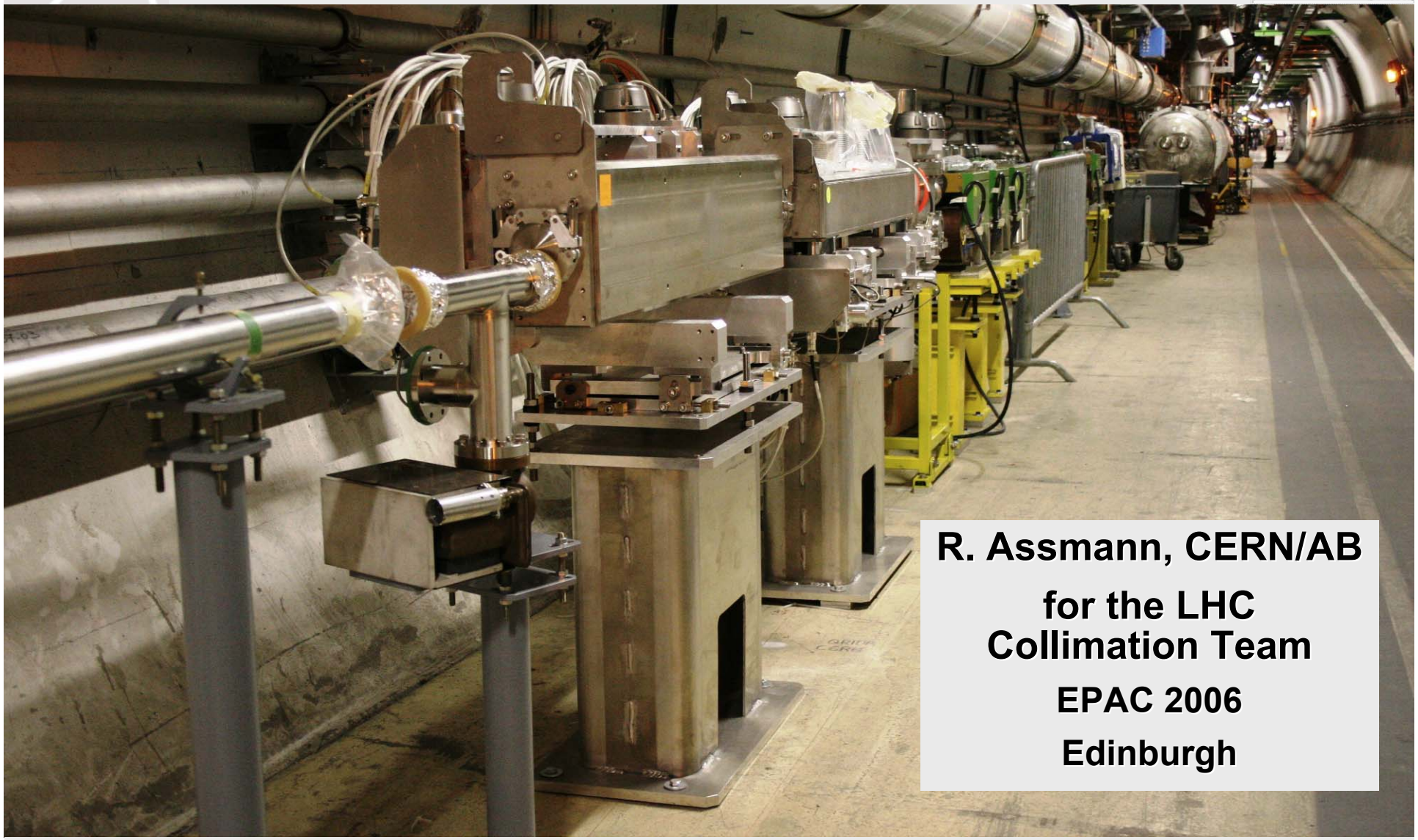
The Final LHC Collimation System



R. Assmann, CERN/AB

for the LHC Collimation Team

EPAC 2006

Edinburgh

The LHC Collimation Team

Collimation team:

About 60 CERN technicians, engineers and physicists… in various groups and departments.

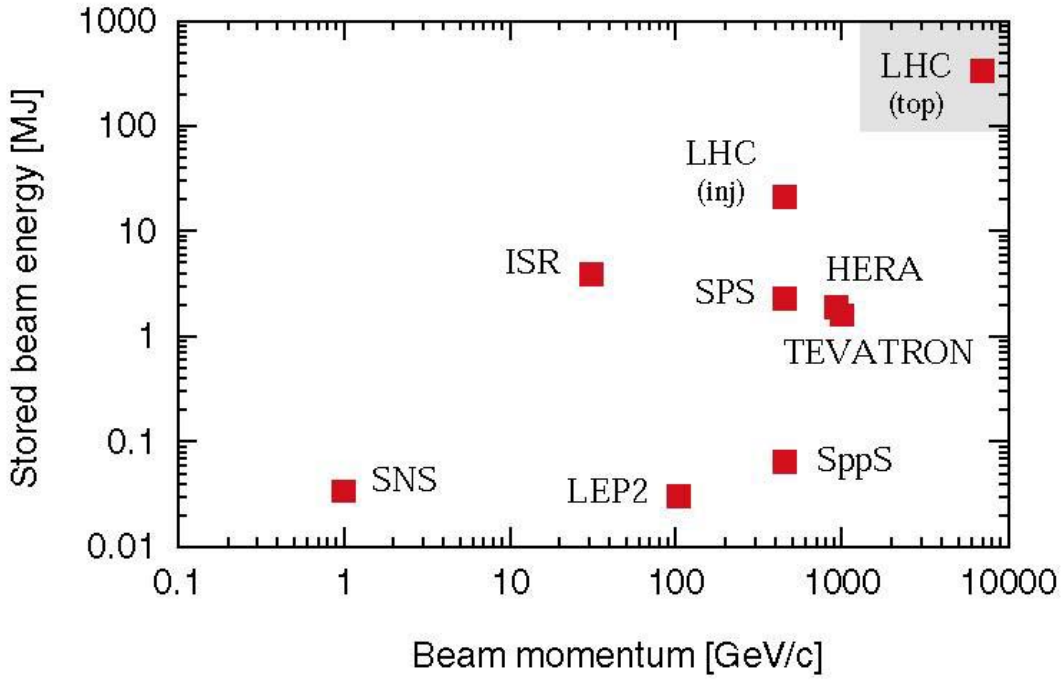
➔ *Several at EPAC06*

\+ collaborators in various laboratories…

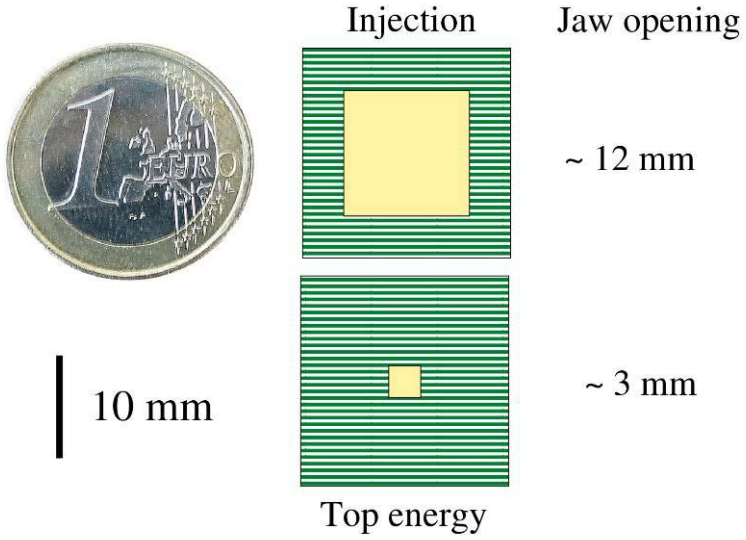
The LHC Challenge

- Talk at EPAC 2002 in Paris: “Requirements and Design Criteria for the LHC Collimation System”.

