Search for the rare decays of Z and Higgs bosons to J/ψ plus photon at √s=13TeV

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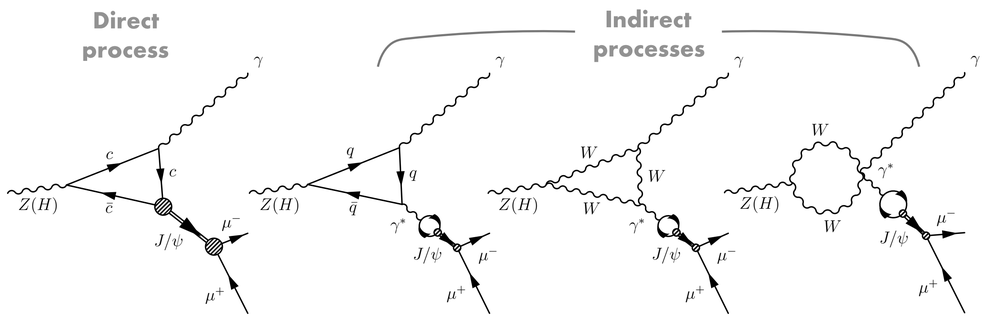
Abstract

A search for rare decays of Z and Higgs bosons to J/ψ meson and a photon, with the subsequent decay of J/ψ→μ+μ−, is presented. The analysis uses a data sample corresponding to an integrated luminosity of 35.9 fb^{-1} in proton-proton collisions at √s =13 TeV collected with the CMS detector at the LHC in 2016.

Introduction

Higgs-Charm coupling is currently loosely constrained !

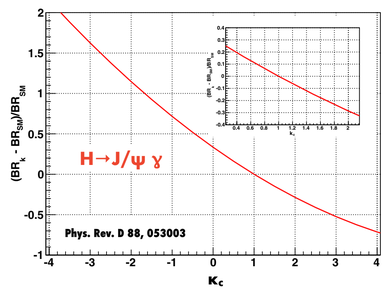


In the standard model (SM), branching fractions are predicted to be small

$BR_{SM}(Z→J/ψ\ γ)$	$9.0×10^{-8}$
$BR_{SM}(H→J/ψ\ γ)$	$3.0×10^{-6}$

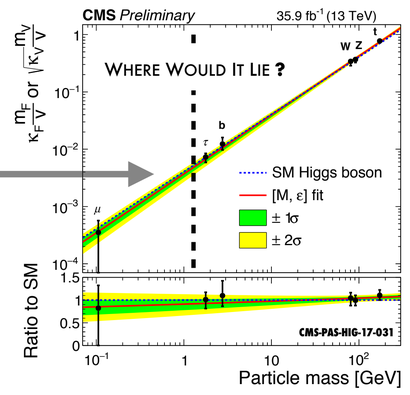
Any deviation from the SM Hc$\bar{c}$ coupling would affect the amplitude of the direct process and the interference term, and leads to the shift in the branching fraction

Destructive interference between direct and indirect processes



Extensions of the SM can modify the Hc$\bar{c}$ coupling

- Effective field theory at high cutoff scale Λ
- 2HDM with flavor symmetry violation
- The composite pNGB model (charm partner in SUSY ?)



Analysis Strategies

Event Selection

Trigger Muon-Photon trigger with p_T^{μ} >17 GeV and E_T^{γ} > 30GeV

Muon **Id**entify muons promptly produced at the primary event vertex (PV)

Isolation applied on μ_{lead} to reject decays of hadrons within jets

$p_T^{\ lead\ \mu}$ > 20 GeV; $p_T^{\ trail\ \mu}$ > 4 GeV; $|\eta^{\mu}|$ < 2.4;

Photon General-purpose MVA ID; $|\eta_{SC}^{\gamma}|$< 2.5, those in ECAL gap are rejected

Kinematic cuts to reject pp→Z/γ*+γ_{FSR}, pp→γ*+jets, and pp→γ+jets events
Consistent with J/ψ mass: 3.0 < $m_{\mu\mu}$ < 3.2 GeV

