Search for a Higgs boson decaying to $\gamma\gamma^* \rightarrow \gamma l^+ l^-$ in pp collisions at $\sqrt{s} = 8$ TeV at the CMS Experiment

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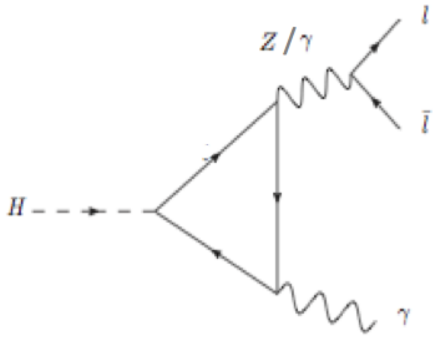
Higgs Dalitz Decay

- In analogy to π^o decays, the Standard Model (SM) scalar Higgs (h) can decay to its "Dalitz mode": via an internal conversion of one of the Photons: $h \rightarrow \gamma\gamma^* \rightarrow \gamma ll$
  - This is the first measurement in this topology
- Brings extra handle to $h \rightarrow \gamma\gamma$ channel and $h \rightarrow ff$ coupling measurement.
  - Sensitive to new-physics due to loops
- An important step towards $h \rightarrow J/Psi\ \gamma$ measurement and other V-resonances.

Feynman Diagrams



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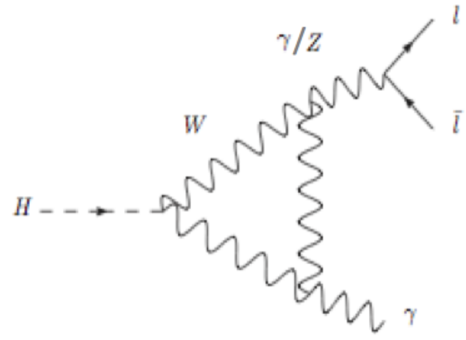

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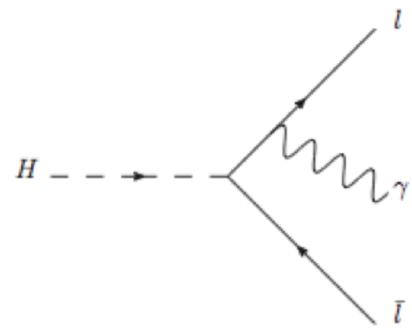

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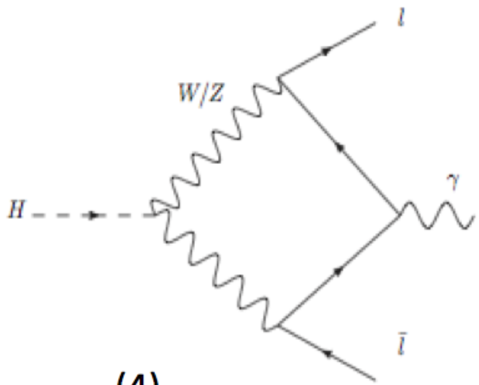

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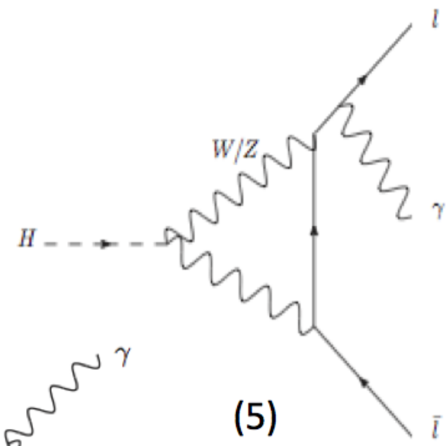

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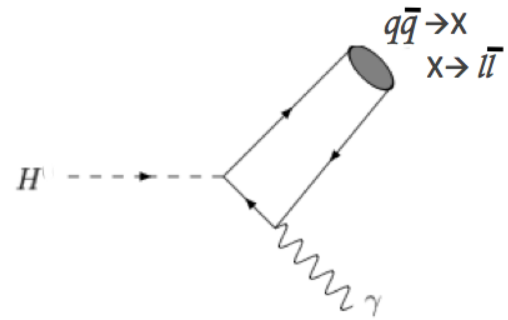

