$\gamma\gamma + E_{\mathrm{T}}$ Study

Shikma Bressler (Weizmann Institute of Science), Stefania Gori, Rafael Texeira de Lima (Northeastern University), Abdollah Mohammadi (Kansas State University), Toyoko Orimoto (Northeastern University), Jessie Shelton (University of Illinois at Urbana-Champaign)

1 Introduction

Exotic decays of the Higgs can produce the final state consisting of two photons and missing transverse energy (E_{T}) [1]. In the non-resonant case, the photons arise from opposite sides of the initial two-body decay, $h \to XX, X \to \gamma Y$, where Y is a stable neutral particle. For instance, such a decay can occur within general gauge mediation models, in which the X corresponds to a neutralino NLSP with mass less than half the mass of the Higgs, and the Y corresponds to a gravitino LSP [2, 3, 4]. In the resonant case, the photons are produced through an intermediate resonance, $h \to XX$, with $X \to \gamma\gamma$ on one side of the decay and $X \to E_{\mathrm{T}}$ on the other side. The resonant scenario benefits from the fact that the signal will produce a peak in the diphoton invariant mass spectrum.

2 Methodology

2.1 MC Samples

The signal and background samples were modeled using the Snowmass LHE simulation samples [5].

2.2 Event Selection

2.3 Background Estimation

3 Results

3.1 Efficiencies

3.1.1 Gluon Fusion

Non Resonant Signal											
Cut	60 GeV	55 GeV	50 GeV	45 GeV	40 GeV	35 GeV	30 GeV	25 GeV	20 GeV	15 GeV	10 GeV
Total	1	1	1	1	1	1	1	1	1	1	1
$\#Photons > 1$	0.51434	0.50241	0.48409	0.45388	0.41766	0.38132	0.33371	0.27167	0.19816	0.12221	0.06242
$p_T(\gamma_1) > 30$ GeV, $\lvert\eta(\gamma_1)\rvert < 2.5$	0.34774	0.34757	0.34216	0.32699	0.30318	0.2766	0.23679	0.18866	0.128	0.07303	0.03313
$p_T(\gamma_2) > 25$ GeV, $\lvert\eta(\gamma_2)\rvert < 2.5$	0.18697	0.16896	0.16346	0.15384	0.14288	0.12813	0.1053	0.07904	0.04989	0.02538	0.00984
Missing $E_T > 40$ GeV	0.08447	0.06658	0.05838	0.05023	0.04438	0.04007	0.0326	0.0261	0.01774	0.00991	0.00444
$M(\gamma\gamma) < 100$ GeV	0.08436	0.06646	0.05814	0.04966	0.04376	0.03923	0.03172	0.02533	0.01735	0.0097	0.00428
Lepton veto	0.08434	0.06646	0.05814	0.04965	0.04376	0.03923	0.03171	0.02533	0.01734	0.0097	0.00428

Resonant Signal											
Cut	60 GeV	55 GeV	50 GeV	45 GeV	40 GeV	35 GeV	30 GeV	25 GeV	20 GeV	15 GeV	10 GeV
Total	1	1	1	1	1	1	1	1	1	1	1
$\#Photons > 1$	0.51898	0.50713	0.48222	0.45738	0.42313	0.40063	0.38249	0.36999	0.35572	0.3414	0.26678
$p_T(\gamma_1) > 30$ GeV, $\lvert\eta(\gamma_1)\rvert < 2.5$	0.40639	0.39552	0.36909	0.33967	0.30721	0.28989	0.2834	0.27902	0.27212	0.26035	0.18633
$p_T(\gamma_2) > 25$ GeV, $\lvert\eta(\gamma_2)\rvert < 2.5$	0.16685	0.11019	0.09699	0.09087	0.08979	0.09204	0.09306	0.09364	0.08858	0.07414	0.03187
Missing $E_T > 40$ GeV	0.05977	0.05026	0.04686	0.04654	0.04988	0.05299	0.05735	0.06057	0.06113	0.05576	0.02615
$M(\gamma\gamma) < 100$ GeV	0.05947	0.05011	0.04664	0.04634	0.04976	0.05287	0.05726	0.06036	0.06099	0.05557	0.02604
Lepton veto	0.05947	0.0501	0.04664	0.04632	0.04976	0.05286	0.05726	0.06036	0.06098	0.05556	0.02604

