11th US-LARP Collaboration Meeting
Fermilab, Batavia, IL 60510 USA
27th October 2008

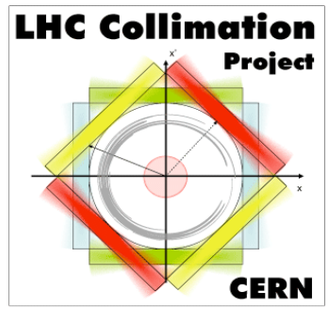
Operational Experience with the LHC Collimation System

Stefano Redaelli - AB Department, Operation Group

R. Assmann and A. Masi - AB Department

with O. Aberle, C. Bracco, R. Chamizo, M. Donze, P. Gander, Y. Kadi,

M. Lamont, J. Lendaro, R. Losito, V. Previtali, T. Weiler, ...



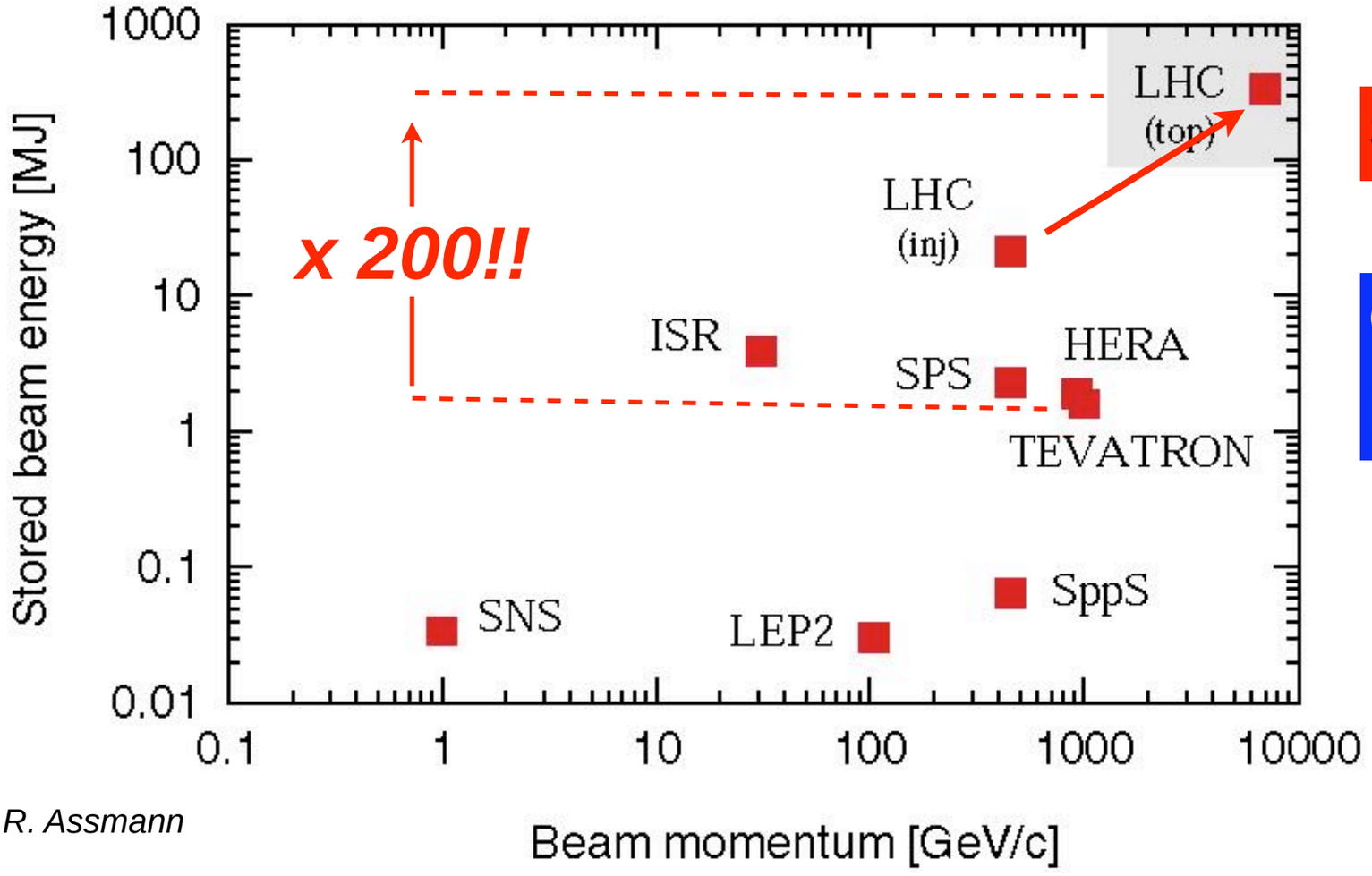
Acknowledgments

- Results of the work of many people presented
- Control team
  - LHC Software Application (LSA) team: M. Lamont, G. Kruk, ...
  - LHC logging team: R. Billen, C. Roderick
  - Top-level implementations: E. Veyrunes, D. Jacquet, ...
  - Temperature acquisition system: E. Blanco, J. Brahy, M. Jonker
- Operation / beam tests
  - M. Lamont, R. Bailey, G. Arduini, J. Wenninger
  - LHC operation shift crew
- LHC Injection & Dump teams: E. Carlier, C. Boucly, B. Boddard, V. Kain
- LHC beam interlock team (B. Puccio, J. Wenninger, R. Schmidt, ...)

Outline

- **Introduction**
  - Requirements
  - The 2008 system
  - Operation aspects
- **Commissioning without beam**
  - Synchronized energy ramps
  - Accuracy / Reproducibility
  - Interlock commissioning
- **Experience with beam**
  - Transfer line commissioning
  - Operation of ring collimators
- **Conclusions**

Introduction



R. Assmann

E_b = 0.45 → 7 TeV; I_b = 3.4x10^{14}

Stored energy	**362 MJ (7 TeV)**
	23 MJ (450 GeV)
Quench limit	~ 10 mJ / cm^3
Damage (metal)	~ 50 kJ / mm^2

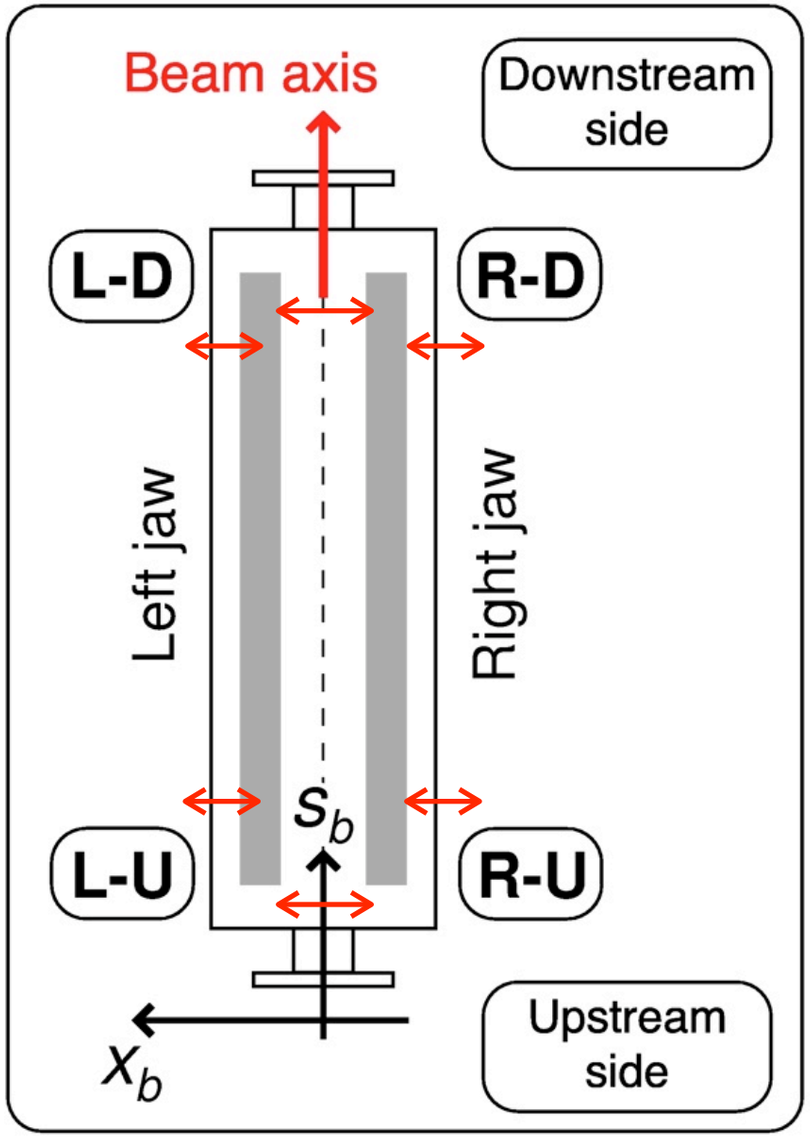
LHC enters in a ***new territory*** for handling ultra-intense beams in a super-conducting environment!

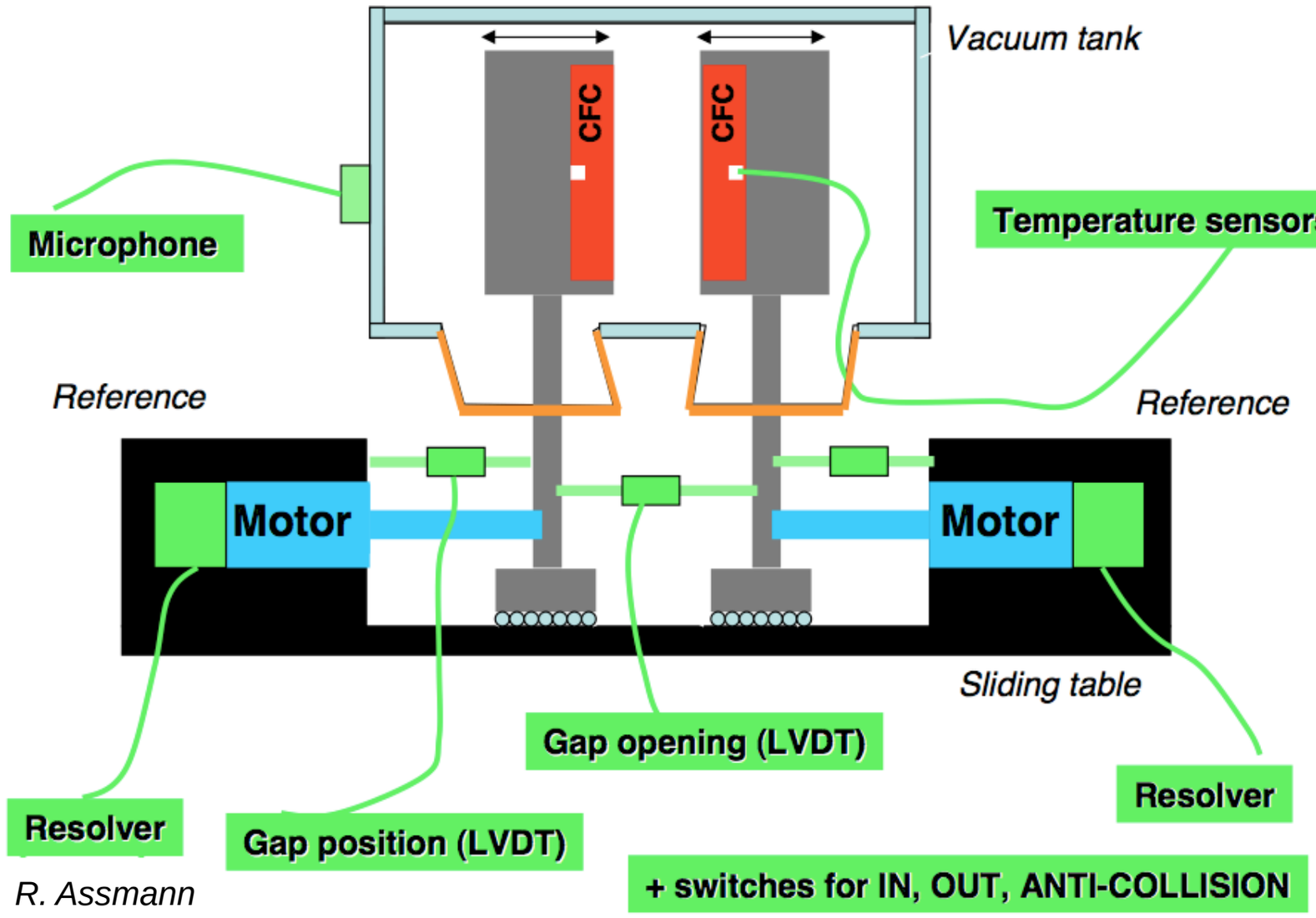
- *Control losses **1000 times** better than the state-of-the-art!*
- *Important role in **machine protection***
- *Need collimation in **all machine states**: injection, ramp, squeeze, physics*

System requirements

Mechanical control σ_b = 250 µm at 7 TeV	**40 µm** surface flatness over L=1m **20 µm** positioning reproducibility **20 ms** synchronization around ring **Function-driven** movements
Heat load (7 TeV) Minimum lifetime: $\tau_{min} \approx 0.2$h	Up to **30 kW** at top energy Keep T < 50 °C
Critical for machine protection Total stored energy = 362 MJ	Interlock positions (functions) Interlock temperatures Redundancy Energy-based limits functions
High radiation environment ~10^{16} protons per years!	Radiation hardness of components Stepping motors: **~10-15 MGy** Position sensors: **~ 30 MGy**
Failure scenarios [Robustness!] Full **injection** batch 8 nominal bunches at **7 TeV/c**	 → 288 bunches ≈ **2 MJ (7.2 µsec)** → 8 bunches ≈ **1 MJ (0.2 µsec)**

Operational aspects: positioning





Settings: **4 stepping motors** for jaw corners - 1 motor for tank position.

Survey: 7 direct measurements: **4 corners** + **2 gaps** + tank

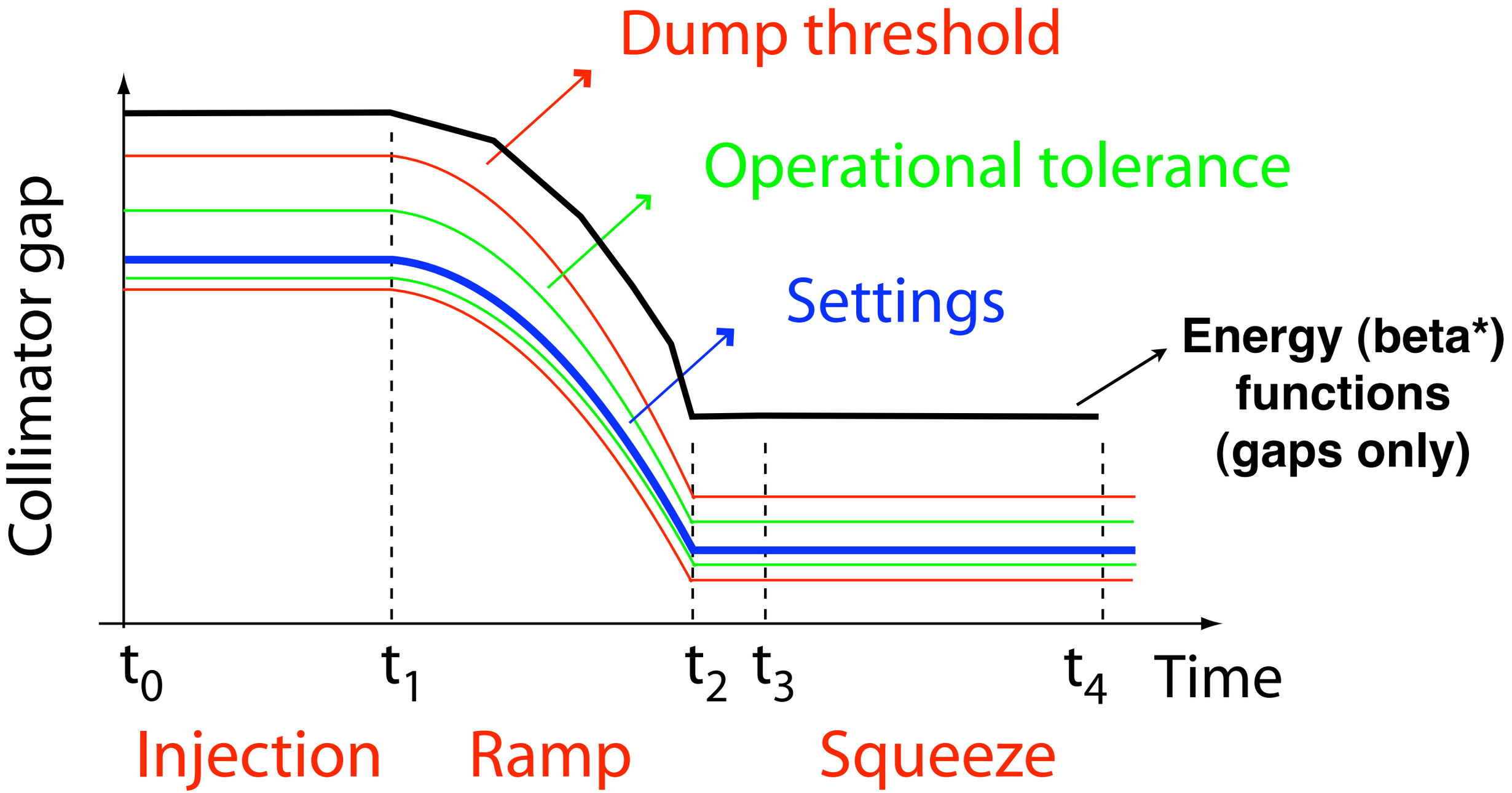
4 resolvers that count motor steps

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

Redundancy: motors+resolvers+LVDT's (*Linear Variable Differential Transformer*) =

14 position measurements per collimator

Function driven settings and limits



- Time-functions for settings in all machine states
- Time-limit functions for each motor axis + for the 2 gap meas.
- Energy- (beta*-)limit functions only for gap

The 2008 collimation system

Ring collimators:

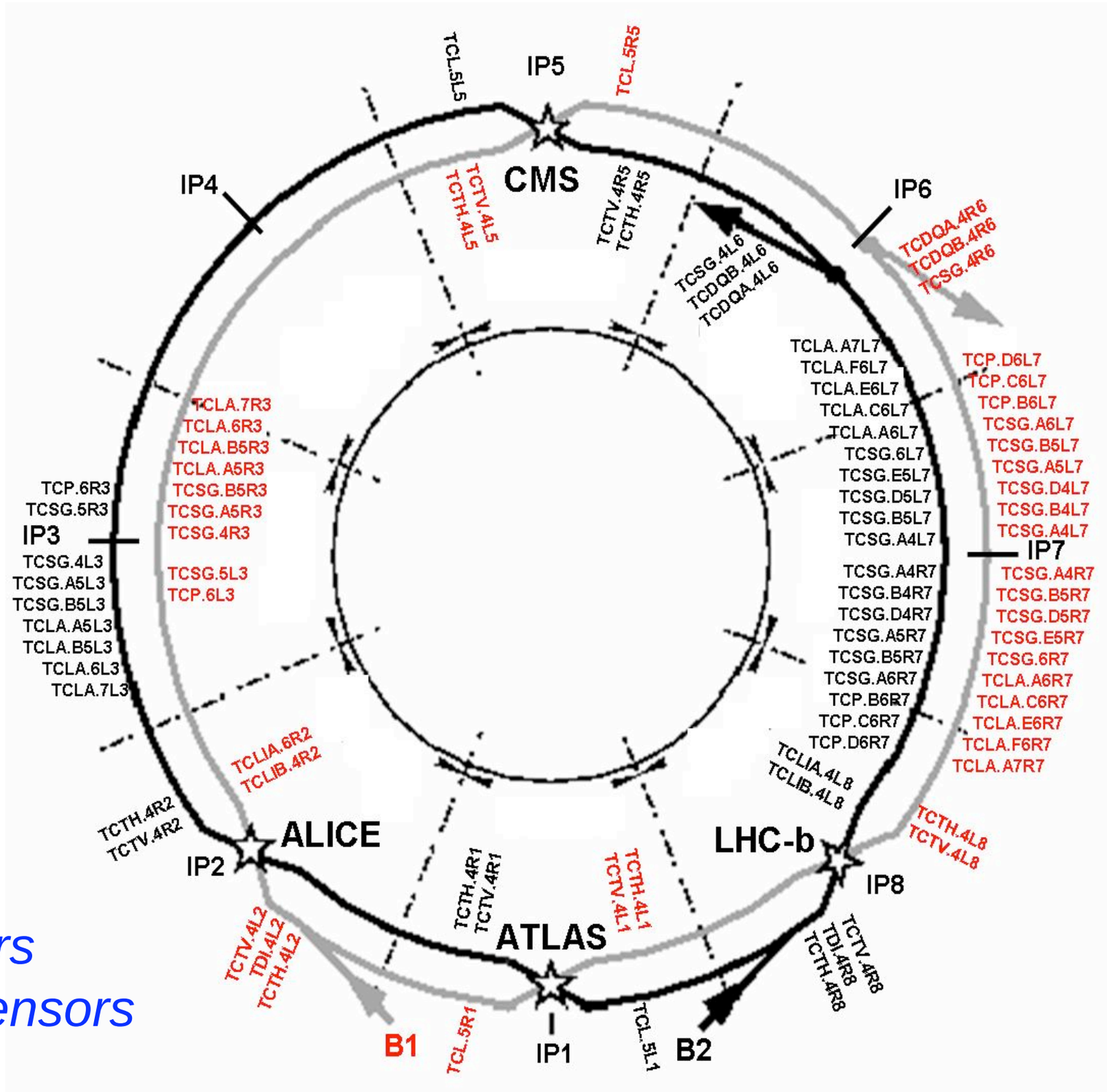
- 62 of type TCP, TCSG, TCLA, TCLI and TCT
- 2 TCDQ (dump)
- 2 TDI + 1 TCDD (inj. prot.)

Transfer lines:

- 13 TCDI's

***80 movable** LHC collimators for the 2008 system:*

- ***316** stepping motors*
- ***468** interlocked position sensors*
- ***403** interlocked temperature sensors*
- ***160** beam loss monitors for beam-based set-up*

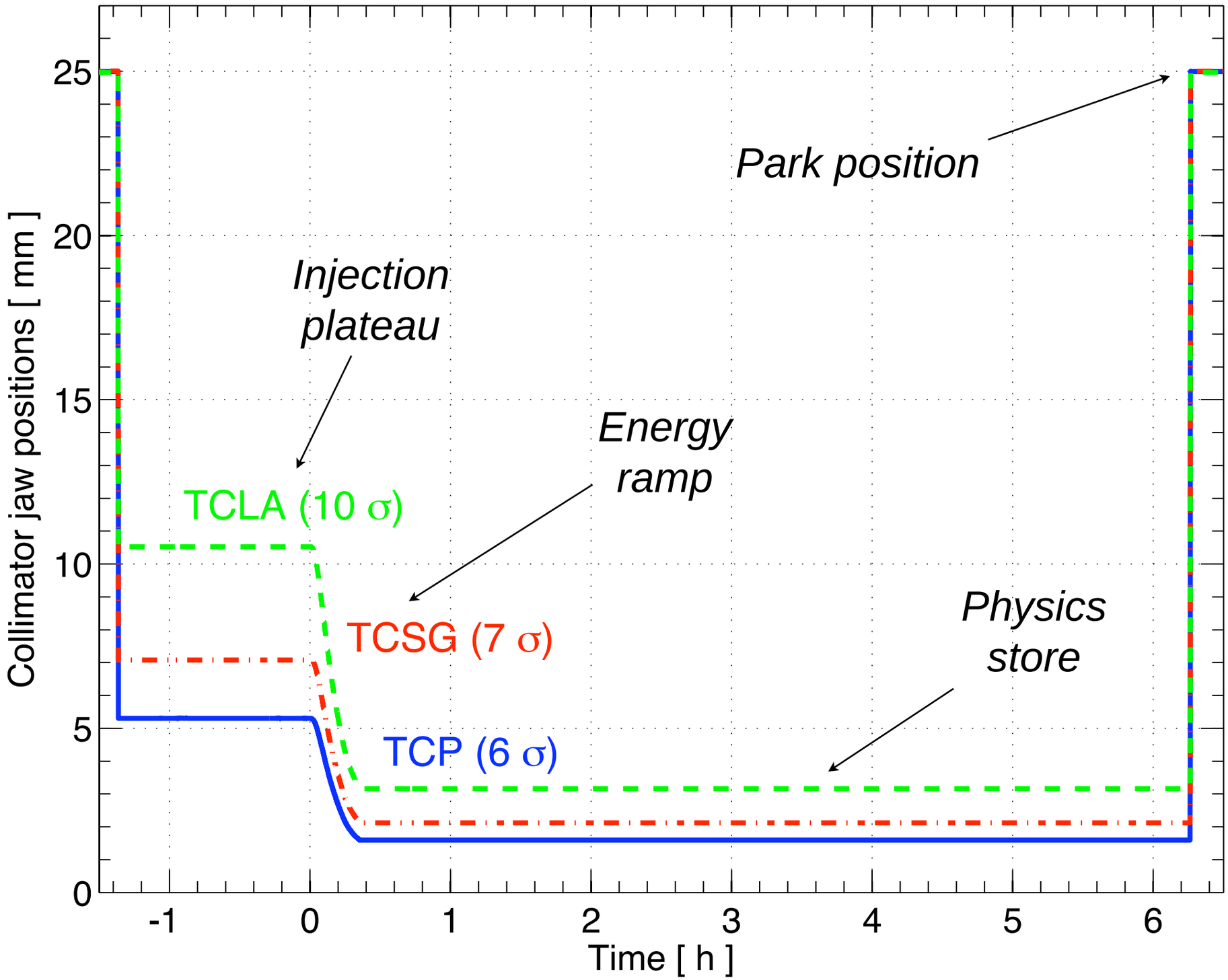


Outline

- **Introduction**
  - Design/operational requirements
  - Recap. of collimator design
  - The 2008 system
- **Commissioning without beam**
  - **Synchronized energy ramps**
  - **Accuracy / reproducibility**
  - **Interlock commissioning**
- **Experience with beam**
  - Transfer line commissioning
  - Operation of ring collimators
- **Conclusions**

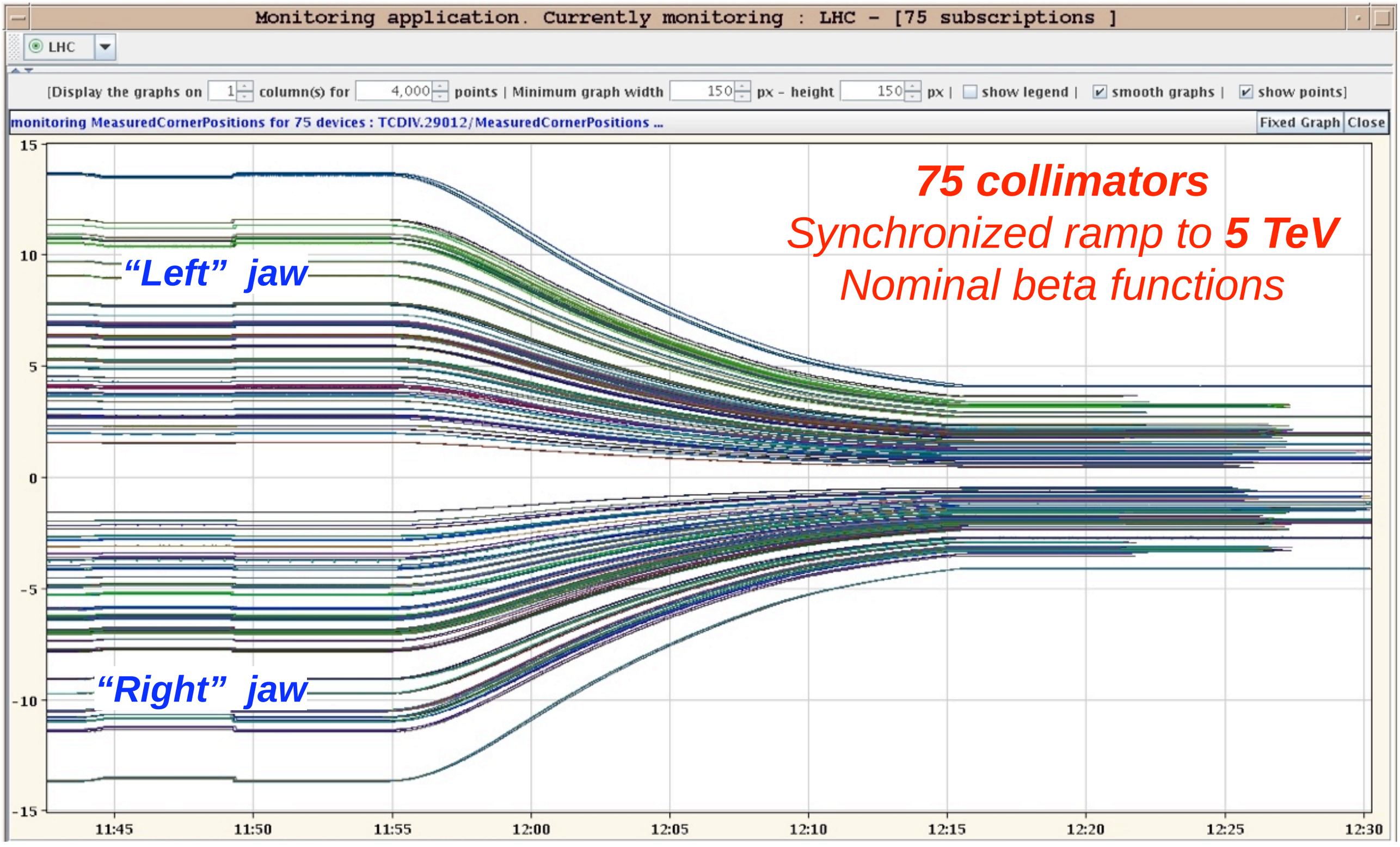
Collimator operational cycle

Measure jaw position (half gap) for three collimators in IP7

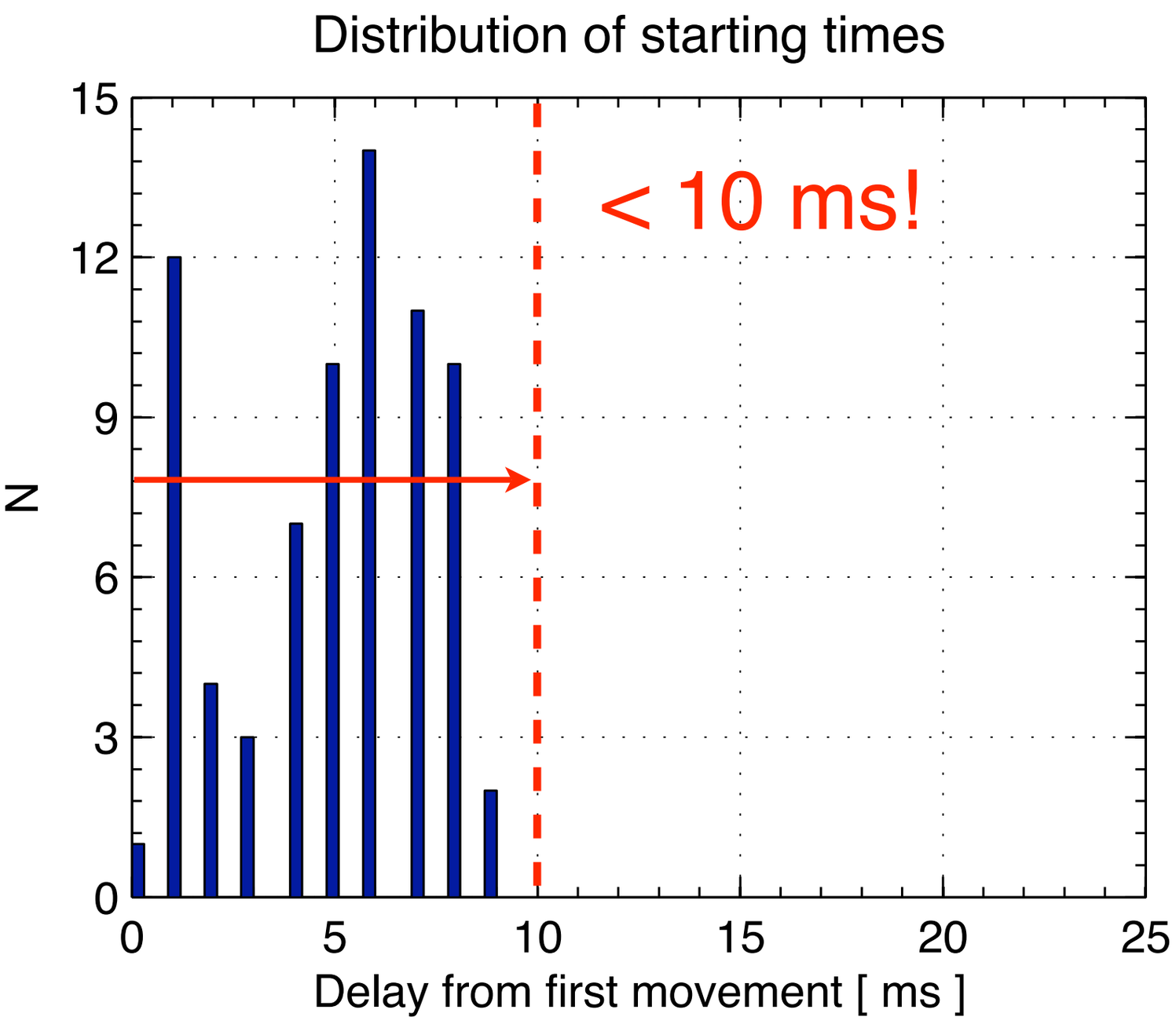


Synchronized ramp tests

Measured collimator jaw positions versus time



Synchronization of motion



74 collimators *armed with ramp functions. Start of movements triggered by* ***hardware timing event****, distributed along the 27 km tunnel. Look at maximum* ***delay*** *after the first collimator starts moving.*

