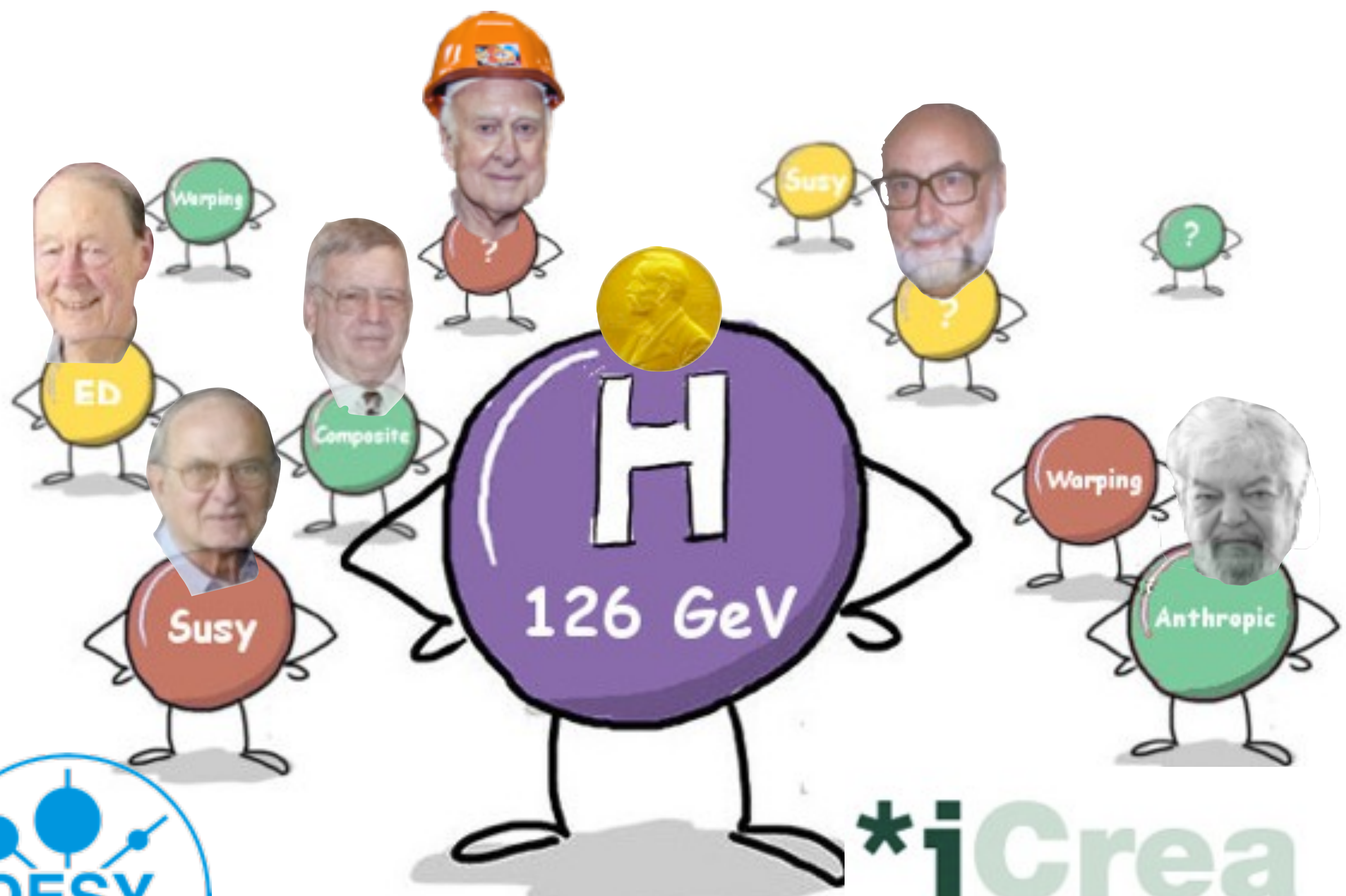
# Beyond the Standard Model

*CERN summer student lectures 2015*




*Exercises 3/5*

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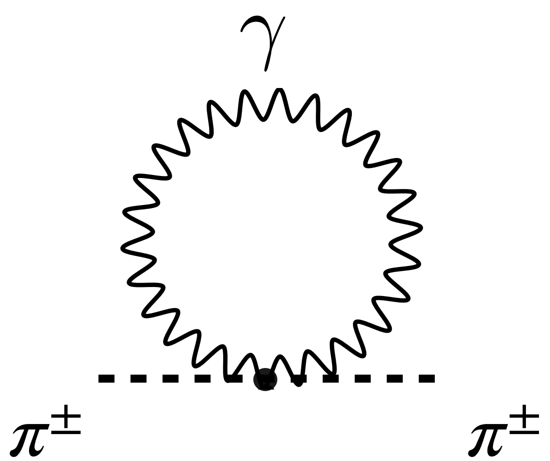
# Pion mass difference and the $\rho$ meson

The pions are Goldstone bosons associated to the breaking of chiral symmetry
electromagnetic interactions breaks $SU(2)_{isospin}$ symmetry between u and d
EM gives rise to a mass difference between $\pi^0$ and $\pi^\pm$




$$\delta m^2 \equiv m^2_{\pi^\pm} - m^2_{\pi^0} \sim \frac{3\alpha_{\rm em}}{4\pi}\Lambda^2$$

By requiring that this contribution to the mass difference remains smaller than the experimentally measured mass difference (4 MeV), deduce that there should be new state(s) below 850 MeV

What is the QCD state that regulates the pion mass difference?

Das et al. in '67 showed that $$\delta m^2 \simeq \frac{3\alpha_{\rm em}}{4\pi}\frac{m_\rho^2 m_{a_1}^2}{m_{a_1}^2 - m_\rho^2}\log(m_{a_1}^2/m_\rho^2)$$