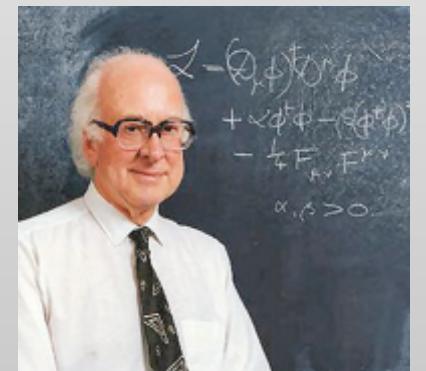
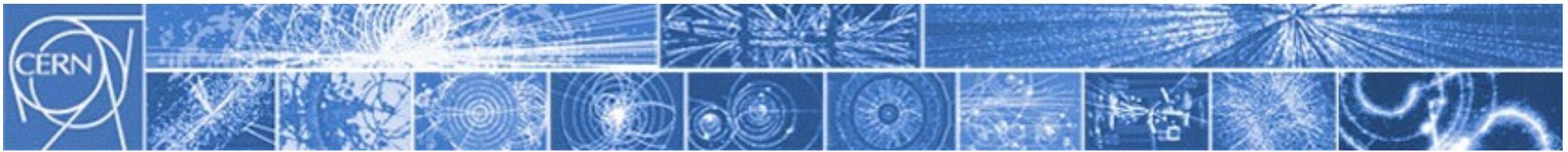


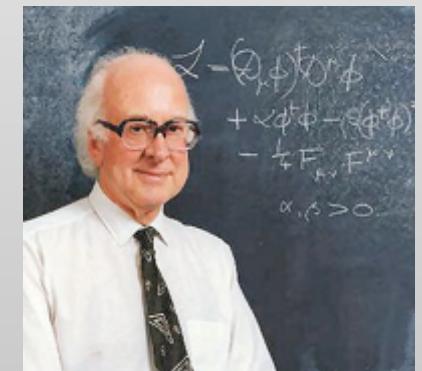
Il bosone di Higgs

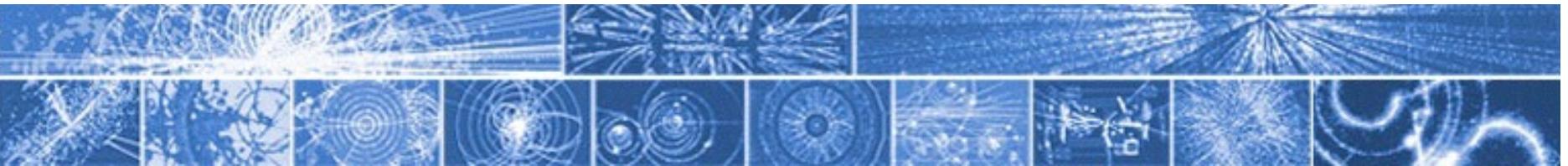




Il bosone di ~~Higgs~~

Englert-Brout-Higgs-Guralnik-Hagen-Kibble



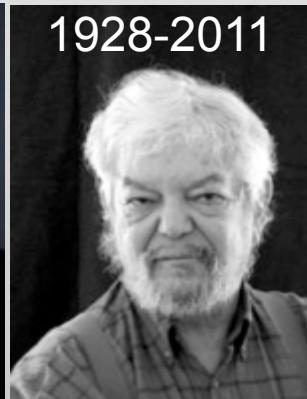


Il bosone di Higgs

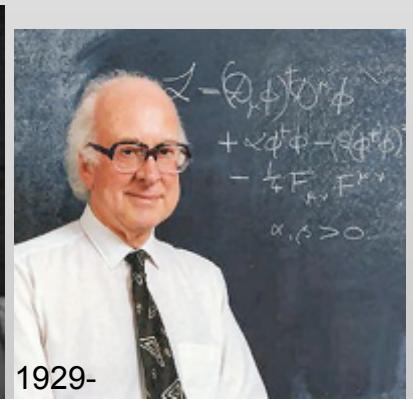
Englert-Brout-Higgs-Guralnik-Hagen-Kibble



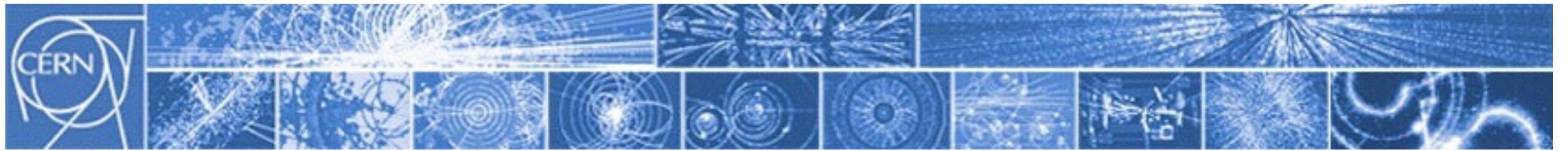
1932-



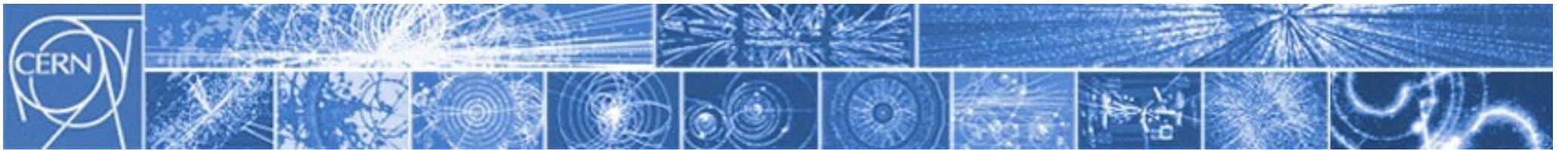
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1929-

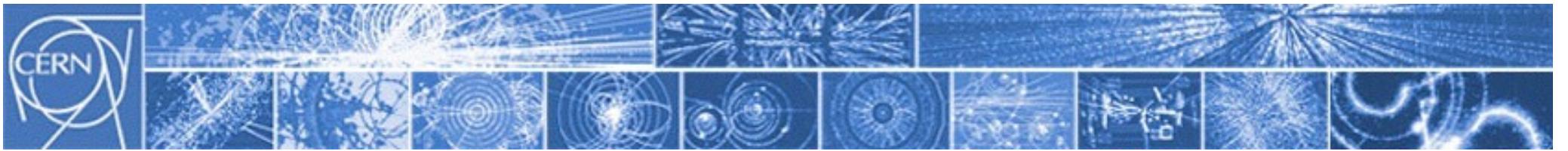


Q. Perché una particella ha massa m ?



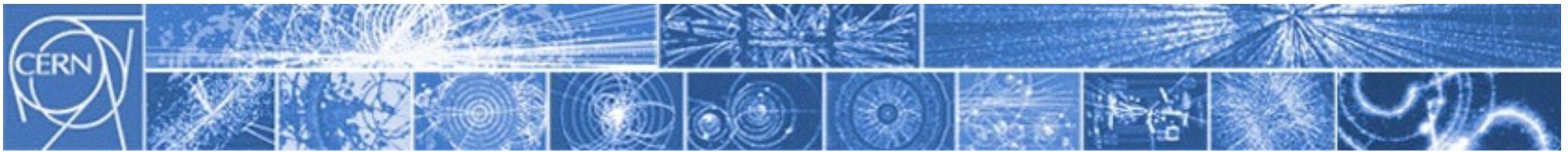
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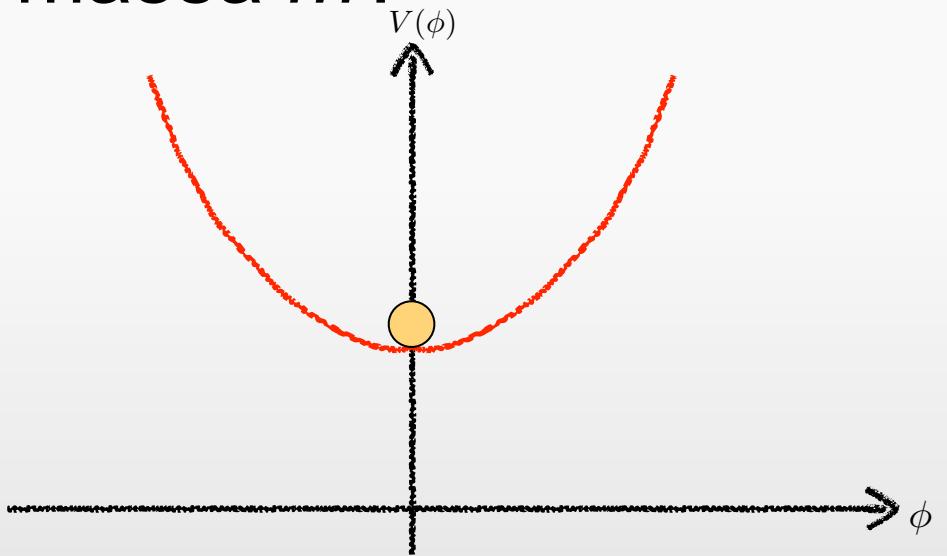
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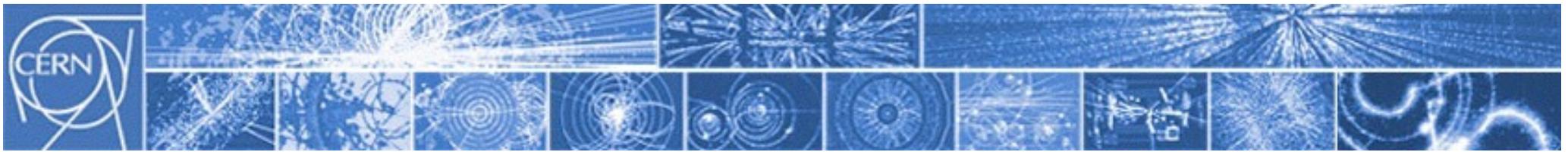
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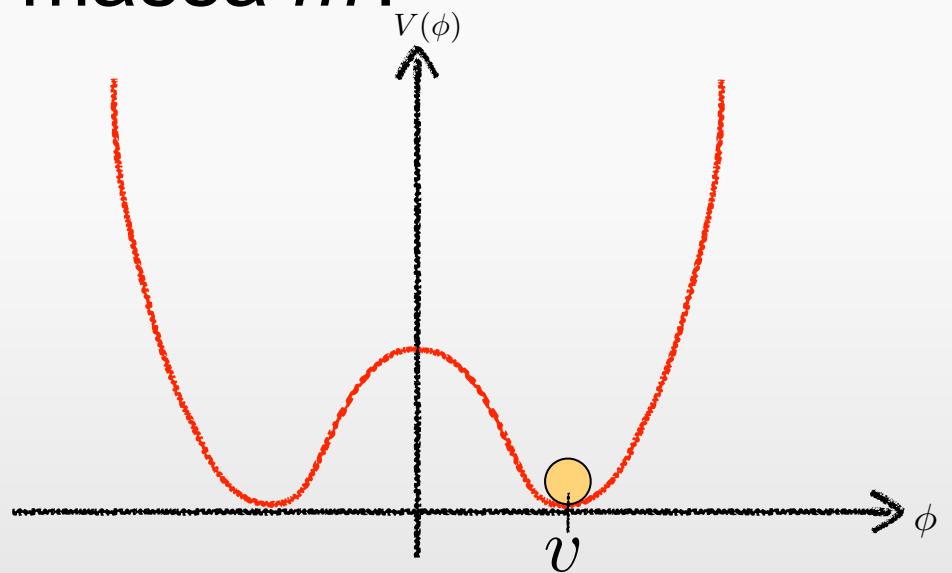
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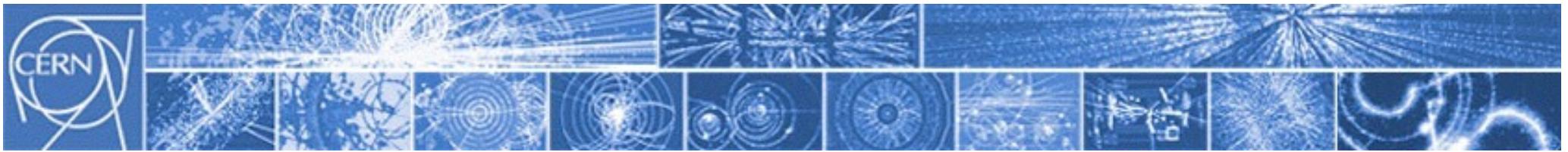


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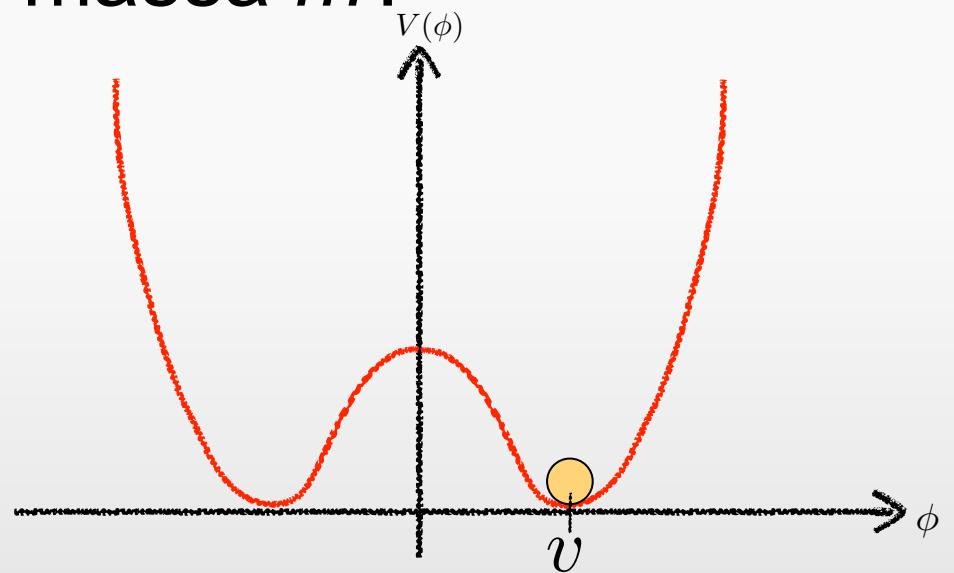


$$\phi \simeq v + h$$

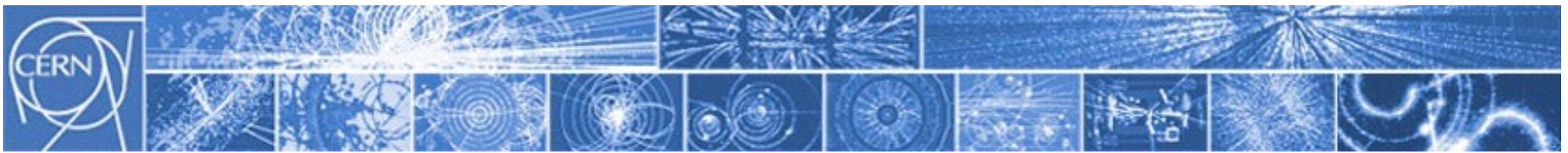


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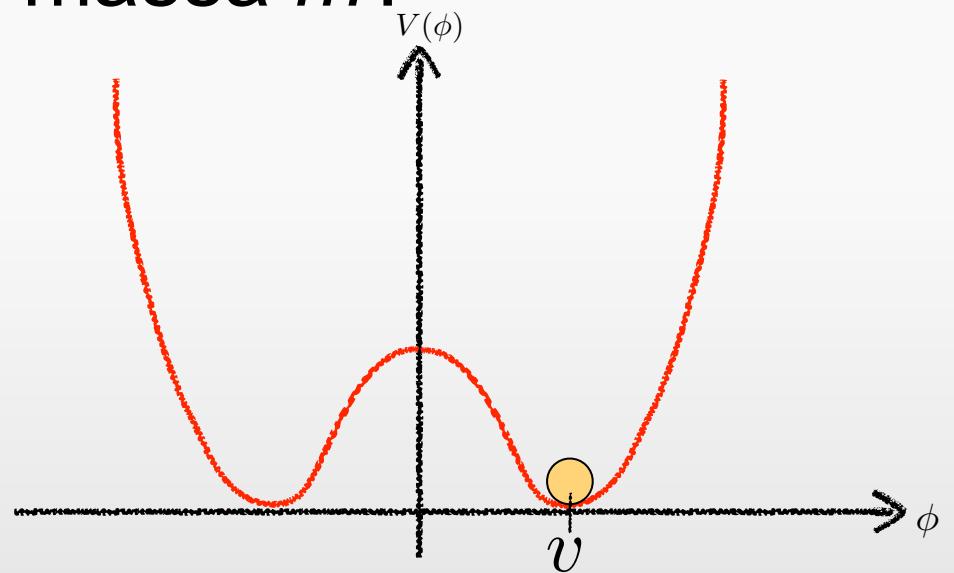


$$\phi = \frac{1}{\sqrt{2}}(v + h)$$



Q. Perché una particella ha massa m ?

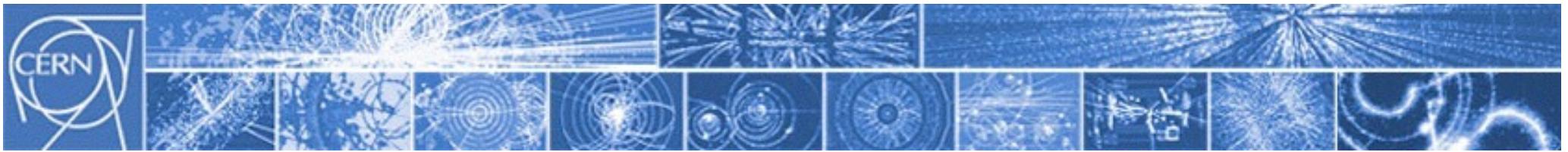
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$$y_{ij}\Psi_i\Psi_j \frac{1}{\sqrt{2}}(v+h) \rightsquigarrow \frac{y_\mu v}{\sqrt{2}}\mu\mu + \frac{y_\mu}{\sqrt{2}}\mu\mu h$$

