Nuclear and Particle Physics

Participation project

Prepared by:

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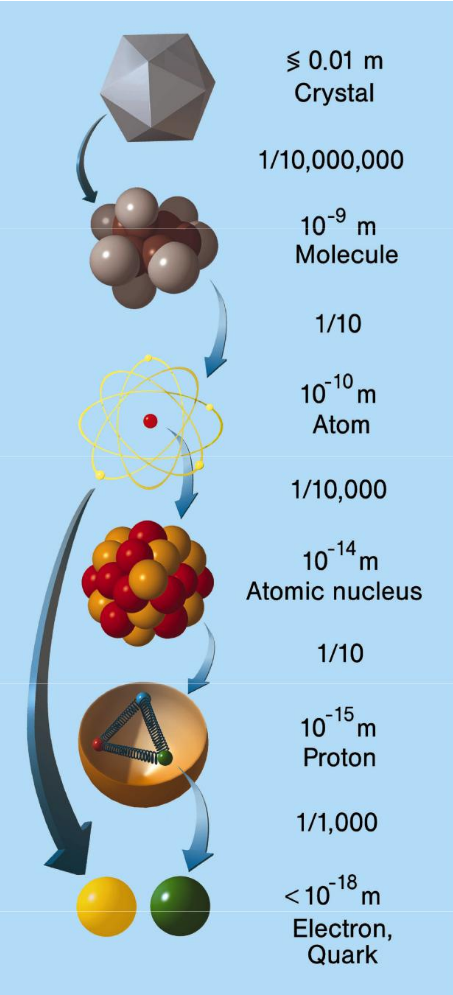
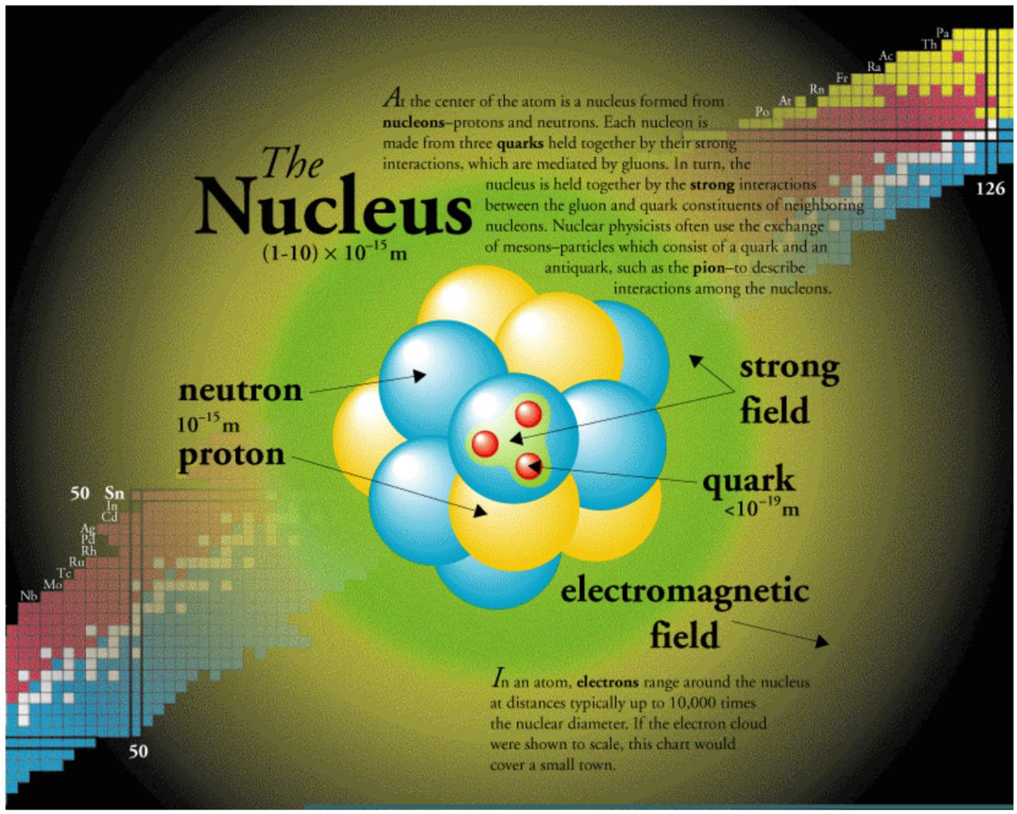
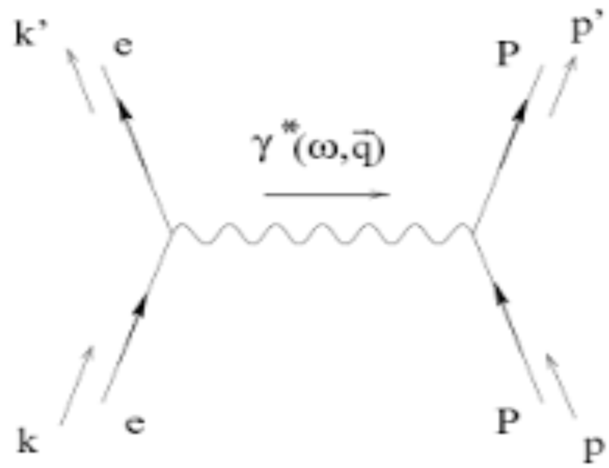
Constituents of the Universe:





Elastic Scattering:



Through elastic scattering experiments we knew:

- Radius of proton(R_p) $\neq$ 0
- Spatial Magnetization density for proton $\neq$ 0
- Spatial Electric charge density for proton $\neq$ 0

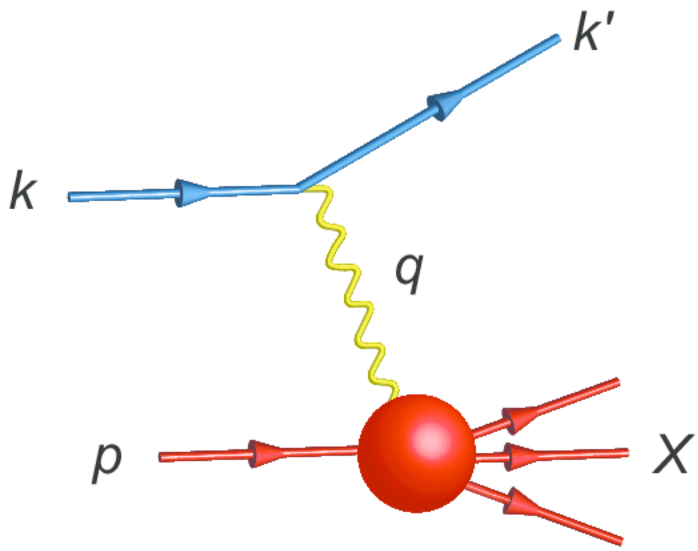
Through scattering experiments we derived form factors for protons which mean it proves protons are not elementary spin-half Dirac particles.

"Low energy" inelastic scattering:

- Through low energy inelastic scattering we get excitations of nucleons into resonances. (Just like atoms has excited states nucleons also have excited states , for example one excited state of proton is Δ^+)
- It proves nucleon is not an elementary particle i.e it has structure.

- Excited states of nucleons can be made by hitting a nucleon with anything(e.g. Cosmic rays, Muon, Neutrino)

Deep Inelastic scattering:



- If we transfer lot of energy to nucleon (high Q^2) such that we give a substantial kick to nucleon we are in deep inelastic region.
- We derived structure functions F_1 and F_2 independent of Q^2
- This demonstrates nuclei are not fundamental but we are scattering of point like particle inside nucleon.
- DIS found evidence for infinitely small, hard, nearly massless things.
- These point like particles were Dirac spin- half particles called partons (quarks and gluons)

Quarks and Gluons:

Hadrons:

They are composite particles made of two or more quarks held by strong force. They can be produced by collisions of protons or they can be produced in more complicated reaction.

