Analysis of Higgs bosons decaying to two photons at CMS

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PG Initial Report Talks, 2014

Outline

The Standard Model Higgs boson

History

The authors of the "1964 PRL symmetry breaking papers" won the Sakurai Prize in 2010. Higgs and Englert won the Nobel prize in 2013. Left: Kibble, Guralnik, Hagen, Englert, Brout. Right: Higgs

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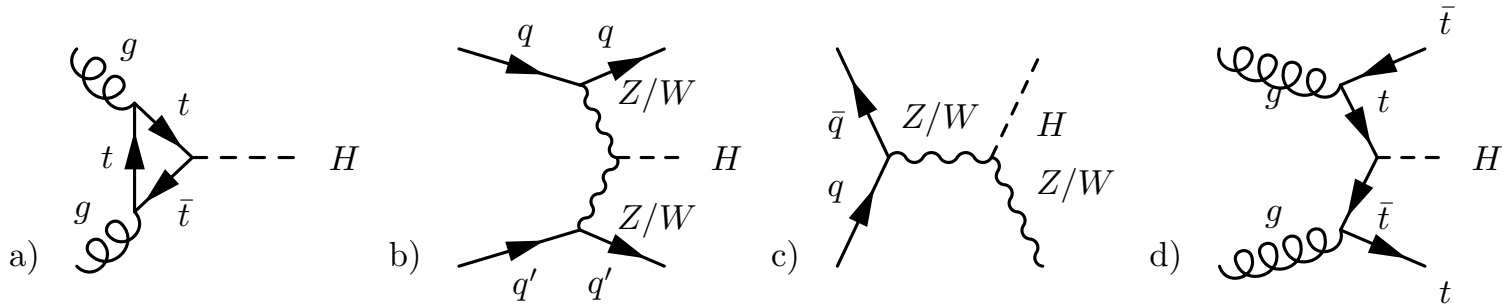
- Couples to particles proportional to their mass.
- Only one Higgs boson in SM, while other BSM theories predict more.

The Standard Model Higgs boson

Production and decay at LHC

- H couples to particles $\propto m$, so main production modes at LHC are:



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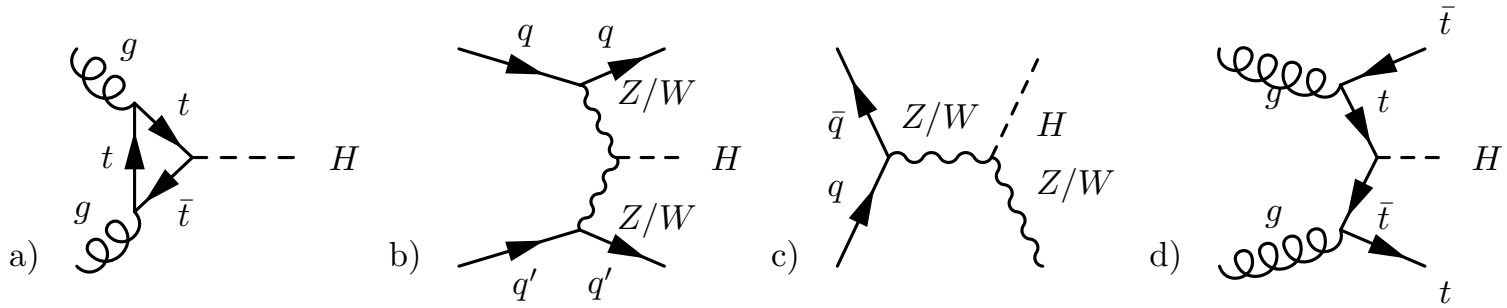

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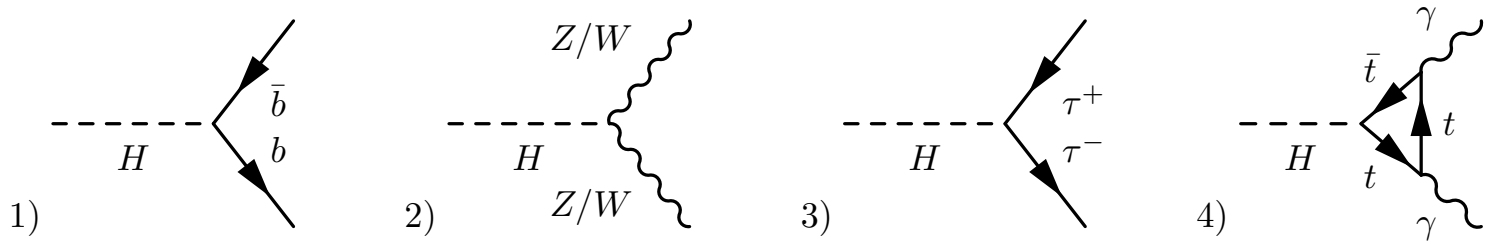
- By the same token, it decays mostly to heavy particles:

