LHC Status and Upgrade Scenario

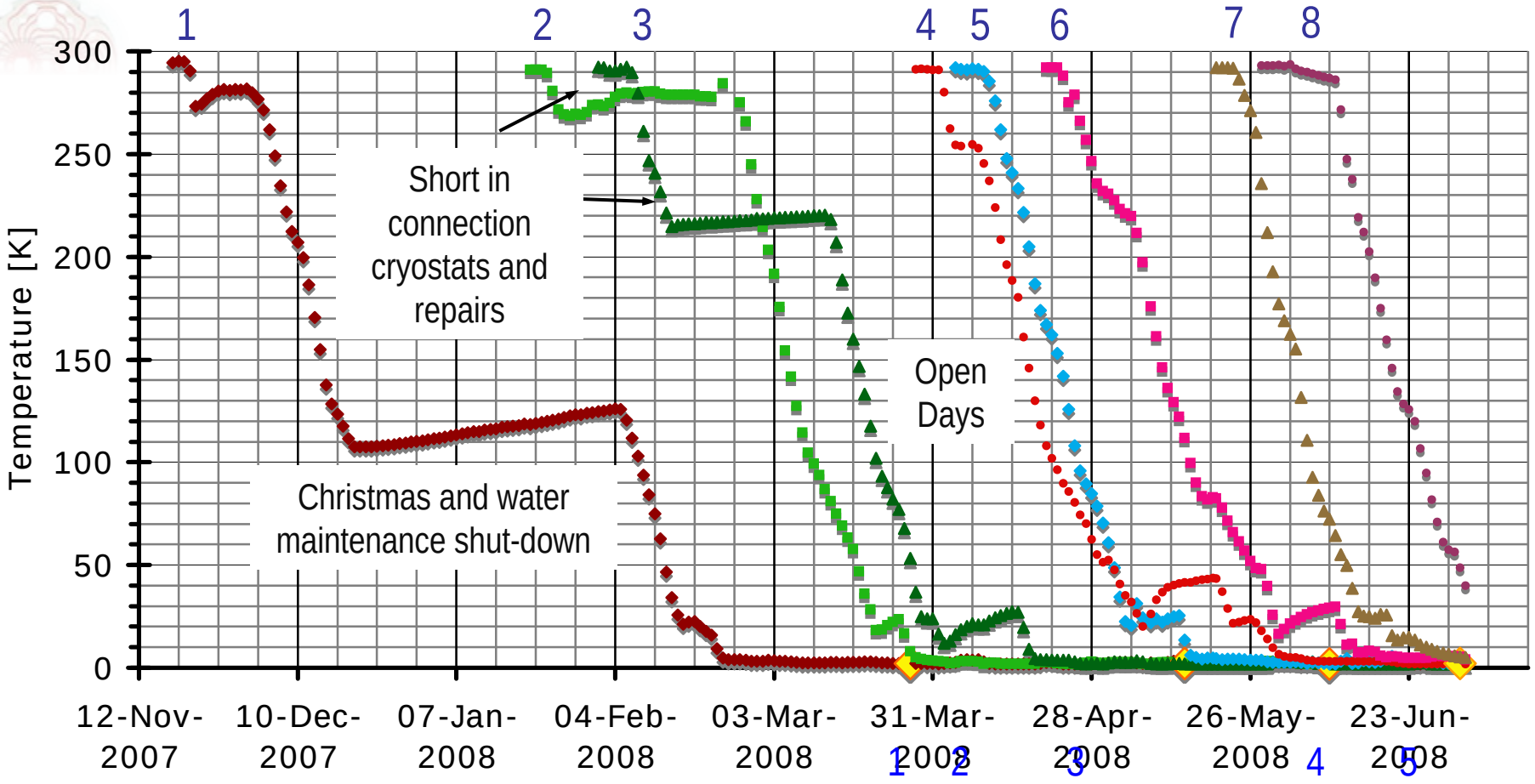
Lyn Evans

Fall HEPAP meeting, Washington 14th 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

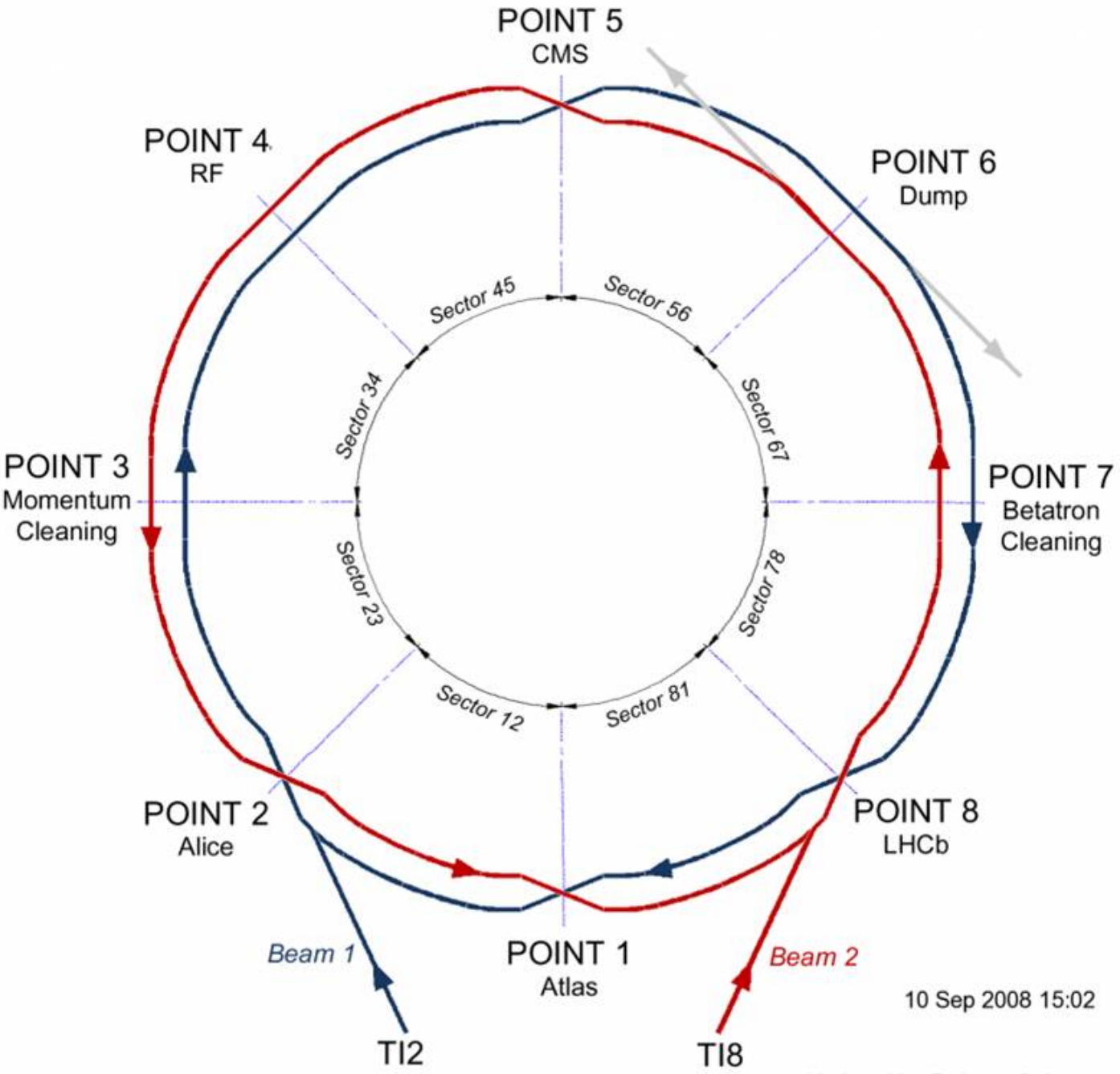


Sectors
< 2 K
+ 2 < 5 K

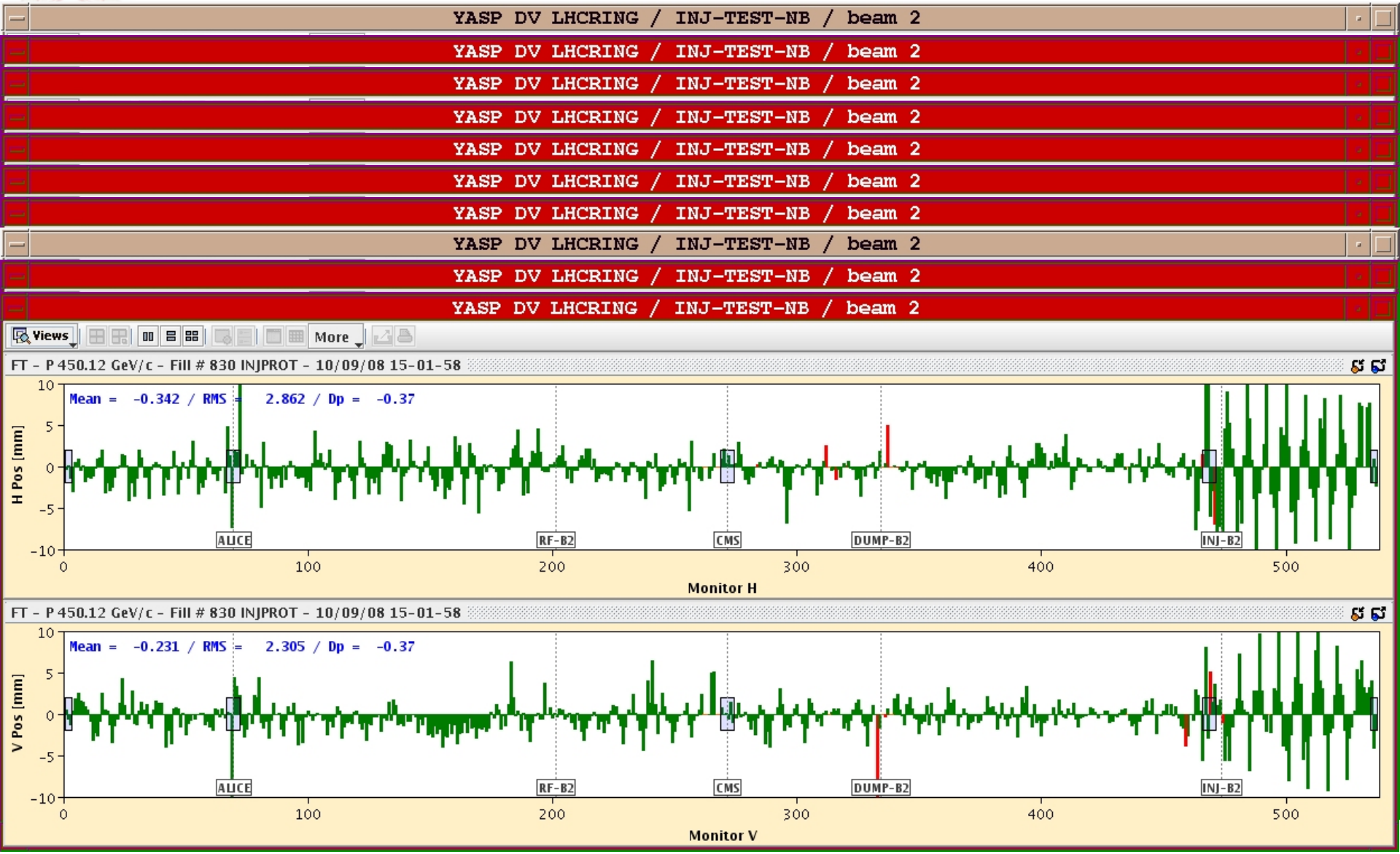
Cooling sectors + Cryo tuning + Powering activities

