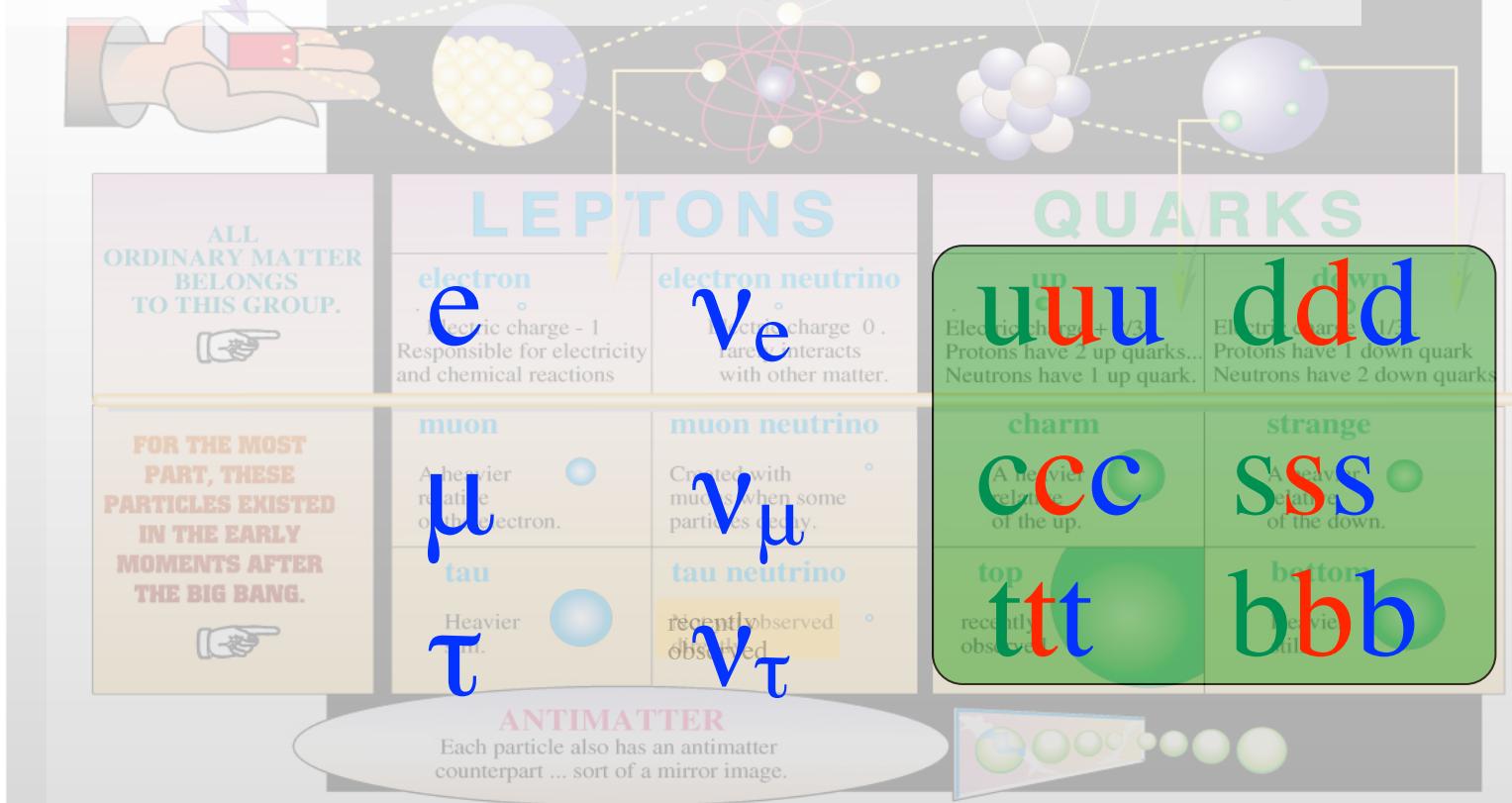
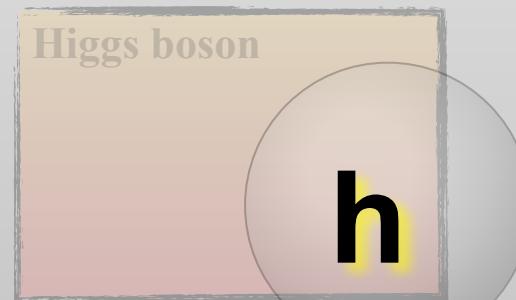


STANDARD MODEL

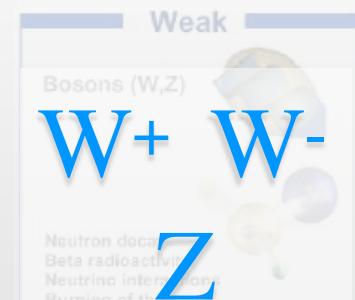
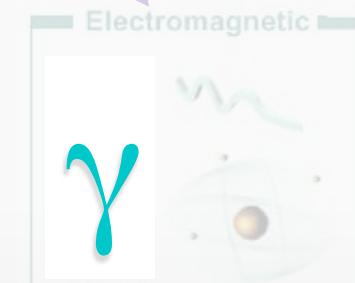
Interazioni (& simmetrie)

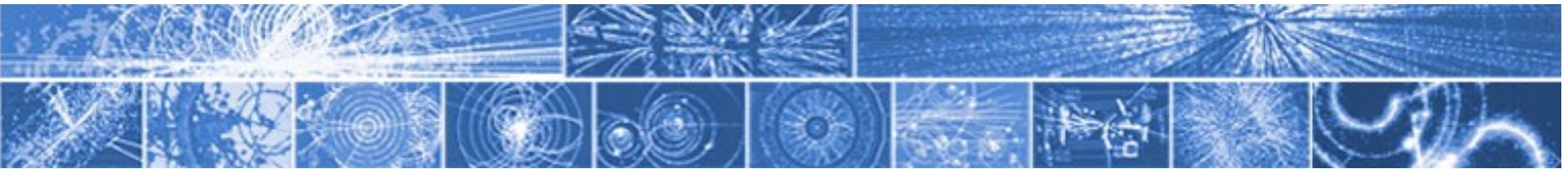


- $SU_c(3) \times SU_w(2) \times U_Y(1) \rightarrow SU_c(3) \times U_{\text{em}}(1)$
- colore e carica elettrica
- sapore barionico totale



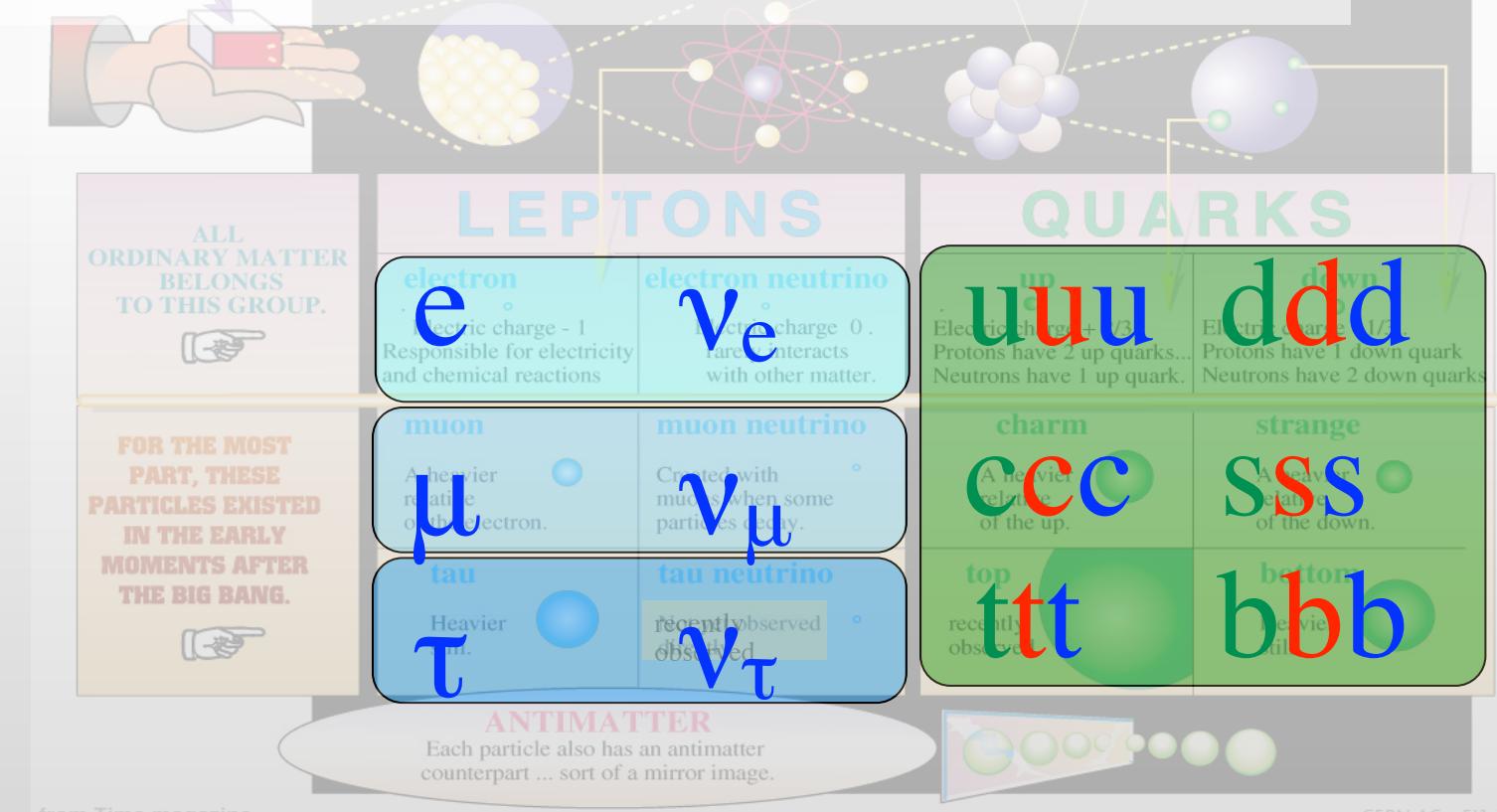
FORCES





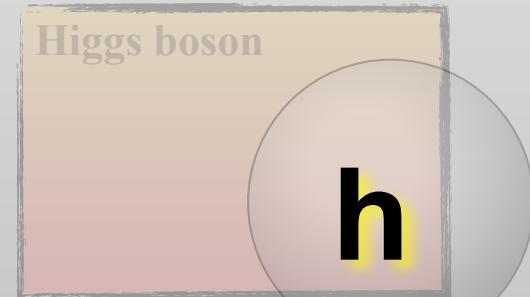
STANDARD MODEL

Interazioni (& simmetrie)



from Time magazine

- $SU_c(3) \times SU_w(2) \times U_Y(1) \rightarrow SU_c(3) \times U_{\text{em}}(1)$
- colore e carica elettrica
- sapore barionico totale
- sapore leptonico individuale (ma: oscillazioni ν)



FORCES

Electromagnetic



Weak

Bosons (W,Z)

W^+ W^-

Neutron decay
Beta radioactive
Neutrino interaction
Burning of the sun



Strong

Gluons (8)

g (8)

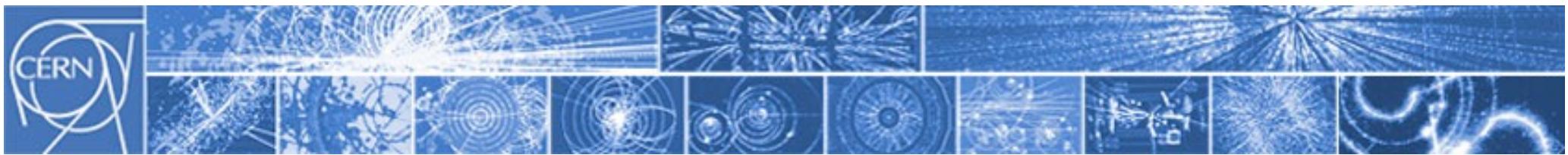
Baryons Nuclei

Gravitational

Graviton ?

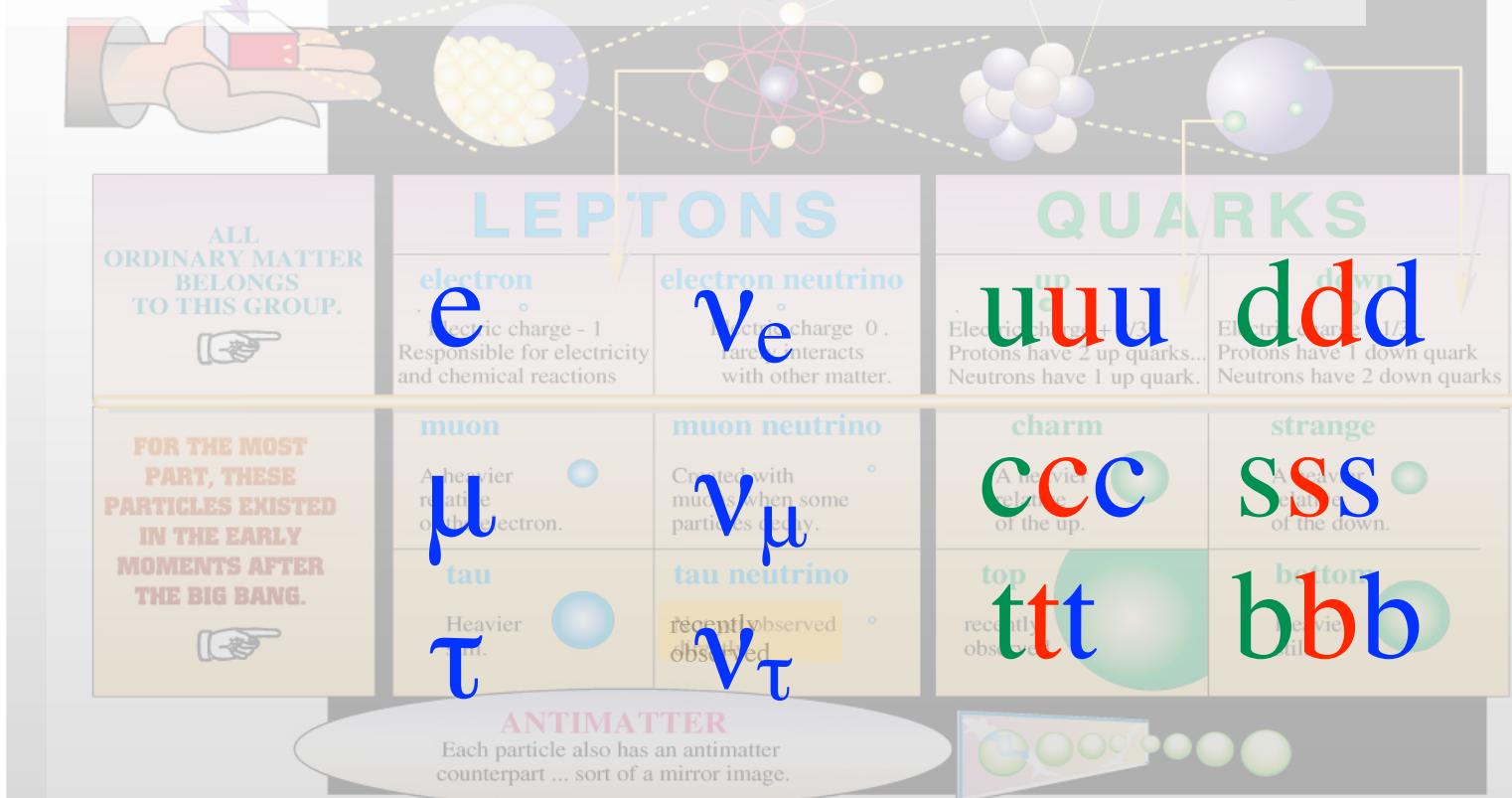
G

Solar system
Galaxies
Black holes



STANDARD MODEL

Interazioni (& simmetrie)



Adroni: stati composti di quarks

FORCES

Electromagnetic



Weak

Bosons (W,Z)

W^+ W^-

Neutron decay
Beta radioactive
Neutrino interaction
Burning of the stars



Strong

Gluons (8)

g (8)

Baryons Nuclei

Gravitational

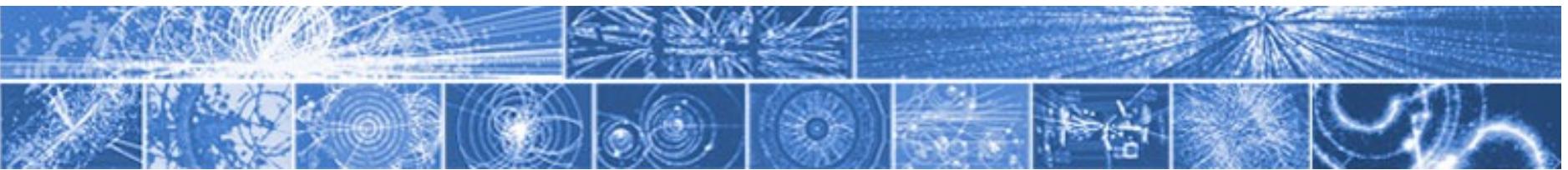
Graviton ?

G

Solar system
Galaxies
Black holes

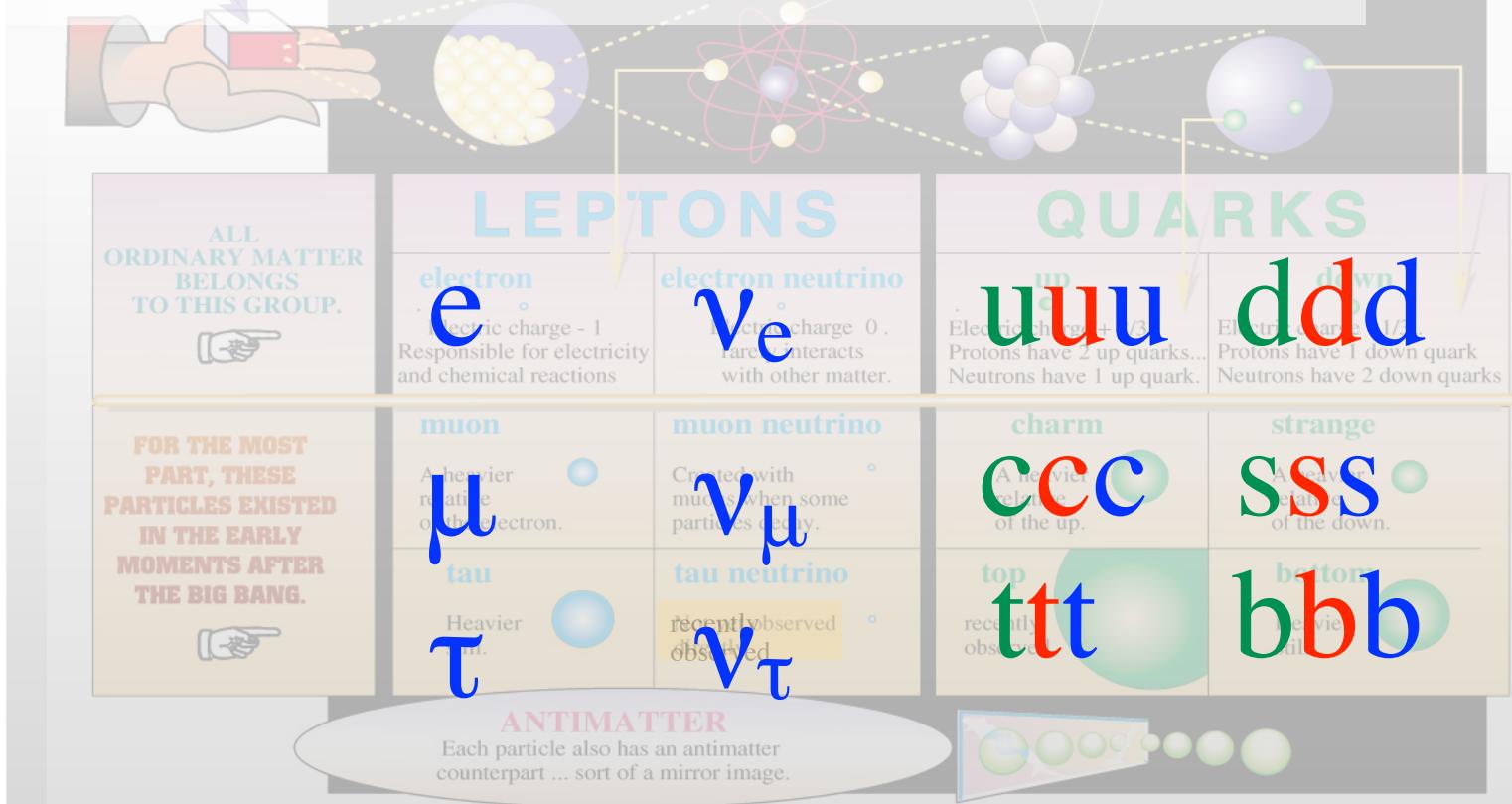
Higgs boson

h

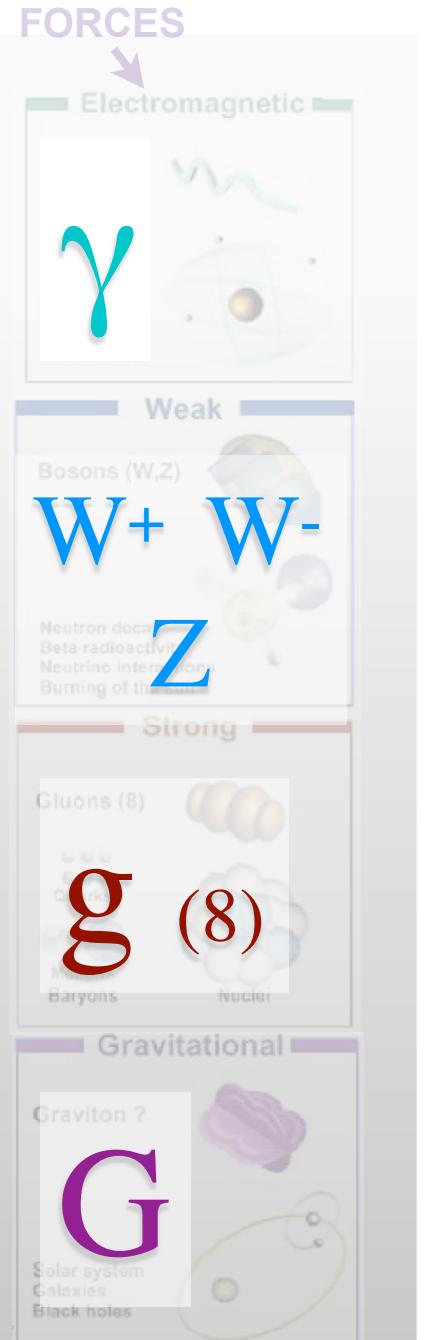
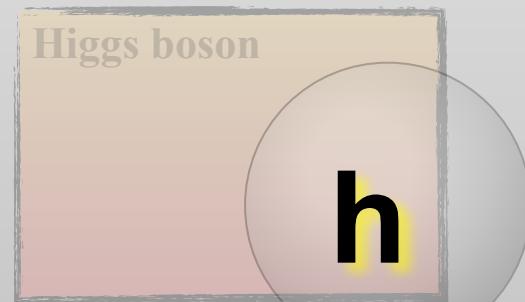
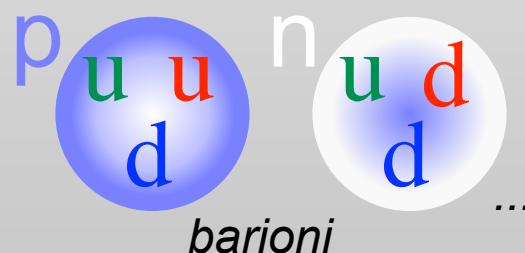


