AYUDA BEATRIZ GALINDO JUNIOR BG23

Física más allá del Modelo Estándar

Clara Murgui (UAB/IFAE/CERN)

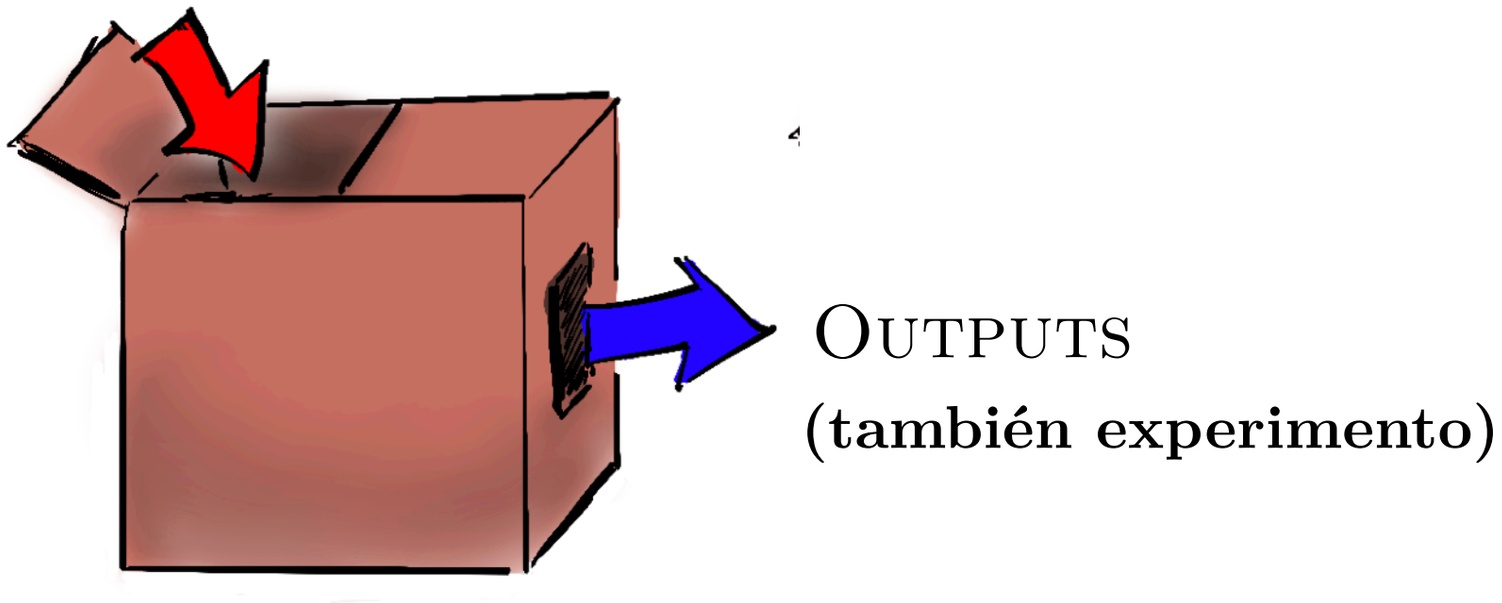
Programa Español para Profesores

CERN

28 Junio 2024

El Modelo Estándar (recap)

(experimento) Inputs

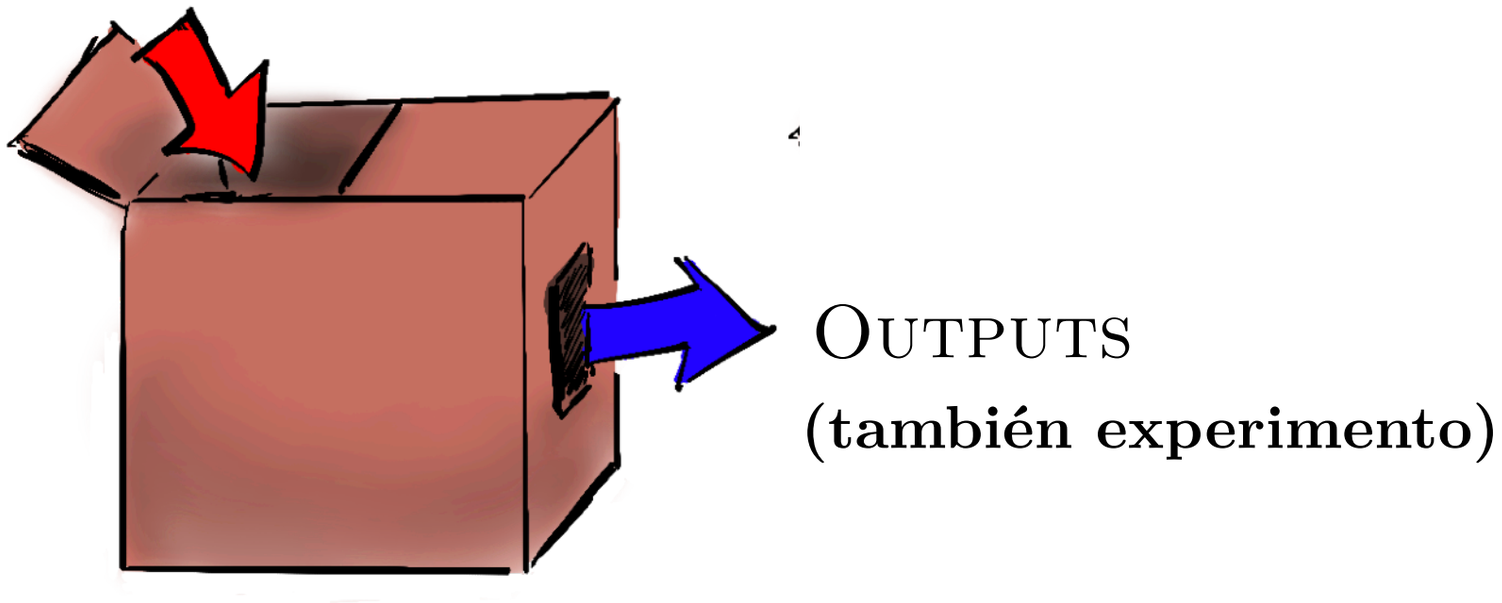


Outputs

(también experimento)

El Modelo Estándar (recap)

(experimento) INPUTS



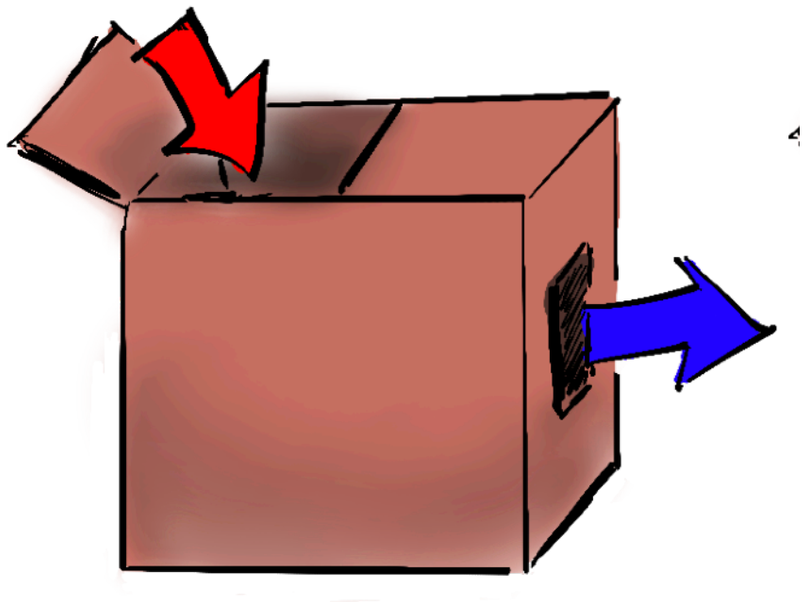
OUTPUTS

(también experimento)

(teoricos) “BONITA” , “SIMPLE”...

El Modelo Estándar (recap)

(experimento) INPUTS



OUTPUTS

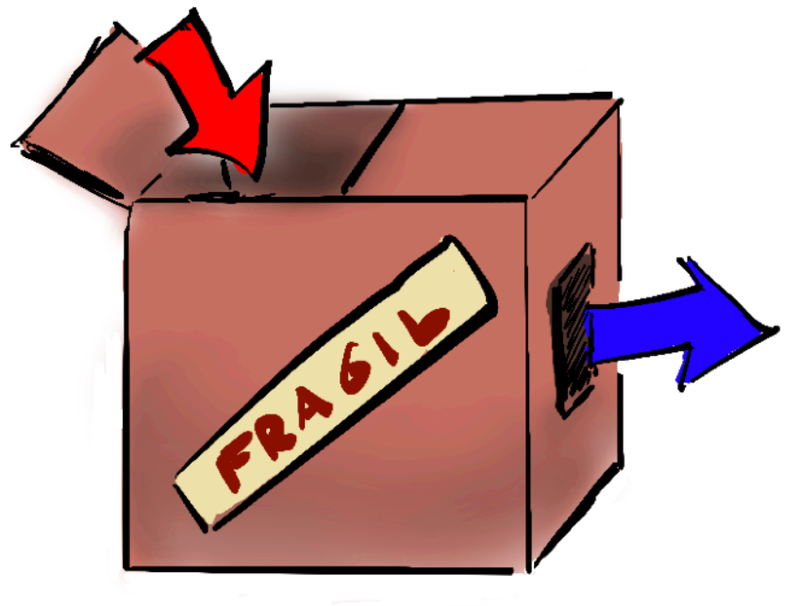
(también experimento)

(teoricos) "BONITA" , "SIMPLE"... $\equiv$ POTENTE

$$\frac{\text{INPUTS}}{\text{OUTPUTS}} \ll 1$$

El Modelo Estándar (recap)

(experimento) INPUTS



OUTPUTS

(también experimento)

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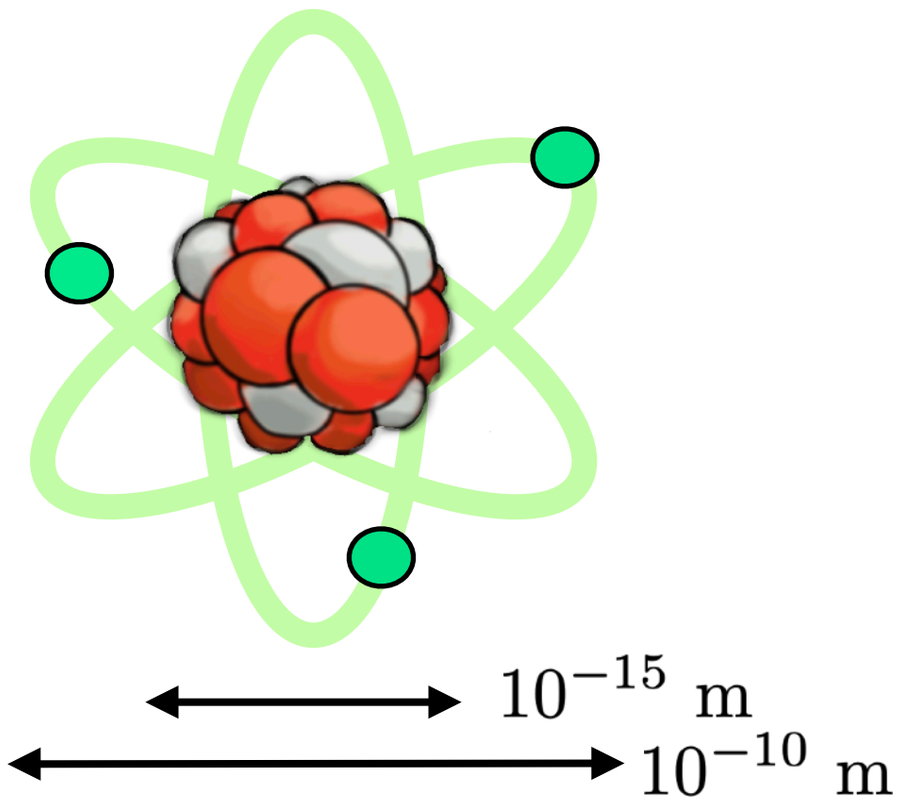
El Modelo Estándar (recap)

09:15

El Modelo estándar y la física fundamental (I)

Speaker: Miguel Escudero Abenza (CERN)



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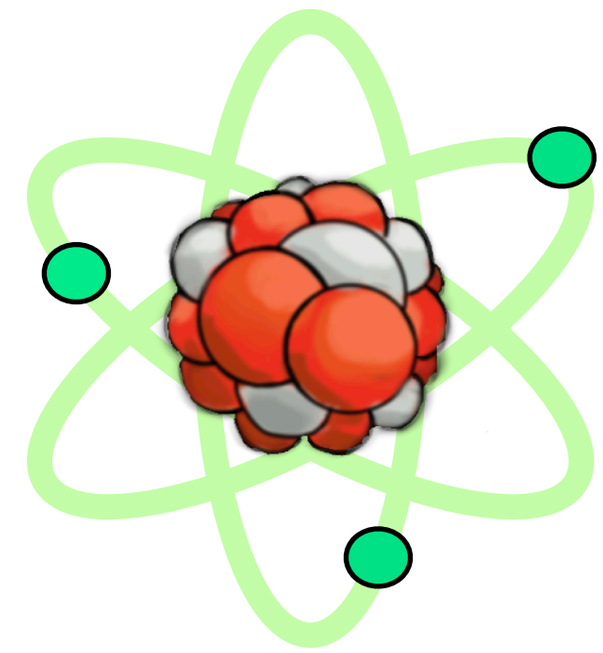

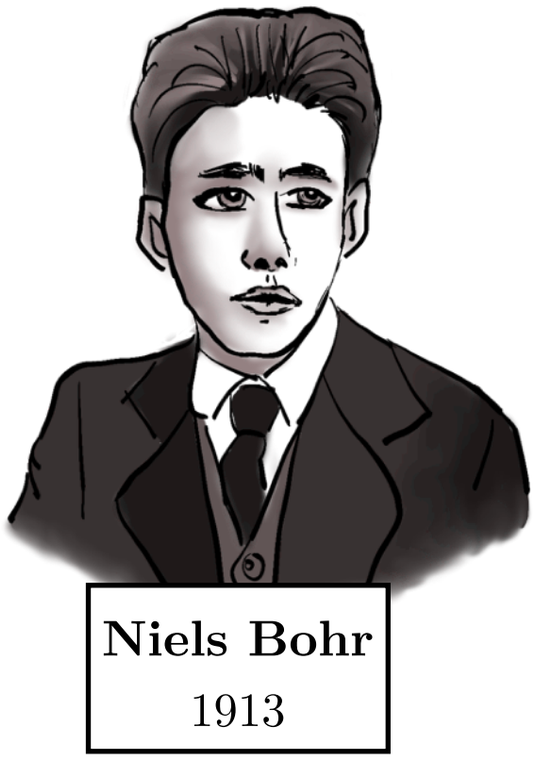

Niels Bohr
1913

10^{-15} m

10^{-10} m

protones

neutrones

electrones

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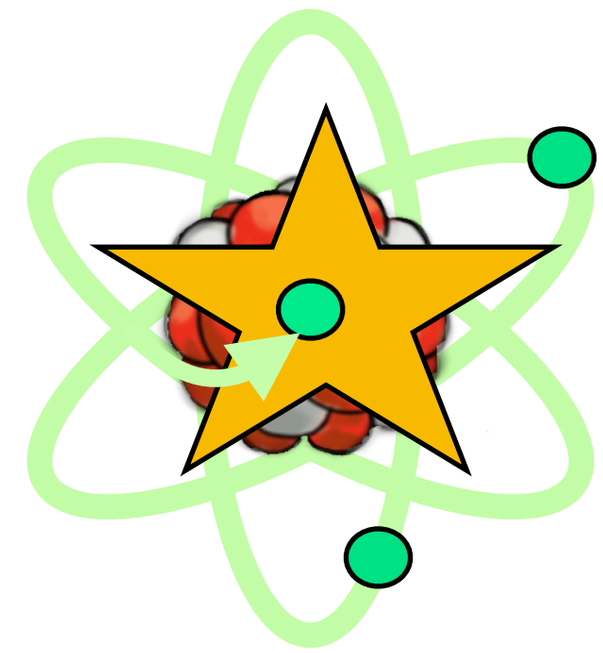

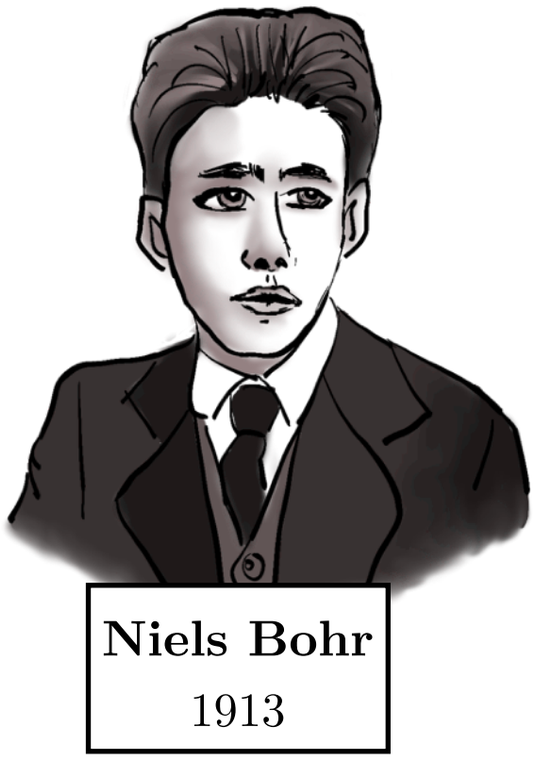

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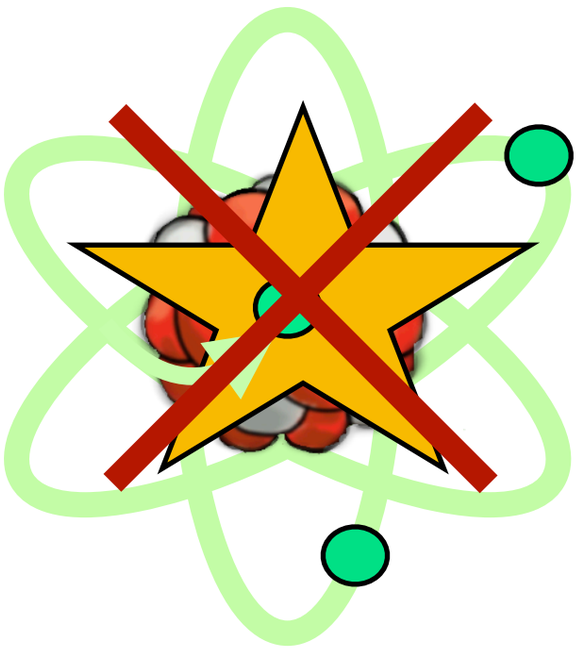

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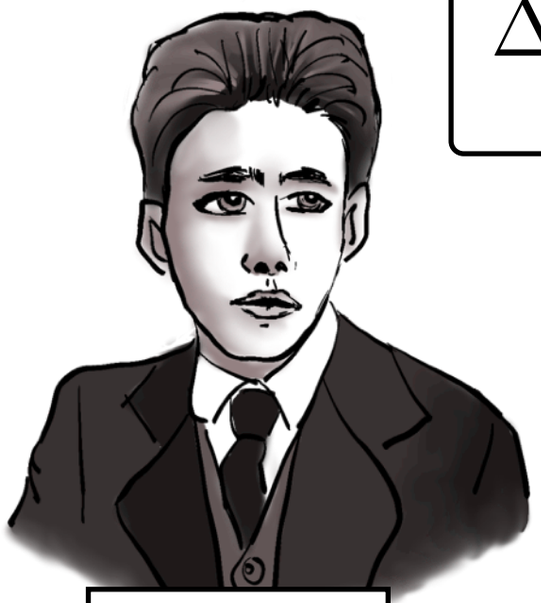

Niels Bohr
1913

$$\Delta x \, \Delta v \geq \frac{\hbar}{2m}$$

Werner Heisenberg
1927

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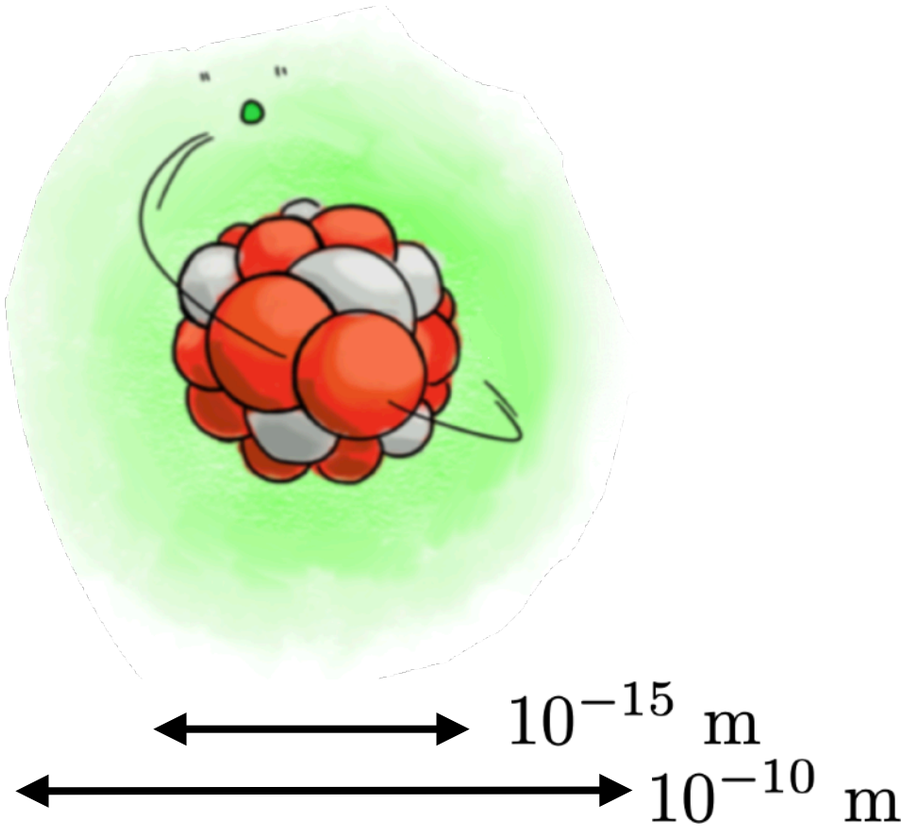

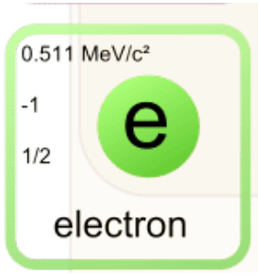

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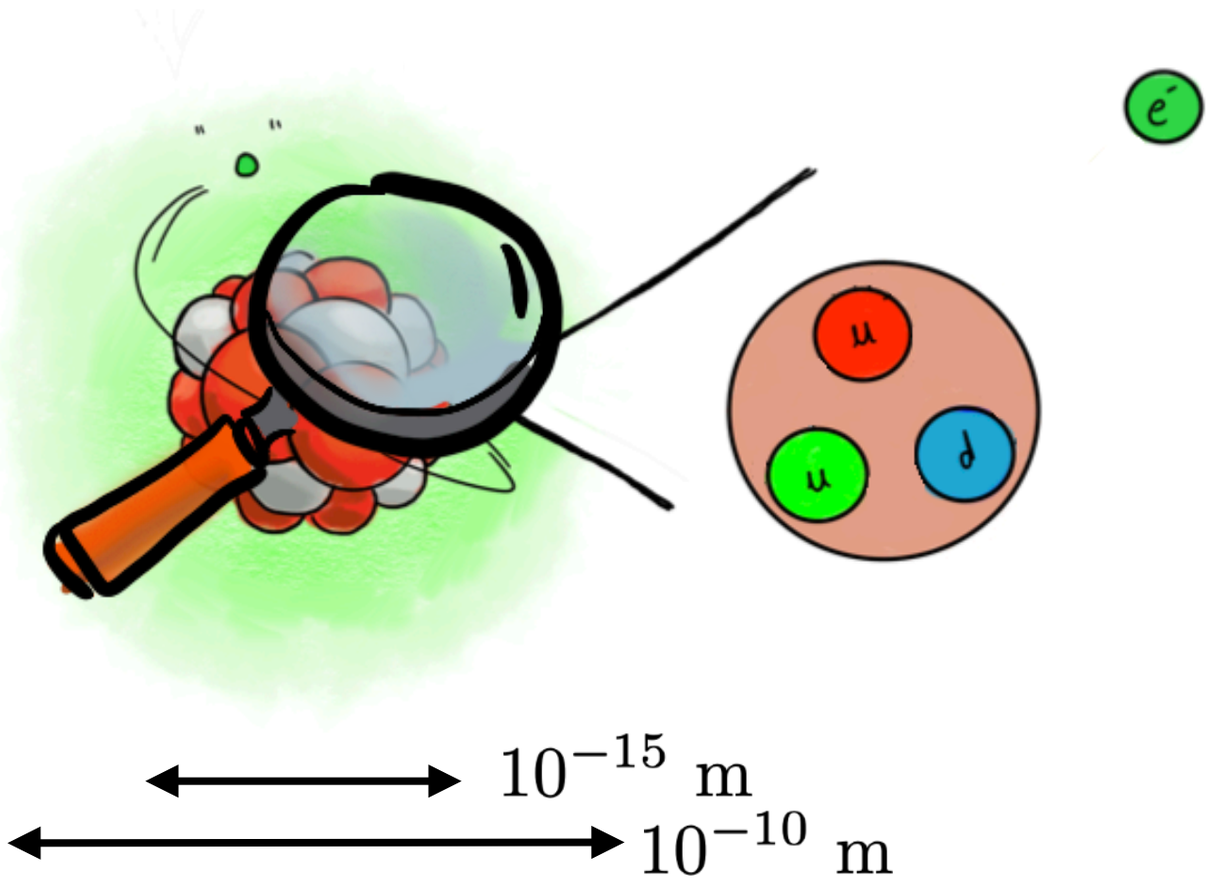

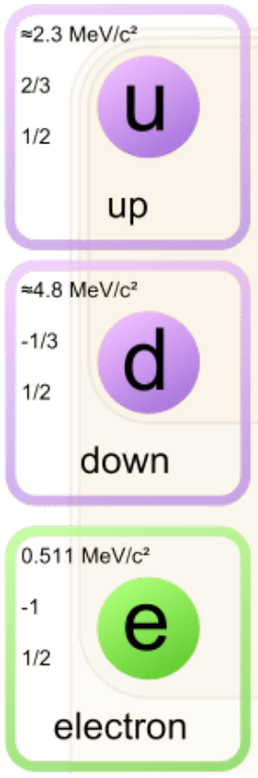

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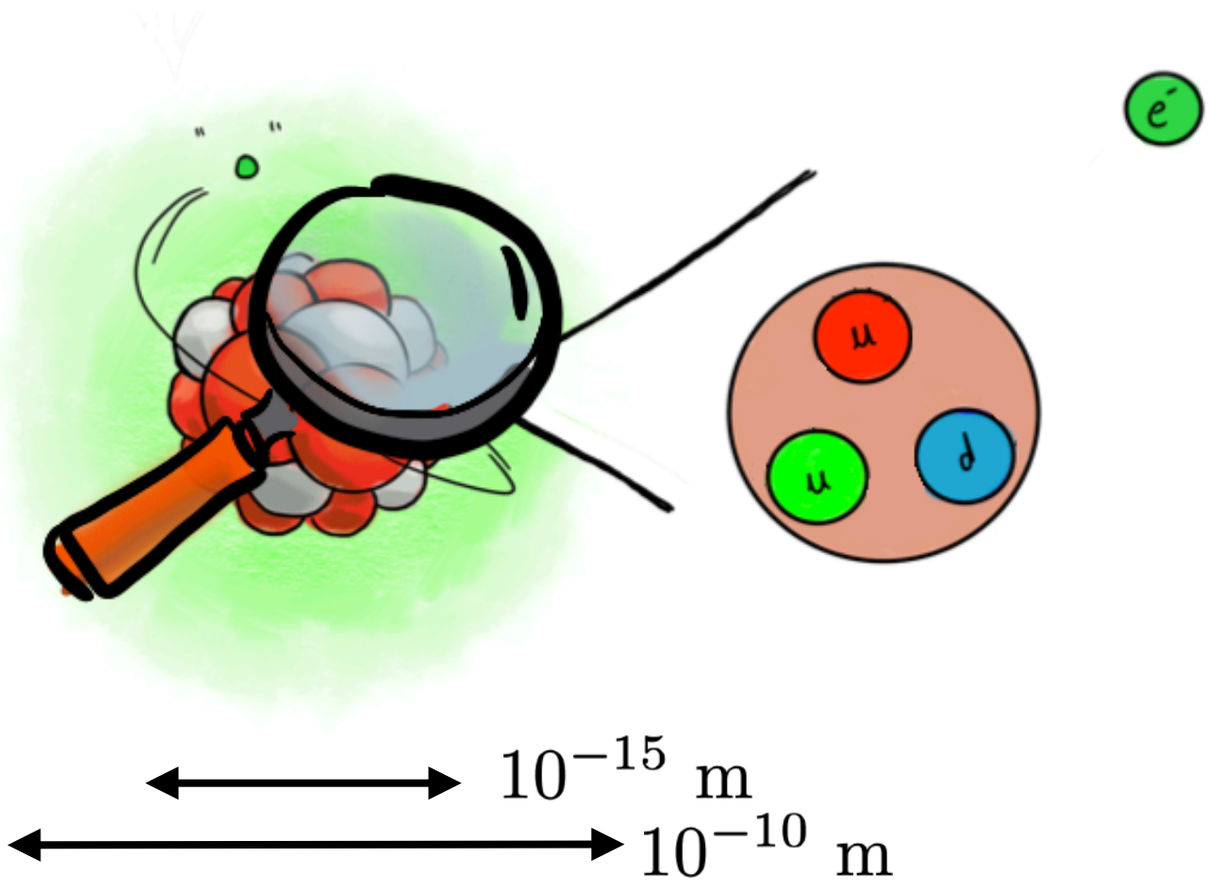
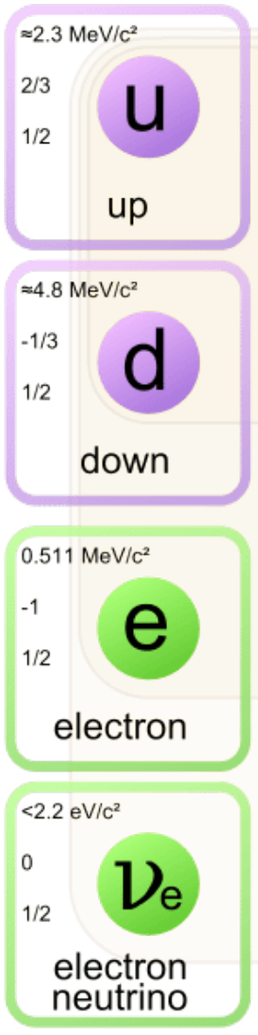
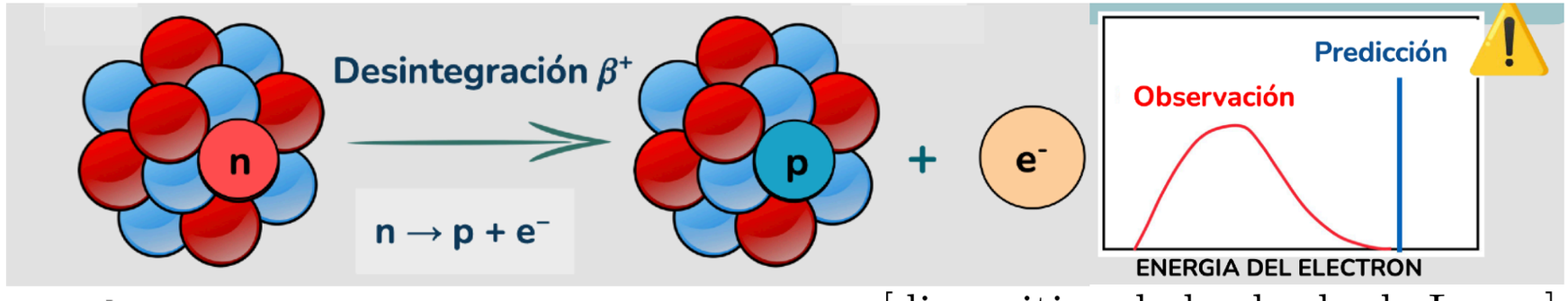




protones

neutrones

electrones



[diapositiva de la charla de Laura]

08:30

Neutrinos

Speaker: Laura Perez Molina (CIEMAT - Centro de Investigaciones Energéticas Medioambientales y Tec. (ES))

El Modelo Estándar (recap)

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

09:15

El Modelo estándar y la física fundamental (I)

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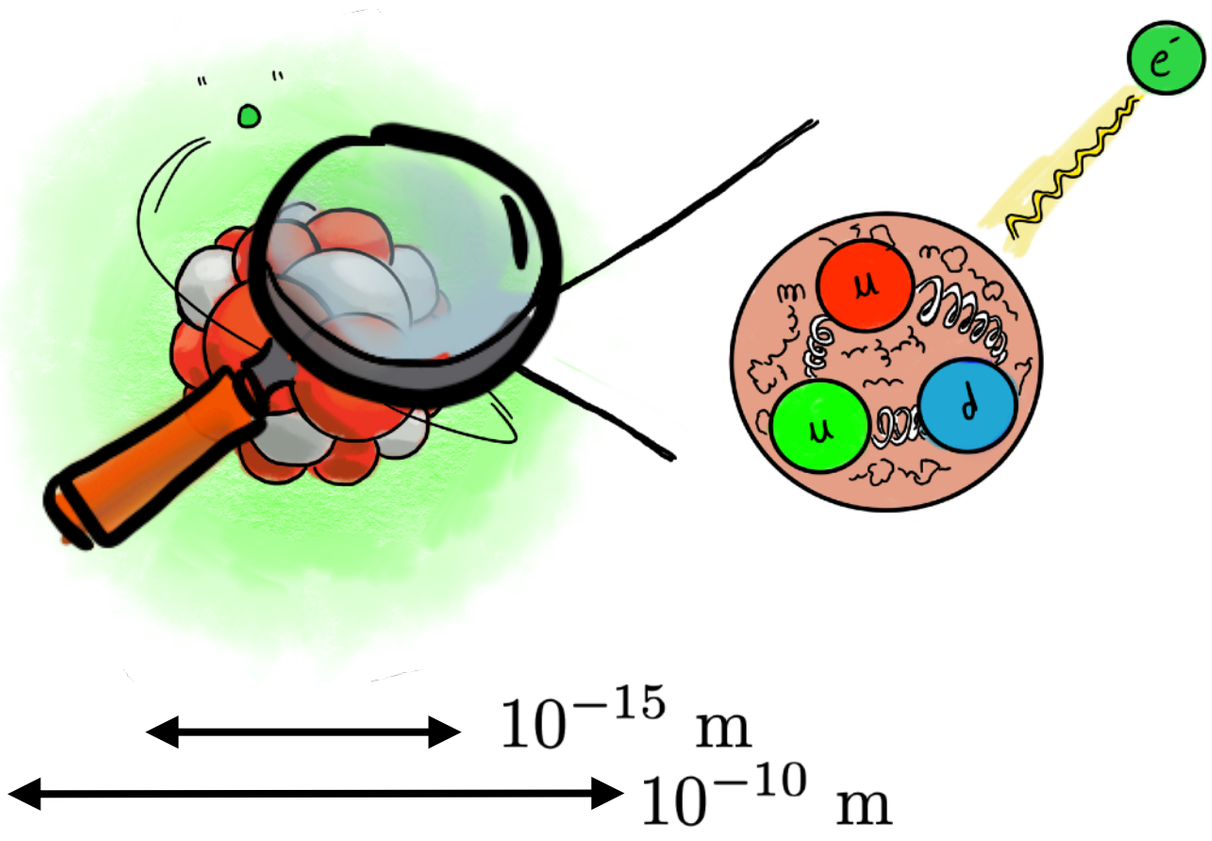

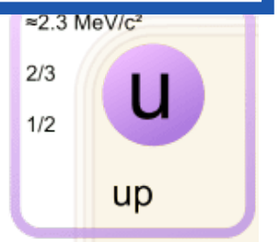

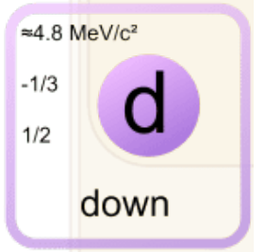

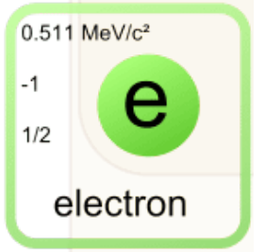

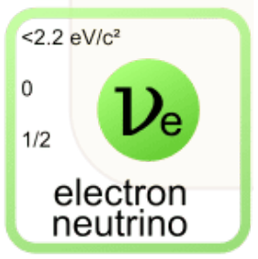

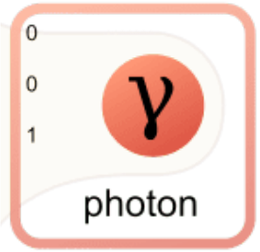

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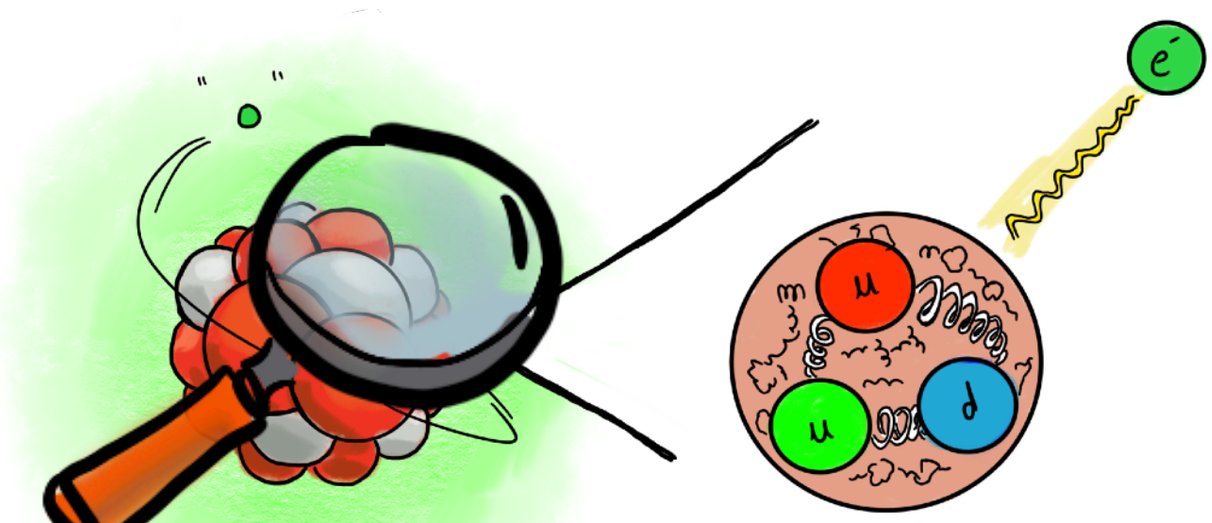

10^{-15} m

10^{-10} m

protones

neutrones

electrones

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\Psi} \not{D} \Psi$$

≈2.3 MeV/c²	≈4.8 MeV/c²	0.511 MeV/c²	<2.2 eV/c²
2/3	-1/3	-1	0
1/2	1/2	1/2	1/2
u	d	e	ν_e
up	down	electron	electron neutrino

