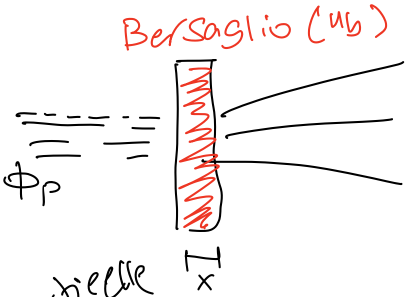
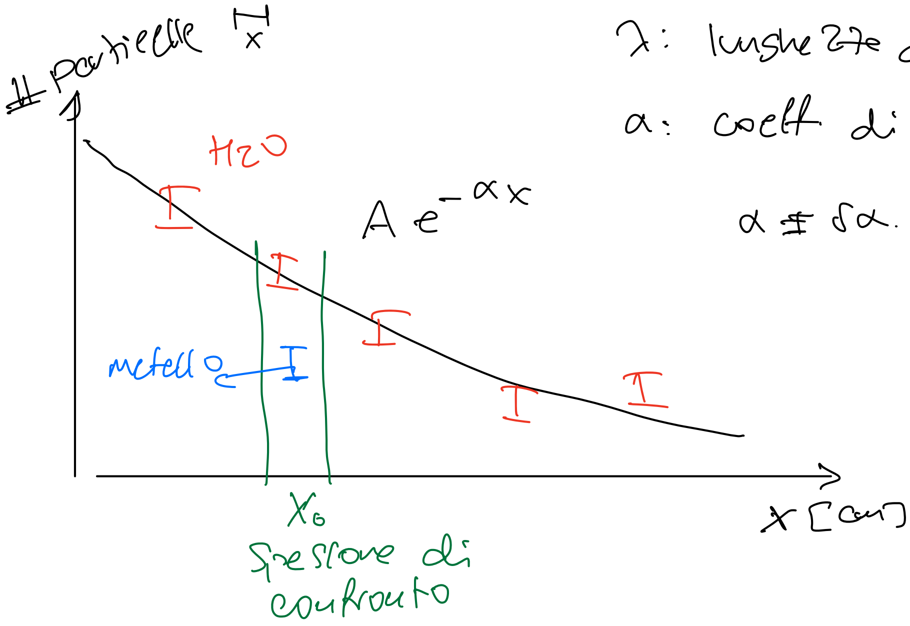


$$\Phi_p(x) = \underbrace{\Phi_p(x=0)}_{\Phi_p^{in}}\, e^{-\alpha x}$$

$$\alpha = n_b \cdot \sigma = \frac{1}{\lambda}$$

λ: lunghezza di attenuazione

α: coeff di assorbimento



$$\alpha \pm \delta\alpha \Rightarrow \sigma = \frac{\alpha}{n_b}$$

$\rho_{H_2O} = 1\ g/cm^3$

$\rho_{metallo} \simeq 10\ g/cm^3$

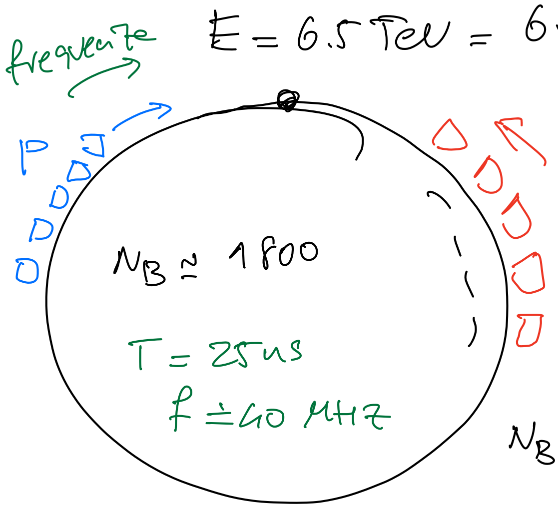
In generale $\frac{dN_r}{dt} = \sigma \frac{dN_p}{dt} n_b \cdot d$

