Introduzione ai principi fondamentali della fisica delle particelle

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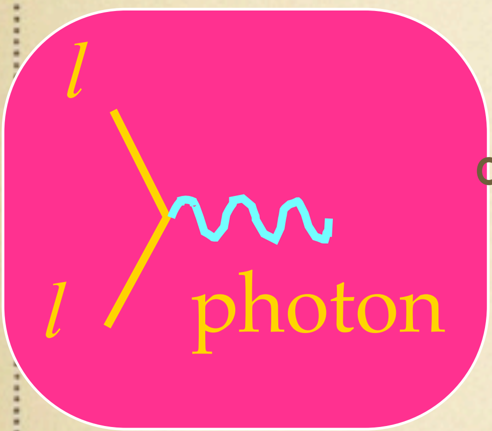
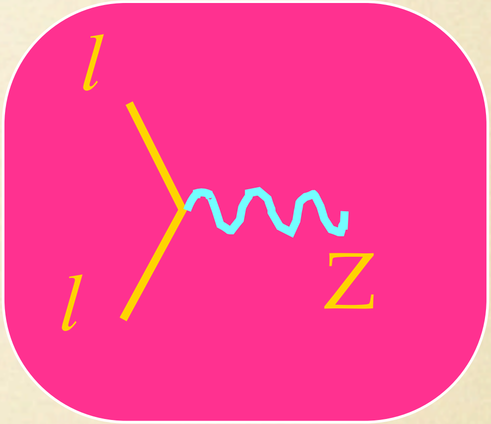
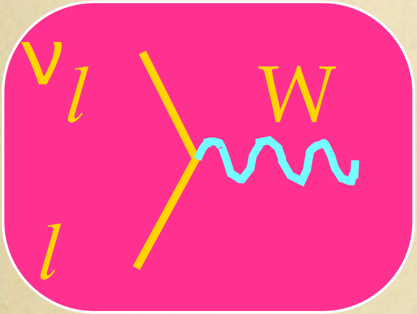
Visita CERN professori di fisica italiani

Lepton Interactions (l=e,μ,τ)

