# Searches for the Higgs boson in $l^+l^-$ plus photon decay channels using the CMS detector

Luisa Fernanda Chaparro Sierra*

On behalf of CMS Experiment.

## Abstract

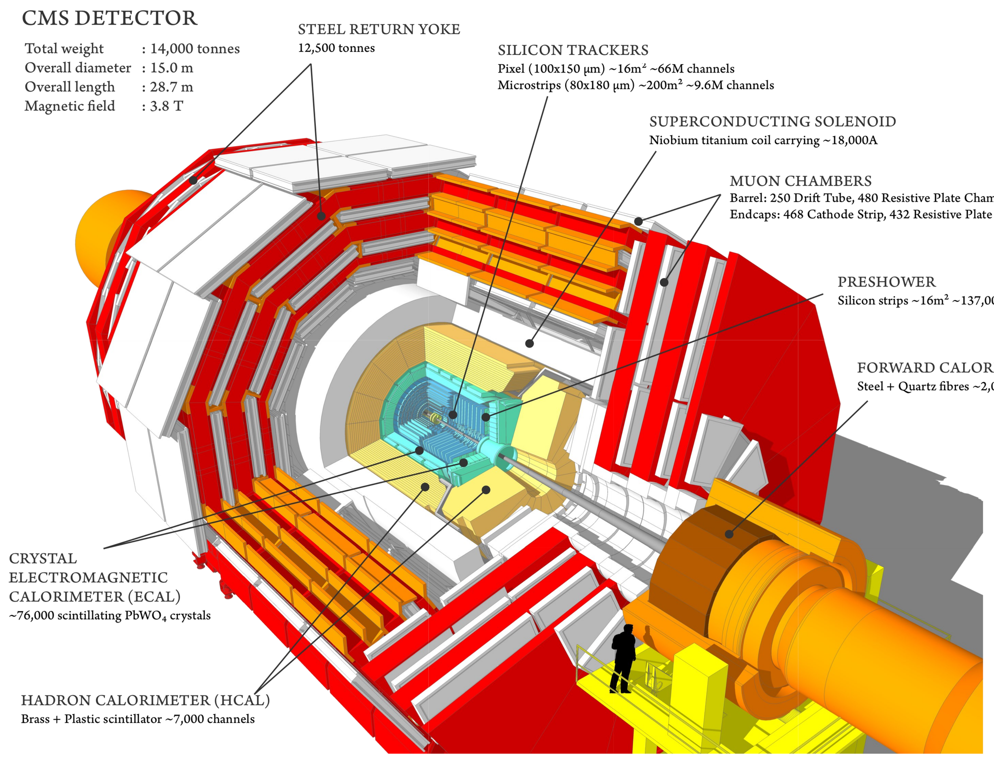
The results of the Higgs boson decays into a dilepton plus a photon are presented. The analyses are performed proton-proton collision data recorded by the CMS detector at the LHC. The events were collected at 8 TeV and 13 TeV center-of-mass energy.

Searches for the rare decay of a 125 GeV scalar boson into a Z boson and a photon have been conducted by ATLAS and CMS experiments. In these analyzes the Z bosons are reconstructed from opposite sign lepton pairs (electron or muon) **H → ll γ.**

- Due to the recent report from CMS and ATLAS about a modes excess around 750 GeV in the diphoton mass spectrum, the most recent search looks for high-mass resonances (**A → Z γ → ll γ**) (EXO-16-021).
- Looking at the low region in the dilepton invariant mass spectrum, the search of **H → γγ* → γ ll** is performed. This process is called Higgs Dalitz decay (HIG-14-003)

## CMS EXPERIMENT

- The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T.
- Within the superconducting solenoid volume are a silicon pixel and strip tracker, a lead tungstate crystal electromagnetic calorimeter (ECAL), and a brass and scintillator hadron calorimeter (HCAL), each composed of a barrel and two endcap sections. They provide measurements of the energy of photons, electrons and jets.
- Muons are detected in gas-ionization detectors embedded in the steel flux return yoke outside the solenoid.
- Extensive forward calorimeter complements the coverage provided by the barrel and endcap detectors




