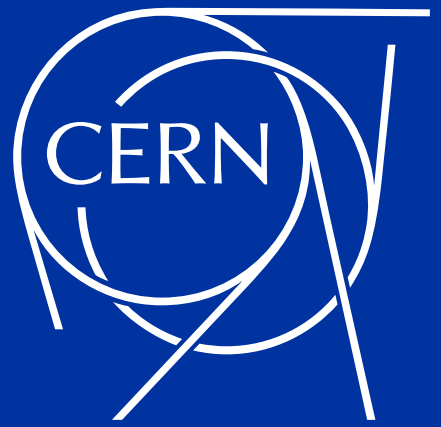
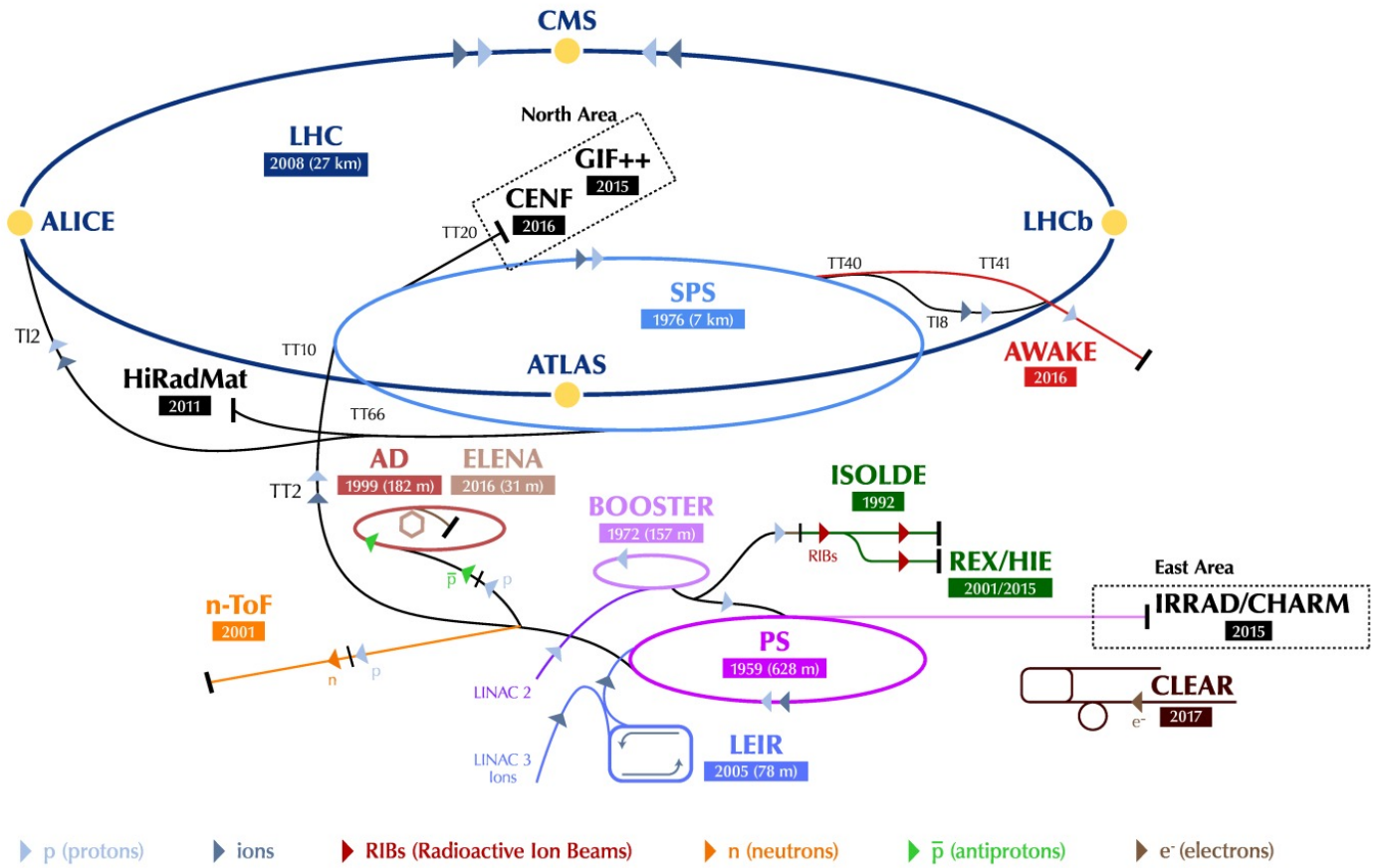


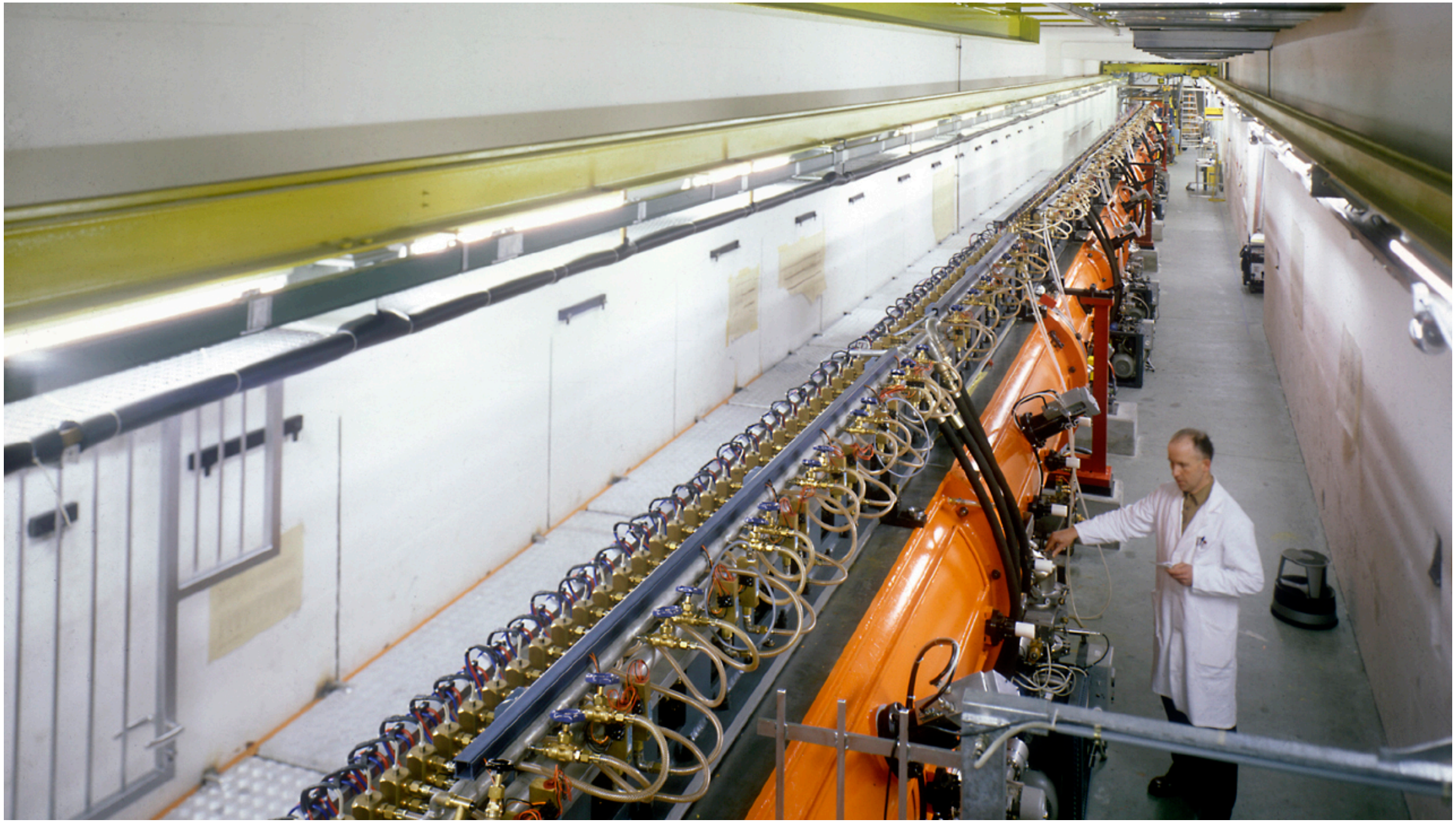
A virtual tour of the Large Hadron Collider sources

