

# LHC Status and Upgrade Scenario

Lyn Evans



Fall HEPAP meeting, Washington 14<sup>th</sup> November 2008



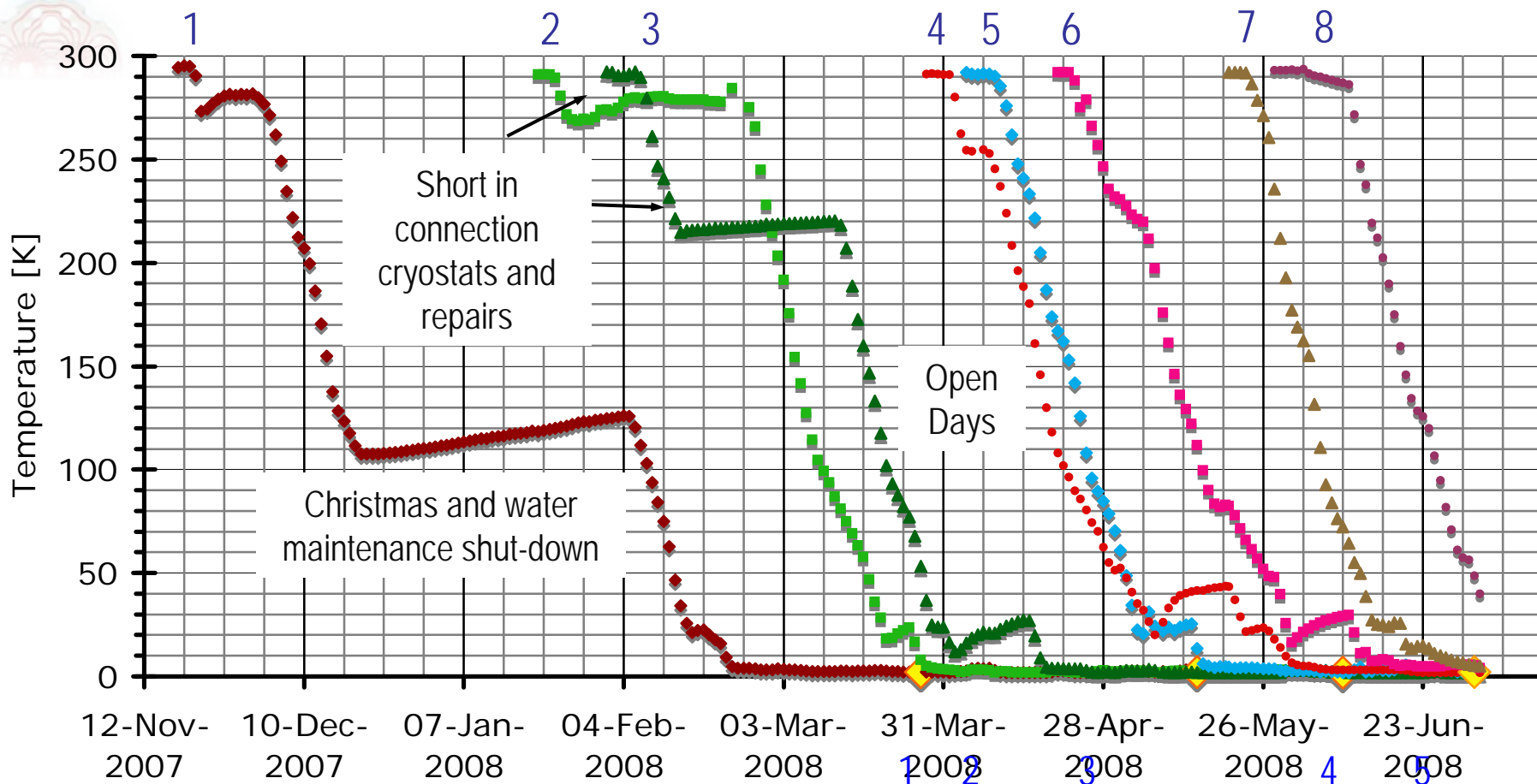


# Cooldown of sectors



- From RT to 80K precooling with LN2. 1200 tons of LN2 (64 trucks of 20 tons). Three weeks for the first sector.
- From 80K to 4.5K. Cooldown with refrigerator. Three weeks for the first sector. 4700 tons of material to be cooled.
- From 4.2K to 1.9K. Cold compressors at 15 mbar. Four days for the first sector.

# Cool-down of LHC sector



- ◆ ARC56\_MAGS\_TTAVG.POSST    ■ ARC78\_MAGS\_TTAVG.POSST    ▲ ARC81\_MAGS\_TTAVG.POSST    ◆ ARC23\_MAGS\_TTAVG.POSST
- ARC67\_MAGS\_TTAVG.POSST    ■ ARC34\_MAGS\_TTAVG.POSST    ▲ ARC12\_MAGS\_TTAVG.POSST    ● ARC45\_MAGS\_TTAVG.POSST

Sectors  
 $< 2\text{ K}$   
 $+ 2 < 5\text{ K}$

Cooling sectors + Cryo tuning + Powering activities

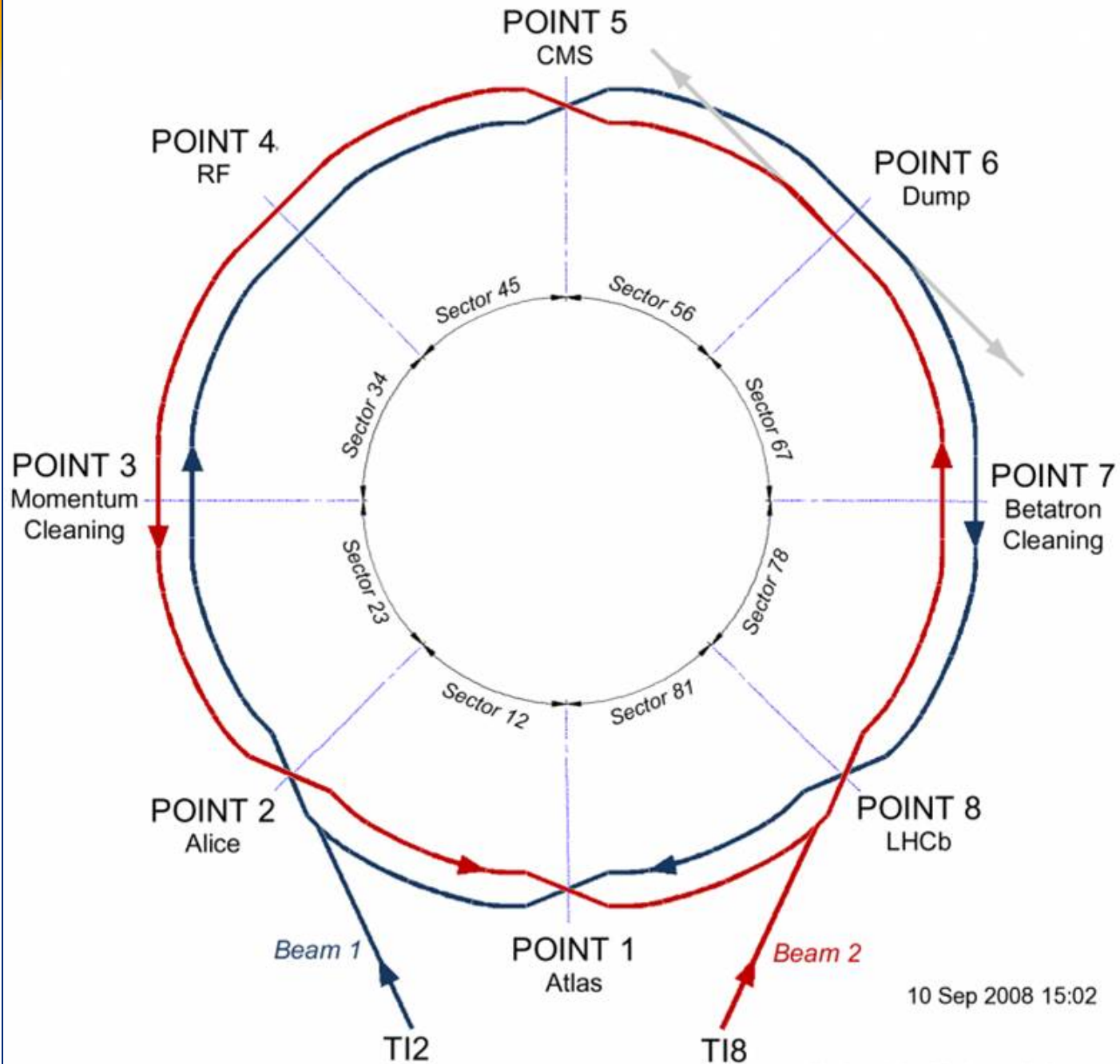


# Situation on 10th September



- 7 out of 8 sectors fully commissioned for 5 TeV operation and 1 sector (3-4) commissioned up to 4 TeV.





10 Sep 2008 15:02

Updated by Roberto Saban



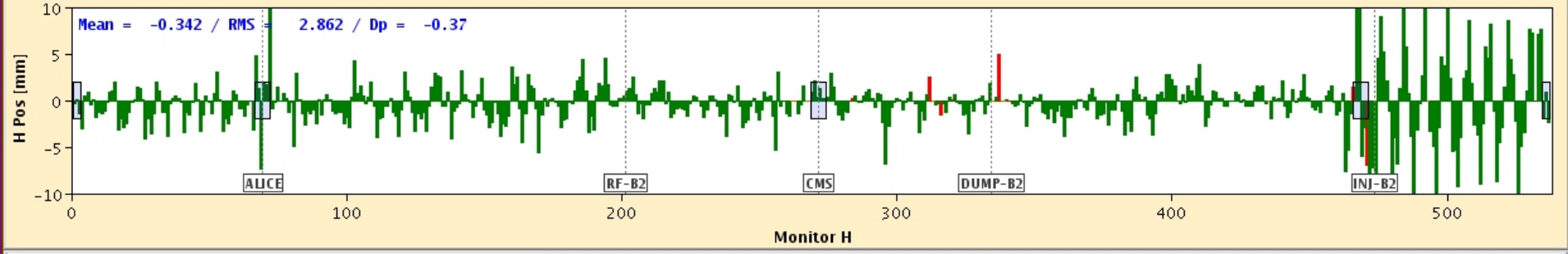
# Beam 2 first beam – D-Day



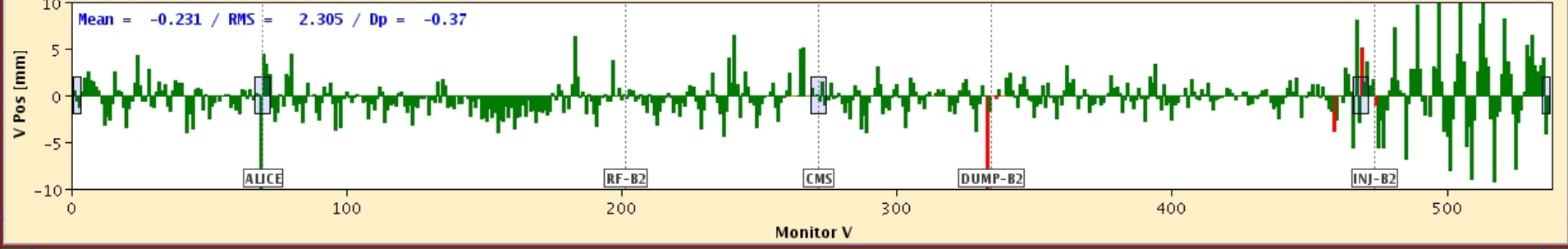
YASP DV LHCRING / INJ-TEST-NB / beam 2
YASP DV LHCRING / INJ-TEST-NB / beam 2
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YASP DV LHCRING / INJ-TEST-NB / beam 2

Views [Icons] More [Icons]

FT - P 450.12 GeV/c - Fill # 830 INJPROT - 10/09/08 15-01-58



FT - P 450.12 GeV/c - Fill # 830 INJPROT - 10/09/08 15-01-58





# Beam on turns 1 and 2



BTV - SPS.USER.LHCFAS2

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File Tools

Sep 10 10:26:13 SPS - LHCFAS2
CNGS5 - 03

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**Selection**

Device:

- LHC.BTVSLA5R8.B2
- LHC.BTVSLC5L2.B1
- LHC.BTVSLC5R8.B2
- LHC.BTVSS.6L2.B1
- LHC.BTVSS.6R8.B2
- LHC.BTVST.A4L2.B1
- LHC.BTVST.A4R8.B2
- ...

