BEAM INDUCED RF HEATING

B. Salvant, O. Aberle, G. Arduini, R. Assmann, V. Baglin, M. J. Barnes, W. Bartmann, P. Baudrenghien, O. Berrig, C. Bracco, E. Bravin, G. Bregliozzi, R. Bruce, A. Bertarelli, F. Carra, G. Cattenoz, F. Caspers, S. Claudet, H. Day, M. Garlasche, L. Gentini, B. Goddard, A. Grudiev, B. Henrist, R. Jones, O. Kononenko, G. Lanza, L. Lari, T. Mastoridis, V. Mertens, E. Métral, N. Mounet, J. E. Muller, A. A. Nosych, J. L. Nougaret, S. Persichelli, A. M. Piguiet, S. Redaelli, F. Roncarolo, G. Rumolo, B. Salvachua, M. Sapinski, R. Schmidt, E. Shaposhnikova, L. Tavian, M. Timmins, J. Uythoven, A. Vidal, J. Wenninger, D. Wollmann, M. Zerlauth (CERN, Geneva, Switzerland), P. Fassnacht, S. Jakobsen (ATLAS-ALFA), M. Deile (TOTEM).

Abstract

After the 2011 run, actions were put in place during the 2011/2012 winter stop to limit beam induced radio frequency (RF) heating of LHC components. However, some components could not be changed during this short stop and continued to represent a limitation throughout 2012. In addition, the stored beam intensity increased in 2012 and the temperature of certain components became critical.

In this contribution, the beam induced heating limitations for 2012 and the expected beam induced heating limitations for the restart after the Long Shutdown 1 (LS1) will be compiled. The expected consequences of running with 25 ns or 50 ns bunch spacing will be detailed, as well as the consequences of running with shorter bunch length.

Finally, actions on hardware or beam parameters to monitor and mitigate the impact of beam induced heating to LHC operation after LS1 will be discussed.

INTRODUCTION

The quest for higher LHC luminosity required a significant increase of the proton beam brightness in 2011[1] and 2012 [2]. In particular, both number of bunches and bunch intensity were pushed to the limits of what was available from the injectors. Increasing these intensities is known to increase beam induced heating and in 2011 indeed, several beam induced heating problems were encountered in the LHC [3, 4, 5] and are summarized in Table 1. Temperature increase in LHC devices can cause several issues (damage, delays or dumps).

This contribution deals with heating caused by the RF fields generated by the beam interacting with the longitudinal beam coupling impedance of its surrounding equipment, and is a follow-up of several reviews performed since June 2011 when heating issues started to become visible [3-10].

The equations for this beam induced RF heating have been covered in particular in [4, 5, 11]. We recall here for reference the power P_{loss} lost by a beam composed of M equispaced equipopulated bunches of N_b protons travelling in the aperture of an LHC equipment of longitudinal impedance Z_{long} is [6]:

$$P_{loss} = 2\left(eMN_b f_{rev}\right)^2 \left(\sum_{p=1}^{\infty} \mathrm{Re}\left[Z_{long}\left(2\pi pMf_{rev}\right)\right] \times Powerspectrum\left(2\pi pMf_{rev}\right) \right)$$

where e is the proton charge, f_{rev} is the revolution frequency, and *Powerspectrum(f)* is the power spectrum of the bunch as a function of frequency.

Table 1: Summary of LHC equipment heating in 2011 and prospects for 2012 before the run[*].

equipment	**Problem**	**2011**	**Expected 2012**
VMTSA	Damage		replaced
TDI	Damage		
MKI	Delay		
TCP_B6L7_B1	Few dumps		
TCTVB	Few dumps		2 TCTVBs removed
Beam screen Q6R5	Regulation at the limit		
ALFA	Risk of damage		
BSRT	Deformation suspected		

[*] The colour code indicates the need for follow up of the considered heating problem on LHC operation after the 2011 run and what was expected for 2012. During the winter shutdown 2011-2012, 2 TCTVBs (out of 4) were taken out of the machine (including TCTVB.4R2, which was heating the most), and the VMTSA double bellow module was reinforced [10]. Black means damaged equipment; red means detrimental impact on operation (dump or delay or reduction of luminosity); yellow indicates need for follow up; green means solved.

After the first LHC power spectrum measurements at the end of 2011 [12], the beam spectra measurements became much more systematic in the second half of 2012.

In the following chapter, the observations of beam induced heating on equipment during the 2012 run are gathered.

OBSERVATIONS AND LIMITATIONS DURING THE 2012 RUN

Example of heating during physics fills

The example of temperature increase on kickers, collimators and ALFA detector for 4 fills in mid-November 2012 is shown in Fig. 1.

