

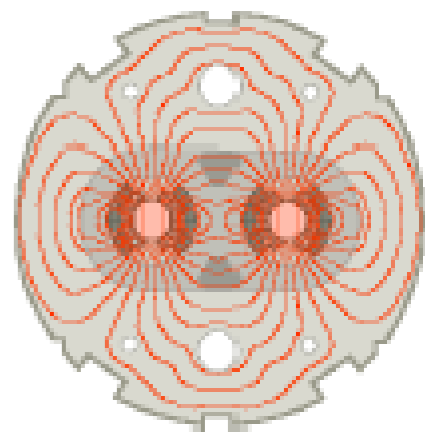
CMS Commissioning Meeting

August 15th, 2008

CERN - Geneva (CH)

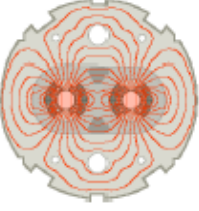
Highlights of T12-LHC Synchronization Test with Beam

M. Lamont and S. Redaelli
on behalf of the OP team

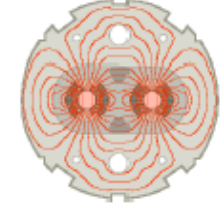




Outline



- **Introduction: goals / layouts**
- **Beam and magnet availability**
- **List of “Firsts”**
- **Detailed beam measurements**
- **Conclusions**



Acknowledgments

Hardware Commissioning Coordination (HCC)

Survey group

Access System team

Cryogenics

Magnets [PO, MPP, QPS, PIC...]

Accelerator systems:

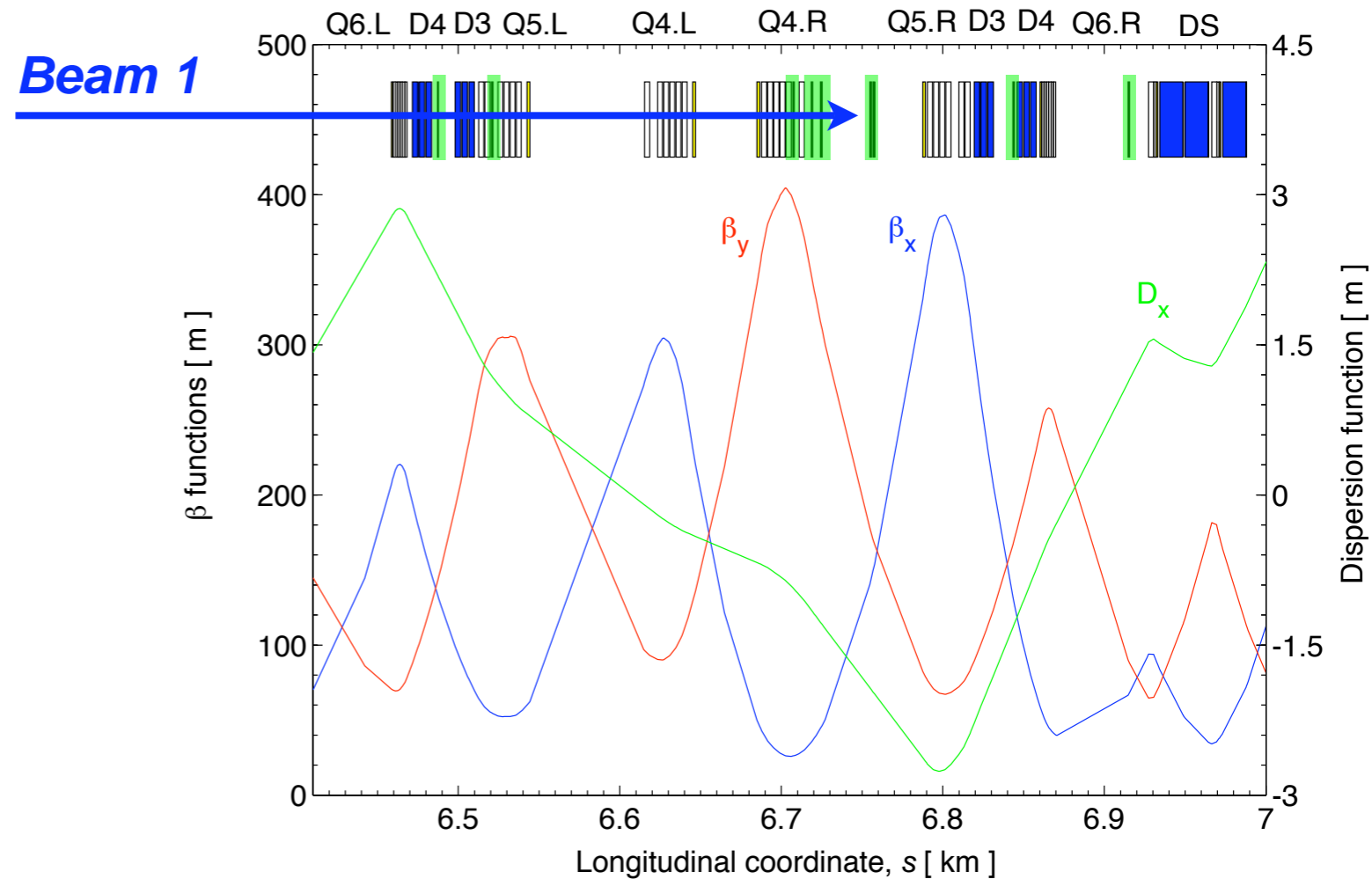
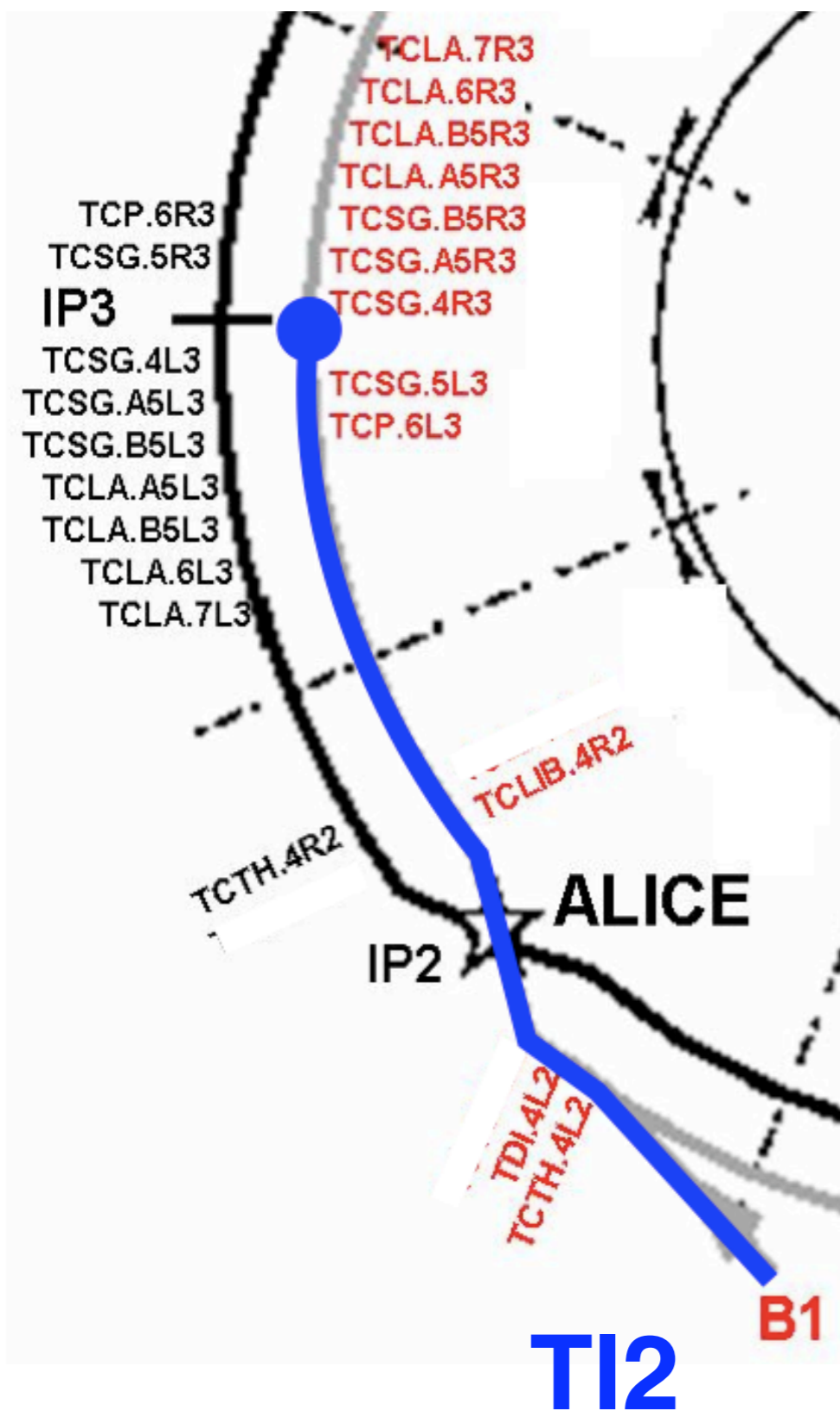
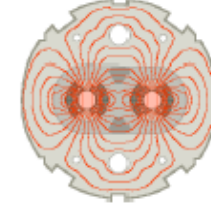
Injection team, beam instrumentation, (BPM, BLM, BCT, screens ...), beam interlock system, radio-protection, collimators, controls ...

