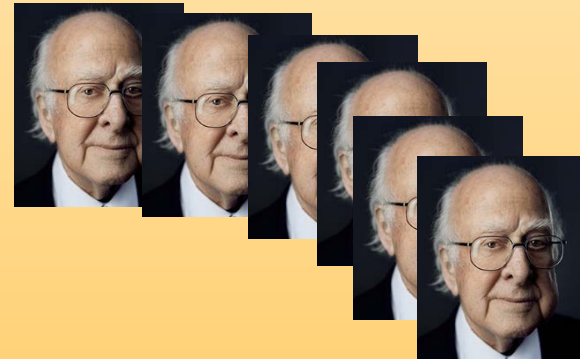


# Higgs Reloaded

**João P. Silva**

**DF & CFTP (IST)**



# Physics is an experimental science

- Where is data coming from?

**LHC**

(Atlas + CMS ~350 articles in 2016)

- What have we learned?

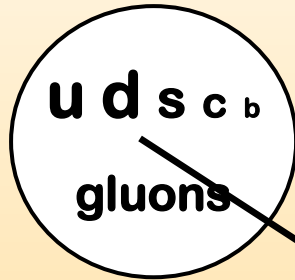
There is a fundamental spin 0 particle :

**the Higgs**

mass:	<b>125 GeV</b>	
width:	<b>&lt; ~ 1 GeV</b> (direct)	[SM ~4 MeV]
elmg charge:	<b>none</b>	
color charge:	<b>none</b>	

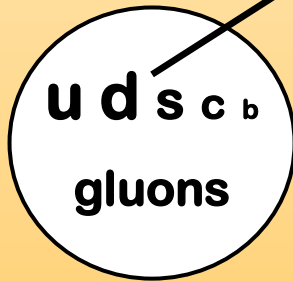
# Higgs is difficult to produce

proton



$$\left( \frac{m_u}{m_H} \right) \sim \left( \frac{2 \text{ MeV}}{125 \text{ GeV}} \right) \sim 10^{-5}$$