Situation on 10th September

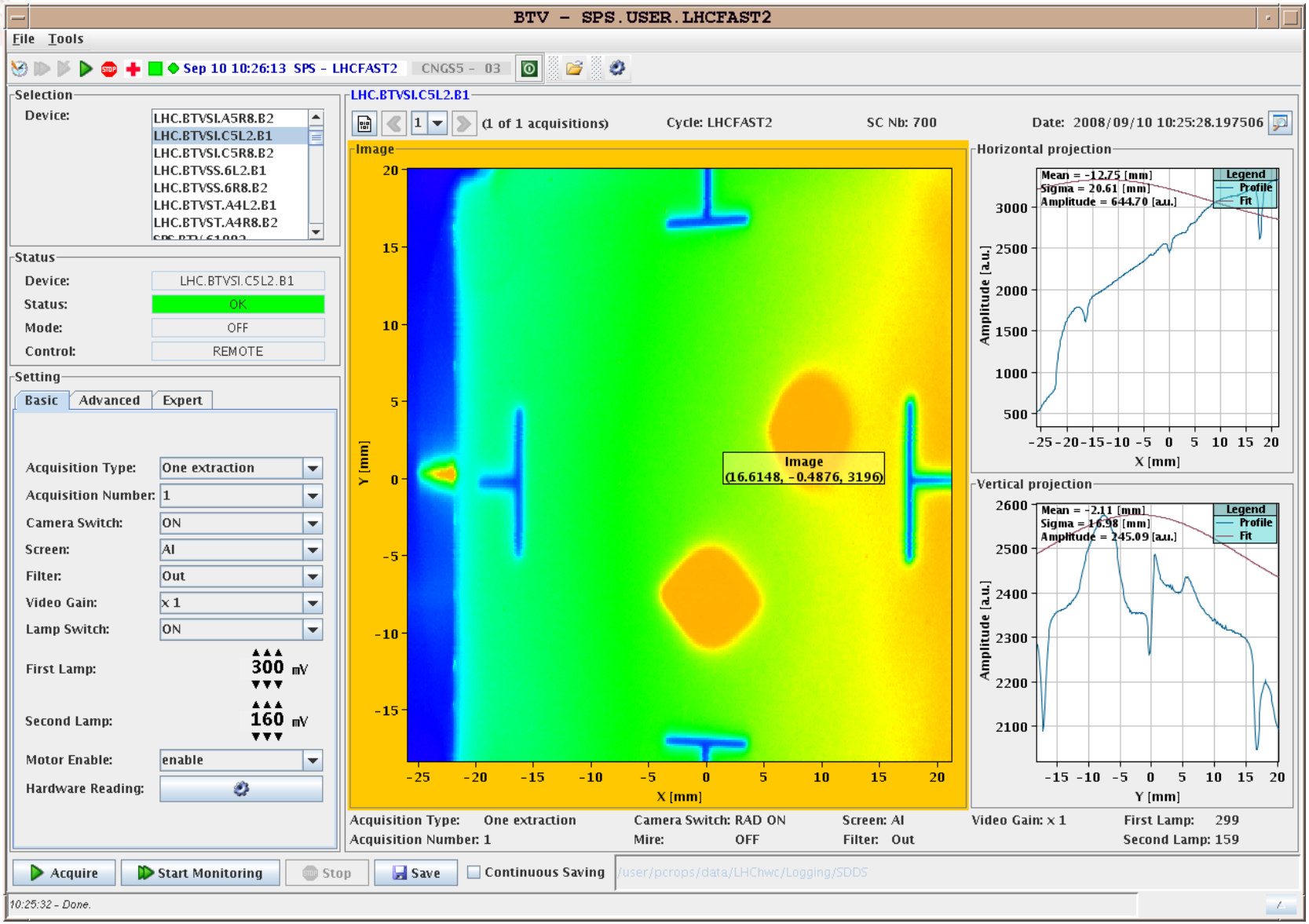
- 7 out of 8 sectors fully commissioned for 5 TeV operation and 1 sector (3-4) commissioned up to 4 TeV.


POINT 5
CMS
POINT 4
RF
POINT 6
Dump
POINT 3
Momentum
Cleaning
POINT 7
Betatron
Cleaning
POINT 2
Alice
POINT 8
LHCb
POINT 1
Atlas
Sector 45
Sector 56
Sector 34
Sector 67
Sector 23
Sector 78
Sector 12
Sector 81
Beam 1
Beam 2
TI2
TI8
10 Sep 2008 15:02
Updated by Roberto Saban

