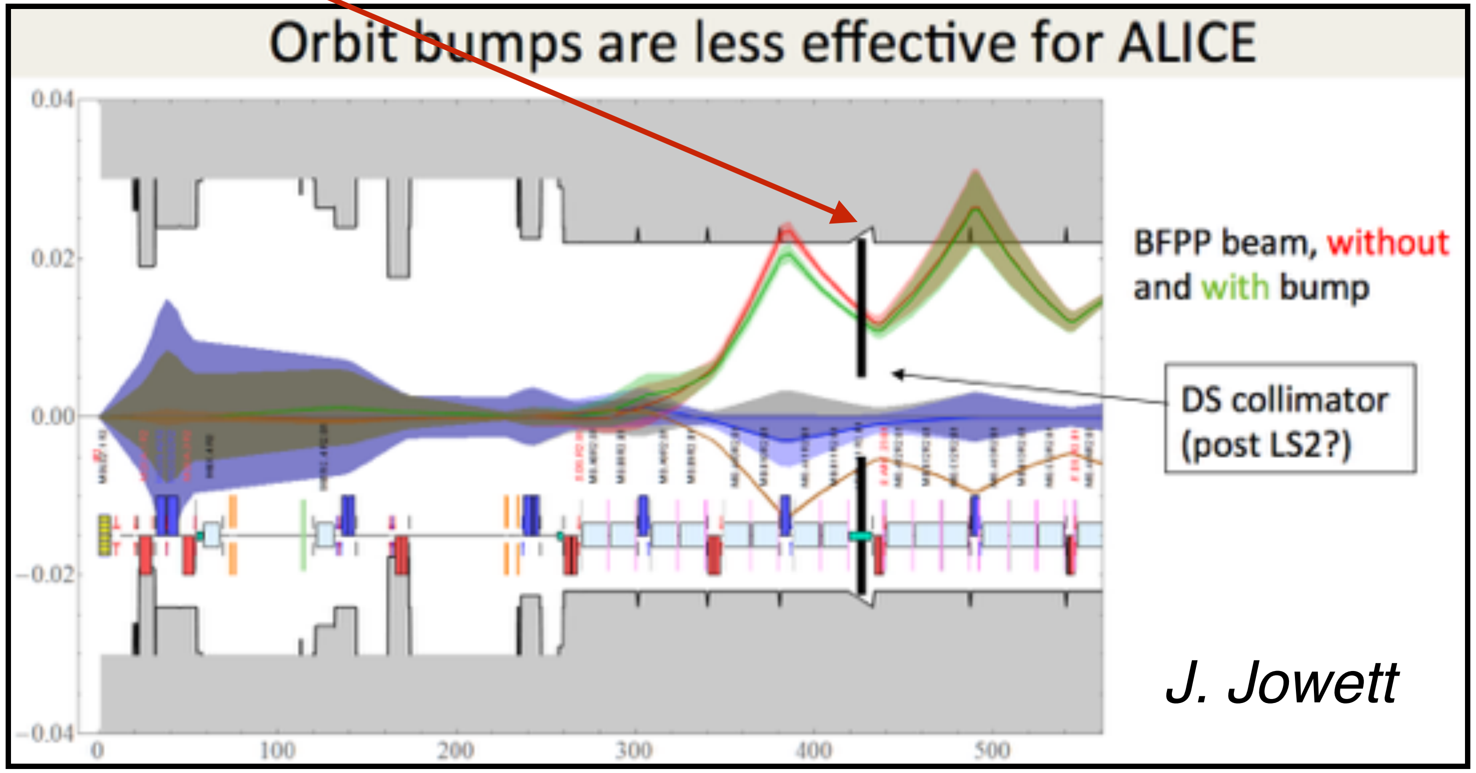
1) Bumps in IR2 and IR1/5

2) Status of design for TCLD integration

Bumps in IR2 and IR1/5 for ions

Connection cryostat ("missing dipole")





Fundamental layout/optics differences between IR1/5 and IR2:

- Bumps in IR1/5 can move ion losses to connection cryostat with no risk of quenches → no need for collimator nor for 11T dipoles
- Protons: Losses under control with new TCL layout (*TBC for V1.2*)
- Bumps in IR2 can move the losses such that the first magnet is missed → we still need a collimator, but likely not the 11T dipoles

Various considerations

It is crucial to demonstrate as soon as possible that the **new solutions** based on bumps work reliably in IR2 and IR1/5:

We still have important uncertainty on quench margins at 7 TeV.

Need perform quench tests with beam for proton and ion beams!

Bump technique for all IRs needs to be demonstrated operationally.

Remark on bumps in IR1/5:

Bump technique tested in 2011 and presented at the 2013 review. Then, concluded then bumps were not fully reliable and the TCLD were expected to be needed. Now: we consider it as baseline based on simulations only.

Detailed energy deposition studies (*A. Lechner et al.*) indicated potential issues beyond quench limits (like loads to cryogenics). To be understood.

Looking forward to seeing results of "collimation" quench tests next week and of ion operation.

Status of TCLD design

60cm baseline agreed.

Final design for integration between 11T dipoles: ok

→ *decided "cold" solution for other beam*

Still possible to change material

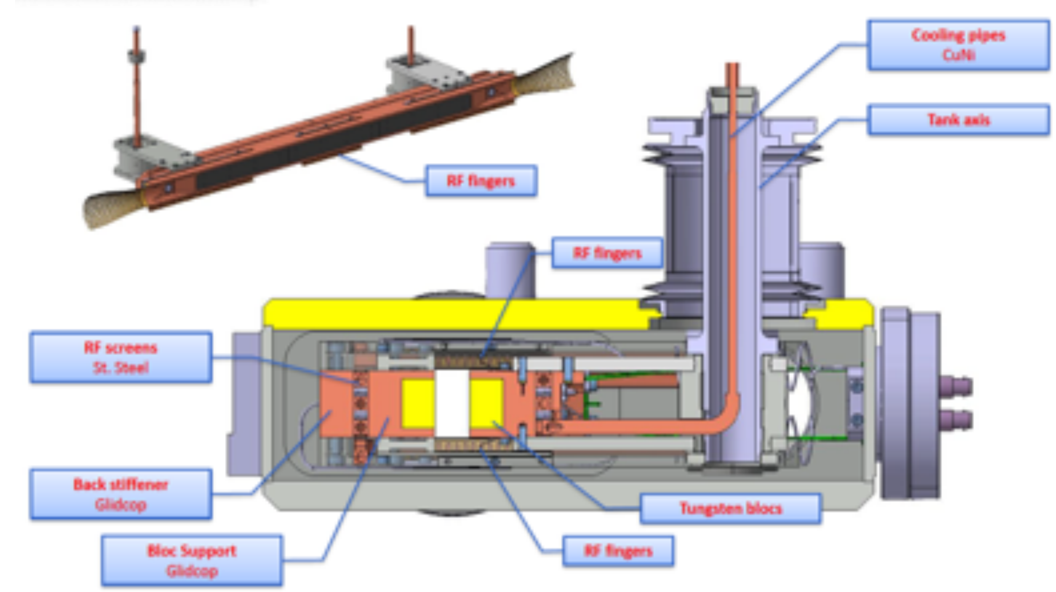
→ *launched construction W prototype*

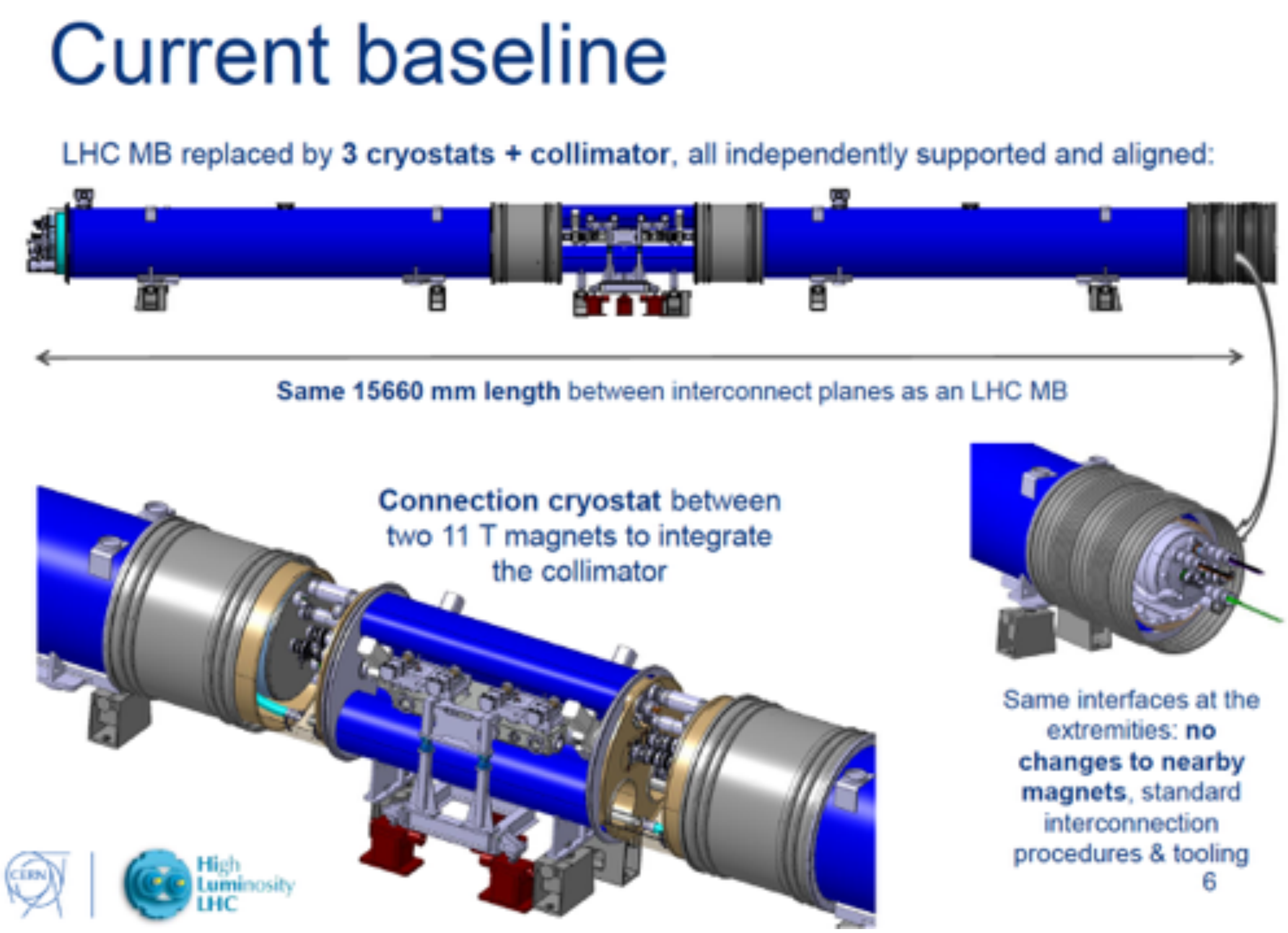
Preparing production of 2+1 units for LS2 (solution without 11T dip)

→ *prototype conform might be used as spare.*

Need to work on the integration into the connection cryostat

→ *WP11 now busy, still ok if we launch that in 2016 as no obvious issues are expected.*





See detailed talks by Delio D. and Luca G. at last ColUSM, 18/09/2015

Status of TCLD design

60cm baseline agreed.