LHC.BTVSLC5L2.B1

1
(1 of 1 acquisitions)
Cycle: LHCFAS2
SC Nb: 700
Date: 2008/09/10 10:25:28.197506

Horizontal projection

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**Status**

Device: LHC.BTVSLC5L2.B1

Status: OK

Mode: OFF

Control: REMOTE

Image

Image (16.6148, -0.4876, 3196)

Vertical projection

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**Setting**

Basic | Advanced | Expert

Acquisition Type: One extraction

Acquisition Number: 1

Camera Switch: ON

Screen: AI

Filter: Out

Video Gain: x 1

Lamp Switch: ON

First Lamp: ▲▲▲ 300 mV ▼▼▼

Second Lamp: ▲▲▲ 160 mV ▼▼▼

Motor Enable: enable

Hardware Reading:

Acquisition Type: One extraction    Camera Switch: RAD ON    Screen: AI

Acquisition Number: 1    Mire: OFF    Filter: Out

Video Gain: x 1    First Lamp: 299

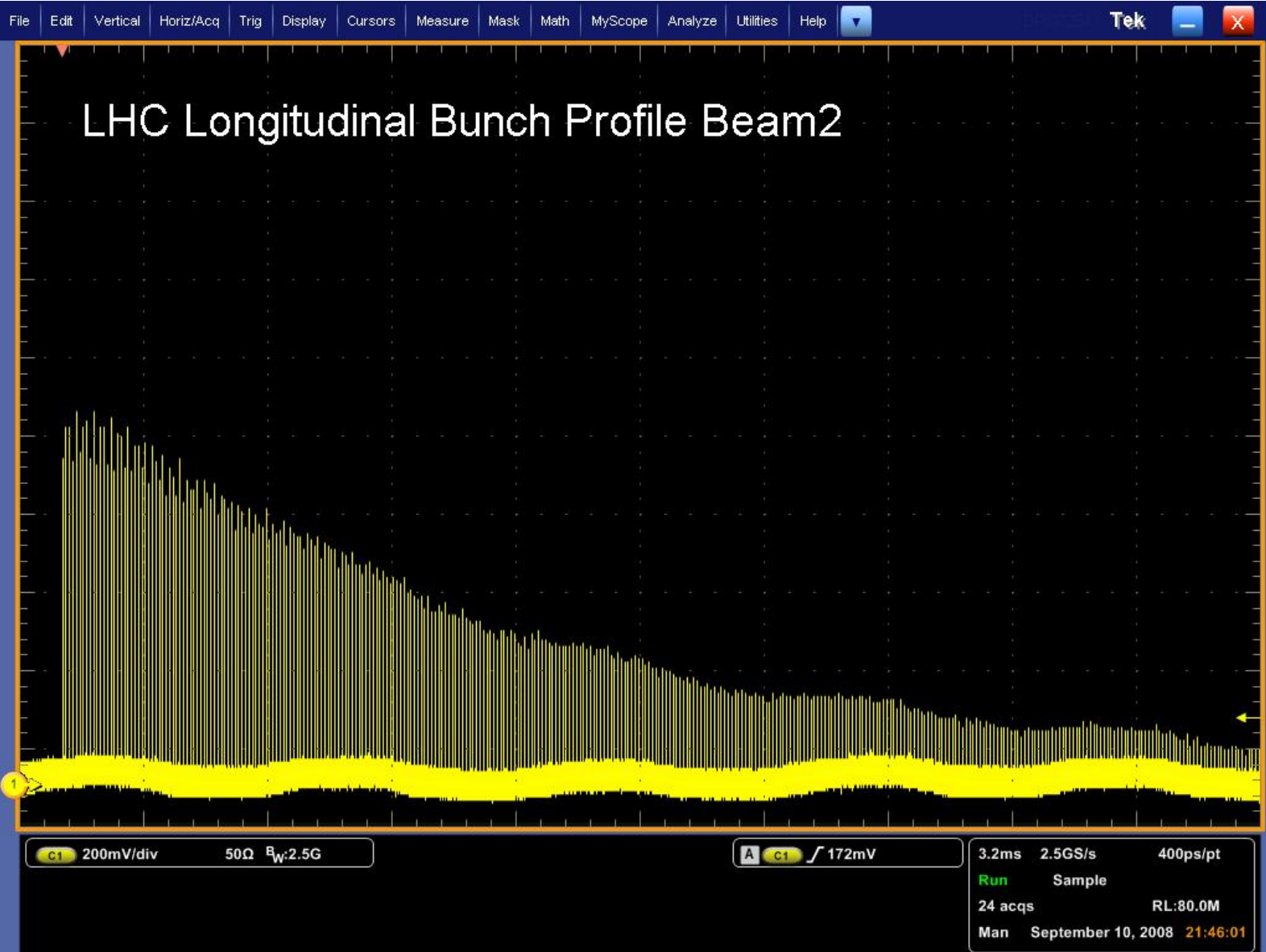
Second Lamp: 159

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

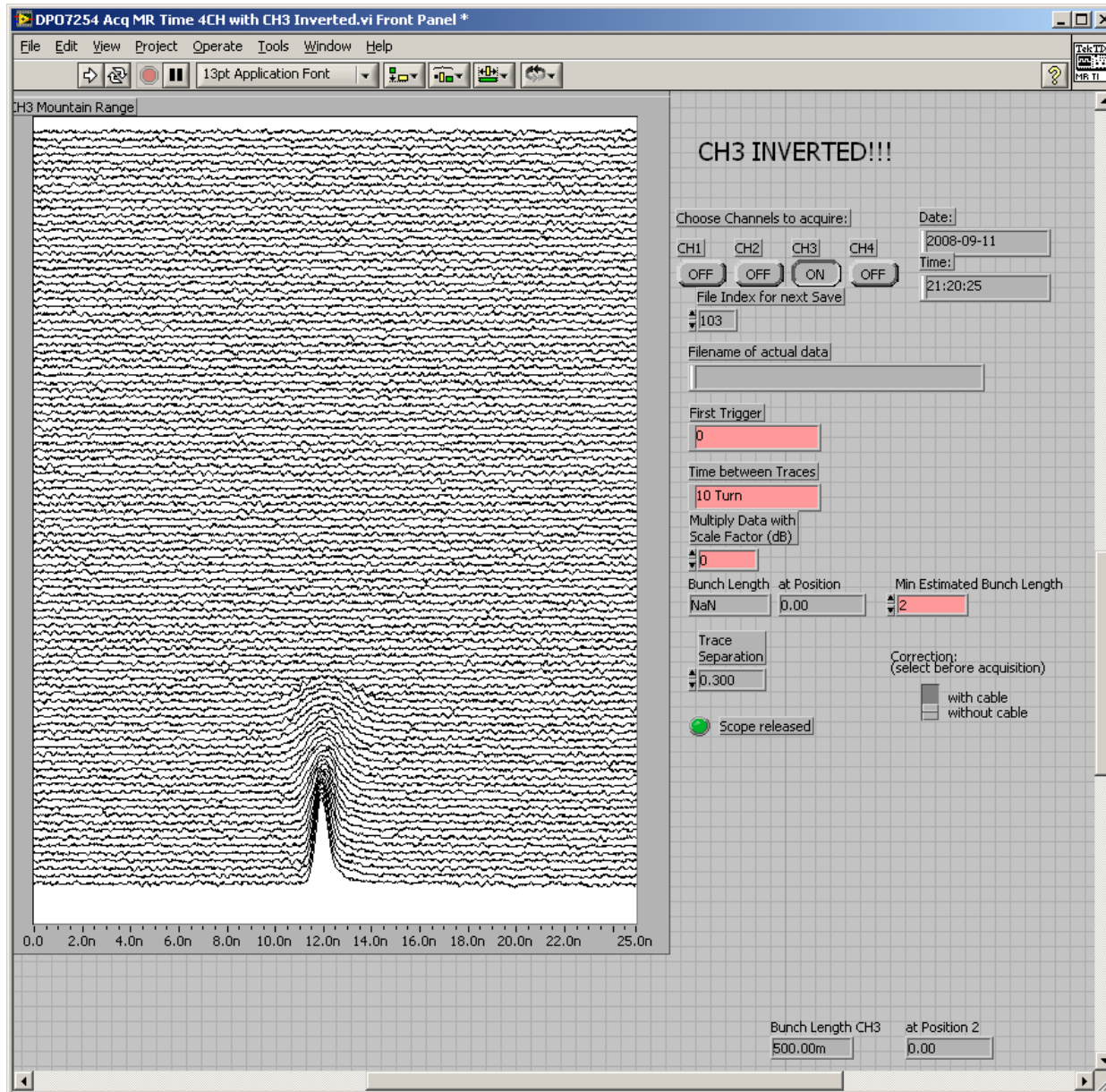
10:25:32 - Done.