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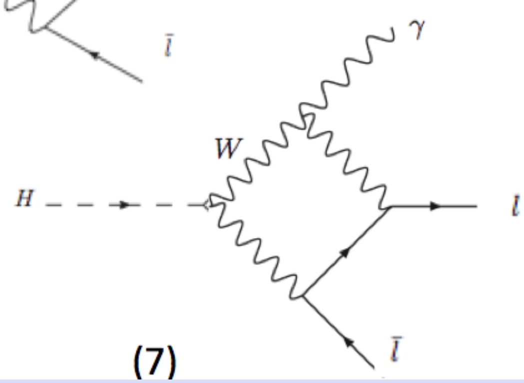

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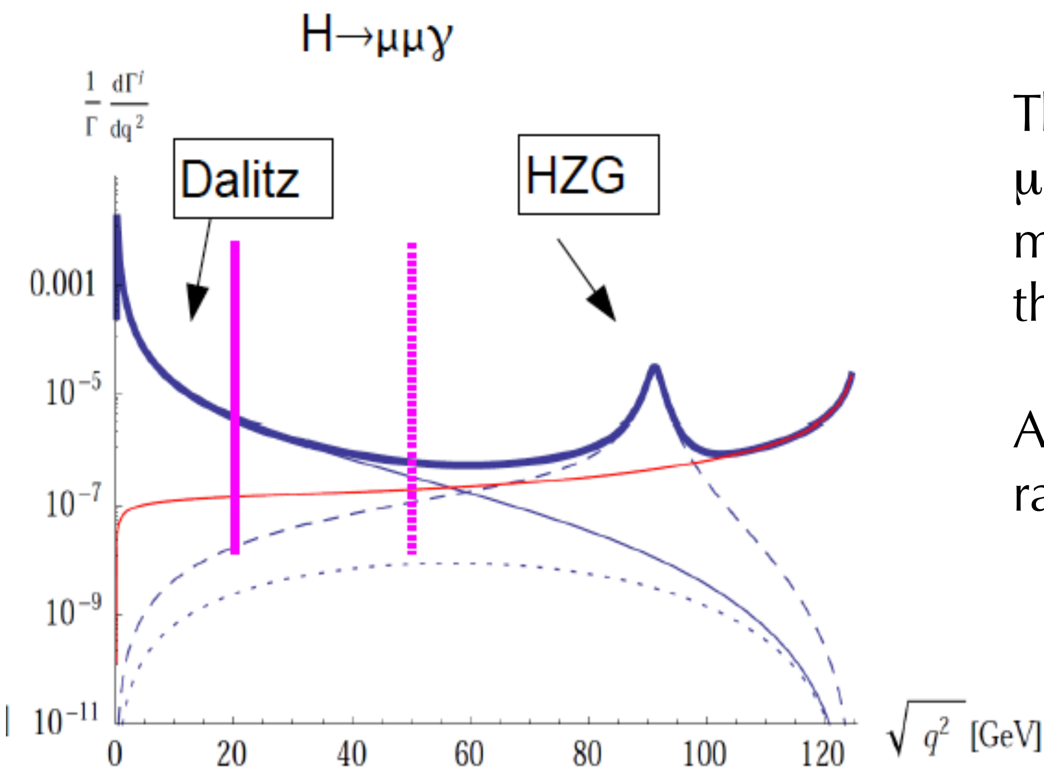
Dalitz Branching Ratio



