IZBIRNA PRAVILA PRI RAZPADIH BETA

OHRANITEV VRTILNE KOLIČINE $\vec{J}_i = \vec{J}_f + \vec{J}_{e\nu}$ $\quad \vec{J}_{e\nu}$: CELOTNA VRTILNA KOLIČINA PARA $e, \bar{\nu}_e$

$\vec{J}_{e\nu} = \vec{S}_{e\nu} + \vec{l}$ $\quad s_e = \frac{1}{2}, \; s_\nu = \frac{1}{2} \Rightarrow S_{e\nu} = 0$ ali 1 ! $\quad S_{e\nu} = 0$: FERMIJEV RAZPAD F

$S_{e\nu} = 1$: GAMOW-TELLERJEV RAZPAD GT.

$\vec{J}_{e\nu}$: FERMI : $J_{e\nu} = l$, GT : $J_{e\nu} = l, \; l \pm 1$, $\quad \Delta \vec{J} = \vec{J}_i - \vec{J}_f = \vec{J}_{e\nu}$

OHRANITEV PARNOSTI OPER. PARNOSTI : $\hat{P}\psi(\vec{r}) = \psi(-\vec{r})$ $\quad \hat{P}\hat{P}\psi(\vec{r}) = \psi(\vec{r})$

$$\hat{P}^2\psi(\vec{r}) = \hat{P}(P\psi(\vec{r})) = \underbrace{P^2\psi(\vec{r})}_{=\psi(\vec{r})} \Rightarrow P^2 = 1 \Rightarrow P = \pm 1$$

$$P_i = P_f \cdot P_{e\nu}$$
$$P_i = P_f \cdot (-1)^l$$

$(e\nu)$ IMA l : VALOVNA F. $Y_{lm}(\vartheta, \varphi)$ $\quad \hat{P}\,Y_{lm}(\vartheta, \varphi) = (-1)^l$

PRIMER: SPINA ZAČETNEGA IN KONČNEGA JEDRA ENAKA $J_i = J_f$

1.) F PREHOD z $l = 0$ ČE $P_i = P_f$

2.) GT PREHOD z $l = 1$, $s_{e\nu} = 1$ $\quad P_i = -P_f$

$\Delta J = J_{e\nu}$	$P_i = P_f$	TIP
0	JA	F0
0	NE	GT1
1	NE	F1
1	JA	GT0
⋮	⋮	⋮

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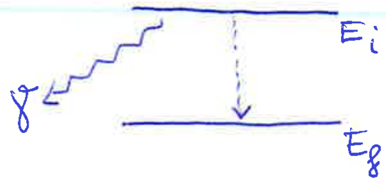
RAZPADI GAMA



ELEKTROMAGNETNA INTERAKCIJA

KLASIČNO: OSCILIRANJE ELEKTRIČNEGA DIPOLA

$$\bar{P} = \frac{\omega^4 p_{eo}^2}{3\pi \varepsilon_0 c^3}$$ IZSEVANA MOČ DIPOLA

$p_{eo} = e\, r_0$ AMPLITUDA ODMIKA

VERJETNOST ZA IZSEVANJE FOTONA (ŽARKA γ)

$$w_e = \frac{\bar{P}}{\hbar\omega} = \frac{k^3 p_{eo}^2}{3\pi \varepsilon_0 \hbar} \qquad \left(\frac{\omega}{c} = k\right)$$

$$f(\vartheta,\varphi) = \sum_{l=0}^{\infty} \sum_{m=-l}^{+l} c_{l,m} Y_{lm}(\vartheta,\varphi)$$

WIGNER ECKARTOV TEOREM

NERAZCEPEN TENZOR RANGA k: SKUPINA $2k+1$ KOLIČIN, KI SE TRANSFORMIRAJO KOT Y_{kq} SFERIČNI HARMONIKI PRI ROTACIJAH

PRIMER $\vec{r}$: TENZOR RANGA 1 : $Y_{10} = \sqrt{\frac{3}{4\pi}} \cos\vartheta = \sqrt{\frac{3}{4\pi}} \frac{z}{r}$; $Y_{1,\pm1} = \mp\sqrt{\frac{3}{8\pi}} \cdot \frac{x \pm iy}{r}$