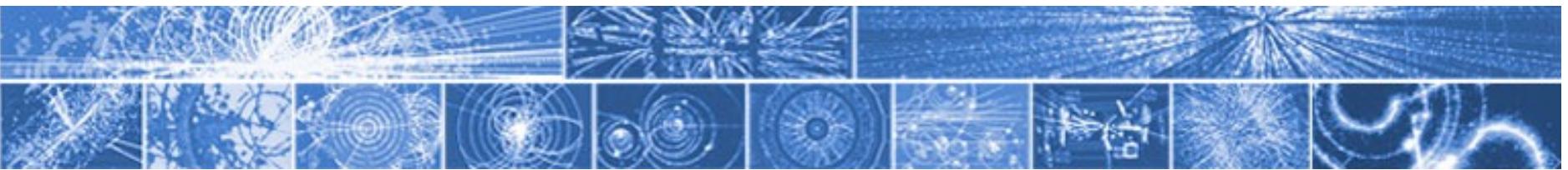
STANDARD MODEL

Interazioni (& simmetrie)



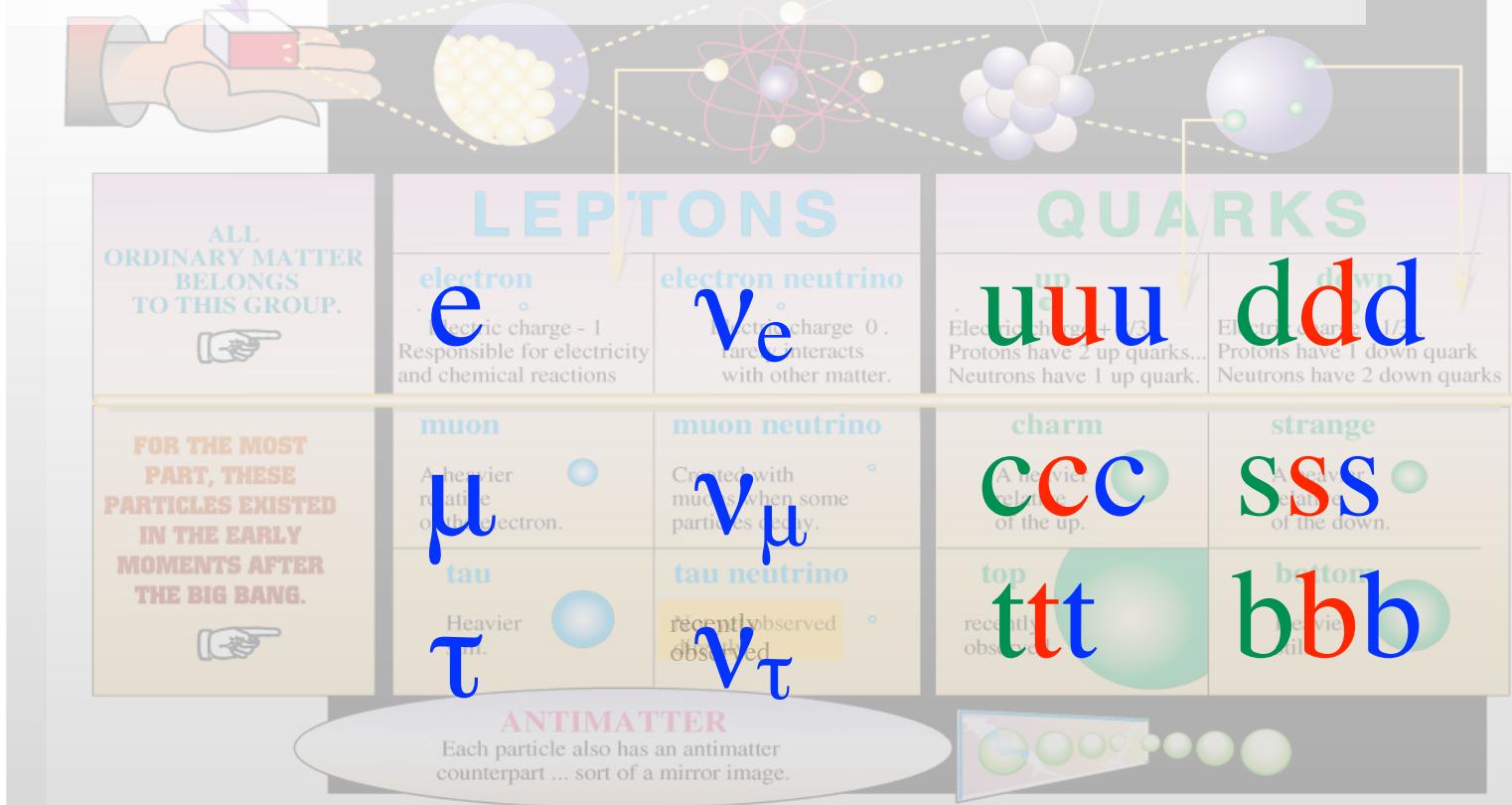
Adroni: stati composti di quarks



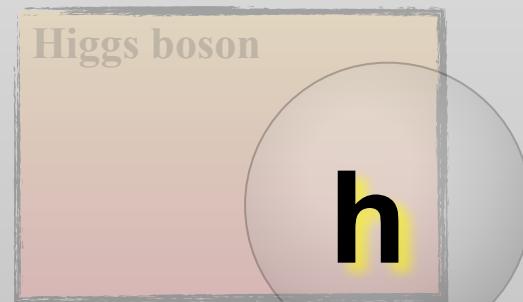
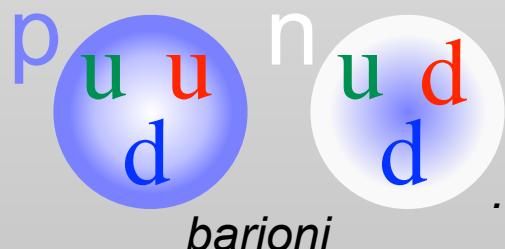


STANDARD MODEL

Interazioni (& simmetrie)



Adroni: stati composti di quarks



FORCES

Electromagnetic



Weak

Bosons (W,Z)

W^+ W^-



Strong

Gluons (8)

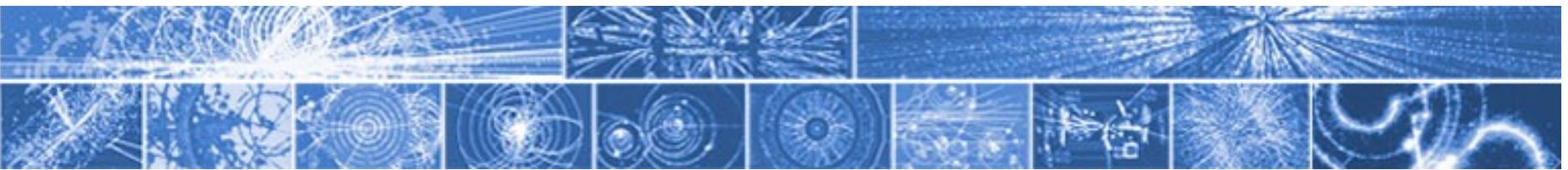
g (8)

Gravitational

Graviton ?

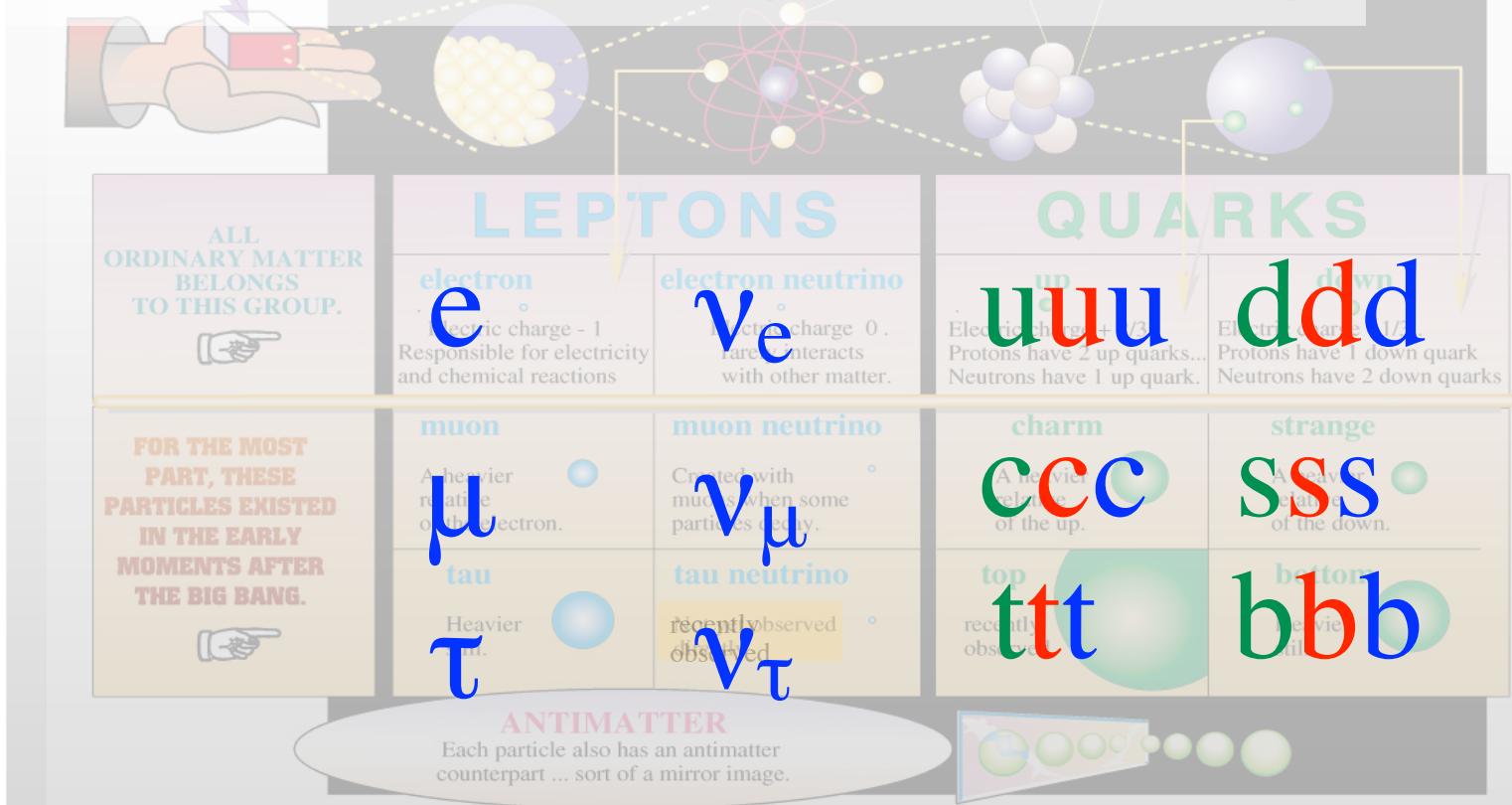
G

Solar system
Galaxies
Black holes



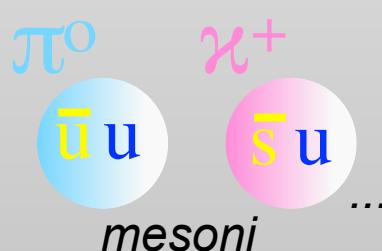
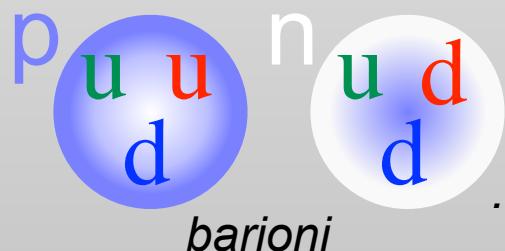
STANDARD MODEL

Interazioni (& simmetrie)

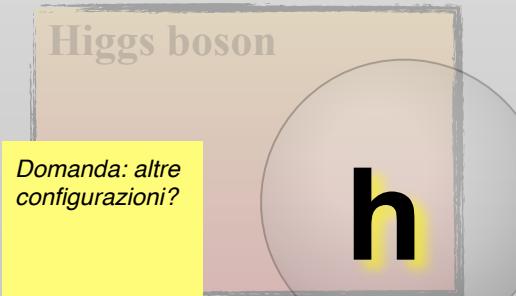


from Time magazine

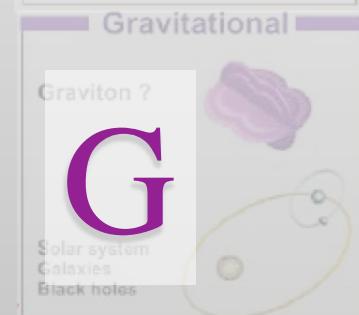
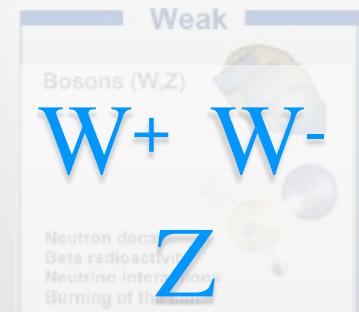
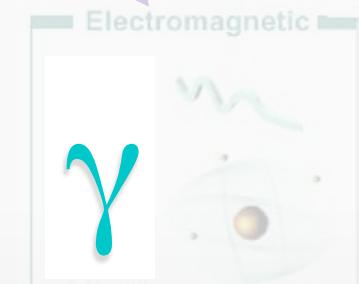
Adroni: stati composti di quarks

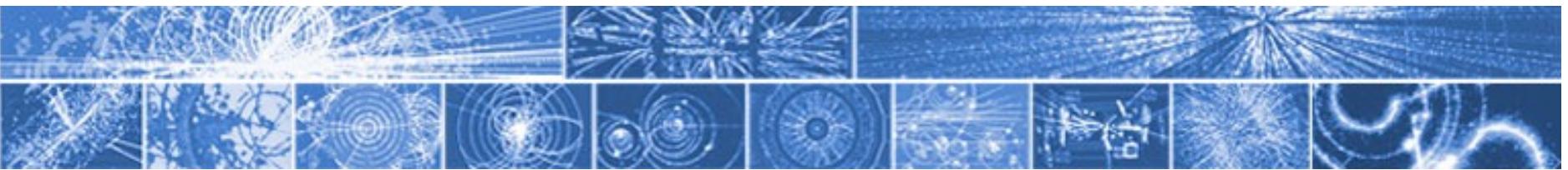


Domanda: altre configurazioni?



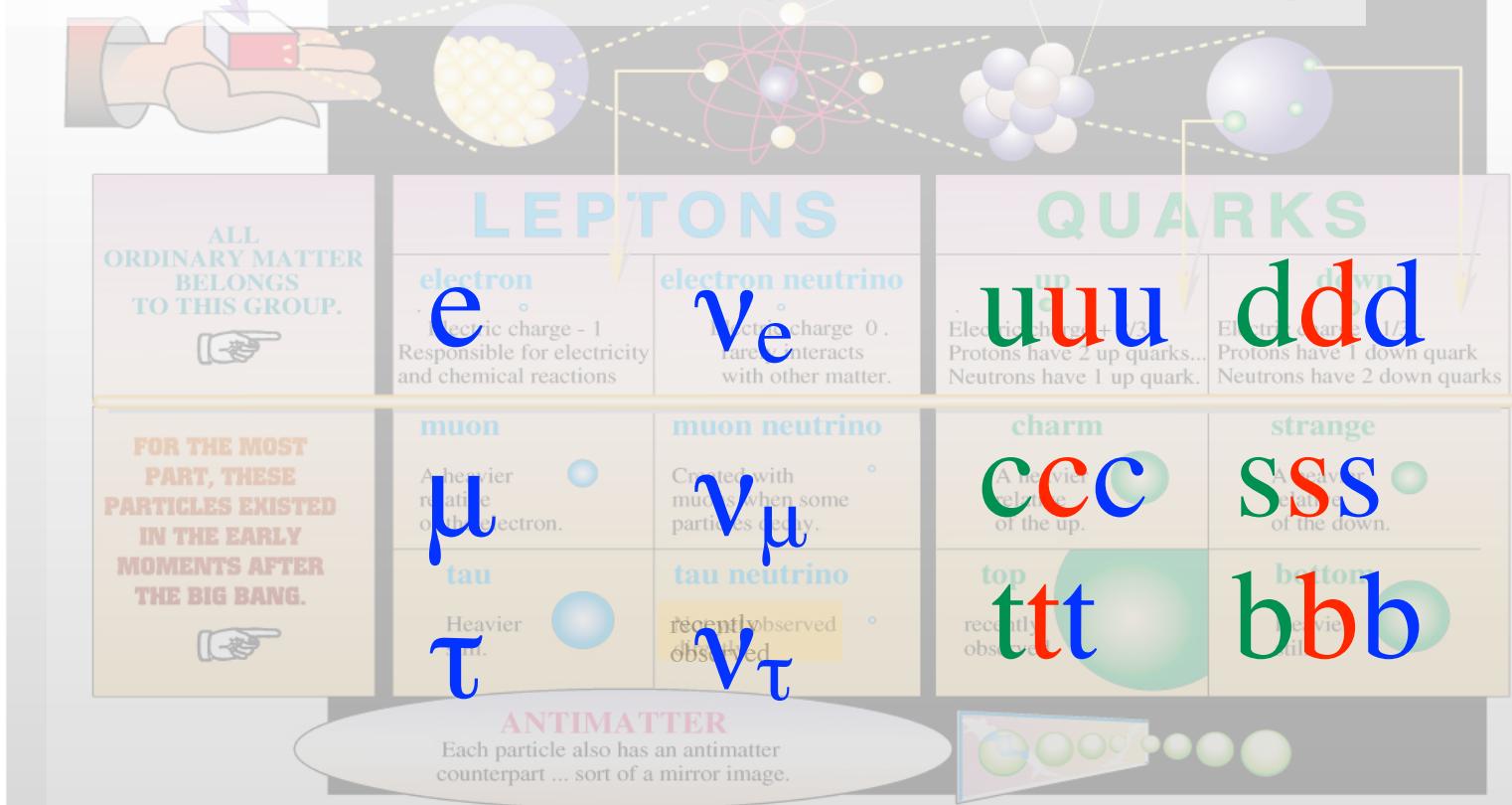
FORCES





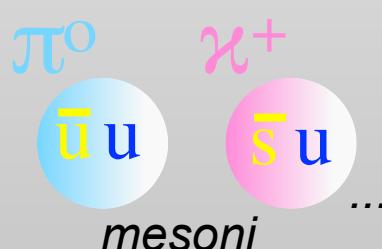
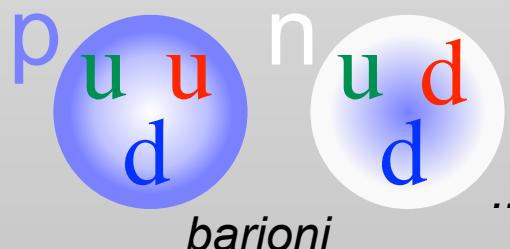
STANDARD MODEL