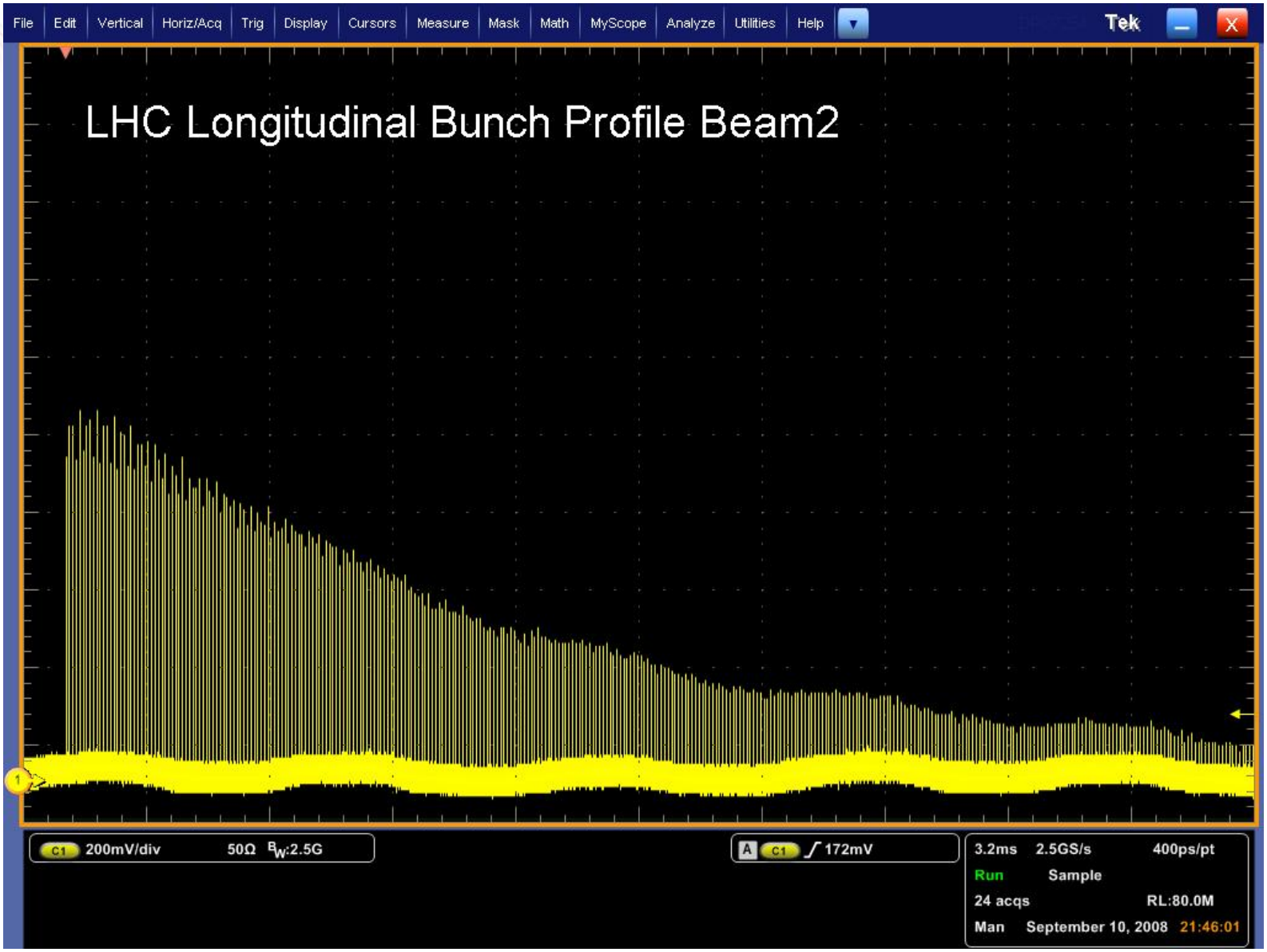
Beam 2 first beam – D-Day



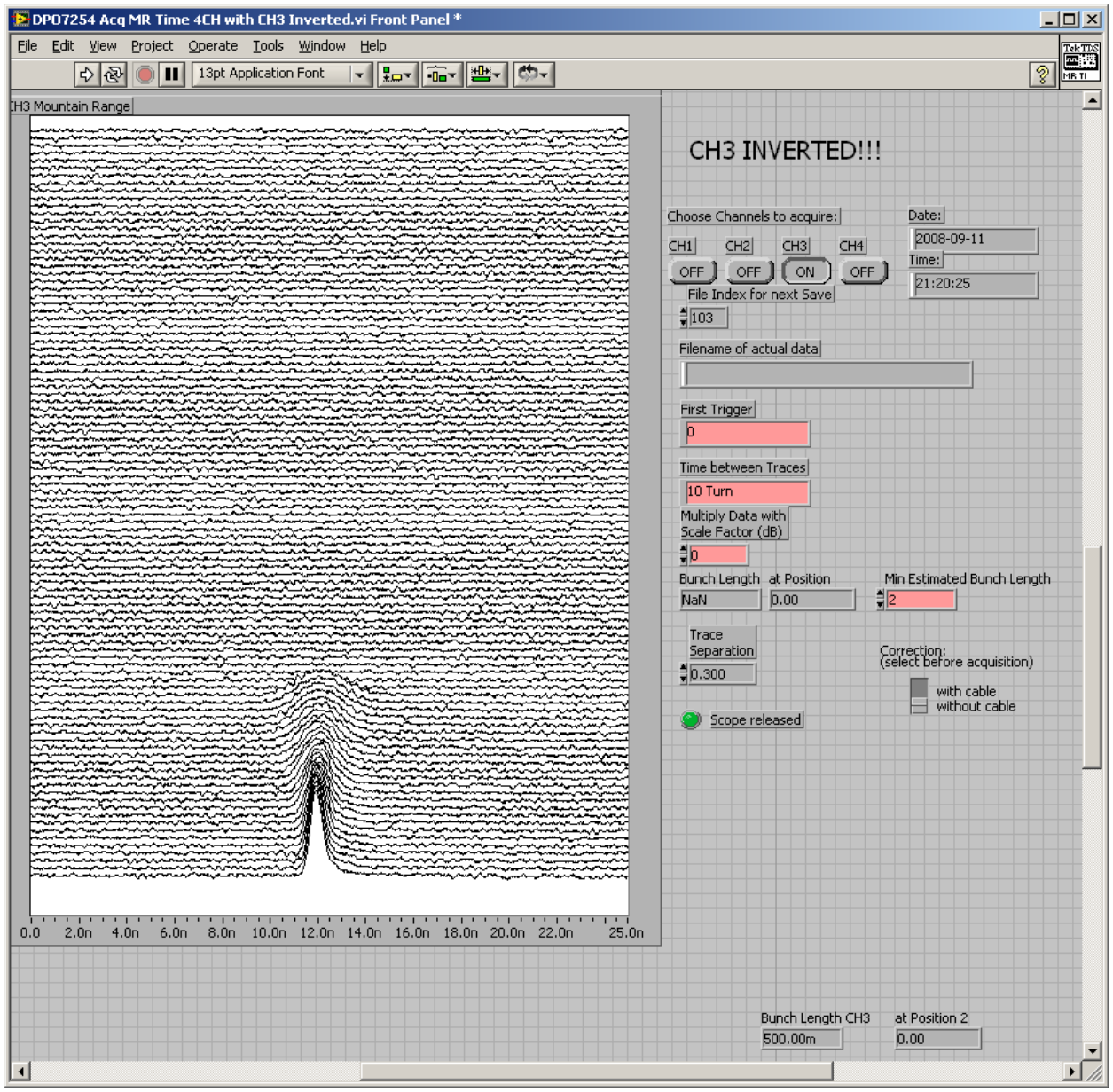
Beam on turns 1 and 2



Few 100 turns

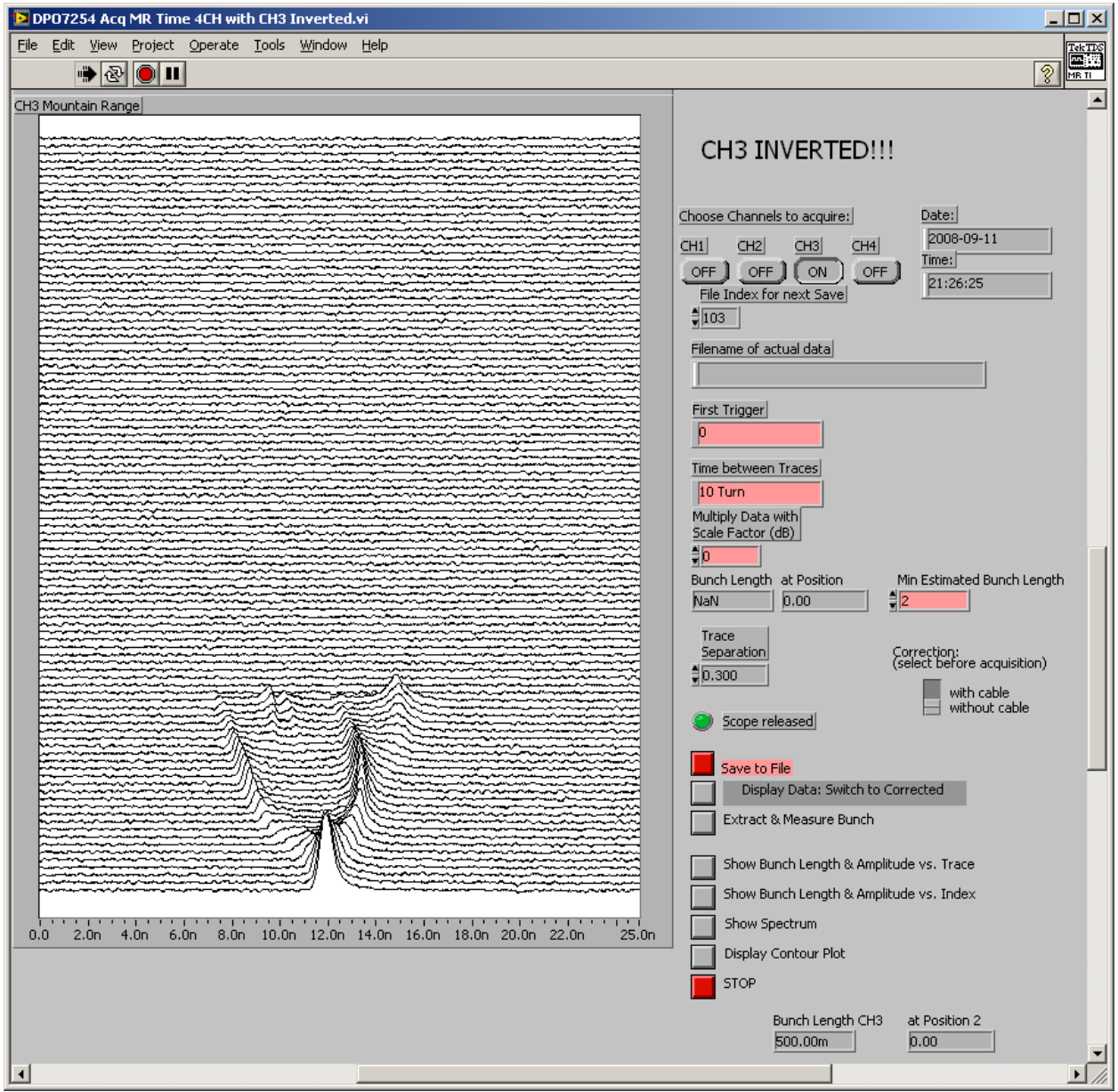


No RF, debunching in ~ 25*10 turns, i.e. roughly 25 mS