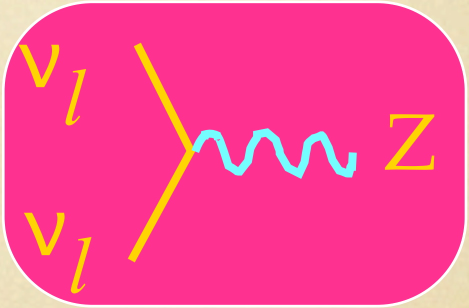


∝ -e=electric charge



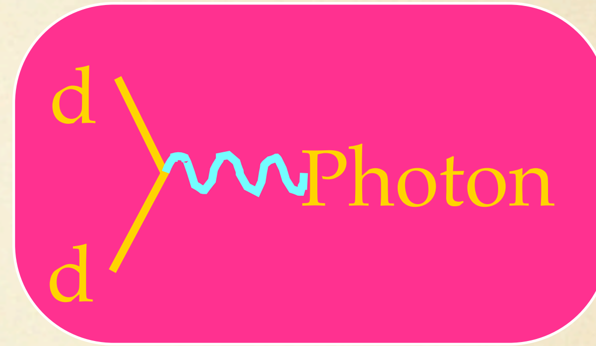


∝ g_W=weak charge

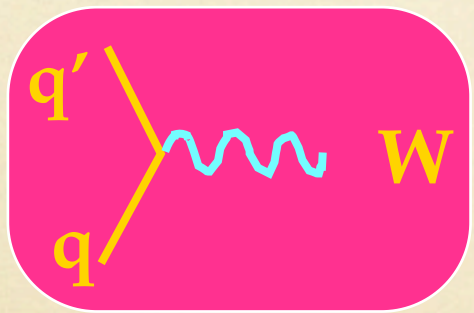


Quark Interactions

$\propto 2/3\ e$



$\propto -1/3\ e$

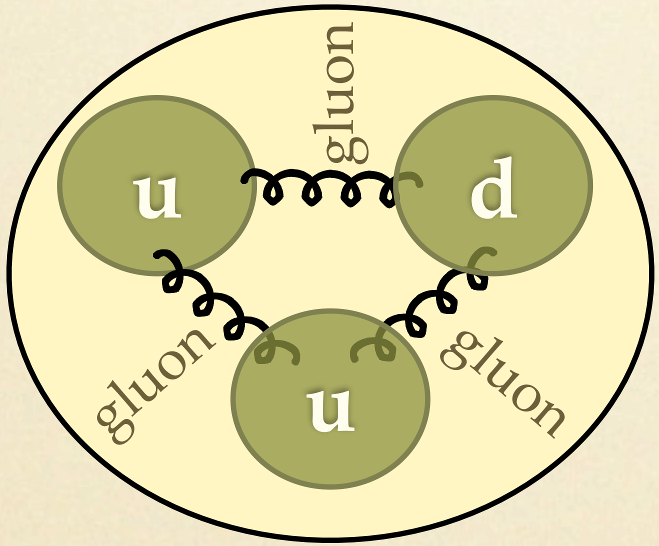


$\propto g_W$

$\propto g_s$ =strong coupling

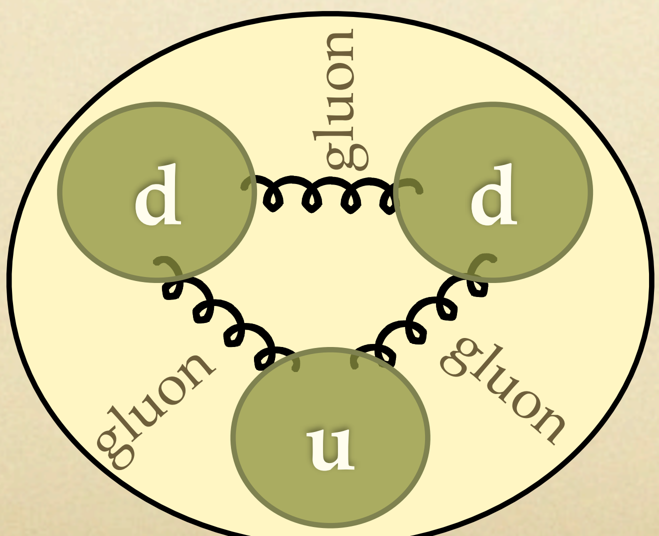
Example

Proton



Q = 2/3 e +2/3 e –1/3 e
= e

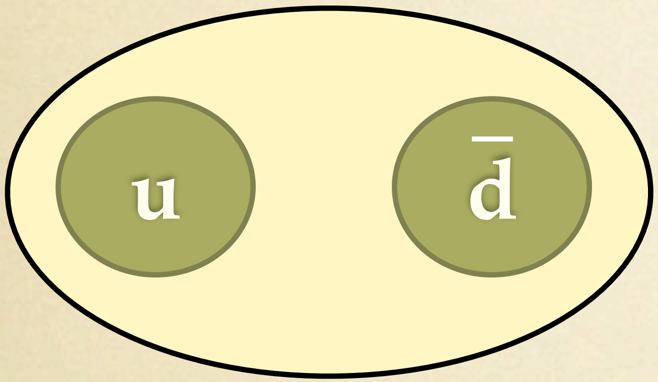
Neutron



Q = 2/3 e –1/3 e –1/3 e
= 0

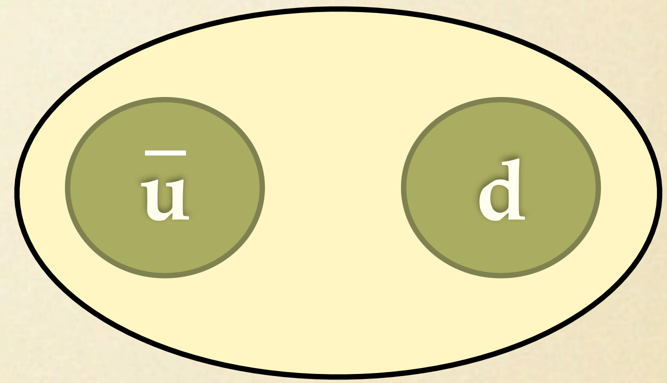
Esempio, i "pioni"

