LHC Performance Workshop - Chamonix 2011

Hotel "Les Aiglons", Chamonix, France

January 24th-28th, 2011

Collimator improvements for 2011 and 2012 upgrade: What do we plan?

S. Redaelli for the LHC Collimation Team

CERN, Geneva, Switzerland

Outline

- Introduction
- 2010 operational experience
- Changes for 2011
- Improvements after 2011
- Conclusions

Acknowledgments

Results are presented on behalf of the LHC collimation teams.

In particular, material taken from

R. Assmann, A. Bertarelli, A. Dallocchio,

D. Wollmann, A. Rossi, G. Valentino,

M. Gasior, et al.

Additional thanks:

A. Masi and team, ABP collimation team.

FLUKA team, BE-BI team,

Injection team

J. Wenninger + SMP team

Layout of LHC collimation system

Two warm cleaning insertions

- **IR3: Momentum cleaning**
  - **1 primary (H)**
  - **4 secondary (H,S)**
  - **4 shower abs. (H,V)**
- **IR7: Betatron cleaning**
  - **3 primary (H,V,S)**
  - **11 secondary (H,V,S)**
  - **5 shower abs. (H,V)**

Local cleaning at triplets

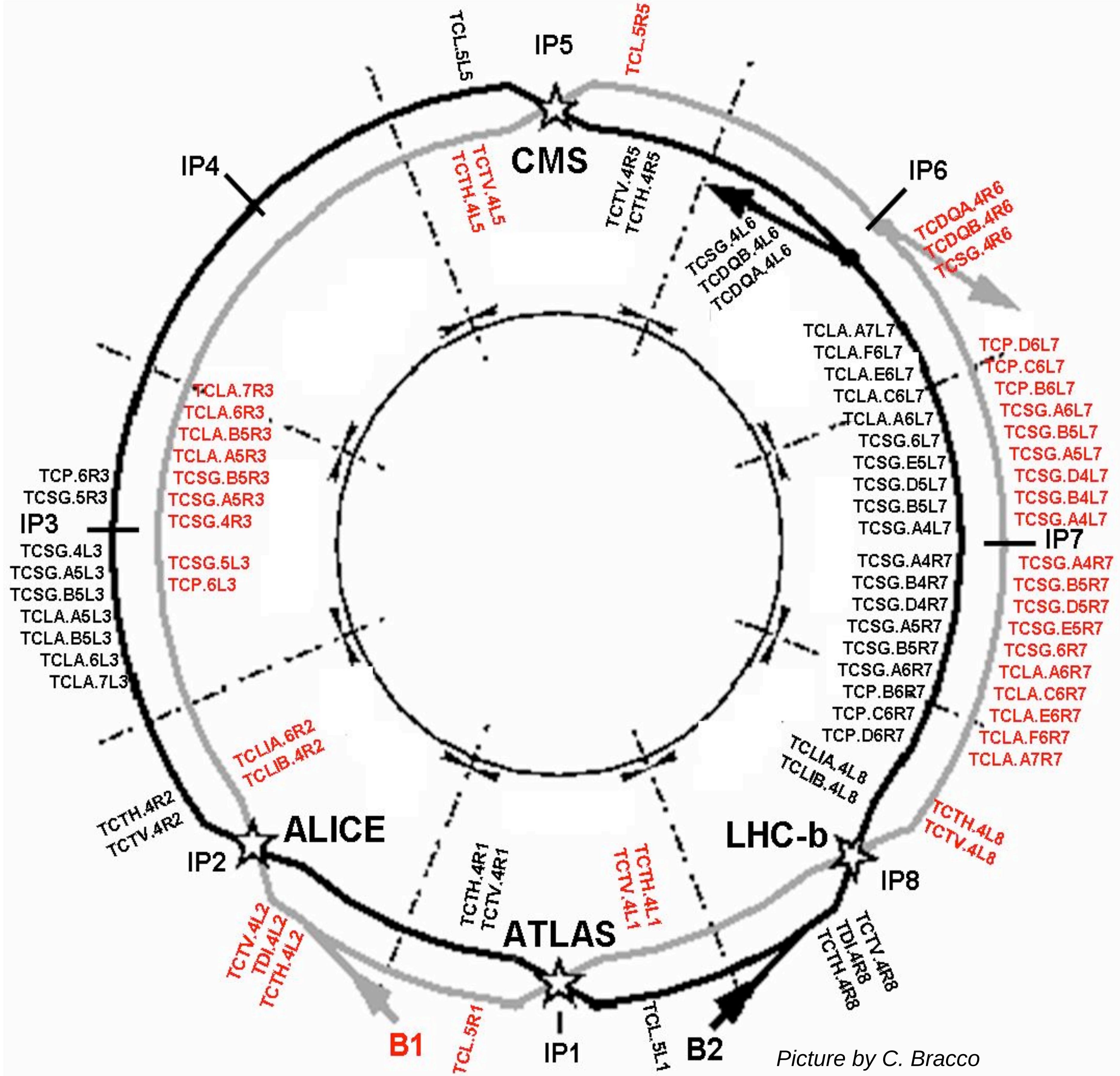
- **8 tertiary (2 per IP)**

Passive absorbers for warm magnets

Physics debris absorbers

Transfer lines (13 collimators)
Injection and dump protection (10)

Total of 108 collimators (100 movable). Two jaws (4 motors) per collimator!



Picture by C. Bracco

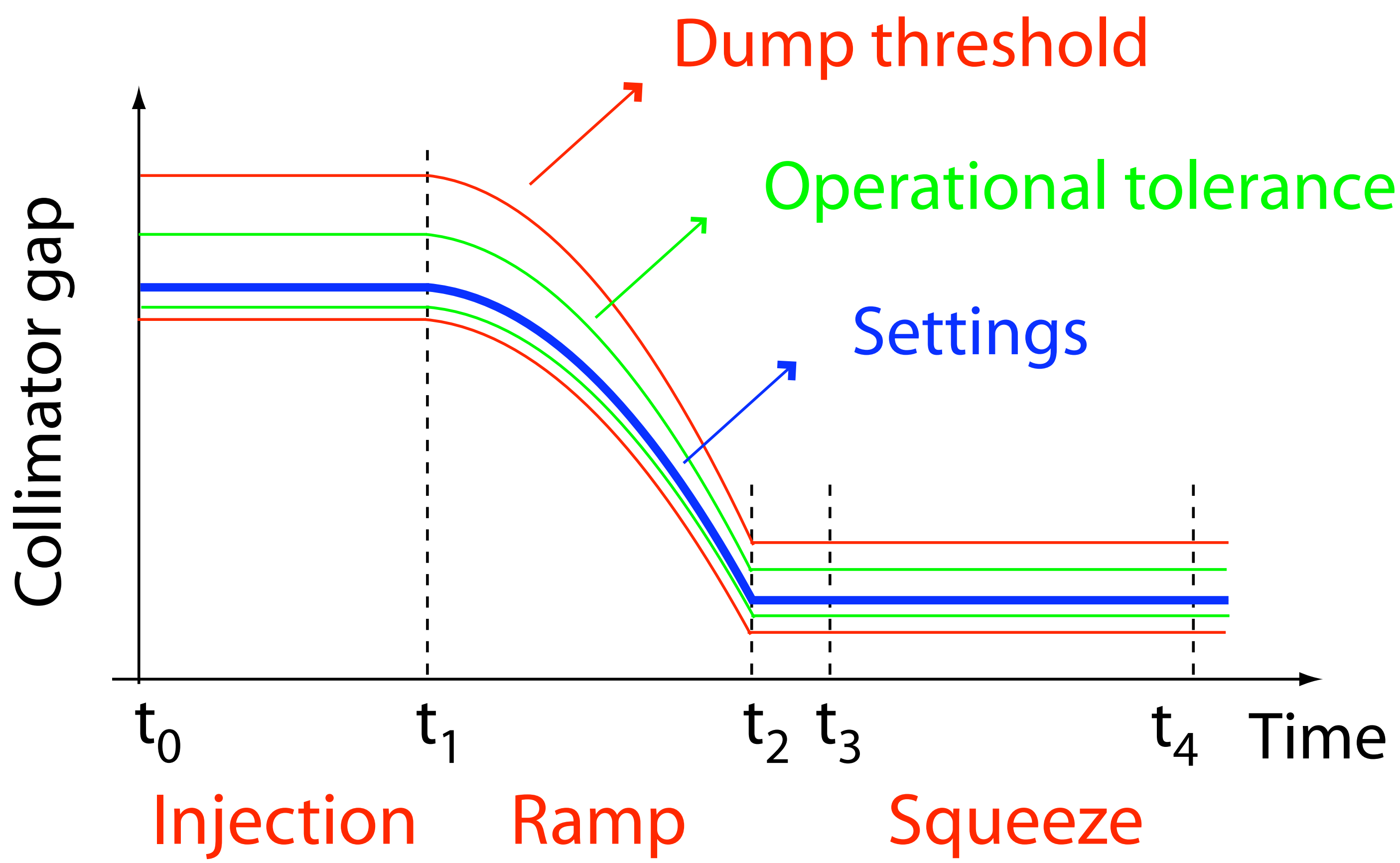
LHC Collimators: Some numbers

Collimators are needed in ALL machine cycles: from injection to collision.

They are driven by functions of time, triggered synchronously to power converters and RF.

Table 1: Main system parameters

Parameters	**2008**	**2009**
Number of movable collimators	80	100
Degrees of freedom	316	396
Position sensors	788	998
Interlocked position sensors	472	592
Motor settings versus time	316	396
Threshold settings versus time	1896	2376
Threshold settings versus energy	154	194
Collimators with fifth motor	30	46



Total number of settings to manage in 2010:

396 degrees of freedom x 5 = 1980

2376 limit functions x 5 = 11880

194 energy limit functions x 1 = 194

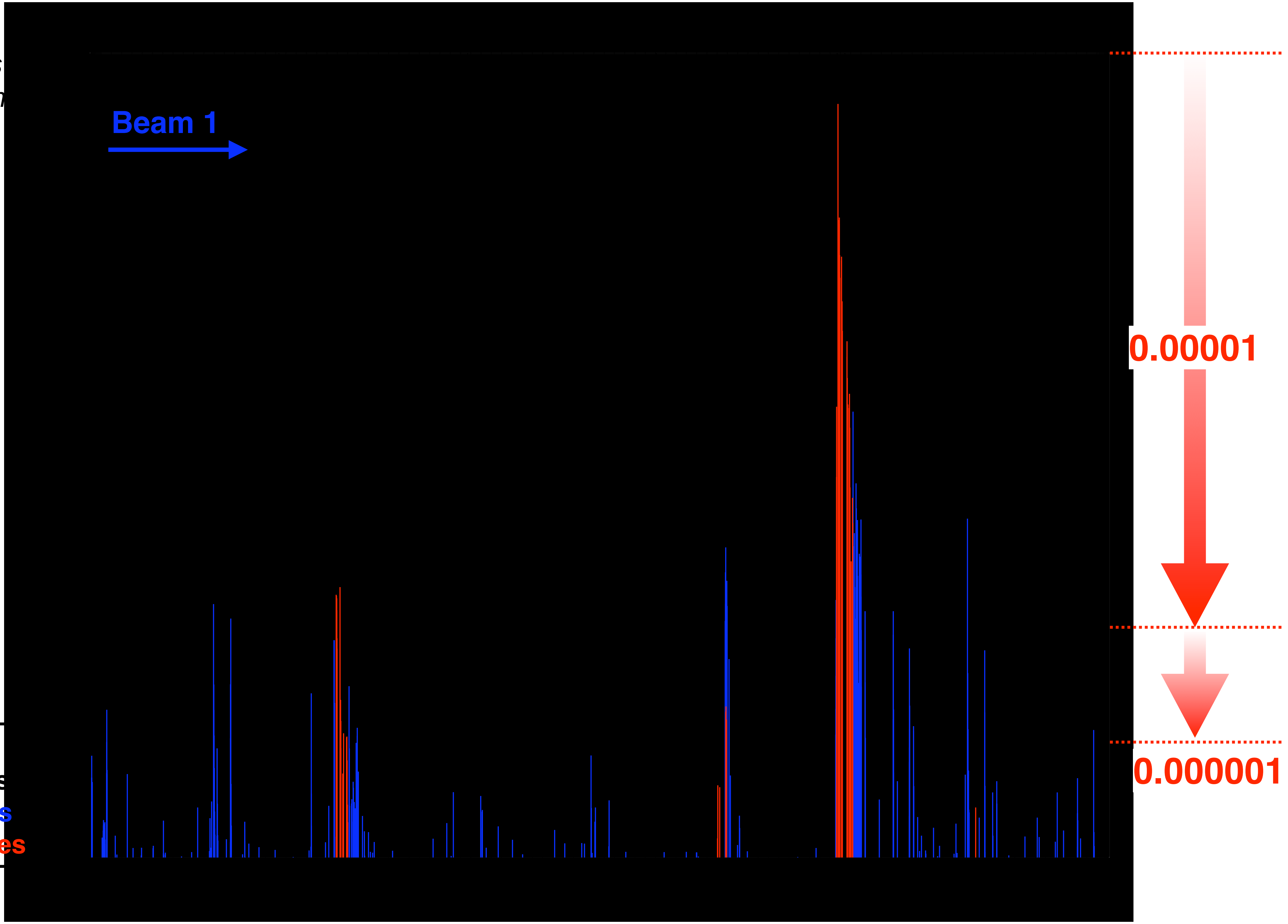
*= **14054 settings***

Crucial to control tightly the collimator positions in all machine phases!

2010 cleaning at 3.5 TeV

Higher loss rates: beam across the 3rd order resonance.

Repeated for ALL run configs.



Legend:
Collimators
Cold losses
Warm losses

2010 operational feedback

- The Phase I collimation system works **very well**! *See Ralph's talk.*

  Close to nominal cleaning with relaxed settings at 3.5 TeV!

  Projected performance show no limitations for 2011-2012 run.

- **Outstanding cleaning performance** has been important for smooth and safe commissioning and operation.

  No single quench with circulating beam yet!

- The key design choices were fully validated.