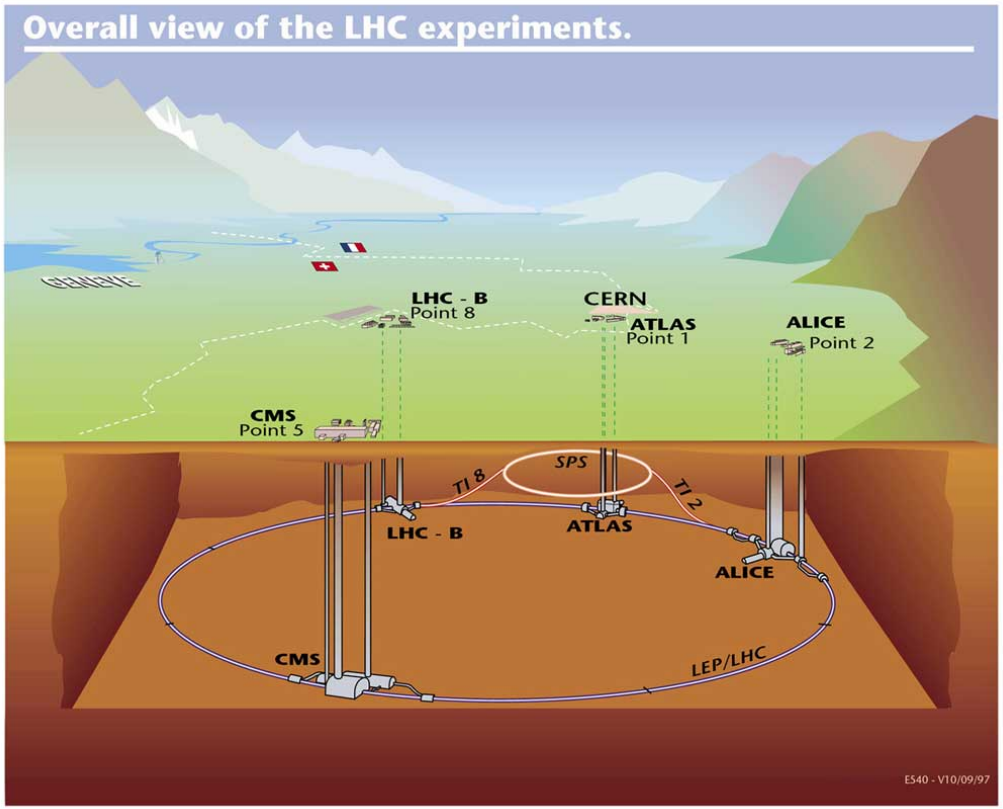


Decay to 1) $b\bar{b}$ pair, 2) vector boson pair, 3) τ^+, τ^-, 4) two photons via t loop (can also be W or Z).

- t, $\bar{t}$ pair kinematically forbidden. $H \to \gamma\gamma$ is rare, but one of the most sensitive channels at the LHC.

