The LaTeX report

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Contents

1 Setup

1.1 Command history

```
ma5># set directory where running "./bin/ma5"; set lumi; define the signal significance
ma5>set main.currentdir = /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno # need to
change this directory path -> exit and type "pwd" to get the path
ma5>set main.lumi = 40.0
ma5># import samples -> change the path to the LHE file
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/axion_signal/-
axion_signal_gurrola_cuts_1MeV.lhe.gz as signal
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_0_100_merged.lhe.gz as bg_vbf_0_100
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_100_200_merged.lhe.gz as bg_vbf_100_200
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_200_400_merged.lhe.gz as bg_vbf_200_400
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_400_600_merged.lhe.gz as bg_vbf_400_600
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_600_800_merged.lhe.gz as bg_vbf_600_800
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_800_1200_merged.lhe.gz as bg_vbf_800_1200
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_1200_1600_merged.lhe.gz as bg_vbf_1200_1600
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/vbf_diphoton_background_
merged_lhe/vbf_diphoton_background_ht_1600_inf_merged.lhe.gz as bg_vbf_1600_inf
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_0_100_merged.lhe.gz as bg_dip_0_100
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_100_200_merged.lhe.gz as bg_dip_100_200
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_200_400_merged.lhe.gz as bg_dip_200_400
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_400_600_merged.lhe.gz as bg_dip_400_600
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_600_800_merged.lhe.gz as bg_dip_600_800
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_800_1200_merged.lhe.gz as bg_dip_800_1200
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_1200_1600_merged.lhe.gz as bg_dip_1200_1600
ma5>import /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/madgraph_data/diphoton_double_isr_back
merged_lhe/diphoton_double_isr_background_ht_1600_inf_merged.lhe.gz as bg_dip_1600_inf
ma5># define bg and signal samples
ma5>set signal.type = signal
ma5>set bg_vbf_0_100.type = background
ma5>set bg_vbf_100_200.type = background
ma5>set bg_vbf_200_400.type = background
ma5>set bg_vbf_400_600.type = background
ma5>set bg_vbf_600_800.type = background
```

```
ma5>set bg_vbf_800_1200.type = background
ma5>set bg_vbf_1200_1600.type = background
ma5>set bg_vbf_1600_inf.type = background
ma5>set bg_dip_0_100.type = background
ma5>set bg_dip_100_200.type = background
ma5>set bg_dip_200_400.type = background
ma5>set bg_dip_400_600.type = background
ma5>set bg_dip_600_800.type = background
ma5>set bg_dip_800_1200.type = background
ma5>set bg_dip_1200_1600.type = background
ma5>set bg_dip_1600_inf.type = background
ma5># define weights for the samples
ma5>#set sample_1.weight = 1
ma5>#set sample_2.weight = 1
ma5># a jet can be from a light quark or b quark
ma5>define jets = j
ma5>define e = e+ e-
ma5>define mu = mu+ mu-
ma5>define ta = ta+ ta-
ma5>define lept = e mu ta
ma5>define ax = 9000005
ma5># selections
ma5>select (sdETA(jets[1] jets[2]) > 2.6 or sdETA(jets[1] jets[2]) < -2.6) and M(jets[1]
jets[2]) > 1250
ma5>select PT(a[1]) > 500 and M(a[1] a[2]) > 600
ma5>submit analysis_loose_pta500_maa600
```

1.2   Configuration

- MadAnalysis version 1.6.33 (2017/11/20).

- Histograms given for an integrated luminosity of 40.0fb^{-1}.

2   Datasets

2.1   signal

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: signal events.

- Generated events: 1000000   events.

- Normalization to the luminosity: 4094+/- 2   events.

- Ratio (event weight): 0.0041   .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/-madgraph_data/axion_signal/-axion_signal_gurrola_cuts_1MeV.lh	1000000	0.102 @ 0.028%	0.0

2.2   bg_vbf_0_100

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 1000000   events.

- Normalization to the luminosity: 12150+/- 24   events.

