The CERN Accelerator Complex

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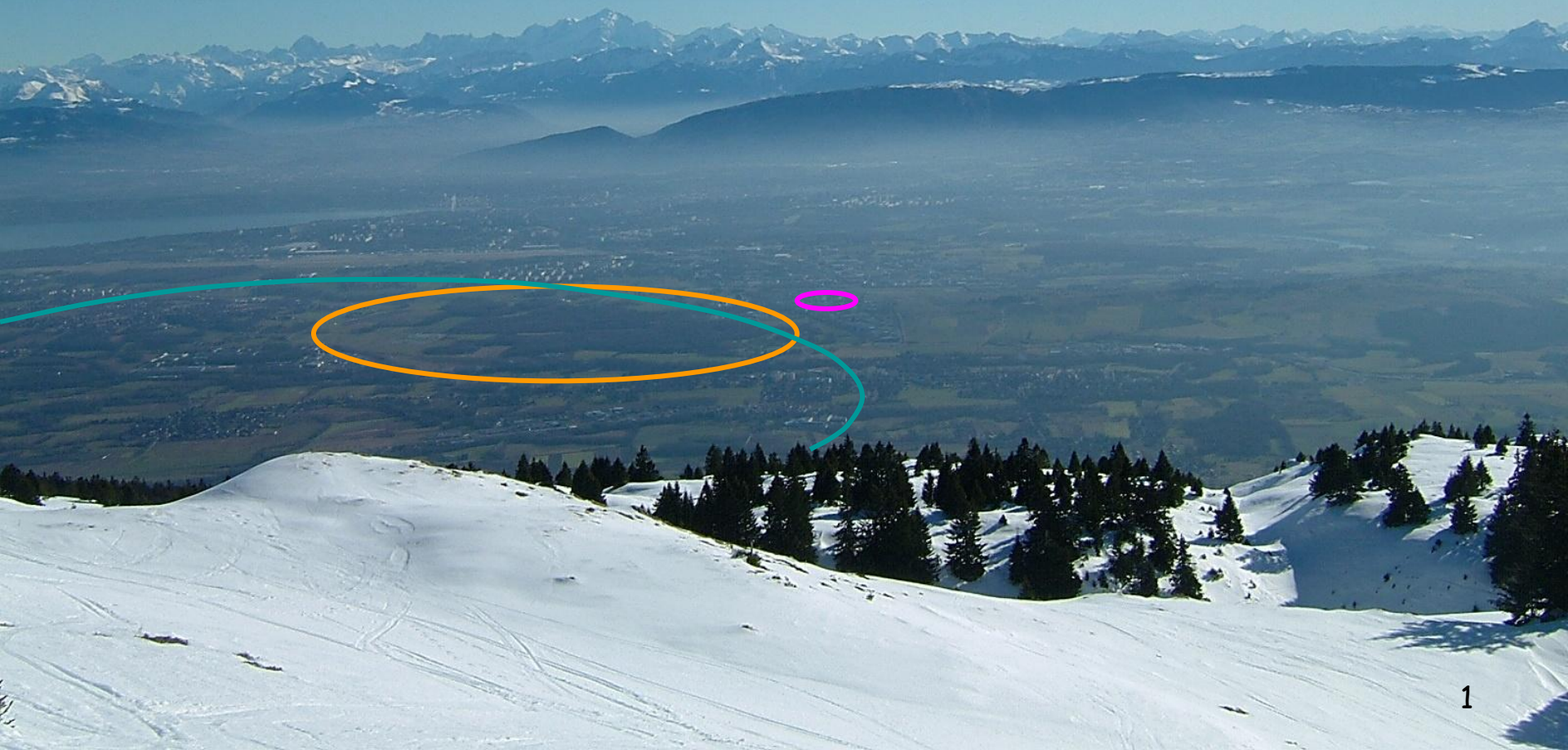
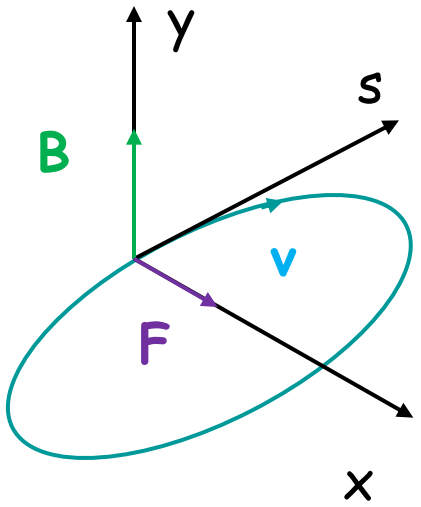


