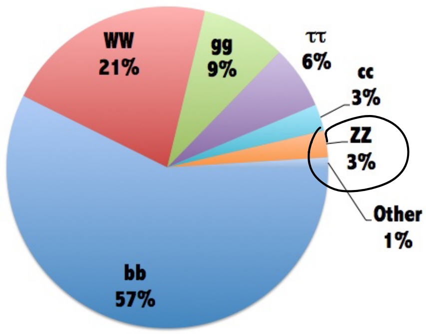
$N_H = 16 \times 10^6$ bosoni di Higgs prodotti $\qquad m_H = 125$ GeV

Higgs decays at m_H=125GeV



$H \to ZZ$;
WW ;
$b\bar{b}$
$c\bar{c}$
gg

$$N(p+p \to H+X,\ H \to ZZ) = \underbrace{\sigma_H \cdot L_{int}}_{16\times10^6} \times \underbrace{BF(H \to ZZ)}_{0.03}$$

$$= 48 \times 10^4 = 480 \text{ mila}$$

Z^0 instabile, decade

$BF(Z^0 \to$ canale i)

Z DECAY MODES

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	e^+e^-		(3.363 ±0.004) %	
Γ_2	$\mu^+\mu^-$		(3.366 ±0.007) %	
Γ_3	$\tau^+\tau^-$		(3.370 ±0.008) %	
Γ_4	$\ell^+\ell^-$	[a]	(3.3658±0.0023) %	
Γ_5	invisible		(20.00 ±0.06) %	
Γ_6	hadrons		(69.91 ±0.06) %	
Γ_7	$(u\bar{u}+c\bar{c})/2$		(11.6 ±0.6) %	
Γ_8	$(d\bar{d}+s\bar{s}+b\bar{b})/3$		(15.6 ±0.4) %	
Γ_9	$c\bar{c}$		(12.03 ±0.21) %	
Γ_{10}	$b\bar{b}$		(15.12 ±0.05) %	
Γ_{11}	$b\bar{b}b\bar{b}$		(3.6 ±1.3) $\times 10^{-4}$	
Γ_{12}	ggg		< 1.1 %	CL=95%
Γ_{13}	$\pi^0\gamma$		< 5.2 $\times 10^{-5}$	CL=95%
Γ_{14}	$\eta\gamma$		< 5.1 $\times 10^{-5}$	CL=95%
Γ_{15}	$\omega\gamma$		< 6.5 $\times 10^{-4}$	CL=95%
Γ_{16}	$\eta'(958)\gamma$		< 4.2 $\times 10^{-5}$	CL=95%
Γ_{17}	$\gamma\gamma$		< 5.2 $\times 10^{-5}$	CL=95%
Γ_{18}	$\gamma\gamma\gamma$		< 1.0 $\times 10^{-5}$	CL=95%
Γ_{19}	$\pi^\pm W^\mp$	[b]	< 7 $\times 10^{-5}$	CL=95%

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\# eventi = ?

$p+p \to H+X$
$\quad H \to Z^0 Z^0$
$\qquad Z^0 \to \mu^+\mu^-$
$\qquad Z^0 \to \mu^+\mu^-$

$\tau_\mu = 2.2\ \mu s$

nei rivelatori ai collisori μ si comportano come se fossero stabili.

