

# LHC status and CERN plans

Lyn Evans

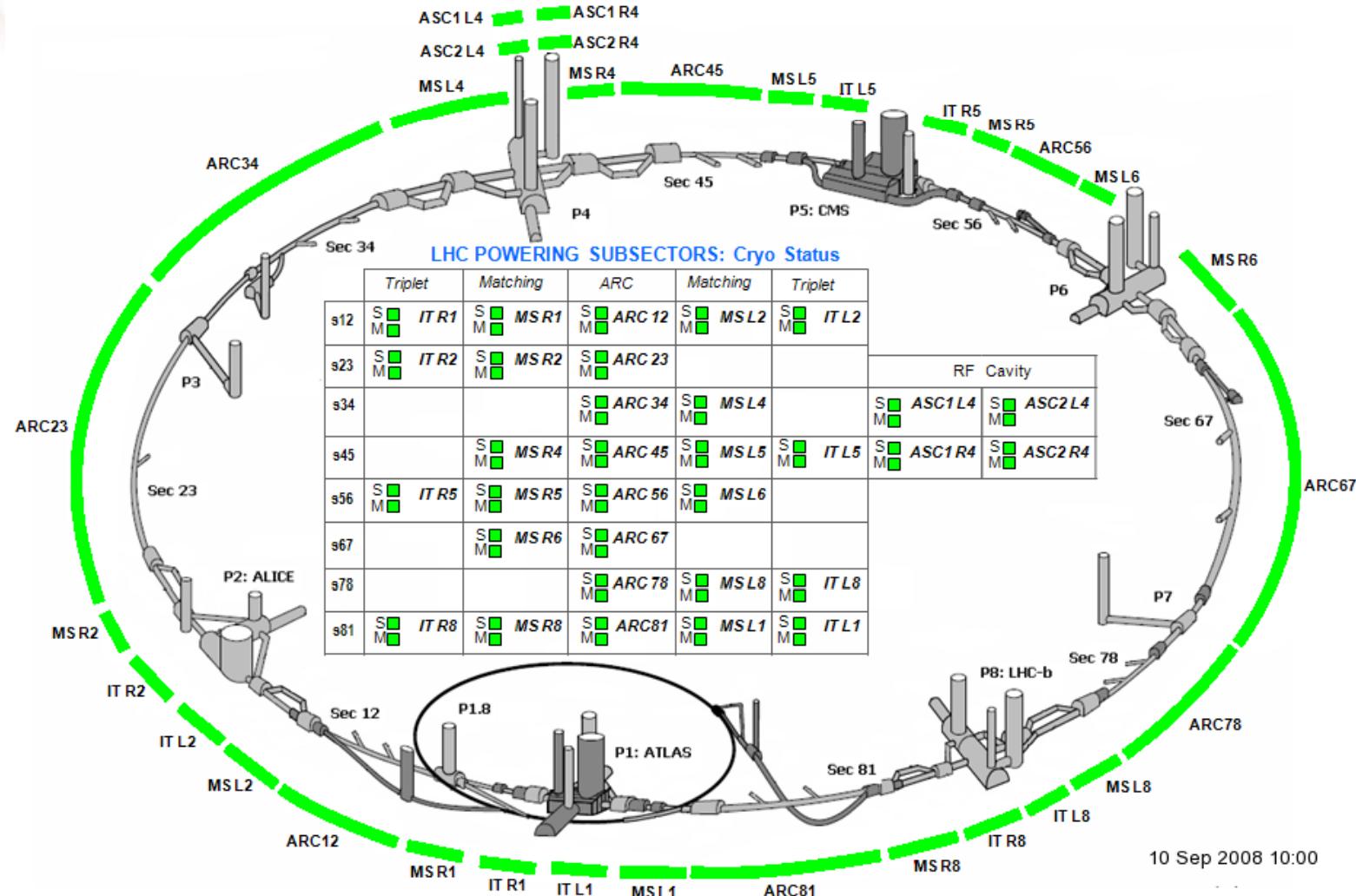


Les Rencontres de Physique de la Vallée d'Aoste  
La Thuile 5<sup>th</sup> March 2009





# LHC Cryogenics for D-day



Cryogenic status on 10<sup>th</sup> September 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.



# Large helium refrigerator for cooling down to 4.5 K



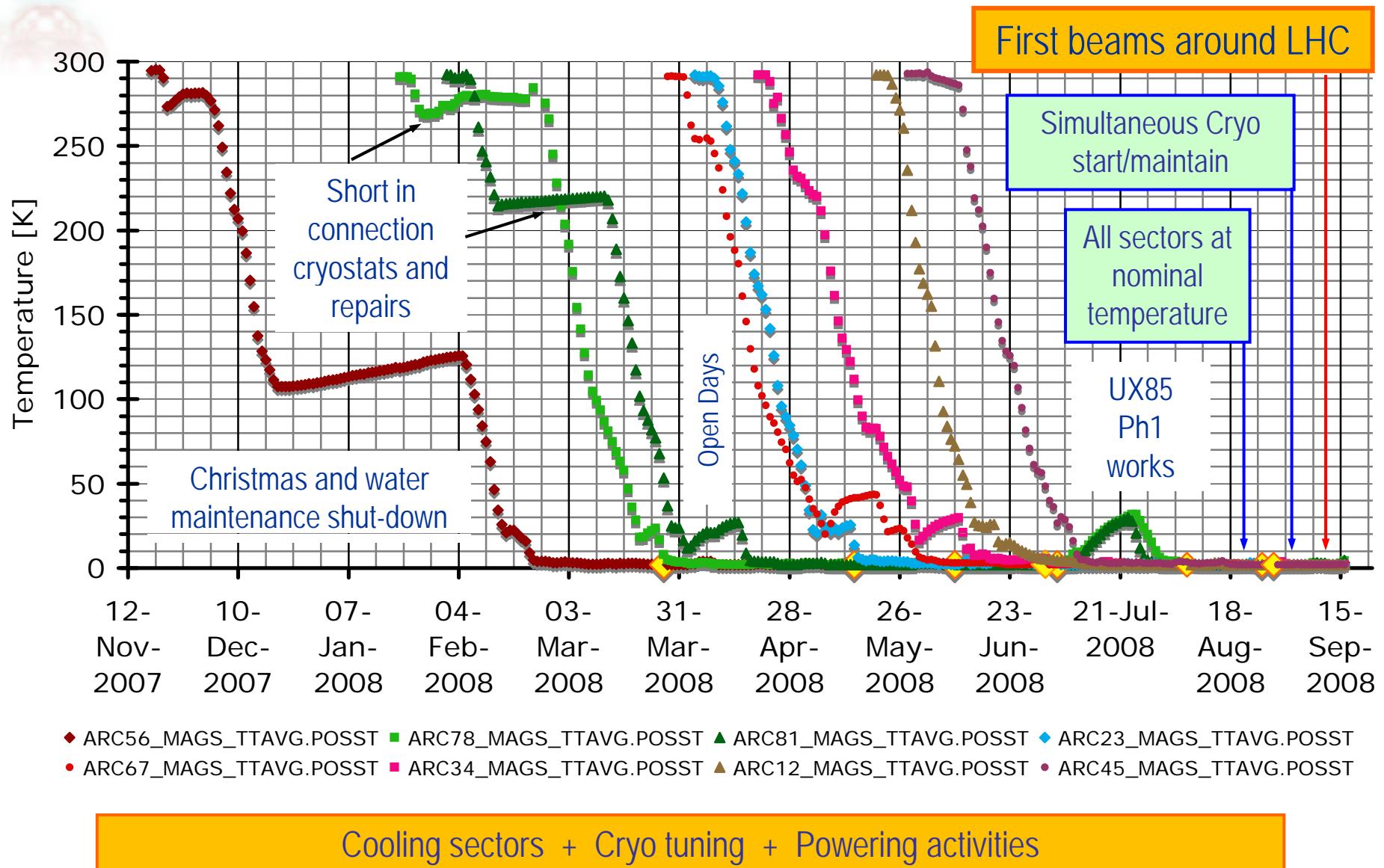
33 kW @ 50 K to 75 K  
23 kW @ 4.6 K to 20 K  
41 g/s liquefaction

600 kW precooling to 80 K  
with LN<sub>2</sub> (up to ~5 tons/h)





# First cool-down of LHC sectors

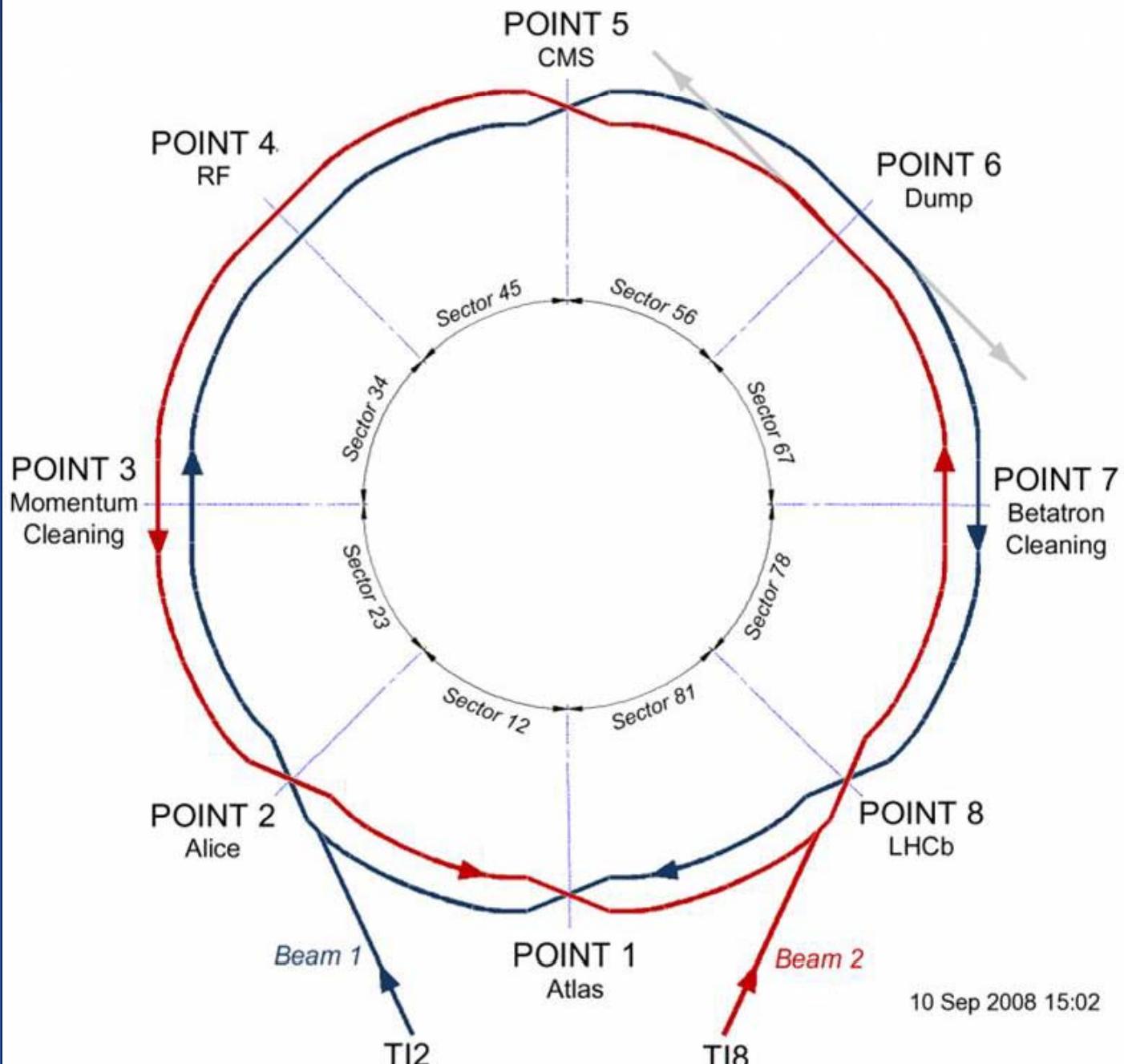




# Situation on 10th September

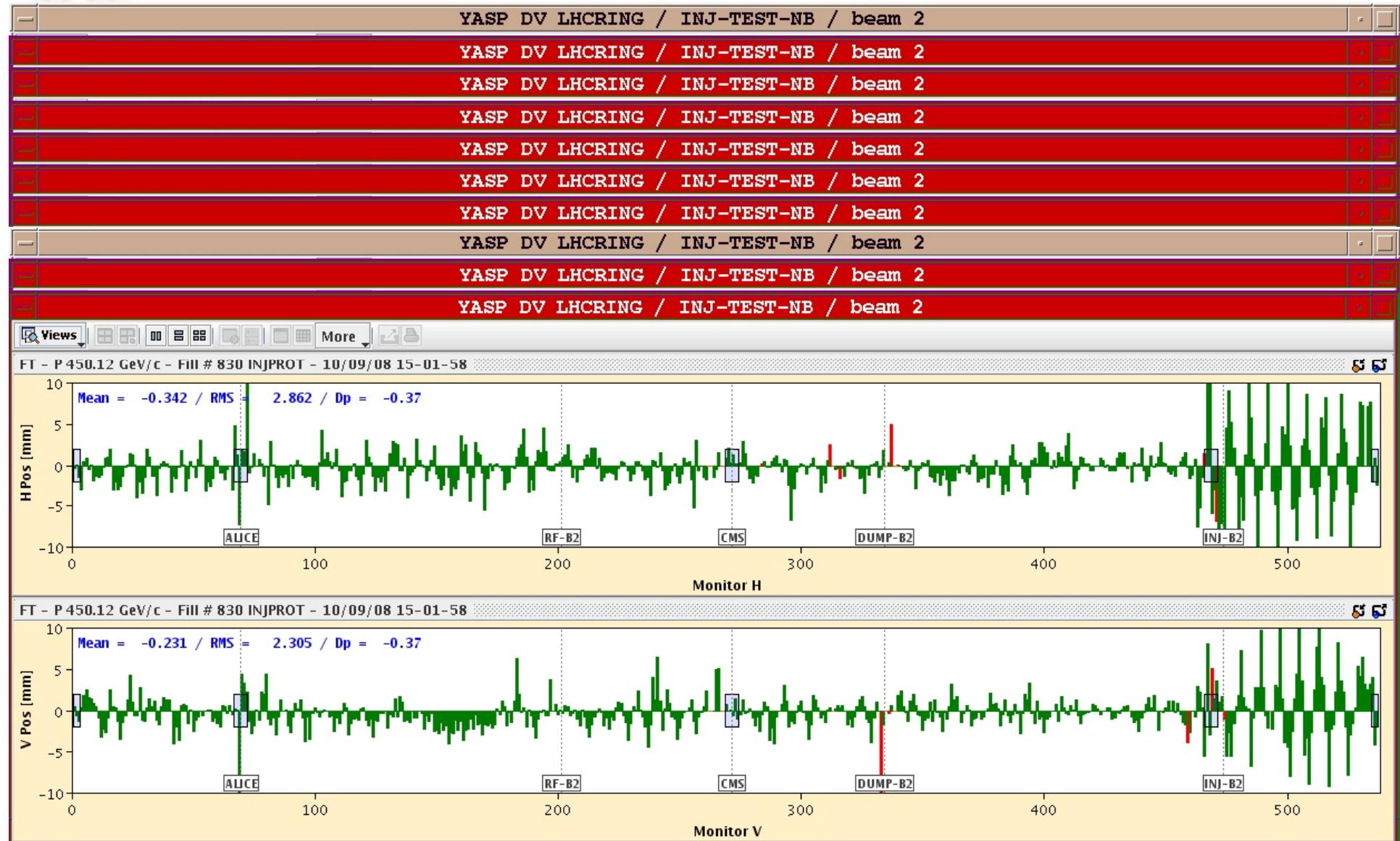


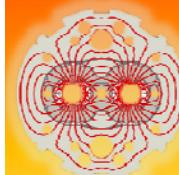
- 7 out of 8 sectors fully commissioned for 5 TeV operation and 1 sector (3-4) commissioned up to 4 TeV.



