HADRONI V KVARKOVSKEM MODELU

BARIONI IZ TREH KVARKOV $+\frac{2}{3}e_0$, $-\frac{1}{3}e_0$, u, d, s ($u = +\frac{2}{3}e_0$; $d, s = -\frac{1}{3}e_0$)

u, d, s : $3^3 = 27$ RAZLIČNIH KOMBINACIJ

SIMETRIČNE KOMBINACIJE

S KVARKI u IN d

$\psi_{S_1} = |uuu\rangle$ $\psi_{S_2} = |ddd\rangle$

23.3. IZOSPIN pp, pn, nn ENAKO INTERAGIRAJO ; $m_n \simeq m_p$

$I_3(p) = +\frac{1}{2}$ $I_3(n) = -\frac{1}{2}$ I IZOSPIN, $I_3 = 3.$ KOMPONENTA

PO ANALOGIJI OPERATORJA $I_+|p\rangle = 0$ $I_+|n\rangle = |p\rangle$ $I_+|u\rangle = 0$ $I_+|d\rangle = |u\rangle$

$I_-|p\rangle = |n\rangle$ $I_-|n\rangle = 0$ $I_-|u\rangle = |d\rangle$ $I_-|d\rangle = 0$

$$\hat{I}_-|uuu\rangle = \sum_{i=1}^{3} I_{i-}|uuu\rangle = |duu\rangle + |udu\rangle + |uud\rangle$$

$$\psi_{S_3} = \frac{1}{\sqrt{3}}\left(|duu\rangle + |udu\rangle + |uud\rangle\right)$$

$$\hat{I}_+|ddd\rangle = \sum_{i=1}^{3} I_{i+}|ddd\rangle = |udd\rangle + |dud\rangle + |ddu\rangle$$

$$\psi_{S_4} = \frac{1}{\sqrt{3}}\left(|udd\rangle + |dud\rangle + |ddu\rangle\right)$$

ČUDNOST ČUDNI DELCI NASTANEJO V PARIH $\pi^- p \rightarrow K^0 \Lambda^0$ ($S=0$, $S=0$; $S=+1$, $S=-1$)

PRI RAZPADU: $\Lambda^0 \rightarrow \pi^- p$ ($S=-1$; $S=0$) $\tau \sim 10^{-10}$ s ŠIBKA INTERAKCIJA

$\Delta^0 \rightarrow \pi^0 n$, $\rightarrow \pi^- p$ ($S=0$; $S=0$) $\tau \sim 10^{-23}$ s MOČNA INTERAKCIJA

ČUDNOST SE OHRANJA PRI MOČNI IN E.M. INTERAKCIJI, NE PA PRI ŠIBKI

KVARK s : ČUDNOST $S=-1$

ψ_{S3} : $d \rightarrow s$ $\qquad$ $\psi_{S5} = \frac{1}{\sqrt{3}}\left(|suu\rangle + |usu\rangle + |uus\rangle\right)$

ψ_{S4} : $u \rightarrow s$ $\qquad$ $\psi_{S6} = \frac{1}{\sqrt{3}}\left(|sdd\rangle + |dsd\rangle + |dds\rangle\right)$

$$\psi_{S3} = \frac{1}{\sqrt{3}}\left(|duu\rangle + |udu\rangle + |uud\rangle\right) \xrightarrow{u \rightarrow s}$$

$$\frac{1}{\sqrt{6}}\left(|dsu\rangle + |dus\rangle + |sdu\rangle + |uds\rangle + |sud\rangle + |usd\rangle\right) = \psi_{S7}$$

$$\frac{1}{\sqrt{3}}\left(|suu\rangle + |usu\rangle + |uus\rangle\right) \rightarrow \frac{1}{\sqrt{3}}\left(|ssu\rangle + |sus\rangle + |uss\rangle\right) = \psi_{S8}$$

$$\frac{1}{\sqrt{3}}\left(|ssd\rangle + |sds\rangle + |dss\rangle\right) = \psi_{S9}$$

$$|sss\rangle = \psi_{S10}$$

$\Rightarrow$ 10 SIMETRIČNIH VALOVNIH FUNKCIJ

ANTISIMETRIČNA VALOVNA FUNKCIJA $\qquad$ ZA DVA KVARKA $|ud\rangle - |du\rangle$

$$\psi_{A1} = \frac{1}{\sqrt{6}}\left(|uds\rangle - |dus\rangle + |dsu\rangle - |usd\rangle + |sud\rangle - |sdu\rangle\right)$$

