22nd US-LARP Collaboration Meeting - CM22
May 7th-9th, 2013
Brookhaven National Laboratory

LHC Collimation Project Status

Stefano Redaelli, CERN, BE-ABP
for the Collimation Project and HL-LHC-WP5 teams

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.

Scope of this session

☑ Present recent news from collimation

- *Status of LS1 upgrade activities;*
- *Recap. recent results on upgrades, following our 2013 review.*

☑ Report recent results from US-LARP collimation activities:

- *Conceptual design report on hollow e-lens for the LHC;*
- *CERN validation tests on SLAC RC collimator;*
- *Status of irradiation tests on collimator materials.*

☑ Discuss together next steps on various fronts and synergies

- *"Kick-off" of CERN studies on alternative halo excitation methods;*
- *Review electron beam parameters: collimation versus BB compensation;*
- *Discuss need / scope of beam tests at RHIC;*
- *Review the status of halo monitoring methods;*
- *Student exchange programs with BNL and FNAL;*
- *Definition of beam test strategy for SLAC RC (if ok for SPS and/or LHC).*

Let us profit of our "light" agenda today to discuss in details these points!

Outline

- ☑ Scope
- ☑ Update on LS1 upgrades
- ☑ Followup of 2013 review
- ☑ US-LARP activities
- ☑ Conclusions

LS1 upgrades

System upgrades

- ☑ **Upgrade of the 16 TCTs** in all IRs and of the **TCSG in IP6** with the new BPM-embedded design!
  - *In-house production of 2+1 CFC TCSP's;*
  - *Industrial production of 16+4 W TCTP's.*

  Gain: direct orbit measurement at collimators. Faster alignment, better β*!
- ☑ Upgrade physics debris collimation in IR1/5
  - *Add the TCL collimators in cell 4 after removal of TOTEM stations;*
  - *Improve cleaning further with new TCL collimators in cell 6.*
- ☑ **2 new passive absorbers** in IR3 to improve the MQW lifetime
  - *In-house production of 2 TCAPD's.*

- ☑ Improved vacuum layout in IR8 (remove 2-in-1 TCTVB's)
- ☑ Replace one TCP that showed over-heating with a spare
  - *Depending on status of what we take out, more spares might be needed.*

System consolidation

List of LS1 collimation changes

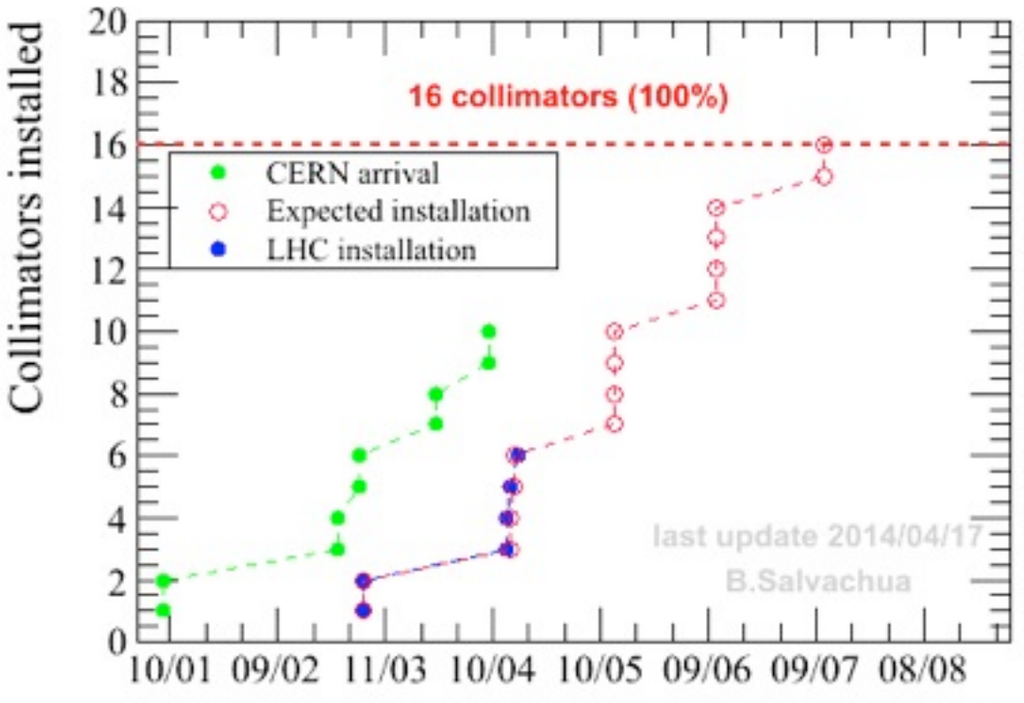
Insertion region	Collimator name	Acronyms	Functionality	Material	End of Run1	Post LS1	New in LS1
IR7: Betatron cleaning	Primary collimator	TCP	Primary betatron cut	CFC	6	6	0
	Secondary collimator - Graphite	TCSG	Secondary betatron cut	CFC	22	22	0
	Shower absorber	TCLA	Absorber of larger-amplitude showers	W	10	10	0
	Secondary collimator - Metallic	TCSM	Secondary betatron cut	MoGr?	0	0	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
	Passive absorbers	TCAP	Reduce total doses in warm magnets	W	6	6	0
IR3: Momentum cleaning	Primary collimator	TCP	Primary momentum cut	CFC	2	2	0
	Secondary collimator - Graphite	TCSG	Secondary momentum cut	CFC	8	8	0
	Shower absorber	TCLA	Absorber of larger-amplitude showers	W	8	8	0
	Secondary collimator - Metallic	TCSM	Secondary momentum cut	MoGr?	0	0	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
	Passive absorbers	TCAP	Reduce total doses in warm magnets	W	2	4	2
IR6: beam dump	Primary dump protection	TCSG	Aperture definition for dump protection	CFC	2	0	-2
	Primary dump protection with pickup	TCSP	Aperture definition for dump protection	CFC	0	2	2
	Secondary dump protection	TCDQ	Dump absorption block (one-sided)	C	2	2	0
	Shower absorber	TCLA	Shower absorbers for Q4 and Q5	W	0	0	0
IR1/5: High-lumi experiments	Tertiary collimators	TCTH/V	Local triplet protection	W	8	0	-8
	Tertiary collimators with position pickup	TCTPH/V	Local triplet protection	W	0	8	8
	Physics debris absorbers	TCL	Clean matching section and DS from debris	Cu (W)	4	12	8
	Tertiary collimators with position pickup for MS	TCTPH/V	Additional local protection for D2/Q4/Q5	W	0	0	0
	Dispersion suppressor	TCLD	Local dispersion suppressor cleaning	W?	0	0	0
IR2: ALICE and B1 injection	Tertiary collimators	TCTH/V	Local triplet protection	W	4	0	-4
	Tertiary collimators with position pickup	TCTPH/V	Local triplet protection	W	0	4	4
	Absorbers for injection protection	TCLIA/B	Auxiliary injection protection devices	C	2	2	0
	Primary injection protection aperture	TDI	Inje	C	1	1	0
	Injection protection mask	TCDD	Mo				
	Dispersion suppressor	TCLD	Loc				
IR8: LHCb and B2 injection	Tertiary collimators	TCTH	Loc				
	Tertiary collimators (2-in-1 design)	TCTVB	Loc				
	Tertiary collimators with position pickup	TCTPH/V	Loc				
	Absorbers for injection protection	TCLIA/B	Aux				
	Primary injection protection aperture	TDI	Inje				
	Dispersion suppressor	TCLD	Loc				
	Physics debris absorbers	TCL	Cle				
TI2/TI8	Injection protection collimators	TCDIH/V	Injection protection in the transfer lines	Gr	13	13	0
				Total	108	118	28
				Movable	100	108	26

We plan to install 29 “new” collimators during LS1!
3 TCP’s go OUT and IN for ventilation works.
The system will grow to 118 devices built within the LHC collimation project (108 for run1)!