High stored energy and stored energy density!



Small collimation gaps!



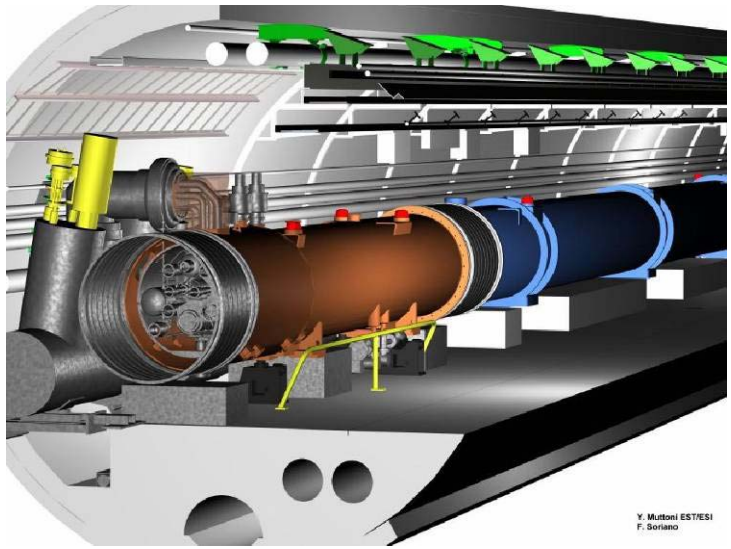
Preventing Quenches

- Shock beam impact: **2 MJ/mm^2 in 200 ns (0.5 kg TNT)**
- Maximum **beam loss at 7 TeV**: 1% of beam over 10 s

500 kW

- **Quench limit** of SC LHC magnet:

8.5 W/m



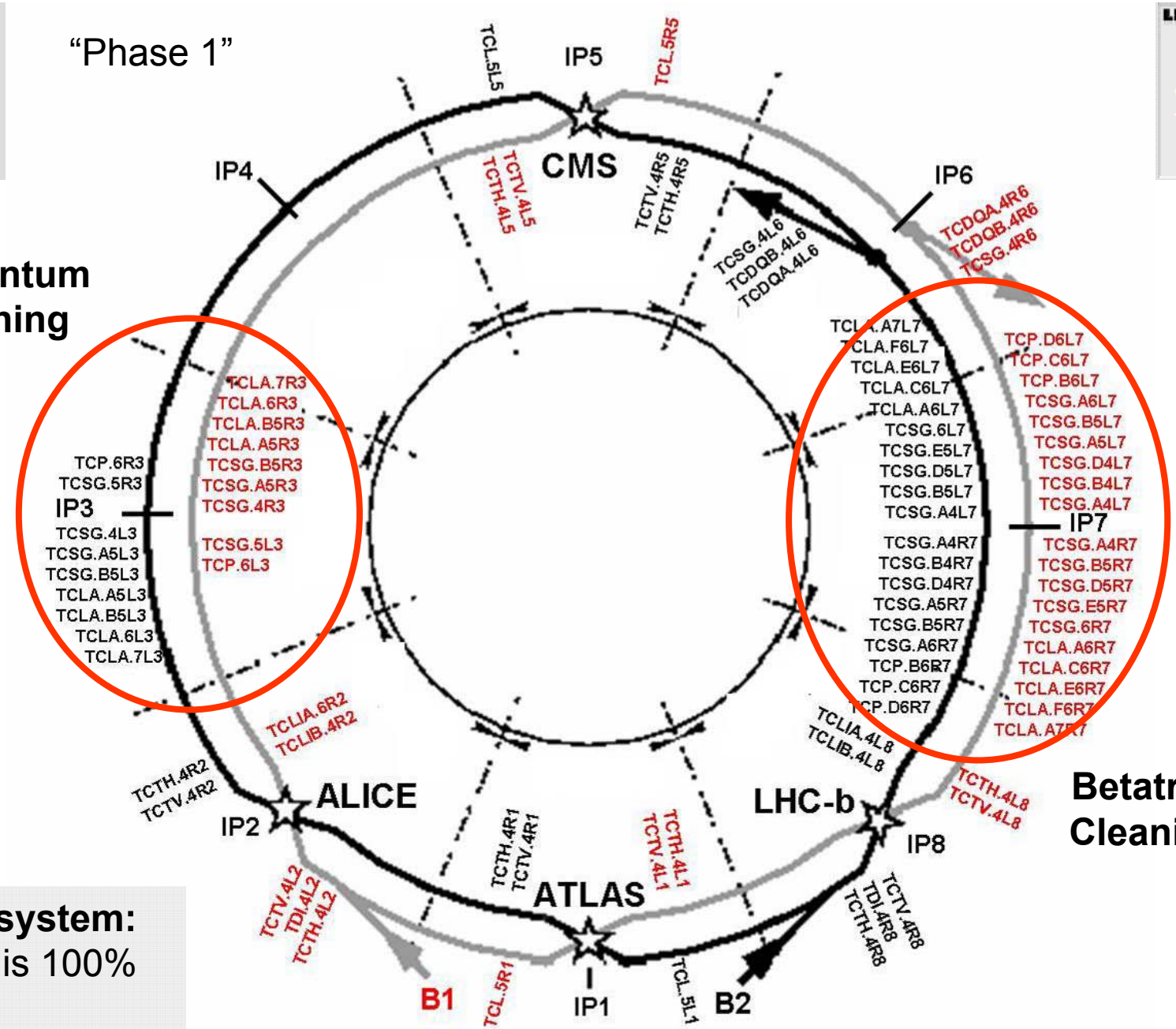
Phased LHC Collimation System

- In total 8 different types of collimators plus masks and absorbers.
- In total 138 ring and 28 transfer line locations for LHC collimators and absorbers:

Phase	# collimators	Intensity limit
Initial	88	≤ 40% of nominal
Upgrade 1 (all prepared)	34	> 100% of nominal
Upgrade 2	*16*	*ultimate efficiency*

- Series production ongoing for 125 ring and transfer line collimators.

“Phase 1”

