Fisica delle particelle *oggi*

Il Modello Standard

and Beyond

- Bosone di Higgs
- SuperSimmetria
- Astroparticle & Materia Oscura

Marco CIRELLI [CNRS LPTHE Jussieu & Sorbonne]

Mini-intro:
- livello variabile
- non storico
- about MC

Cosa si fa al CERN

Ricerca fondamentale in Fisica delle Particelle

- i costituenti elementari della materia
- le forze fondamentali che li governano
- l'origine, il contenuto e la struttura dell'Universo

Come risolvere questi problemi?
o... Come si fanno le scoperte?

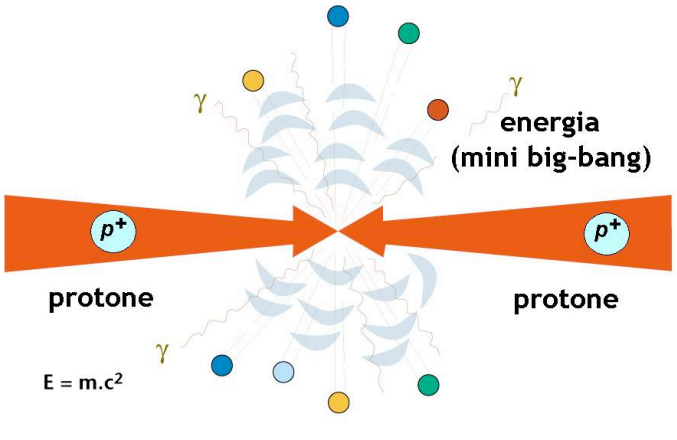
Accelerare le particelle elementari *(protoni, elettroni...)*

fino a energie elevatissime *(14 TeV)*

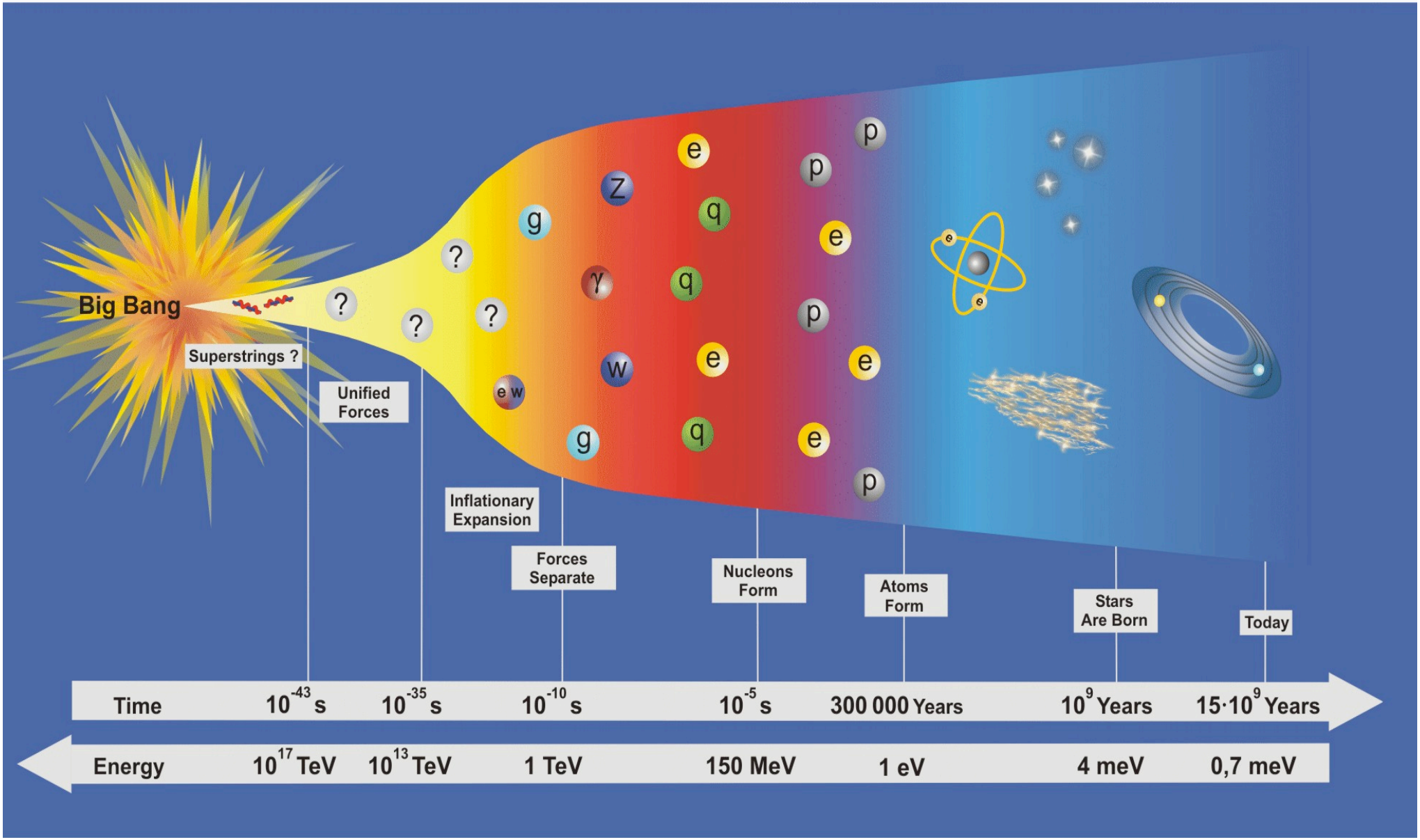
e portarle a collidere. $E=mc^2$

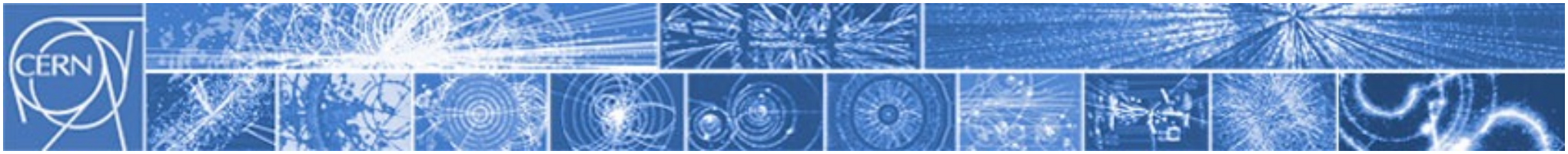
Analizzare accuratamente i prodotti

per scoprire nuove particelle,
nuove forze,
'nuova fisica'...



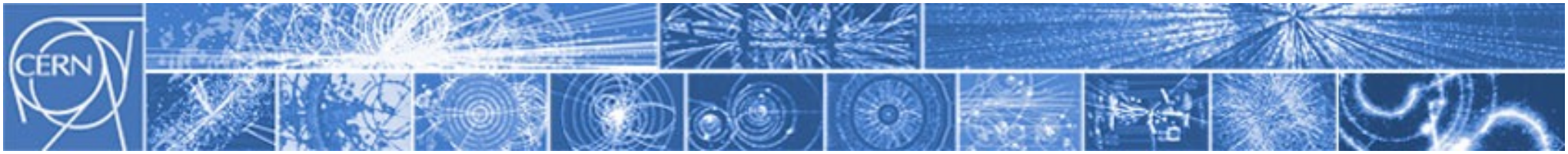
Ripercorrere all'indietro la storia dell'Universo





Modello Standard

(della fisica delle particelle elementari)



Il Modello Standard è la costruzione ('scoperta') fondamentale della fisica delle particelle, nella seconda metà del XX secolo.

XIX secolo elettromagnetismo

1932 teoria di Fermi del decadimento beta - interazioni deboli

1960's unificazione em-debole: teoria ElectroWeak
(Glashow, Weinberg, Salam)

1981 scoperta bosoni W e Z (Rubbia)

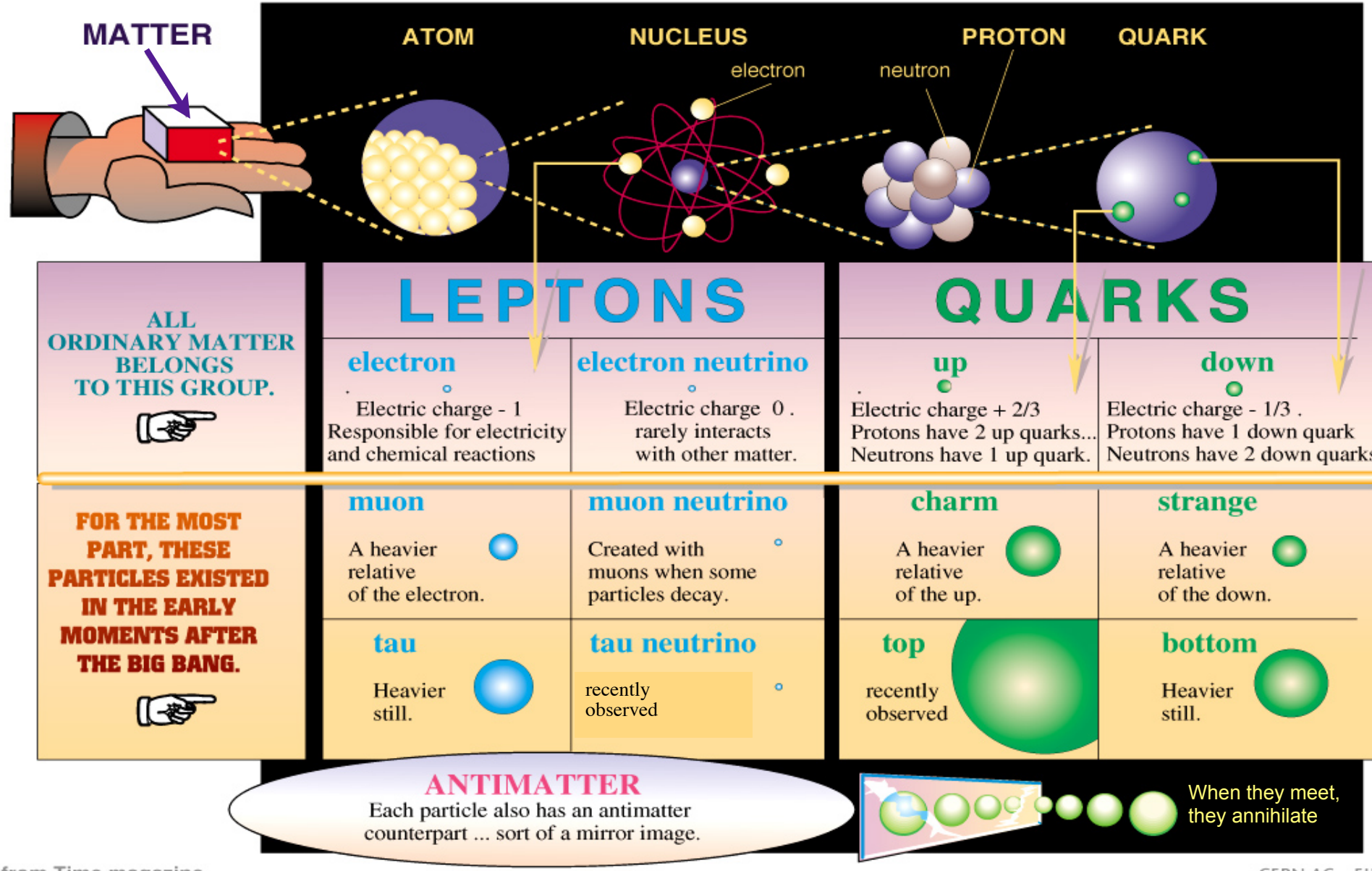
1970's teoria della QCD - interazioni nucleari forti
(Gross, Politzer, Wilczek)

