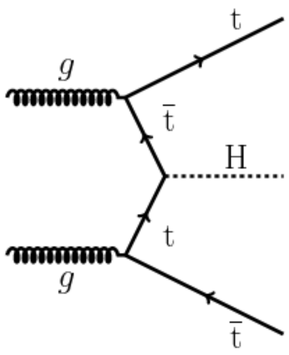
Search for the production of the Higgs boson in association with a pair of top quarks

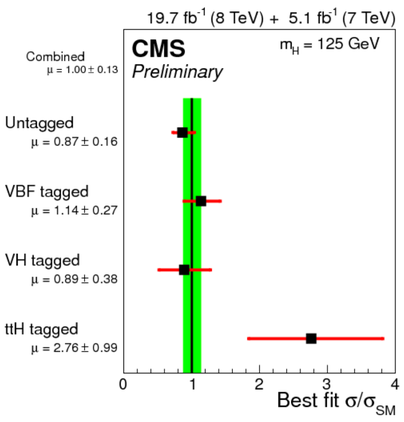
Saranya Ghosh
IRFU, CEA-Saclay

Introduction and Motivation

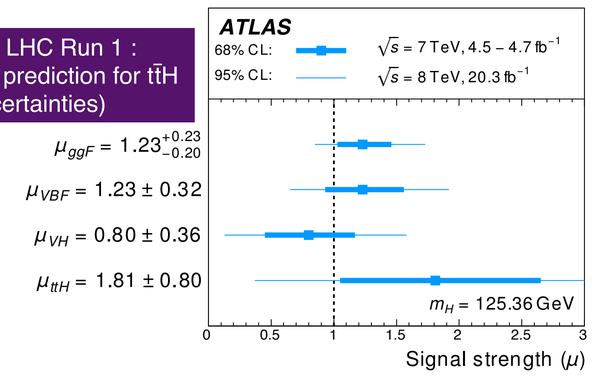
$t\bar{t}H$ production



- Measurements of the properties of the Higgs boson is a major goal of Run 2 of the LHC (2015 - 2018).
- Production of Higgs boson through the fusion of a top quark-antiquark pair, leading to a final state with a Higgs and a pair of top quarks ($t\bar{t}H$), is a rare but important process.
- It provides direct access to the top quark Yukawa coupling (top-Higgs coupling)
  - Top quark is most strongly coupled SM particle to Higgs boson.
  - Top quark Yukawa coupling may play a key role in Electroweak Symmetry Breaking.
  - It is a fundamental parameter of SM.
  - Deviation from value predicted by SM is an indication of new physics.
- $t\bar{t}H$ production cross section is predicted to be 4 times higher in Run 2 compared to Run 1 due to the increase in the energy of proton-proton collisions.

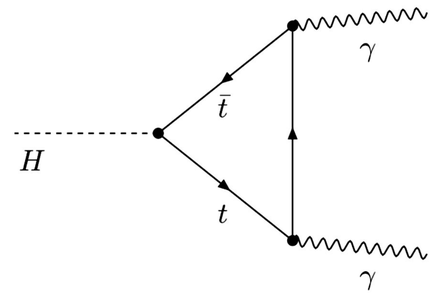


Results from LHC Run 1 : Excess over SM prediction for $t\bar{t}H$ (large uncertainties)

