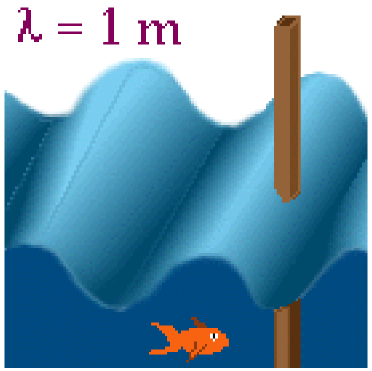
Accelerators

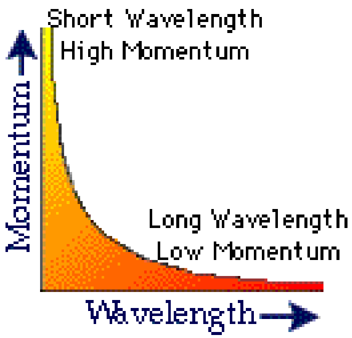
- Why do we use accelerators (and colliders)?
- Examples of accelerators: linear, synchroton, cyclotron
- Accelerators for particle physics: LEP and LHC at CERN

http://pdg.web.cern.ch/pdg/particleadventure/frameless/wave_res.html
http://public.web.cern.ch/Public/whatisdone.html
http://public.web.cern.ch/Public/ACCELERATORS/Welcome.html

Why do we accelerate (and collide) particles?

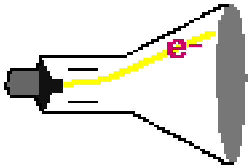
- to use them as microscopes ($\lambda = h/p$)



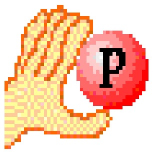


- to produce radiation
- to study the properties of particles
- to study the interactions between particles
- to produce new particles ($E=mc^2$)

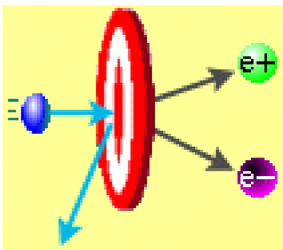
Where do we find particles to accelerate ?



Electrons: they are produced when we hit a piece of metal (cathode)



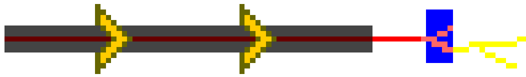
Protons: they are obtained by ionizing hydrogen



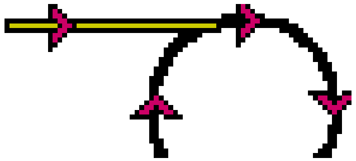
Antiparticles (e.g. positrons, $\bar{p}$): ordinary (matter) particles hit a target and pairs of particles and antiparticles are produced

Types of accelerators

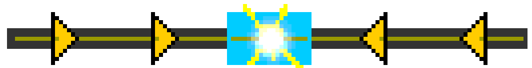
1. Linear (linacs):



(a) fixed target

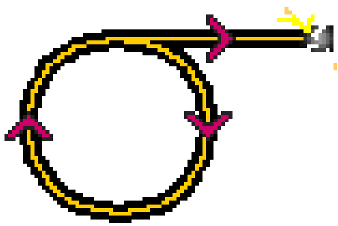


(b) injector to a circular machine

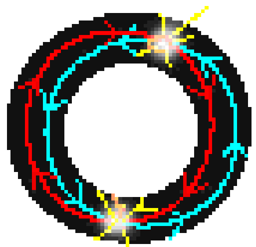


(c) linear collider

2. Circular (synchrotrons):



(b) fixed target



(a) colliding beams

Advantages and disadvantages

Circular machines:

- a particle can go round many times
- many collision points

but

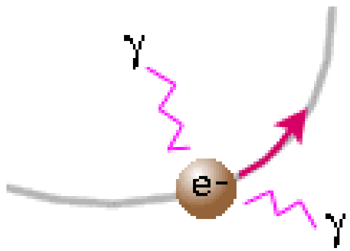
- large energies require large radii

Linear machines:

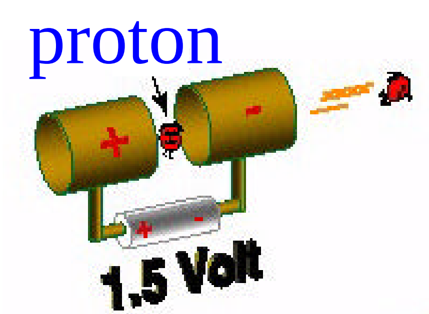
- easier to built (no bending magnets)
- less radiation loss (e^- and e^+)