WIGNER-ECKARTOV TEOREM: PRIČAKOVANA VREDNOST KOMPONENT NERAZCEPNEGA TENZORA T^k_q $(q = -k, \dots, +k)$ MED STANJI $|j', m'\rangle$ IN $|j, m\rangle$

$$\langle j, m | T^k_q | j', m' \rangle = C^{jm}_{kq\, j'm'} \langle j \| T^k \| j' \rangle$$

CLEBSCH-GORDONOV KOEFICIENT ($C^{jm}_{kq\,j'm'}$) ; REDUCIRAN MATRIČNI ELEMENT ($\langle j \| T^k \| j' \rangle$)

MATRIČNI ELEMENT $\neq 0$ ČE $m = m' + q$ IN $|j' - k| \leq j \leq j' + k$

$$\vec{p}_e = \int \psi_f^* e\vec{r}\, \psi_i\, d^3r$$ MATRIČNI ELEMENT ZA E. DIPOLNI PREHOD

PODOBEN IZRAZ VELJA ZA MAG. DIPOLNO SEVANJE $$w_m = \frac{\mu_0 k^3 p_{mo}^2}{3\pi\hbar}$$

$$\vec{p}_m = \mu_N \int \psi_f^* (g_l \hat{l} + g_s \hat{s}) \psi_i\, d^3r$$

MULTIPOLNA SEVANJA: KOTNA ODVISNOST KOT $Y_{lm}(\vartheta,\varphi)$ ZA ELEKTRIČNI PREHOD IN $\vec{l} \cdot \vec{\nabla}\, Y_{lm}(\vartheta,\varphi)$

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SPLOŠEN PREHOD γ $V_{fi} = \int \psi_f^* \left[\sum_l \left(\hat{O}_l^{(m)} + \hat{O}_l^{(e)} \right) \right] \psi_i \, d^3 r$

$\hat{O}_l^{(e)}$: ZA $l=1$ $= e\vec{r}$

$\vec{l} + \vec{J}_f = \vec{J}_i$ E1 : el. naboj z $l=1$, M1 : mag. naboj z $l=1$

ZA DAN l VERJETNOST ZA $El \gg Ml$

POGLEJMO ZA DIPOLNA PREHODA $\frac{W_m}{W_e} = \frac{\mu_0 k^3 p_{m0}^2}{3\pi\hbar} \frac{3\pi\varepsilon_0 \hbar}{k^3 p_{e0}^2} = \frac{p_{m0}^2}{c^2 p_{e0}^2} \sim$

El

$\sim \frac{\mu_N^2}{c^2 e R^2} = \frac{(\hbar c)^2}{(2 m_N c^2 R)^2} = \frac{(200\,\mathrm{MeV\,fm})^2}{(2 \cdot 900\,\mathrm{MeV}\, 5\,\mathrm{fm})^2} \sim 4 \cdot 10^{-4}$

ZA EL. PREHOD

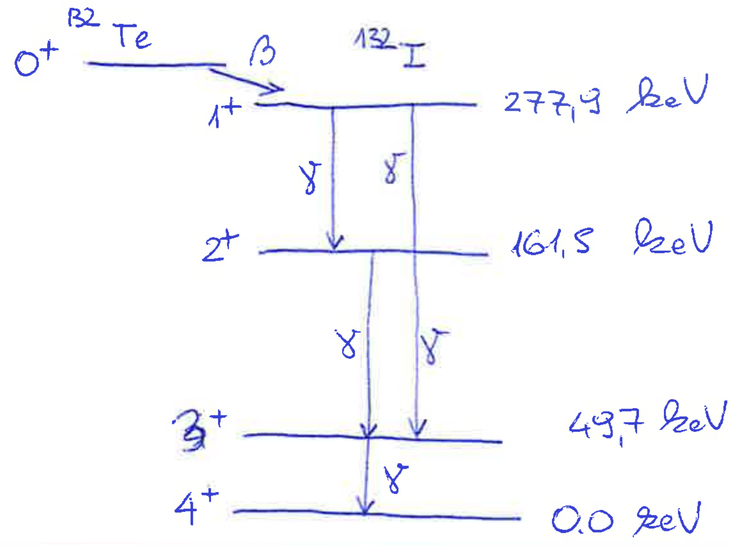
OHRANITEV PARNOSTI ! $P_i = P_f \cdot P_{Y_{lm}} = P_f (-1)^l$