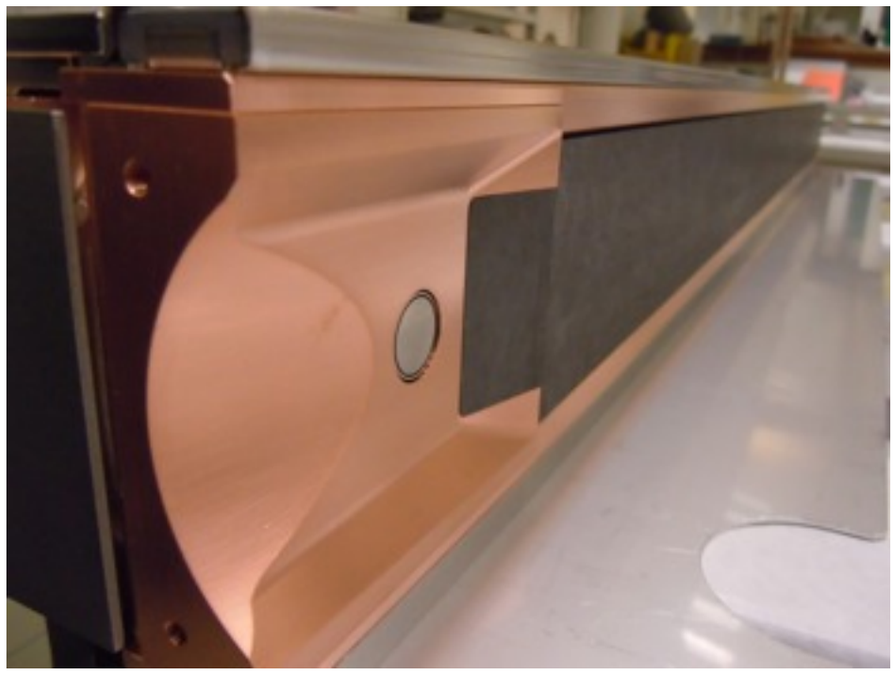
+ one TCP replaced.

Status of BPM collimators

- The contract with the initial contractor was stopped in **Feb. 2013** (common agreement) following a major crisis.
- The main production contract could be re-assigned to another company that had the know-how, but the **schedule** was **tight**!
- The new company managed to keep the promised production schedule within about 2 week!
- Status now:
  - 14 new collimators TODAY at CERN (out of 16 needed)!
  - Basically on track for the LS1 schedule as of today.
  - Completed installation of 4 colls produced in house.



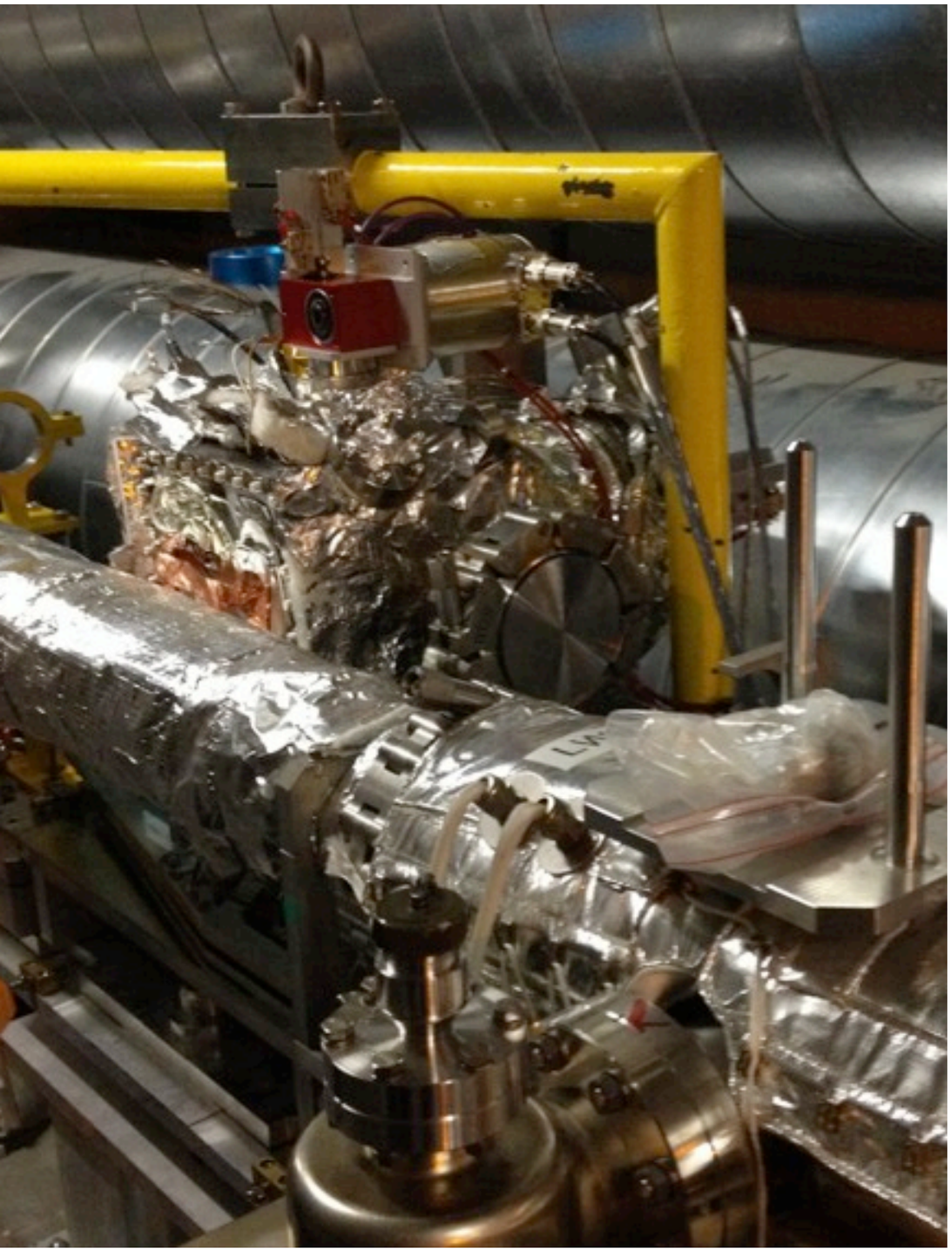
TCSGP jaw



O. Aberle, A. Bertarelli, R. Losito, et al.

Installation date LHC LS1

LHC crystal collimation studies



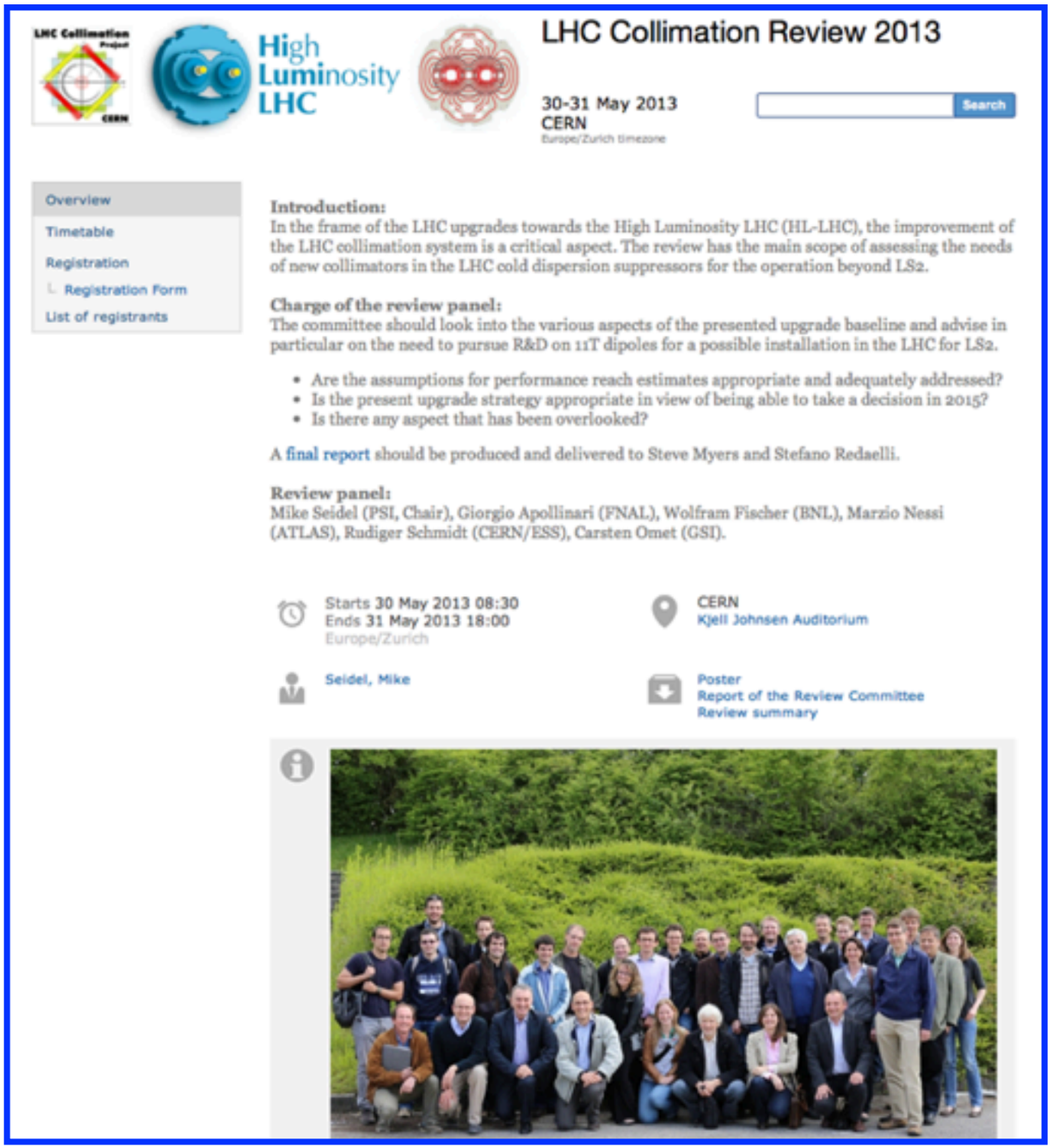
Courtesy of W. Scandale et al.