Electromagnetic Fields

Almost all the physics (and therefore the design) of accelerators is based on the long known **Lorentz force** that describes the interaction of charged particles with electromagnetic fields:

The force is proportional to the charge, and to the vector product of velocity and magnetic field – i.e. The force is orthogonal to the plane of **v** and **B**.

$$\vec{\mathbf{F}} = q \cdot (\vec{\mathbf{E}} + \vec{\mathbf{v}} \times \vec{\mathbf{B}})$$



In a homogenous vertical magnetic field B, a particle of charge e_0 and momentum p describes a circle of radius R :

$$B = \frac{p}{e_0 \cdot R}$$

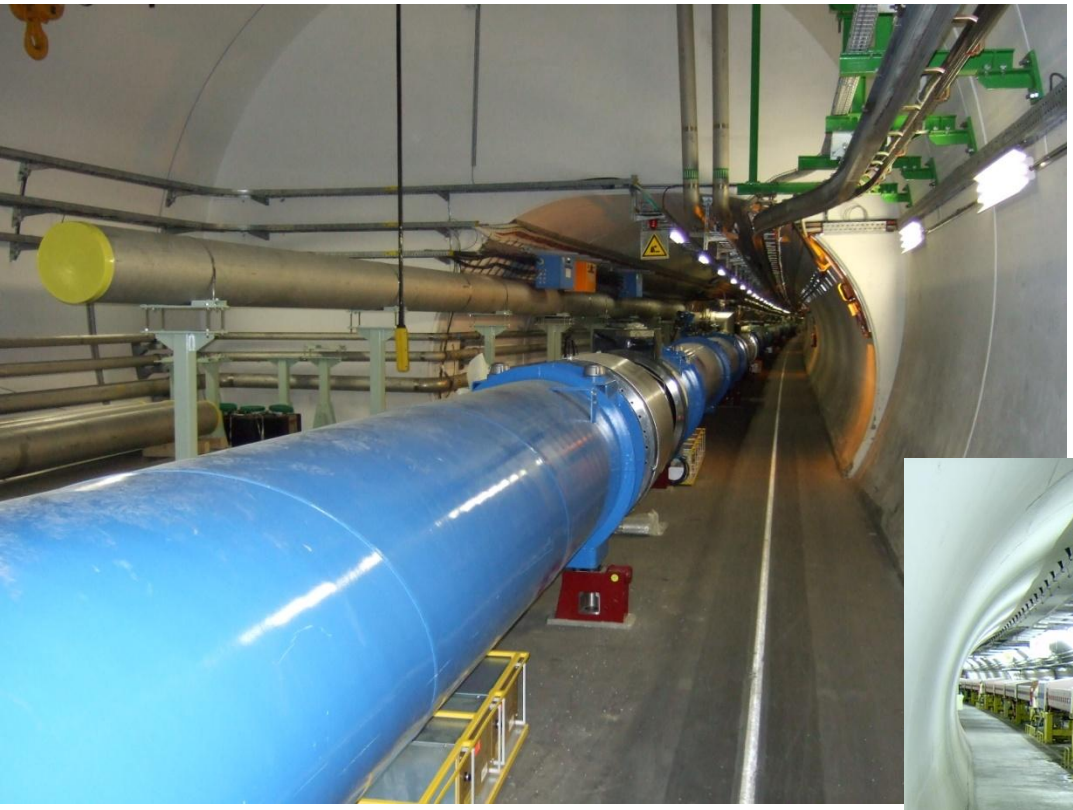
→ To build an accelerator of a given energy (or momentum) **p**, one needs to "achieve" a product **magnetic field** x **radius**

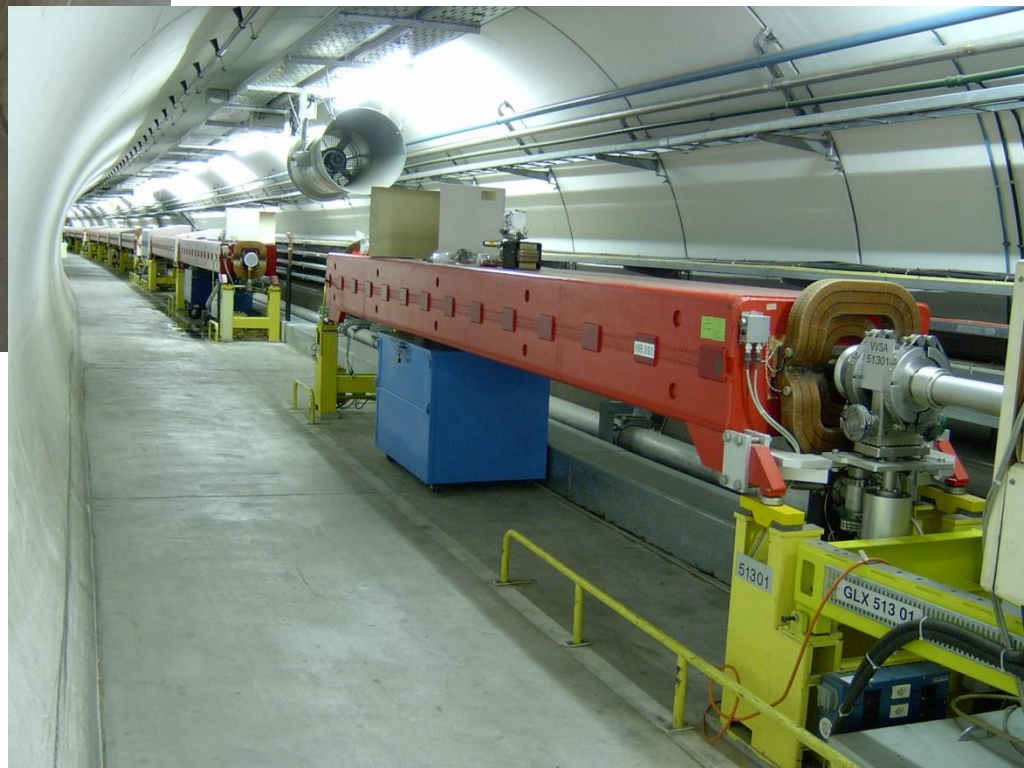
Magnetic fields

- **Ferro-magnets** : classical **iron magnets** are used in the vast majority of the world's accelerators.
  - They are 'easy' to build (there's a lot of experience).
  - But the field is limited to **B = 2 Tesla** (saturation of the ferromagnet).
  - Once you reach 2 T, the only way to get to higher energy is to increase the size of the accelerator !!!

- **Super-conducting magnets** : present-day top energy accelerators use magnets made of super-conducting wires to overcome the field limit of iron magnets.
  - In a super-conductors the Ohmic resistance is 0, and very high currents can be fed into very small cables!
  - State of the art magnets reach **B = 5 Tesla**, LHC magnets reach **B = 8.3 Tesla.**
  - But since super-conductivity only appears at very low temperature, the magnets must be cooled to 2-4 K – the price to pay !

'Cold' versus 'Warm'





Accelerator types

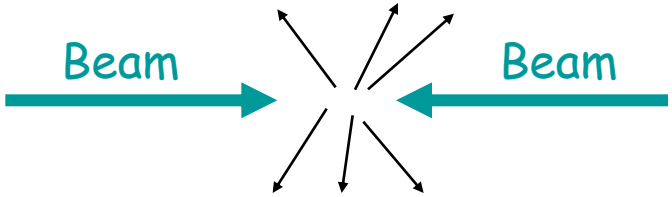
- Fixed-target accelerators : the beam is accelerated and send to a fixed target where the beam interacts and creates a secondary beam. Repeats every few seconds.

Provides beams of short lived particles

Available energy ~ √beam energy

- Colliders : two beams circulate in opposite directions and are brought into collision a one or more points over many hours. A few collisions may occur at each beam encounter.