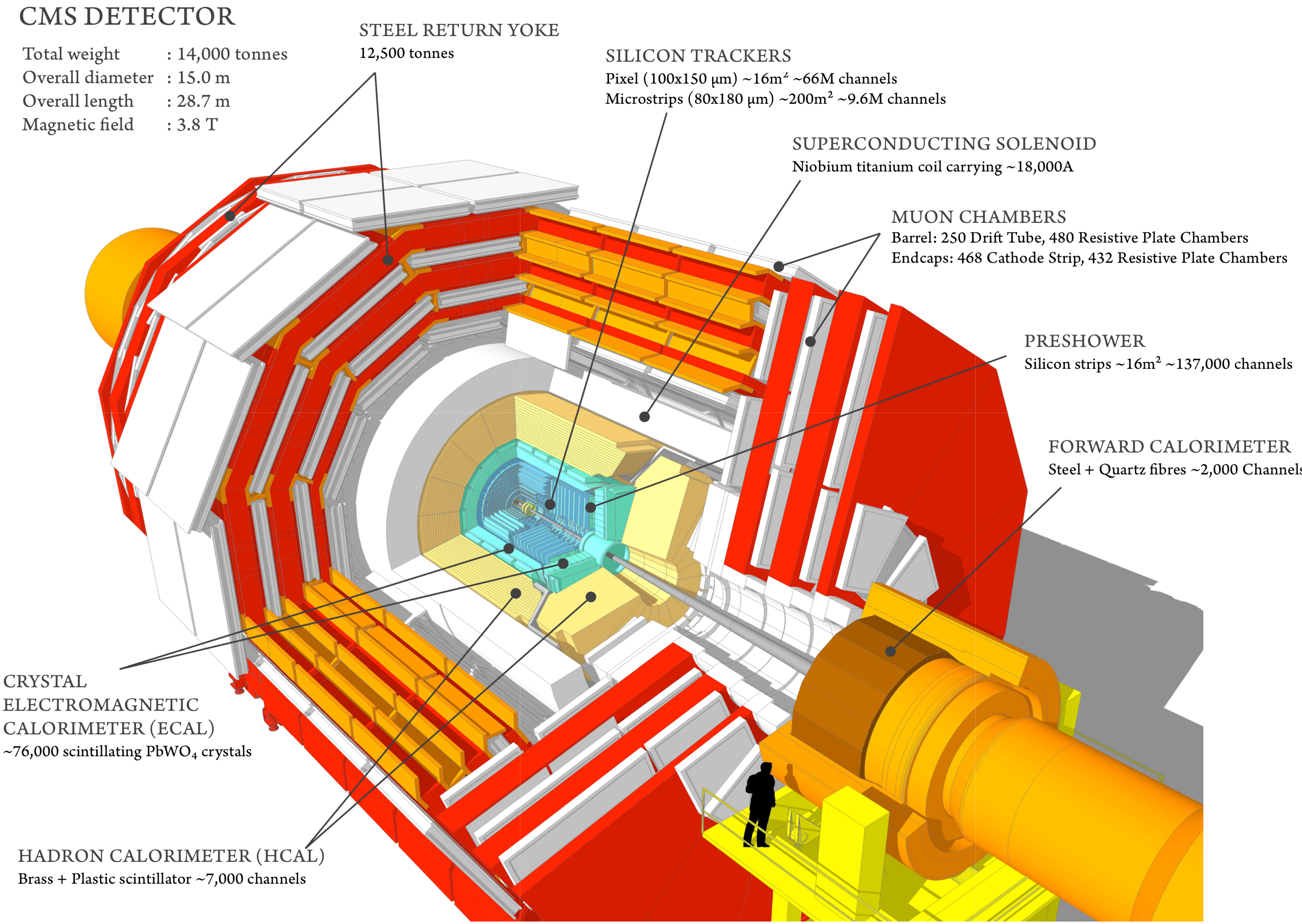
The Higgs boson branching fraction to μμγ is dominated by Dalitz and Zγ modes when the invariant mass is less than 100 GeV

At higher invariant mass, final-state radiation in h➔μμ dominates

$$\Gamma_{\gamma\mu^+\mu^-}/\Gamma_{\gamma\gamma} = 5.8\%$$

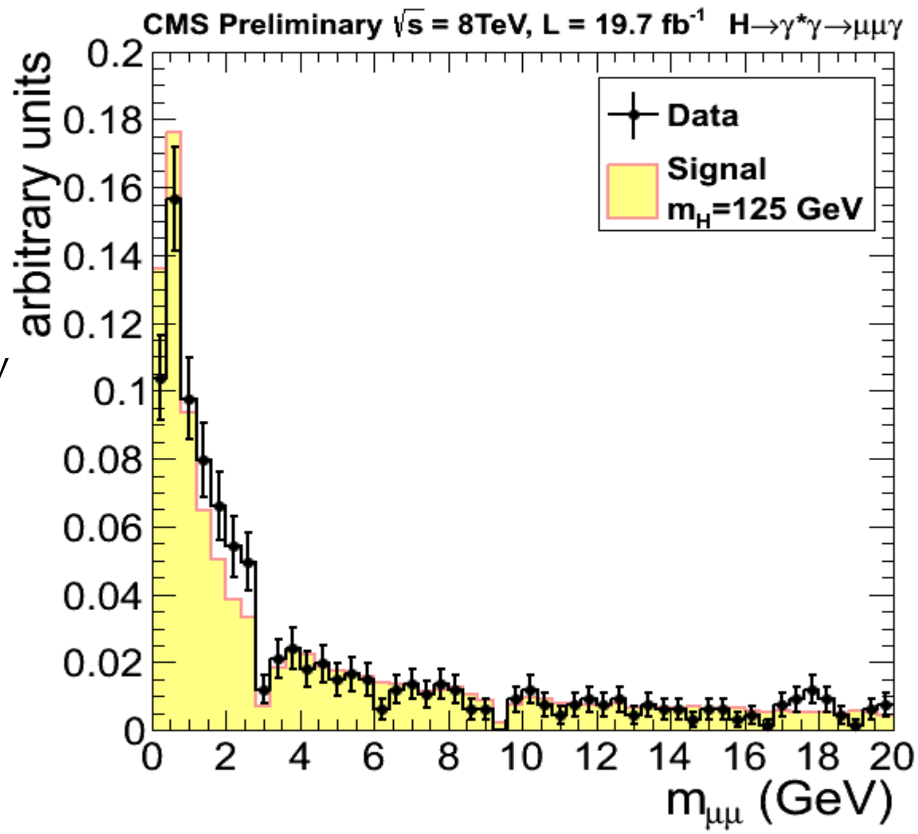
✓The red line denotes the contribution of the tree diagrams
✓The thin solid line denotes the contribution from the γ^* pole diagrams.
✓The dashed line shows the contribution from the Z^* pole diagrams while thick line gives the total contributions.
✓ The dotted line denotes the contribution from the four-point box diagrams.

