Search for the Standard Model Higgs boson in the Z boson plus a photon channel in CMS

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On behalf of the CMS Collaboration

Motivation

Within the SM, the partial width for the $H \to Z\gamma$ decay channel ($\Gamma_{Z\gamma}$) is rather small, resulting in a branching fraction ranging between 0.11% and 0.25% for the mass range $120 < m_H < 160$ GeV. Nonetheless, the Large Hadron Collider (LHC) experiments should be sensitive to this channel in the near future. A measurement of $\Gamma_{Z\gamma}$ provides important information on the underlying dynamics of the Higgs sector because it is incuded by loops of heavy charged particles, just as for the $H \to \gamma\gamma$ decay channel. Ultimately, $\Gamma_{Z\gamma}$ is sensitive to physics beyond the standard model, and could be substantially modified by new charged particles [1], such as derived from an extended Higgs sector [2] or by the presence of new scalars [3].

Data

Events were collected at center-of-mass energies of 7 TeV and 8 TeV, corresponding to integrated luminosities of 5.0 fb^{-1} and 19.6 fb^{-1}.

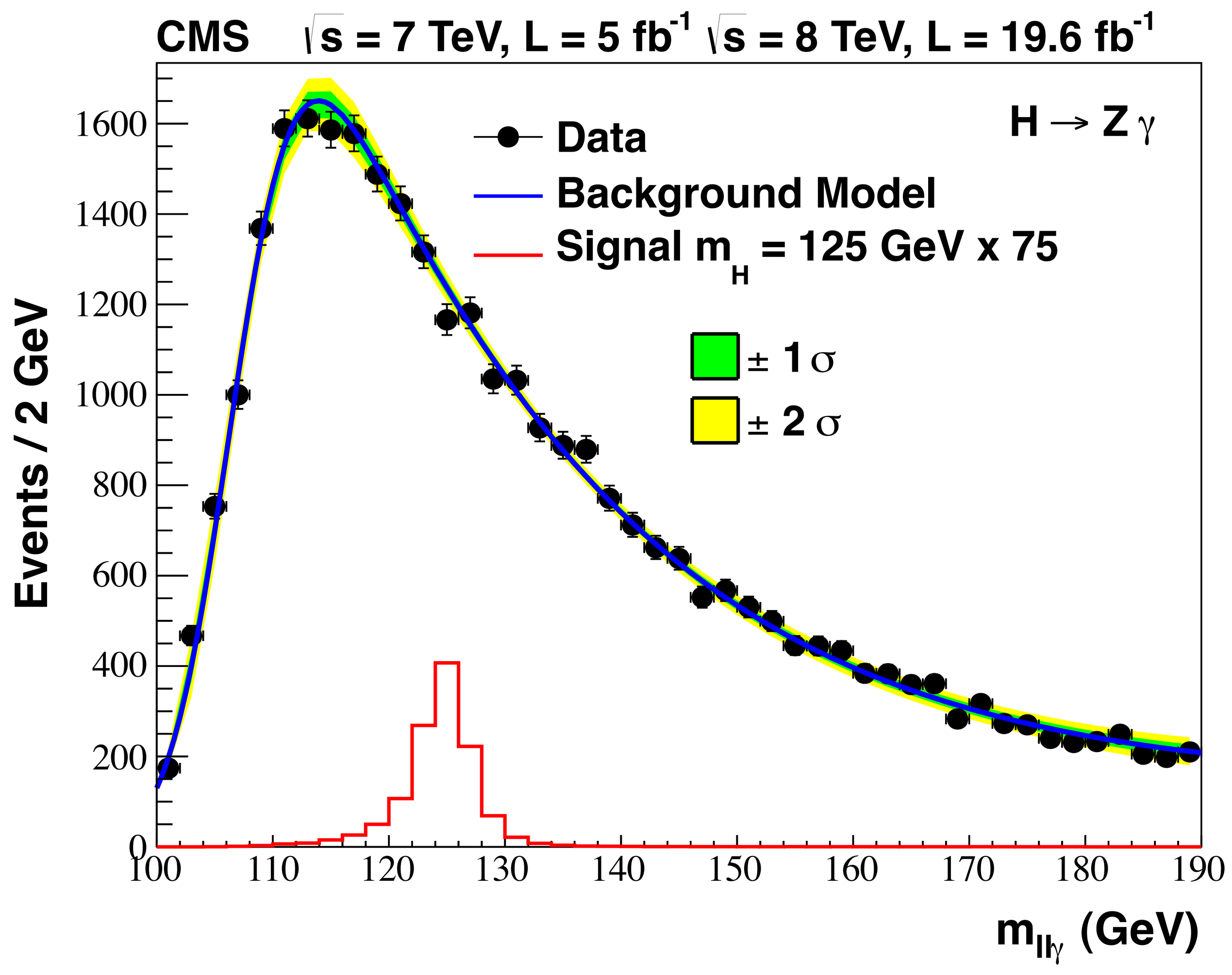
Event selection

- Two opposite-sign, same-flavor leptons (e or μ) and a photon: $e^+e^-\gamma$, $\mu^+\mu^-\gamma$
- Trigger : dielectron or dimuon trigger