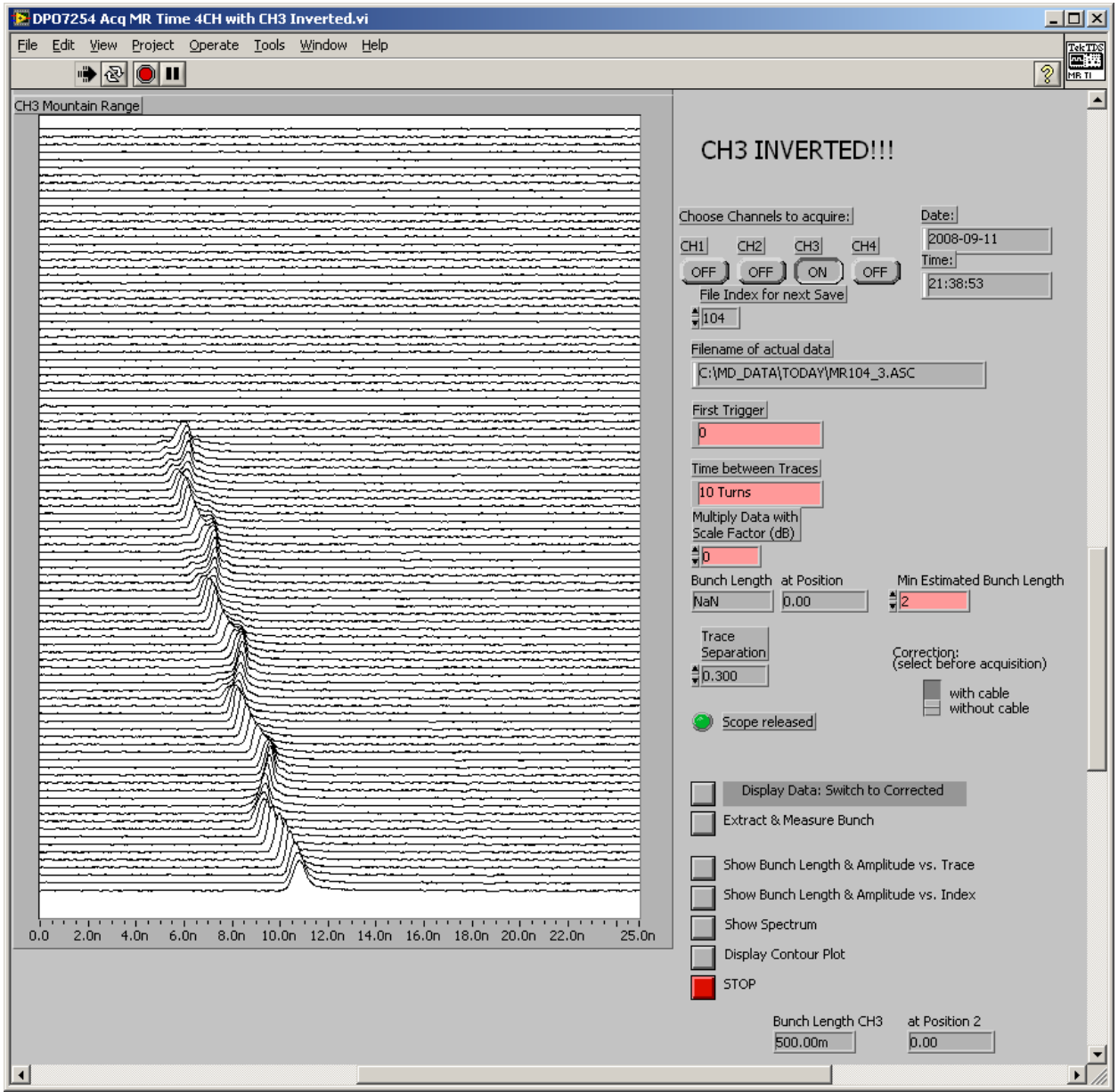
Courtesy E. Ciapala

First attempt at capture, at exactly the wrong injection phase…



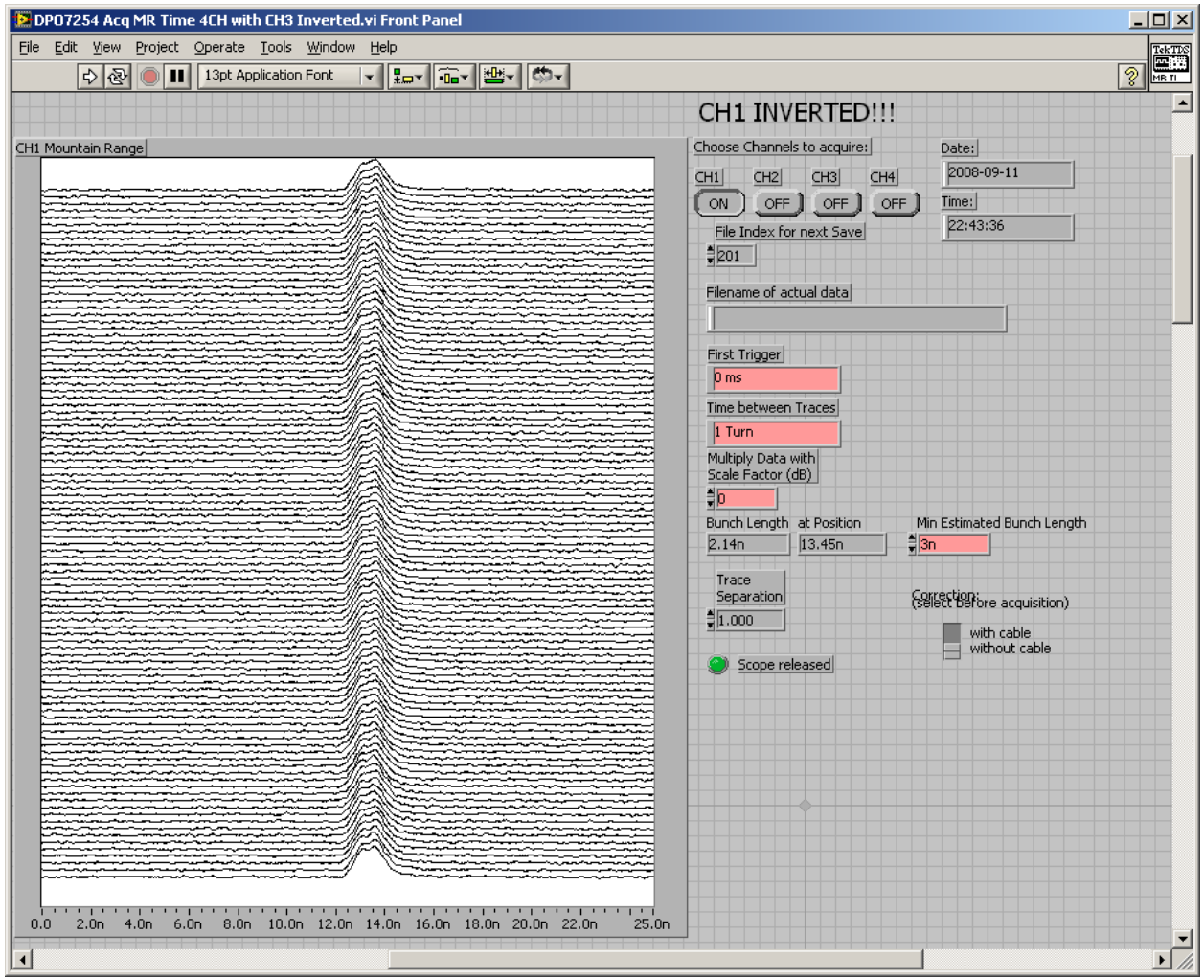
Courtesy E. Ciapala

Capture with corrected injection phasing



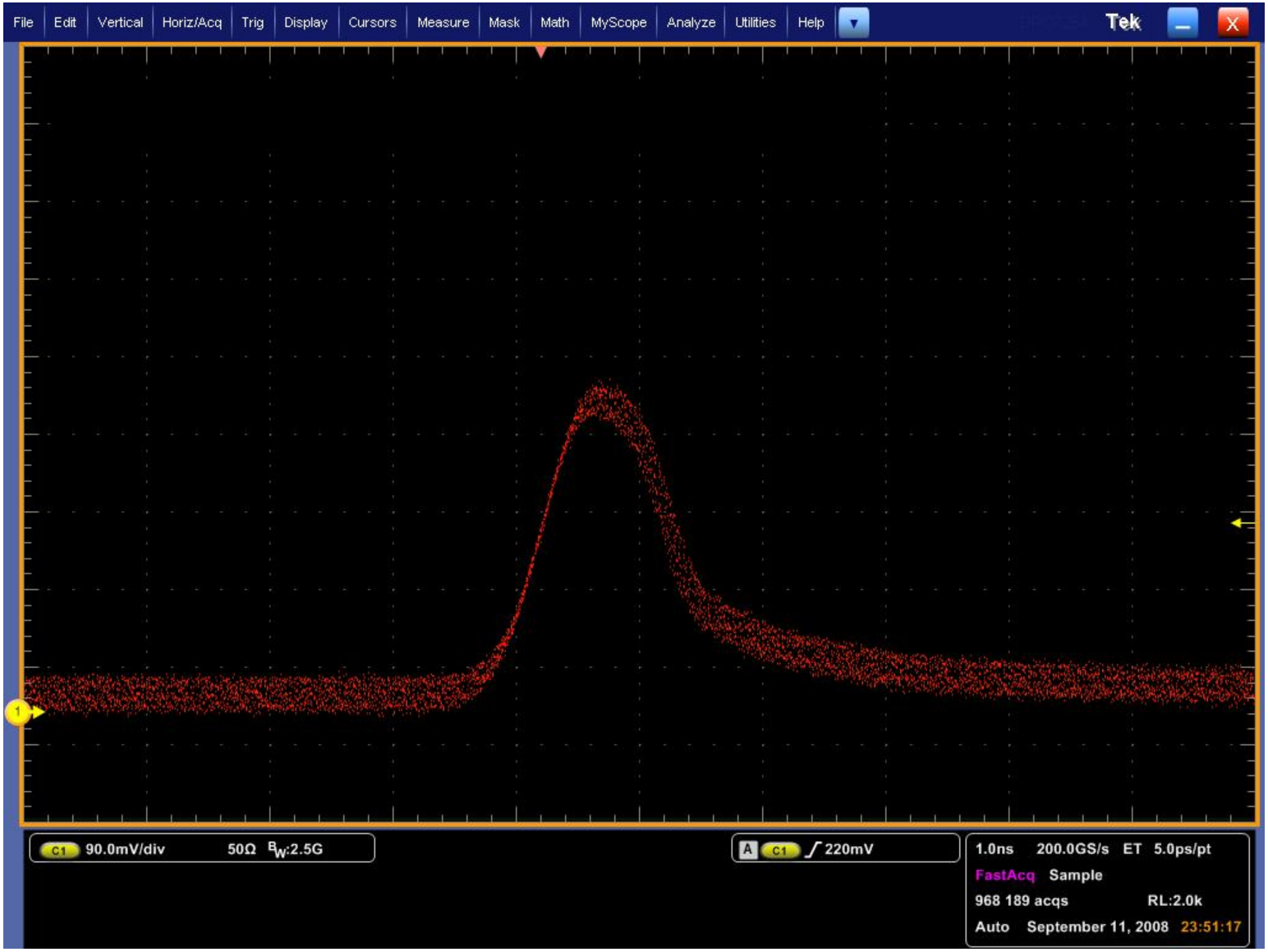
