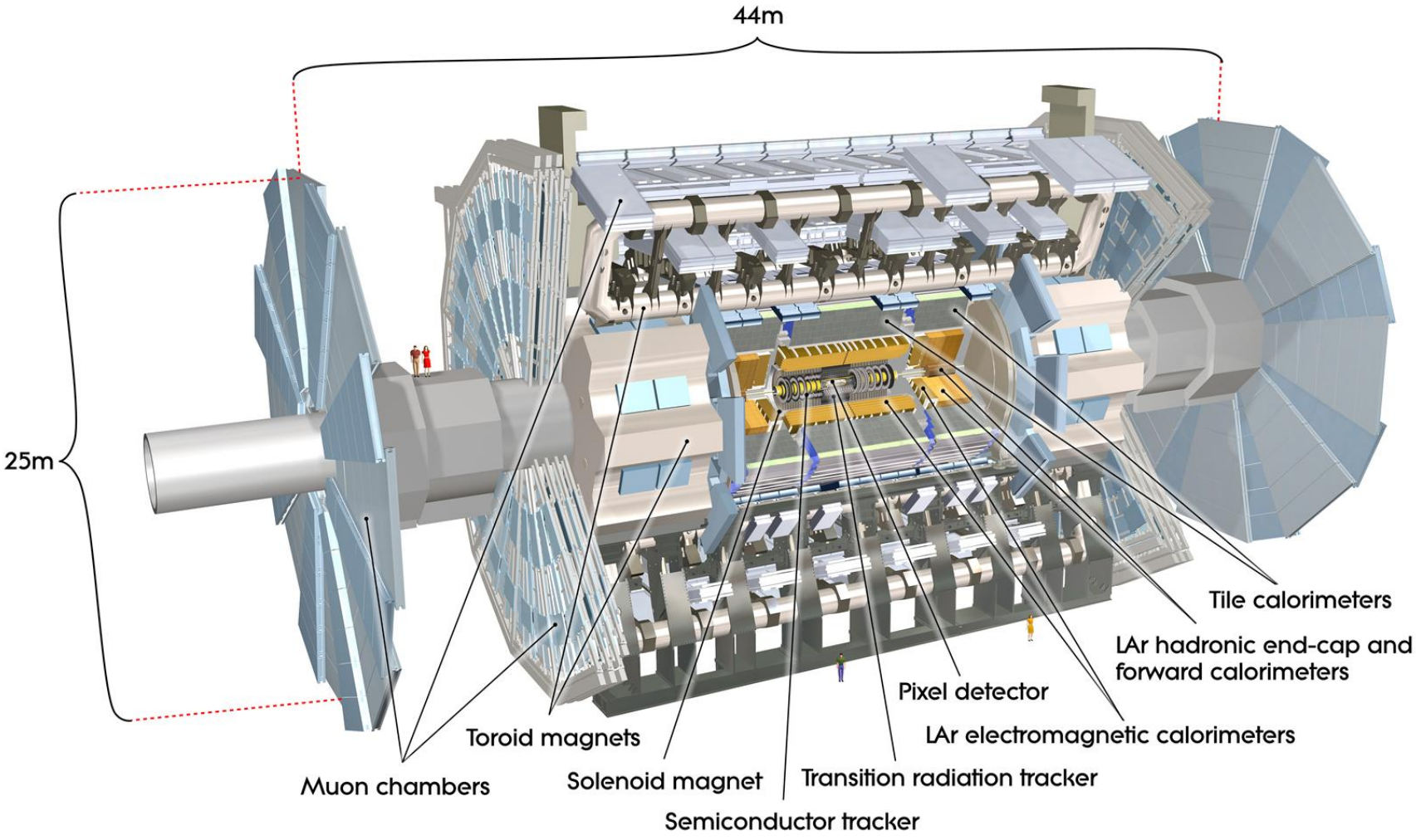
## The Higgs particle — history of the experimental search

### reduction of the allowed mass range

- 2004 LEP limit: $m_H > 114.4\,\text{GeV}$
  - uses data, collected from the LEP experiments until 2000
- 2010 Tevatron exclusion: $158 < m_H/\text{GeV} < 175$ is excluded
  - data from the Fermilab experiments CDF and DØ
- July 2011 LHC exclusion: $145 < m_H/\text{GeV} < 466$ is excluded
  - data from the ATLAS and CMS from 2010 and 2011
- December 2011 LHC limits the allowed mass range
  - ATLAS: $116 < m_H/\text{GeV} < 130$
  - CMS: $115 < m_H/\text{GeV} < 127$
- July $4^{\text{th}}$ 2012 CERN announces the detection of a boson compatible with the SM Higgs boson
  - ATLAS: $m_H \sim 126.5\,\text{GeV}$ @ 5 $\sigma$ significance
  - CMS: $m_H = 125.3 \pm 0.6\,\text{GeV}$ @ 4.9 $\sigma$ significance

