



CERN

European Organization for Nuclear Research
Organisation Européenne pour la Recherche Nucléaire



New Dark

Fisica delle particelle oggi Il Modello Standard and Beyond

- Bosone di Higgs
- SuperSimmetria
- Astroparticle & Materia Oscura

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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



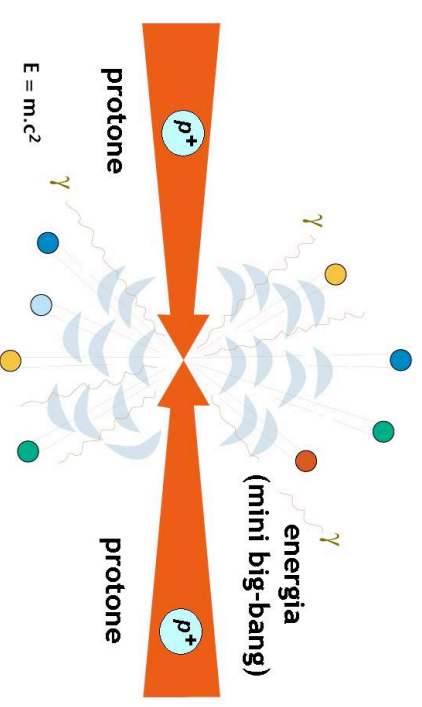
**Come risolvere questi problemi?
o... Come si fanno le scoperte?**

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

fino a energie elevatissime (14 TeV)

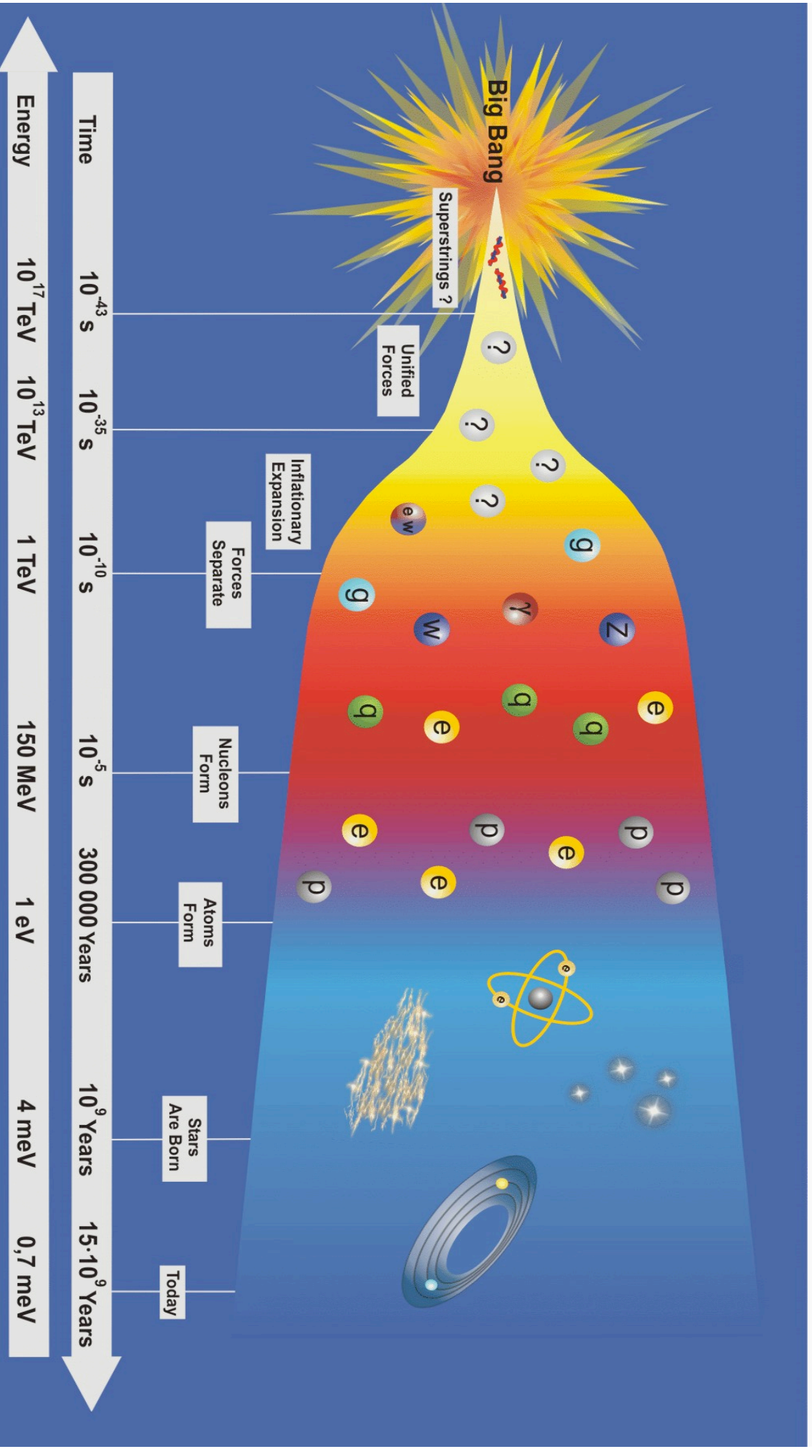
e portarle a collidere. **$E=mc^2$**

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 1968 s quark

1956 ν_e 1974 c quark

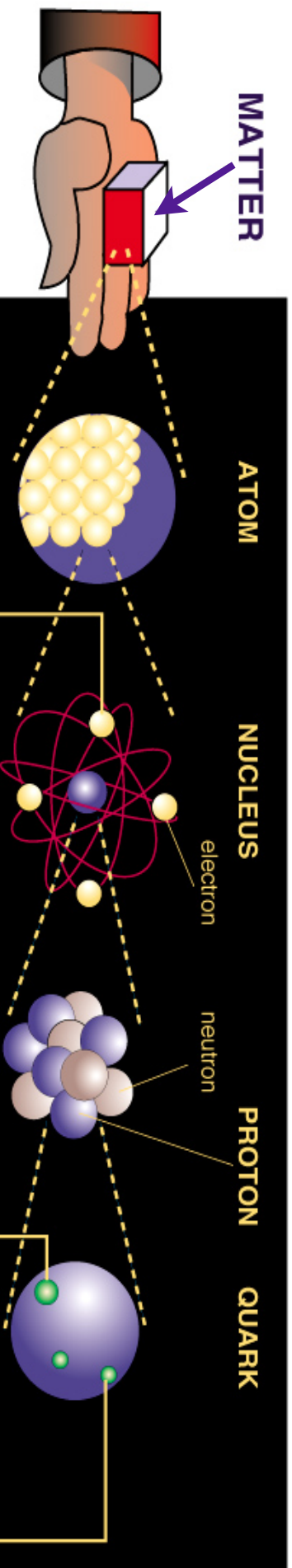
1962 ν_μ 1977 b quark

1974 τ 1995 t quark

2000 ν_τ



STANDARD MODEL



ALL ORDINARY MATTER BELONGS TO THIS GROUP.




LEPTONS

electron	Electric charge - 1 Responsible for electricity and chemical reactions	electron neutrino	Electric charge 0. rarely interacts with other matter.
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muon	A heavier relative of the electron.	muon neutrino	Created with muons when some particles decay.
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tau	Heavier still.	tau neutrino	recently observed
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FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.



QUARKS

up	Electric charge + 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.	down	Electric charge - 1/3. Protons have 1 down quark Neutrons have 2 down quarks
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charm	A heavier relative of the up.	strange	A heavier relative of the down.
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top	recently observed	bottom	Heavier still.
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ANTIMATTER