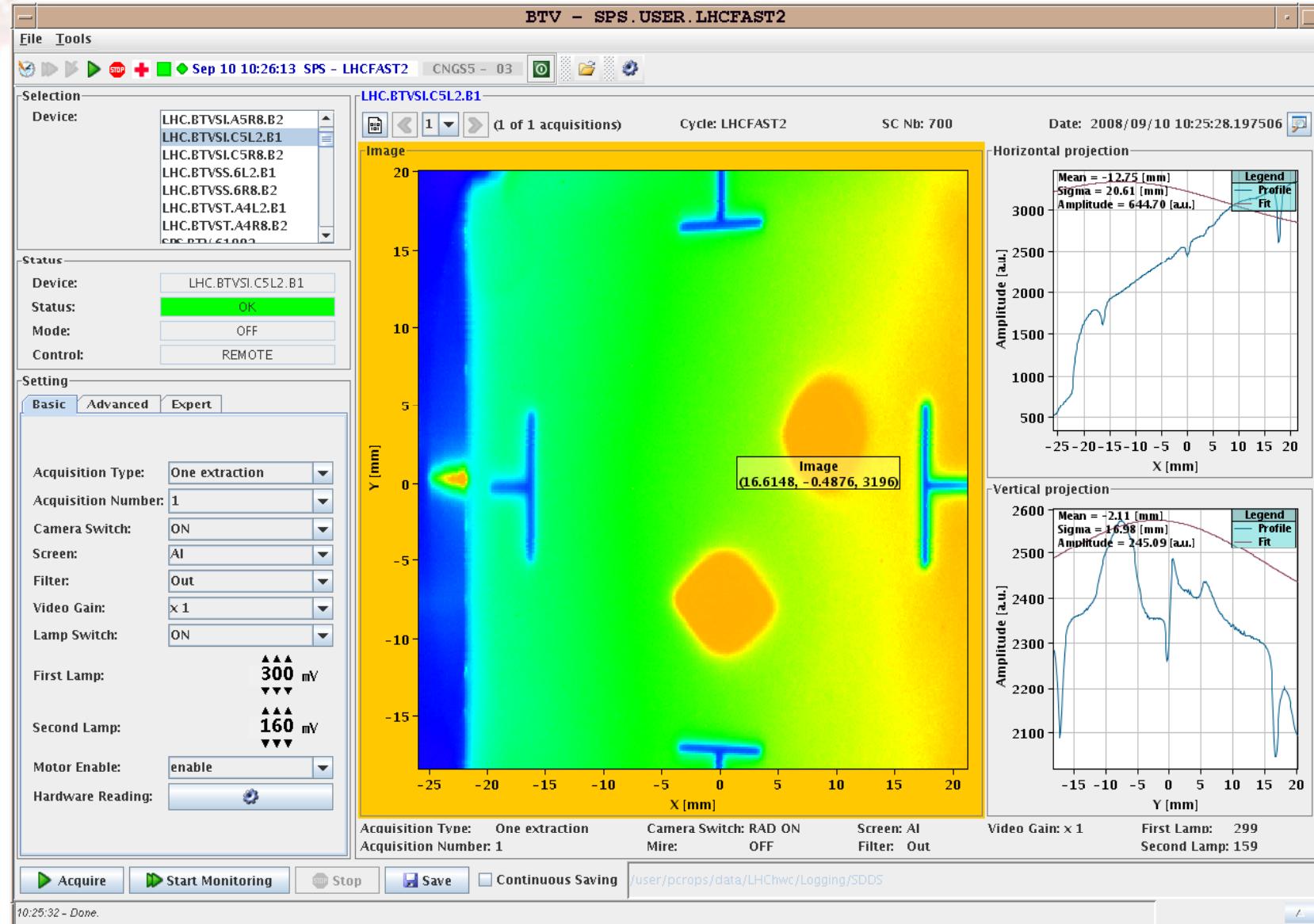


# Beam 2 first beam – D-Day



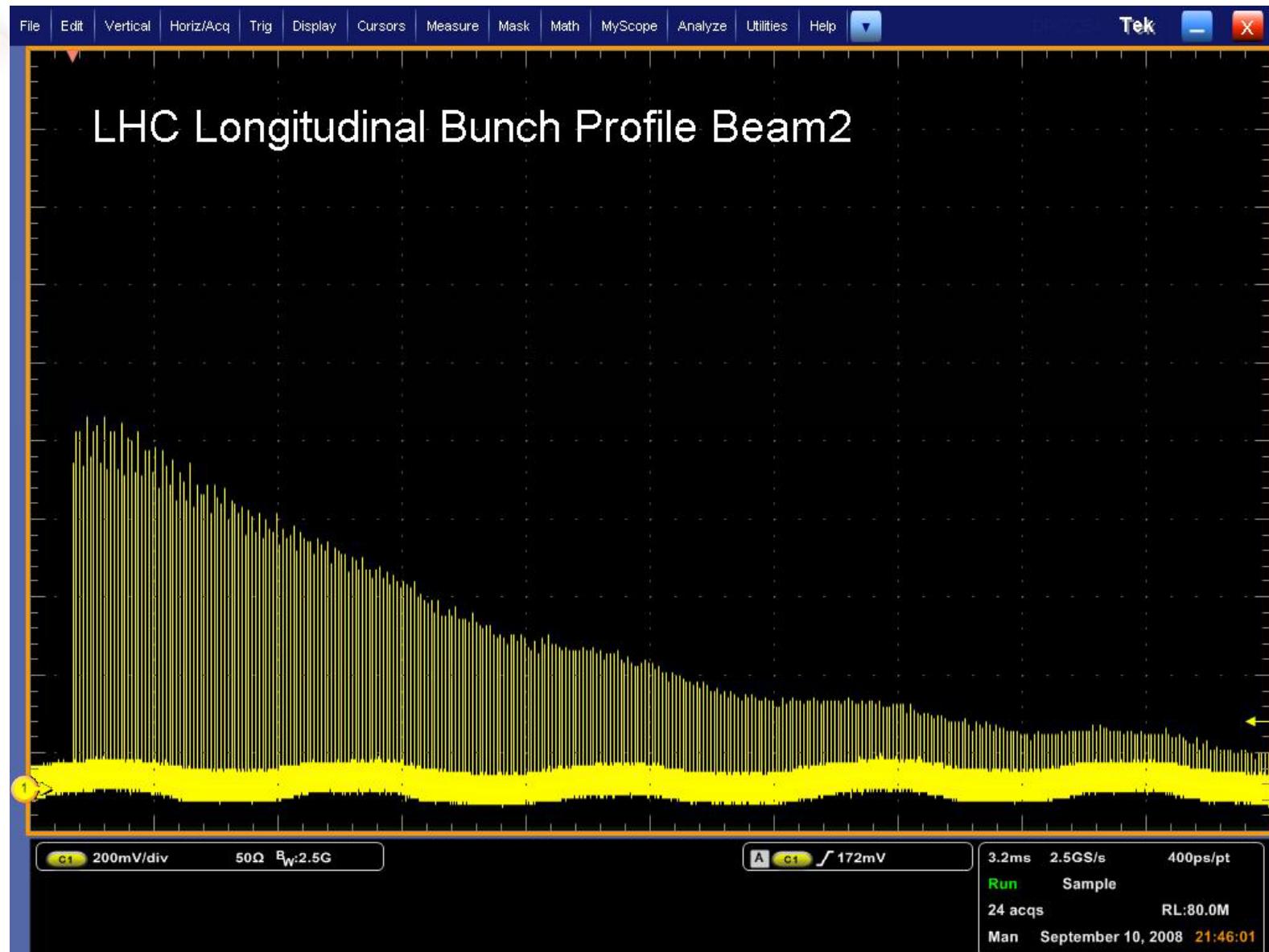


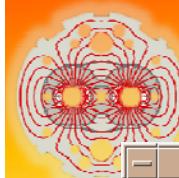
# Beam on turns 1 and 2



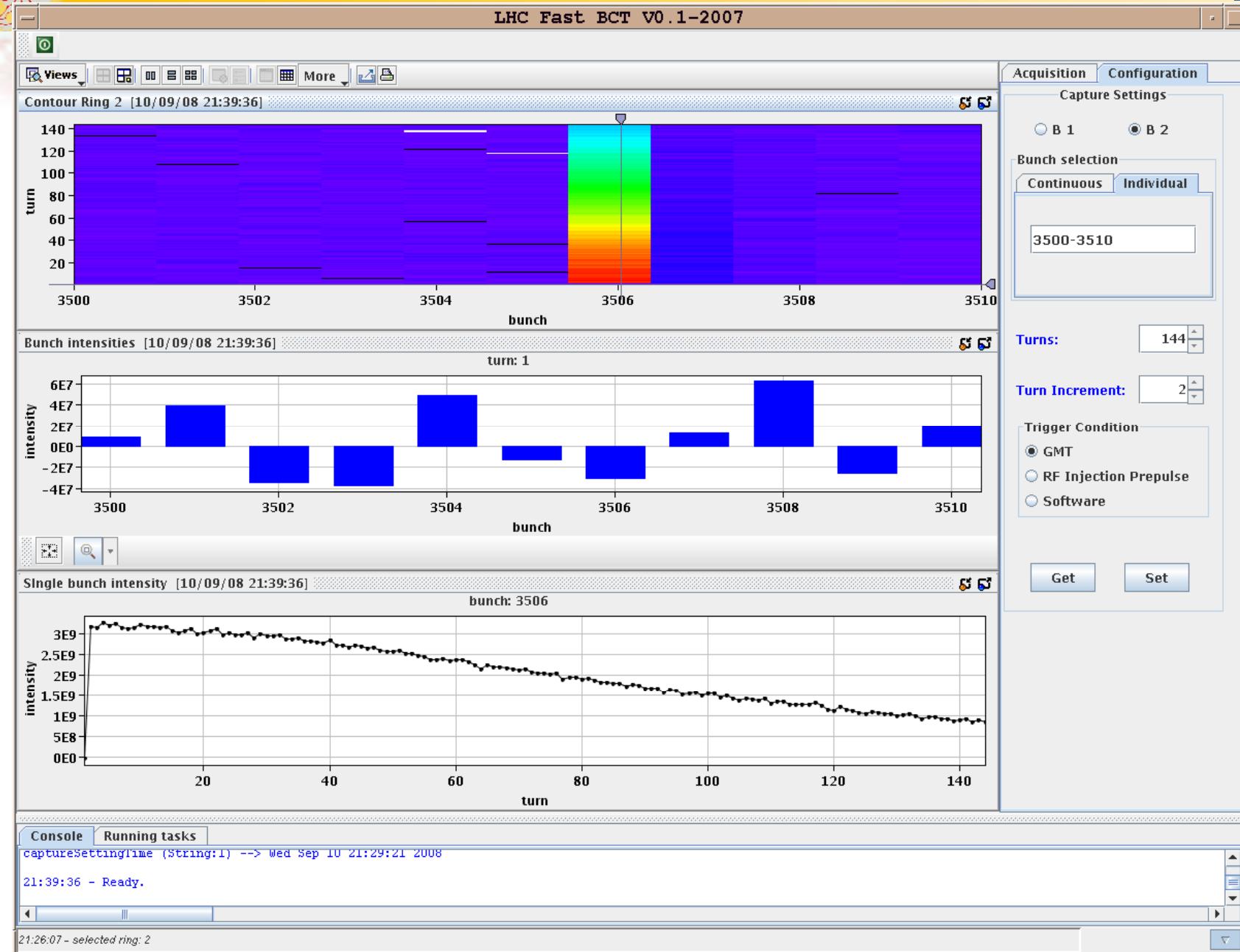


# Few 100 turns



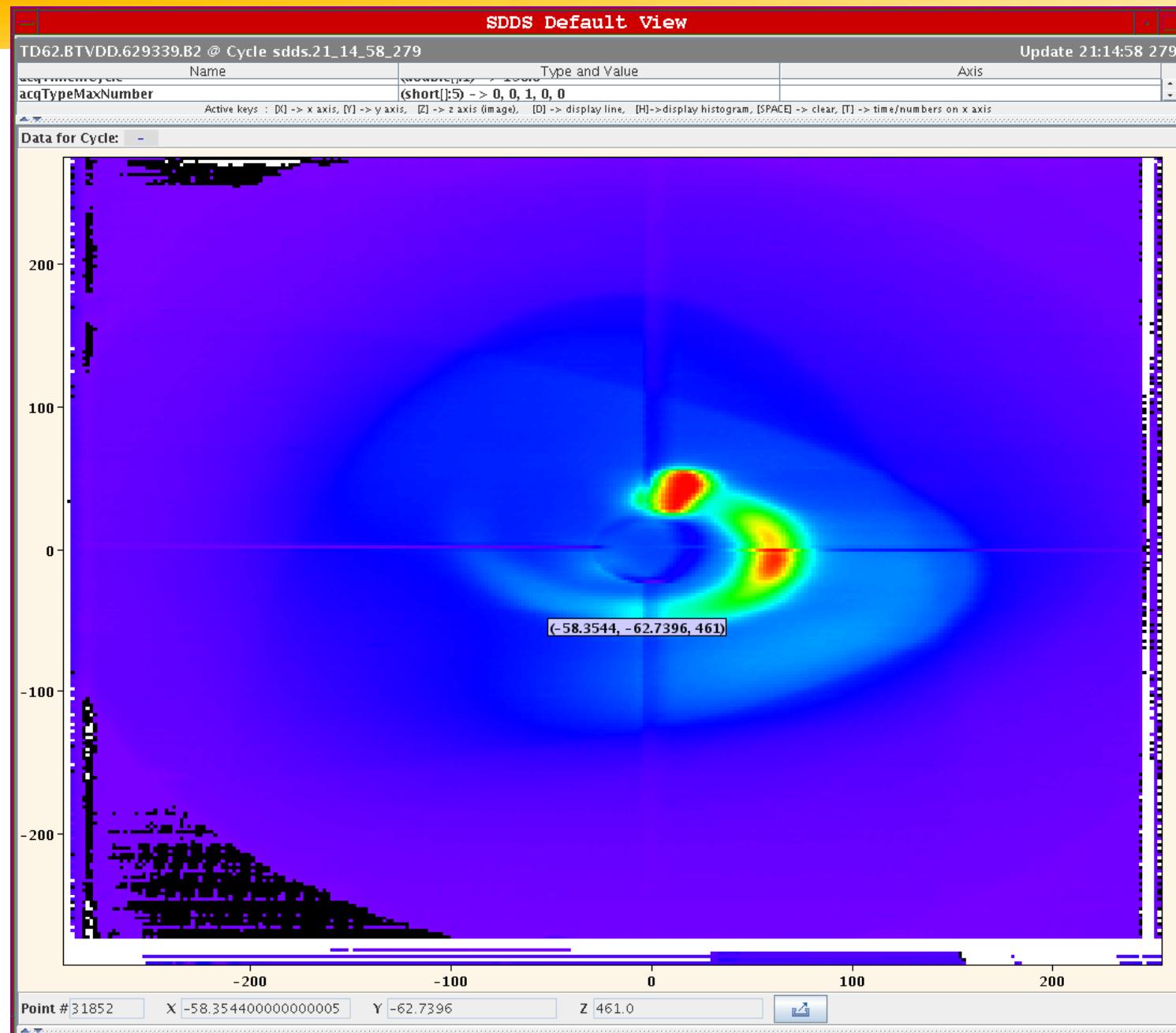


# Fast BCT



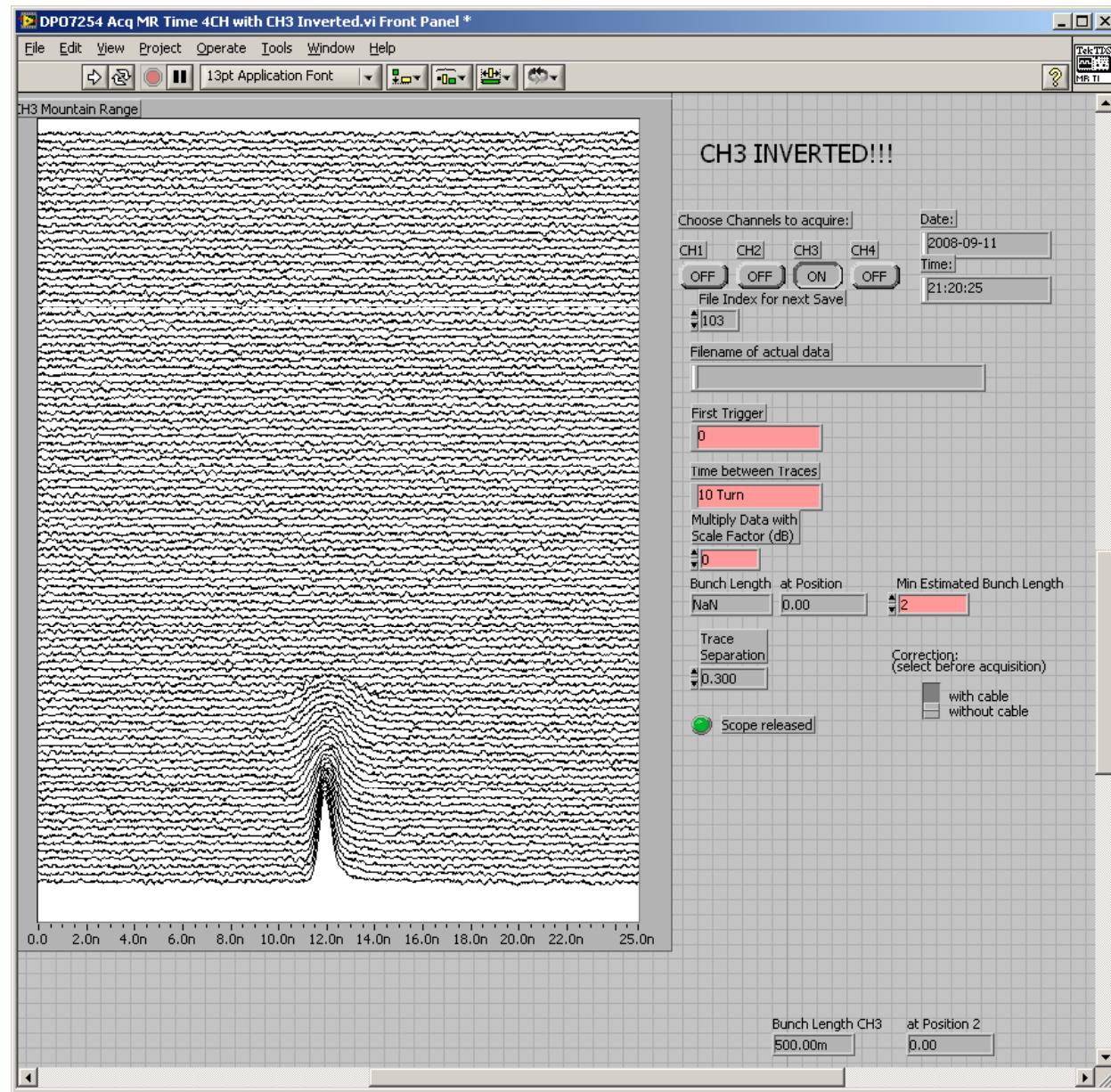


