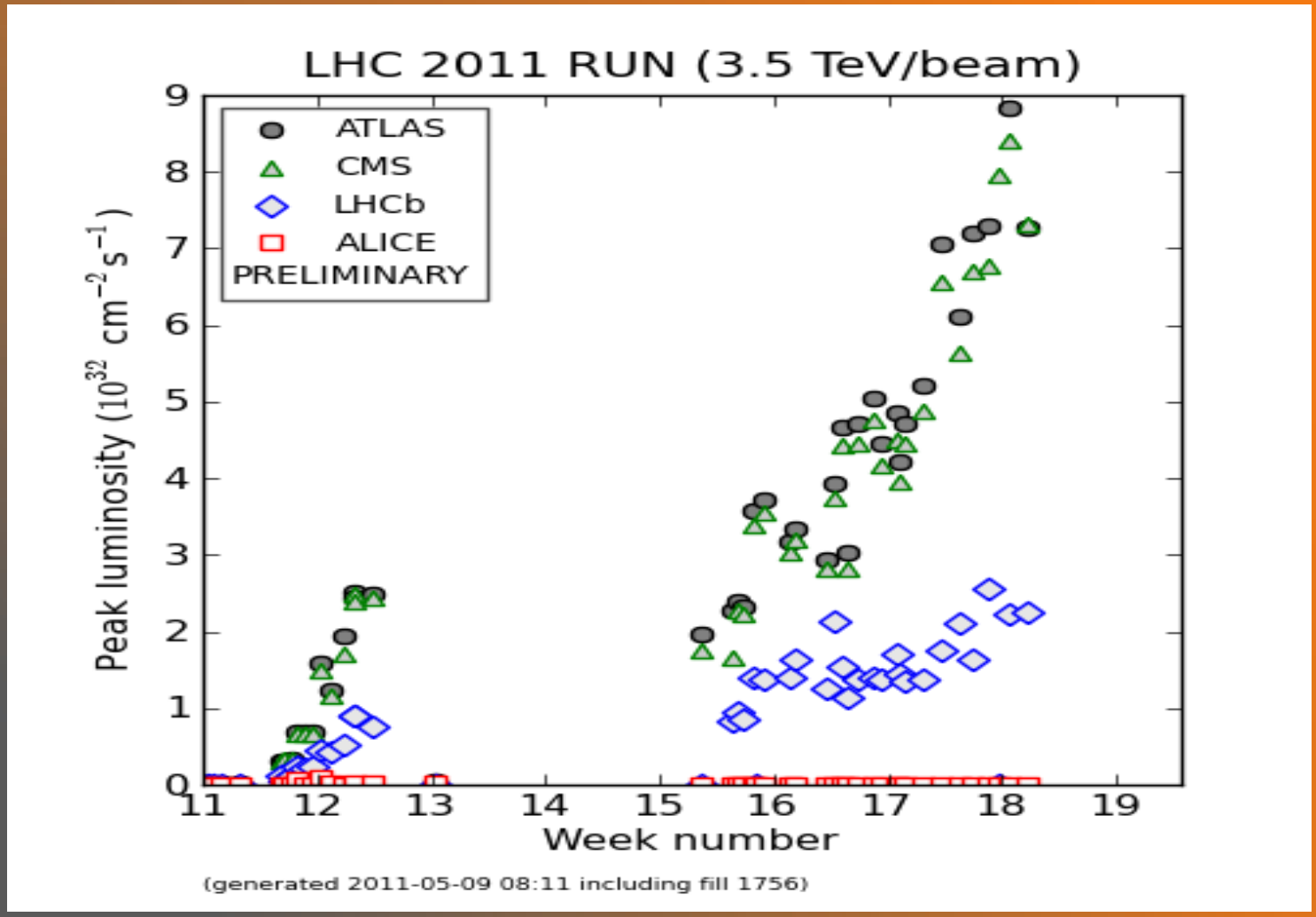
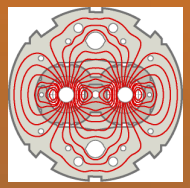
The Large Hadron Collider

Lyn Evans Imperial College/CERN



Royal Society 16th May 2011

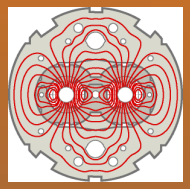


The birth of the LHC

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 got together for the first time.

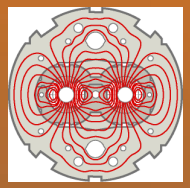
In reality, the LHC adventure started much earlier…

ISR

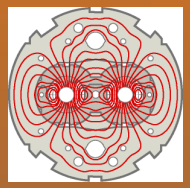


Approval of the LHC

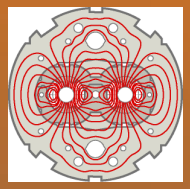
In December 1993, a plan was presented by the Director General designate Chris Llewellyn Smith to the CERN Council to build the machine over a ten-year period by reducing the other experimental program of CERN to the absolute minimum, with the exception of the full exploitation of the LEP collider. An external expert panel 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.



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.



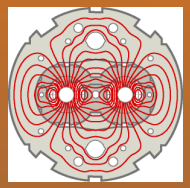
In order to deal with this new constraint, we were forced to propose a “missing magnet” machine where only two thirds of the dipoles would be installed in a first stage. The deadlock concerning extra host-state contributions was broken when France and Switzerland agreed to make extra voluntary contributions 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.



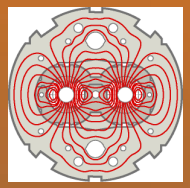
1996

March

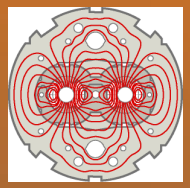
- India makes a financial contribution to the construction of the LHC.
- And in June, Russia announces a financial contribution to the project.

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.

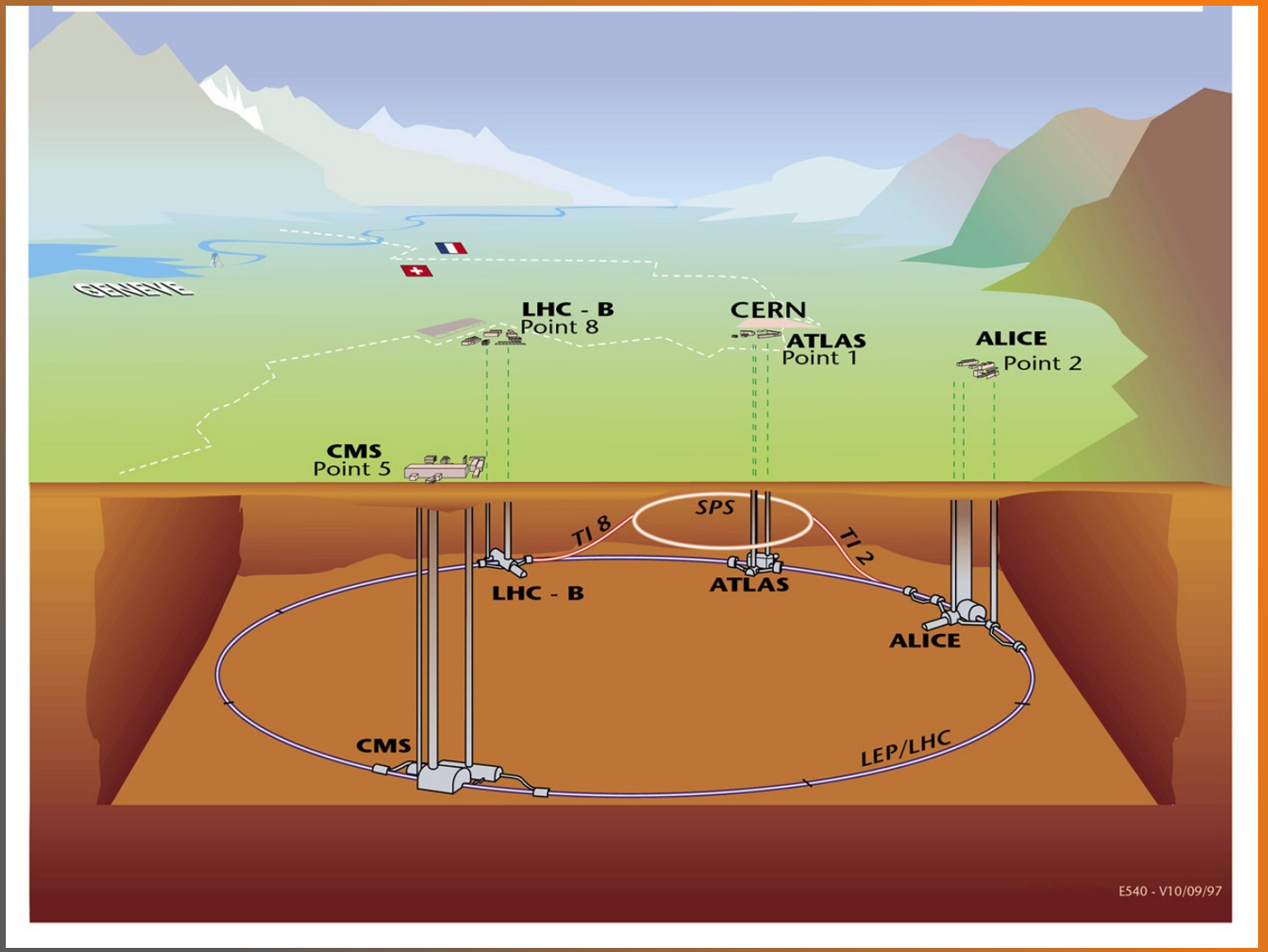


A final sting in the tail came in June 1996 from Germany who unilaterally announced that, in order to ease the burden of reunification, it intended to reduce its CERN subscription by between 8% and 9%. Confining the cut to Germany proved impossible. The UK was the first to demand a similar reduction 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.



