Physics 125 – Elementary Particle Physics.

Visit http://hep.ucsb.edu/courses/ph125/
→ most course info there.

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+ Appointments

Text : Griffiths. get second edition

Reserve Texts too.

Learn to read/research independently.

→ PS#1 → get RMP article yourself

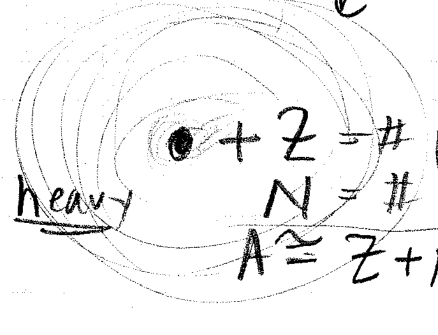
The "Micro world"...

Probe at small distances

atoms : $\sim 10^{-8}$ cm (Bohr Radius)

(tire wear, soap bubbles, oil spread)

Atom :



Ze^-

neutral overall

heavy

$+Z$ = # protons

N = # neutrons (isotopes)

$A \cong Z + N$ (Atomic Weight)

But atoms are mostly empty space, because nuclear size << atomic size

10^{-13} cm << ~ 10^{-8} cm

10^5 smaller !!

Rutherford, Bohr

Basketball.. $r \simeq 10$ cm ~ nucleus

Atom : $\simeq 10^6$ cm
$\simeq 10^4$ m
$\simeq 10$ km !

easy
- wave property of electrons
- strength of electromagnetic interaction

Gaussian e+m !!!

$$a_0 = \frac{\hbar^2}{m_e e^2} \simeq \frac{1}{2} 10^{-8} \text{ cm}$$

$$F = \frac{q_1 q_2}{r^2}$$

$$\neq \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

particle physics view

$$a_0 = \frac{\hbar c}{m_e c^2} \cdot \left(\frac{\hbar c}{e^2}\right)$$

Particle Physics : $m_e c^2 = 0{,}511$ MeV (10^6 eV)

$\hbar c = 197{,}3$ MeV · fm

Gaussian
$$\left[\frac{e^2}{\hbar c} = \frac{1}{137} \quad \text{dimensionless} \right]$$

1 fm = 10^{-15} cm

check: $\frac{197.3 \text{ MeV}\cdot\text{fm}}{0.511 \text{ MeV}} \times 137$

$\simeq 4 \cdot 10^2 \cdot 140 \text{ fm}$

$\simeq 560 \cdot 10^2 \cdot 10^{-13} \text{ cm}$

$\simeq 0.6 \cdot 10^{-8} \text{ cm}$ (close)

$a_0 = \frac{\hbar c}{m_e c^2} \times \left(\frac{1}{\alpha}\right)$

$\frac{\hbar c}{m_e c^2}$: $ƛ_e$, "reduced" compton wavelength of electron — wave-nature of e^-

$\frac{1}{\alpha}$: "feebleness" of electrostatic interaction.

A "strong" interaction would confine particles to their $ƛ$. Hmm....

