Study of Z and Higgs boson decaying into (J/ψ)γ in pp collisions at √s=13TeV

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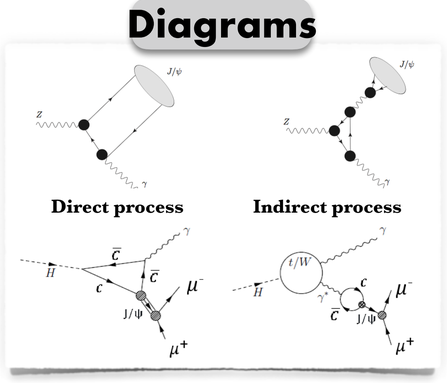
Abstract

A search for the decays of the SM Z and Higgs bosons decaying to (J/ψ)γ, with subsequent decay of the J/ψ to μ+μ−, is presented. The analysis is performed using data recorded by the CMS detector from pp collisions at center-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 35.86 fb^{-1}.

Introduction

Diagrams



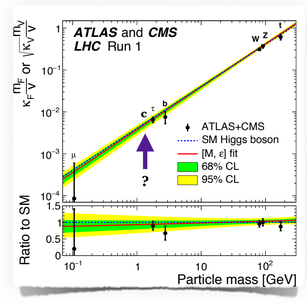
- SM rare decay
  - Suppressed by Zγγ* coupling
- Experimental benchmark for the Higgs decay

- Rare decay of the Higgs boson
- Alternative probe to **Higgs-Charm coupling**

Signatures
- High-p_T photon and J/ψ are produced in back-to-back direction
- Muons from J/ψ decay will be close to each other spatially

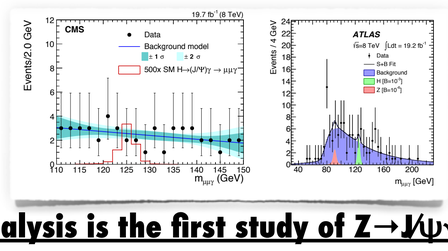
Physical Significance

- Quarkonium production in pp collisions



Previous Results

			Expected	Observed
Z→J/ψγ	ATLAS	95% C.L (upper limit)	**2.0×10⁻⁶**	2.6×10⁻⁶
H→J/ψγ	CMS		**1.6×10⁻³**	1.5×10⁻³
	ATLAS		**1.2×10⁻³**	1.5×10⁻³



This analysis is the first study of Z→J/ψγ in CMS!

Analysis Strategy

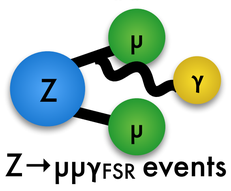
Event Selection

Trigger	Muon-Photon trigger with p_T^{μ} >17 GeV and E_T^{photon} > 30GeV
Muon	H→ZZ→4ℓ ID, Isolation is applied on μ_{lead} p_T lead μ > 20 GeV; p_T trail μ > 4 GeV; $\lvert\eta^{\mu}\rvert$ < 2.4;
Photon	Photon MVA ID; $\lvert\eta_{SC}^{photon}\rvert$< 2.5

Kinematic cuts to further suppress the Drell-Yan process with FSR
Di-muon mass : 3.0<$m_{\mu\mu\gamma}$ < 3.2 GeV
$p_T^{\mu\mu}$,$E_T^{photon}/m_{\mu\mu\gamma}$ > 0.384(0.280) for the Z(Higgs) decay

Trigger

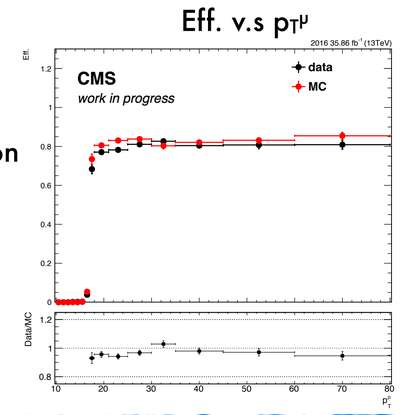
- The special trigger was designed for this analysis
  - The efficiency of the single and double muon trigger will be low due to closed-by muons



