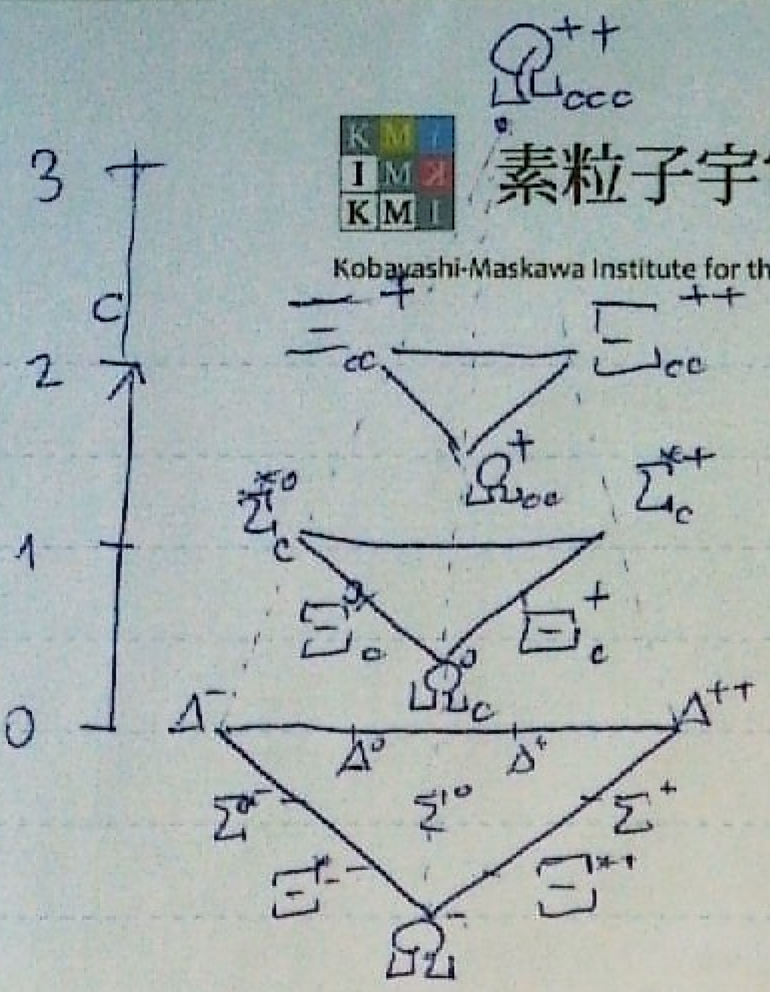

MAGNETNI MOMENT p IN n

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

$$\Psi = \left[\psi_{MS1}(\text{okus})\,\psi_{MS1}(\text{spin}) + \psi_{MA1}(\text{okus})\,\psi_{MA1}(\text{spin})\right]$$
$$\psi(\vec{r}) \cdot \psi(\text{barve})$$

OPERATOR i-ti kvark $\quad \vec{\mu}_i = g_s \frac{e_0 Q_i \vec{s}_i}{2 m_i}$

$$\mu_{3i} = g_s \frac{e_0 Q_i s_{3i}}{2 m_i} \quad \Rightarrow \quad \mu_p = \langle \underset{\uparrow \atop \psi_p}{p} | \sum_{i=1}^{3} \mu_{3i} | p \rangle$$

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

$$\mu_p = \frac{e_0}{2m_q} \qquad \mu_n = -\frac{2}{3}\frac{e_0}{2m_q}$$

$$\frac{\mu_n}{\mu_p} = -\frac{2}{3} \qquad \text{EKSPERIMENT: } \frac{\mu_n}{\mu_p} = -0.685$$

$\mu_p = ?$ $\quad m_q$ NAIVNO: $\frac{m_p}{3}$ $\quad \mu_p = \frac{3e_0}{2m_p}$

V NARAVI $\quad \mu_p = g_{s,p}\frac{e_0 s}{2m_p} = \frac{5.6 \cdot e_0 \frac{1}{2}}{2m_p} = \frac{2.8\, e_0}{2m_p}$

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MEZONI $q_i \bar{q}_j$

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

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

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

$\hat{I}_-|u\rangle = I_- |I=\frac{1}{2}, I_3=+\frac{1}{2}\rangle = |I=\frac{1}{2}, I_3=-\frac{1}{2}\rangle = |d\rangle$
$\hat{I}_+|d\rangle = |u\rangle$