The CMS Detector



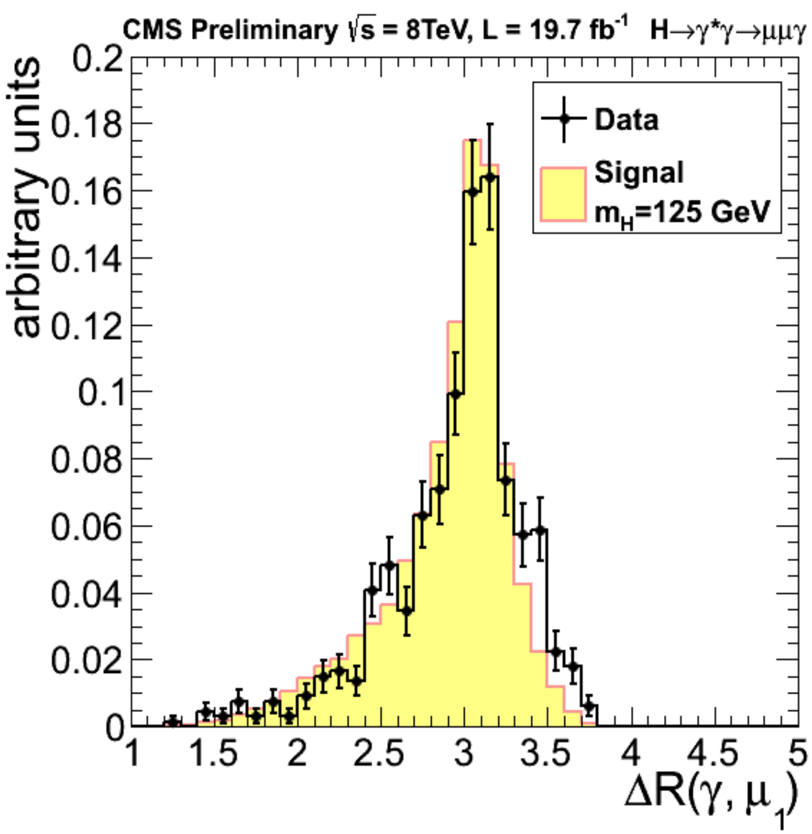
Event Selection

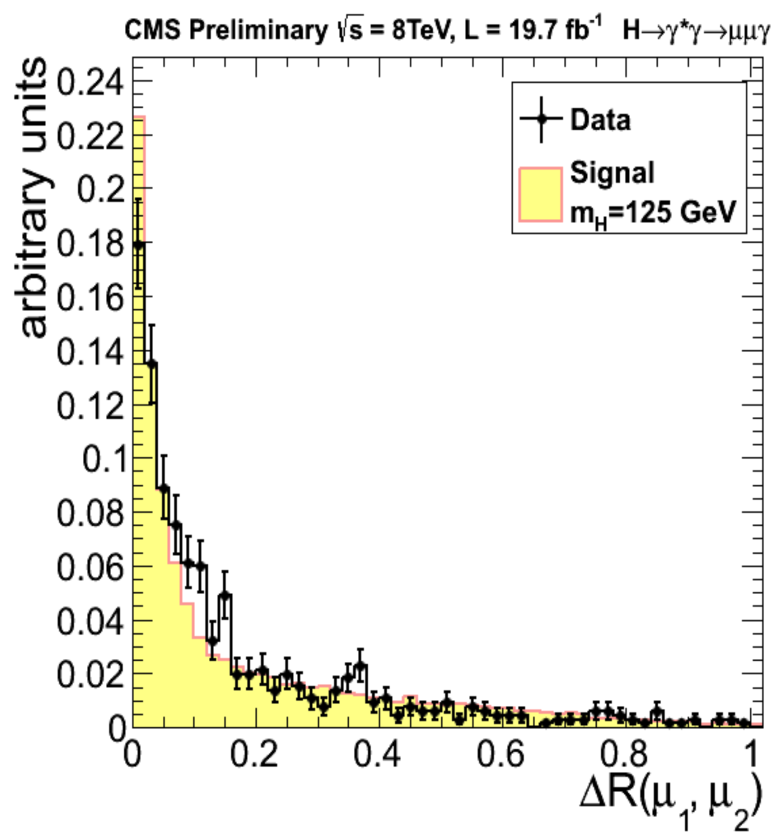
- Trigger: muon plus photon
- Two opposite sign muons.
- Muons: $|\eta| < 2.4$, Photons: $|\eta| < 1.44$
- All particles must be isolated.
- Transverse momentum: greater than 23 GeV for the highest-pT lepton and greater than 4 GeV for next to highest-pT lepton.
- $p^{\gamma}_T/m_{\mu\mu\lambda}>0.3$ for photon, $p^{\mu\mu}_T/m_{\mu\mu\lambda}>0.3$ for the muon pair.
- Dilepton invariant mass less than 20 GeV.
- Mass window: invariant mass of the dilepton-photon system between 110 and 170 GeV



Event Selection

- Events with dilepton mass between 2.9 – 3.3 GeV to reject **J/Ψ** and 9.3 – 9.7 GeV to reject Upsilon **(U)** contamination.
- ΔR separation between each lepton and the photon must be greater than 1.0