## HIGH-MASS RESONANCES

(EXO-16-021) ATLAS and CMS reported a modest excess of data over the expected background around 750 GeV in the diphoton mass spectrum. If this excess is confirmed to be due to a new physics process, the Z γ channel may be needed to characterized it. The analysis search for a high mass spin-0 resonance, **A**, with mass between 200 GeV and 2 TeV, decaying to Z γ. **A → Z γ → ll γ**

### EVENT SELECTION

- Two opposite-sign, same flavour leptons plus a photon.
- Leading leptons pT > 20 (25) GeV for 8 (13) TeV.
- Subleading leptons pT > 10 (20) GeV for 8 (13) TeV.
- Isolation in all particles.
- Photon pT > 40 GeV.
- At least one primary vertex.
- Δ R(l,γ) > 0.4 to reject FSR events.
- Mll > 50 GeV

### SIGNAL MODELLING

- Scalar resonances decaying to Z γ were generated with Pythia.
- Samples with masses between 200 (350) GeV to 1.2 (2.0) TeV for 8 (13) TeV for signal were generated.
- The fitting function is a Gaussian plus a Crystall ball function for 8 TeV and a function with a Gaussian core and two -power law tails an extended form of the Crystal ball for 13 TeV

### BACKGROUND MODELLING

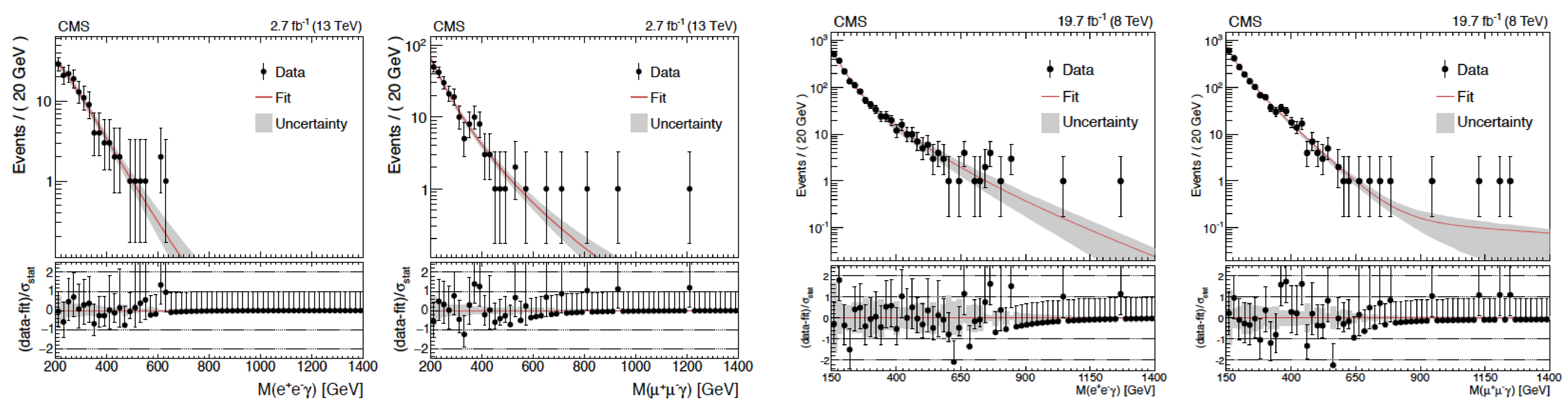
Based on simulated events, the dominant background after the full selection is ISR SM Z γ productions (80-90%). The rest is due to the contribution from Z+jets.

The mll distributions are steeply and smoothly falling with increasing mass.

At 8 TeV the background shape is parametrized with the sum of three exponential decay functions. The exponential bias is studied by using different pseudo-data from different functional forms and tilled with the function under test.