# Dump dilution sweep



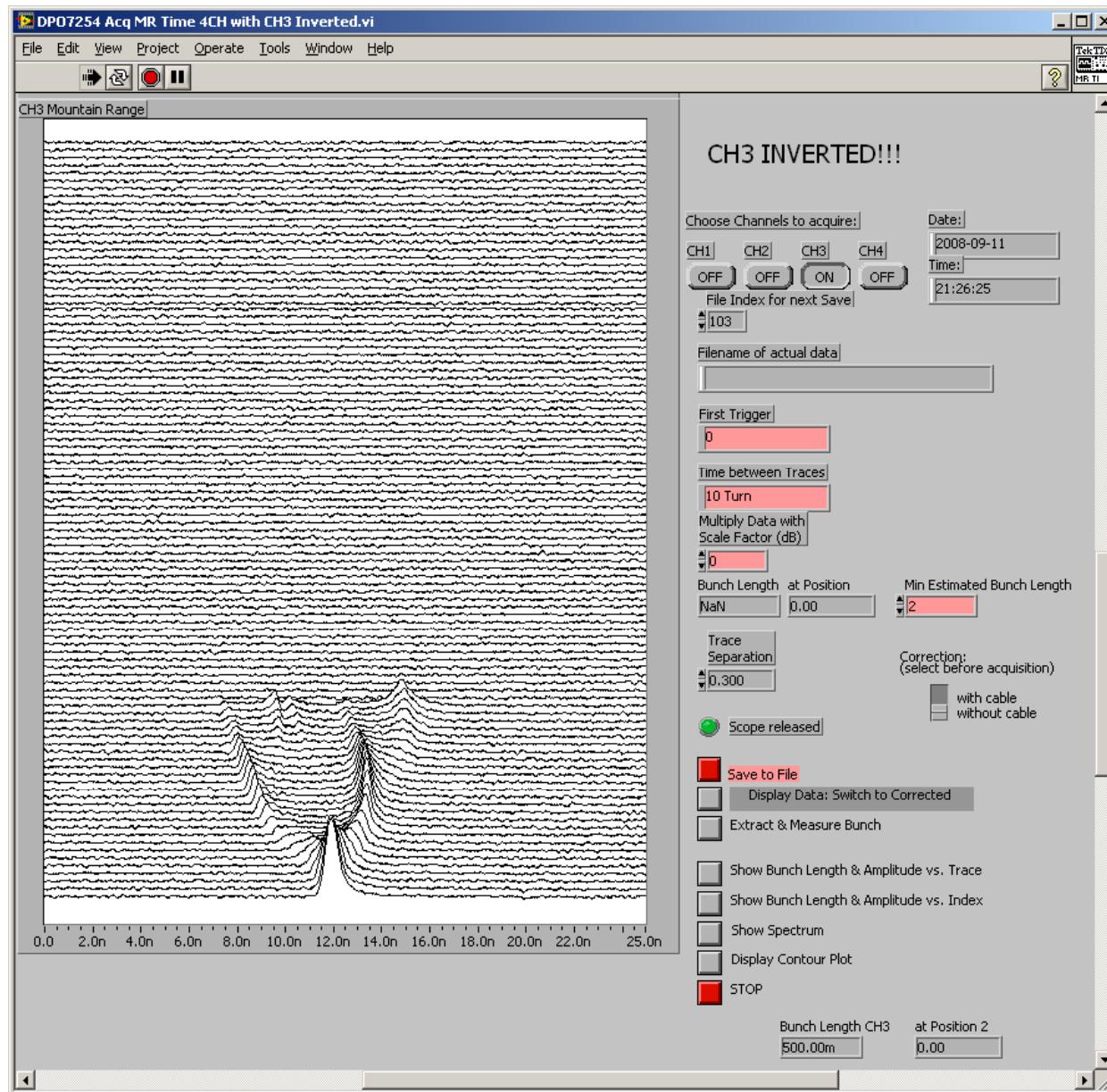


# No RF, debunching in ~ 25\*10 turns, i.e. roughly 25 mS





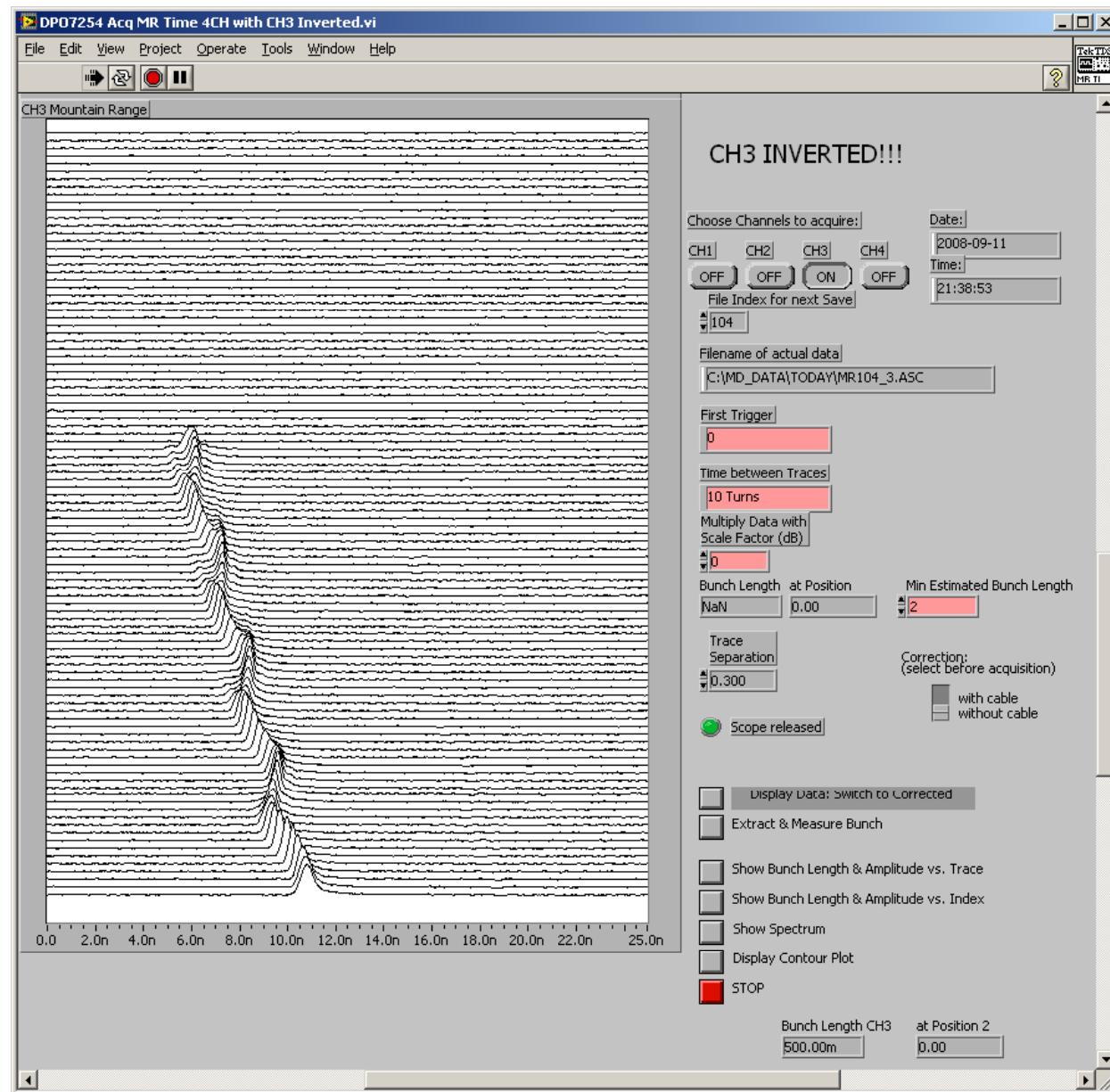
# First attempt at capture, at exactly the wrong injection phase...



Courtesy E. Ciapala



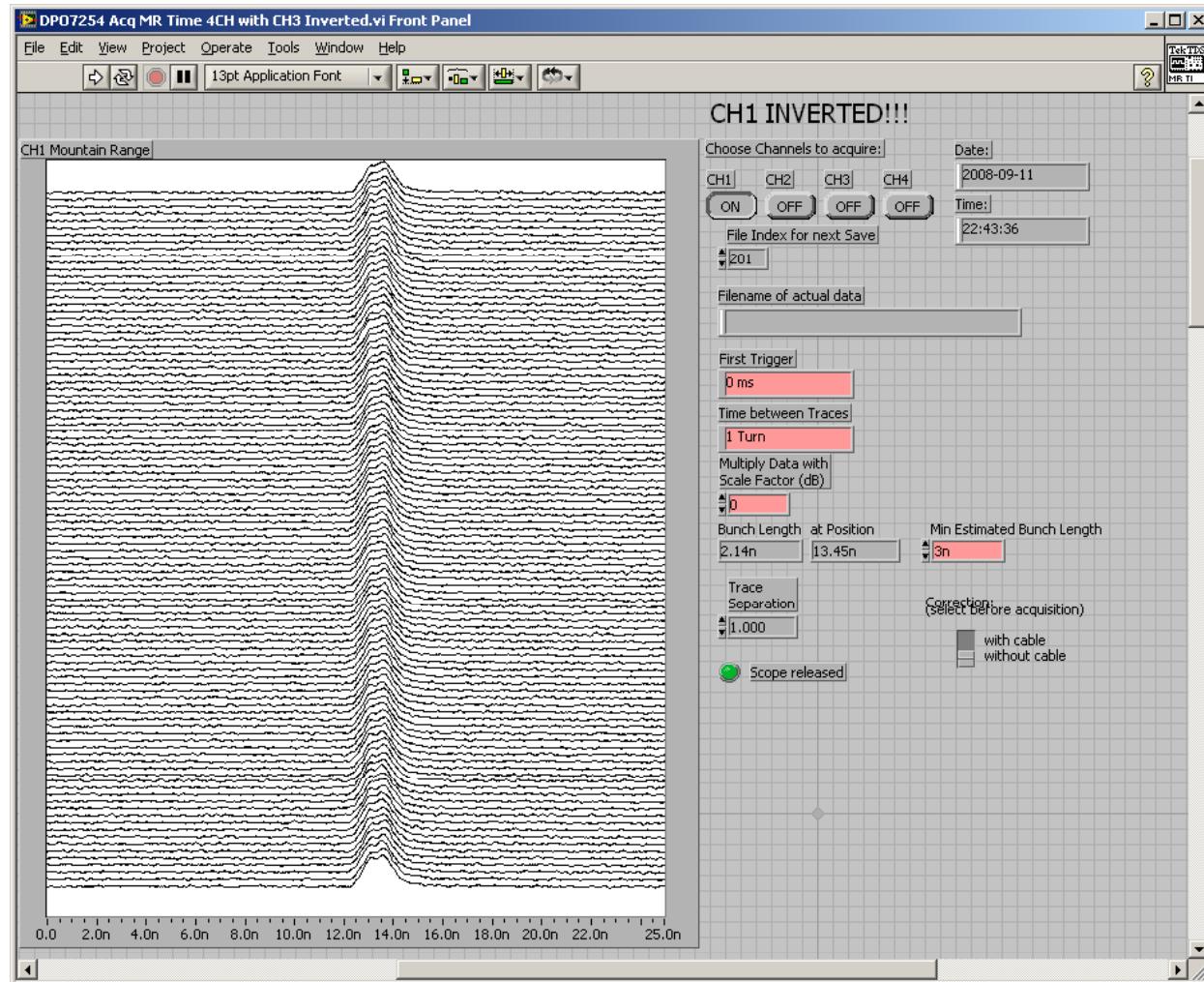
# Capture with corrected injection phasing