- **But**:

  - Cleaning **limitations** are found at the expected locations: this will eventually limit the total intensity.
  - The system setup is **difficult** and **lengthly**!
  - The collimation system **constrains** significantly the operation:

    Tight orbit and optics tolerances; limited range for luminosity scans;

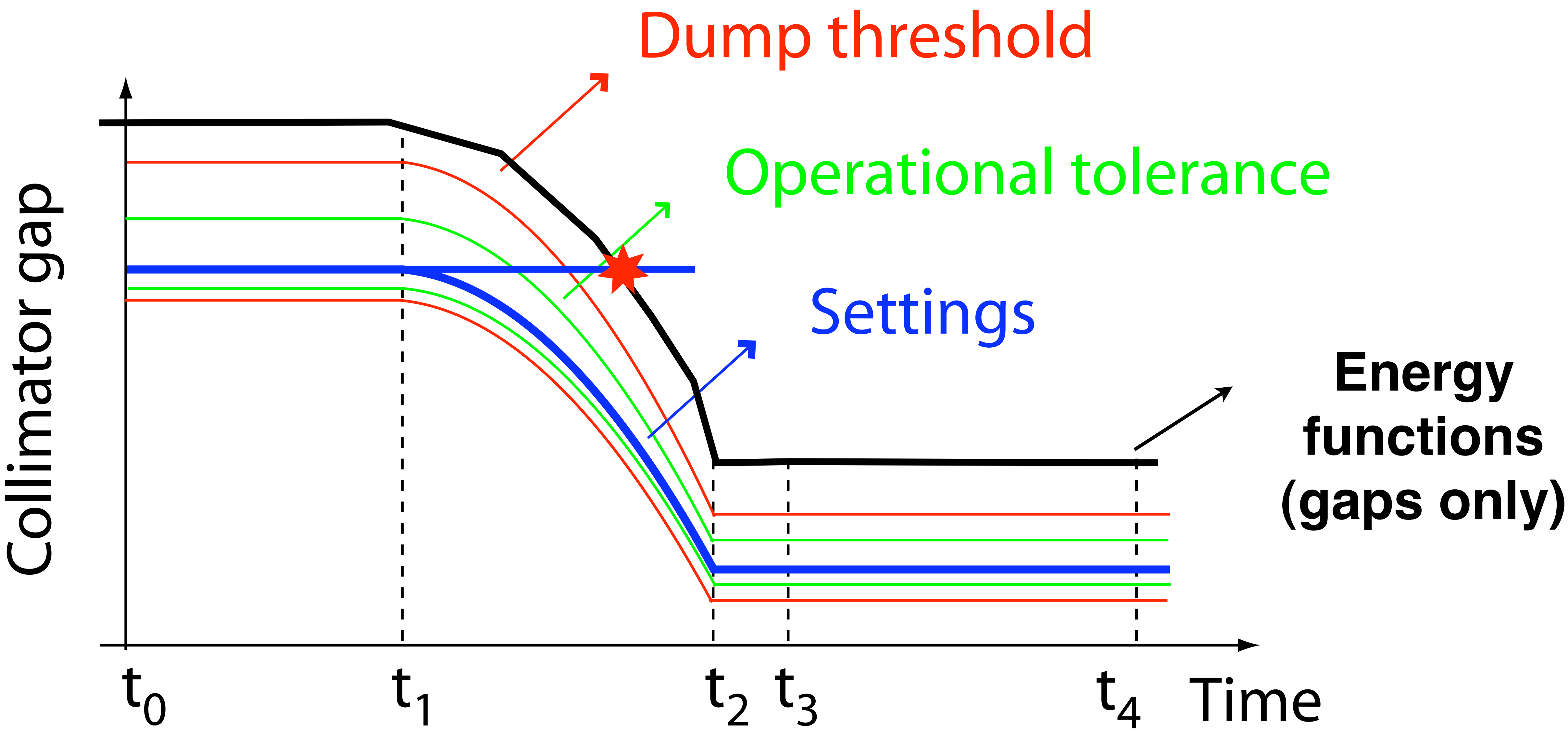
    Limits imposed on the values of beta due to collimation hierarchy.*
  - We have seen limitation from radiation to equipment (ion operation).

Upgrade scenarios must address these aspects!

Outline

- Introduction
- 2010 operational experience
- **Changes for 2011**
  - **- Improved MP functionality**
  - **- Faster beam-based setup**
- Improvements after 2011
- Conclusions

Collimator dump thresholds



- **Inner** and **outer thresholds** as a functio[n]
  gap (<u>24 per collimator</u>). Triggered by timi[n]
- Internal clock: check at 100 Hz!
- "Double protection" → BIC loop broken A[l]
- <u>Redundancy</u>: **maximum allowed gap ve[…]**

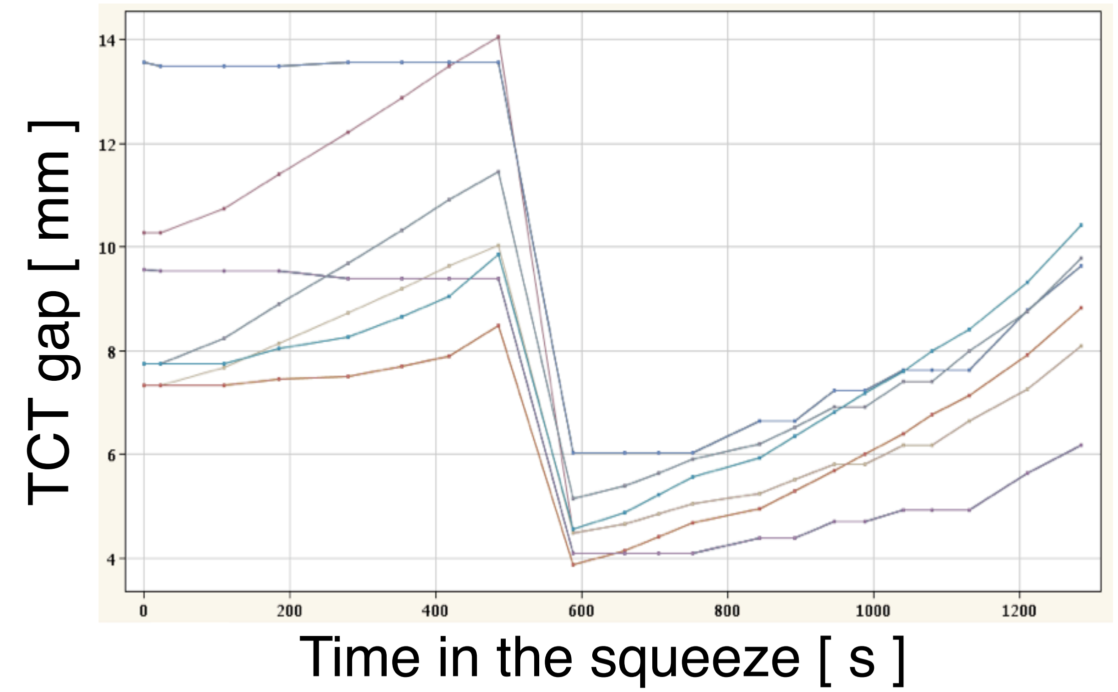
Improvements for 2011:
(1) limits vs. β* during squeeze
(2) Concept of energy limit for injection protection in the ring

Collimation improvements for 2011

(1) New gap limits as a function of BetaStar in the different IPs

- Always foreseen in the system but delayed as β* not available in SMP last year.
- 2010: no problems seen as movements done with well debugged sequences.

TCT gap settings during squeeze



(2) Energy limits added to ring injection protection (TDI, TCLI)

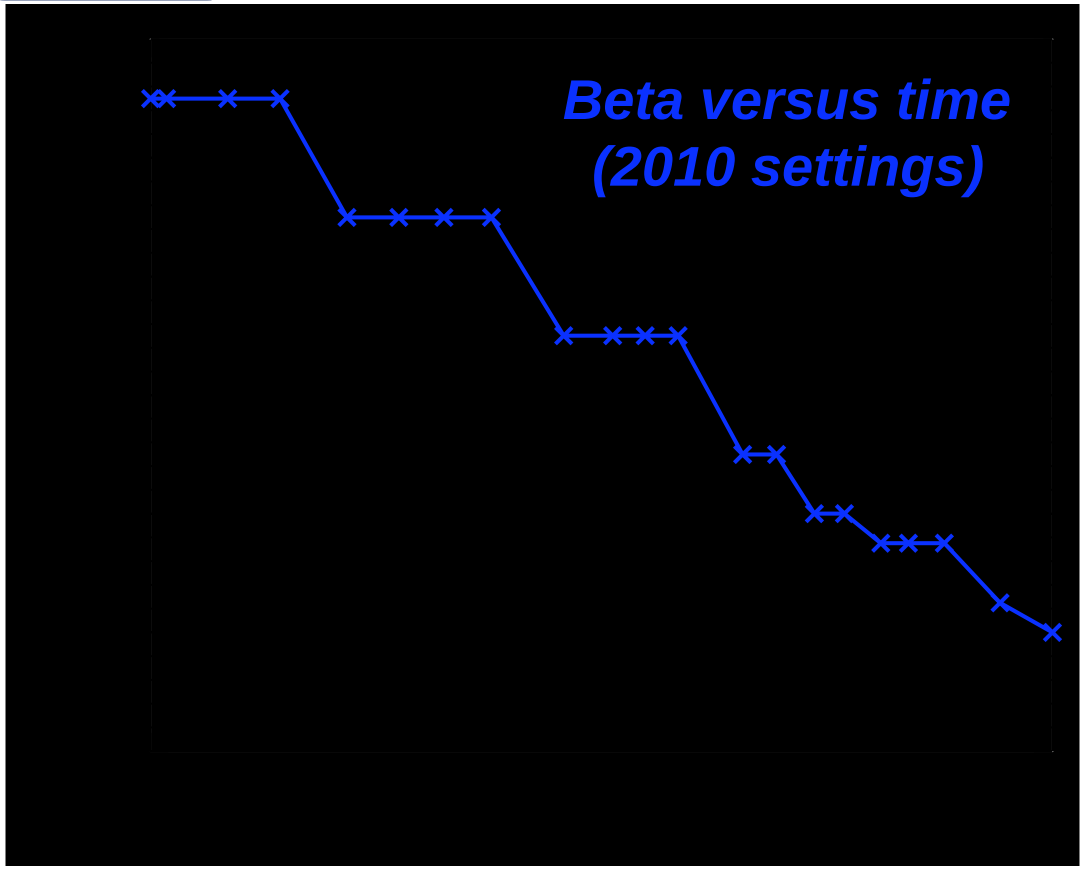
- In 2010, protection relied on OP execution of nominal sequence.
- Now: redundant limits that will prevent injection if TDI/TCLI OPEN.

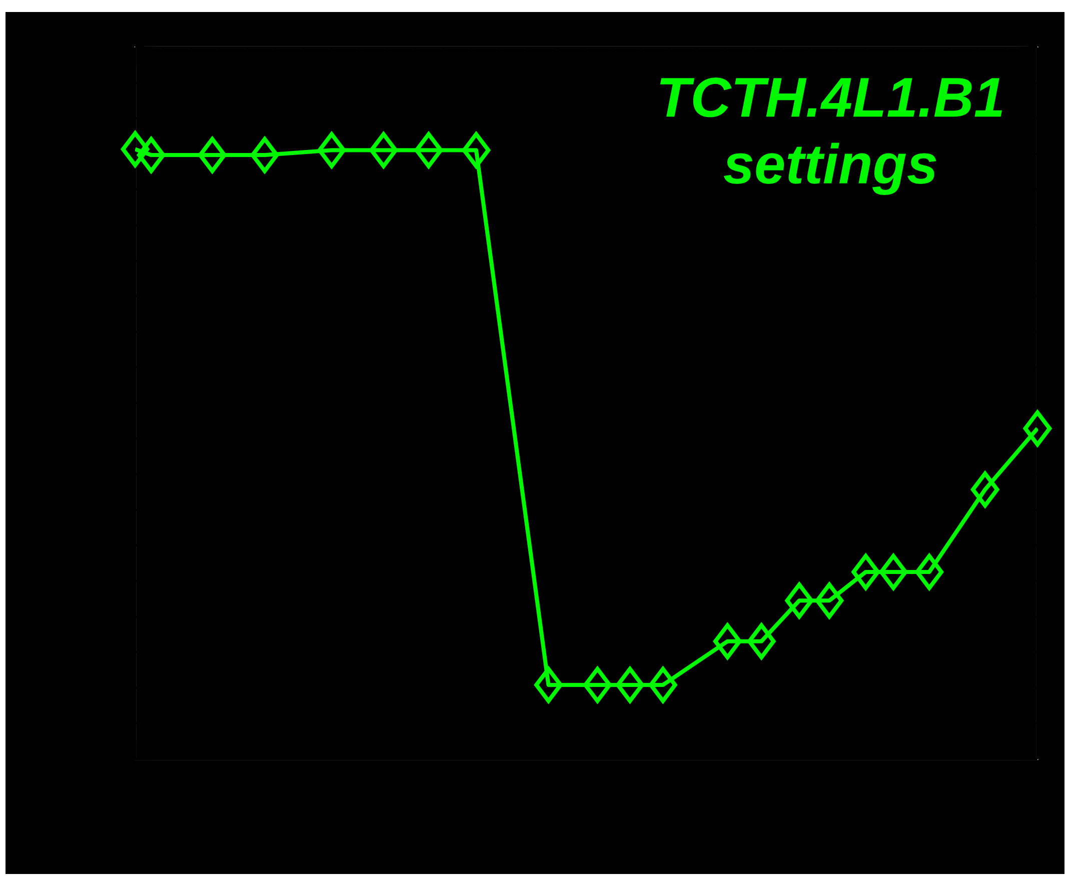
(3) Updated strategy to block collimator motors w position limits are reached:

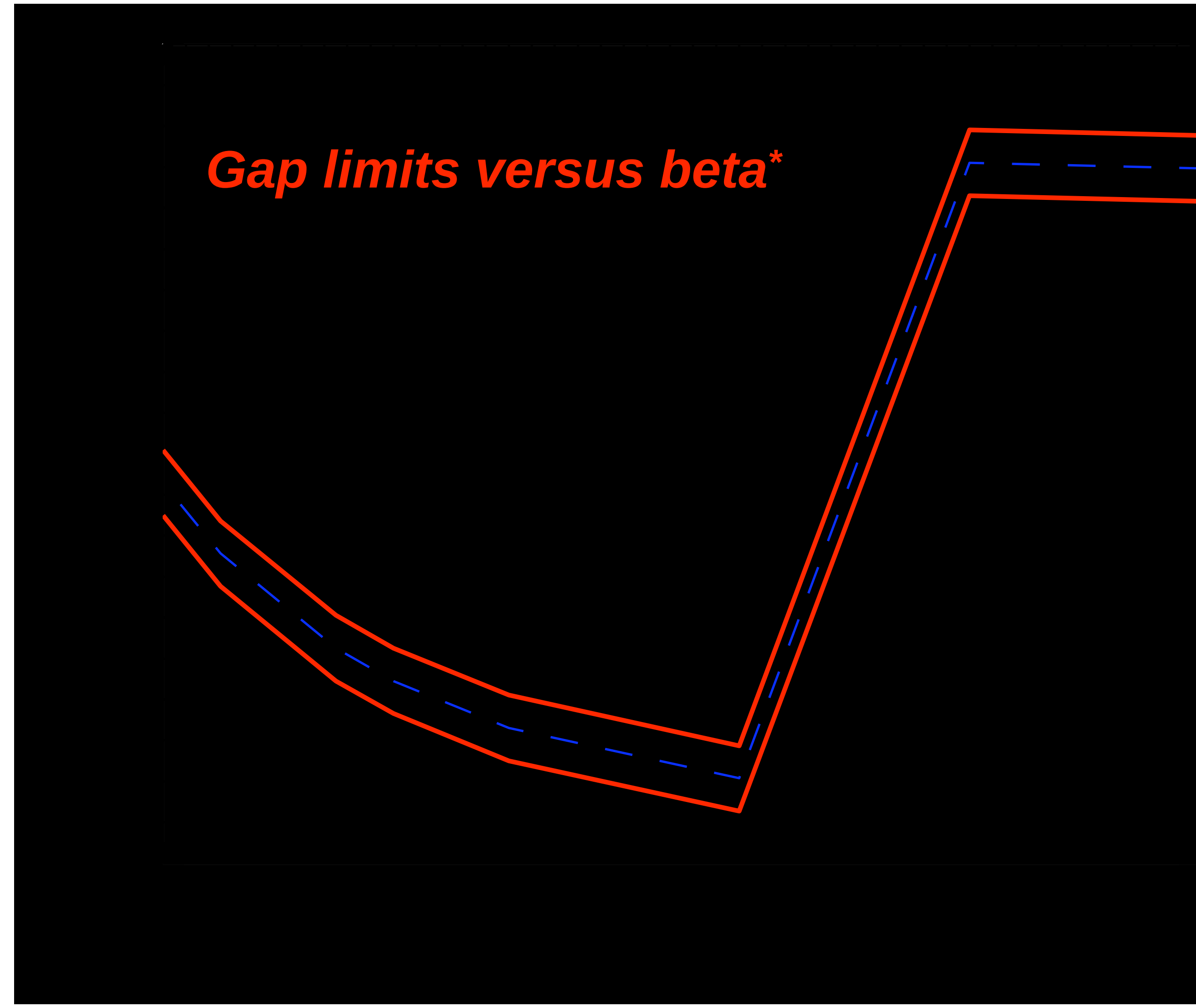
- Ring: collimator stop to avoid running into th
- Feature partly DISABLED for injection prot ors.
- Requires checks for all collimators: shared c oning effort with ABT.

No HWC change: update of the controls software.

Collimator limits as a function of β*







- Redundancy with respect to time functions. *Will dump if TCTs are not set according to β*.*
- Completely separated chain of interlocks.
- Robust implementation: unfrequent changes.
- Different limits possible for individual IP or overall minimum of β*.
- Also available for in IP3/7 collimators!

Details in an Engineering Spec

Date:2010-12-20

Engineering Specification

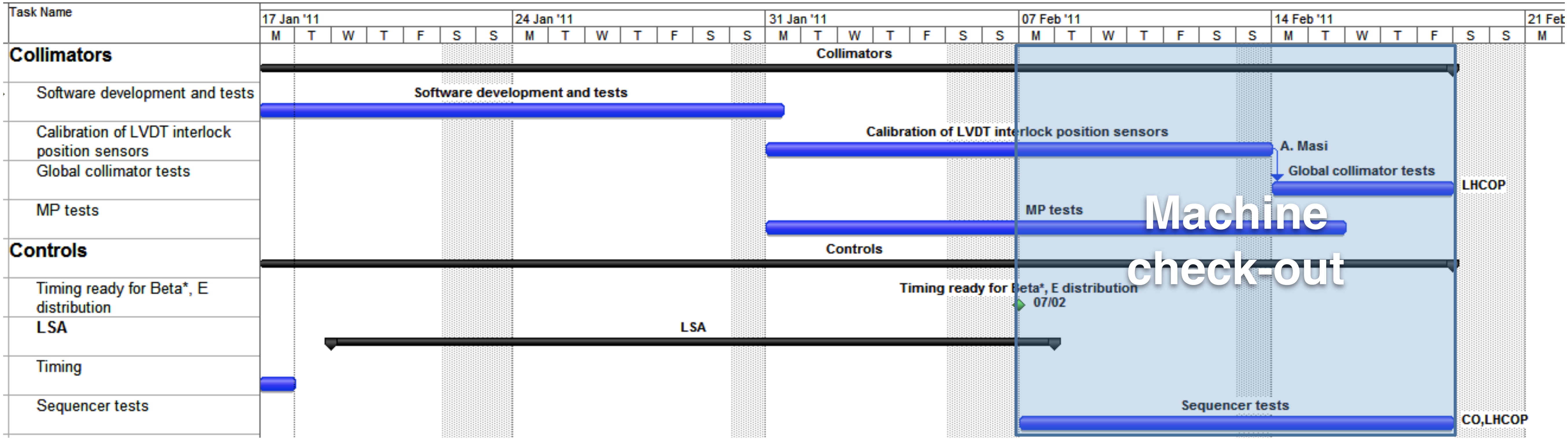
2011 MODIFICATION OF THE LHC COLLIMATOR CONTROLS RELEVANT FOR MACHINE PROTECTION

Abstract

This document describes the modifications of the control system of the LHC collimators foreseen for the 2010 shutdown. Only the changes relevant for machine protections are discussed. The changes proposed here will be effective for the 2011 beam operation.

Prepared by:	Checked by:	Approved by:
S. Redaelli, V. Kain, A. Masi,	J.C. Bau, E. Carlier, B. Puccio, B. Todd, M. Zerlauth	R. Assmann, B. Goddard, M. Lamont, R. Losito, R. Schimdt, J. Wenninger

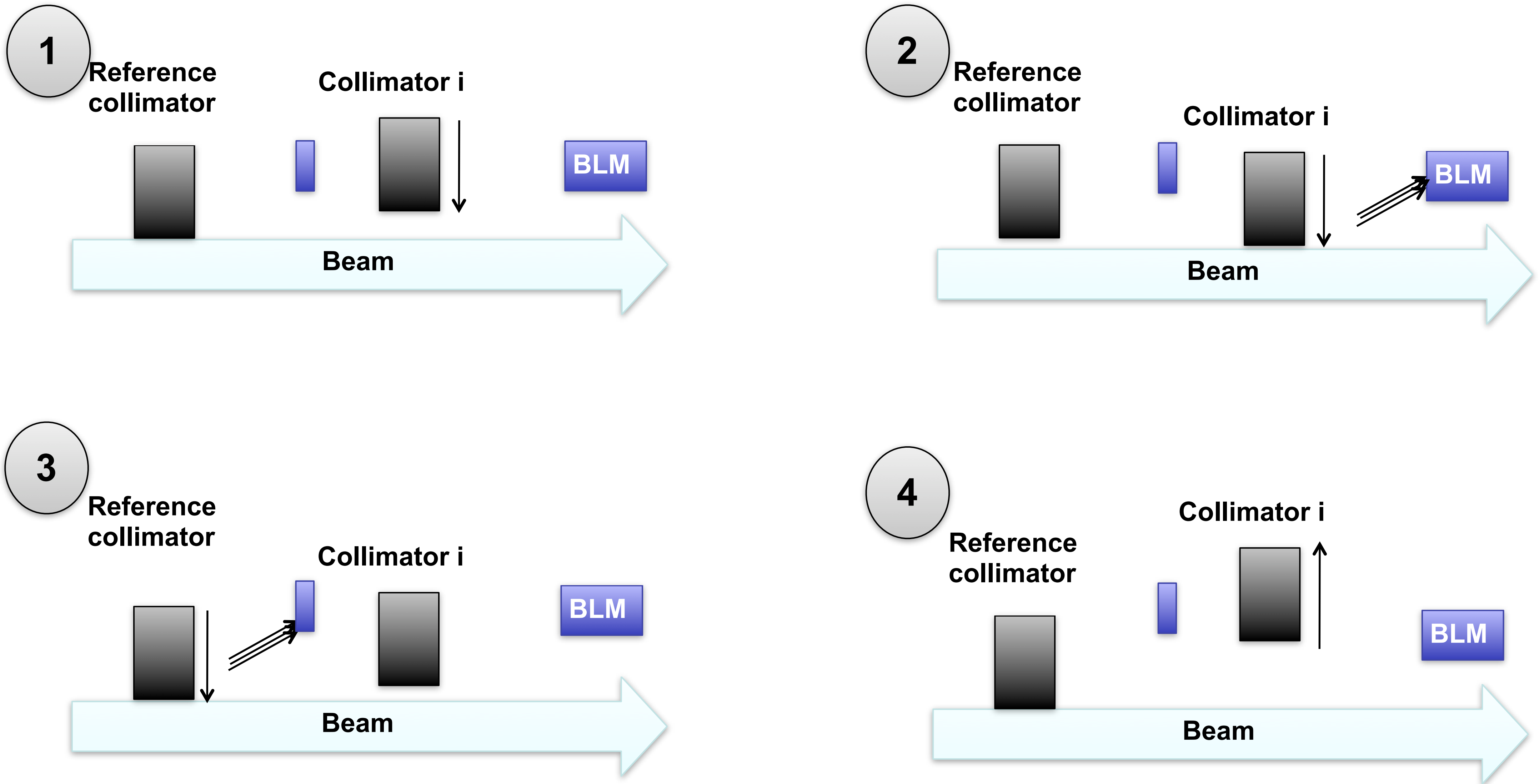
Collimator test planning



Plot by M. Albert, R. Giachino

- Development still ongoing.
- New signals in the timing only available at the end of next week.
- Two weeks to perform the setup and perform machine protection tests.
- Tight schedule but so far on track. If unforeseen problems, decision on roll-back to 2010 software at end of next week.

Collimator beam-based setup



R. Assmann

(1) Reference halo generated with primary collimators (TCPs) close to 3-5 sigmas.

(2) “Touch” the halo with the other collimators around the ring (**both sides**) → <u>local beam position</u>.

(3) Re-iterate on the reference collimator to determine the relative aperture → <u>local beam size</u>.

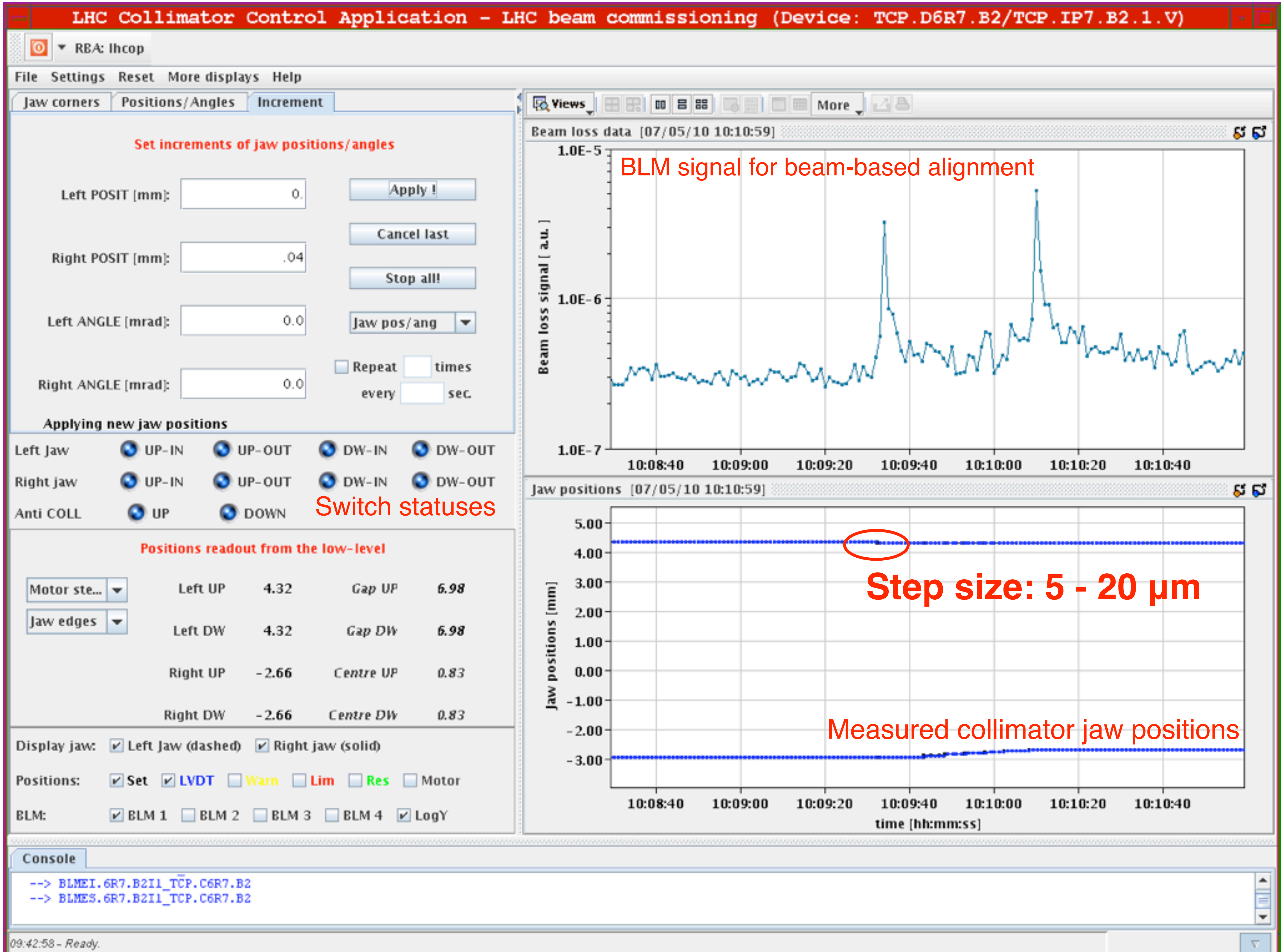
(4) Retract the collimator to the correct settings.