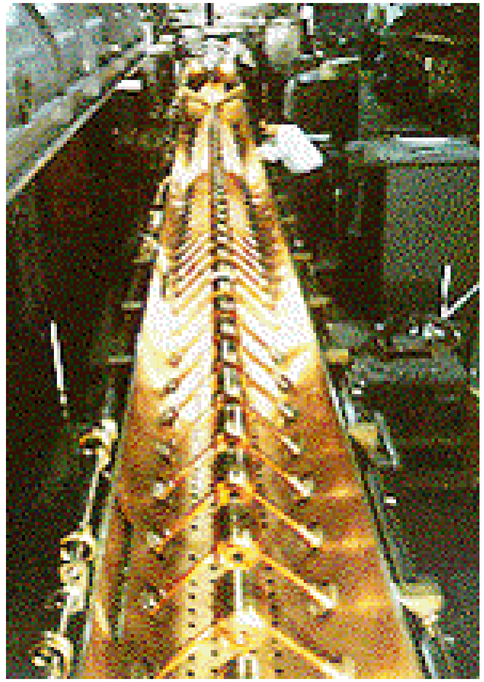
but

- less acceleration

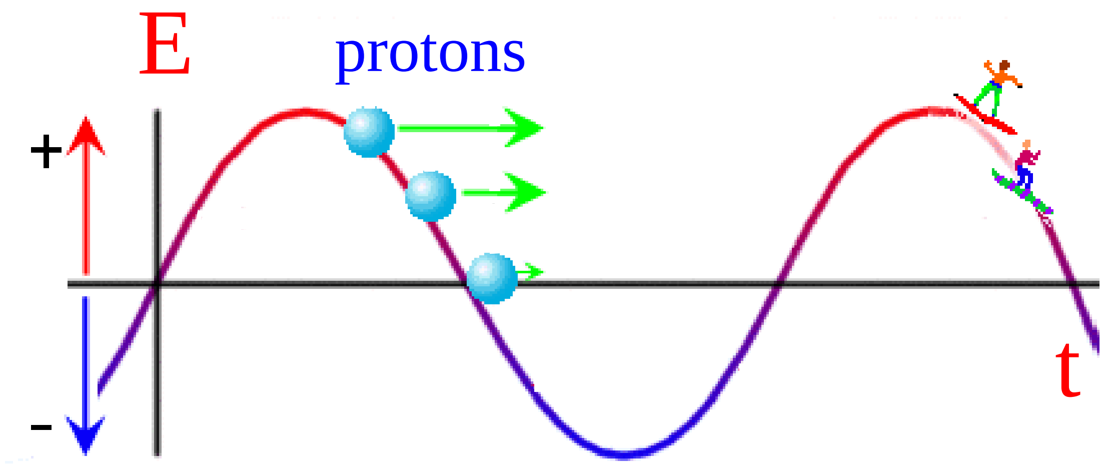


Linear accelerators



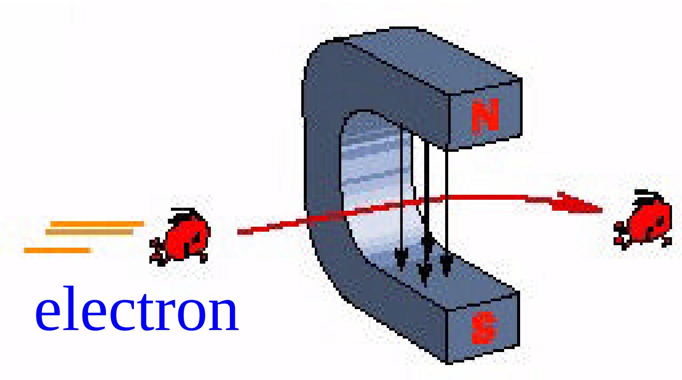


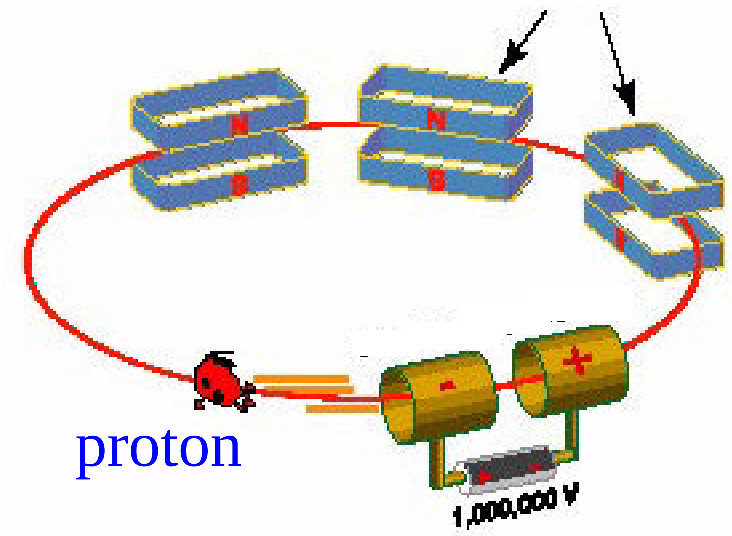
Electromagnetic waves for acceleration



'autophasing' = some particles make bunches, some particles are lost

Circular accelerators (synchrotrons)





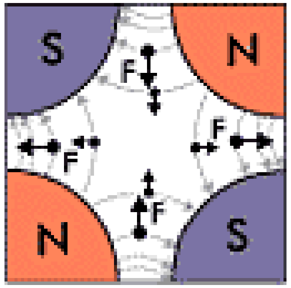
fast particles are difficult to 'bend' :

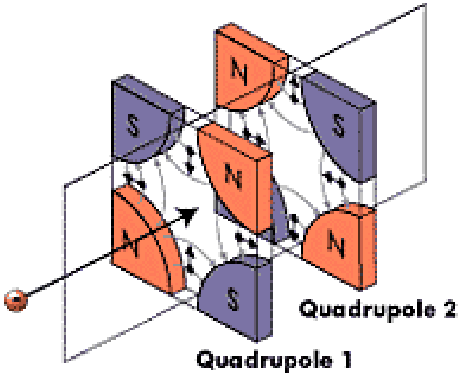
