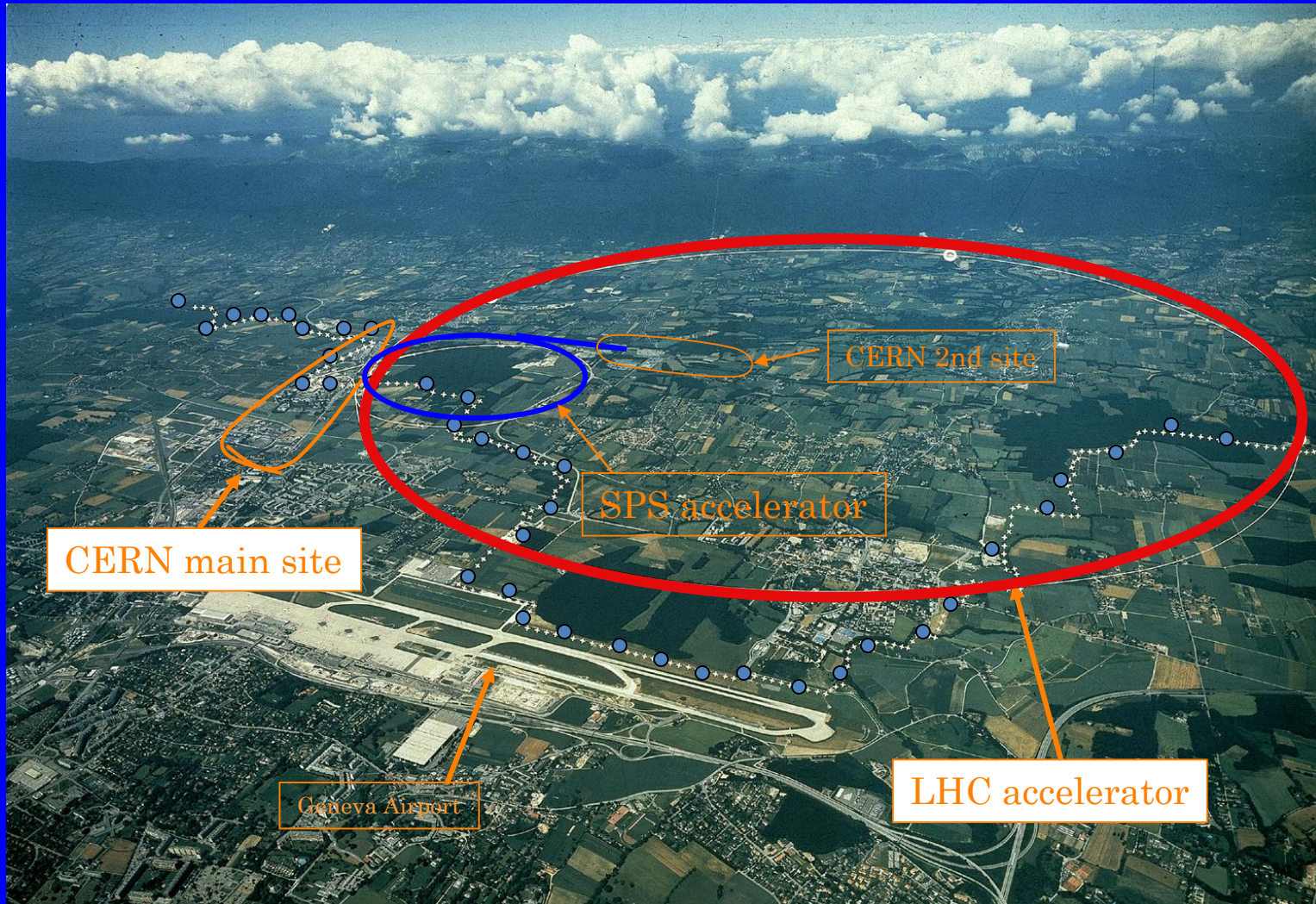