Tedious procedure that must be repeated for each machine configuration.

Beam-based parameters entered manually in big tables used for function setting generation.

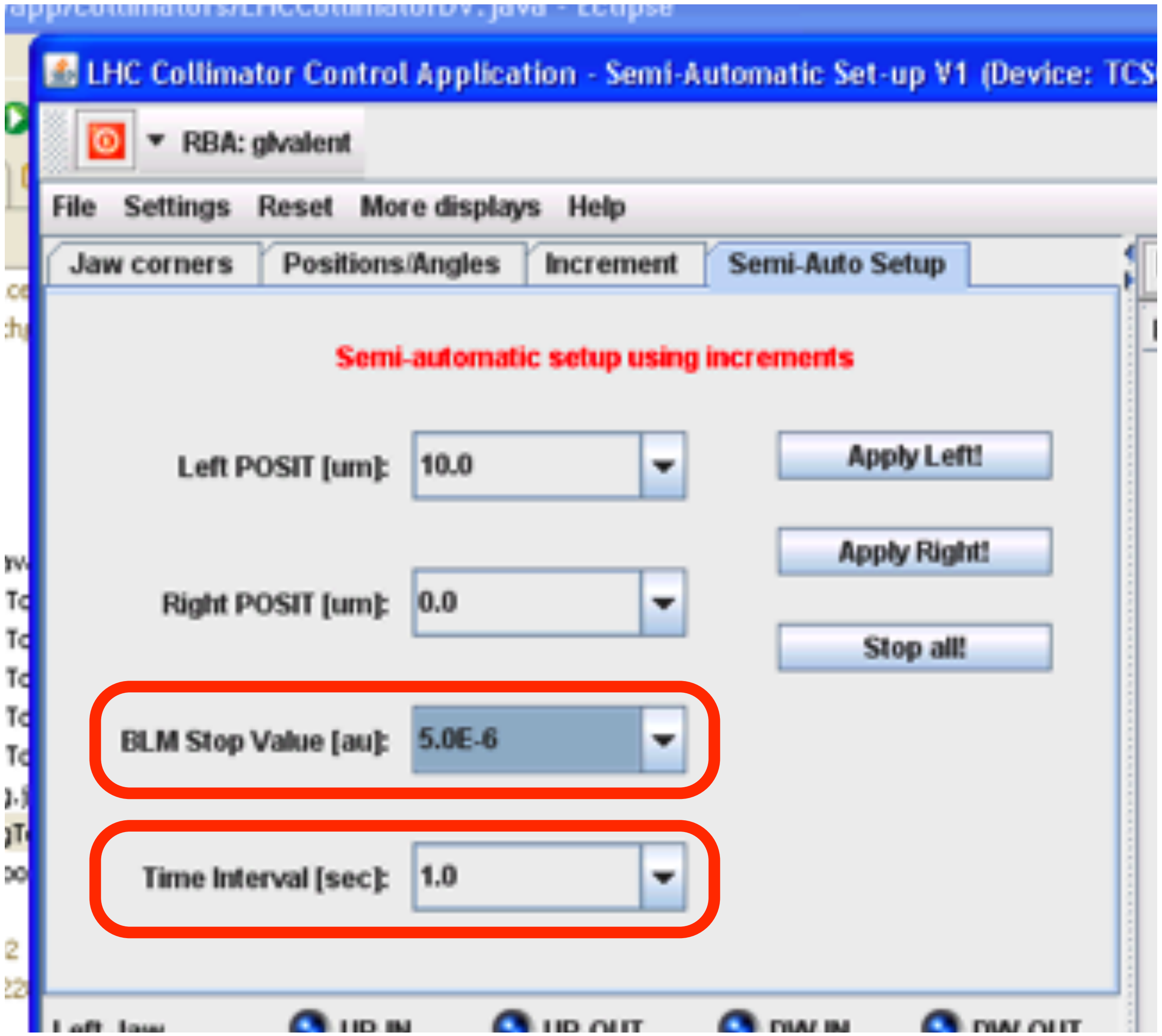
Setup in practice

Settings panel



Semi-automated alignment tool

New application panel under development



- Semi-automated setup functionality:
  - Choose BLM threshold;
  - Choose repetition rate;
  - Choose jaw and step size.
- Automated collection of beam-based parameters for whole system.
- Need tuning up...
- Working on full automated for 2012 (direct data from BLM system).
- PhD thesis work by G. Valentino.

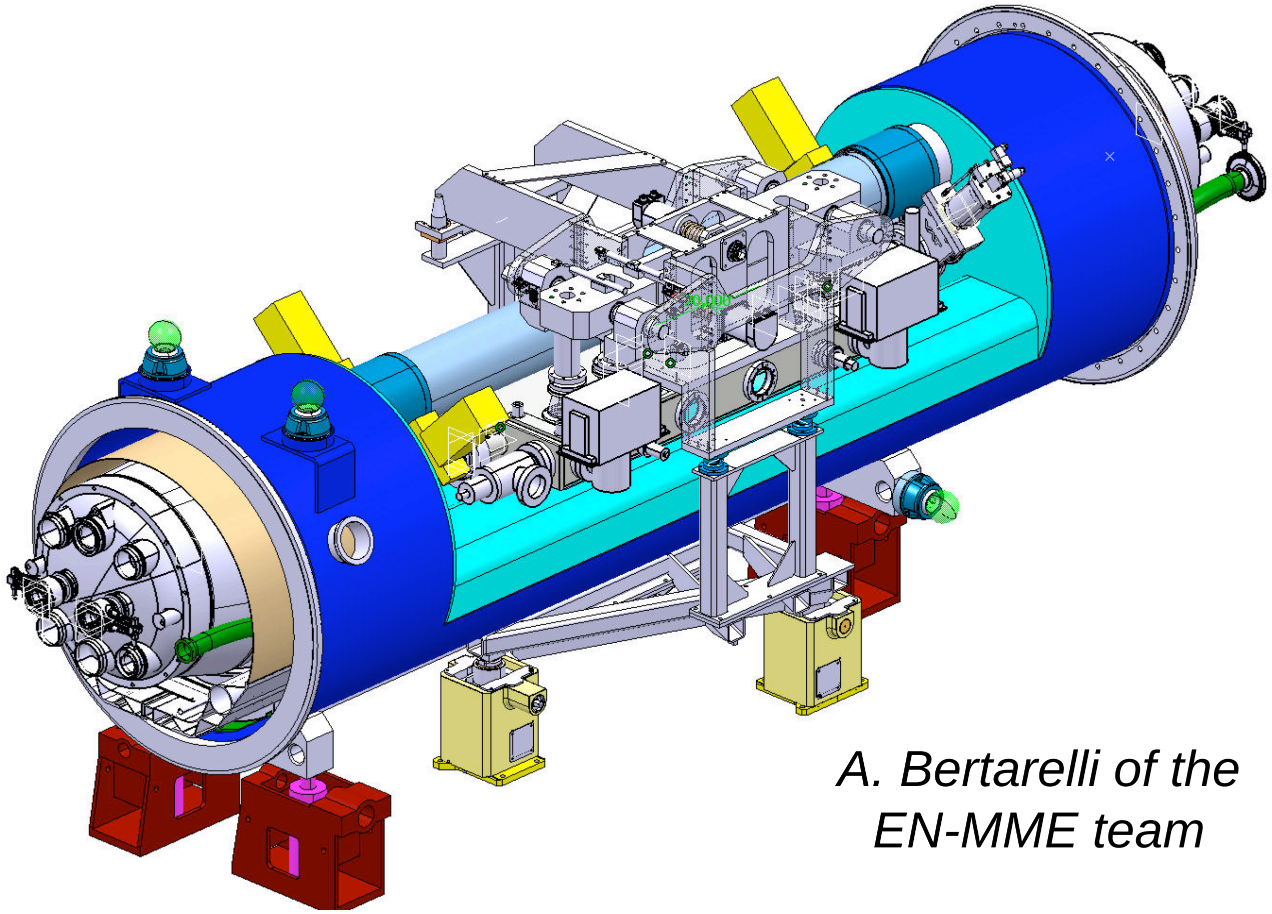
Outline

- ☑ Introduction
- ☑ 2010 operational experience
- ☑ Changes for 2011
- ☑ **Improvements after 2011**
  - **- IR3 changes**
  - **- Integrated BPM design**
  - **- Optimized layout in IP2**
- ☑ Conclusions

IR3 collimation upgrade

(1) Catch local losses in the dispersion suppressor (DS): two DS collimators per beam

- Layout change of the DS: moving dipoles to create space;
- New design of warm collimators.

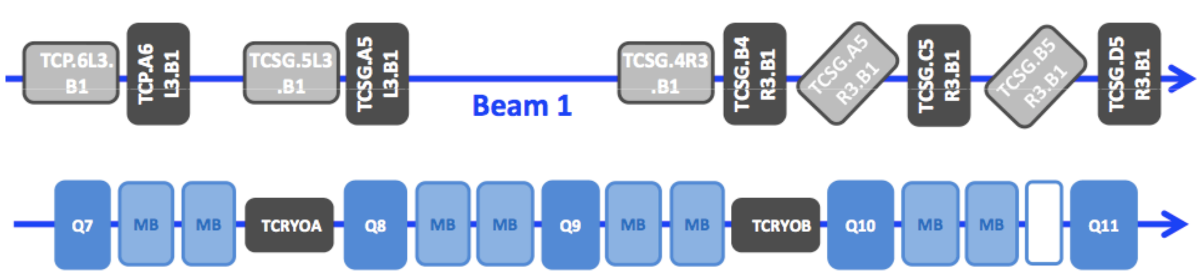


A. Bertarelli of the EN-MME team

(2) Combine momentum/betatron cleaning in IP3 by adding 5 vertical collimators per beam

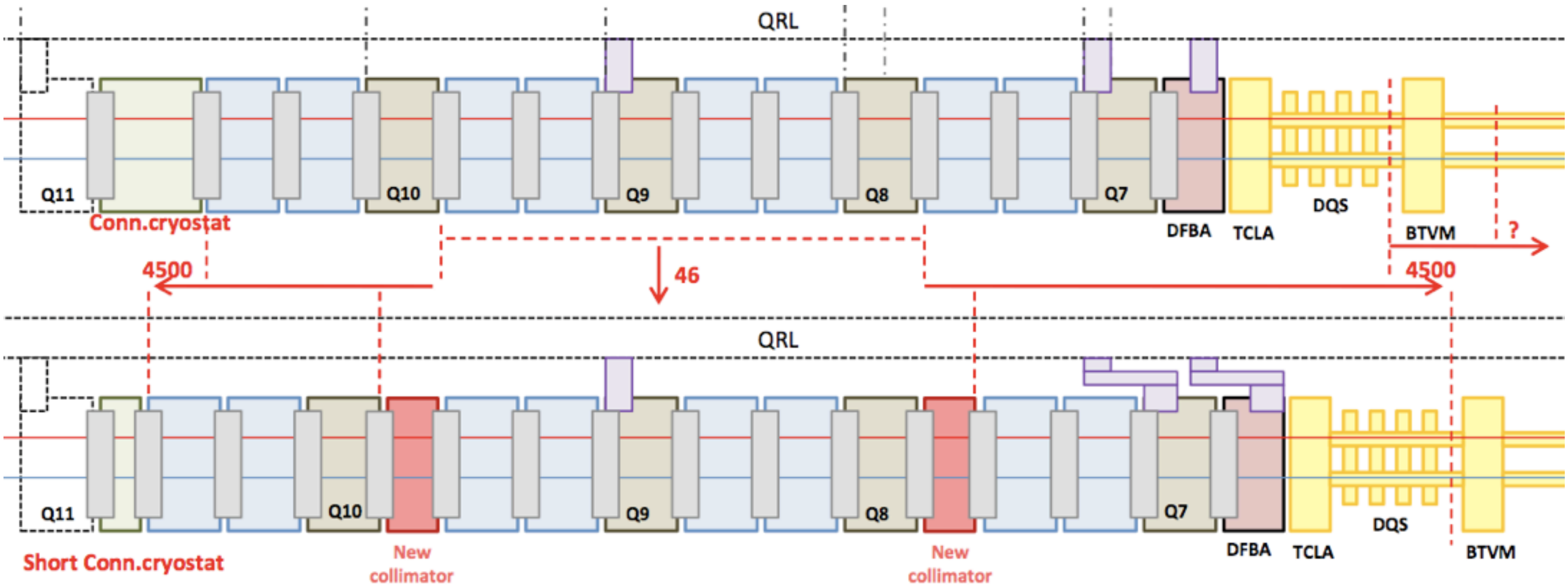
- Standard technology of Phase I.
- Essentially using existing slots.
- New production chain for building the missing collimators.