- Ratio (event weight): 0.012   .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/madgraph_data/-vbf_diphoton_background_data/-merged_lhe/-vbf_diphoton_background_ht_0_1(	1000000	0.304 @ 0.19%	0.0

2.3   bg_vbf_100_200

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 965662   events.

- Normalization to the luminosity: 9695+/- 17 events.

- Ratio (event weight): 0.01 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/madgraph_data/-vbf_diphoton_background_data/-merged_lhe/-vbf_diphoton_background_ht_100_	965662	0.242 @ 0.17%	0.0

2.4 bg_vbf_200_400

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 984165 events.

- Normalization to the luminosity: 5413+/- 11 events.

- Ratio (event weight): 0.0055 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/madgraph_data/-vbf_diphoton_background_data/-merged_lhe/-vbf_diphoton_background_ht_200_	984165	0.135 @ 0.2%	0.0

2.5 bg_vbf_400_600

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 1000000 events.

- Normalization to the luminosity: 986+/- 2 events.

- Ratio (event weight): 0.00099 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- vbf_diphoton_background_data/- merged_lhe/- vbf_diphoton_background_ht_400_	1000000	0.0247 @ 0.14%	0.0

2.6 bg_vbf_600_800

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/- optimization .

- Sample consisting of: background events.

- Generated events: 1000000 events.

- Normalization to the luminosity: 252+/- 1 events.

- Ratio (event weight): 0.00025 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- vbf_diphoton_background_data/- merged_lhe/- vbf_diphoton_background_ht_600_	1000000	0.0063 @ 0.13%	0.0

2.7 bg_vbf_800_1200

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/- optimization .

- Sample consisting of: background events.

- Generated events: 400839 events.

- Normalization to the luminosity: 114+/- 1 events.

- Ratio (event weight): 0.00028 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- vbf_diphoton_background_data/- merged_lhe/- vbf_diphoton_background_ht_800_	400839	0.00287 @ 0.16%	0.0

2.8 bg_vbf_1200_1600

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 953803 events.

- Normalization to the luminosity: 20+/- 1 events.

- Ratio (event weight): 2.1e-05 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/madgraph_data/-vbf_diphoton_background_data/-merged_lhe/-vbf_diphoton_background_ht_1200	953803	0.000515 @ 0.16%	0.0

2.9 bg_vbf_1600_inf

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 270148 events.

- Normalization to the luminosity: 7+/- 1 events.

- Ratio (event weight): 2.6e-05 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/madgraph_data/-vbf_diphoton_background_data/-merged_lhe/-vbf_diphoton_background_ht_1600	270148	0.000191 @ 0.11%	0.0

2.10 bg_dip_0_100

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 1040000 events.

- Normalization to the luminosity: 2710847+/- 4614 events.

- Ratio (event weight): 2.6 - warning: please generate more events (weight larger than 1)!

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- diphoton_double_isr_background_c merged_lhe/- diphoton_double_isr_background_l	1040000	67.8 @ 0.17%	0.0

2.11   bg_dip_100_200

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/- optimization .

- Sample consisting of: background events.

- Generated events: 1040000 events.

- Normalization to the luminosity: 1095362+/- 1528 events.

- Ratio (event weight): 1.1 - warning: please generate more events (weight larger than 1)!

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- diphoton_double_isr_background_c merged_lhe/- diphoton_double_isr_background_l	1040000	27.4 @ 0.14%	0.0

2.12   bg_dip_200_400

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/- optimization .

- Sample consisting of: background events.

- Generated events: 1040000 events.

- Normalization to the luminosity: 239548+/- 414 events.

- Ratio (event weight): 0.23 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- diphoton_double_isr_background_c merged_lhe/- diphoton_double_isr_background_l	1040000	5.99 @ 0.17%	0.0

2.13   bg_dip_400_600

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 1040000 events.

- Normalization to the luminosity: 28798+/- 53 events.

- Ratio (event weight): 0.028 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/madgraph_data/-diphoton_double_isr_background_c merged_lhe/-diphoton_double_isr_background_l	1040000	0.72 @ 0.18%	0.0

2.14   bg_dip_600_800

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 662009 events.

- Normalization to the luminosity: 6674+/- 28 events.