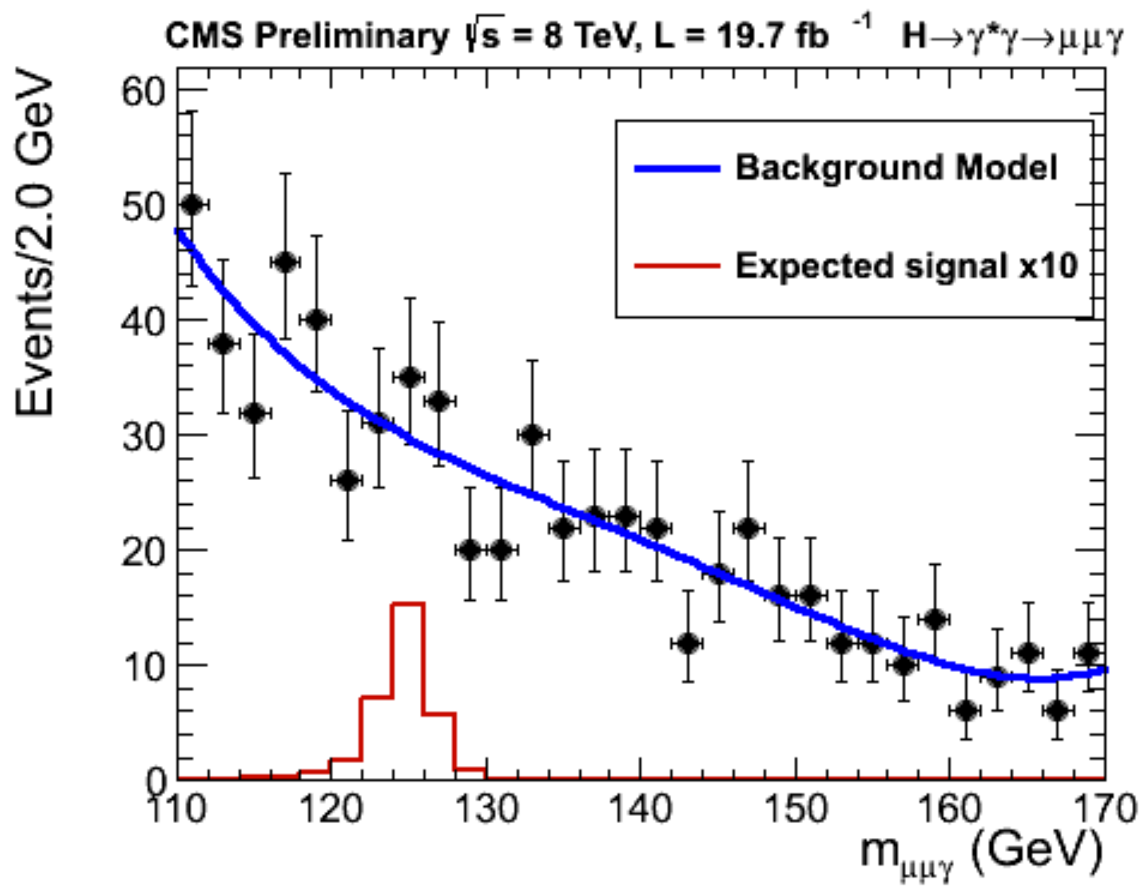


Event Selection

Requirement	Observed event yield	Expected number of signal events for $m_{\mathrm{H}} = 125$ GeV
Trigger, photon selection, $p_T^{\gamma} > 25$ GeV	0.6M	6.2
Muon selection, $p_T^{\mu 1} > 23$ GeV and $p_T^{\mu 2} > 4$ GeV	55836	4.7
110 GeV $< m_{\mu\mu\gamma} <$170 GeV	7800	4.7
$m_{\mu\mu} < 20$ GeV	1142	3.9
$\Delta\mathrm{R}(\gamma, \mu) > 1$	1138	3.9
Removal of resonances	1020	3.7
$p_T^{\gamma}/m_{\mu\mu\gamma} > 0.3$ and $p_T^{\mu\mu}/m_{\mu\mu\gamma} > 0.3$	665	3.3
122 GeV $< m_{\mu\mu\gamma} <$ 128 GeV	99	2.9

