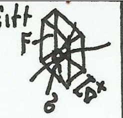
KET Blatt
Julien Kluge

$E = \hbar\omega = h\cdot\frac{c}{\lambda}$
$c = \lambda\cdot\nu \mid \omega = 2\pi\cdot\nu = \sqrt{\frac{k}{m}}$
$p = \hbar\cdot q = h/\lambda$
$k = \frac{2\pi}{\lambda} = \frac{\omega}{c} \mid \hbar = \frac{h}{2\pi}$

Bohr Radius:
$a_0 = \frac{4\pi\varepsilon_0\cdot\hbar^2}{m_e\cdot e^2} = \frac{\hbar^2}{m_e\cdot c\cdot\alpha}$

molare Formeln
$V_m = \frac{V}{n} = \frac{M}{\rho}$
$m = \frac{m}{n} = N_A\cdot m_m$
$N_A = \frac{N}{n} = R/k_B$
$\rho = m/V$

Wirkungsquerschnitt



N_S = "# Streuzentren"
$n = \frac{N_S}{F\cdot\Delta x}$
$P = \frac{N_S\cdot\sigma}{F} = n\cdot\sigma\cdot\Delta x$
$\sigma = \frac{1}{n}\frac{P}{\Delta x} = F\frac{P}{N_S}$

Absorption:
$dN = -\mu\cdot N(x)\,dx$
Abschwächungskoeff.
$N(x) = N_0\exp(-\mu\cdot x)$
$\mu = 1/\lambda$ ← mittlere freie Weglänge
$\lambda = \frac{1}{n\cdot\sigma} \mid \mu = n\cdot\sigma = \sigma\frac{N_A\cdot\rho}{M}$

1 barn = 1 b ≡ $10^{-24}\,cm^2$
Massenabsorptionskoeff.:
$\tilde\mu = \frac{\mu}{\rho} = \sigma\cdot\frac{N_A}{M}$
$[\tilde\mu] = cm^2/g$
$N = N_0\exp(-\tilde\mu\cdot\rho\cdot x)$, $\rho\cdot x$ = Massenbelegung

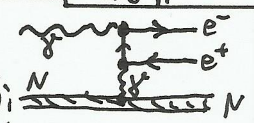
Luminosität: $\dot N_{WW} = \mathcal{L}\cdot\sigma \mid \dot N_{WW}$ "WW-Rate"
$\mathcal{L} = \dot N_{WW}\cdot\frac{1}{\sigma} = \frac{\dot N_{WW}}{P}\cdot\frac{N_S}{F} = \dot N\cdot\frac{N_S}{F} = \Phi_{in}\cdot N_S$
$[\Phi_{in}] = \frac{1}{s\cdot cm^2}$ | $\dot N$: "Teilchenrate" | Teilchenstrom

Zerfallsbreite: $\Gamma = \hbar/\tau = \hbar/\langle t\rangle$, τ mittlere Lebensdauer
$\tau = \hbar/\Gamma$

natürliche Einheiten

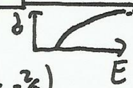
Länge	1/eV	$\frac{c\cdot\hbar}{eV}$	$1{,}97\cdot10^{-7}\,m$
Zeit	1/eV	$\hbar/eV$	$6{,}58\cdot10^{-16}\,s$
Masse	eV	eV/c^2	$1{,}78\cdot10^{-36}\,kg$
Temp	eV	eV/k_B	$1{,}16\cdot10^{4}\,K$

Compton-Streuung:
$\Delta\lambda = \lambda' - \lambda = \frac{h}{m_e\cdot c}(1-\cos\theta)$



Thomson W.Q.: (e^--Dipol)
$\sigma_T = \frac{1}{6\pi\varepsilon_0^2}\frac{e^4}{m_e^2\cdot c^4}$
niederenergetisch:
$\frac{d\sigma_T}{d\Omega} = \frac{1}{2}\frac{d^2}{m^2}(1+\cos^2\theta)$
hochenerg.:
$\sigma_T = \frac{\pi\cdot d^2}{E\cdot m}\left(\frac{1}{2}+\ln\frac{2E}{m}\right)$

Paarbildung:



$\sigma_P = \frac{28}{9}z^2\cdot\alpha\cdot r_e^2\left(\log\frac{183}{z^{1/3}} - \frac{2}{7}\right)$

Verzweigungsverhältnis:
$B_i = \frac{\dot N_i}{\sum_j \dot N_j} \mid \sum_i B_i = 1$
Partialbreite: $\Gamma_i = B_i\cdot\Gamma_{ges.}$