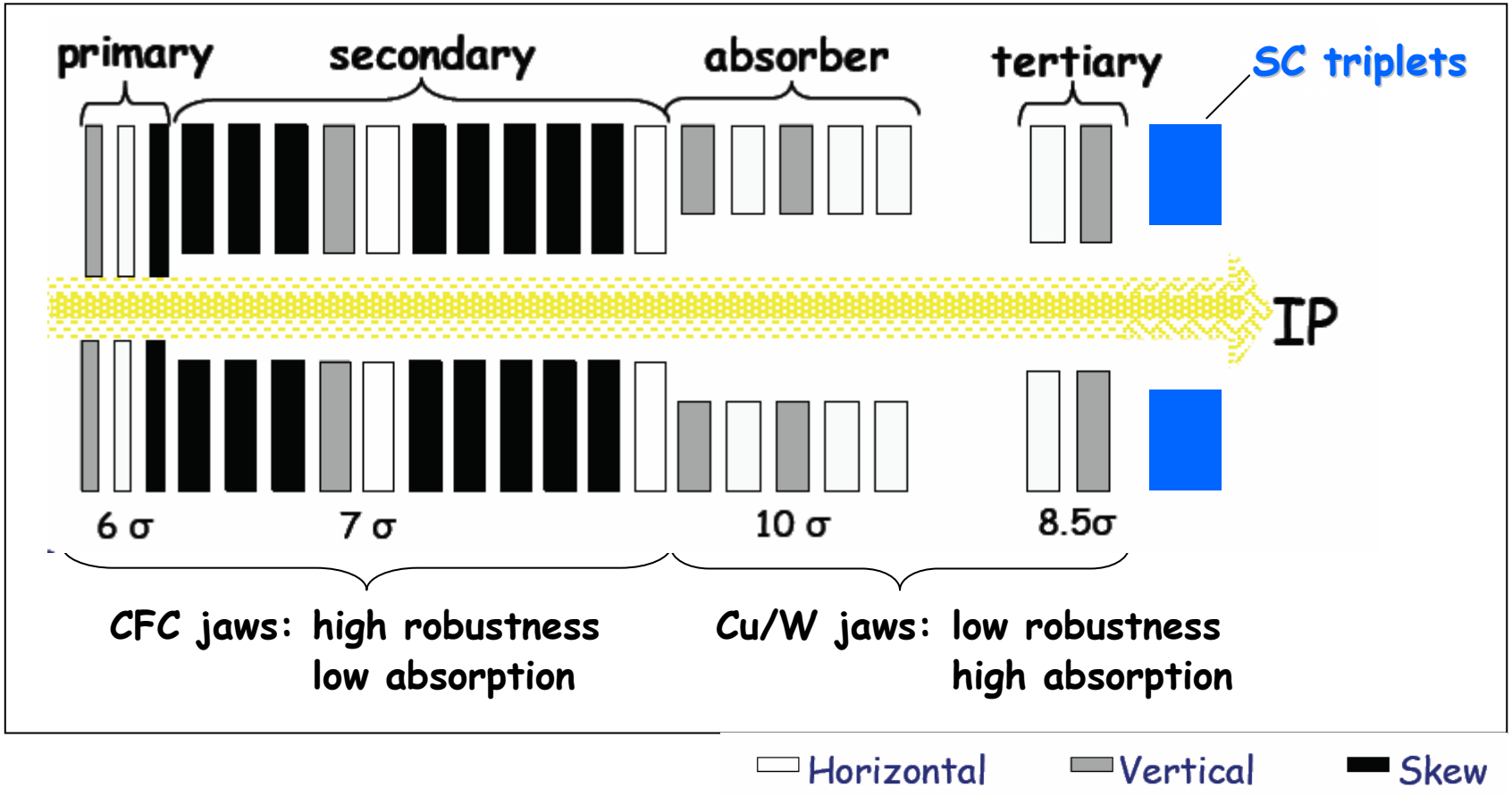


Momentum Cleaning

Betatron Cleaning

“Final” system:
Layount is 100% frozen!

Multi-Stage Betatron Cleaning



Effectively **4-stage cleaning process** at 7 TeV to triplets!

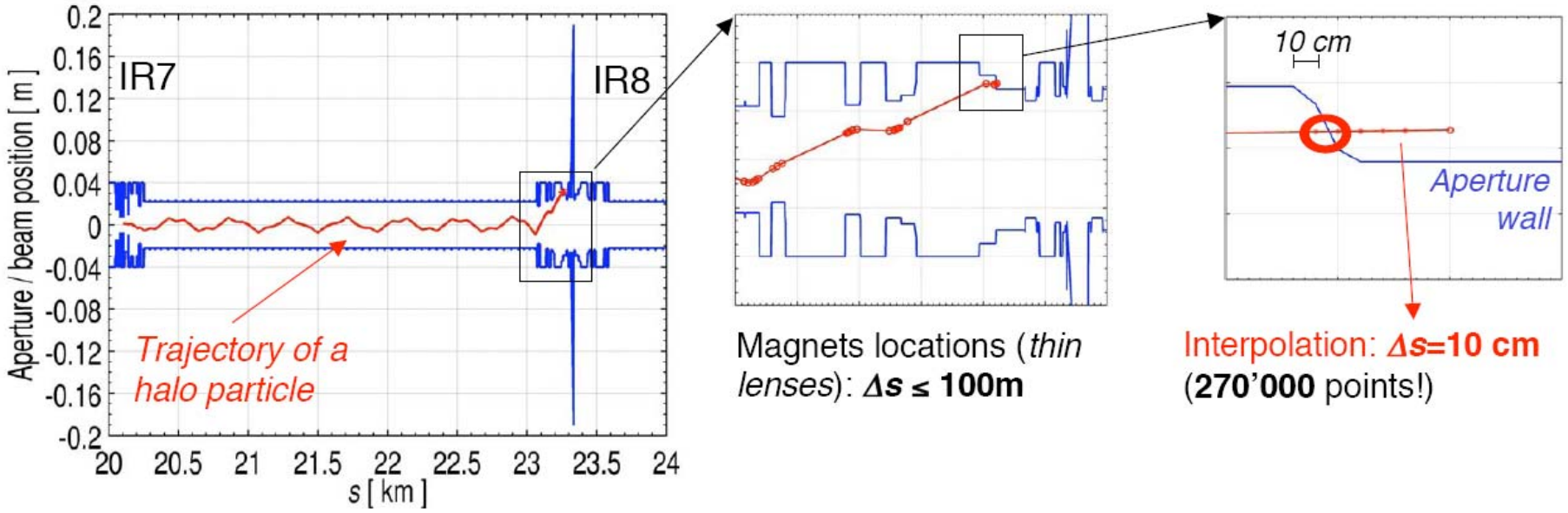
Performance Reach

Simulations: 5 million halo protons

200 turns

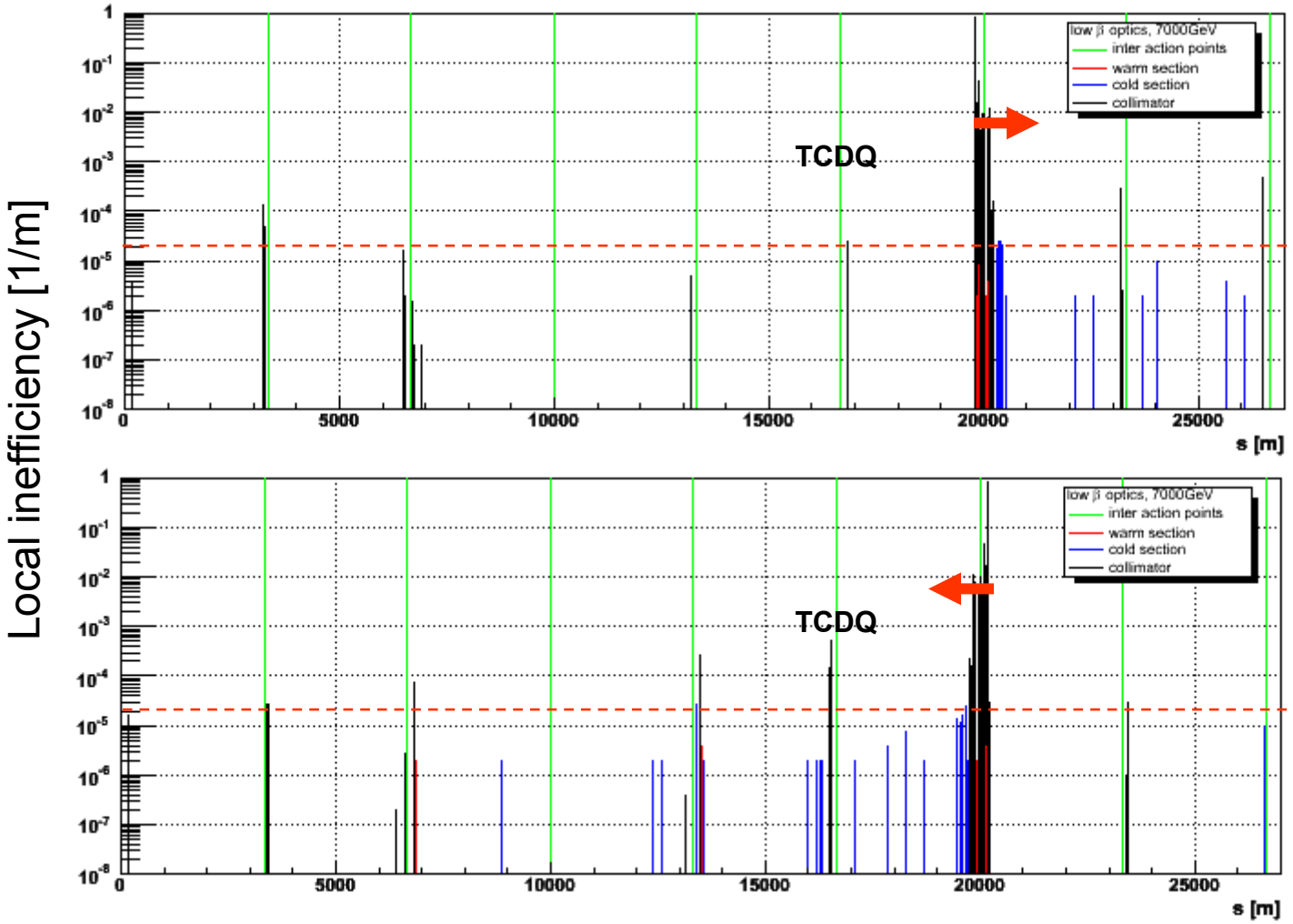
realistic interactions in all collimator-like objects

