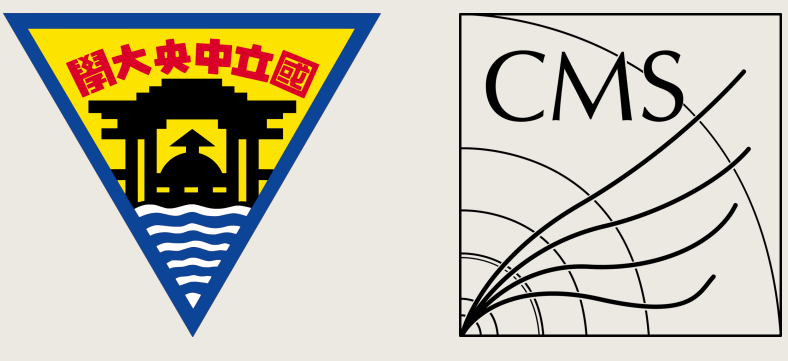


Studies of rare Higgs decay $H \rightarrow Z\gamma$ in CMS at $\sqrt{s} = 13\text{TeV}$

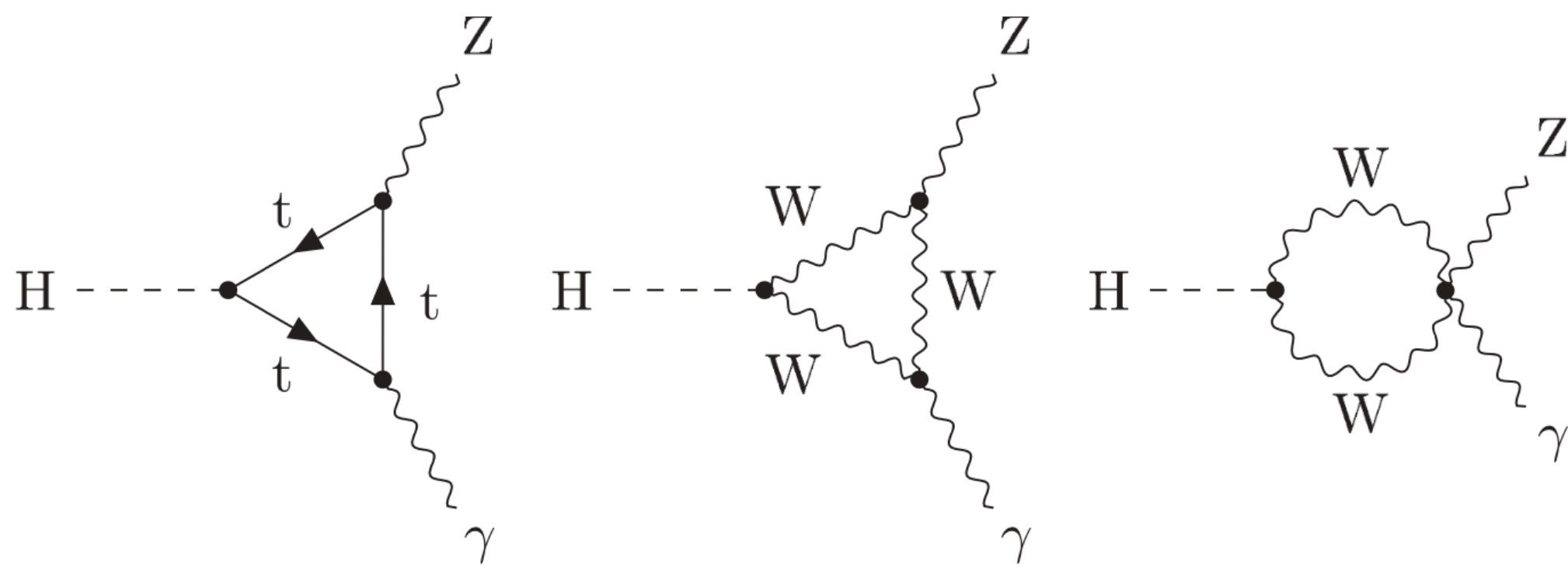


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Introduction

The rare decay channel $H \rightarrow Z\gamma \rightarrow l\bar{l}\gamma$ has the clean final state that the Higgs boson can be reconstructed with high mass resolution. The loop diagrams make it sensitive to BSM.