Beam requirements: ***< 20 ms***

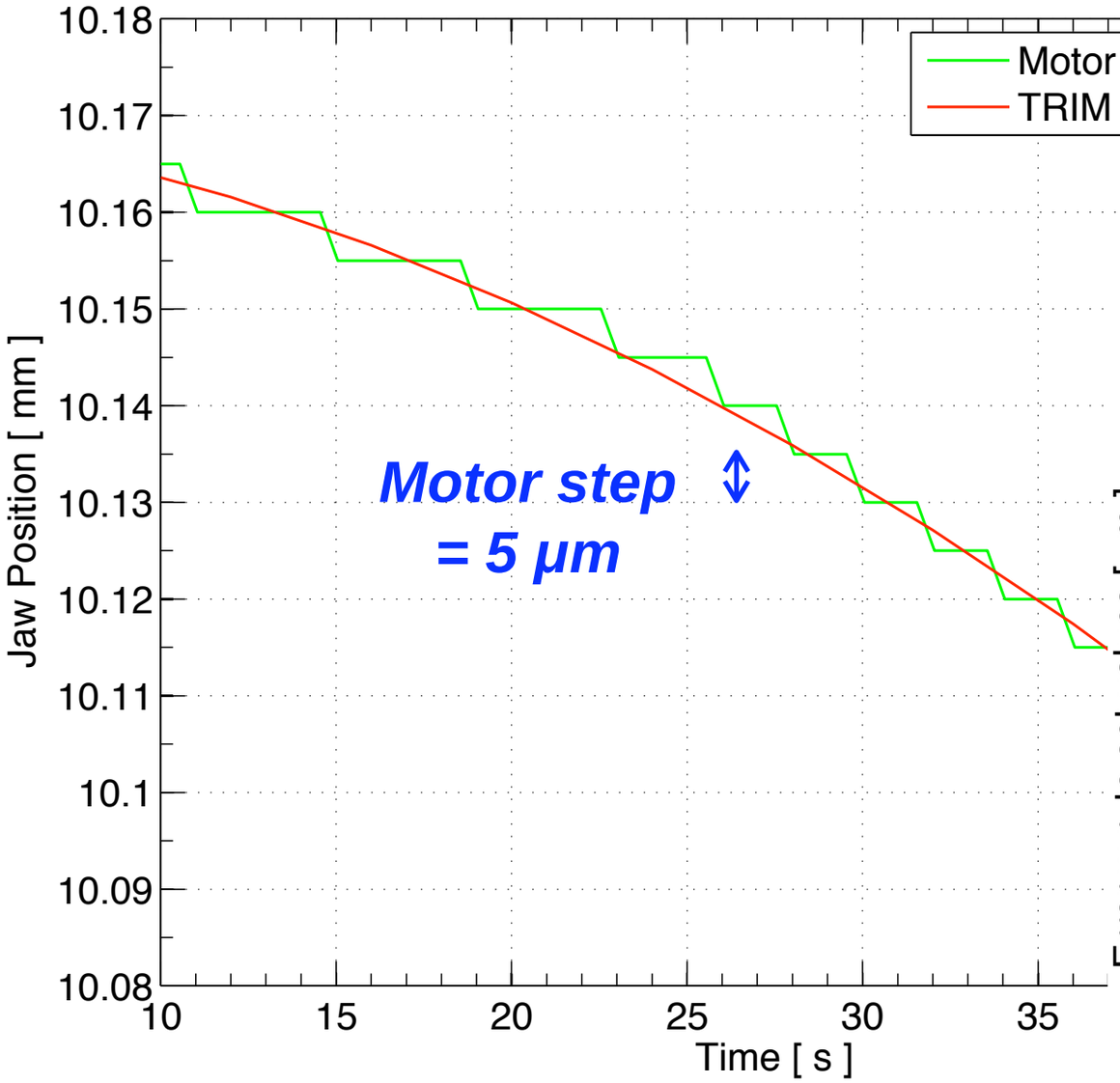
Achieved < 10 ms!

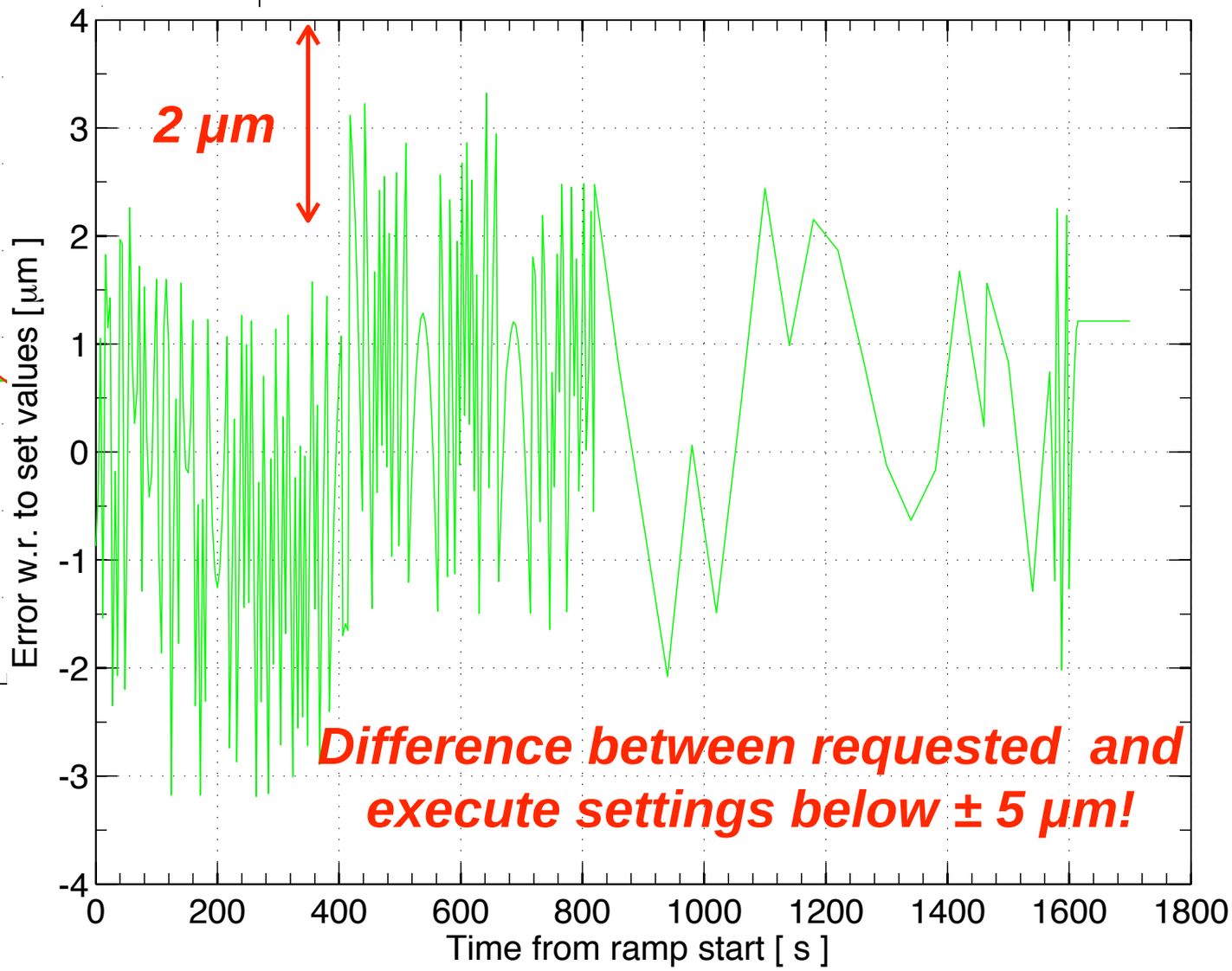
HW can do ***100 times better (<1 ms)****, observed delays are determined by the read-back form the middle-ware.*

Ongoing: synchronization with other accelerator systems (e.g., power converters, RF). No issue expected.

Accuracy of function execution

Requested/executed settings vs. time



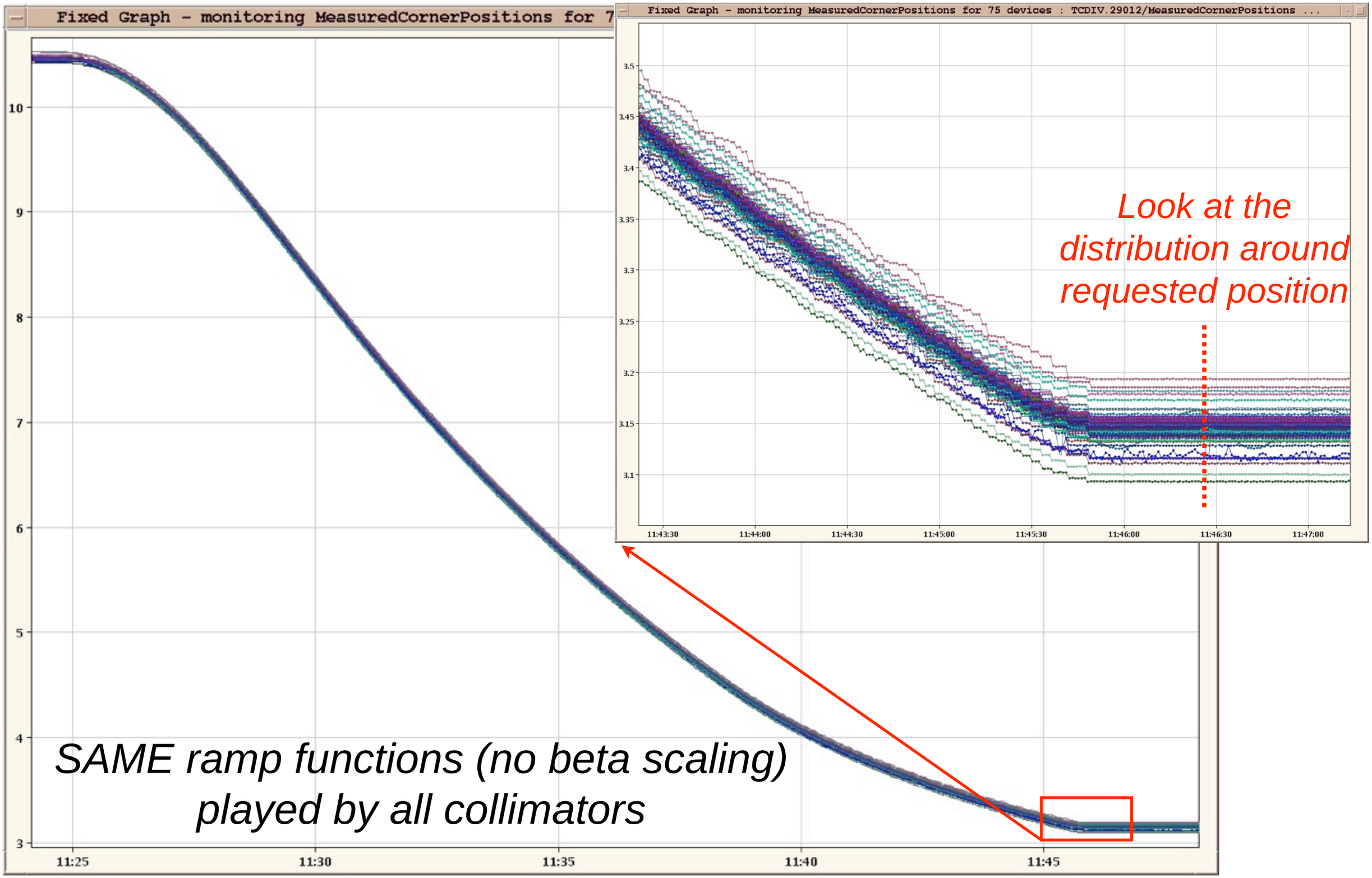


- Motor step = **5 µm**
- Operational motor speed = 2 mm/s
- "Slow" functions are interpolated with the appropriate rate of step execution

Low-level implementation in the PXI system by A. Masi

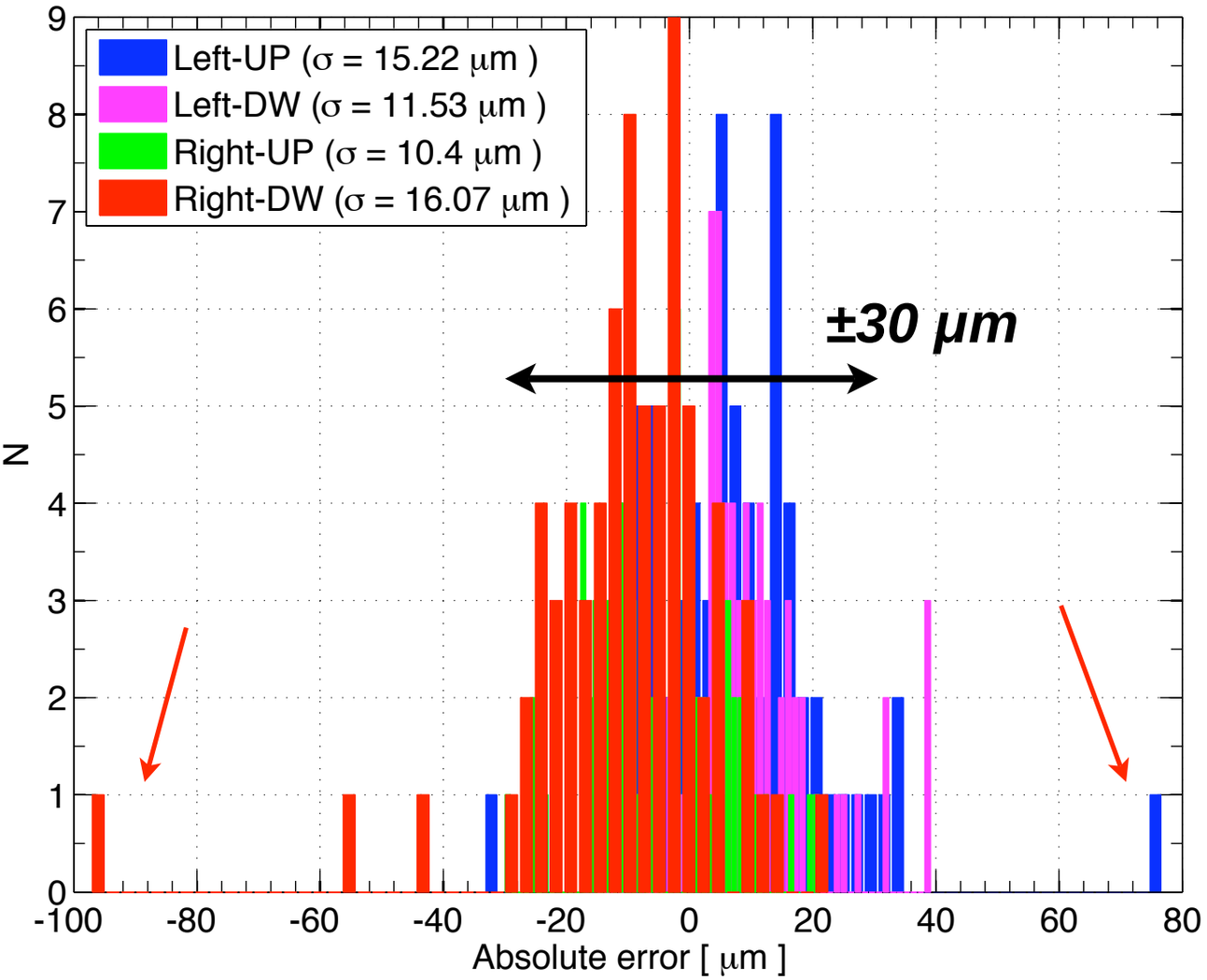
Synchronized ramp tests

Position of one collimator axis versus time

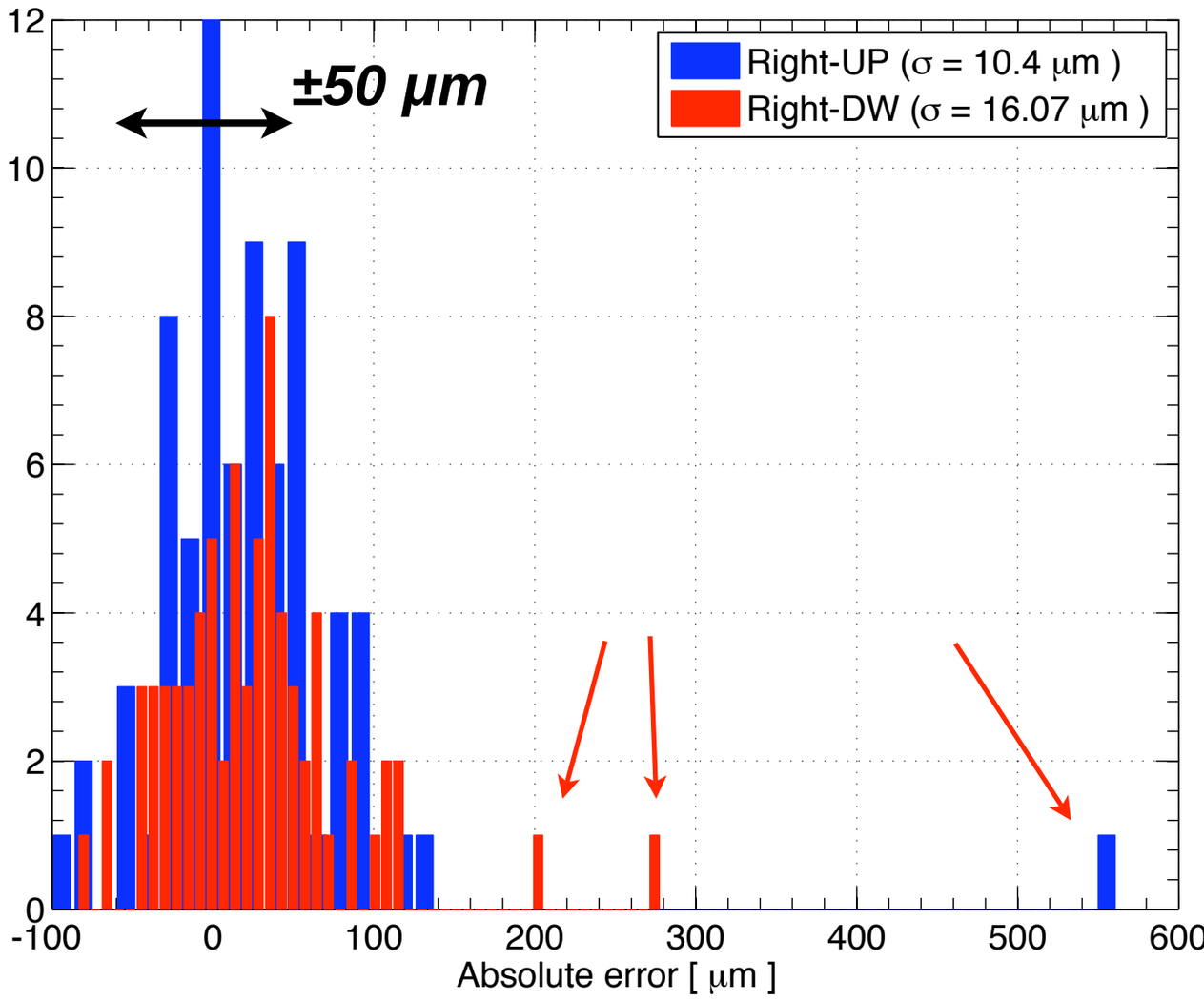


Distribution of errors (end of ramp)

Motor axes (300 sensors)

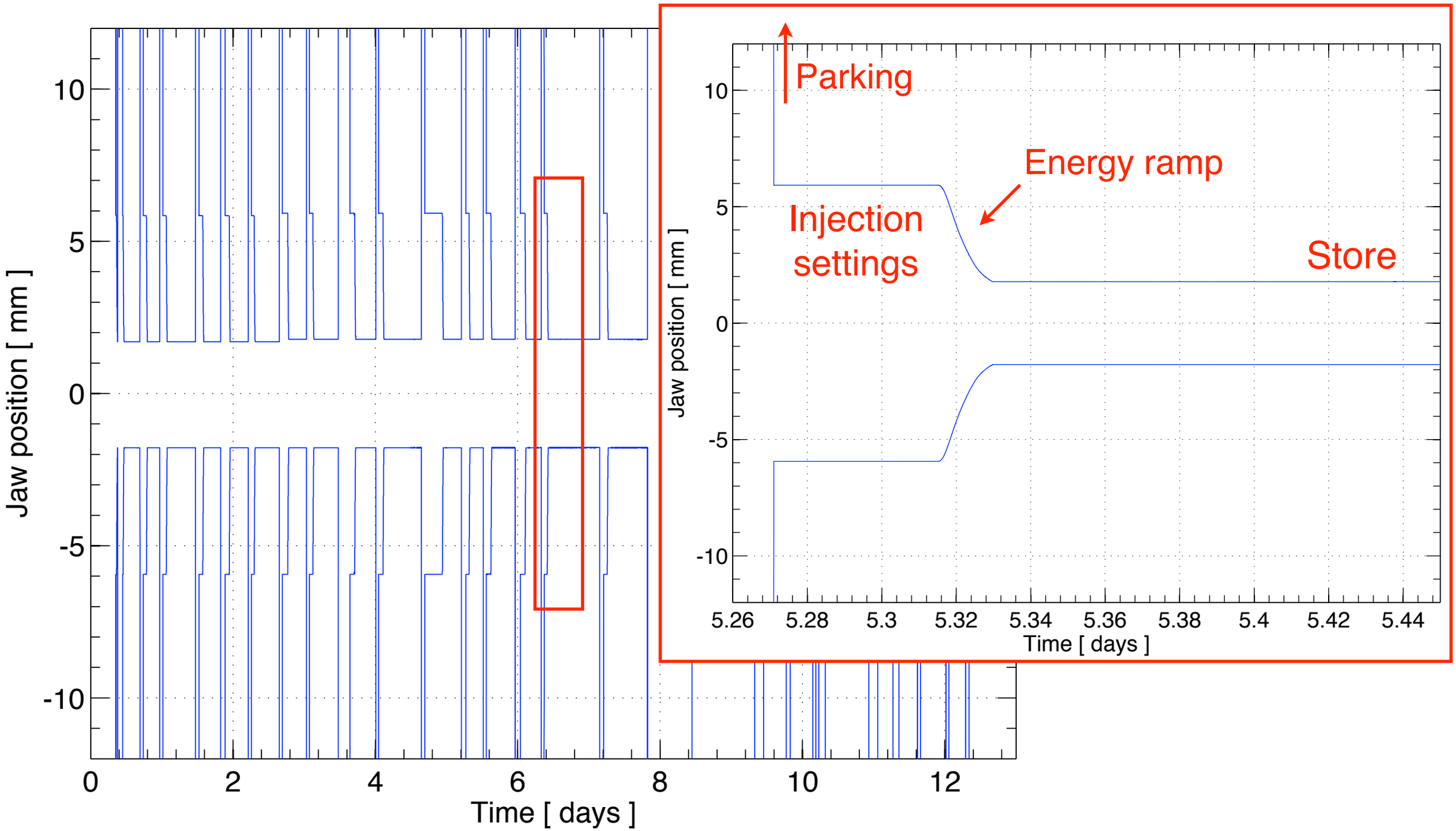


Gap measurements (150 sensors)



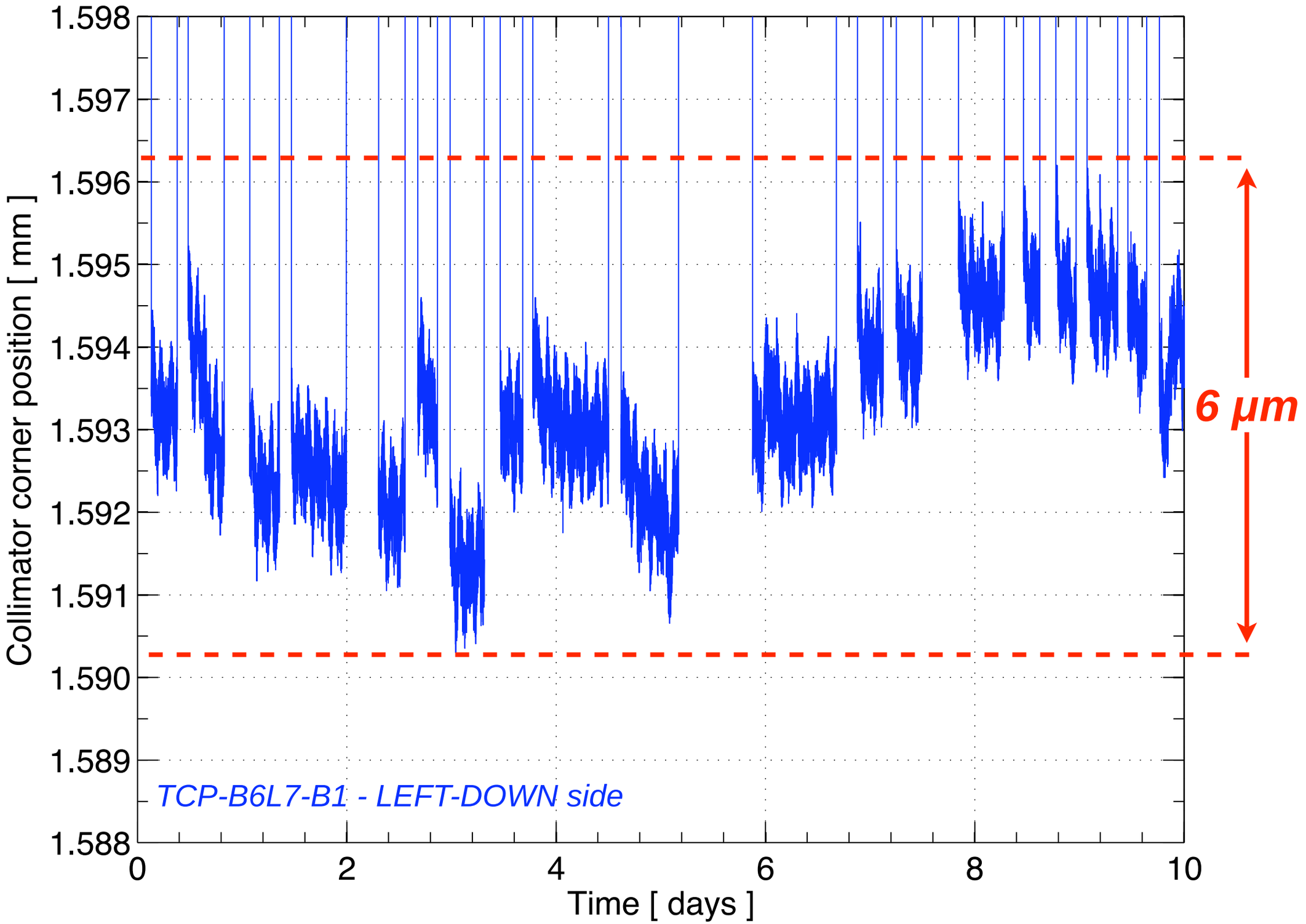
- Statistics on 75 collimators in the tunnel, end-of-ramp settings for physics store.
- A few “bad guys” that need re-calibration (or possibly replacement)
- Motor axes more precise because stroke is shorter (35 mm instead of 60 mm for gaps).
- Errors stay mainly CONSTANT during function execution: **REPRODUCIBILITY** will determine the system performance!