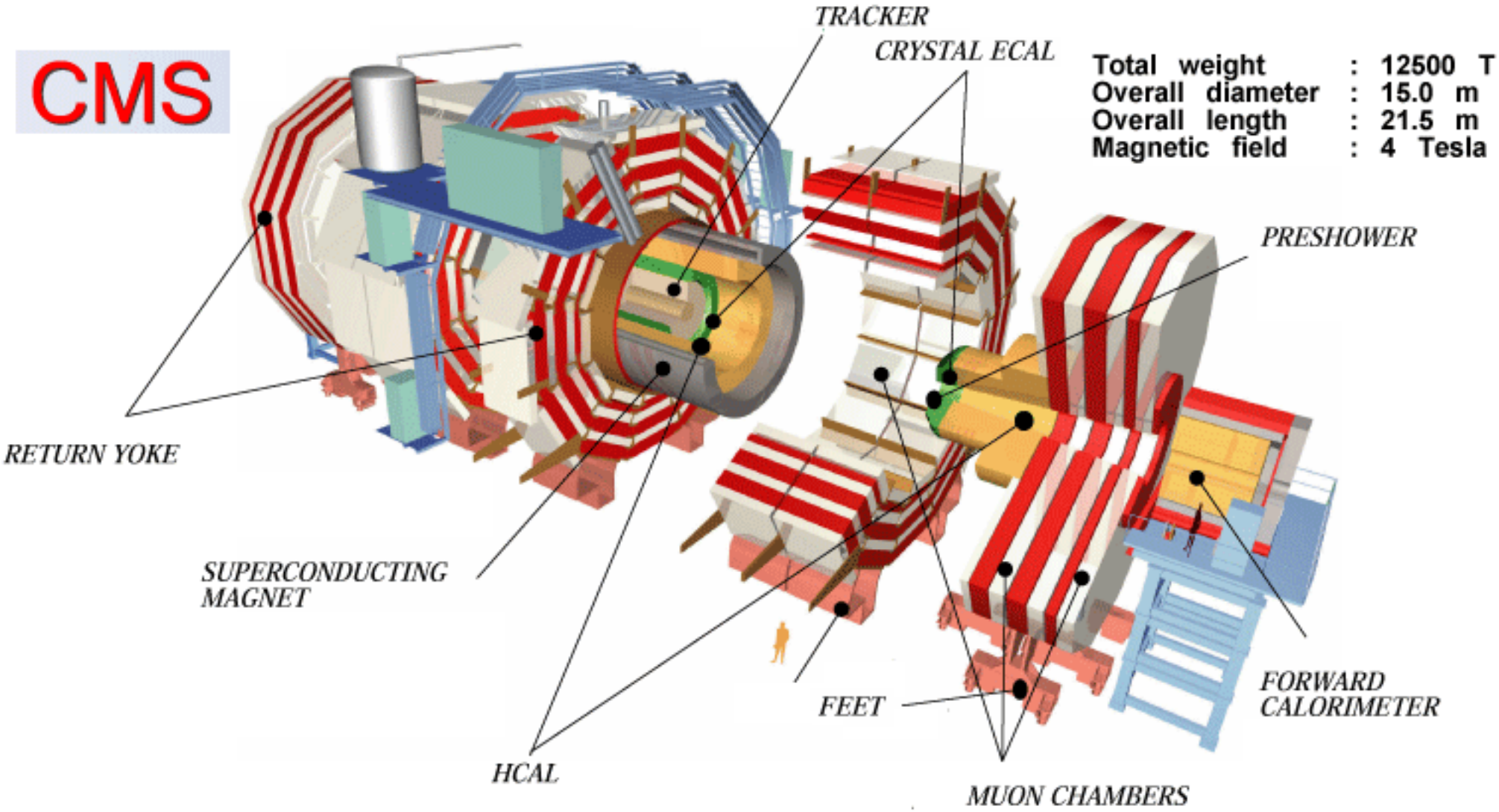
# The Higgs particle — experimental search

