* Pauli exclus° prin
all 4 qnt states 2e in same atom cannot =

Fermions
- ½ k spin
- obey Pep*

Bosons
- k = int spin
- don't obey Pep

Hadrons — quarks & antiquarks (q, $\bar{q}$)

$B = \frac{1}{3}(N(q) - N(\bar{q}))$

Baryons — 3q or 3aq (uuu, udd, sss); grs of distinct colour

decay to p/$\bar{p}$, leptons & photons

Mesons — q-antiq pair; decay to leptons & photons; grouped meson nonets

$u\bar{d} \to \pi^+$

$\bar{u}d \to \pi^-$

$\frac{(u\bar{u} - d\bar{d})}{\sqrt{2}} \to \pi^0$ — Mix $u\bar{u}$ & $d\bar{d}$ state

Leptons
- e point-like, not composite
- ~6 likely leptons: electron, $\bar{e}$ neutrino, muon, ...
- el & neut = STABLE

Quarks: u d / s c / b t

Gauge bosons: γ

CP transform
- process equally likely to occur particle / anti-p ($P_+ \leftrightarrow ap$)
- CP violat° responsible matter dominance universe

FYI Dims°s

	Atomic	Nuclear
LENGTH	$1 Å = 10^{-10}$ m	$1 fm = 10^{-15}$ m
TIME	10^{-18} s $\leq$	$10^{-23} \leq \; \leq 10^{5}$ s
MASS	$m_e = 0.511$ MeV/c²	$m_p = 938$ MeV/c², $m_\pi = 139$ MeV/c²
KENG	10–1000 eV	1–10 MeV

Heisenberg uncertainty principle
- $\Delta x \, \Delta p \geq \hbar/2$
- $\Delta E \, \Delta t \geq \hbar/2$

INTERACT°s — Feynman diag (TIME, SPACE)

$L_{e/\mu/\tau} = N(e^-) - N(e^+) + N(\nu_e) - N(\bar{\nu}_e) \ldots$

- **E.M** — virtual photon emmitted abs; lifet $10^{-16} \sim 10^{-20}$ s
- **Strong**
- **Weak** — conserv quark flav; lift $< 10^{-20}$ s; neutrino/anti-n flavour; change quark flavour

4 FORCES

Electromag Force
- electrically charged particles
- PHOTON: γ

Gravity
- all masses
- always attractive
- GRAVITON
- negligible nuclear ph
- long range force

$Fr^2 >> \hbar c$

Strong force (spring like)
- quarks & hadrons, leptons
- GLUON ∈ colour charge
- holds nucleons & nuclei together

$Fr^2 << \hbar c$

Weak force
- all nucleons / leptons
- BOSONS: W^+, W^-, Z^0
- nuclear & particle decay

Conservat° Laws

I. Electric charge conserved

II. Momentum (ang) con

III. E_{tot} con: $E_{TOT} = KE + E_c$

IV. Quark flavor conserved in strong & EM interact°s (not weak)

V. Individual Lepton n° con $\{L_e, L_\mu$ — can break down b/c ? lift E

Decay laws

Prob decay propor tional t

- λ decay const
- $t_{1/2}$ half-life
- N particles
- δt time
- $N\lambda\delta t$ time
- $N_0 = N(t=0)$

$\therefore \delta N = -N\lambda\delta t$

$\frac{dN}{dt} = -N\lambda$

N° particles: $\Rightarrow N = N_0 e^{-\lambda s}$

Half life: $e^{-\lambda s} = \frac{1}{2} \Rightarrow t_{1/2} = \frac{\ln 2}{\lambda}$

Mean life $= 1/\lambda$

1 Curie = 3.7×10^{10} decays s⁻¹

1 Bq = 1 decay s⁻¹

Activity of source = n° decays per unit t $= \lambda N = \lambda N_0 e^{-\lambda t}$

Initial activity $= \lambda N_0$

Average activity over 1st $t_{1/2} = A = \frac{N_0/2}{\ln 2/\lambda} = \frac{N_0 \lambda}{2 \ln 2}$

STANDARD MODEL {Electroweak model + QCD model}

Q gravity th — Planck (size reg)
- length: $\left(\frac{G\hbar}{c^3}\right)^{1/2} \sim 10^{-35}$ m
- energy: $\left(\frac{\hbar c^5}{G}\right) \sim 10^{19}$ GeV

can chang flavour mid-flight: Neutrinos
- solar
- atmospheric
- beam

Particle not (wave)

$\psi = e^{ikx}$, $k = p/\hbar$ (wave-n°)

object is "seen" by wavefield iff $\lambda \leq a$

Broglie wavelength $\lambda_B = \frac{h}{p}$ ⊛

Special relativity $E^2 = (pc)^2 + (m_0 c^2)^2$

E = tot Energy $= m_0 c^2 + KE$

⊛ $KE >> m_0 c^2 \Rightarrow \lambda_B \approx \frac{hc}{KE}$

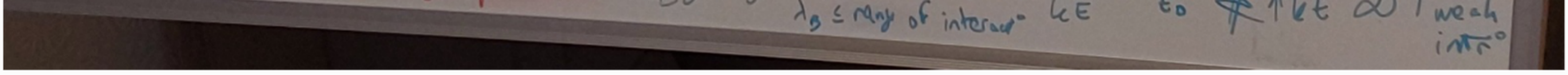
sym broken lower E ↓ unificat°

1/40 eV = 300 K

100 GeV = 10^{15} K

KE > 90 GeV: $\frac{W}{Z} = \frac{EM}{F}$

Range force exchange particle E_0 $= \frac{\hbar c}{E_0}$ } if $KE \geq E_0 \to \frac{\hbar c}{\ldots} \leq \frac{\hbar c}{\ldots}$


λB ≤ rang of interact°
kE
weak
intr°