Mass of Top quark and Higgs boson

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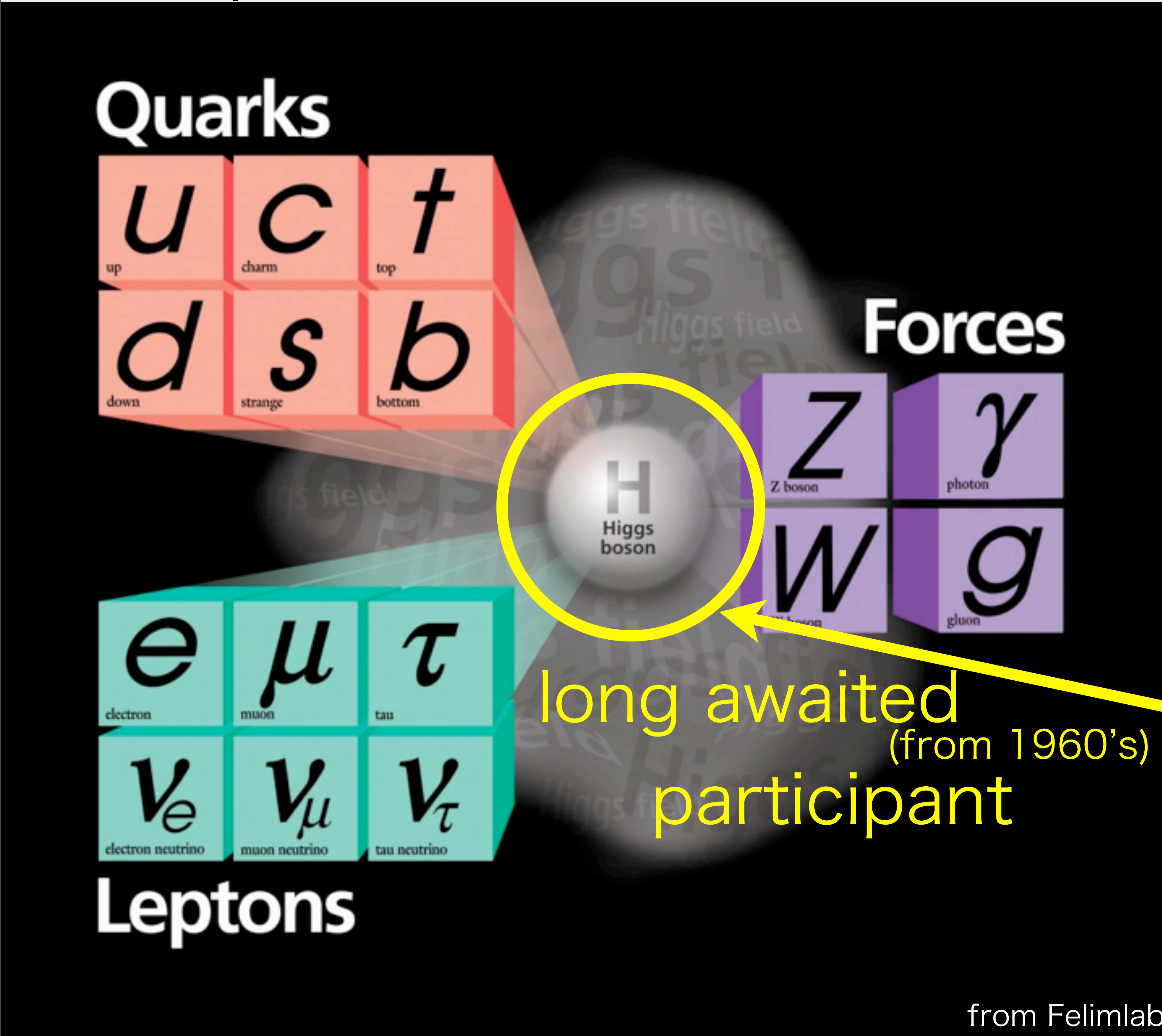
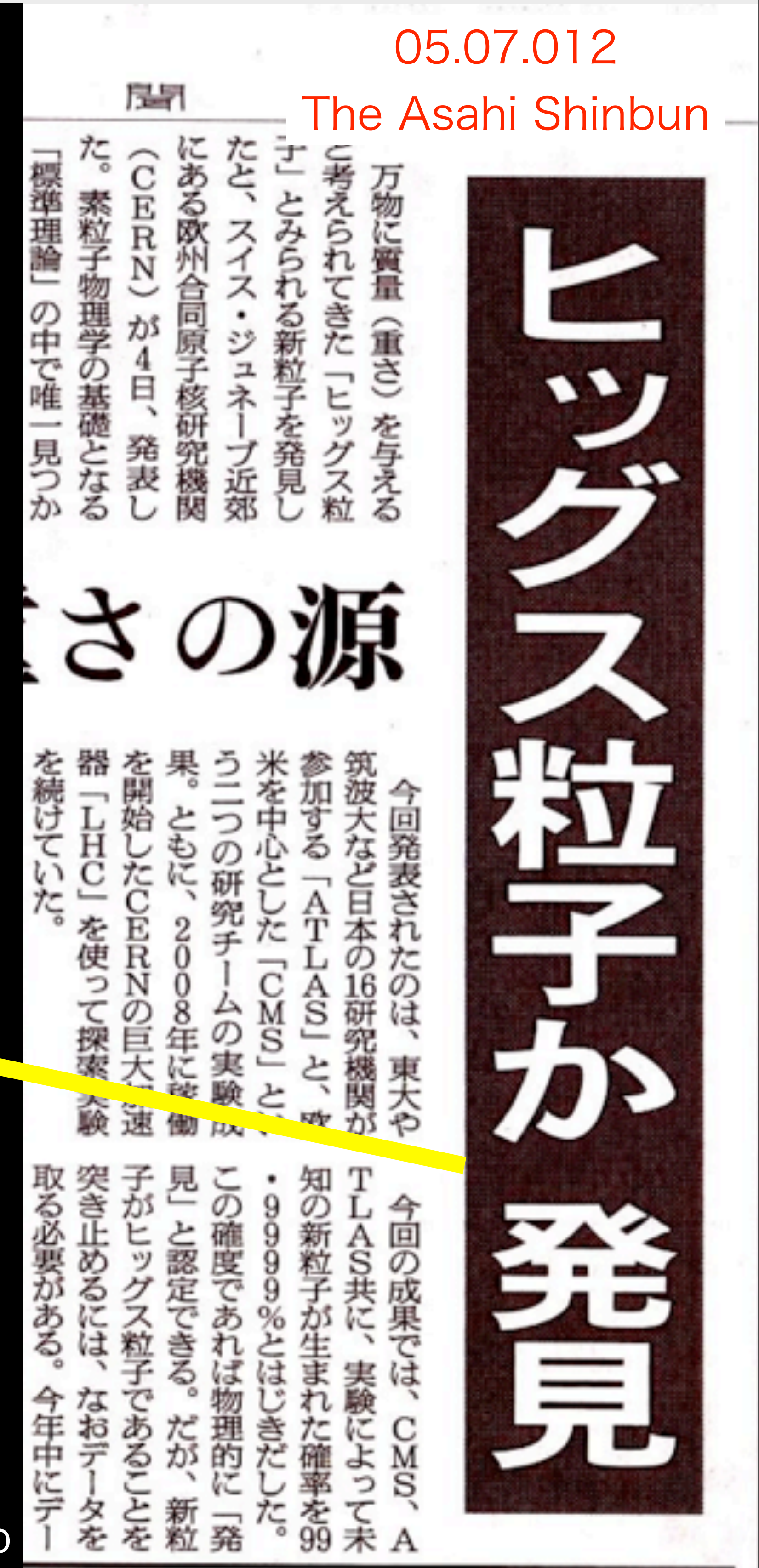
Participants in the Standard Model



from Felimlab

05.07.012
The Asahi Shinbun



ヒッグス粒子か 発見

さの源

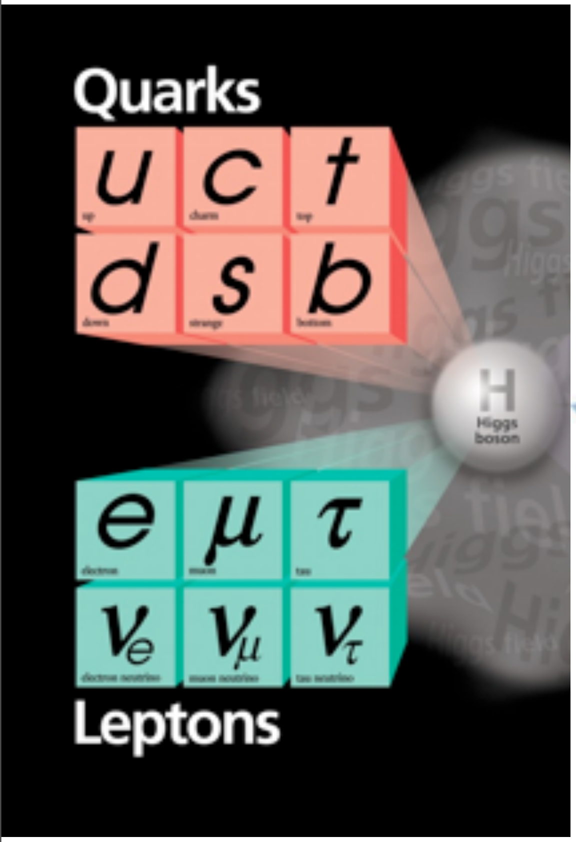
万物に質量（重さ）を与えると考えられてきた「ヒッグス粒子」とみられる新粒子を発見したと、スイス・ジュネーブ近郊にある欧州合同原子核研究機関（CERN）が4日、発表した。素粒子物理学の基礎となる「標準理論」の中で唯一見つか