New IP3 schematic layout (by A. Rossi)



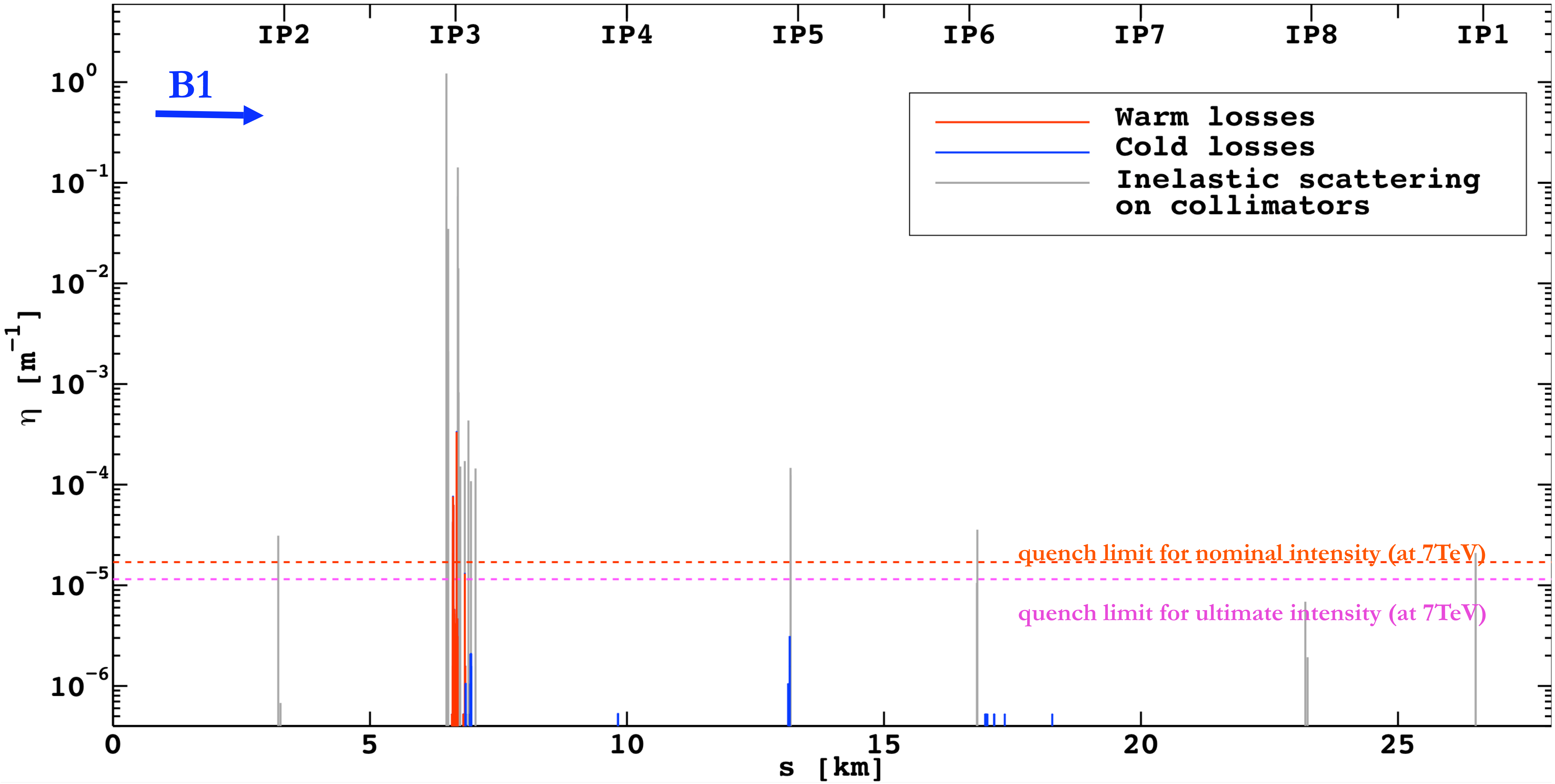
Details: Review of DS work, July 2010:
http://indico.cern.ch/conferenceDisplay.py?confId=100156

New DS layout (IR3-Left)



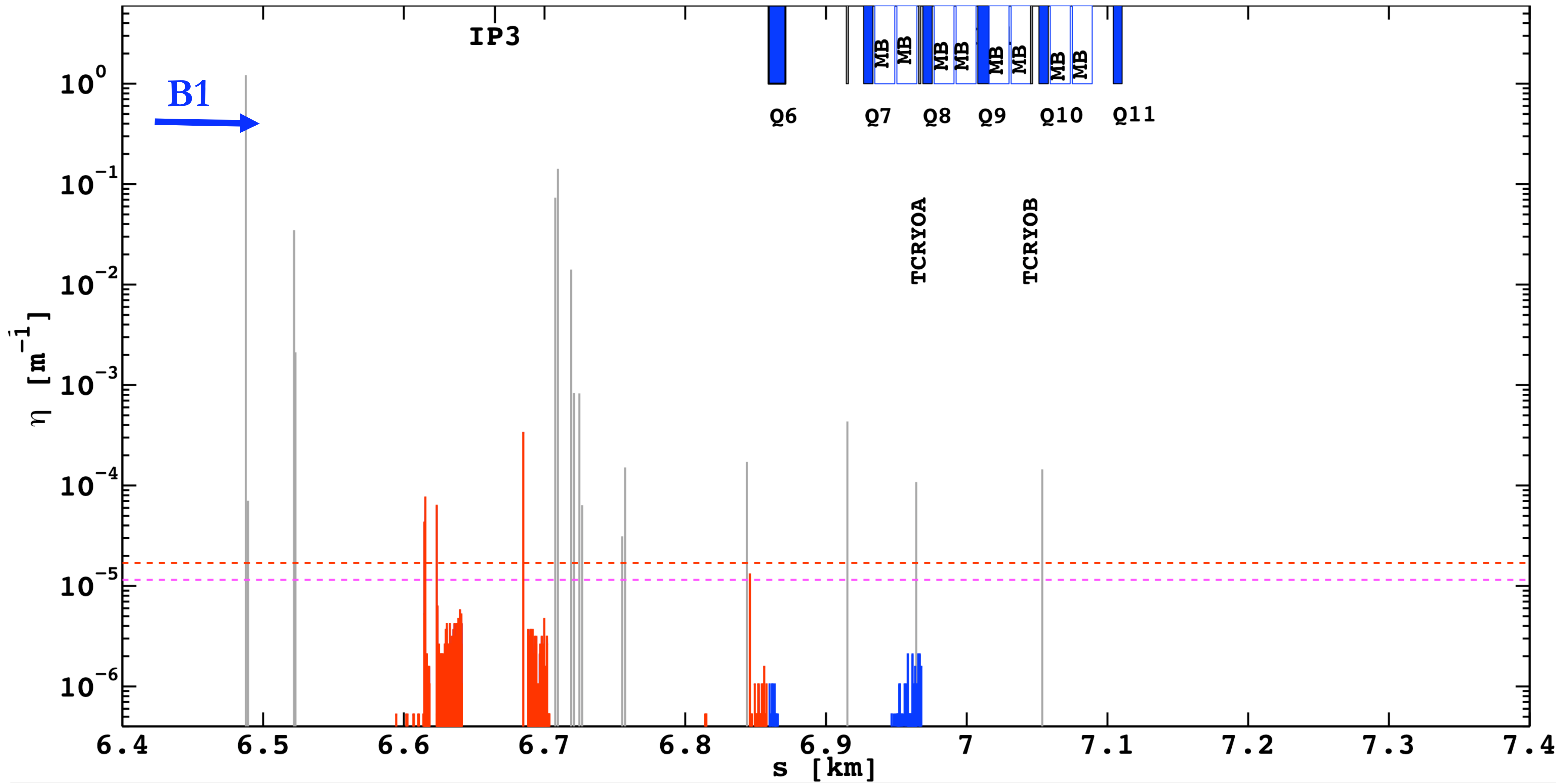
J. Coupard, presented in the talk by V. Parma

Expected performance



- Updated simulations by **D. Wollmann** and A. Rossi
- 7 TeV case, nominal parameters, <u>perfect machine.</u>
- Cleaning below quench limit for nominal and ultimate intensity.
- Simulations with imperfection are ongoing. Expect to be less sensitive.

Expected performance



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IR3 work: How it will help in the LHC

(1) Simulations indicate that we can reach **nominal performance** at 7 TeV. To be confirmed with detailed error model (imperfections).

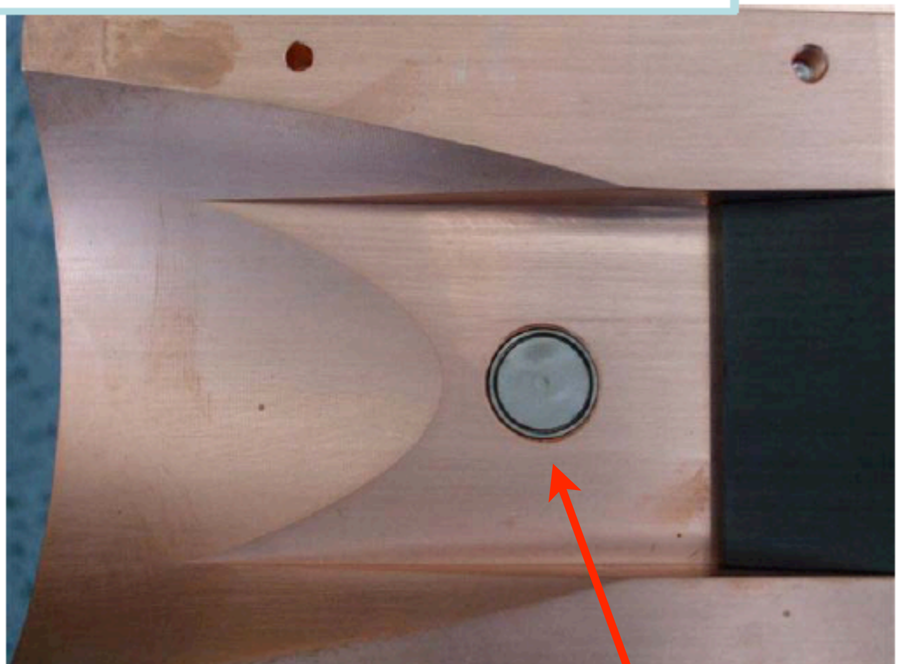
(2) This assumes that the impedance is stabilized (transverse damper, Landau octupoles).

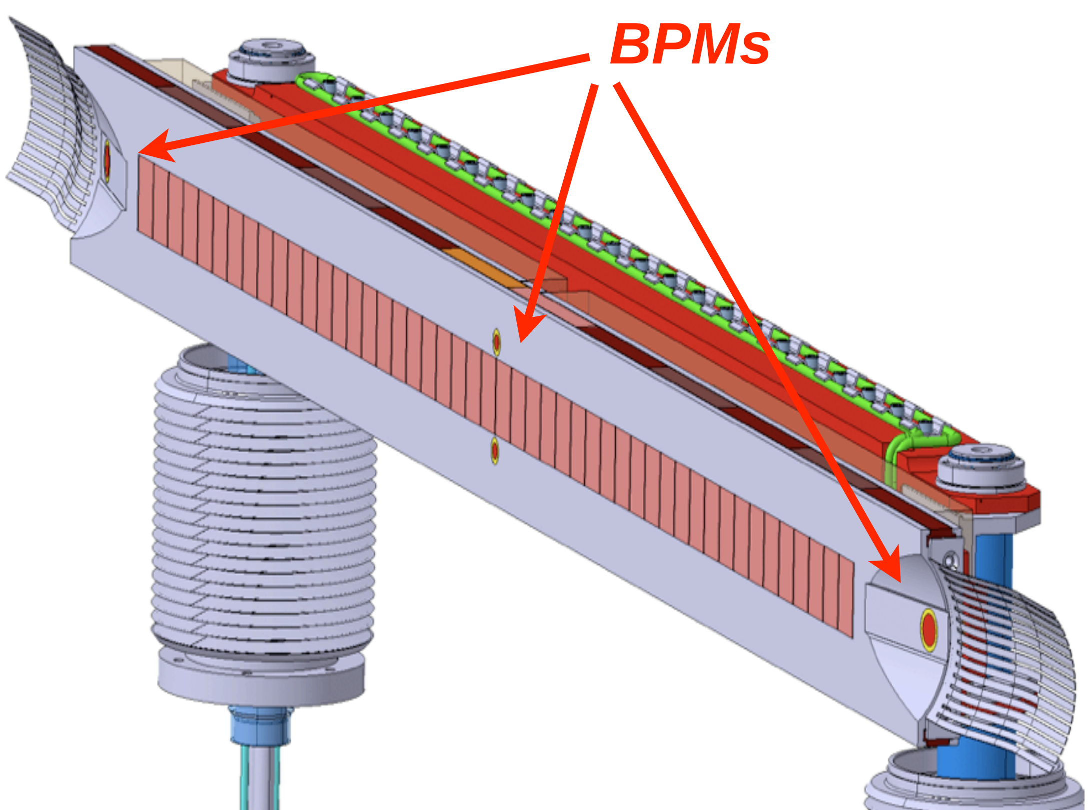
(3) New layout improves by a factor **80-100** the radiation to electronics (FLUKA simulations).

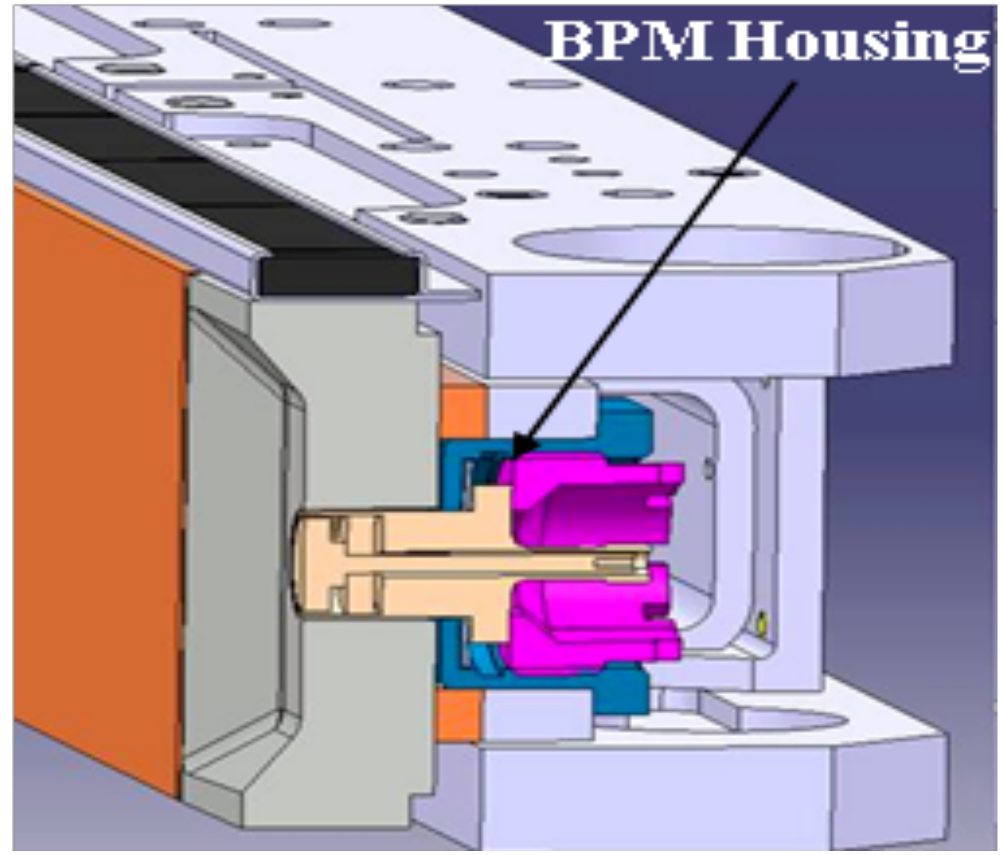
(4) Somewhat faster setup (less collimators) until we get BPM-integrated design.

