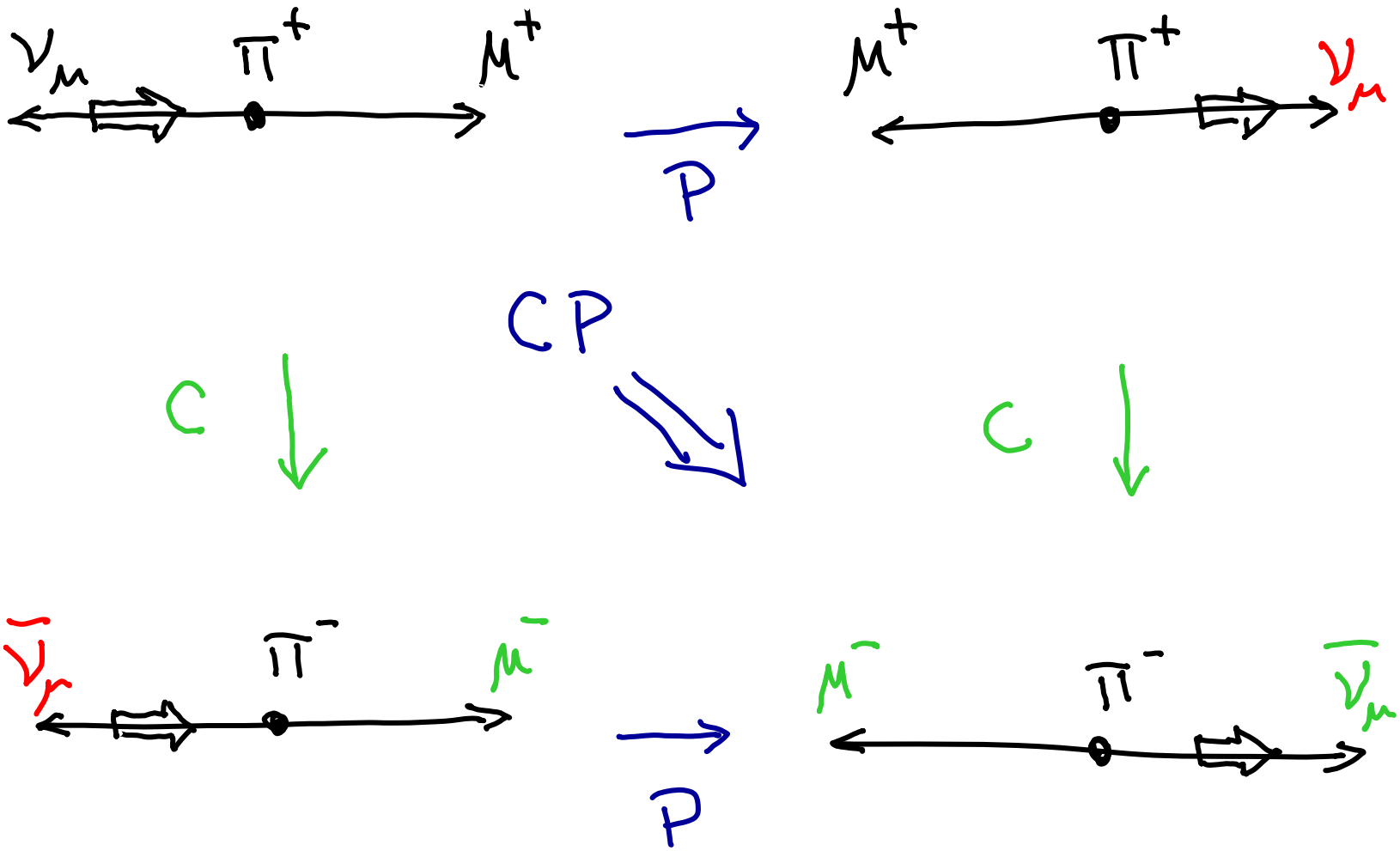
VIII. Slabi procesi (III)

