Neutrinos: the portal to Physics beyond the SM

Challenges for the new particle physicists

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DF DEPARTAMENTO DE FÍSICA TÉCNICO LISBOA

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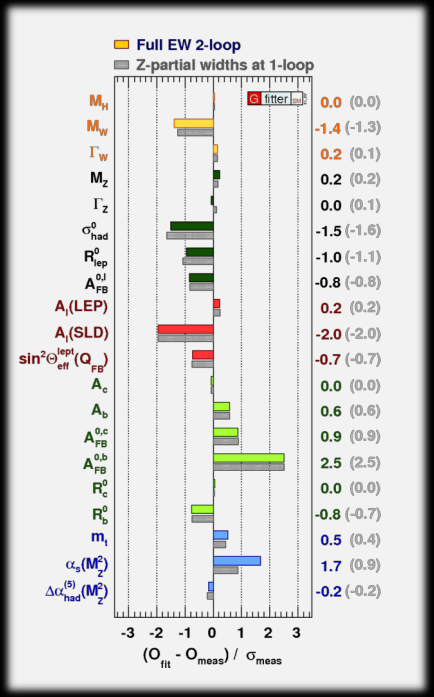
A successful THEORY



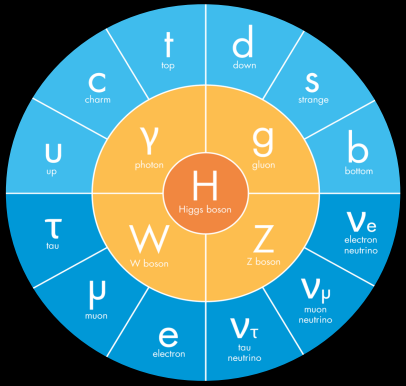
The Nobel Prize in Physics 1979 was awarded jointly to Sheldon Lee **Glashow**, Abdus Salam and Steven **Weinberg** *"for their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including, inter alia, the prediction of the weak neutral current".*

The Nobel Prize in Physics 1999 was awarded jointly to Gerardus **'t Hooft** and Martinus J.G. **Veltman** *"for elucidating the quantum structure of electroweak interactions in physics".*

The Nobel Prize in Physics 2013 was awarded jointly to François **Englert** and Peter W. **Higgs** *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"*

The Standard Model (SM)

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + |D_\mu\phi|^2 - V(\phi)$$
$$+ i\bar{\psi}D\!\!\!/\psi + \bar{\psi}_i y_{ij}\psi_j\phi + h.c$$

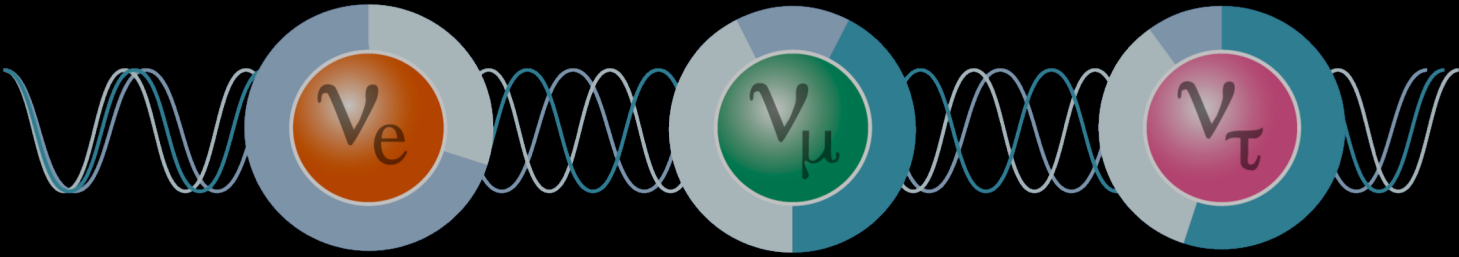


SIMMETRY

and its breaking...