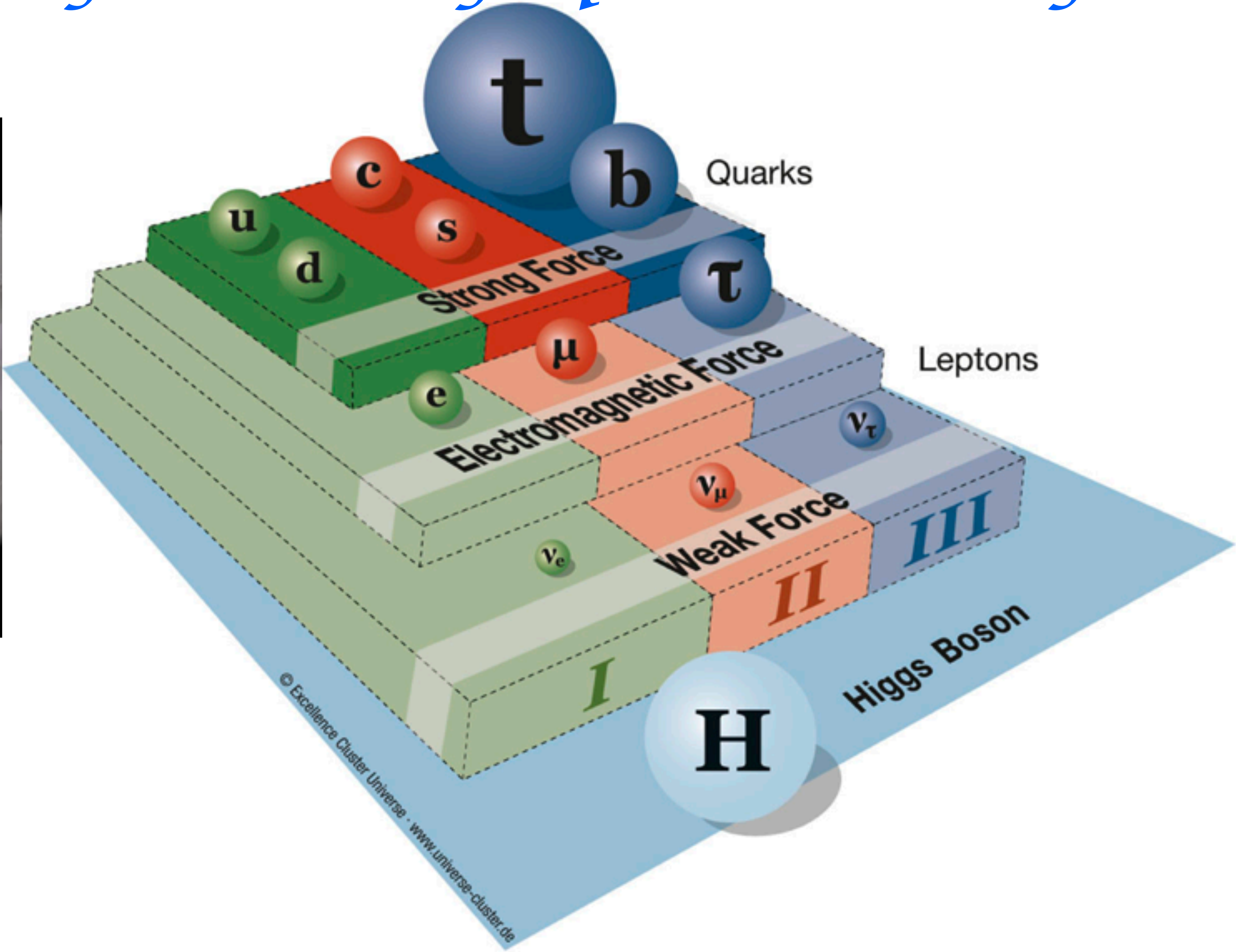
今回発表されたのは、東大や筑波大など日本の16研究機関が参加する「ATLAS」と、欧米を中心とした「CMS」とう二つの研究チームの実験成果。ともに、2008年に稼働を開始したCERNの巨大加速器「LHC」を使って探索実験を続けていた。

今回の成果では、CMS、ATLAS共に、実験によって未知の新粒子が生まれた確率を99・9999%とはじきだした。この確度であれば物理的に「発見」と認定できる。だが、新粒子がヒッグス粒子であることを突き止めるには、なおデータを取る必要がある。今年中にデー

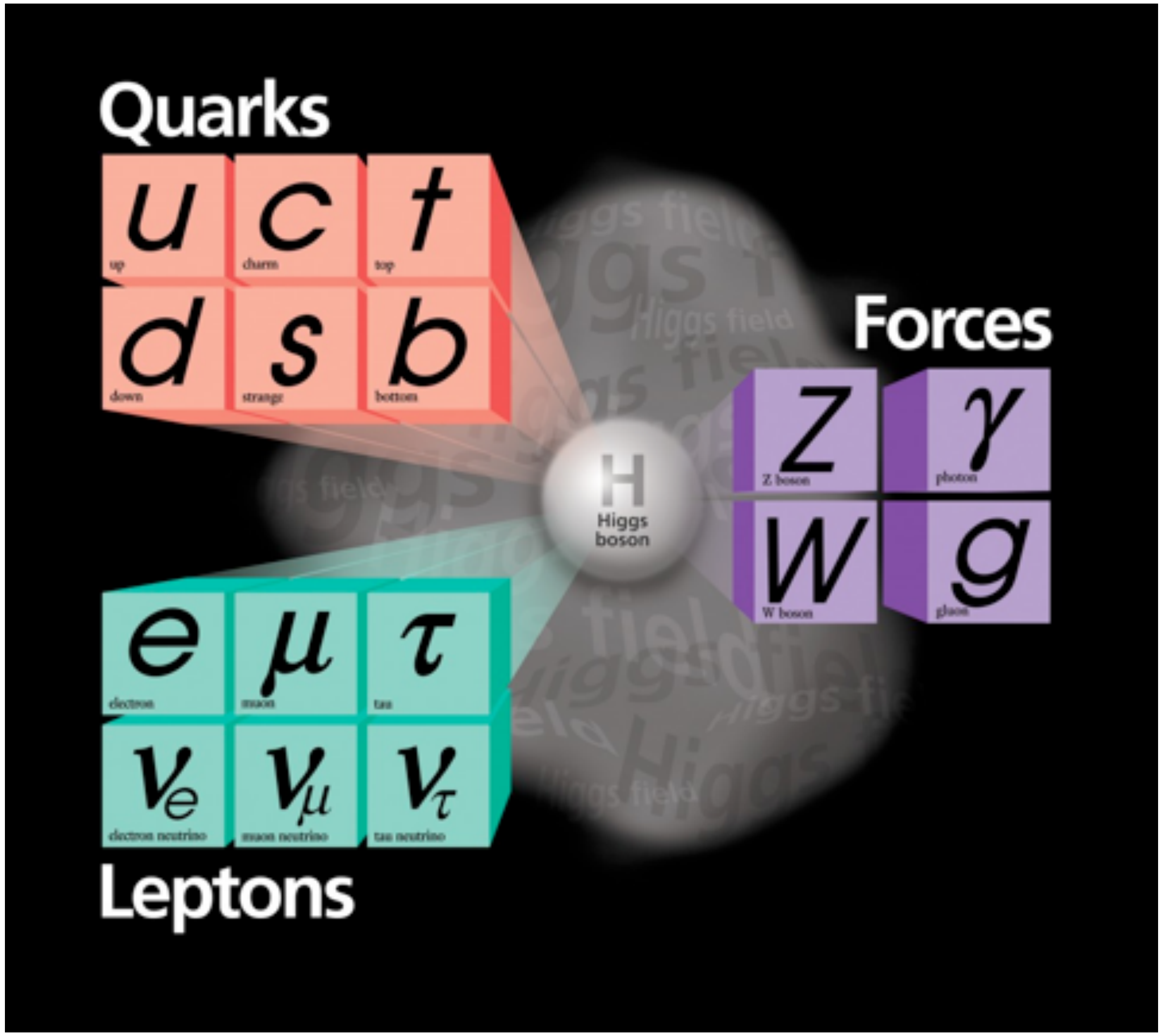
My question

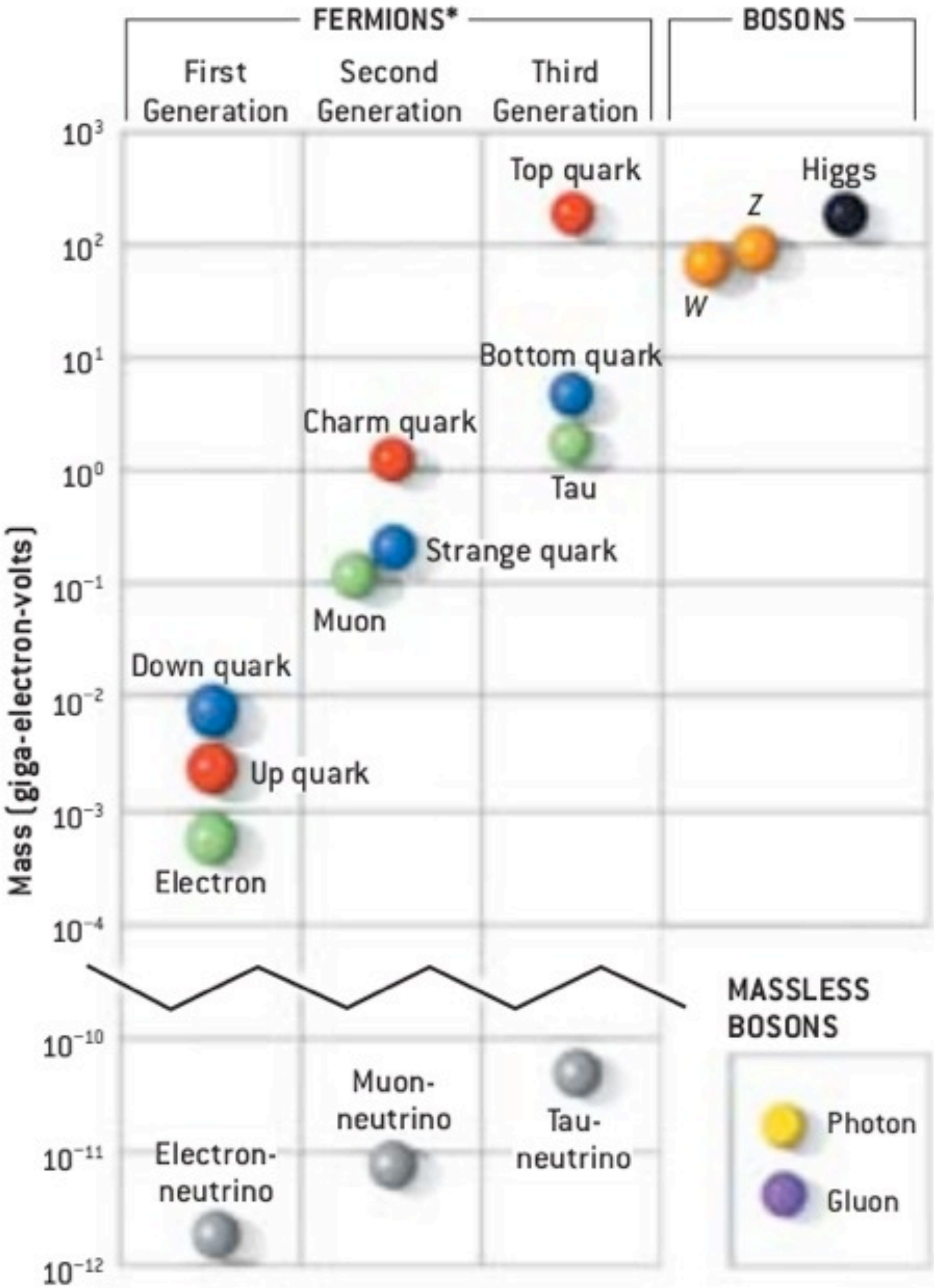
Why is the top quark heavy ?