Hadrons are generally divided into two groups.

- **Baryons:** Fermions-half integral spin (usually made of 3 quarks)
- **Mesons:** Bosons- integral spin (usually made of 2 quarks)

Table of (constituent) quark properties.

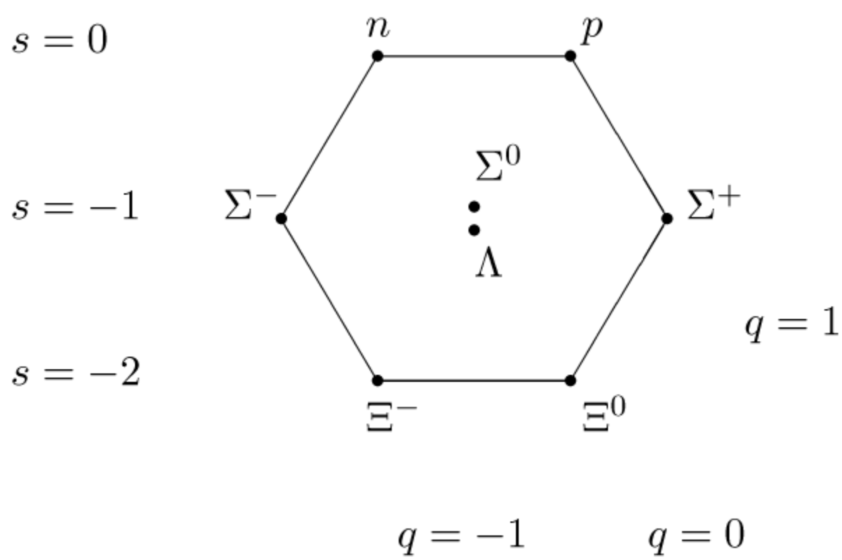
(Note: "REAL" = current quarks have different masses: m_u = 2 MeV, m_d = 5 MeV, m_s = 100 MeV, m_c = 1300 MeV, m_b = 4500 MeV, m_t > 170,000 MeV)

Properties	Up (u)	Down (d)	Charm (c)	Strange (S)	Top (T)	Bottom (b)
Mass	350	350	1800	550	20.000	4500
Q-charge in unites of (e)	2/3	-1/3	2/3	-1/3	2/3	-1/3
B-Baryon number	1/3	1/3	1/3	1/3	1/3	1/3
C-charmness	0	0	+1	0	0	0
S-strangeness	0	0	0	-1	0	0
b-bottomness	0	0	0	0	0	-1
T-topness	0	0	0	0	+1	0
S-spin	1/2	1/2	1/2	1/2	1/2	1/2
I-isospin	1/2	1/2	0	0	0	0
I_z-isospin in z-dirction	1/2	-1/2	0	0	0	0
p-parity	+1	+1	+1	+1	+1	+1

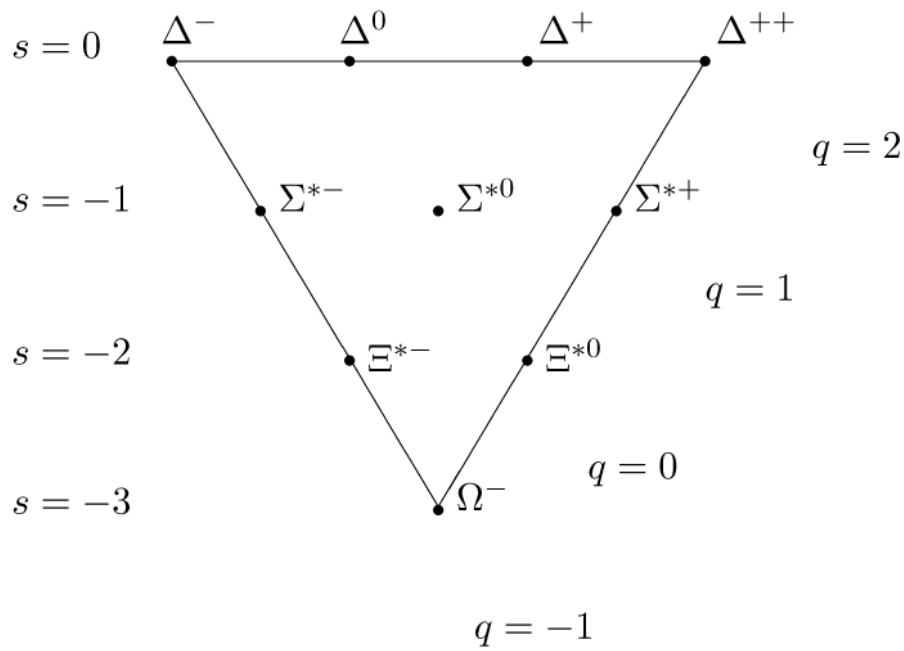
Generally free hadrons and antihadrons are not stable (with an exception of proton, which has not been observed to decay, with theoretical decay time > age of universe).