- **The crystal collimation experiment was approved for installation in the LHC IR7**
  - *Scope: low-intensity beam tests will be part of the regular MD program.*
- **Two goniometers for horizontal and vertical crystals installed!**
  - *Detailed layouts were reported at previous US-LARP and HiLumi meetings.*
- **Next steps ahead:**
  - *Definition of safe boundaries respecting machine protection constraints.*
  - *Sort out a detailed MD program.*

Outline

- ☑ Scope
- ☑ Update on LS1 upgrades
- ☑ **Followup of 2013 review**
- ☑ US-LARP activities
- ☑ Conclusions

2013 collimation review



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

Main focus: dispersion suppressor (DS) collimation and 11 T dipole needs.
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 magnets + bypass + collimator) since this would cover 2 possible cases…"
Additionally: **supported for low-impedance collimators and hollow elens works!**

https://indico.cern.ch/event/251588

2013 collimation review

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https://

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 LS7 but we cannot guarantee that at this stage.*
- is certainly beneficial for the HL-LHC era (ATS optics).
Recommendation*: work hard to achieve a minimum of 4 units by LS2!*

Other recommendations

RECOMMENDATION: Complete the analysis of all tests with the objective of a coherent understanding of the quench limits as a function of the loss duration.

RECOMMENDATION: Perform quench tests at high energy, e.g. 6.5 TeV, as soon as possible after the restart of LHC in 2015, including tests with ions.

RECOMMENDATION: The team should proceed with further studies on the proposed thin Mo coating, to verify its mechanical stability during grazing beam impact as well as during full impact of a few bunches. A possible impact on adjacent equipment in case of accidental beam impact on a jaw needs also to be taken into account. Another option for reducing the impedance that also could be explored is operation with asymmetric collimator jaw settings. In this scenario the impact on machine protection needs to be discussed.

The longer-term plans with respect to collimation were outlined. Ideas of scraping off halo particles with other methods and an improved understanding of halo formation are being discussed. One option is to use hollow electron beams as it has been demonstrated at FNAL. Other alternatives should be explored, such as tune modulation, crystal collimation etc. The committee considers studies on halo cleaning with different methods for controlling beam losses and for machine protection as very interesting.

Other recommendations

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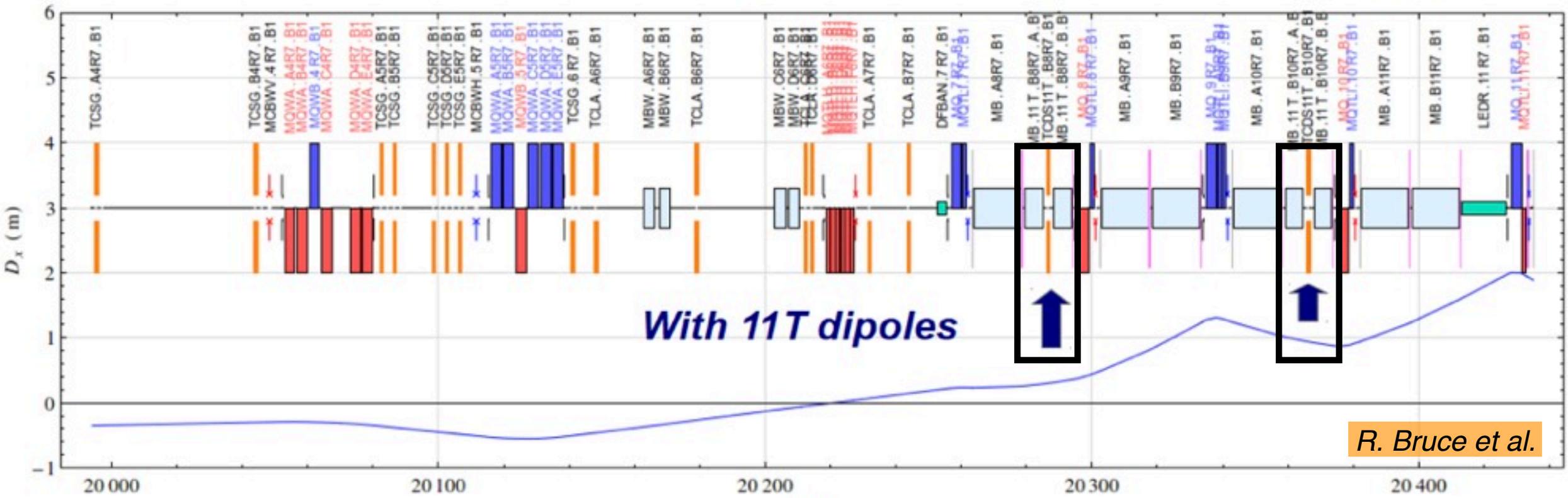
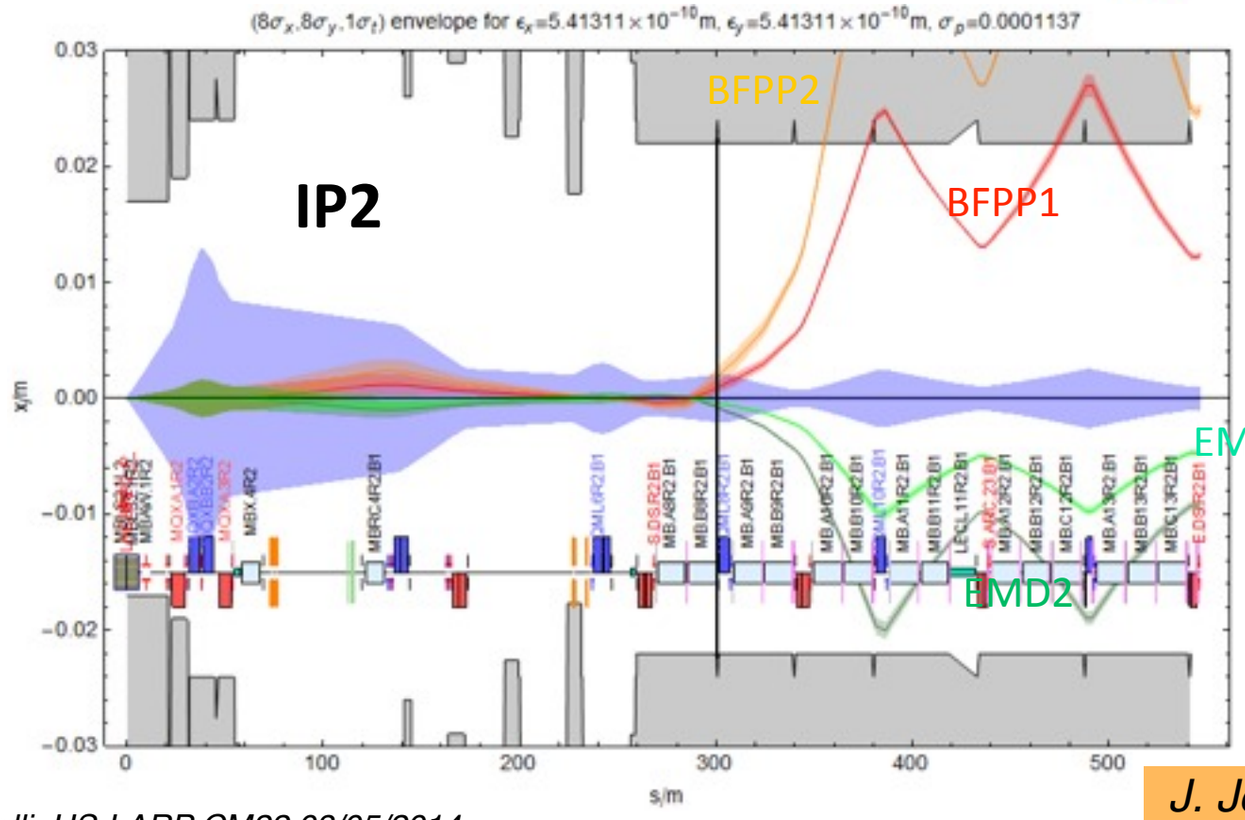
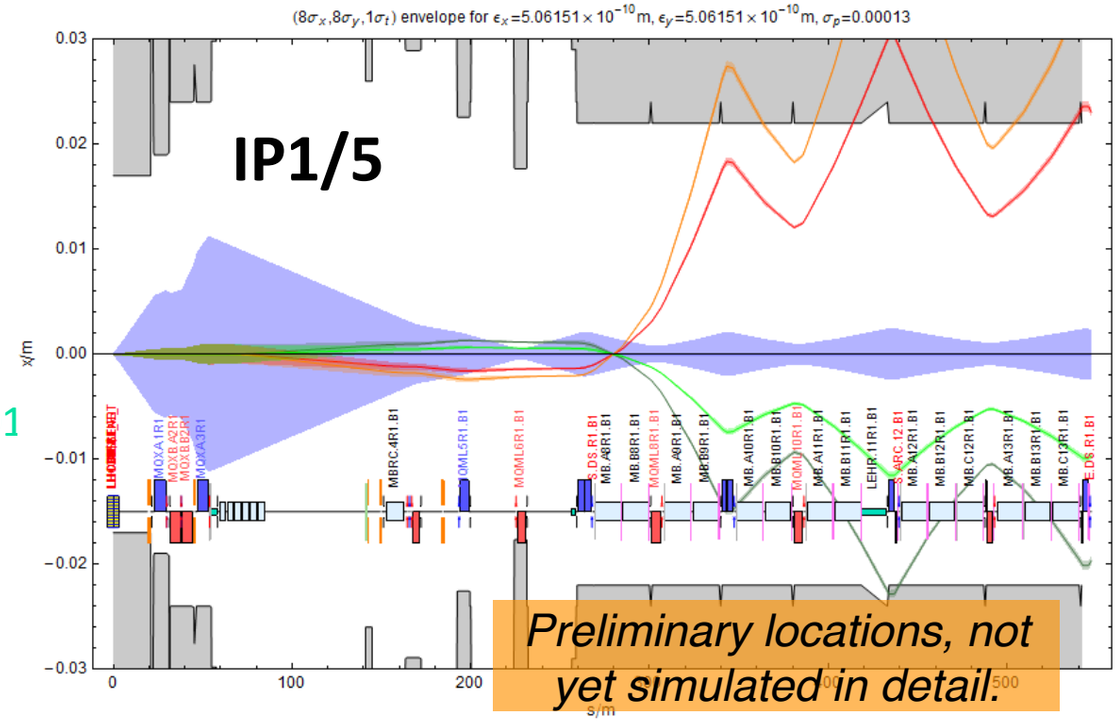
The review panel:
- *Acknowledged the **uncertainties** on the performance scaling to nominal LHC and HL-LHC.*
- *Recommended to push forward urgently **low-impedance designs**.*
- *Recommended to study **active halo control** mechanisms.*
- *Stressed the importance to study effect of radiations on new materials.*

