Higgs Reloaded

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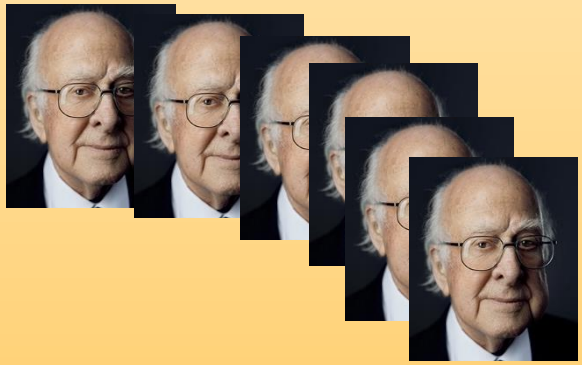


Physics is an experimental science

- **Where is data coming from?**

LHC

(Atlas + CMS ~4066 publ in 2016-18)

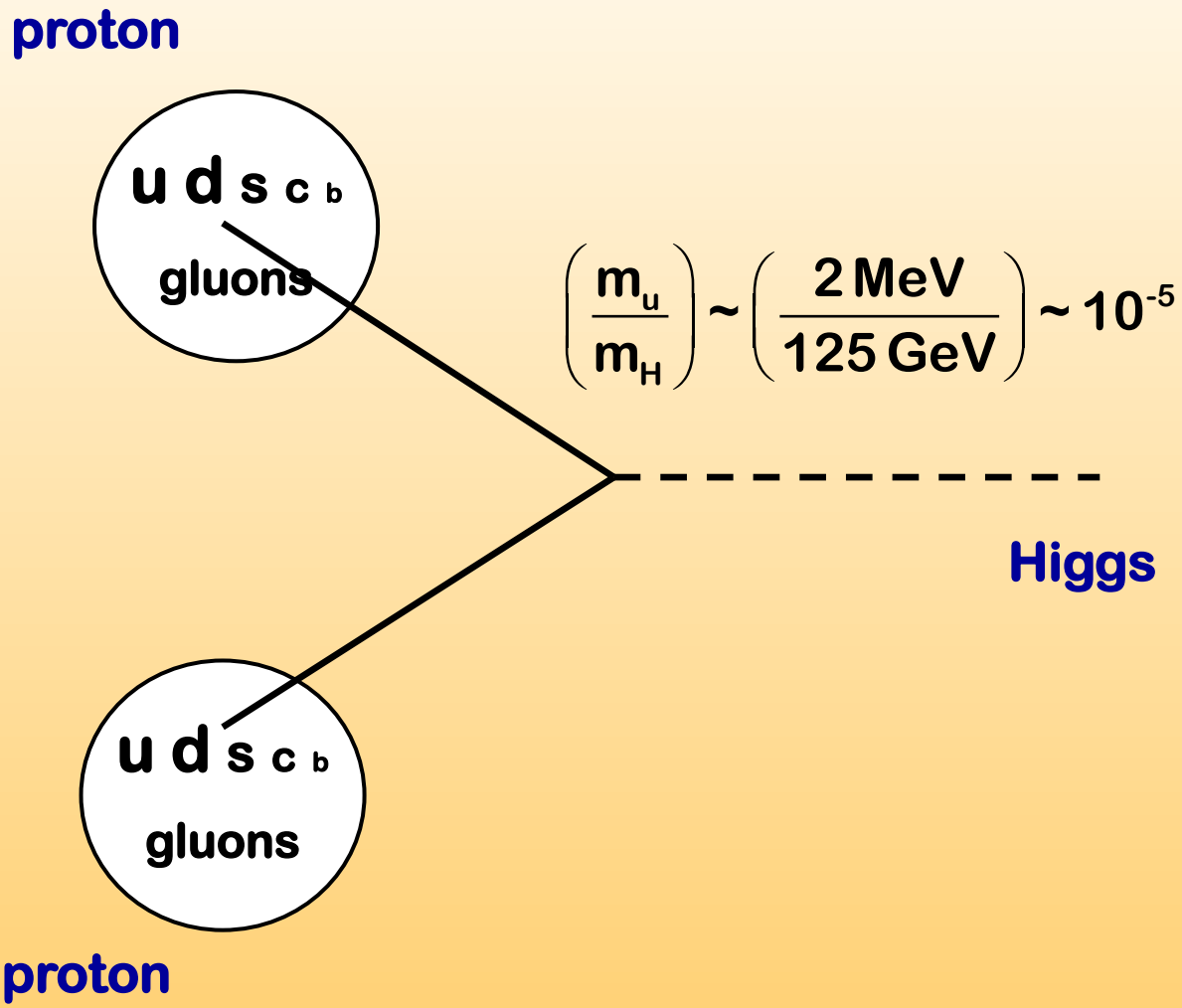
- **What have we learned?**

There is a fundamental spin 0 particle :

