

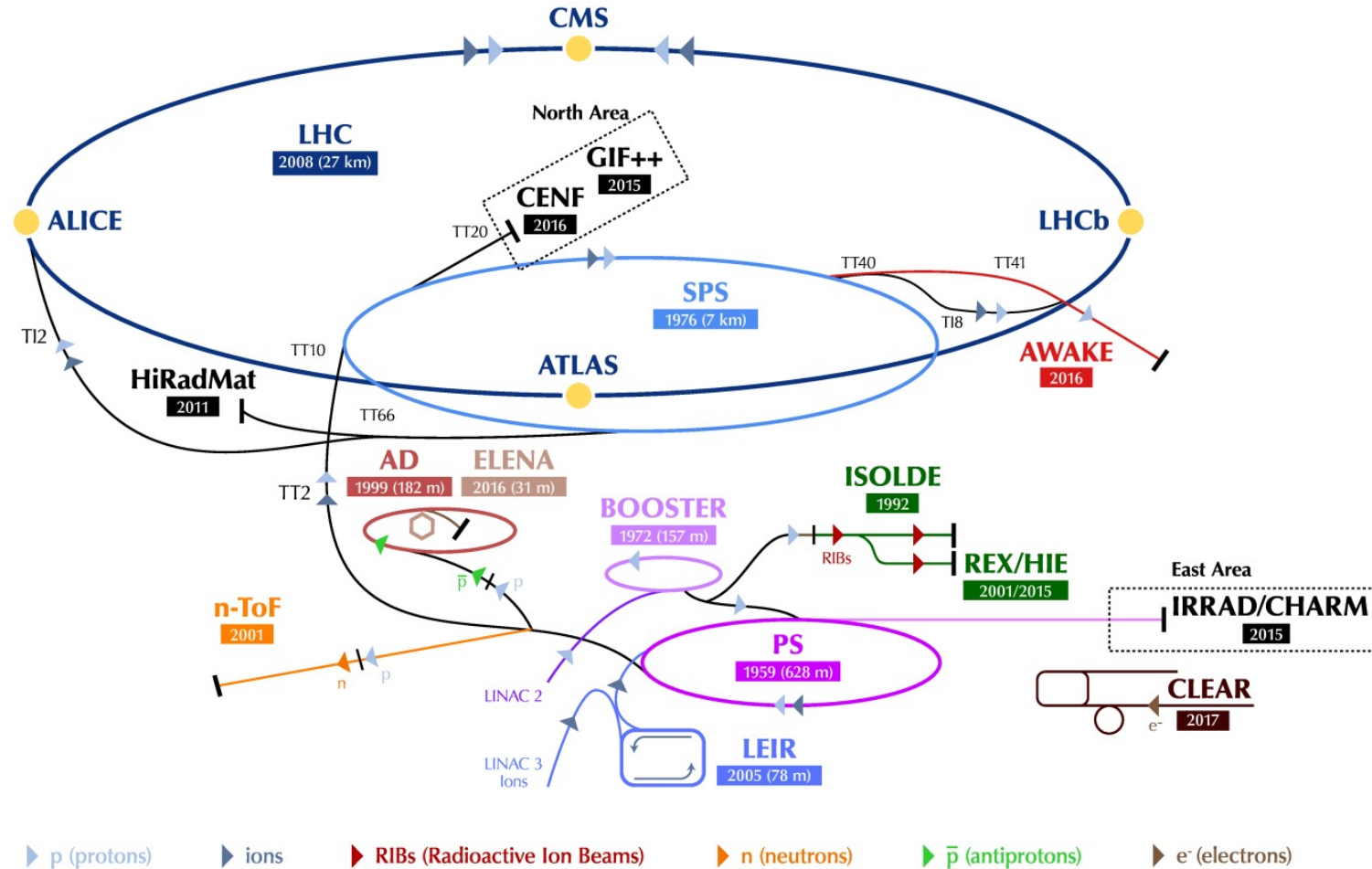


# A virtual tour of the LHC Magnets Tests Facility (SM18)

Cristiano Alpigiani

# The CERN accelerator complex

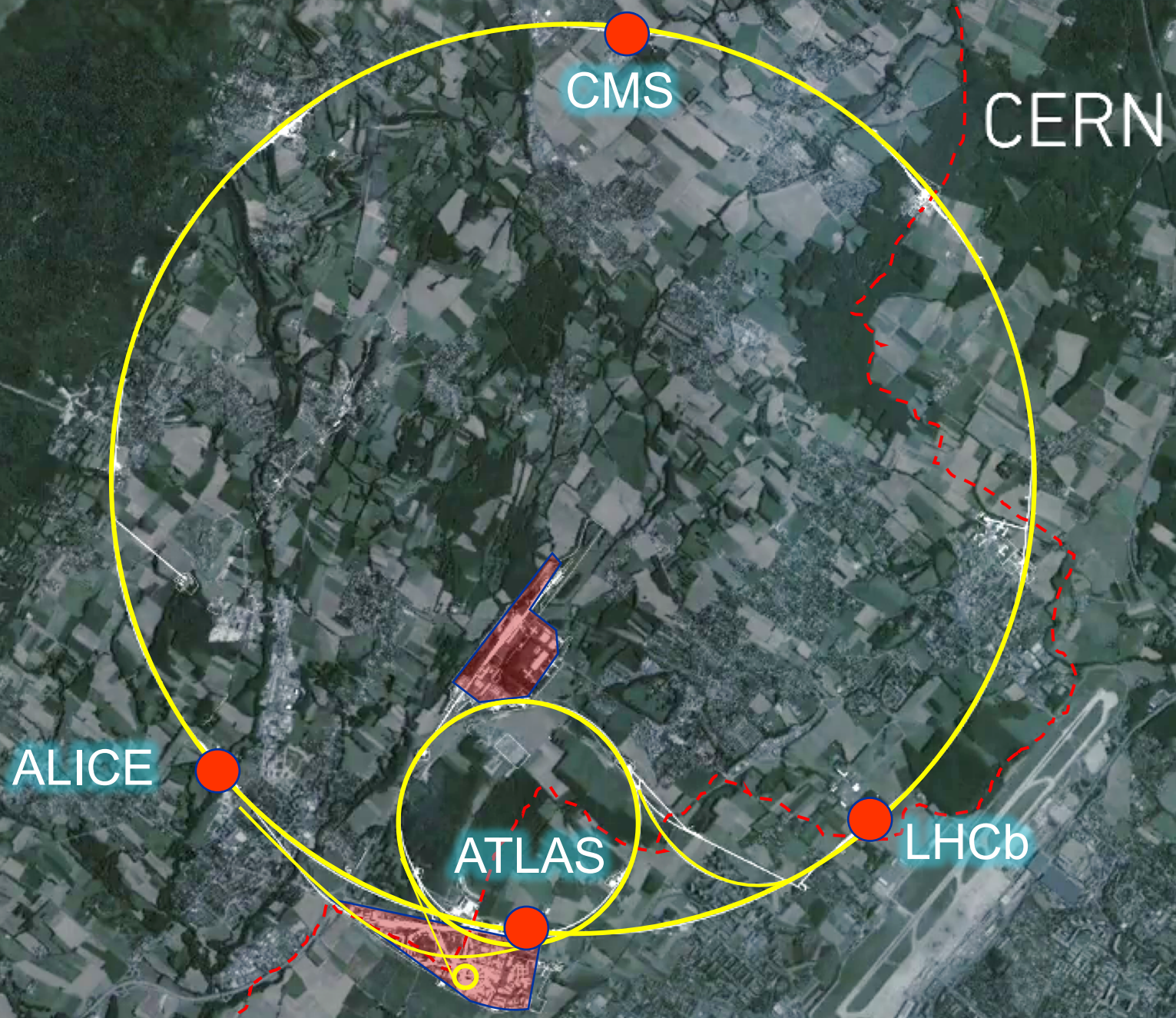
## Complexe des accélérateurs du CERN



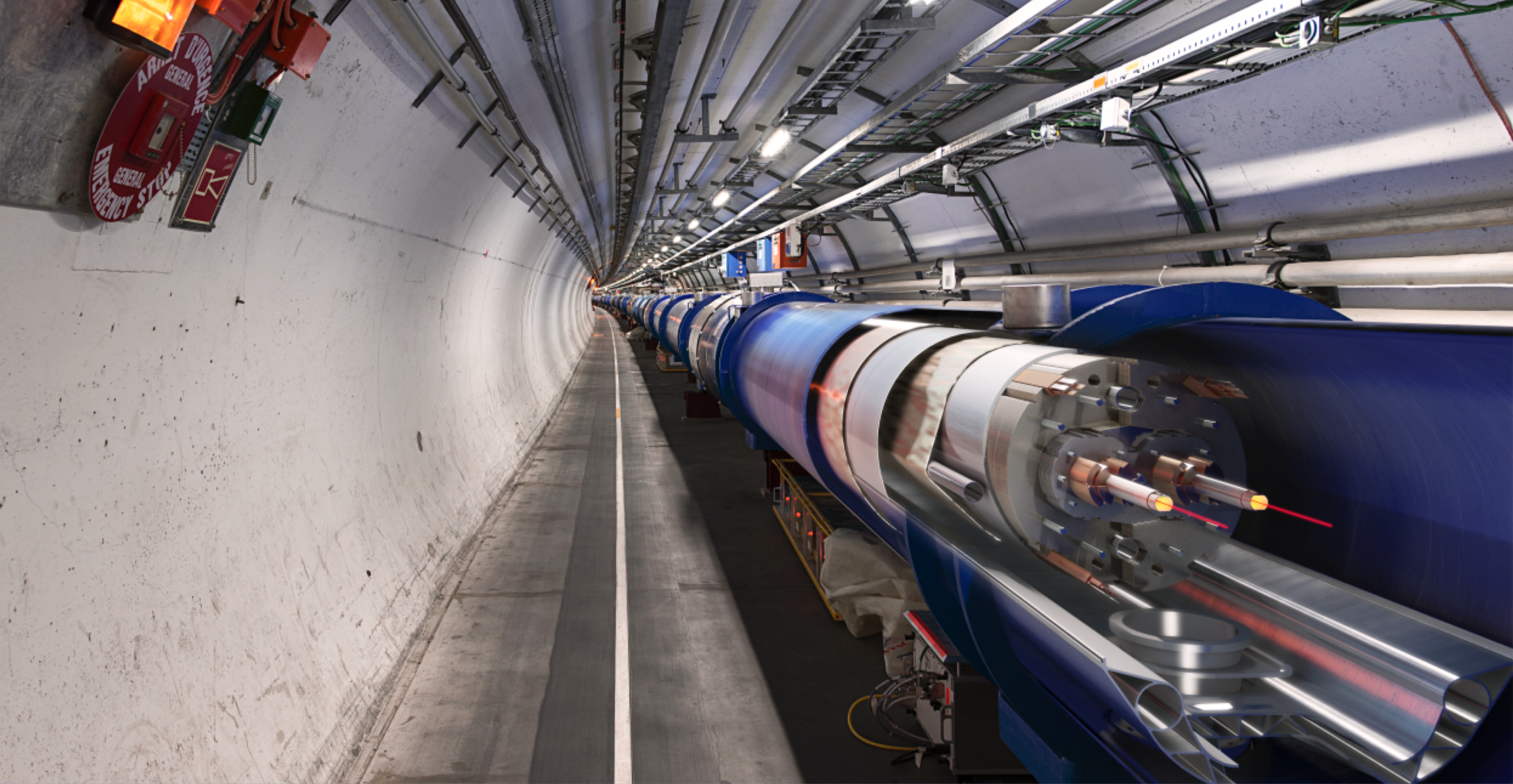
LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE - Radioactive EXperiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n-ToF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials // CHARM - Cern High energy AcceleRator Mixed field facility // IRRAD - proton IRRADIation facility // GIF++ - Gamma Irradiation Facility // CENF - CErn Neutrino platForm