Contributions of many people who actively participated to the first LHC beam studies.

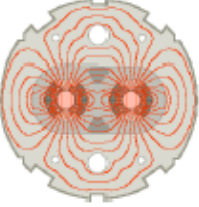
Comprehensive overview of achieved results at

<http://cern.ch/lhc-injection-test/meetings/120808/injection-test-120808.htm>

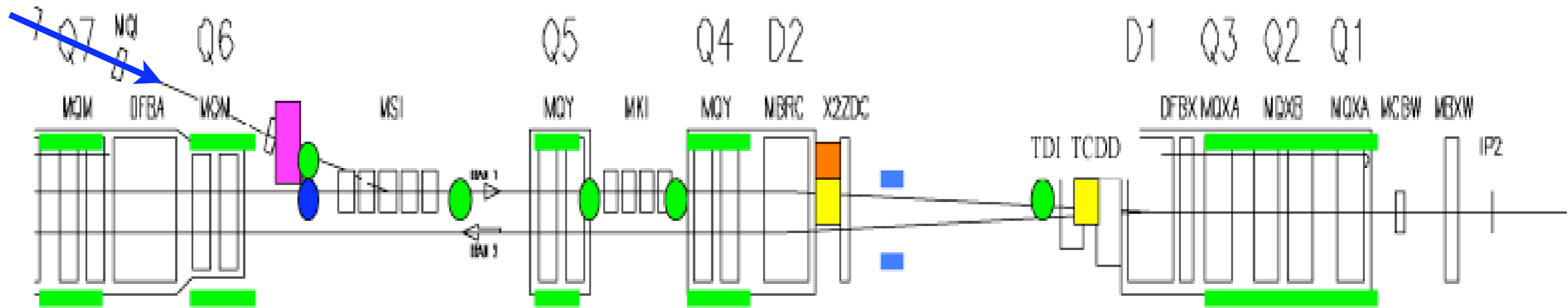
Layout of beam path



- (1) Commission end of TI2
(beam on TDI on IP2-left)
- (2) Steer beam up to IP3
- (3) Stop beam on the collimators
(5 Carbon primary+secondary colls;
4 Tungsten absorbers)



TI2



B. Goddard

— BPM and BLM

— Beam-beam rate monitors

■ BTPX timing PU - 0.5 m

■ BPMW position PU - 0.5 m
● BTV first turn screen - 0.5 m

● BTVI screen for injection - 0.5 m

■ BCTI beam current transformer - 1 m

■ TCL injection collimator - 1m

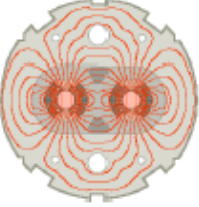
Septum (MSI), beam offset in Q5, kicker (MKI)

Beam instrumentation: beam position and current monitors, screens

TDI collimator to protect ALICE during injection steering



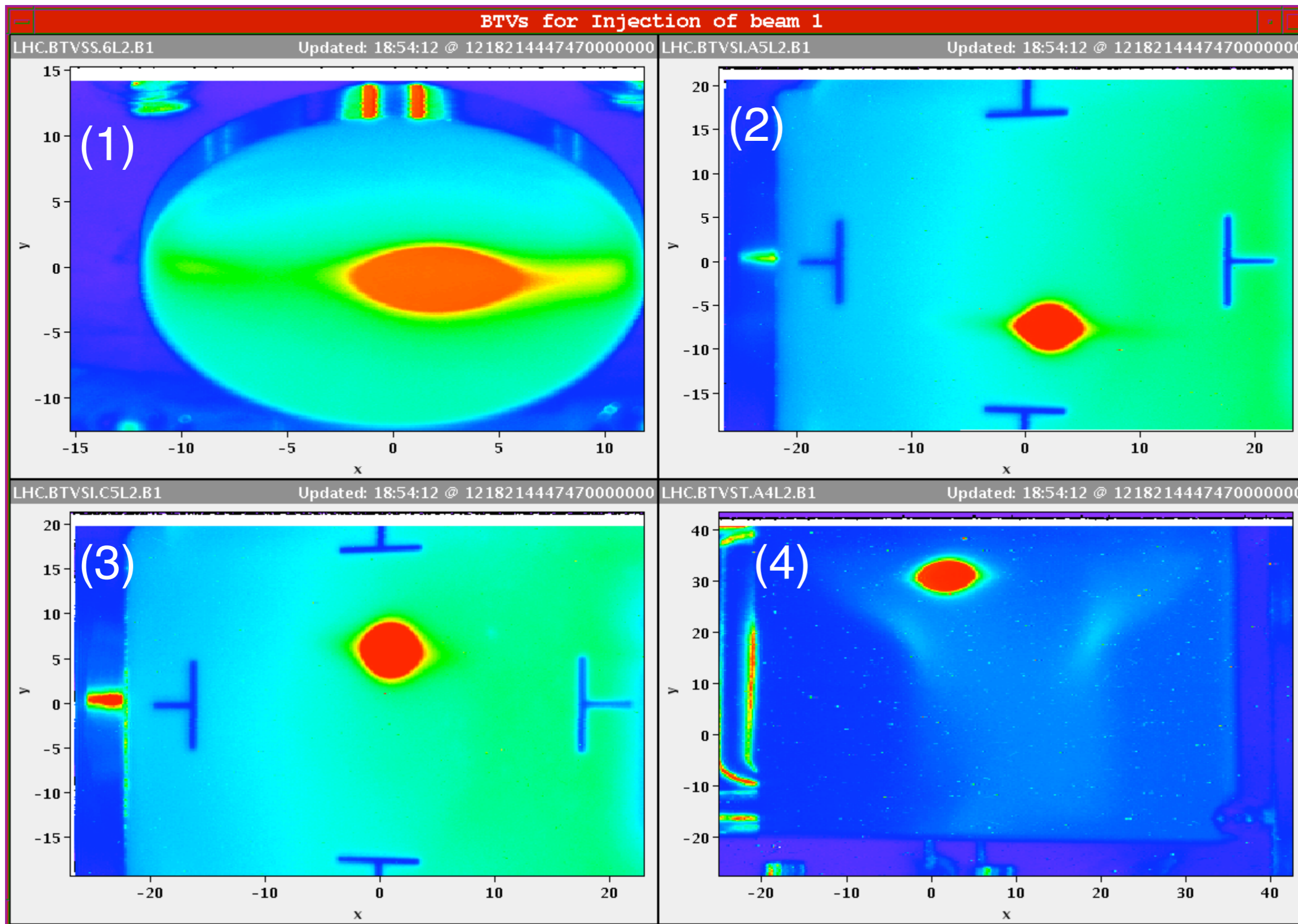
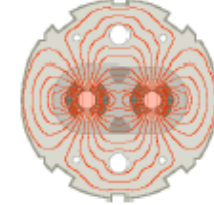
Goals of beam test



		Duration	Intensity	# shots	f Intensity	Comments
		h	p+		p+	
1	End T12, Injection Steering, commission BDI, timing	4	5E+09	100	5.0E+11	TDI in, protecting Alice
2	Trajectory acquisition commissioning, trajectory correction, threading	6	5E+09	200	1.0E+12	To IR3 collimators
3	Momentum matching (if required)	1	5E+09	50	2.5E+11	
	RECYCLE & recover	2				
4	Kick response	3	5E+09	300	1.5E+12	Data used for , coupling, BPM polarity checks, corrector polarity checks
5	Injection region aperture	3	5E+09	300	1.5E+12	TDI in, protecting Alice
6	Screens	2	5E+09	50	2.5E+11	
7	Dispersion	1	5E+09	200	1.0E+12	Pi bumps, BLMs, BCT
8	Check BLM system		5E+09	100	5.0E+11	
9	Higher order polarity checks	3	5E+09	150	7.5E+11	
10	Aperture - oscillations	4	5E+09	300	1.5E+12	
11	Aperture - sliding bumps where required	6	5E+09	150	7.5E+11	
12	Momentum aperture	2	5E+09	100	5.0E+11	
13	Effects of magnetic cycle, variations during decay, reproducibility	6	5E+09	100	5.0E+11	Reserve
	TOTAL	43		2100	9.0E+12	On to TCP
	DAYS	2			5.0E+11	On to TDI

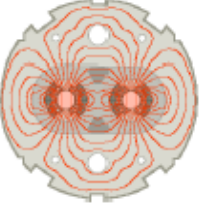
M. Lamont: <http://lhc-injection-test.web.cern.ch/lhc%2Dinjection%2Dtest/>

Beam on the injection region screens





Beam on screen at IR3 (first shot!)