Higgs



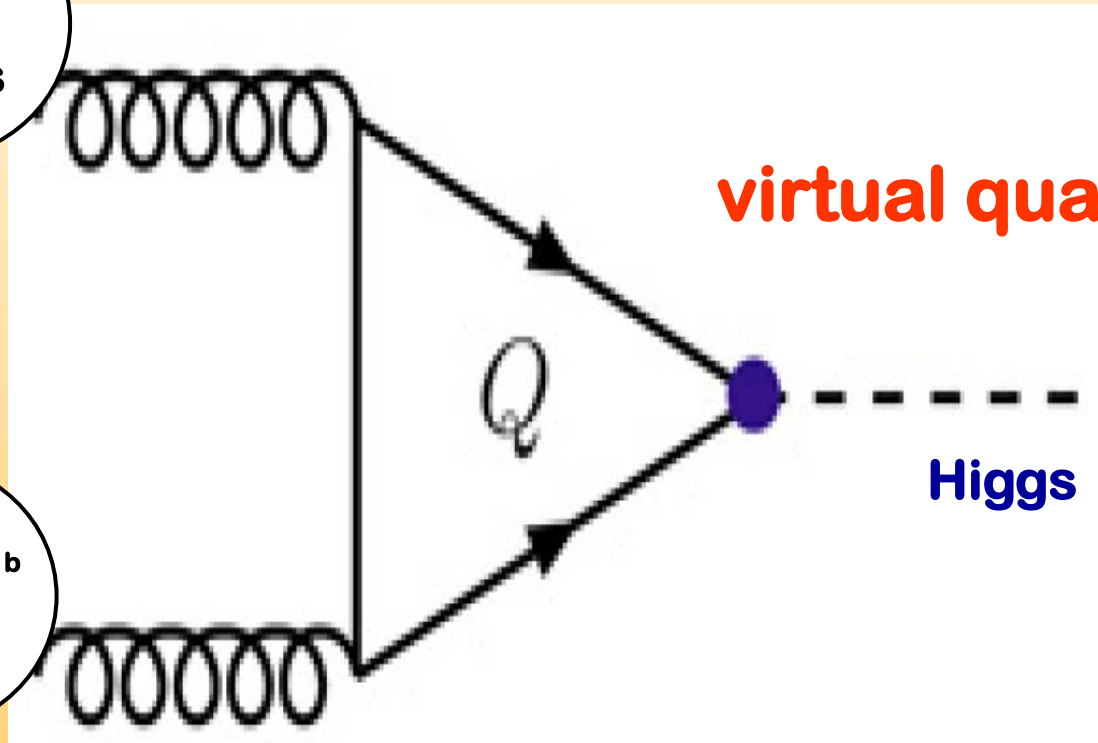
proton

# Higgs is difficult to produce

proton

u d s c b  
gluons

u d s c b  
gluons

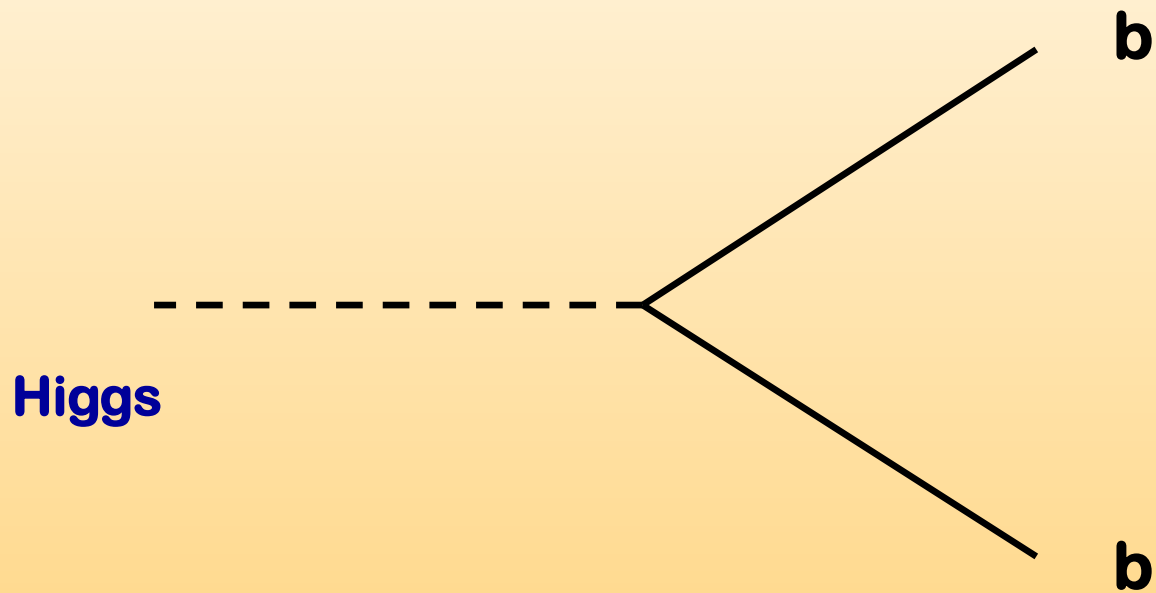


virtual quarks

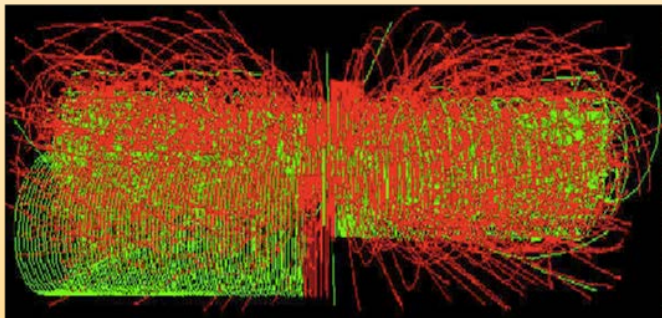
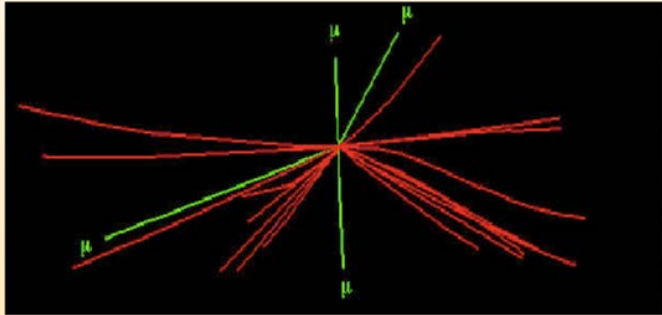
Higgs