Final desig

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→ *decided "*

Still possibl

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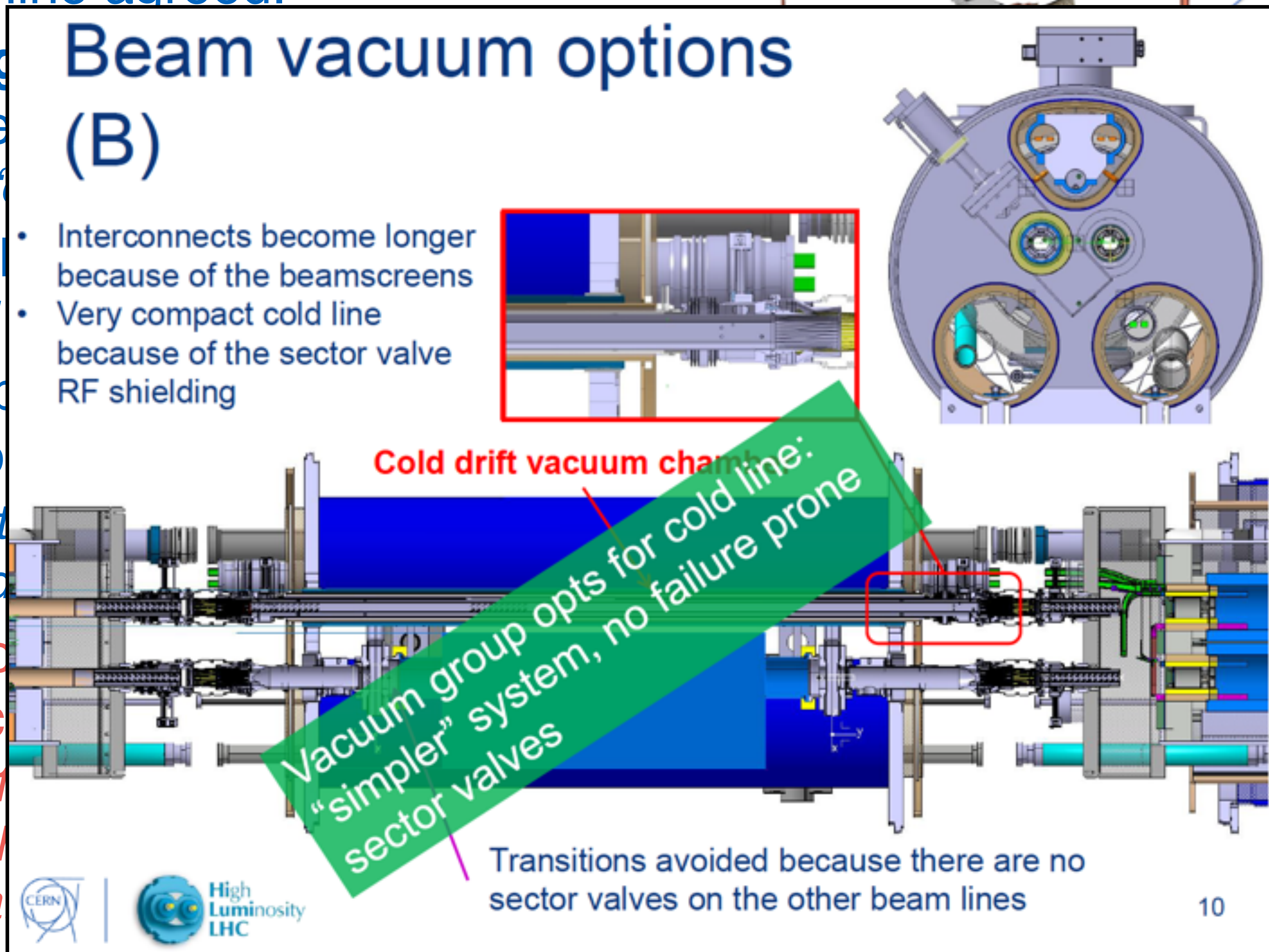
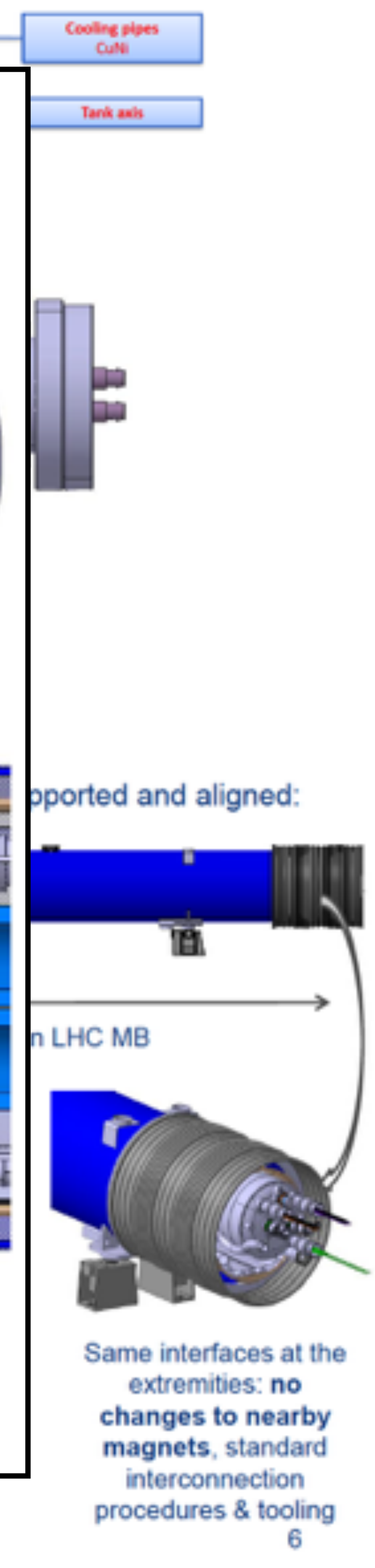
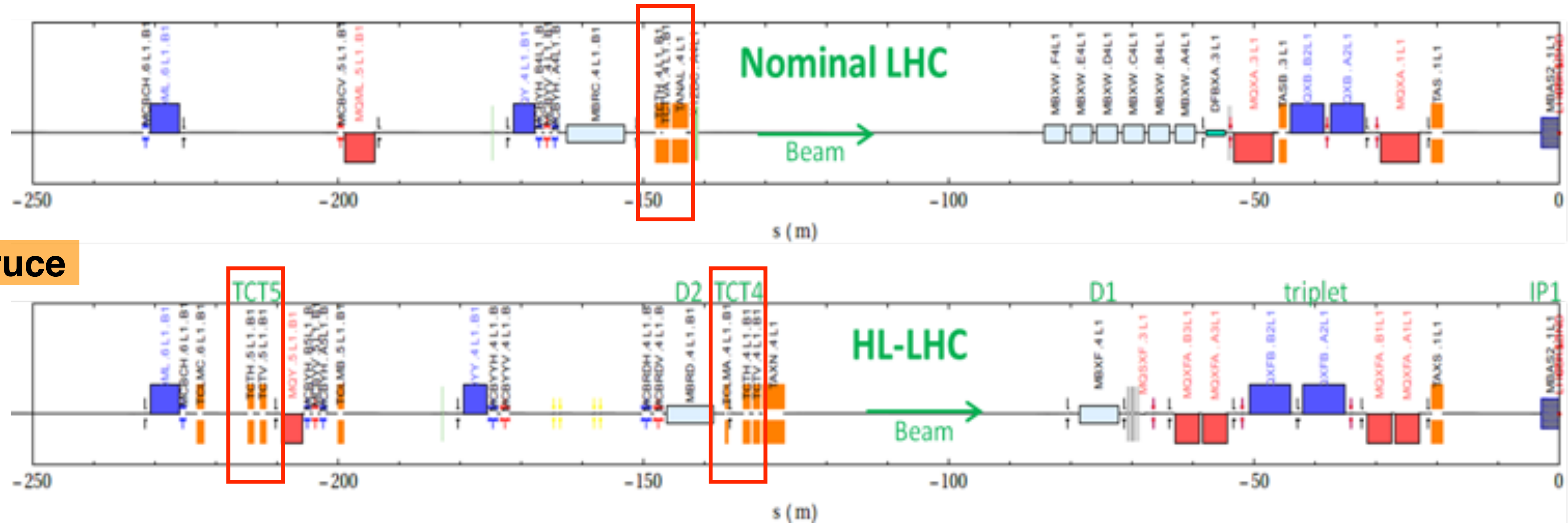




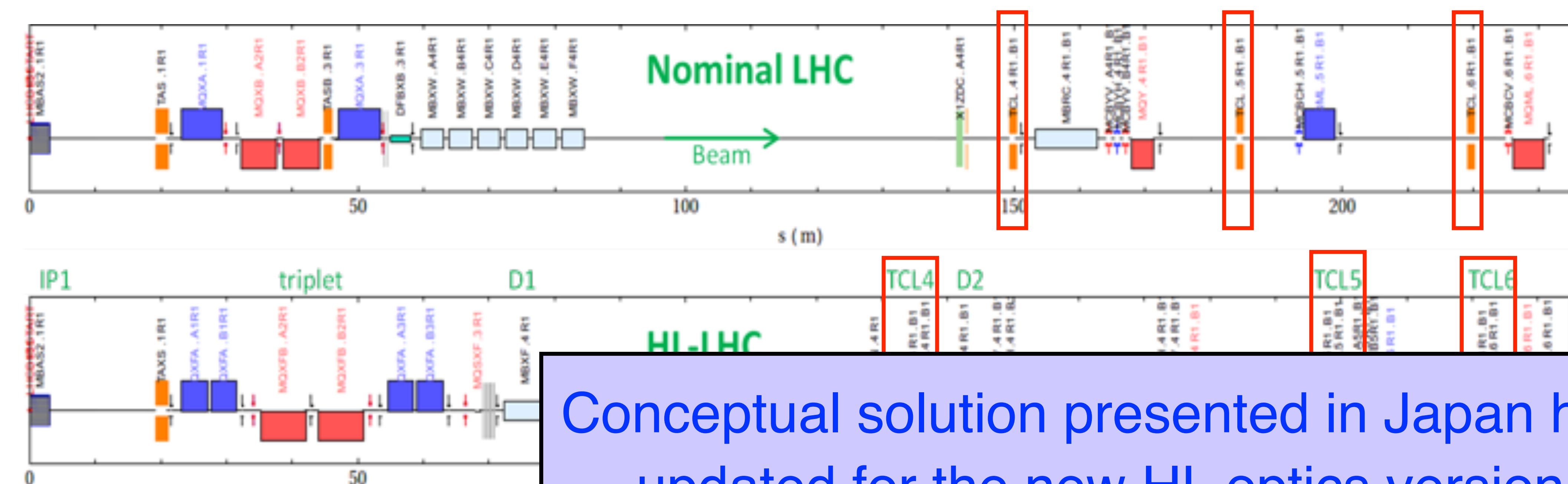
See detailed talks by Delio D. and Luca G. at last ColUSM, 18/09/2015

IR collimation

R. Bruce



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

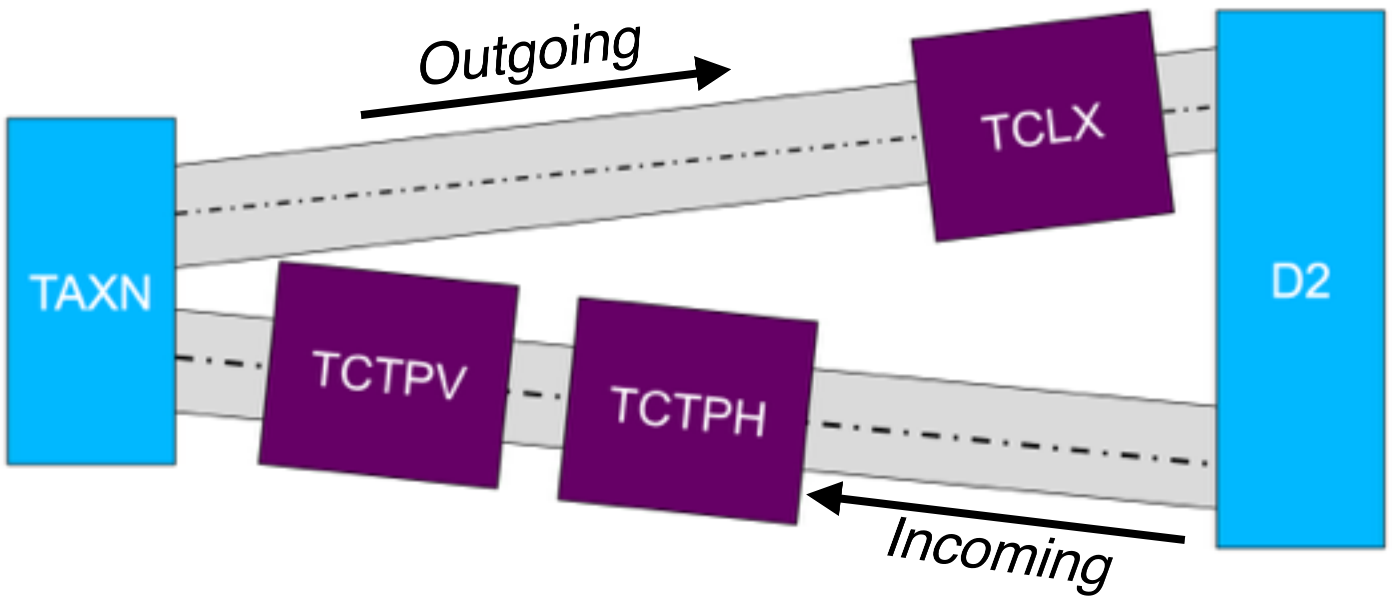


Conceptual solution presented in Japan has been updated for the new HL optics version v1.2.