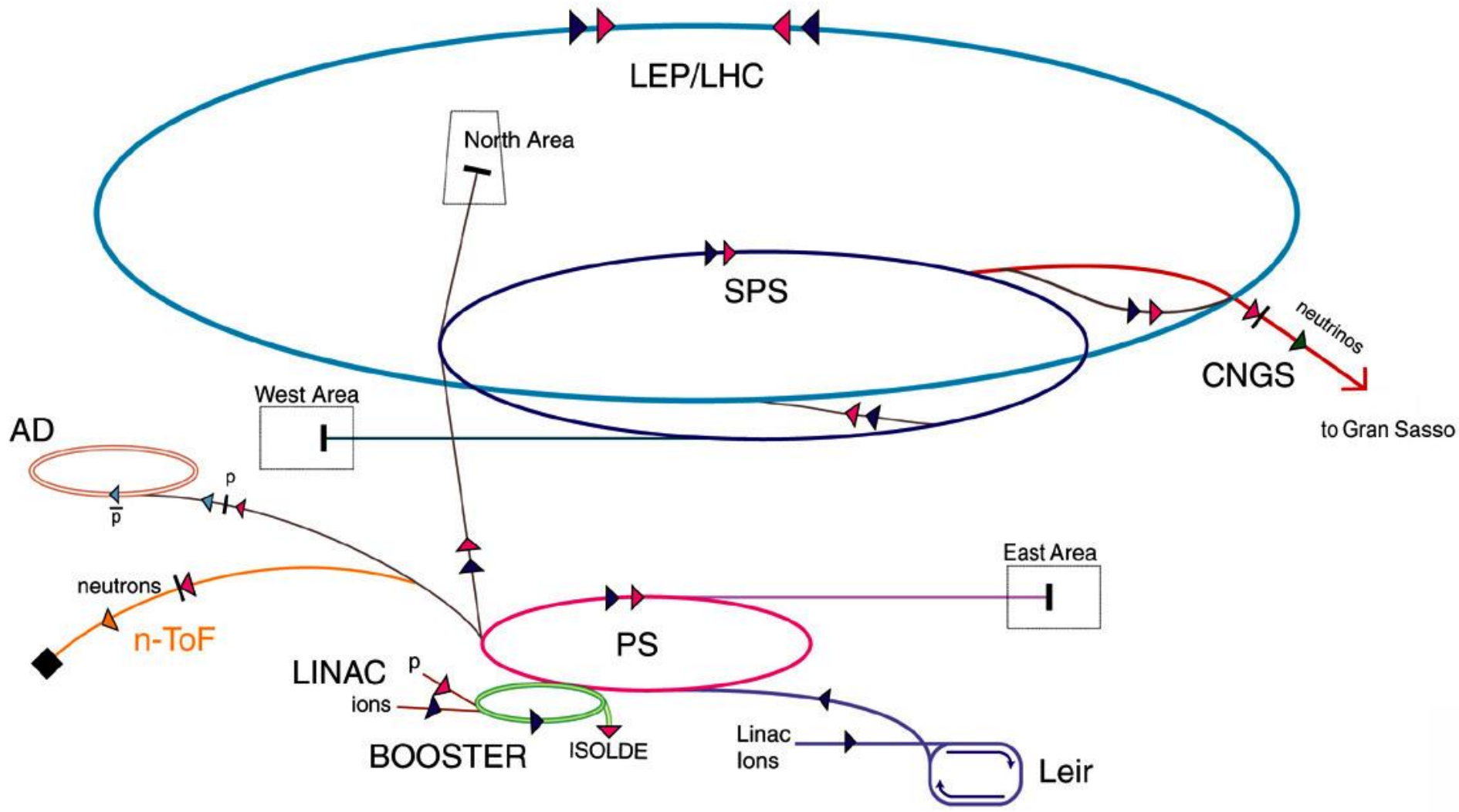


