

The LHC Adventure

Lyn Evans



From the PS to the LHC: 50 Years of Nobel Memories
in High-Energy Physics, CERN 3 December 2009



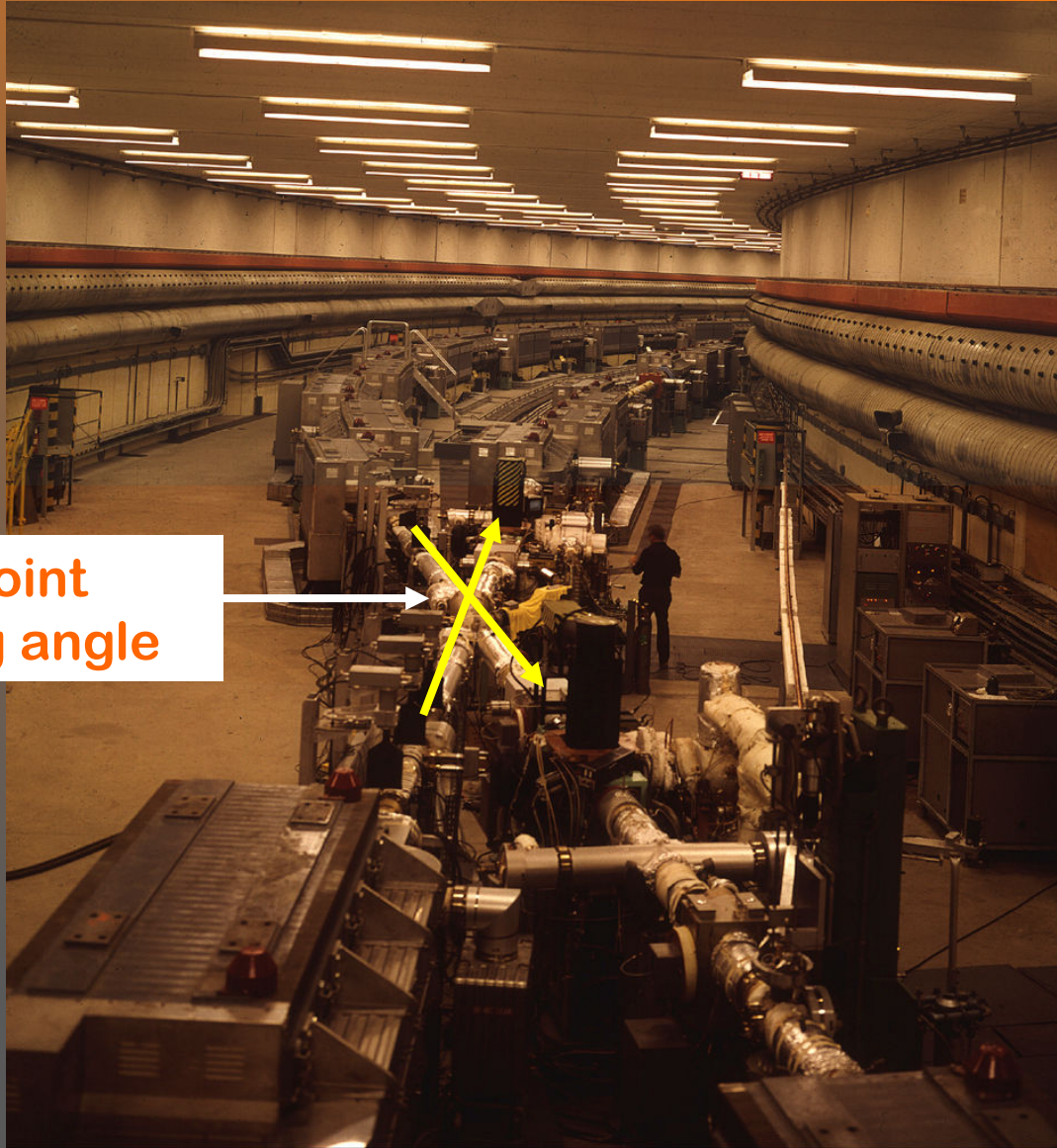
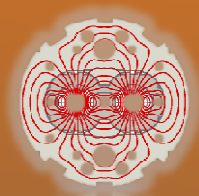


The birth of the LHC

It is generally accepted that the kick-off of the LHC Project was the Lausanne Workshop in March 1984 where particle physicists and machine builders under the leadership of Giorgio Brianti got together for the first time.

In reality, the LHC adventure started much earlier...

ISR

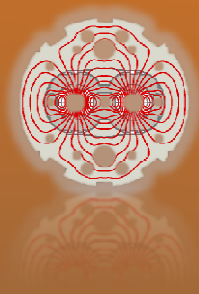


Interaction point
with crossing angle



Approval of the LHC

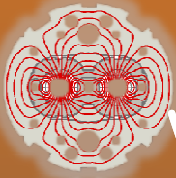
The LHC had a difficult birth. Although the idea of a large proton-proton collider at CERN had been around since at least 1977, the approval of the Superconducting Super Collider (SSC) in the United States in 1987 put the whole project into doubt. The SSC, with a centre-of-mass energy of 40 TeV was almost three times more powerful than what could ever be built at CERN. It was only the resilience and conviction of Carlo Rubbia that kept the project alive.



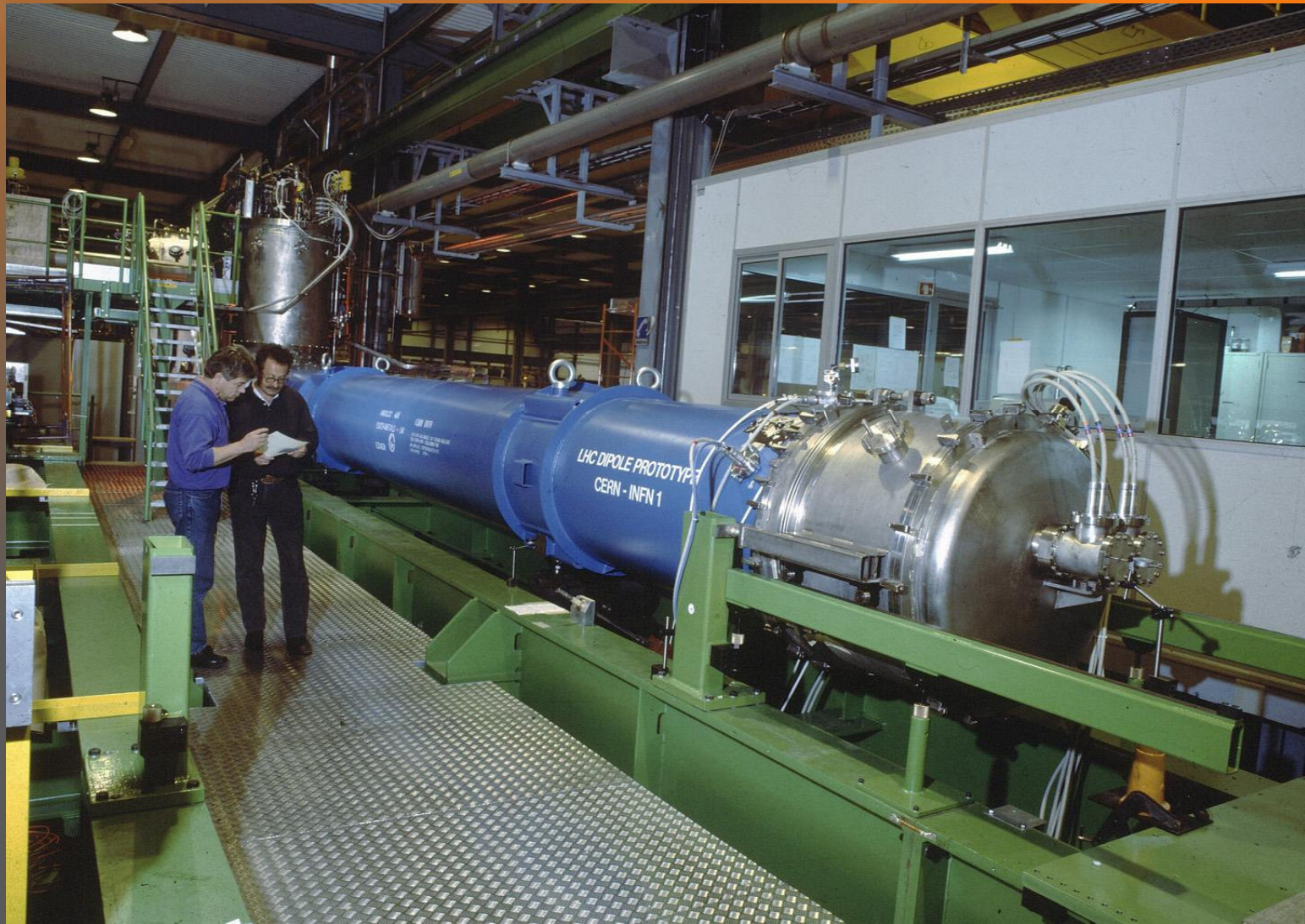
In December 1993, a plan was presented to the CERN Council to build the machine over a ten-year period by reducing the other experimental program of CERN to the absolute minimum, with the exception of the full exploitation of the LEP collider. An external expert panel chaired by Robert Aymar endorsed the design.



Although the plan was generally well received, it became clear that two of the largest contributors, Germany and the United Kingdom, were very unlikely to agree to the budget increase required. They also managed to get Council voting procedures changed from a simple majority to a double majority, where much more weight was given to the large contributors so that they could keep control.

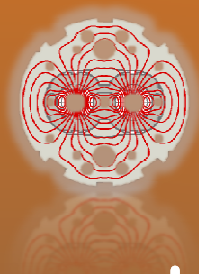


The 10 metre long prototype bending magnet for LHC, which has reached a field of 8,73 Tesla on 14 April 1994

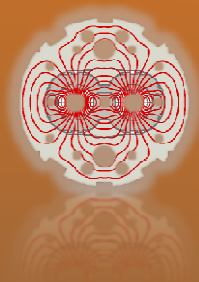


Finance Committee April 1994

Message de J.-P. Goumber et R. Perin
à L. Evans
- on a atteint 8,73 tesla
100 french



In June 1994, the proposal to build the LHC was made once more to Council. Seventeen member states voted to approve the project. However, because of the newly adopted double voting procedure, approval was blocked by Germany and the UK, who demanded substantial additional contributions from the two host states, France and Switzerland, claiming that they obtained disproportionate returns from the CERN budget. They also requested that financial planning should proceed under the assumption of 2% annual inflation, with a budget compensation of 1%, essentially resulting in a 1% annual reduction in real terms.



In order to deal with this new constraint, we were forced to propose a “missing magnet” machine where only two thirds of the dipoles would be installed in a first stage. The deadlock concerning extra host-state contributions was broken when France and Switzerland agreed to make extra voluntary contributions in the form of a 2% annual inflation adjustment, compared with the 1% adjustment from the other member states. The project was approved for two-stage construction, to be reviewed in 1997 after the size of the contribution offered by non-member states interested in joining the LHC program would be known.

Japan becomes an Observer

June 1995

Japan becomes an Observer of CERN and announces a financial contribution to the LHC.

The Japanese Minister for Education, Sciences and Culture offers a Daruma doll to CERN's Director-General. According to Japanese tradition, an eye is painted on the doll to mark the beginning of the LHC project and the second eye must be drawn at the time of its completion.

Japan makes two other major financial contributions to the LHC project in 1996 and 1998.





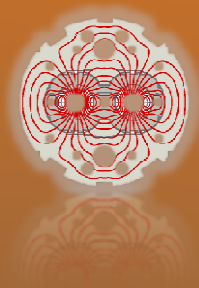
1996

March

- India makes a financial contribution to the construction of the LHC.
- And in June, Russia announces a financial contribution to the project.

December

- Canada announces a financial contribution for the LHC, while a protocol of co-operation is defined for participation of the United States.
- In December 1997, the US declares a contribution.



A final sting in the tail came in June 1996 from Germany who unilaterally announced that, in order to ease the burden of reunification, it intended to reduce its CERN subscription by between 8% and 9%. Confining the cut to Germany proved impossible. The UK was the first to demand a similar reduction in its contribution in spite of a letter from the UK Minister of Science during the previous round of negotiations stating that the conditions are “reasonable, fair and sustainable”. The only way out was to allow CERN to take out loans, with repayment to continue after the completion of LHC construction.



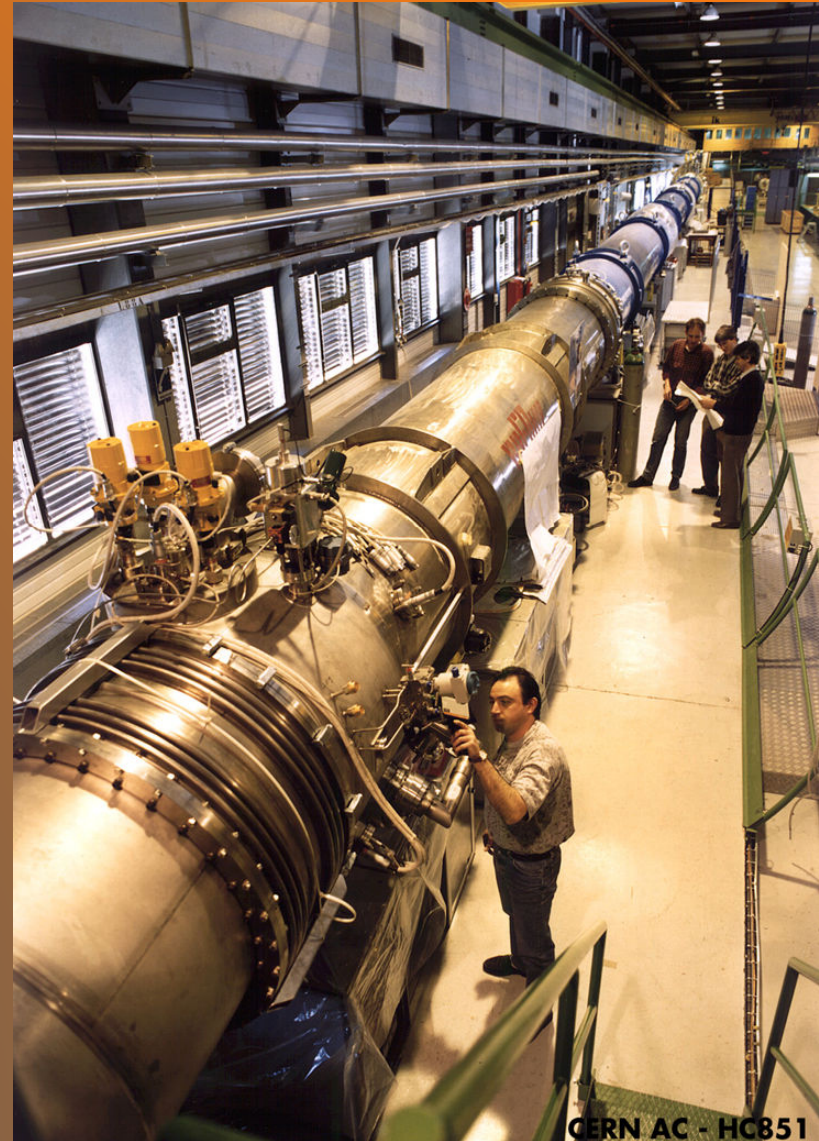
In December 1996 Council, Germany declared that “a greater degree of risk would inevitably have to accompany the LHC”. The project was approved for single-stage construction with the deficit financed by loans. It was also agreed that the final cost of the project was to be reviewed at the half-way stage with a view to adjusting the completion date. With all contingency removed, it was inevitable that a financial crisis would occur at some time, and this was indeed the case when the cost estimate was revised upwards by 18% in 2001.