# Few 100 turns

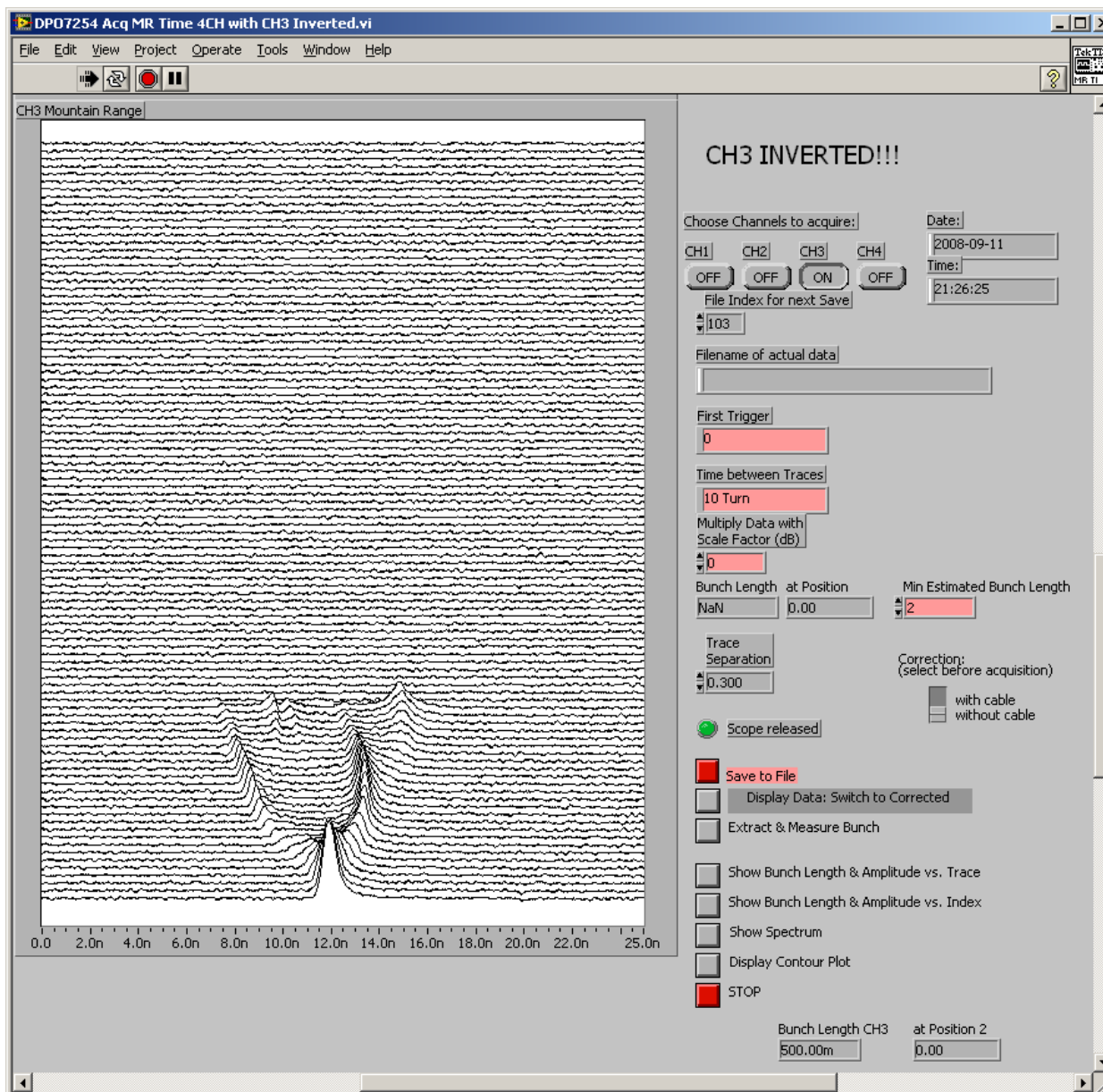




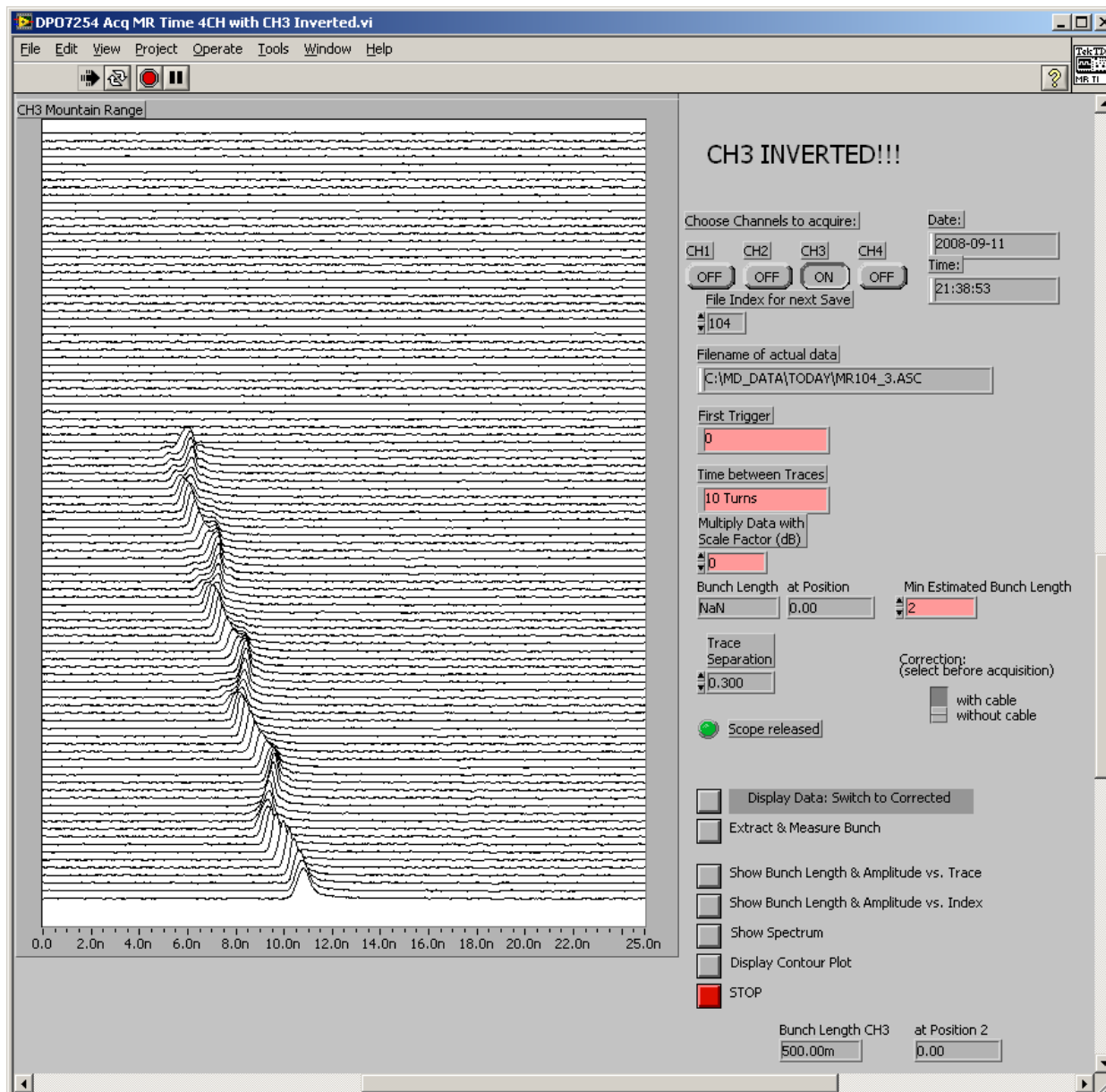
# No RF, debunching in $\sim 25 \cdot 10$ turns, i.e. roughly 25 mS



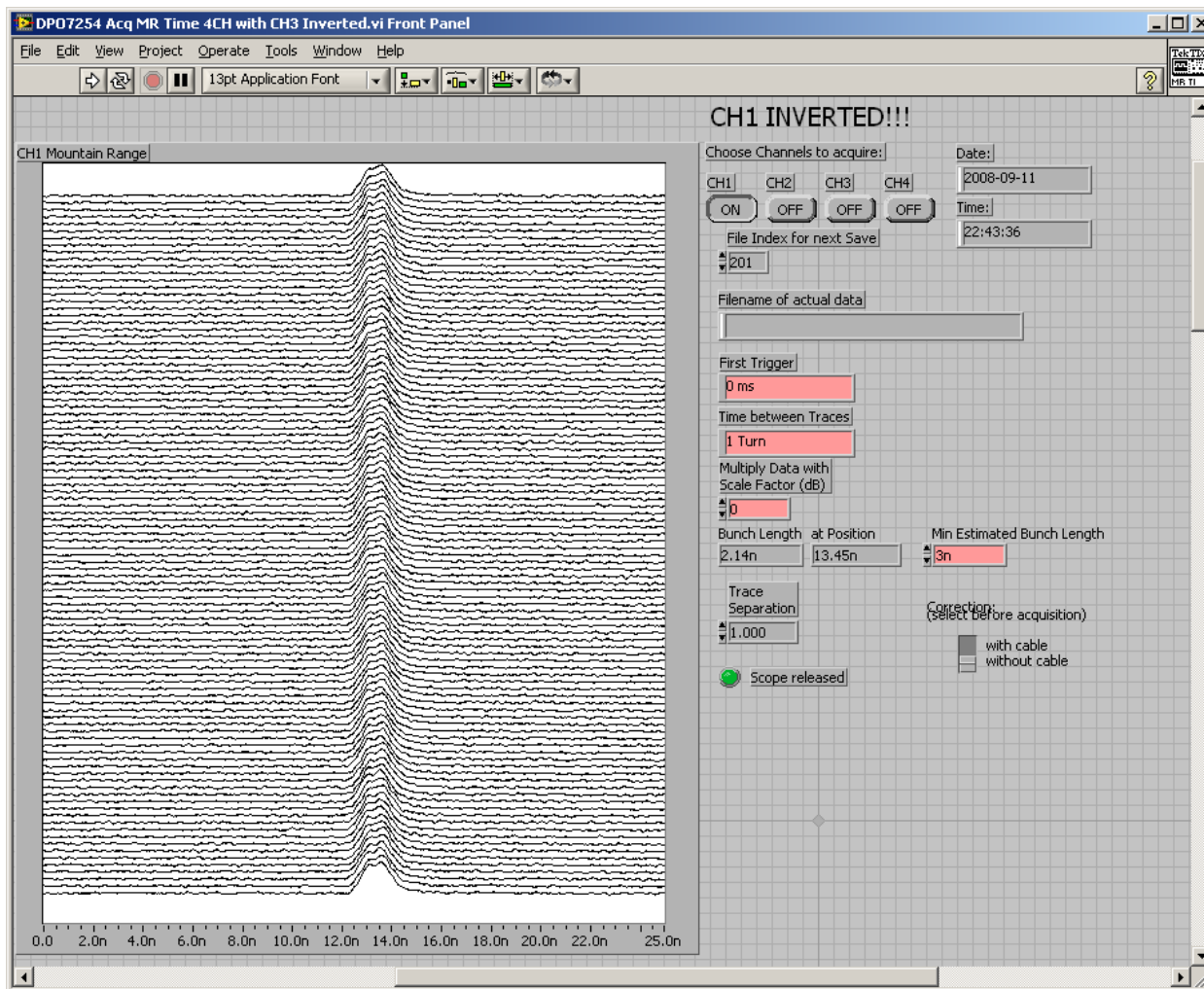
# First attempt at capture, at exactly the wrong injection phase...