- Lepton selections : leading $p_T > 20$ GeV, sub-leading $p_T > 10$ GeV, dilepton invariant mass > 50 GeV, pass CMS official lepton identification criteria
- Photon selections : within ECAL fiducial volume, $p_T > 15$ GeV, pass CMS official photon identification criteria, $\Delta R(l,\gamma) > 0.4$
- $m_{ll\gamma}$ requirements : $100 < m_{ll\gamma} < 190$ GeV, $p_T^\gamma/m_{ll\gamma} > 15/110$, $m_{ll\gamma} + m_{ll} > 185$ GeV
- Jet selections (used in dijet-tagged class) : anti-k_T clustering algorithm with distance algorithm of 0.5, $E_T > 30$ GeV, $|\eta| < 4.7$, $\Delta R(l, \text{jet}) > 0.5$

Event classes

The sensitivity of the search is enhanced by dividing the selected events into mutaully-exclusive classes according to the expected mass resolution and the signal-to-background ratio, and then combining the results from each class. Four untagged event classes and a dijet-tagged event class for vector boson fusion (VBF) are used in this analysis. The signal-to-background ratio that is more than an order of magnitude larger than events in the four untagged classes. The dijet tag requirements are: (1) $\Delta\eta$ between dijet > 3.5, (2) the Zeppenfeld variable $\eta_{Z\gamma} - (\eta_{jet1} + \eta_{jet2}) / 2 < 2.5$, (3) $m_{jj} > 500$ GeV, and (4) $\Delta\Phi$ between dijet and $Z\gamma$ system > 2.4.