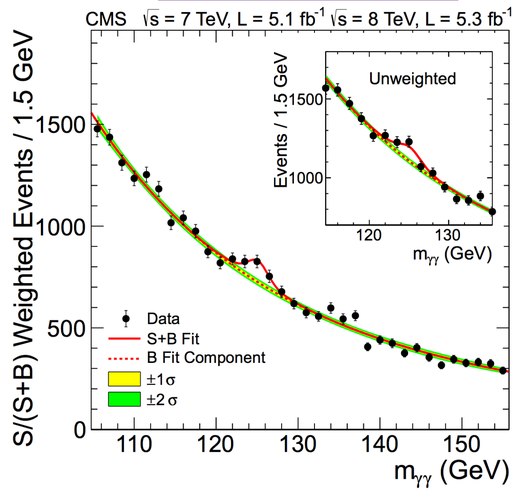


$H\rightarrow\gamma\gamma$ channel

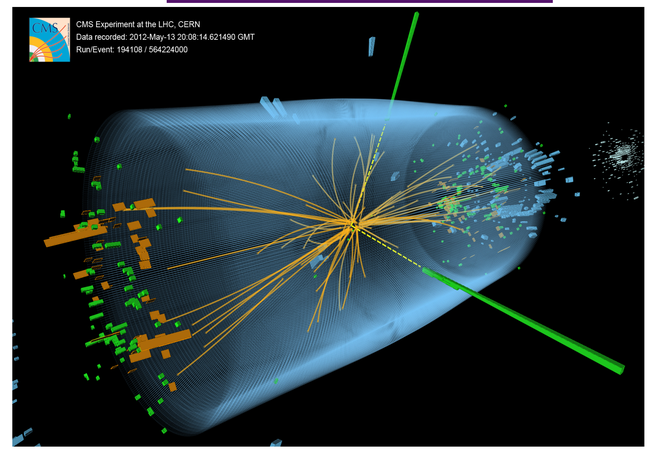
- Decay of the Higgs to two photons provides a clear signal.
- Despite a small branching ratio (~0.2%), it produces a narrow peak in the diphoton mass spectrum on top of a falling background distribution.
- This channel played a crucial role in the discovery of the Higgs boson during Run 1 of the LHC.
- This is the most promising channel for $t\bar{t}H$ measurement because of the clear signature of $t\bar{t}H$ process and also since it is dominated by statistical uncertainties.



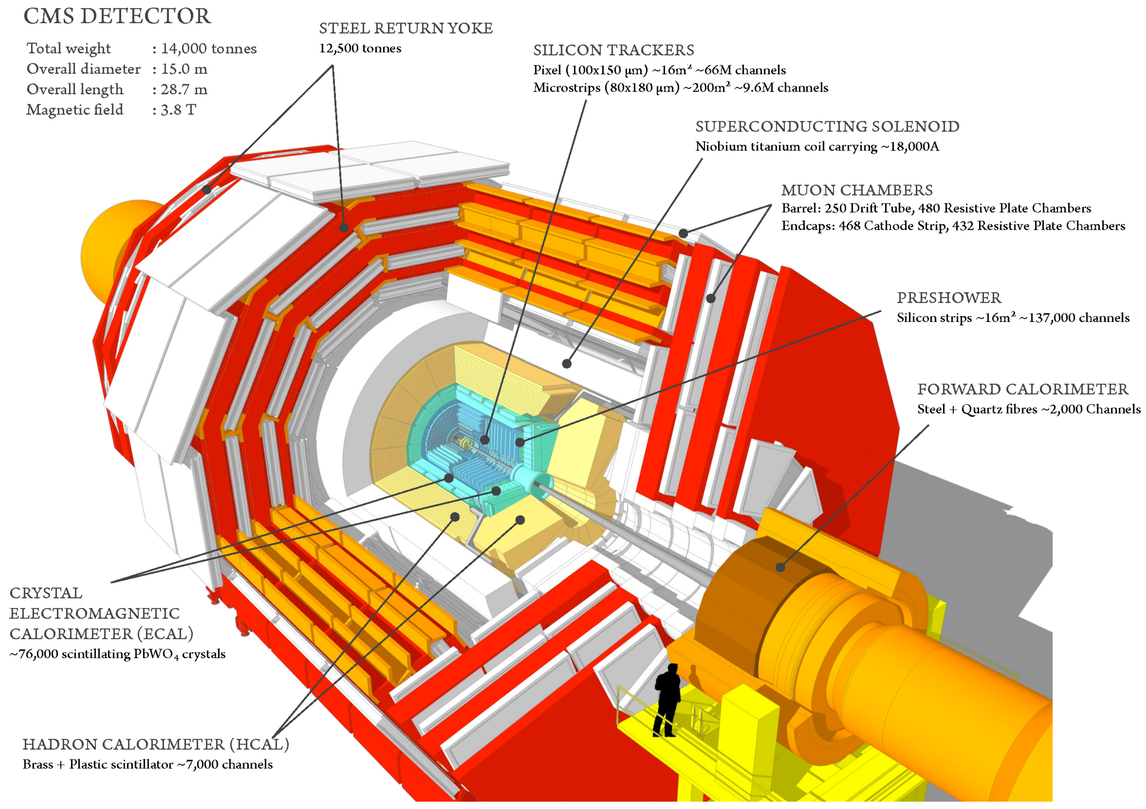
$H\rightarrow\gamma\gamma$ from LHC Run 1



$H\rightarrow\gamma\gamma$ candidate event at CMS



Compact Muon Solenoid (CMS) detector



- ECAL detects photons with very good energy resolution (~0.8% for 100 GeV photons) leading to excellent diphoton mass resolution.
- ECAL and Tracker are used to detect electrons.
- Muon chambers and Tracker system are used to reconstruct muons.
- The various detector sub-parts play a role in the reconstruction of jets.