Interazioni (& simmetrie)

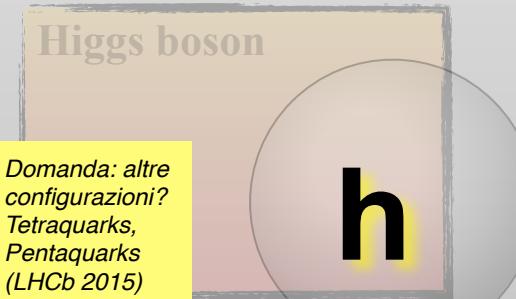


from Time magazine

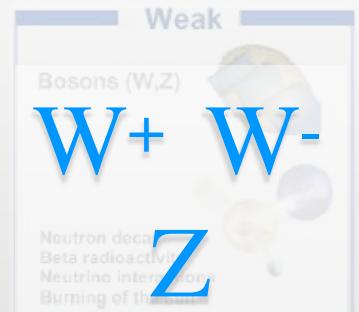
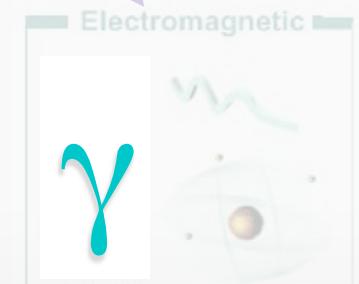
Adroni: stati composti di quarks

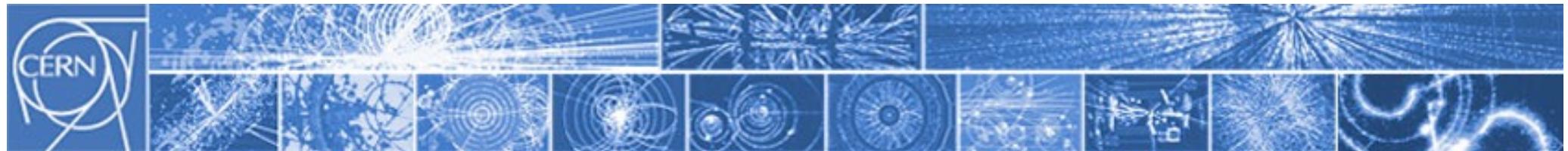


Domanda: altre configurazioni?
Tetraquarks,
Pentaquarks
(LHCb 2015)

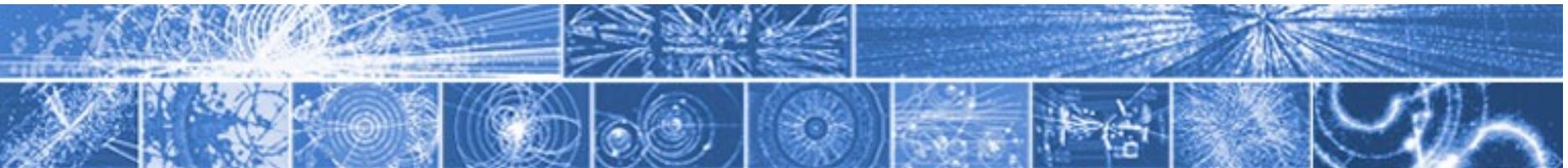


FORCES





Mass



Mass

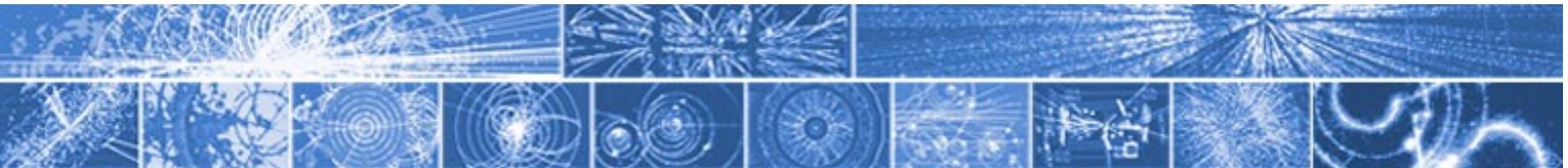
KeV

MeV

GeV

TeV

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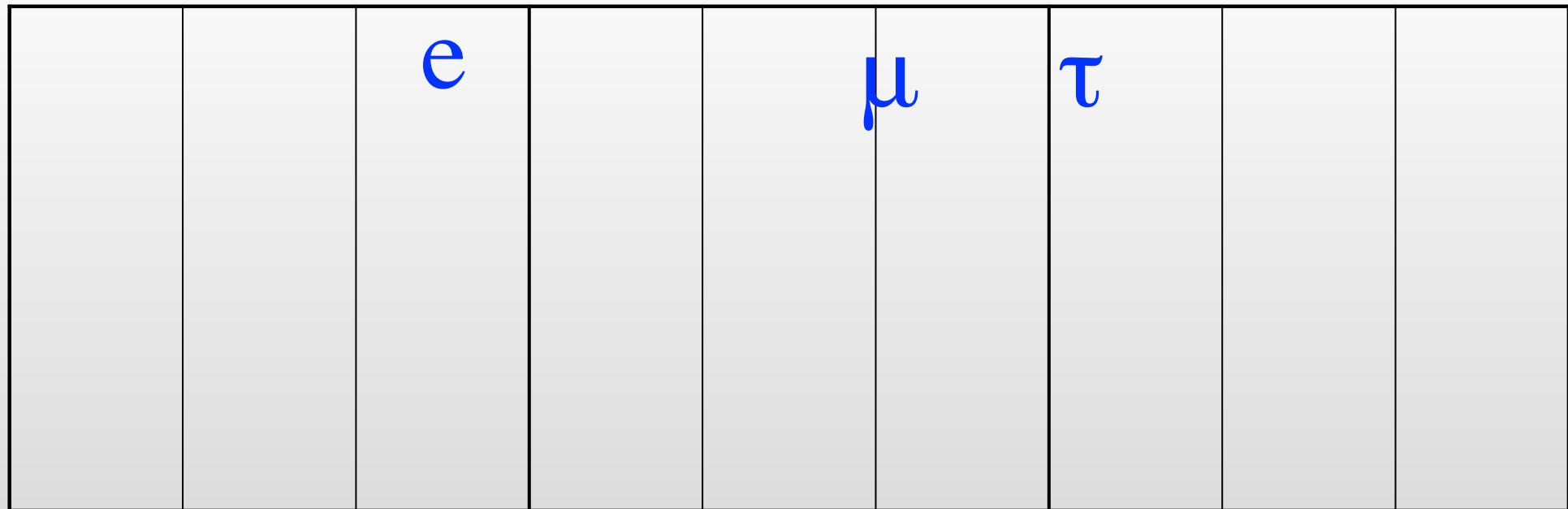
Mass

KeV

MeV

GeV

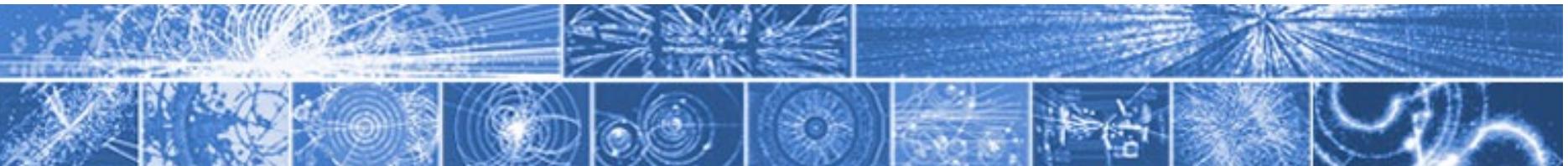
TeV



e 511 KeV

μ 105.7 MeV

τ 1.777 GeV



Mass

KeV

MeV

GeV

TeV

		e u d		μ s		τ c b		t
--	--	-------------	--	------------	--	------------------	--	---

e 511 KeV

μ 105.7 MeV

τ 1.777 GeV

u ~2.3 MeV

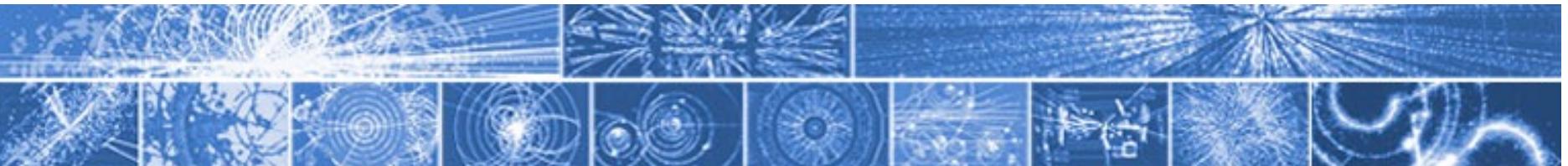
d ~5 MeV

s ~95 MeV

c 1.27 GeV

b 4.2 GeV

t 173.2 GeV



Mass

KeV

MeV

GeV

TeV

		e	u d		μ s		τ c b		t W Z
--	--	---	--------	--	------------	--	------------------	--	-----------------