Review followup - recent results

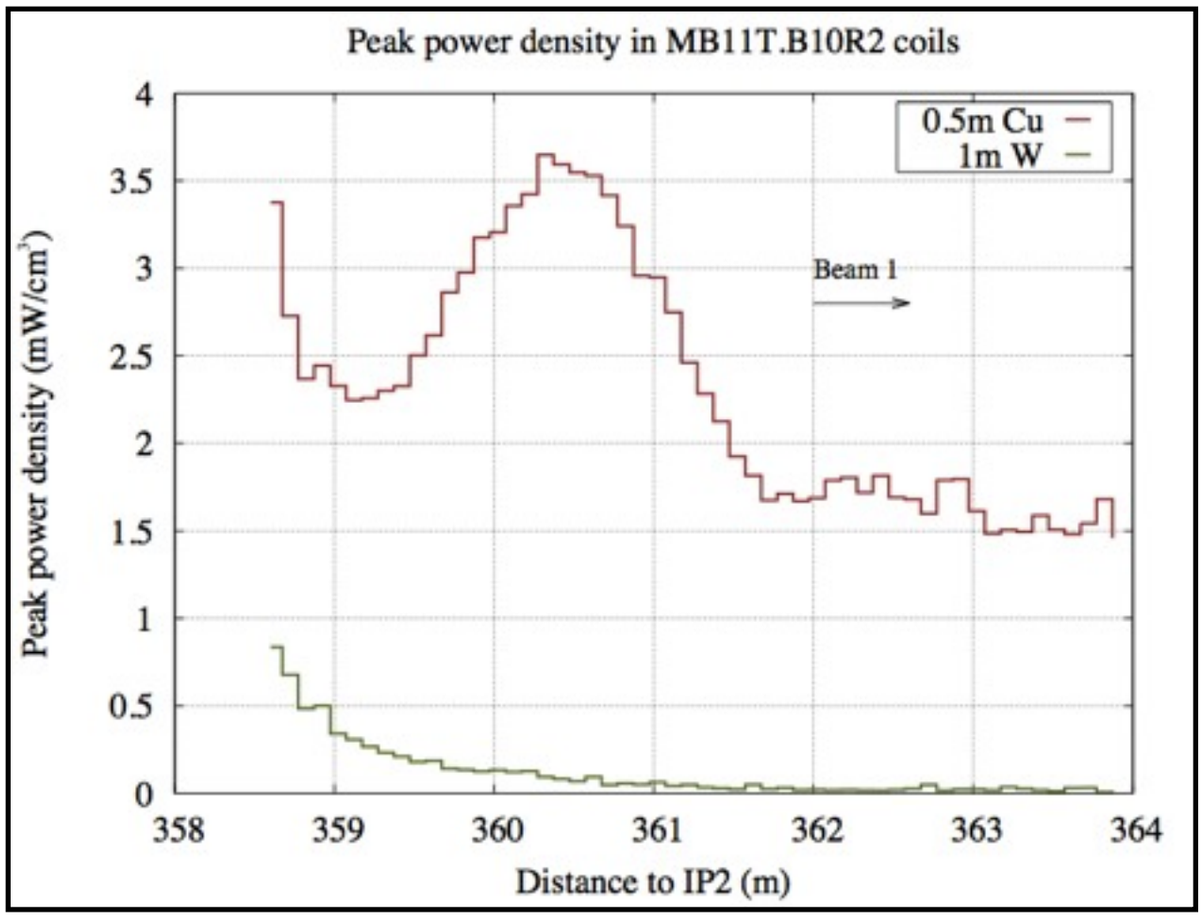






Most urgent IRs

Ions - IR2

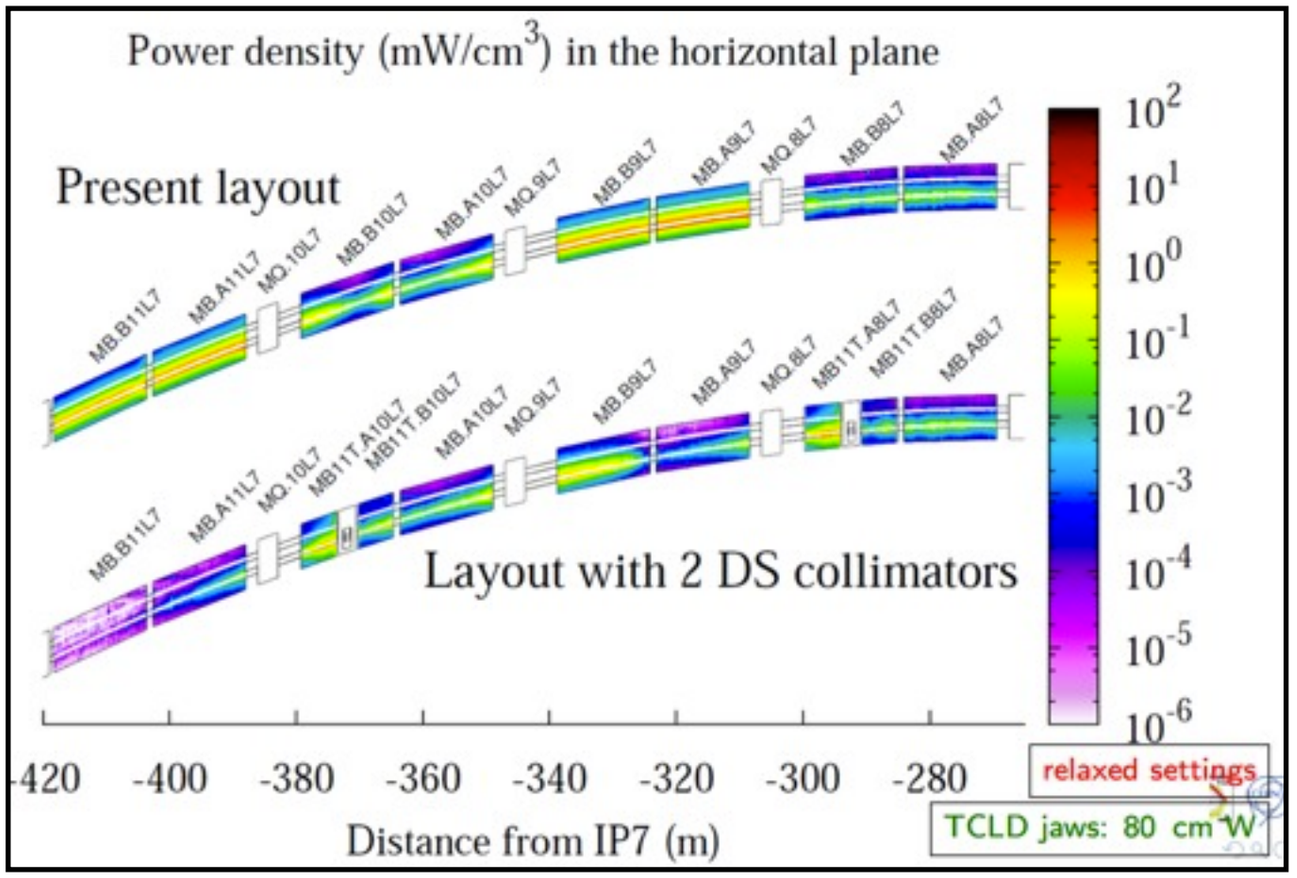


- 11T dipole downstream of TCLD: peak power density in coils for 6× design lumi ranges from 0.8 mW/cm^3 (1 m W) to 3.7 mW/cm^3 (50 cm Cu)

