R2E and Availability workshop report and Upgrade plans for injection protection absorbers (WP14)

D. Wollmann, J. Uythoven

with input from M. Brugger, B. Goddard, A. Lechner, R. Losito,
L. Rossi, R. Schmidt, B. Todd, S. Uznanski

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.

Outline

- R2E and Availability workshop
  - Objectives and covered topics
  - Main conclusions
- Upgrade plans for injection protection absorbers (WP14)
  - TDIS
  - TCLIA, TCLIB
  - TCDD

R2E and Availability Workshop

14-17 October 2014
CERN
Europe/Zurich timezone

Search

R2E/Availability 2014 Workshop

- Overview
- Timetable
- Dinner Registration
  - Modify my Registration
- Dinner Details

Tue 14/10 | Wed 15/10 | Thu 16/10 | Fri 17/10 | All days

Print | PDF | Full screen | Detailed view | Filter

Session legend

09:00	**Vision for LHC - from LS1 to LS2, past LS2 and during HL-LHC operation**	*Prof. Lucio ROSSI*	*BE Auditorium Prevessin, CERN*	09:00 - 09:30
	Introduction to radiation effects and modeling of radiation damage	*Ruben GARCIA ALIA*	*BE Auditorium Prevessin, CERN*	09:30 - 10:00
10:00	**Radiation tests, methods & facilities and how they relate to reality**	*Markus BRUGGER*	*BE Auditorium Prevessin, CERN*	10:00 - 10:30
	Coffee break		*BE Auditorium Prevessin, CERN*	10:30 - 11:00
11:00	**Introduction to Availability and Re-Cap of Run-1**	*Laurette PONCE*	*BE Auditorium Prevessin, CERN*	11:00 - 11:20
	Availability and Integrated Luminosity	*Andrea APOLLONIO*	*BE Auditorium Prevessin, CERN*	11:20 - 11:50
	Experience from the Experiments	*Jorgen CHRISTIANSEN*	*BE Auditorium Prevessin, CERN*	11:50 - 12:20
12:00	**Lunch**			

- Slides available in INDICO.
- Organizers: M. Brugger, L. Rossi, R. Schmidt, B. Todd, J. Wenninger, D. Wollmann
- 20 – 65 participants during the sessions

Objectives

- Understand **availability limitations** due to **radiation** effects (SEE, TID, DD) as well as other effects onto accelerator **equipment** and quantify the required equipment **performance** to reach the luminosity goals → **Run 2, Run 3, HL-LHC**.
- Identify what is **required** (tools, facilities, expertise) to quantify and mitigate radiation effects on equipment.
- Identify appropriate **mitigation measures**: radiation tolerant developments (tunnel electronics, PC), displacement of sensitive equipment (superconducting links etc.) and other aspects.
- Identify **the long-term requirements** for electronic systems.
- Address **IR3-IR7 life time issues** linked to radiation and equipment maintenance planning.
- Understand how **development of electronics** for radiation environment is addressed in the **LHC experiments**.

Session 1 – Fundamentals of R2E and Availability

Motivation, Methodology, Implications of Single Event Effects (SEE), Availability limitations and Ageing.

- **Vision for LHC** – from LS1 to LS2, past LS2 and during HL-LHC operation - L. Rossi

Methodology and modelling.

- Introduction to **radiation effects** and modeling of radiation damage – R.G. Alia
- **Radiation tests, methods & facilities** and how they relate to reality – M. Brugger
- Introduction to **Availability** and Re-Cap of Run-1 – L. Ponce
- Availability and **Integrated Luminosity** – A. Apollonio

- **Experience** from the Experiments – J. Christiansen

Radiation levels and monitoring

- **Radiation levels** today and in the future – F. Cerutti
- Experience from Past LHC and Injector Operation and scaling to the future – G. Spezia
- **Radiation monitoring**: what do we have and what do we need? - M. Calviani
- Experience from **injectors** concerning radiation levels and radiation damage – J. Saraiva

- **Tracking of faults** and follow-up – J. Janczyk

High Luminosity LHC

Session 2 – Equipment exposed to radiation

Ongoing developments, plans for the next 5 years and requirements beyond.

The Big 4

- RF: Current Systems + Damper – W. Hoefle
- RF: New Systems – R. Calaga
- Power Converters: Control – S. Uznanski
- Power Converters: Power – Y. Thurel
- Cryogenics – J. Casa-Cubillos
- QPS – J. Steckert

Protection

- Interlock Systems – M. Zerlauth
- LHC Beam Dumping System – V. Senaj
- BLM – B. Dehning