Di solito misuro $\frac{\#\text{reazioni}}{\Delta t} \Rightarrow$ stimare σ

Fasci collidenti

$E = 6.5$ TeV $= 6500$ GeV

LHC $= 27$ km



pacchetti di 10^{11} protoni N_p

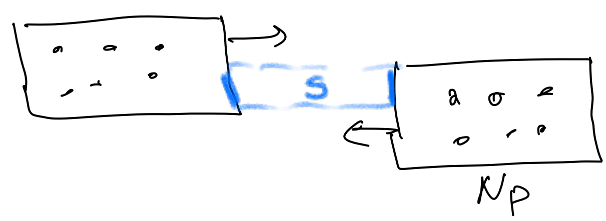
N_B: numero di bunch o pacchetti

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

$$= \sigma \frac{dN_r}{dt} \frac{1}{S} n_b d \cdot S$$

$$= \sigma \Phi_p N_{Bersaglio}$$

$$= \sigma \Phi_p N_{Bunch} \cdot N_p$$



$$\Phi_p = \frac{N_p}{S} freq.$$

$$= \underbrace{\sigma}_{\text{interazione}} \frac{N_p}{S} f N_B \cdot N_p = \sigma \underbrace{f \frac{N_p^2 N_B}{S}}_{\text{Bontà della macchina}} = \sigma \mathcal{L}$$

luminosità istantanea

$$\frac{dN_r}{dt} = \sigma\,[cm^2]\ \mathcal{L}\ [cm^{-2}s^{-1}] \qquad \mathcal{L} \simeq 10^{34}\ cm^{-2}s^{-1}$$

1 MB/collisione   quantità di dati = $1\ MB \times 40 \times 10^6\ Hz$

$= 10^6\ MB/s. \simeq 1\ TB/s$

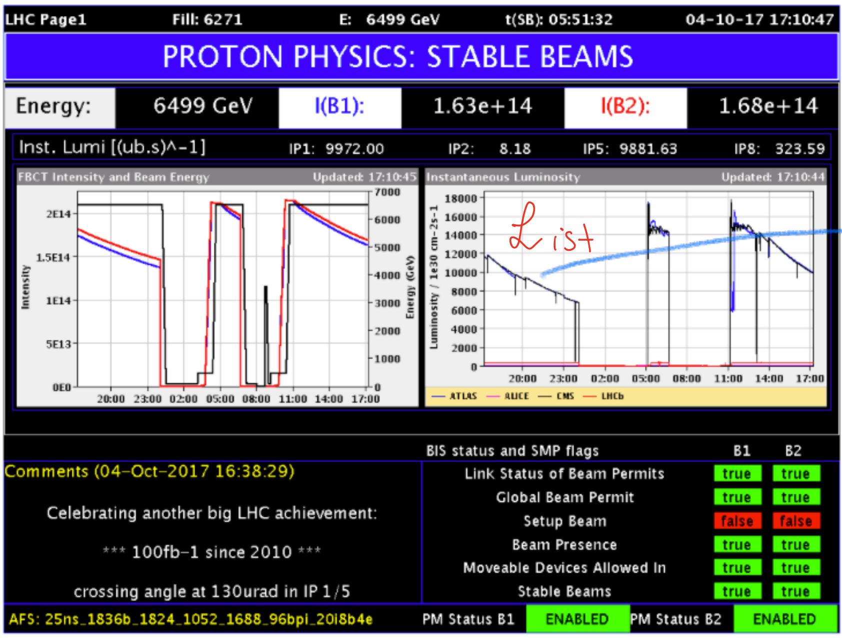
$$N_{reazioni} = \sigma \times \mathcal{L}_{ist.} \times \Delta T = \sigma \underbrace{\int \mathcal{L}_{ist}\, dt}_{\text{luminosità integrata}} = \sigma\, L_{int}$$