Backgrounds									
Cut	γ+Jets	Z+Jets	W+Jets	$\gamma\gamma$	ZZ	WW	$Z\gamma$	ZW	$W\gamma$
Total	1	1	1	1	1	1	1	1	1
#Photons > 1	6.34×10^{-3}	3.63×10^{-4}	1.35×10^{-4}	7.52×10^{-1}	9.16×10^{-4}	4.24×10^{-4}	1.78×10^{-2}	6.93×10^{-4}	1.59×10^{-2}
$p_T(\gamma_1) > 30$ GeV, $\lvert\eta(\gamma_1)\rvert < 2.5$	5.72×10^{-3}	2.38×10^{-4}	9.01×10^{-5}	3.82×10^{-1}	5.89×10^{-4}	2.79×10^{-4}	1.91×10^{-2}	4.20×10^{-4}	6.38×10^{-3}
$p_T(\gamma_2) > 25$ GeV, $\lvert\eta(\gamma_2)\rvert < 2.5$	4.19×10^{-3}	1.87×10^{-4}	6.99×10^{-5}	2.83×10^{-1}	4.57×10^{-4}	2.10×10^{-4}	1.24×10^{-2}	3.22×10^{-4}	4.21×10^{-3}
Missing $E_T > 40$ GeV	1.21×10^{-5}	3.53×10^{-5}	2.02×10^{-5}	5.16×10^{-4}	1.36×10^{-4}	9.27×10^{-5}	1.72×10^{-3}	1.27×10^{-4}	1.16×10^{-3}
$M(\gamma\gamma) < 100$ GeV	6.42×10^{-6}	1.63×10^{-5}	9.73×10^{-6}	2.71×10^{-4}	8.67×10^{-5}	5.13×10^{-5}	9.74×10^{-4}	7.11×10^{-5}	7.00×10^{-4}
Lepton veto	6.38×10^{-6}	1.50×10^{-5}	5.68×10^{-6}	2.71×10^{-4}	6.40×10^{-5}	2.44×10^{-5}	9.00×10^{-4}	4.15×10^{-5}	3.71×10^{-4}

3.1.2 Associated Production: ZH

Non Resonant Signal											
Cut	60 GeV	55 GeV	50 GeV	45 GeV	40 GeV	35 GeV	30 GeV	25 GeV	20 GeV	15 GeV	10 GeV
Total	1	1	1	1	1	1	1	1	1	1	1
$\#Photons > 1$	0.49847	0.48708	0.4682	0.4418	0.40974	0.37109	0.32405	0.26559	0.19575	0.1276	0.07497
$p_T(\gamma_1) > 30$ GeV, $\lvert\eta(\gamma_1)\rvert < 2.5$	0.39355	0.38422	0.36964	0.35164	0.32402	0.29054	0.24893	0.19661	0.13924	0.08686	0.04731
$p_T(\gamma_2) > 25$ GeV, $\lvert\eta(\gamma_2)\rvert < 2.5$	0.22938	0.21493	0.19488	0.17838	0.15863	0.14013	0.11677	0.08741	0.05879	0.03415	0.01735
Missing $E_T > 40$ GeV	0.12827	0.11556	0.1044	0.09297	0.0819	0.07554	0.06377	0.05028	0.03565	0.02264	0.01228
$M(\gamma\gamma) < 100$ GeV	0.12063	0.10775	0.09665	0.08498	0.07359	0.06674	0.05586	0.04283	0.02963	0.0183	0.0093
$\#Muons > 1$	0.073	0.06466	0.05858	0.05224	0.04644	0.04122	0.0346	0.02622	0.01712	0.01028	0.00464
$p_T(\mu_1) > 25$ GeV, $\lvert\eta(\mu_1)\rvert < 2.5$	0.0728	0.06446	0.05846	0.0522	0.0464	0.04114	0.03458	0.02614	0.01712	0.01028	0.00462
$p_T(\mu_2) > 20$ GeV, $\lvert\eta(\mu_2)\rvert < 2.5$	0.06534	0.05896	0.0533	0.04724	0.04228	0.03728	0.03192	0.02384	0.01544	0.00948	0.0042
$70 < M(\mu\mu) < 110$	0.064	0.05774	0.052	0.0461	0.04138	0.03646	0.03106	0.02332	0.01512	0.00916	0.00414