Courtesy E. Ciapala

Capture with optimum injection phasing, correct reference

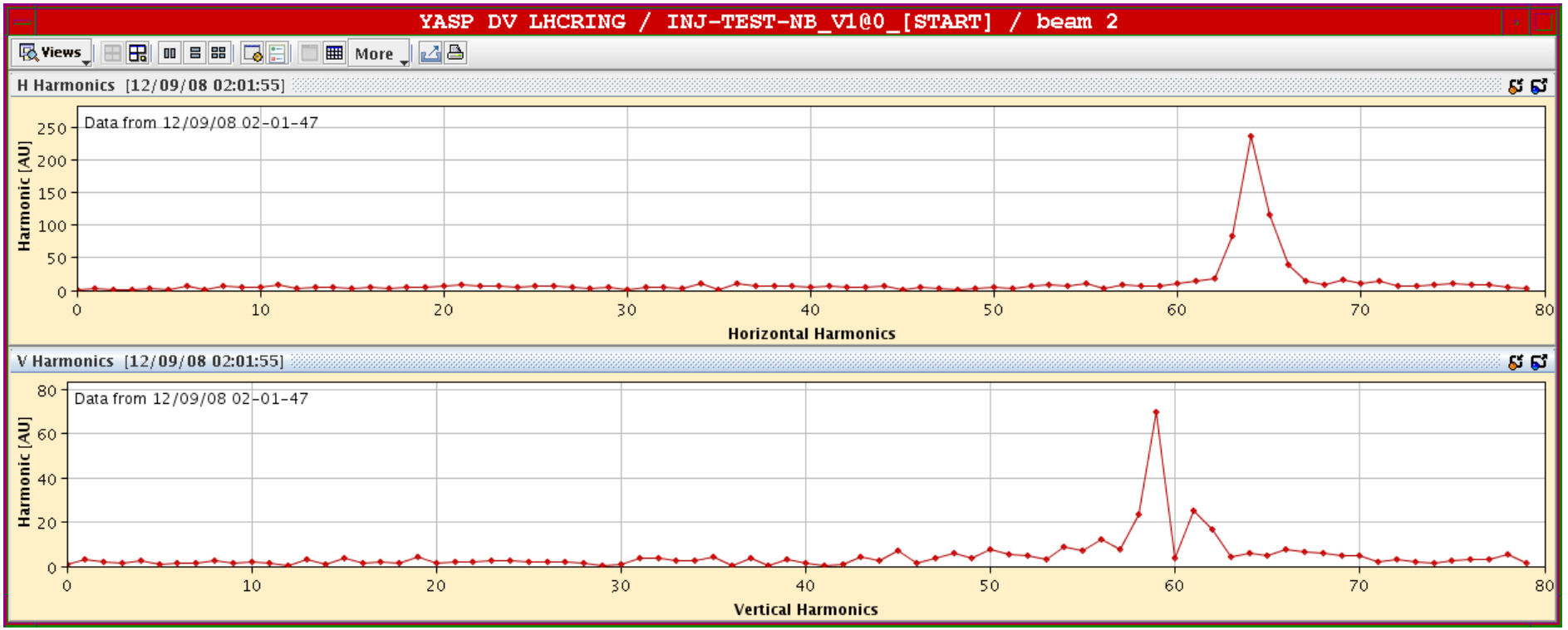


Courtesy E. Ciapala

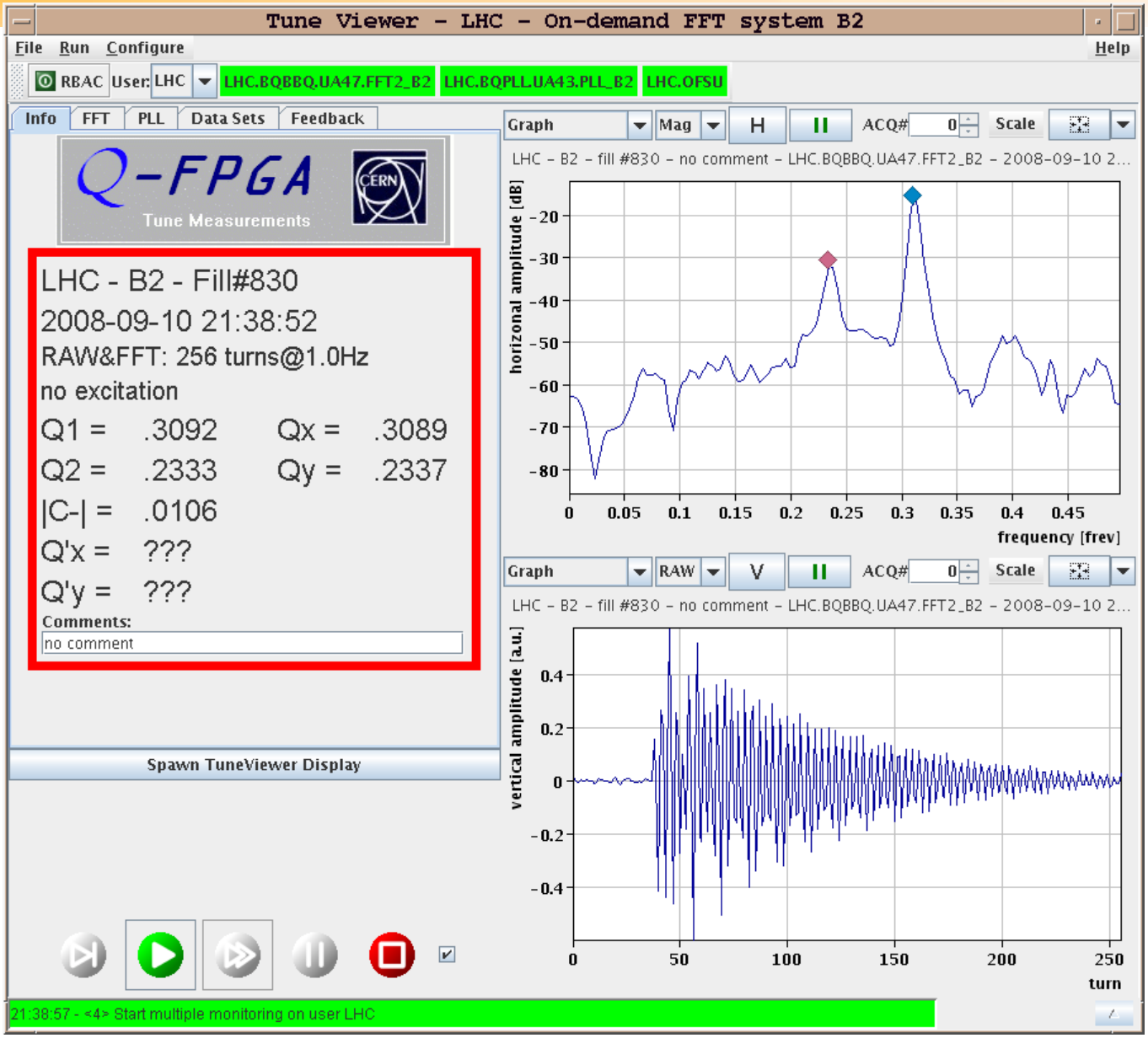
LHC longitudinal bunch profile Beam 2



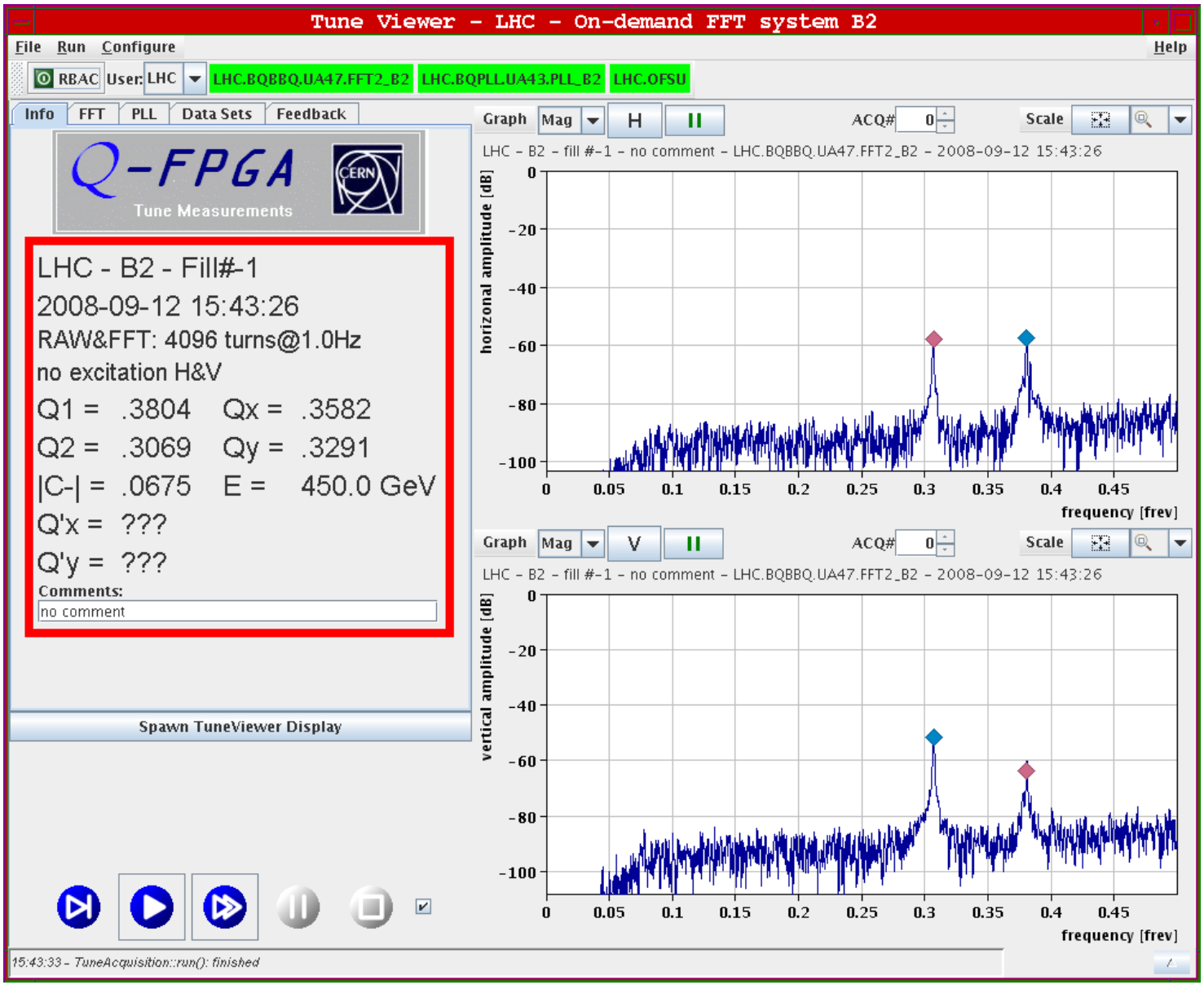