PRIMERI : $l=1$; $J_i = 0$, $J_f = 1$, $\Rightarrow l=1$ $\begin{cases} P_f \neq P_i & \Rightarrow E1 \\ P_f = P_i & \Rightarrow M1 \end{cases}$

MAGNETNI PREHOD $P_i = P_f (-1)^{l+1}$ KER $\hat{O}_{\vec{r} \to -\vec{r}} : \underset{(-1)}{\vec{\nabla}} \underset{(-1)^l}{Y_{lm}}$

RAZPADNA SHEMA : ZAPOREDJE RAZPADA β IN γ

${}^{132}_{52}Te \longrightarrow {}^{132}_{53}I \; e^- \bar{\nu}_e$



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OSNOVNI DELCI

12 DELCEV S SPINOM 1/2 (FERMIONI)

LEPTONI: e^- μ^- τ^- KVARKI u c t $+\frac{2}{3}e_0$

ν_e ν_μ ν_τ d s b $-\frac{1}{3}e_0$

KVARKI NASTOPAJO SAMO V VEZANIH STANJIH $q_1\bar{q}_2$ MEZON $q_1q_2q_3$ BARION

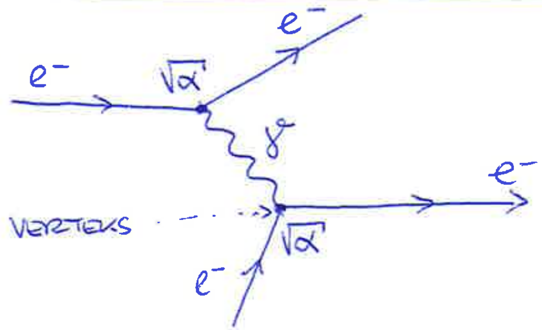
(NAJDEMO TUDI STANJA $qq\bar{q}\bar{q}$ TETRAKVARK, $qqqq\bar{q}$ PENTAKVARK)

INTERAKCIJE ELEKTROMAGNETNA FOTON

ŠIBKA ŠIBKI BOZONI W^+, W^-, Z^0 } SPIN 1

MOČNA GLUONI

PRIMER: EM INTERAKCIJA



$\Delta E \, \Delta t \geq \frac{\hbar}{2}$

VIRTUALNI γ: $E_\gamma \neq p_\gamma c$

$|V_{fi}| \propto \frac{e^2}{4\pi\varepsilon_0} = \alpha \hbar c$

$\frac{e^2}{4\pi\varepsilon_0} \cdot \frac{\hbar c}{\hbar c} = \alpha \hbar c$

α KONSTANTA FINE STRUKTURE $= \frac{1}{137}$

VALOVNA ENAČBA ZA RELATIVISTIČNE DELCE

NERELATIVISTIČNA POT : KLASIČNA ZVEZA $E = T + V$
KVANTNA MEHANIKA $\hat{E} = \hat{T} + \hat{V} \Rightarrow \hat{E}\psi = (\hat{T}+\hat{V})\psi$

RELATIVISTIČNI DELCI : (PROST DELEC) KLASIČNA ZVEZA $E^2 = p^2c^2 + m^2c^4$

VALOVNA ENAČBA $\hat{E}^2\psi = (\hat{p}^2c^2 + m^2c^4)\psi$

$\hat{E} = i\hbar\frac{\partial}{\partial t}$ $\hat{p} = -i\hbar\vec{\nabla}$ $-\hbar^2\frac{\partial^2}{\partial t^2}\psi = -\hbar^2\nabla^2c^2\psi + m^2c^4\psi$