## by the Atlas detector

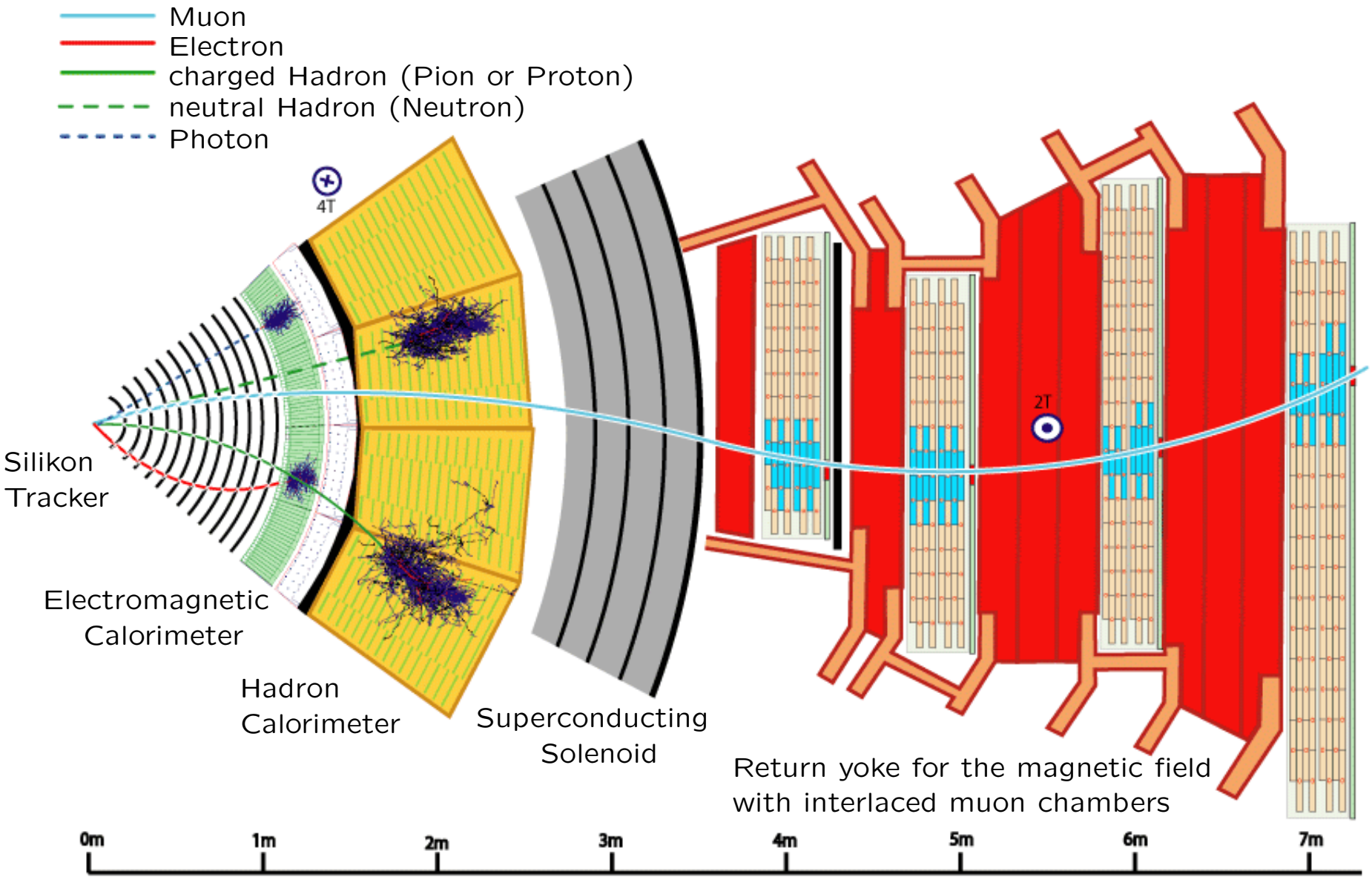


# The Higgs particle — experimental search

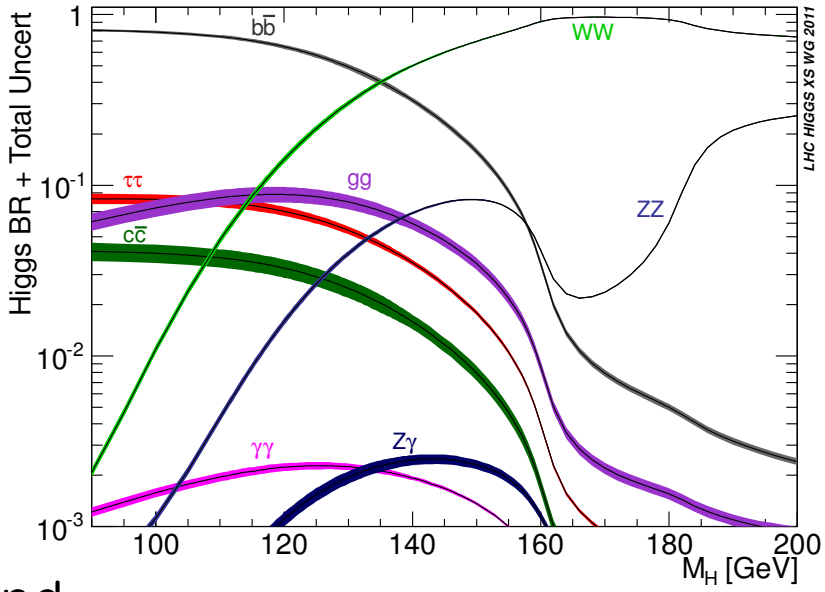
## by the CMS detector



## CMS: a modern detector



## How was that measurement achieved?




- combining the production channels with the decay channels of the Higgs boson