$$[L_{int}] = [cm^{-2}]$$

unità di misura: $1\ \text{barn} \to 1\ b = 10^{-28}\ m^2 = 10^{-24}\ cm^2$

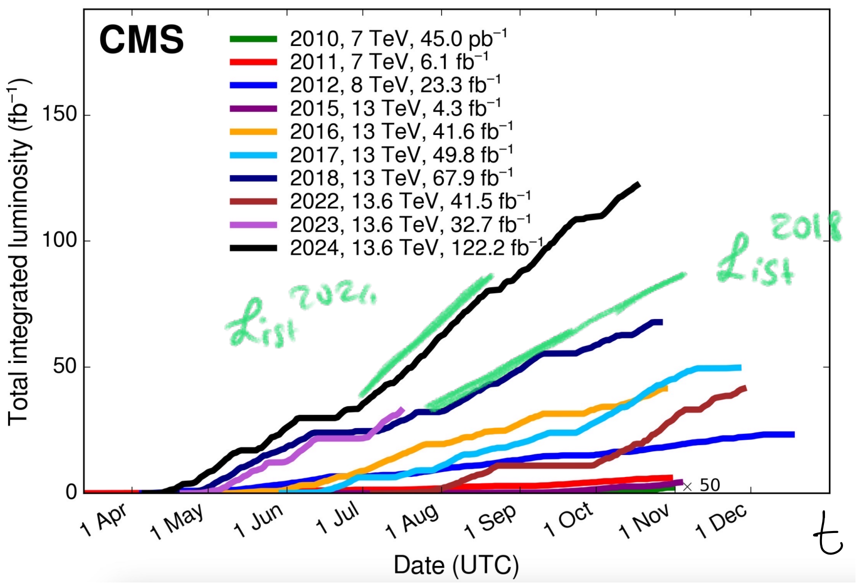
(Stalla)

sezioni d'urto tipiche di particelle elem. pb, fb, μb.
(10^{-12}, 10^{-15}, 10^{-6})



$N_p = N_p(t=0)\, e^{-\frac{t}{\tau}}$

τ tempo di attenuazione del fascio



$$L_{int} = \int_{anno} \mathcal{L}_{ist} \cdot dt$$

$$\mathcal{L}_{ist} \sim \frac{N_p^2 N_B}{S} f$$

$p+p \longrightarrow p+p$ elastico σ_1

$H+X$ produzione di Higgs. σ_2

Z^0+X σ_3

$$N^{\text{totale}}_{\text{eventi}} = \underbrace{\left(\sum_i \sigma_i\right)}_{\sigma_{tot}} \mathcal{L}_{int} \times \Delta t$$

σ_{tot} sezione d'urto totale di tutti i processi

processo noto $p+p \to a+b$

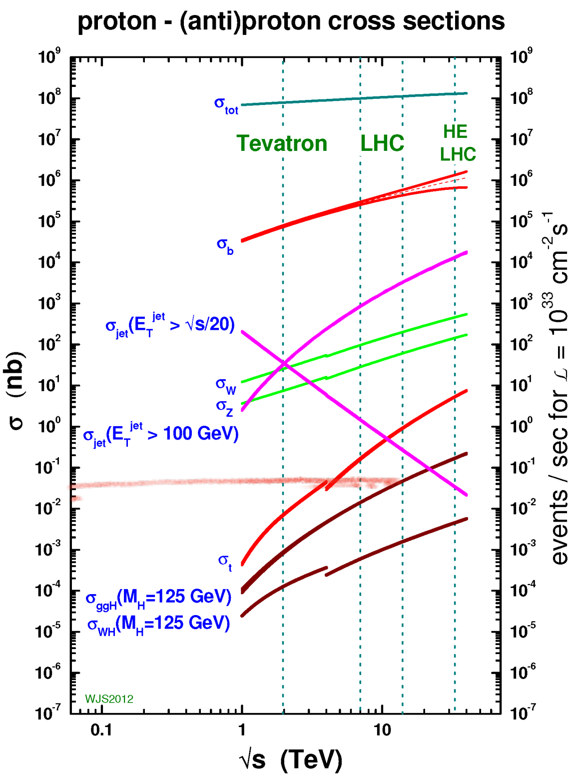
di cui conosco $\sigma(p+p \to a+b)$ calcolata con buona precisione.

$$N(p+p \to a+b) = \sigma_{calc.}(p+p \to a+b)\, L_{int}$$

$$\Rightarrow L_{int} = \frac{N(a+b)}{\sigma_{calc}(a+b)}$$

$e^+ + e^- \longrightarrow e^+ + e^-$ Bhabha scattering.

macchine e^+e^- $\mathcal{L}_{int} = \dfrac{N(e^+e^- \to e^+e^-)}{\sigma(\text{Bhabha})}$ calcolata con altissima precisione.