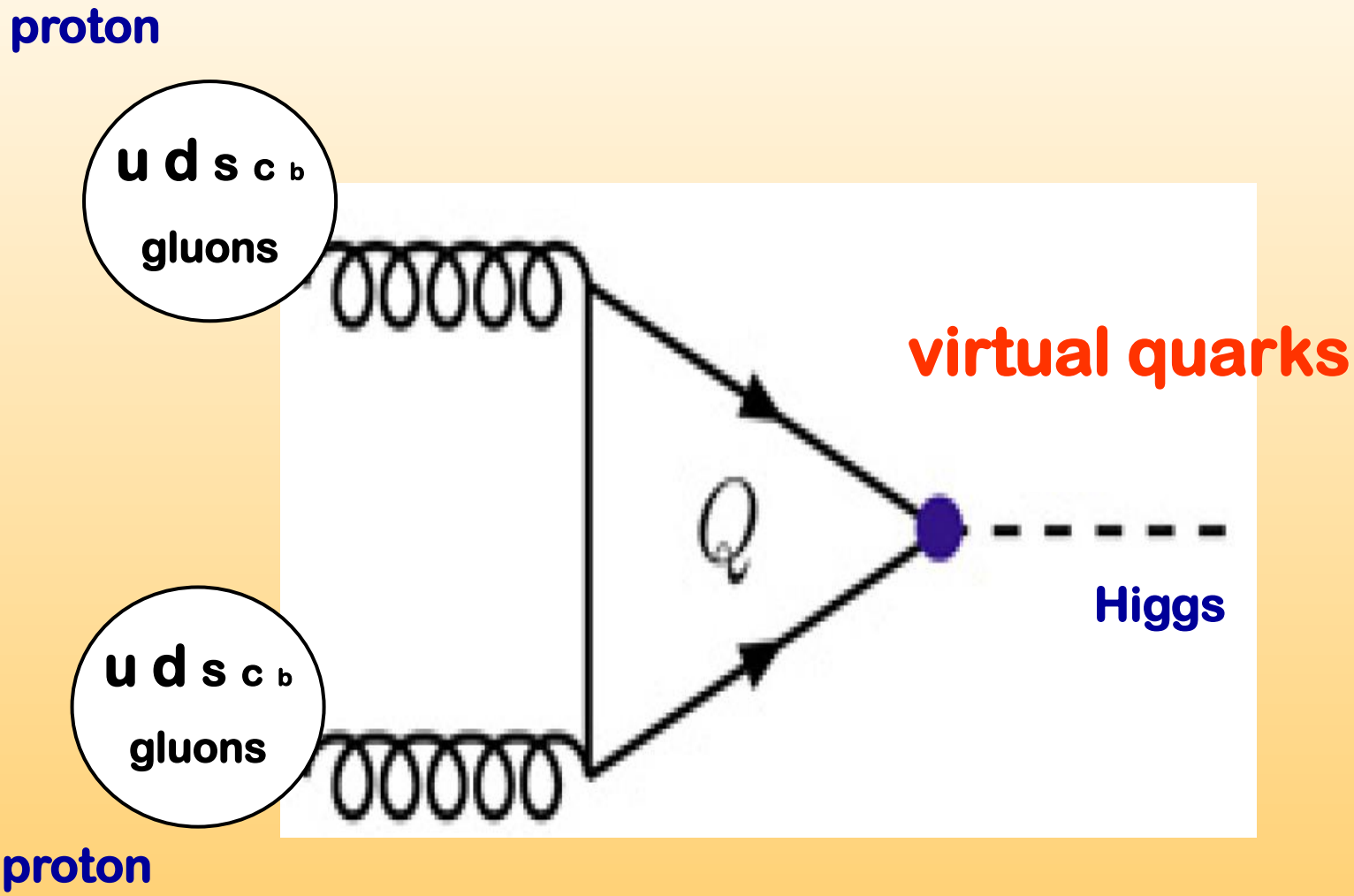
the Higgs

mass:	**125 GeV**
width:	**< ~ 1 GeV (direct)** **[SM ~4 MeV]**
elmg charge:	**none**
color charge:	**none**