Photoeffekt < 30 keV, $\sim z^4, z^5$
Compton-Str. 30 keV…5 MeV, $\sim z$
Paarbildung > 5 MeV, $\sim z^2$

Mößbauer Effekt:
$\Delta E = E_\gamma^2/(2M)$

Übergangsstrahlung: $I \sim \gamma = E/m$
Tscherenkow: $\cos\theta = 1/(\beta\cdot n)$

Rutherford-Streuung: $\sigma \sim 1/(\sin^4\theta/2)$

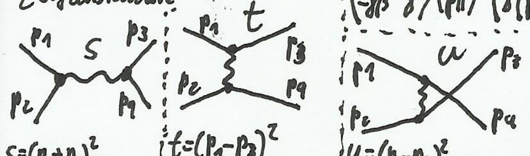
Bethe-Bloch:
$\frac{dE}{dx} = 0{,}307\frac{MeV}{mol}cm^2\cdot\frac{z\cdot\rho}{M\cdot\beta^2}\left[\ln\left(\frac{2\cdot m_e\cdot c^2\cdot\beta^2\cdot\gamma^2}{I}\right) - \beta^2 - \frac{\delta}{2}\right]$
$\frac{4\pi\cdot n\cdot z^2}{m_e\cdot c^2\cdot\beta^2}\left(\frac{e^2}{4\pi\varepsilon_0}\right)^2$ | $\delta = 0$ für $\gamma\approx1$ | $\delta = 2\cdot\log\gamma$ + const.

$\frac{dE}{dx} = -\frac{E}{X_0}$ | X_0 = "Strahlungslänge" $\sim\frac{m_e^2}{z^2}$ | $\bar\ell = \frac{9}{7}X_0 = \frac{1}{\mu_P}$
Höhenstrahlung: $\int_H^\infty \rho(h)\,dh = X_0$ | $\tilde\ell = 20\cdot X_0$ für Hadronen

Kinematik: $p_1\cdot p_2 = p_1^0 p_2^0 - \vec p_1\cdot\vec p_2$ | $\beta = \frac{p}{E}$
$E^2 = m^2 + p^2 \mid p^2 = E^2 - \vec p^2 = m^2$ | $\gamma = \frac{E}{m}$
$\beta = v/c \mid \gamma = \frac{1}{\sqrt{1-\beta^2}}$

Lorentz-Trafo: $\begin{pmatrix}\gamma & -\gamma\beta\\ -\gamma\beta & \gamma\end{pmatrix}\begin{pmatrix}E\\ \vec p_\parallel\end{pmatrix} = \begin{pmatrix}\gamma(E-\beta\cdot\vec p_\parallel)\\ \gamma(\vec p_\parallel - \beta\cdot E)\end{pmatrix}$

Zerfallskanäle:



$s = (p_1+p_2)^2 = (p_3+p_4)^2$
$t = (p_1-p_3)^2 = (p_2-p_4)^2$
$u = (p_1-p_4)^2 = (p_2-p_3)^2$

Multipolübergänge:
$E: \pi_f = \pi_i\cdot(-1)^L$ | $|I_1 - I_2| \le L \le |I_1 + I_2|$
$M: \pi_f = \pi_i\cdot(-1)^{L+1}$ | $\Delta m = \pm1\,(0)$ | $\Delta\ell = \pm1$

$s+t+u = \sum_i m_i^2 = \sum_i p_i^2$
$E_B = (Z\cdot m_p + N\cdot m_n - M_K)c^2$, M_K "Massendefekt"

Bremsstrahlung:
$\frac{dE}{dx_{rad}} \approx -4z^2\frac{N_A\cdot\rho}{M}\cdot\alpha\cdot r_e^2\cdot E\cdot\ln\frac{183}{z^{1/3}}$

Krit. Energie: $\frac{dE}{dx_{rad}} = \frac{dE}{dx_{ion}} \Rightarrow E \approx \frac{950\,MeV}{Z}$ für $z \ge 13$

magn. Momente:
$\vec\mu = \frac{q}{2m}\vec L \mid \vec\mu_L = -\mu_B\cdot\vec L$ | $\mu_B = \frac{e\cdot\hbar}{2\cdot m_e}$ | $\mu_K = \frac{m_e}{m_p}\mu_B$
$\vec\mu_S = -2\mu_B\cdot\vec s$ | $\vec j = \vec L + \vec s$
$\vec\mu_I = g_K\cdot\mu_K\cdot\frac{\vec I}{\hbar}$ | $\Rightarrow \vec\mu_j = -\mu_B(g_L\cdot\vec L + g_S\cdot\vec S)$

	e^-	p	n
g_L	1	1	0
g_S	2	5,58	-3,83

$g_K = \frac{g_L(\langle I^2\rangle + \langle L^2\rangle - \langle S^2\rangle) + g_S(\langle I^2\rangle - \langle L^2\rangle + \langle S^2\rangle)}{2\cdot\langle I^2\rangle}$