0	0	91.2 GeV/c²	80.4 GeV/c²
0	1	0	±1
1	g	1	Z	1	W
gluon	photon	Z boson	W boson

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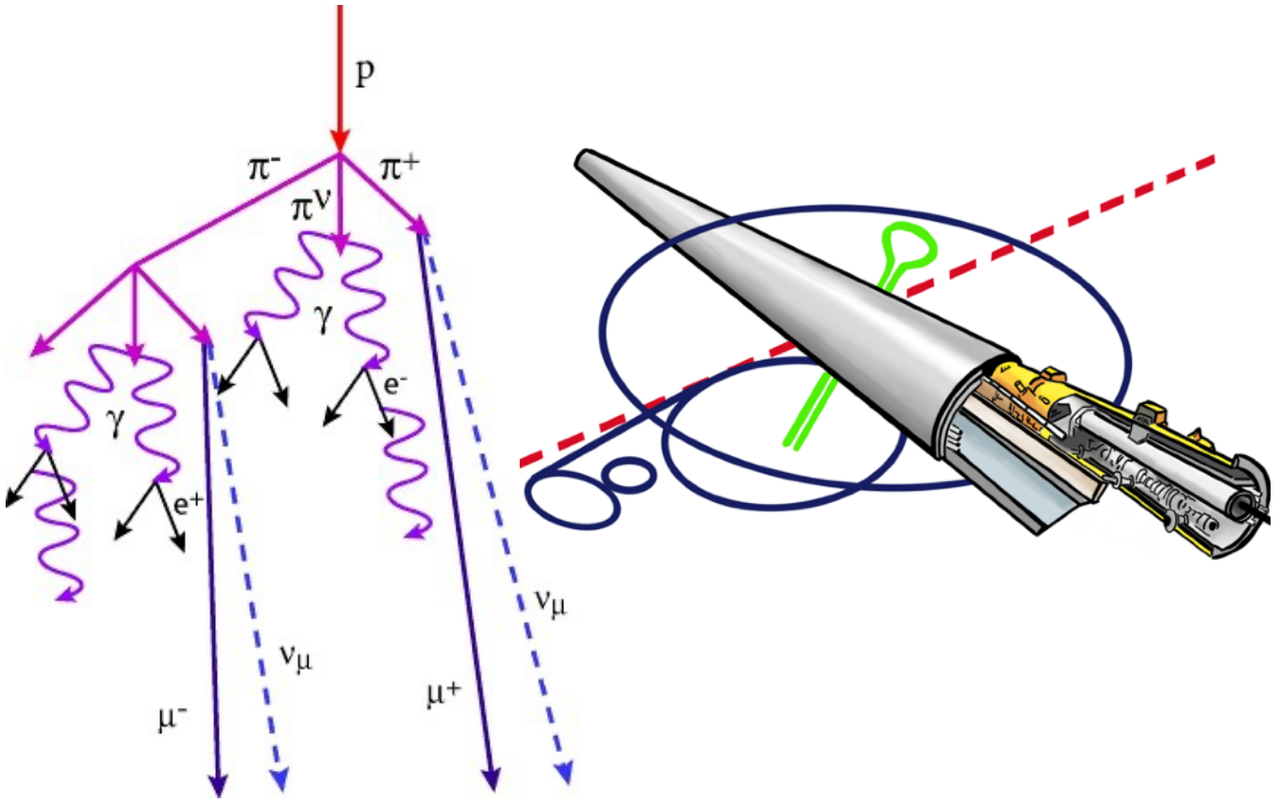
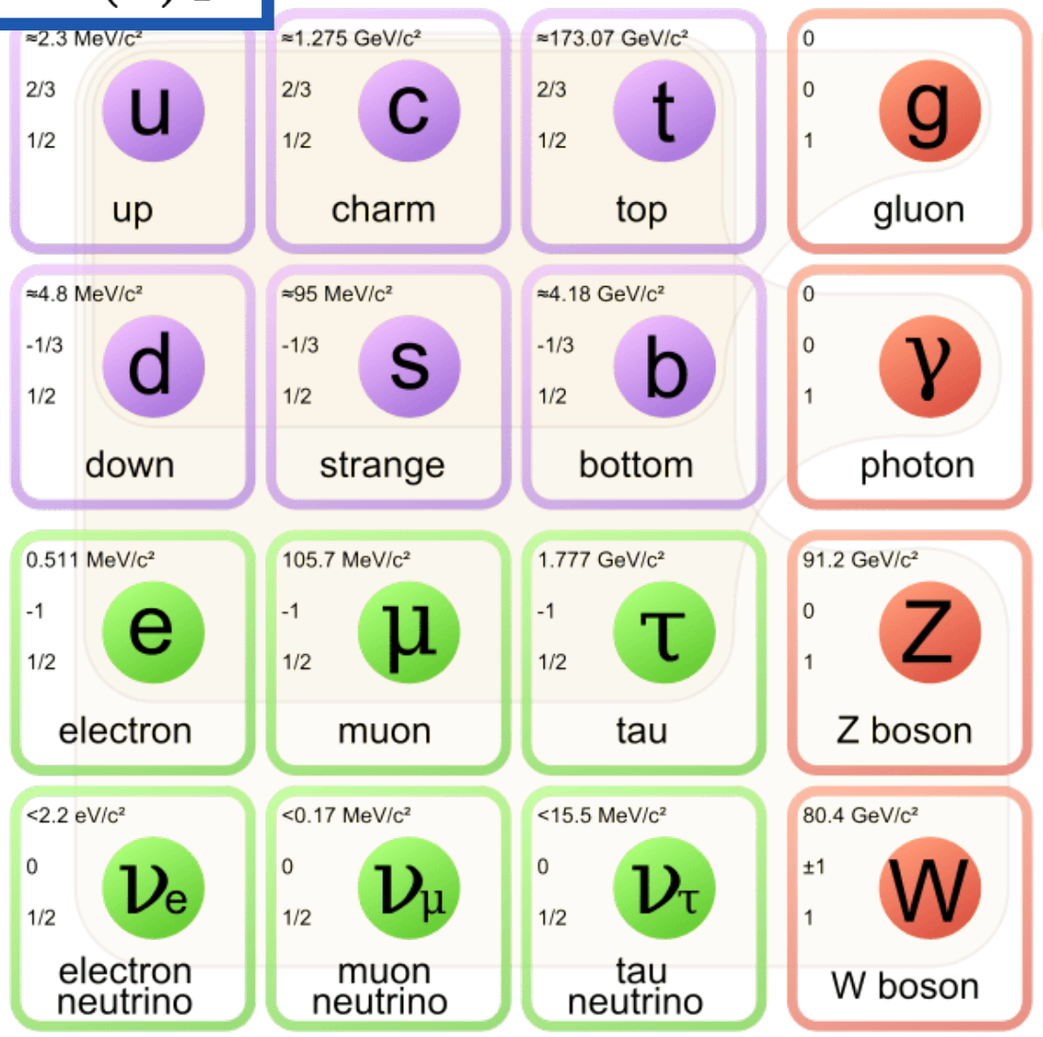




$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\psi} \not{D} \psi$$

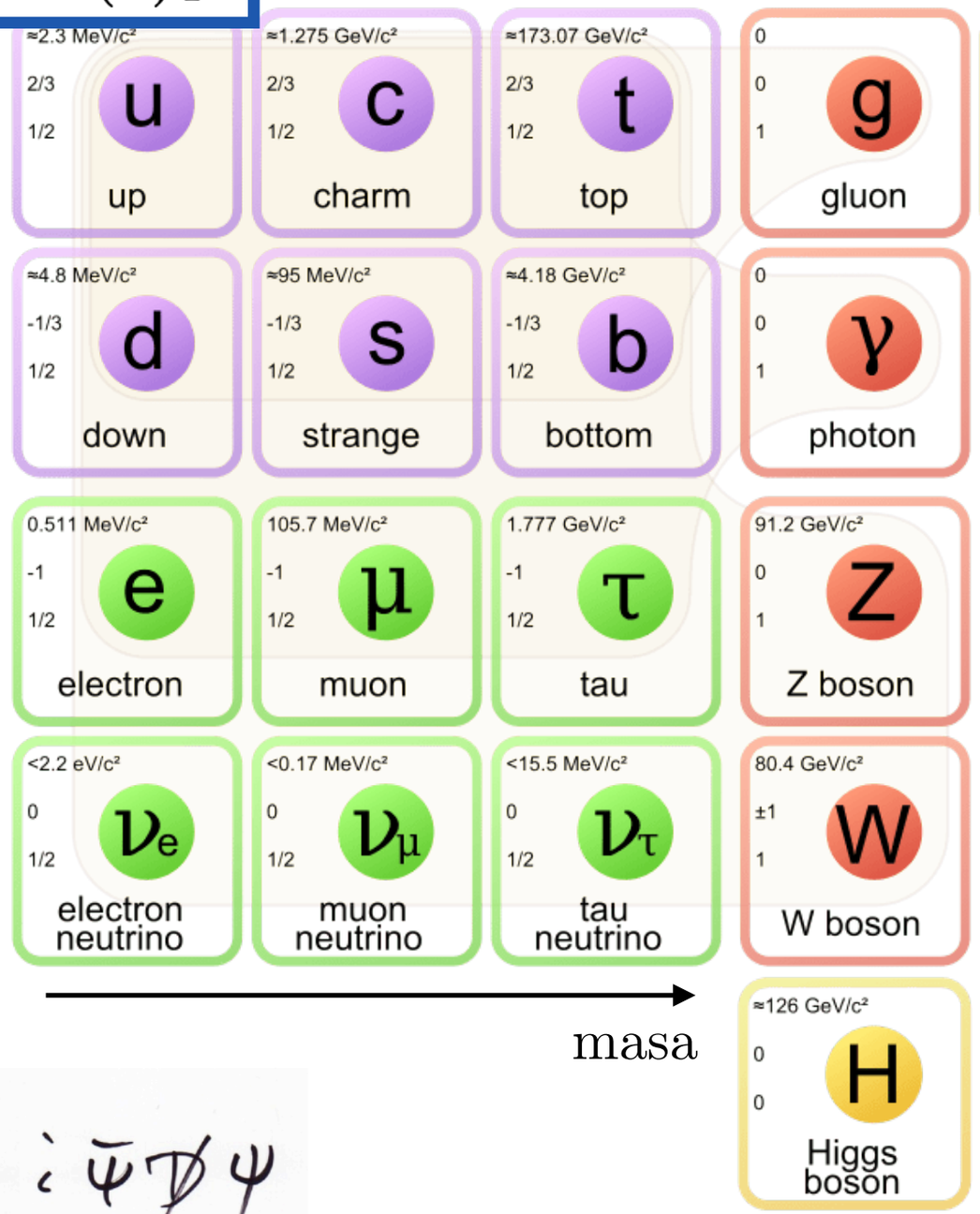
El Modelo Estándar (recap)

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

17:30

Special lecture: El mecanismo de Higgs, pero en serio

Speaker: Alvaro De Rujula (Universidad Autonoma de Madrid (ES))



$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\Psi} \not{D} \Psi$$

$$+ \bar{\Psi}_i y_{ij} \Psi_j \phi + \text{h. c.}$$

El Modelo Estándar (recap)

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

17:30 **Special lecture: El mecanismo de Higgs, pero en serio**

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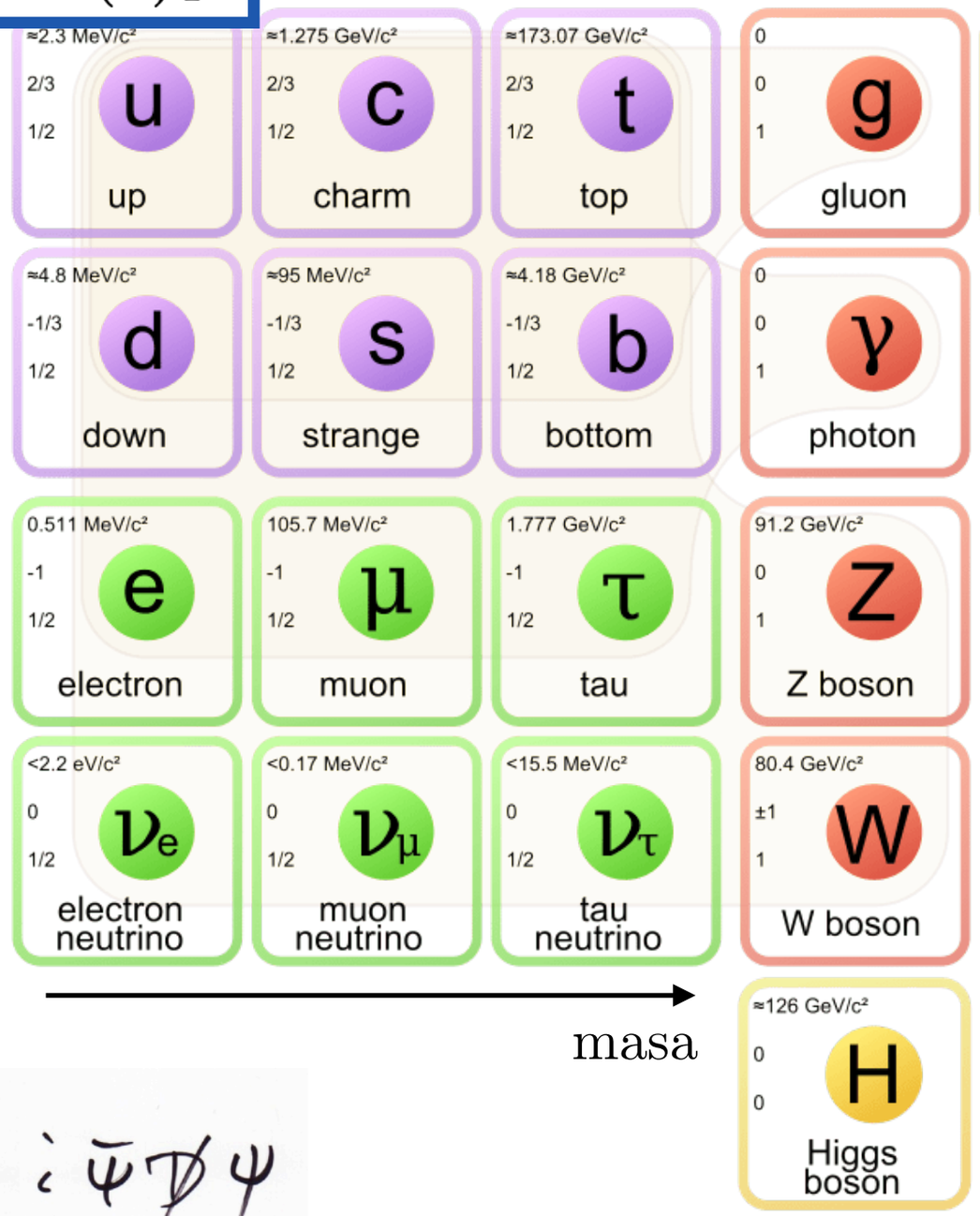
e.g. $\underbrace{\begin{pmatrix} \bar{e}_L^i & \bar{\nu}_L^i \end{pmatrix}}_{\bar{L}_L^i} y_{ij} \begin{pmatrix} 0 \\ H_0 \end{pmatrix} e_R^j + \text{h.c.}$



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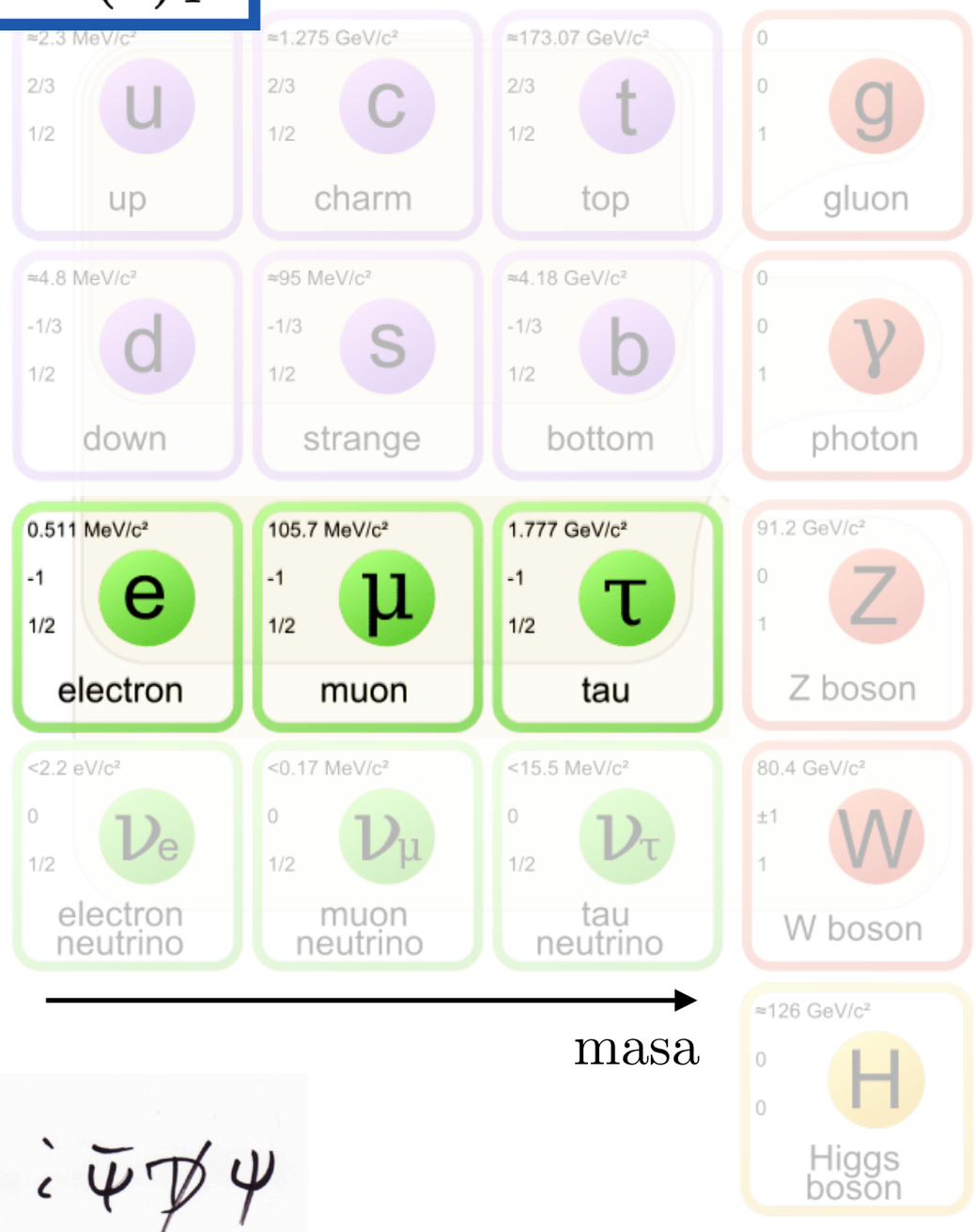
$= \bar{e}_L^i y_{ij} H_0 e_R^j + \text{h.c.}$



$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\Psi} \not{\partial} \Psi$$

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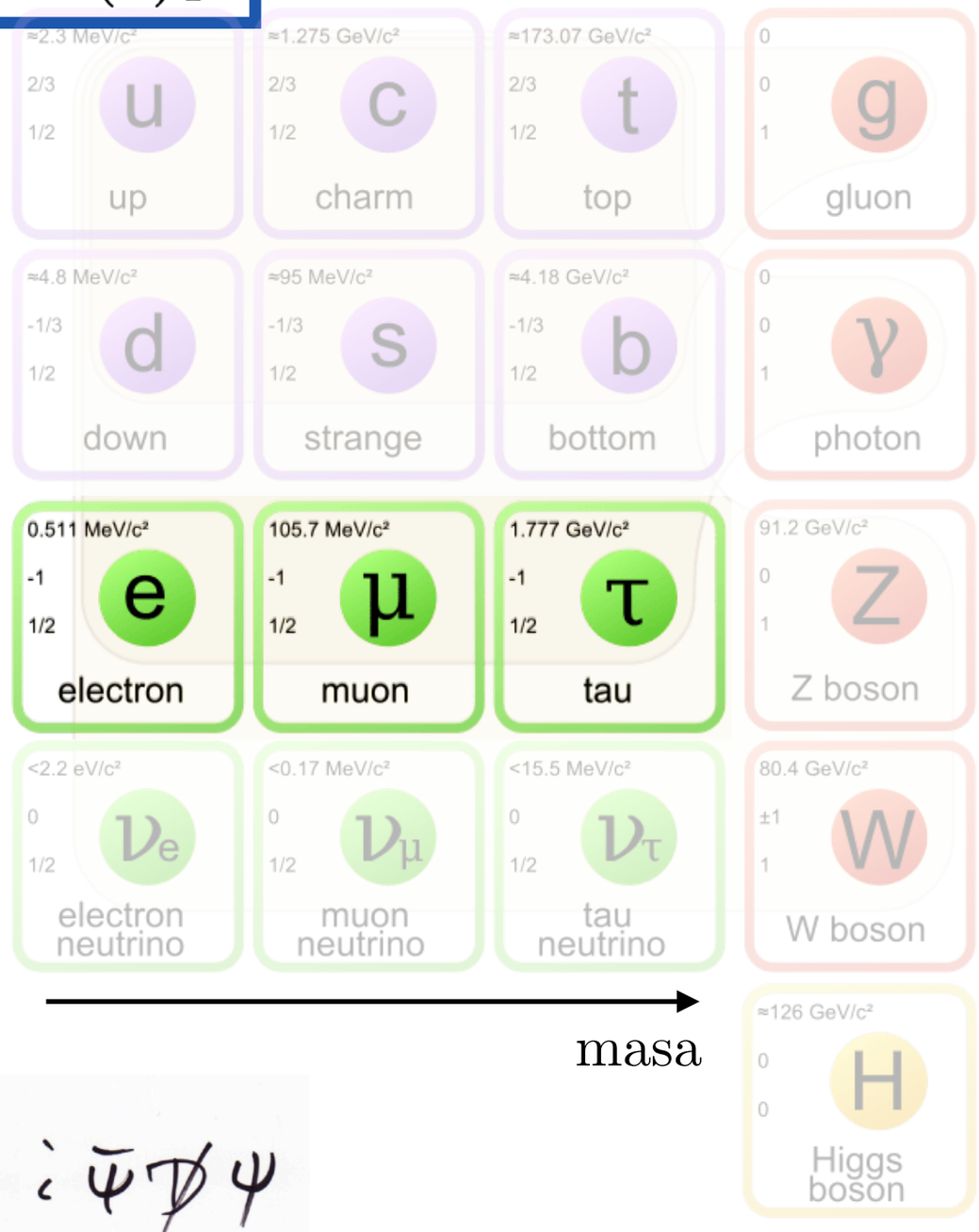

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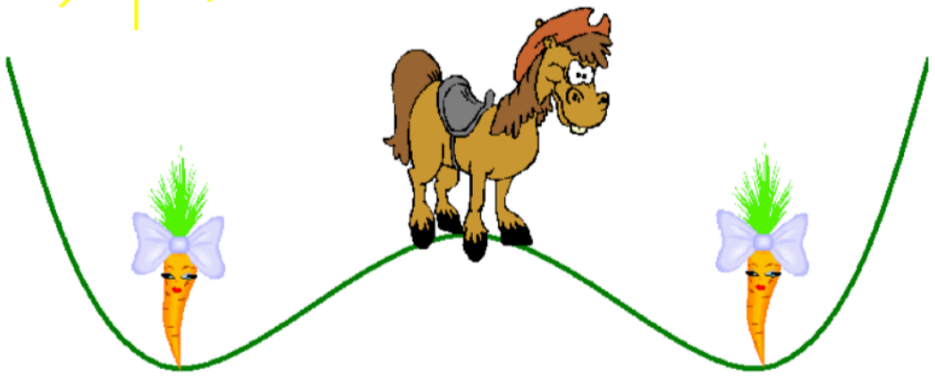
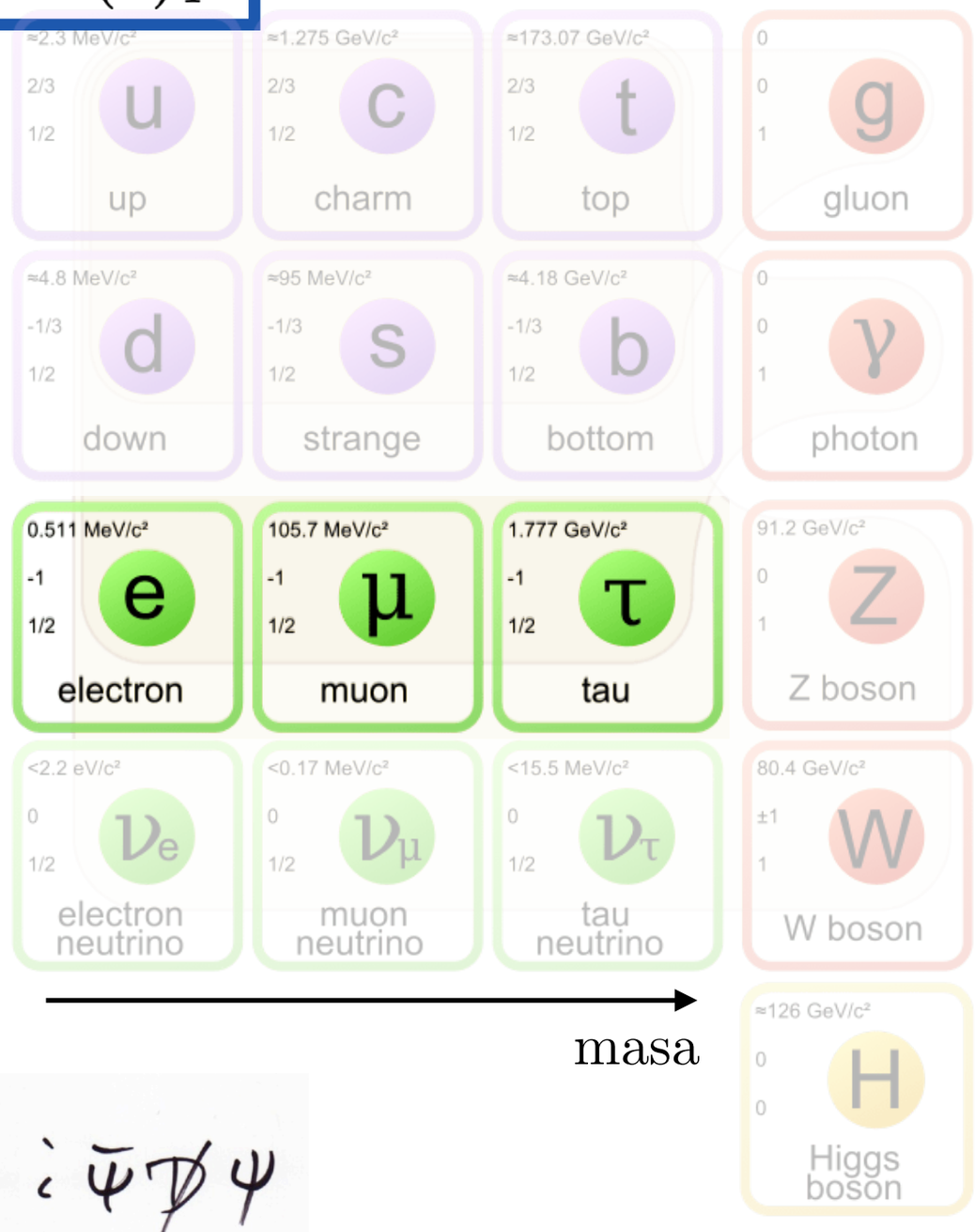
$= \bar{e}_L^i y_{ij} (h_0 + 0) e_R^j + \text{h.c.}$



@Toni Pich
"Nicolás"

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\Psi} \not{D} \Psi$$

$$+ \bar{\Psi}_i y_{ij} \Psi_j \phi + \text{h.c.} + |D_\mu \phi|^2 - V(\phi)$$



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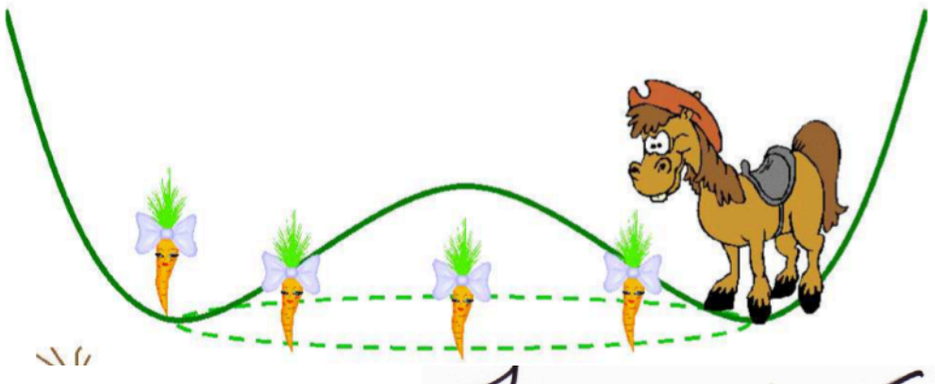

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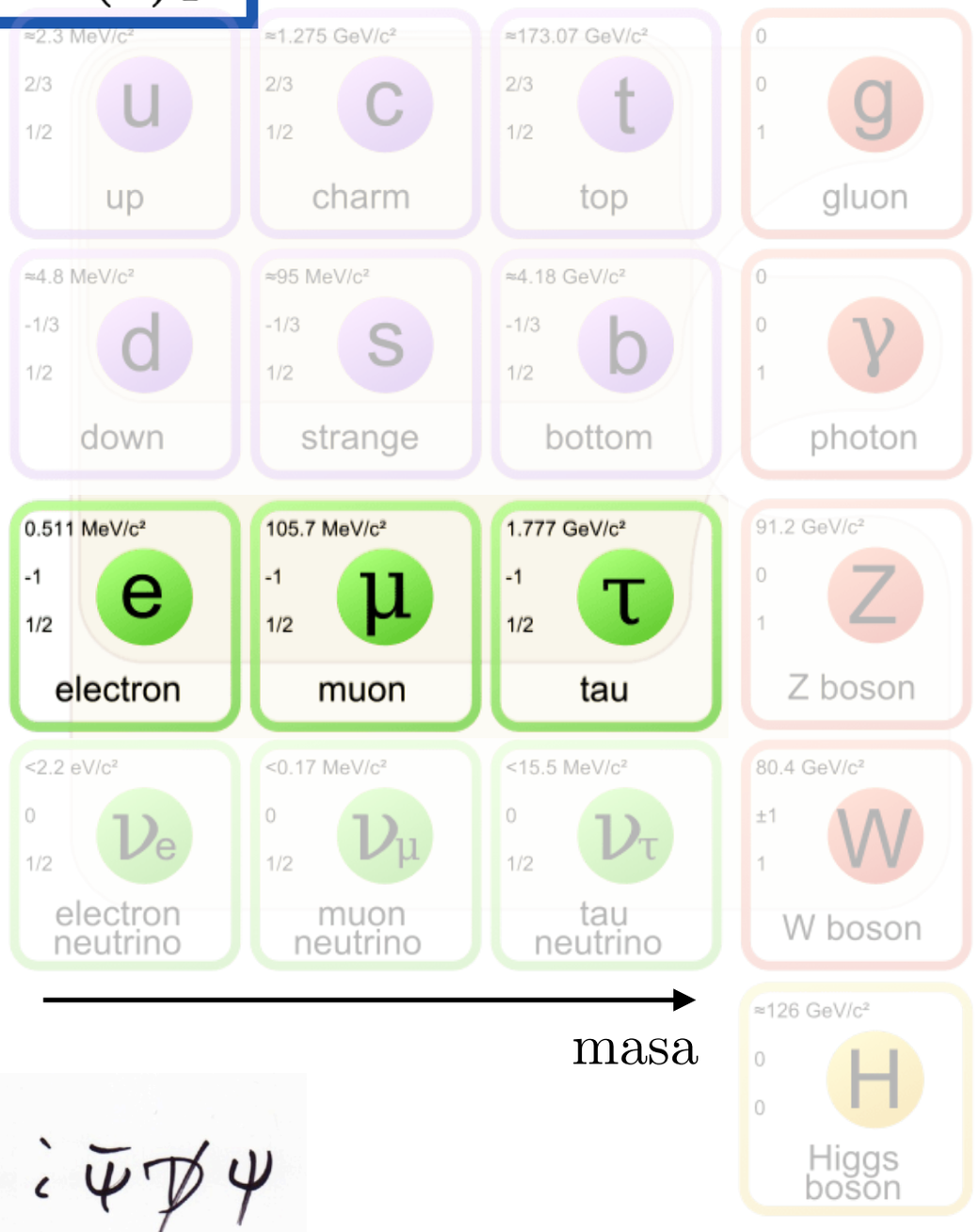

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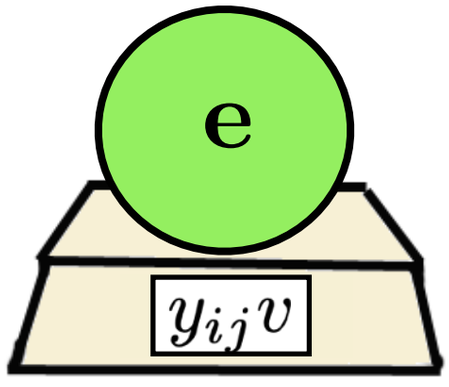

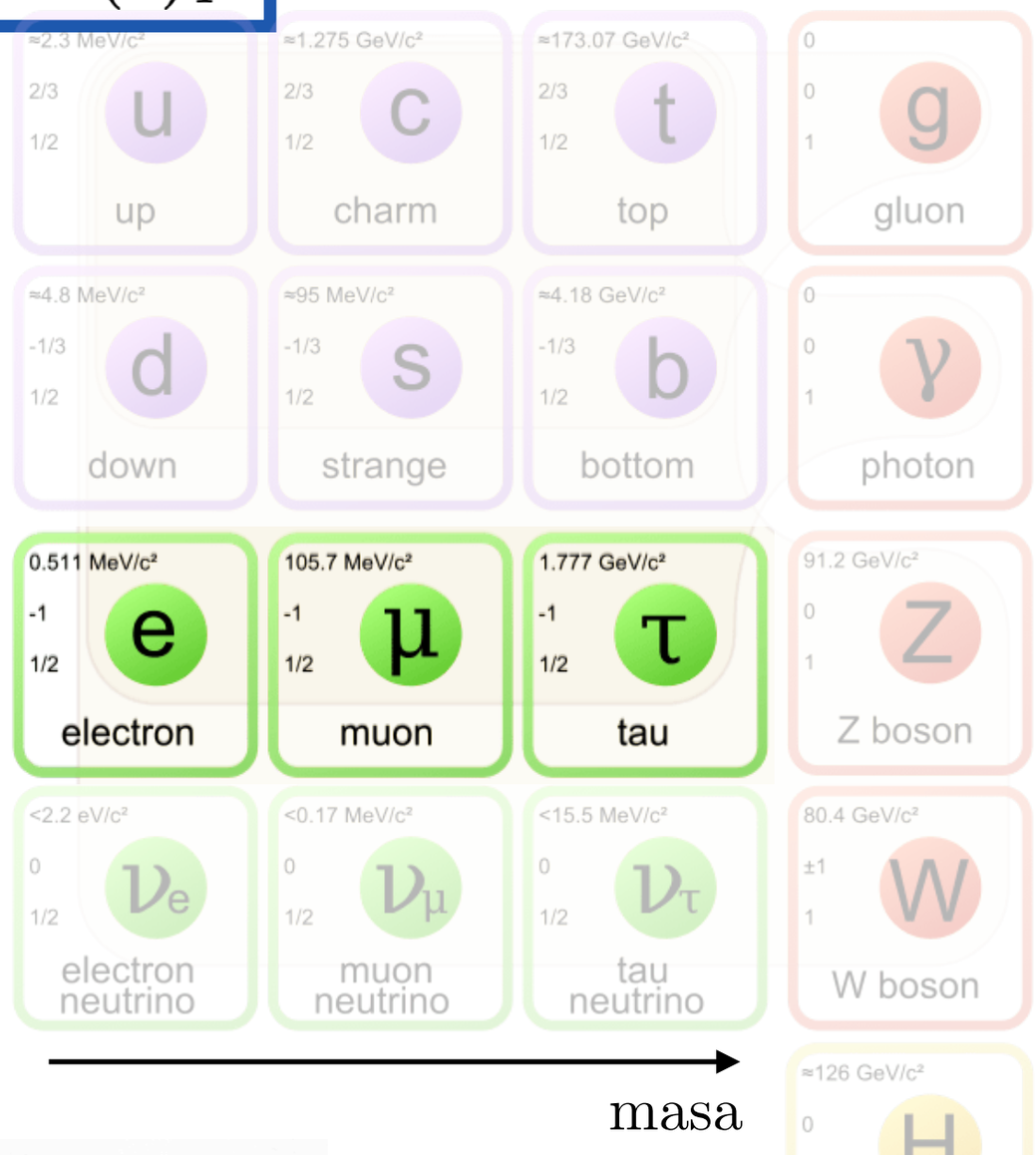

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El Modelo Estándar (recap)

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

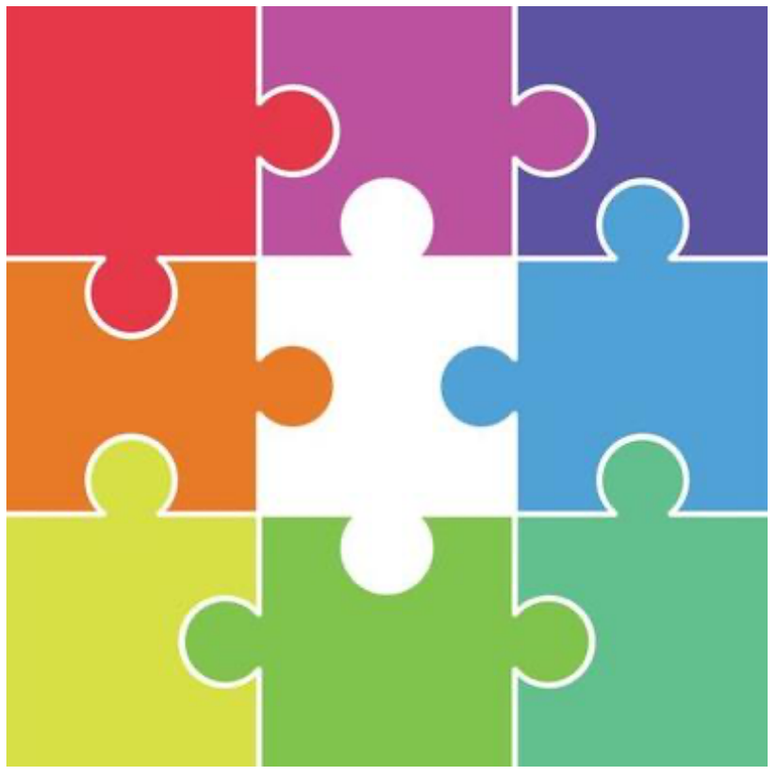
2013

Descubrimiento del bosón de Higgs - 4 Julio 2012

El Modelo Estándar (recap)

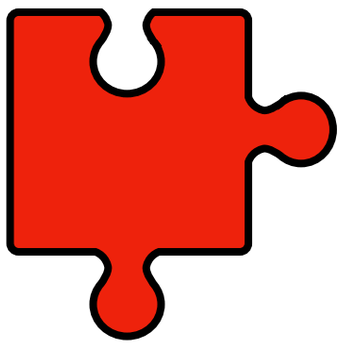
$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

La última pieza del puzzle deja muchos otros puzzles por resolver...



