E.M. INTERAKCIJA V NERELATIVISTIČNI LIMITI

$$[\gamma^\mu p_\mu + e\gamma^\mu A_\mu - m]\psi = 0 \qquad \gamma^\mu = (\beta, \beta\vec\alpha) \qquad A^\mu = (A_0, \vec A)$$

$$[\beta E - \beta\vec\alpha\vec p + e\beta A_0 - e\beta\vec\alpha\vec A - m]u = 0 \qquad 1\cdot\beta \text{ Z LEVE}$$

$$[E - \vec\alpha\vec p + eA_0 - e\vec\alpha\cdot\vec A - \beta m]u = 0$$

$$[\vec\alpha\cdot(\vec p + e\vec A) - eA_0 + \beta m]u = E u$$

$$\begin{bmatrix} m - eA_0 & \vec\sigma\cdot(\vec p + e\vec A) \\ \vec\sigma(\vec p + e\vec A) & -m - eA^0 \end{bmatrix}\begin{bmatrix} u_A \\ u_B \end{bmatrix} = E\begin{bmatrix} u_A \\ u_B \end{bmatrix}$$

↓ SKICIRAM BEŽNO, DETAJLI V GOLOB, ZAPISKI

$$(E + m + eA^0)^{-1}\vec\sigma(\vec p + e\vec A)u_A = u_B$$

$$\vec\sigma(\vec p + e\vec A)(E + m + eA^0)^{-1}\vec\sigma(\vec p + e\vec A)u_A = (E - m + eA^0)u_A$$

$$m \gg p, \quad m \gg eA^0 \qquad E - m + eA^0 = E_{NR} + eA^0$$

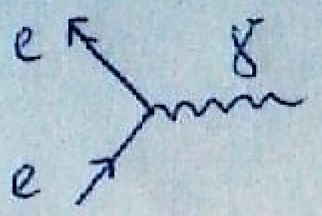
⋮

$$\left(\frac{(\vec p + e\vec A)^2}{2m} + \frac{e}{2m}\vec\sigma\cdot\vec B - eA^0\right)u_A = E_{NR}u_A$$

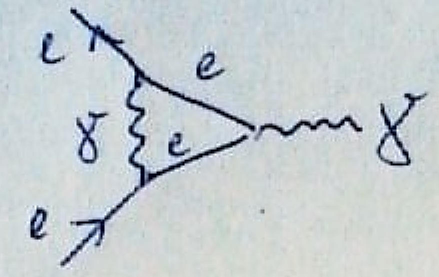
↑ $-\vec\mu\cdot\vec B$ ↑ ELEKTROST. INT.

$$-\frac{e}{2m}\vec\sigma = \vec\mu = -\frac{e}{2m}g_s\frac{\vec\sigma}{2} \Rightarrow g_s = 2$$

$$\vec\mu = -\frac{e}{2m}g_s\vec s$$



1. RED PERTURBACIJSKEGA RAZVOJA



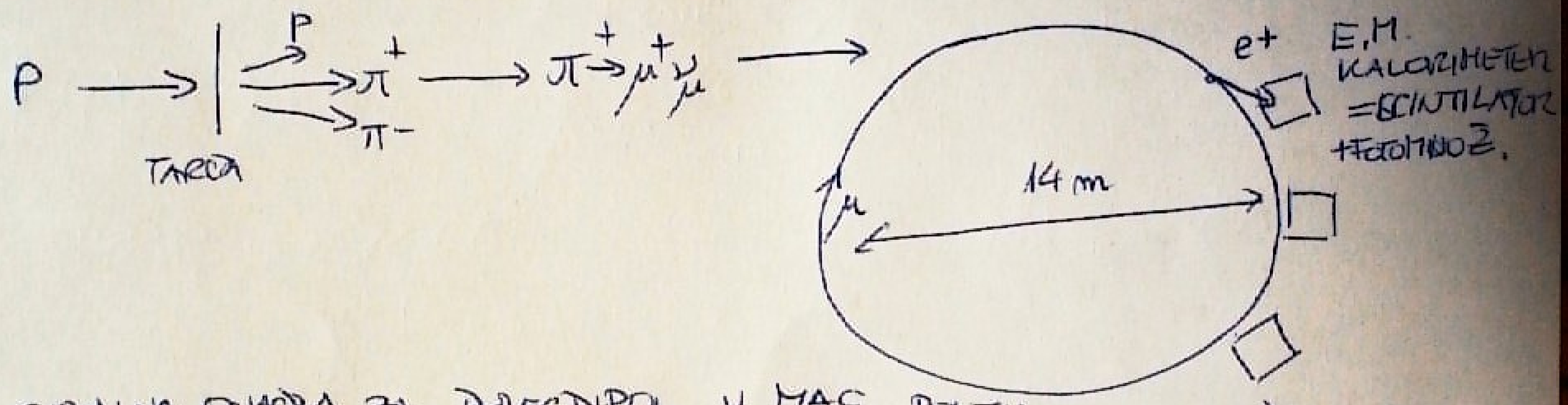
$\Rightarrow g_s \neq 2$

TUDI ZA MION VELJA PODOBNO

$$\frac{g_s(\mu)-2}{2}$$

NAJBOLJ NATANČEN POSKUS IN RAČUN V FIZIKI DELCEV

$$(g_s-2)_\mu = 11{,}659214 \cdot 10^{-4}$$



GIBALNA ENAČBA ZA ~~ELEC~~ DIPOL V MAG. POLJU

→ $g_s = 2$ ⇒ M. DIPOL VRTI SKUPAJ S $\vec{p}$

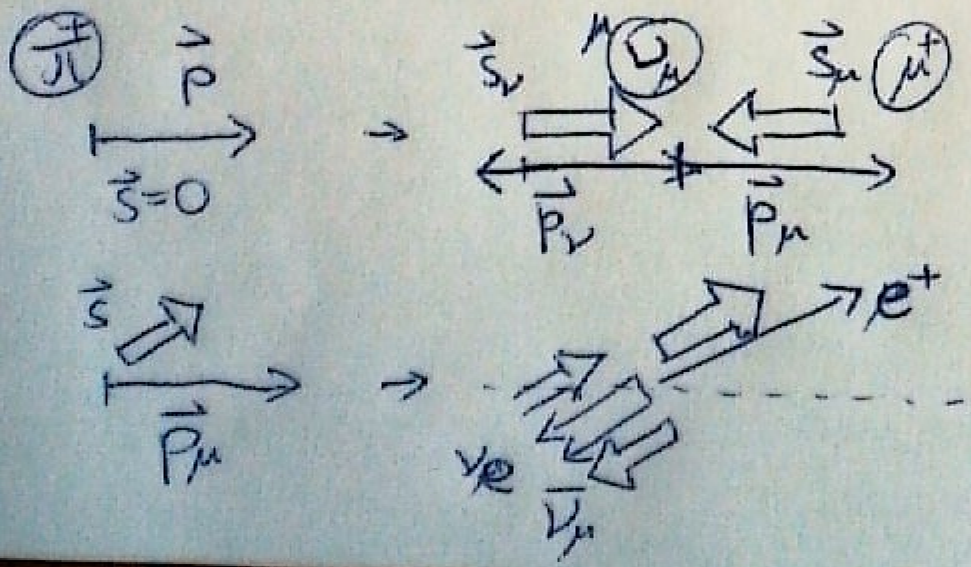
NA ZAČETKU VZPOREDNA → VES ČAS VZPOREDNA

IDEJA EKSPERIMENTA: MERIMO FREKVENCO VRTENJA $\vec{\mu}$ GLEDE NA $\vec{p}$

(1.) ZAČETNO STANJE (KO μ MION VSTOPI V OBROČ)

$\vec{p} \parallel \vec{\mu} \parallel \vec{s}$

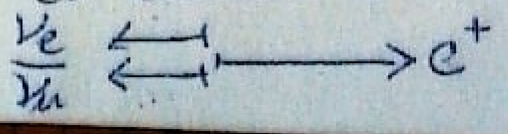
SPIN ν_μ JE VEDNO NASPROTEN $\vec{p}_\nu$