Integer tunes



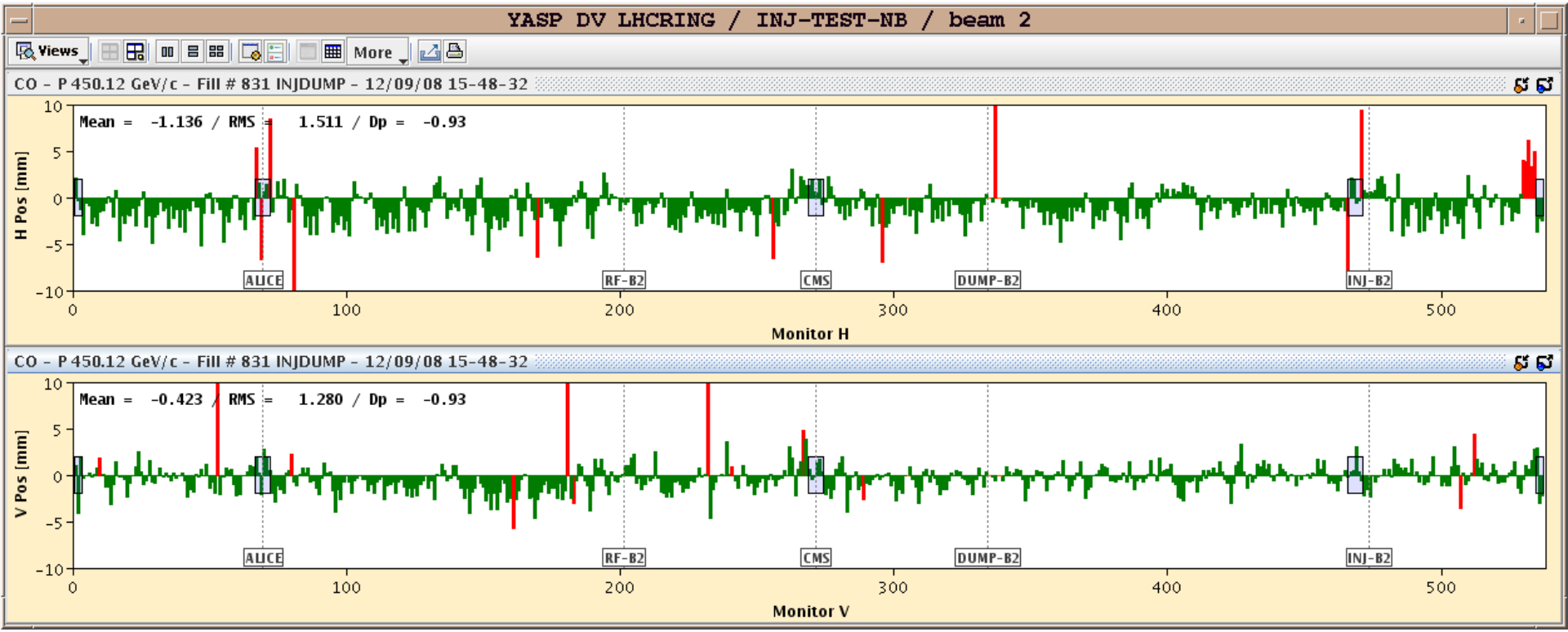
Tune measurements



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

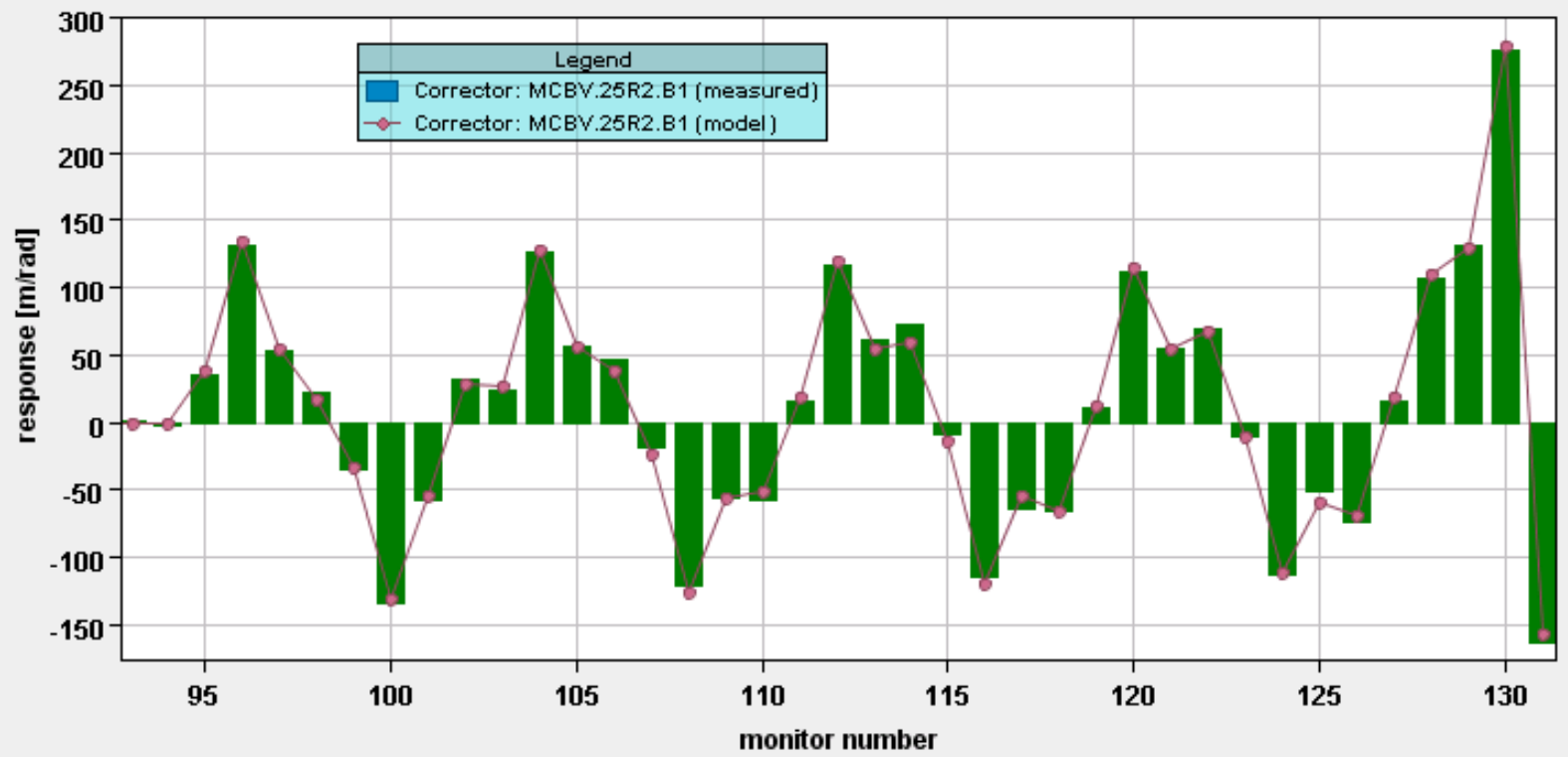


Corrected closed orbit on B2.
Energy offset of ~ -0.9 permill due to the capture frequency.