Reproducibility tests

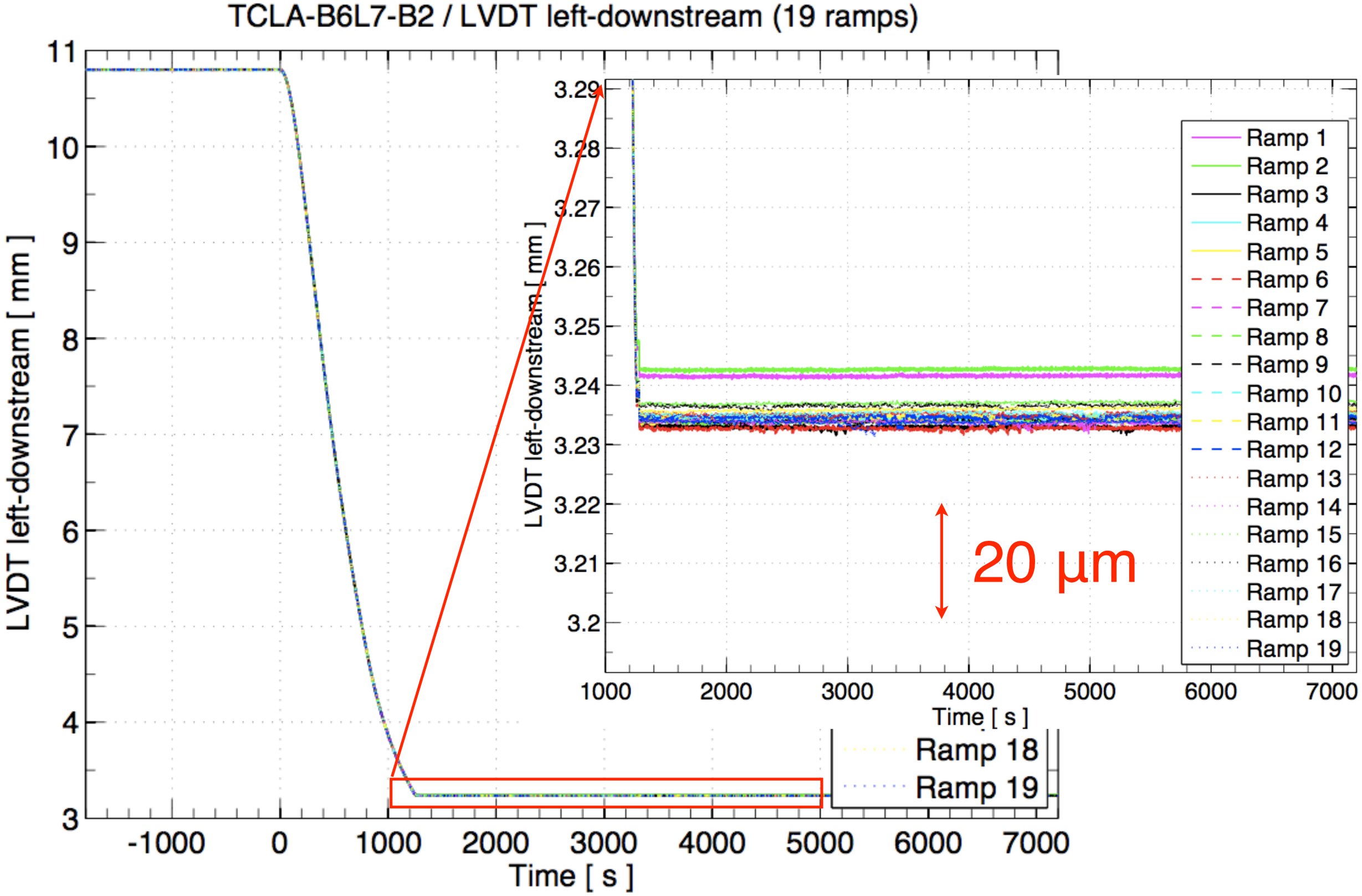


- Reproducibility tests: nominal operational cycles on **all 28 collimators in IP7**
- ~30 full cycles repeated during 10 days
- Real ramp functions to 5 TeV, nominal optics (different for each collimator)
- "Handed over" to operation crew *(special thanks to the LHC OP team)*

Reproducibility of physics settings

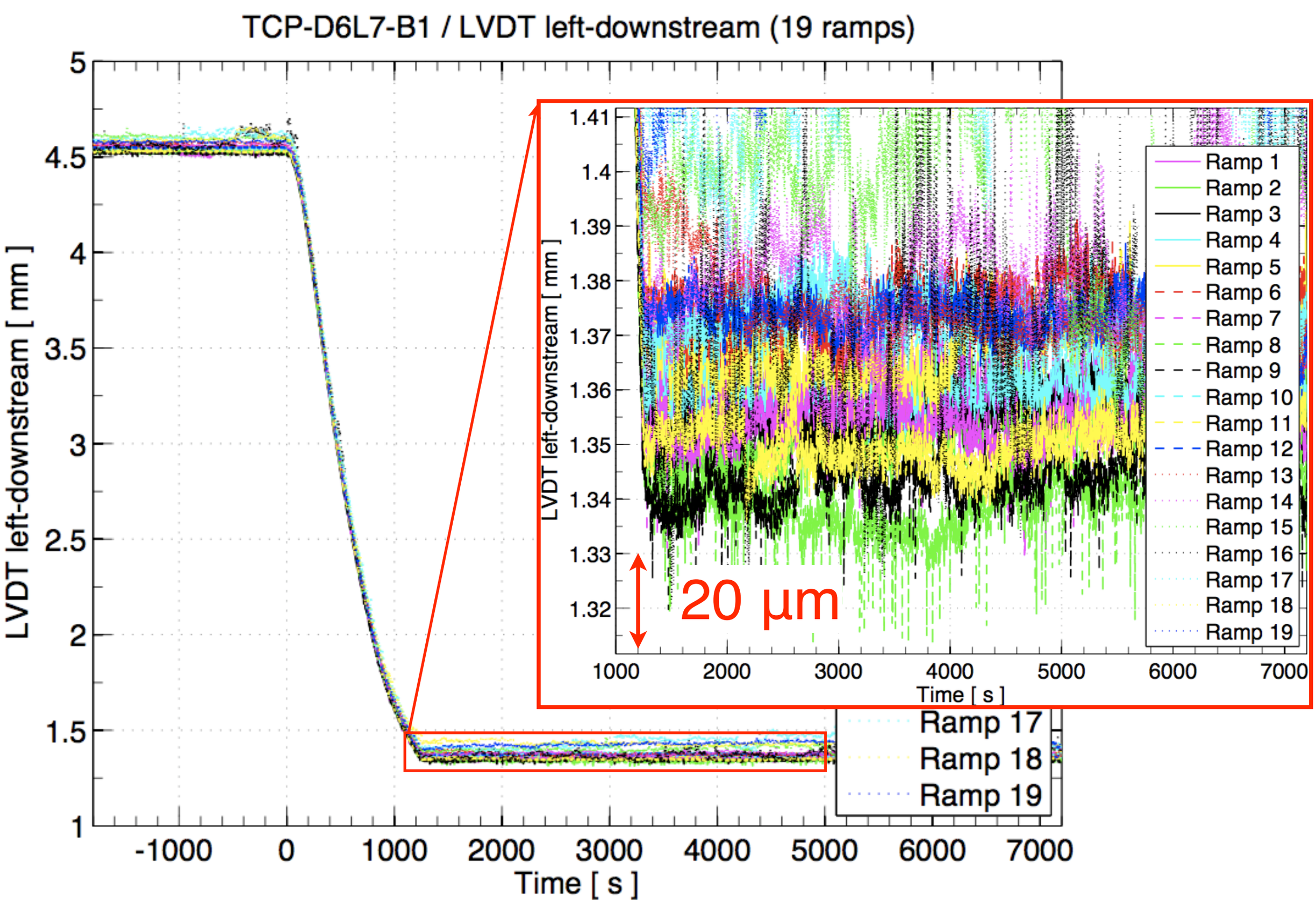


A few examples

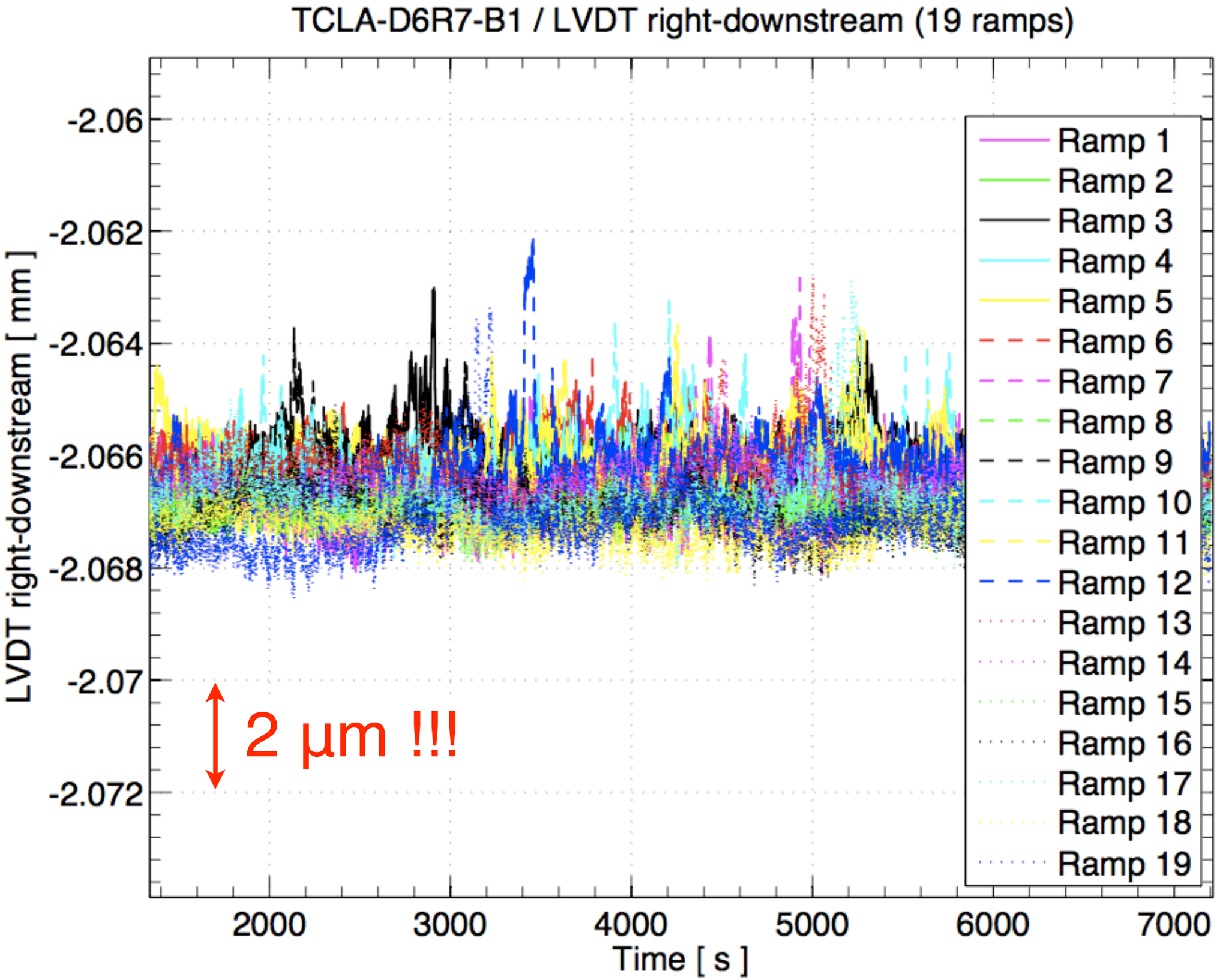


For each sensor (6 per coll), can put together all the ramp data

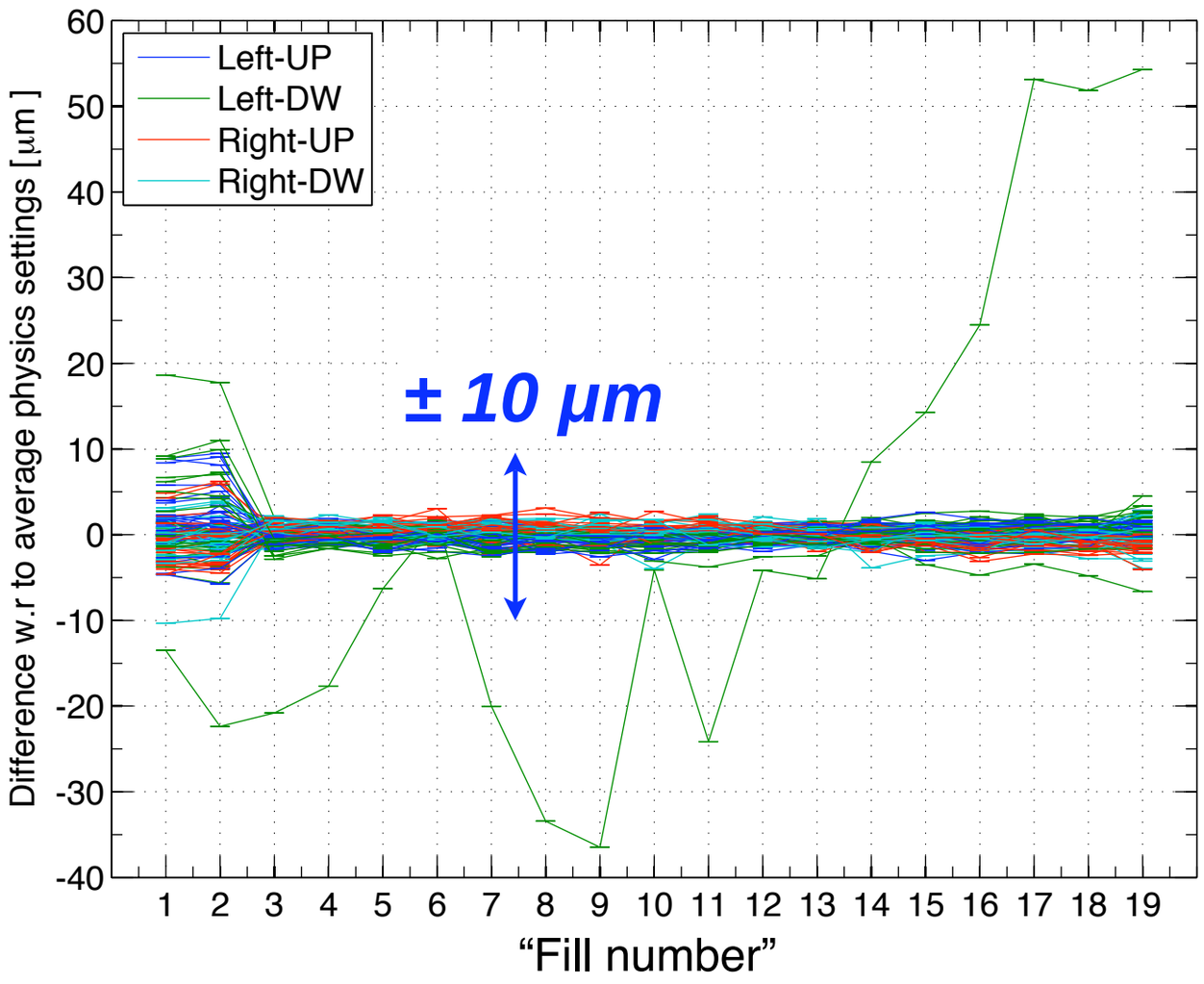
The worst case

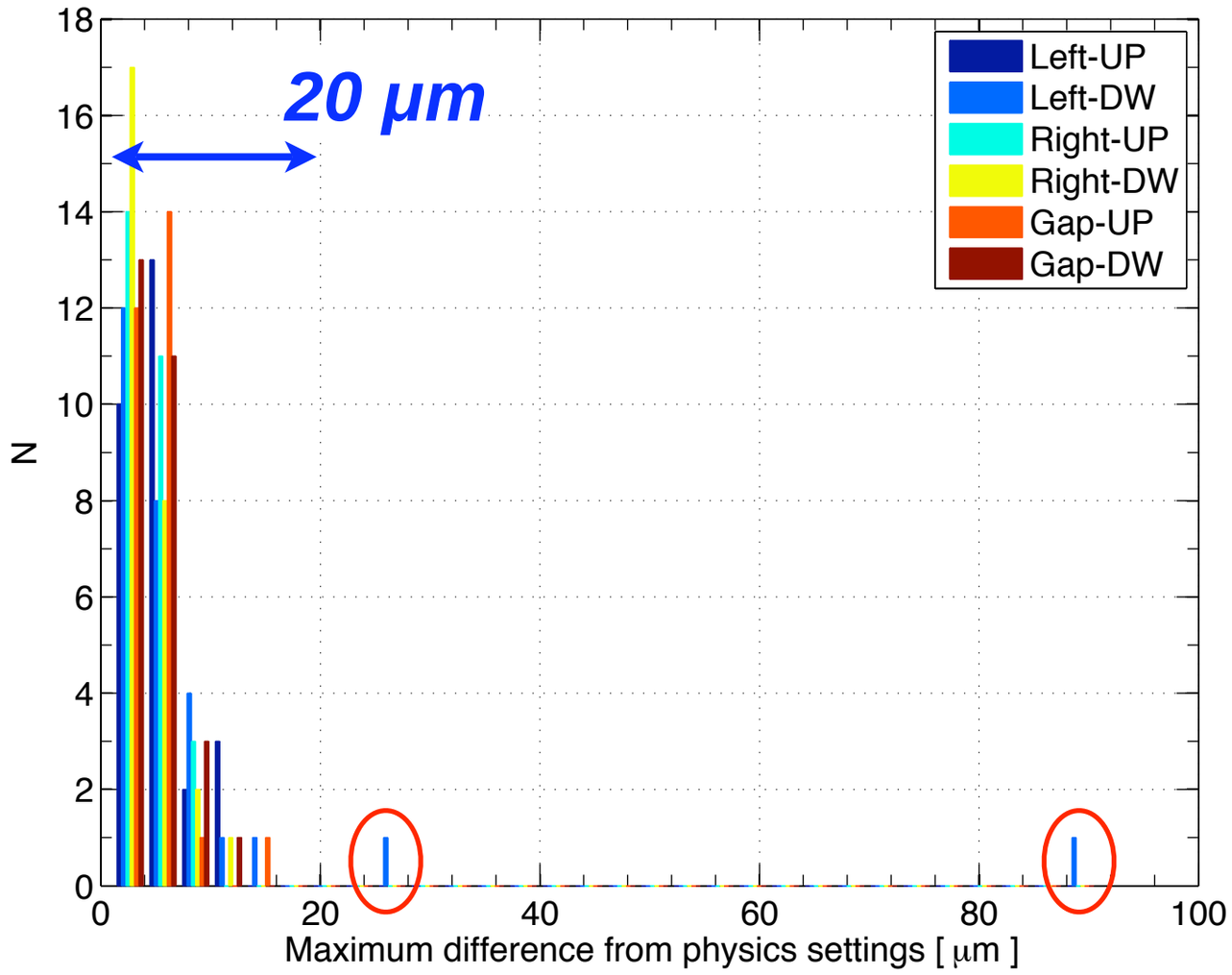


The best case



Summary of reproducibility results



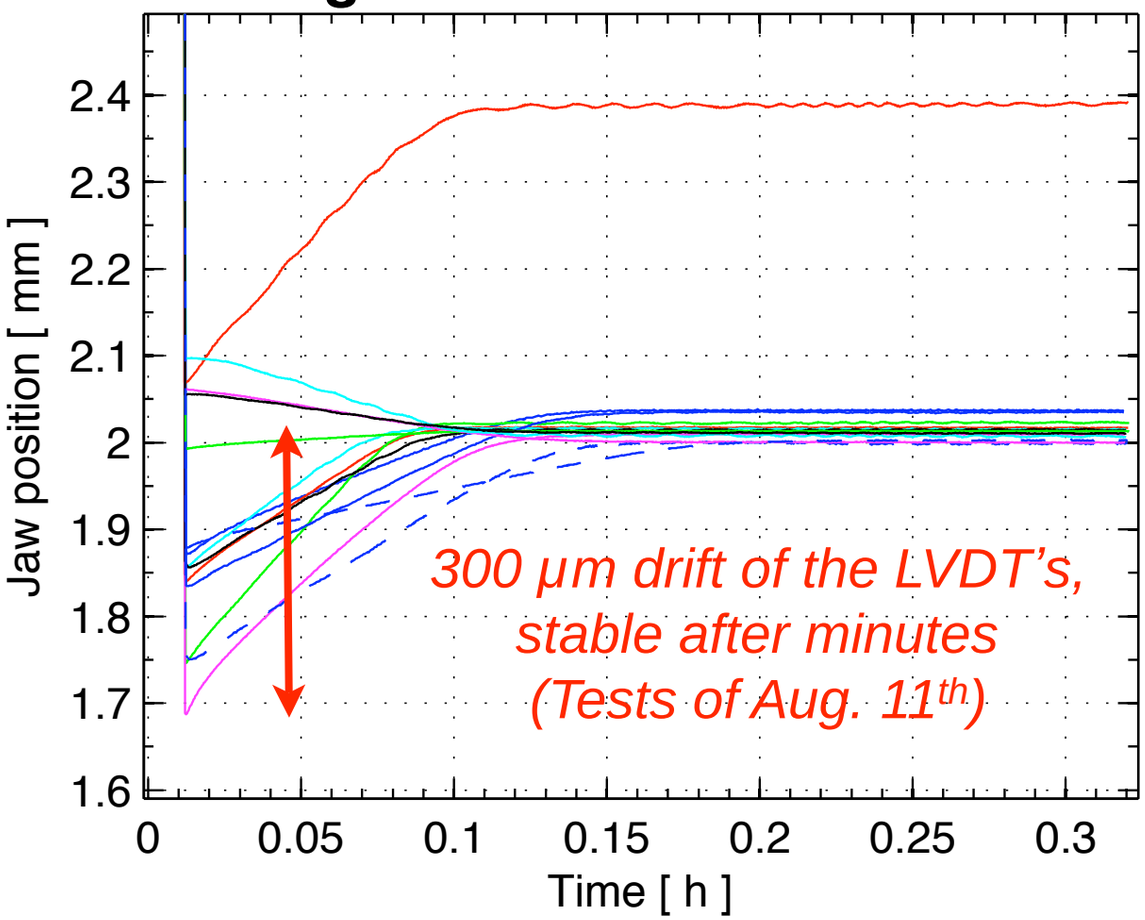


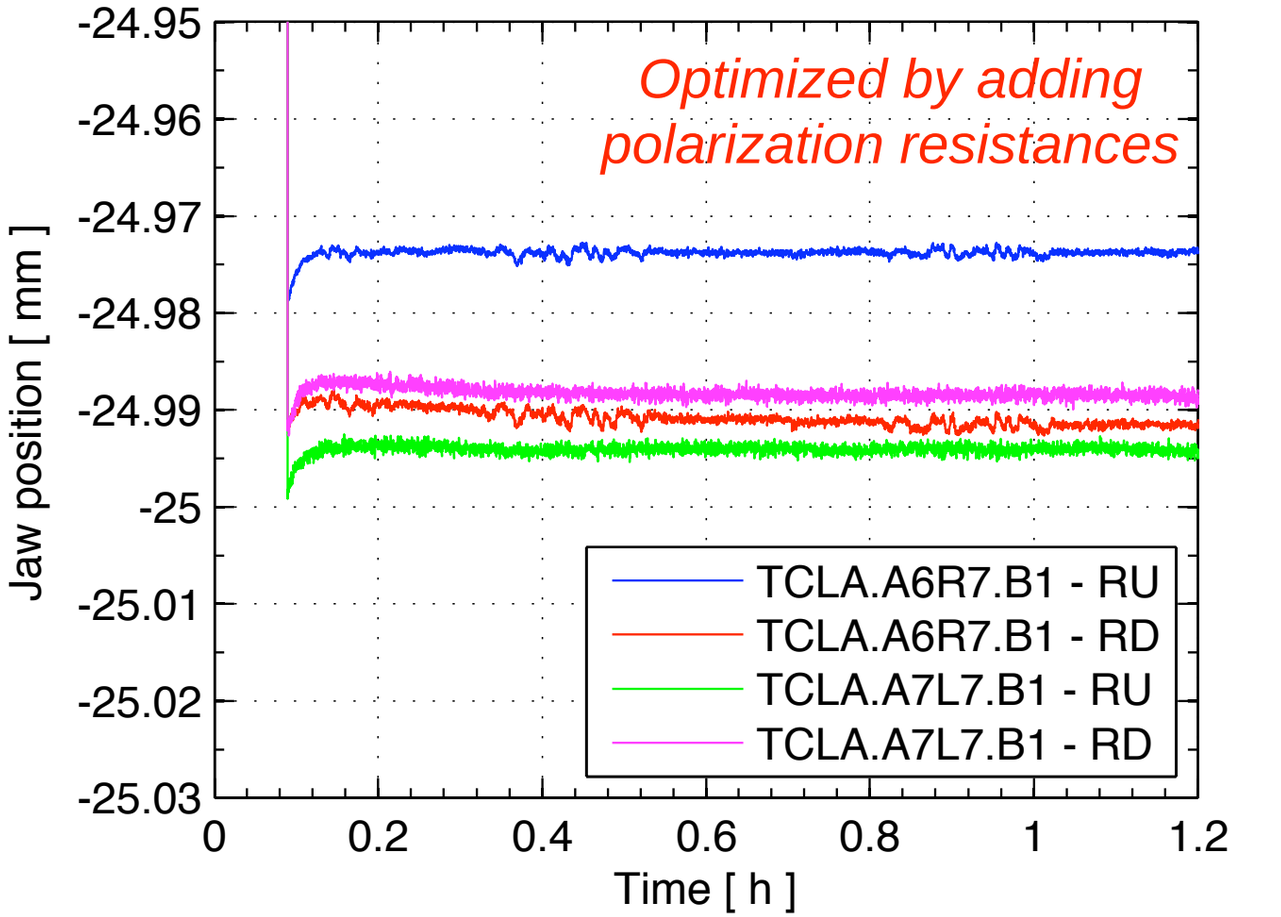
- 28 collimators (both beams of IR7)
- 112 stepping motors
- 168 position sensors (LVDT's)
- 19 consecutive nominal ramps over 10 days

Specs on reproducibility of settings are achieved: measured **BELOW 20 µm!!**

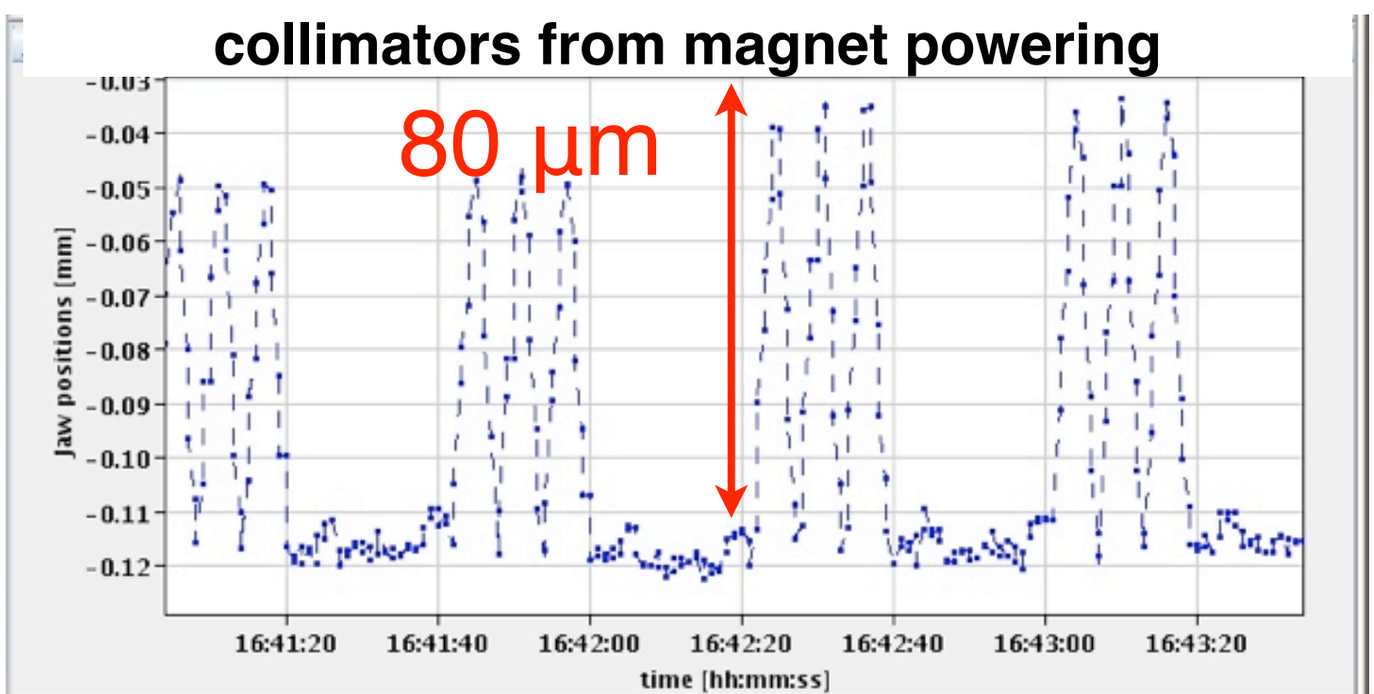
Isolated problems encountered

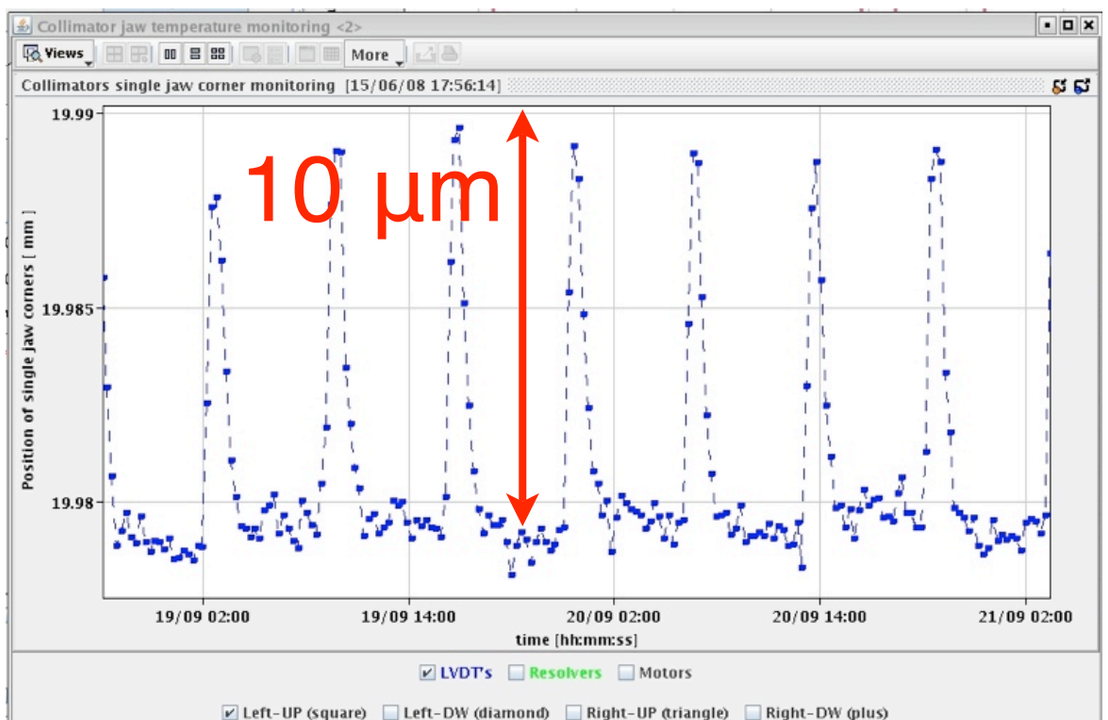
Signal drift of LVDT sensors





EM interference with the transfer line collimators from magnet powering





Interlock commissioning

4 motor axes and 2 gap: **4 limit functions** each (dump/warn IN and OUT)

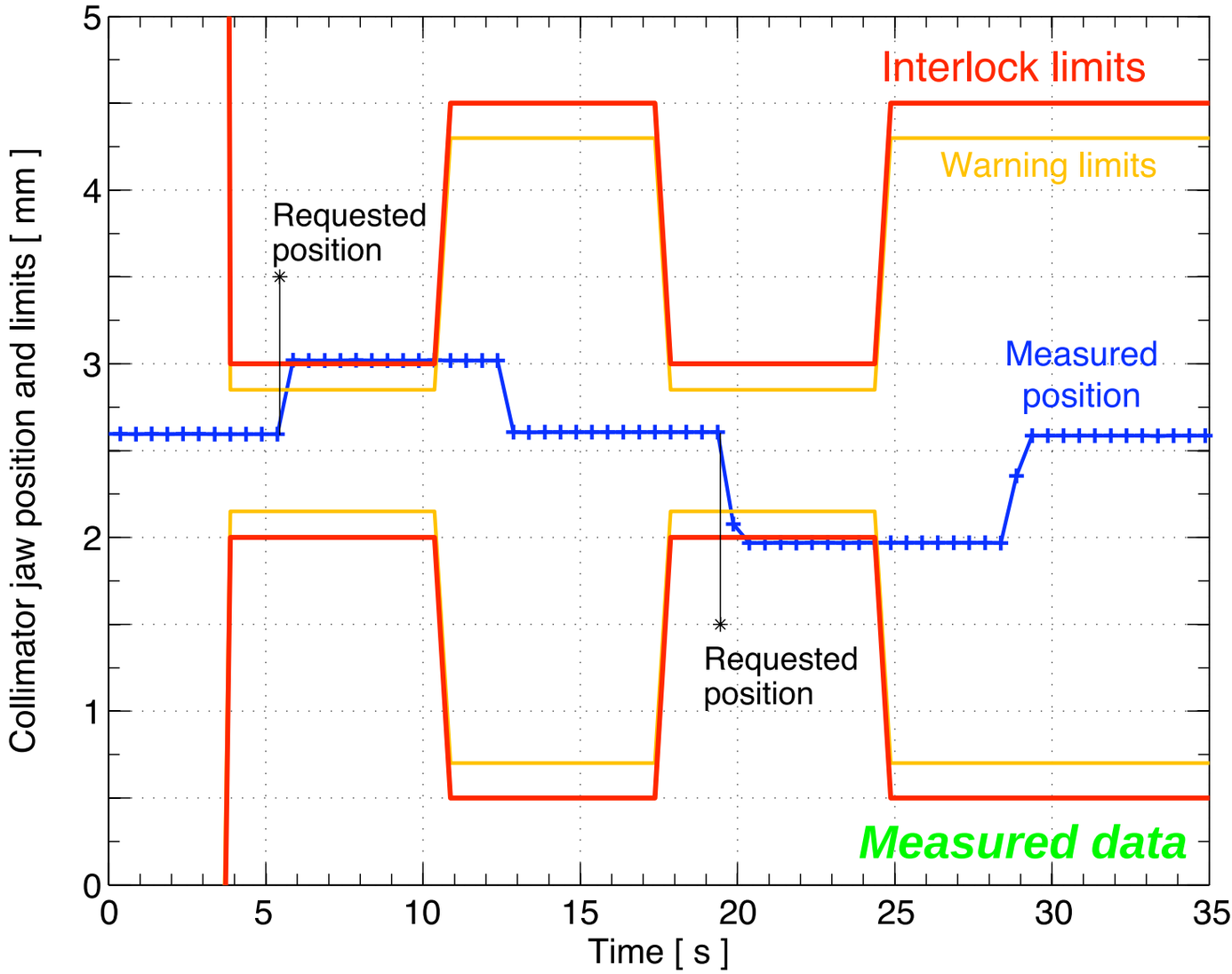
24 limit functions per collimator

In addition, *2 energy limits* for the gaps

Violation of tolerance: (1) stop the movement, (2) system internal fault and (3) activation of the beam interlock.