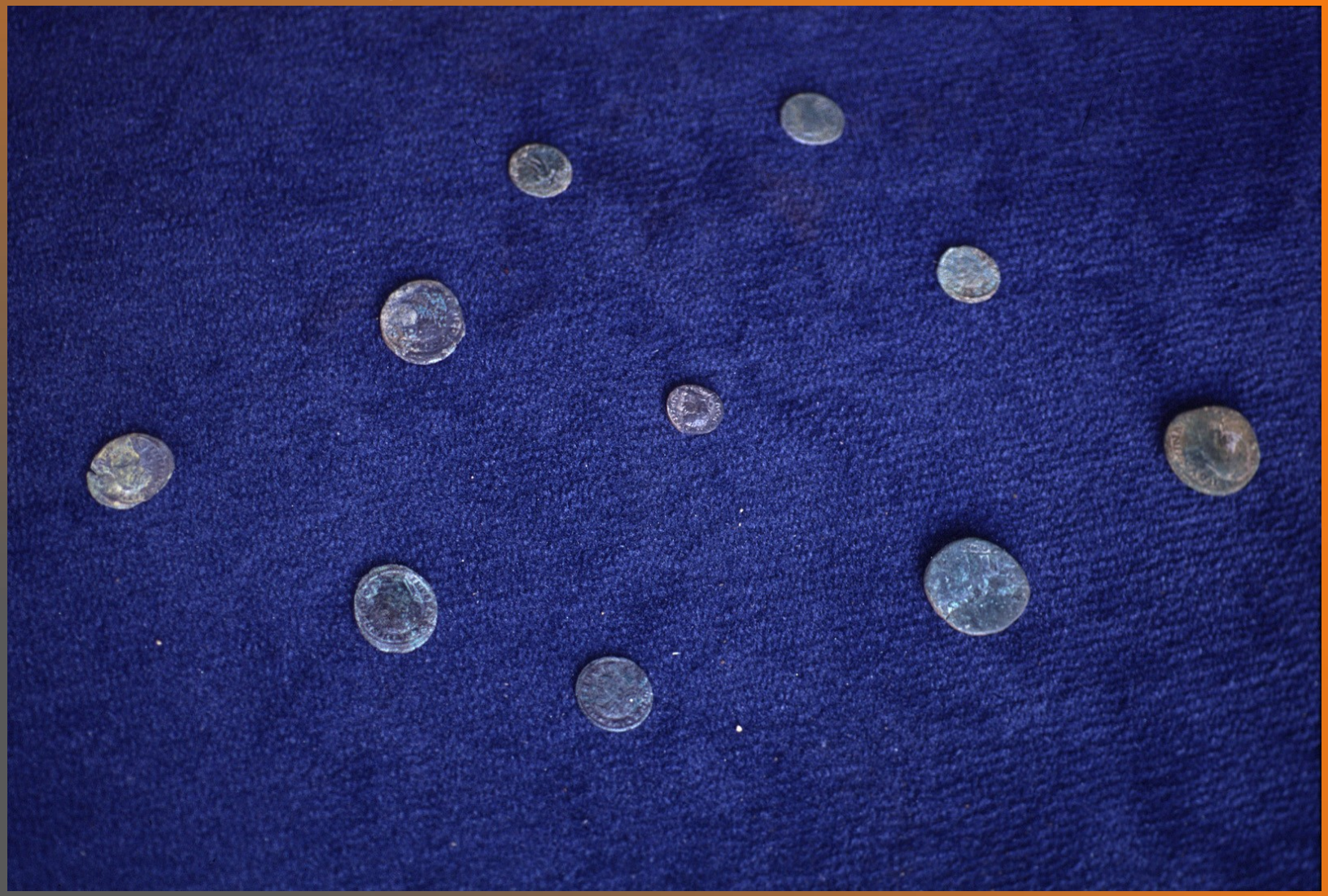
In December 1996 Council, Germany declared that “a greater degree of risk would inevitably have to accompany the LHC”. The project was approved for single-stage construction with the deficit financed by loans. It was also agreed that the final cost of the project was to be reviewed at the half-way stage 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.

