

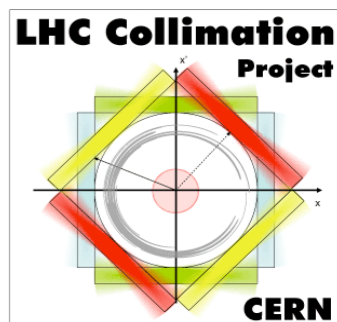
*LHC Machine Protection Panel meeting*

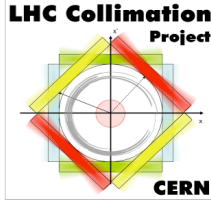
*Geneva, 15<sup>th</sup> October 2008*

# **Results of Collimator Machine Protection Commissioning**

***Stefano Redaelli, AB-OP***

***one behalf of the Collimation team***





# Outline

- Introduction / procedures**
- Positioning interlocks**
- Special devices**
- Temperature interlocks**
- Outlook**

- ☑ Overall strategy for the commissioning of collimator MP functionality defined in EDMS document
- ☑ Detailed procedure outlined and implemented in the application software
- ☑ Operational procedures documented and “handed-over” to OP team

**MPS Commissioning Procedure**

---

**THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM**

**MPS ASPECTS OF THE COLLIMATION SYSTEM COMMISSIONING**

---

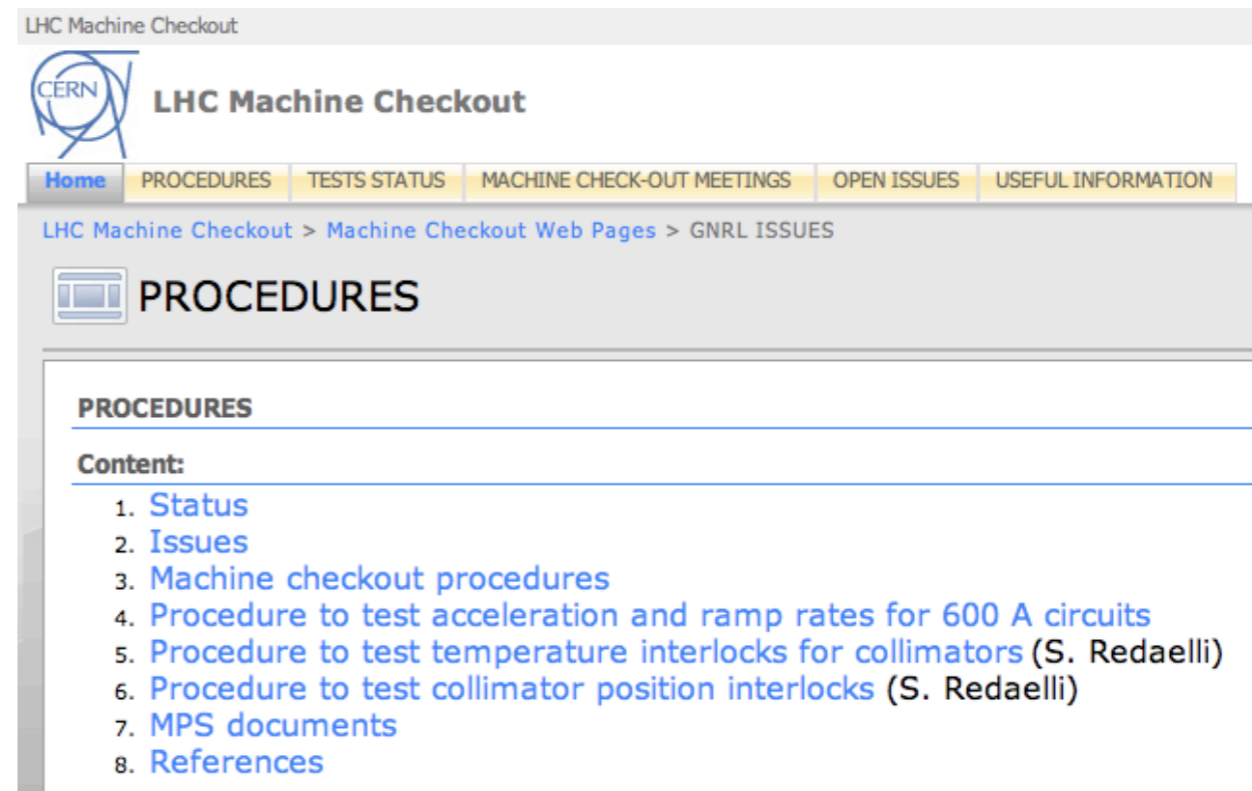
*Abstract*

This document describes the set of tests which will be carried-out to validate for operation the machine protection aspects of the **LHC collimation system**. The area concerned by these tests extends over 7 out of the 8 long straight sections.

These tests include the Hardware Commissioning, the machine check-out and the tests with beam, to the extent that they are relevant for the machine protection functionality of collimation.

---

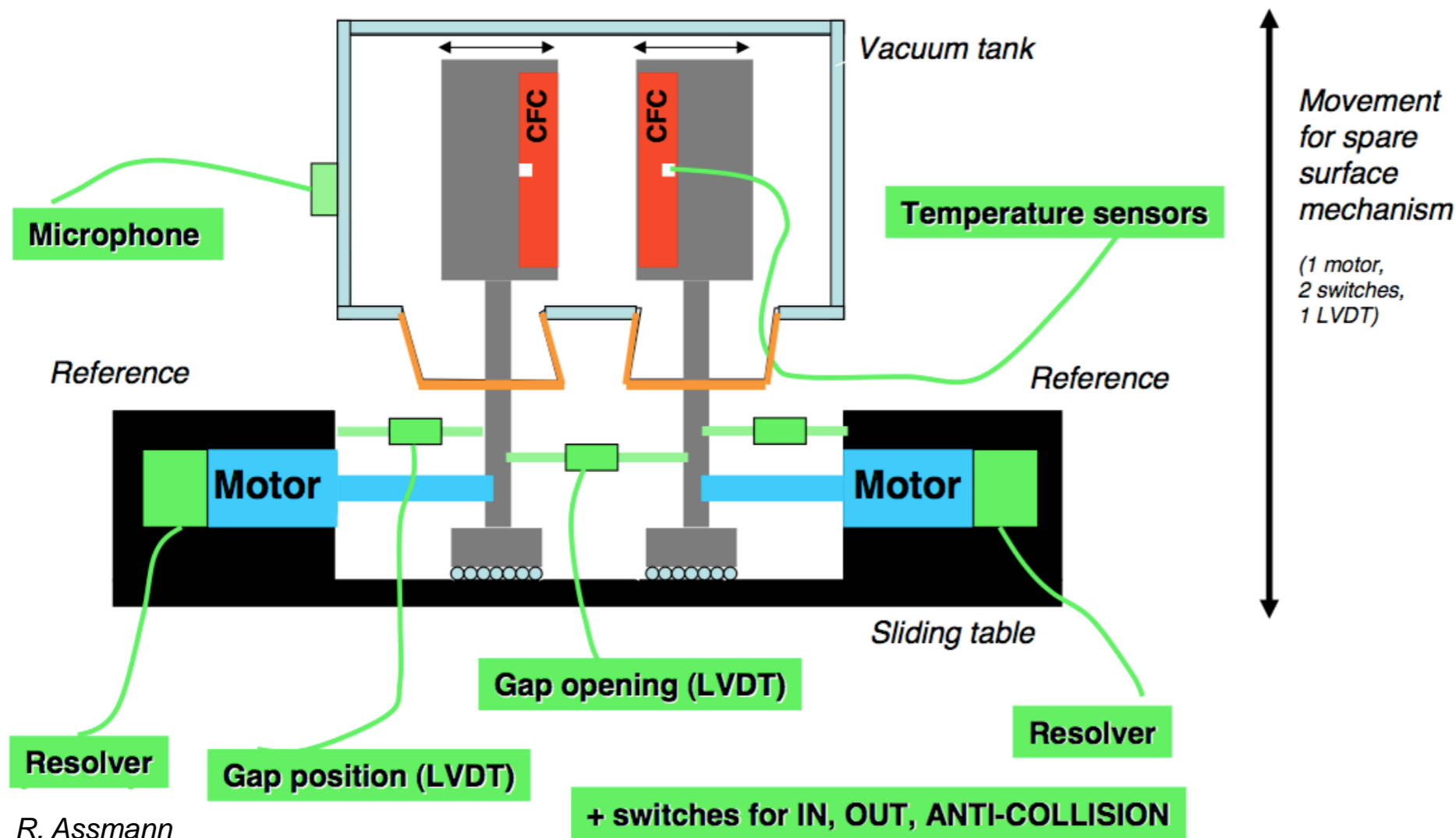
<i>Prepared by :</i> <b>Ralph Assmann Michel Jonker Roberto Losito Stefano Redaelli Thomas Weiler</b>	<i>Checked by :</i> <b>Roger Bailey Andy Butterworth Bernd Dehning, Brennan Goddard, Eva Barbara Holzer, Verena Kain, Mike Lamont,</b>	<i>Approved by :</i> <b>Rüdiger Schmidt</b>
--	---	--