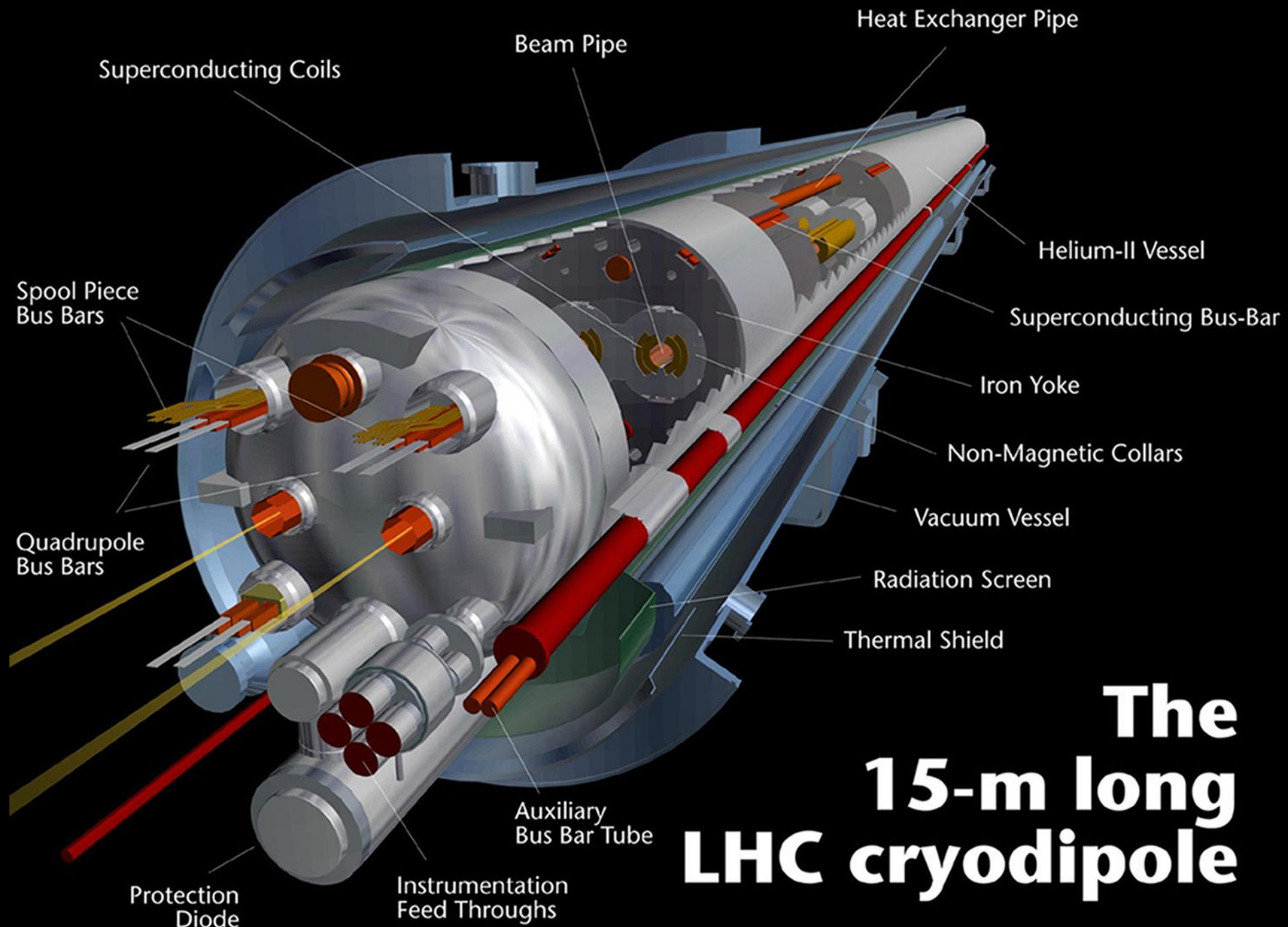
# Large Hadron Collider





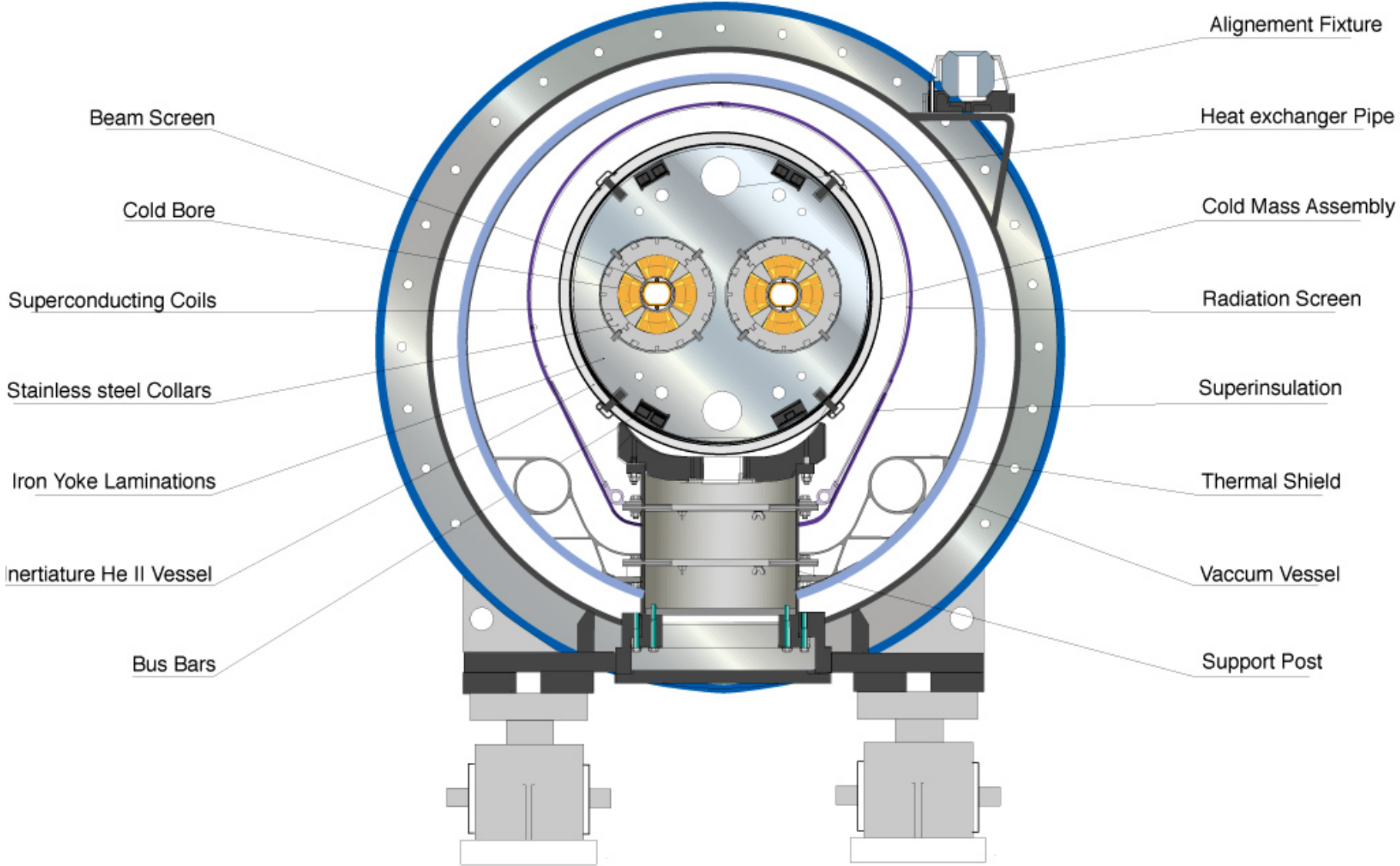




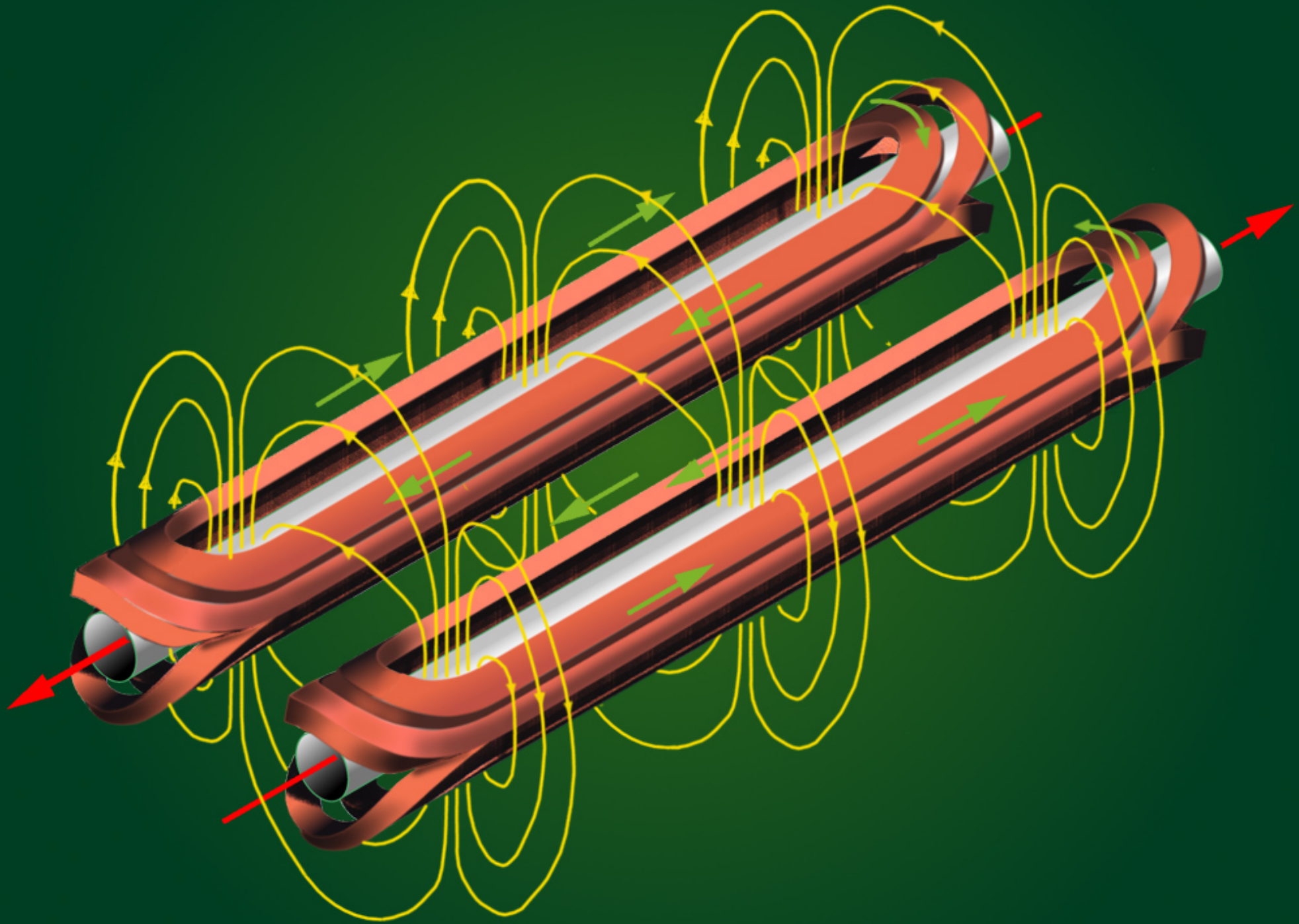


# The 15-m long LHC cryodipole

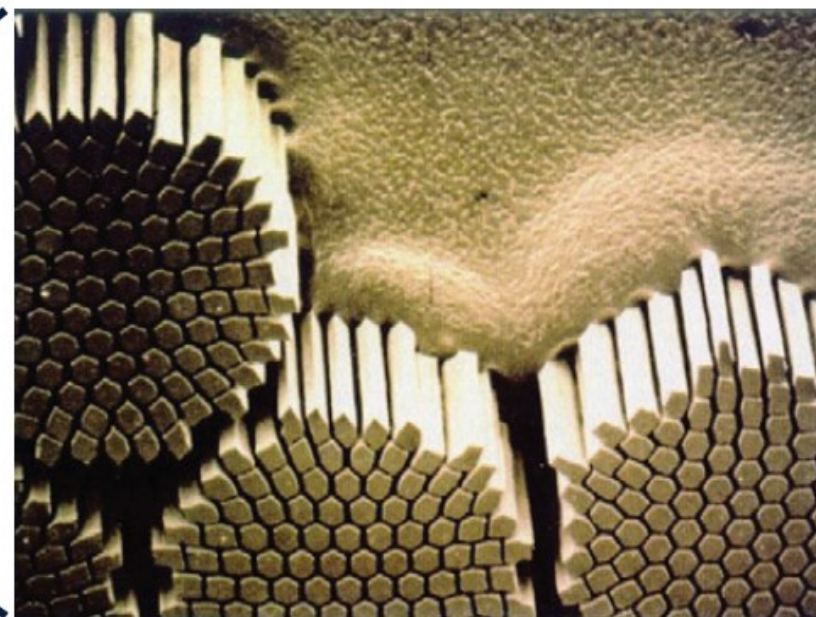
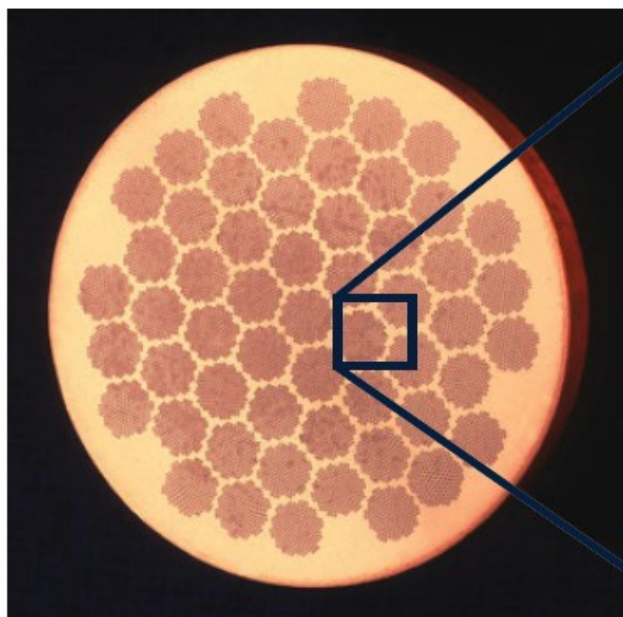
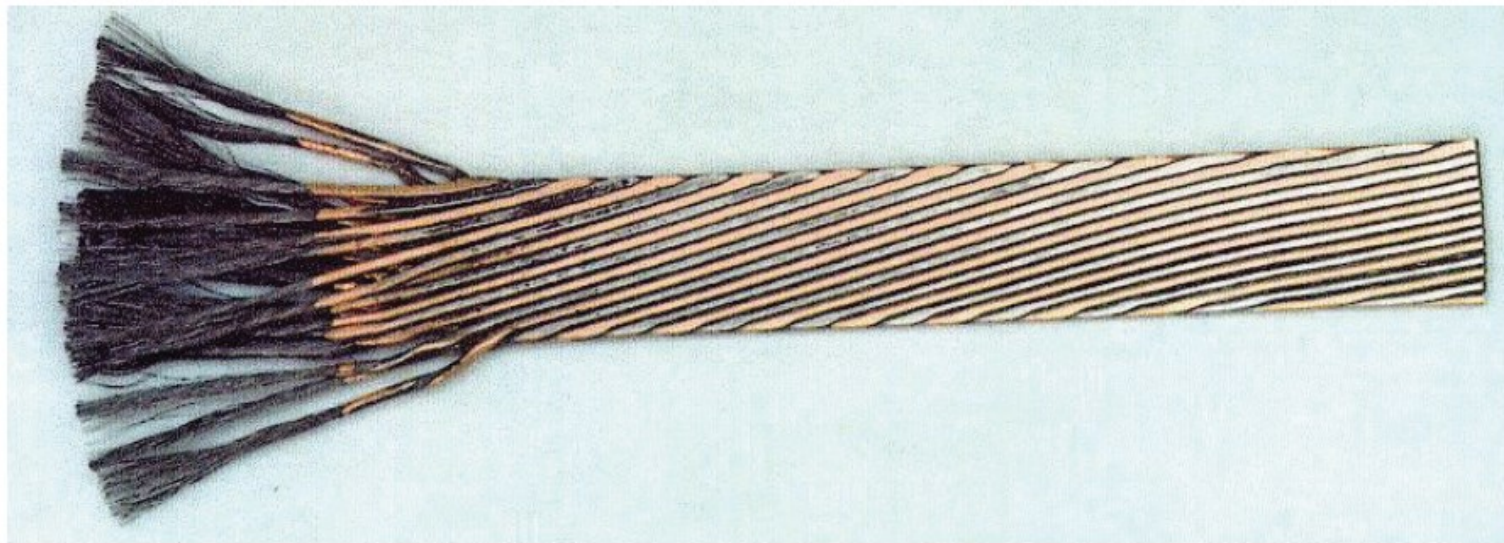
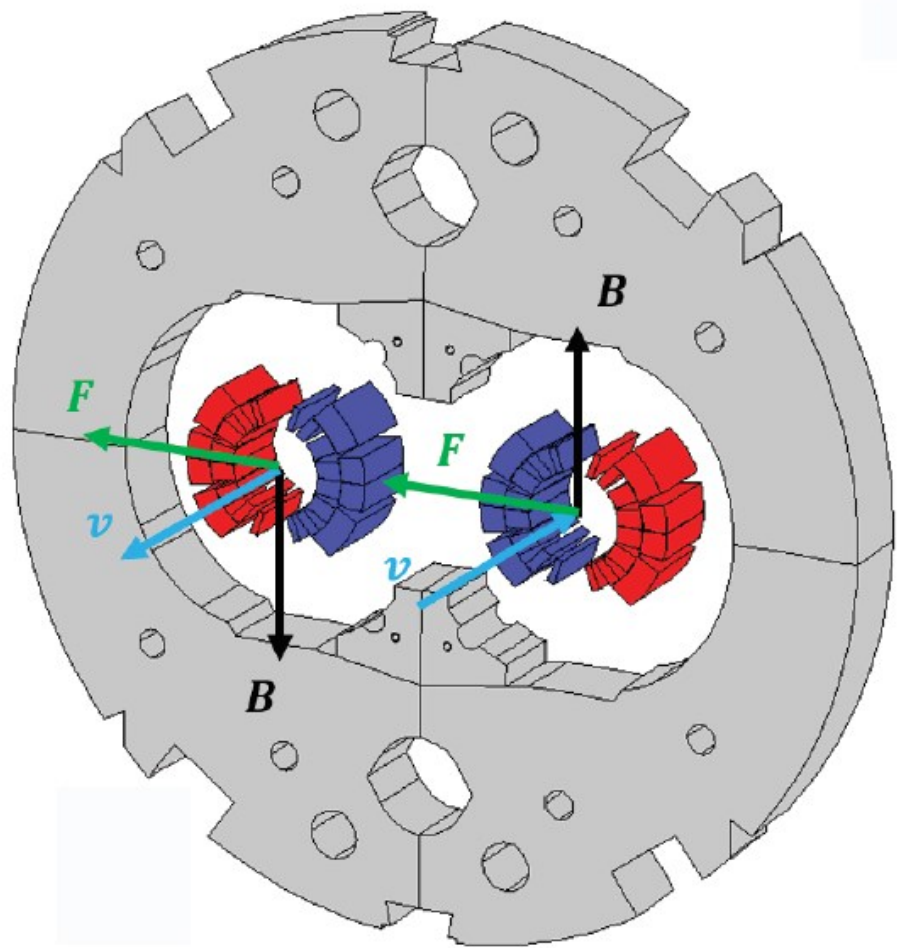
# LHC quadrupole cross section



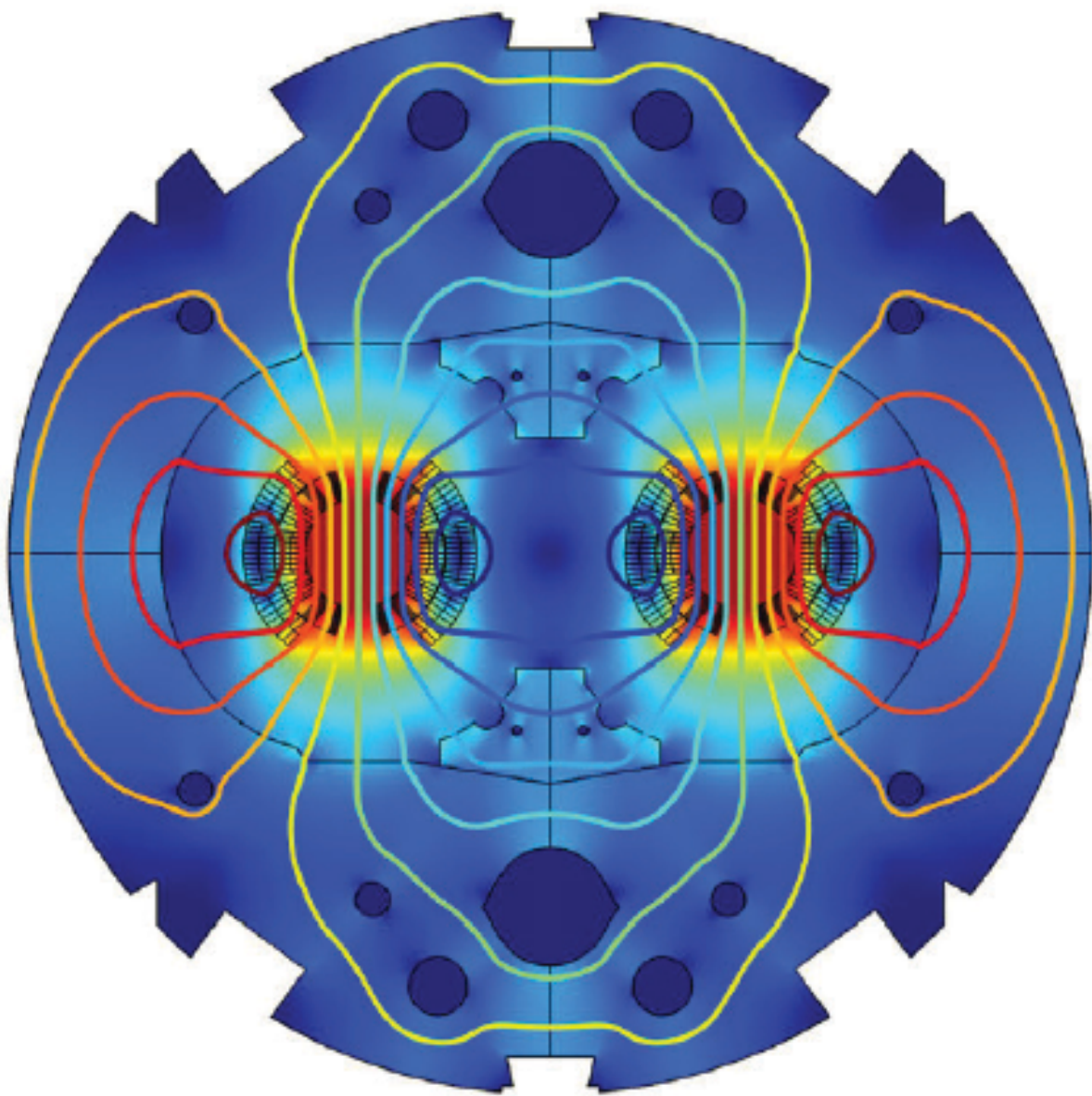