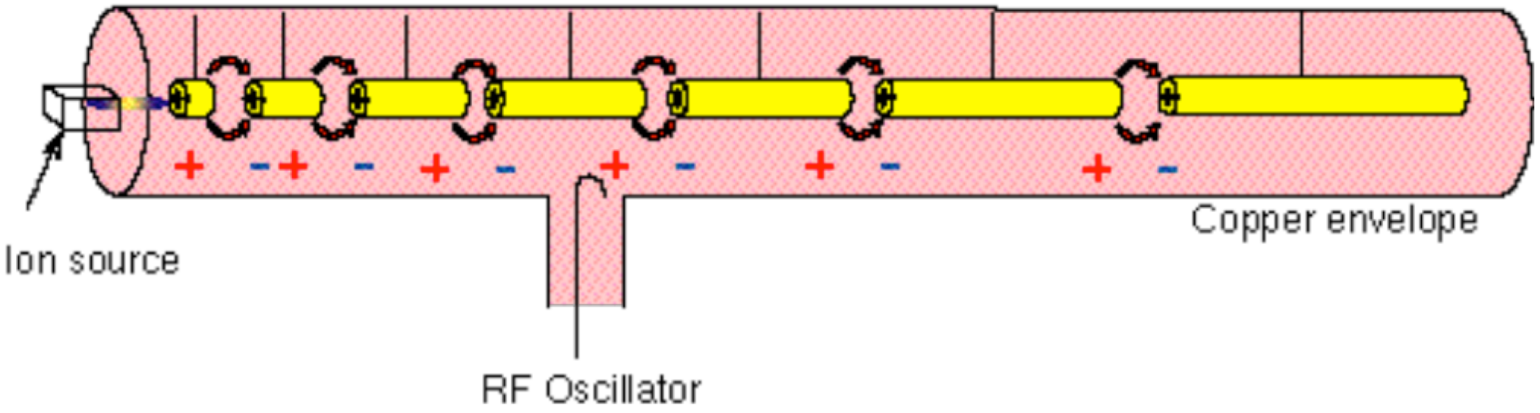
Cristiano Alpigiani

The CERN accelerator complex
Complexe des accélérateurs du CERN



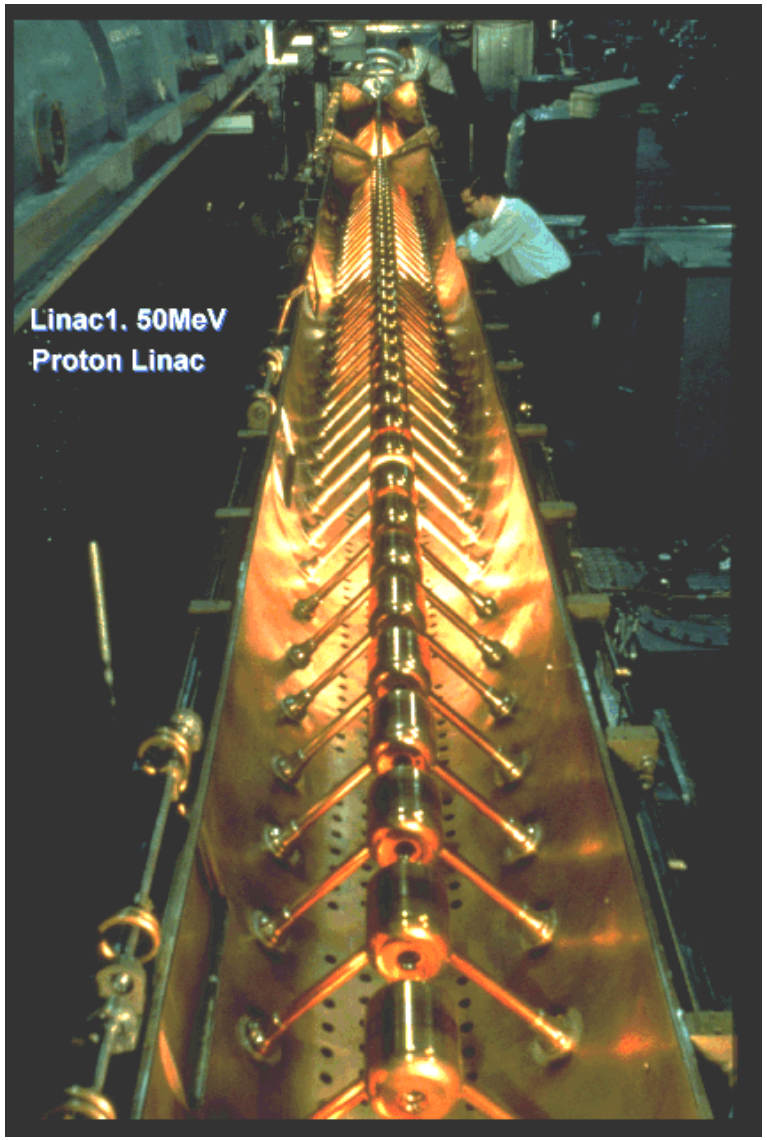
LHC - Large Hadron Collider // **SPS** - Super Proton Synchrotron // **PS** - Proton Synchrotron // **AD** - Antiproton Decelerator // **CLEAR** - CERN Linear Electron Accelerator for Research // **AWAKE** - Advanced WAKefield Experiment // **ISOLDE** - Isotope Separator OnLine // **REX/HIE** - Radioactive 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



