Interlock and alarms for beam induced heating: a first iteration

B. Salvant for the impedance team,

With very useful inputs from

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MPP meeting May 16th

- Disclaimer:
  - It is only a 1st iteration and it needs discussion
  - These are suggestions that may - from our point of view - help at quickly detecting issues with equipment but more importantly issues with beam parameters.
  - Temperature interlocks are the responsibility of the equipment owners.
  - Numbers given here are orders of magnitude and should be reviewed with the experience of the new designs and the new beam parameters during the run.
  - Many thanks to all equipment owners for their very useful help and suggestions!

Context

- Beam induced heating in LHC in 2011 and 2012
  - Damage to equipment (RF fingers of VMTSA double bellow modules, BSRT mirror, TDI beam screen, TDI jaw deformation, damage came a few degrees close for ALFA detector)
  - Beam dumps (due to interlock on TCP and TCTVB collimator temperatures, and maybe also vacuum interlock next to TOTEM pot)
  - Delay to reinject (MKI temperature)
  - Believed to have affected temperature regulation of Q6R5 standalone (due TOTEM pot heating)

- Mitigations put in place by equipment groups
  - VMTSA double bellows were all removed in 2012 → TE-VSC
  - All non conform RF fingers were repaired during LS1 → TE-VSC and LRFF task force (also working on new design)
  - TCTVBs were all removed (half in 2012, half in LS1)→ EN-STI
  - TCP.B6L7.B1 that was heating was exchanged during LS1 (investigations to know what happened will be performed in September with EN-STI to allow sufficient radiation cooldown) →EN-STI
  - New design of the BSRT mirror during LS1 to reduce heating was installed → BE-BI
  - The TDI beam screen was stiffened and more support was installed during LS1 → EN-STI/TE-ABT
  - Copper coating on TDI jaw was planned but had to be abandoned at the last moment due to technical issues → EN-STI/TE-ABT
  - Installed shielding on ATLAS-ALFA and TOTEM detectors during LS1 are planned to reduce heating, however TOTEM plans to approach high luminosity beams may increase heating
  - MKI screening was significantly improved and the two non-conform magnets that were causing heating problems were repaired (MKI8C and in particular MKI8D) → TE/ABT

→ Very significant effort by all groups to protect their equipment

Summary table of elements that were subject to obvious heating problems before LS1

	Element	Problem	2011	2012	Expected situation after LS1
	~~Double-bellow VMTSA~~	Damage			All VMTSA removed
New design in preparation (LS2)	Injection protection collimator TDI	Damage			Beam screen reinforced; copper coating on the jaws abandoned
New design installed during LS1	Injection kicker MKI	Delay			Beam screen and tank emissivity upgraded
Replaced during LS1	Primary collimator TCP B6L7.B1	Few dumps			non-conformity should be removed (suspected cooling system issue)
	~~Tertiary collimators TCTVB~~	Few dumps			All TCTVBs have been removed; situation with new TCTP should be followed up
Valves replaced	Beam screen standalone Q6R5	Regulation at the limit			Upgrade of the valves; TOTEM check
New design installed during LS1,	ATLAS- ALFA roman pot	Risk of damage			New design being installed
New design being installed during LS1, ECR circulating	Synchrotron light telescope BSRT	Damage			New design being installed

Problems after LS1?

- Causes of issues before LS1:
  - Non-conformities
  - Weak design with respect to heating
  - Abnormal bunch length or longitudinal beam distribution

- Chance for weak design is reducing with experience, but unexpected non-conformities and unwanted beam parameters can occur.

- After LS1, we expect that most known issues will be solved, but we should be ready to detect and mitigate the other issues that will come up.

→ Monitoring is very important to detect the issues early and take action.

Temperature monitoring is not available at all devices, and is not always able to monitor the critical parts that are heating due to low heat transfer in vacuum.

