Higgs Decaying to two Photons Experiment

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Experiment Procedure

Preparing

By plotting variables of both ATLAS data and the relevant MC simulation, a preliminary understanding of experimental variables can be obtained.

$\Downarrow$

Preliminary Signal/Background Modelling

The fitted MC signal function is used to determine the signal entries. The background is modelled using data excluding the signal region and a quartic function.

$\Downarrow$

Determining Selection Cuts

Apply different selection cuts, acquire a default cut combination by optimising $S/\sqrt{B}$.

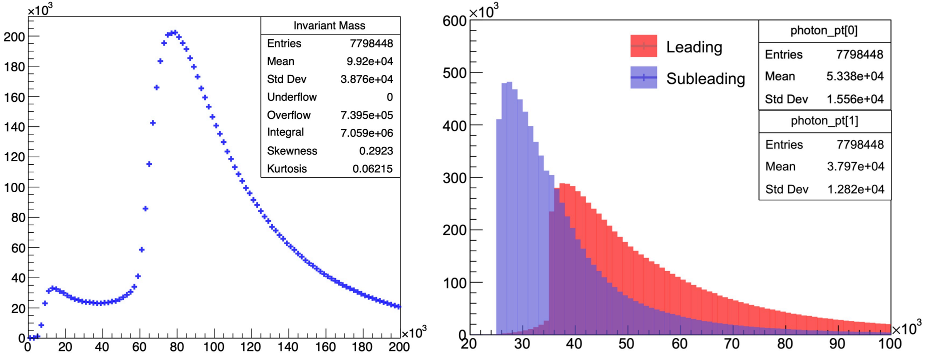
$\Downarrow$

Compute Cross Section with Uncertainties

Using the default cut to get the cross section value. Statistical uncertainties are determined by varying background fitting functions.

Variables of Interest

$$m_{\gamma\gamma} = \sqrt{2p_{T1}p_{T2}\left(\cosh\left(\eta_1 - \eta_2\right) - \cos\left(\phi_1 - \phi_2\right)\right)}$$



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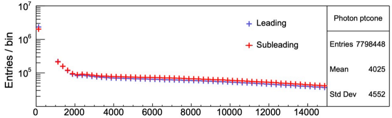
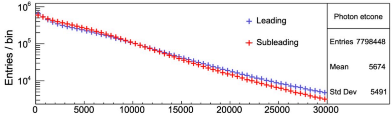
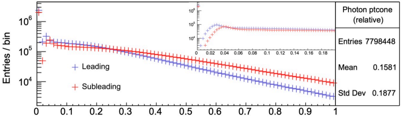
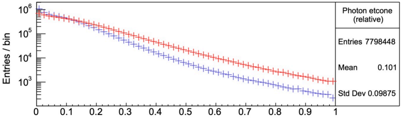
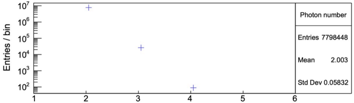
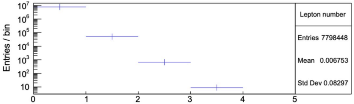


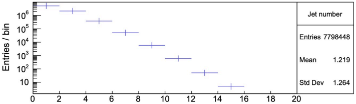


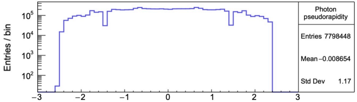


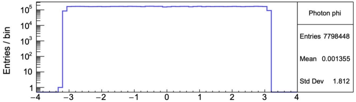






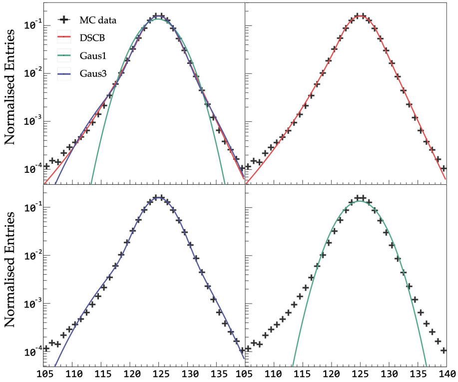






Signal Modelling

$$\mathcal{S}^{\mathrm{DSCB}} = N \begin{cases} e^{-s^2/2} & -\alpha_{\mathsf{low}} \leq s \leq \alpha_{\mathsf{high}} \\ \left(\frac{n_{\mathsf{low}}}{|\alpha_{\mathsf{low}}|}\right)^{n_{\mathsf{low}}} e^{-\alpha_{\mathsf{low}}^2/2} \left(\frac{n_{\mathsf{low}}}{|\alpha_{\mathsf{low}}|} - |\alpha_{\mathsf{low}}| - s\right)^{-n_{\mathsf{low}}} & s < -\alpha_{\mathsf{low}} \\ \left(\frac{n_{\mathsf{high}}}{|\alpha_{\mathsf{high}}|}\right)^{n_{\mathsf{high}}} e^{-\alpha_{\mathsf{high}}^2/2} \left(\frac{n_{\mathsf{high}}}{|\alpha_{\mathsf{high}}|} - |\alpha_{\mathsf{high}}| + s\right)^{-n_{\mathsf{high}}} & s > \alpha_{\mathsf{high}} \end{cases}$$



