Física Nuclear i de partícules

pod

Primavera, 2003

Alcance $R \leq \frac{c\hbar}{M_x c^2}$.
C-paridad $\hat{C}\left|f\bar{f}, JLS\right\rangle = (-1)^{s+\ell}\left|f\bar{f}, JLS\right\rangle$.

Sec. eficaz $W = J\,N\sigma$.
Atenuación $\mu = n_t\sigma$, $\tilde{\mu} = \mu/\rho$, $t = \rho x$:

$$\frac{\mathrm{d}I}{\mathrm{d}x} = -\mu I \ , \quad I(x) = I_0 \mathrm{e}^{-\mu x} \ .$$

$$\lambda = \frac{1}{\mu} \ , \quad P(x)\mathrm{d}x = \left|\frac{\mathrm{d}I}{I_0}\right| = \mu \mathrm{e}^{-\mu x}\mathrm{d}x \ .$$

$$\begin{aligned} x' &= \gamma(x - vt) \ , & ct' &= \gamma(ct - vx/c) \ , \\ u'_x &= \frac{u_x - v}{1 - u_x v/c^2} \ , & \vec{u} &= \frac{\vec{p}c^2}{E} \ , \\ p'_x &= \gamma(p_x - vE/c^2) \ , & E' &= \gamma(E - vp_x) \ , \\ E &= m\gamma(u)c^2 \ , & \vec{p} &= m\gamma(u)\vec{u} \ , \\ m^2c^4 &= E^2 - p^2c^2 \ , & s &= E^2_{\mathrm{cm}} = E^2 - \vec{P}^2_{\mathrm{cm}} \ , \end{aligned}$$

Rutherford $\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \left(\frac{z_1 Z_2\, e^2}{2mv_0^2}\right)^2 \frac{1}{\sin^4\frac{\theta}{2}}$, $T = \frac{z_1 Z_2\, e^2}{d_{\min}}$

Lippman-Schwinger $\hat{T} = \hat{V} + \hat{V}\hat{G}_0\hat{T} \approx \hat{V}$,

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = (2\pi\hbar)^4\left(\frac{p_i}{v_i\hbar}\right)^2 \left|T_{E_i}(\vec{p}_f, \vec{p}_i)\right|^2 \ ,$$

$$T_{E_i}(p_f, p_i) = \left\langle p_f\middle|\hat{T}\middle|p_i\right\rangle = \left\langle\hat{V}\right\rangle = -\frac{Ze^2}{2\pi q^2}F(\vec{q}) \ ,$$

$$F(\vec{q}) = \int \mathrm{d}^3r'\,\rho(\vec{r}')\mathrm{e}^{i\vec{q}\cdot\vec{r}} = \frac{4\pi}{q}\int_0^\infty \mathrm{d}r\, r\rho(r)\sin qr \ ,$$

$$F(\vec{q}) \underset{\rho(\vec{r})=\rho(-\vec{r})}{\sim} 1 - \frac{1}{6}q^2\left\langle r^2\right\rangle \ ,$$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = (2\pi)^4\left(\frac{p_i}{v_i}\right)^2\left|\frac{Ze^2}{2\pi^2q^2}F(\vec{q})\right|^2 \ . \quad q = 2p\sin\frac{\theta}{2} \ .$$

$$e^-\text{–N:} \quad \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \left(\frac{Ze^2}{2E_i}\right)\frac{F^2(\vec{q})}{\sin^4\frac{\theta}{2}} \ ,$$

$$e^-\text{–N (spin):} \quad \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \left(\frac{Ze^2}{2E_i}\right)\frac{\cos^2\frac{\theta}{2}}{\sin^4\frac{\theta}{2}}F^2(\vec{q}) \ ,$$

$$\text{no rel.:} \quad \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \left(\frac{Ze^2}{4T}\right)\frac{F^2(\vec{q})}{\sin^4\frac{\theta}{2}} \ ,$$

$$\rho_F(r) = \frac{\rho_0}{1 + \mathrm{e}^{(r-R)/a}} \ , \ a = 0{,}54\mathrm{fm} \ ,$$