BTV - LHC.USER.ALL

File Tools

Aug 08 21:38:46 LHC - LHC LHC - 01

Selection

Device: LHC.BTVM.6L4.B1
LHC.BTVM.6L4.B2
LHC.BTVM.7L3.B1
LHC.BTVM.7L3.B2
LHC.BTVSE.A4L6.B1
LHC.BTVSE.A4R6.B2
LHC.BTVSL.A7R7.B2

Status

Device: LHC.BTVM.7L3.B1
Status: **OK**
Mode: ON
Control: REMOTE

Setting

Basic Advanced Expert

First Lamp: 200 mV
Second Lamp: 200 mV
Motor Enable: enable
Hardware Reading:

LHC.BTVM.7L3.B1/Image

(1 of 1 acquisitions) Cycle: LHC SC Nb: 0

Image

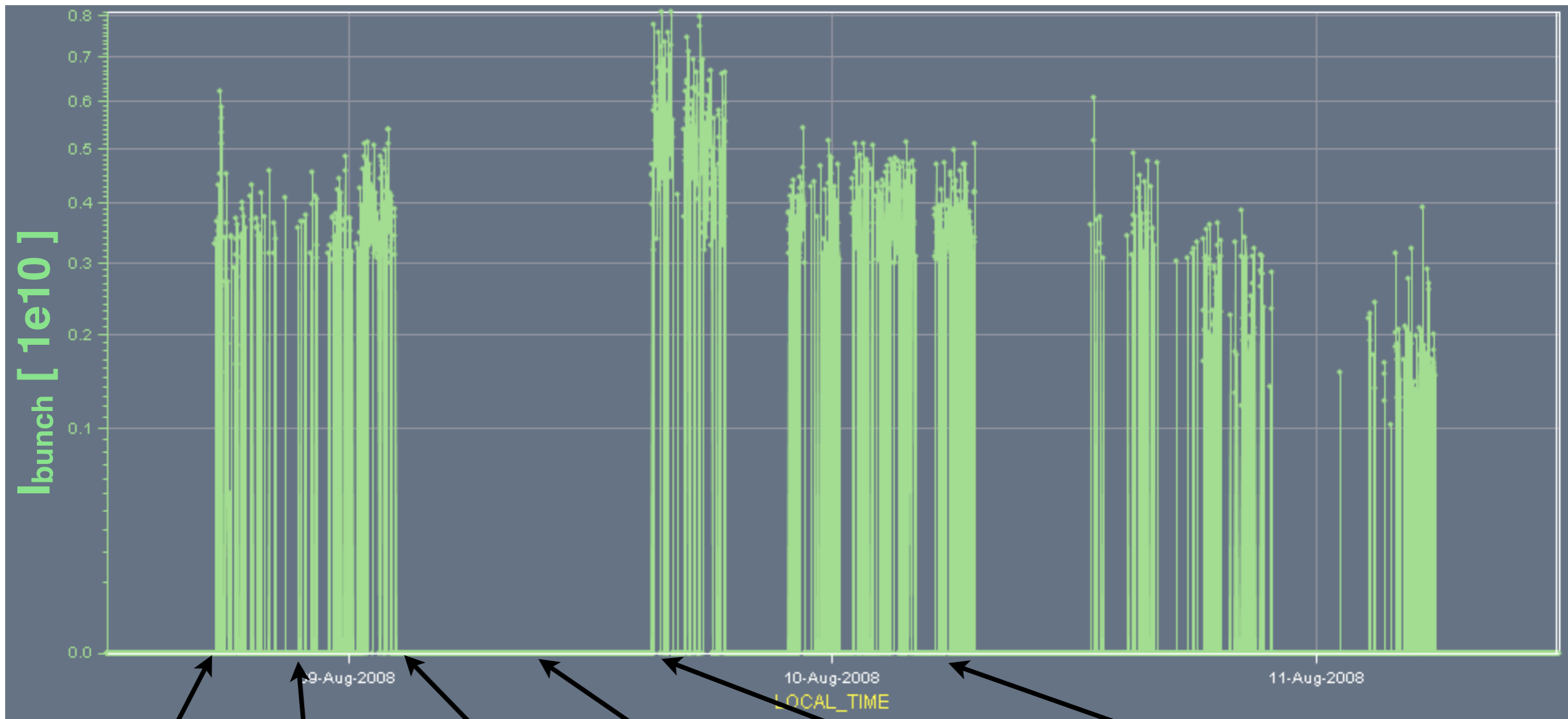
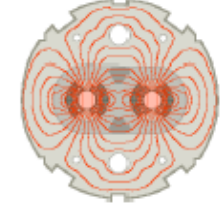
Y [mm] X [mm]

Acquisition Type: One Acquisition Camera Switch: RAD ON Screen: All
Acquisition Number: 1 Mire: OFF Filter: Out

Acquire Start Monitoring Stop Save Continuous Saving /user/pcrops/data/LHChwc/Logging/SDDS

21:37:53 - Done.

Extracted beams (9th to 11th Aug.)