high magnetic fields are needed to reach high energies

How are beams focused?

by quadrupole magnets

forces on a negative particle moving into the picture:





The cyclotron

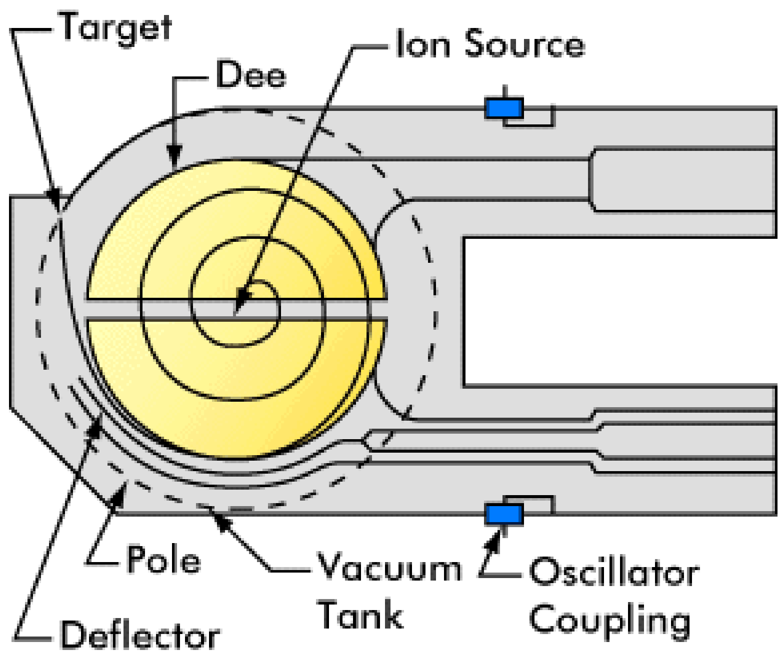
http://www.phy.ntnu.edu.tw/java/cyclotron/cyclotron.html
http://www2.slac.stanford.edu/vvc/accelerators/circular.html

force from the magnetic field:

$$qv_TB = mv_T^2/r$$

momentum of the particle:

$$P_T = qBr$$



CERN (European centre for nuclear research)