RASPADI PIONA I KAONA

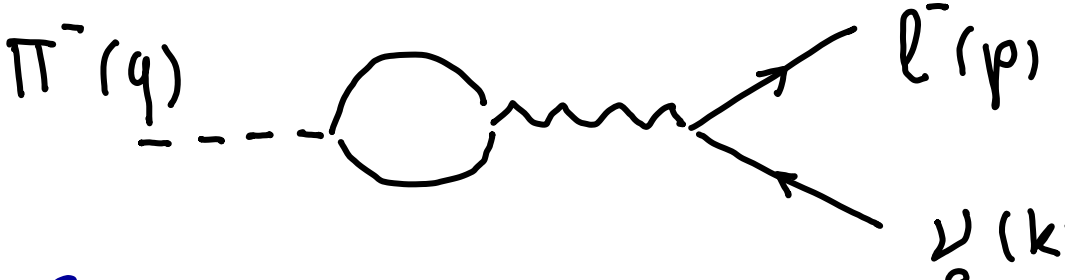
- RASPAD NABIJENOG PIONA I POTISNUĆE HELICITETOM
- RASPADI NABIJENIH I NEUTRALNIH KAONA (ODSUTNOST FCNC)

RASPAD NABIJENOG PIONA

- **POTISNUĆE HELICITETOM (za fazni prostor usp. DZ)**
- **JEDNAKOST CP-KONJUGIRANIH RASPADA (u slabim raspadima C-narušenje dolazi zajedno s P-narušenjem):**


ν_μ
π^+
μ^+
P
μ^+
π^+
ν_μ
C
CP
C
$\bar{\nu}_\mu$
π^-
μ^-
P
μ^-
π^-
$\bar{\nu}_\mu$

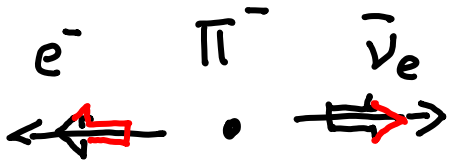
RASPAD NABIJENOG PIONA



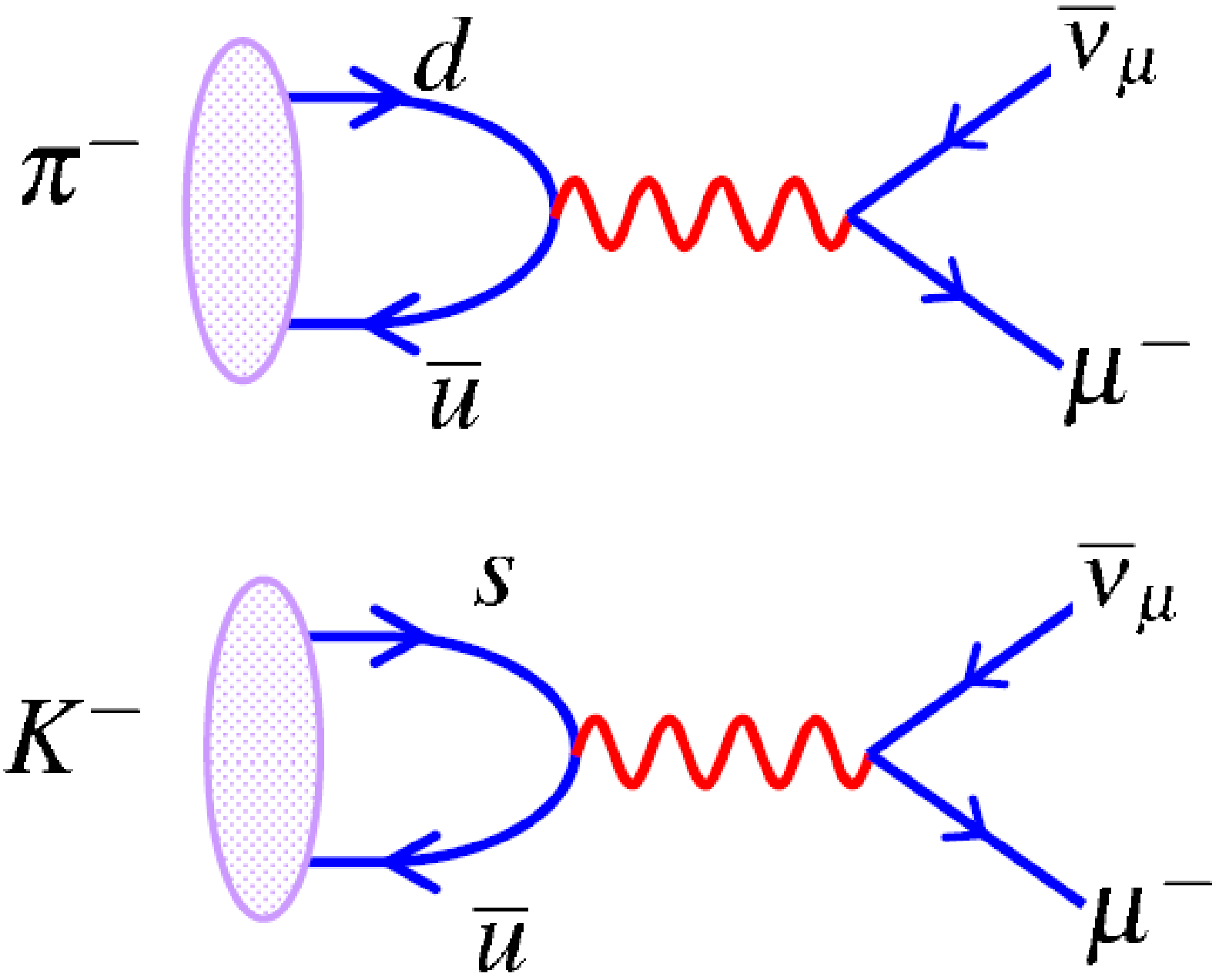
$$M = \frac{G_F}{\sqrt{2}} \bar{u}_\ell \gamma^\alpha (1-\gamma_5) v_{\nu_e} \underbrace{\langle 0 | J_\alpha^{hadr} | \pi^- \rangle}_{= i f_\pi q}$$