**First shot
on TDI**

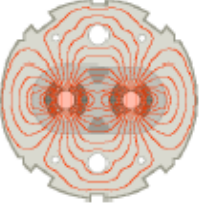
**First beam
through an
LHC arc**

**First beam-
induced
quench**

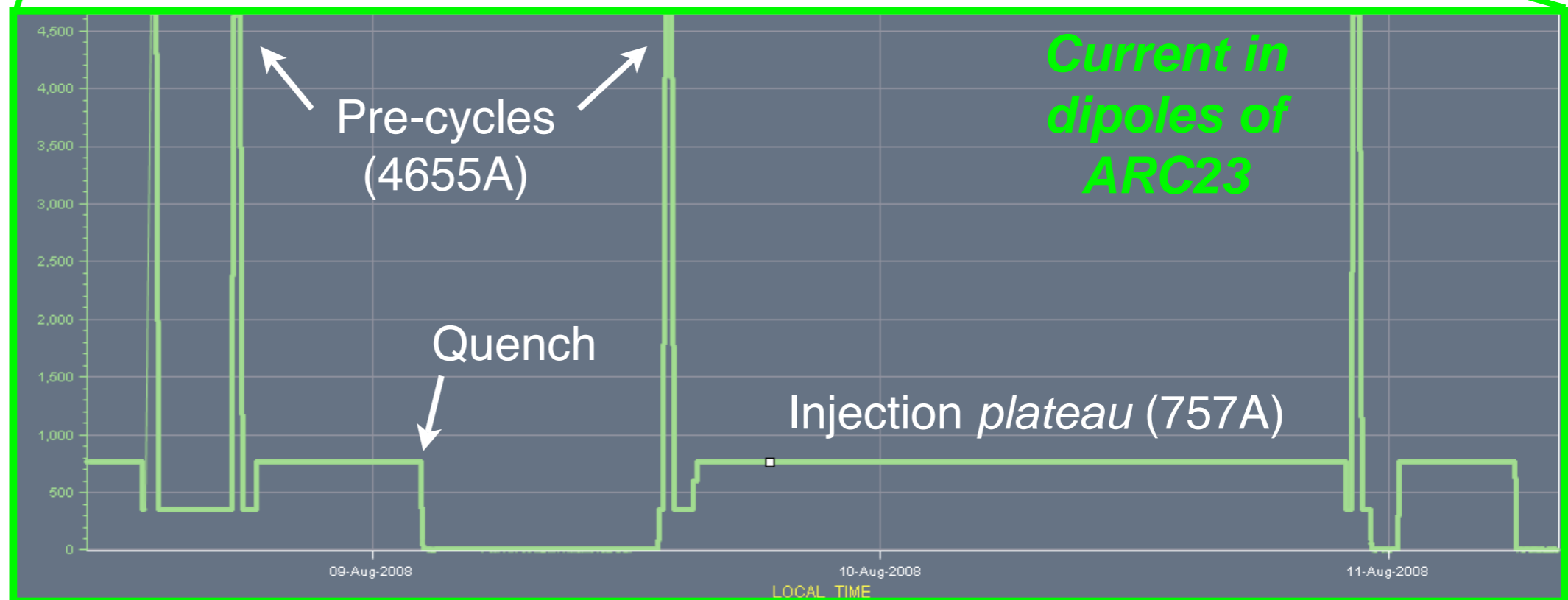
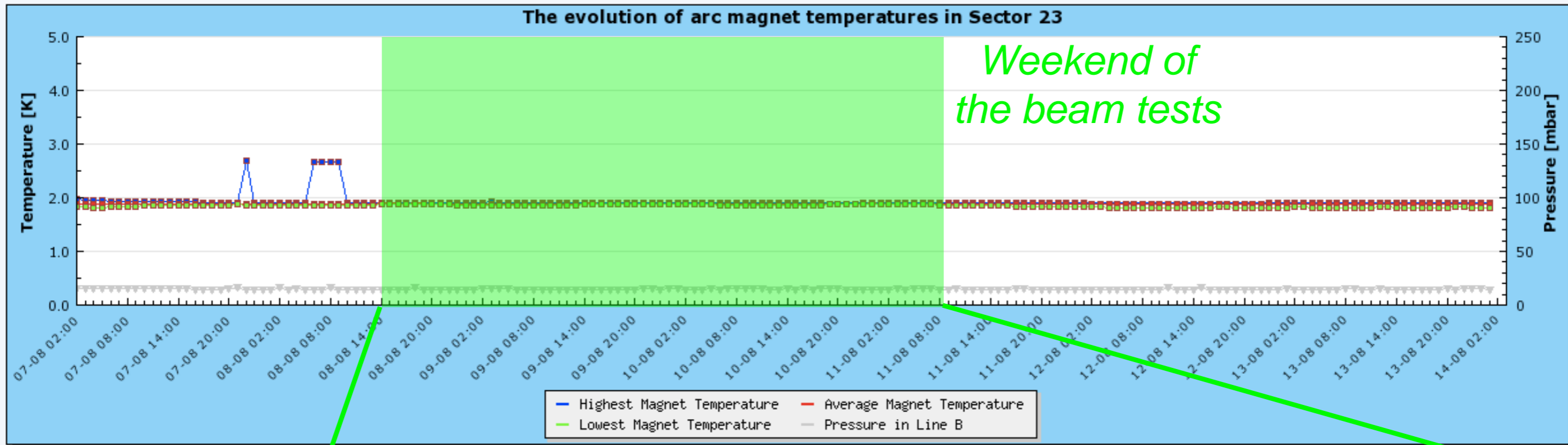
**First access
during beam
operation**

**First recovery
after pre-cycle**

**First arc
aperture
scans**



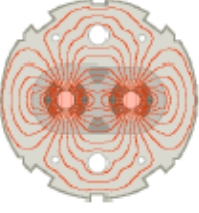
Cryo main page - Sector 23



Also sector 56 kept at E_{inj} throughout the weekend (connected to energy tracking system)

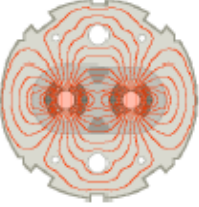


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First trajectory (after a few corrections)

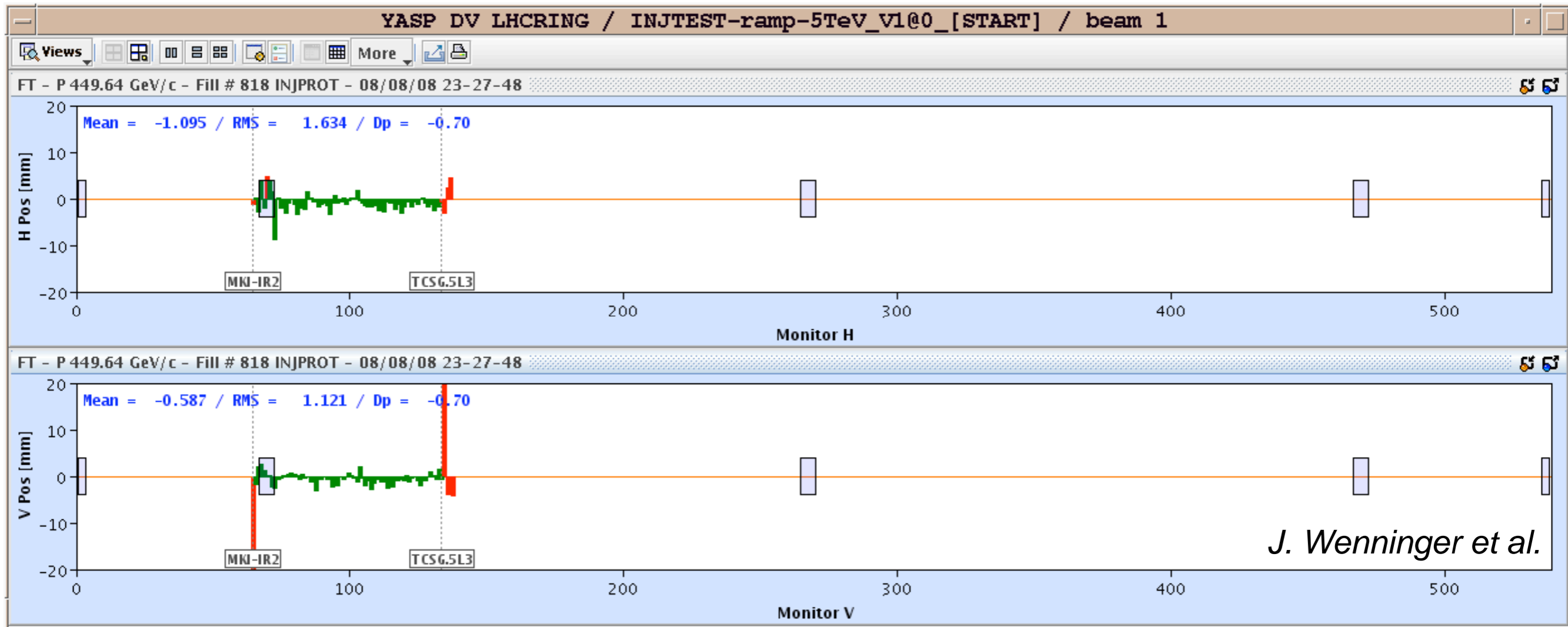
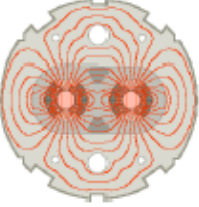


J. Wenninger et al.

Beam position monitors (BPM s) triggered at the first passage (asynchronous acq.)