1936 μ
1956 ν_e
1962 ν_μ
1974 τ
2000 ν_τ

1968 s quark
1974 c quark
1977 b quark
1995 t quark

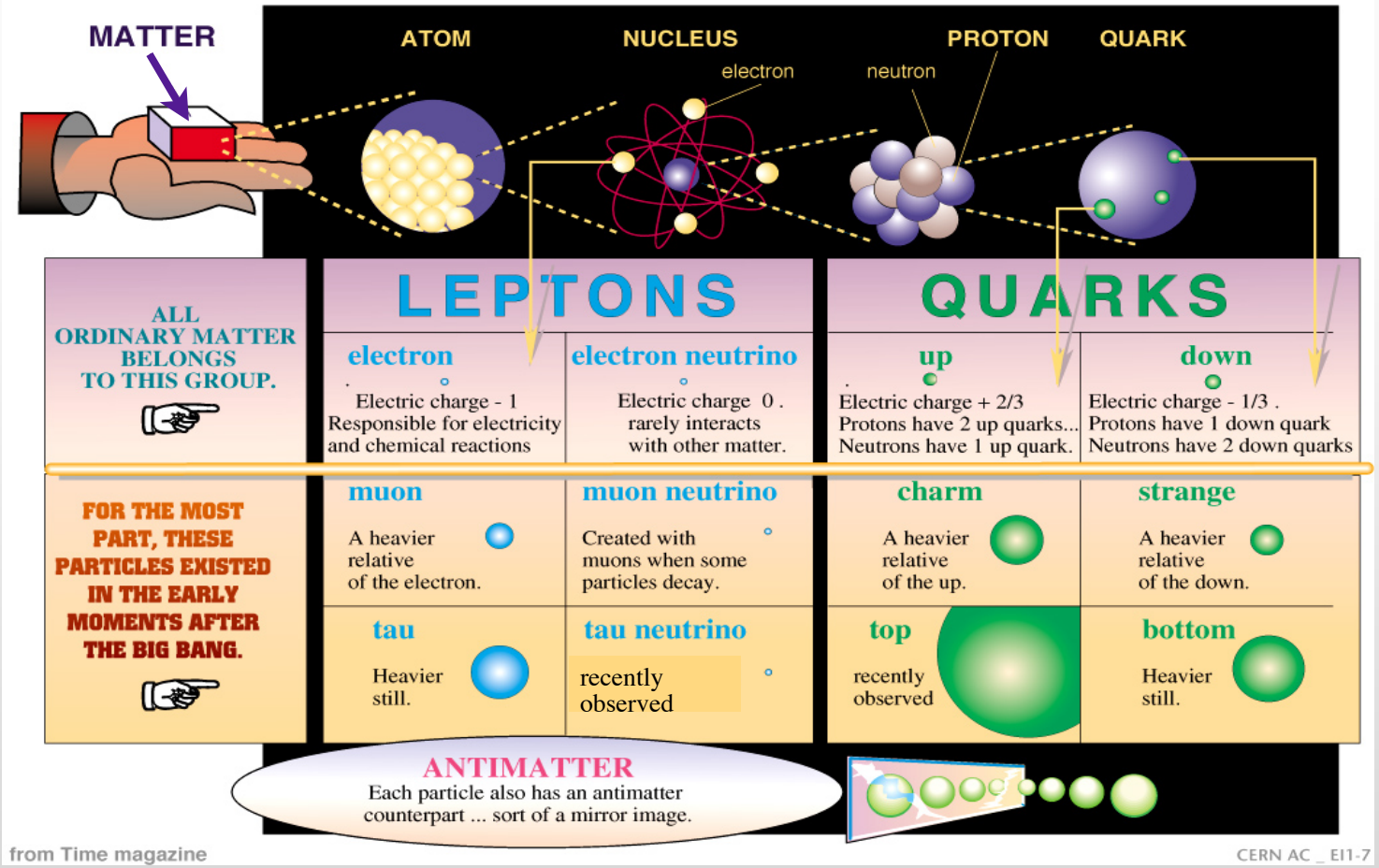
2012 higgs

STANDARD MODEL



from Time magazine

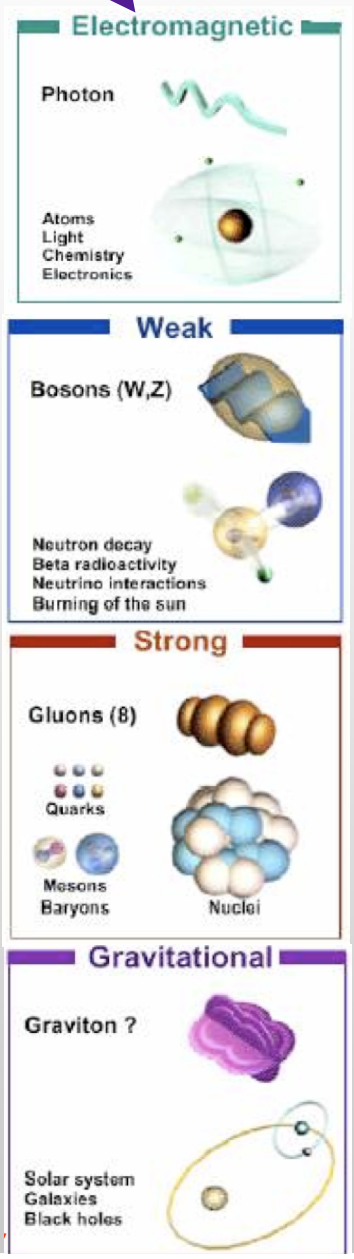
STANDARD MODEL



from Time magazine

CERN AC _ EI1-7

FORCES



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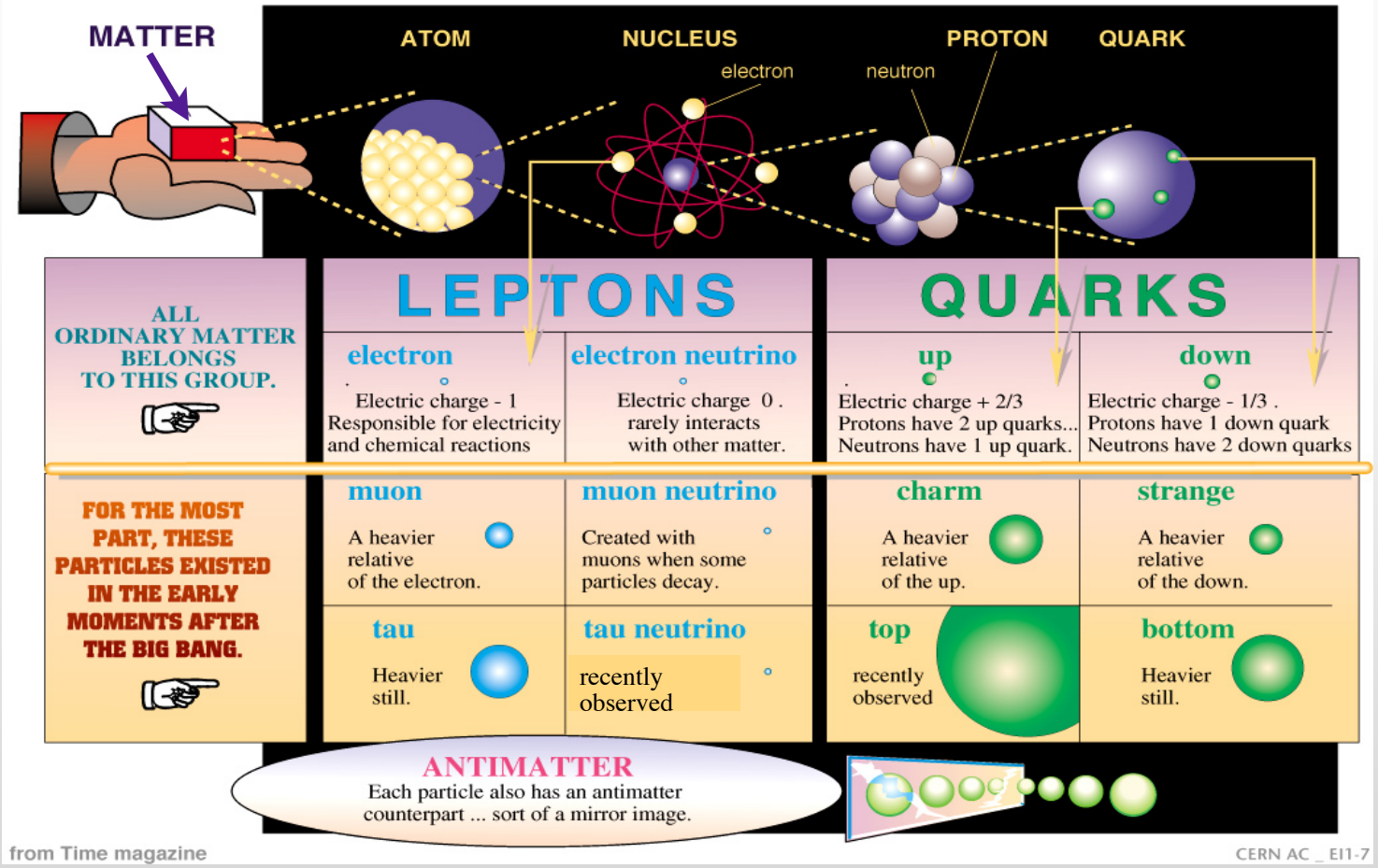

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CERN AC _ EI1-7

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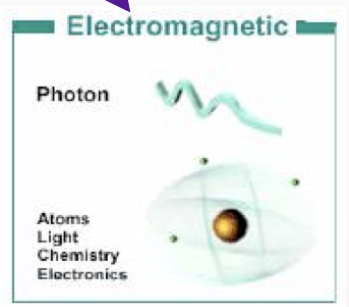

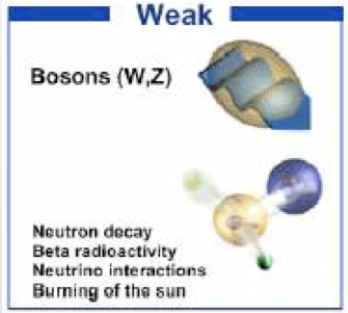

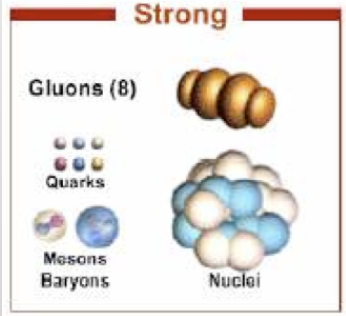

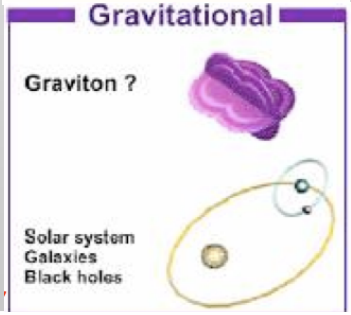

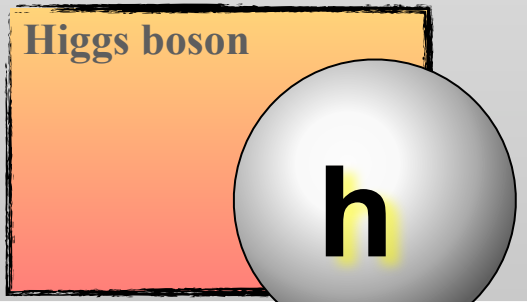

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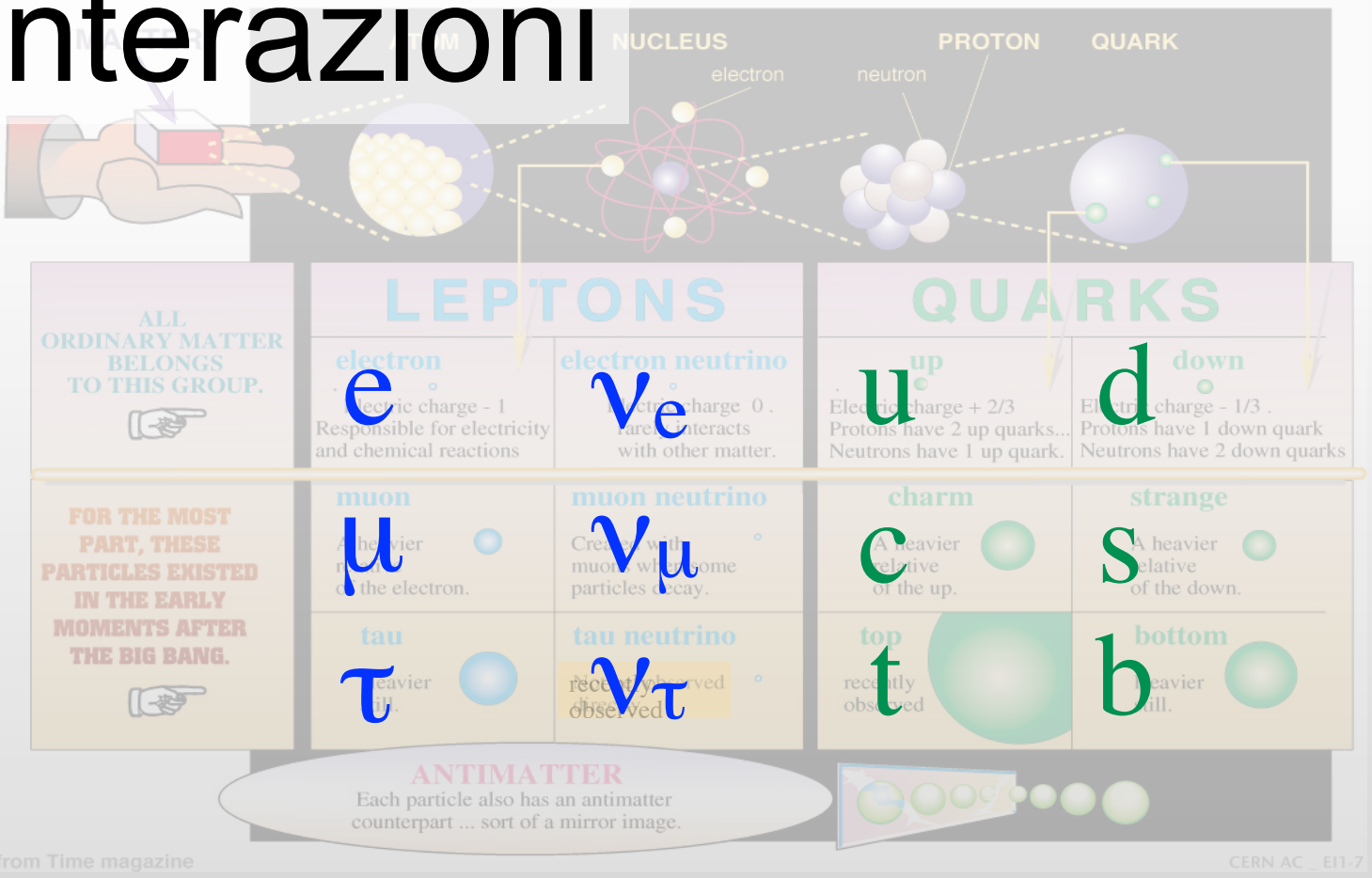

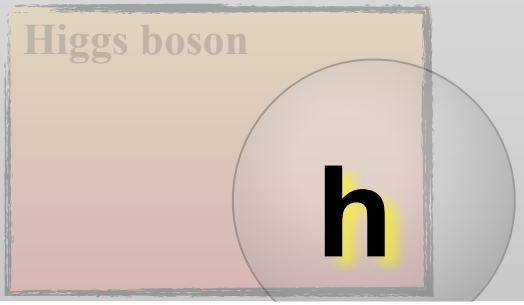

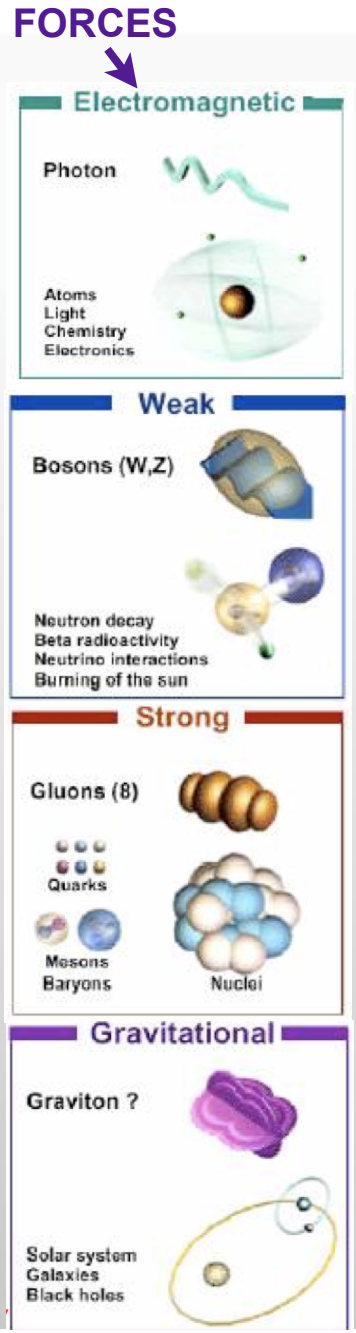

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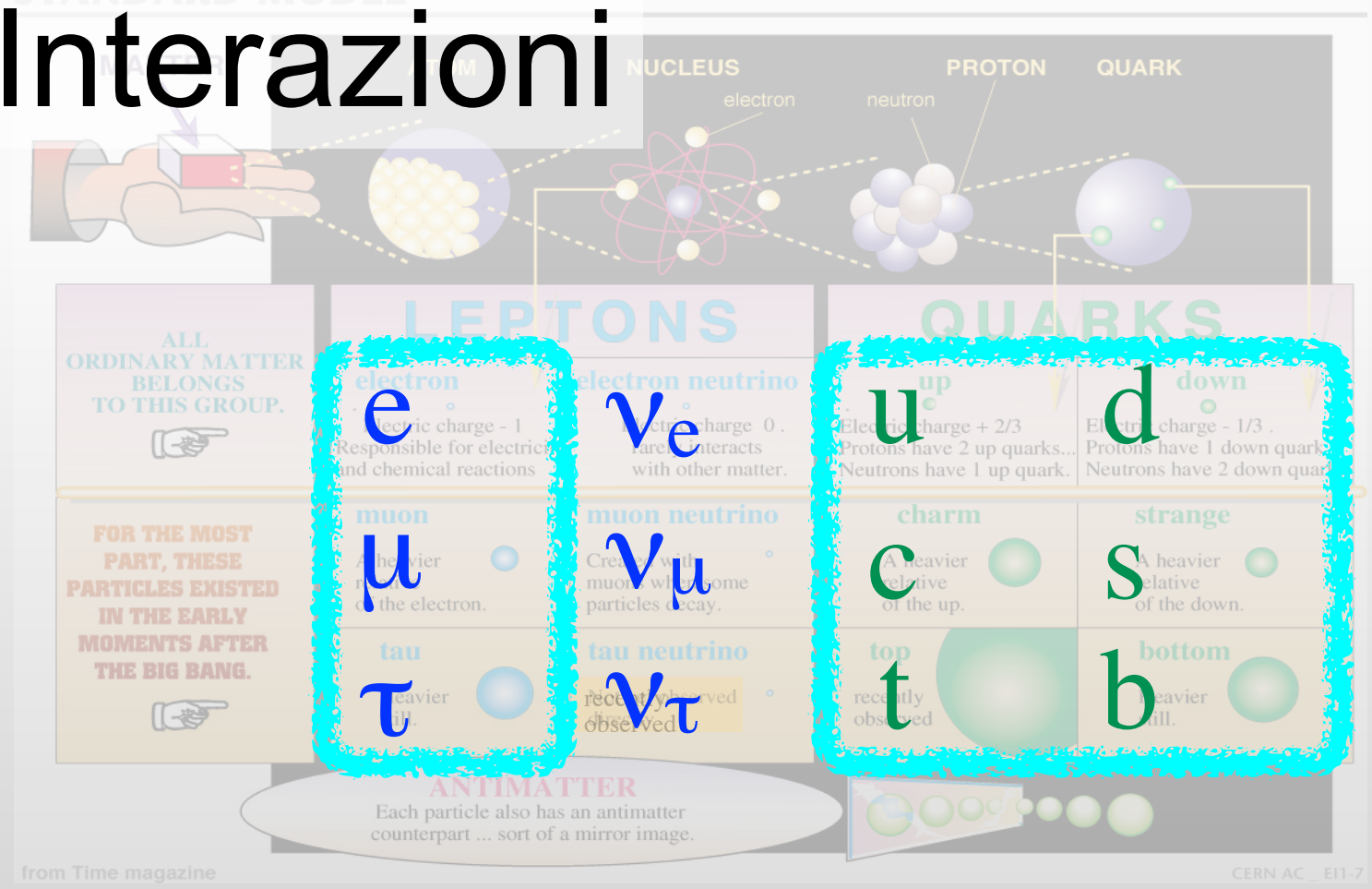

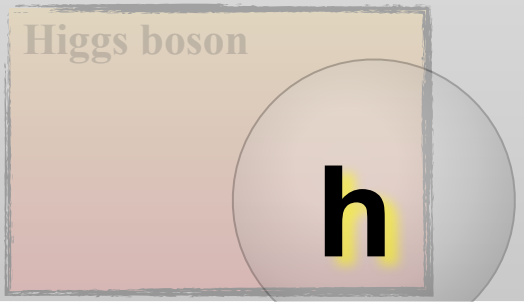

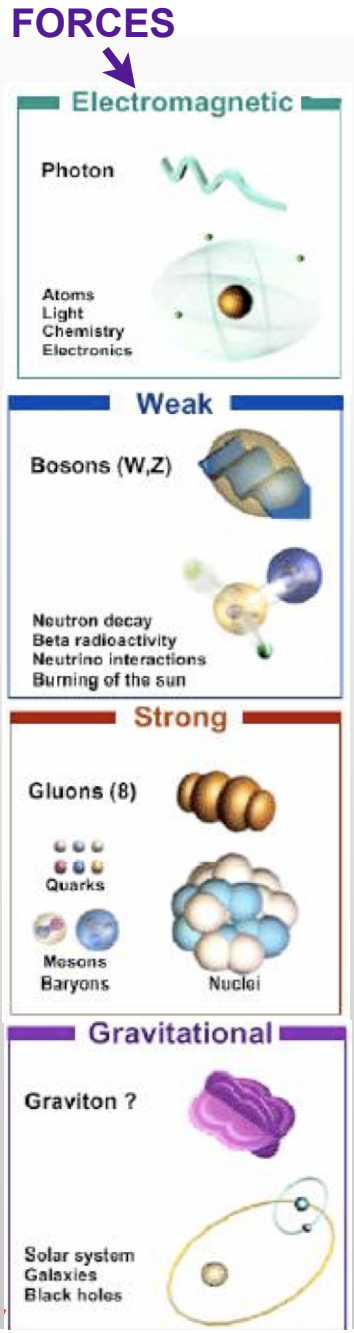

Interazioni

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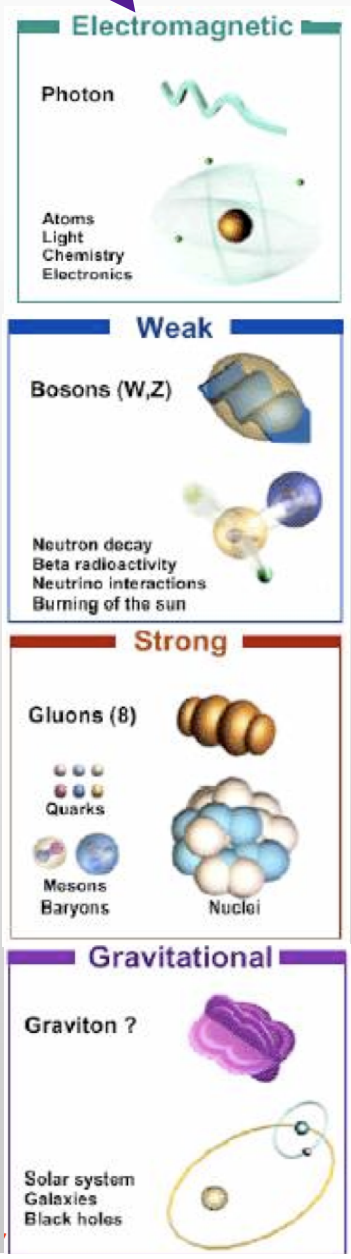