$I_3(u) = +\frac{1}{2} \quad I_3(\bar{u}) = -\frac{1}{2} \quad I_3(\bar{d}) = +\frac{1}{2}$

$\hat{I}_-|\bar{d}\rangle = -|\bar{u}\rangle$
$\hat{I}_+|\bar{u}\rangle = -|\bar{d}\rangle$

KONSTRUKCIJA VEZANIH STANJA

$|u\bar{d}\rangle \qquad I_3=+1$
$\hat{I}_-|u\bar{d}\rangle = |d\bar{d}\rangle - |u\bar{u}\rangle \qquad I_3=0$
$\hat{I}_-(|d\bar{d}\rangle - |u\bar{u}\rangle) = -|d\bar{u}\rangle - |d\bar{u}\rangle \qquad I_3=-1$

$|\pi^+\rangle = |u\bar{d}\rangle = |I=1, I_3=+1\rangle$
$|\pi^0\rangle = \frac{1}{\sqrt{2}}(|d\bar{d}\rangle - |u\bar{u}\rangle) = |I=1, I_3=0\rangle$
$|\pi^-\rangle = |d\bar{u}\rangle = |I=1, I_3=-1\rangle$

$u, d \to s, \ \bar{u}, \bar{d} \to \bar{s} \qquad |\pi^+\rangle \xrightarrow[d\to\bar{s}]{} |u\bar{s}\rangle = |K^+\rangle$

$|\pi^+\rangle \xrightarrow[u\to s]{} |s\bar{d}\rangle = |K^0\rangle$

$|\pi^-\rangle \xrightarrow[d\to s]{} |s\bar{u}\rangle = |K^-\rangle \qquad |\pi^-\rangle \xrightarrow[\bar{u}\to\bar{s}]{} |d\bar{s}\rangle = |\bar{K}^0\rangle$

NABOJ 0, $I_3=0$, $S=0$ $|d\bar{d}\rangle$, $|u\bar{u}\rangle$, $|s\bar{s}\rangle$

$$\frac{1}{\sqrt{3}}\left(|u\bar{u}\rangle + |d\bar{d}\rangle + |s\bar{s}\rangle\right) = |\eta_0\rangle \quad u\Leftrightarrow s,\ u\Leftrightarrow d,\ d\Leftrightarrow s$$

SINGLET $\qquad SU(3)_{\text{okus}}$

$$|\eta_8\rangle = a|u\bar{u}\rangle + b|d\bar{d}\rangle + c|s\bar{s}\rangle$$

$\langle\eta_8|\eta_0\rangle = 0$
$\langle\eta_8|\pi^0\rangle = 0$
$\langle\eta_8|\eta_8\rangle = 1$

$$0 = \frac{1}{\sqrt{2}}\left(\langle u\bar{u}|a + \langle d\bar{d}|b + \langle s\bar{s}|c\right)\left(|d\bar{d}\rangle - |u\bar{u}\rangle\right) = \frac{1}{\sqrt{2}}(b-a) \Rightarrow b=a$$

$$0 = \frac{1}{\sqrt{3}}\left(a\langle u\bar{u}| + b\langle d\bar{d}| + c\langle s\bar{s}|\right)\left(|u\bar{u}\rangle + |d\bar{d}\rangle + |s\bar{s}\rangle\right) = \frac{1}{\sqrt{3}}(a+b+c) \Rightarrow 2a+c=0$$

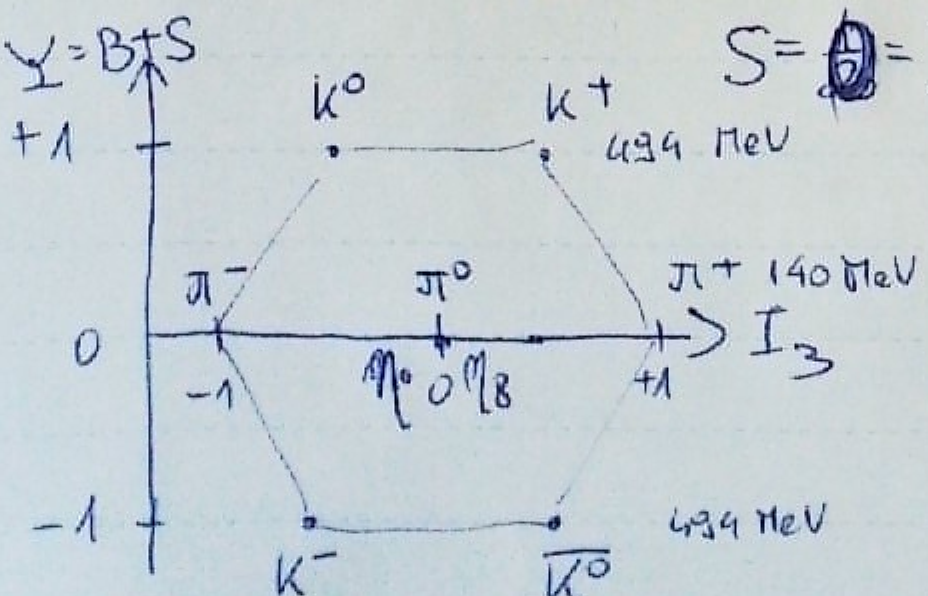
$$|\eta_8\rangle = \frac{1}{\sqrt{6}}\left(|u\bar{u}\rangle + |d\bar{d}\rangle - 2|s\bar{s}\rangle\right)$$