Courtesy E. Ciapala

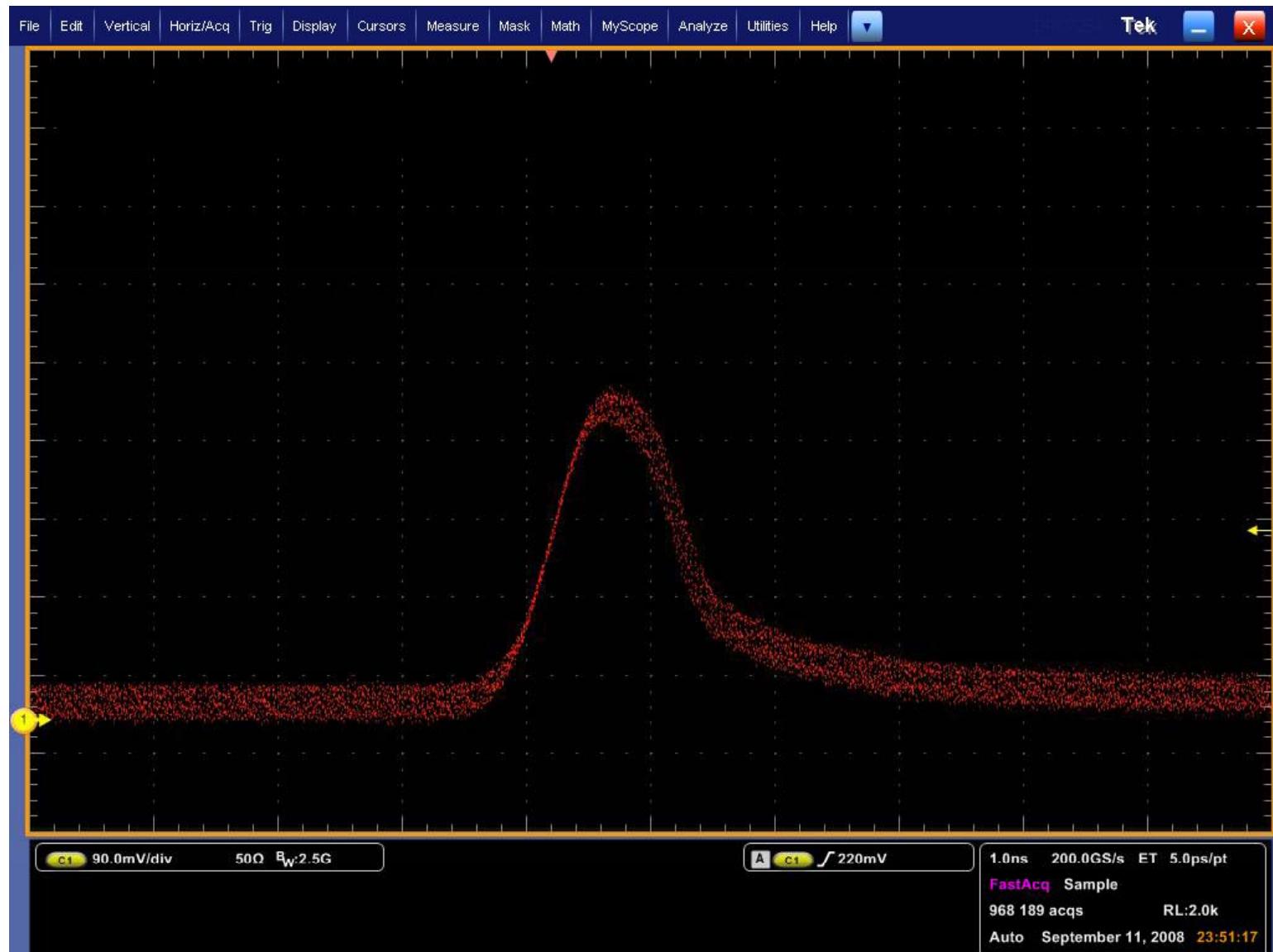


# Capture with optimum injection phasing, correct reference



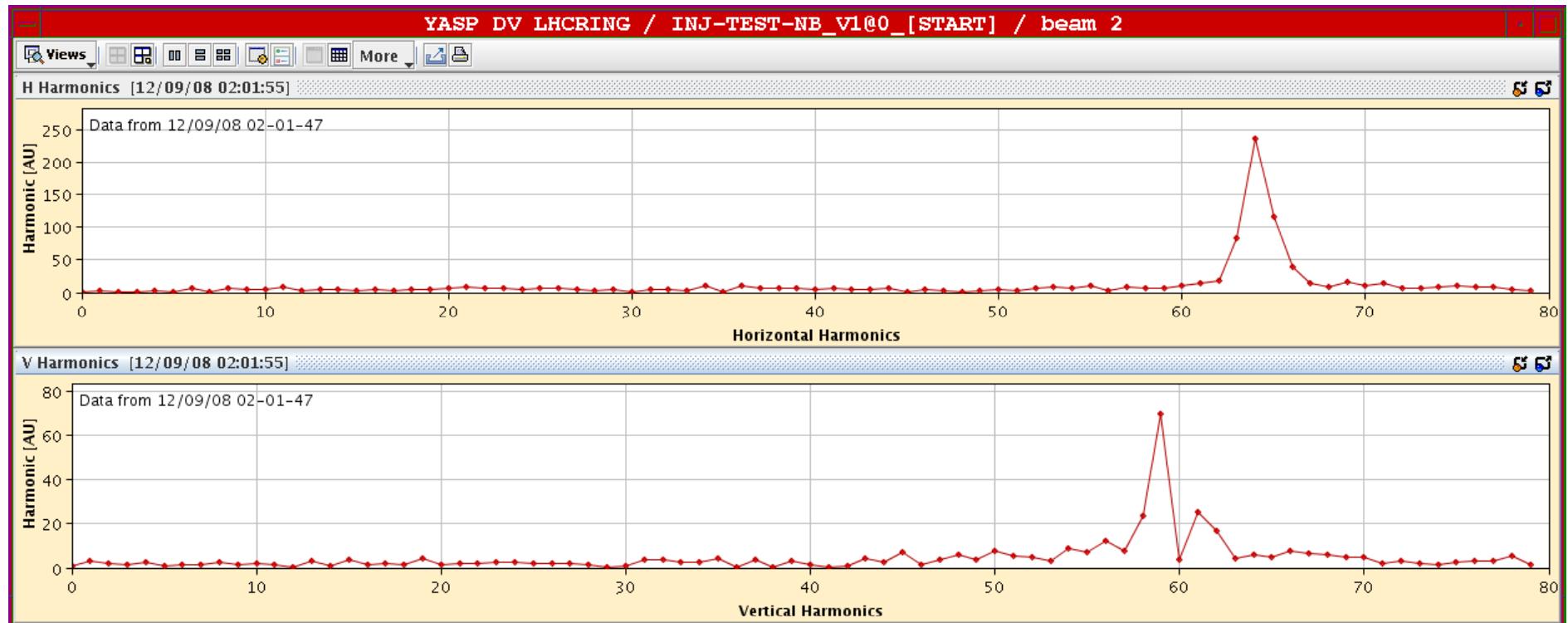


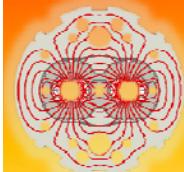
# LHC longitudinal bunch profile Beam 2



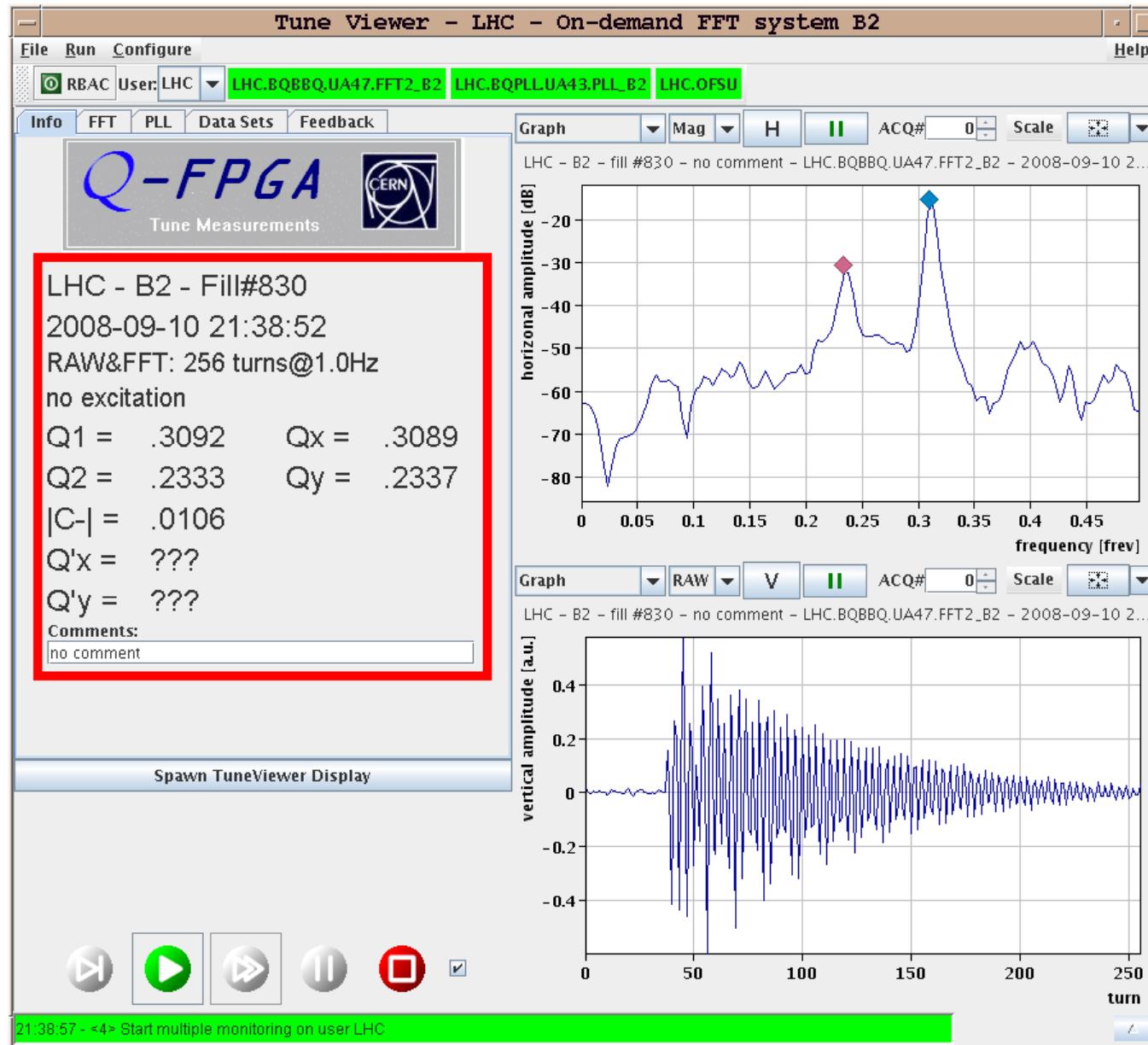


# Integer tunes



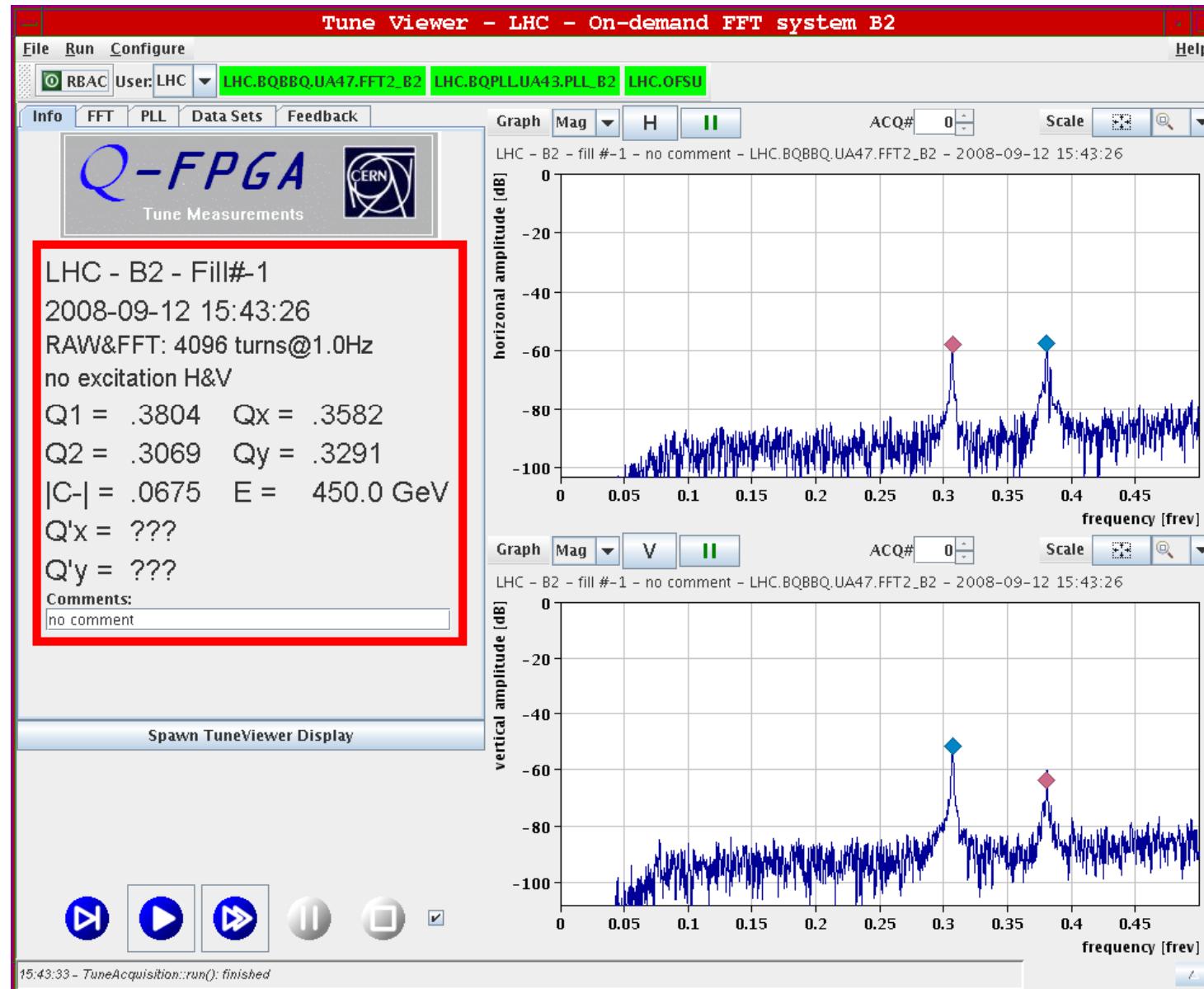


# Tune measurements



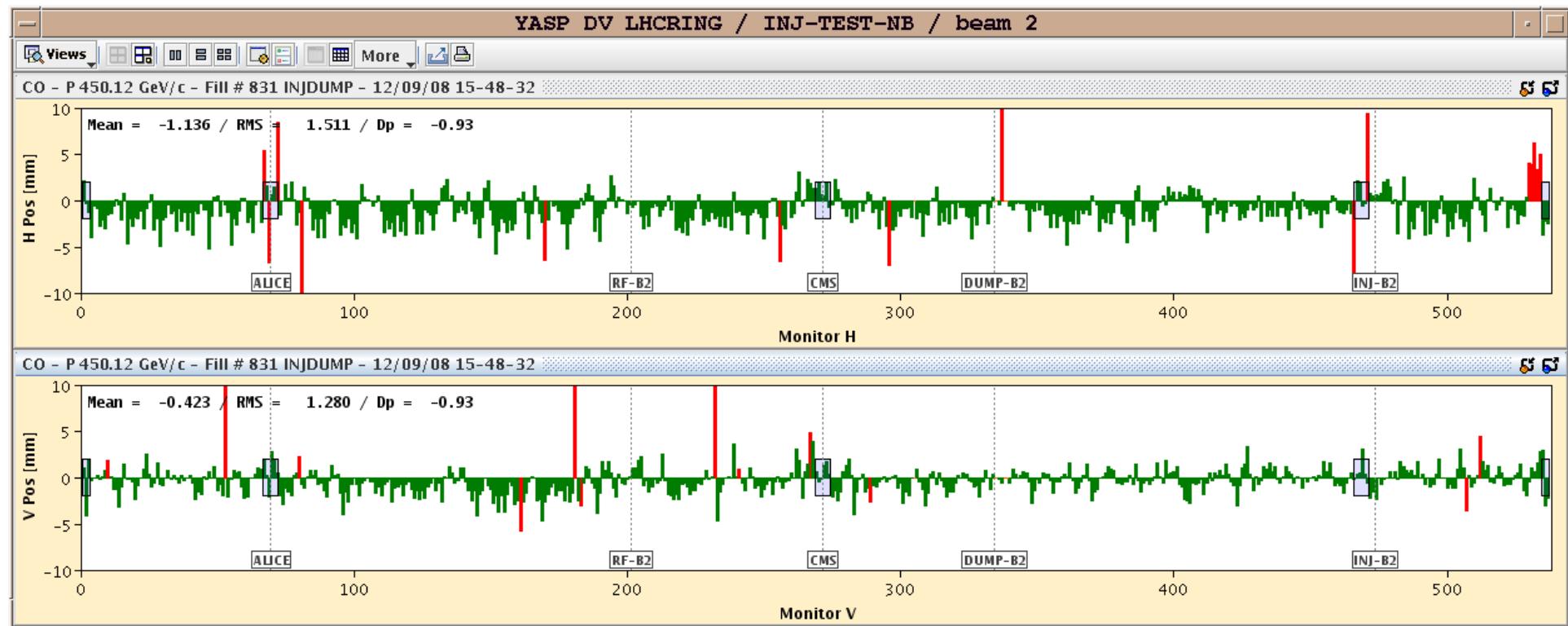


# Fractional tune spectrum H & V (Beam2) – closest Q approach ~ 0.06 due to coupling



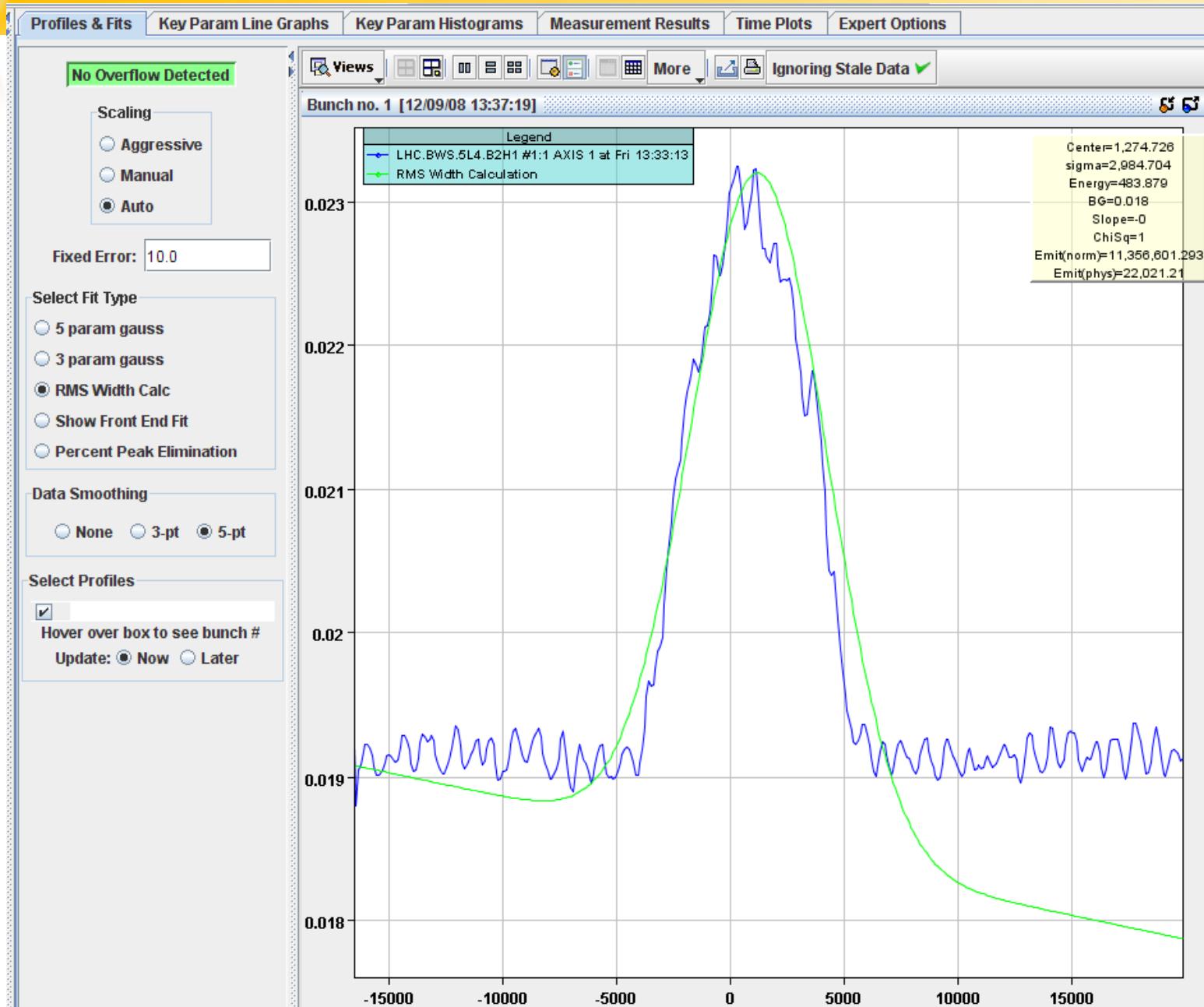


## Corrected closed orbit on B2. Energy offset of ~ -0.9 permill due to the capture frequency.



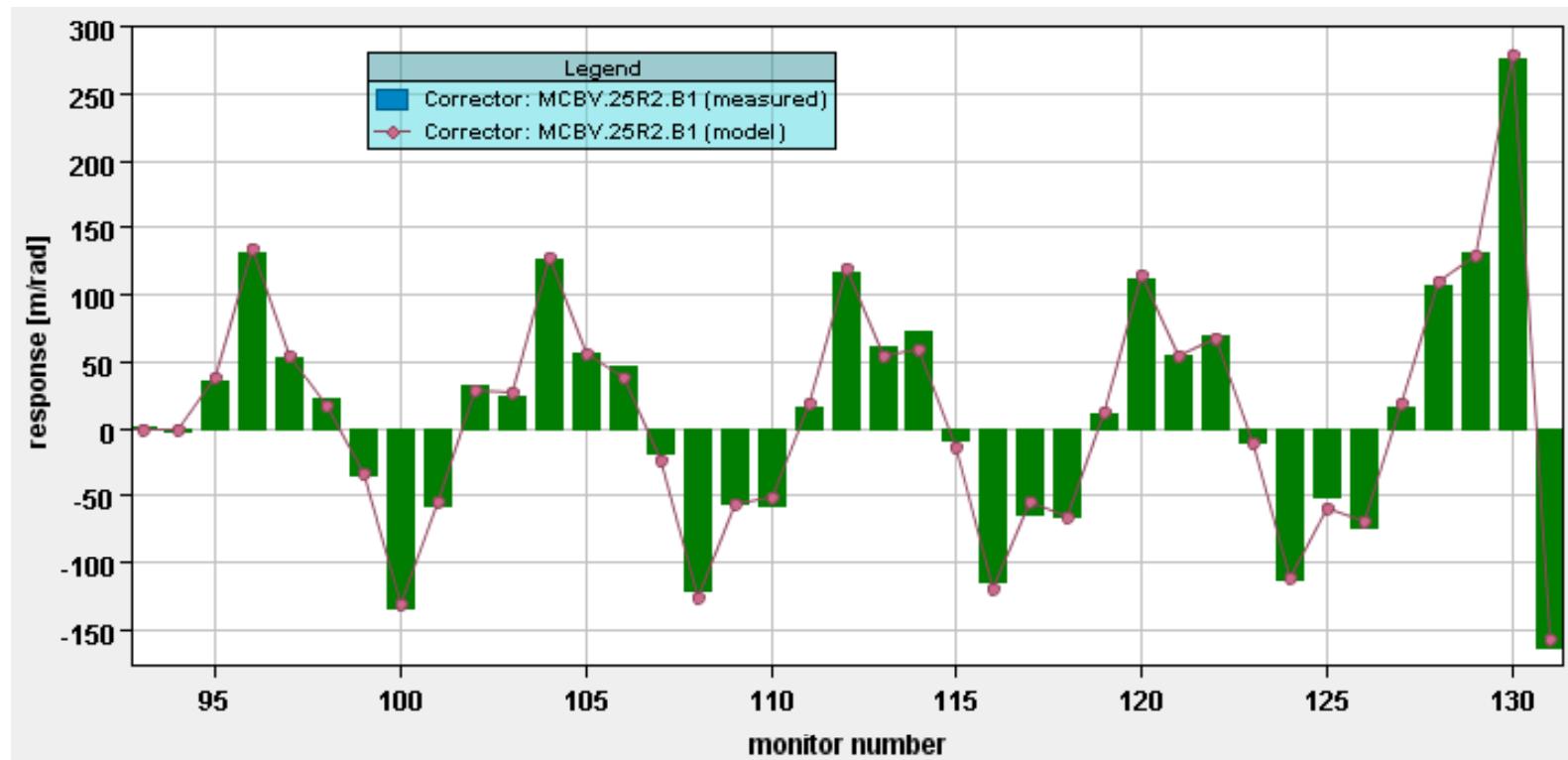


# H wire scan



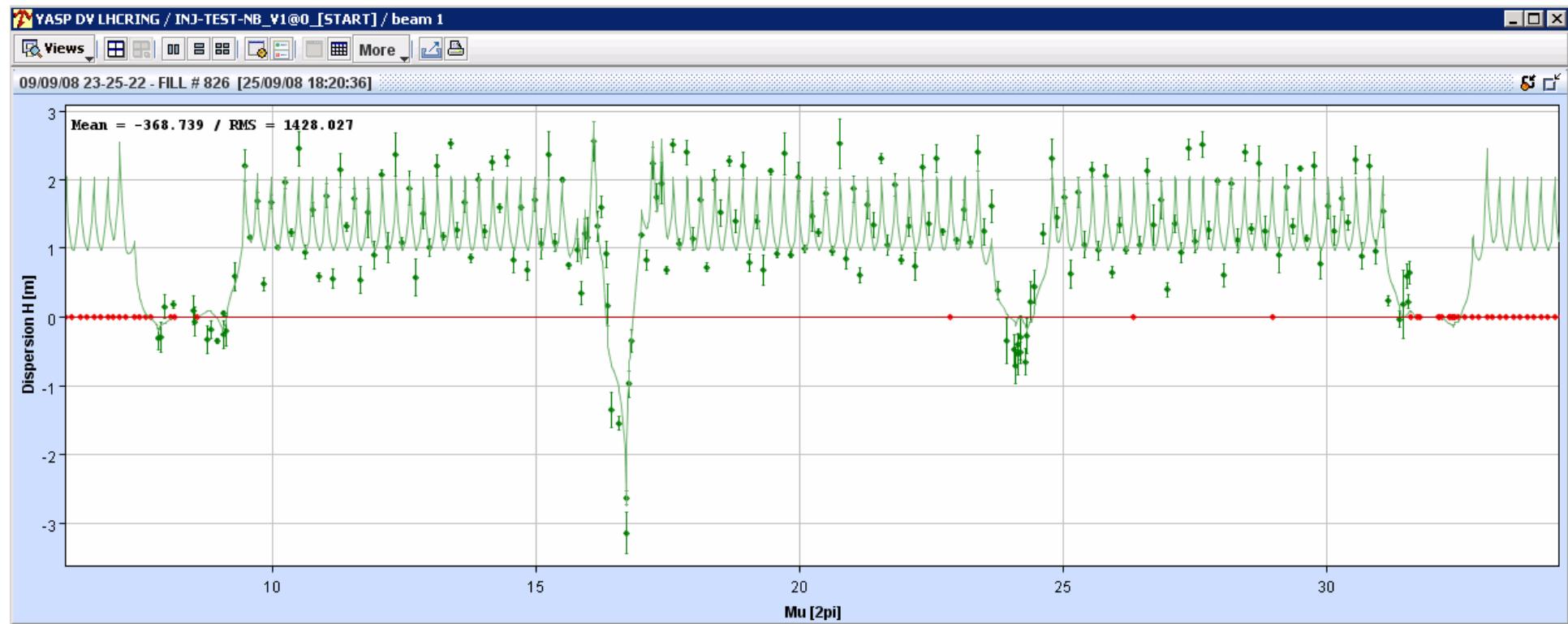


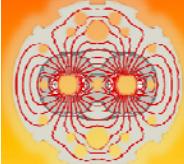
# Kick response compared with theoretical optics



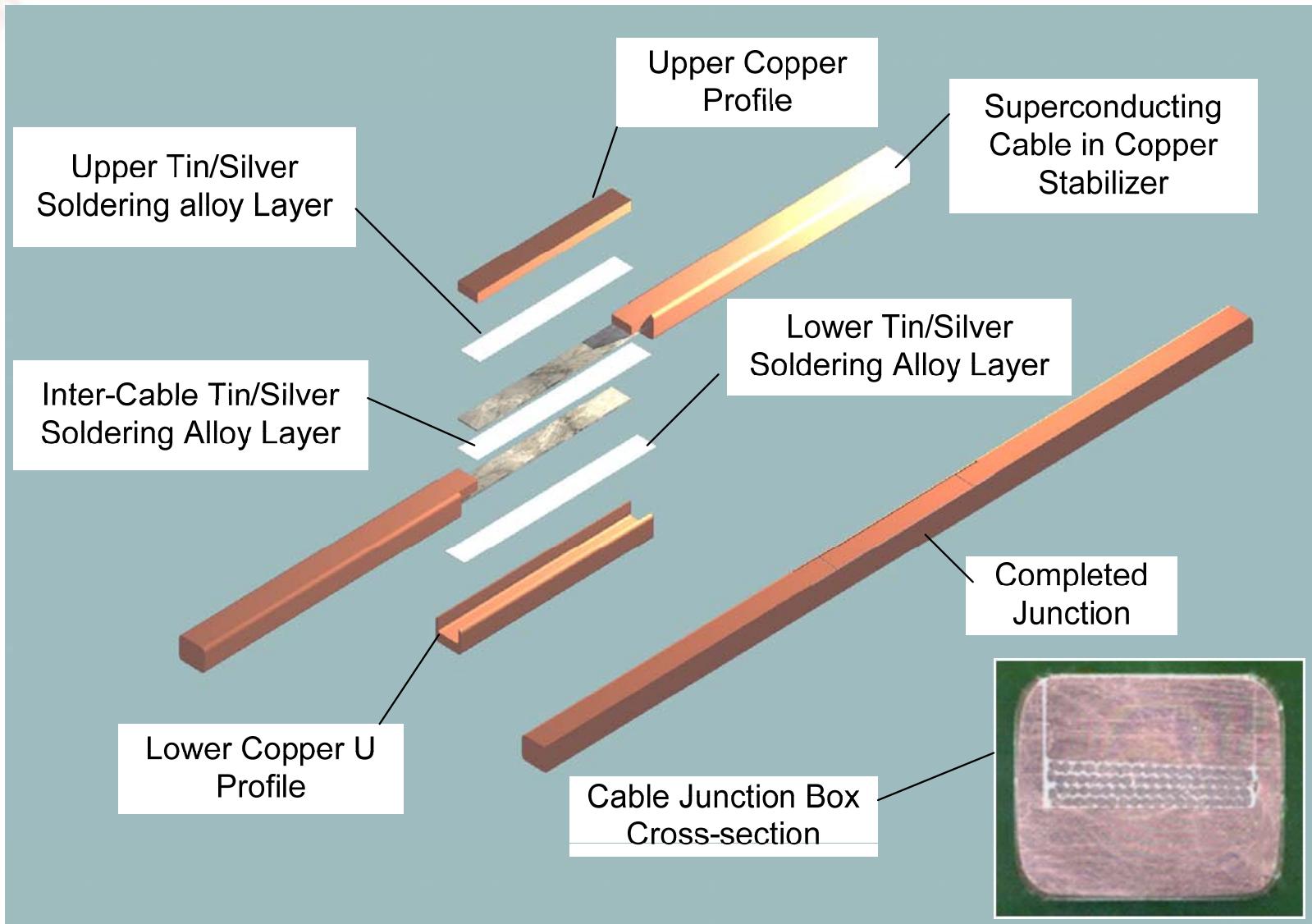


# Beam 1 H dispersion on first turn Injection to beam dump



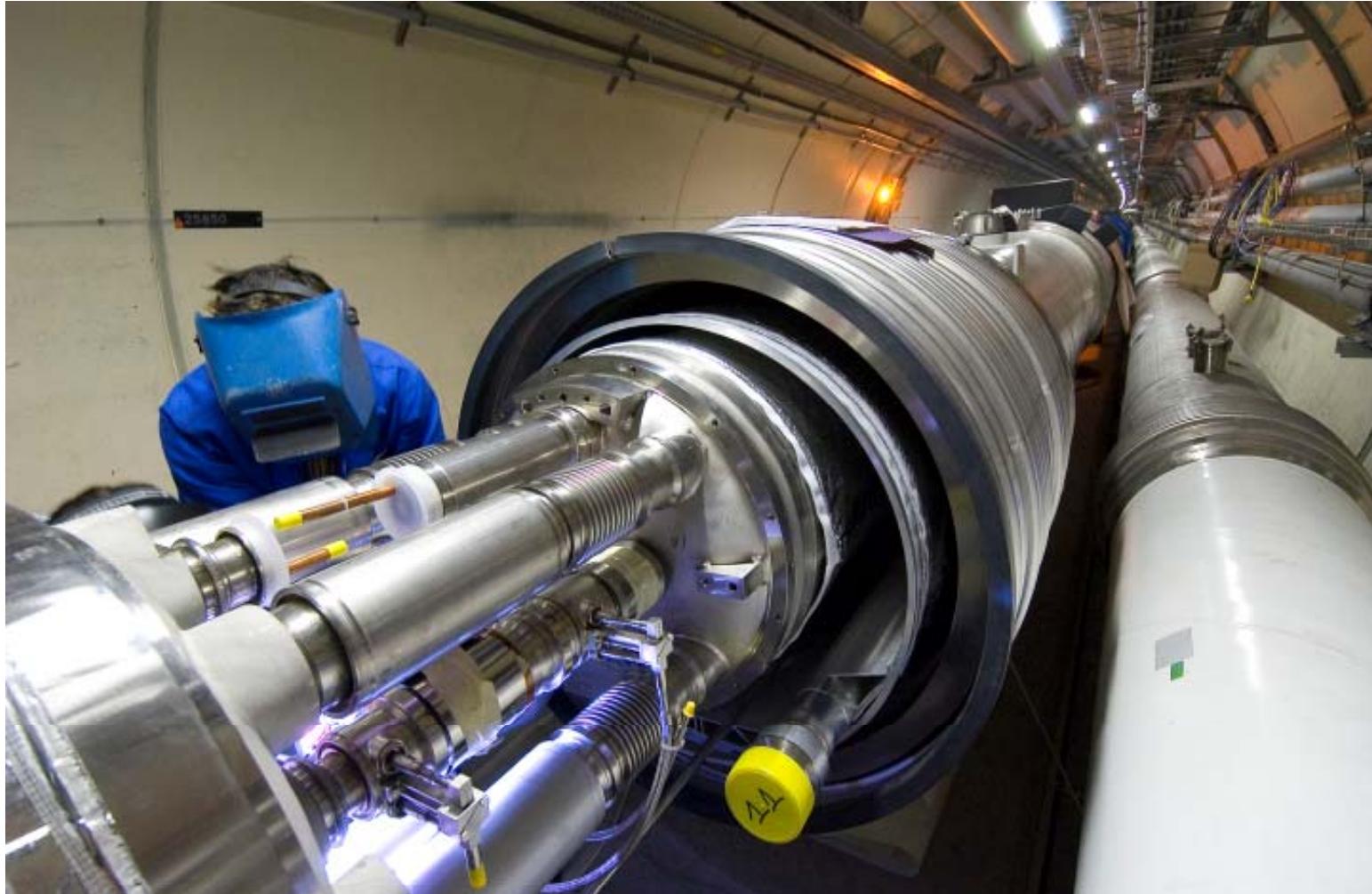


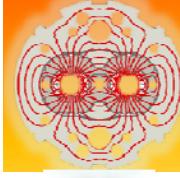