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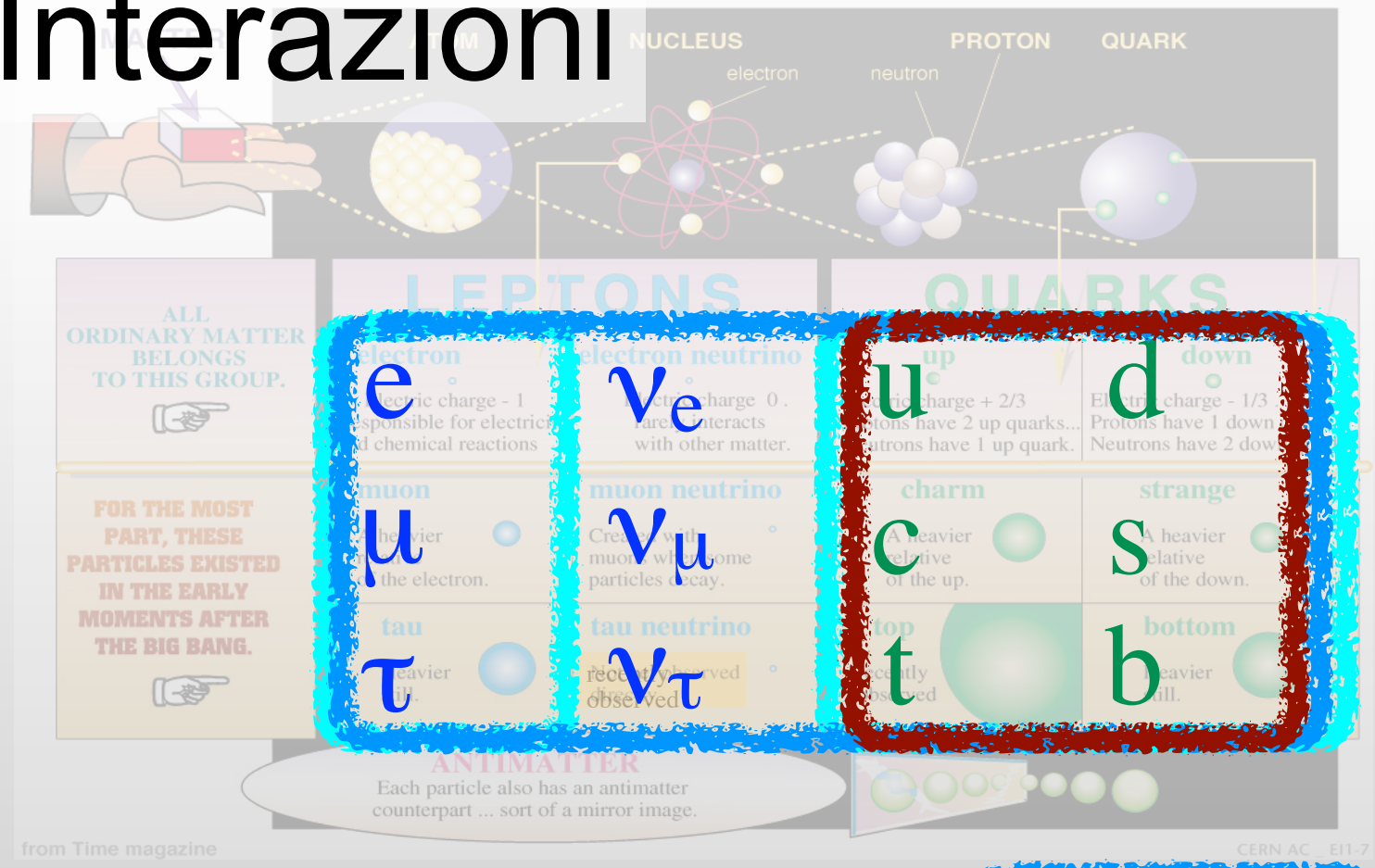

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μ ν_μ c s

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Higgs boson

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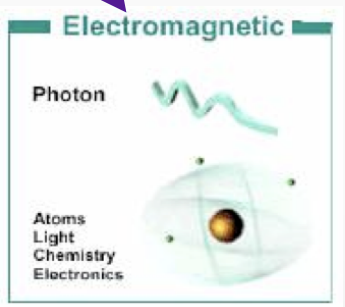
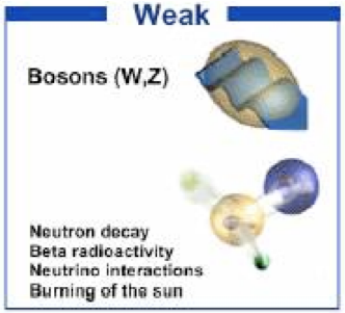
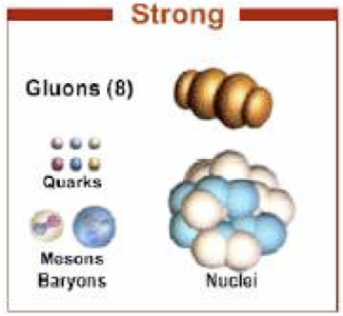
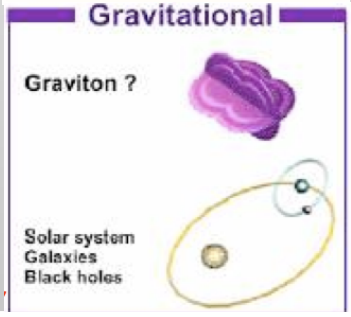
FORCES









Interazioni

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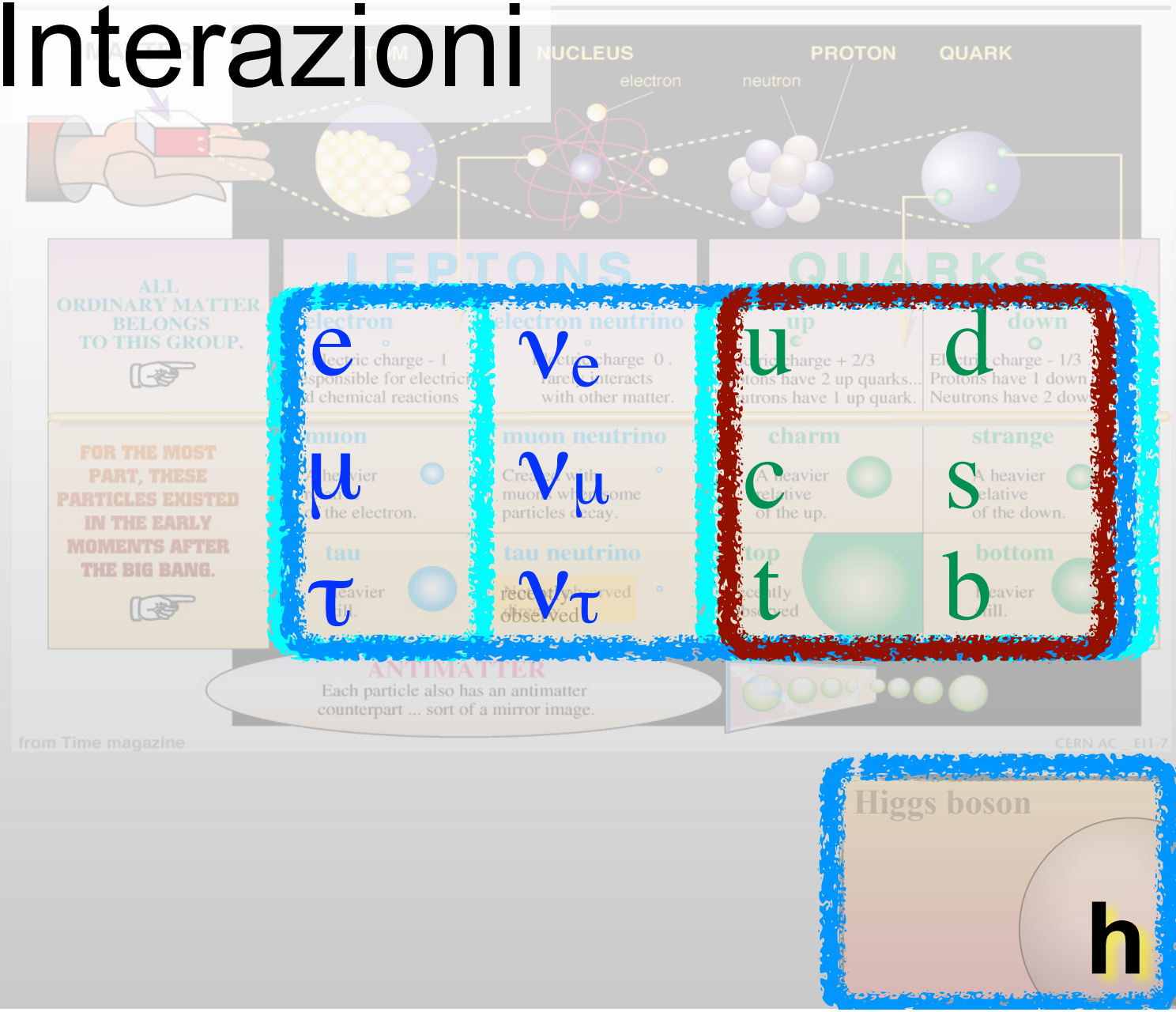

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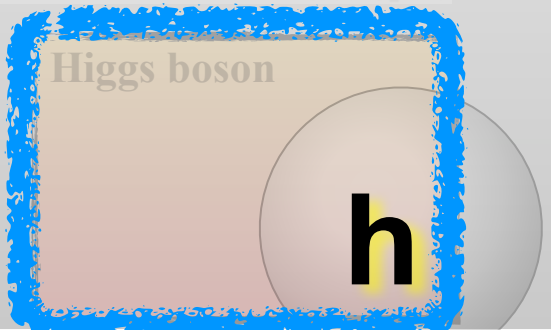
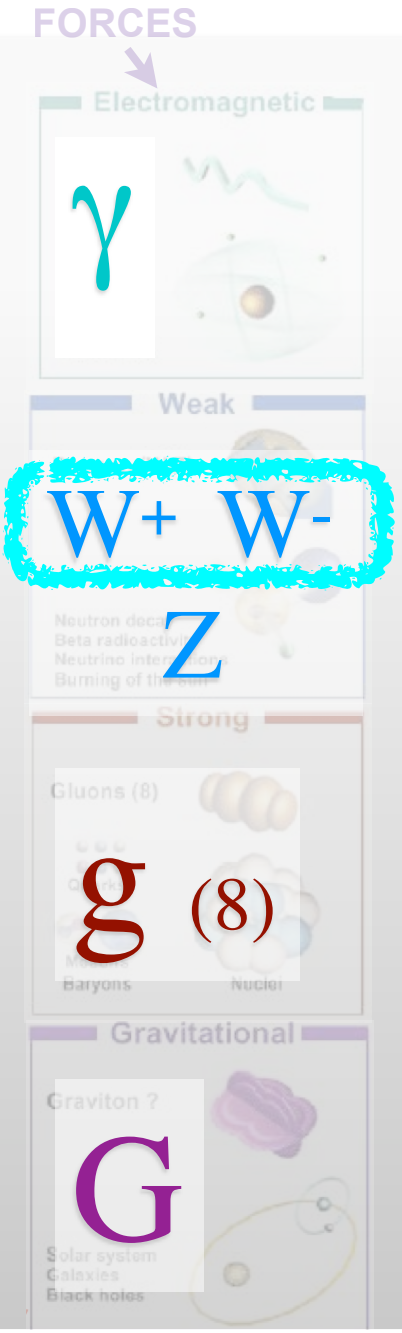
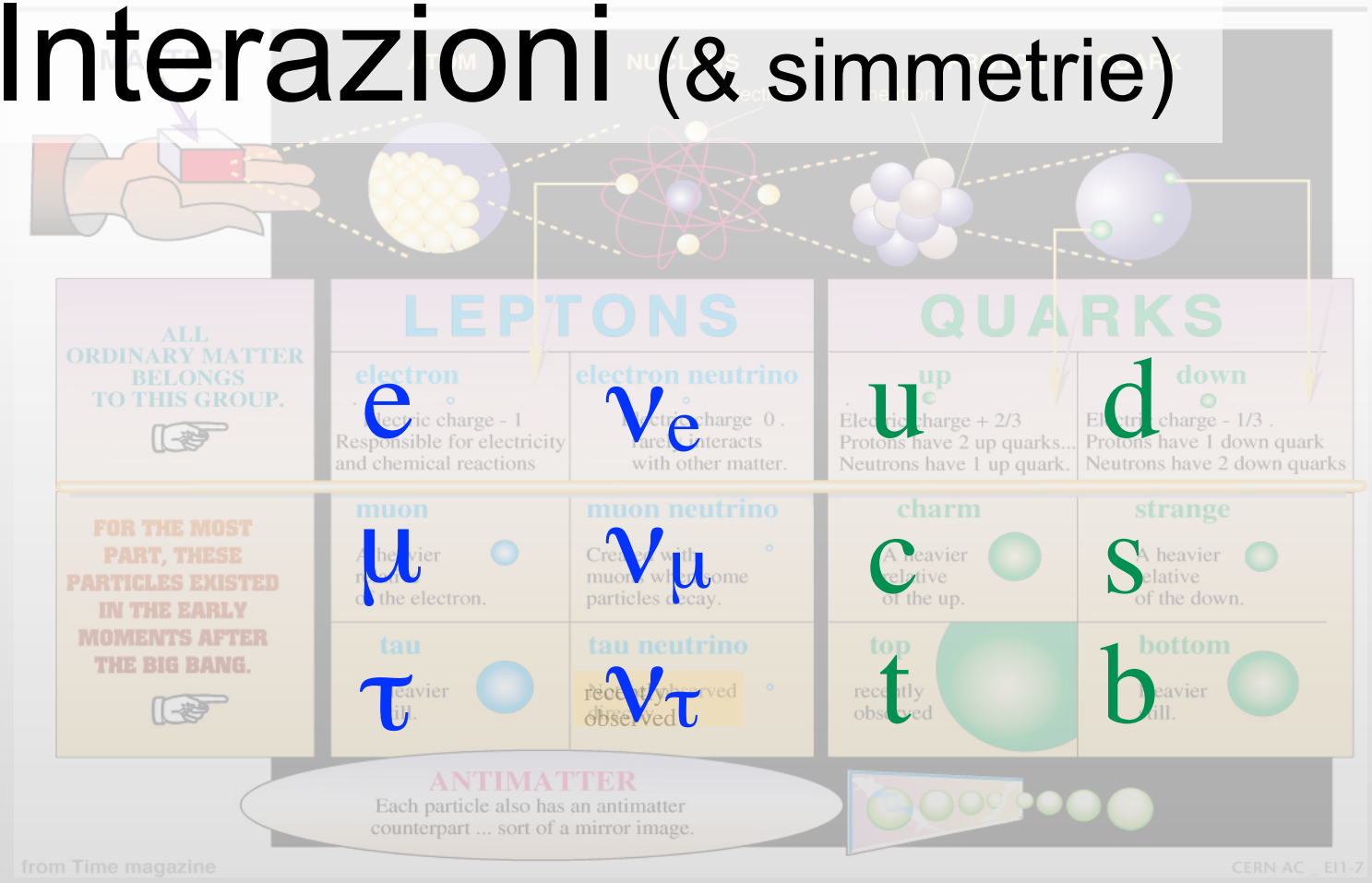
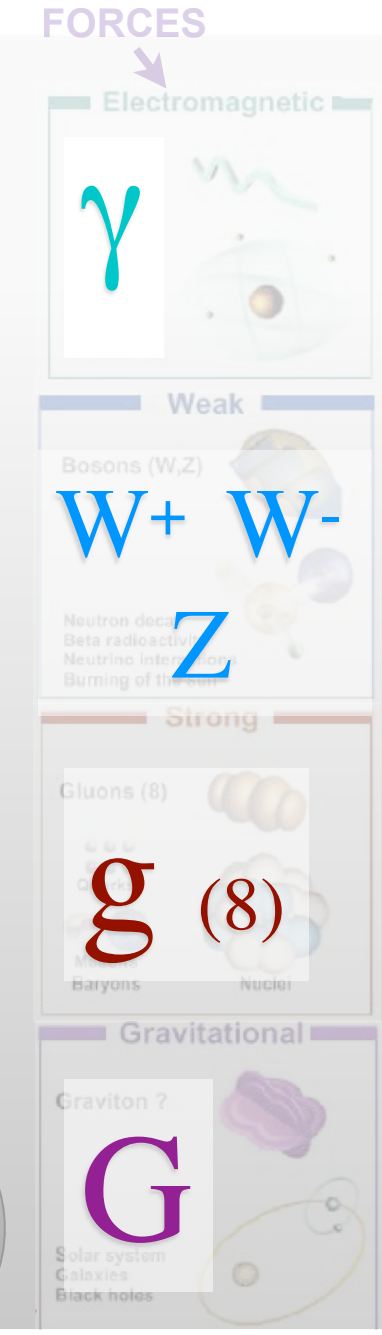
u d c s t b