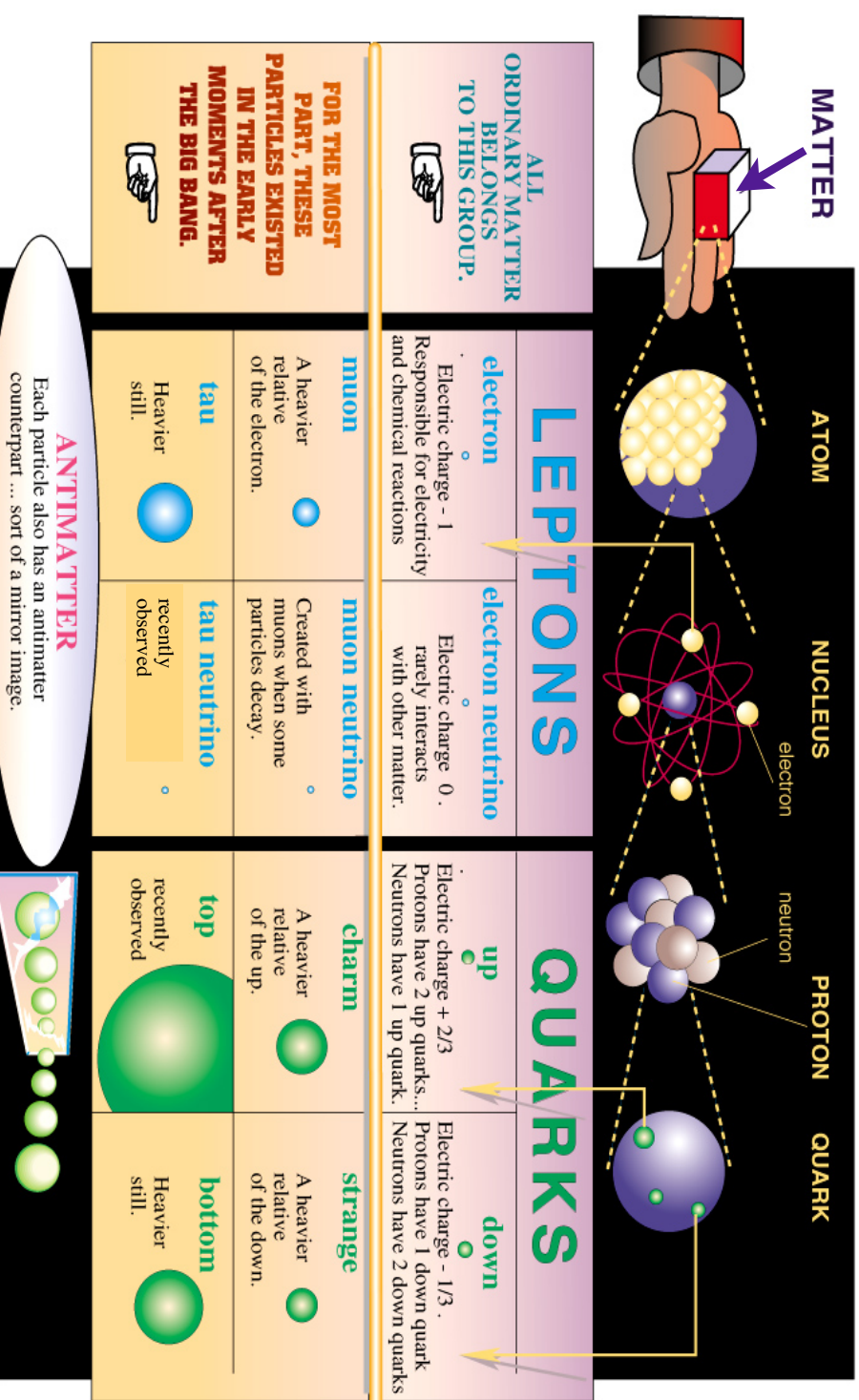
Each particle also has an antimatter counterpart ... sort of a mirror image.



When they meet, they annihilate



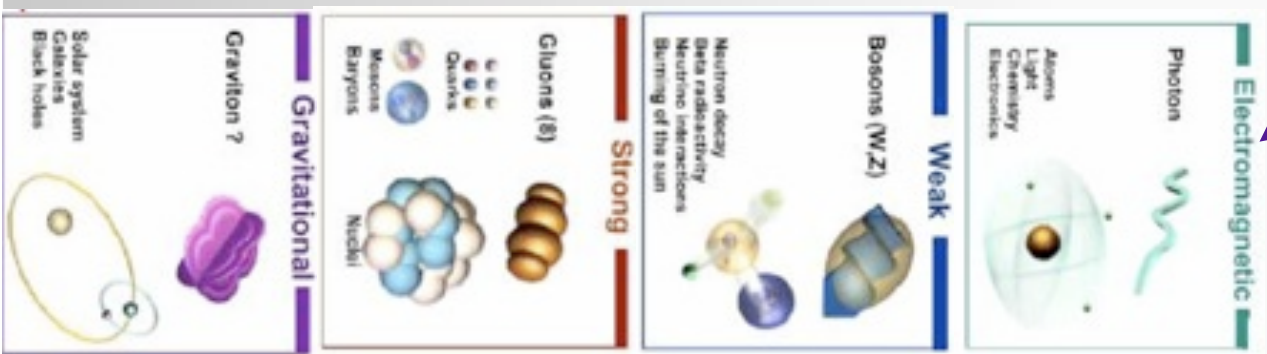
STANDARD MODEL



from Time magazine

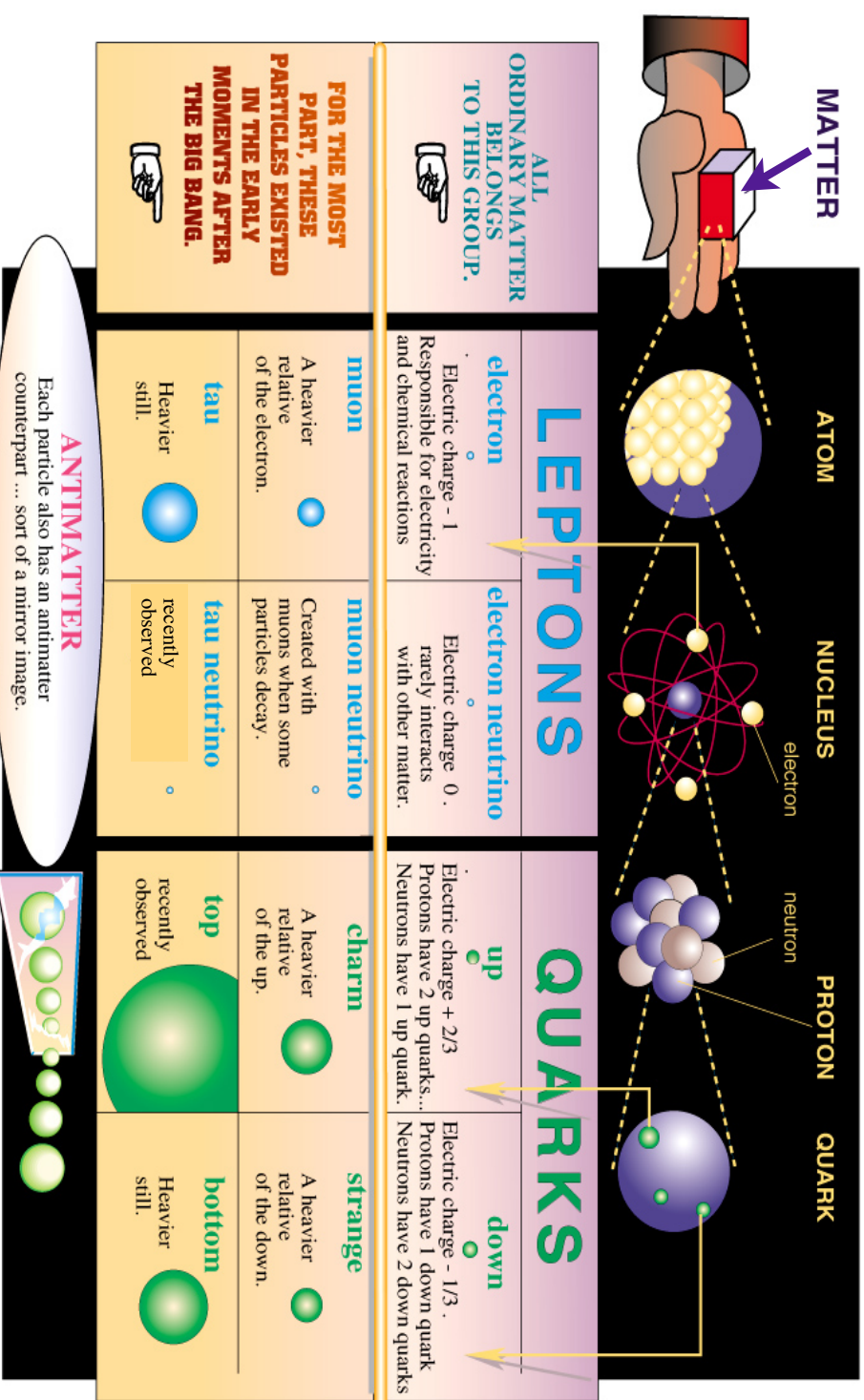
CERN AC_E11-7

FORCES





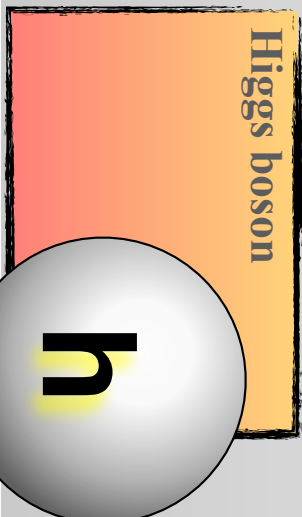
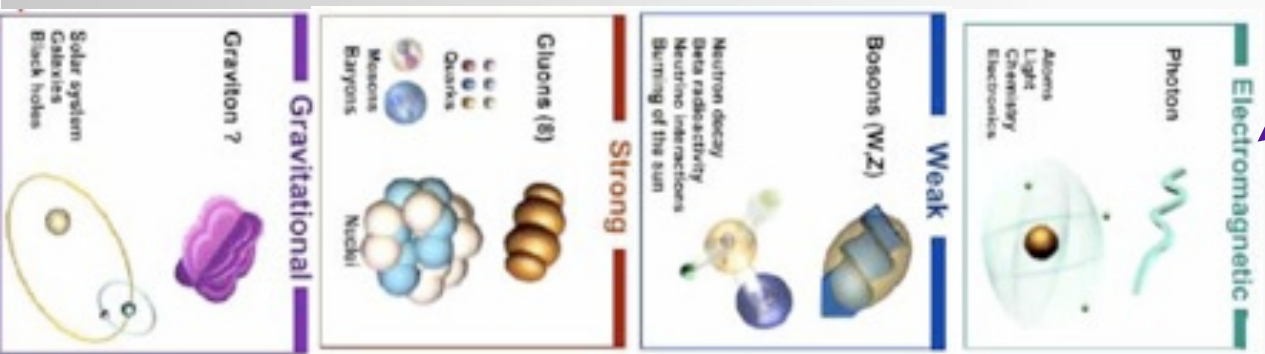
STANDARD MODEL



from Time magazine

CERN AC_E11-7

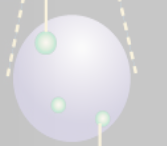
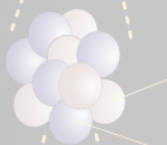
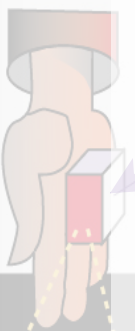
FORCES