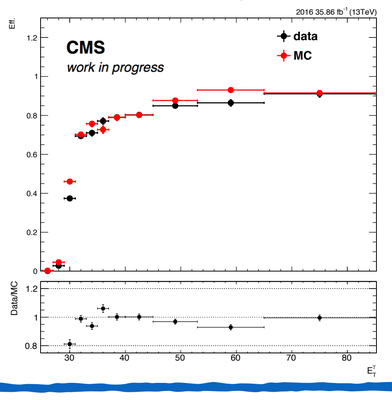
$Z\to\mu\mu\gamma_{FSR}$ events

Tag:Muon
Probe: Muon & Photon
→Measure the efficiency on probe μ and γ

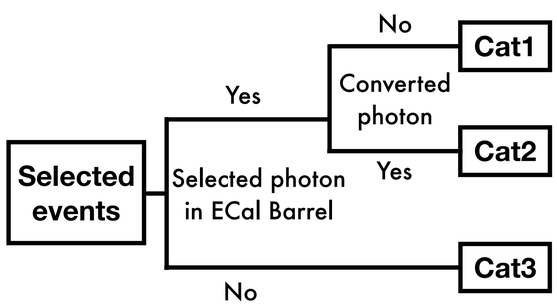
Eff. v.s p_T^{μ}



Eff. v.s E_T^{γ}



Event Categorization

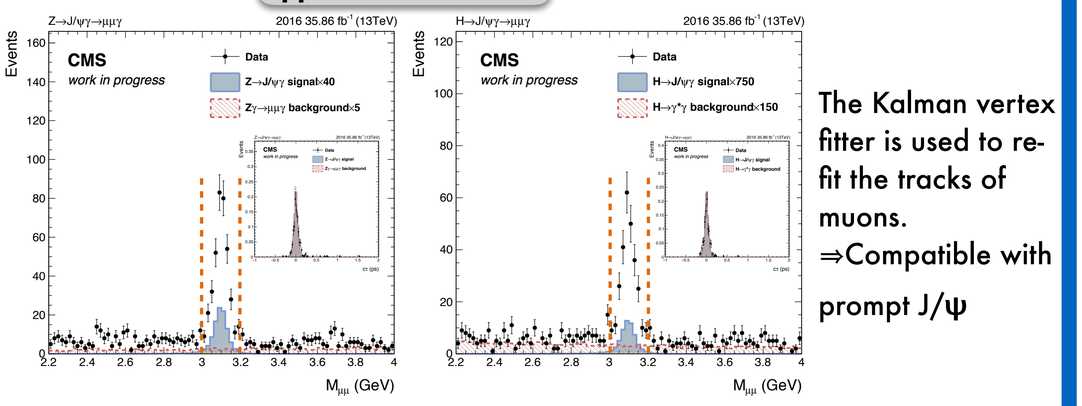


Event Yields

	Z→J/ψγ Data	Z→J/ψγ Signal	Z→μμγ$_{FSR}$ [2]	H→J/ψγ [1] Data	H→J/ψγ [1] Signal	H→γ*γ [2]
Inclusive	384	1.53	4.47	279	0.0649	0.193
Cat1	148	0.762	2.14			
Cat2	144	0.473	1.20			
Cat3	92	0.296	1.12			

[1] No categorization in the Higgs search
[2] The background exhibits a peak in $m_{\mu\mu\gamma}$

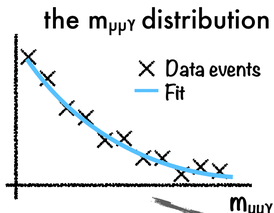
$m_{\mu\mu}$ distributions



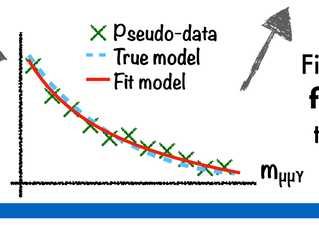
The Kalman vertex fitter is used to re-fit the tracks of muons.
⇒Compatible with prompt J/ψ