LHC aperture model



➔ **Multi-turn loss predictions**

Beam1 and Beam 2 Loss Simulations



Beam1, 7 TeV
Betatron cleaning
Ideal performance

Quench limit
(nominal I, τ=0.2h)

Beam2, 7 TeV
Betatron cleaning
Ideal performance

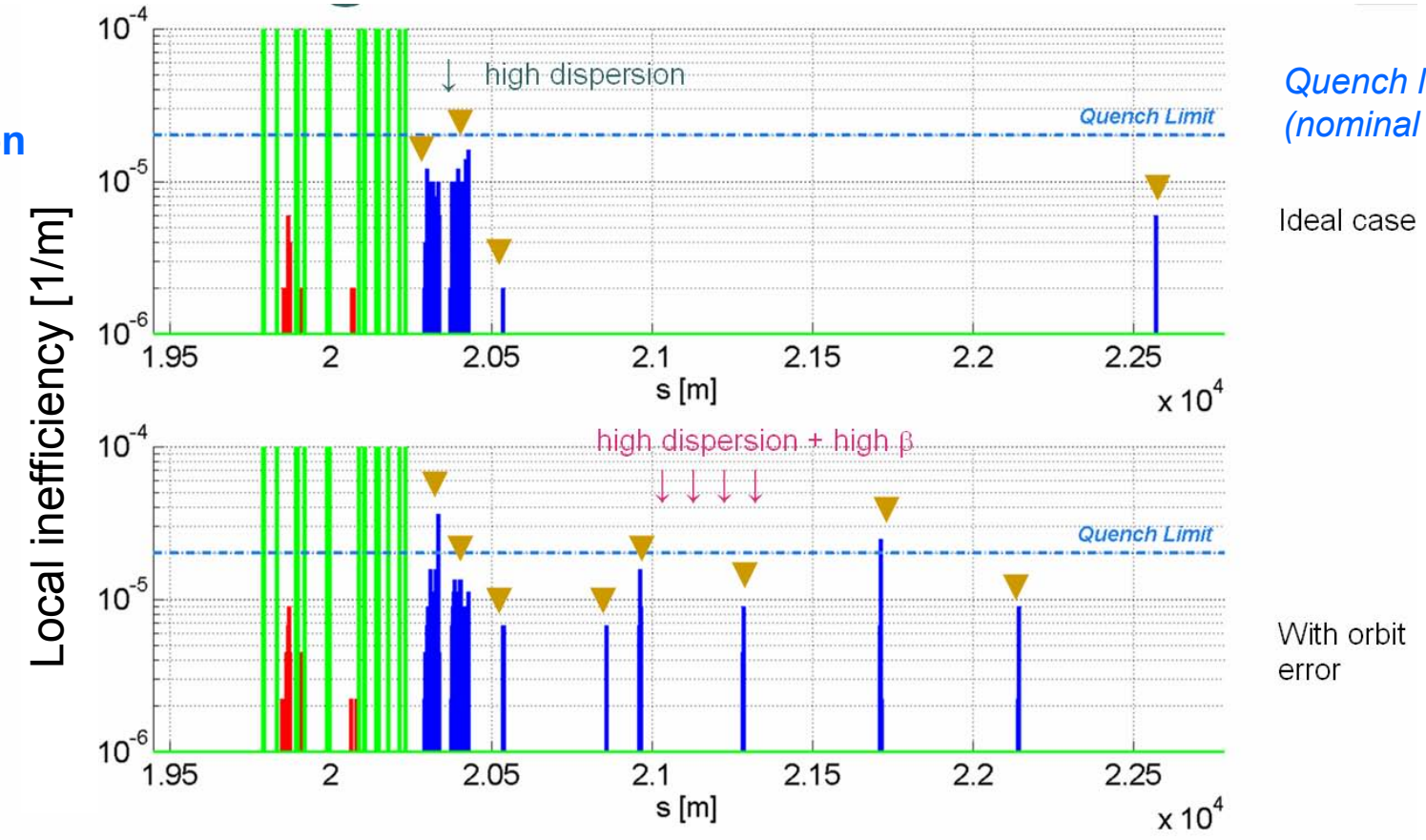
Quench limit
(nominal I, τ=0.2h)

Local inefficiency: #p lost in bin over total #p lost over length of aperture bin! New!

Effect of Closed Orbit (Static & Beam1)

IR7

Betatron collimation



Quench limit (nominal I, τ=0.2h)