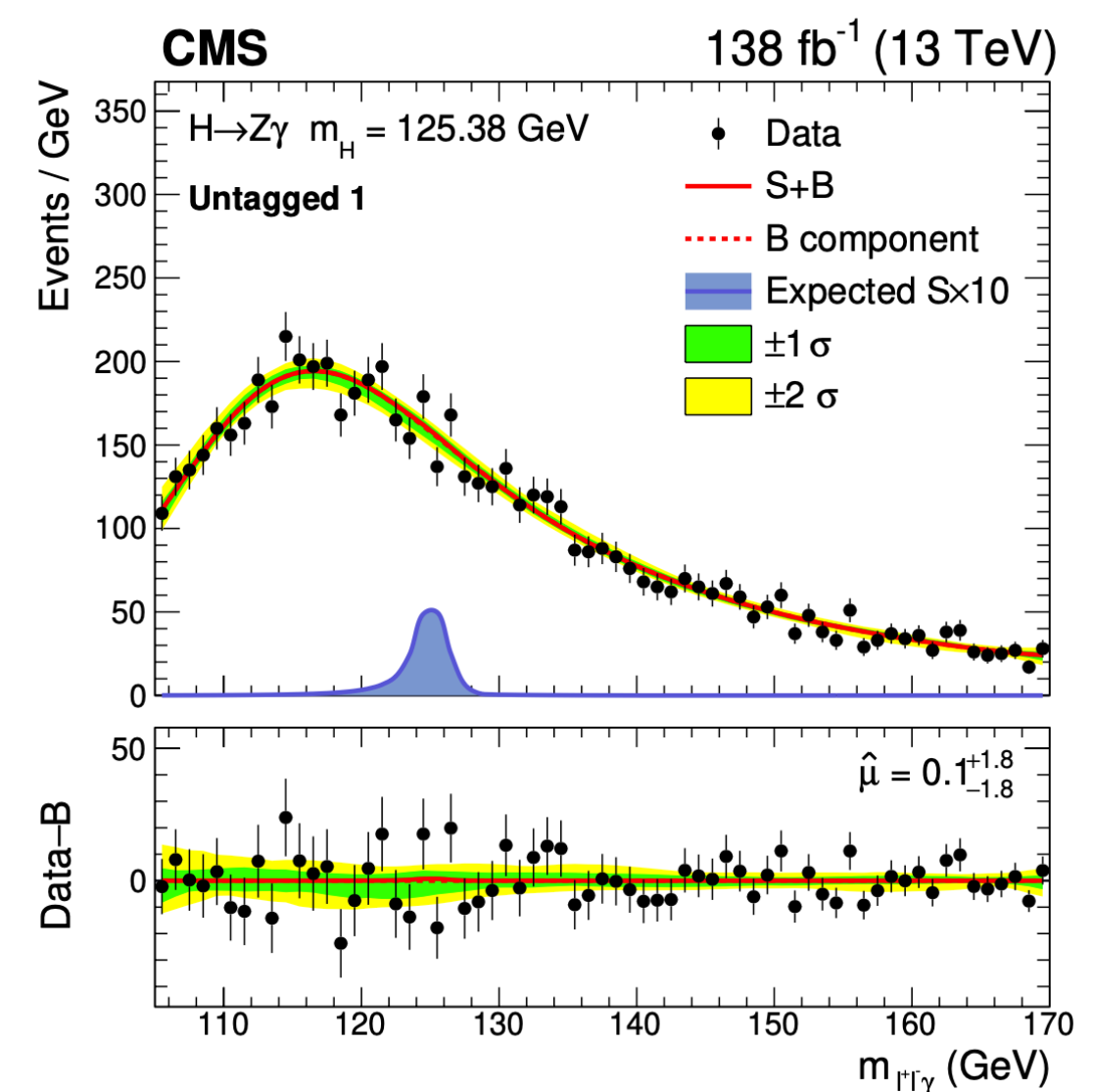


Signal & Background modeling

The fitting on refit $M_{ll\gamma}$ in 105-170 GeV is performed.