# Capture with corrected injection phasing

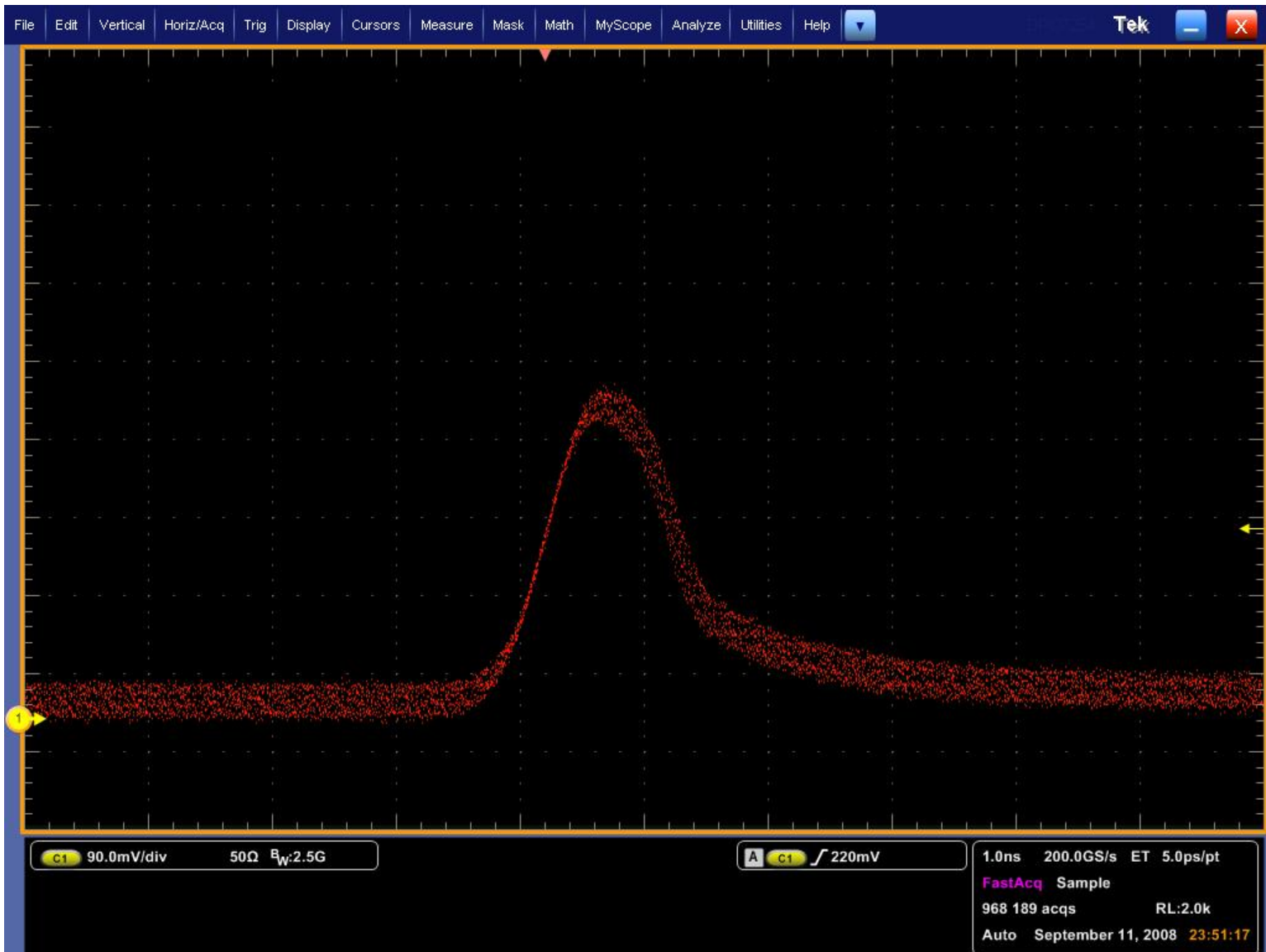


# Capture with optimum injection phasing, correct reference

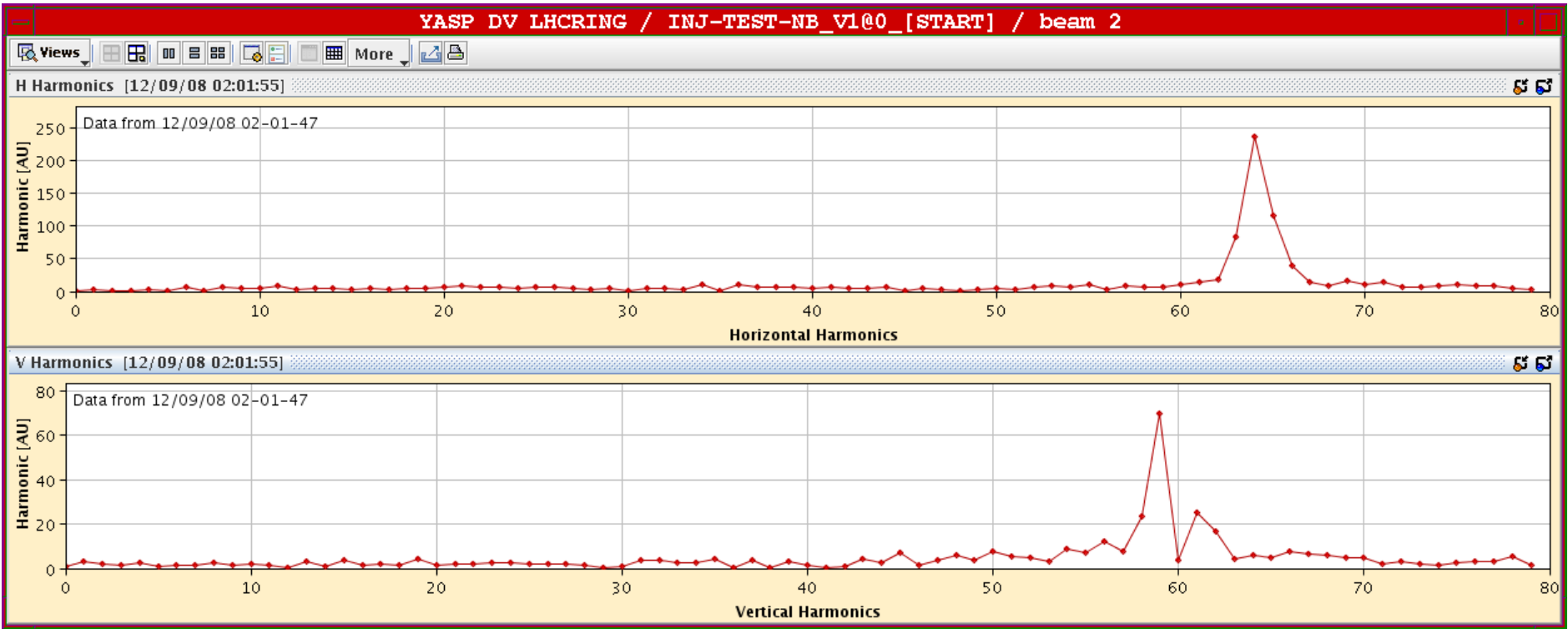




# LHC longitudinal bunch profile Beam 2



# Integer tunes



# Tune measurements



Tune Viewer - LHC - On-demand FFT system B2

File Run Configure Help

RBAC User: LHC LHC.BQBBQ.UA47.FFT2\_B2 LHC.BQPLL.UA43.PLL\_B2 LHC.OFSU

Info FFT PLL Data Sets Feedback

**Q-FPGA** Tune Measurements CERN

LHC - B2 - Fill#830  
2008-09-10 21:38:52  
RAW&FFT: 256 turns@1.0Hz  
no excitation

Q1 = .3092	Qx = .3089
Q2 = .2333	Qy = .2337
C-  = .0106	
Q'x = ???	
Q'y = ???	

Comments:  
no comment

Spawn TuneViewer Display

Graph Mag H ACQ# 0 Scale

LHC - B2 - fill #830 - no comment - LHC.BQBBQ.UA47.FFT2\_B2 - 2008-09-10 2...

horizontal amplitude [dB]

frequency [frev]

Graph RAW V ACQ# 0 Scale

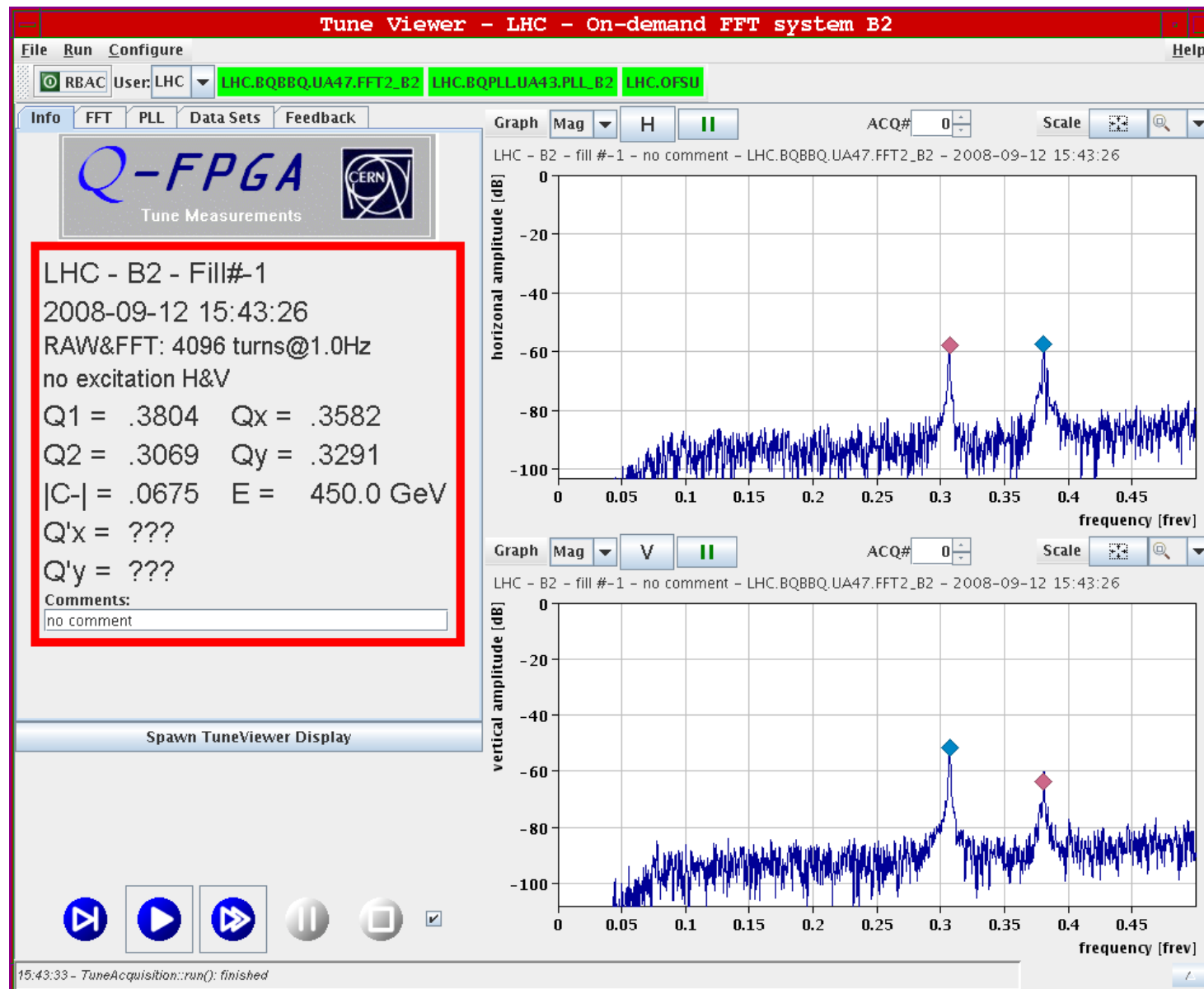
LHC - B2 - fill #830 - no comment - LHC.BQBBQ.UA47.FFT2\_B2 - 2008-09-10 2...