$\pi^+ = u\bar{d}$



$Q = 2/3\ e + (-)(-1/3)\ e = e$

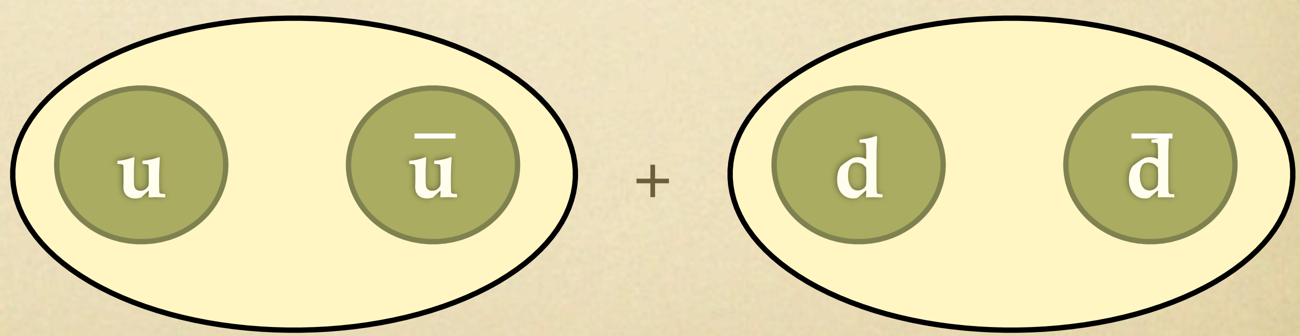
$\pi^- = \bar{u}d$



$Q = -\,2/3\ e + (-1/3)\ e = -\,e$

dove $\bar{\mathbf{q}}$ e' l'**antiquark** del quark **q**

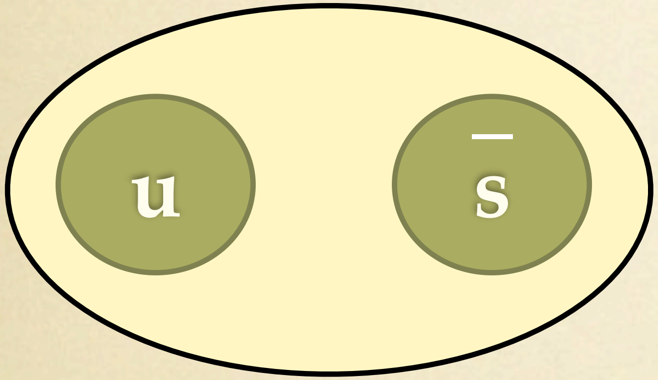
$\pi^0 = d\,\bar{d} + u\,\bar{u}$



$Q = 0$

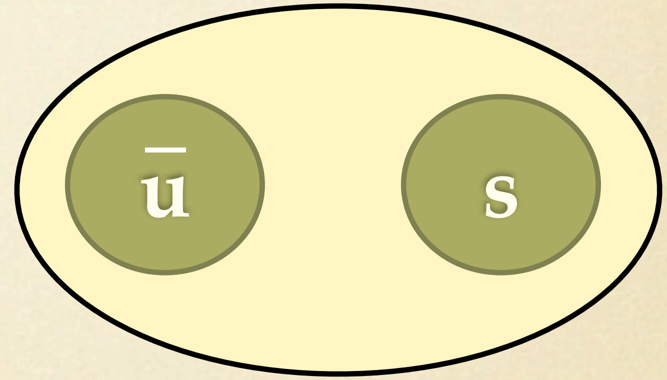
Esempio, i “kaoni”