# CERN accelerators



# The CERN accelerators



▶ p (proton)  
▶  $\bar{p}$  (antiproton)  
▶ ion  
▶ neutron

▶ ▶ proton/antiproton conversion  
▶ neutrino

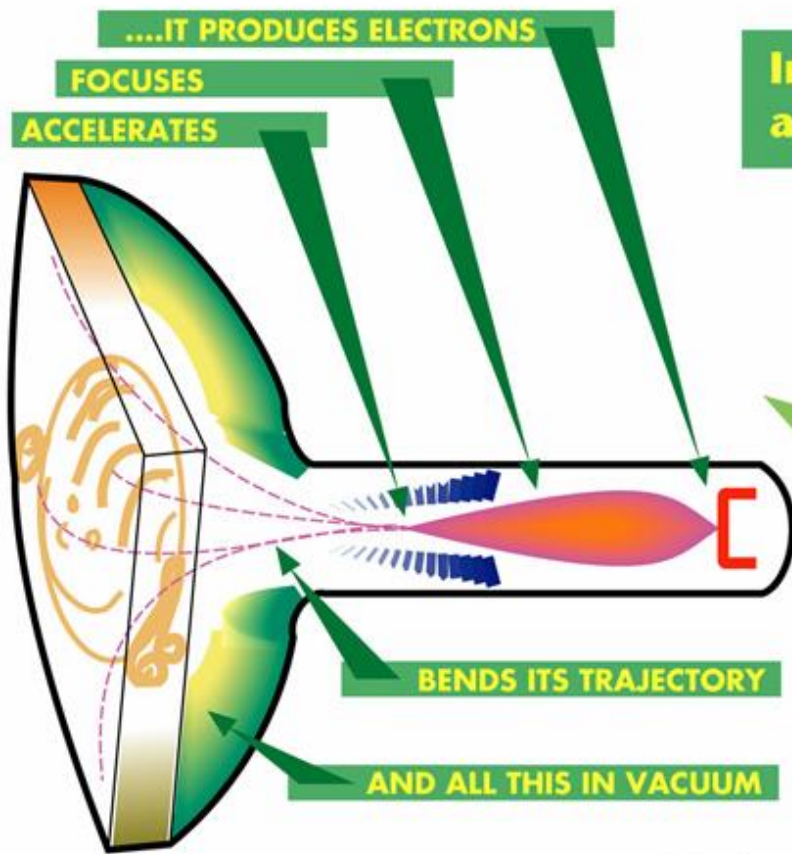
AD Antiproton Decelerator  
 PS Proton Synchrotron  
 SPS Super Proton Synchrotron

LHC Large Hadron Collider  
 n-ToF Neutron Time of Flight  
 CNGS CERN Neutrinos to Gran Sasso<sup>2</sup>