Aerial view of Point 5 Gallo-roman vestiges 1998



December 1998

Four years after its start-up, the first test string of the LHC comes to the end of its operation. Composed of prototypes, it made it possible to test and validate the various components and systems of the LHC.





Point 1 - UX15 cavern - Concreting of vault panel n°2 - April 10, 2001 - CERN ST-CE



LHC Point 1 - UX 15 Cavern - Concrete walls 6th lift - 20-02-2003 - CERN ST-CE



Point 5 -Excavation commencement of PM54 shaft - July 09, 1999 - CERN ST-CE

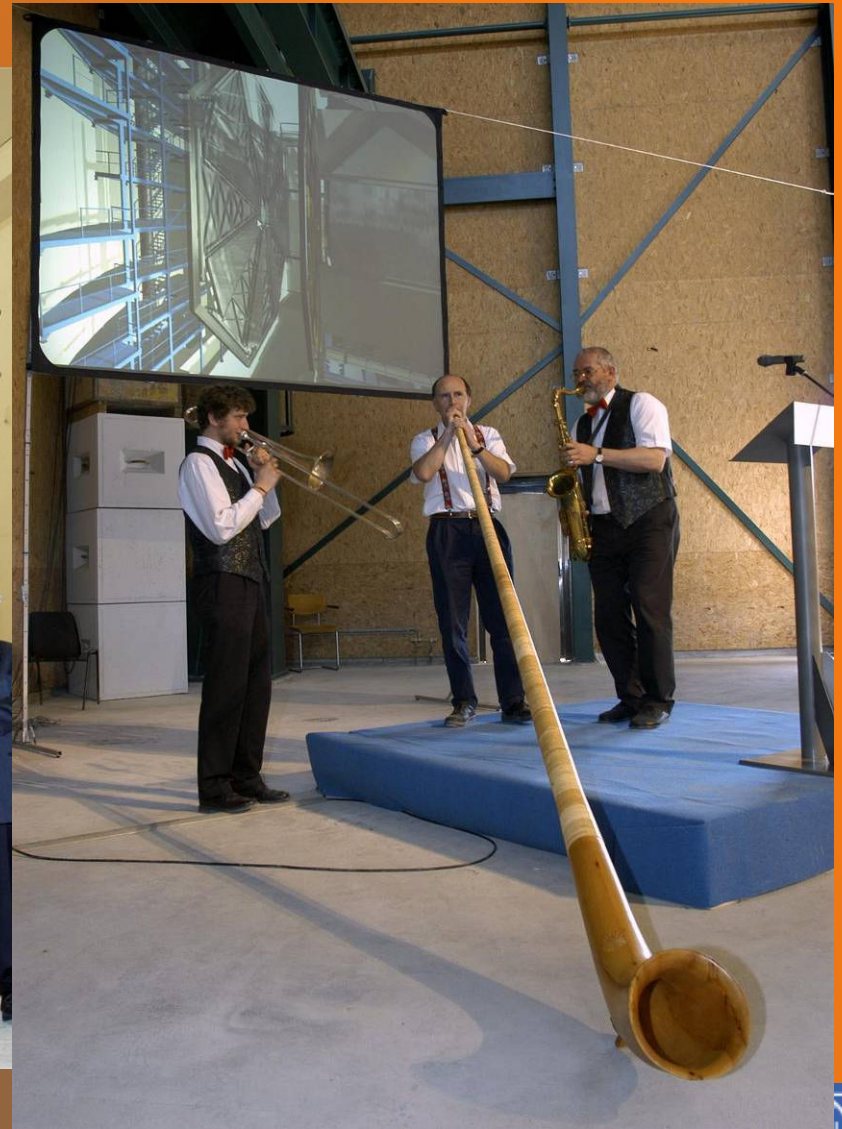


Point 5 - UXC55 cavern excavation - LEP demolition - January 23, 2002 - CERN ST-CE

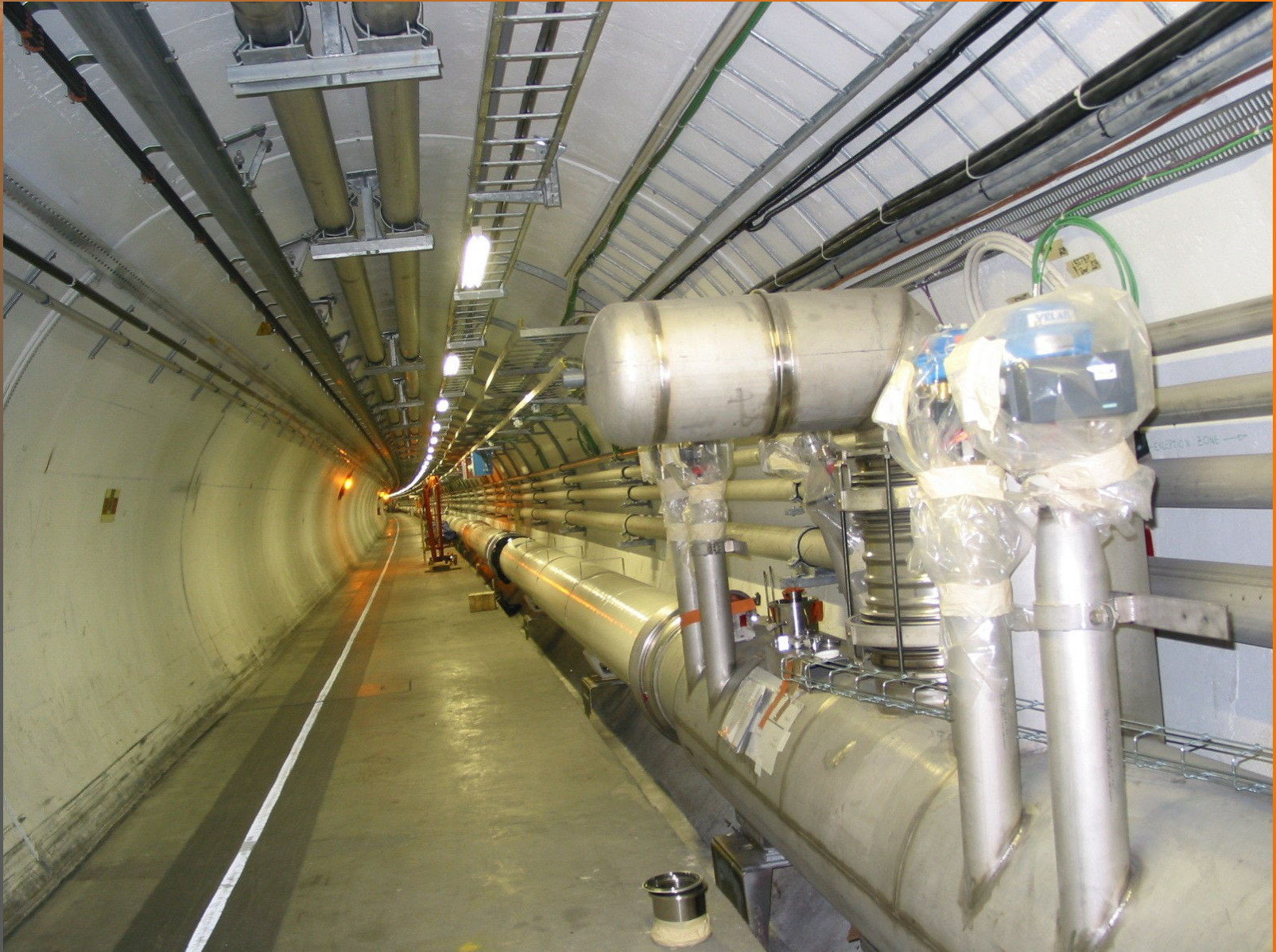


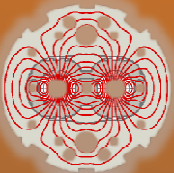
TI2 Area - Start of excavation of PMI 2 shaft - February 17, 1999 - CERN ST-CE

ATLAS cavern inauguration 2003



QRL crisis June 2004



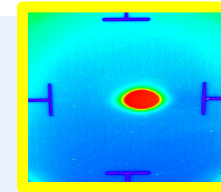


General situation

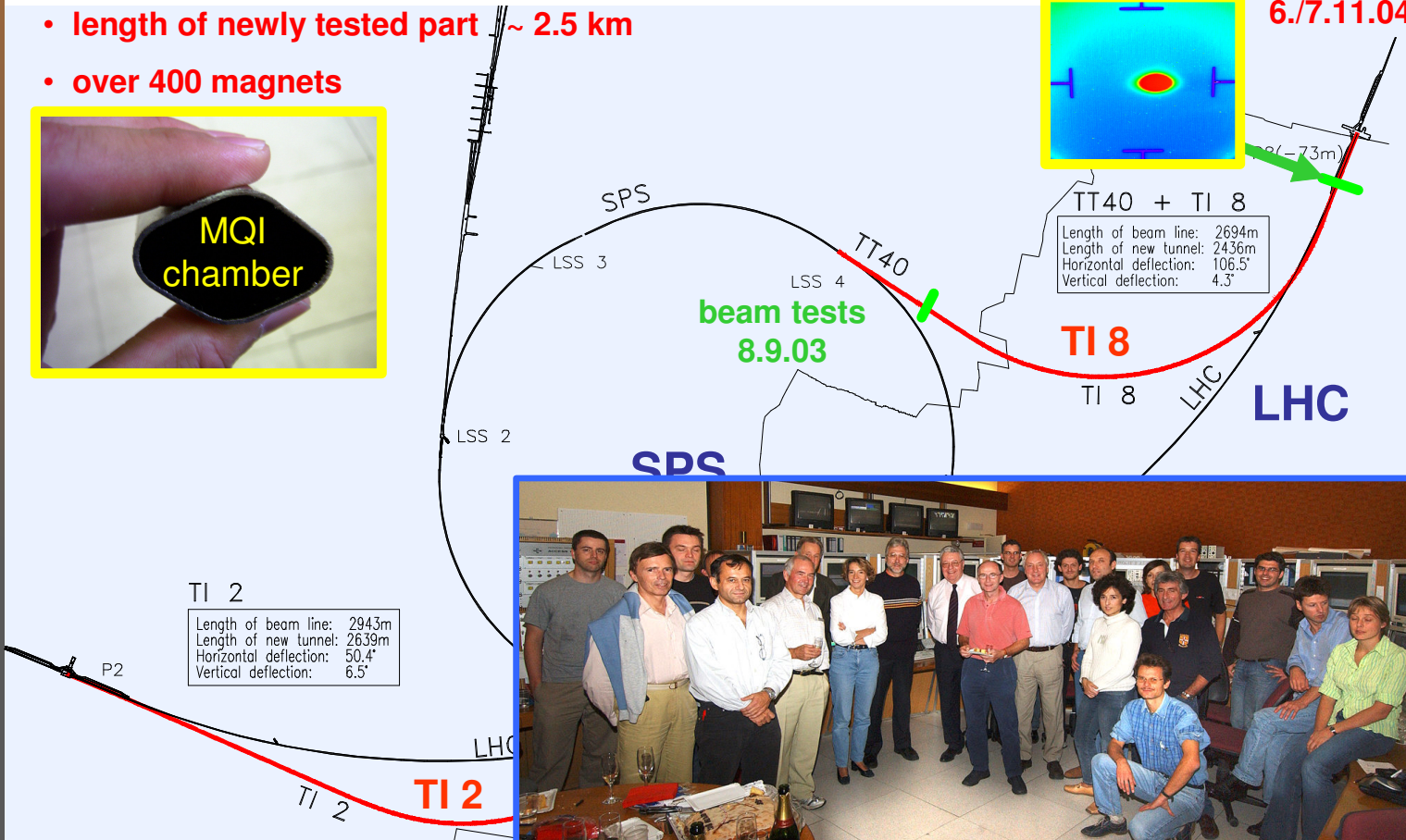
13:39 → beam at the end of TI 8, some 2.5 km away, at first attempt

beam tests
23./24.10.04
6./7.11.04

- length of newly tested part ~ 2.5 km
- over 400 magnets



TT40 + TI 8
 Length of beam line: 2694m
 Length of new tunnel: 2436m
 Horizontal deflection: 106.5°
 Vertical deflection: 4.3°



TI 2
 Length of beam line: 2943m
 Length of new tunnel: 2639m
 Horizontal deflection: 50.4°
 Vertical deflection: 6.5°



