LHC Performance Workshop, Chamonix2014
Hôtel Les Aiglons, Chamonix, France
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LHC Collimation Upgrade and MP Roadmap

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for the Collimation Project and HL-LHC-WP5 teams
Material from J. Uythoven, A. Lechner for the FLUKA team, I. Efthymiopoulos

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.

Introduction

- The LHC Collimation system worked well during the Run I
  - *No quenches with up to >140MJ stored beam energies*
  - *Stability of cleaning with 1 alignment per year in cleaning insertions*
  - *High reliability of a complex system (100 collimators, >400 motors)*
- Several review organized in the past year. Recent milestones:
  - ***2011**: decision to postpone major cleaning upgrades after LS1;*
  - ***2013**: recommended important upgrades for LS2.*
- Recommendations consistently emphasized that
  - *Scaling to higher energies entails important **uncertainties***
    Cleaning, quench limits, beam loss rates.
  - *Collimation **impedance** is a important limitation for the performance.*
  - *We have to watch out for **loss spikes** in presence of overpopulated tails.*
  - *Consolidation and maintenance of a high-precision system in tunnel and high-radiation environment is a concern.*
- Many uncertainties can be solved only with beam experience.
- HL-LHC brings new challenges: beam parameters, layouts...

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- Many uncertaint
- HL-LHC brings

Our strategy: Prepare solutions for known and potential performance limitations to be prepared for upgrade decisions in 2015 and study HL baseline solutions.

Outline

- ☑ Introduction
- ☑ Collimation for Run II
- ☑ Collimation upgrade solutions
- ☑ Collimation around experiments
- ☑ Conclusions

Upgraded collimation for Run II

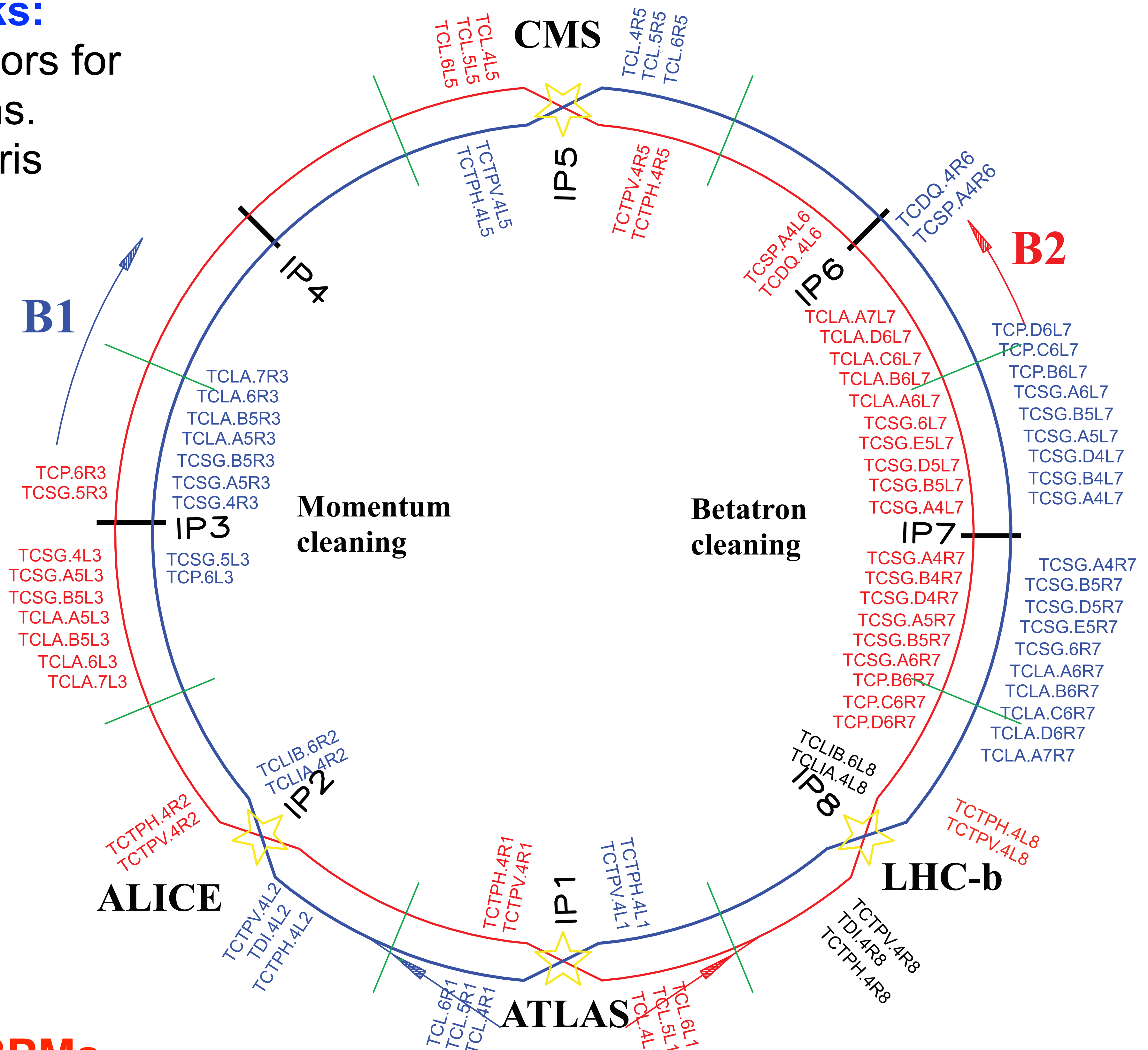
Planned LS1 hardware works:

1) Production of BPM collimators for experiments + dump regions.
2) New layout for physics debris collimation in ATLAS/CMS.
3) Improved warm magnet shielding in the momentum cleaning.
4) Survey/maintenance.
5) Preparation of layout slots for future upgrades.

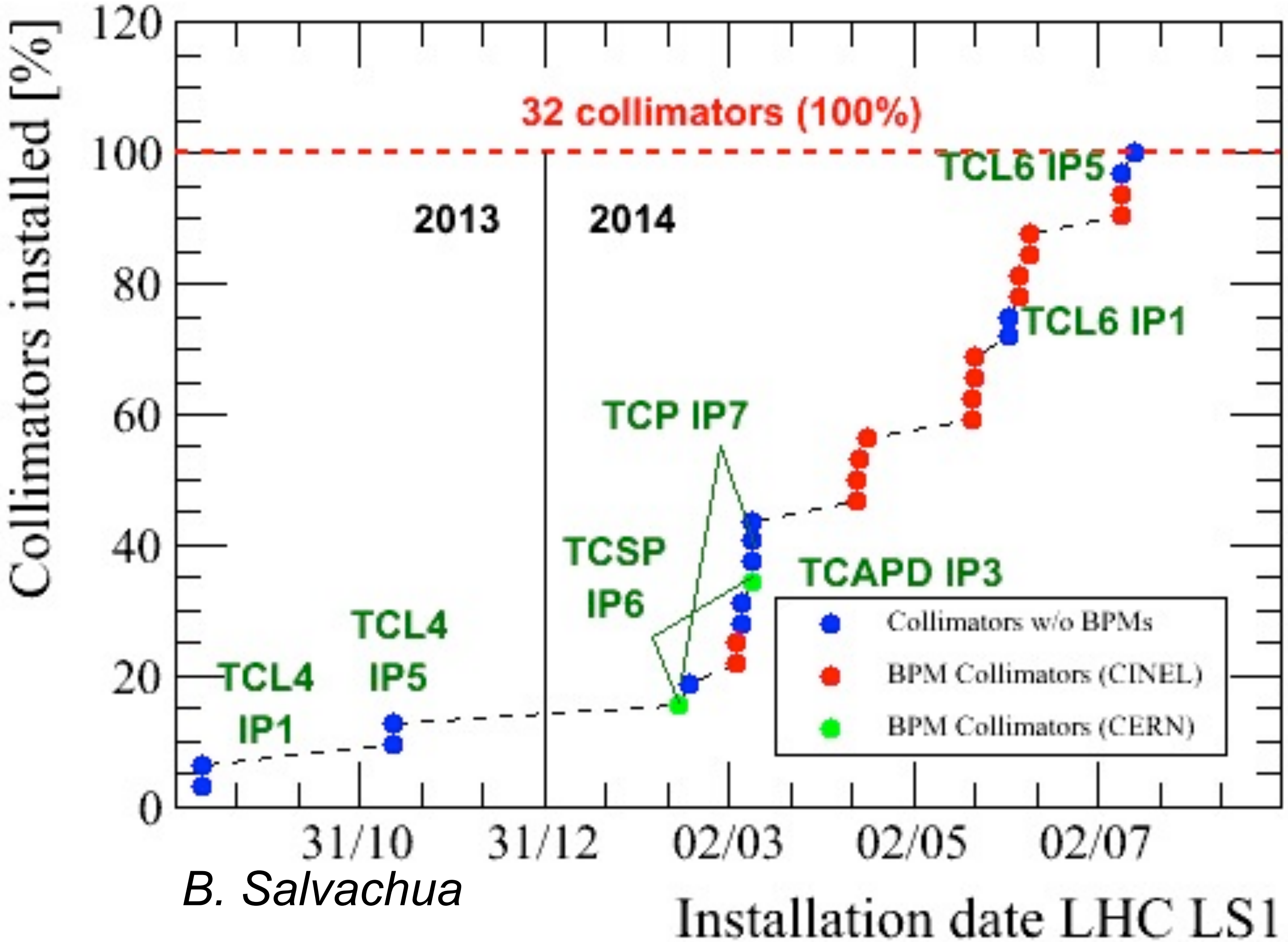
32 collimators in the machine, i.e. 30% of the system!

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

18 new collimators with BPMs.

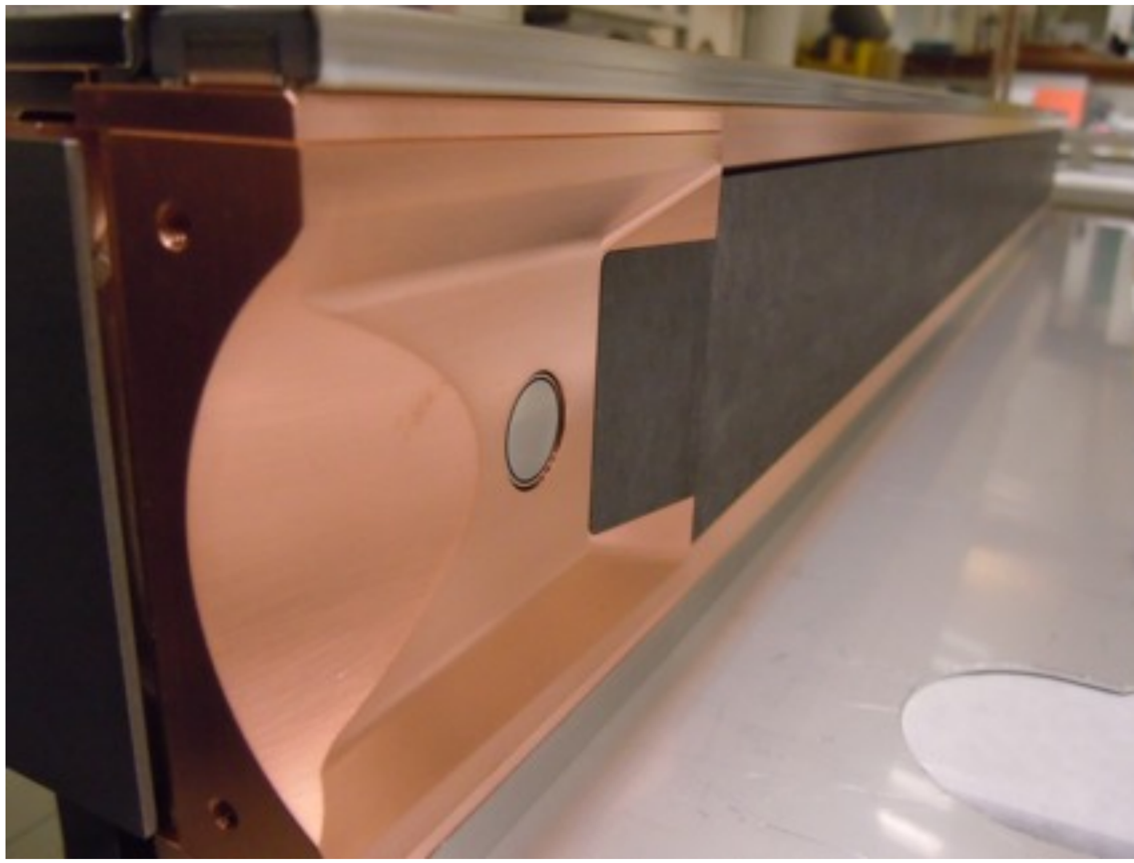


Status of LS1 collimation upgrades



B. Salvachua

CFC jaw with BPM

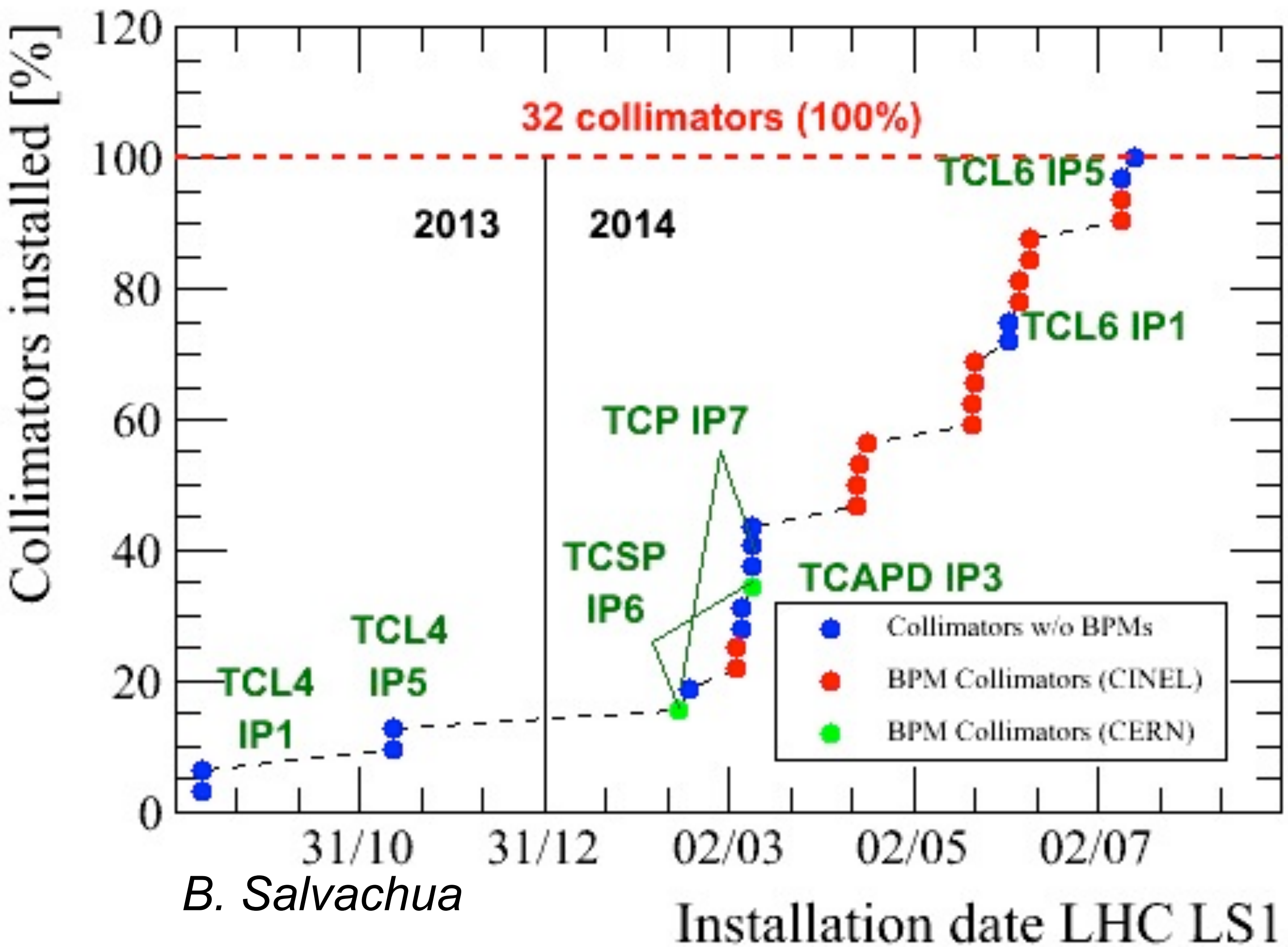


Two minor issues:

- 1 carbon-based collimator with BPMs not vacuum conform (TCSP);
- 1 primary collimator to be replaced because of a problem of overheating (TCP).

We are re-build spares for that (under consolidation).

Status of LS1 collimation upgrades



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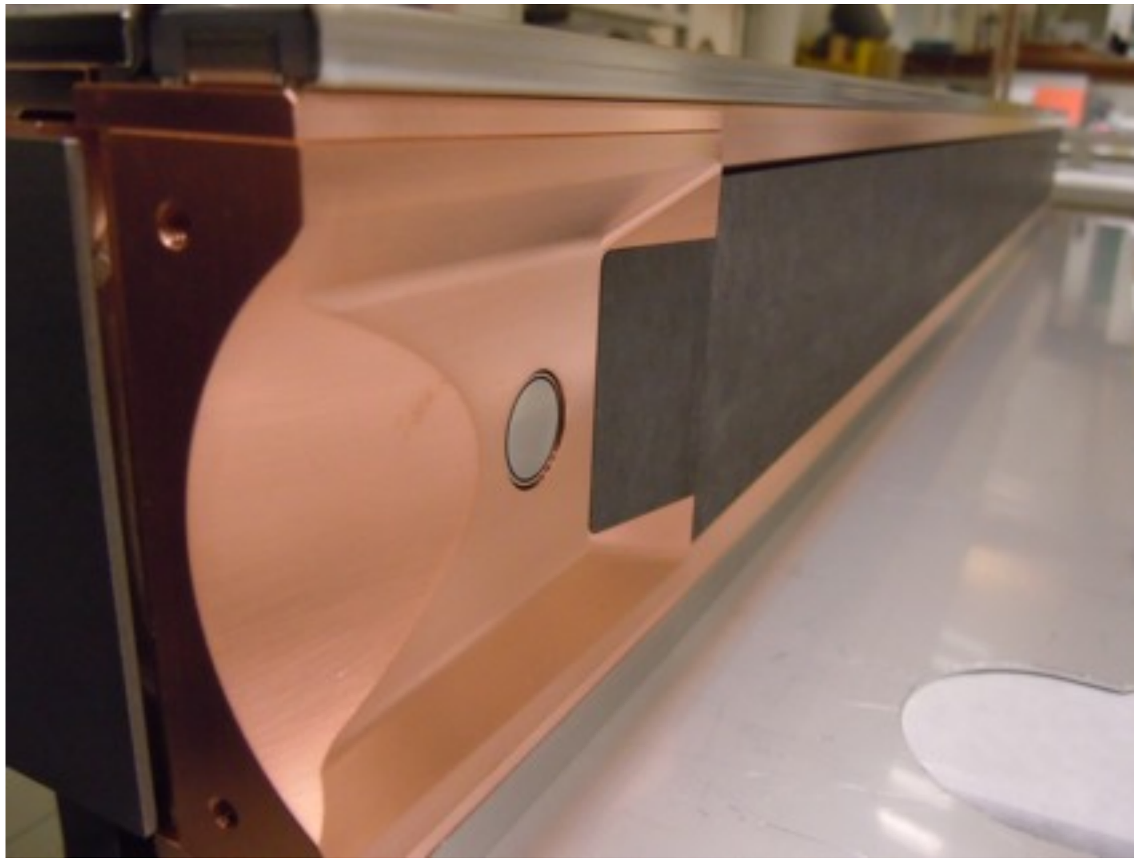

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Many thanks to the project teams involved!
In particular: production teams in EN/MME, EN/STI, BE/BI, TE/VSC; but also planning, alignment,... ABP: collimation and impedance teams.