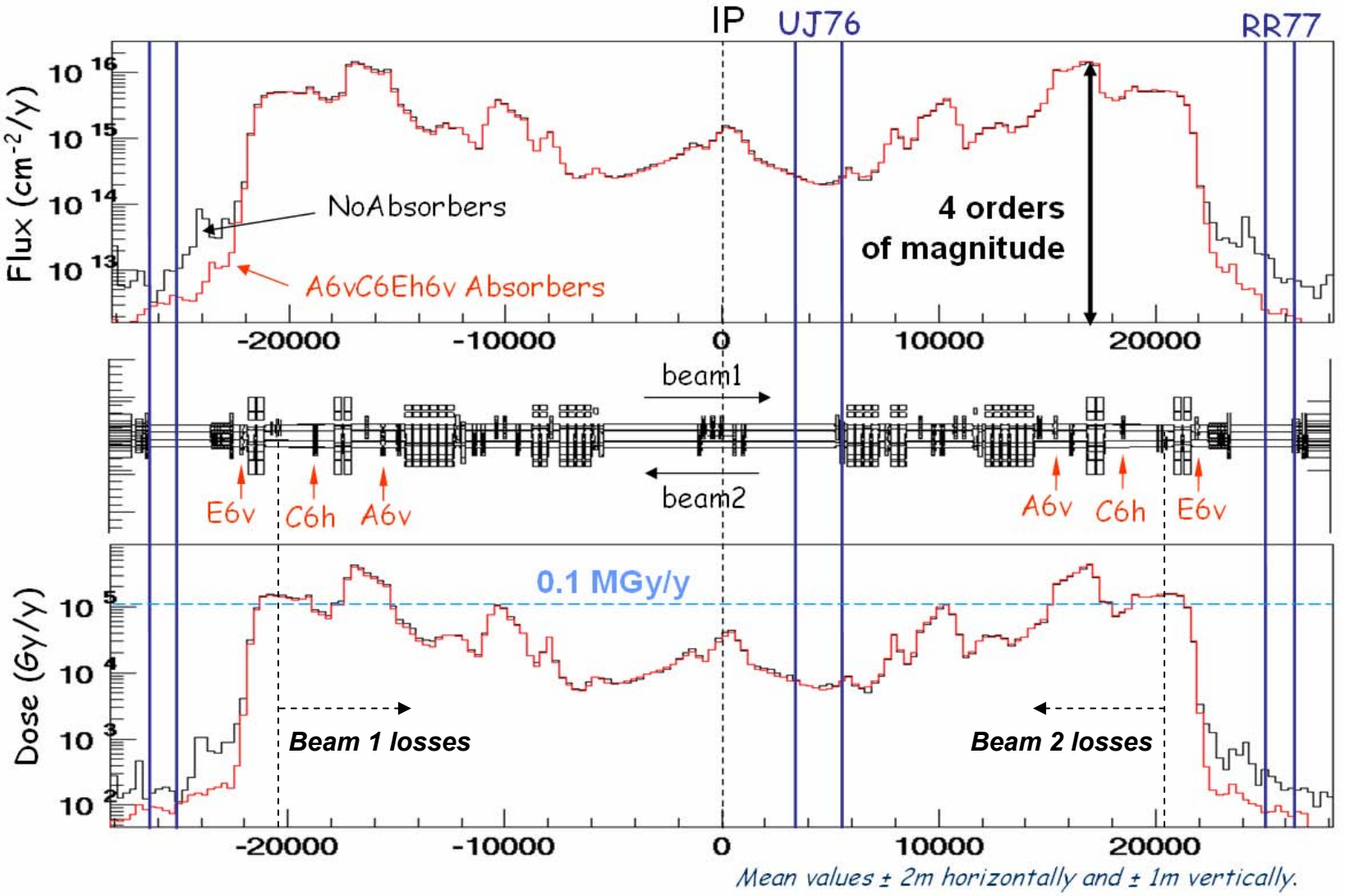
Ideal case

With orbit error

➔ **Higher inefficiency (factor 2) ➔ Less performance!**

➔ **Impact on machine design: Allocation of ring BLM's!**

Energy Deposition (FLUKA)



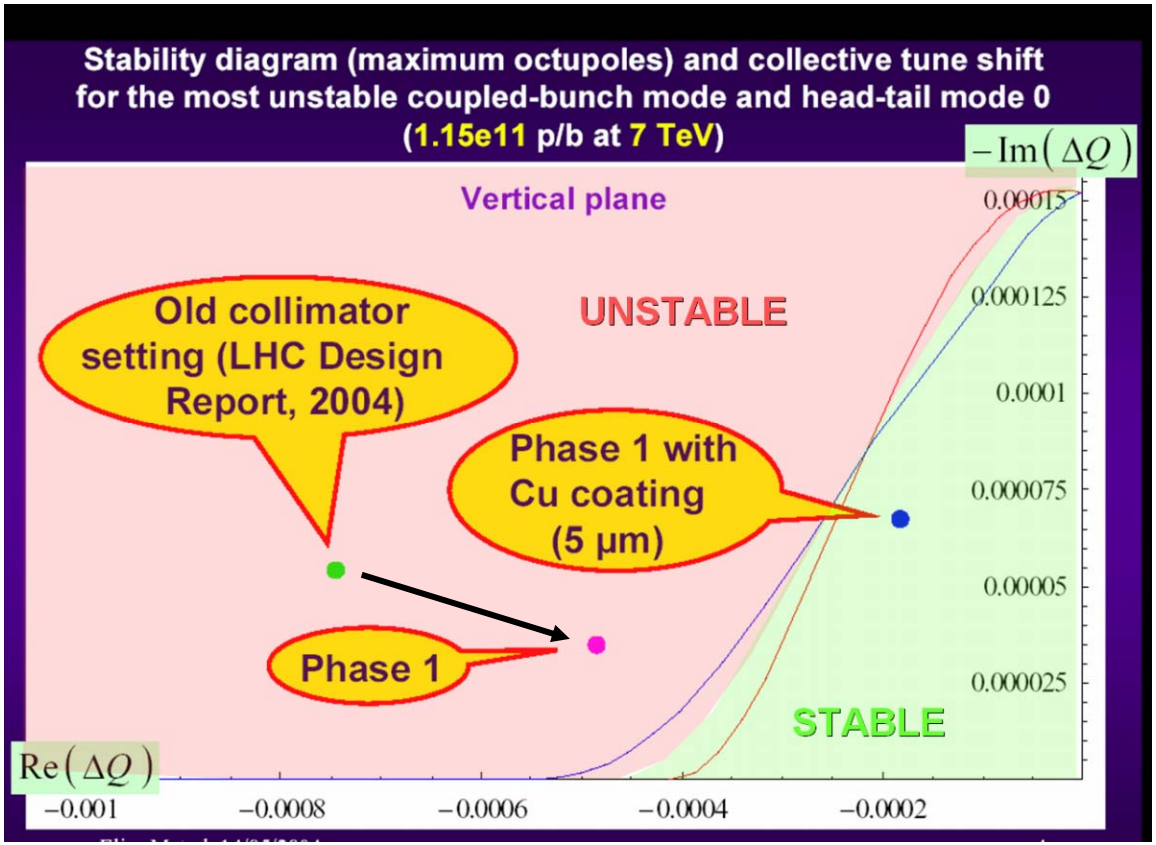
IR7

Betatron collimation

High activation!

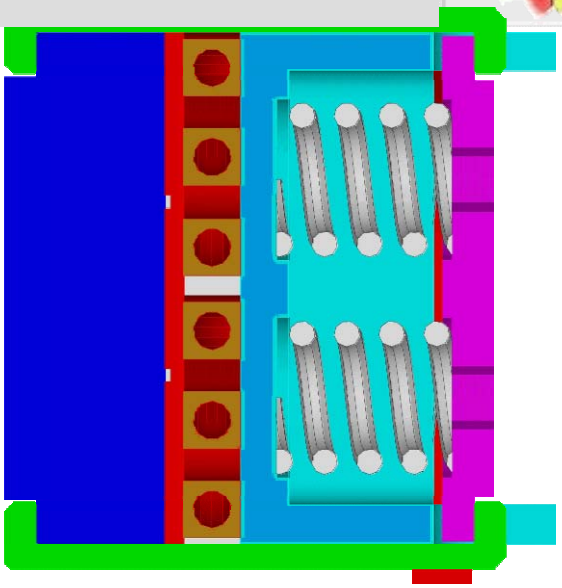
Impedance

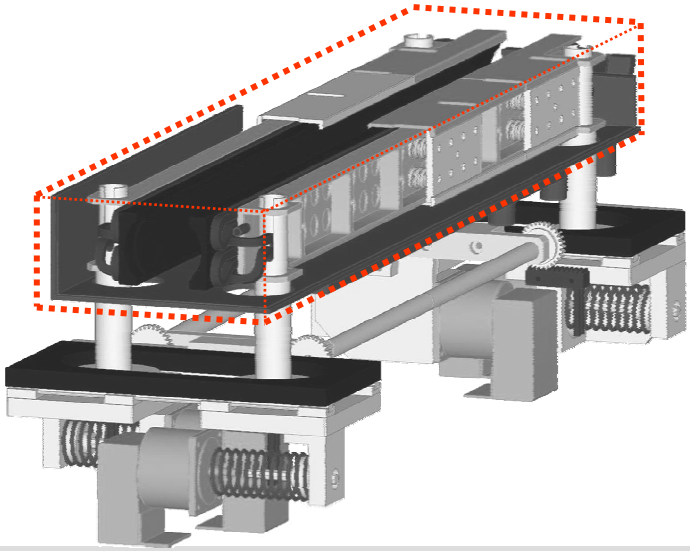
- Increase from collimators (nominal settings) for the imaginary part of the effective vertical impedance:
  - 8 kHz:
    factor 3 for injection
    factor 69 for 7 TeV
  - 20 kHz:
    factor 3 for injection
    factor 145 for 7 TeV
- Large increase in impedance must be actively counteracted by transverse feedback and octupoles!
- Phase 2 collimators to overcome impedance and improve efficiency!