TI 8 commissioning / V.Mertens / TCC, 29.10.2004



Magnet rows



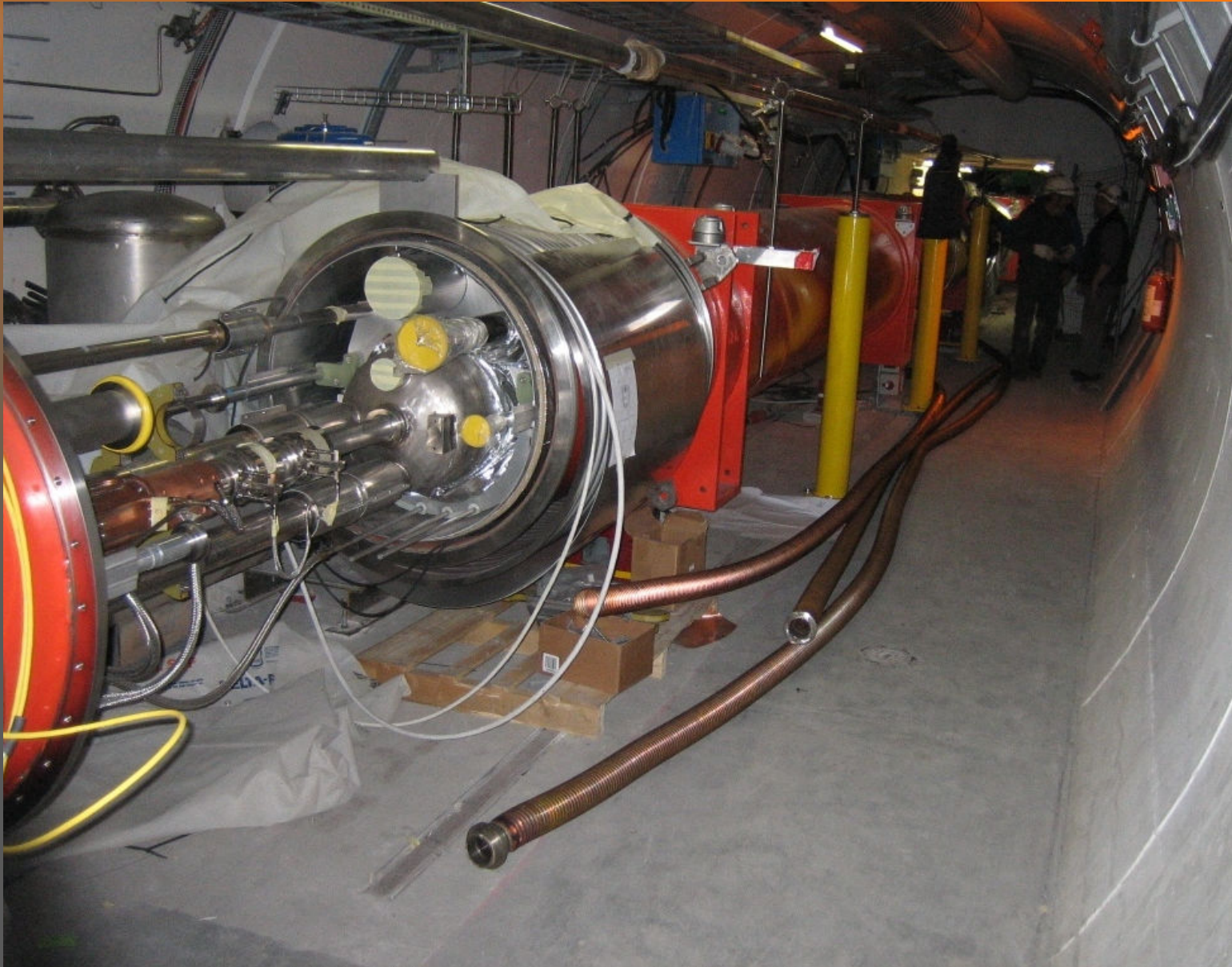
Magnet rows



End of civil engineering works in Point 5 (1st February 2005)



Inner triplet crisis Feb 2005



First cryodipole lowered on 7 March 2005



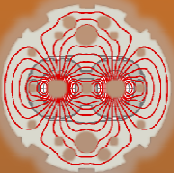
Quarks and Photons: The Strangest Little Things in Nature

FOX NEWS.COM, THURSDAY, NOVEMBER 09, 2006



AP

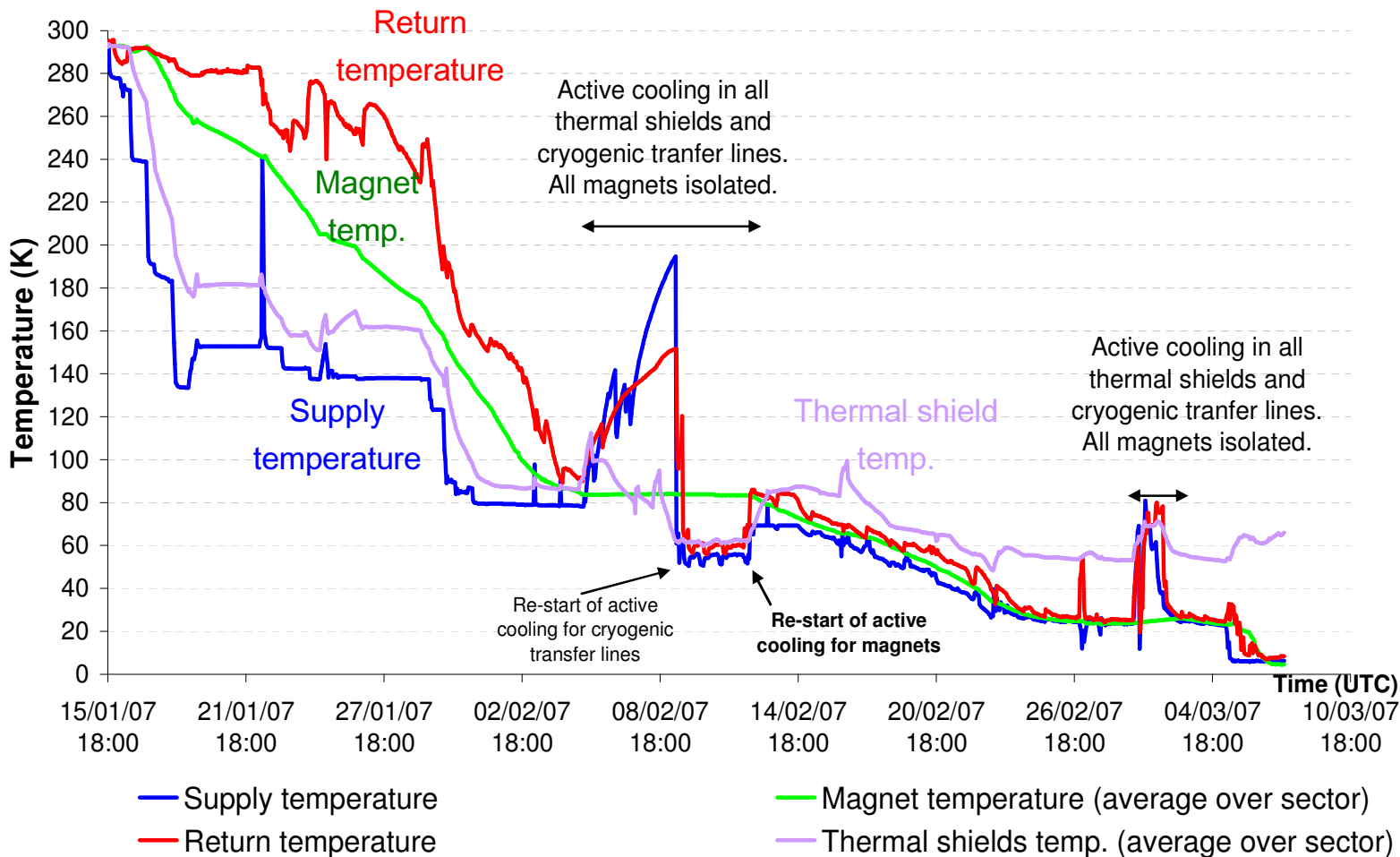
The CERN Large Hadron Collider in Geneva, Switzerland, which will be the world's largest particle accelerator when it enters full operation in 2008.

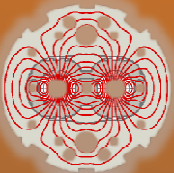


First cool-down of Sector 7-8



LHC sector 78 - First cooldown

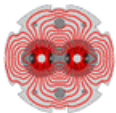




Last delivered dipole 27 November 2006



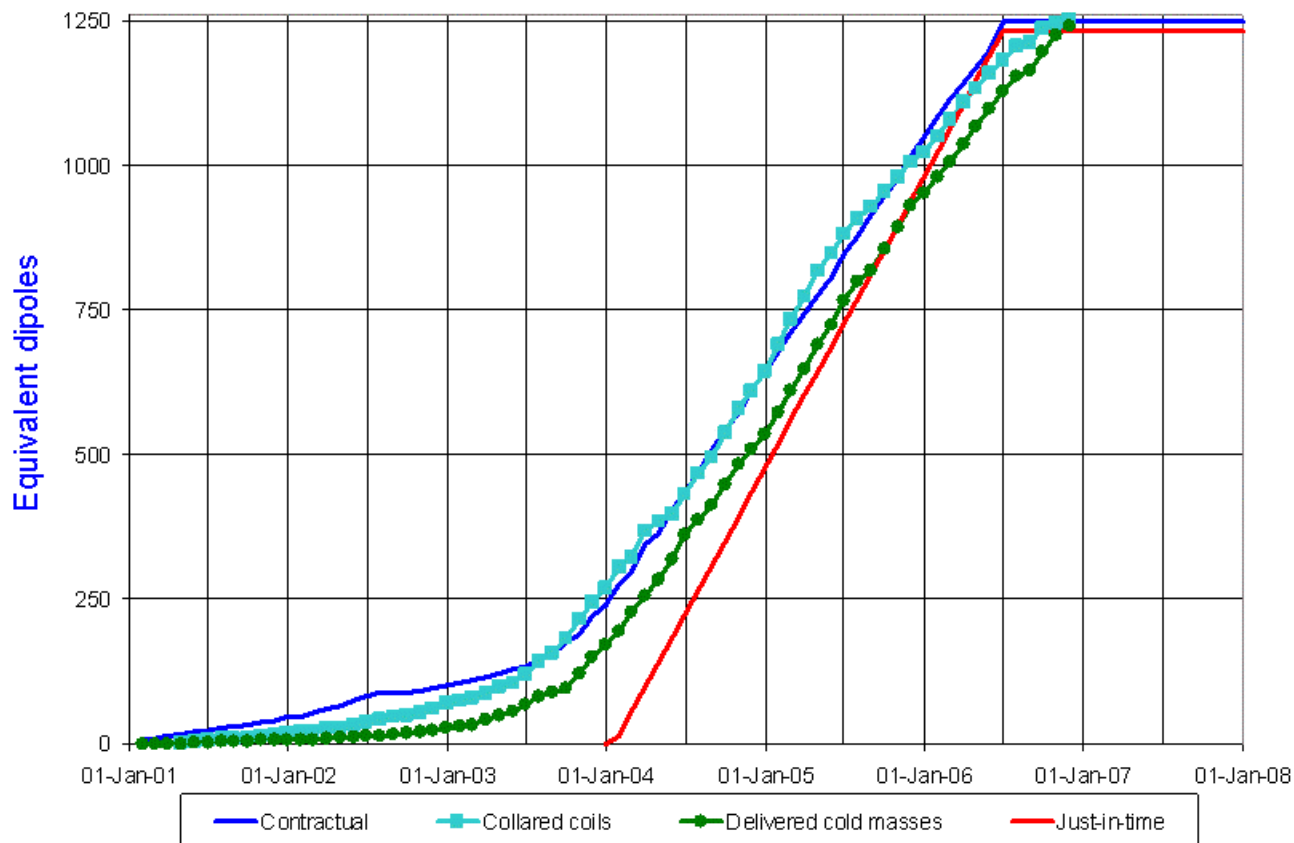
Dipole cold masses



LHC Progress
Dashboard

Accelerator
Technology
Department

Dipole cold masses



Updated 30 Nov 2006

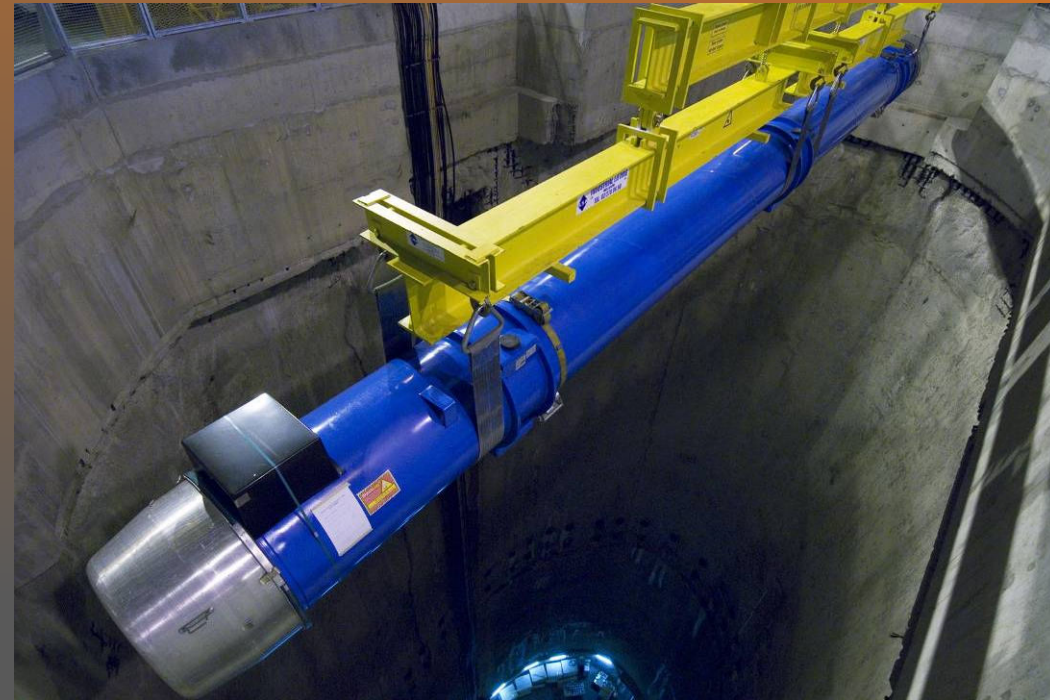
Data provided by

G. de Rijk AT-MCS



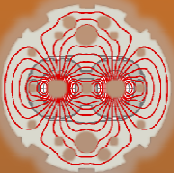
Descent of the last magnet

26 April 2007



30'000 km underground at 2 km/h!