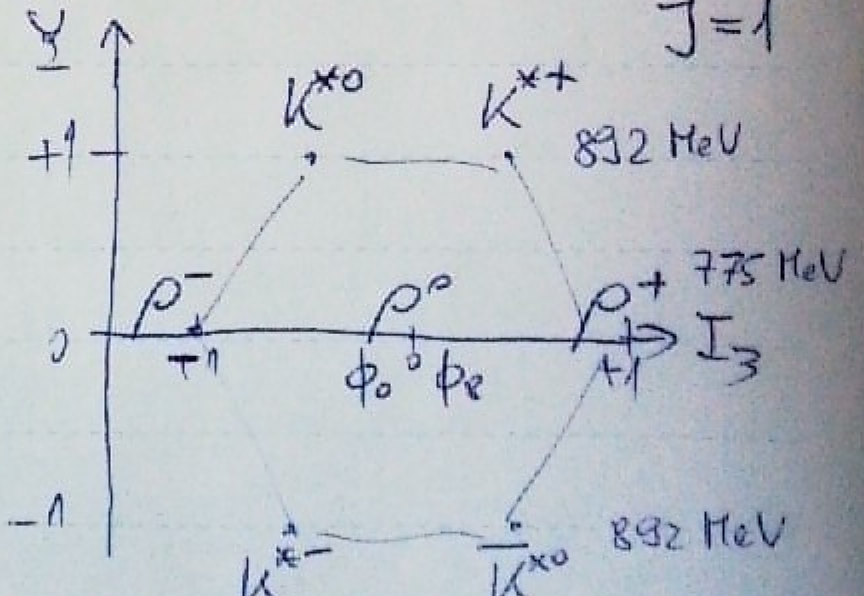
SPINSKI DEL VALOVNE FUNKCIJE ZA MEZONE

$$|\uparrow\uparrow\rangle = |S=1, S_3=+1\rangle$$
$$\hat{S}_-|\uparrow\uparrow\rangle \Rightarrow \frac{1}{\sqrt{2}}\left(|\downarrow\uparrow\rangle + |\uparrow\downarrow\rangle\right) = |S=1, S_3=0\rangle \qquad 2s+1$$
$$\hat{S}_-\frac{1}{\sqrt{2}}\left(|\downarrow\uparrow\rangle + |\uparrow\downarrow\rangle\right) \Rightarrow |\downarrow\downarrow\rangle = |S=1, S_3=-1\rangle$$

$$\frac{1}{\sqrt{2}}\left(|\downarrow\uparrow\rangle - |\uparrow\downarrow\rangle\right) = |S=0, S_3=0\rangle$$

$S=0=J$ $\qquad J=1$





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$J=0$ $|\eta_0\rangle, |\eta_8\rangle$