e 511 KeV

μ 105.7 MeV

τ 1.777 GeV

u ~2.3 MeV

d ~5 MeV

s ~95 MeV

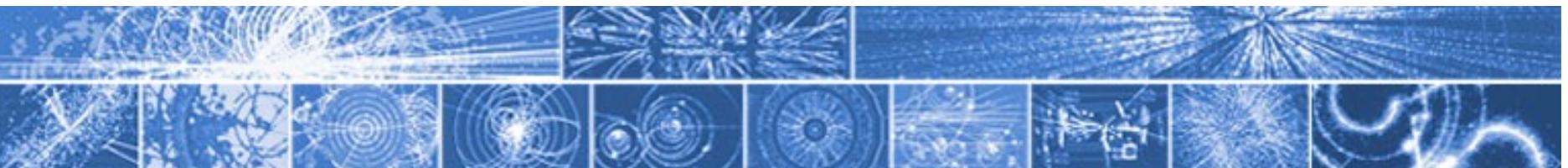
c 1.27 GeV

b 4.2 GeV

t 173.2 GeV

W^\pm 80.385 GeV

Z 91.1876 GeV



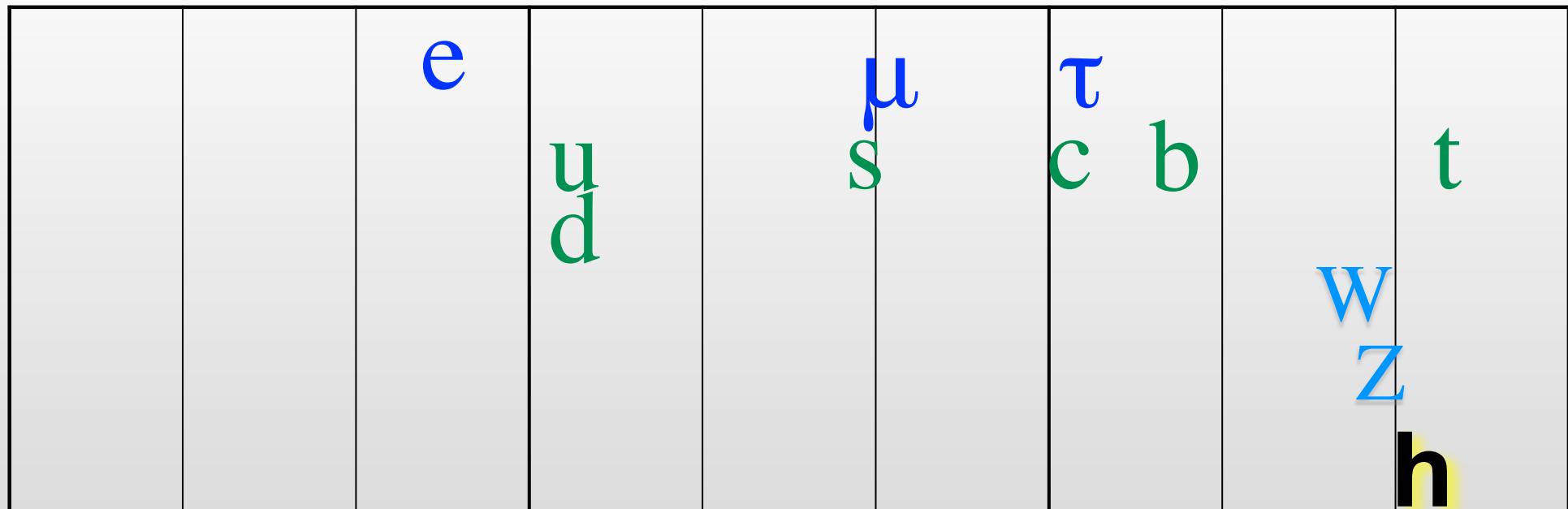
Mass

KeV

MeV

GeV

TeV



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τ 1.777 GeV

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s ~95 MeV

c 1.27 GeV

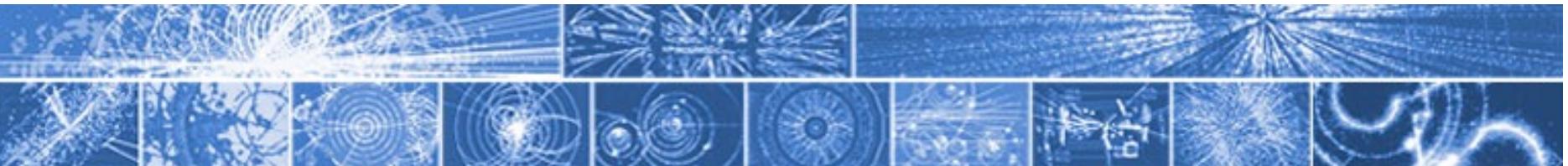
b 4.2 GeV

t 173.2 GeV

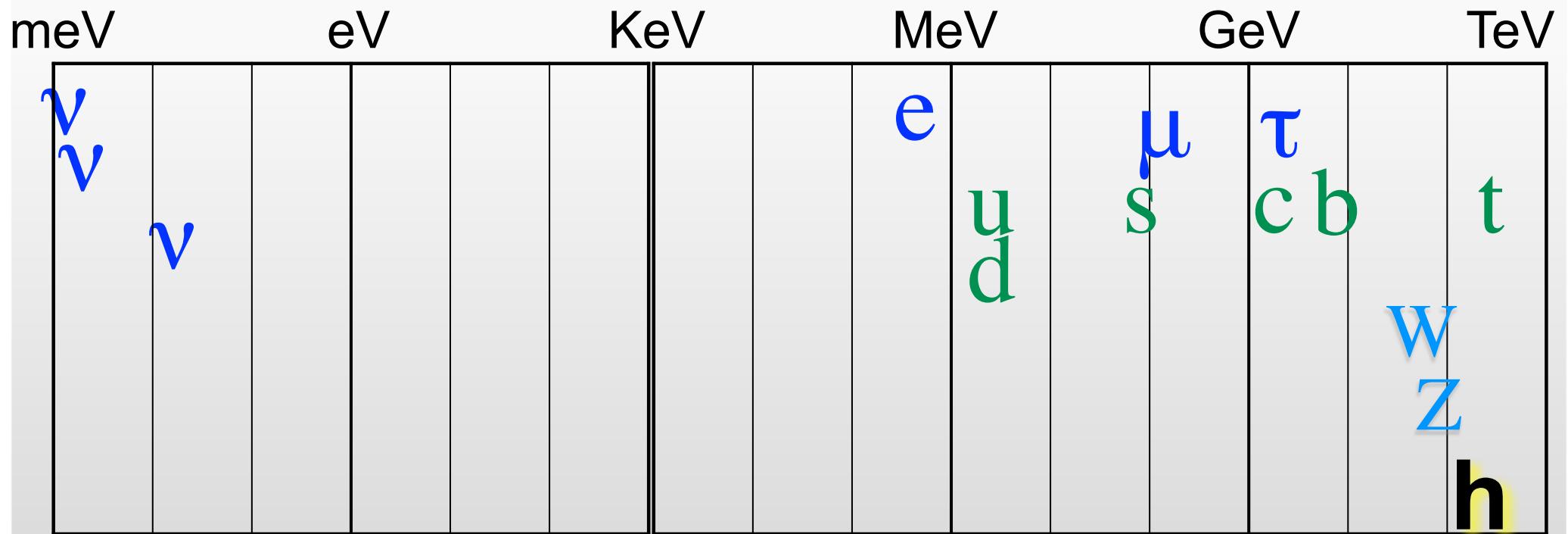
w^\pm 80.385 GeV

Z 91.1876 GeV

h 125.09 GeV



Mass



e 511 KeV

μ 105.7 MeV

τ 1.777 GeV

$9 \cdot 10^{-3} \text{ eV} \leq \nu_i \leq 0.2 \text{ eV}$

u ~2.3 MeV

d ~5 MeV

s ~95 MeV

c 1.27 GeV

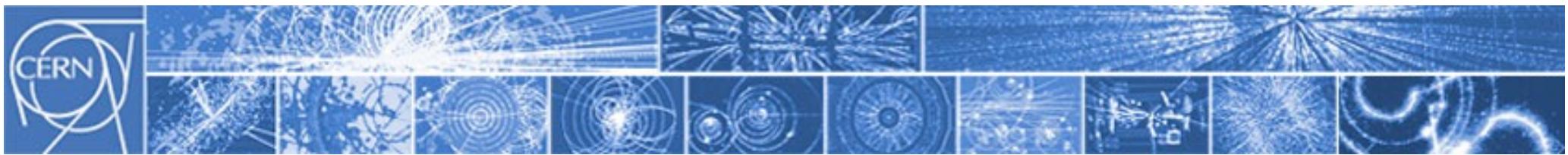
b 4.2 GeV

t 173.2 GeV

W[±] 80.385 GeV

Z 91.1876 GeV

h 125.09 GeV

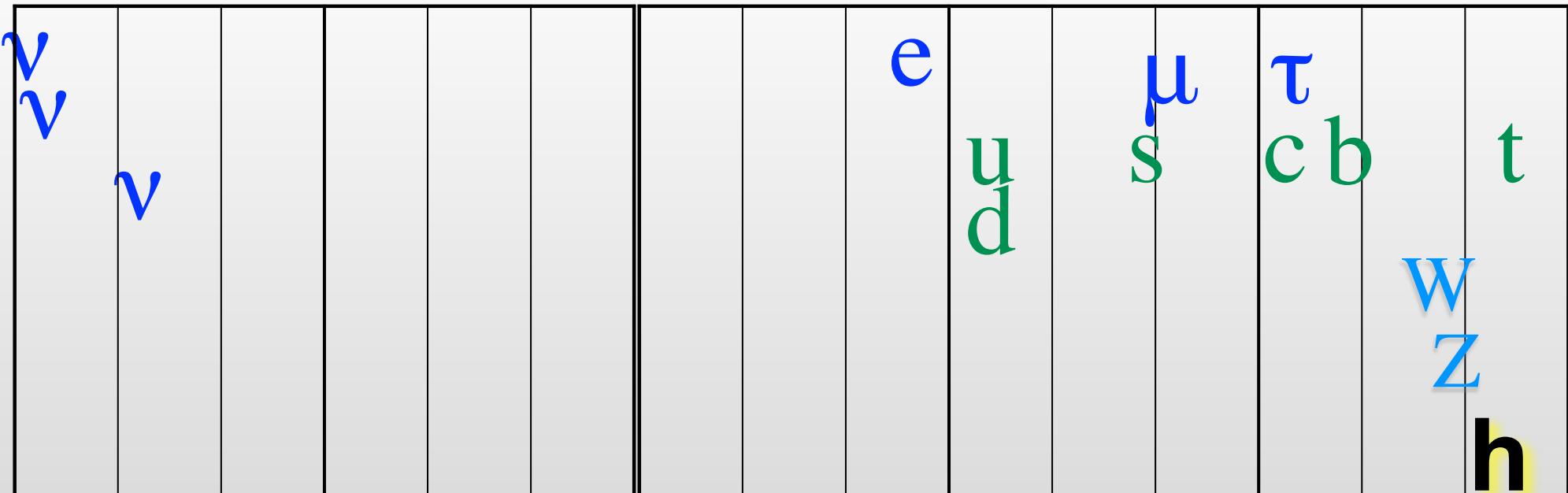


Mass

massa zero: γ g G

p
 ^{238}U

meV eV KeV MeV GeV TeV



e 511 KeV

μ 105.7 MeV

τ 1.777 GeV

$9 \cdot 10^{-3} \text{ eV} \leq \nu_i \leq 0.2 \text{ eV}$

u ~2.3 MeV

d ~5 MeV

s ~95 MeV

c 1.27 GeV

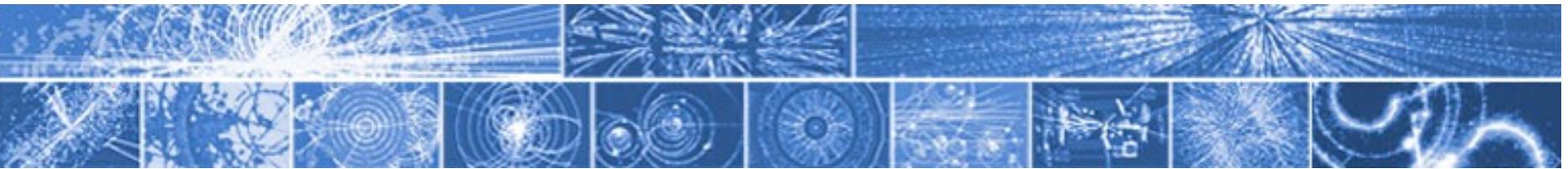
b 4.2 GeV

t 173.2 GeV

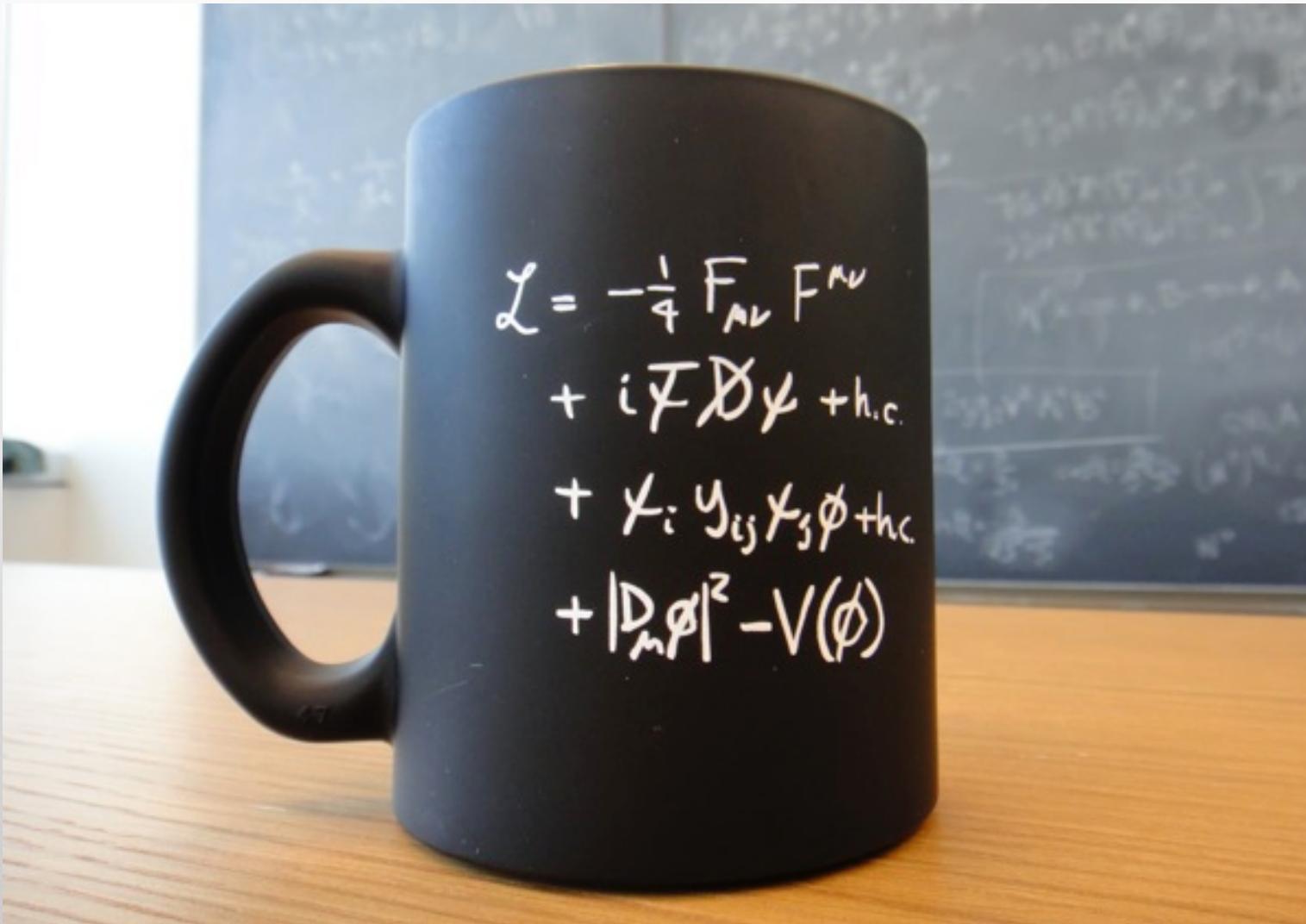
W^\pm 80.385 GeV

Z 91.1876 GeV

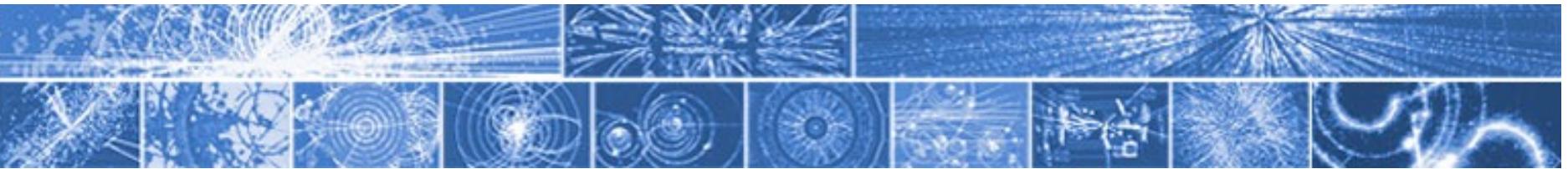
h 125.7 GeV



Lagrangiana del Modello Standard



Credit: Flip Tanedo, QuantumDiaries.org



Lagrangiana del Modello Standard

mediatori delle forze

$$F_{\mu\nu} \rightarrow \gamma^W Z g$$
$$\mathcal{D} \rightarrow$$

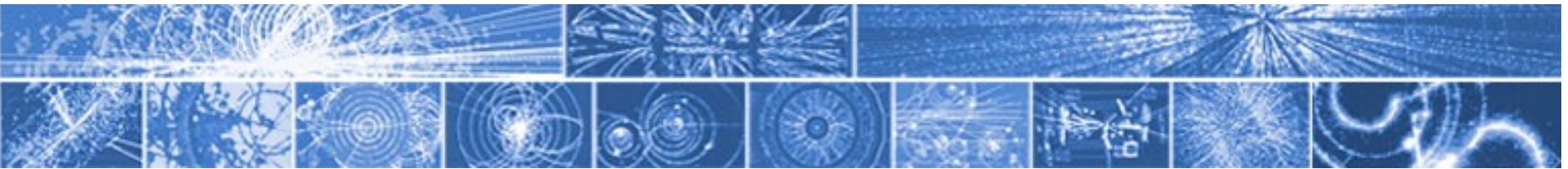
campi di materia

$$\psi \rightarrow e \mu \tau \nu_i$$
$$u d s c b t$$

campo scalare
(-> di higgs)

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\psi} \mathcal{D} \psi + h.c. + Y_i Y_{ij} Y_j \phi + h.c. + |\mathcal{D}_\mu \phi|^2 - V(\phi)$$

Credit: Flip Tanedo, QuantumDiaries.org



Lagrangiana del Modello Standard

mediatori delle forze

$$F_{\mu\nu} \rightarrow \gamma^W Z g$$

\mathcal{D}

campi di materia

$$\psi \rightarrow e \mu \tau \nu_i$$

udscbt

campo scalare
(-> di higgs)

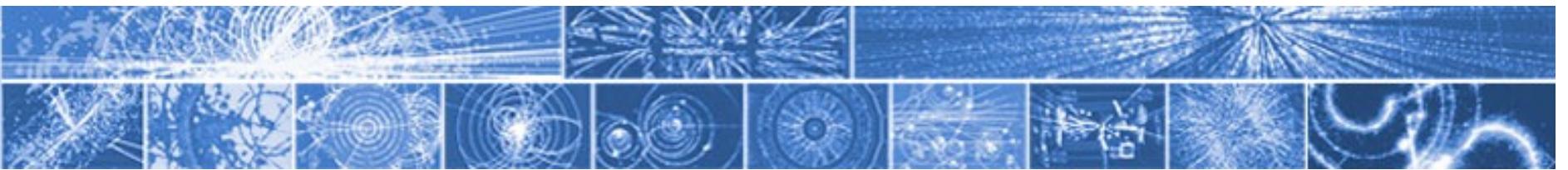
propagazione
delle forze

interazione
forze-materia

interazione
higgs-materia

'settore
di higgs'

$$\begin{aligned}\mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\ & + i \bar{\psi} \mathcal{D} \psi + h.c. \\ & + Y_i Y_{ij} Y_j \phi + h.c. \\ & + |\mathcal{D}_\mu \phi|^2 - V(\phi)\end{aligned}$$



Lagrangiana del Modello Standard

mediatori delle

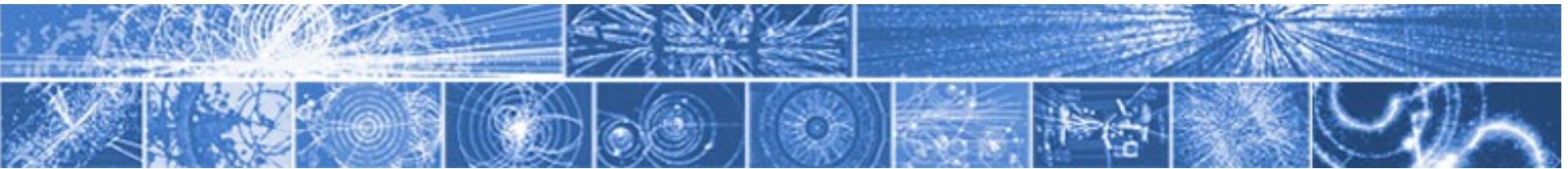


campi di materia

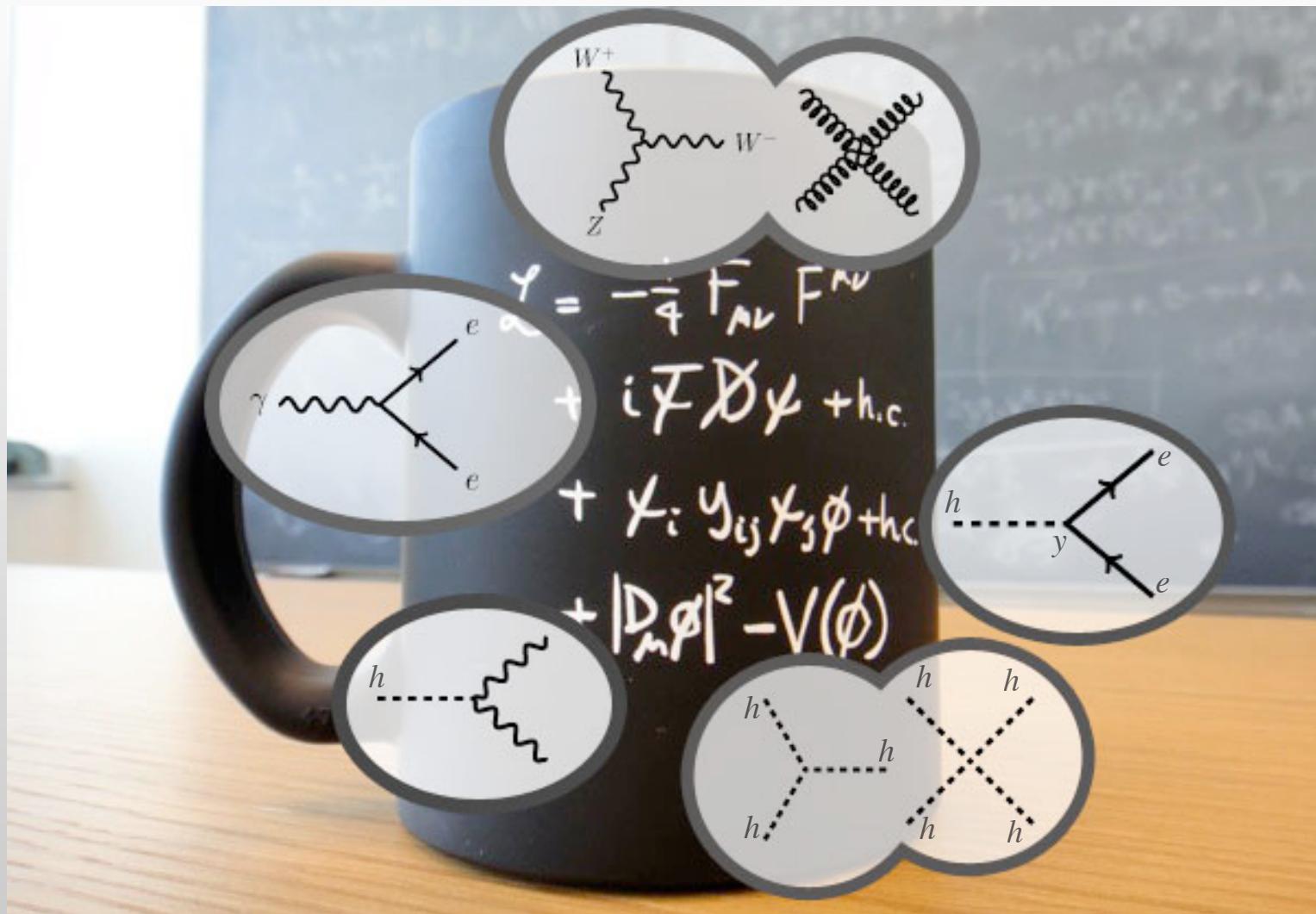


campo scalare
(> di higgs)

$$\begin{aligned}
 & -\frac{1}{2}\partial_\nu g_\mu^a \partial_\nu g_\mu^a - g_s f^{abc} \partial_\mu g_\nu^a g_\mu^b g_\nu^c - \frac{1}{4}g_s^2 f^{abc} f^{ade} g_\mu^b g_\nu^c g_\mu^d g_\nu^e + \\
 & \frac{1}{2}ig_s^2 (q_i^\sigma \gamma^\mu q_j^\sigma) g_\mu^a + \bar{G}^a \partial^2 G^a + g_s f^{abc} \partial_\mu \bar{G}^a G^b g_\mu^c - \partial_\nu W_\mu^+ \partial_\nu W_\mu^- - \\
 & M^2 W_\mu^+ W_\mu^- - \frac{1}{2}\partial_\nu Z_\mu^0 \partial_\nu Z_\mu^0 - \frac{1}{2c_w^2} M^2 Z_\mu^0 Z_\mu^0 - \frac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \frac{1}{2}\partial_\mu H \partial_\mu H - \\
 & \frac{1}{2}m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2 \phi^+ \phi^- - \frac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \frac{1}{2c_w^2} M \phi^0 \phi^0 - \beta_h [\frac{2M^2}{g^2} + \\
 & \frac{2M}{g} H + \frac{1}{2}(H^2 + \phi^0 \phi^0 + 2\phi^+ \phi^-)] + \frac{2M^4}{g^2} \alpha_h - ig c_w [\partial_\nu Z_\mu^0 (W_\mu^+ W_\nu^- - \\
 & W_\nu^+ W_\mu^-) - Z_\nu^0 (W_\mu^+ \partial_\nu W_\nu^- - W_\mu^- \partial_\nu W_\mu^+) + Z_\mu^0 (W_\nu^+ \partial_\nu W_\mu^- - \\
 & W_\nu^- \partial_\nu W_\mu^+)] - ig s_w [\partial_\nu A_\mu (W_\mu^+ W_\nu^- - W_\nu^+ W_\mu^-) - A_\mu (W_\mu^+ \partial_\nu W_\nu^- - \\
 & W_\nu^- \partial_\nu W_\mu^+) + A_\mu (W_\mu^+ \partial_\nu W_\nu^- - W_\nu^- \partial_\nu W_\mu^+)] - \frac{1}{2}g^2 W_\mu^+ W_\nu^- W_\nu^+ W_\mu^- + \\
 & \frac{1}{2}g^2 W_\mu^+ W_\nu^- W_\mu^+ W_\nu^- + g^2 c_w^2 (Z_\mu^0 W_\mu^+ Z_\nu^0 W_\nu^- - Z_\mu^0 Z_\nu^0 W_\nu^+ W_\nu^-) + \\
 & g^2 s_w^2 (A_\mu W_\mu^+ A_\nu W_\nu^- - A_\mu A_\nu W_\mu^+ W_\nu^-) + g^2 s_w c_w [A_\mu Z_\nu^0 (W_\mu^+ W_\nu^- - \\
 & W_\nu^+ W_\mu^-) - 2A_\mu Z_\mu^0 W_\nu^+ W_\nu^-] - g \alpha [H^3 + H \phi^0 \phi^0 + 2H \phi^+ \phi^- + 2(\phi^0)^2 H^2] - \\
 & \frac{1}{8}g^2 \alpha_h [H^4 + (\phi^0)^4 + 4(\phi^+ \phi^-)^2 + 4(\phi^0)^2 \phi^+ \phi^- + 4H^2 \phi^+ \phi^- + 2(\phi^0)^2 H^2] - \\
 & g M W_\mu^+ W_\mu^- H - \frac{1}{2}g \frac{M}{c_w^2} Z_\mu^0 Z_\mu^0 H - \frac{1}{2}ig [W_\mu^+ (\phi^0 \partial_\mu \phi^- - \phi^- \partial_\mu \phi^0) - \\
 & W_\mu^- (\phi^0 \partial_\mu \phi^+ - \phi^+ \partial_\mu \phi^0)] + \frac{1}{2}g [W_\mu^+ (H \partial_\mu \phi^- - \phi^- \partial_\mu H) - W_\mu^- (H \partial_\mu \phi^+ - \\
 & \phi^+ \partial_\mu H)] + \frac{1}{2}g \frac{1}{c_w} (Z_\mu^0 (H \partial_\mu \phi^0 - \phi^0 \partial_\mu H) - ig \frac{s_w^2}{c_w} M Z_\mu^0 (W_\mu^+ \phi^- - W_\mu^- \phi^+) + \\
 & ig s_w M A_\mu (W_\mu^+ \phi^- - W_\mu^- \phi^+) - ig \frac{1-2c_w^2}{2c_w} Z_\mu^0 (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) + \\
 & ig s_w A_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) - \frac{1}{4}g^2 W_\mu^+ W_\mu^- [H^2 + (\phi^0)^2 + 2\phi^+ \phi^-] - \\
 & \frac{1}{4}g^2 \frac{1}{c_w^2} Z_\mu^0 Z_\mu^0 [H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2 \phi^+ \phi^-] - \frac{1}{2}g^2 \frac{s_w^2}{c_w} Z_\mu^0 \phi^0 (W_\mu^+ \phi^- + \\
 & W_\mu^- \phi^+) - \frac{1}{2}ig^2 \frac{s_w^2}{c_w} Z_\mu^0 H (W_\mu^+ \phi^- - W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu \phi^0 (W_\mu^+ \phi^- + \\
 & W_\mu^- \phi^+) + \frac{1}{2}ig^2 s_w A_\mu H (W_\mu^+ \phi^- - W_\mu^- \phi^+) - g^2 \frac{s_w}{c_w} (2c_w^2 - 1) Z_\mu^0 A_\mu \phi^+ \phi^- - \\
 & g^1 s_w^2 A_\mu A_\mu \phi^+ \phi^- - \bar{e}^\lambda (\gamma \partial + m_e^\lambda) e^\lambda - \bar{\nu}^\lambda \gamma \partial \nu^\lambda - \bar{u}_j^\lambda (\gamma \partial + m_u^\lambda) u_j^\lambda - \\
 & d_j^\lambda (\gamma \partial + m_d^\lambda) d_j^\lambda + ig s_w A_\mu [-(\bar{e}^\lambda \gamma^\mu e^\lambda) + \frac{2}{3}(\bar{u}_j^\lambda \gamma^\mu u_j^\lambda) - \frac{1}{3}(\bar{d}_j^\lambda \gamma^\mu d_j^\lambda)] + \\
 & \frac{ig}{4c_w} Z_\mu^0 [(\bar{\nu}^\lambda \gamma^\mu (1 + \gamma^5) \nu^\lambda) + (\bar{e}^\lambda \gamma^\mu (4s_w^2 - 1 - \gamma^5) e^\lambda) + (\bar{u}_j^\lambda \gamma^\mu (\frac{4}{3}s_w^2 - \\
 & 1 - \gamma^5) u_j^\lambda) + (\bar{d}_j^\lambda \gamma^\mu (1 - \frac{8}{3}s_w^2 - \gamma^5) d_j^\lambda)] + \frac{ig}{2\sqrt{2}} W_\mu^+ [(\bar{\nu}^\lambda \gamma^\mu (1 + \gamma^5) e^\lambda) + \\
 & (\bar{u}_j^\lambda \gamma^\mu (1 + \gamma^5) C_{\lambda\kappa} d_j^\kappa)] + \frac{ig}{2\sqrt{2}} W_\mu^- [(\bar{e}^\lambda \gamma^\mu (1 + \gamma^5) \nu^\lambda) + (\bar{d}_j^\kappa C_{\lambda\kappa}^\dagger \gamma^\mu (1 + \\
 & \gamma^5) u_j^\lambda)] + \frac{ig}{2\sqrt{2}} \frac{m_e^\lambda}{M} [-\phi^+ (\bar{\nu}^\lambda (1 - \gamma^5) e^\lambda) + \phi^- (\bar{e}^\lambda (1 + \gamma^5) \nu^\lambda)] - \\
 & \frac{g}{2} \frac{m_e^\lambda}{M} [H (\bar{e}^\lambda e^\lambda) + i\phi^0 (\bar{e}^\lambda \gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}} \phi^+ [-m_e^\kappa (\bar{u}_j^\lambda C_{\lambda\kappa} (1 - \gamma^5) d_j^\kappa)] + \\
 & m_u^\lambda (\bar{u}_j^\lambda C_{\lambda\kappa} (1 + \gamma^5) d_j^\kappa)] + \frac{ig}{2M\sqrt{2}} \phi^- [m_d^\kappa (\bar{d}_j^\lambda C_{\lambda\kappa}^\dagger (1 + \gamma^5) u_j^\kappa) - m_u^\kappa (\bar{d}_j^\lambda C_{\lambda\kappa}^\dagger (1 - \\
 & \gamma^5) u_j^\kappa)] - \frac{g}{2} \frac{m_\lambda}{M} H (\bar{u}_j^\lambda u_j^\lambda) - \frac{g}{2} \frac{m_\lambda}{M} H (\bar{d}_j^\lambda d_j^\lambda) + \frac{ig}{2} \frac{m_\lambda}{M} \phi^0 (\bar{u}_j^\lambda \gamma^5 u_j^\lambda) - \\
 & \frac{ig}{2} \frac{m_\lambda}{M} \phi^0 (\bar{d}_j^\lambda \gamma^5 d_j^\lambda) + \bar{X}^+ (\partial^2 - M^2) X^+ + \bar{X}^- (\partial^2 - M^2) X^- + X^0 (\partial^2 - \\
 & \frac{M^2}{c_w^2}) X^0 + \bar{Y} \partial^2 Y + ig c_w W_\mu^+ (\partial_\mu \bar{X}^0 X^- - \partial_\mu \bar{X}^+ X^0) + ig s_w W_\mu^+ (\partial_\mu \bar{Y} X^- - \\
 & \partial_\mu \bar{X}^+ Y) + ig c_w W_\mu^- (\partial_\mu \bar{X}^- X^0 - \partial_\mu \bar{X}^0 X^+) + ig s_w W_\mu^- (\partial_\mu \bar{X}^- Y - \\
 & \partial_\mu \bar{Y} X^+) + ig c_w Z_\mu^0 (\partial_\mu \bar{X}^+ X^+ - \partial_\mu \bar{X}^- X^-) + ig s_w A_\mu (\partial_\mu \bar{X}^+ X^+ - \\
 & \partial_\mu \bar{X}^- X^-) - \frac{1}{2}g M [\bar{X}^+ X^+ H + \bar{X}^- X^- H + \frac{1}{c_w^2} \bar{X}^0 X^0 H] + \\
 & \frac{1-2c_w^2}{2c_w} ig M [\bar{X}^+ X^0 \phi^+ - \bar{X}^- X^0 \phi^-] + \frac{1}{2c_w} ig M [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + \\
 & ig M s_w [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + \frac{1}{2}ig M [\bar{X}^+ X^+ \phi^0 - \bar{X}^- X^- \phi^0]
 \end{aligned}$$



