

## Lez. due precedente

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

$a(t)$ : sopravv.

$b(t)$  decad.

$$\mu^+ \rightarrow \mu^+$$

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

$$|b(t)|^2 = |\langle \mu^+ | e^+ \nu e \bar{\nu}_\mu | t \rangle|^2$$

$$|\psi(t)\rangle = a(t) |\mu^+ \rangle + b(t) |e^+ \nu e \bar{\nu}_\mu \rangle$$

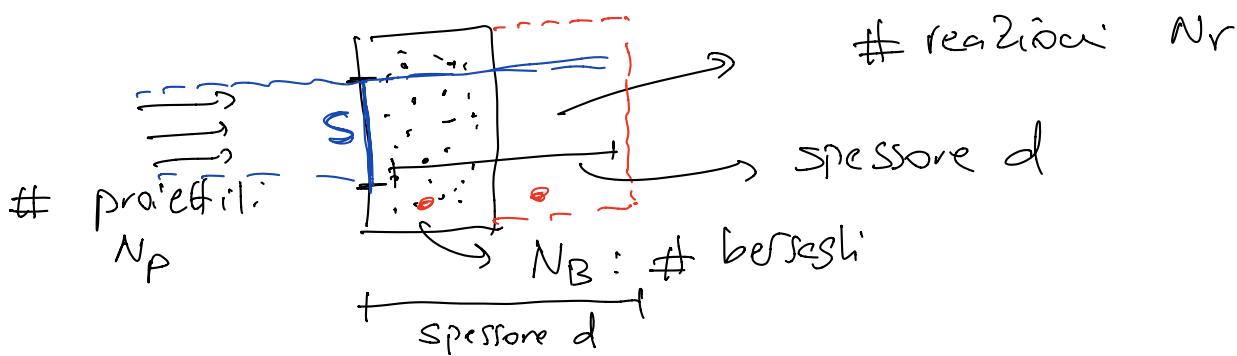
$$|\psi(t)\rangle \equiv |\psi(t)\rangle$$

$$\begin{aligned} a(0) &= 1 \\ b(0) &= 0 \end{aligned} \quad \left. \begin{array}{l} \text{Cond.} \\ \text{iniz.} \end{array} \right\}$$

## Crit. o collisioni

Esperimenti di diffusione.

$I^\infty$  Esp. di Rutherford fine '800



$$Nr \propto N_p N_B$$

$T$ : tempo di misura influenzato  $N_p$ ,  $N_r$

$$\frac{\# \text{ proiettili}}{T} =: \frac{dN_p}{dt} \quad \# \text{ proiettili / unità di tempo.}$$

$$\frac{\# \text{ reazioni}}{T} =: \frac{dNr}{dt} \quad \# \text{ reazioni / per unità di tempo.}$$

$$\frac{dNr}{dt} \propto \frac{dN_p}{dt} N_B d$$

$$N_B = n_b \cdot S \cdot d$$

$n_b$ : densità numerica del bersaglio

$$\underbrace{\frac{dN_r}{dt}}_{\text{tasso di reazione}} \propto \frac{dN_p}{dt} \frac{N_B}{S} = \frac{dN_p}{dt} \frac{n_b \cdot S \cdot d}{S} = \underbrace{\frac{dN_p}{dt}}_{\substack{\text{proiettile} \\ \text{tempo}}} \underbrace{n_b \cdot d}_{\text{bersaglio}}$$

$$[\frac{dN}{dt}] = T^{-1}$$

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

spessore bersaglio.

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

$\int$   
densità bersaglio.

$$[\sigma] = L^2$$

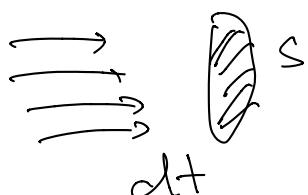
sezione d'urto delle reazioni.

- proiettile interagisce al più con 1 bersaglio
- prob. di interaz. non dipende dalla v.c.m. di altri bersagli.