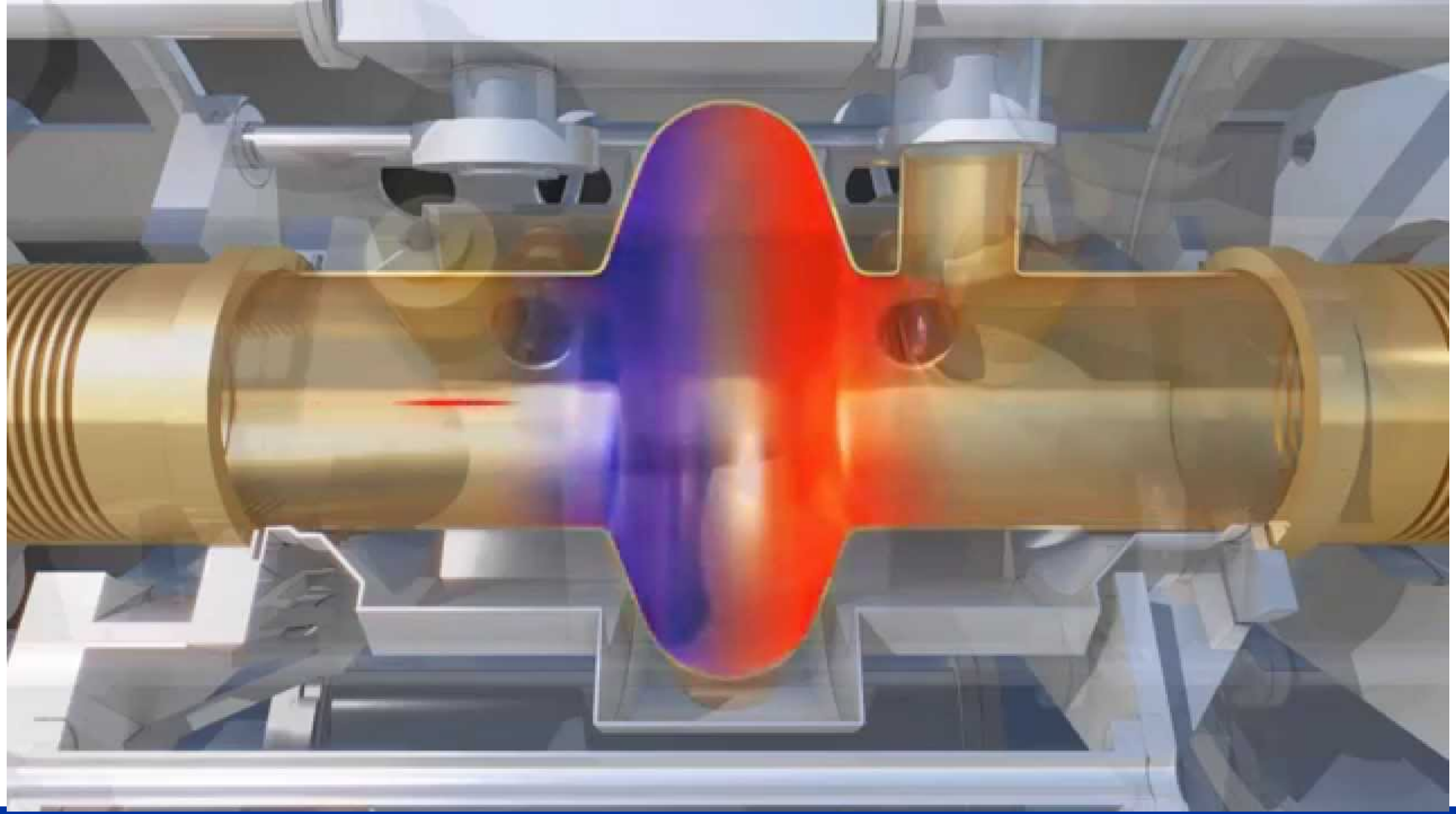


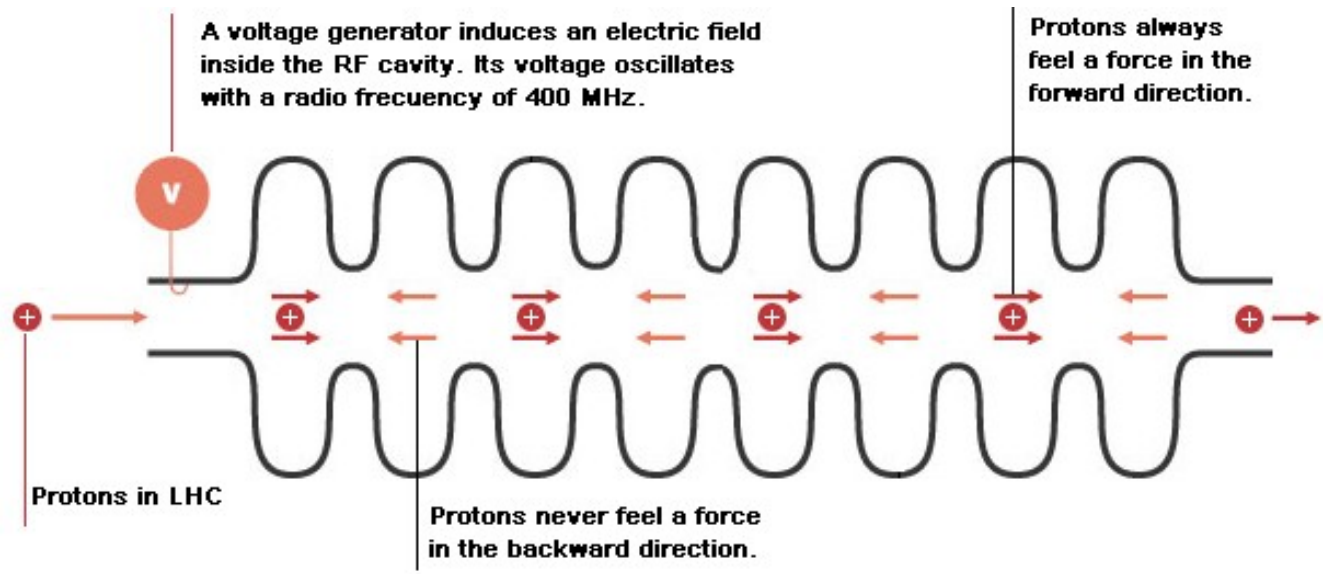
45 MeV

Linac 2 (1978)



Linac 1 (1958)





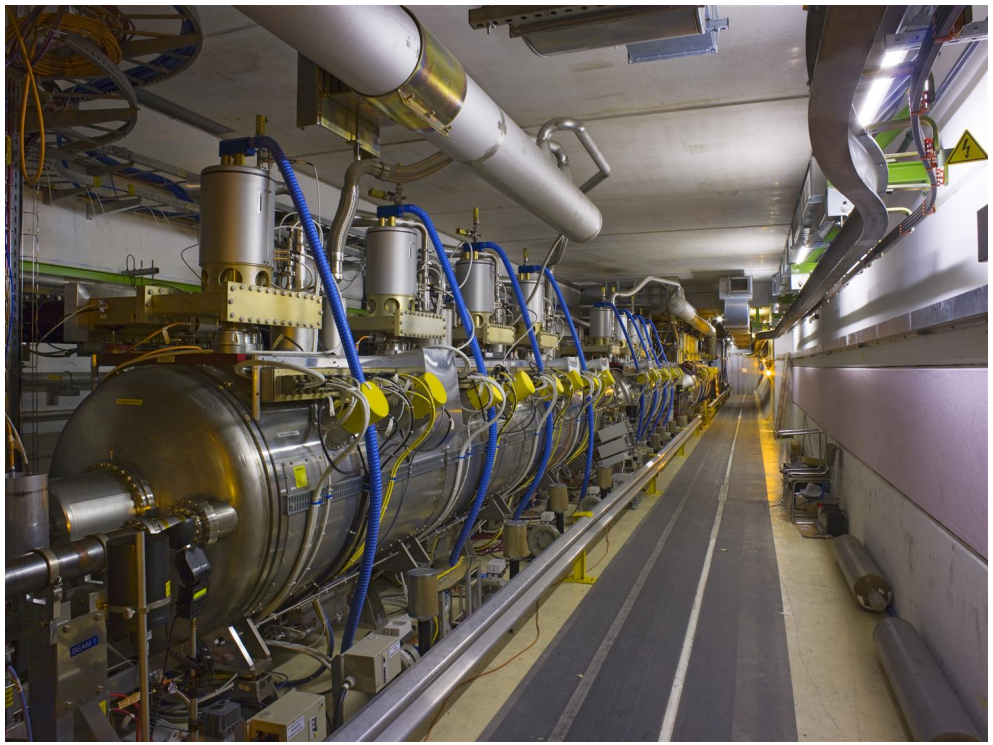
- Each cavity delivers 2MV
- Accelerating field of 5 MV/m @ 400 MHz
- Cavities operate @ 4.5 K

