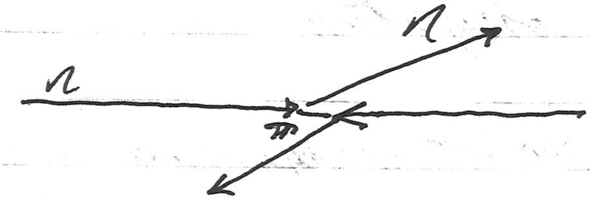
Strong Nuclear Interactions

- force binding atomic nucleus together
  - also interactions between hadrons
    - may be approximated by π exchange
  - also governs binding of quarks + gluons into hadrons → gluons messenger
  - very short range (10^{-14} m)

Become important when
- reactions create hadrons
- large momentum transfer interactions
- interactions involving neutral hadrons

Different Types of Interactions

Elastic

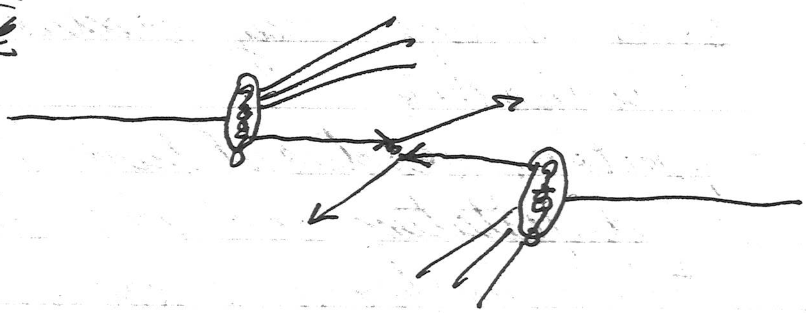


secondary hadrons produced in collisions

- coherent scattering

- cross section (σ_{el}) fairly constant for energies from 2 GeV - 100 TeV

Inelastic



"absorption process"

- Initial hadrons disrupted
  - loose their identity as quark composition changes
- cross section energy dependent at low energy ← $\sigma_{inel.}$

Quasielastic

- intermediate ~~state~~ regime where particle identity retained but wave-like character important

Absorption Length

Total cross section

$$\sigma_{TOT} = \sigma_{el} + \sigma_{q} + \sigma_{inel.}$$

Number of particles surviving thru distance 'x' of material

$$N = N_0 \, e^{-x/\lambda}$$

where $\lambda = A/(N_A \rho \sigma_{TOT})$.

A = atomic weight
ρ = density
N_0 = incident # of particles
x = thickness

To obtain characteristic distance scale to have inelastic ('absorption') interaction

Absorption length

$$\boxed{\lambda_{abs} = A/(N_A \rho \sigma_{inel.})}$$

Note: approximation since cross sections depend somewhat on particle type and energy

Absorption Cross Section

The absorption cross section can be established by looking at the total cross section and subtracting known contributions from σ_{el} + σ_q (+ Coulomb scattering)

→ cross section above 20 GeV roughly independent of momentum

For $A \geq 9$, observe

$$\sigma_{inel} \text{ or } \sigma_{abs} = \sigma_0 A^{\alpha}$$

where $\sigma_0 = 41.2$ mb, $\alpha = 0.711$

Simple Model:

- assume uniform density for nucleus, + same density for all nuclei

$$\text{Volume} \propto A \quad \text{(sphere)}$$

$$\therefore r_{nucleus} = r_0 A^{1/3}$$

→ observed nuclear sizes yield $r_0 \sim 1.4 \times 10^{-13}$ cm

- cross section of the sphere

$$\sigma_{inel} = \pi r_{nucleus}^2 = \pi r_0^2 A^{2/3} \sim 0.71$$

<u>Particle Multiplicity</u>

Particularly in inelastic processes (eg. in pp collisions)

- new particles produced as originals disrupted
- particle multiplicity increases overall with increasing energy
  - more energy → masses of particles

$$\langle N \rangle = 1.8 \ln s - 2.8$$

Particle spectrum

- π^s up to 90%
  - roughly $\frac{1}{3}$ per species: π^- less than π^0/π^+
- $p + K^s \geq 10\%$
- $K^0, \Lambda, \bar{p}$ another order of magnitude lower

e^+e^- collisions

- virtual γ^* can look like vector meson and interact strongly
- somewhat faster increase in $\langle N \rangle$ with s
- somewhat fewer π^s