As a part of the system cold-check out, ALL the degrees of freedom were verified with the final interlock chain

~ 30 s per axis, 5 min per collimator!



Sequence **automatized** and **implemented** in the collimator application software

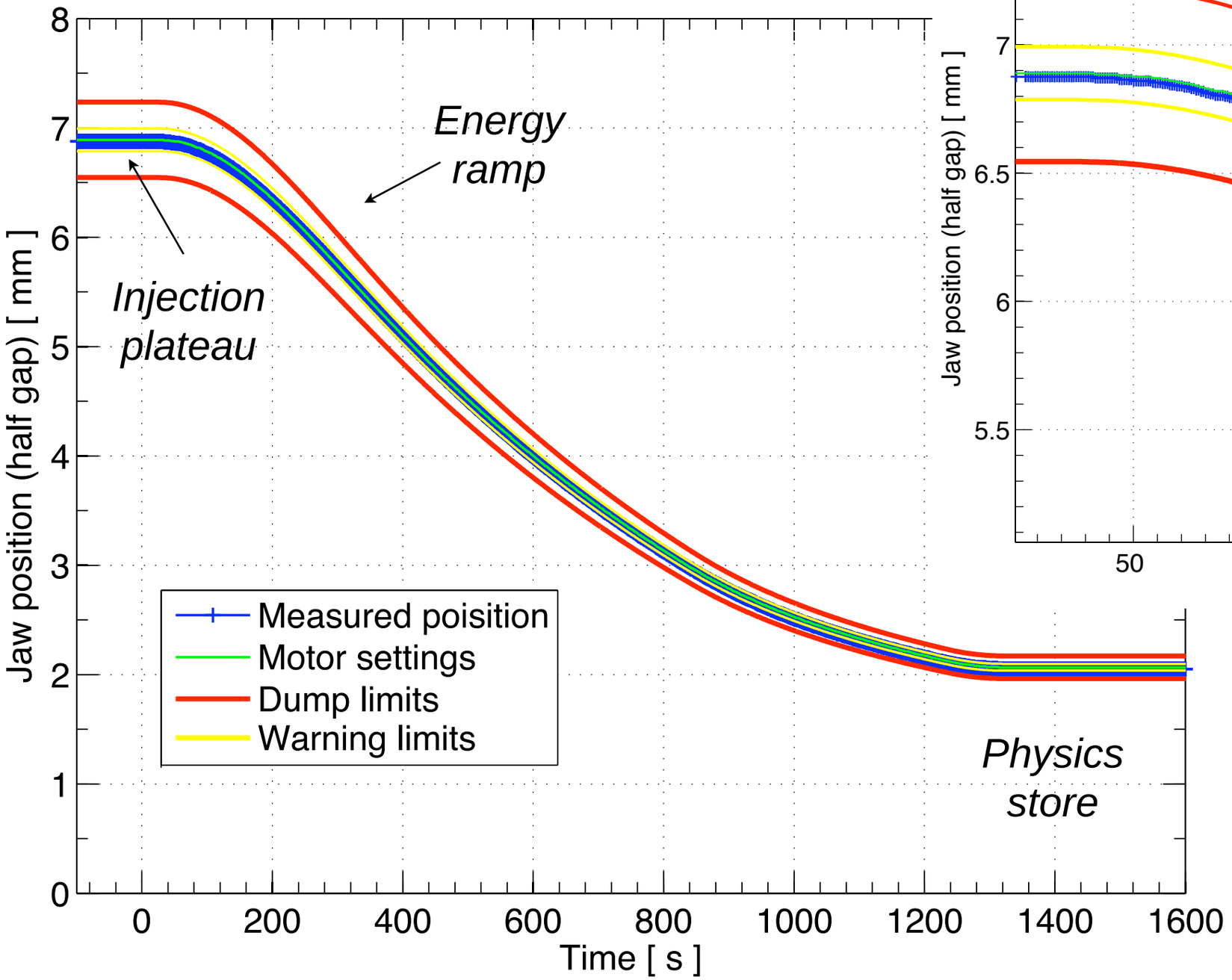
Results **documented** as a part of the machine protection validation

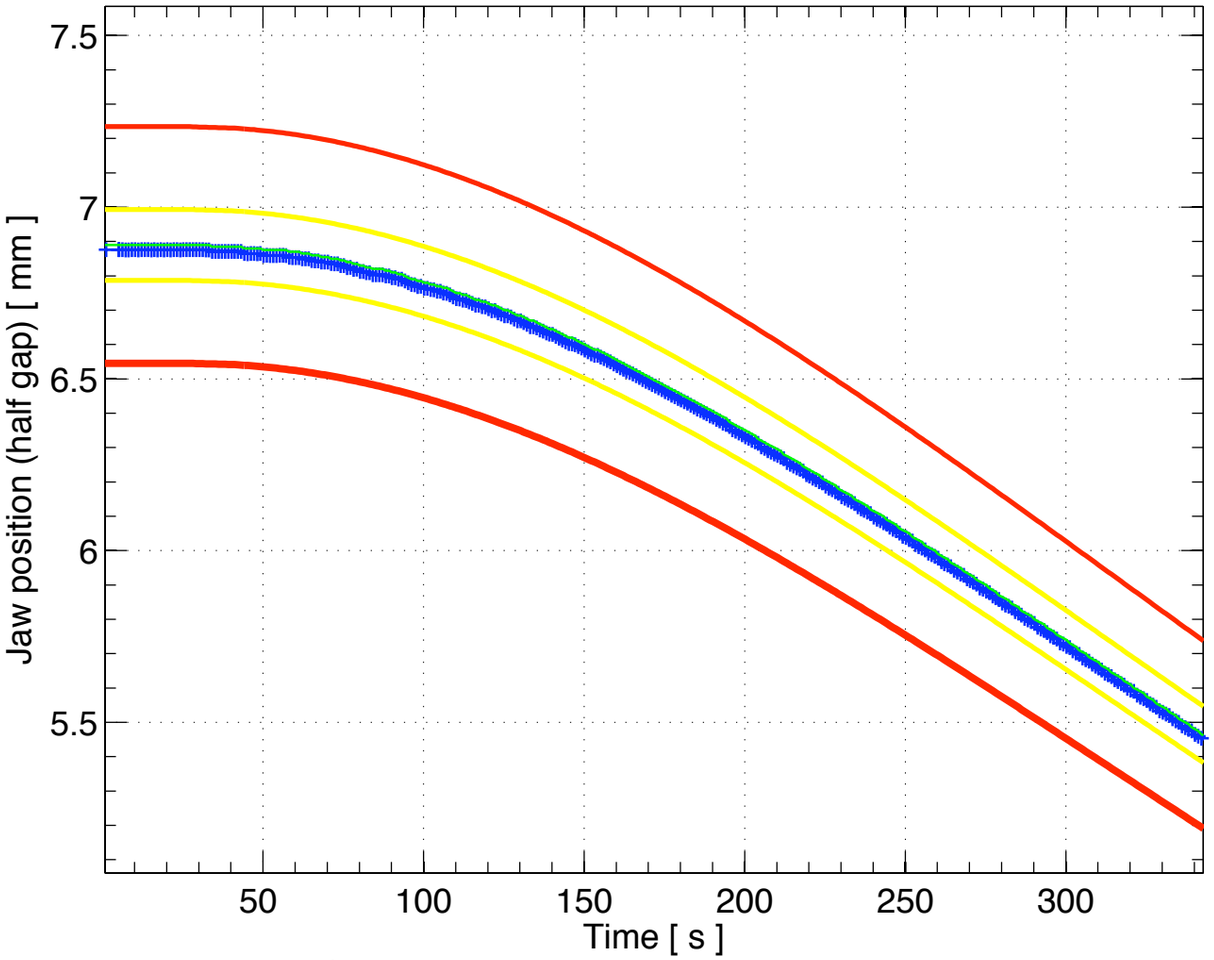
Similarly, all the interlocks for the **403 temperature sensors** were also verified

Outcome: A few problems encountered and solved.

Functionality FULLY validated. Ready for higher stored energies!

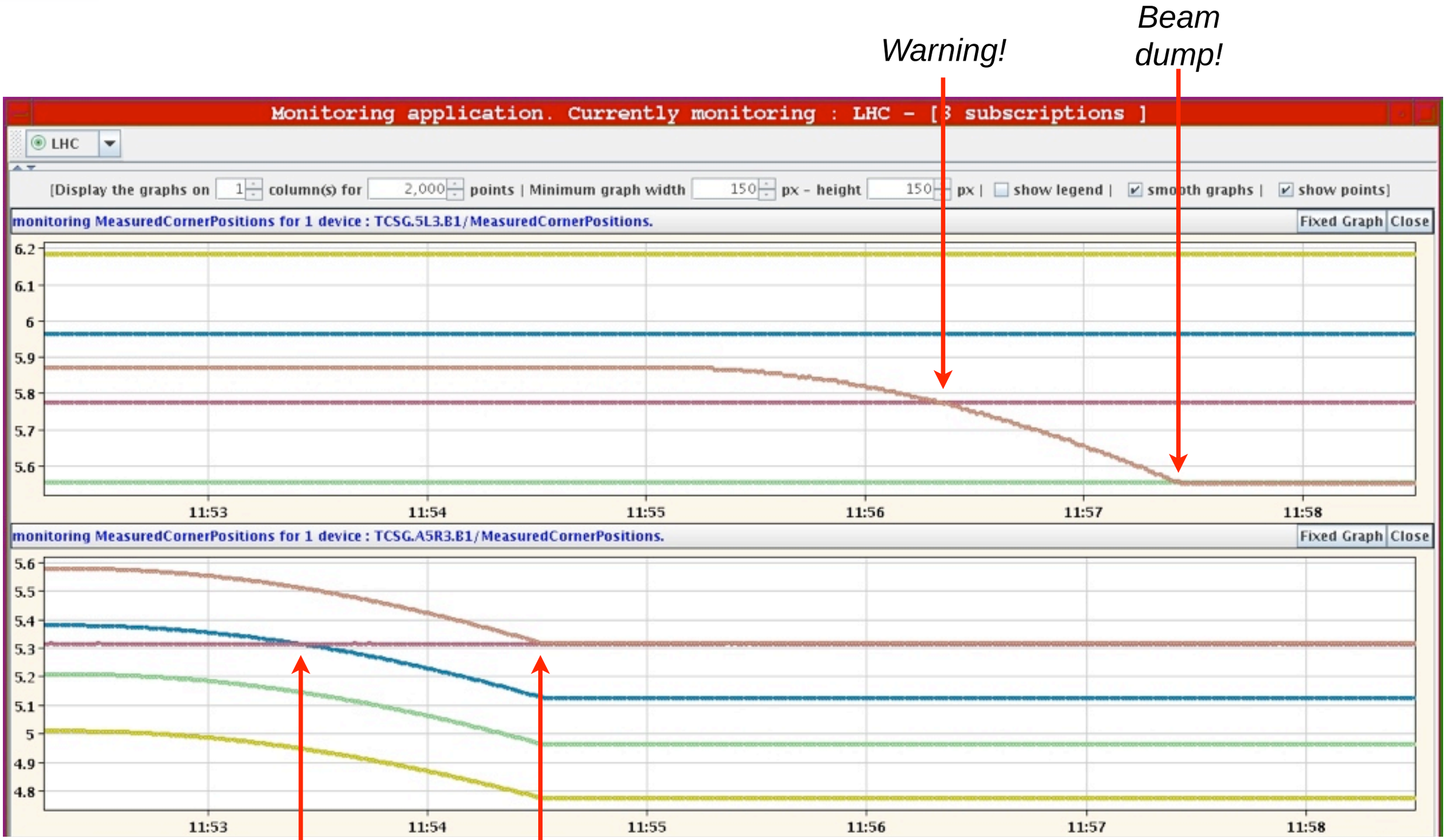
Function-driven limits





- Individual system tests performed with several collimators in the tunnel
- Synchronization with the LHC power converters
- Reproducibility studies will tell how tight can we set the operational window

Systematic checks of limit functions



Warning!

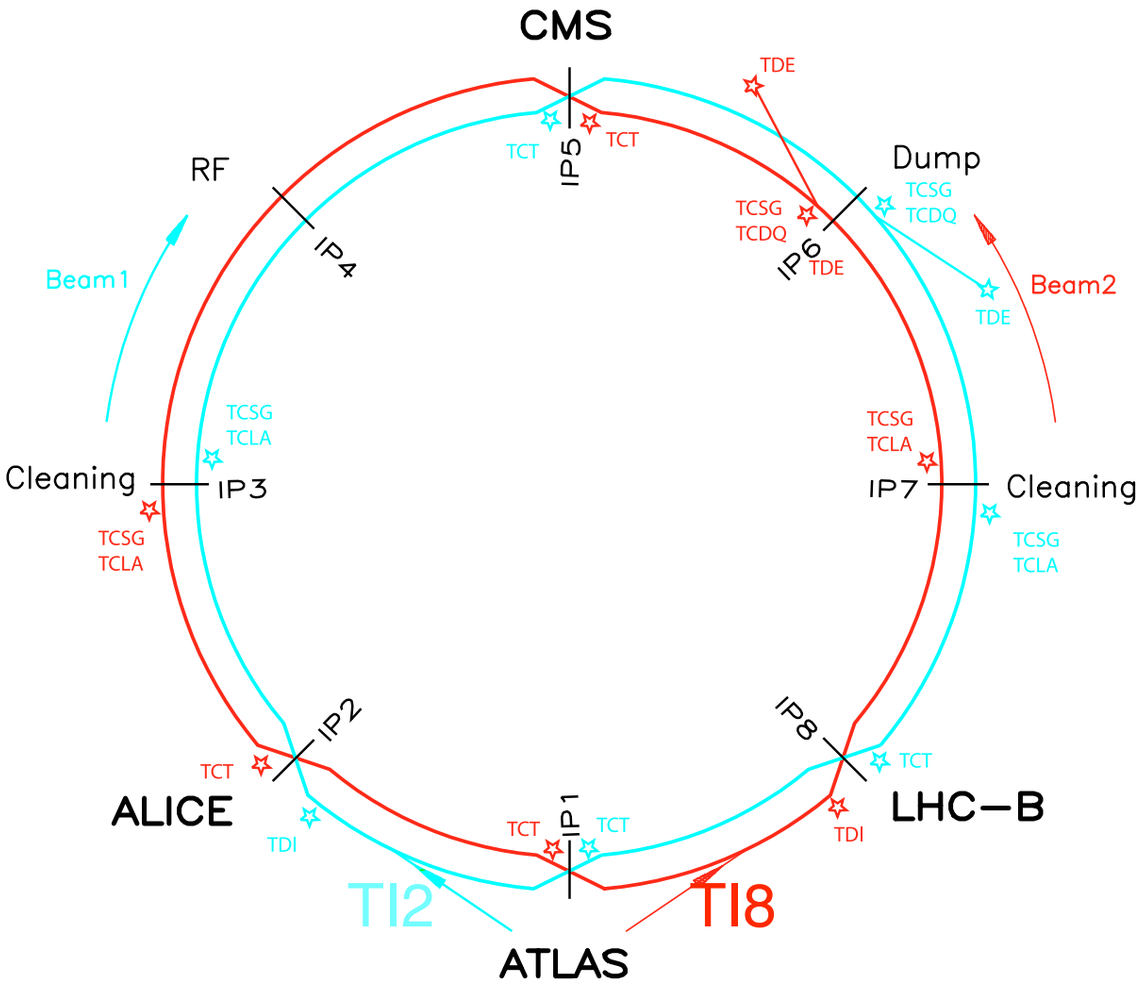
Beam dump!

Various case studies for failure cases: settings or limits do not start as expected...

Outline

- **Introduction**
  - Operational requirements
  - Recap. of collimator design
  - The 2008 system
- **Commissioning without beam**
  - Synchronized energy ramps
  - Accuracy / Reproducibility
  - Interlock commissioning
- **Experience with beam**
  - **Transfer line commissioning**
  - **Operation of ring collimators**
- **Conclusions**

Overview of collimator beam tests



1) Beam commissioning of three transfer line collimators in TI2 (June 2008)
2) Various "synchronization" and circulating beam tests in the LHC:
   - Collimators used to stop the beam during 4 synchronization tests (Aug./Sep.)
   - and in beam commissioning of Set. 10th

Not possible to beam-commission the cleaning role with circulating beam.

LHC Performance Note 1

2008-10-21

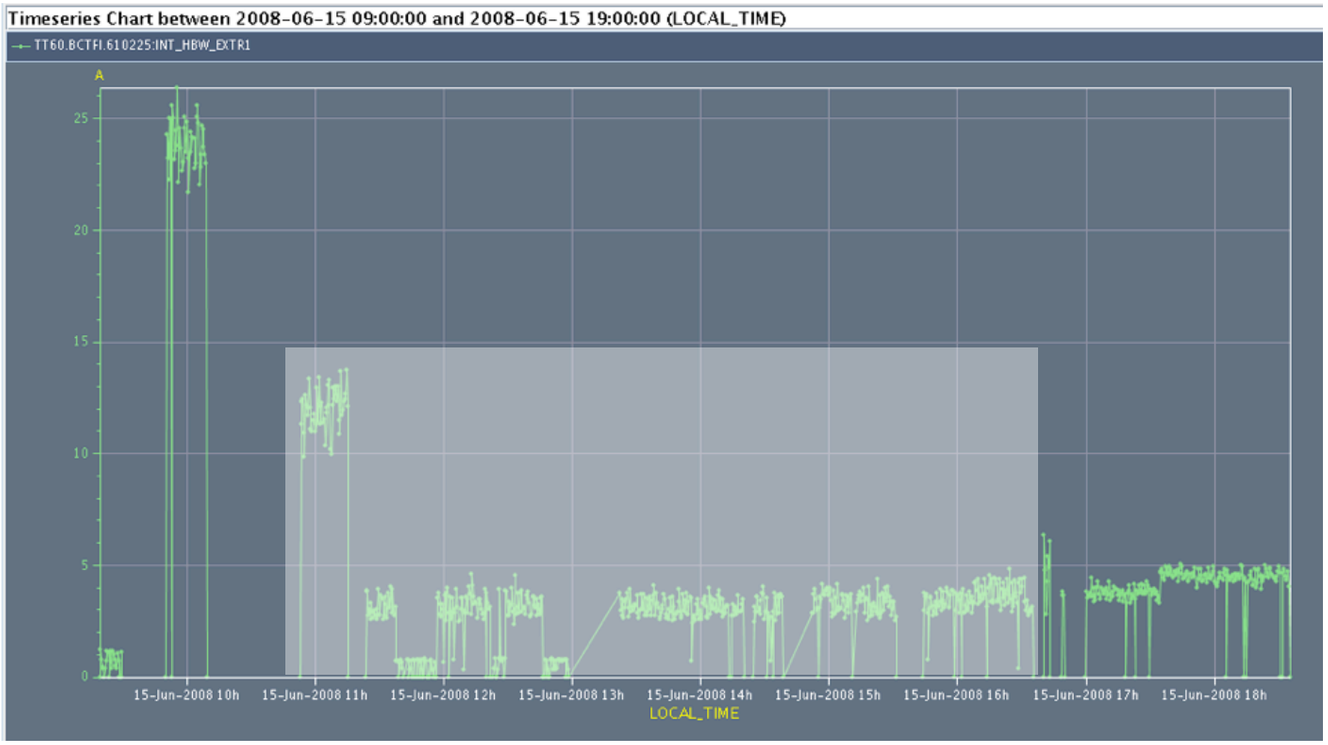
Mike.Lamont@cern.ch

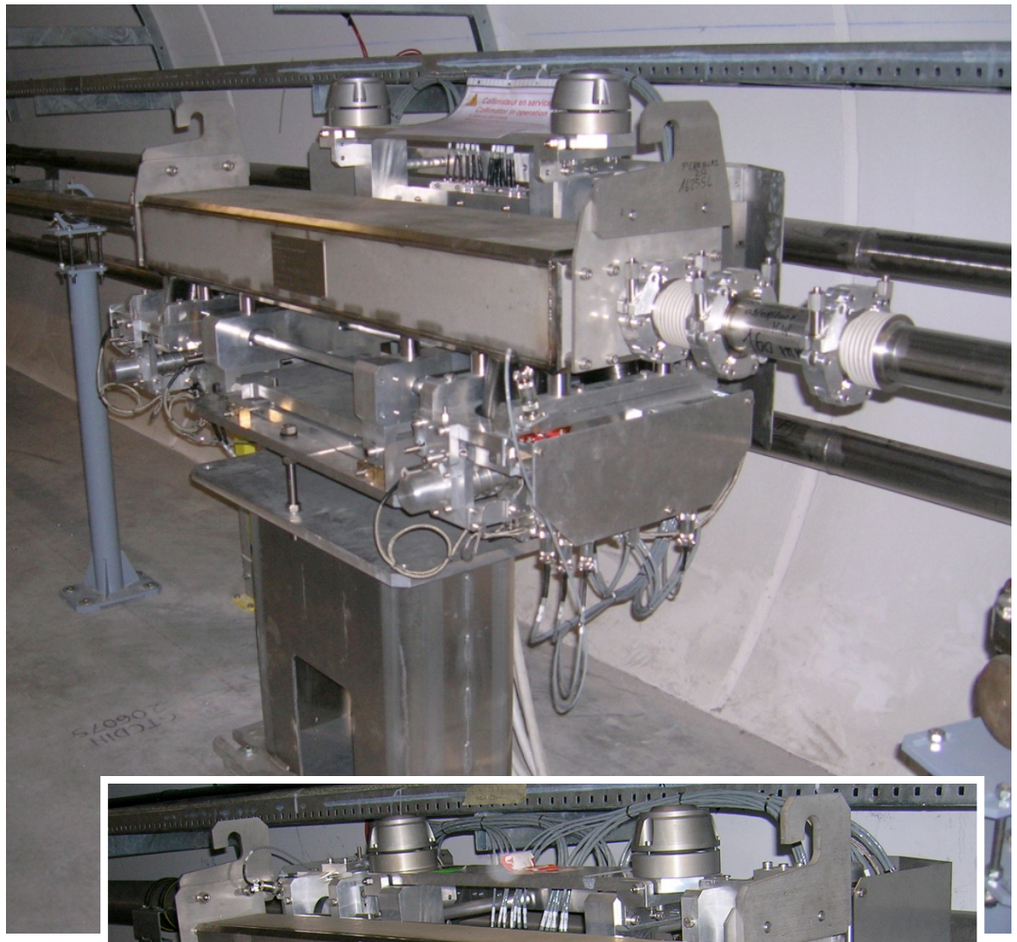
The LHC Injection Tests

I. Agapov, M. Aiba, M. Albert, R. Alemany Fernandez, G. Arduini, R. Assmann, R. Bailey, R. Billen, L. Bottura, O. Brüning, A. Butterworth, R. Calaga, E. Carlier, P. Collier, B. Dehning, L. Deniau, S. Fartoukh, F. Follin, D. Forkel-Wirth, K. Fuchsberger, R. Giachino, M. Giovannozzi, B. Goddard, J-J. Gras, E. Hatziangeli, P. Hagen, D. Jacquet, L. Jensen, R. Jones, V. Kain, I. Kozsar, T. Kramer, G. Kruk, M. Lamont, J. Lewis, A. Macpherson, M. Meddahi, V. Mertens, M. Misiowiec, S. Page, L. Ponce, B. Puccio, S. Redaelli, C. Roderick, S. Roesler, F. Roncarolo, M. Sapinski, F. Schmidt, R. Schmidt, W. Sliwinski, R. Steinhagen, M. Strzelczyk, Y. Sun, B. Todd, E. Todesco, R. Tomas Garcia, J. Uythoven, W. Venturini Delsolaro, Heinz Vincke, Helmut Vincke, E. Veyrunes, J. Wenninger, R. Wolf, C. Zamantzas, F. Zimmermann.