Resonant Signal											
Cut	60 GeV	55 GeV	50 GeV	45 GeV	40 GeV	35 GeV	30 GeV	25 GeV	20 GeV	15 GeV	10 GeV
Total	1	1	1	1	1	1	1	1	1	1	1
$\#Photons > 1$	0.50127	0.48716	0.47309	0.45791	0.4387	0.4172	0.40109	0.38675	0.36348	0.325	0.22608
$p_T(\gamma_1) > 30$ GeV, $\lvert\eta(\gamma_1)\rvert < 2.5$	0.44657	0.42029	0.39424	0.37381	0.35039	0.33109	0.32188	0.31446	0.29717	0.25988	0.16034
$p_T(\gamma_2) > 25$ GeV, $\lvert\eta(\gamma_2)\rvert < 2.5$	0.20569	0.17675	0.16194	0.16104	0.16021	0.15839	0.15502	0.15251	0.13691	0.10405	0.04343
Missing $E_T > 40$ GeV	0.12733	0.11034	0.09726	0.09382	0.09383	0.09341	0.0943	0.09596	0.08856	0.07286	0.03341
$M(\gamma\gamma) < 100$ GeV	0.11754	0.1016	0.08894	0.08594	0.08578	0.0858	0.08643	0.08803	0.08112	0.06581	0.02826
$\#Muons > 1$	0.0758	0.06706	0.05676	0.0502	0.05248	0.0515	0.0491	0.04946	0.04542	0.03474	0.01204
$p_T(\mu_1) > 25$ GeV, $\lvert\eta(\mu_1)\rvert < 2.5$	0.07566	0.06698	0.05672	0.05004	0.05244	0.0514	0.04894	0.0493	0.04516	0.0346	0.01194
$p_T(\mu_2) > 20$ GeV, $\lvert\eta(\mu_2)\rvert < 2.5$	0.0692	0.06114	0.05132	0.04584	0.0475	0.04626	0.04378	0.0441	0.04016	0.03016	0.01046
$70 < M(\mu\mu) < 110$	0.06746	0.05976	0.05	0.04458	0.0462	0.04508	0.04278	0.04286	0.03912	0.02932	0.01002

Backgrounds									
Cut	γ+Jets	Z+Jets	W+Jets	$\gamma\gamma$	ZZ	WW	$Z\gamma$	ZW	$W\gamma$
Total	1	1	1	1	1	1	1	1	1
$\#Photons > 1$	6.34×10^{-3}	3.63×10^{-4}	1.35×10^{-4}	7.52×10^{-1}	9.16×10^{-4}	4.24×10^{-4}	1.78×10^{-2}	6.93×10^{-4}	1.59×10^{-2}
$p_T(\gamma_1) > 30$ GeV, $\lvert\eta(\gamma_1)\rvert < 2.5$	5.72×10^{-3}	2.38×10^{-4}	9.01×10^{-5}	3.82×10^{-1}	5.89×10^{-4}	2.79×10^{-4}	1.91×10^{-2}	4.20×10^{-4}	6.38×10^{-3}
$p_T(\gamma_2) > 25$ GeV, $\lvert\eta(\gamma_2)\rvert < 2.5$	4.19×10^{-3}	1.87×10^{-4}	5.06×10^{-4}	2.83×10^{-1}	4.57×10^{-4}	2.10×10^{-4}	1.24×10^{-2}	3.22×10^{-4}	4.21×10^{-3}
Missing $E_T > 40$ GeV	1.21×10^{-5}	3.53×10^{-5}	1.46×10^{-4}	5.16×10^{-4}	1.36×10^{-4}	9.27×10^{-5}	1.72×10^{-3}	1.27×10^{-4}	1.16×10^{-3}
$M(\gamma\gamma) < 100$ GeV	6.42×10^{-6}	1.63×10^{-5}	7.05×10^{-5}	2.71×10^{-4}	8.67×10^{-5}	5.13×10^{-5}	9.74×10^{-4}	7.11×10^{-5}	7.00×10^{-4}
$\#Muons > 1$	0	2.07×10^{-8}	3.80×10^{-10}	0	1.50×10^{-6}	4.29×10^{-7}	1.42×10^{-6}	1.29×10^{-6}	1.20×10^{-7}
$p_T(\mu_1) > 25$ GeV, $\lvert\eta(\mu_1)\rvert < 2.5$	0	1.52×10^{-8}	1.65×10^{-10}	0	1.46×10^{-6}	4.04×10^{-7}	1.05×10^{-6}	1.26×10^{-6}	9.19×10^{-8}
$p_T(\mu_2) > 20$ GeV, $\lvert\eta(\mu_2)\rvert < 2.5$	0	9.02×10^{-9}	0	0	1.25×10^{-6}	3.04×10^{-7}	6.28×10^{-7}	1.06×10^{-6}	7.34×10^{-8}
$70 < M(\mu\mu) < 110$	0	7.13×10^{-9}	0	0	1.17×10^{-6}	9.79×10^{-8}	4.03×10^{-7}	8.75×10^{-7}	2.77×10^{-8}