# From Hydrogen gas to the LHC

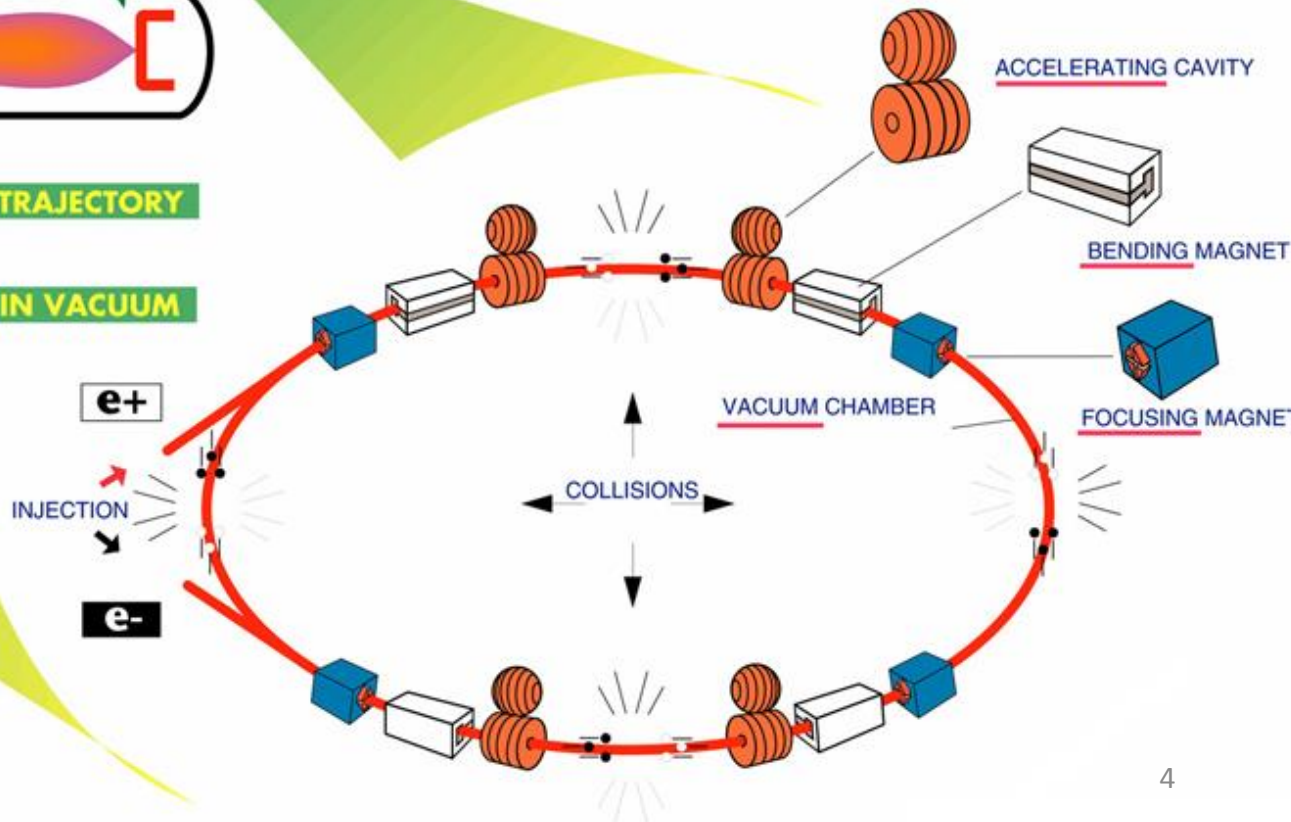


# DID YOU KNOW YOUR TELEVISION SET IS AN ACCELERATOR ?



In your TV set, the electrons are accelerated to 20000 volts.

In LEP, they are accelerated to 100 000 000 000 volts.





8 radiofrequency (RF) cavities for each beam, installed in groups of 4 in cryomodules, accelerate the beams

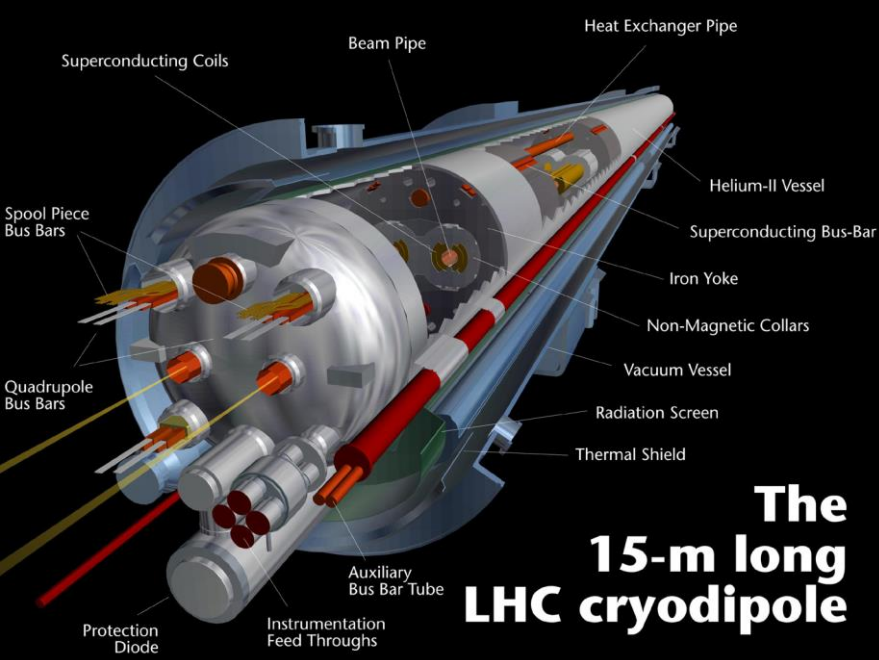
Each delivers 2 MV  
Frequency : 400 MHz