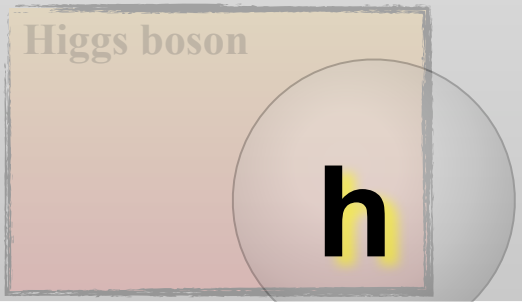


Interazioni (& simmetrie)





- $SU_c(3) \times SU_w(2) \times U_Y(1) \rightarrow SU_c(3) \times U_{em}(1)$



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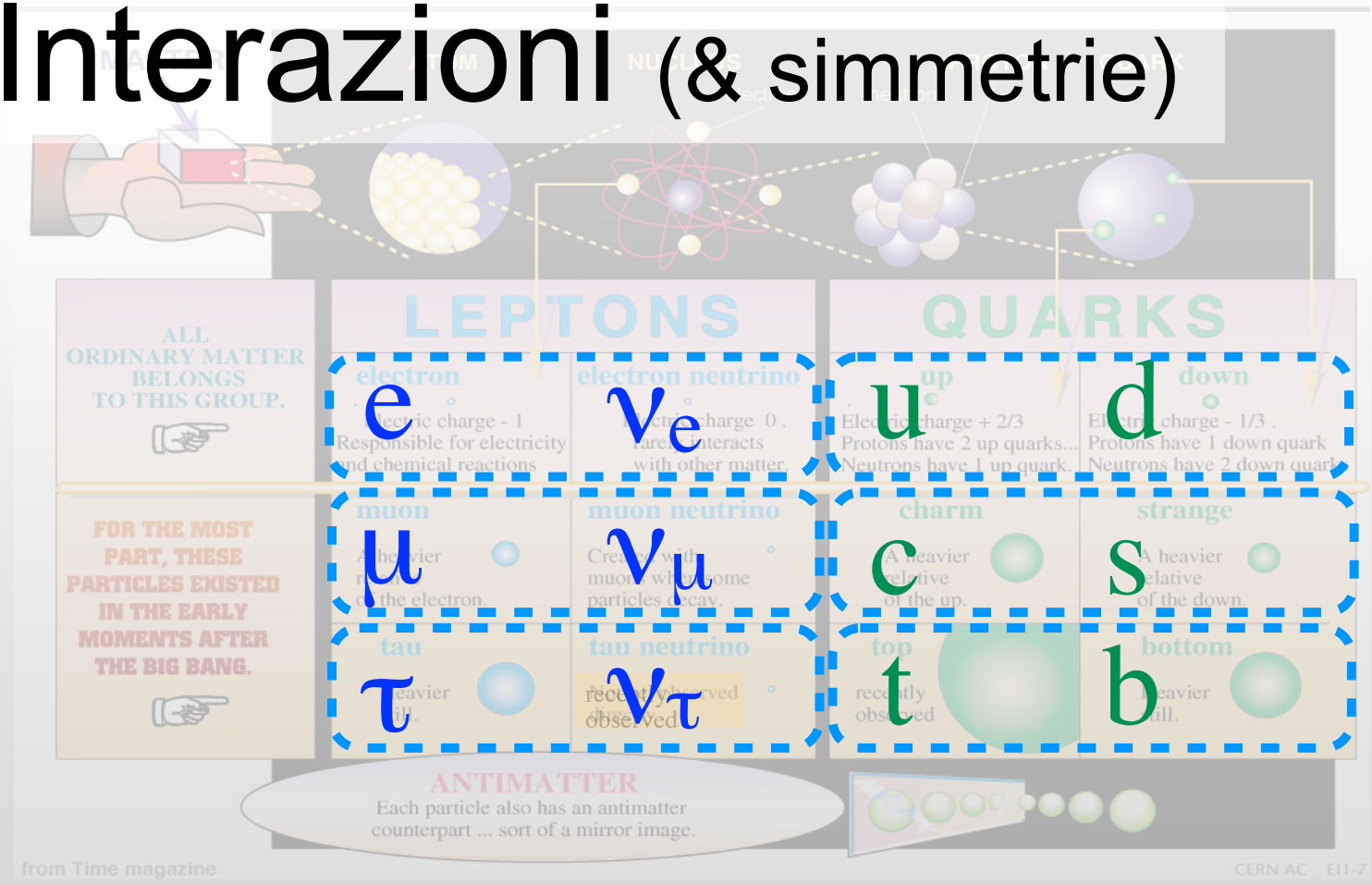
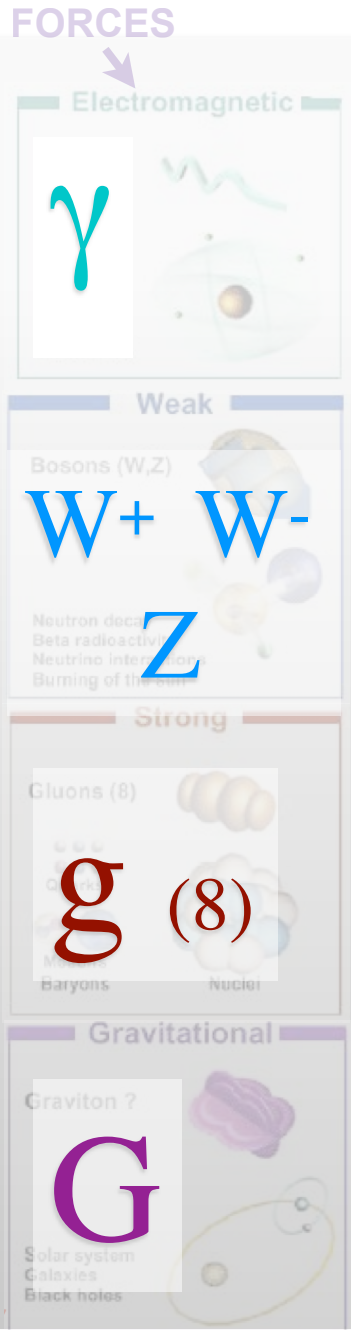
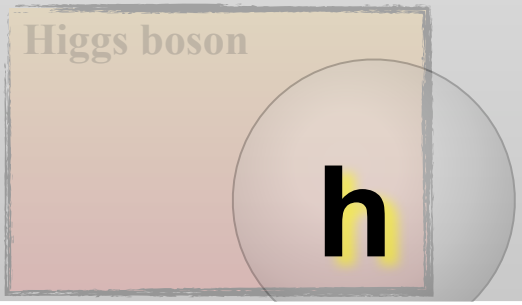




- $SU_c(3) \times SU_w(2) \times U_Y(1) \rightarrow SU_c(3) \times U_{em}(1)$



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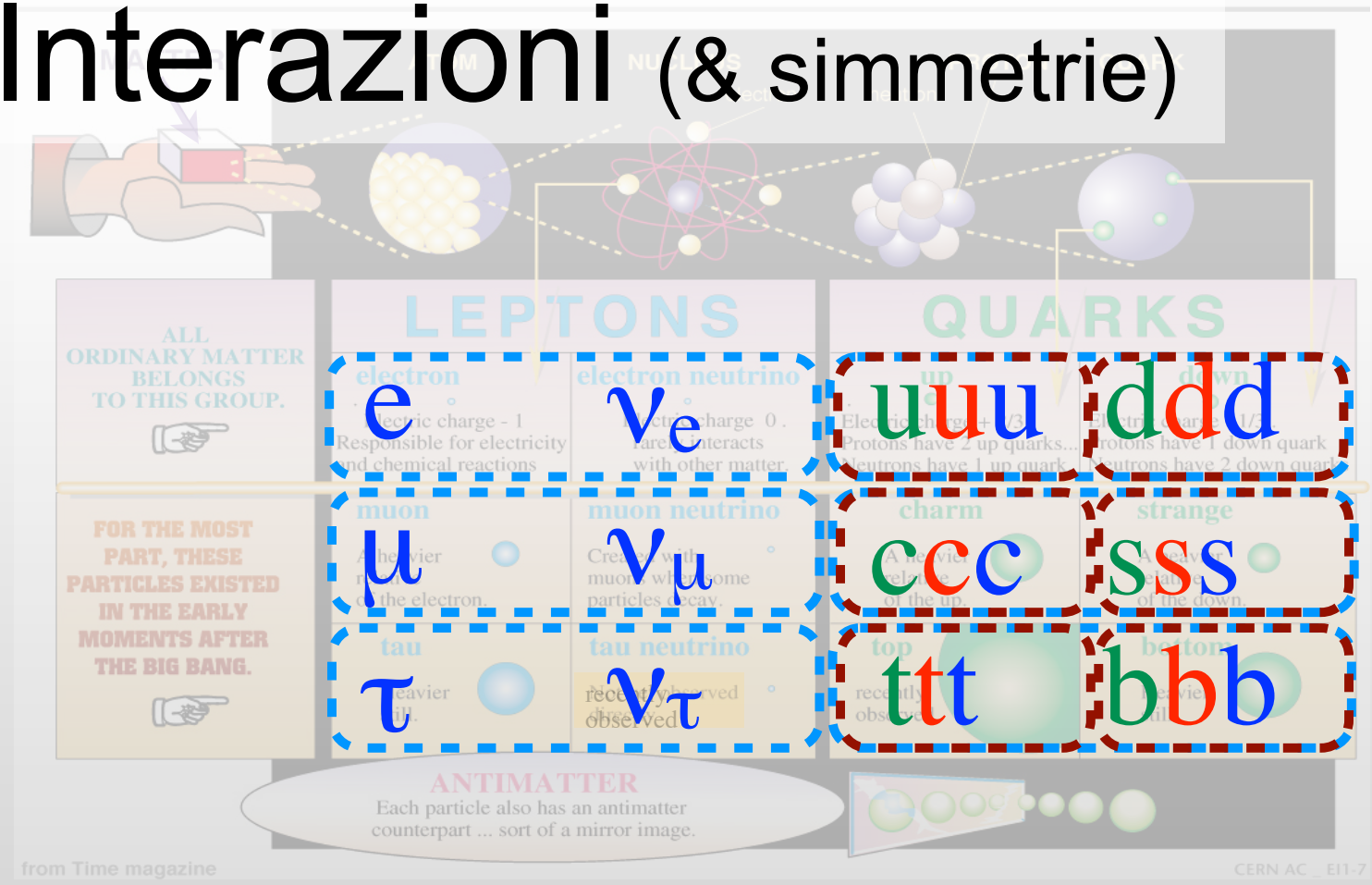
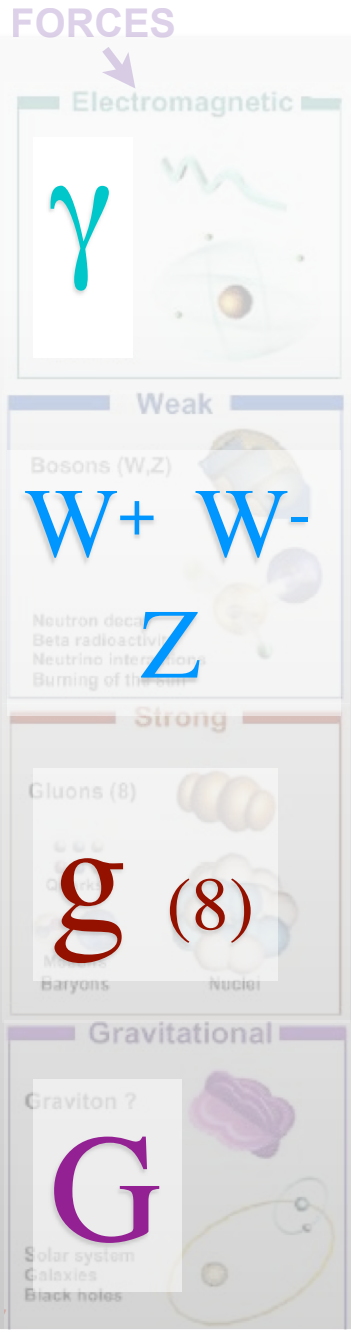
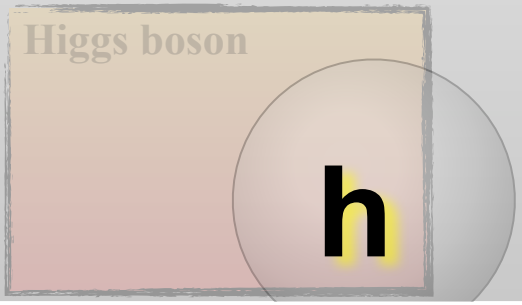




- $SU_c(3) \times SU_w(2) \times U_Y(1) \rightarrow SU_c(3) \times U_{em}(1)$



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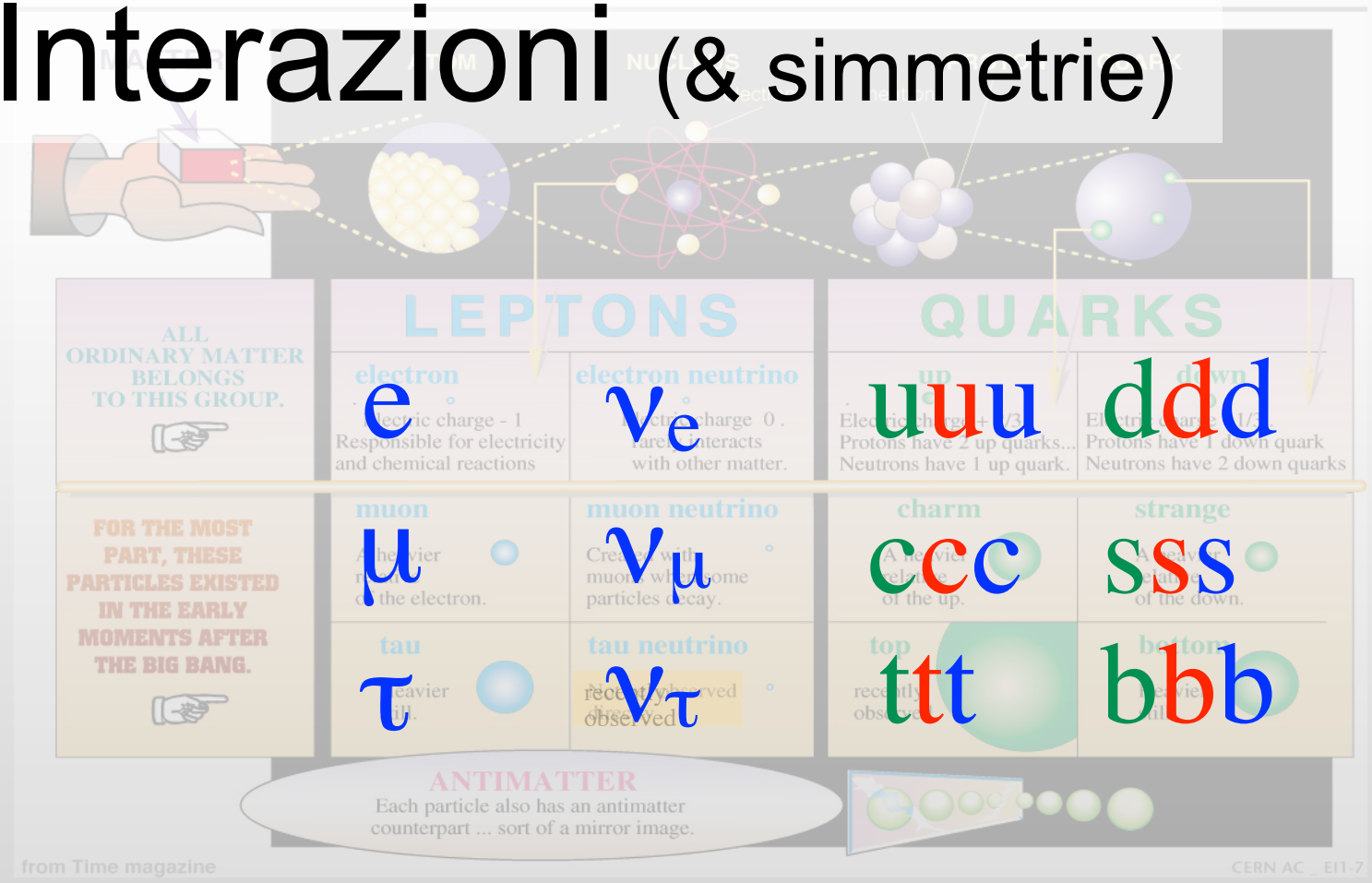
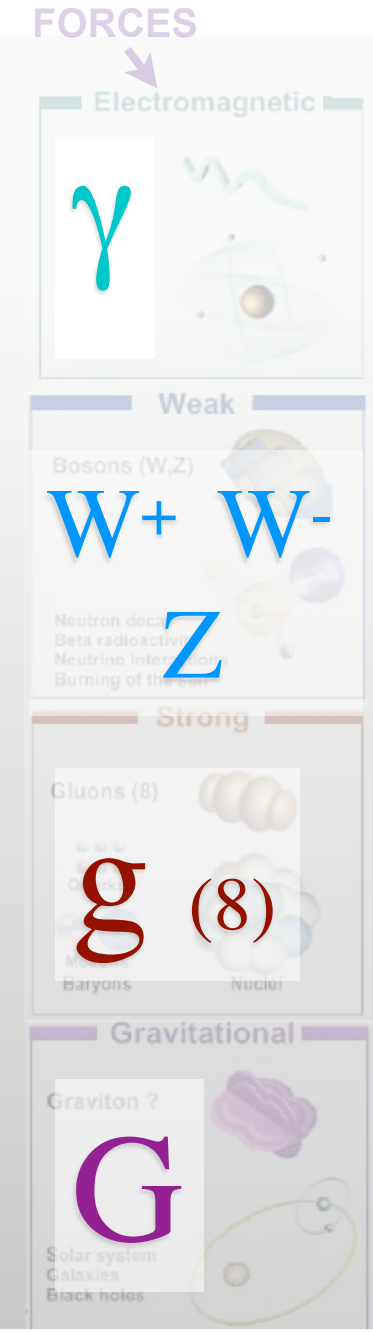
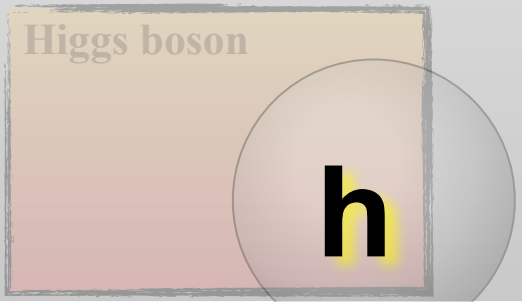