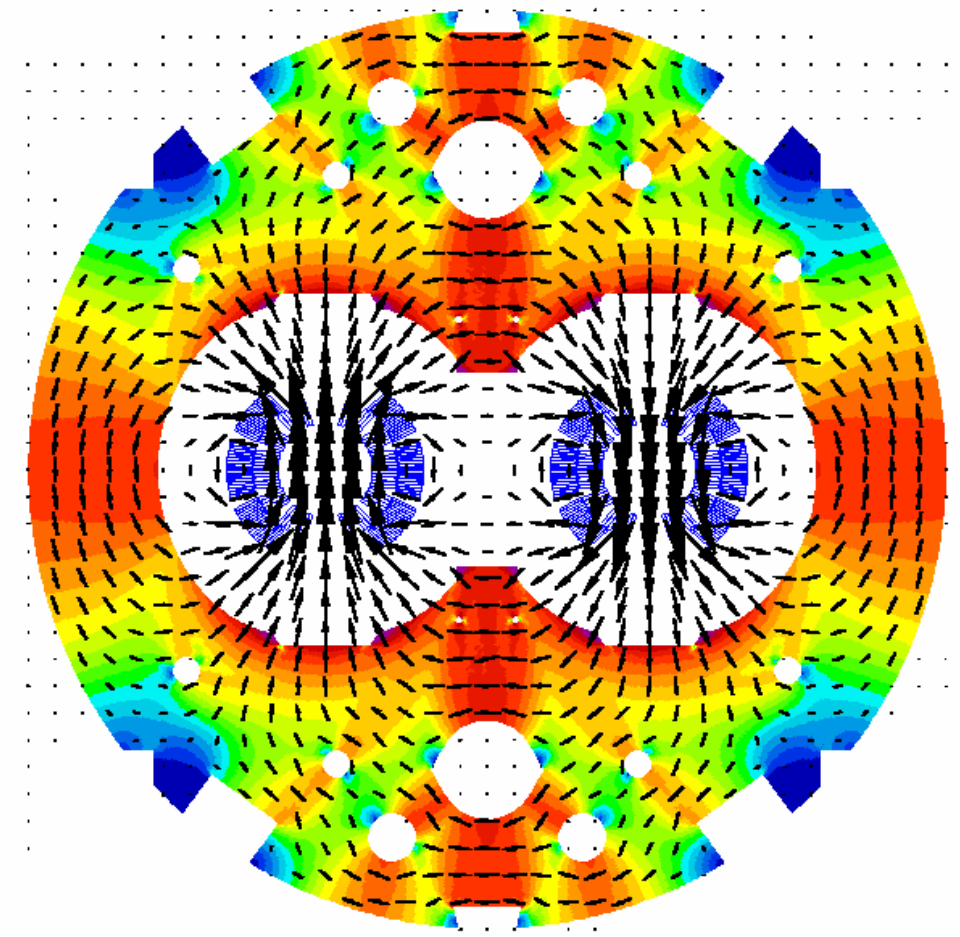
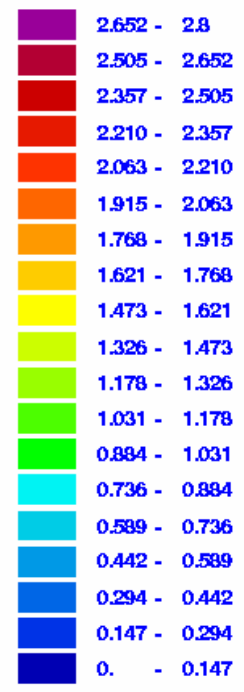








$|B_{tot}|$  (T)



# MACHINE DEVELOPMENT: BEAM DUMP

Energy:

450 Z GeV

I(B1):

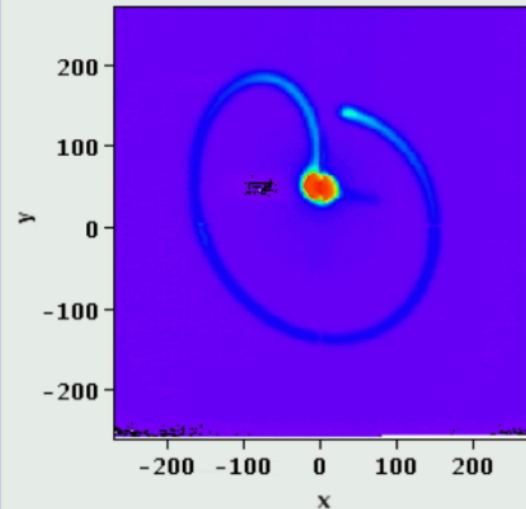
4.24e+08

I(B2):

0.00e+00

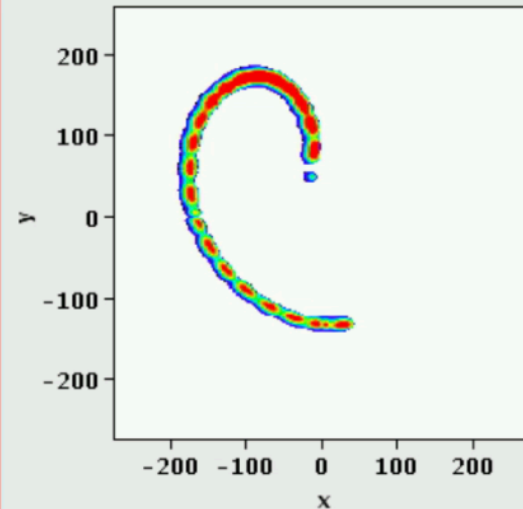
BTVDD.689339.B1

Updated: 04:37:17



BTVDD.629339.B2

Updated: 04:37:17



Comments (03-Dec-2018 04:38:24)

This was the last dump of Run2 !

