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

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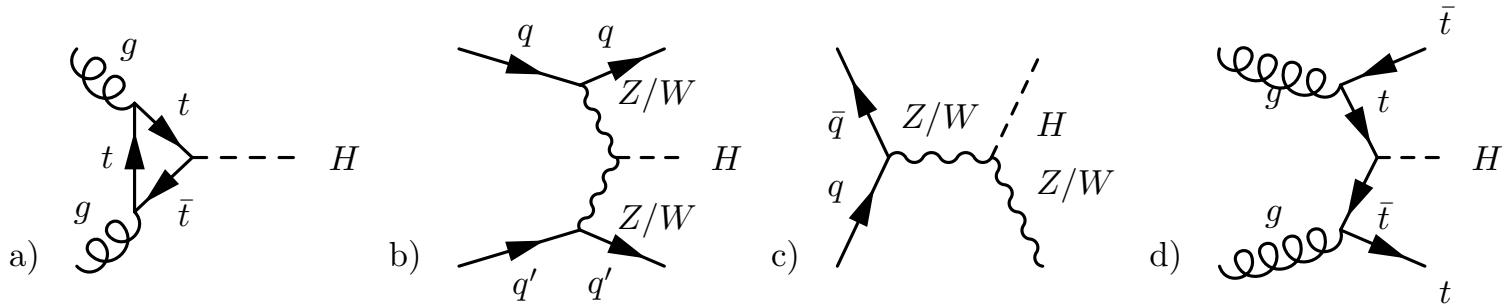
- Couples to particles proportional to their mass.
- Only one Higgs boson in SM, while other BSM theories predict more.

The Standard Model Higgs boson

Production and decay at LHC

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



a) gg fusion via t loop, b) Vector Boson Fusion (VBF), c) Assoc. Z, W production, d) Assoc. $t\bar{t}$ production.

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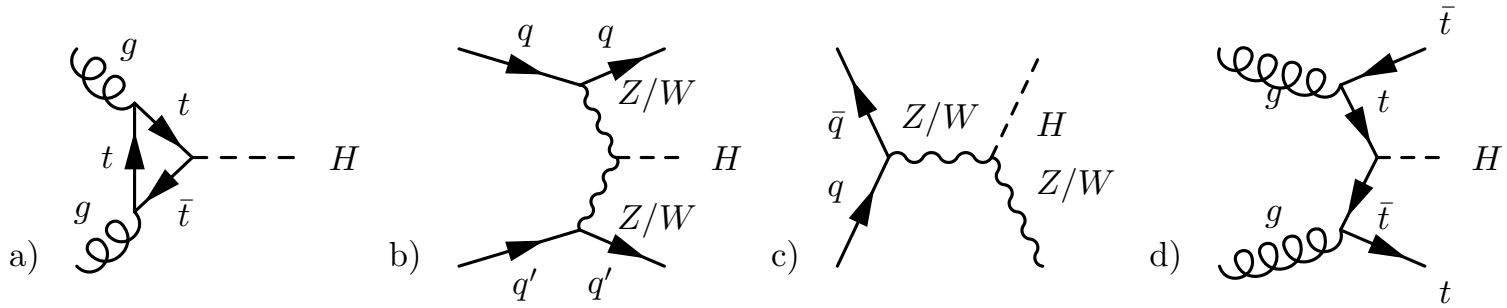
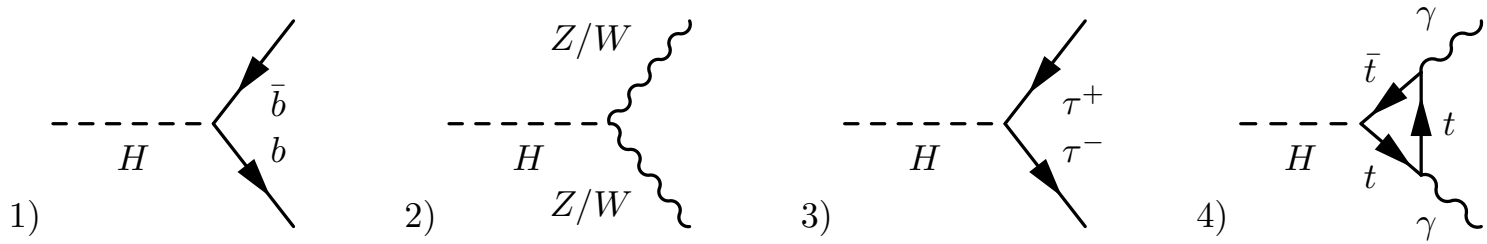


a) gg fusion via t loop, b) Vector Boson Fusion (VBF), c) Assoc. Z, W production, d) Assoc. $t\bar{t}$ production.