Phase 1 is limited from collimator-induced impedance!

Hardware: Water Cooled Jaw

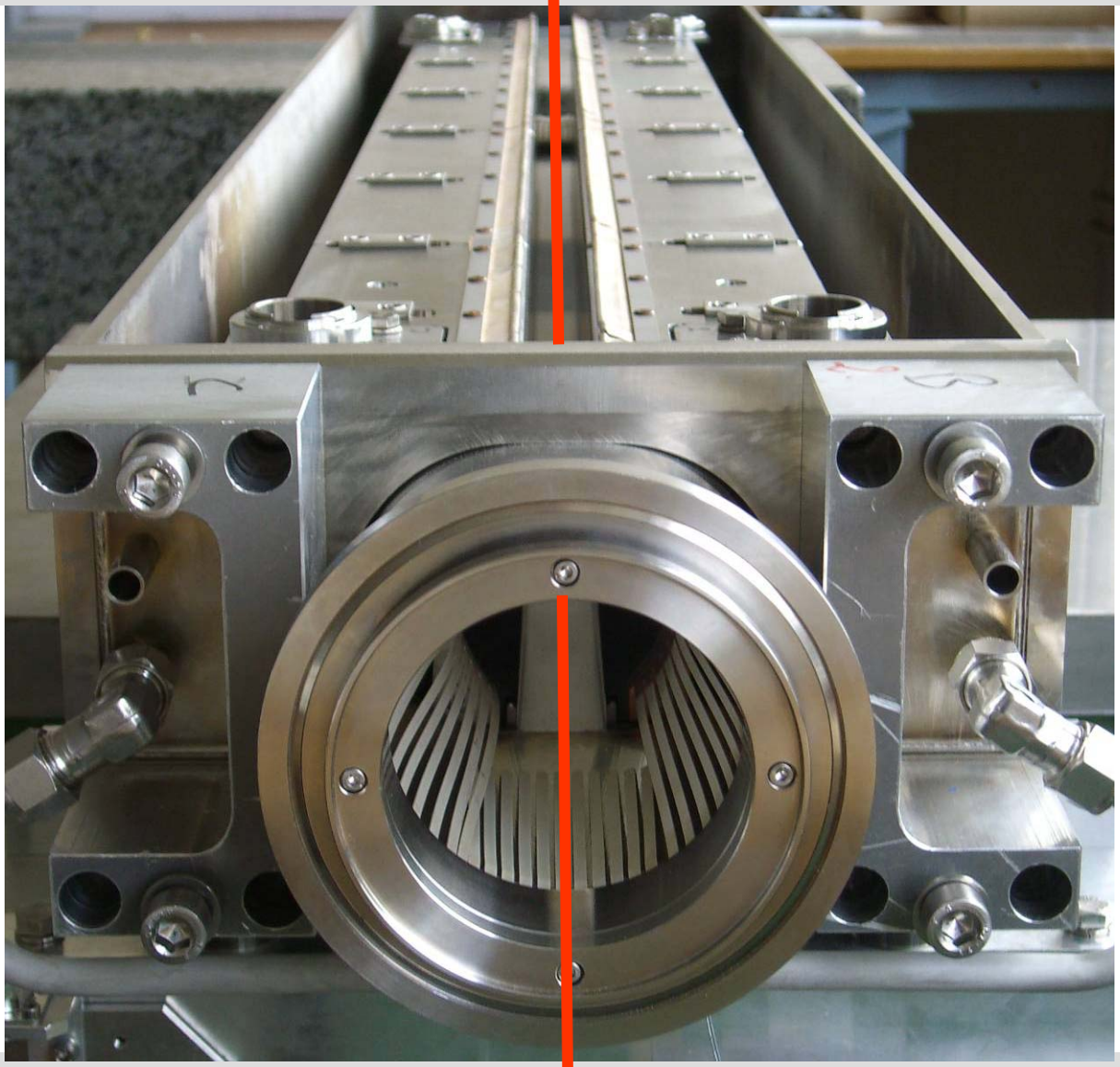




➔Up to 500 kW impacting on a jaw (< 7 kW absorbed in jaw)…

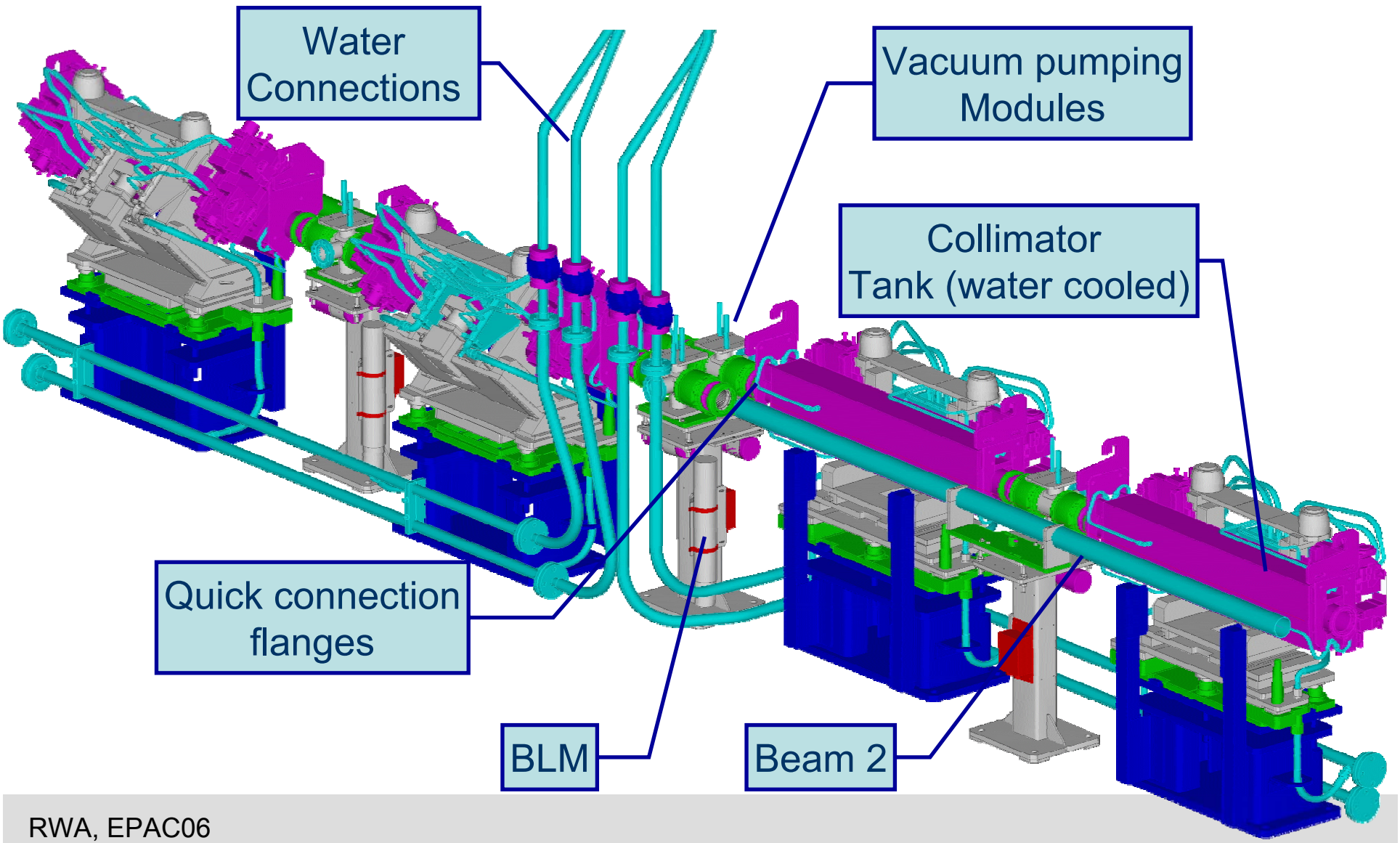
Advanced material: Fiber-reinforced graphite (CFC)