- 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

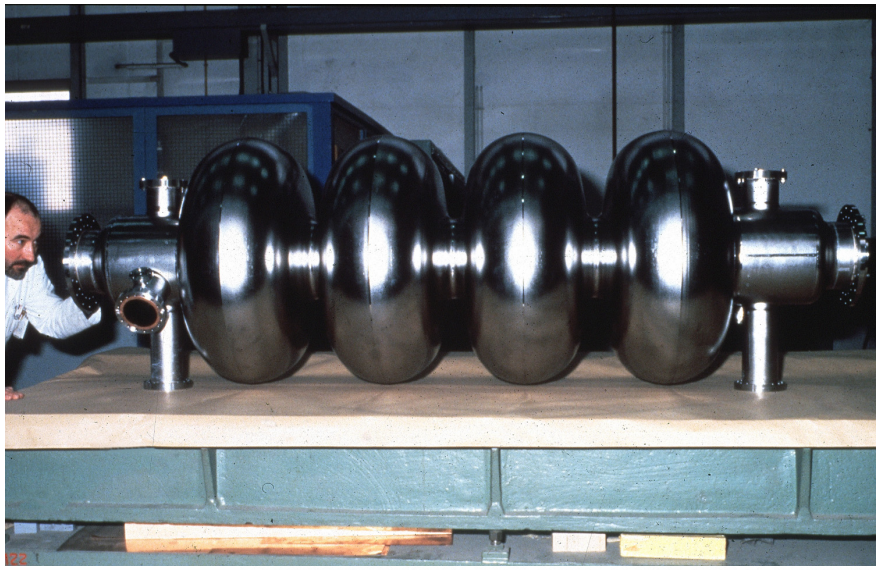
$$7 - 0.45 = 6.55\ \text{TeV}$$

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

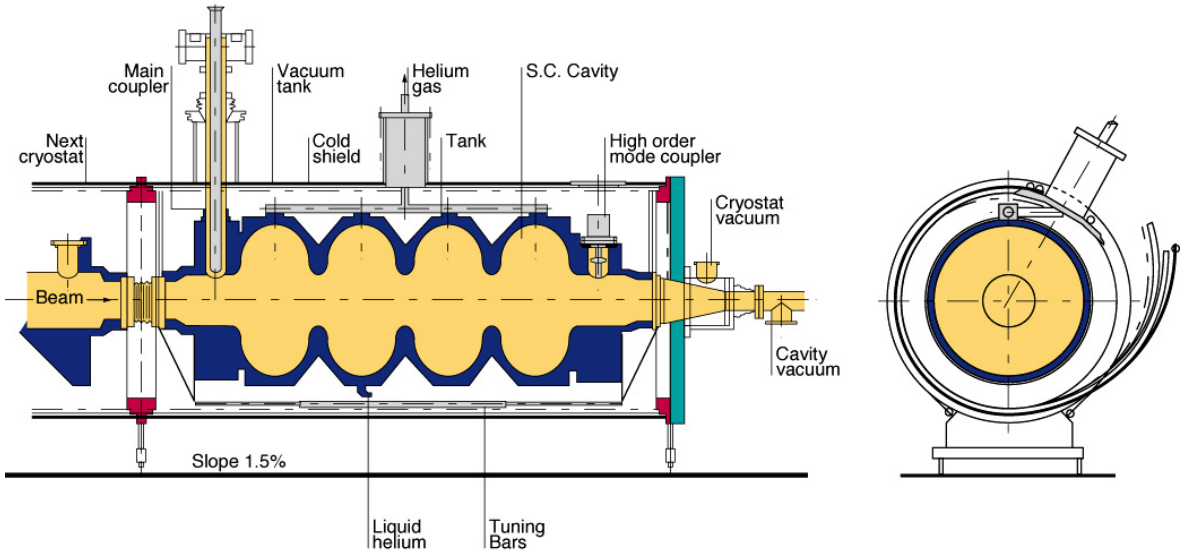
$$6.55\ /\ 0.18 = 36.4\ \text{s}$$

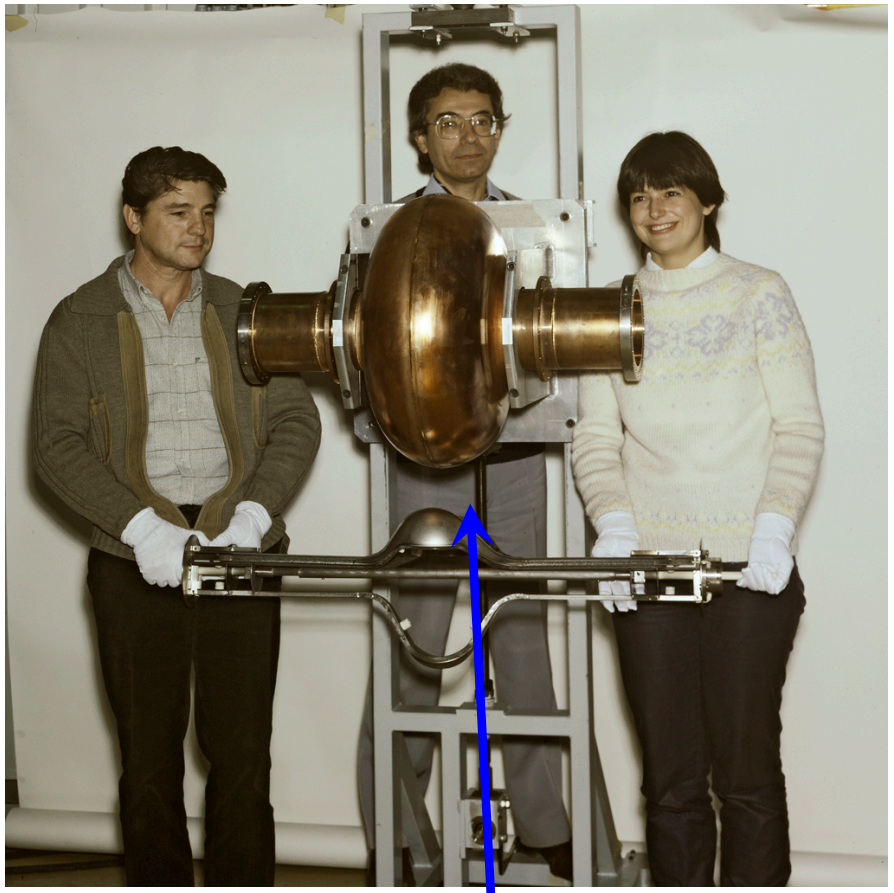
- The right results is about 20 minutes, this is due to the fact the proton is not fully affected by the total voltage of the cavity. It is also important to keep bunches compact to increase the chance of collision.
- The RF frequency must always be an integer multiple of the revolution frequency