$$t_{0,9\rho_0\to 0,1\rho_0} = a\ln 81 = 2{,}4\mathrm{fm} \ .$$

$$\int \mathrm{d}^3r\,\rho(r) = 1 \ , \quad \rho(r) = \left(1 + w\frac{r^2}{R^2}\right)\rho_F \ .$$

$$\begin{aligned} B(A,z) &= \Big[ZM_p + NM_n - M(A,Z)\Big]c^2 \\ &= \Big[ZM_{^1H} + NM_n - M(A,z)\Big]c^2 \end{aligned}$$

$$M(A,Z) = (A+\Delta)\cdot(1\mathrm{u}) \ , \ \frac{B}{A} \approx 8{,}5\mathrm{MeV}\ (A \geq 12) \ .$$

$$\begin{aligned} B(A,z) = & a_V A - a_s A^{2/3} - a_c\frac{Z^2}{A^{1/3}} \\ & - a_A\frac{(A-2Z)^2}{A} + a_P\frac{\delta}{A^{1/2}} \ , \end{aligned}$$

$$a_V = 15{,}56\mathrm{MeV} \ , \quad a_S = 17{,}27\mathrm{MeV} \ ,$$
$$a_C = 0{,}697\mathrm{MeV} \ , \quad a_A = 23{,}285\mathrm{MeV} \ ,$$
$$a_P = 12\mathrm{MeV} \ , \qquad \delta = \begin{cases} +1 & \text{si N,Z parells} \\ -1 & \text{si N,Z senars} \\ 0 & \text{si A senar} \end{cases} \ .$$

$$Z_{\text{más estable}} = \frac{A}{2}\frac{1}{1+\frac{a_C}{4a_A}A^{2/3}} = \frac{A/2}{1+0{,}00748A^{2/3}} \ .$$

$$\phi(\vec r) = \int \mathrm{d}^3r' \, \frac{\rho(\vec r')}{|\vec r - \vec r'|} = \sum_{l=0}^{\infty}\sum_{m=-\ell}^{\ell} \frac{4\pi q_{\ell m}}{2\ell+1}\frac{Y_{\ell m}(\theta,\phi)}{r^{\ell+1}}$$

$$q_{lm} = \int \mathrm{d}^3r' \, r'^{\ell}\rho(\vec r')Y^*_{\ell m}(\Omega') \ .$$

m. eléctric: $Q_{\ell m} = e\left\langle Q_{JM}\Big|\overbrace{\sum_{i=1}^{Z} r_i^{\ell}Y^*_{\ell m}(\hat r_i')}^{\hat Q_{\ell m}}\Big|Q_{JM}\right\rangle.$

m.quad.el: $Q = \sqrt{\frac{16\pi}{5e^2}}Q_{20}\ , \ Y_{20} = \sqrt{\frac{5}{16\pi}}\frac{3z^2-r^2}{r^2}$

m.dip.magn.: $\vec\mu = \frac{1}{2}\sum_i q_i\vec x_i \times \vec v_i = \sum_i \frac{q_i}{2m_i}\vec\ell_i \ ,$

$$\mu = \langle JM=J|\hat\mu_z|JM=J\rangle \ ,$$

$$\mu_\ell = g_\ell\mu_N\vec\ell\ , \quad \mu_s = g_s\mu_N\vec S \ , \ \mu = \mu_\ell + \mu_s \ ,$$

$$g_\ell = \begin{cases} 0 & \text{prot} \\ 1 & \text{neut}\end{cases} \ , \ g_s = \begin{cases} 5{,}5856912(22) & \text{prot} \\ -3{,}8260837(18) & \text{neut}\end{cases} \ ,$$

$B(np) = 2{,}22463(4)\text{MeV}$, $R = \sqrt{\langle r^2\rangle} = 2{,}1\text{fm}$, $V_0 = -35\text{MeV}$, $\pi(np) = +1$, $L=0$ (96 %) i $L=2$ (4 %), $Q = 0{,}00288(2)\text{b}$ C. spin $3\frac{1}{r^2}(\vec\sigma_1\vec r)(\vec\sigma_2\vec r) - \vec\sigma_1\vec\sigma_2$, $\Delta L = \Delta S = 2$.