$$\overline{|M|^2} = 4 G_F^2 f_\pi^2 m_\ell^2 (p \cdot k)$$

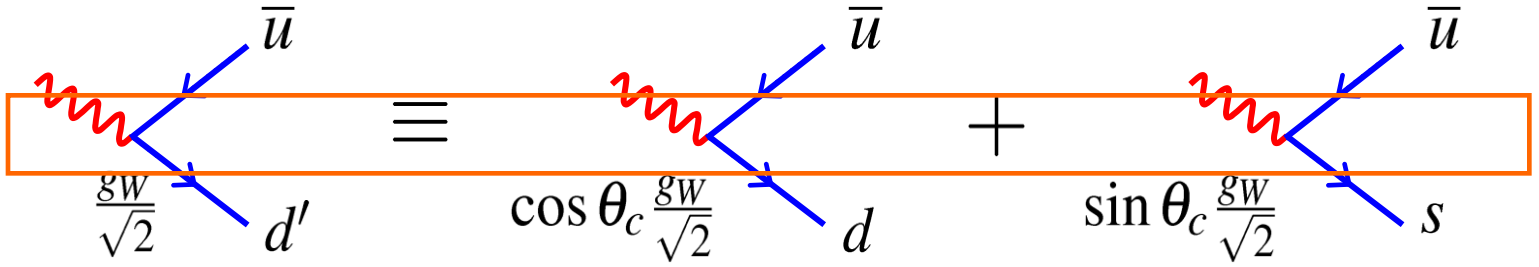
$$\Gamma = \frac{G_F^2}{8\pi} f_\pi^2 m_\ell^2 m_\pi \left(1 - \frac{m_\ell^2}{m_\pi^2}\right)^2$$