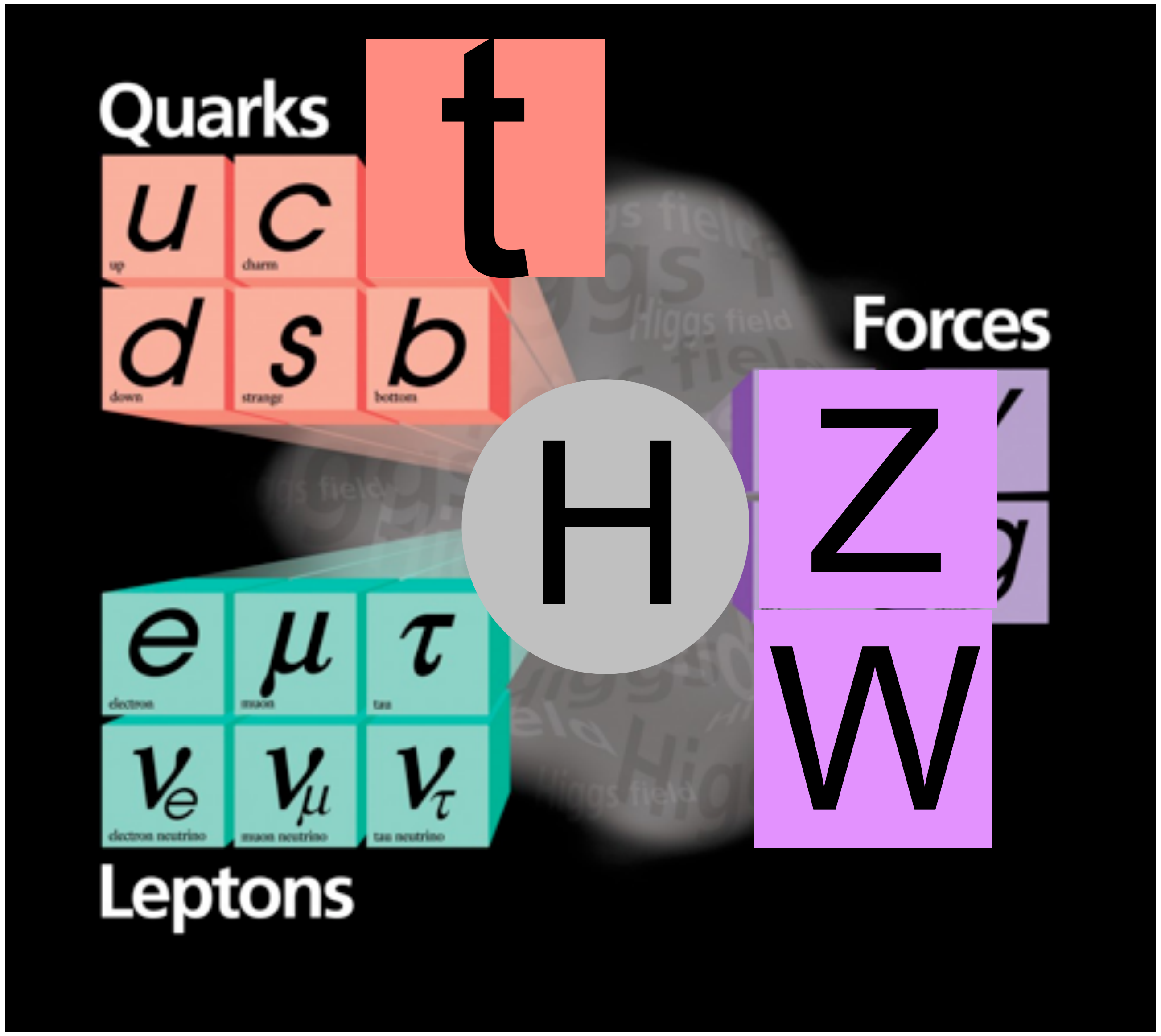
Mass : all SM participants

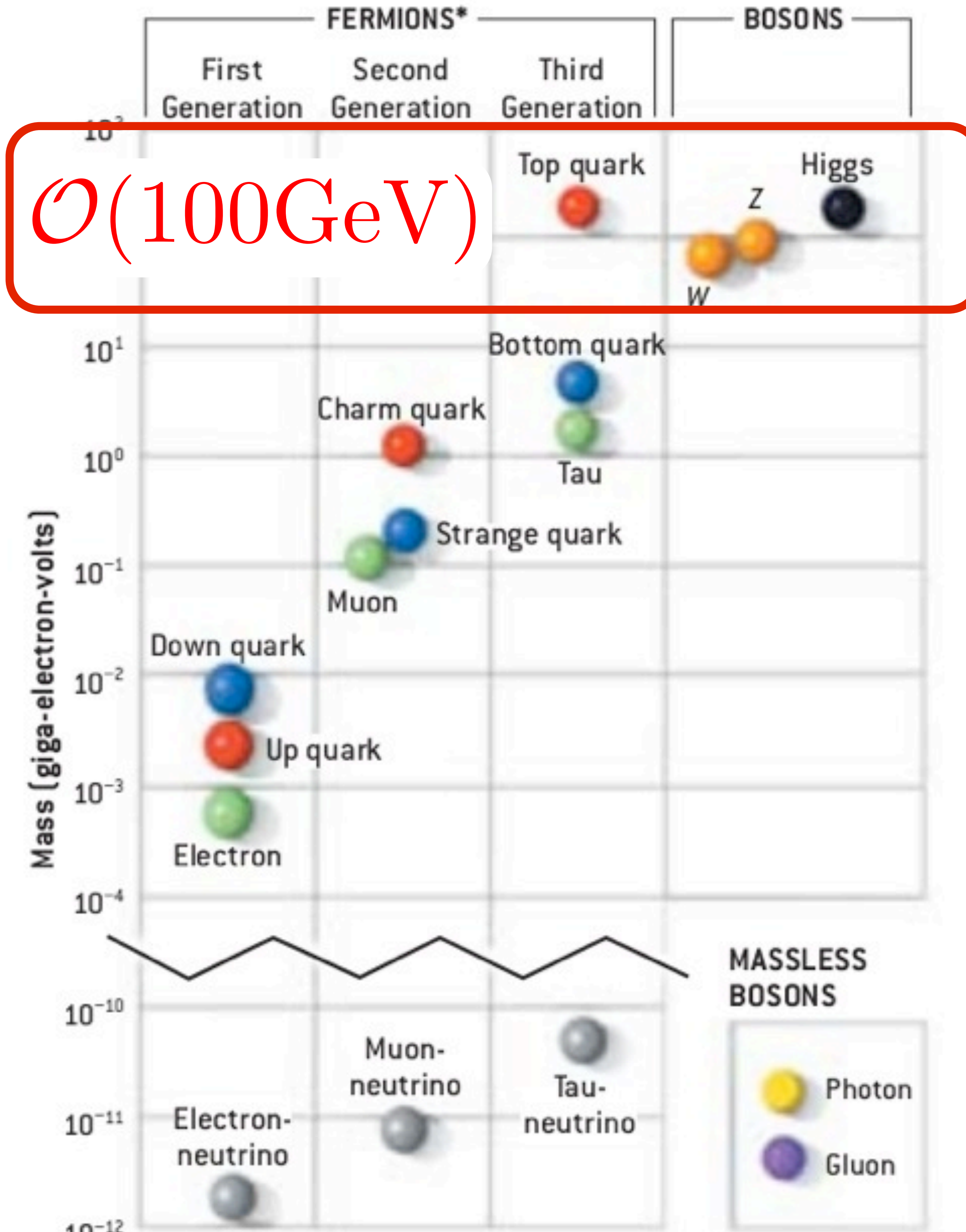




Gordon Kane,Scientific American 2003.

Mass : all SM participants

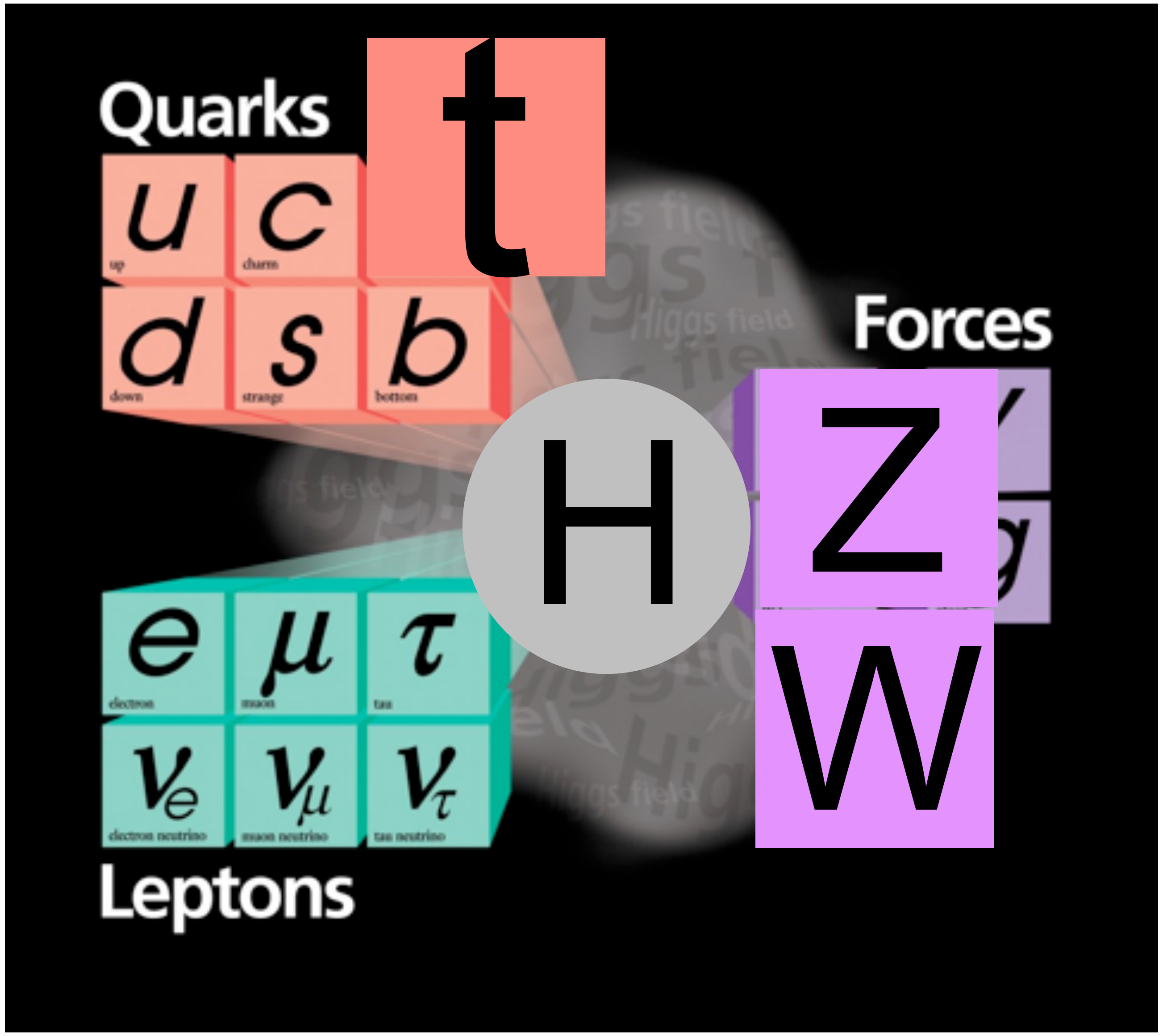




Gordon Kane,Scientific American 2003.

Mass (t,Z,W,h)

$$m_t = 173.07\,\mathrm{GeV}$$ PDG,central value (Direct mesurements)