3.2 Figures

3.2.1 Gluon Fusion

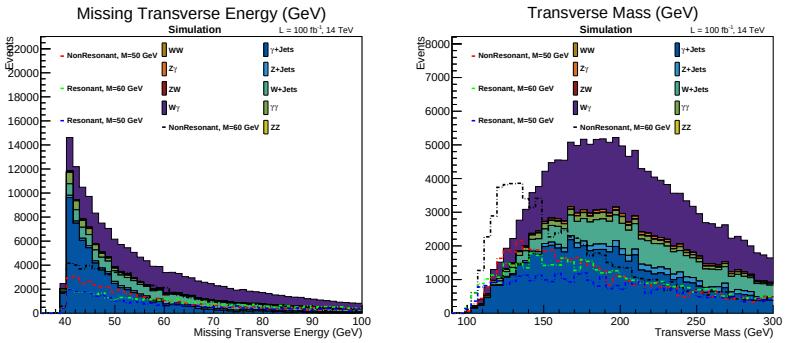

Figure 1: (left) E_{T} and (right) transverse mass.

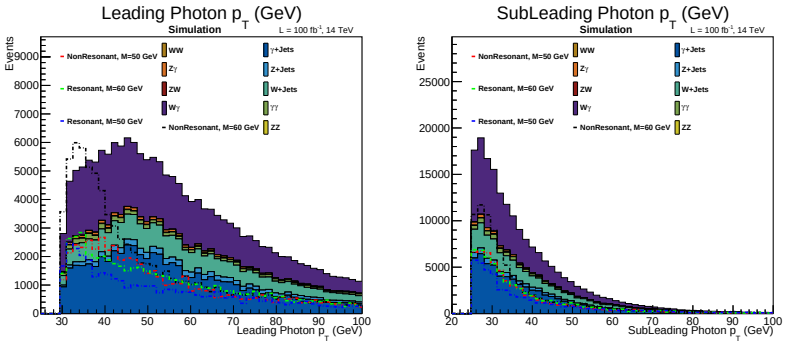

Figure 2: (left) Leading photon p_{T} and (right) sub-leading photon p_{T}.

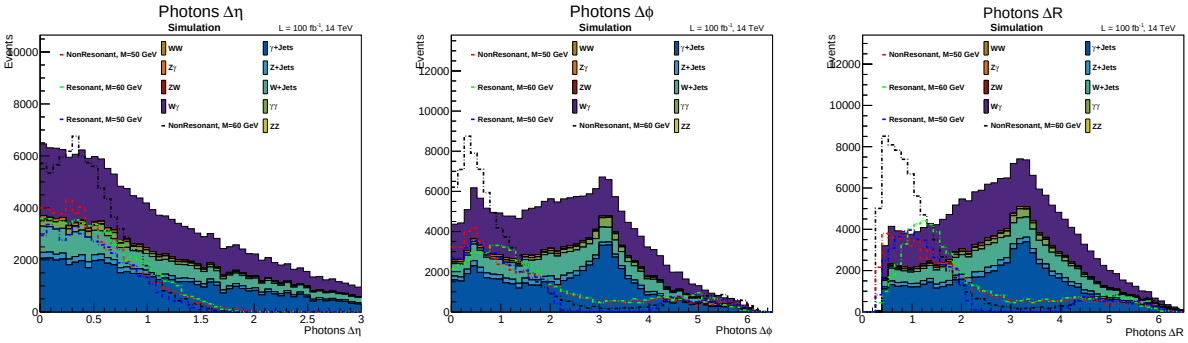

Figure 3: (left) $\Delta\eta$, (center) $\Delta\phi$, (right) ΔR.

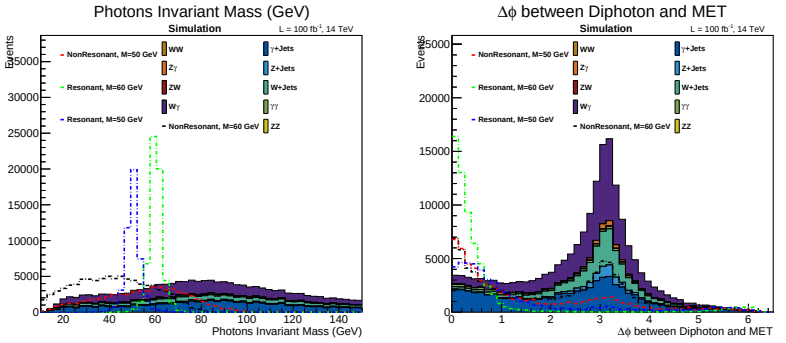

Figure 4: (left) Diphoton invariant mass and (right) $\Delta\phi$ between leading and sub-leading photons.