Date	*Test Outline*
8-11 August	Beam 1 through sector 23
22-25 August	Beam 2 though sector 78, beam 1 through sector 23
5-8 September	Beam 2 through sectors 78,67, beam 1 through sectors 23, 34, 45
9 September	Preparation for 10th September – beam 1 through sectors 23, 34, 45
10 September	Beam 1 and beam 2 around the whole circumference of the LHC

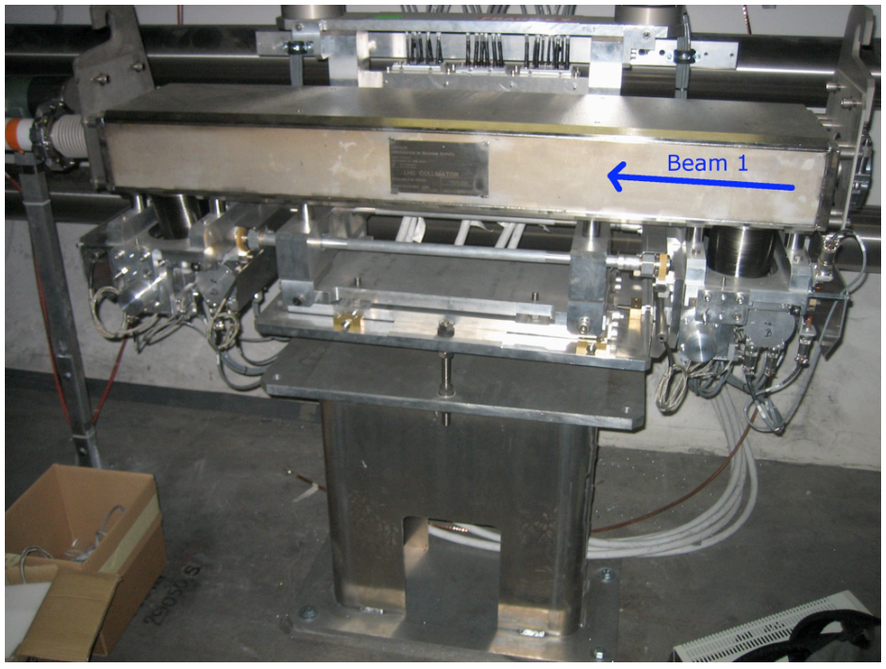
Transfer line collimation tests

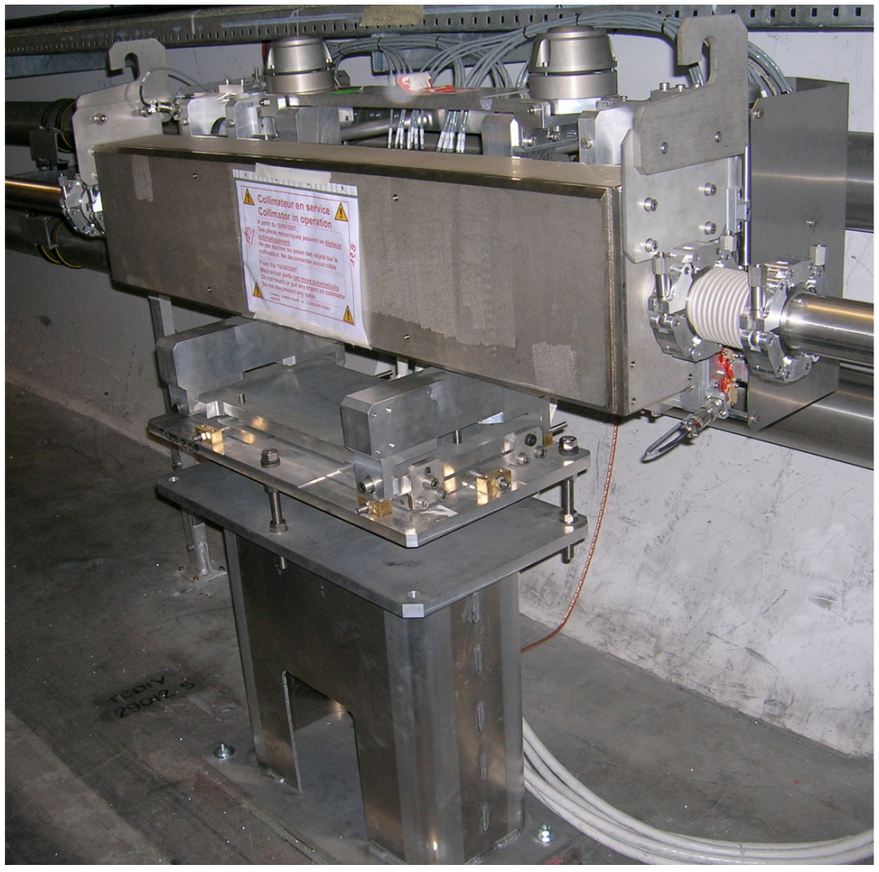




Beam commissioning of **THREE TCDI collimators in TI2**

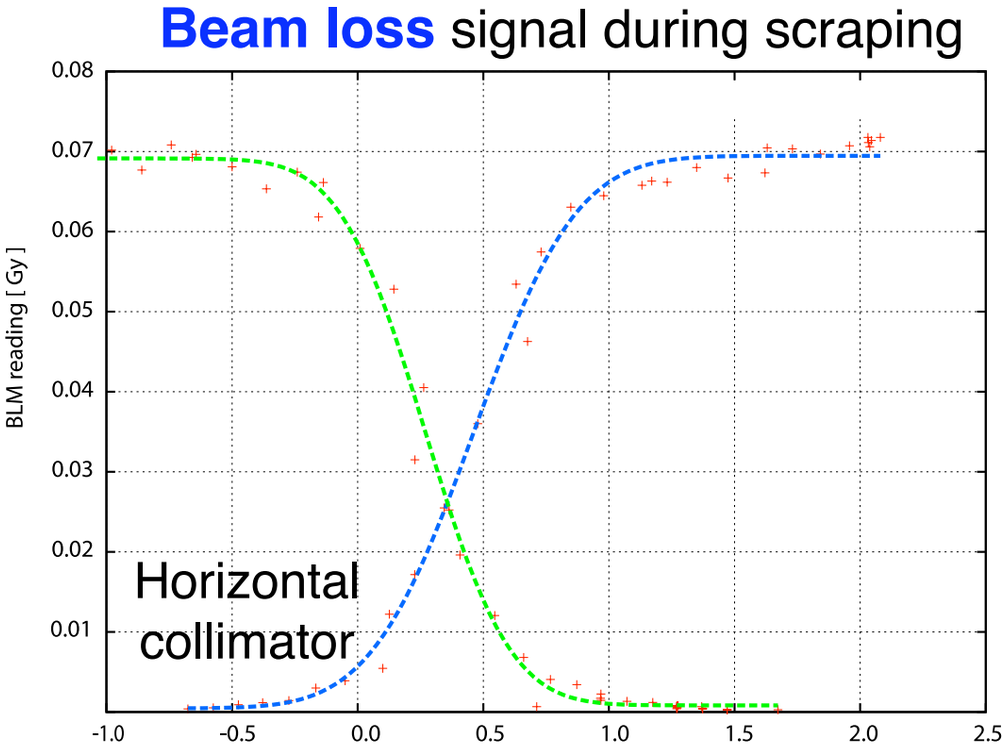
Beam conditions:
single and multi-bunches,
~5x10^{10}p per bunch
Limited time available

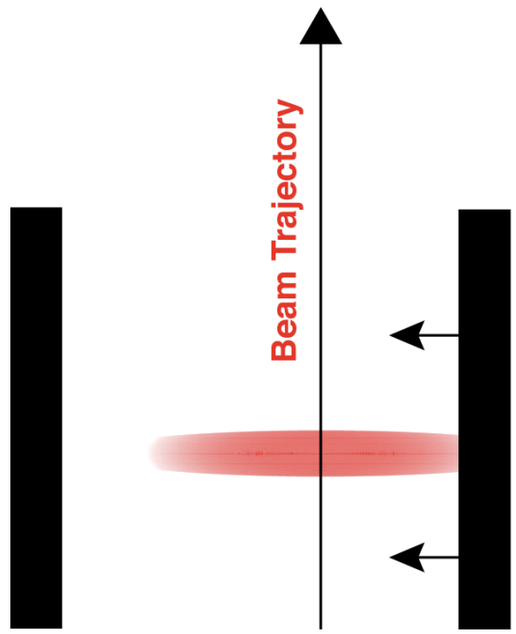




O. Aberle, R. Assmann, M. Brugger, V. Kain, A. Masi, V. Previtali, S. Redaelli, T. Weiler, J. Uythoven

Beam-based alignment

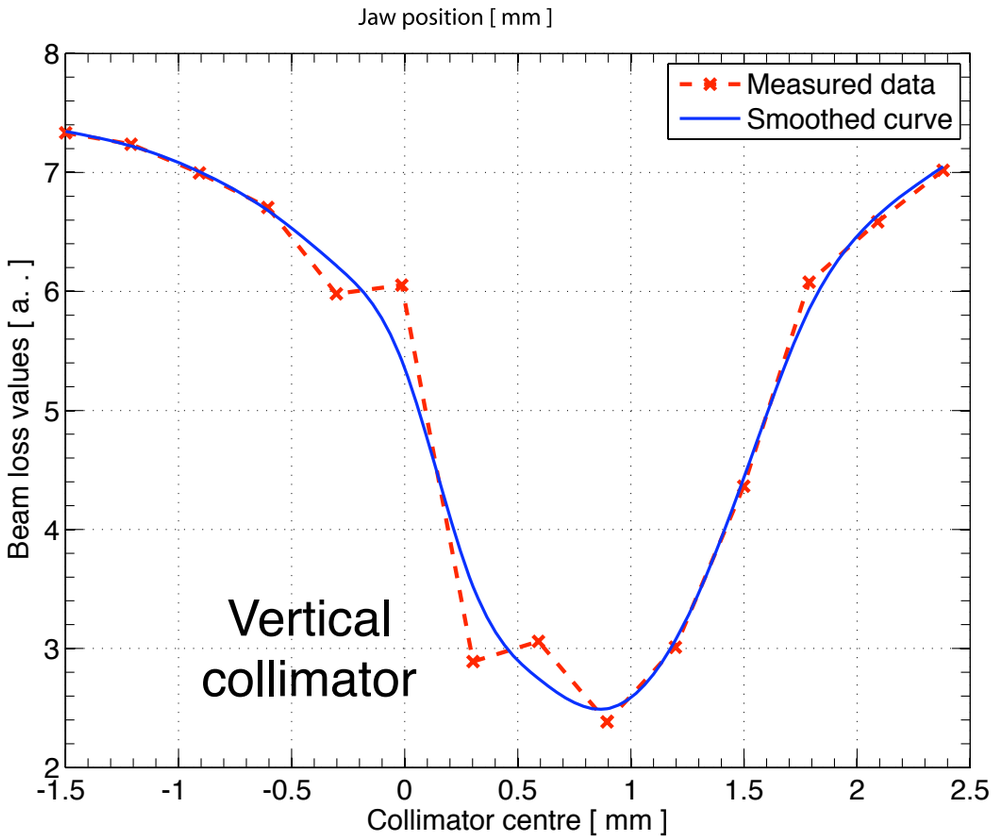


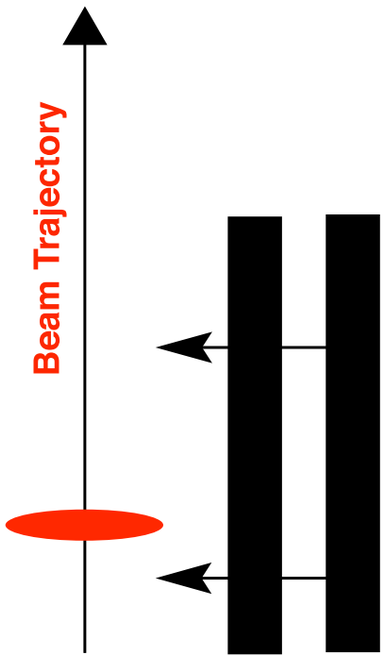


Beam scraping based on the reading of the beam loss monitors.

Beam centre and **beam sizes** at the collimator were measured.

Accuracy below **50 µm**, results in agreement with other beam measurements (orbit, emittance, ...).





Beam-based parameters used on-line to generate nominal **protection settings**!

Generation of protection settings

Trim Editor

LHC | BP | OP

return

Beams	IPs	Families	ParametersTypeGroups	Parameters
B1	TI2	TCDIH	PHYSICS : COLL_JAW_TOLERANCE	TCDIH.20607/BBCentre
B2		TCDIV	PHYSICS : COLL_JAW	TCDIH.20607/BBParam#sigma_x
			PHYSICS : COLL_BBOptics	TCDIH.20607/BBParam#sigma_xp
			PHYSICS : COLL_NSIGMA	TCDIH.20607/BBParam#sigma_y
			PHYSICS : COLL_BBParam	TCDIH.20607/BBParam#sigma_yp
			PHYSICS : COLL_BBCentre	TCDIH.20607/NSIGMA
			PHYSICS : COLL_HalfGap_TOL	TCDIH.29050/BBCentre
Select All	Select All	Select All	Select All	Select All

Setting part: Value / Target / Correction | Trim History | Time base: SuperCycle / Cycle/BeamProcess

Parameter	ramp_5TeV_ir5@0_[START]
TCDIH.20607/BBCentre	0.85
sigma_x	0.62
TCDIH.20607/NSIGMA	4.5

Trim

return

Beam Processes
_NON_MULTIPLEXED_LHC
DISCRETE_LHCRING_INJ_KICKER_V1
ramp_5TeV_ir5@0_[START]
Collimator_testV1.TRACKING-TEST-7TeV.BP0
PRECYCLE-TEST-V2_MIKE-V1
RAMP-IR5-4.135TeV@0_[START]
RAMP-IR5-4.135TeV_V1
RAMP-IR5-4.2TeV_V1
RAMP-IR5@0_[START]

Show hidden

Beams	IPs	Families	ParametersTypeGroups	Parameters
B1	TI2	TCDIH	PHYSICS : COLL_JAW	TCDIH.29465/RequiredAbsPositionFunct#left_downstr
B2		TCDIV	PHYSICS : COLL_BBOptics	TCDIH.29465/RequiredAbsPositionFunct#left_upstrean
			PHYSICS : COLL_NSIGMA	TCDIH.29465/RequiredAbsPositionFunct#right_downst
			PHYSICS : COLL_BBParam	TCDIH.29465/RequiredAbsPositionFunct#right_upstrea
			PHYSICS : COLL_BBCentre	TCDIH.20607/RequiredAbsPositionFunct#left_downstr
			PHYSICS : COLL_HalfGap_TOL	TCDIH.20607/RequiredAbsPositionFunct#left_upstrean
			PHYSICS : COLL_HalfGap	TCDIH.20607/RequiredAbsPositionFunct#right_downst
			PHYSICS : COLL_NSIGMA_TOL	TCDIH.20607/RequiredAbsPositionFunct#right_upstrea
			HW SETTINGS : COLL_MOTOR_TOLERANC	TCDIH.29050/RequiredAbsPositionFunct#left_downstr
			HW SETTINGS : COLL_MOTOR_POSITION	TCDIH.29050/RequiredAbsPositionFunct#left_upstrean
Select All	Select All	Select All	Select All	Select All

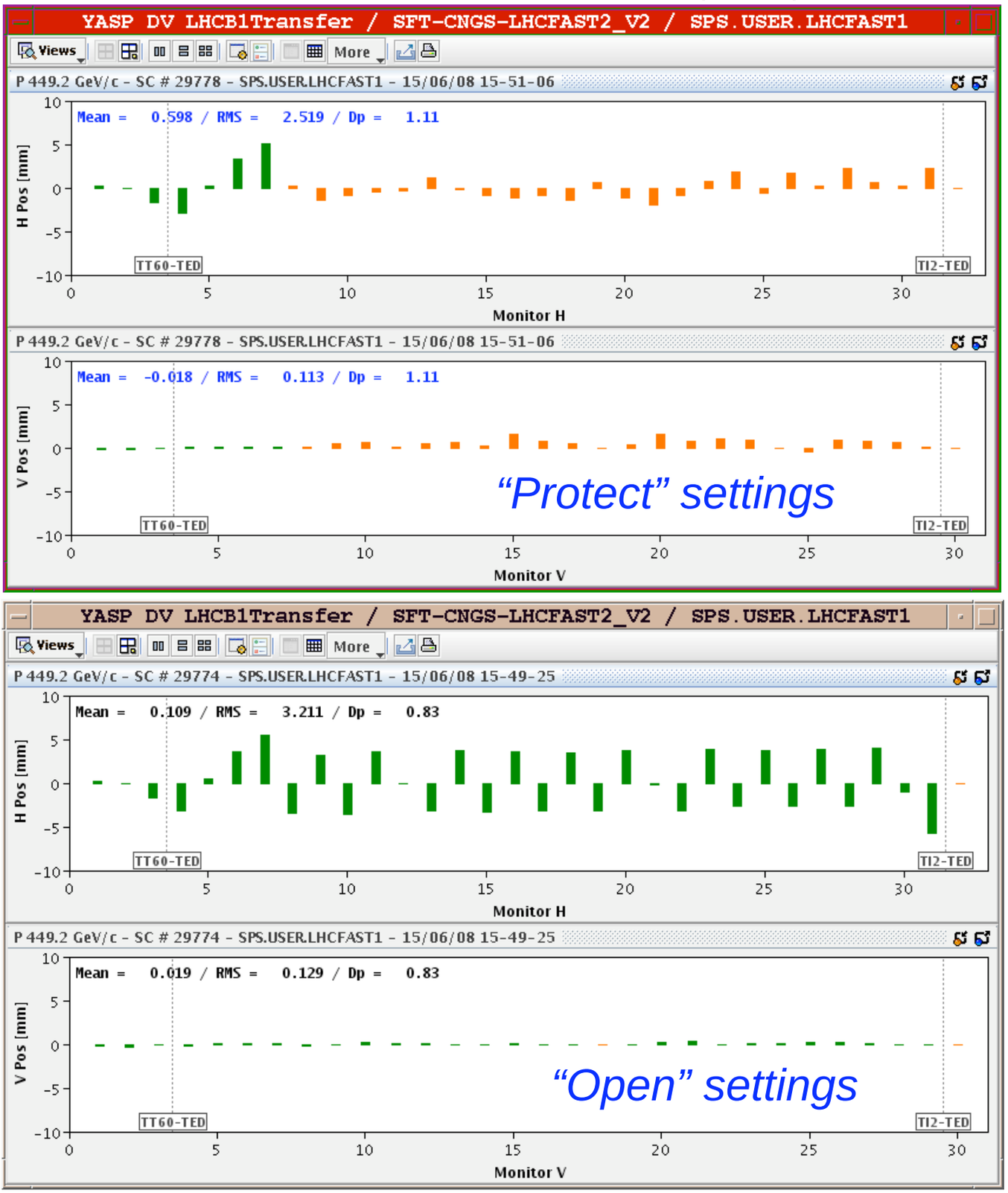
Setting part: Value / Target / Correction | Trim History | Time base: SuperCycle / Cycle/BeamProcess

Parameter	ramp_5TeV_ir5@0_[START]
left_downstream	3.6399500556074607
left_upstream	3.6400499443925396
right_downstream	-1.9400499443925394
right_upstream	-1.9399500556074605

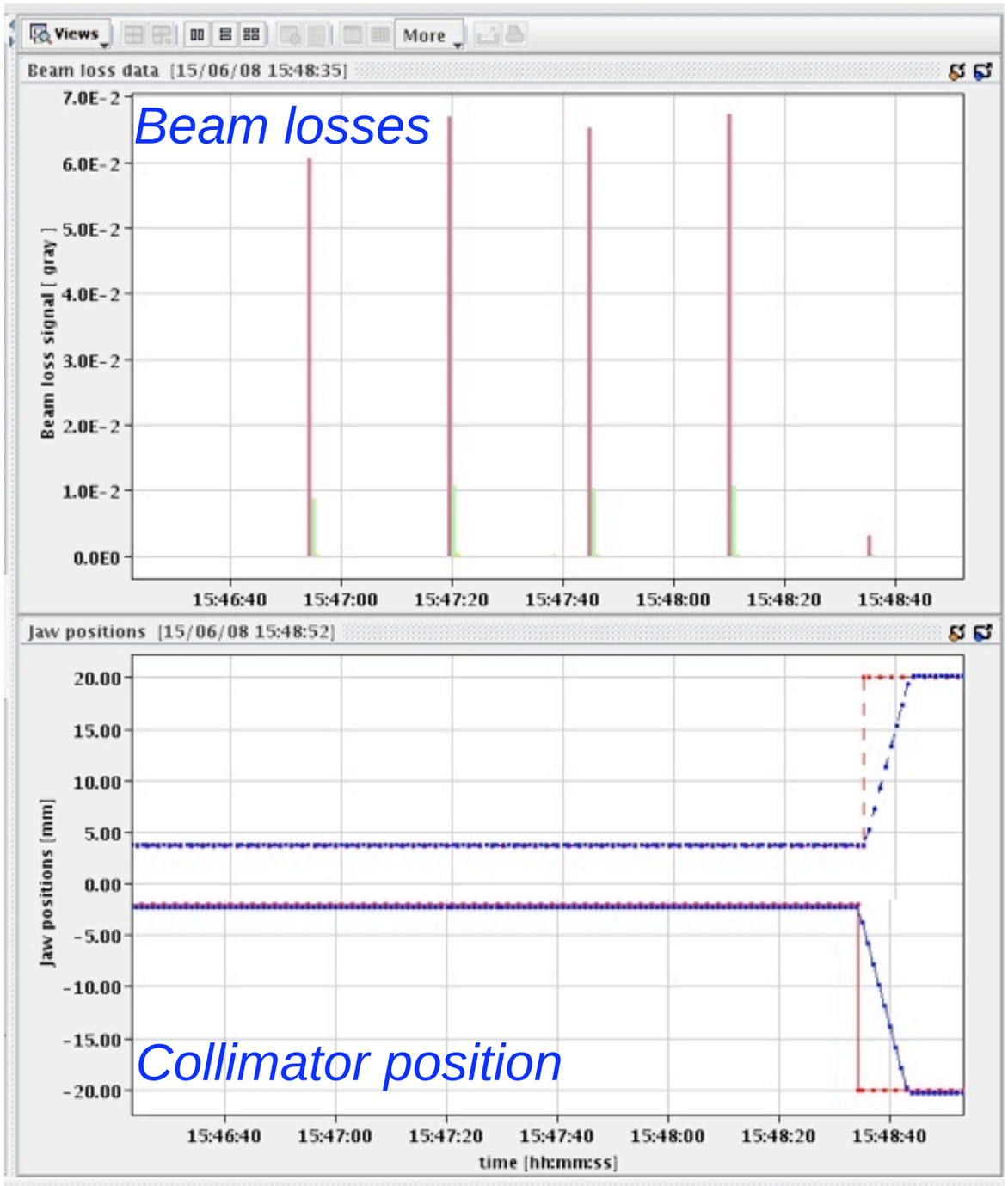
Trim

Beam verification of protection settings

Measured beam orbit (H/V)



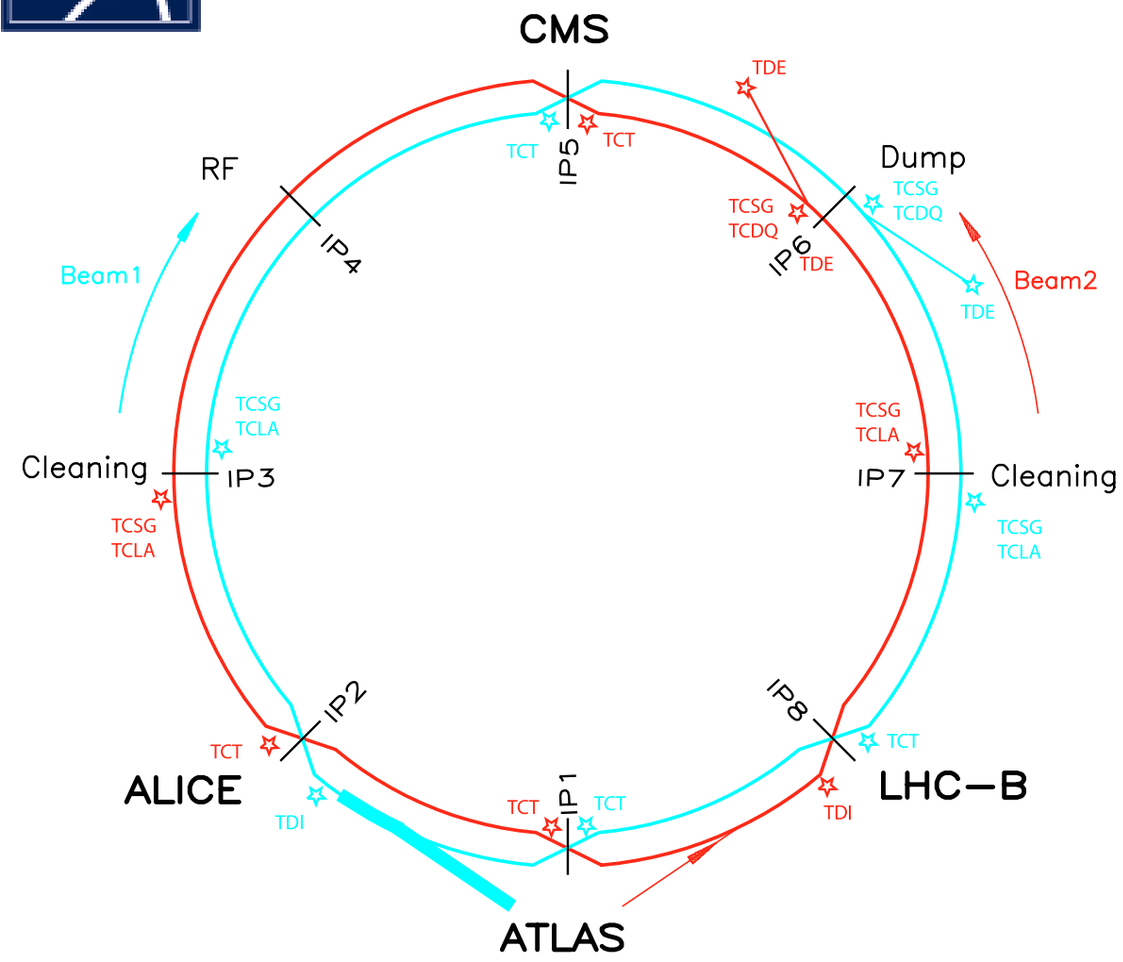
Beam losses at the collimator

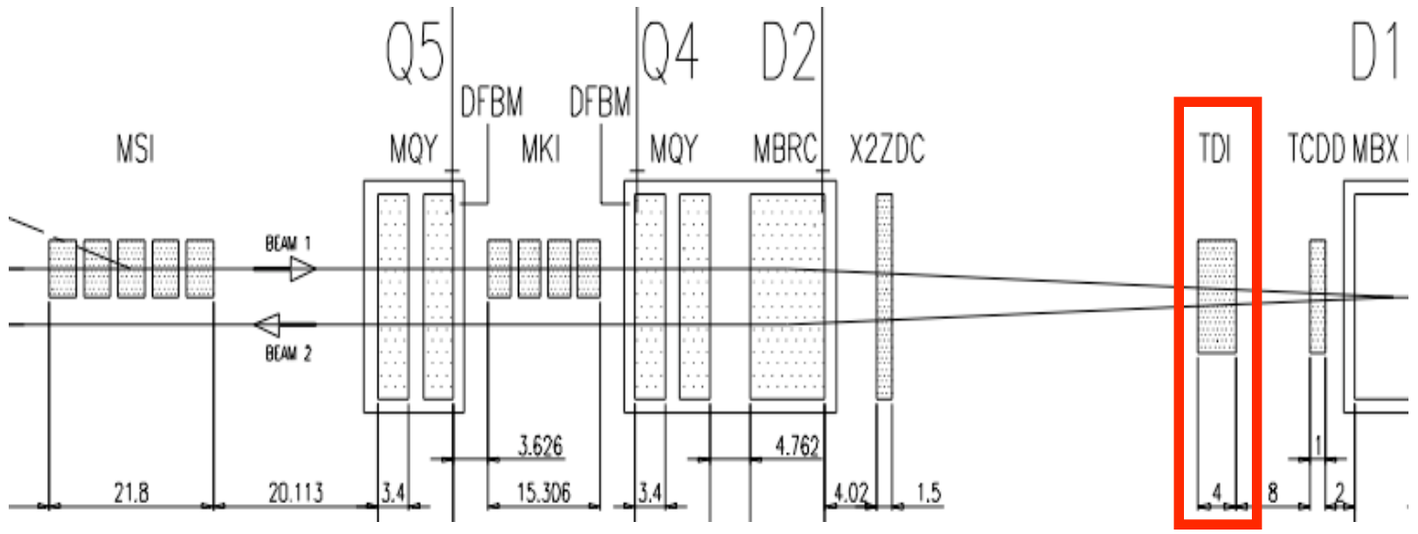


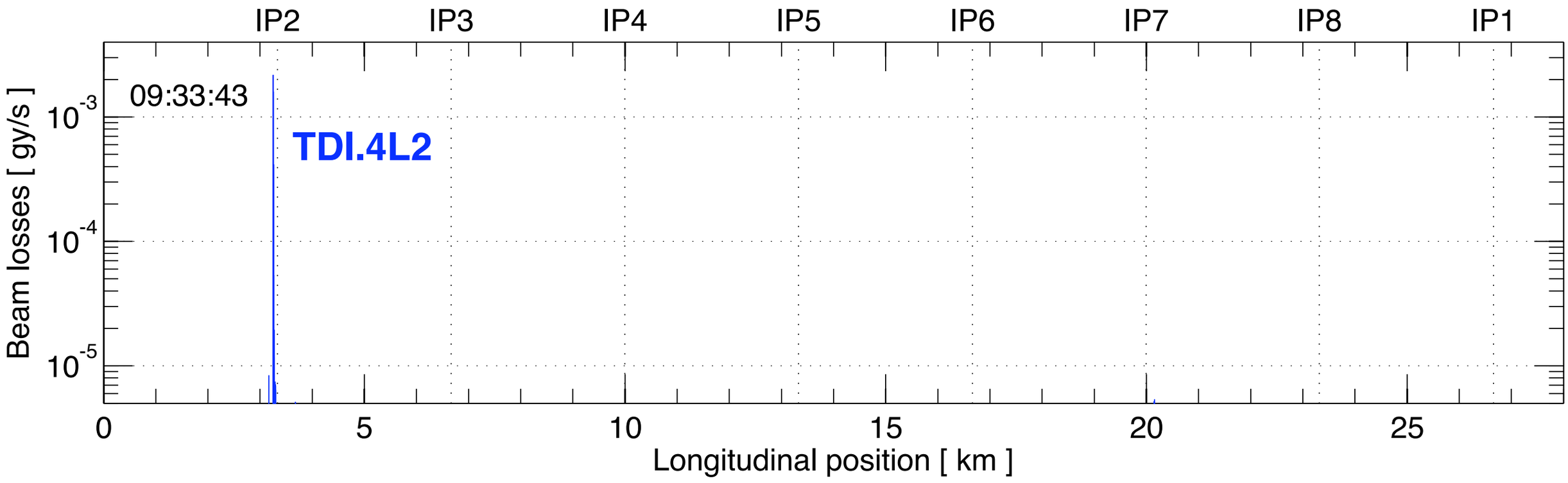
Tested systematically one collimator.

