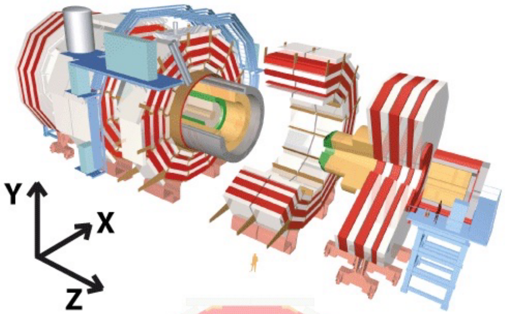
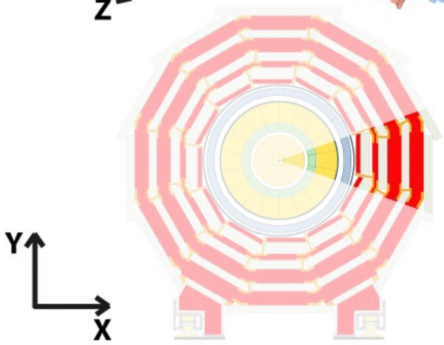
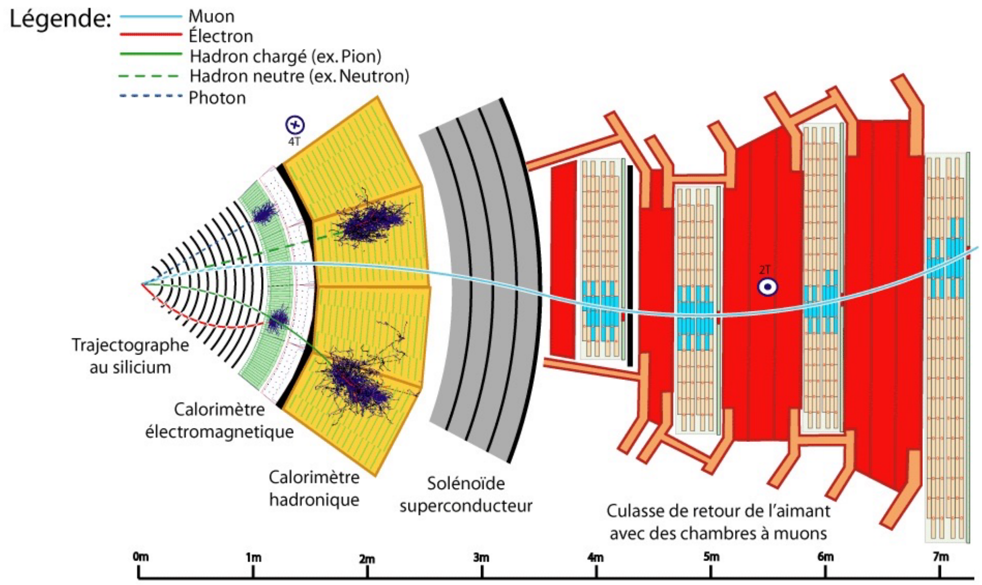
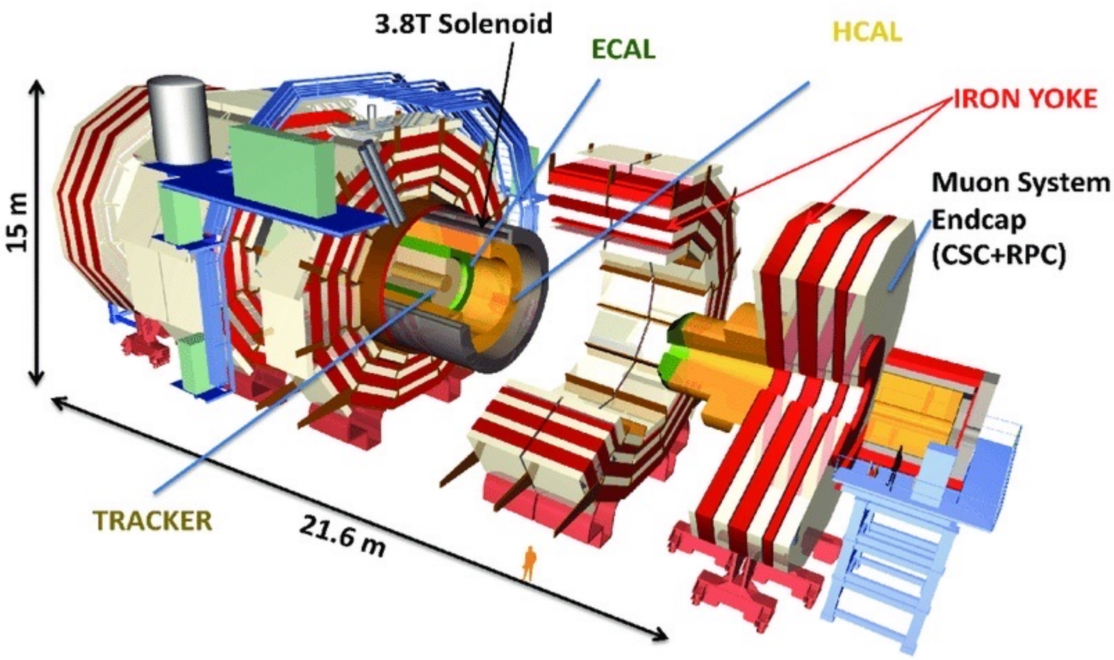