Available energy ~ beam energy



The CERN accelerator complex

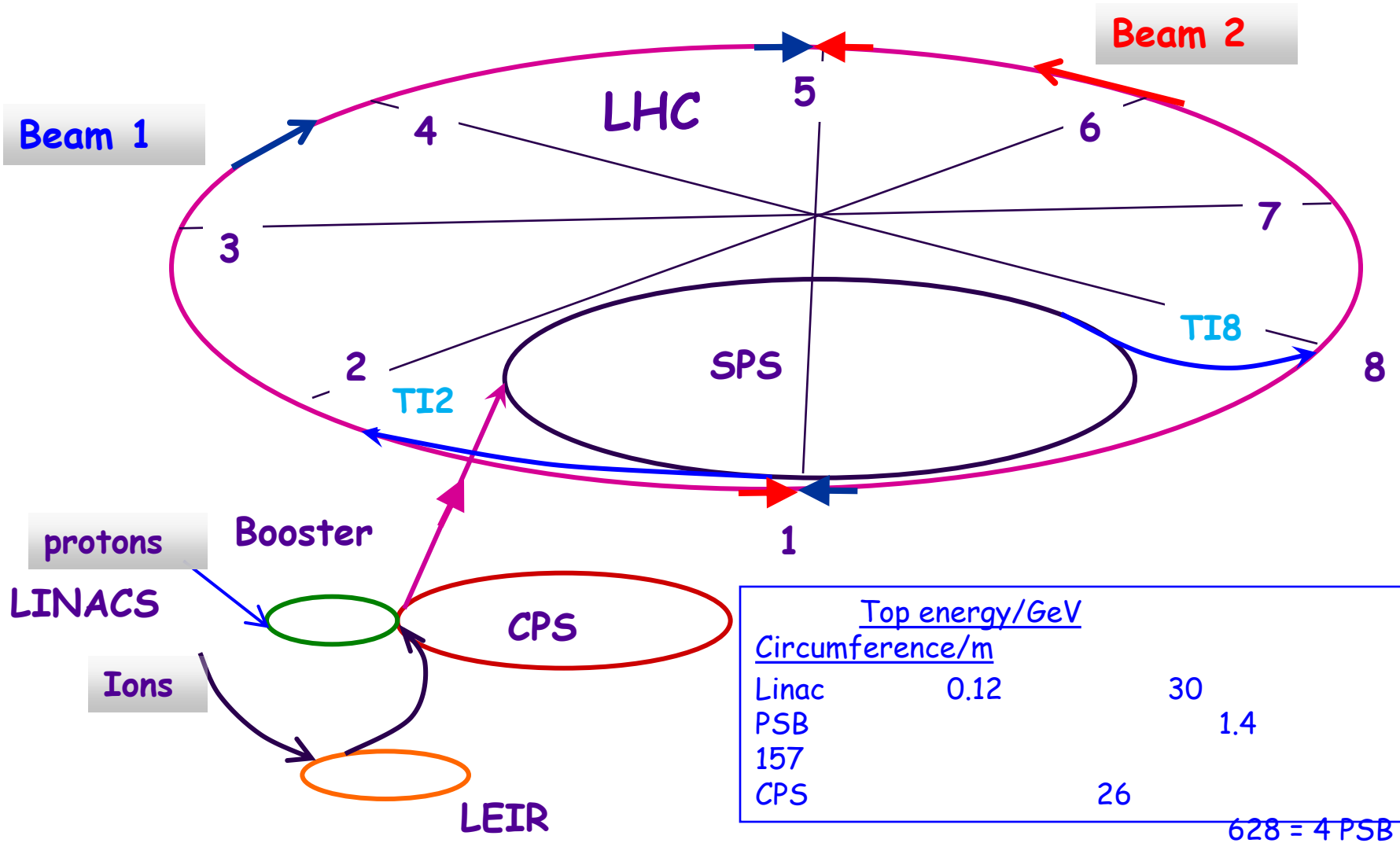
- The present CERN proton accelerators:
  - Linac (since 1979)
  - Proton Synchrotron Booster - PSB (since 1972)
  - Proton Synchrotron – PS (since 1959)
  - Super Proton Synchrotron – SPS (since 1976)

  Iron magnets
  'Fixed targets'

  - Large Hadron **Collider** – LHC (from 2008?)

