8.701

Introduction to Nuclear and Particle Physics

Markus Klute - MIT

10. Instrumentation

3. Calorimetry

Calorimetry

In nuclear and particle physics calorimetry refers to the detection of particles, and measurements of their properties, through total absorption in a block of matter, the calorimeter

Common feature of all calorimeter is that the measurement is destructive

- unlike, for example, wire chambers that measure particles by tracking in a magnetic field, the particles are not longer available for inspection once the calorimeter is done with them.
- the only exception concerns muons.

Calorimetry is widely used in particle physics

- instrumented targets
  - neutrino experiments
  - proton decay
  - cosmic ray detectors
- shower counter
- 4π detector for collider experiments

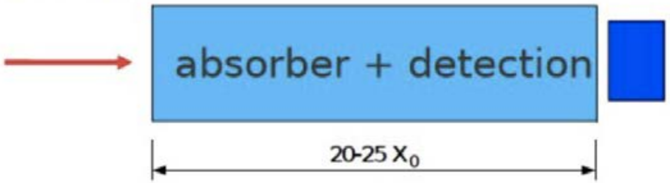
Calorimetry makes use of various detection mechanism

- Scintillation, Cherenkov radiation, ionization, cryogenic phenomena

Calorimetry

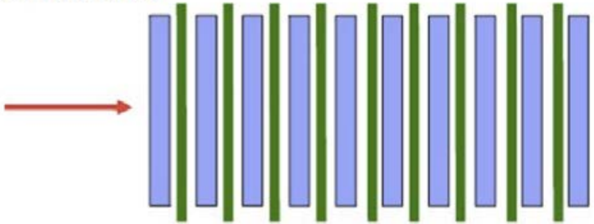
Homogeneous calorimeters

- Absorber material (generation of the showers) = detector material
  - Typically an electromagnetic shower is created in an optical transparent absorber, photons created in the shower are collected and detected with a photo detector



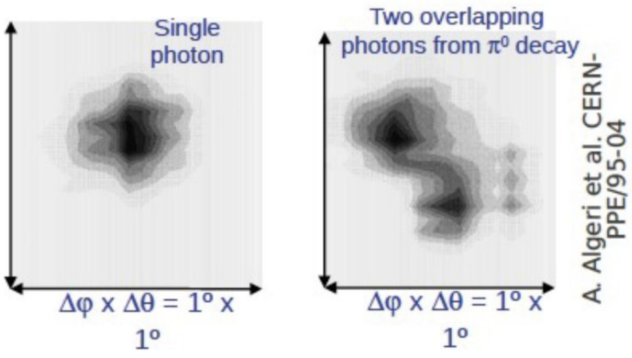
Sampling calorimeters

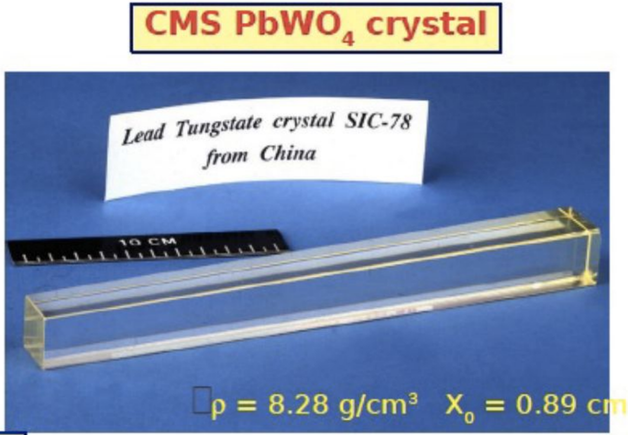
- Passive (heavy) absorber material (iron, copper, lead, tungsten, uranium) interleaved with active detector material



Homogeneous Calorimetry

- Very good energy resolution (nothing is lost in the absorber)
- Limited granularity, no information on shower shape in longitudinal direction





dense, transparent materials needed with short radiation length and high light yield

Photon Detectors

We need to convert photons into an electronic signal (photo effect)

Requirements

- Sometimes only a few photons available
    - High quantum efficiency (1γ -> 1 e^-)
- Multiplication to get signal well above noise level

Main types

- Vacuum-based (classical Photo Multiplier Tube (PMT))
- Gas-based
- Solide-state photo diodes
- hybrids

Energy Resolution

- Number of particles in shower should be proportional to energy of initial particle $N_{track} = \frac{E}{E_c}$
  - Error of measurement mainly determined by fluctuations.

$$\sigma(N_{track}) = \sqrt{N_{track}}$$

  - So the relative energy measurement error is

$$\frac{\sigma(E)}{E} \propto \frac{1}{\sqrt{E}}$$

  - More contributions from detector inhomogenities, noise, etc.

$$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

8.701 Introduction to Nuclear and Particle Physics
Fall 2020