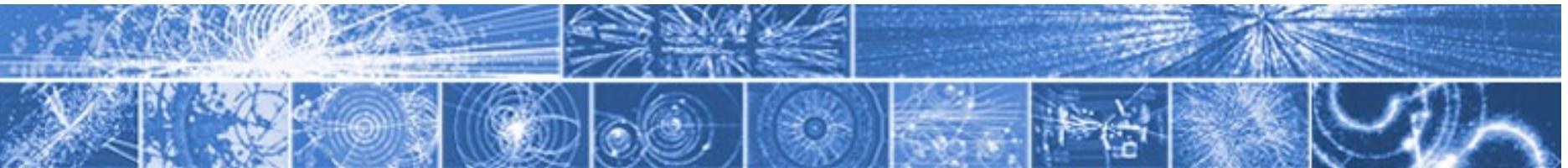
Lagrangiana del Modello Standard



Credit: Flip Tanedo, QuantumDiaries.org

presentazione
per insegnanti:

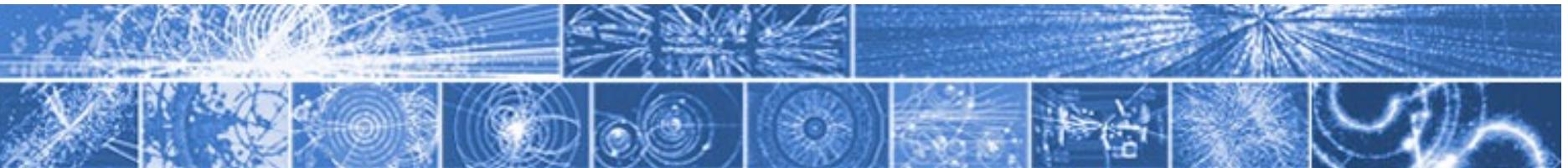
J. Woithe, J. Wiener, F. Van der Veken, *Let's have a coffee with the Standard Model of particle physics!*, Phys. Educ. 52 (2017) 034001



I diagrammi di Feynman al lavoro

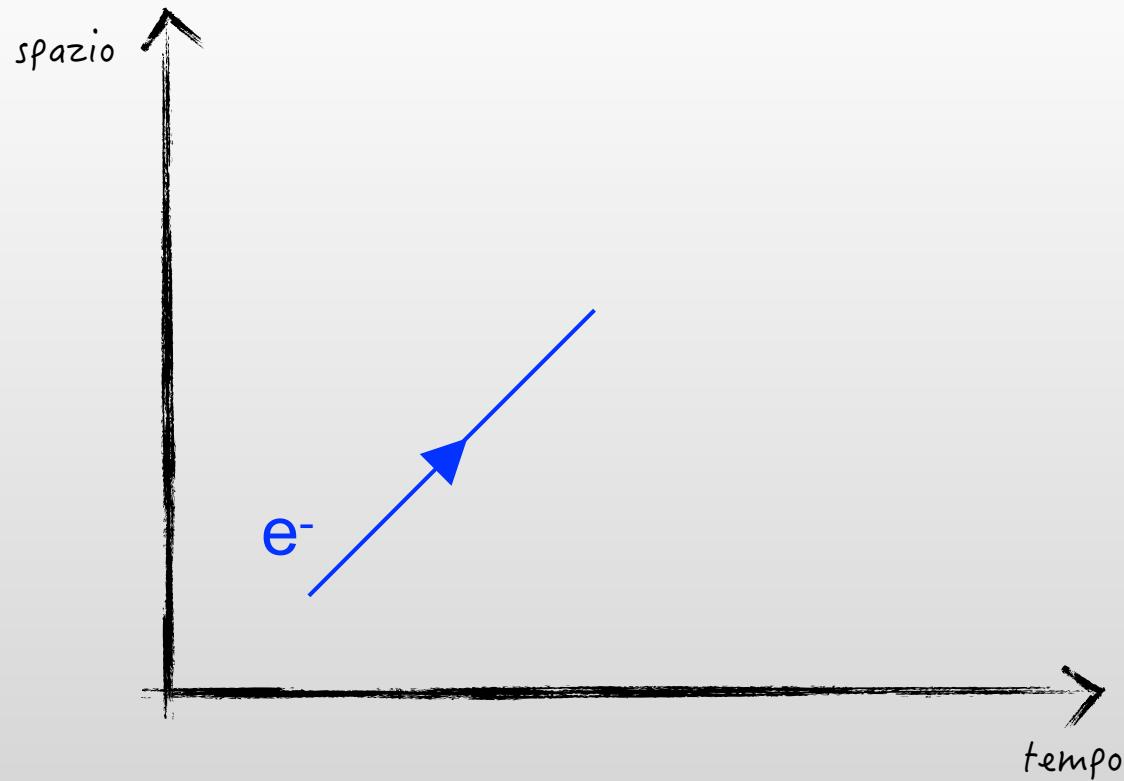
Esempio 1: collisione e^+e^-

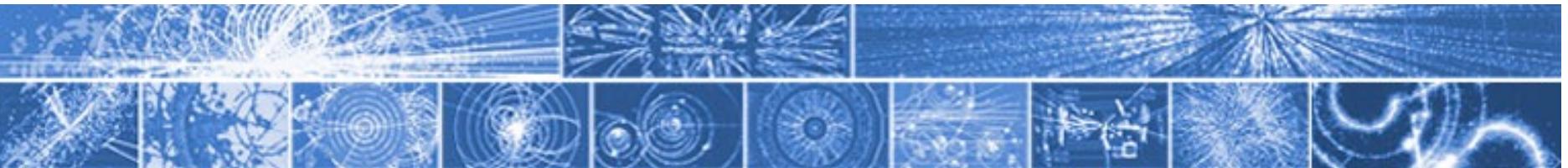
(semirigoroso)



