

Videolezione-2020-03-11

Decadimento $A \rightarrow a+b$

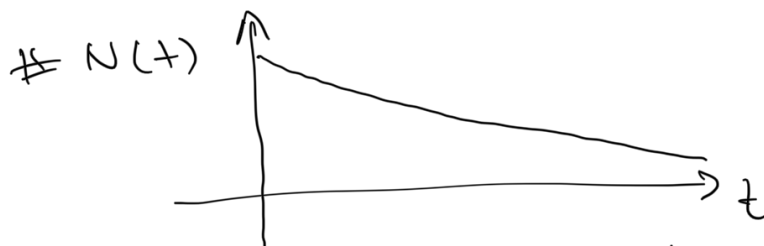
$$dt : P = \lambda dt \quad \text{prob. dekad.}$$

$$dN = -PN = -\lambda dt N$$

$$\Rightarrow N(t) = N_0 e^{-\lambda t}$$

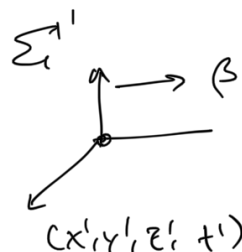
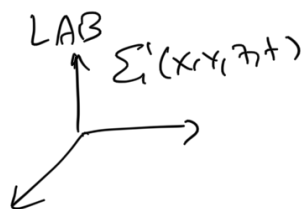
$$\langle t \rangle := \tau = \frac{1}{\lambda} \quad \text{vita media propria}$$

$N_0 = N(t=0)$ particelle instabili



$$N(t) = N_0 e^{-\frac{t}{\tau_0}}$$

misurato in rif. c.d.m.
vita media propria



c.d.m.
Rif solide con le particelle

$$\begin{pmatrix} ct \\ x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \gamma & \beta\gamma & 0 & 0 \\ \beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} ct' \\ x' \\ y' \\ z' \end{pmatrix}$$

$$\tau_{\mu} \text{ in LAB} = 0 \tau_0$$

$$\text{muon: } |\vec{p}| = 10 \text{ GeV}$$

$$\beta\gamma = \frac{p}{m} = \frac{10 \text{ GeV}}{0.1 \text{ GeV}} = 100$$

$$\beta\gamma = \frac{\beta}{\sqrt{1-\beta^2}} \Rightarrow \beta = \frac{\beta\gamma}{\sqrt{1+(\beta\gamma)^2}}$$

$$\beta = \frac{(p/m)}{\sqrt{1+(p/m)^2}} = \frac{100}{\sqrt{1+100^2}}$$

$$= 0.99995$$

$$\gamma = \frac{100}{0.99995} = 100$$

$$\tau_{\text{LAB}} = 100 \tau_0 = 100 \times 2.2 \times 10^{-6} \text{ s} \\ = 2.2 \times 10^{-4} \text{ s} = \underline{0.2 \text{ ms}}$$

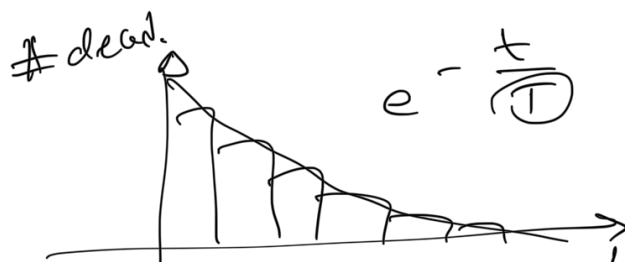
$$\Delta x_{\text{LAB}} = v \cdot \tau_{\text{LAB}} = \beta c \gamma \tau_0$$

$$= \beta\gamma c \tau_0$$

$$= \underline{100} \times 3 \times 10^8 \frac{\text{m}}{\text{s}} \times 2.2 \times 10^{-6} \text{ s}$$

$$= 6.6 \times 10^4 \text{ m} = \boxed{66 \text{ km}}$$

in LAB



$$\tau = \gamma \tau_0$$

Significato di τ e Λ in MQ

$$A \rightarrow a + b$$

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

interazione debole

$$H = H_0 + H_W$$

Cint debole

solo
2
stati
fisici

$$\left\{ \begin{array}{l} |\mu^+\rangle \\ |e^+ \nu_e \bar{\nu}_\mu\rangle \end{array} \right.$$