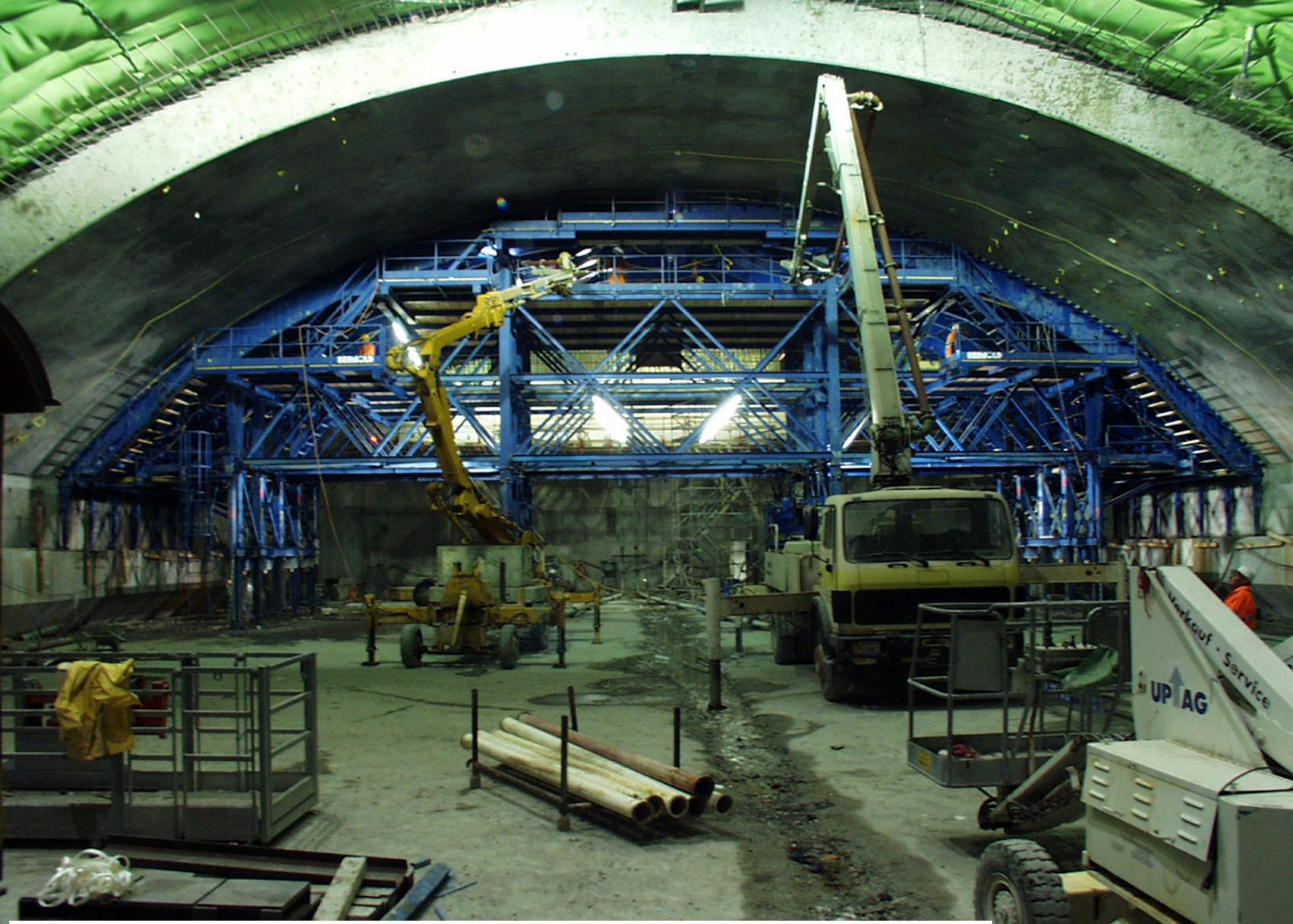
The LHC and its detectors



Aerial view of Point 5 Gallo-roman vestiges 1998

Roman coins found during archeological excavations at Point 5





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

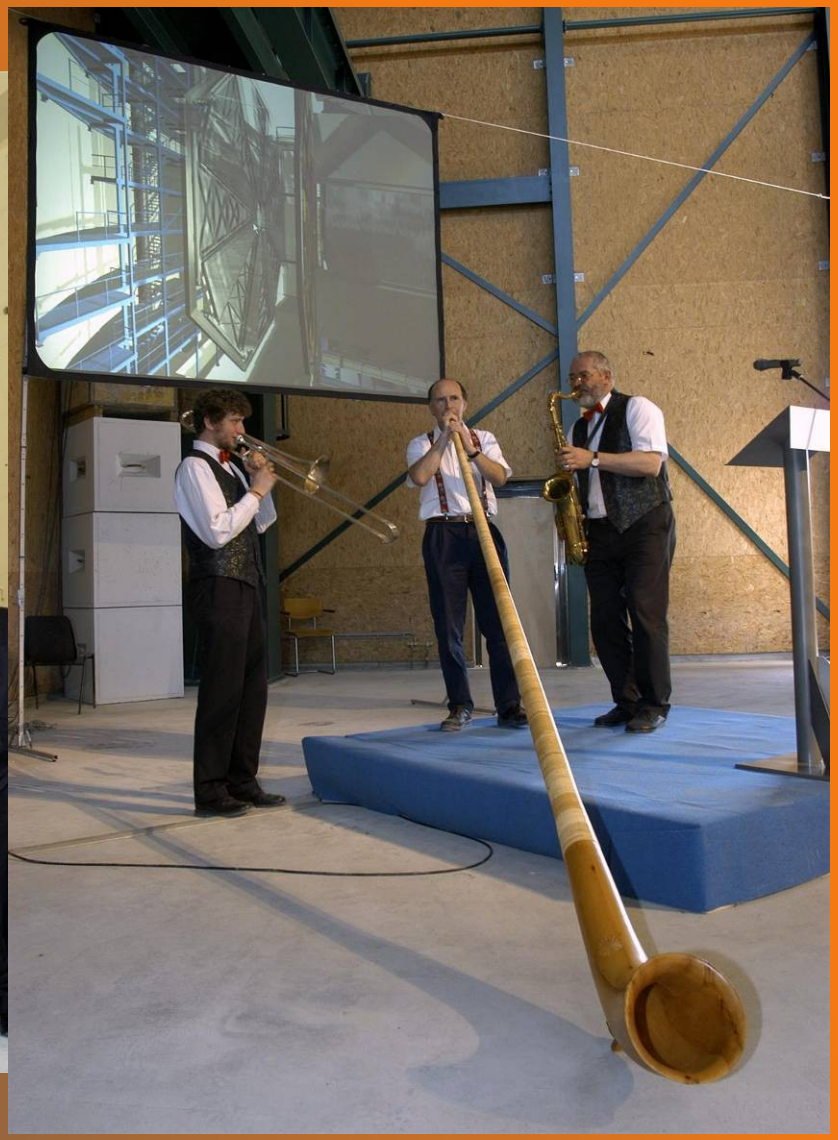
LHC Point 1 - UX 15 Cavern - Concrete walls 6th lift - 20-02-2003 - CERN ST-CE

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

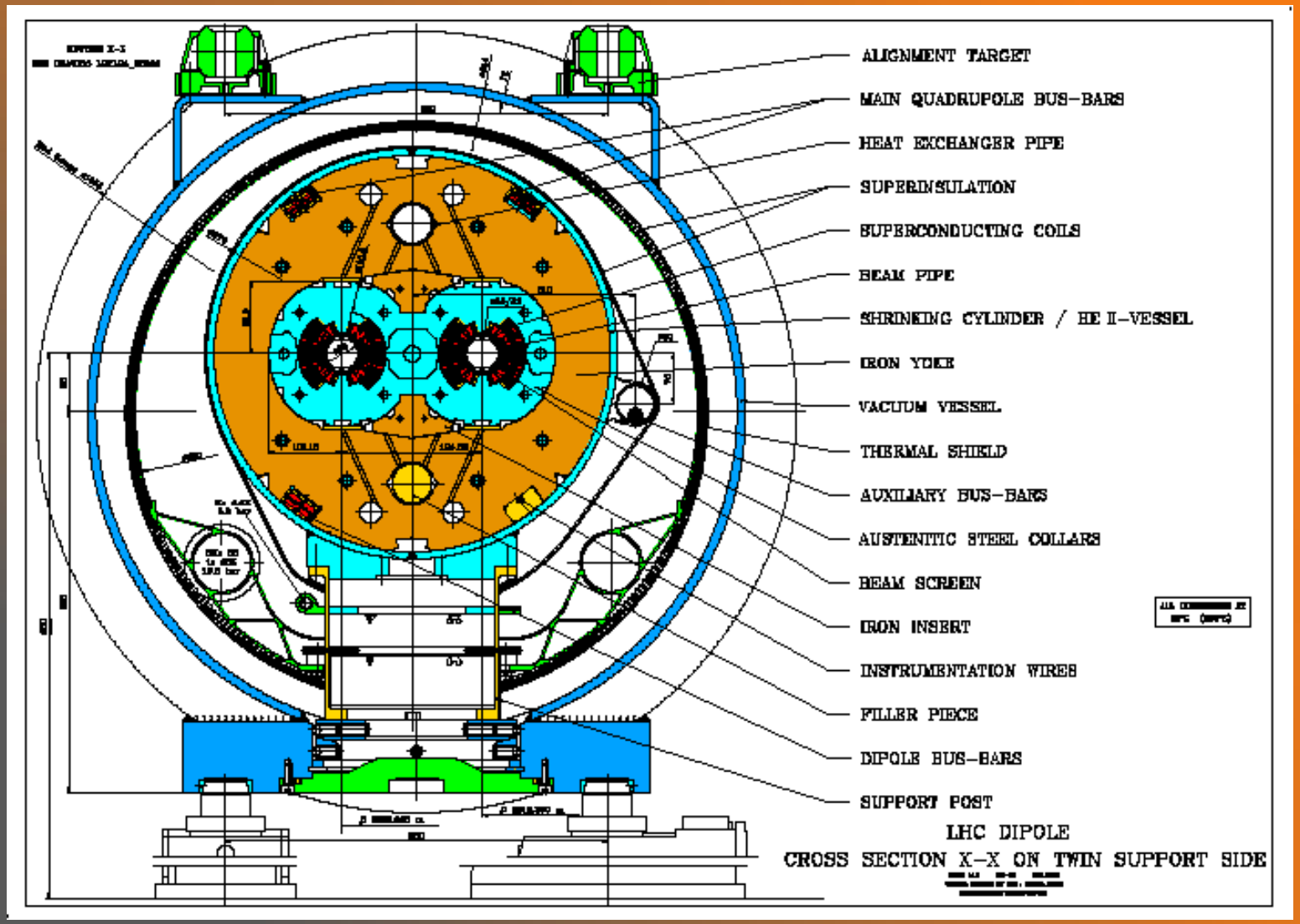
ATLAS cavern inauguration 2003



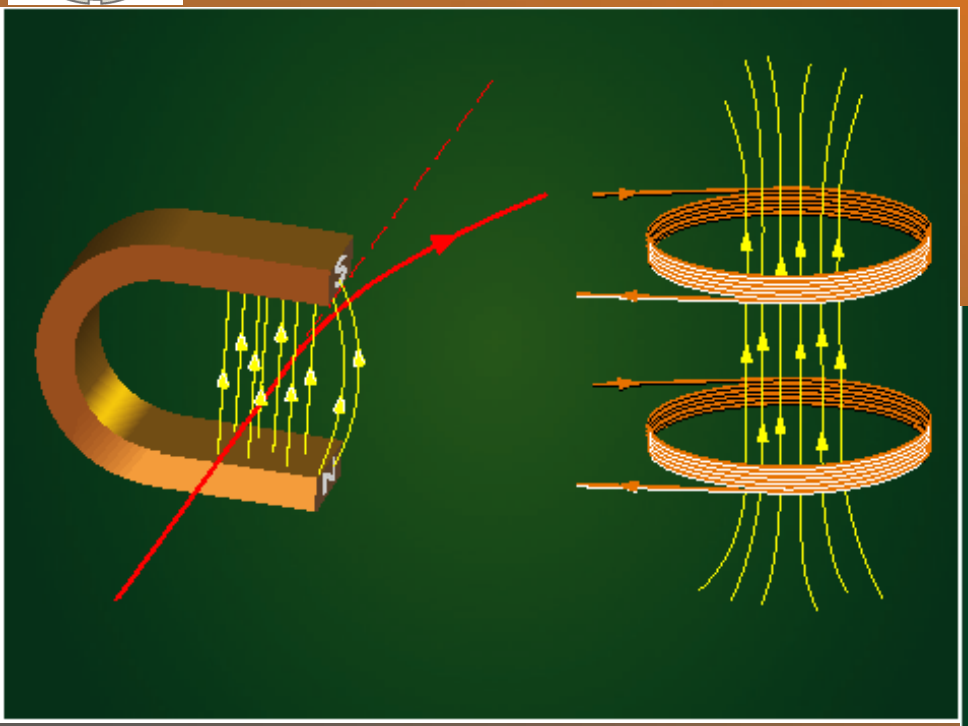
End of civil engineering works in Point 5 (1st February 2005)