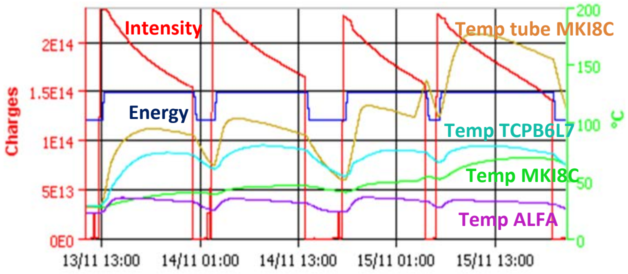

Fig.1: extraction from the logging database for the beam intensity (red) and energy (dark blue), along with the temperature of a "tube" probe of the injection kicker MKI-8C (orange), the temperature of the skew primary collimator TCP.B6L7.B1 (light blue), the temperature of a "magnet" probe of the injection kicker MKI-8C (green) and the temperature of one probe of the ALFA detector (purple).

Summary of observations in 2012

The suspected beam induced heating limitations reported by/to the impedance team in 2012 have been gathered in Table 2, and compared to the situation in 2011.

Table 2: Summary of LHC equipment heating during the 2012 run and comparison with what was expected before the run[†].

equipment	Problem	Expected 2012	What happened in 2012
VMTSA	Damage		replaced
TDI	Damage		Still problems even in parking position
MKI	Delay		MKI8D (MKI8C after TS3)
TCP.B6L7.B1	Few dumps		Interlock increased
TCTVB	Few dumps		Interlock increased
Beam screen Q6R5	Regulation at the limit		Disappeared since TS3. Correlation with TOTEM?
ALFA	Risk of damage		Due to Intensity increase
BSRT	Deformation suspected		damage

The following paragraphs will review the studies on these LHC elements in more detail.

VMTSA double bellow

At the end of the 2011 run, 8 bellows (out of 20) were found damaged.

Following studies by TE/VSC, the LRFF working group was mandated to understand the issues with LHC RF fingers. Concerning the VMTSA, the LRFF working group concluded that:

- simulations and measurements showed that there is no problem if good contact is ensured;
- consolidation of the design is needed to avoid bad contacts;
- 8 modules should be reinstalled with new shorter RF fingers, ferrite plates and reinforcement corset (see Fig. 2)

No problem of heating was observed since then (both on vacuum gauges and temperature).

The plans for LS1 are to remove all these modules and identify other modules that could fail.

[†] The colour code indicates the impact on operation of the considered heating problem on LHC operation after the 2011 and during the 2012 runs. Black means damaged equipment; red means detrimental impact on operation (dump or delay or reduction of luminosity); yellow indicates need for follow up; green means solved.

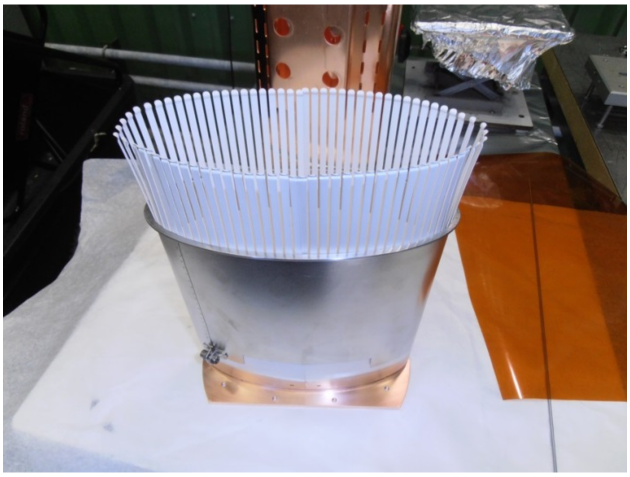

Fig.2: picture of the new shorter fingers inside the reinforcement corset (courtesy B. Henrist, TE/VSC).

TDI injection protection collimator

Abnormal deformation of the two TDI beam screens was found during the winter shutdown 2011-2012 [13]. Temperature, vacuum, and jaw deformation during the run suggested significant heating as the TDIs were not retracted to parking position. Electromagnetic simulations confirmed that the heating can be significant. It is however not completely clear that beam induced heating alone generated the damage. Both TDIs were left in that state as there was no time to prepare a new design and a reinforced spare was prepared by EN/STI.

During the 2012 run, suspicious pressure curves could indicate that additional heating occured in or close to the TDI4L2 since mid-2012 (see Fig. 3). Many mechanical issues occurred on both TDIs towards the end of the 2012 run [14], and RF heating in 2012 could potentially have made things worse.

Current plans for LS1 include reinforcing the beam screen but it is not clear if it will be enough in view of the recent problems: in particular it will not decrease the heating to the jaw.‡

‡ After the workshop, the feasibility to add a thin copper coating is now being studied to limit RF heating to the jaw, as proposed already proposed in [5].