Background composition

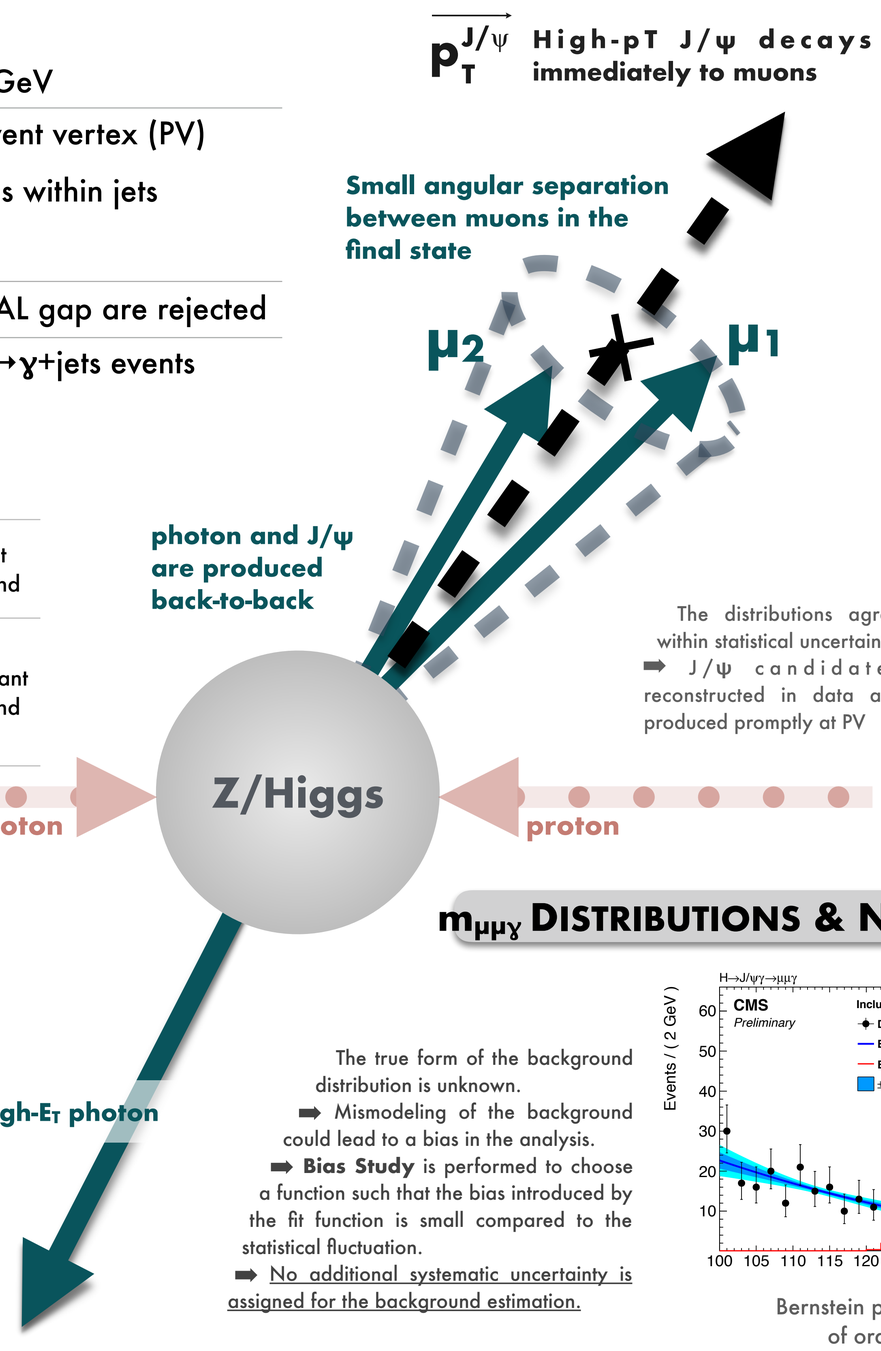
pp→Z/γ*→μμ$\gamma_{FSR/ISR}$	$m_{\mu\mu}$ in the J/ψ mass window $m_{\mu\mu\gamma}$ in the Z/Higgs mass window	Resonant background
pp→H→γ*γ		
pp→Z/γ*+jets	Jet misidentified as an energetic photon	Non-resonant background
pp→γ + jets	Muons from heavy-flavor decay in jets	
pp→J/ψ + jets/γ	Muons from J/ψ, jets misidentified as a photon	

- Resonant background is modeled independently
  - Estimated from simulated events
- Non-resonant background is modeled as a whole
  - Estimated from data (Currently no proper simulated sample)

Event Yields

Channel	Inclusive yields		
	Data	Signal	Resonant background
Z→J/ψ γ	384	1.5	4.5
H→J/ψ γ	279	$7.7×10^{-2}$	0.2

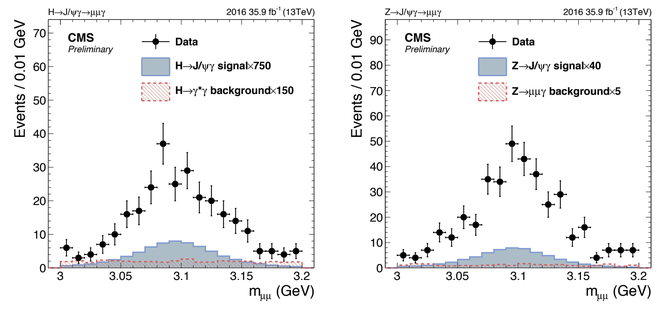
- J/ψ in the Higgs decay assumes the transverse polarization
- J/ψ in the Z decay is assumed to be unpolarized, and extreme polarizations give variation from -8% (transverse) to +16% (longitudinal) on expected yields