I diagrammi di Feynman al lavoro

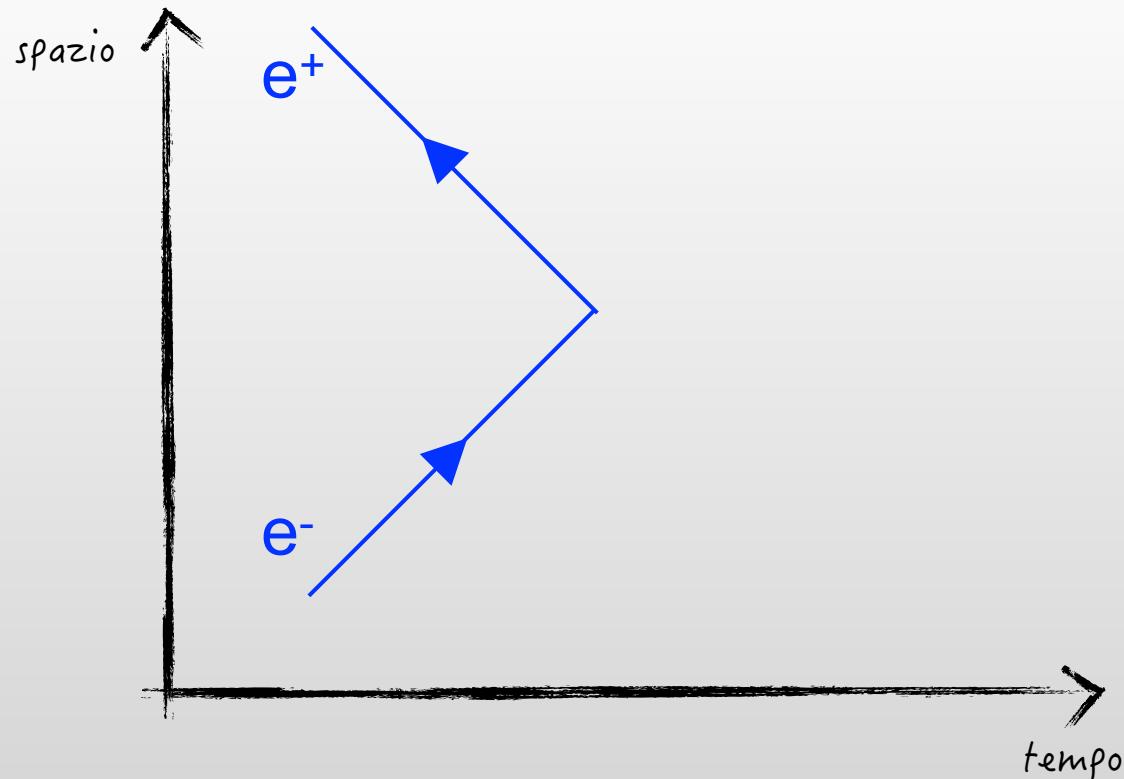
Esempio 1: collisione e^+e^-

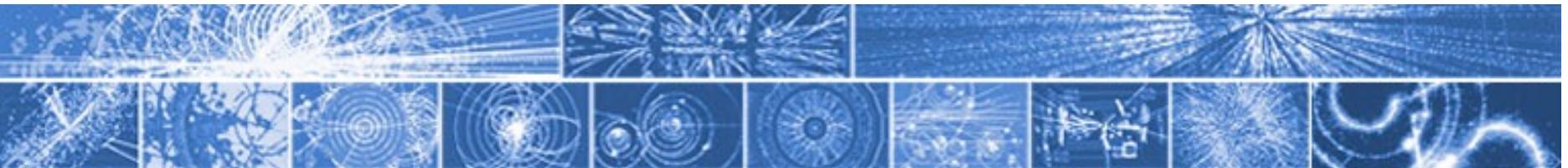




I diagrammi di Feynman al lavoro

Esempio 1: collisione e^+e^-

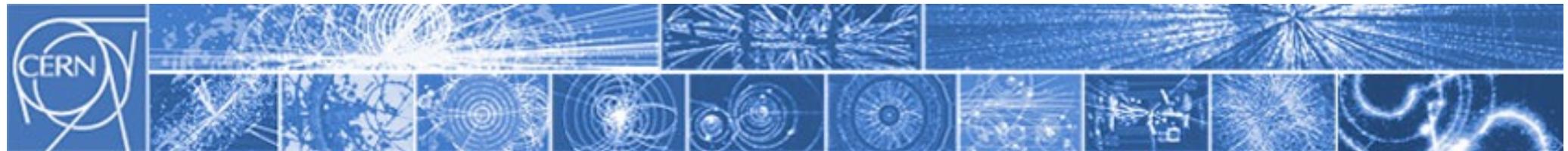




I diagrammi di Feynman al lavoro

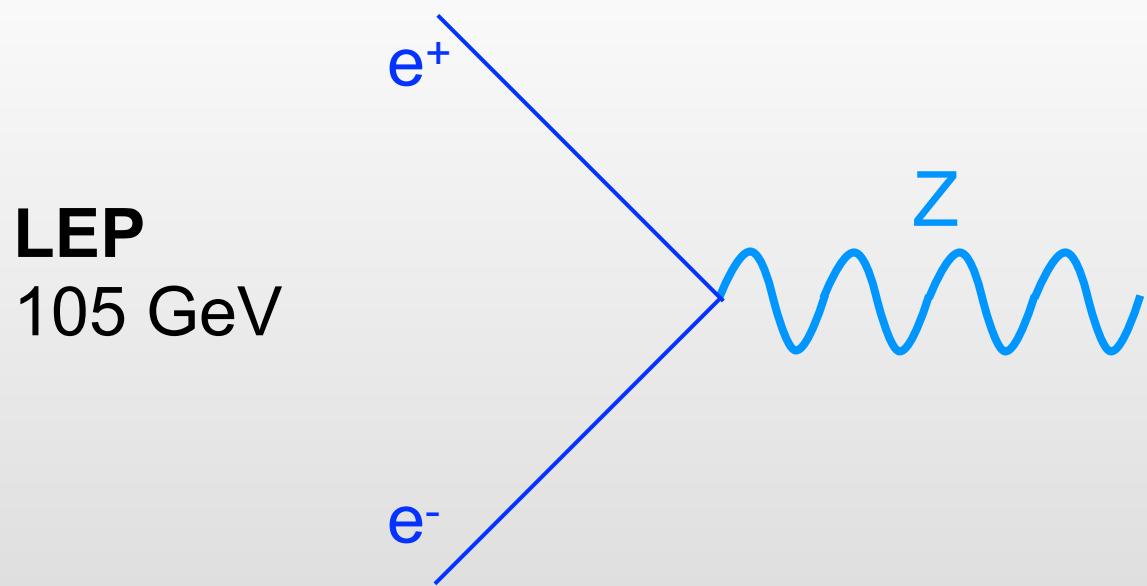
Esempio 1: collisione e^+e^-

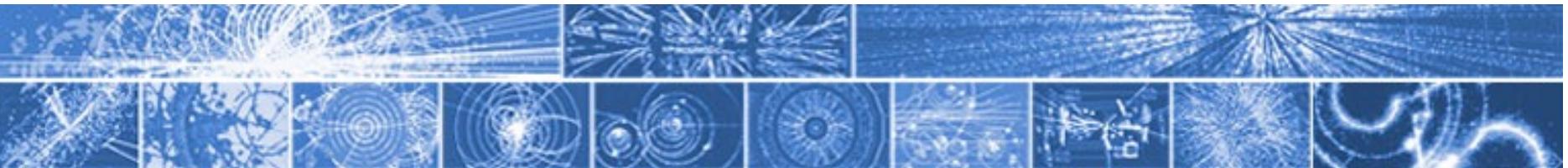




I diagrammi di Feynman al lavoro

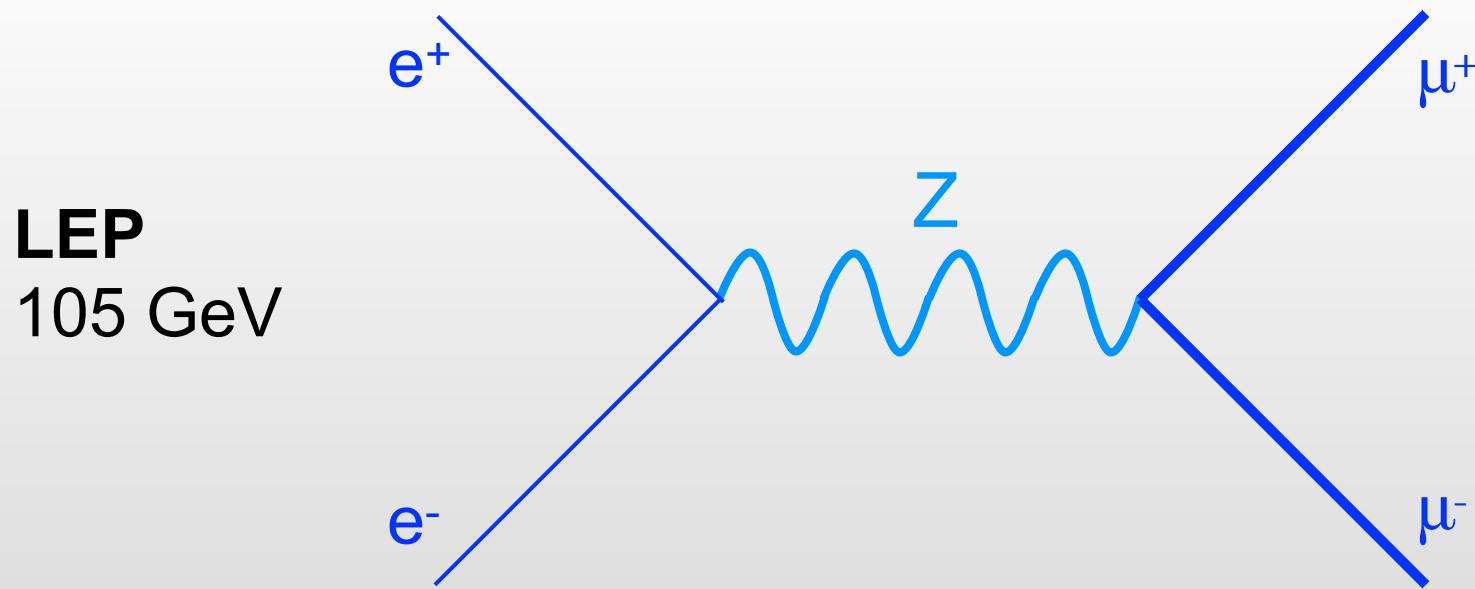
Esempio 1: collisione e^+e^-

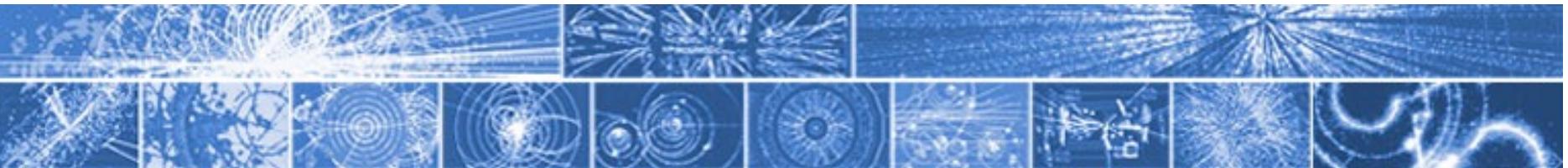




I diagrammi di Feynman al lavoro

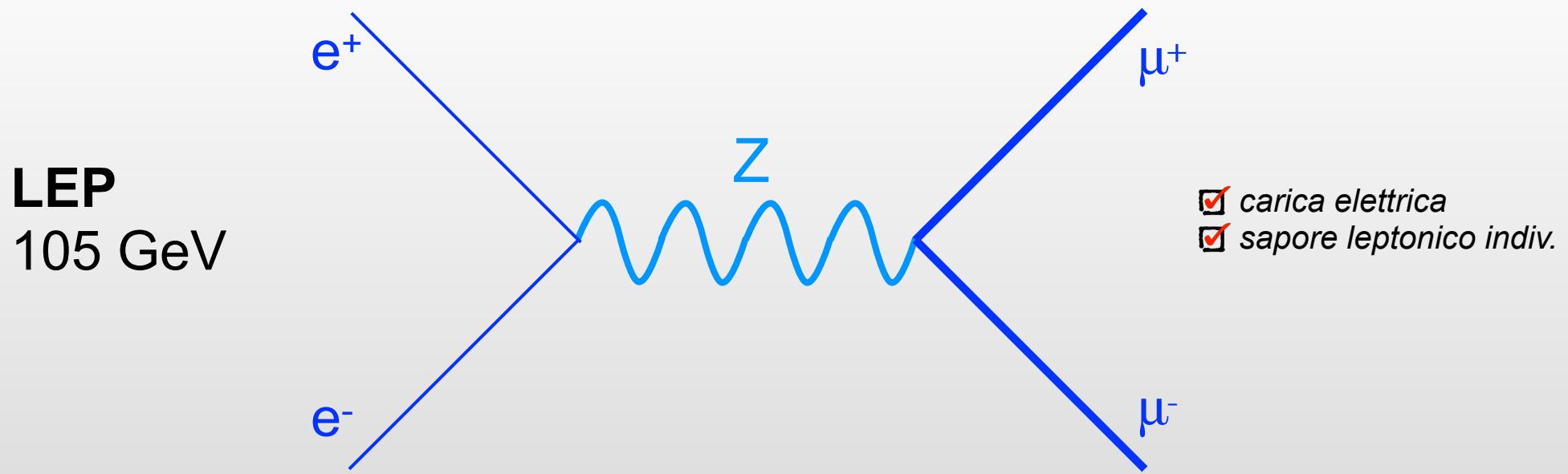
Esempio 1: collisione e^+e^-





I diagrammi di Feynman al lavoro

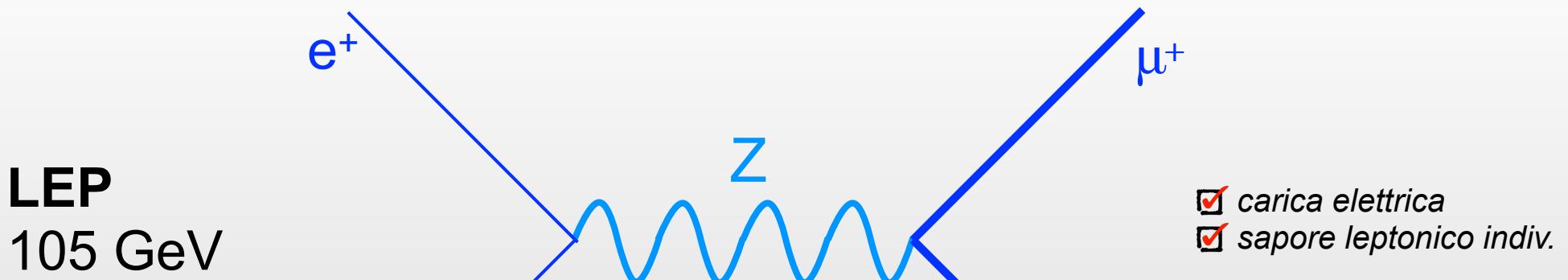
Esempio 1: collisione e^+e^-





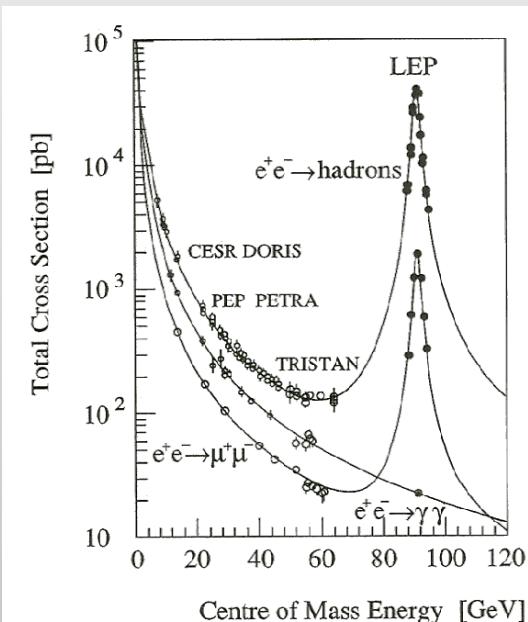
I diagrammi di Feynman al lavoro

Esempio 1: collisione e^+e^-

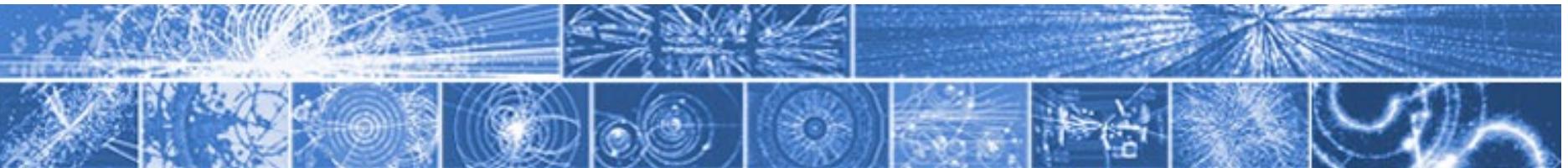


La *risonanza* tradisce la produzione del *mediatore*.

Magari scopriremo così un nuovo *mediatore*.

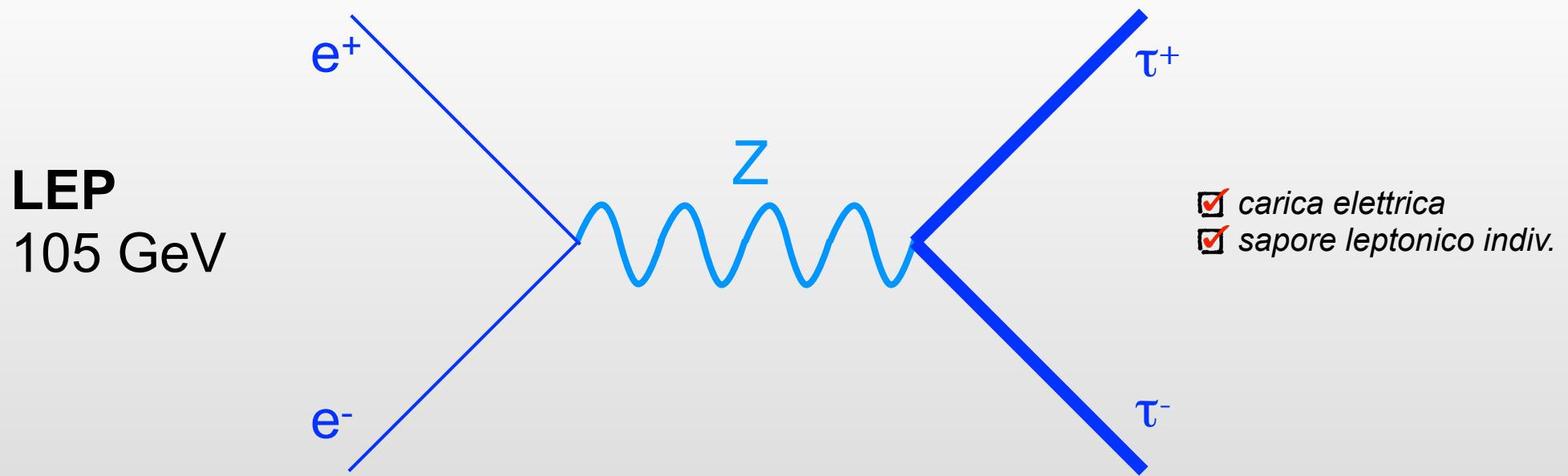


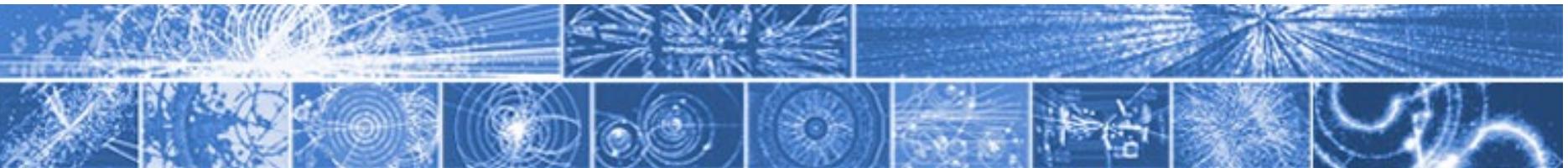
Domande per i più motivati:
perché la sezione d'urto $e^+e^- \rightarrow \text{hadrons}$ è più grande di quella $e^+e^- \rightarrow \mu^+\mu^-$?
sai calcolare a priori il rapporto?
e perché quella $e^+e^- \rightarrow \gamma\gamma$ si comporta diversamente?