$t\bar{t}H(H\rightarrow\gamma\gamma)$ Analysis

- The $t\bar{t}H$ analysis in the $H\rightarrow\gamma\gamma$ channel is performed as a part of the combined $H\rightarrow\gamma\gamma$ analysis including all the production modes of the Higgs.

$H\rightarrow\gamma\gamma$ Analysis

- The $H\rightarrow\gamma\gamma$ analysis looks for a peak in the diphoton invariant mass ($M_{\gamma\gamma}$) distribution.
  - Events containing two isolated photons with high transverse momentum and diphoton invariant mass in the region of 100 GeV to 180 GeV are selected.
  - A fit is performed on the $M_{\gamma\gamma}$ distribution, with the background model taken from the $M_{\gamma\gamma}$ distribution is the data sideband region, and the signal model using simulated samples.
  - The analysis is optimised in the sideband region and the signal region (115 GeV to 135 GeV) is kept blind until the final fits to the diphoton invariant mass distribution.
  - The fits are performed separately for events belonging to different categories corresponding to different production modes for the Higgs (different final states) or different regions of sensitivity.
- There are 2 categories corresponding to the $t\bar{t}H$ production mechanism, based on the final states corresponding to the different decay channels of the top quarks:

$t\bar{t}H$ Leptonic

$$t\bar{t} \rightarrow b\ell\nu_\ell\bar{b}\ell'\nu'_\ell \quad \text{or} \quad t\bar{t} \rightarrow b\ell\nu_\ell\bar{b}q\bar{q}'$$

- Leptonic and semi-leptonic decay
  - At least 1 isolated lepton (electron or muon) with high transverse momentum
  - At least 2 jets
  - At least one of the jets tagged as originating from a b quark

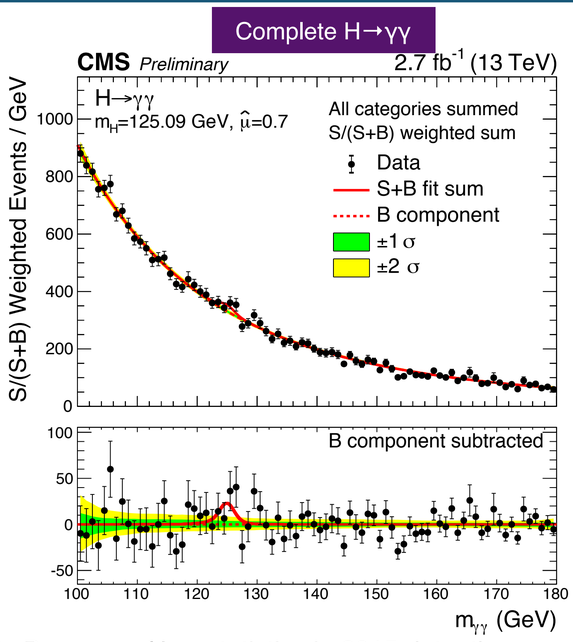
$t\bar{t}H$ Hadronic

$$t\bar{t} \rightarrow bq\bar{q}'\bar{b}q'\bar{q}$$

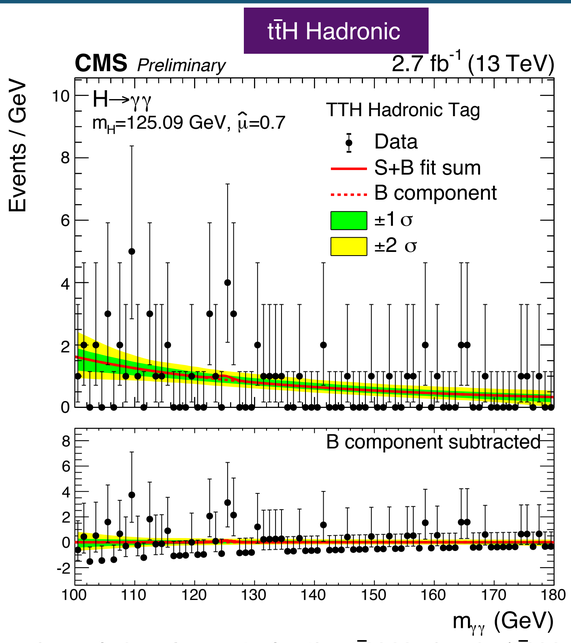
- Hadronic decay
  - 0 leptons
  - At least 5 jets
  - At least one of the jets tagged as originating from a b quark