The screenshot shows the 'LHC Machine Checkout' website. The page title is 'LHC Machine Checkout' and it features a navigation menu with 'Home', 'PROCEDURES', 'TESTS STATUS', 'MACHINE CHECK-OUT MEETINGS', 'OPEN ISSUES', and 'USEFUL INFORMATION'. The current page is 'PROCEDURES', which lists a table of contents with 8 items: 1. Status, 2. Issues, 3. Machine checkout procedures, 4. Procedure to test acceleration and ramp rates for 600 A circuits, 5. Procedure to test temperature interlocks for collimators (S. Redaelli), 6. Procedure to test collimator position interlocks (S. Redaelli), 7. MPS documents, and 8. References.

OP procedures for MP test documented on the OP checkout page:  
<https://espace.cern.ch/LHCMachineCheckout/Machine%20Checkout%20Web%20Pages/GNRL%20ISSUES.aspx?PageView=Shared>

# Collimator positioning survey



R. Assmann

**2008 system:  
76 collimators  
+ 2 TCDQ s  
+ 2 TDI s**

**Full system:  
~400 degrees  
of freedom  
~2000 limit  
functions**

**Settings:** 2 jaws → 4 motor positions; 1 motor for tank position.

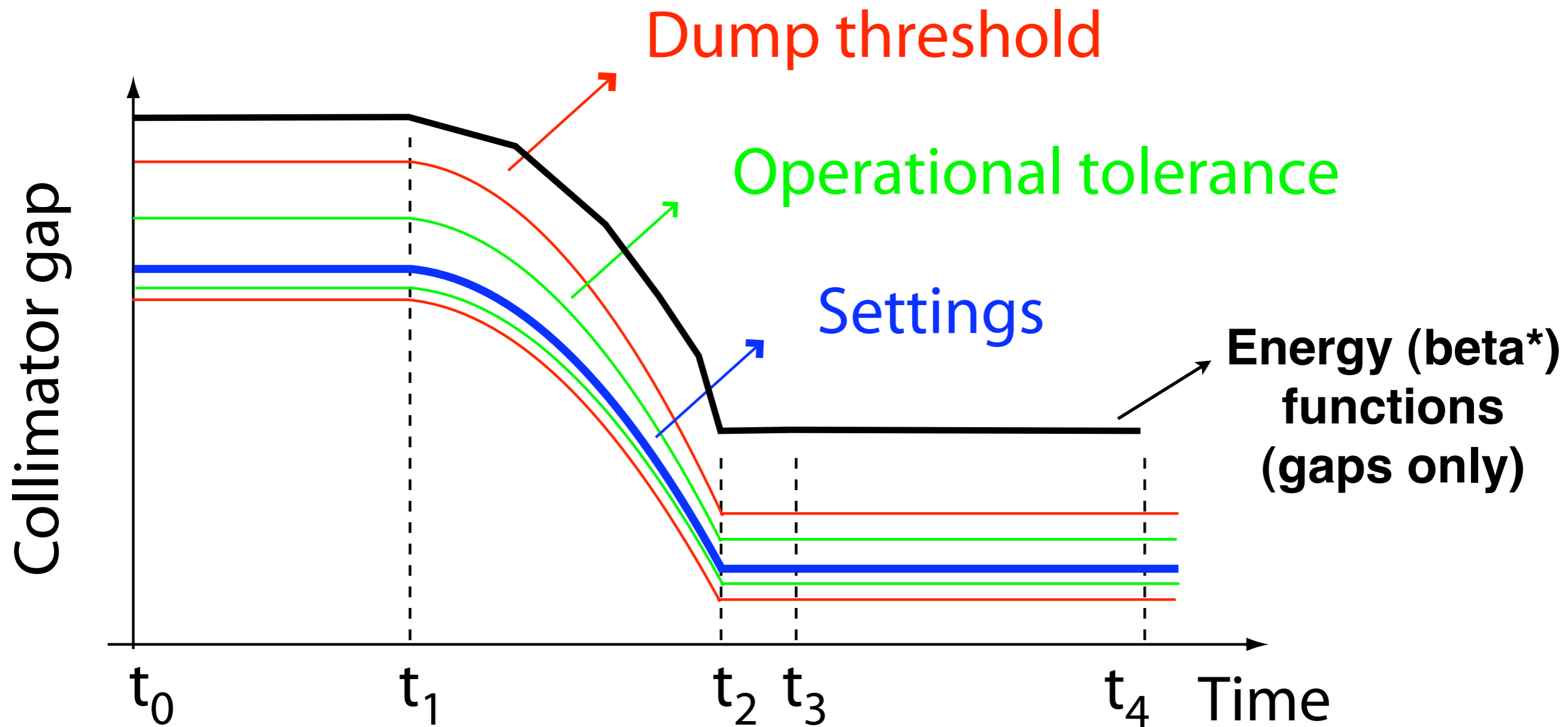
**Survey:** 7 position measurements (4 corners + 2 gaps + tank)

4 motor resolvers

10 switch statuses (full-in, full-out, anti-collision)