I diagrammi di Feynman al lavoro

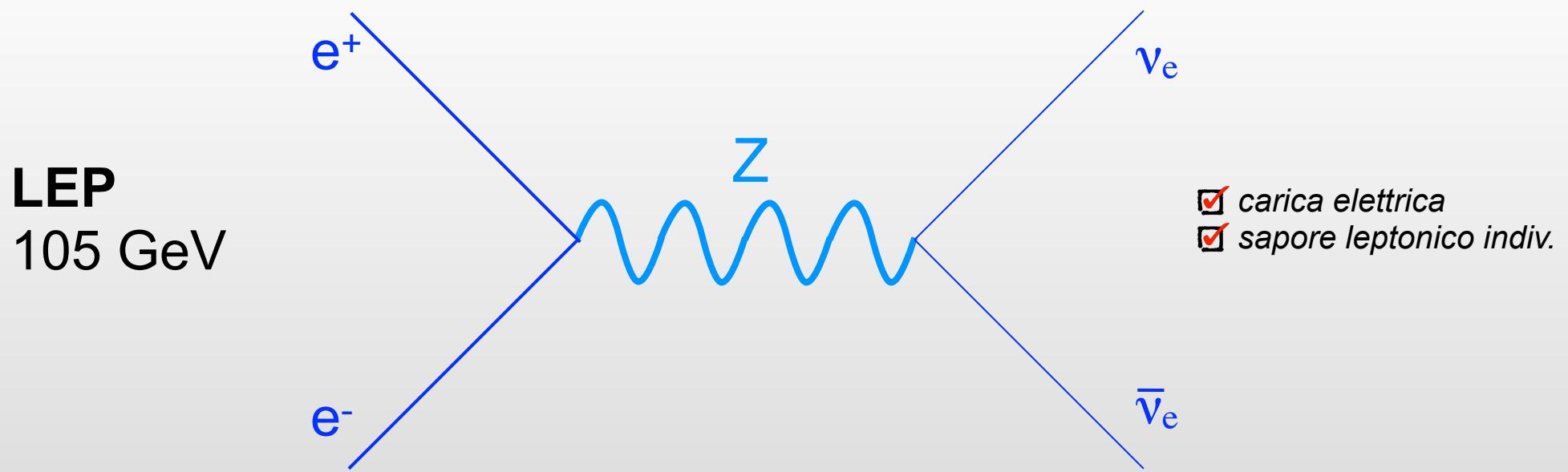
Esempio 1: collisione e^+e^-

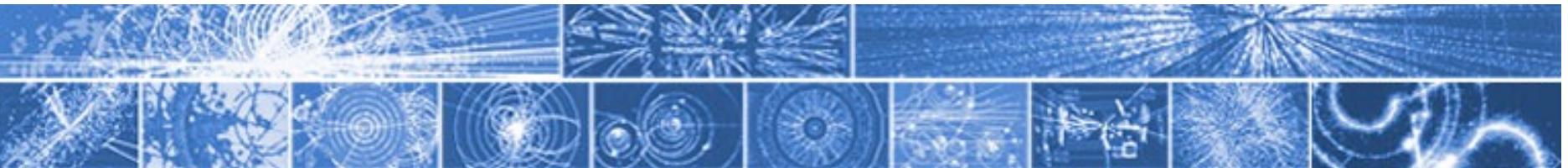




I diagrammi di Feynman al lavoro

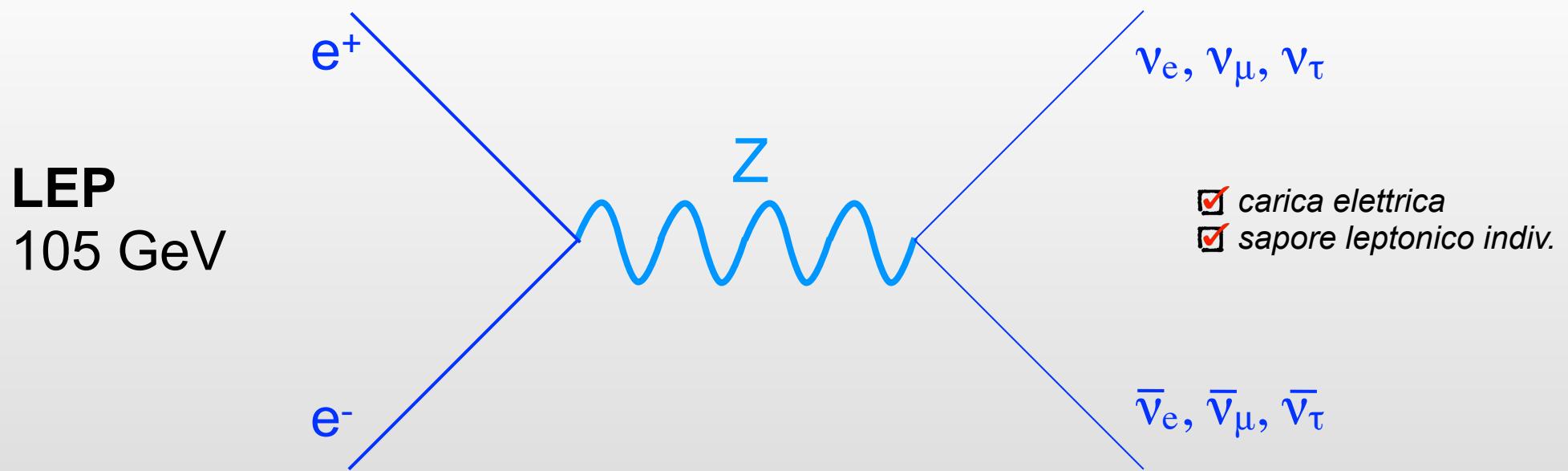
Esempio 1: collisione e^+e^-

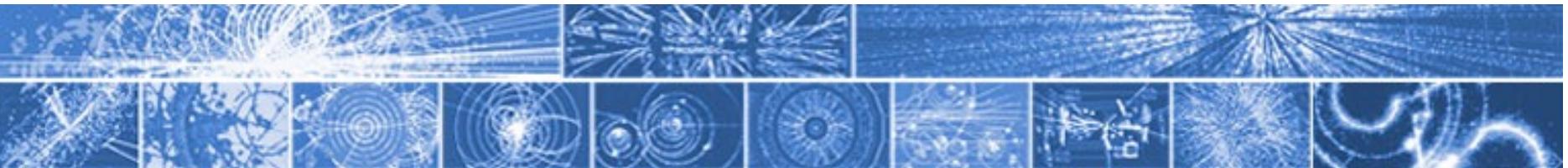




I diagrammi di Feynman al lavoro

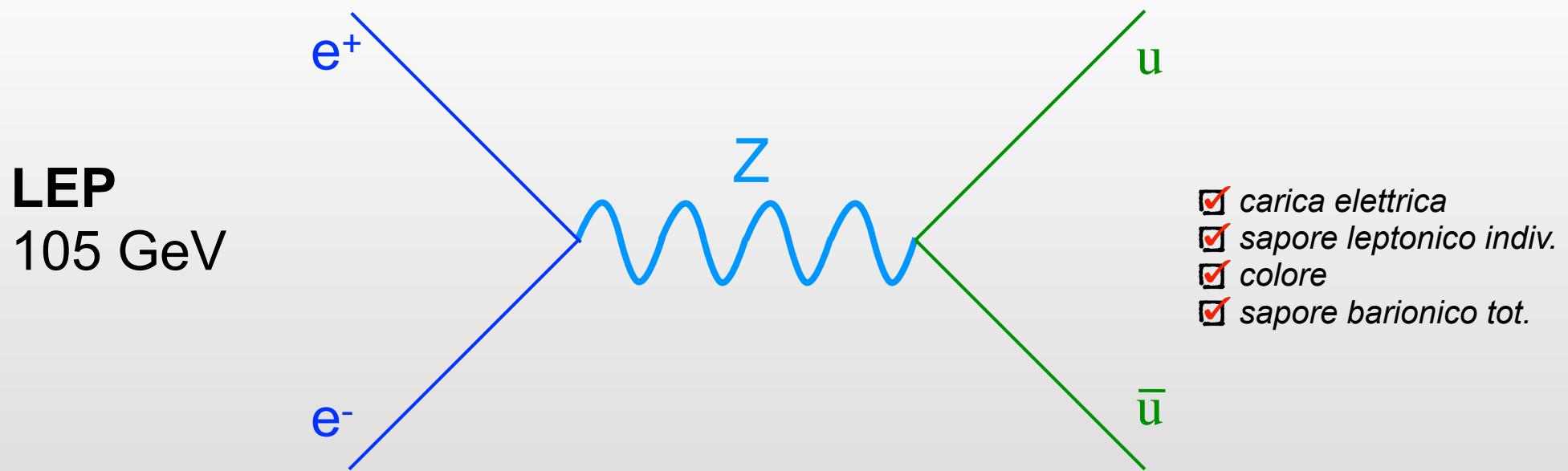
Esempio 1: collisione e^+e^-

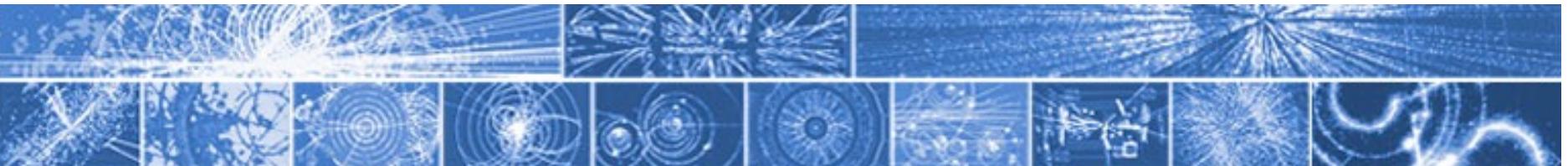




I diagrammi di Feynman al lavoro

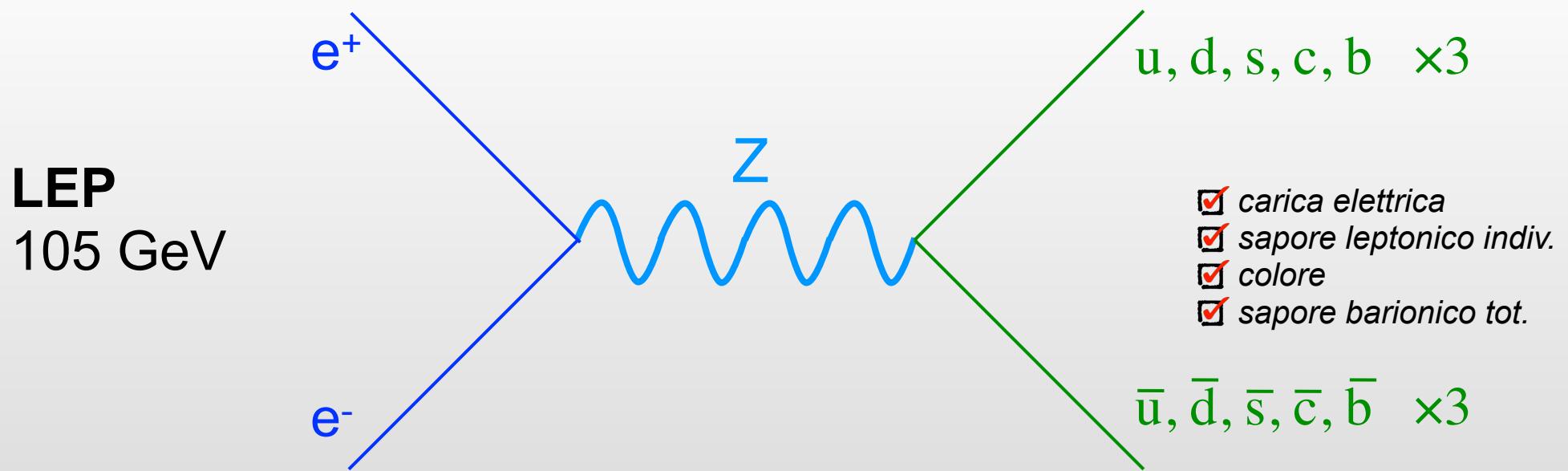
Esempio 1: collisione e^+e^-

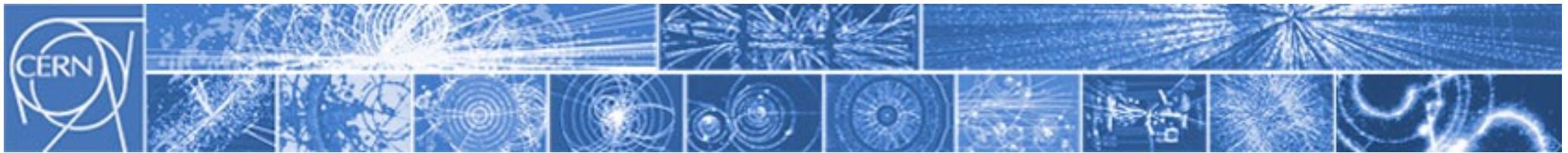




I diagrammi di Feynman al lavoro

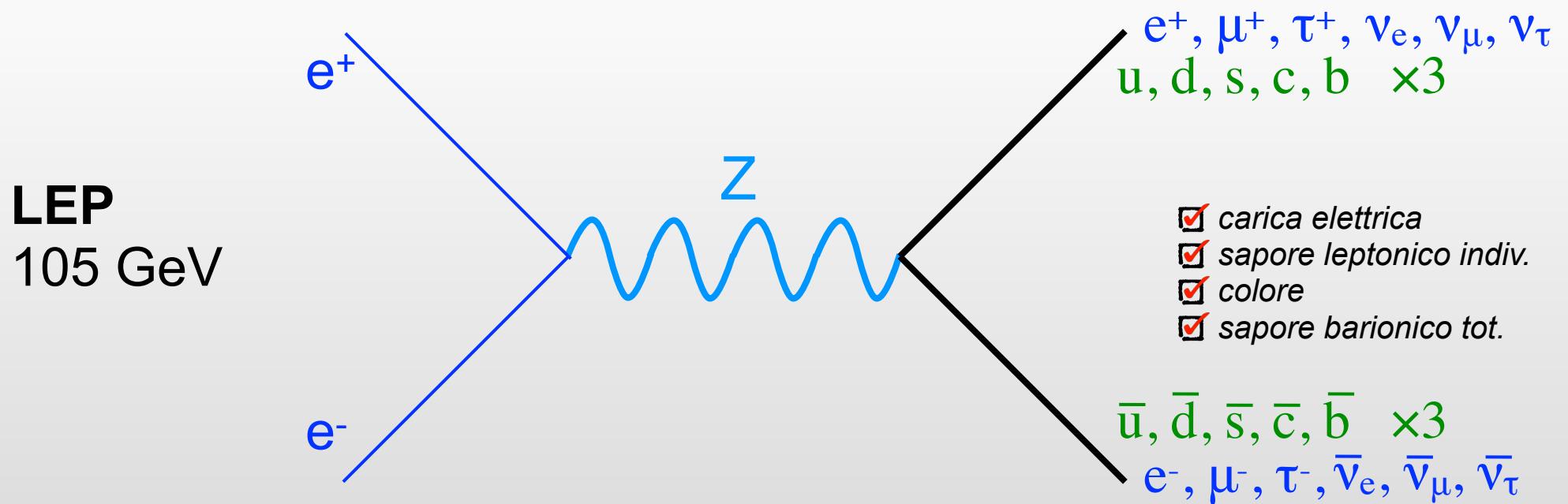
Esempio 1: collisione e^+e^-





I diagrammi di Feynman al lavoro

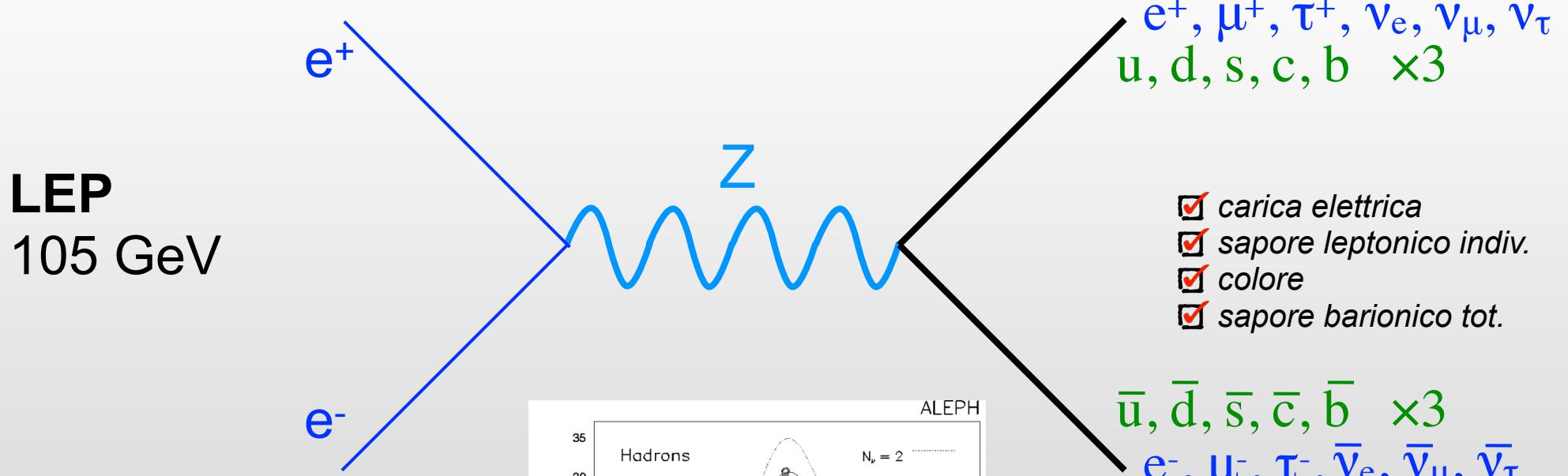
Esempio 1: collisione e^+e^-





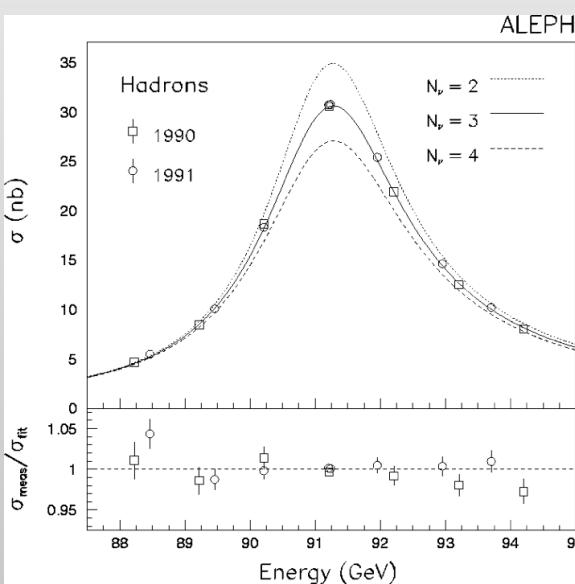
I diagrammi di Feynman al lavoro

Esempio 1: collisione e^+e^-



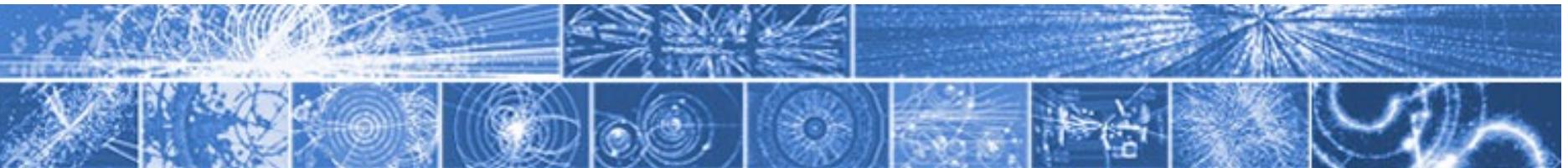
La larghezza della Z permette di determinare il numero di famiglie:

più canali aperti =
decadimento più veloce =
più larga



$\Rightarrow 3$ famiglie!

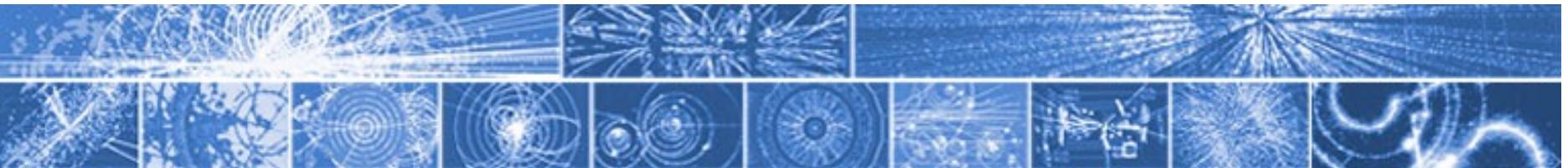
(a meno che il quarto neutrino non abbia massa $> \sim 45$ GeV)



I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p}$

(semirigoroso)

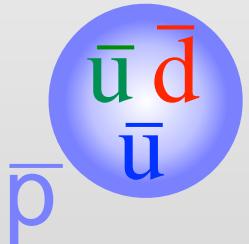
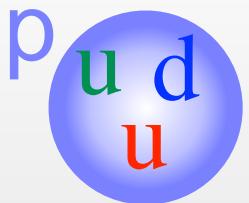


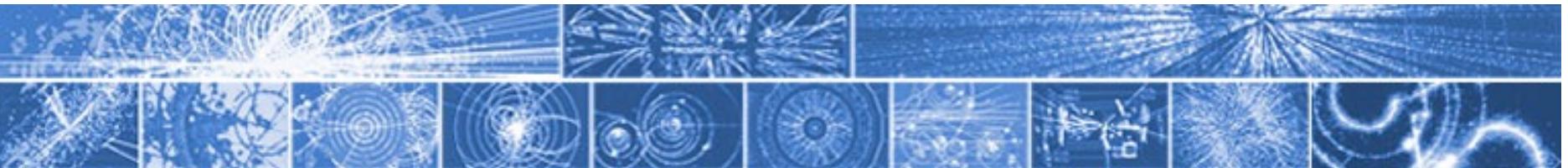
I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p}$

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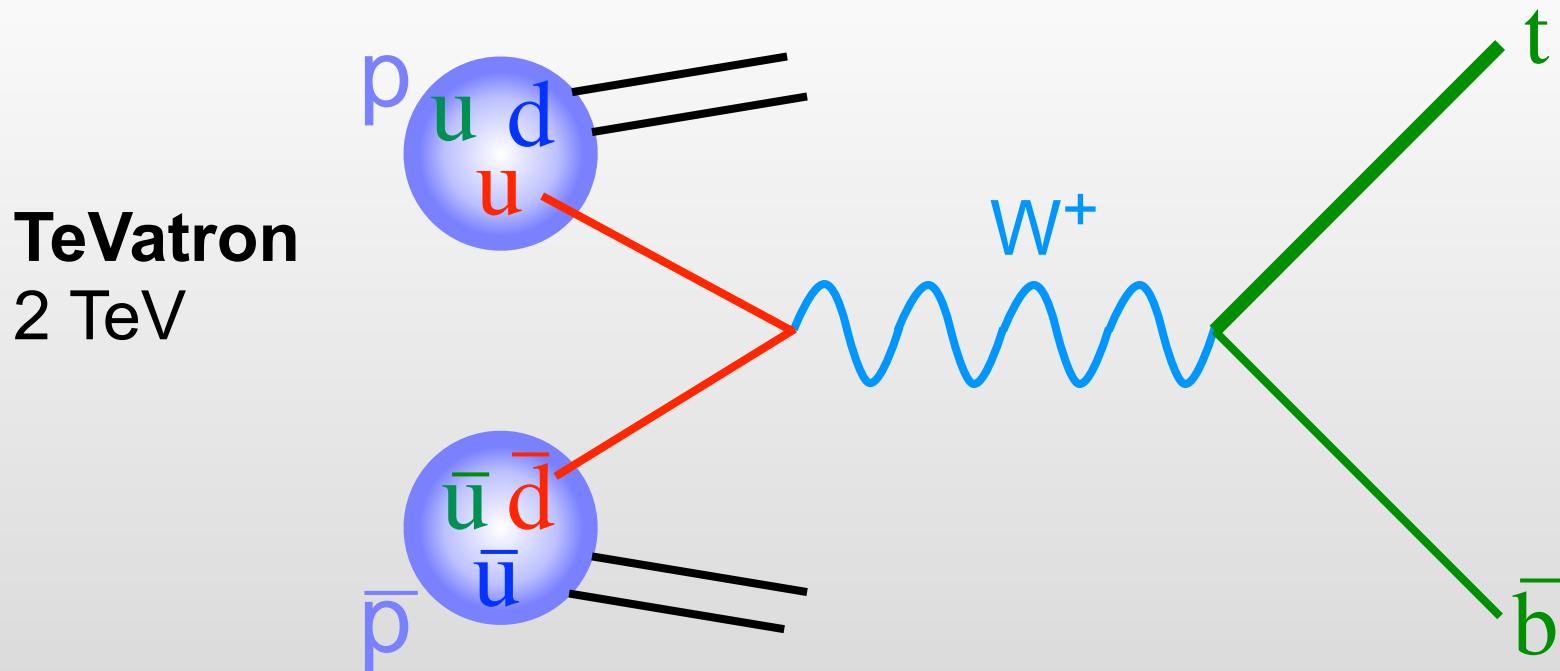
TeVatron
2 TeV



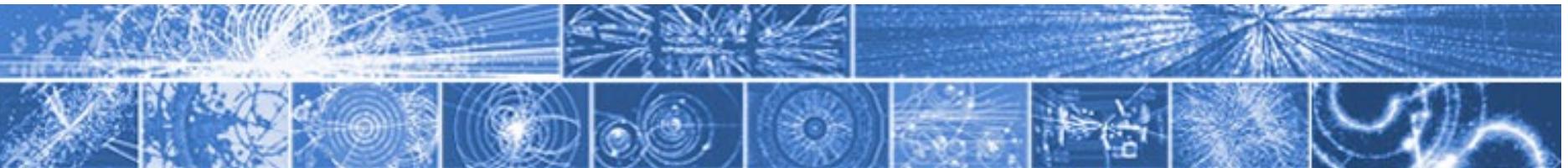


I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p} \rightarrow$ produzione di quark top
(semirigoroso)

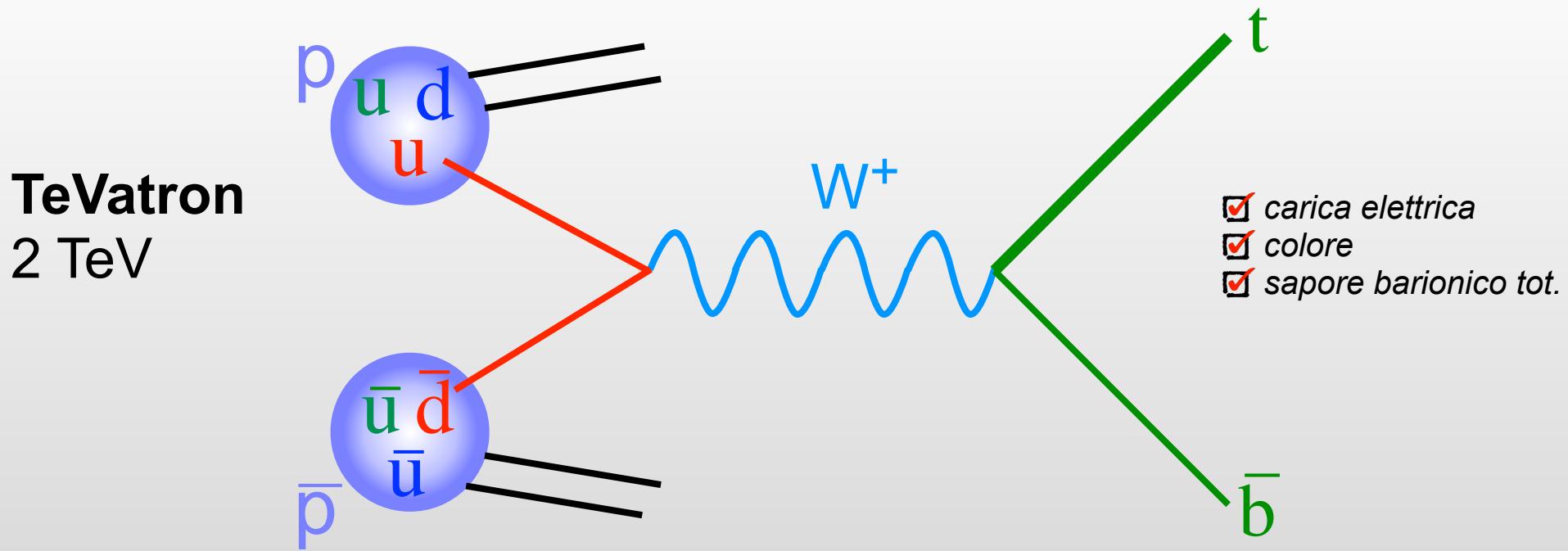


Nota: non è il canale più efficace per produrre un top quark al TeVatron, ma vabbè.



I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p} \rightarrow$ produzione di quark top
(semirigoroso)

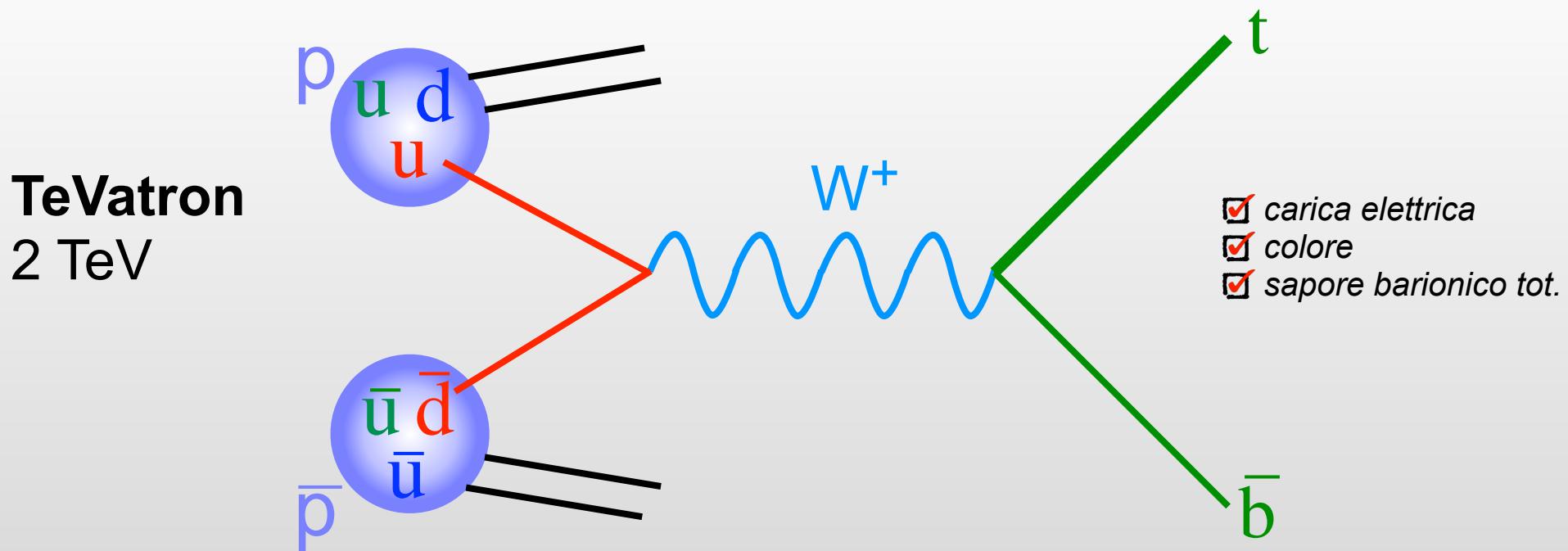


Nota: non è il canale più efficace per produrre un top quark al TeVatron, ma vabbè.