V NARAVI

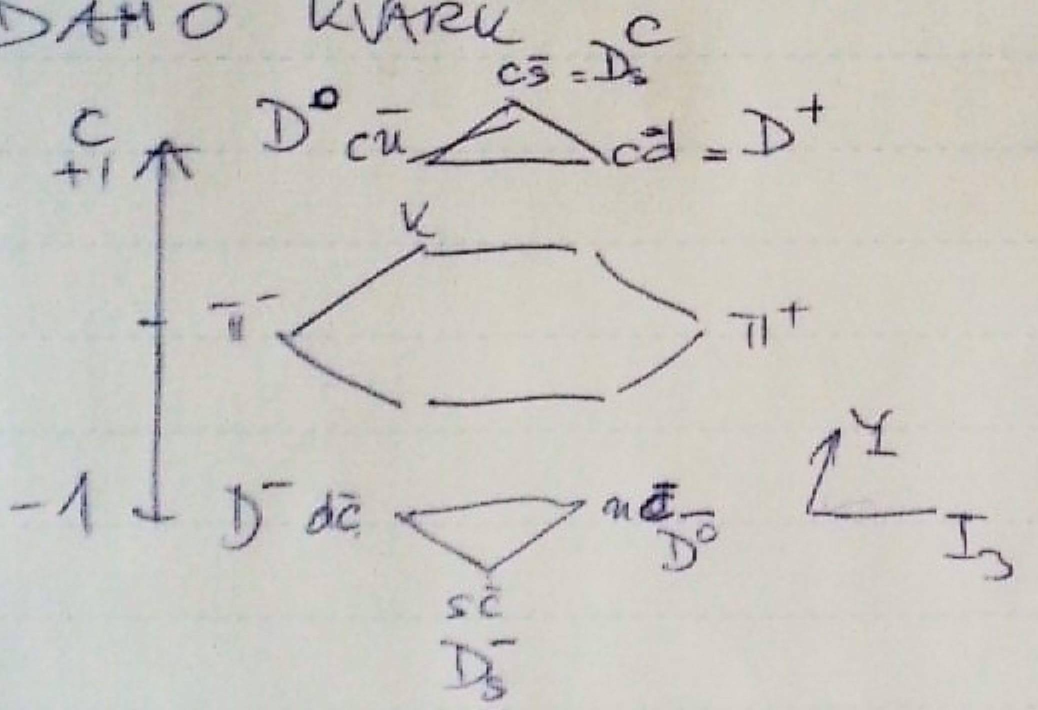
$$|\eta\rangle = \sin\Theta\,|\eta_0\rangle + \cos\Theta\,|\eta_8\rangle$$
$$|\eta'\rangle = \cos\Theta\,|\eta_0\rangle - \sin\Theta\,|\eta_8\rangle$$

$J=1$ $|\phi_0\rangle, |\phi_8\rangle$

$$|\phi\rangle = \sin\Theta'\,|\phi_0\rangle + \cos\Theta'\,|\phi_8\rangle$$
$$|\omega\rangle = \cos\Theta'\,|\phi_0\rangle - \sin\Theta'\,|\phi_8\rangle$$

$$|\phi\rangle \sim |s\bar{s}\rangle \quad , \Theta' = -0.615$$

DODAMO KVARK C



$J=0$

VERJETNOSTNA GOSTOTA, TOK DELCEV, ANTI DELCI

$$E = \frac{p^2}{2m} \qquad E \to \hat{E} = -i\hbar\frac{\partial}{\partial t} \quad \vec{p} \to \hat{\vec{p}} = -i\hbar\vec{\nabla}$$

$$\hat{E}\psi = \frac{\hat{p}^2}{2m}\psi \;\to\; i\hbar\frac{\partial\psi}{\partial t} + \frac{\hbar^2}{2m}\nabla^2\psi = 0$$

$|\psi|^2 = \psi^*\psi$ = VERJETNOSTNA GOSTOTA , $|\psi|^2 dV$

TOK DELCEV $\vec{j}$

KONTINUITETNA ENAČBA $\frac{\partial\rho}{\partial t} + \vec{\nabla}\vec{j} = 0$

$$i\hbar\frac{\partial\psi}{\partial t}+\frac{\hbar^2}{2m}\nabla^2\psi=0 \qquad \Big| -i\psi^*$$

$$-i\hbar\frac{\partial\psi^*}{\partial t}+\frac{\hbar^2}{2m}\nabla^2\psi^*=0 \qquad \Big| i\psi$$

$$\frac{\partial\psi}{\partial t}\psi^*-\frac{i\hbar}{2m}(\nabla^2\psi)\psi^*=0$$

$$\frac{\partial\psi^*}{\partial t}\psi+\frac{i\hbar}{2m}(\nabla^2\psi^*)\psi=0$$

$$\underbrace{\frac{\partial\psi}{\partial t}\psi^*+\frac{\partial\psi^*}{\partial t}\psi}+\frac{i\hbar}{2m}\left[(\nabla^2\psi^*)\psi-(\nabla^2\psi)\psi^*\right]=0$$