$\beta\gamma c\tau$. $\qquad \beta = \frac{p}{m}$

$p = 10$ GeV

$$N(p+p \to H+X,\ H \to Z^0Z^0,\ Z^0 \to \mu^+\mu^-,\ Z^0 \to \mu^+\mu^-) =$$

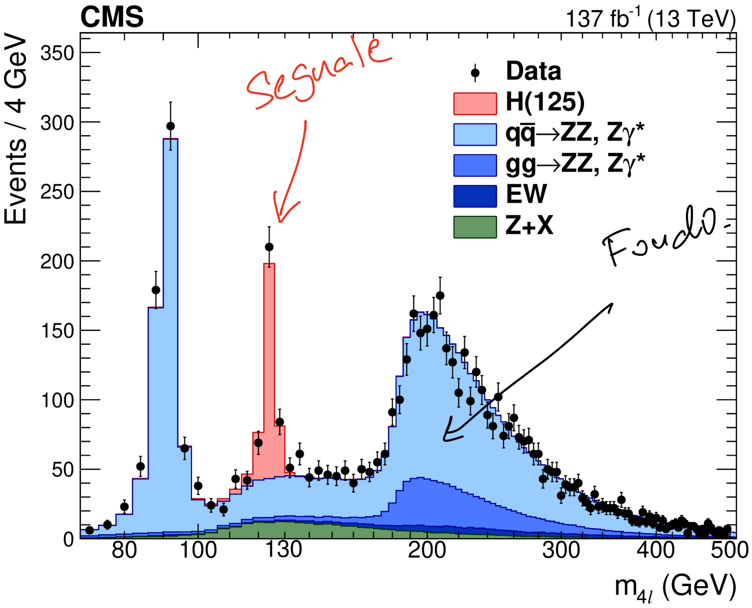
$$= \sigma_H \times L_{int} \times BF(H \to Z^0Z^0) \times BF(Z^0 \to \mu\mu) \times BF(Z^0 \to \mu^+\mu^-)$$

$$= 48 \times \cancel{10^4} \times 3 \times \cancel{10^{-2}} \times 3 \times \cancel{10^{-2}} = 9 \times 48 = 432$$

$$Z^0 Z^0 \to \left.\begin{array}{l} \mu^+\mu^- \ \mu^+\mu^- \\ e^+e^- \ e^+e^- \\ e^+e^- \ \mu^+\mu^- \\ \mu^+\mu^- \ e^+e^- \end{array}\right\}$$

$H \to Z^0 Z^0 \to 4\ell$

$\sim$ 1600 totale prodotti.



$H \to Z^0 Z^0$

$\hookrightarrow \mu^+\mu^-$

$\hookrightarrow \mu^+\mu^-$

4 particelle cariche nel laboratorio

$\underline{P}_\mu = (E, \vec{P})$

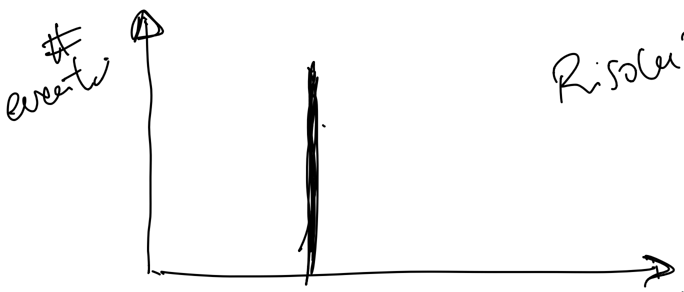
massa invariante

conservazione impulso energia

$$\underline{P}_{\mu^+} + \underline{P}_{\mu^-} + \underline{P}_{\mu^+} + \underline{P}_{\mu^-} = \underline{P}_{tot} = \underline{P}_H$$

$$|\underline{P}_H|^2 = E_H^2 - |\vec{P}_H|^2 = M_H^2$$

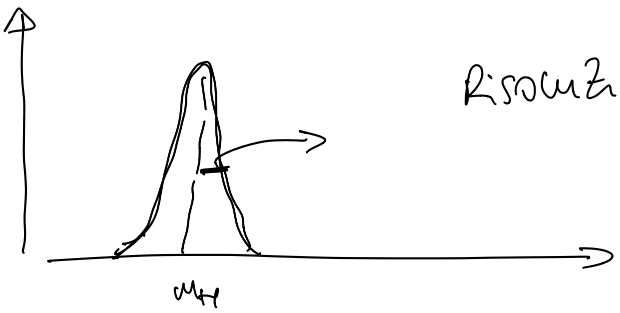
↪ modulo del 4-impulso, invariante relativistico.



Risoluzione ∞.