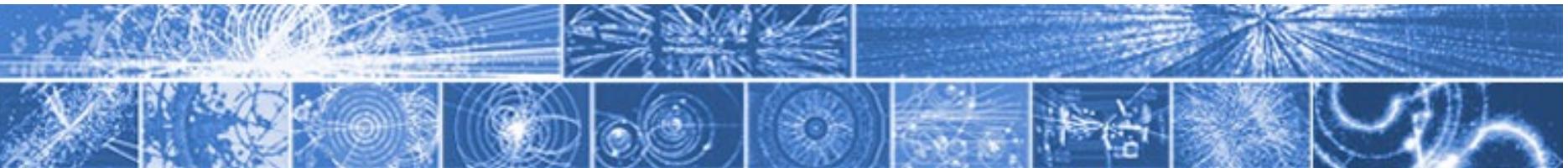
I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p} \rightarrow$ produzione di quark top
(semirigoroso)



Ogni q porta una frazione del momento del p : serve una grande energia.

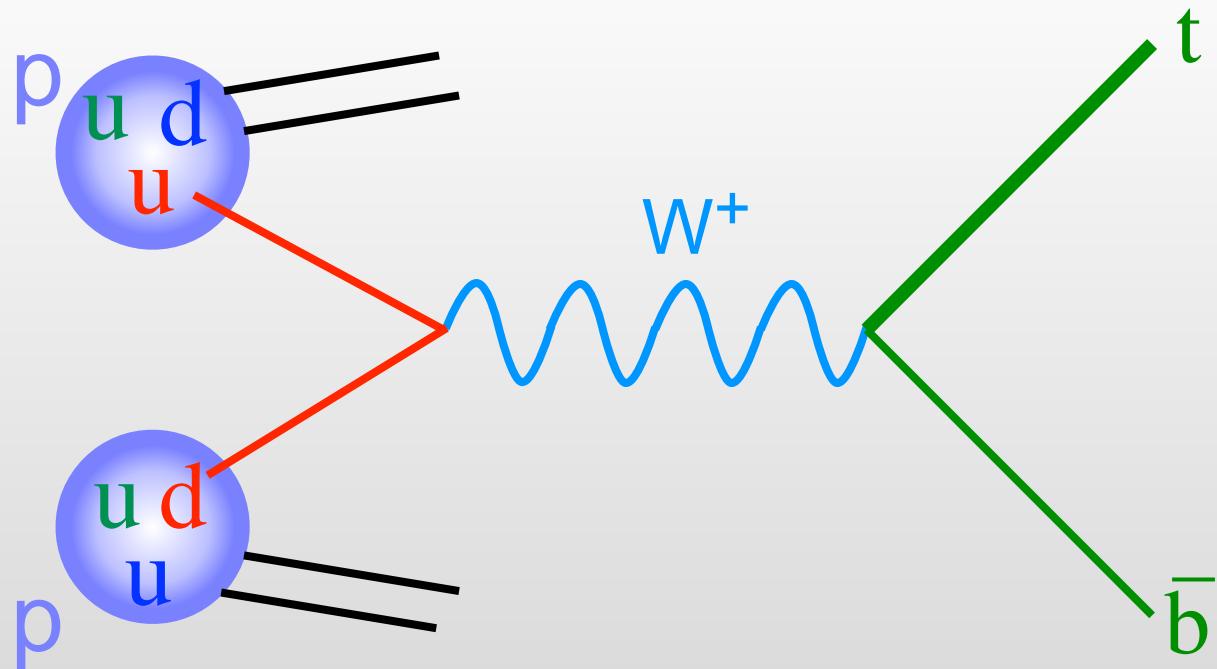
Magari scopriremo così una nuova particella pesante (un *nuovo 'quark'*?).

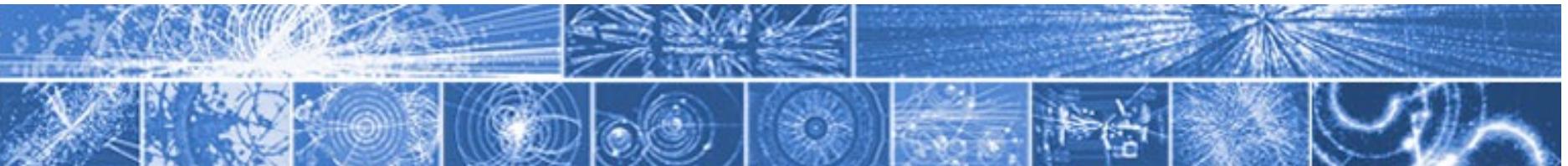


I diagrammi di Feynman al lavoro

Esempio 2b: collisione $pp \rightarrow$ produzione di quark top
(semirigoroso)

LHC
'14 TeV'



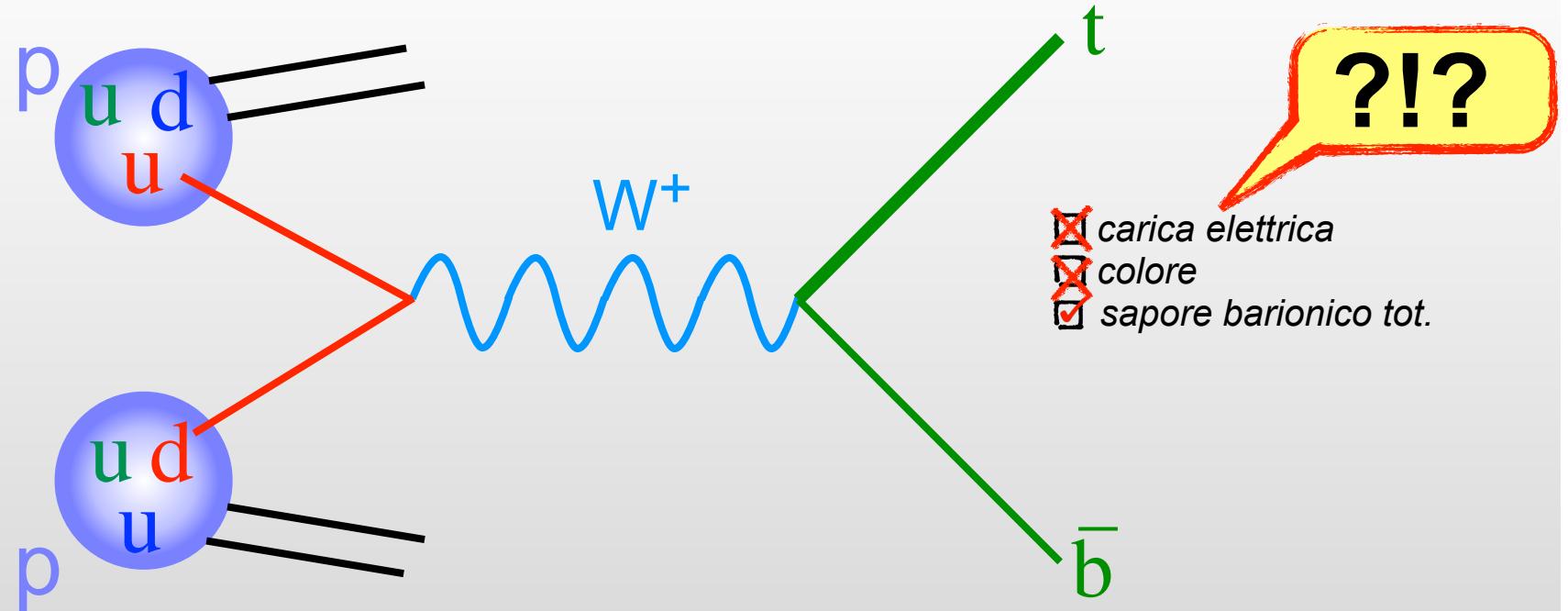


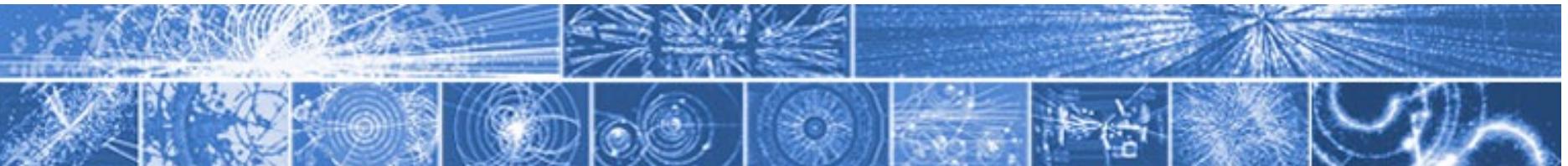
I diagrammi di Feynman al lavoro

Esempio 2b: collisione $pp \rightarrow$ produzione di quark top

(semirigoroso)

LHC
'14 TeV'

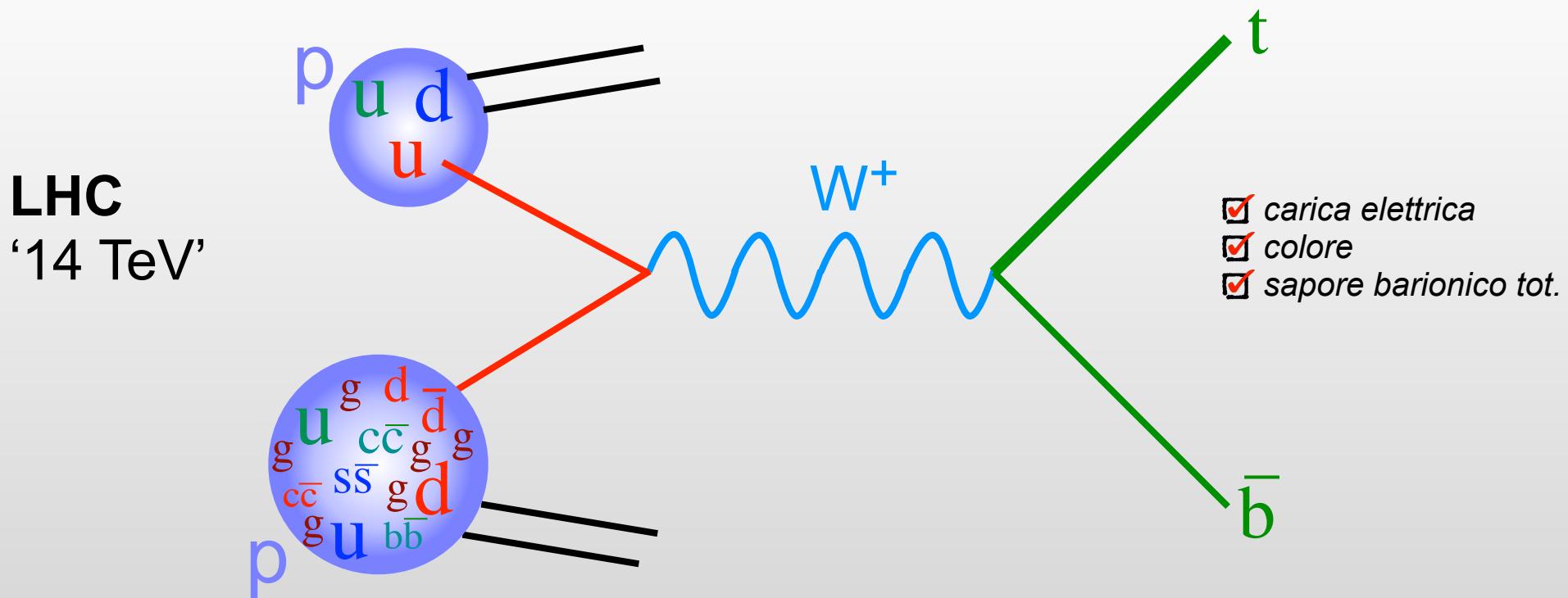




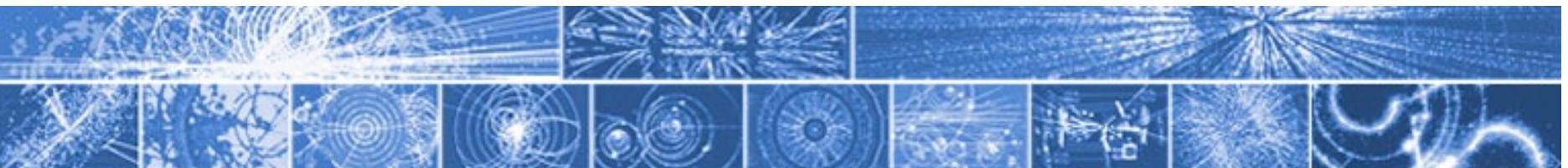
I diagrammi di Feynman al lavoro

Esempio 2b: collisione $pp \rightarrow$ produzione di quark top

(semirigoroso)

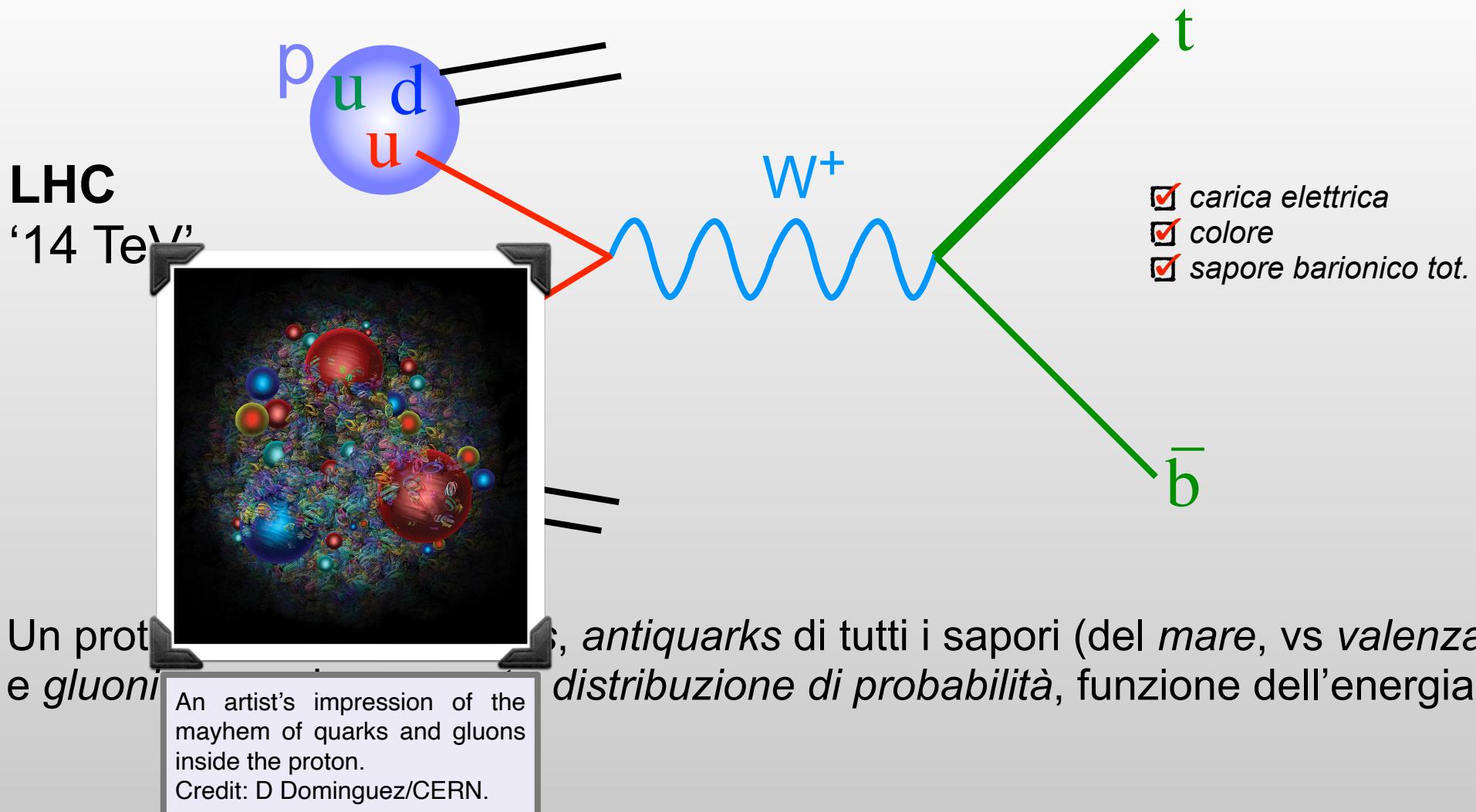


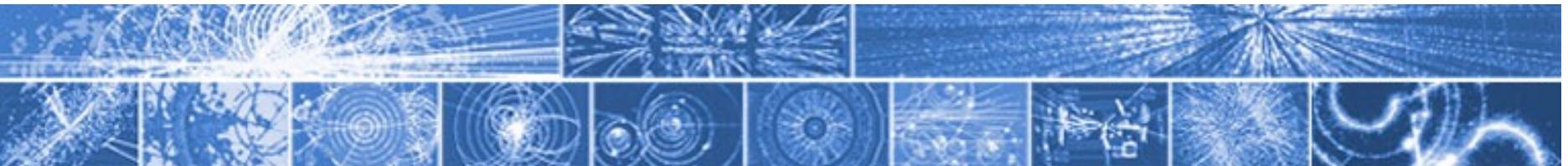
Un protone 'contiene' quarks, antiquarks di tutti i sapori (del *mare*, vs *valenza*), e gluoni, secondo una certa *distribuzione di probabilità*, funzione dell'energia.



I diagrammi di Feynman al lavoro

Esempio 2b: collisione $pp \rightarrow$ produzione di quark top
(semirigoroso)

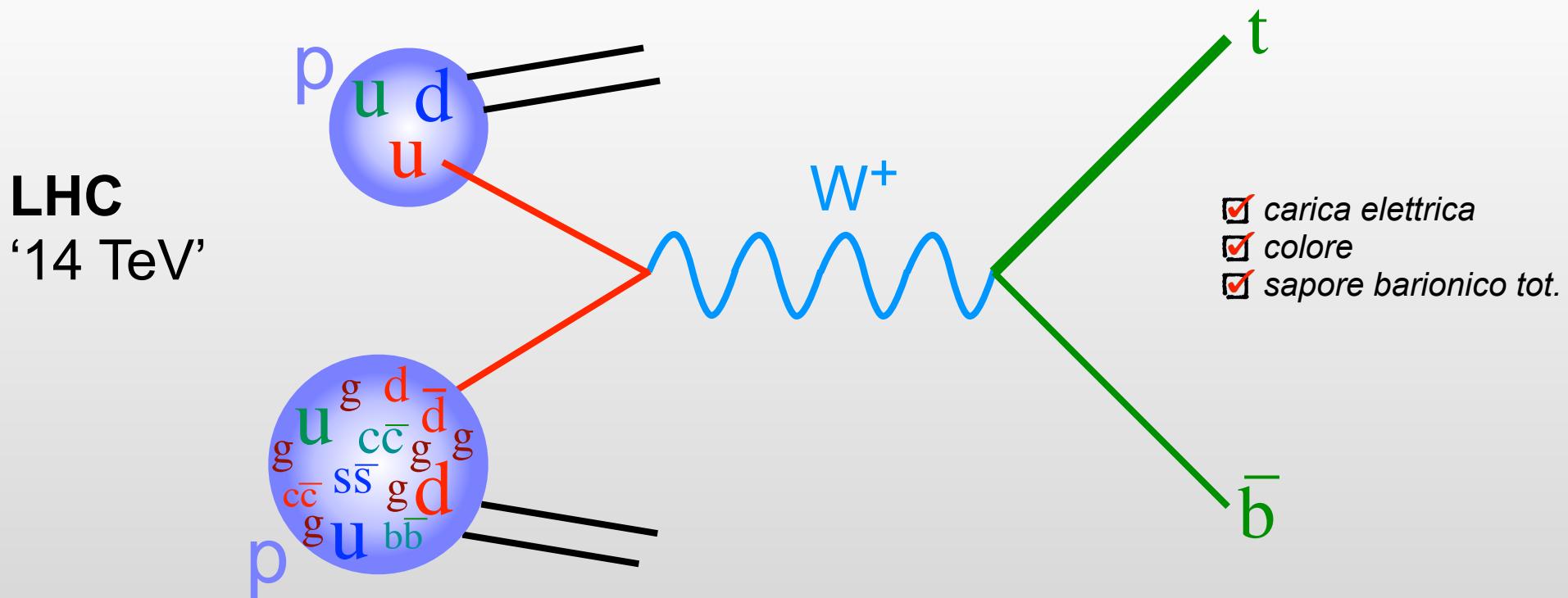




I diagrammi di Feynman al lavoro

Esempio 2b: collisione $pp \rightarrow$ produzione di quark top

(semirigoroso)



Un protone ‘contiene’ quarks, antiquarks di tutti i sapori (del mare, vs valenza), e gluoni, secondo una certa *distribuzione di probabilità*, funzione dell’energia.