vertical amplitude [a.u.]

turn

21:38:57 - <4> Start multiple monitoring on user LHC

# Fractional tune spectrum H & V (Beam2) – closest Q approach ~ 0.06 due to coupling

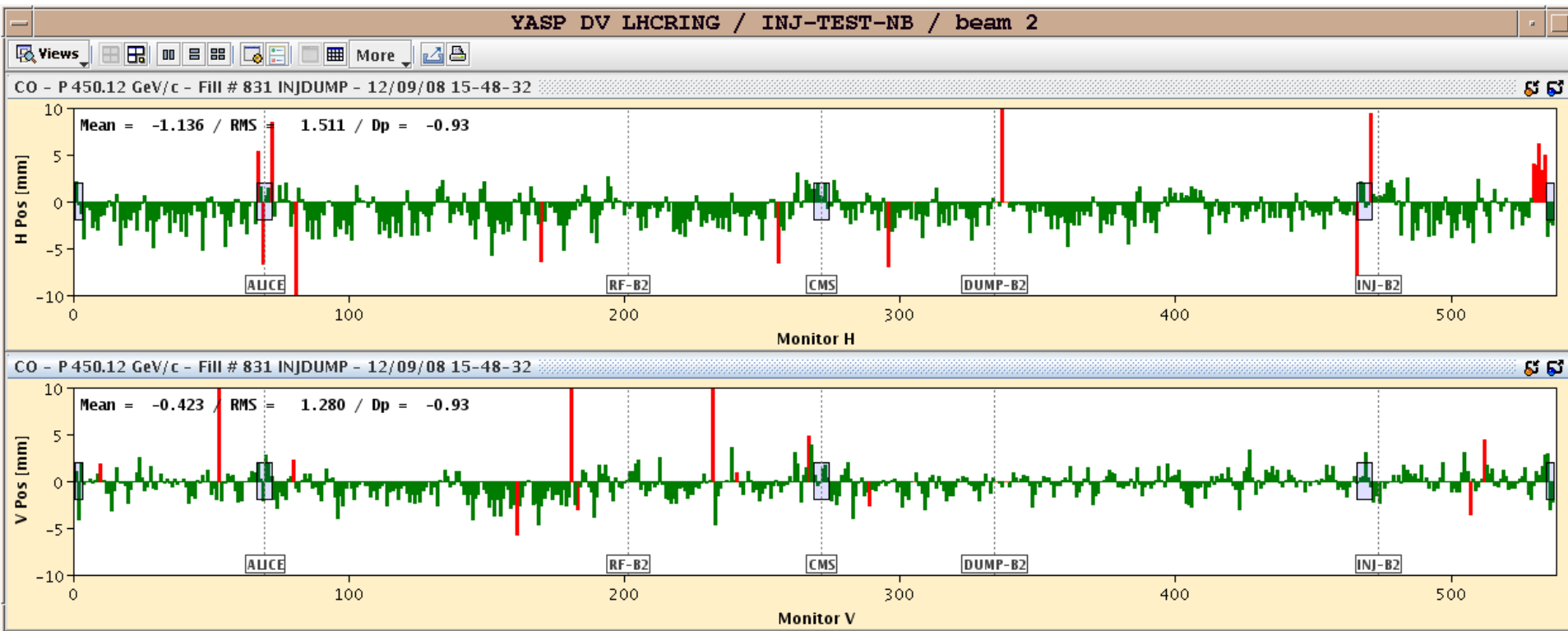






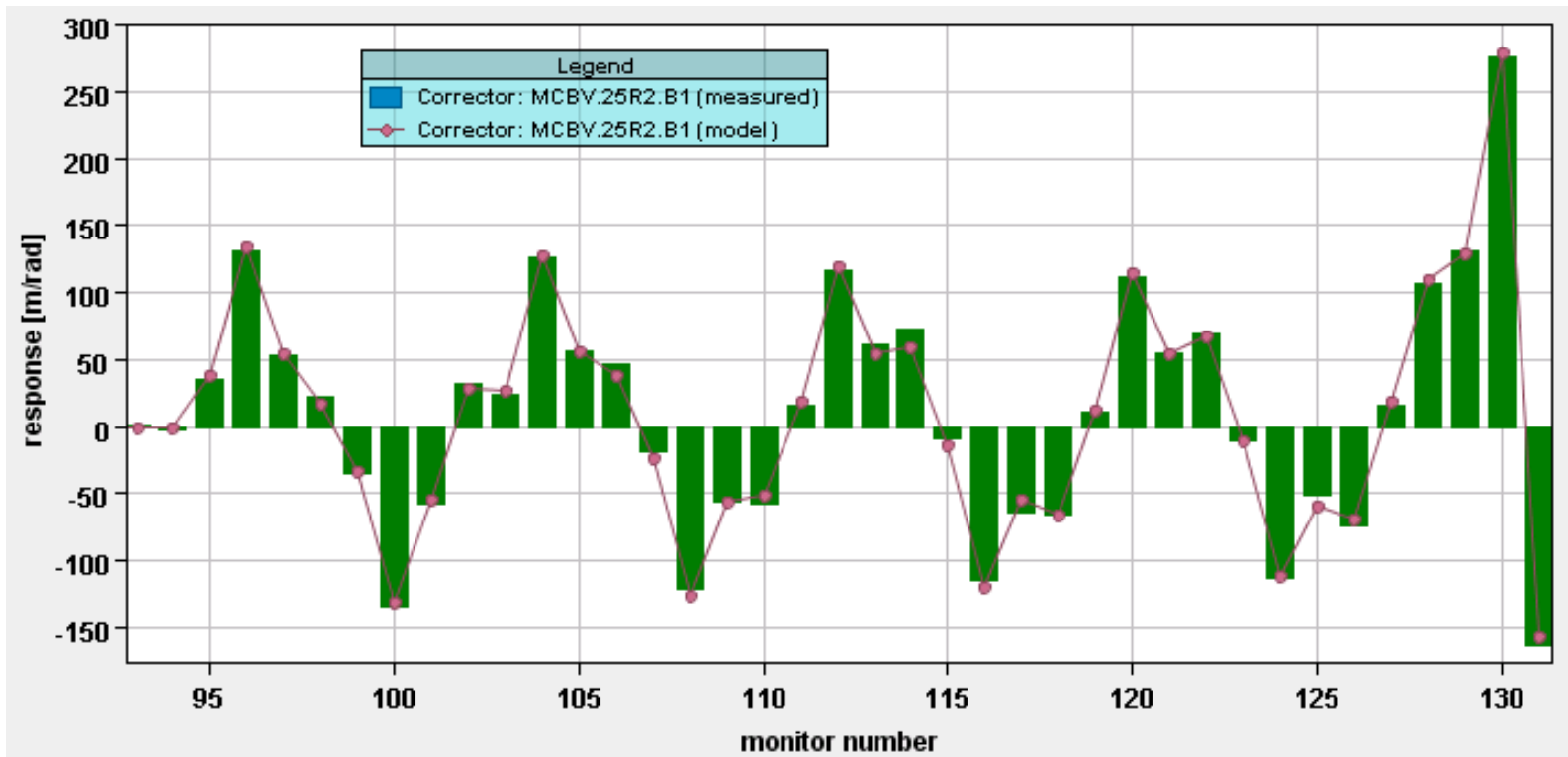
# Corrected closed orbit on B2.

Energy offset of  $\sim -0.9$  permill due to the capture frequency.