STANDARD MODEL

Interazioni



NUCLEUS

electron

PROTON

neutron

QUARK

LEPTONS

ALL ORDINARY MATTER BELONGS TO THIS GROUP.



electron

Electric charge - 1
Responsible for electricity and chemical reactions

electron neutrino

Electric charge 0.
Interacts with other matter.

QUARKS

up

Electric charge + 2/3
Protons have 2 up quarks...
Neutrons have 1 up quark.

down

Electric charge - 1/3.
Protons have 1 down quark
Neutrons have 2 down quarks

muon

A heavier relative of the electron.

muon neutrino

Created with muons which decay into some particles & neutrinos.

charm

A heavier relative of the up.

strange

A heavier relative of the down.

FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.



tau

A heavier relative of the electron.

tau neutrino

recently observed

top

recently observed

bottom

A heavier relative.

ANTIMATTER

Each particle also has an antimatter counterpart ... sort of a mirror image.

from Time magazine

CERN AC_E11.7

FORCES

Electromagnetic

Photon



Atoms
Light
Chemistry
Electronics



Weak

Bosons (W,Z)



Neutron decay
Beta radioactivity
Neutrino interactions
Burning of the sun



Strong

Gluons (g)



Quarks



Neutrons
Baryons



Gravitational

Graviton ?



Solar system
Galaxies
Black holes



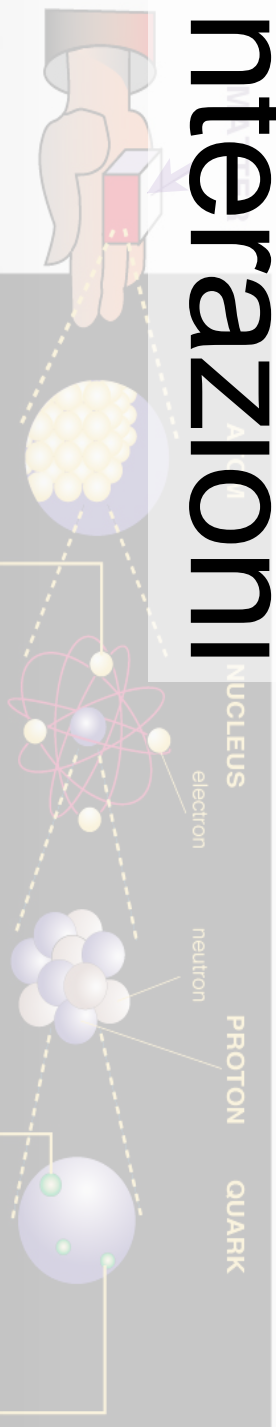
Higgs boson

h



STANDARD MODEL

Interazioni



ALL ORDINARY MATTER BELONGS TO THIS GROUP.

LEPTONS

e electron
Electric charge - 1
Responsible for electricity and chemical reactions.

μ muon
A heavier relative of the electron.

τ tau lepton
The heaviest of the leptons.

ν_e electron neutrino
Electric charge 0. Interacts with other matter.

ν_μ muon neutrino
Created with muons and some particles decay.

ν_τ tau neutrino
Recently observed.

u up
Electric charge + 2/3
Protons have 2 up quarks... Neutrons have 1 up quark.

d down
Electric charge - 1/3
Protons have 1 down quark... Neutrons have 2 down quark.

c charm
A heavier relative of the up.

s strange
A heavier relative of the down.

t top
Recently observed.

b bottom
A heavier relative.

FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.

ANTIMATTER

Each particle also has an antimatter counterpart ... sort of a mirror image.

from Time magazine

CERN AC_E11.7

FORCES

Electromagnetic

Photon

Atoms
Light
Chemistry
Electronics

Weak

Bosons (W,Z)

Neutron decay
Beta radioactivity
Neutrino interactions
Burning of the sun

Strong

Gluons (8)

Quarks
Mesons
Baryons

Nickel

Gravitational

Graviton ?

Solar system
Galaxies
Black holes

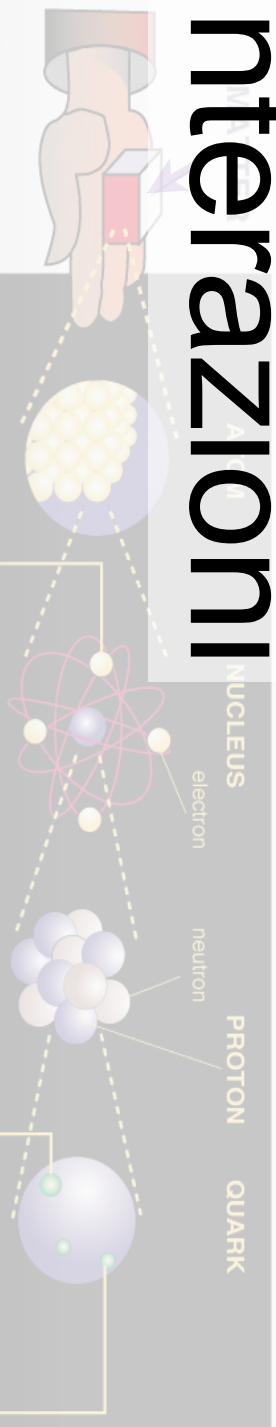
Higgs boson

h



STANDARD MODEL

Interazioni



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FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.

LEPTONS

QUARKS

<p>e electron</p> <ul style="list-style-type: none"> Electric charge - 1 Responsible for electricity and chemical reactions 	<p>ν_e electron neutrino</p> <ul style="list-style-type: none"> Electric charge 0. Interacts with other matter.
<p>μ muon</p> <ul style="list-style-type: none"> Heavier than the electron. 	<p>ν_μ muon neutrino</p> <ul style="list-style-type: none"> Created with muons when some particles decay.
<p>τ tau lepton</p> <ul style="list-style-type: none"> Heaviest of observed leptons. 	<p>ν_τ tau neutrino</p> <ul style="list-style-type: none"> Created with tau leptons when some particles decay.
<p>u up quark</p> <ul style="list-style-type: none"> Electric charge + 2/3 Protons have 2 up quarks... Neutrons have 1 up quark. 	<p>d down quark</p> <ul style="list-style-type: none"> Electric charge - 1/3 Protons have 1 down quark... Neutrons have 2 down quarks.
<p>c charm quark</p> <ul style="list-style-type: none"> A heavier relative of the up. 	<p>s strange quark</p> <ul style="list-style-type: none"> A heavier relative of the down.
<p>t top quark</p> <ul style="list-style-type: none"> Heaviest of observed quarks. 	<p>b bottom quark</p> <ul style="list-style-type: none"> Heavier than all.

ANTIMATTER

Each particle also has an antimatter counterpart ... sort of a mirror image.

from Time magazine

CERN AC - E11.7

FORCES

<p>Electromagnetic</p> <p>Photon</p> <ul style="list-style-type: none"> Atoms Light Chemistry Electronics
<p>Weak</p> <p>Bosons (W,Z)</p> <ul style="list-style-type: none"> Neutron decay Beta radioactivity Neutrino interactions Burning of the sun
<p>Strong</p> <p>Gluons (g)</p> <ul style="list-style-type: none"> Quarks Neutrons Baryons
<p>Gravitational</p> <p>Graviton ?</p> <ul style="list-style-type: none"> Solar system Galaxies Black holes

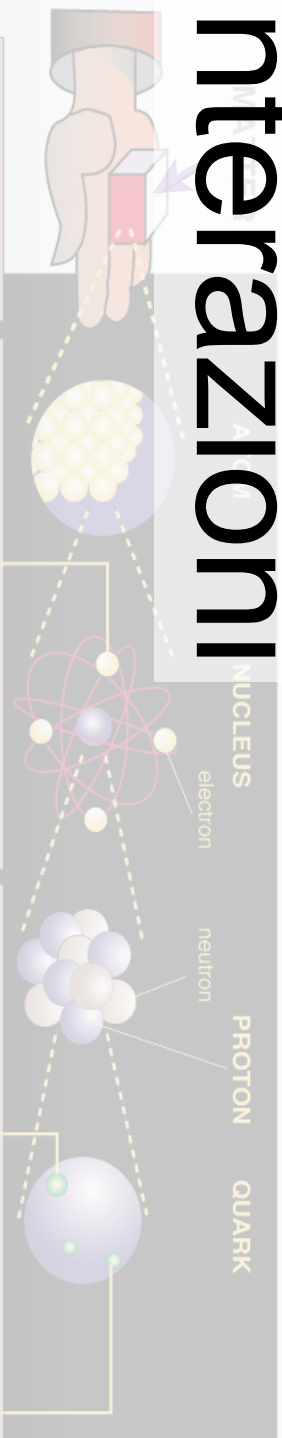
Higgs boson

h



STANDARD MODEL

Interazioni



ALL ORDINARY MATTER BELONGS TO THIS GROUP.

FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.

ANTIMATTER

Each particle also has an antimatter counterpart ... sort of a mirror image.

<p>e electron</p> <p>Electric charge - 1</p> <p>Responsible for electricity and chemical reactions</p>	<p>e electron neutrino</p> <p>Electric charge 0.</p> <p>Interacts with other matter.</p>
<p>u up</p> <p>Electric charge + 2/3</p> <p>Protons have 2 up quarks... Neutrons have 1 up quark.</p>	<p>d down</p> <p>Electric charge - 1/3</p> <p>Protons have 1 down Neutrons have 2 down</p>
<p>μ muon</p> <p>Heavier than the electron.</p>	<p>ν_μ muon neutrino</p> <p>Created with some particles & decays.</p>
<p>τ tau</p> <p>Heavier than muon.</p>	<p>ν_τ tau neutrino</p> <p>Heaviest neutrino observed</p>
<p>c charm</p> <p>A heavier relative of the up.</p>	<p>s strange</p> <p>A heavier relative of the down.</p>
<p>t top</p> <p>Heaviest quark ever observed</p>	<p>b bottom</p> <p>Heavier than up.</p>

CERN AC E11.7

Higgs boson

h

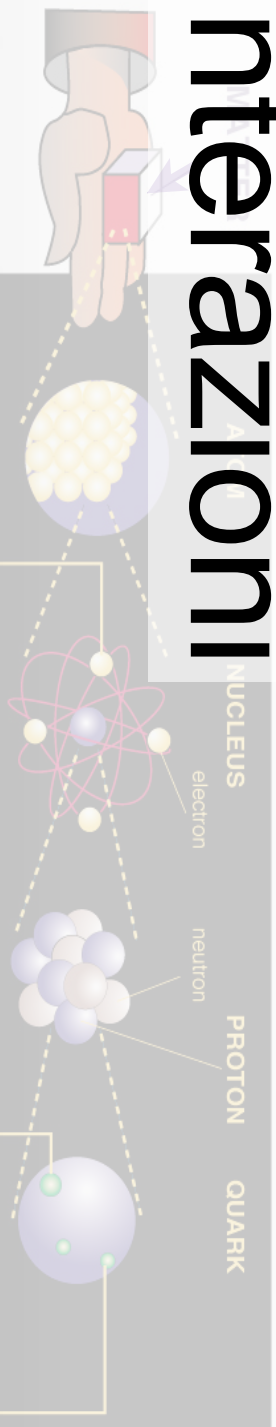
FORCES

<p>Electromagnetic</p> <p>Photon</p> <p>Atoms Light Chemistry Electronics</p>	<p>Weak</p> <p>Bosons (W,Z)</p> <p>Neutron decay Beta radioactivity Neutrino interactions Burning of the sun</p>	<p>Strong</p> <p>Gluons (g)</p> <p>Quarks Mesons Baryons</p> <p>Nuclei</p>	<p>Gravitational</p> <p>Graviton ?</p> <p>Solar system Galaxies Black holes</p>
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STANDARD MODEL

Interazioni



ALL ORDINARY MATTER BELONGS TO THIS GROUP.

FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.

LEPTONS

e electron Electric charge - 1 Responsible for electricity and chemical reactions.	ν_e electron neutrino Electric charge 0. Interacts with other matter.
μ muon Heavier than the electron.	ν_μ muon neutrino Created with some particles & decays.
τ tau lepton The heaviest lepton.	ν_τ tau neutrino Heaviest neutrino observed.

Each particle also has an antimatter counterpart ... sort of a mirror image.

QUARKS

u up Electric charge + 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.	d down Electric charge - 1/3 Protons have 1 down Neutrons have 2 down
c charm A heavier relative of the up.	s strange A heavier relative of the down.
t top The heaviest quark ever observed.	b bottom The second heaviest quark.

ANTIMATTER

from Time magazine

CERN AC E11-7

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

$W^+ W^-$

Z

Neutrino decays
Beta radiation
Nuclear fission
Nuclear fusion
Burning of the Sun

Strong

Glueballs (g)

g (8)

Quarks
Nuclei

Gravitational

Graviton (?)

G

Solar system
Galaxies
Black holes

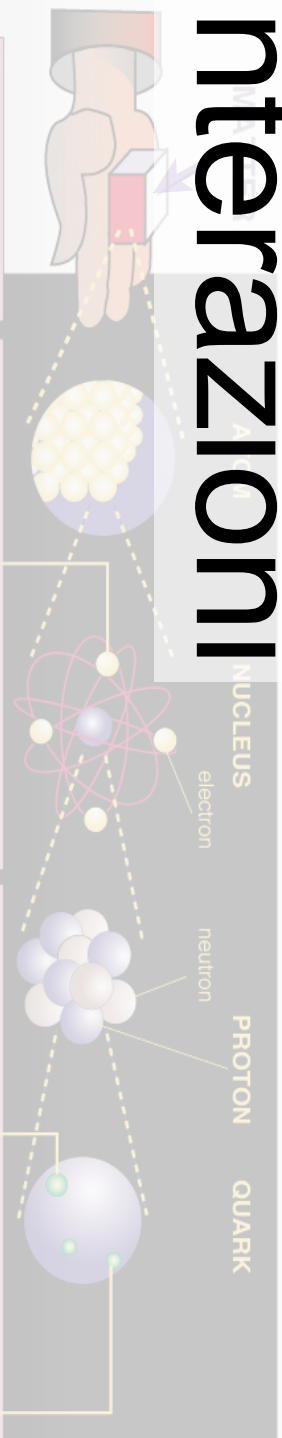
Higgs boson

h



STANDARD MODEL

Interazioni



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LEPTONS

e electron Electric charge - 1 Responsible for electricity and chemical reactions.	ν_e electron neutrino Electric charge 0. Interacts with other matter.
μ muon Heavier than the electron.	ν_μ muon neutrino Created with some particles & decays.
τ tau lepton The heaviest lepton.	ν_τ tau neutrino Heaviest neutrino observed.

Each particle also has an antimatter counterpart ... sort of a mirror image.

QUARKS

u up quark Electric charge + 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.	d down quark Electric charge - 1/3 Protons have 1 down... Neutrons have 2 down.
c charm quark A heavier relative of the up.	s strange quark A heavier relative of the down.
t top quark The heaviest quark ever discovered.	b bottom quark The heaviest quark ever discovered.

from Time magazine

FORCES

Electromagnetic

γ

Weak

W⁺ W⁻

Strong

g (8)