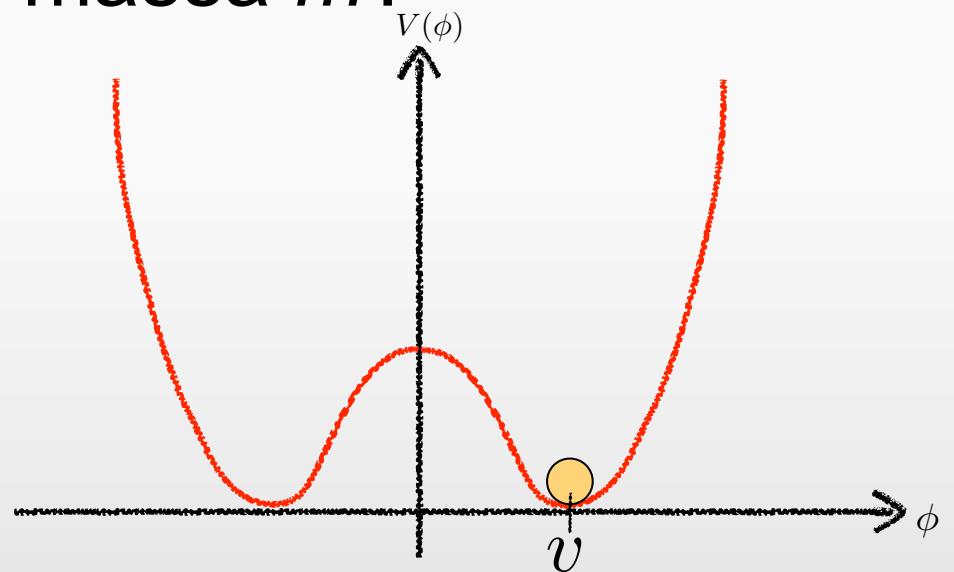
$$\frac{\mu}{\mu} + \frac{\mu}{\mu} \cdot \cdots \cdot h$$

$$\phi = \frac{1}{\sqrt{2}}(v+h)$$



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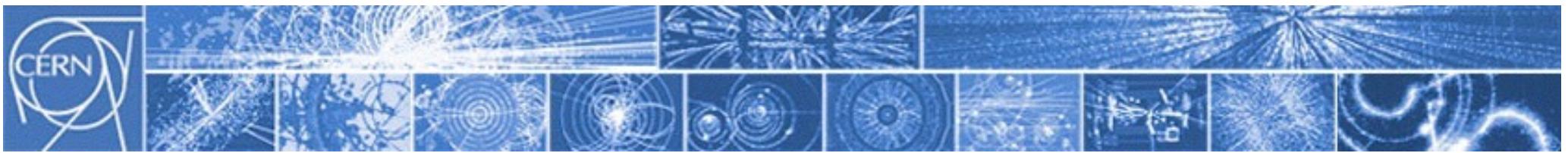
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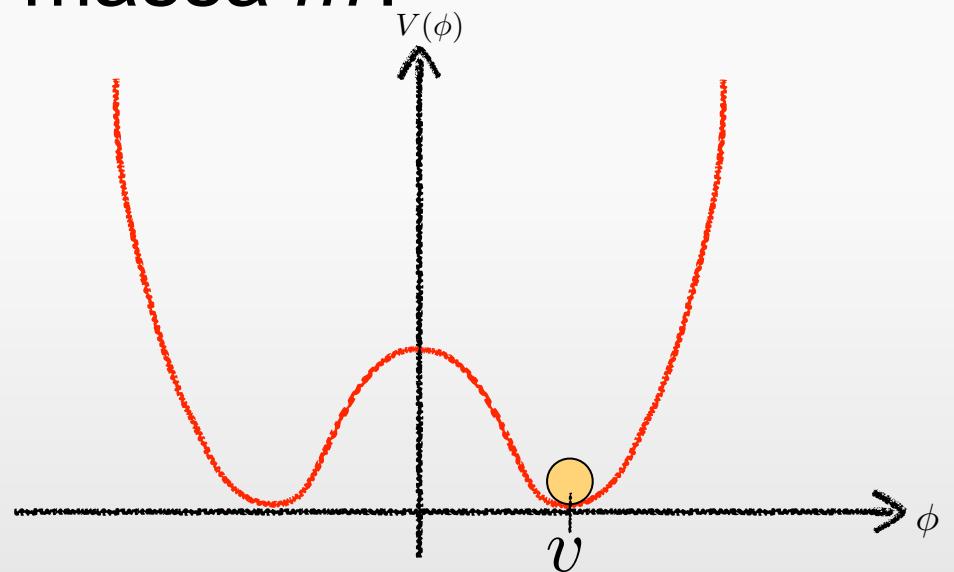
$\phi = \frac{1}{\sqrt{2}}(v + h)$

$y_\mu/\sqrt{2}$



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$$\begin{aligned}\mathcal{L} \simeq & -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} \\ & + i\bar{\Psi}\not{D}\Psi \\ & + y_{ij}\Psi_i\Psi_j\phi \\ & + |D_\mu\phi|^2 - V(\phi)\end{aligned}$$

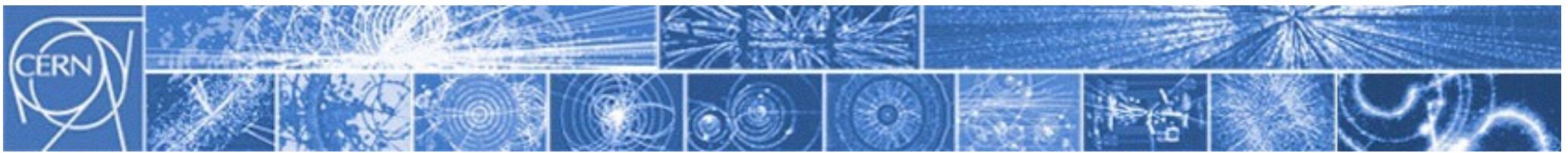


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$$\phi = \frac{1}{\sqrt{2}}(v+h)$$

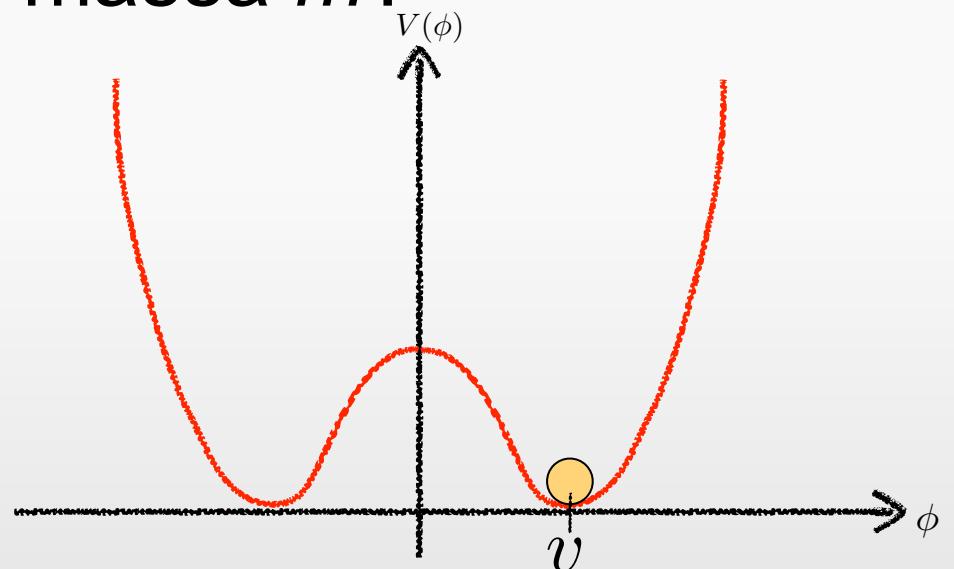
μ → μ + h
y_μ/√2 ↗

$$|D_\mu\phi|^2 \rightsquigarrow \frac{g}{2}v W^+W^-$$



Q. Perché una particella ha massa m ?

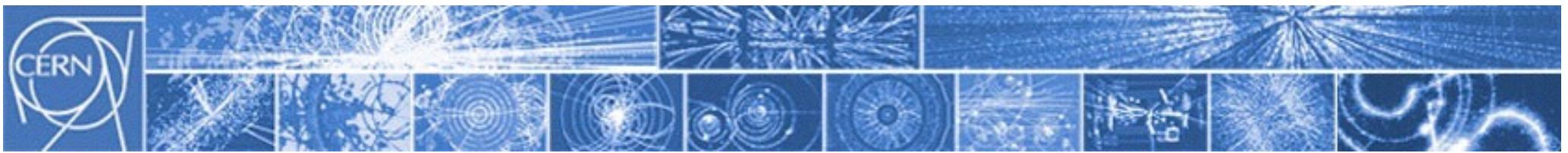
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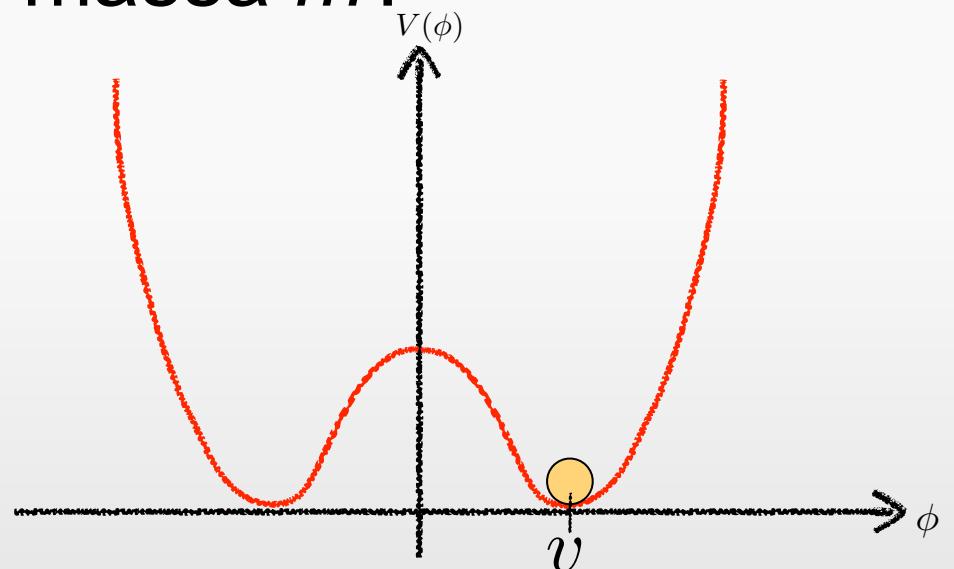
$$|D_\mu\phi|^2 \rightsquigarrow \frac{g v}{2}W^+W^-$$

$$\begin{aligned}\mu &\quad \phi = \frac{1}{\sqrt{2}}(v+h) \\ \mu &+ \quad \text{--- --- h} \\ \mu &\quad y_\mu/\sqrt{2}\end{aligned}$$



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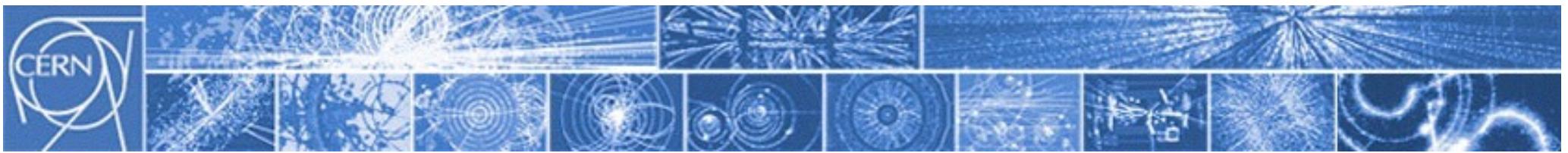


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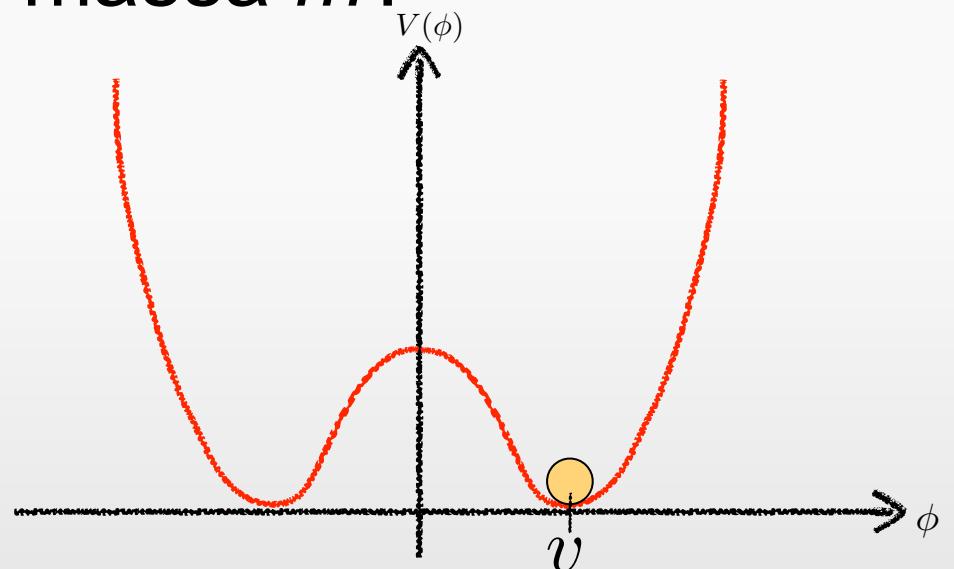
$$V(\phi) \rightsquigarrow \frac{1}{2}(2\lambda v^2)hh$$

$$\begin{array}{c} \mu \quad \quad \quad \phi = \frac{1}{\sqrt{2}}(v+h) \\ \mu \longrightarrow \mu + \text{---} \text{---} \text{---} h \\ \mu \quad \quad \quad y_\mu/\sqrt{2} \end{array}$$



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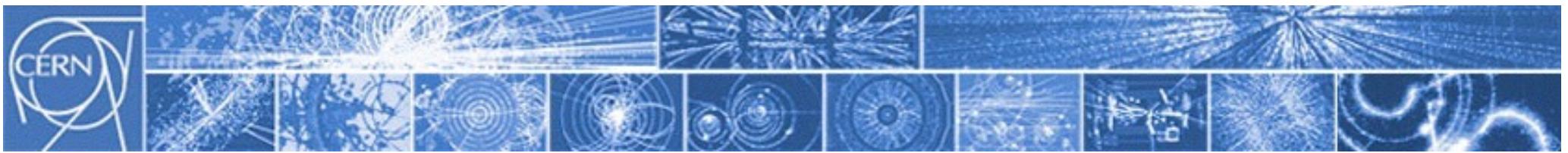


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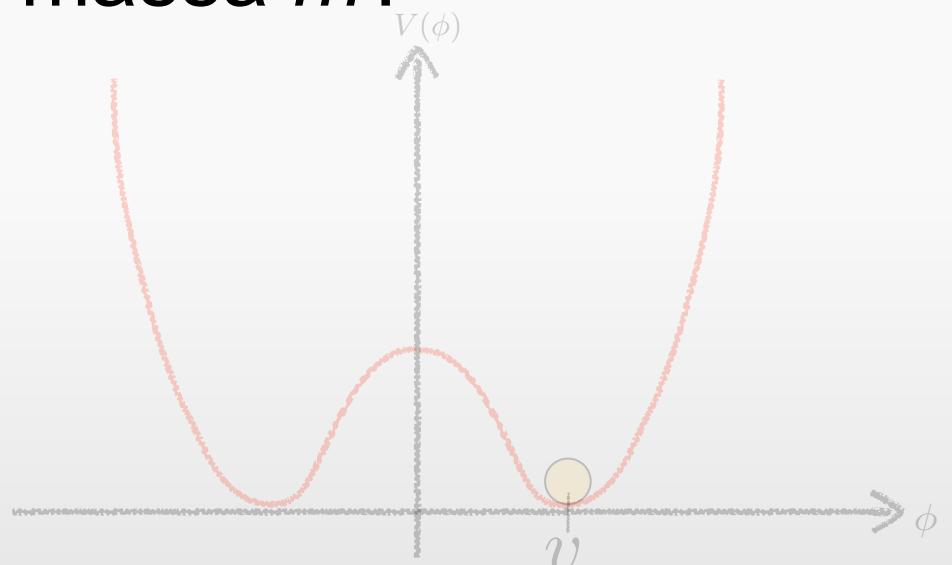
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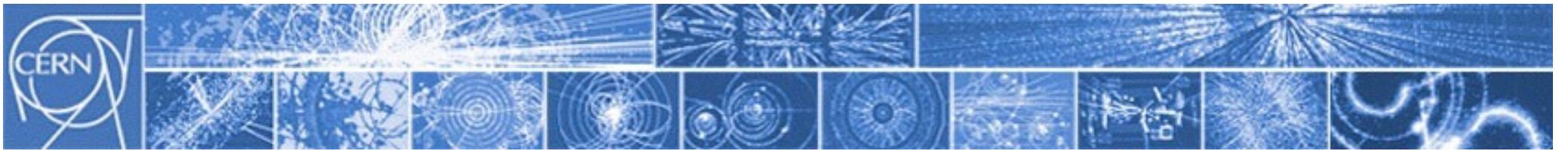
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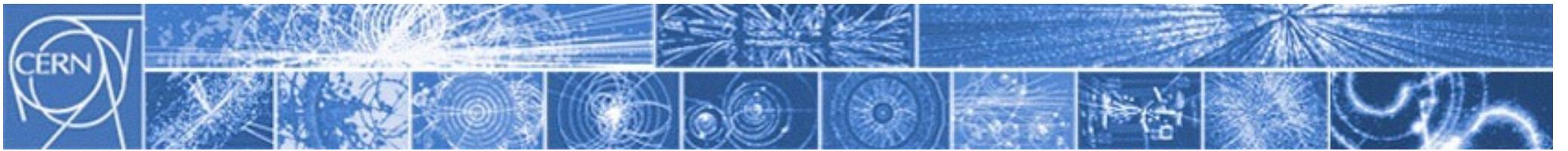
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Q. E se il campo di higgs non esistesse?



Q. Perché una particella ha massa m ?

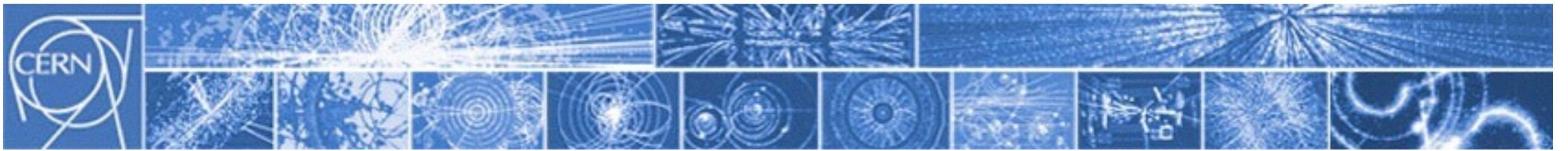
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Q. Perché una particella ha massa m ?

$$\begin{aligned}\mathcal{L} \simeq & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} & F_{\mu\nu} = \partial_\mu W_\nu - \partial_\nu W_\mu \\ & + i\bar{\Psi} D\Psi \\ & + y_{ij} \Psi_i \Psi_j \phi \\ & + |D_\mu \phi|^2 - V(\phi)\end{aligned}$$

$$F_{\mu\nu} F^{\mu\nu} \rightsquigarrow \partial_\mu W_\nu \partial_\nu W_\mu + \dots$$

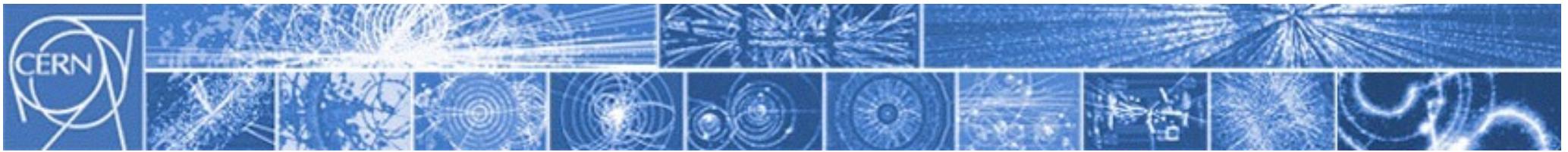


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$$F_{\mu\nu} F^{\mu\nu} \rightsquigarrow \partial_\mu W_\nu \partial_\nu W_\mu + \dots$$

$$i\bar{\Psi} D\Psi \rightsquigarrow \mu \partial \mu - ig \mu W \mu$$



Q. Perché una particella ha massa m ?

$$\mathcal{L} \simeq -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

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$$+ i \bar{\Psi} D\Psi$$

$$D \simeq \partial - igW$$

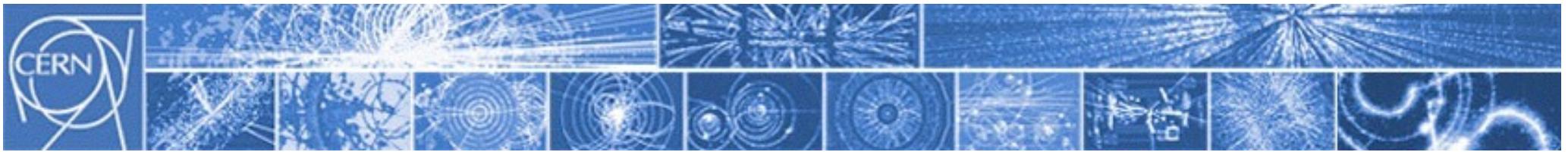
$$+ y_{ij} \Psi_i \Psi_j \phi$$

$$+ |D_\mu \phi|^2 - V(\phi)$$

$$F_{\mu\nu} F^{\mu\nu} \rightsquigarrow \partial_\mu W_\nu \partial_\nu W_\mu + \dots$$

niente termini di massa!