# Busbar splice





# Dipole-dipole interconnect





# 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

	Q17	A18	B18	C18	Q18	A19	B19	C19	Q19	A20	B20	C20	Q20	A21	B21	C21	Q21
Cryostat	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Cold mass	?	?	?	?	?	?	?	?	?	?	<5	<5	<5	<5	<5	<5	<5
	Q21	A22	B22	C22	Q22	A23	B23	C23	Q23	A24	B24	C24	Q24	A25	B25	C25	Q25
Cryostat	<2	<2	<2	<2	-7	<2	<2	<2	-187	<2	<2	<2	<2	<2	<2	<2	<2
Cold mass	<5	<5	<5	<5	-25	-67	-102	-144	<5	-190	-130	-60	<5	<5	<5	<5	<5
	Q25	A26	B26	C26	Q26	A27	B27	C27	Q27	A28	B28	C28	Q28	A29	B29	C29	Q29
Cryostat	<2	<2	<2	<2	<2	<2	<2	<2	474	-4	<2	<2	11	<2	<2	<2	<2
Cold mass	<5	<5	<5	<5	<5	57	114	150?	-45	230	189	144	92?	50	35	<5	<5
	Q29	A30	B30	C30	Q30	A31	B31	C31	Q31	A32	B32	C32	Q32	A33	B33	C33	Q33
Cryostat	<2	<2	<2	<2	<2	<2	<2	<2	188	<2	<2	<2	5	<2	<2	<2	<2
Cold mass	<5	<5	<5	<5	<5	19	77	148	<5	140	105	62	18	<5	<5	<5	?

>0  
[mm]  
?

SSS with vacuum barrier  
Towards P4  
Values are in mm  
Not measured yet  
Cold mass displacement  
Cryostat displacement

Open interconnection  
Electrical interruptions  
Dipole in short circuit  
Electrically damaged IC