Q: dovrebbe dipendere solo da

- prop. fisiche del proiettile: conico, # quantifici,  $\rho$
- prop. fisiche del singolo bersaglio
- tipo interazione tra proiettile e bersaglio.

$$\frac{dN_r}{dt} = \sigma \frac{dN_p}{dt} n_b \cdot d = \sigma \cdot \underbrace{\frac{dN_p}{dt} \frac{1}{S}}_{\frac{dN_p}{dt \cdot S}} \underbrace{\frac{n_b \cdot d \cdot S}{N_B}}_{N_B}$$



$$\phi_p = \frac{dN_p}{dt \cdot S}$$

$$\sigma = \frac{\left(\frac{dN_r}{dt}\right)}{\phi_p} \frac{1}{N_B}$$

$$\sigma = \frac{\left(\frac{dN_r}{dt}\right)}{\left(\frac{dN_p}{dt}\right)} \frac{S}{N_B}$$

reazione

$$\frac{\left(\frac{dN_r}{dt}\right)}{\left(\frac{dN_p}{dt}\right)} \frac{1}{N_B} = \frac{\sigma}{S}$$

intervallo  $\Delta t$

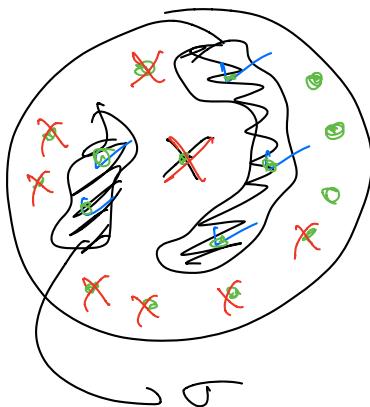
proiettili:

Se  $N_B = 1$

$$\frac{\left(\frac{dN_r}{dt}\right)}{\left(\frac{dN_p}{dt}\right)}$$

prob. di interazione  
per singolo bersaglio

Interp. prob:  $\frac{\sigma}{S}$  prob. di interazione fra  
1 proiettile e 1 bersaglio.



Sezione del  
fascio incidente

- : proiettile.
- ✓ : colpito
- ✗ : non colpito

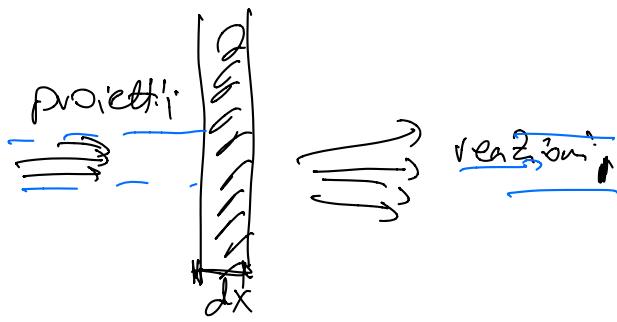
$$\frac{\frac{dN_r}{dt}}{\left(\frac{dN_p}{dt}\right)} \frac{1}{n_b \cdot d} = \sigma$$

$$n_b = \frac{N_B}{S \cdot d}$$

spessore  $dx$ .

$$P(\text{reazione}) = \frac{(dN_r/dt)}{(dN_p/dt)} = \sigma_{nb} \cdot dx$$

per spessore  $dx$



prob. numero prob.

$$\langle dx \rangle = L. \quad \sigma_{nb} = \mu \quad \text{coeff. di assorbimento.}$$

$$P(\text{reazione}, dx) = \mu \cdot dx$$

$$\phi_p = \phi_0 = \phi_p(t=0)$$

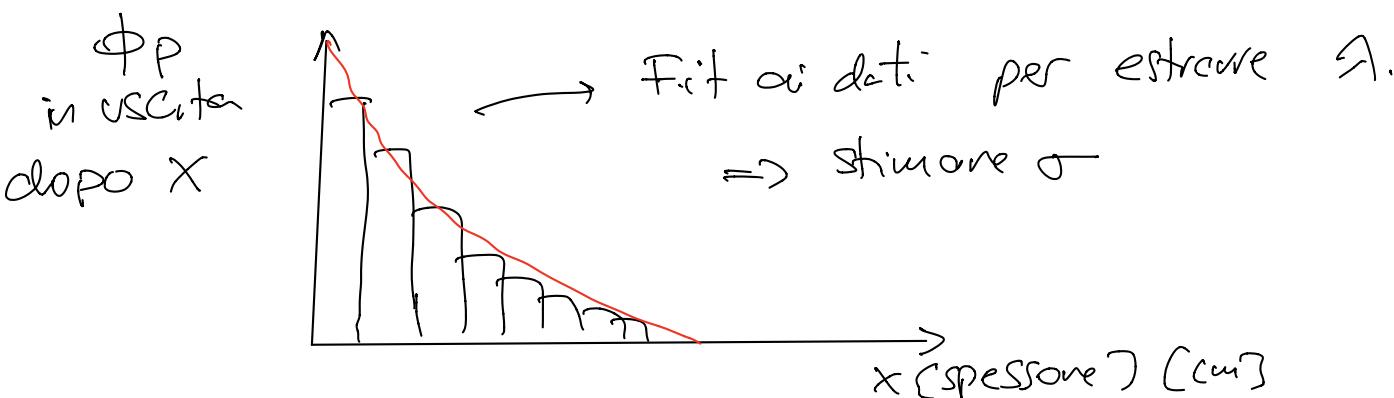
$$d\phi_p = -\phi_p \cdot P(\text{reazione}) = -\mu dx \phi_p.$$