  Super-conducting magnets
  Collider

- In 2008 there will be more than **50 km of beam lines/accelerators at CERN !**
  About $\frac{1}{2}$ of the total is made up by the LHC.
- The 'older' PSB-PS-SPS complex was upgraded between 1995 and 2004 to be ready to provide beams that are appropriate for the LHC !



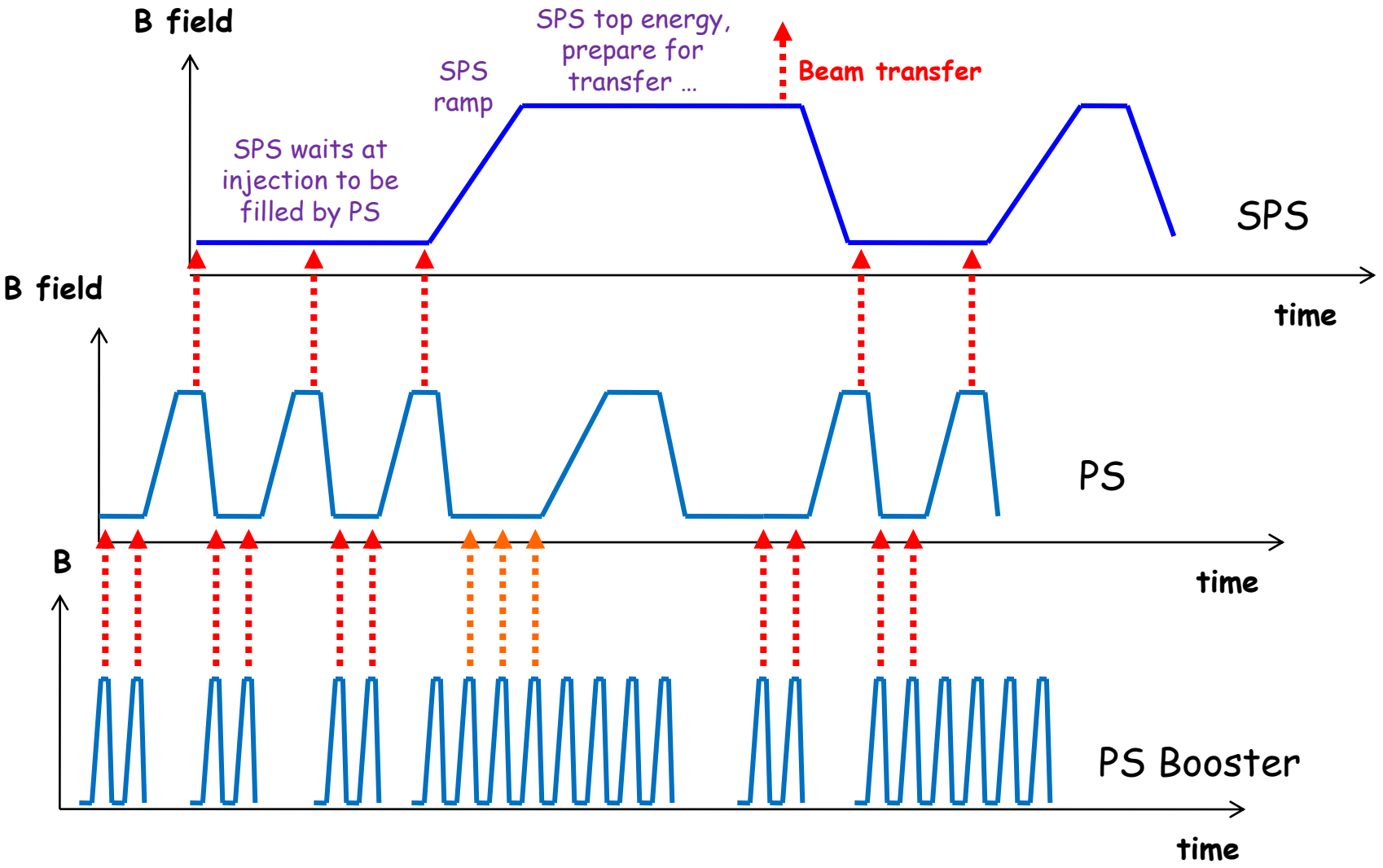
	Top energy/GeV	Circumference/m	
Linac	0.12	30	
PSB		1.4	628 = 4 PSB
157			
CPS	26		6'911 = 11 x PS
SPS	450	26'657 = 27.7 x SPS	
LHC	7000		

Note the energy gain/machine of 10 to 20 – and not more!