$$i \bar{\Psi} D\Psi \rightsquigarrow \mu \partial \mu - ig \mu W \mu$$



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$$+ |D_\mu \phi|^2 - V(\phi)$$

$$F_{\mu\nu} F^{\mu\nu} \rightsquigarrow \partial_\mu W_\nu \partial_\nu W_\mu + \dots$$

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$$i \bar{\Psi} \not{D} \Psi \rightsquigarrow \mu \partial \mu - ig \mu W \mu$$

E se li mettessimo a mano?

$$+\textcolor{red}{M} W W \dots \quad +\textcolor{red}{m} \mu \mu \dots$$



Q. Perché una particella ha massa m ?

$$\mathcal{L} \simeq -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

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$$F_{\mu\nu} = \partial_\mu W_\nu - \partial_\nu W_\mu$$

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$$F_{\mu\nu} F^{\mu\nu} \rightsquigarrow \partial_\mu W_\nu \partial_\nu W_\mu + \dots$$

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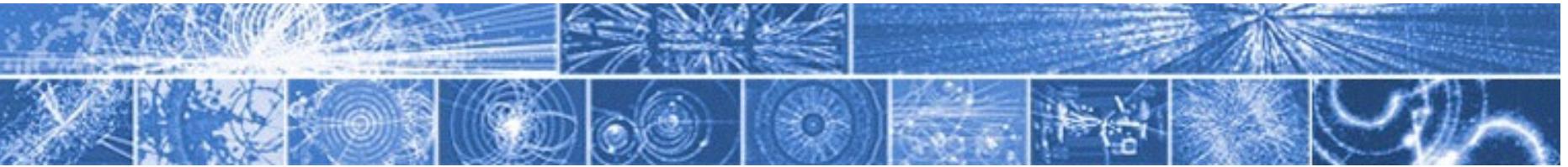
E se li mettessimo a mano?

$$+\textcolor{red}{M} W W \dots$$

$$+\textcolor{red}{m} \mu \mu \dots$$



rottura esplicita della simmetria di gauge



Q. P. - h' -> t + b + l + ν

$$\mathcal{L} = \frac{1}{2} (\partial_\mu A_\nu - \partial_\nu A_\mu) F_{\mu\nu} - \partial_\nu W_\mu$$



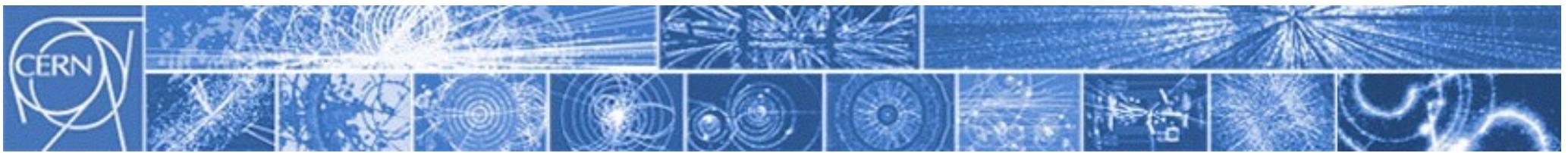
$$F_{\mu\nu}$$

$$i\bar{\Psi} \not{D}$$

E se

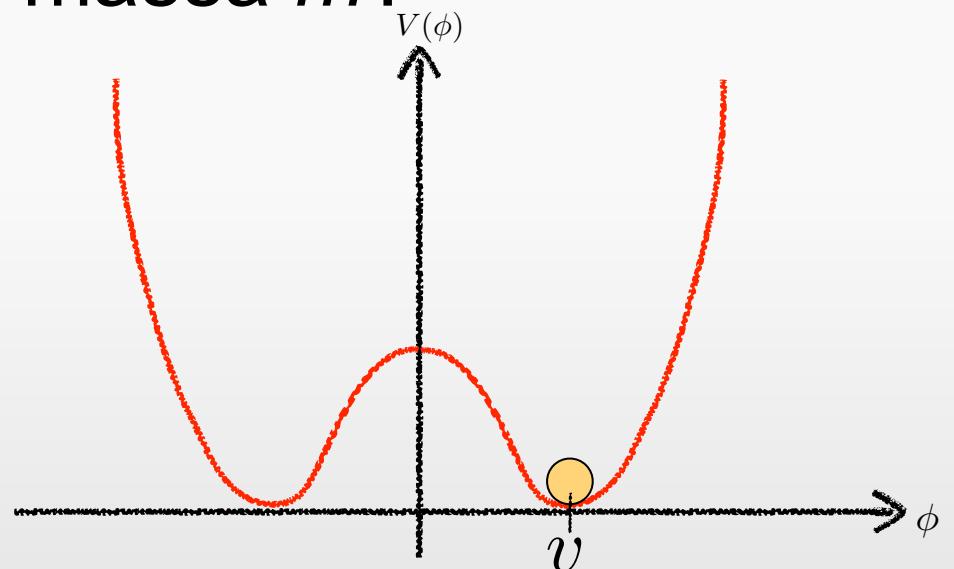
$$+ M$$

di gauge



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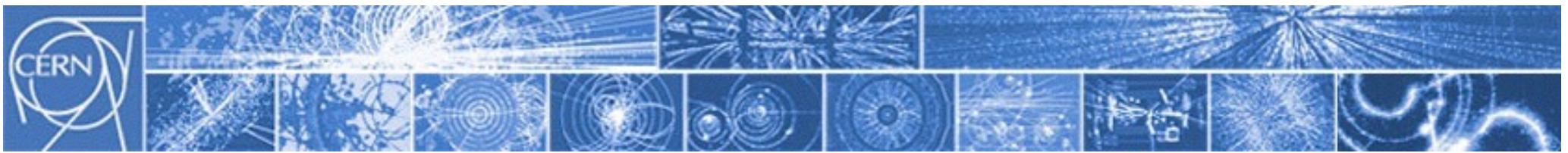


$$y_{ij}\Psi_i\Psi_j \frac{1}{\sqrt{2}}(v+h) \rightsquigarrow \frac{y_\mu v}{\sqrt{2}}\mu\mu + \frac{y_\mu}{\sqrt{2}}\mu\mu h$$

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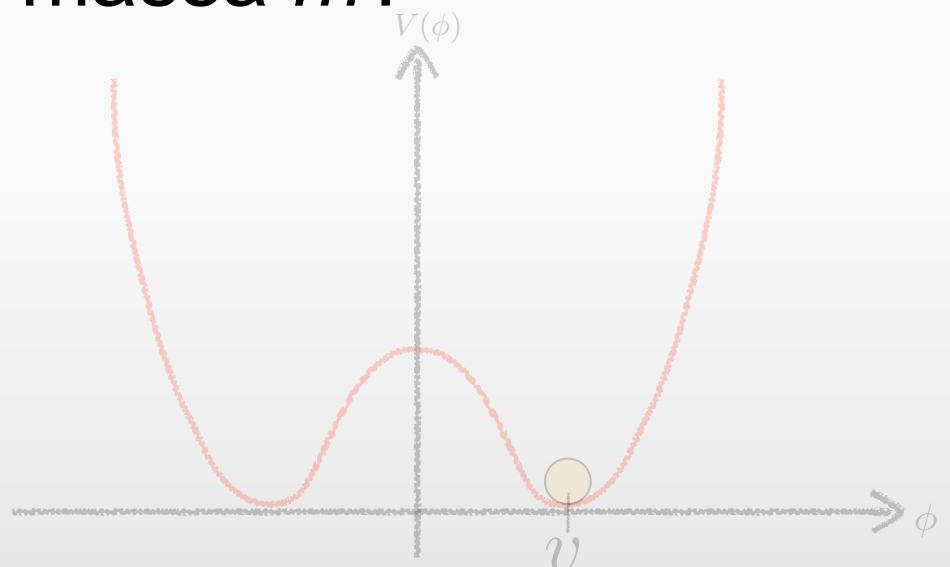
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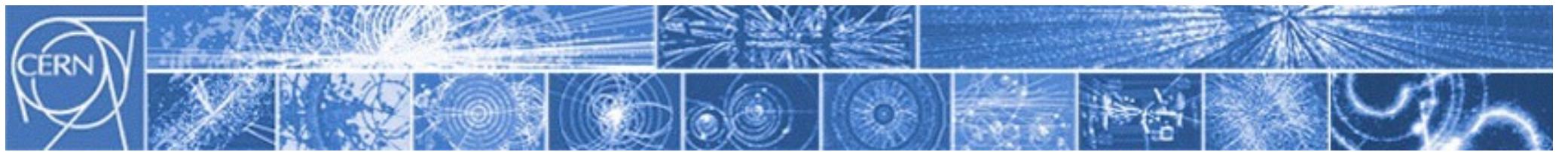
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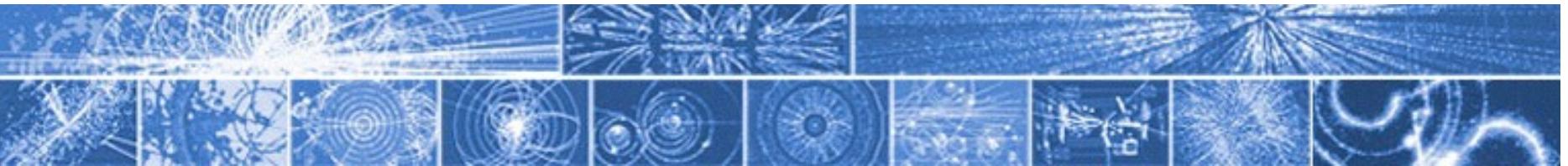
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A. Perché interagisce con l'higgs con intensità $y=\sqrt{2}m/v!$



Q. Perché una particella ha massa m ?

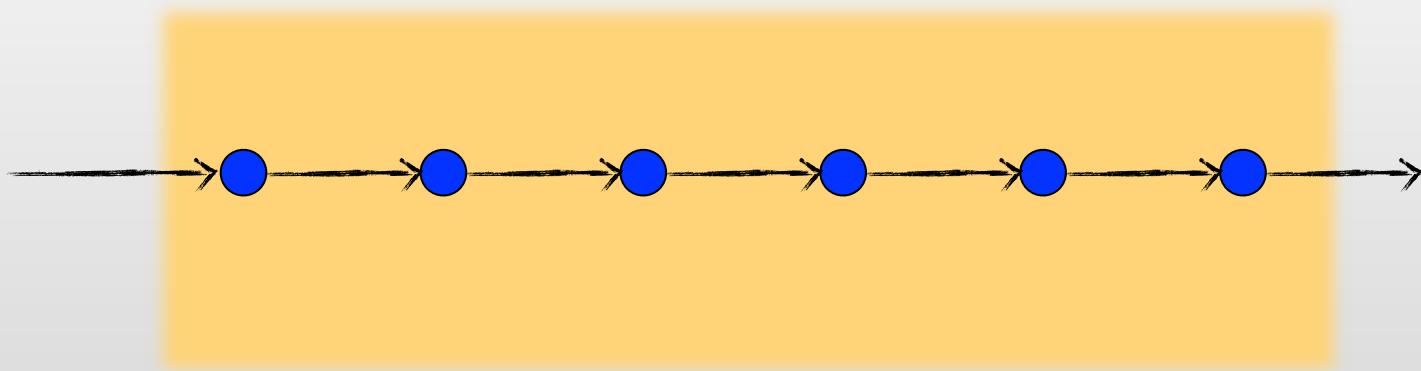
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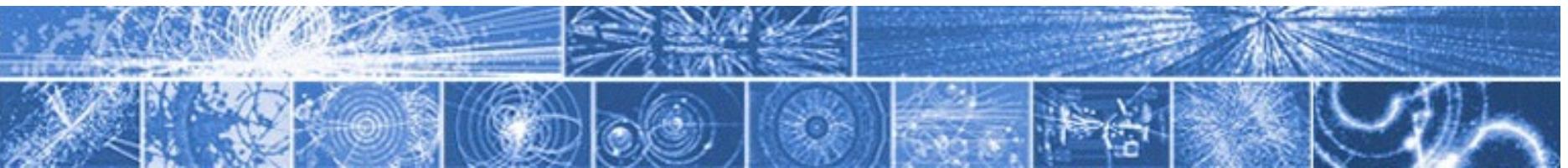
Q. Perché una particella ha massa m ?

A. Perché interagisce con l'higgs con intensità $y=\sqrt{2}m/v!$

Il campo di higgs è un mezzo continuo che permea l'universo.
Le particelle, interagendo col campo, acquistano un'inerzia/massa.



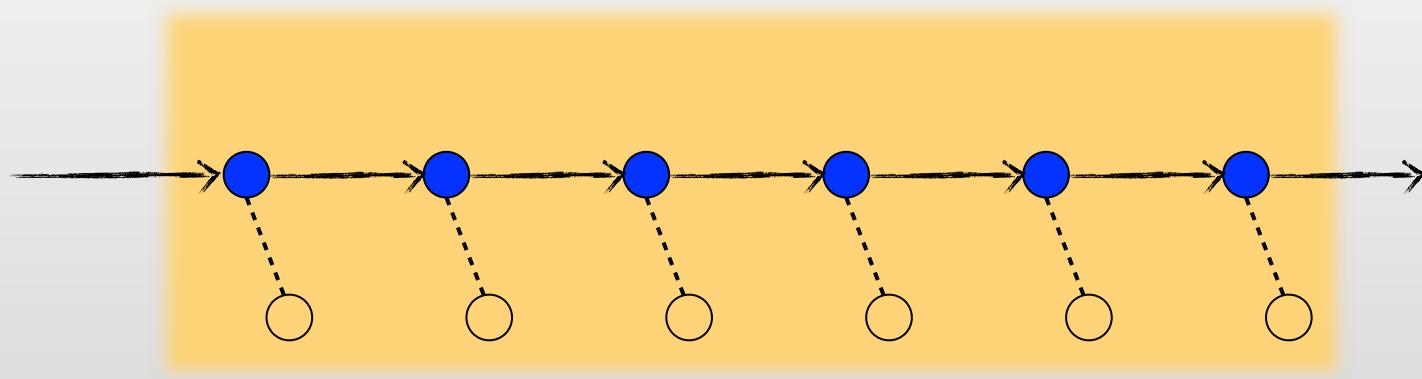
Credit: Michelangelo Mangano



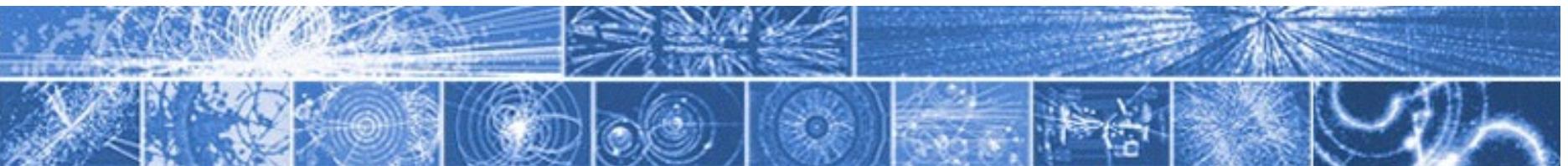
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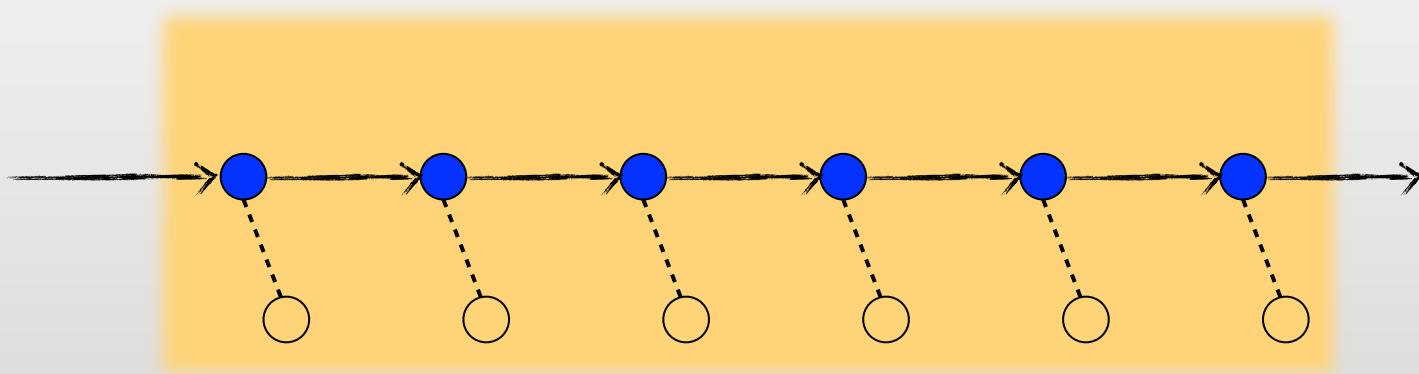
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Le 'onde' del campo di Higgs sono una *particella*:
la particella di Higgs (bosone).