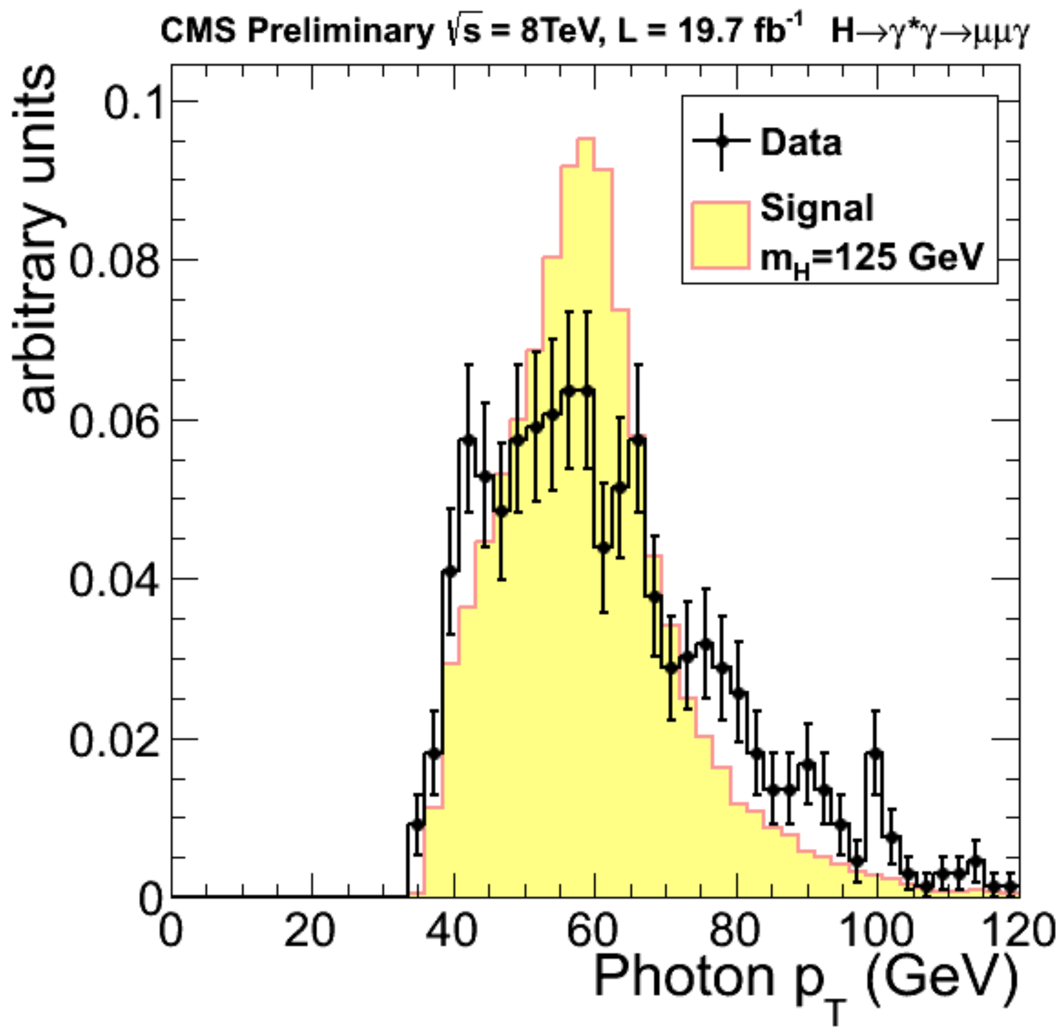
Background and signal modeling

- ✓ The background model is obtained by fitting the observed $\mu\mu\gamma$ mass distribution.
- ✓ The fitting is performed over 110-170 GeV mass range.
- ✓ The $\mu\mu\gamma$ spectrum is a falling