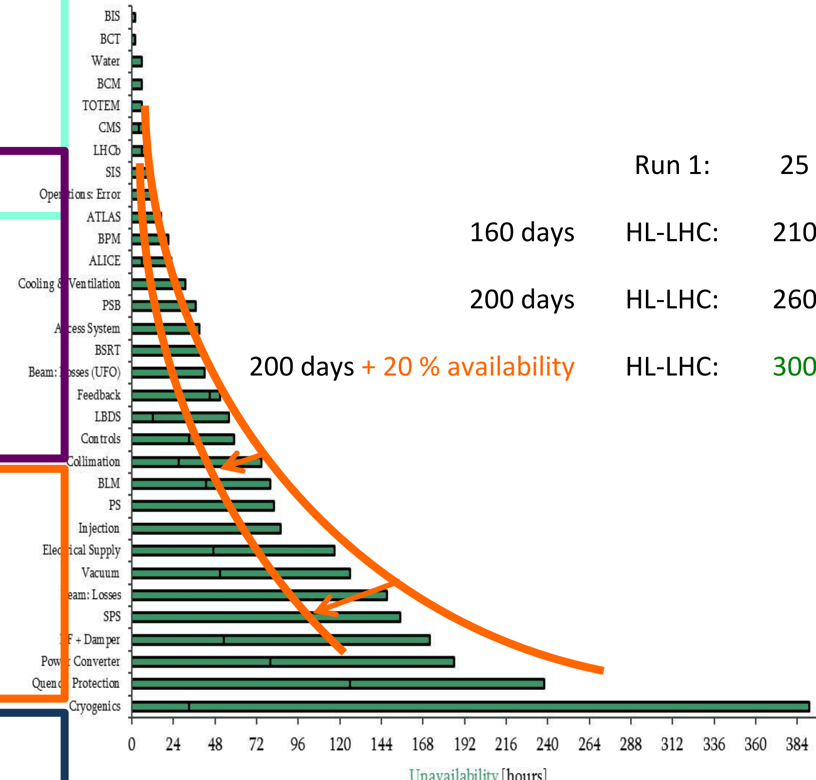
Close to Machine

- Beam Instrumentation – T. Lefevre
- Vacuum Systems – P. Krakowski
- Survey and Alignment – M. Sosin

Infra-structure

- WorldFIP – E. Gousiou
- Electronics in the RE – G. Spiezia

Not complete list of equipment



	Run 1:	25 fb^{-1}
160 days	HL-LHC:	210 fb^{-1}
200 days	HL-LHC:	260 fb^{-1}
200 days + 20 % availability	HL-LHC:	300 fb^{-1}

High Luminosity LHC

Session 3 – Cleaning insertions IR3 - IR7

Radiation damage issues and equipment maintenance planning.

Future radiation levels and their measurement.

- Possible **operational scenarios** and respective loss distributions – B. Salvachua
- Prompt **radiation levels** at critical locations – E. Skordis
- Radiation **monitoring**: what do we have and what do we need – M. Brugger
- Activation constraints, residual dose rate maps and **intervention scenarios** – C. Adorisio
- Assisted and **remote handling** options and tools – M. di Castro

Impact on equipment lifetimes, maintenance procedures, etc.

- **Vacuum** equipment, optimization of dose/intervention times – V. Baglin
- **Magnet** lifetimes, optimization and dose/intervention times – P. Fessia
- **Cryo** equipment, optimization of dose/intervention times – S. Claudet
- **Collimator** equipment, optimization of dose/intervention times – O. Aberle
- **Cables, Optical Fibers & Lights** (including safety LEDs) – J. Devine
- **Alignment** systems & requirements – J.-F. Fuchs
- **Enclosed** section and affected equipment – I. Efthymiopoulos

Session 4 – Longterm vision in respect to R2E and Availability

Two options for Mitigation of R2E effects

- Radiation tolerant **power-converters** status, requirements & strategy – J.-P. Burnet
- **Superconducting links** – A. Ballarino

Summaries

- Summary of Session 1 – D. Wollmann
- Summary of Session 2 – R. Schmidt
- Summary of Session 3 – J. Wenninger

Discussion of options

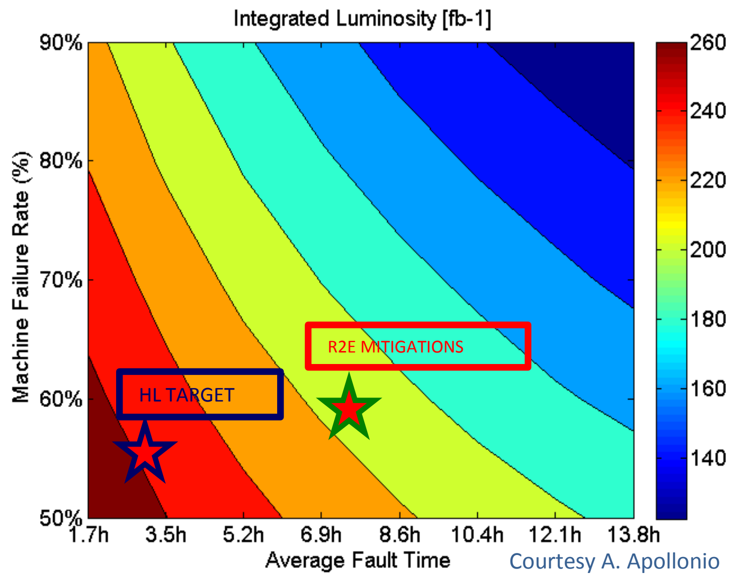
- **Strategy** for the LHC Machine Electronics: limitations and risks – B. Todd
- ADC and **common development** options – G. Spezia
- Possibilities from Experiments – P. Farthouat