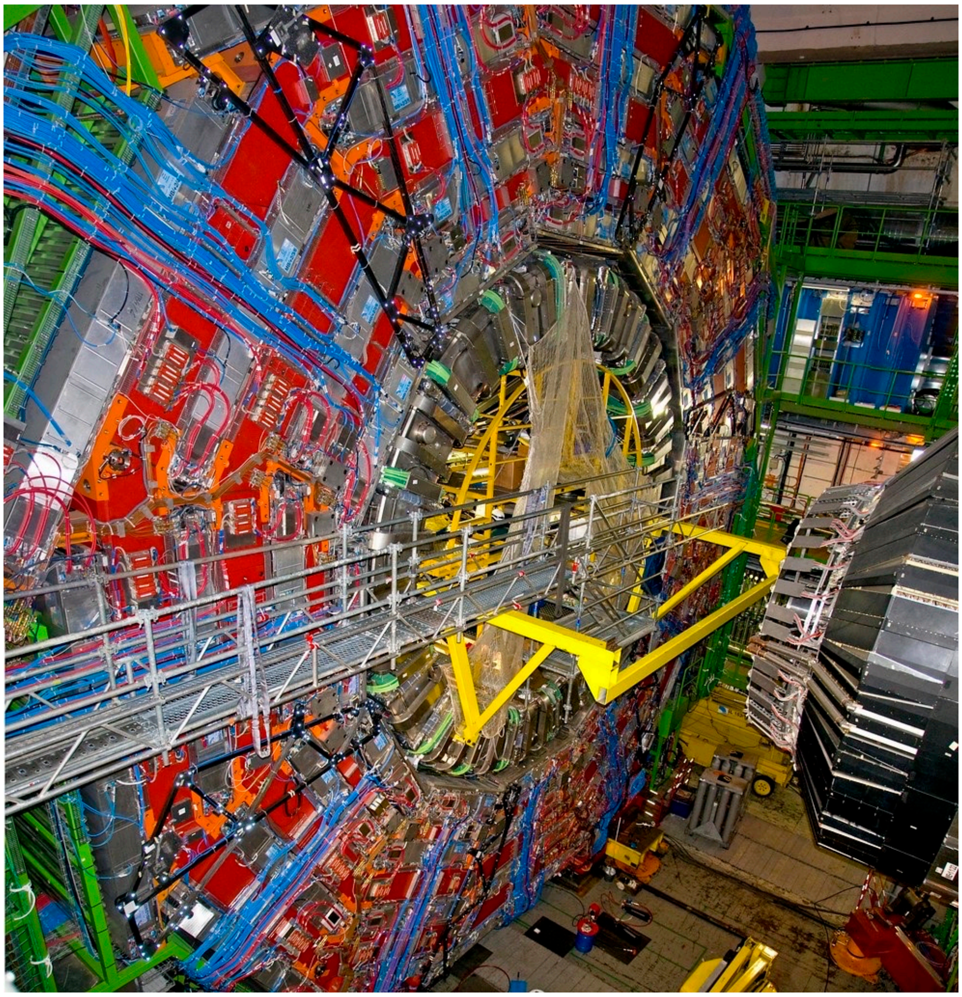



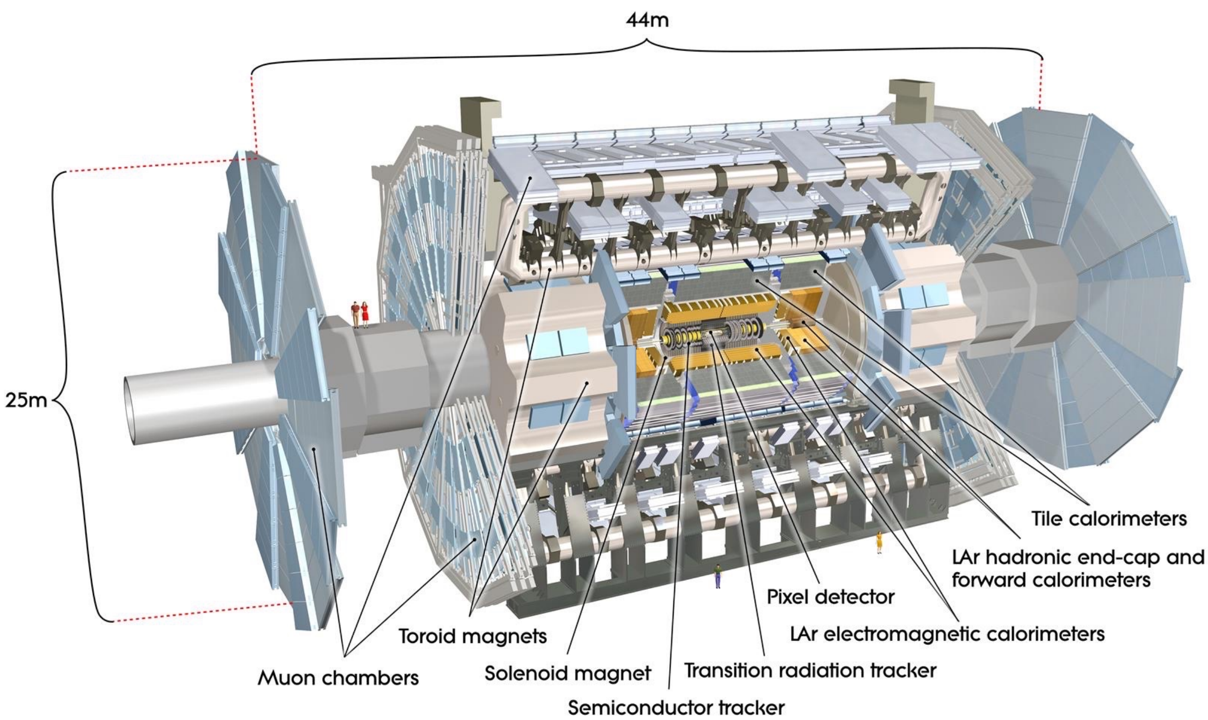

CMS: Compact Muon Solenoid



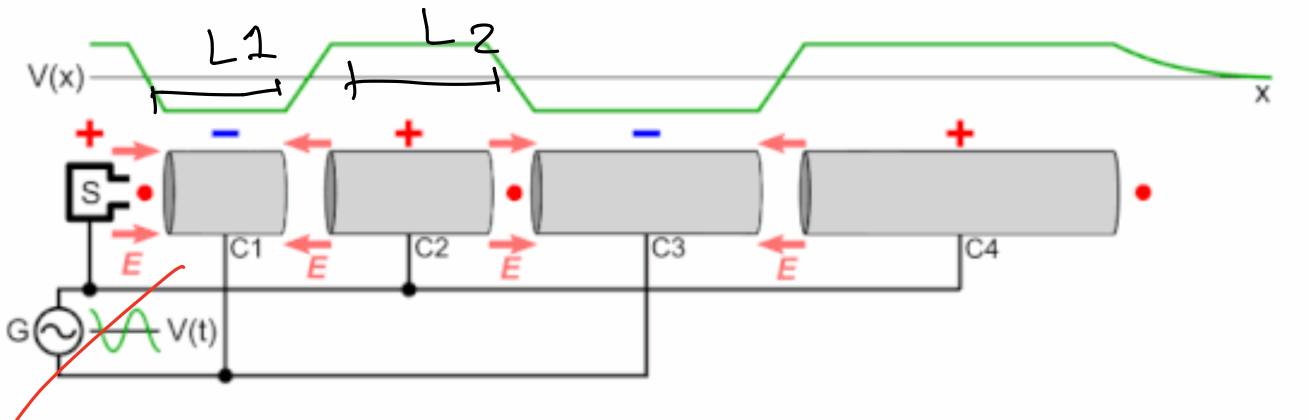

2muons + 2 electrons
https://www.youtube.com/watch?v=oINI9V508q4

4 muons
https://youtu.be/QAnSuhn27TE




44m
25m
Tile calorimeters
LAr hadronic end-cap and
forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Muon chambers
Solenoid magnet
Transition radiation tracker
Semiconductor tracker

