particles

Fermion — ½k spin, Pauli exclus°✓

Bosons — k spin, ~~Pauli exclus°~~

→ Hadrons ←

Baryons — $B = \frac{1}{3}\left(N(q) - N(\bar{q})\right)$ — 3q or 3 a-q — decay → p/$\bar{p}$, leptons, photons

Mesons — grouped form: "meson nonets" — quark - anti quark pair — → leptons / photon

Leptons
- point like
- ~~composite~~

e^- neutrino
μ^- muon
⋮

Quarks
- up +2/3
- down −1/3

} basic pair

- strange −1/3
- ⋮ ⋮

Gauge Bosons

Lepton n°: $L_e = N(e^-) + N(e^+) + N(\nu_e) - N(\bar{\nu}_e)$

$L_\mu = N(\mu^-) + N(\mu^+ \ldots$
⋮

atomic VS nuclear

Atomic		Nuclear
$1\text{Å} = 10^{-10}\,\text{m}$	Length	$1\,\text{fm} = 10^{-15}\,\text{m}$
$\sim 10^{-18}\,\text{s}$	Time	$\sim 10^{-17} / 10^{-23}\,\text{s}$
$m_e = 0.511$	Mass [MeV/c^2]	$m_p = 938.5$, $m_n = 939.6$
10 - 1000 eV	KE	1-10 MeV

4 Forces

I. GRAVITY: Graviton $\propto \frac{1}{r^2}$

acts on all mass /E

II. ELECTROMAG FORCE $< 10^{-16}\,\text{s}$: Photon γ $\propto 1/r^2$

acts btw electrically charged parts

III. WEAK F... 10^{-12}: ... W^+ W^- Z^0 ...

III WEAK F ~10 s: Bosons W, W, Z

$\gamma\gamma$ spring like → experienced hadrons | leptons

non-quark flavour conserved

IV STRONG F ~10^{21} s: Gluon $\qquad Fr^2 \gg \hbar c$

colour charge (r, g, b) → acts on quarks ~~leptons~~

holds hadrons & nuclei together

Conservat° laws

I. Electric charge: always conserved

II. Momentum (angular): always conserved

III. E always conserved (overall: $E_{TOT} = kE + E_e$)

- can be uncertain $\Delta t \approx \hbar / 2\Delta E$
- rest mass m_0: $\Delta E = m_0 c^2 = E_0$

↳ can exist for $\Delta t = \hbar / 2 m_0 c^2$ ↳ max range $= c\,\Delta t = \hbar c / 2E_0$

$m_0 = 0 \Rightarrow$ virtual photon $\Rightarrow$ long range F ($m = 0$) $\qquad$ short range

virtual wave can travel 2×10^{-10} m $\qquad$ ∴ F weak appears weak

IV. Quark flavour conserved { EM, Strong } interact°s

V. Baryon n° always conserved = NOT WEAK

(rare except°s exist)

VI. Indiv Lept° n° always conserved { L_e, L_μ }

Interact° & Transformat°

Transf°: CP

$p \leftrightarrow \bar{p}$ Charge conjugat°; $\qquad$ Parity $\qquad P(\psi(\vec{r})) = \psi(-\vec{r})$ $\qquad \vec{r} \to -\vec{r}$: mirror img

Process & C-P transform = likely happen: symmetry

VIOLAT° CP

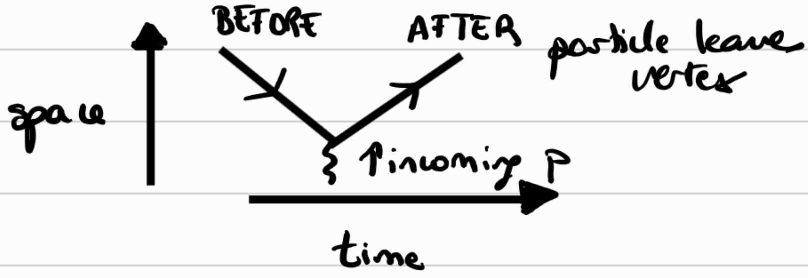
dominance matter universe [weak interact°s are not

Interact°s → WEAK – neutrino, a-n involved; – change quark flavour

$10^{-16} - 10^{-20}$ s → E.M – real photon emitted or absorbed

$< 10^{-20}$ s → STRONG – quark flavour consvd

Feynman diag



Decay laws

% decay at $\propto N$ $\therefore \delta N = -N\lambda\delta t$

$\frac{dN}{dt} = -N\lambda \Rightarrow N = N_0 e^{-\lambda t}$

- Half life : $e^{\lambda t} = 1/2 \Rightarrow t_{1/2} = \frac{\ln(2)}{\lambda}$
- Mean life = $1/\lambda$
- Activity of source $= \lambda N$ $\therefore$ $\overbrace{\text{initial act}}^{\text{i.e. decay rate}} = \lambda N_0$ [Bq]
- < Activity 1^{st} 1/2 life > : $A = N_0 \lambda / 2\ln(2)$