Outline

- R2E and Availability workshop
  - Objectives and covered topics
  - **Main conclusions**
- Upgrade plans for injection protection absorbers (WP14)
  - TDIS
  - TCLIA, TCLIB
  - TCDD

Machine availability

- Increasing integrated luminosity in HL-LHC only possible with **longer time** in collision → Machine **availability** becomes key factor.
- To achieve 300fb^{-1}/year **global increase of availability by 20%** required (in addition to already planned improvements; 200 days operation).
- 1/3 of failures/fault time due to R2E affects (→ mitigations during LS1 and run2 [FGC lite]), **2/3 due to other effects**.
- **Effects besides R2E** are likely to play a dominating role in the future → **extend availability studies** to append allowed un-availability per system and extend to **more systems**.
- Possible **shortening of LHC cycle** by installing 2 quadrant PCs for MQs→ ~10% gain for stable beams time.
- Reduction of (generous) **safety margins** in interlock levels (Vacuum thresholds, BLMs, …) could reduce machine failure rate.



Courtesy A. Apollonio

Radiation to Electronics (R2E)

- Change of paradigm: **Mitigation → Prevention**
- **COTS are used** by many equipment teams in (high) **radiation areas → SEEs + TID/DD** in the long-term.
- **Monitoring** of radiation levels (LHC, injectors) in combination with FLUKA studies is key to **understand the radiation fields** and **identify lifetime issues** in equipment → re-launch Measurement and Calculation WG.
- Radiation tolerant **developments ongoing** in many teams (PCs, QPS, Cryogenic, Survey, Communication, …) → ensure availability of development **guidelines** and (digested) **test results**.
- **Testing of components** is essential → **CHARM** radiation test facility is required for the long-term future (in combination with CC60 and external facilities).

Tracking of faults

- Tracking of faults is of paramount importance for an efficient **detection and mitigation** of faults and **improvement of availability**.
- Accelerator fault tracker (project/tool):
  - Track faults which affect **accelerator operation** → ready for restart of LHC.
  - Track **faults in equipment**, which do not directly affect operation.
  - Integration of equipment group data is possible.
  - **Broad interest** has been signaled by equipment teams: R2E, EPC, LBDS, …

LHC Physic Experiments

- **> 25 years experience** with radiation hard electronics.
- **New generation** of systems under development.
- **Common development** of components and systems for all experiments (ASICs, DC-DC converters, ADC, optical transceiver, …).
- **Electronics coordinator** in each experiment.

Electronics equipment

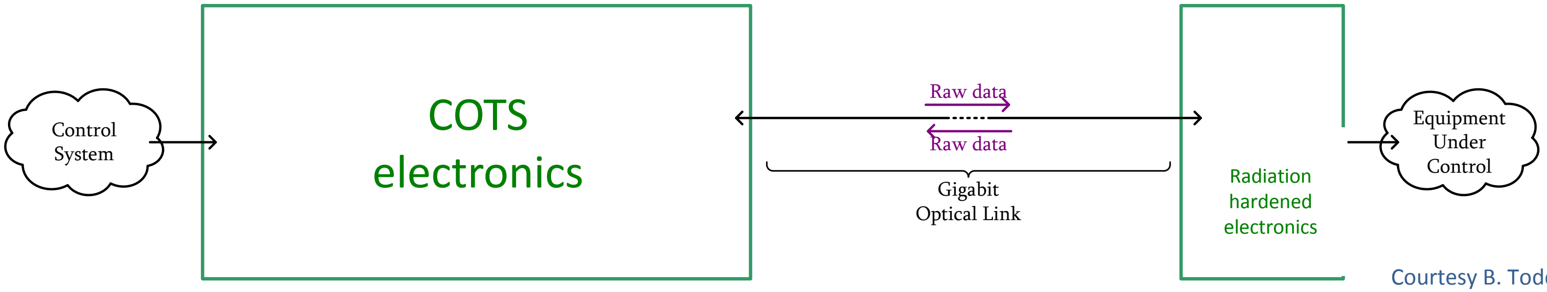
- Equipment needs to be ready to **run beyond 2035** and stand up to 4000fb^{-1}.
- **Majority** of electronic systems **has to be replaced** (ageing, obsolescence) before or during HL-LHC → new machine.
- Use **synergies** between teams → possibility of development of **common** radiation tolerant/hard components?
- Implement strategy for **highly available systems**.
- Consider using **components from PH**.
- Continue and **extend** close collaboration with PH..
- **Management of spares** (1000s of boards for >25years) will become a challenge for many teams.
- Identify and if necessary perform radiation tests with **electronics in the REs**.