POTISNUĆE HELICITETOM


π^-
d
$\bar{u}$
$\bar{\nu}_\mu$
μ^-
K^-
s
$\bar{u}$
$\bar{\nu}_\mu$
μ^-

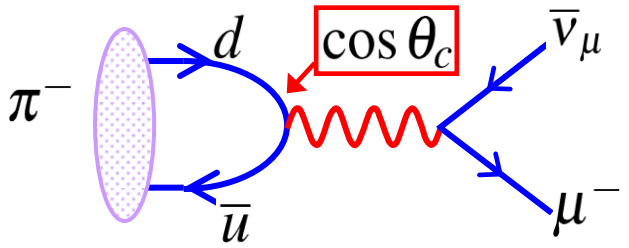
i.e. weak interaction couples different generations of quarks

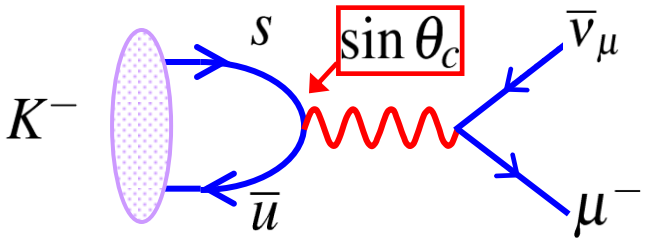


(The same is true for leptons e.g. $e^- \nu_1$, $e^- \nu_2$, $e^- \nu_3$ couplings – connect different generations)

★ Can explain the observations on the previous pages with $\theta_c = 13.1^\circ$

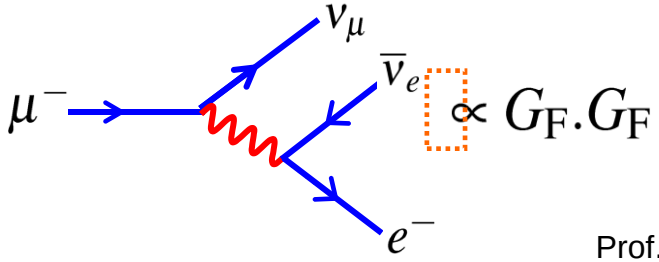
•Kaon decay suppressed by a factor of $\tan^2\theta_c \approx 0.05$ relative to pion decay



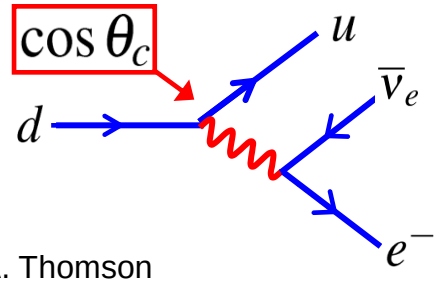


$$\Gamma(\pi^- \to \mu^- \bar{\nu}_\mu) \propto |M|^2 \propto \cos^2\theta_c \qquad \Gamma(K^- \to \mu^- \bar{\nu}_\mu) \propto |M|^2 \propto \sin^2\theta_c$$