23 km of superconducting magnets

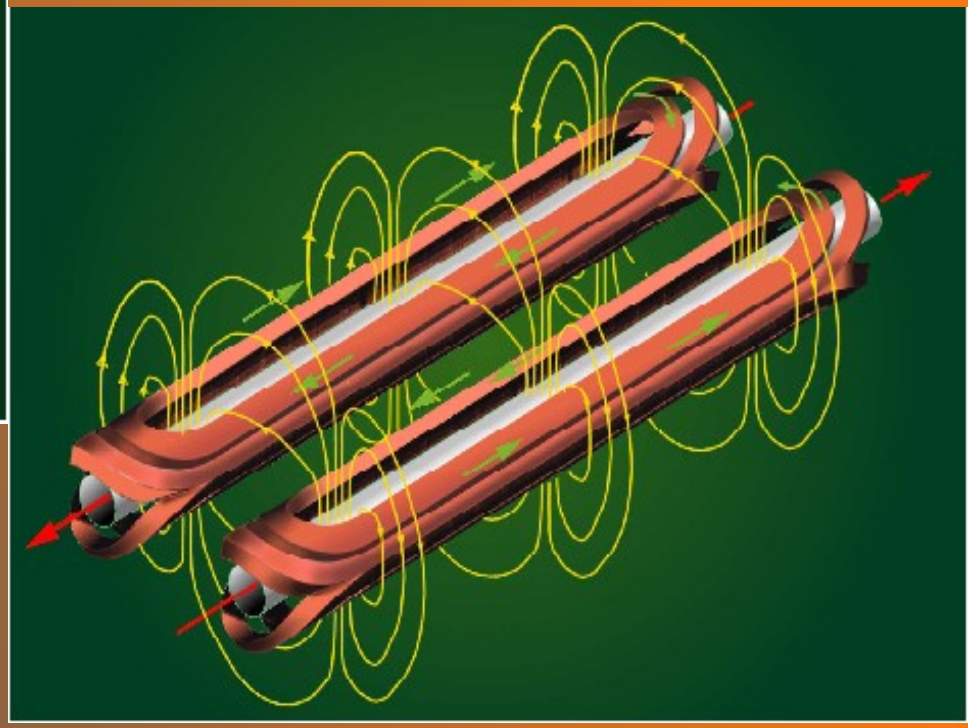
Cryodipole cross-section



Superconducting accelerator magnets



In a superconducting magnet, the field level and geometry is basically given by the current distribution in the coils.

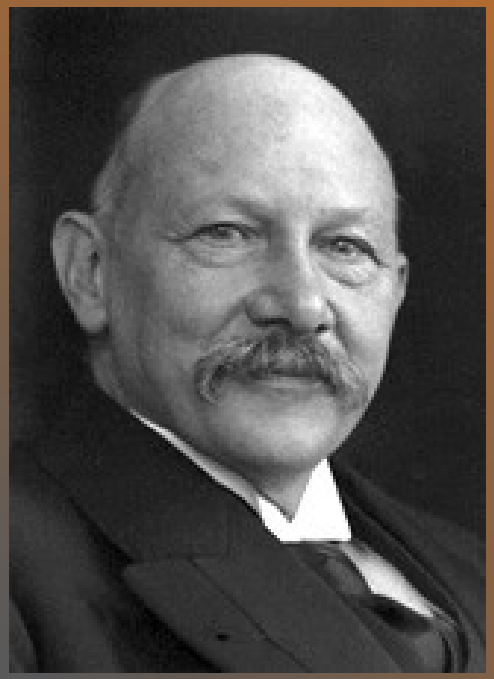


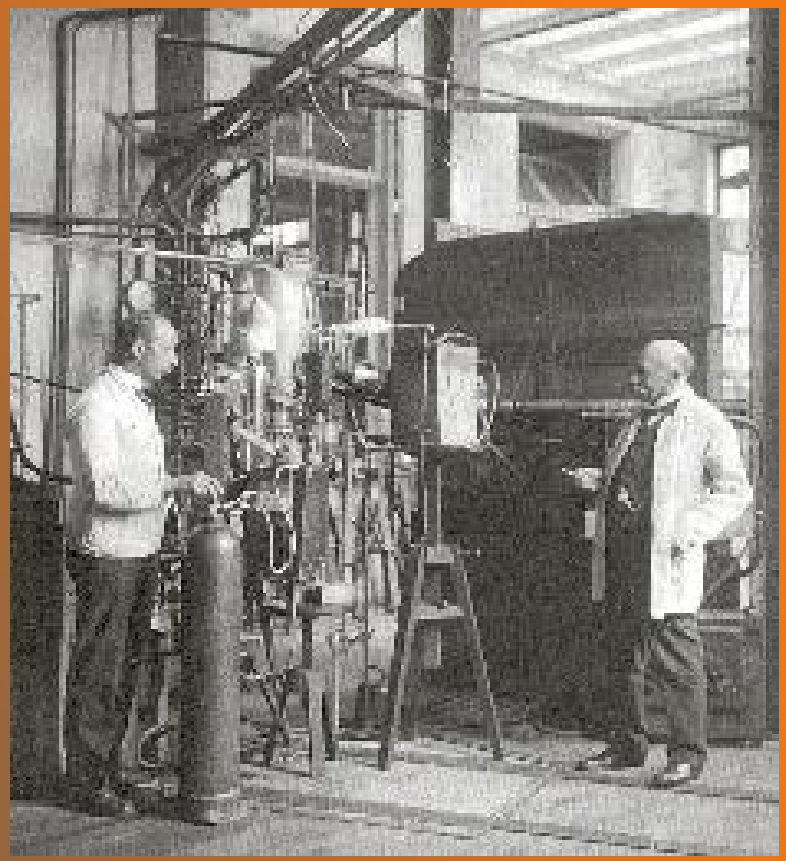
To match the geometry of the beam tubes, the coils are saddle-shaped & elongated.

In the LHC, two sets of coils create opposite fields in the neighbouring apertures.