# Accelerator:

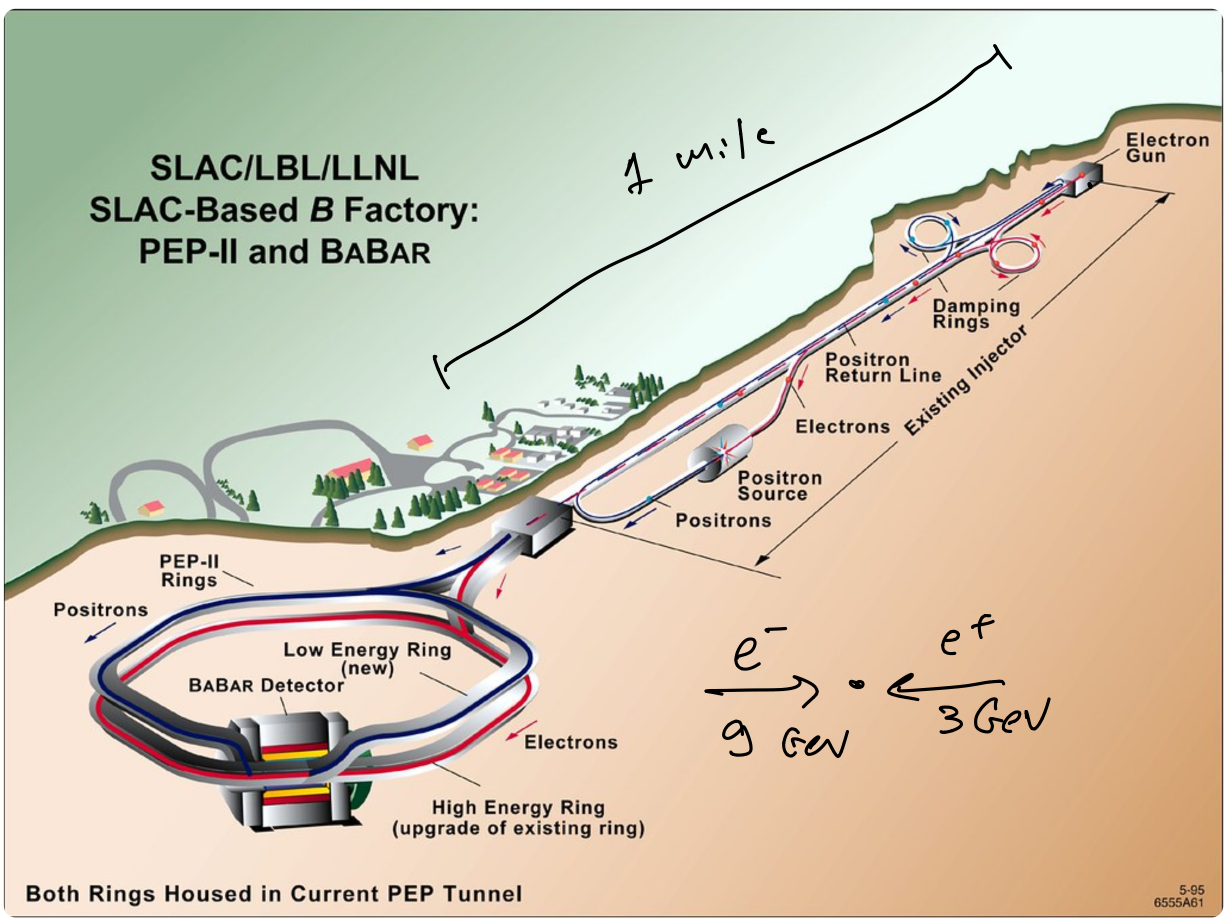



Acceler. lineare

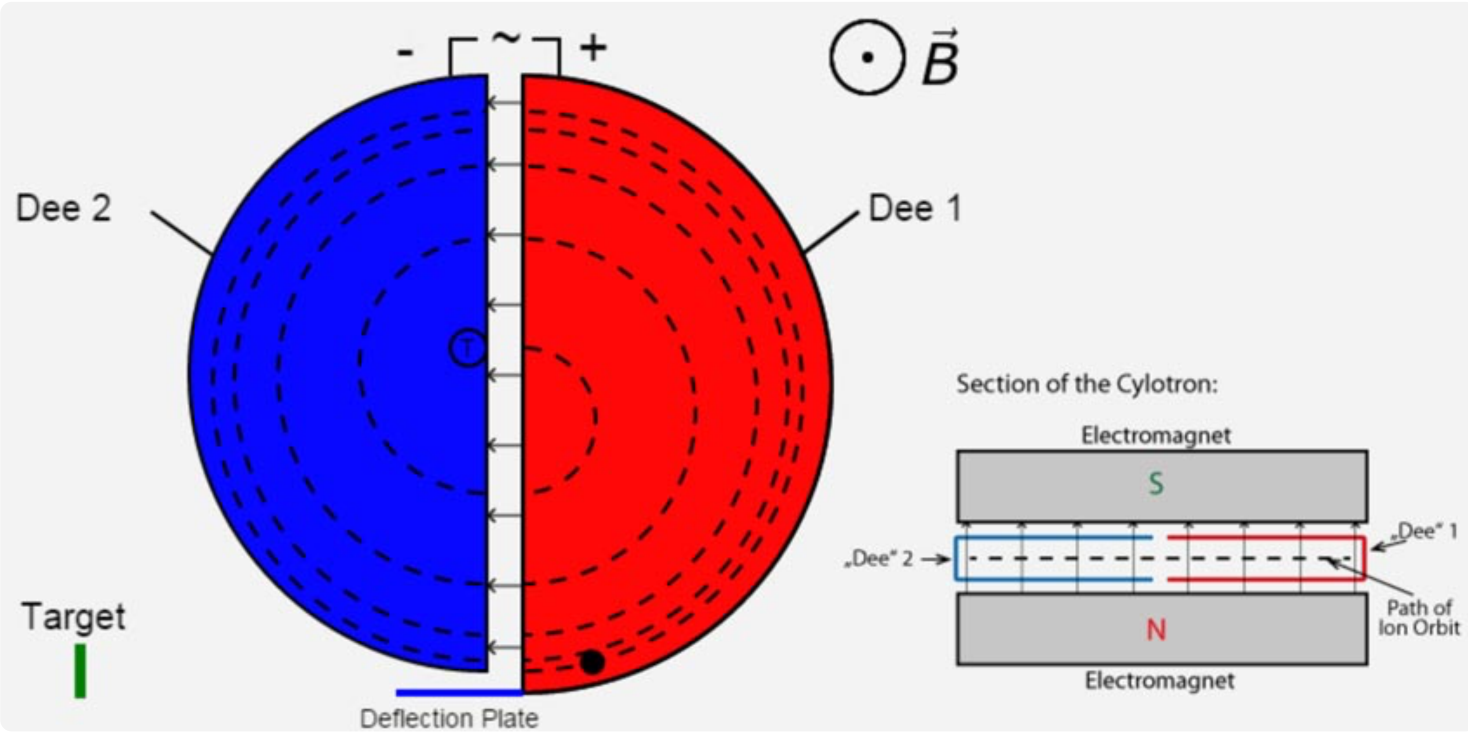
$$\Delta t_2 = \frac{L_2}{v_2}$$

$v_1$

$$\Delta t_1 = \frac{L_1}{v_1}$$



Lawrence 1929




$$F = ma = m\frac{v^{\cancel{2}}}{r} = q\cancel{v}B \Rightarrow \omega = \frac{v}{r} = \frac{qB}{m}$$

$$\frac{1}{\nu} = T = \frac{2\pi r}{v} = 2\pi\frac{r}{v} = 2\pi\frac{m}{qB}$$

frequenza di betatrone $\boxed{\frac{1}{T} = \frac{qB}{2\pi m}}$

$$T_{max} = \frac{1}{2} m v_{max}^2 = \frac{1}{2} m \left(\frac{v}{R}\right)^2 R^2$$

$$= \frac{\cancel{m}}{2}\frac{(qB)^2}{m^{\cancel{2}}} R^2$$

Funziona bene per ioni

$$\nu = \frac{qB}{2\pi m} \xrightarrow{\text{relativistico}} \nu_c = \frac{1}{\gamma}\frac{qB}{2\pi m}$$

$$\nu_c = \frac{qB}{2\pi m}\sqrt{1-v^2/c^2}$$

1) $B \nearrow$ per $v \nearrow$     $B$ compensa $\frac{1}{\gamma}$

$\nu_c$ costante     Sincro-ciclotrone.

$R = 10$ m. spessore del magnete sia 1 m.

$B = 2T$     $p = 0.3 \times \left(\frac{q}{e}\right) B \cdot R$

volume del magnete $= \pi R^2 \times$ spessore.