- Hence expect $G_F^\beta = G_F^\mu \cos\theta_c$

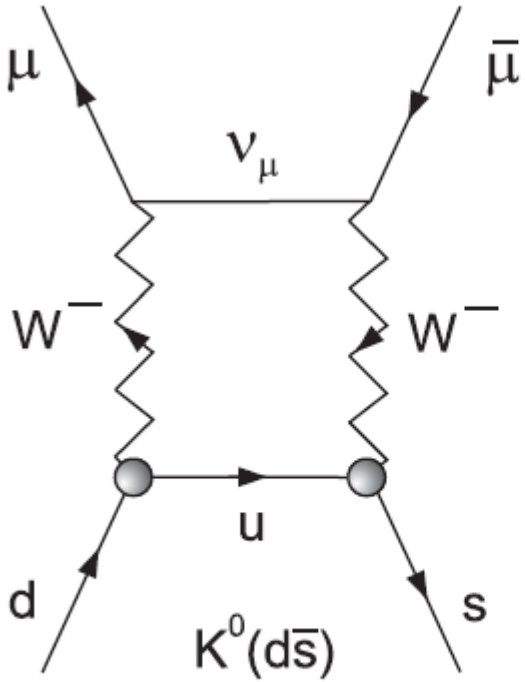


$\propto G_F . G_F$



$\propto G_F . (G_F \cos^2\theta_c)$

ODSUTNOST FCNC

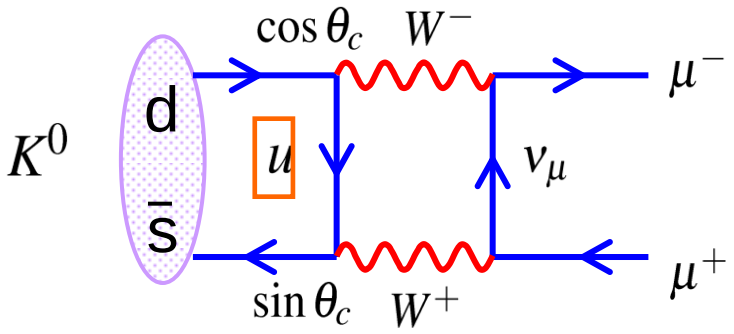


$\cos\Theta_C \sin\Theta_C$

Slika 5.13: *Sastavnica raspada* $K_L \to \mu^-\mu^+$

GIM Mechanism

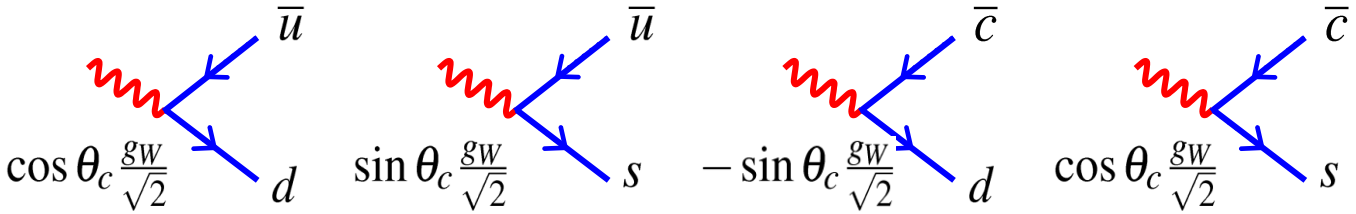
★ In the weak interaction have couplings between both ud and us which implies that neutral mesons can decay via box diagrams, e.g.



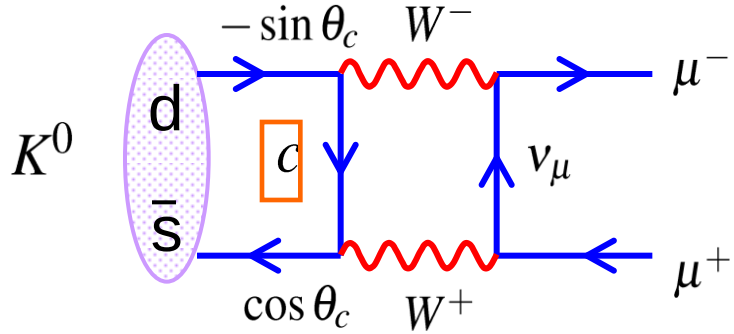
$$M_1 \propto g_W^4 \cos\theta_c \sin\theta_c$$

•Historically, the observed branching was much smaller than predicted

★ Led Glashow, Illiopoulos and Maiani to postulate existence of an extra quark - before discovery of charm quark in 1974. Weak interaction couplings become