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

Layout of TAXN-D2 region

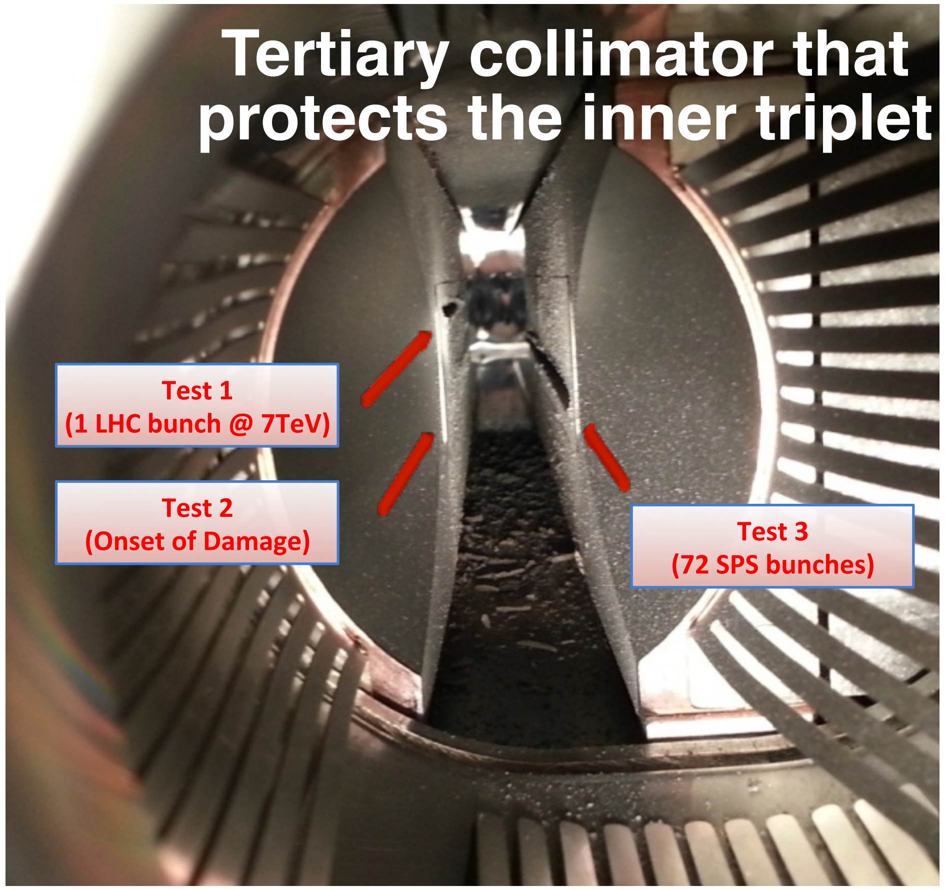
- Key features:
  - *- Improved performance for round and flat beams;*
  - *- removed fixed mask on D2;*
  - *- new, "thicker" TCLX jaw.*



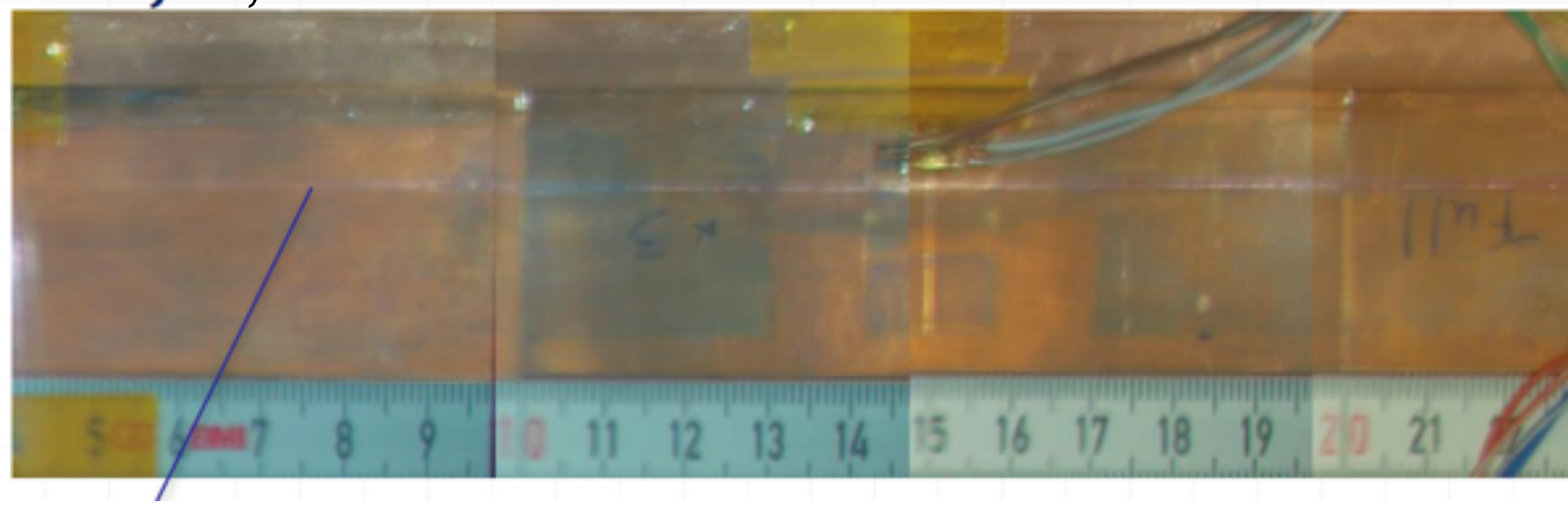
- Optics version v1.2: the layout proposed has transverse integration constraints in the **D2-TAN** region.

  Reduced transverse separation and larger aperture requirements for HL optics make it difficult to fit present collimator designs (see A. Rossi at 63rd ColUSM)
- Need to work out detailed design of new collimators
- Ongoing simulations for v1.2 (WP10) - try to converge by end of 2015.
- Backup solution: if TCLX ok, might move TCT's on the other side.

Recent news on collimator materials

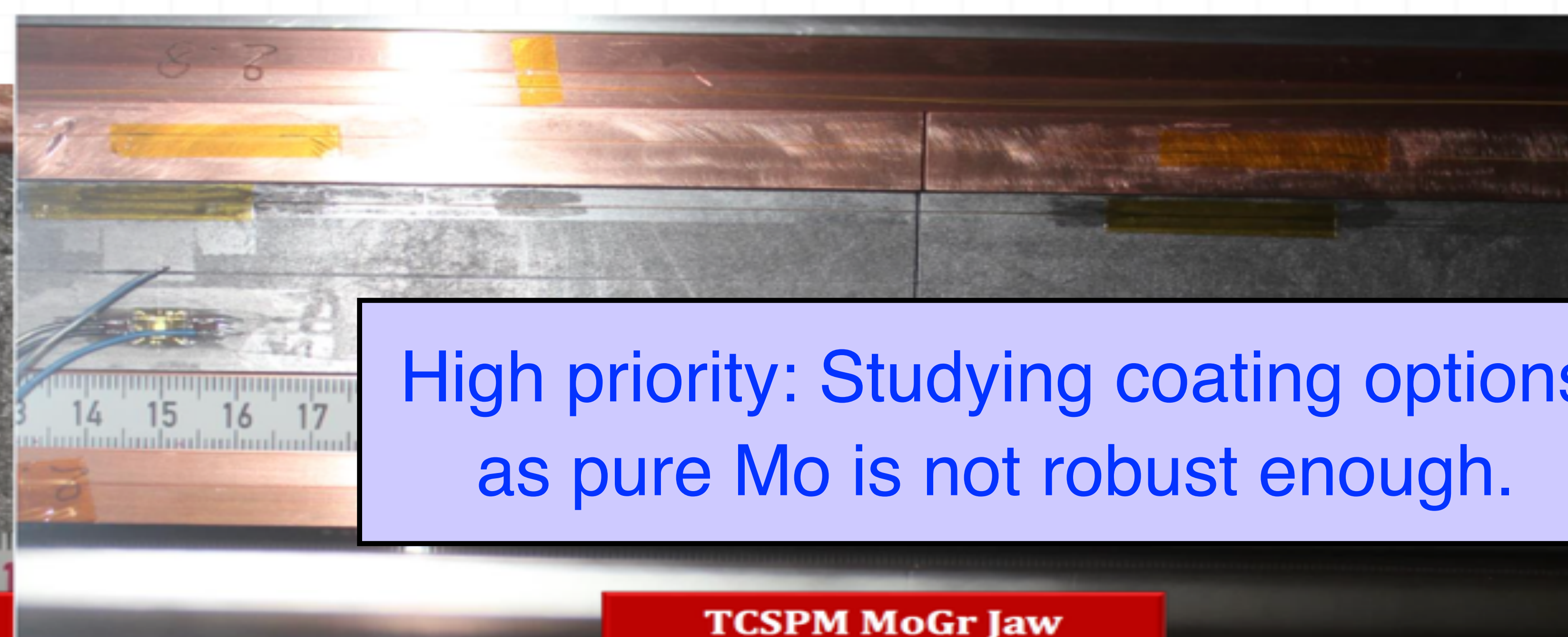


Copper Diamond: candidate TCT material, 10-15 times more robust.



A. Bertarelli, F. Carra

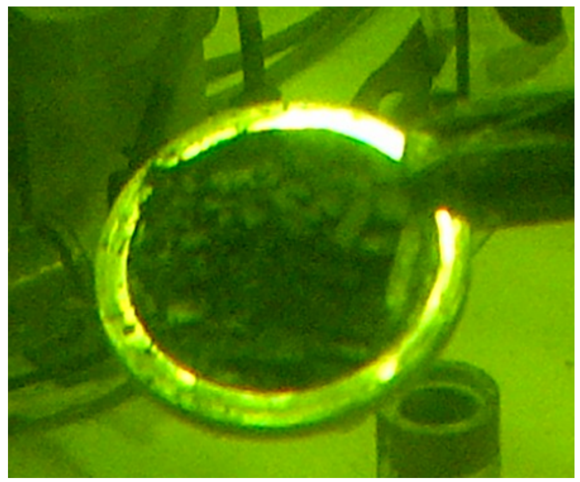
Excellent results at HRM: full MoGR jaw survived as well as CFC to impact of 288b of 1.3x1011p with σ=350μm (density beyond LIU)



High priority: Studying coating options as pure Mo is not robust enough.

Radiation tests of new materials - MoGR

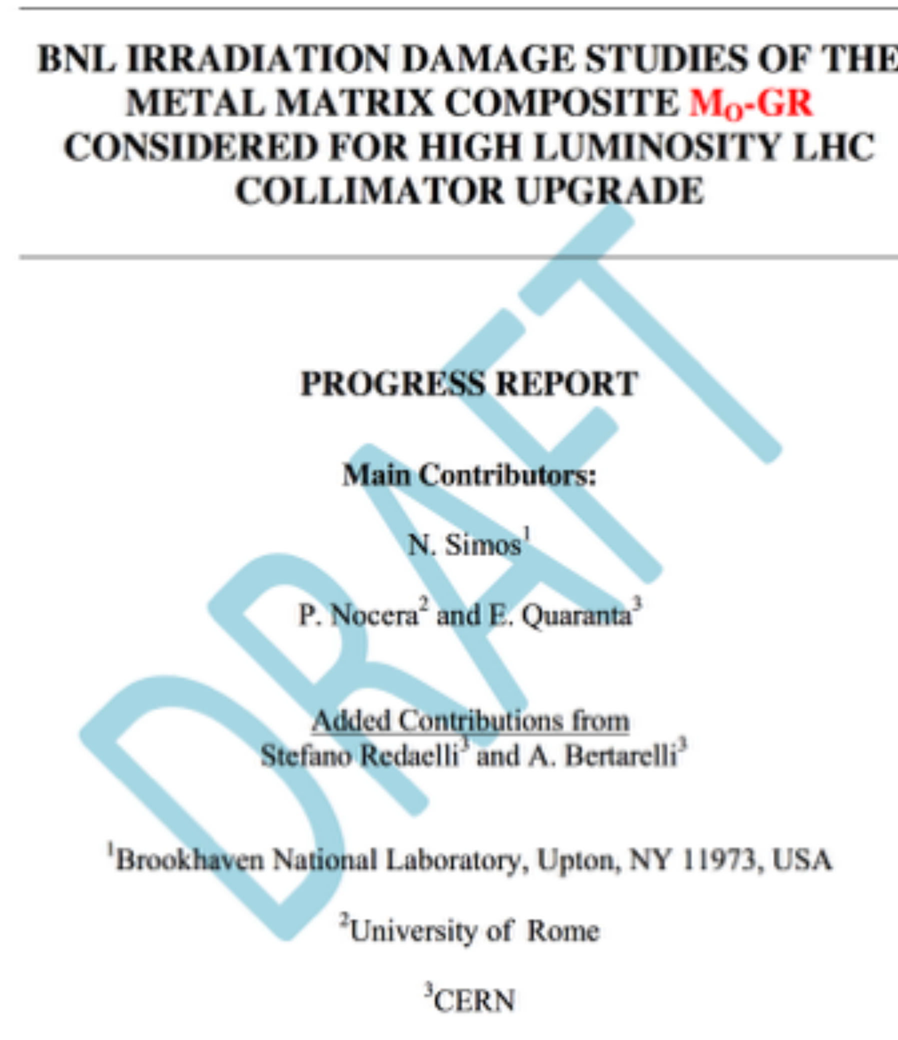
Two main regimes for tests with beam: fast failures (thermo-mechanical robustness) and high radiation doses (long times).



State of Mo-GR after 1.1 10^{21} p/cm^2 FLUENCE !!!!

Very high doses at BNL: some MoGR samples broke!