Descubrimiento del bosón de Higgs - 4 Julio 2012

El puzzle de los neutrinos solares



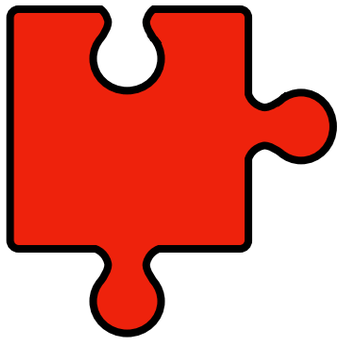
08:30

Neutrinos

Speaker: Laura Perez Molina (CIEMAT - Centro de Investigaciones Energéticas Medioambientales y Tec. (ES))

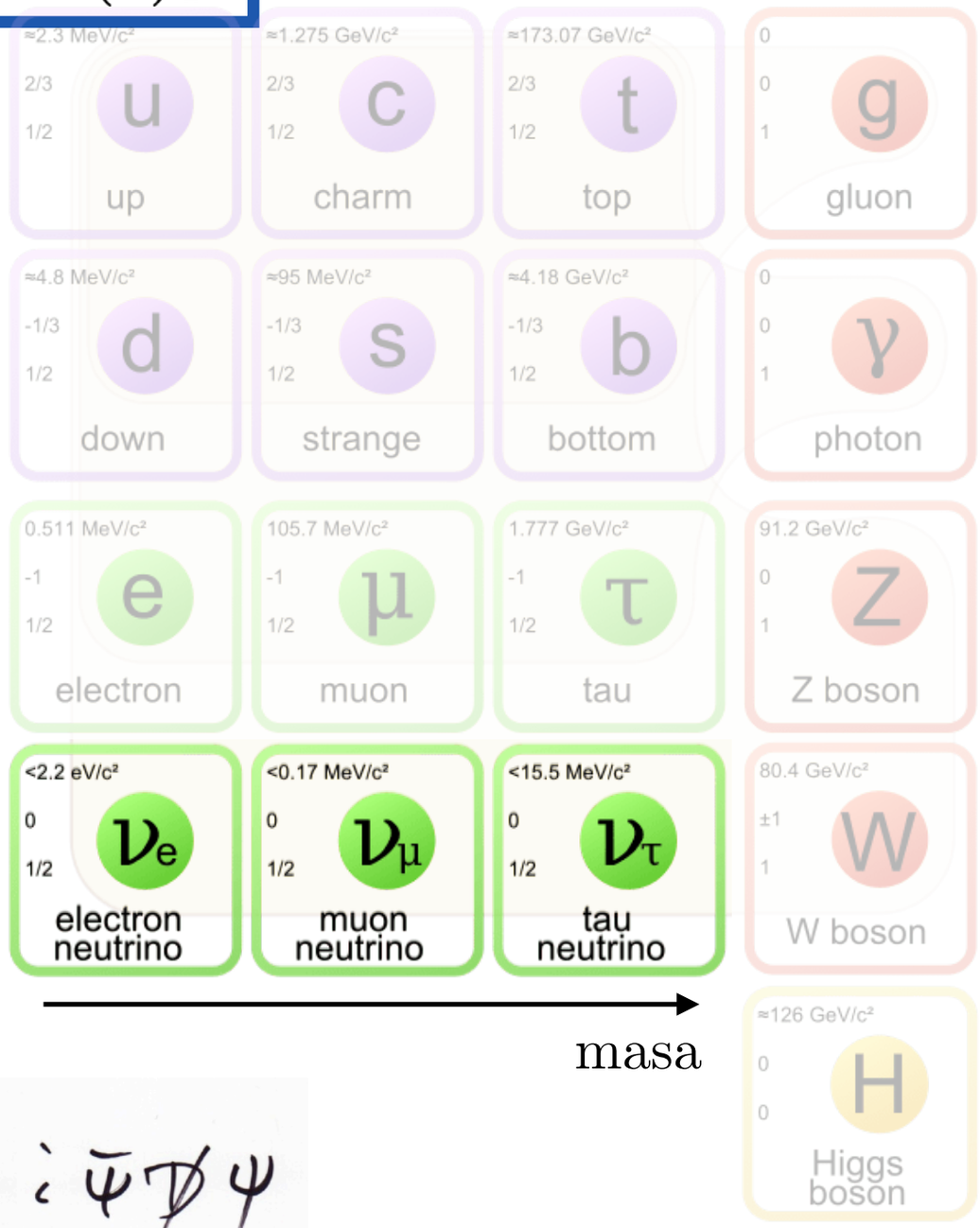
El puzzle de los neutrinos solares

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



e.g. $\underbrace{\begin{pmatrix} \bar{e}_L^i & \bar{\nu}_L^i \end{pmatrix}}_{\bar{L}_L^i} y_{ij} \begin{pmatrix} 0 \\ H_0 \end{pmatrix} e_R^j + \text{h.c.}$

$$= \bar{e}_L^i y_{ij} (h_0 + v) e_R^j + \text{h.c.}$$

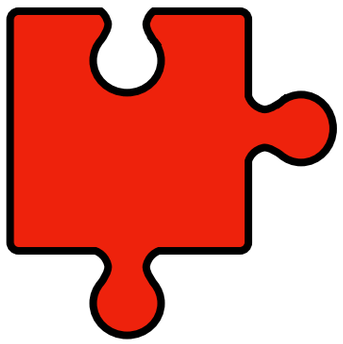


$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\Psi} \not{D} \Psi$$

$$+ \bar{\Psi}_i y_{ij} \Psi_j \phi + \text{h.c.} + |D_\mu \phi|^2 - V(\phi)$$

El puzzle de los neutrinos solares

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



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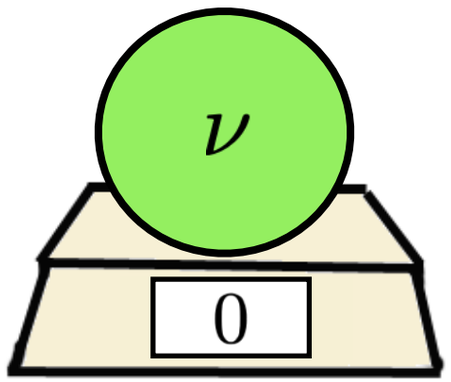

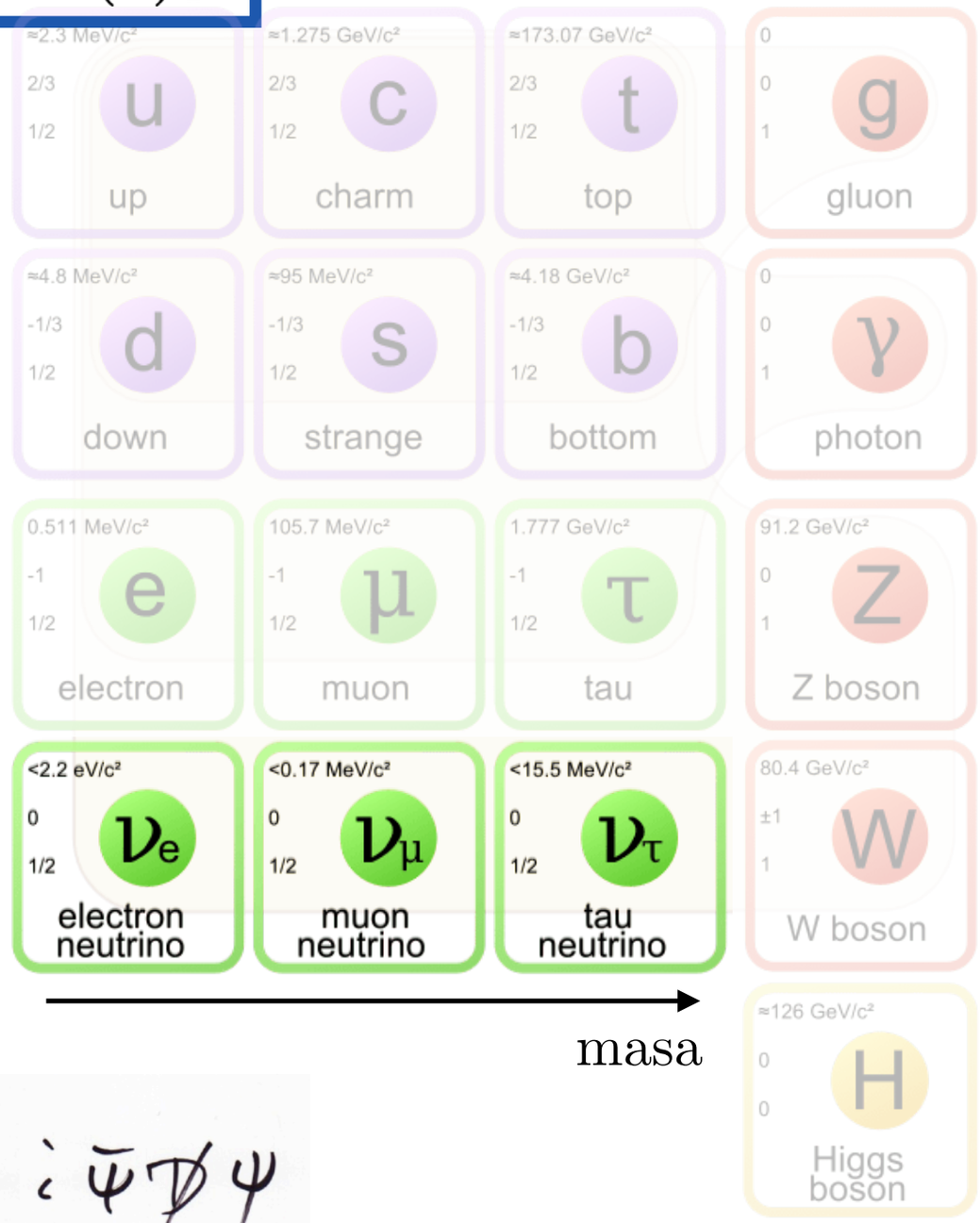

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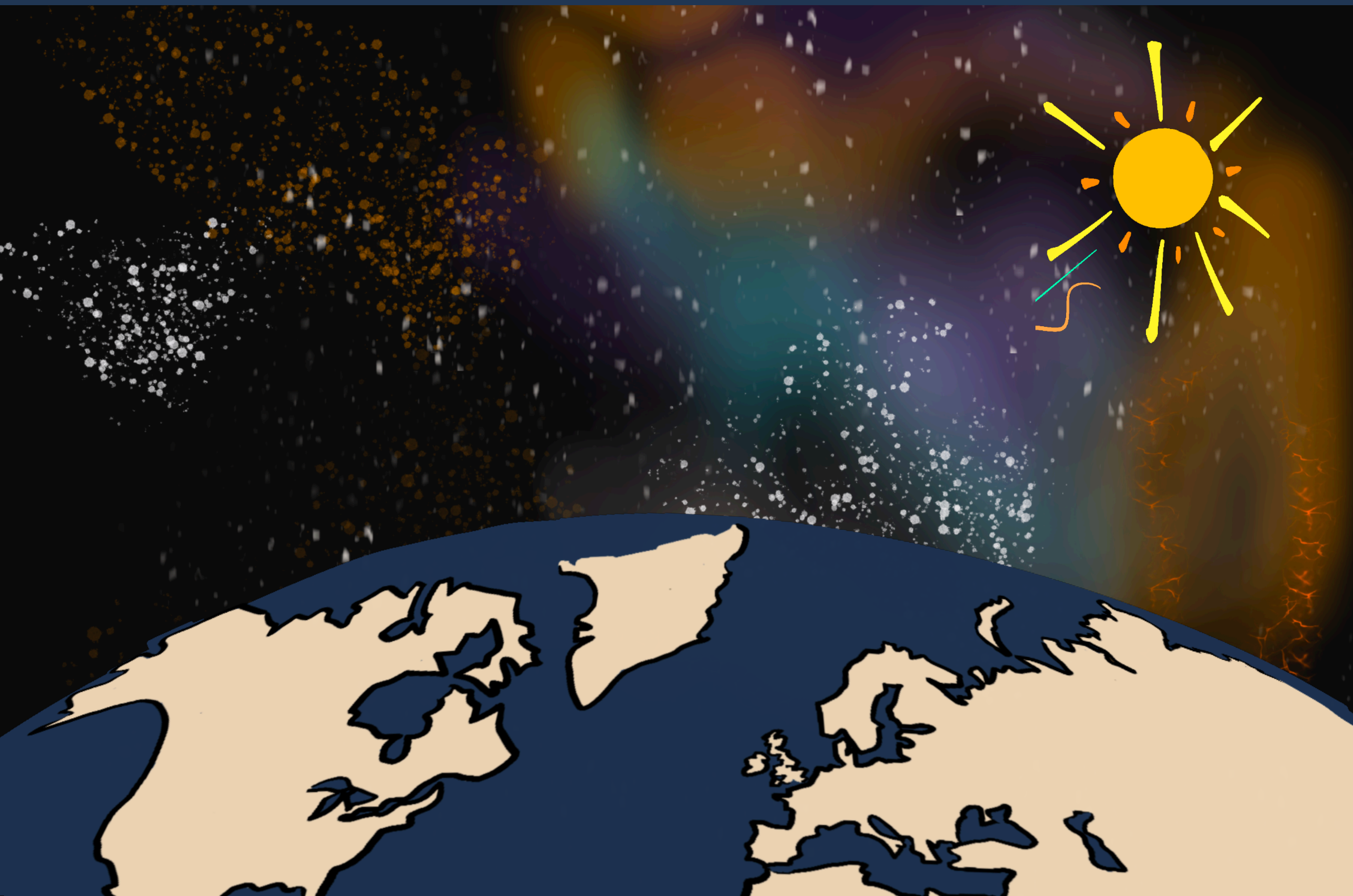
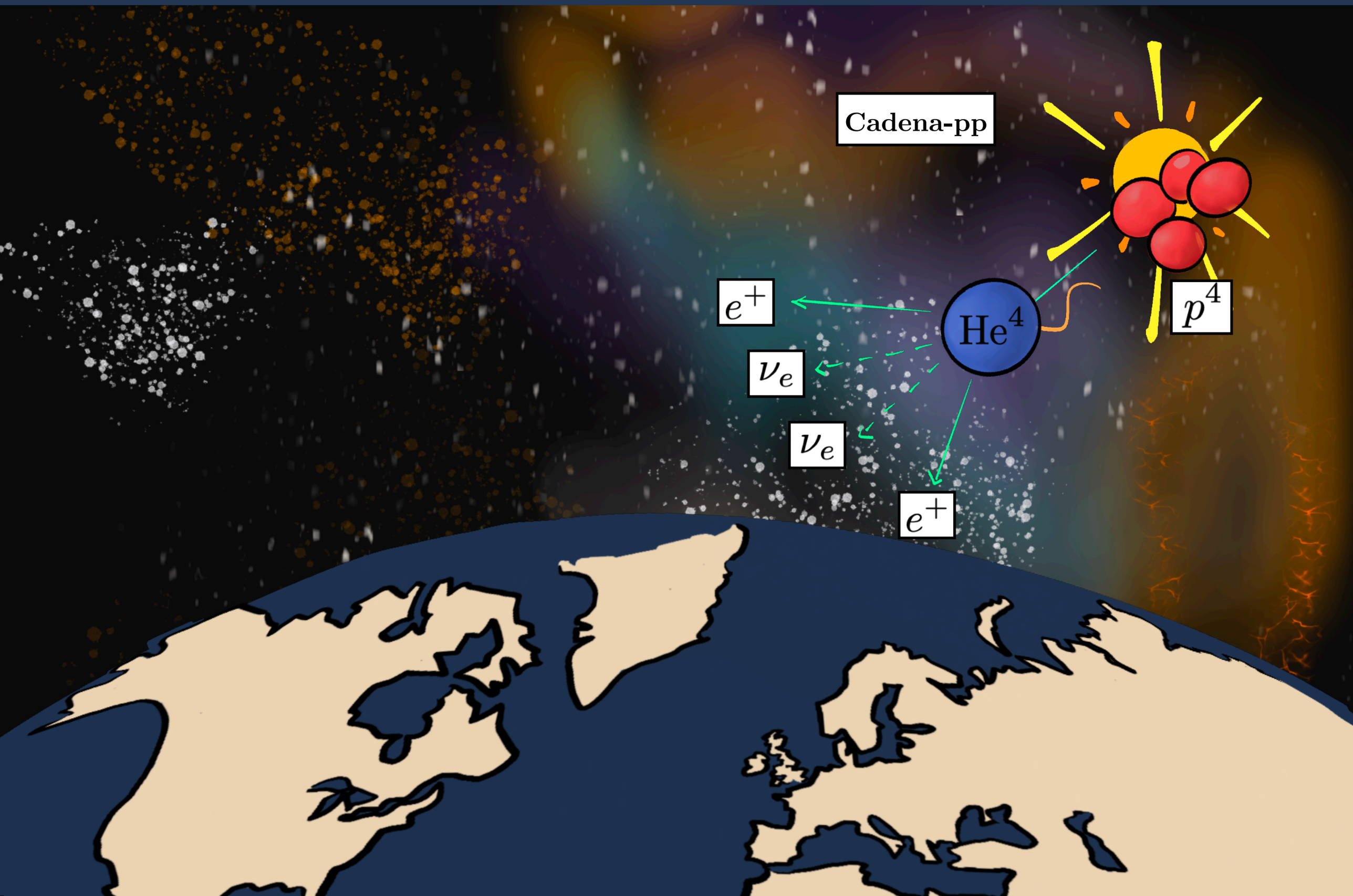
El puzzle de los neutrinos solares



El puzzle de los neutrinos solares



El puzzle de los neutrinos solares

Cadena-pp

e^+

ν_e

ν_e

e^+

He^4

p^4

Davis & Bahcall
[Homestake, 1960]

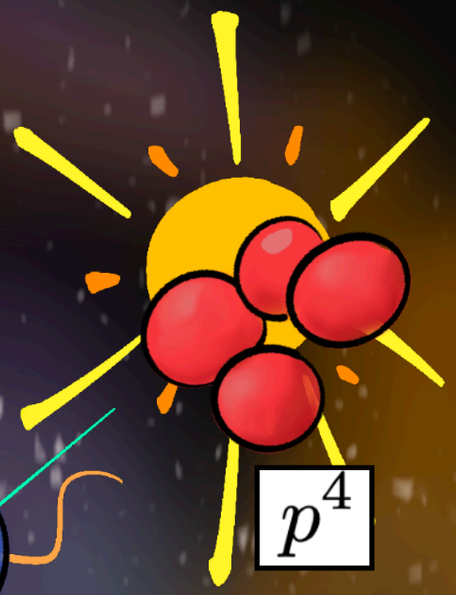
$$\nu_e + {}^{37}\mathrm{Cl} \rightarrow {}^{37}\mathrm{Ar}^+ + e^-$$

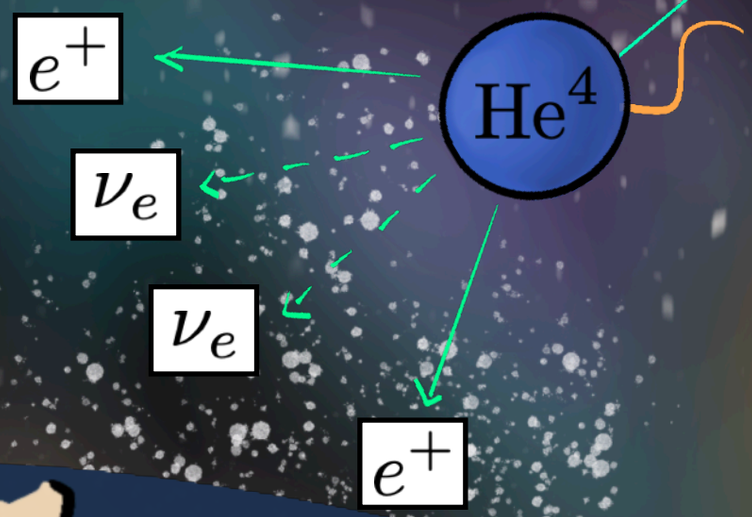
El puzzle de los neutrinos solares

2002 - Davis & Koshiba

1/3

Cadena-pp





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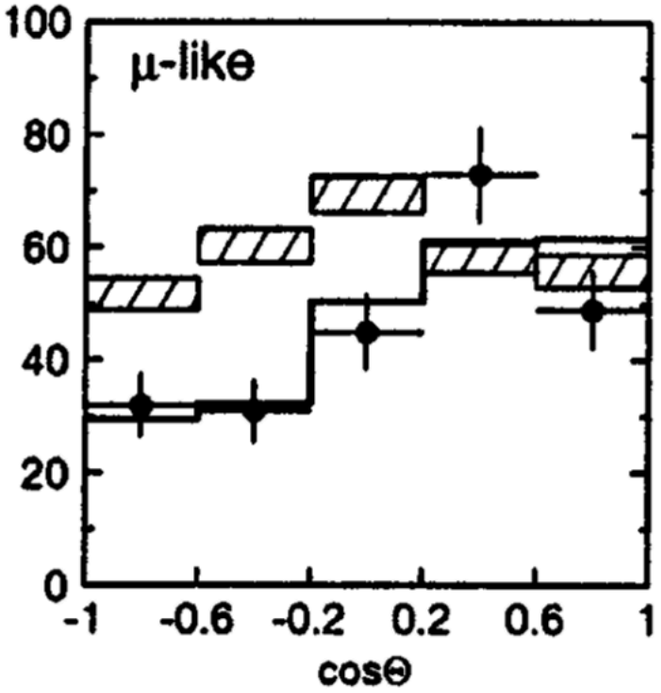
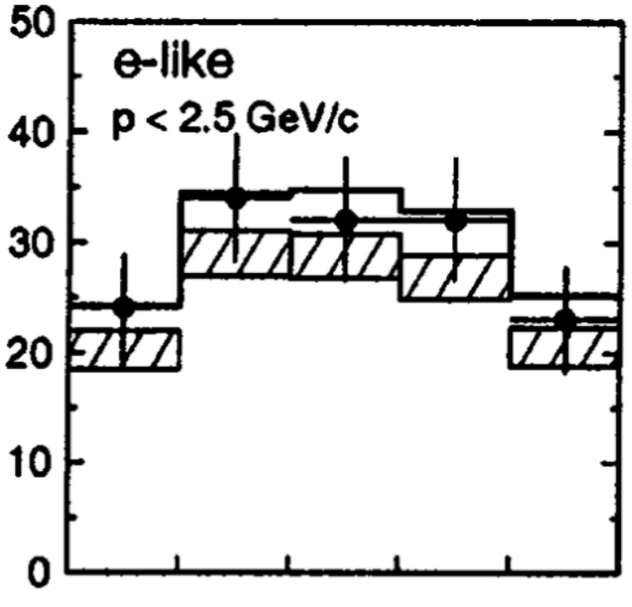
La masa de los neutrinos

2002 - Davis & Koshiba

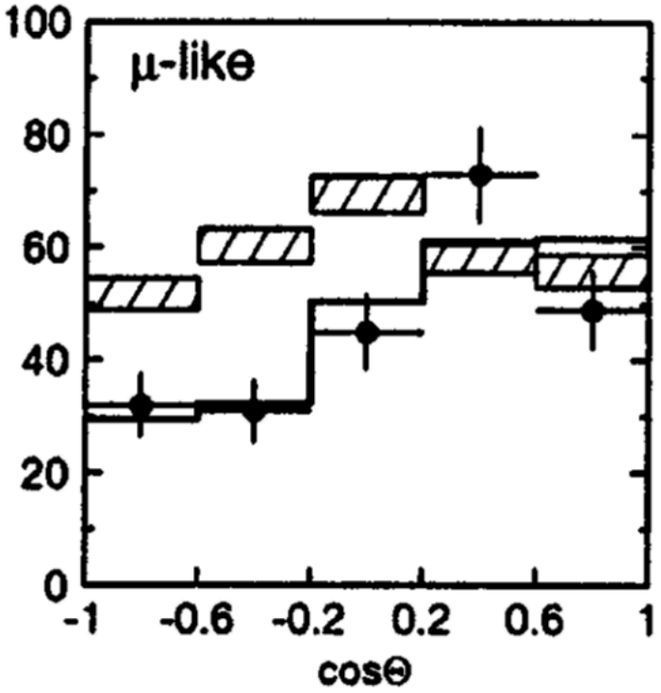


2015 - Kajita & McDonald



La masa de los neutrinos

2002 - Davis & Koshiba



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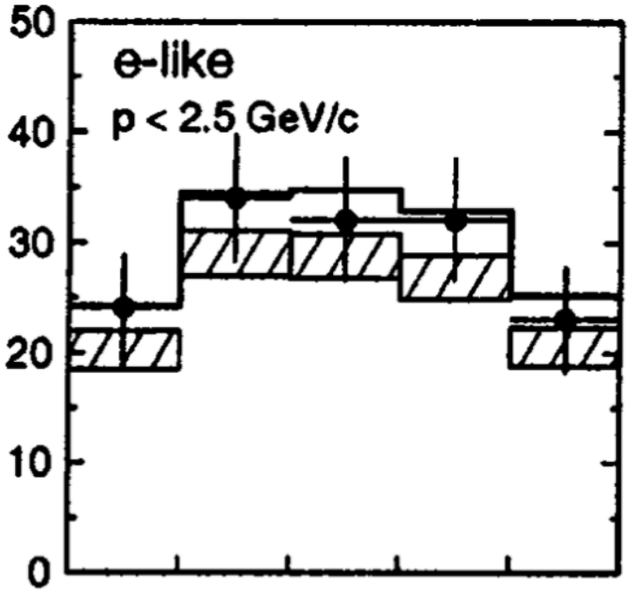
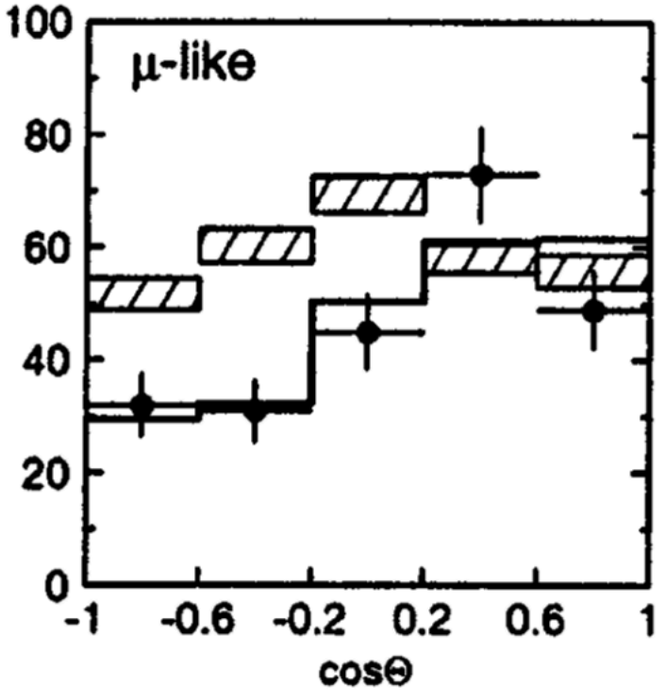


La masa de los neutrinos

2002 - Davis & Koshiba

$$P_{\alpha\to\beta} = |\langle\nu_\beta|\nu_\alpha(L)\rangle|^2 = \left|\sum_j U^*_{\alpha j} U_{\beta j} e^{-im_j^2 L/(2E)}\right|^2$$



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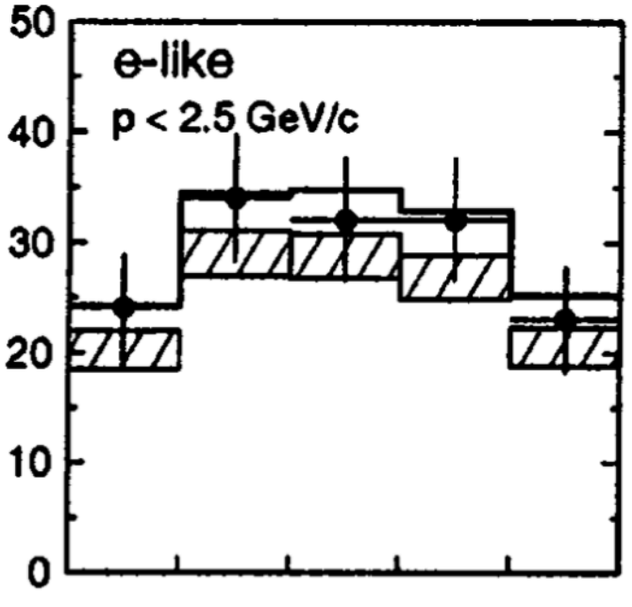

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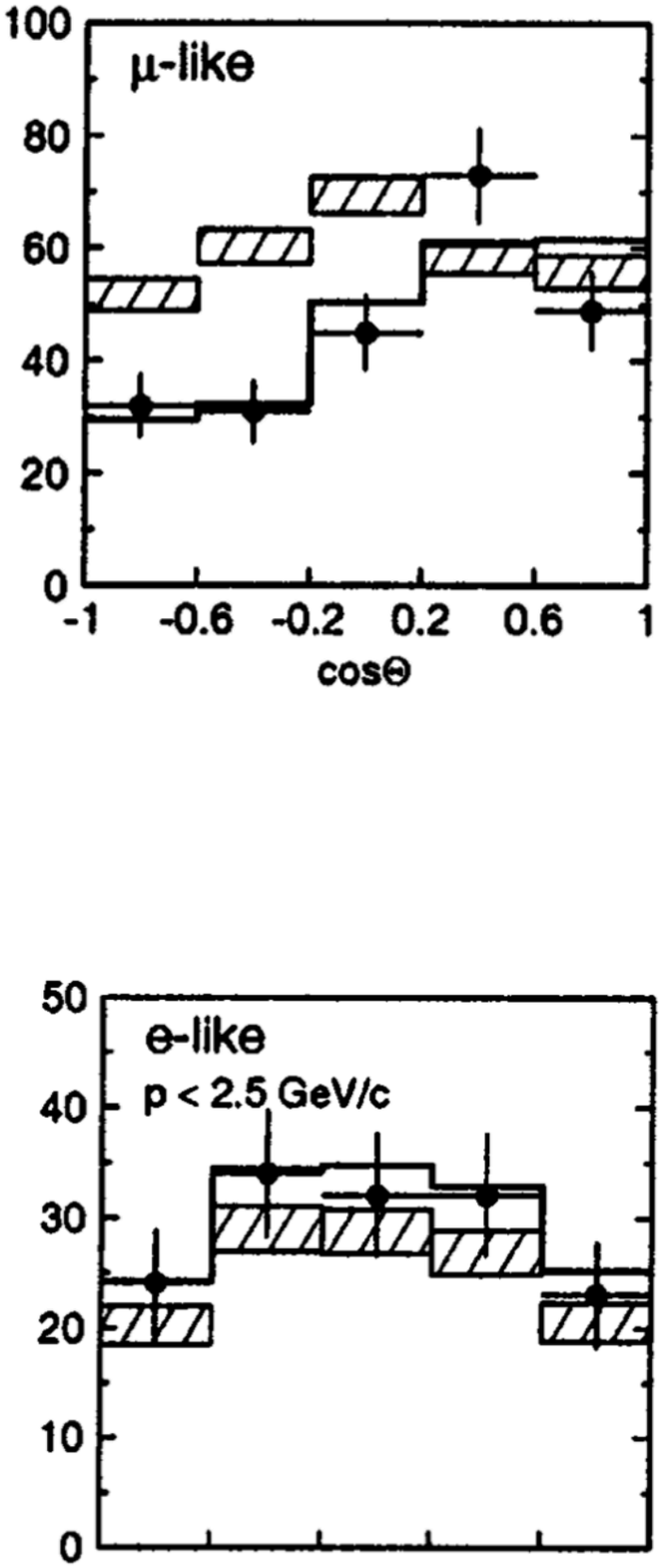
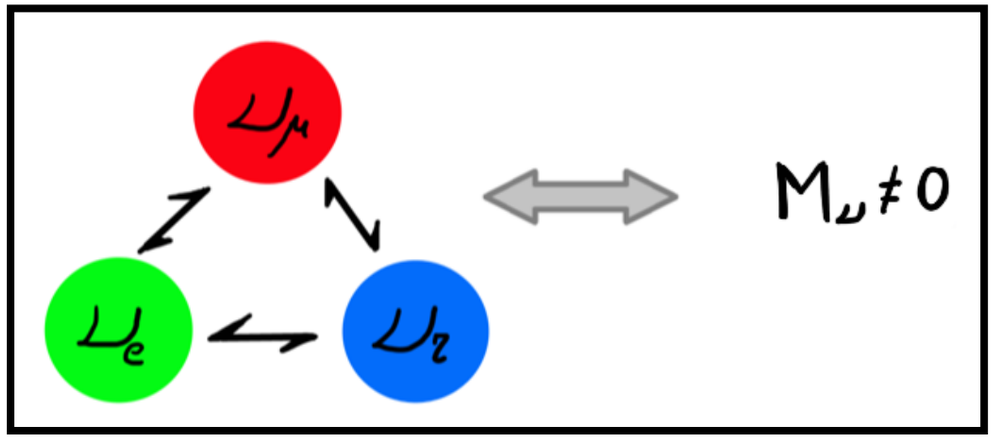
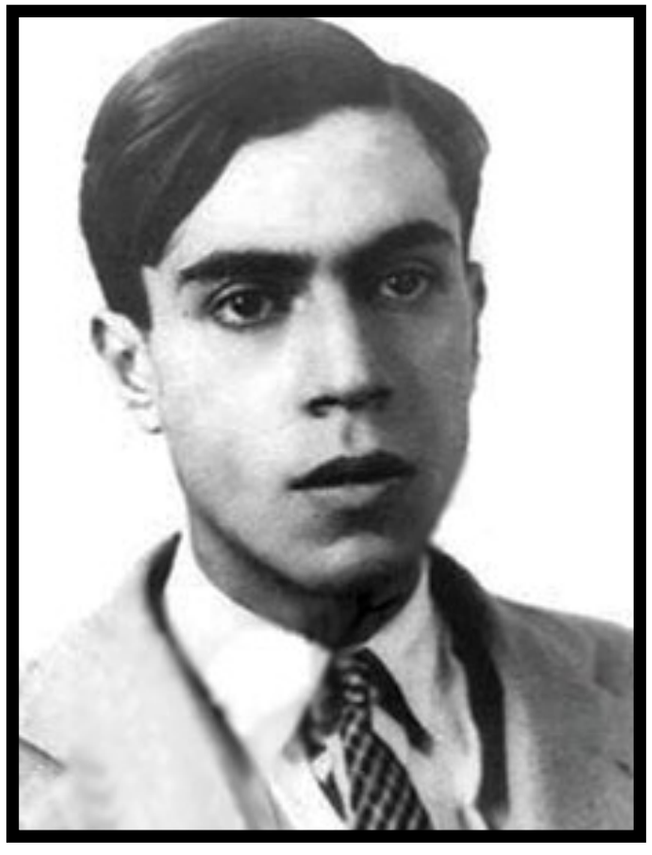




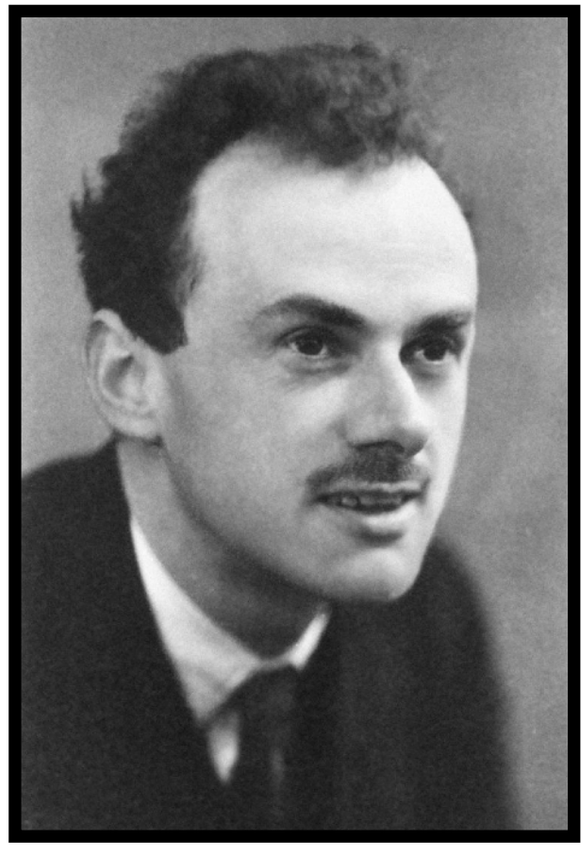
2015 - Kajita & McDonald

Majorana o Dirac?

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



VS



$$\nu = \bar{\nu}$$

$$M_M \nu^T C \nu$$

$$\nu \neq \bar{\nu}$$

$$m_D \bar{\nu} \nu$$

Majorana o Dirac?