- Signal model :**
Fit the signal MC sample with Crystal Ball function+Gaussian.
- Background model :**
Fit the data with turn-on considered.

$$\int_{105}^{170} N(m_{ll\gamma} - t; \mu, \sigma) f(t; \vec{\alpha}) \Theta(s, t) dt$$



Event selection

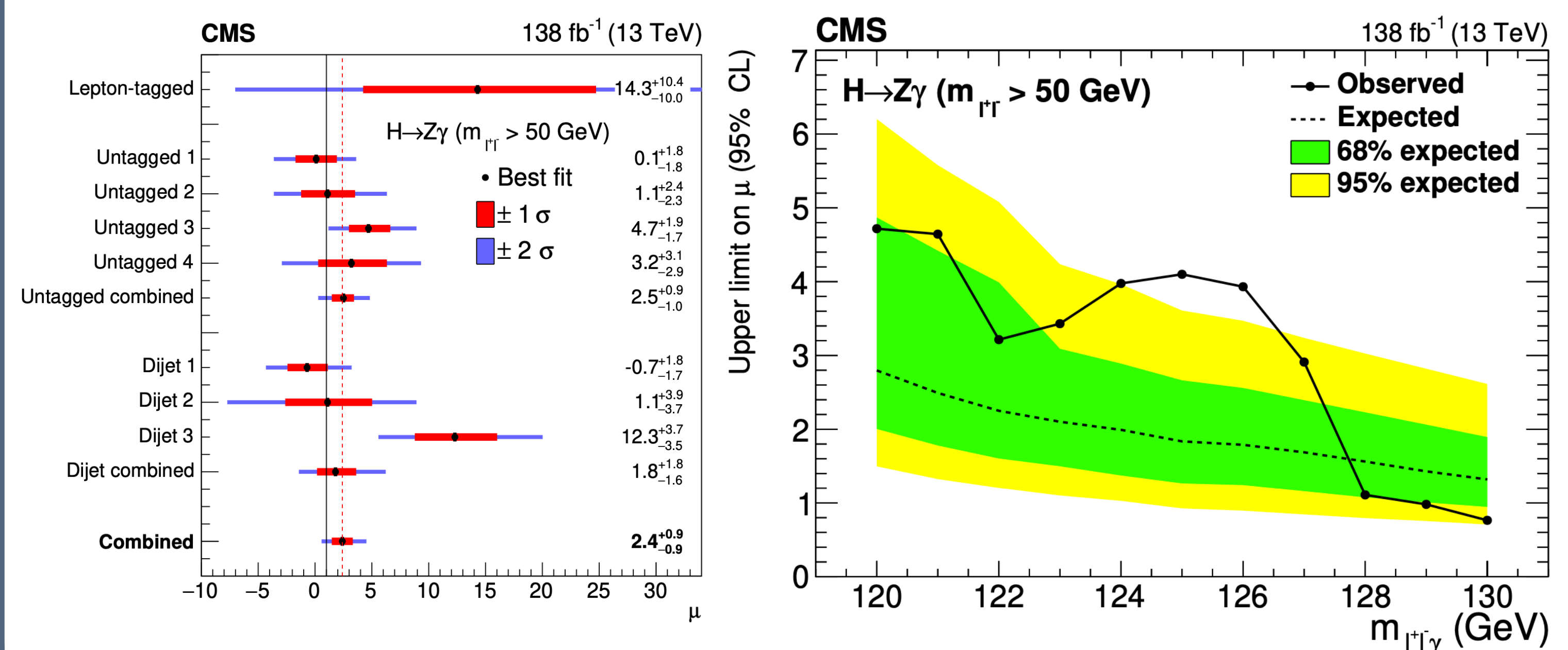
The total integrated luminosity of Run-2 data is 138 fb⁻¹. The dominant backgrounds are SM Z+jets and Zγ process.

High level trigger	Dielectron/Dimuon → reduce the event rate
Lepton selection	Leading e(μ) P _T > 25(20) GeV Trailing e(μ) P _T > 15(10) GeV M _{ll} > 50 GeV → exclude H → γ*γ channel
Photon selection	E _T > 15 GeV
3-body selection	Photon E _T /M _{llγ} > 15/110 ΔR(l, γ) > 0.4 M _{ll} +M _{llγ} > 185 GeV → reject Z+jets background
Analysis method	Final state radiation (FSR) recovery → add FSR γ energy to reconstructed muon Kinematic refit → refit the M _{ll} distribution by true Z shape

CMS Run-2 results

Dijet 1 is the most sensitive category among 8 categories. The observed(expected) limit on the signal strength relative to the SM prediction is 4.1 (1.8).

After all analysis methods are applied, the expected and observed significance is 1.2σ and 2.7σ, respectively.