Going to access today, estimate 2 years

BIS status and SMP flags

B1

B2

Link Status of Beam Permits

false

false

Global Beam Permit

false

false

Setup Beam

true

true

Beam Presence

false

false

Moveable Devices Allowed In

false

false

Stable Beams

false

false

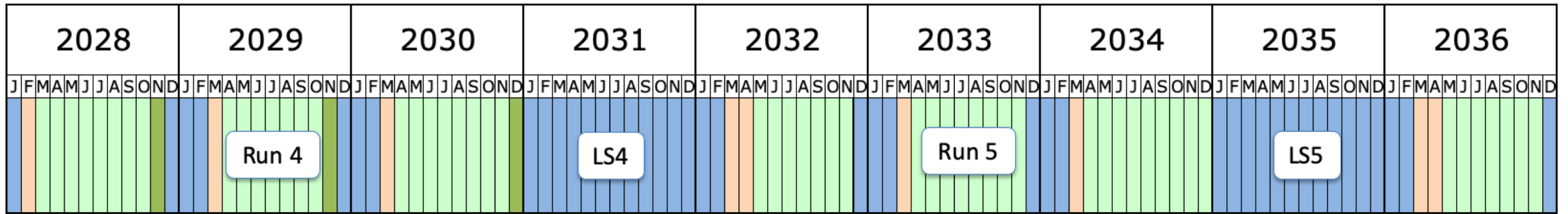
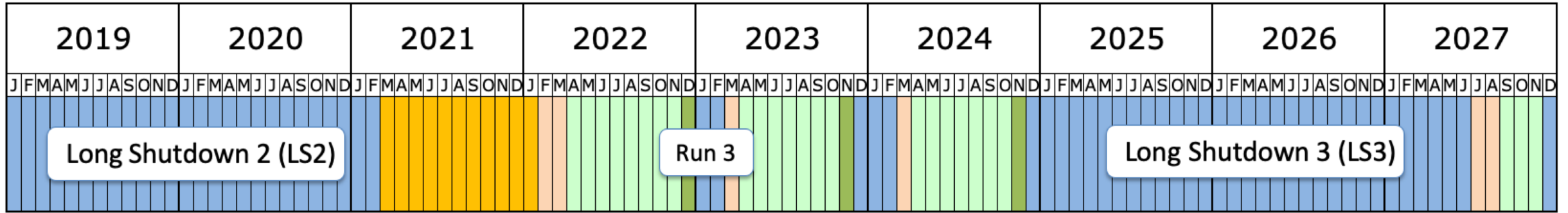
AFS: 75\_150ns\_733Pb\_733\_702\_468\_42bpi\_20inj

PM Status B1

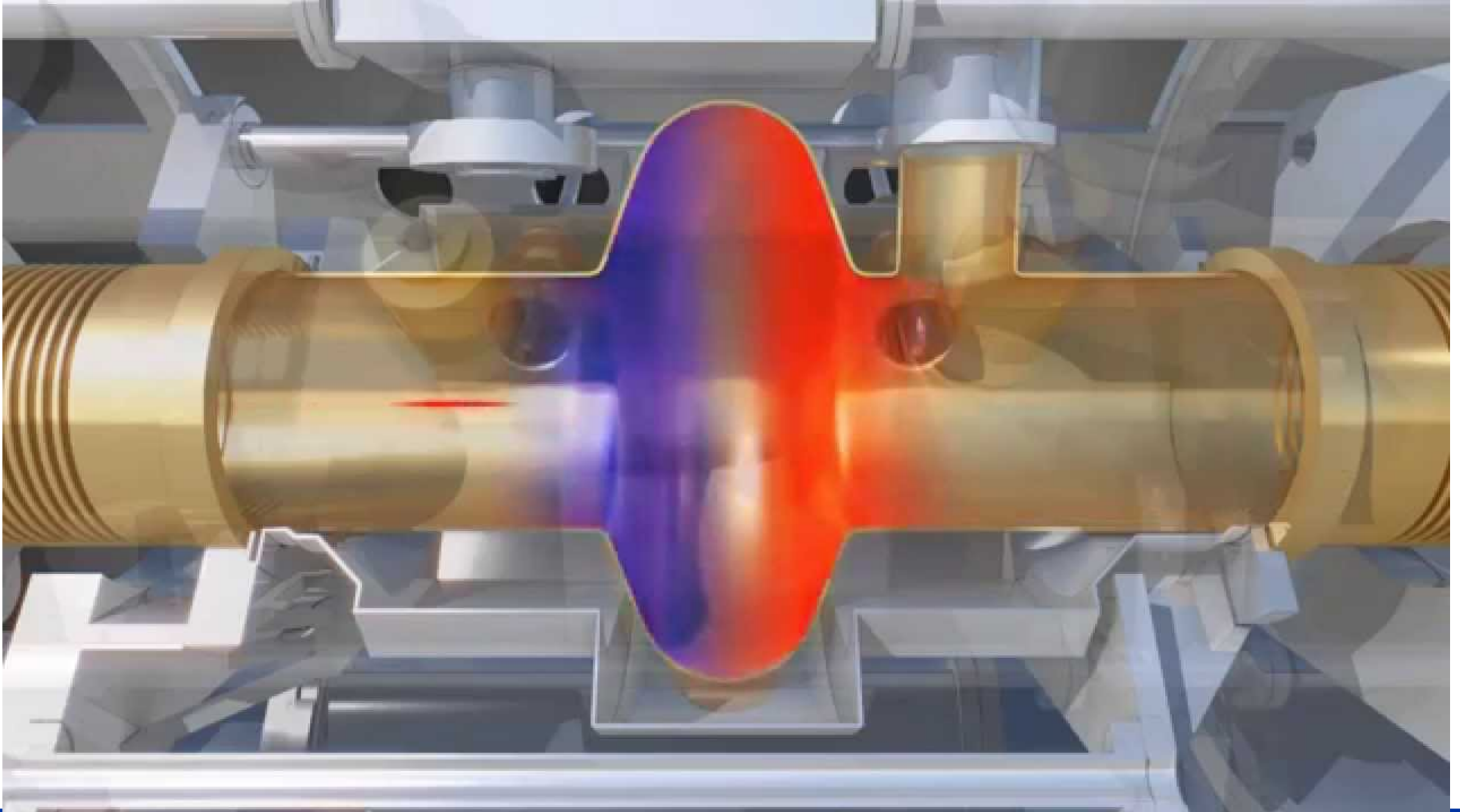
ENABLED

PM Status B2

ENABLED



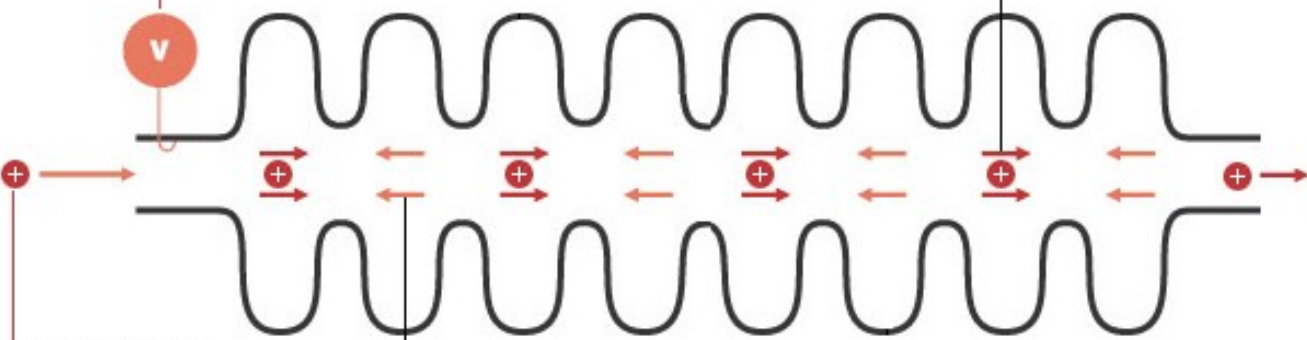
- Shutdown/Technical stop
- Protons physics
- Ions
- Commissioning with beam
- Hardware commissioning/magnet training





A voltage generator induces an electric field inside the RF cavity. Its voltage oscillates with a radio frequency of 400 MHz.

Protons always feel a force in the forward direction.



Protons in LHC

Protons never feel a force in the backward direction.

- Each cavity delivers 2MV
- Accelerating field of 5 MV/m @ 400 MHz
- Cavities operate @ 4.5 K
- Every proton passing through the RF cavities is affected for  $2 \cdot 8 \text{ MV} = 16 \text{ MV}$  so it receives an extra energy of 16 MV.
- Since every proton goes around 11245 laps per second the total energy received per second is:

$$(16 \text{ MeV/lap}) \cdot (11245 \text{ laps/s}) = 1.8 \cdot 10^5 \text{ MeV/s} \equiv 0.18 \text{ TeV/s}$$

- From SPS every proton enters LHC with 0.45 TeV, so the amount of energy that cavities has to provide is

$$7 - 0.45 = 6.55 \text{ TeV}$$

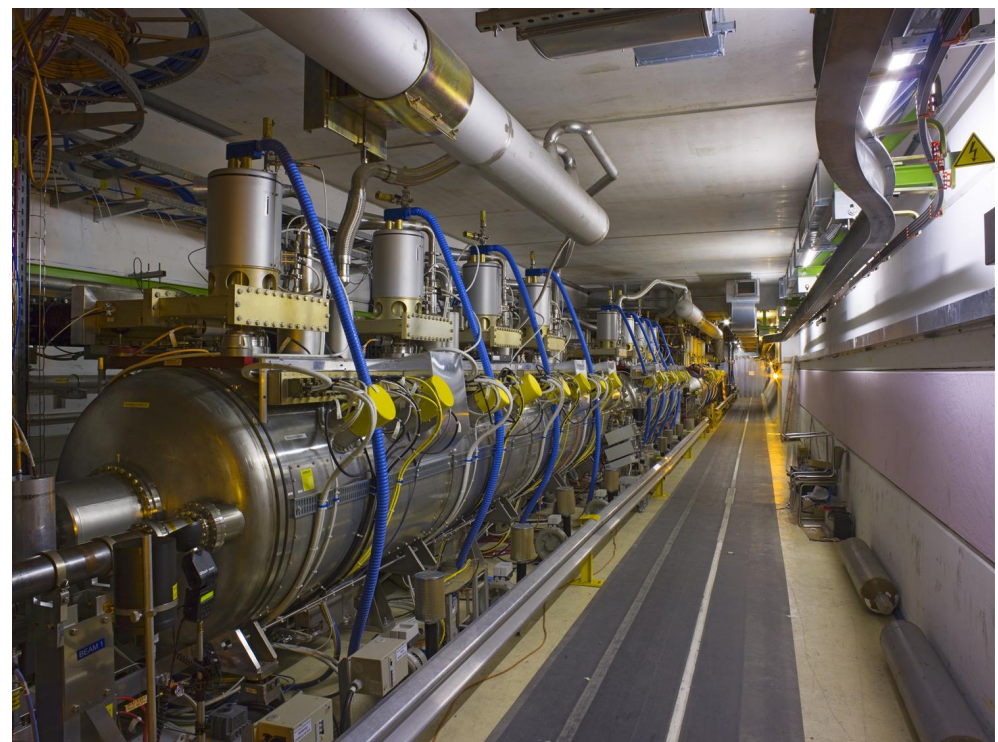
- The length of time required to accelerate the beam to full energy is

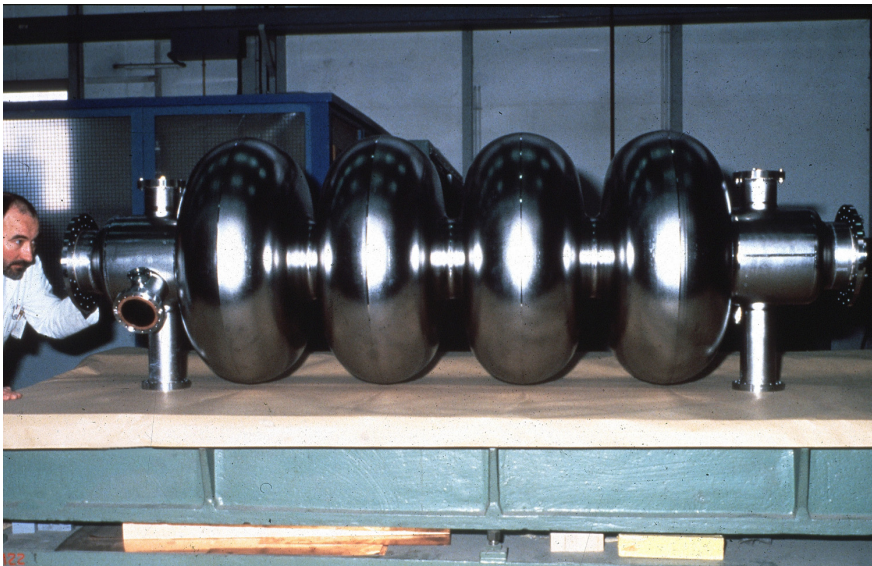
$$6.55 / 0.18 = 36.4 \text{ s}$$

- The right results is about 20 minutes, this is due to the fact the proton is not fully affected by the total voltage of the cavity. It is also important to keep bunches compact to increase the chance of collision.