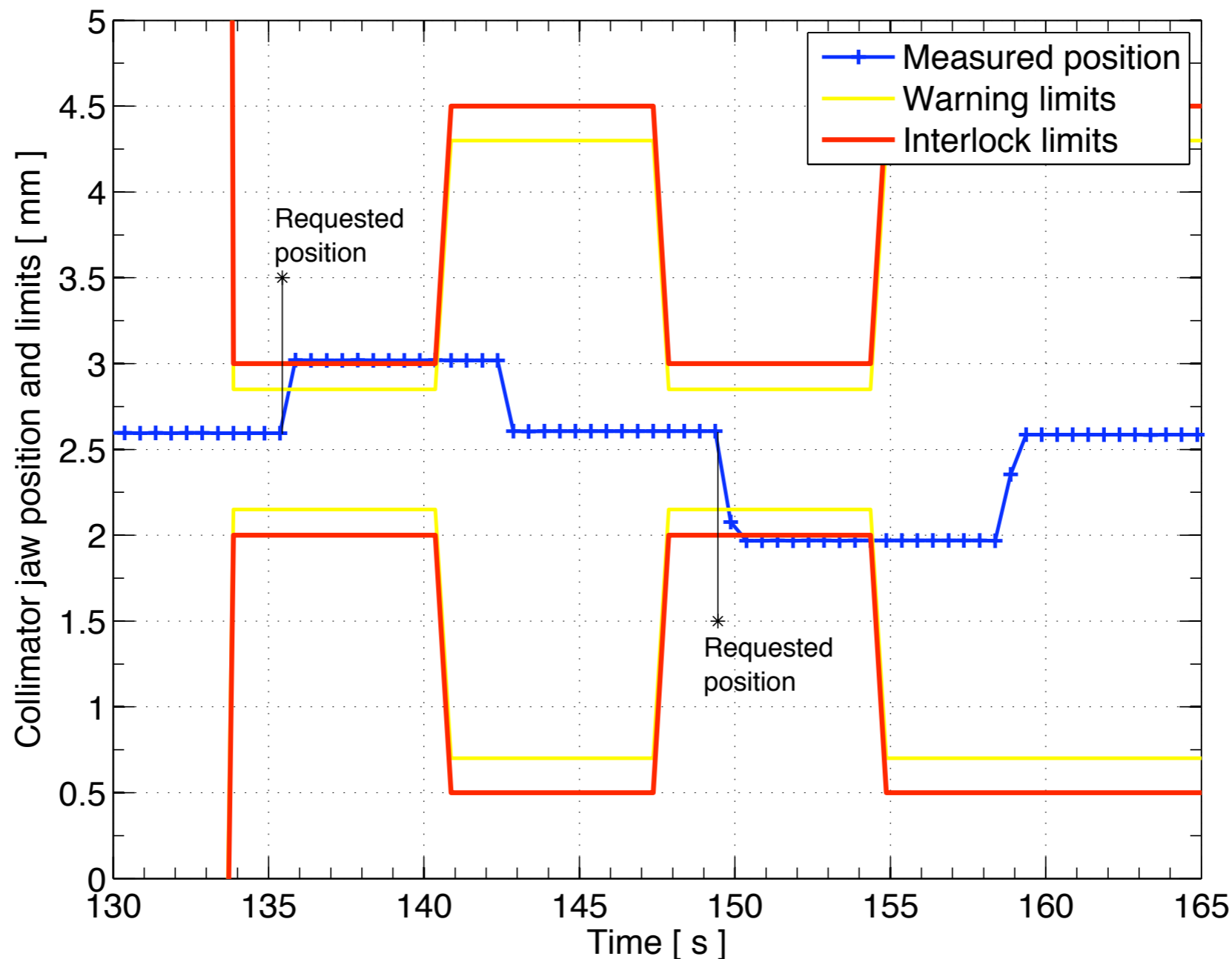
**Dump thresholds (functions+discrete):** 6 x 2 jaw positions/gaps; some gap values vs. energy and beta\* factor; 5 temperatures; switch statuses vs. machine mode.

# Position interlocking strategy



- ☑ Two regimes: discrete (“actual”) and time-functions  
*Both use the same internal clock at 100 Hz for comparison*
- ☑ Time-limit functions for each motor axis + for gap measure
- ☑ “Double protection” → BIC loop broken AND jaw stopped
- ☑ Energy- (beta\*-)limit functions only for gap (no frequent change)

# Sequence for MP validation



*Example for 1 degree of freedom*

Sequence implemented in the collimator application software:

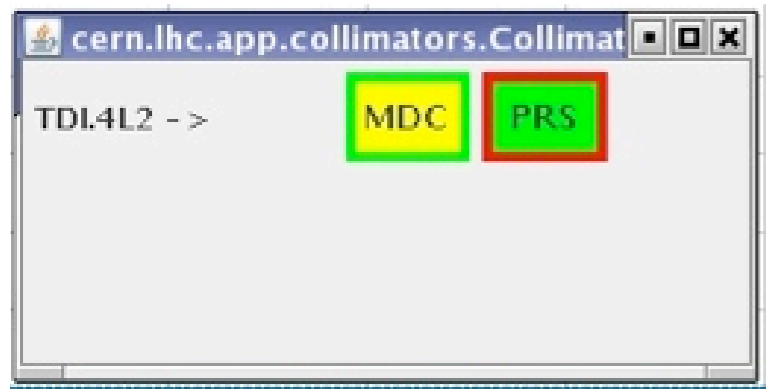
- “Hit” 12 interlock limits (inner+outer for 6 LVDT’s) as well as 12 warning functions