Orbit generated by V. Kain

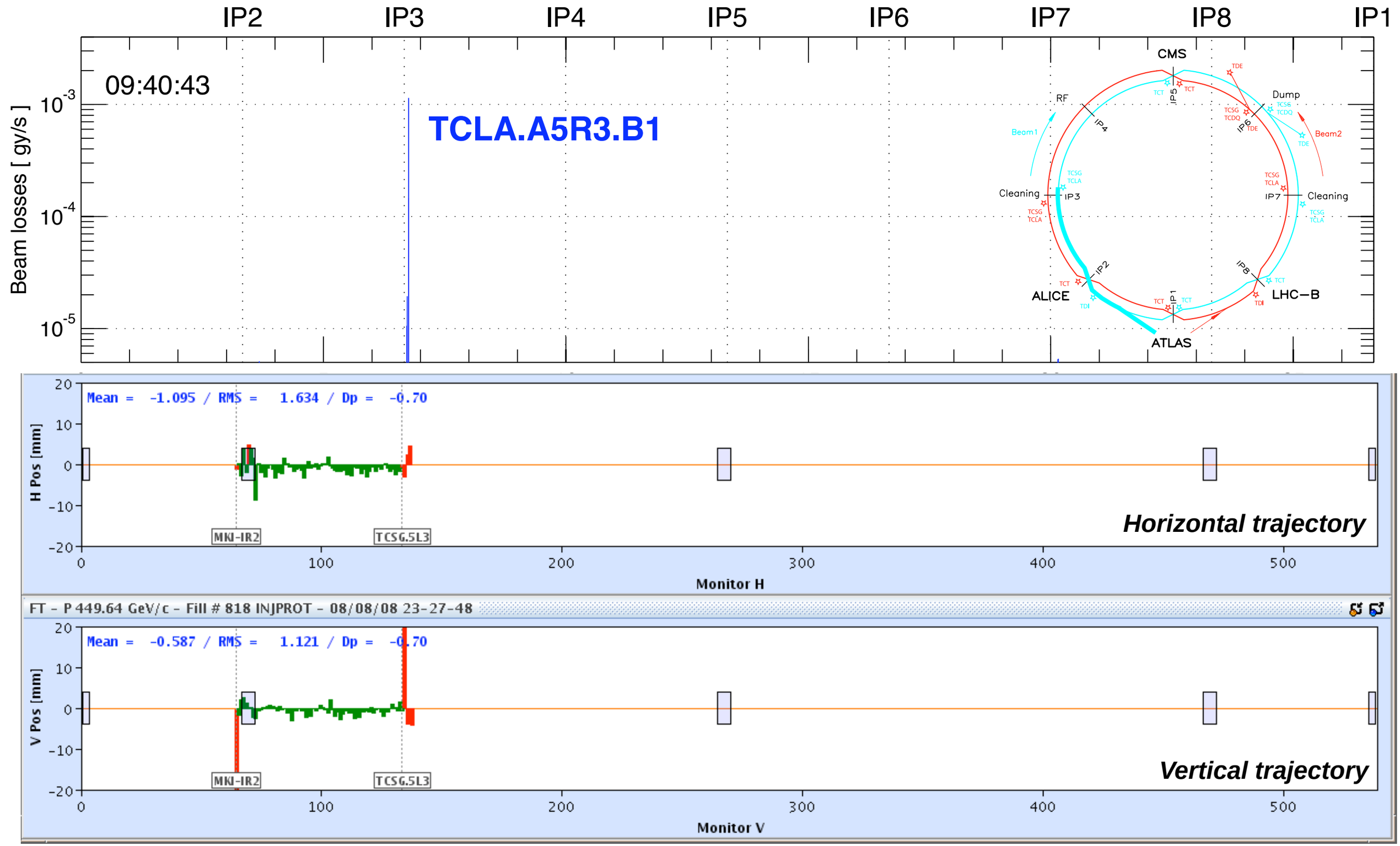
Beam on TDI


CMS
IP5
TCT
TCT
TDE
Dump
TCSG
TCDQ
IP6
TCSG
TCDQ
TDE
TDE
Beam2
RF
IP4
Beam1
TCSG
TCLA
Cleaning
IP3
TCSG
TCLA
TCSG
TCLA
IP7
Cleaning
TCSG
TCLA
IP2
TCT
ALICE
TDI
IP1
TCT
TCT
IP8
TCT
LHC—B
TDI
ATLAS

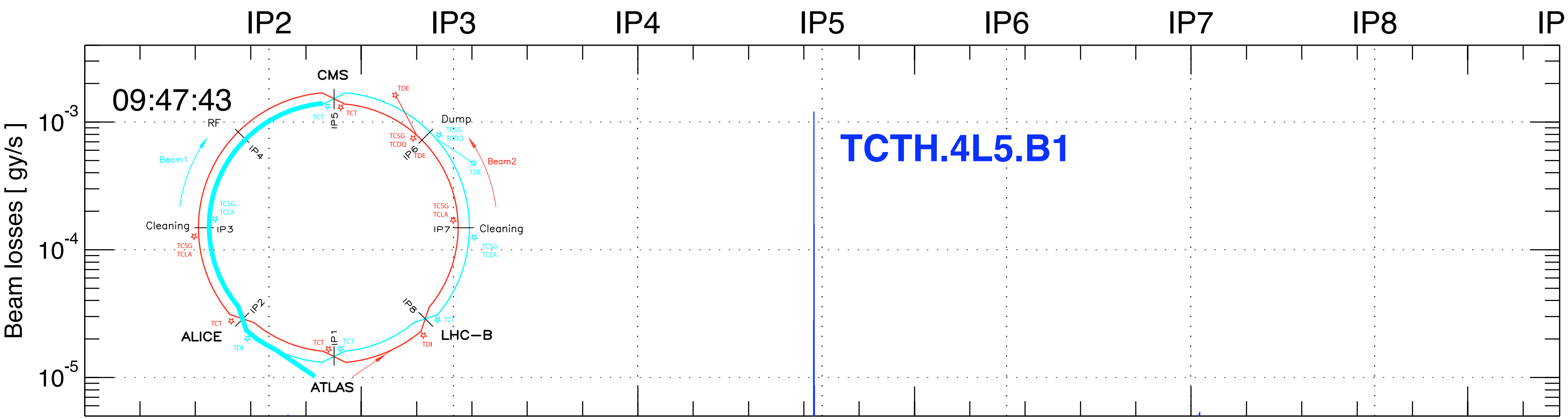

Q5
DFBM
DFBM
Q4
D2
D1
MSI
MQY
MKI
MQY
MBRC
X2ZDC
TDI
TCDD
MBX
BEAM 1
BEAM 2
3.626
4.762
21.8
20.113
3.4
15.306
3.4
4.02
1.5
4
8
1
2


IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
09:33:43
TDI.4L2
Beam losses [gy/s]
10-3
10-4
10-5
0
5
10
15
20
25
Longitudinal position [km]

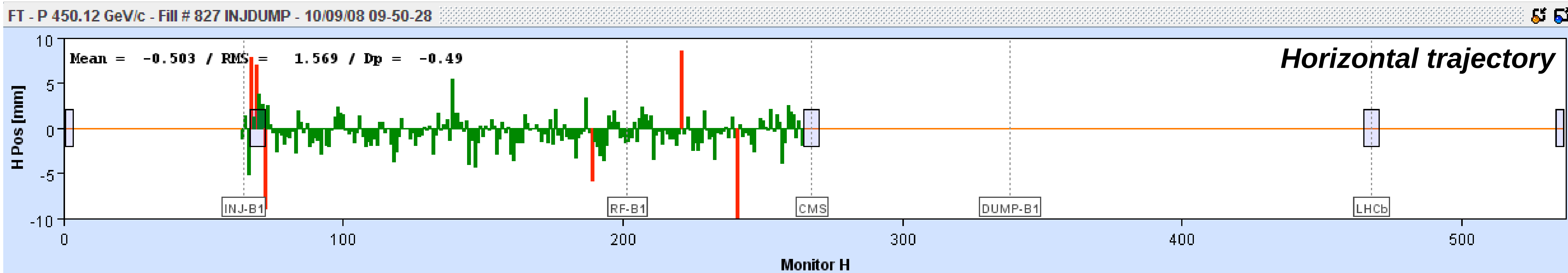
Beam to IP3


IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
09:40:43
TCLA.A5R3.B1
Beam losses [gy/s]
10^{-3}
10^{-4}
10^{-5}
CMS
RF
IP4
IP5
IP6
Dump
Beam1
Beam2
TDE
TCT
TCSG
TCDQ
TCLA
Cleaning
IP3
IP7
IP2
IP8
IP1
ALICE
LHC−B
ATLAS
TDI
Mean = -1.095 / RMS = 1.634 / Dp = -0.70
H Pos [mm]
MKI-IR2
TCSG.5L3
Monitor H
Horizontal trajectory
FT - P 449.64 GeV/c - Fill # 818 INJPROT - 08/08/08 23-27-48
Mean = -0.587 / RMS = 1.121 / Dp = -0.70
V Pos [mm]
Monitor V
Vertical trajectory

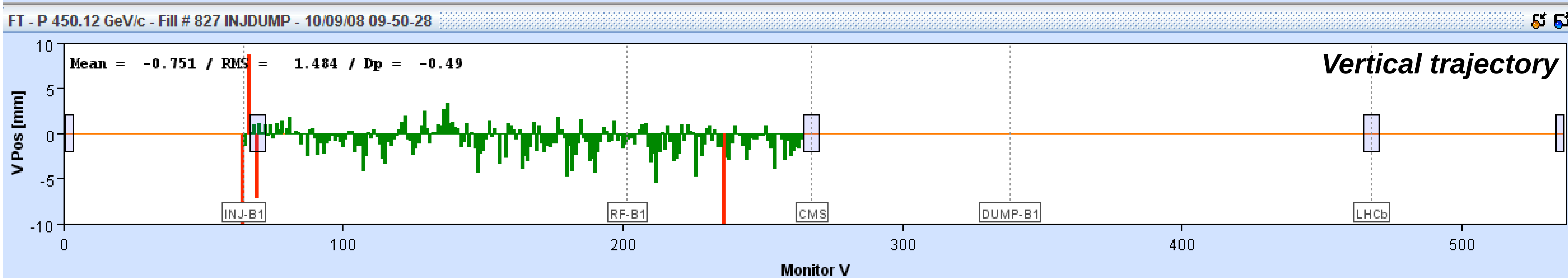
Beam to IP5



IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
09:47:43
Beam losses [gy/s]
10^{-3}
10^{-4}
10^{-5}
TCTH.4L5.B1
CMS
ATLAS
ALICE
LHC−B
RF
Dump
Cleaning
Cleaning
Beam1
Beam2

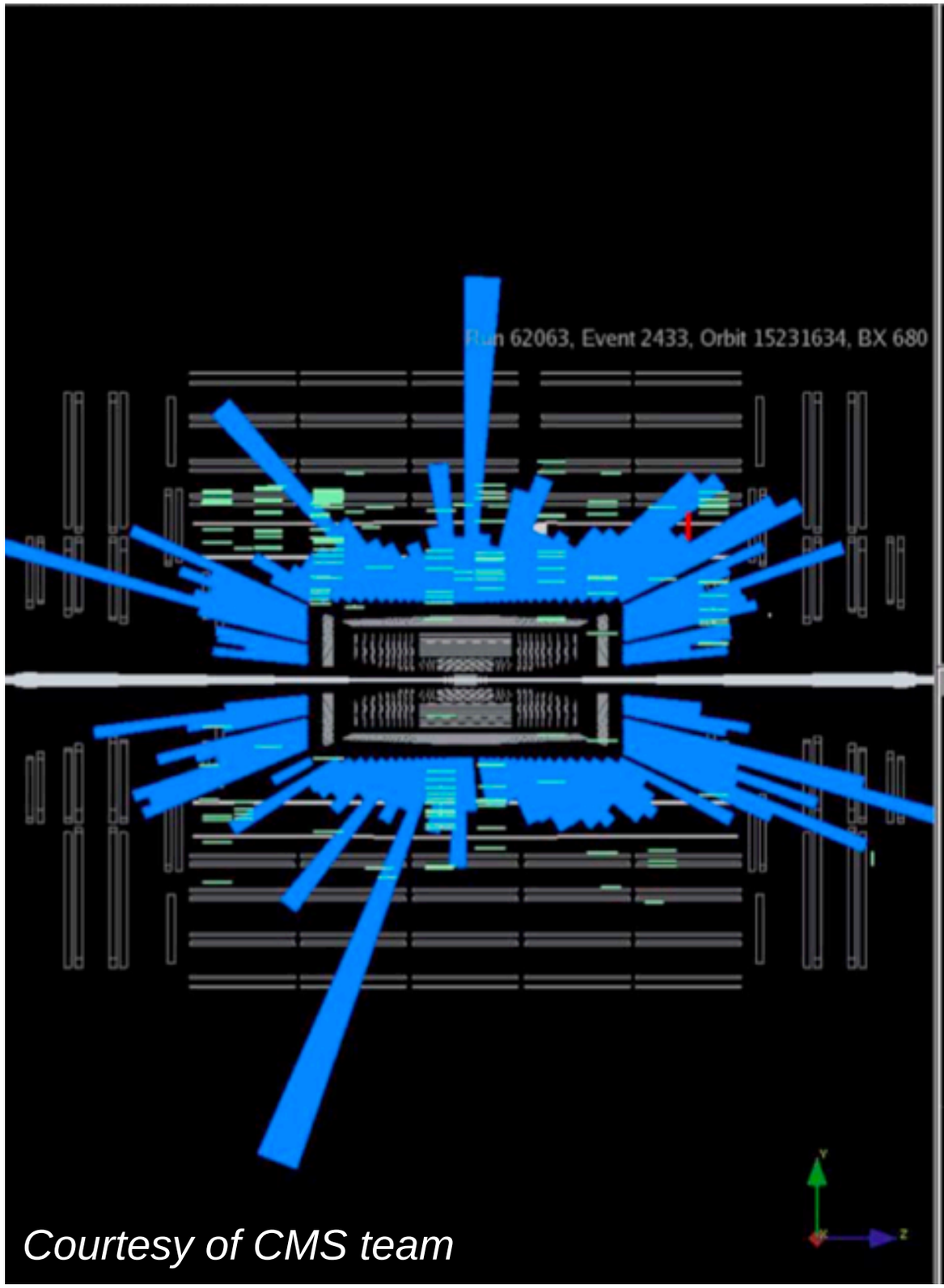


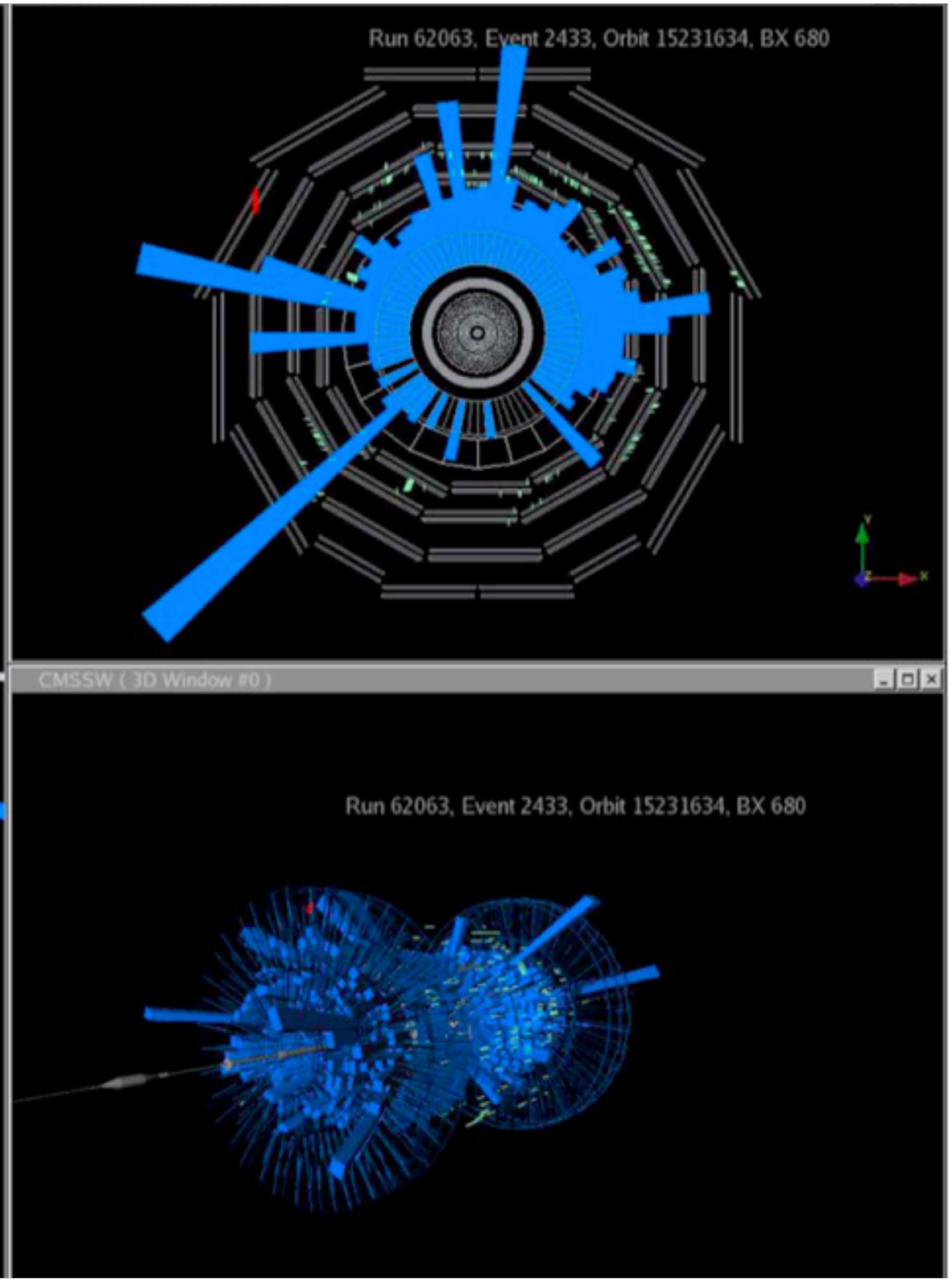
FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 09-50-28
Mean = -0.503 / RMS = 1.569 / Dp = -0.49
Horizontal trajectory
H Pos [mm]
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb
Monitor H



FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 09-50-28
Mean = -0.751 / RMS = 1.484 / Dp = -0.49
Vertical trajectory
V Pos [mm]
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb
Monitor V

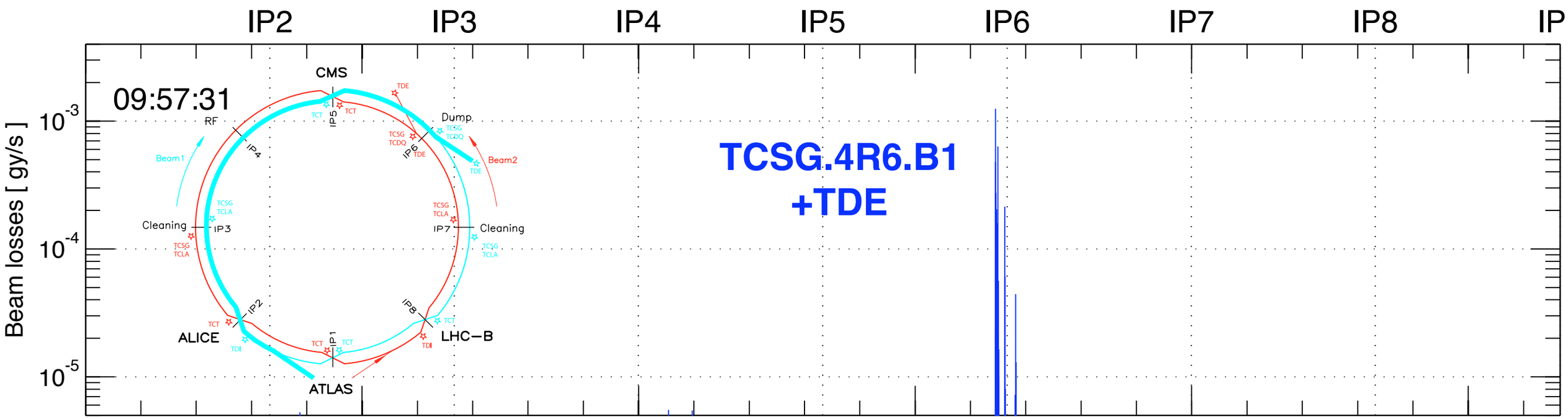
Collimator events in CMS

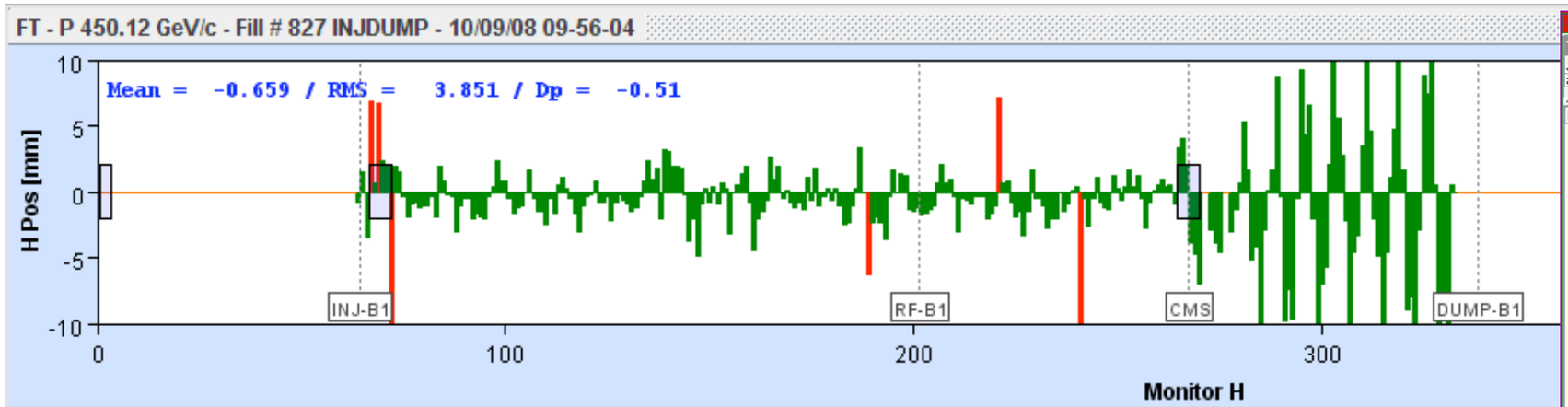


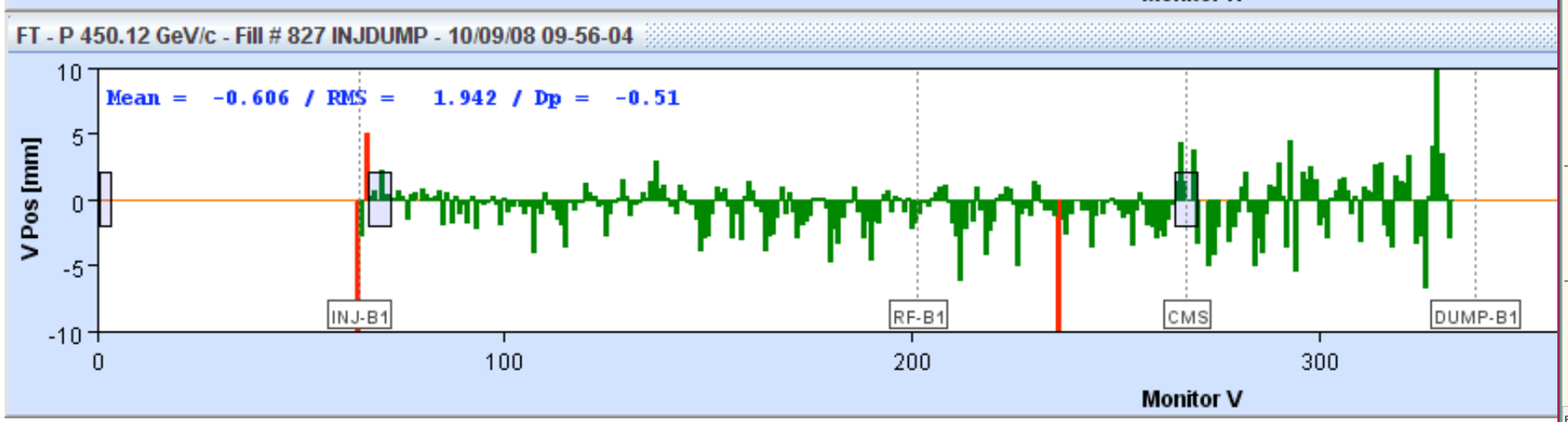


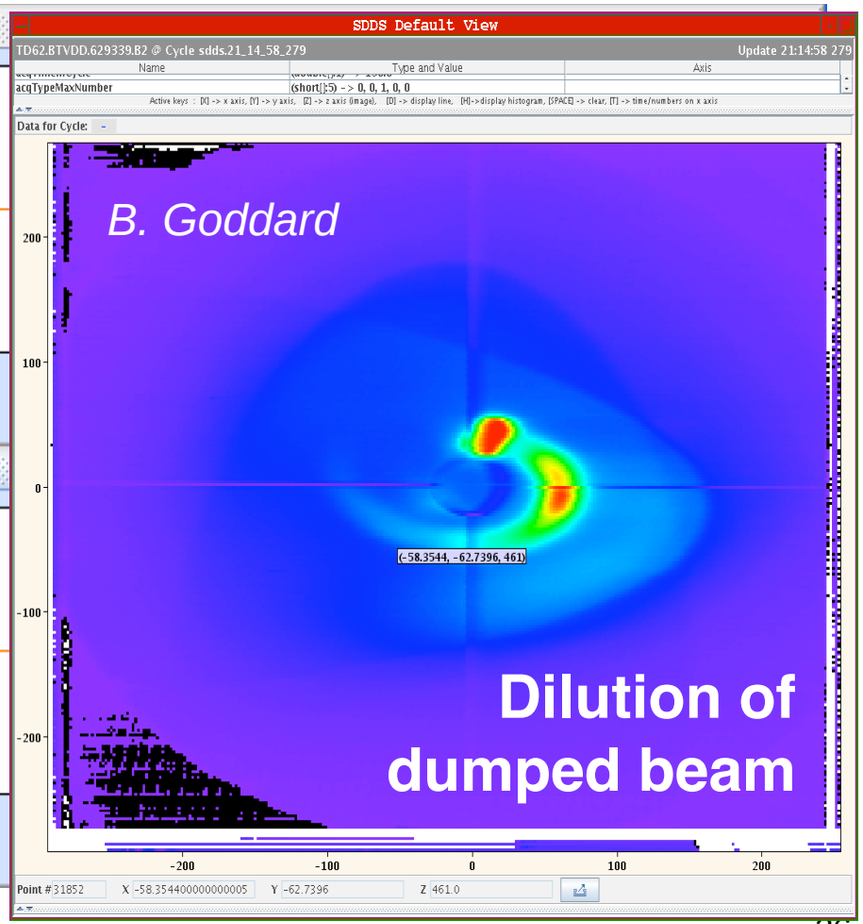
Courtesy of CMS team

Beam to IP6

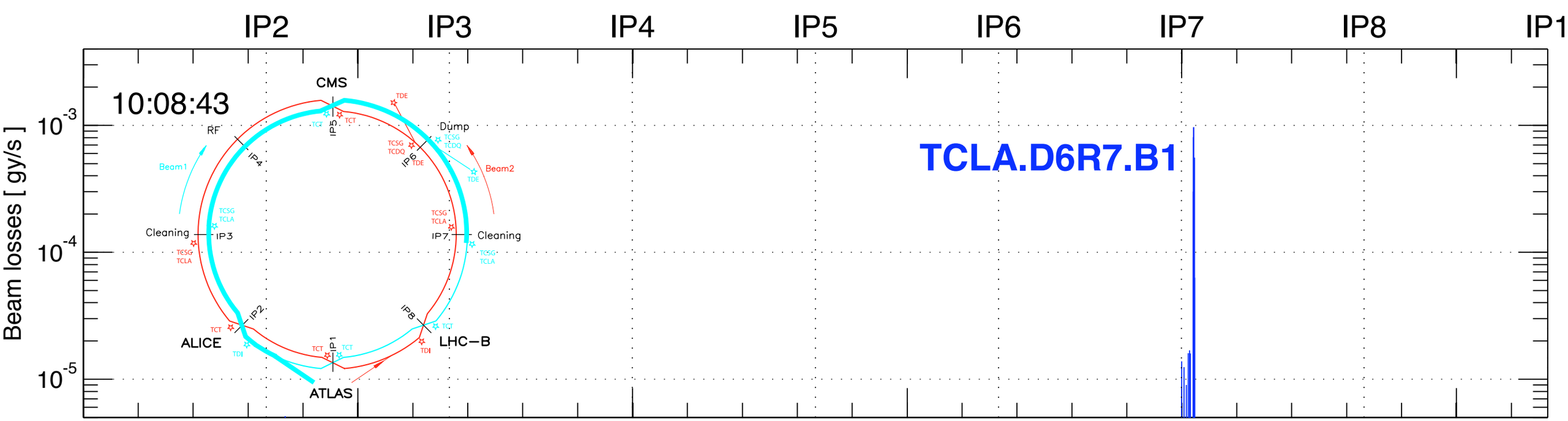

IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
09:57:31
CMS
RF
Dump
Beam1
Beam2
Cleaning
IP3
IP7
Cleaning
ALICE
LHC–B
ATLAS
IP4
IP5
IP6
IP2
IP8
IP1
TCT
TDE
TDI
TCSG
TCLA
TCDQ
Beam losses [gy/s]
10^{-3}
10^{-4}
10^{-5}
TCSG.4R6.B1
+TDE

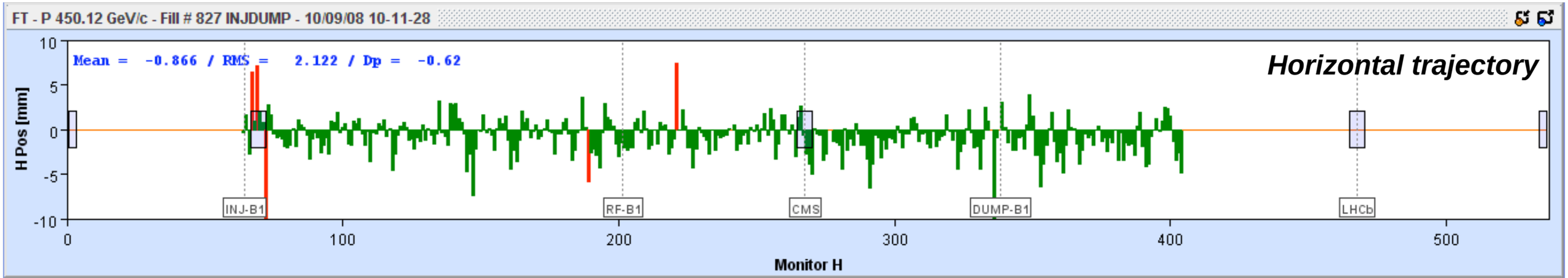

FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 09-56-04
Mean = -0.659 / RMS = 3.851 / Dp = -0.51
H Pos [mm]
INJ-B1
RF-B1
CMS
DUMP-B1
Monitor H

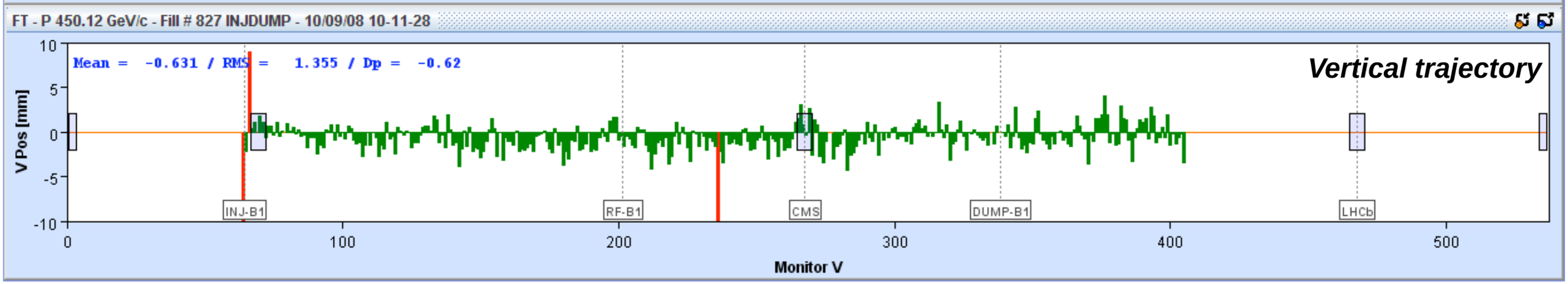

FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 09-56-04
Mean = -0.606 / RMS = 1.942 / Dp = -0.51
V Pos [mm]
INJ-B1
RF-B1
CMS
DUMP-B1
Monitor V


SDDS Default View
TD62.BTVDD.629339.B2 @ Cycle sdds.21_14_58_279
Update 21:14:58 279
Name
Type and Value
Axis
acqTypeMaxNumber
(short[]5) -> 0, 0, 1, 0, 0
Data for Cycle:
B. Goddard
(-58.3544, -62.7396, 461)
Dilution of dumped beam
Point # 31852
X -58.354400000000005
Y -62.7396
Z 461.0