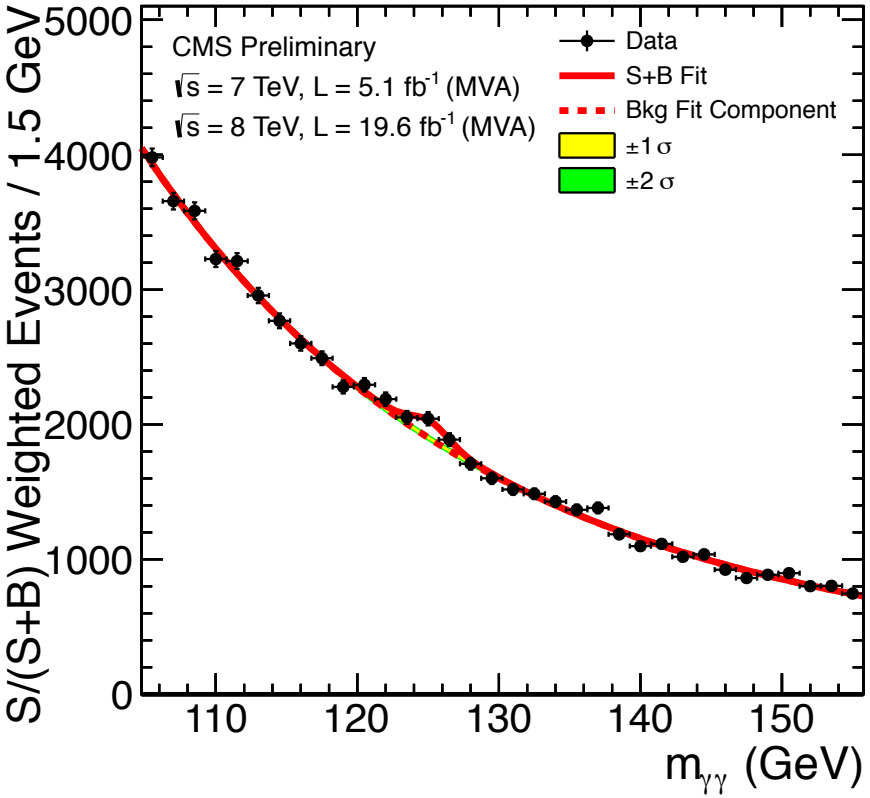
- the largest branching ratios
  - $b\bar{b}$, $\tau^-\tau^+$, $c\bar{c}$, and $gg$
    - hard to distiguish from background
  - $WW \to 4q$
    - similar: also hard to distiguish from background
  - $WW \to 2\ell 2\nu$
    - neutrinos are not measured $\Rightarrow$ bad reconstruction