LHC Cleaning insertions (IR3-IR7)

- Activation in IR7 will become **comparable to hottest region in injectors** for HL-LHC (35x LS1).
- FLUKA calculations predict **~1MGy / 40fb^{-1}** up to LS3 on **MBW and MQW**.
- **No** known **lifetime issues** until LS3 for the equipment, but first **problems encountered** in cables/connectors (profibus) for vacuum equipment.
- General interest and **support for robotics** solutions (survey, vacuum, …) → **data transmission** as bottleneck.
- **Better understanding** of losses in IR7 required and their **dependency** on operational parameters.
- **2015/16** radiation data essential **to refine the predictions** → improved monitoring required (including radical and ozone levels).
- Better understanding of **future radiation levels** important for the choice of replacement date of MQWs/MBWs → activation levels should still **allow interventions** on them.

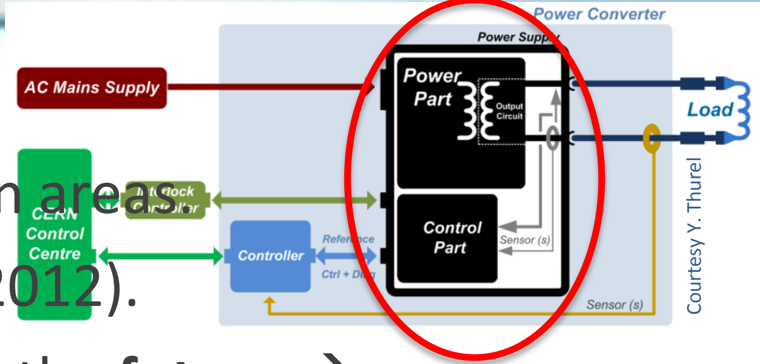
Communication links

- WorldFIP is **required** by many teams and needs therefore to be **continued until the end** of HL-LHC → complete insourcing of technology.
- **Low bandwidth** communication links require **smart electronics close to** equipment in **radiation** areas.
- New **high bandwidth**, radiation tolerant **field bus required** by several systems (QPS, BLMs, …).
- **GBT link** available from LHC-Experiments?



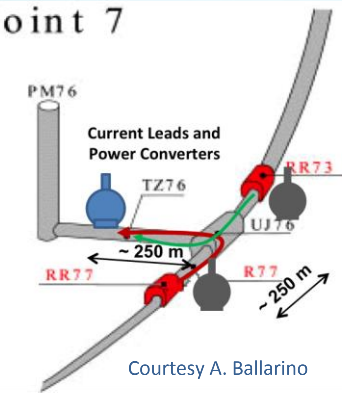
Courtesy B. Todd

Power Converters (PC)



- > 1000 (of 1700) PC installed in radiation areas.
- Impressive real **MTBF of PC ~ 72000h** (2012).
- **PC control: radiation tolerant FGClite** is the **future** → implementation during run2 will go to end of HL-LHC.
- **600A, 4-6-8kA radiation tolerant** power parts are under development → **no technological show stoppers** for implementation in **LS2**.
- Consolidation of **60A and 120A** converters **to be envisaged**.
- **PC** can be built for different current levels **compatible to HL-LHC radiation environment**.
- < 100 piquet calls/year (< 5 dumps/year due to SEE), 1 dump/week due to PCs remaining in the long term.
- 60A PCs: **improve availability** by compensating single trips with **orbit feedback**.

Superconducting links



Courtesy A. Ballarino

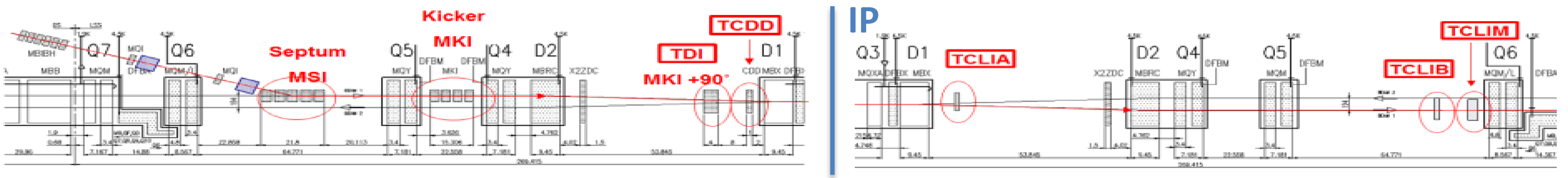
- IR7:
  - **~500m links** from RR77 (RR73) to TZ76.
  - Powering of **48 x 600A circuits** via the link (48 cables + spares) – 13kA circuits stay in DFB.
  - HTC strands (MgB2), cables and flexible cryostat **available**.
  - Cold powering system **under development**.
  - **Technical solution** for routing of the link exits.
- IR1/5:
  - Powering of **2 x 13kA, 12 x 6kA and 28 x 600A** circuits.
  - Development of **high current cable** under way.
  - Baseline: SC Links from the **tunnel to the surface** but on-going studies on need for civil engineering for Hi-Luminosity equipment may offer the possibility of **using new underground caverns** for housing the new electrical feedboxes (DFBs).
  - Implementation foreseen for LS3.

