8.701

Introduction to Nuclear and Particle Physics

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0. Introduction

0.7 Units

Units in Nuclear and Particle Physics

Using convenient units which are not SI units or avoid carrying around large exponents.

E.g. interaction cross sections which have units of area are usually quoted in *barns*, where

$$1 \text{ barn} \stackrel{\text{def}}{=} 10^{-28} \text{ m}^2$$

Interesting physics processes at high energies are typically picobarn or femtobarn, where 1 pb = 10^{-12} barn and 1 fb = 10^{-15} barn.

Natural Units

System in nuclear and particle physics based on fundamental constants of quantum mechanics and special relativity.

Replacing [kg, m, s] by [ħ, c, GeV], where
$\hbar = 1.055 \times 10^{-34}$ Js, $c = 2.998 \times 10^{8}\ ms^{-1}$, and 1 GeV = 10^{9}eV = 1.602×10^{-10}J.

Simplifying by choosing **ħ = c = 1**

quantity	SI units [kg,m,s]	[ħ,c,GeV]	natural units ħ=c=1
Energy	kg $m^2\ s^{-2}$	GeV	GeV
Momentum	kg m s^{-1}	GeV/c	GeV
Mass	kg	GeV/c^2	GeV
Time	s	ħ/GeV	GeV^{-1}
Length	m	ħc/GeV	GeV^{-1}
Area	m^2	$(\hbar c/GeV)^2$	GeV^{-2}

Exercise: Natural Units

The charge radius of the proton is

$$R_p = 4.1 \text{ GeV}^{-1}$$

Convert this back to SI units.

Note: is seems like information is lost when choosing **$\hbar = c = 1$** but dimension of the quantities is still preserved.

Hint: **$\hbar c$ = 0.197 GeV fm** and you should already know the answer :)

Heaviside-Lorentz units

The equations of classical electromagnetism can be simplified by using Heaviside-Lorentz units. In a combined system we set

$$\hbar = c = \varepsilon_0 = \mu_0 = 1$$

As a result, the dimensionless fine structure constant, strength of QED interactions becomes

$$\alpha = 1/137 = e^2 / 4\pi$$