…at the physics laboratory of Leyden, helium was first liquified

Heike Kamerlingh Onnes

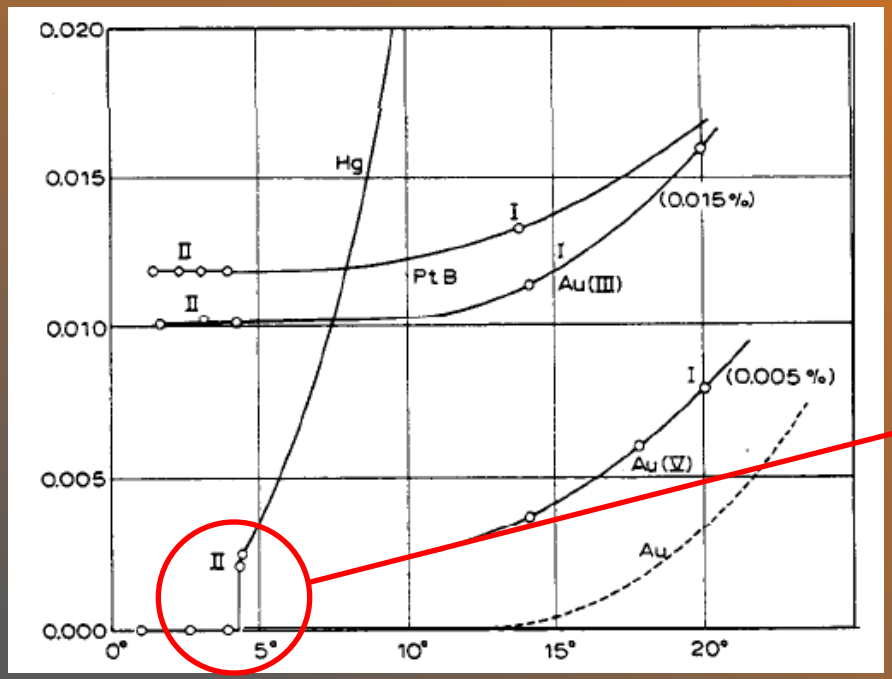


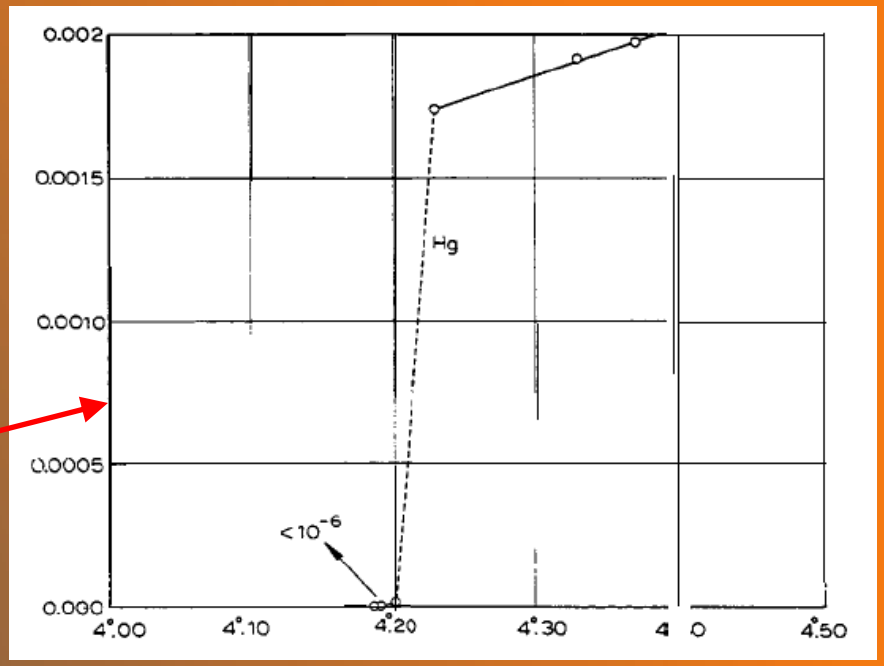


"Door meten tot weten"
To knowledge through measurement

Discovery of superconductivity

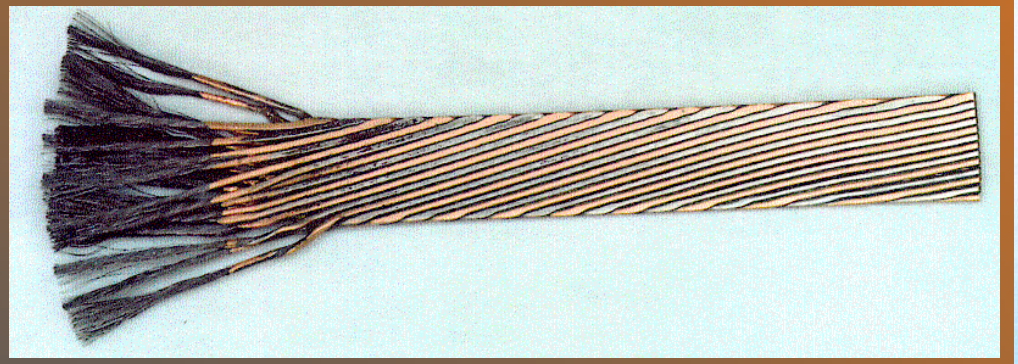
8th April 1911

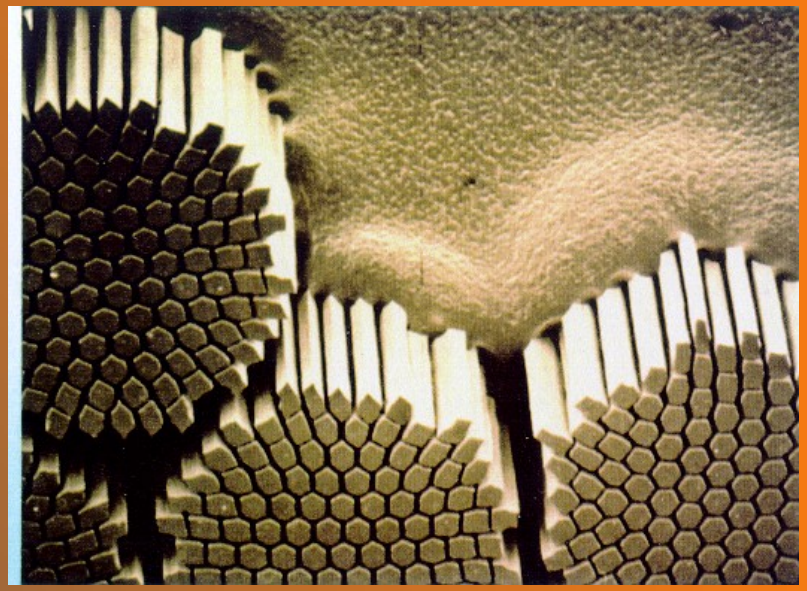




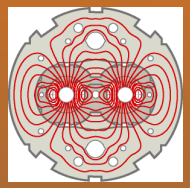
Thus the mercury at 4.2°K has entered a new state, which, owing to its particular electrical properties, can be called the state of superconductivity.

7000 km of superconducting cable Nb-Ti





Superfluid helium



J. F. Allen

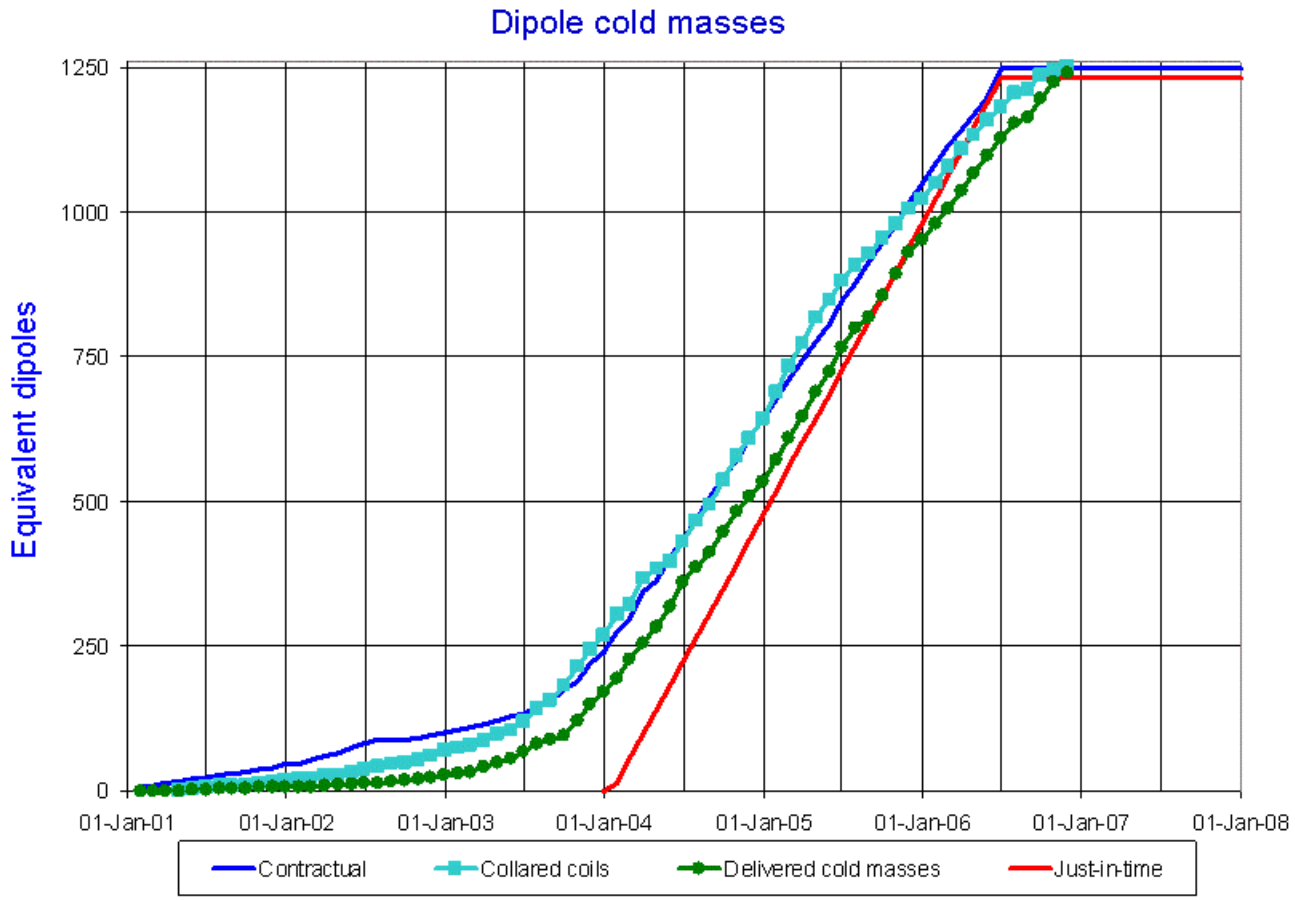
« In my PhD work in Toronto on superconductivity, I had often seen the sudden cessation of boiling at the lambda temperature T_λ but had paid it no particular attention. It never occured to me that it was of fundamental significance. »