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

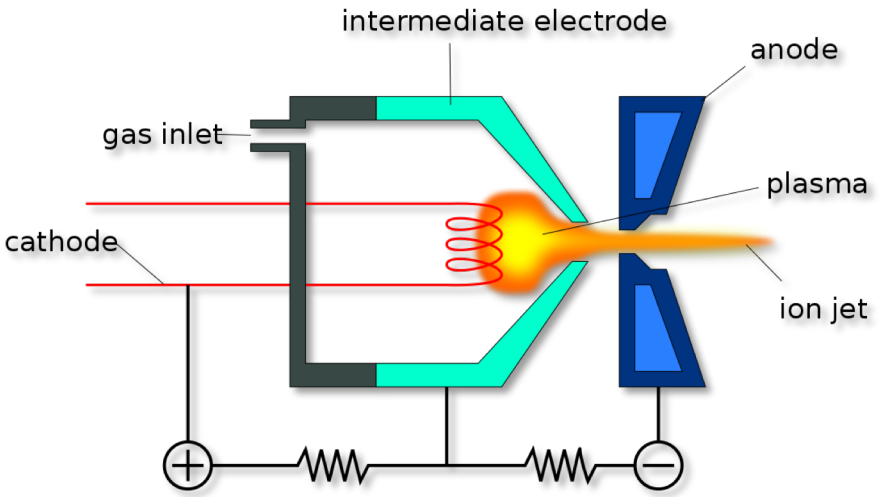


SUPERCONDUCTING CAVITY WITH ITS CRYOSTAT





RF cavity for LEP

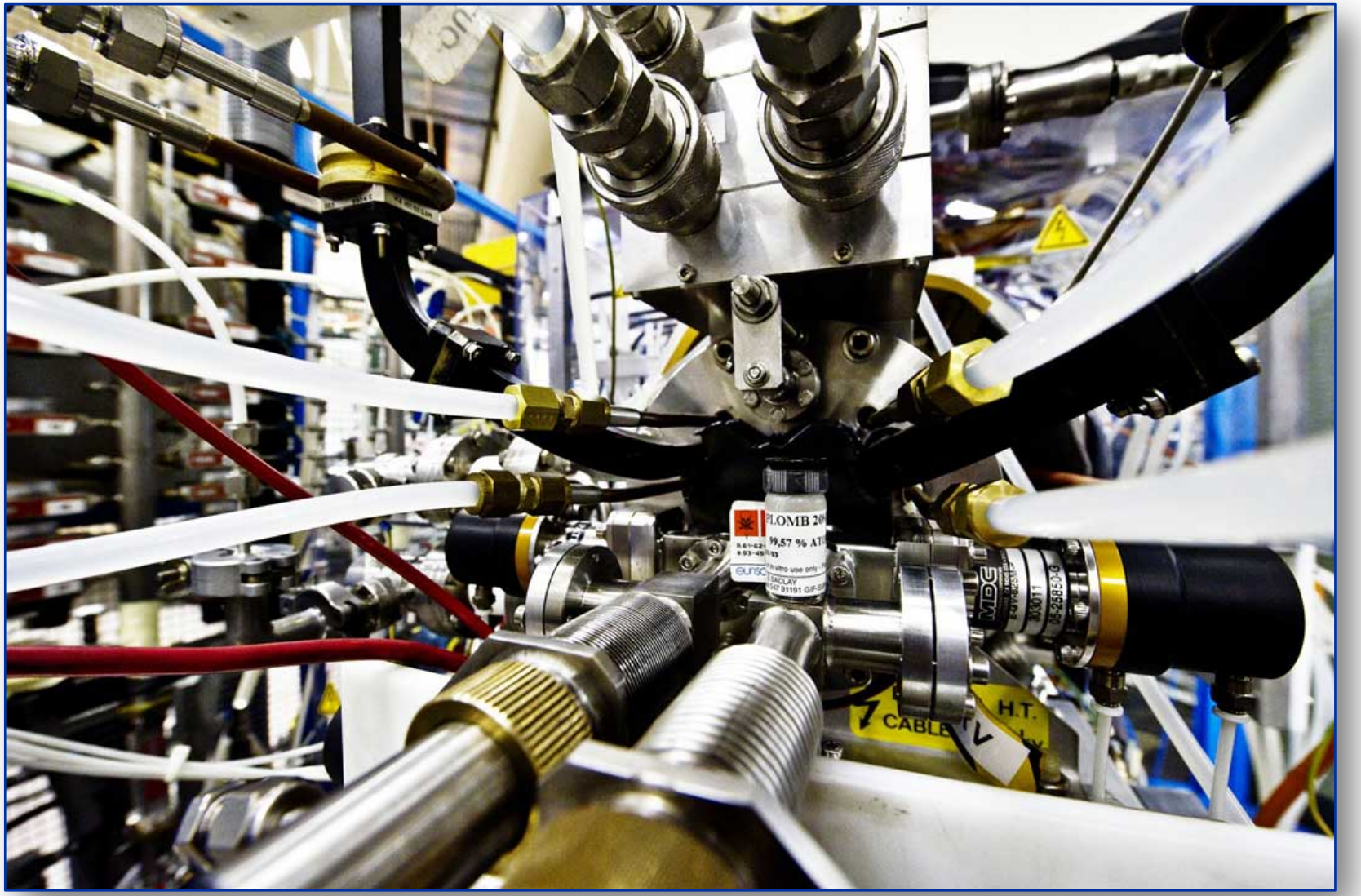


1

H

Hydrogen
1 proton
0 neutron

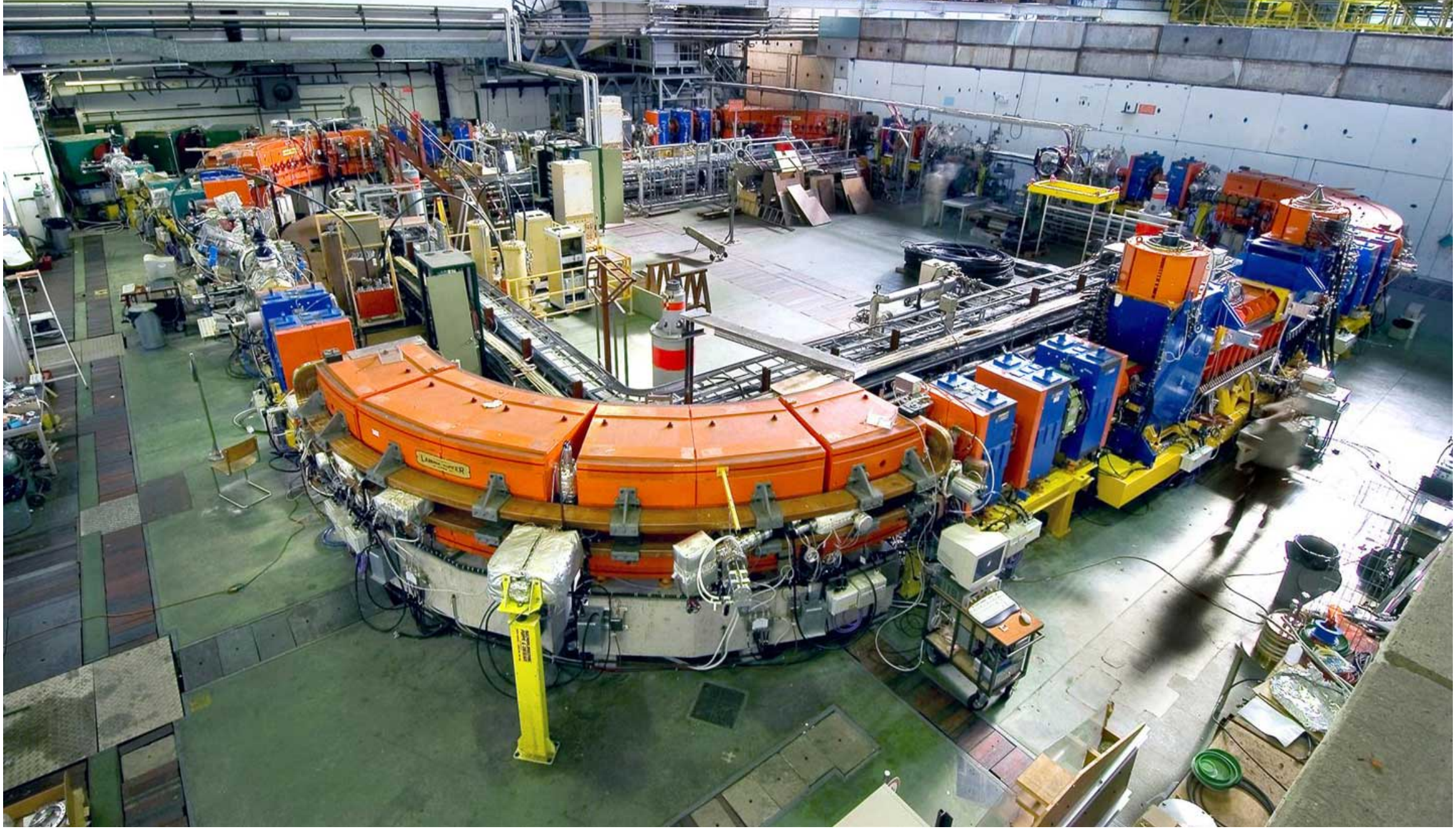
1. Cathode filament emits electrons into a vacuum chamber
2. H_2 gas is introduced in very small
3. Gas become charged or ionised through interactions with the free electrons
4. Plasma is accelerated through a series of charged grids