Nuclear size: $\approx 10^{-13}$ cm

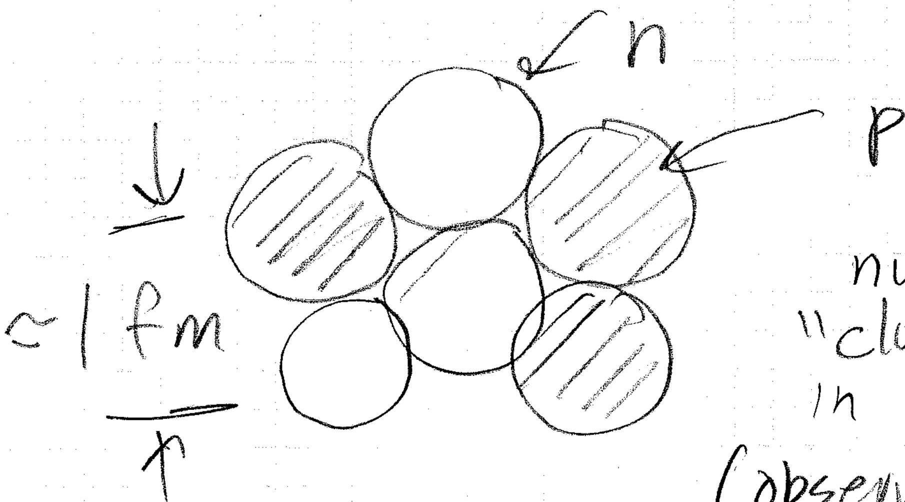
$m_p c^2 \simeq 938 \text{ MeV}$

$m_n c^2 \simeq 939 \text{ MeV}$

$\} \simeq 940$ MeV

"Nucleon" $\frac{\hbar c}{m_N c^2} \simeq \frac{200 \text{ MeV-fm}}{940 \text{ MeV}} \simeq 0.2 \text{ fm}$

Nuclear Structure:



nucleons "close packed" in nucleus (observation)

NOT LIKE ATOM AT ALL!

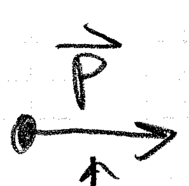
$$1\text{ fm} = \frac{\hbar c}{m_N c^2} \cdot \frac{1}{\text{"coupling"}}$$

$$1\text{ fm} = 0.2 \cdot \boxed{\simeq 5}$$

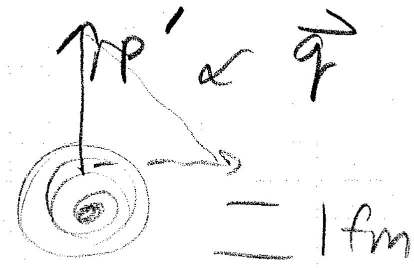
much stronger interaction!

How was nuclear structure discerned?

→ Scattering, but, projectile must have sufficient momentum to "resolve" target...



$\lambda = \frac{h}{p}$



$|\vec{q}| \simeq \sqrt{2}\, p$ typically

interference pattern depends on $|\vec{q}|$

need $\frac{h}{|\vec{q}|} \simeq \frac{2\pi\hbar}{\sqrt{2}\,p} \simeq 1\text{ fm}$

$$\frac{2\pi\,\hbar c}{\sqrt{2}\,cp} \simeq 1\text{ fm}$$

$$\sim \frac{4\cdot\hbar c}{1\text{ fm}} \simeq cp$$

note inverse relationship...

$$4\cdot 200 \simeq cp$$

$$cp \simeq 800\text{ MeV}$$

What is nature of strong force?

Now we know:

6 quarks (fractional electric charge)

	Gen 1	Gen 2	Gen 3
$Q=-1/3$	d (7 MeV)	s (120 MeV)	b (4300 MeV)
$Q=+2/3$	u (3 ")	c (1200 MeV)	t (174000 MeV)

all spin $\frac{1}{2}$

proton: "valence" (uud) $Q = \frac{2}{3} + \frac{2}{3} + -\frac{1}{3} = +1$

$j = 1/2$

neutron: (udd) $Q = \frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0$

$j = \frac{1}{2}$

But: $m_p c^2 = 938$ MeV

$2 m_u c^2 + m_d c^2 = 6 + 7 = 13$ MeV

This is the biggest surprise, peculiarity...

Resolution: most of the proton/neutron rest mass is not from u/d quarks, but due to their interaction.

That ("chromodynamic") interaction is EXTREMELY STRONG. How do we know?

$$\underbrace{1\ \text{fm}}_{\text{nucleon size}} \simeq \frac{\overbrace{\hbar c}^{\simeq 200\ \text{MeV}\cdot\text{fm}}}{\underbrace{m_q c^2}_{\simeq 5\ \text{MeV}}} \cdot \underbrace{\text{"}\frac{1}{\alpha_s}\text{"}}_{\text{strong interaction}}$$

$$1\ \text{fm} = 40\ \text{fm}\ \frac{1}{\alpha_s}$$