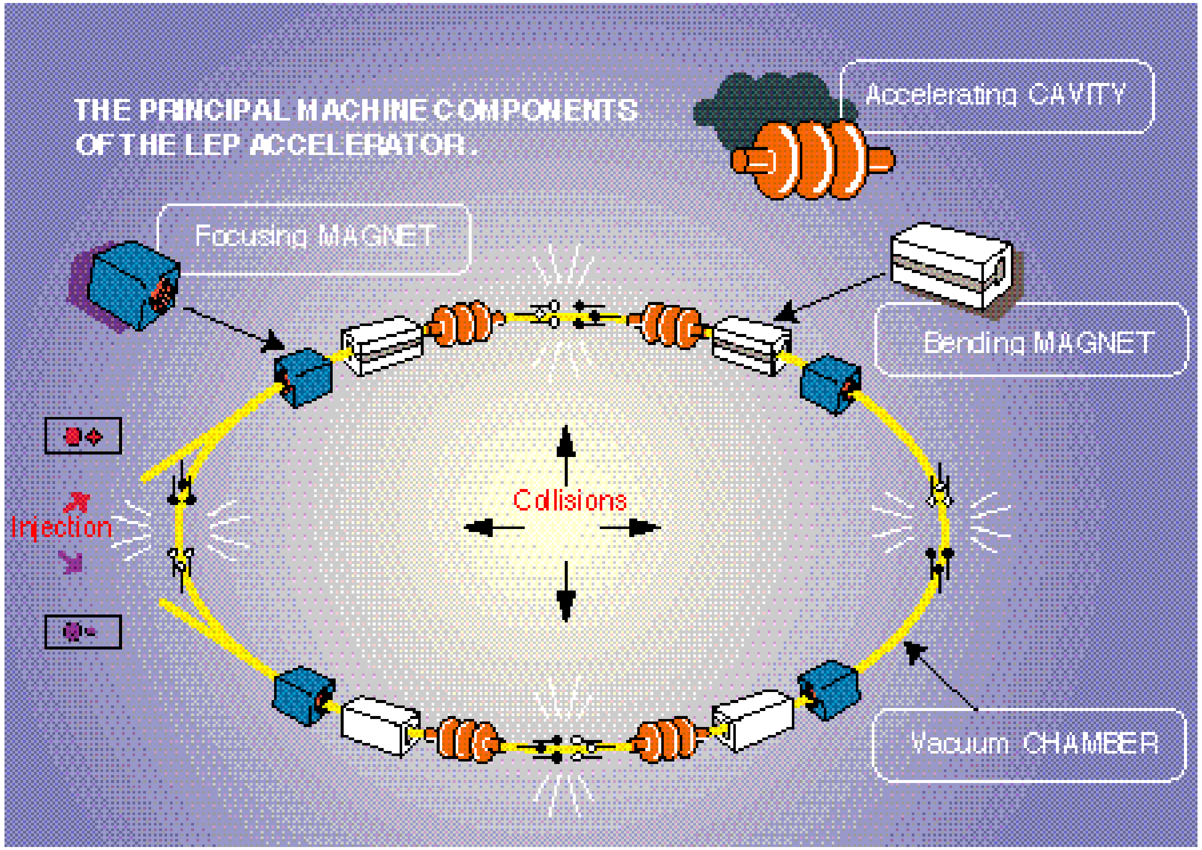
- 12 founder member states in 1953
- 20 member states and 30 non-member states today
- 6500 particle physicists from 500 universities and 80 countries use CERN’s facilities
- Sweden: Chalmers (GU), Stockholm U and KTH, Lund U