Ferro: $\rho = 8\ g/cm^3$

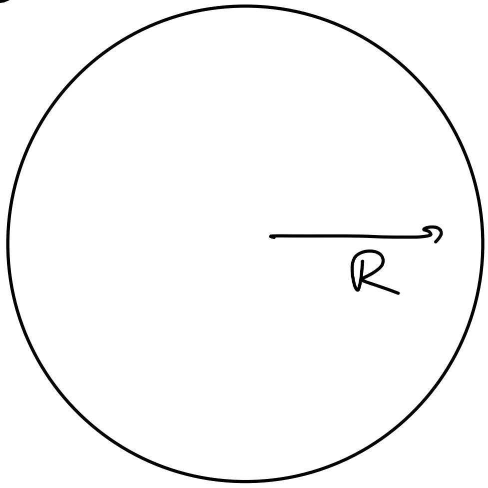
volume $= 64 \times 10^6$ kg di ferro

Sincro-ciclotrone usato per $E \simeq 10-100$ MeV

2) sincrotrone.

Cambiare $\nu_c$ con $B$.

tenere Raggio costante.

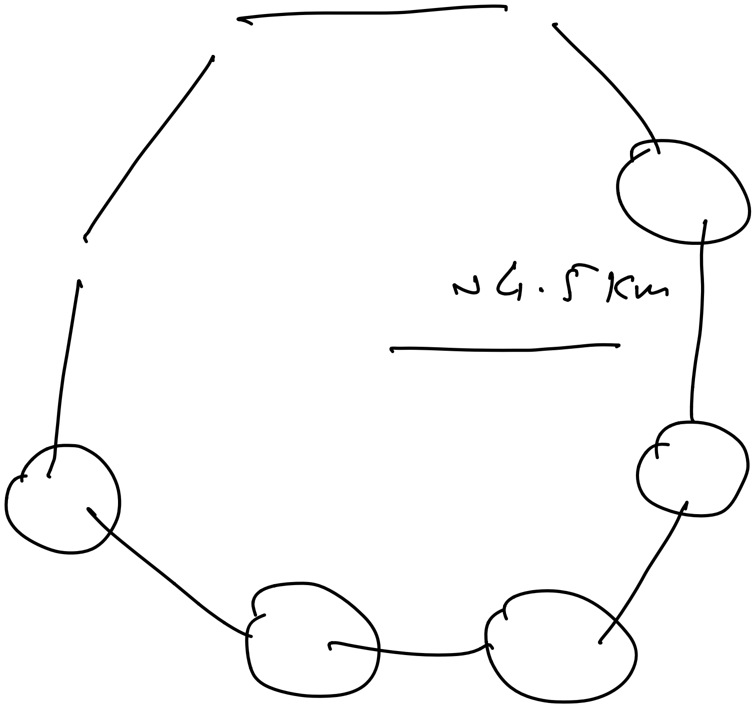



$p = 0.3 \times B \times R.$

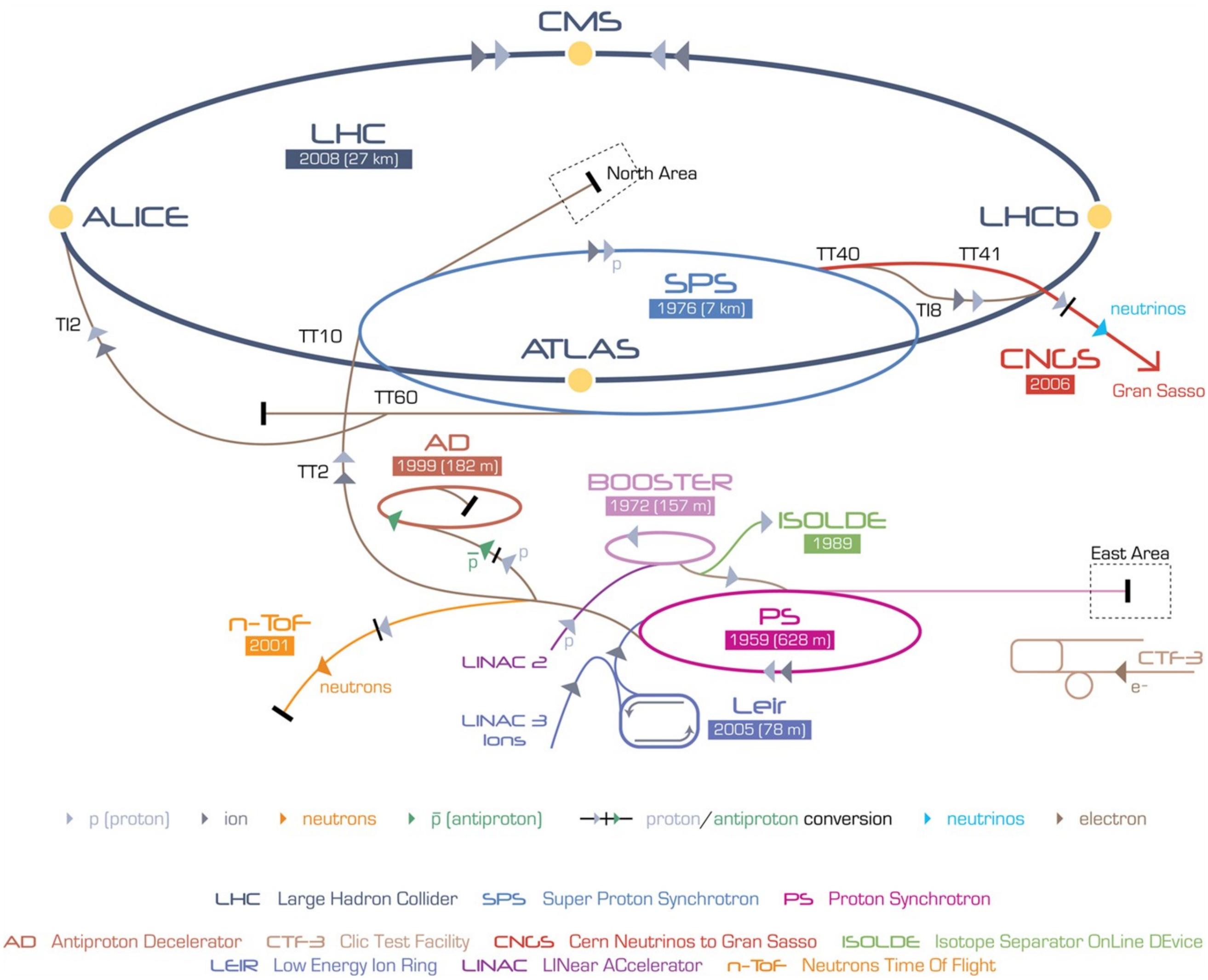
$p = 6.5$ TeV

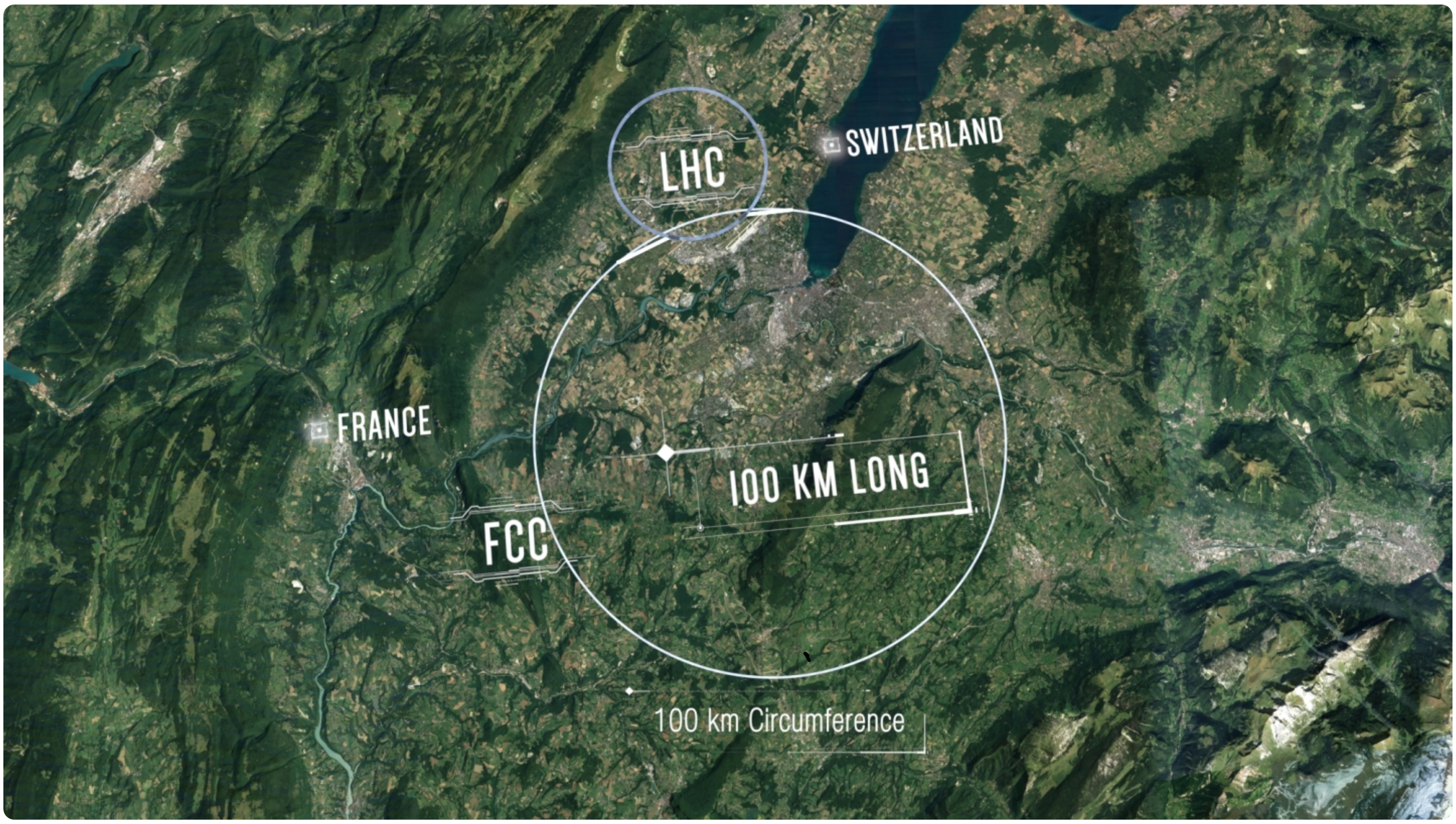
protoni.

$p = 0.3 \times B \times R.$




B molto grande.