NEW Physics

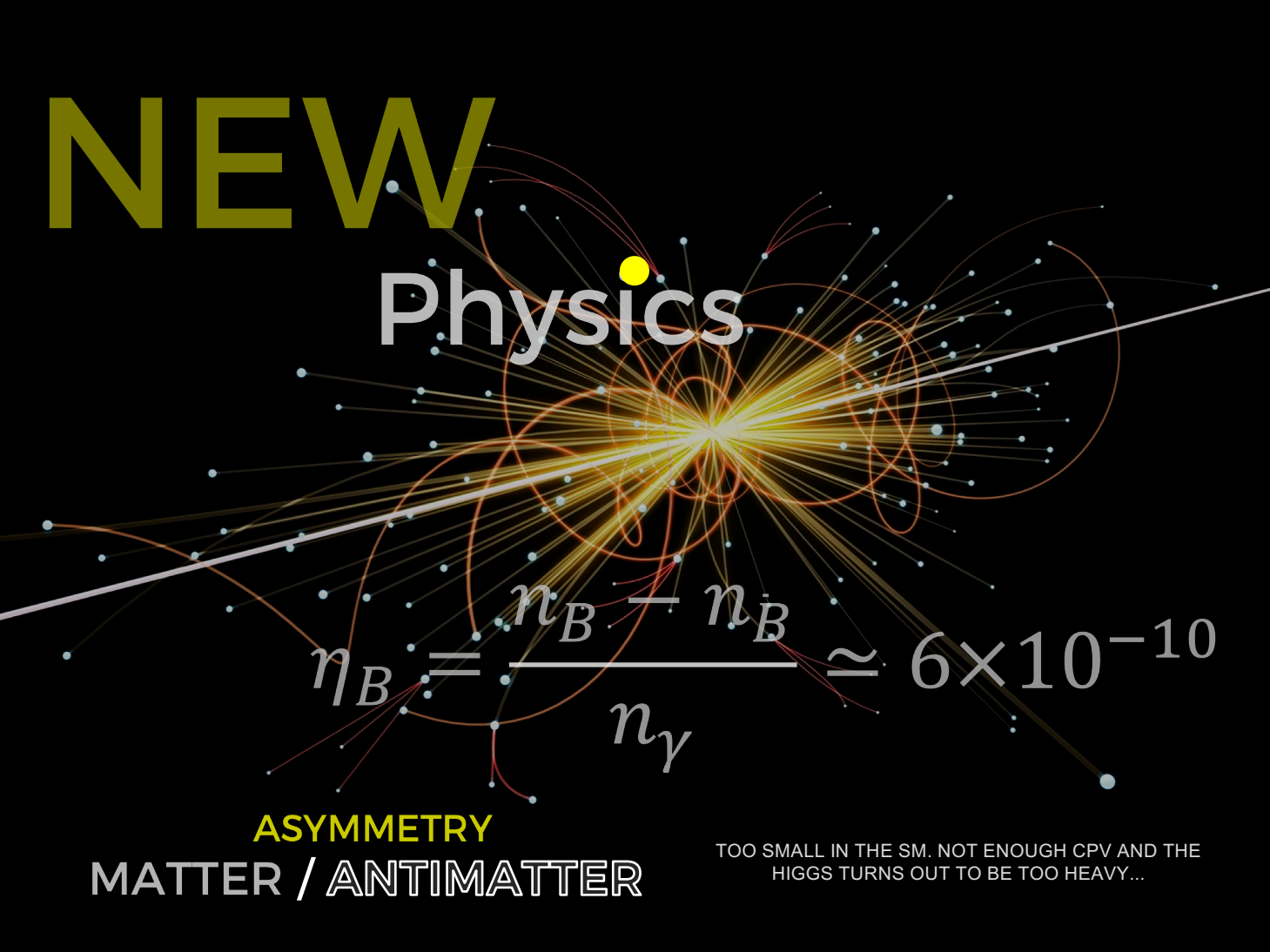
The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald *"for the discovery of neutrino oscillations, which shows that neutrinos have mass"*



In the SM neutrinos are massless!
But you know neutrinos have mass and also mix. How to explain the mass and mixing pattern observed by oscillation experiments?

NEUTRINO masses

NEW Physics



$$\eta_B = \frac{n_B - n_{\bar{B}}}{n_\gamma} \simeq 6 \times 10^{-10}$$

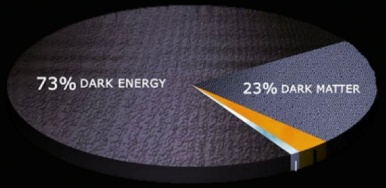
ASYMMETRY

MATTER / ANTIMATTER

TOO SMALL IN THE SM. NOT ENOUGH CPV AND THE HIGGS TURNS OUT TO BE TOO HEAVY...

NEW Physics

DARK MATTER

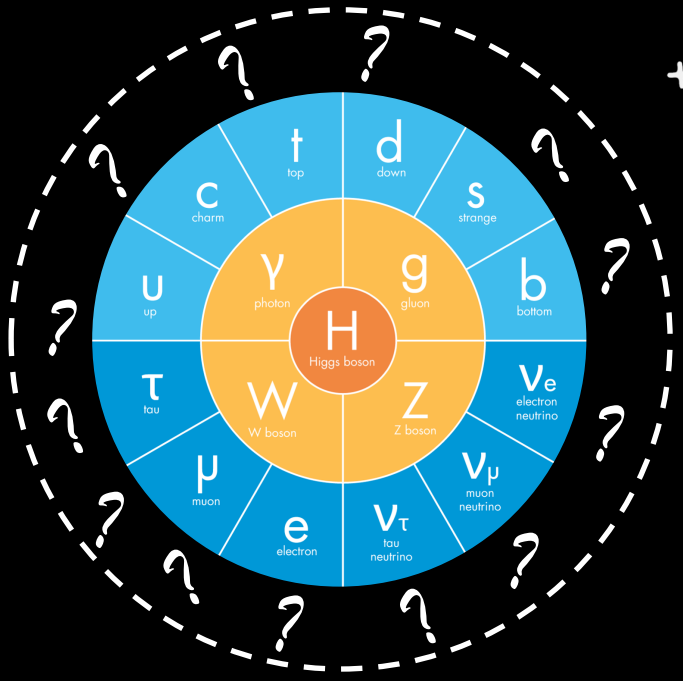


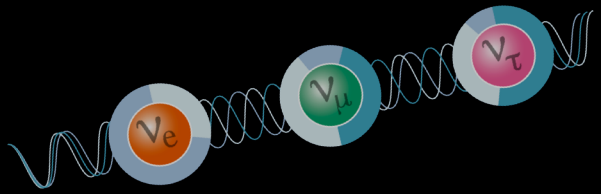
Around ¼ of the energy budget of the Universe comes in the form of dark matter.

THE SM HAS NO DARK MATTER CANDIDATE

A more complete THEORY

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





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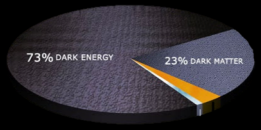

NEW Physics

(by MEFT students)