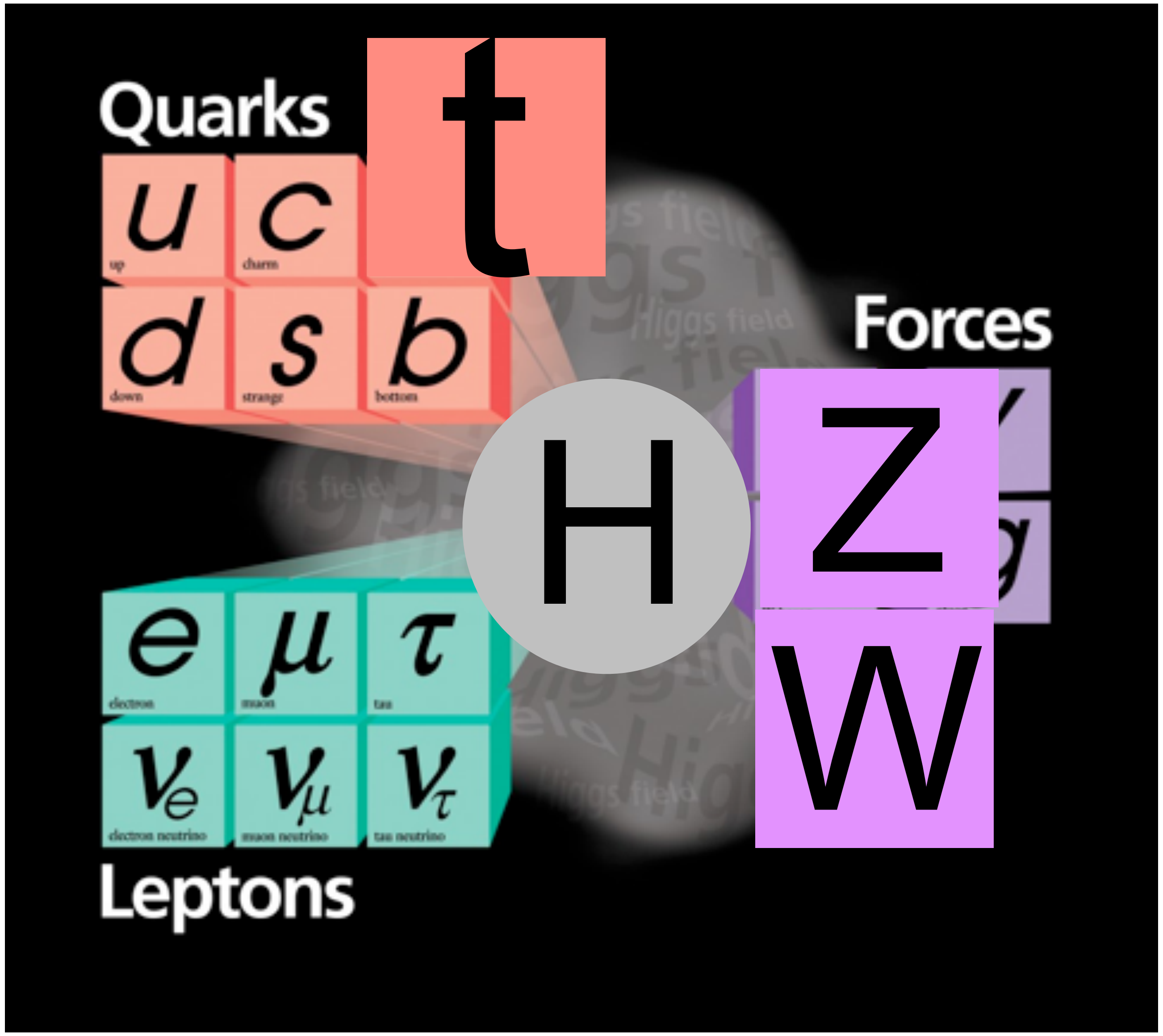
$\mathcal{O}(100\mathrm{GeV})$

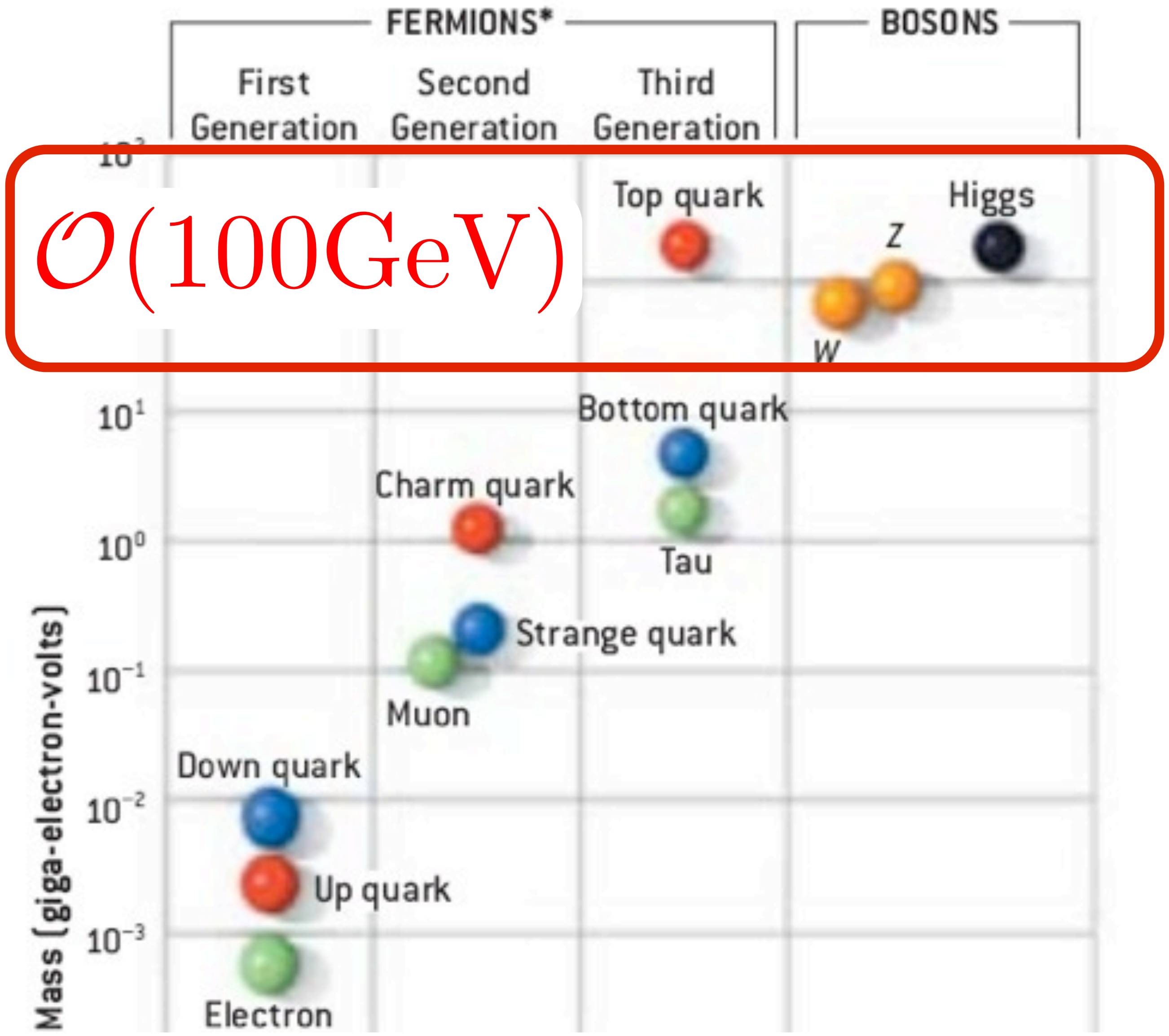
$$m_Z = 91.1876\,\mathrm{GeV}$$ PDG,central value

$$m_W = 80.385\,\mathrm{GeV}$$ PDG,central value

$$m_h = 125.5\,\mathrm{GeV}$$ ATLAS-CONF-2013-014,central value

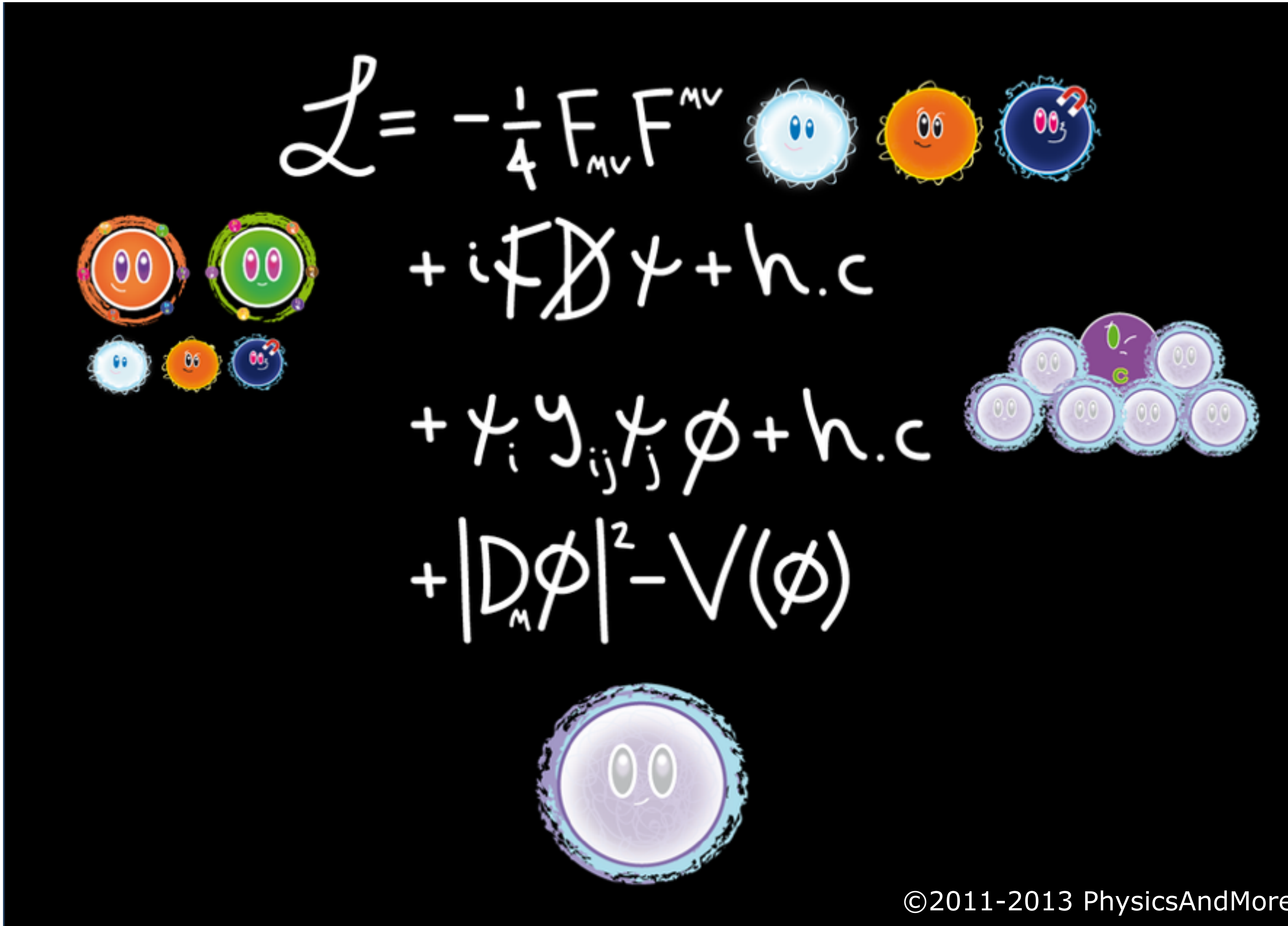
My Question





Why do they have the almost same order masses ?