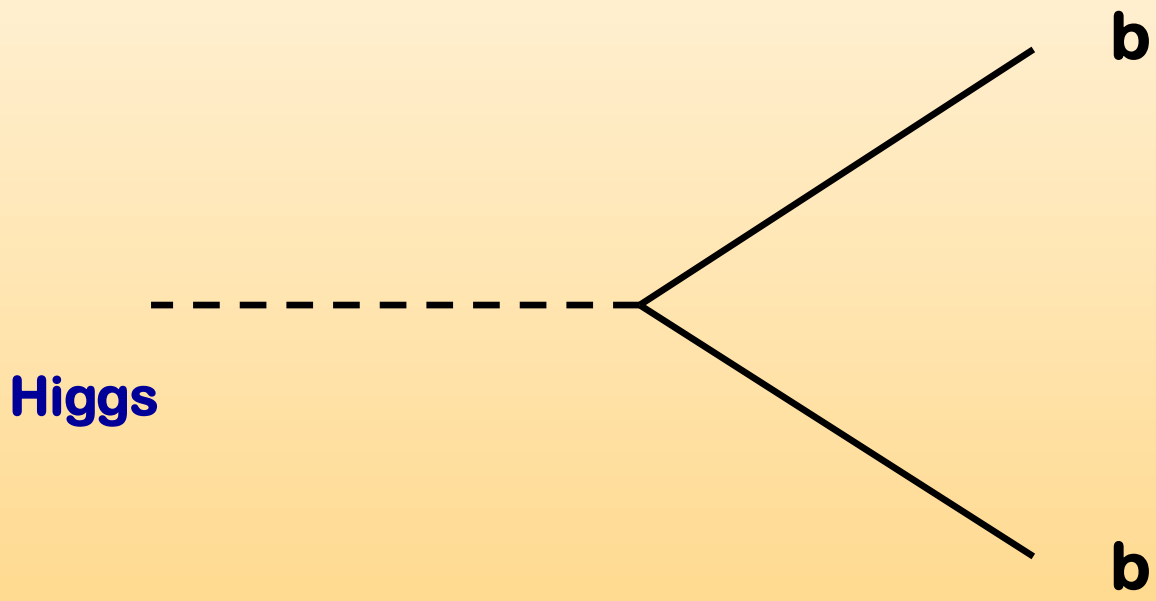
Higgs is difficult to produce



Higgs is difficult to produce



Higgs is difficult to detect