Gain factor > 25

A. Lechner et al.

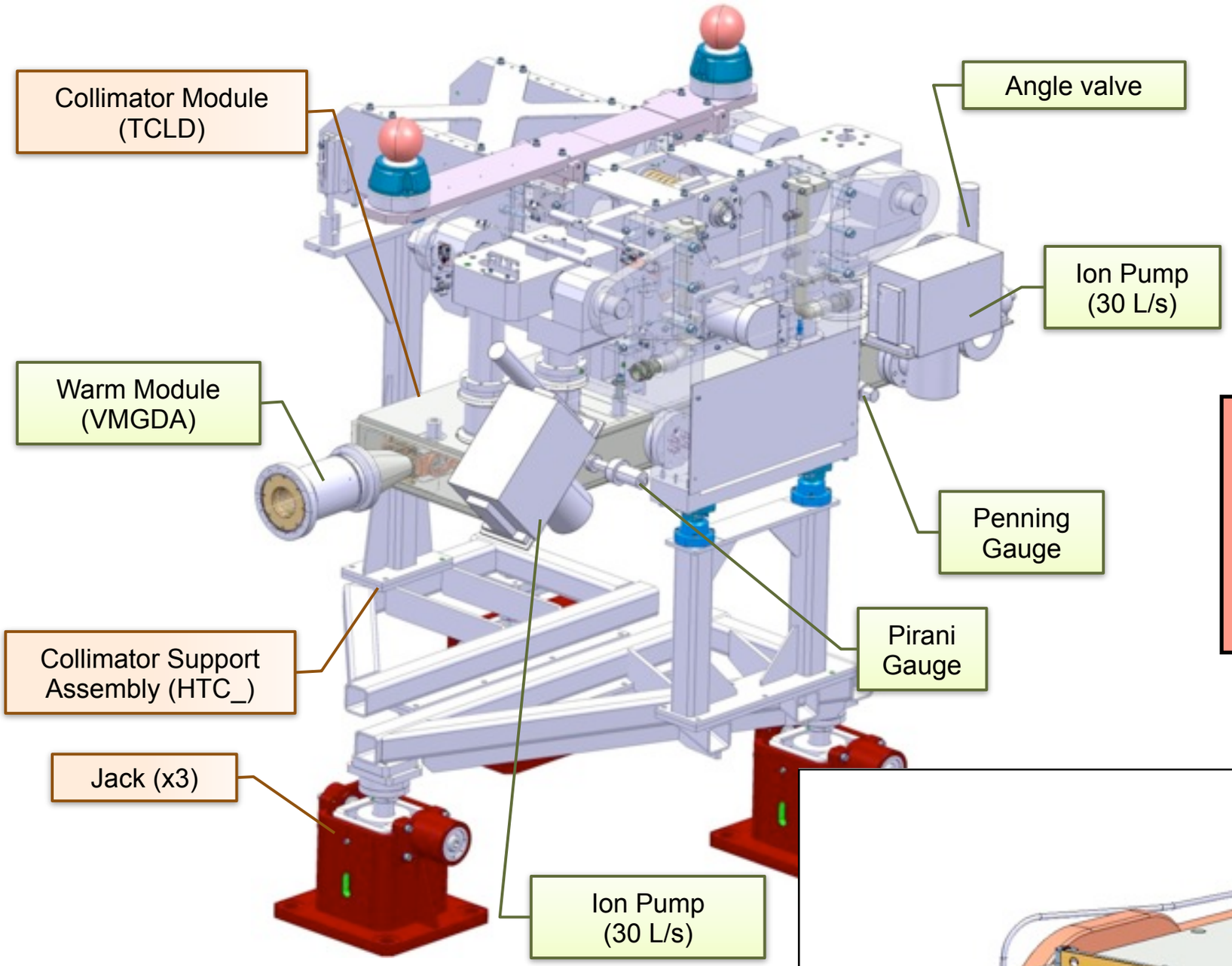
Protons - IR7



Gain factor ~ 10

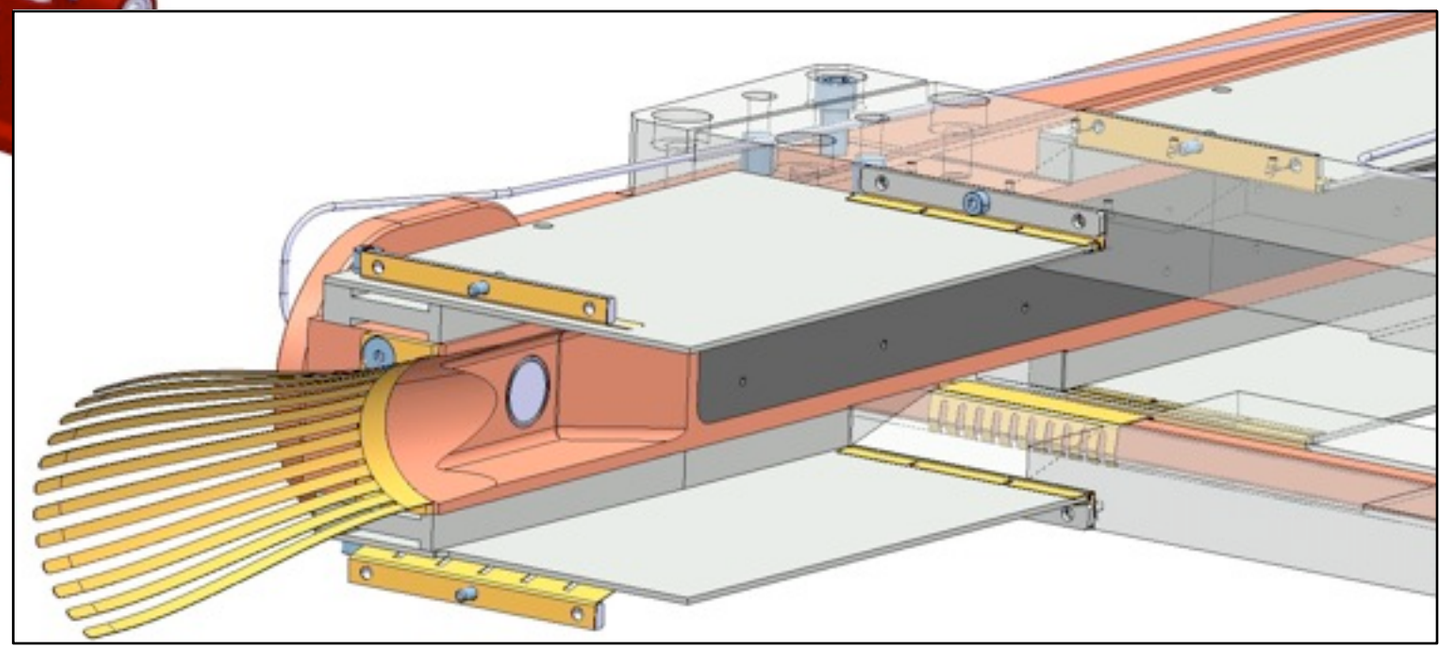
Quench limits of 11 T dipoles have a factor ~2 additional safety margin (P.P. Granieri)
→ very comfortable situation with local cleaning

“TCLD” collimator design



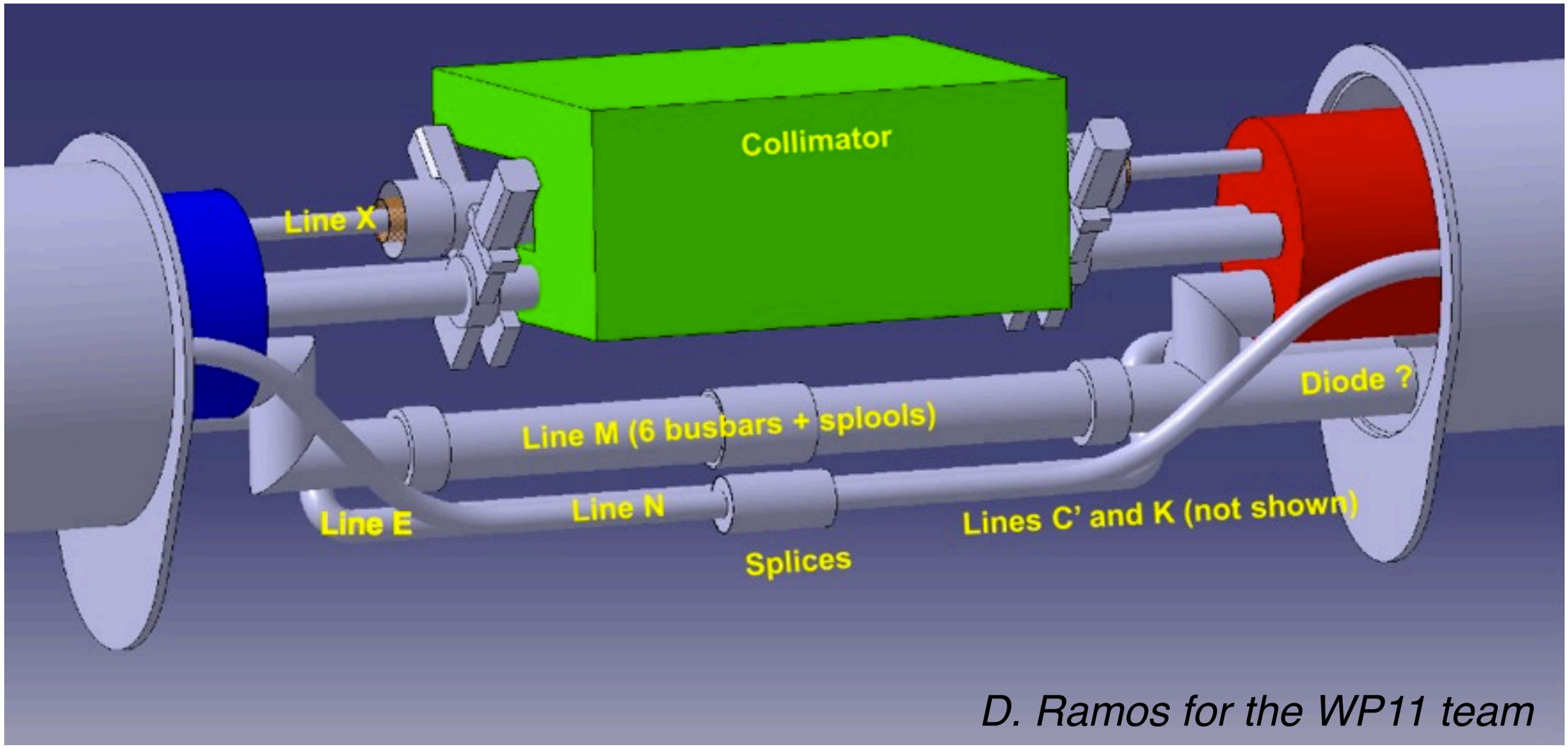
Agreed on a baseline of 80 cm!

Ongoing detailed integration work. Installation between 11T dipoles seems feasible with present design!



L. Gentini et al.

TCLD integration



Related ongoing activities:
- iterations with vacuum team for integration optimization;
- finalize bus-bar design;
- finalizing TCLD design (RF fingers vs ferrite) for prototyping phase;
- tests of cryogenics by-pass scheduled at the SM18.

Low-impedance, robust collimators

TCTP prototype assembly

Cu-CD composite

Mo-Gr composite

BREVETTI BIZZ

Cu-CD Fracture Analysis

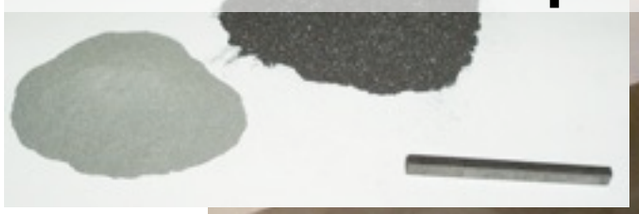
Low-impedance, robust collimators