$m_H = |\underline{P}_H| = |\underline{P}_{\mu^+} + \dots|$

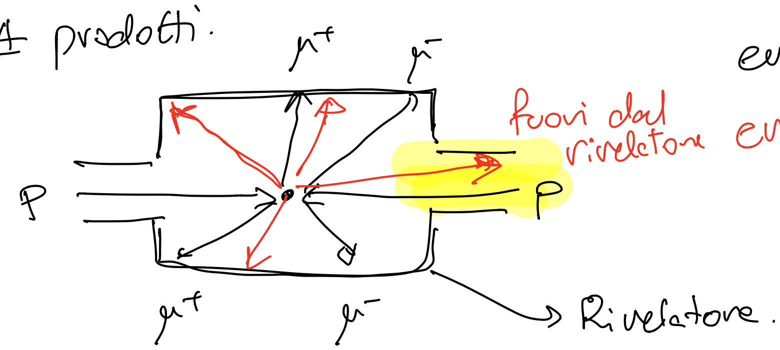
Risoluzione sperimentale



Risoluzione σ

$$N_{eventi} = \sigma_{H} \times L_{int} \times BF(H \to ZZ) \times BF(Z^0 \to \mu\mu)^2$$

\# prodotti:



evento 1 ✓

evento 2: perso un μ.

evento perso.

$$N_{osservati} = N_{prodotti} \times \underset{\text{rivelatore}}{\text{accettanza}} \times \text{efficienza}.$$

$$A \leq 1 \qquad \varepsilon \leq 1$$

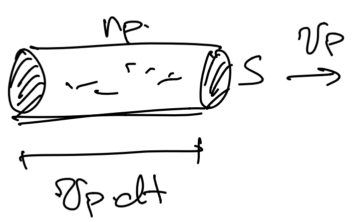
$$N_{oss} \leq N_{prodotti}$$

Sezione d'urto differenziale

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

misura σ: $\qquad \sigma = \dfrac{\left(\frac{dN_r}{dt}\right)}{\Phi_p} \dfrac{1}{N_B}.$

tempo T di misura. $\qquad \dfrac{dN_r}{dt} = \dfrac{\#\text{ reazioni}}{T}$



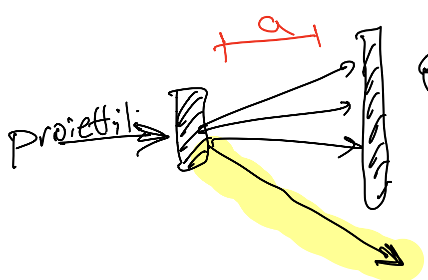
$$N_p = n_p \cdot v\,dt\; S.$$

$$\Rightarrow \Phi_p = \frac{N_p}{dt \cdot S} = n_p \cdot v_p$$

n_p: densità proiettili

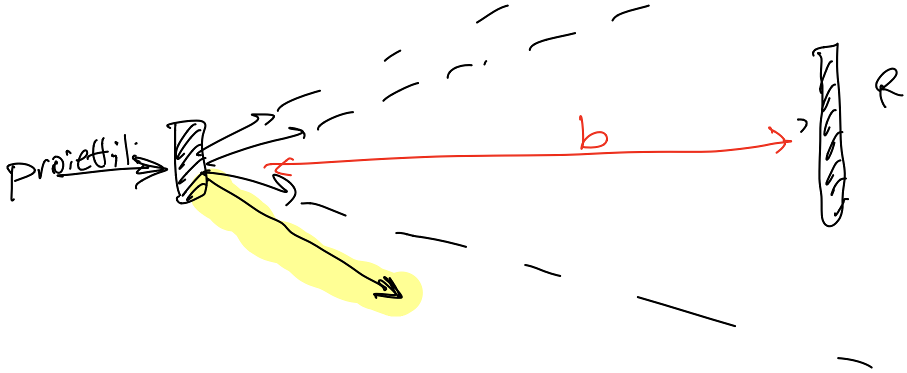
v_p: velocità proiettili

Due contesti $\longrightarrow$ misure di σ.



Rivelatore.

reazione non vista dal rivelatore.