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

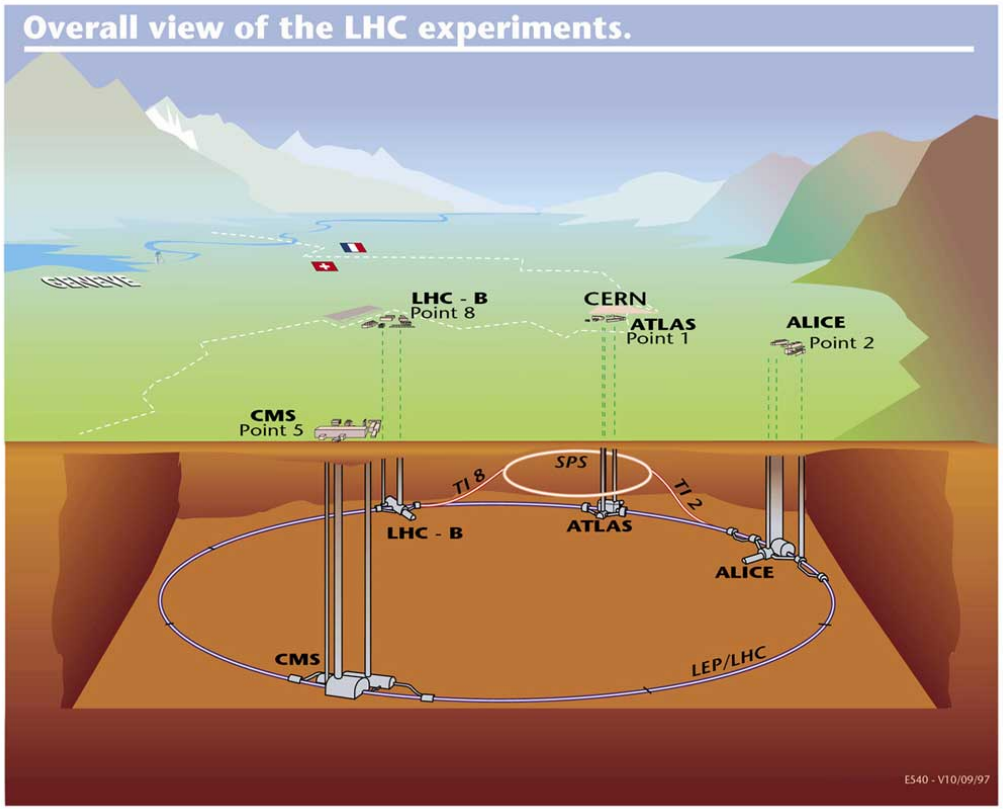


Decay to 1) $b\bar{b}$ pair, 2) vector boson pair, 3) τ^+, τ^-, 4) two photons via t loop (can also be W).