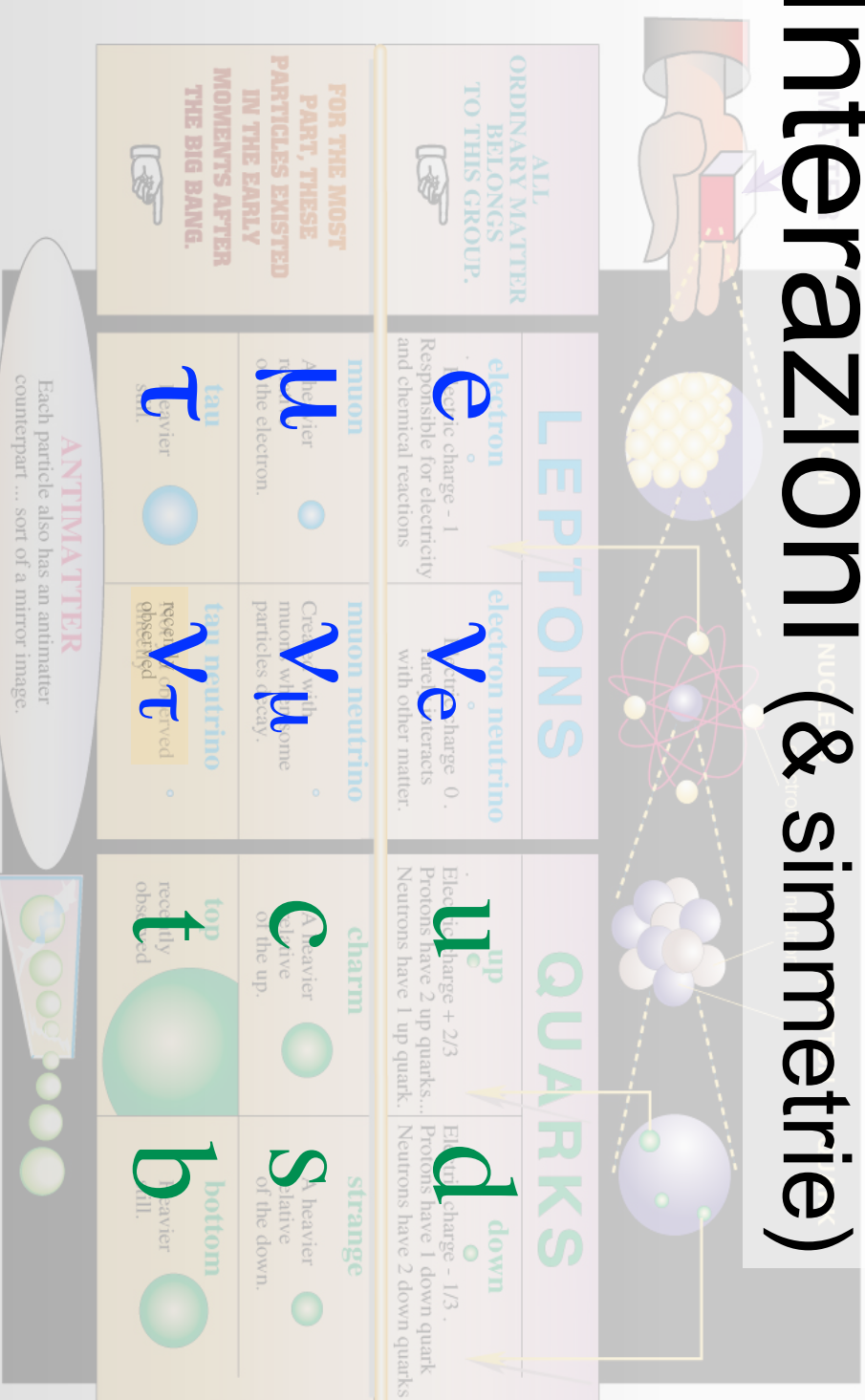
Gravitational

G



STANDARD MODEL

Interazioni (& simmetrie)



from Time magazine

CERN AC_E11-7

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

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

$W^+ W^-$

Z

Neutrino decays
Beta radiation
Nuclear fission
Nuclear fusion
Nuclear energy
Sterling of the Sun

Strong

Cherons (8)

g (8)

Quarks
Nuclei

Gravitational

Graviton ?

G

Solar system
Galaxies
Black holes

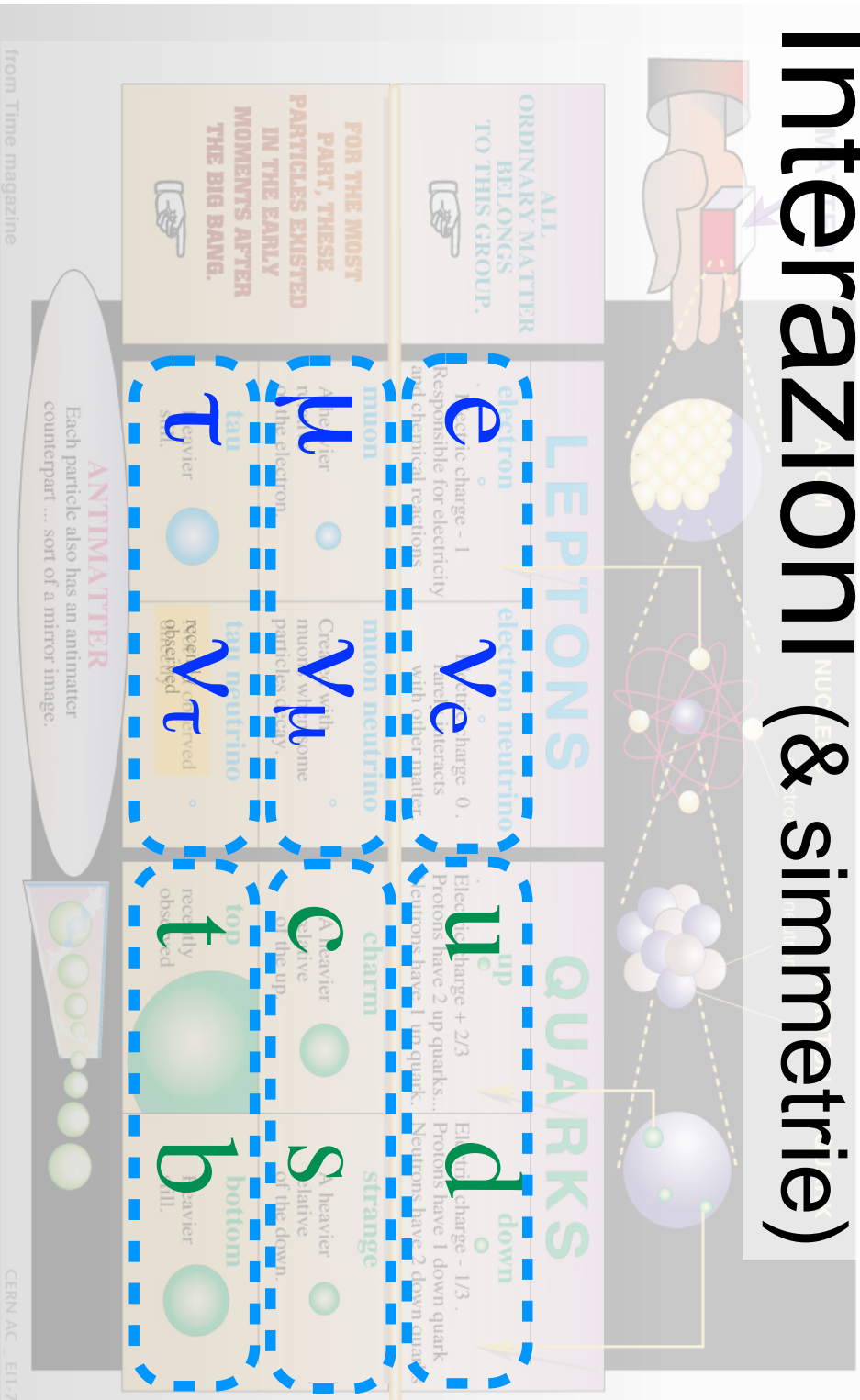
Higgs boson

h



STANDARD MODEL

Interazioni (& simmetrie)



from Time magazine

CERN AC_E11-7

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

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

$W^+ W^-$

Z

Strong

Clusons (8)

g (8)

Gravitational

Graviton ?

G

Higgs boson

h



STANDARD MODEL

Interazioni (& simmetrie)



ALL ORDINARY MATTER BELONGS TO THIS GROUP.

FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.

LEPTONS

QUARKS

ANTIMATTER

Each particle also has an antimatter counterpart ... sort of a mirror image.

from Time magazine

CERN AC_E11-7

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

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

$W^+ W^-$

Z

Neutrino decays, beta radiation, nuclear fusion, neutrino oscillation, burning of the sun.

Strong

Clusons (8)

$g (8)$

Quarks, Nuclei

Gravitational

Graviton ?

G

Scalar system, Exchange, Each force

Higgs boson

h



STANDARD MODEL

Interazioni (& simmetrie)



<p>ALL ORDINARY MATTER BELONGS TO THIS GROUP.</p> <p>LEPTONS</p>	<p>electron e</p> <p>Electric charge - 1 Responsible for electricity and chemical reactions</p>	<p>electron neutrino ν_e</p> <p>Electric charge 0. Interacts with other matter.</p>	<p>QUARKS</p>	<p>up u</p> <p>Electric charge 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.</p>	<p>down d</p> <p>Electric charge 1/3 Protons have 1 down quark Neutrons have 2 down quarks</p>
	<p>muon μ</p> <p>Electric charge - 1 Heavier than the electron.</p>	<p>muon neutrino ν_μ</p> <p>Created in high energy collisions Some particles decay.</p>		<p>charm c</p> <p>Electric charge 2/3 Produced in high energy collisions Decays quickly.</p>	<p>strange s</p> <p>Electric charge - 1/3 Produced in high energy collisions Decays quickly.</p>

<p>FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.</p>	<p>tau τ</p> <p>Electric charge - 1 Heavier than the muon.</p>	<p>tau neutrino ν_τ</p> <p>Created in high energy collisions Observed in neutrino experiments.</p>	<p>top t</p> <p>Electric charge 2/3 Heaviest of the quarks Observed in high energy collisions.</p>	<p>bottom b</p> <p>Electric charge - 1/3 Heavier than the strange quark Observed in high energy collisions.</p>
	<p>ANTIMATTER</p> <p>Each particle also has an antimatter counterpart ... sort of a mirror image.</p>			

from Time magazine

CERN AC_E11-7

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

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

$W^+ W^-$

Z

Neutrino oscillation
Beta radiation
Neutrino interaction
Burning of the Sun

Strong

Clusons (8)

g (8)

Gravitational

Graviton ?