The RF cavities are superconducting, cooled at 4.5 K

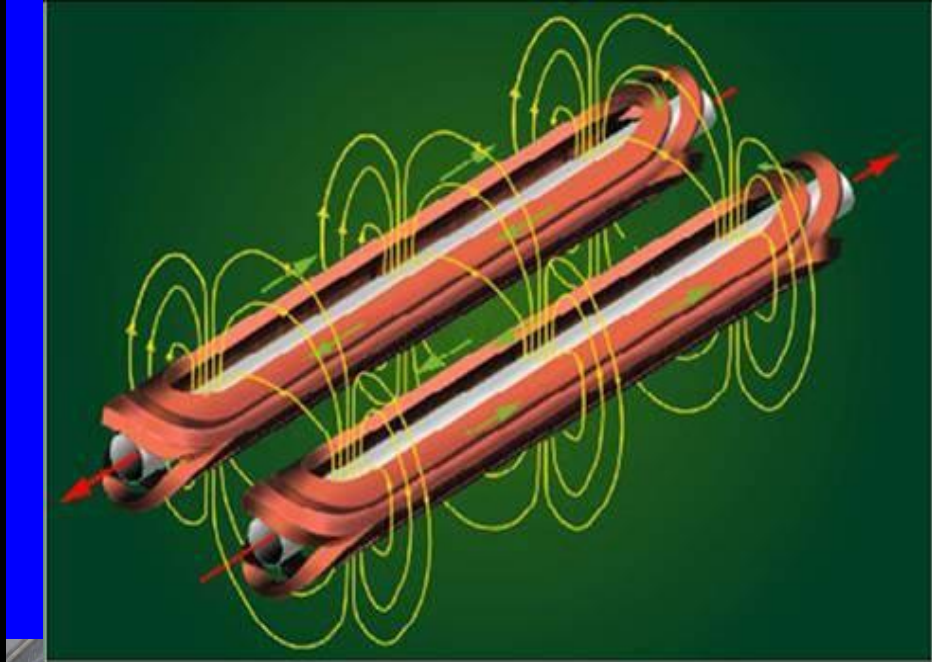
The beams circulate in specially designed beam pipes, with very high vacuum,  $10^{-13}$  atm