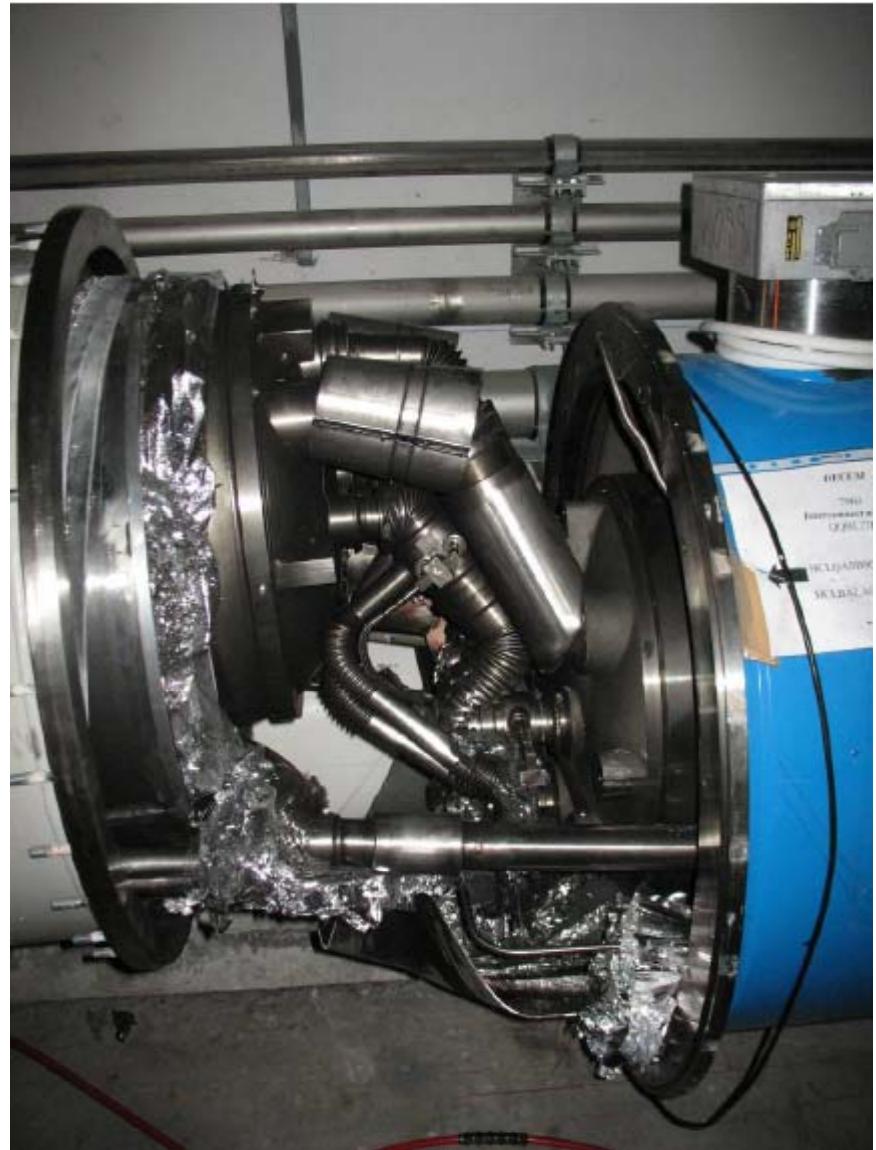
Disconnected

Buffer zones

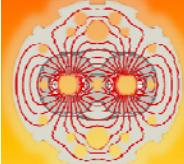
Courtesy JP. Tock



# QQBI.27R3



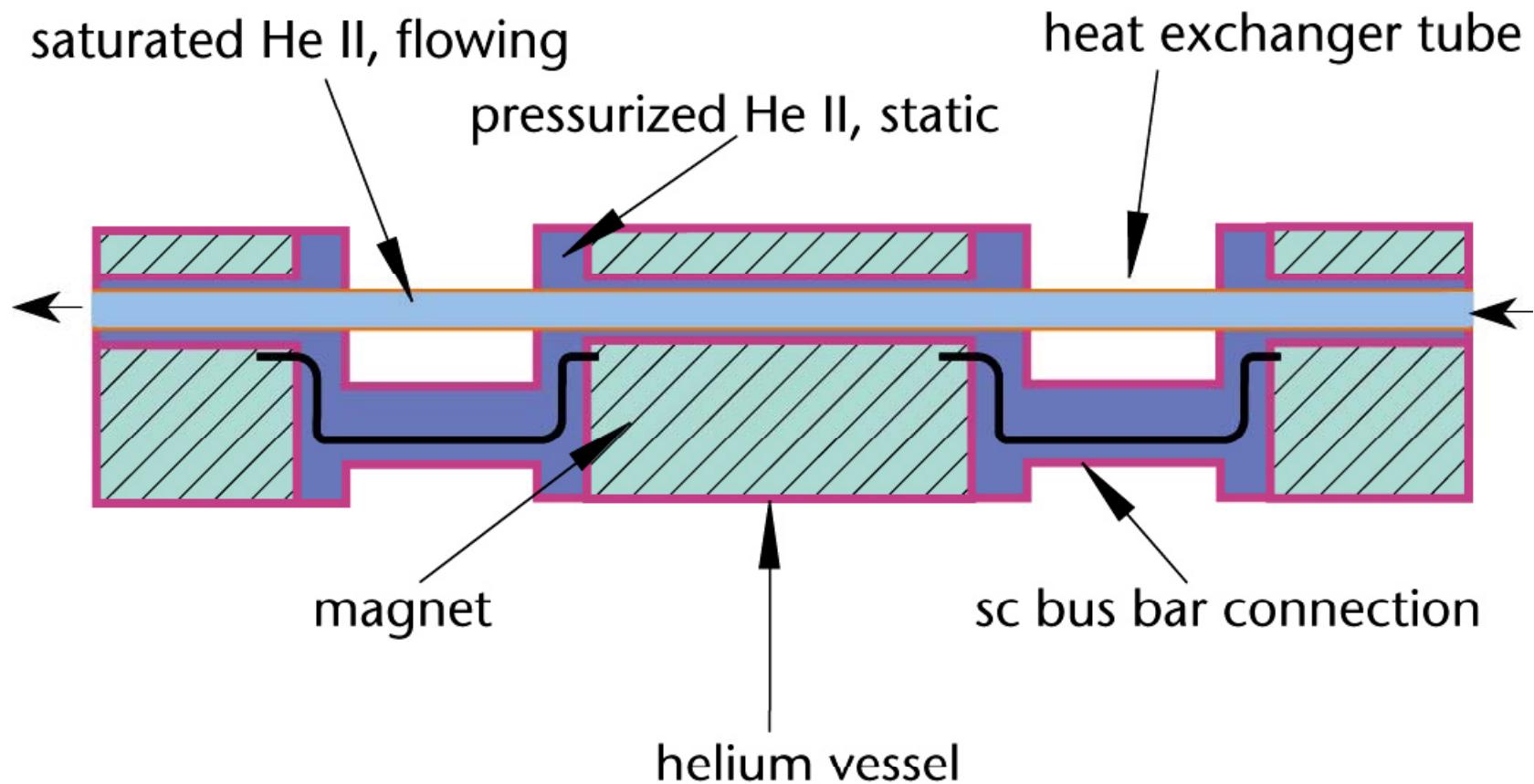
Lyn Evans – EDMS document no. 989177



# Magnet cooling scheme



## LHC magnet string cooling scheme

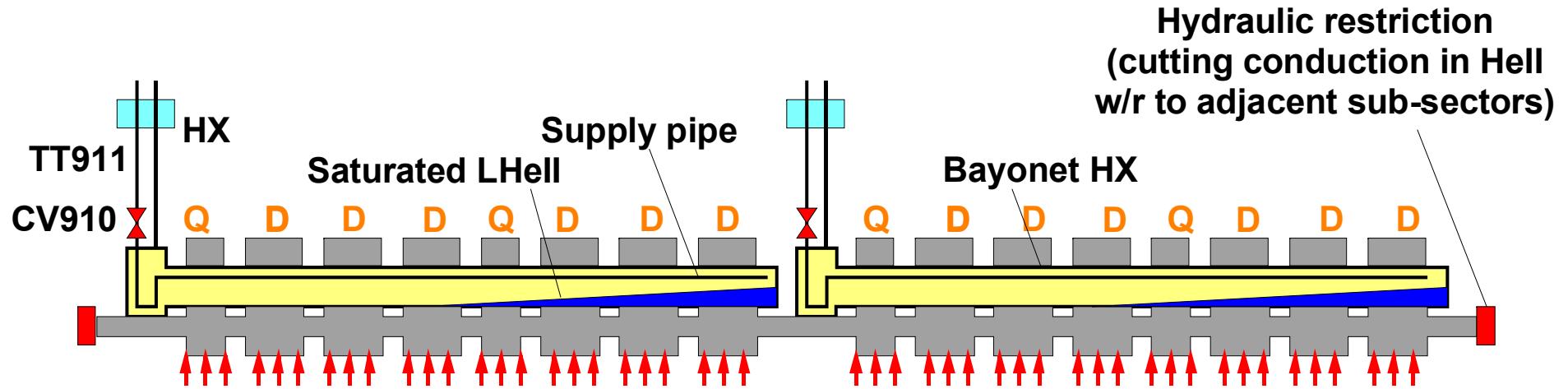


CERN AC \_ EI2-12 VE \_ V9/9/1997

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# Sub-sector magnet cooling scheme

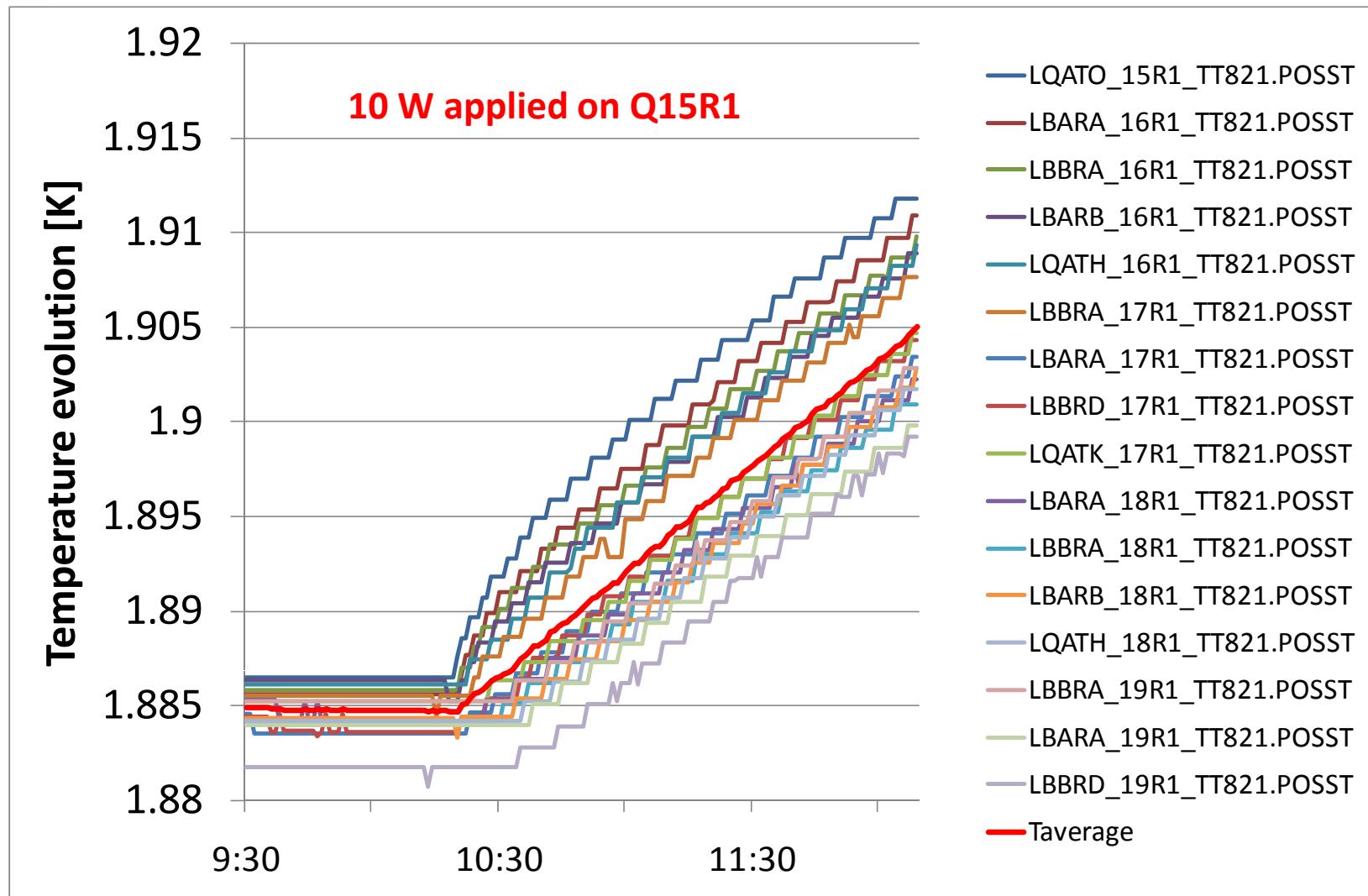


## Principle:

- Blocking of the JT valve (CV910) at a value to extract the static heat inleaks before the powering
- Then, the temperature drift is mainly due to electrical resistive heating dissipated during the powering



# Experimental validation: temperature evolution





# Experimental validation: calorimetry

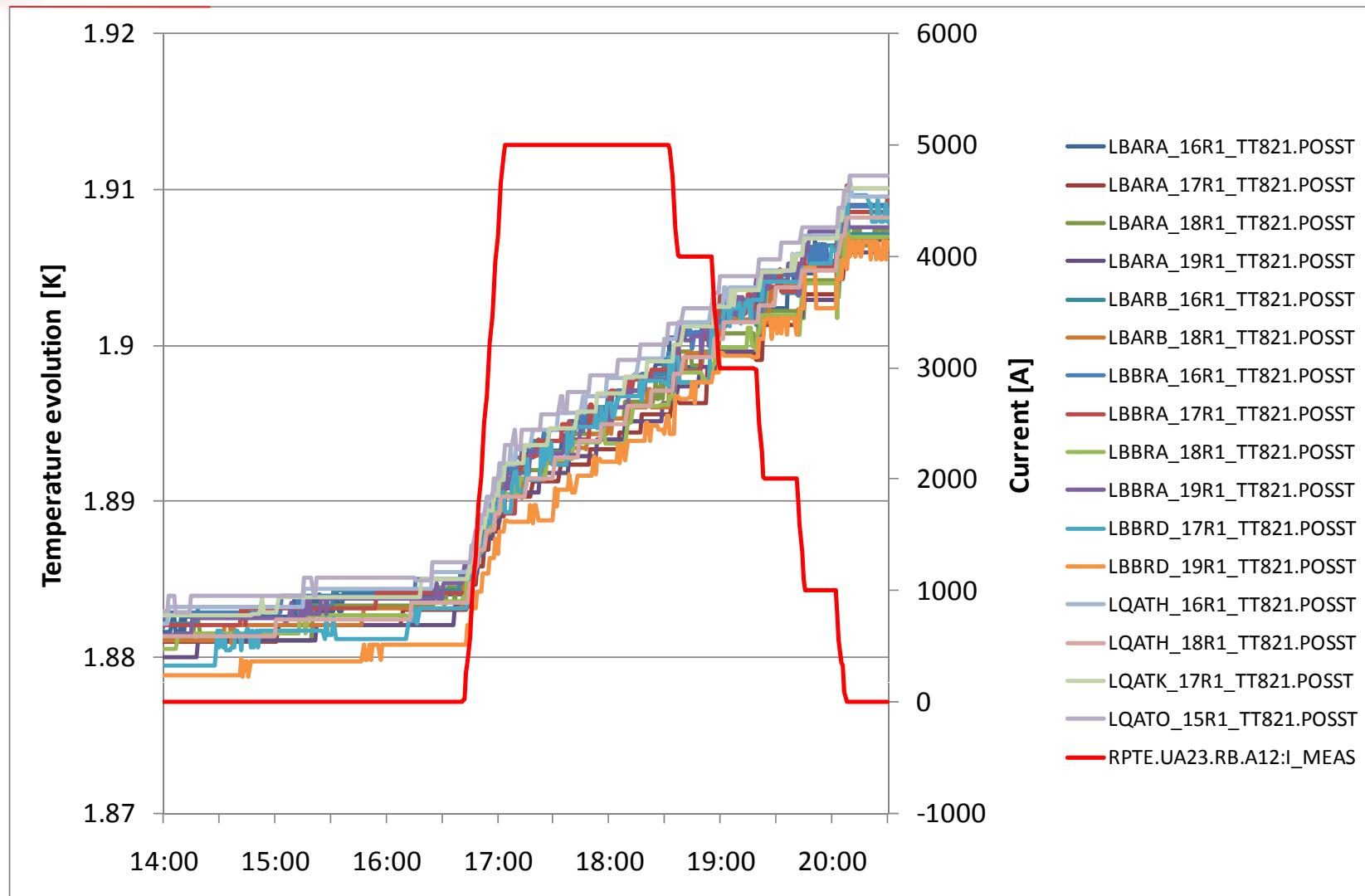


	Before heating	With heating
$\Delta U \text{ [J/kg]}$	-1.1	78
M [kg]		823
$\Delta U \text{ [kJ]}$	-0.92	64.2
t [s]	2880	6600
W [W]	-0.3	9.7
$\Delta W \text{ [W]}$		10

- The power variation calculated by calorimetry is 10 W and is corresponding to the applied electrical power
- Validation of the method !



# Powering example: 15R1 powering @ 5000A



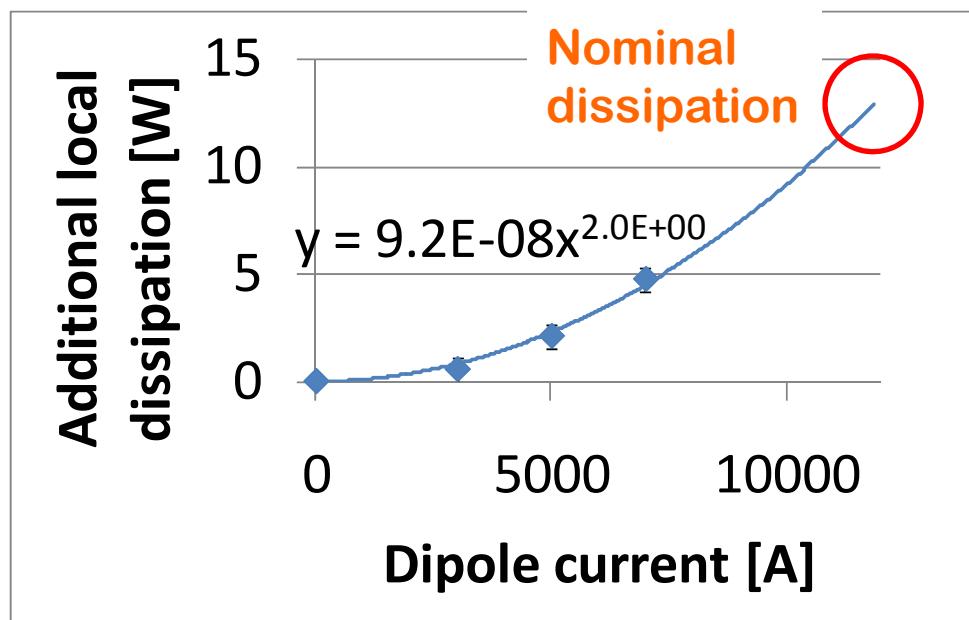


# The 15R1 case: additional heat dissipation due to a bad splice in B16R1



Current	Total (measured)		Nominal Splices*	Add. local dissipation	Uncertainty
[A]	[mW/m]	[W]	[W]	[W]	[W]
3000	4.4	1.0	0.4	0.6	0.6
5000	14.9	3.2	1.1	2.1	0.6
7000	32.2	6.9	2.1	4.8	0.6

\*: Calculated on the basis of 0.33 nW per splice and verified with the 5000 A plateaus

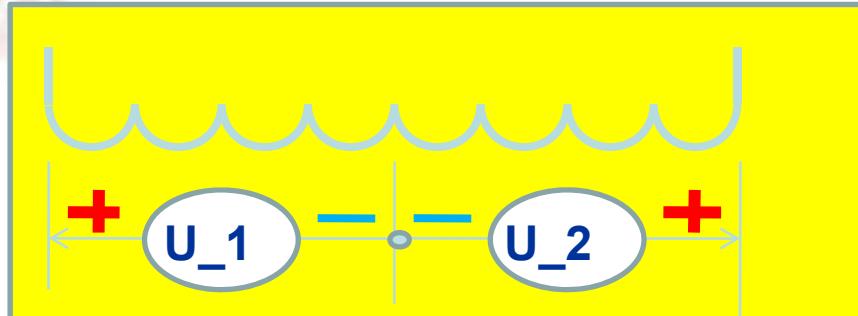


→ Local resistance: ~90 ohms confirmed by electrical measurement !