$$\phi_p(\text{dopo } x) = \phi(t=0) e^{-\mu x}$$

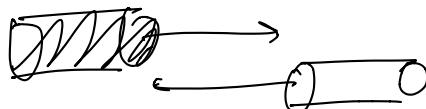
$$[\mu] \in \text{cm}^{-1} \Rightarrow \lambda = \frac{1}{\mu} = \frac{1}{\sigma_{nb}}$$

$$\phi_p(x) = \phi_0 e^{-\frac{x}{\lambda}}$$

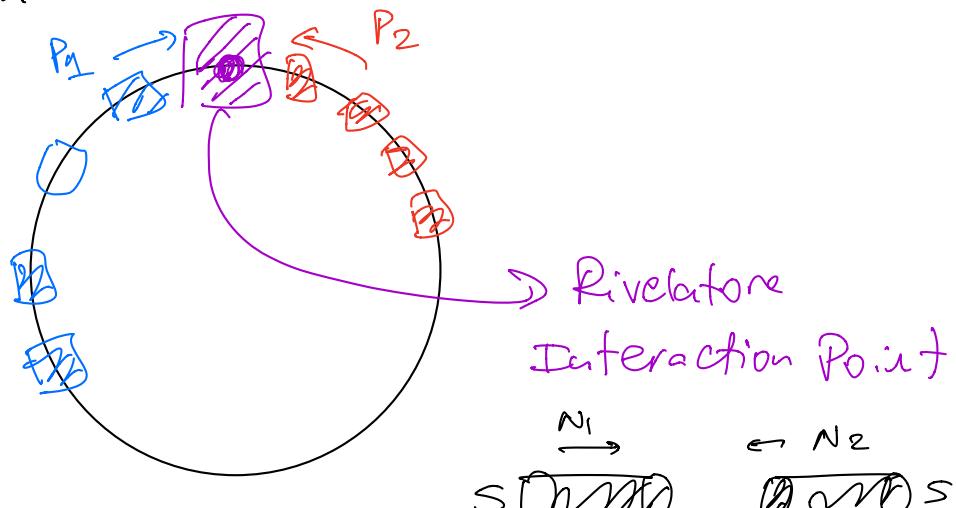
$\lambda$ : lunghezza d'attenuazione.



### Collisioni con fasci microscopici



Acceleratori: lineari o circolari.



LHC: 27 km.

$$S = \frac{N_1}{\text{cm}^2/\text{ns}} \cdot \frac{N_2}{\text{cm}^2/\text{ns}}$$

$$\begin{aligned} \frac{dN_r}{dt} &= \sigma \cdot \frac{dN_P}{dt \cdot S} \cdot N_b \cdot d \cdot S \\ &= \sigma \cdot \frac{\frac{dN_P}{dt \cdot S}}{N_2} \cdot N_1 \\ &\quad \phi_1 \end{aligned}$$

$$N_1 = \int_{\text{# pacchetti}}^{M_p} N_p \rightarrow \text{num. part./pacchetto.}$$

$$\text{LHC: } M_p \approx 1800 \quad N_p \approx 10^{12} \text{ protoni/pacchetto.}$$

$f_i$ : freq. di collisione.

$$\frac{dN}{dt \cdot S} = \frac{N_1}{S} f_i$$

$$\frac{dN_r}{dt} = \sigma \cdot N_1 \cdot \frac{f}{S} \cdot N_2$$

$$= \sigma \cdot \frac{(M_p)^2 (N_p)^2}{S} f$$

$$N_1 = N_2 = M_p \cdot N_p$$

S: sezione del fascio.

f: freq. di collisione

LHC

f: 40 MHz.  $\rightarrow$  1 collisione ogni 25 ns

$$\left[ \frac{dN_V}{dt} \right] = \frac{\text{events}}{\text{sec.}}$$

$$\frac{dN_V}{dt} = \tau \cdot L$$

$L$ : lum. istantanea delle macchine.