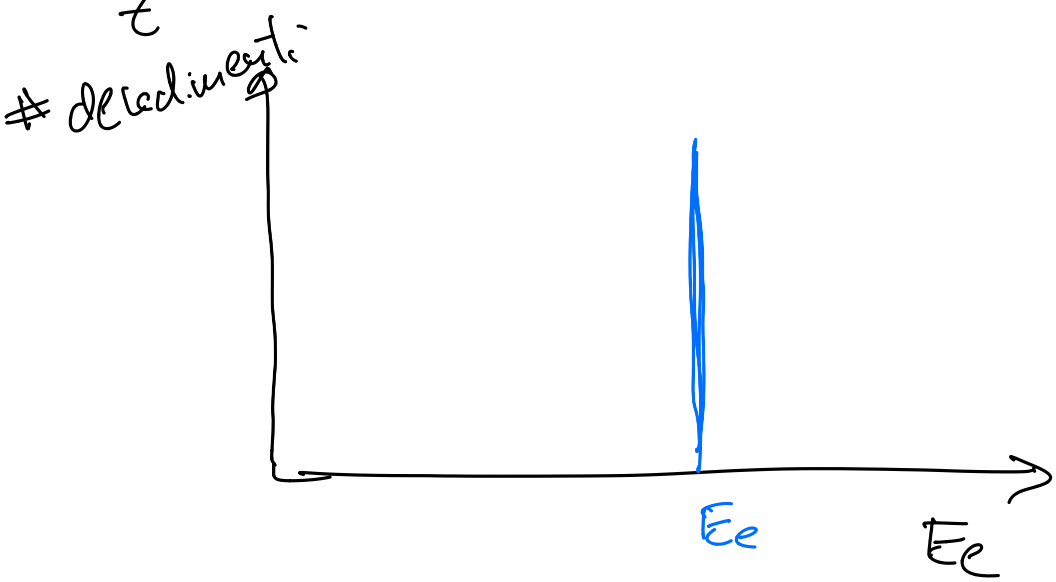





# Decadimento β

$$n \to p + e^- + \bar{\nu}_e$$

$$ {}^{A}_{Z}X \to {}^{A}_{Z+1}Y + e^- + \bar{\nu}_e $$



nel rif. solidale con X

$$m_X = E_Y + E_e = \sqrt{m_Y^2 + p^{*2}} + \sqrt{m_e^2 + p^{*2}}$$

$$p^* = \frac{m_X^2 - m_Y^2 - m_e^2}{2m_X}$$

$m_X \simeq m_Y \simeq A \cdot m_p$. $\qquad Q = m_X - m_Y - m_e$

$$m_X \simeq m_Y + \varepsilon$$

$$m_e^2 \ll m_X^2$$

$$p^* = \frac{m_X^2 - m_Y^2}{2m_X} = \frac{(m_X - m_Y)(m_X + m_Y)}{2m_X}$$

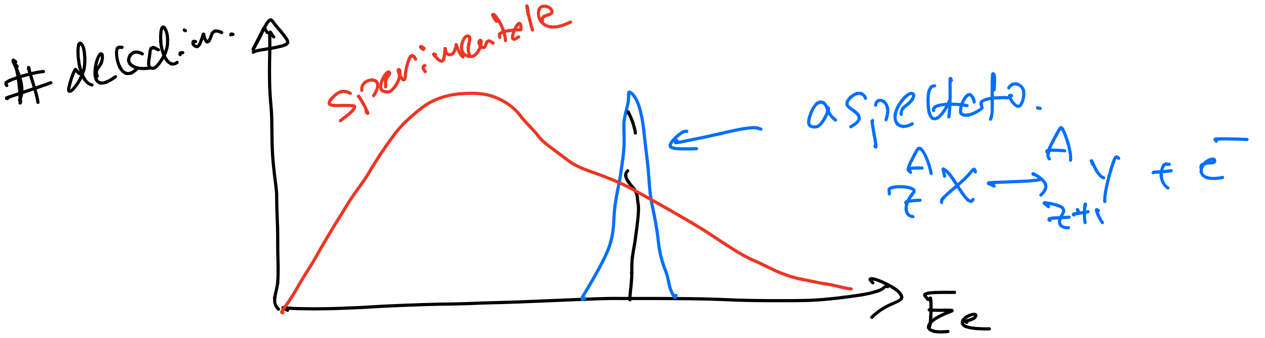
$$m_X = E_Y + E_e = m_Y + K_Y + E_e.$$

$$K_Y = E_Y - m_Y = \sqrt{p^{*2} + m_Y^2} - m_Y$$

$$\simeq \frac{p^{*2}}{2m_Y} \ll 1.$$

$$E_e = m_X - m_Y \implies K_e = m_X - m_Y - m_e = Q$$

$\implies E_e \simeq$ MeV nel caso di $n \to p + e^-$



Pauli 1930 $\quad {}^{A}_{Z}X \to {}^{A}_{Z+1}Y + e^- +$

| | | | | |
|---|---|---|---|---|
| $q$ | $Z$ | $Z+1$ | $-1$ | $0$ |
| $B$ | $A$ | $A$ | | $0$ |
| $m$ | | piccola. | | |

$\Rightarrow$ neutrino.