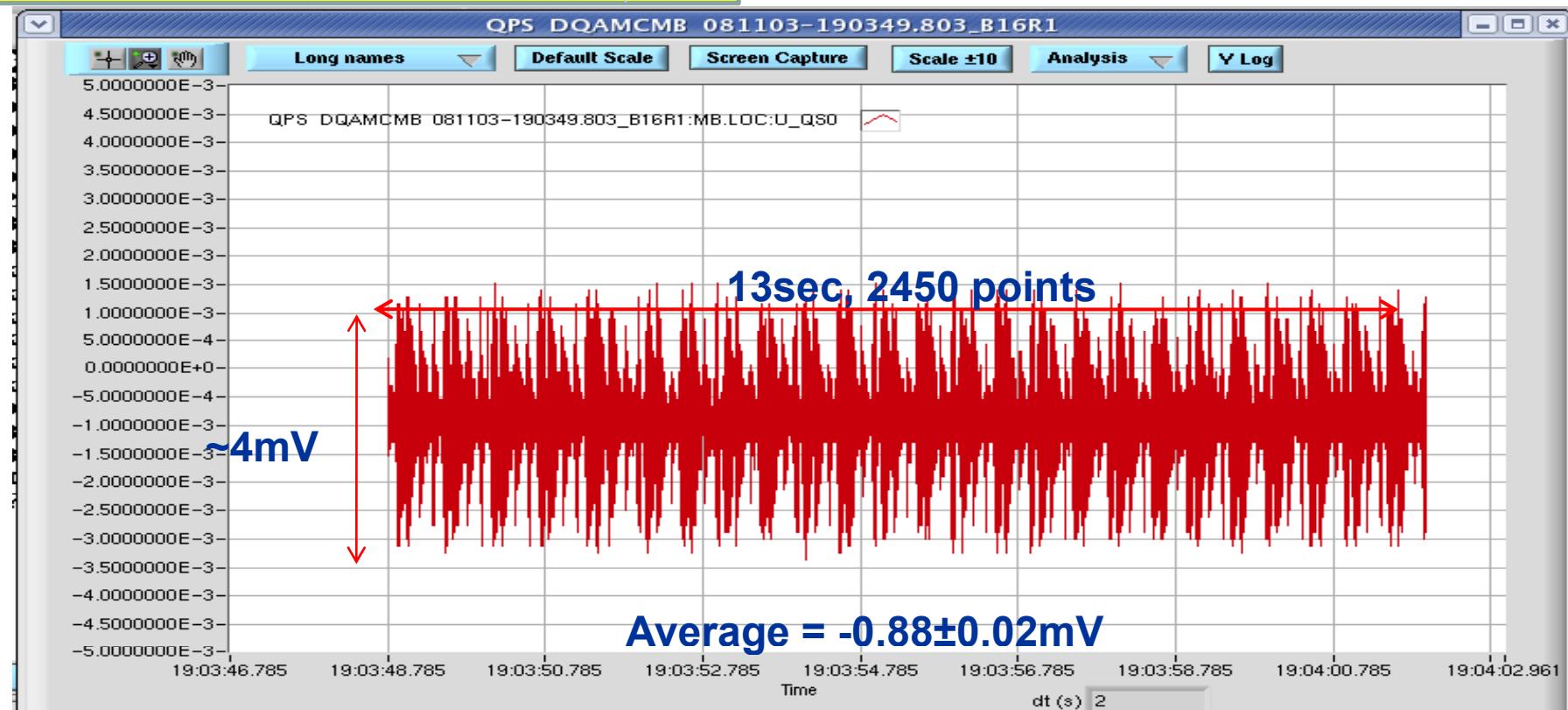
→ Nominal dissipation 13 W: OK w/r to the cooling loop capacity margin



# Sector A12: A15R1 – C19R1: “splice” measurements on 03.11.08

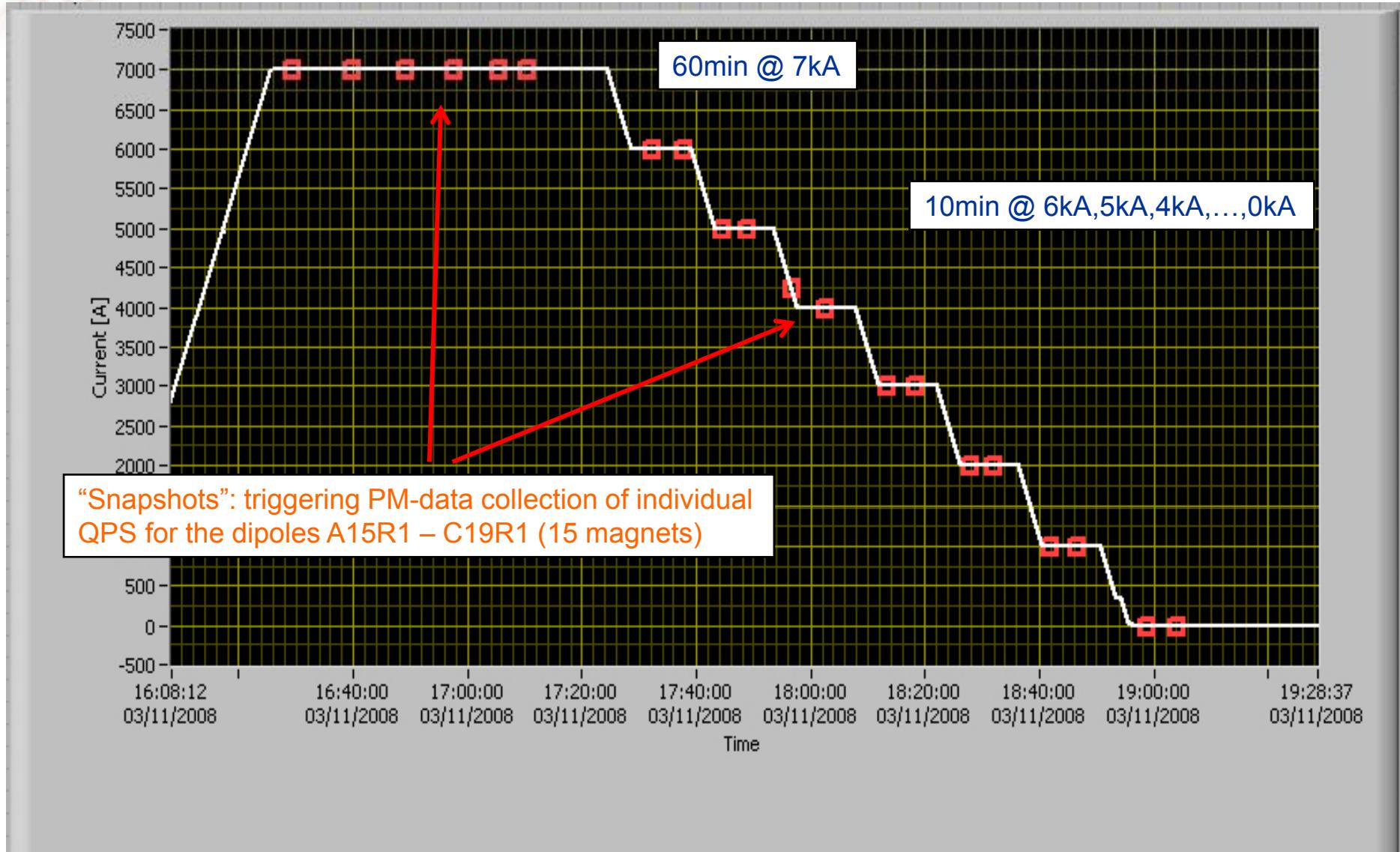


$U_{QS0} \Rightarrow -(U_1 + U_2)$   
Sampling Rate = 5ms  
Resolution = 0.125mV  
Quench Threshold = 100mV@10ms





# Sector A12: A15R1 – C19R1: measurements on 03.11.08

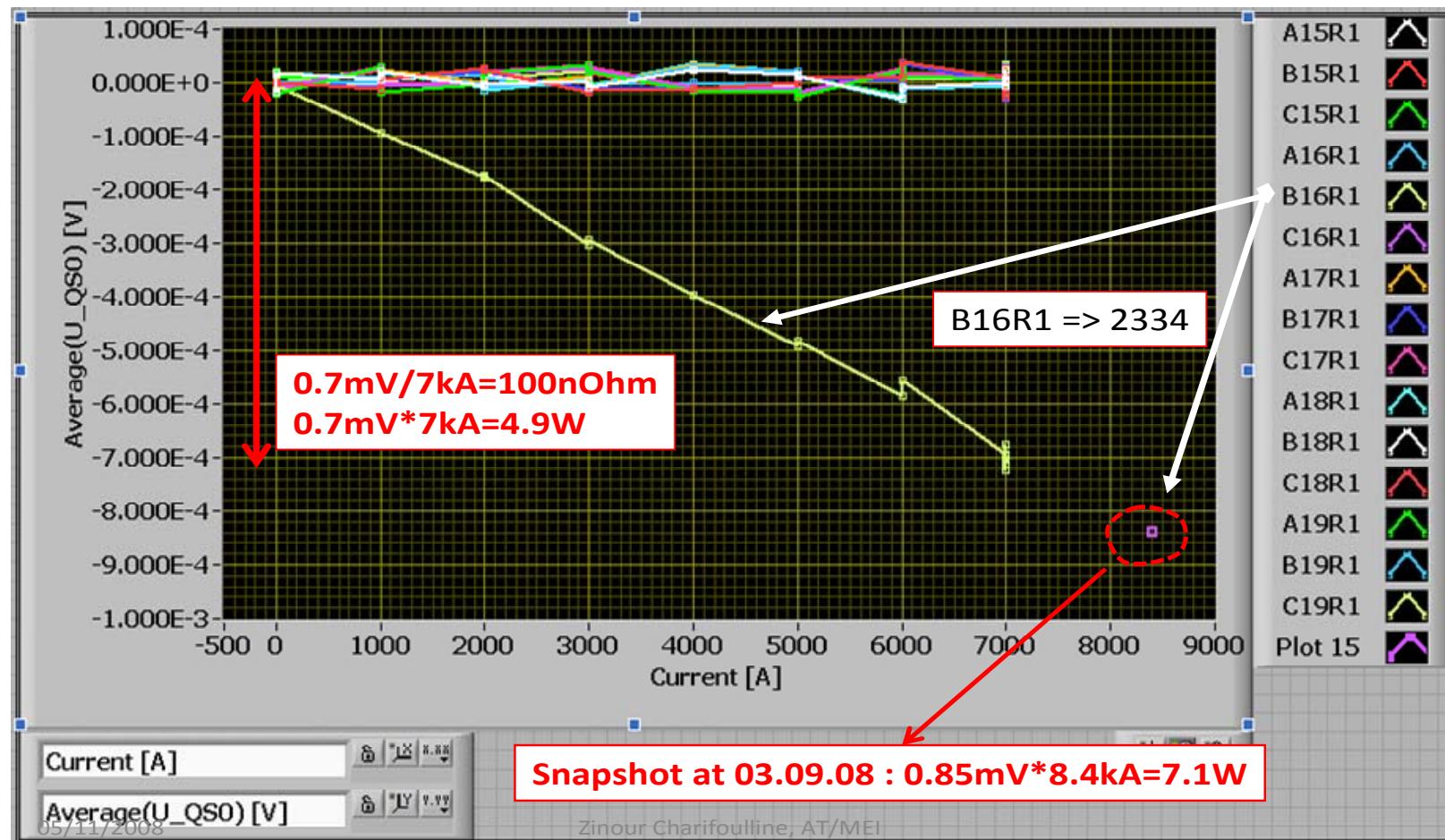




## Proof of the missing source of heating, representing 100 nΩ, located in dipole B16.R1 (in the joint between the two apertures).



Sector A12: A15R1 – C19R1: Dipole Measurements made on 03.11.08

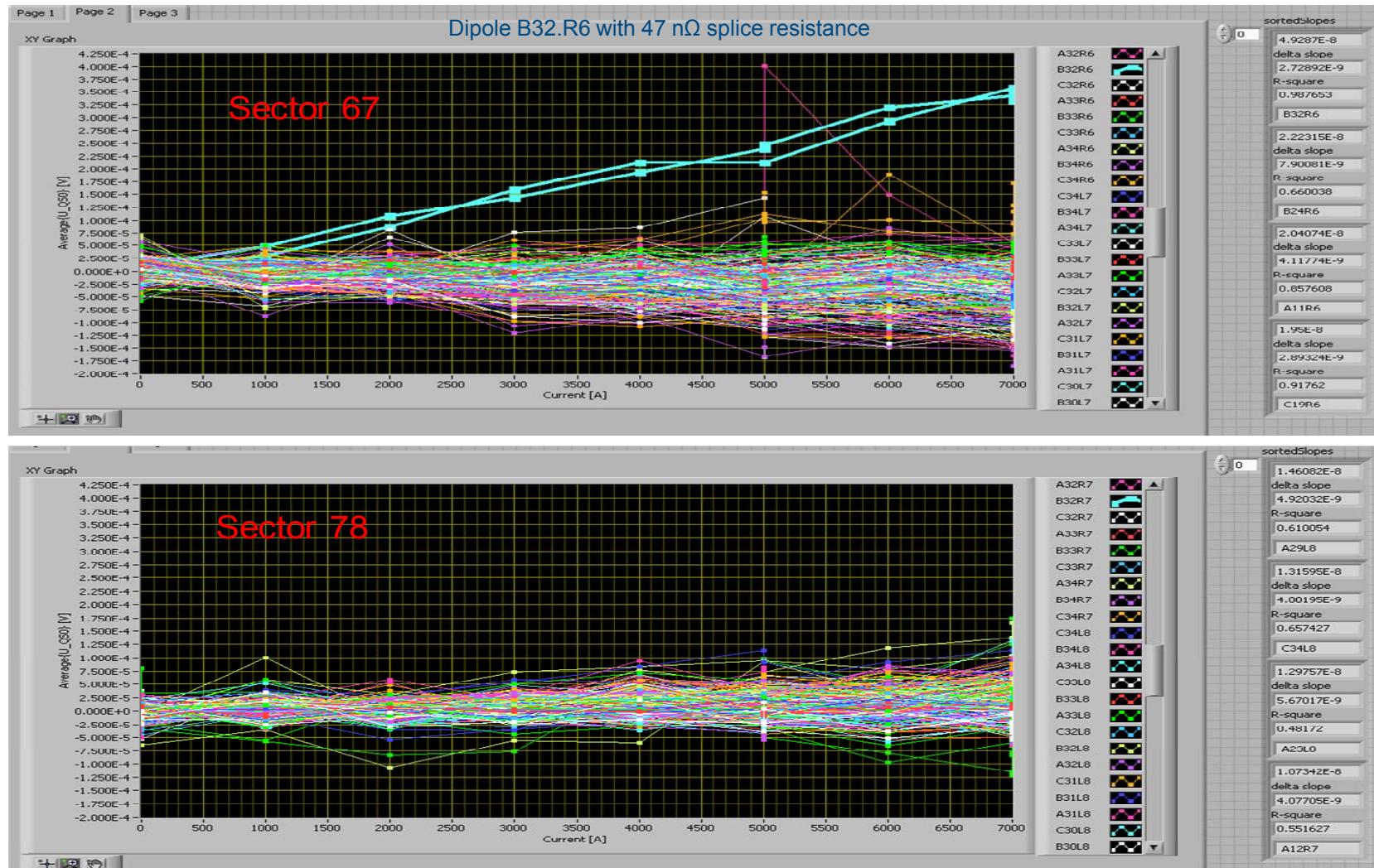




# Snapshots in S67 and S78 on all 154 dipoles - B32.R6 with a high (47 nΩ) joint resistance between the poles of one aperture