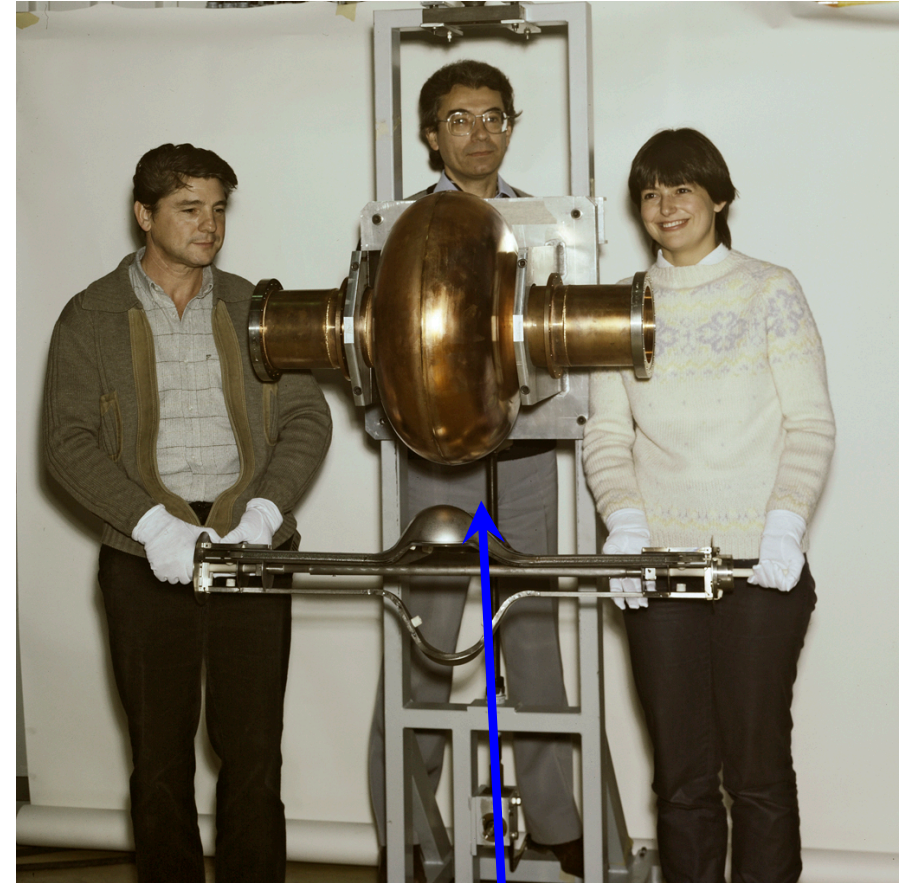
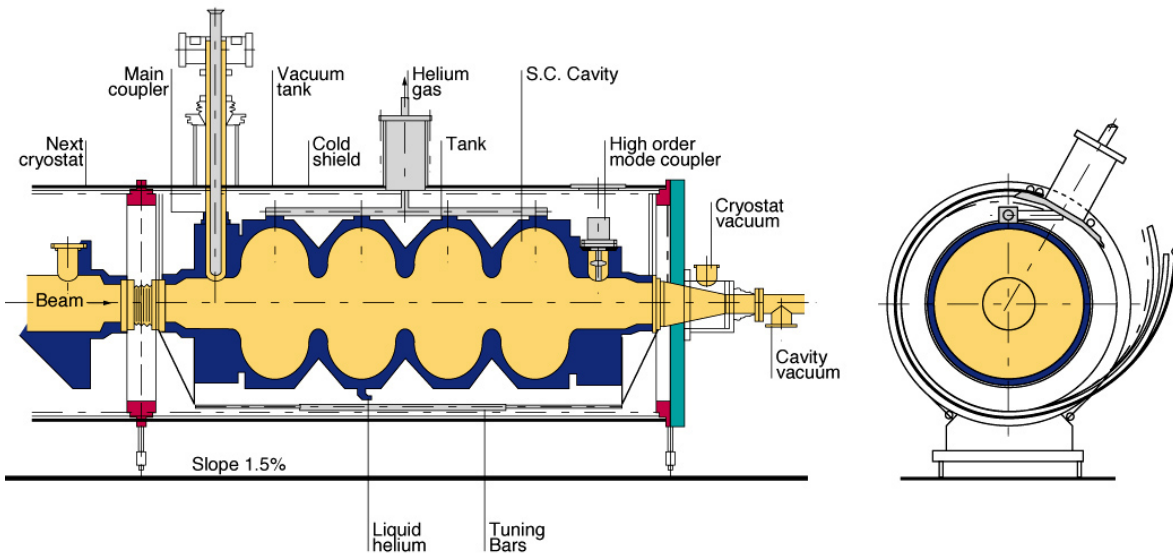
- The RF frequency must always be an integer multiple of the revolution frequency