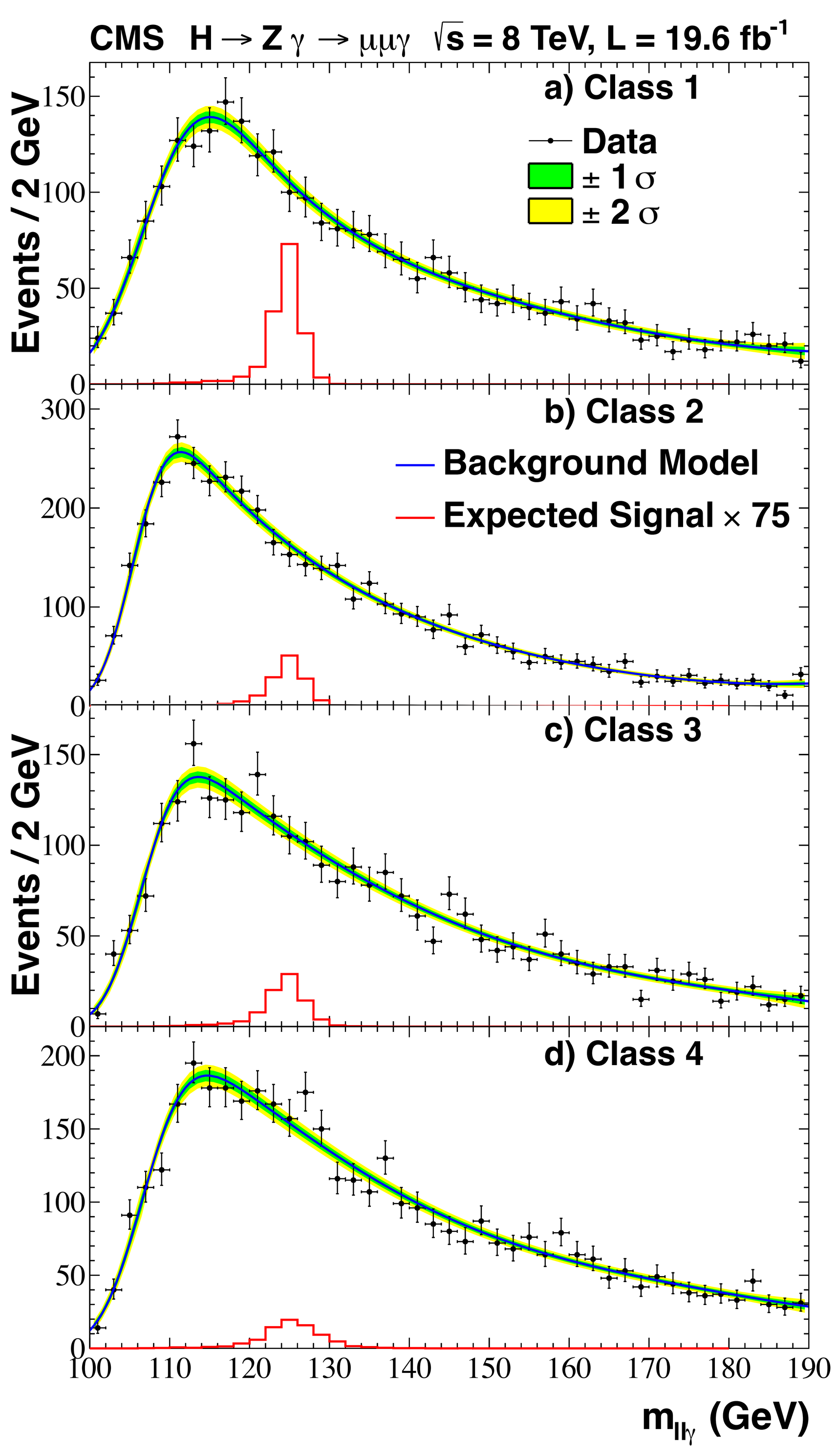
$m_{ll\gamma}$ spectrum



	$e^+e^-\gamma\ (\mu^+\mu^-\gamma)$				
Event classes	1	2	3	4	Dijet-tagged
Photon	$0<\|\eta\|<1.44$	$0<\|\eta\|<1.44$	$0<\|\eta\|<1.44$	$1.57<\|\eta\|<2.5$	$0<\|\eta\|<2.5$
Lepton 1	$0<\|\eta\|<1.44(2.1)$	$0<\|\eta\|<1.44(2.1)$	$0<\|\eta\|<2.5(0.9)$	$0<\|\eta\|<2.5(2.4)$	$0<\|\eta\|<2.5(2.4)$
Lepton 2	$0<\|\eta\|<1.44(0.9)$	$0<\|\eta\|<1.44(0.9)$	$1.44(0)<\|\eta\|<2.5(2.4)$	$0<\|\eta\|<2.5(2.4)$	$0<\|\eta\|<2.5(2.4)$
R_9	> 0.94	< 0.94	–	–	–
Data	17% (20%)	26% (31%)	26% (20%)	31% (29%)	0.1% (0.2%)
Signal	29% (33%)	27% (30%)	23% (18%)	19% (17%)	1.8% (1.7%)
σ_{eff}(GeV)	1.9 (1.6)	2.1 (1.9)	3.1 (2.1)	3.3 (3.2)	2.6 (2.2)
FWHM(GeV)	4.5 (3.7)	5.0 (4.6)	7.3 (5.0)	7.8 (7.5)	4.4 (3.8)