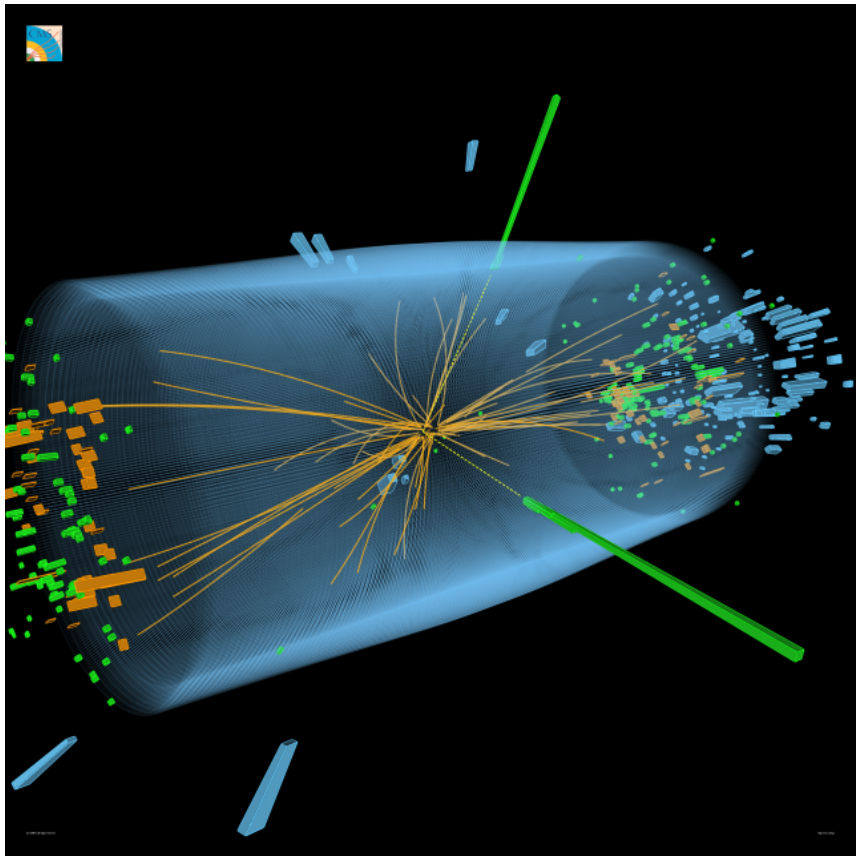
  $\Rightarrow$ looking for $\gamma\gamma$ and $ZZ \to 4\ell$
    - has also very good mass resolution

      $\Rightarrow$ "golden channel"