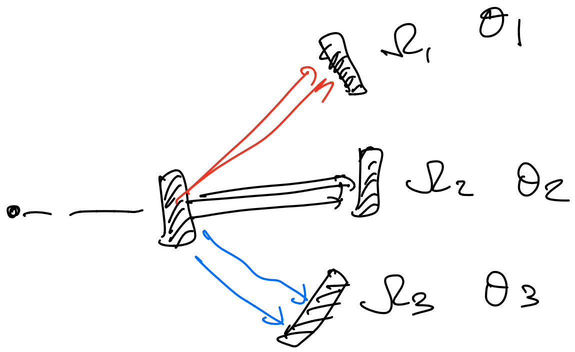
$\Omega_b \ll \Omega_a.$

$\Omega = \dfrac{S}{L^2}$ angolo solido del rivelatore

steradianti

$$\frac{dN}{dt}\,\frac{1}{\Delta\Omega} = \frac{d\sigma}{d\Omega}\,\Phi_p \cdot N_B.$$

sezione d'urto differenziale.



$\Omega_1 = \Omega_2 = \Omega_3$

Tipicamente $\dfrac{d\sigma}{d\Omega}(\theta, \varphi)$

$$\frac{dN}{dt}\,\frac{1}{\Delta\Omega}\ \begin{cases} @\ \theta_1 \\ @\ \theta_2 \\ @\ \theta_3 \end{cases}$$

misurare $\dfrac{d\sigma}{d\Omega}$ @ θ_1

$\dfrac{d\sigma}{d\Omega}$ @ θ_2

$\dfrac{d\sigma}{d\Omega}$ @ θ_3

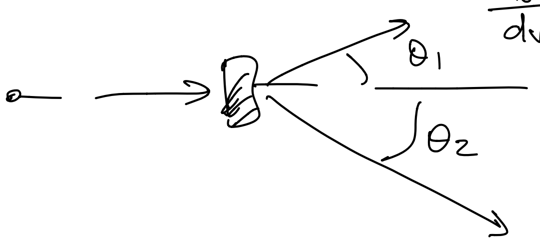
$$\frac{dN}{dt\,d\Omega} \equiv \frac{\#\text{eventi}}{\Delta T \quad \Delta\Omega}$$

ΔT: misura.

$\Delta\Omega = \dfrac{S_{rive}}{L^2}$

@ θ_1. $\longrightarrow$ $\dfrac{d\sigma}{d\Omega} = \dfrac{\#\text{eventi}}{\Delta T \quad \Delta\Omega}$ @ θ_1. N_1

$\dfrac{\#\text{eventi}}{\Delta T \quad \Delta\Omega}$ @ θ_2 N_2

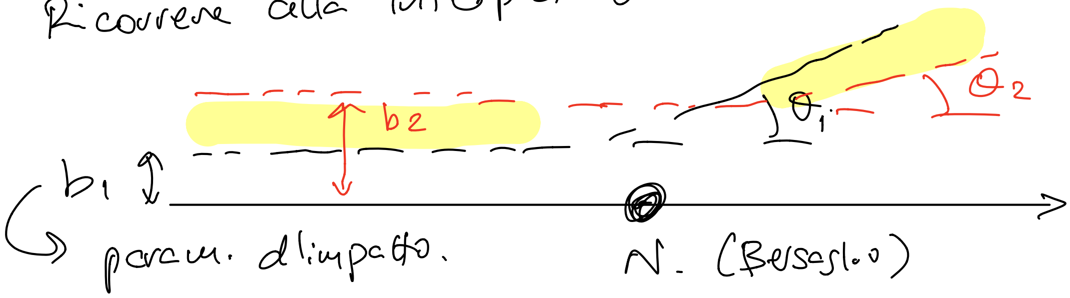


$$\left.\frac{d\sigma}{d\Omega}\right|_{\theta_1} \qquad \left.\frac{d\sigma}{d\Omega}\right|_{\theta_2}$$