- “Hit” the 2 limits of maximum gap values versus energy

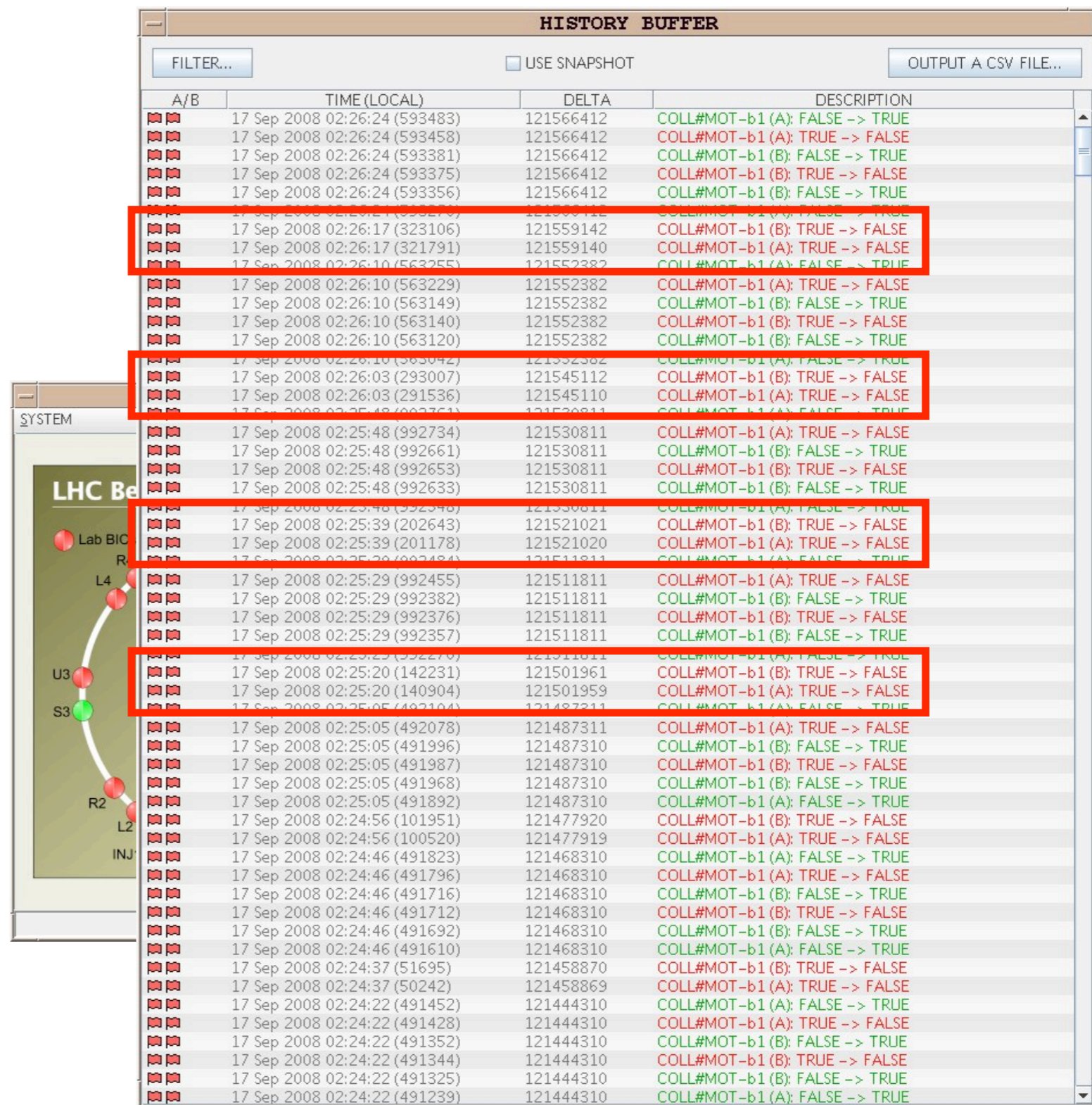
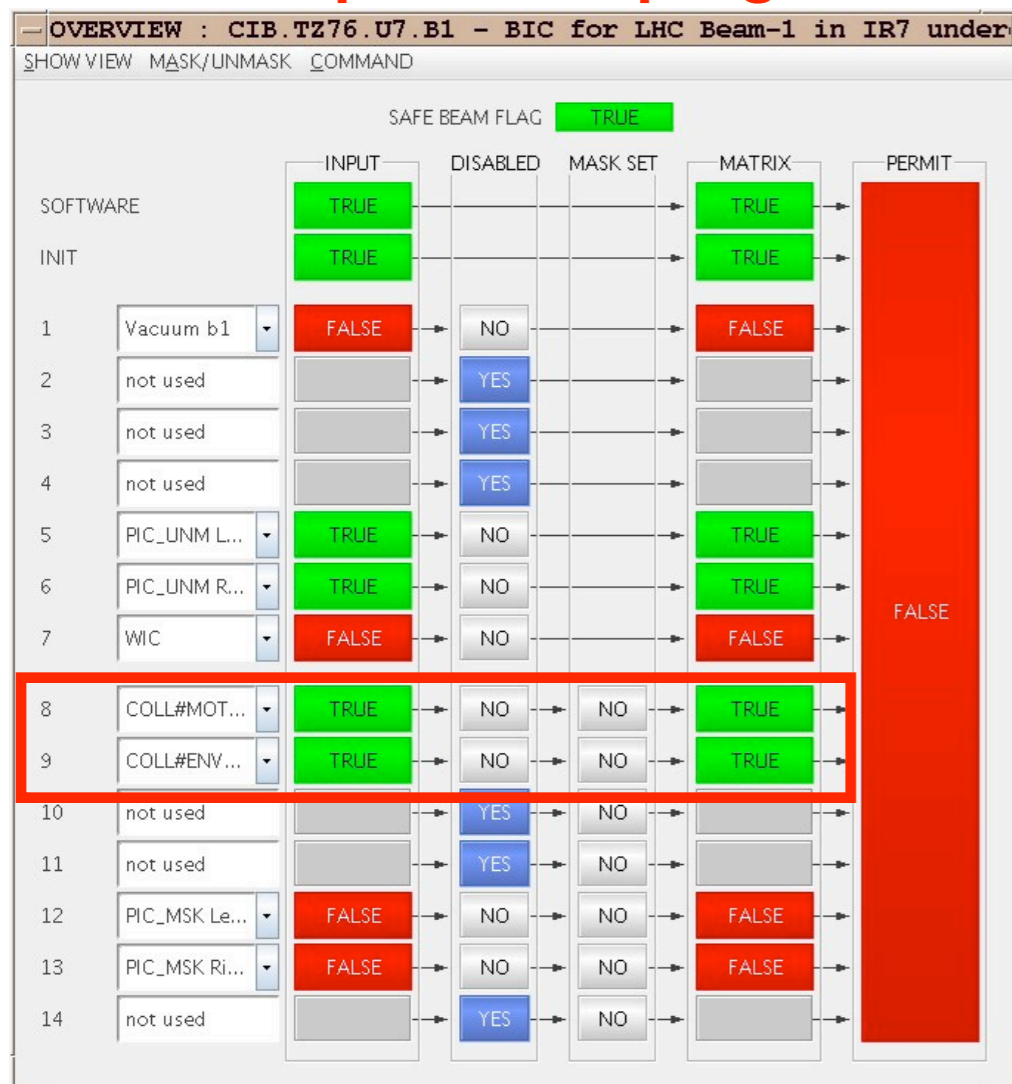
Monitor on-line: (1) collimator status and (2) status of collimator BIC input

It takes less than 5 minutes; Can be applied to many collimators on different BIC’s

## Collimator status display

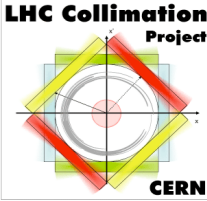


## BIC supervision program





# On-line status monitoring (II)



## BIC history buffer

```

...
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:26:10 (563255),1221611170563255,121552382,COLL#MOT-b1 (A): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:26:10 (563149),1221611170563149,121552382,COLL#MOT-b1 (B): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:26:03 (293007),1221611163293007,121545112,COLL#MOT-b1 (B): TRUE -> FALSE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:26:03 (291536),1221611163291536,121545110,COLL#MOT-b1 (A): TRUE -> FALSE

CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:48 (992761),1221611148992761,121530811,COLL#MOT-b1 (A): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:48 (992661),1221611148992661,121530811,COLL#MOT-b1 (B): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:39 (202643),1221611139202643,121521021,COLL#MOT-b1 (B): TRUE -> FALSE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:39 (201178),1221611139201178,121521020,COLL#MOT-b1 (A): TRUE -> FALSE

CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:29 (992484),1221611129992484,121511811,COLL#MOT-b1 (A): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:29 (992382),1221611129992382,121511811,COLL#MOT-b1 (B): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:20 (142231),1221611120142231,121501961,COLL#MOT-b1 (B): TRUE -> FALSE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:20 (140904),1221611120140904,121501959,COLL#MOT-b1 (A): TRUE -> FALSE

CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:05 (492104),1221611105492104,121487311,COLL#MOT-b1 (A): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:25:05 (491996),1221611105491996,121487310,COLL#MOT-b1 (B): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:24:56 (101951),1221611096101951,121477920,COLL#MOT-b1 (B): TRUE -> FALSE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:24:56 (100520),1221611096100520,121477919,COLL#MOT-b1 (A): TRUE -> FALSE

CIB.UJ33.U3.B1,False False,17 Sep 2008 02:24:46 (491823),1221611086491823,121468310,COLL#MOT-b1 (A): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:24:46 (491716),1221611086491716,121468310,COLL#MOT-b1 (B): FALSE -> TRUE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:24:37 (51695),1221611077051695,121458870,COLL#MOT-b1 (B): TRUE -> FALSE
CIB.UJ33.U3.B1,False False,17 Sep 2008 02:24:37 (50242),1221611077050242,121458869,COLL#MOT-b1 (A): TRUE -> FALSE
...

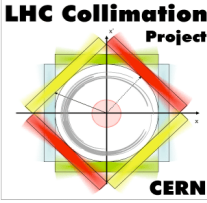
```

Thanks to Alick +  
BIC team for the  
implementation of  
the buffer history in  
text format.