Outline

- Introduction
- Collimation for Run II
- **Collimation upgrade solutions**
  - ***Impedance/robustness*** — HL baseline
  - ***Cleaning*** — HL baseline
  - ***Halo control*** — Design study
  - ***Crystal collimation*** — R&D
- Collimation around experiments
- Conclusions

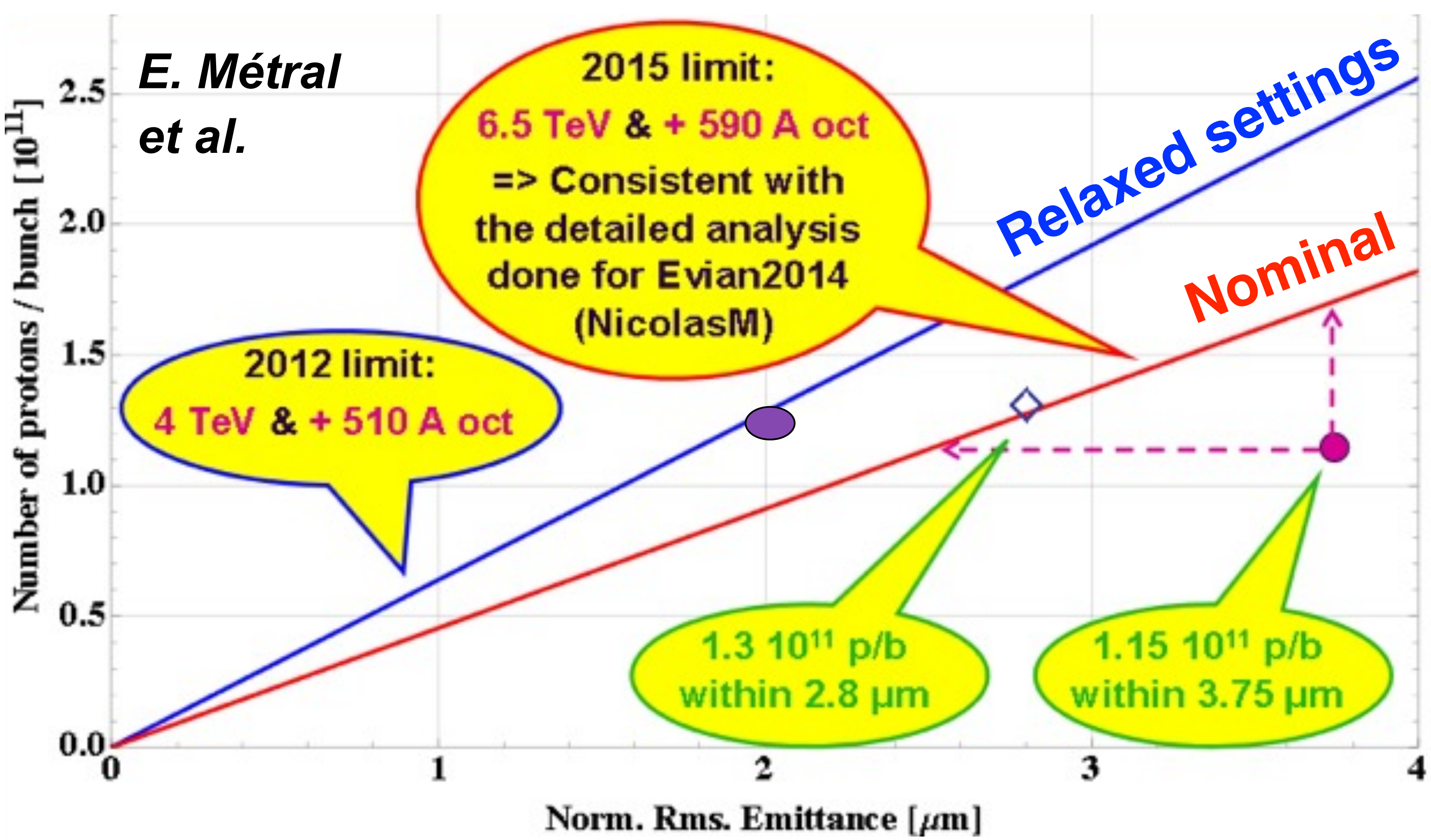
Low-impedance and robust collimators

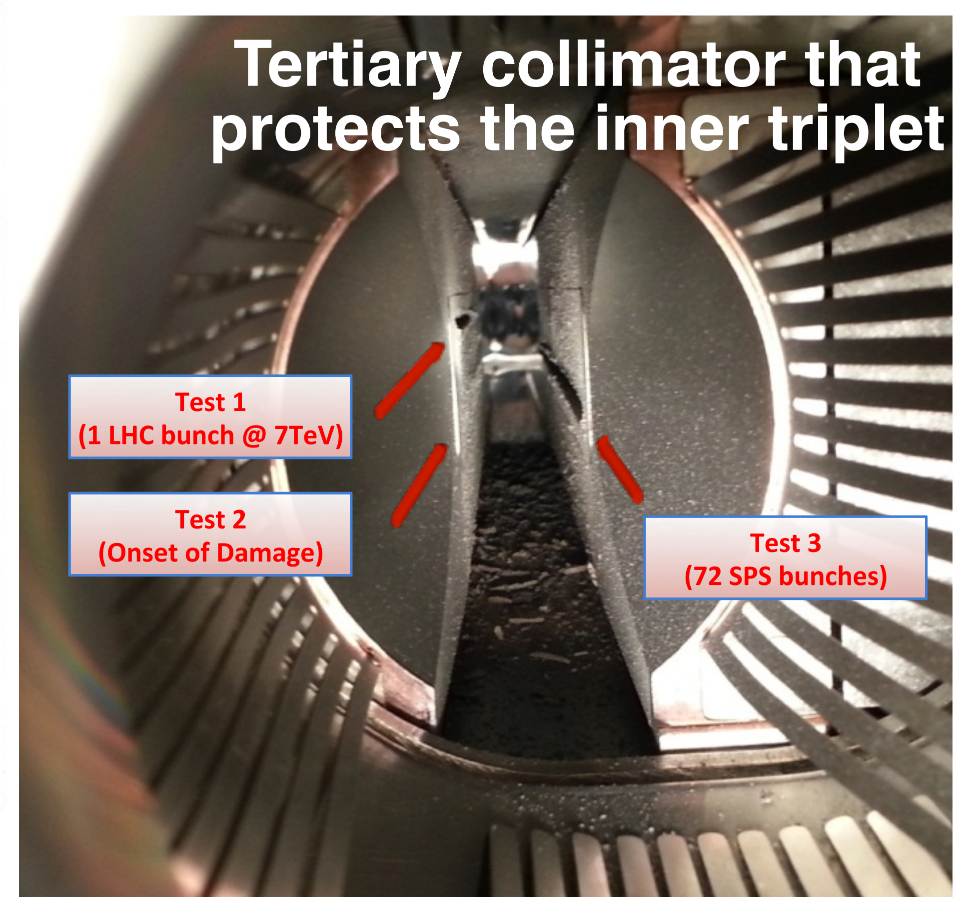
Run I → see already **limitations** from impedance and protection constraints!

Rich and inter-disciplinary R&D on **novel collimator materials** on-going to **:**

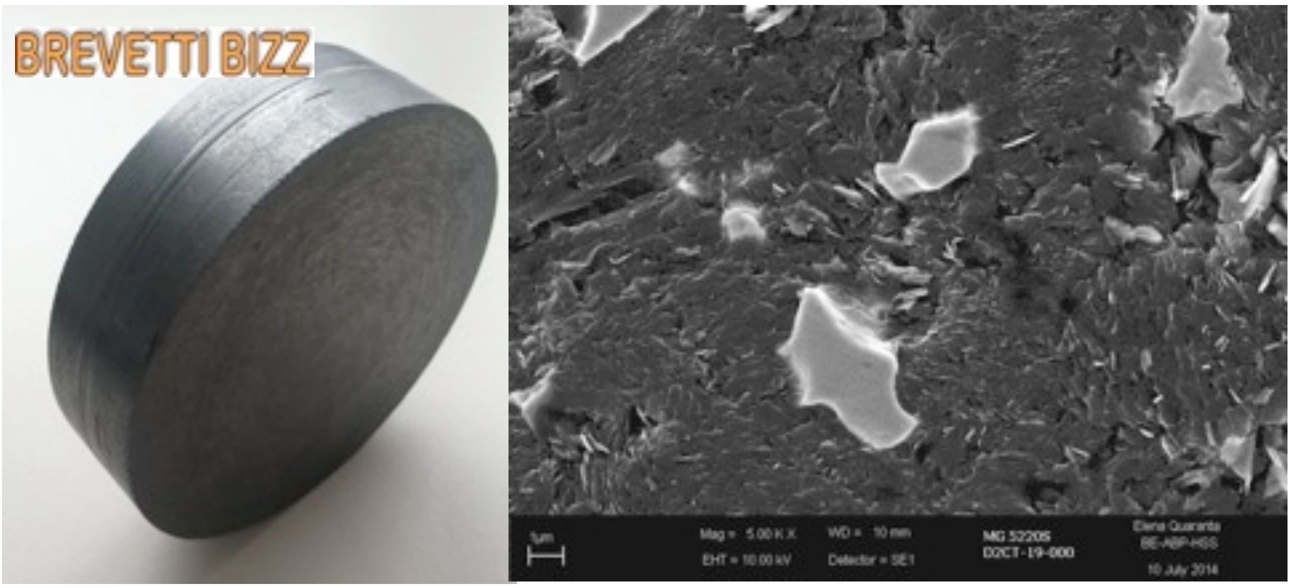
- *reduce single collimator impedance by a factor ~10;*
- *improve robustness against beam impacts at 7 TeV: factor > 100;*
- *withstand injection failures (x2 intensity; x0.3 emittance compared to LHC).*

Baseline solution: Novel Mo-Gr composites, possibly with coating. *(developed by CERN and the BrevettiBizz company).*



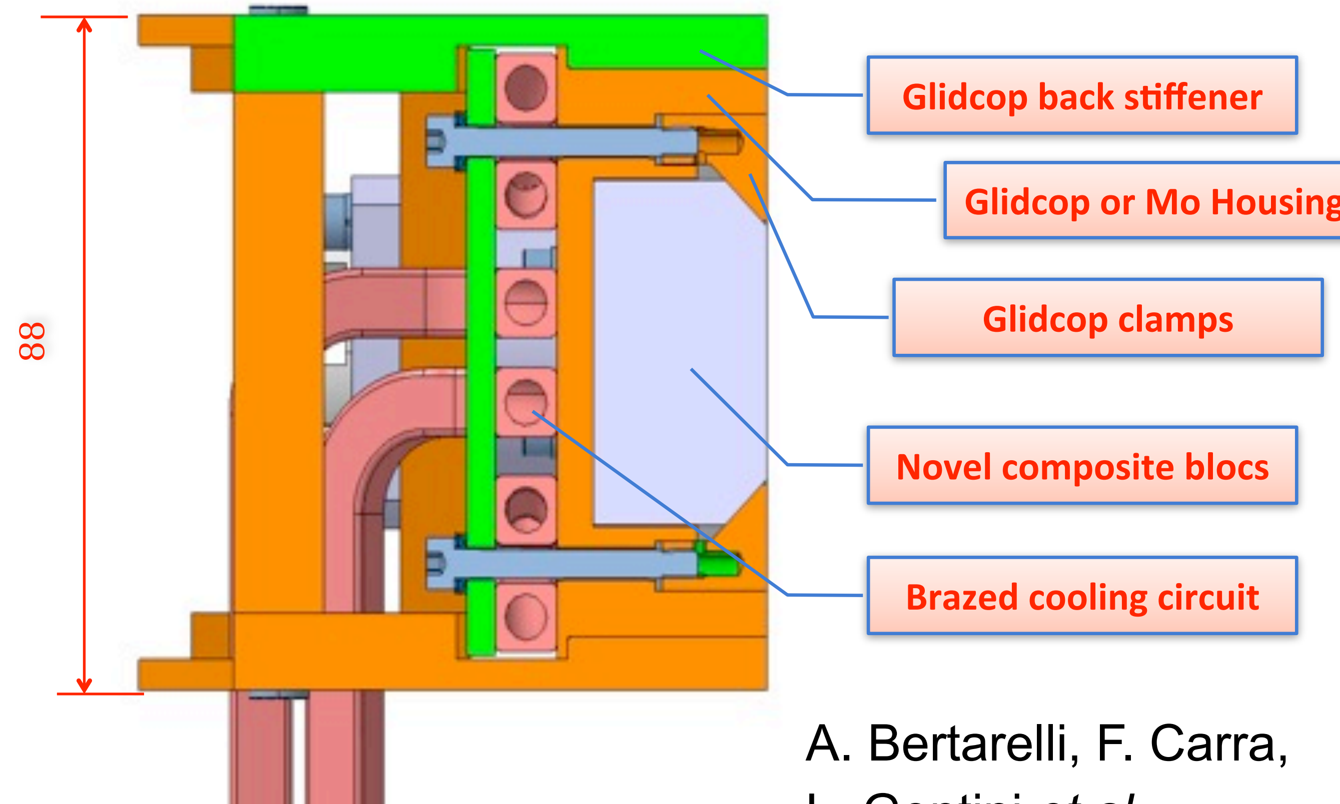


Status of design and prototyping

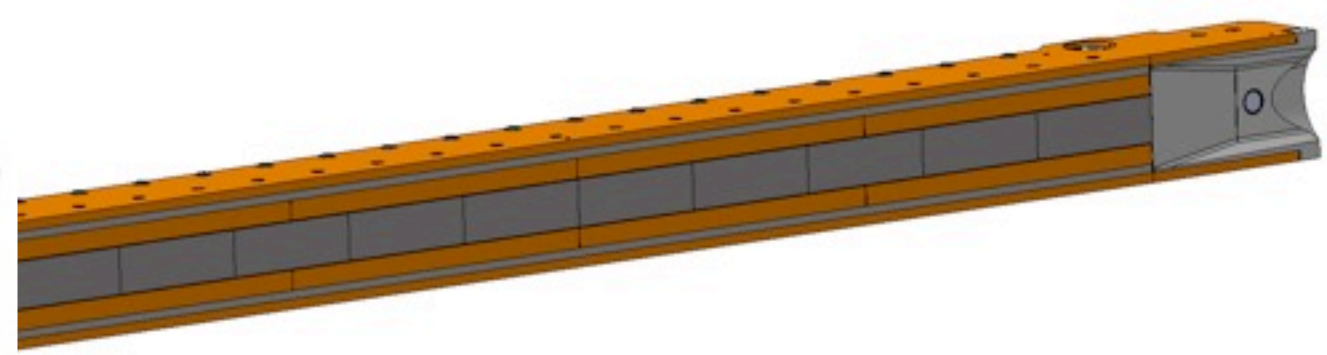


MoGr plate recently produced by Brevetti Bizz, Italy. Dimensions of the plate: 90mm diameter and 24.3mm thickness. It is a massive piece prepared in view of the production
Graphite flakes matrix well sintere
together with few molybdenum carbid

This is the main topics of the FP7-EuCARD² study.



A. Bertarelli, F. Carra, L. Gentini *et al.*



(Ambitious) timeline *(defined by the ATS directorate after the 2013 review)*:

- Prototype of new secondary collimators for beam tests in LHC in 2016.
- Slots are ready in the IR3/7: can even install new collimators in EYTS's!

Pre-requisite: full validation of new **design** and **materials** at HiRadMat!

History of collimator damage tests

- 2004: full TCSG collimator in TT40 (CFC + Gr jaws)

  Material ok but found an un-acceptable deformation of a Cu jaw back plate that was than changed to Glidcop.

- 2006: full TCSG collimator in TT40 (CFC)

  Validated final design!

- 2012: HRM-09: full tertiary collimator jaw

  Empirical definition of damage limit of tertiary collimator jaw.

- 2012: HRM-14: First test of novel material samples

  Characterization of collimator materials

- **2015-2016: <u>3 experiments</u> (2 already approved)**

  - Rotation test of SLAC rotatable collimator (HRMT-21);

  - 3-jaw set-up to test complete jaws (HRMT-23);

  - Material test with new material samples (submitted).

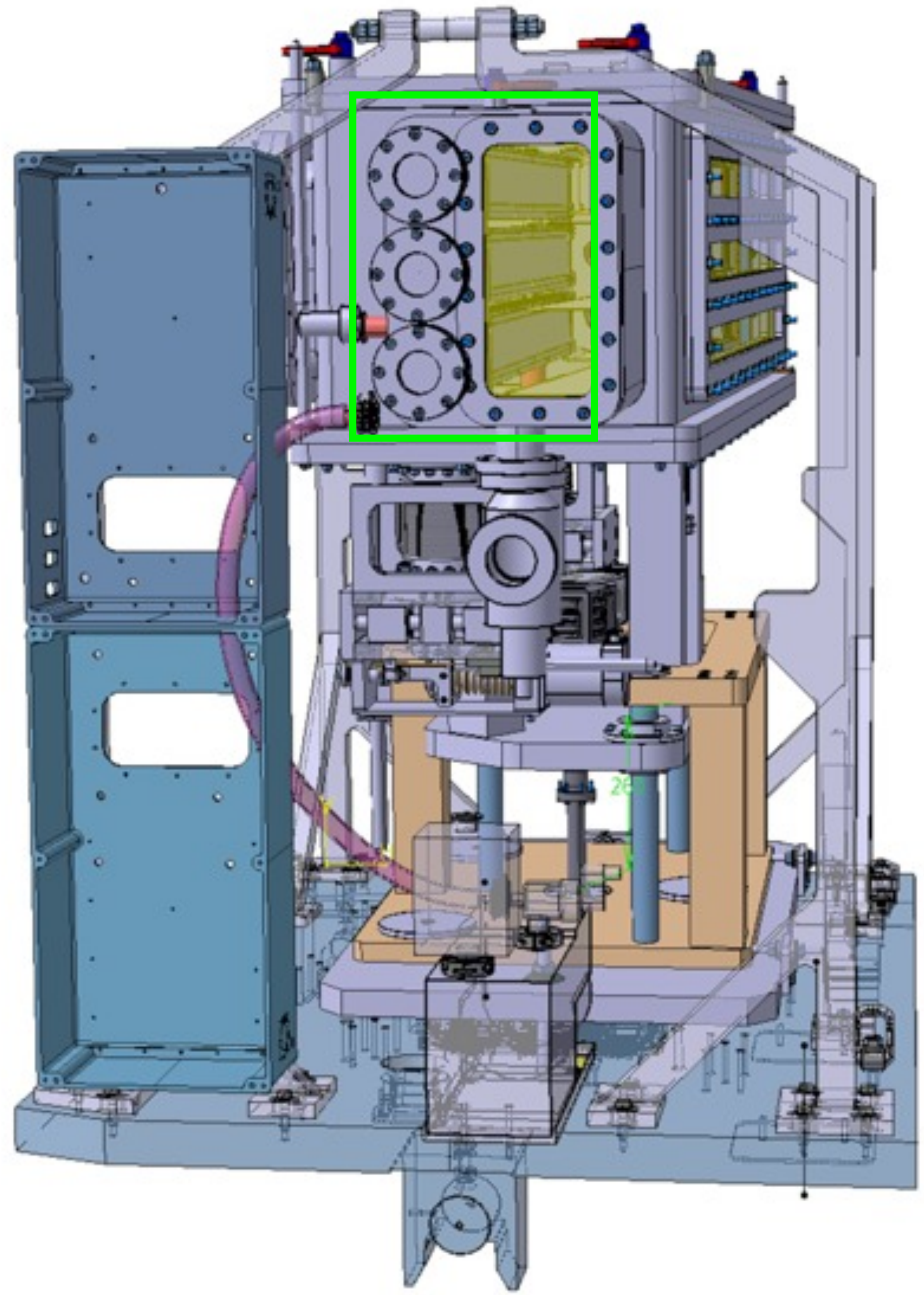
We proposed the inj&dump team to "join forces": as we might update our experiment to add materials for injection protection collimators.

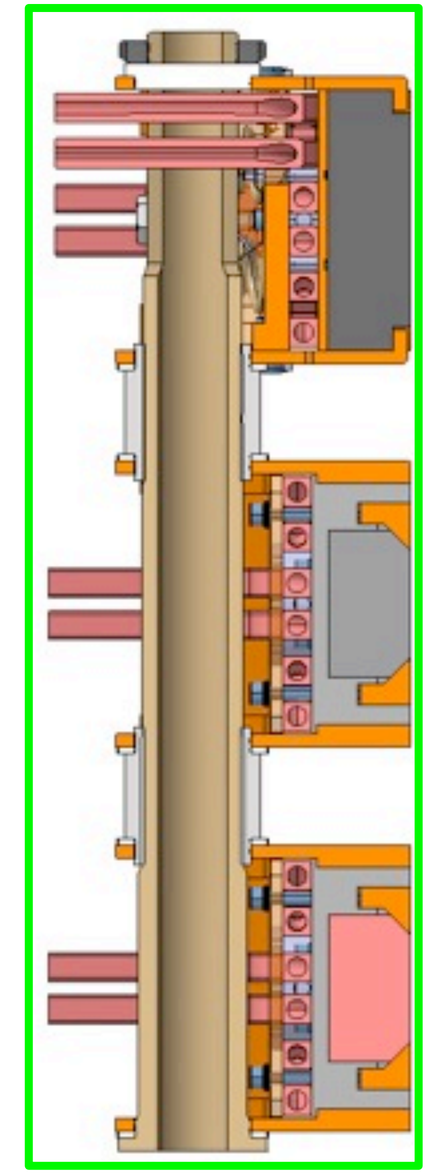
Planned validation at HiRadMat

Currently envisaged proposal for Jaws:

1. **HL-LHC Secondary Collimator Jaw** (TCSx) with 10 **MoGr** inserts (some inserts possibly **coated**).
2. **HL-LHC Secondary Collimator Jaw** (TCSx) with 10 **CuCD** inserts.
3. **LS1 secondary collimator jaw with BPMs**: to verify the resistance of the jaw components (tapering, BPM button, active jaw), possibly up to HL-LHC intensity

On good track for tests in 2015!





A. Bertarelli, F. Carra, L. Gentini *et al.*

Complemented by an extensive R&D to address material behaviour under high radiation doses: Kurchatov, BNL, GSI.

Update on SLAC rotatable collimator

The LARP Rotatable Collimator Prototype
Candidate for a Phase II Secondary Collimator

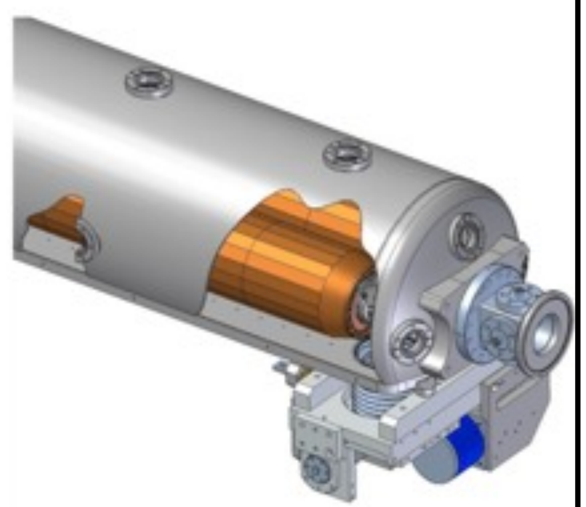
LARP

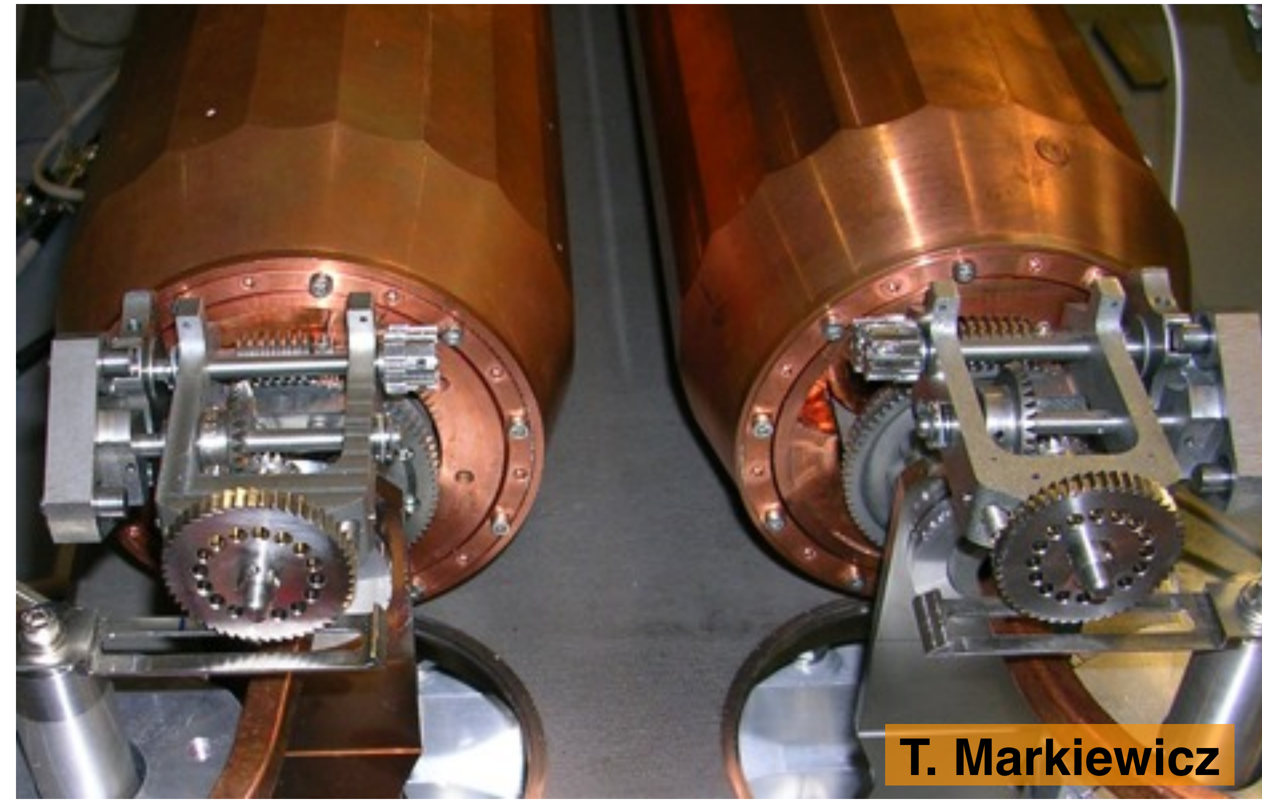
Two jaw collimator made of Glidcop
- Rotate jaw after 1MJoule beam abort failure accident occurs

Each jaw is a cylinder with an embedded brazed cooling coil
- No vacuum-water braze; 12kW/jaw cooling; minimal thermal distortion
- Maximum radius cylinder possible given beam pipe separation
- BPMs integrated on ends of tank

Advantages:
- Not exotic material
- High Z for better collimation efficiency & more debris absorption
- Low resistance for better impedance
- Elemental for high radiation resistance

Disadvantages:
- Glidcop WILL be damaged in asynchronous beam abort





- Nice concept. Might be reconsider it in light of the recent material tests and updated safe limits?
- Cannot be considered as candidate until fully validated by beam tests (HRM, SPS?)
- A beam test strategy will be established as soon as we have the chance to test it at CERN!
- Being shipped to CERN **now**!