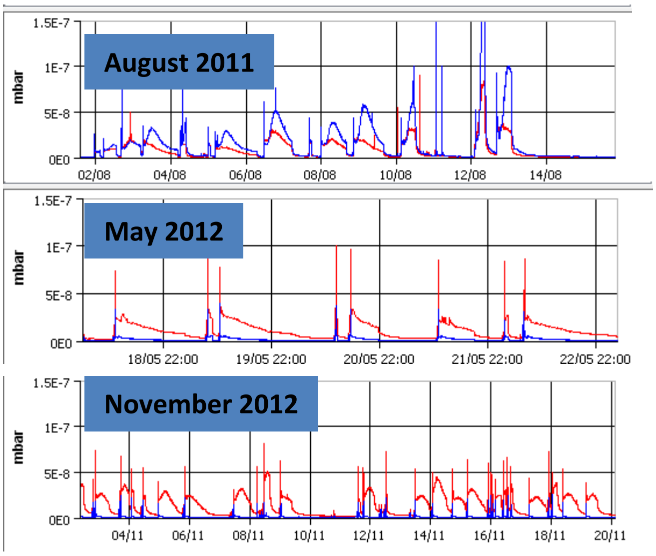

Fig. 3: pressure at TDI.4L2 (red) and TDI.4R8 (blue) in August 2011 (top), May 2012 (center), and November 2012. Even though the jaw was retracted to parking position throughout 2012, signs of beam induced heating became visible again in November 2012 on TDI.4L2.

MKI injection kickers

Some MKIs have delayed injection after a dump by up to a few hours. Electromagnetic simulations and measurements as well as thermal simulations are consistent with observations (despite the very high complexity of the device). Extensive studies have been performed within the MKI strategy meetings [15] to:

- reduce the electric field on screen conductors,
- reduce the longitudinal impedance,
- improve heat radiation from the ferrite by increasing the tank emissivity.

Selected bake-out jackets were removed and indeed reduced the measured magnet temperature by resp. 3°C to 7°C on resp. MKI8B and MKI8D: these reductions correspond to ~15% of the measured temperature rise above ambient. However it is preferred, in the future, to keep the bake-out jackets on the tanks [15].

Before the technical stop 3 (TS3) at the end of September 2012, the most critical kicker was MKI8D. Bench measurements and simulations had predicted that a new MKI design - with 19 screen conductors - would better screen the ferrite from the beam than the current MKI design – with only 15 screen conductors [16] (see Fig. 4), and would hence significantly reduce the beam induced heating. During TS3, this MKI8D kicker was replaced by a spare with 19 conductors and a clear improvement was observed for this kicker (see Fig. 5).

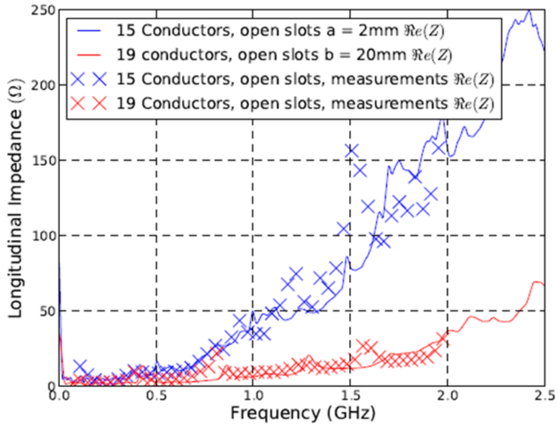

Fig. 4: Comparison between 3D electromagnetic simulations (full lines) and bench measurements (crosses) of the real longitudinal impedance of MKI kickers as a function of frequency with 15 conductors (in blue) and with 19 screen conductors (in red) [15, 16].

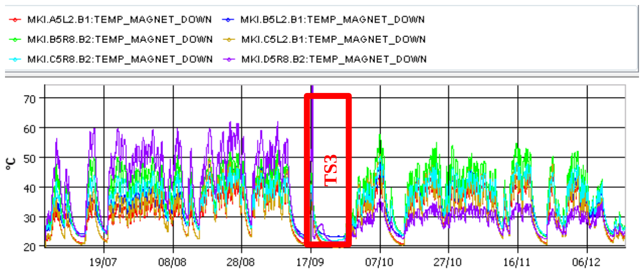

Fig. 5: Temperatures measured by the "magnet" PT100 probes of MKI kickers, before and after TS3. During TS3, magnet MKI8D (in purple)), which had 15 screen conductors prior to TS3, was replaced with a new design with 19 screen conductors, and it is observed that it moved from the hottest magnets to the coolest thanks to this change, which is very promising for the upgrade of all MKIs during LS1.