$N_{eventi} = N(\theta, \varphi)$

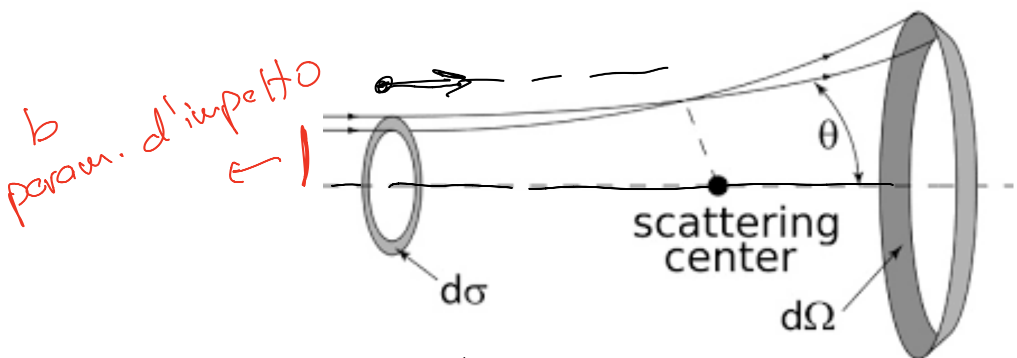
Calcolo sezione d'urto differenziale

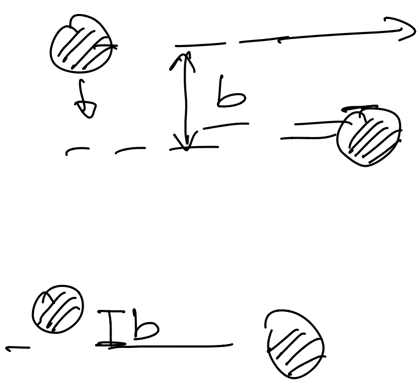
Ricorrere alla interpret. geom. della sezione d'urto

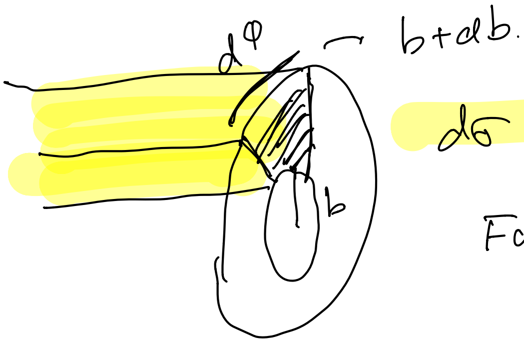


variare $b \longrightarrow$ varia. θ in uscita del proiettile.

urti elastici: $p + p \longrightarrow p + p$







$d\sigma = b\, d\varphi\, db.$

Fascio di proiettili: $[b, b+db]$.
$[\varphi, \varphi+d\varphi]$

$d\sigma$: sup effettiva colpita dai proiettili.

$b = f(\theta) \qquad b = b(\theta) \longleftrightarrow \theta = \theta(b)$

$$d\sigma = b\,db\,d\varphi = b\,\frac{db}{d\theta}\,d\theta\cdot d\varphi$$

relazione fra $b \longleftrightarrow \theta$.

par. impatto proiettile — angolo deviazione.

$d\sigma > 0$ sempre.

$$d\sigma = b\left|\frac{db}{d\theta}\right| d\theta\,d\varphi.$$

$$d\Omega = \sin\theta\,d\theta\,d\varphi. \implies d\theta\,d\varphi = \frac{d\Omega}{\sin\theta}.$$