G

Scalar spin-2
Exchange
Earth tides

Higgs boson

h



STANDARD MODEL

Interazioni (& simmetrie)



<p>ALL ORDINARY MATTER BELONGS TO THIS GROUP.</p> <p>FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.</p>		<p>ANTIMATTER</p> <p>Each particle also has an antimatter counterpart ... sort of a mirror image.</p>	
<p>LEPTONS</p>		<p>QUARKS</p>	
<p>electron e⁻</p> <p>Electric charge - 1 Responsible for electricity and chemical reactions</p>	<p>electron neutrino ν_e</p> <p>Electric charge 0. Interacts with other matter.</p>	<p>up u</p> <p>Electric charge 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.</p>	<p>down d</p> <p>Electric charge 1/3 Protons have 1 down quark Neutrons have 2 down quarks</p>
<p>muon μ</p> <p>A heavier relative of the electron.</p>	<p>muon neutrino ν_μ</p> <p>Created with muons which decay into some particles & decay.</p>	<p>charm c</p> <p>A heavy quark relative of the up.</p>	<p>strange s</p> <p>A heavy quark relative of the down.</p>
<p>tau τ</p> <p>A heavy lepton</p>	<p>tau neutrino ν_τ</p> <p>Recently observed</p>	<p>top t</p> <p>Heaviest quark observed</p>	<p>bottom b</p> <p>A heavy quark</p>

from Time magazine

CERN AC_E11-7

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

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

$W^+ W^-$

Z

Neutrino decays
Beta radioactivity
Neutrino oscillation
Burning of the Sun

Strong

Cherons (8)

g (8)

Quarks
Nuclei

Gravitational

Graviton ?

G

Solar system
Galaxies
Black holes

Higgs boson

h



STANDARD MODEL

Interazioni (& simmetrie)



ALL ORDINARY MATTER BELONGS TO THIS GROUP.

LEPTONS

electron
 Responsible for electricity and chemical reactions.
 electric charge - 1

electron neutrino
 electric charge 0. Interacts with other matter.

QUARKS

up
 Electrons have 2 up quarks... Protons have 2 up quarks.

down
 Electrons have 1 down quark... Neutrons have 2 down quarks.

FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.

muon
 After the formation of the electron.

muon neutrino
 Created with muon particles & decay.

charm
 A heavy quark of the up.

strange
 A heavy quark of the down.

ANTIMATTER
 Each particle also has an antimatter counterpart ... sort of a mirror image.

from Time magazine

CERN AC_E11-7

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)
 W^+ W^-

Neutrino decays
 Beta radiation
 Neutrino oscillation
 Burning of the Sun

Z

Strong

Clusons (8)

8 (8)

Higgs boson

h

Gravitational

Graviton ?

Scalar system
 Exchange
 Earth tides

G

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



STANDARD MODEL

Interazioni (& simmetrie)



ALL ORDINARY MATTER BELONGS TO THIS GROUP.	LEPTONS		QUARKS	
<p>e electron</p> <p>Electric charge - 1 Responsible for electricity and chemical reactions</p>	<p>ν_e electron neutrino</p> <p>Electric charge 0. Interacts with other matter.</p>	<p>u up</p> <p>Electric charge 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.</p>	<p>d down</p> <p>Electric charge 1/3 Protons have 1 down quark Neutrons have 2 down quarks</p>	

<p>FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.</p>	<p>μ muon</p> <p>After the Big Bang, the muon is heavier than the electron.</p>	<p>ν_μ muon neutrino</p> <p>Created shortly after the Big Bang, some muon neutrino particles decay.</p>	<p>c charm</p> <p>After the Big Bang, charm quarks were produced in the early moments of the universe.</p>	<p>s strange</p> <p>After the Big Bang, strange quarks were produced in the early moments of the universe.</p>
	<p>τ tau</p> <p>tau lepton</p>	<p>ν_τ tau neutrino</p> <p>tau neutrino</p>	<p>t top</p> <p>top quark</p>	<p>b bottom</p> <p>bottom quark</p>

ANTIMATTER
Each particle also has an antimatter counterpart ... sort of a mirror image.

CERN AC_E11-7

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

W⁺ W⁻

Z

Neutrino oscillation
Beta radiation
Neutrino interaction
Burning of the Sun

Strong

Clusons (8)

g (8)

Quarks
Nuclei

Gravitational

Graviton ?

G

Solar system
Galaxies
Black holes

Higgs boson

h

from Time magazine
Adroni: stati composti di quarks



STANDARD MODEL

Interazioni (& simmetrie)

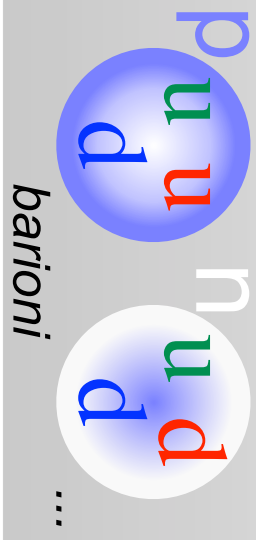


<p>ALL ORDINARY MATTER BELONGS TO THIS GROUP.</p> <p>FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.</p>	<p>LEPTONS</p>		<p>QUARKS</p>	
	<p>electron e^-</p> <p>Electric charge - 1 Responsible for electricity and chemical reactions</p>	<p>electron neutrino ν_e</p> <p>Electric charge 0. Interacts with other matter.</p>	<p>up u</p> <p>Electric charge 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.</p>	<p>down d</p> <p>Electric charge 1/3 Protons have 1 down quark Neutrons have 2 down quarks</p>
<p>muon μ^-</p> <p>Electric charge - 1 Heavier than the electron.</p>	<p>muon neutrino ν_μ</p> <p>Electric charge 0. Created with muons and some particles decay.</p>	<p>charm c</p> <p>Electric charge 2/3 Appears in some particles on the up.</p>	<p>strange s</p> <p>Electric charge 1/3 Appears in some particles on the down.</p>	
<p>Tau τ^-</p> <p>Electric charge - 1 Heavier than muon</p>	<p>tau neutrino ν_τ</p> <p>Electric charge 0. Recently observed</p>	<p>top t</p> <p>Electric charge 2/3 Recently observed</p>	<p>bottom b</p> <p>Electric charge 1/3 Recently observed</p>	

ANTIMATTER
Each particle also has an antimatter counterpart ... sort of a mirror image.

CERN AC_E11-7

Adroni: stati composti di quarks



FORCES

<p>Electromagnetic</p> <p>γ</p>	<p>Weak</p> <p>Bosons (W/Z)</p> <p>$W^+ W^-$</p>	<p>Strong</p> <p>Medon decays Beta radiation Nuclear energy Nuclear burning of the sun</p> <p>Z</p>	<p>Gravitational</p> <p>Cravton 7</p> <p>Scalar system Exchange Each force</p> <p>G</p>
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STANDARD MODEL

Interazioni (& simmetrie)



<p>ALL ORDINARY MATTER BELONGS TO THIS GROUP.</p> <p>FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.</p>	<p>LEPTONS</p>		<p>QUARKS</p>	
	<p>electron e^-</p> <p>Electric charge - 1 Responsible for electricity and chemical reactions</p>	<p>electron neutrino ν_e</p> <p>Electric charge 0. Interacts with other matter.</p>	<p>up u</p> <p>Electric charge 2/3 Protons have 2 up quarks... Neutrons have 1 up quark.</p>	<p>down d</p> <p>Electric charge 1/3 Protons have 1 down quark Neutrons have 2 down quarks</p>
<p>muon μ^-</p> <p>Electric charge - 1 Heavier than the electron.</p>	<p>muon neutrino ν_μ</p> <p>Created in high energy particles decay.</p>	<p>charm c</p> <p>Electric charge 2/3 Discovered in 1974.</p>	<p>strange s</p> <p>Electric charge 1/3 Discovered in 1964.</p>	
<p>tau τ^-</p> <p>Electric charge - 1 Heaviest of the leptons.</p>	<p>tau neutrino ν_τ</p> <p>Electric charge 0. Recently observed.</p>	<p>top t</p> <p>Electric charge 2/3 Heaviest of the quarks. Discovered in 1995.</p>	<p>bottom b</p> <p>Electric charge 1/3 Discovered in 1975.</p>	

ANTIMATTER
Each particle also has an antimatter counterpart ... sort of a mirror image.

CERN AC_E11-7

FORCES

Electromagnetic

γ

Weak

Bosons (W/Z)

$W^+ W^-$

Z

Neutrino decays
Beta radiation
Nuclear fission
Neutrino oscillation
Sawing of the DNA

Strong

Glucos (8)

g (8)

Quarks
Nuclei

Gravitational

Graviton ?

G

Scalar system
Celestial
Earth tides

Adroni: stati composti di quarks

barioni

p uud n udd ...

mesoni

π^0 $u\bar{u}$ K^+ $u\bar{s}$...