OSTANE 16 VALOVNIH FUNKCIJ : NITI POPOLNOMA SIMETRIČNE NITI ANTISIM.
– MEŠANA SIMETRIJA

$\psi_{MA1} = \frac{1}{\sqrt{2}}\left(|udu\rangle - |duu\rangle\right)$ $\qquad$ ψ_{MS1} " $= \frac{1}{\sqrt{2}}$ " $\left(|udu\rangle + |duu\rangle\right)$ "

→ GLEJ STRAN 27

PROBLEM DELCA Δ^{++} $\qquad$ Δ^{++} BARION $|uuu\rangle$ $\qquad$ SPIN $J = \frac{3}{2}$

$\psi_{\Delta^{++}} = \psi(\vec{r})\, \psi_{SPIN}\, \psi_{OKUS}\, \psi_{BARVA}$ $\qquad$ $\psi_{\Delta^{++}}$ MORA BITI ANTISIMETRIČNA (FERMION $J = 3/2$)

$\psi(\vec{r})$ ↑ KRAJEVNI DEL SIMETRIČEN

ψ_{SPIN} ↑ $|\uparrow\uparrow\uparrow\rangle$ SIMETRIČNA

ψ_{OKUS} ↑ SIMETRIČEN

ψ_{BARVA} → ANTISIMETRIČNA

⇒ POTREBUJEM DODATNO PROSTOSTNO STOPNJO : BARVA

KVARKI : TRIJE MOŽNI BARVNI NABOJI R : RDEČA , B: MODRA , G: ZELENA

$$\psi_A(\text{BARVA}) = \frac{1}{\sqrt{6}}\left(|RGB\rangle + |GBR\rangle + |BRG\rangle - |GRB\rangle - |RBG\rangle - |BGR\rangle\right)$$

ENAKA ZA <u>VSE</u> BARIONE

KAKO SESTAVITI BARIONSKE VAL. FUNKCIJE IZ OKUSNIH VAL. F. Z MEŠANO SIMETRIJO?

$$\psi = \underset{\text{SIMETRIČNA}}{\psi(\vec{r})}\ \underbrace{\psi_{SPIN}\,\psi_{OKUS}}_{\text{SIMETRIČNA}}\ \underset{\text{ANTISIMETRIČNA}}{\psi_{BARVA}}$$

$$\psi_{MA1} = \frac{1}{\sqrt{2}}\left(|udu\rangle - |duu\rangle\right)$$

$$\psi_{MS1} = \text{"}\frac{1}{\sqrt{2}}\left(|udu\rangle + |duu\rangle\right)\text{"}$$

ANALOGIJA : SPINSKA

$$\frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\uparrow\rangle - |\downarrow\uparrow\uparrow\rangle\right)$$

$$\text{"}\frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\uparrow\rangle + |\downarrow\uparrow\uparrow\rangle\right)\text{"}$$

SPIN $\frac{1}{2}$

SESTAVIM

$$\psi_{MS1}(\text{okus})\,\psi_{MS1}(\text{spin}) + \psi_{MA1}(\text{okus})\,\psi_{MA1}(\text{spin})$$

PRAVA OBLIKA M. SIMETRIČNE VAL. FUNKCIJE : POGOJI

$$\langle \psi_{MA1} | \psi_{MS1} \rangle = 0 \qquad \langle \psi_{S3} | \psi_{MS1} \rangle = 0 \qquad \langle \psi_{MA1} | \psi_{S3} \rangle = 0$$

$$|\psi_{MS1}\rangle = a\,|uud\rangle + b\,|udu\rangle + c\,|duu\rangle$$

$$\hookrightarrow\ 0 = \left(\langle udu| - \langle duu|\right)\left(a|uud\rangle + b|udu\rangle + c|duu\rangle\right)$$

$$0 = b - c \Rightarrow c$$

$$0 = \left(\langle uud| + \langle udu| + \langle duu|\right)\left(a|uud\rangle + b|udu\rangle + c|duu\rangle\right)$$