Equation (2b) describes waves whose quanta have
(bare) mass $2\varphi_0[V''(\varphi_0^2)]^{1/2}$

VOLUME 13, NUMBER 9

PHYSICAL REVIEW LETTERS

31 AUGUST 1964

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout

Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

VOLUME 13, NUMBER 16

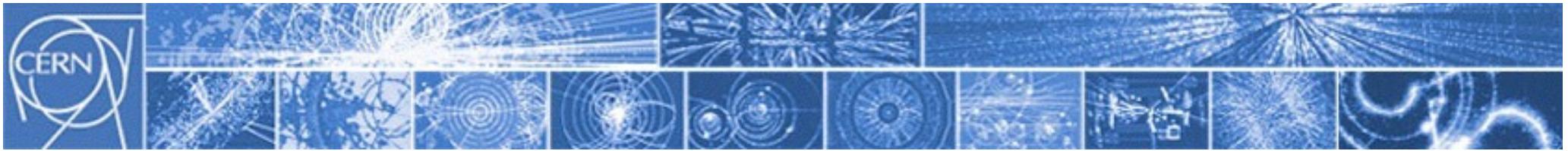
PHYSICAL REVIEW LETTERS

19 OCTOBER 1964

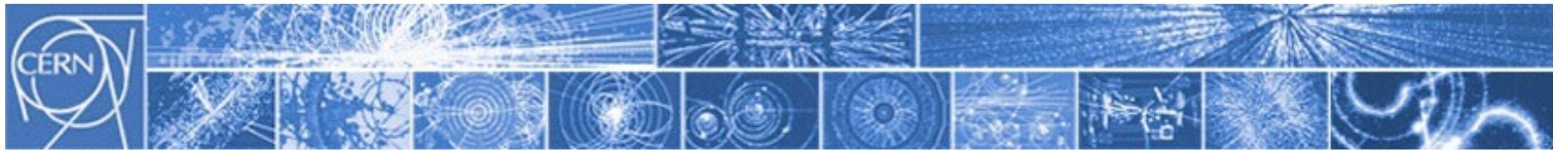
BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs

Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)



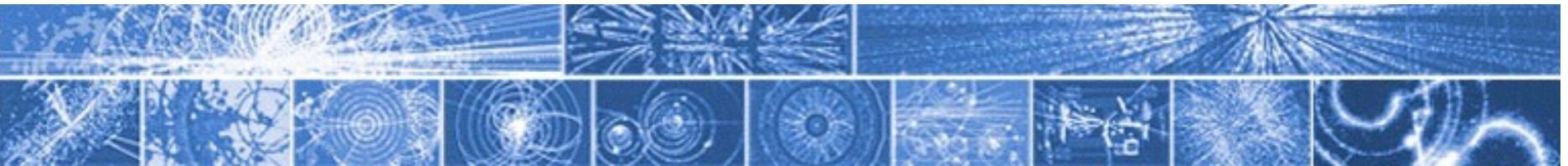
Oltre il Modello Standard



Problemi aperti in Fisica delle Particelle

- il *pattern* delle masse e le proprietà dell'higgs

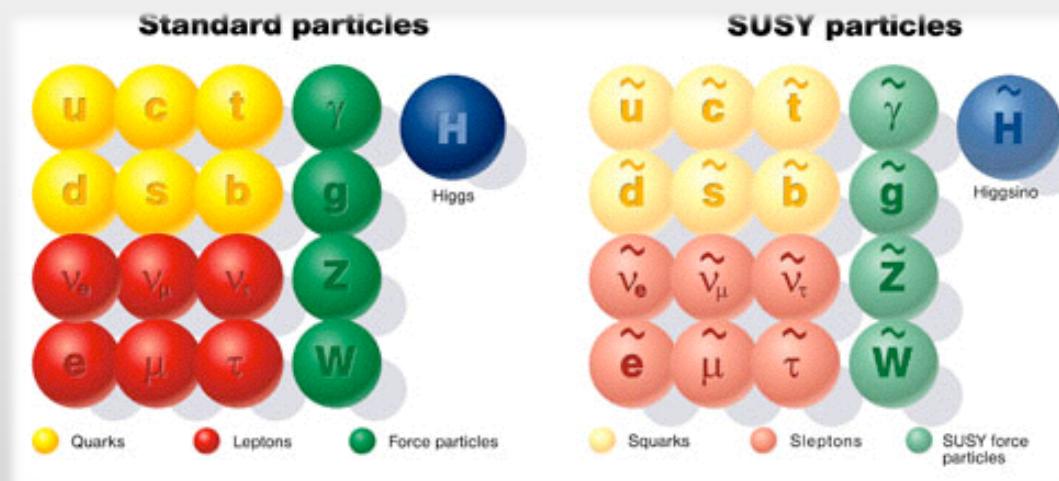


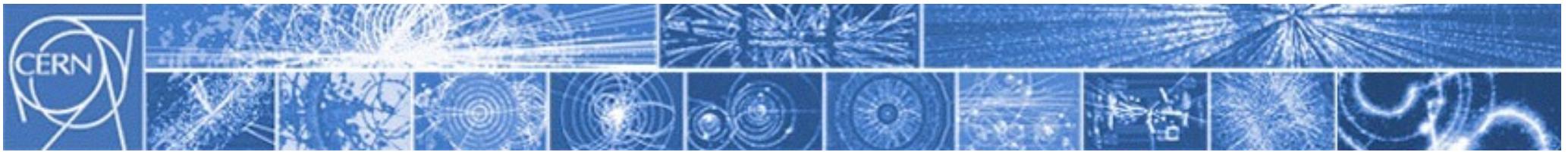


Problemi aperti in Fisica delle Particelle



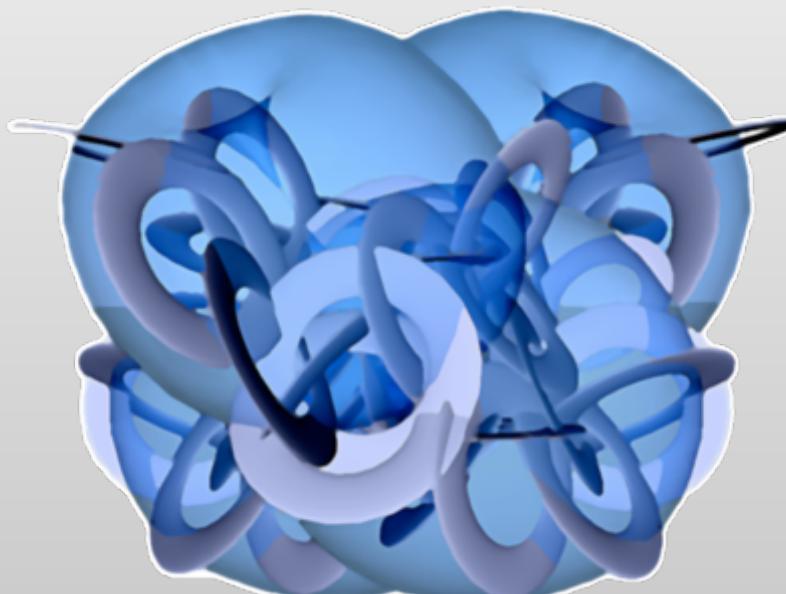
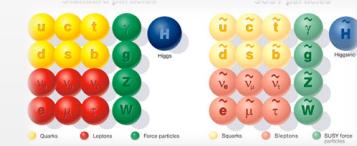
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(forse c'è un partner supersimmetrico per ogni tipo di particella nota!)

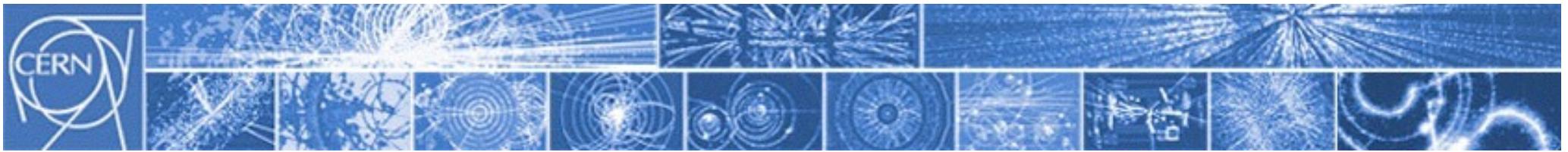




Problemi aperti in Fisica delle Particelle

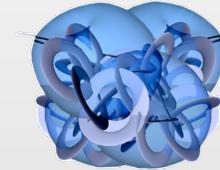
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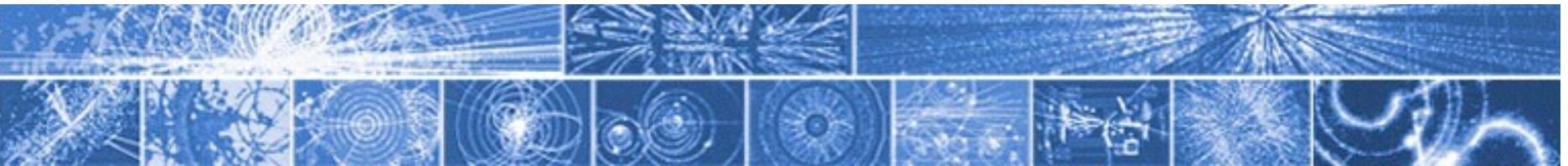




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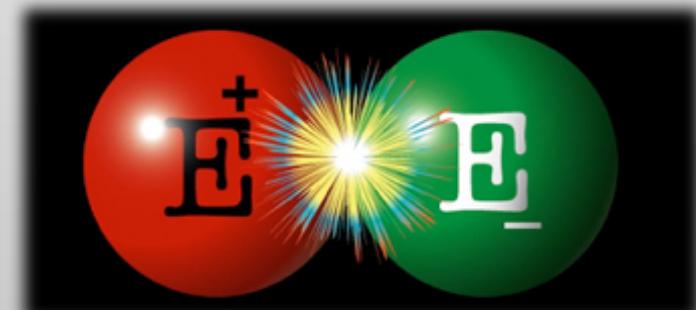
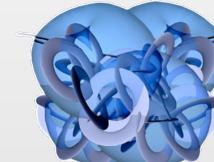
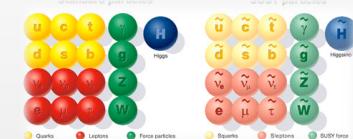
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(una particella sconosciuta che costituisce l'80% della materia dell'Universo!)

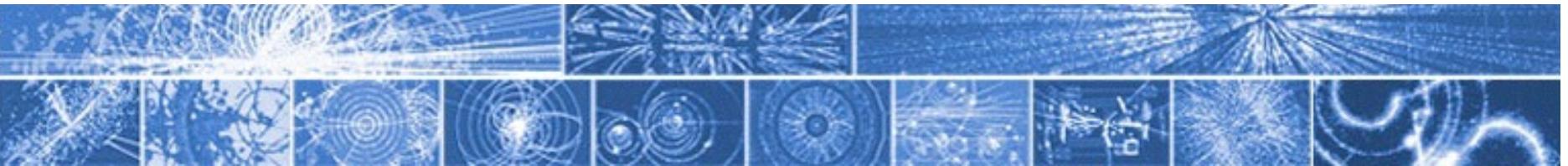




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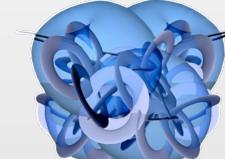
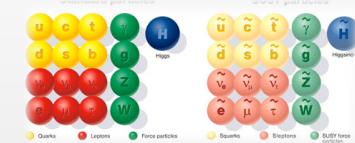
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(dove è finita tutta l'antimateria dell'Universo?)

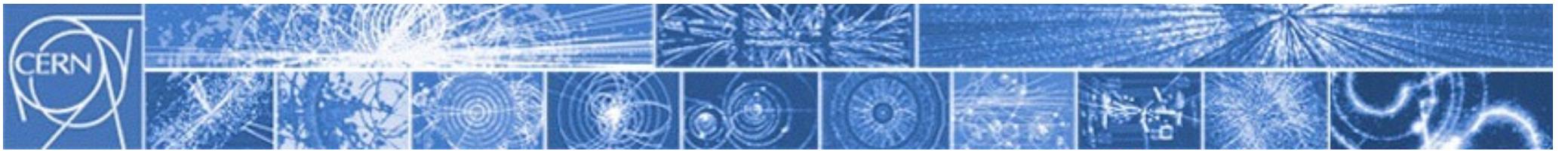




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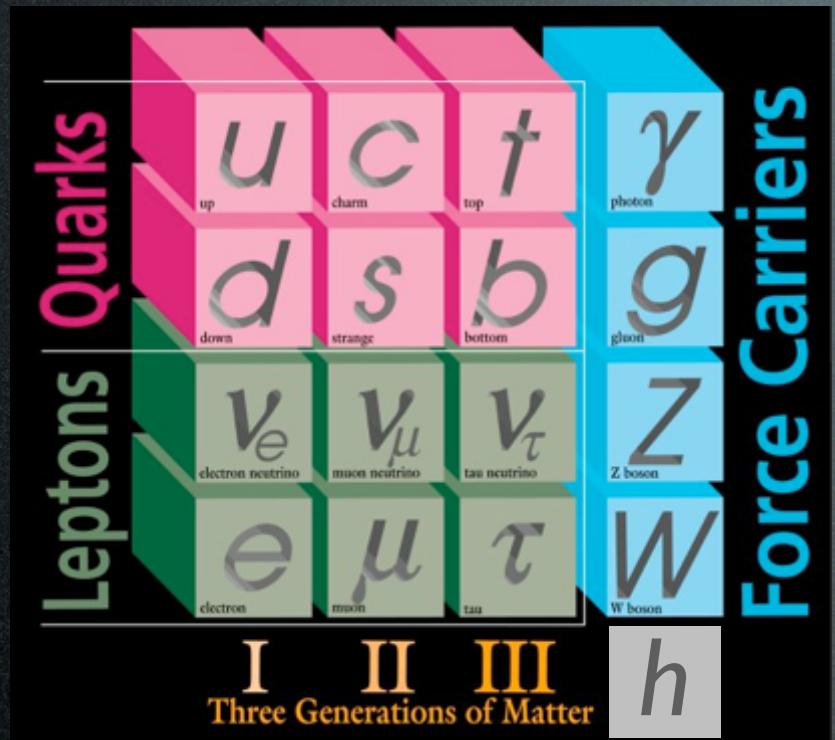
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(dove è finita tutta l'antimateria dell'Universo?)
- il plasma di quark e gluoni
(come diventa la materia nucleare a energie e densità elevatissime?)
- ...



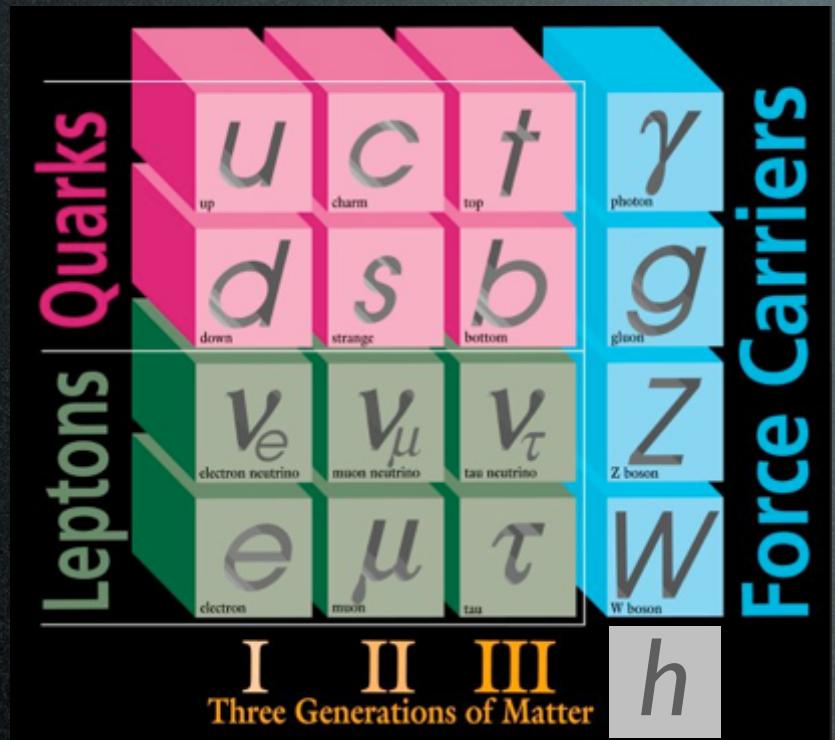


SuperSymmetry (SuSy)

SuSy in 2 minutes

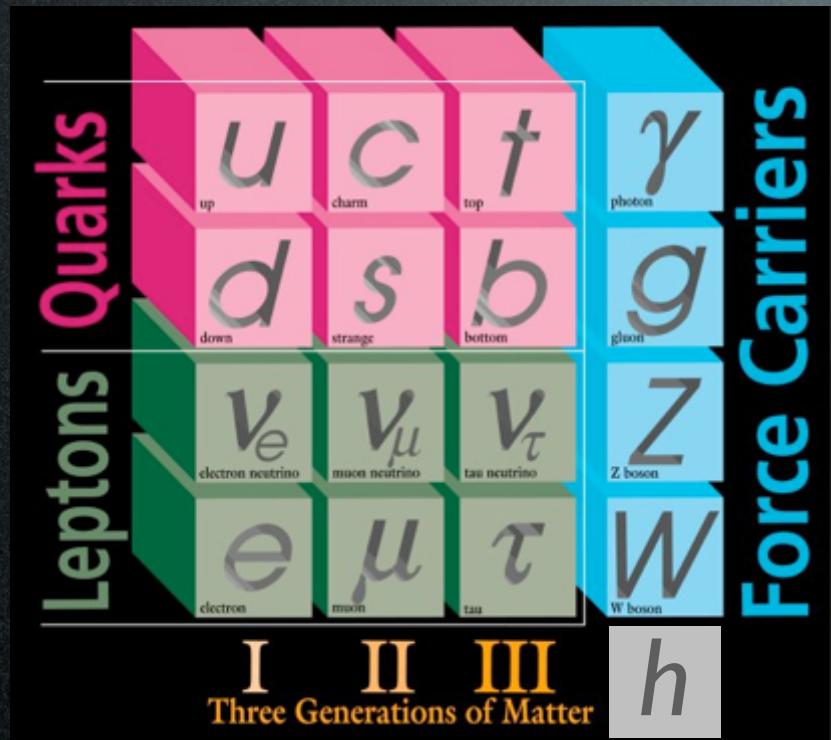


SuSy in 2 minutes



$$m_h \simeq 126 \text{ GeV}$$

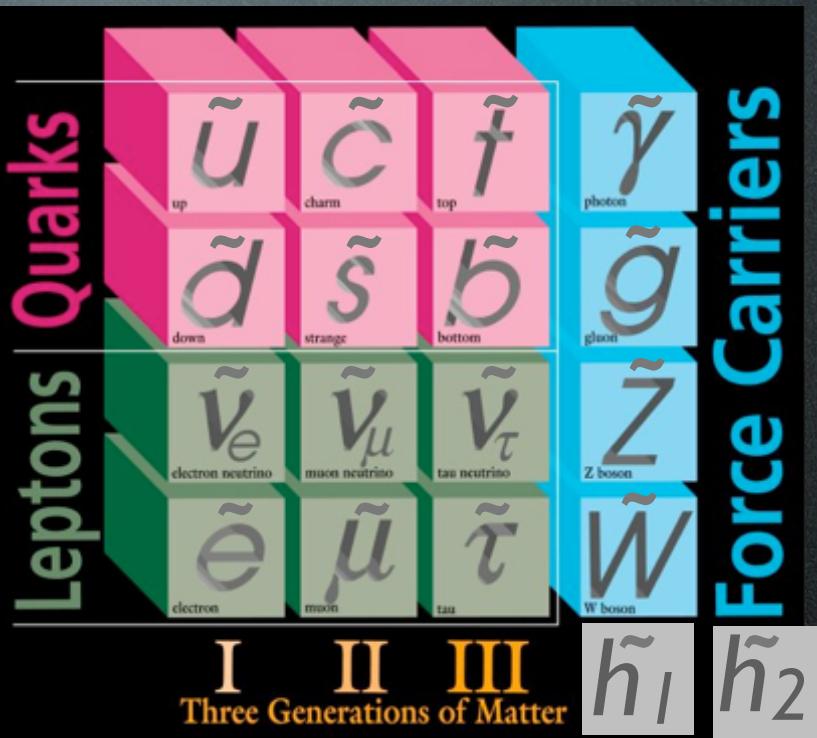
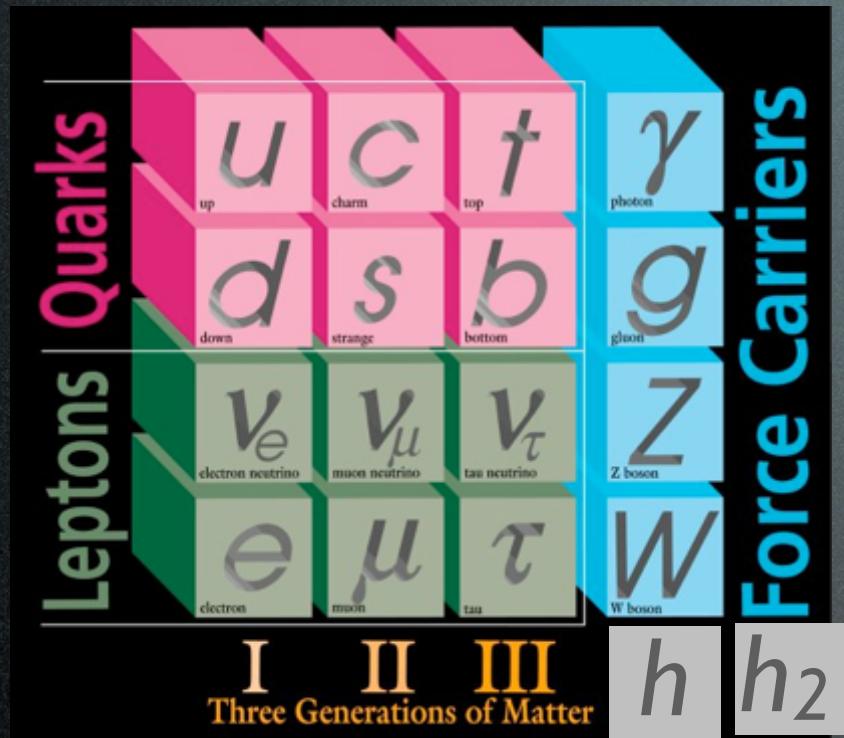
SuSy in 2 minutes