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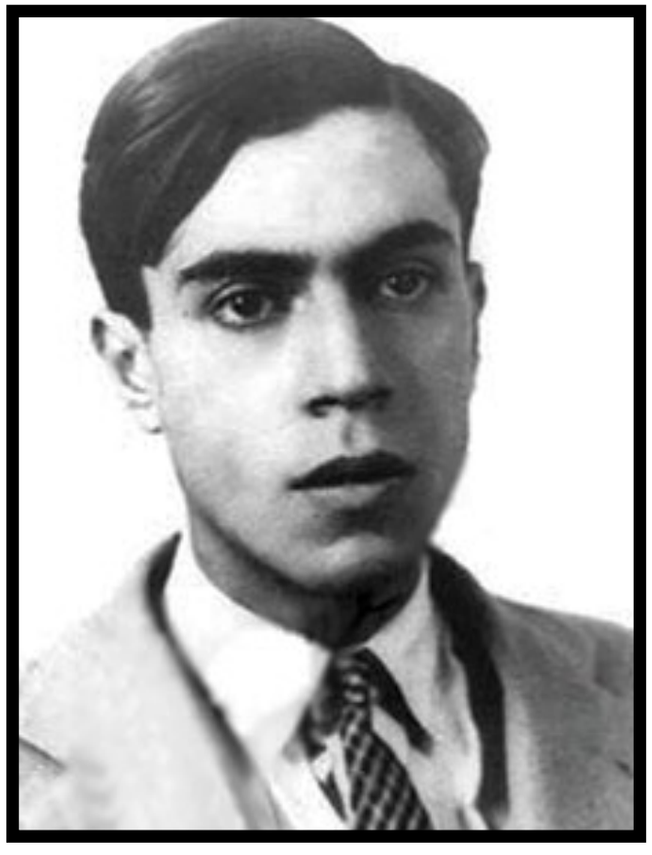
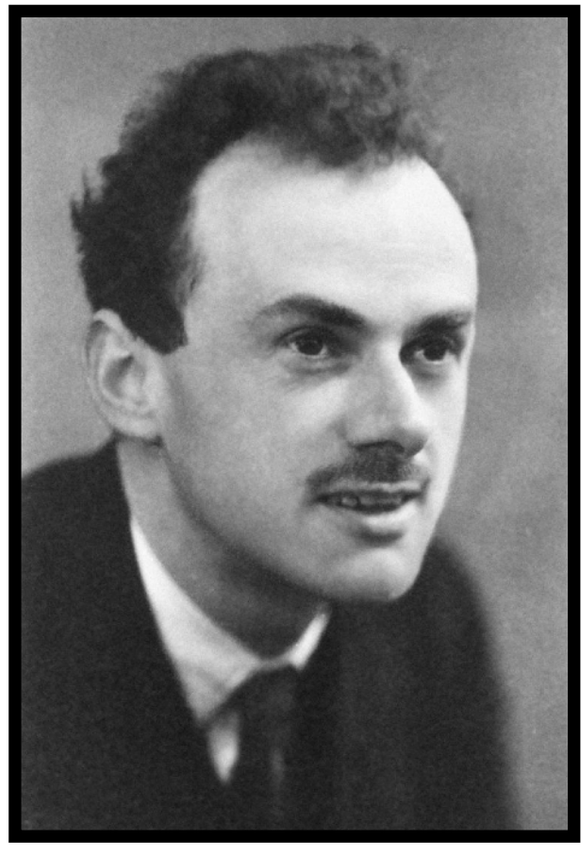


VS



$$\nu = \bar{\nu}$$

$$M_M \nu^T C \nu$$

$$\nu \to e^{i\theta}\nu \quad \Rightarrow \Delta L = 2$$

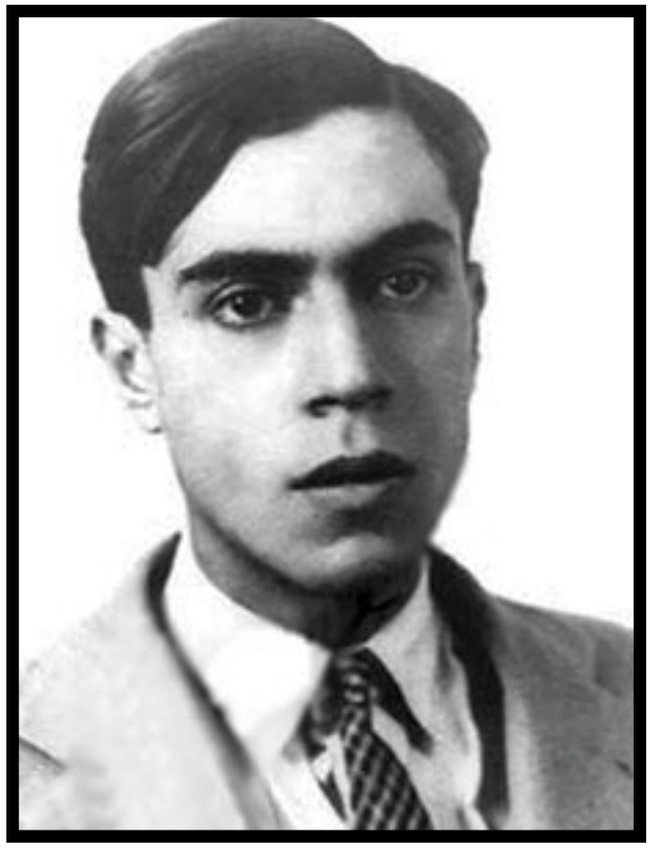
$$\nu \neq \bar{\nu}$$

$$m_D \bar{\nu} \nu$$

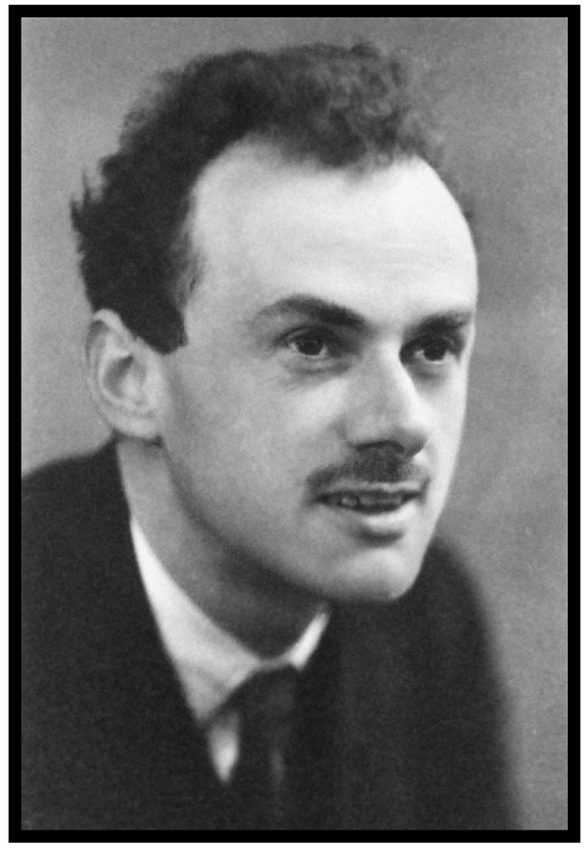
$$\nu \to e^{i\theta}\nu \quad \Rightarrow \Delta L = 0$$

Majorana o Dirac?

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



V/S



$\nu = \bar{\nu}$

$M_M \nu^T C \nu$

$\nu \to e^{i\theta}\nu \quad \Rightarrow \Delta L = 2$

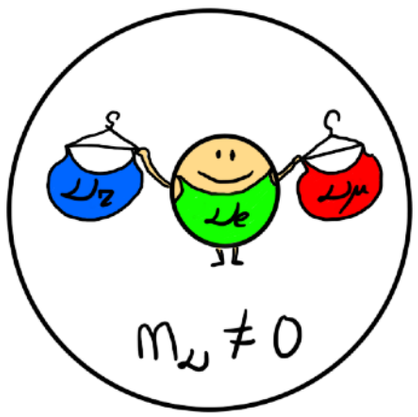
Se necesita contenido extra!

$\nu \neq \bar{\nu}$

$m_D \bar{\nu}\nu$

$\nu \to e^{i\theta}\nu \quad \Rightarrow \Delta L = 0$

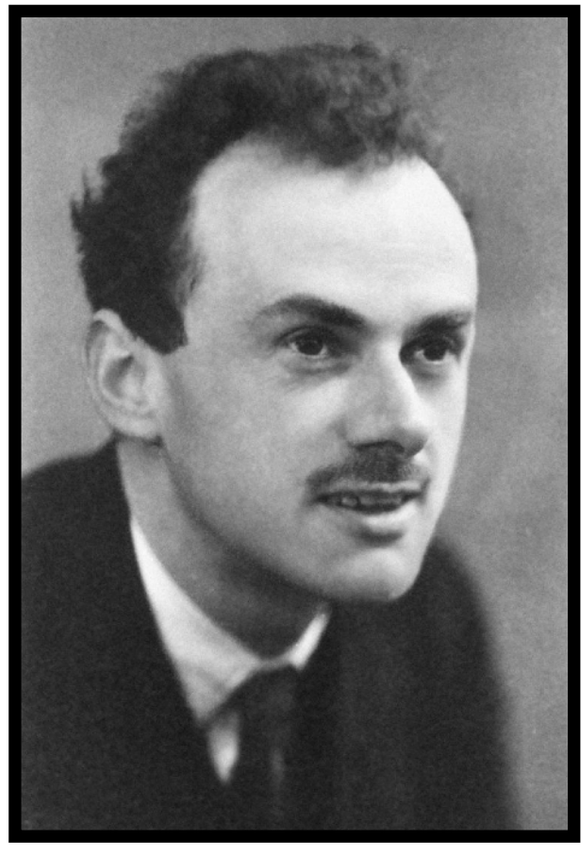
Más allá del modelo estandar



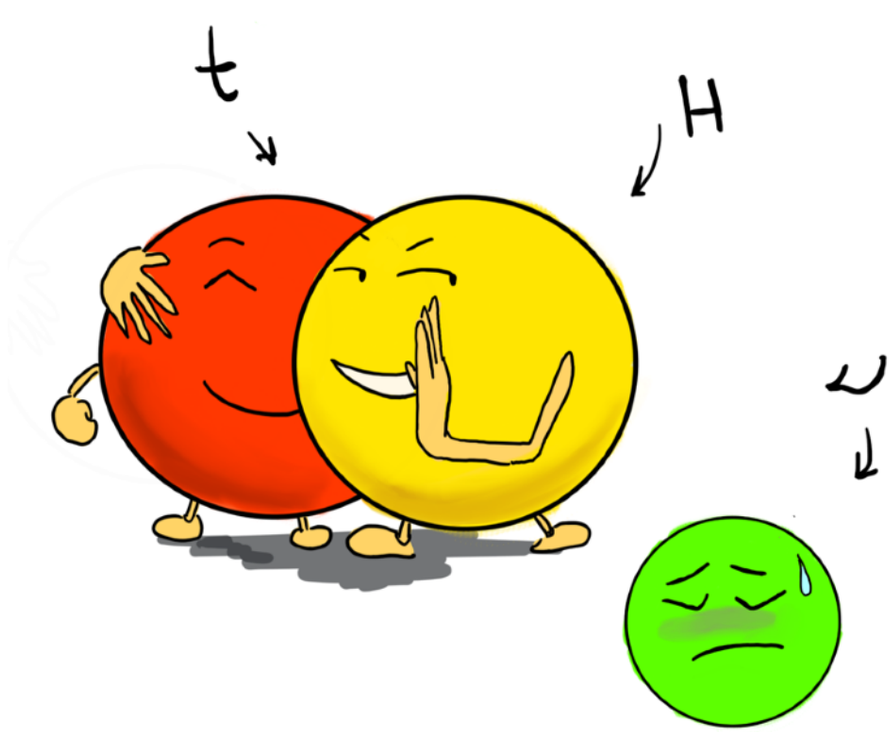
Mecanismos para generar la masa

Añadimos un singlete ν_R

Si son **Dirac**...



$$m_\nu < 10^{-10}\ \text{GeV} \quad \Rightarrow \quad Y_\nu \sim 10^{-12}$$

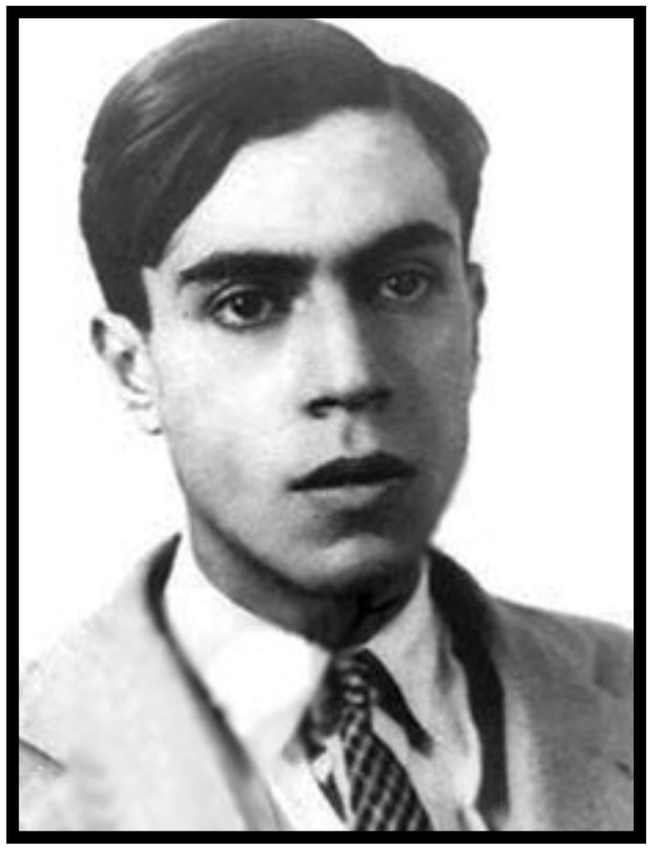


$$\nu \neq \bar{\nu}$$

$$\mathcal{L} \supset Y_\nu \, \bar{L}_L (i\sigma_2) H^* \nu_R$$

Mecanismos para generar la masa

Añadimos un singlete ν_R



Si en vez son **Majorana**...

$$M_\nu = \begin{pmatrix} 0 & y_\nu v \\ y_\nu v & M_R \end{pmatrix}$$

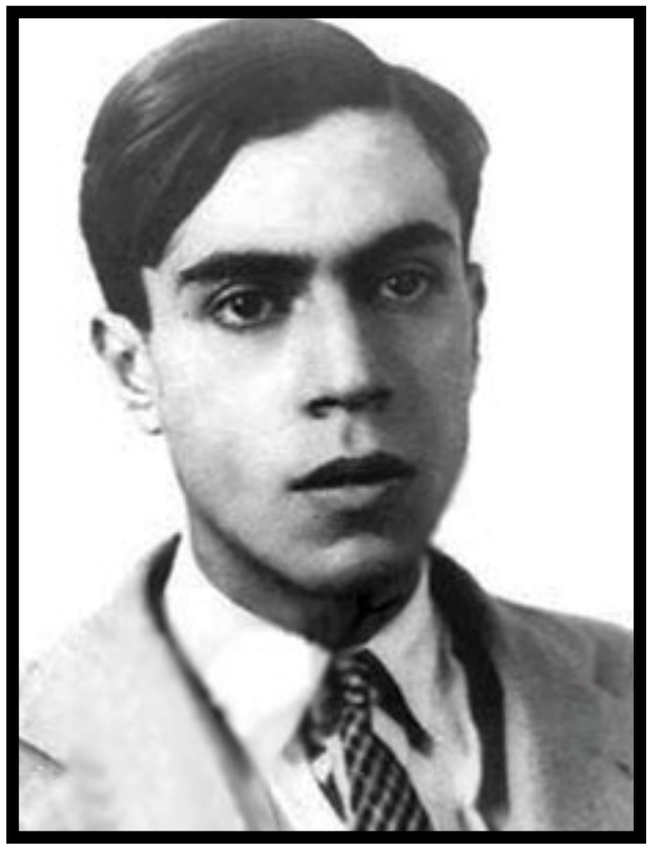
$$\nu = \bar{\nu}$$

$$M_R \nu_R^T C \nu_R$$

$$\Delta L = 2$$

Mecanismos para generar la masa

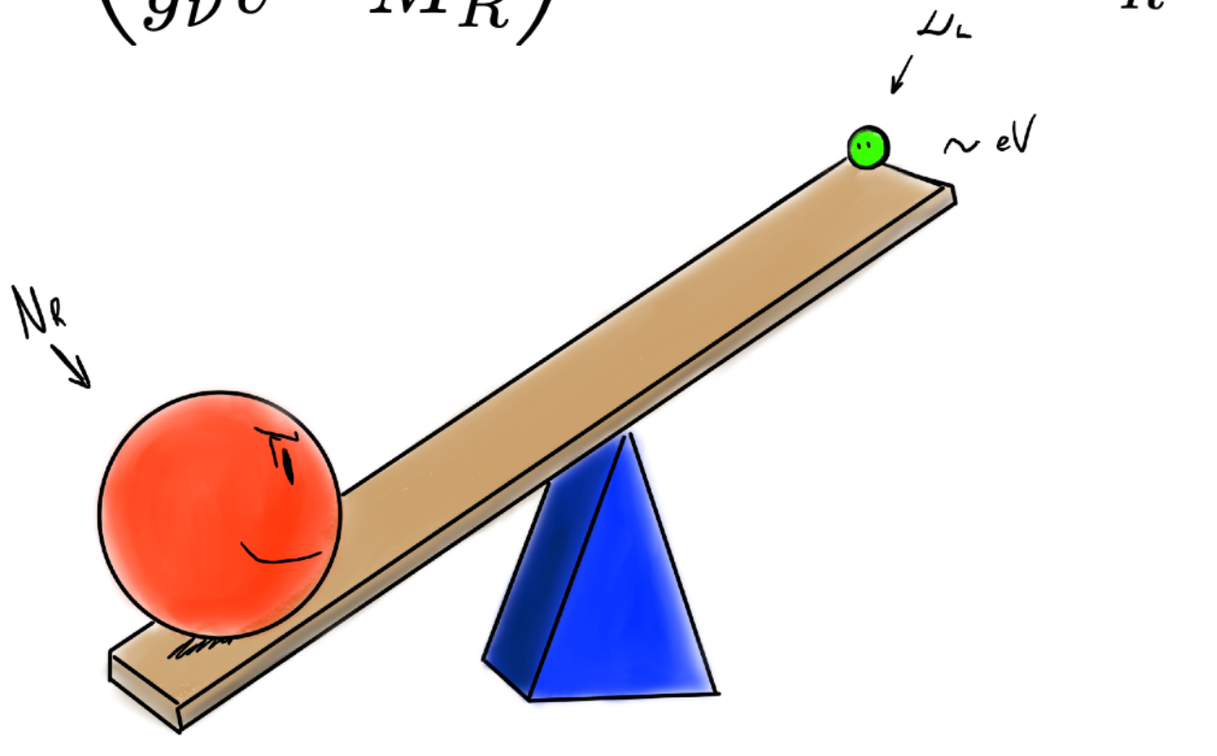
Añadimos un singlete ν_R



Si en vez son **Majorana**...

El mecanismo del "balancín"

$$M_\nu = \begin{pmatrix} 0 & y_\nu v \\ y_\nu v & M_R \end{pmatrix} \qquad m_\nu \sim \frac{(y_\nu v)^2}{M_R}$$



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Y la antimateria?

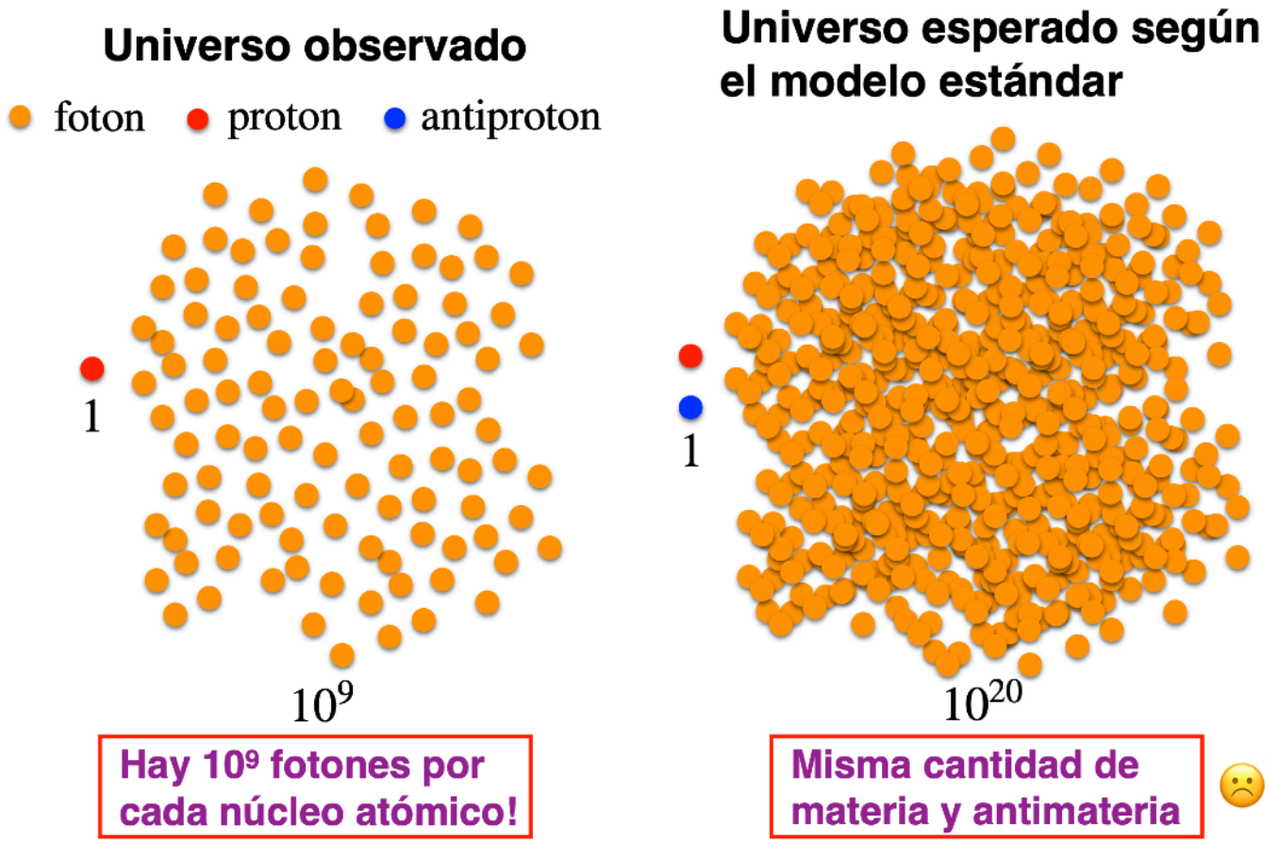
[diapositiva de la charla de Hector]

12:05 **Physics Snacks: Antimateria**

Speaker: Hector Garcia Morales

Y la antimateria?

[diapositiva de la charla de Hector]



[diapositiva de la charla de Miguel]

12:05 **Physics Snacks: Antimateria**

Speaker: Hector Garcia Morales

10:35 **El Modelo estándar y la física fundamental (II)**

Speaker: Miguel Escudero Abenza (CERN)

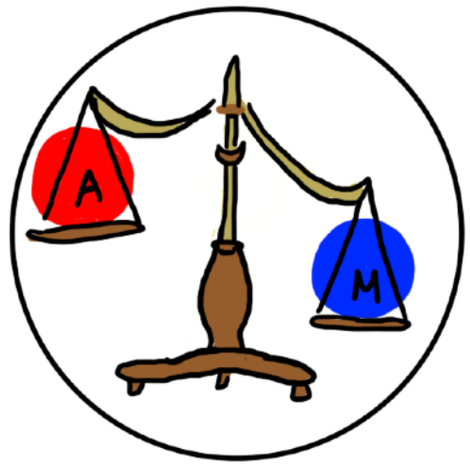
Y la antimateria?

~~**El baile del Chiki Chiki**~~

~~**Uno**: el brikindanse~~

~~**Dos**: el crusaito~~

~~**Tres**: el maiquelyason~~



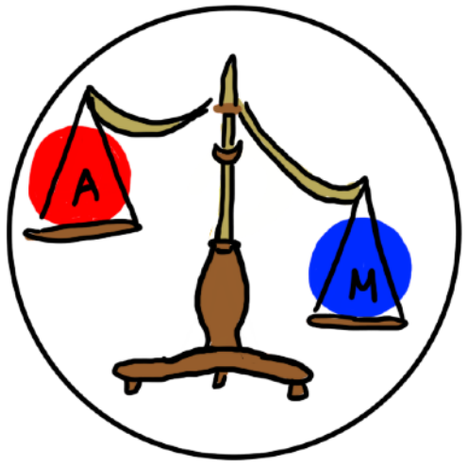
Y la antimateria?

Condiciones de Sakharov

Uno: Violación de Carga conjugada - Paridad (CP)

Dos: Violación del número bariónico

Tres: Salida del equilibrio térmico



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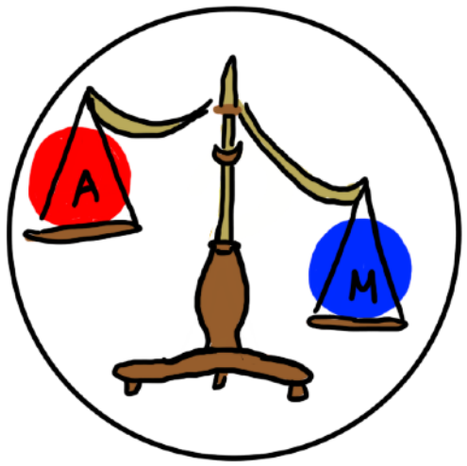

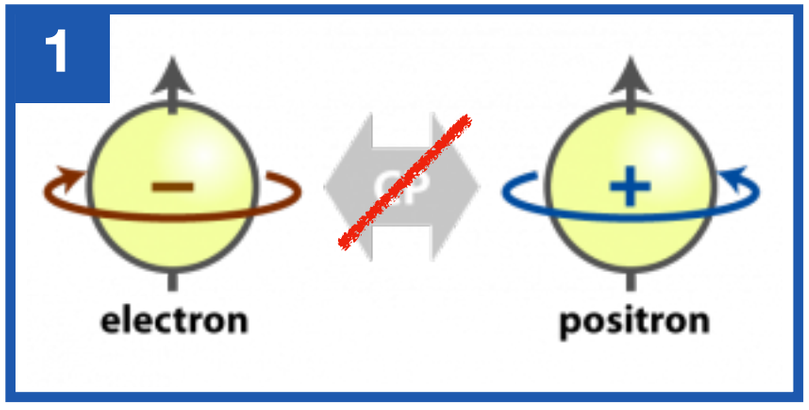

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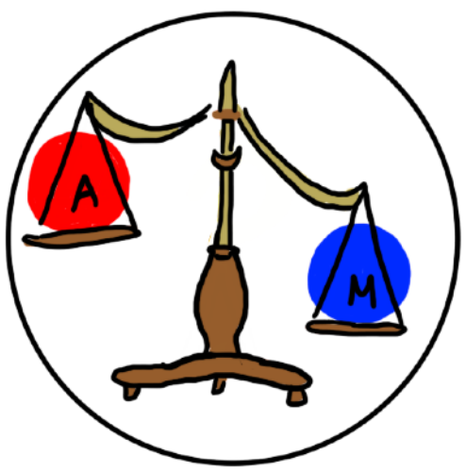

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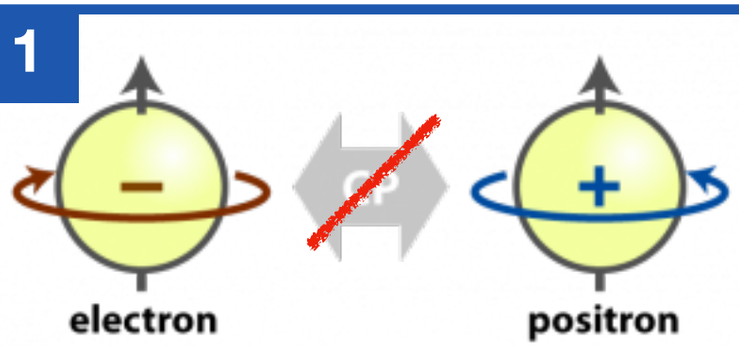
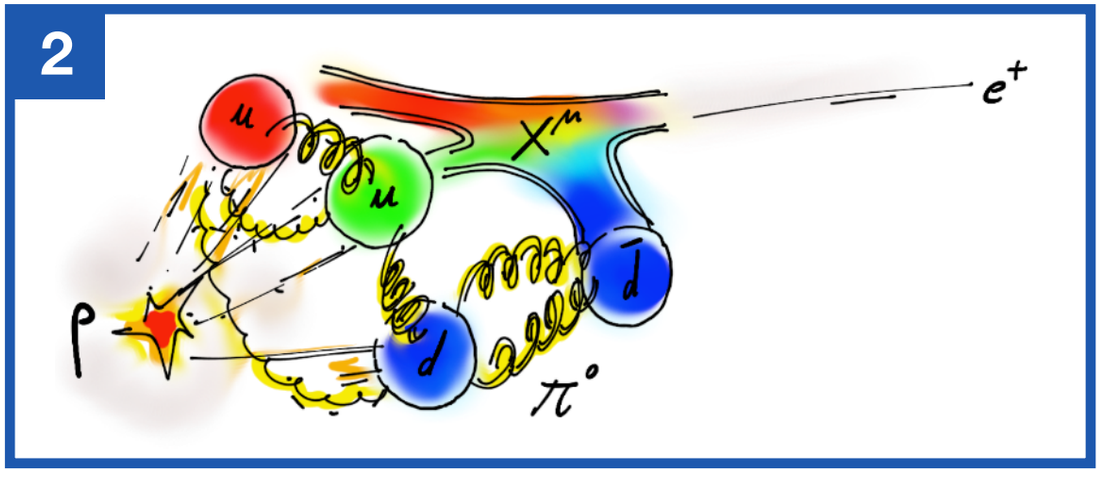


2



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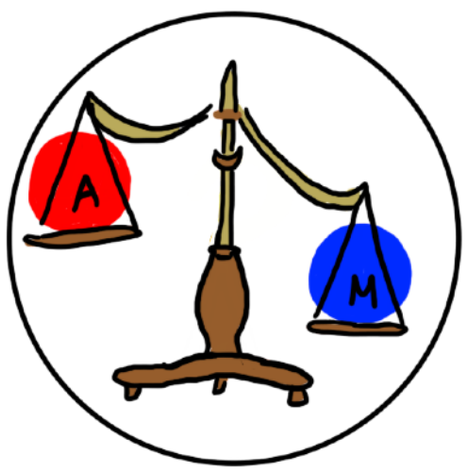

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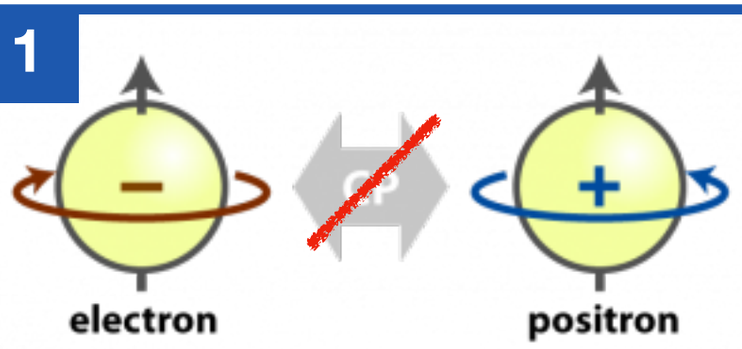
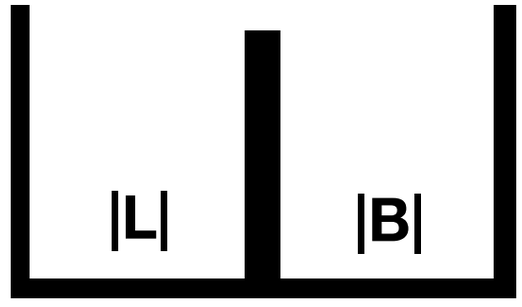


2



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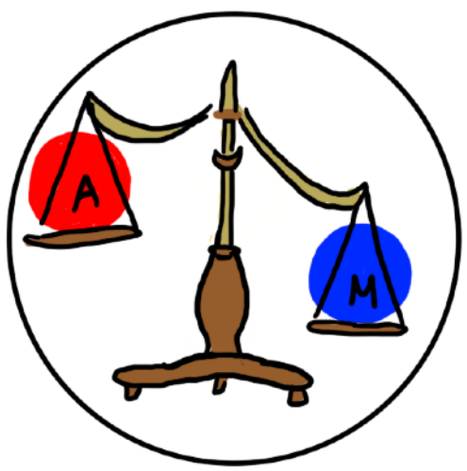

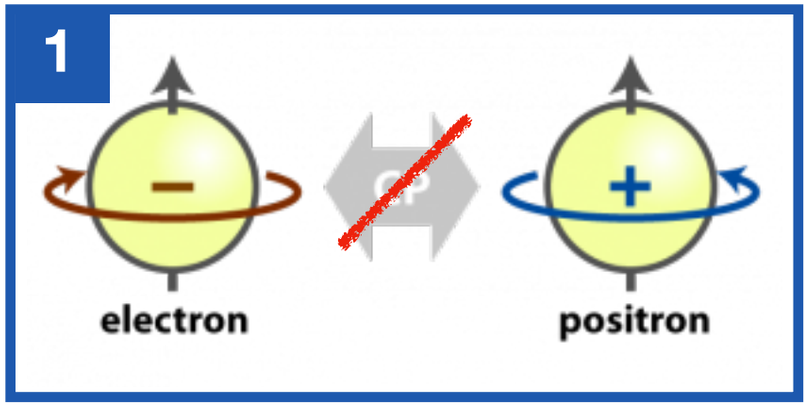

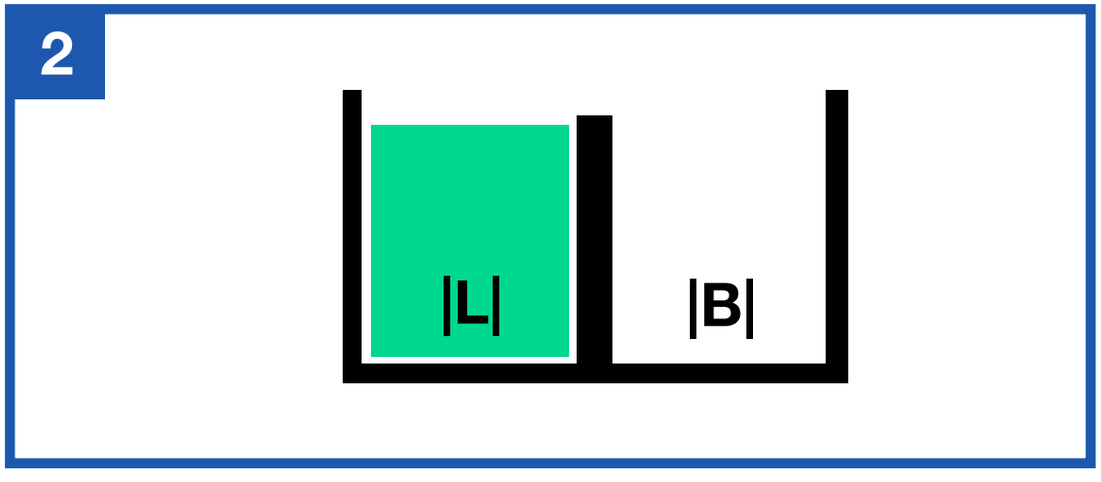

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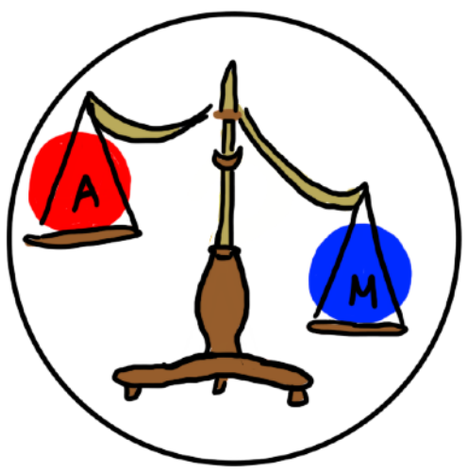
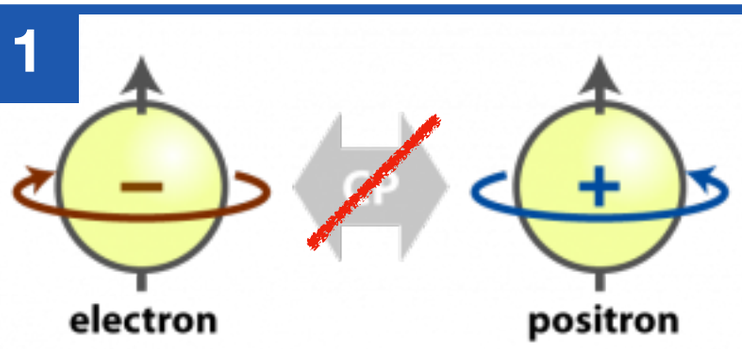
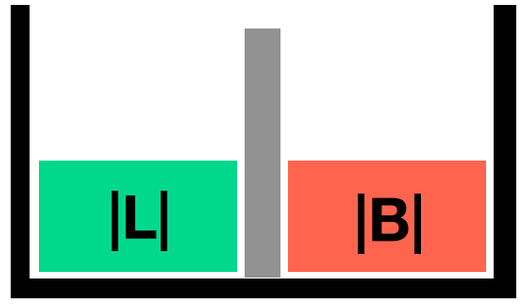


1



2



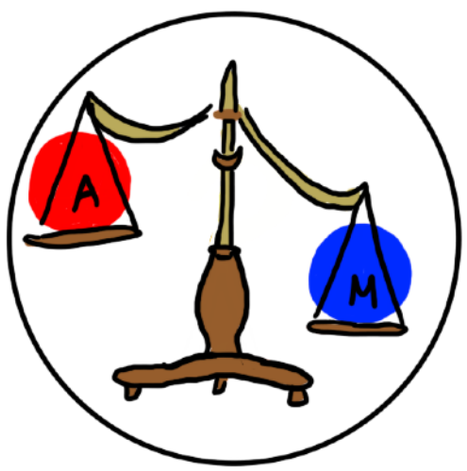
Y la antimateria?