See detailed talks on Sc. links in **WP6 parallel session** on Tue., Wed. and Thu.

Outline

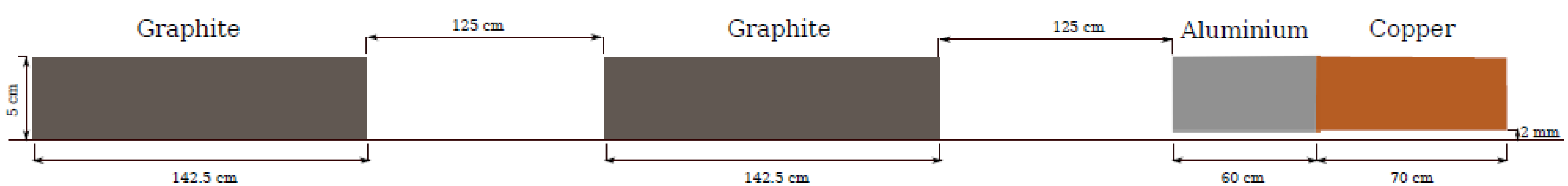
- R2E and Availability workshop
  - Objectives and covered topics
  - Main conclusions
- Upgrade plans for injection protection absorbers (WP14)
  - TDIS
  - TCLIA, TCLIB
  - TCDD

WP14: Injection protection upgrade



- Injection protection IP2 and IP8 : **to be installed in LS2**
- Absorber design taking into account
  - **Protection** of downstream elements (D1, Q6 etc.).
  - **Survival** of absorber, especially the TDIS.
  - **Impedance** considerations.
  - Experiments: opening angle for ALICE ZDC.
- **TDI → Segmented TDIS**
  - **Most important** and complicated element for injection protection
  - Decided to go for **3 x 1.5 m modules**
    - 2 x low Z (graphite) + 1 x high Z (materials to be optimized)

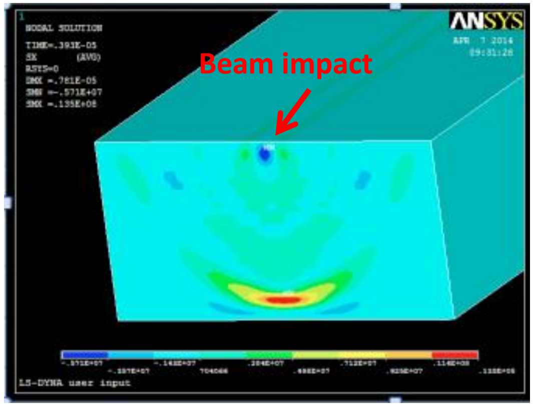
See J. Uythoven, parallel session WP5/7/14 Wednesday morning



TDIS – Most critical

- **Protection** of downstream elements
  - **TDIS** can have about same integrated absorber length as present TDI
    - Critical case is **grazing impact** (~1 σ), almost independent of absorber length.
    - **Full impact** of HL-LHC beams is **fine** with present length.
- **Survival** of absorber: TDIS
  - Critical is again grazing impact (~ 1 σ)
    - Presently assume graphite as low Z absorber.
    - Research on materials like **3D Carbon/Carbon.**
    - Material can be ‘exchanged’ during design phase.
    - **HiRadMat tests** foreseen in 2015.

A. Lechner, N. Shetty, G. Steel, F. Lorenzo Maciariello, A. Perillo Marcone



Beam	Emit. x,y [μm]	N_b [p/bunch]	# bunches	M-C Safety Factor
Standard	2.0	2.3e11	288	1.01
BCMS	1.3	2.0e11	288	0.90
BCMS	1.3	2.0e11	240	1.43

Considering no error from energy deposition calculations.

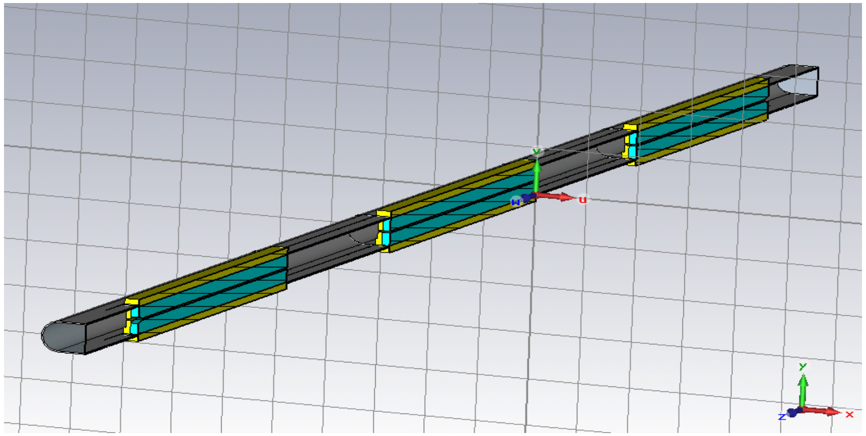
- Deliverable D2.6: Specification of Machine and Beam Parameters:

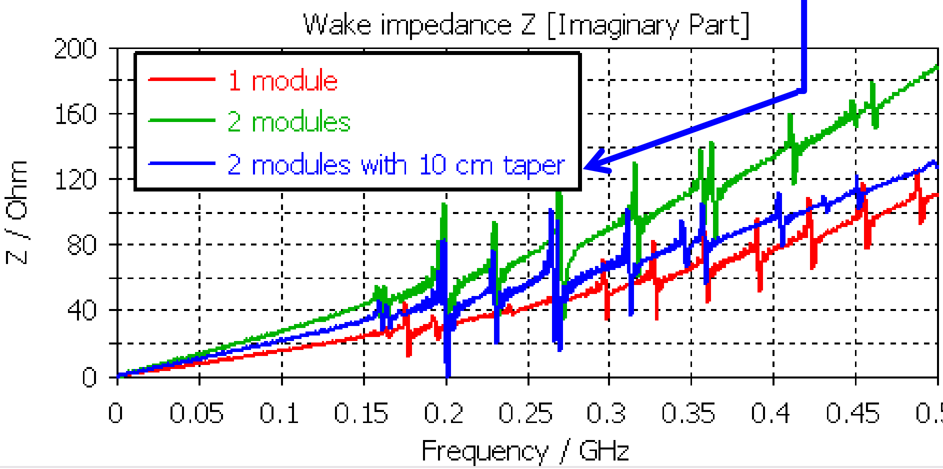
It must be noted that the feasibility of a design of the injection absorber TDIS to absorb safely the nominal and especially BCMS beam with the bunch population <u>listed in Table 1</u> and small emittances is very challenging and it is presently under study.

2.3×10^{11} p+/b

TDIS impedance

- Present TDI impedance is critical due to **beam induced heating** causing **damage** to the TDI and **outgassing.**
- Addressed with priority in the new design
  - **Improve the cooling**, ensure it is cooling what and where it should.
  - **Surface coating**.
  - **Closure of gap** between the jaw and the beam screen for different jaw positions.
  - **Evaluation** of impedance of the interconnections for different jaw positions.
- Large parameter space to **optimize** including tapering of the absorbers
  - First simulations made, positive effect of 10 cm taper.
  - Beginning of next year second iteration with preliminary design.