- $SU_c(3) \times SU_w(2) \times U_Y(1) \rightarrow SU_c(3) \times U_{em}(1)$
- colore e carica elettrica



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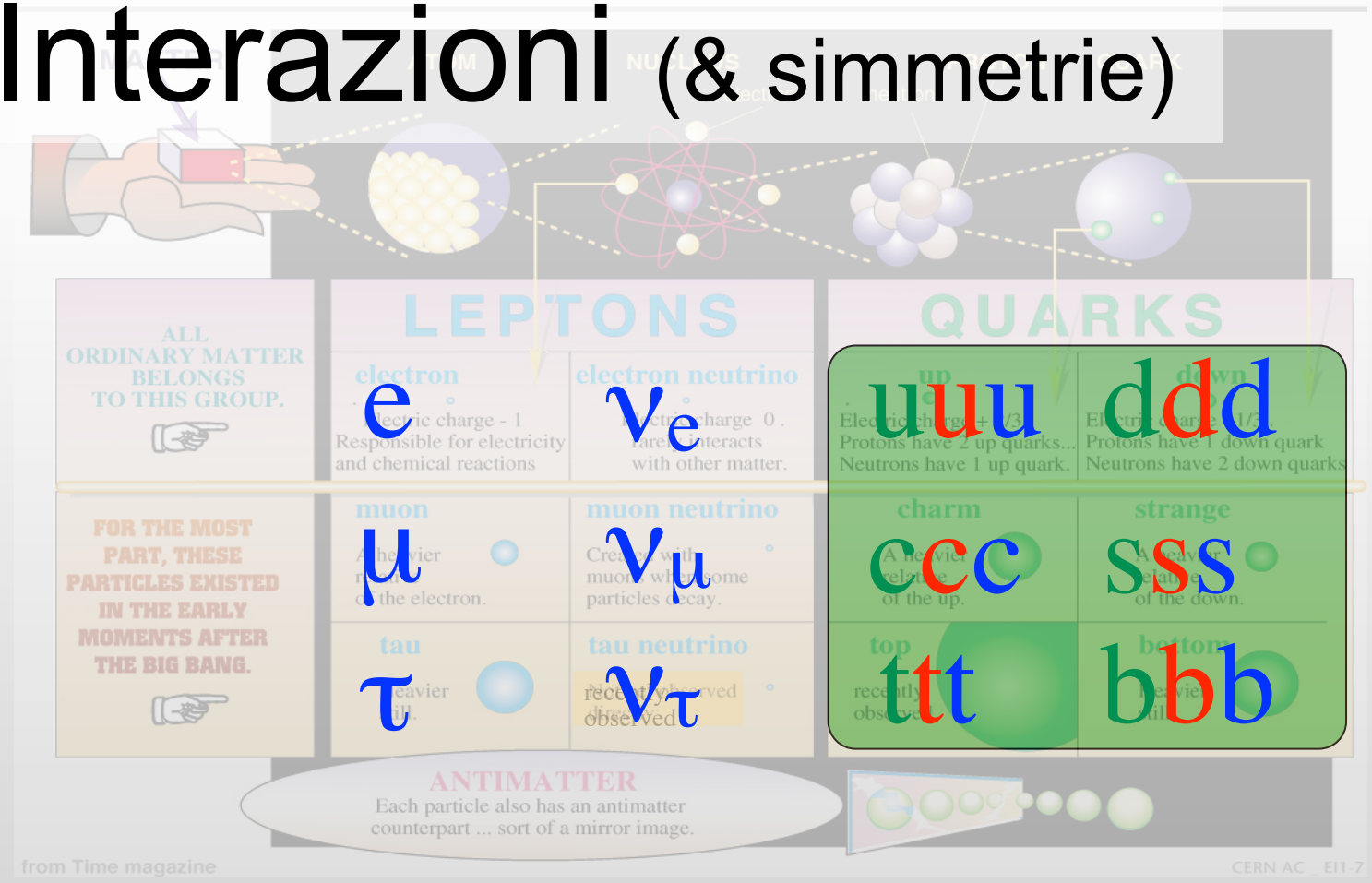
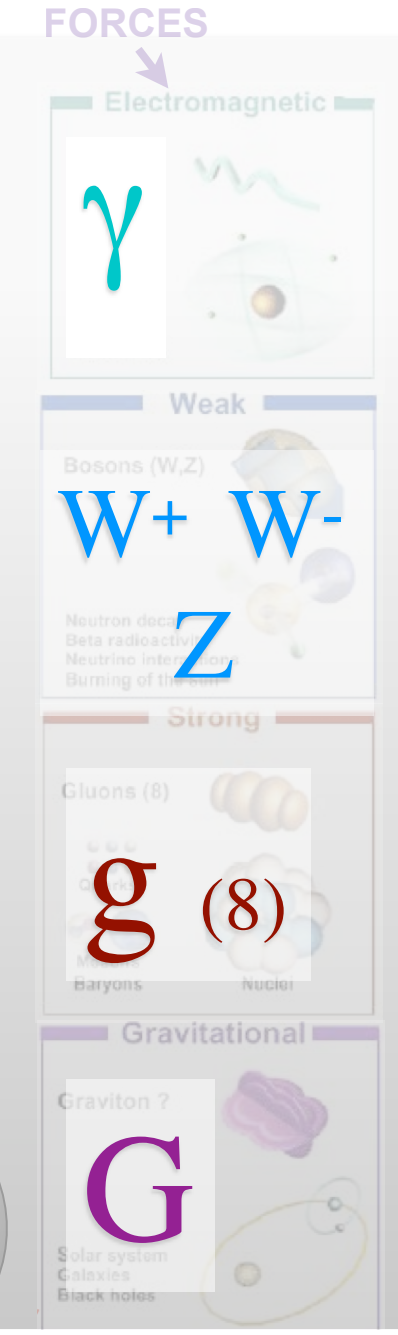
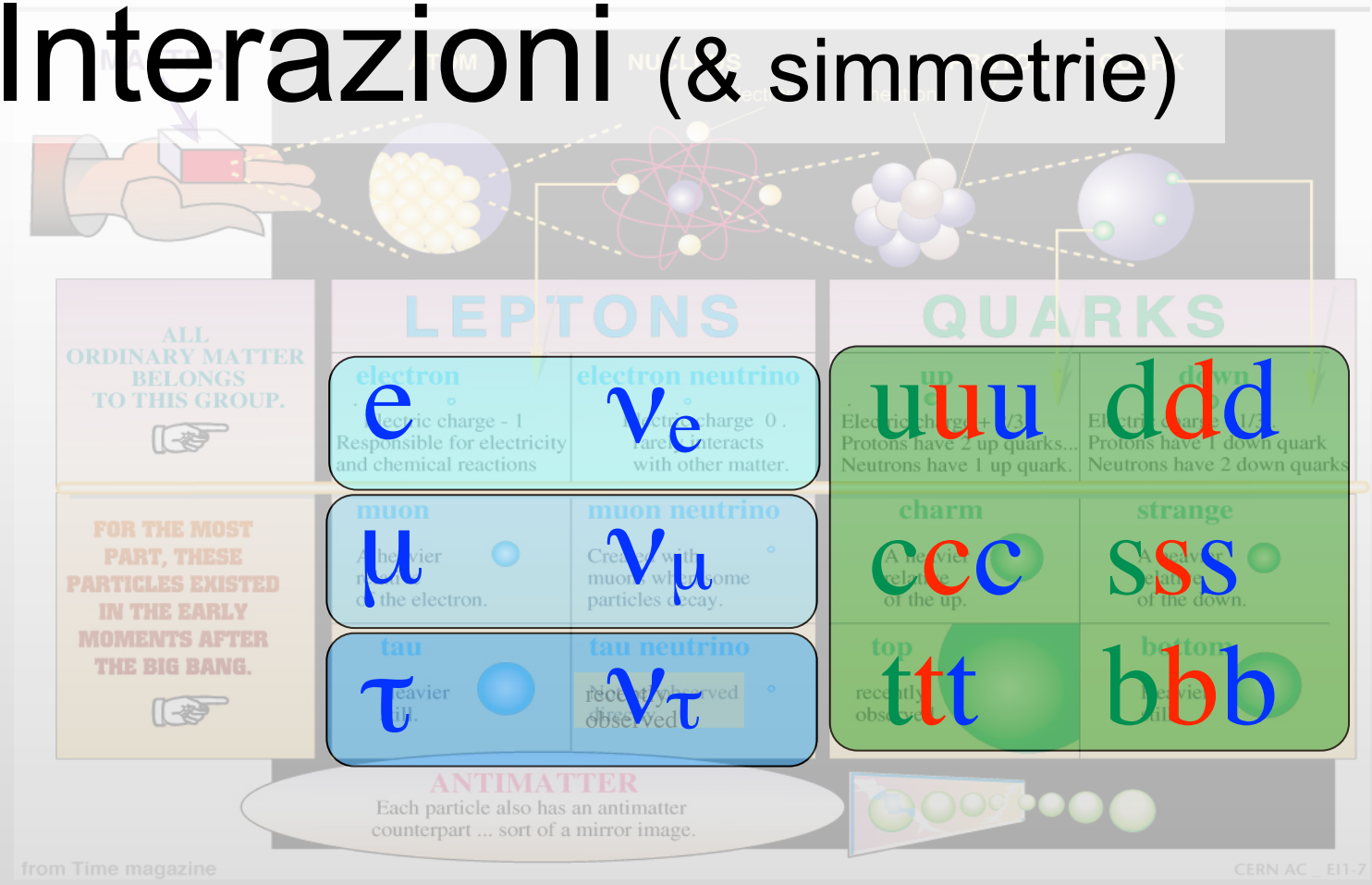
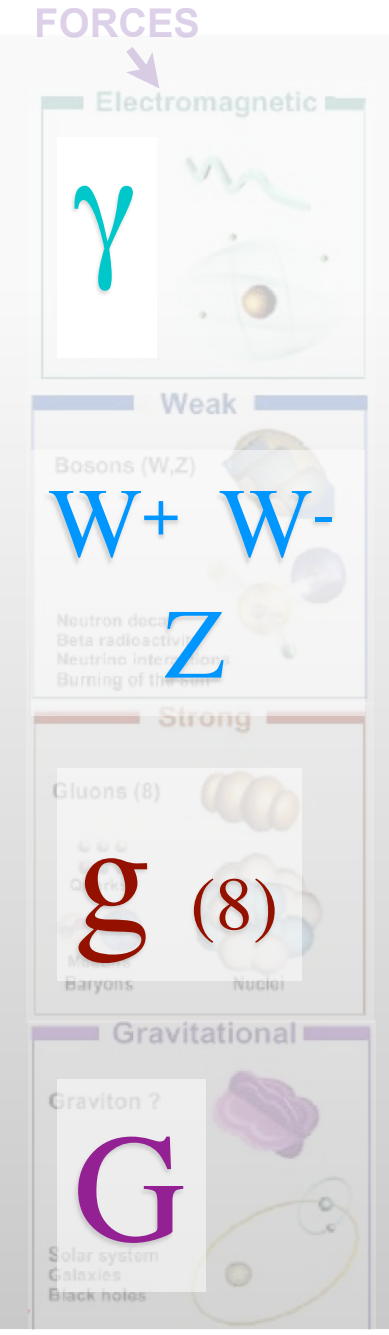




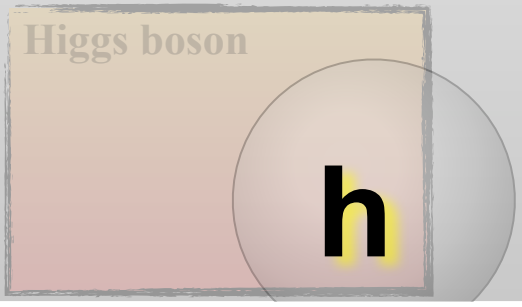
- $SU_c(3) \times SU_w(2) \times U_Y(1) \rightarrow SU_c(3) \times U_{em}(1)$
- colore e carica elettrica
- sapore barionico totale

Interazioni (& simmetrie)





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



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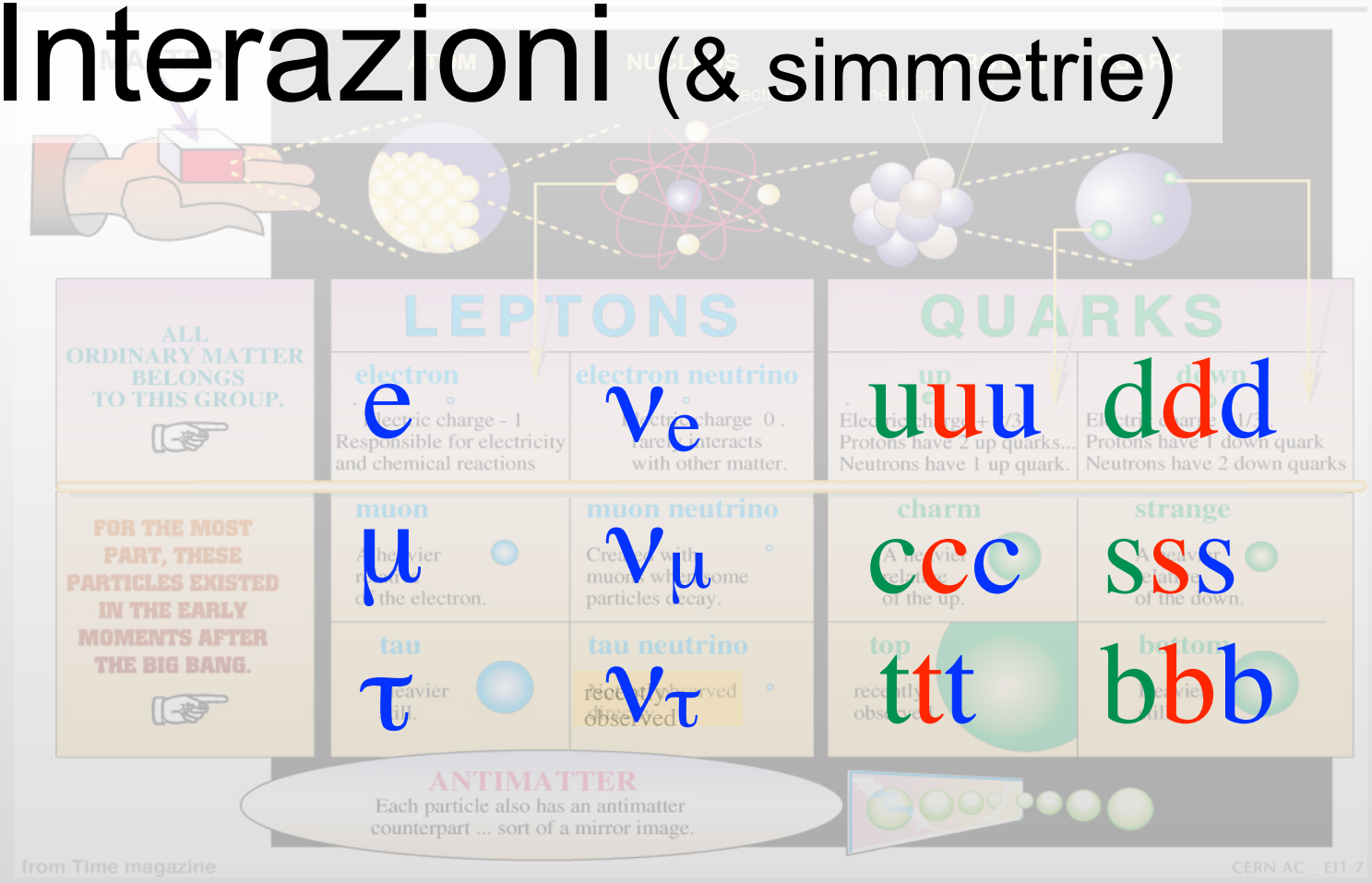
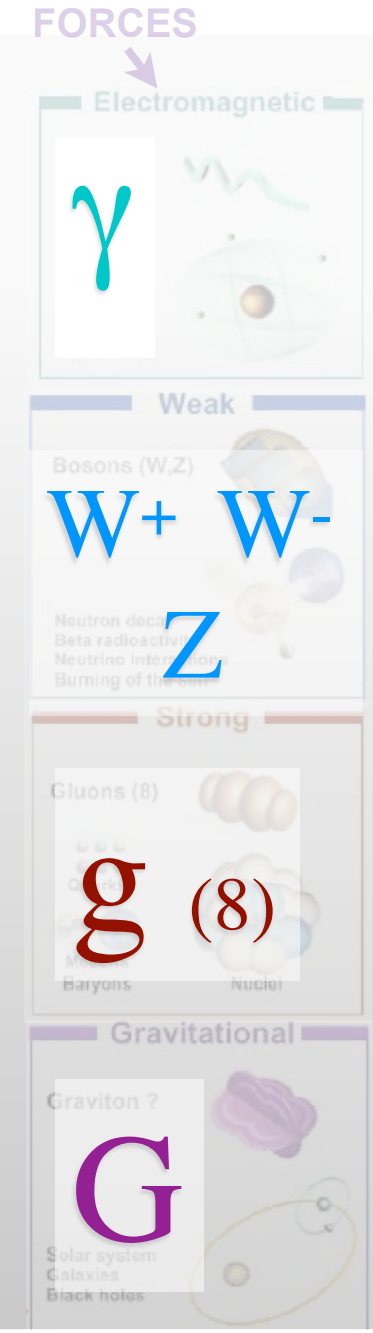
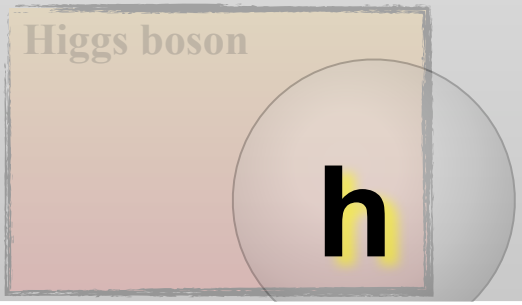