# Documentation of results (I)



TIMBER v2.1.2

Data Source: Logging Database (PRO) Elapsed: 725ms

Query Output Query Variable Hierarchies Variable Search Variable Lists About

Variable List Selection

Guest User Group

Variable List Filters

Name: % Description: %

Search Results

Variable Name	Description	Unit	Datatype
TCDIV.87804:MEAS_LIMIT_DUMP_INNER_RU	Value of dump limit...	mm	NUMERIC
TCDIV.87804:MEAS_LIMIT_DUMP_OUTER_RU	Value of dump limit...	mm	NUMERIC
TCDIV.87804:MEAS_LIMIT_WARN_INNER_RU	Value of warning li...	mm	NUMERIC
TCDIV.87804:MEAS_LIMIT_WARN_OUTER_RU	Value of warning li...	mm	NUMERIC
TCDIV.87804:MEAS_LVDT_RU	LVDT position read...	mm	NUMERIC
TCDIV.87804:MEAS_MOTOR_RU	Motor position read...	mm	NUMERIC
TCDIV.87804:SET_RU	Discrete setting val...	mm	NUMERIC
TCDIV.87804:STATUS_MDCERRORS	Error state of MDC		NUMERIC
TCDIV.87804:STATUS_PRSEERRORS	Error state of PRS		NUMERIC

Timeseries Chart between 2008-07-14 11:00:00 and 2008-07-14 20:00:00 (LOCAL\_TIME)

Requested position

Measured positions

Warning / dump levels

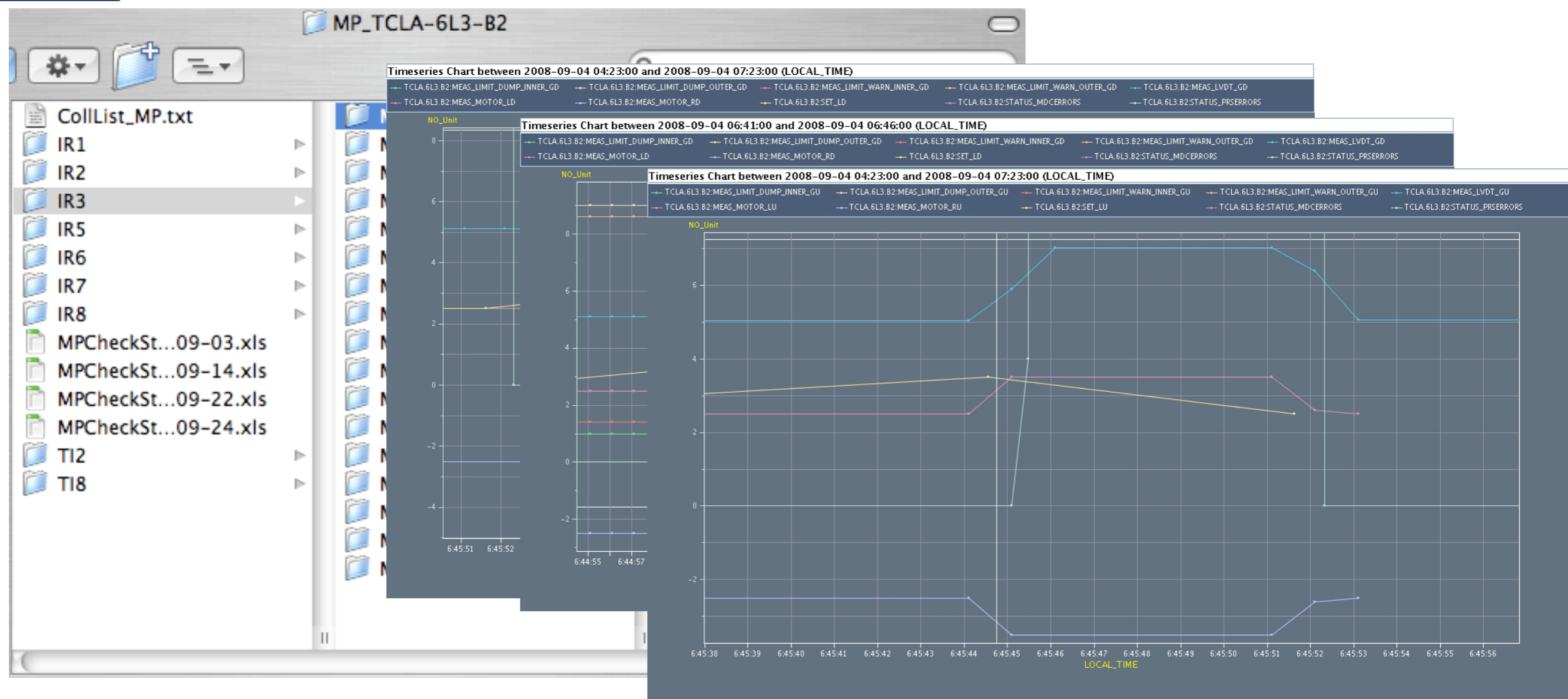
Warn/Error status

LOCAL\_TIME

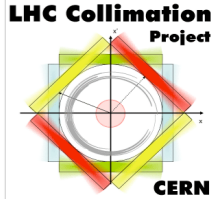
All sequences recorded in the permanent logging database

Pre-defined sets of **logged variable lists** for a “fast” analysis of the sequence results!

Special thanks to R. Billen and C. Roderick



- ☑ ALL logged data are **SYSTEMATICALLY** extracted as images for each sequence successfully run.
- ☑ Original plan: put this in MTF as a commissioning step together with data from BIC history
- ☑ Will prepare a web page to document the results of 2008 system