Background Model - Bias Study

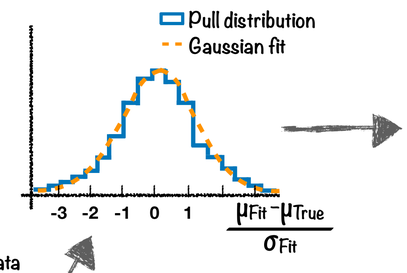
A function is chosen to fit the $m_{\mu\mu\gamma}$ distribution



Use the resulting fit as the **true model** to generate pseudo-data

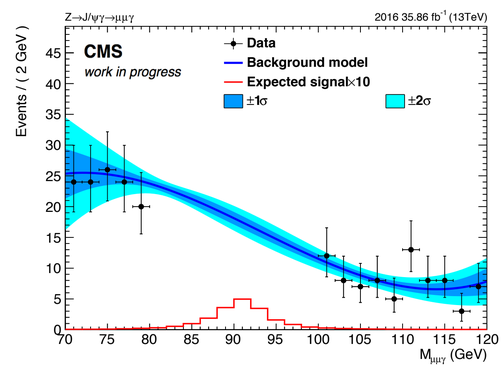


Fit the pseudo-data (with **fit model**) and extract the signal strength(μ_{Fit})

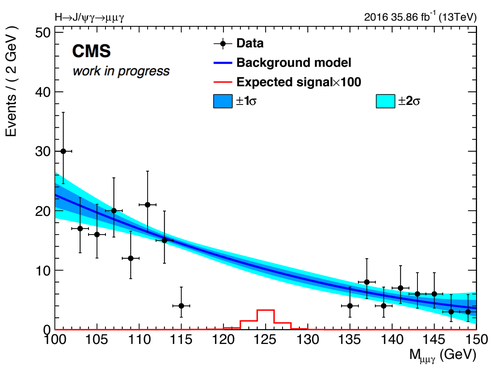


The bias is quantified as the mean value of the pull distribution.
- The final function must have **bias<20%**
- The bias introduced by the choice of the background function is less than 20% of the statistic error. Hence, this bias can be treated as negligible.
- No additional systematic uncertainty will be quoted on background function

$m_{\mu\mu\gamma}$ distributions & Final Fits



Bernstein polynomial of order 3



Bernstein polynomial of order 2

Result

Systematic uncertainty

Integrated luminosity	2.5%
Theoretical uncertainty	
QCD scale, PDF, α_s, decay branching	1.7~6.7%
Detector simulation, reconstruction, efficiency	
Pile-up weight	0.79~1.4%
Trigger	3.0~6.5%
Muon ID/Iso	2.3~3.6%
Photon MVA ID	1.1~2.0%
Electron veto	0.45~1.2%
Signal model	
$m_{\mu\mu\gamma}$ scale	< 0.1%
$m_{\mu\mu\gamma}$ resolution	0.80~4.0%

Limits

The expected exclusion upper limit at 95% C.L

Channel	σ(pp→Z/H)×BR(Z/H→(J/ψ)γ→μμγ)	BR(Z/H→(J/ψ)γ)
Z→(J/ψ)γ	**< 6.08 fb** (with 1σ band: 4.31 < σ×B < 8.72 fb)	**< 1.80×10⁻⁶** (**18.1** times the SM prediction) **SM prediction = 9.96×10⁻⁸**
H→(J/ψ)γ	**< 2.37 fb** (with 1σ band: 1.66 < σ×B < 3.43 fb)	**< 7.21×10⁻⁴** (**258** times the SM prediction) **SM prediction = 2.79×10⁻⁶**

σ(pp→H) = 55.6 pb, σ(pp→Z, m_{ll} > 50GeV) = 57094.5 pb, BR(J/ψ→μμ)=0.059

Summary

- A search for the decay of the SM Z and Higgs bosons decaying to (J/ψ)γ is performed.
- The expected upper limits at 95% C.L on branching fraction of Z(H)→J/ψ+γ : **1.80×10⁻⁶(7.21×10⁻⁴)**, which is **18.1(258)** times SM predictions.