The 13 TeV search employees a fitting strategy similar to the 8 TeV search. The adopted fitting function in the background estimate :

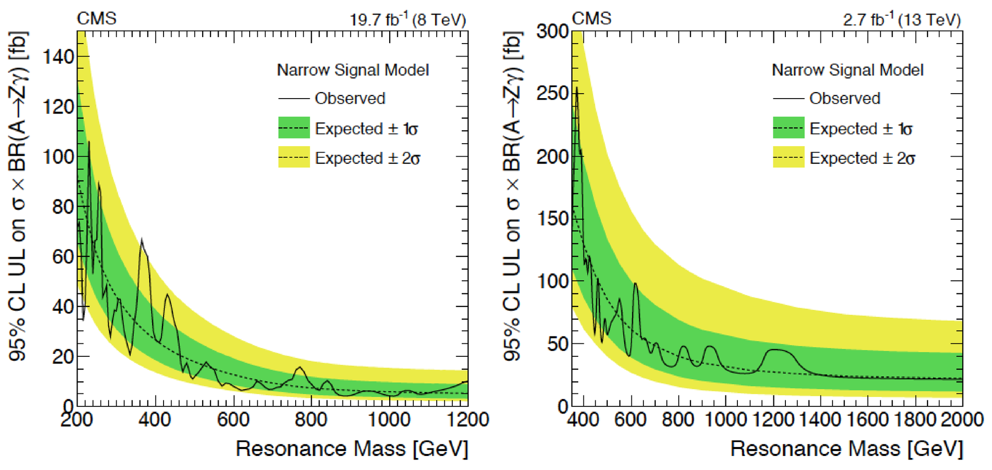
$$f(m_{Z\gamma}) = m_{Z\gamma}^{a+b\log m_{Z\gamma}}$$




### RESULTS

No significant excess is observed with respect to the background predictions.

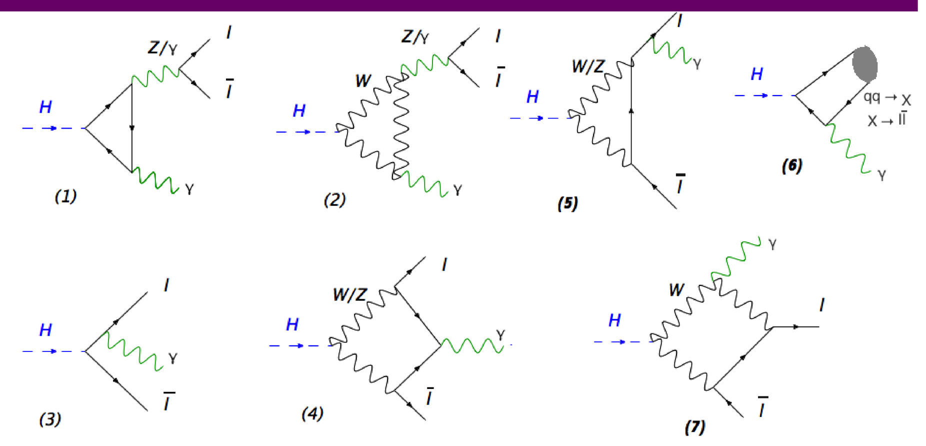
The individual expected and observed limits, at the 95% confidence level on the cross section times branching ratio for A -> Z γ are shown.




## DALITZ DECAY

(HIG-14-003) Higgs boson decay into μμγ final state, although rare, provides interesting information on the properties of the SM Higgs boson:

(a) it gives an extra handle on the measurement of Higgs' couplings;
(b) it consists of non-trivial angular correlations that could result in forward-backward asymmetry;
(c) sensitive to new-physics via loops.



The dominant contribution to the final state come from H⟶γ*γ and H⟶Z*γ processes, with an internal conversion of the γ */Z* into a dilepton.

The main contributions to this channel are loop-induced processes, but tree-level diagrams with initial-state and final-state radiation, also contribute. Other high-order box diagrams have negligible contributions.