# Summary of results

	A	B	C	D	E	F	G	H
1	Collimator	IP	Beam	Family	Date of test	Start time	Status	Operator comment
2	TCTH.4R1.B2	IP1	B2	TCTH	14-Sep-08	19:24:00	OK	
3	TCTH.4L1.B1	IP1	B1	TCTH	14-Sep-08	19:24:00	OK	
4	TCTVA.4L1.B1	IP1	B1	TCTV	05-Sep-08	4:56:54	OK	
5	TCTVA.4R1.B2	IP1	B2	TCTV	05-Sep-08	3:50:30	OK	
6	TCL.4L2	IP2	B1	INJP	14-Sep-08	18:18:00	OK	
7	TCLD.4L2	IP2	B1	INJP	14-Sep-08	18:18:00	OK	
8	TCLIB.6R2.B1	IP2	B1	INJP	14-Sep-08	18:18:00	OK	Energy limit check done on Sep. 16th at 05:23
9	TCTH.4L2.B1	IP2	B1	TCTH	14-Sep-08	18:49:00	OK	Energy limit check done on Sep. 16th at 05:23
10	TCTH.4R2.B2	IP2	B2	TCTH	14-Sep-08	18:49:00	OK	Energy limit check done on Sep. 22nd at 19:20
11	TCP.6L3.B1	IP3	B1	TCP	16-Sep-08	3:09:00	OK	
12	TCP.6R3.B2	IP3	B2	TCP	16-Sep-08	4:41:00	OK	
13	TCSG.5B5L3.B2	IP3	B2	TCSG	17-Sep-08	5:21:00	OK	
14	TCSG.5B5R3.B1	IP3	B1	TCSG	17-Sep-08	5:21:00	OK	
15	TCSG.A5R3.B1	IP3	B1	TCSG	17-Sep-08	4:50:00	OK	
16	TCSG.A5L3.B2	IP3	B2	TCSG	17-Sep-08	4:50:00	OK	
17	TCSG.5R3.B2	IP3	B2	TCSG	17-Sep-08	2:51:00	OK	
18	TCSG.5L3.B1	IP3	B1	TCSG	17-Sep-08	5:56:00	OK	
19	TCSG.4R3.B1	IP3	B1	TCSG	17-Sep-08	2:20:00	OK	
20	TCSG.4L3.B2	IP3	B2	TCSG	17-Sep-08	2:20:00	OK	
21	TCLA.A5L3.B2	IP3	B2	TCLA	01-Aug-08	19:56:00	No yet EN	Preparation for sector test; Now motors are OFF
22	TCLA.A5R3.B1	IP3	B1	TCLA	01-Aug-08	18:18:00	No yet EN	Preparation for sector test; Now motors are OFF
23	TCLA.B5L3.B2	IP3	B2	TCLA	16-Sep-08	5:47:00	OK	
24	TCLA.B5R3.B1	IP3	B1	TCLA	16-Sep-08	5:47:00	OK	
25	TCLA.6R3.B1	IP3	B1	TCLA	16-Sep-08	5:47:00	OK	
26	TCLA.6L3.B2	IP3	B2	TCLA	16-Sep-08	5:47:00	OK	
27	TCLA.7R3.B1	IP3	B1	TCLA	16-Sep-08	5:47:00	OK	Was blocked due to the problem with the resolver (lost steps).
28	TCLA.7L3.B2	IP3	B2	TCLA	04-Sep-08	5:23:32	OK	
29	TCTH.4L5.B1	IP5	B1	TCTH	13-Sep-08	21:51:00	OK	
30	TCTH.4R5.B2	IP5	B2	TCTH	13-Sep-08	21:51:00	OK	
31	TCTVA.4L5.B1	IP5	B1	TCTV	13-Sep-08	21:58:00	OK	
32	TCTVA.4R5.B2	IP5	B2	TCTV	13-Sep-08	21:58:00	OK	
33	TCDQA.A4R6.B1	IP6	B1	TCDQ	03-Sep-08	10:30:00	OK	Preparation for sector test (done manually with Christophe)
34	TCDQA.A4L6.B2	IP6	B2	TCDQ	03-Sep-08	10:30:00	OK	Preparation for sector test (done manually with Christophe)
35	TCSG.4R6.B1	IP6	B1	TCSG	02-Sep-08	18:50:00	OK	Preparation for sector test
36	TCSG.4L6.B2	IP6	B2	TCSG	02-Sep-08	18:50:00	OK	Preparation for sector test

All collimators tested; status file maintained as followup

Overall: very satisfactory, no major issues encountered

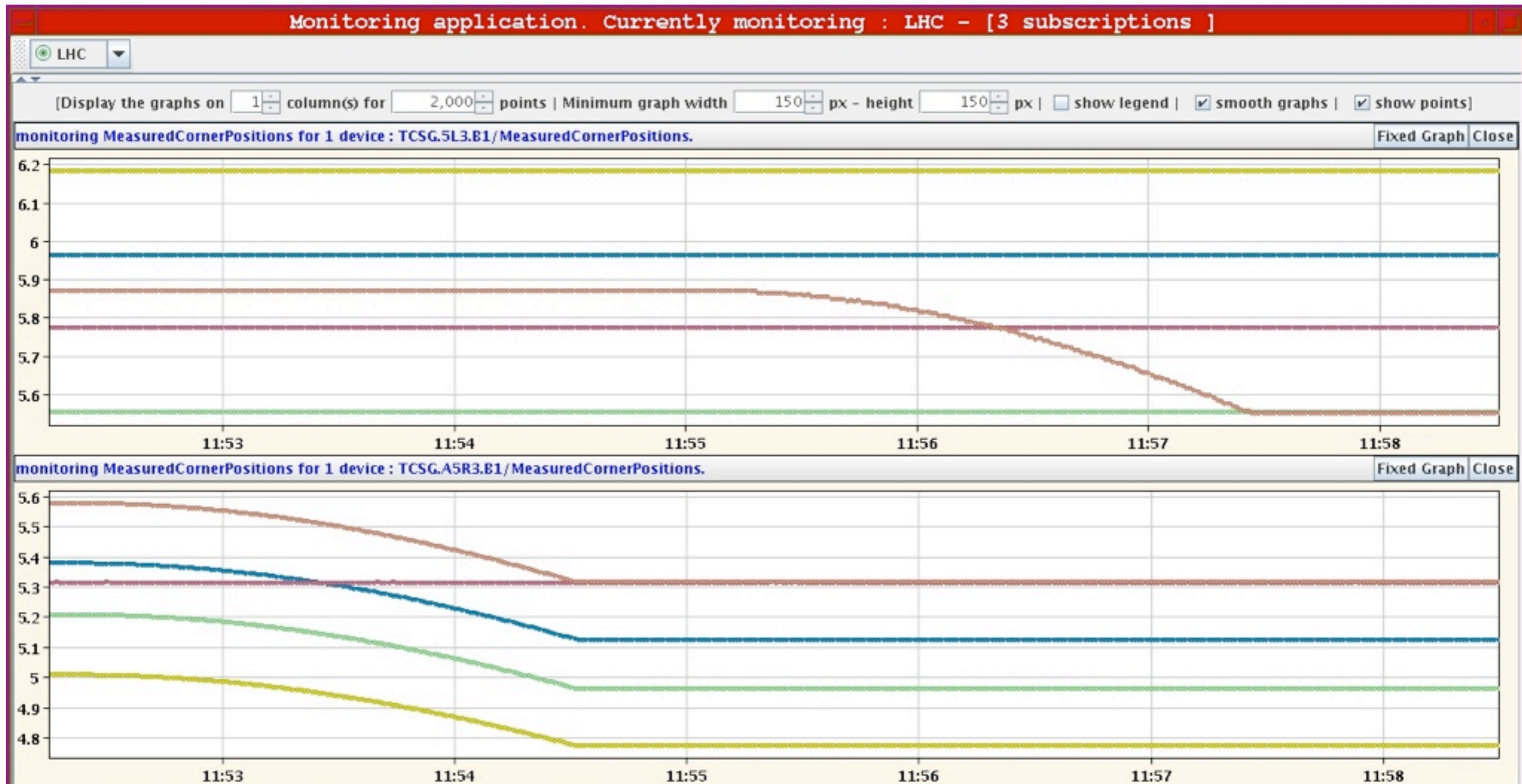
Focused on discrete limits so far

List of problems encountered:

- TCDIH.20607 not connected to BIC
- Few energy limit checks missing in IP3
- 1 gap value in T18 badly calibrated - could not run sequence for gaps
- Early on, found two collimators where MP functionality was NOT activated after calibration (very dangerous!)