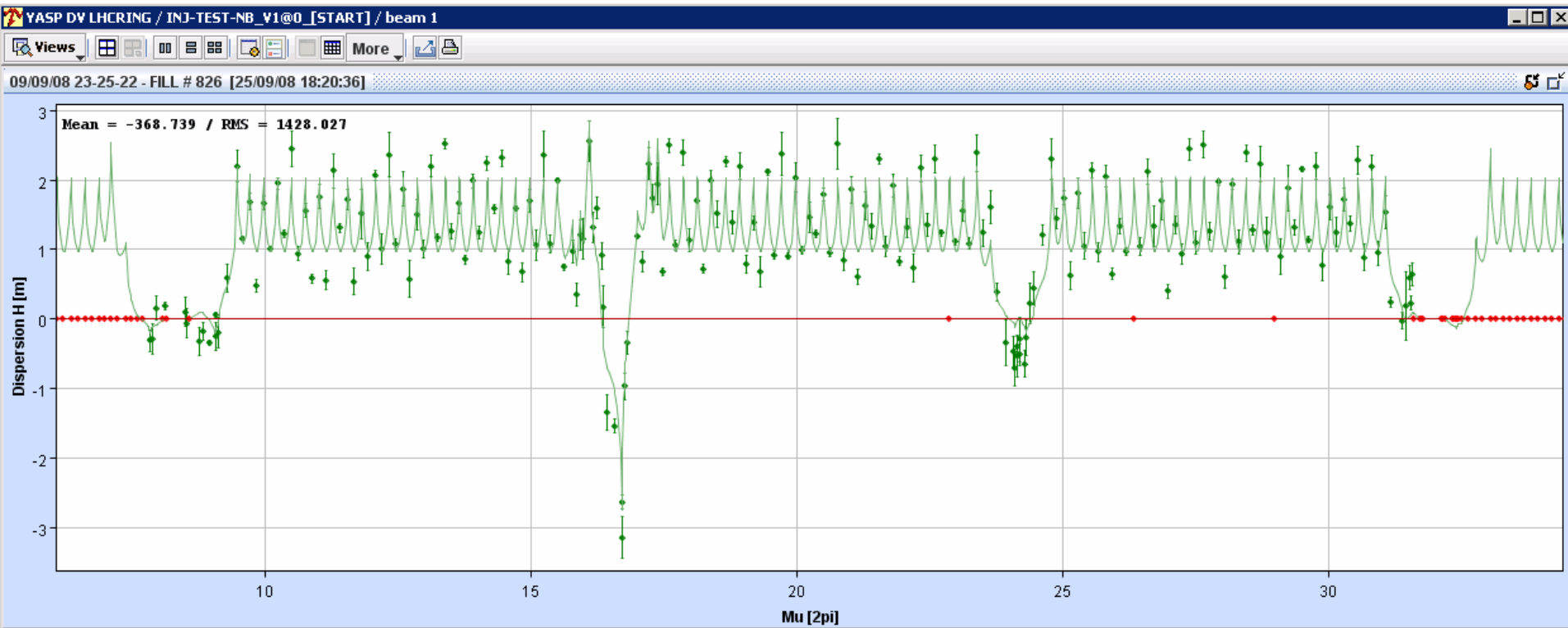




# Kick response compared with theoretical optics

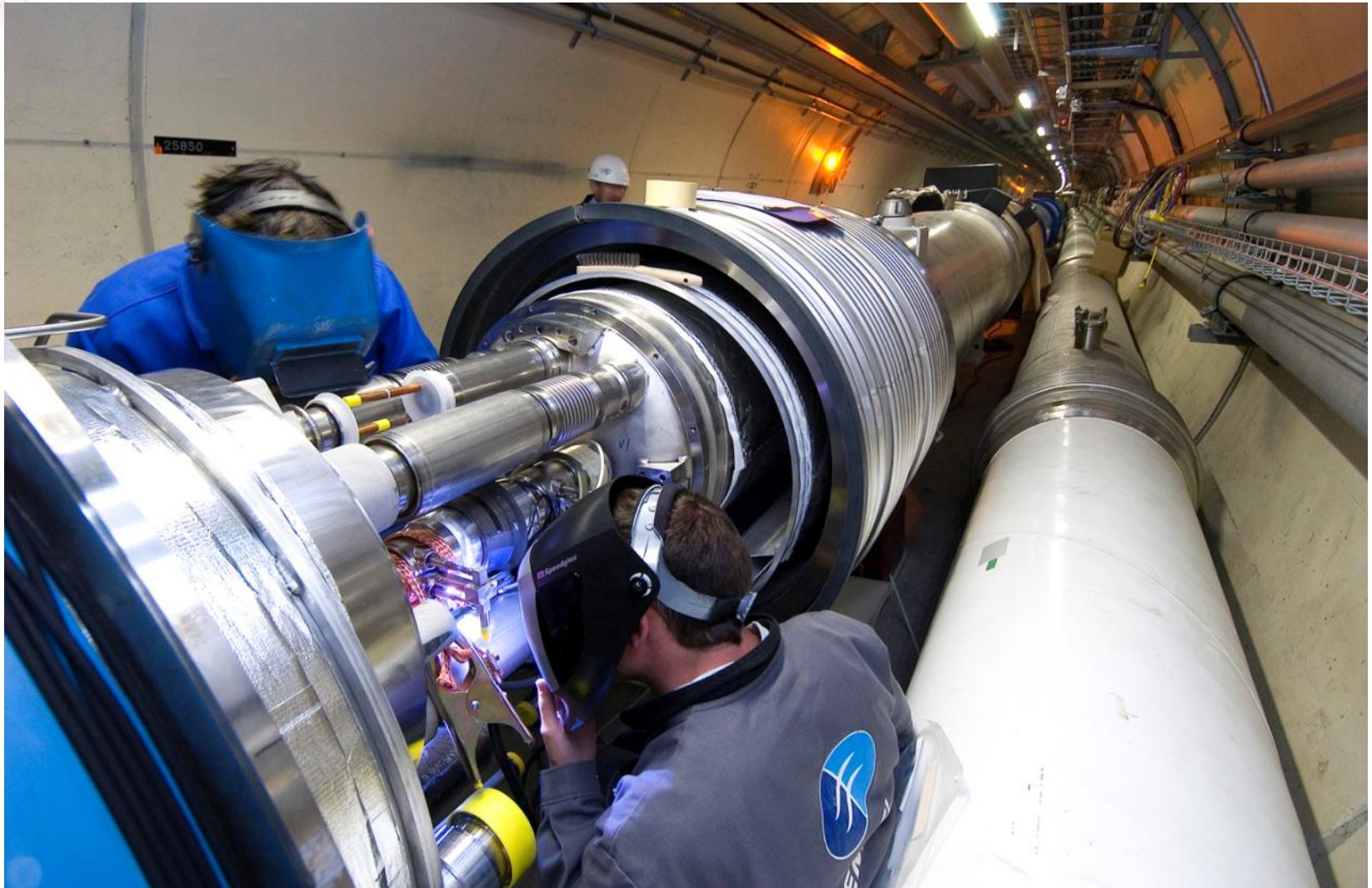


# Beam 1 H dispersion on first turn Injection to beam dump





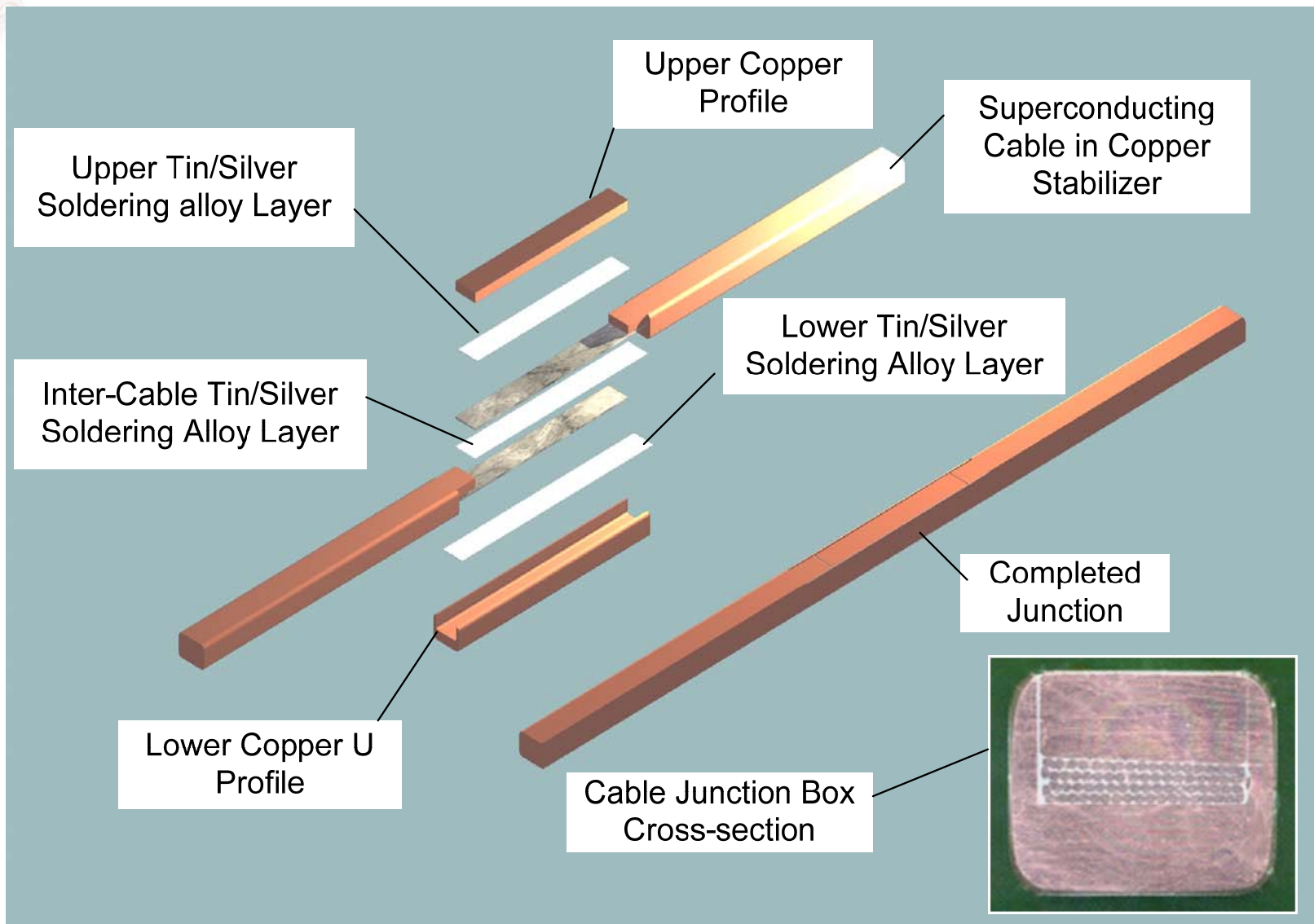
# 19<sup>th</sup> september incident





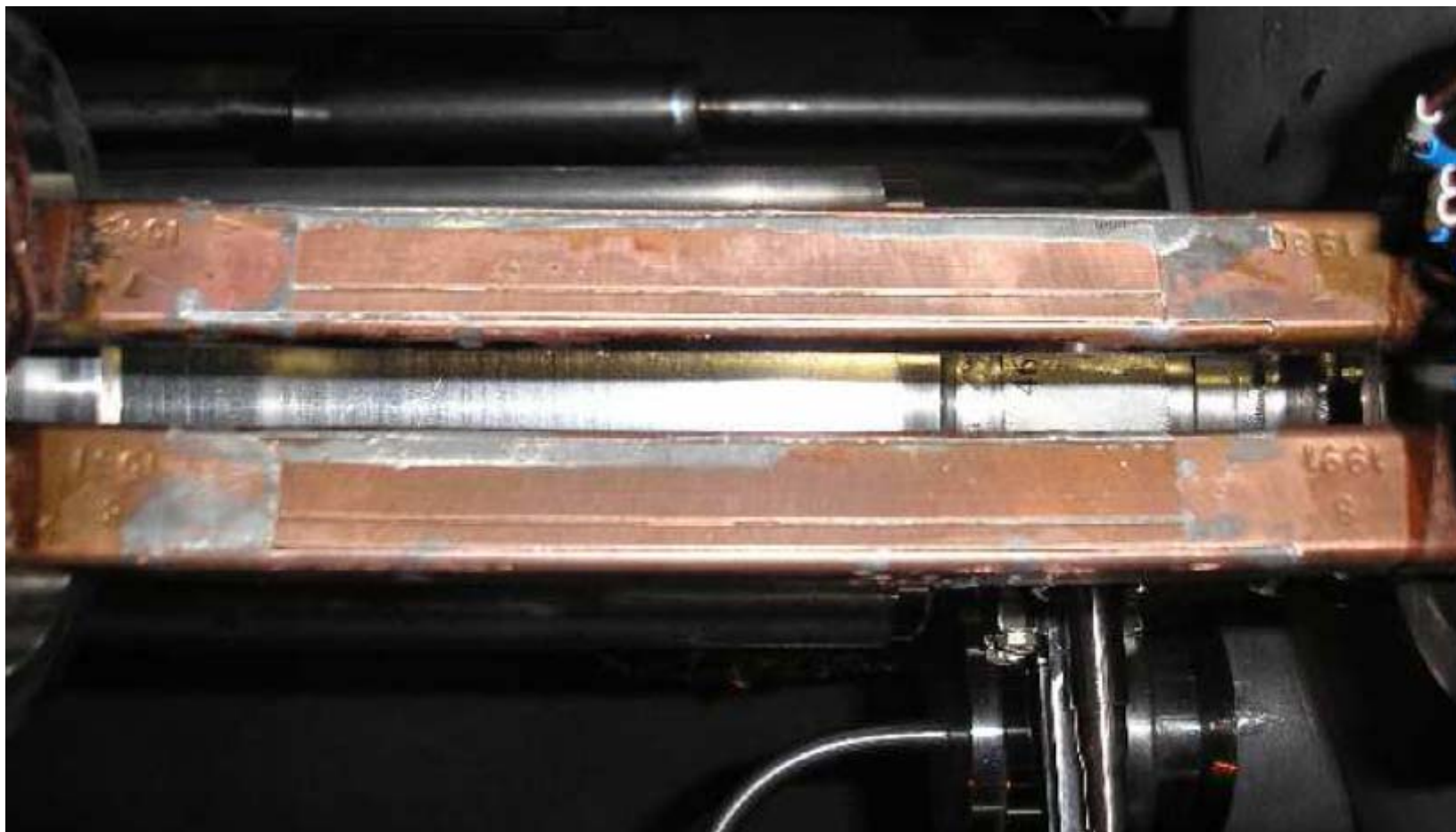


# Busbar splice





# Busbar splice





# Cryostat and cold masses longitudinal displacements



## Displacements status in sector 3-4 (From Q17R3 to Q33R3) : P3 side

Based on measurements by TS-SU, TS-MME and AT-MCS

Cryostat  
Cold mass

Q17	A18	B18	C18	Q18	A19	B19	C19	Q19	A20	B20	C20	Q20	A21	B21	C21	Q21
<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
?	?	?	?	?	?	?	?	?	?	<5	<5	<5	<5	<5	<5	<5

Cryostat  
Cold mass

Q21	A22	B22	C22	Q22	A23	B23	C23	Q23	A24	B24	C24	Q24	A25	B25	C25	Q25
<2	<2	<2	<2	-7	<2	<2	<2	-187	<2	<2	<2	<2	<2	<2	<2	<2
<5	<5	<5	<5	-25	-67	-102	-144	<5	-190	-130	-60	<5	<5	<5	<5	<5

Cryostat  
Cold mass

Q25	A26	B26	C26	Q26	A27	B27	C27	Q27	A28	B28	C28	Q28	A29	B29	C29	Q29
<2	<2	<2	<2	<2	<2	<2	<2	474	-4	<2	<2	11	<2	<2	<2	<2
<5	<5	<5	<5	<5	57	114	150?	-45	230	189	144	92?	50	35	<5	<5

Cryostat  
Cold mass

Q29	A30	B30	C30	Q30	A31	B31	C31	Q31	A32	B32	C32	Q32	A33	B33	C33	Q33
<2	<2	<2	<2	<2	<2	<2	<2	188	<2	<2	<2	5	<2	<2	<2	<2
<5	<5	<5	<5	<5	19	77	148	<5	140	105	62	18	<5	<5	<5	?

>0 SSS with vacuum barrier  
 Towards P4  
 Values are in mm  
 Not measured yet  
→ Cold mass displacement  
→ Cryostat displacement  
\* Open interconnection  
\* Dipole in short circuit  
↑ Electrically damaged IC  
□ Disconnected  
↔ Buffer zones



## Preliminary recommendations

Recommendations made by the task force aim at two different goals, namely to prevent any other occurrence of this type of initial event, and to mitigate its consequences should it however reproduce accidentally. Possible precursors of the incident in sector 3-4 are being scrutinized in the electrical and calorimetric data recorded on all sectors, in order to spot any other problem of the same nature in the machine. An improvement of the quench detection system is under way, to generate both early warnings and interlocks, and to encompass magnets, bus bars and interconnects. The relief devices on the cryostat vacuum vessels will be increased in discharge capacity and in number, so as to contain a possible pressure rise to below 0.15 MPa absolute even in presence of an electrical arc. The external anchoring of the cryostats at the locations of the vacuum barriers will be reinforced to guarantee mechanical stability.