Storage rings and colliders at CERN

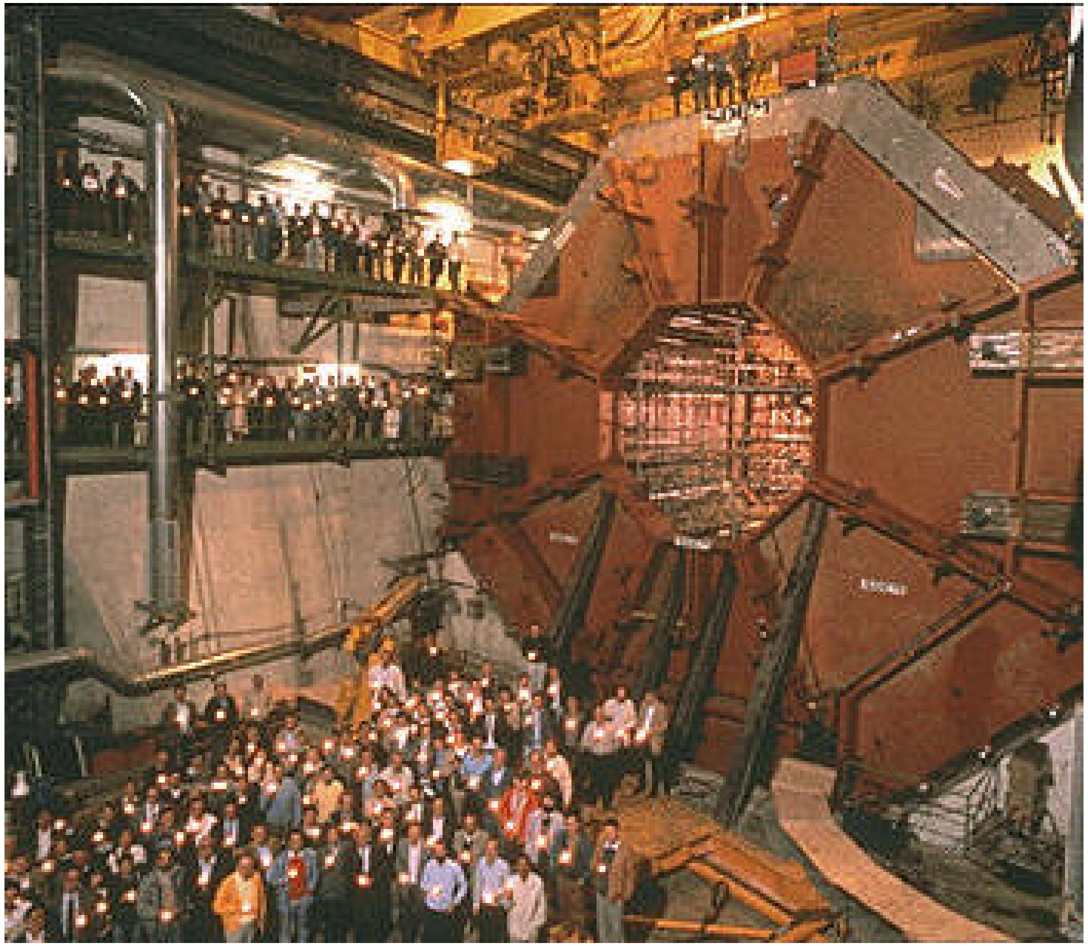
Examples:

- electron-positron beams at the LEP collider (available energy = 90-210 GeV) Experiments: L3, ALEPH, OPAL, DELPHI
- proton-antiproton beams at the LHC collider (designed available energy = 14 TeV) Experiments: ATLAS, CMS, ALICE, LHCb

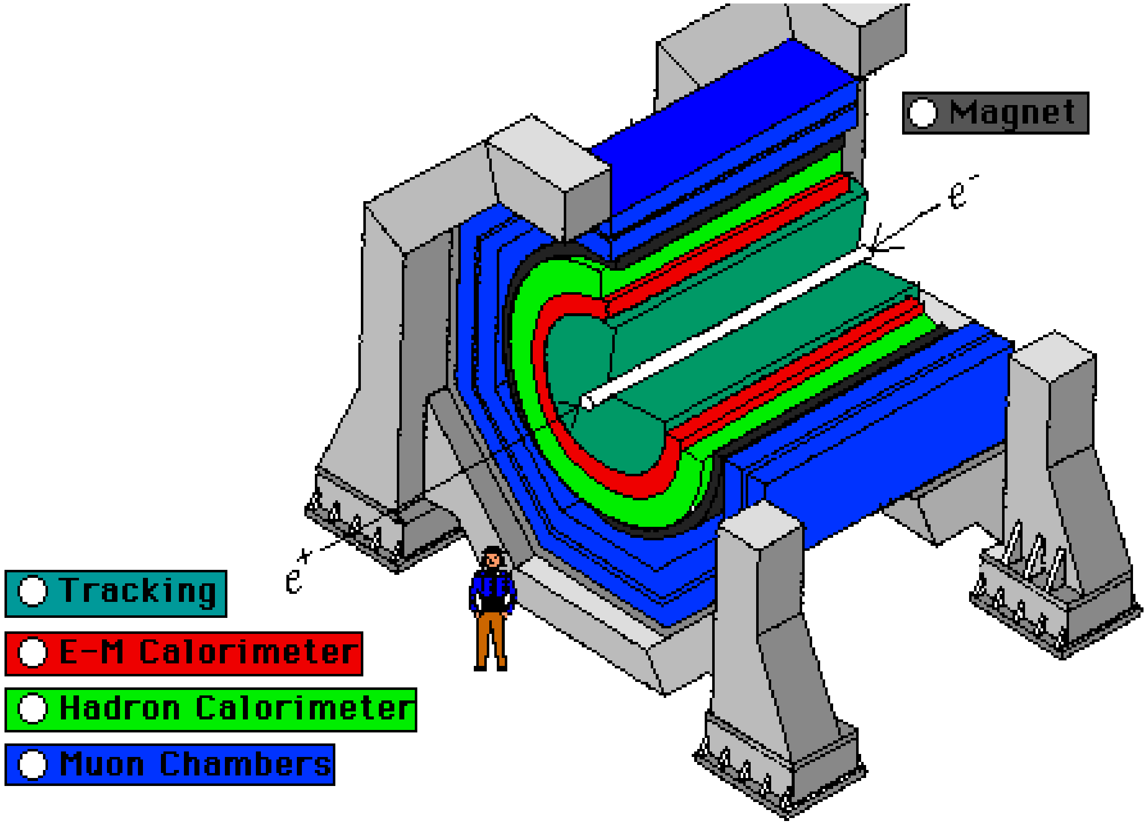
The Large Electron Proton collider (LEP)