Higgs boson

h



Masse



Masse

KeV

MeV

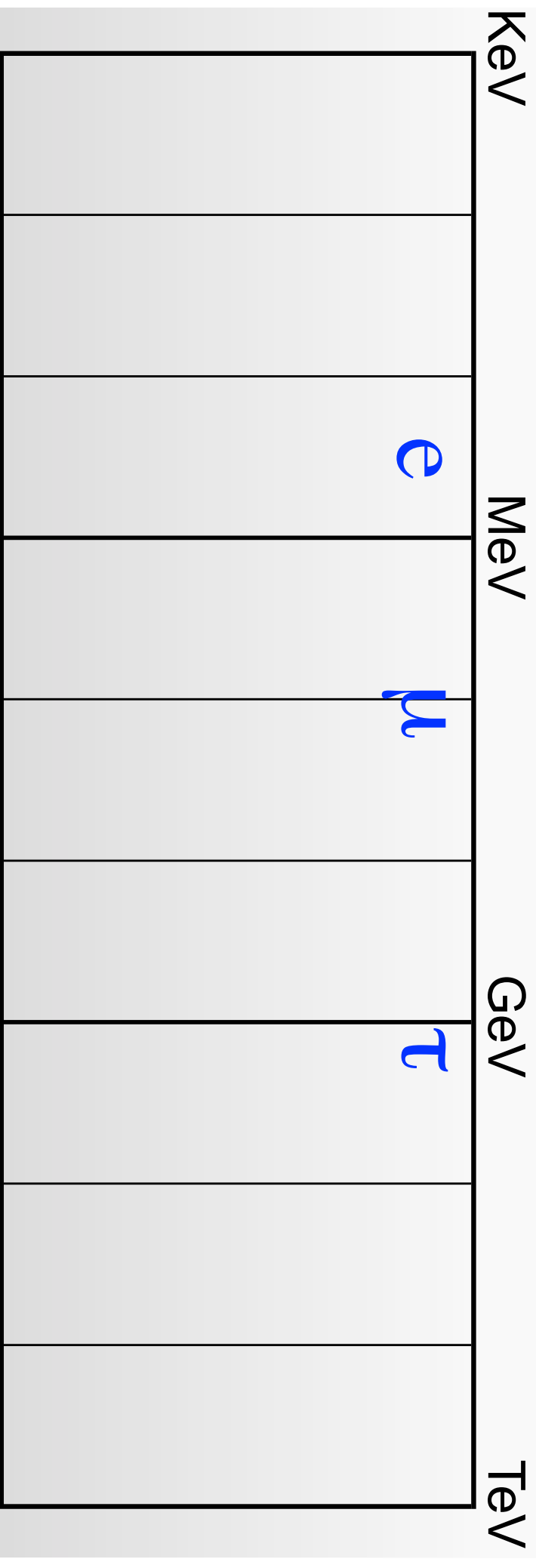
GeV

TeV

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Masse



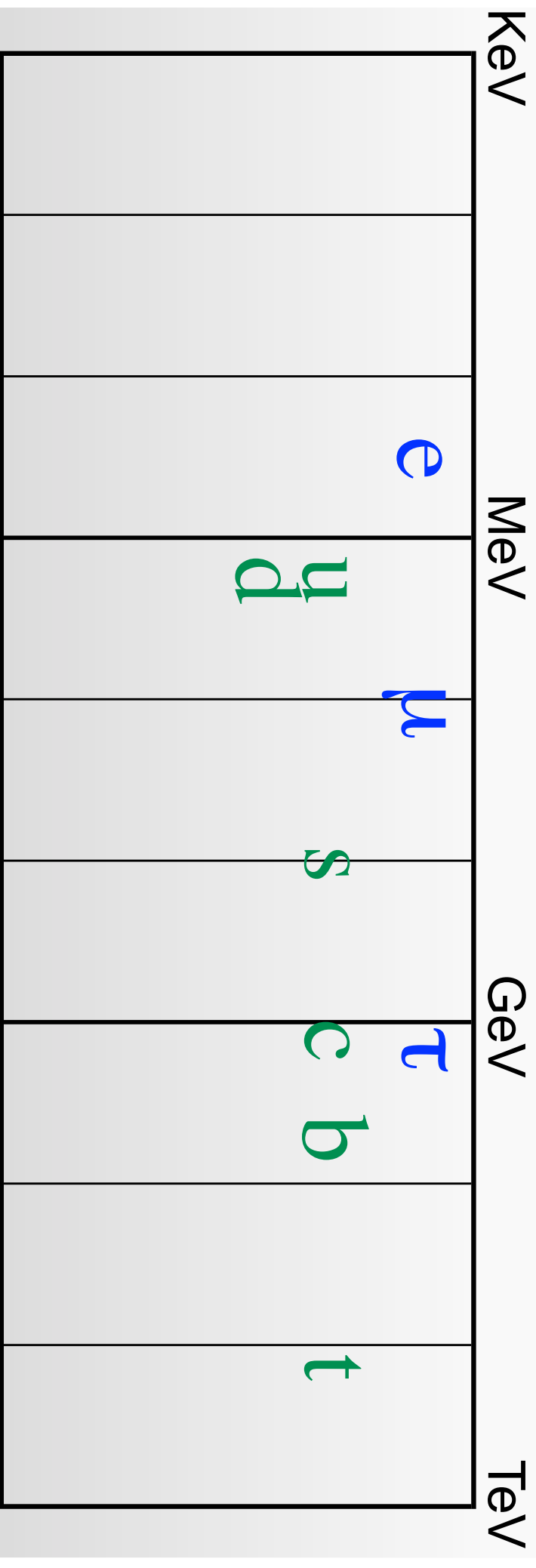
e 511 KeV

μ 105.7 MeV

τ 1.777 GeV



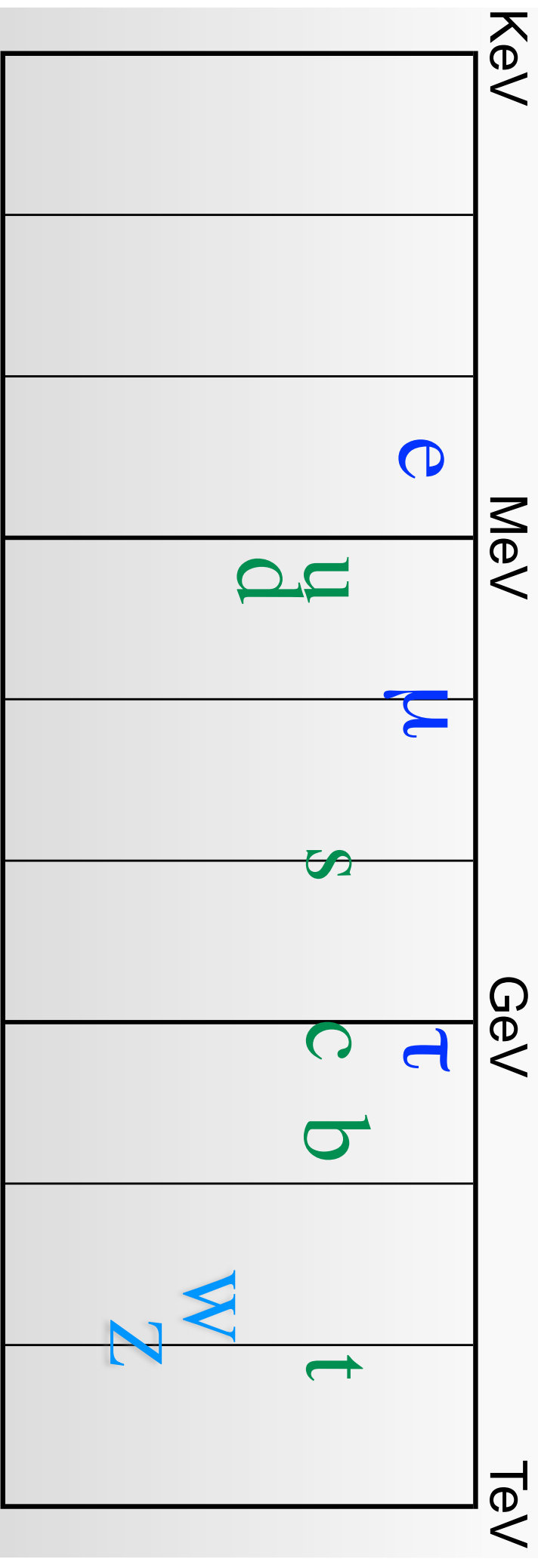
Masse



- 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



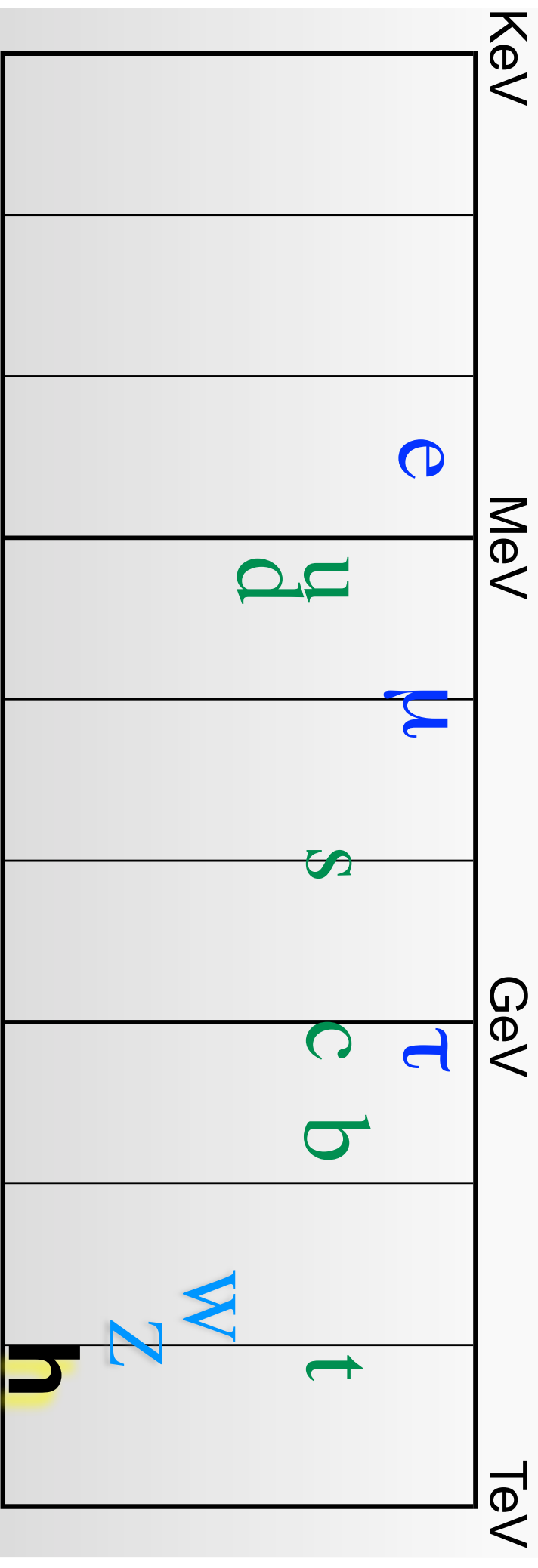
Masse



e 511 KeV 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



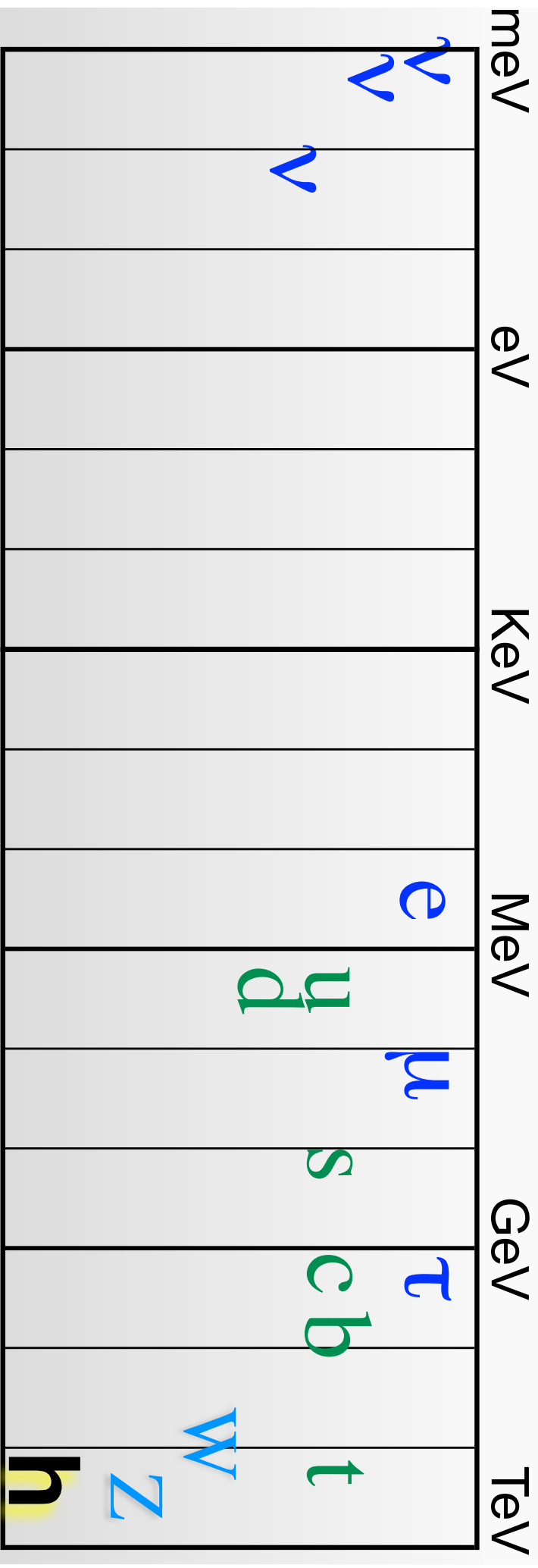
Masse



- e 511 KeV
- u ~2.3 MeV
- d ~5 MeV
- s ~95 MeV
- c 1.27 GeV
- b 4.2 GeV
- t 173.2 GeV
- W \neq 80.385 GeV
- Z 91.1876 GeV