$$\nu_{RF} = K \cdot \nu_{rev}$$





**SUPERCONDUCTING CAVITY WITH ITS CRYOSTAT**



**RF cavity for LEP**



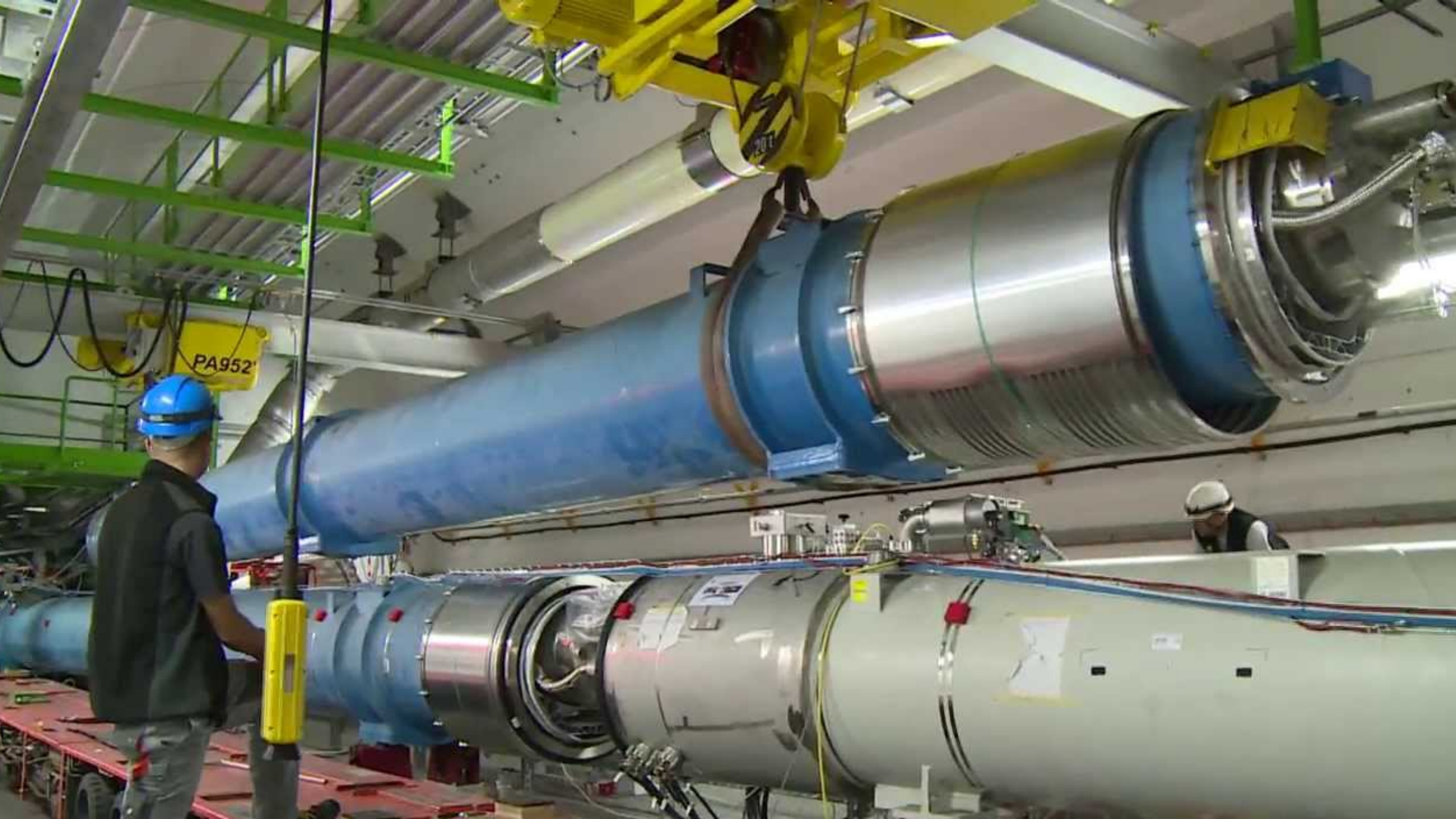






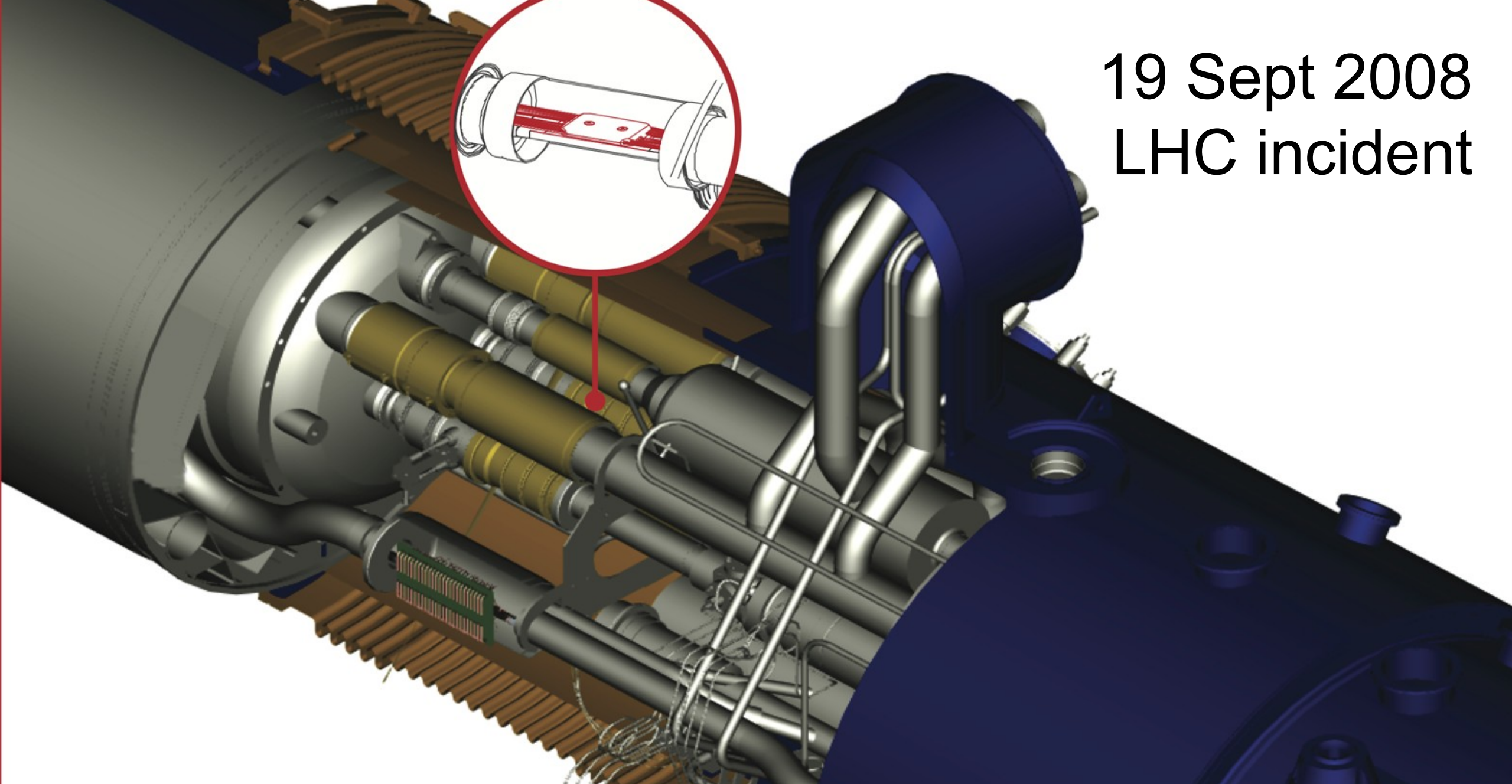
**ROCLA**  
**ROBOTRUCK**







19 Sept 2008  
LHC incident

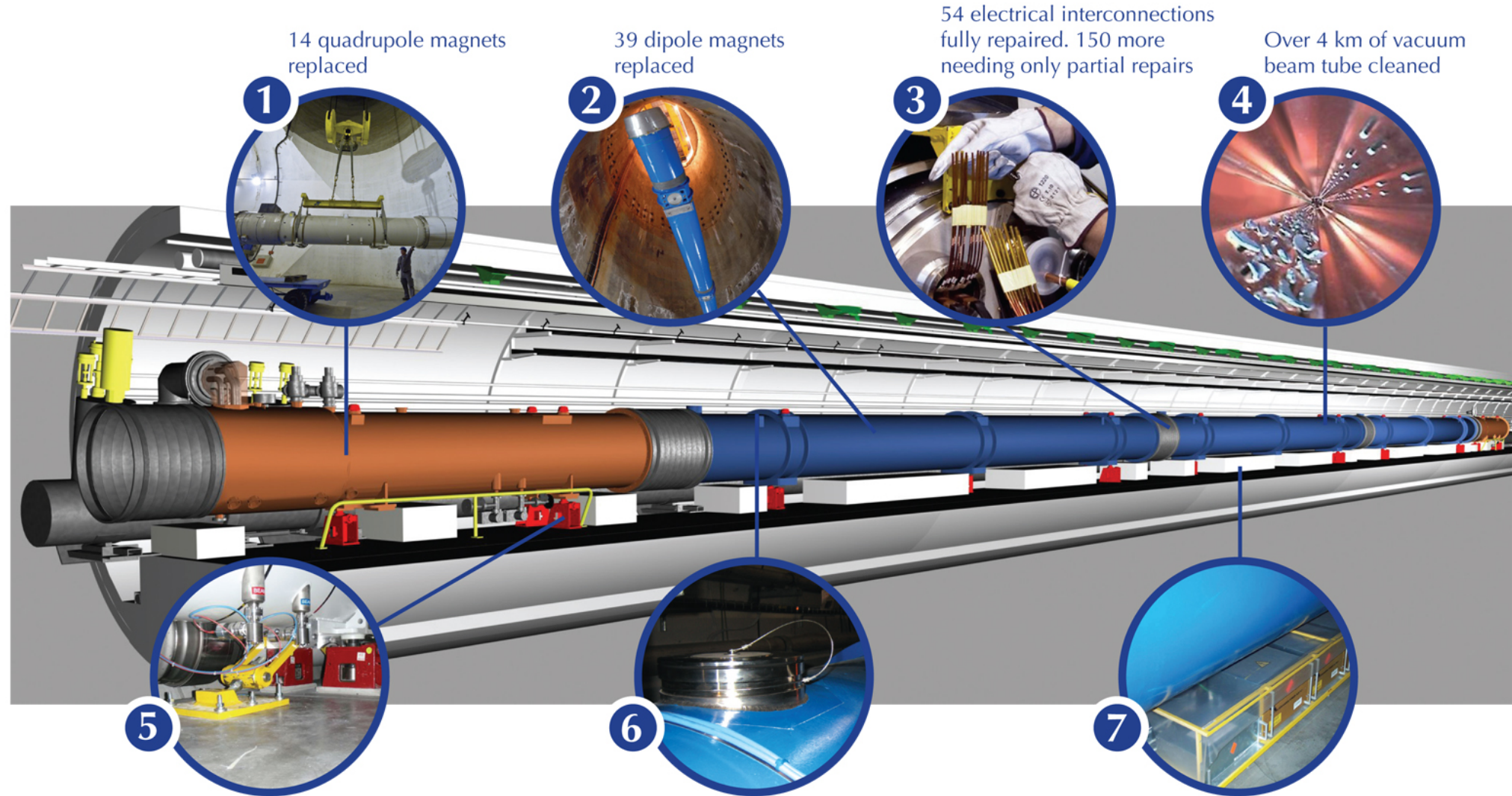








# The LHC repairs in detail



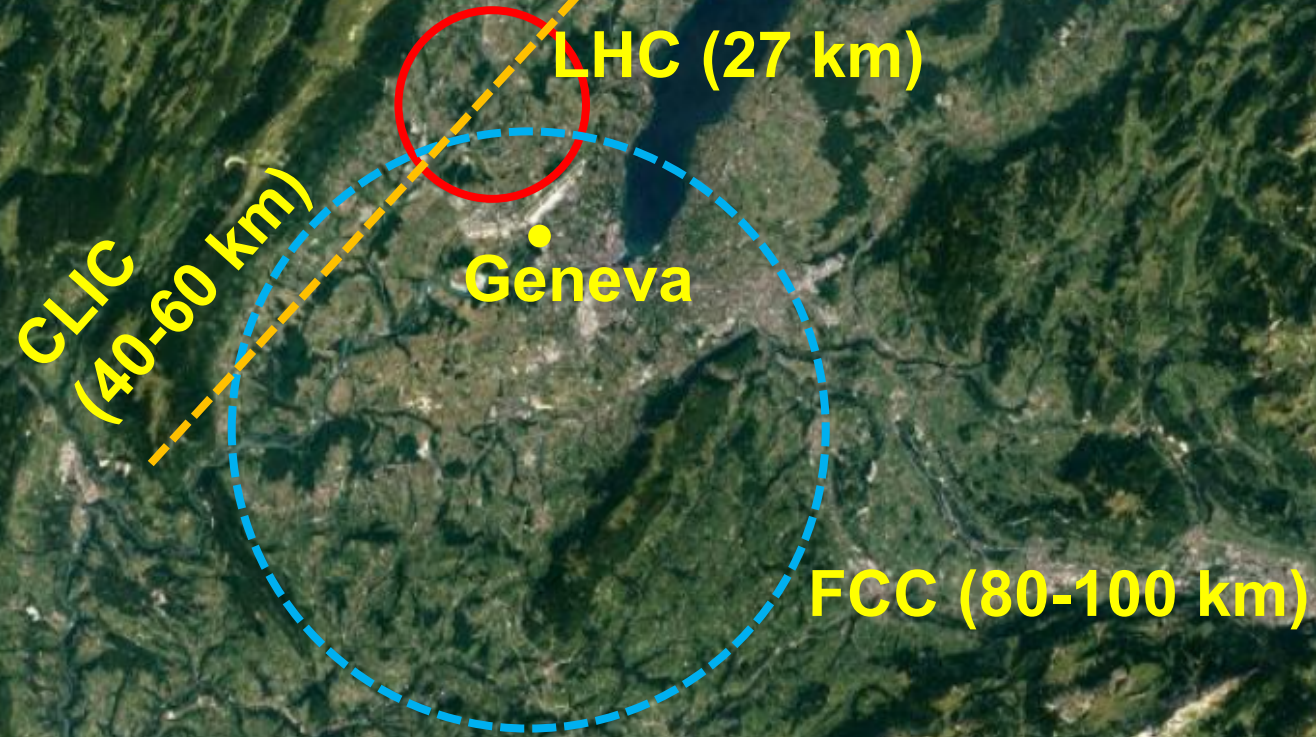
A new longitudinal restraining system is being fitted to 50 quadrupole magnets

Nearly 900 new helium pressure release ports are being installed around the machine

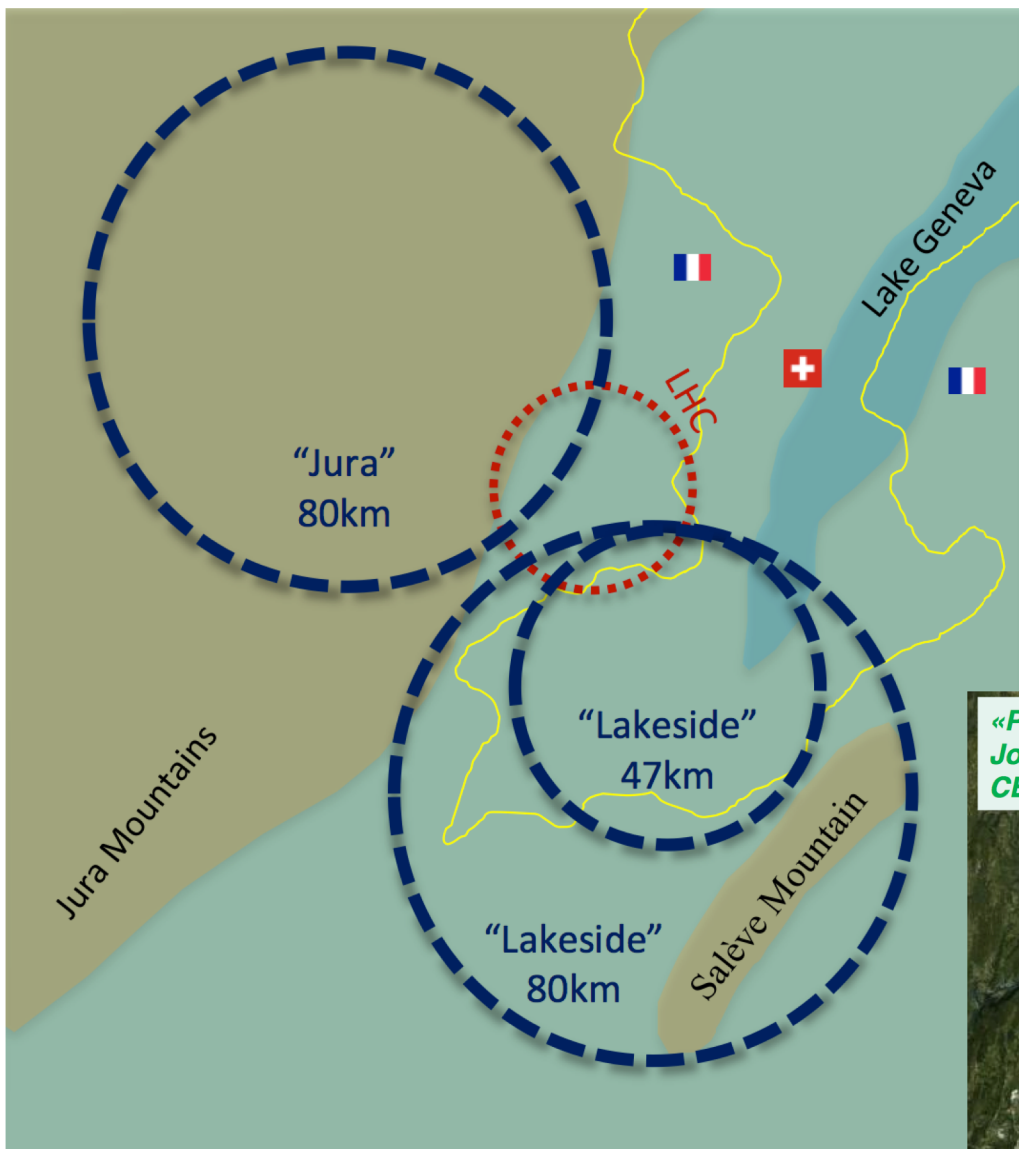
6500 new detectors are being added to the magnet protection system, requiring 250 km of cables to be laid