$$[L] = L^{-2} S^{-1} \text{ cm}^{-2} \text{ s}^{-1}$$

$$[\sigma] = \text{cm}^2.$$

$$1 \text{ barn} = 10^{-28} \text{ m}^2 = 10^{-24} \text{ cm}^2$$

$$\text{barn} \equiv \text{stalla}$$

$$1 \text{ pb} = 10^{-12} \text{ barn}$$

$$1 \text{ fb} = 10^{-15} \text{ barn.}$$

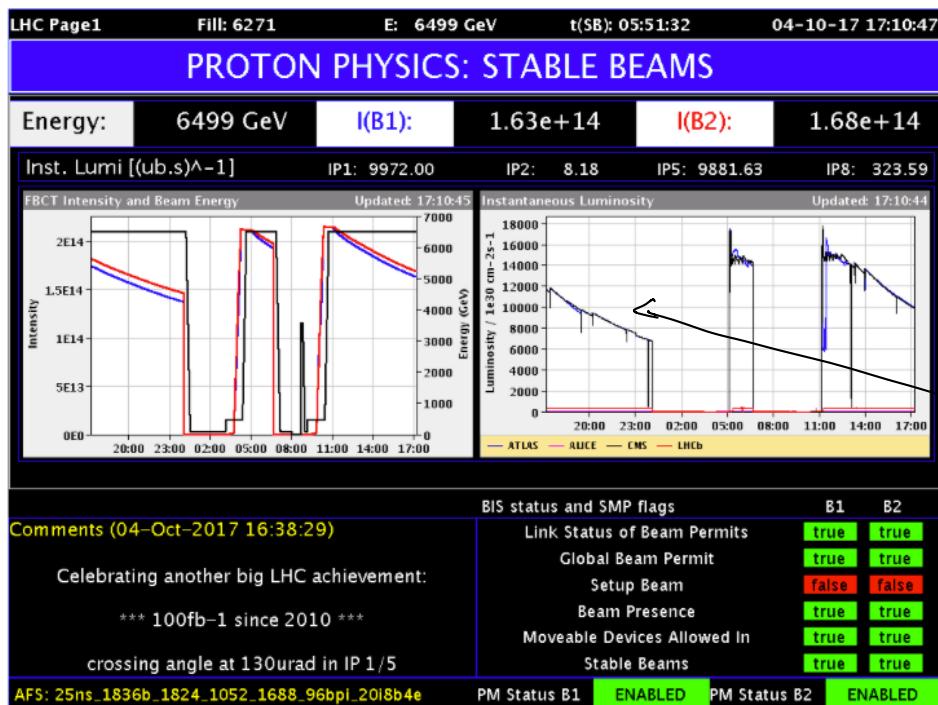
un'inf di misure sezione d'auto.

$$L = b^{-1} S^{-1} \text{ come.}$$

$$\# \text{ events} = \left( \frac{dN_V}{dt} \right) \Delta t = \sigma \int_{\text{pres defi}} L \cdot dt = \tau \cdot L$$

$$L = \int_{\Delta t} L \cdot dt \neq L \cdot \Delta t$$

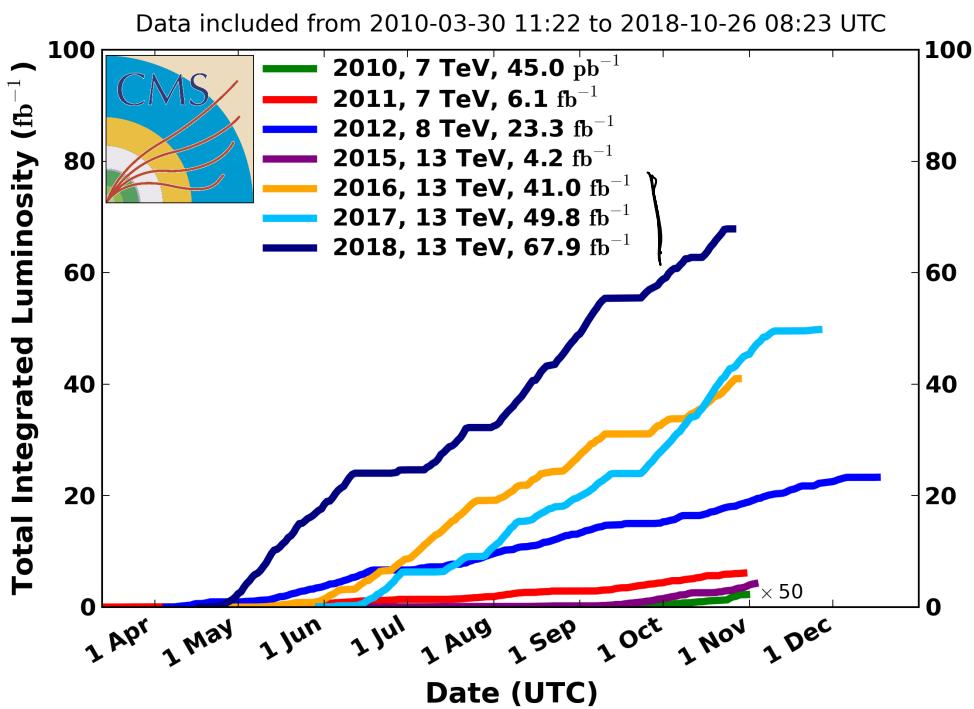
luminosità  
integrale.  
 $b^{-1}$



$$L = 100 \text{ fb}^{-1}$$

luminosità  
istantanea  
scade nel tempo.