proton

# Higgs is difficult to detect

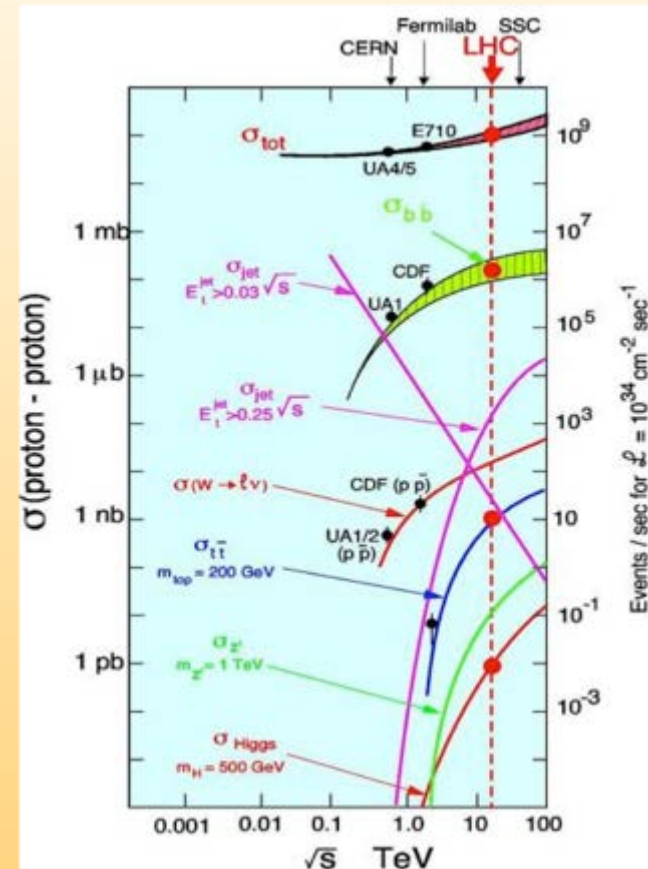


# Higgs is difficult to detect



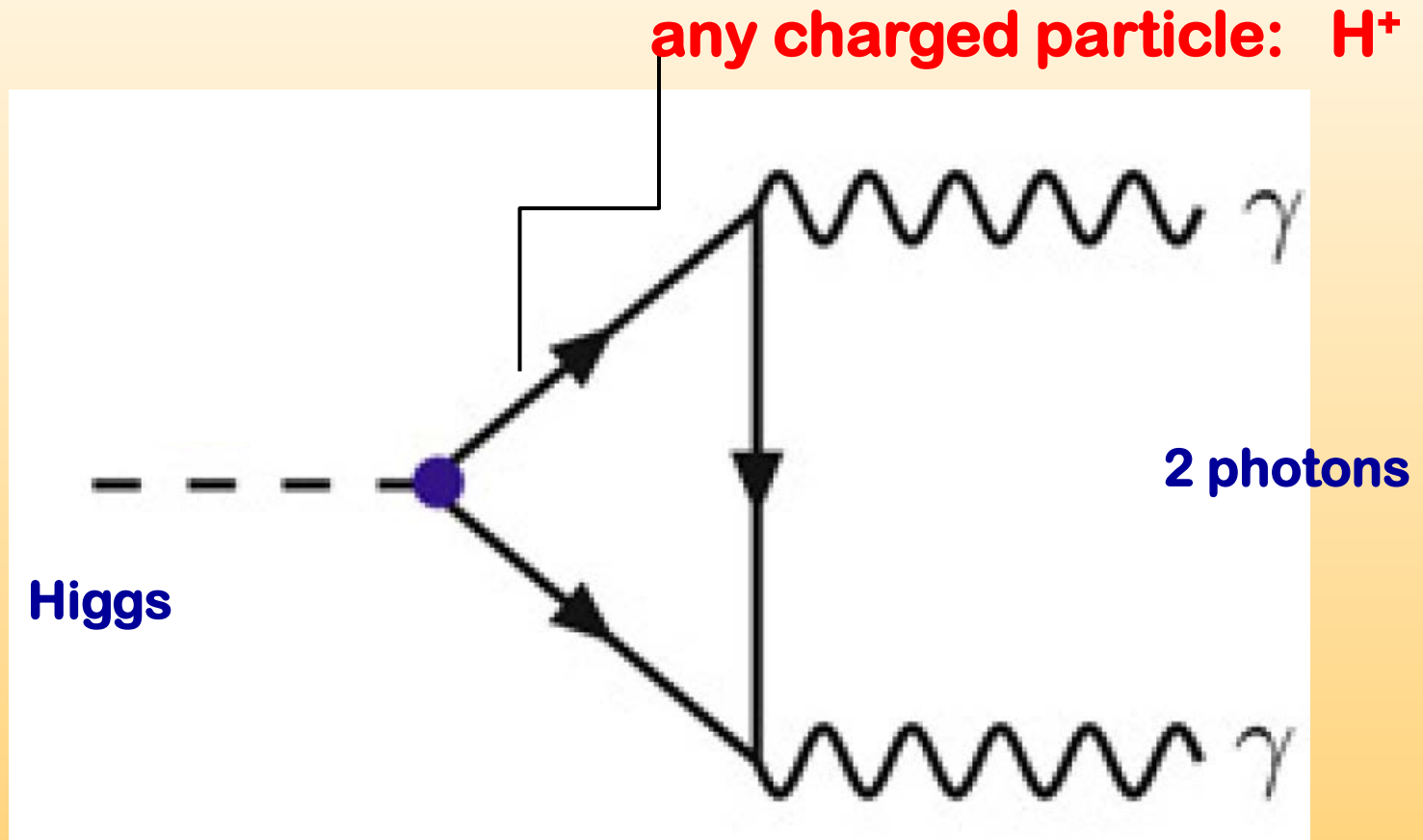
## ATLAS

- $\sim 300 \times 10^{12}$  collisions
- $\sim 1300$  Higgs created
- $\sim 450$  h  $\rightarrow \gamma\gamma$



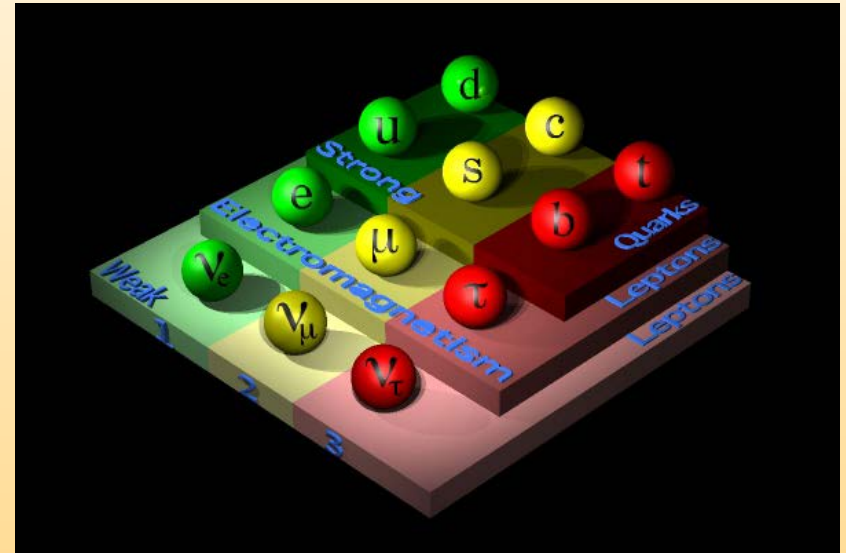
thanks to: Ricardo Gonalo

# Higgs is difficult to detect



# Why 1 Higgs?

- # Spin 1 fixed by gauge group:  
 $SU(3) \times SU(2) \times U(1) \Rightarrow W^\pm, Z^0, \gamma, g_{1..8}$
- Nothing fixes # Spin 1/2:  
Settled by experiment



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



# Comercial break



# Novelties in Multi-Higgs

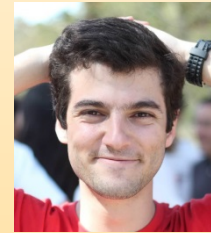
- **Multiple spin-0 particles**
  - **Neutral:**
    - Scalar** ( **$h, H$** )
    - Pseudoscalar** ( **$A$** )
    - Mixed** ( **$h_1, h_2, h_3$** )
  - **Charged** ( **$H^\pm$** )
- **Rich vacuum structure**
  - **May have charge breaking minimum**
  - **May have two local minima of unequal depths**