J. Allen, Physics World, November 1988, p 29.

Dipole cold masses

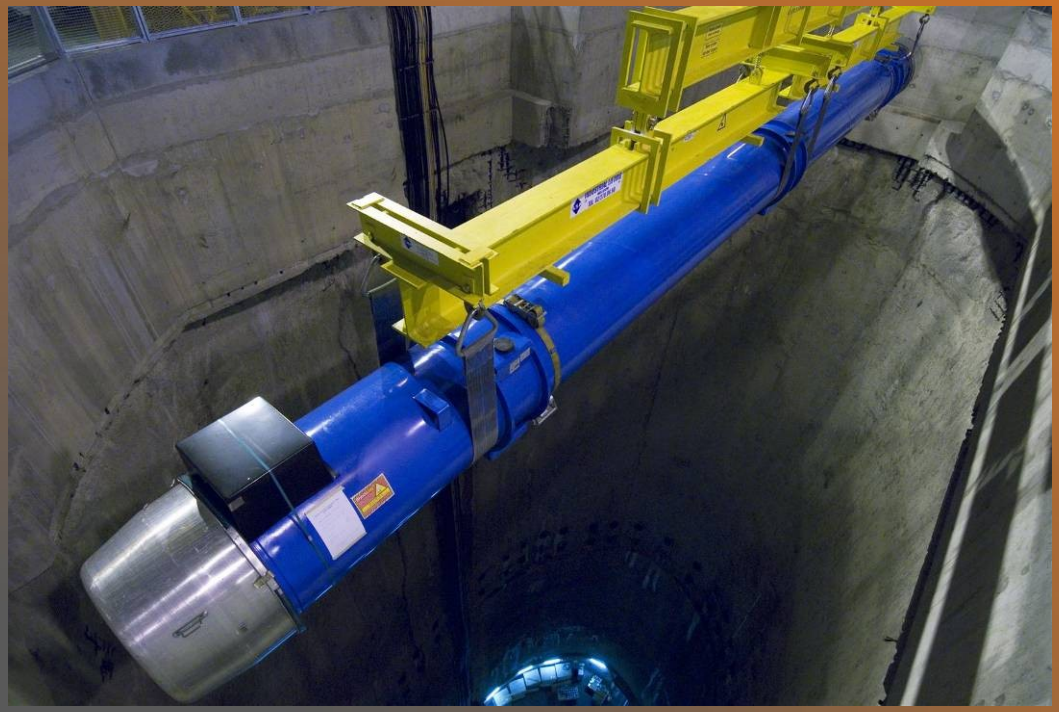
LHC Progress Dashboard

Accelerator Technology Department



Updated 30 Nov 2006 Data provided by G. de Rijk AT-MCS

Descent of the last magnet 26 April 2007

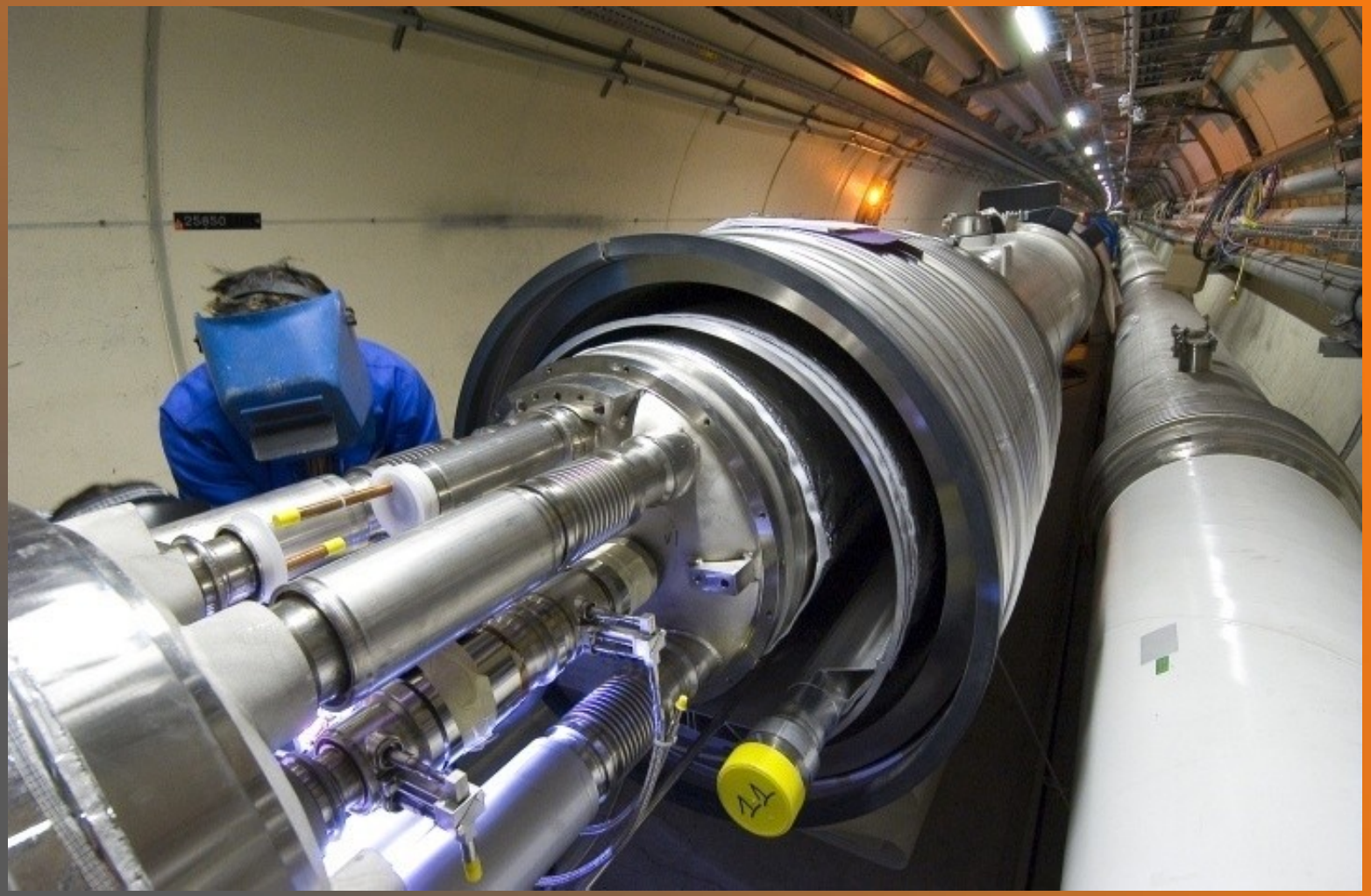


30’000 km underground at 2 km/h!

