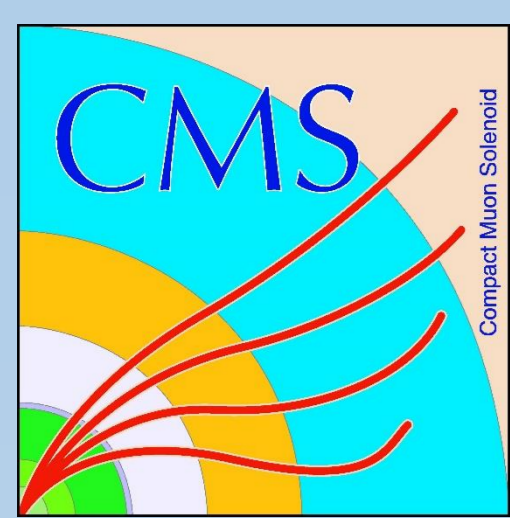# Study of a Higgs boson decaying into $J/\psi + \gamma$ in pp collisions at $\sqrt{s} = 13\text{TeV}$

Hao-Ren Jheng, Andrey Pozdnyakov, Chia-Ming Kuo for CMS collaboration
Department of Physics, National Central University, Jhongli, Taiwan

Abstract

With the discovery of Higgs boson around 125 GeV in 2012, the tasks have turn to understand the couplings of Higgs to examine whether this particle is the one predicted by Standard Model. The process $H \to J/\psi + \gamma$, with the subsequent decay $J/\psi \to \mu^+\mu^-$, is a promising channel to study the Higgs-Charm coupling which is a challenge at LHC. This analysis looks into the final state with $J/\psi \to \mu^+\mu^-$ and a photon. The results with data of pp collisions of 2.57 fb^{-1} at center-of-mass energy of 13 TeV will be presented.

Introduction

$H \to (J/\psi)\gamma \to \mu\mu\gamma$ is a promising process to access the couplings of the Higgs boson to the second generation quarks, charm quark, at the LHC [1, 2].

The advantage of this process is that it's a clean channel, while the disadvantage is that the expected Branching Ratio is small [3].
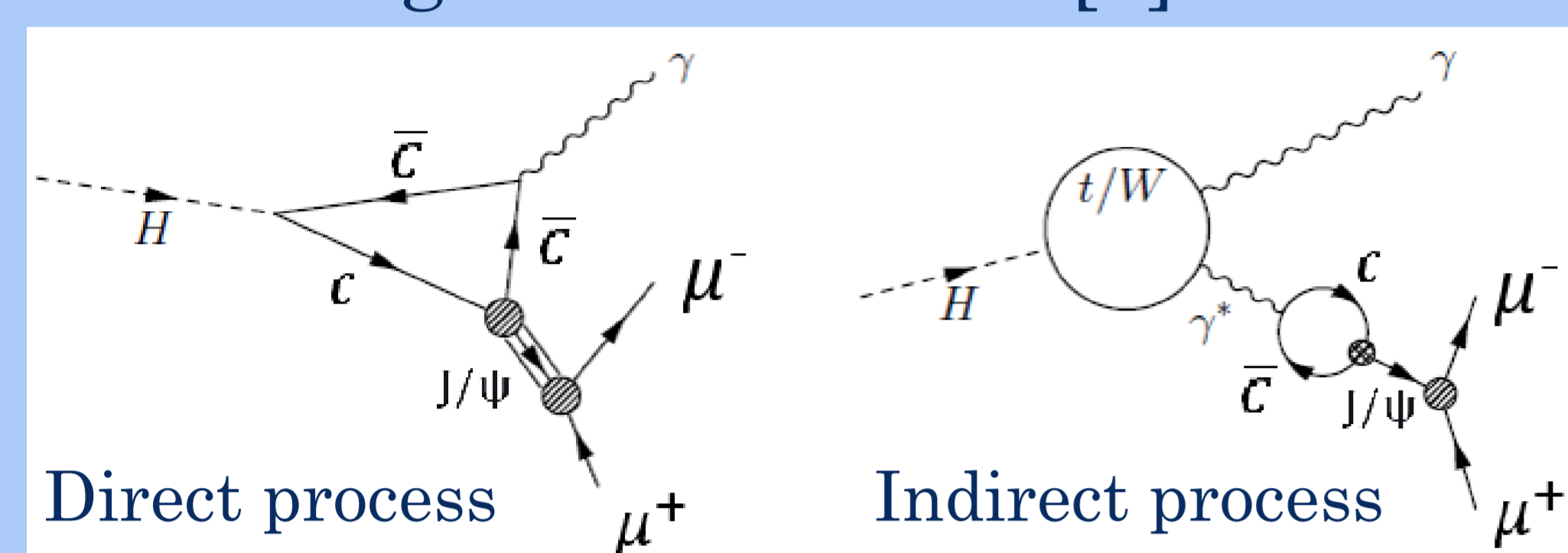