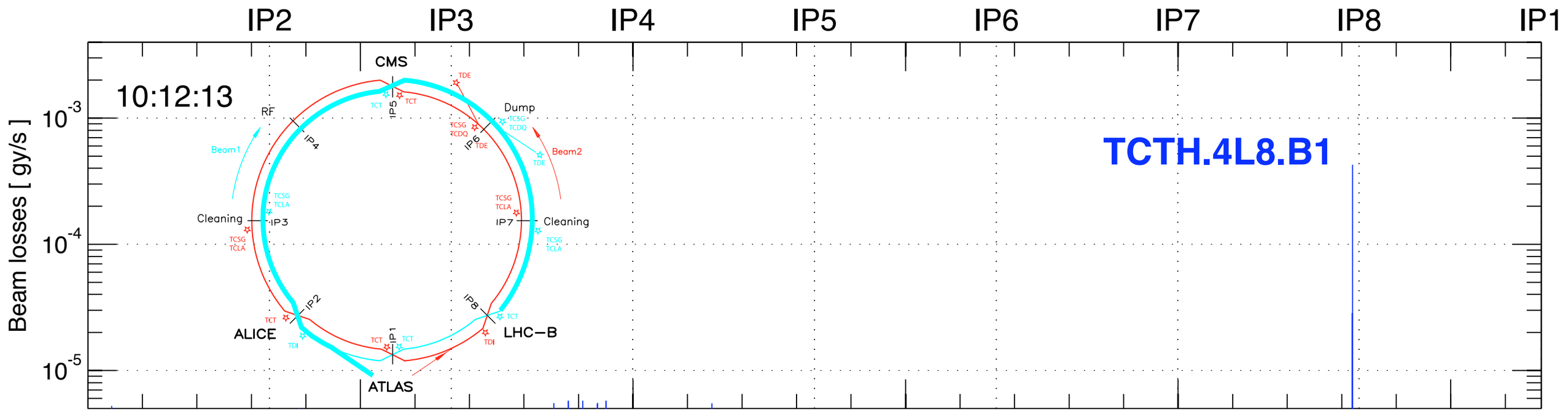
Beam to IP7

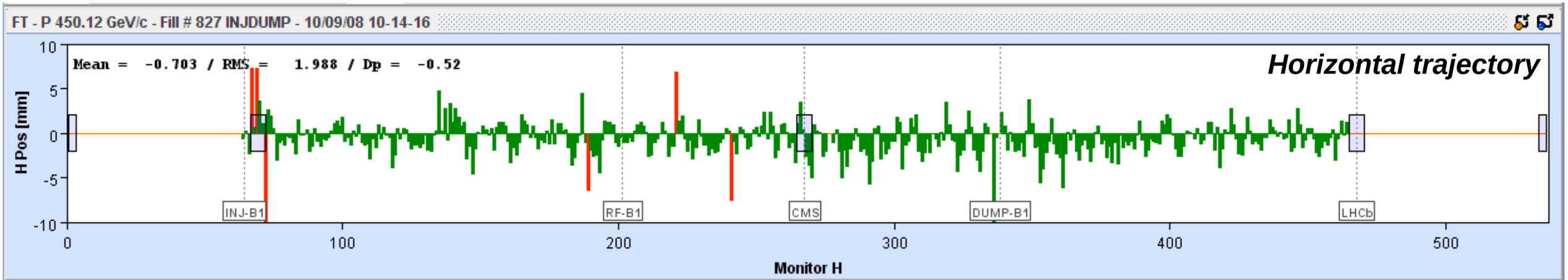

IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
10:08:43
CMS
Dump
RF
Beam1
Beam2
Cleaning
Cleaning
IP3
IP7
ALICE
LHC−B
ATLAS
IP2
IP4
IP5
IP6
IP8
IP1
TCSG
TCLA
TCT
TDI
TDE
TCSG
TCDQ
Beam losses [gy/s]
10^{-3}
10^{-4}
10^{-5}
TCLA.D6R7.B1

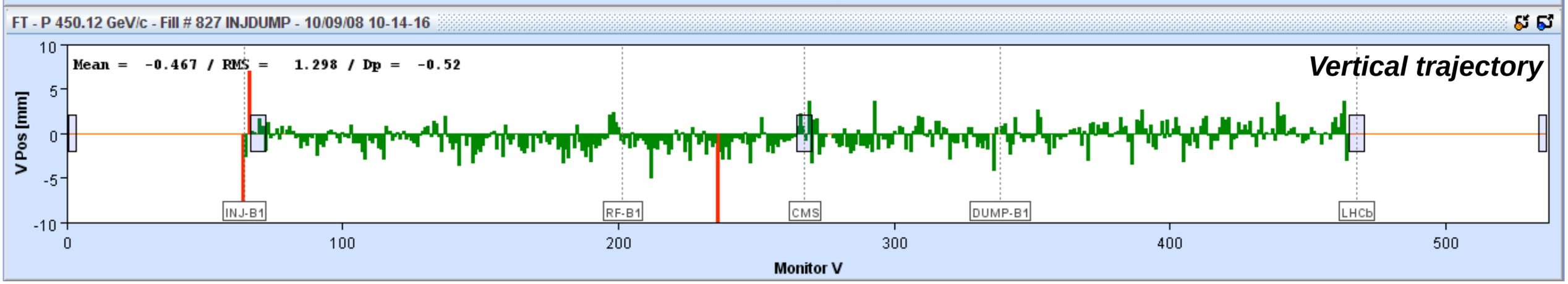

FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-11-28
Mean = -0.866 / RMS = 2.122 / Dp = -0.62
Horizontal trajectory
H Pos [mm]
10
5
0
-5
-10
0
100
200
300
400
500
Monitor H
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb


FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-11-28
Mean = -0.631 / RMS = 1.355 / Dp = -0.62
Vertical trajectory
V Pos [mm]
10
5
0
-5
-10
0
100
200
300
400
500
Monitor V
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb

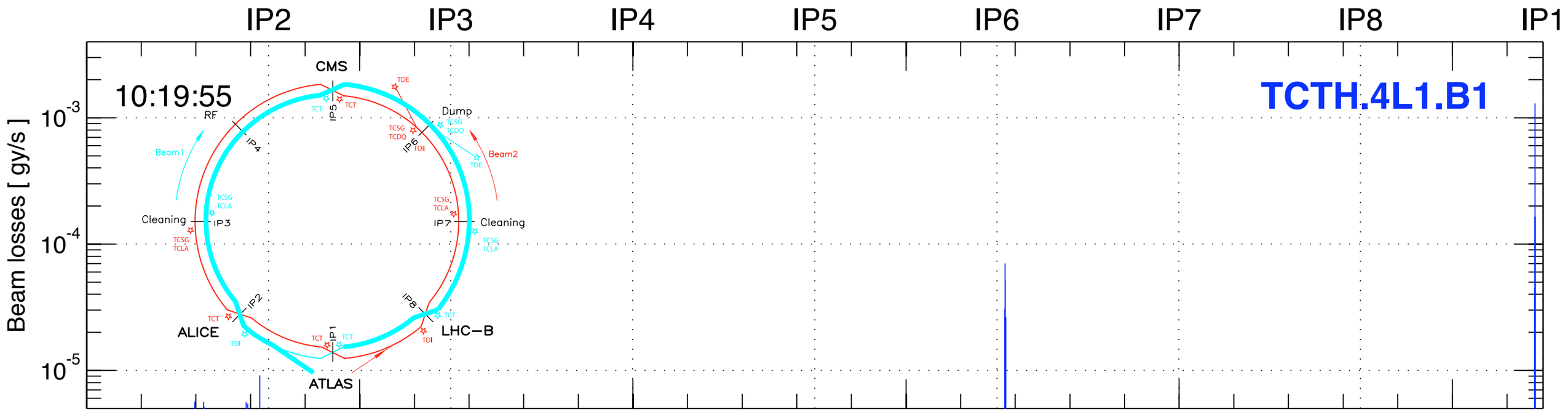
Beam to IP8

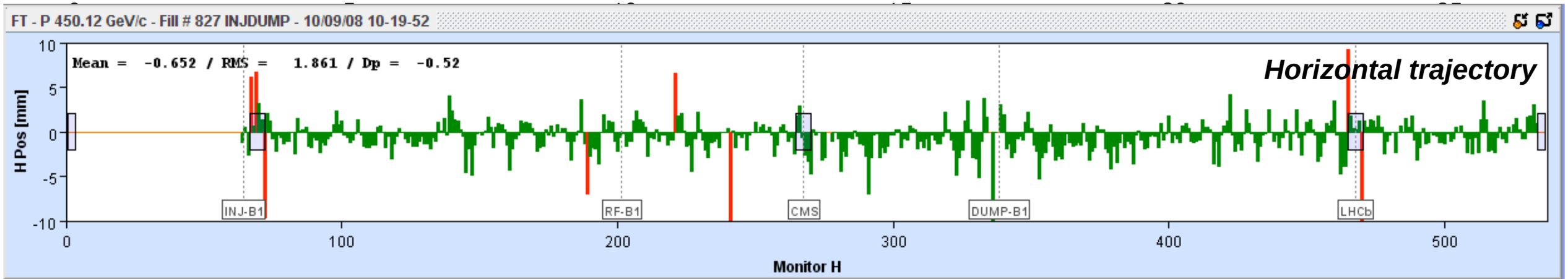

IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
10:12:13
CMS
RF
Dump
Beam1
Beam2
Cleaning
IP3
IP7
Cleaning
ALICE
LHC−B
ATLAS
IP4
IP5
IP6
IP2
IP8
IP1
TCT
TDE
TDI
TCSG
TCLA
TCDQ
Beam losses [gy/s]
10^{-3}
10^{-4}
10^{-5}
TCTH.4L8.B1

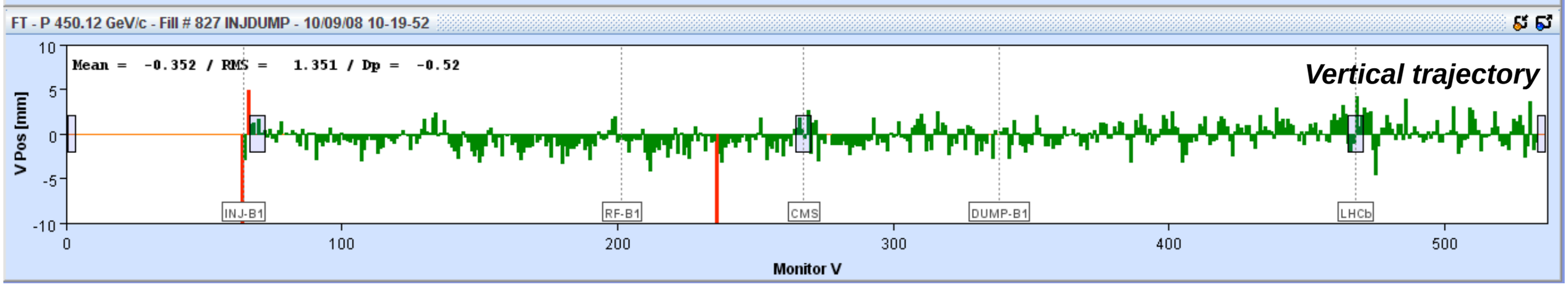

FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-14-16
Mean = -0.703 / RMS = 1.988 / Dp = -0.52
Horizontal trajectory
H Pos [mm]
10
5
0
-5
-10
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb
0
100
200
300
400
500
Monitor H


FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-14-16
Mean = -0.467 / RMS = 1.298 / Dp = -0.52
Vertical trajectory
V Pos [mm]
10
5
0
-5
-10
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb
0
100
200
300
400
500
Monitor V

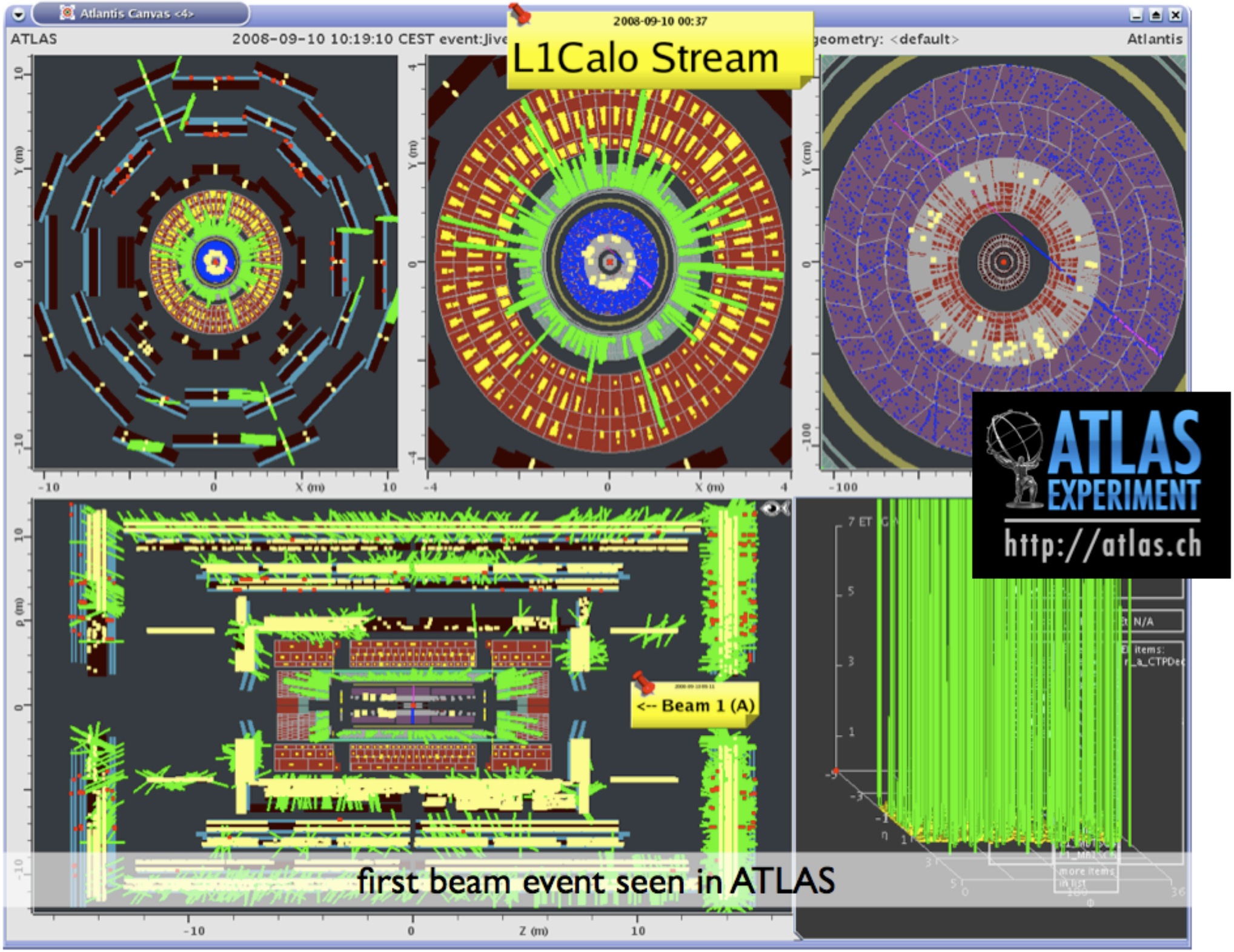
Beam to IP1


IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
Beam losses [gy/s]
10^{-3}
10^{-4}
10^{-5}
10:19:55
TCTH.4L1.B1
CMS
ATLAS
ALICE
LHC−B
Dump
RF
Beam1
Beam2
Cleaning
Cleaning
IP4
IP5
IP6
IP7
IP8
IP2
IP1
IP3
TDE
TCT
TCSG
TCDQ
TCLA
TDI


FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-19-52
Mean = -0.652 / RMS = 1.861 / Dp = -0.52
Horizontal trajectory
H Pos [mm]
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb
Monitor H

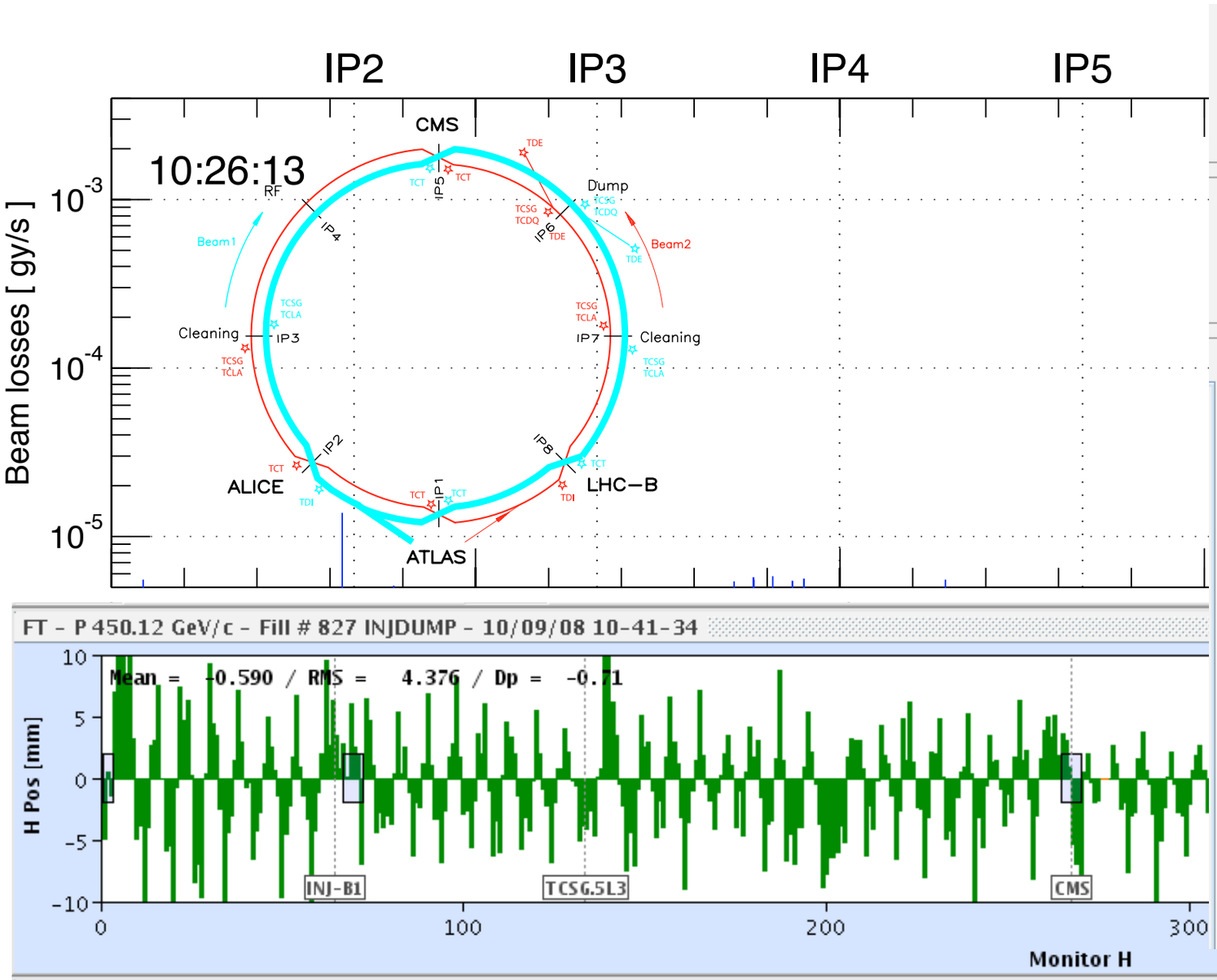

FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-19-52
Mean = -0.352 / RMS = 1.351 / Dp = -0.52
Vertical trajectory
V Pos [mm]
INJ-B1
RF-B1
CMS
DUMP-B1
LHCb
Monitor V

Collimator events at ATLAS



Courtesy of T. Wengler for the ATLAS team

First turn!


IP2
IP3
IP4
IP5
10:26:13
Beam losses [gy/s]
10^{-3}
10^{-4}
10^{-5}
CMS
Dump
Beam1
Beam2
RF
IP4
IP6
IP5
IP7
IP8
IP2
IP1
IP3
Cleaning
Cleaning
ALICE
LHC–B
ATLAS
TCT
TDE
TDI
TCSG
TCLA
TCDQ

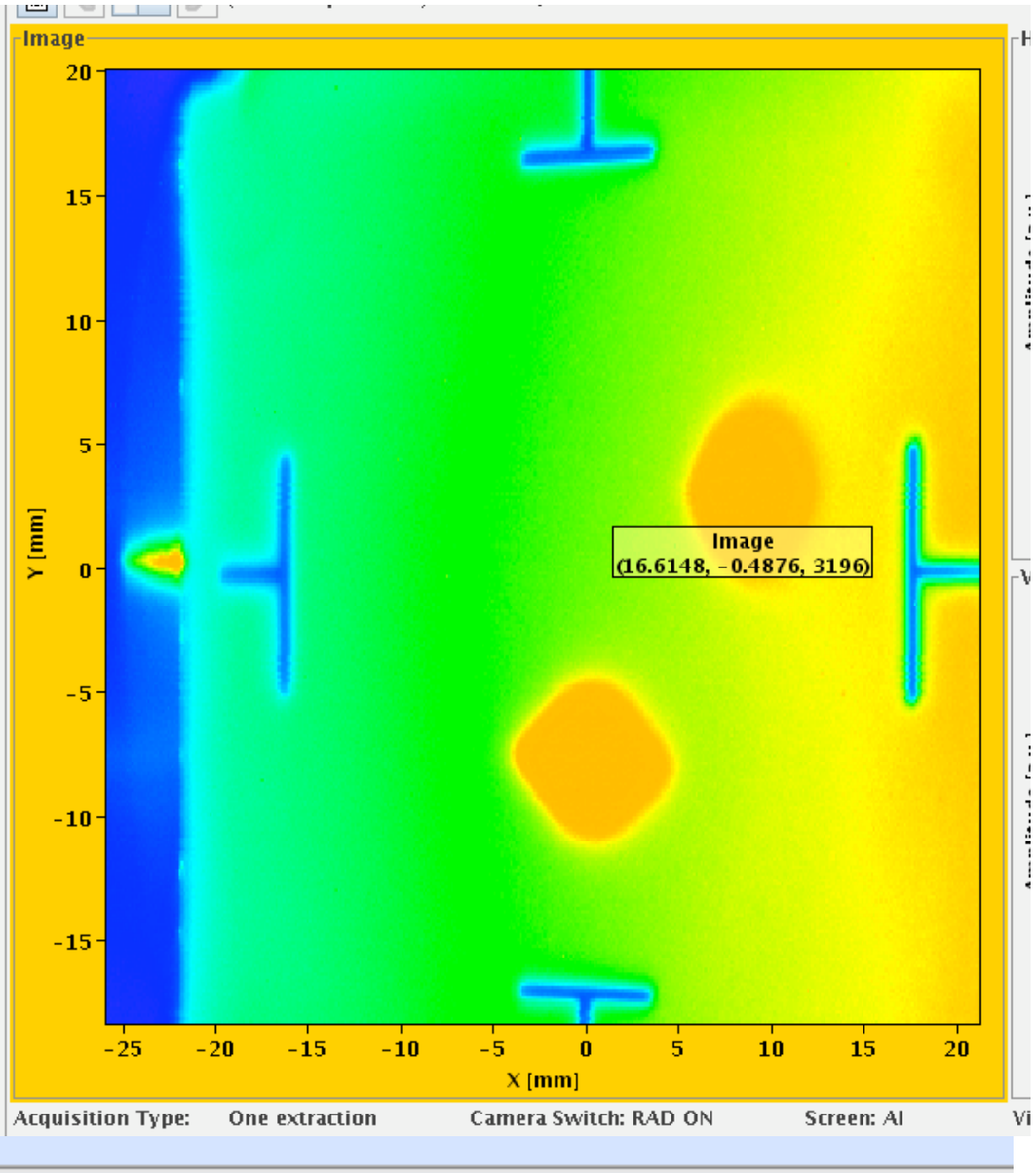
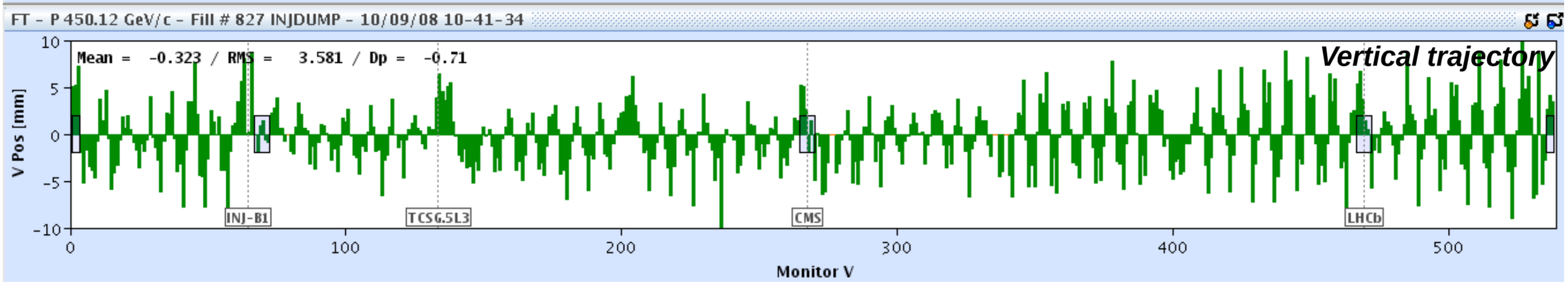


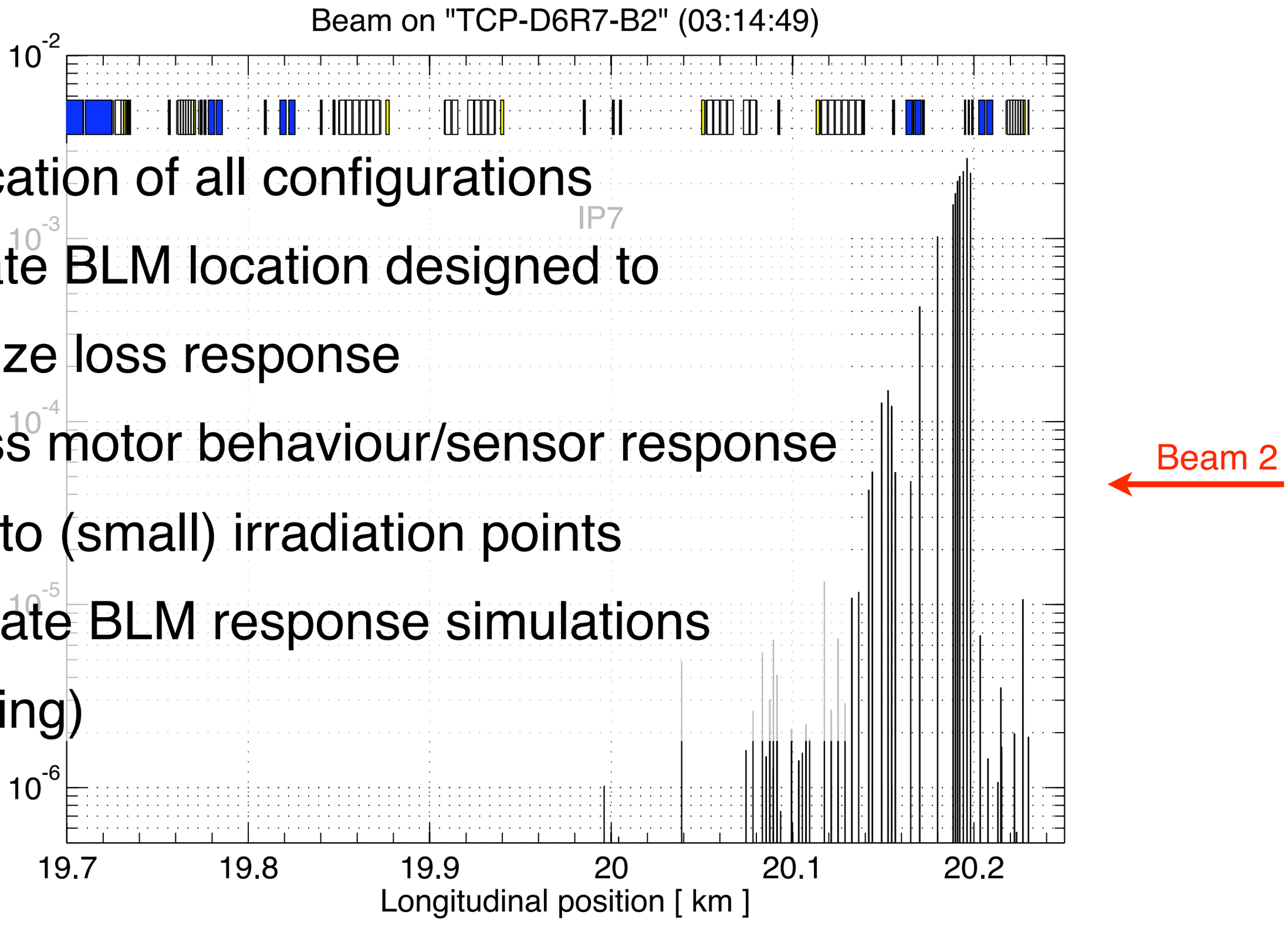
Image
Image
(16.6148, -0.4876, 3196)
Y [mm]
X [mm]
Acquisition Type: One extraction
Camera Switch: RAD ON
Screen: AI

FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-41-34
Mean = -0.590 / RMS = 4.376 / Dp = -0.71
H Pos [mm]
INJ-B1
TCSG.5L3
CMS
Monitor H


FT - P 450.12 GeV/c - Fill # 827 INJDUMP - 10/09/08 10-41-34
Mean = -0.323 / RMS = 3.581 / Dp = -0.71
V Pos [mm]
INJ-B1
TCSG.5L3
CMS
LHCb
Monitor V
Vertical trajectory

Detailed response studies in IP7

- ☑ Verification of all configurations
- ☑ Validate BLM location designed to optimize loss response
- ☑ Assess motor behaviour/sensor response close to (small) irradiation points
- ☑ Calibrate BLM response simulations (ongoing)