$$V_{NN}(\vec r) = V(r) + V_s(\vec r)\vec\sigma_1\vec\sigma_2 + V_{LS}(r)\vec L\vec S + V_T S_{12}(\hat r) \ .$$

$|p\rangle = |t_z = 1/2\rangle$, $|n\rangle = |t_z = 1/2\rangle$, $q_i = \frac{1}{2}(1+t_{z_i})$
$\frac{1}{2}|N-Z| \le T \le \frac{1}{2}A$

$\mathrm{d}N = -Nw\mathrm{d}t$, $w = \sum w_i$, $\tau = 1/w$, $T_{1/2} = \tau \ \ln 2$, $\Gamma = \hbar/\tau$, $B_i = \Gamma_i/\Gamma$

$$N(t) = N_0\,\mathrm{e}^{-wt} = N_0 \ , \mathrm{e}^{-t/\tau} \ ,$$

$$h\nu = \Delta E\frac{1+\frac{\Delta E}{2M_fc^2}}{1+\frac{\Delta E}{M_fc^2}} \approx \Delta E\left(1 - \frac{\Delta E}{2M_fc^2}\right)$$

$\Delta S \uparrow \Rightarrow \ \tau \uparrow$, $J \neq 0$, $\pi_{\gamma,\mathrm{e}} = (-1)^J$, $\pi_{\gamma,\mathrm{m}} = (-1)^{m+1}$.

$$\begin{aligned} Q_{\beta^-} &= \big(M(A,Z) - M(A,Z+1) - M_e\big)c^2 \\ &= \big(\mathcal{M}(A,Z) - \mathcal{M}(A,Z+1)\big)c^2 \ , \\ Q_{\beta^+} &= \big(M(A,Z) - M(A,Z-1) - M_e\big)c^2 \\ &= \big(\mathcal{M}(A,Z) - \mathcal{M}(A,Z-1) - 2M_e\big)c^2 \ , \\ Q_{EC} &= \big(M(A,Z) - M(A,Z-1) + M_e\big)c^2 \\ &= \big(\mathcal{M}(A,Z) - \mathcal{M}(A,Z-1)\big)c^2 \ . \end{aligned}$$

$$\begin{aligned} Q_\alpha &= (M(A,Z) - M(A-4,Z-2) - M(4,2))\,c^2 \\ &= (B(A-4,Z-2) + B(4,2) - B(A,Z))\,c^2 \ , \end{aligned}$$

$$\frac{B}{A} < \frac{B(4,2)}{4} - \frac{\partial(B/A)}{\partial A}A = 7{,}075 + 7{,}6\times 10^{-3}A \ .$$

Fusión

$$V_{\text{barrera}} = Z_1Z_2e^2/2R \ ,$$

$$\frac{3}{2}kT = V_{\text{barrera}}/2 \ .$$

$$S_n = (M(A-1,Z) + M_n - M(A,Z))\,c^2 \ ,$$

$$S_p = (M(A,Z-1) + M_p - M(A,Z))\,c^2 \ ,$$

Campo central $\psi_{n\ell m}(\vec r) = R_{n\ell}(r)Y_{\ell m}(\hat r)$:

$$\Big\{ -\frac{\hbar^2}{2\mu}\left(\frac{\mathrm{d}^2}{\mathrm{d}r^2} + \frac{2}{r}\frac{\mathrm{d}}{\mathrm{d}r}\right) + \frac{\hbar\ell(\ell+1)}{2\mu\,r^2} + U(r)\Big\}R_{n\ell}(r) = ER_{n\ell}(r) \ ,$$