Slides from Nov. 2013

- Initial plan: destructive tests at HiRadMat to verify rotation (experiment HRMT-21 approved!).
- Extensive tests done in 2014 showed:
  - Movement system ok;
  - Vacuum ok for SPS (and LHC!);
  - Impedance ok for SPS in 2015;
  - Rotation ok bef/aft bake out.

014

Could this be useful for injection protection?

http://lhc-collimation-project.web.cern.ch/lhc-collimation-project/slac_collimator.php

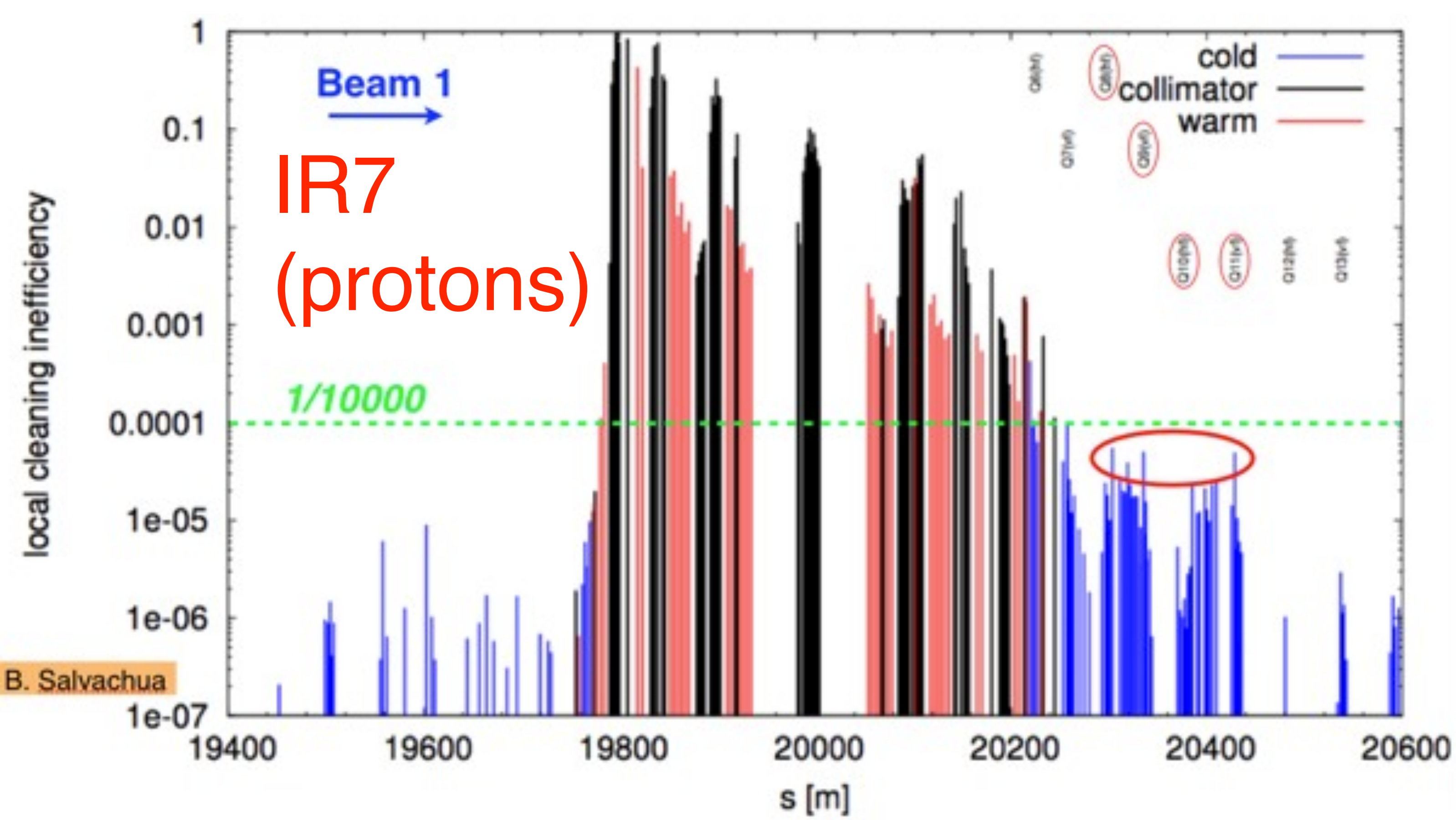
Dispersion suppressor collimation

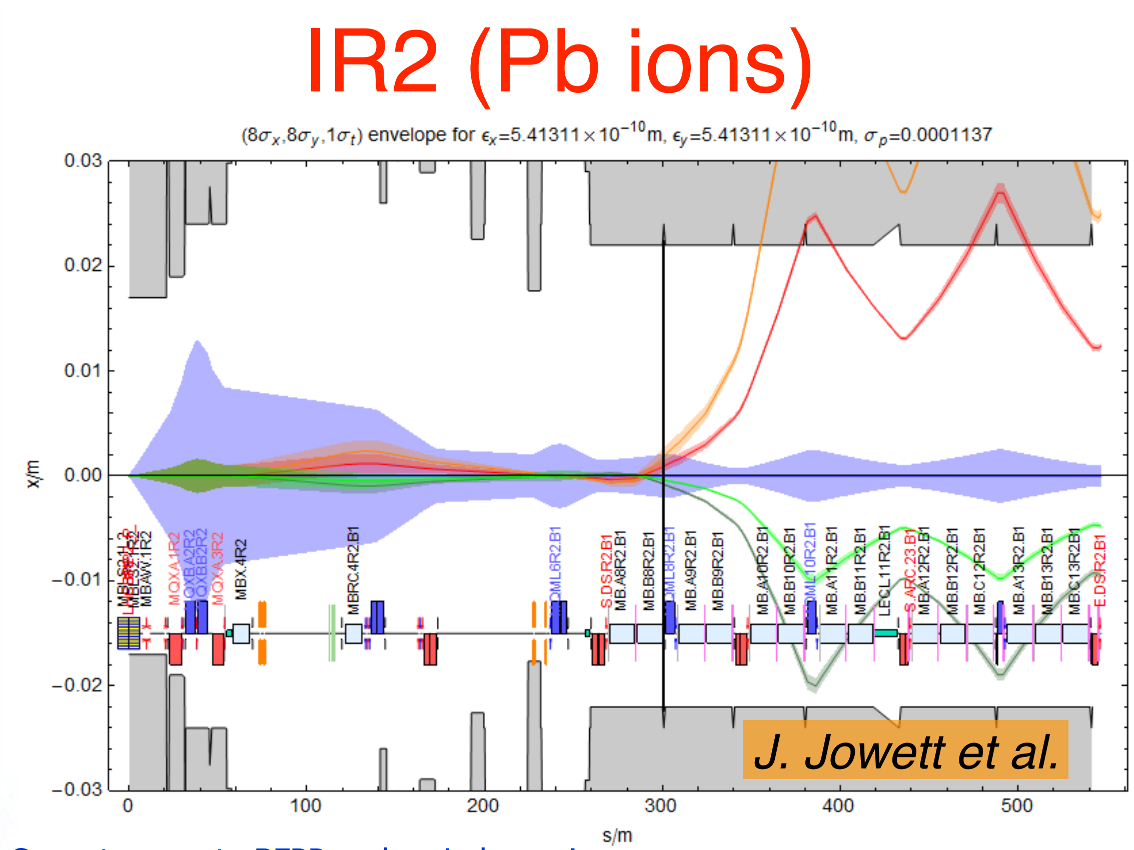
Motivation: Particles that change rigidity from IP collisions or interaction with cleaning collimators are lost at the first high-dispersion locations in the DS's. Present LHC collimation layouts not efficient in catching these losses!

Outstanding issues:
- High-luminosity collisions of ion beams (ALICE upgrade)
- Betatron cleaning in IR7 (if old quench limits) [p + Pb]

[p+p collisions in high-luminosity points seem under control with upgrades TCL layouts]

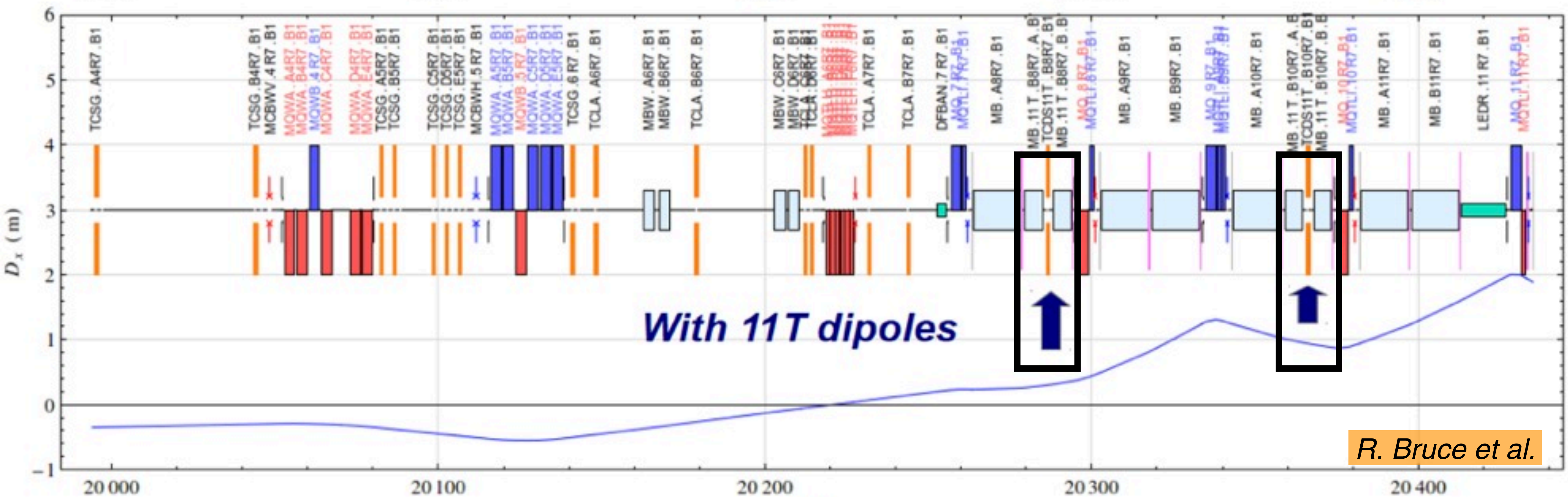
Baseline solution: Local collimation associated with higher-field 11T dipoles!

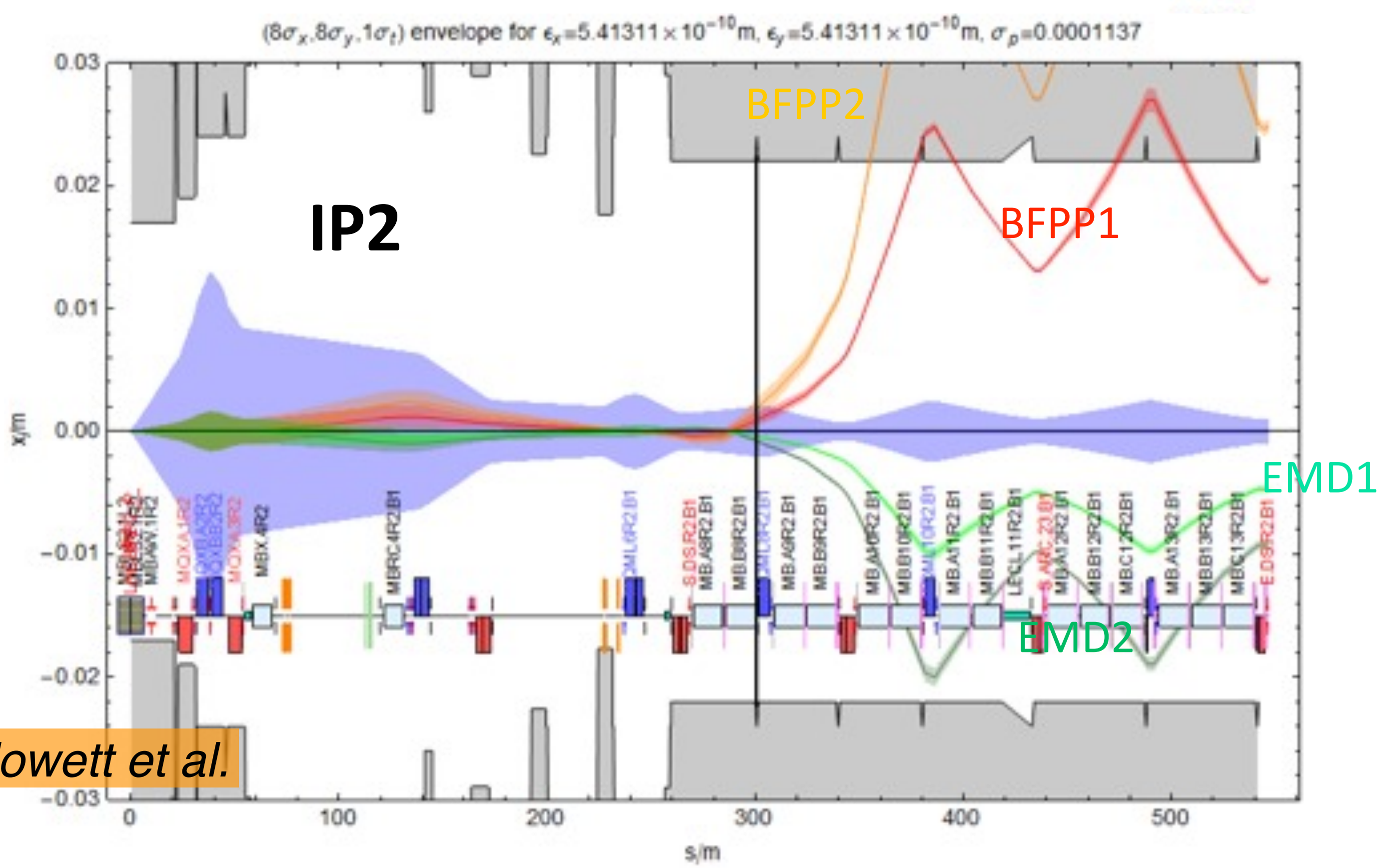




Cannot separate BFPP and main beam in warm area
(eg by Roman pots a la TOTEM).

Layouts: baseline defined!

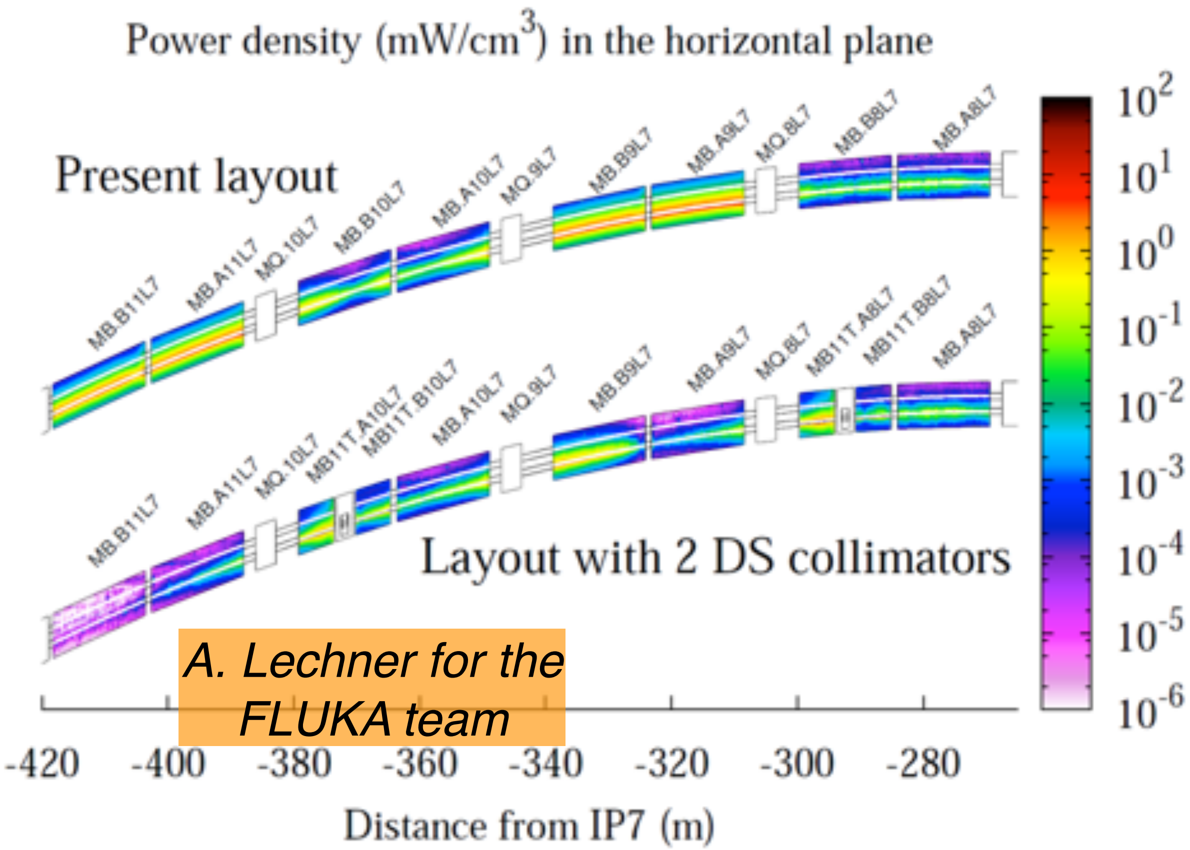


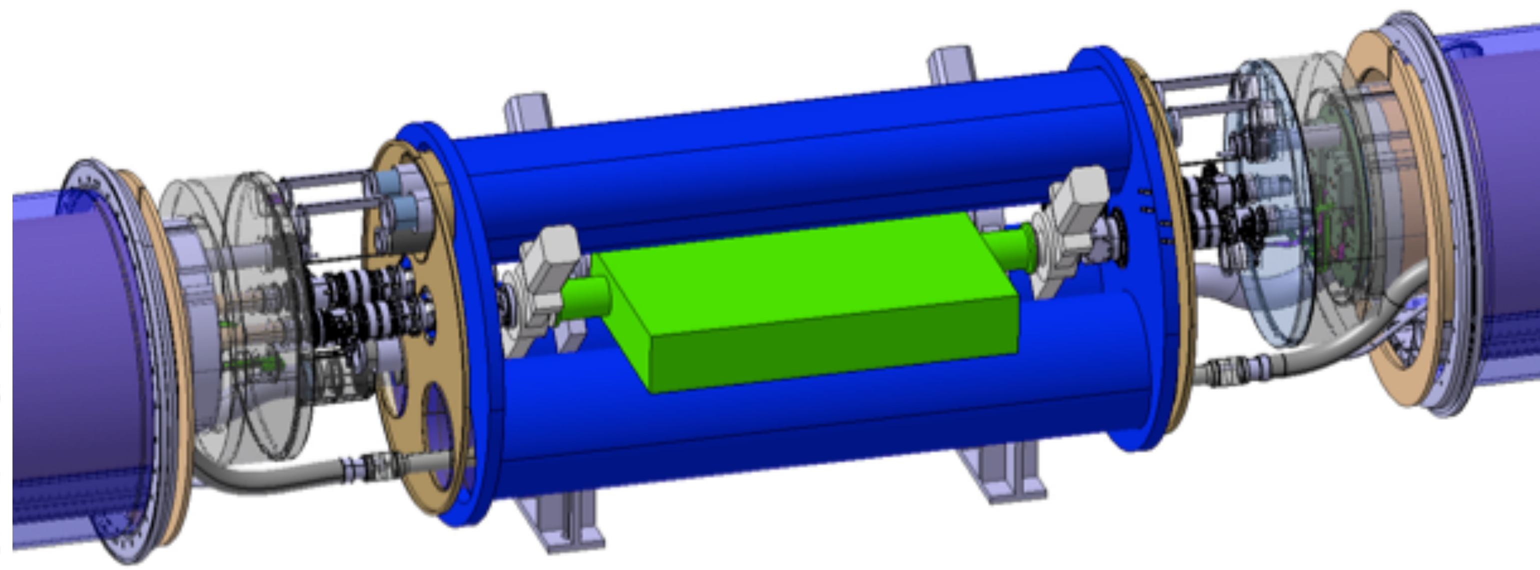


Layouts finalized and validated in simulations (Nov. 2013). Passed to magnet and integration teams for detailed studies.

See Ezio's and Paolo's talks for integration and magnet status.

Status and timeline





D. Ramos

Timeline *(management endorsed 2013 review recommendations)***:**

- With the present understanding of quench limits,

  we aim at an **implementation of 2 units (4 dipoles) in IR2 during LS2**.

- Other IR's can follow in LS3, unless there are un-expected quench issues in IR7.