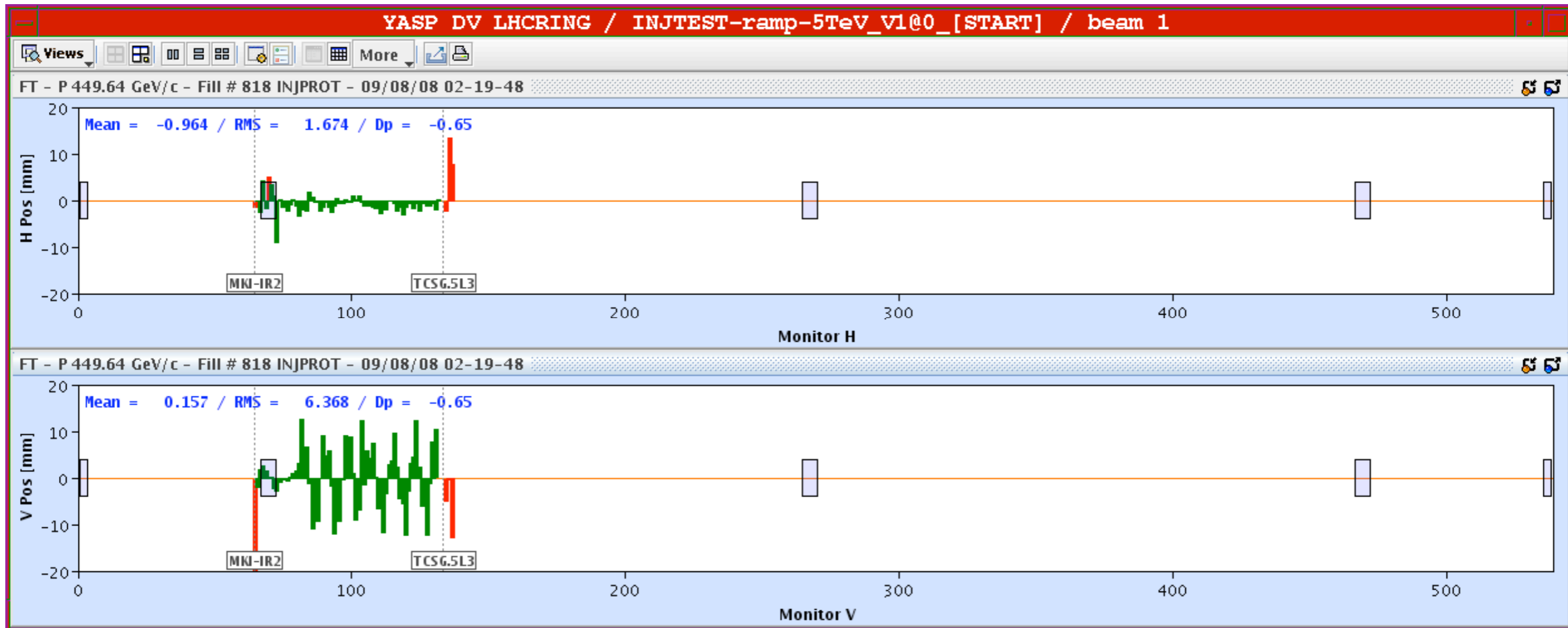
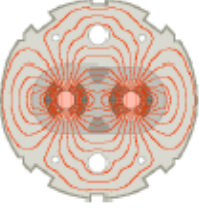
Orbit correction to ± 10 mm in both planes within a few shots!

First optimized trajectory



Peak-to-peak: ± 3 mm (LHC design specs: ± 4 mm!)

First aperture scan...

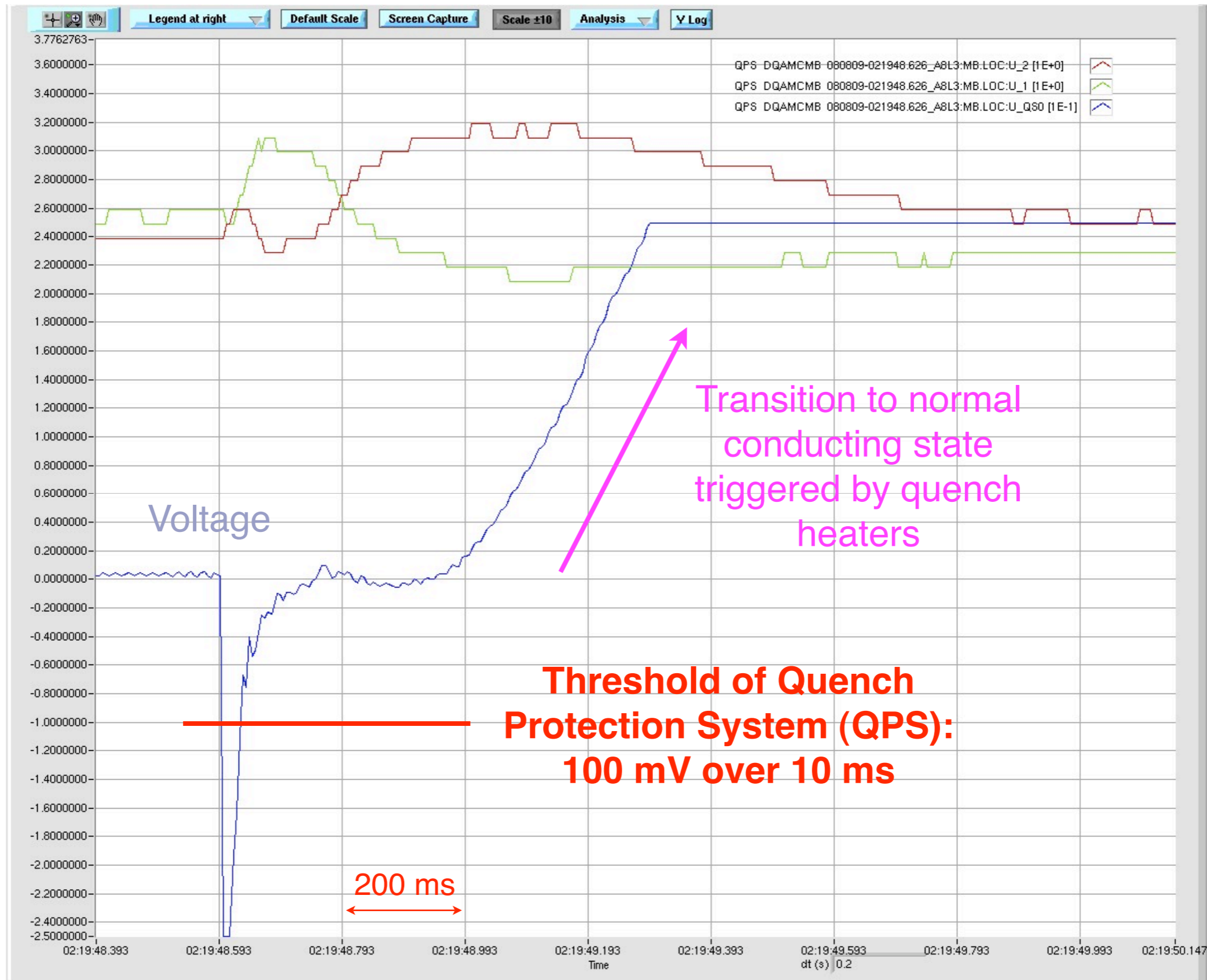
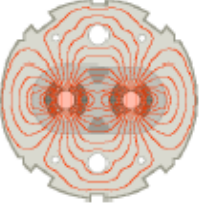


LHC Project Report 44 (1996)

"The intensity of the bunch shall therefore not be much larger than $3 \cdot 10^9$ protons."