Summary of the monitoring situation (discussed with equipment groups)

Element	Situation before LS1	Situation after LS1	Additional request?
Injection protection collimator TDI	No relevant temperature probes	8 temperature probes per TDI	
Injection kicker MKI	4 temperature probes per kicker, linked to a fixed display and to injection abort threshold	Same	
Collimators (TCP, TCS, TCT)	5 temperature probes per collimator linked to a Fixed display, a warning level and to BIC dump threshold (decided in collaboration with TE/VSC)	Same (additional probes on cooling circuit for new TCTPs)	
TOTEM roman pot (electronics)	Temperature probes on the detector electronics (heavily cooled)	Additional temperature probes on the pot	Link the temperature to logging database (through DIP)
ATLAS-ALFA roman pot (4 detectors per beam)	Many temperature probes per pot linked to the ATLAS database, some readings sent to LDB since October 2012	same	Link all temperature to logging database (through DIP)
Synchrotron light telescope BSRT	Temperature monitoring added in 2012 after observed deformation, not linked to LDB	5 probes per BSRT	Link temperature to logging database

Proposal for the beginning of the run

(of course to be decided by equipment owners, and reviewed during the intensity ramp-up)

Element	Alarm temperature	Injection abort temperature	Dump temperature	Who to inform in case of problems
Injection protection collimator TDI	50 degrees C	Not wanted yet, should be refined with experience with beam	Not wanted yet	EN-STI, Antonio Perillo Marcone, Anton Lechner TE-ABT, Jan Uythoven
Injection kicker MKI	50 degrees C	To be given by soft start data for each individual kicker (~60 degrees C before LS1)	Not wanted (or 300 degrees)	TE/ABT, Mike Barnes
Dump kicker MKD	30 degrees C	?	?	TE/ABT Jan Uythoven
Collimators	30 degrees C (warning at 35 degrees C)	Not requested	50 degrees C (same as before LS1)	EN-STI, EN-MME, collimation team
TOTEM roman pot (electronics)	35 degrees C	Average + 8 degrees C	Not wanted for now	TOTEM, Mario Deile
ATLAS-ALFA roman pot (4 detectors per beam)	35 degrees C	40 degrees C (should be linked to SIS)	Not wanted for now	ATLAS-ALFA team Sune Jakobssen, on-call piquet
Synchrotron light telescope BSRT	50 degrees C	80 degrees C (should be linked to SIS)	100 degrees C	BE-BI, Federico Roncarolo

→ If thresholds are linked only to equipment protection, these thresholds are absolute.

→ If they are indicative for something wrong, they should be scaled with beam intensity ($M*N_b^2$)

Proposals for the restart

- Ask all temperature monitoring to be logged on Timber with enough sampling (in particular BSRT, ALFA, TOTEM)
- Take advantage of the cryo heat load and phase error measurement applications requested for electron cloud purpose.
- Temperature alarms at reasonable levels (send email or SMS to equipment responsible (if desired), us, and info to OP)
- Interlocks at higher temperatures if requested (first injection abort, then beam dump).
  → Beam dumps due to heating were several times a useful sign of a serious problem with beam control.
  → Dumping the beam may be the adequate action if nothing else catches this issue.
- Proposal to develop a "Temperature fixed display" in the CCC to quickly inform OP team of what is happening in case of alarm or interlock. This display should gather all relevant data for beam induced heating assessment:
  - Temperature data for all current and future relevant devices (these that are feared to be problematic, but also those that could indicate if there are issues with beam control)
  - Bunch length
  - Possibility to display beam spectrum at given time stamp and compare with other time stamps
  - Beam energy
  - Number of bunches
  - Bunch intensity
  - Phase error
  - Cryo heat load
  - Vacuum pressure measurements

  → Need to be able to compare several fills and observe trends over many days → should gather data from LDB.

Longer term

- Dedicated vacuum fixed display and postprocessing to detect issues in areas where there is no temperature monitoring.