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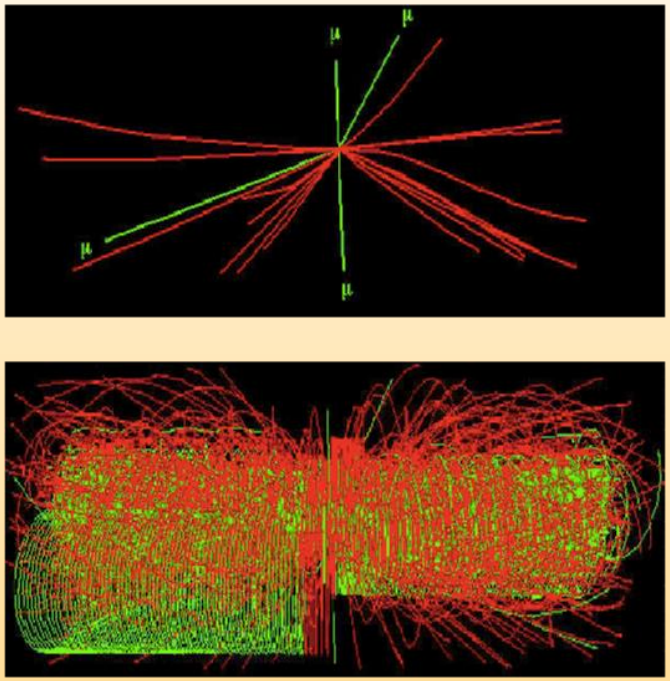
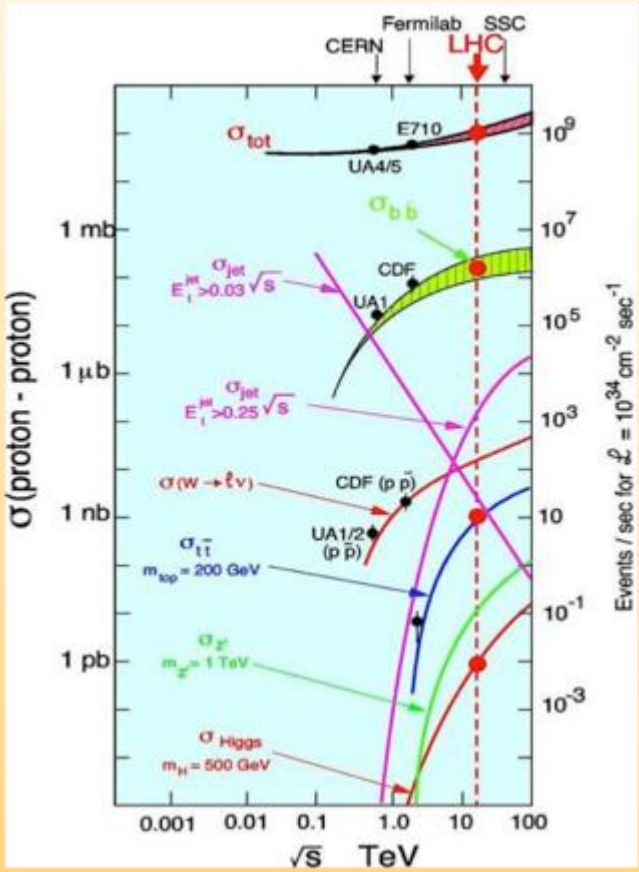