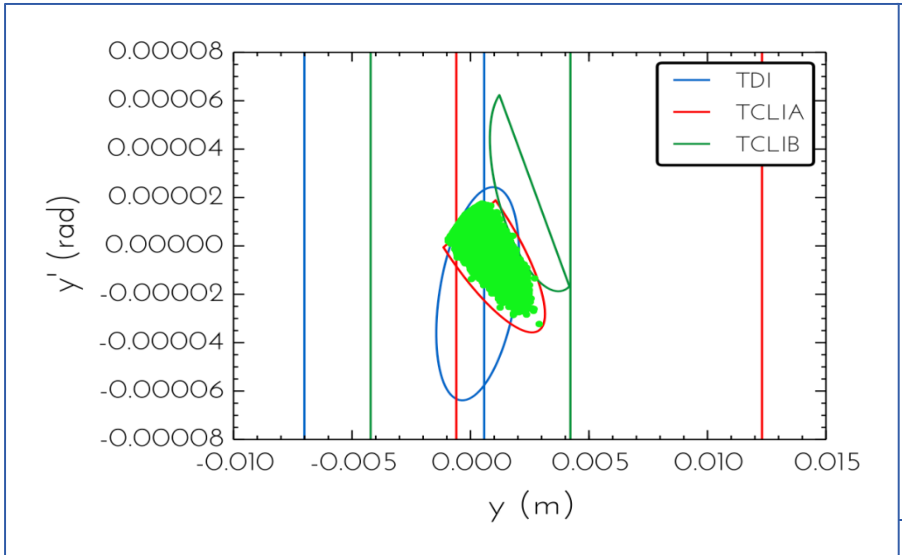


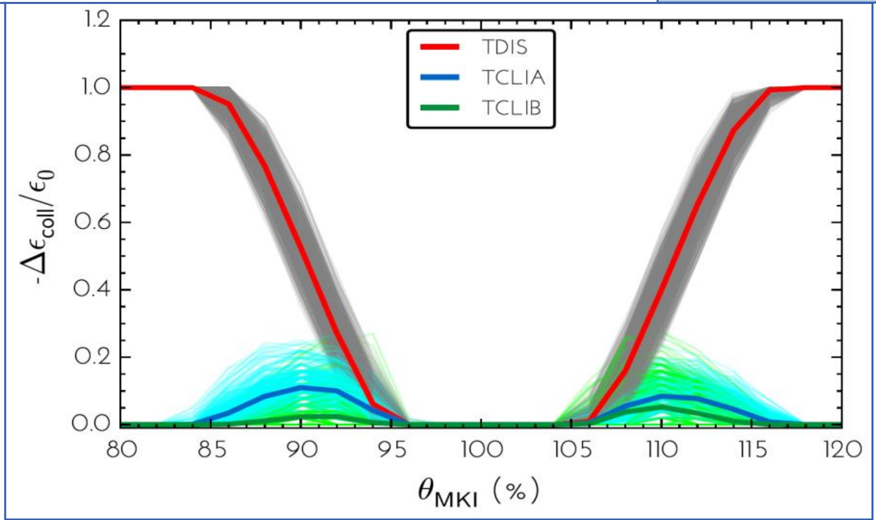
B.Salvant, N.Biancacci, E.Metral, A.Danisi, O.Frasciello (INFN), M.Zobov (INFN)

TCLIA and TCLIB

- Initial tracking studies show relatively **small beam impact** on TCLIA and TCLIB.
- Likely **not necessary** to be replaced. Final **decision** before the **end of 2014** following more detailed tracking studies.
- However, **opening angle** TCLIA might need to be **enlarged** for ALICE ZDC, Follow-up TREX & WP8.
  - Sufficient argument to replace TCLIA in IP2?
- Damage levels of downstream Q6 **should not be reached.**

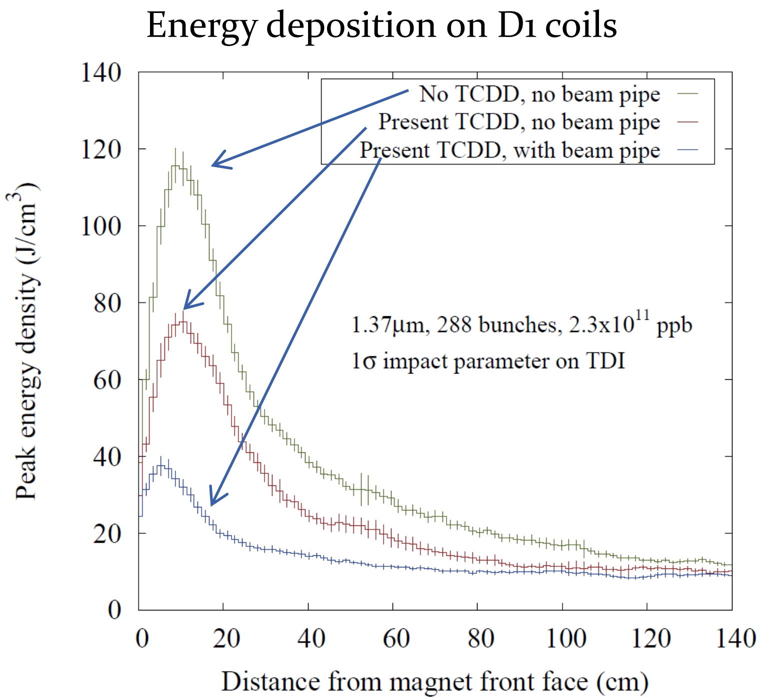
F.Velotti





Beam impact on TCLIA and TCLIB assuming uniform 5 σ particle emittance, but realistic machine errors: gives very pessimistic results. Proper particle tracking ongoing.

TCDD: mask in front of D1

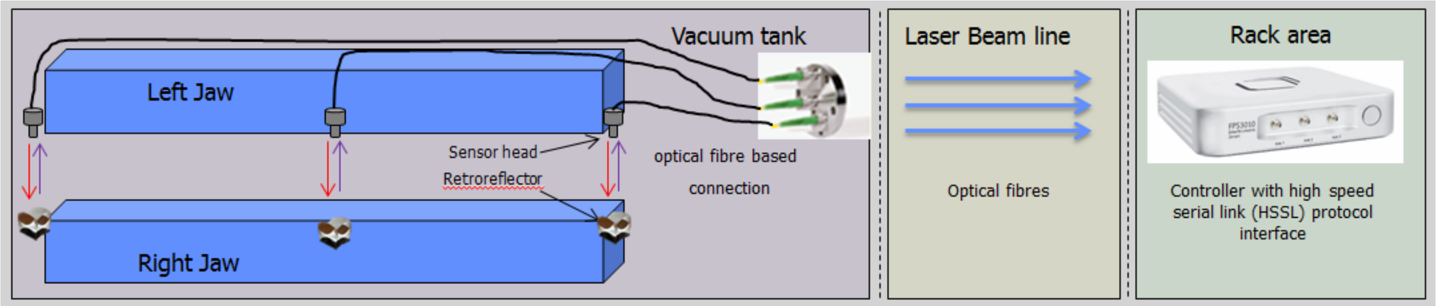


- Results depend strongly on geometry.
- Beam pipe is shielding as much as the TCDD.
- Improvements – of about a factor 2 – can be obtained by reducing TCDD aperture and bringing TCDD closer to the D1.
- Study mask within the D1 cryostat.