## $H \to \gamma\gamma$

- Monte Carlo and data:
  - gives a signal
    on a background

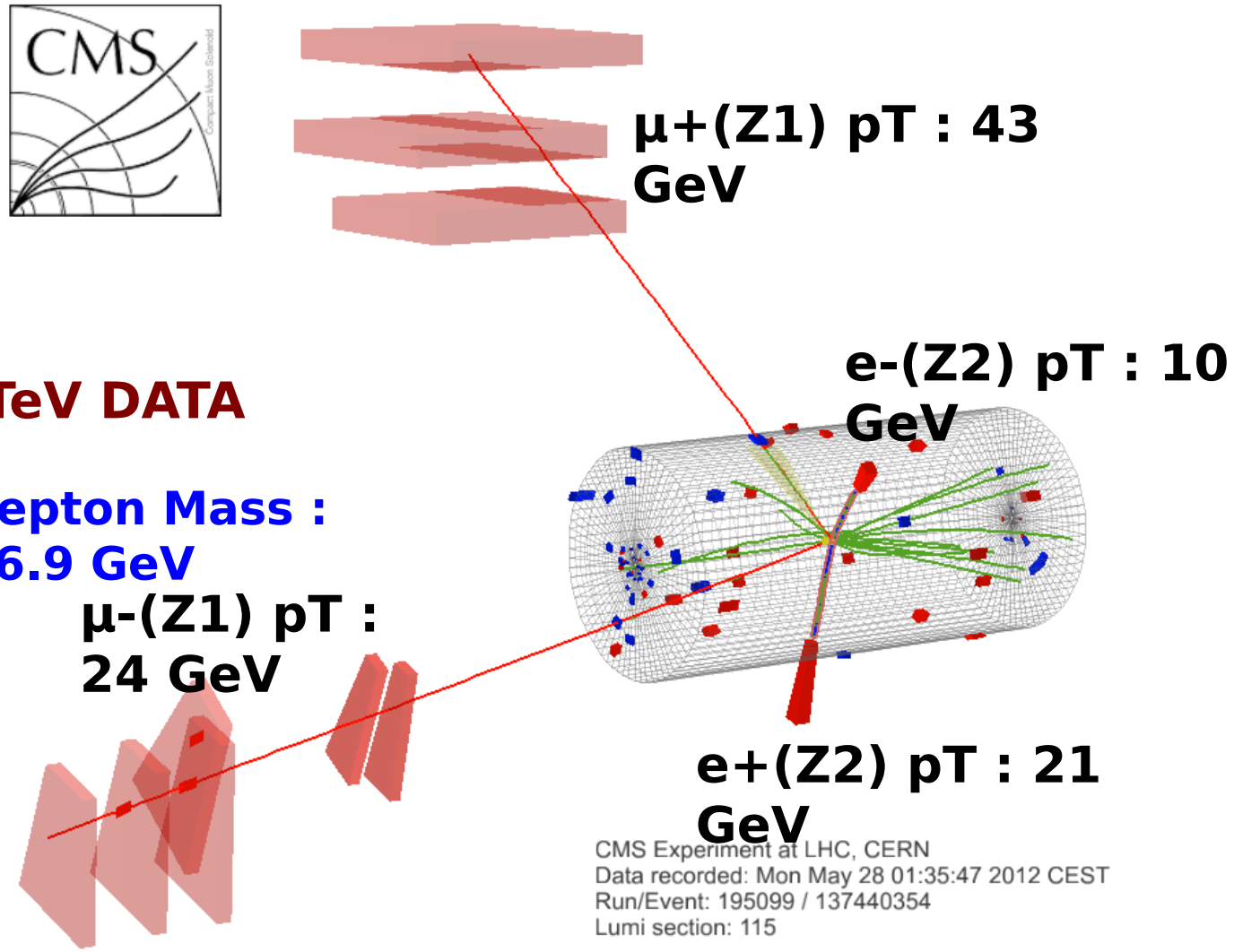


a possible $H \to \gamma\gamma$ event

with local p-value at 125 GeV with a local significance of 4.1 $\sigma$

$H \to ZZ^* \to \mu^-\mu^+ + e^-e^+$

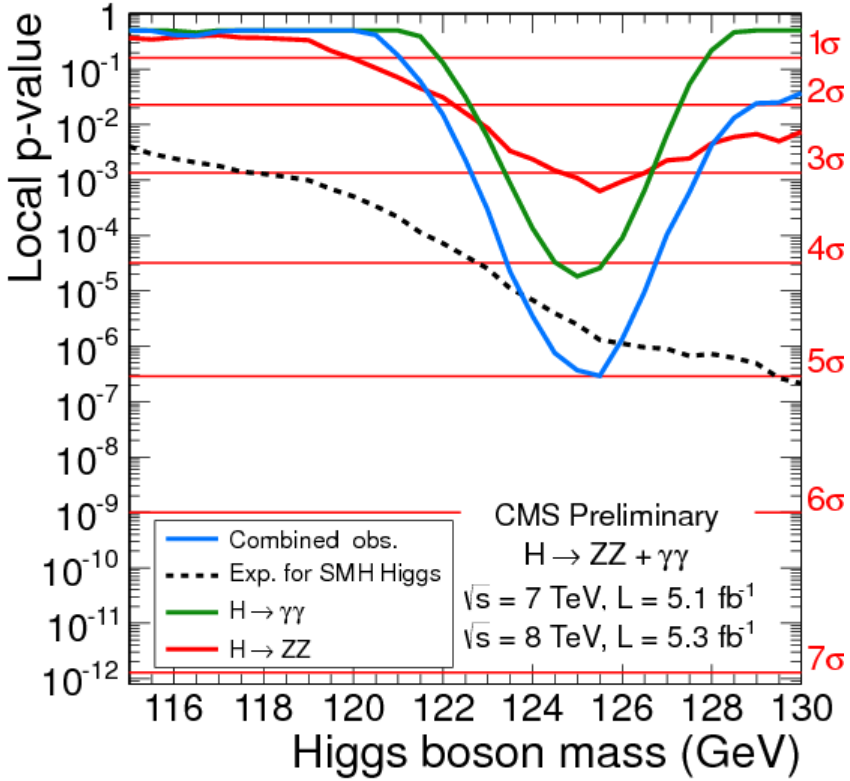


## Combining $H \to \gamma\gamma$ and $H \to ZZ^* \to 4\ell$

- combining the high sensitivity, high mass resolution channels: $H \to \gamma\gamma$ and $H \to ZZ^* \to 4\ell$
  - $\gamma\gamma$ has 4.1 $\sigma$ excess
  - $4\ell$ has 3.2 $\sigma$ excess
- near the same mass of 125 GeV