Zerfallslänge
$\tau^* = \tau\cdot\gamma$
$\ell = V\cdot\tau^* = c\beta\cdot\gamma\cdot\tau$

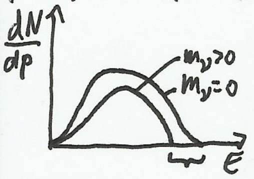
s-Kanal im CMS
$s = (p_1+p_2)^2 = (E_1+E_2)^2$

Standardabw. in Gauss mit Halbwertsbreite
$E_{HB} = 2\sqrt{2\cdot\ln2}\cdot\sigma_E$

Bethe-Weizsäcker:
$E_B = E_B^V + E_B^O + E_B^C + E_B^S + E_B^P$
$E_B^V = a_V\cdot A$, $a_V \approx 15{,}9\,MeV$ | Volumenterm
$E_B^O = -a_O A^{2/3}$, $a_O \approx 18{,}3\,MeV$ | Oberflächenterm
$E_B^C = -a_C z^2\cdot A^{-1/3}$, $a_C \approx 0{,}7\,MeV$ | Coulombterm
$E_B^S = -a_S\cdot\frac{(Z-N)^2}{4A}$, $a_S \approx 92{,}9\,MeV$ | Symmetrieterm
$E_B^P = a_P\cdot\delta\cdot A^{-1/2}$, $a_P \approx 11{,}5\,MeV$ | Paarungsterm
$\delta = \begin{cases}1 & ;gg\\ -1 & ;uu\\ 0 & ;\ldots\end{cases}$

Fermis goldene Regel
$d\Gamma = 2\pi|\langle f|\hat H|i\rangle|^2\cdot dN$

β-Zerfall: $n \to p\,e^-\,\bar\nu_e$ | $p \to n\,e^+\,\nu_e$



$\frac{dN}{dp} \sim p^2(E_0-E)^2\sqrt{1-\frac{m_\nu^2}{(E_0-E)^2}}$

Parität:
$\eta_P = \prod\eta_{P_i}\cdot(-1)^\ell$ | $\pi = (-1)^L$

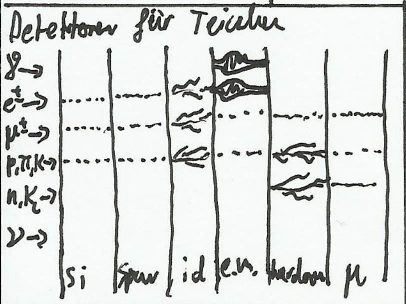
Radioaktivität:
Aktivität: $[1/s] = A = N/t$
E-Dosis: $D = E/m$
Ion-Dosis: $D_{ion} = Q/m$
Äquivalenzdosis: $H = Q\cdot D$
$\beta\gamma$: $Q\approx1$ | α: $Q\approx20$
schnell n: $Q\approx10$ | Kern: $Q\approx20$
$A = \dot N(t) = \frac{N_0}{\tau}\exp(-t/\tau)$
$\tau = \frac{T_{1/2}}{\log 2}$

Ionisationsanzahl im Detektor:
$N = \frac{\langle\frac{dE}{dx}\rangle_{min}\cdot d}{E_{ion}}$

Gamow-Faktor:
$G = \frac{2}{\hbar}\sqrt{\frac{2\cdot m_r}{E}}\frac{z_1\cdot z_2\cdot e^2}{4\pi\varepsilon_0}\left[\arccos\sqrt{R} - \sqrt{R(1-R)}\right]$
$R = E/V_0$ | $G \sim \frac{1}{\sqrt E}$ | $\Gamma \approx W\cdot\nu\cdot\exp(-G)$ ← Stoßrate, ← Bildungswahrsch.
$T = \exp(-G)$
alternativ:
$G = \frac{2}{\hbar}z_1 z_2\cdot V(R)\cdot\sqrt{\frac{2mc^2}{E}}\left[\arccos\sqrt{R} - \sqrt{R(1-R)}\right]$, $\approx\pi/2$
$= \frac{2}{\hbar}\sqrt{\frac{2m}{E}}\frac{e^2\cdot z_1\cdot z_2}{4\pi\varepsilon_0}\frac{\pi}{2}$
Geiger-Nuttall:
$\ln T_{1/2} \sim \ln 1/\Gamma = const. + G = C + C\cdot\frac{1}{\sqrt E}$