KLEIN-GORDONOVA ENAČBA

$$\boxed{\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\psi - \frac{m^2c^2}{\hbar^2}\psi = 0}$$

ZA $m=0$ $\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\psi = 0$ VALOVNA ENAČBA ZA EM VALOVANJE

STACIONARNA REŠITEV u $\frac{\partial u}{\partial t} = 0 \Rightarrow u = u(\vec{r})$

$$\nabla^2 u = \frac{m^2c^2}{\hbar^2}u$$

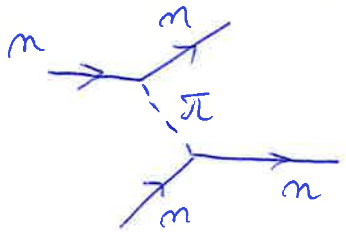
SFERIČNO SIMETRIČNA REŠITEV $u = u(r)$

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{du}{dr}\right) = \frac{m^2c^2}{\hbar}u$$

$\hookrightarrow$ $u = \frac{g}{r}e^{-\frac{r}{R}}$ $R = \frac{\hbar}{mc}$

$\Rightarrow$ POTENCIAL V POLJU, KI GA PRENAŠA DELEC ZA MASO m

HIDEKI YUKAWA : POTENCIAL MED NUKLEONI IMA KONČEN DOSEG



R DOSEGA : YUKAWA $m \sim 100\ \mathrm{MeV}/c^2$

$R \sim$ nekaj fm $mc^2 = \frac{\hbar c}{R} = \frac{200\ \mathrm{MeV\ fm}}{\text{nekaj fm}} \sim 100\ \mathrm{MeV}$

NAJPREJ ODKRILI MION : $m_\mu c^2 = 104\ \mathrm{MeV}$, A NE INTERAGIRA DOVOLJ
NATO ŠELE π^-, $\pi^- \to \mu^- X \to e^- X'$

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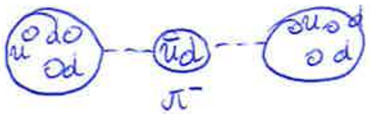
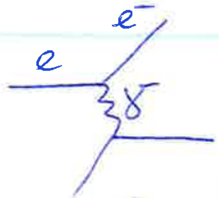


IZMENJAVA PIONA
– ANALOGIJA Z
VAN DER VAALSOVIMI SILAMI



PO ANALOGIJI: SIPANJE ELEKTRONA NA JEDRU

$$f = \int u(r)\, e^{i\vec{q}\cdot\vec{r}}\, d^3r$$

$$f = \int \frac{g}{r} e^{-\frac{r}{R}} \underbrace{d^3r}_{4\pi r^2 dr} \cdot e^{i\vec{q}\vec{r}} = g4\pi \int r^2 dr\, e^{-\frac{r}{R}} e^{i\vec{q}\cdot\vec{r}} \frac{1}{r}$$

$$w = \frac{r}{R} - i\vec{q}\cdot\vec{r} = r\left(\frac{1}{R} - iq\right)$$

$$dw = dr\left(\frac{1}{R} - iq\right)$$

$$= g4\pi \int e^{-w} \frac{w}{\left(\frac{1}{R} - iq\right)^2} dw =$$

$$= \frac{g4\pi}{\left(\frac{1}{R} - iq\right)^2} \underbrace{\int_0^\infty e^{-w} w\, dw}_{= \text{konstanta (neodvisna od } q)}$$

$$\sigma \propto |f|^2 \propto \frac{g^2}{\left(\left|\frac{1}{R} - iq\right|^2\right)^2} \frac{g^2}{\left(\frac{1}{R^2} + q^2\right)^2} = \frac{g^2}{\left(\frac{m^2c^2}{\hbar^2} + q^2\right)^2} = \frac{g^2}{(m^2c^4 + \hbar^2 q^2 c^2)^2} (\hbar c)^4$$

$$\Rightarrow \sigma \propto \frac{g^2}{(m^2c^4 + \hbar^2 q^2 c^2)^2}$$

ČE $m = 0$

16.3.