The gain is typical for the useful range of magnets !!!

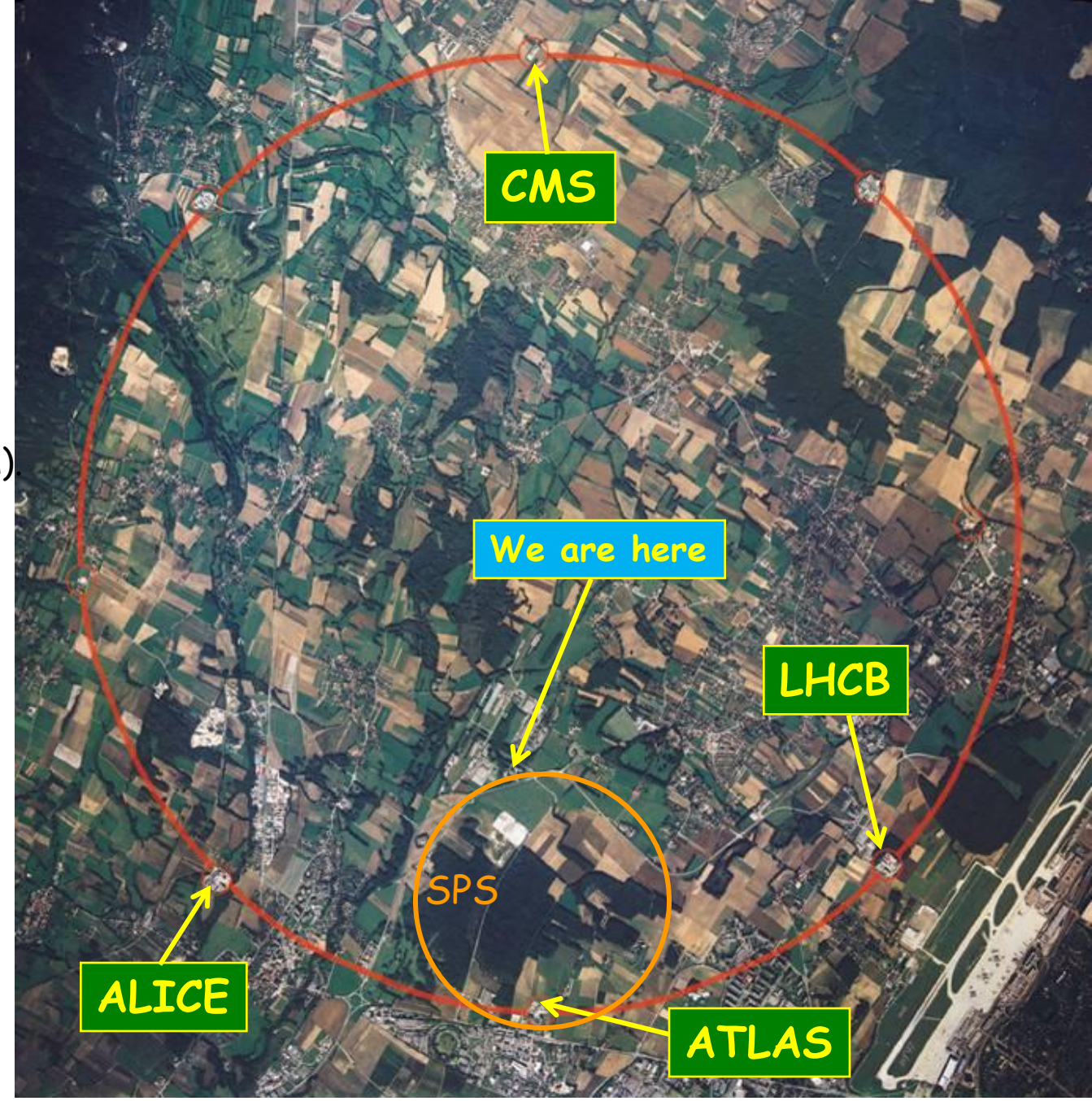
Accelerator chains

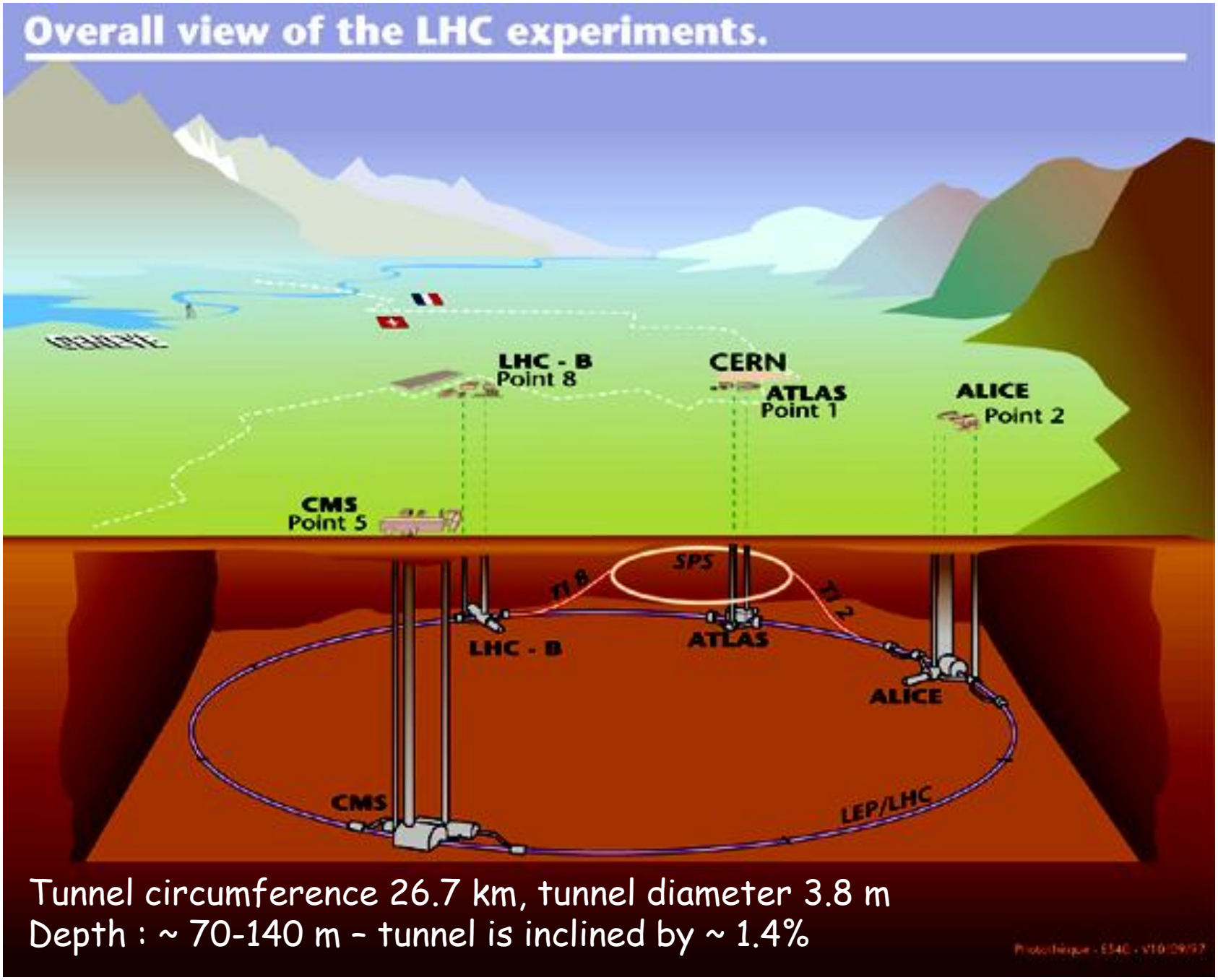
The beams are handed from one accel. to the next or used for its own customers !



LHC : 2008-2020+

- proton-proton & ion-ion collider in the LEP tunnel.
- 4+ experiments.
- energy 7 TeV.
- installed in the existing tunnel of the former LEP collider (electron-positron).
- tunnel circumference of 26.7 km.





Tunnel circumference 26.7 km, tunnel diameter 3.8 m
Depth : ~ 70-140 m – tunnel is inclined by ~ 1.4%