distribution and it is fitted to a polynomial.



Background and signal modeling

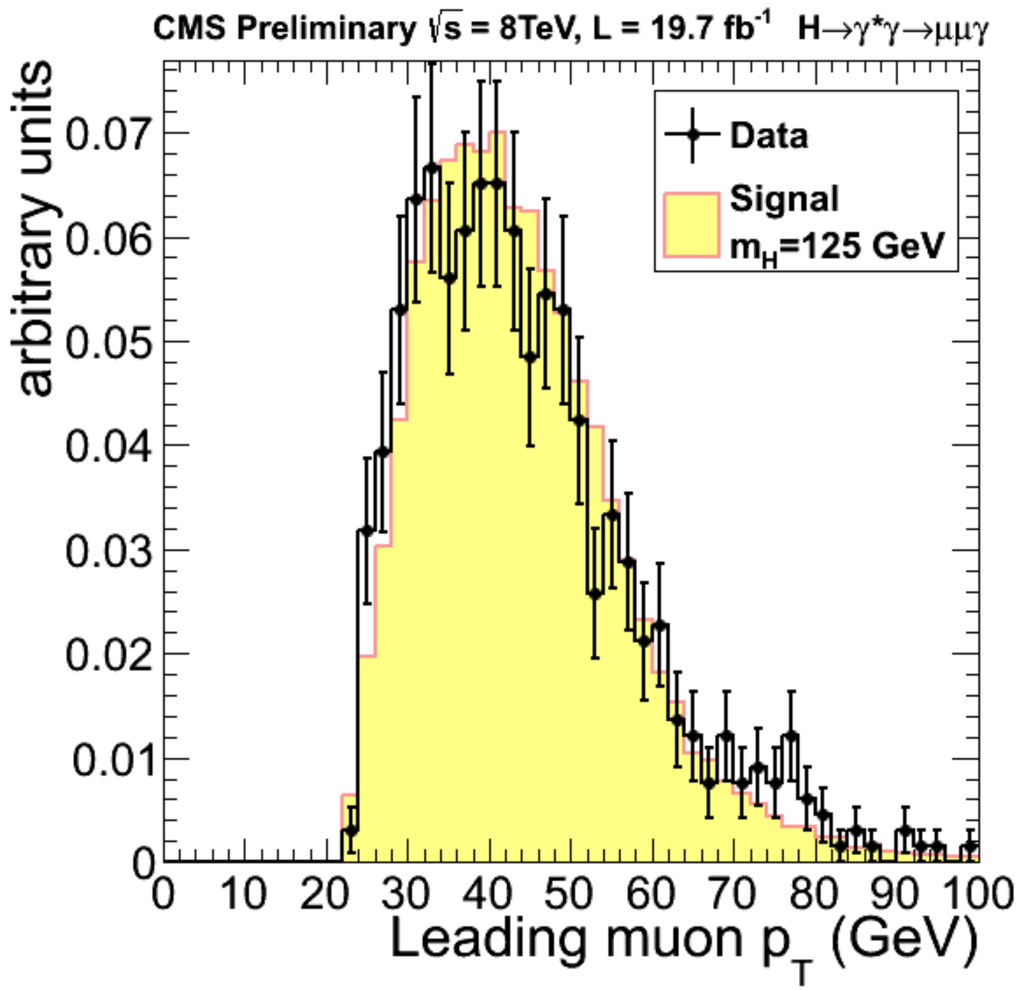
- The description of the Higgs boson signal used in the search is obtained from simulated events produced at leading order using Madgraph.