$\underline{P_1} = (E_1, E_1, 0, 0)$ $\underline{P_2} = (E_1, -E_1, 0, 0)$ $\longrightarrow x$

$\underline{P_{tot}} = (2E_1, 0, 0, 0)$

$$s = (\underline{P_1} + \underline{P_2})^2 = (2E)^2$$

$$\sqrt{s} = 2E = 13 \text{ TeV}.$$

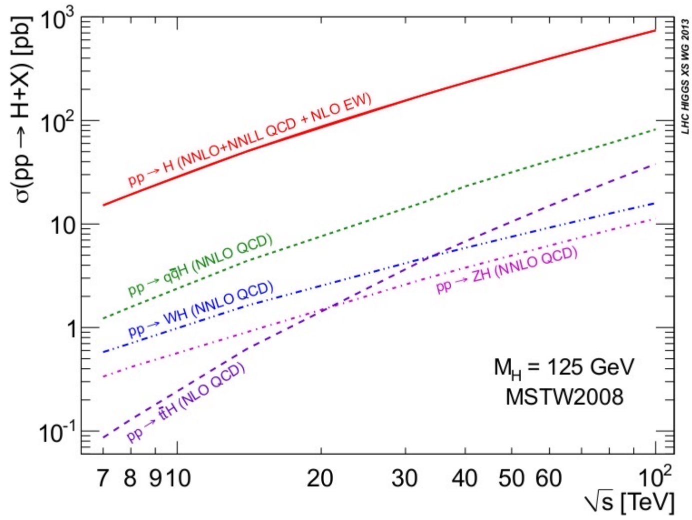
$$E = 6.5 \text{ TeV}$$

$$\sigma_{tot\, p+p} = 10^8 \text{ nb} = 10^8 10^{-9} \text{ b} = 10^{-1} \text{ b}$$

$$\boxed{\Gamma(p+p \to H+X) \sim}\quad 10^{-2}\ nb.$$

$$10^{2}\ pb = 10^{2}\,10^{-12}\ \cancel{p}b$$

$$= 10^{-10}\ b = \boxed{10^{-1}\ nb.}$$



$$N_H = \sigma_{H+X}\ L_{int}$$

$$L_{int} = 150\ fb^{-1} \quad (2016-2018)$$

$$N_H = 150\ fb^{-1} \times 10^{-1}\ nb.$$

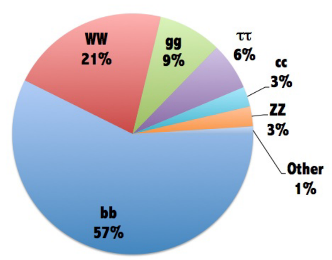
$$= 150\ \cancel{fb^{-1}} \times 10^{-1} \times 10^{6}\ \cancel{fb} = 1.5 \times 10^{2} \times 10^{5} = 1.5 \times 10^{7}$$

$= 15$ milioni # totale Higgs prodotto

H DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	WW^*	(25.7 ± 2.5) %	
Γ_2	ZZ^*	(2.80 ± 0.30) %	
Γ_3	$\gamma\gamma$	$(2.50 \pm 0.20) \times 10^{-3}$	
Γ_4	$b\bar{b}$	(53 ± 8) %	
Γ_5	e^+e^-	$< 3.0 \times 10^{-4}$	95%
Γ_6	$\mu^+\mu^-$	$(2.6 \pm 1.3) \times 10^{-4}$	
Γ_7	$\tau^+\tau^-$	$(6.0^{+0.8}_{-0.7})$ %	
Γ_8	$Z\gamma$	$(3.4 \pm 1.1) \times 10^{-3}$	
Γ_9	$Z\rho(770)$	< 1.21 %	95%
Γ_{10}	$Z\phi(1020)$	$< 3.6 \times 10^{-3}$	95%
Γ_{11}	$Z\eta_c$		
Γ_{12}	ZJ/ψ	$< 1.9 \times 10^{-3}$	95%
Γ_{13}	$Z\psi(2S)$	$< 6.6 \times 10^{-3}$	95%
Γ_{14}	$J/\psi\gamma$	$< 2.0 \times 10^{-4}$	95%
Γ_{15}	$J/\psi J/\psi$	$< 3.8 \times 10^{-4}$	95%