Condiciones de Sakharov

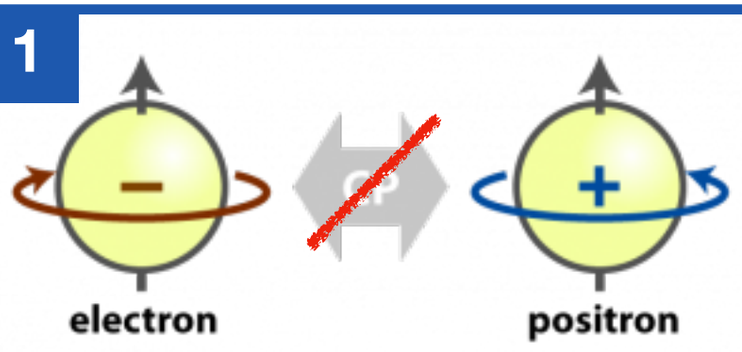
Uno: Violación de Carga conjugada - Paridad (CP)

Dos: Violación del número bariónico

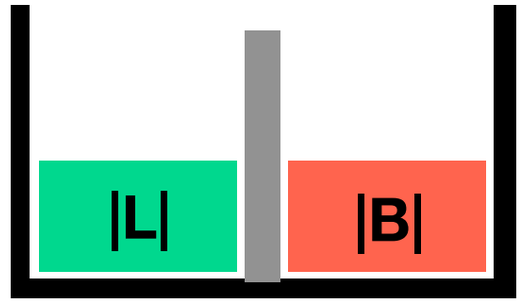
Tres: Salida del equilibrio térmico



1



2



3

Bariogénesis

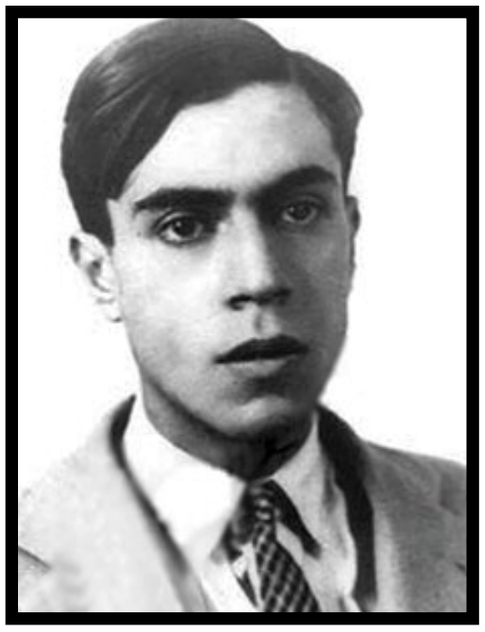
Bariogénesis via Leptogenesis

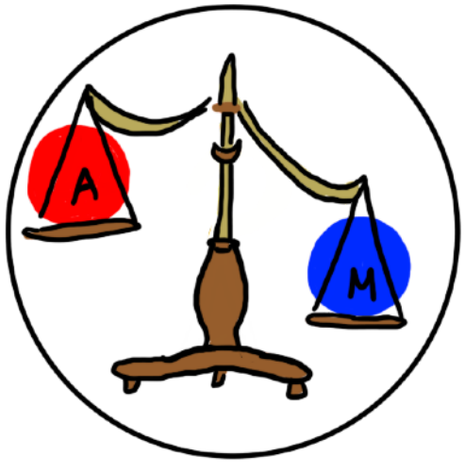
Condiciones de Sakharov

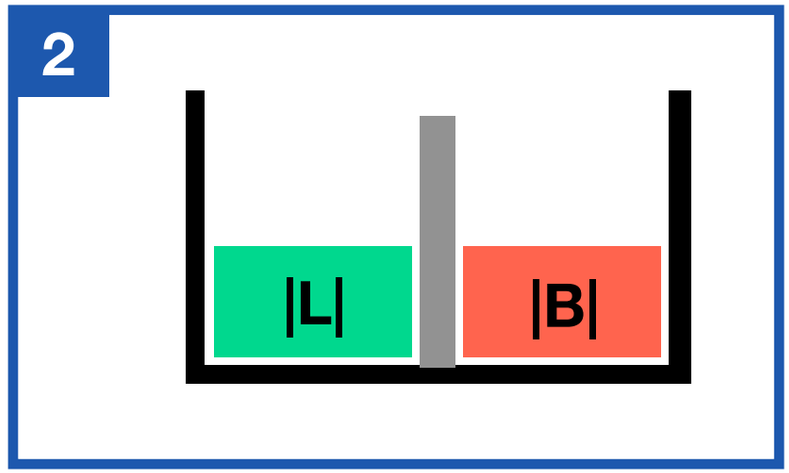
Uno: Violación de Carga conjugada - Paridad (CP)

Dos: Violación del número bariónico

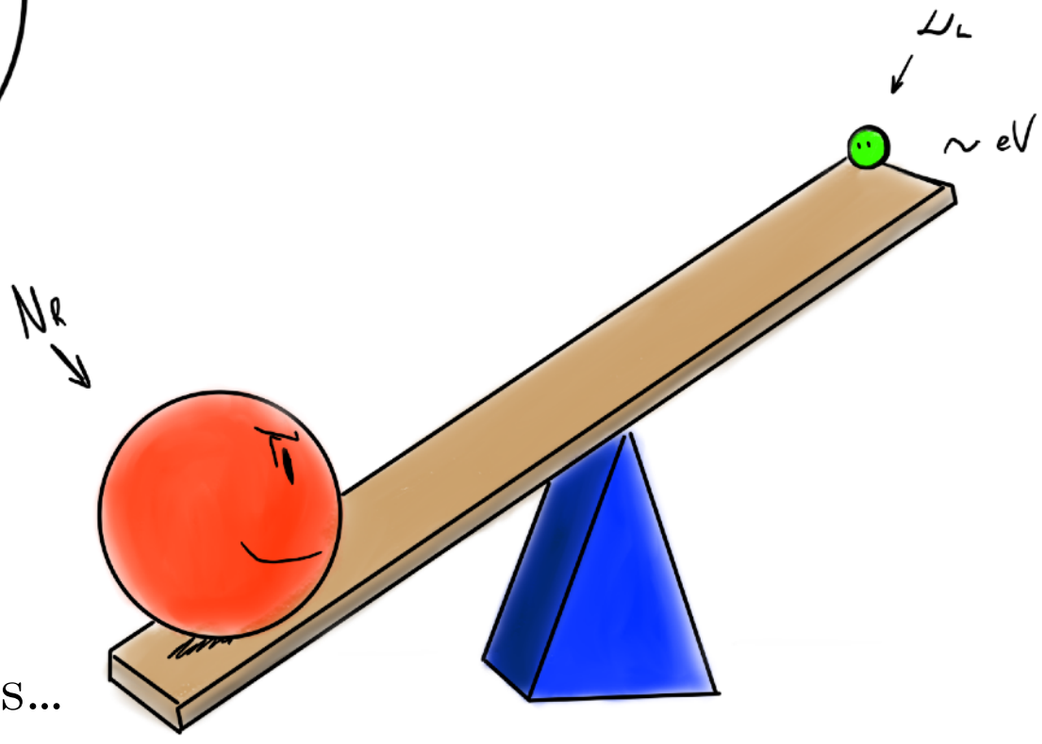
Tres: Salida del equilibrio





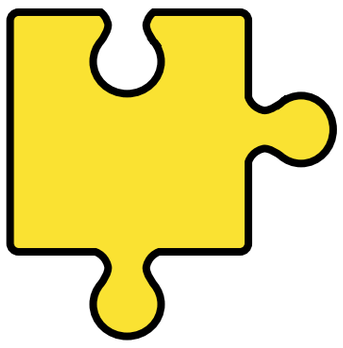


$$\nu = \bar{\nu} \quad \Delta L = 2$$

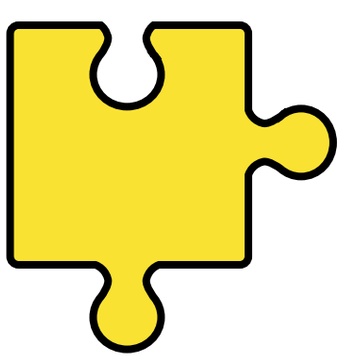


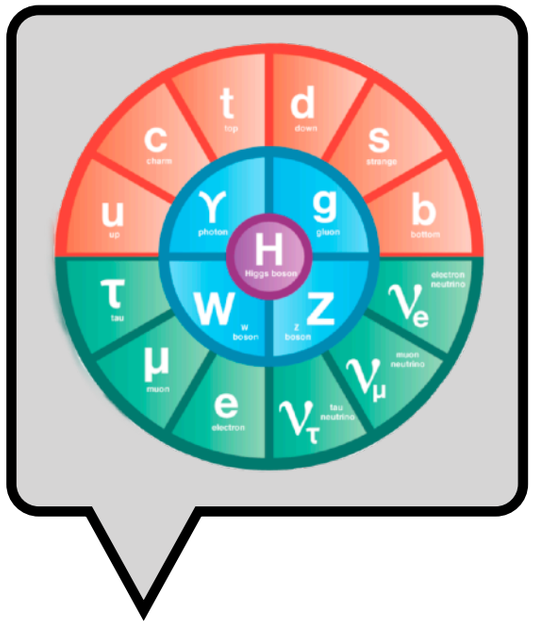
e.g. EW baryogenesis, Affleck-Dine, B-mesogenesis...

Más “materia” de la que vemos!



Más “materia” de la que vemos!

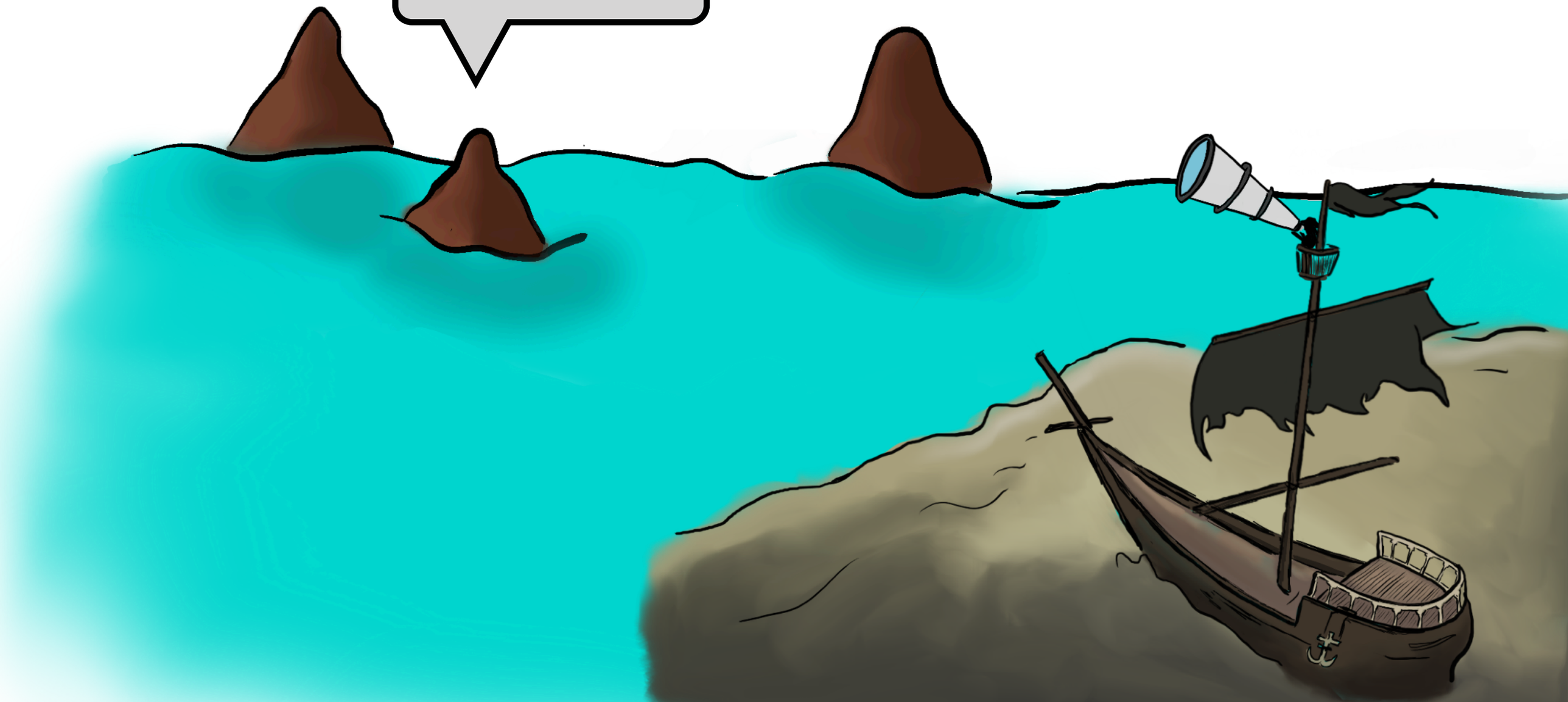




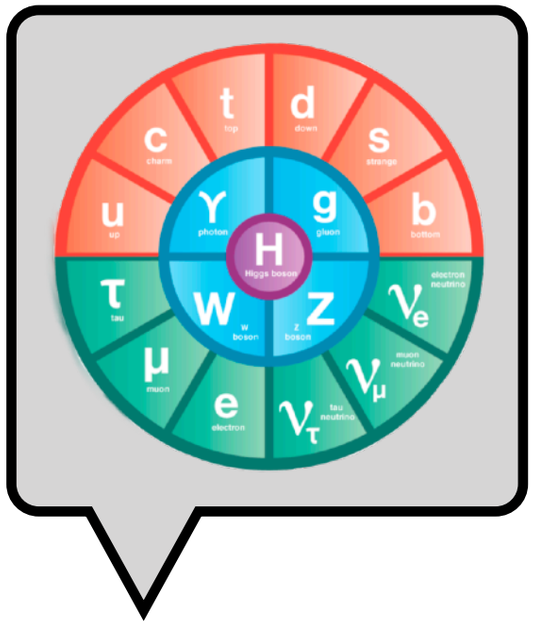
10:35

El Modelo estándar y la física fundamental (II)

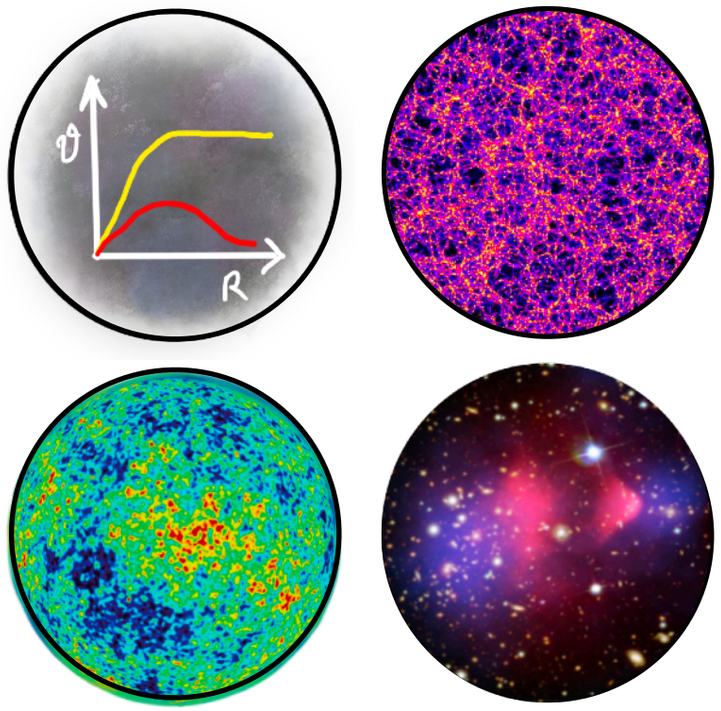
Speaker: Miguel Escudero Abenza (CERN)



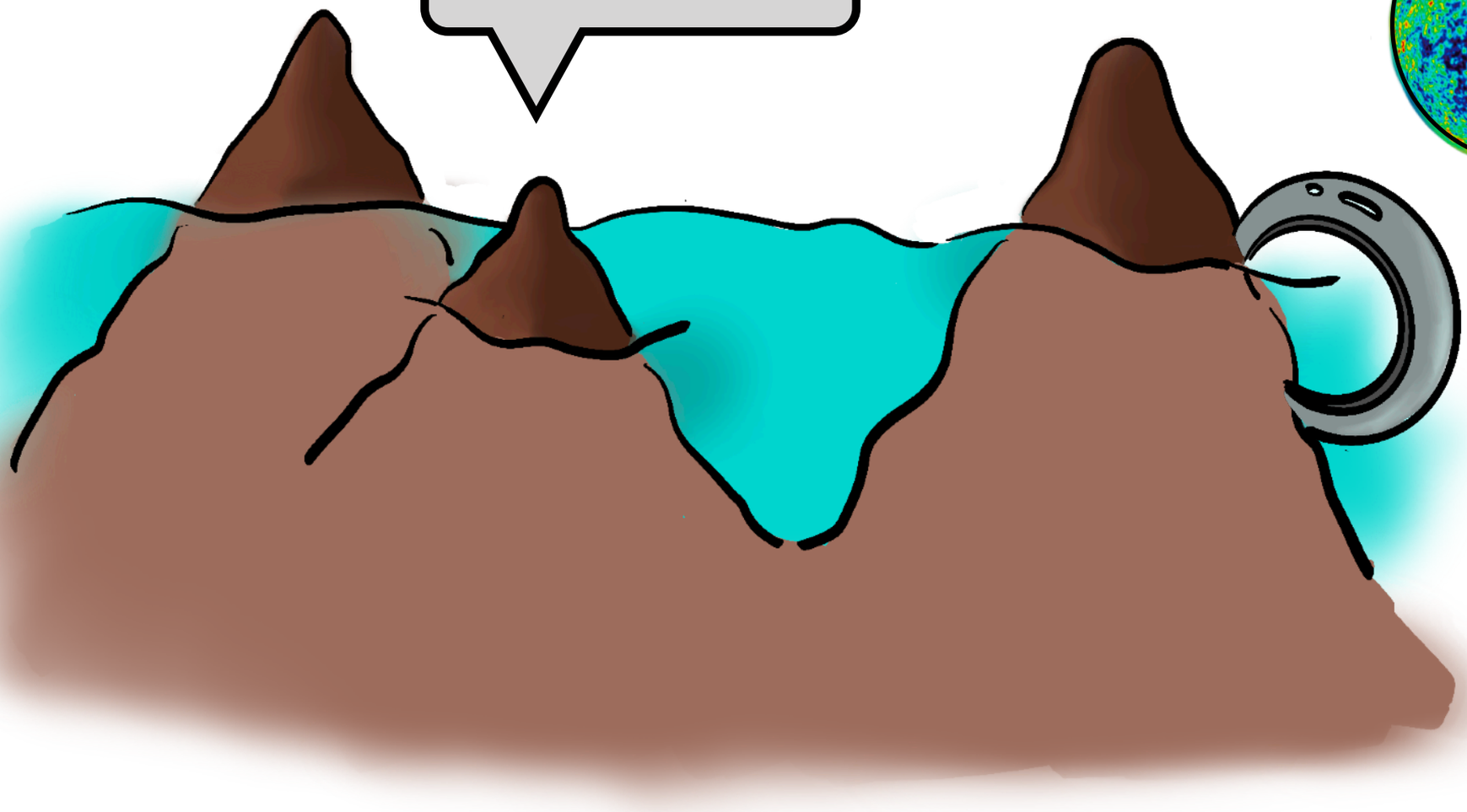
Más “materia” de la que vemos!



$\sim 5\%$

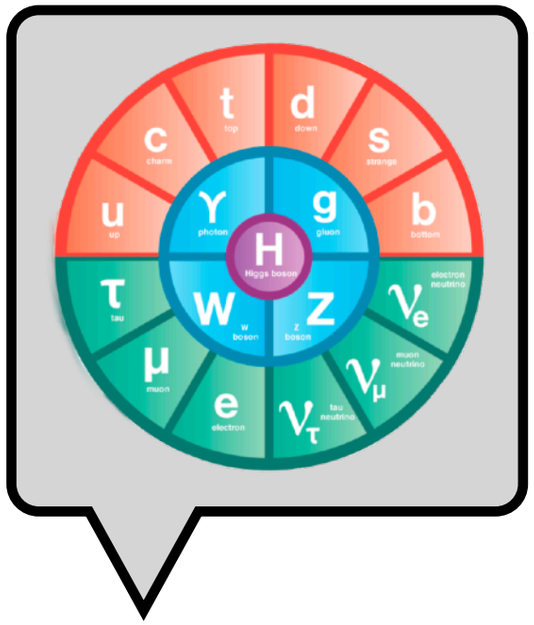


Evidencia **gravitatoria**

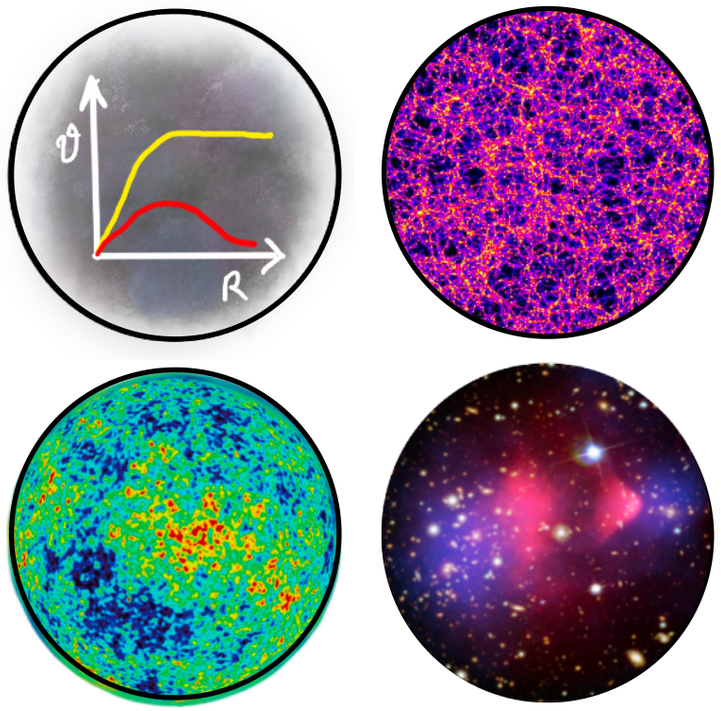


$\sim 25\%$

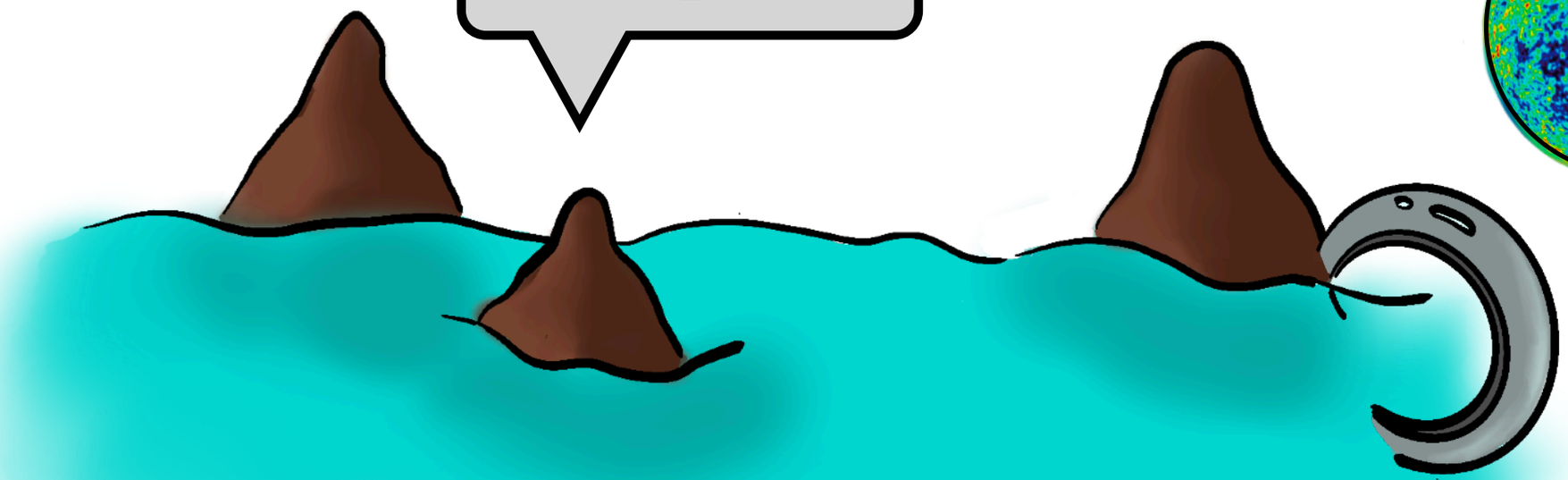
Más “materia” de la que vemos!



$\sim 5\%$



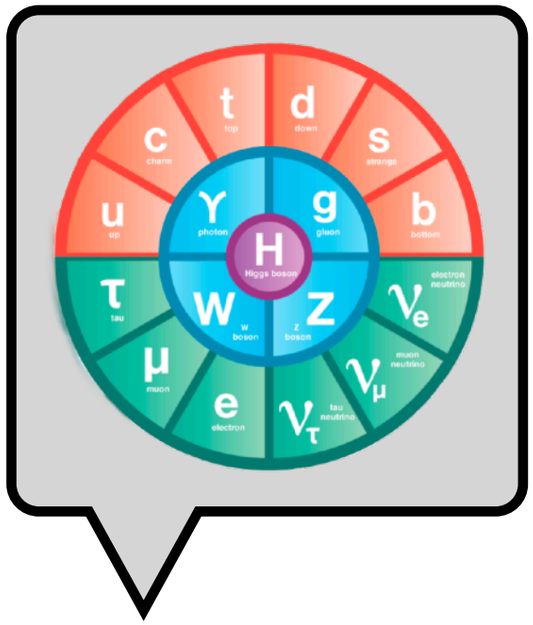
Evidencia **gravitatoria**



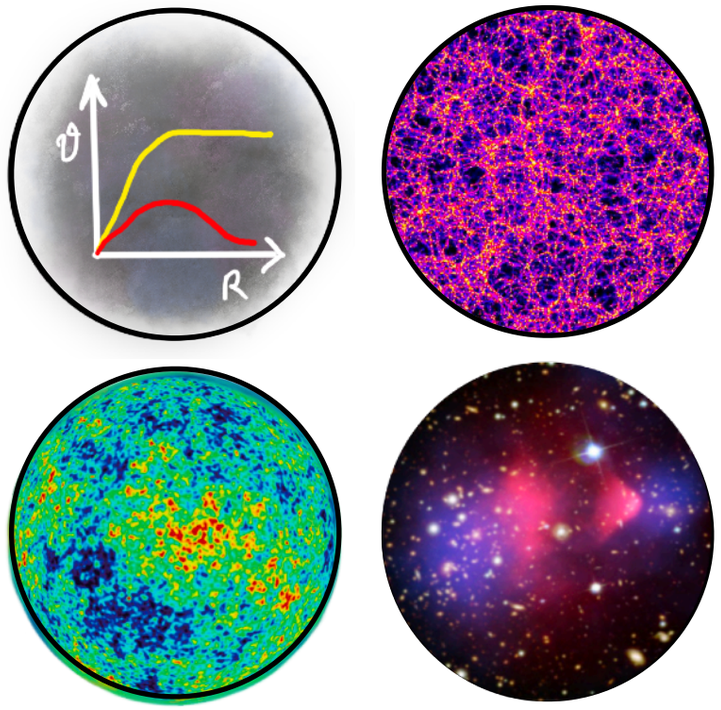
Sabemos muy poco... pero para lo poco sabemos, sabemos bastante

$$\Omega_{\mathrm{DM}} h^2 = 0.12$$

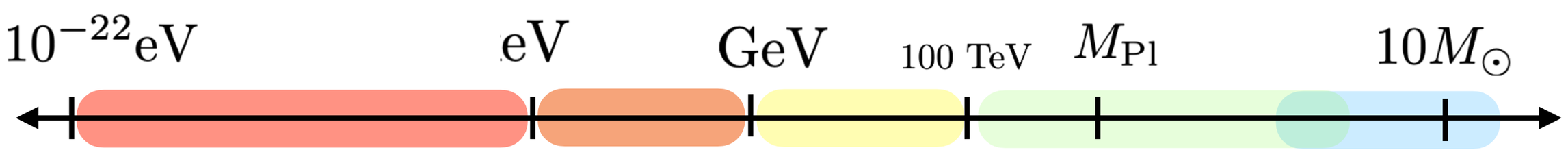
Más “materia” de la que vemos!



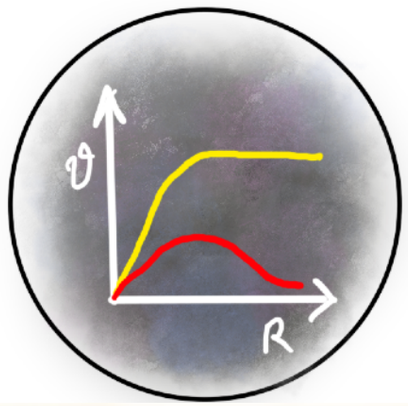
$\sim 5\%$



Pero de la masa ni idea

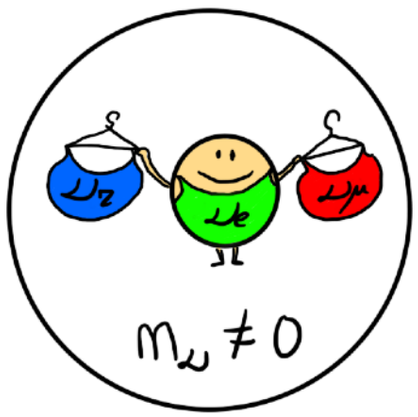


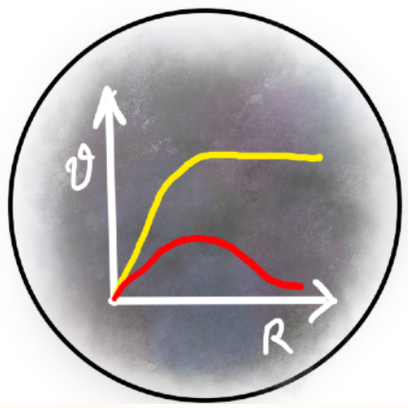
La materia oscura



Más allá del modelo estandar

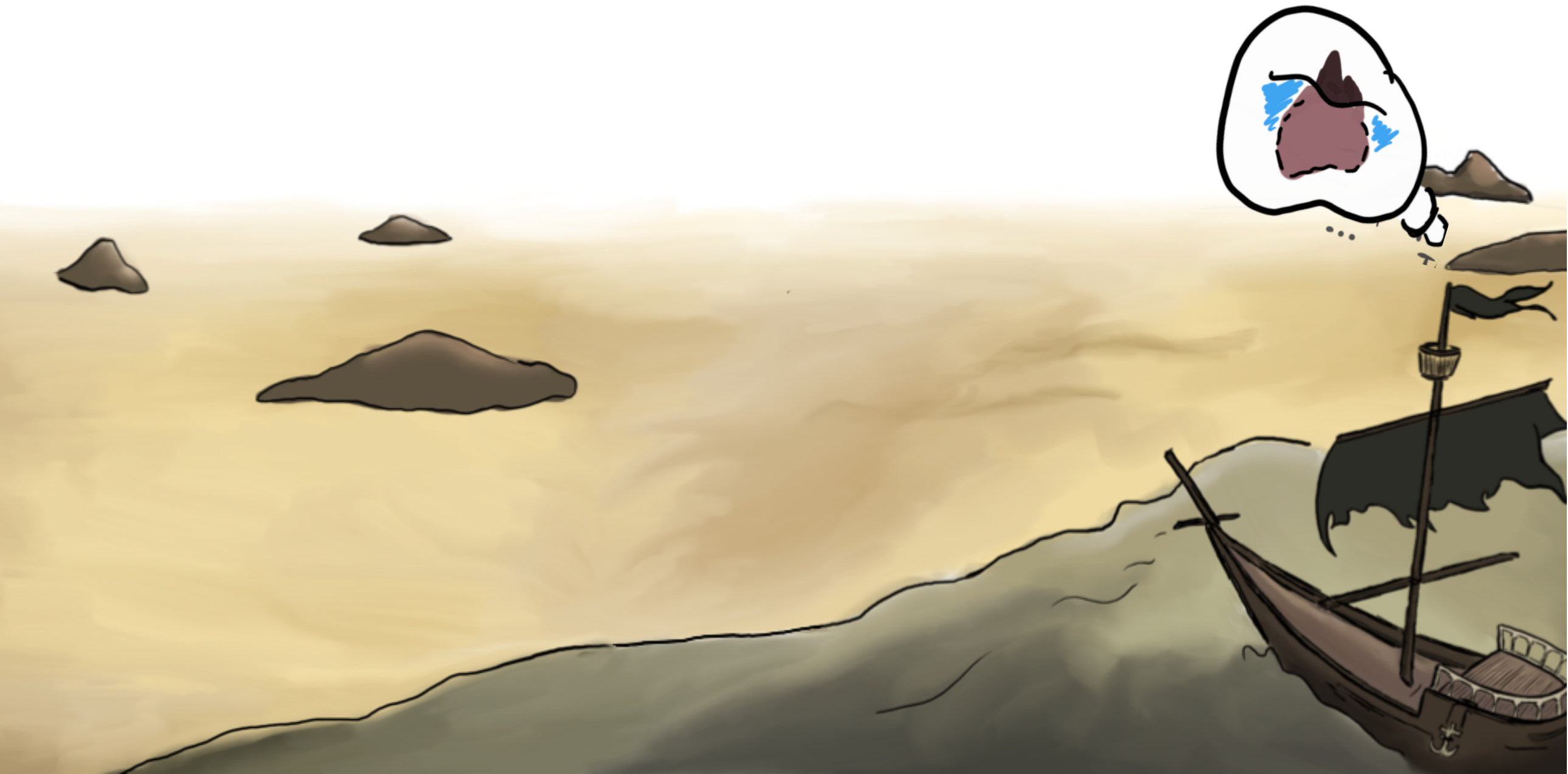
EVIDENCIAS





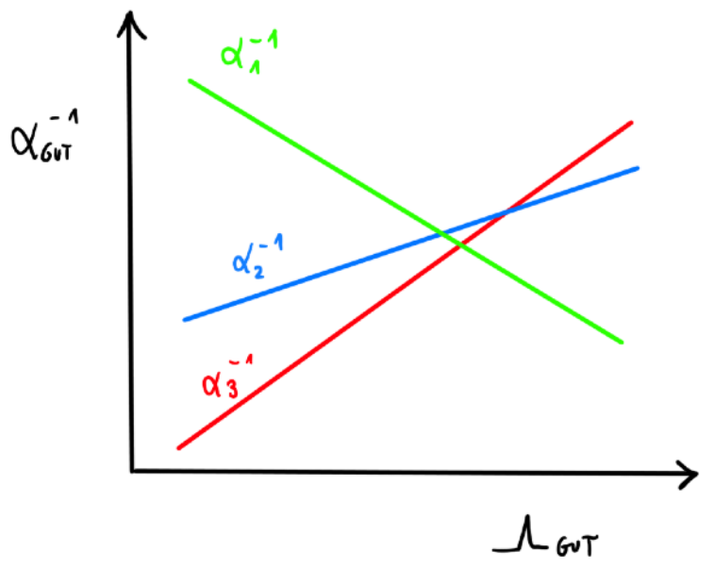
Más allá del modelo estandar

PISTAS



Gran Unificación (GUT)

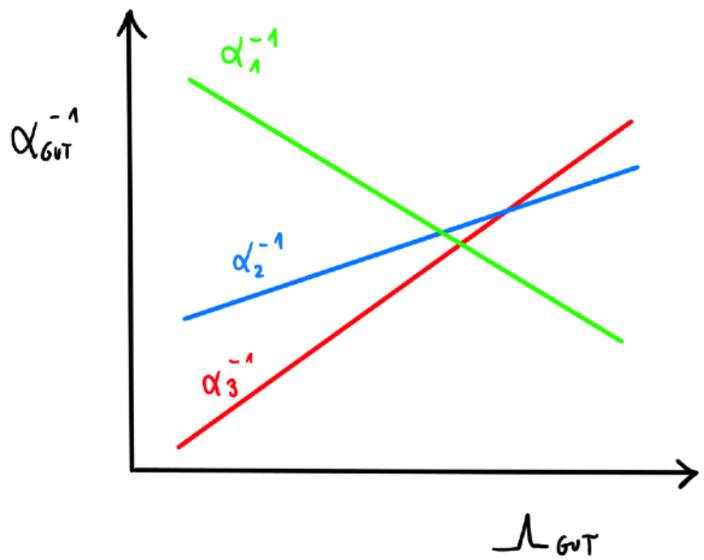
$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

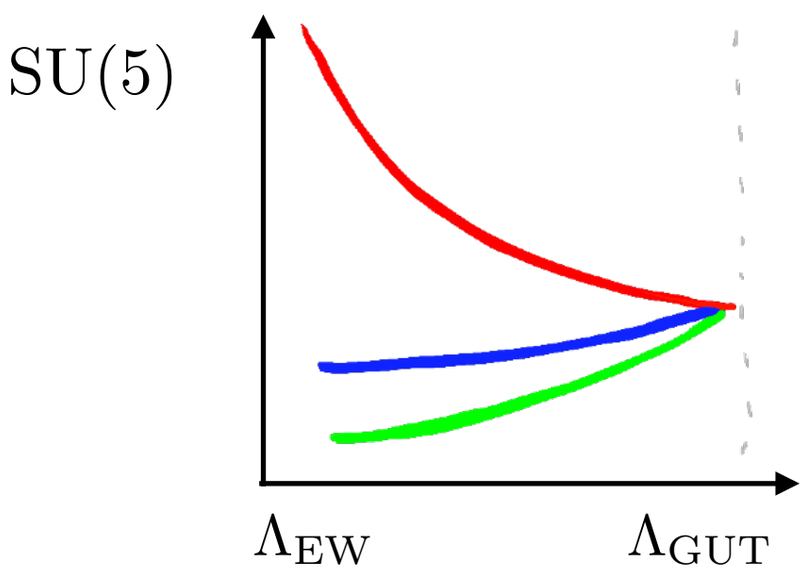


Gran Unificación (GUT)

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

$$\mathrm{SU}(5)$$

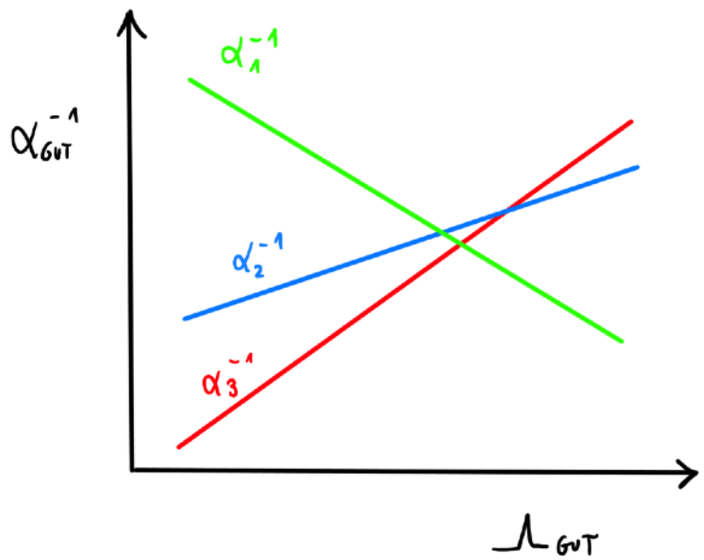




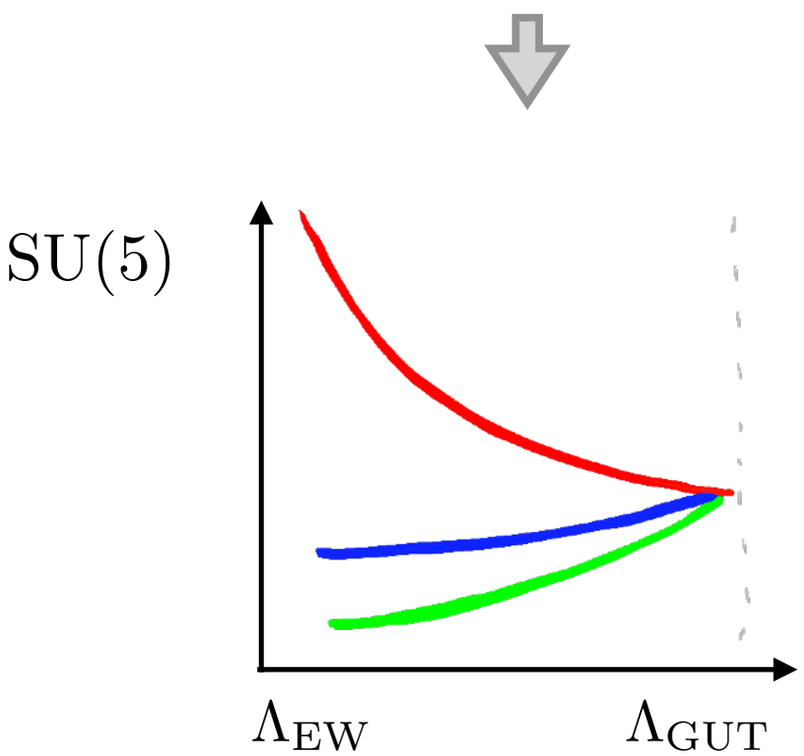
Gran Unificación (GUT)

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

$$\mathrm{SU}(5)$$



$$\bar{5} = \begin{pmatrix} (d_R)^c \\ L_L \end{pmatrix}, \qquad 10 = \begin{pmatrix} (u_R)^c & Q_L \\ -Q_L^T & (e_R)^c \end{pmatrix}$$



Gran Unificación (GUT)

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

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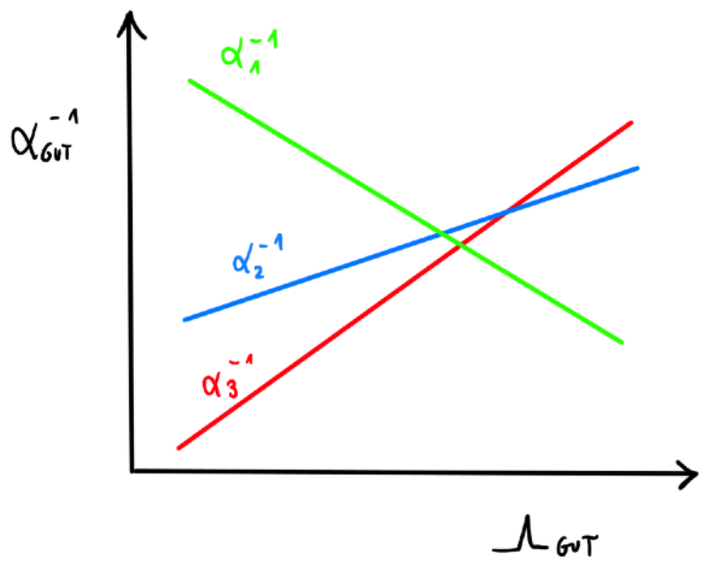
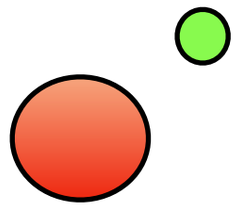
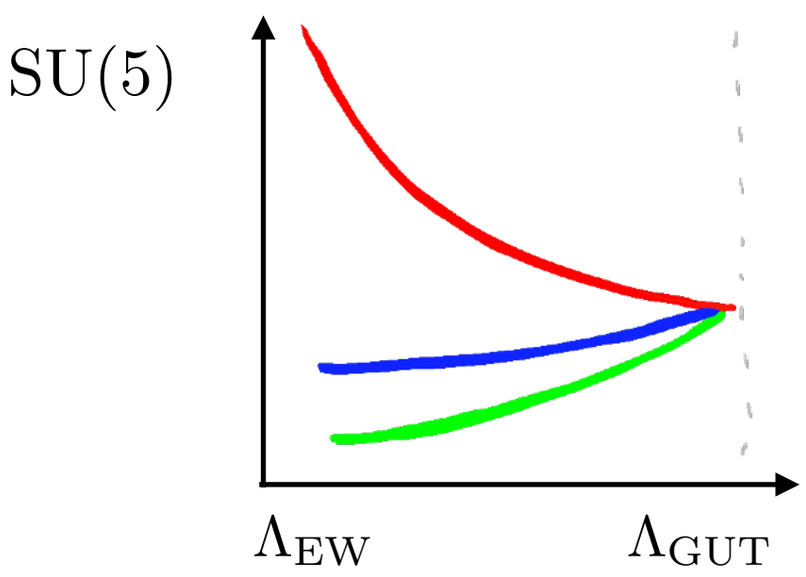


$$\bar{5} = \begin{pmatrix} (d_R)^c \\ L_L \end{pmatrix}, \qquad 10 = \begin{pmatrix} (u_R)^c & Q_L \\ -Q_L^T & (e_R)^c \end{pmatrix}$$



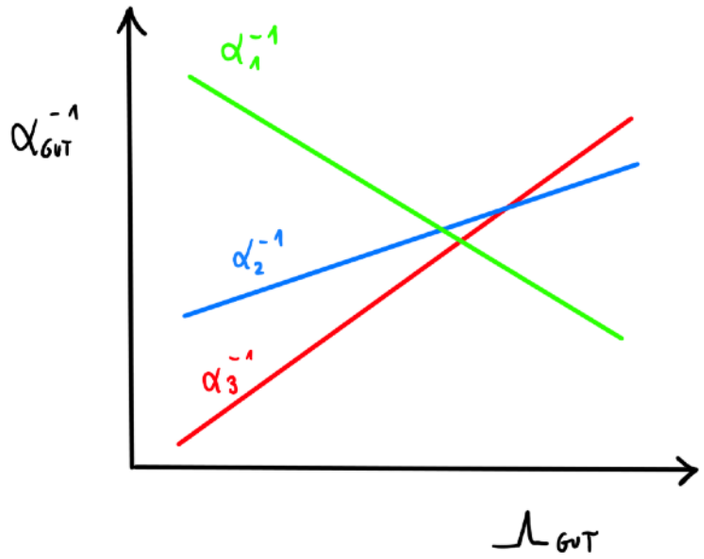
$$Q(p) + Q(e) = 0$$



Gran Unificación (GUT)

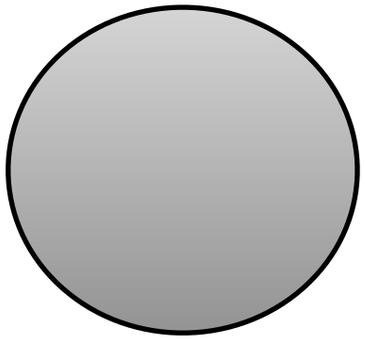
$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

$$\mathrm{SU}(5)$$

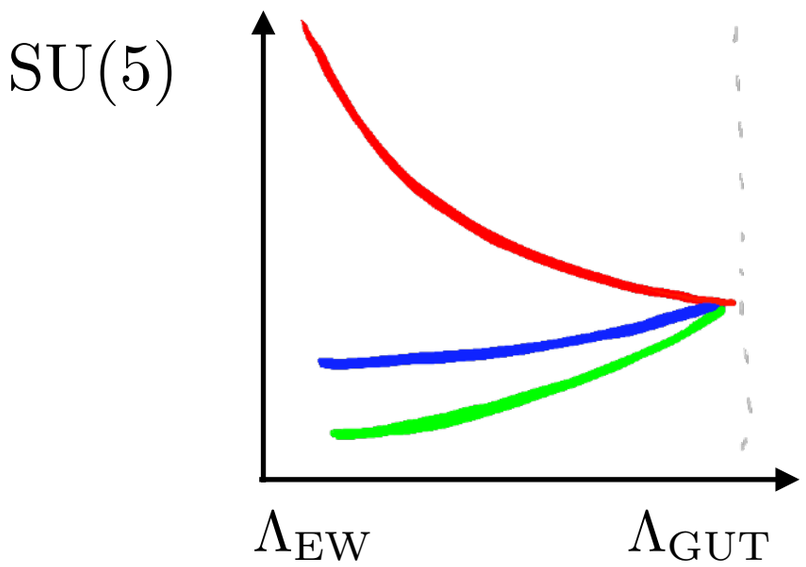


$$\bar{5} = \begin{pmatrix} (d_R)^c \\ L_L \end{pmatrix}, \qquad 10 = \begin{pmatrix} (u_R)^c & Q_L \\ -Q_L^T & (e_R)^c \end{pmatrix}$$

El átomo de hidrogen es neutro!