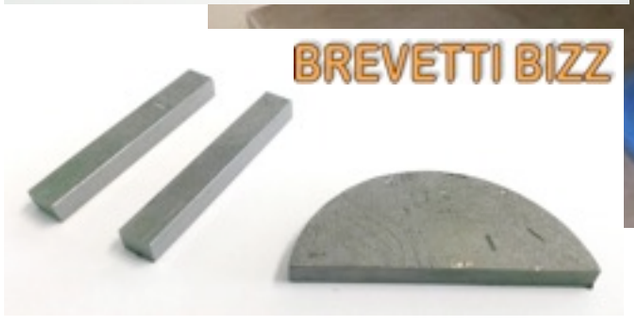
- **Scope: more robust tertiary collimators; low-impedance secondaries.**
  Main interest now: Mo-GR composited with or without Mo coating.
- **Our ambitious plan:**
  - **Build a machine-ready prototype for installation in the Christmas stop 2015!**
  - **Based on post-LS1 experience and results of prototyping, prepare a possible production for action in LS2 (replace IR7 secondary collimators)!**
- **Many challenges ahead (for a short time):**
  - **Finalize new collimator design**
  - **Production techniques for new materials, including coating**
  - **Beam validation of full scale prototype at CERN HiRadMat**
  - **Crucial tests of material properties under high irradiation**
  Results expected from US-LARP (BNL) and Kurchatov.

TCTP prototype assembly

Cu-CD composite

Mo-Gr composite





Material choices for future collimators: we now want to build into the design choices the knowledge/constraints on material behaviour under high radiation doses!