$\Rightarrow$ combined significance of 5 $\sigma$

( as of 2012 ... now it is more )



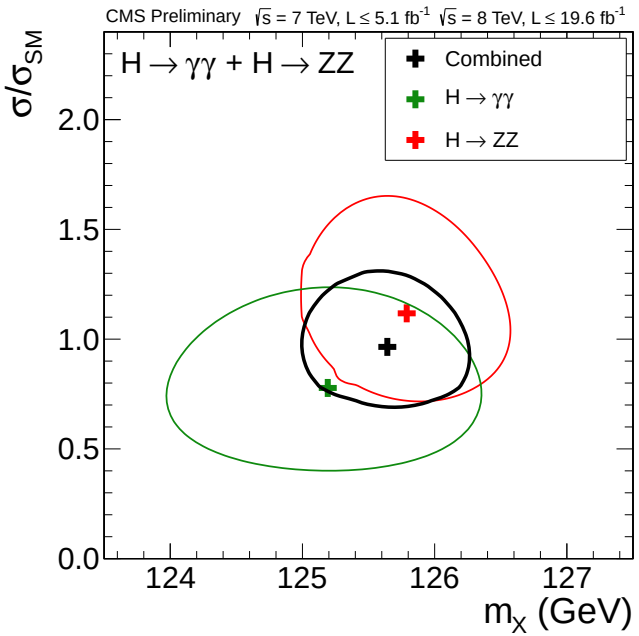
## Characterising the excess in all channels

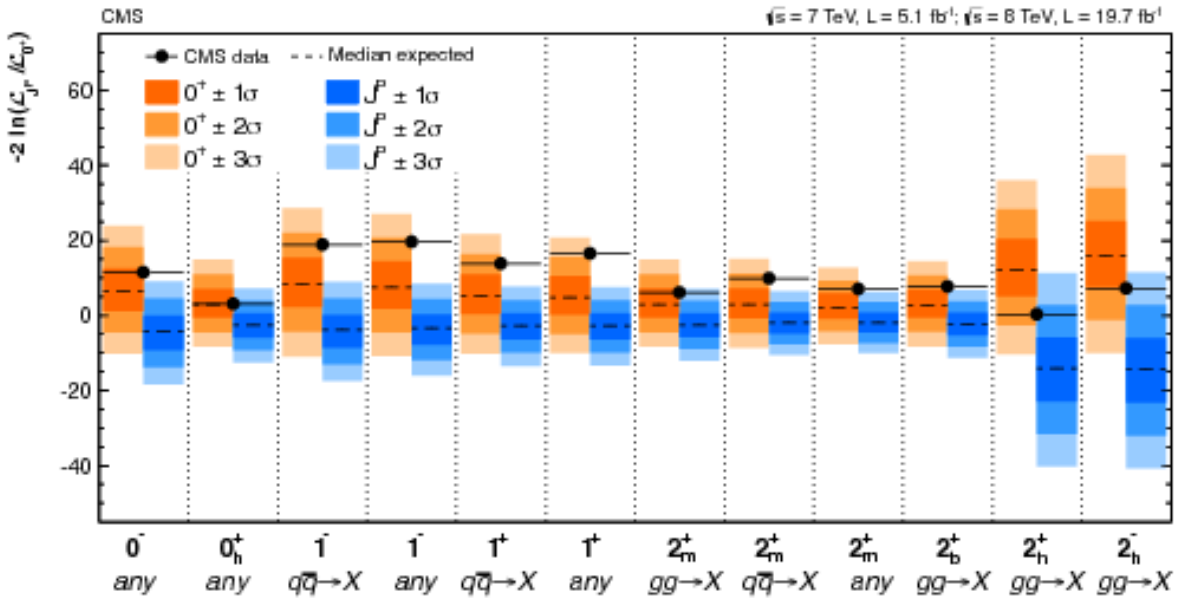
- results for the mass are self consistent
- and can be combined

  $\Rightarrow$ $m_X = 125.9 \pm 0.4\,\text{GeV}$

- But is it the SM Higgs boson?