BPM-integrated design

Button 1 at upstream port on D side
Distance from Jaw face: 10 mm



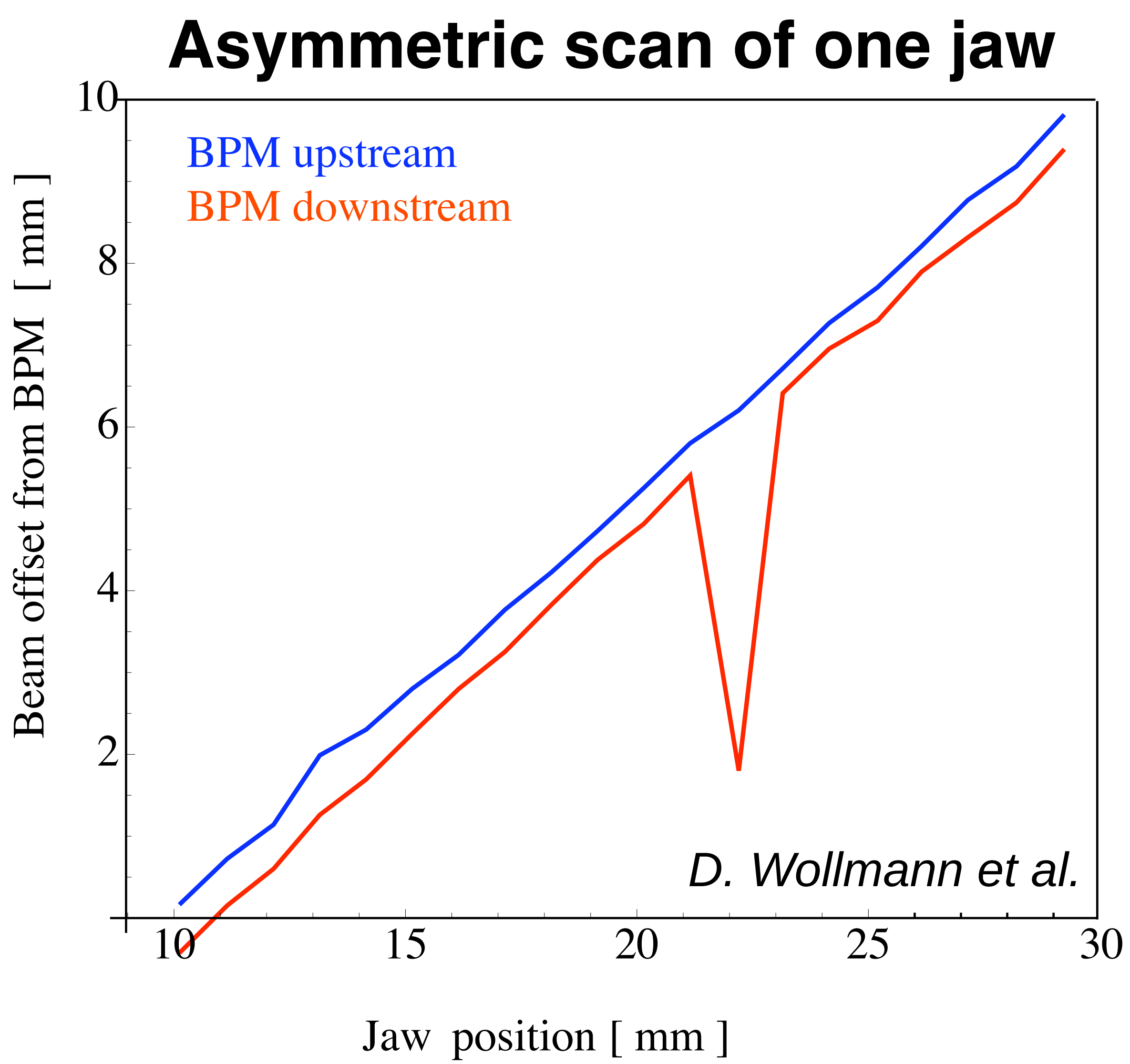


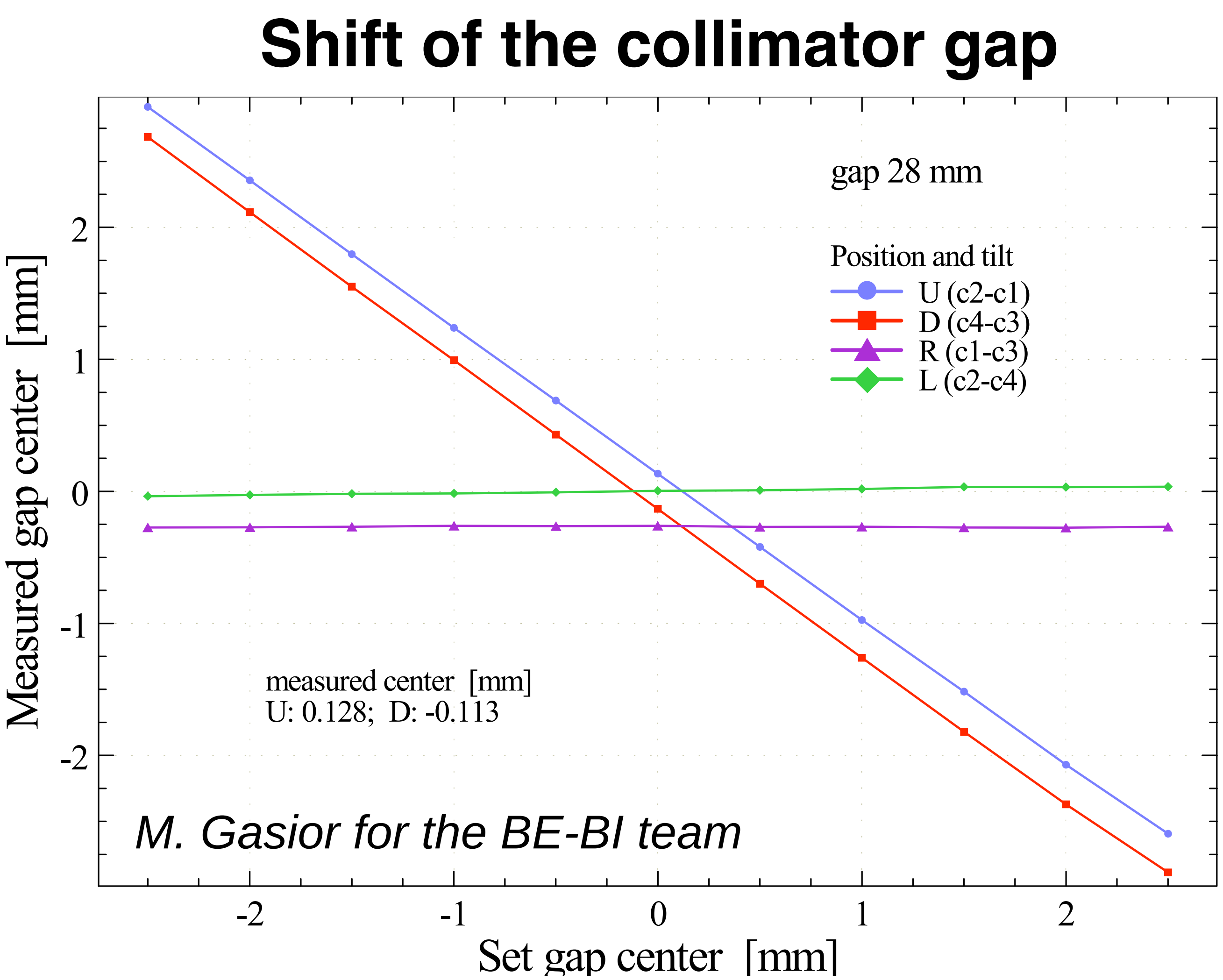


A. Dallocchio for the MME team

- BPM bottoms integrated in the collimator jaws to measure the local beam position.
- Benefits:
  - Reduce setup time from 15-20 min to ~ 10 s;
  - Continuous monitoring during standard OP.
- Prototype built: EN-MME, BE-BI, Coll. Team
- SPS beam tests in 2010 as proof of principle of this concept: very promising results!

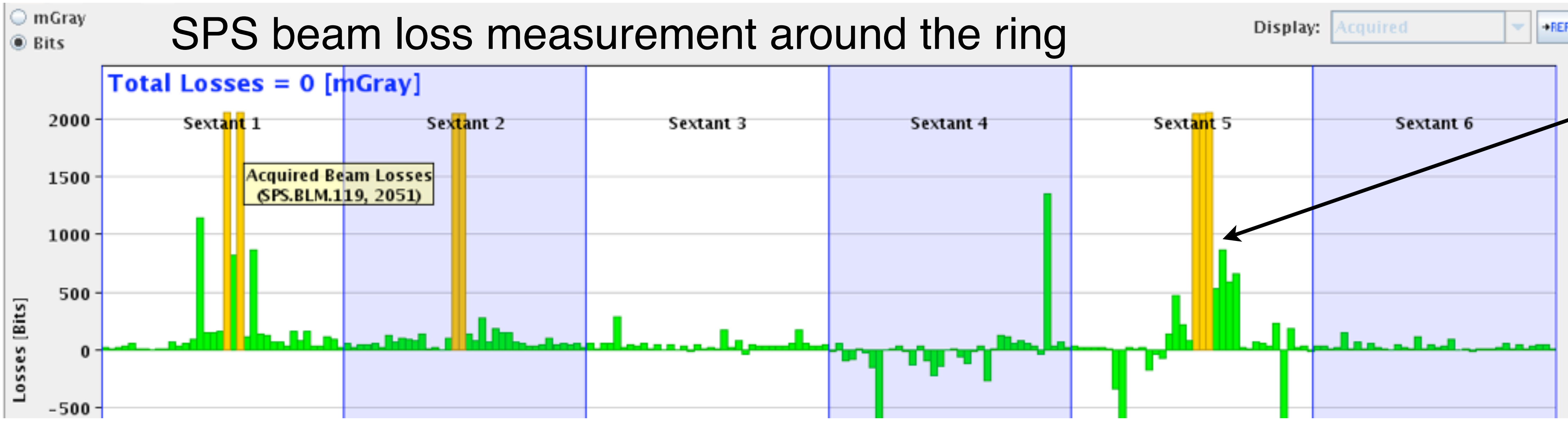
Preliminary results of SPS beam tests



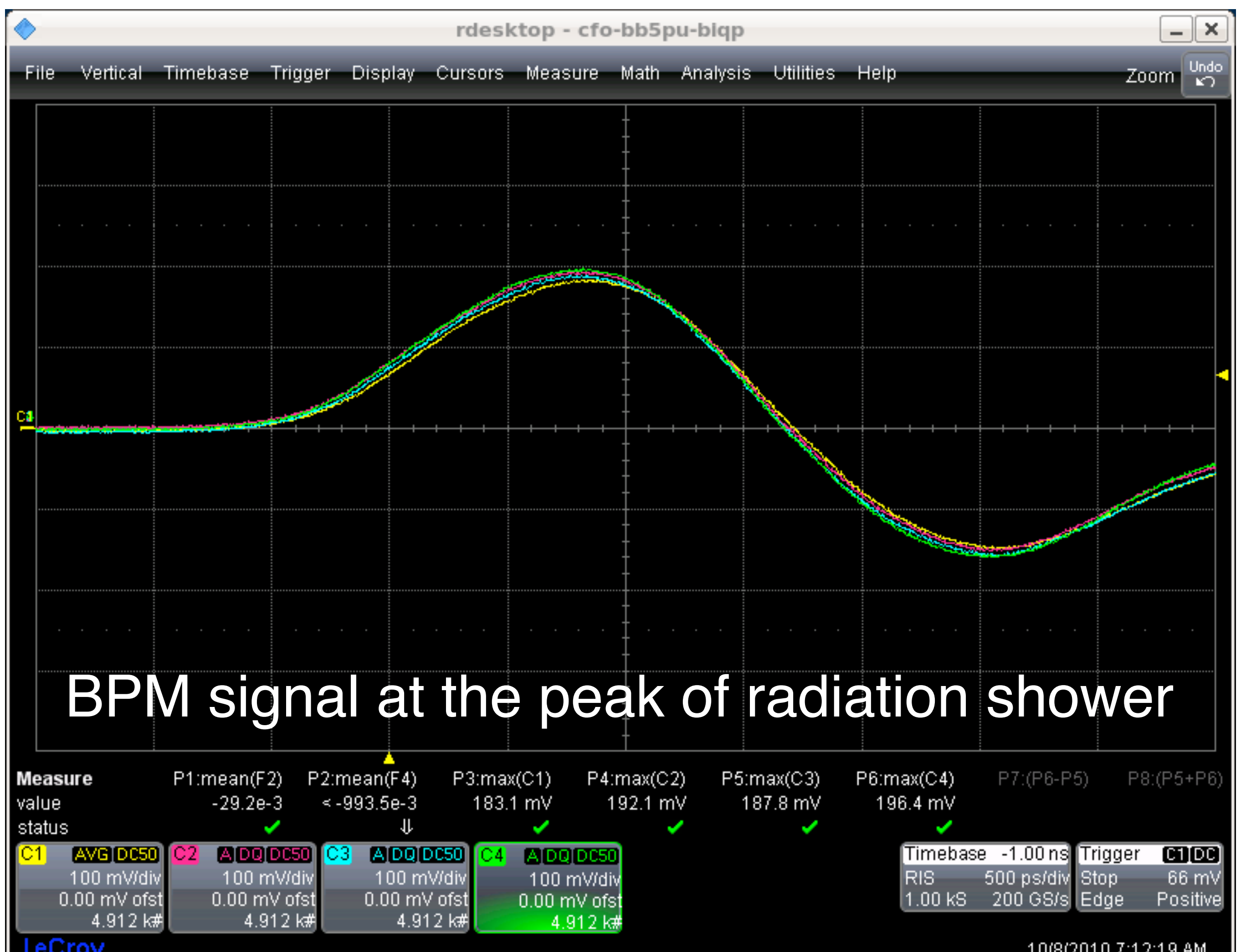


- Comparison between standard centring method based on beam losses. ✓
- BPM response versus known change of collimator gap position. ✓
- Various tests of signal linearity ✓
- Effect of radiation on the BPM signal ✓