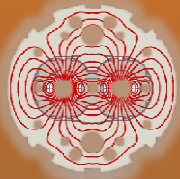


June 2007

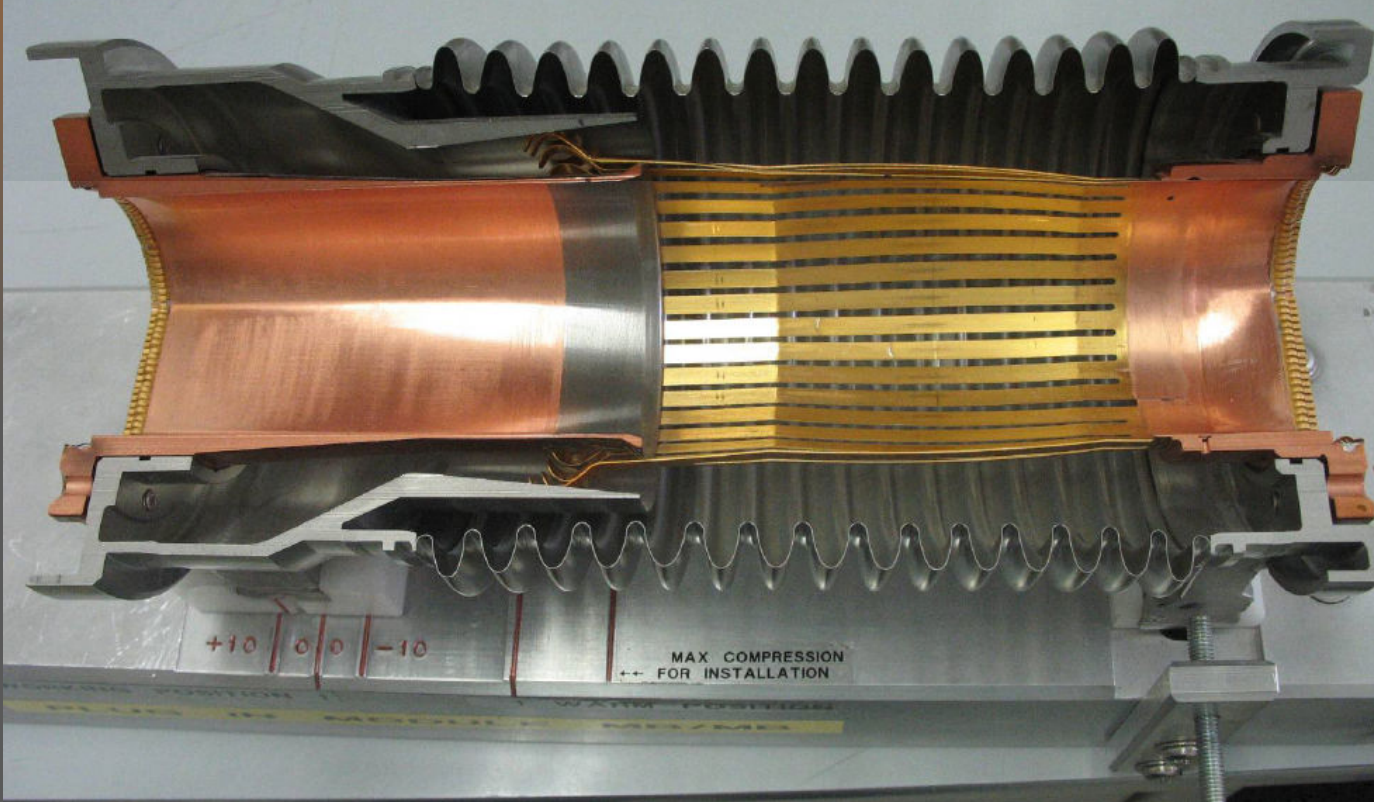
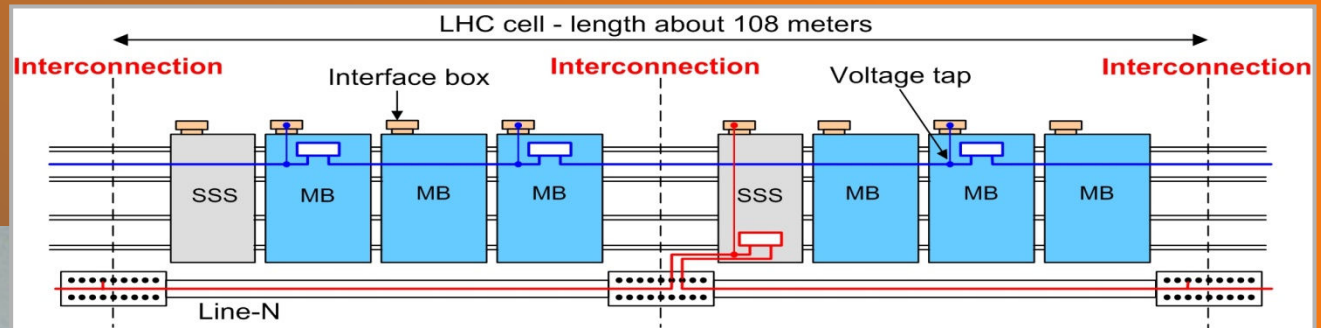
- A complete LHC sector 3.3 km-long and cooled at -271°C is powered up for the first time.
- Several thousands of amps circulate in the superconducting magnets installed in the tunnel. Members of the groups involved celebrated with champagne.



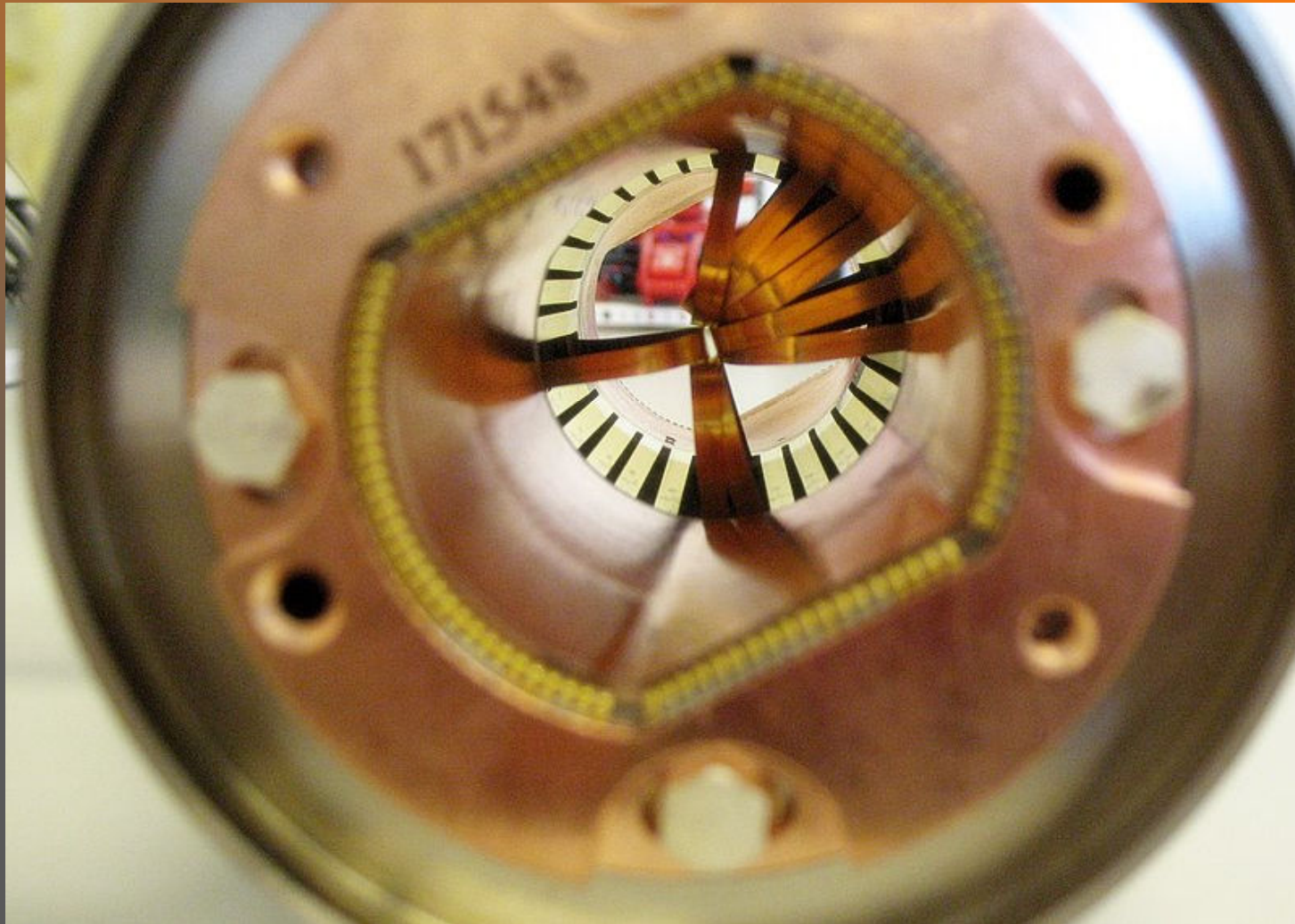
Closure of continuous cryostat November 2007