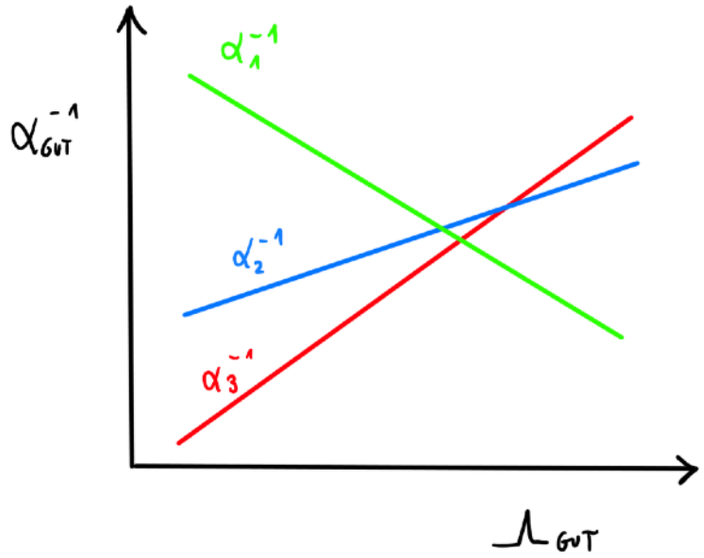
$$Q(p) + Q(e) = 0$$



Gran Unificación (GUT)

$$\mathrm{SU(3)} \otimes \mathrm{SU(2)} \otimes \mathrm{U(1)}_Y$$

$$\mathrm{SU(5)}$$



$$\bar{5} = \begin{pmatrix} (d_R)^c \\ L_L \end{pmatrix}, \qquad 10 = \begin{pmatrix} (u_R)^c & Q_L \\ -Q_L^T & (e_R)^c \end{pmatrix}$$

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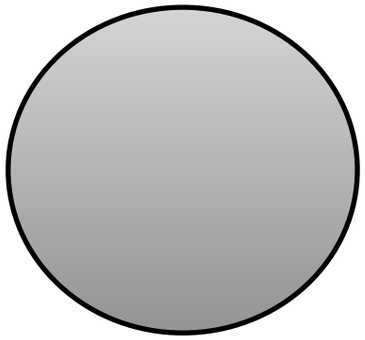
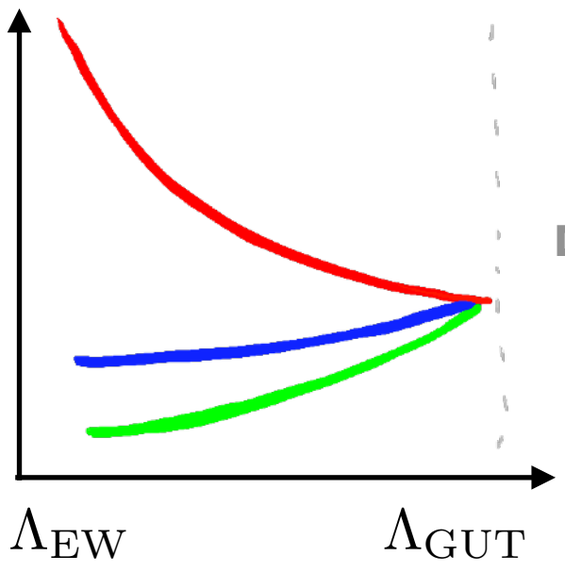
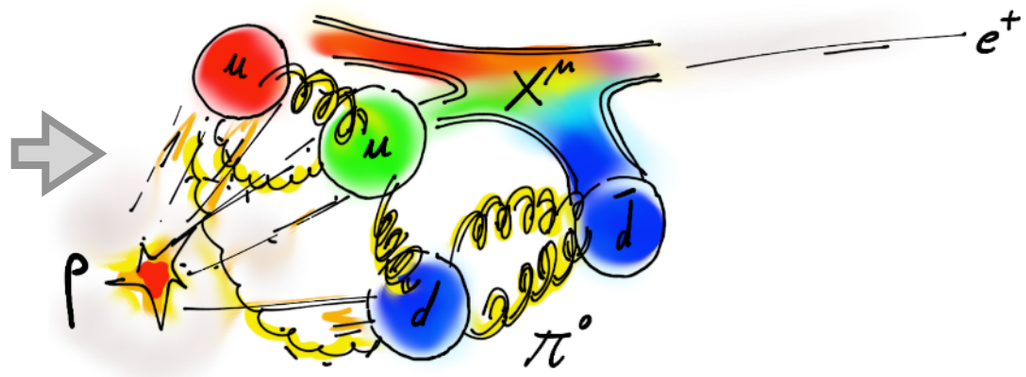


$$Q(p) + Q(e) = 0$$

SU(5)

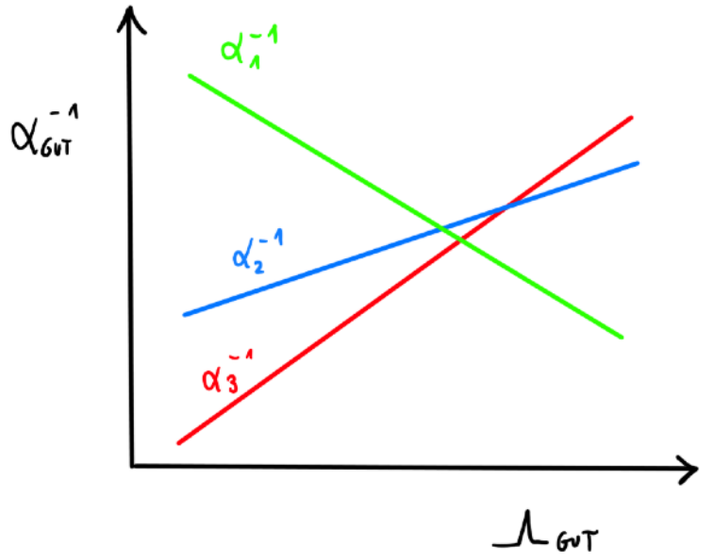




Gran Unificación (GUT)

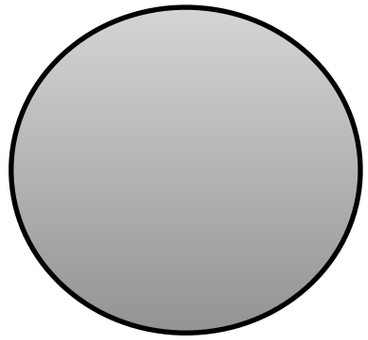
$$\mathrm{SU(3)} \otimes \mathrm{SU(2)} \otimes \mathrm{U(1)}_Y$$

$$\mathrm{SU(5)}$$



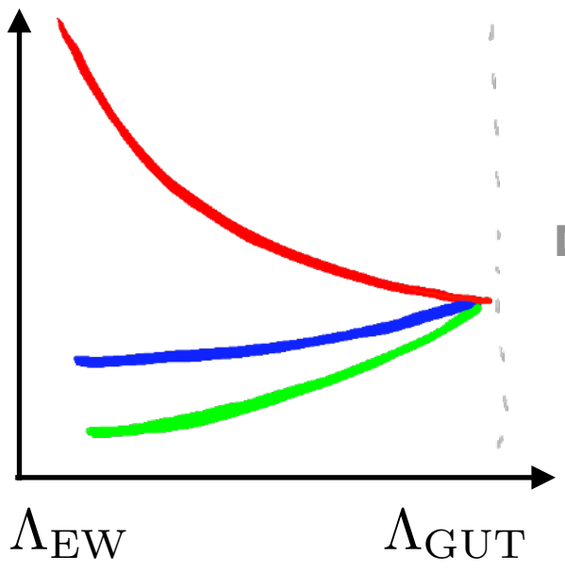
$$\bar{5} = \begin{pmatrix} (d_R)^c \\ L_L \end{pmatrix}, \qquad 10 = \begin{pmatrix} (u_R)^c & Q_L \\ -Q_L^T & (e_R)^c \end{pmatrix}$$

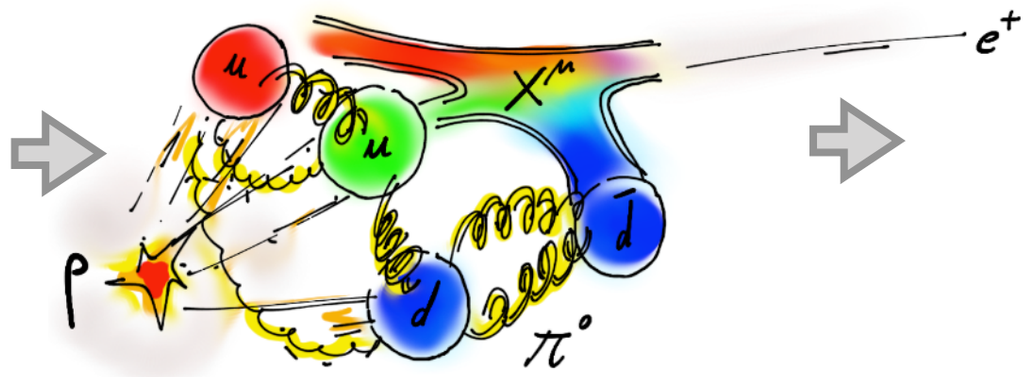
El átomo de hidrogen es neutro!

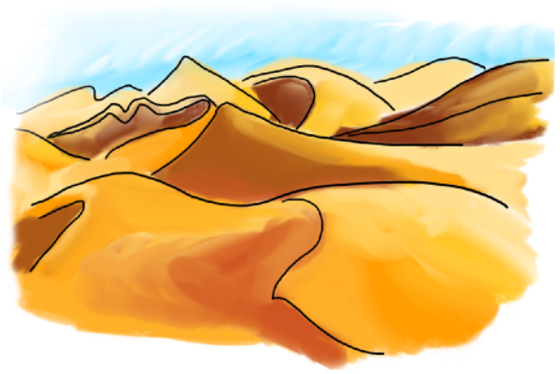


$$Q(p) + Q(e) = 0$$

SU(5)



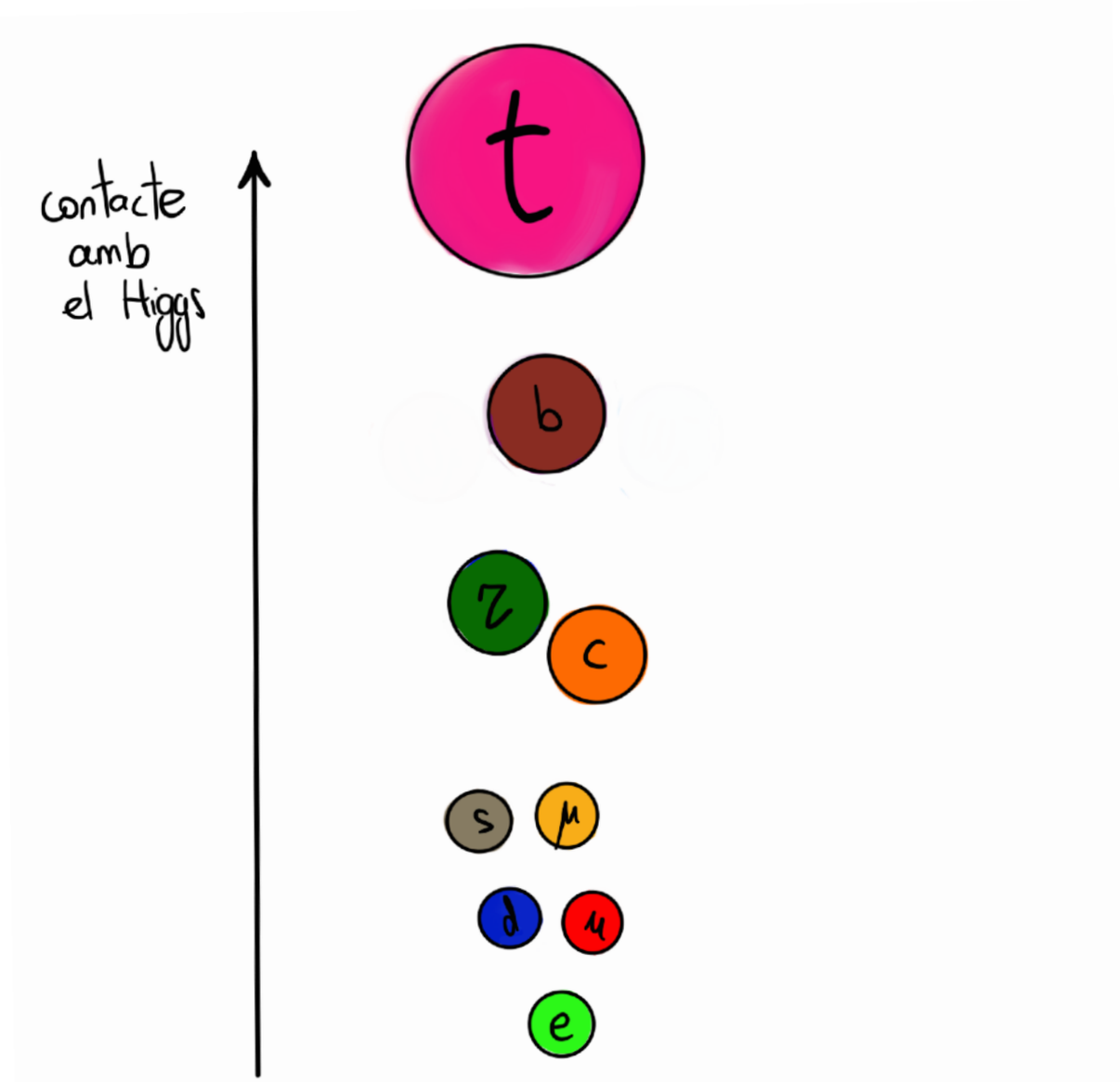




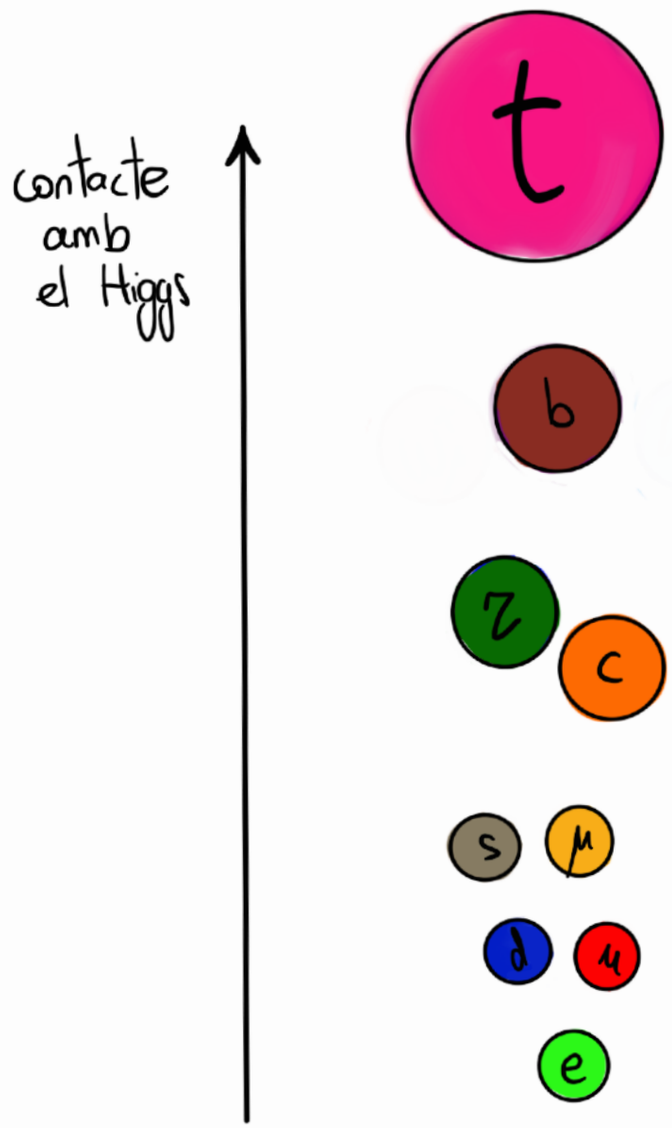
$\tau_p > 10^{34}$ años!!

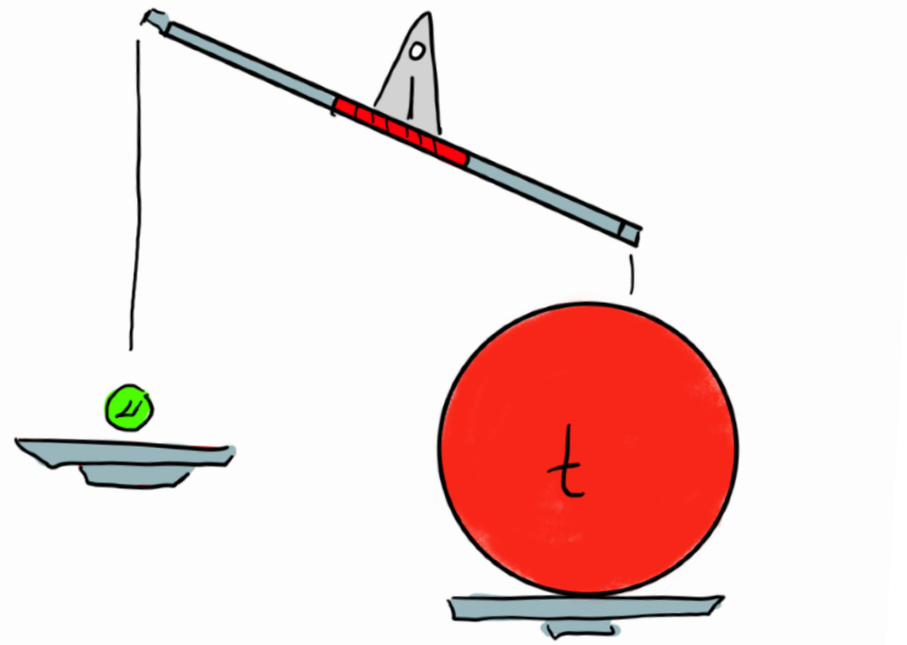
$\Lambda_{GUT} \gtrsim 10^{15}$ GeV

Herarquías



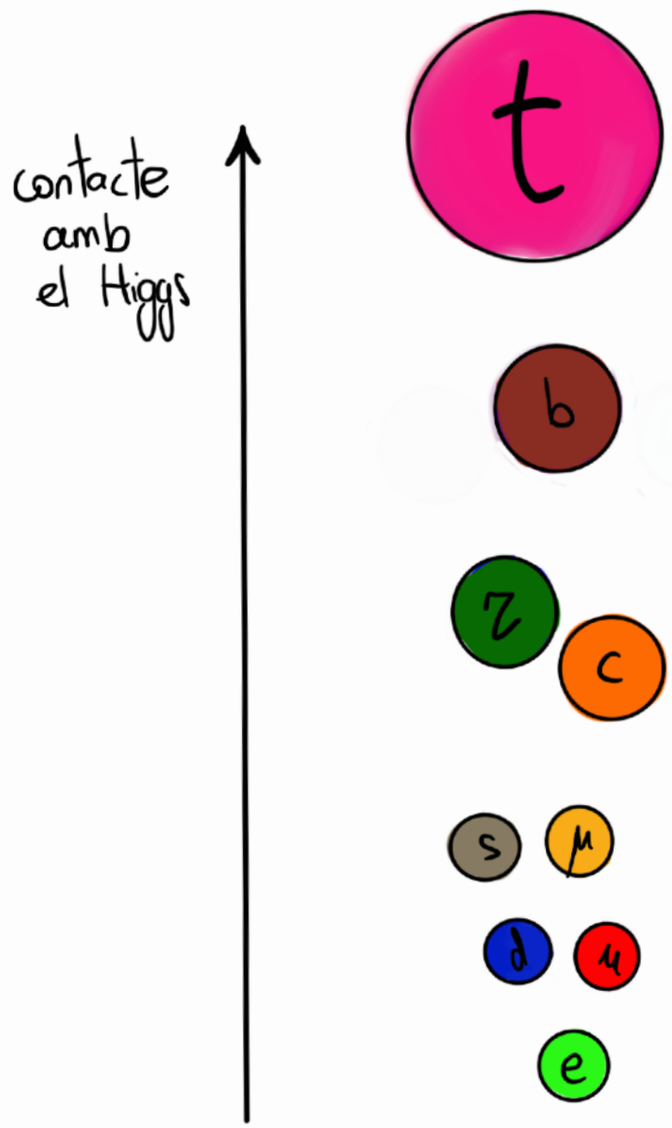
Herarquías

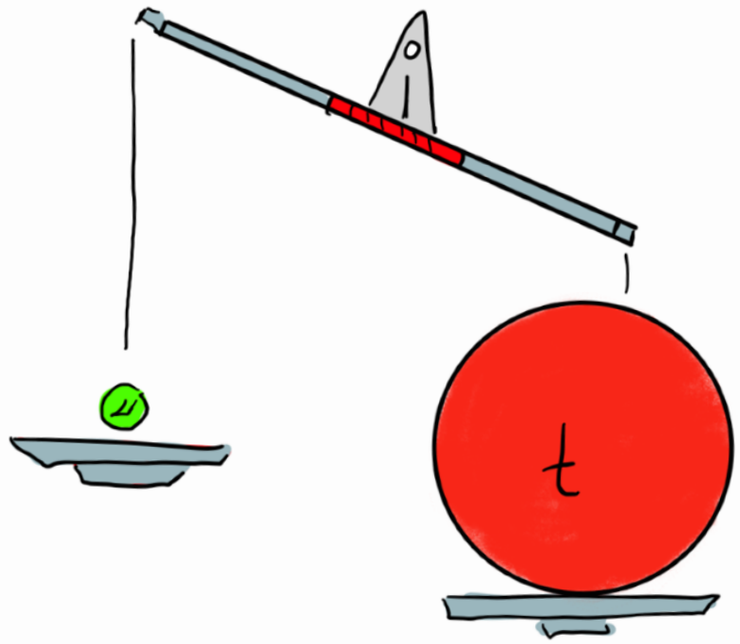




$m_t \sim 100000000000\ m_\tau$

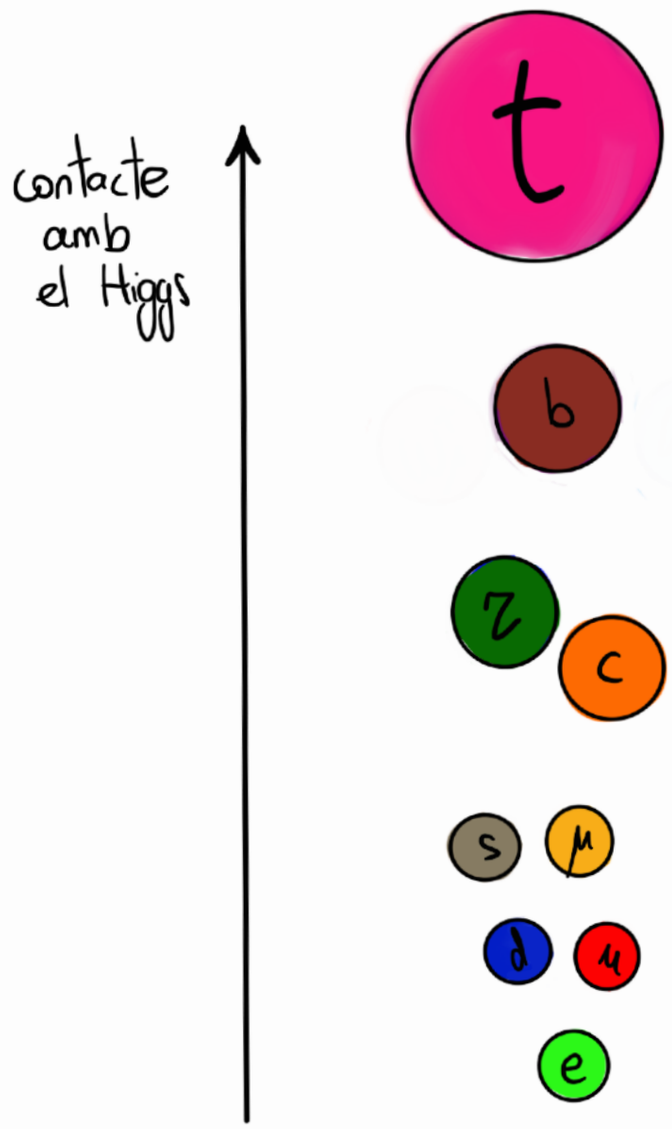
Herarquías

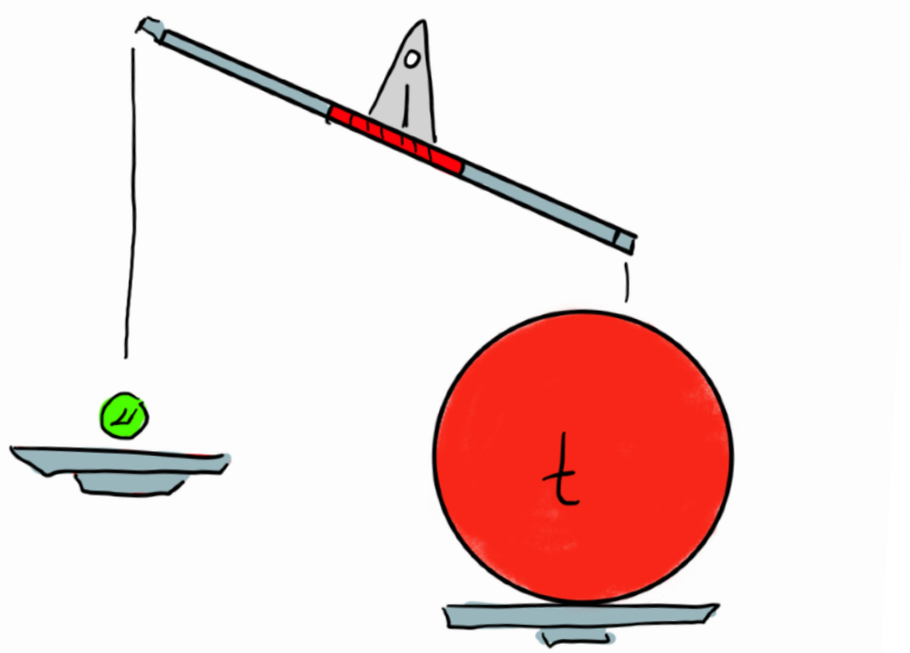




$m_t \sim 100000000000\ m_e$

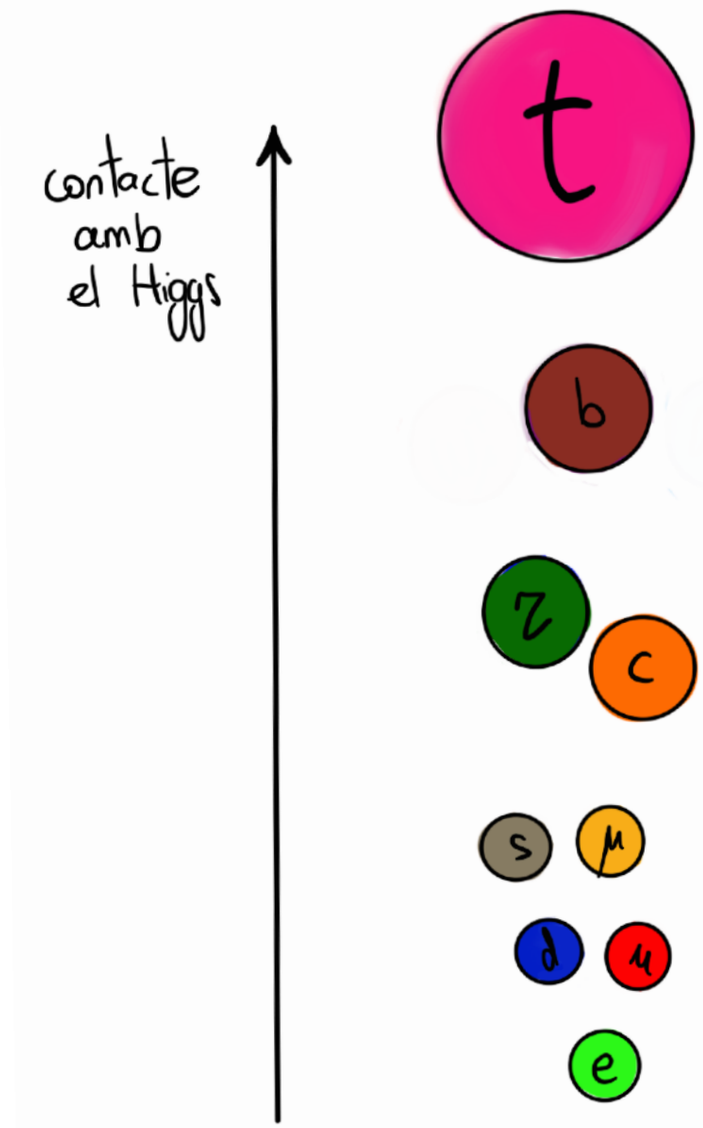
Herarquías

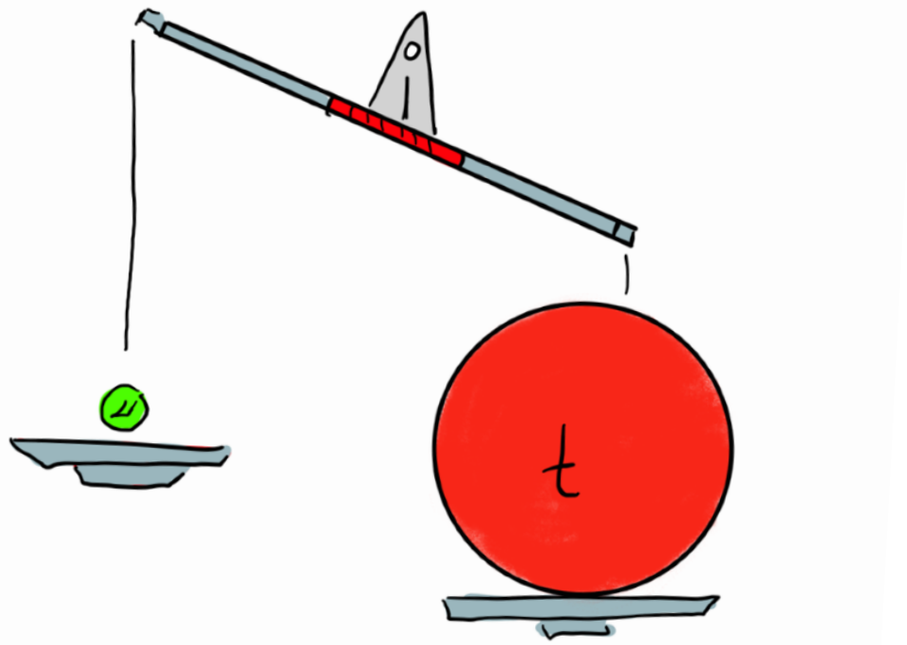




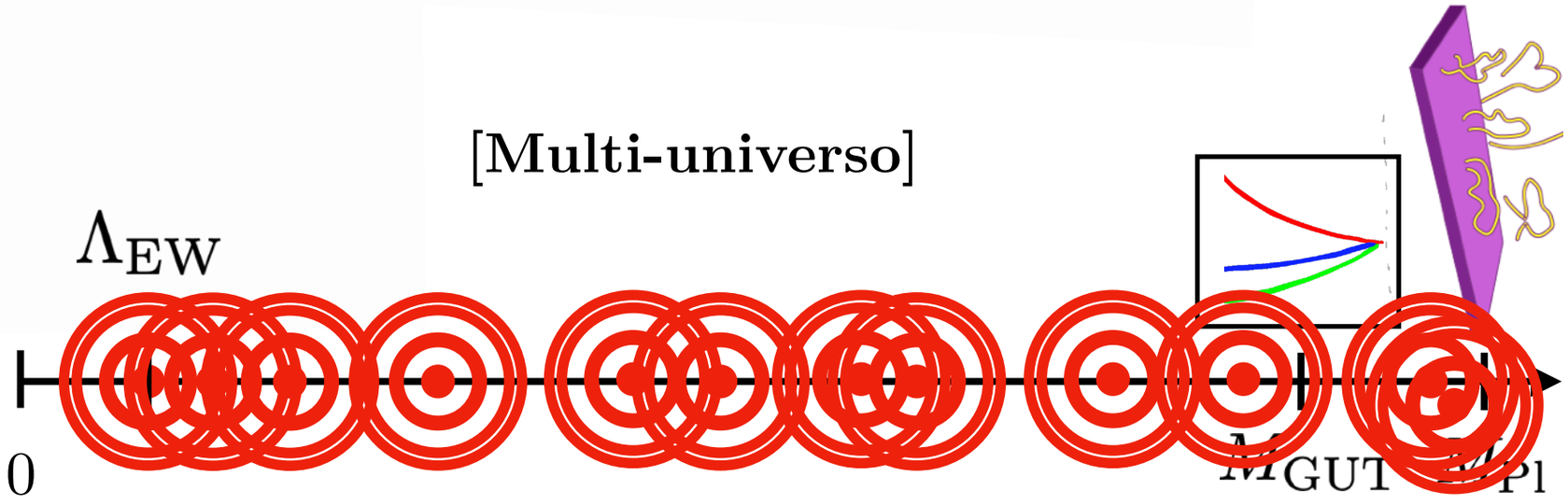
$m_t \sim 100000000000\ m_\nu$

Herarquías



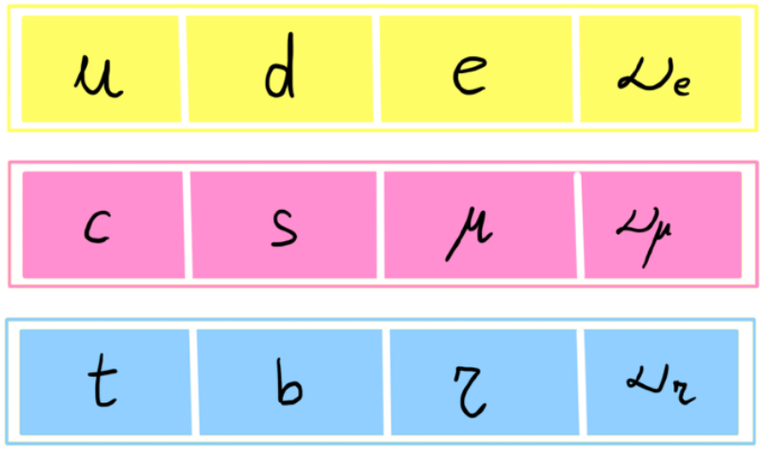


$m_t \sim 100000000000\ m_w$



El puzzle de sabor

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



Por qué 3? Y no 5? O sólo 1? O 40000?