- 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

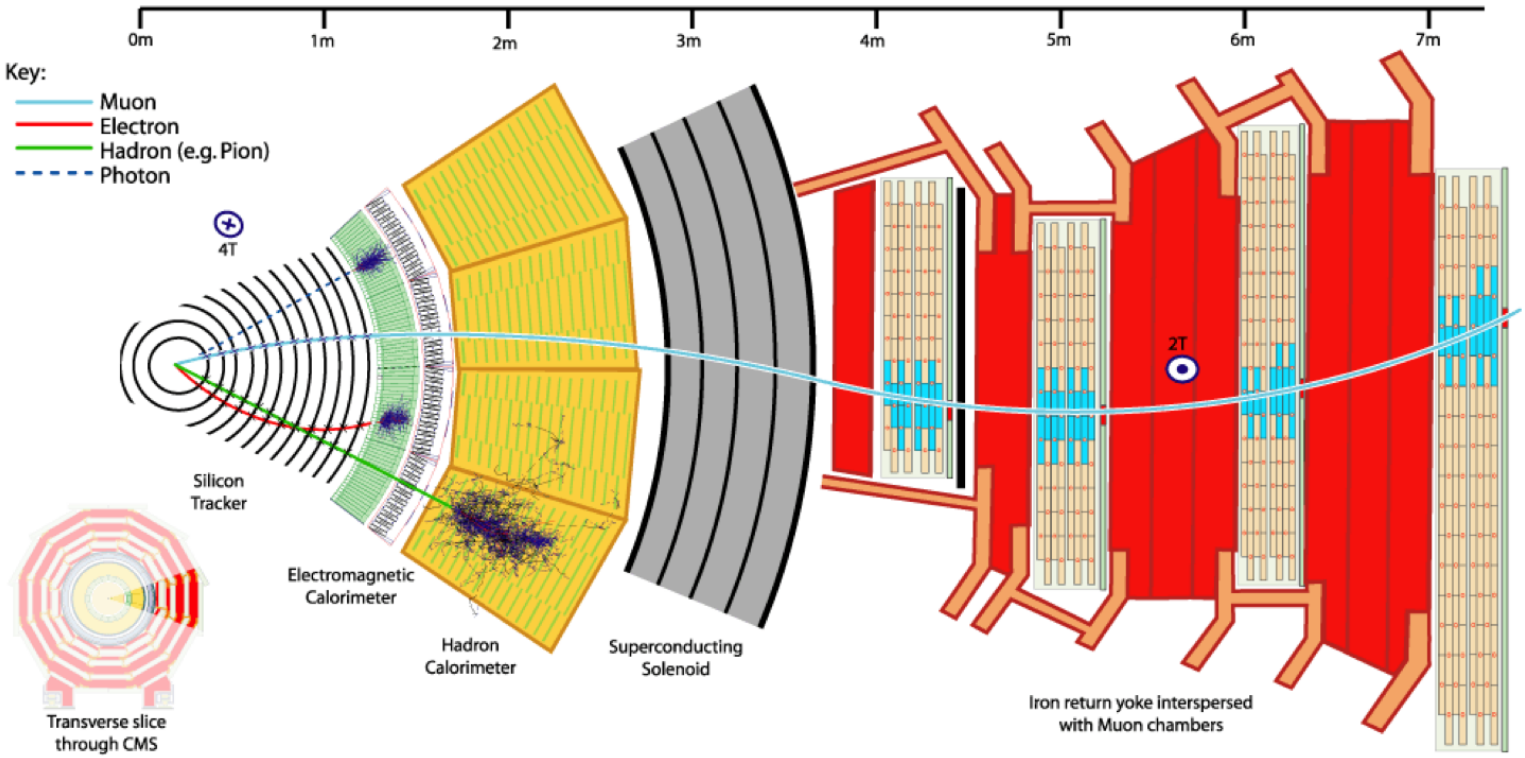
The Large Hadron Collider



- The LHC is a 27km circumference synchrotron at CERN. CMS is one of 7 experiments.