$$|\Psi(t)\rangle = a(t) |\mu^+\rangle + c(t) |e^+ \nu_e \bar{\nu}_\mu\rangle$$

$t=0$ No muoni

$$a(0) = 1$$

$$c(0) = 0$$

t : tempo proprio del μ^+

$$a(t) = ?$$

$c(t)$ non mi interessa

Weisskopf - Wigner 1930

$$|\mu^+, t\rangle = ?$$

$$i \frac{d}{dt} |\mu^+, t\rangle = H_{\text{eff}} |\mu^+, t\rangle$$

Se $H_{eff} = H_{eff}^\dagger \Rightarrow E_i$ reali

$$|\mu^+, t\rangle = a(t) |\mu^+\rangle \\ = e^{-iE_i t} |\mu^+\rangle$$

$$E_i = m_\mu$$

$$|\mu^+, t\rangle = e^{-im t} |\mu^+\rangle$$

$$|\langle \mu^+ | \mu^+, t \rangle|^2 \equiv 1$$

$\Rightarrow \mu^+$ non decade

Tuttavia μ^+ decade

Usiamo H_{eff} non hermit.

$$H_{eff} = M - i \frac{\Gamma}{2}$$

$$M = M^\dagger \quad \Gamma = \Gamma^\dagger$$

legare tra M, Γ e H_W ?
 \hookrightarrow int
debole?

teoria delle perturb. al \mathcal{O}^2 ordine

M, Γ si possono calcolare
da H_W

$$\rightarrow |\mu^+, t\rangle = e^{-im t} e^{-\frac{\Gamma}{2} t} |\mu^+\rangle$$

$$a(t) = \underbrace{e^{-im t}}_{-m t} e^{-\frac{\Gamma}{2} t}$$

$$|\langle \mu^+ | \mu^+, t \rangle|^2 = e$$

μ^+ a $t=0$ potrebbe non essere
 μ^+ a $t > 0$

$$|\mu^+\rangle_{a(t)}, |e^+ \nu_e \bar{\nu}_\mu\rangle_{c(t)}$$

$$|a(t)|^2 + |c(t)|^2 = 1$$

$$P(\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu) = |c(t)|^2 = 1 - e^{-\Gamma t}$$

$$N_\mu(t) = N_0 e^{-\Gamma t}$$

$t=0$ nessun decad.

$t \rightarrow \infty$ tutti muoni decadono

$$\lambda \equiv \Gamma = \frac{1}{\tau}$$

larghezza totale
di decadimento

vita
media
propria

Γ : si può calcolare da H_W
 usando le regole d'oro di Fermi

prob. di decad. in dt

$$dP = \Gamma dt \equiv \lambda dt$$

Γ : prob. di decadim. in unità di
tempo.

$$P \approx \left(\frac{dP}{dt} \right)$$

misura in Δt

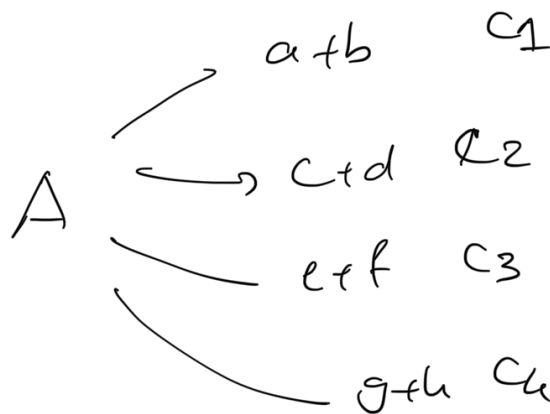
misura $\tau \Rightarrow$ stuo τ_{uis}

Calcolo τ_{th} de $th + perturb.$

Confronto τ_{uis} con τ_{th}

\downarrow misurato speriun $\tau_{uis} \pm \delta P$
 \downarrow stiueto dalla teork calcolato

Decidm. in generale



$$dN = -dP N$$

$$dP = ?$$

$$P_1 : P(A \rightarrow c_1)$$

\vdots

$$P_n : P(A \rightarrow c_n)$$

— — — — —

$$dP = (P_1 \cdot P_2 \cdot P_3 \cdot \dots \cdot P_N) dt$$

$$dN = - (P_1 \cdot P_2 \cdot \dots \cdot P_N) dt \cdot N$$

$$N(t) = N_0 e^{-P_1 t} e^{-P_2 t} \dots e^{-P_N t}$$

$$= N_0 e^{-P_{\text{tot}} t}$$

$$P_{\text{tot}} := \sum_i P_i$$

\downarrow
 larghezze di
 decad. totale

\hookrightarrow larghezze di
 decad. parziale

$$\langle t \rangle = \tau = \frac{1}{P_{\text{tot}}}$$

N larghezze parziali:

$$P_i: \text{Prob}(A \rightarrow C_i)$$

\uparrow larghezza totale $P_{\text{tot}} = \sum_i P_i$

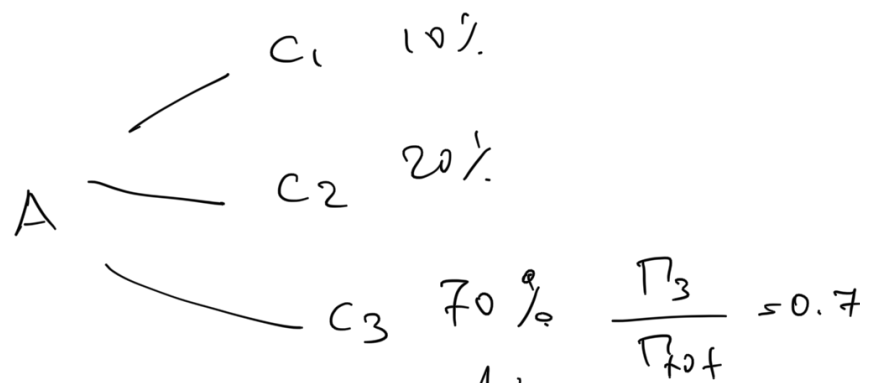
\uparrow vite media: $\tau = \frac{1}{P_{\text{tot}}} = \frac{1}{\sum_i P_i}$

$$BF(A \rightarrow C_i) = B_i = \frac{P_i}{\sum_i P_i}$$

Branching fraction

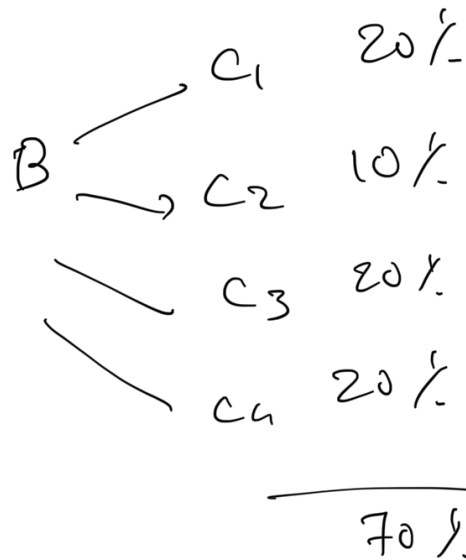
Branching ratio

$$\sum_i BF(A \rightarrow C_i) = 1$$



Conosco tutti i decadimenti.

Sperimentalmente non sempre conoscete tutti i canali.



\Rightarrow Esiste almeno un altro canale.

$$BF(A \rightarrow X) = 1 - \sum_i^{BF_{note}} BF_i$$

$$= 0.3$$

esiste canale

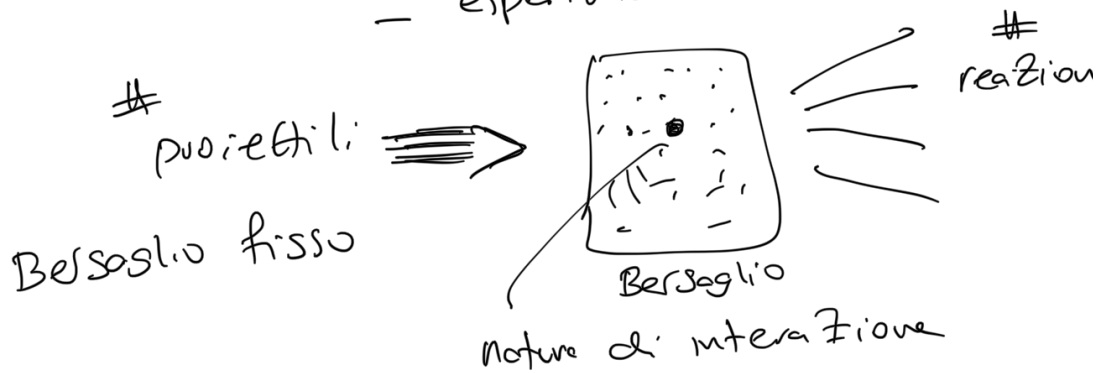
C_5	}	30%
C_6		
C_7		
\vdots		
\dots		

Bosone $Z^0 \rightarrow$ e^+e^- 3.3%
 $\mu^+\mu^-$ 3.3%
 $\tau^+\tau^-$ 3.3%

$$N_{Z^0} = 10^9 \quad N(Z^0 \rightarrow e^+e^-) = 3 \times 10^{-2} \times 10^9 \\ = 3.3 \times 10^7 \\ = 33 \text{ million}$$