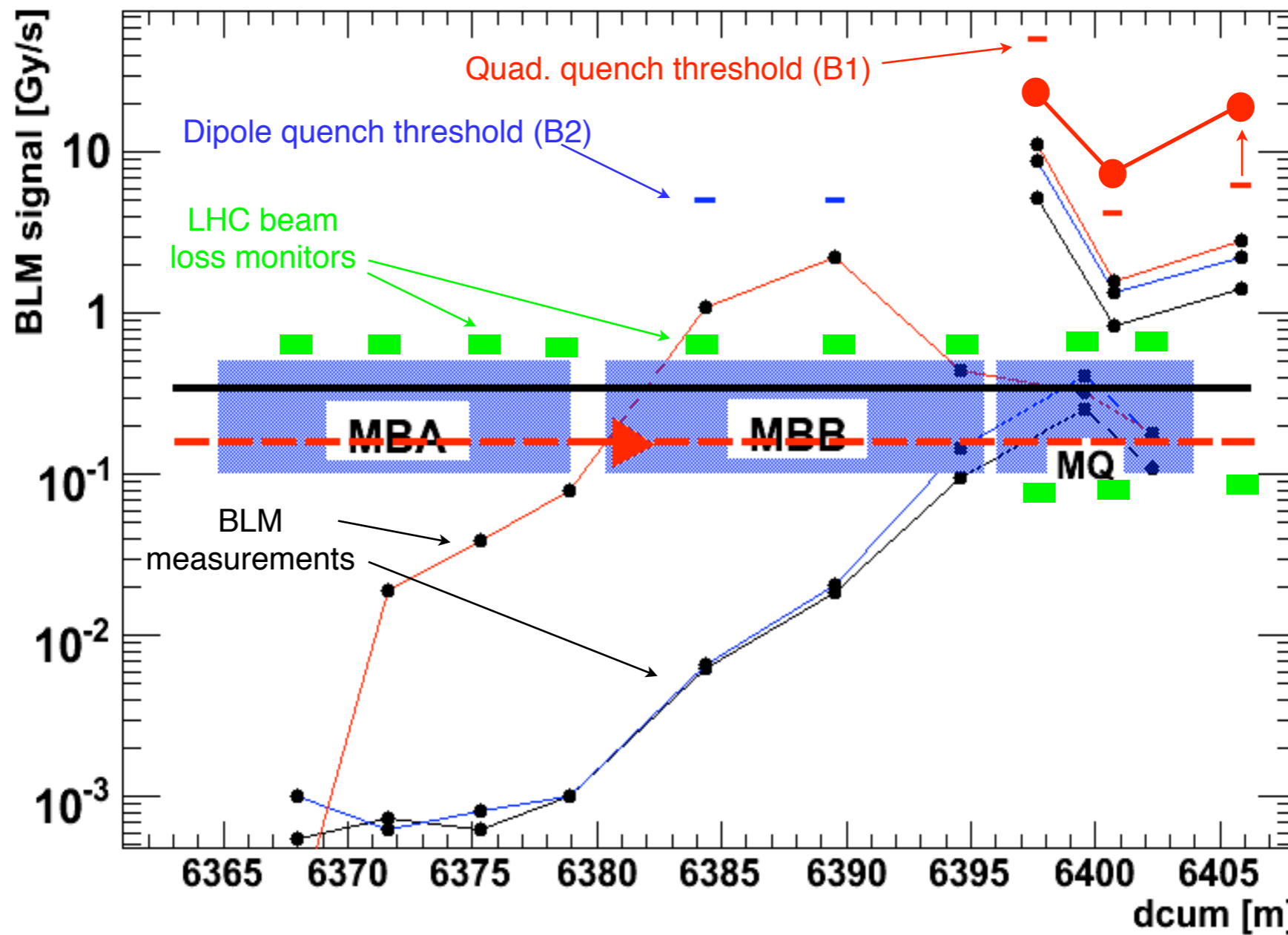
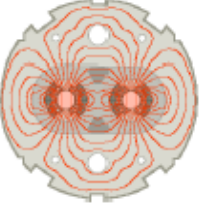
Indeed, we quenched a main dipole in the region Q8→Q7 left of IP3 with a pilot beam of less than $4 \cdot 10^9$ p!!

... and first beam-induced quench!



Extracted from QPS post-mortem buffer

First beam loss analysis



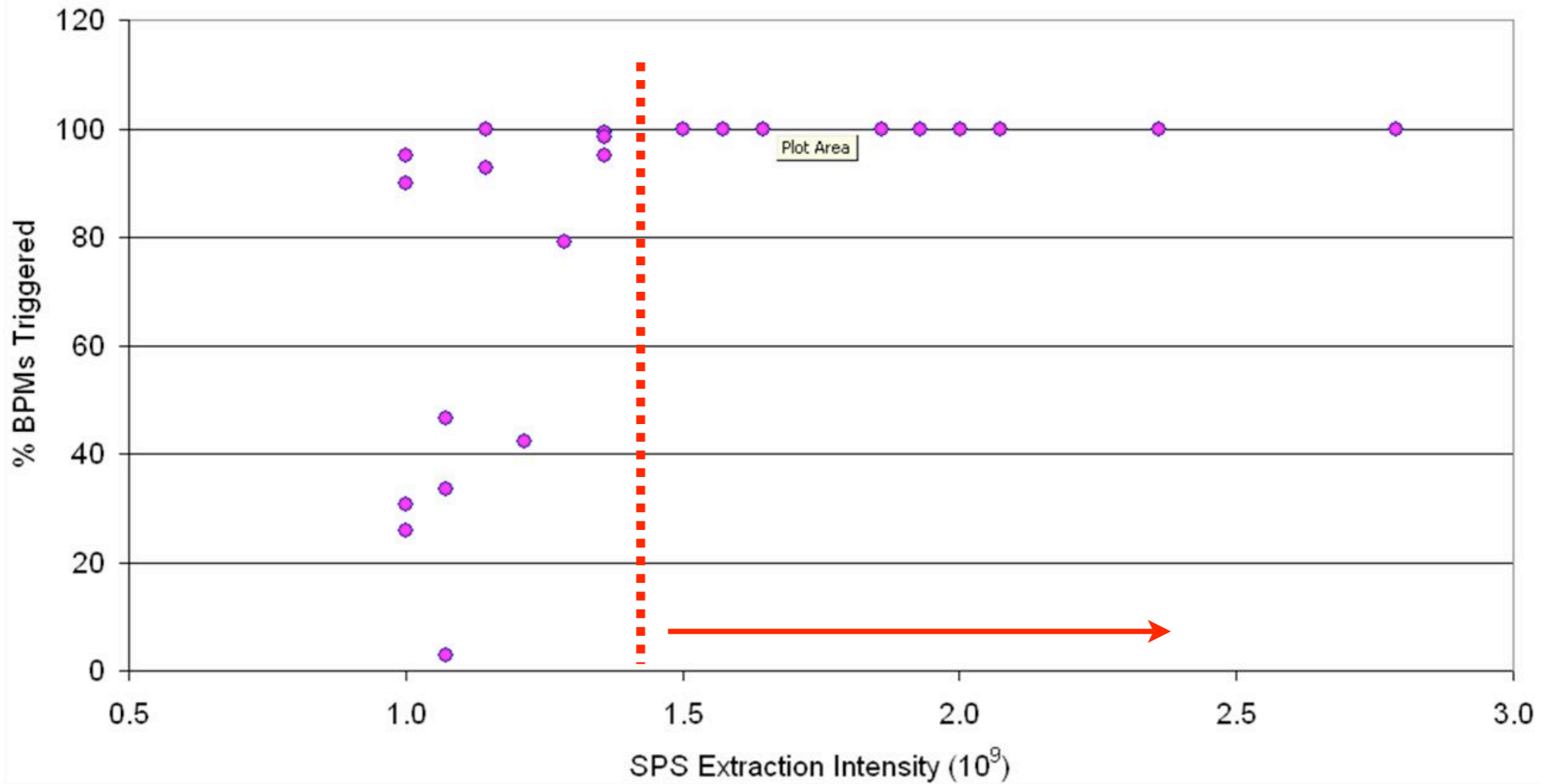
During “gentle” aperture scans: Up to a factor 4 higher than calculated limit, but did not quench!

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**Room for improvement/fine tuning on the definition of quench thresholds!
Comprehensive collection of data!**

First solution

Intensity Threshold for LHC BPM System

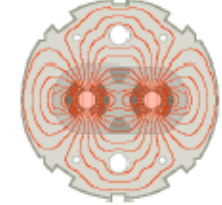


Baseline: pilot “probe” beams of $\sim 5 \times 10^9$ protons to trigger asynchronous BPM acquisitions (no fine timing)

By reducing the injected beam intensity, we established that **the BPMs can trigger also at $< 2 \times 10^9$ protons!** More margin during commissioning phases!