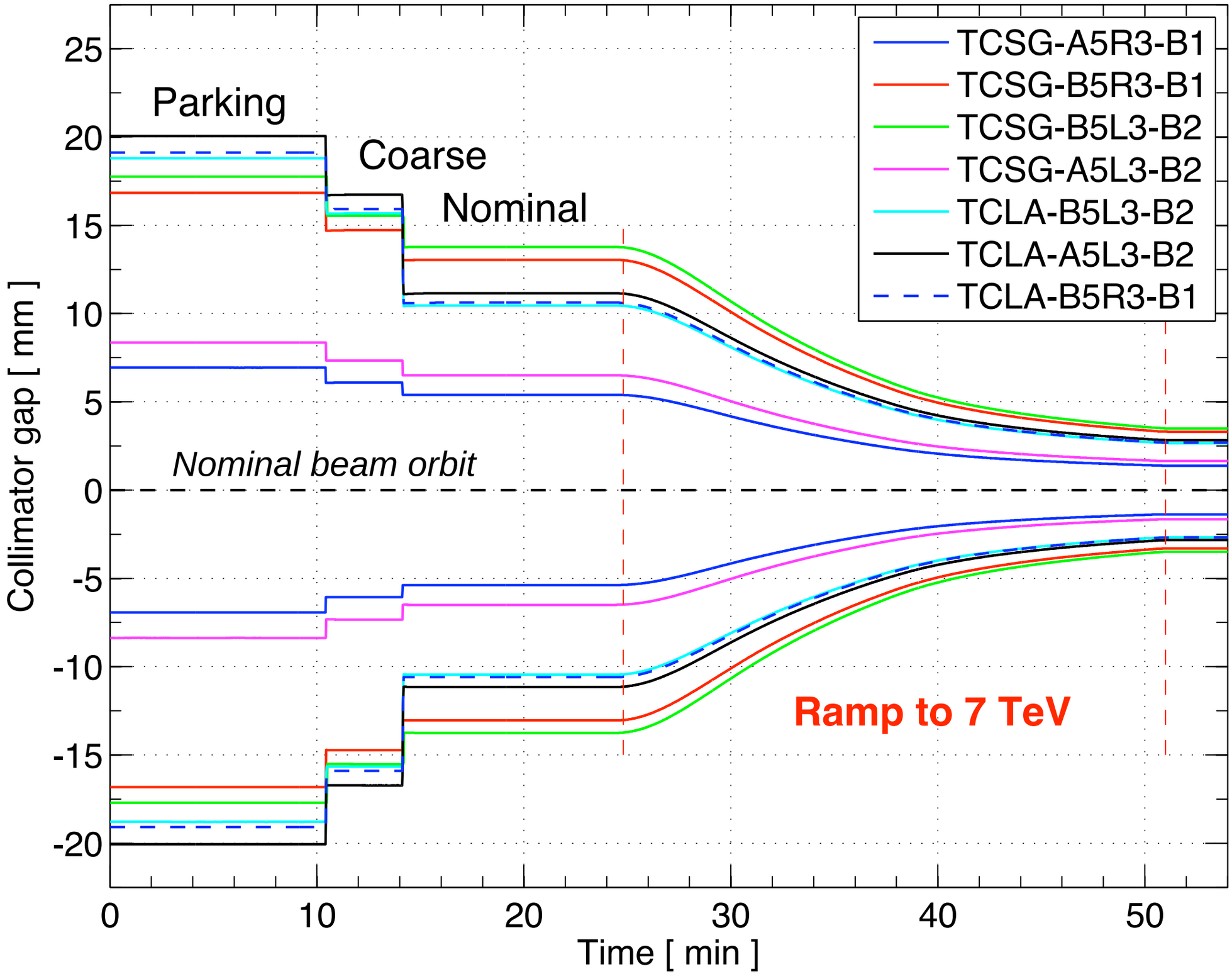


Conclusions

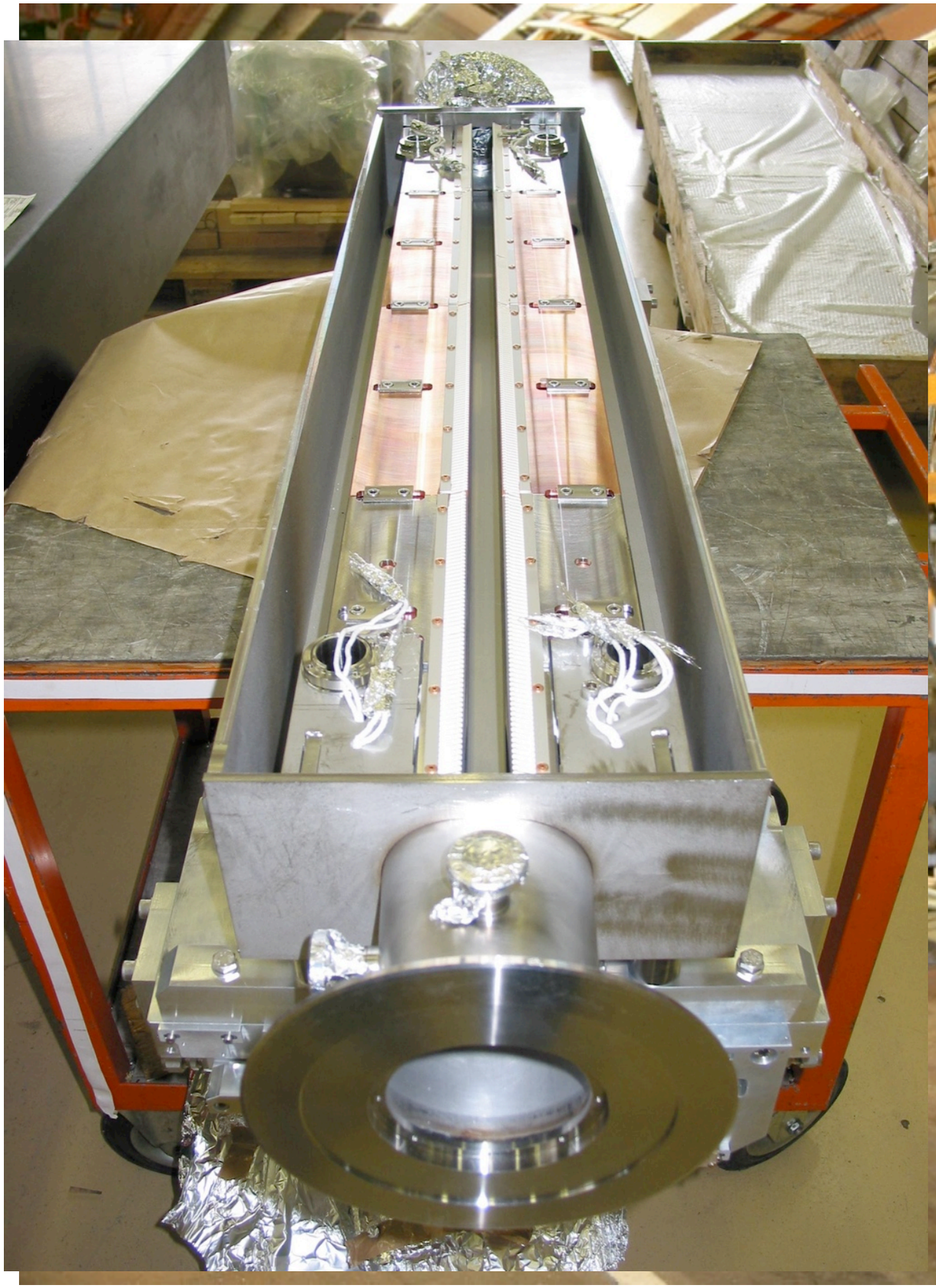
- **Operational experience of the collimation system was reviewed**
  - *Mainly "dry-runs" as a part of system HW commissioning*
  - *Missed the chance to perform circulating beam tests*
- **HW commissioning of 2008 system was completed**
  - *The main design tolerance are basically achieved*
  - *Machine protection functionality validated*
  - *Controls at all levels fully deployed, very satisfactory performance*
- **First successful usage with beam**
  - *First systematic commissioning in the transfer lines*
  - *Collimators as beam stoppers, which made the injection tests possible*
  - *Unforeseen but entertaining use for physics events in IP1/5*
- **Outlook:**
  - *Implementation of 2009 system*
  - *TODO list for improvements compiled, will be followed up*
  - *Further tests of reproducibility to optimized operational settings*

Reserve slides

Nominal operational cycle



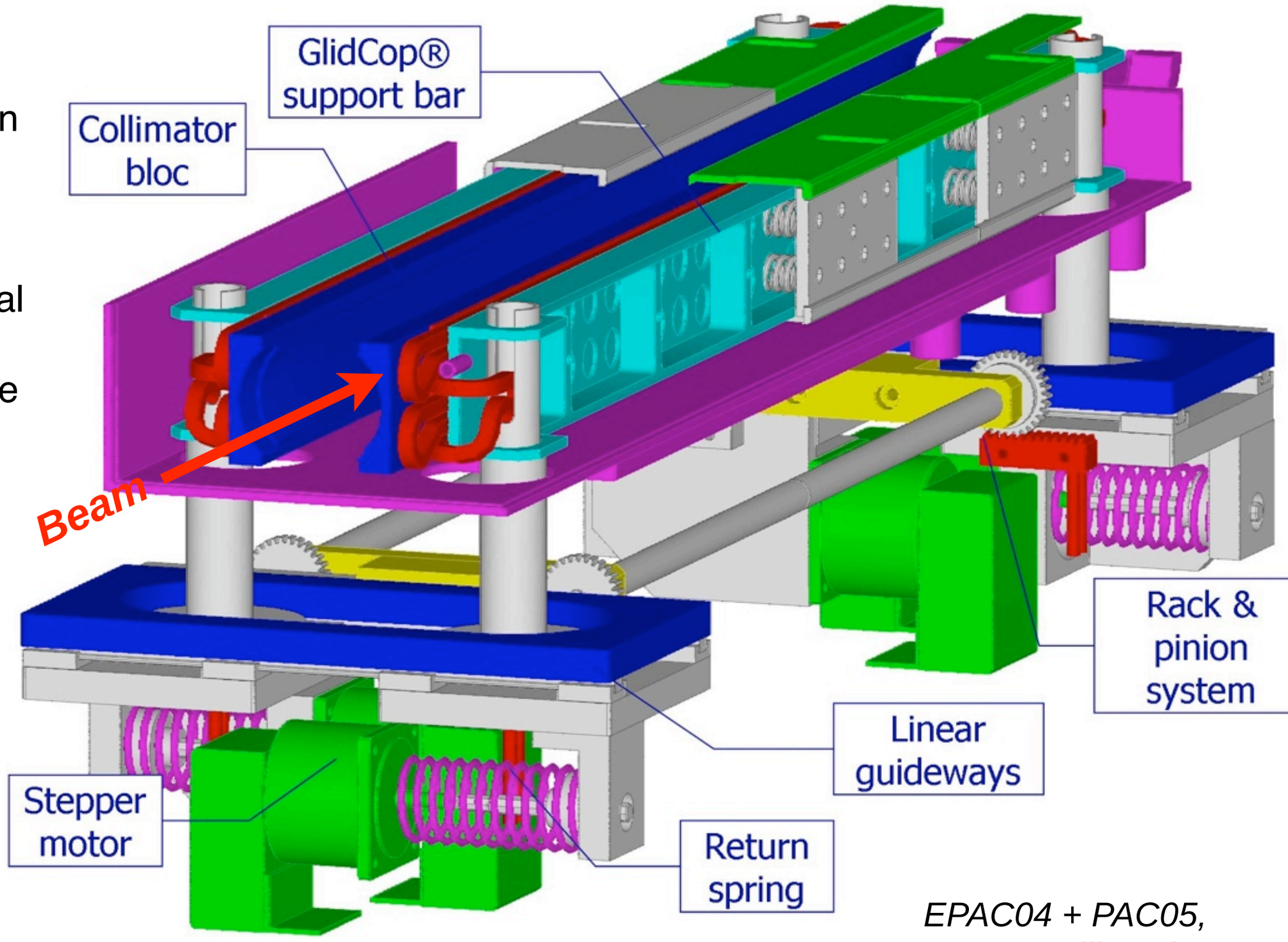
The LHC collimator



The collimator assembly

Main design features:

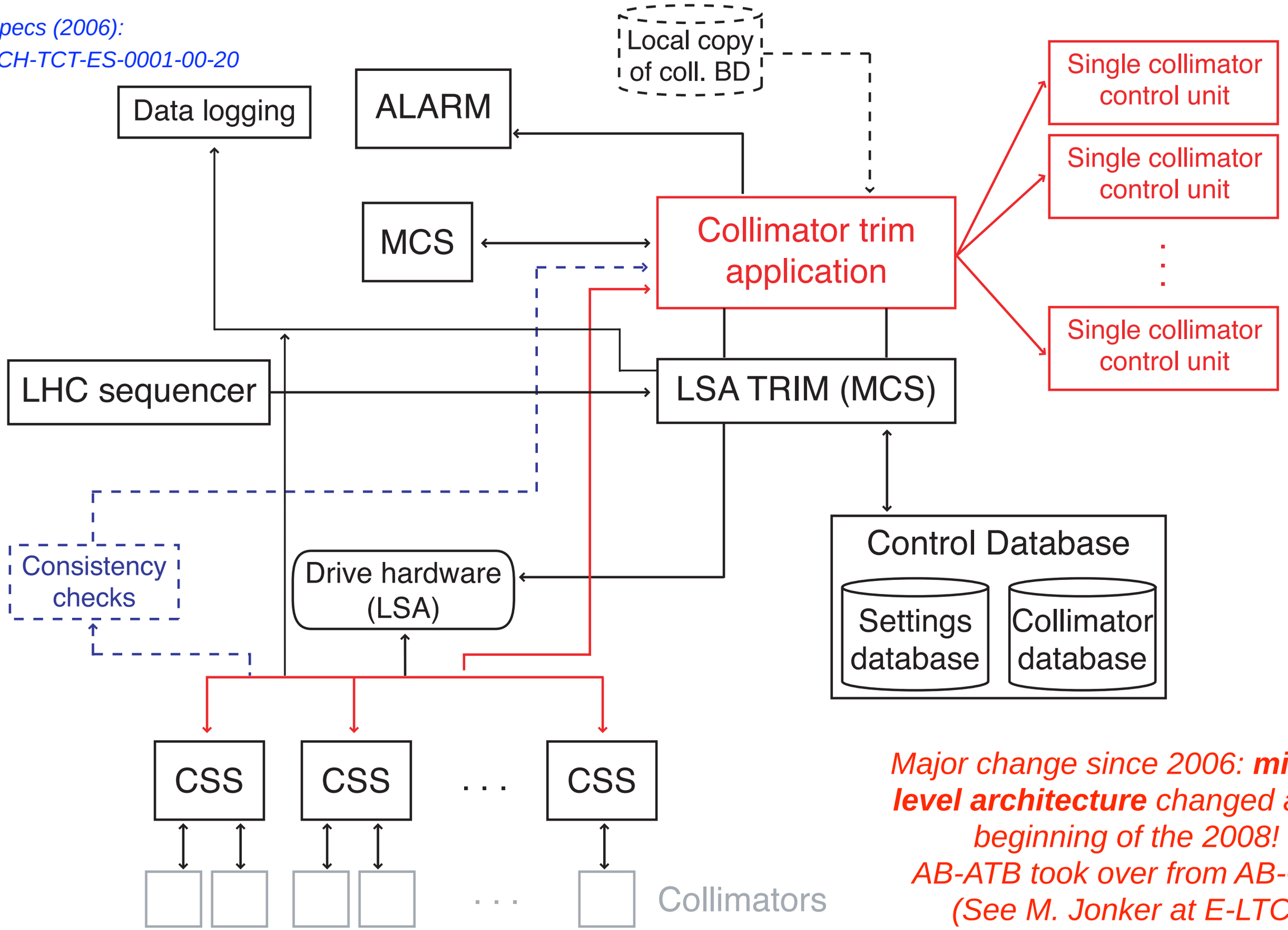
- Two jaws (position and angle)
- Concept of spare surface
- Different azimuthal angles (H,V,S)
- External reference of jaw position
- Auto-retraction
- RF fingers
- Jaw cooling



EPAC04 + PAC05,
A. Bertarelli et al.

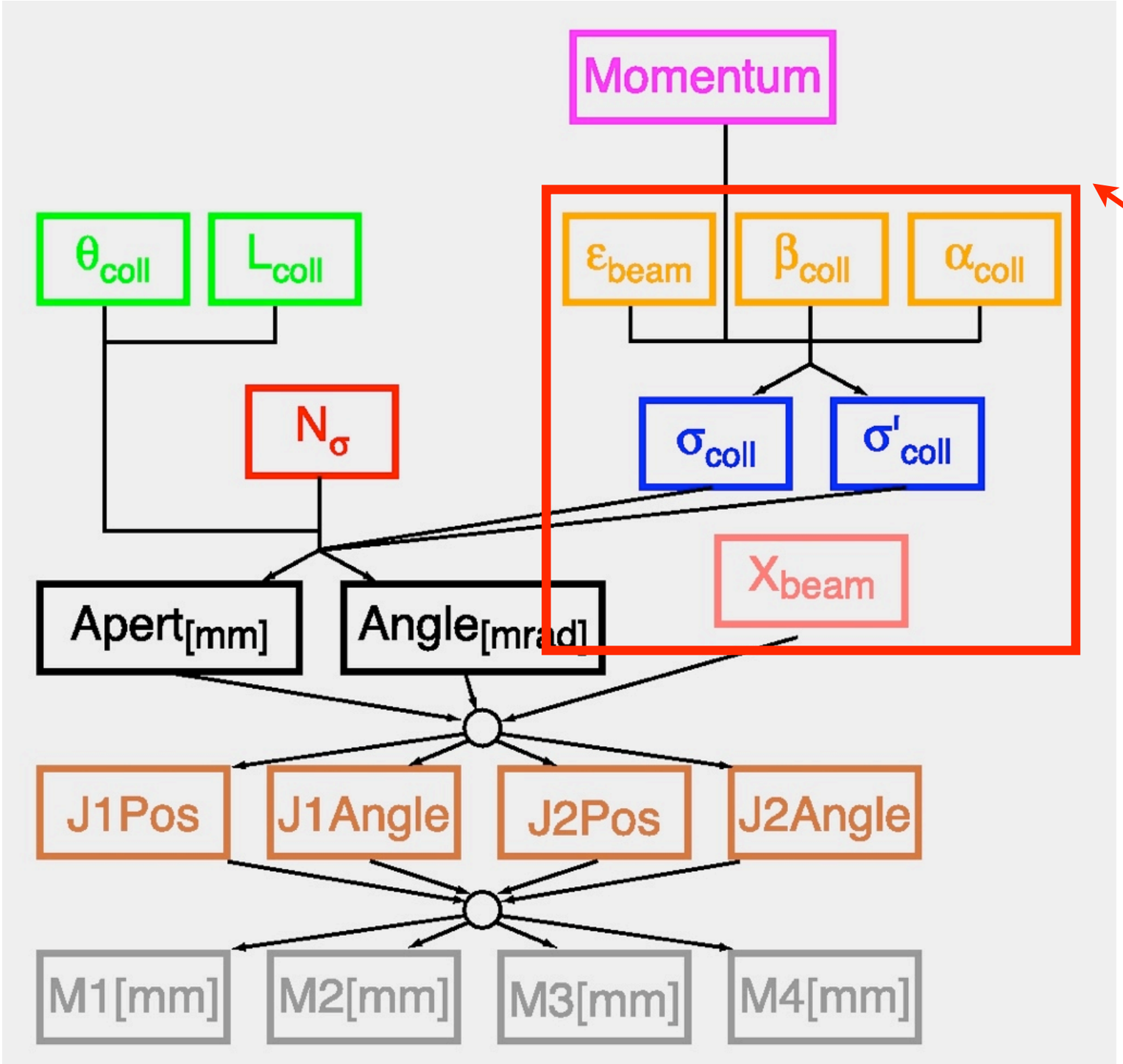
Top-level controls architecture

Specs (2006):
LCH-TCT-ES-0001-00-20



*Major change since 2006: **middle-level architecture** changed at the beginning of the 2008!*
AB-ATB took over from AB-CO.
(See M. Jonker at E-LTC)

Settings in beam sigma units



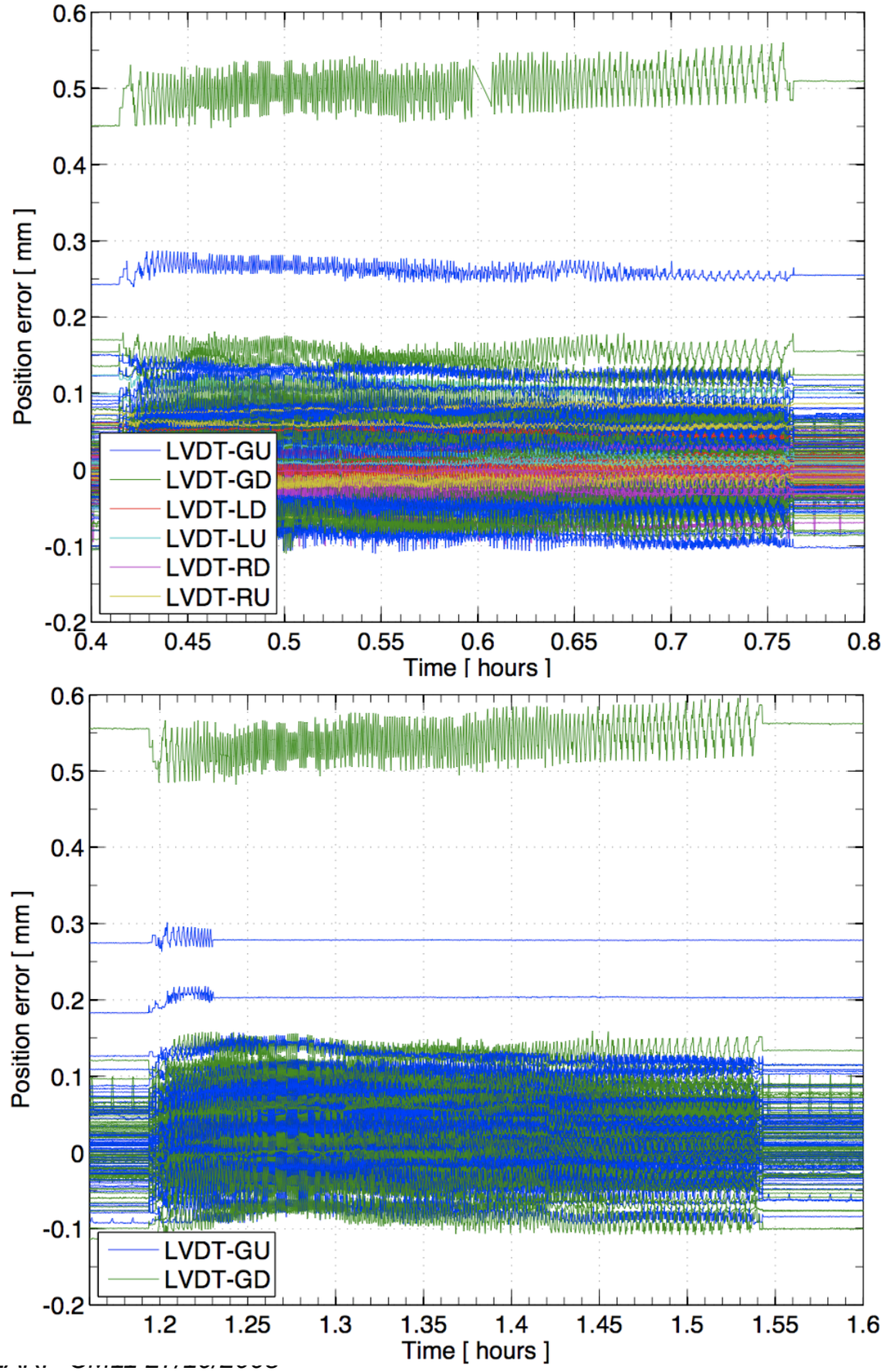
Parameter space for settings in **units sigma**!
(trims at all levels possible!)
Canonical settings:
TCP → 6 σ
TCSG → 7 σ
TCT → 8.5 σ

Beam-based parameters will be determined for each collimator with beam and stored in the setting DB
(now: nominal values imported at the generation level)

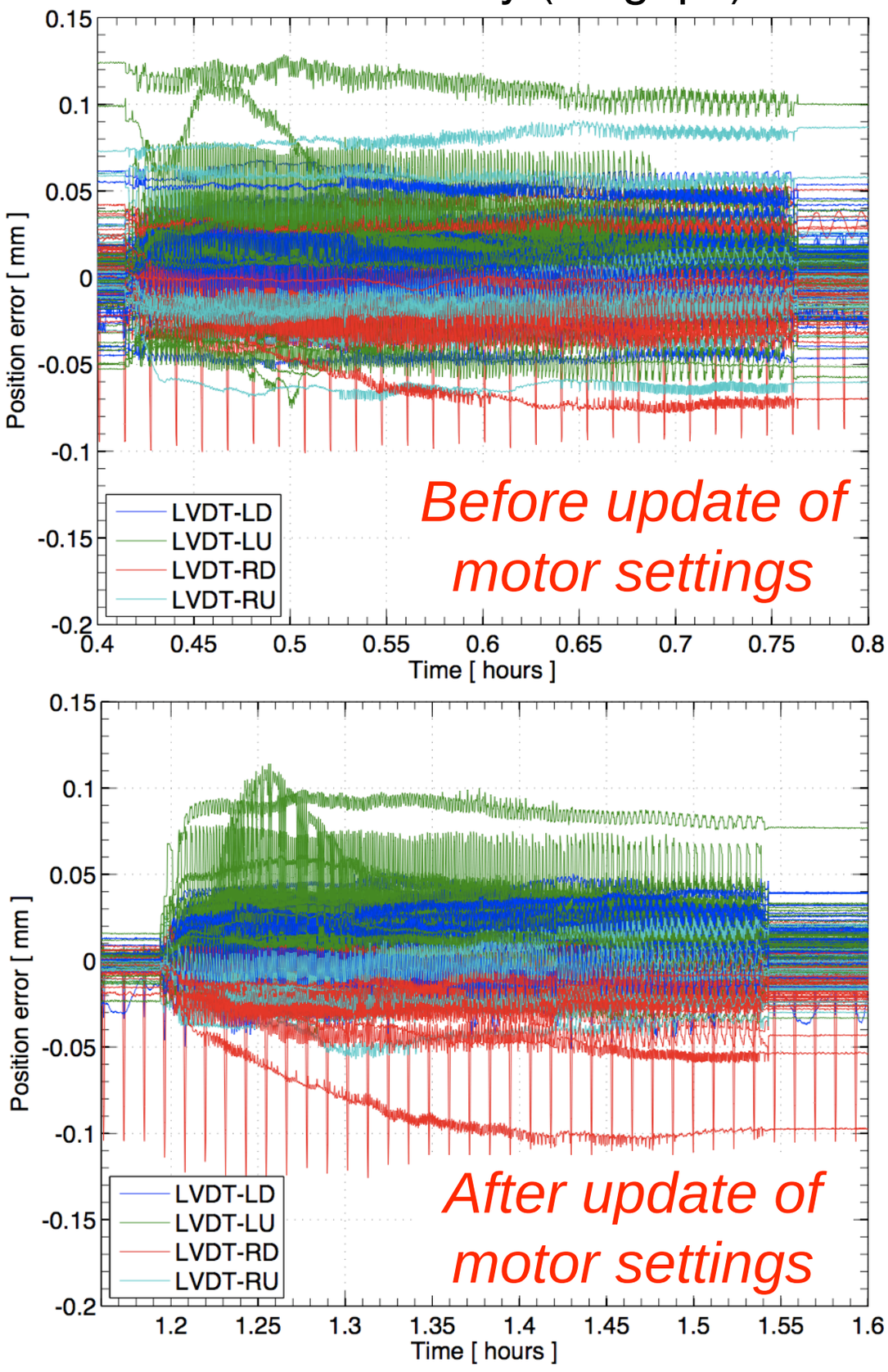
Database definition of the parameter space and the associate makerules maintained by D. Jacquet, great support from LSA team!

Distribution of setting / LVDT errors

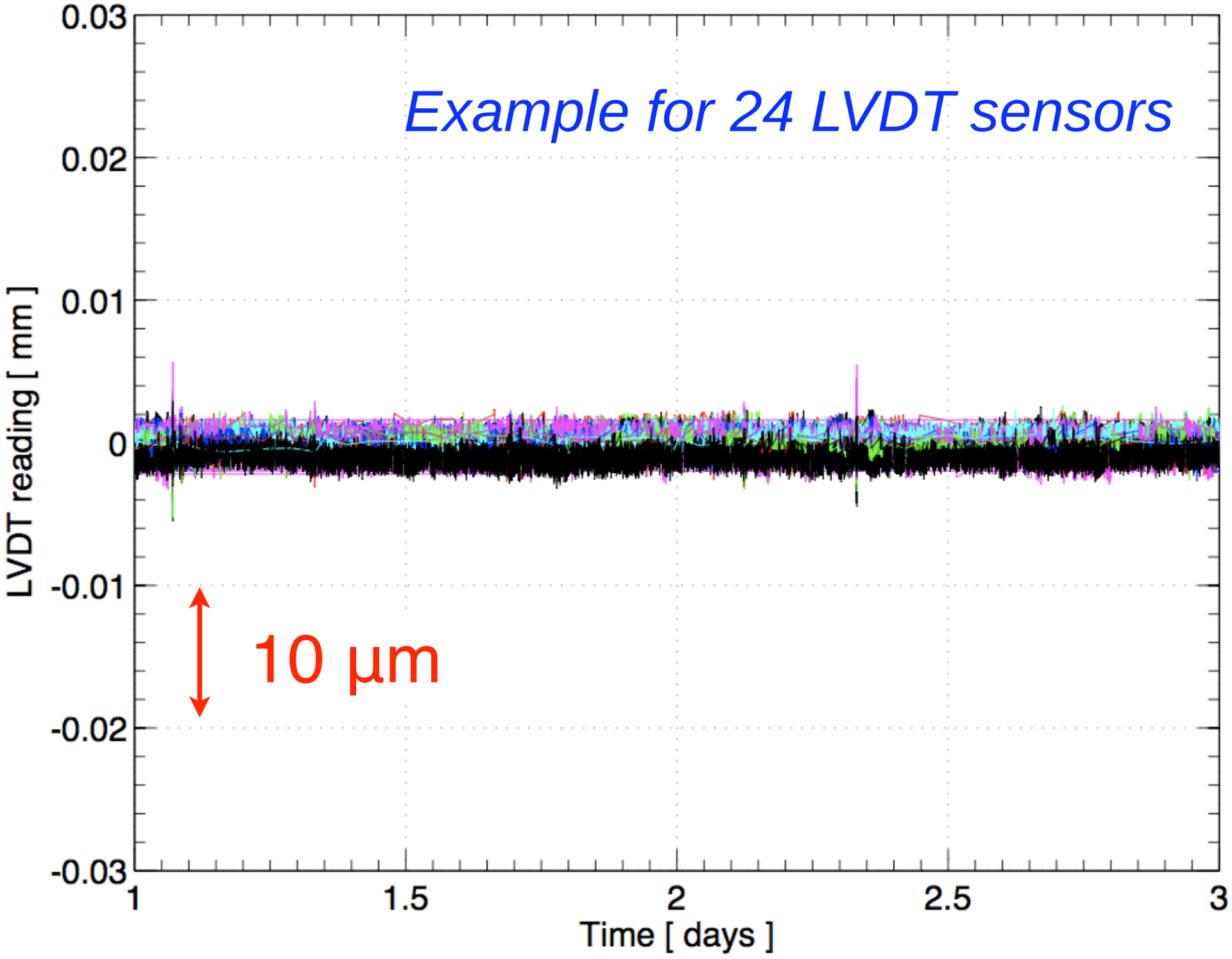
All sensors



Corners only (no gaps)



Long term stability



Collimators gap during IR7 BLM response