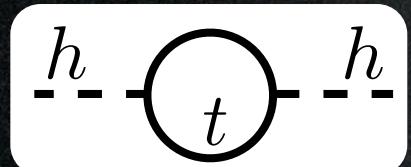
$$m_h \simeq 126 \text{ GeV}$$

$$\begin{array}{c} h \\ \cdots \\ t \\ \cdots \\ h \end{array} \quad \Delta m_h \propto 10^{19} \text{ GeV}$$

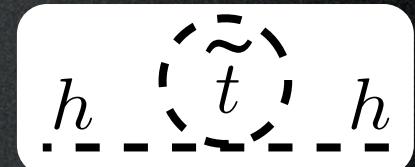
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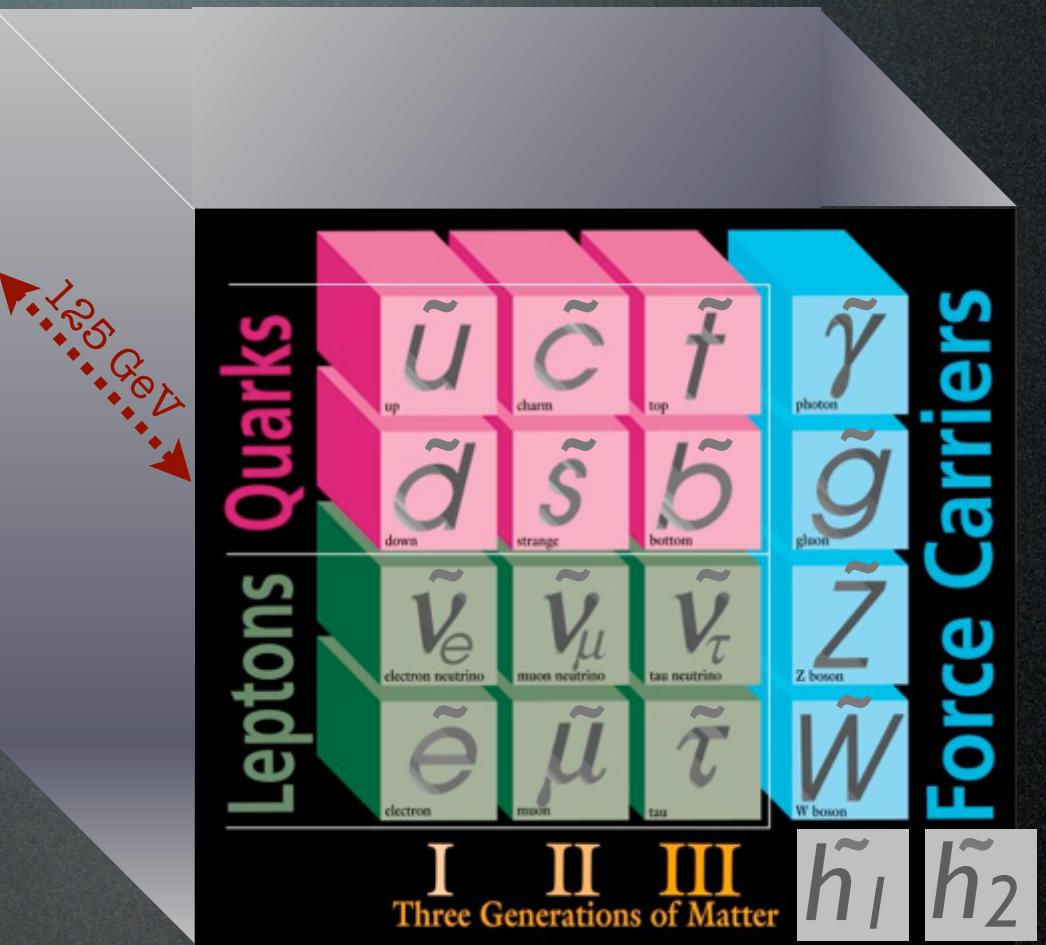
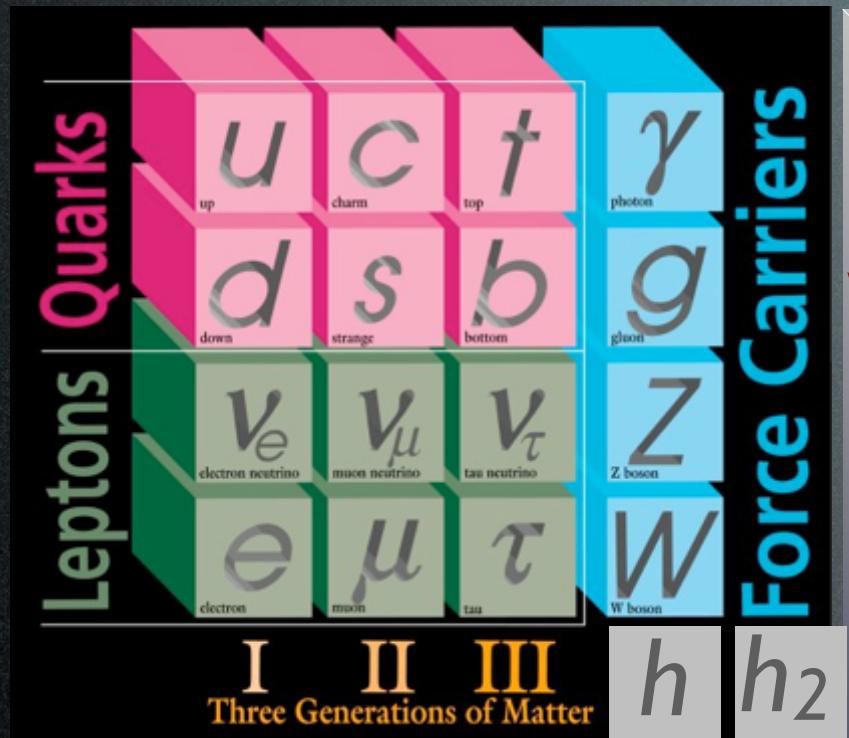


$$\Delta m_h \propto 10^{19} \text{ GeV}$$

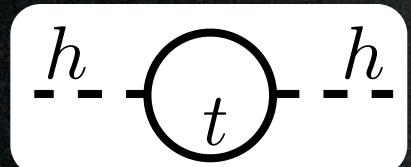


$$\Delta m_h \propto -10^{19} \text{ GeV}$$

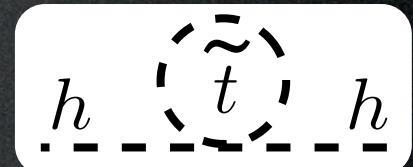
SuSy in 2 minutes



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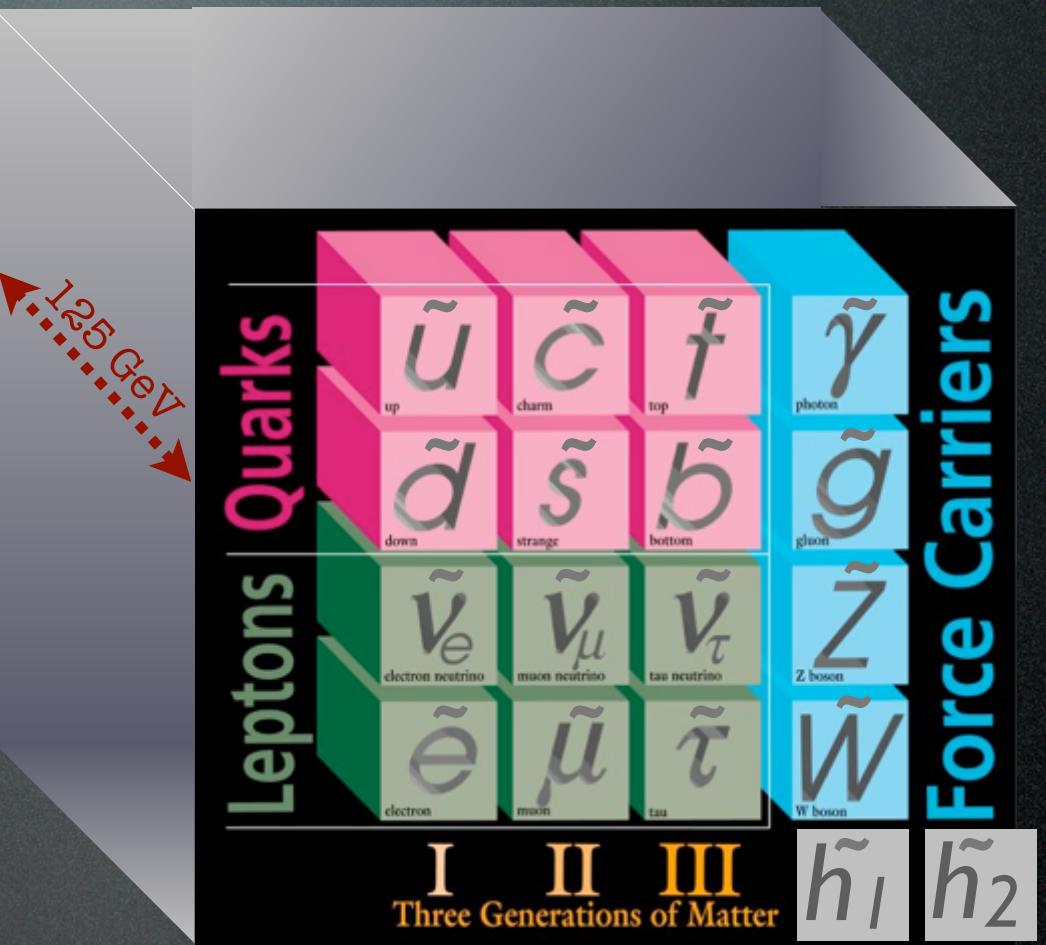
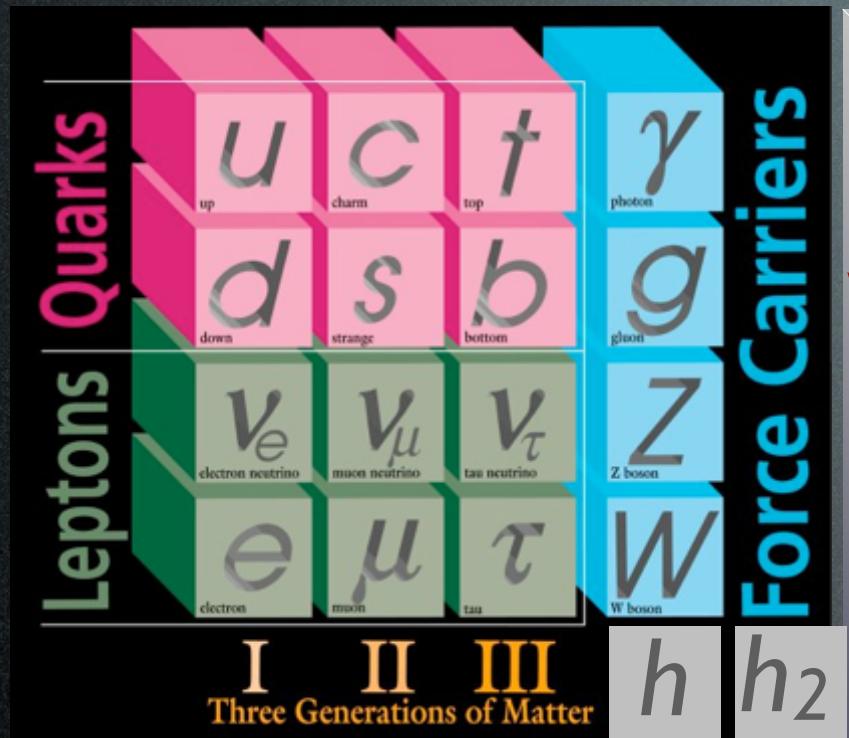


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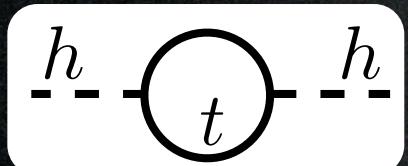
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SuSy in 2 minutes



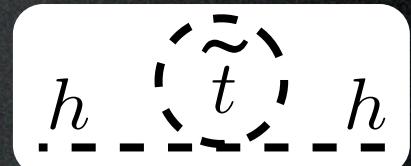
$$R = +1$$

$$m_h \simeq 126 \text{ GeV}$$



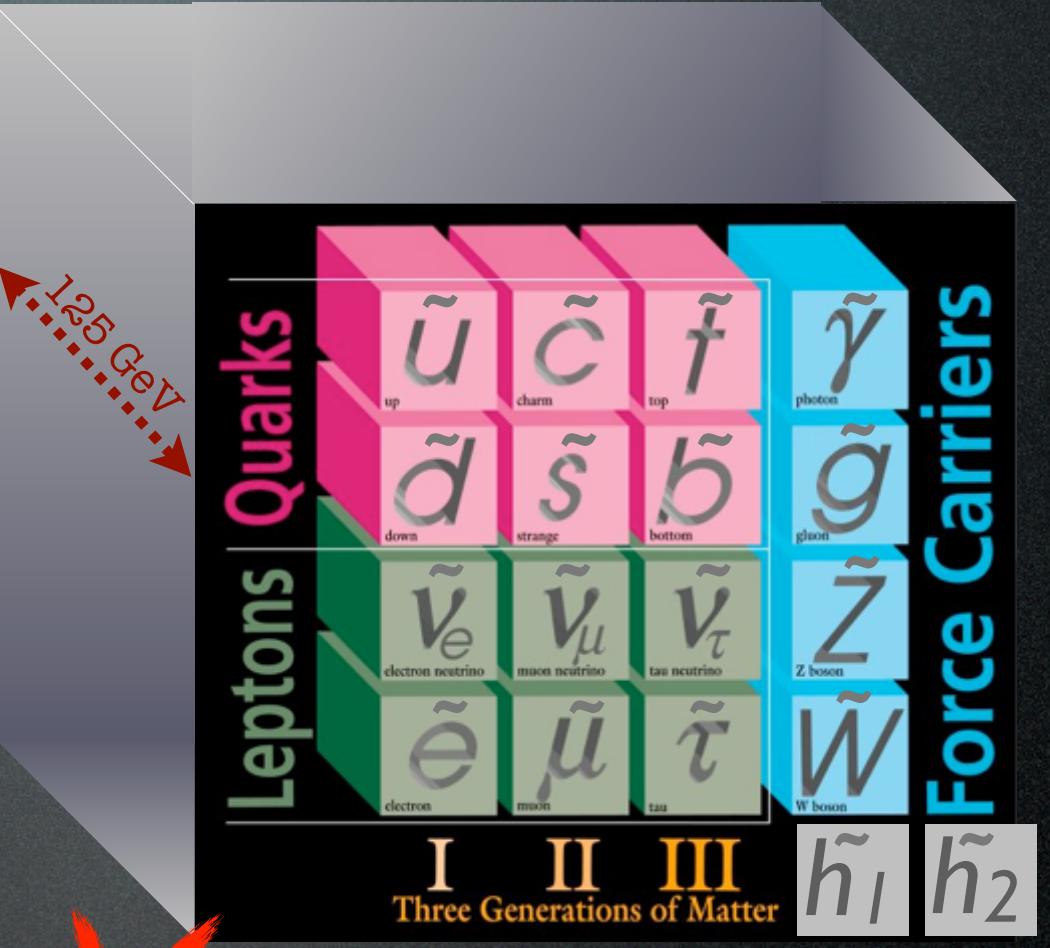
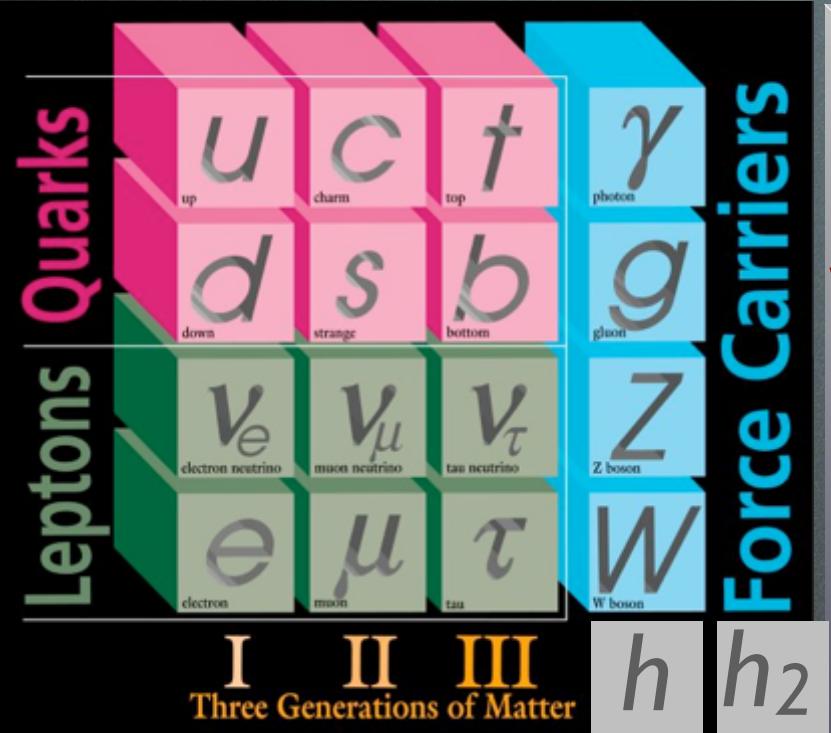
$$\Delta m_h \propto 10^{19} \text{ GeV}$$