However, after this same TS3, it was realized that kicker MKI8C became limiting, and it was traced to a large temperature on the probe placed on the tube, which measures the temperature of ferrite toroids outside of the magnet yoke (up to 190°C). Analysis of kicker rise time and delay shows that the kicker performance is not affected by the increase of temperature on the probes [15]. A plausible hypothesis is that the additional source of heating is not the magnet ferrites but lies next to the "tube Up" probe. In this case the temperature increase should not directly affect the kicker performance and the interlock level for that magnet was increased accordingly.

Plans for LS1 are followed up closely by the MKI strategy meetings. All MKIs are planned to be upgraded in order to:

- Reduce the longitudinal impedance by improving the screening of the ferrite from the beam:
  - o Reduce the high electric field of the screen conductors (tests are planned early January to confirm promising results from simulations) to permit more screen conductors to be installed,
  - o Aim at full complement of 24 screen conductors (instead of 15 or 19 screen conductors),
  - o Impedance bench measurements on a smaller scale setup to confirm promising results from simulations.
- Improve the radiation of heat by increasing the emissivity of the tank (tests of a prototype on-going). Active cooling with fluid would be a very efficient option but it is very difficult to envisage inside vacuum due to high voltage operation - however it is an option being considered for under the bake-out jacket.
- Reduce the likelihood of a spark from the beam screen conductors (by reducing the electric field. In addition a coating is under consideration [15]).
- Understand and suppress the anomalous heating presently exhibited by the ferrite toroids of MKI8C.

TCP.B6L7.B1 skew primary collimator

The TCP.B6L7.B1 collimator caused beam dumps in 2011 and 2012, and the steady increase of its jaws' temperature during physics fills with increasing intensity required increasing the interlock to 95°C.

It is important to note that the temperature of all other primary collimators (including its symmetric for B2) has increased to less than 38°C, and with a pattern that indicates that it is due to beam losses and not beam induced heating.

Joint analysis of heat deposition and measured temperatures by EN/MME and BE/ABP points to an absence of efficient cooling, and hence a suspected non-conformity of the cooling system is expected [18, 19].

It is interesting to note that beam induced heating was clearly observed but sharp heating increase was also observed to be correlated to beam losses.

Nothing wrong was seen with visual and X-ray inspections by EN/STI and EN/MME on both cooling systems and RF fingers at several occasions.

Plans for LS1 include a thorough check of the cooling system by EN/STI and the collimation working group. In addition, this collimator will be replaced with a spare for a detailed inspection.

ALFA Roman pot

The ALFA detectors' temperature reached 42°C close to the inner detector and entered the range that is expected to lead to detector damage (around 45°C), see for instance on Fig. 1. The ALFA temperature became particularly critical at the end of October 2012 on beam 2 when strong changes in longitudinal beam spectrum at flat top were observed [9].

Joint studies by BE/ABP and ATLAS-ALFA showed that the temperature increase is consistent with impedance heating of the ferrite damper ring (which is efficiently preventing more harmful heating) [19].

The TOTEM detector has a similar geometry but its inner detector structure did not suffer from temperature increase as it had been designed with efficient active cooling. In fact, during two days with stopped detector cooling, similar temperature increases as in ALFA were observed. The metallic box around the detector was however not cooled.

As emergency measures, the ALFA team removed the bake-out jackets and added some fans.

Plans for LS1 foresee the implementation of a new design with reduced impedance and active cooling in order to allow for a more comfortable operational margin in 2015.

Beam screen temperature regulation

Until TS3, the Q6R5 standalone had no margin for more cooling. This could have been an issue for 7 TeV operation.

Tests were performed (Xrays on both bellows and cooling circuit) and so far nothing special was seen that could explain the singularity of Q6R5.

Since September 2011 (TS3), the situation improved significantly. Only a few fills have been affected since then, in particular the fills following a movement of the neighbouring TOTEM roman pot, indicating a possible correlation (through vacuum or losses or both). This is under study with the TOTEM, TE/VSC and TE/CRG teams.[§]

During LS1 the valves for standalones will be replaced to allow a higher cooling flux.

BSRT synchrotron light monitor

The beam 2 synchrotron light monitor (BSRT) mirror and support suffered from damage that could be due to significant heating [20]. Indeed the reduction of B2 bunch length was observed to increase the temperature of BSRT B2 measured outside vacuum (see Fig. 6).

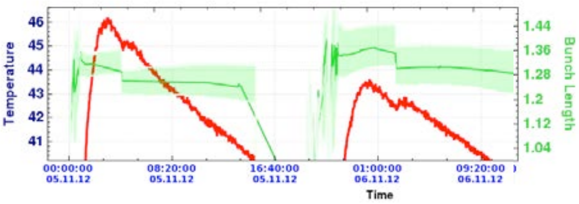

Fig. 6: temperature of the BSRT B2 (in red) and B2 bunch length (in green). The decrease of B2 bunch length on Nov. 6^{th} generated an increase of the temperature of the BSRT B2, and can be explained by beam induced heating.