Oscil. $U(r) = \frac{1}{2}\mu\omega^2r^2 - V_0$,
$E_{n\ell m} = \hbar\omega\left(2(n-1) + \ell\frac{3}{2}\right) - V_0$, $deg = 2\ell+1$
Wood-Saxon

$$U(r) = \frac{-U_0}{1+\mathrm{e}^{(r-R)/a}} \ ,$$

$U_0 = 50\text{MeV}$, $a = 0{,}65\text{fm}$, $R = A^{1/3}1{,}25\text{fm}$.
s-o:

$$V_{L-S} = -V_1(r)\vec\ell\vec s = -\frac{1}{2}V_1(r)\left(\vec j^2 - \vec\ell^2 - \vec s^2\right) \ .$$

$$\langle \ell_z \rangle = \left\langle \frac{\vec{\ell}\vec{\jmath}}{\vec{\jmath}^2} j_z \right\rangle \ , \ \langle S_z \rangle = \left\langle \frac{\vec{S}\vec{\jmath}}{\vec{\jmath}^2} j_z \right\rangle \ ,$$

$$\begin{aligned} \mu/\mu_N =& g^{(\ell)} \frac{\frac{1}{2}\left[j(j+1) + \ell(\ell+1) - 3/4\right]}{j(j+1)} \\ &+ g^{(s)} \frac{\frac{1}{2}\left[j(j+1) - \ell(\ell+1) + 3/4\right]}{j(j+1)} \ , \end{aligned}$$

$$\mathrm{n} \quad \mu = \mu_N \begin{cases} -1{,}913 & j = \ell + 1/2 \\ 1{,}913\frac{j}{j+1} & j = \ell - 1/2 \end{cases} \ ,$$

$$\mathrm{p} \quad \mu = \mu_N \begin{cases} j + 2{,}293 & j = \ell + 1/2 \\ \frac{j(j-1{,}293)}{j+1} & j = \ell - 1/2 \end{cases} \ .$$

$|u\rangle = |t_z = 1/2\rangle$, $|d\rangle = |t_z = -1/2\rangle$,

$$Y = B + S + C + \tilde{B} + T \ , \ I_3 = Q - Y/2 \ ,$$

$$\mu_q = 2\frac{qe}{2m_q\hbar} S_{q,z} = q\frac{m-p}{m-q}\mu_N,$$

Gluons $|r\bar{g}\rangle$, $|r\bar{b}\rangle$, $|g\bar{r}\rangle$, $|g\bar{b}\rangle$, $|b\bar{r}\rangle$, $|b\bar{g}\rangle$, $\frac{1}{\sqrt{2}}|r\bar{r} - g\bar{g}\rangle$, $\frac{1}{\sqrt{2}}|r\bar{r} - g\bar{g}\rangle$.

$V(r) \sim -\dfrac{\alpha_s(r)}{r} + \lambda r \ , \ \alpha_s(r < 0{,}1\mathrm{fm}) \sim 0{,}15 \pm 0{,}03 \ .$

$$\left|K_1^0, \vec{p} = 0\right\rangle = \frac{1}{\sqrt{2}}\left(\left|\bar{K}^0, \vec{p} = 0\right\rangle + \left|K^0, \vec{p} = 0\right\rangle\right) \ ,$$

$$\left|K_2^0, \vec{p} = 0\right\rangle = \frac{1}{\sqrt{2}}\left(\left|\bar{K}^0, \vec{p} = 0\right\rangle - \left|K^0, \vec{p} = 0\right\rangle\right) \ ,$$

$$K_S^0 = \frac{1}{\sqrt{1 + |\varepsilon|^2}}\left(K_1^0 - \varepsilon K_2^0\right) \ ,$$

$$K_L^0 = \frac{1}{\sqrt{1 + |\varepsilon|^2}}\left(K_1^0 + \varepsilon K_2^0\right) \ ,$$

$$\varepsilon \approx 2{,}3 \times 10^{-3} \ .$$

$\hbar c = 197{,}327\mathrm{MeVfm}$, $e^2 = \alpha\,\hbar c$, $\alpha = \frac{e^2}{\hbar c} = \frac{1}{137}$.

$\mu_N = \frac{e\hbar}{2m_p c}$.

$R \sim 1{,}2\mathrm{fm}\ A^{1/3}$, $R \approx (1{,}12A^{1/3} - 0{,}86A^{-1/3})\mathrm{fm}$.

$1\mathrm{b} = 10^{-28}\mathrm{m}^2 = 10^{-24}\mathrm{cm}^2$.