Unif° F

Unif° F < initial strength, range

Particle mot° : $\underbrace{\Psi = e^{ikx}}_{\text{wavefield mot° only "sees" obj size } x \leq a}$ ← $k = \frac{p}{\hbar}$

dB wave : $\lambda_B = \frac{h}{p}$

$KE \gg m_0 c^2$: EXTREME CASE → $= \frac{hc}{KE}$ ← Special relat:

$E^2 = (pc)^2 + (m_0 c^2)^2 = KE + m_0 c^2$

Range F by exchange particle : $p = \hbar c / E_0$

KE → > 90 GeV : weak F = E.M F ⇓ implies UNIFICAT° (broken at low E)

- $\geq E_0$: large % weak int $\frac{\hbar c}{KE} \leq \frac{\hbar c}{E_0}$
- $\leq E_0$: weak int [really weak W ~ 90 GeV]

High E ⇒ G.U.T ⇓ possibility proton decay ~ $t_{1/2} \geq 10^{32}$ years

Standard model $\left\{\begin{array}{l}\text{Electroweak model} \\ + \\ \text{QCD model}\end{array}\right.$ ⇒ heavy bosons : Higgs boson (mass giver) ← neutral, spin 0

Quantum gravity quantities

(not a priority)

	$\hbar$	G	c
	ML^2T^{-1}	$M^{-1}L^3T^2$	LT^{-1}

Planck $\left\{\begin{array}{l}\text{length} : (G\hbar/c^3)^{1/2} \sim 10^{-35}\,m \\ \text{energy} : (\hbar c^5/G)^{1/2} \sim 10^{19}\,GeV\end{array}\right.$

Research topic

→ Neutrino oscillat°

(dep not priority ~ worth a read night/morning before)

→ Origin cosmic rays

→ Dark Matter

Nucleon & it's interact°s

exchange particle MESONS

Protons or neutrons ← strong F

p-p, n-n, n-p

DEUTERON ($E \sim 2.2$ MeV) longest rng

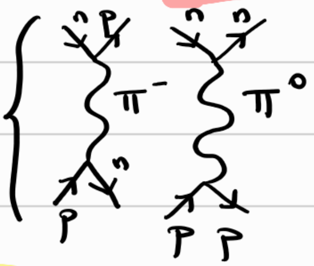
↳ bound sts ~~exist~~: PEP

2 identical fermions in lgnd st not allowed

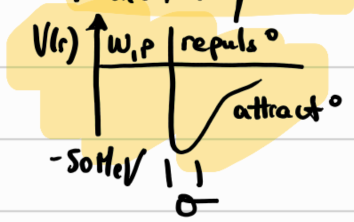
range $\sim \frac{\hbar}{2m_0 c}$

from $\sim c\Delta t \sim \hbar c / 2E_0$

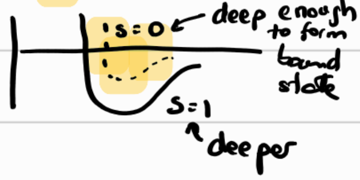
light-est meson ~ 1.4 fm



Nucleon-N potential



0, 1 - Spin s & p Potential



Nuclear size

P & N → heavier nuclei

spherical

For all but light nuclei (i.e $A \leq 12$)

↳ reasonably well def rad

↳ narrow surface rg° (≈2.5 fm)

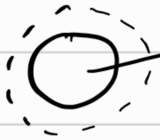
↳ cnst density near centre

$\lambda \leq 1$ fm

$E \geq 100$ MeV

F short rnge

$R_{nuc} = 1.1 A^{1/3}$ fm



size: scattering exp

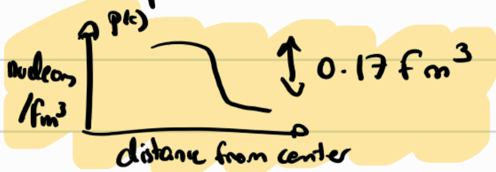
with high E/h

$\lambda_B \approx$ nuclear size

$\lambda = 2\pi\hbar/p$

$E^2 = p^2c^2 + m_0^2c^4$

N° nucleons = $A = \frac{4\pi}{3} R_{nuc}^3 \times$ nucleon density



Binding E Nuclei

$^A_Z X \to Z_p + N_n$

$B(Z,N) \geq 0$

$B(Z,N)/A$ = binding E per nucleon

B(Z,N) light nuclei

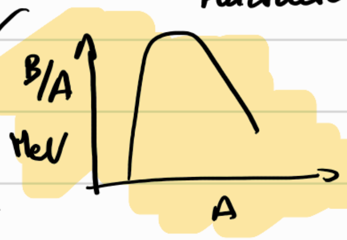
↗ ~8 MeV/nucleon

↳ large for even-even nuclei

↘ last nucleon fluctuates

$$m_{atom}(Z,N) = Z(m_p + m_e) + Nm_n - \frac{B(Z,N)}{c^2} - \underbrace{\frac{b(e^-)}{c^2}}_{\text{negligeble}}$$

SHELL EFFECTS ⇐ deviat° (<1%) from formula



Radiactive decay

... to continue