The Collimator Tank Assembly

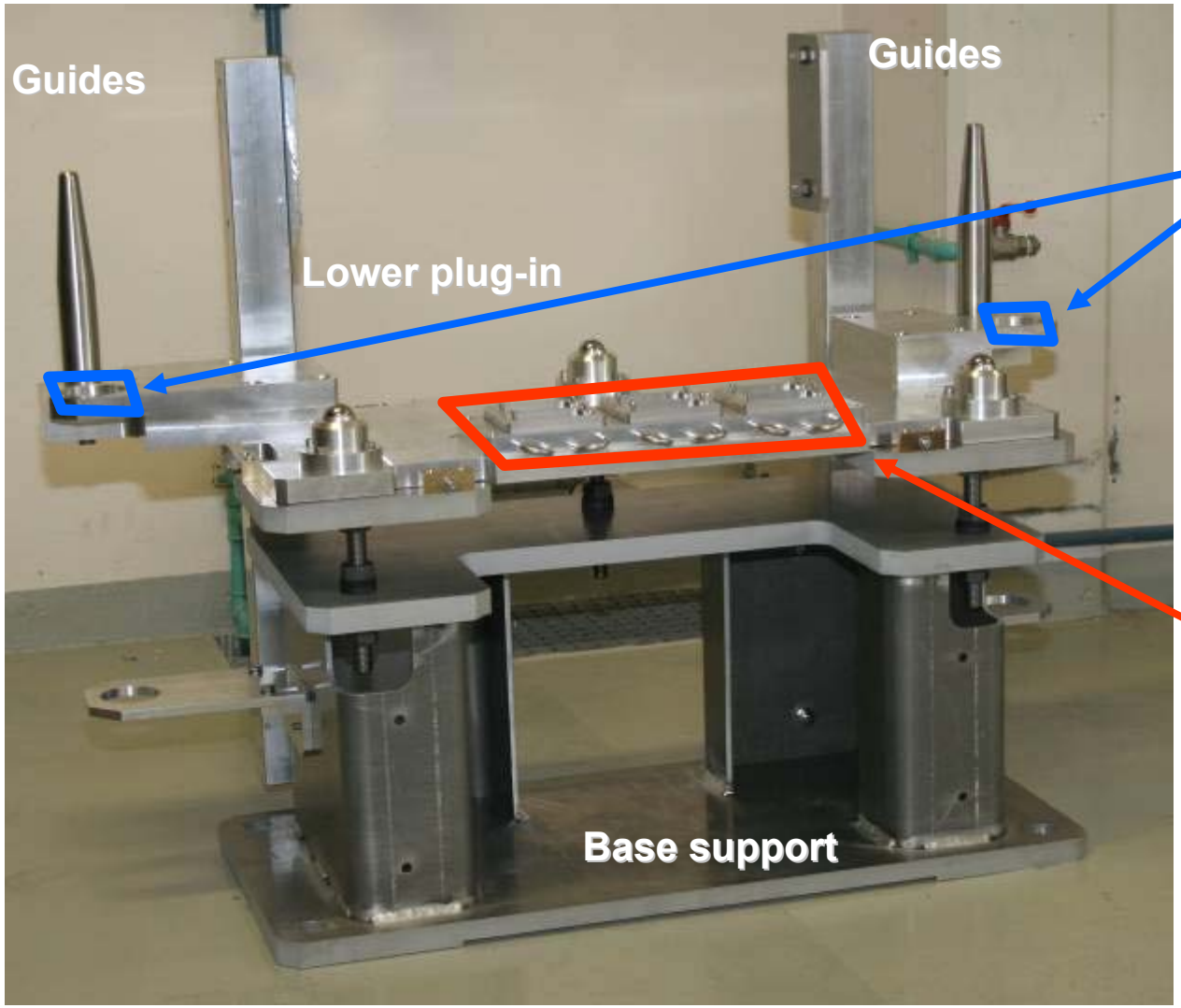


Collimator General Layout

(vertical and skew shown)



Base Support and Lower Plug-In



Water plugs

Electrical plugs

First LHC collimators installed…

10 minutes installation: checking on quick-plugs…

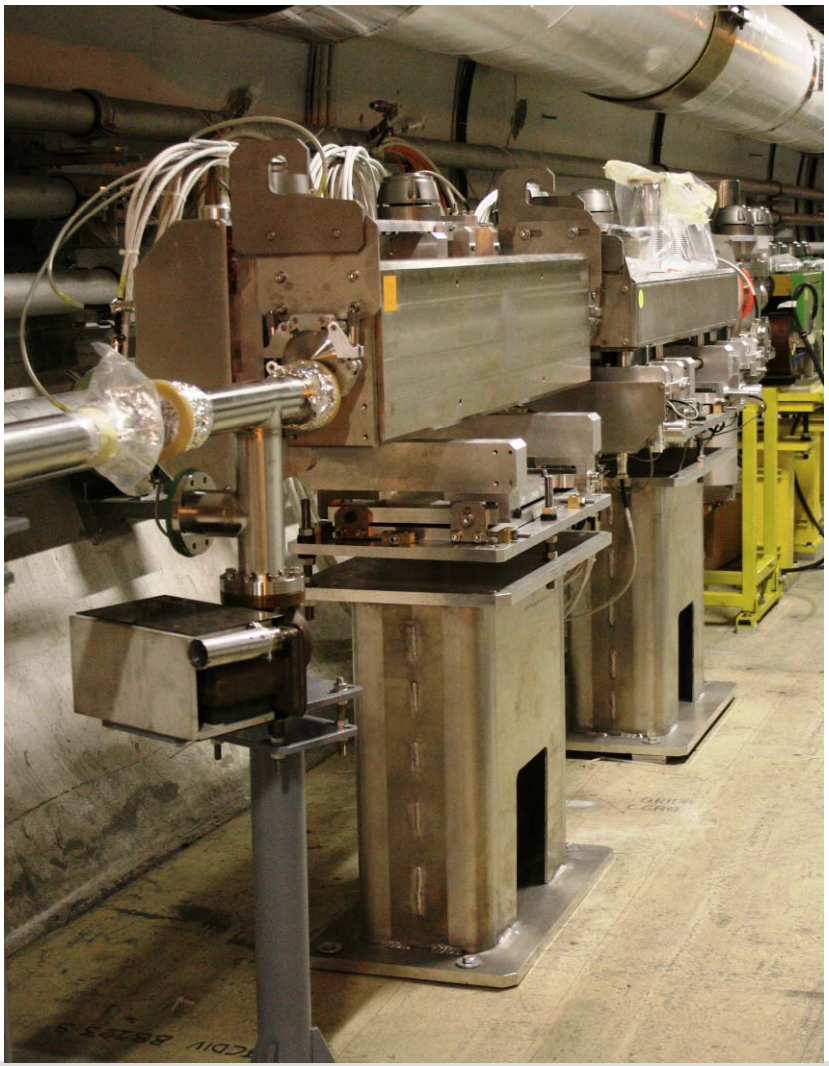
First ring collimator in 8L. (triplet protection for beam 1)

- June 14th -

First LHC collimators installed…

Injection protection: Transfer line collimators in the ring, just before injection 8R.