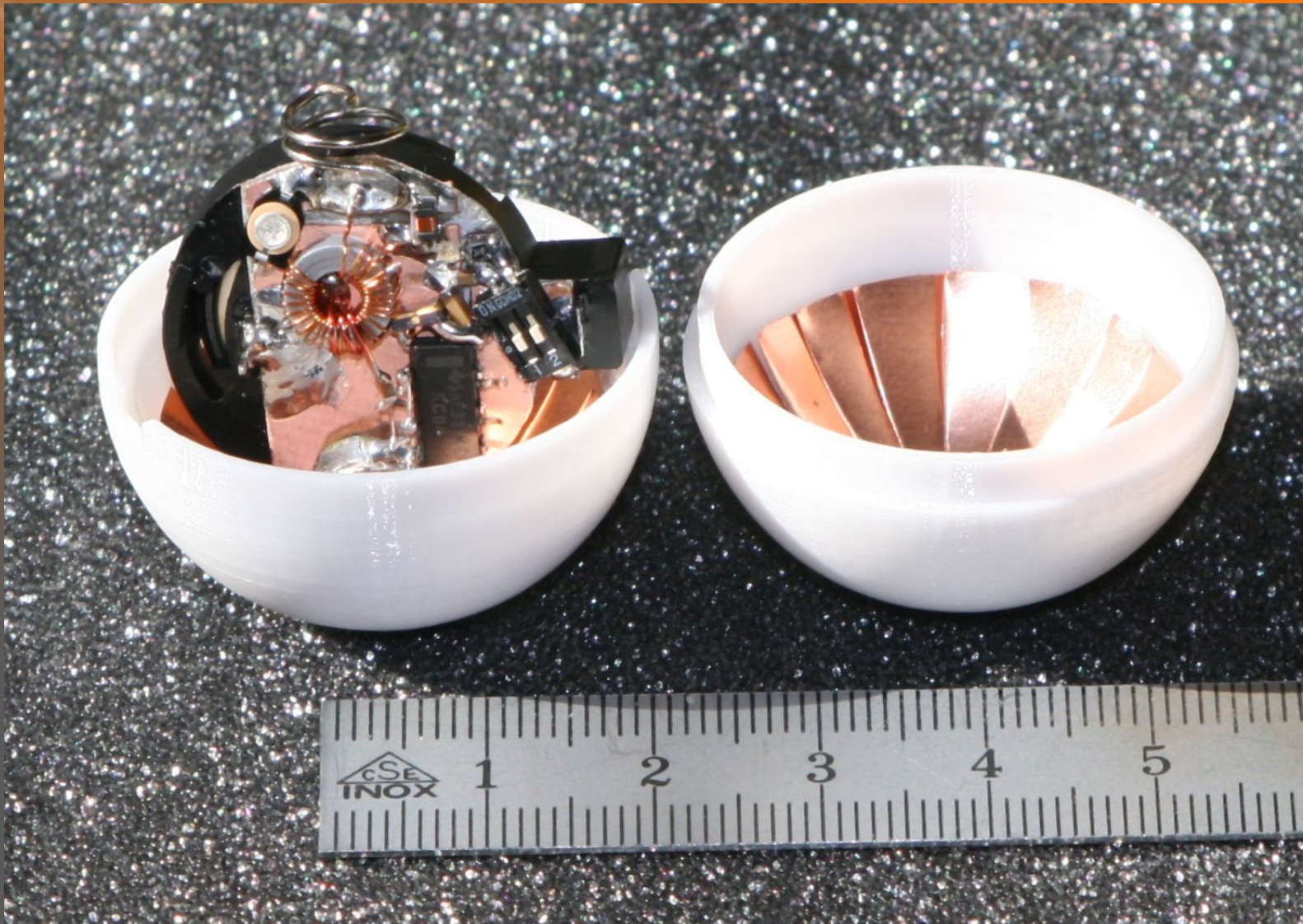
The crisis of the PIM's

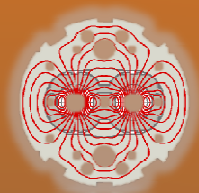


Arc plug-in module with damaged fingers



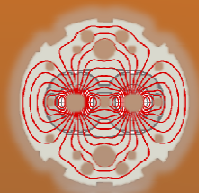
Transmitter ball





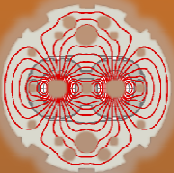
10 September 2008



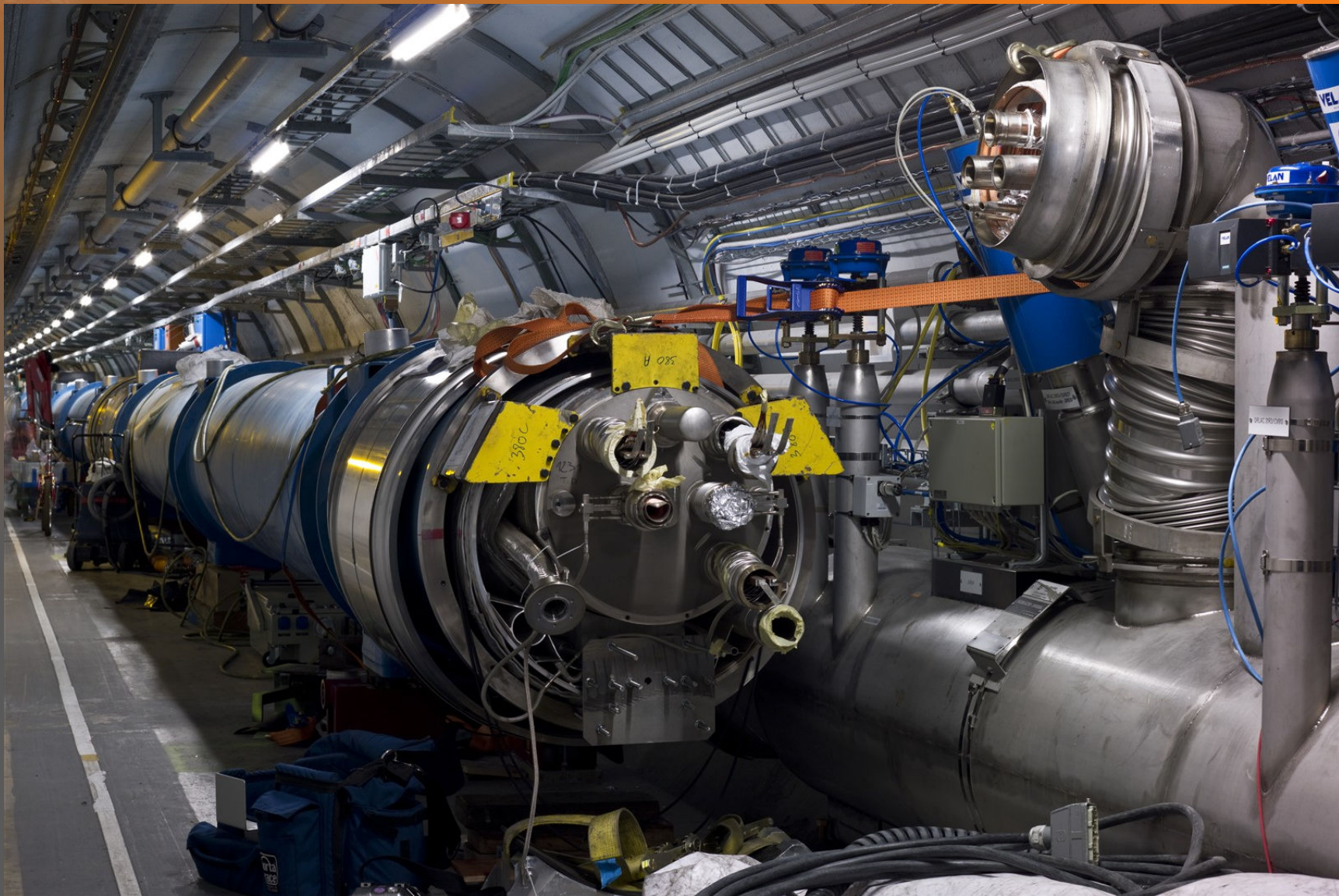


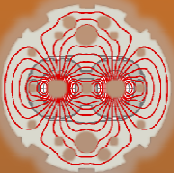
5 DGS



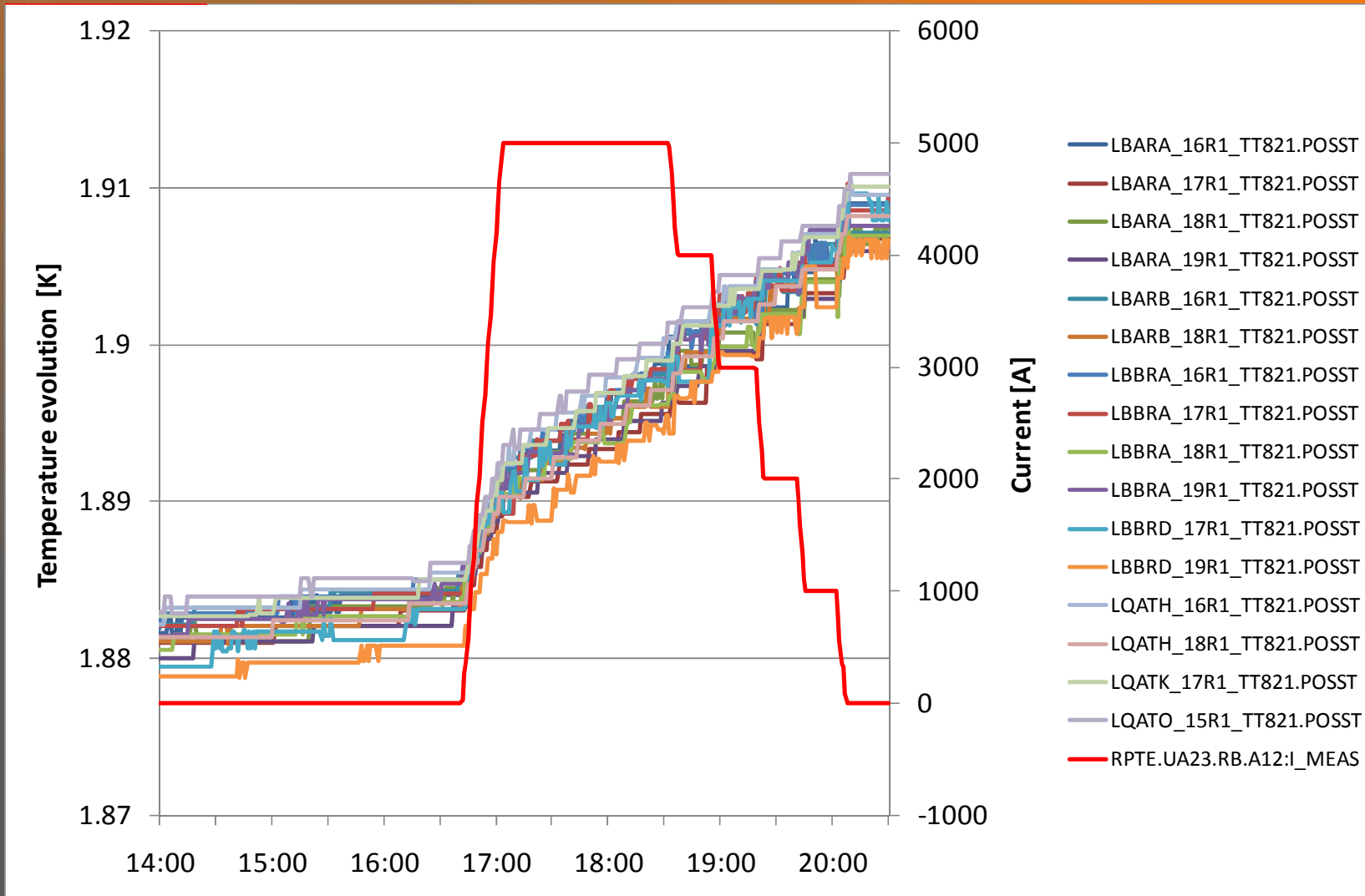


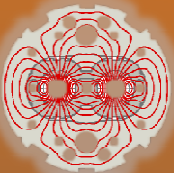
19 September 2008





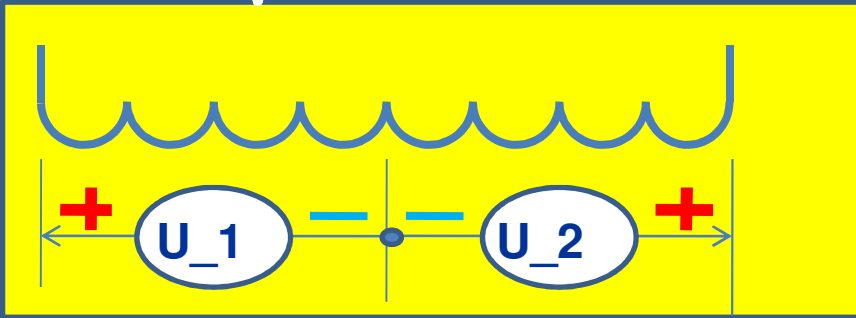
Powering example 15R1 powering @ 5000A



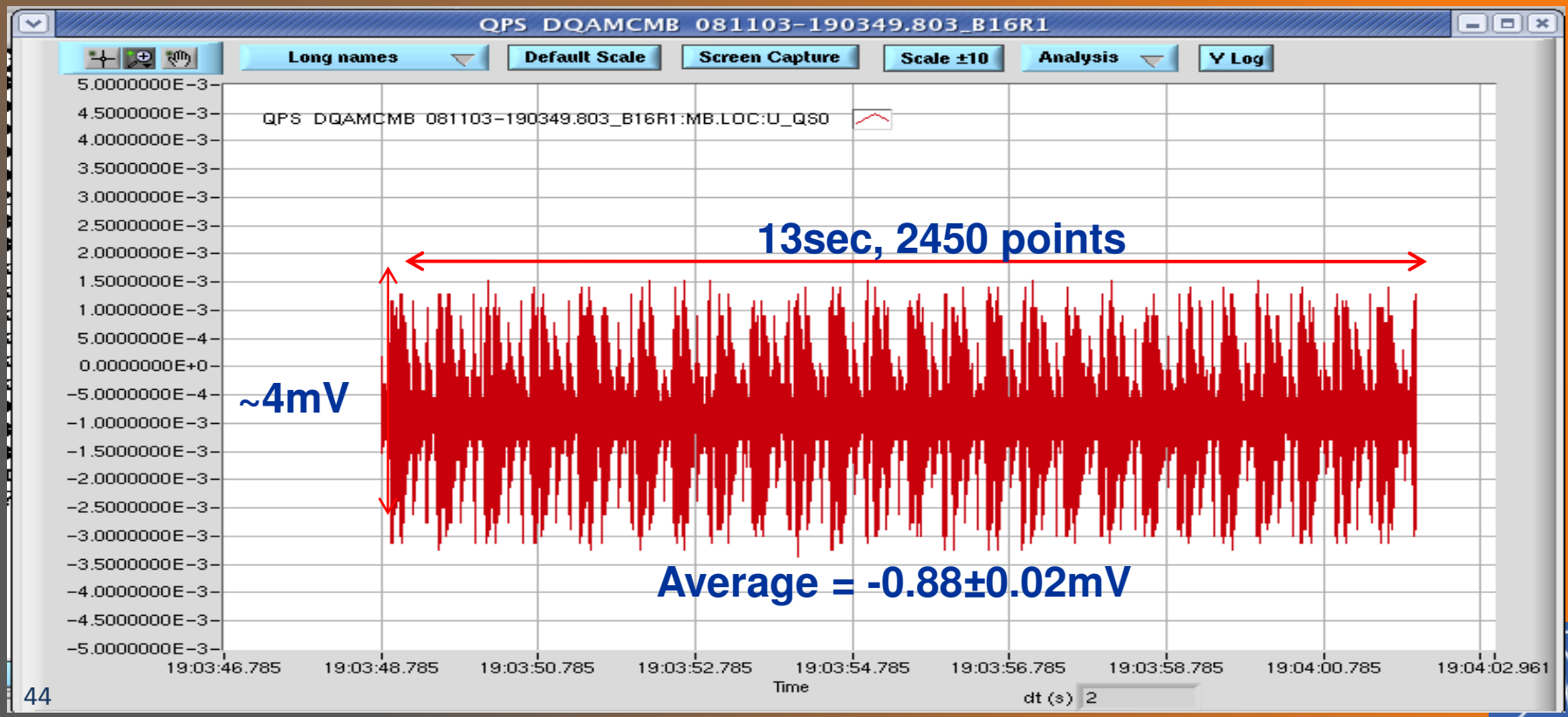


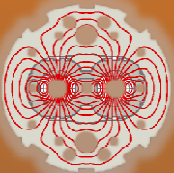
Sector A12: A15R1 – C19R1

“splice” measurements on 03.11.08

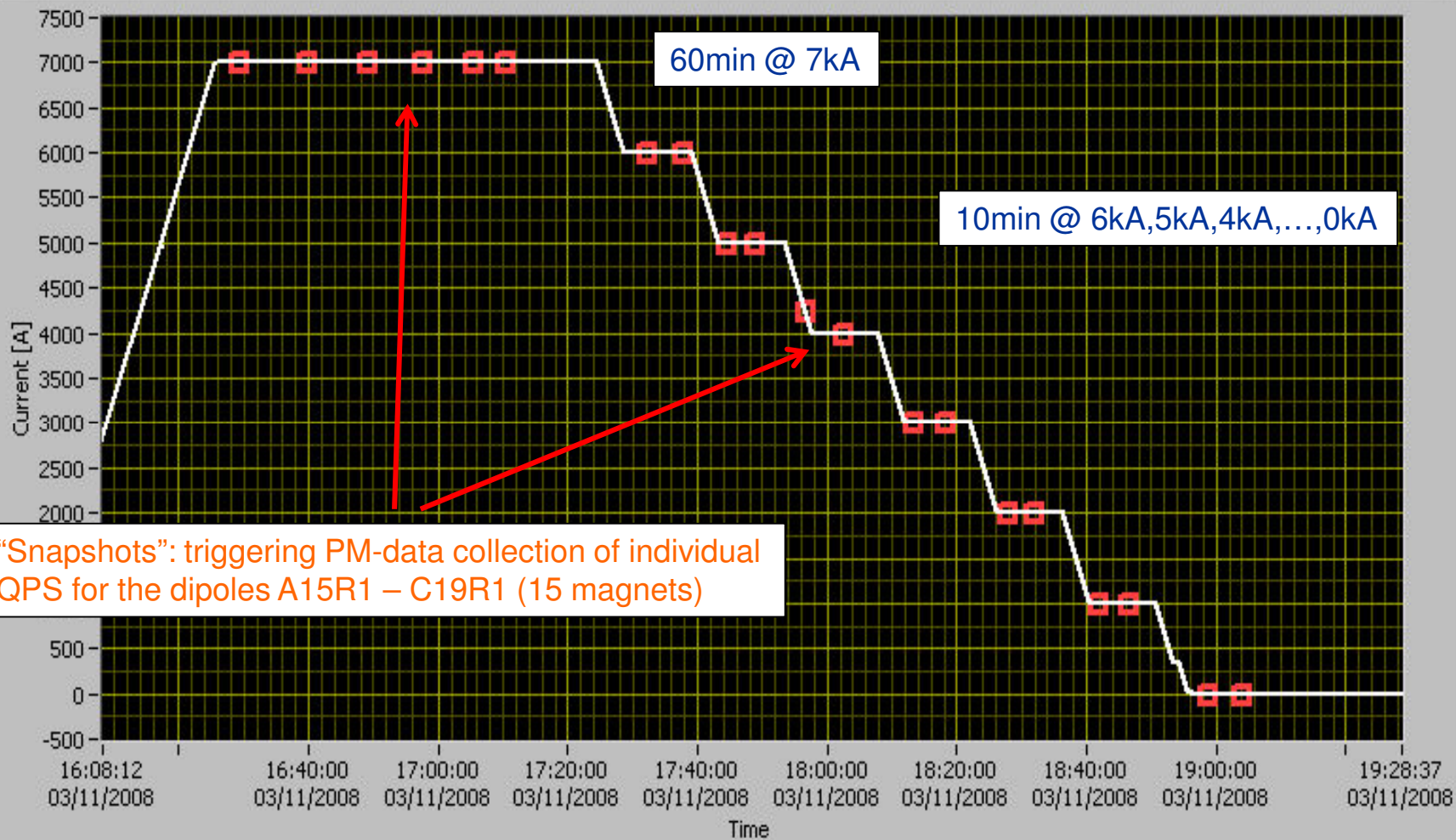


$U_{QS0} \Rightarrow -(U_1 + U_2)$
Sampling Rate = 5ms
Resolution = 0.125mV
Quench Threshold = 100mV@10ms