# Studies for Future colliders





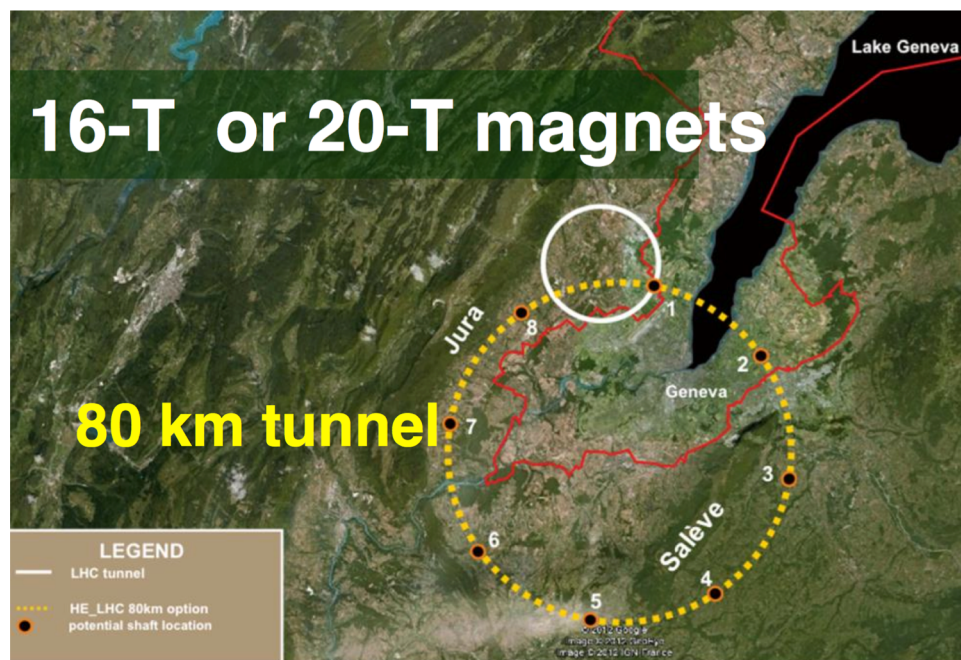


# 16-T or 20-T magnets

80 km tunnel

**LEGEND**

- LHC tunnel
- HE\_LHC 80km option
- potential shaft location

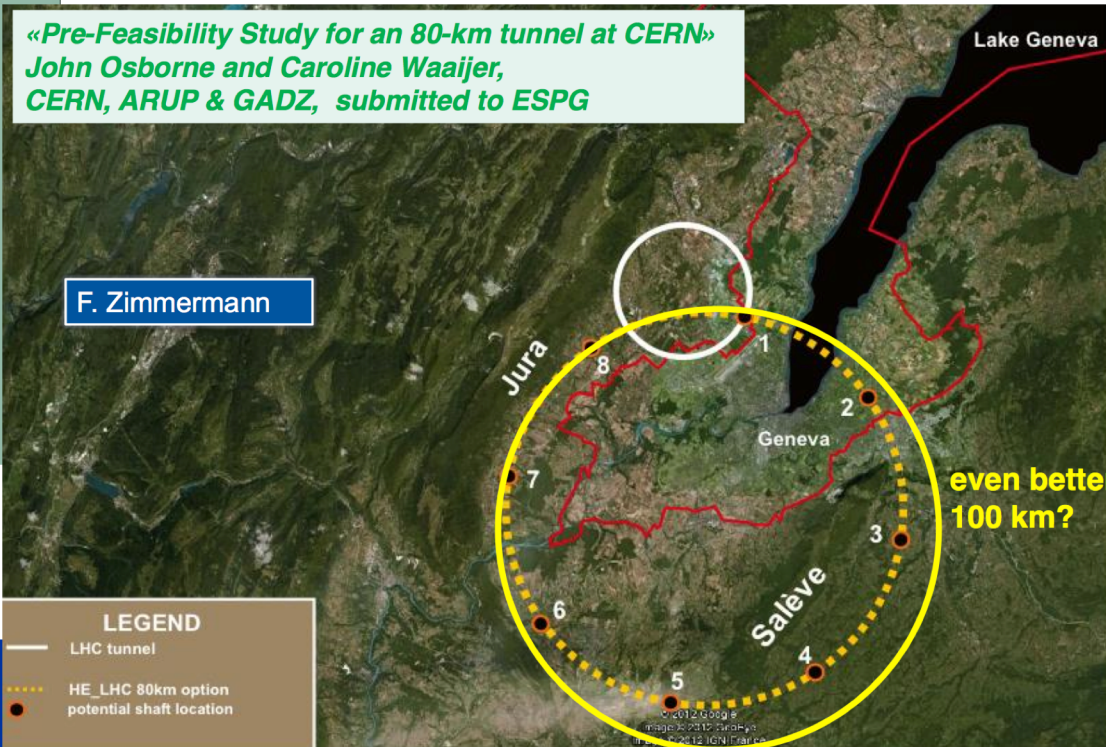


«Pre-Feasibility Study for an 80-km tunnel at CERN»  
John Osborne and Caroline Waaijer,  
CERN, ARUP & GADZ, submitted to ESPG

F. Zimmermann

**LEGEND**

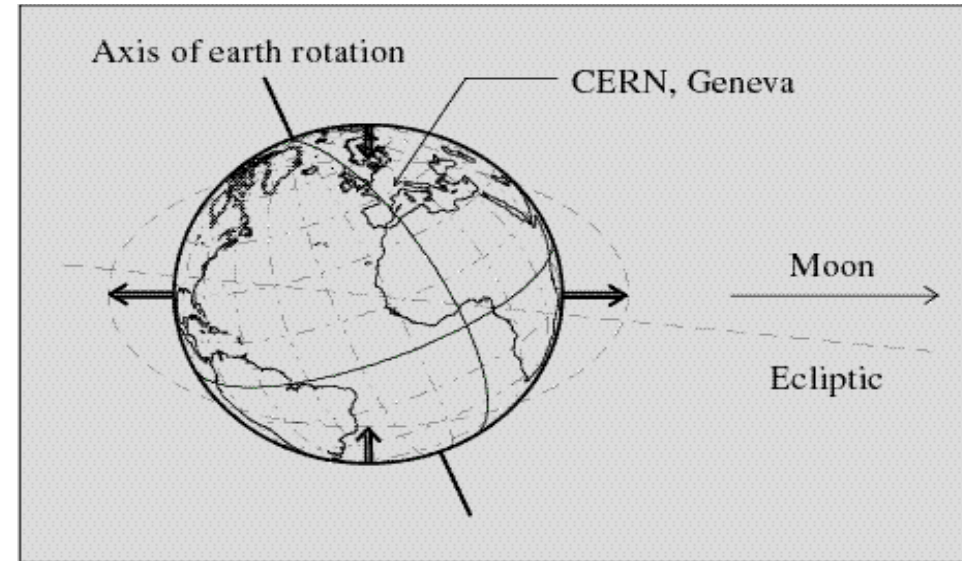
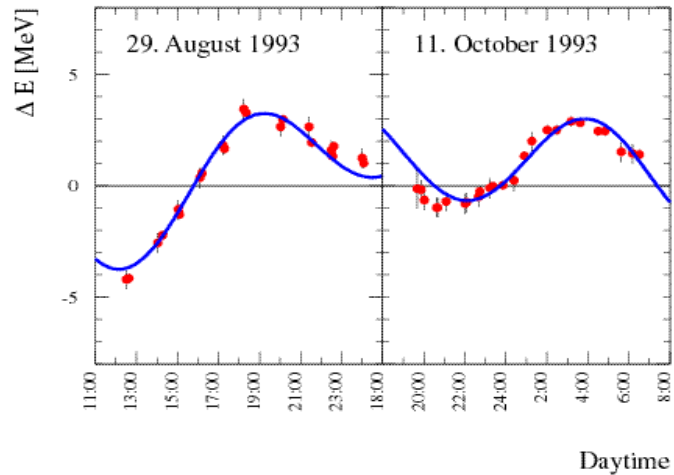
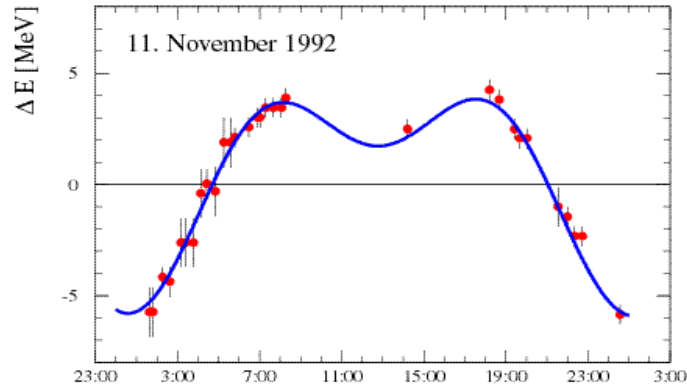
- LHC tunnel
- HE\_LHC 80km option
- potential shaft location



# Very Unexpected Problems: Moon

Precise determination of the LEP beam energy  
Precise measurement of the Z mass and width

( $10^{-5}$  relative accuracy,  $\sim 1$  MeV)

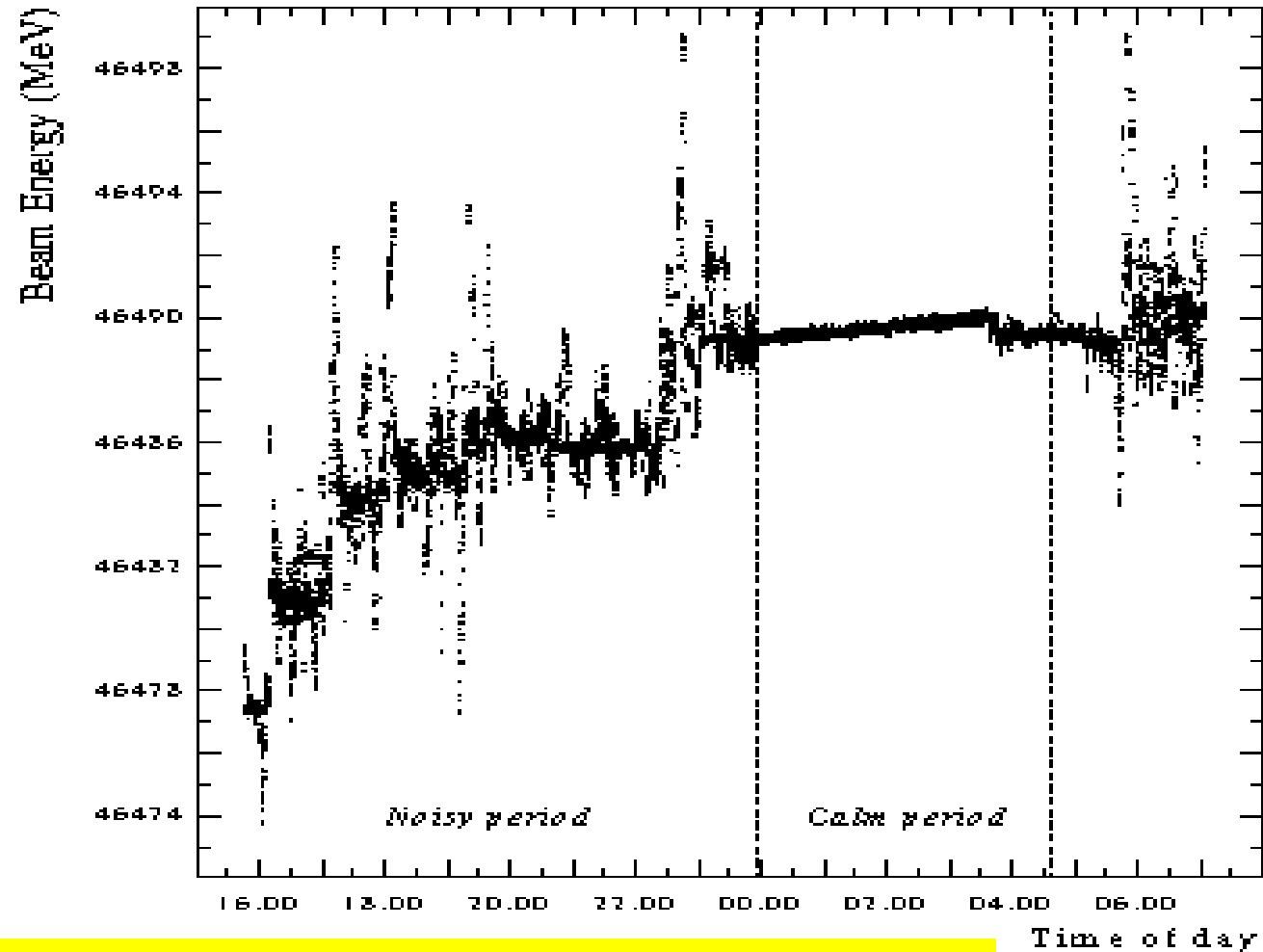


Small changes of energy accurately measured  
(energy change from 1mm circumference change)

LEP energy affected by:

Tides, water levels, ...

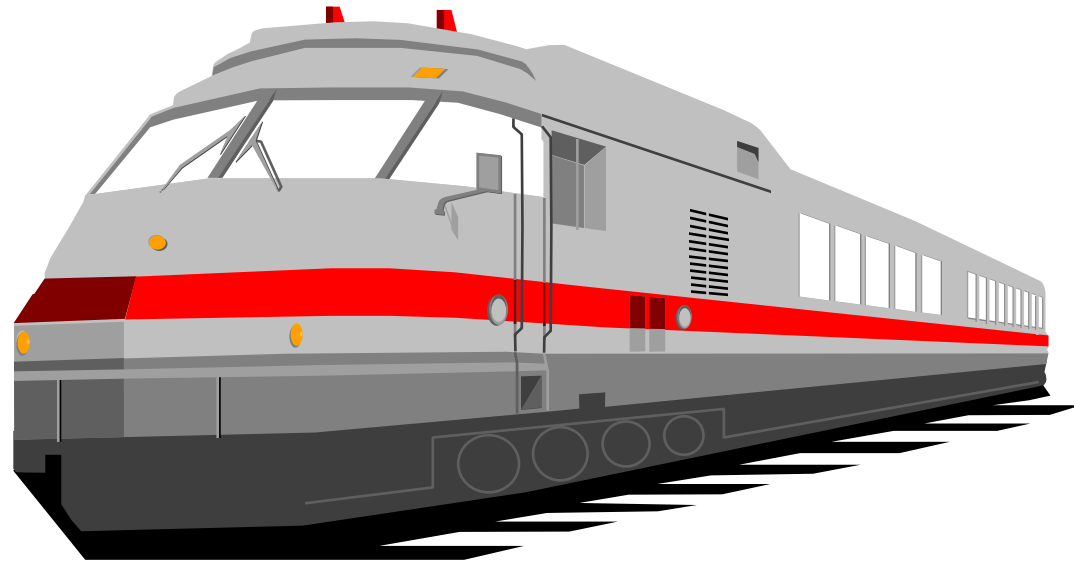
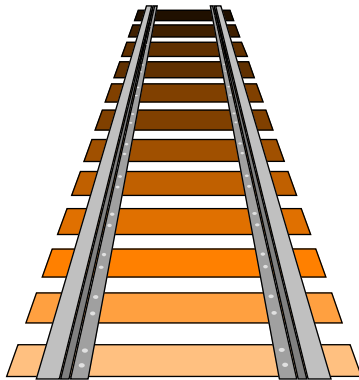
# Noise on the Beam Energy