*Launching another set of measurements with **latest MoGR grades**. Very important for us.*



BNL IRRADIATION DAMAGE STUDIES OF THE METAL MATRIX COMPOSITE M_O-GR CONSIDERED FOR HIGH LUMINOSITY LHC COLLIMATOR UPGRADE

PROGRESS REPORT

Main Contributors:

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P. Nocera[2] and E. Quaranta[3]

Added Contributions from

Stefano Redaelli[3] and A. Bertarelli[3]

[1]Brookhaven National Laboratory, Upton, NY 11973, USA

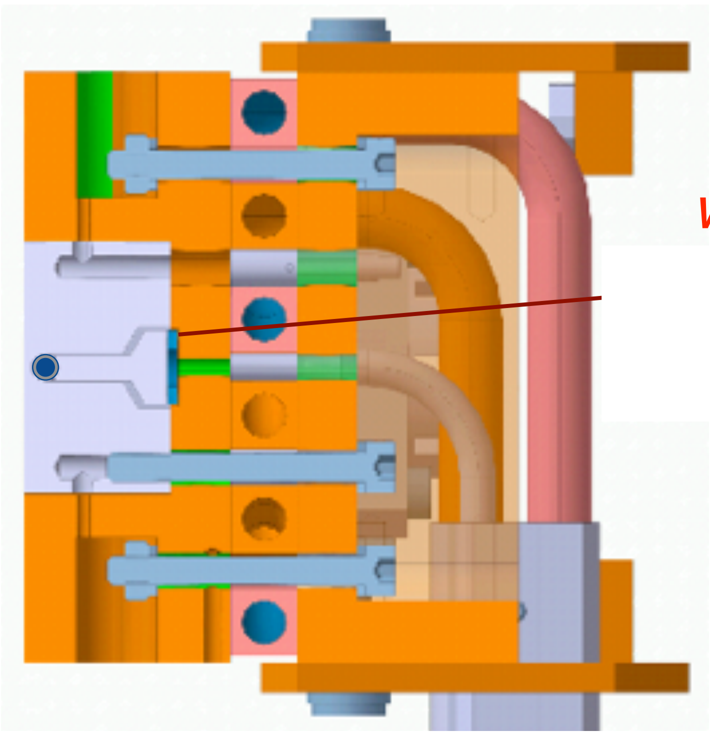
[2]University of Rome

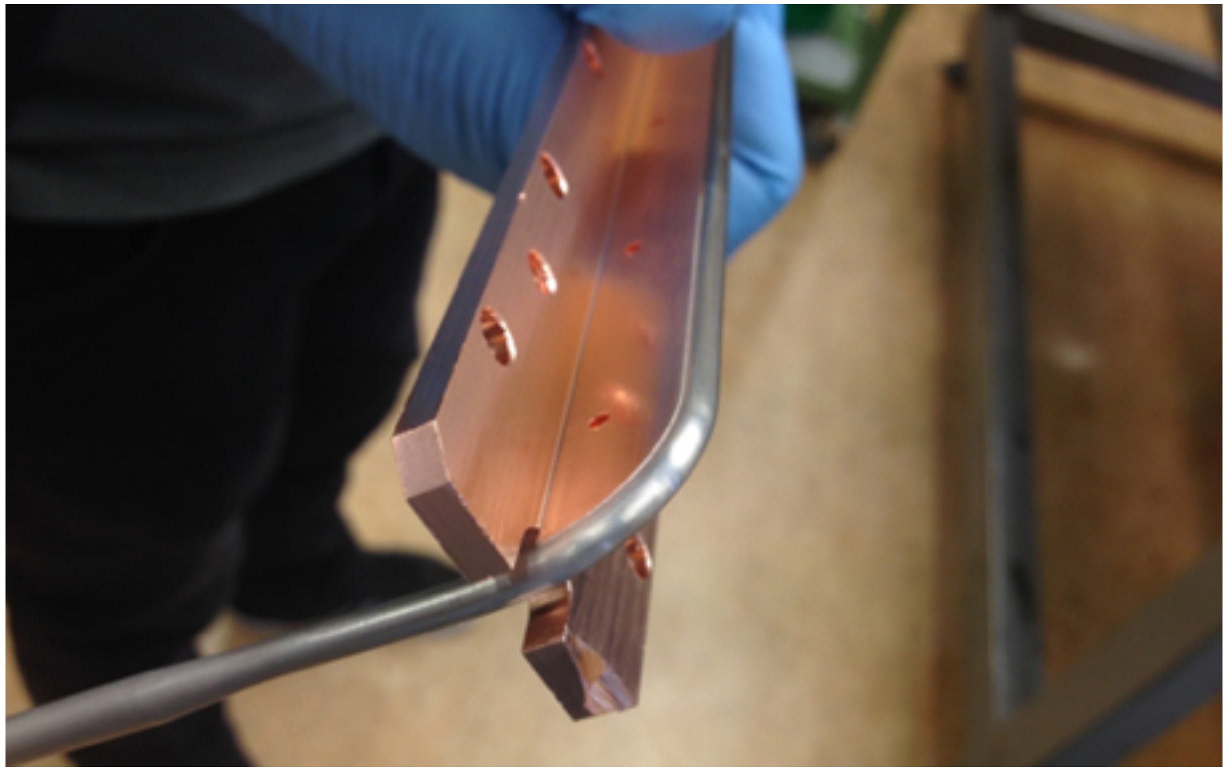
[3]CERN

N. Simos participating to this meeting - presented report on Mon. and detailed discussion ongoing. Hope to see this topics in LARP2!

Recent progress on new designs

Jaws with embedded wires for LRBB compensation





4 units being produced - ready for installation in EYETS 2016

Very positive beam tests with the SLAC rotatable collimator at the SPS.

Proved basic alignment features, measured impedance.
Next year: final validation at HiRadMat.

Outline

- Introduction
- Collimation upgrade baseline
- Status of baseline items
- **News on upgrade options**
- Conclusions

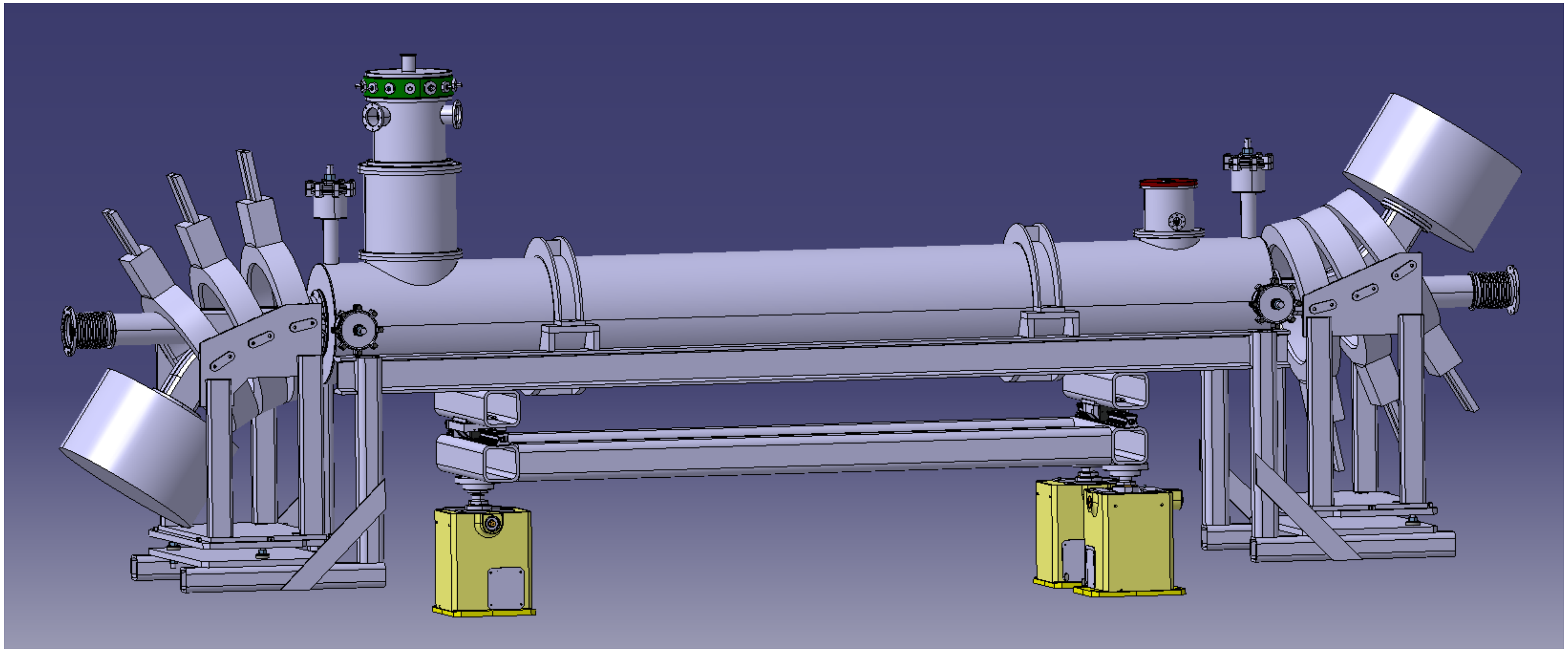
Active halo control

Goal: Control actively transverse halo above 3-4 σ. Essential in order to
- mitigate loss spikes on primary collimators with HL intensities;
- control static halo population → **fast failures of crab-cavities**.

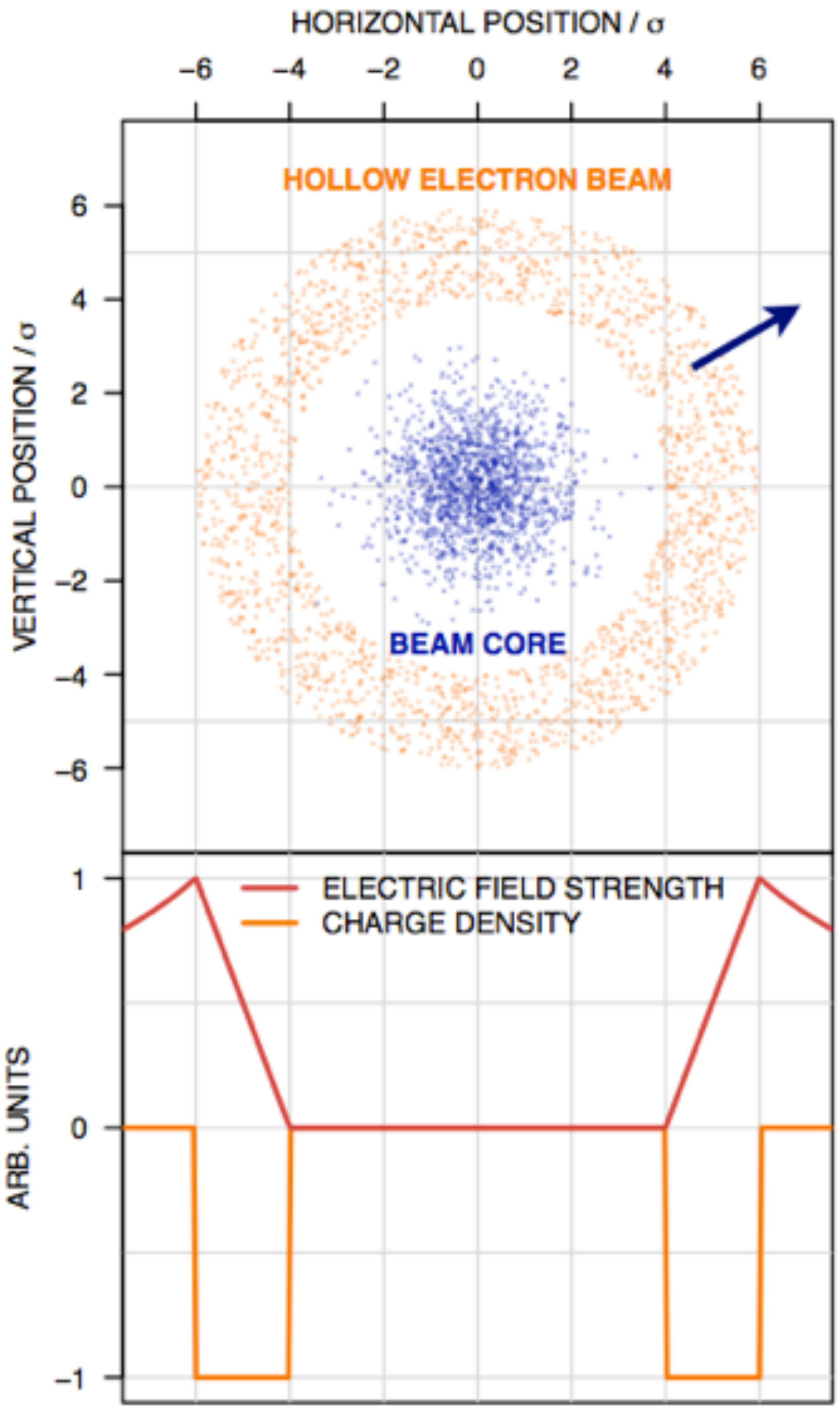
Several talks on this topics tomorrow.

Recently come up: concerns for losses during earthquakes (O. Brüning)

Proposed solution: Hollow electron lens to be installed in IR4 (1 per beam).