Adroni: stati composti di quarks



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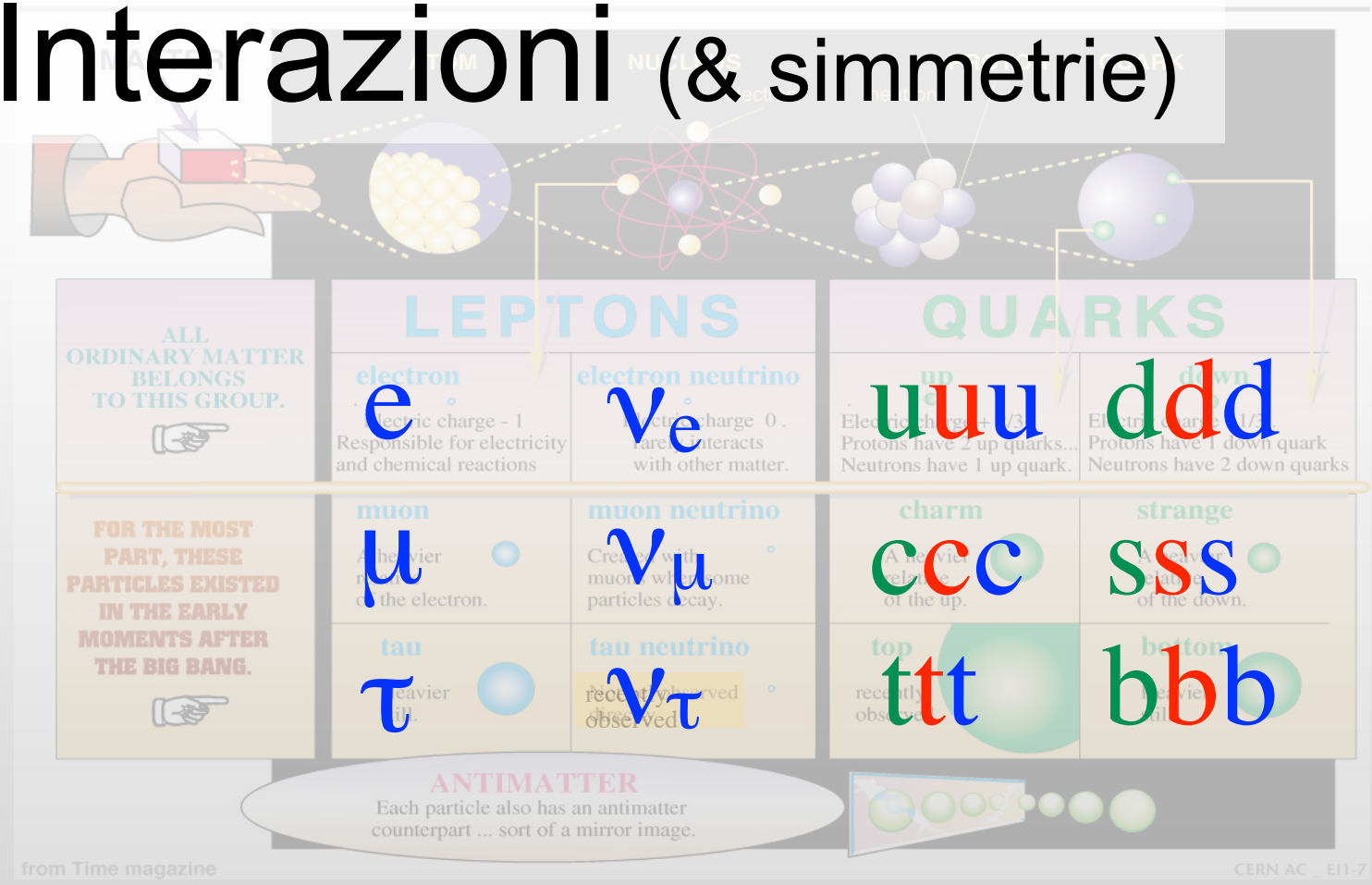
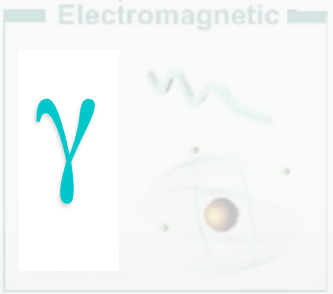
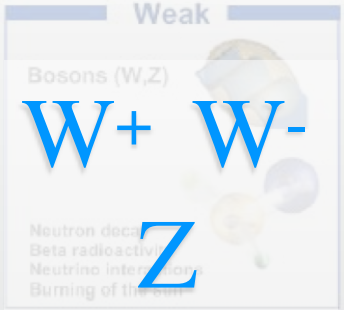
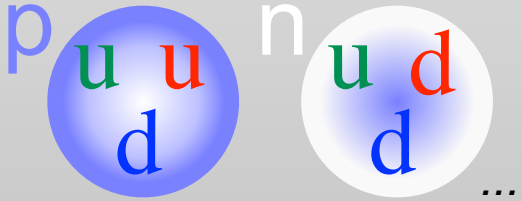


FORCES

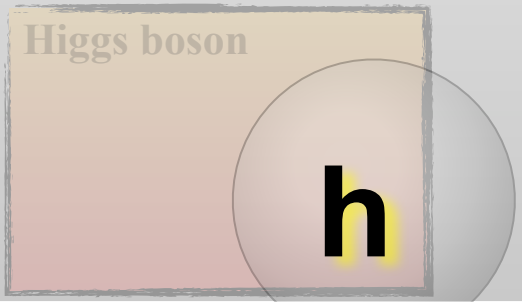




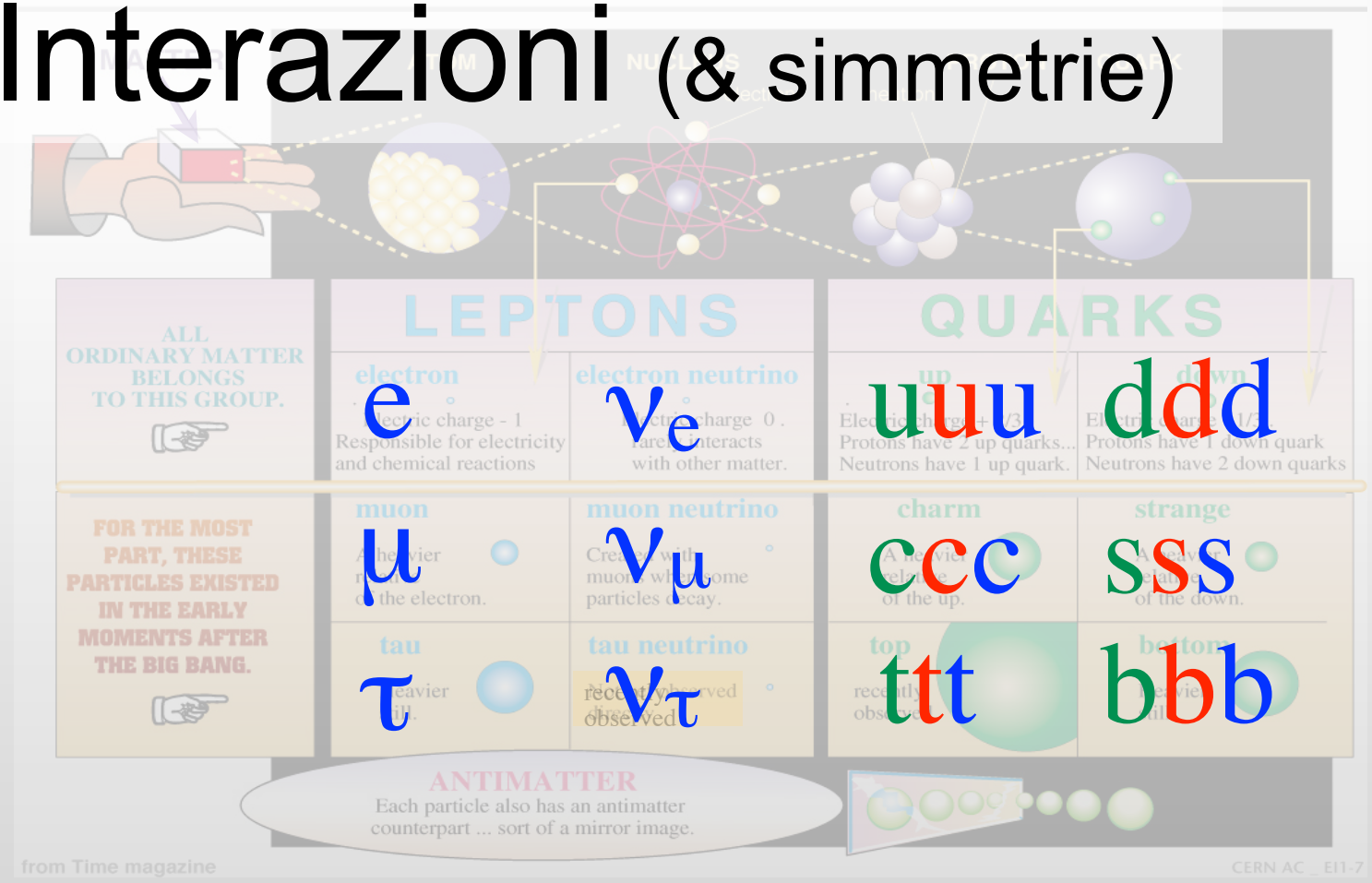
Adroni: stati composti di quarks

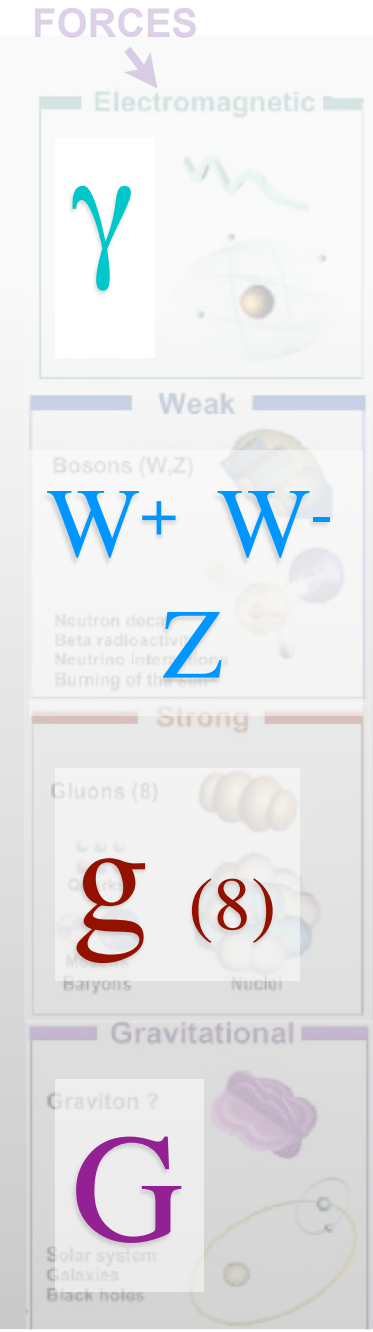


barioni

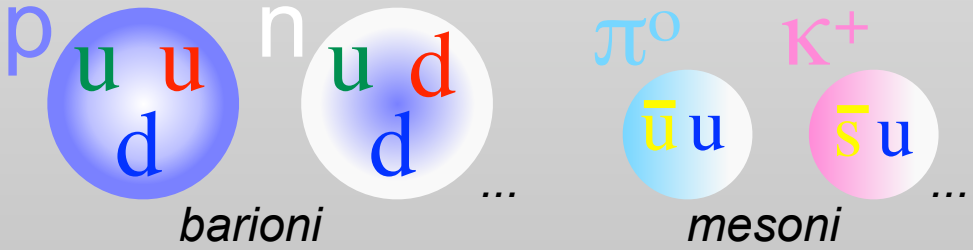


Interazioni (& simmetrie)

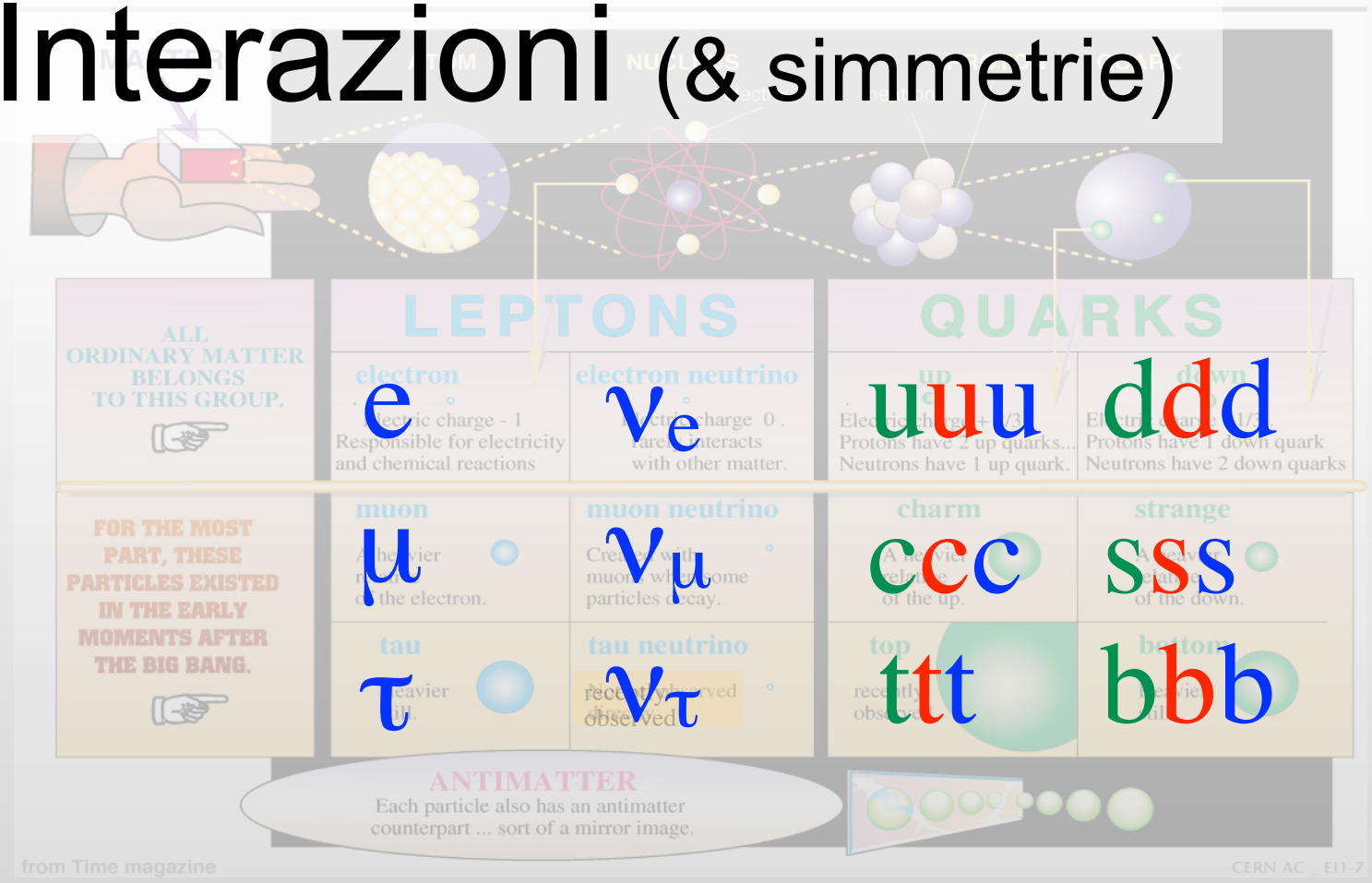


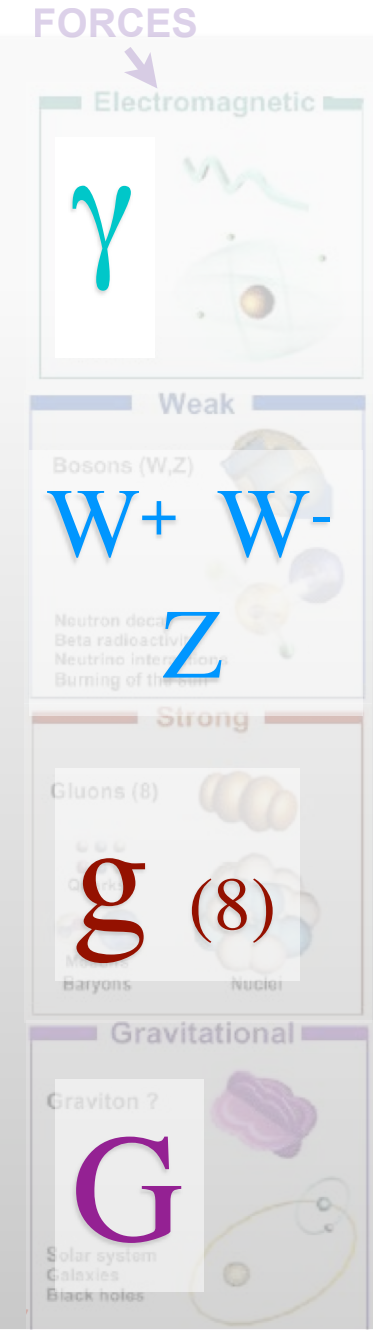


Adroni: stati composti di quarks

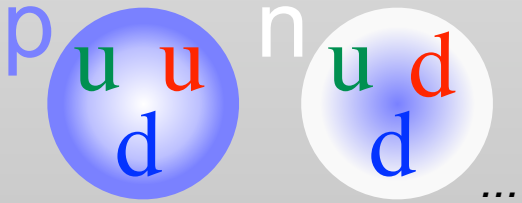


Interazioni (& simmetrie)

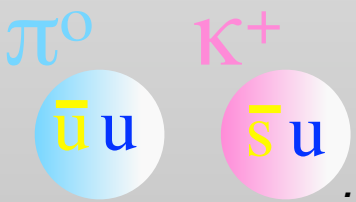




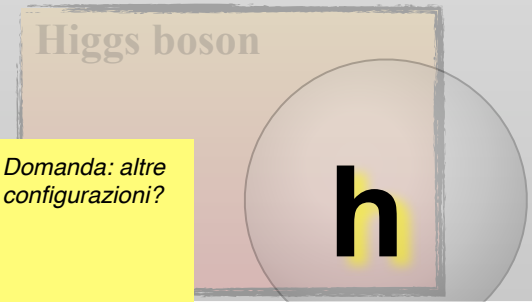
Adroni: stati composti di quarks



barioni ...