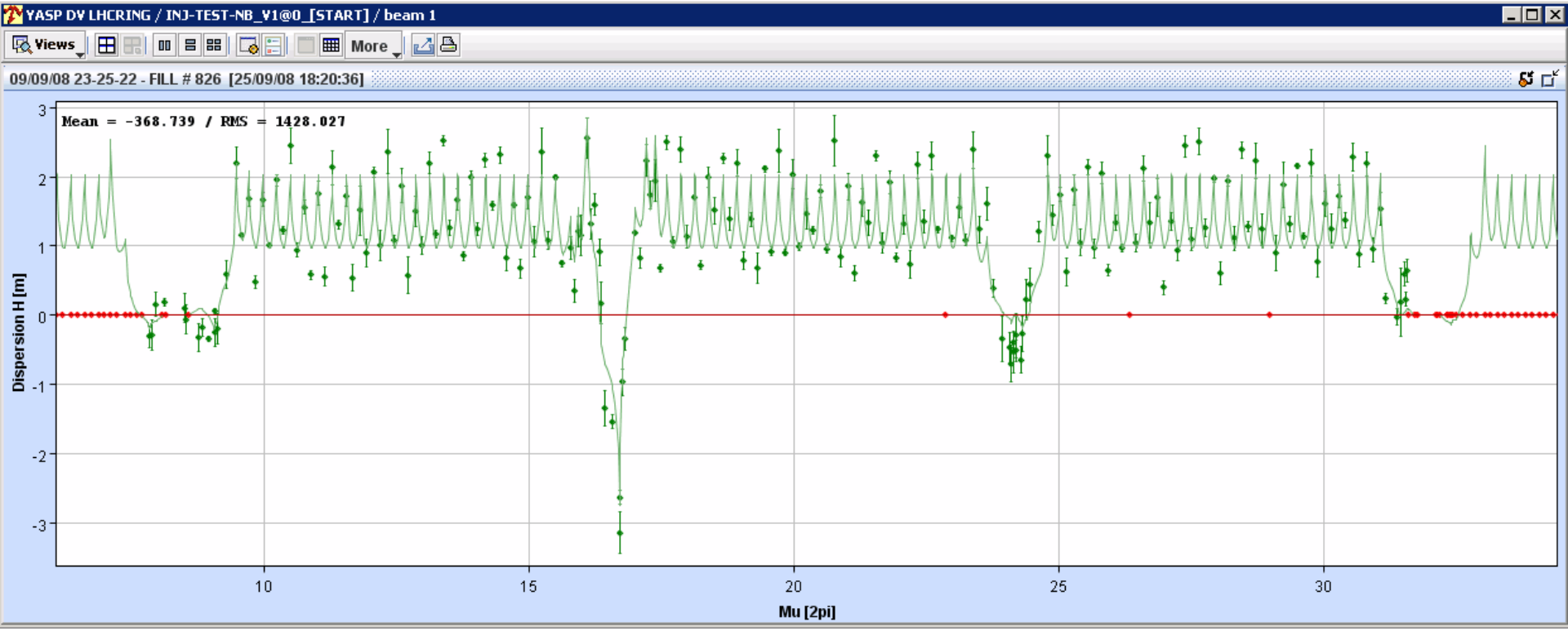


Courtesy J. Wenninger

Kick response compared with theoretical optics

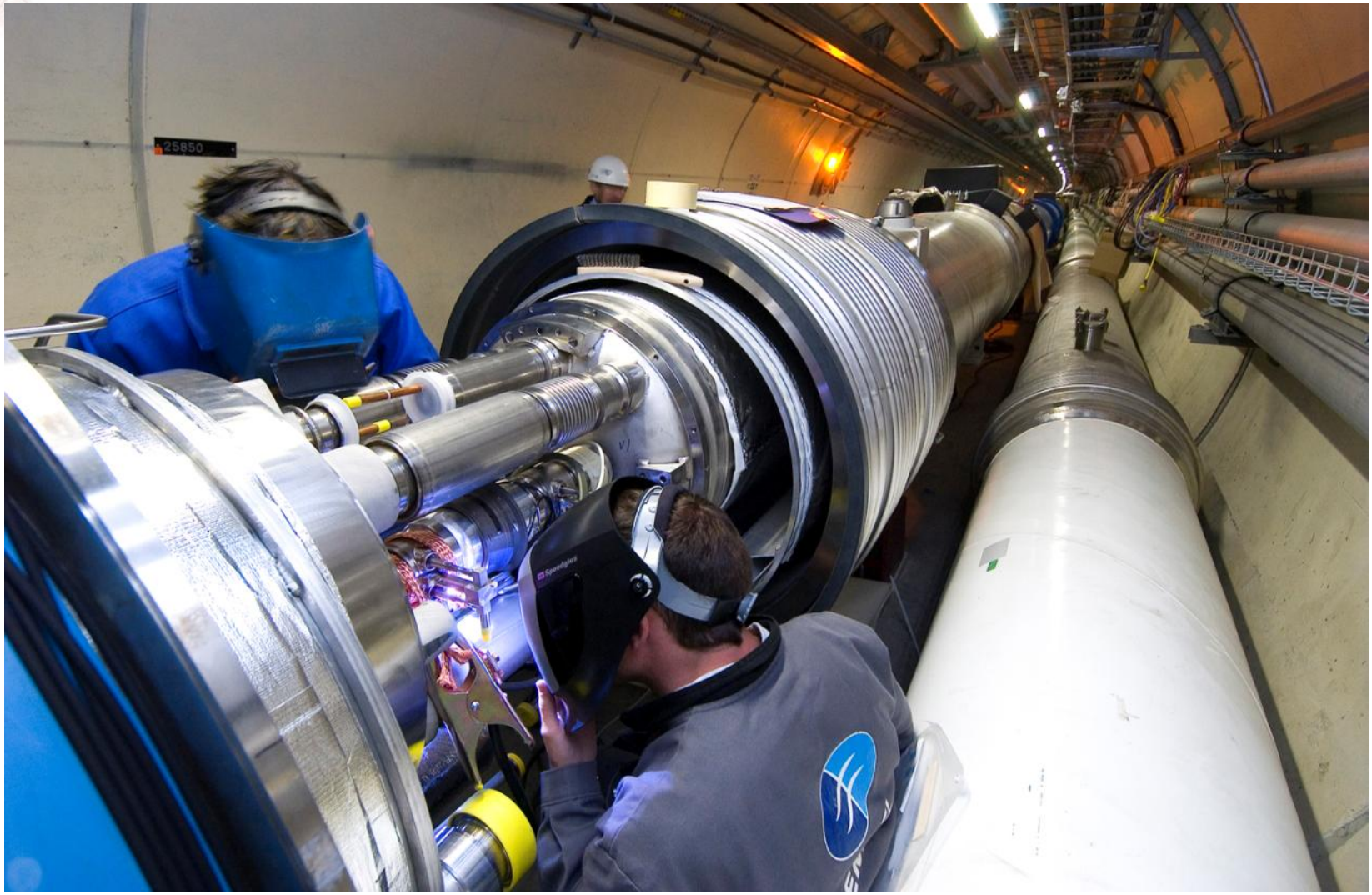


Beam 1 H dispersion on first turn
Injection to beam dump

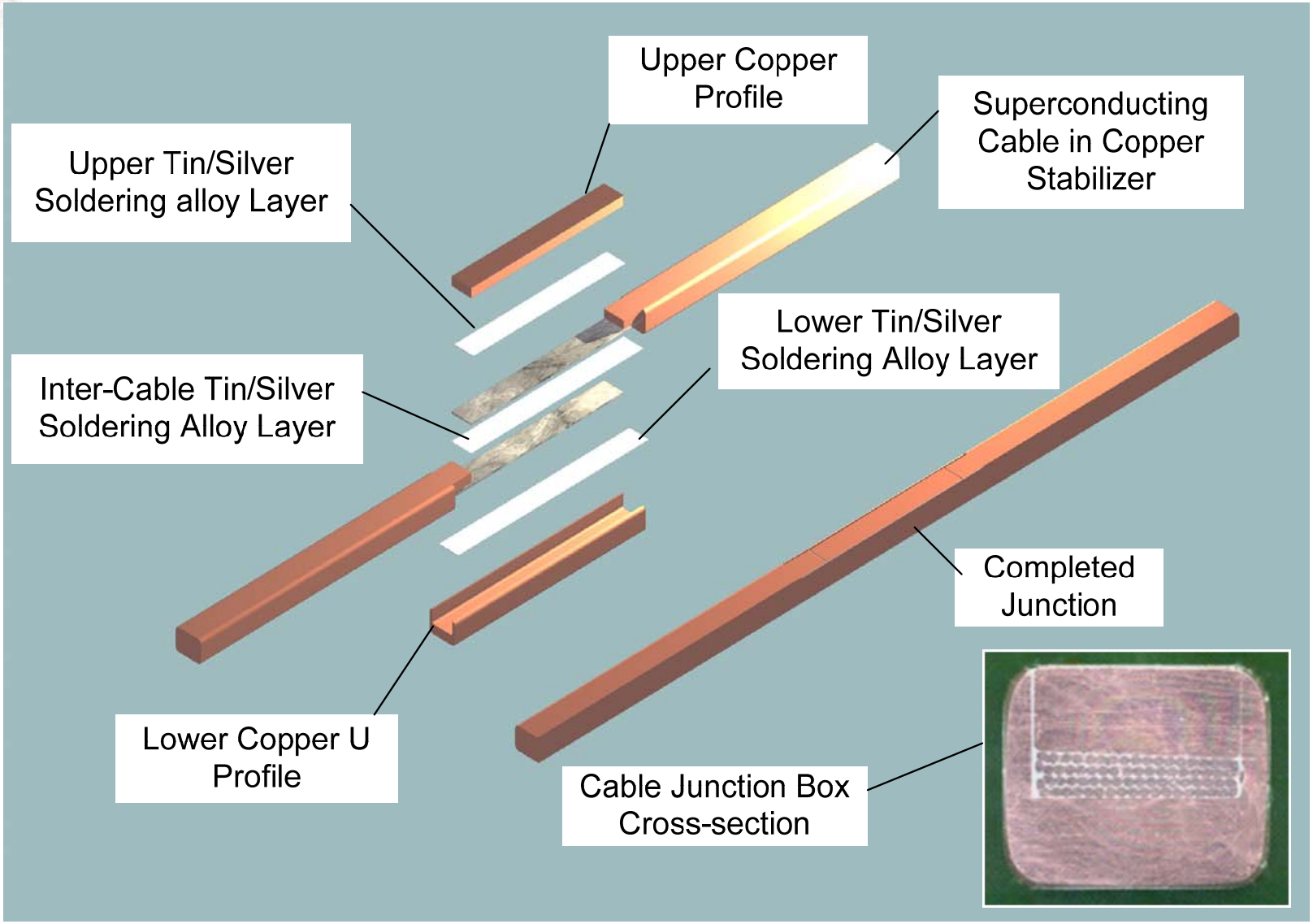


Courtesy J. Wenninger

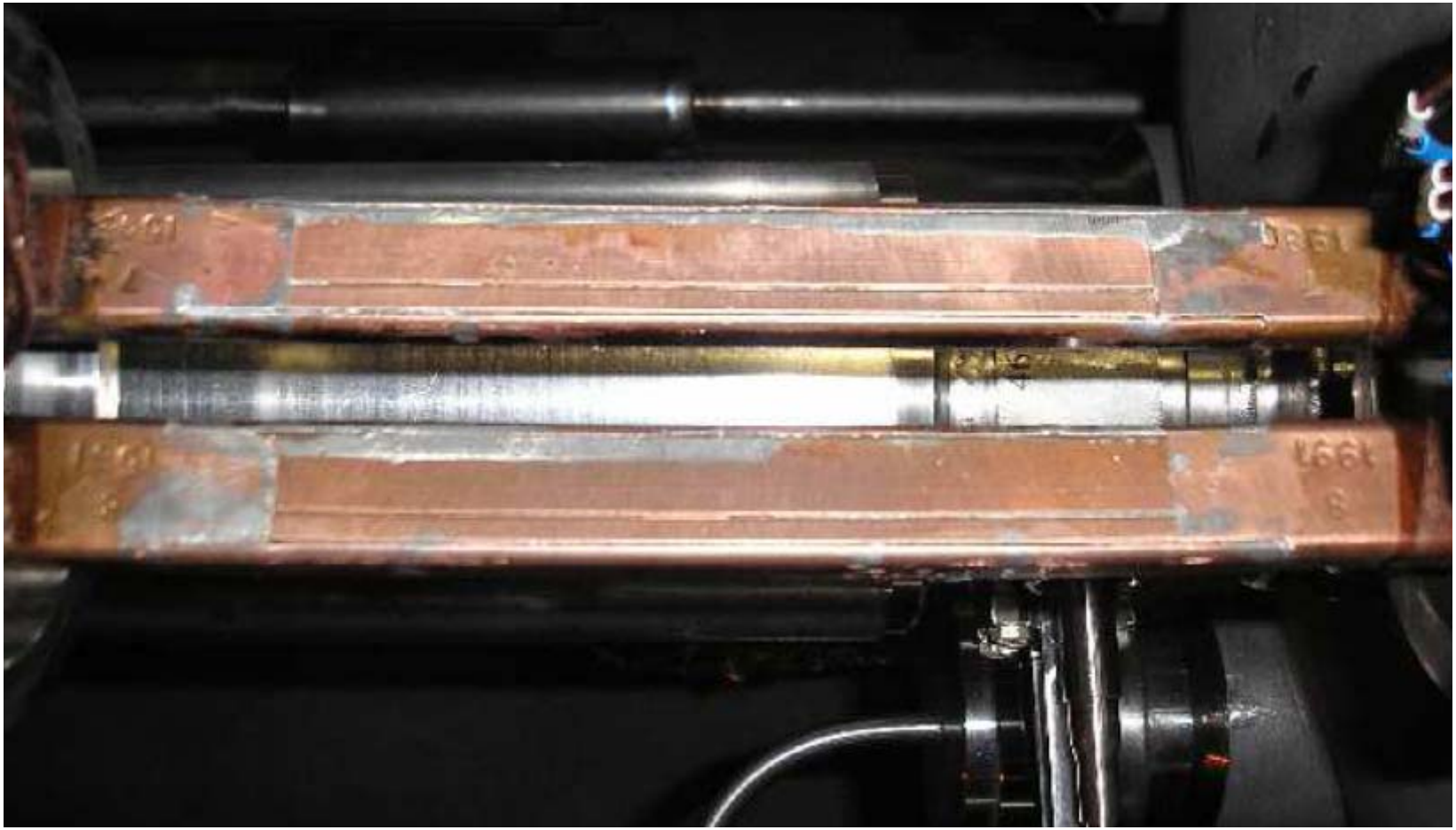
19th september incident



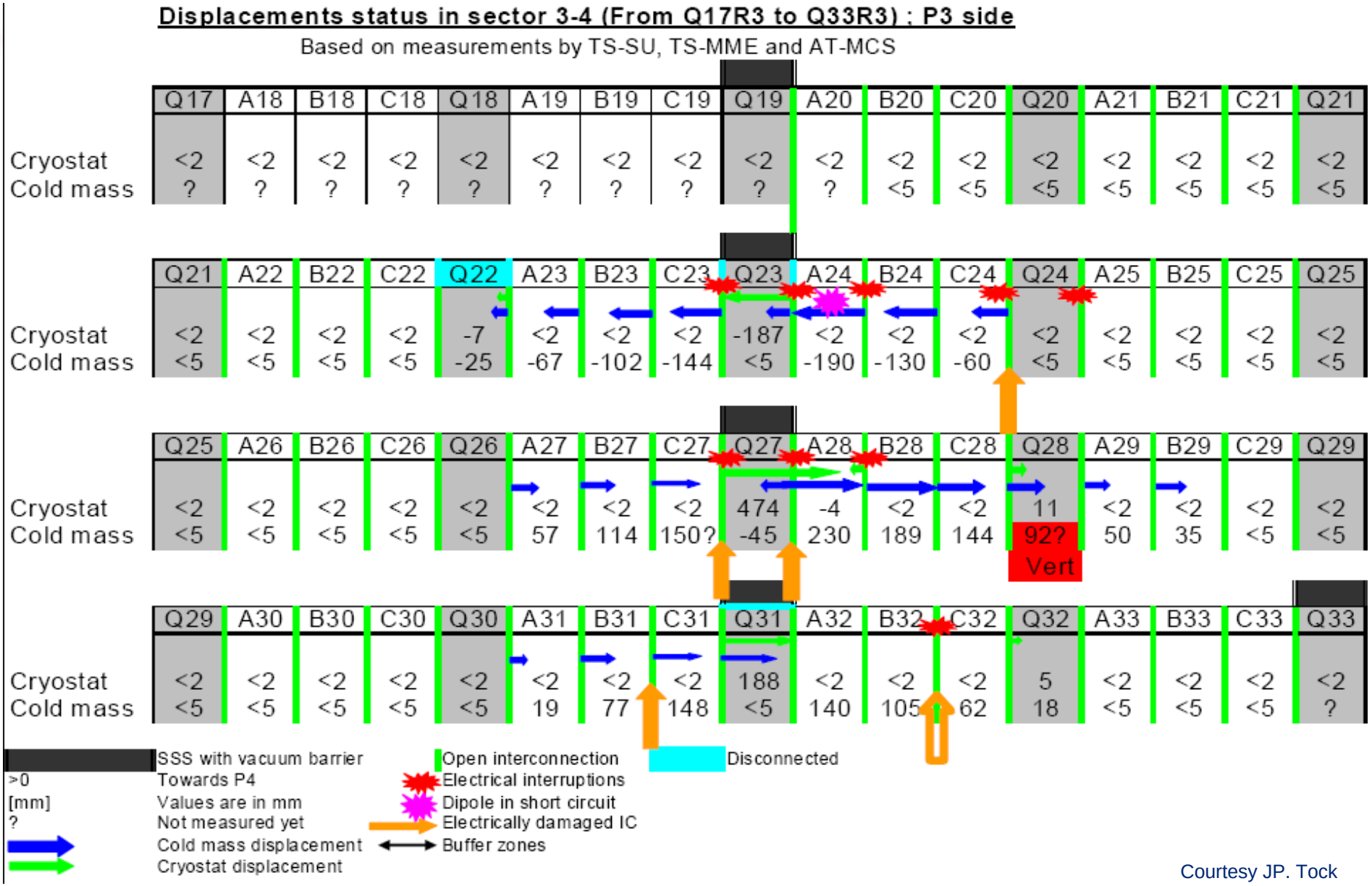
Busbar splice



Busbar splice



Cryostat and cold masses longitudinal displacements



Courtesy JP. Tock

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

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

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

- N_b, ε_n → injector chain
- β^* → 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 ± 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, …