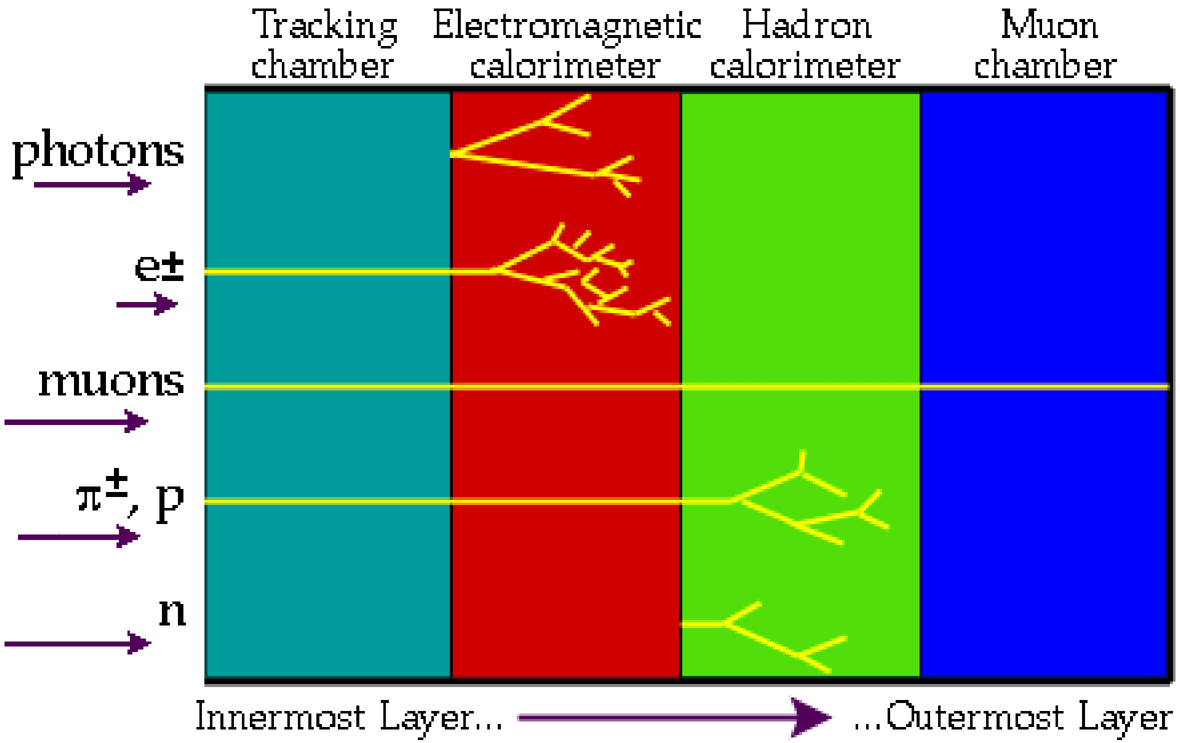
The detectors...