Fig. 1: The Feynman diagrams of $H \to (J/\psi)\gamma \to \mu\mu\gamma$ decay

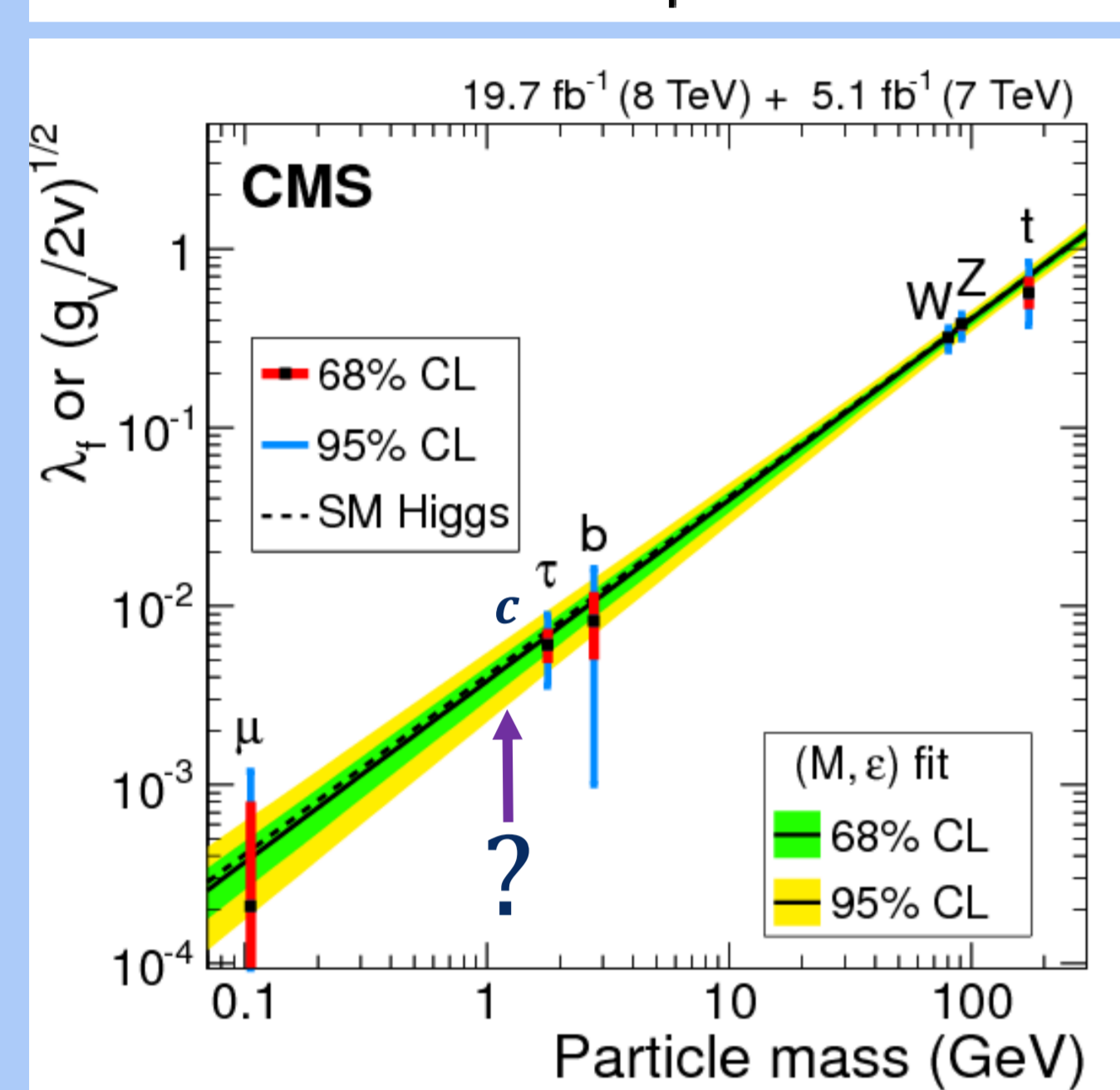Direct process   Indirect process

Fig. 2: The couplings of Higgs and other particles [4].