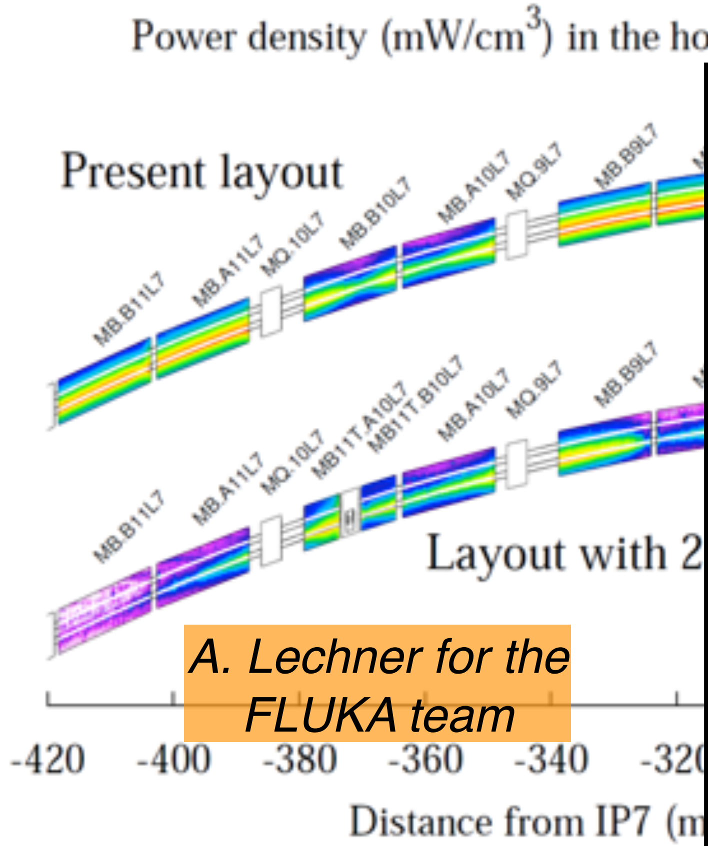
- Timeline determined by the availability of 11 T dipole.

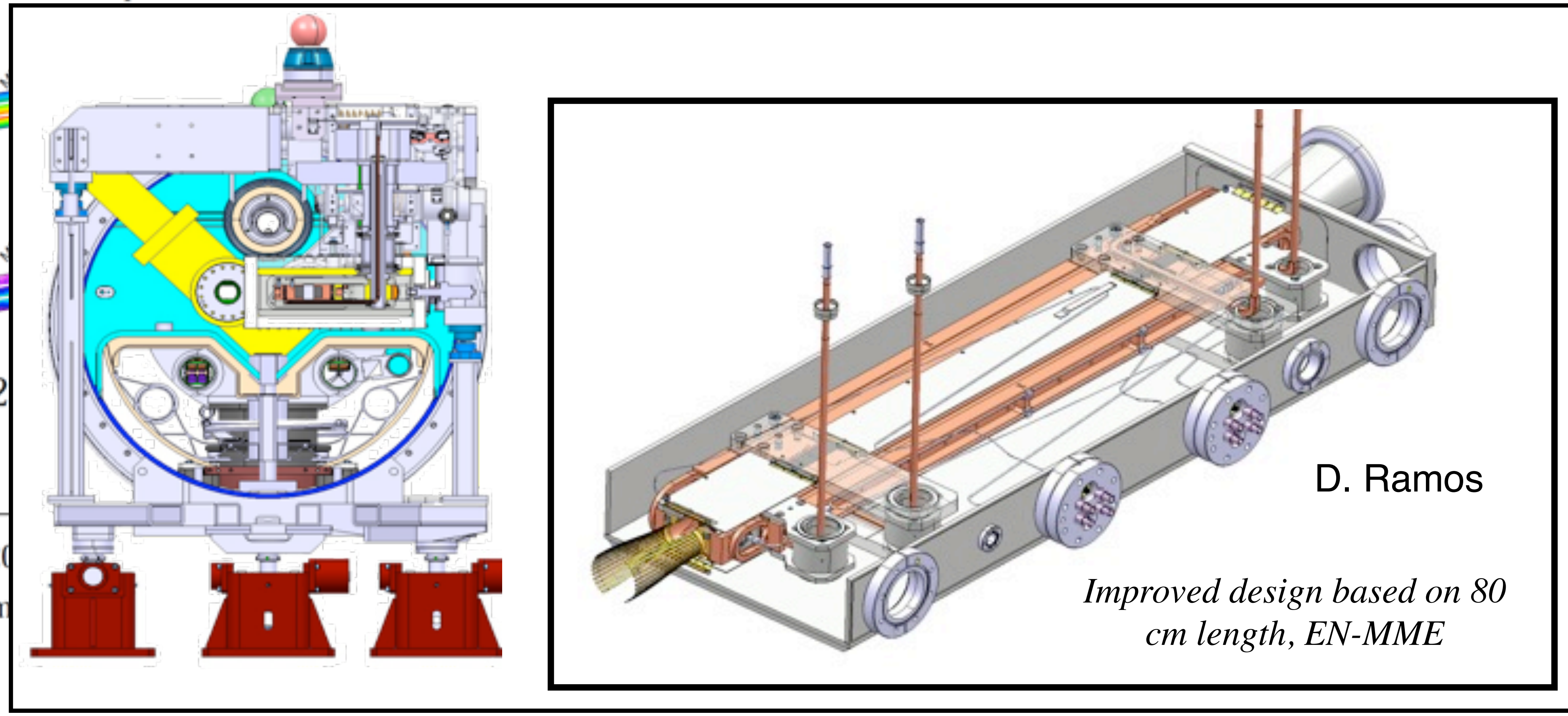
  Need to re-evaluate alternative solutions (moving magnets) in case of issues.

Aim to built a collimator prototype in 2015-16.

Important re-design work on-going following an updated integration study...

Status and timeline





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<u>Need to re-</u>

Aim to built a collin

Important re-desig

Reminder: intensity reach from quench is OK for Run II and Run III.
BUT: cleaning not everything: operation at high intensity might damage collimators as well.

Strategy for active halo control

Goal: Control actively transverse halo above 3-4 σ is essential in order to
- mitigate loss spikes on primary collimators (even if ok for quenches);
- control static halo population → **fast failures of crab-cavities**.

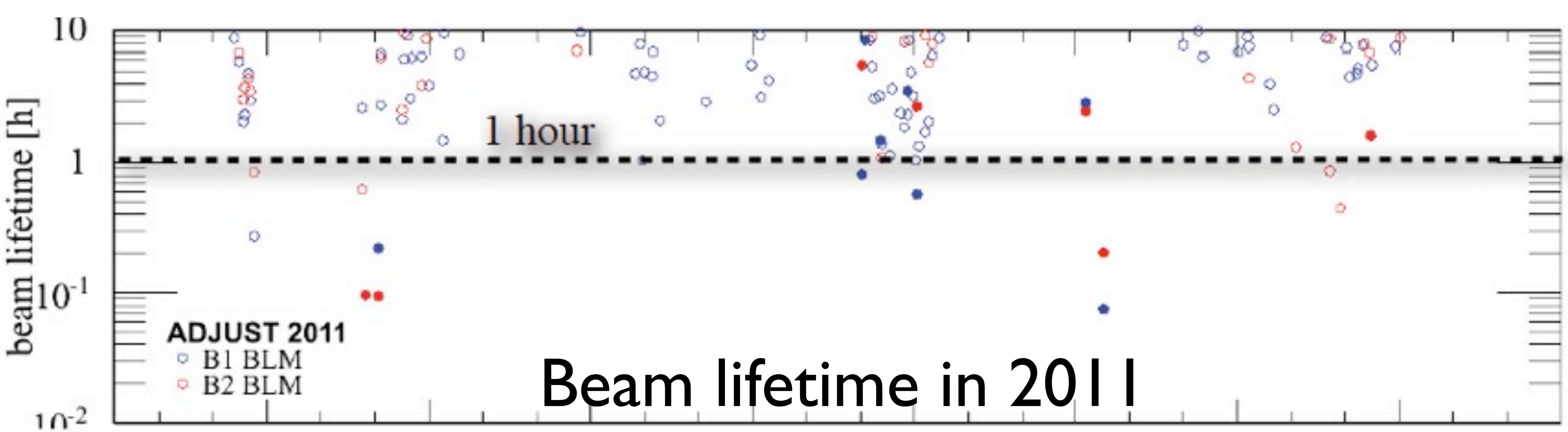
Backup slides on MP aspects of the CC operation.

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

Strategy established in 2012:

→ Focus the resources on design work for LHC for deployment in LS2.

→ Study with beam **alternative methods** (tune ripple, transverse damper).



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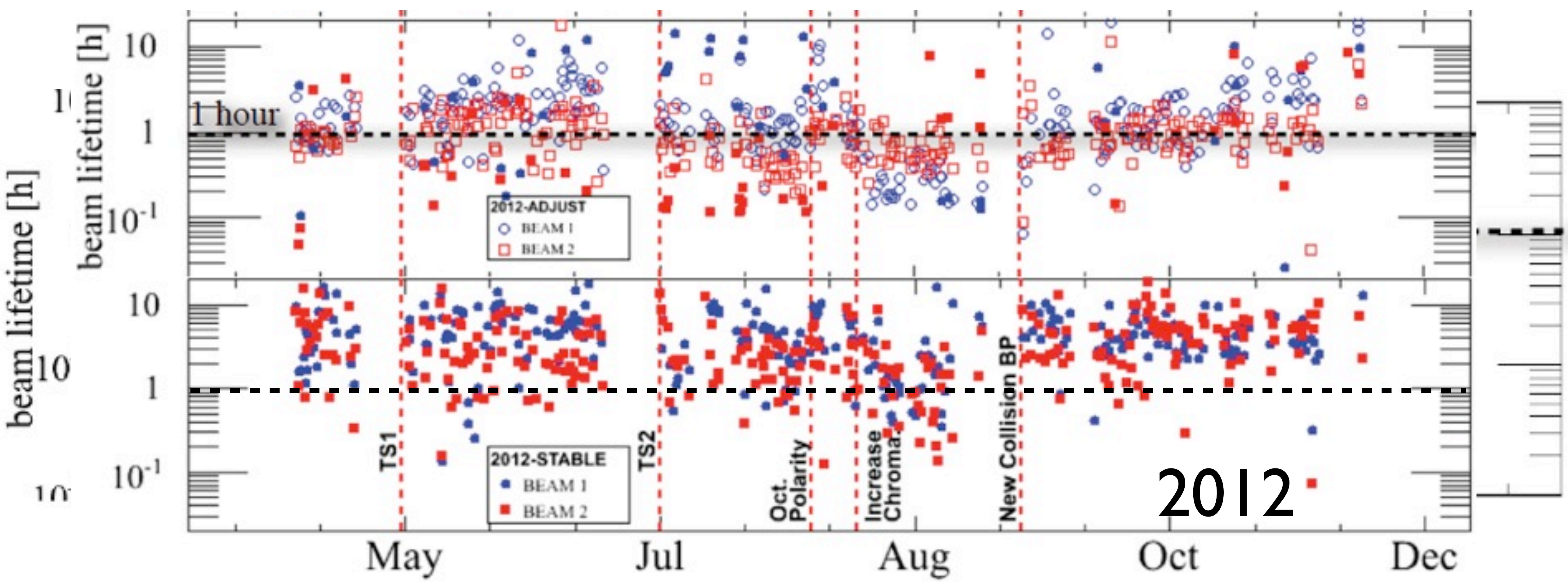
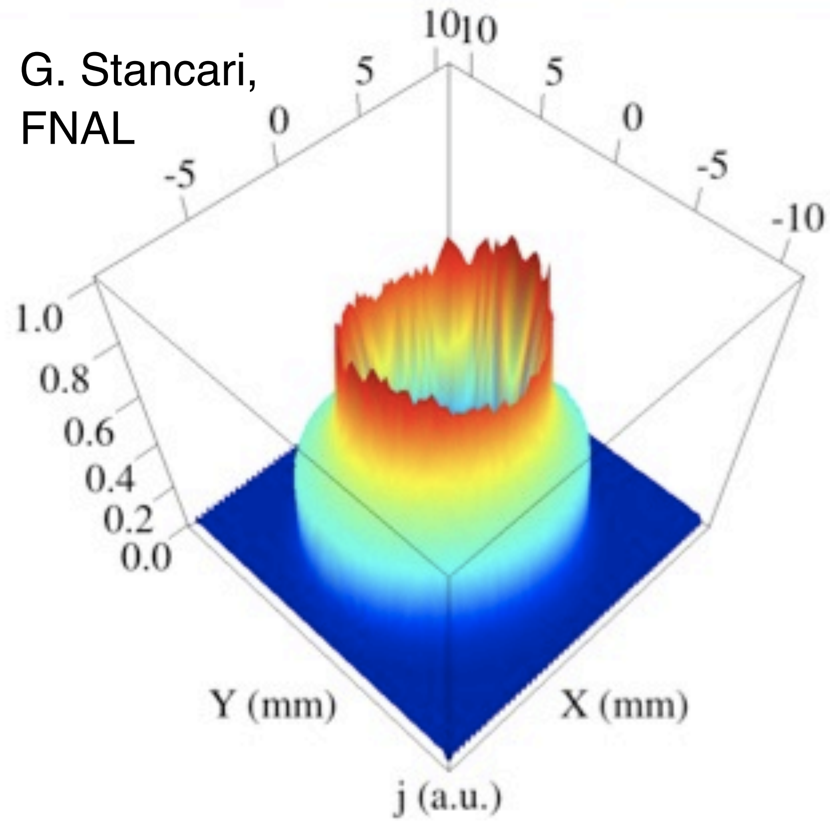
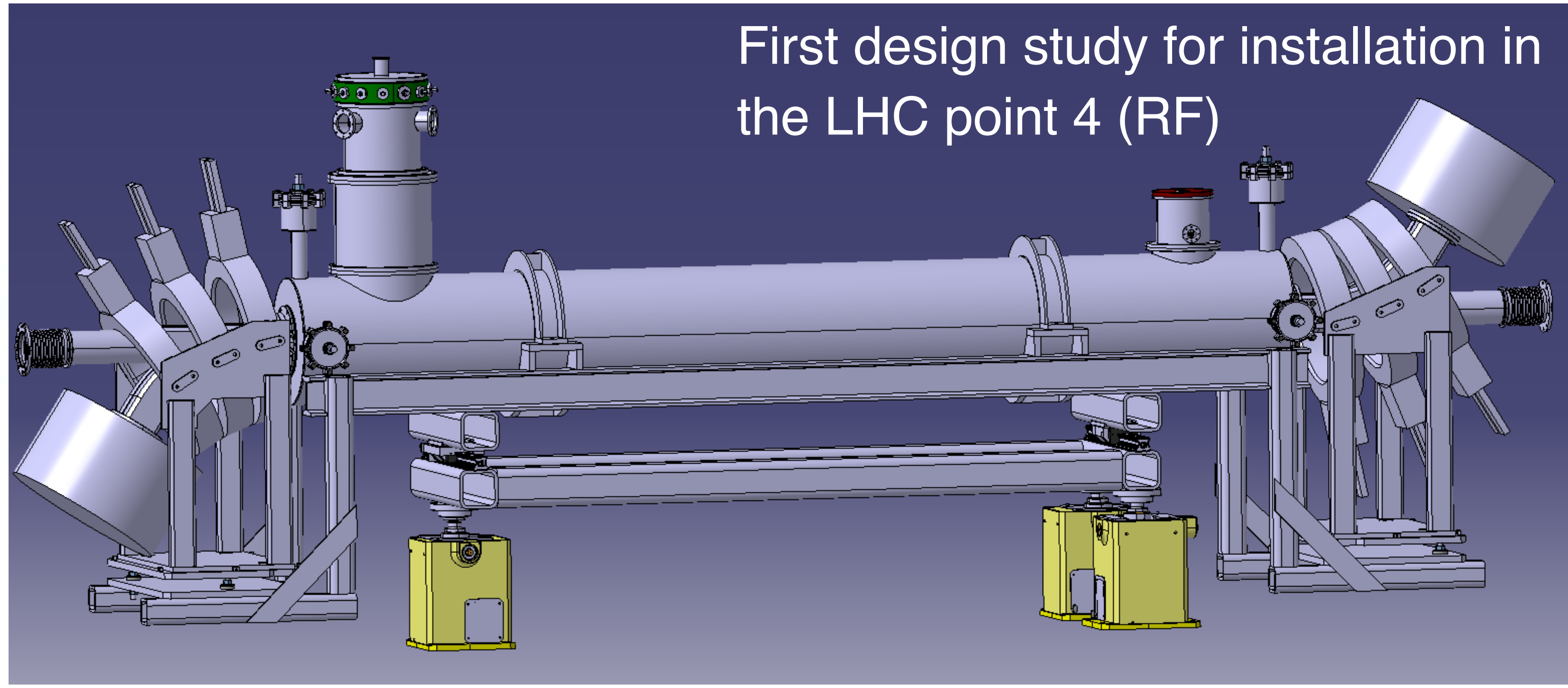


Status of hollow e-beams studies



G. Stancari, FNAL



D. Perini, MME

Timeline: essentially on track with our plans.

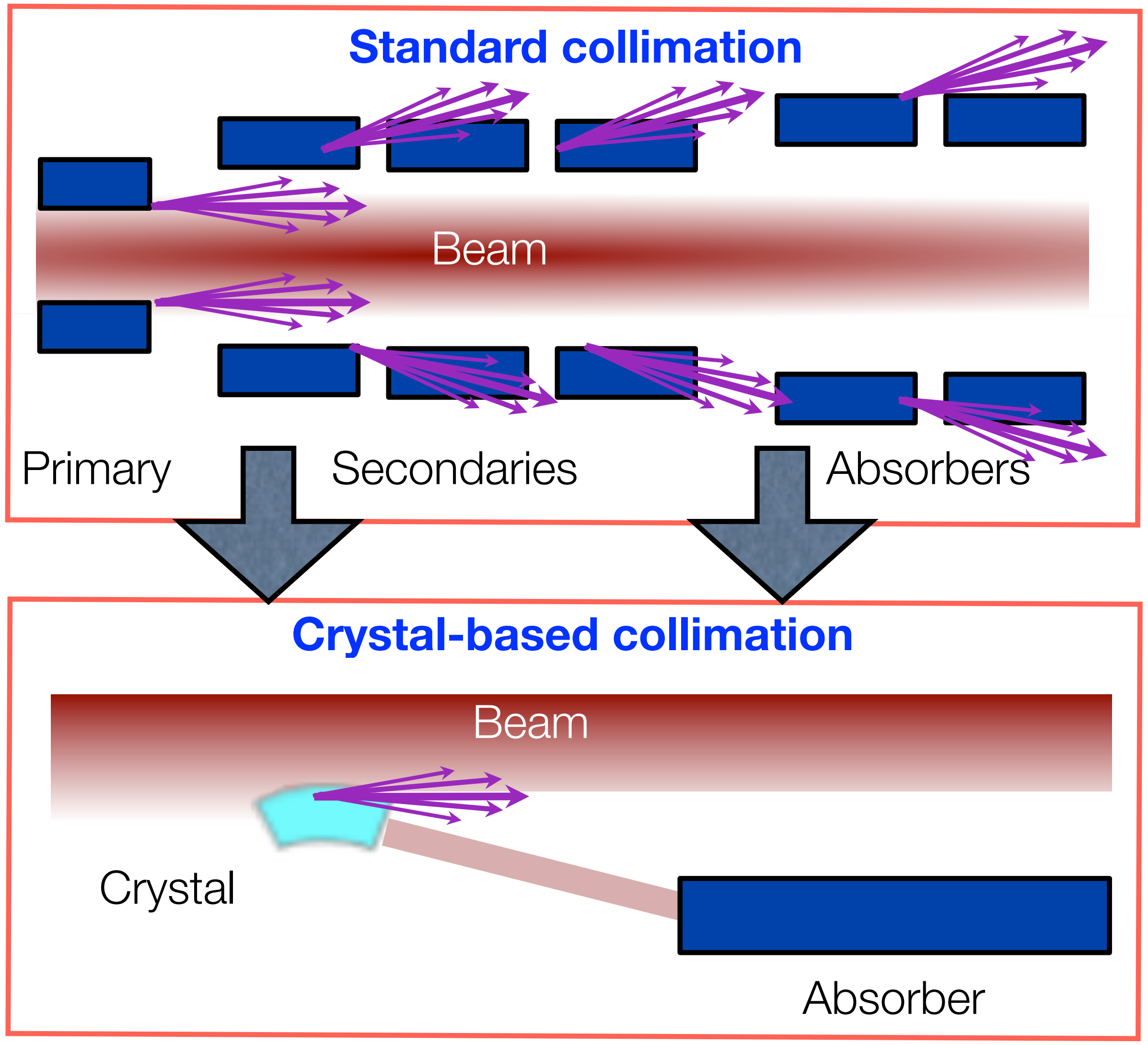
- Conceptual design report published a few months ago by G. Stancari *et al.*
- If the functionality is needed and not suitable alternative are available, we could proceed with an implementation in LS2!

Solid technical solution based on Tevatron state-of-the-art! Preliminary design ongoing.

Even if not needed for LHC, HL-LHC would profit from the installation of 1 device in LS2 for prototyping !