magn. Quark Momente:
$\vec\mu = \sum_i\vec\mu^{(i)} = \sum 2\mu_q\cdot\vec s$ mit $\mu_q = \frac{Q_q}{2\cdot m_q} = \frac{Q_q}{e}\underbrace{\frac{e}{2\cdot m_q}}_{\mu_B^q}$
für Baryonen:
$\mu(B) = 2\cdot\sum_{i=1}^3\langle\hat B|\hat\mu_{q_i}\cdot\hat S_z^{(i)}|\hat B\rangle$
z.B.: $|p\rangle = \frac{1}{\sqrt{18}}\,cycl\left(2|\hat u\hat u\check d\rangle - |\hat u\check u\hat d\rangle - |\check u\hat u\hat d\rangle\right)$
$\mu(p) = 2\cdot\frac{1}{18}\left[4\left(\mu_u\cdot\frac{1}{2}\cdot2 + \mu_d\cdot\left(-\frac{1}{2}\right)\right)\cdot3 + 2\cdot\left(\mu_u\frac{1}{2} + \mu_u\left(-\frac{1}{2}\right) + \mu_d\frac{1}{2}\right)\cdot3\right]$

Detektoren für Teilchen



$R = 1{,}2\,fm\cdot A^{1/3}$
$\eta_P(q) = 1$ (Konv.)
$Q(u,c,t) = 2/3$
$Q(d,s,b) = -1/3$
Fermi Bew. im Kern $p \approx 250\,MeV$

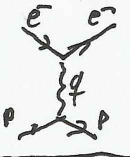
$\frac{Q}{e} = I_3 + \frac{Y}{2}$ | $Y = B + \tilde S + \tilde C + \tilde B + \tilde T$
$I = \frac{1}{\sqrt2}\sqrt{I(I+1)}\,I_3(I_3+1)\ldots$

$B(q) = 1/3 = -B(\bar q)$
$\tilde C(c) = 1$ | $\tilde T(t) = 1$
$\tilde S(s) = -1$ | $\tilde B(b) = -1$
$I_3(u) = 1/2 = -I_3(d)$

Mesonenmassen: $\langle S_1\cdot S_2\rangle = \frac{1}{2}(\langle j^2\rangle - \langle S_1^2\rangle - \langle S_2^2\rangle)$
pseudoskalar: $j = 0$
vektormesonen: $j = 1$ | $M = m_1 + m_2 + A\frac{\langle S_1\cdot S_2\rangle}{m_1\cdot m_2}$

Kraftreichweite: $r \sim 1/Q^2 \sim \frac{1}{m^2}$

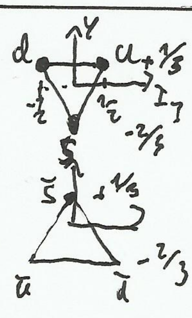
$x_{Bj} = \frac{Q^2}{2\cdot p_2\cdot q}$



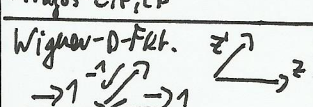
$Q^2 = -q^2$, Photon-Quark

WW-Verletzungen:
- Neutrinooszillation: L_e, L_μ, L_τ
- Flavour: $\tilde U, \tilde D, \tilde S, \tilde C, \tilde B, \tilde T$
- Trafos: $\hat C, \hat P, \hat C\hat P$

	$\hat T$	$\hat P$
$\vec p$	−	−
$\vec v$		
$\vec L$	+	−
$\vec S$	−	+
$\vec E$	+	−
$\vec B$	−	+
$\vec S\cdot\vec p$	+	−
$\vec S(\vec p_1\times\vec p_2)$	−	+



Wigner-D-Fkt.



$d^J_{m_1,m_2}$

$L_e(e^-) = 1$ | $\beta\cdot\gamma\cdot m = p$

$\frac{\sigma(e^+e^- \to 3\,Jets)}{\sigma(e^+e^- \to 2\,Jets)} = \alpha_s$
$\frac{\sigma(\Upsilon \to gg\gamma)}{\sigma(\Upsilon \to ggg)} = \frac{\alpha}{\alpha_s}$

typische Lebensdauer
$\tau_s \approx 10^{-23}\,s$
$\tau_{em} \approx 10^{-20}\,s$
$\tau_w \approx 10^{-10}\,s$

$p + p \to H_2 + e^+ + \nu_e$
$H + p \to He + \gamma$
$^3He + ^3He \to {}^4He + 2p$
$4H \to {}^4He$ + 26,2 MeV

im Proton:
$\int_0^1 u(x)\,dx = 2$ | $\int_0^1 d(x)\,dx = 1$
Impulserwartung:
$\int_0^1 u(x)\cdot x\,dx$