$$R = -1$$



$$\Delta m_h \propto -10^{19} \text{ GeV}$$

SuSy in 2 minutes



$$R = +1$$

$$m_h \simeq 126 \text{ GeV}$$

h

prevent
proton decay

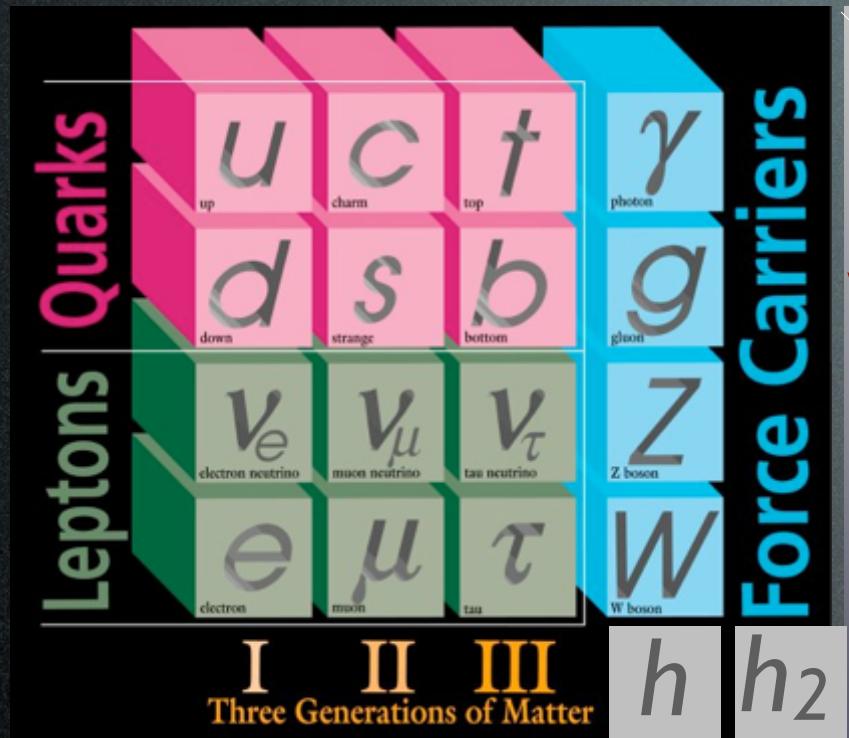
$$^{10} \text{ GeV}$$

$$R = -1$$

h $\langle \tilde{t} \rangle$ h

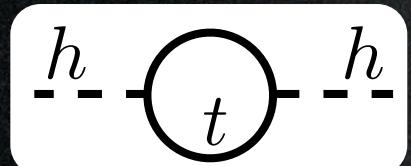
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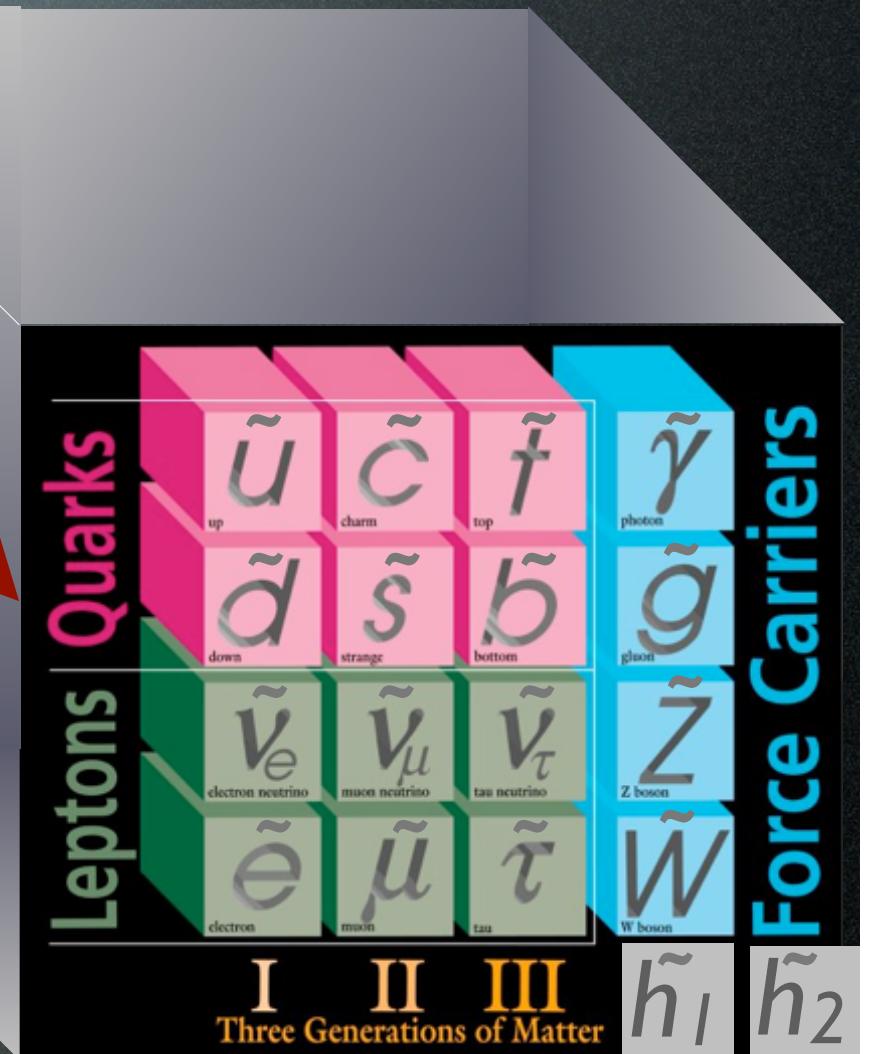


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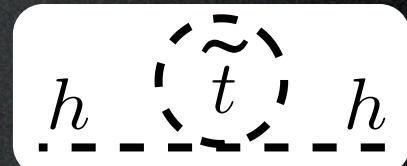
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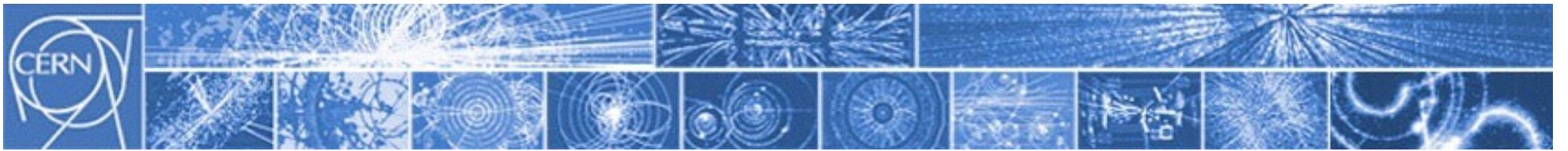
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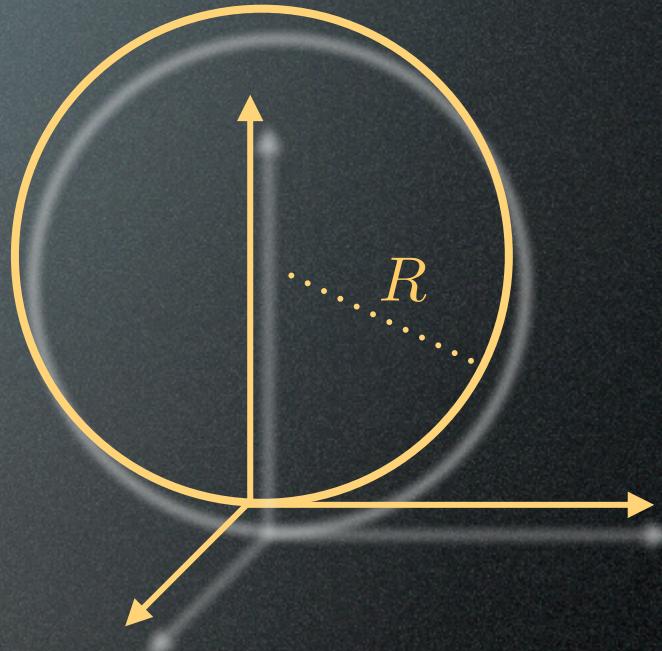
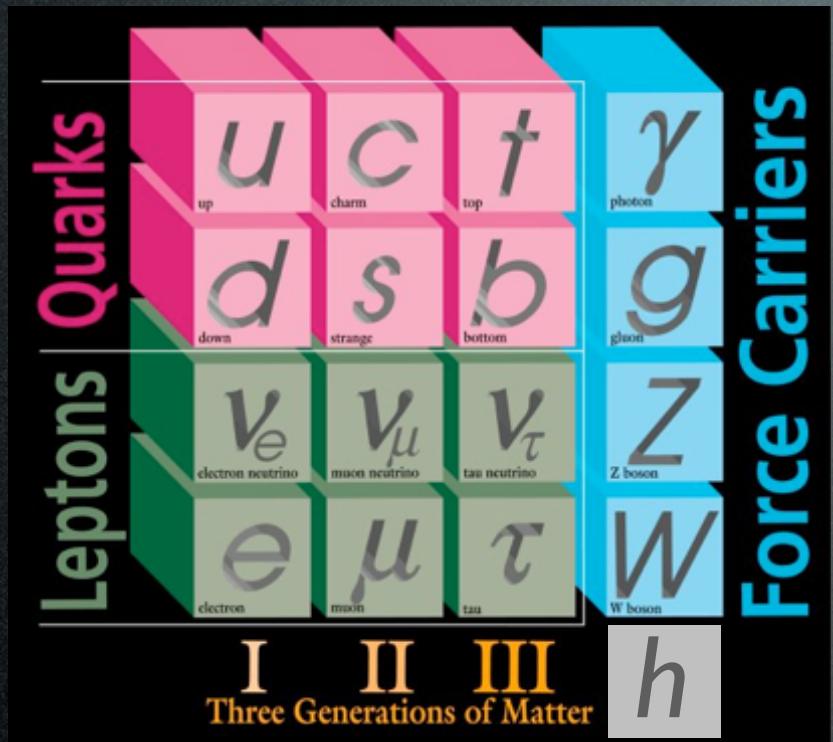


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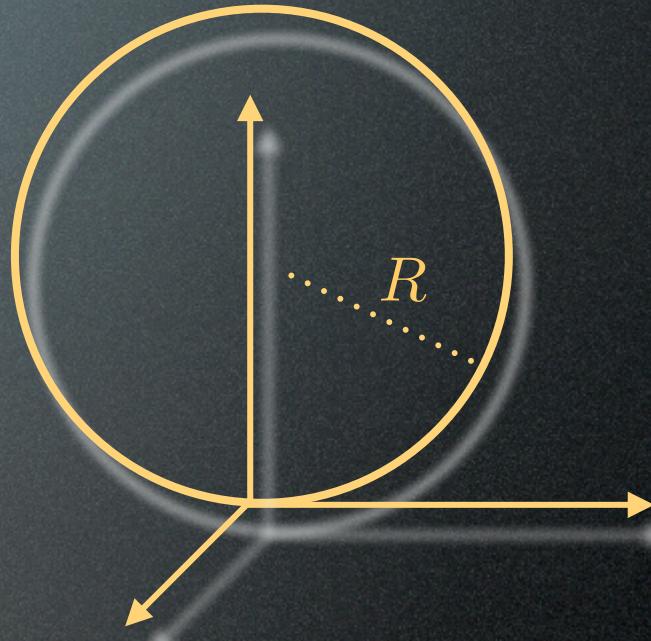
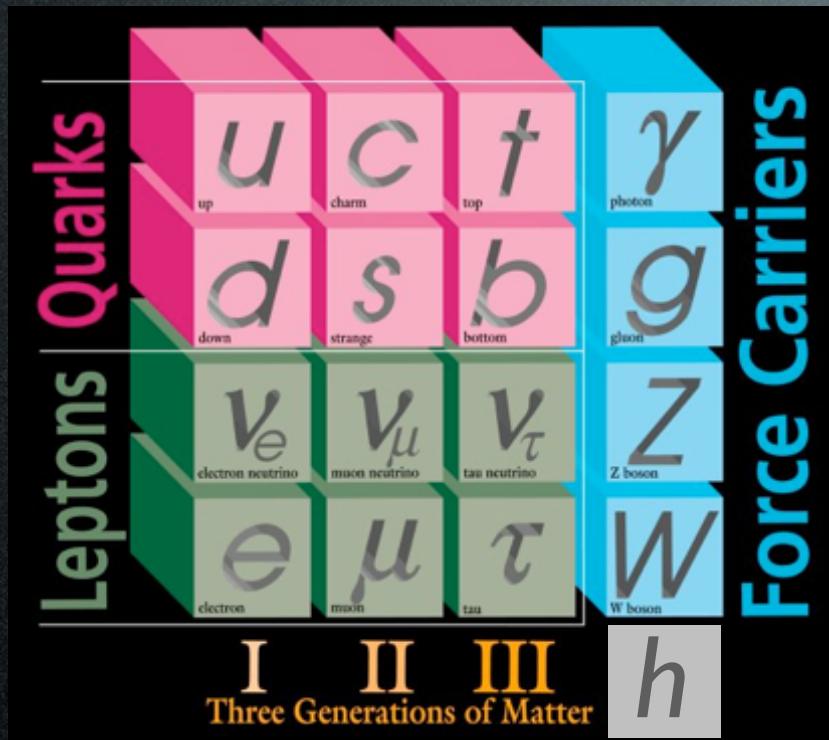
Extradimensioni (xDims)

ExDim DM in 2 minutes

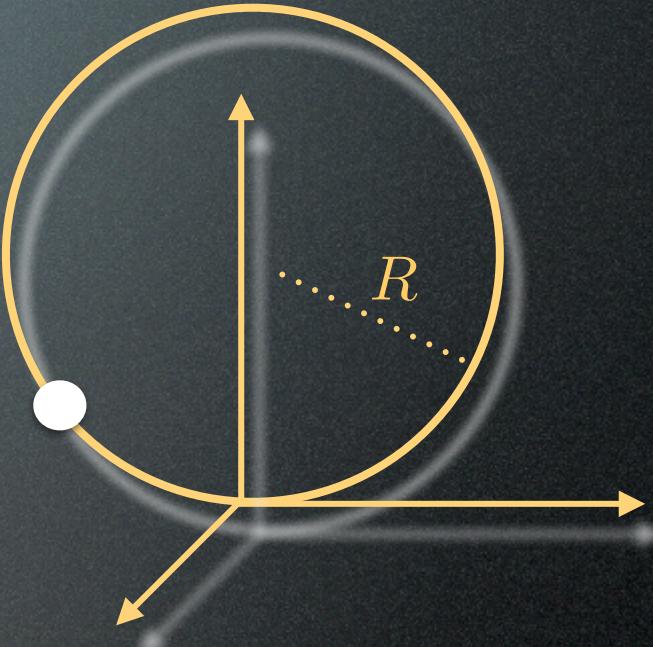
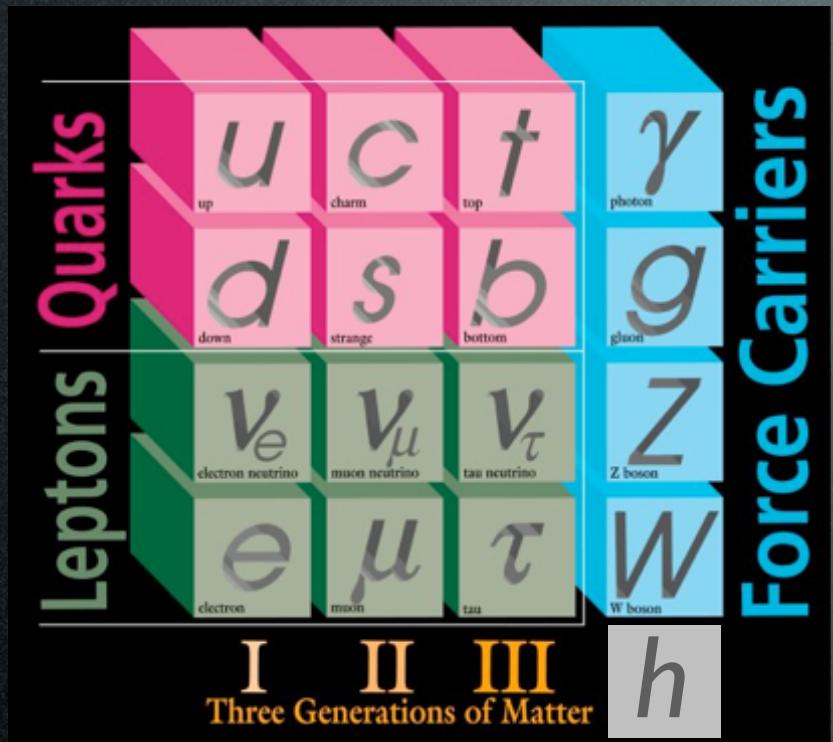