<https://videos.cern.ch/record/1709737>

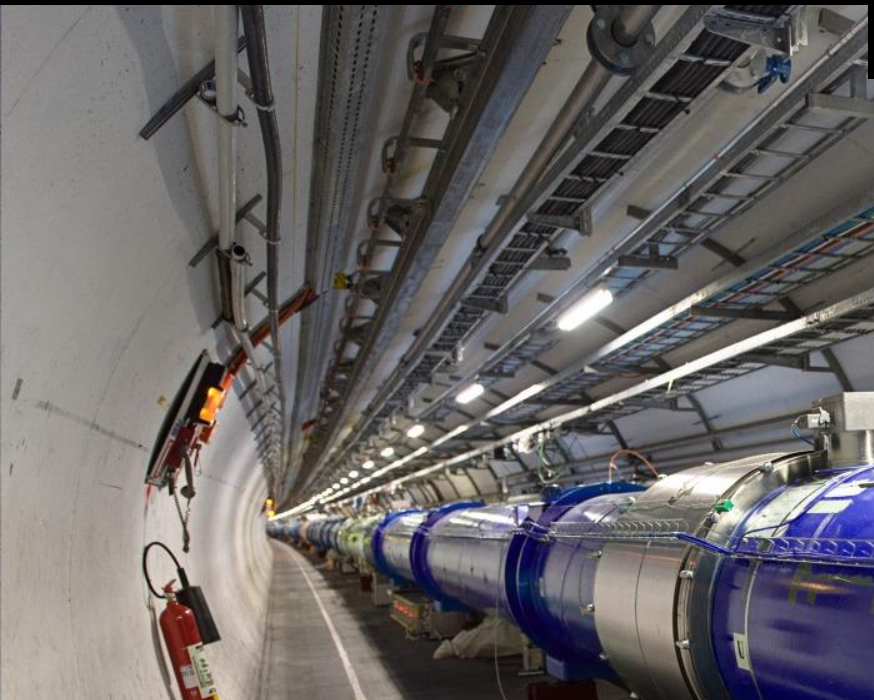




# The 15-m long LHC cryodipole



8.3 Tesla for 7 TeV beams; ~ 12 000 A needed

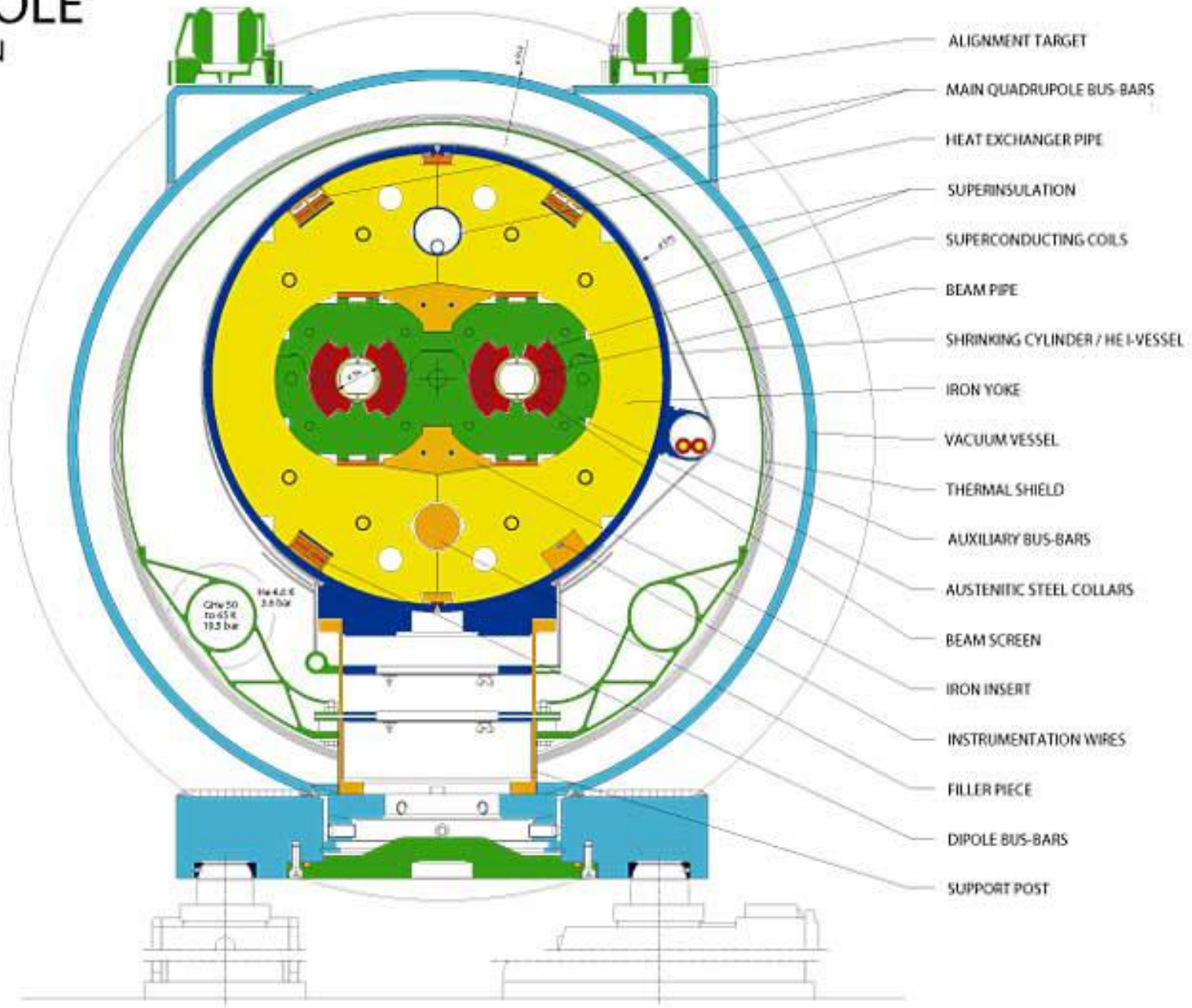


1232 magnetic dipoles bend the beams



<https://videos.cern.ch/record/1709735>

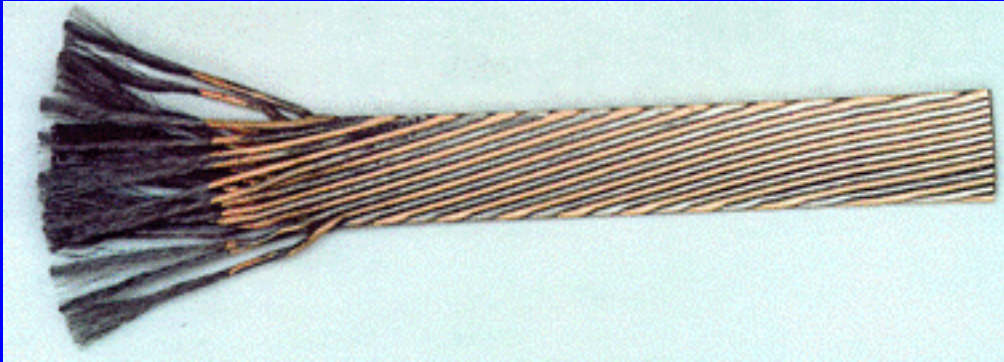
# LHC DIPOLE CROSS SECTION



- ALIGNMENT TARGET
- MAIN QUADRUPOLE BUS-BARS
- HEAT EXCHANGER PIPE
- SUPERINSULATION
- SUPERCONDUCTING COILS
- BEAM PIPE
- SHRINKING CYLINDER / HE I-VESSEL
- IRON YOKE
- VACUUM VESSEL
- THERMAL SHIELD
- AUXILIARY BUS-BARS
- AUSTENITIC STEEL COLLARS
- BEAM SCREEN
- IRON INSERT
- INSTRUMENTATION WIRES
- FILLER PIECE
- DIPOLE BUS-BARS
- SUPPORT POST

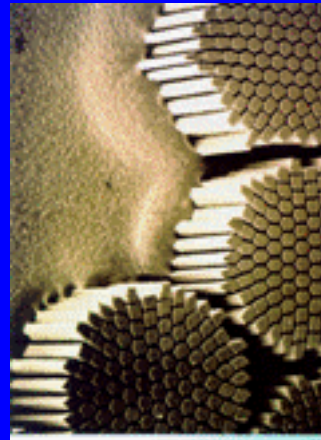
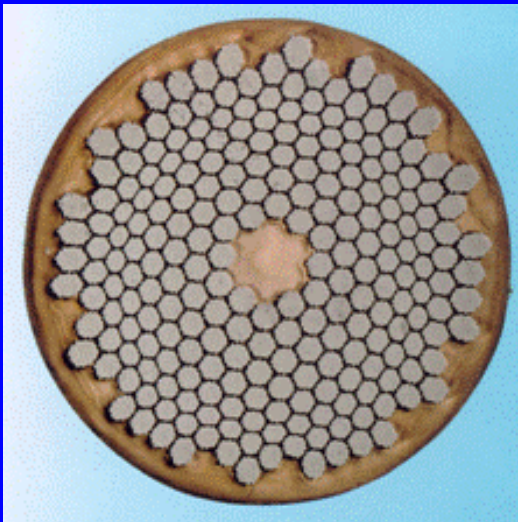
20 to 45 bar