$J \quad A \cdot \frac{\hbar}{2} \quad \frac{\hbar}{2}(A+1)$

$${}^{A}_{Z}X \to {}^{A}_{Z+1}Y + e^- + \gamma$$

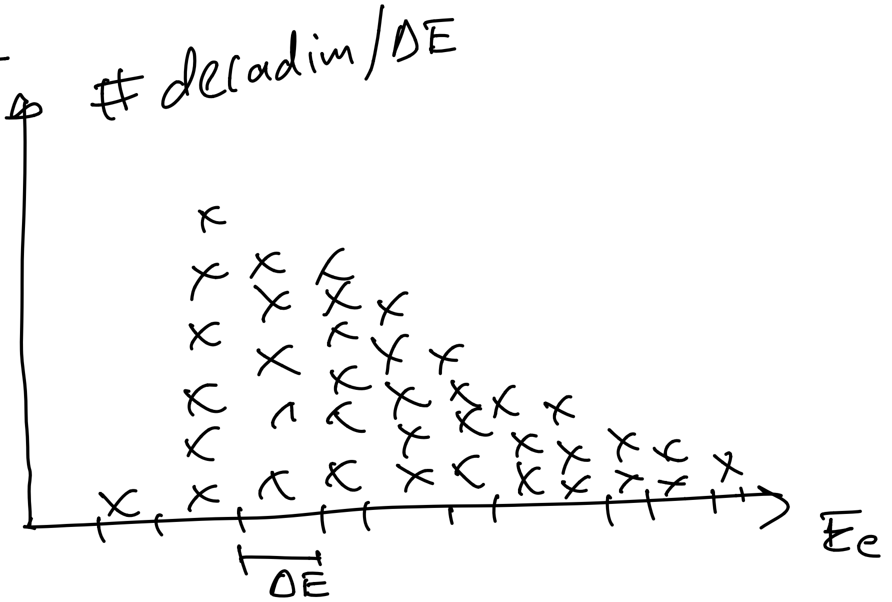
$\Rightarrow$ neutrino fermione.

Ipotesi: $\quad {}^{A}_{Z}X \to {}^{A}_{Z+1}Y + e^- + \bar{\nu}$

$N$(decadim) in funzione di $E_e$

$$\frac{N(\#\,\text{decadim})}{\Delta E}$$

$$\frac{d\Gamma}{dE}$$



$\Gamma(X \to Y + e^- + \bar{\nu}_e)$ larghezza di decadimento.

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

campione di X $\quad N(t) = N(0)\, e^{-t/\tau} = e^{-\Gamma t}$

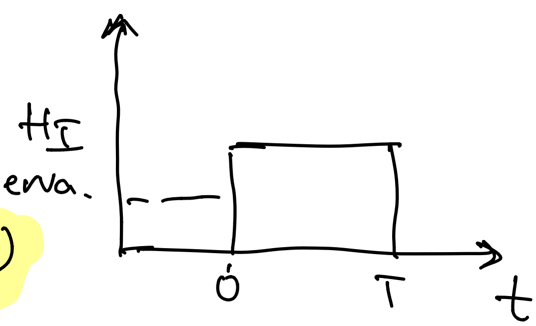
singole particelle $\quad \psi(\vec{r}, t) = \psi(\vec{r})\, e^{-iE_0 t}\, e^{-\frac{\Gamma}{2} t}$

$$|\psi|^2 \propto e^{-\Gamma t}$$

$\Gamma$ : (prob. di decadim.)/(unità di tempo)

$i \longrightarrow f \qquad \Gamma(i \to f)$.

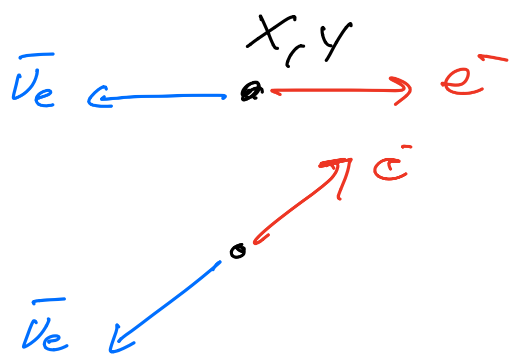

$H = H_0 + H_I$




En. si conserva.

$$P(i \to f) = 2\pi\, |M_{fi}|^2\, \delta(E_f - E_i)$$

$$M_{fi} = -i \int d^3r\, \psi_f^*\, H_I\, \psi_i$$ elemento di matrice.



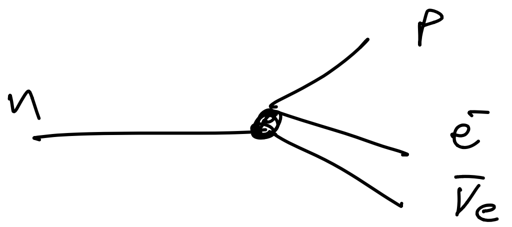
Densità di stati: # modi per realizzare lo stato finale.

$$\Gamma(i \to f) = \int_{\text{stati}} P(i \to f) \cdot dn$$

$$= \int 2\pi \, |M_{fi}|^2 \, \delta(E_f - E_i) \frac{dn}{dE_f} \, dE_f$$

$$= 2\pi \, |M_{fi}|^2 \underbrace{\rho(E_f)}_{\left.\frac{dn}{dE}\right|_{E_f = E_i}}$$

Teoria di Fermi per l'interazione debole.



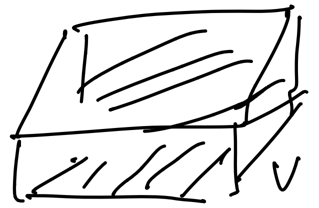

teoria a 4 fermioni

$$H_I = G_F$$

$$M_{fi} = -i \int d^3r \, \psi_f^* \, G_F \, \psi_i$$

$$|f\rangle = |p \, e^- \nu_e\rangle \qquad |i\rangle = |n\rangle$$

$$M_{fi} = -i \, G_F \int d^3r \, \psi_{e^-}^* \, \psi_\nu^* \, \psi_p^* \, \psi_n$$




$$\psi = \frac{1}{\sqrt{V}} e^{i \vec{p} \cdot \vec{r}}$$

$$V = L_x L_y L_z$$