LHC, CMS and the ECAL

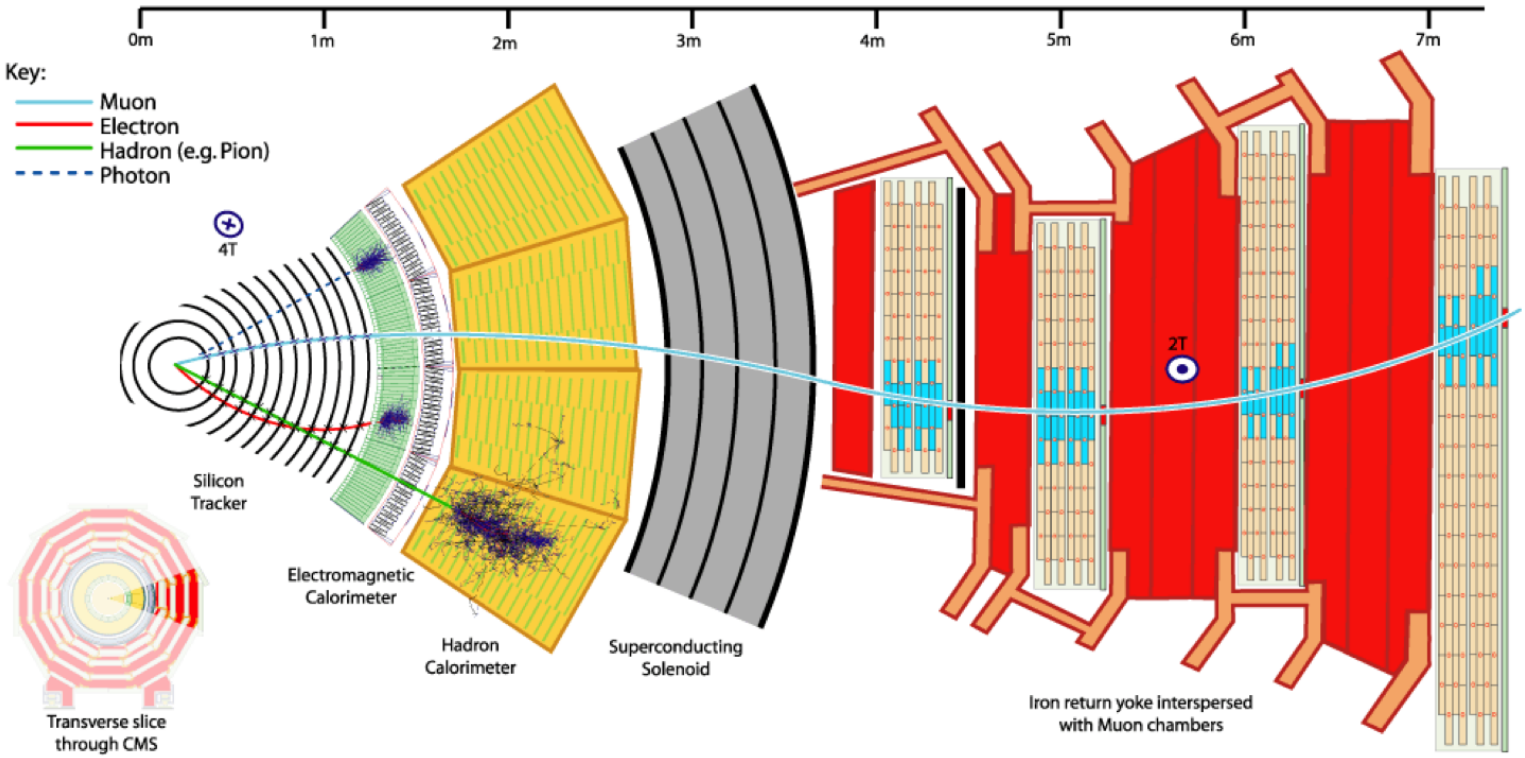
The Large Hadron Collider



- The LHC is a 26km radius synchrotron at CERN. CMS is one of 7 experiments.