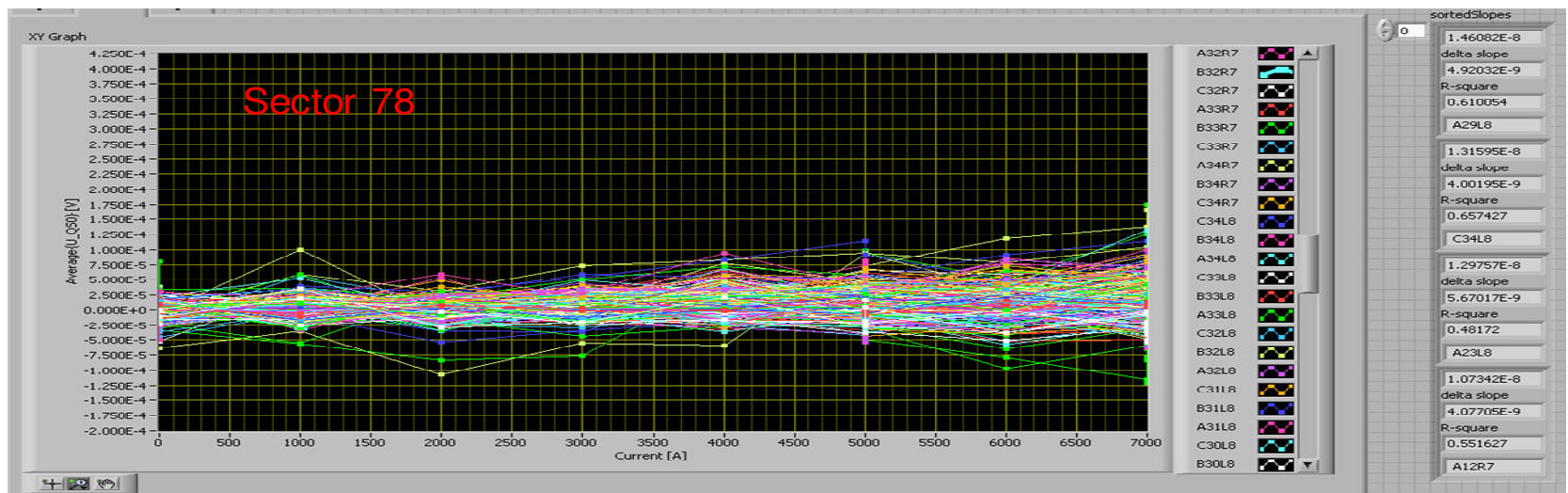
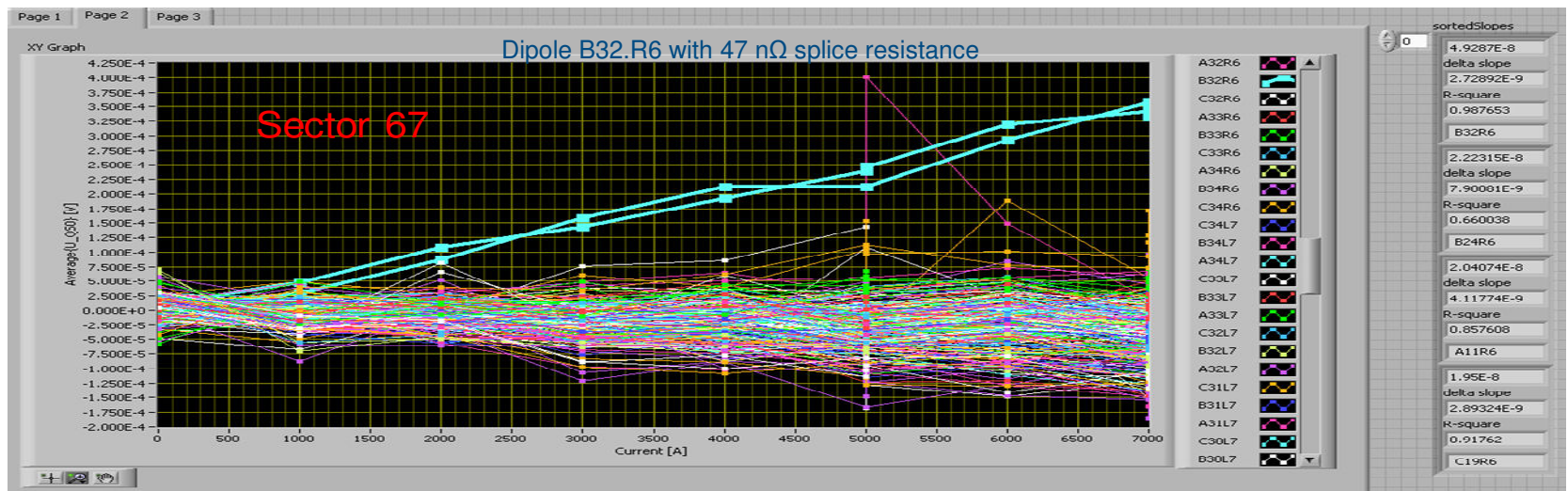


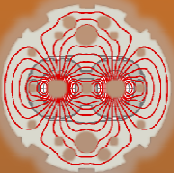
Sector A12: A15R1 – C19R1 measurements on 03.11.08



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





20th November 2009

BTV - SPS.USER.LHCFAST2

File Tools Help

Nov 20 20:37:55 SPS - LHCFAST2, 39 CNGS1 - 03

Selection

Device: LHC.BTVSLC5L2.B1

Status

Device: LHC.BTVSLC5L2.B1
Status: OK
Mode: OFF
Control: REMOTE

Setting

Basic Advanced Expert

Acquisition Type: One extraction
Acquisition Number: 1
Camera Switch: ON
Screen: Ti
Filter: Out
Video Gain: x 6.5
Lamp Switch: ON

First Lamp: 0 mV
Second Lamp: 0 mV
Motor Enable: enable
Hardware Reading:
Shutdown Camera:

LHC.BTVSLC5L2.B1/Image

(1 of 1 acquisitions) Cycle: SPS.USER.LHCFAST2 SC Nb: 59 Date: 2009/11/20 20:37:53.462853

Image

Horizontal projection

Amplitude [a.u.] vs X [mm]

Mean = 4.01 [mm]
Sigma = 4.71 [mm]
Amplitude = 110.74 [a.u.]

Vertical projection

Amplitude [a.u.] vs Y [mm]

Mean = 0.85 [mm]
Sigma = 1.51 [mm]
Amplitude = 241.44 [a.u.]

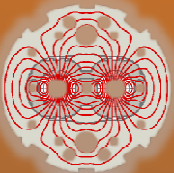
Acquisition Type: One extraction Camera Switch: RAD ON Screen: Ti
Acquisition Number: 1 Mire: OFF Filter: Out

Video Gain: x 6.5 First Lamp: 0
Second Lamp: 0

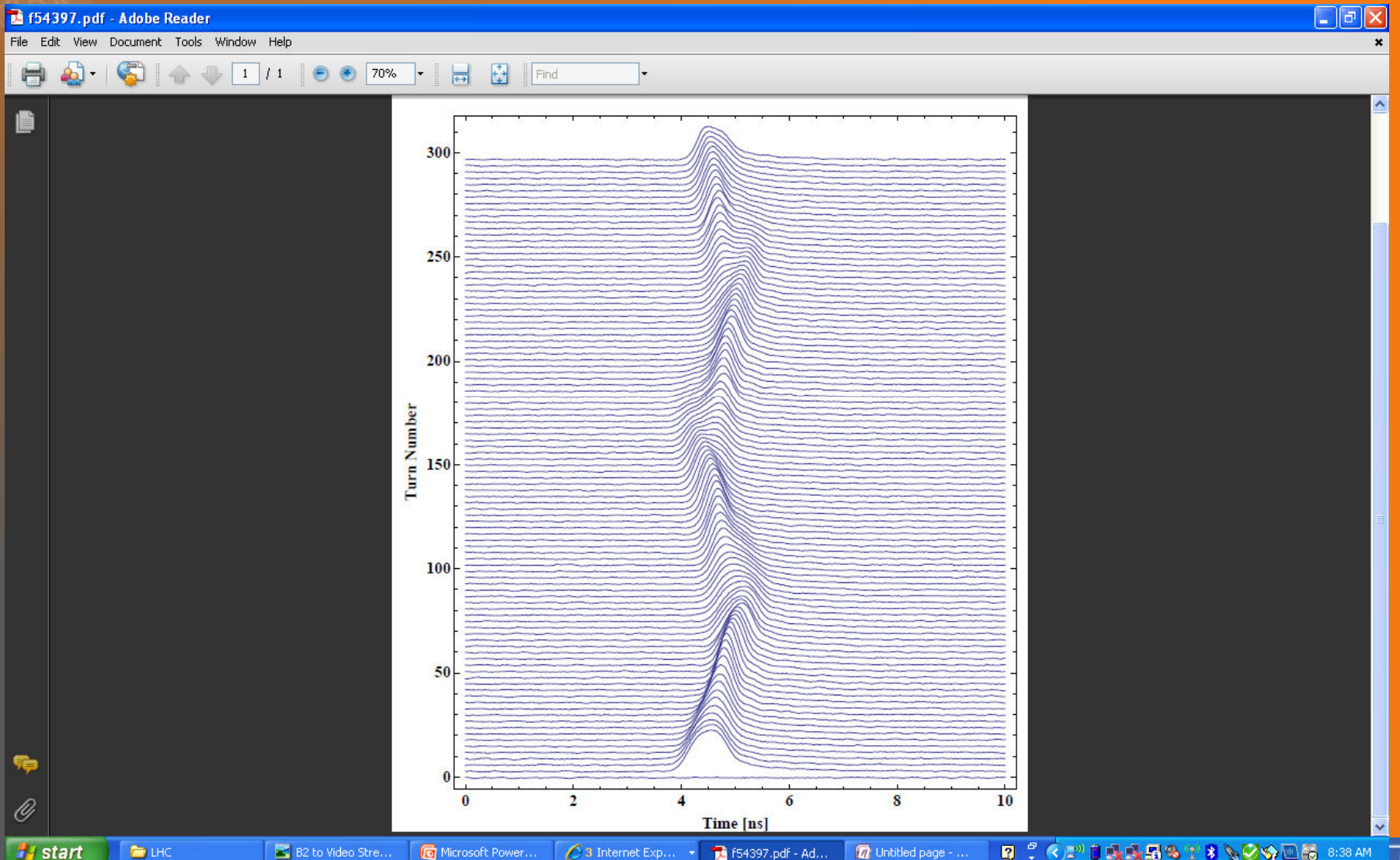
Acquire Start Monitoring Stop Save Continuous Saving /user/pcrops/data/LHChwc/Logging/SDDS

20:37:56 - Done.