$$\frac{\partial}{\partial t}(\psi^*\psi)+\frac{i\hbar}{2m}\left[\psi(\nabla^2\psi^*)-\psi^*(\nabla^2\psi)\right]=0$$

$$0=\frac{\partial}{\partial t}(\psi^*\psi)+\frac{i\hbar}{2m}\nabla\left[\psi\vec\nabla\psi^*-\cancel{(\nabla\psi)(\nabla\psi^*)}-\psi^*\vec\nabla\psi+\cancel{(\nabla\psi^*)(\nabla\psi)}\right]$$

$$0=\frac{\partial}{\partial t}(\psi^*\psi)+\frac{i\hbar}{2m}\vec\nabla\left[\psi\vec\nabla\psi^*-\psi^*\vec\nabla\psi\right]$$

$$\frac{\partial\rho}{\partial t}+\vec\nabla\cdot\vec j=0 \Rightarrow \boxed{\vec j=\frac{i\hbar}{2m}\left[\psi\vec\nabla\psi^*-\psi^*\nabla\psi\right]}$$

NARAVNE ENOTE $\quad \hbar=1,\ c=1$

$\hbar c=197\ \mathrm{MeV\,fm}\ ,\ c=3\cdot10^8\ \frac{m}{s}$

$$\psi=\frac{1}{\sqrt V}e^{i\vec p\cdot\vec x-iEt} \qquad \Rightarrow \begin{matrix}p=k\\ E=\omega\end{matrix}$$

$$\rho=\psi^*\psi=\frac{1}{V} \qquad \vec j=\frac{i\hbar}{2m}\frac{1}{V}\left[-i\vec p-i\vec p\right]=\frac{2\vec p}{2m}\frac{1}{V}=$$

$$=\frac{1}{V}\cdot\vec v \qquad (\vec j=\rho\vec v)$$

KLEIN GORDONOVA E. $$-\frac{\partial^2\phi}{\partial t^2}+\nabla^2\phi = m^2\phi \;\Big|\cdot(-i\phi^*)$$

$$-\frac{\partial^2\phi^*}{\partial t^2}+\nabla^2\phi^* = m^2\phi^* \;\Big|\cdot(-i\phi)$$

$$i\left[\frac{\partial^2\phi}{\partial t^2}\phi^* - \frac{\partial^2\phi^*}{\partial t^2}\phi\right] - i\left[(\nabla^2\phi)\phi^* - (\nabla^2\phi^*)\phi\right]=0$$

$$\frac{\partial}{\partial t}\left[i\left(\phi^*\frac{\partial\phi}{\partial t}-\phi\frac{\partial\phi^*}{\partial t}\right)\right]+i\vec\nabla\left[\phi\vec\nabla\phi^*-\phi^*\vec\nabla\phi\right]=0$$

$$\frac{\partial\rho}{\partial t}+\vec\nabla\cdot\vec j=0$$

$$\vec j = i(\phi\vec\nabla\phi^* - \phi^*\vec\nabla\phi) \qquad \rho = i\left(\phi^*\frac{\partial\phi}{\partial t}-\phi\frac{\partial\phi^*}{\partial t}\right)$$

RAVNI VAL $\phi=\frac{1}{\sqrt V}e^{i\vec p\cdot\vec r - iEt}$ $\quad j=\frac{2\vec p}{V}$ $\quad \rho=\frac{2E}{V}$

NORMALIZACIJA : 1 DELEC NA V SCHRÖD.
2E DELCEV NA V KLEIN-GORDON

$$\left.\begin{array}{l} d^3x \xrightarrow[\text{LORENTZOVA T.}]{} dx^3\sqrt{1-(v/c)^2} \\ \rho \to \dfrac{\rho}{\sqrt{1-\frac{v^2}{c^2}}} \end{array}\right\} \rho\, d^3x \to \rho\, d^3x$$

CETVEREC ODVODOV $\partial^\mu=\left(\frac{\partial}{\partial t},-\vec\nabla\right)$ $\quad \partial_\mu=\left(\frac{\partial}{\partial t},\vec\nabla\right)$

$$\partial^\mu\partial_\mu=\sum_{\mu=0}^{3}\partial^\mu\partial_\mu=\frac{\partial^2}{\partial t^2}-\nabla^2$$

KLEIN-GORDONOVA E. $(\partial^\mu\partial_\mu+m^2)\phi=0$

KONTINUITETNA E. $\partial^\mu j_\mu=0$ $\quad j^\mu=(\rho,\vec j)$, $j_\mu=(\rho,-\vec j)$