LHC, CMS and the ECAL

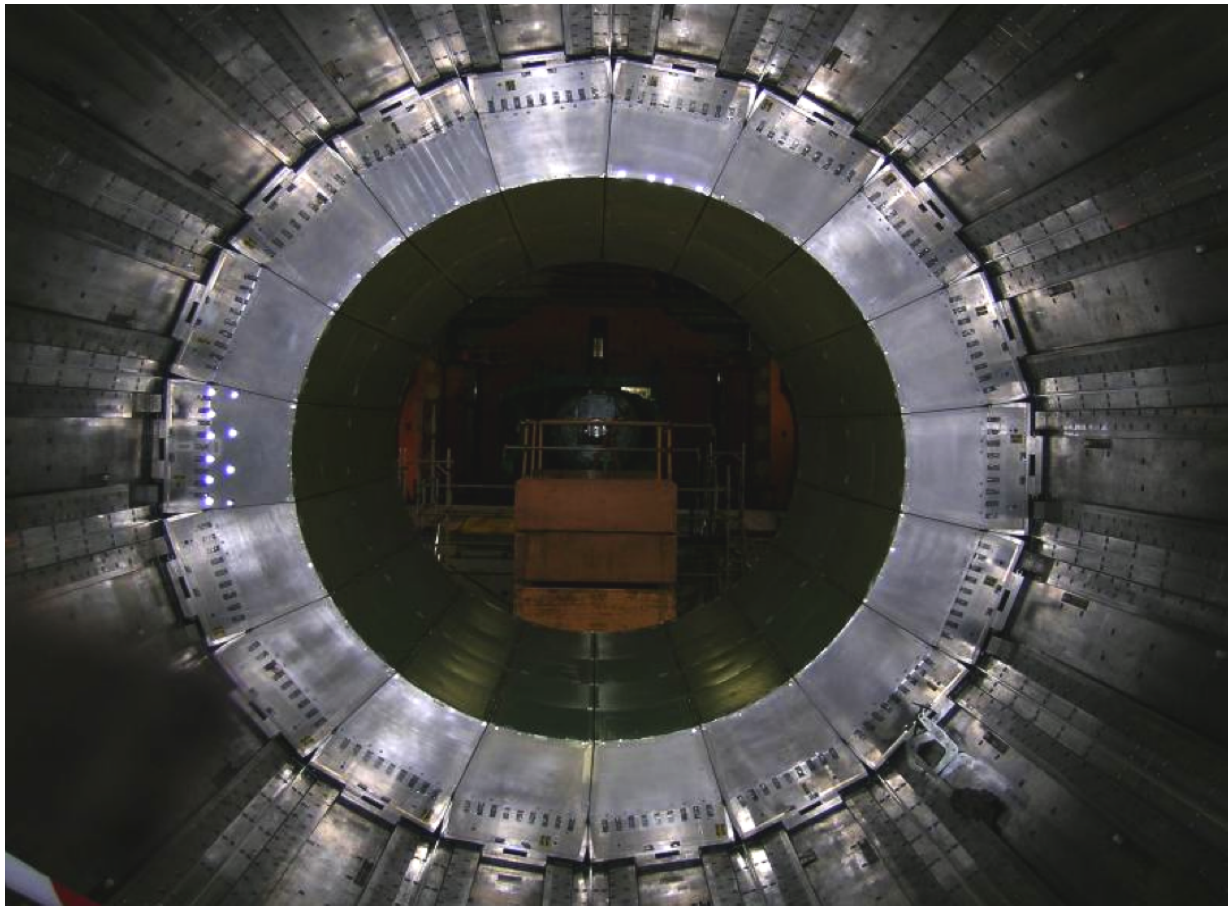
The Compact Muon Solenoid



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

LHC, CMS and the ECAL

The Electromagnetic Calorimeter



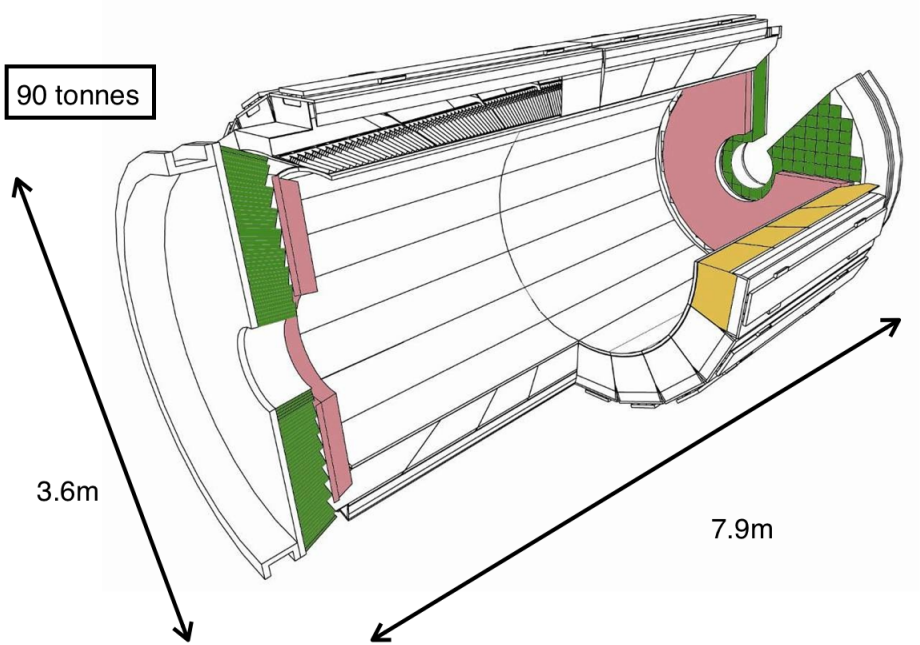
A view of the inside of the ECAL Barrel (from Chris Seez's lecture notes).