★ Gives another box diagram for $K^0 \rightarrow \mu^+\mu^-$



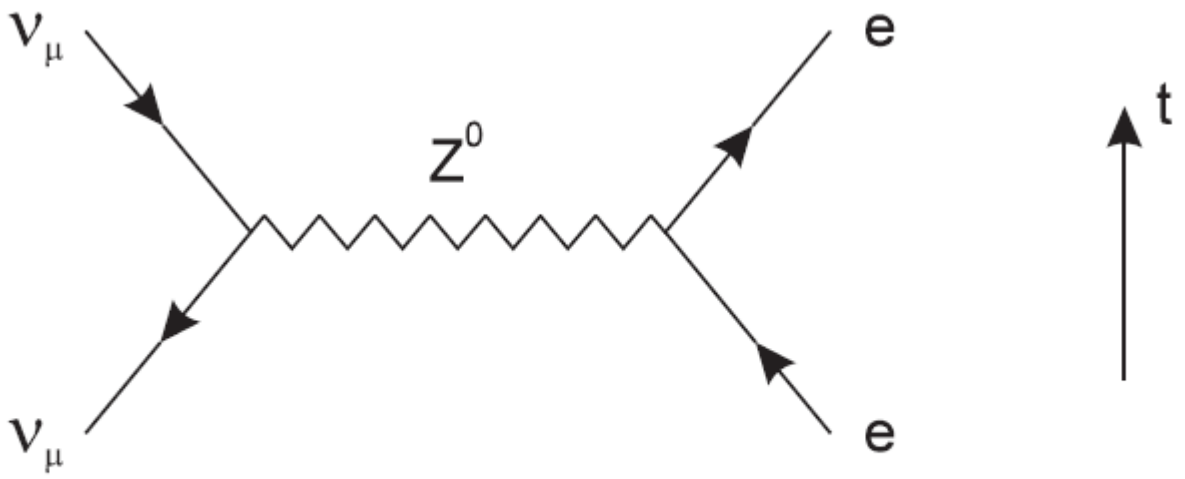
$$M_2 \propto -g_W^4 \cos\theta_c \sin\theta_c$$

•Same final state so sum amplitudes

$$|M|^2 = |M_1 + M_2|^2 \approx 0$$

•Cancellation not exact because $m_u \neq m_c$

OTKRIĆE NEUTRALNIH STRUJA (CERN 1973)