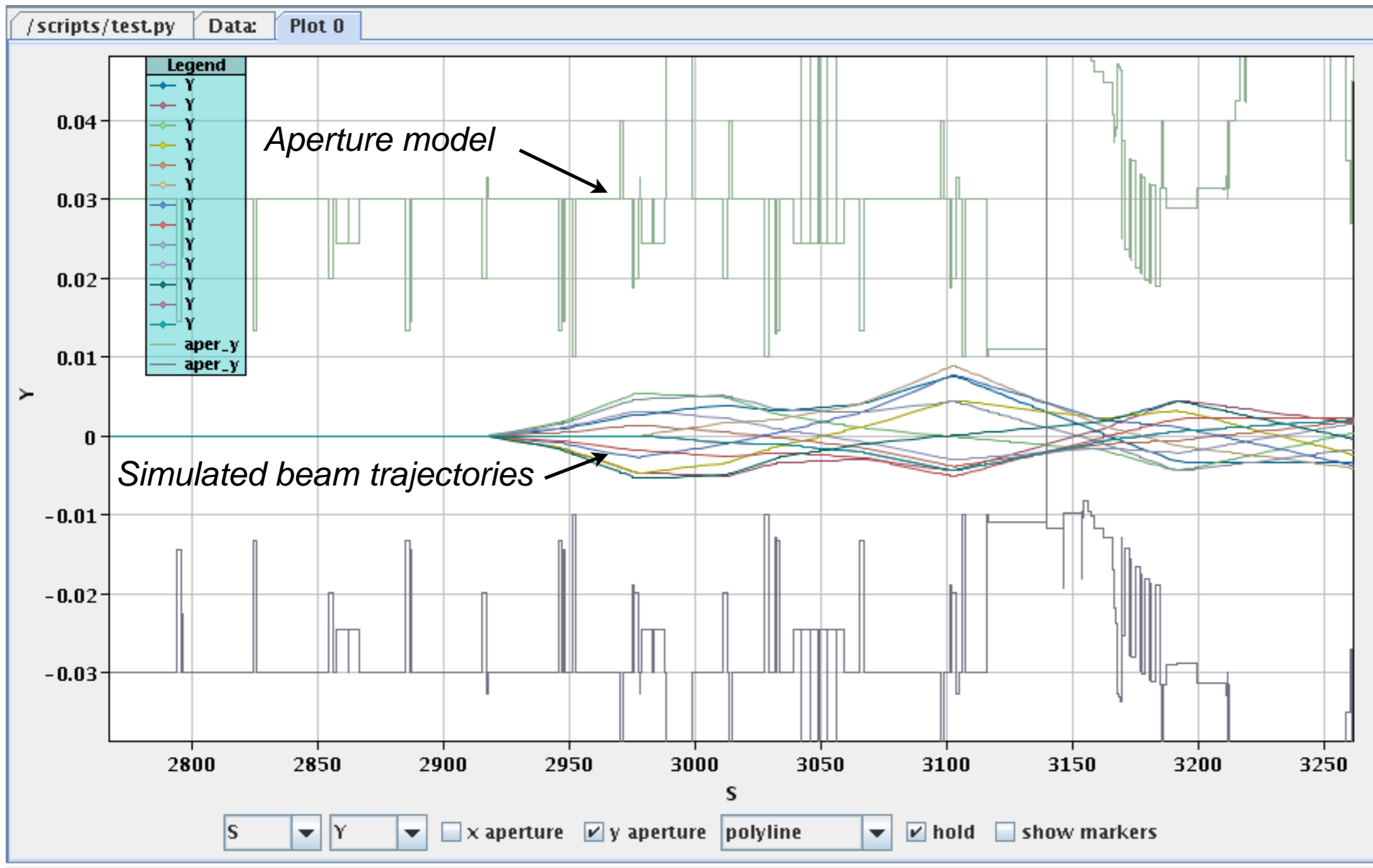
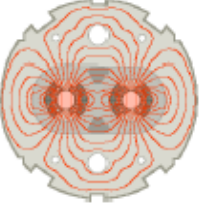


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Injection aperture scans

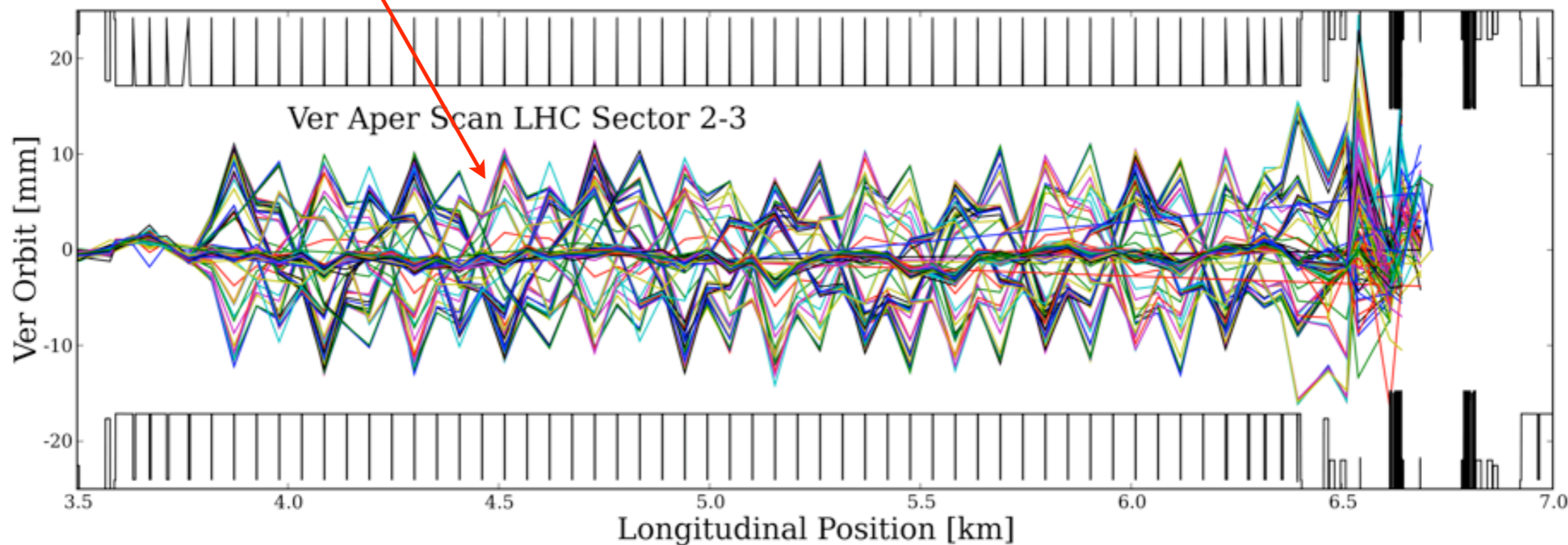
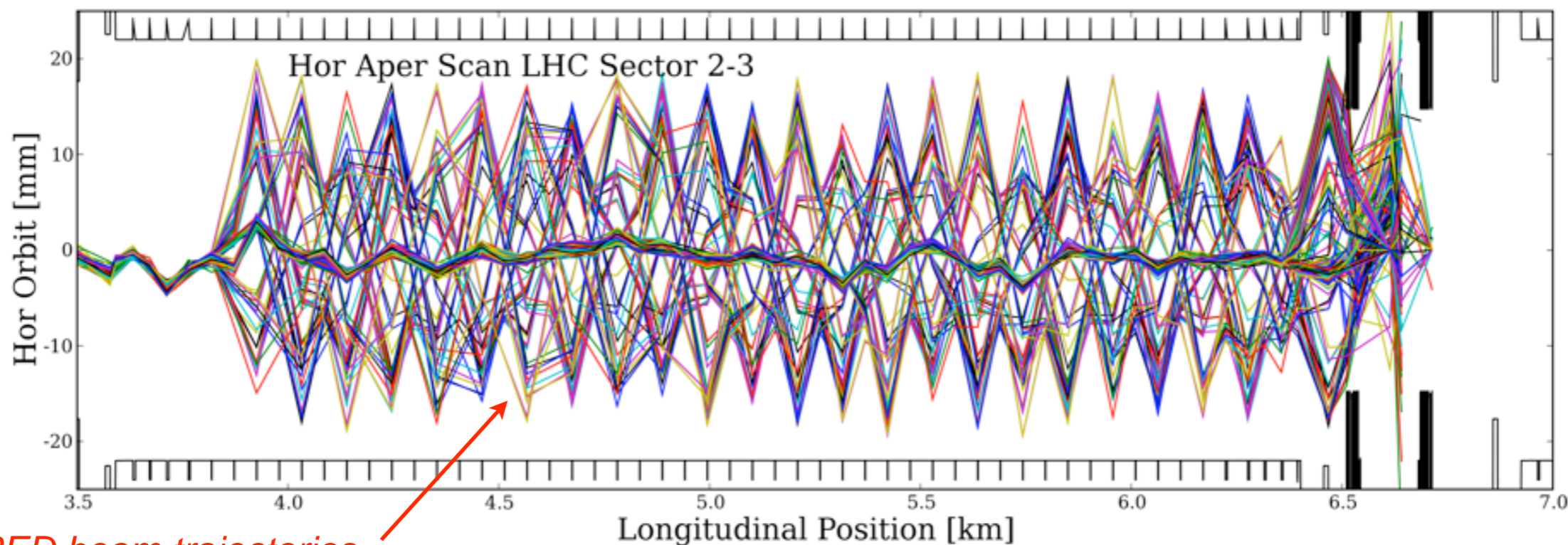
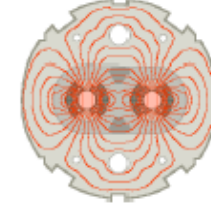


Probe the aperture in the injection region by inducing beam oscillations at the end of TI2.

*B. Goddard,
I. Agapov et al.*

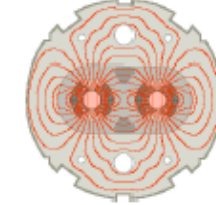
Bottleneck in injection region found, now fixed!