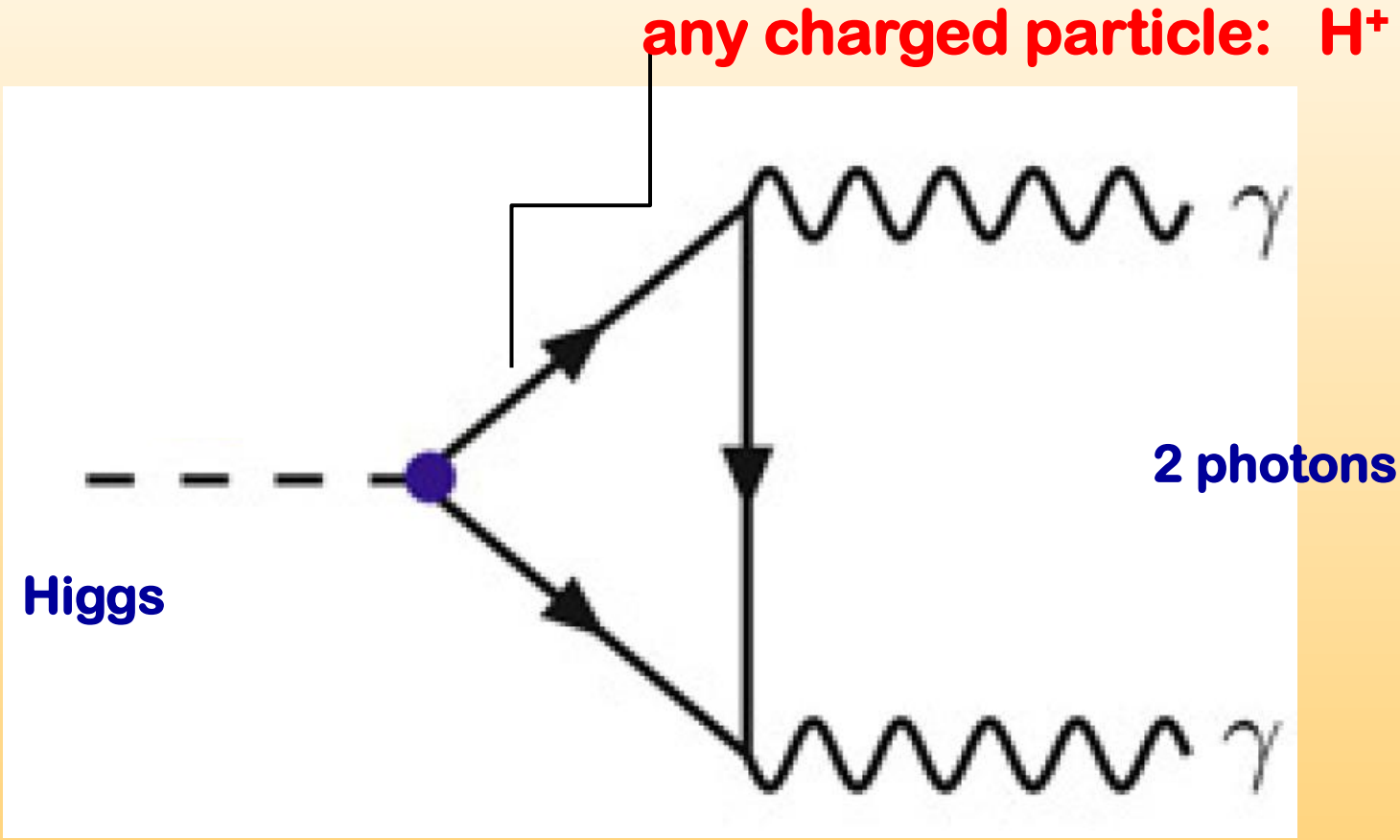


ATLAS

- **~ 300 x 10^{12} collisions**
- **~ 1300 Higgs created**
- **~ 450 h --> γγ**

thanks to: Ricardo Gonçalo

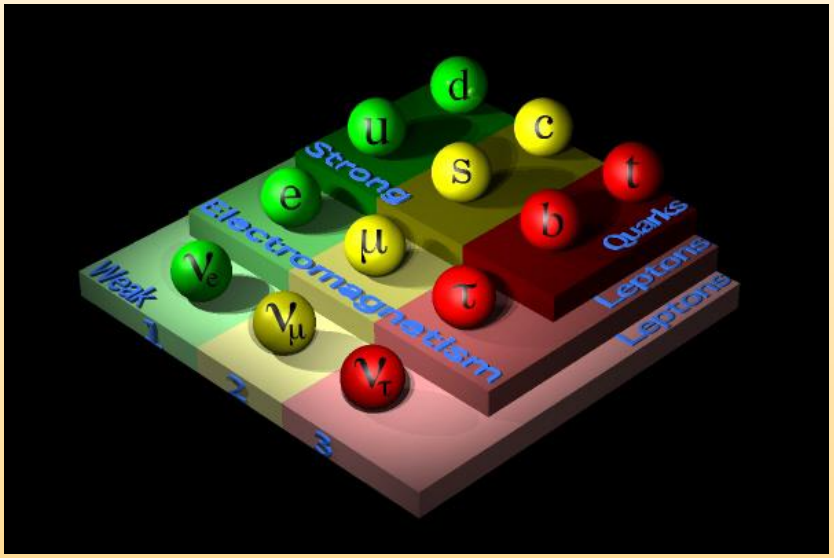
Higgs is difficult to detect



Why 1 Higgs?

- **# Spin 1 fixed by gauge group:**
  $SU(3)xSU(2)xU(1) \Rightarrow W^{\pm}, Z^0, \gamma, g_{1..8}$

- **Nothing fixes # Spin 1/2:**
  Settled by experiment



- **Nothing fixes # Spin 0:**
  MUST be settled by experiment

Comercial break

Novelties in Multi-Higgs

- **Multiple spin-0 particles**
  - **Neutral:** **Scalar (h, H)**
    Pseudoscalar (A)
    Mixed (h1, h2, h3)
  - **Charged ($H^{\pm}$)**

- **Rich vacuum structure**
  - **May have charge breaking minimum**
  - **May have two local minima of unequal depths**

Novelties in Multi-Higgs

- **CP violation in the Higgs sector**
  - **Theory:** **Explicit**
    Spontaneous
  - **Experiment:** **Scalar-pseudoscalar mixing**
    Mixing of charged Higgs
    Diagonal coupling to fermions
    Off-diagonal coupling to fermions **(FCNSI)**

- **Possible Cosmological implications**
  - **Candidates for Dark Matter**
  - **Baryogenesis / Higgsogenesis**

Unitarity bounds for any number of Higgs

- **MEFT student – Miguel Bento**

1. **JHEP 1711, 095 (2017) (67 pages!)**
2. **JHEP 1810, 143 (2018)**

Multi-Higgs doublet models: physical parametrization, sum rules and unitarity bounds