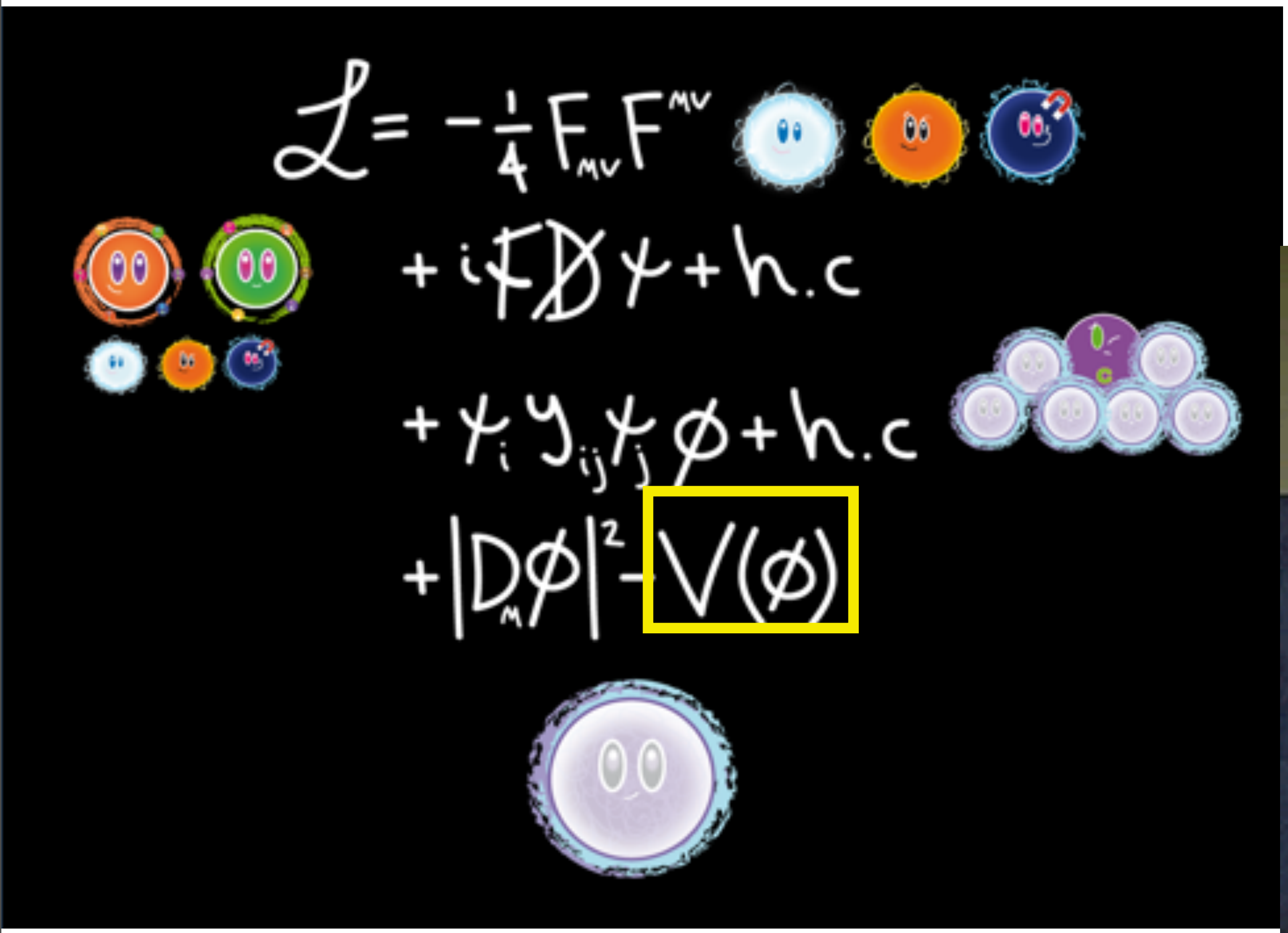
The Standard Model (Lagrangian)

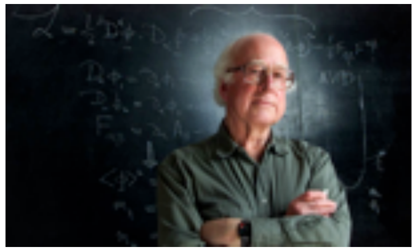


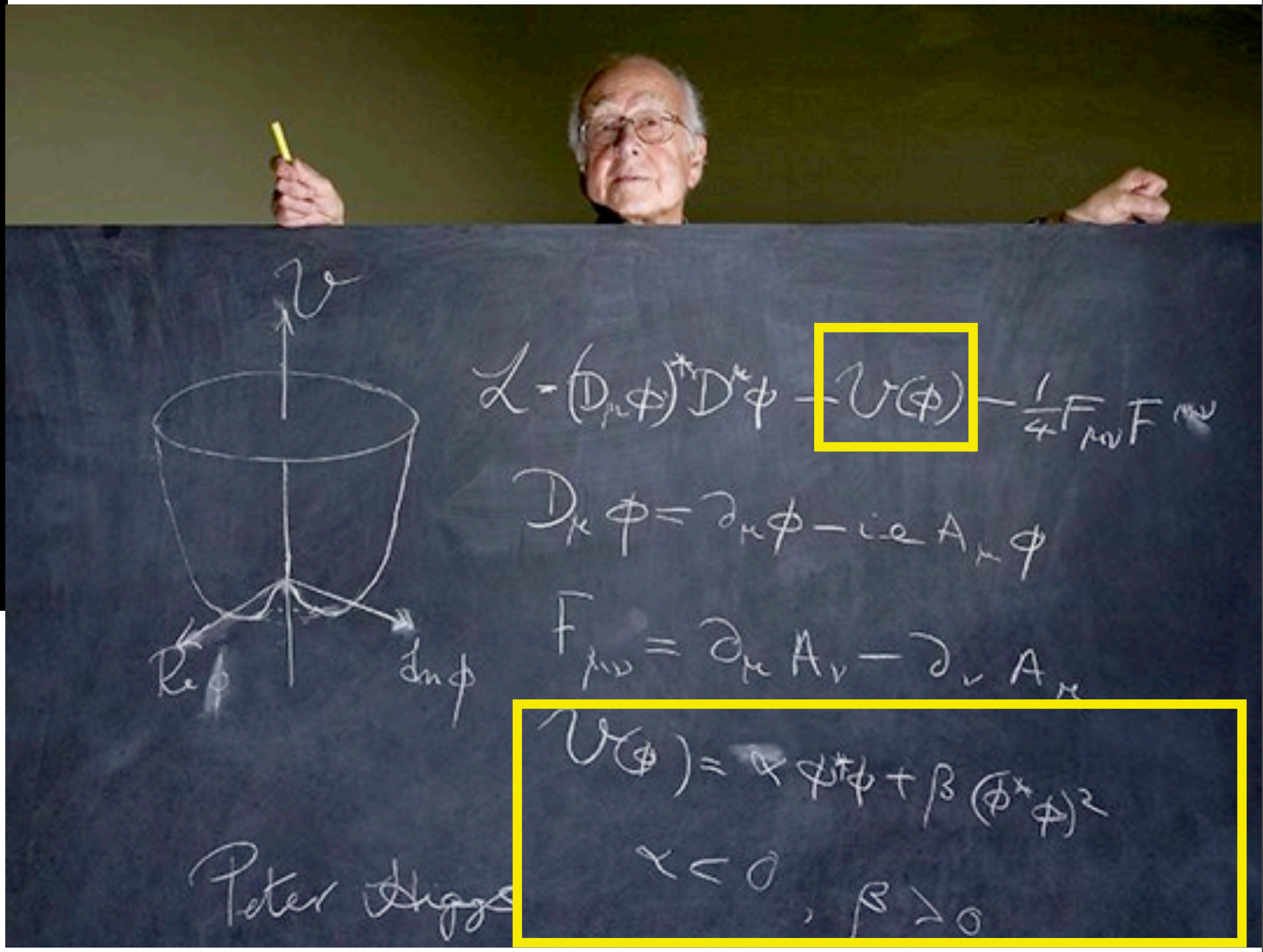
Origin of mass in the SM

In the SM,

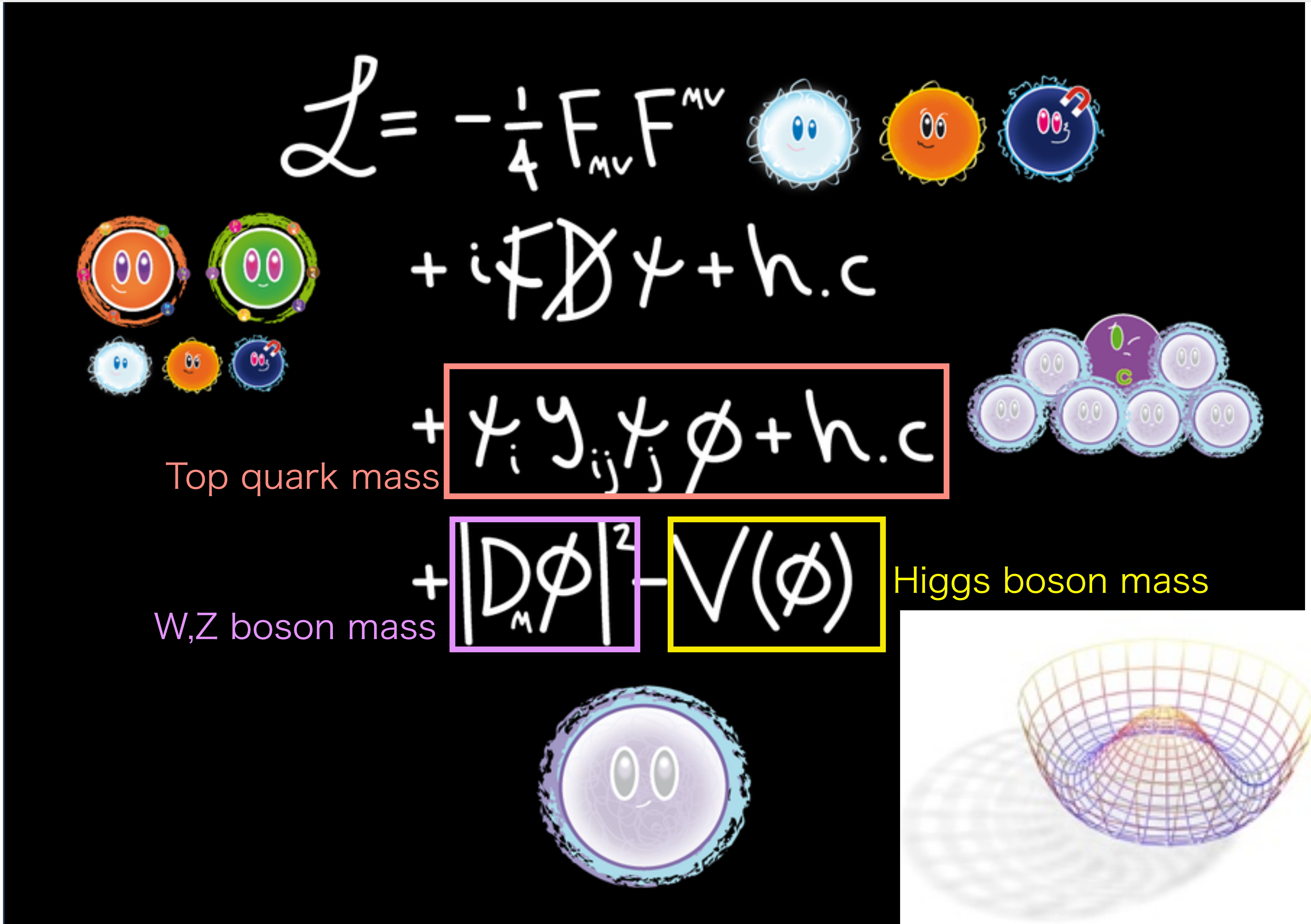
Origin of mass is **the Higgs mechanism**