- Ratio (event weight): 0.01 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/-MG5_aMC_v2_6_5/-axion_pheno/madgraph_data/-diphoton_double_isr_background_c merged_lhe/-diphoton_double_isr_background_l	662009	0.167 @ 0.41%	0.0

2.15   bg_dip_800_1200

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 1040000 events.

- Normalization to the luminosity: 2942+/- 6 events.

- Ratio (event weight): 0.0028 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- diphoton_double_isr_background_o merged_lhe/- diphoton_double_isr_background_l	1040000	0.0736 @ 0.17%	0.0

2.16   bg_dip_1200_1600

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 337115 events.

- Normalization to the luminosity: 513+/- 3 events.

- Ratio (event weight): 0.0015 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- diphoton_double_isr_background_o merged_lhe/- diphoton_double_isr_background_l	337115	0.0128 @ 0.51%	0.0

2.17   bg_dip_1600_inf

- Samples stored in the directory: /Users/elijahsheridan/MG5_aMC_v2_6_5/axion_pheno/-optimization .

- Sample consisting of: background events.

- Generated events: 1040000 events.

- Normalization to the luminosity: 187+/- 1 events.

- Ratio (event weight): 0.00018 .

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
/Users/elijahsheridan/- MG5_aMC_v2_6_5/- axion_pheno/madgraph_data/- diphoton_double_isr_background_o merged_lhe/- diphoton_double_isr_background_l	1040000	0.00469 @ 0.15%	0.0

3 Histos and cuts

3.1 Cut 1

* Cut: select (sdETA (jets[1] jets[2]) > 2.6 or sdETA (jets[1] jets[2]) < -2.6) and M (jets[1] jets[2]) > 1250.0

Dataset	Events kept: K	Rejected events: R	Efficiency: K / (K + R)	Cumul. efficiency: K / Initial
signal	1711.8 +/- 31.6	2382.3 +/- 31.6	0.41812 +/- 0.00771	0.41812 +/- 0.00771
bg_vbf_0_10	204.2 +/- 14.2	11946.1 +/- 26.8	0.01681 +/- 0.00117	0.01681 +/- 0.00117
bg_vbf_100_	950.9 +/- 29.3	8744.4 +/- 32.9	0.09808 +/- 0.00302	0.09808 +/- 0.00302
bg_vbf_200_	1147.9 +/- 30.2	4265.4 +/- 31.3	0.21205 +/- 0.00556	0.21205 +/- 0.00556
bg_vbf_400_	349.4 +/- 15.0	637.5 +/- 15.0	0.3540 +/- 0.0152	0.3540 +/- 0.0152
bg_vbf_600_	111.21 +/- 7.88	140.87 +/- 7.89	0.4412 +/- 0.0313	0.4412 +/- 0.0313
bg_vbf_800_	40.31 +/- 5.11	74.45 +/- 5.12	0.3513 +/- 0.0446	0.3513 +/- 0.0446
bg_vbf_1200	4.49 +/- 1.87	16.10 +/- 1.87	0.218 +/- 0.091	0.218 +/- 0.091
bg_vbf_1600	0.784 +/- 0.839	6.874 +/- 0.839	0.102 +/- 0.110	0.102 +/- 0.110
bg_dip_0_10	229.4 +/- 15.1	2710617 +/- 4612	8.46e-05 +/- 5.59e-06	8.46e-05 +/- 5.59e-06
bg_dip_100_	990.1 +/- 31.5	1094372 +/- 1526	9.04e-04 +/- 2.87e-05	9.04e-04 +/- 2.87e-05
bg_dip_200_	1641.8 +/- 40.5	237907 +/- 412	0.006854 +/- 0.000169	0.006854 +/- 0.000169
bg_dip_400_	1066.5 +/- 32.1	27732.1 +/- 59.6	0.03703 +/- 0.00111	0.03703 +/- 0.00111
bg_dip_600_	531.3 +/- 22.2	6143.1 +/- 33.7	0.07960 +/- 0.00331	0.07960 +/- 0.00331
bg_dip_800_	193.3 +/- 13.4	2749.1 +/- 14.2	0.06568 +/- 0.00457	0.06568 +/- 0.00457
bg_dip_1200	21.80 +/- 4.57	491.71 +/- 5.22	0.0424 +/- 0.0089	0.0424 +/- 0.0089
bg_dip_1600	4.1 +/- 2.0	183.71 +/- 2.01	0.0217 +/- 0.0106	0.0217 +/- 0.0106