$$\mathcal{S}^{\mathsf{Gaus3}} = N_1 \exp\left(-\frac{(m_{\gamma\gamma} - \mu_1)}{2\sigma_1^2}\right) + N_2 \exp\left(-\frac{(m_{\gamma\gamma} - \mu_2)}{2\sigma_2^2}\right) + N_3 \exp\left(-\frac{(m_{\gamma\gamma} - \mu_3)}{2\sigma_3^2}\right)$$

The signal with default cuts are fitted by a DSCB function, a Gaussian function and three Gaussian functions.

Background Modelling

The Background is fitted with data excluding the region $[120\mathrm{e}3, 130\mathrm{e}3]$ using a quartic function.

$$\mathsf{Bkg}^{\mathsf{quartic}} = a_4 m_{\gamma\gamma}^4 + a_3 m_{\gamma\gamma}^3 + a_2 m_{\gamma\gamma}^2 + a_1 m_{\gamma\gamma} + m_{\gamma\gamma}$$

Determining Cuts

$P_T\text{cone}^{\text{rel}}$	SIG	SIG eff.	BKG	BKG rej.	$S/\sqrt{B}$
0.025	431.46	77.38	56531.01	86.57	1.8146
0.026	438.82	78.70	57422.03	86.36	1.8312
0.027	443.27	79.50	58325.10	86.14	1.8354
0.028	447.46	80.25	59238.94	85.93	1.8384
0.029	451.33	80.94	60122.04	85.72	1.8406
0.030	455.03	81.61	60960.94	85.52	1.8429
0.031	458.51	82.23	61901.14	85.29	1.8428
0.032	461.92	82.84	62736.73	85.10	1.8441
0.033	465.18	83.43	63586.41	84.89	1.8447
0.034	468.17	83.96	64433.23	84.69	1.8443
0.035	470.98	84.47	65291.79	84.49	1.8432
0.036	473.76	84.97	66135.87	84.29	1.8422
0.037	476.20	85.40	66996.72	84.08	1.8397
0.038	478.86	85.88	67824.74	83.89	1.8387
0.039	481.23	86.31	68600.32	83.70	1.8373
0.040	483.66	86.74	69401.78	83.51	1.8359
0.045	492.91	88.40	73045.41	82.65	1.8237
0.050	501.12	89.87	76463.86	81.84	1.8122
0.055	507.53	91.02	79481.97	81.12	1.8002
0.060	512.78	91.97	82338.43	80.44	1.7870
0.065	516.47	92.63	85174.05	79.77	1.7696
0.070	520.75	93.39	87848.42	79.13	1.7569

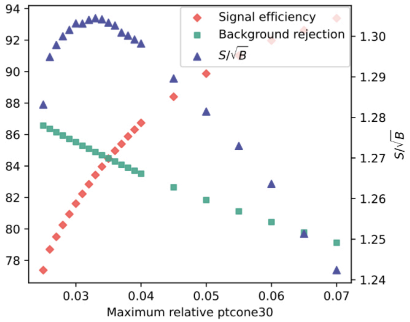
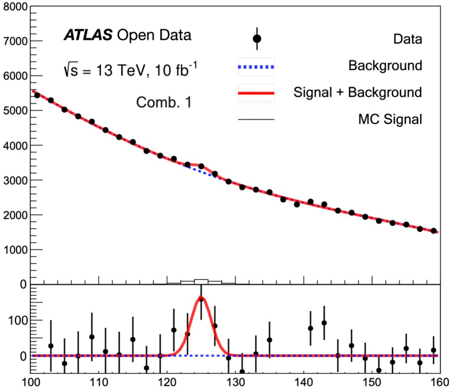


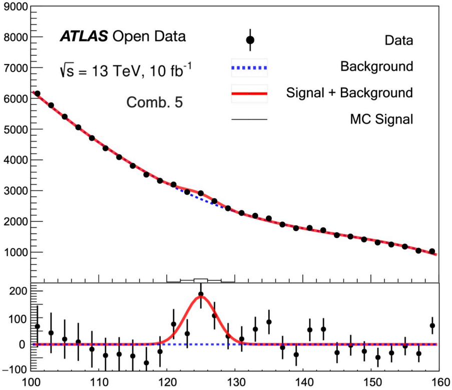
Table 3: Demonstration of efficiency and background rejection of $P_T\text{cone}^{\text{rel}}$ singular cut.