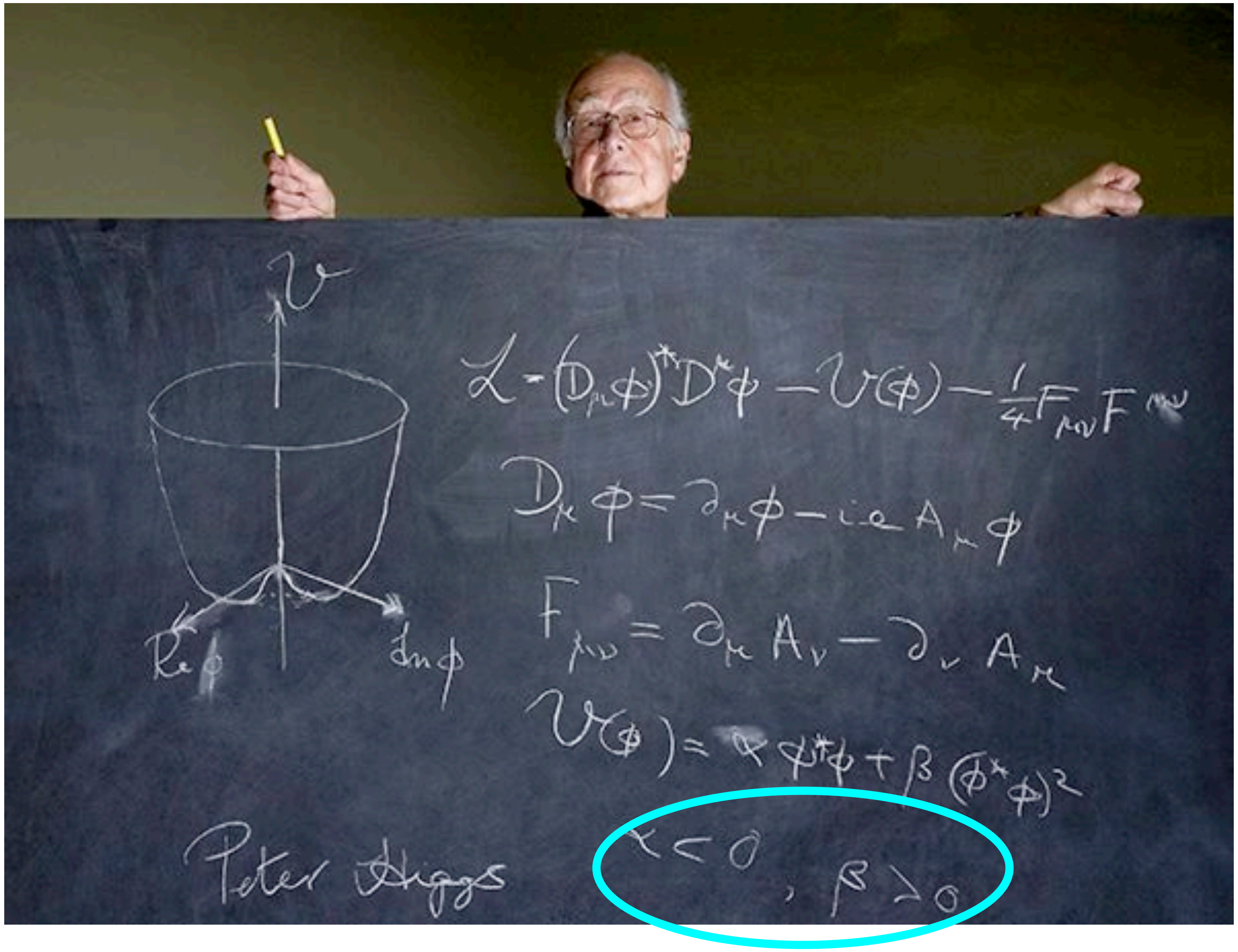


t,W,Z,H masses in the SM



My Question

New physics is hidden behind the Higgs mechanism ?

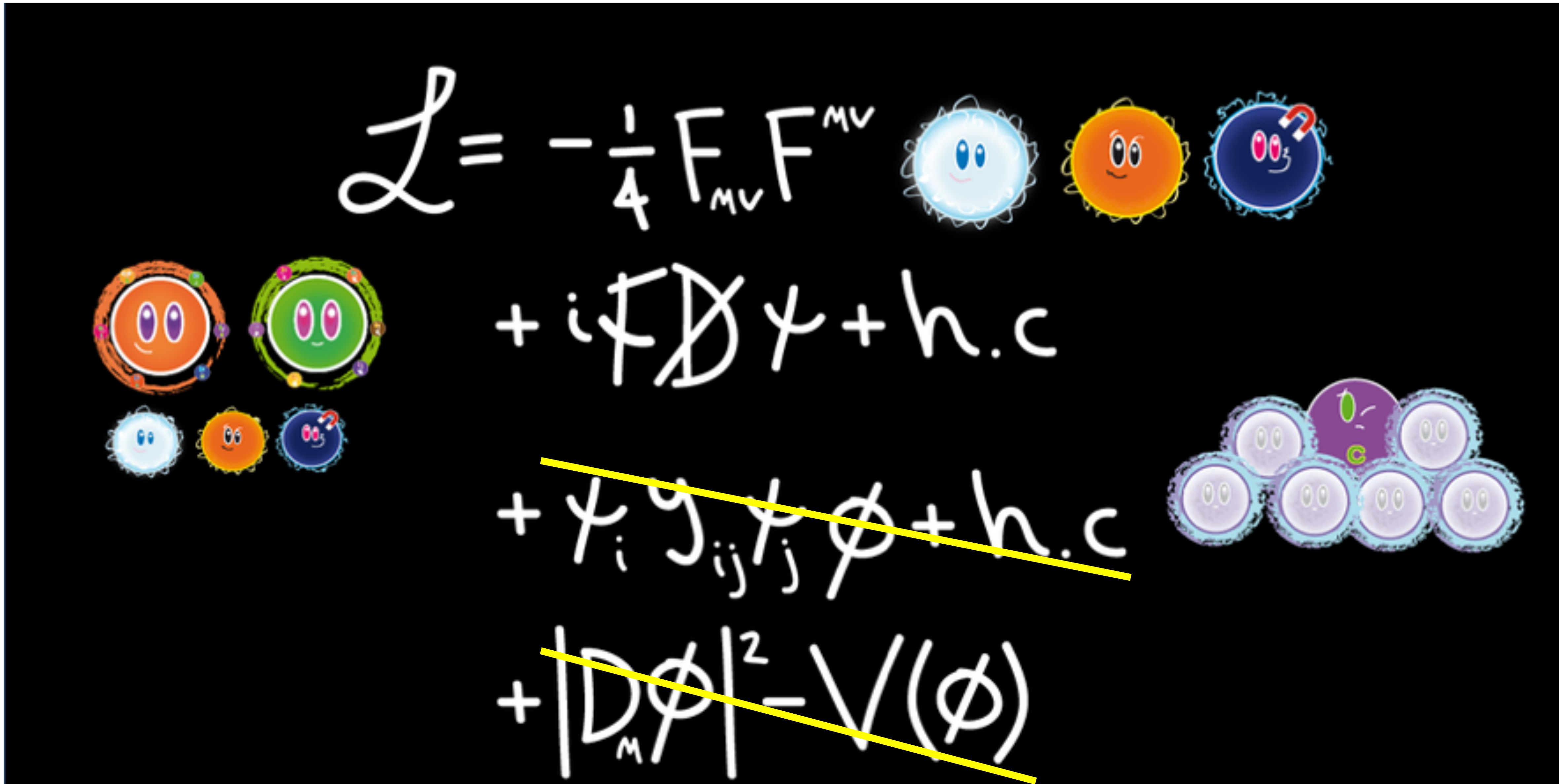


New physics in the market

- Representative scenarios in New physics market

* Supersymmetry
* Extra dimension
* Dynamical electroweak symmetry breaking

Technicolor (for W,Z boson)



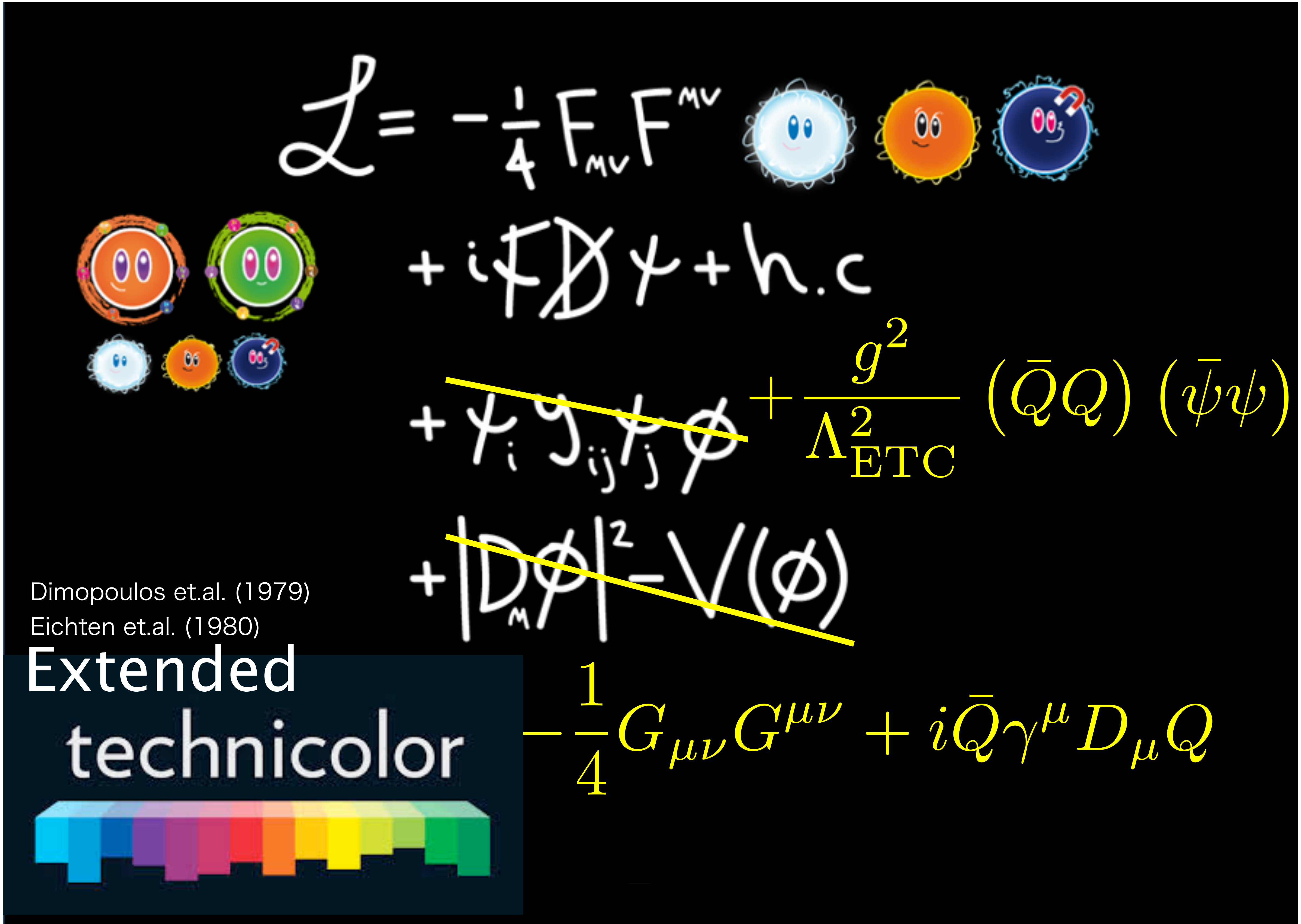
Weinberg(1976); Susskind (1979)

technicolor

$$-\frac{1}{4}G_{\mu\nu}G^{\mu\nu} + i\bar{Q}\gamma^{\mu}D_{\mu}Q$$

New interaction : G, New fermion : Q

Technicolor (for top quark mass)



$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\psi}\not{D}\psi + h.c + \bar{\psi}_i g_{ij}\psi_j\phi + |D_\mu\phi|^2 - V(\phi)$$

$$+ \frac{g^2}{\Lambda_{\rm ETC}^2}(\bar{Q}Q)(\bar{\psi}\psi)$$

$$-\frac{1}{4}G_{\mu\nu}G^{\mu\nu} + i\bar{Q}\gamma^\mu D_\mu Q$$

Technicolor (for Higgs boson)

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

$$+\frac{g^2}{\Lambda_{\mathrm{ETC}}^2}\left(\bar{Q}Q\right)\left(\bar{\psi}\psi\right) - \frac{1}{4}G_{\mu\nu}G^{\mu\nu} + i\bar{Q}\gamma^{\mu}D_{\mu}Q$$

Walking technicolor

technicolor w/ would-be light Higgs boson

Yamawaki et.al. (1986)

Technicolor (large top quark mass ?)