Hollow e-lens beam (HEB)



G. Stancari

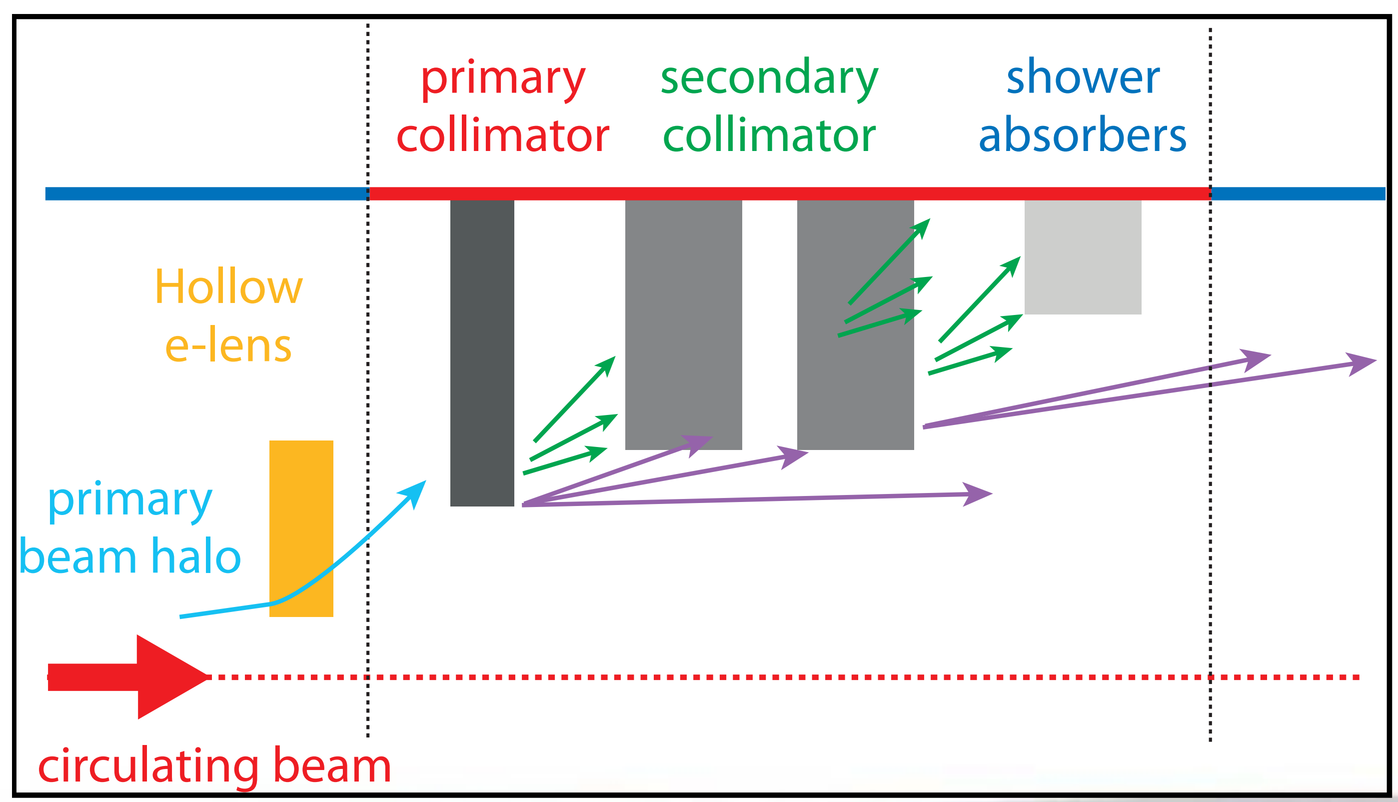
Provides selective and controllable excitation of halo particles above amplitude of the r_{in}.

Mitigation of loss spikes can help cleaning requirements but HEB cannot cure all loss.

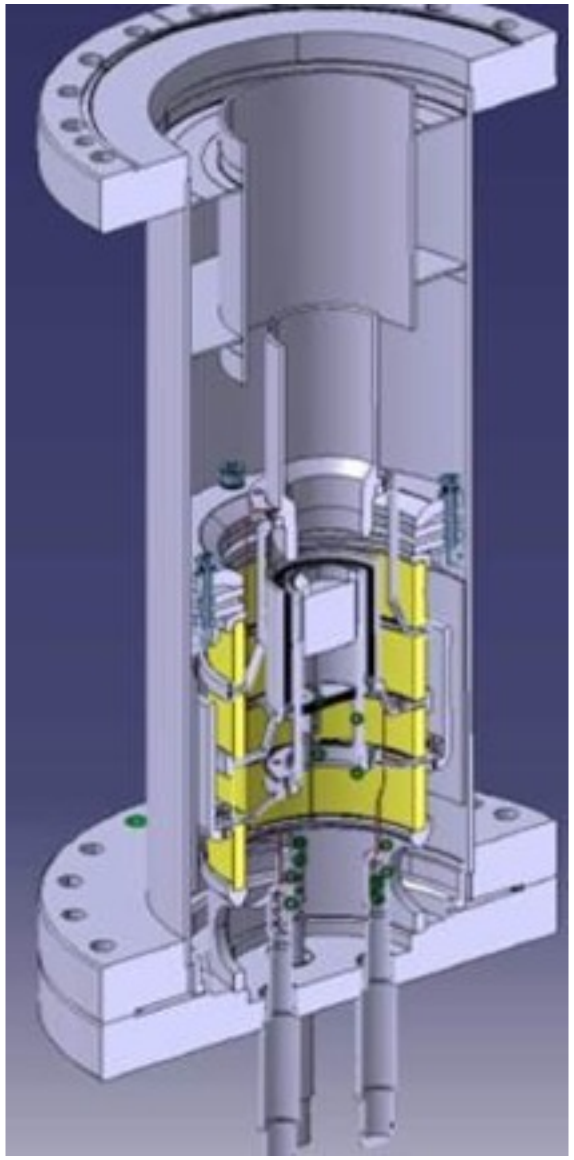
Not in "competition" to DS collimation.

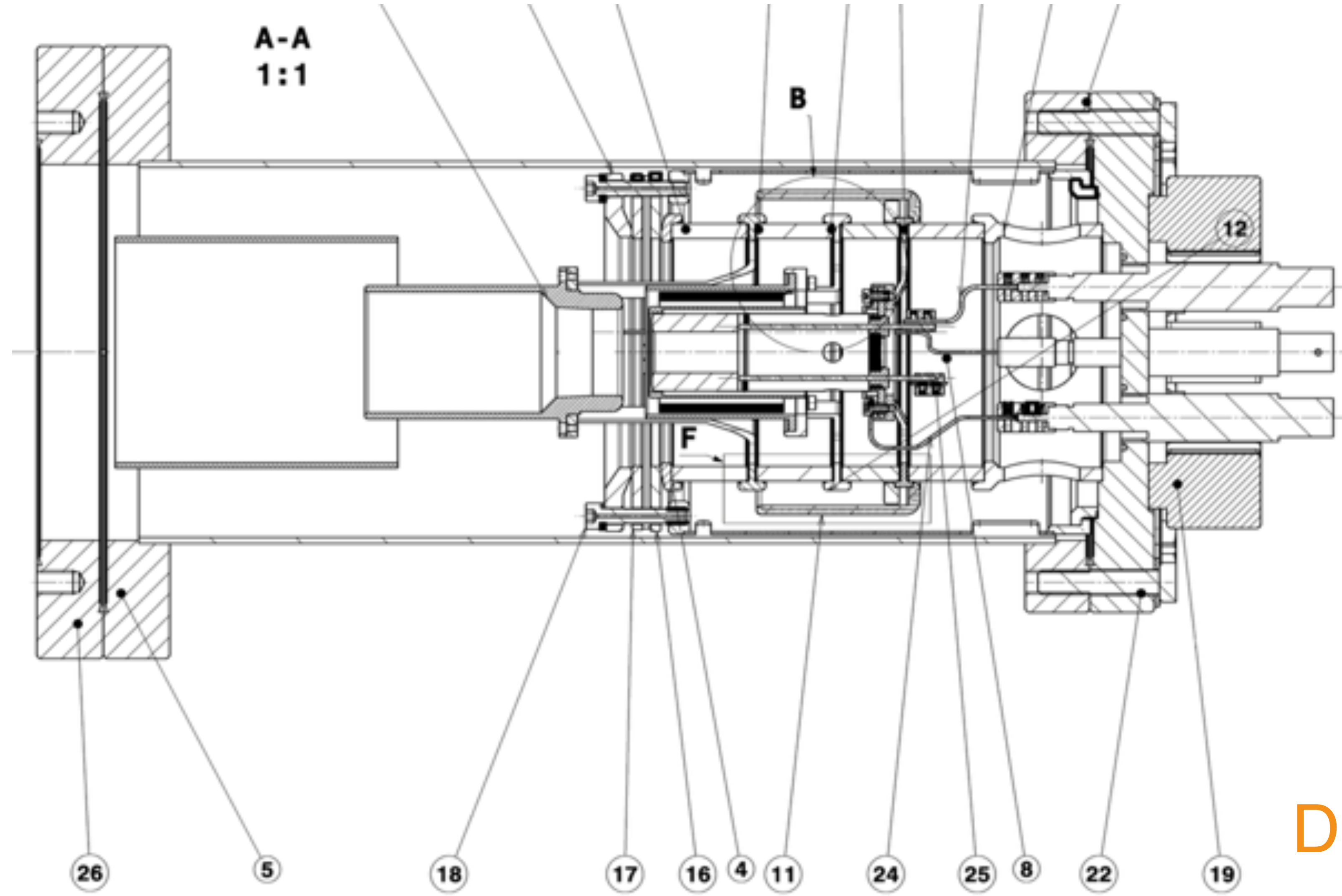
Complementary to present system and other upgrades, like crystals.

Outstanding for LHC: need modulated currents to excite halos fast enough.



Recent news on improved designs





D. Perini

We are building a gun based on the Tevatron design.

Plan to ship it in January to FNAL for tests at their e-beam facility.

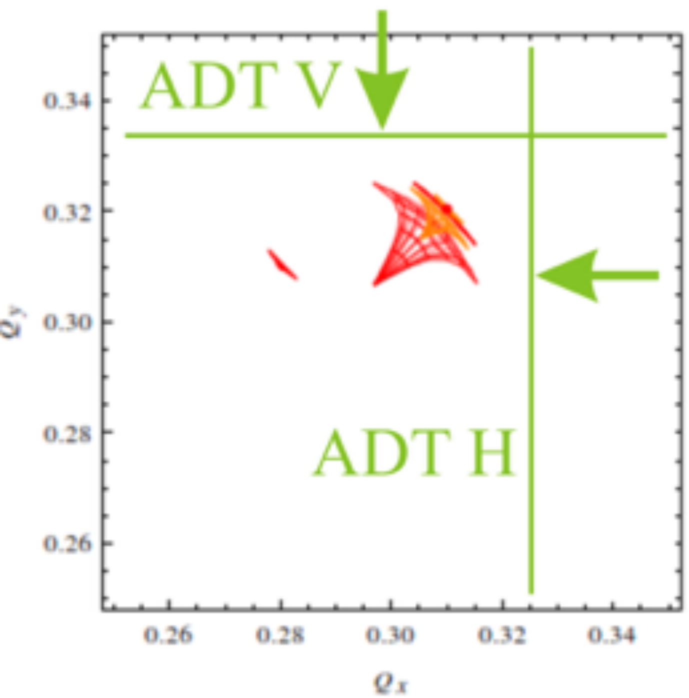
Thanks to continued support by LARP (fellow) and FNAL.

Ongoing studies of integration in IR4 for layout v1.2 (A. Rossi)

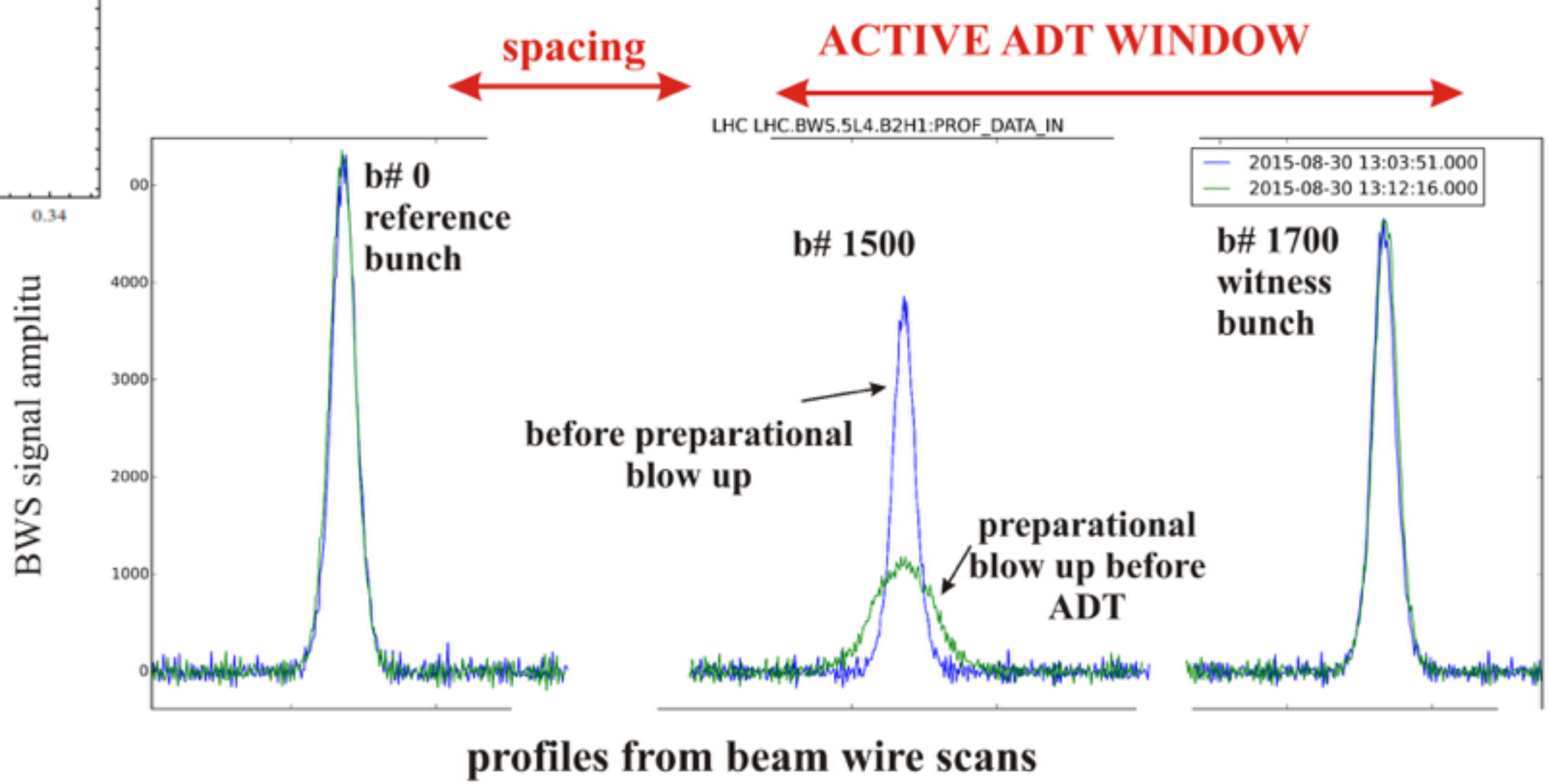
Ongoing simulation effort in EU: Merlin and Sixtrack.