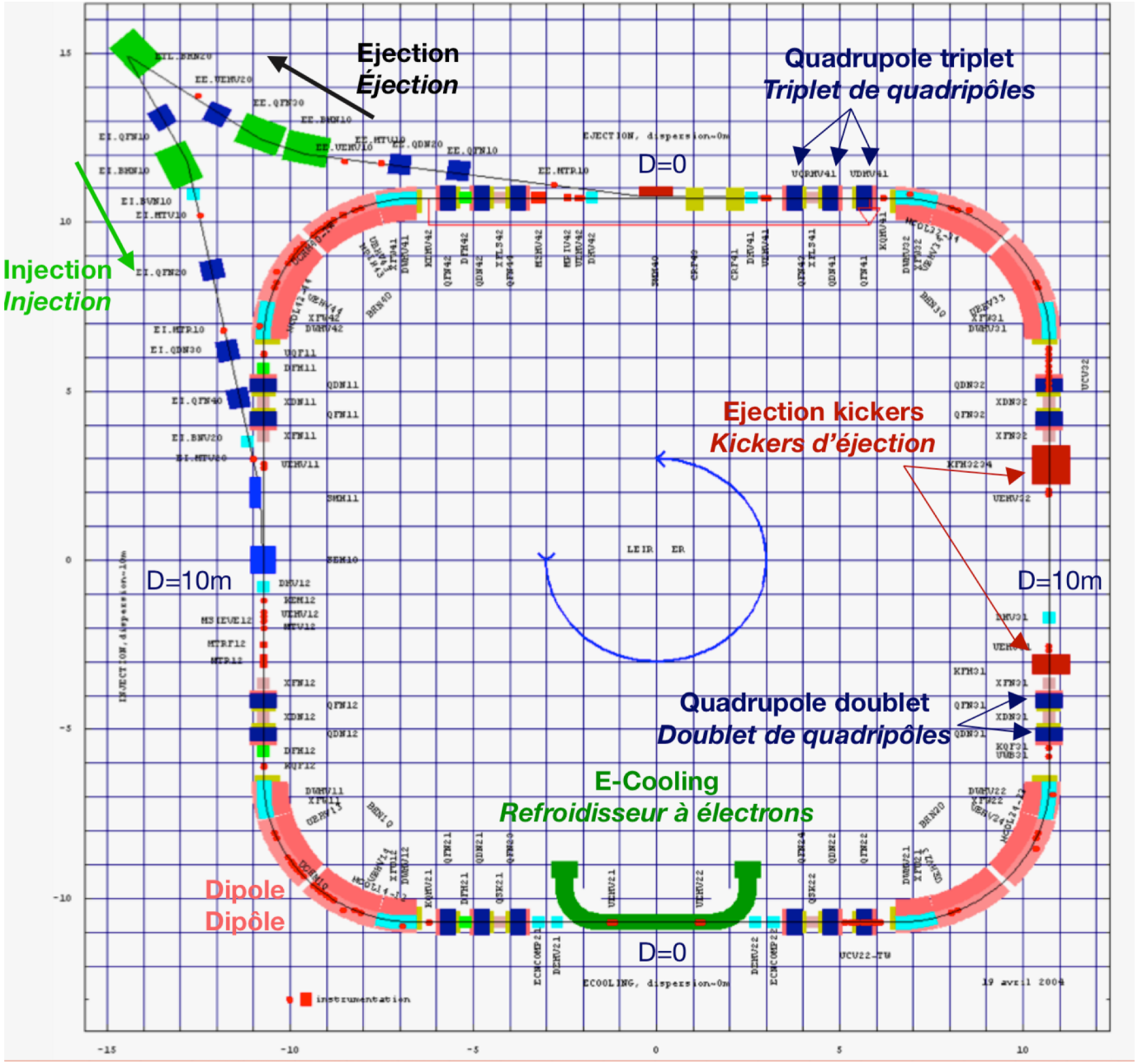


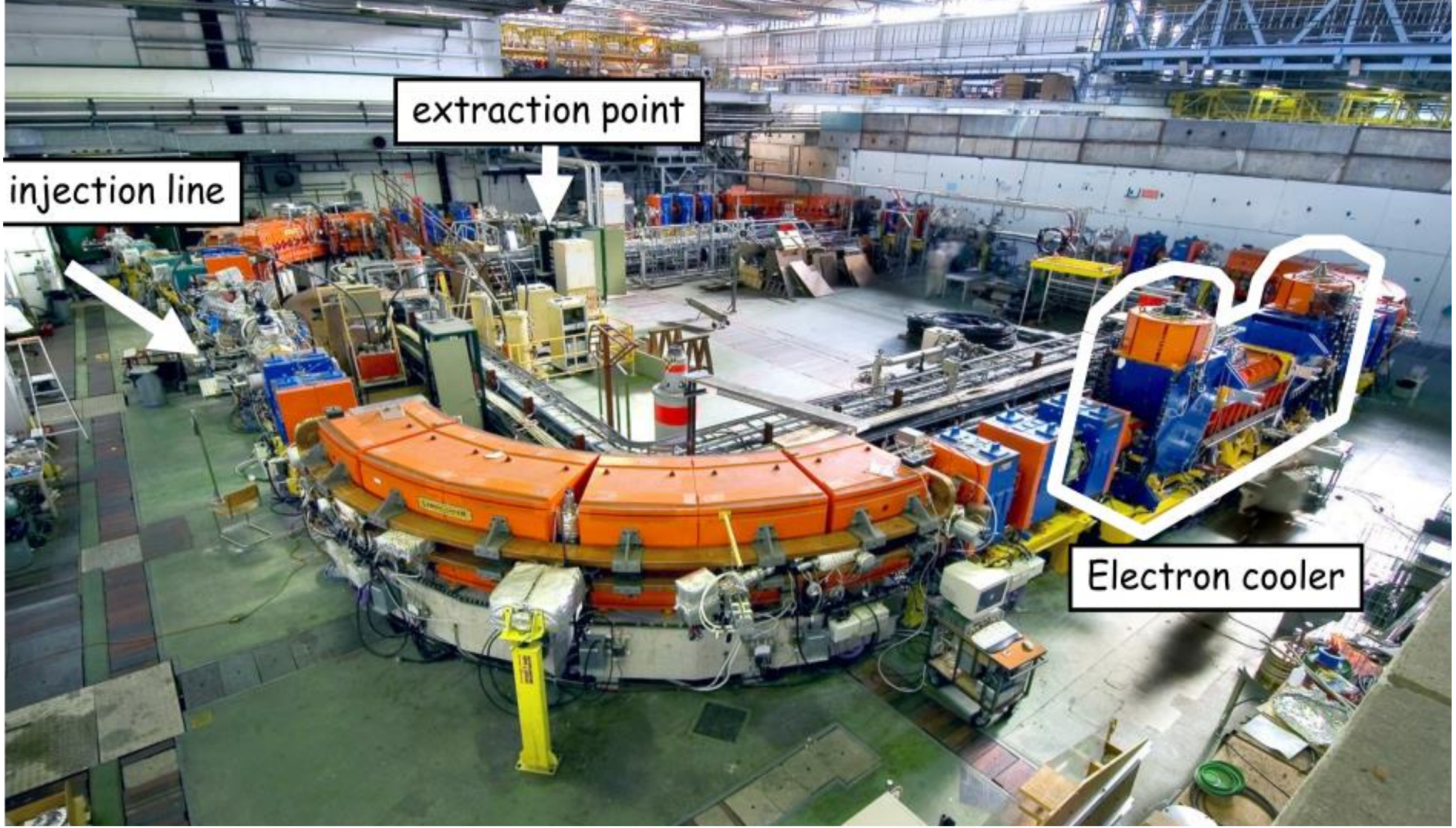
208 *(stable)*

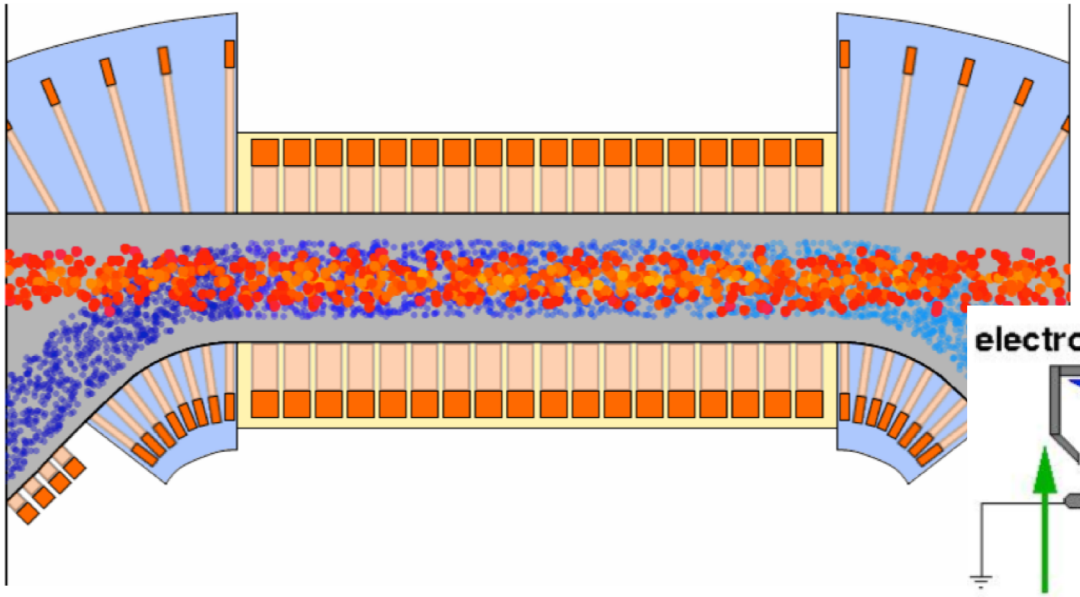
Pb

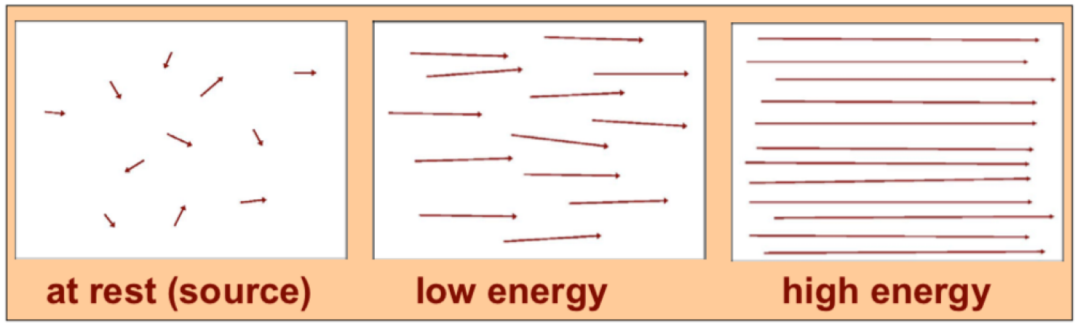
Lead
82 protons
126 neutrons

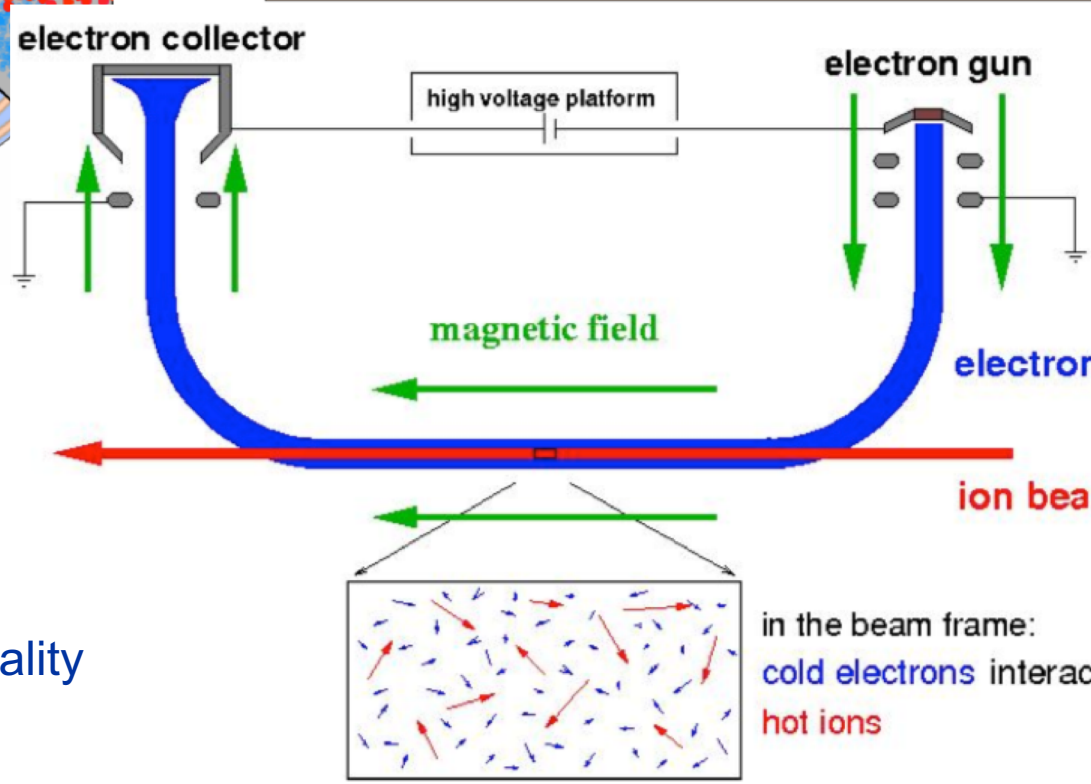



Ejection
Éjection
Quadrupole triplet
Triplet de quadripôles
Injection
Injection
D=0
Ejection kickers
Kickers d'éjection
D=10m
D=10m
Quadrupole doublet
Doublet de quadripôles
E-Cooling
Refroidisseur à électrons
Dipole
Dipôle
D=0


extraction point