Electromagnetic simulation studies had been underway before the incident as there were signs of deformation to beam induced heating already in 2011 [4]. A combined effort between BE-BI, BE-ABP, BE-RF and EN-MME was invested to understand the heat deposition, to assess whether the Curie temperature of the ferrite has been reached, and to look for adequate solutions for the end of the run and for after LS1. There was still no clear conclusion at the moment of the workshop as the temperature probes were installed outside of the tank.[**] A BSRT working group was set up within BE/BI to find a more robust design for operation after LS1 [20].

TCTVB tertiary collimators

Despite active cooling, the 2 TCTVBs in IR8 consistently heat by around 10 degrees in most fills.

As mentioned in the introduction, the most critical IR2 TCTVB from the point of view of heating was taken out in 2011 for background reasons with the other IR2 TCTVB.

It is interesting to note that beams were dumped by TCTVB.4L8 temperature when the longitudinal blow up stopped working on May 30^{th} 2012. This could be a worry if the bunch length is significantly reduced in physics, but the two remaining TCTVBs in IR8 should be replaced by single beam TCTPs after LS1. In any case, the bunch length reached at this occasion was much lower than the nominal bunch length: (0.85 ns instead of 1-1.05 ns).

EXPECTATIONS AFTER LS1

Beam parameters

After LS1, possible beam parameters include:

- Nominal beam at 6.5 TeV: ~1.15 10^{11} protons per bunch (p/b) with 25 ns bunch spacing
- Current beam at 6.5 TeV: ~1.6 10^{11} protons per bunch (p/b) with 50 ns bunch spacing
- New high brightness 25 and 50 ns beam with the h=9 option with batch compression, merging and splitting (BCMS), obtained so far with slightly lower intensities than the current production schemes [21].

Another crucial point for estimating beam induced heating after LS1 is the choice of operating bunch length. Before LS1, the operating full bunch length was set between 1.2 ns and 1.3 ns whereas nominal bunch length is below 1.05 ns.

Effect of bunch spacing on beam induced heating

Assuming the same bunch length and same bunch distribution for 50 and 25 ns bunch spacing, the equation in the introduction expects the same beam spectrum with 25 ns spacing as with 50 ns, but with half of the peaks.

In the frame of this assumption, switching to 25 ns for the case of a broadband impedance should yield an

[§] Other possibilities have been investigated since this workshop: in particular (1) electron cloud and (2) the consequences of the fact that the detector itself is cooled and not the metallic pot, combined with the supposed absence of high temperature bake out of the ferrite, which could lead to large outgassing when heated up.

[**] In 2013, a test was allowed after temperature probes were installed inside the vacuum and it was observed that the temperature of the ferrite reached well above its Curie temperature.

increase by a factor $M^{25}*(N_b^{25})^2/\ M^{50}*(N_b^{50})^2 = 1.05$, where M^{50}=1380, M^{25}=2808, N_b^{50}=1.6 10^{11} p/b, Nb^{25}=1.15 10^{11} p/b.

Switching to 25 ns for the case of a narrow band impedance falling on a beam harmonic line (i.e. its resonant frequency is $f_{res}= k*20$ MHz with k an integer) should yield an increase by a factor $(M^{25}*N_b^{25})^2/(M^{50}*N_b^{50})^2 = 2$ if $f_{res}= 2*k*20$ MHz with k an integer, or a total suppression if $f_{res}= (2*k+1)*20$ MHz with k an integer.

The effect of switching to 25 ns could therefore have a detrimental impact on some of the undamped narrow band resonators. Among the elements which are observed to suffer from beam induced heating, most are expected to be broadband and should not be affected by the change of bunch spacing (except the VMTSA before the 2012 run and the geometric TDI contribution, and of course all elements for which no observable has indicated issues).

Effect of bunch length on beam induced heating

Assuming the same distribution for various bunch lengths and bunch spacing, reducing the bunch length is expected to extend the beam spectrum to higher frequencies homothetically (see Fig. 7).

As a consequence, switching to lower bunch length for a broadband impedance with a resonant frequency below around 1.2 GHz leads to a regular increase of beam induced heating in general. Switching to lower bunch length for narrow band resonances enhances some resonances, damps others, and may excite higher frequency resonances.