The distributions agree within statistical uncertainty
➡ J/ψ candidates reconstructed in data are produced promptly at PV

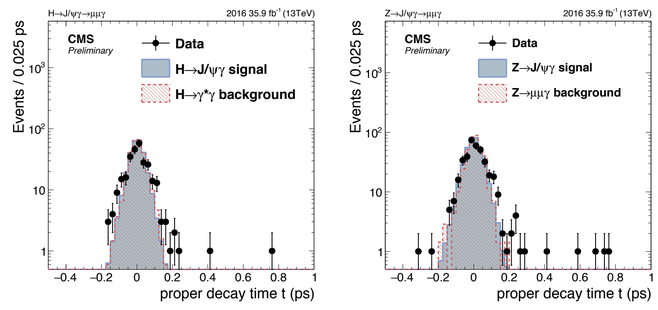
The true form of the background distribution is unknown.
➡ Mismodeling of the background could lead to a bias in the analysis.
➡ **Bias Study** is performed to choose a function such that the bias introduced by the fit function is small compared to the statistical fluctuation.
➡ No additional systematic uncertainty is assigned for the background estimation.

$m_{\mu\mu}$ Distributions

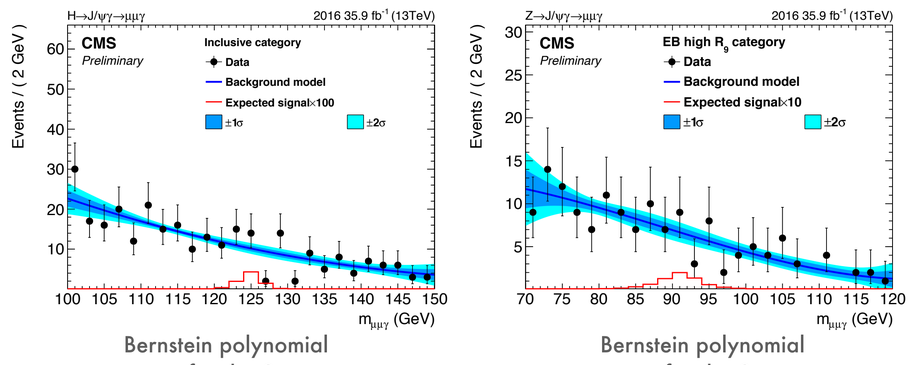


Proper Decay Time t Distributions

Distributions are normalized to the number of selected events in data



$m_{\mu\mu\gamma}$ Distributions & Non-resonant Background Model



Bernstein polynomial of order 3

Bernstein polynomial of order 2

Results

Systematic Uncertainty

Integrated luminosity	2.5%
Theoretical uncertainty	
QCD scale, PDF, α_s, decay branching ratio	1.7～6.7%
Detector simulation, reconstruction	
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	1.0～4.8%

The Observed And (Expected) Exclusion Upper Limits At 95% C.L

Channel	Polarization scenario	$BR(Z\ (H)→J/ψ\ γ)$	$\frac{BR(Z\ (H)→J/ψ\ γ)}{BR_{SM}(Z\ (H)→J/ψ\ γ)}$	Run1 results	
				ATLAS Phys. Rev. Lett. 114, 121801	CMS Phys. Lett. B 753 (2016) 341
Z→J/ψ γ	Unpolarized	$1.4(1.6^{+0.7}_{-0.5})×10^{-6}$	15 (17)	Assumed longitudinally polarized	-
	Transverse	$1.5(1.7^{+0.7}_{-0.5})×10^{-6}$	16 (19)		
	Longitudinal	$1.2(1.4^{+0.6}_{-0.4})×10^{-6}$	13 (15)	$2.6(2.0^{+1.0}_{-0.6})×10^{-6}$	
H→J/ψ γ	Transverse	$7.6(5.2^{+2.4}_{-1.6})×10^{-4}$	260 (170)	$1.5(1.2^{+0.6}_{-0.3})×10^{-3}$	$1.5(1.6^{+0.8}_{-0.8})×10^{-3}$

Combination with CMS Run1 result leads to an upper limit of **220 (160)**×SM

Summary

- **A search for rare decays of Z and Higgs boson to J/ψ meson and a photon is performed.**
- **The results provide the most stringent limits on both channels**
- **More data are required to approach the SM sensitivity.**

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