- string theory
- hierarchy problem

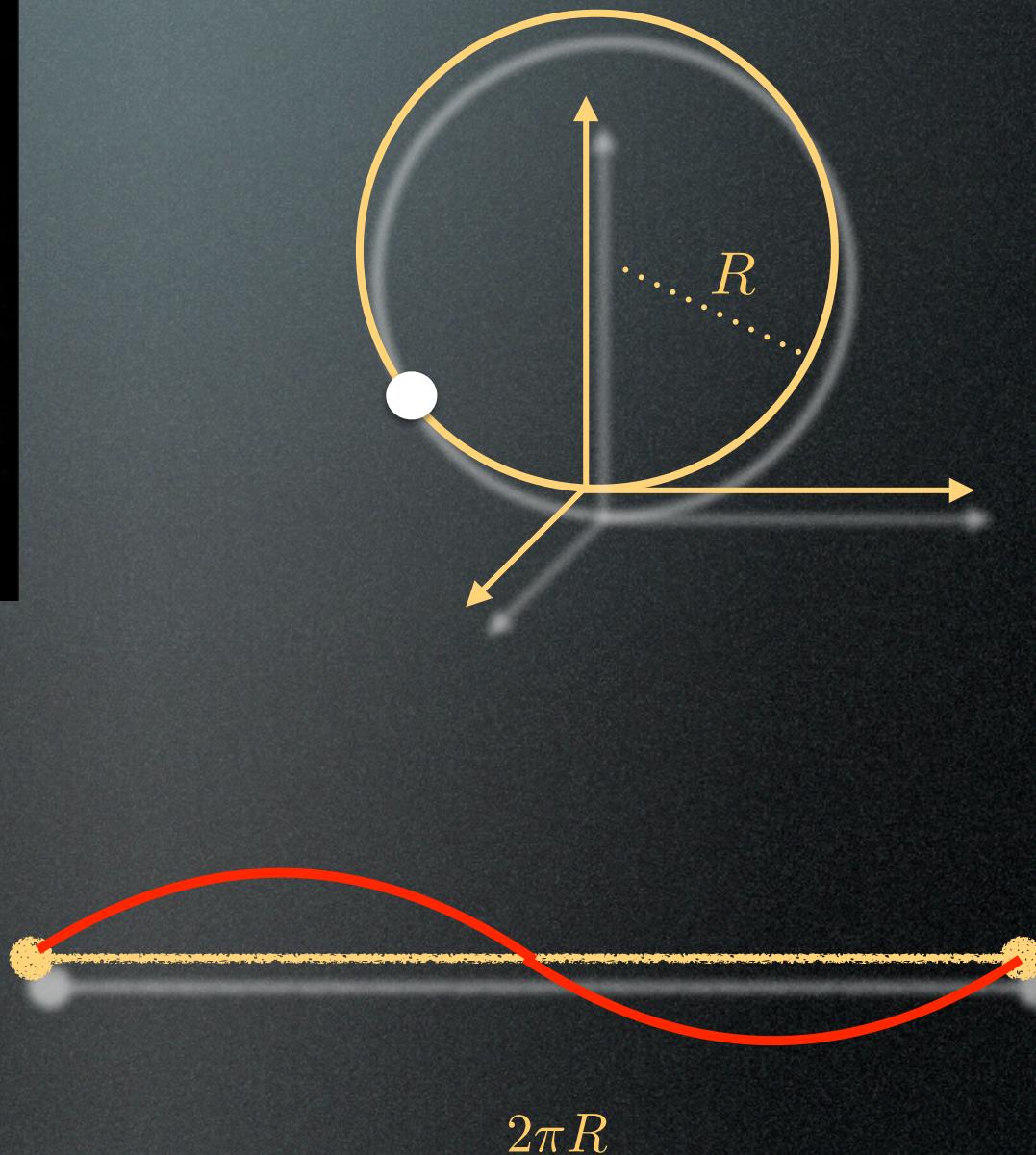
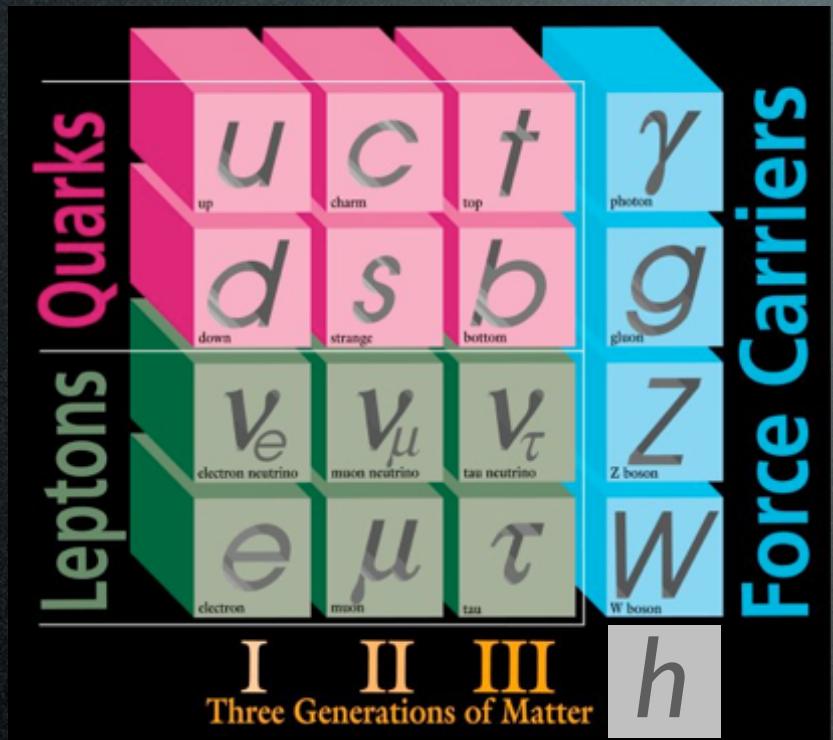
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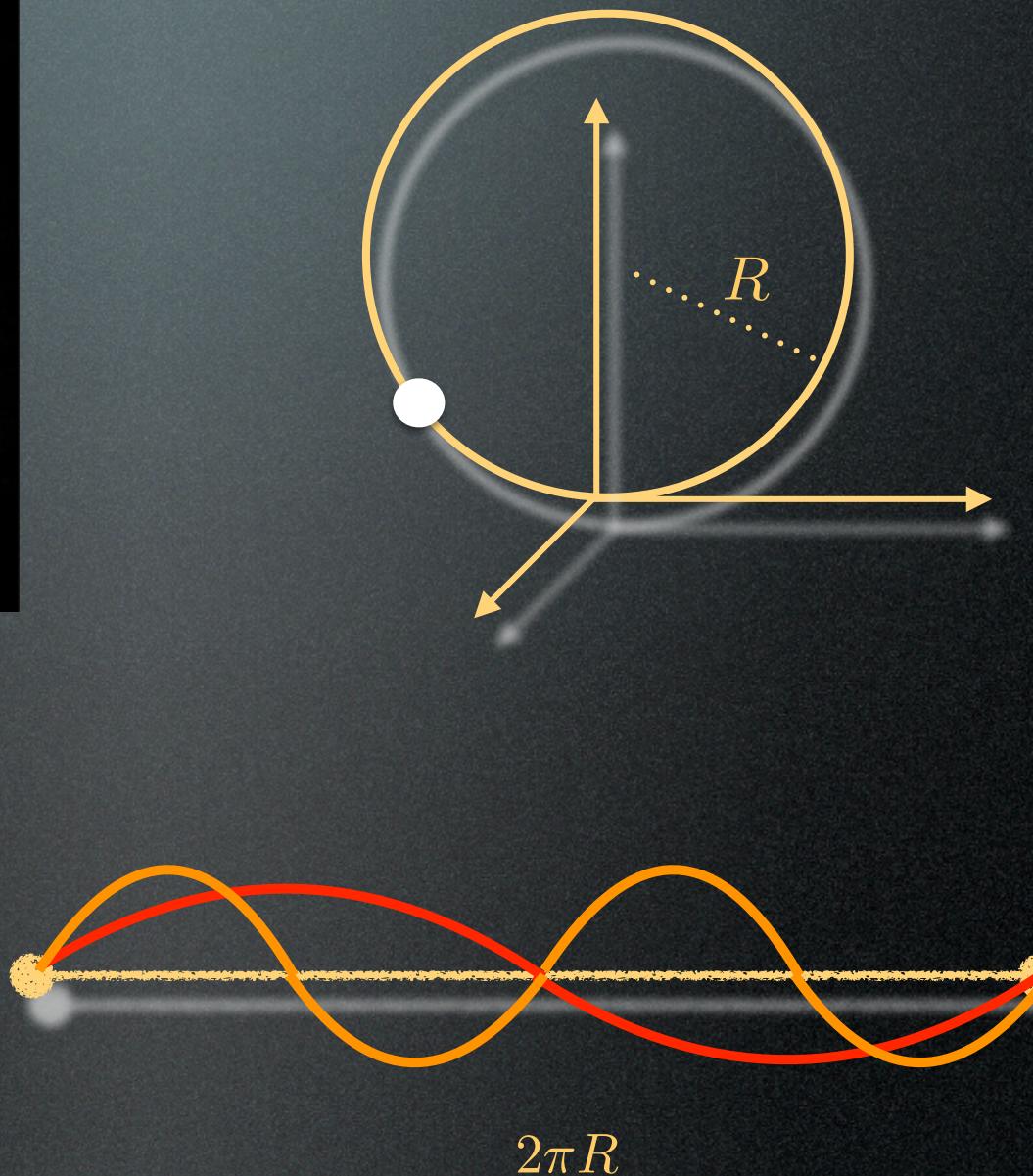
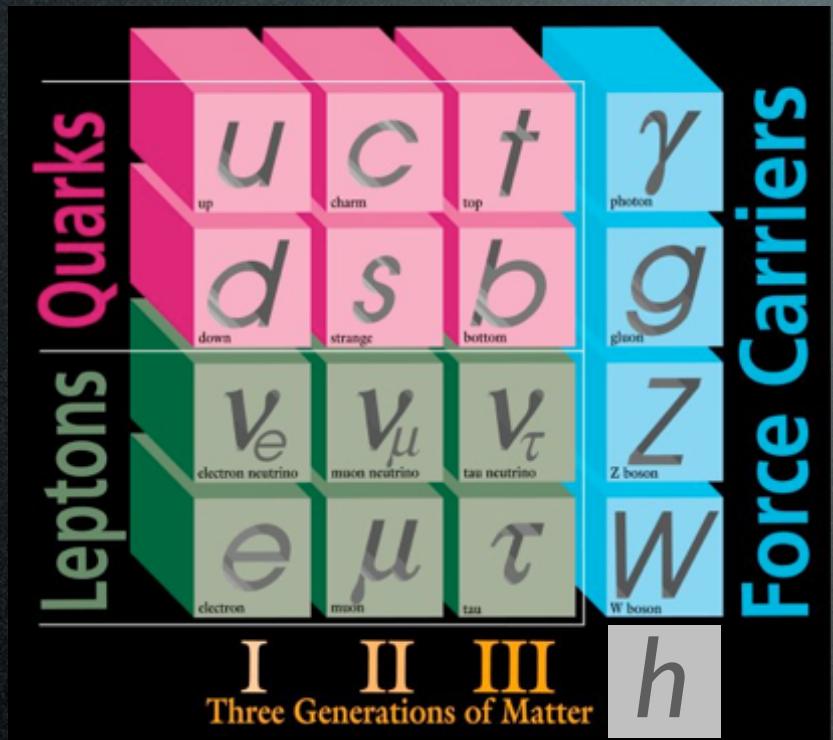
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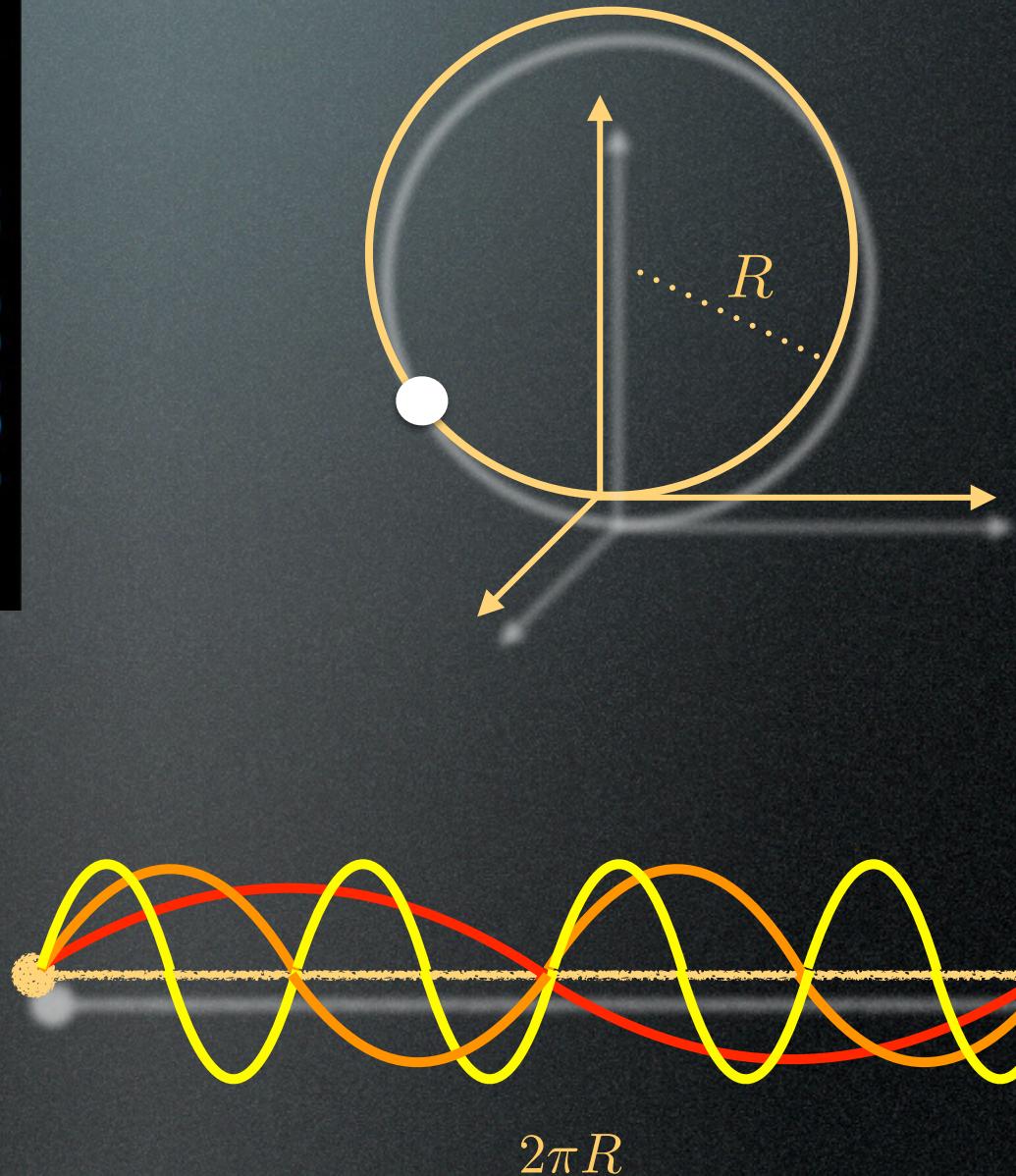
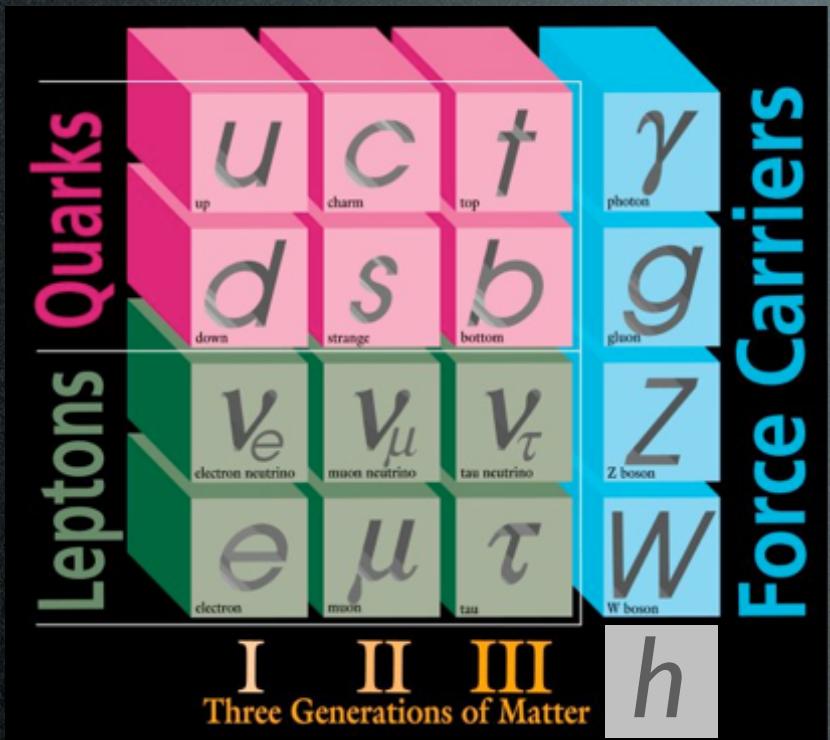
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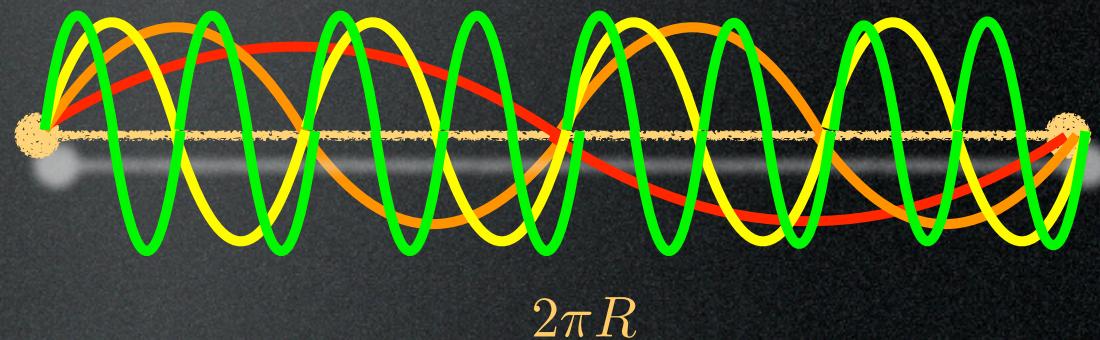
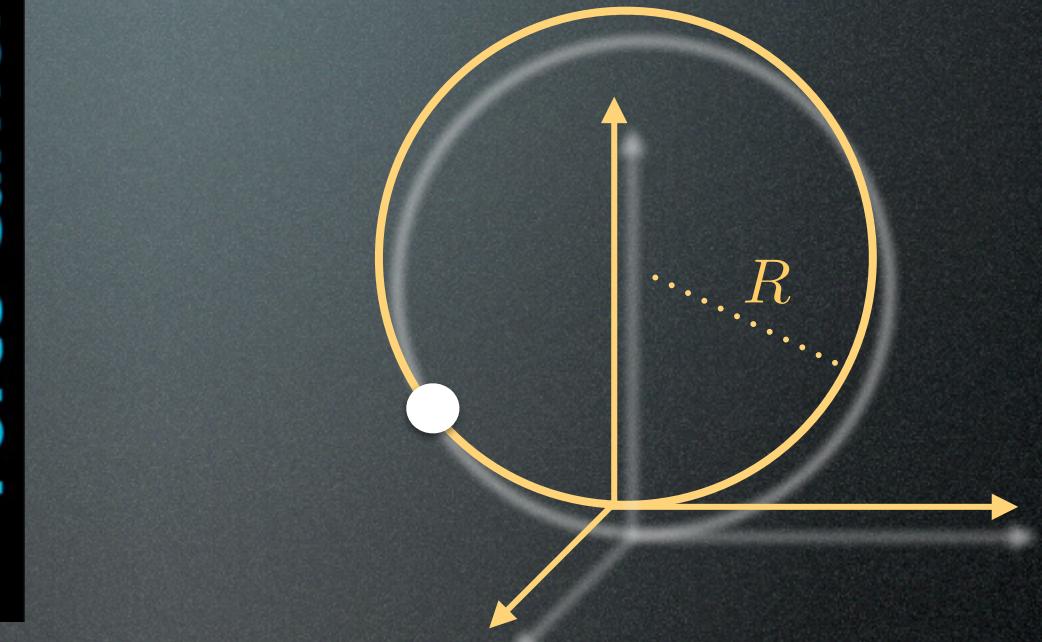
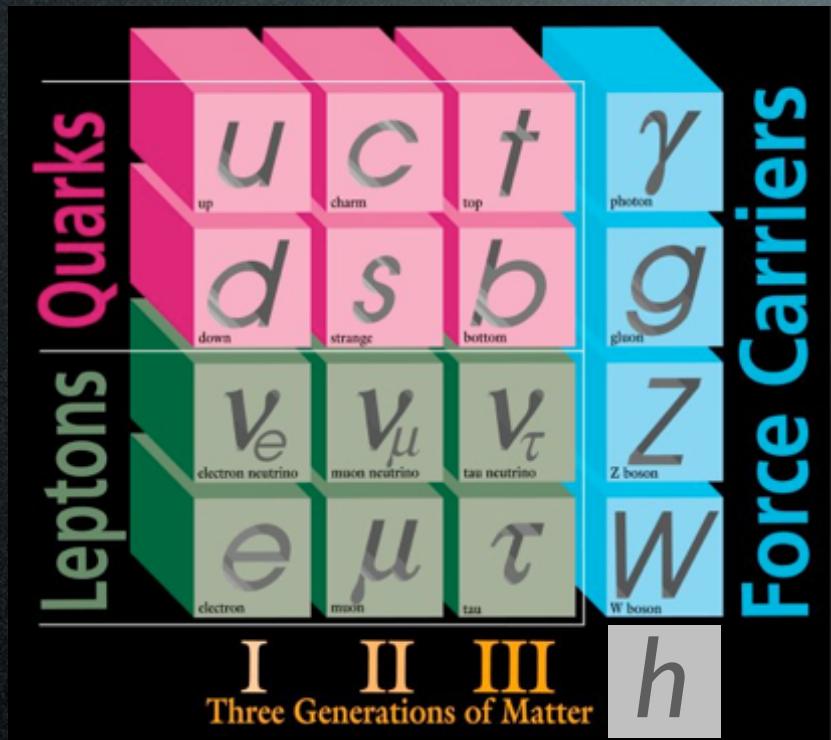
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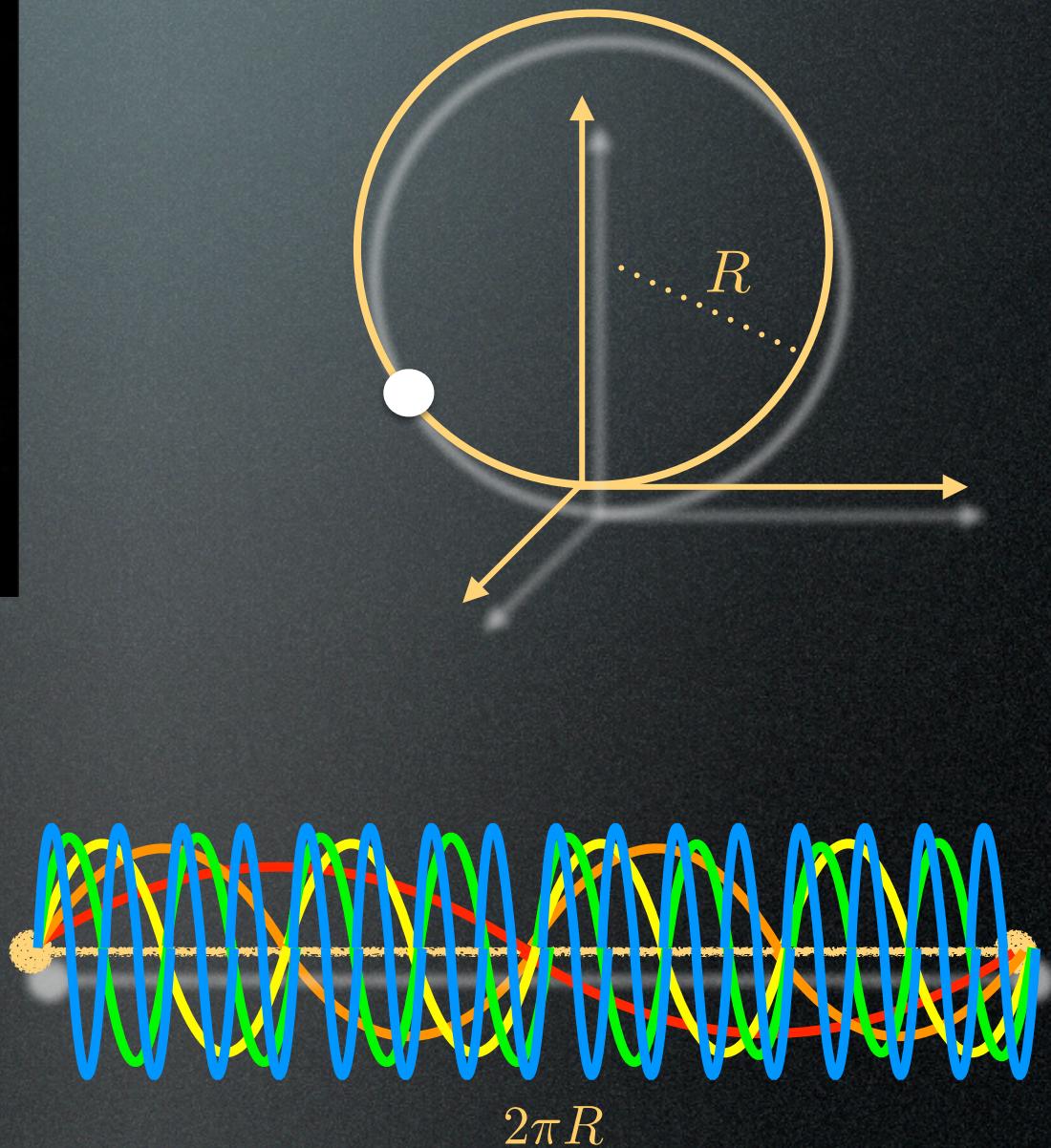