El puzzle de sabor

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

u	d	e	ν_e
c	s	μ	ν_μ
t	b	τ	ν_τ

Por qué 3? Y no 5? O sólo 1? O 40000?

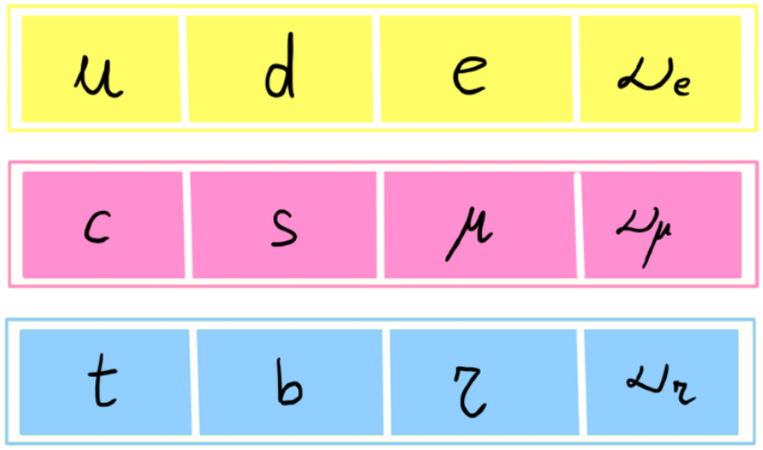
1st GEN

2nd GEN

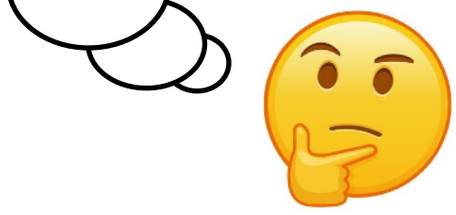
3rd GEN

El puzzle de sabor

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



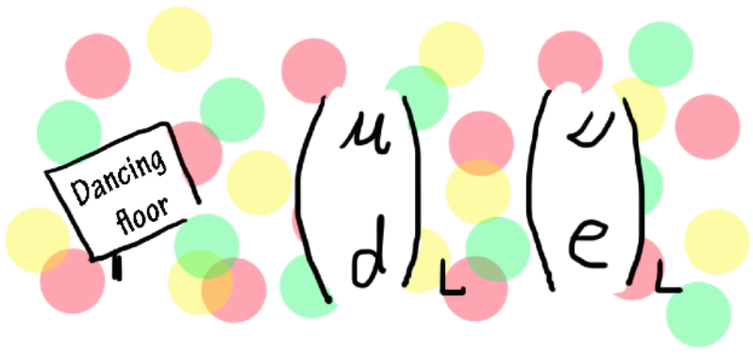
Por qué 3? Y no 5? O sólo 1? O 40000?



1st GEN

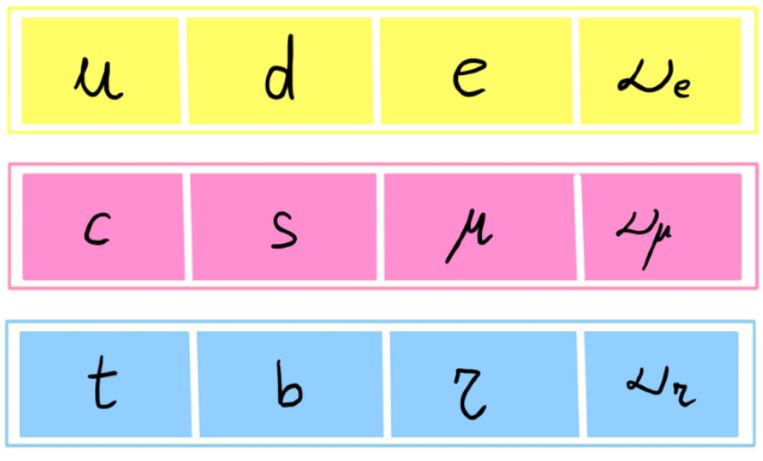
2nd GEN

3rd GEN



El puzzle de sabor

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

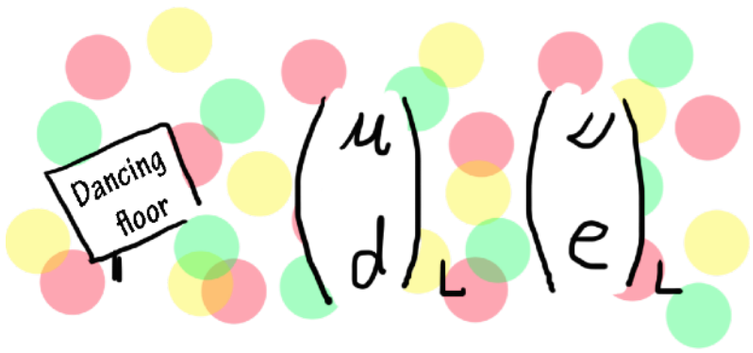


e.g. $\mathrm{SO}(18)$

1st GEN

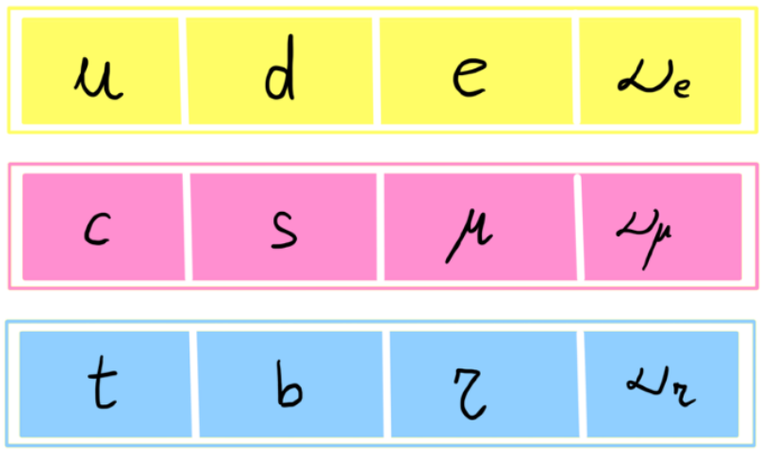
2nd GEN

3rd GEN

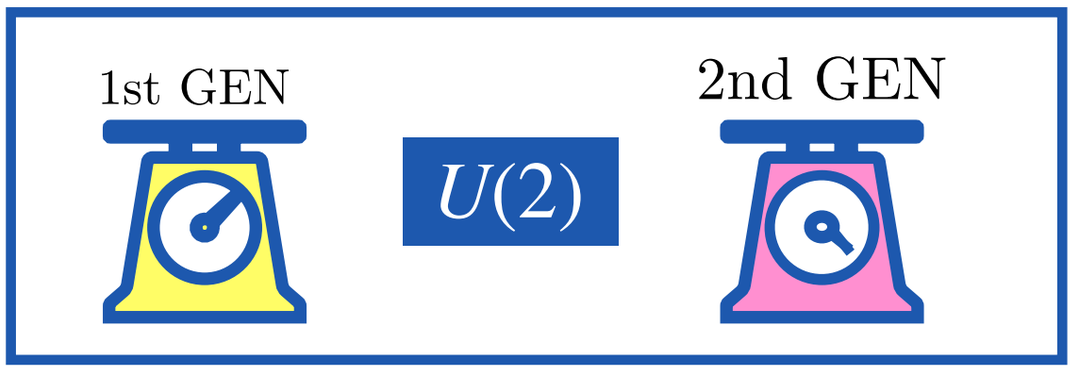


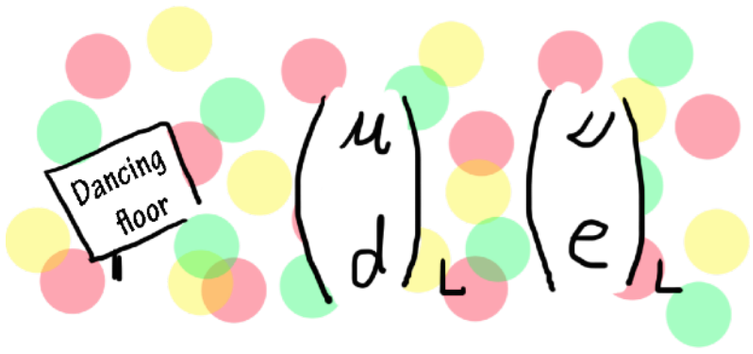
El puzzle de sabor

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



e.g. $\mathrm{SO}(18)$





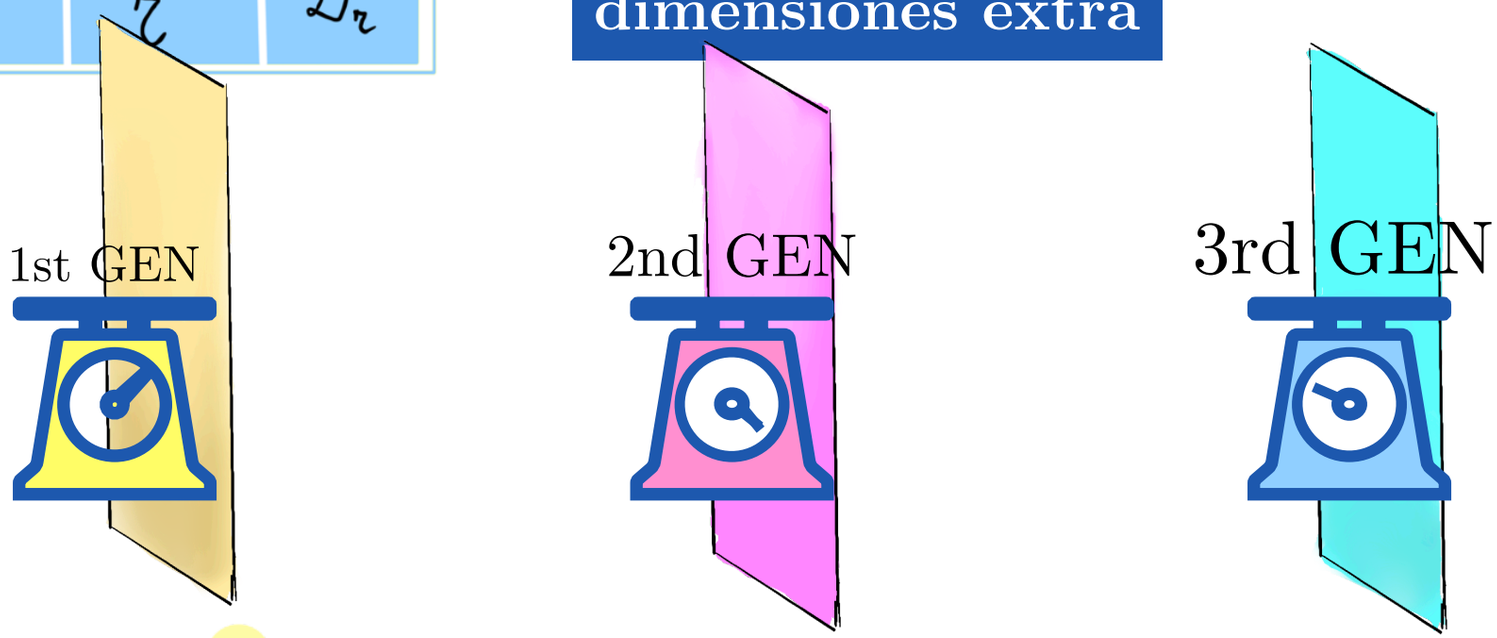
El puzzle de sabor

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

u	d	e	ν_e
c	s	μ	ν_μ
t	b	τ	ν_τ

e.g. SO(18)

dimensiones extra



El puzzle de sabor

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

u	d	e	ν_e
c	s	μ	ν_μ
t	b	τ	ν_τ

$$F_L = \left[\begin{pmatrix} u \\ d \end{pmatrix}_L \right] \qquad F_R = \left[\begin{pmatrix} u \\ d \end{pmatrix}_R \right]$$

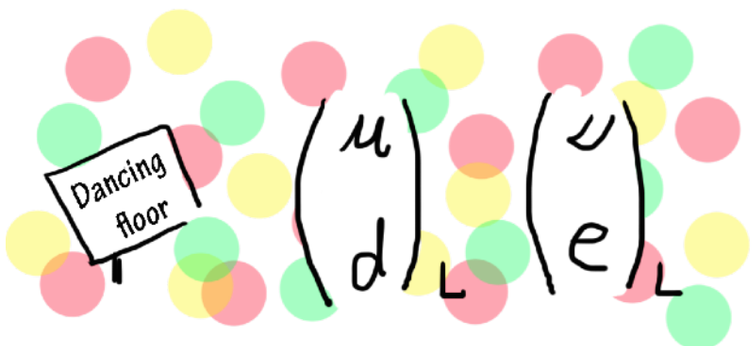
$$\left[\begin{pmatrix} \nu \\ e \end{pmatrix}_L \right] \qquad \left[\begin{pmatrix} \nu \\ e \end{pmatrix}_R \right]$$

Quark-lepton unification

1st GEN

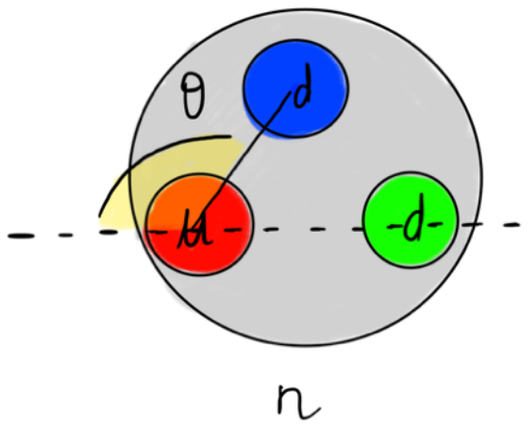
2nd GEN

3rd GEN



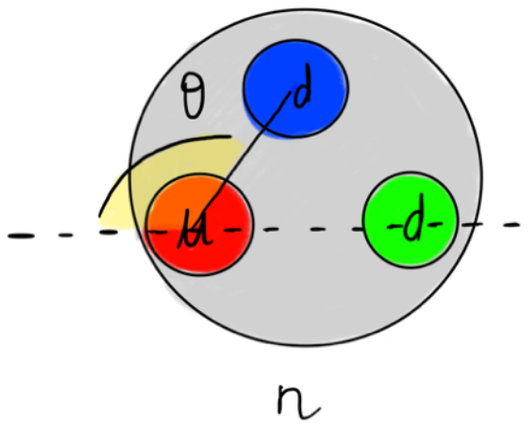
El problema fuerte de CP

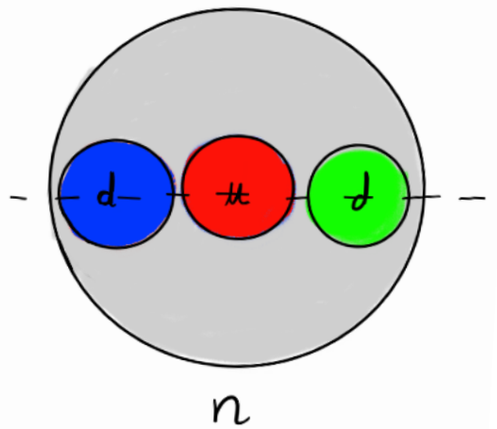
$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



El problema fuerte de CP

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$

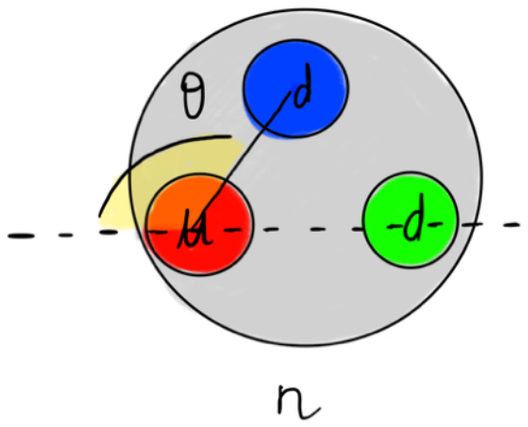


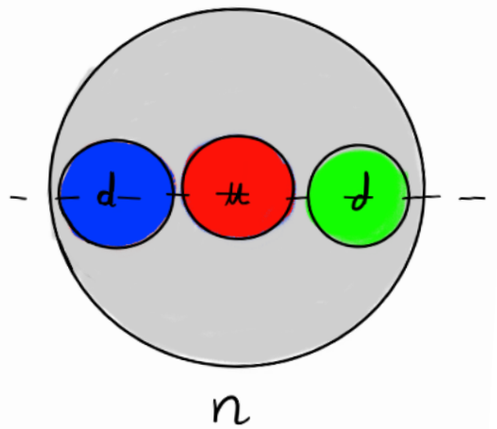


$$\theta_{\mathrm{QCD}} < 10^{-10}$$

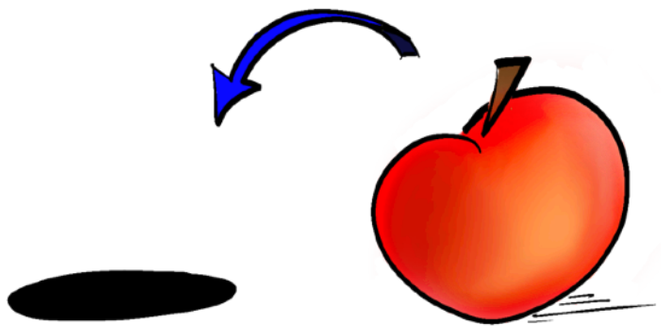
El problema fuerte de CP

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



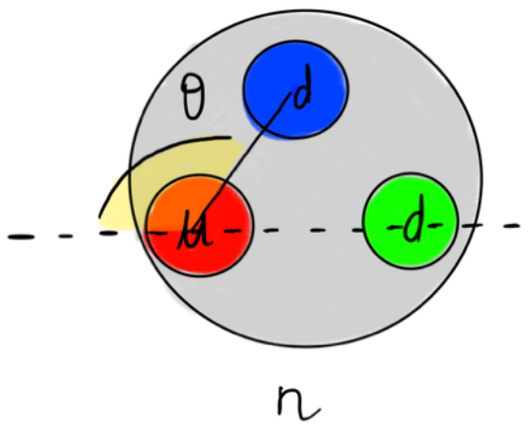


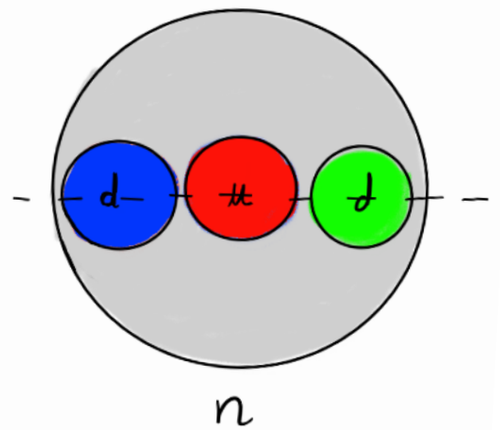
$$\theta_{\mathrm{QCD}} < 10^{-10}$$



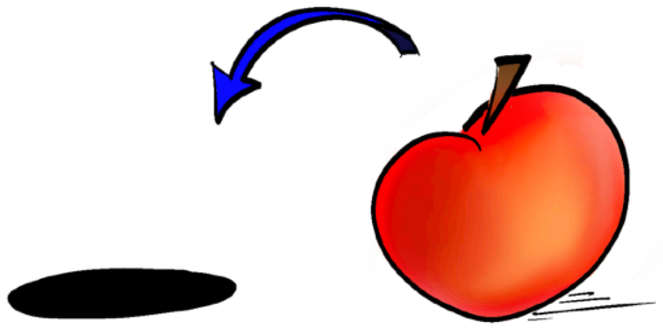
El problema fuerte de CP

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$



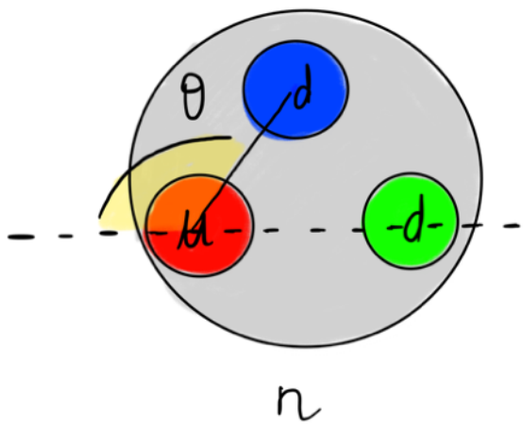


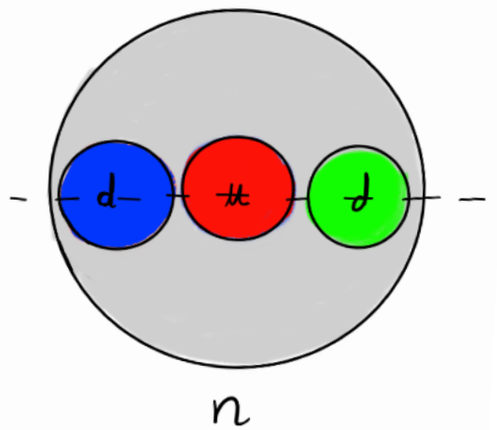
$$\theta_{\mathrm{QCD}} < 10^{-10}$$



El problema fuerte de CP

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$





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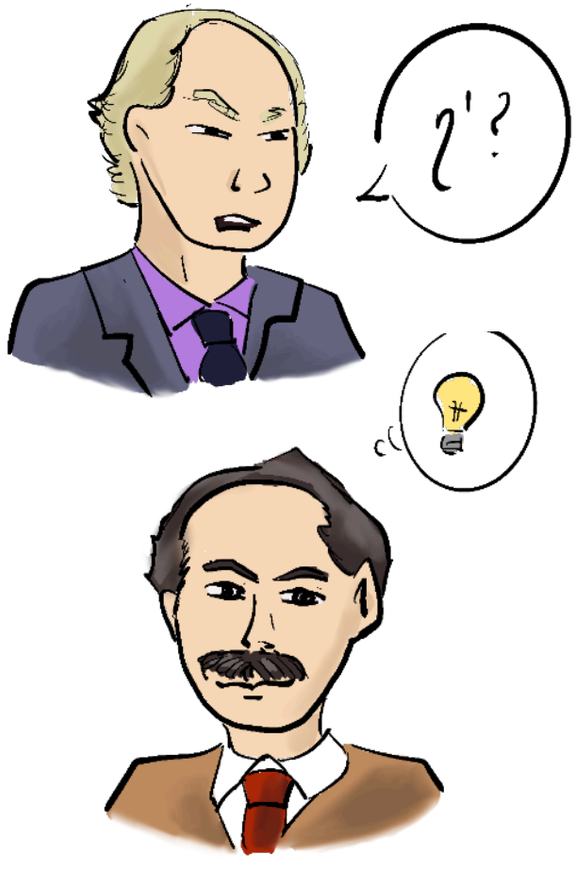

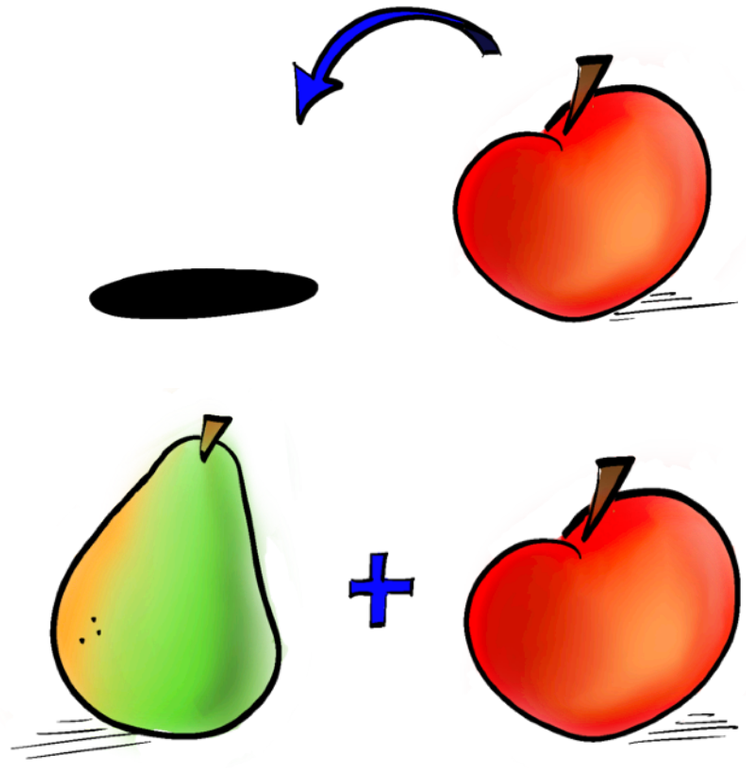

El problema fuerte de CP

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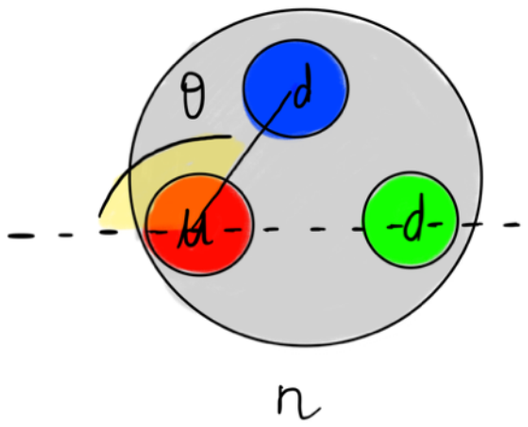

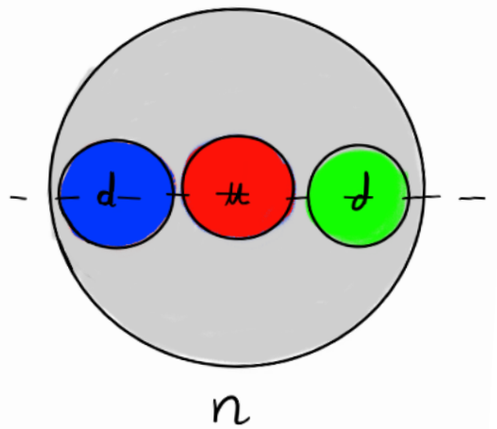

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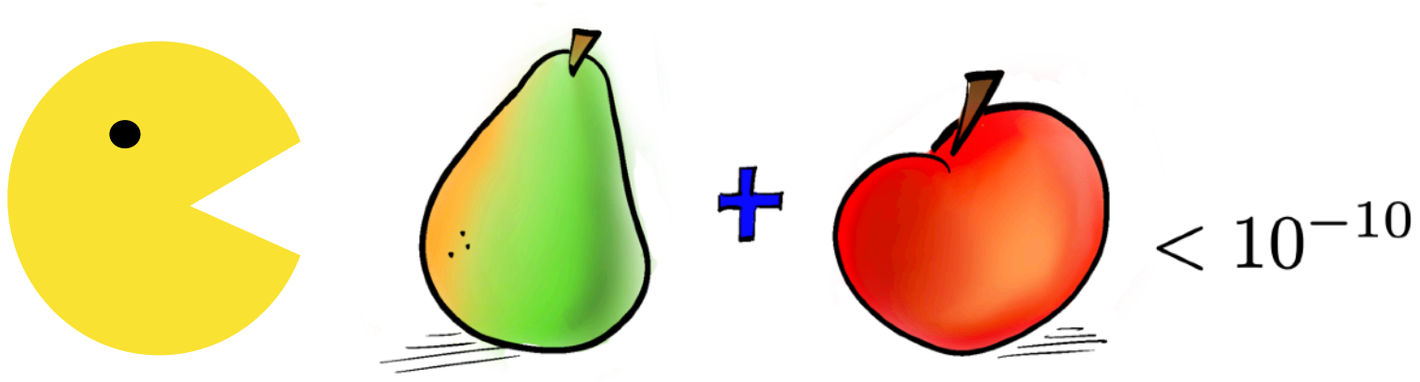
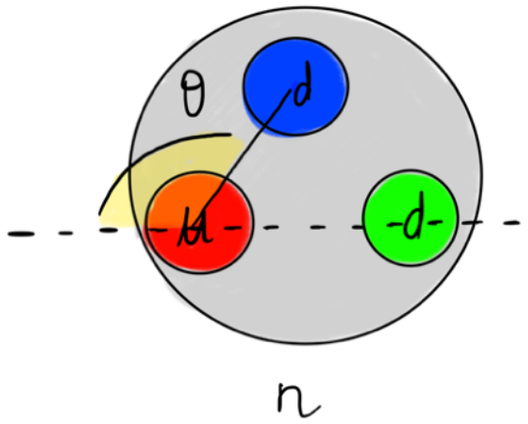
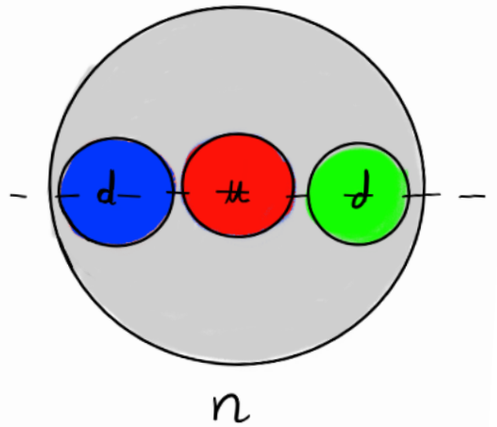


$< 10^{-10}$

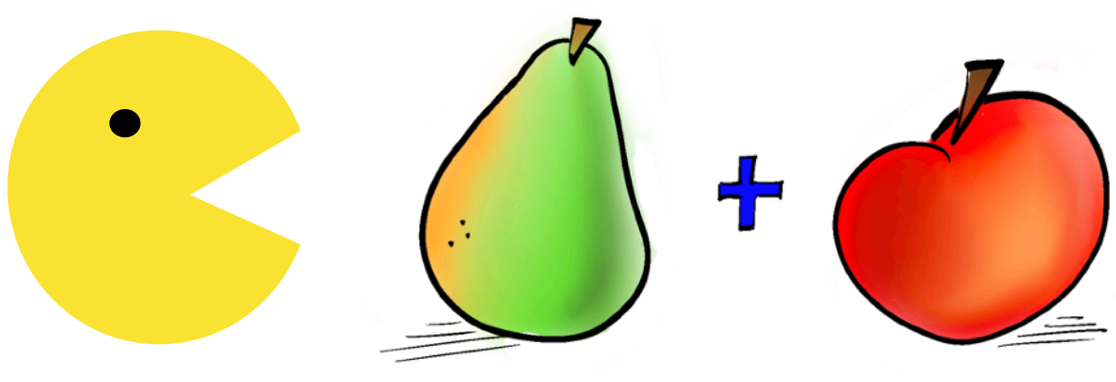
El problema fuerte de CP

$$\mathrm{SU}(3) \otimes \mathrm{SU}(2) \otimes \mathrm{U}(1)_Y$$





$$\theta_{\mathrm{QCD}} < 10^{-10}$$



$$< 10^{-10}$$

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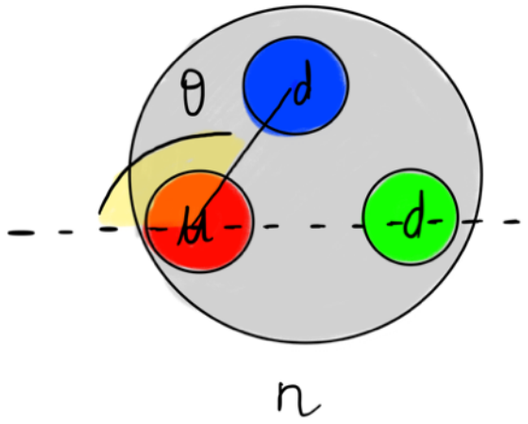
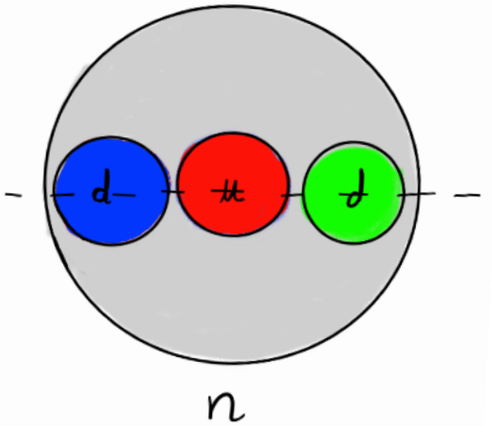
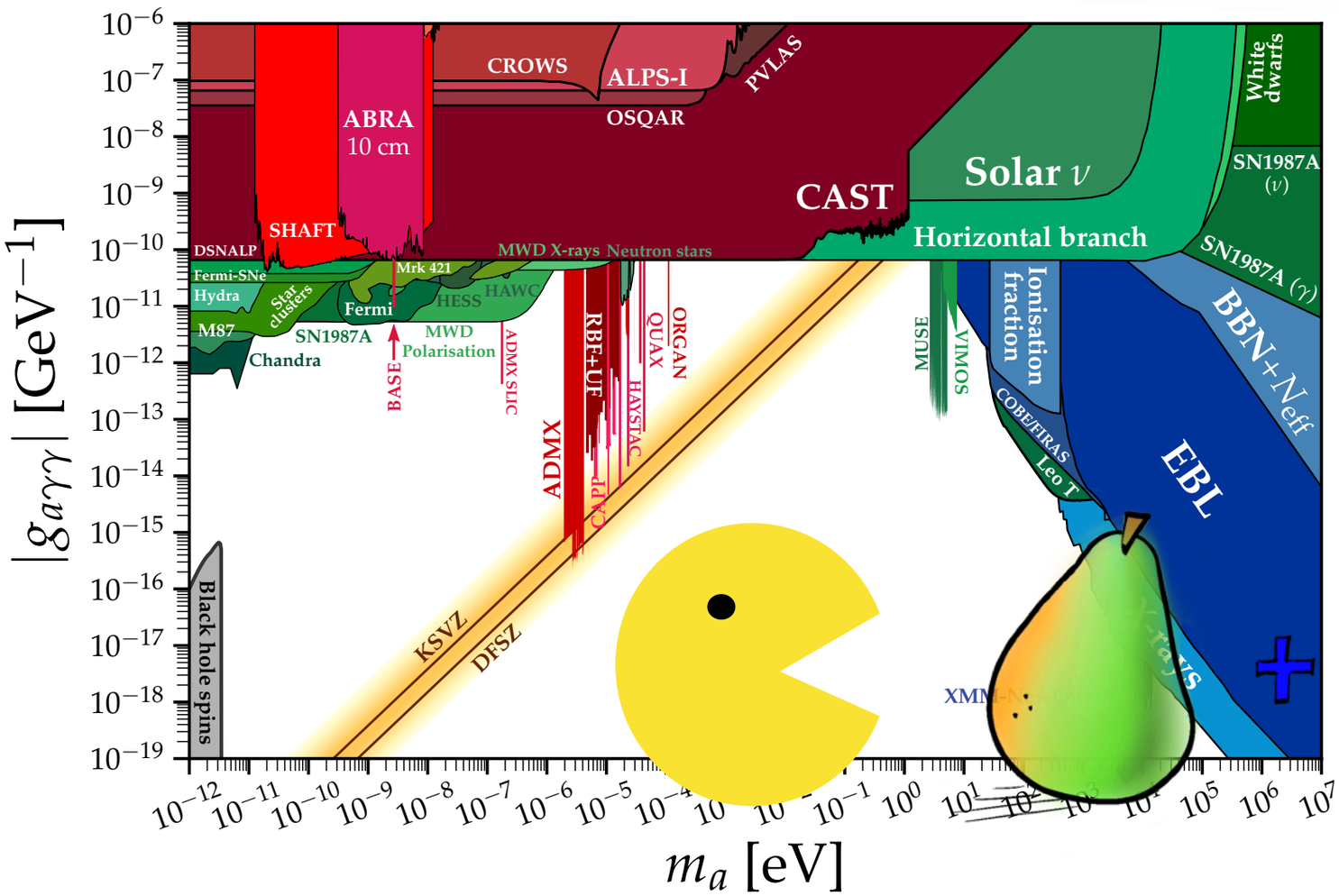


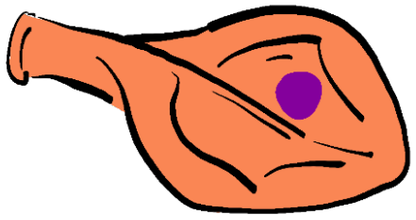


$$\theta_{\mathrm{QCD}} < 10^{-10}$$

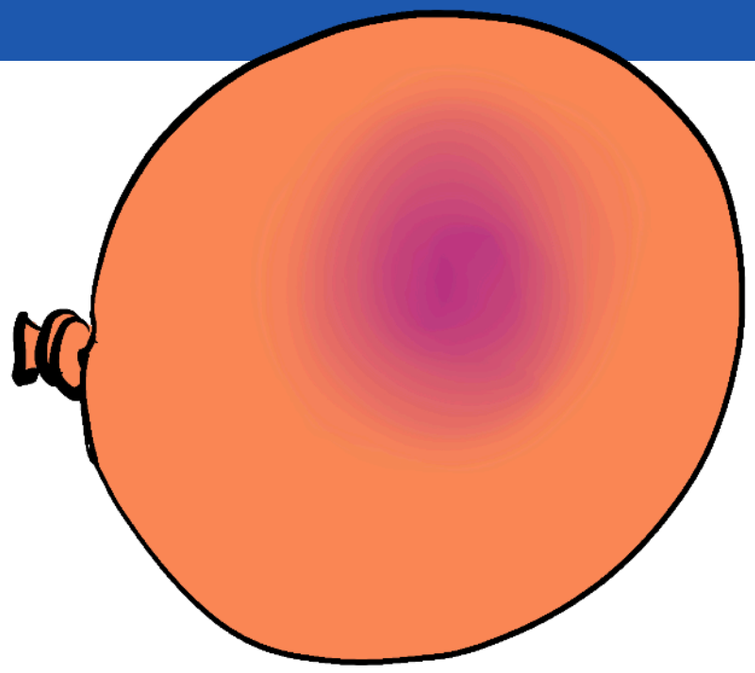


$< 10^{-10}$

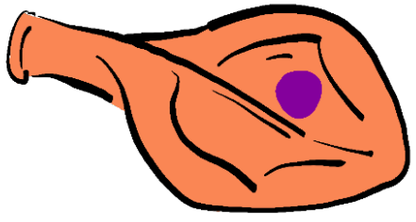
Parámetros del universo



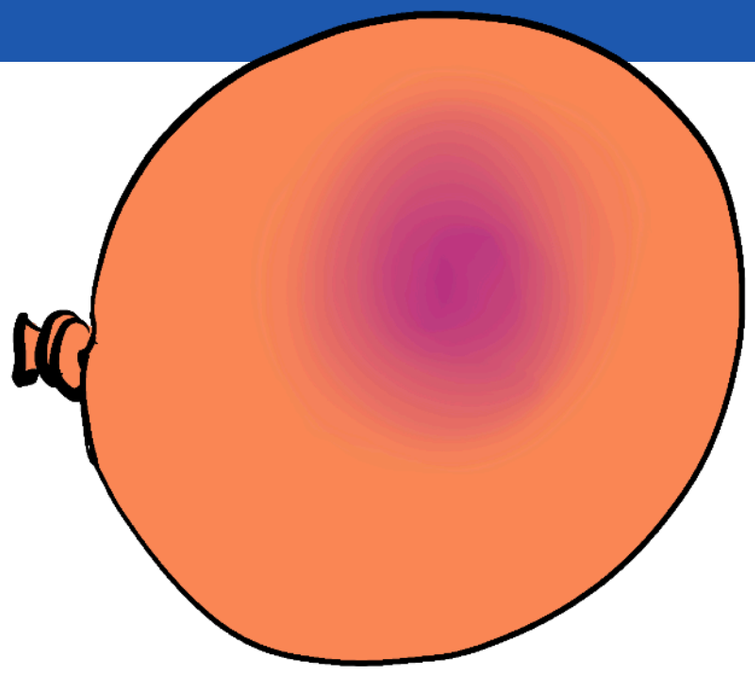
Inflación?