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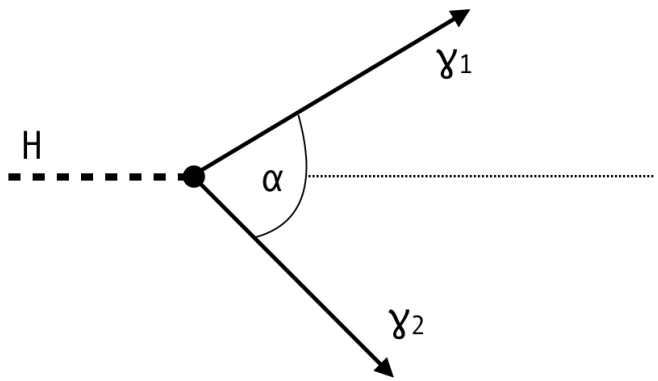
$$m_H = m_{\gamma\gamma} = \sqrt{2E_{\gamma 1}E_{\gamma_2}(1 - \cos\alpha)}$$



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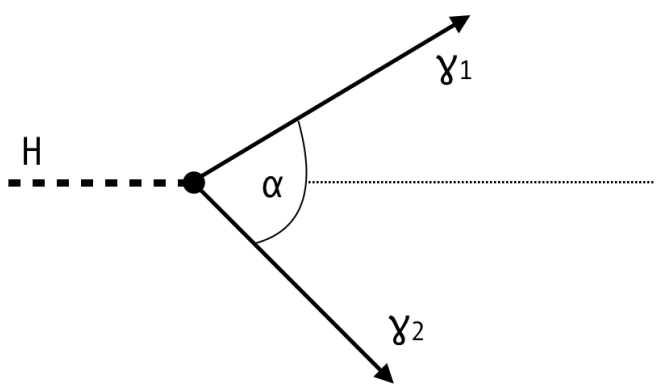

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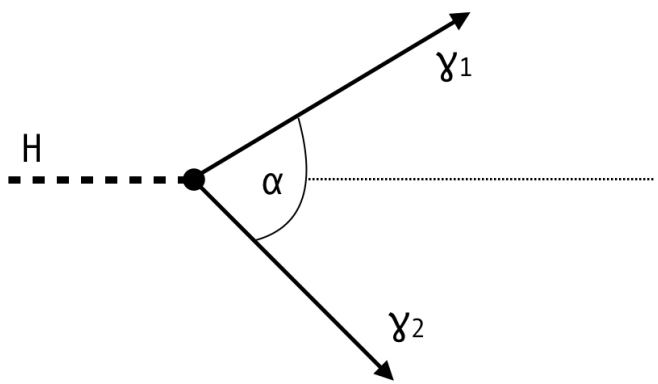

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- **The better the vertex reconstruction, the better the angle resolution!**