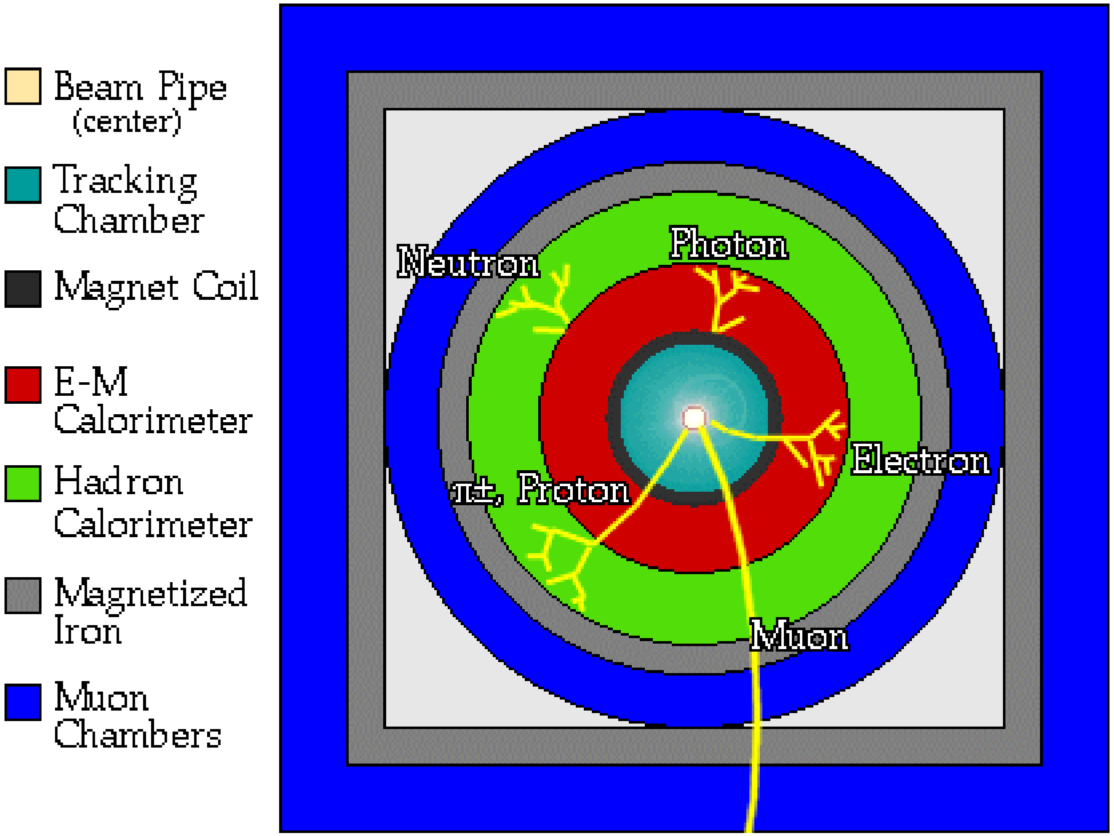
...and the subdetectors



Interaction of particles with the detector

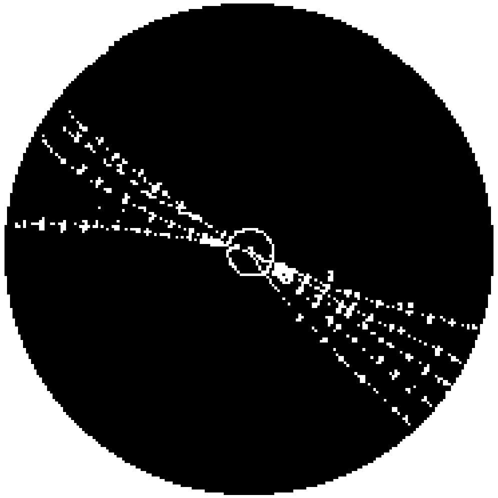


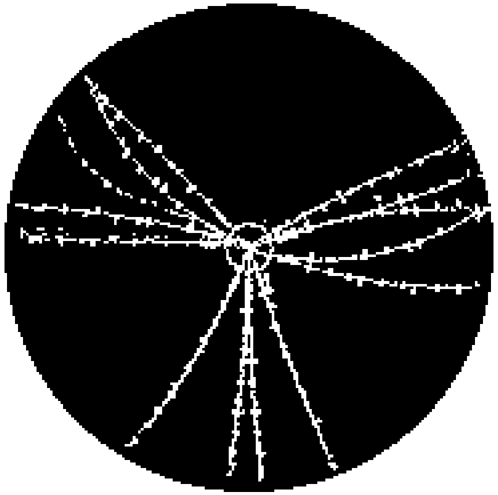
A ‘slice’ of the detector



The products of collisions

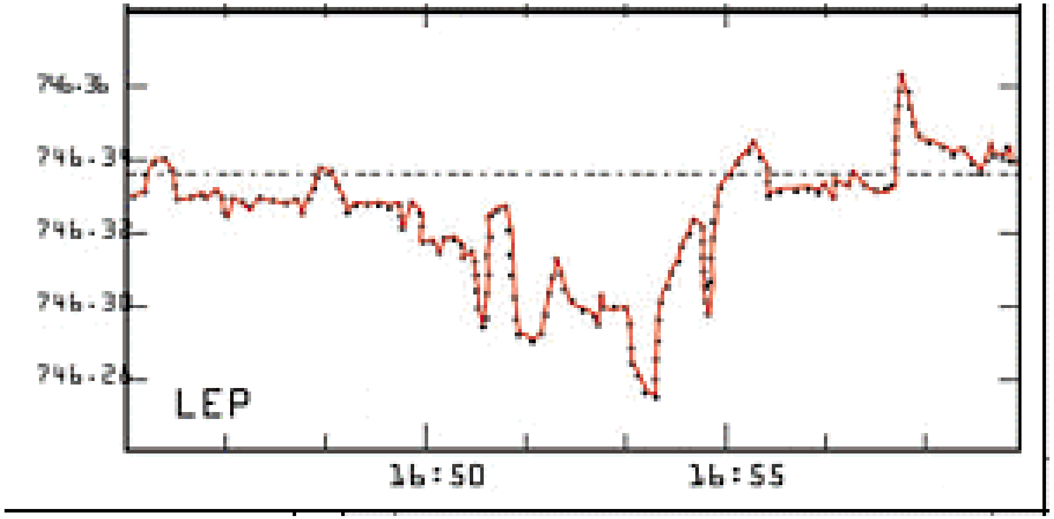