Bound Hadrons (protons and neutrons) inside atomic nuclei are considered stable against decay.

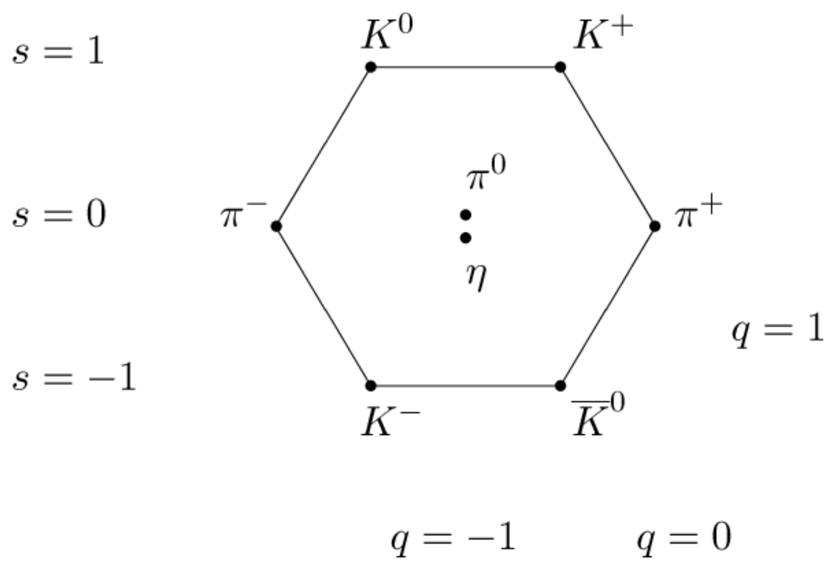
Baryons octet: Spin 1/2



Baryon Decuplet: Spin 3/2



Meson octet: Spin 0



Meson singlet: Spin 0 η'

Quark Gluon Interaction:

Color:

Let us consider a Δ^{++} resonance.

- It is lightest baryon with $J^p=3/2^+$
- So we can assume it is in ground state, so orbital angular momenta l=0
- So, it has a symmetric spatial wave function
- In order to yield total angular momentum 3/2 all quarks has to be parallel

  $$|\Delta^{++}\rangle = |u^{\uparrow}u^{\uparrow}u^{\uparrow}\rangle$$

  So, spin wavefunction is also symmetric.
- Under the interchange of quark also the wave function is symmetric.
- Hence total wave function appears symmetric.

But....

- Quarks are fermions
- So, they follow Pauli's exclusion principle
- Wavefunction must be antisymetric under exchange of any two quarks

Hence, to remove this inconsistency physicists allocated new quantum number, "color" for quarks. They can be:

Quark	Antiquark
red	antired

blue	antiblue
green	antigreen

Now the three u quarks in Δ^{++} may be separated by their color.Hence an antisymmetric color wave function may be created making total wave function antisymmetric. Later experiments verified existence of color in quarks.