Study of alternative methods

Working with high priority on 2 alternative methods: tune ripple and narrow-band excitation from transverse damper (ADT)

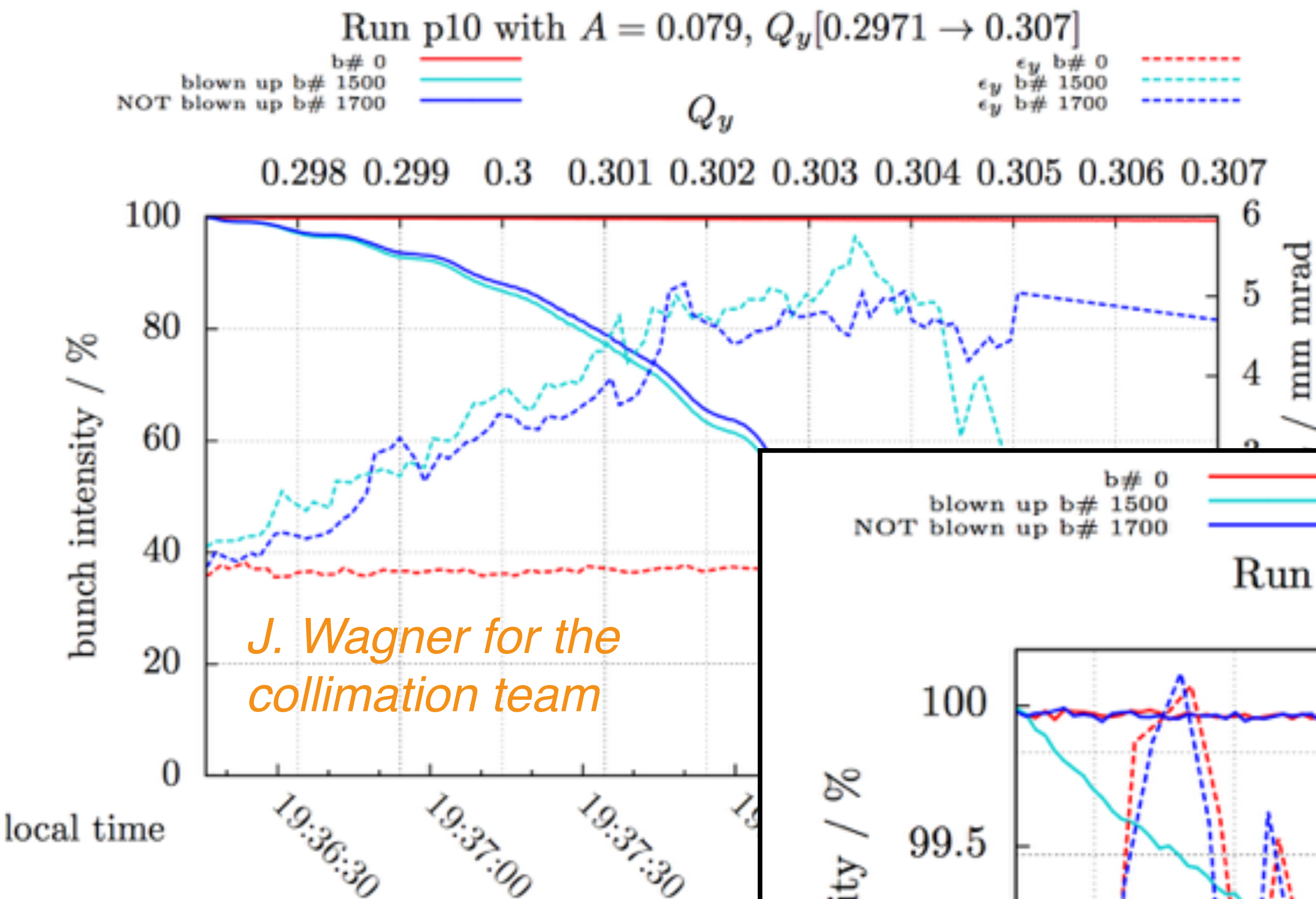


2015: tests with beam the ADT method at 450 GeV

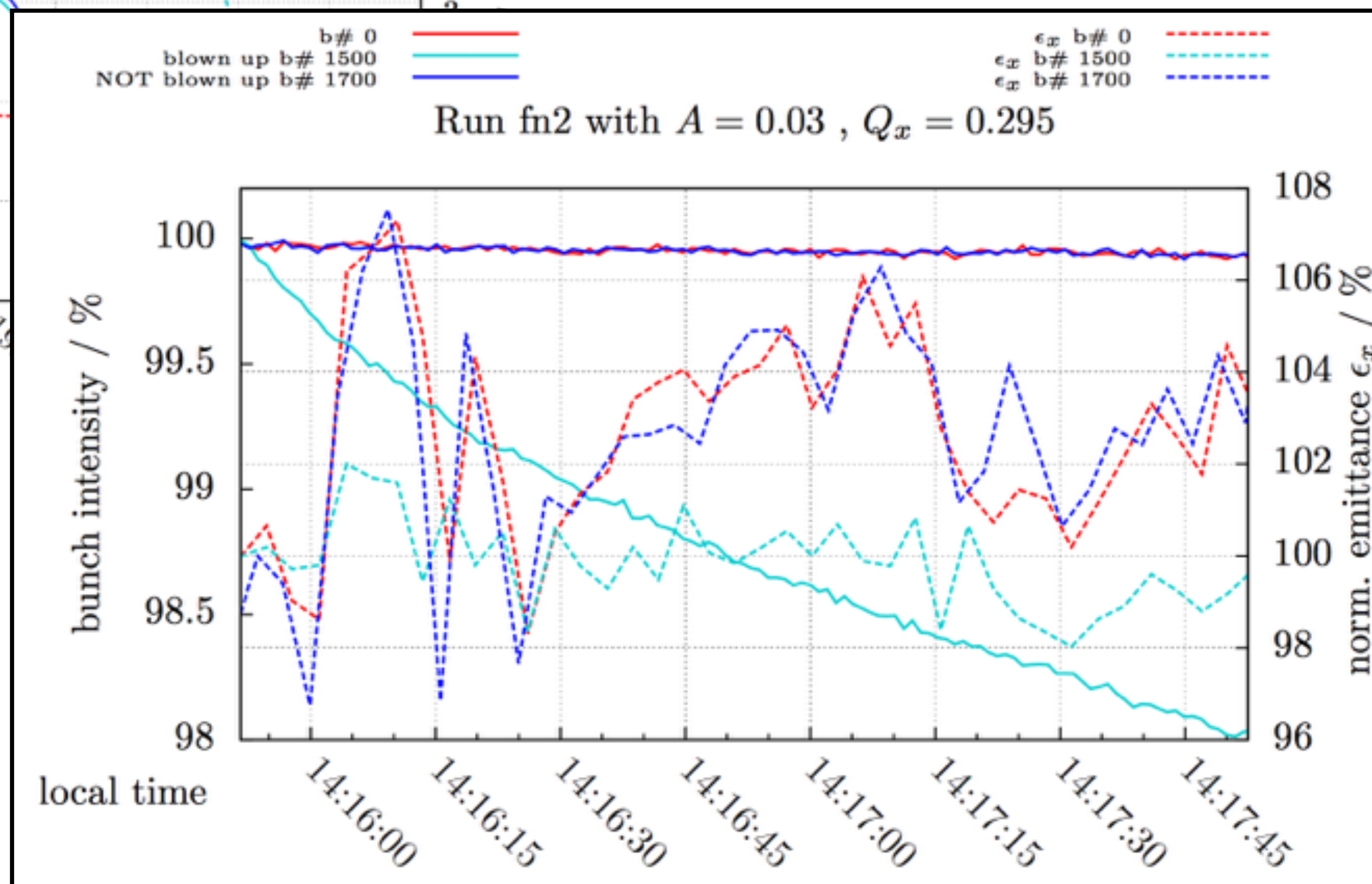


J. Wagner for the collimation team

Preliminary results

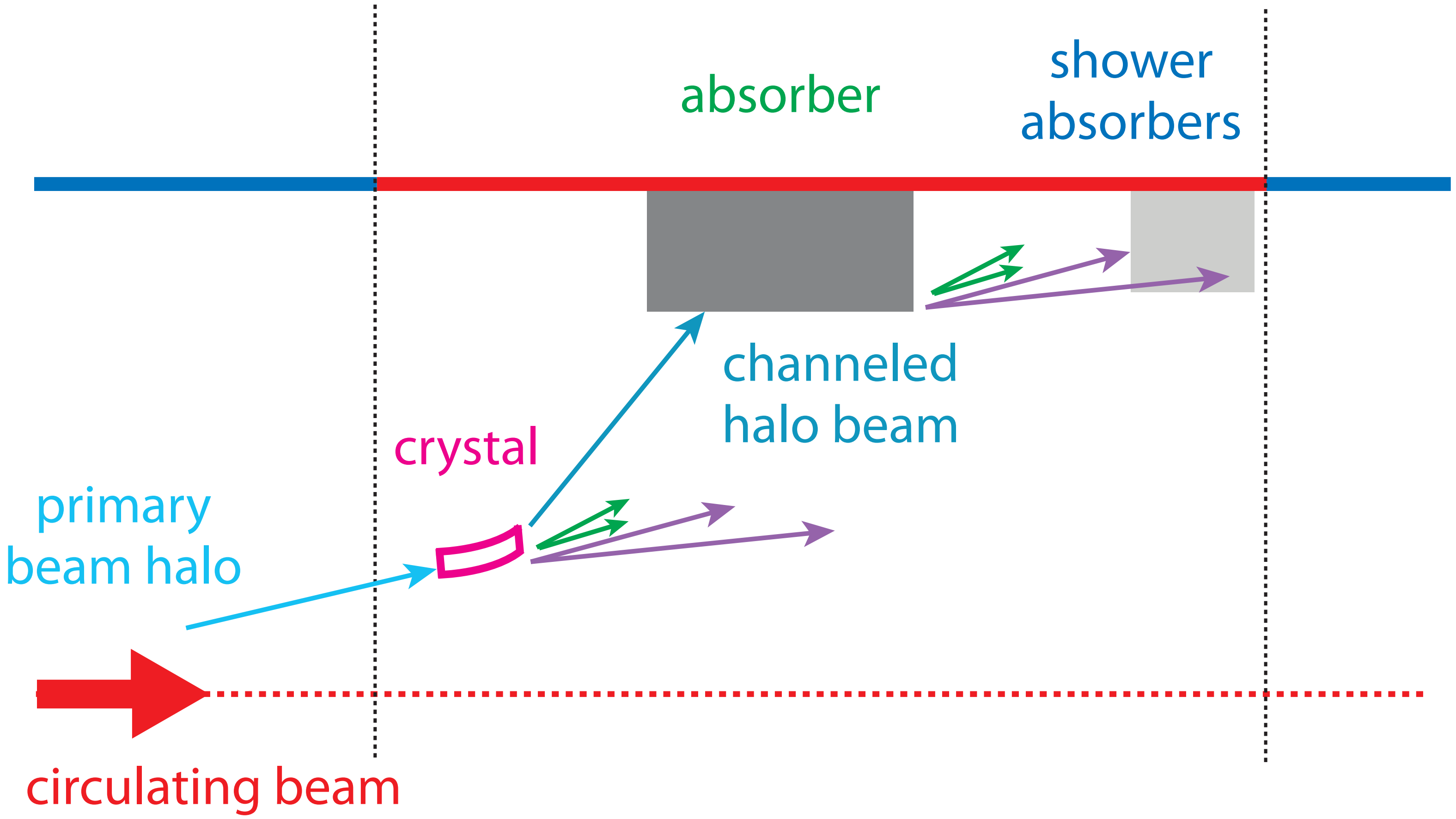


1 promising "candidate" configuration where we managed to attach tails without blowing up the core.



Will be repeated at 6.5TeV next week in MD.

Crystal collimation



Promises of crystal collimation:

1. Improve **collimation cleaning** achieved with fewer collimators;
2. Reduce collimation impedance;
3. Improve significantly the cleaning for **ion beams**.

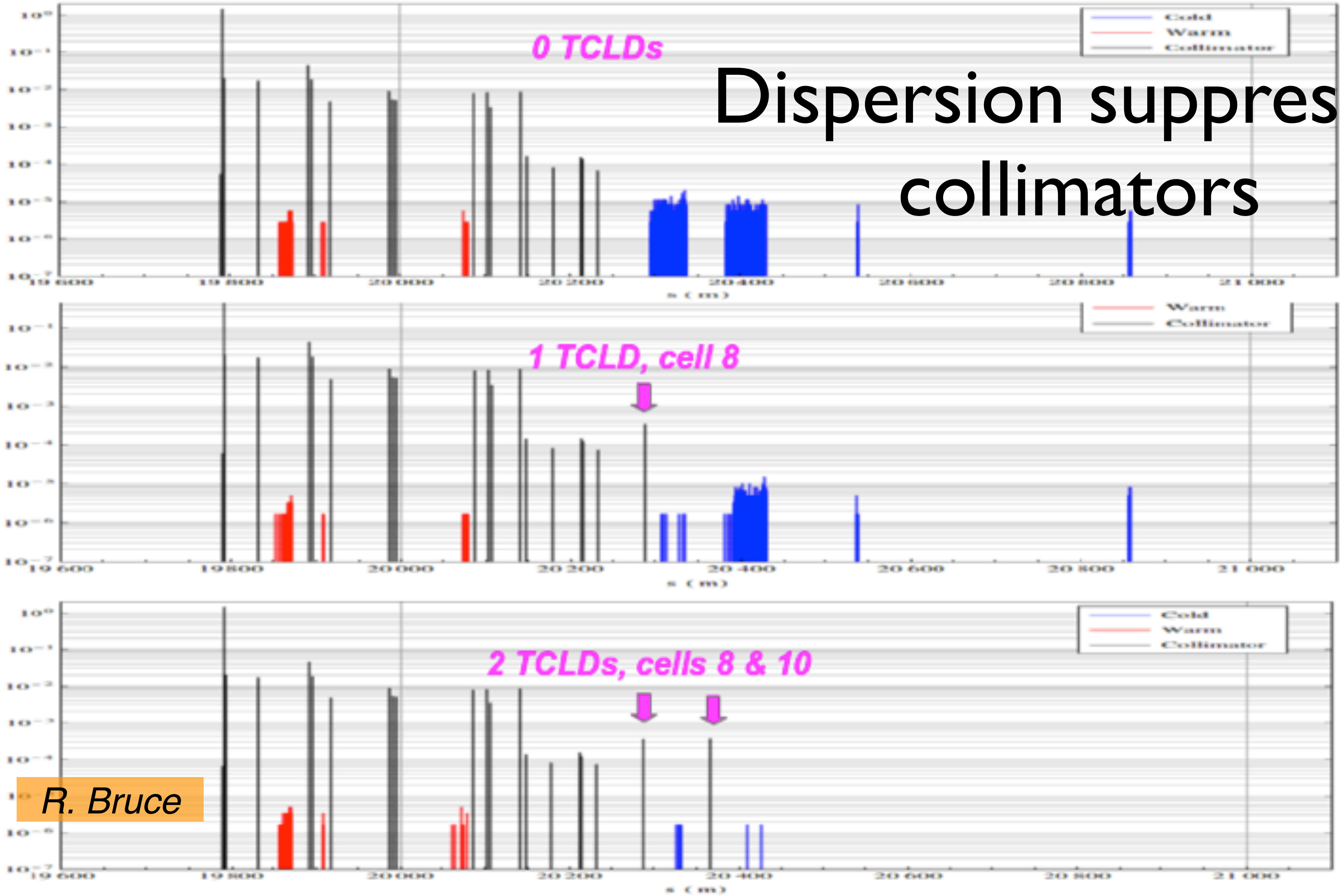
Crystal collimation concept **only works in collimation insertions**.

Possible alternative to 11T dipoles in IR7 for ion and proton beams.

Good experience at the SPS from UA9 experiment, but less conclusive results from Tevatron and RHIC ➤ ***Beam tests at the LHC deemed necessary before relying on crystal collimation****.*

H and V crystals installed in IR7 for low-intensity collimation tests (collaboration with UA9 team)

IR7 cleaning: crystal vs 11T dipoles



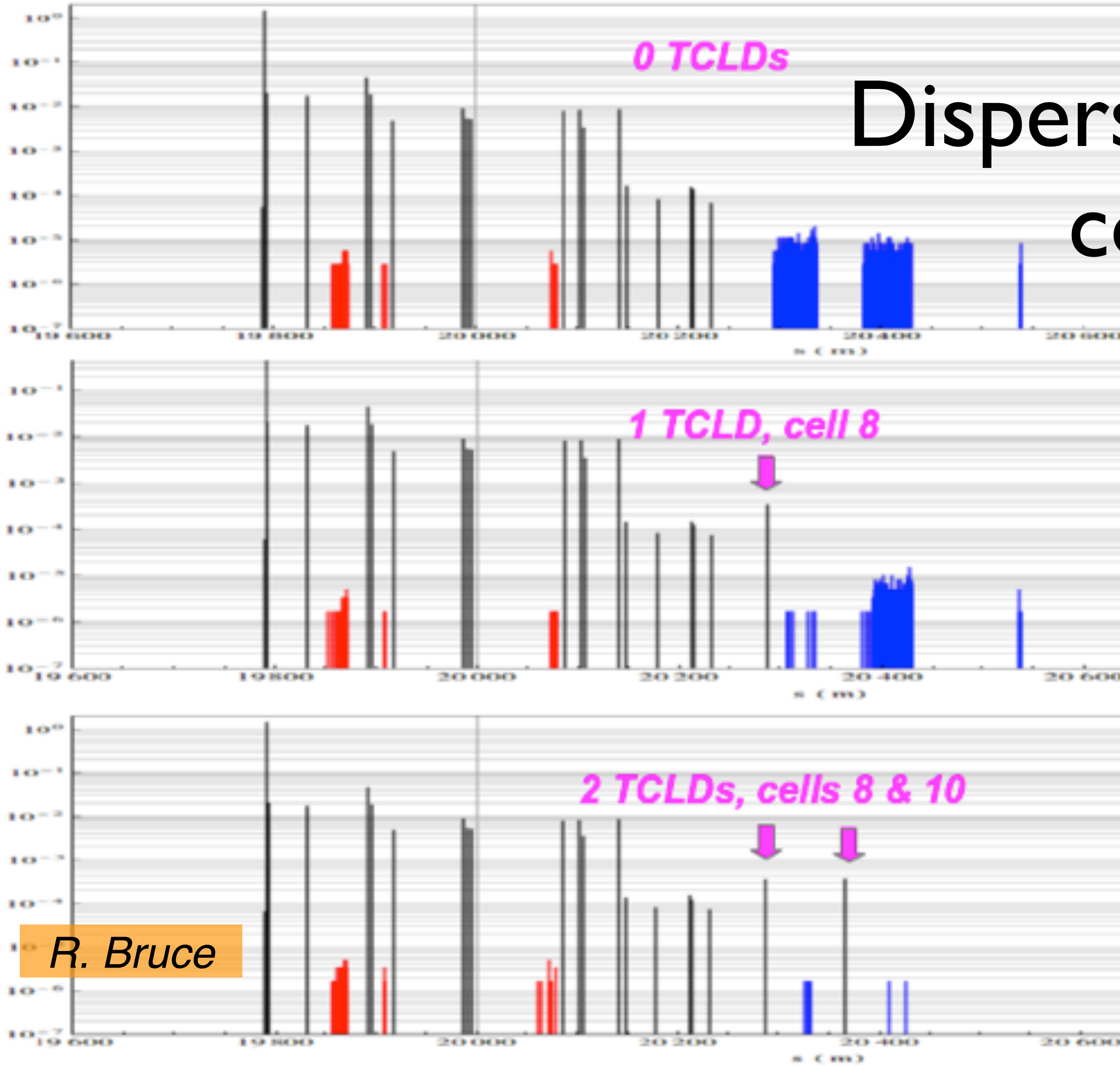
Note: TCLD -> "adiabatic" addition to present system.
Crystal: change of paradigm.

Simulations with ATS optics to be done (R. Rossi, PhD work)

