Experimental particle physics

esipap
European School of Instrumentation in Particle & Astroparticle Physics

A. kinematics, particle interactions and detector response

Muon decay kinematics

Compute maximum momentum of electrons in decay

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$

in muon reference frame, ignoring neutrino masses

$$|\boldsymbol{p}_3| = \frac{\left[\left(M^2 - (m_{12} + m_3)^2\right)\left(M^2 - (m_{12} - m_3)^2\right)\right]^{1/2}}{2M}$$

Muon lifetime and acceleration

- In PDG book particle lifetime is usually expressed as a distance

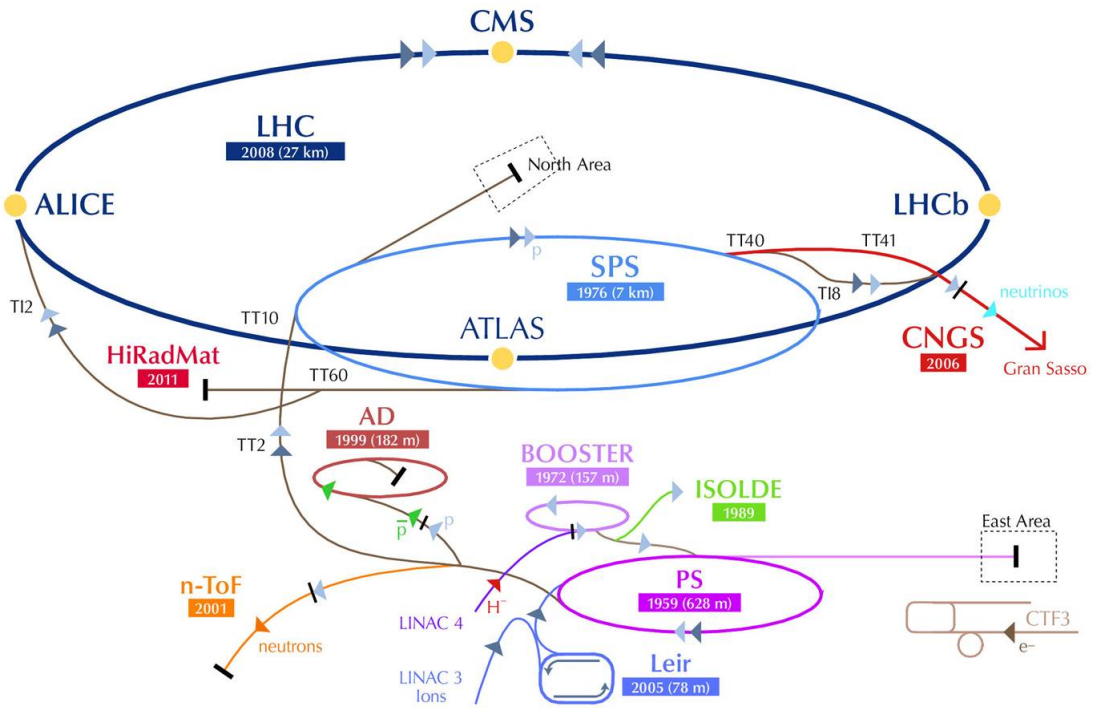
$$d = c\tau$$

For what energy d_μ = 658 m, as quoted in PDG, is valid? How long is it?

- How long muon lifetime be in a muon beam of 200 GeV momentum?
- If we inject 10^{10} of such muons in a storage ring of R = 100 m, how many rounds would they do before beam intensity get reduced by a 10^6 factor?

Protons in LHC

- Compute proton speed and Lorentz factors at different stage of acceleration in CERN complex



Accelerator	Kinetic energy [GeV]
LINAC2	0.05
PS Booster	1.4
PS	25
SPS	450
LHC	7000

$$E = m + K$$

LEP, LHC, future accelerators

- How much energy did electrons and positrons of E = 50 GeV and 100 GeV loose in one round at LEP?
  - ✓ L = 27 km

$$\Delta E = \frac{4\pi}{3}\frac{1}{4\pi\epsilon_0}\left(\frac{e^2\beta^3\gamma^4}{R}\right)$$

- What magnetic field intensity was necessary to keep them in orbit?
  - ✓ Assume a constant magnetic field along all accelerator ring

$$B = \frac{E}{0.3R}$$

- LHC is equipped 1239 quadrupoles of 14.4 m length each. Assuming a circulating proton beam of E = 7 TeV, how much energy would a proton radiate if it circulate for 10 hours?

- Calculate the required radius of a circular accelerator if we would build a 1 TeV e^- e^+ collider, while keeping synchrotron radiation losses at the same level as for LEP

Particle production at LHC

Suppose a initial LHC luminosity at 14 TeV will be L = 10^{34} cm^{-2} s^{-1}

- How many top quark pairs will be produced in a year of operations?

$$\sigma(t\bar{t}) \sim 800pb$$

Particle interactions

- Calculate how much Pb, Fe or Cu is needed to stop a 10 GeV electron
  - ✓ Pb : Z=82 , A=207, ρ =11.34 g/cm3
  - ✓ Fe : Z=26 , A=56, ρ =7.87 g/cm3
  - ✓ Cu : Z=29 , A=63, ρ =8.92 g/cm3

- Compute the threshold energies an electron and a proton must possess in water to emit Cherenkov radiation
  - ✓ N_{water} = 1.3

- Calculate the wavelength below which it would be impossible for photons to ionize hydrogen atoms. The first ionization potential for hydrogen is $E_\gamma \geq 13.6$ eV

Particle detection

- The number N of the particles which are created in shower is proportional to the energy E of the original particle. Use this to show that the relative energy resolution is given by

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}}$$