Tests of function limits systematically done for a few cases

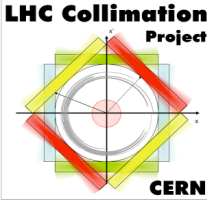
Ready to start global tests, synchronized with other accelerator systems (ramps PC's, final Energy ditribution)



*Individual system test done for the function-based limits (time- and energy-dependent) as a part of IST s*

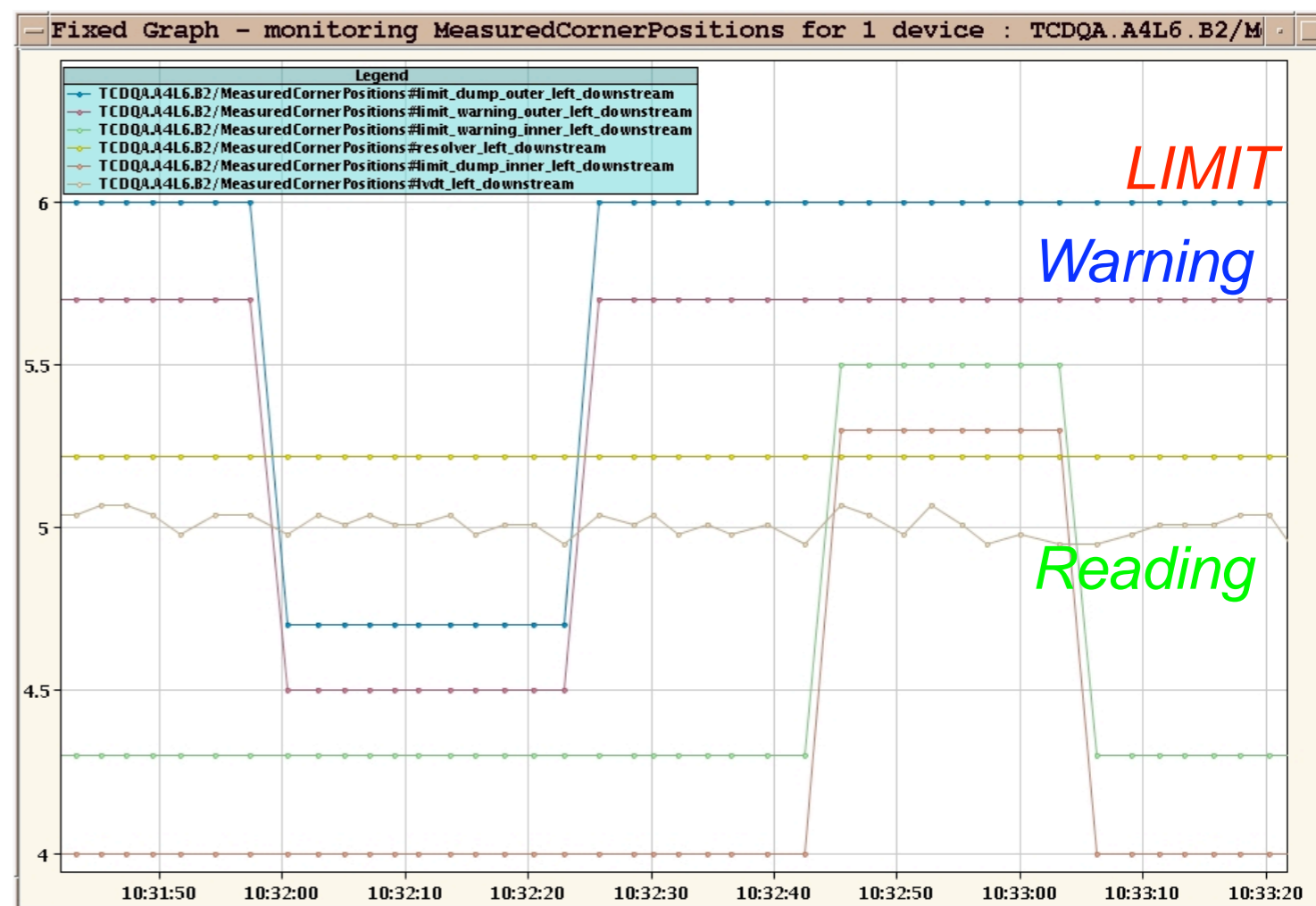


# Outline



- Introduction / procedures
- Positioning interlocks
- Special devices**
- Temperature interlocks
- Outlook

- ☑ Same basic functionality but **different hardware** and **software**  
*One-sided elements (2 position measures), no gap measurements*  
*Different low-level controls: servo-loop based on potentiometers*  
*Same LVDTs as collimators added for interlocking purpose*  
*Not yet energy limits possible (under discussion)*
- ☑ Defined a middle-level FESA interface to minimize impact  
*Could re-use most of the tools, including logging!*
- ☑ Sequence for discrete limit checks run manually (only 4 LVDT's).  
**Successful!**
- ☑ Function limits not yet operational as of 3 weeks ago

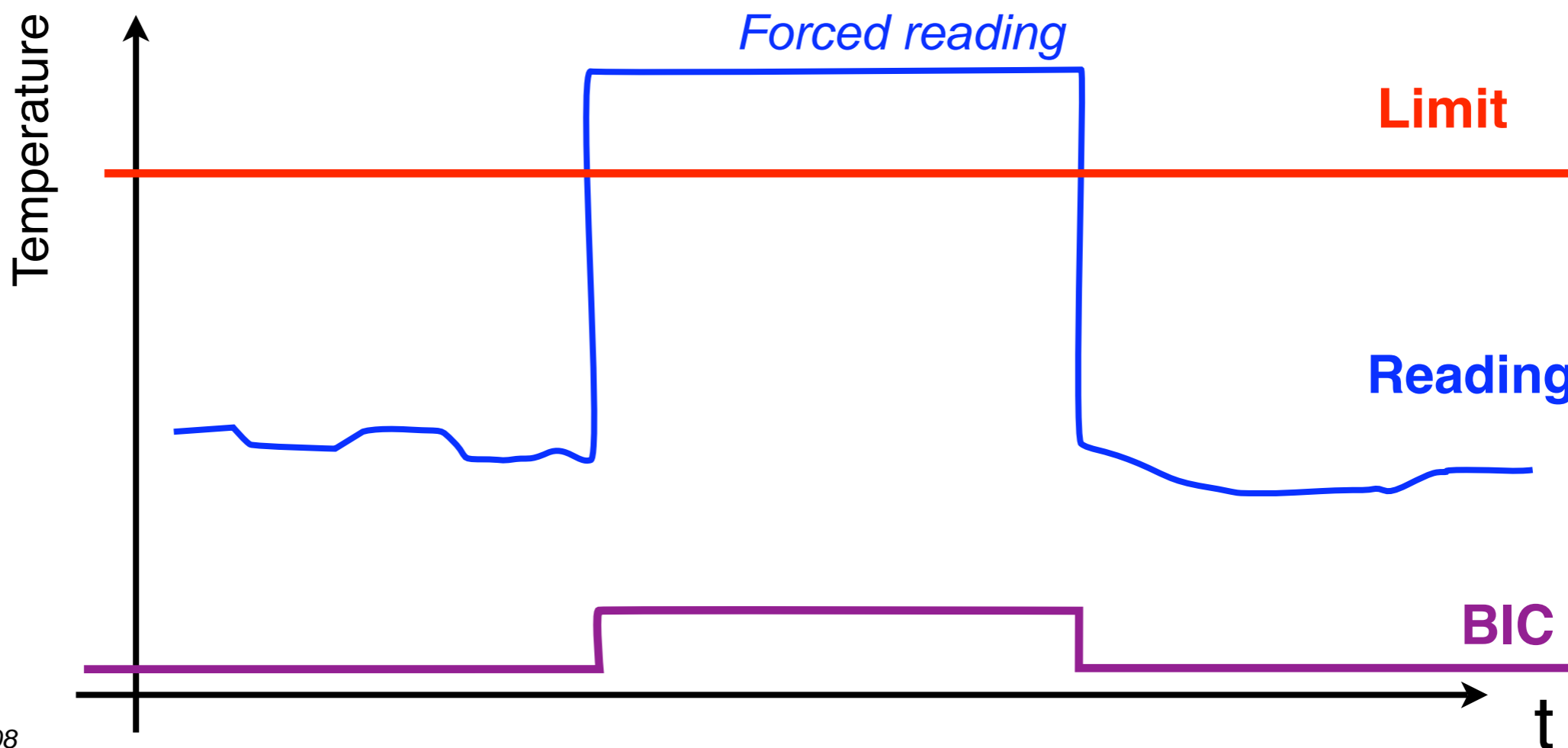


*Full chain tests done with  
C. Boucly, E. Carlier*

- ☑ Different hardware but basically same software
  - Missing direct gap measurements*
  - No need of energy limits*
- ☑ Important difference: connection also to injection BIC
- ☑ Special interlock implementation:
  - OUTER limits for injection permit (Don't inject if OUT)
  - INNER limits for circulating beam permit
- ☑ Implemented but first tests failed because wrong sensors were connected to BIC (2 LVDT's per motor axis)
- ☑ Will repeat that as soon as this is fixed