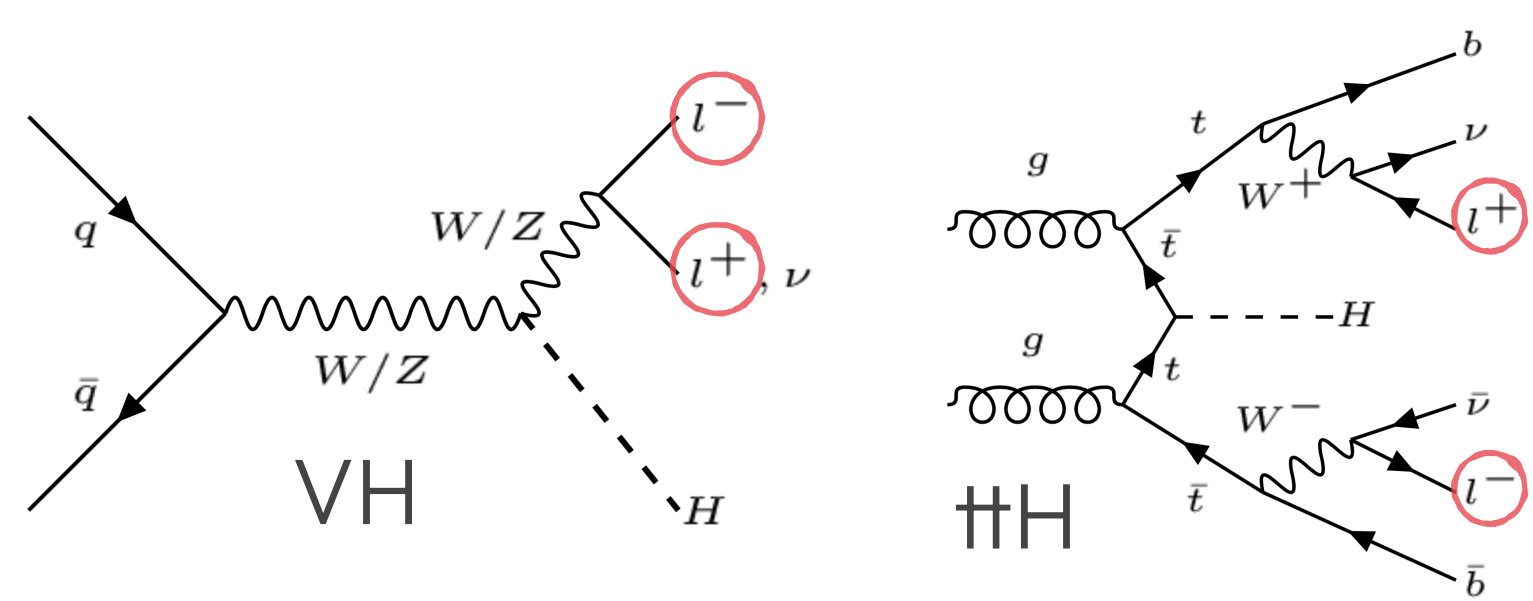


Categorization

To improve the sensitivity, the events are separated into inclusive categories by tagging the additional particles from different Higgs production processes.

Lepton tag

Select additional e(μ) with p_T > 7(5) GeV.