Event selection

The two muons are selected by *Loose ID*. Then, the leading muon needs to pass the loose cut of Particle Flow Isolation in cone 0.4. The photon has to pass MVA ID. The kinematic selections are also applied and listed below:

- $P_t^{\mu_{lead}} > 20$ GeV, $P_t^{\mu_{trail}} > 4$ GeV, $|\eta^\mu| < 2.4$
- $P_t^{\mu\mu} > 40$ GeV (di-muon transverse momentum)
- $E_t^\gamma > 40$GeV, $|\eta_{SC}^\gamma| < 2.5$, where SC is for supercluster (exclude those in ECAL gap region)
- $\Delta R(\mu_{lead}, \gamma) > 1$ & $\Delta R(\mu_{trail}, \gamma) > 1$
- $50 < m_{\mu\mu\gamma} < 150$ GeV

The following table shows the event yields in data.

Cut	Data events	Efficiency(%)	Signal events	Efficiency(%)
Total	12511292	-	50000	-
Trigger	2040155	16.3	26845	53.7
Muon Pt and eta cut	612964	4.9	22699	45.4
Muon selection	31802	0.3	16434	32.9
Photon selection	2963	0.02	11930	23.9
Muon-photon selection	1748	0.01	11651	23.3
Three-body mass	666	0.005	11413	22.8

Previous results from CMS and ATLAS

The search for the process $H \to (J/\psi)\gamma$ has been performed in CMS and ATLAS with $\sqrt{s} = 8$ TeV pp collision. Both show that no significant excess of events is observed above the background.

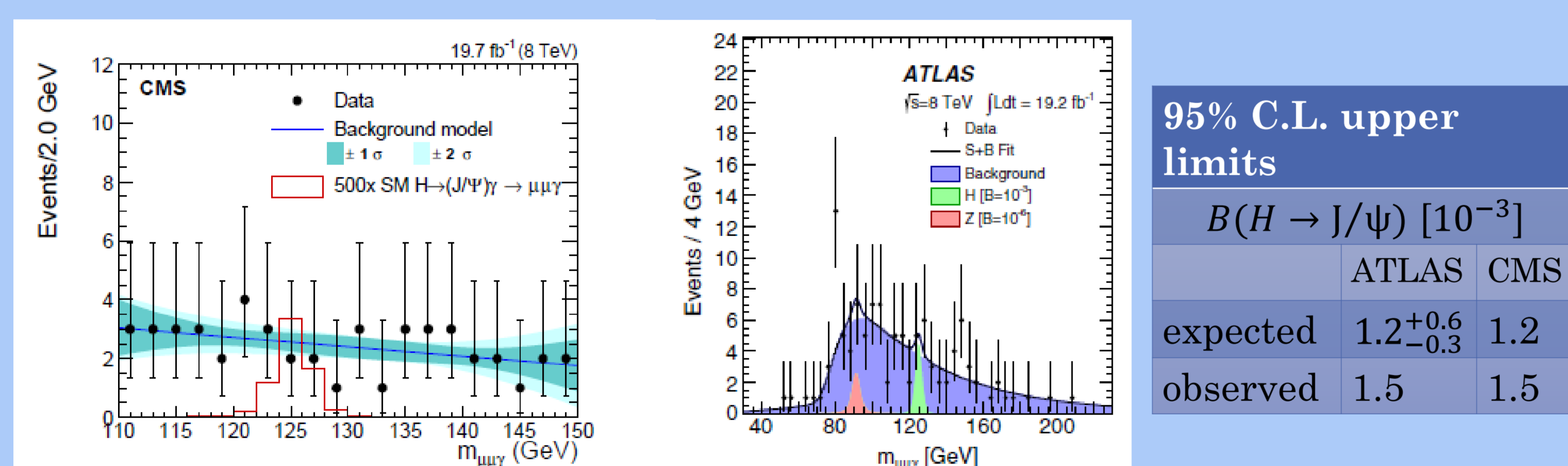| 95% C.L. upper limits		
$B(H \to J/\psi)$ $[10^{-3}]$		
	ATLAS	CMS
expected	$1.2^{+0.6}_{-0.3}$	1.2
observed	1.5	1.5

Fig. 2: The left plot is the result of CMS [5], while the middle one is of ATLAS [6]. The right table shows the expected and observed branching fraction limits at 95% C.L. for $\sqrt{s} = 8$ TeV.