# Upgrade scenario for the LHC complex





# Peak Luminosity



$$L = \frac{N_b^2 n_b f_r \gamma}{4\pi \epsilon_n \beta^*} F$$

- $N_b$**  number of particles per bunch
- $n_b$**  number of bunches
- $f_r$**  revolution frequency
- $\epsilon_n$**  normalised emittance
- $\beta^*$**  beta value at Ip
- $F$**  reduction factor due to crossing angle

- $N_b, \epsilon_n$**  → injector chain
- $\beta^*$**  → LHC insertion
- $F$**  → beam separation schemes
- $n_b$**  → electron cloud effect



# LHC Upgrade-Phase I



## Goal of “Phase I” upgrade:

Enable focusing of the beams to  $b^*=0.25$  m in IP1 and IP5, and reliable operation of the LHC at double the operating luminosity on the horizon of the physics run in 2013.

## Scope of “Phase I” upgrade:

1. Upgrade of ATLAS and CMS experimental insertions. The interfaces between the LHC and the experiments remain unchanged at  $\pm 19$  m.
2. Replace the present triplets with wide aperture quadrupoles based on the LHC dipole cables (Nb-Ti) cooled at 1.9 K.
3. Upgrade the D1 separation dipole, TAS and collimation system so as to be compatible with the inner triplet aperture.
4. The cooling capacity of the cryogenic system and other main infrastructure elements remain unchanged.
5. Modifications of other insertion magnets (e.g. D2-Q4) and introduction of other equipment in the insertions to the extent of available resources.



# Participants and Milestones



## Several departments are involved in the “Phase I” project:

**AT Department:** low-beta quadrupoles and correctors, D1 separation dipoles, magnet testing, magnet protection and cold powering, vacuum equipment, QRL modifications.

**AB Department:** optics and performance, power converters, instrumentation, TAS and other beam-line absorbers, ...

**TS Department:** cryostat support and alignment equipment, interfaces with the experiments, installation, design effort, ...

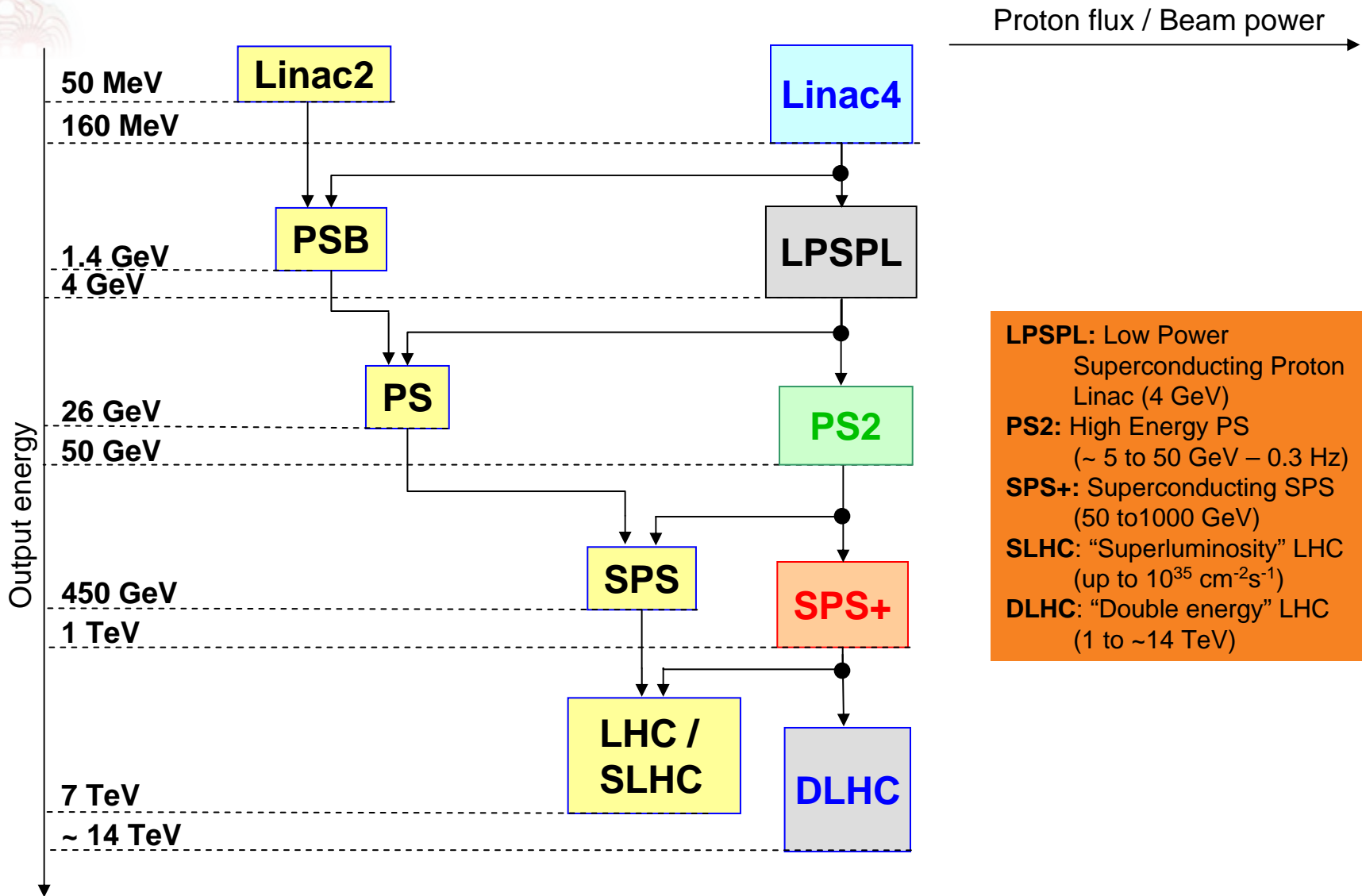
**SLHC-PP** collaborators.