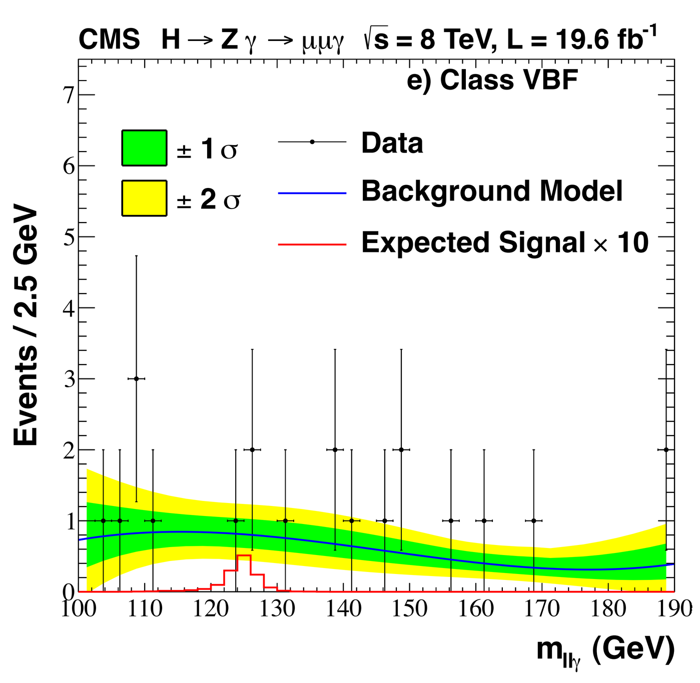
Definition of the event classes, the fraction of selected events for a signal with m_H = 125 GeV and mass resolutions

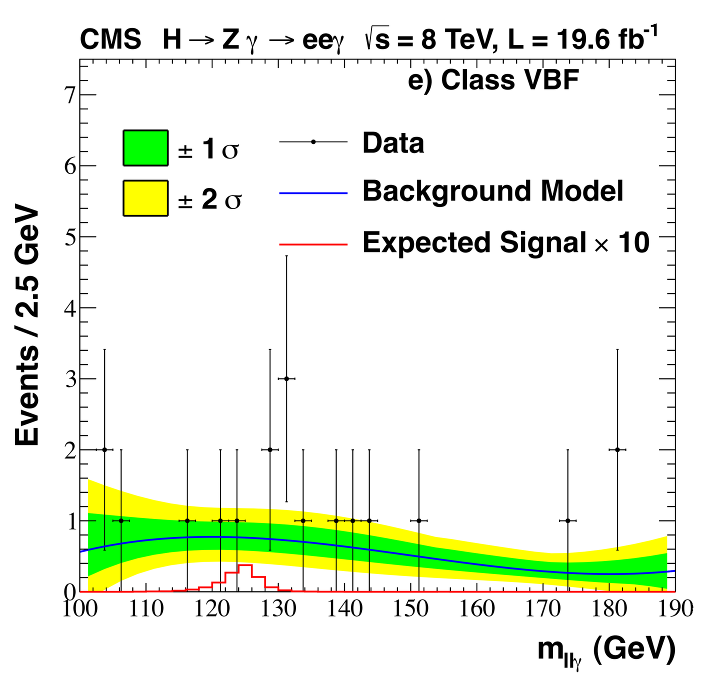
Background and signal modeling



Signal : events are simulated with NLO ME generator, POWHEG, and corrected for data/MC differences