Higgs decays at m_H=125GeV



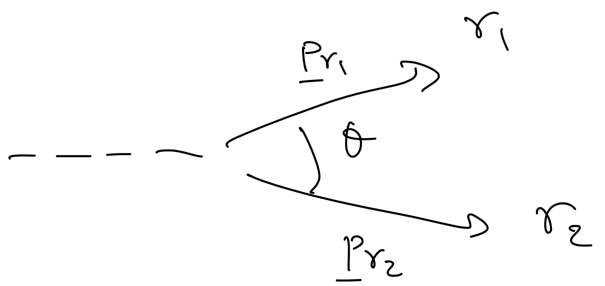
$H \to \gamma\gamma$ BF 2.5×10^{-3}.

$$N(H \to \gamma\gamma) = 1.5 \times 10^{7} \times 2.5 \times 10^{-3} = 3.75 \times 10^{4}$$

$$\gamma_1:\ E_{\gamma_1} \equiv P_{\gamma_1}$$

$$\underline{P}_H = \underline{P}_{\gamma_1} + \underline{P}_{\gamma_2}$$

$$\gamma_2:\ E_{\gamma_2} \equiv P_{\gamma_2}$$



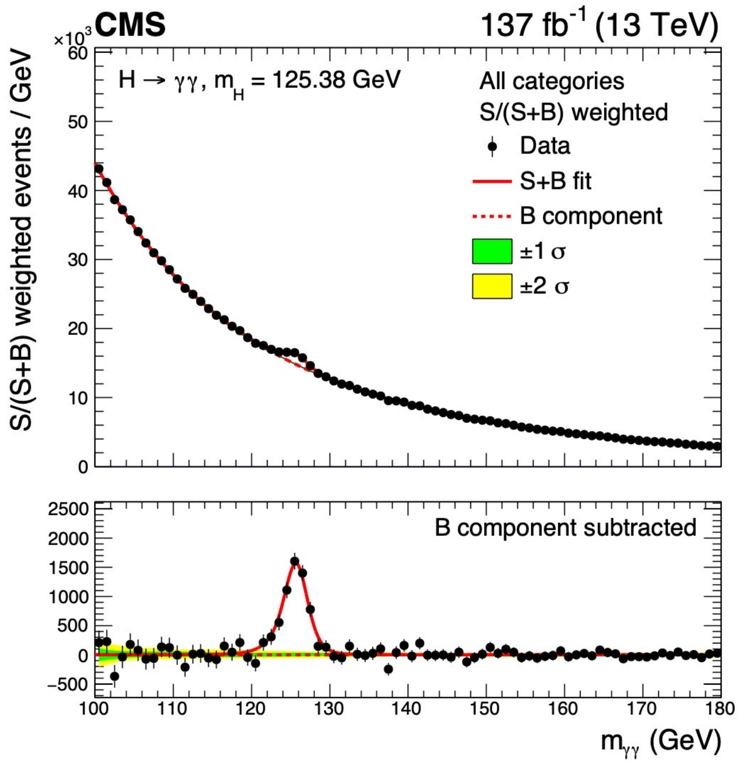
$$m_{\gamma\gamma} = \sqrt{(\underline{P}_{\gamma_1} + \underline{P}_{\gamma_2})^2}$$

$$= \sqrt{(\underline{P}_H)^2} = m_H$$

Nel rivelatore misure E_{r1}, E_{r2}.

$(E_{r1}, \theta_1, \varphi_1)$

$(E_{r2}, \theta_2, \varphi_2)$



$$p + p \longrightarrow H + X$$
$$\hookrightarrow Z^0 \; Z^0$$
$$\hookrightarrow \mu^+\mu^- / e^+e^-$$
$$\hookrightarrow e^+e^- / \mu^+\mu^-$$

$$N(p+p \to H+X \to \mu^+\mu^- e^+e^-) =$$

$$N(pp \to H+X) \times BF(H \to ZZ) \times BF(Z \to \mu\mu) \times BF(Z \to ee)$$

$$= \underbrace{\sigma_H \times L_{int}}_{1.5\times 10^7} \times 3\times 10^{-2} \times 3\times 10^{-2} \times 3\times 10^{-2}$$

$$= 1.5\times 10^7 \times 27 \times 10^{-6} =$$

$$= 40 \times 10^1 = 400$$

×2 perché entrambi: Z possono decadere in ee/μμ.