# Temperature interlocks

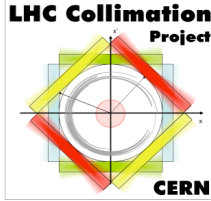
- ☑ UNYCOS system under PVSS (E. Blanco)
- ☑ 4 sensors per jaw + 1 for cooling water: 403 sensors for 2008 system
- ☑ All sensors connected to BIC, INDIVIDUAL dump + warning limits
- ☑ Cannot heat the sensors. Forced the temperature reading to check the functioning of the interlock chain.







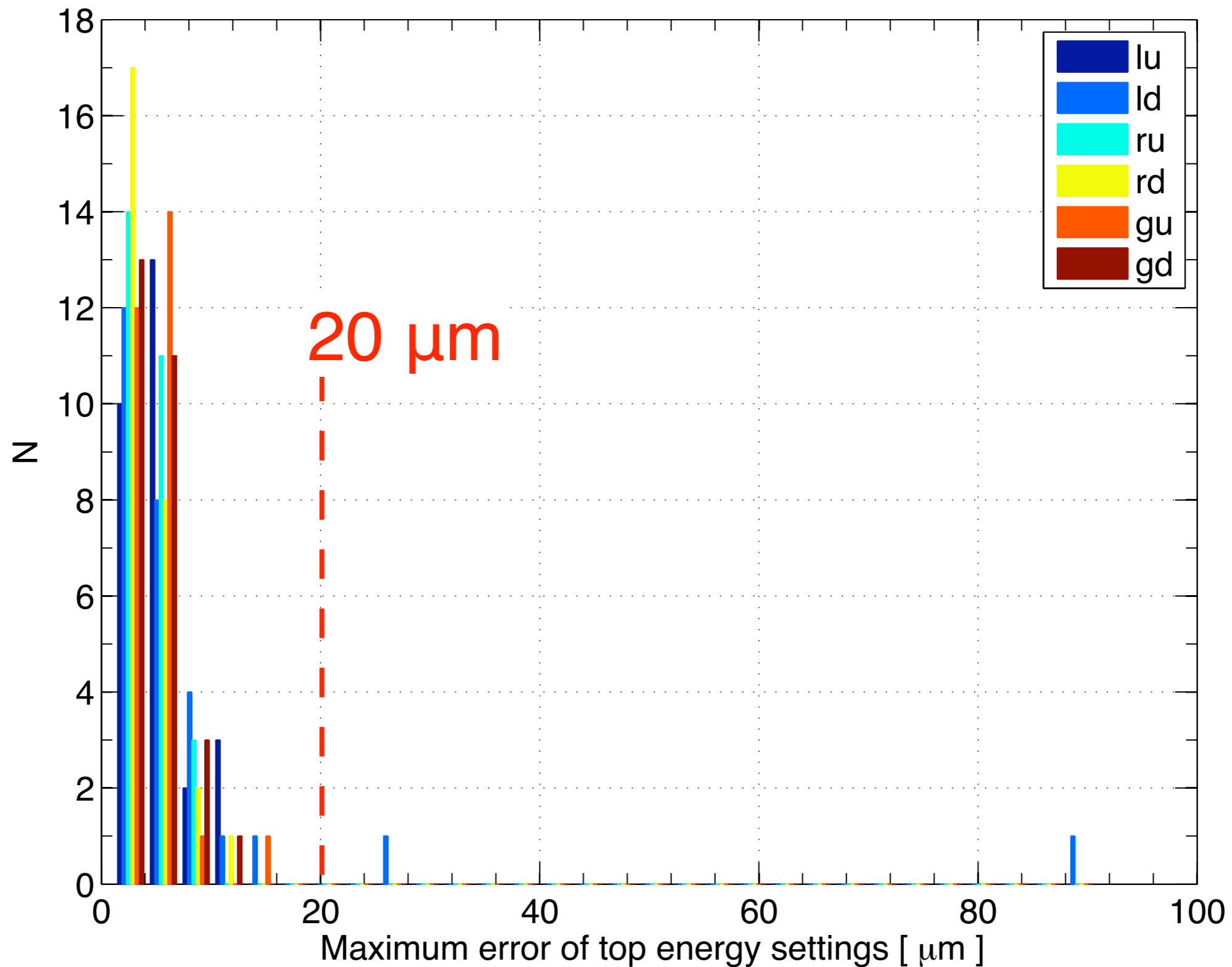
# Temperature interlocking - summary



- ☑ Verified individually all 400 sensors (*thanks Delphine, Eric*)
- ☑ Overall: **no major problems**, system works very well
- ☑ A few punctual **problems** submitted to Quique:
  - 4 problems found. A couple of dead sensors.
- ☑ Need to work on the **sensor calibration**
  - Sensor readouts are not always as expected.
- ☑ **Special elements: TCDQ, TDI**
  - Reading available from FESA (provided by BT/ATB)
  - Different control chain. Interlocks not yet implemented.
  - If interlocks needed, propose to have the same FESA interface for limits for both, to be implemented.

- ☑ Machine protection tests for the collimation system was basically completed
- ☑ Tests were very useful and successful
  - Few problems encountered, minor list of TODO s*
- ☑ Confident that the system provides the functionality that it was designed for!
- ☑ Outlook:
  - Interlocks from switch statuses not tested for all colls*
  - Automatize the analysis?*
  - Implementation of TCDQ energy limits*
  - Roman pot interlocking (a whole chapter...)*
  - Systematic MCS tests for the full system*
  - Follow-up the implementation of beta\*-limit functions*
  - Setting reproducibility tests to define the limit windows*

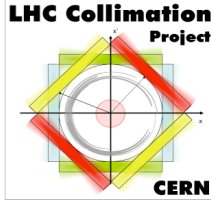
# Results of reproducibility tests



*Setting reproducibility errors for 28 collimator in IP7 (168 LVDT s).  
 Performed about 20 nominal ramp functions to 5 TeV.*



# Acknowledgments



- ☑ Work of MANY people from the collimation team, in particular the ATB control team
- ☑ Ralph, Joerg, Ruediger; INJ + DUMP teams; Gianluigi
- ☑ Quique Blanco for all the temperature controls
- ☑ Bruno's team
- ☑ Thanks to R. Billen, C. Roderick + logging team
- ☑ LHC operation crew deeply involved in the tests for
  - Running sequences (Markus, Fabio, ...)*
  - Analyzing sequence results (M, F, Reyes, Funny, ...)*
  - Checking temperature interlocks (Delphine, Eric)*