### CMS Integrated Luminosity Delivered, pp



derivate  
massime.

$\frac{d}{dt}$

$L$  massime

lum. istantanea  
massime.

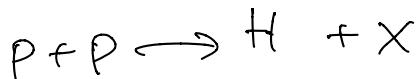
$L (2015 \rightarrow 2018)$

$$\approx 163 \text{ fb}^{-1}$$

Bosoni di Higgs prodotti a LHC

$$N_H = \sigma_H \cdot L$$

prodotti.



LHC: Proton:  $p = 6.5 \text{ TeV}$   $m_p = 1 \text{ GeV}$

$$\underline{p}_1 = (p_1, p_1, 0, 0)$$

$$\underline{p}_2 = (p_2, -p_1, 0, 0)$$

proton  $\longrightarrow$

$\longleftarrow$

proton'

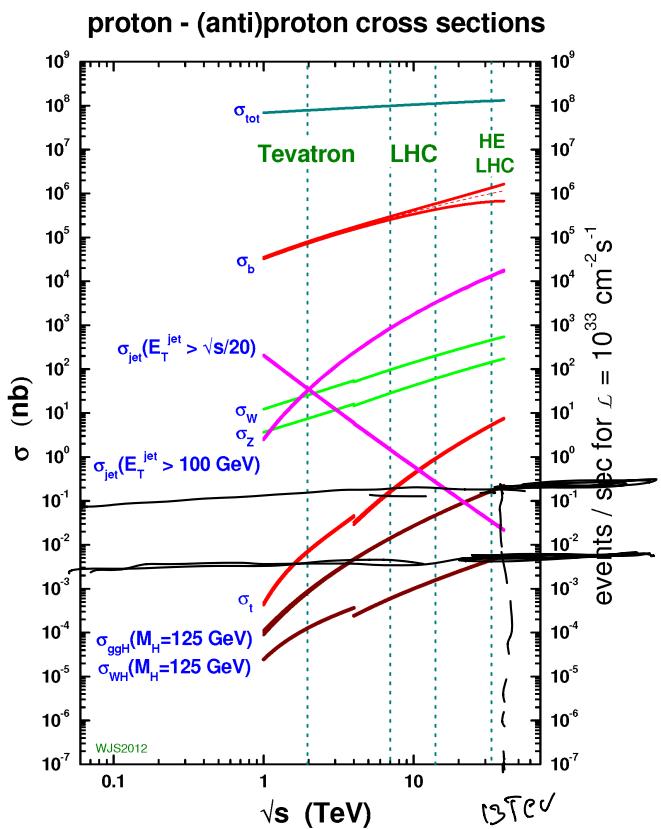
$$E \propto p.$$

$$|\underline{p}_1 + \underline{p}_2| = \sqrt{p^2} = 13 \text{ TeV.}$$

$\tau$ : dipendenza da energ. di collisione.

$\sqrt{s} = 13 \text{ TeV}$  @ LHC

2015-2018



$$\sigma_{\text{tot}} \quad p + \bar{p} \rightarrow X \\ = 10^8 \text{ ab} \approx 0.1 \text{ barn.}$$

$$\sigma_{\text{tot}} \approx 0.1 \text{ ab.}$$

$$\sigma_{\text{tot}} \text{ per } \sqrt{s} = 13 \text{ TeV.}$$

$$N_H = \sigma L = 0.1 \times 10^{-9} \text{ fb} \times 163 (10^{-15} \text{ fb})^{-1} \\ = 16 \times 10^6$$

Boroni di Higgs production

$\sigma$ : Calcola o partone ab Hint

$$\sigma_{\text{tot}} = 0.1 \text{ ab.}$$

$$N_{\text{int}} = 163 \times \text{fb}^{-1} \times 0.1 \text{ ab.}$$

$$= 163 \times 10^{15} \text{ fb} \times 0.1 \text{ ab} = 16 \times 10^{15} \approx 10^{16}$$