Determining Cuts

Photon number	Lepton number	$P_T^{\min}$ [GeV]	$\eta \notin [1.37, 1.52]$	Balance	TightID	$P_T\text{cone}^{\text{rel}}$	$E_T\text{cone}^{\text{rel}}$	$S/\sqrt{B}$	Alias
—	—	—	—	—	—	—	—	0.8593	
2	—	—	—	—	—	—	—	0.8595	
—	0	—	—	—	—	—	—	0.8555	
—	—	[35, 25]	—	—	—	—	—	0.8185	
—	—	[40, 30]	—	—	—	—	—	0.9407	
—	—	—	✓	—	—	—	—	0.8349	
—	—	—	—	✓	—	—	—	0.9613	
—	—	—	—	—	✓	—	—	2.0142	
—	—	—	—	—	—	0.033	—	1.8448	
—	—	—	—	—	—	—	0.03	2.0484	
2	—	[40, 30]	✓	✓	✓	0.033	0.03	2.8861	Comb.1
2	—	[40, 30]	✓	✓	✓	0.055	0.055	3.0454	Comb.2
—	—	[40, 30]	✓	✓	✓	0.055	0.055	3.0239	Comb.3
2	—	[35, 25]	✓	✓	✓	0.055	0.055	3.0514	Comb.4
—	—	[35, 25]	✓	✓	✓	0.055	0.055	3.0529	Comb.5
—	—	[35, 25]	✓	—	✓	0.055	0.055	2.9443	Comb.6

Final plot with default cuts





cross section

$$\sigma = \frac{N_{\text{selected}} - N_{\text{background}}}{\varepsilon \int L \mathrm{d}t}$$

$$\begin{aligned}
[\text{Uncer.}(\sigma)]^2 = &\left(\frac{1}{\varepsilon \int L \mathrm{d}t}\right)^2 [\text{Uncer.}(N_{\text{selected}})]^2 \\
&+ \left(\frac{1}{\varepsilon \int L \mathrm{d}t}\right)^2 [\text{Uncer.}(N_{\text{background}})]^2 \\
&+ \left(\frac{1}{\varepsilon \int L \mathrm{d}t}\right)^4 \left[\text{Uncer.}\left(\int L \mathrm{d}t\right)\right]^2
\end{aligned}$$

Cut comb.	Function Alias	χ^2/ndf	N_{selected}	N_{bkg}	N_{signal}	$N^{\text{err}}_{\text{selected}}$	$N^{\text{err}}_{\text{background}}$	σ	Stats. Uncer.
Comb.1	poly4	0.855	9987	9814.24	172.76	99.93	54.17	46.98	27.251
Comb.1	poly5	0.994	9987	9833.41	153.59	99.93	55.33	41.77	27.252
Comb.1	poly6	0.938	9987	9803.78	183.22	99.93	56.01	49.83	27.253
Comb.1	expPoly2	1.328	9987	9907.61	79.39	99.93	73.90	21.60	27.278
Comb.1	expPoly3	1.286	9987	9911.98	75.02	99.93	99.56*	20.40	27.312*
Comb.1	expPoly4	1.328	9987	9929.36	57.64	99.93	99.65*	15.68	27.312*
Comb.2	poly4	0.697	14155	13887.61	267.39	118.97	64.52	72.72	32.429
Comb.2	poly5	0.854	14155	13900.70	254.30	118.97	65.79	69.16	32.430
Comb.2	poly6	0.732	14155	13865.06	289.94	118.97	66.51	78.85	32.431
Comb.2	expPoly2	1.315	14155	13929.09	225.91	118.97	88.45	61.44	32.456
Comb.2	expPoly3	1.122	14155	13921.42	233.58	118.97	117.99*	63.53	32.490
Comb.2	expPoly4	1.039	14155	13980.74	174.26	118.97	118.24*	47.39	32.490
Comb.5	poly4	1.097	14208	13776.59	431.41	119.20	66.50	117.33	32.494
Comb.5	poly5	0.580	14208	13846.28	361.72	119.20	67.63	98.38	32.495
Comb.5	poly6	0.602	14208	13820.95	387.05	119.20	68.22	105.26	32.496
Comb.5	expPoly2	0.954	14208	14044.59	163.41	119.20	88.69	44.44	32.519
Comb.5	expPoly3	1.017	14208	14059.91	148.09	119.20	118.57*	40.27	32.553*
Comb.5	expPoly4	0.776	14208	13984.15	223.85	119.20	118.25*	60.88	32.552*

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Cut	$\sigma^{\text{Fiducial}}_{H\to\gamma\gamma}$	Statistical	Systematic	Luminosity
Comb.1	46.19	27.25	3.33	9×10^{-4}
Comb.2	60.03	32.47	9.23	9×10^{-4}
Comb.5	67.34	32.50	32.47	9×10^{-4}

Further Selection Cuts