LHC, CMS and the ECAL

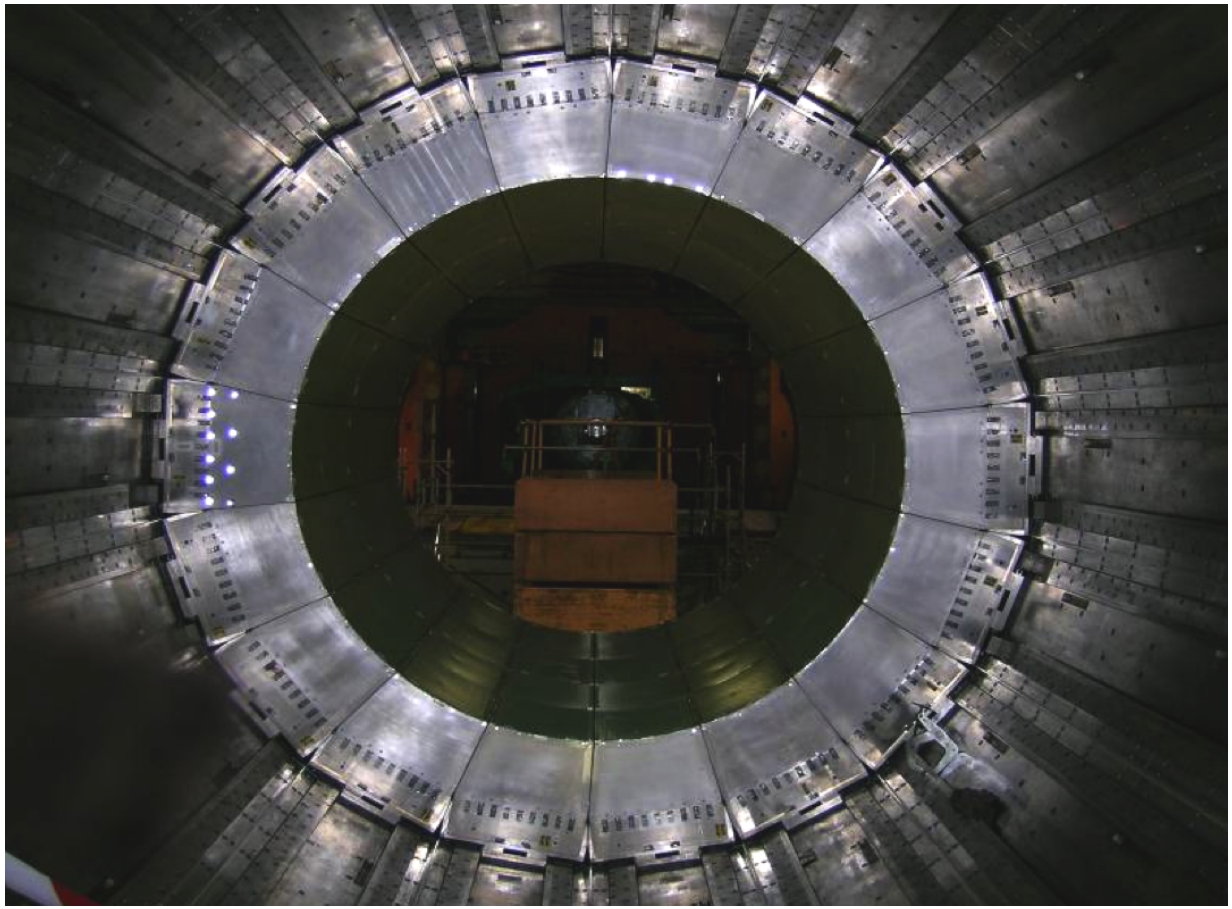
The Compact Muon Solenoid



- Explained already by previous talks - I will focus on ECAL layer.

LHC, CMS and the ECAL

The Electromagnetic Calorimeter



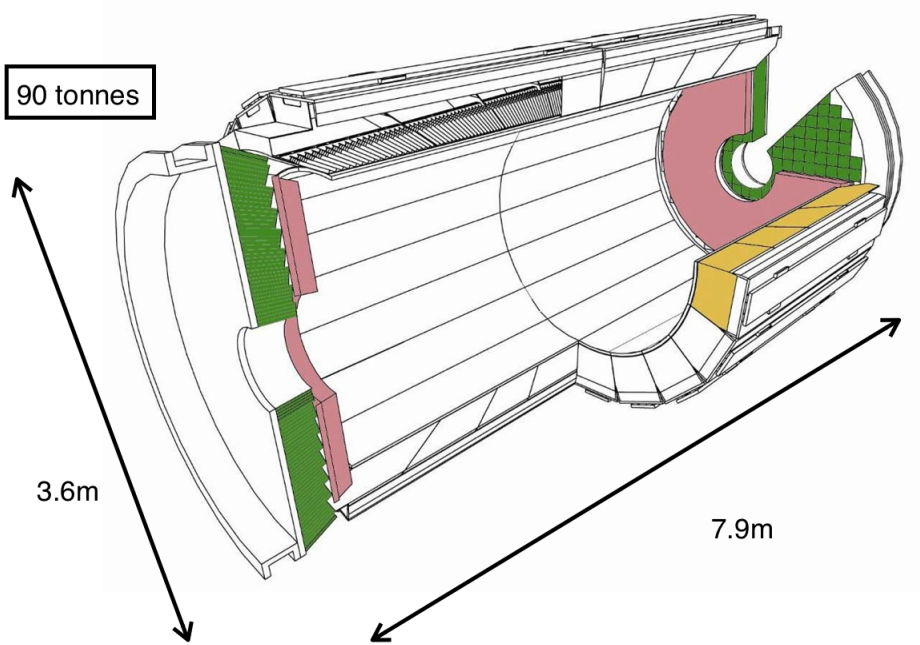
A view of the inside of the ECAL Barrel (from Chris Seez's lecture notes).

LHC, CMS and the ECAL

The Electromagnetic Calorimeter

The CMS ECAL is composed of an array of $PbWO_4$ crystals.