injection line
Electron cooler







$v_{e//} = v_{i//}$

$E_e = m_e/M_i \cdot E_i$

e.g. :220 keV electrons cool 400 MeV/u ions

electron temperature

$k_B T_\perp \approx 0.1$ eV

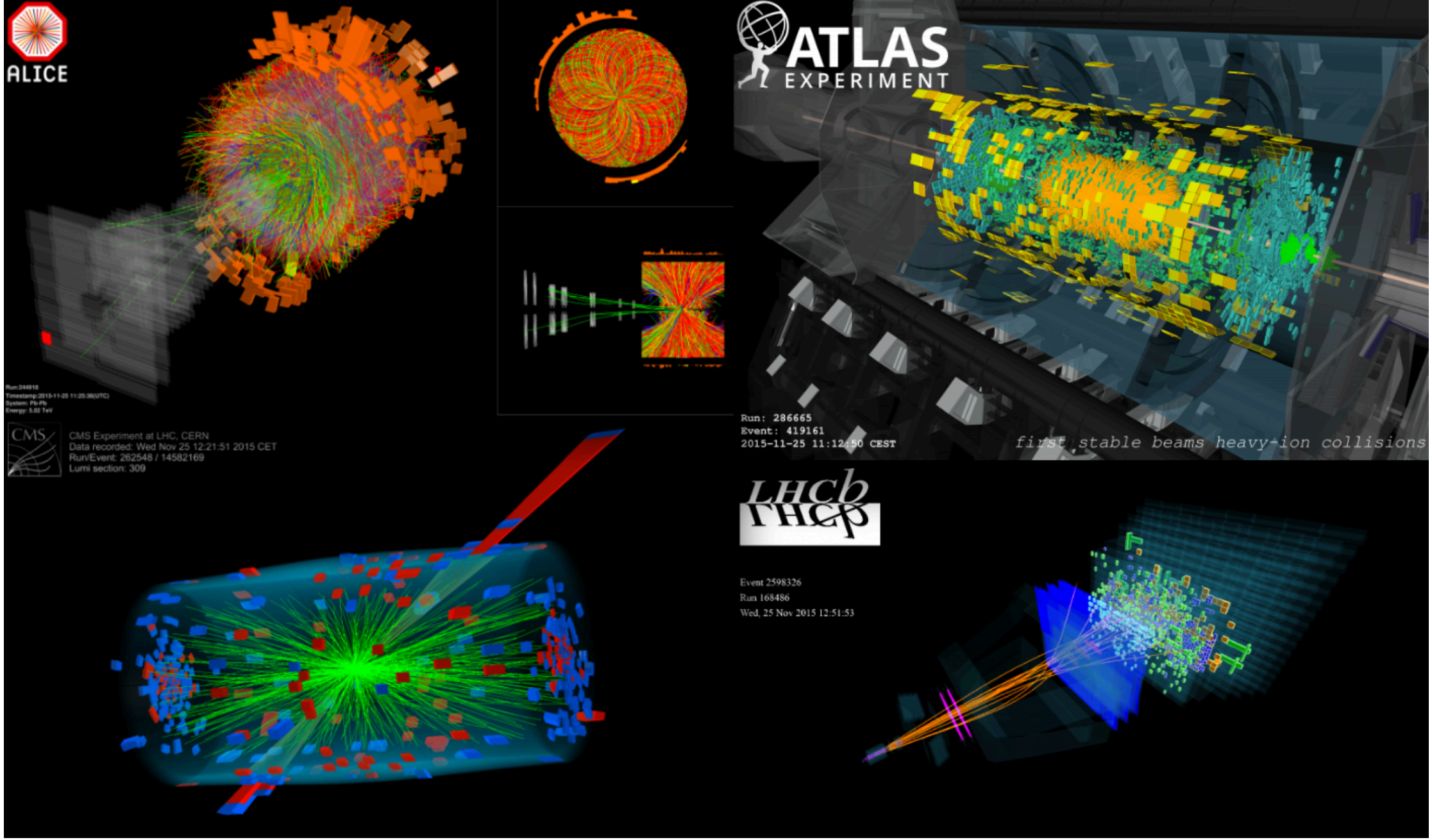
$k_B T_{//} \approx 0.1$ - 1 meV

- Many processes can heat up the beam
  - ✓ Space charge, intra-beam scattering, internal targets, residual gas
- Electron cooling allows Improved beam quality
  - ✓ Precision experiments
  - ✓ Luminosity increase

superposition of a cold intense electron beam with the same velocity

momentum transfer by Coulomb collisions

cooling force results from energy loss in the co-moving gas of free electrons


ALICE
ATLAS
EXPERIMENT
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Event: 419161
2015-11-25 11:12:50 CEST
first stable beams heavy-ion collisions
CMS Experiment at LHC, CERN
Data recorded: Wed Nov 25 12:21:51 2015 CET
Run/Event: 262548 / 14582169
Lumi section: 309
LHCb
Event 2598326
Run 168486
Wed, 25 Nov 2015 12:51:53