Arc aperture measurements

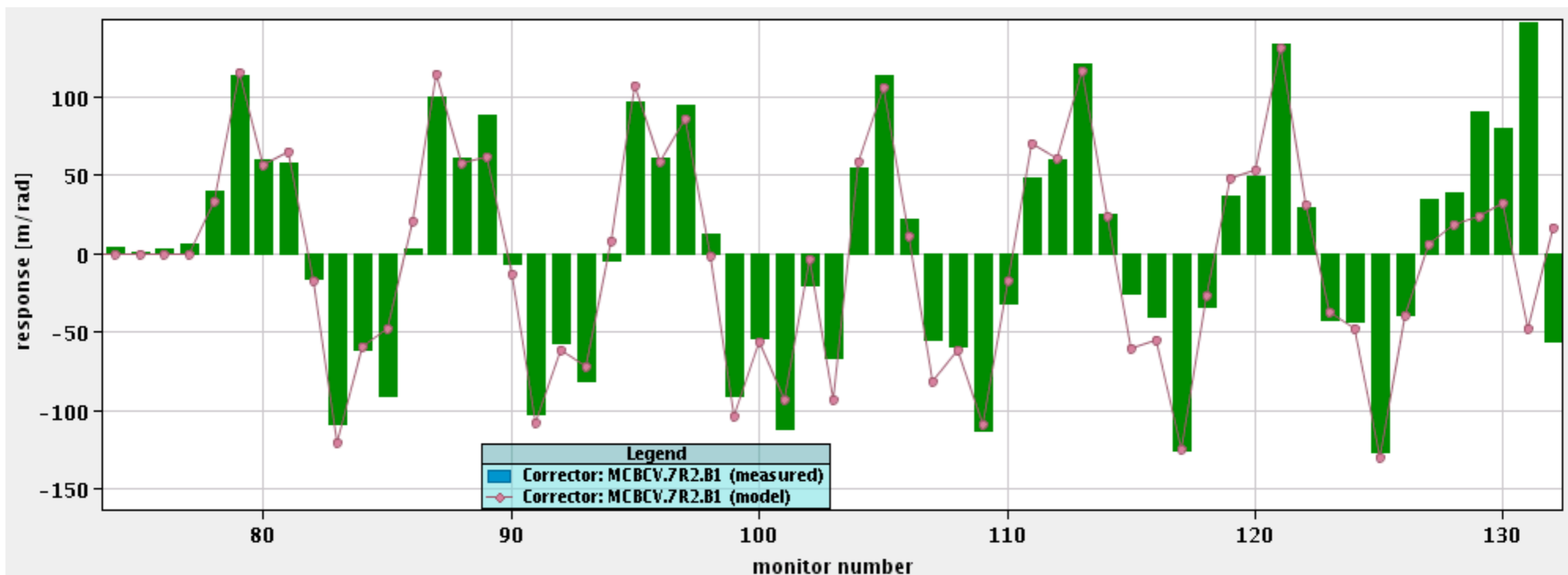


Horizontal arc aperture of 18-20 mm!!

Vertical limitation at Q8/Q7-L3 of about 10 mm.

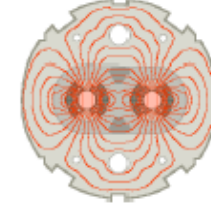


IP2 \longrightarrow ARC-23 \longrightarrow IP3



J. Wenninger, K. Fuchsberger

- Matrix response measurements** by using ~50% of the correctors
- Check BPM/corrector polarities (only 1 wrong BPM found)
- BLM calibrations: good within 15-20%
- Compare with design optics model
- Slight mis-match found close to IP3-left, under investigation



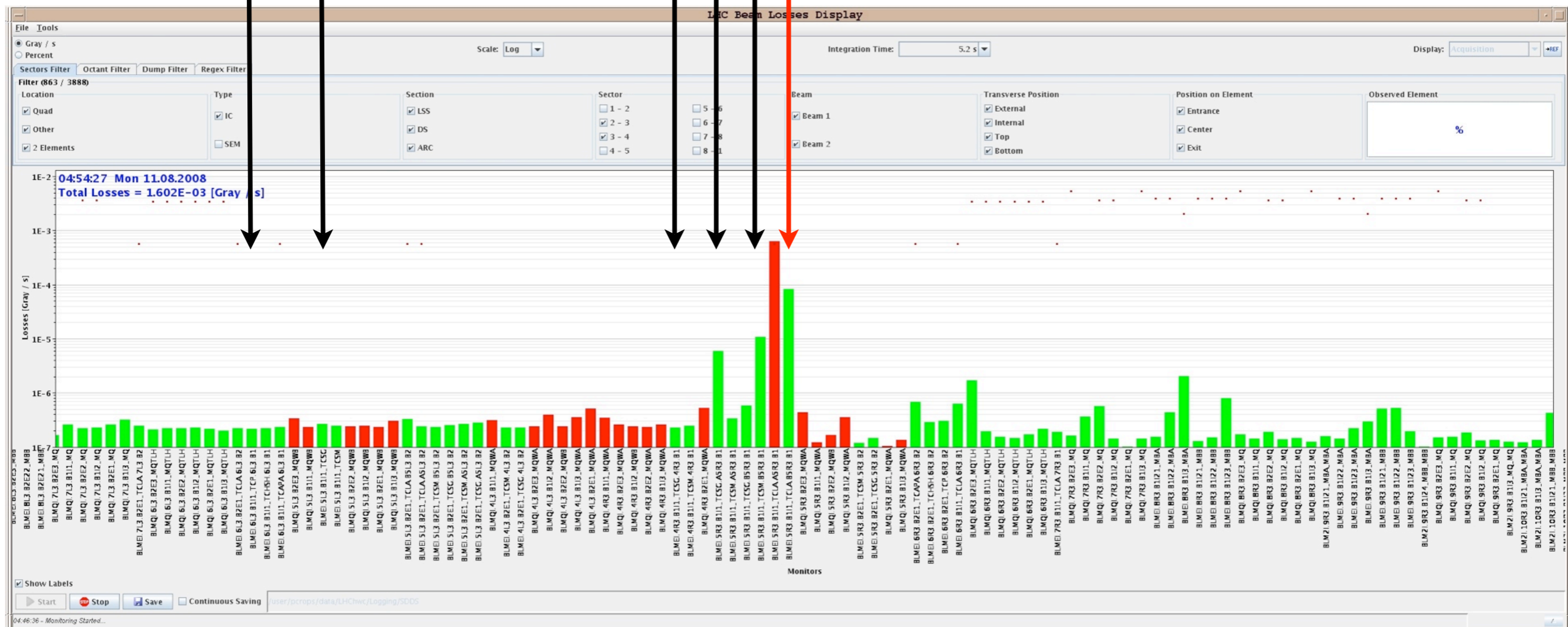
TCP.6L3 TCSG.5L3

TCSG.4R3

A5R3

B5R3

TCLA's



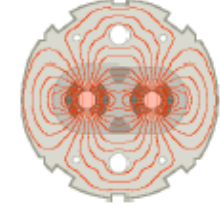
20 LHC collimators on the beam path (7 in TI2 + 4 in IP2 + 9 in IP3)

First BLM response measurements in IR3

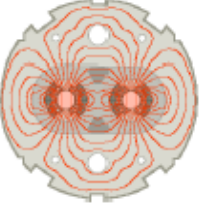
Carbon (TCP/TCSG's) vs Tungsten (TCLA's) response



Conclusions



- ☑ Access system looks good
- ☑ Very good condition during the weekend
 - CRYO, QPS, PIC, BIS, power converters*
- ☑ Aperture looks very good
 - No significant limitations found in the arc 23*
 - Bottle neck in injection region now fixed*
 - No time to measure the insertions*
- ☑ Optics looks good
 - Small phase advance error in arc*
 - Something suspicious left of 3.*
- ☑ Instrumentation looks very good
 - BPMs in asynchronous mode*
 - BLMs up and running from first shot*
 - Screens etc*
- ☑ Magnet model looks good
- ☑ Controls/Databases looks good (some features...)
- ☑ Beam transfer, RF synchronization looks good



Results of first beam tests are very encouraging...

...but there is still a long way to go!

Next challenge in one week!

A journey of a thousand miles begins with a single step!

*Lao-tzu, The Way of Lao-tzu
Chinese philosopher (604 BC - 531 BC)*