The Crystals are offset by an angle of 3^o from the vertex to avoid particles going through the gaps in between.



- 62,100 crystals in 36 supermodules
- Supermodule containing 4 modules
- Endcaps containing 14,648 crystals
- Preshower for π^0 ID.

Photon and Vertex Identification

Initial event selection and mass reconstruction

- Initial trigger identifies γs from ECAL isolation and shower shape. A loose E_T cut is also made, although a tougher one is imposed later to find Higgs decay candidates.

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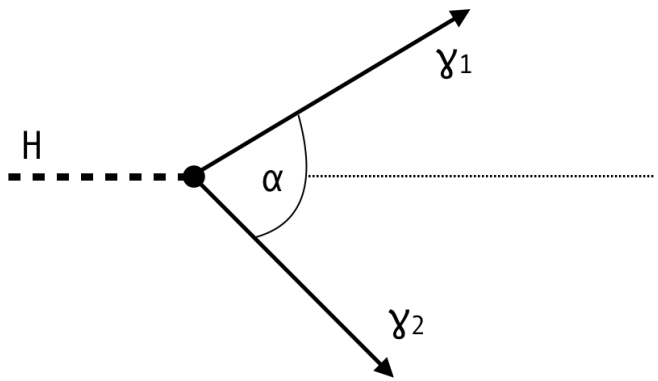
$$m_H = m_{\gamma\gamma} = \sqrt{2E_{\gamma 1}E_{\gamma_2}(1 - \cos\alpha)}$$



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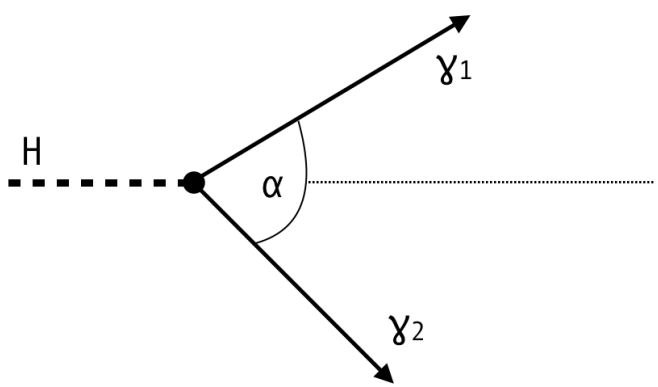

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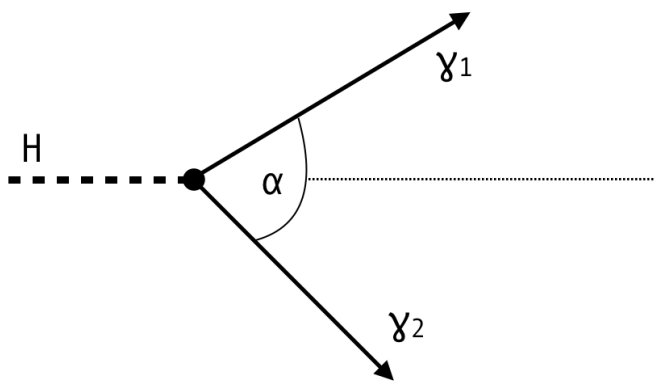

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- **The better the vertex reconstruction, the better the angle resolution!**

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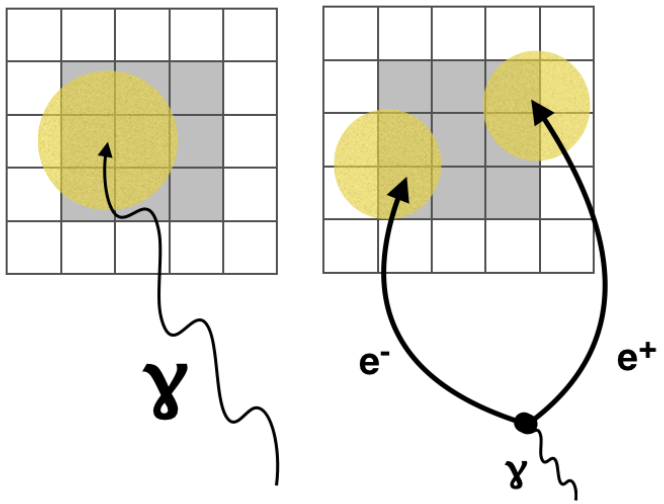
- A BDT is used to identify vertex using kinematic properties as inputs. Also makes use of extra information from tracker if γ has converted to e^+e^-.
- We can tell if γ has converted using $R_9 \equiv \frac{E_{3x3}}{E_{5x5}} < 0.94$.



