Lectures of Elementary particles physics

Lecture -2

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- 2-Introductory nuclear physics
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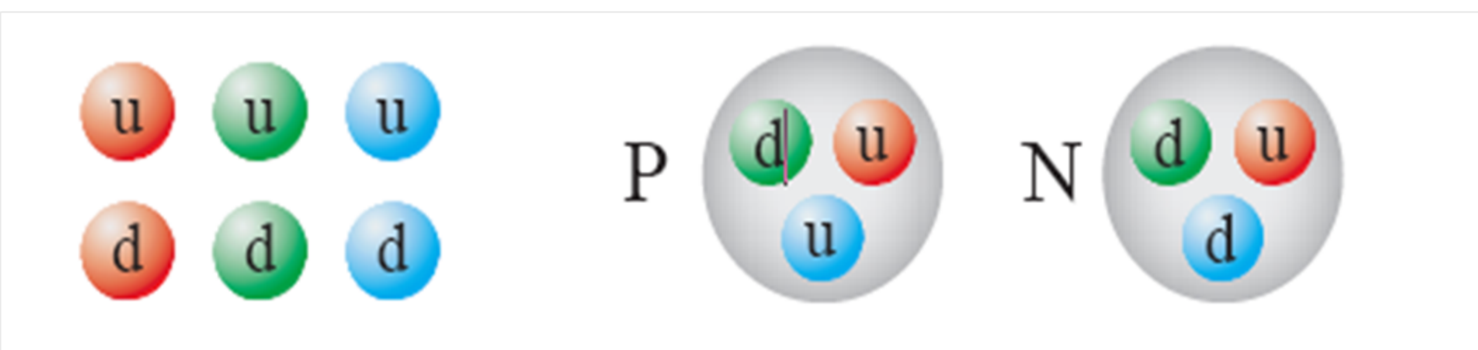
A proton, as we know now, contains three quarks. There are quite a number of different quarks, with names that somehow have come up through the years. There are "up quarks" (u) and "down quarks" (d),and each of them comes in 3 varieties ,color coded red, green and blue (*these are of course not real colors* but just a way to differentiate between the quarks). Thus there is a red up quark, a green up quark and a blue up quark, and similarly for the down quark. A proton contains two up quarks and a down quark, all of different colors, while a neutron contains 1 up quark and 2 down quarks likewise of different colors.
The figures show a symbolic representation of the up and down quarks, and the quark contents of the proton and the neutron. Just to avoid some confusion later on: sometimes we will indicate the color of a quark by a subscript, for example u_r means a red up quark. It should be emphasized that while we shall draw the quarks (as well as electrons



and others) as little balls, it is by no means implied that they are actually something like that. No structure of a quark or electron has ever been observed. We just draw them this way so that we can insert some symbol, give them a rim
in case of an antiparticle and color them. *Protons and neutrons can be observed as free particles*. *For example*, if we strip the electron from a hydrogen atom we are left with a single proton. Single neutrons decay after a while (10 minutes on the average), but live long enough to be studied in detail. However, *the quarks never occur singly*. They are confined, bound within proton or neutron. The way these quarks are bound in a proton or neutron is quite complicated, and not fully understood. Statements about the quark content of proton and neutron must be taken with a grain of salt, *because in addition there are particles called gluons which cause the binding* and which are much more dominantly present than **for example** photons in an atom (the atomic binding is due to electromagnetic forces, thus photons do the job of binding the electrons to the nucleus). In fact, much of the mass of a proton or a neutron resides in the form of energy of the gluons, while the energy residing in the electric field of an atom is very small.

For all we know electrons and quarks are elementary particles, which means that in no experiment has there anything like a structure of these particles been seen. They appear point-like, unlike the proton, neutron, nucleus and atom that have sizes that can be measured. It is of course entirely possible that particles that are called elementary today shall turn out to be composite; let it be said though that they have been probed quite extensively. This book is about elementary particles. The aim is to know all about them, their properties and their interactions. The idea is that from this nuclear physics, atomic physics, chemistry, in fact the whole physical world derives. Thus particles and their interactions are the very fundamentals of nature. That is the view now. An elementary particle physicist studies primarily these elementary particles and not the larger structures such as protons, nuclei or atoms. The main laboratory for elementary particle research *in Europe has been named CERN (Conseil Européen pour la Recherche Nuclear)*, now officially called European Organization for Nuclear Research.

1-2\ Particle Names and the Greek Alphabet

As more and more new particles were discovered the problem of naming the particles became more and more complicated. In many cases one uses Greek characters; one of the first discovered particles was the *muon*, denoted by μ, pronounced mu. Also Latin characters are sometimes used to denote particles, for example there is a *kaon,* indicated by the letter K and there are W's and a Z. Before the muon there was the neutrino, but that name was an Italian invention, derived from the name neutron as both neutrino and neutron did not carry electric charge. The neutrino has a very small or zero mass while the neutron is quite heavy. The Italian language has many ways to indicate diminutives: they could have called it neutretto or neutrello . In print the neutrino became quickly designated by means of the Greek letter ν. You will see the names as they come up, but here it may be useful to reproduce the Greek alphabet. there are two characters, slightly different, for the same letter. there are also upper case characters. Even if there is really no one to one relation between the Latin and the Greek characters we have more or less tried to list them in the order suggested by the names.

α	alpha	β	beta	δ	delta	ϵ ε	epsilon
ϕ φ	phi	γ	gamma	η	eta	ι	iota
κ	kappa	λ	lambda	μ	mu	ν	nu
ω	omega	o	omicron	π ϖ	pi	ρ ϱ	rho
σ ς	sigma	τ	tau	υ	upsilon	ξ	xi
ζ	zeta	ψ	psi	θ ϑ	theta	χ	chi

The upper case characters, listed the Greek way:

Γ	Gamma	Δ	Delta	Θ	Theta	Λ	Lambda
Ξ	Xi	Π	Pi	Σ	Sigma	Υ	Upsilon
Φ	Phi	Ψ	Psi	Ω	Omega		

In addition there are a number of upper case characters that are the same as certain Latin characters:

A	Alpha	B	Beta	E	Epsilon	Z	Zeta
H	Eta	I	Iota	K	Kappa	M	Mu
N	Nu	O	Omicron	P	Rho	T	Tau
X	Chi						

1.3\ Conservation Laws :

1- Conservation Law of Energy and Charge:

Some particles are stable, others are unstable. The most important rule here is conservation of energy. In any reaction the final energy must be exactly equal to the initial energy. A particle of a given mass has a certain amount of energy, given by Einstein's equation $E = mc^2$.

In asking if a particle can decay, one must first try to find a set of particles whose total mass is less than that of the particle under consideration. A particle with a mass of 100 MeV cannot decay into two particles with a total mass exceeding 100 MeV. The law of conservation of energy forbids this, and Nature is very strict about this law. For more massive particles there will usually be enough energy available, and therefore they tend to be unstable. Excess energy is carried away in the form of kinetic energies of the decay products.

Let us turn once more to neutron decay. The neutron has a mass of 939.57 MeV and it decays into a proton, an electron and an antineutrino: