



# 素粒子宇宙起源研究機構

Kobayashi-Maskawa Institute for the Origin of Particles and the Universe

## OSNOVNI DELCI

SPIN  $\frac{1}{2}$  IN SO TOREJ FERMIONI

LEPTONI

$e^-$        $\mu^-$        $\tau^-$   
 $\nu_e$        $\nu_\mu$        $\nu_\tau$

KVARKI

$u$        $c$        $t$        $+\frac{2}{3}e_0$   
 $d$        $s$        $b$        $-\frac{1}{3}e_0$

KVARKI NASTOPIJO SAMO V VEZANIH STANJIH

MEZONI

$q\bar{q}$

BARIONI

$qqq$

## INTERAKCIJE

ELEKTROMAGNETNA

ŠIBKA

MOČNA

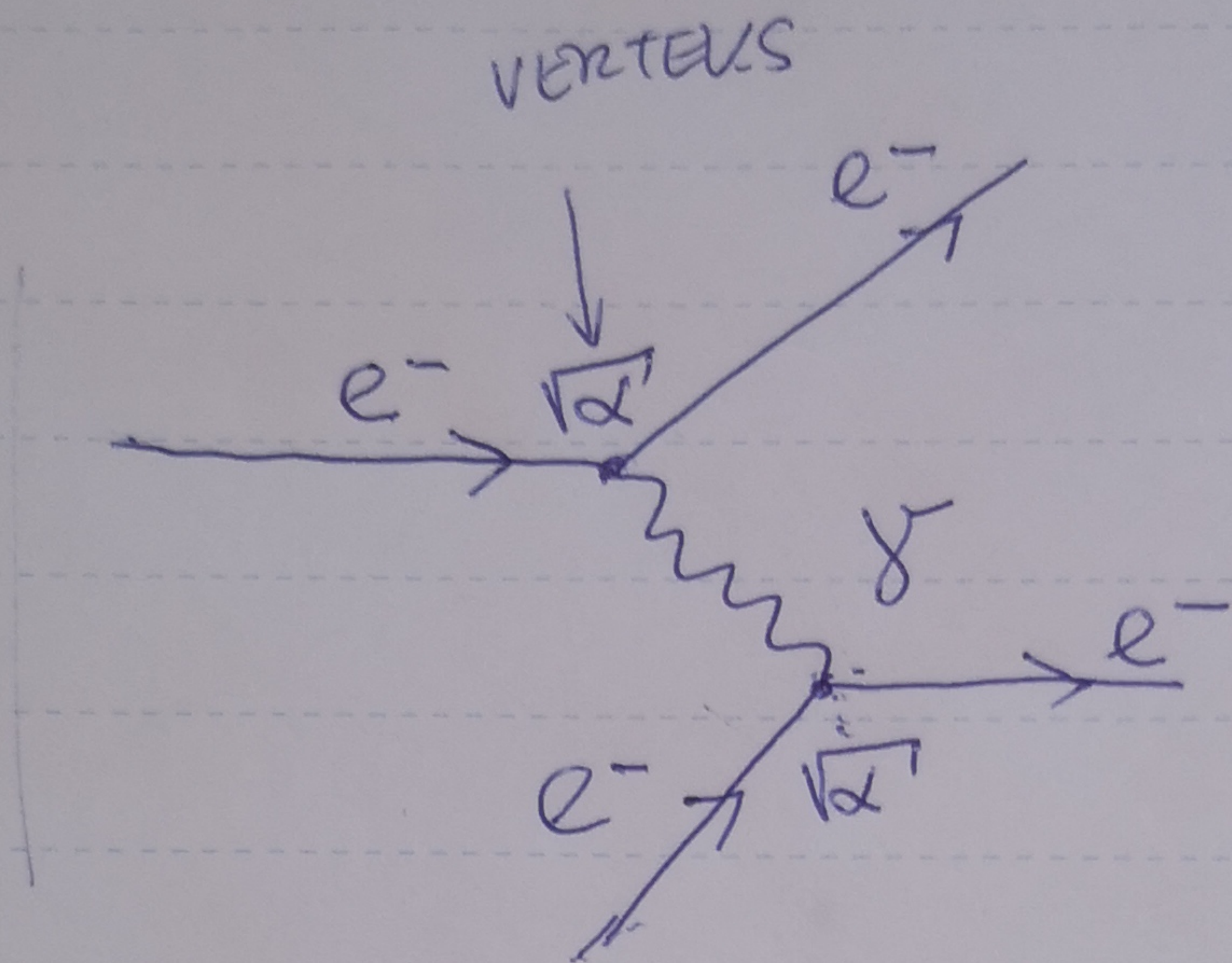
FOTON

ŠIBKI BOZON  $W^\pm, Z^0$

GLUONI



ELEKTROMAGNETNA INTERAKCIJA



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

$$g: E_\gamma \neq p_\gamma c$$

VIRTUALNI FOTON

$$e^- e^- \rightarrow e^- e^-$$

$$\frac{e^2}{4\pi\epsilon_0} = \frac{e^2}{4\pi\epsilon_0 \hbar c} \cdot \hbar c = \alpha \hbar c$$

$$\alpha = \frac{1}{137}$$

KONSTANTA FINE STRUCTURE

$$|V_{fi}| \propto \frac{e^2}{4\pi\epsilon_0} = \alpha \hbar c$$

$$E = T + V$$

$$\hat{E}\psi = \hat{T}\psi + V\psi$$

$$E^2 = p^2 c^2 + m^2 c^4$$

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





$$\hat{E} = i\hbar \frac{\partial}{\partial t} \quad \hat{p} = -i\hbar \vec{\nabla}$$

$$-\hbar^2 \frac{\partial^2}{\partial t^2} \psi = -\hbar^2 \nabla^2 c^2 \psi + m^2 c^4 \psi$$

VAL. ENACBA ZA  
PROST DELEC

KLEIN-GARDONOVA ENACBA

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

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

VALOVNA ENACBA  
ZA ETI VALOVANJE

STACIONARNA RASTEN  
 $u$

$$\frac{\partial \psi u}{\partial t} = 0$$

$$u = u(r)$$

$$\nabla^2 u = \frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial u}{\partial r} \right) = 0 \quad \Rightarrow u = \frac{q}{r}$$

$$q = \frac{e^2}{4\pi\epsilon_0}$$

$\Rightarrow u =$  ELEKTROST. POT.

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

$$u = \frac{q}{r} e^{-\frac{r}{R}}$$

$$R = \frac{\hbar}{mc}$$

~~KONONEN~~





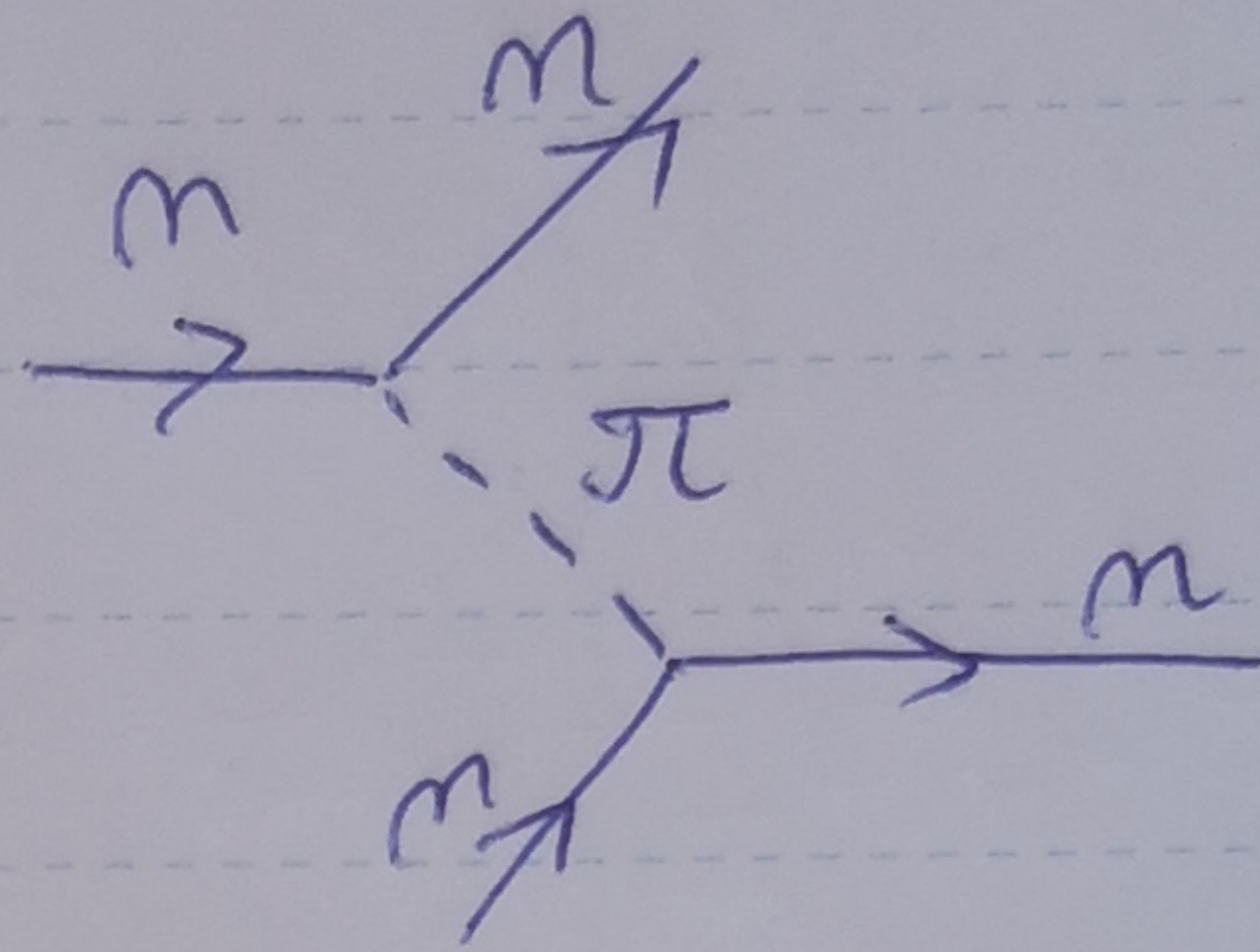
$m \neq 0 \Rightarrow$  POTENCIAL S KONONIM DOSEGOM

HIDEKI YUKAWA! MOŃNA INTERAKCIJA (KONONIM DOSEG)

$\Rightarrow$  NOSILCI MASIVNI DECI! DOSEG  $\rightarrow$  MASA

MEZONI

OCENA  $\sim 100$  MeV



$$\frac{e^{-mR}}{R}$$

YUKAWAN POTENCIAL