- If γ hits, most of the energy is deposited within $3x3$ array, so $E_{3x3} \simeq E_{5x5}$ so $R_9 \simeq 1$
- If γ has converted, less energy will be focused within $3x3$, so $R_9 < 1$

Photon and Vertex Identification

Higgs decay candidates

- Not all diphoton events are of interest! We only want those which are Higgs decay candidates.
- Higgs decay photons should be highly energetic, so impose:

$$E_T^{\gamma 1} > \frac{m_{\gamma\gamma}}{3} \text{ and } E_T^{\gamma 2} > \frac{m_{\gamma\gamma}}{4}$$

- A further BDT is used to remove "non-prompt" photons and particles misidentified as photons, as they are of no interest.

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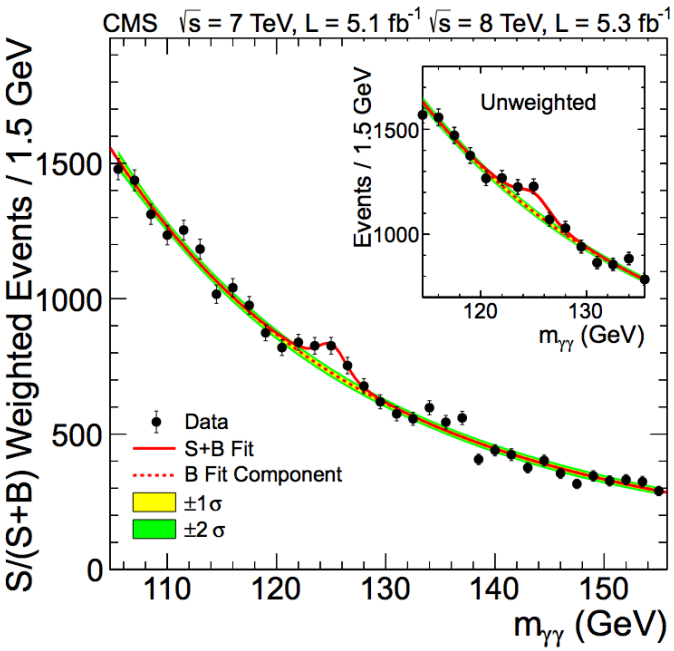
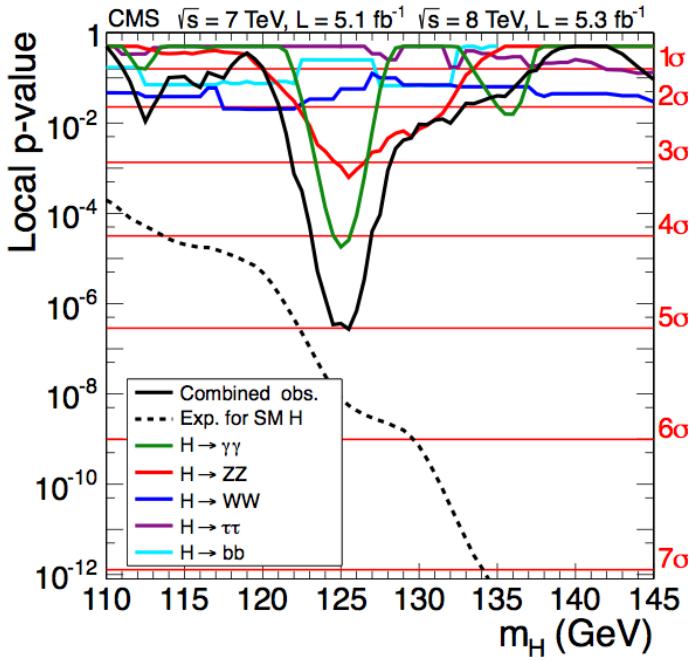
  - Fitting function chosen based on bias minimisation. Bias is negligible for all categories when Bersteins of order 3-5 (depending on category) are used.

Analysis

- The mass distribution is plotted for each category and compared to the background prediction. The categories are then combined to form the global analysis.
- In 2012, this method yielded an observed local significance of 4σ at ~ 125 GeV. Combined with other analyses, the total local significance was 5σ, allowing a discovery to be claimed by CMS.





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- Although we have found the H, further studies are not only desirable but imperative.

Questions

Thanks for listening!
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