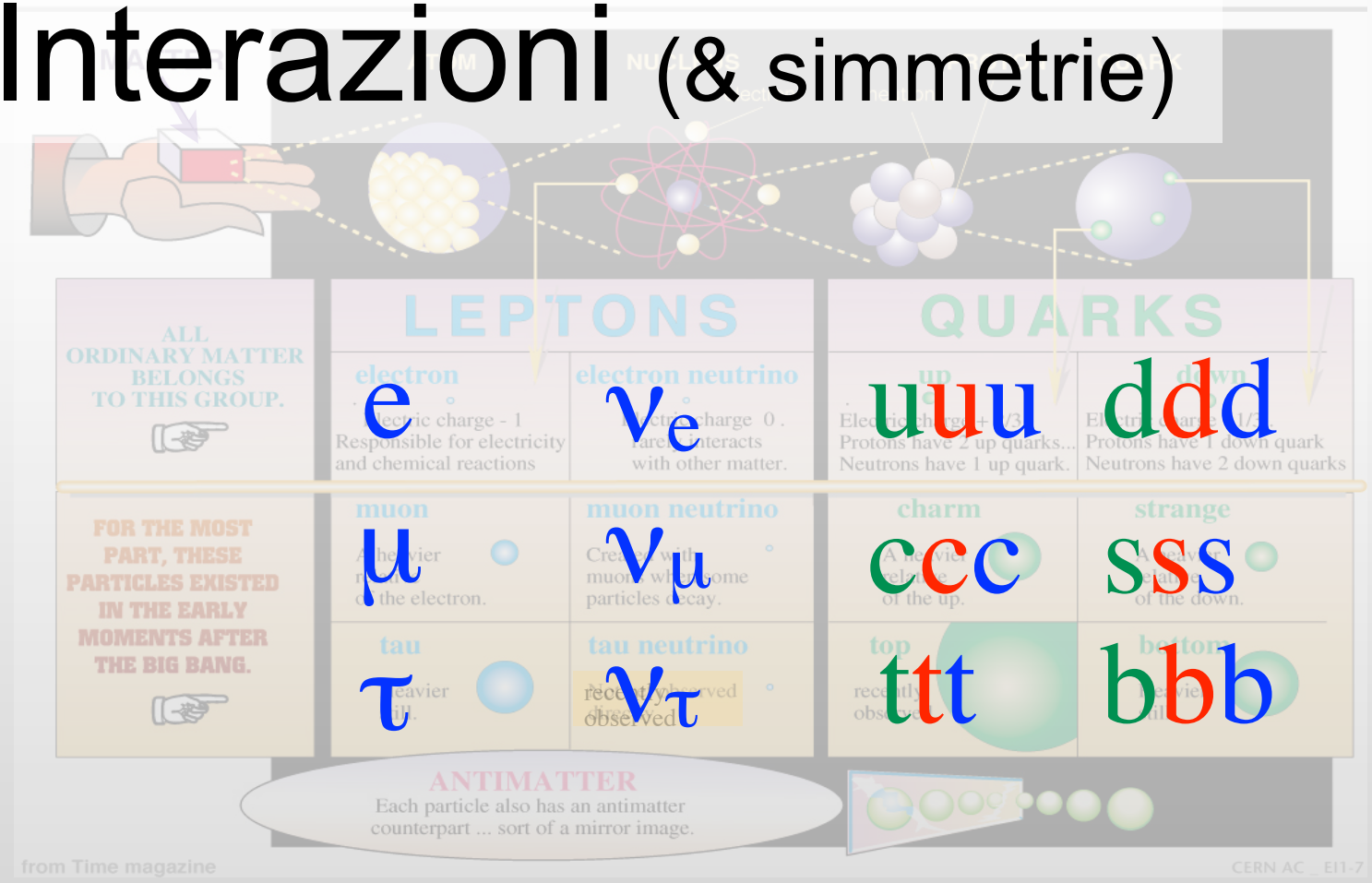


mesoni ...

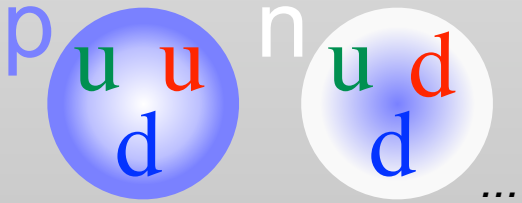


Domanda: altre configurazioni?

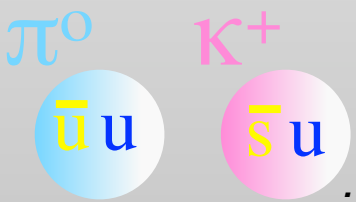
Interazioni (& simmetrie)



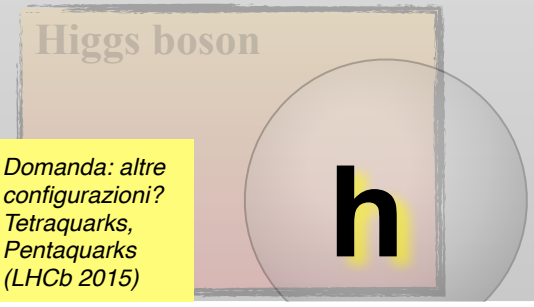
Adroni: stati composti di quarks



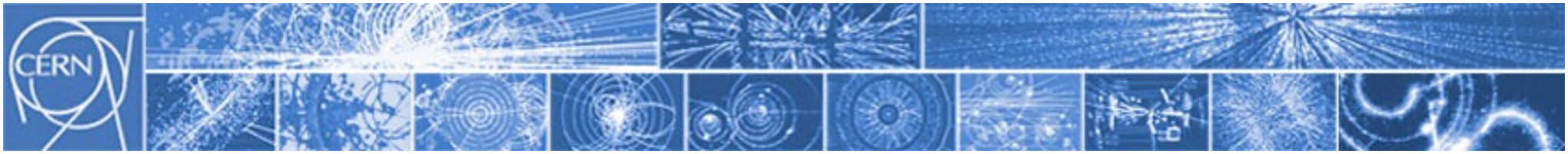
barioni ...



mesoni ...



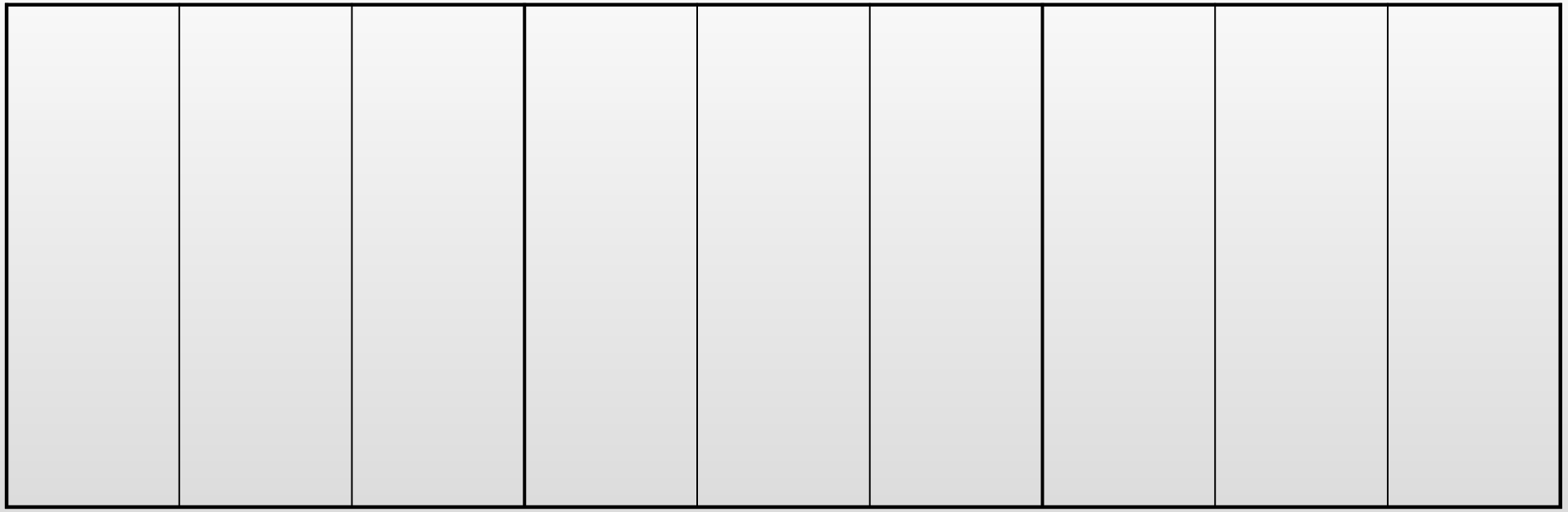
Domanda: altre configurazioni? Tetraquarks, Pentaquarks (LHCb 2015)