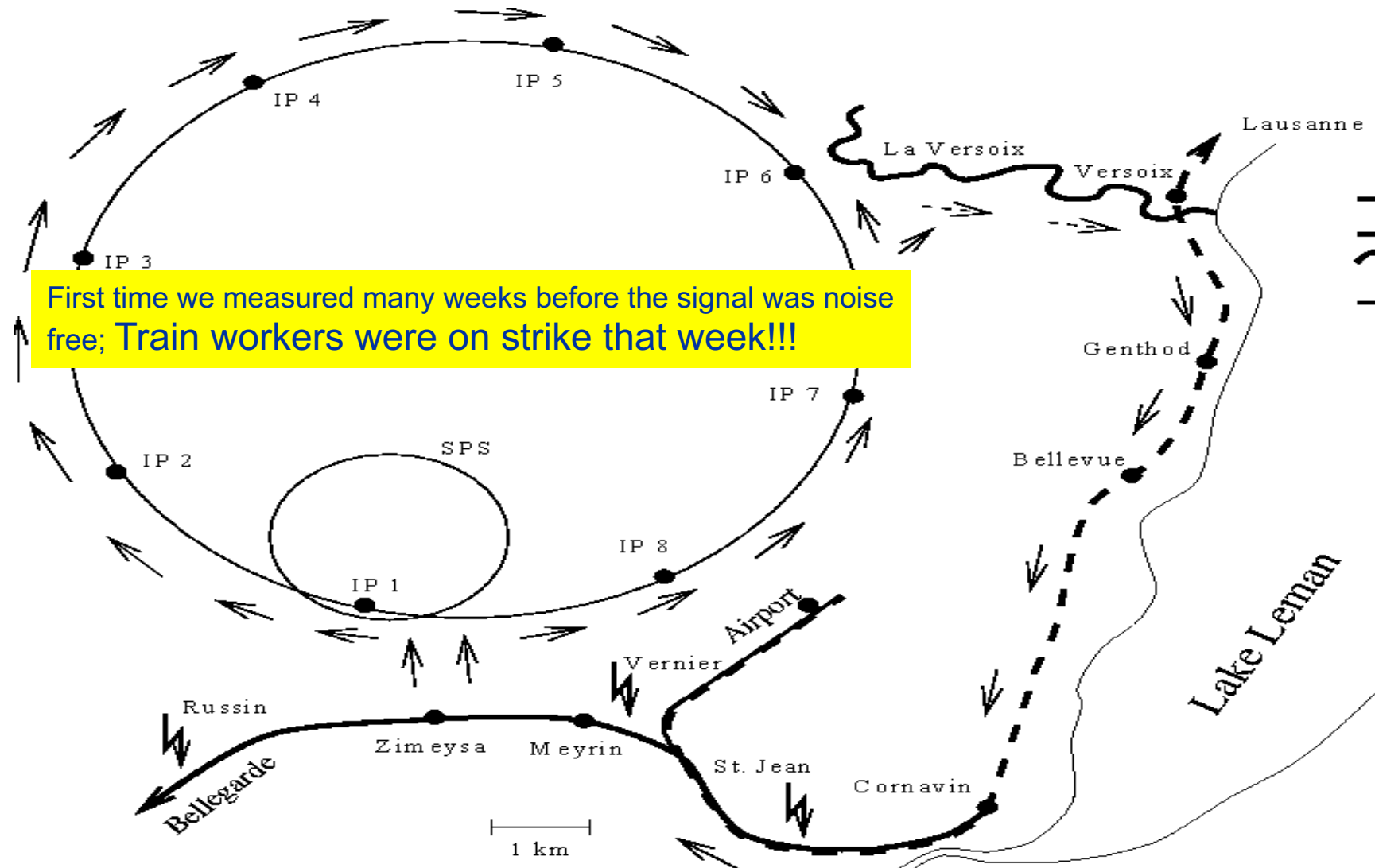
First time we measured many weeks before the signal was noise free

# Very Unexpected Problem

AND now the fast train.....



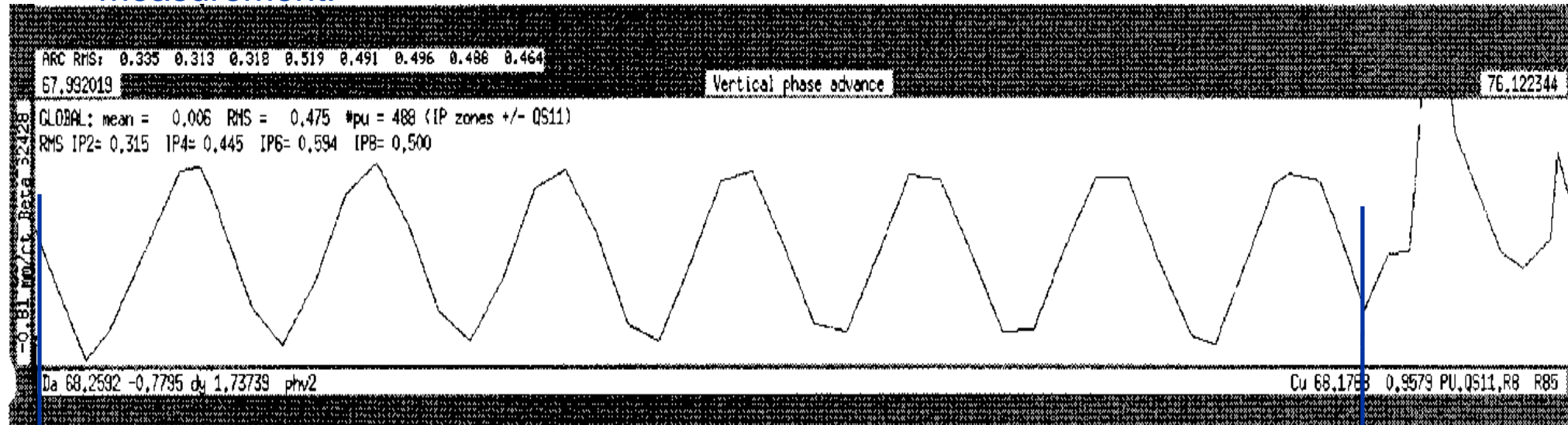
# TGV induces current in LEP vacuum chamber





# Some really unexpected events

Could not get the beam to circulate more than 15 turns even with large bumps all around the ring. Use single turn orbit system and normalised the measurement.



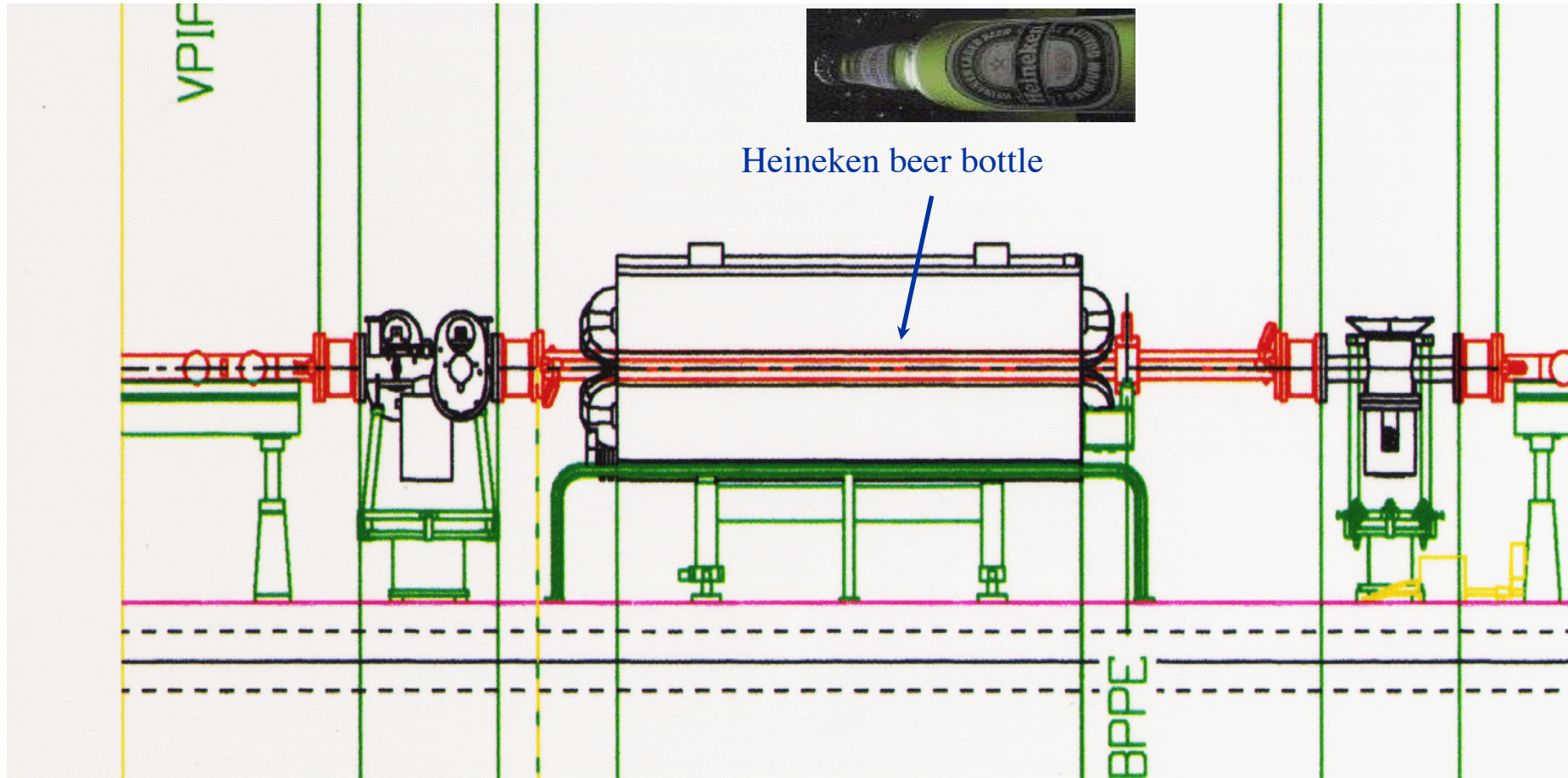
Single Turn  
Stopper

positrons



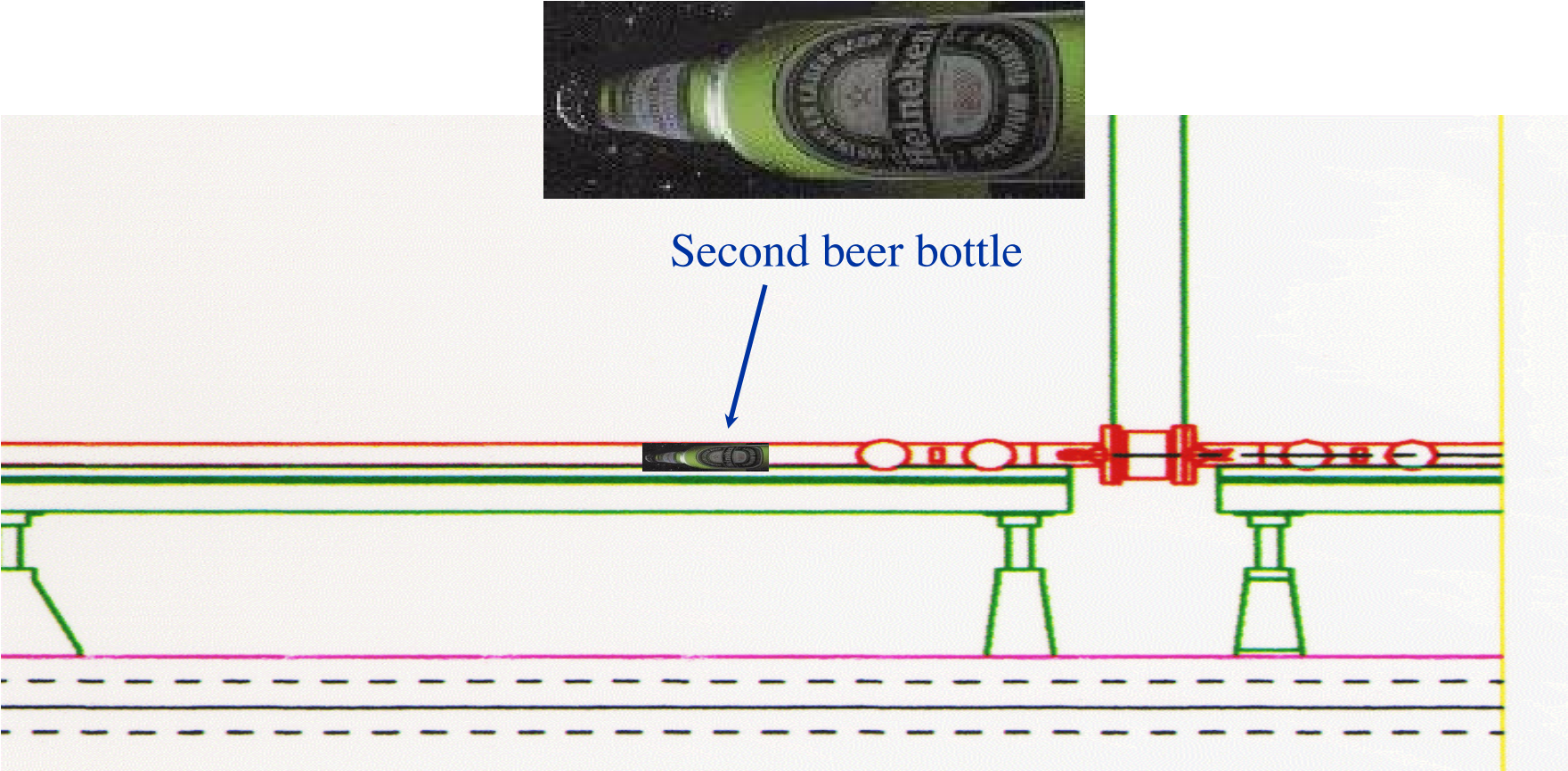
QL10.L1

# Zoom in on Quadrupole





# 10 metres to the right



Unsociable sabotage: both bottles were empty!!



# 1996: Heineken Beam Stopper



UK advertising at the time:

Heineken; the beer that gets to places no other beer can!