Top quark mass V.S. EW precision tests

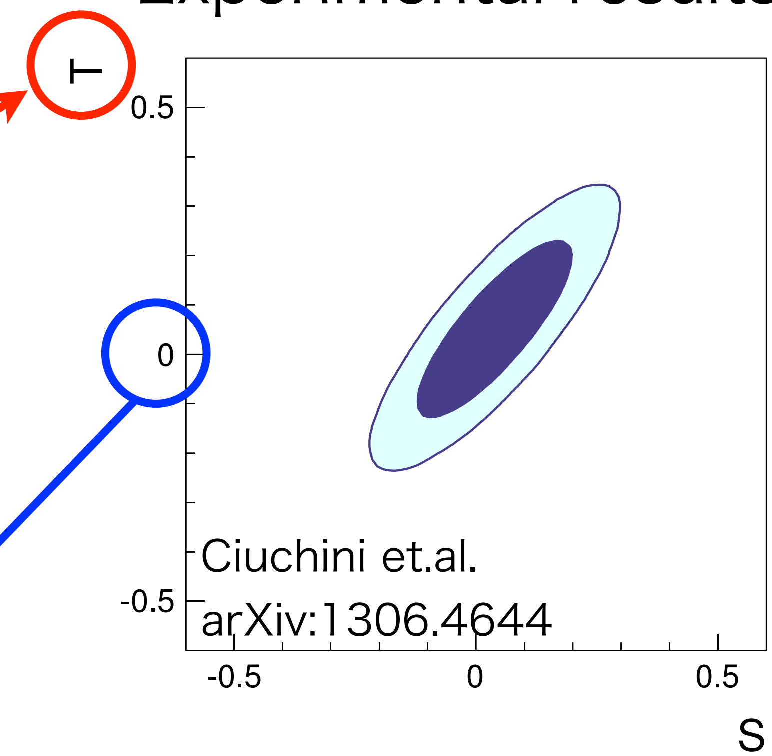
SM result @ tree satisfies

$$\rho \equiv \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = 1$$

Experiments show

$$\delta\rho \simeq 0 \quad (\delta\rho \propto T)$$

Experimental results



Extended technicolor implies

$$T \sim \frac{m_{Q_U}^2 - m_{Q_D}^2}{m_{Q_U}^2 + m_{Q_D}^2} \simeq 1$$

Not realistic !!

$$m_t^2 \simeq \frac{m_{Q_U}^3}{\Lambda_{\rm ETC}^2} \gg m_b^2 \simeq \frac{m_{Q_D}^3}{\Lambda_{\rm ETC}^2}$$

Top quark mass in technicolor

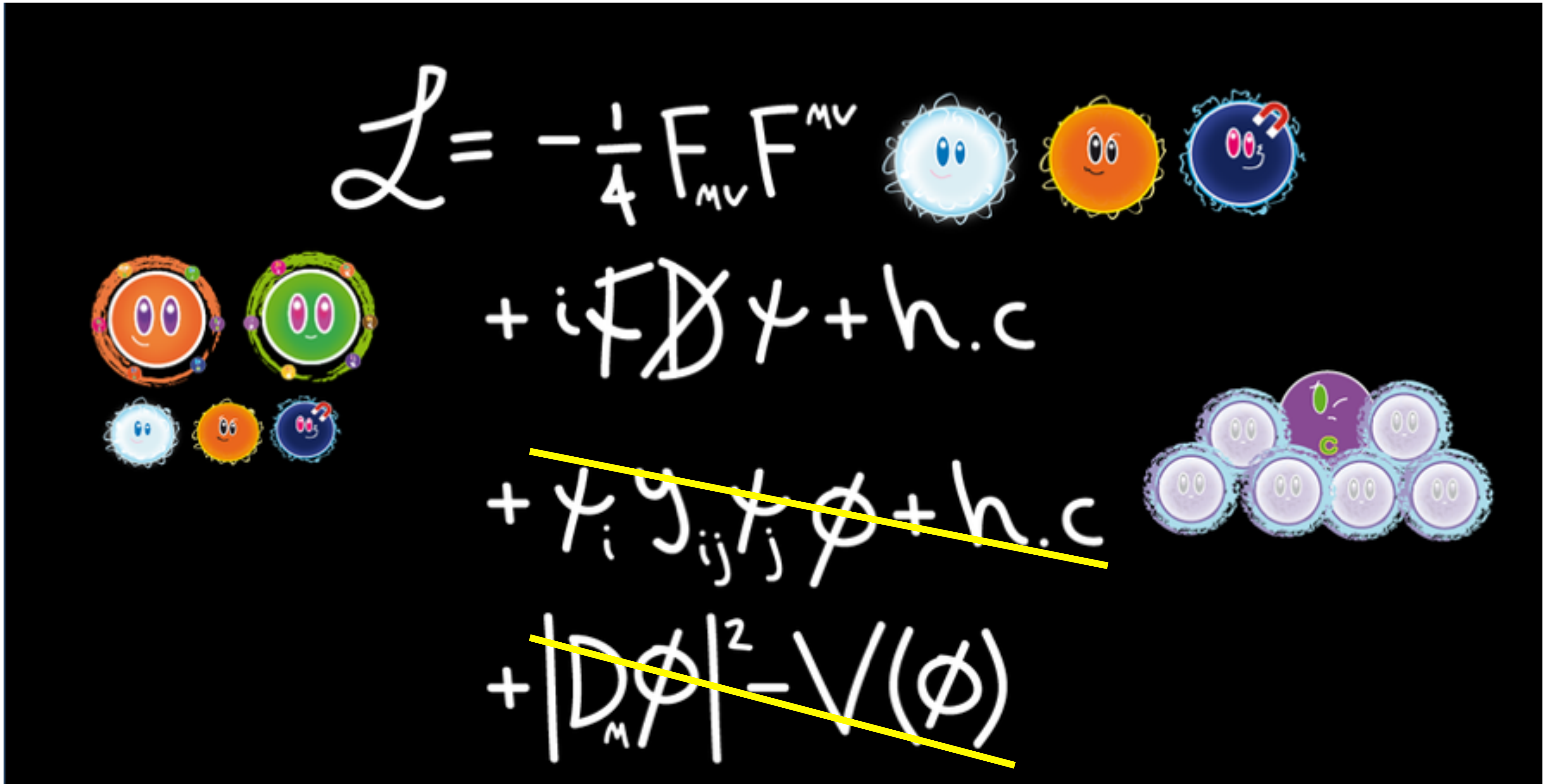
From viewpoint of my question ....

Large top quark mass
CAN NOT be realized
in standard technicolor scenario
even if Walking technicolor

||

technicolor w/
light Higgs boson (dilaton)

Top quark condensation



$$+ \frac{g^2}{\Lambda^2_{\mathrm{topC}}} (\bar{t}_L t_R)(\bar{t}_R t_L)$$

Miransky et.al. (1989)
Nambu (1989)
Bardeen et.al. (1989)

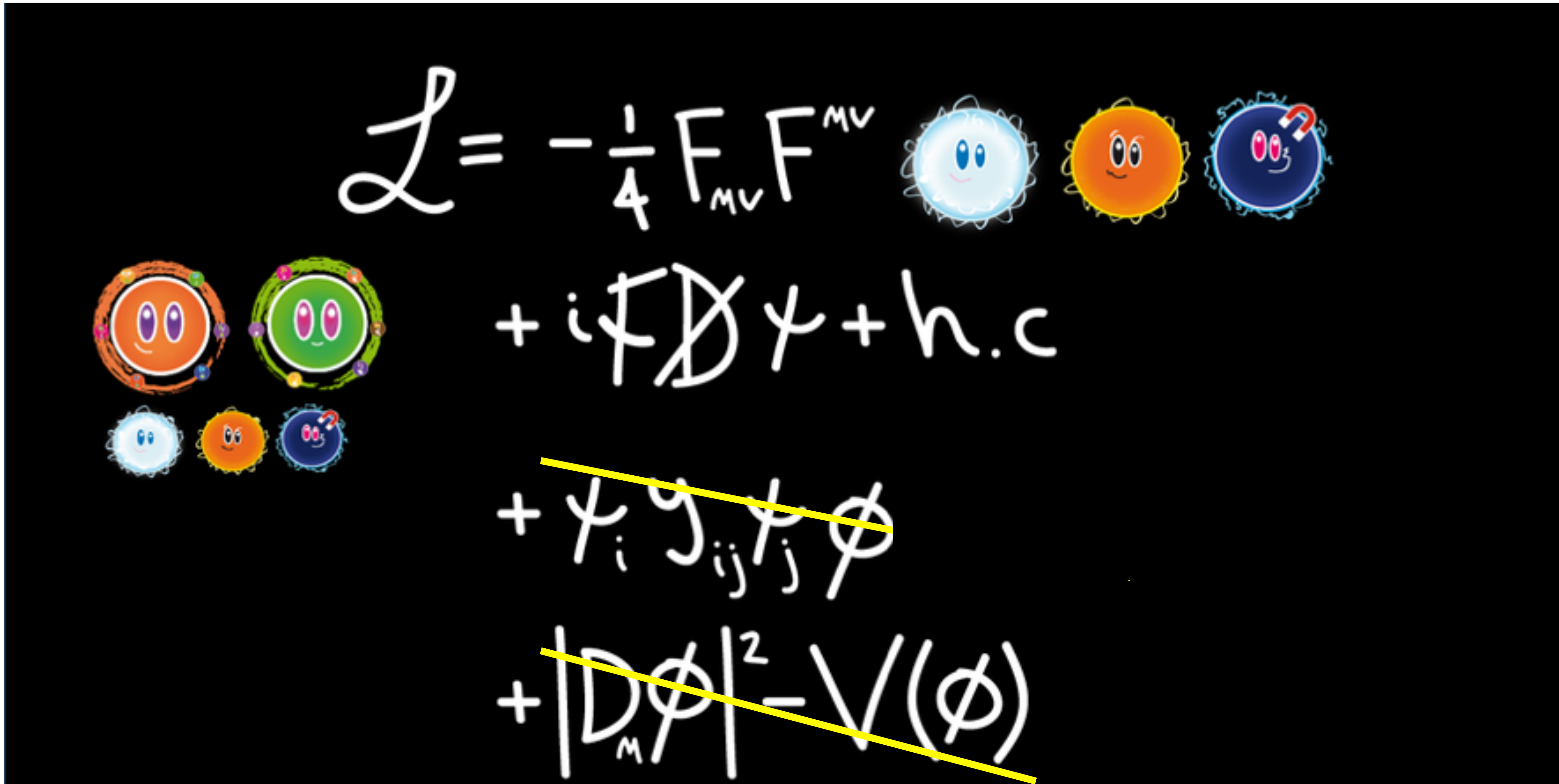
Top quark condensation

The top quark mass can be heavy
in a manner consistent with
the EW precision tests.

However

The top quark mass is too large...