Effect of radiation showers



Collimator in SPS-LSS5

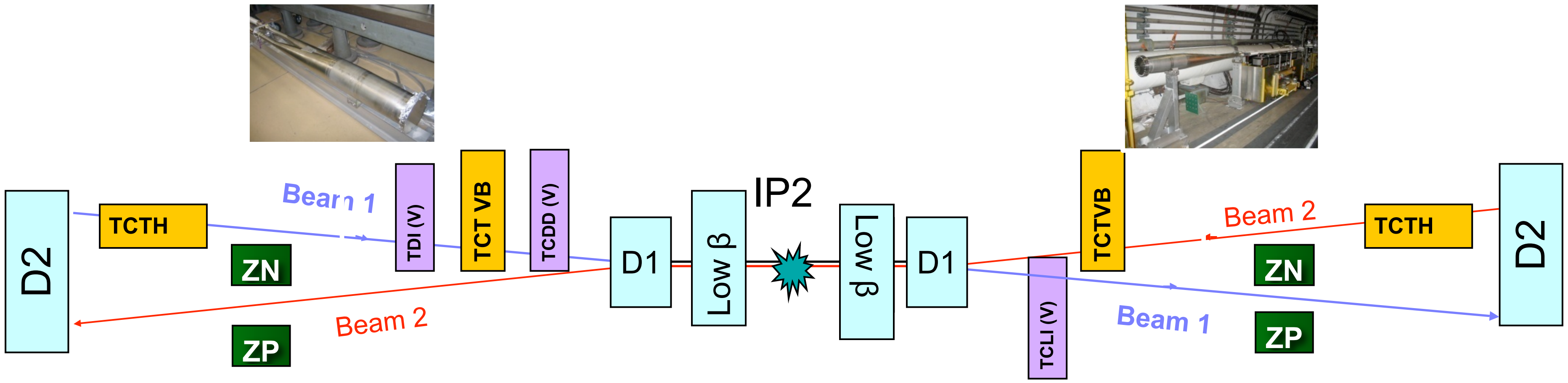


- Showers induced by an upstream collimator.
- No indication of BLM signal being affected by beam losses.
- Promising preliminary results that indicate that we will be able to use the BPMs also for small gaps in the LHC operational conditions.

How it will help the LHC

- **Gain a factor ~ 100 in setup time of one collimator.**
- **Continuous local orbit monitoring:**
  important for maintaining the machine protection conditions and to preserve the collimation hierarchy.
- **Improved operational flexibility** in the setup of machine configurations, in particular in critical regions like the IPs.
- Reduced constraints on **tight orbit stability** fill-to-fill: collimator setup becomes possible at every fill.
- **Unfortunately**:
  Implementation in the LHC does not look feasible even for 2013. Design not completely frozen. Lead time to get collimator produced.
- **Quick plug-in concept**: short shutdowns can be used for installation.

Optimized TCT layout in IP2



- ALICE ZDC partly on the shade of vertical collimators TCTVBs.
  Detector wishes in conflict with the machine protection constraints.
- A technical solution has been found in order to change the collimation layout in the LSS2 keeping the same protection level and without shadowing the ALICE ZDC. The proposal consists in having the same collimation layout as in LSS1 and LSS5, i.e. both TCTVA and TCTH close to D2 behind the ZDC
- Required production and installation of 2 new TCTVA!
- No indication major show stoppers.
- Details discussed at the next LMC (D. Macina).

Full details in a recent meeting:
http://indico.cern.ch/conferenceDisplay.py?confId=121482
On the agenda of the next LMC (D. Macina)

Conclusions

- **The collimator phase I system was fully commissioned in 2010!**
  - *100 movable collimators were operational and delivered the expected cleaning.*
- **The operational experience is very positive but:**
  - *Cleaning limitations for nominal performance are encountered as predicted.*
  - *System setup is lengthly. Poses important constrains on the LHC operation.*
  - *Radiation effects can become a limiting factor.*
- **Improvements are being implemented already for 2011.**
  - *We implemented **additional redundancy** to the Mach. Prot. functionality: BetaStar gap limits, improved injection protection interlocks.*
  - *Semi-automated alignment tools to speed-up the collimator alignment.*
  - *Tight re-commissioning schedule - but fully on track so far.*
- **Collimation improvements beyond 2011:**
  - *Focus on the IR3 combined system (will verify the principle of DS upgrades).*
  - *Important gains from BPM design - strong OP motivation to advance that?*
  - *Optimized layout of IP2 seems under control.*
- **Very rich program for future further beyond - not for this talk.**