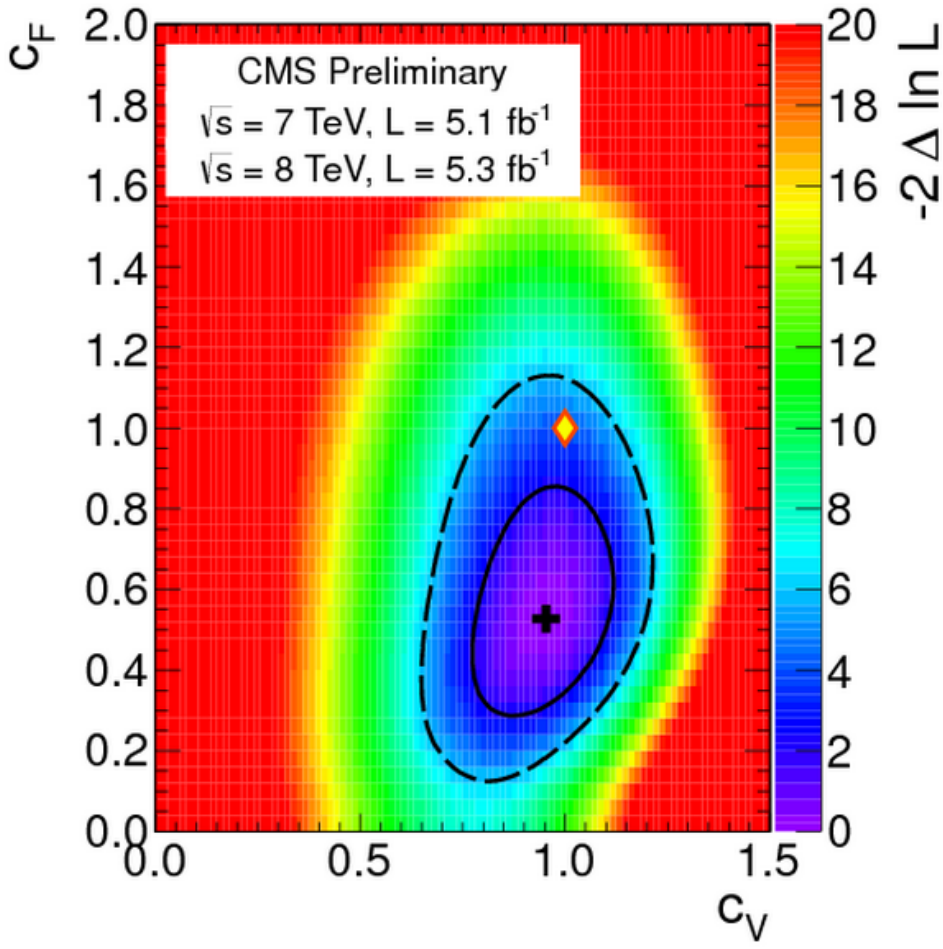
  $\Rightarrow$ comparing to other hypotheses:



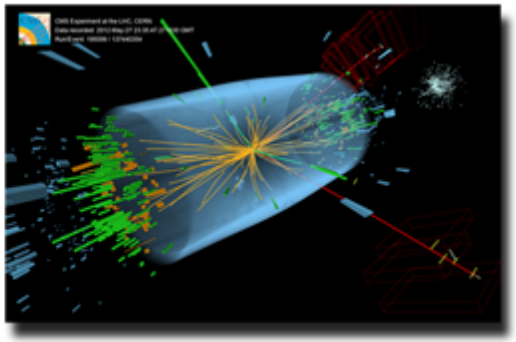
## Comparing couplings to fermions and to vector bosons

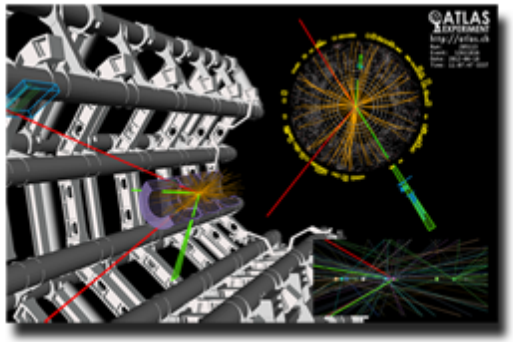
- Group the Higgs couplings into "Vectorial" and "Fermionic" sets.
- with coupling strength relative to the SM value
  - $c_V$ for vectors
  - $c_F$ for fermions
- use theoretical LO prediction for the loop-induced $H \to \gamma\gamma$ and $H \to gg$ vertices
- agreement with SM in 95% range
  - fermio-phobic Higgs ? . . . statistics




⇒ We need more data! . . . and they will come

# Nobelprize in Physics 2013




Francois Englert and Peter W. Higgs