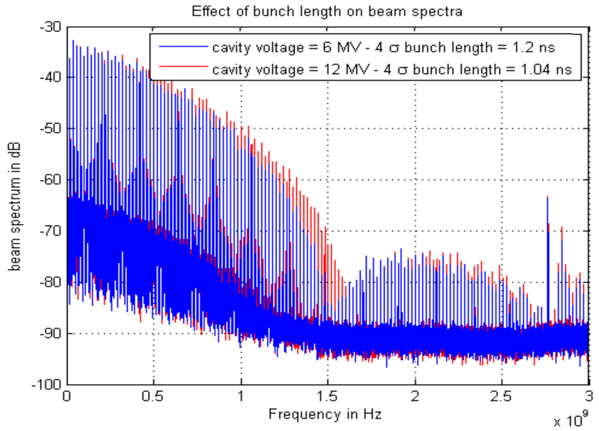

Fig. 7: effect of reducing bunch length on measured LHC beam spectrum (in dB) from 1.2 ns (in blue) to 1.04 ns (in red). The notch of the distribution is observed to shift from 1.5 GHz to 1.7 GHz. The peak at 2.7 GHz is believed to be due to a limitation in the acquisition bandwidth.

Observing the impact of changing beam spectrum and bunch length in LHC

In order to predict the situation after LS1, two tests were performed during the run: an OP test on bunch length reduction and an MD on flattening bunches.

Bunch shortening test

The bunch shortening test was performed by increasing the cavity voltage at injection, and it confirmed that shorter bunch length increases heating for most monitored devices (see Figs. 8 and 9). At this occasion, the LHC stayed 1h between 1 ns and 1.1 ns with 1380 bunches at 1.5 10^{11} p/b without detecting a major issue. It is important to note that the final distribution reached during this test should not be the same as what would be obtained if the target bunch length was decreased during the ramp.

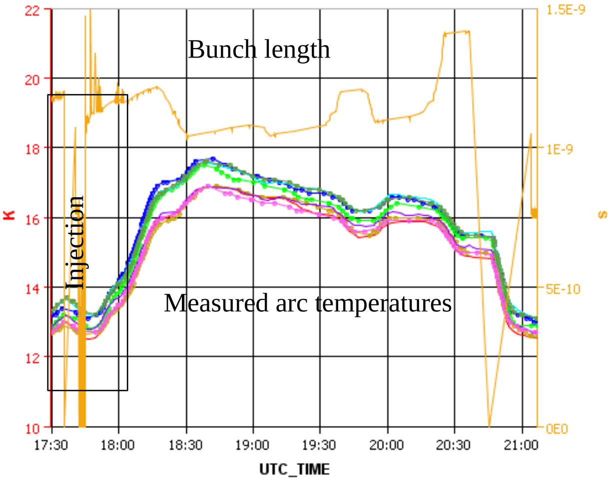

Fig. 8: Measurement of average temperature of all arcs during the bunch length reduction test. The correlation of measured temperatures with bunch length is clearly visible, in particular between 19:30 and 20:00 UTC when the bunch length was changed back and forth from ~1.1 ns to 1.2 ns.

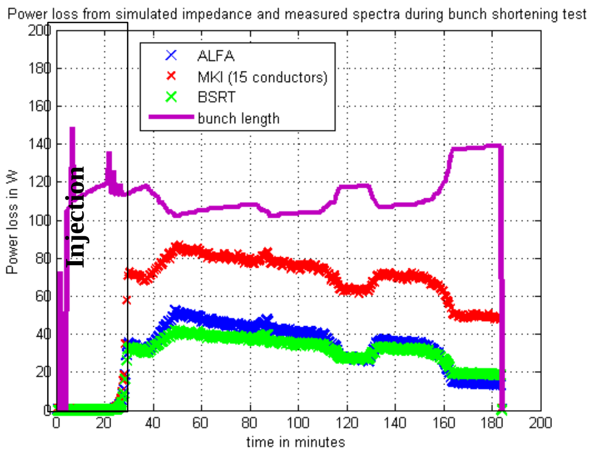

Fig. 9: Power loss predicted for the ALFA detector, MKI,

and BSRT during the bunch length reduction test. The power loss was obtained from the measured beam spectra and the simulated impedance of the respective elements.

Very different patterns were observed with bunch length (see Table 3), and these help to understand the origin of the beam induced heating. The items that heated more are planned to be upgraded (ALFA, MKI8C, TDI, BSRT) or removed (TCTVB). Finally, no hard showstopper was unveiled by this test to run at lower bunch length.