Results with 2015 data (CMS : 2.7 fb^{-1} at √s = 13 TeV)

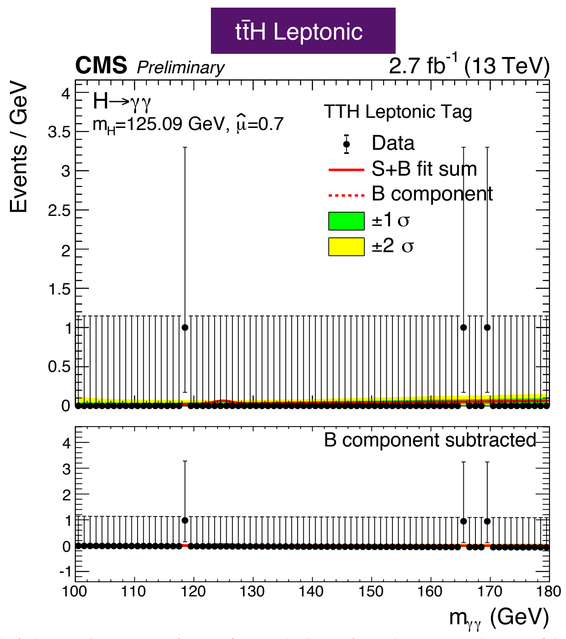
Complete $H\rightarrow\gamma\gamma$



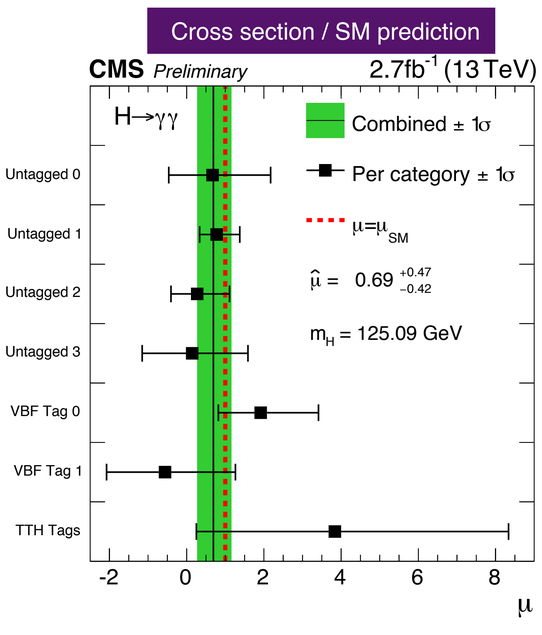
$t\bar{t}H$ Hadronic



$t\bar{t}H$ Leptonic



Cross section / SM prediction



- Because of low statistics in 2015 data, the expected number of signal events for the $t\bar{t}H$ Hadronic ($t\bar{t}H$ Leptonic) is only 0.64 (0.23) and that for the number of background events per GeV is 0.90 (0.03).
- An excess of events is observed in the $t\bar{t}H$ Hadronic category leading to a preferred cross section for $t\bar{t}H$ above the SM prediction, but with large uncertainty due to the low statistics.

Conclusions and Outlook

- Search for $t\bar{t}H$ production is the $H\rightarrow\gamma\gamma$ channel has been performed using 2.7 fb^{-1} of data collected by the CMS detector in proton-proton collisions at center of mass energy of 13 TeV during 2015.
- The statistics collected in 2015 is insufficient for this search and to have a meaningful measurement of the $t\bar{t}H$ cross section.
- The basic framework for the analysis is in place, and work is ongoing to improve the sensitivity.
- Data collection in 2016 has already begun, 30 fb^{-1} of data is expected to be recorded by the end of 2016, 100 fb^{-1} by the end of Run 2 (2018). Stay tuned!