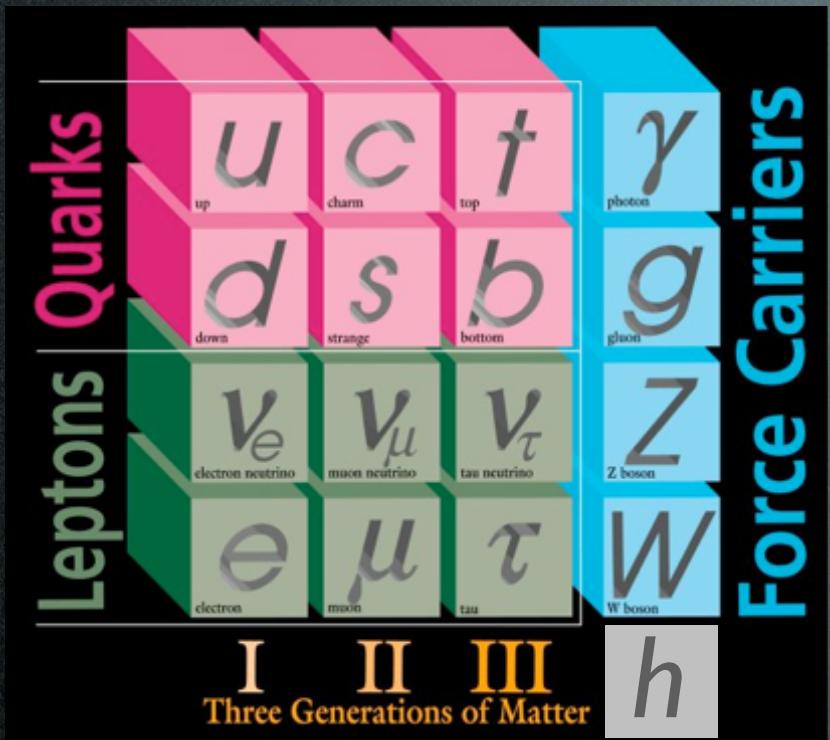
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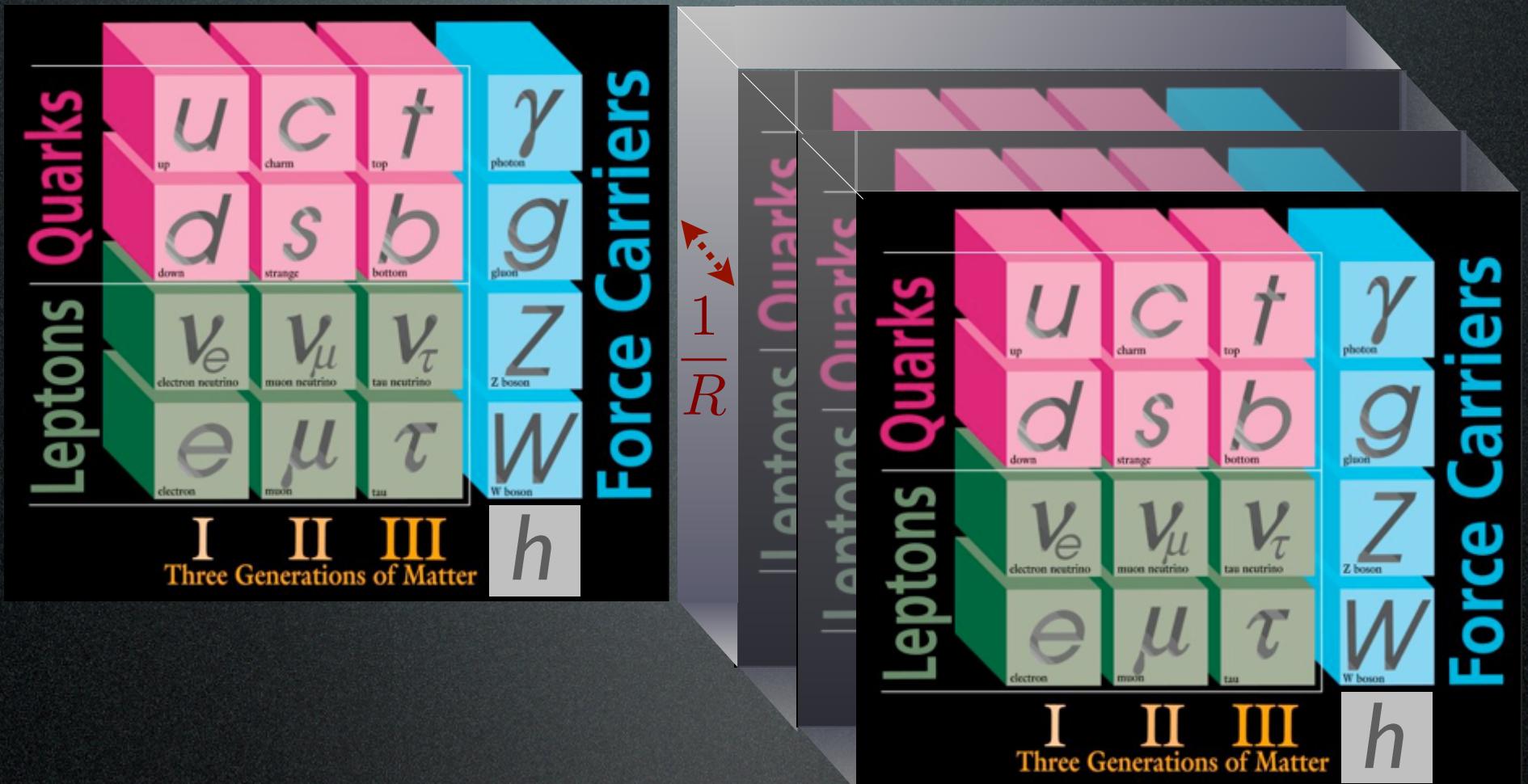
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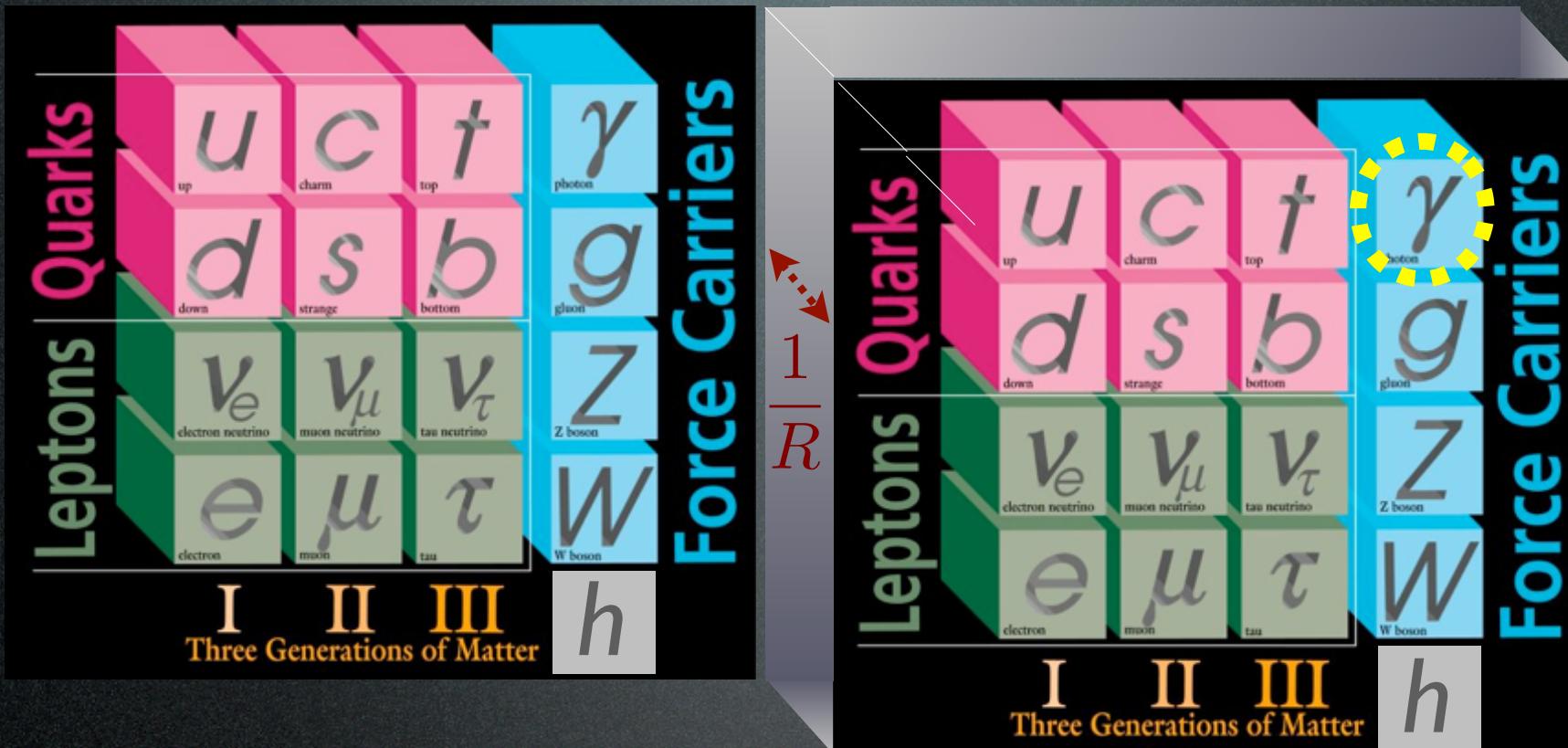
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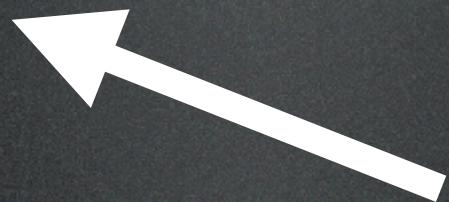
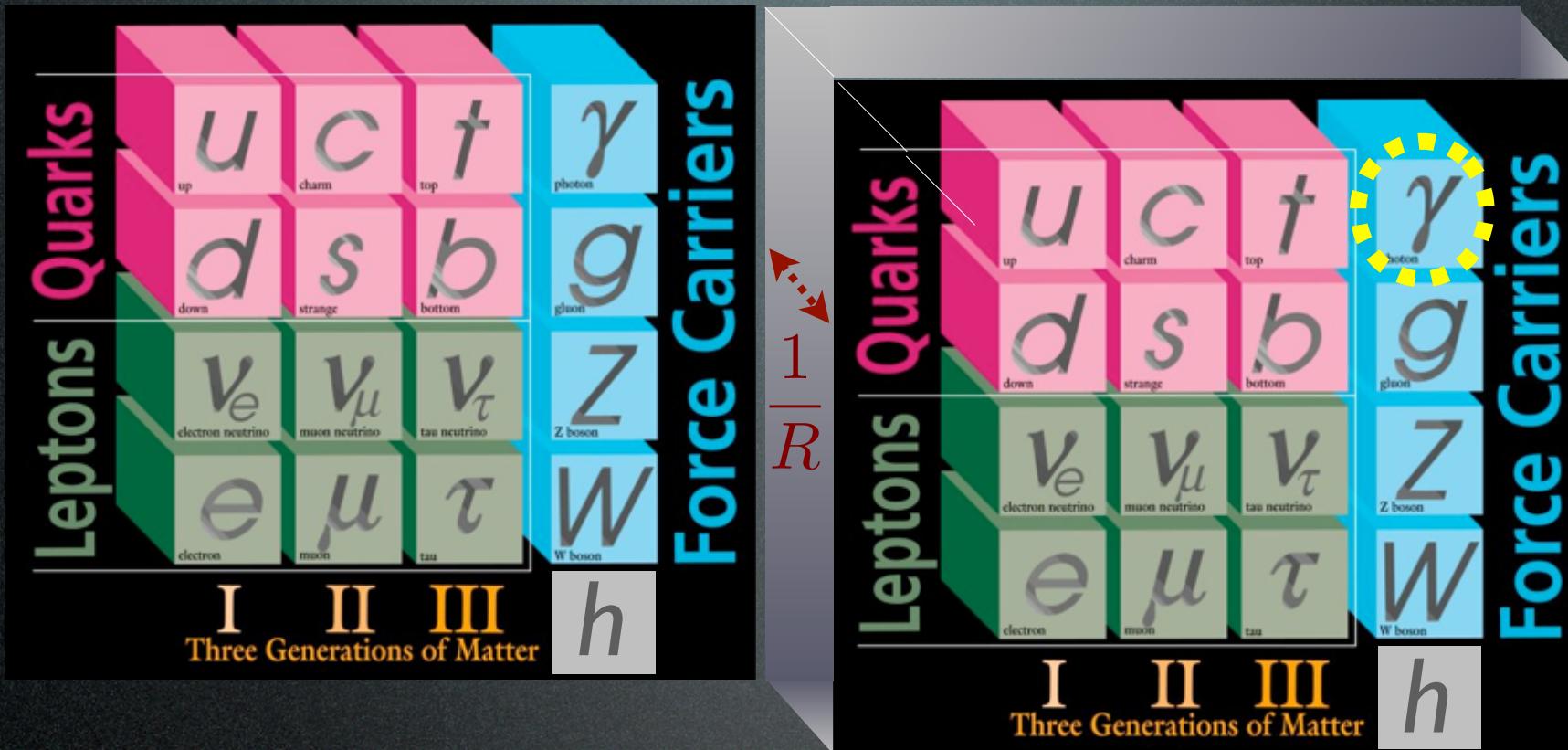
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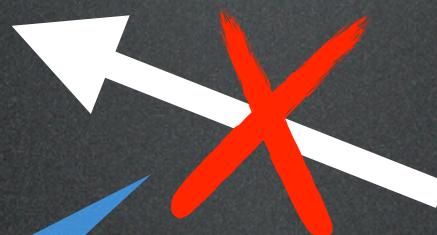
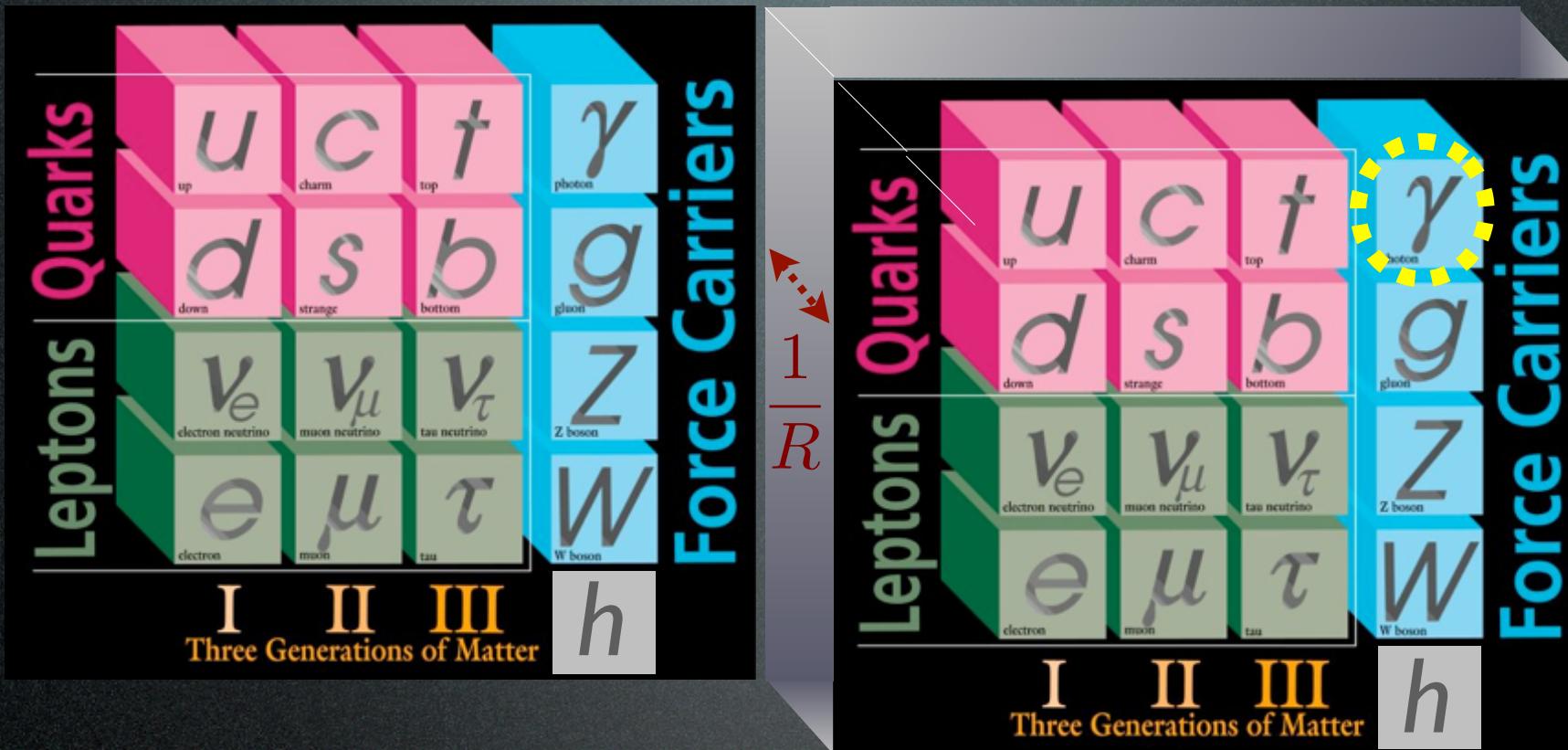
ExDim DM in 2 minutes



ExDim DM in 2 minutes



ExDim DM in 2 minutes



conservation
of 5D momentum

(on orbifold boundary conditions,
needed to have chiral SM fermions)