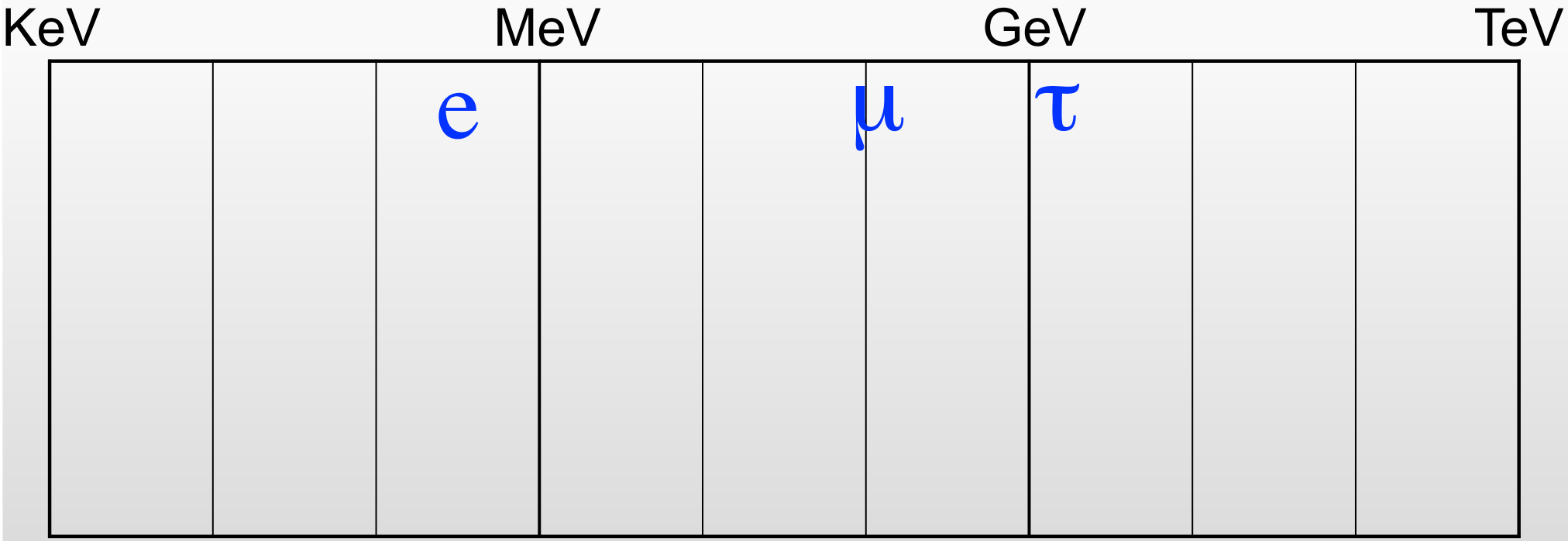
Masse

Masse

KeV MeV GeV TeV

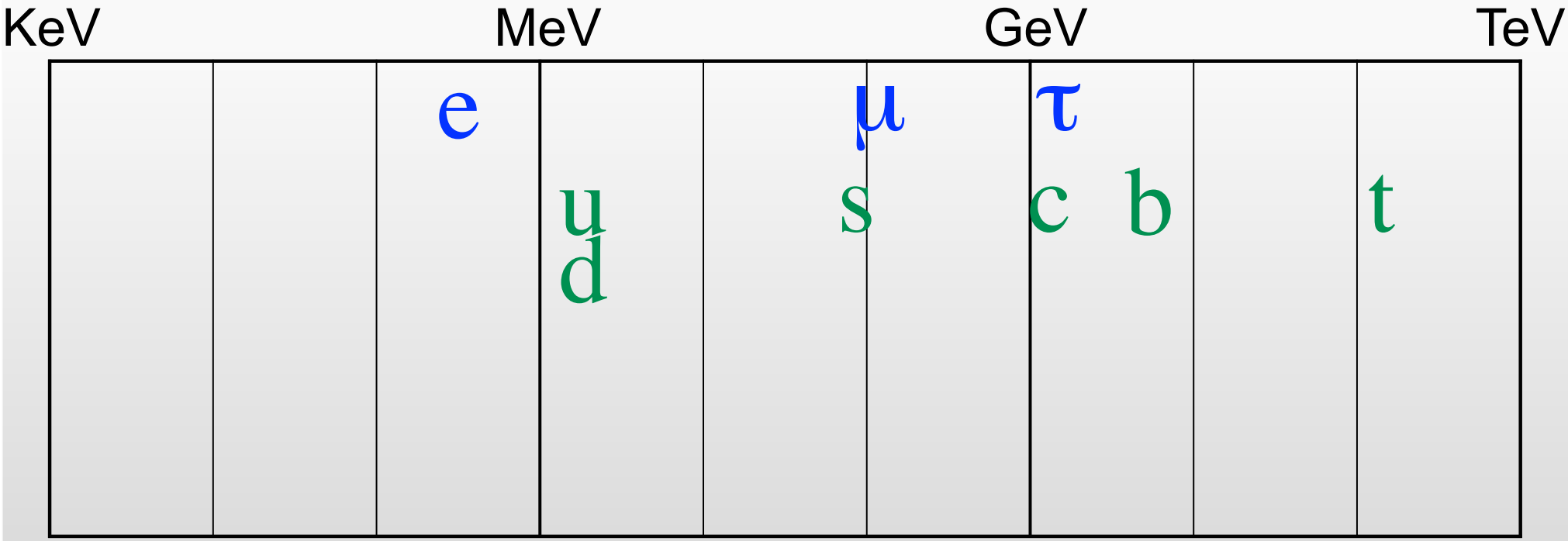


Masse



e 511 KeV
μ 105.7 MeV
τ 1.777 GeV

Masse

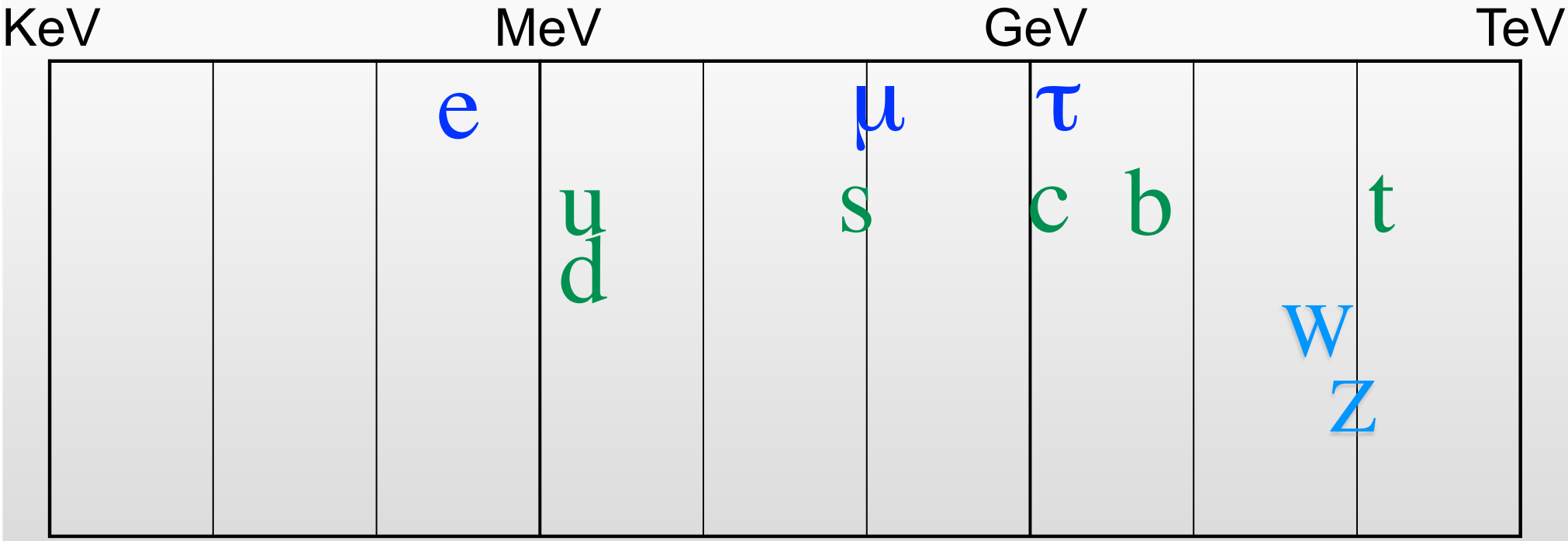


e 511 KeV
μ 105.7 MeV
τ 1.777 GeV

u ~2.3 MeV
d ~5 MeV
s ~95 MeV

c 1.27 GeV
b 4.2 GeV
t 173.2 GeV

Masse



e 511 KeV
μ 105.7 MeV
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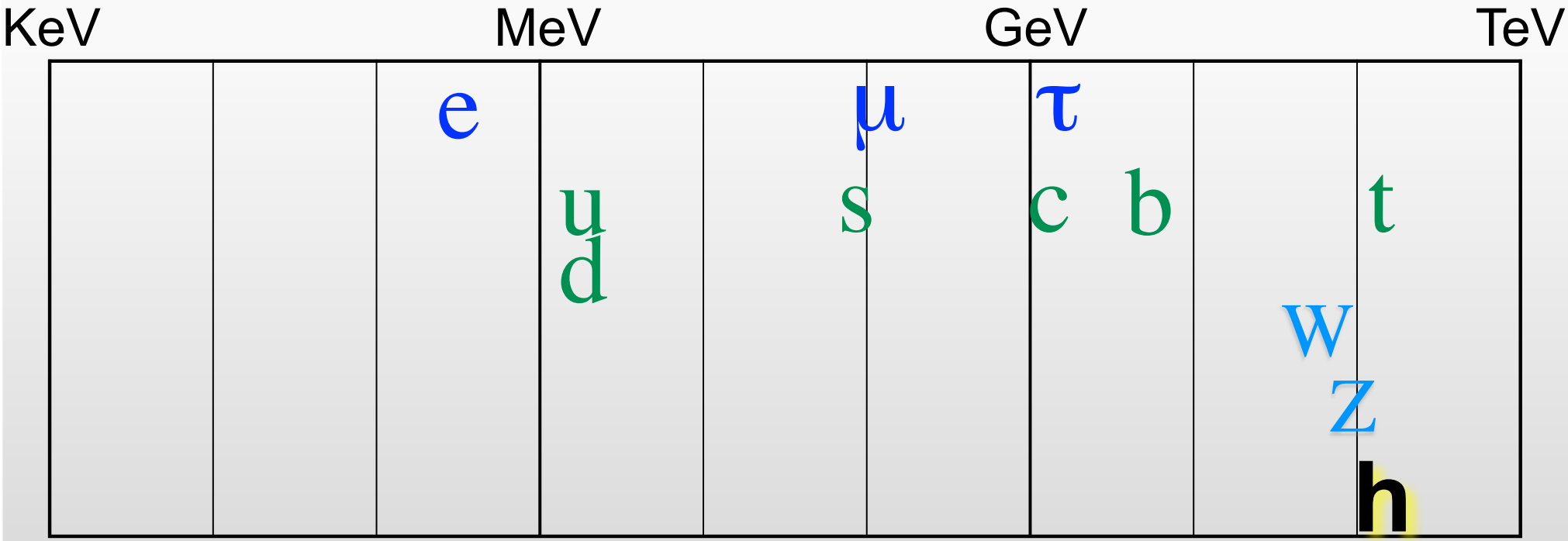
u ~2.3 MeV
d ~5 MeV
s ~95 MeV

c 1.27 GeV
b 4.2 GeV
t 173.2 GeV

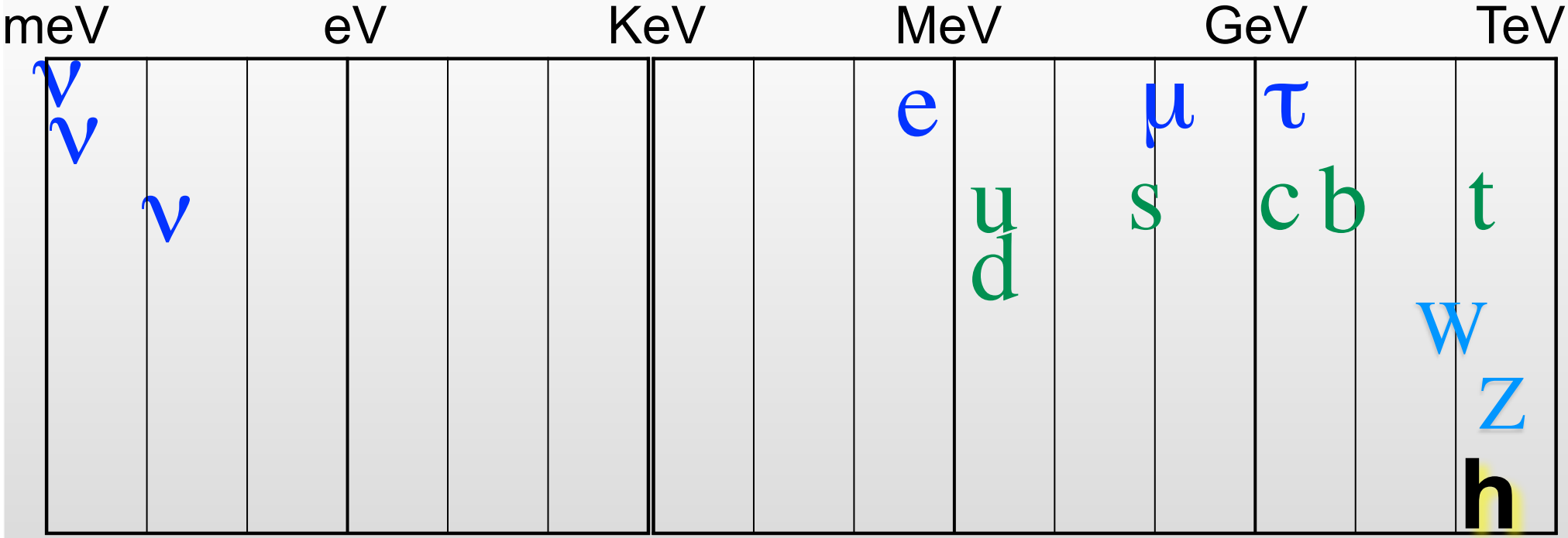
$W^{\pm}$ 80.385 GeV
Z 91.1876 GeV

Masse



e 511 KeV	u ~2.3 MeV	c 1.27 GeV	$W^{\pm}$ 80.385 GeV
μ 105.7 MeV	d ~5 MeV	b 4.2 GeV	Z 91.1876 GeV
τ 1.777 GeV	s ~95 MeV	t 173.2 GeV	**h** 125.7 GeV

Masse



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

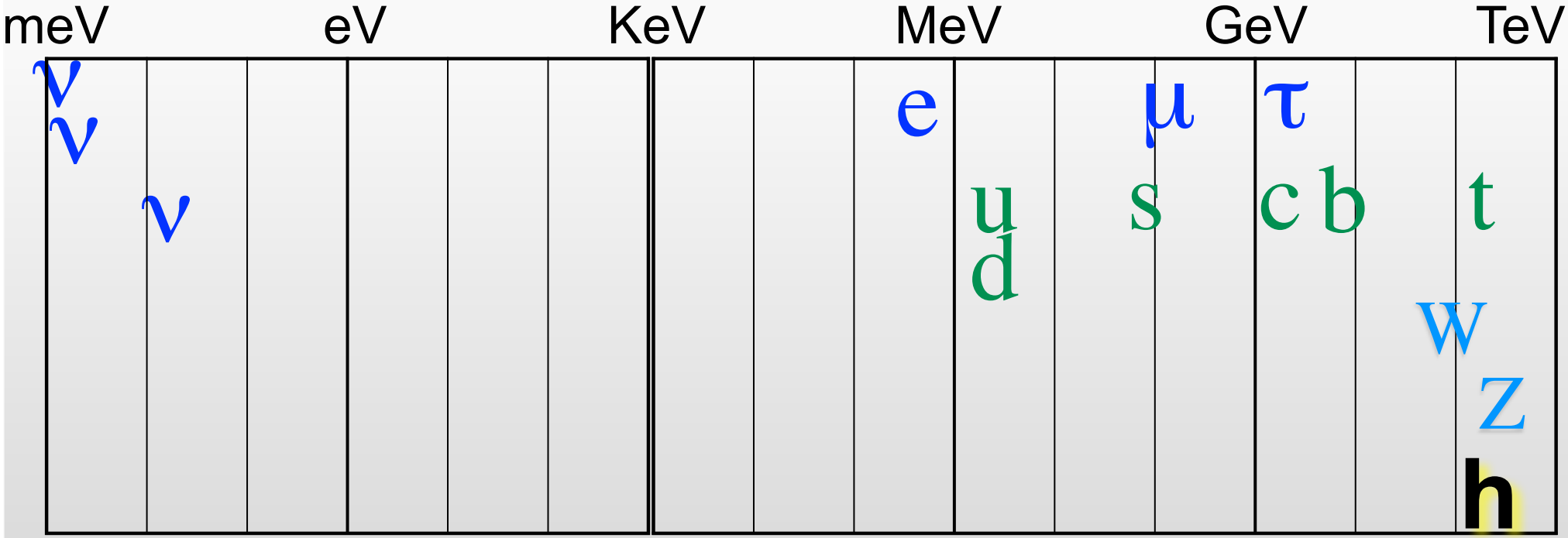
$W^{\pm}$ 80.385 GeV
Z 91.1876 GeV
h 125.7 GeV

$9\ 10^{-3}$ eV $\lesssim \nu_i \lesssim$ 0.2 eV

Masse

massa zero: γ g G

p ^{238}U



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Z 91.1876 GeV
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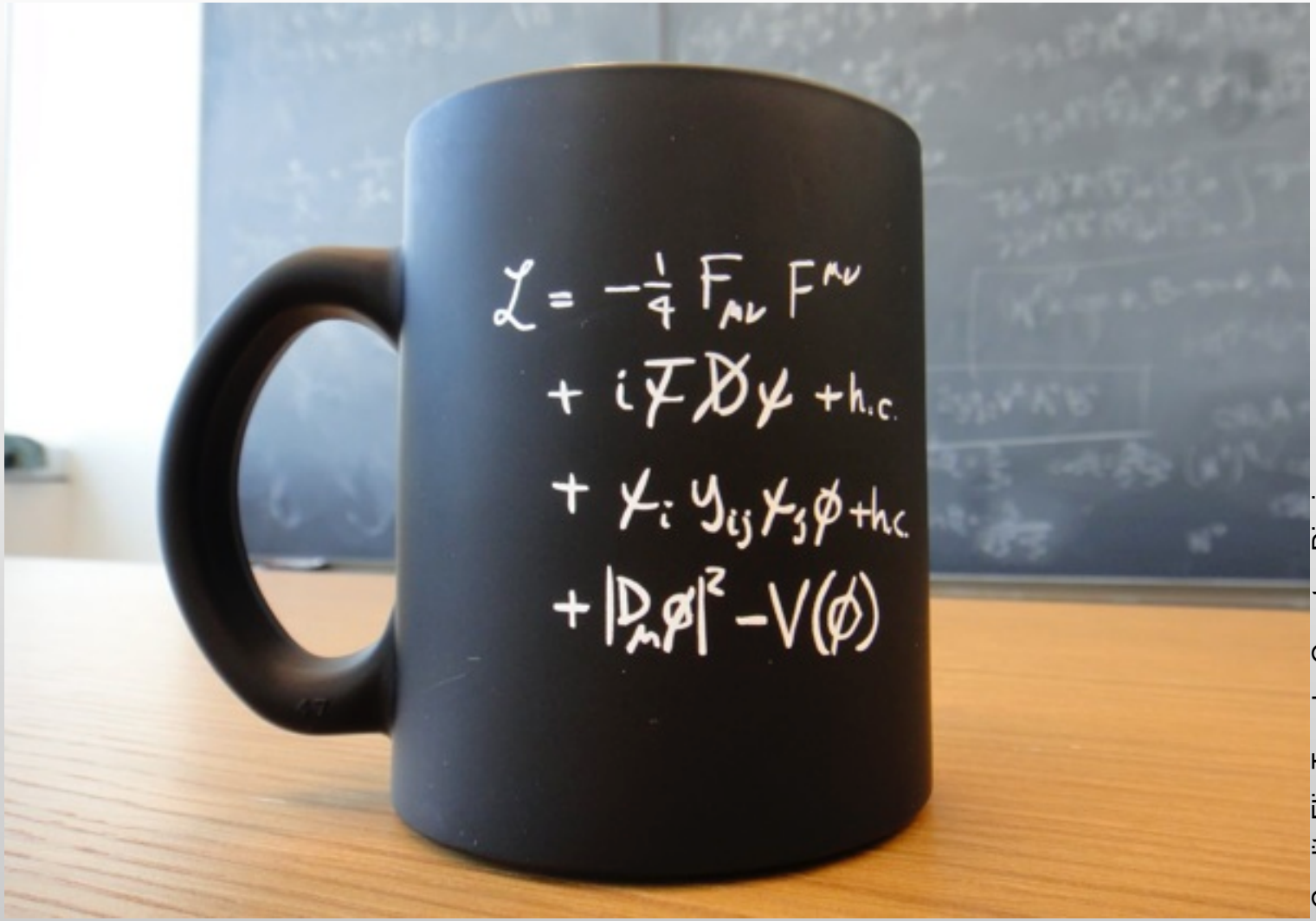
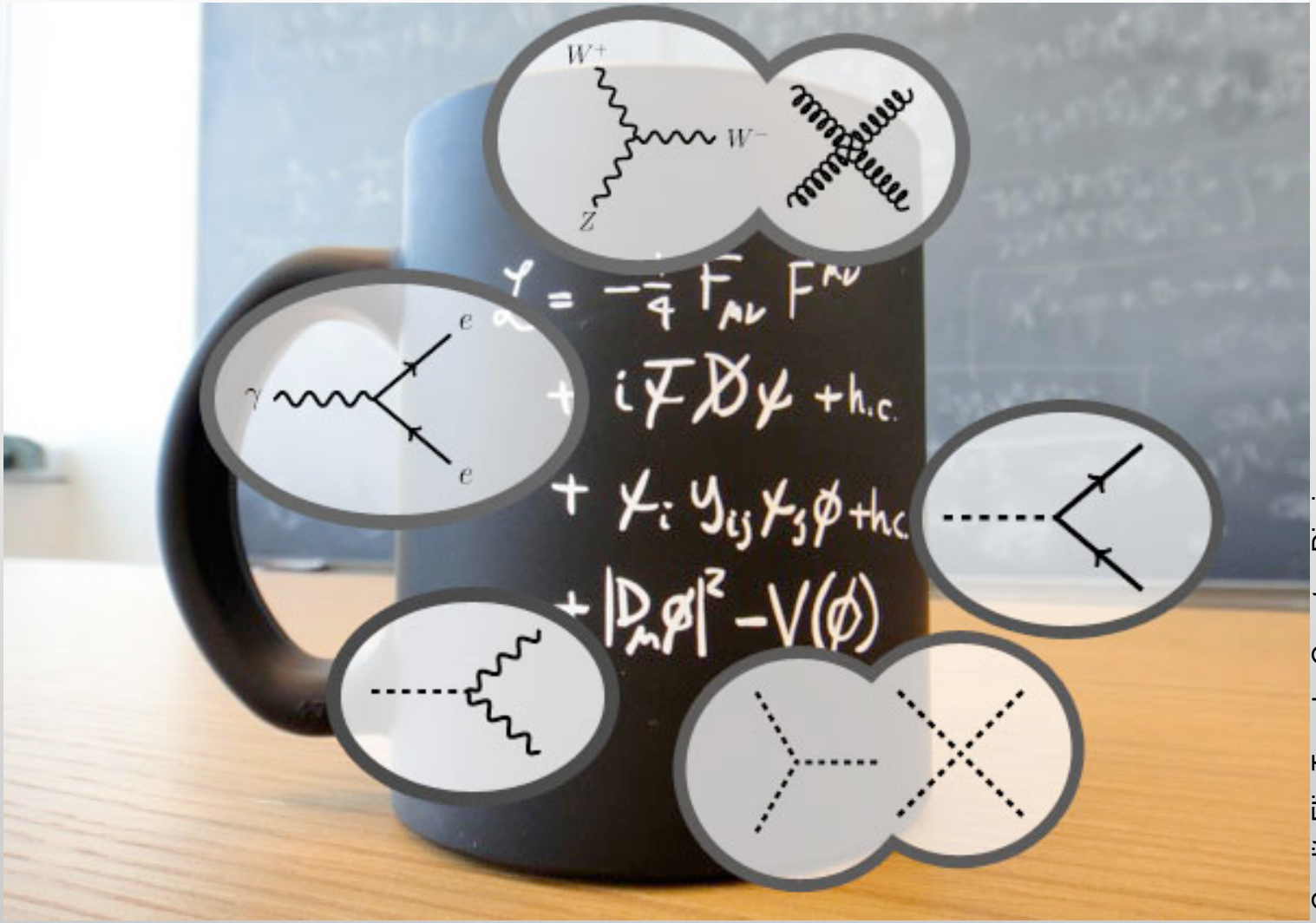
$9\ 10^{-3}$ eV $\lesssim \nu_i \lesssim$ 0.2 eV

Lagrangiana del Modello Standard



Credit: Flip Tanedo, QuantumDiaries.org

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