Additional comments

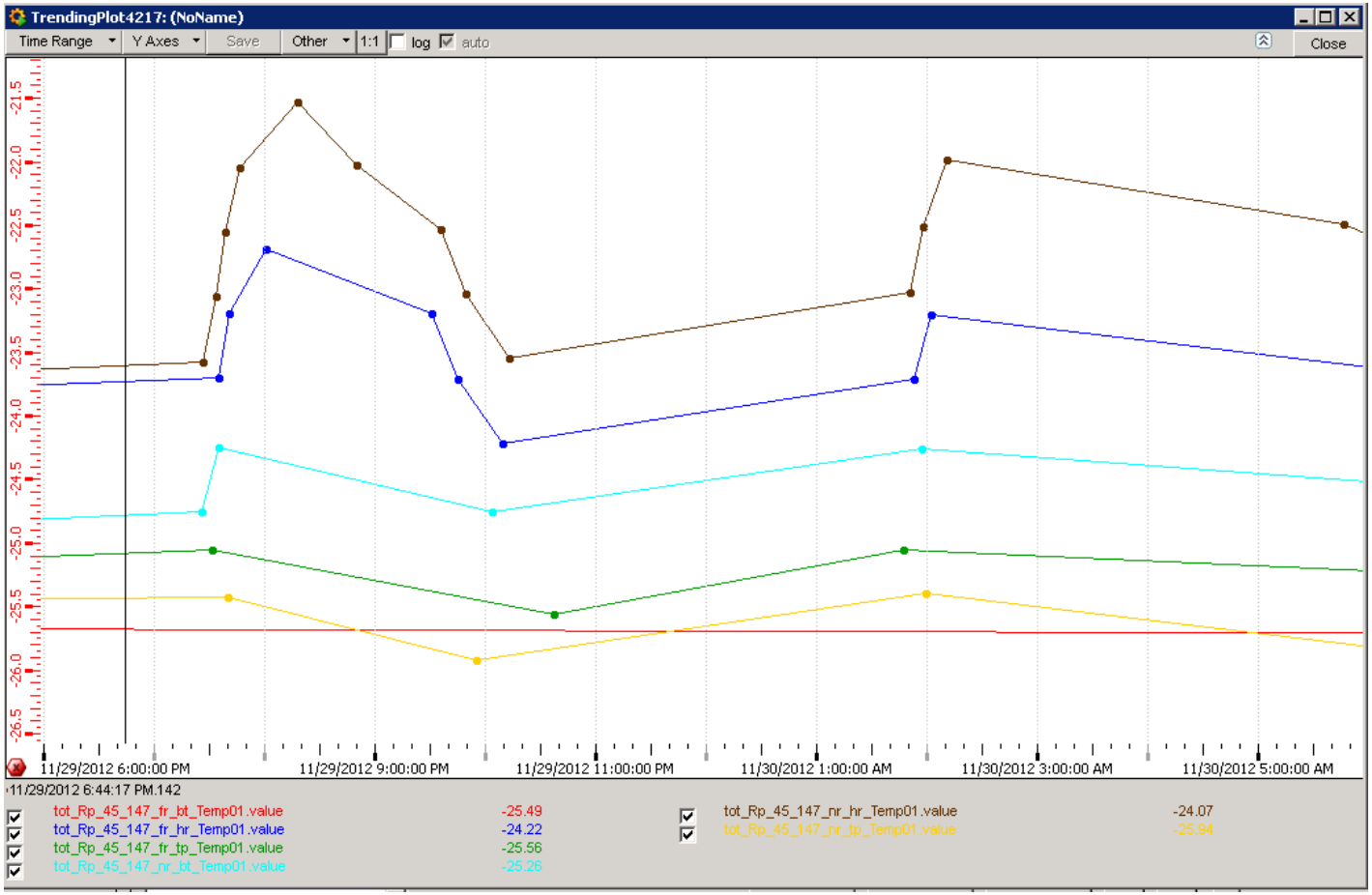
- New equipment to be installed and monitored: BGV in point 4 (only B2)
- Now systematically ask to install temperature probes when there are doubts (e.g. BGV, TDI, BSRT).
- Other temperature monitored devices (LHCb Velo, BGI?)
- feedback from equipment groups:
  - Globally positive response to warning, logging and display
  - Should we use the already existing fixed displays (Collimator or MKI?)
  - Not so thrilled about setting dump interlocks at restart:

    → more risky to add temperature probes as dump interlocks as they could cause fake dumps due to bad readings.

    → need to gain experience during intensity ramp-up

    → damage threshold is usually reached at very high temperature→ other indirect issues drive the limits (vacuum)

Thank you for your attention!