3.2.2 Associated Production: ZH

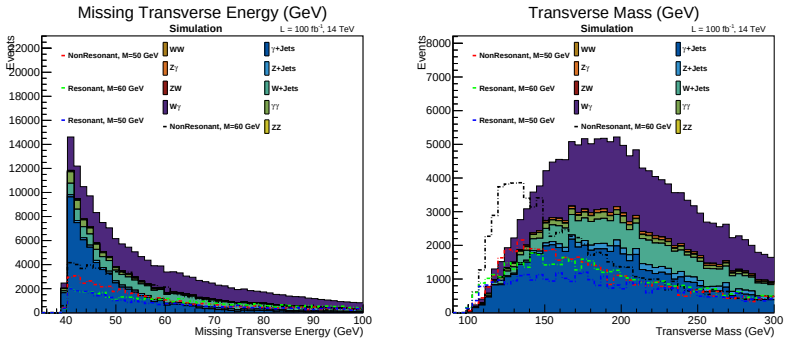

Figure 5: (left) E_{T} and (right) transverse mass.

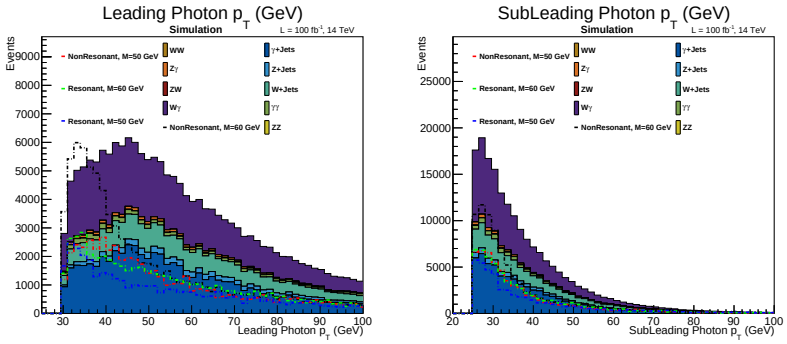

Figure 6: (left) Leading photon p_{T} and (right) sub-leading photon p_{T}.

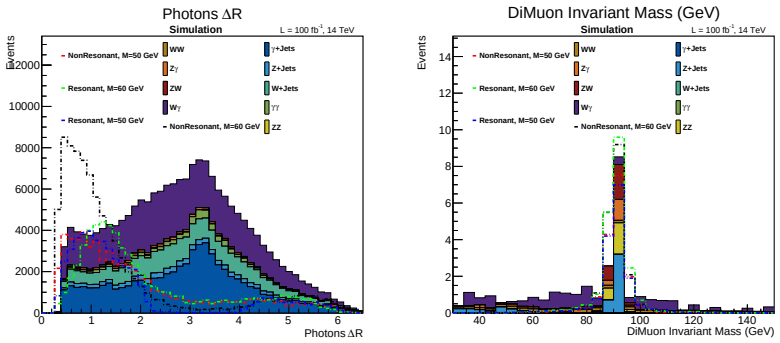

Figure 7: (left) ΔR and (right) dimuon invariant mass.

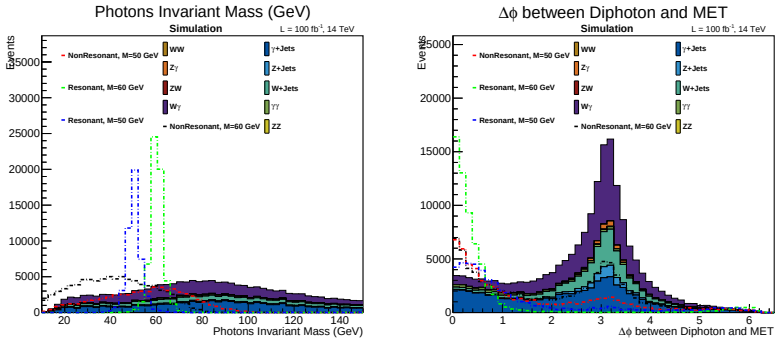

Figure 8: (left) Diphoton invariant mass and (right) $\Delta\phi$ between leading and sub-leading photons.

4 References

[1] D. Curtin *et al.*, Phys. Rev. D **90**, no. 7, 075004 (2014).

[2] A. Djouadi and M. Drees, Phys. Lett. B **407**, 243 (1997).

[3] J. D. Mason, D. E. Morrissey and D. Poland, Phys. Rev. D **80**, 115015 (2009) [arXiv:0909.3523 [hep-ph]].

[4] C. Petersson, A. Romagnoni and R. Torre, JHEP **1210**, 016 (2012).

[5] J. Anderson *et al.*, arXiv:1309.1057 [hep-ex].