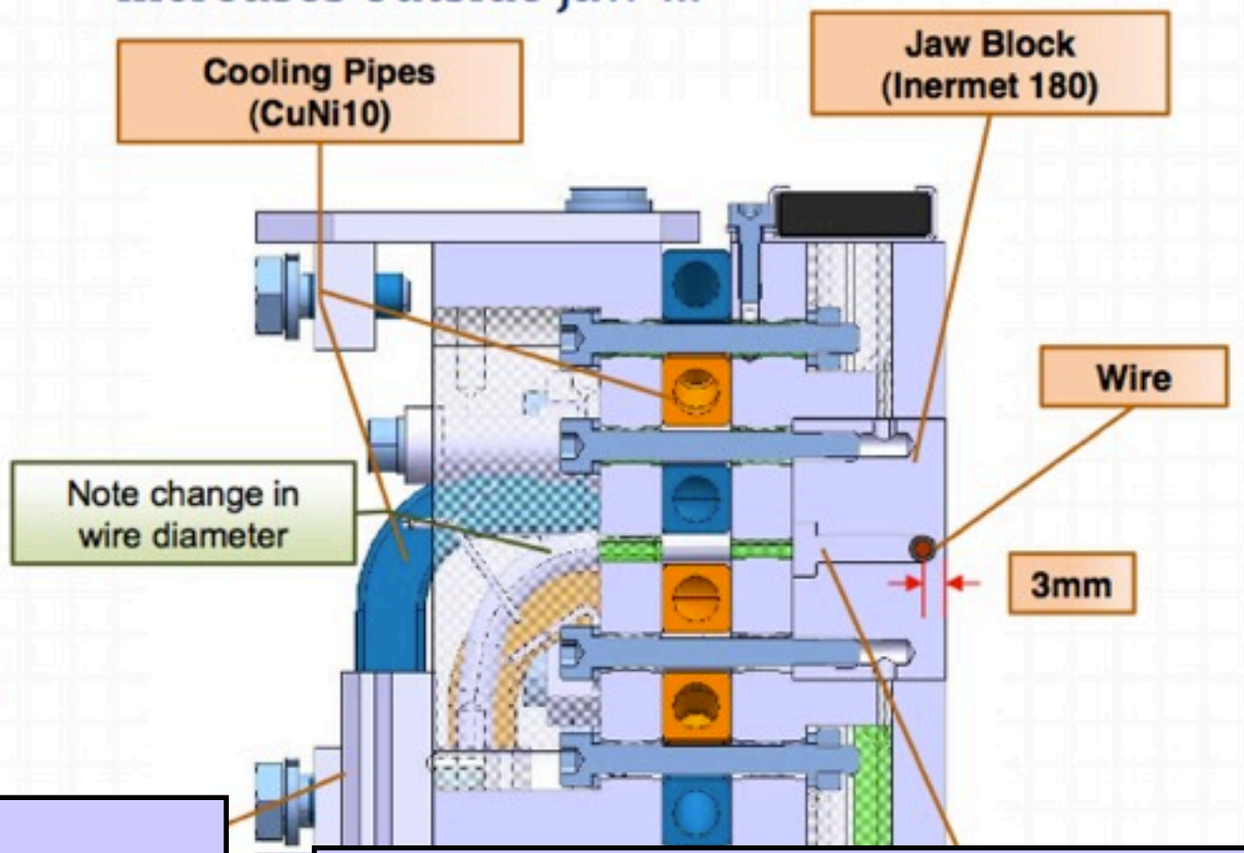
Cu-CD Fracture Analysis

Advanced designs: TCT with BBLRC

LHC Beam-Beam Compensator

Challenge: Embed an **electric wire in a TCTP collimator jaw** to compensate long-range Beam-Beam effects (see R. Steinhagen's talk)

Concept: Insulated wire pressed against W block by a pushrod. Wire diameter increases outside jaw …



Requirements:

- High DC current (up to **350 A**)
- Thin wire (**Ø≤ 2.5 mm**)
- In-jaw wire (**depth ≤ 3 mm**)
- Maintain **TCTP complete**

*For machine development (MD) studies we are preparing the production of a few collimators with an embedded wire for **Beam-Beam Long Range Compensation (BBLRC)**. Goal: MD's before LS2!*

N. Mokhov proposed to assess possible locations for the final layouts by energy deposition studies in IR1/5.

Outline

- ☑ Scope
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- ☑ **US-LARP activities**
- ☑ Conclusions

An introduction of the next talks in this session.

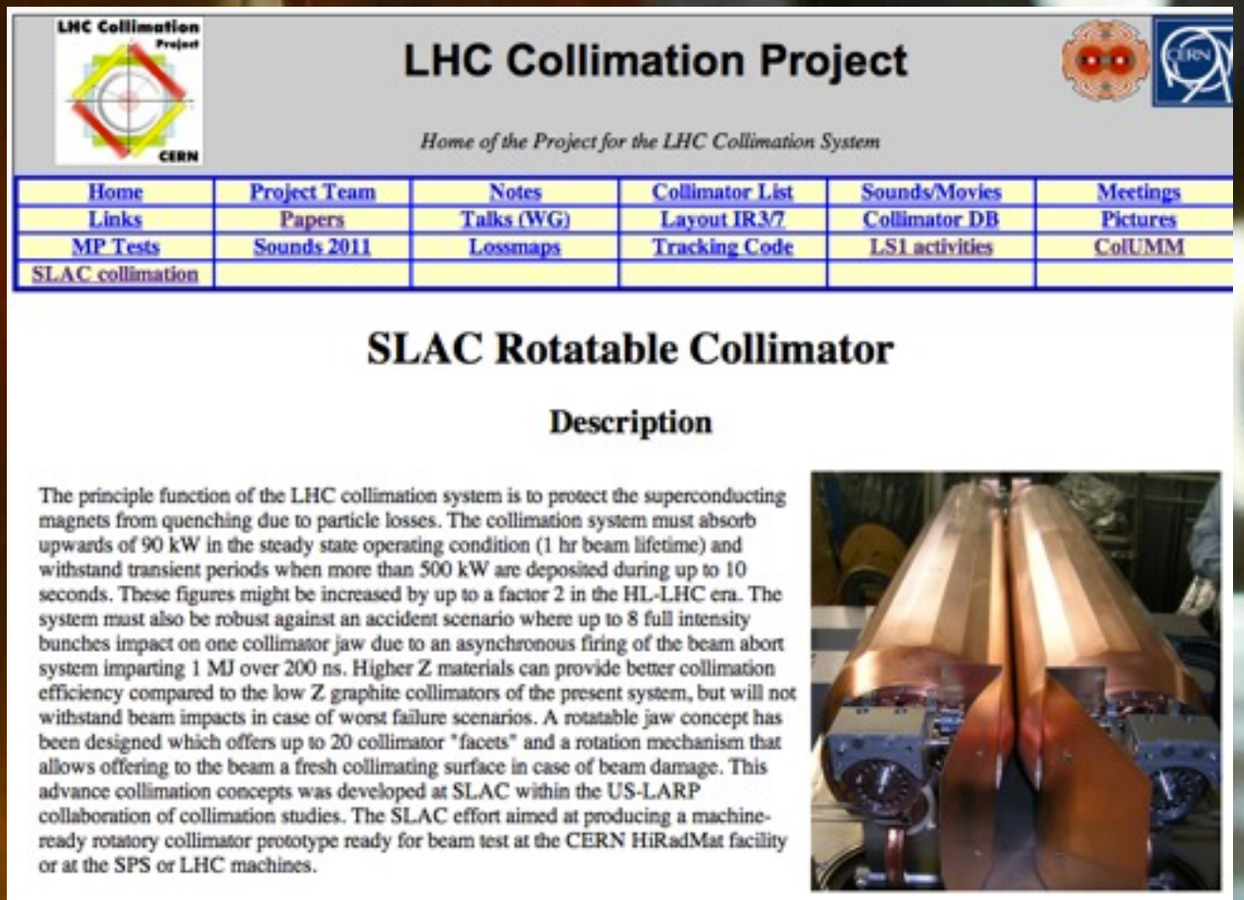
RC collimator tested at CERN

RC collimator tested at CERN

Timeline

21st May 2014	Foreseen end of bakeout
28th Apr 2014	Foreseen start of vacuum tests
22nd Apr 2014	Controls tests (torque measurements, LVDT calibration, rotation tests)
20th Mar 2014	Start of wire impedance tests
11th Mar 2014	First jaw movement tests made
05th Mar 2014	SLAC collimator passed first leakage test
12th Feb 2014	SLAC collimator tank opened
27th Nov 2013	Arrival of SLAC rotatable collimator at CERN!