# 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)**

# A most interesting possibility: Higgs with large pseudoscalar content

- **Jorge Romão, Rui Santos**
- **MEFT student – Duarte Fontes**

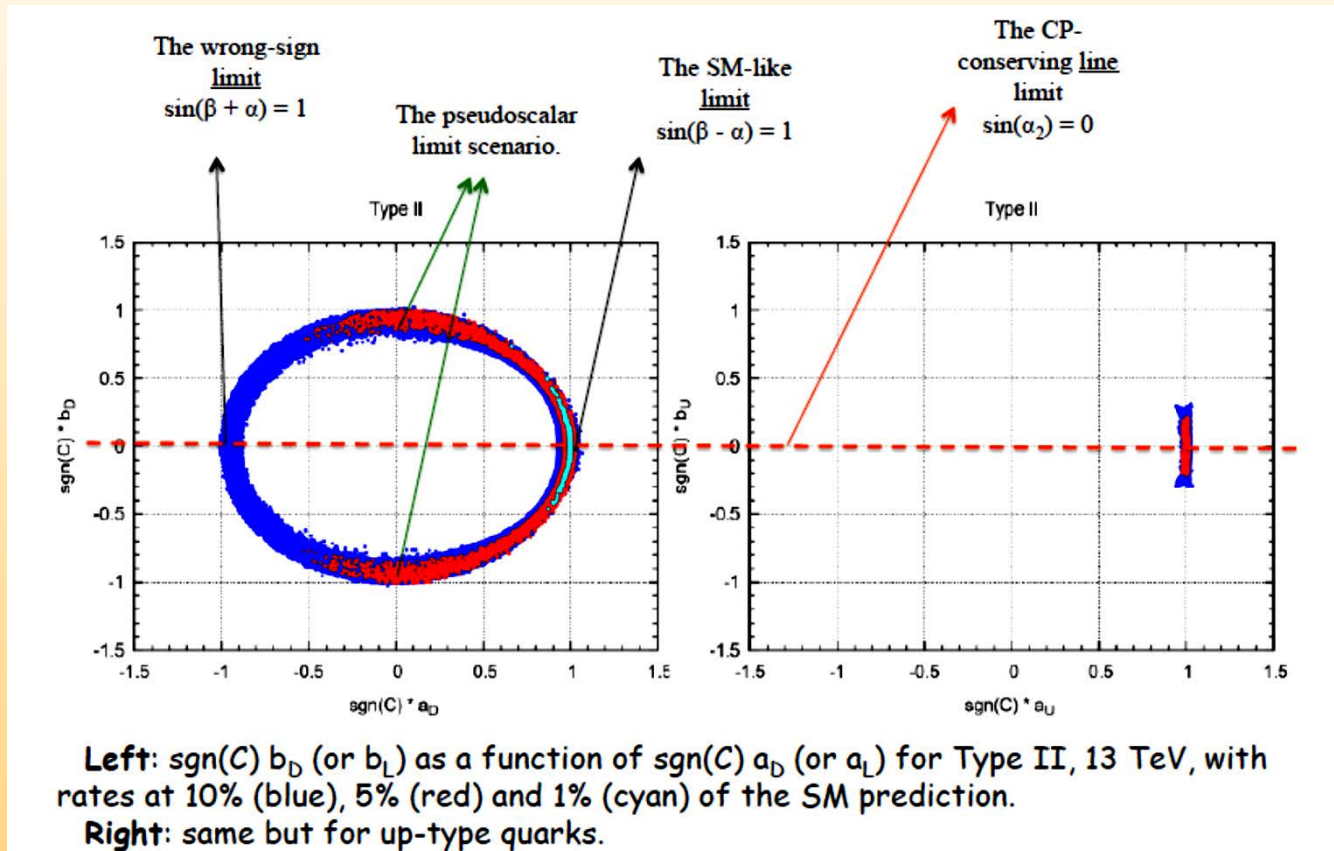


Fontes, Romão and JPSilva,  
Phys. Rev. D90, 015021 (2014), JHEP 1412, 043 (2014)

Fontes, Romão, Santos and JPSilva,  
JHEP 1506, 060 (2015), Phys. Rev. D92, 055014 (2015)

Benchmarks for CERN Yellow Report

# Higgs pseudoscalardness?



Fontes, Romão, R. Santos, JPSilva : Toyama

# Multi-Higgs Workshops

**Workshop on  
Multi-Higgs Models**

**6-9 September 2016**

Lisbon - Portugal

This Workshop brings together those interested in the theory and phenomenology of Multi-Higgs models. The program is designed to include talks given by some of the leading experts in the field, and also ample time for discussions and collaboration between researchers. A particular emphasis will be placed on identifying those features of the models which are testable at the LHC.