## Superconducting cable : zero resistance; no losses (no heat)



- 1200 tons of superconducting cable
- 7600 km of cable
- Total length of filaments : 10 times the distance earth - sun

### Rutherford cable : 36 strands



Each strand ( $d = 0.825$  mm)  $\sim$  6500 filaments ( $d = 8$   $\mu$ m)  
Niobium – Titanium superconducting filament  
(+ 0.5  $\mu$ m layer of high-purity copper)

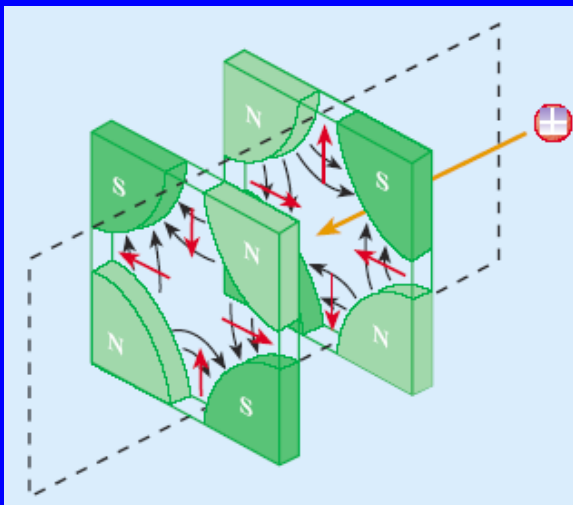
### Cryogenics

- Cooled with 5000 tons of liquid Helium at 1.9 K
- 10000 tons of liquid Nitrogen cool the gaseous Helium to 80 K





quadrupole magnets focus the beams



<https://videos.cern.ch/record/1709736>

Beam visualisation screens <https://videos.cern.ch/record/1750709>

Wire scanners for beam diagnostics <https://videos.cern.ch/record/1750707>

Collimators <https://videos.cern.ch/record/1750704>

Current lead <https://videos.cern.ch/record/1709734>