$$e^{+} + e^{-} \rightarrow q + \bar{q} \qquad\qquad e^{+} + e^{-} \rightarrow q + \bar{q} + g$$





Large machines, many problems...

bending field (G)

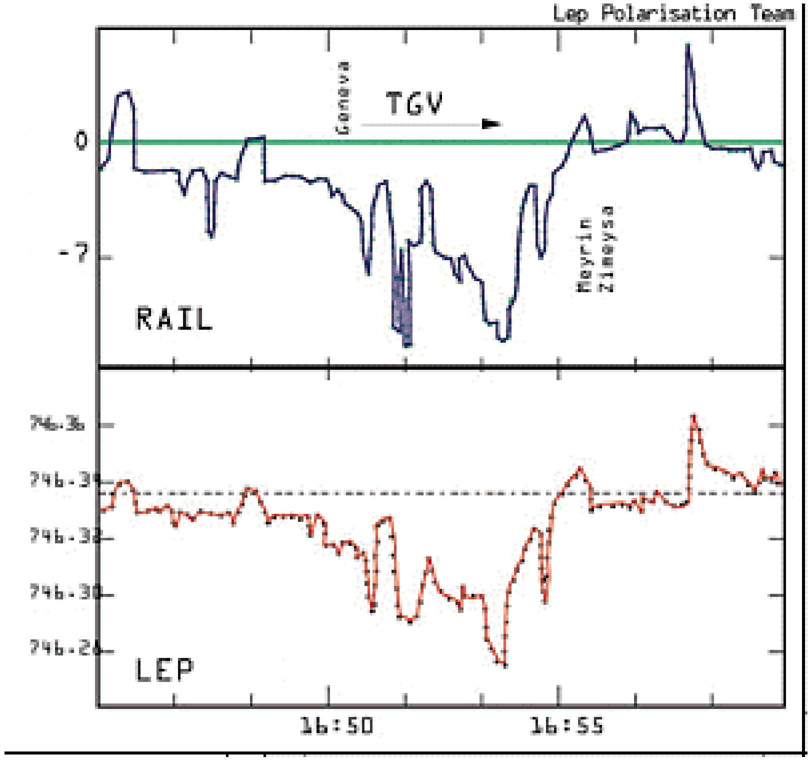


time

Large machines, many problems...

voltage
on rails
(V)

bending
field (G)



time