$$d\sigma = b\left|\frac{db}{d\theta}\right|\frac{d\Omega}{\sin\theta}.$$

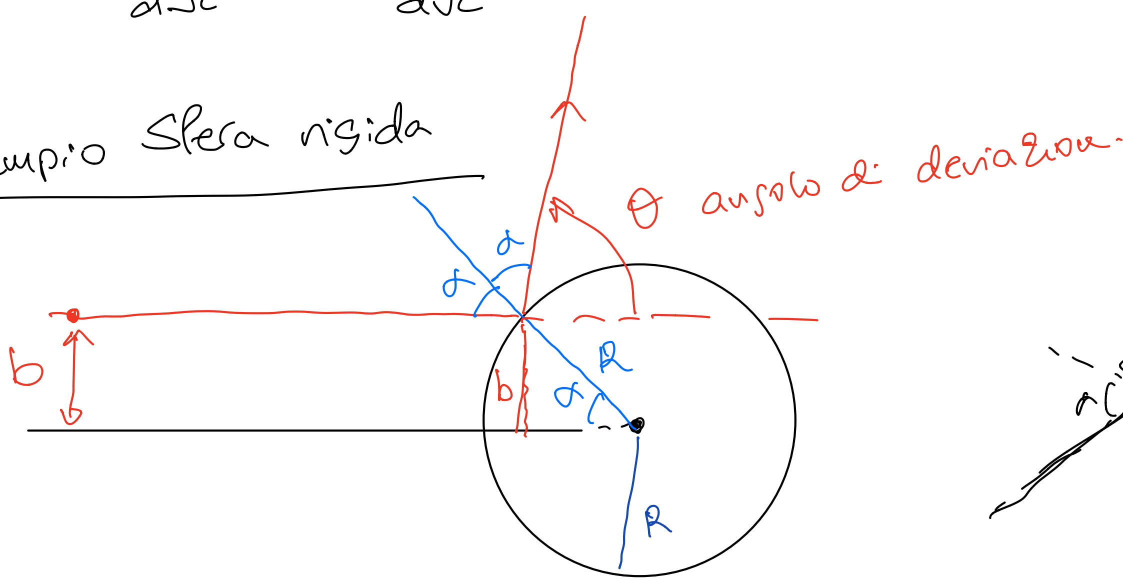
$$\frac{d\sigma}{d\Omega} = \frac{b}{\sin\theta}\left|\frac{db}{d\theta}\right|$$

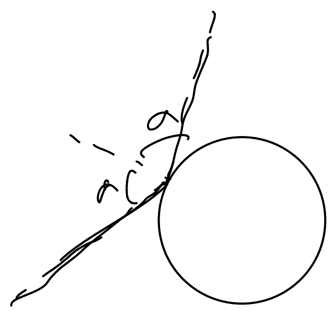
Def. della Sezione d'urto differenziale.

$$\frac{d\sigma}{d\Omega} \equiv \frac{d\sigma(\theta,\varphi)}{d\Omega}$$

può dipendere da θ e φ

Esempio Sfera rigida





$\theta = \pi - 2\alpha$: angolo di deviazione.

$b = R\cdot\sin\alpha$

$$\alpha = \frac{1}{2}(\pi - \theta) \implies \boxed{b = R\cos\frac{\theta}{2}}$$

relazione fra $b \longleftrightarrow \theta$.

par. d'impatto — angolo deviazione.

$$\frac{db}{d\theta} = -\frac{R}{2}\sin\frac{\theta}{2}$$

$$\frac{d\sigma}{d\Omega} = \frac{b}{\sin\theta}\left|\frac{db}{d\theta}\right| = R\cos\cancel{\frac{\theta}{2}}\ \frac{1}{\sin\theta}\ \frac{R}{2}\sin\cancel{\frac{\theta}{2}}$$

$$\sin\theta = \sin\left(2\frac{\theta}{2}\right) = 2\sin\cancel{\frac{\theta}{2}}\cos\cancel{\frac{\theta}{2}}$$

$$= \frac{R^2}{4} \qquad \frac{d\sigma}{d\Omega} = \frac{R^2}{4}$$

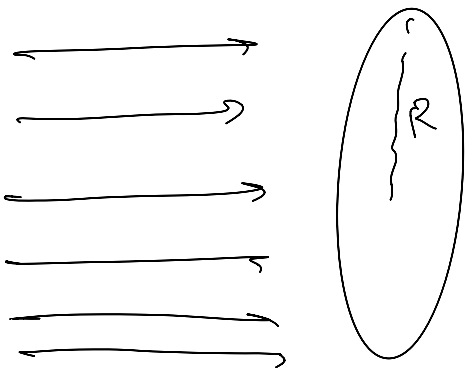
non dipende da θ, e φ.

$$\sigma_{tot} = \int \frac{d\sigma}{d\Omega}\, d\Omega = \int \frac{R^2}{4}\, d\Omega = \frac{R^2}{4}\int d\Omega$$

$$= \frac{R^2}{\cancel{4}}\cancel{4}\pi = \pi R^2$$

$$\sigma_{tot} = \pi R^2$$

sez. d'urto contro sfera rigida raggio R.



$r < R$: colpita sfera.

$r > R$ non colpita.