Table 3 shows a summary of the observations during the bunch length test:

equipment	**Heating increases with lower bunch length?**	**Difference with a regular fill with ramp (3318)?**
BSRT	Yes (slightly)	Similar
TCTVB	Yes	Heated more
TCP.B6L7	No (long time constants)	Heated less
MKIs (other than MKI8C)	Not observed (long time constants)	Similar
MKI8C	Difficult to see	Heated more
ALFA	Yes	Heated more
TDI pressure and deformation	Difficult to see	Seemed to be larger for TDI2
Arcs temperature	Yes	Similar
Q6R5	No (but saturated)	Heated less, indication that it may not be an RF heating issue

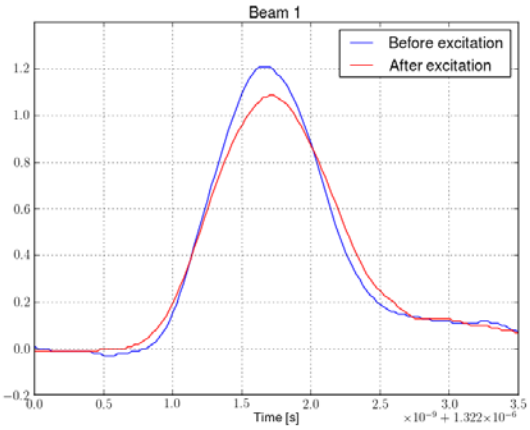

Fig. 10: bunch profile before and after RF phase modulation (courtesy J.E. Mueller et al).

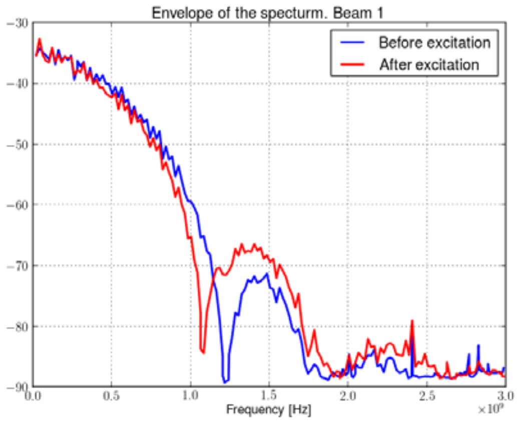

Fig. 11: beam spectrum before and after RF phase modulation (courtesy J.E. Mueller et al).

<u>MD on flattening bunches</u>

The MD on flattening bunches was aiming at changing the longitudinal beam spectrum by applying a sinusoidal RF phase modulation [22]. The bunch profile and the beam spectra before and after excitation are presented in Figs. 10 and 11. It can be seen that a small change of the bunch profile changes significantly the beam spectrum over a large frequency range (note that the beam spectrum is in dB scale). It is also observed that the beam spectrum is larger at frequencies above 1.2 GHz after the RF modulation, as expected. This method is hence very promising as shown in Fig. 12 but is to be used with caution if critical resonances above 1.2 GHz are present. As for the bunch lengthening test, there was no alarming sign of heating detected during this bunch flattening test.

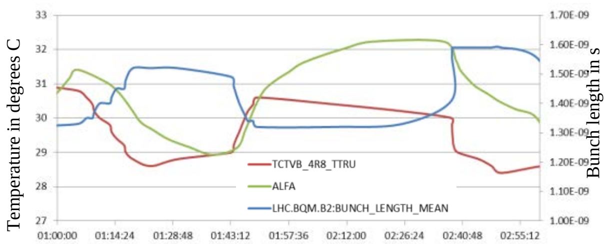

Fig. 12: measured temperatures for the ALFA detector and the TCTVB.4R8 collimator during a bunch length change at top energy with the LHC nominal physics beam (between 1:00 and 1:50) and the bunch flattening test (at 2:35). The temperatures were observed to sharply decrease after the RF modulation was applied (moment at which the measured bunch length increases sharply to 1.6 ns). It is important to note that the measured bunch length increased significantly whereas the bunch profile did not change much as seen in Fig. 10. The method used to measure bunch length therefore shows its limits in this case (courtesy J.E. Mueller et al).

Other interesting observations

Useful information was also gained thanks to unwanted issues with the longitudinal emittance blow-up from October 26th to October 28th 2012 [9]. During these fills, strong changes of beam spectra for B2 were observed (see comparison with B1spectrum in Fig. 13). The power loss expected from these measured beam spectra and simulated ALFA impedance for beam 1 (in blue) and beam 2 (in red) yielded a power loss 40% larger for beam 2 than for beam 1. The difference in beam spectrum could then explain the significant temperature difference measured at the ALFA pots and BSRT mirrors on beam 1 and beam 2 for these fills, which demonstrates the need to control the shape of the beam spectrum in order to reduce beam induced heating.