Collimator collaborators

INFN

CERN

AUSTRIAN RESEARCH CENTERS

GSI

FAIR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

MANCHESTER 1824

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RUSSIAN RESEARCH CENTRE KURCHATOV INSTITUTE

POLITECNICO DI TORINO

UNIVERSITY OF MALTA
L-Università ta' Malta

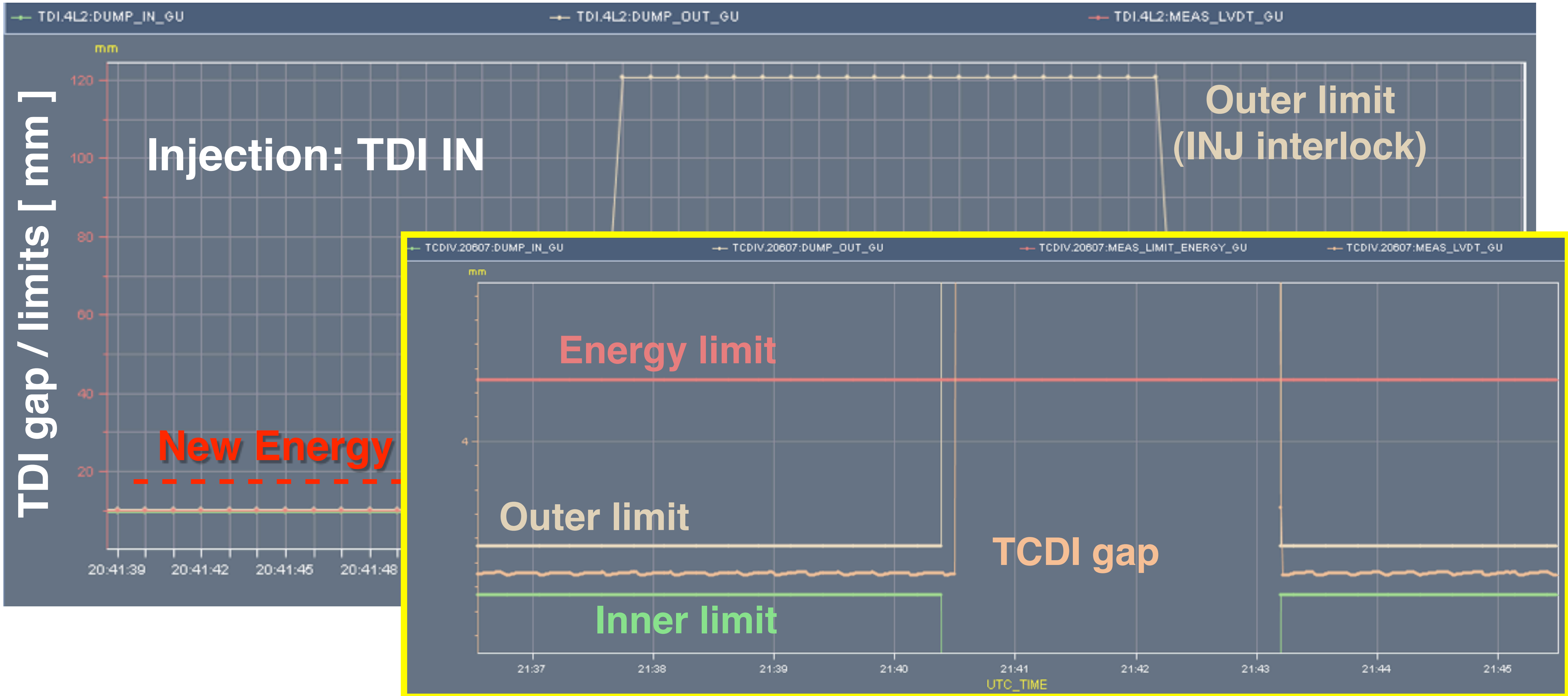
Fermilab

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

TECHNISCHE UNIVERSITÄT DARMSTADT

Reserve slides

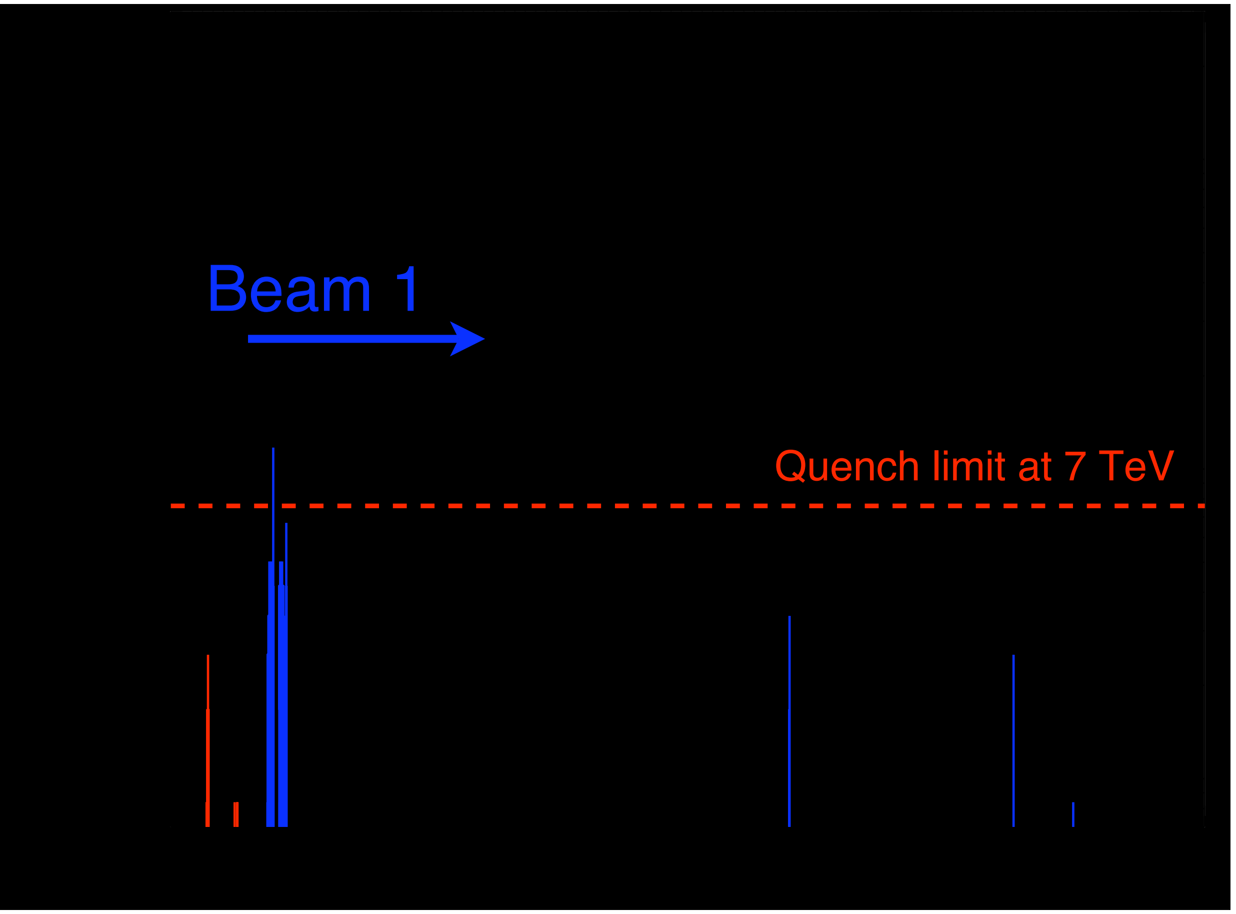
Improvement on injection protection

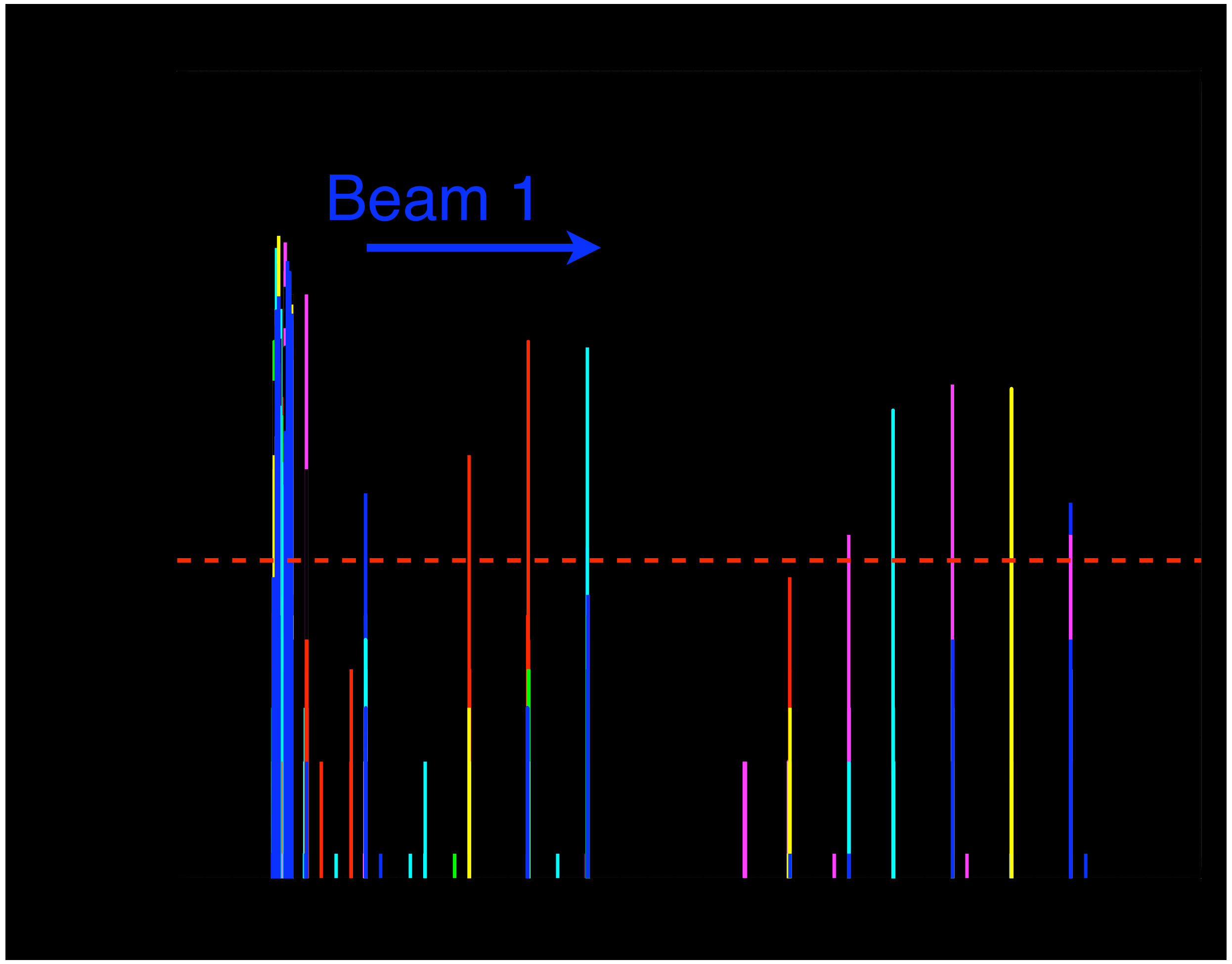


- Same energy limits of cleaning collimators used to stop injection if TDI/TCLI OUT
- Redundant and robust (unfrequent changes); independent of OP sequences.
- Already fully operational for the TCDI in the transfer lines.
- In addition, injection protection collimators will be able to move across the limits: partially reduce change of settings.

Details worked out with the Injection team (Bren&Verena)

Sensitivity to imperfections

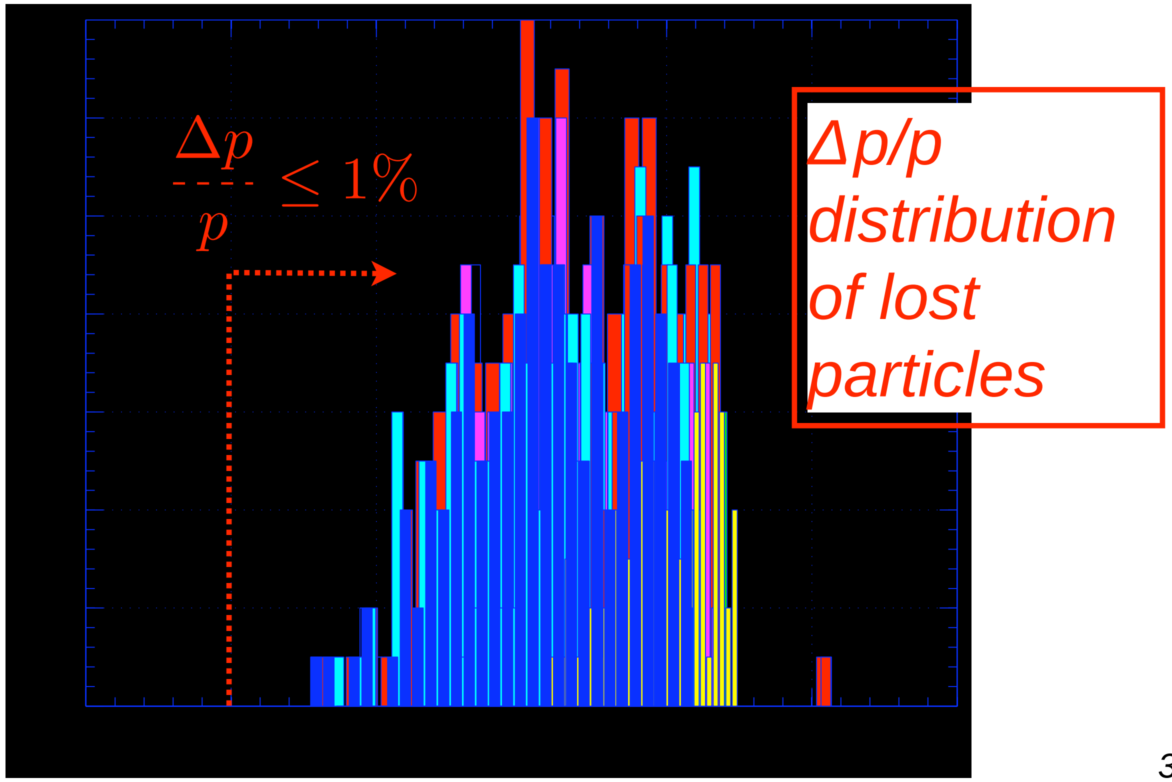




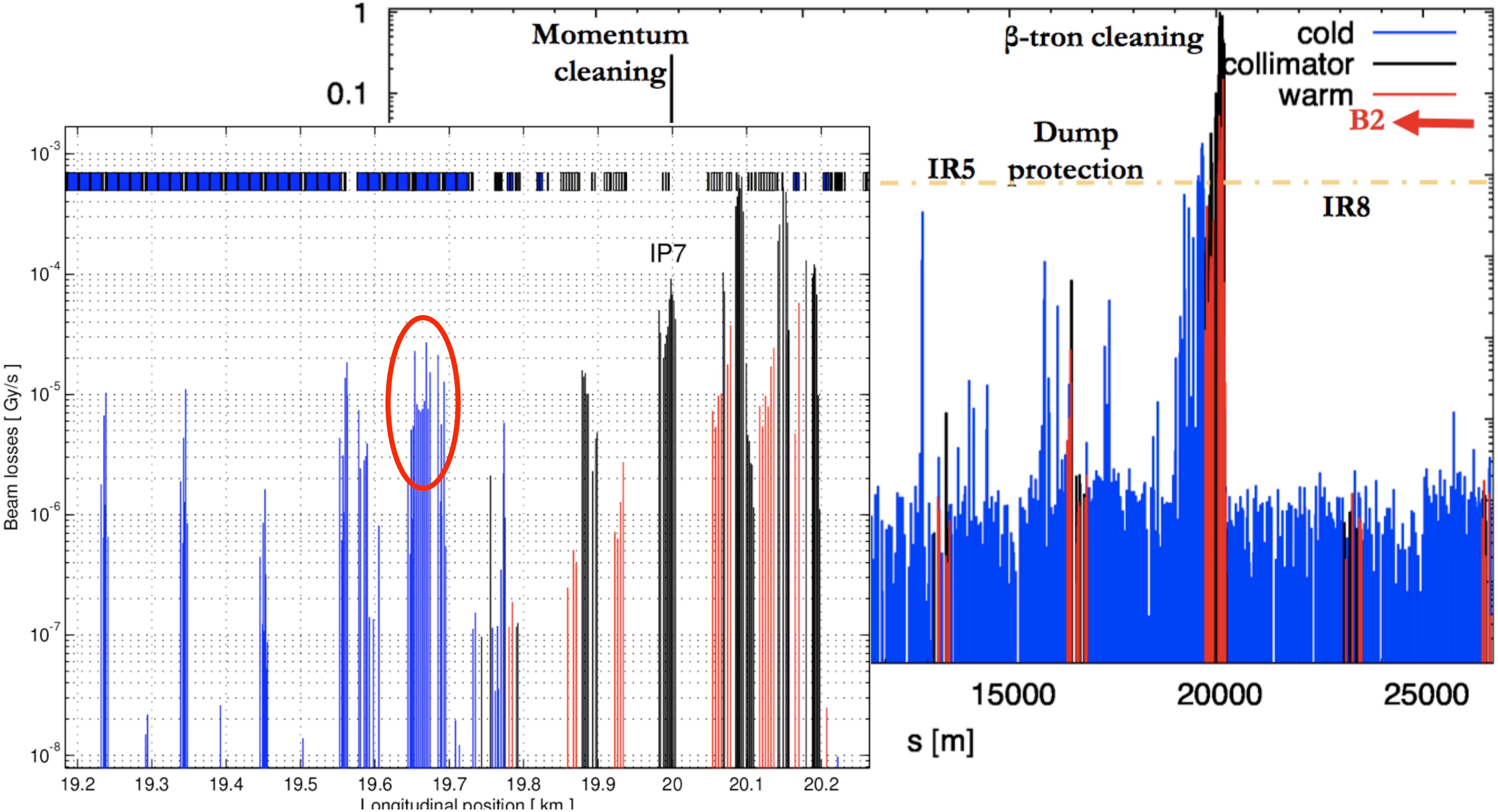
Example simulations for DS collimators in IR7.

DS collimators catch off-momentum halo that, with imperfection, causes additional losses in the arcs downstream.

Reduced sensitivity to imperfection because "dirty" leakage is caught early only (TBC by detailed simulations.)



System performance - ions



LHC OP CREATOR > Shift Summary

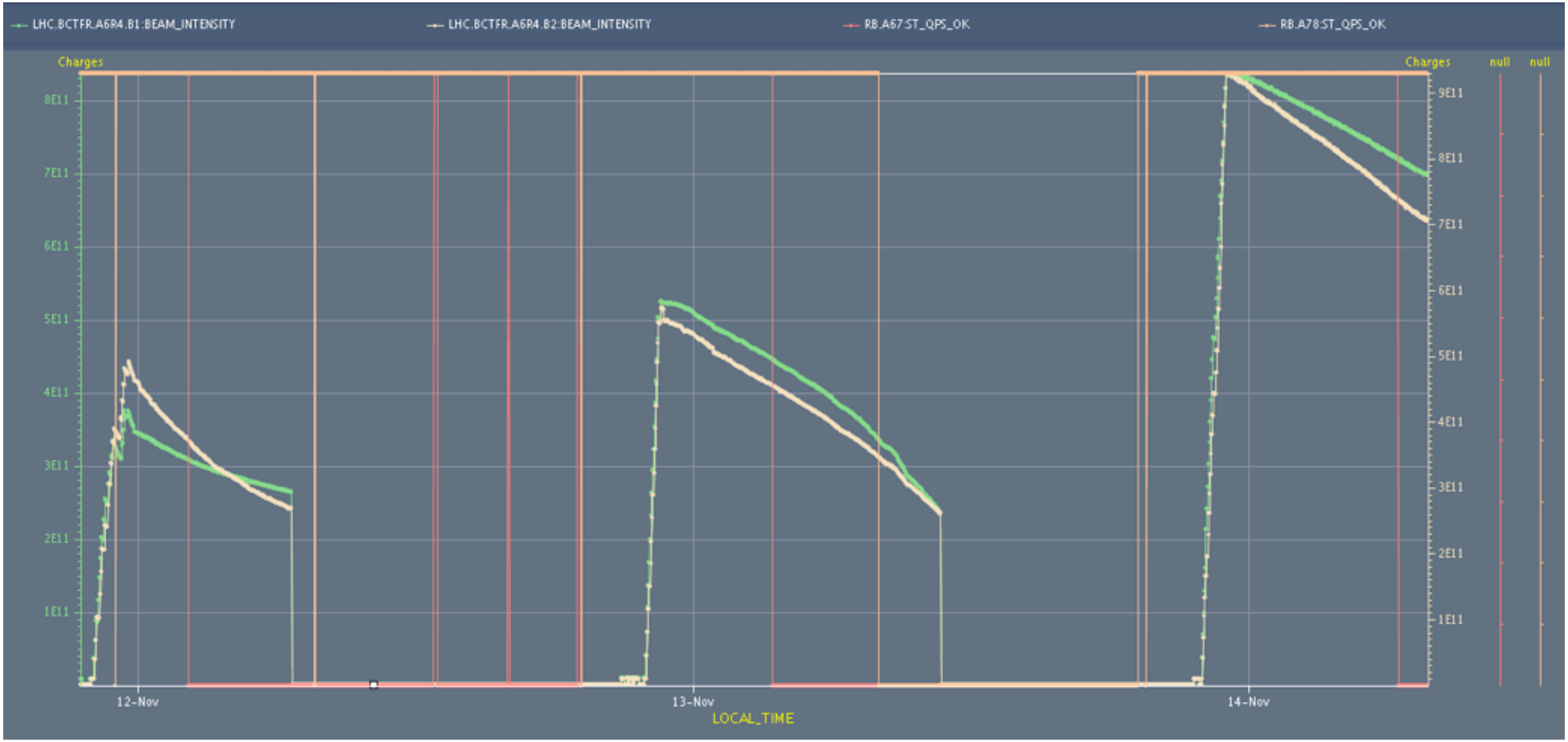
We dumped the beam of yesterday night fill with a programmed dump.

Before dumping, we noticed that the Q9 magnets at either sides of IP7 had QPS problems (L7: same as yesterday1 R7: fip communication problem, also induced by radiation according to Reiner). These issues required access. As Reiner was available for preparing the software upgrate for automatic re-start of the QPS units, we decided to do it now and deploy it for the two magnets.

Statistics on the QPS trips:
1) 9L7: 02h11 (~2h after end of ramp)
2) 9L7: 03h24 (~4.5h after end of ramp)
3) 9R7: 08h01 (~9h after end of ramp)

LHC eLog, Nov. 13th, 2010

QPS trip history



Three trips in 3 consecutive physics fills (Nov. 12th-14th),
requiring accesses in the tunnel.
Partly fixed by automatic reboot.