$K^+ = u\bar{s}$



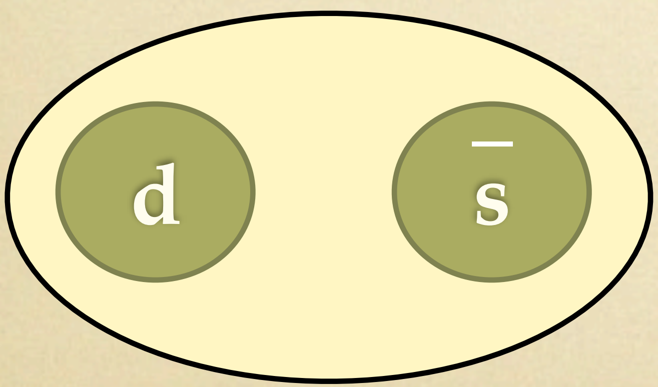
$Q = 2/3\ e + (-)(-1/3)\ e = e$

$K^- = \bar{u}s$



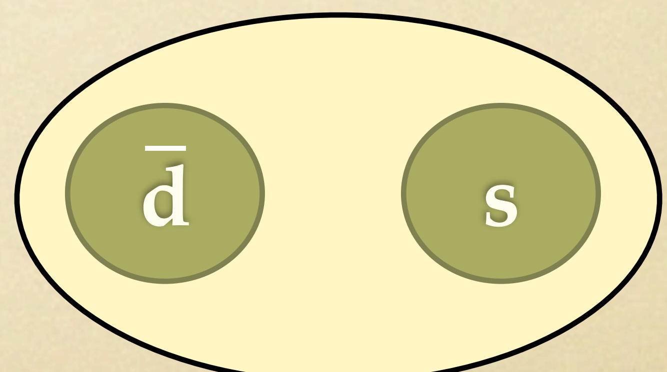
$Q = -\ 2/3\ e + (-1/3)\ e = -\ e$

$\bar{K}^0 = d\ \bar{s}$



$Q = -1/3\ e + (-)(-1/3)\ e = 0$

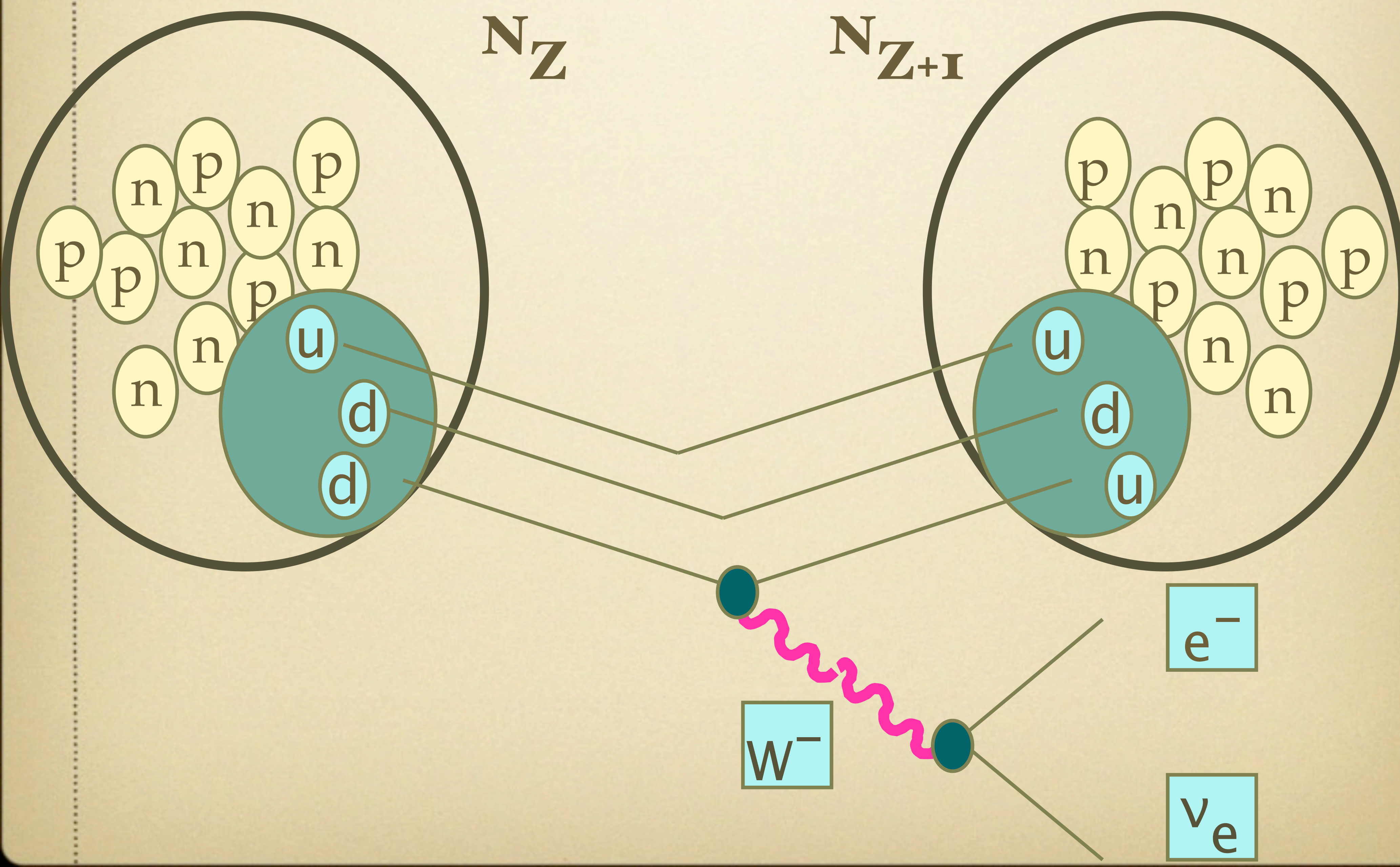
$K^- = \bar{d}s$



$Q = (-)(-1/3)\ e\ \ + (-1/3\ e) = 0$

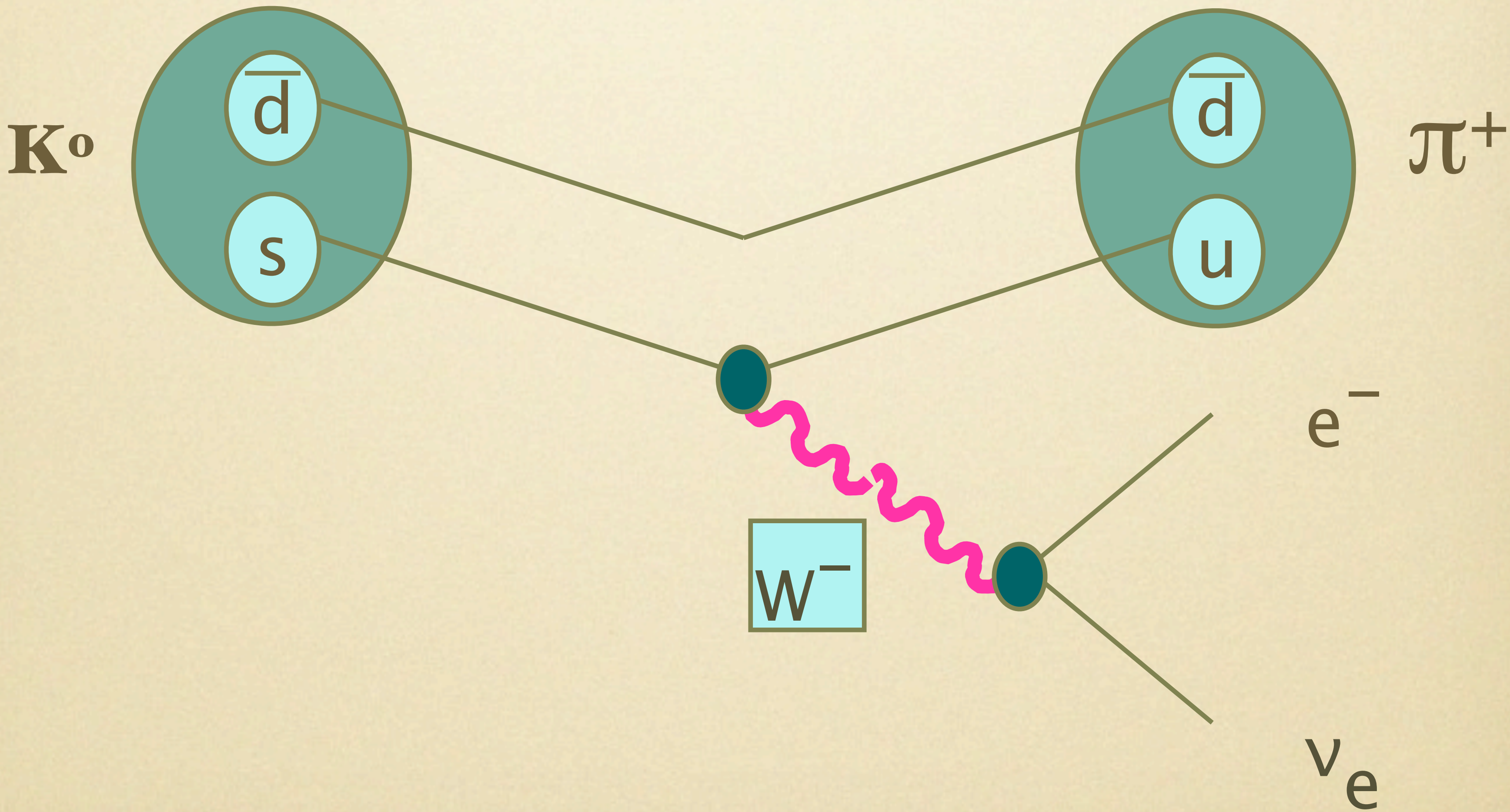
Example: radioactivity

$N_Z \rightarrow N_{Z+1}\, e\, \nu$



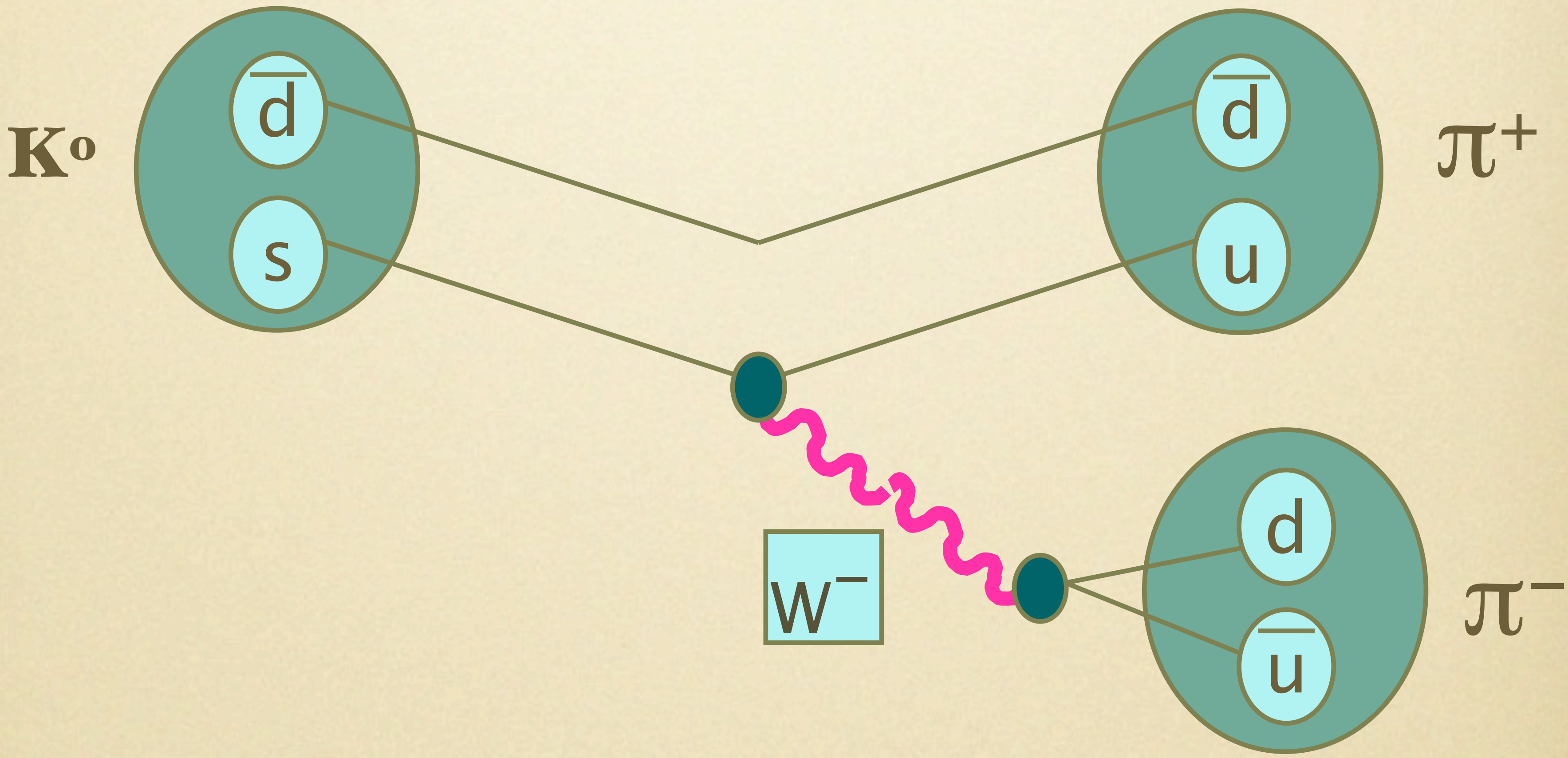
Example: kaon decays