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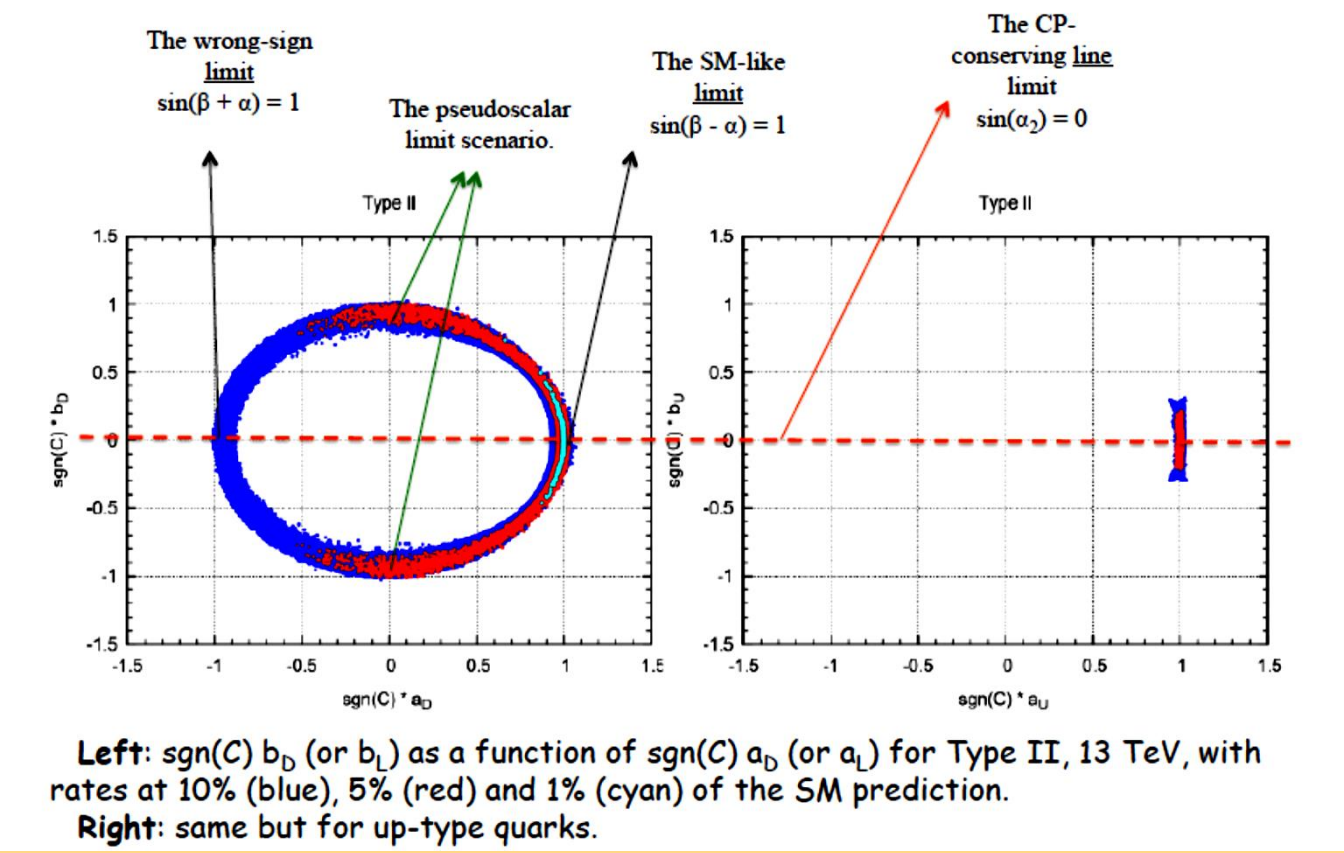
Miguel P. Bento,[a] Howard E. Haber,[b] J.C. Romão[a] and João P. Silva[a]

A most interesting possibility: Higgs with large pseudoscalar content

- **MEFT → PhD student – Duarte Fontes**

1. Phys. Rev. D90, 015021 (2014)
2. JHEP 1412, 043 (2014)
3. JHEP 1506, 060 (2015)
4. Phys. Rev. D92, 055014 (2015)
5. Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector **(>500 citations)**
6. Eur. Phys. J. C77 (2017) no.3, 176 **(EFT)**
7. JHEP 1804, 002 (2018) **(EFT)**
8. JHEP 1802, 073(2018)

Higgs pseudoscalardness?



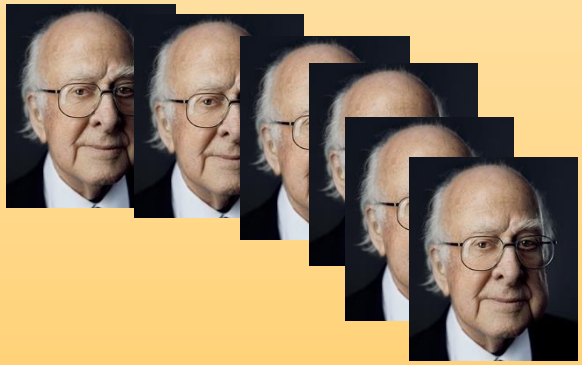
Left: sgn(*C*) b_D (or b_L) as a function of sgn(*C*) a_D (or a_L) for Type II, 13 TeV, with rates at 10% (blue), 5% (red) and 1% (cyan) of the SM prediction.
Right: same but for up-type quarks.

Fontes, Romão, R. Santos, JPSilva : Toyama

Multi-Higgs Workshops

Join us

- **Very active field**
- **Many experimental results**
- **Many interesting theoretical features**
- **Strong international impact**



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