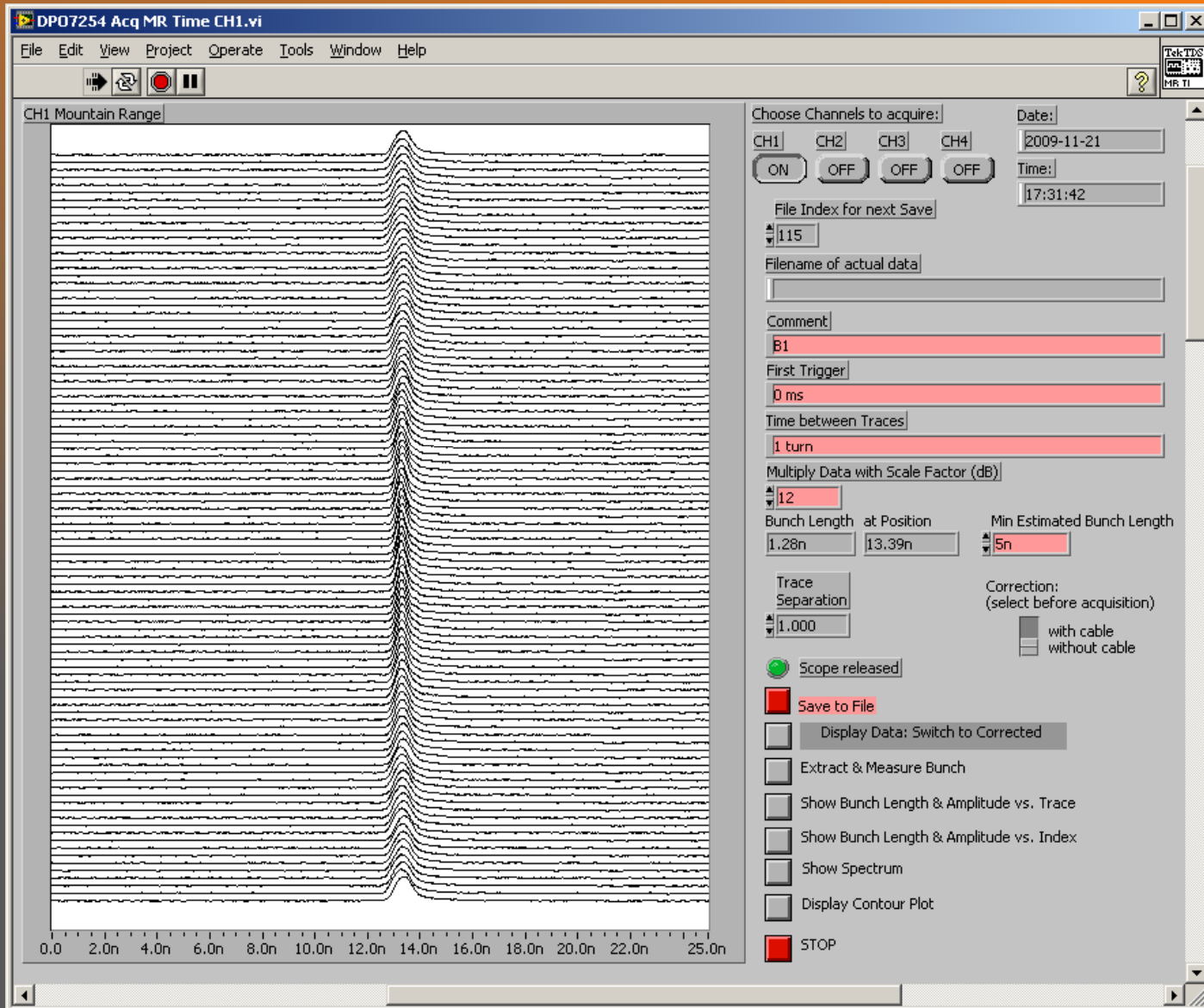




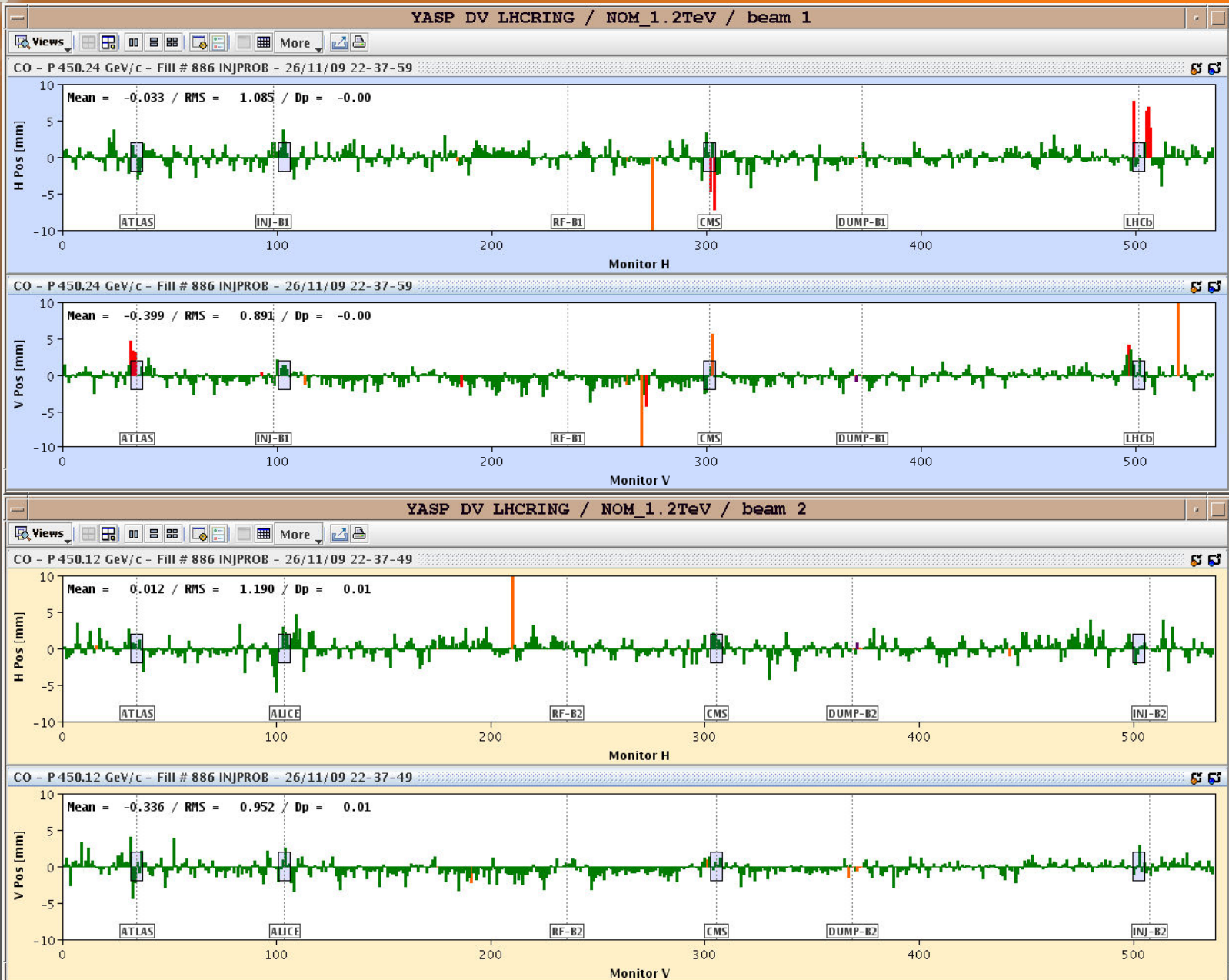
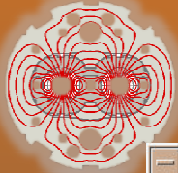
Beam 2 first capture