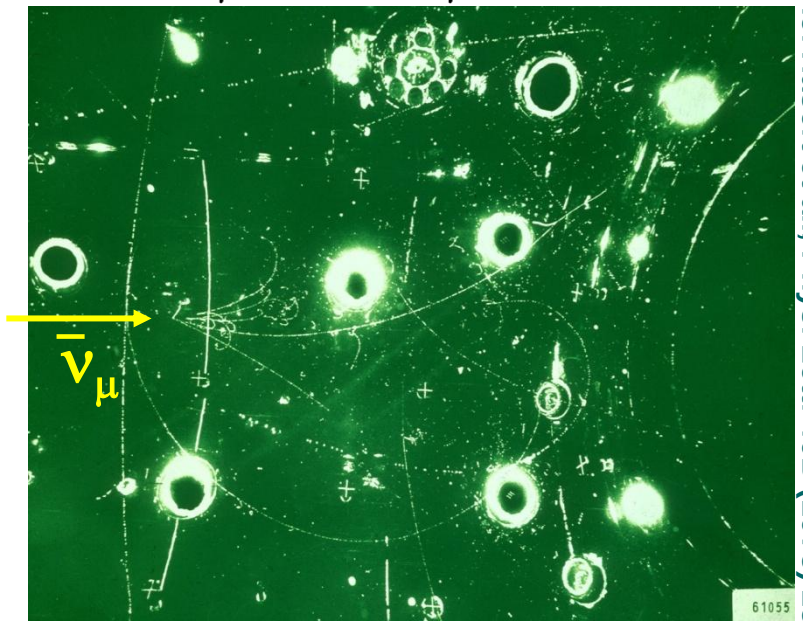


Slika 5.15: *Proces s neutralnim strujama na **CERN**-u*

Weak Neutral Current

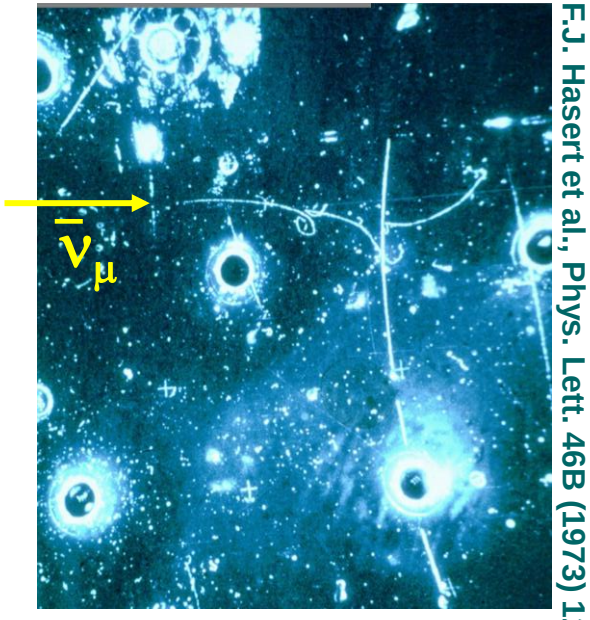
★ **Neutrinos also interact via the Neutral Current. First observed in the Gargamell bubble chamber in 1973. Interaction of muon neutrinos produce a final state mu**

$\overline{\nu}_\mu + N \rightarrow \overline{\nu}_\mu + \text{hadrons}$



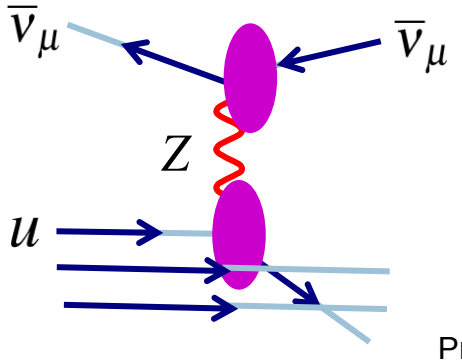
F.J. Hasert et al., Phys. Lett. 46B (1973) 138

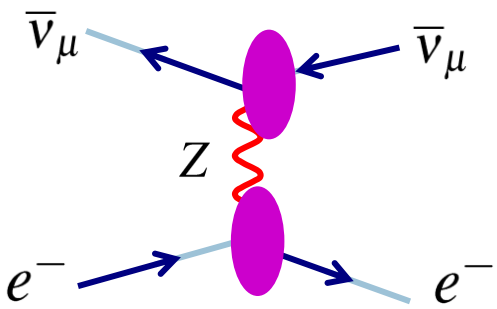
$\overline{\nu}_\mu + e^- \rightarrow \overline{\nu}_\mu + e^-$



F.J. Hasert et al., Phys. Lett. 46B (1973) 121

★ **Cannot be due to W exchange - first evidence for Z boson**



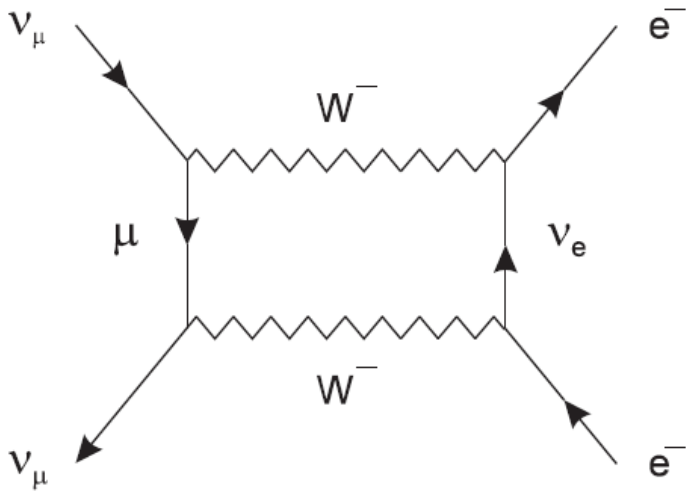


$$\bar{\nu}_\mu + e \rightarrow \bar{\nu}_\mu + e$$

$$\begin{aligned} \bar{\nu}_\mu + N &\rightarrow \bar{\nu}_\mu + X \\ \nu_\mu + N &\rightarrow \nu_\mu + X \end{aligned}$$

$$\sigma_{neutralni} \simeq \frac{1}{3}\sigma_{nabijeni}$$

- **u usporedbi s potisnutim**



Slika 5.16: *Potisnut W proces višeg reda*