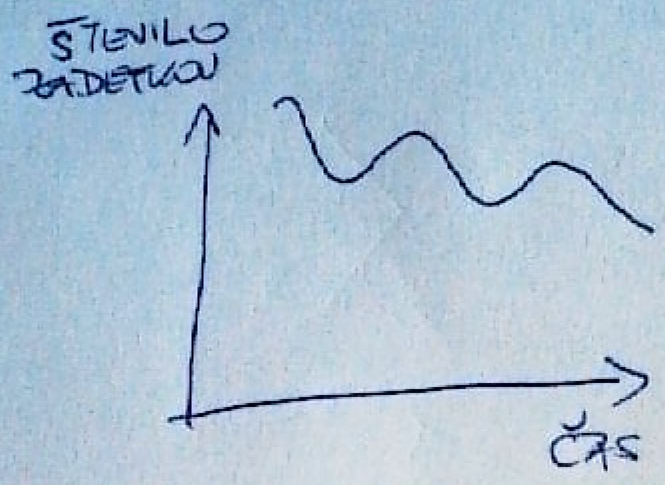


NASTAVEK

RAZPAD $\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$

ČE IZBEREM e^+ MAX. MOŽNA





MERIMO TIPIČNO ~~[illegible]~~ $t > 700\,\mu s$

$\tau_\mu = 2.1\,\mu s$

VELIKA TEMA: EKSPERIMENT IN TEORIJA SE NE UJEMATA DO POTANKOSTI.

NORMALIZACIJA REŠITEV DIRACOVE ENAČBE ZA PROST DELEC

KLEIN-GORDONOVA E. → REŠITVE NORMIRAMO NA VOLUMEN NA 2E DELCEV V VOLUMNU.

ISTA NORMALIZACIJA TUDI PRI DIR. ENAČBI

$$\rho = \bar{\psi}\gamma^0\psi = \psi^+\psi \qquad \bar{\psi}\gamma^0 = \psi^+\gamma^0\gamma^0 = \psi^+$$

$$\psi = \frac{1}{\sqrt{V}} e^{ipx} u$$

$$\int \psi^+\psi \, dV = u^+u = 2E$$

$$u^{(s)} = N \begin{bmatrix} \chi^{(s)} \\ \frac{\vec{\sigma}\cdot\vec{p}}{E+m}\chi^{(s)} \end{bmatrix}$$

$$u^+u = |N|^2 \left[\chi^{(s)T} \quad \left[\frac{\vec{\sigma}\cdot\vec{p}}{E+m}\chi^{(s)}\right]^T\right] \begin{bmatrix} \chi^{(s)} \\ \frac{\vec{\sigma}\cdot\vec{p}}{E+m}\chi^{(s)} \end{bmatrix}$$

$$(\vec{\sigma}\cdot\vec{p})(\vec{\sigma}\cdot\vec{p}) = \vec{p}^{\,2}$$

$$= |N|^2 \left(1 + \chi^{(s)T} \frac{(\vec{\sigma}\cdot\vec{p})^T}{E+m} \frac{(\vec{\sigma}\cdot\vec{p})}{E+m} \chi^{(s)}\right) =$$

$$= |N|^2 \left(1 + \frac{p^2}{(E+m)^2}\right) = |N|^2 \left(\frac{(E+m)^2 + p^2}{(E+m)^2}\right)$$

$$= |N|^2 \left(\frac{2E}{E+m}\right) = 2E \qquad E^2 + 2mE + m^2 + p^2 = 2E(E+m)$$