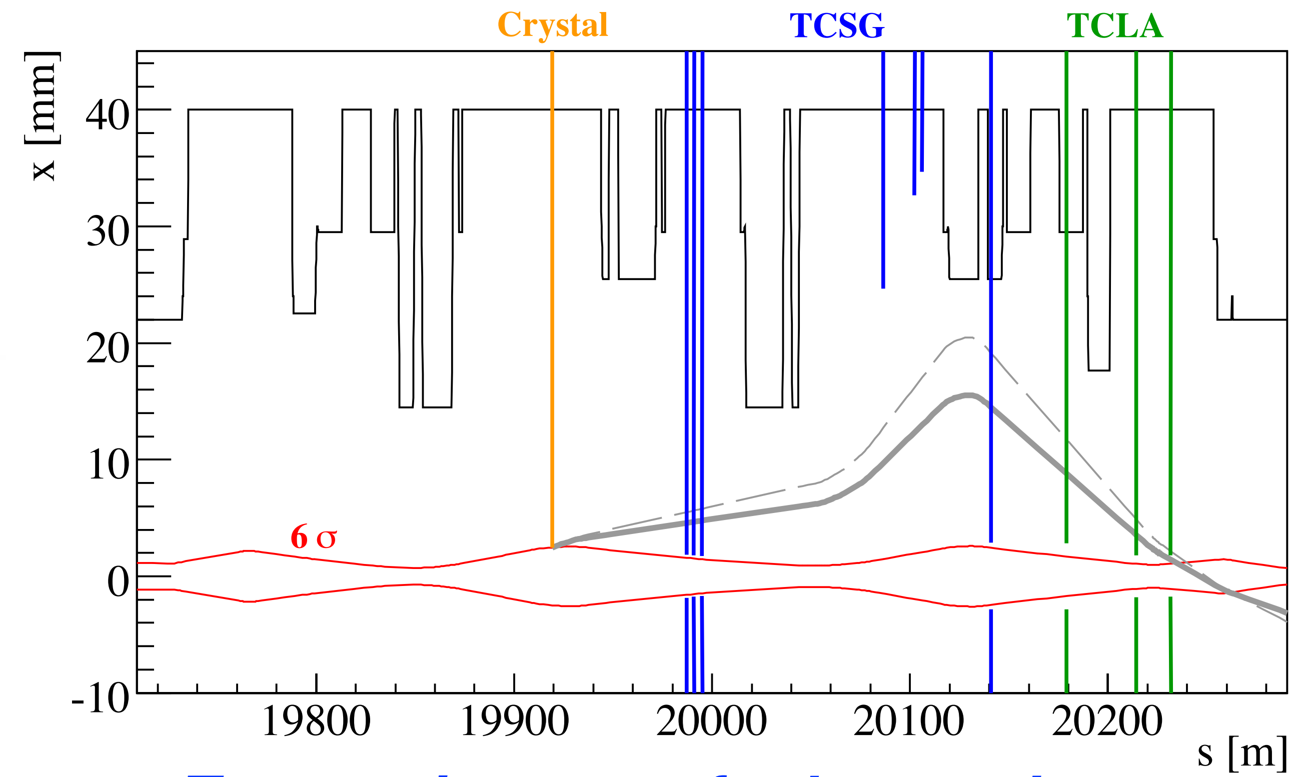
Strong synergy with long-range beam-beam compensation (H. Schmickler *et al.*)

Crystal collimation studies



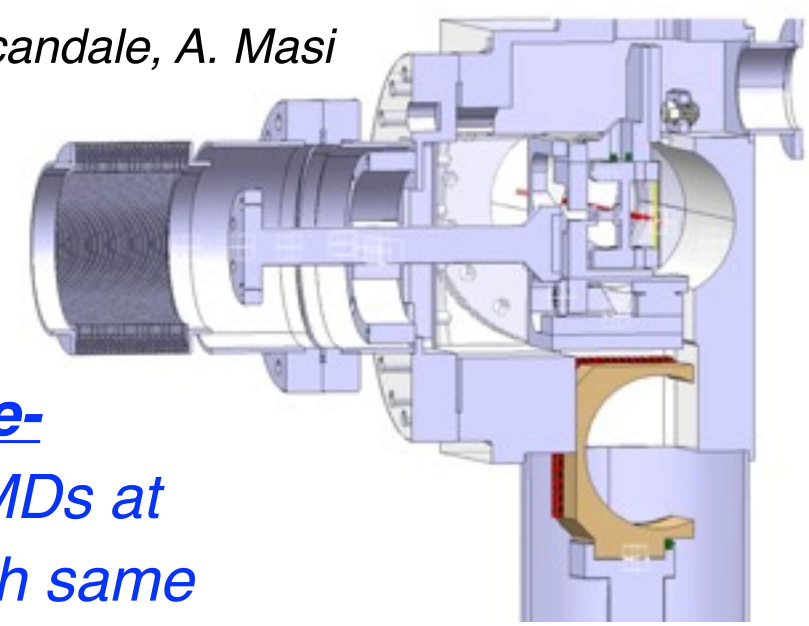
Promises of crystal collimation:
1. Improved dispersion suppressor cleaning;
2. Reduce **impedance**: less secondary collimators and larger gaps;
3. Much improved cleaning for **ion beams**.

Note: only applicable to IR7 betatron cleaning, not useful for physics debris!



Two goniometers for hor. and vert. crystals installed in Apr. 2014

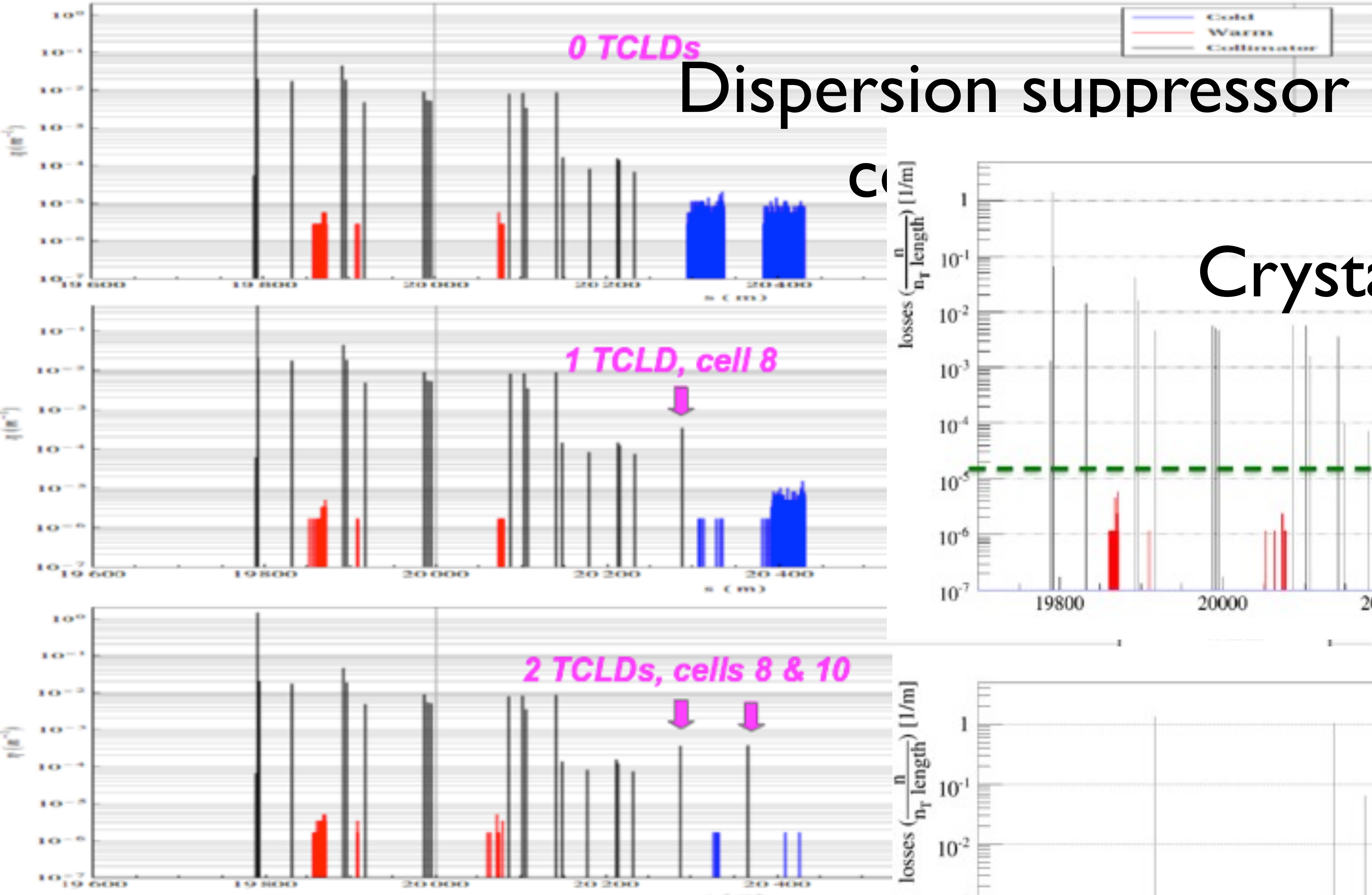
Cour. W. Scandale, A. Masi



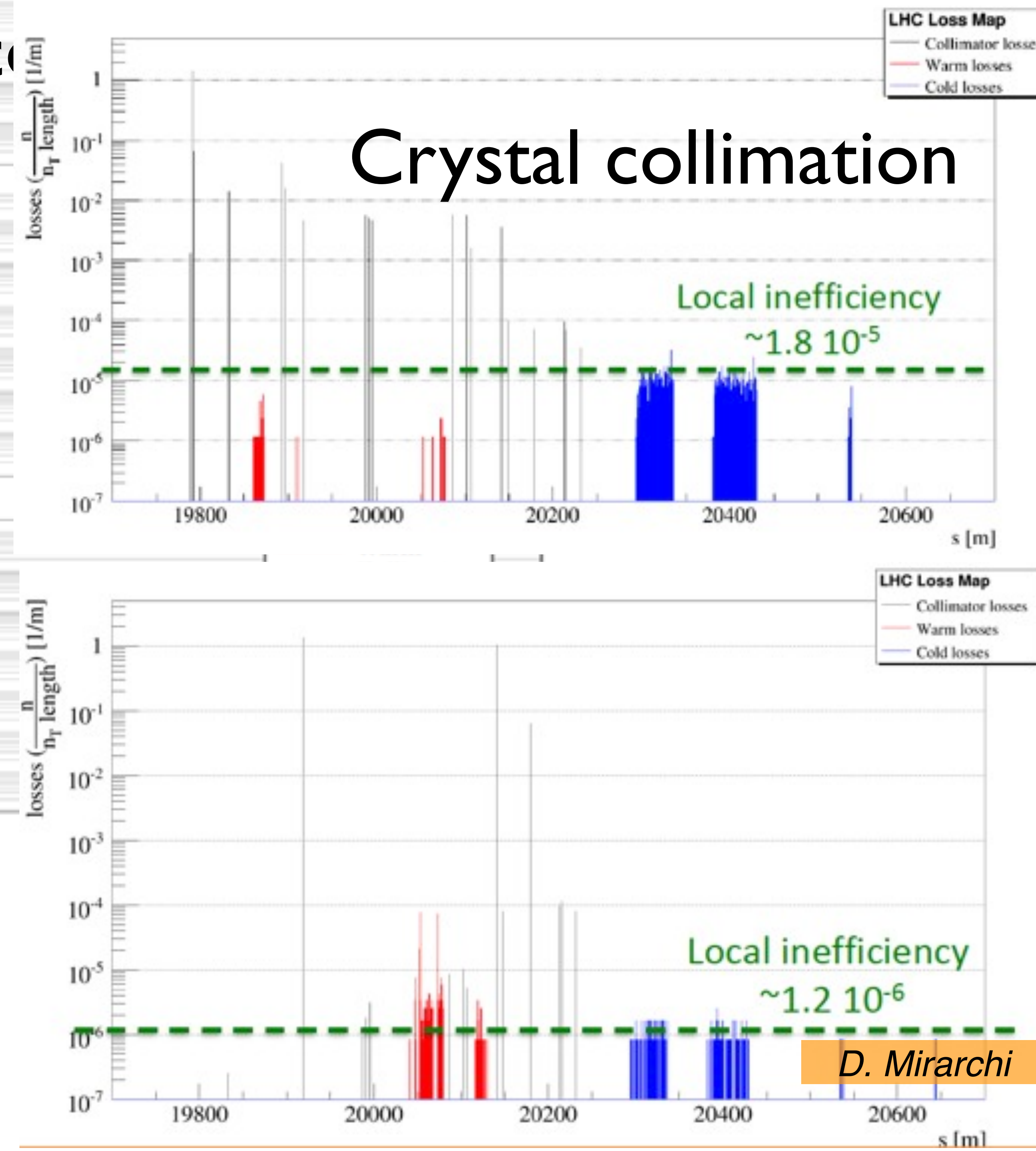
*Using very advanced goniometer designs. __**Pre-requisite**__: MDs at the SPS with same hardware -> LHC MD's after SPS ok.*

IR7 cleaning: crystal vs 11T dipoles

Dispersion suppressor c...



Crystal collimation



Important to have MD time in 2015: See next talk!

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- ☑ **Collimation around experiments**
- ☑ Conclusions

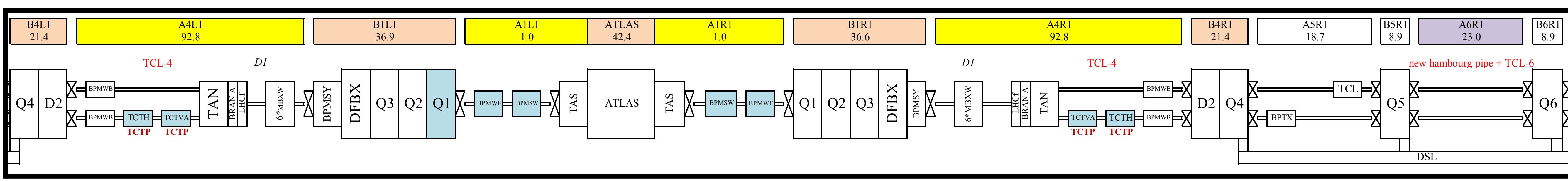
Collimation in experimental regions

Three functionalities for the collimation in the experimental regions:

1. **Clean** and **protect** the triplets from beam halo (and optimize background)
   TCTH, TCTV collimators in IR1, IR2, IR5, IR8
2. **Clean** the collision debris in high-luminosity experiments
   - TCL collimators in IR1 and IR5
3. **Protect** the machine from injection errors
   - TDI, TCLIA, TCLIB, TCDD in IR2 and IR8

As discussed above, debris cleaning might be complemented by dispersion suppressor collimation.

IR1 - ATLAS



This is the main topics of the FP7-HiLumi study.

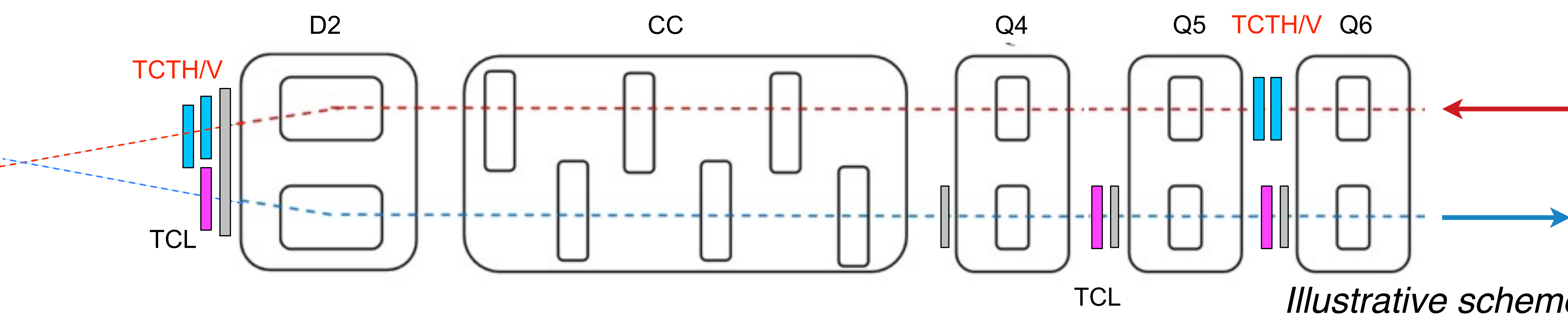
Layouts, timeline and status

Present collimation layouts after LS1 ok until LS3 for proton operation (except for tertiary collimator robustness mentioned earlier).

Challenges of HL-LHC

Larger peak and integrated luminosity -> better debris cleaning
New layouts and aperture bottlenecks -> better aperture for incoming beam

Baseline solution: New layouts in synch with the magnet layout change in LS3



Illustrative scheme

Strong collaboration: WP2/5/8/10
Significant design work expected due to integration issues.

TAXN for HL-LHC

(I. Efthymiopoulos, H. Burkhardt)

Baseline HL optics: round beams. But the flat **beam optics** is very promising!

- Optimum TAXN design is different for the two options.

We are working to find a solution with a fixed TAXN that suits both options, by combining TAXN with movable (TCL) and fixed (TCLM) collimators.

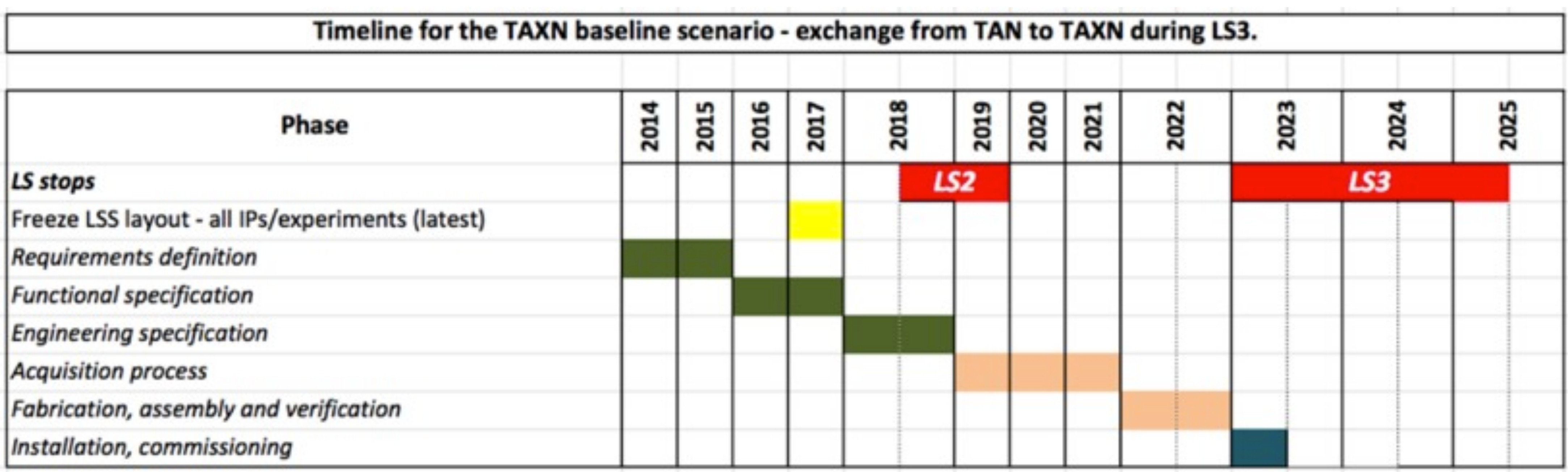
- Joint WP2/5/8/10 meeting on 03/10/2014.

Issue under study: protected aperture for incoming beam vs collimation hierarchy.

Alternative solution: consider a movable TAXN for "unfrequent" changes of machine configurations (yearly or so). We prefer the previous option...

We have time until 2018. Clearly, important feedback on optics after crab test at SPS!
BUT feedback for magnet aperture needed earlier → plan a solid baseline by Nov.

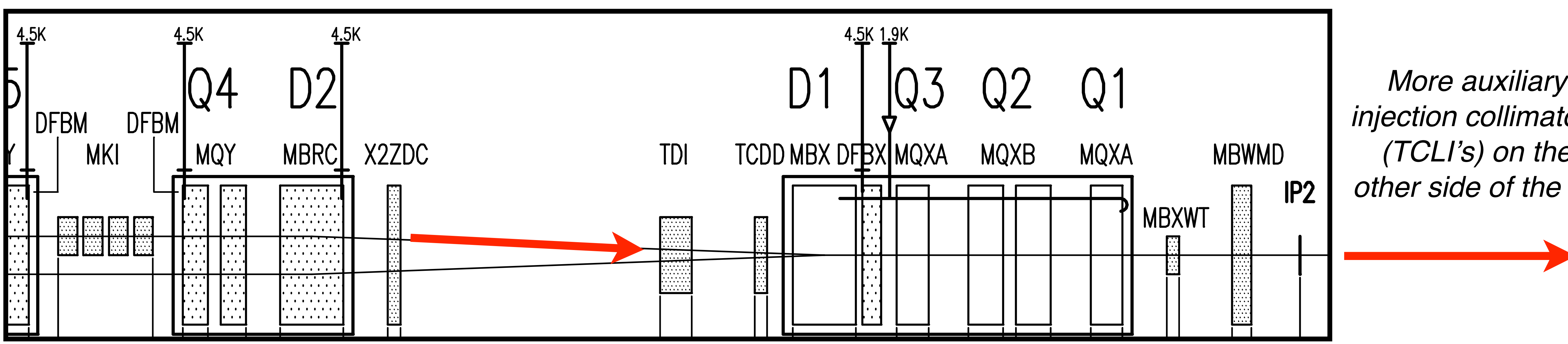
Report WP8 meeting :
C. Adorisio,
H. Burkhardt,
F. Cerutti,
R. De Maria,
I. Efthymiopoulos,
L.Esposito,
S. Redaelli,
F. Sanchez



New injection protection in the ring

(J. Uythovan, A. Lechner for WP14)

- Schedule:
  - Following the timeline of LIU, the LHC injection protection devices will be upgraded in LS2 to cope with the increased brightness of LIU and HL-LHC beams (HL-LHC WP14).
- Injection absorbers and masks:
  - The TDI will be replaced by a new multi-module absorber TDIS with new absorber materials.
  - The TCDD likely needs to be replaced with a smaller-aperture mask to provide sufficient protection to neighboring superconducting magnets in case of injection failures.
- Auxiliary collimators:
  - It is presently evaluated if TCLIA/TCLIB also need to be modified and replaced.



More auxiliary injection collimators (TCLI's) on the other side of the IP.

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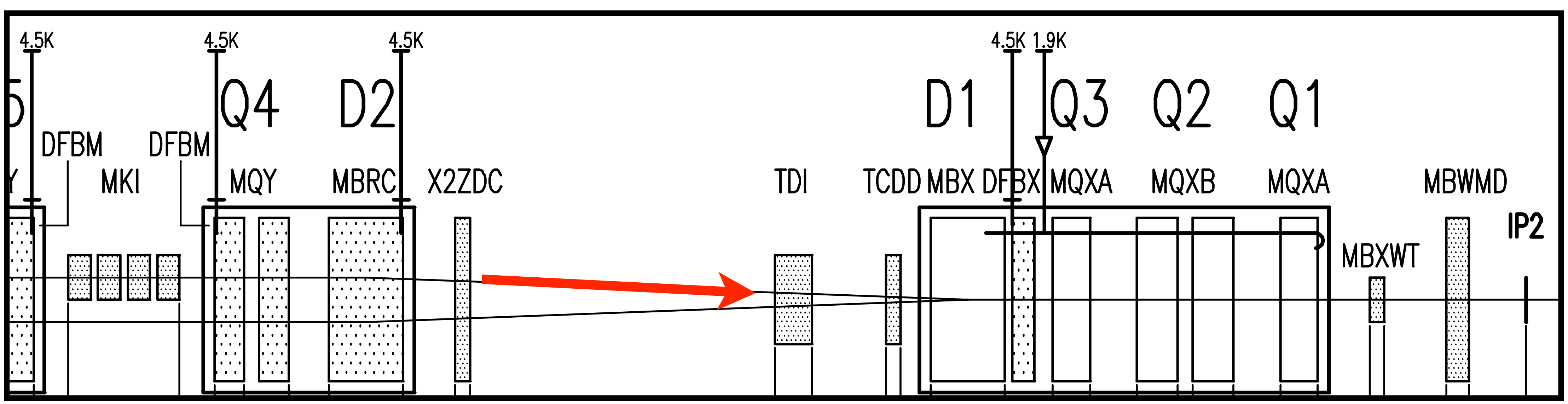
- Auxiliary collima
  - It is presently e replaced.

- Modifications to the spare TDI injection absorbers during Run 2:
  - The spare TDIs are equipped with interferometry sensors to provide a redundant and direct gap measurement to be used for the BETS interlock. Vacuum and functional tests are ongoing.
  - In addition, if tests are successful, the hBN blocks will be coated with few µm of Copper to reduce their resistive heating.
- Swap with installed TDIs
  - It is planned to swap the TDIs, which are presently installed in IR2/8, with the modified spares during a technical stop (2015 – 2016 YETS).