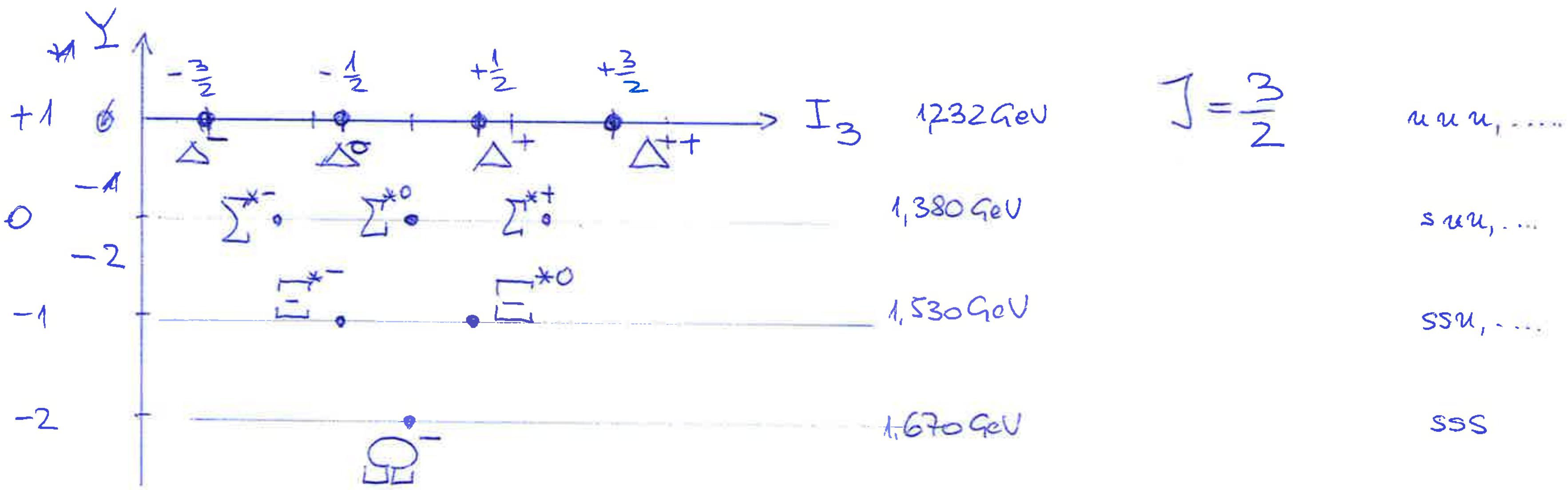
$$0 = a + b + c = a + 2b \Rightarrow a = -2b \qquad a^2 + b^2 + c^2 = 1 \quad \psi_{MS1}\ \text{NORMIRANA}$$

$$|\psi_{MS1}\rangle = b\left(-2|uud\rangle + |udu\rangle + |duu\rangle\right) = \frac{1}{\sqrt{6}}\left(-2|uud\rangle + |udu\rangle + |duu\rangle\right)$$