ZAHTEVA

$$\Rightarrow |N| = \sqrt{E+m}$$

$$[\gamma^\mu p_\mu - m]\psi = 0 \quad \Rightarrow \quad [\not p - m]\psi = 0$$

DEFINICIJA ZA POLJUBEN ČETVEREC a_μ

$$\not a = \gamma^\mu a_\mu$$

LASTNOST BISPINORJEV

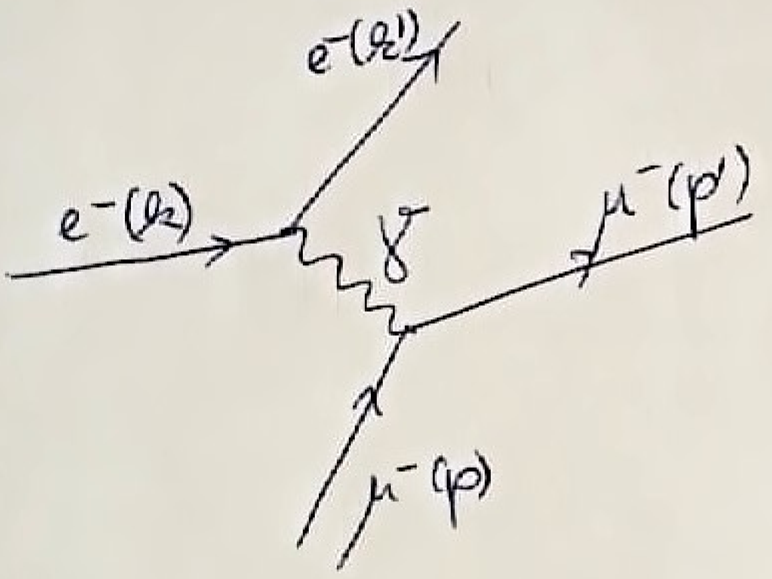
$$\boxed{\sum_{s=1,2} u^{(s)}(p)\,\bar u^{(s)}(p) = \not p + m}$$

← 4x4 MATRIKA

POLNOSTNA RELACIJA

ELEKTROMAGNETNO SIPANJE DIRACOVIH DELCEV

1. PRIMER $e^-\mu^- \to e^-\mu^-$



$$T_{fi} = -i\int j^e_\nu\left(-\frac{1}{q^2}\right) j^\nu_\mu \, d^4x$$

$$j^e_\nu = -e\,\bar u(k')\gamma_\nu u(k)\, e^{i(k-k')x}$$

$$j^\mu_\nu = -e\,\bar u(p')\gamma_\nu u(p)\, e^{i(p-p')x}$$

$$T_{fi} = -i\left[-e\,\bar u(k')\gamma_\nu u(k)\right]\left(\frac{-1}{q^2}\right)\left[-e\,\bar u(p')\gamma^\nu u(p)\right]\underbrace{\int e^{i(k'+p'-k-p)x}\,d^4x}_{(2\pi)^4\delta^4(k'+p'-k-p)}$$

$$T_{fi} = -(2\pi)^4\delta^4(k'+p'-k-p)\,\mathcal{M}$$

$\Rightarrow$ OHRANITEV $E, \vec p$

$$-i\mathcal{M} = \left[-e\,\bar u(k')\gamma^\kappa u(k)\right]\left(\frac{-g_{\kappa\nu}}{q^2}\right)\left[-e\,\bar u(p')\gamma^\nu u(p)\right]$$

$\mathcal{M}$ INVARIANTNA AMPLITUDA

$$g_{\kappa\nu}\gamma^\nu = \gamma_\kappa$$

NEPOLARIZIRANI PRESEK

s_1, s_2: POLARIZIRANI e, μ

s_3, s_4: MERIM POLARIZACIJO (SMER SPINA)

$$\underset{s_1\ \ s_2}{e^- \mu^-} \to \underset{s_3\ \ s_4}{e^- \mu^-}$$

NEPOLARIZIRAN PRESEK: SIPALNI PRESEK ZA 'NEPOLARIZIRANE' VPADNE DELCE IN ZA PRIMER, KO NE MERIM SPINOV V KONČNEM STANJU.

$$\sigma \propto |\mathcal{M}|^2$$

POLARIZIRAN PRESEK

$$\sigma \propto |\mathcal{M}_{s_1 s_2 s_3 s_4}|^2$$

NEPOLARIZIRAN PRESEK

$$\sigma \propto \frac{1}{(2s_a+1)(2s_b+1)} \sum_{s_1, s_2, s_3, s_4} |\mathcal{M}_{s_1, s_2, s_3, s_4}|^2$$

s_a, s_b ZA NAŠ PRIMER: $s_e = \frac{1}{2}$, $s_\mu = \frac{1}{2}$

$$\frac{1}{(2s_a+1)(2s_b+1)} = \frac{1}{4}$$

ZAKAJ

$$\sum |\mathcal{M}_{s_1, s_2, s_3, s_4}|^2 \quad \text{IN NE} \quad \cancel{\left|\sum \mathcal{M}_{s_1, s_2, s_3, s_4}\right|^2}$$

ZATO, KER <u>LAHKO</u> SPINE V ZAČETKU IN NA KONCU <u>V PRINCIPU IZMERIMO</u>. SEŠTEVANJE AMPLITUD PRIDE V POŠTEV, KADAR PROCESI <u>NISO</u> LOČLJIVI.