More auxiliary injection collimators (TCLI's) on the other side of the IP.

Conclusions

- The main upgrade plans for collimation were presented, covering LHC and HL-LHC operation.
- HL-LHC baseline upgrades were presented:

  Re-design of the collimation in the experimental regions!
  Dispersion suppressor collimation in IR2 (Pb), IR7 (p+Pb), IR1/5 (Pb only?)
  Low-impedance and improved robustness collimators.
  Promising study: hollow electron beam for halo control and machine protection.
  Other ongoing studies: crystal collimation.
- The requirement until LS3 depends critically on Run II performance

  *Collimation impedance, tertiary collimator robustness, operational efficiency and halo control might become **critical** also for the operation until LS3!!*
- So far we studied extensively alternatives for the known and potential limitations: 2015 operational experience will tell where to put priority!
- Recalled also TAXN design issues and relevant MP aspects...
- We should not underestimate the role of system consolidation because, by LS3, our high-precision collimators will be > 15 year old!

  Not discussed here our consolidation plan.

Acknowledgements

Collimation project activities steered by the CERN teams in collaboration with several extern collaborators:

- **EuCARD**
- **HiLumi**
- **EuCARD2**
- **US-LARP**

Dedicated collaborations/contracts with other institutes/companies:

- **Kurchatov**
- **BNL**
- **. . .**

Strong synergy with other HL work packages:
WP2 (Accelerator Physics), **WP7** (Machine Protection), **WP8** (Detector interface), **WP11** (11T dipoles), **WP14** (Inj&Dump); with strong support from **WP10** (energy deposition).
But also several other WP's.

Reserve slides

Details of preliminary design

FERMILAB

Conceptual design of hollow electron lenses for beam halo control in the Large Hadron Collider*

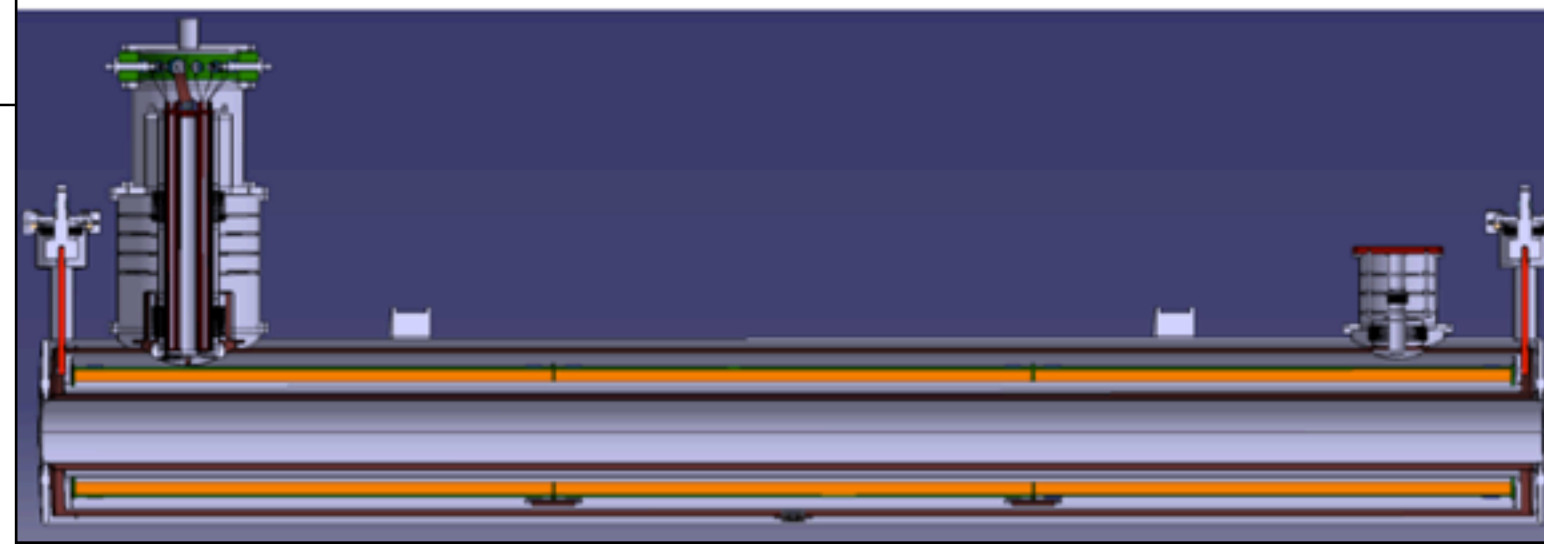
G. Stancari,[†] V. Previtali, and A. Valishev
Fermi National Accelerator Laboratory, PO Box 500, Batavia, Illinois 60510, USA

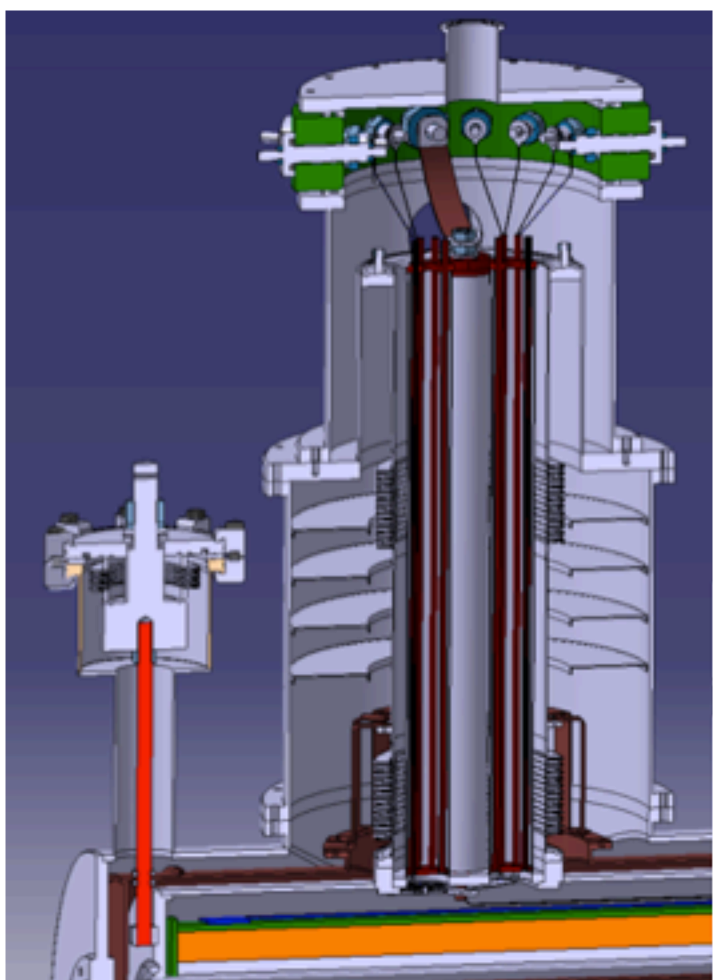
R. Bruce, S. Redaelli, A. Rossi, and B. Salvachua Ferrando
CERN, CH-1211 Geneva 23, Switzerland

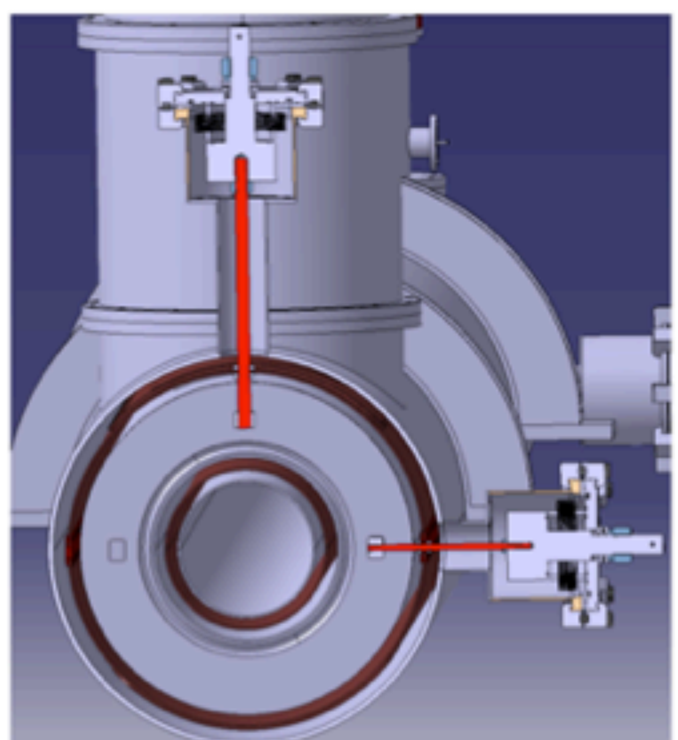
(Dated: August 12, 2014)

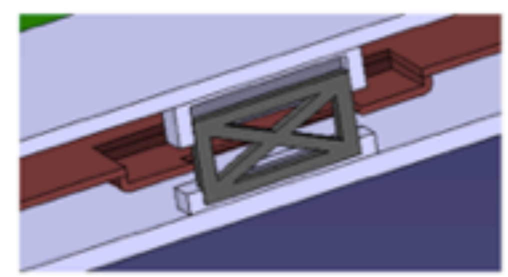
Superconducting solenoid

- Operation temperature: 4.2 K, current:about 250A, magnetic field: 5 Tesla
- Cooled by liquid helium
- Three vessels: for liquid helium, thermal screen and vacuum
- The helium vessel is supported by the permaglass bars in vertical and horizontal directions and in axial direction with plastic piece
- The main coils and the correction coils are inside the helium vessel









Fix point for axial direction

D. Perini coordinating this design effort from our side: contacts with HW teams at FNAL and coordination of CERN teams involved (work just started)

Main improvements from Run I

Recap.: in-jaw BPM's allow fast collimator alignment (~ seconds) and continuous measurements of the local orbit.

- Better β^* reach from BPM collimators!

  Through a better control of the orbit at the dump and at the tertiary collimator locations.

- Improved alignment flexibility close to experiments

  Tertiary collimator in the interaction regions are aligned several times in the run following the experiment's requests.

- More performing and more flexible physics debris collimation (3 TCL's per beam in ATLAS/CMS instead than 1 in Run I)

  Mainly done to allow operation of forward physics!

- Possibility to share/optimize radiation doses between momentum and betatron insertions (IR3/7) thanks to new passive absorbers in IR3.

- Important consolidation of the electronics (R2E, reliability, ...)

Recap. of collimation activities

- Until LS2

  Installation of a low-impedance/high robustness prototype
  Isolated replacement of collimators:
  - More collimators with BPMs
  - More robust TCT's at limiting locations for β^* reach.
  Monitoring of collimators and feedback on collimator lifetime.

- LS2

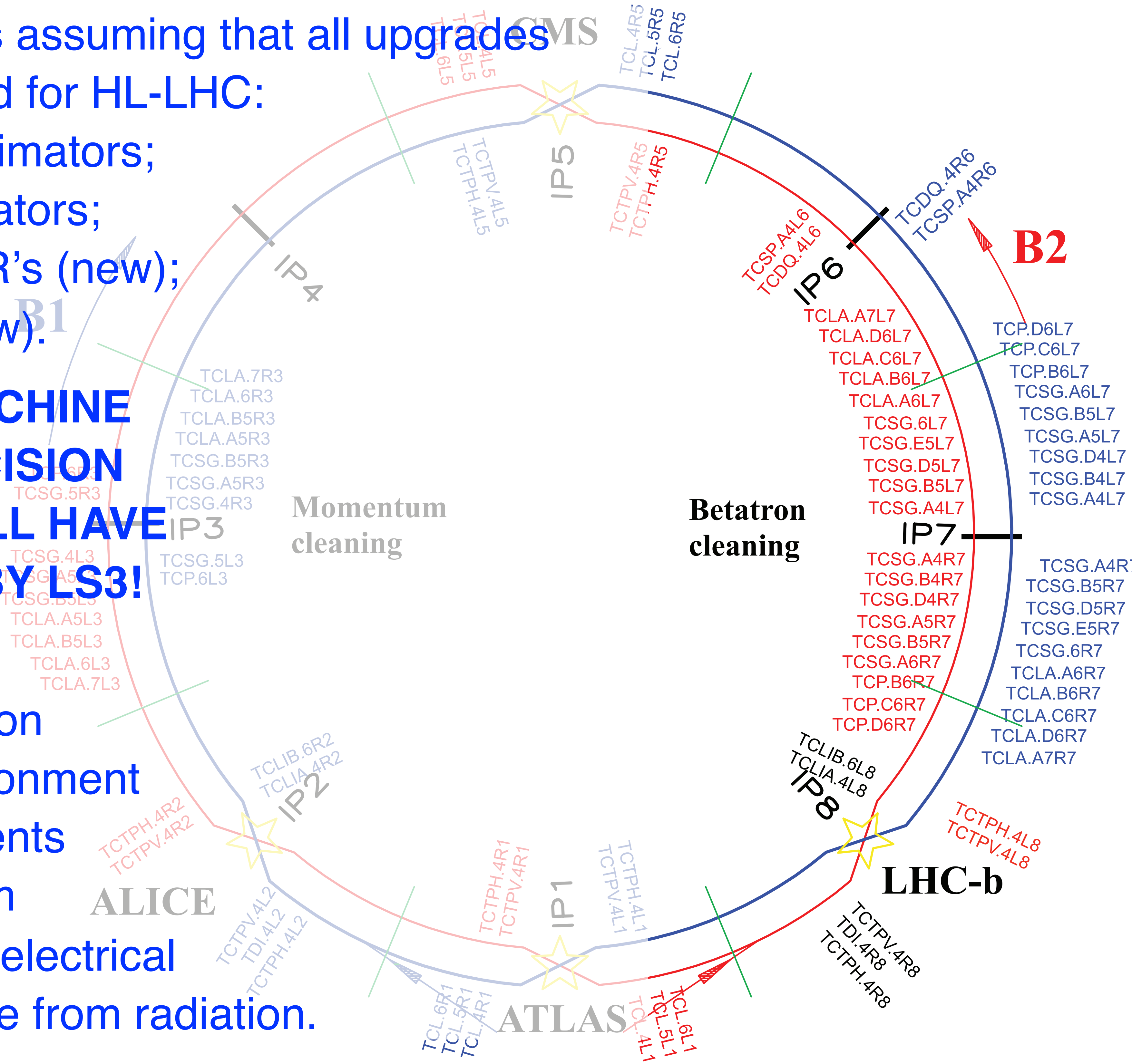
  Dispersion suppressor collimation: IR2 (baseline) or partially in IR7 (pending evaluation of 2015 performance + ion quench tests).
  Installation of a few to several low-impedance collimators: IR3/7.
  Installation of hollow e-lenses in IR4.
  Adaptation of cryogenics in IR4 (in case no hollow e-lenses are needed).
  Isolated changes of collimators because of mechanical wear?

- LS3

  Full deployment of new IR collimation solutions.
  Completion of dispersion suppressor collimation in missing IR's.
  Completion of low-impedance collimator installation.
  Hollow lenses in IR4.
  System consolidation - replacement of collimators that showed wear issues.

Importance of collimation consolidation

- "Optimistic" ballpark figures assuming that all upgrades discussed here are adopted for HL-LHC:
  - 22-30 new secondary collimators;
  - 4 more robust TCT collimators;
  - additional collimators in IR's (new);
  - several DS collimator (new).
- **THIS LEAVES IN THE MACHINE AT LEAST 70 HIGH-PRECISION COLLIMATORS THAT WILL HAVE MORE THAN 15 YEARS BY LS3!**
- Several concerns:
  Mechanical wear in operation
  Challenging radiation environment
  Radiation wear of components
  Performance reduction from
    thermo-mechanical and electrical
    property degradation due from radiation.



DS collimation: requirements by IR

Uncertainty on quench limits and performance, solved in 2015.

		Until HL-LHC (before LS3) [L=2.5x10^{34}cm^{-2}s^{-1}, I_{tot}=3.2x10^{14}p]		HL-LHC era (after LS3) (L=5x10^{34}cm^{-2}s^{-1}, I_{tot}=6.2x10^{14}p)	
		Protons	Ions	Protons	Ions
IR7	Betatron cleaning	**Needed?** *(unlikely)*	**Needed?** *(unlikely)*	Needed TBC (ATS?)	Needed?
IR3	Momentum cleaning	Not needed	Not needed	Not needed	Not needed
IR1/5	ATLAS/CMS	Not needed	**Needed**	Needed? *(unlikely)*	Needed
IR2	ALICE	Not needed	**Needed**	Not needed	Needed
		needed	Not operating	Not needed	Not needed *LHCb operating?*

Can we have 11 T dipoles in time? Do we need to consider alternative layouts (moving magnets)?

Goal for the collimation project: have a solution available to address already in **LS2** possible cleaning **limitations** reveale

Larger uncertainties for HL-LHC era, but mo

Local collimation in DS addresses successfully limitations in all IRs!

Collimation review outcome


LHC Collimation Review 2013

30-31 May 2013
CERN
Europe/Zurich timezone

Overview
Timetable
Registration
Registration Form
List of registrants

Introduction:
In the frame of the LHC upgrades towards the High Luminosity LHC (HL-LHC), the improvement of the LHC collimation system is a critical aspect. The review has the main scope of assessing the needs of new collimators in the LHC cold dispersion suppressors for the operation beyond LS2.

Charge of the review panel:
The committee should look into the various aspects of the presented upgrade baseline and advise in particular on the need to pursue R&D on 11T dipoles for a possible installation in the LHC for LS2.

- Are the assumptions for performance reach estimates appropriate and adequately addressed?
- Is the present upgrade strategy appropriate in view of being able to take a decision in 2015?
- Is there any aspect that has been overlooked?

A final report should be produced and delivered to Steve Myers and Stefano Redaelli.

Review panel:
Mike Seidel (PSI, Chair), Giorgio Apollinari (FNAL), Wolfram Fischer (BNL), Marzio Nessi (ATLAS), Rudiger Schmidt (CERN/ESS), Carsten Omet (GSI).

Starts 30 May 2013 08:30
Ends 31 May 2013 18:00
Europe/Zurich

CERN
Kjell Johnsen Auditorium

Seidel, Mike

Poster
Report of the Review Committee
Review summary

https://i

External review panel:
Mike Seidel (PSI, Chair), Giorgio Apollinari (FNAL), Wolfram Fischer (BNL), Marzio Nessi (ATLAS), Rudiger Schmidt (CERN/ESS), Carsten Omet (GSI).

Main outcome on DS collimation:
Due to the **uncertainties on the extrapolations of beam lifetime and quench limits at 7 TeV**, "The committee strongly encourages the development and prototyping of one 11 T (5.5 m) dipole magnet, and the cryogenic bypass collimator unit. … Build at least 4 units (1 unit consists of 2

The review panel *recognized that DS collimation:*
- is needed for ions in IR2/1/5, already in LS2 (ALICE upgrade).
- is probably ***not*** *needed in LS2 but we cannot guarantee that at this stage.*
- is certainly beneficial for the HL-LHC era (ATS optics).
- this technology will be clearly useful for the HL-LHC era
Recommendation to work hard to achieve a minimum of 4 by LS2!

MP aspects at HL-LHC while crabbing

Failure mitigation: get rid of the tails!

Assuming primary collimation set to ~6 sigma, one could try to deplete the amplitudes between 3-4 sigma and primary collimation:

- Those particles do not contribute significantly to luminosity.
- If they are 'no' particles out there, failures may be acceptable.

➡ **Use CCs in combination with a hollow electron lens acting as tail scrapper?**

- CC operation would be coupled to e-lens.
- How to verify that tail population is acceptable?

J.Wenninger

16.12.2010 CC & MP - CC10 - CERN 11

Intensity reach from collimation cleaning

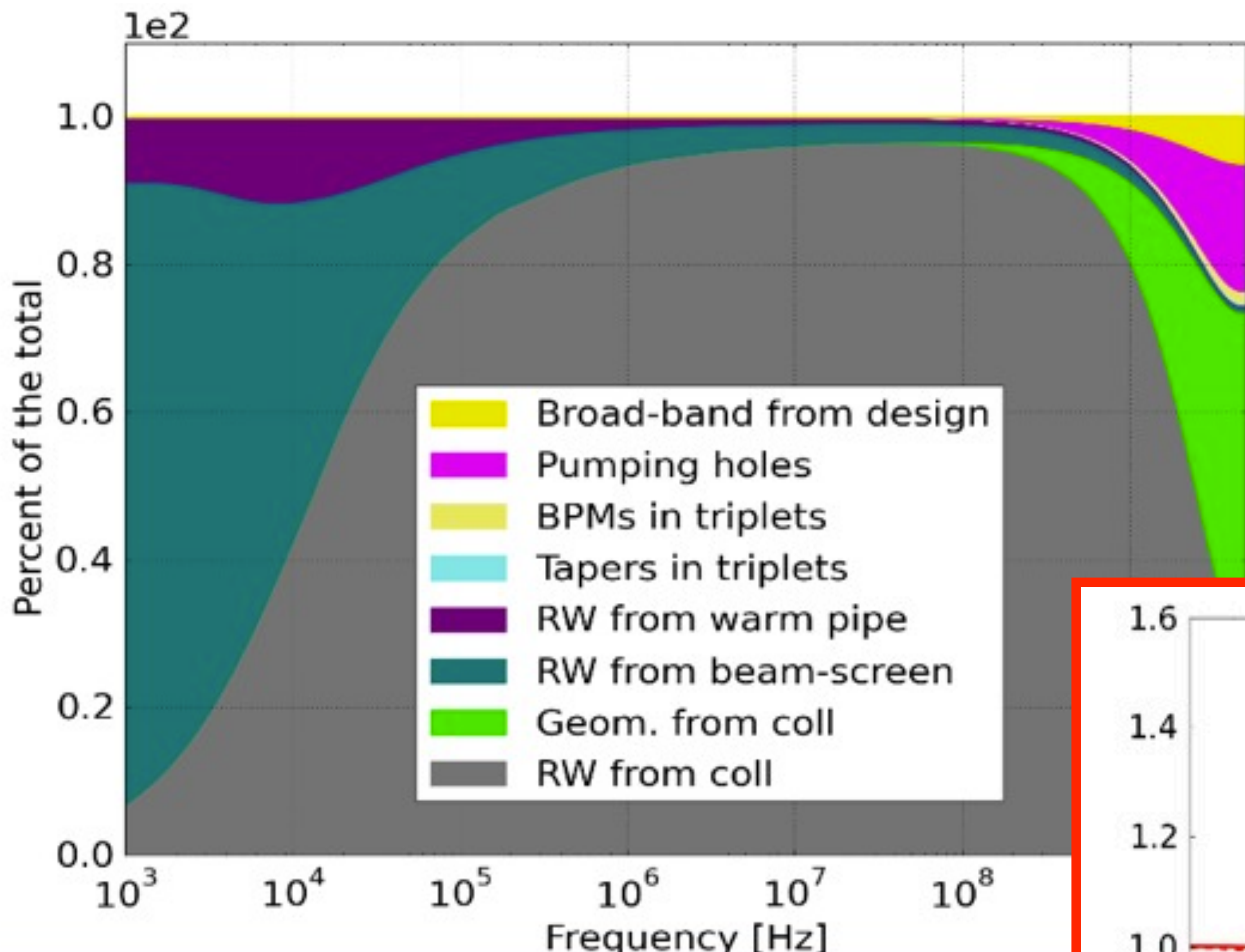
Predicted intensity reach from cleaning

- Consider minimum lifetime of **0.2 h** based on the 2012 experience
  - *- Perhaps pessimistic, but ~10% of fills reached τ_b<0.5-1h!*
  - *- Reviewers felt that it could get worse (25ns vs 50ns, higher E, larger impedance)*
- Different models to scale losses to 6.5 TeV: Intensity reach from proton cleaning in IR7 is **3 to 6 times the nominal LHC** (3.2×10^{14}p).
  Less margin at 7 TeV (different for 2 available quench models).
  HL-LHC intensity goal reduce this window by a factor ~2.
- For more than a factor 2 above LHC design, we have to worry also about **collimator robustness**!
  We might have to set BLM thresholds to protect the collimators!
- Ions: ALICE luminosity upgrade target is at least a factor 2 above quench limits.
  Same limitations apply for IR1 and IR5 that have less priority for ion runs.
- No additional limitations in IR1/5 until LS3 from physics debris thanks to the use of 3 TCL collimators.
  Expect the same result for HiLumi, but need to prove this with final IR layouts.