TrendingPlot4217: (NoName)
Time Range
Y Axes
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Other
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11/30/2012 1:00:00 AM
11/30/2012 3:00:00 AM
11/30/2012 5:00:00 AM
11/29/2012 6:44:17 PM.142
tot_Rp_45_147_fr_bt_Temp01.value -25.49
tot_Rp_45_147_fr_hr_Temp01.value -24.22
tot_Rp_45_147_fr_tp_Temp01.value -25.56
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tot_Rp_45_147_nr_hr_Temp01.value -24.07
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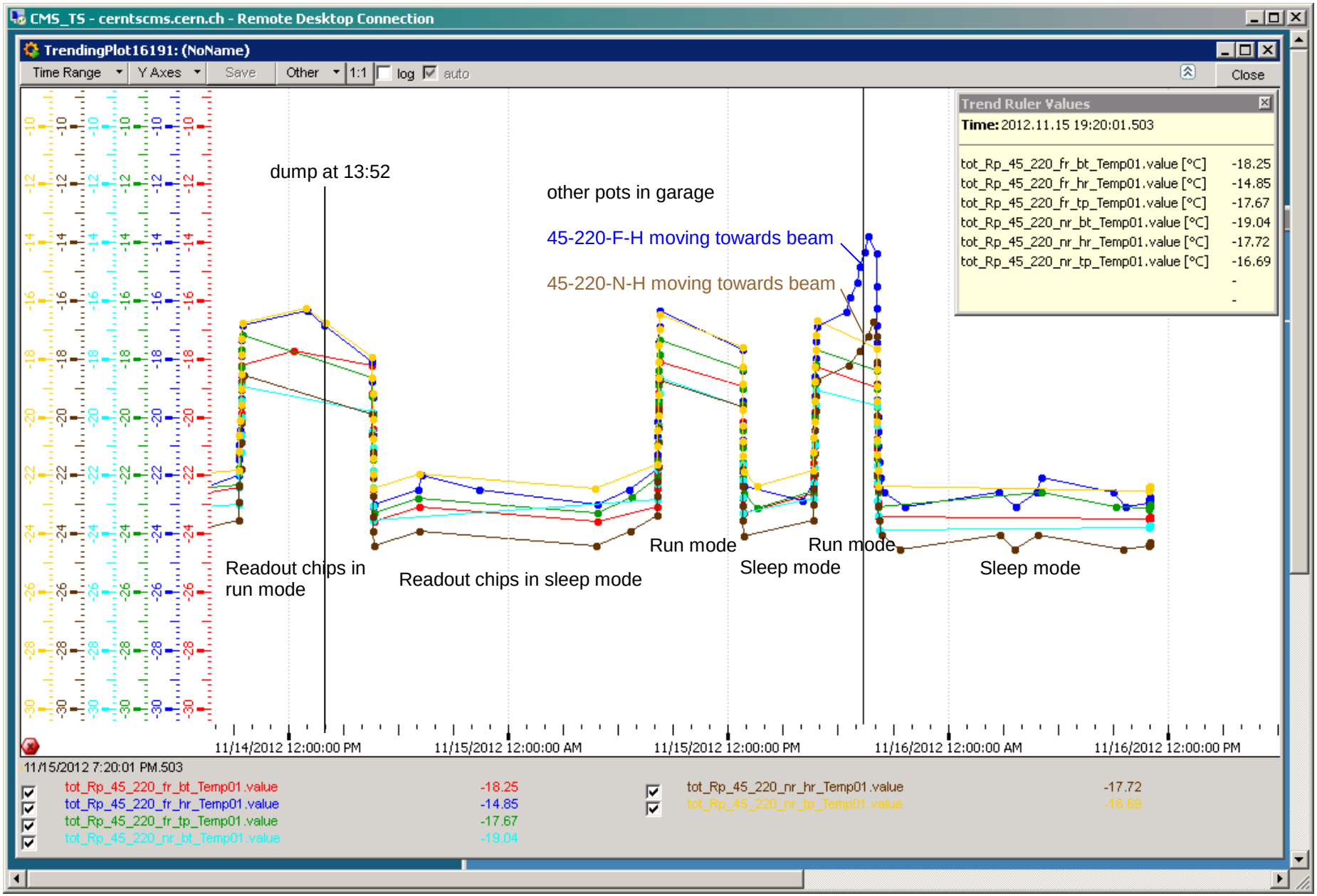
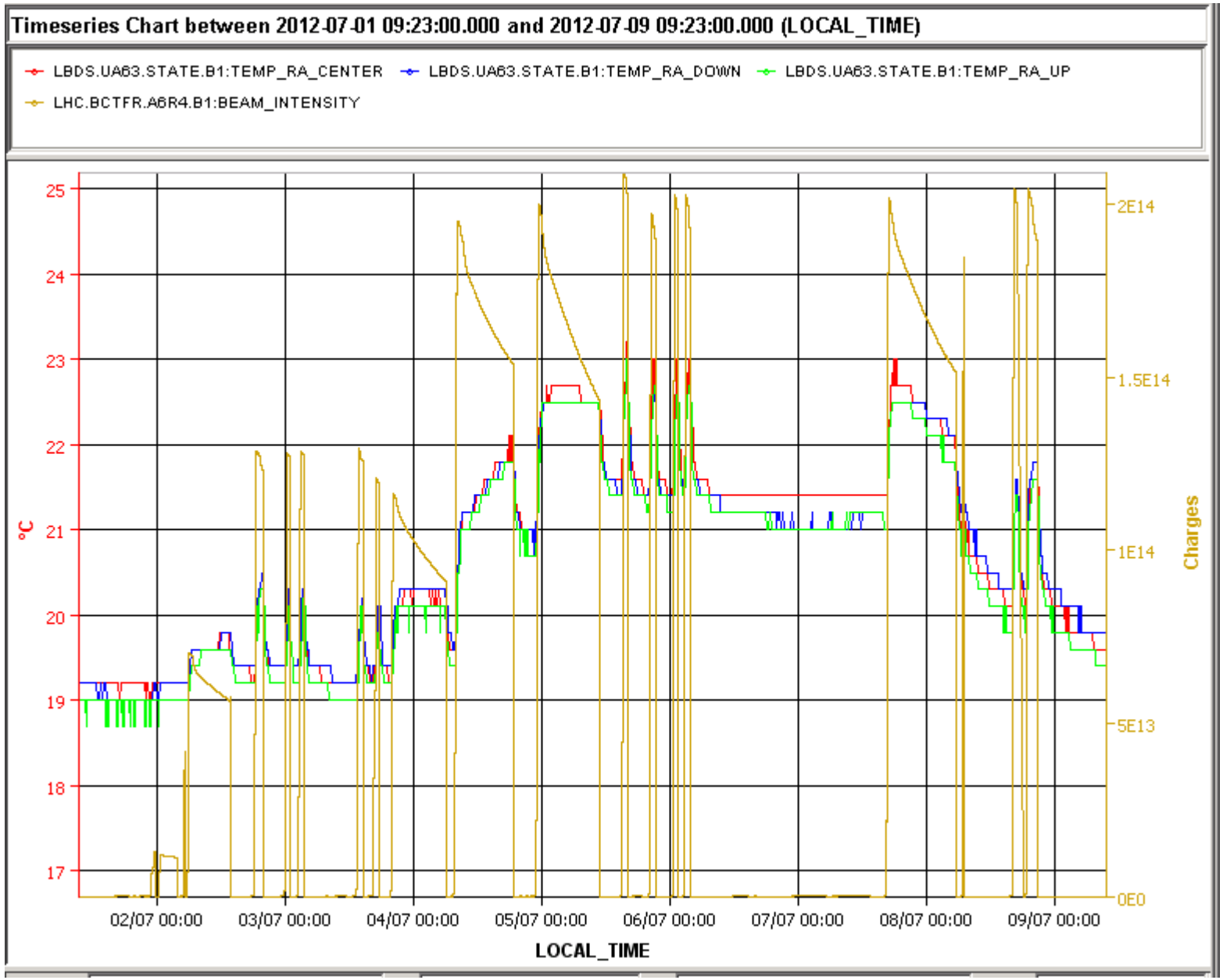
Temperature Sensors on Detector Hybrid Boards: Sector 4-5 (Beam 2)