Background and signal modeling

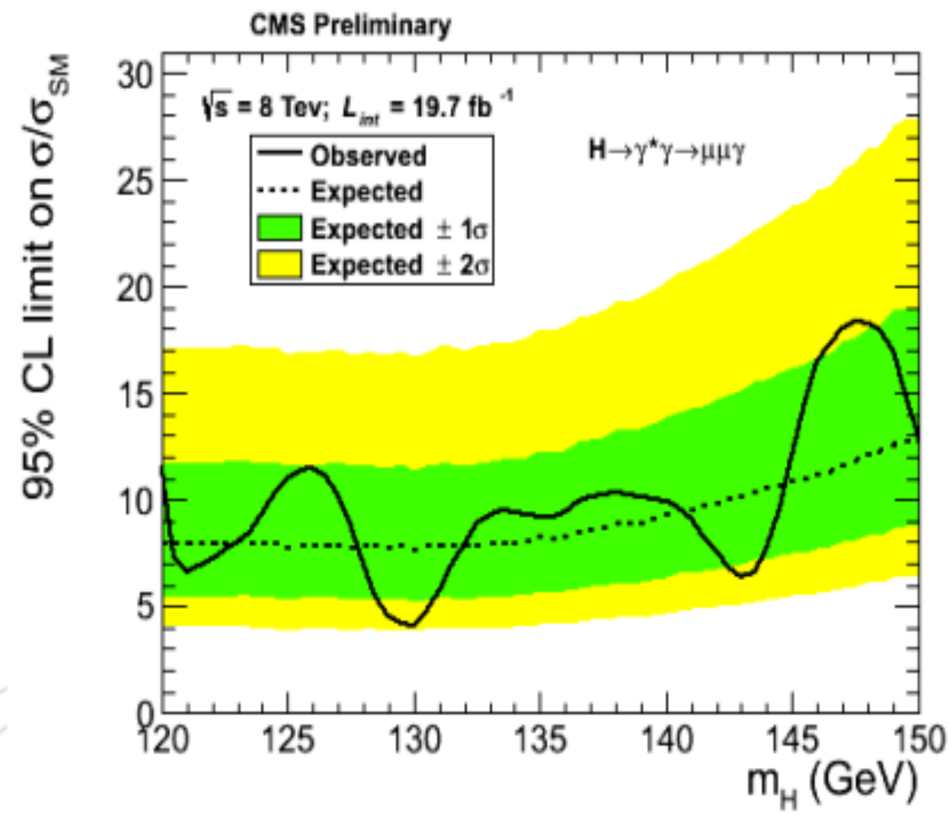
- ✓ The branching fractions are estimated using MCFM

- ✓ The simulated signal events are weighted by scale factors to take into account the difference between data and simulated events.



Results

- ✓ No excess above standard model predictions has been found and the first limits on the Higgs boson production cross section times the h → $\gamma^*\gamma$ branching fraction at the LHC have been derived.
- ✓ The expected exclusion limits at 95% confidence level are between 8 and 13 times the standard model cross section in the 120–150 GeV mass range.
- ✓ The observed limit for $m_{\mu\mu\gamma}$ at 125 GeV and $m_{\mu\mu} < 20$ GeV is within one order of magnitude of the SM prediction



Perspectives

- ✓ The trigger for the next run at 13 TeV is under development.

- ✓ The studies for the electron channel are in progress.

BACKUP

Event Selection

- The trigger efficiency for signal events containing dimuons and a photon satisfying the offline event selection requirements is measured to be 85%.
- The transverse momentum requirement on the highest-pT muon is driven by the trigger threshold and on the next to highest-pT by the minimum energy needed to reach the muon system
- The photon threshold is optimized for high signal efficiency and background rejection.
- The leptons are required to originate from the same primary vertex.

Event Selection

- A cone of size $\Delta R = 0.4$ is constructed around the momentum direction of each lepton candidate.
- To reduce the background from misidentified jets in the photon reconstruction, photon clusters are required to be isolated from other particles within a cone size of $\Delta R = 0.3$.
- If two dilepton pairs are present the pair with the lowest dilepton invariant mass is chose.

Background and signal modeling

- The wide $m_{\mu\mu\gamma}$ fitting range in the background modeling is found to be necessary to remove potential bias.
- The results of these fits are used to determine an appropriate degree of polynomial model for background.
- A fourth-order polynomial is chosen to fit the data.