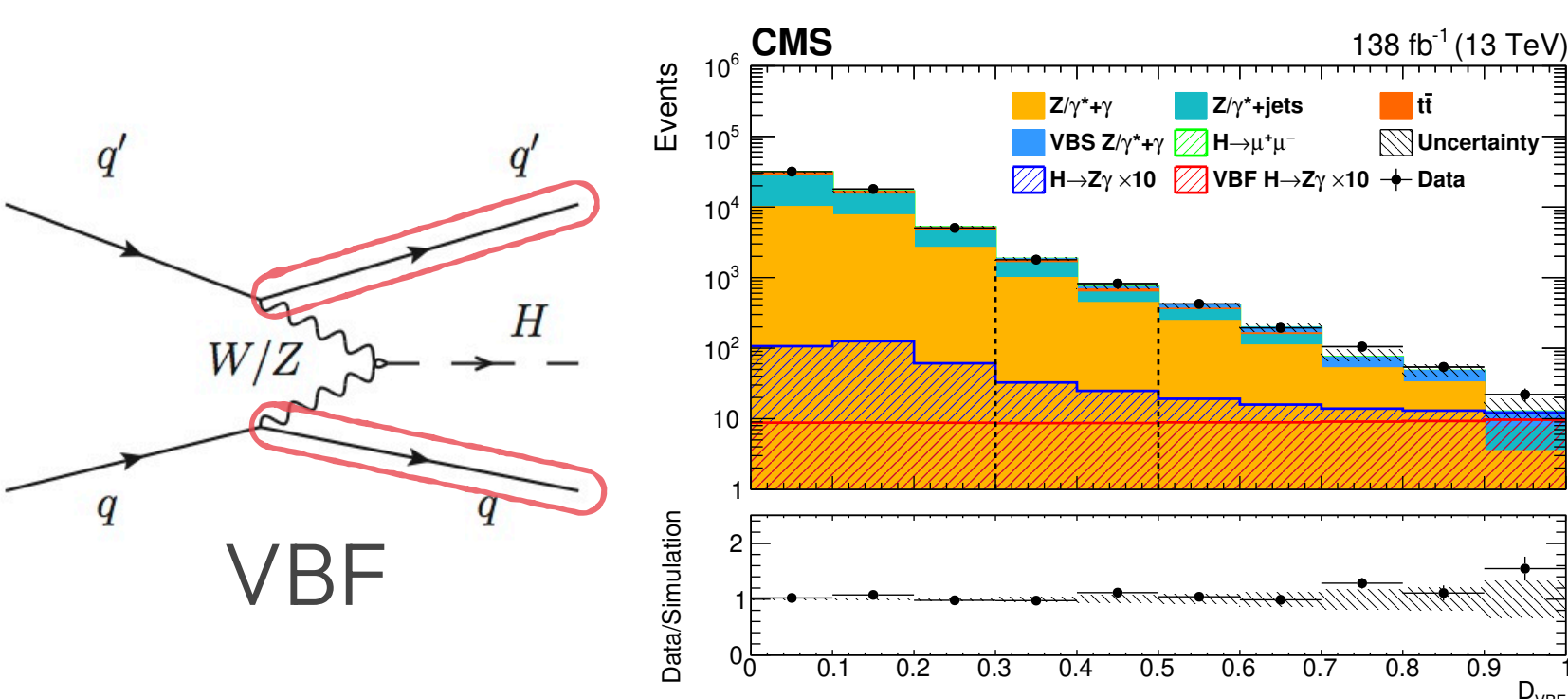


Dijet tag

Select additional dijet.