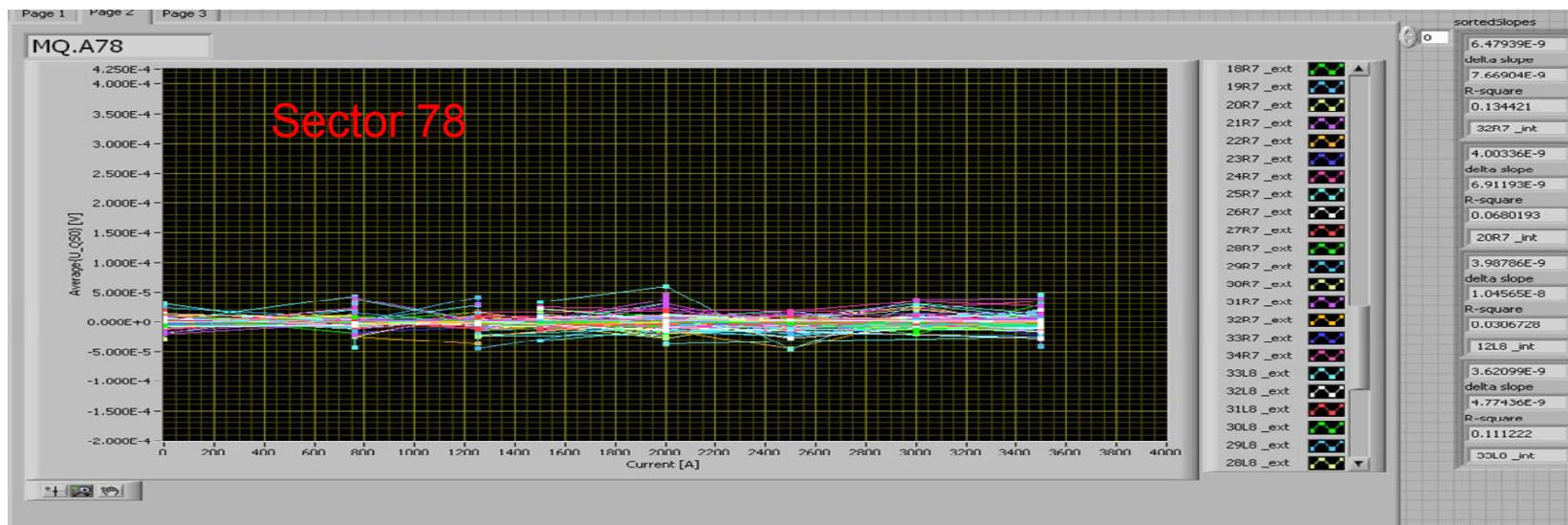
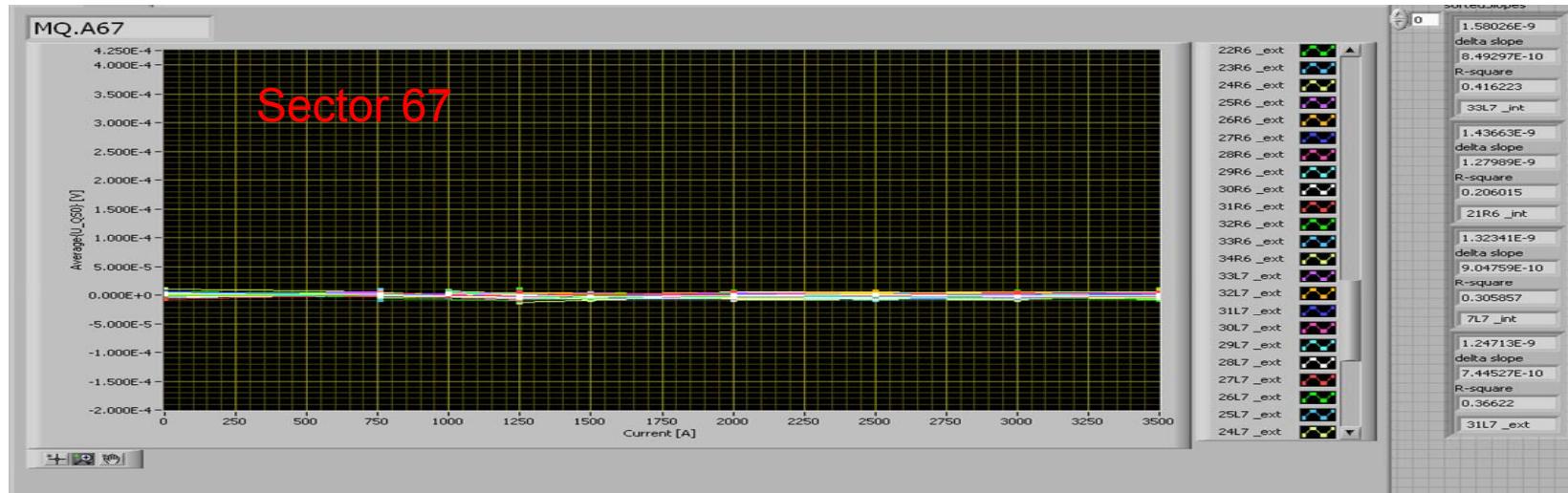


Results from provoked massive Post-Mortem of all dipoles in sectors 67 & 78



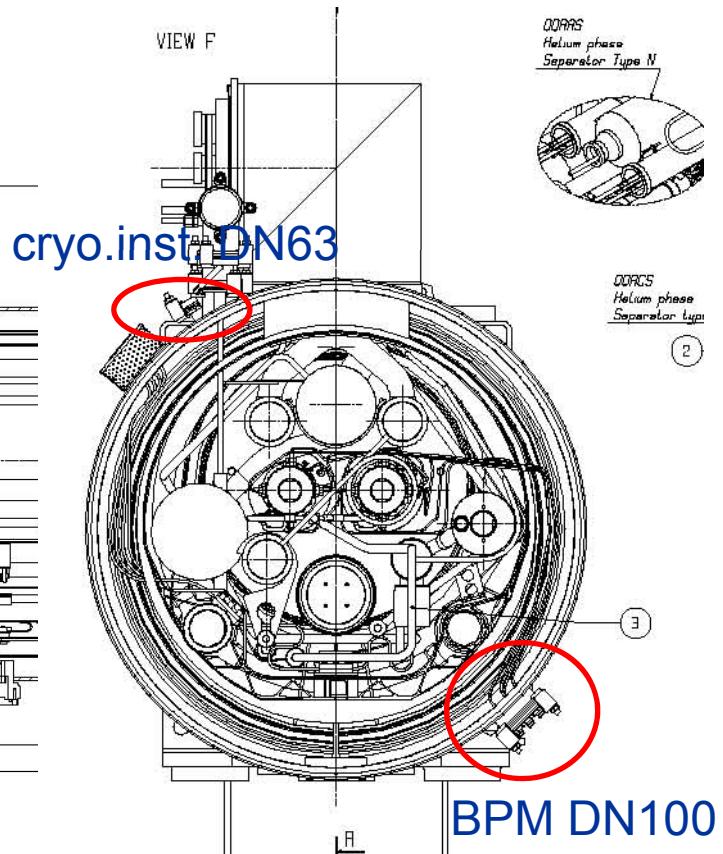
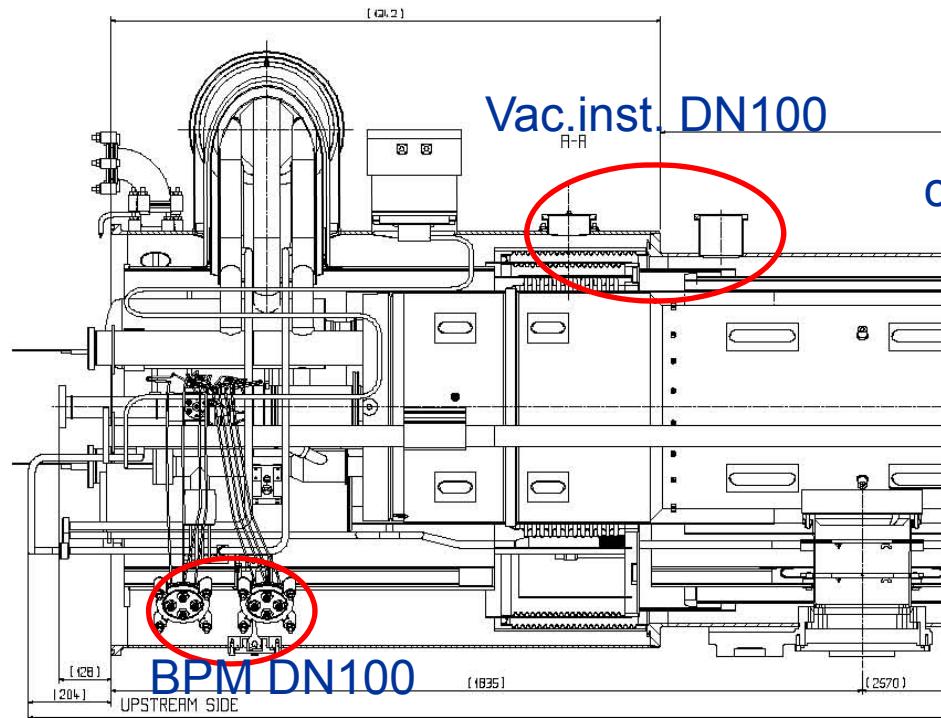


# Main quadrupoles in S67 and S78 – Results of global snapshots





# Existing ports: all on SSS



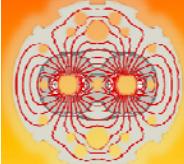
Each SSS:

- 4 DN100 ports (2 for vac.devices, 2 for BPM cable feedthrough)
- 1DN63 port (for cryo instrumentation)



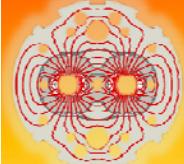
# Repairs and restart

- The four warm sectors will be equipped with extra pressure relief valves on all dipole cryostats.
- The four cold sectors will get extra PRVs on all short straight section cryostats. This can be done with the sectors cold and is adequate for 5 TeV operation.
- The quench protection system will be upgraded everywhere to cover all busbar splices.
- The whole machine will be cold by mid August, ready for first injected beam in late September.
- The machine will run at 5 TeV until autumn 2010 after which the remaining 4 sectors will be equipped with PRVs and will be prepared for high energy operation.



# LHC upgrade: future plans





# Peak Luminosity

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

**N<sub>b</sub>** number of particles per bunch

**n<sub>b</sub>** number of bunches

**f<sub>r</sub>** revolution frequency

**ε<sub>n</sub>** normalised emittance

**β\*** beta value at Ip

**F** reduction factor due to crossing angle

**N<sub>b</sub>, ε<sub>n</sub>** → injector chain

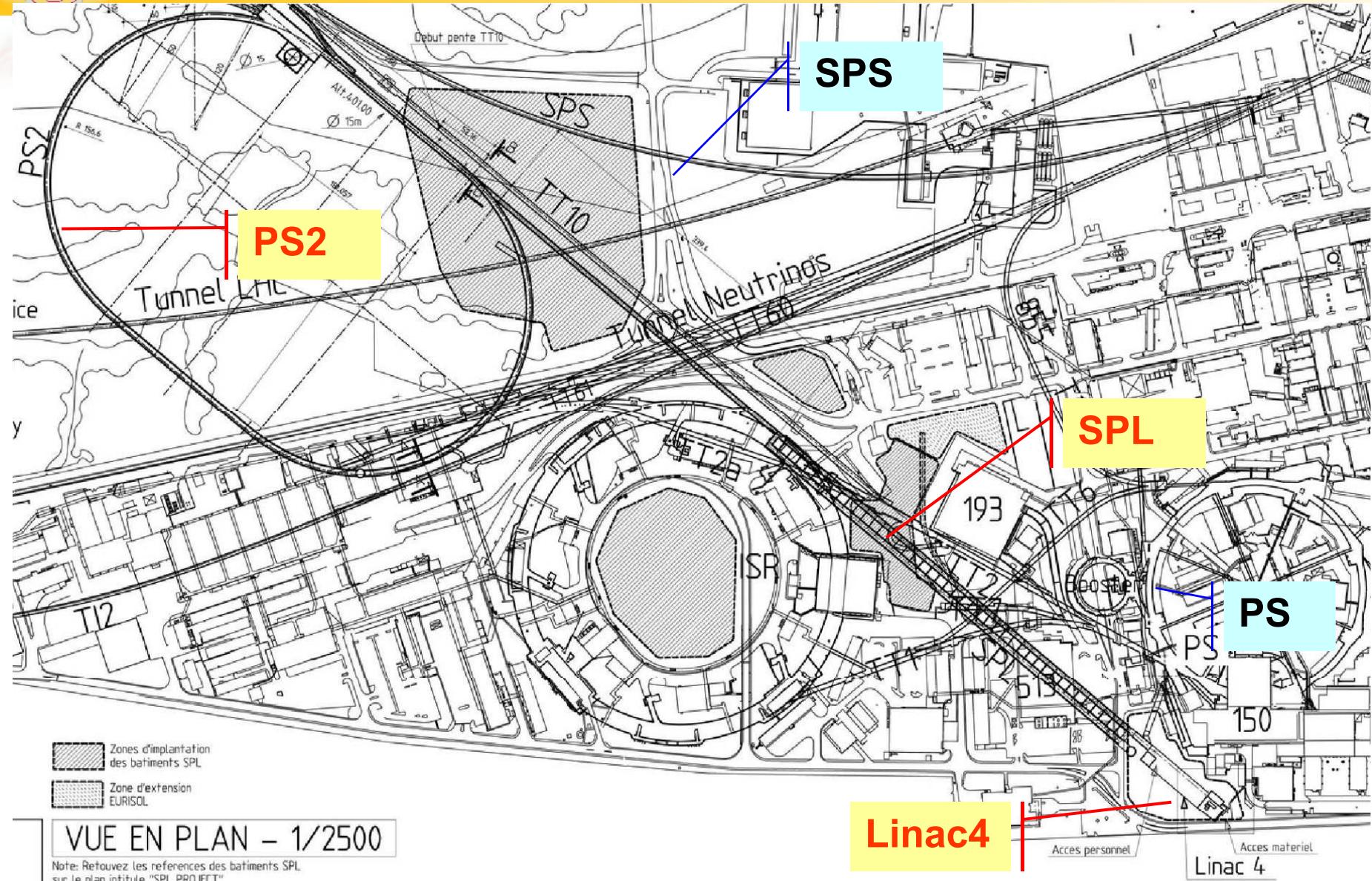
**β\*** → LHC insertion

**F** → beam separation schemes

**n<sub>b</sub>** → electron cloud effect

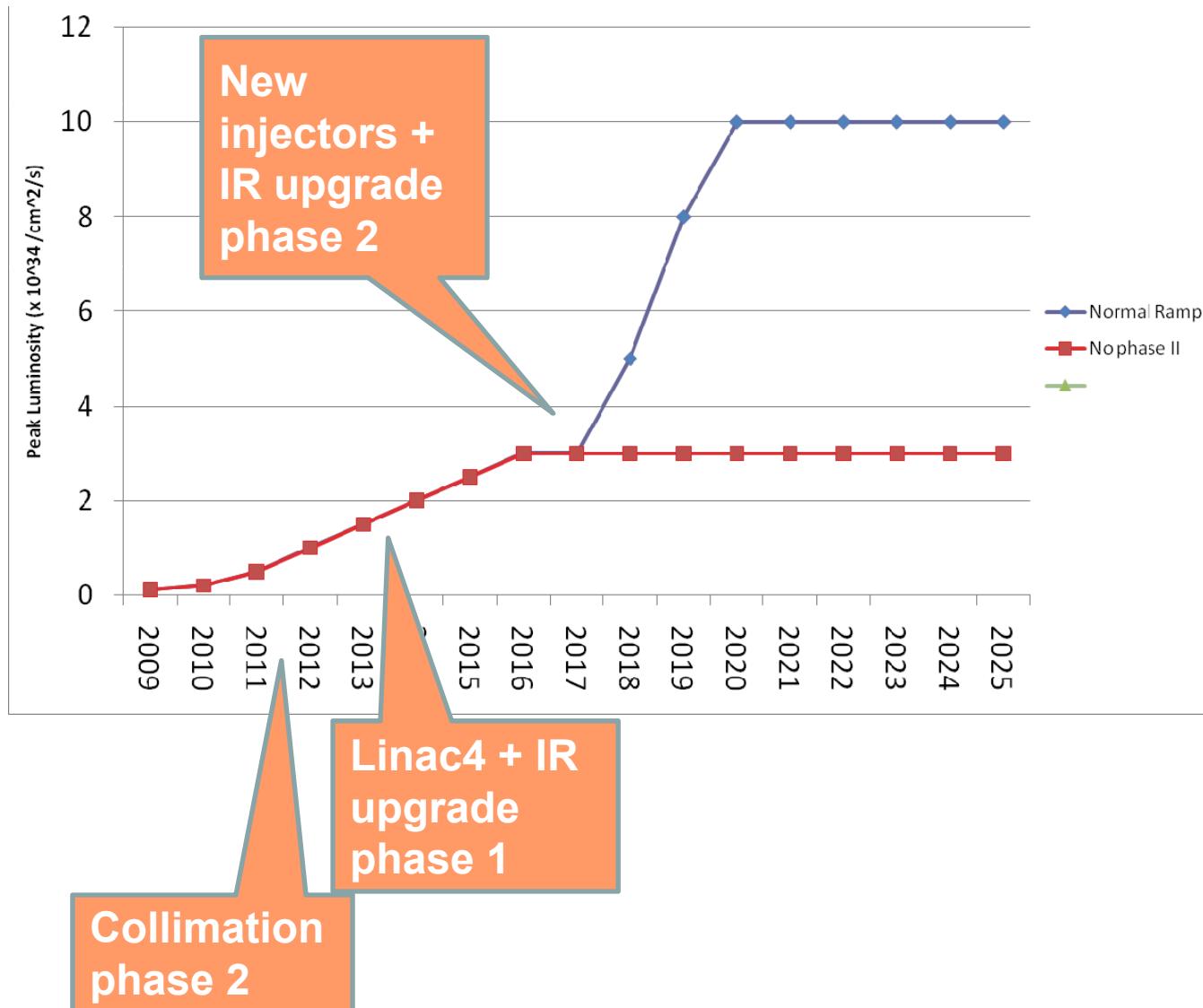


# Layout of the new injectors





# Peak luminosity...





# Integrated luminosity...