- Protection of D1 **against damage**.
- Quench cannot be avoided.
- Grazing impact on TDI.
  - Effect on D1 rather **independent** on beam size.
- Peak power deposition of **37 J/cm^3**.
- What is the damage limit of the D1?
  - Previously published value of 50 J/cm^3 not correct.
  - Need at least a safety margin of factor 3.
  - Study has been **started** by TE-MPE but results **not expected in time**.
  - **Collecting safe/damage limit estimations from magnet experts → decision on TCDD upgrade 12.2014.**

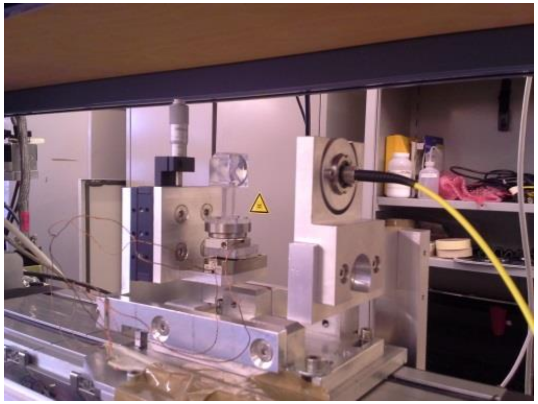
See A. Lechner, parallel session WP5/7/14 Wednesday morning

TDI(S) interferometric system

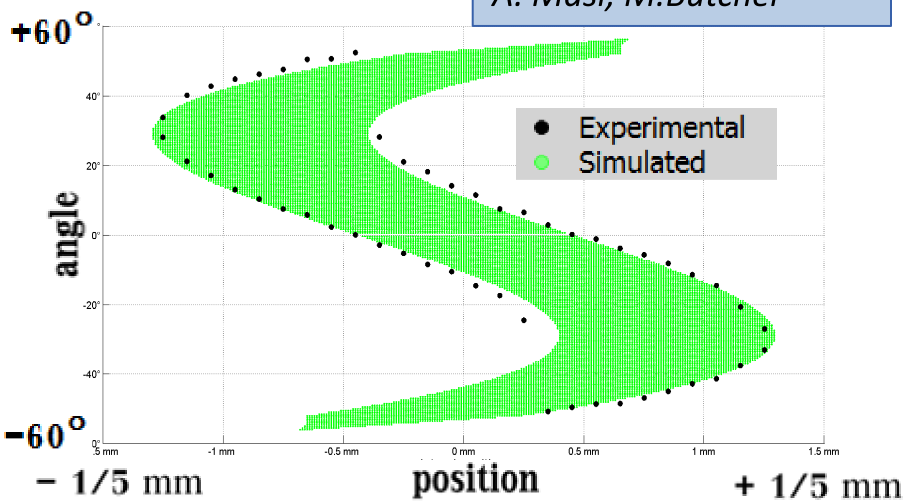


- Interferometry very important for safety as to **guarantee the correct positioning** of the TDI jaws in combination with the Beam Energy Tracking System.
- To be installed on spare TDIs for Run II, installation during Run II. Test bench developments, new sensor heads, feed through tests: so far so good.

A. Masi, M.Butcher



Test Bench Set-up for experimental alignment characterisation



Comparison theoretical and measured tolerances

Conclusions

Upgrade of injection protection devices

- Upgrade of injection protection absorbers, including the 3 module TDIS, to be **installed in LS2**.
- **TDIS** feasibility withstanding **nominal** HL-LHC beams is **challenging** → **new absorber materials** under study.
- **Damage limit** of D1 (IP2/8) to be determined in 2014 → replacement of TCDD absorber yes/no.

R2E and Availability workshop

- **Machine availability** will become a **key factor** for integrated luminosity at HL-LHC → fault tracking can provide essential input.
- **R2E: Mitigation → Prevention**; Radiation monitoring in LHC / Injectors and testing of components (CHARM @ CERN).
- Majority of **electronic systems** has to be **replaced** before or during HL-LHC → use synergies between teams and with LHC physics experiments.
- Low bandwidth **communications links** require smart electronics close to equipment in radiation areas. → new **high bandwidth,** radiation tolerant field bus **required** by several systems (QPS, BLMs, …).
- Many power converters will remain in areas with radiation → the **feasibility of radiation tolerant PCs** for different current levels has been shown.
- **SC links** for IP7 on track for installation during LS2. Sc link IP1/5 development ongoing for LS3 installation.

END