3 subcategories by VBF MVA

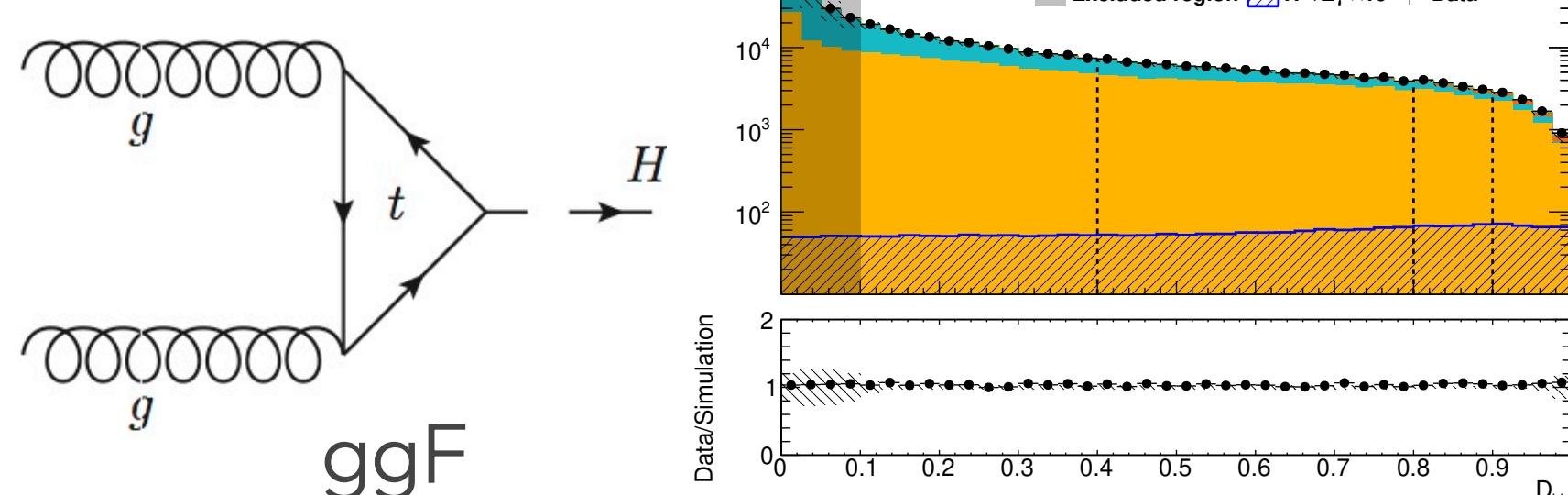
dijet variable, kinMVA



Untagged events

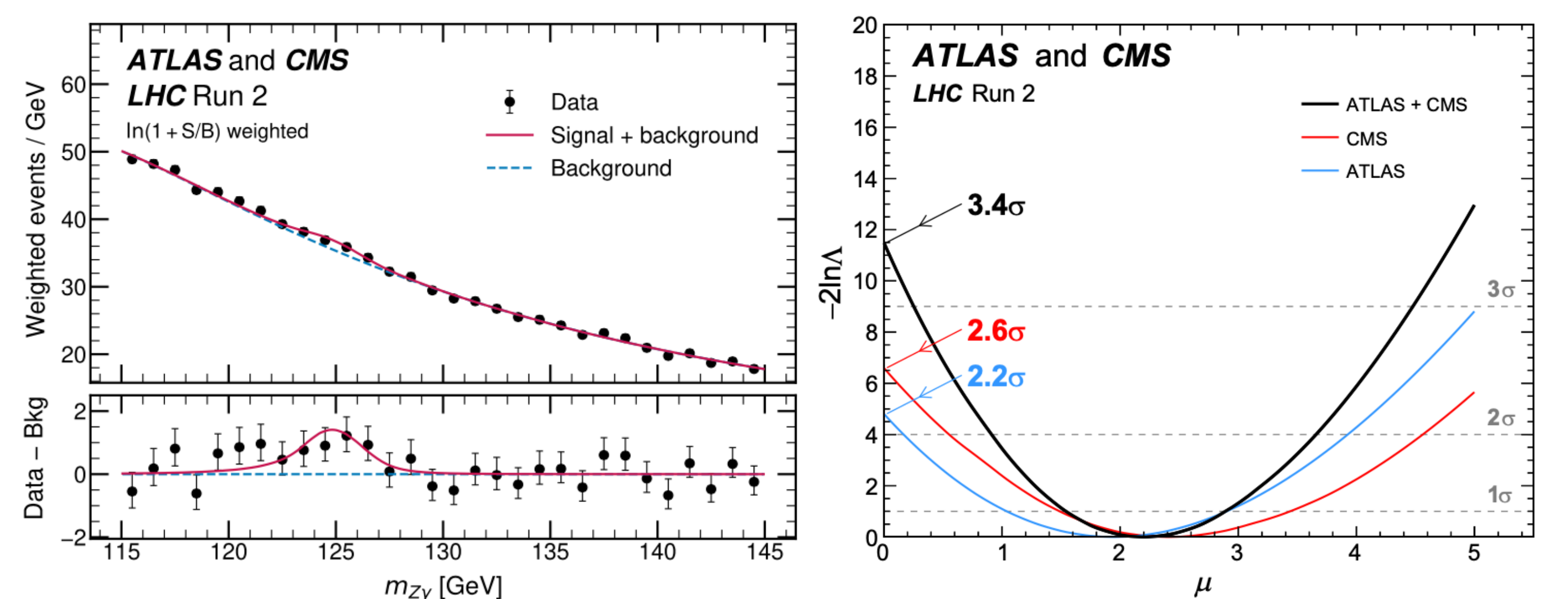
4 subcategories by kinematic MVA

angle and kinematics of final state particles, γ IDMVA, σ_γ/E_γ, p_T^H/m_H



ATLAS & CMS combination

Evidence for $H \rightarrow Z\gamma$ decay has been found after the combined results of ATLAS and CMS experiment, with an observed significance of 3.4σ. The observed signal yield is 2.2 ± 0.7 times the SM prediction.



Conclusions

- The study of rare Higgs boson decay channel $H \rightarrow Z\gamma \rightarrow l\bar{l}\gamma$ is performed and analysis workflow is introduced.
- The observed significance of CMS Run-2 results is 2.7σ and the observed limit is 4.1.
- The first evidence of this channel with 3.4σ by the combination of CMS and ATLAS results.

[1] Evidence for the Higgs Boson Decay to a Z Boson and a Photon at the LHC, Physical Review Letters, 132(2309.03501)

[2] Search for Higgs Boson Decays to a Z boson and a Photon in Proton-Proton Collisions at $\sqrt{s} = 13\text{TeV}$, J. High Energy Phys. 05 (2023) 233.