Thanks a lot to the teams involved in the TE, EN and BE departments for the support!



LHC Collimation Project

Home of the Project for the LHC Collimation System

Home | Project Team | Notes | Collimator List | Sounds/Movies | Meetings
Links | Papers | Talks (WG) | Layout IR3/7 | Collimator DB | Pictures
MP Tests | Sounds 2011 | Lossmaps | Tracking Code | LS1 activities | ColUMM
SLAC collimation

SLAC Rotatable Collimator

Description

The principle function of the LHC collimation system is to protect the superconducting magnets from quenching due to particle losses. The collimation system must absorb upwards of 90 kW in the steady state operating condition (1 hr beam lifetime) and withstand transient periods when more than 500 kW are deposited during up to 10 seconds. These figures might be increased by up to a factor 2 in the HL-LHC era. The system must also be robust against an accident scenario where up to 8 full intensity bunches impact on one collimator jaw due to an asynchronous firing of the beam abort system imparting 1 MJ over 200 ns. Higher Z materials can provide better collimation efficiency compared to the low Z graphite collimators of the present system, but will not withstand beam impacts in case of worst failure scenarios. A rotatable jaw concept has been designed which offers up to 20 collimator "facets" and a rotation mechanism that allows offering to the beam a fresh collimating surface in case of beam damage. This advance collimation concepts was developed at SLAC within the US-LARP collaboration of collimation studies. The SLAC effort aimed at producing a machine-ready rotatory collimator prototype ready for beam test at the CERN HiRadMat facility or at the SPS or LHC machines.

RC leaving SLAC

See details in Alessandro's talk.

Hollow e-lens collimation studies

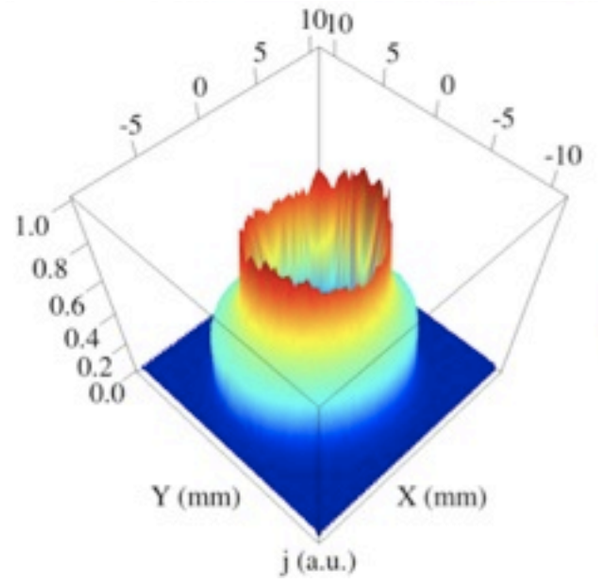
CERN-xxx
FERMILAB-TM-2572-APC

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: December 12, 2013)



☑ **Conceptual design report was compiled by G. Stancari et al.**

*- Final version to be released soon - see **Giulio's talk**.*

☑ **Very solid basis for the present design effort starting at CERN (D. Pierini, A. Bertarelli et *al.*,)**

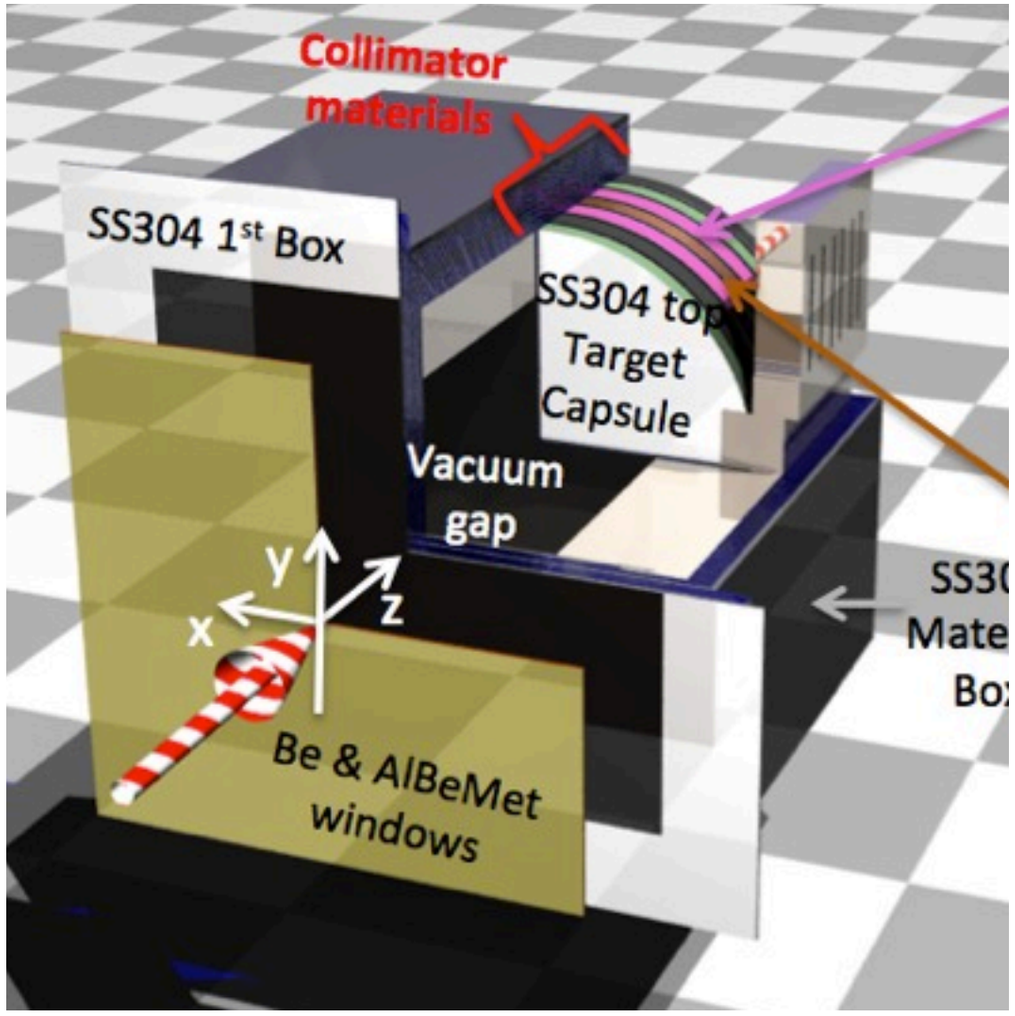
- Starting on a first parameter set that is not pushed but solidly based on achieved parameters of e-beam, solenoid, modulator, BI, ...

- Alessandro, Diego and I just visited FNAL: contacts with engineering teams.

☑ **Started at CERN simulation work on alternatives. Immediate goal is to prepare and perform beam tests in 2015.** *See **Roderik's talk**.*

Irradiation studies at BNL

- **Very important for us!**
  - *Testing new materials for low-impedance: need to decide around summer 2014!*
  - *Interesting scientific program: synergy with tests on Russia and at GSI.*
- **High-energy beam irradiation at BLIP is nearly completed**
  - *Missing 8 days at 200 MeV.*
  - *See **Simos' talk** for first results!*
- **Funding issue being solved by a CERN/BNL contract.**
  - *Could not recuperate LARP money "borrowed" to CC's in 2013.*
  - *Updating list of irradiation tests and analysis to be performed.*
- **I wish that we find an appropriate setup to continue this collaboration beyond the present irradiation campaign!**



Conclusions

- Reviewed various collimation upgrade aspects with emphasis on US-LARP activities!

  LARP contributions are within the main streams of collimation upgrade studies.

- In the last few years, we achieved very important results and developed tighter links with USA laboratories.

  Hollow (and non-hollow) e-lens: simulations and hardware.
  Irradiation and characterization of collimator advanced materials.
  Advanced collimator designs.

  These are exciting topics that attract interested people.

- It is a pity if the US-LARP discontinues the fruitful framework in which these collaboration started and evolved!

- We must find alternative ways to continue to work together on these activities.