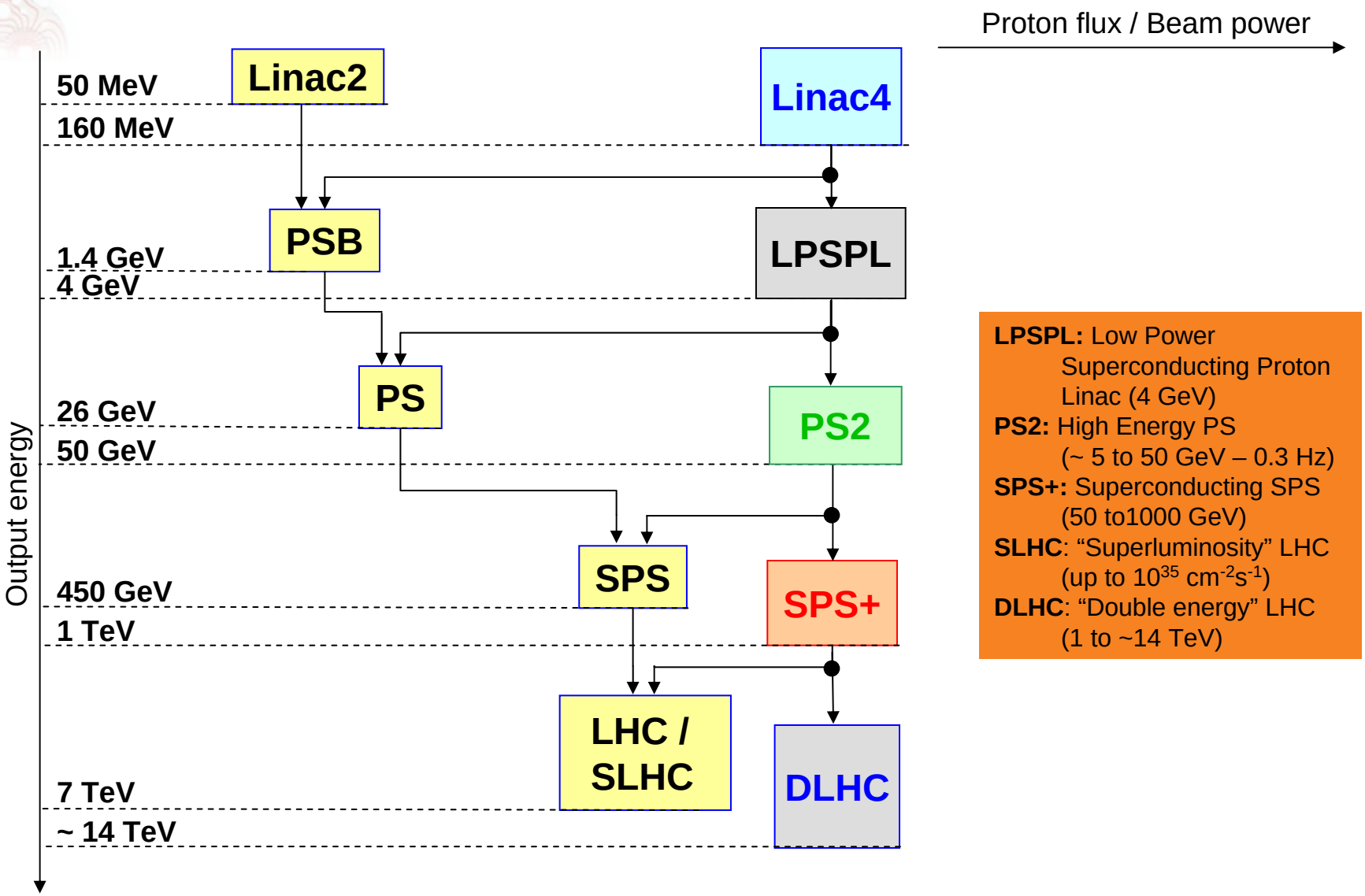
TS Department: cryostat support and alignment equipment, interfaces with the experiments, installation, design effort, …

SLHC-PP collaborators.

Milestones:

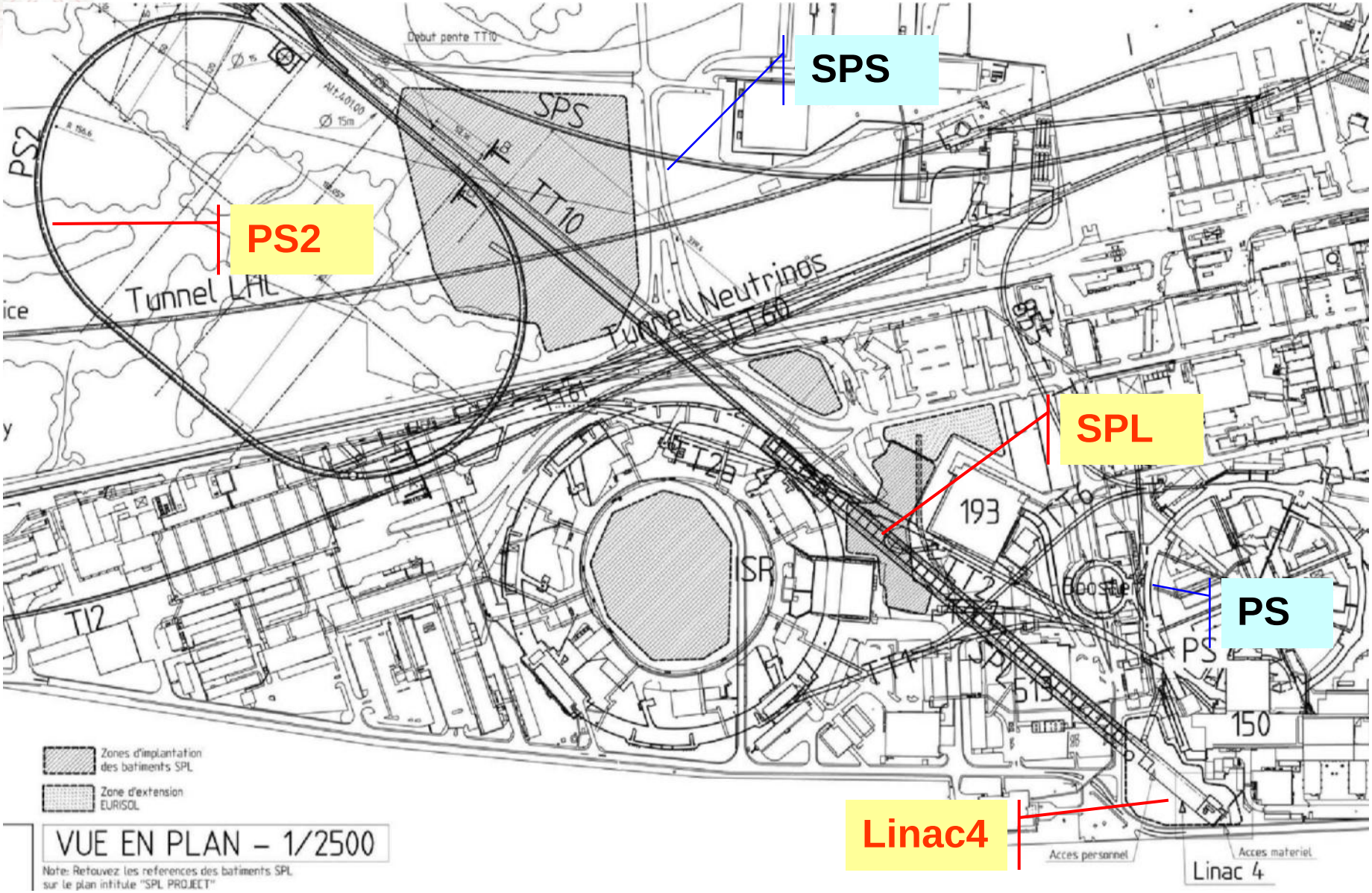
Conceptual Design Report	mid 2008
Technical Design Report	mid 2009
Model quadrupole	end 2009
Pre-series quadrupole	2010
String test	2012
Installation	shutdown 2013

Upgrade components

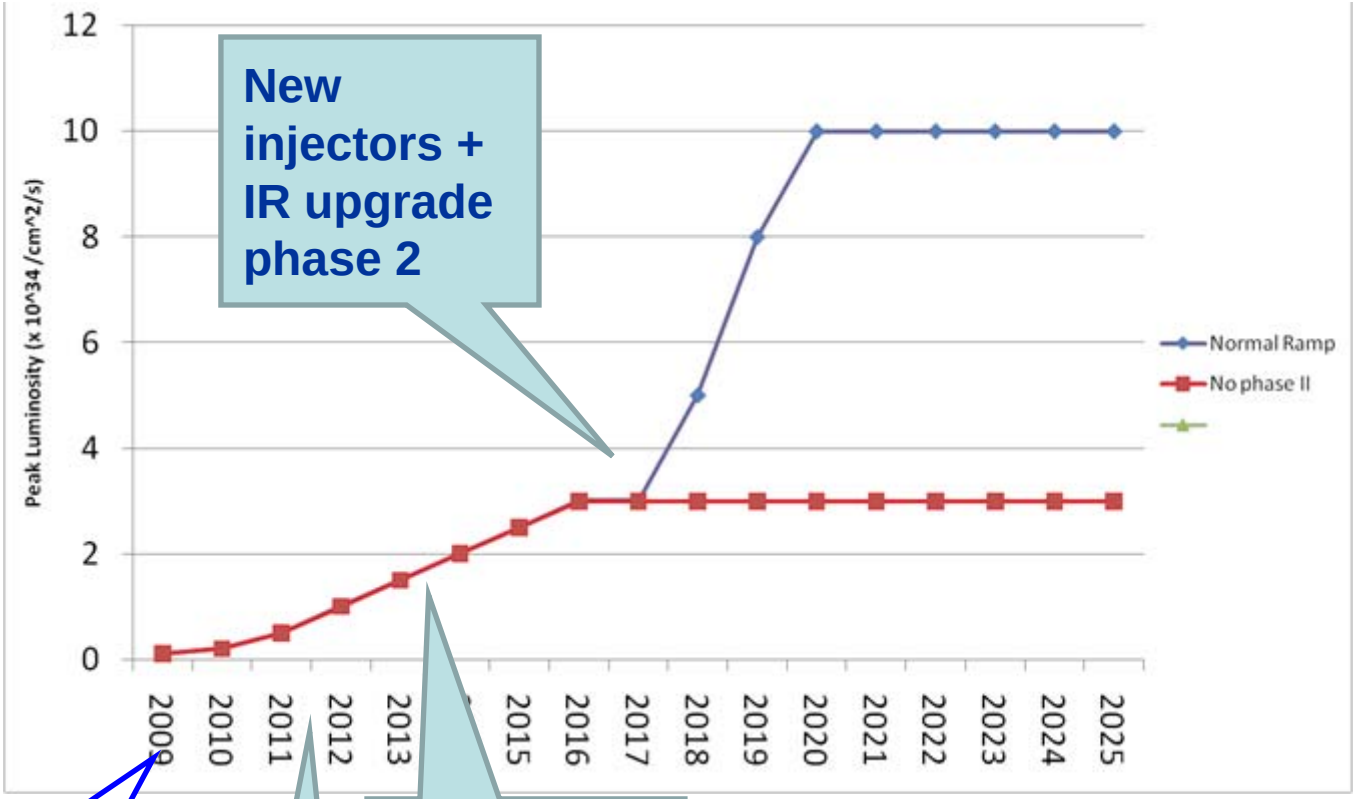


LPSPL: Low Power Superconducting Proton Linac (4 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
SPS+: Superconducting SPS (50 to1000 GeV)
SLHC: "Superluminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)
DLHC: "Double energy" LHC (1 to ~14 TeV)

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…