Indagine sub nucleare, nucleare

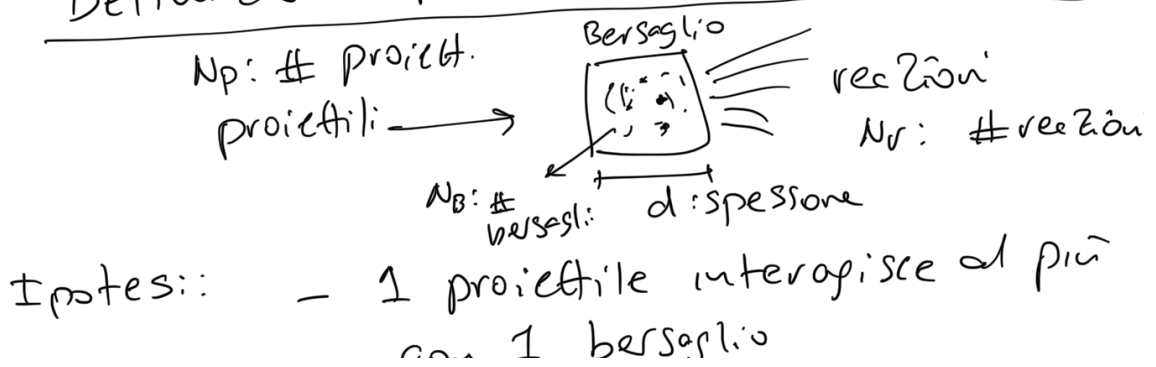
- decadimenti
- esperm. di diffusione



Fascio contro fascio $\xrightarrow{N_1} \cdot \xleftarrow{N_2}$

I esperm. di Rutherford fine '800
 Scoperta del nucleo

Definizione operativa di Sezione d'urto

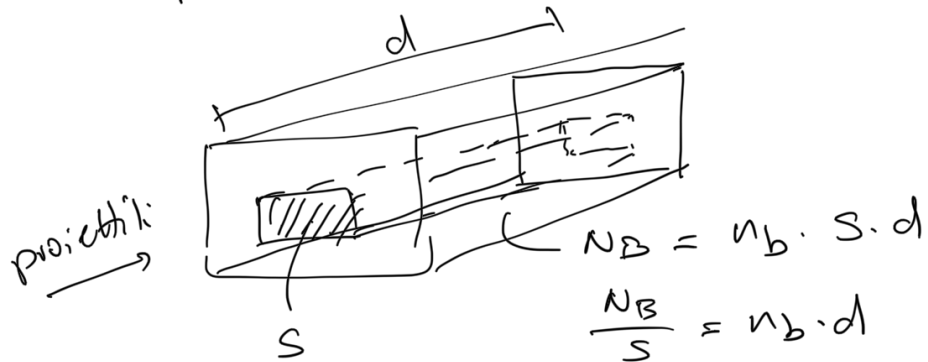


- prob. di interazione con B
non dipende dalle vicin
di altri Bersagli

$$\underline{N_r} \propto \underline{N_p} N_B \underline{T}$$

$$\frac{\# \text{ reazioni}}{T} : \frac{dN_r}{dt}$$

$$\frac{\# \text{ proiettili}}{T} : \frac{dN_p}{dt}$$



$$\frac{dN_r}{dt} \propto \frac{dN_p}{dt} \cdot n_b \cdot d$$

$$\int \quad \int \quad [n_b \cdot d] = L^{-3} L = L^{-2}$$

$[] = T^{-1} \quad T^{-1}$

$$\frac{dN_r}{dt} = \sigma_r \frac{dN_p}{dt} n_b \cdot d$$

$\frac{\# \text{ reazioni}}{\text{tempo}}$

sezione d'urto

$\frac{\# \text{ proiettili}}{\text{tempo}}$

spess

densità num. bersagli

temperatura in tempo finito T

10.1 -

Idee $T \rightarrow \infty$

Misurare
$$\sigma_r = \frac{\left(\frac{dN_r}{dt}\right)}{\left(\frac{dN_p}{dt}\right)} \frac{1}{n_b \cdot d}$$

Sezione d'urto totale di reazione

- natura del proiettile
- natura del bersaglio
- tipo di interazione tra loro

Dalla teoria se conosco H_{int}

UScendo le regole d'oro di Fermi

Calcolo/Stima σ per processo.

σ_{th} vs. σ_{exp}

σ dipende da energia
num. quantici
del proiettile
bersaglio

In tempo T manda N_p proiettili
contro bersaglio.

$$\frac{dN_p}{dt} = \frac{N_p}{T}$$

$$\frac{dN_r}{dt} = \frac{N_r}{T}$$

$$T_r = \frac{N_r}{N_p} \left(\frac{1}{n_b \cdot d} \right) \text{ in Temp } T$$

constant

$$N_p = \frac{dN_p}{dt} \cdot T$$