- h 125.7 GeV



Masse



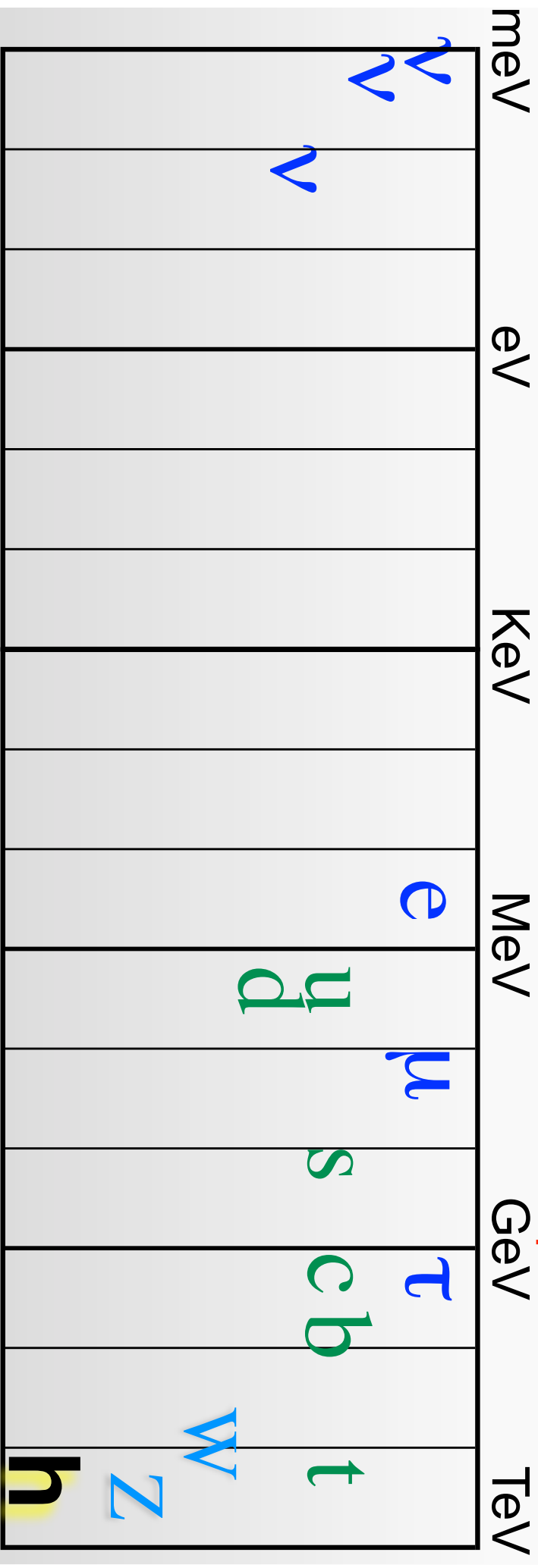
- e 511 KeV
- μ 105.7 MeV
- τ 1.777 GeV
- $9 \cdot 10^{-3} \text{ eV} \approx \nu_i \approx 0.2 \text{ eV}$
- u $\sim 2.3 \text{ MeV}$
- d $\sim 5 \text{ MeV}$
- s $\sim 95 \text{ MeV}$
- c 1.27 GeV
- b 4.2 GeV
- t 173.2 GeV
- W^\pm 80.385 GeV
- Z 91.1876 GeV
- h 125.7 GeV



Masse

massa zero: γ ν G

p ^{238}U



- e 511 KeV
- μ 105.7 MeV
- τ 1.777 GeV
- $9 \cdot 10^{-3} \text{ eV} \approx \nu_i \approx 0.2 \text{ eV}$
- $u \sim 2.3 \text{ MeV}$
- $d \sim 5 \text{ MeV}$
- $s \sim 95 \text{ MeV}$
- 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