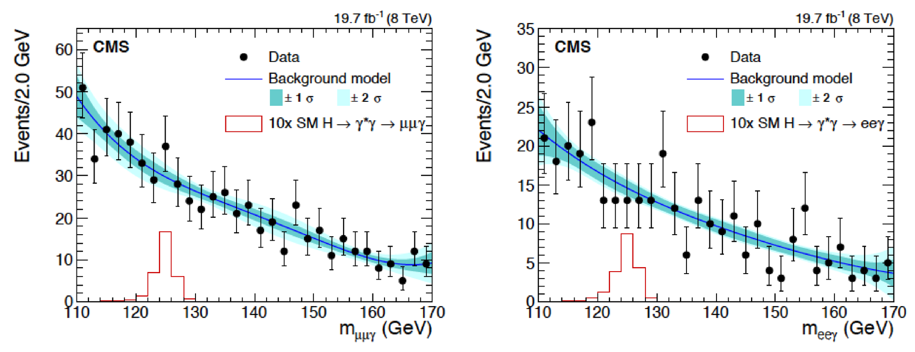
### EVENT SELECTION

For this analysis the events were required to pass a:

- Two opposite-sign, same flavour and a photon.
- For muon, the pseudorapidity (η) is less than 2.4, while for the photon and electrons, |η| < 1.44.
- All particles must be isolated.
- Transverse momentum: greater than 23 GeV for the highest-pT lepton and greater than 4 GeV for next to the highest-pT lepton.
- The dilepton invariant mass ($m_{ll}$) is required to be less than 20 GeV in order to reject contributions from pp⟶ γ Z and H⟶γ Z.
- Events with dilepton mass between 2.9 GeV and 3.3 GeV as well as events with dilepton mass between 9.3 and 9.7 GeV are rejected to avoid J/Ψ and Υ contributions respectively.
- The mass window for the system *ll* γ, is require to be between 110 and 170 GeV.

### SIGNAL & BACKGROUND MODELING

The background model is modeled by fitting a polynomial function to the *ll* γ mass distribution in data. The fitting is unbinned and is performed over the three body invariant mass range of 110-170 GeV. This spectrum is a falling distribution that is fitted to a fourth-order polynomial. The potential bias on the background measurement is studied by using pseudo-data generated from background-only fits to the observed three-body mass spectrum. These pseudo-data sets are fitted to a signal combined with a polynomial background model.



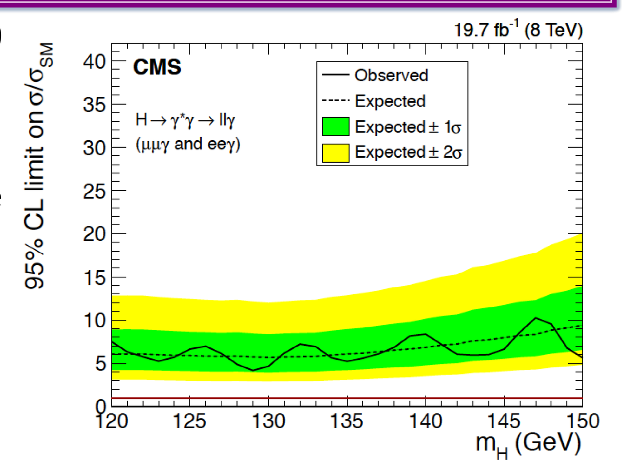

The signal model in both channels is obtained from an unbinned fit to the mass distribution of the corresponding simple of simulated events to a Crystal Ball function plus a Gaussian function.

### RESULTS

No significant excess above background is observed in the full mass range (120 <mH <150) with a maximum excess of less tan 2 sigma.

The expected and observed combined μμγ and ee γ limits are show in the right.

The 95% CL exclusion limits are between 6 and 10 times the SM prediction and the observed limits between 5 and 11 times the SM.

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**References:**

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Search for a Higgs boson decaying into a Z and a photon in pp collisions at √s = 7 and 8 TeV, CMS Collaboration, Phys.Lett., B726, arxiv:1307.5515

*lchaparr@uniandes.edu.co

luisillafer@cern.ch