## Milestones:

Conceptual Design Report	mid 2008
Technical Design Report	mid 2009
Model quadrupole	end 2009
Pre-series quadrupole	2010
String test	2012
Installation	shutdown 2013



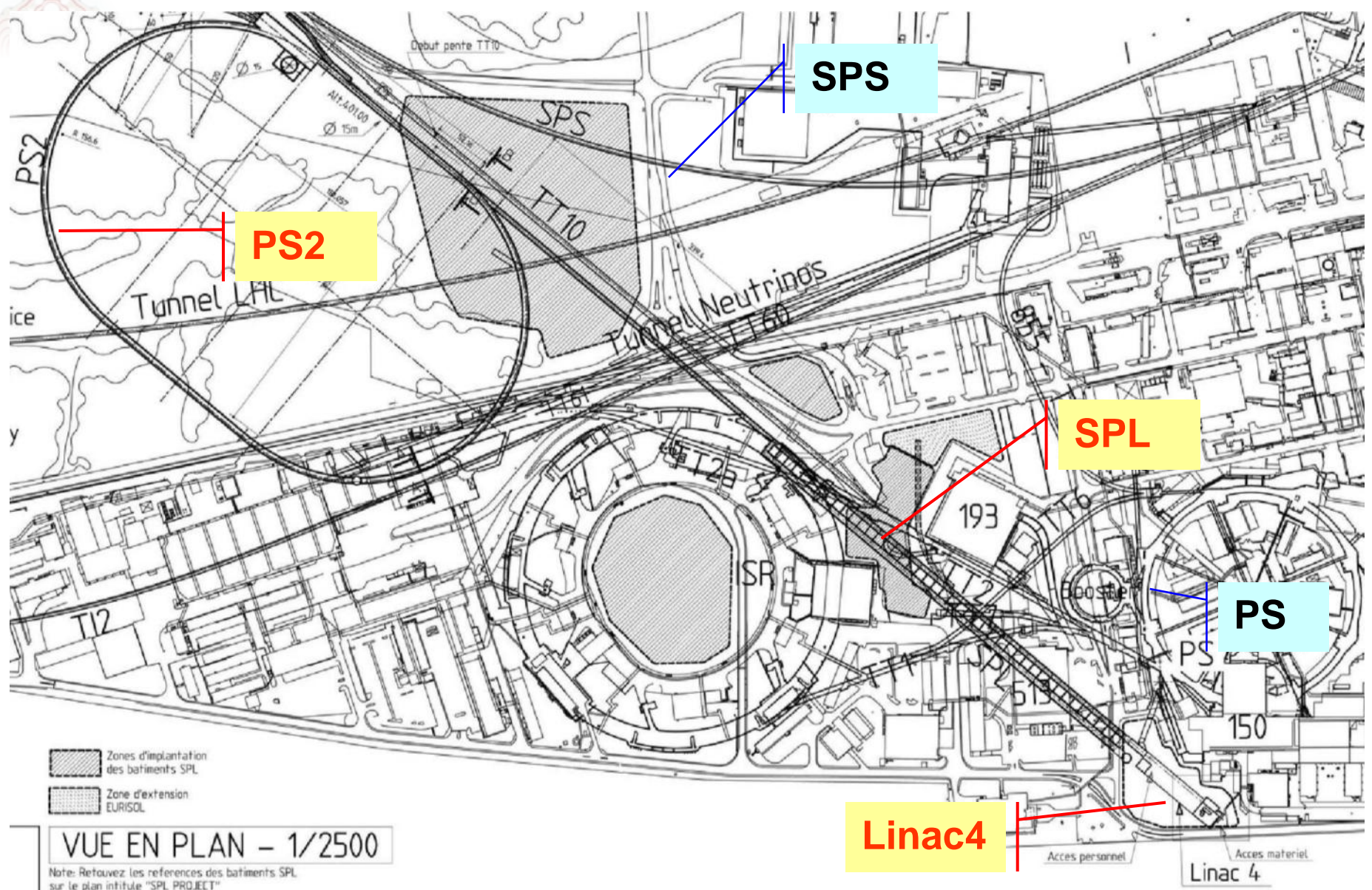
# Upgrade components



**LPSPL:** Low Power Superconducting Proton Linac (4 GeV)  
**PS2:** High Energy PS (~ 5 to 50 GeV – 0.3 Hz)  
**SPS+:** Superconducting SPS (50 to 1000 GeV)  
**SLHC:** “Superluminosity” LHC (up to  $10^{35} \text{ cm}^{-2}\text{s}^{-1}$ )  
**DLHC:** “Double energy” LHC (1 to ~14 TeV)

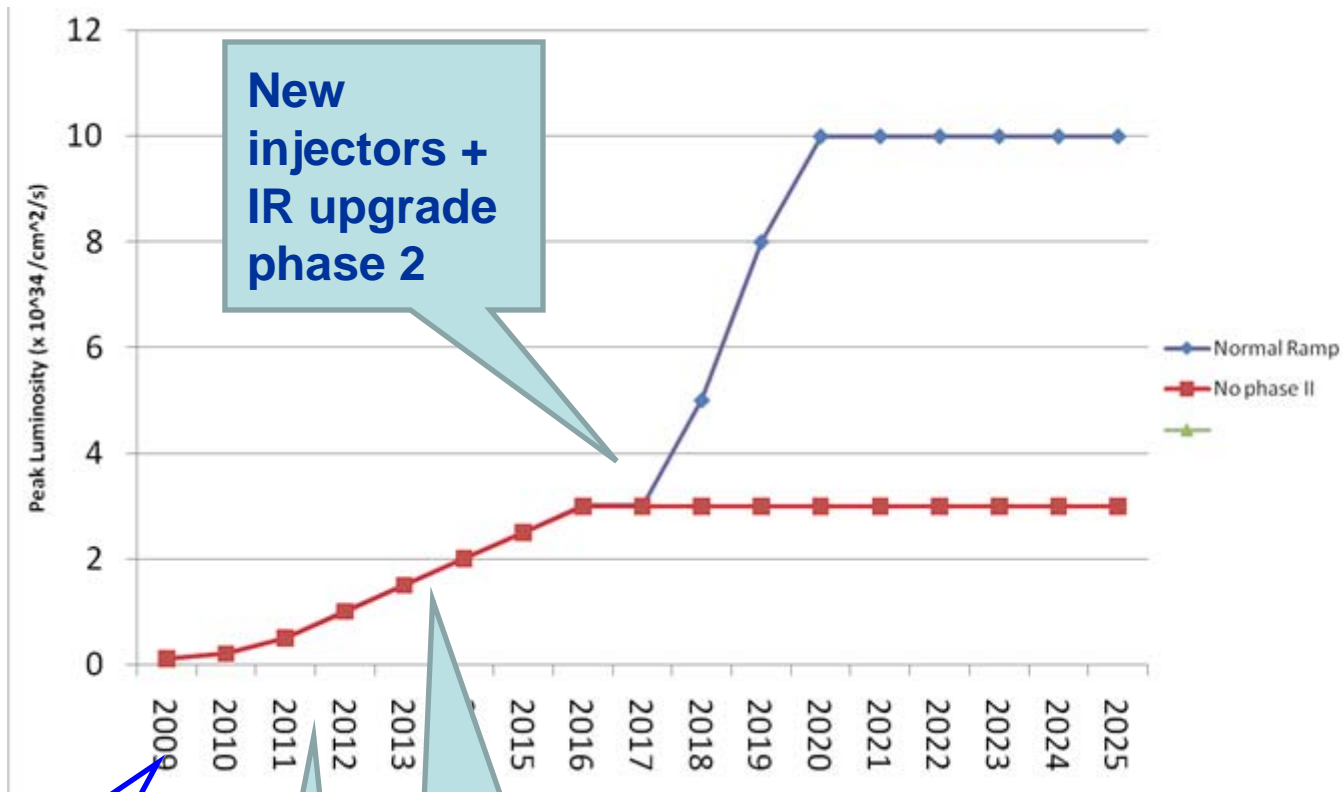


# Layout of the new injectors





# Peak luminosity...



**New injectors + IR upgrade phase 2**

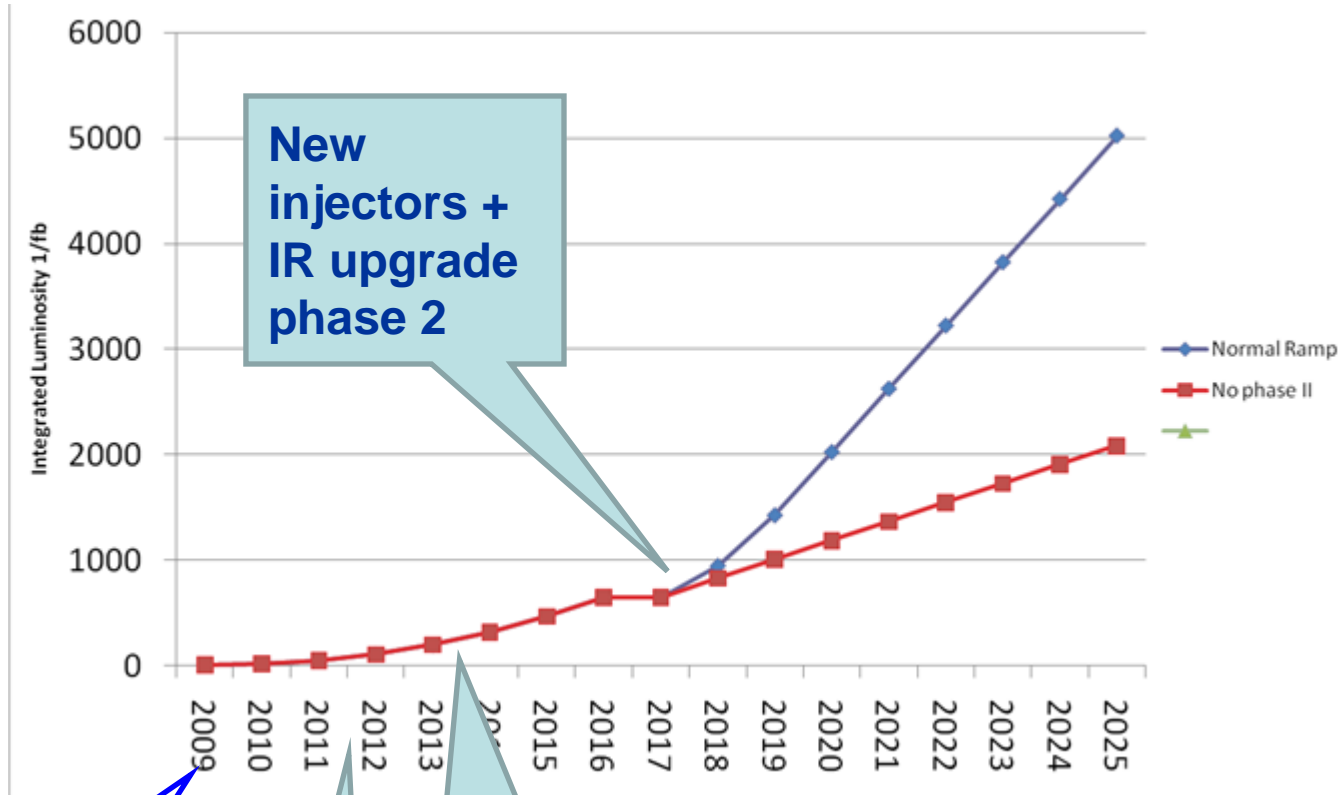
**Early operation**

**Collimation phase 2**

**Linac4 + IR upgrade phase 1**



# Integrated luminosity...



Early operation

Collimation phase 2

Linac4 + IR upgrade phase 1

New injectors + IR upgrade phase 2