Generator level study

Fig. 3: The generator level study is performed. (a) The distribution of transverse momentum of leading and trailing muons. (b) The distribution of transverse momentum of photon. (c) The distribution of pseudorapidity of leading and trailing muons. (d) The distribution of pseudorapidity of photon. (e) The distribution of angular separation of muons and photon. (f) The distribution of angular separation of the leading muon and the trailing one.

Current results and Outlook

Now the data after event selection is available. The next step is to fit the signal and data distribution of three-body invariant mass and set the limit on the signal, and extend the analysis to $Z \to (J/\psi)\gamma$.
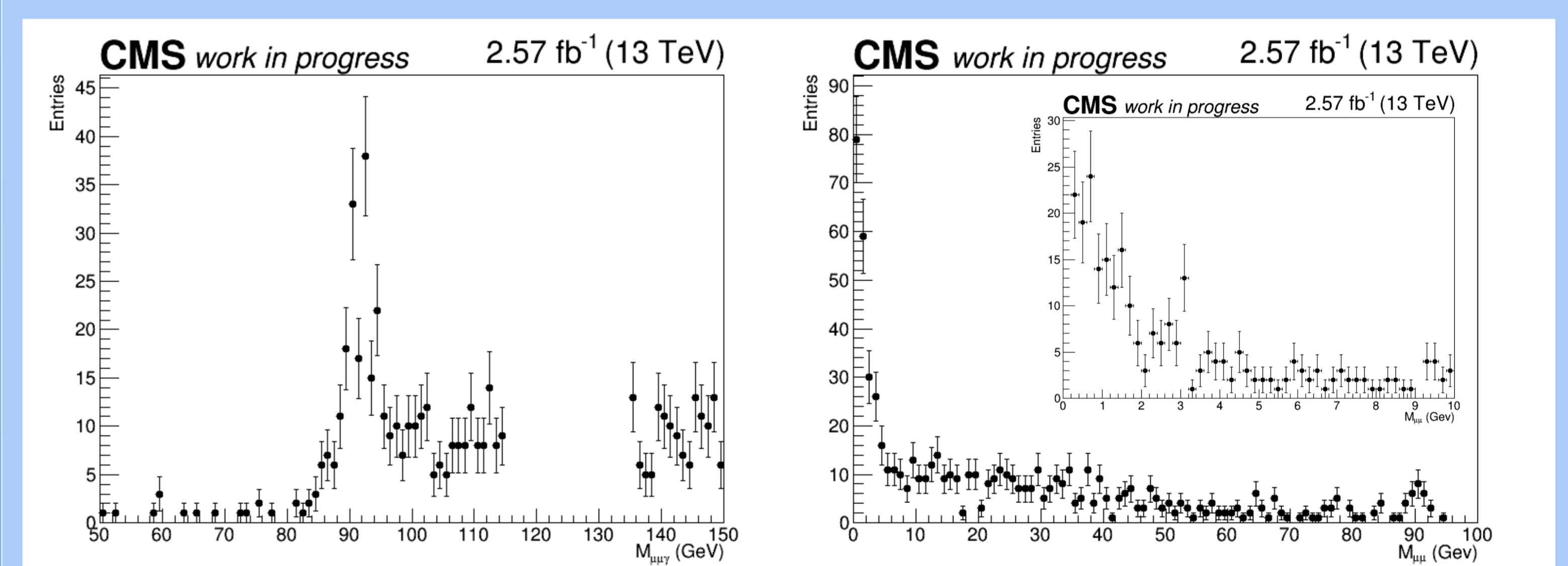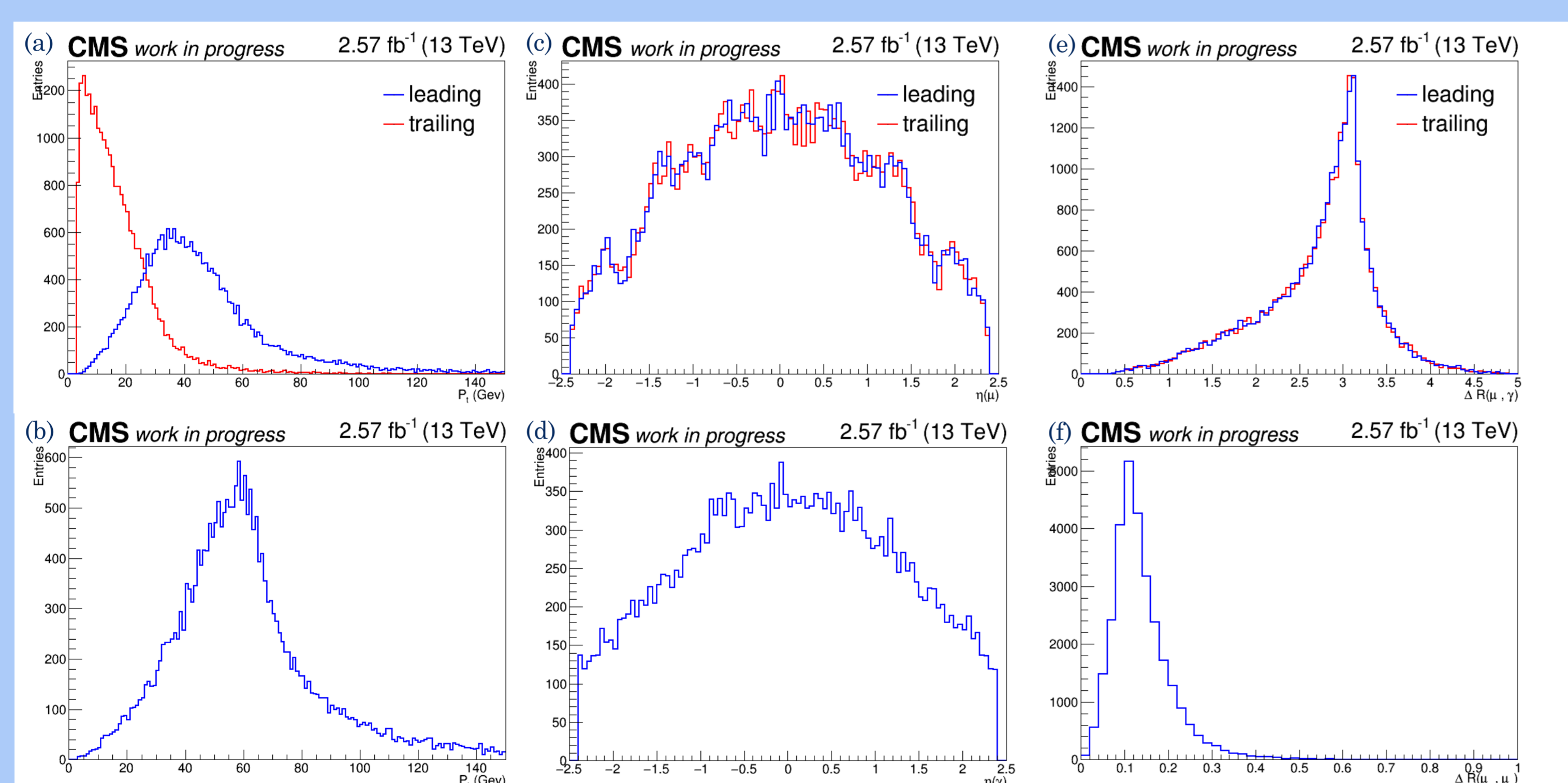