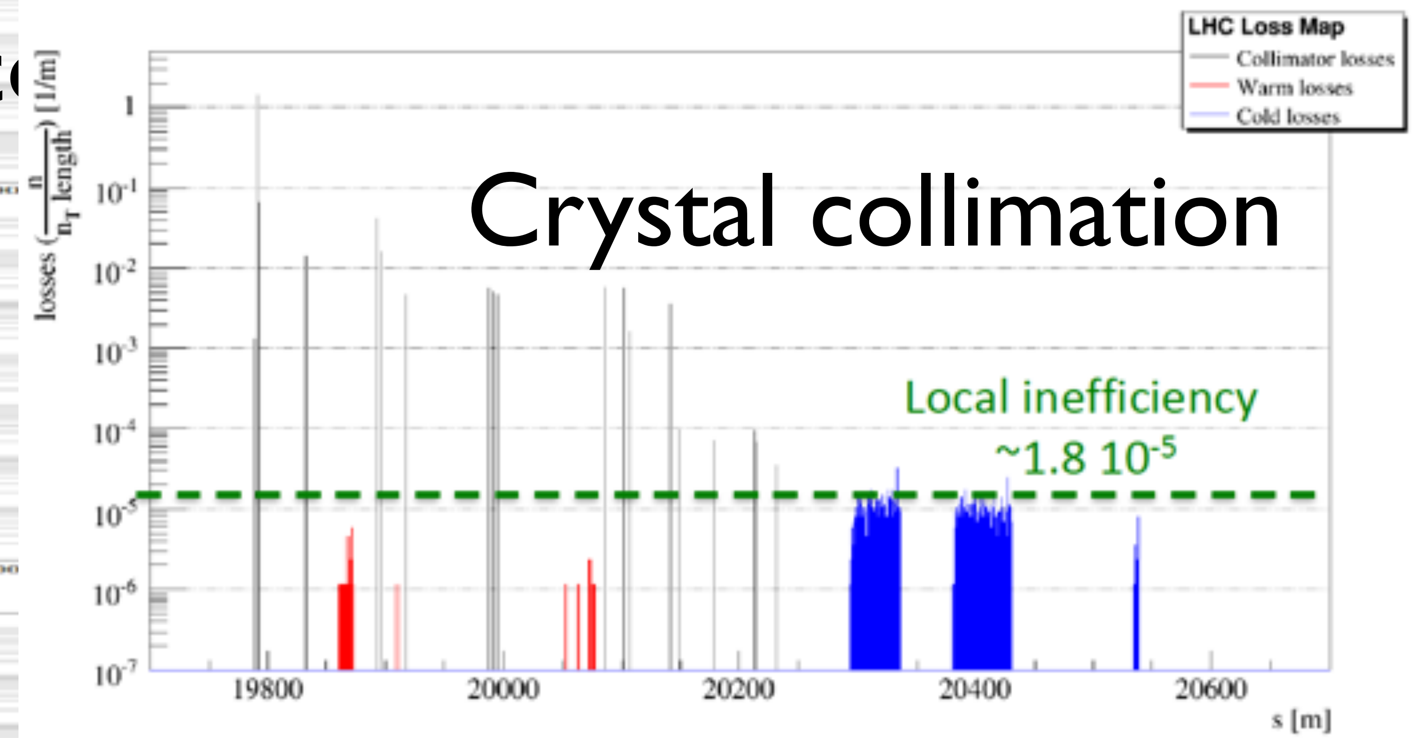
D. Mirarchi

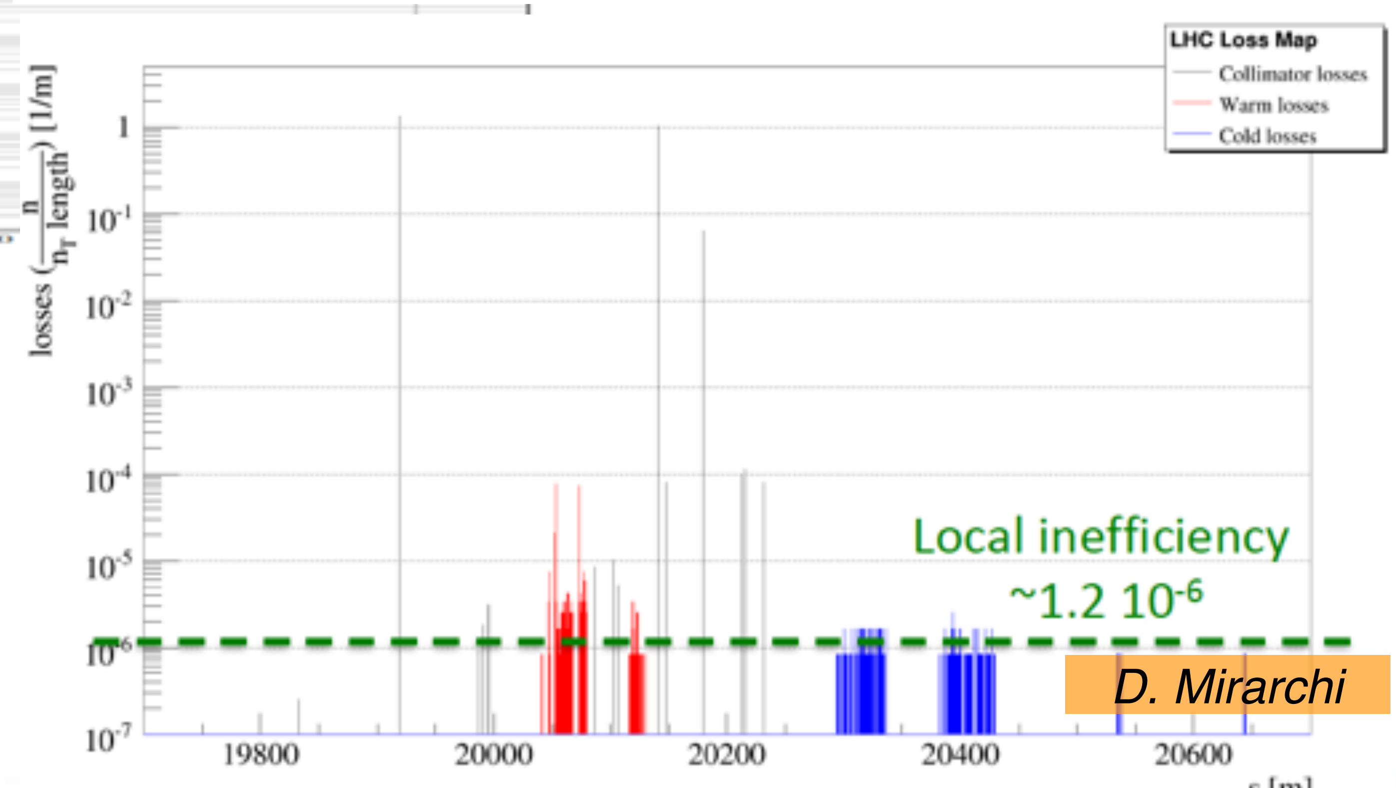
IR7 cleaning: crystal vs 11T dipoles

Dispersion suppressor



Crystal collimation



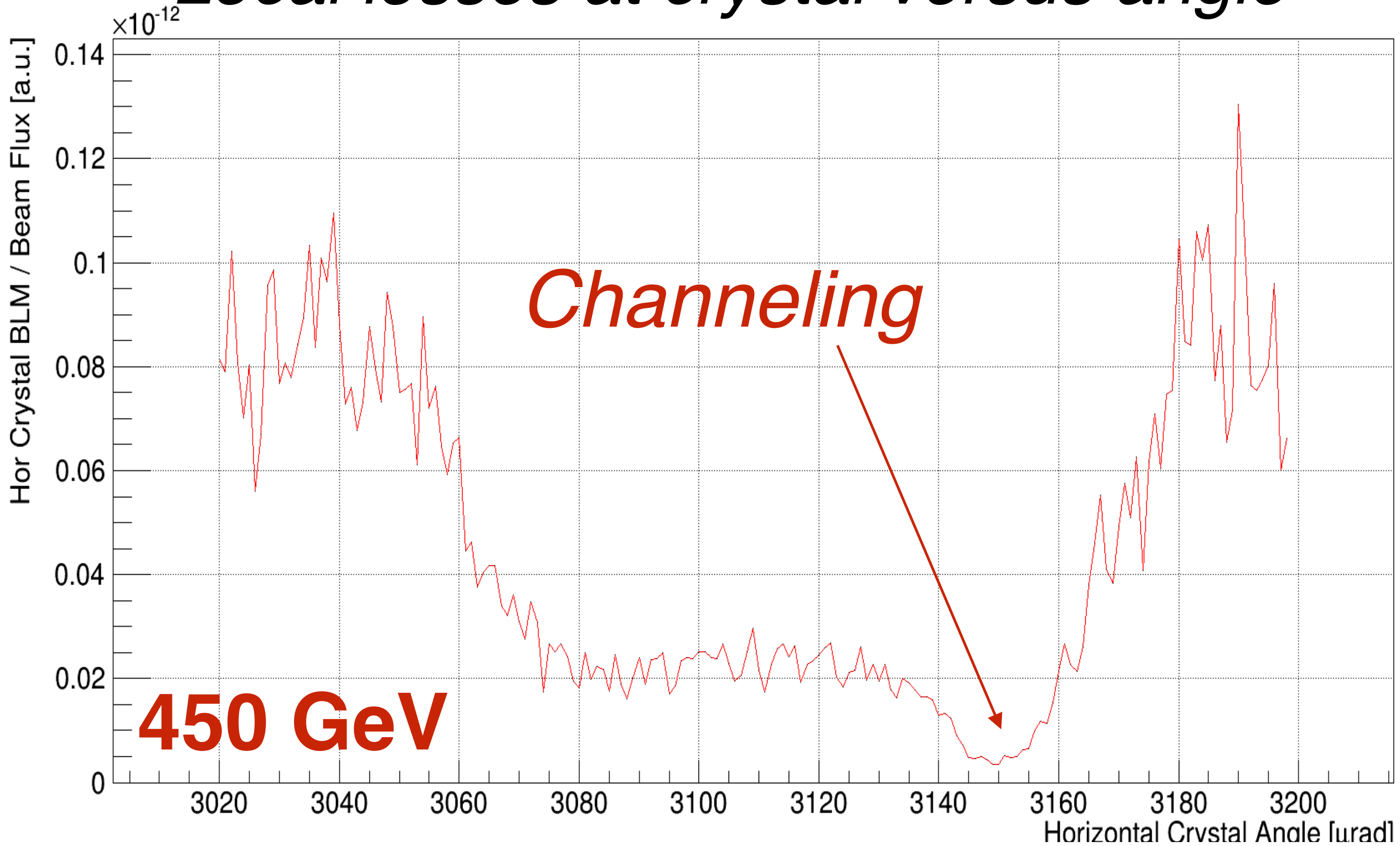


Note: TCLD -> "adiabatic" addition to present system. Crystal: change of paradigm.

Simulations with ATS optics to be done (R. Rossi, PhD work)

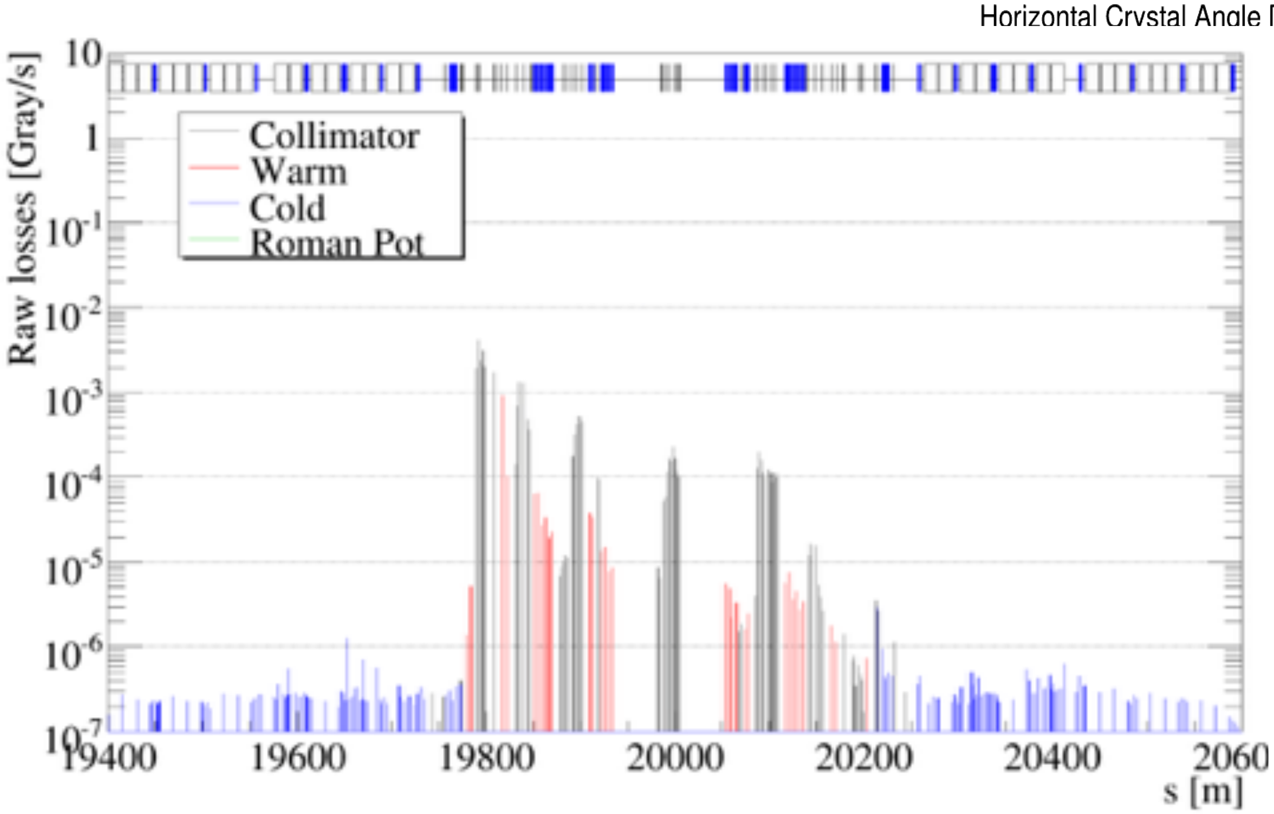
Status of beam tests at the LHC

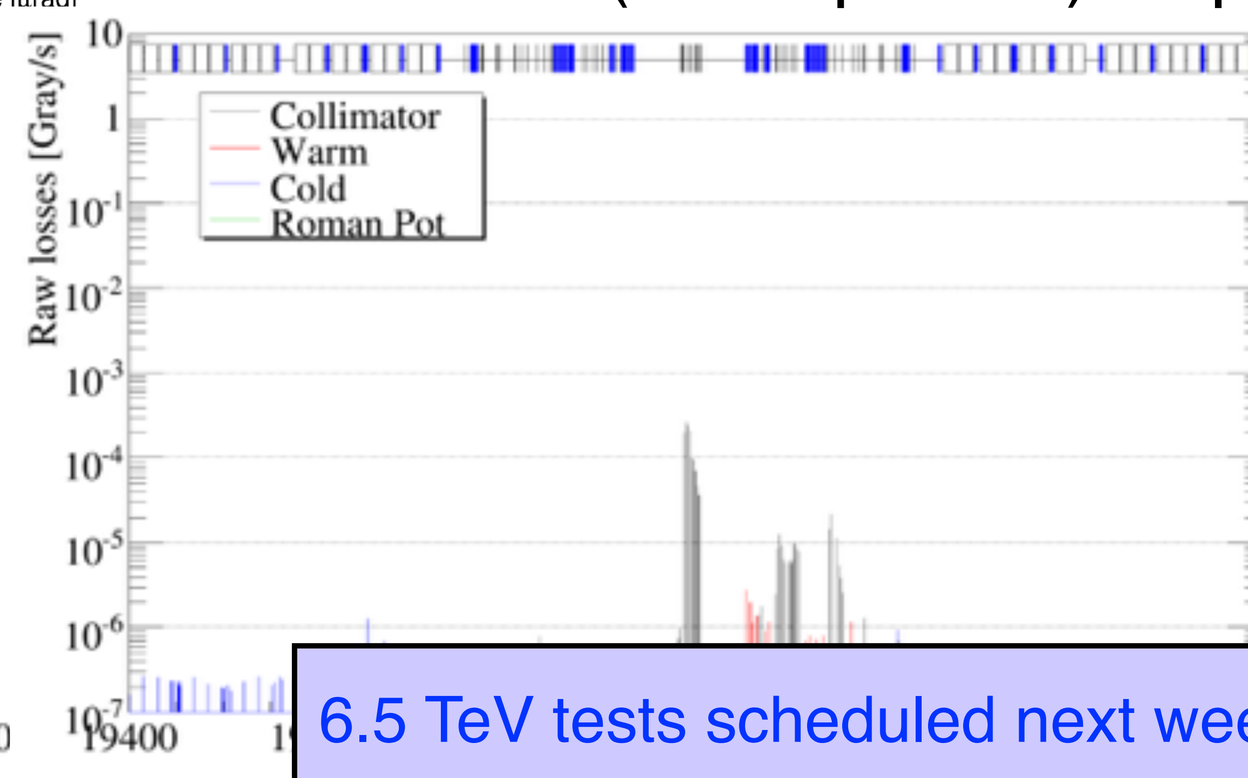
Local losses at crystal versus angle



Promising result at injection:

- Observed channeling with 2 crystal technologies!
- Cleaning looks close to expected figures at 450GeV.
- Important tests of technology developed by EN/STI, with applications to other collimator controls (like TDI)
- Just a first (but important) step…





6.5 TeV tests scheduled next week!

Conclusions

- ☑ **Reviewed the collimation upgrade baseline for the HL**
  - *Acknowledgements to important collaborations: FP7-HiLum + EuCARD, LARP, etc.*
- ☑ **We have converged to a solid baseline**
  - *Reviewed the status for the dispersion suppressor implementation*
  - *New layouts in IR1/5 ↦ integration concerns are under investigation*
  - *Low-impedance / high robustness collimator progresses well with beam test*
    - *Investigating possible limitations from high radiation doses and jaw coating.*
- ☑ **Continued working on various promising upgrade options**
  - *Thanks to the LHC team for support with MD time!*
  - *Important upcoming tests next week (in particular, quench tests at 6.5TeV)*
- ☑ **Recent important progress on hollow e-lens collimation**
  - *Started building components at CERN for tests here and at FNAL*
  - *Ongoing effort on simulation not discussed here*
- ☑ **First positive results on crystal collimation at injection**