For registration and/or to propose a talk, send an email to:

[2hdmwork@cftp.tecnico.ulisboa.pt](mailto:2hdmwork@cftp.tecnico.ulisboa.pt)


Web Page : <http://cftp.tecnico.ulisboa.pt/~2hdmwork/>

**Organizing Committee:**

Augusto Barroso, CFTC  
 Jorge Romão, CFTP  
 Rui Santos, ISEL and CFTC  
 João P. Silva, CFTP  
 Pedro Ferreira, ISEL and CFTC  
 Luís Lavoura, CFTP

**International Advisory Committee:**

F.J. Botella  
 G.C. Branco  
 H. Haber  
 M. Krawczyk  
 P. Osland



**Workshop on  
Multi-Higgs Models**

**2-5 September 2014**

Lisbon - Portugal

This Workshop brings together those interested in the theory and phenomenology of Multi-Higgs models. The program is designed to include talks given by some of the leading experts in the field, and also ample time for discussions and collaboration between researchers. A particular emphasis will be placed on identifying those features of the models which are testable at the LHC.

For registration and/or to propose a talk, send an email to:

[ferreira@cii.fc.ul.pt](mailto:ferreira@cii.fc.ul.pt)

Web Page : <http://www.ciiul.ul.pt/~2hdmwork/>

**Organizing Committee:**

Augusto Barroso, CFTC  
 Pedro Ferreira, ISEL and CFTC  
 Rui Santos, ISEL and CFTC  
 João P. Silva, CFTP  
 Luís Lavoura, CFTP

**International Advisory Committee:**

F.J. Botella  
 G.C. Branco  
 H. Haber  
 M. Krawczyk  
 P. Osland



**Workshop on  
Multi-Higgs Models**

**September 2012**

Lisbon - Portugal

This Workshop brings together those interested in the theory and phenomenology of Multi-Higgs models. The program is designed to include talks given by some of the leading experts in the field, and also ample time for discussions and collaboration between researchers. A particular emphasis will be placed on identifying those features of the models which are testable at the LHC.

For registration and/or to propose a talk, send an email to:

[ferreira@ciiul.ul.pt](mailto:ferreira@ciiul.ul.pt)


Web Page : <http://www.ciiul.ul.pt/~2hdmwork/>

**Organizing Committee:**

Augusto Barroso, CFTC  
 Pedro Ferreira, ISEL and CFTC  
 Rui Santos, ISEL and CFTC  
 João P. Silva, CFTP  
 Luís Lavoura, CFTP

**International Advisory Committee:**

F.J. Botella  
 G.C. Branco  
 H. Haber  
 M. Krawczyk  
 P. Osland



**Workshop on  
Multi-Higgs Models**

**September 2009**

Lisbon - Portugal

This Workshop brings together those interested in the theory and phenomenology of Multi-Higgs models. The program is designed to include talks given by some of the leading experts in the field, and also ample time for discussions and collaboration between researchers. A particular emphasis will be placed on identifying those features of the models which are testable at the LHC.

For registration and/or to propose a talk, send an email to:

[ferreira@ciiul.ul.pt](mailto:ferreira@ciiul.ul.pt)


Web Page : <http://www.ciiul.ul.pt/~2hdmwork/>

**Organizing Committee:**

Augusto Barroso, CFTC  
 Pedro Ferreira, ISEL and CFTC  
 Rui Santos, ISEL and CFTC  
 João P. Silva, CFTP  
 Luís Lavoura, CFTP

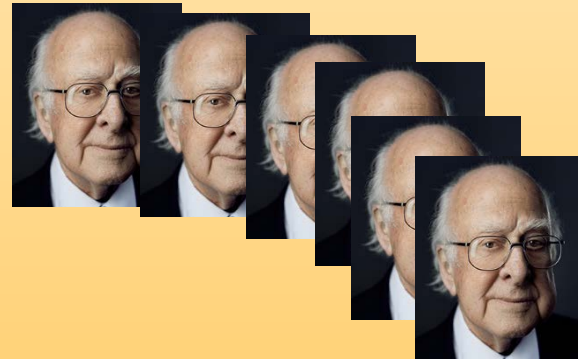
**International Advisory Committee:**

F.J. Botella  
 G.C. Branco  
 H. Haber  
 M. Krawczyk  
 P. Osland



# Join us

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



**END**