Transport in the tunnel with an optical guided vehicle

Transfer on jacks

Dipole dipole interconnect

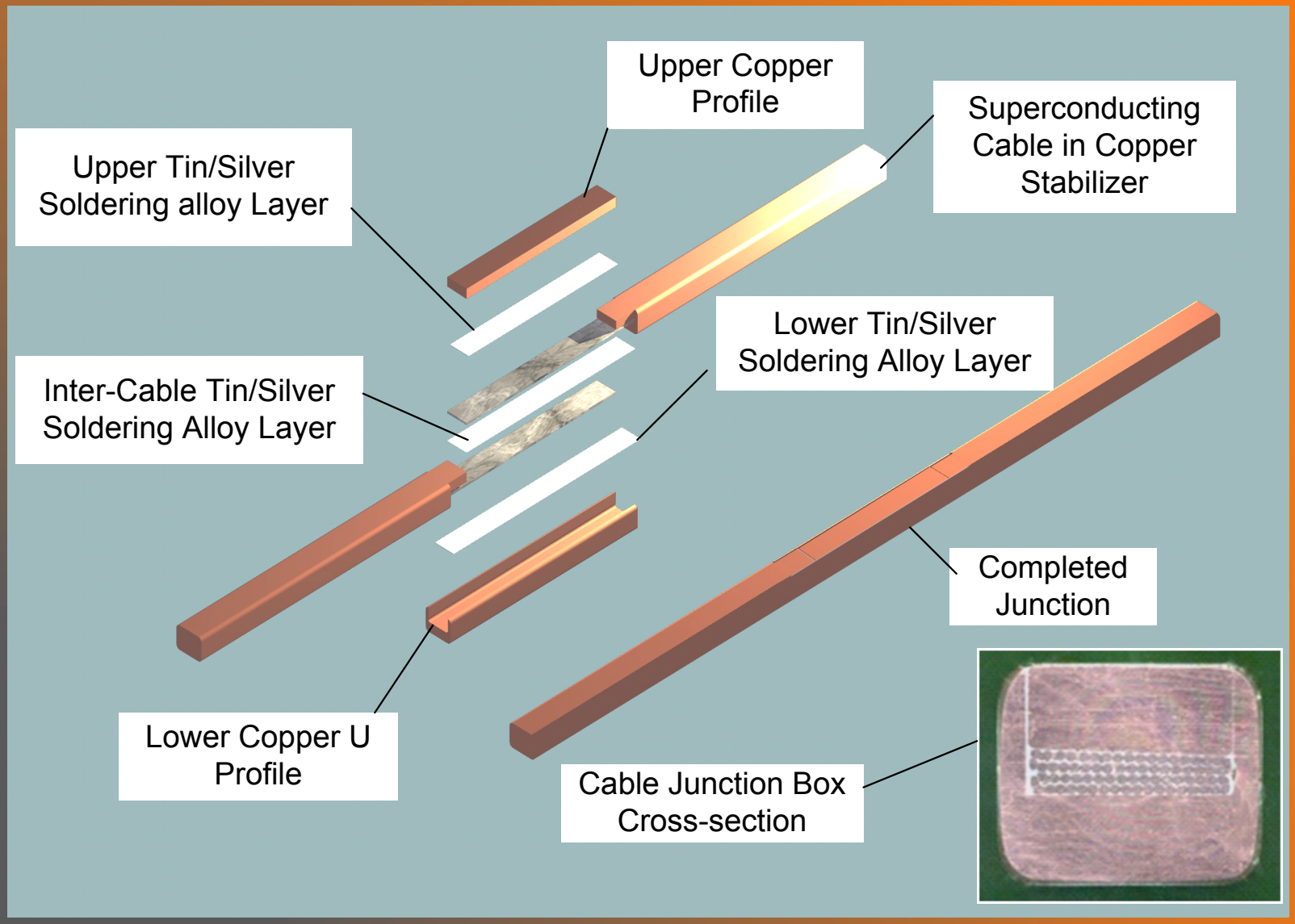


10 September 2008

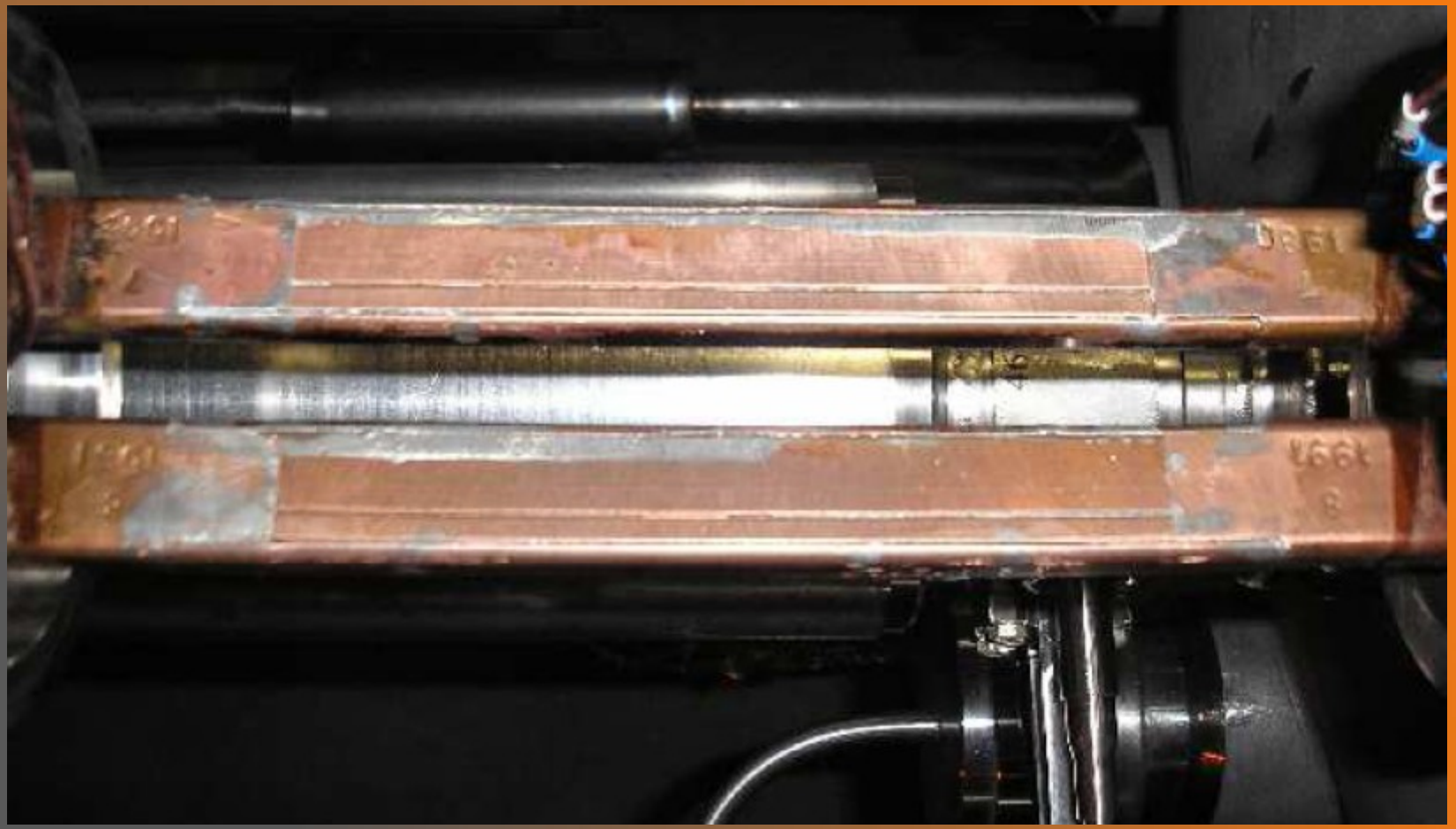
5 DGS

Electrical splice

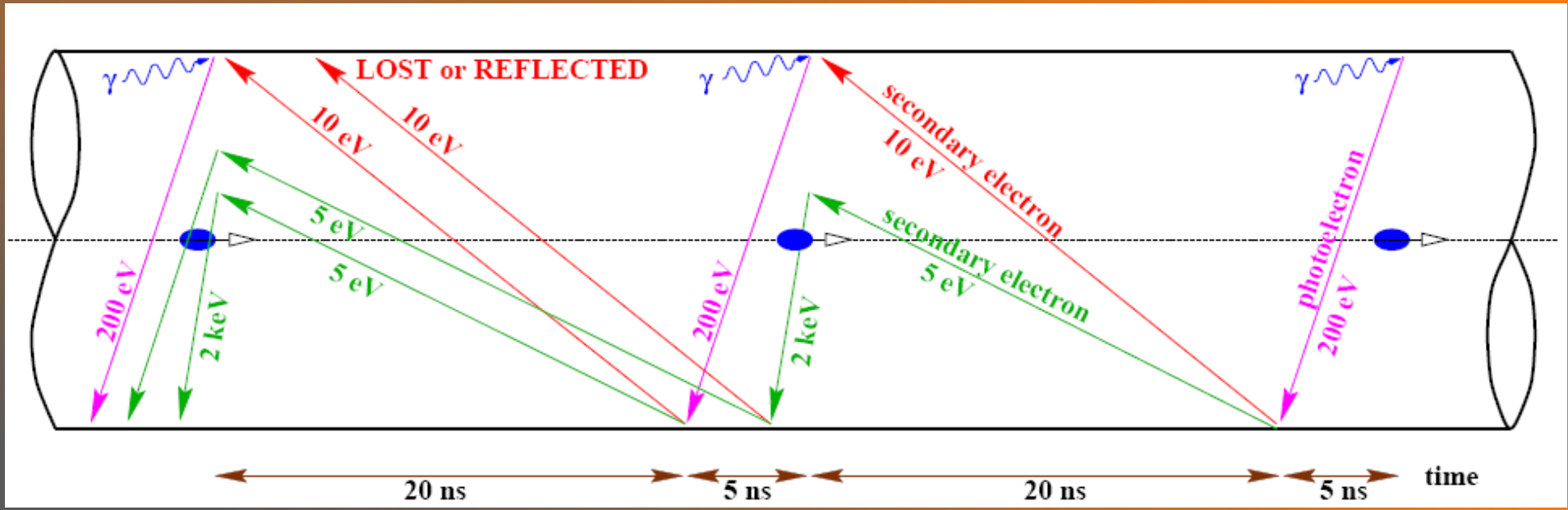
Busbar splice



Busbar splice

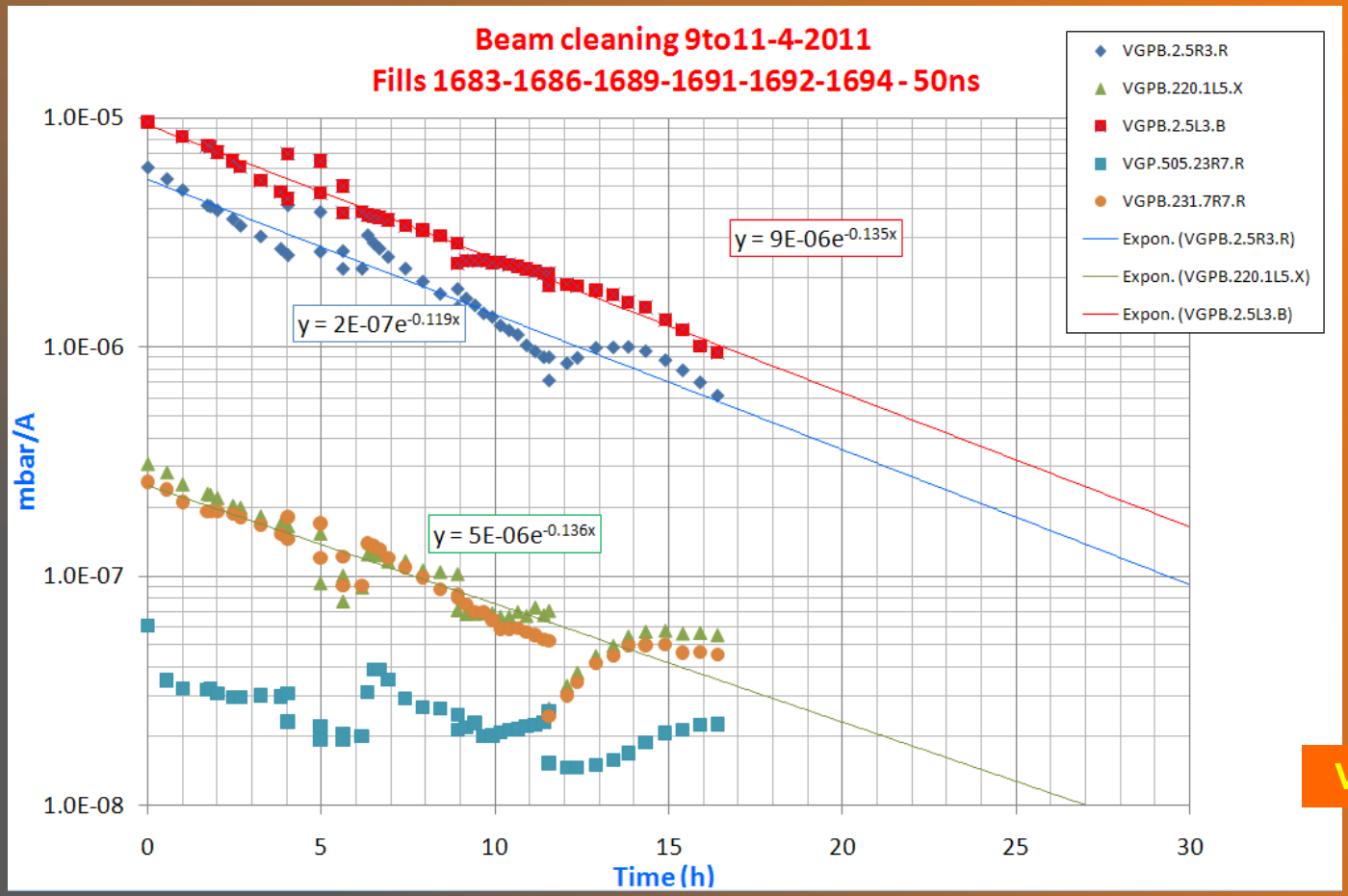


The electron cloud effect



Vacuum pressure evolution with 50 ns

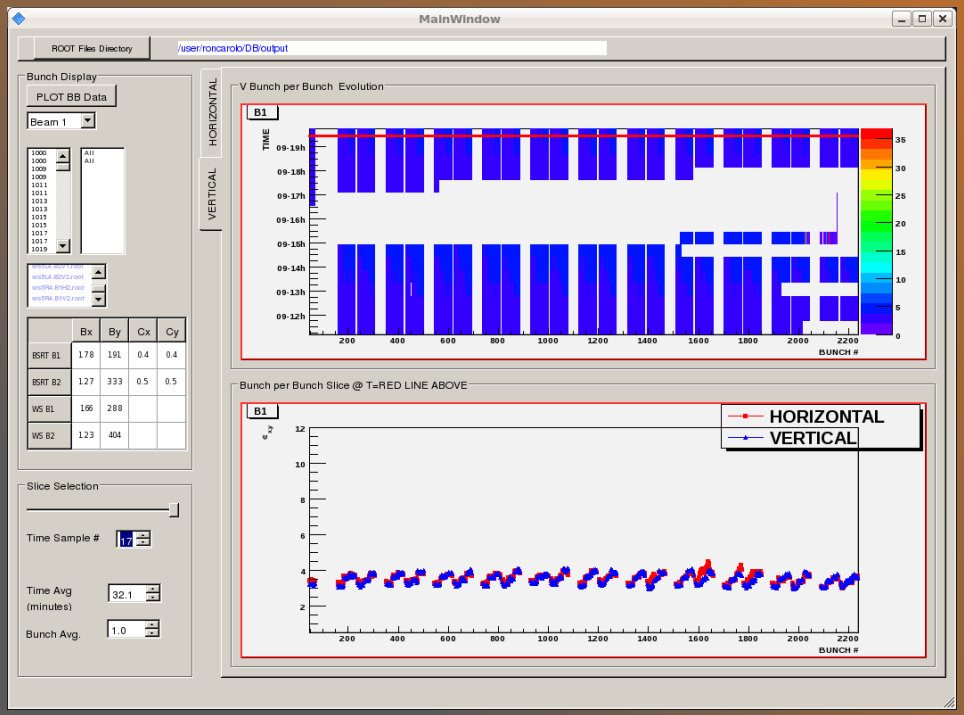