Main temperature effect from chips changing to run mode; small additional increase (3 deg.) from pots moving very close to the beam. UFOs cannot be resolved.


Timeseries Chart between 2012-07-01 09:23:00.000 and 2012-07-09 09:23:00.000 (LOCAL_TIME)
LBDS.UA63.STATE.B1:TEMP_RA_CENTER
LBDS.UA63.STATE.B1:TEMP_RA_DOWN
LBDS.UA63.STATE.B1:TEMP_RA_UP
LHC.BCTFR.A6R4.B1:BEAM_INTENSITY
°C
25
24
23
22
21
20
19
18
17
2E14
1.5E14
1E14
5E13
0E0
Charges
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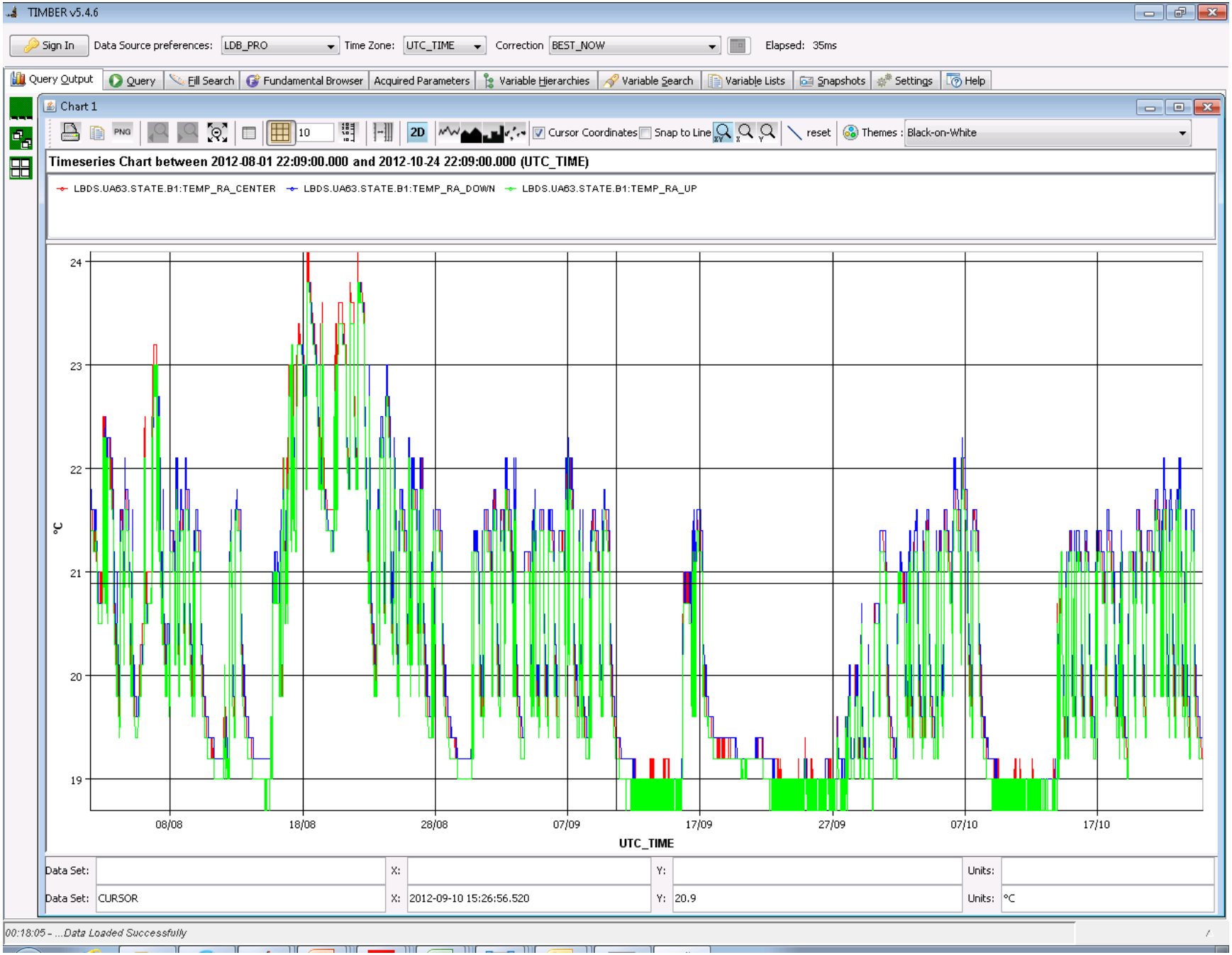
03/07 00:00
04/07 00:00
05/07 00:00
06/07 00:00
07/07 00:00
08/07 00:00
09/07 00:00
LOCAL_TIME

MKD


TIMBER v5.4.6
Sign In
Data Source preferences:
LDB_PRO
Time Zone:
UTC_TIME
Correction
BEST_NOW
Elapsed: 35ms
Query Output
Query
Fill Search
Fundamental Browser
Acquired Parameters
Variable Hierarchies
Variable Search
Variable Lists
Snapshots
Settings
Help
Chart 1
PNG
10
2D
Cursor Coordinates
Snap to Line
reset
Themes :
Black-on-White
Timeseries Chart between 2012-08-01 22:09:00.000 and 2012-10-24 22:09:00.000 (UTC_TIME)
LBDS.UA63.STATE.B1:TEMP_RA_CENTER
LBDS.UA63.STATE.B1:TEMP_RA_DOWN
LBDS.UA63.STATE.B1:TEMP_RA_UP
24
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18/08
28/08
07/09
17/09
27/09
07/10
17/10
UTC_TIME
Data Set:
X:
Y:
Units:
Data Set:
CURSOR
X:
2012-09-10 15:26:56.520
Y:
20.9
Units:
°C
00:18:05 - ...Data Loaded Successfully