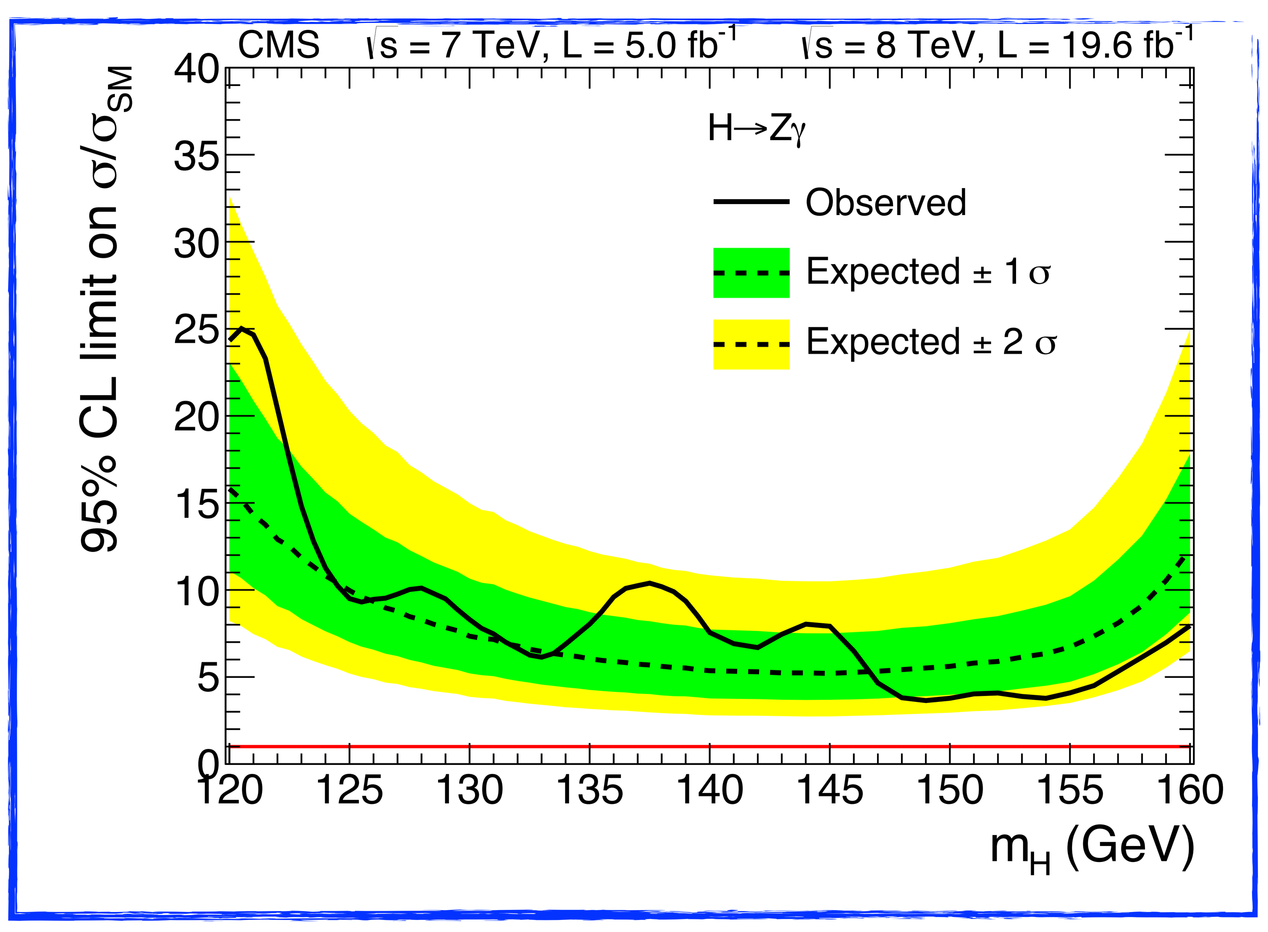
Background : The fitting is unbinned. To describe the background shape around 120 GeV, the $m_{ll\gamma}$ turn-on distribution for the low mass region is included by fitting a step function multiplied by a polynomial for the untagged classes. That product is then convolved with a Gaussian distribution to yield the final shape. The potential bias is studied using toy data generated from background only fits to the observed $m_{ll\gamma}$ spectrum. These pseudo-datasets are fitted to a signal combined with a polynomial background model. The appropriate degree of polynomial model for background are chosen so that the bias introduced on the limit of the signal strength measurement is smaller than a fifth of the background statistical uncertainty.





Results

The observed limit ranges between ~4 and 25 times the SM cross section. The observed and expected limits for $m_{ll\gamma}$ at 125 GeV is within one order of magnitude of the SM prediction.



References

[1] M. Carena, I. Low, and C. E. Wagner, JHEP 8 (2012) 60, arXiv:1206.1082

[2] C. W. Chiang, and K. Yagyu, PRD 87 (2013) 033003

[3] I. Low, J. Lykken, and G. Shaughnessy, PRD 84 (2011) 035027