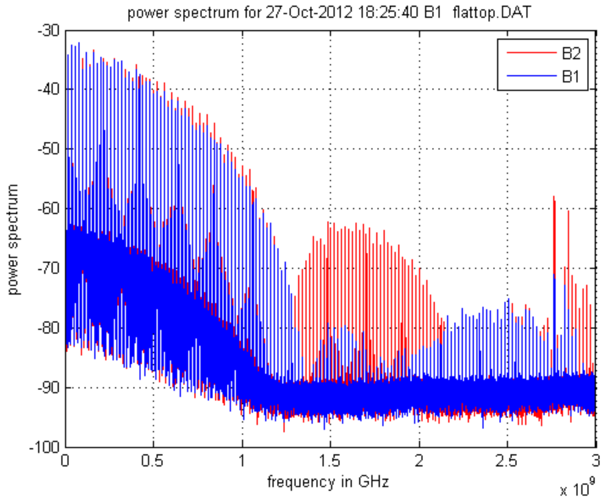

Fig. 13: comparison between beam spectrum at the beginning of flat top on October 27th for beam 1 (in blue) and beam 2 (in red). Both low and high beam frequencies are observed to be significantly enhanced in beam 2 for this fill.

All these observations show the importance of (1) keeping the bunch length large enough and (2) controlling closely the longitudinal bunch distribution in order to keep the beam induced heating to a minimum. A trade-off should however be found as increasing the bunch length also reduces luminosity through the geometric factor.

ELEMENTS PLANNED TO BE INSTALLED IN LS1

To the knowledge of the impedance team, the following changes are planned to be performed during LS1:

- Tertiary collimators replaced by new design with BPMs and ferrites replacing the longitudinal RF fingers on top of the jaws;
- 2-beam TCTVBs in IR8 will be replaced by single beam TCTVAs.
- Secondary collimators in IR6 replaced by new design with BPMs;
- New passive absorbers in IR3;
- New TCL collimators in IR1 and IR5
- Smaller radius for experimental beam pipes;
- Modifications in view of installation of the forward detectors in 2015;
- Improved roman pots (both ALFA and TOTEM);
- Improved BSRTs, TDIs, MKIs, improved cooling for TCP.B6L7;
- Maybe 1 or 2 UA9 goniometers for one beam only (to be confirmed).

Recall of general guidelines to minimize power loss

- Need to minimize RF heating already at the design stage to reduce resp. the geometric and resistive contributions of the real part of the longitudinal impedance. This optimization should be performed for all new equipment planned to be installed in the LHC, and is being performed for many project designs with the precious help of equipment groups and experiments (new collimators, new kickers, new instrumentation, new forward detectors, new LHCb VELO, new vacuum chambers, new bellows and shieldings, etc).
- Need for efficient cooling of near-beam equipment to avoid what has happened to TDI, BSRT and ALFA.
- Maximize evacuation of heat (optimize emissivity and thermal conduction).
- Need to ensure good RF contact to avoid what happened to the VMTSA double bellows (LRFF working group guidelines).
- If ferrites need to be used to damp resonant modes, use high Curie temperature ferrites whenever possible (e.g. Transtech TT2-111R or Ferroxcube 4E2 but beware of vacuum compatibility).
- Need for more monitoring of temperature inside critical equipment (e.g.: TDI, BSRT, TOTEM pot).

OUTLOOK

Many LHC devices have been heating at a faster rate in 2012 following the bunch intensity ramp-up.

Actions are/should be planned to be taken in LS1 to prepare safe and smooth running:

- Efficient cooling should be installed for all near beam equipment (in particular BSRT, TDI, ALFA)
- RF contacts should be consolidated according to the conclusions of the LRFF working group
- Suspected non-conformities should be investigated (TCPB6L7, MKI8C, and Q6R5 with its correlation with TOTEM movements).
- Logged pressure and temperatures should be systematically analysed to detect potential issues

- More temperature monitoring of critical equipment should be installed
- The longitudinal beam distribution should be controlled and optimized to reduce heating (if it is technically possible and as long as it does not impact longitudinal stability).

The summary table of the expected situation for the 2013 restart is in Table 4.

Since most heating devices have shown dominating broadband impedance, the operation with 25 ns is expected to lead to slightly larger power loss (for the same bunch length, bunch distribution and nominal bunch intensity).

TDI and maybe BSRTs which also exhibit large narrow band impedances should be monitored closely. Other devices might start suddenly heating much more if the distribution changes.

From beam induced heating point of view, the main worries for after LS1 seems to be:

- The extent of the upgrade of the TDI
- the operation with nominal bunch length (~1 ns, compared to ~1.2-1.3 ns)
- Uncontrolled longitudinal beam distribution during the ramp.

Table 4: summary of the expected situation after LS1 at the moment of the workshop.

Element	**Problem**	**2011**	**2012**	**Hopes after LS1**
VMTSA	Damage			All VMTSA will be removed
TDI	Damage			Beam screen reinforced, and the jaws?
MKI	Delay			Beam screen and tank emissivity upgrade
TCP B6L7.B1	Few dumps			Cooling system checked
TCTVB	Few dumps			All TCTVBs will be removed
Beam screen Q6R5	Regulation at the limit			Upgrade of the valves + TOTEM check
ALFA	Risk of damage			New design + cooling
BSRT	Deformation suspected			New design + cooling

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