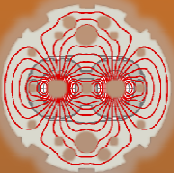


Mountain range beam 1

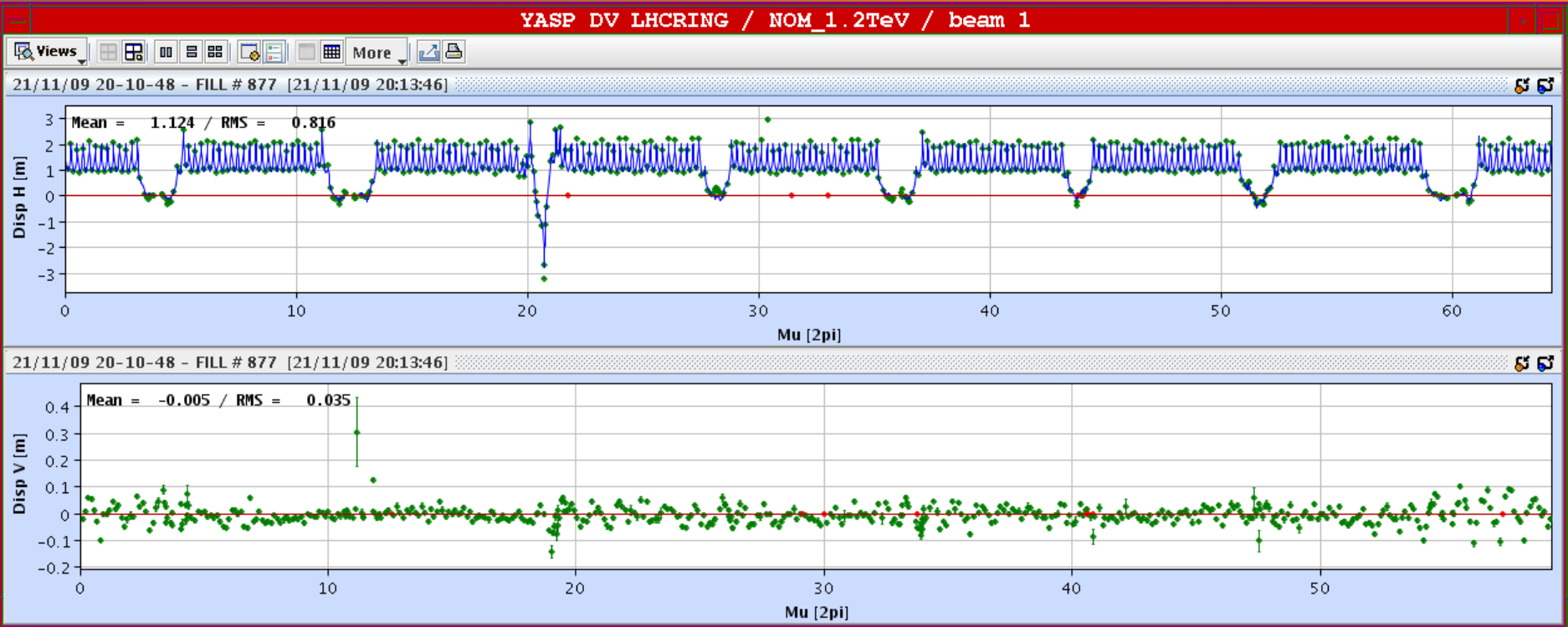


Orbits

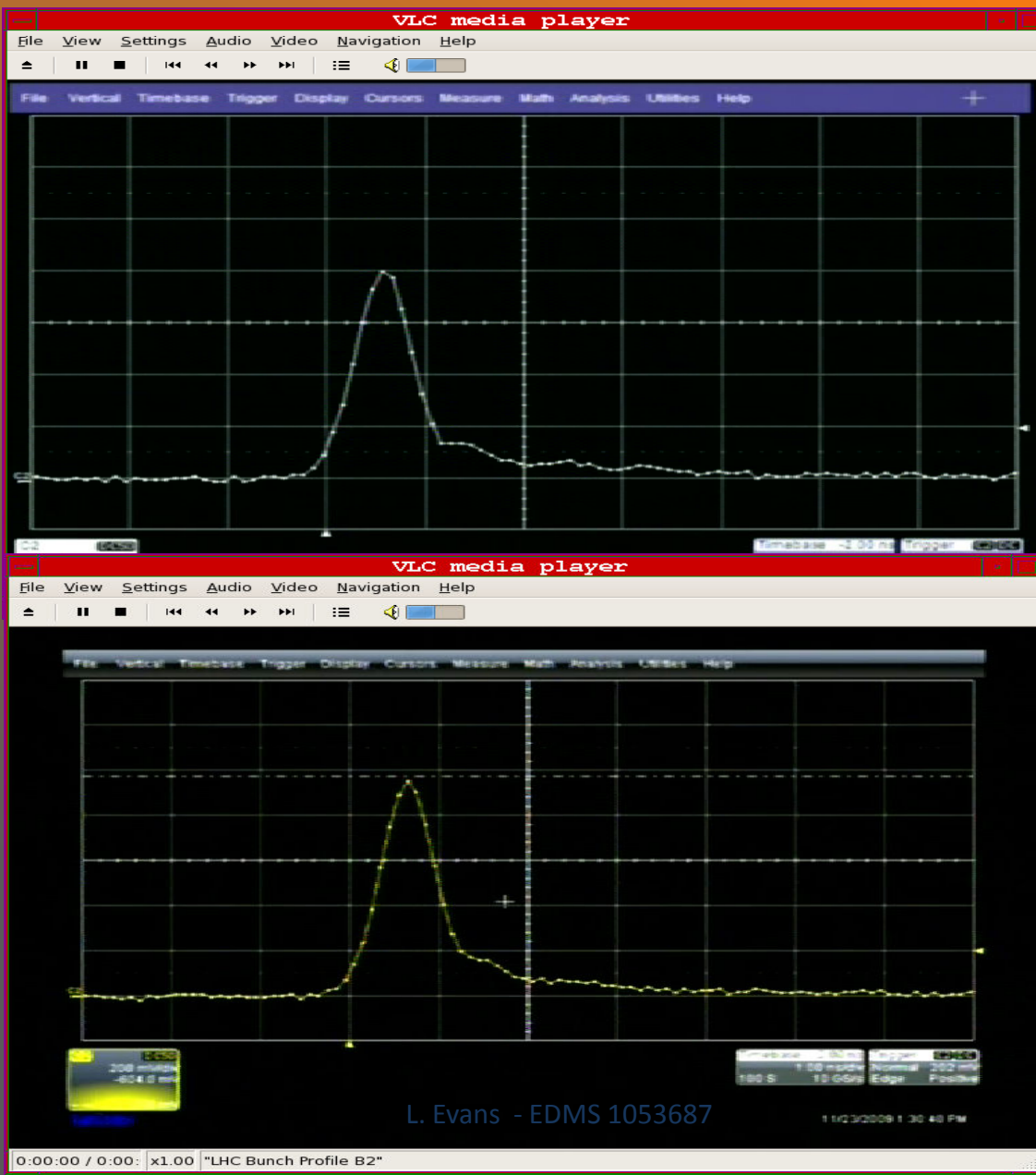


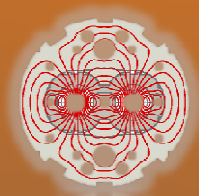


Dispersion B1

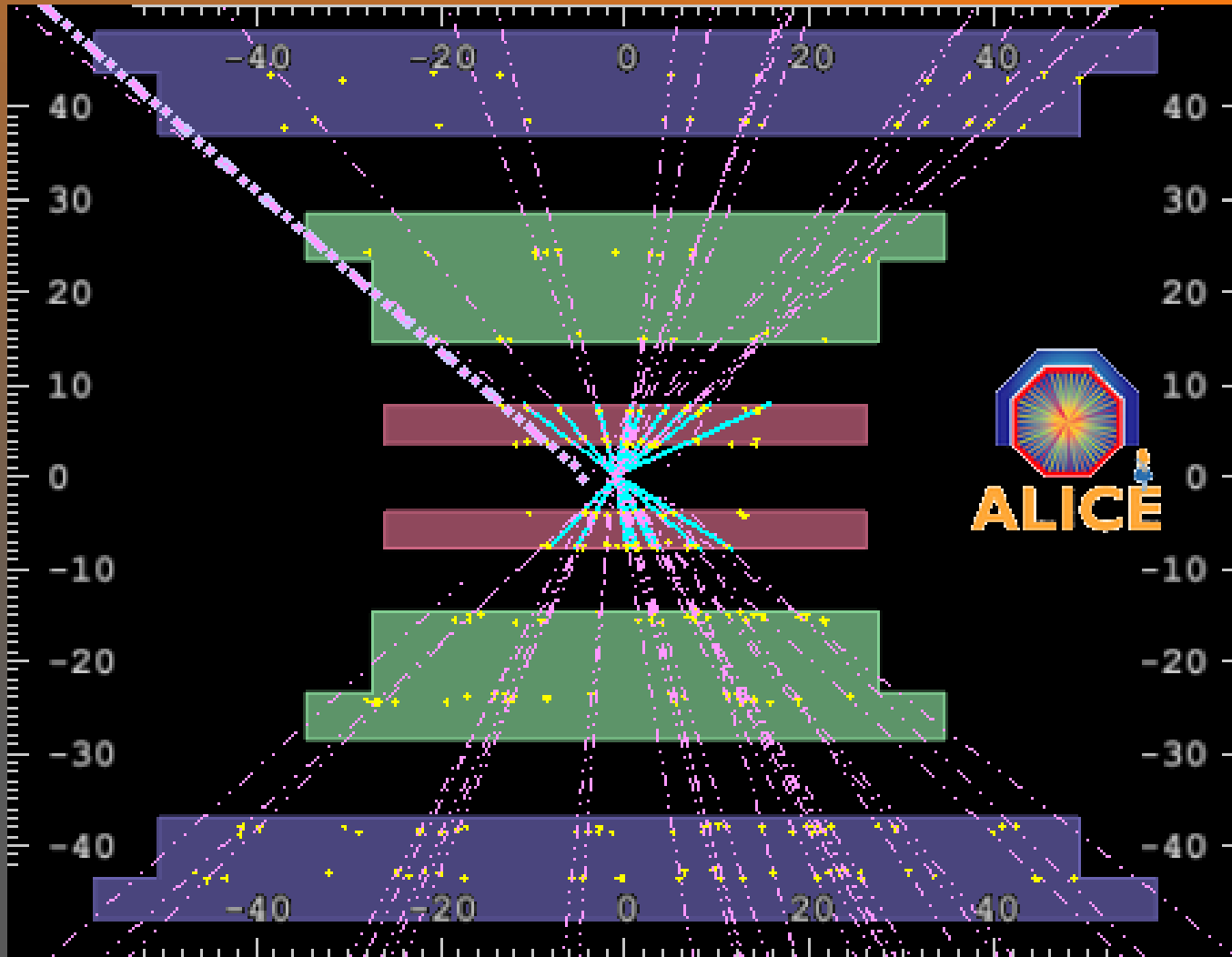


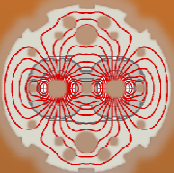
2 beams in the machine





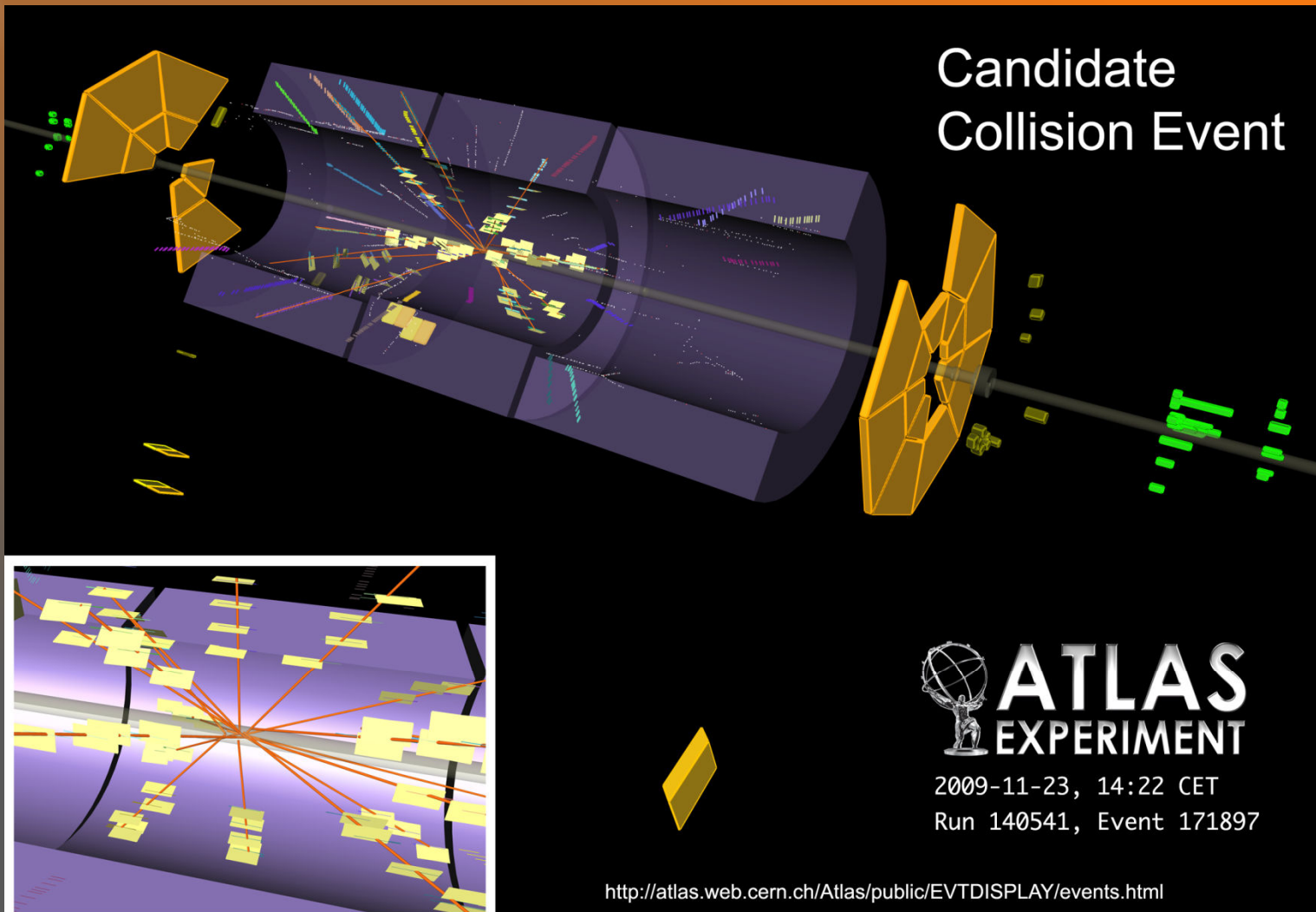
ALICE





ATLAS

Candidate
Collision Event

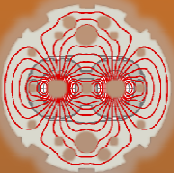


 **ATLAS**
EXPERIMENT

2009-11-23, 14:22 CET
Run 140541, Event 171897

<http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html>





CMS

cmsShow: rfi:///castor/cern.ch/cms/store/temp/express/BeamCommissioning09/ExpressPhysics/FEVT/v2/000/122/314/7AAB2A4D-5ED8-DE1

File Edit View Window Help

Delay 3.0s Run 122314 Event 15145452 Mon Nov 23 19:20:55 2009 CEST Lumi block id: 25

Event Filtering is OFF

Summary View

Add Collection

- ECal
- HCal
- Jets
- Tracks

	pt	eta	phi
<input checked="" type="checkbox"/> Track 0	4.9	-0.2	0.3
<input checked="" type="checkbox"/> Track 1	5.0	-0.1	0.2
<input checked="" type="checkbox"/> Track 2	3.7	-0.8	0.3
<input checked="" type="checkbox"/> Track 3	4.0	-0.7	0.3
<input checked="" type="checkbox"/> Track 4	4.6	-0.4	0.6
<input checked="" type="checkbox"/> Track 5	4.8	-0.3	0.6
<input checked="" type="checkbox"/> Track 6	4.9	-0.2	1.0
<input checked="" type="checkbox"/> Track 7	5.0	-0.1	1.1
<input checked="" type="checkbox"/> Track 8	4.4	-0.5	1.1
<input checked="" type="checkbox"/> Track 9	3.0	-1.1	1.1
<input checked="" type="checkbox"/> Track 10	3.0	-1.1	1.0
<input checked="" type="checkbox"/> Track 11	5.0	-0.1	1.2
<input checked="" type="checkbox"/> Track 12	4.1	-0.7	1.5
<input checked="" type="checkbox"/> Track 13	3.6	-0.9	2.6
<input checked="" type="checkbox"/> Track 14	4.9	-0.2	-2.3
<input checked="" type="checkbox"/> Track 15	3.5	0.9	0.4
<input checked="" type="checkbox"/> Track 16	3.7	0.8	0.7
<input checked="" type="checkbox"/> Track 17	5.0	0.1	0.8
<input checked="" type="checkbox"/> Track 18	3.6	0.8	0.9
<input checked="" type="checkbox"/> Track 19	4.3	0.6	1.4
<input checked="" type="checkbox"/> Track 20	4.6	0.4	1.6
<input checked="" type="checkbox"/> Track 21	3.0	1.1	1.9
<input checked="" type="checkbox"/> Track 22	4.6	0.4	2.3
<input checked="" type="checkbox"/> Track 23	3.6	0.9	-2.0
<input checked="" type="checkbox"/> Track 24	2.8	1.2	-0.1

- Muons
- Electrons
- Vertices
- DT-segments
- CSC-segments
- Photons
- MET
- siStripClusters

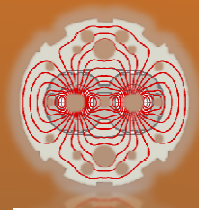
Views

Rho Phi

Rho Z

3D

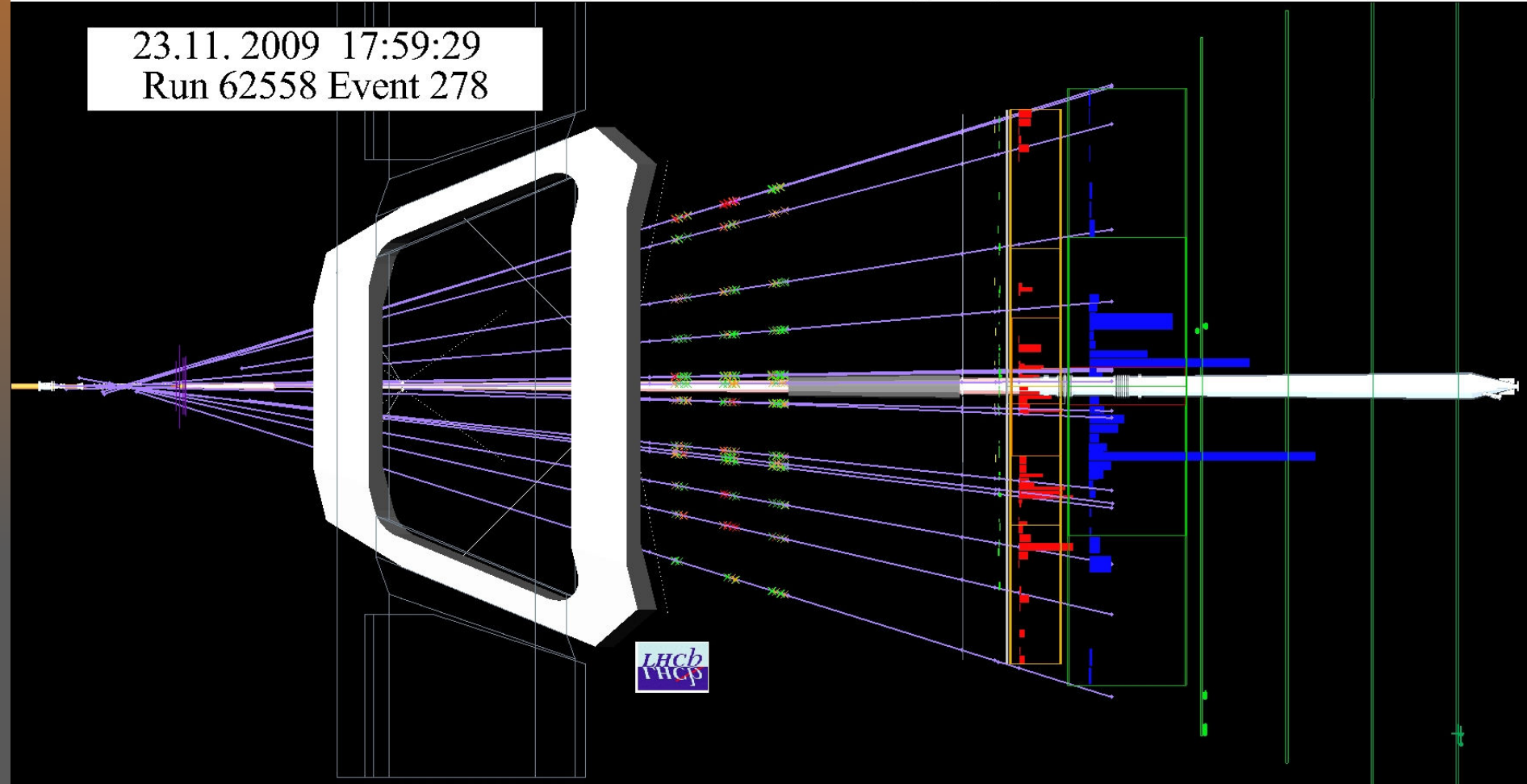




LHCb

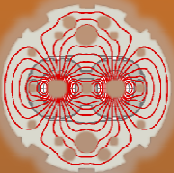
LHCb Event Display

23.11.2009 17:59:29
Run 62558 Event 278

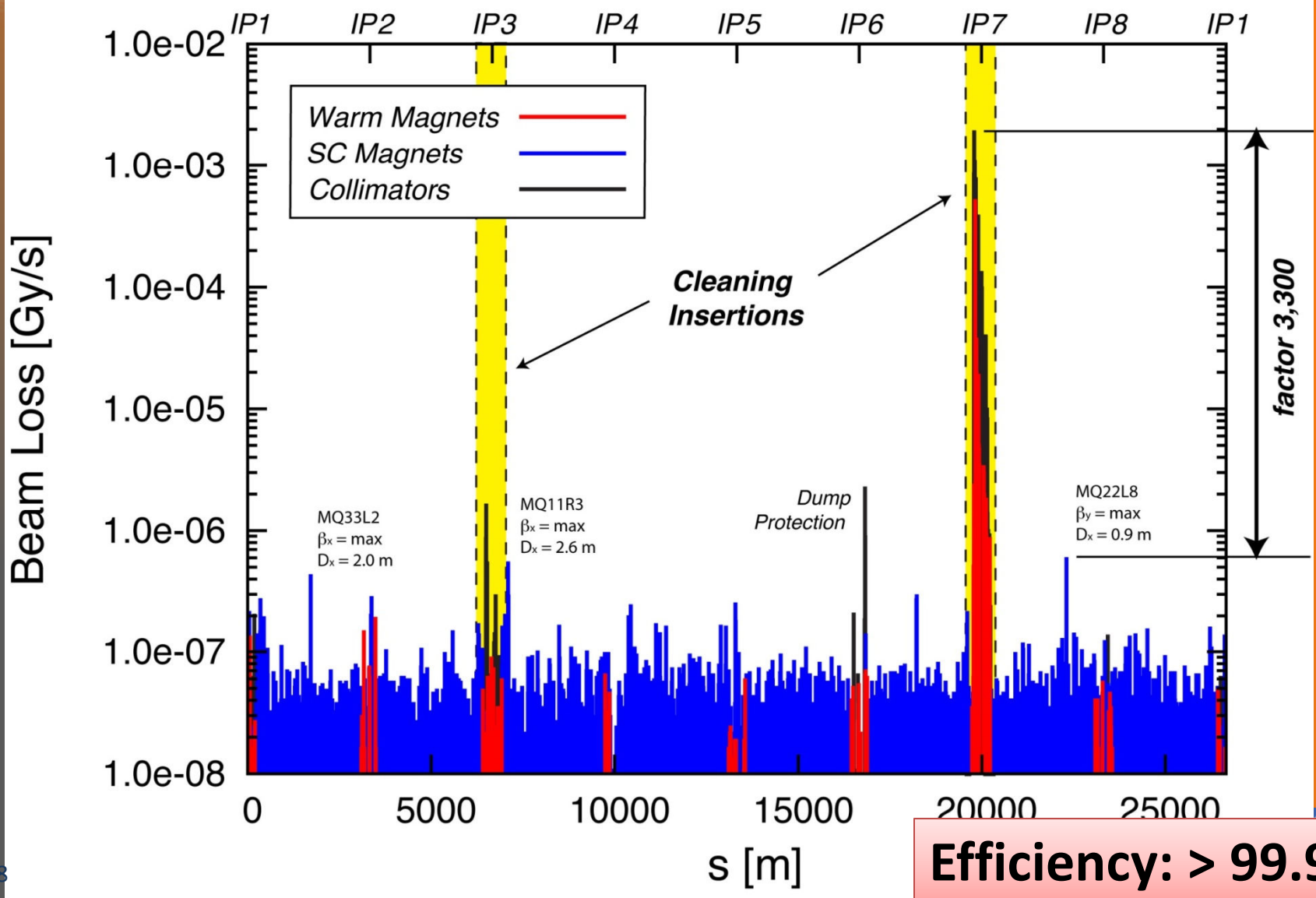


30 November 2009 twin beams at 1.18 TeV





November 29, 21:55:51 - First ramp to 1.18 TeV - Beam 1 - Highest loss in 1.3 s integral





Thanks

I would like to thank all of you, both inside and outside CERN for your work on the construction of the LHC. It has been a privilege to work with you and you should be justly proud of what you have achieved.

The adventure of LHC construction is finished. Now let the adventure of discovery begin.