3.2 Cut 2

* Cut: select PT (a[1]) > 500.0 and M (a[1] a[2]) > 600.0

Dataset	Events kept: K	Rejected events: R	Efficiency: K / (K + R)	Cumul. efficiency: K / Initial
signal	866.1 +/- 26.1	845.7 +/- 25.9	0.5059 +/- 0.0121	0.21154 +/- 0.00638
bg_vbf_0_10	0.0 +/- 0.0	204.2 +/- 14.2	0.0 +/- 0.0	0.0 +/- 0.0
bg_vbf_100_	0.0503 +/- 0.2242	950.8 +/- 29.3	5.29e-05 +/- 2.36e-04	5.18e-06 +/- 2.31e-05
bg_vbf_200_	0.33 +/- 0.57	1147.5 +/- 30.2	0.000287 +/- 0.000500	6.10e-05 +/- 1.06e-04
bg_vbf_400_	0.78 +/- 0.88	348.6 +/- 15.0	0.00223 +/- 0.00252	0.00079 +/- 0.00089
bg_vbf_600_	0.808 +/- 0.898	110.40 +/- 7.88	0.00727 +/- 0.00805	0.00321 +/- 0.00356
bg_vbf_800_	0.685 +/- 0.825	39.63 +/- 5.09	0.017 +/- 0.020	0.00597 +/- 0.00719
bg_vbf_1200_	0.122 +/- 0.348	4.37 +/- 1.86	0.0272 +/- 0.0767	0.00592 +/- 0.01691
bg_vbf_1600_	0.025 +/- 0.158	0.759 +/- 0.827	0.0319 +/- 0.1984	0.00326 +/- 0.02061
bg_dip_0_10	0.0 +/- 0.0	229.4 +/- 15.1	0.0 +/- 0.0	0.0 +/- 0.0
bg_dip_100_	0.0 +/- 0.0	990.1 +/- 31.5	0.0 +/- 0.0	0.0 +/- 0.0
bg_dip_200_	0.461 +/- 0.679	1641.3 +/- 40.5	0.000281 +/- 0.000413	1.92e-06 +/- 2.83e-06
bg_dip_400_	1.77 +/- 1.33	1064.8 +/- 32.1	0.00166 +/- 0.00125	6.15e-05 +/- 4.62e-05
bg_dip_600_	2.27 +/- 1.51	529.0 +/- 22.2	0.00427 +/- 0.00283	0.000340 +/- 0.000226
bg_dip_800_	2.07 +/- 1.44	191.2 +/- 13.4	0.01072 +/- 0.00741	0.000704 +/- 0.000489
bg_dip_1200_	0.343 +/- 0.585	21.45 +/- 4.54	0.0157 +/- 0.0266	0.000667 +/- 0.001140
bg_dip_1600_	0.0583 +/- 0.2414	4.01 +/- 1.98	0.0143 +/- 0.0589	0.000311 +/- 0.001286

4   Summary

4.1   Cut-flow charts

- How to compare signal (S) and background (B): S/sqrt(S+B) .

- Object definition selections are indicated in cyan.

- Reject and select are indicated by 'REJ' and 'SEL' respectively

Cuts	Signal (S)	Background (B)	S vs B
Initial (no cut)	4094.08 +/- 1.13	4113516 +/- 4877	2.01760 +/- 0.00132
SEL: (sdETA (jets[1] jets[2]) > 2.6 or sdETA (	1711.8 +/- 31.6	7487.3 +/- 82.9	17.848 +/- 0.309
SEL: PT (a[1]) > 500.0 and M (a[1] a[2]) > 600	866.1 +/- 26.1	9.77 +/- 3.12	29.264 +/- 0.449