Fig. 4: The left plot is the distribution of the three-body invariant mass, $m_{\mu\mu\gamma}$, after the selections with data. The right plot is the distribution of the di-muon invariant mass, $m_{\mu\mu}$, after the selections with data.

Summary

- The preliminary results on $H \to (J/\psi)\gamma$ search at 13 TeV is performed.
- Limits on the signal need to be set.

Reference

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[2] G. T. Bodwin, F. Petriello, S. Stoynev, and M. Velasco, "Higgs boson decays to quarkonia and the $Hc\bar{c}$ coupling", Phys. Rev. D88 (2013) 053003.

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[4] CMS Collaboration, "Precise determination of the mass of the Higgs boson and tests of compatibility of its couplings with the standard model predictions using proton collisions at 7 and 8 TeV". Eur. Phys. J. C 75 (2015) 212

[5] CMS Collaboration, "Search for a Higgs boson decaying into $\gamma^*\gamma \to ll\gamma$ with low dilepton mass in pp collisions at $\sqrt{s} = 8$ TeV". Physics Letters B 753 (2016) 341–362

[6] ATLAS Collaboration, "Search for Higgs and Z Boson Decays to $J/\psi\gamma$ and $\Upsilon(nS)\gamma$ with the ATLAS Detector", Phys. Rev. Lett. 114 (2015) 121801