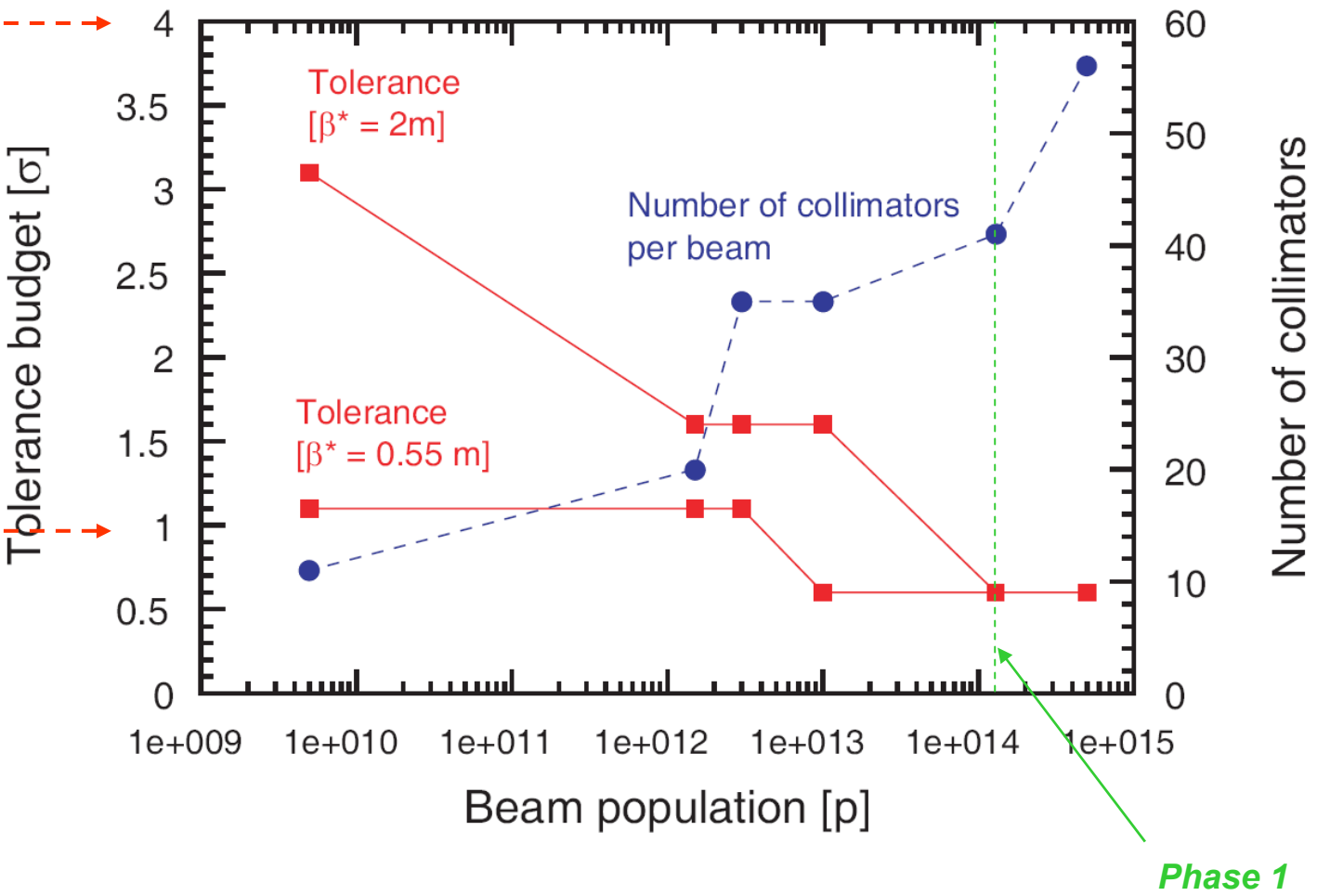
- May 31st -

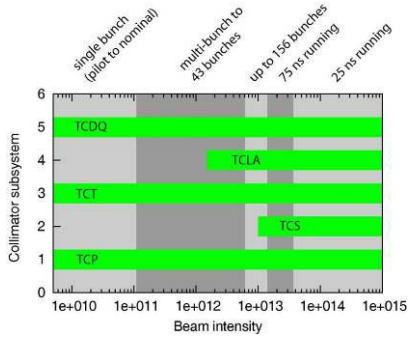


Preparing Commissioning at 7 TeV

0.8 mm at a typical collimator

0.2 mm at a typical collimator





➔ **Commissioning is being prepared: Controls, tools, scenarios, …**

Conclusion

- The LHC collimation system layout is finalized and performance reach is evaluated.
- Simulations: Performance can reach **~10-40% of nominal intensity** for phase 1 after initial and full commissioning (up to 100 times TEVATRON/HERA stored energy). Imperfections and quench limits are critical!
- Production is now running for all major parts in the tunnel. Last collimator for 2007 installation will arrive end of January 2007.
- Installation has started in IR8. All of infrastructure under way in the seven IR's with collimators (also for first upgrade).
- A relatively powerful LHC collimation system will be available for the LHC start-up. It can be upgraded in performance (around 2010).
- Commissioning and operation is being prepared…
- Phase 2 R&D program under preparation (FP7 collaboration).

Collimation-Related Papers

- **MOPCH091 An Alternative Nonlinear Collimation System for the LHC**
  Javier Resta (IFIC, Valencia; CERN, Geneva), Ralph Assmann, Stefano Redaelli, Guillaume Robert-Demolaize, Daniel Schulte, Frank Zimmermann (CERN, Geneva), Angeles Faus-Golfe (IFIC, Valencia)
- **MOPLS003 Tertiary Halo and Tertiary Background in the Low Luminosity Experimental Insertion IR8 of the LHC**
  Vadim Talanov (IHEP Protvino, Protvino, Moscow Region), Ralph Assmann, Daniela Macina, Keith Michael Potter, Stefano Redaelli, Guillaume Robert-Demolaize, Emmanuel Tsesmelis (CERN, Geneva)
- **MOPLS008 Beam Halo on the LHC TCDQ Diluter System and Thermal Load on the Downstream Superconducting Magnets**
  Brennan Goddard, Ralph Assmann, Andrew Presland, Stefano Redaelli, Guillaume Robert-Demolaize, Lucia Sarchiapone, Thomas Weiler, Wim Weterings (CERN, Geneva)
- **TUPLS013 Protection of the LHC against Unsynchronised Beam Aborts**
  Brennan Goddard, Ralph Assmann, Etienne Carlier, Jan Uythoven, Jorg Wenninger, Wim Weterings (CERN, Geneva)
- **TUPLS017 Optics Study for a Possible Crystal-based Collimation System for the LHC**
  Ralph Assmann, Stefano Redaelli, Walter Scandale (CERN, Geneva)
- **TUPLS018 LHC Collimation Efficiency during Commissioning**
  Chiara Bracco, Ralph Assmann, Alfredo Ferrari, Stefano Redaelli, Guillaume Robert-Demolaize, Mario Santana-Leitner, Vasilis Vlachoudis, Thomas Weiler (CERN, Geneva)
- **TUPLS019 Critical Halo Loss Locations in the LHC**
  Guillaume Robert-Demolaize, Ralph Assmann, Chiara Bracco, Stefano Redaelli, Thomas Weiler (CERN, Geneva)
- **TUPLS130 Comparison between Measured and Simulated Beam Loss Patterns in the SPS**
  Stefano Redaelli, Gianluigi Arduini, Ralph *Assmann*, Guillaume Robert-Demolaize (CERN, Geneva)
- **THPCH061 Tune Shift Induced by Nonlinear Resistive Wall Wake Field of Flat Collimator**
  Frank Zimmermann, Gianluigi Arduini, Ralph Assmann, Helmut Burkhardt, Fritz Caspers, Marek Gasior, Owain Rhodri Jones, Tom Kroyer, Elias Métral, Stefano Redaelli, Guillaume Robert-Demolaize, Federico Roncarolo, Giovanni Rumolo, Ralph Steinhagen, Jorg Wenninger (CERN, Geneva)
- **TUPLS131 LHC Collimation Efficiency as a Function of Collimator Jaw Flatness**
  Stefano Redaelli, Ralph Assmann, Chiara Bracco, Guillaume Robert-Demolaize (CERN, Geneva)