$K^o \to \pi^+ e \nu$



Example: kaon decays

$K^o \longrightarrow \pi^+ \pi^-$



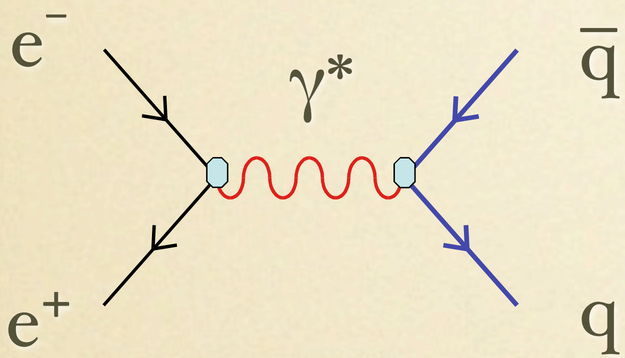
Observables and fundamental quantities

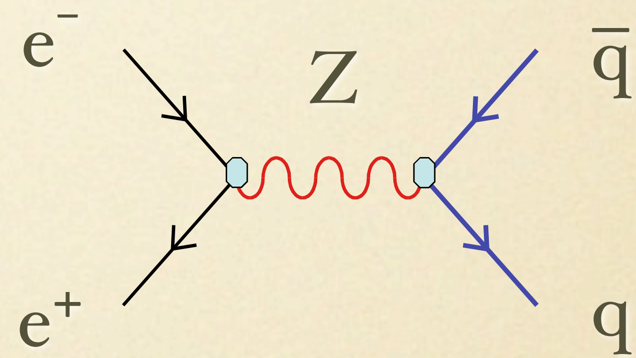
- ***Mass***:
  - Composite particles -> dynamical origin, calculable: **$M=E/c^2$, $E=T+U$**
  - Fundamental particles -> assigned parameter; origin ???
  - Measurement:
    - in decays: **$P=\sum p_i$, $M^2=P^2$**
    - in production: M=minimum energy necessary for creation
- ***Charge***:
  - Which type (electric,weak, strong)?
  - Are there other charges?? What is the origin of charge??
  - Measurment: interaction strength
    - lifetime of a particle before its decay
    - reaction probabilities (rate counting)
- ***Spin*** (intrinsic angular momentum):
  - Integer-> bosons,   Semiinteger -> fermions
  - Origin??
  - Pauli principle (two identical fermions cannot occupy the same quantum state) at the origin of matter stability and diversity
  - Measurement: angular distributions in scattering or decay processes

Examples of mass determination:

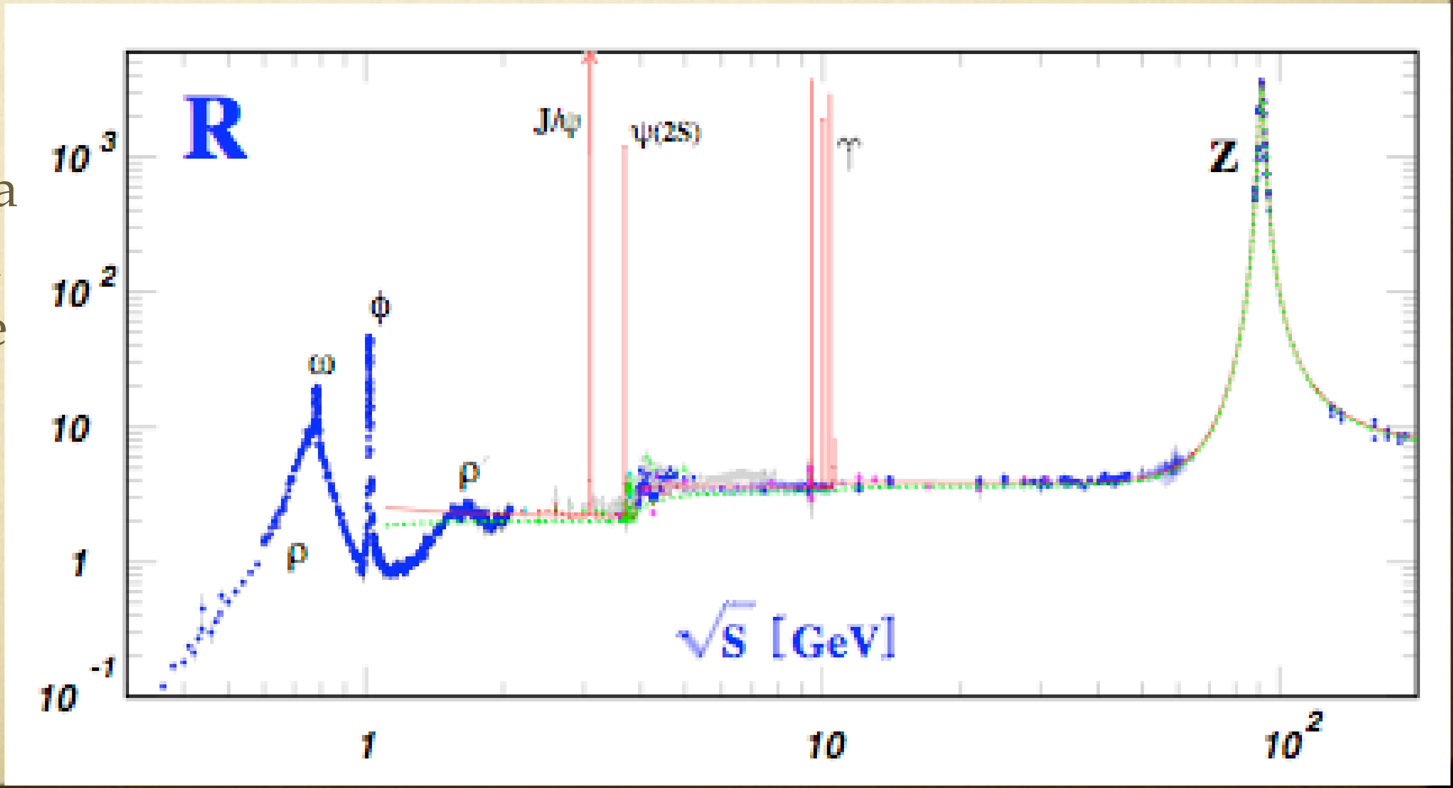
M= energy at production threshold

Production rate for $e^+e^- \rightarrow$ hadrons, as a function of the center of mass energy





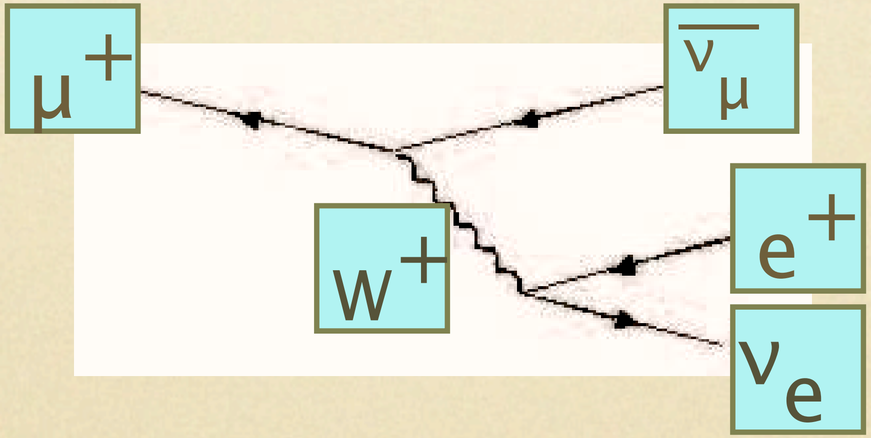
I picchi rappresentano la creazione di una nuova particella, resa possibile dall'avere raggiunto energia grande abbastanza per produrla.



Decadimenti e vite medie

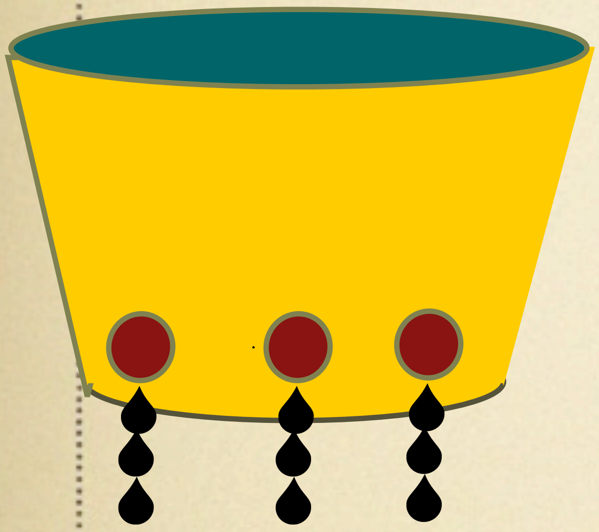
- Se le interazioni di una particella **A** le permettono di trasformarsi in una serie di particelle $\mathbf{B}_1$, ..., $\mathbf{B}_n$, e se $m_A > m_{B1} + ... + m_{Bn}$, **A decade** in $\mathbf{B}_1 + ... + \mathbf{B}_n$. Solo particelle per le quali nessuno canale di decadimento e' possibile sono stabili. Oggi abbiamo solo 3 esempi di particelle stabili: elettrone, protone, e neutrino piu' leggero (sebbene le "teorie di grande unificazione" prevedano il decadimento del protone, con una vita media di circa 10^{34} anni). E' probabile che anche le particelle formanti la materia oscura siano stabili

- Esempio:



- Piu' forte l'interazione, piu' grande la differenza di massa, piu' rapido il decadimento $N(t) = N(0)\, e^{-t/\tau}$ dove $\tau = \tau(M,g)$ e' la **vita media**

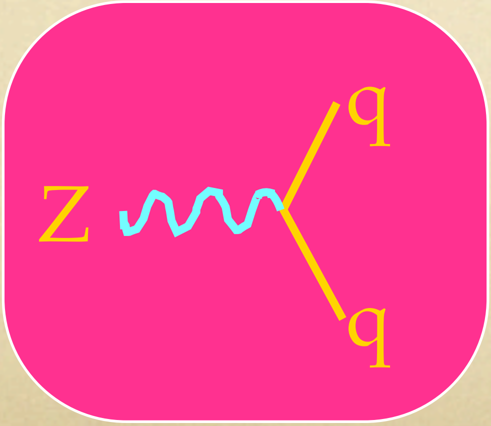
Esempio: il numero di famiglie di neutrini