Top quark seesaw model



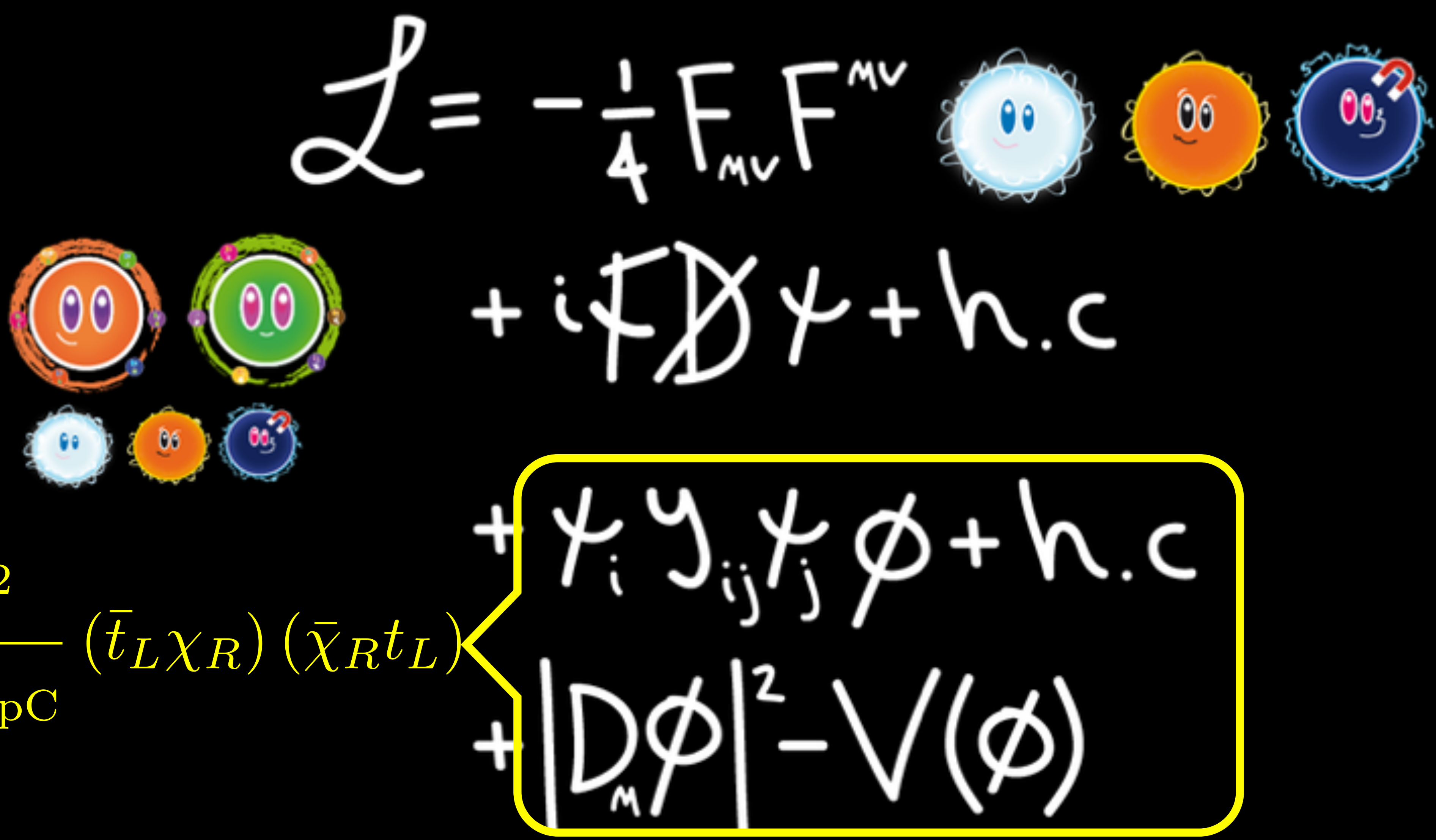
$$+ \frac{g^2}{\Lambda^2_{\rm topC}} (\bar{t}_L \chi_R)(\bar{\chi}_R t_L)$$

$\chi =$

new top-like quark

Dobrescu et.al.; Chivukula et.al. 1998

Top quark seesaw



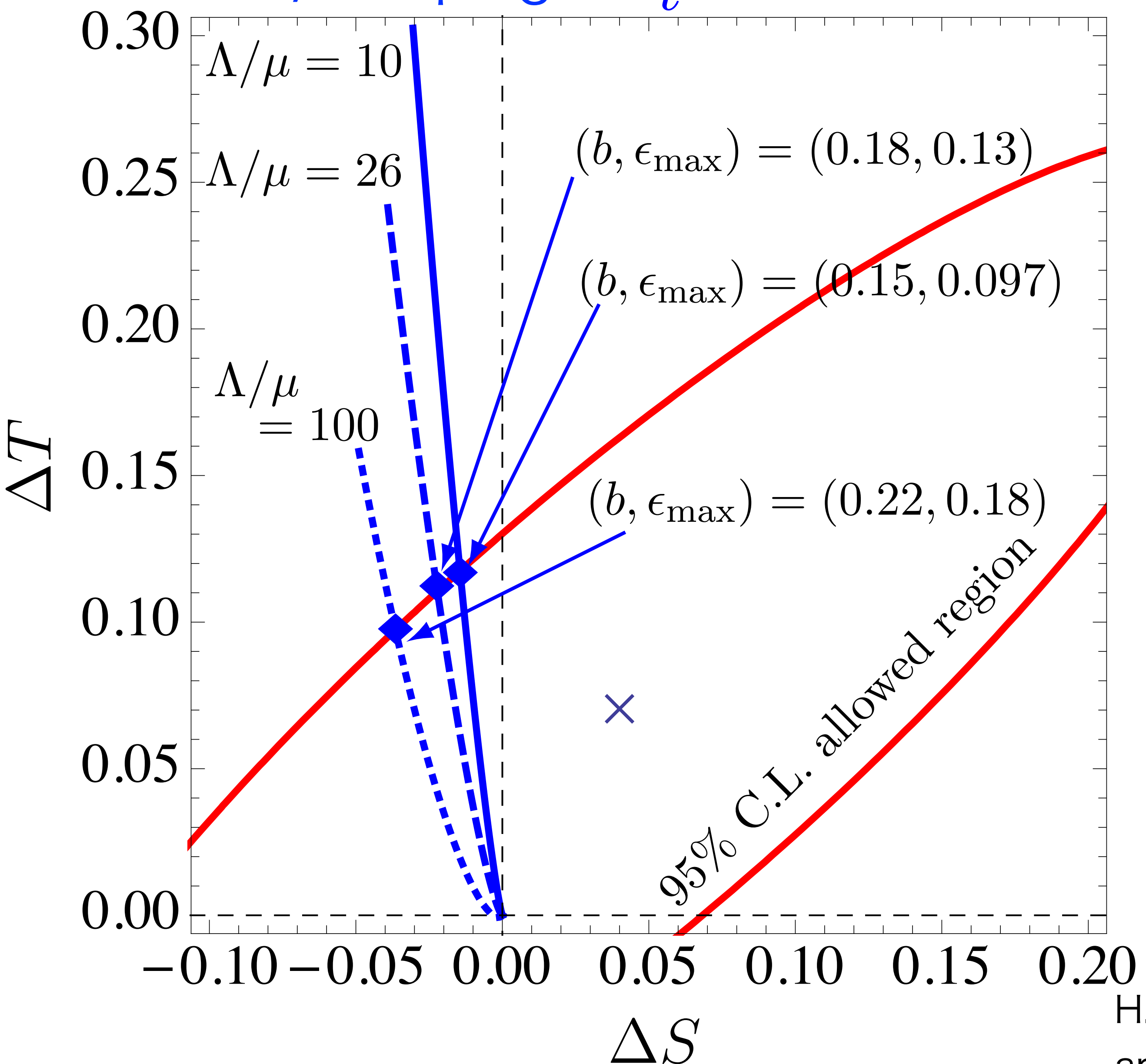
$$\frac{g^2}{\Lambda_{\rm topC}^2} (\bar{t}_L \chi_R) (\bar{\chi}_R t_L)$$

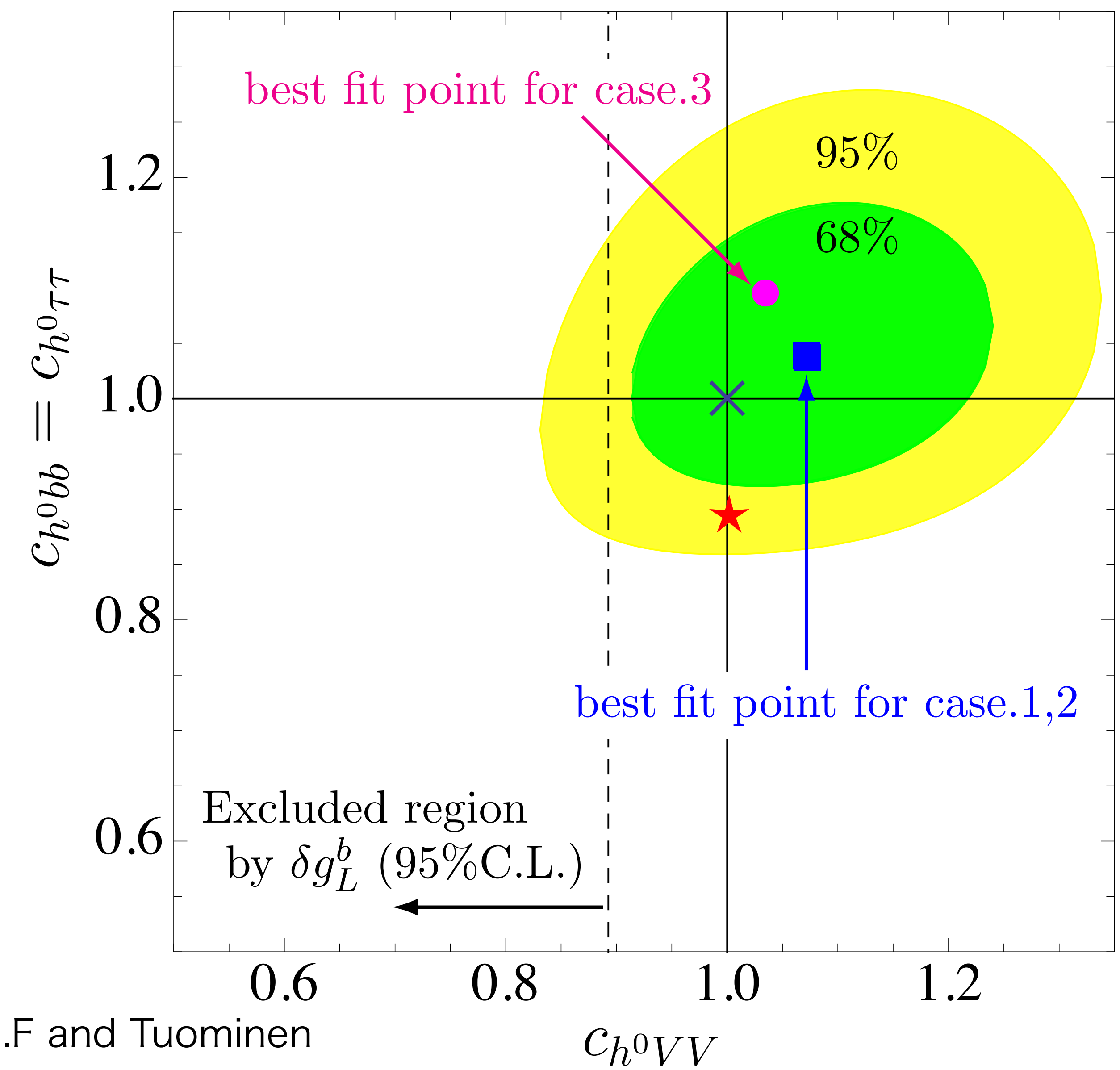
Higgs boson is generated as
a top quark-top partner pair composite

Top quark seesaw V.S. EWPT and LHC

Higgs boson can be parametrically light in the top quark seesaw model

w/ keeping $m_t \simeq 174\text{GeV}$





H.S.F and Tuominen
arXiv:1306.0205

Top quark mass in top quark seesaw

From viewpoint of my question ....

Large top quark mass CAN be realized

AND

Light Higgs boson CAN be realized
w/o conflicting with the EWPT & LHC

Question about Higgs in the TSS

In general, TSS Higgs boson satisfies $m_h \simeq 2m_t$

Why TSS Higgs boson can be lighter than the top quark mass ?

Ongoing ...

TSS Higgs boson might be PNGB...

Summary

- Q : Why is the top quark heavy ?
- A1: Technicolor can not explain it
- A2 : Top seesaw model is good (at least for me)
- Higgs boson = composite state

$$H \sim \bar{\chi}_R t_L$$

Lightness = PNGB ?

Thank you very much