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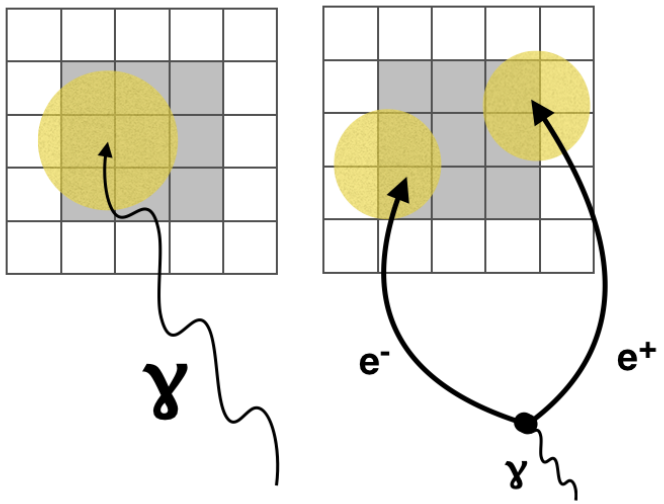
- A BDT is used to identify vertex using kinematic properties as inputs. Also makes use of extra information from tracker if γ has converted to e^+e^-.
- We can tell if γ has converted using $R_9 \equiv \frac{E_{3x3}}{E_{5x5}} < 0.94$.



- 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:

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

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

Event Categorisation and Analysis

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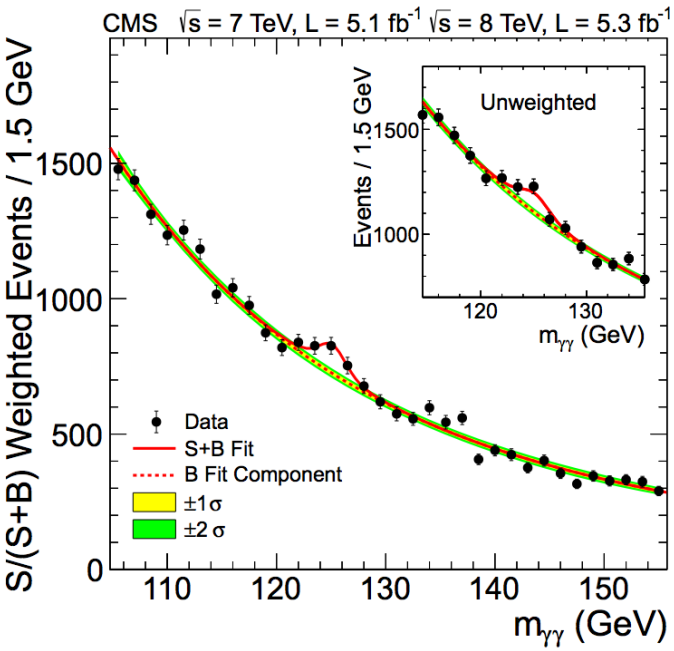
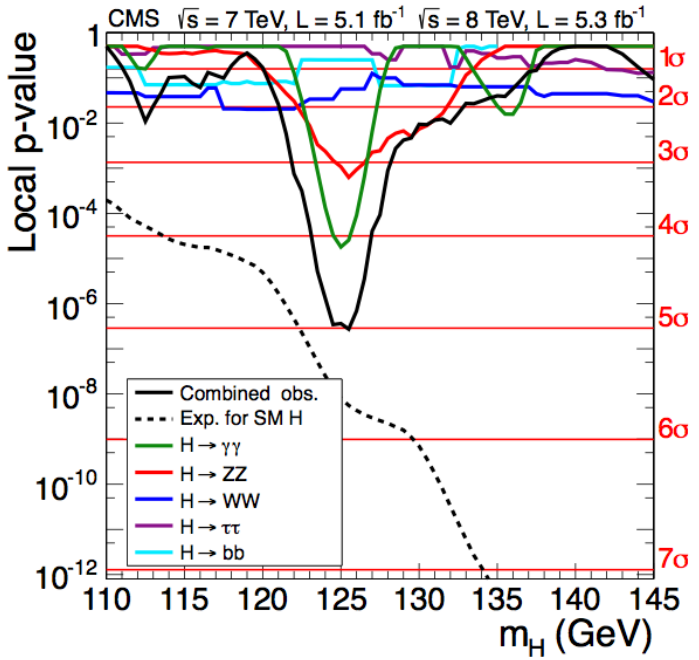
  - Fitting function chosen based on bias minimisation. Bias is negligible for all categories when Bersteins of order 3-5 (depending on category) are used.

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 (and ATLAS).





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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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