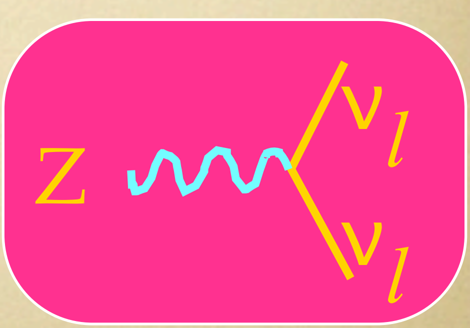


$\tau \propto$ 1/(numero di buchi) ~ 1/(numero di canali di decadimento)

$\tau(Z) = 1 / \Gamma(Z) \propto$ 1/numero di canali di decadimento

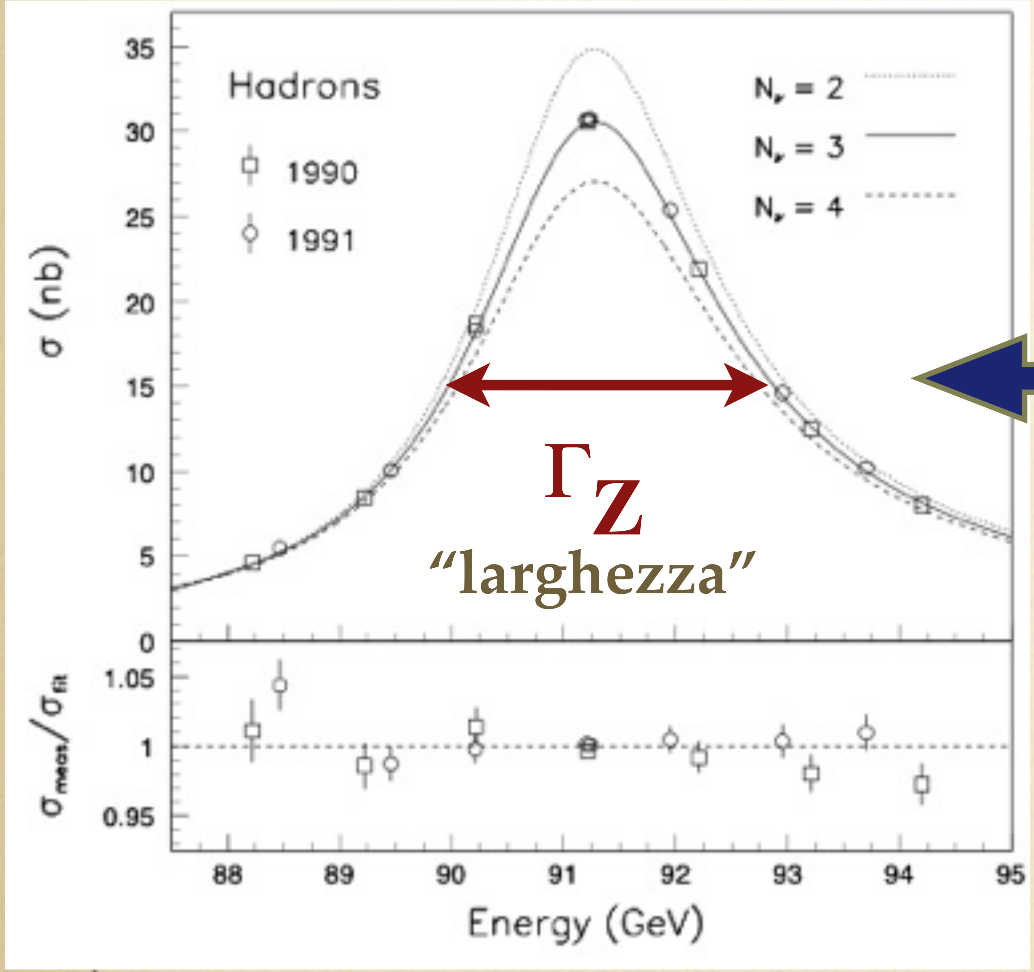
$$\Gamma(Z) = \sum_{q \setminus m_q < m_Z/2} \Gamma(Z \to q\bar{q}) + \sum_{\ell \setminus m_\ell < m_Z/2} \Gamma(Z \to \ell^+\ell^-) + \sum_{\nu \setminus m_\nu < m_Z/2} \Gamma(Z \to \nu\bar{\nu})$$





$$N_{events}(e^+e^- \to Z^0) \propto [(S - M_Z^2)^2 + M_Z^2 \Gamma_Z^2]^{-1}$$

$\sqrt{S}$=Energy(e^+e^-)



LEP $e^+e^- \to Z^0$ data, showing that the number of neutrino species N_ν=3

La misura della larghezza di decadimento puo' dare informazione su cose non direttamente osservabili! Come sapere che c'e' un buco nel serbatoio se finisce la benzina a motore spento!

In generale, la misura della larghezza permette la misura della forza dell'interazione fra particella che decade e quelle in cui decade. La larghezza e vita media non sono proprieta' intrinsiche, ma la conseguenza delle proprieta' fondamentali delle particelle studiate.