Outcome of the detailed discussions at the 2013 collimation review, presented at the HiLumi Annual Meeting (Nov. 2013).

This is specific for “collimation losses” in the IR7 dispersion suppressors!
2015: start with std BLM thresholds as at other locations, as presented at this meeting.
Adjust by the factors achieved during collimation quench tests if needed.
IR7 limits not studied in detail for ion beams! Need dedicated quench tests.

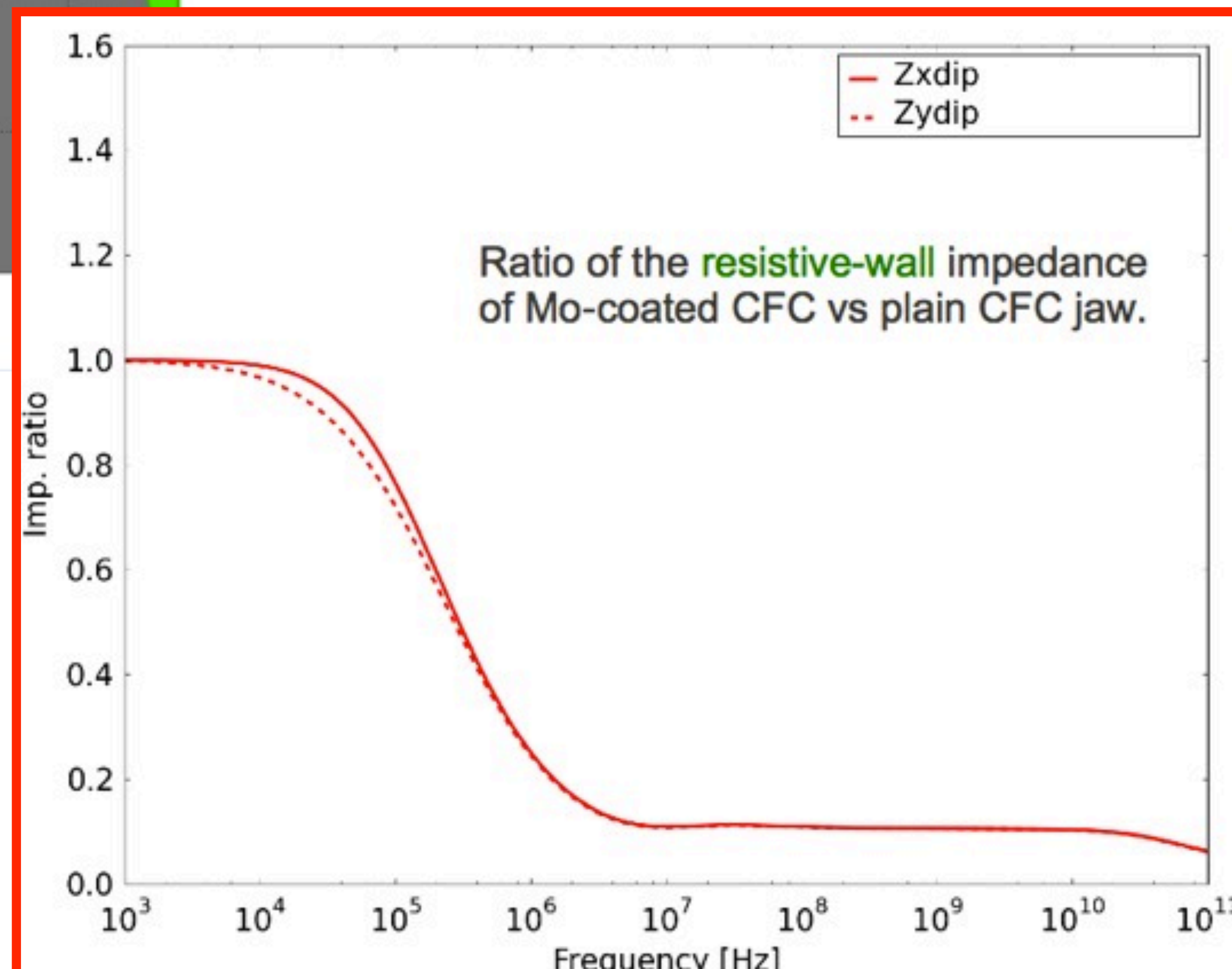
Gain from new collimators



N. Mounet

The present collimators contribute to about 90% of the total machine impedance!

The single collimator contribution is reduced to 10 % if we consider a Mo coating (example here: Mo-Gr jaw coated by Mo).



This is one of the main show stopper to achieve the HL-LHC high intensity goal!

HiRadMat experiment strategy

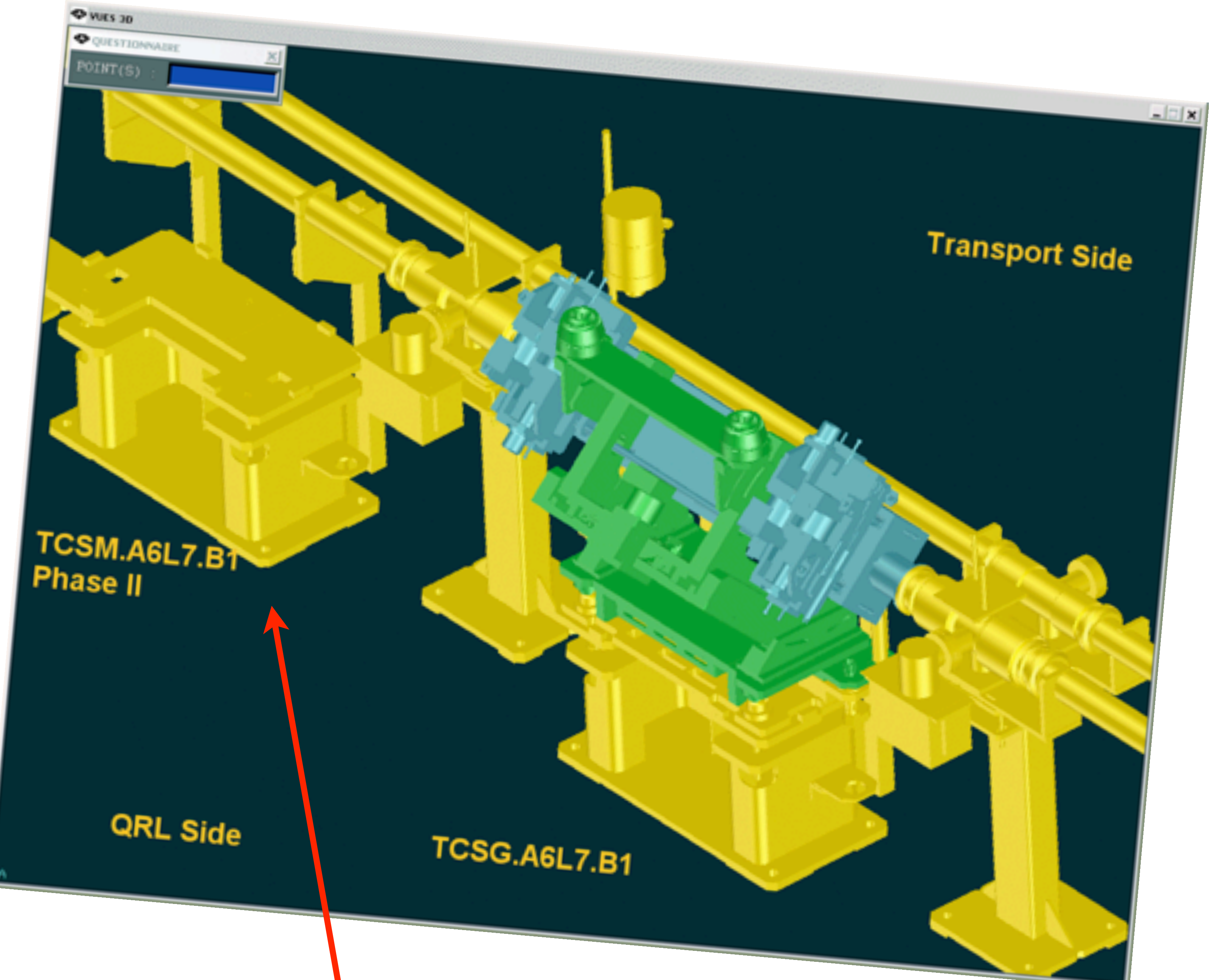
- Integrally test under **LIU/SPS beam train** (up to **288 b**, **2.3e11 p/b?**) jaws for HL-LHC collimators (simulation of LHC Injection Error)
- Impacts from low to high intensity, in order to also determine the **materials damage threshold**
- Acquire online data about response of complete jaws to beam impact
- Assess impact consequences on jaws components after irradiation

HRMT-23 (approved by HiRadMat Scientific Committee):
Test of Fully Assembled Jaws

- Main Features:
  - Three superposed jaws in one tank.
  - Jaws equipped with set of strain gauges, temperature sensors, … for online acquisition.
  - Special tank equipped with viewports for optical acquisition, LDV, electric connections etc. and fast dismounting system for glove box post-irradiation observations.

More information on novel materials

Collimation upgrade layouts



Slots ready for new collimators!
Can install and test new designs/materials in IR3/7 without impact on the present system.
Installation in short tech. stops.

Plan to **replace (add) new secondary collimators** with BPMs and reduced impedance.

Aim: prototype to test in the LHC, machine-ready by end of 2015!

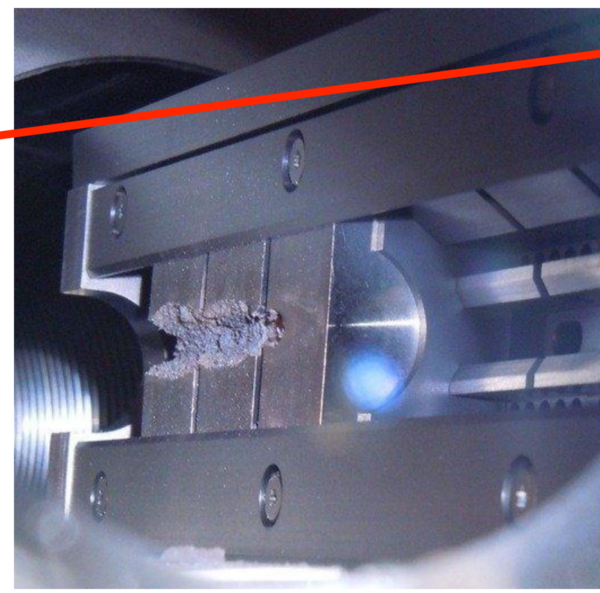
Very rich program of prototyping and beam tests (radiation + shock impacts at HRM) with new composite materials.

If appropriate solutions are found, and if needed after LS1, might add up to 22 collimators in IR7 and 8 in IR3 before LS3!

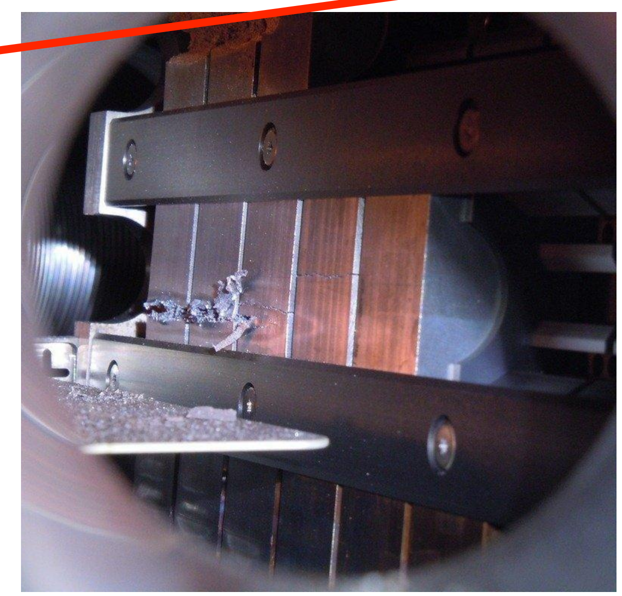
Updated robustness limits

- New damage limits proposed in line with updated accident scenarios (Annecy '13):
  - **Onset of plastic damage : 5×10^{9} p**
  - **Limit for fragment ejection: 2×10^{10} p**
  - **Limit of for 5^{th} axis compensation (with fragment ejection): 1×10^{11} p**

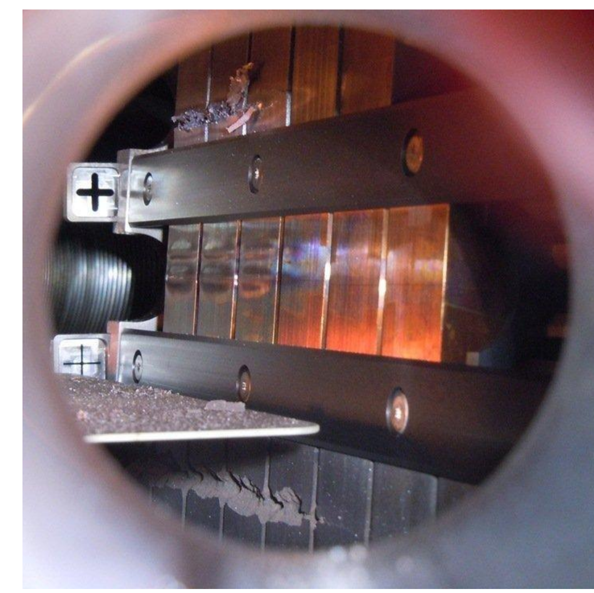
Challenge for the collimator commissioning at 7 TeV that required a few nominal bunches for collision and orbit setup! Need follow up!



Inermet 180, 72 bunches

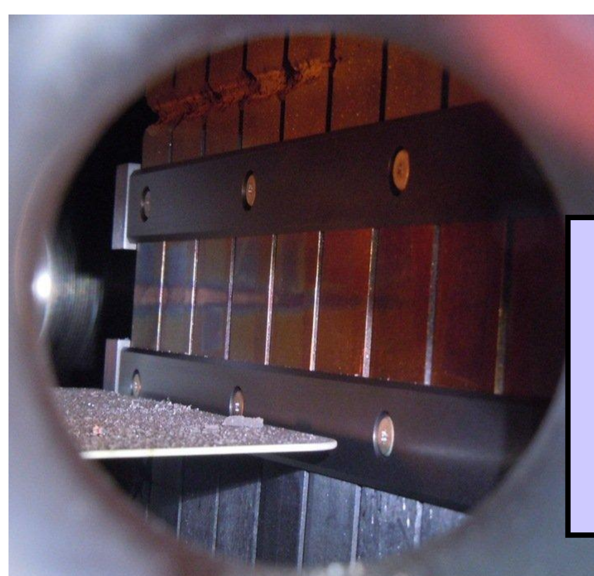


Molybdenum, 72 & 144 bunches



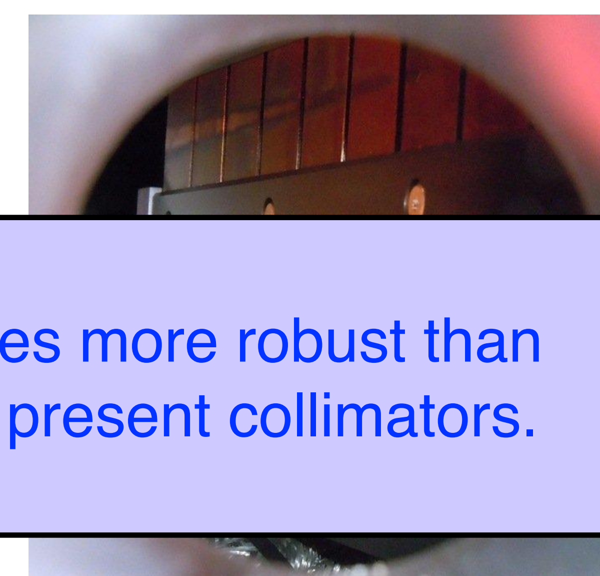
Glidcop, 72 bunches (2 x)

Studied alternative materials for future collimator jaws!



Copper-Diamond
144 bunches

Molybdenum-Copper-Diamond
144 bunches



Molybdenum-Graphite (3 grades)
144 bunches

MoGr: more than 80 times more robust than Tungsten alloy used for present collimators.

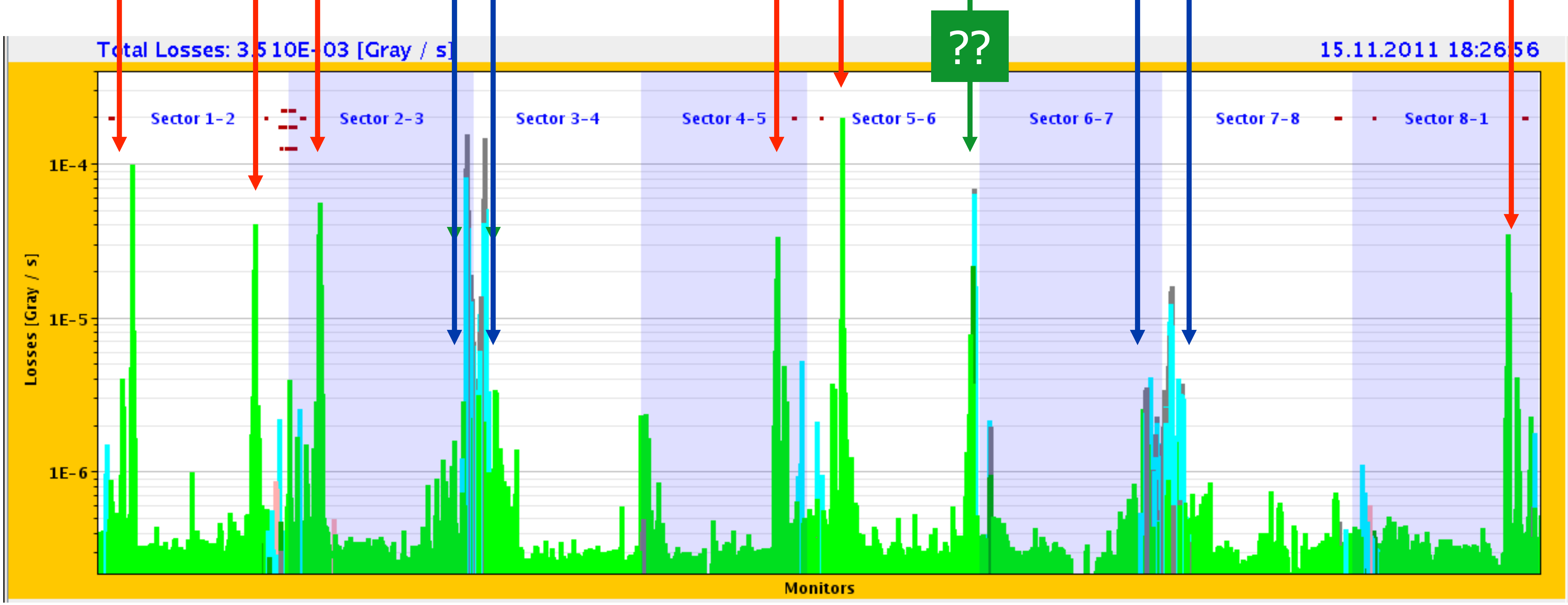
A. Bertarelli:
MP workshop 2013
Recent ATS seminar

3.5 TeV losses with Pb-Pb collisions

Bound-free pair production secondary beams from IPs

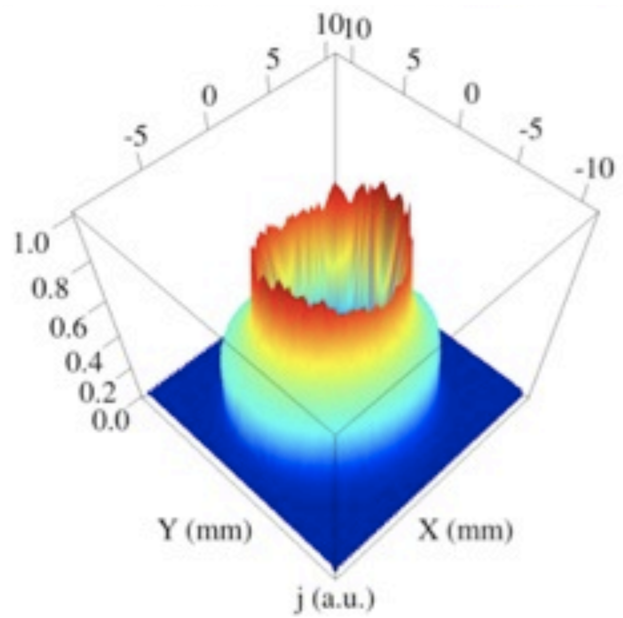
IBS & Electromagnetic dissociation at IPs, taken up by momentum collimators