8 MES. SIM + 8 MES ANTIS → 8 BARIONOV S SPINOM $\frac{1}{2}$

KLASIFIKACIJA BARIONOV V 2D : I_3, $Y = B + S$ HIPERNABOJ

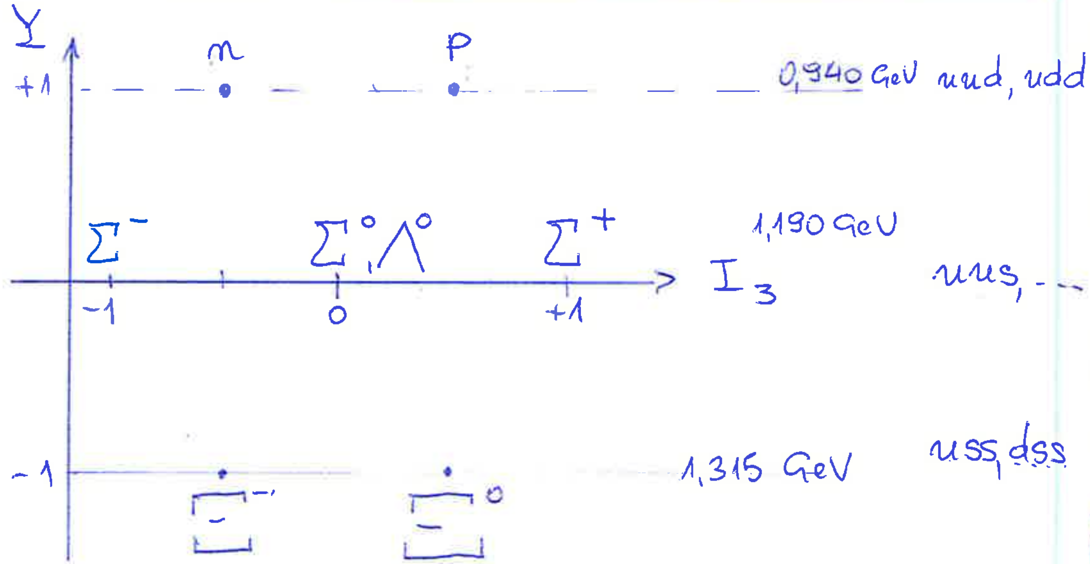
SIMETRIČNE VALOVNE FUNKCIJE



DEKUPLET

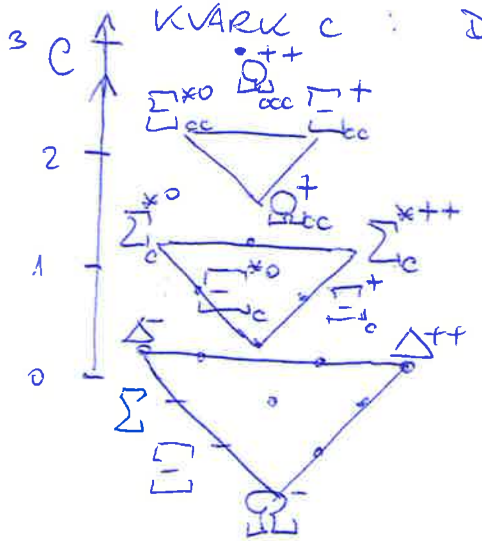
OKTET

$J = \frac{1}{2}$



BARIONI S KVARKI c, b

KVARK c : DODATNO KV. ŠTEVILO C ČAROBNOST $C(c) = +1$



PODOBNO LAHKO TVORIM TUDI BARIONE S KVARKOM b.

MAGNETNI MOMENT p IN n $J = \frac{1}{2}$

$$\psi = [\psi_{MS1}(\text{flavour}) + \psi_{MS1}(\text{spin}) + \psi_{MA1}(\text{flavour})\,\psi_{MA1}(\text{spin})]$$

OPERATOR $\hat{\vec{\mu}}_i$ NA i-TI KVARK $\hat{\vec{\mu}}_i = g_s \frac{e_0 Q_i \hat{\vec{s}}_i}{2m_i}$

TOČKAST DELEC: SPIN $\frac{1}{2} \to g_s = 2$

$$\mu_p = \langle p | \sum_{i=1}^{3} \hat{\mu}_{3i} | p \rangle$$

$$|p\uparrow\rangle = \frac{1}{\sqrt{18}}\big[2|u\uparrow u\uparrow d\downarrow\rangle - |u\uparrow u\downarrow d\uparrow\rangle - |u\downarrow u\uparrow d\downarrow\rangle + 2|d\downarrow u\uparrow u\uparrow\rangle - |d\uparrow u\downarrow u\uparrow\rangle - |d\downarrow u\uparrow u\uparrow\rangle + 2|u\uparrow d\downarrow u\uparrow\rangle - |u\downarrow d\uparrow u\uparrow\rangle - |u\uparrow d\uparrow u\downarrow\rangle\big]$$

$Q_u = +\frac{2}{3}$, $Q_d = -\frac{1}{3}$ $\Rightarrow$ $\mu_p = \frac{e_0}{2m_q}$ $\mu_n = -\frac{2}{3}\frac{e_0}{2m_q}$ → VAJE

$$\frac{\mu_n}{\mu_p} = -\frac{2}{3}$$ EKSPERIMENT: $\frac{\mu_n}{\mu_p} = -0{,}685$ ✓

MEZONI $q_i \bar{q}_j$

$\hat{C}$: OPERATOR KONJUGACIJE NABOJA

$\hat{C}: |q\rangle \to |\bar{q}\rangle$

$\hat{C}|q\rangle = e^{i\varphi}|\bar{q}\rangle$

$\hat{C}^2|q\rangle = \hat{C}(e^{i\varphi}|\bar{q}\rangle) = e^{i\varphi}e^{-i\varphi}|q\rangle = |q\rangle$

$\hat{C}|u\rangle = -|\bar{u}\rangle$

$\hat{C}|d\rangle = |\bar{d}\rangle$