Reduction of one decade in about 17h (periods with constant number of bunches)

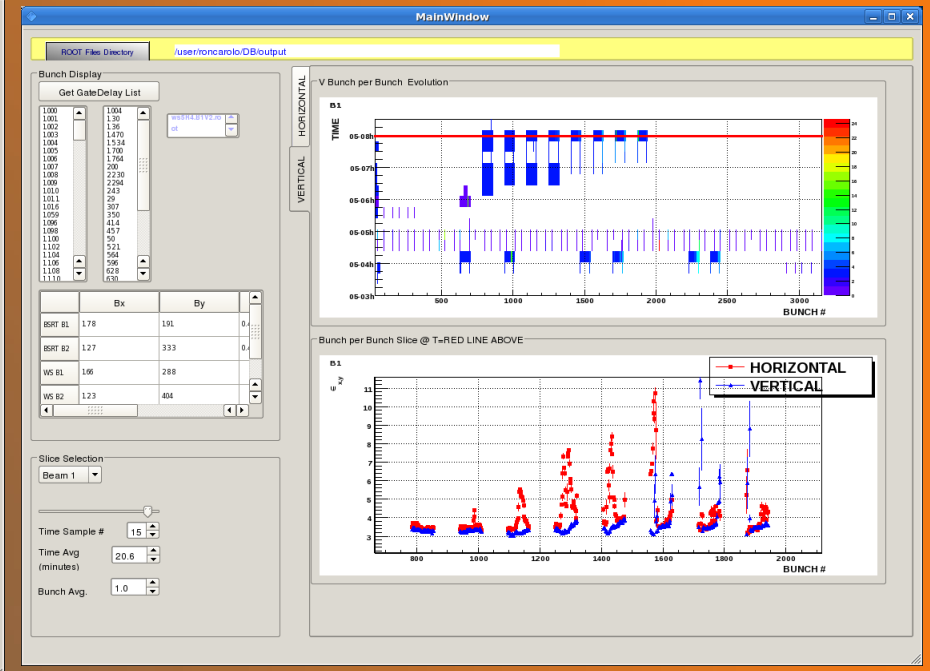


V. Baglin et al.

Emittance preservation

Limited blow-up observed after some hours at injection (injected emittances are in the range 2.5-3 mm), even with 800 and >1000 bunches. **Clear improvement due to reduced activity in the arcs. Low chromaticity (~4)**





Day 3 – 800 bunches

We started like that...

Day 1 – 300 bunches