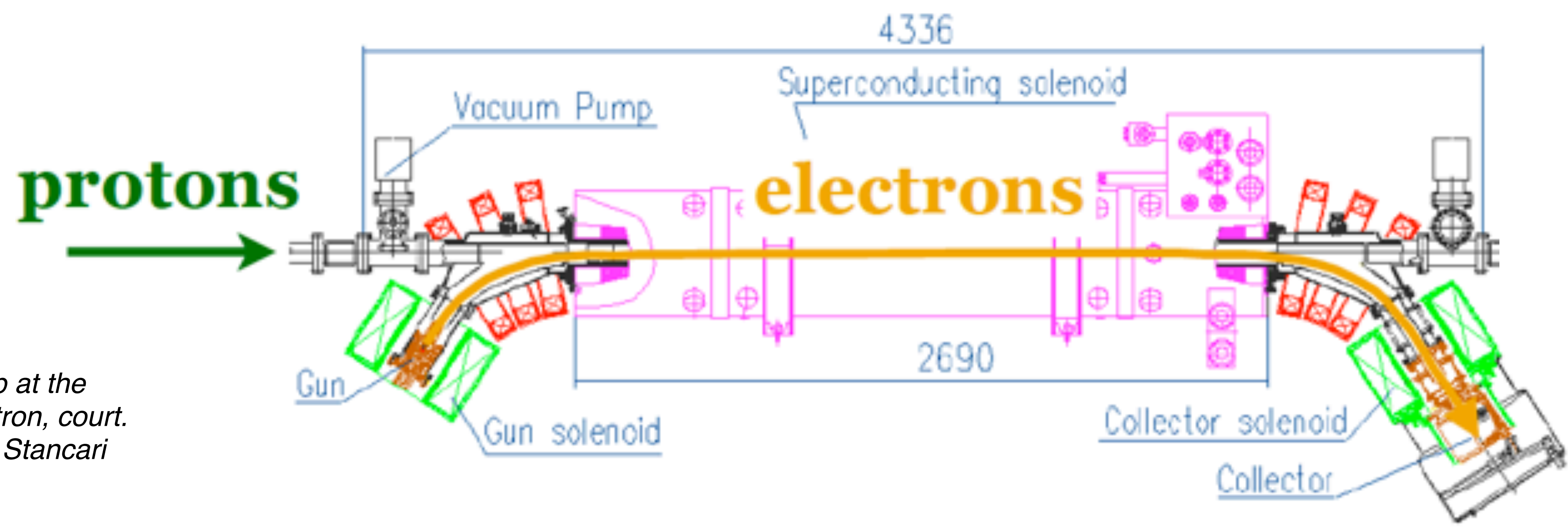
Losses from collimation inefficiency, nuclear processes in primary collimators



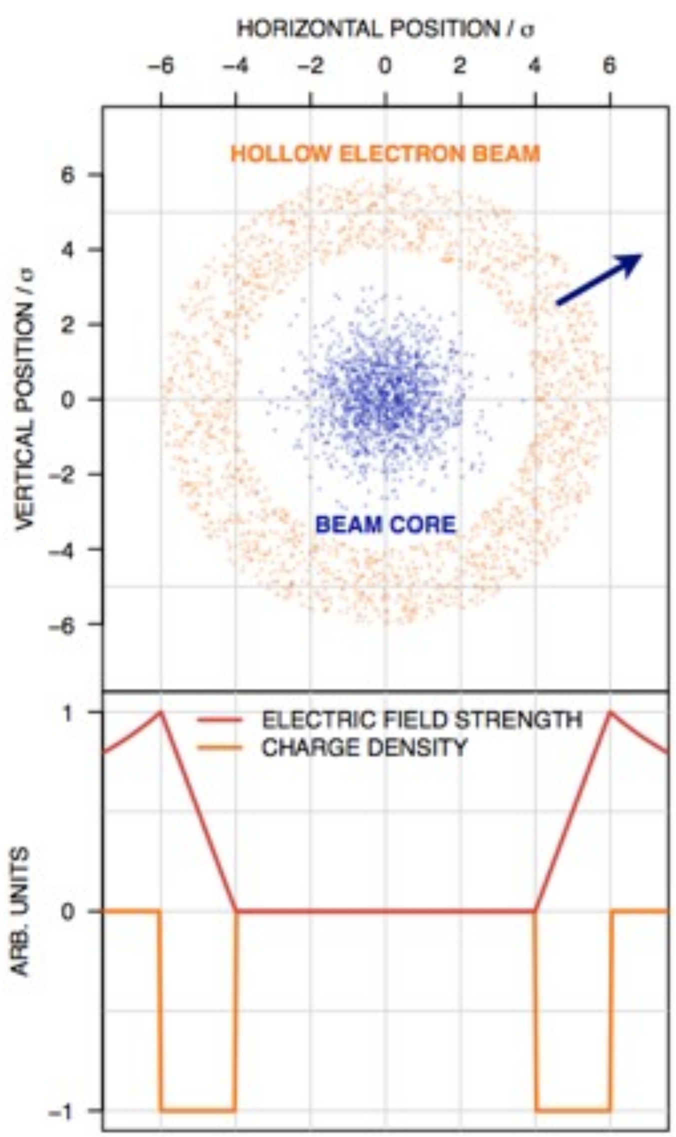
J. Jowett

Basic hollow e-lens concepts





Setup at the Tevatron, court. of G. Stancari



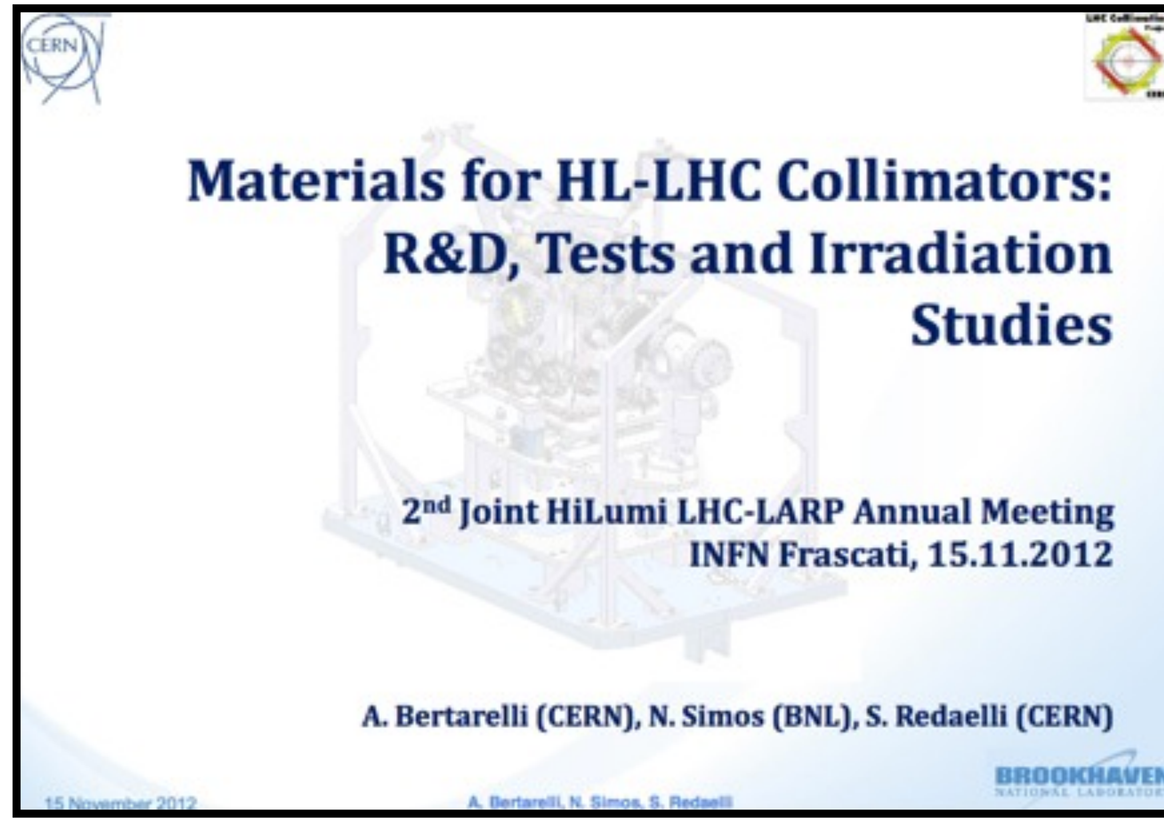
- **A hollow electron beam** runs parallel to the proton beam
  - *- Halo particles see a field that depends on (A_x,A_y) plane*
  - *- Beam core not affected!*
- Adjusting the e-beam parameter, one can **control diffusion speed** of particles in the area that overlaps to e-beam.
  - *- Drives halo particles unstable by enhancing (even small) non-linearities of the machine.*
- Particles excited are selected by their transverse amplitude.
  - *- Completely orthogonal to tune space.*
- This is an ideal scraper that is **robust** by definition.
- Conceptual **integration** in the LHC collimation system:
  - *- The halo absorption is done by the standard collimators.*
  - *- Hollow beam radius smaller than primary collimator aperture.*
- Complex beam dynamics required beam data validation.

Material properties under high doses

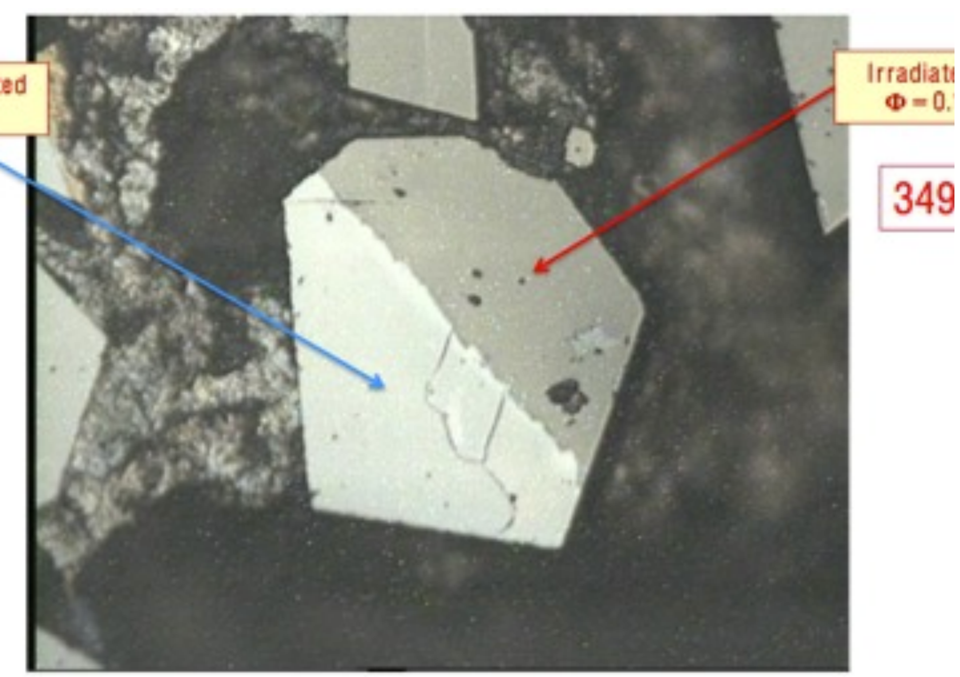
Fast loss studies at HRM address robustness against failure scenario, with impact on β* reach.

We work with high priority on understanding the **material behaviour** under high irradiation doses! Collaboration with Russia (Kurchatov) and USA (BNL within LARP): testing a panel of **6 new materials**.

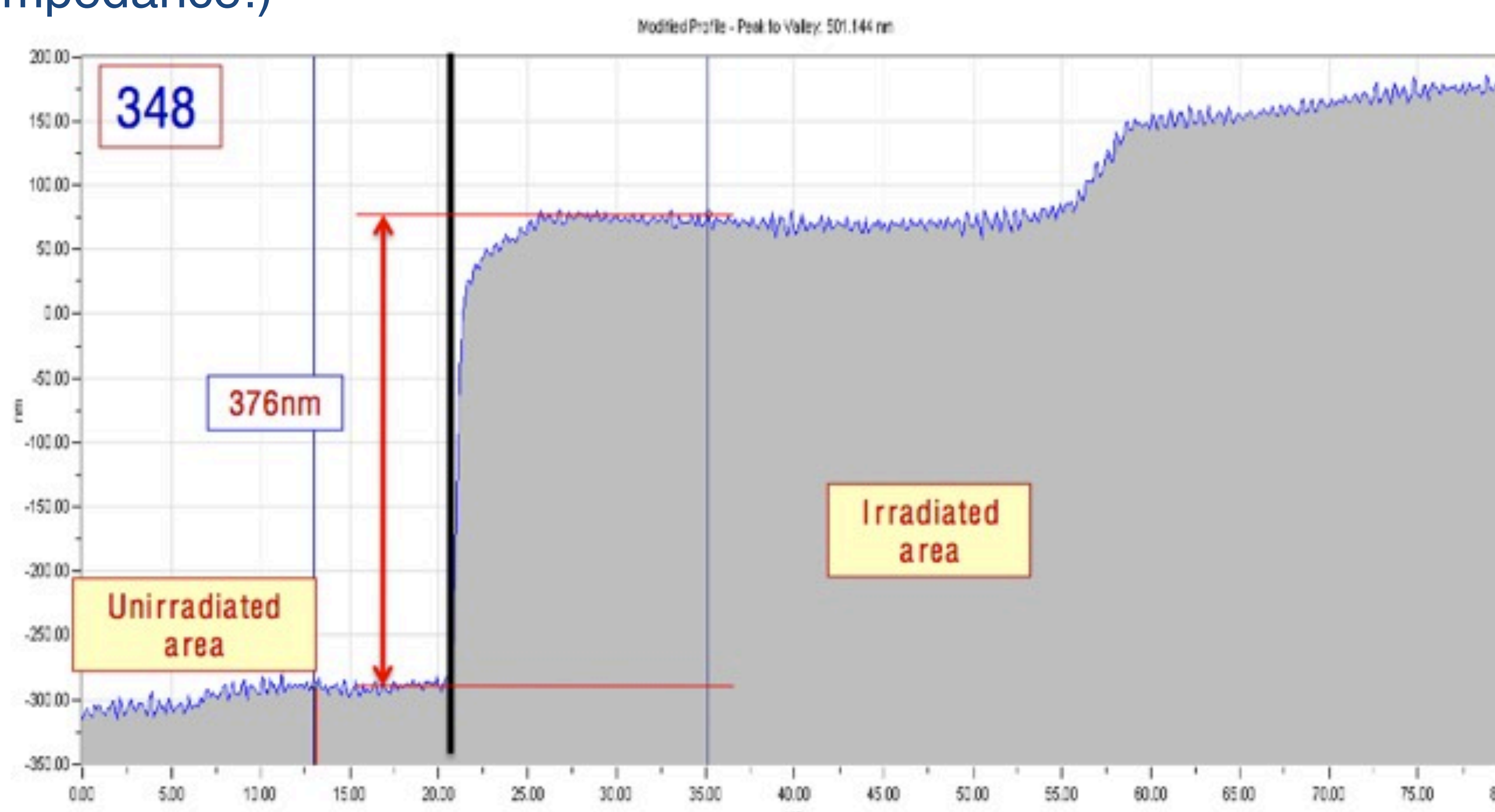
Thanks a lot to the US-LARP friends for supporting this new study proposed in 2012! Supported also by EuCARD + EuCARD2.



Key issues: Variation of dimensions (swelling)
Change of thermo-mechanical properties (increased impedance!)



A. Ryazanov, Kurchatov

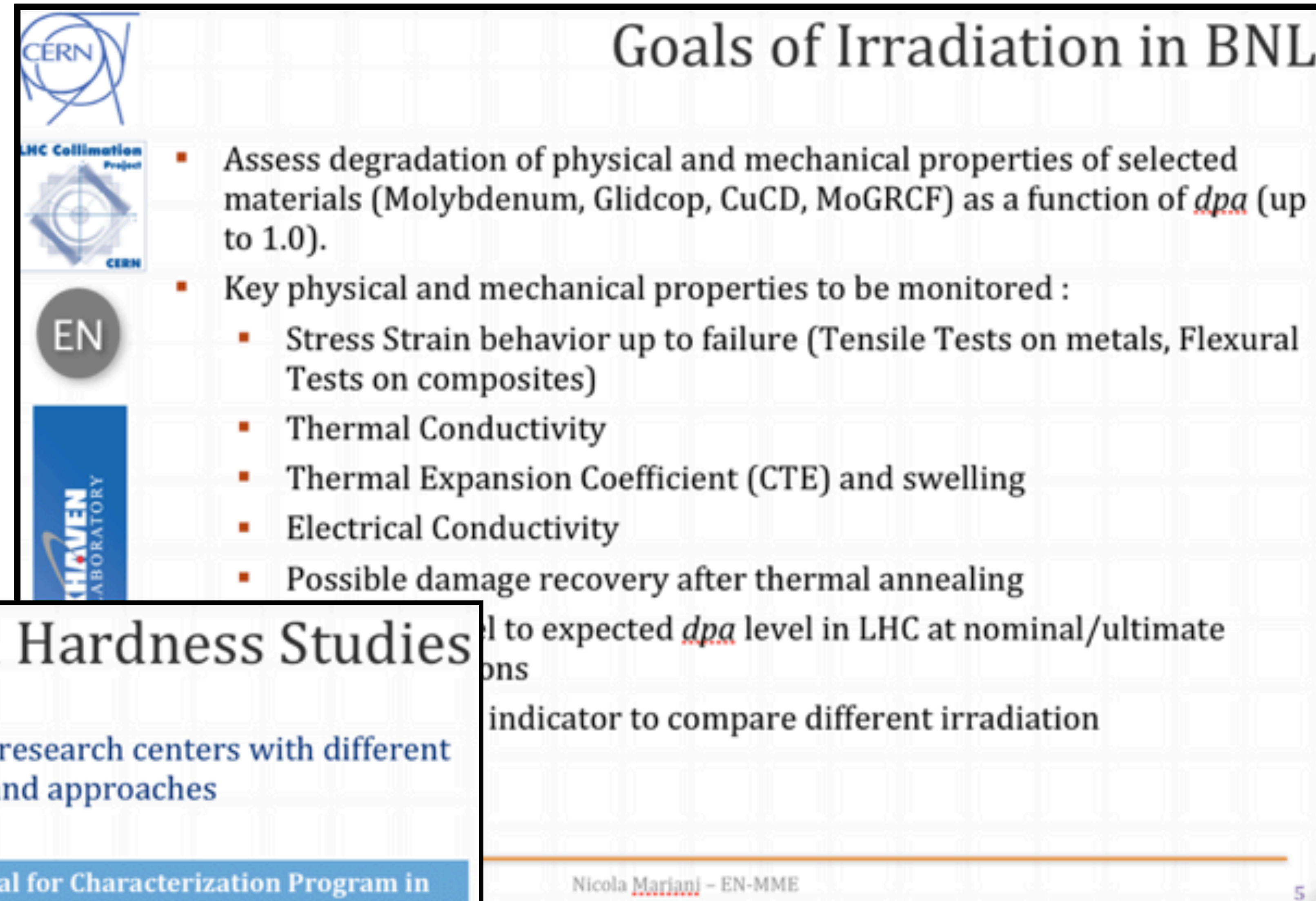


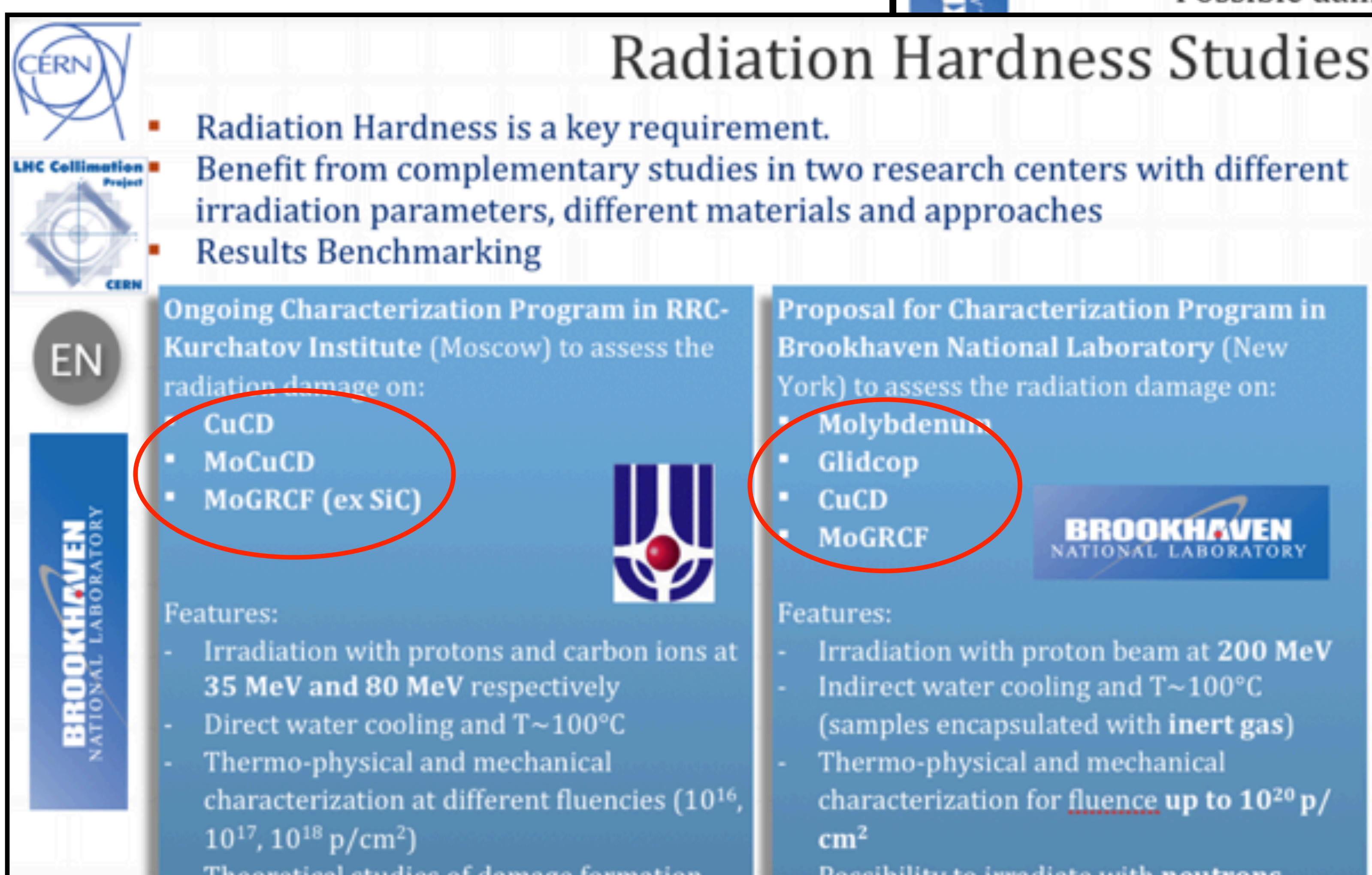
New material studies at BNL

Proposal brought forward at the CM18 a Fermilab (Apr. 2012).

Approved by US-LARP: endorsement at the Frascati meeting in Nov. (when basic program and goals were presented).

Complements and extends important studies ongoing at Kurchatov.





Not possible to give many details here - just brief status.

Status of BNL irradiation tests

Following the US-LARP support announced at the Frascati meeting in Nov., much progress has been made:

- Defined materials and optimum sample shapes.
- Ordered new materials; soon to be shipped to BNL.
- Energy deposition and structural analysis.
- Presentation to the safety committee at BNL
  Experiment Safety Review meeting of 27/03/2013

We are expecting that the tests will take place during this year's RHIC run!

Composite materials samples:
CuCD + MoGRCF