$$H \to ZZ \to \ell_1^- \ell_2^+ \ell_3^- \ell_4^+$$

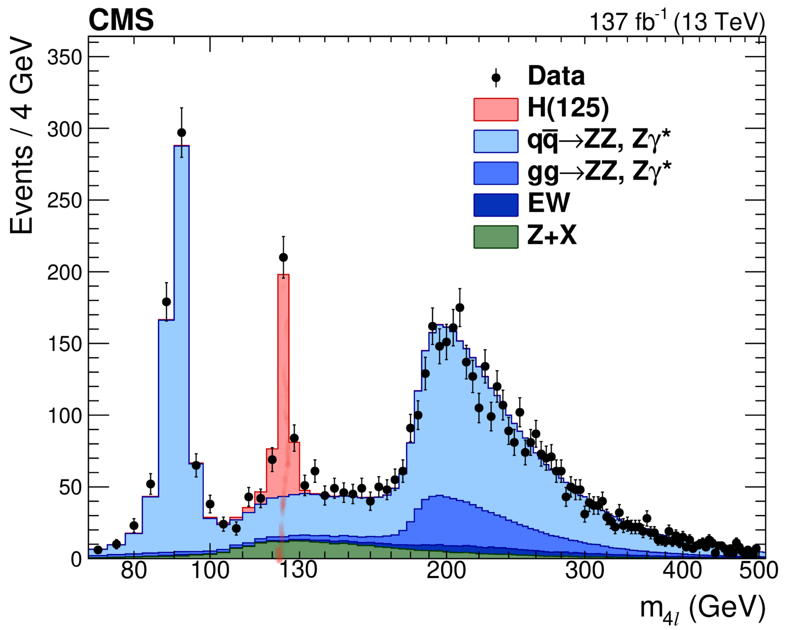
Z DECAY MODES

	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%

$$\underline{P}_H = \underline{P}_{Z_1} + \underline{P}_{Z_2} = (\underline{P}_{\ell_1^-} + \underline{P}_{\ell_2^+}) + (\underline{P}_{\ell_3^-} + \underline{P}_{\ell_4^+})$$

$$M_{\ell\ell\ell\ell} = \sqrt{(\underline{P}_{\ell_1} + \underline{P}_{\ell_2} + \underline{P}_{\ell_3} + \underline{P}_{\ell_4})^2}$$

mi aspetto picco intorno a M_H



M_H da $H \to \ell\ell\ell\ell$

M_H da $H \to \gamma\gamma$

} compatibili ⟹ un'unica particella che decade.

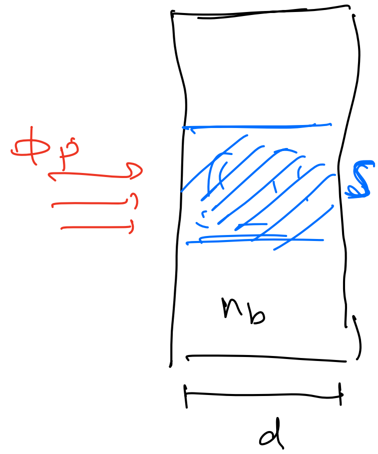
$p+p \to Z\,Z \to \ell\ell\;\ell\ell$ processo di fondo.

$$\sigma_{tot} = \underbrace{\sigma_H + \sigma_{ZZ} + \sigma_{Z\gamma} + \sigma_{pp}}$$

σ_{tot} : sezione d'urto inclusiva

$\sigma(p+p \to H+X)$: sezione esclusiva produzione Higgs

Sezione d'urto e le sue stime



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

$$= \sigma\, n_p \cdot v_p\, N_B$$

$$\underbrace{\frac{1}{N_B} \frac{1}{n_p} \frac{dN_r}{dt}}_{\text{prob. di reazione per unità di tempo.}} = \sigma \cdot v_p$$

$$|i\rangle \longrightarrow |f\rangle$$

Regola d'oro di Fermi:

$$\Gamma(i \to f) = 2\pi\, |M_{fi}|^2 \underbrace{\left.\frac{dn}{dE}\right|_{E_i = E_f}}_{\text{densità degli stati spazio delle fasi}}$$

$\rho(E)$

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

prob. di transizione per unità di tempo.

$$\sigma \cdot v_p = \Gamma(i \to f)$$