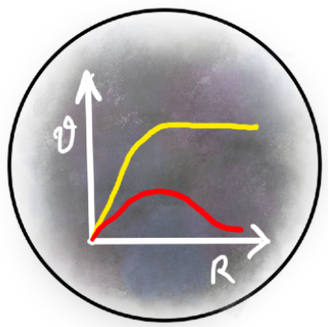
Parámetros del universo



Inflación?

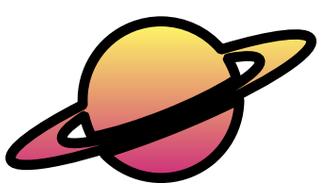


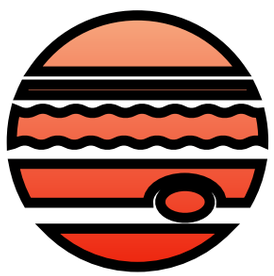
Mecanismo



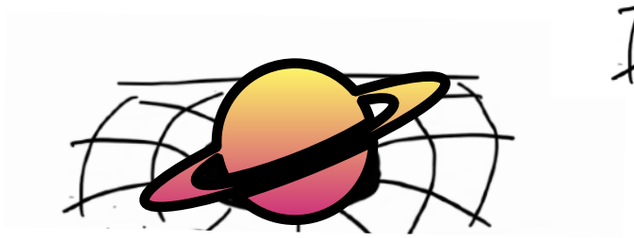
$$\Lambda_{DM} \sim 5\Lambda_B$$

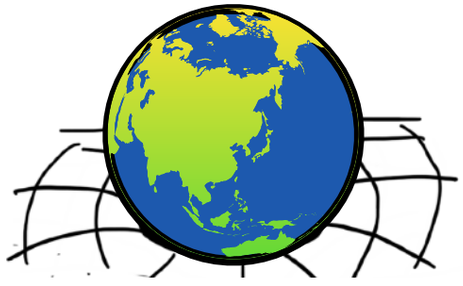
Y la gravedad?



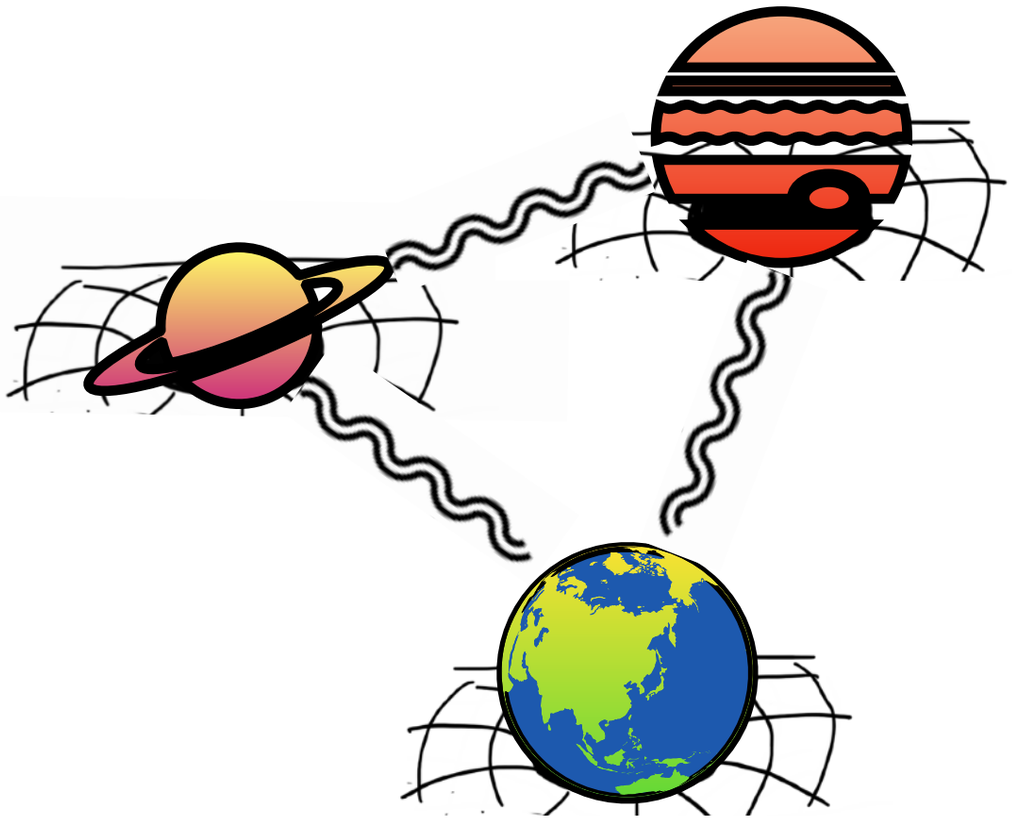


Y la gravedad?



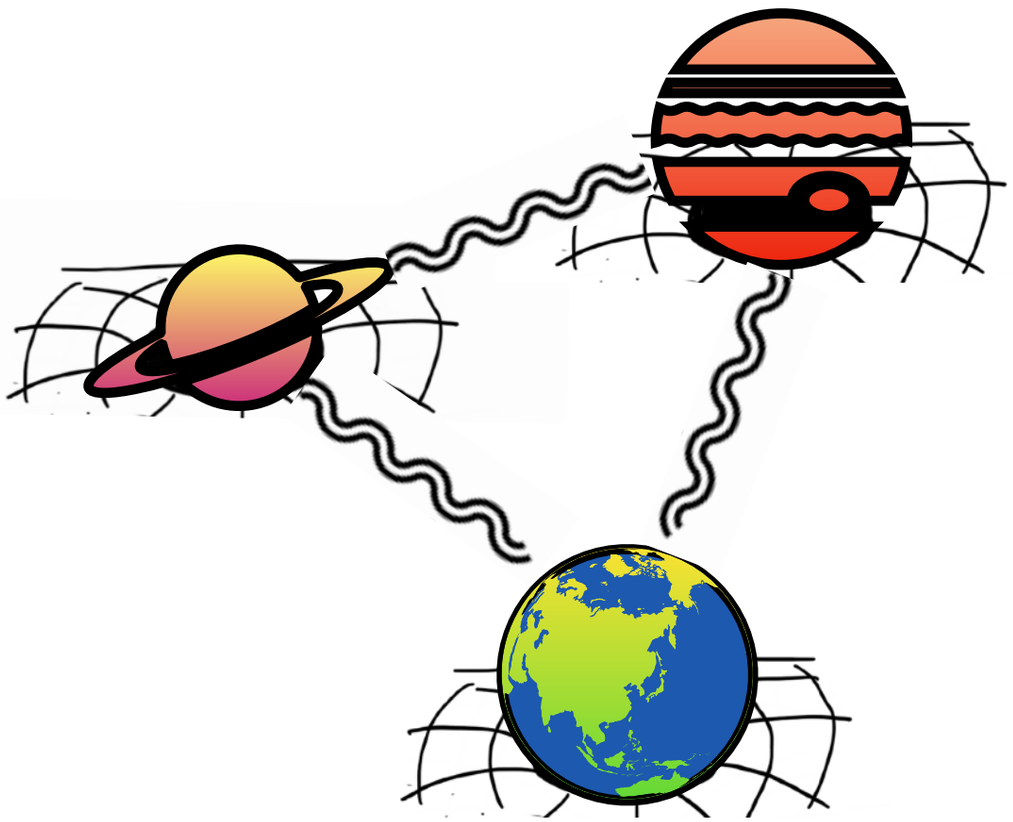


Y la gravedad?



Interacciones	Intensidad	Mediador	Alcance
F. Fuerte	1000	Gluones	Largo (M=0)
Electromagnetismo	1	Fotones	Largo (M=0)
F. Débil	100	W, Z	M
Gravedad		¿¿Gravitón??	Largo (M=0)

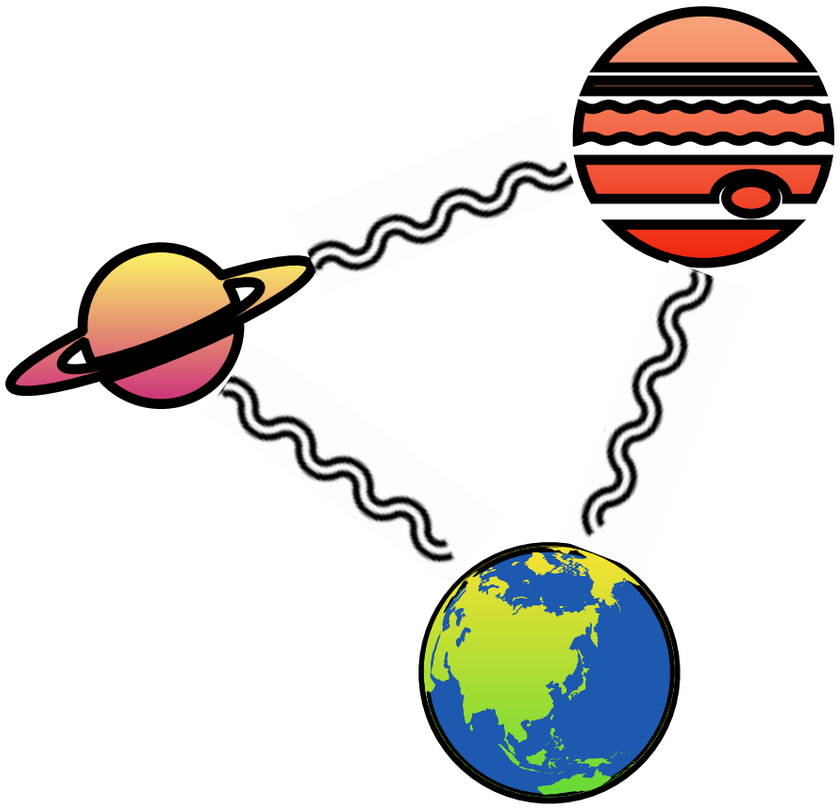
Y la gravedad?

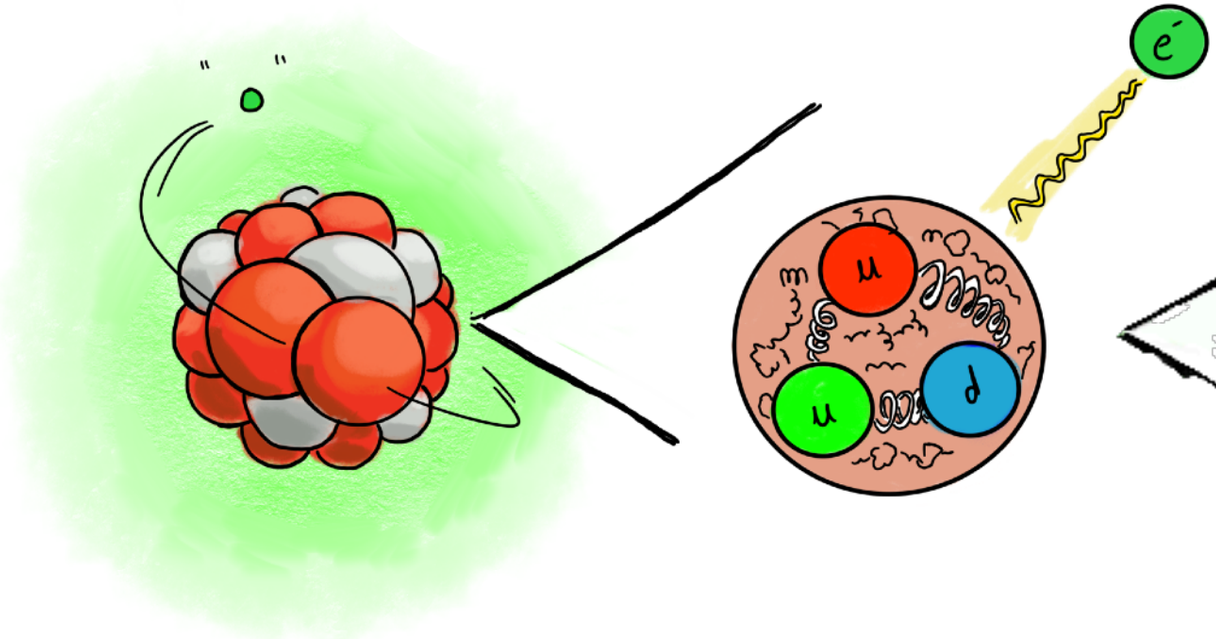


Dimensiones extra?

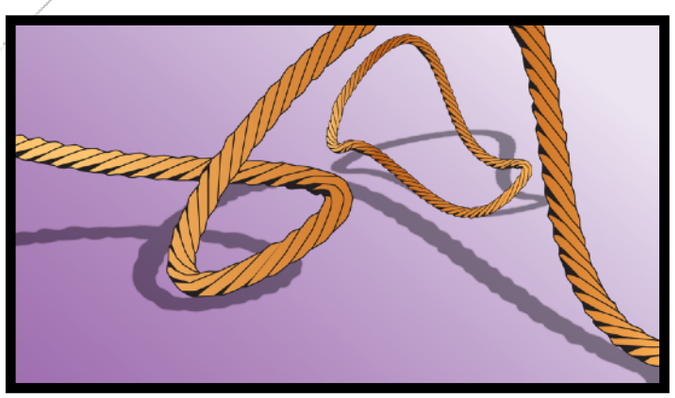
Interacciones	Intensidad	Mediador	Alcance
F. Fuerte	1000	Gluones	Largo (M=0)
Electromagnetismo	1	Fotones	Largo (M=0)
F. Débil	100	W, Z	M
Gravedad	10^{-33}	¿¿Gravitón??	Largo (M=0)

Y la gravedad?

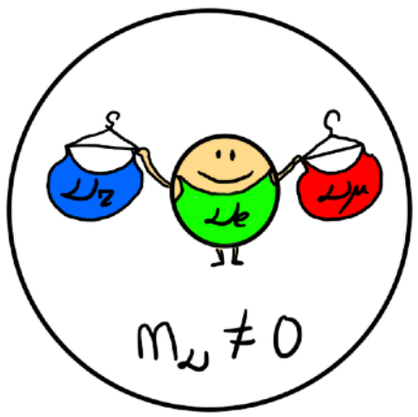


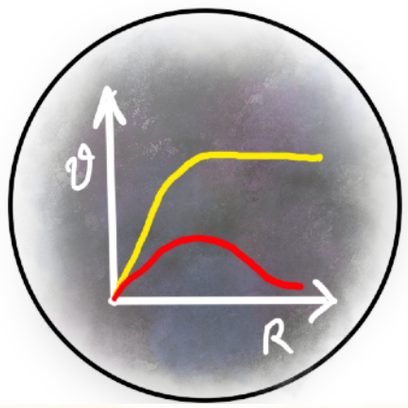


Teoría de cuerdas



En búsqueda de la nueva física





Teorías efectivas

Parametrizando la nueva física

e.g. serie de Taylor

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} + \cdots = \sum_{k=0}^{\infty} \frac{x^{2k+1}}{(2k+1)!}(-)^k$$

Teorías efectivas

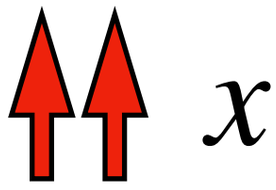
Parametrizando la nueva física

e.g. serie de Taylor

$$?? = x$$

Teorías efectivas

Parametrizando la nueva física



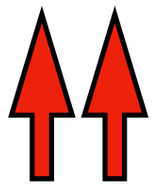
x

e.g. serie de Taylor

$$\sin(x) = x - \boxed{\frac{x^3}{3!} + \frac{x^5}{5!} + \cdots} = \sum_{k=0}^{\infty} \frac{x^{2k+1}}{(2k+1)!}(-)^k$$

Teorías efectivas

Parametrizando la nueva física



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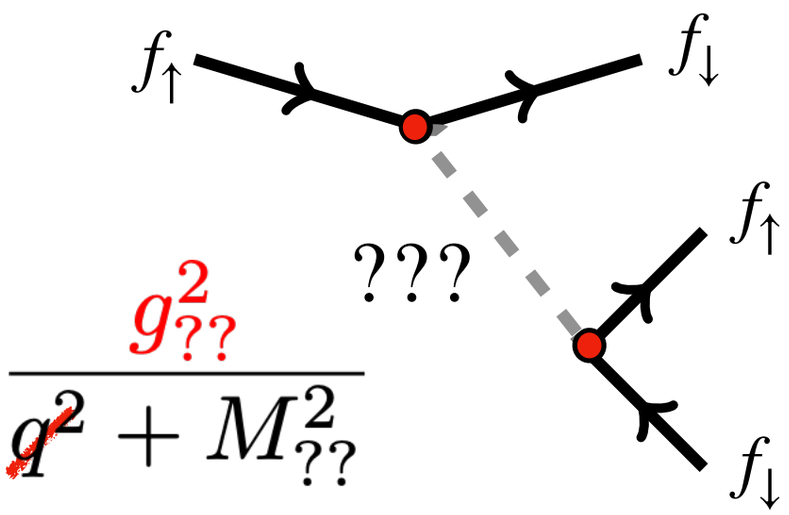
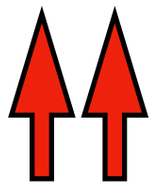
$$x = \frac{E}{M_{??}}$$



Teorías efectivas

Parametrizando la nueva física



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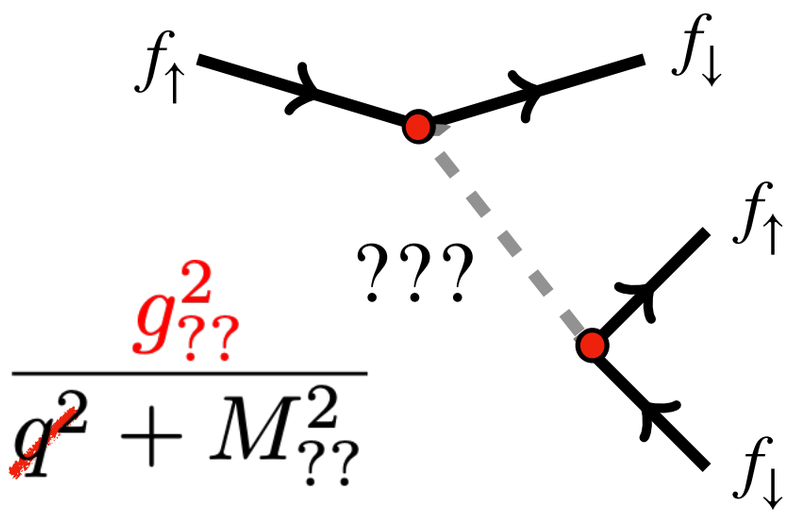
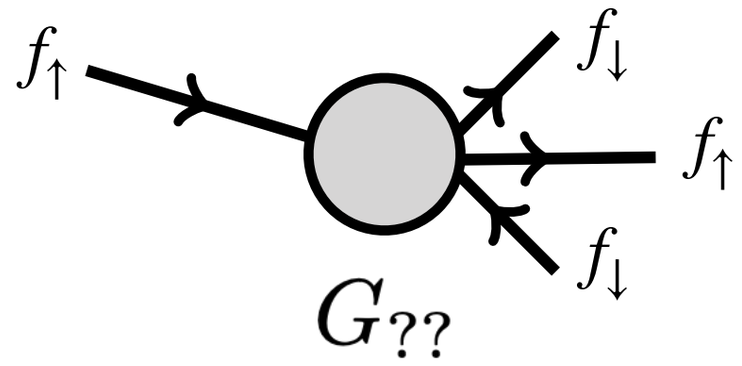


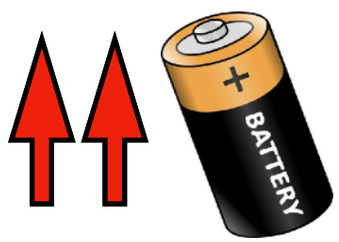
Zoom-out



Teorías efectivas

Parametrizando la nueva física

Construcción de super-colisionadores

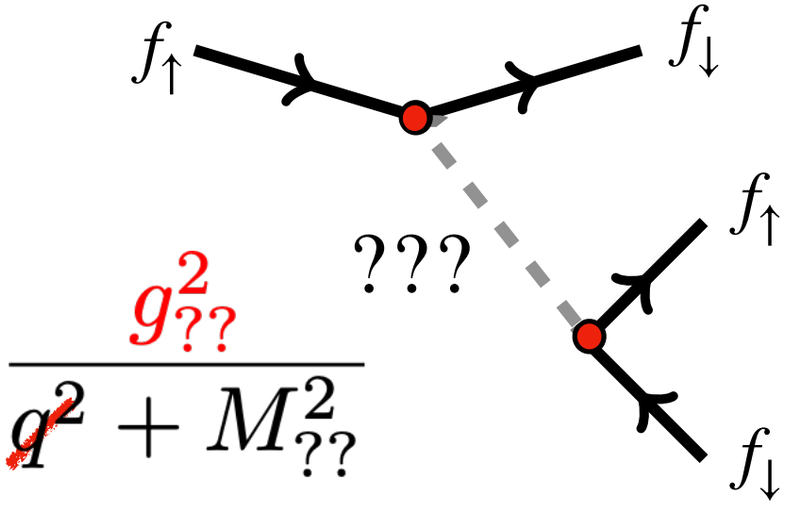


Física de Precisión

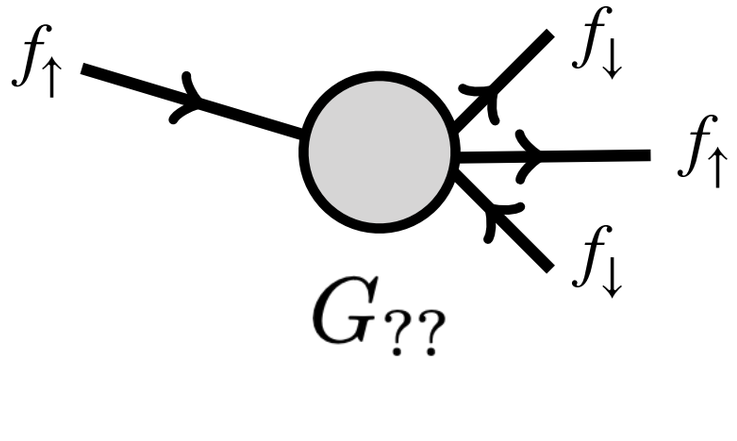
e.g. serie de Taylor

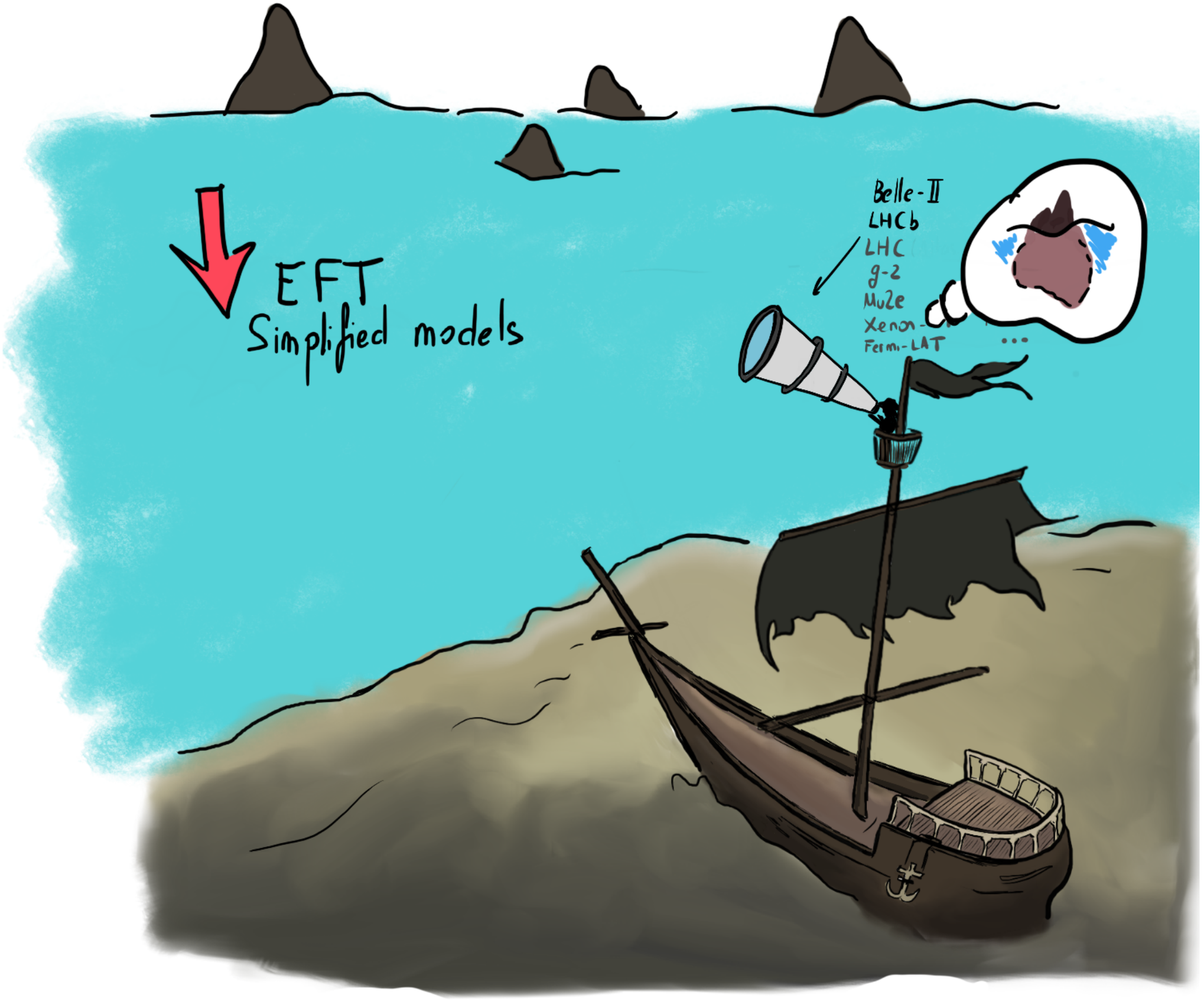
$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} + \cdots = \sum_{k=0}^{\infty} \frac{x^{2k+1}}{(2k+1)!}(-)^k$$

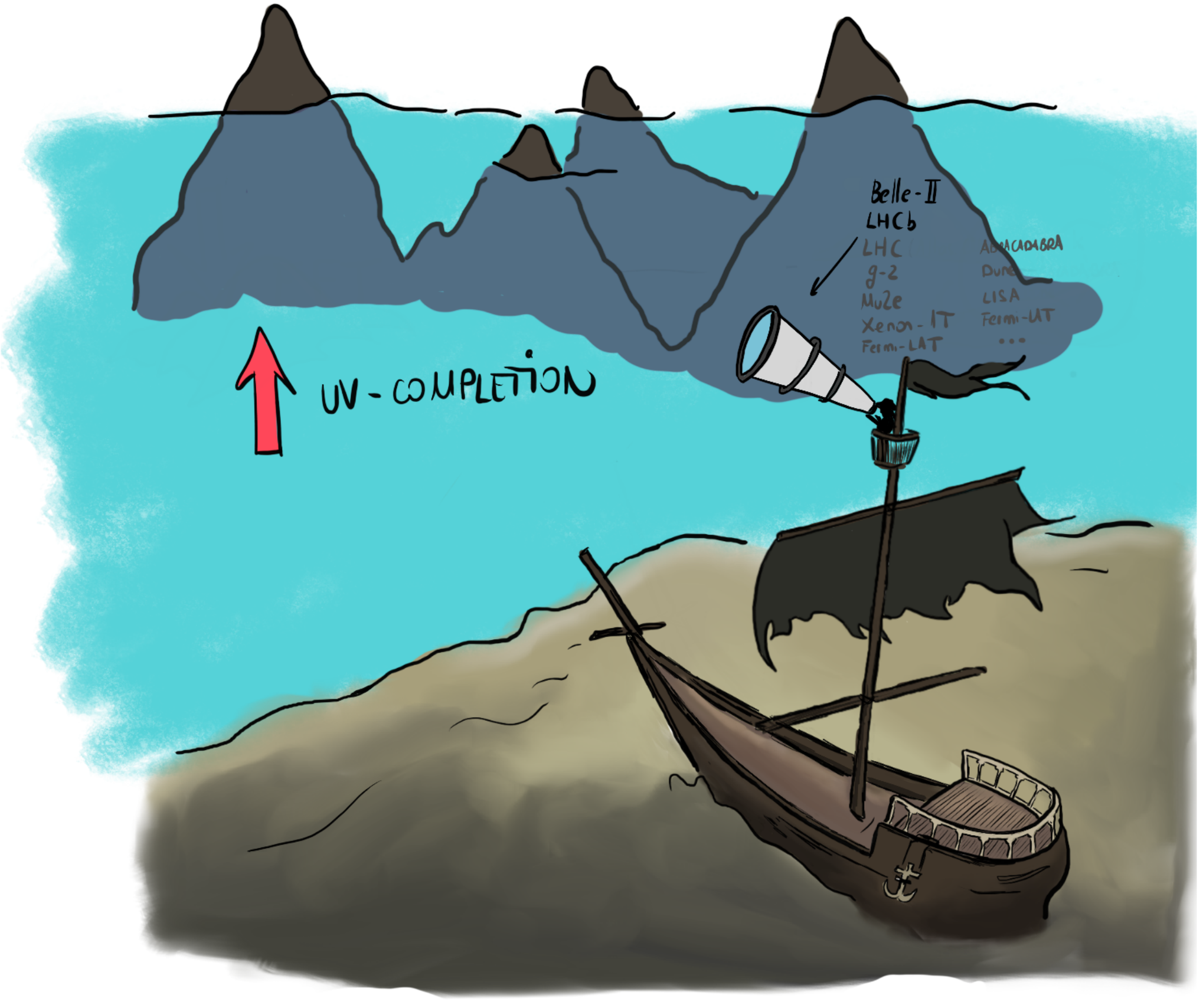
$$x = \frac{E}{M_{??}}$$



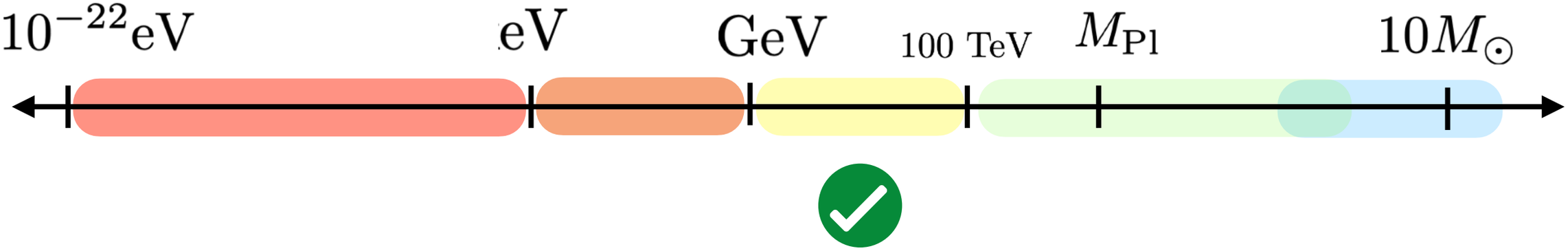
Zoom-out



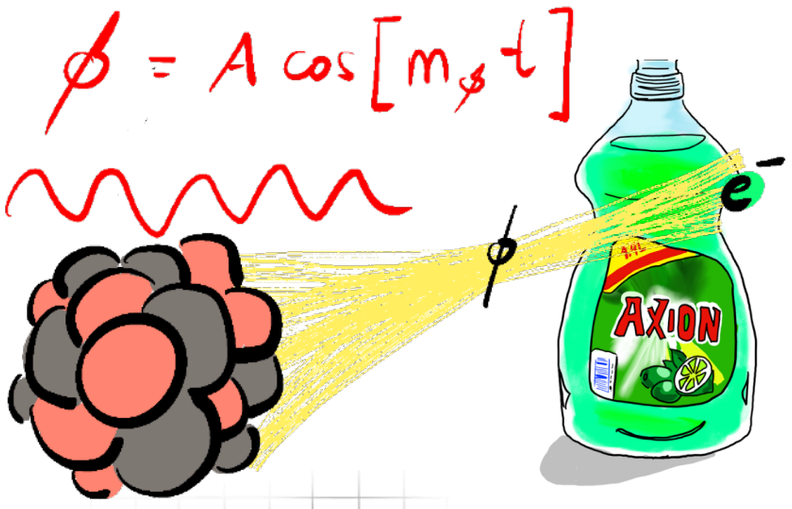

EFT
Simplified models
Belle-II
LHCb
LHC
g-2
MuZe
Xenon-
Fermi-LAT
...

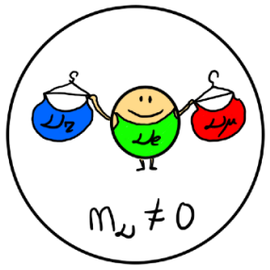

Belle-II
LHCb
LHC
g-2
Mu2e
Xenon-1T
Fermi-LAT
LISA
Fermi-LAT
...
UV-COMPLETION

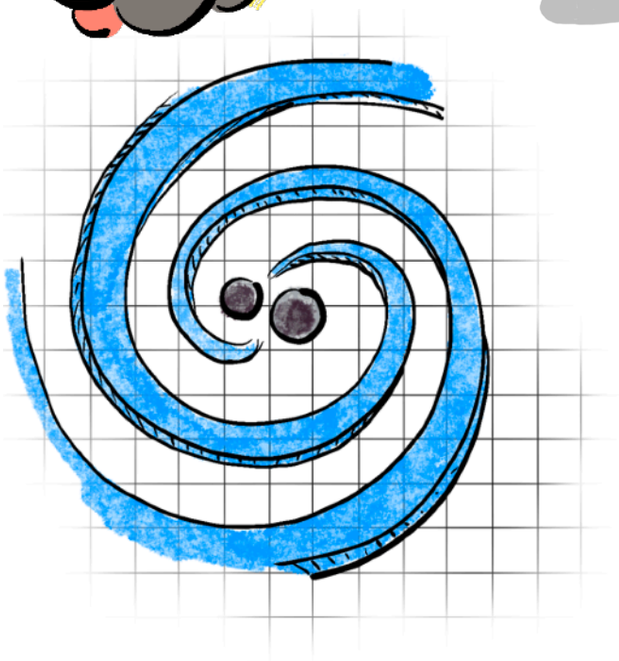
En búsqueda de nueva física (elusiva)

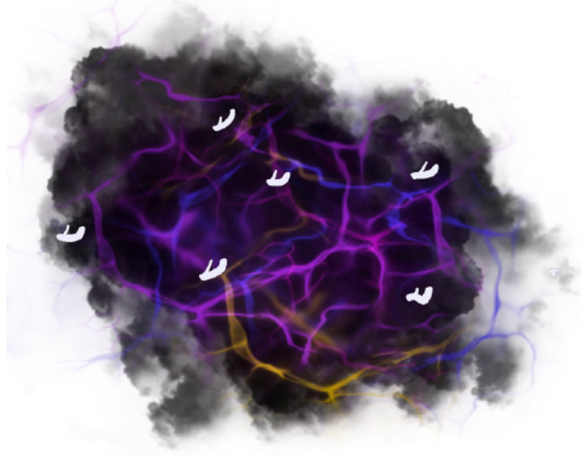


Colisionadores
Experimentos de sabor

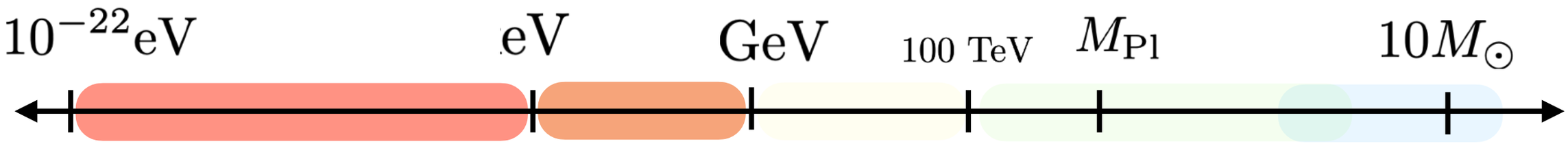




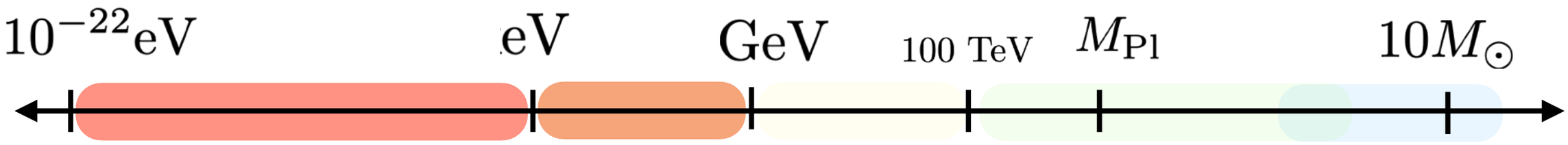




En búsqueda de nueva física (elusiva)



¡Hazte con todos!

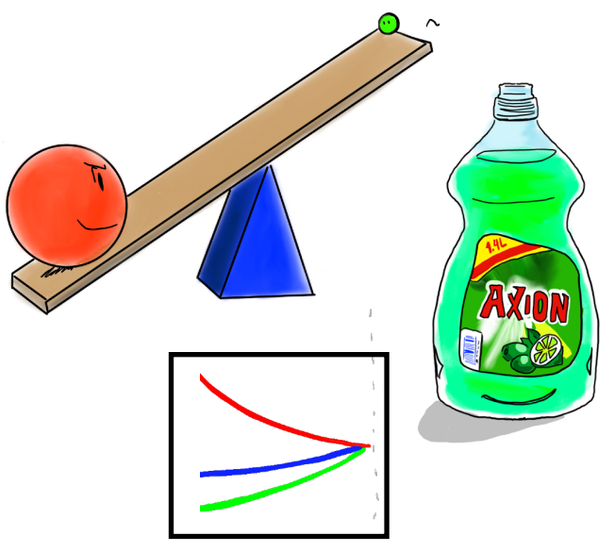


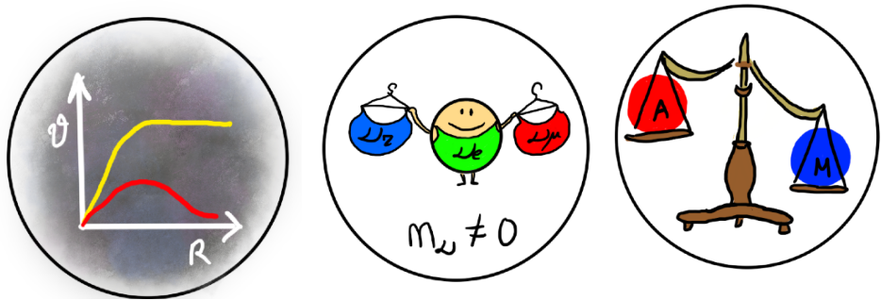
¡Hazte con todos!

(los que buenamente puedas)

El Modelo Estándar (recap)

(experimento) INPUTS





OUTPUTS

(también experimento)

(teoricos) "BONITA" , "SIMPLE"... $\equiv$ POTENTE

$$\frac{\text{INPUTS}}{\text{OUTPUTS}} \ll 1$$

The New World

Beyond the Standard Model

N

W E

S

Flavour Anomalies

Neutrino Masses

Matter - Antimatter asymmetry

CP violation

The Standard Model of particle physics

Dark Matter