

Theoretical Uncertainties——signal

	Parton shower(%)	α_s (%)	PDF(%)	PDF+ α_s (%)	QCD_up	QCD_down
$1l + jets$	+2.51	0.93	3.87	4.29	13.22	-12.47
$1\tau_{had} + jets$	-1.18	0.95	3.93	4.36	13.34	-12.54
$2(l + \tau_{had})$	-2.85	0.93	3.94	4.37	13.17	-12.48

Channel	Low BDTG region	Medium BDTG region	Tight BDTG region
$\gamma\gamma+1\ell 0\tau_{had}$	$\pm 2.34\%$	$\pm 2.76\%$	$\pm 2.09\%$
$\gamma\gamma+0\ell 1\tau_{had}$	$\pm 1.83\%$	$\pm 2.77\%$	$\pm 2.34\%$
$\gamma\gamma+2L$	$\pm 1.74\%$	$\pm 2.55\%$	$\pm 2.68\%$

Table 47: The systematic uncertainties of the background modeling which is described in Section 10.4.2 for different categories in the $\gamma\gamma + ML$ analysis.

Single higgs						Prod. Mode	Events in AOD
						ggH	18.3M
ggH	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)	VBF	7M
						W^+H	0.6M
						W^-H	0.6M
$1l+jets$	3.39	3.67	5.09	25.89	-15.97	$qq\rightarrow ZH$	1.5M
						$gg\rightarrow ZH$	0.15M
						ttH	7.8M
$1\tau_{had}+jets$	3.31	3.59	4.98	26.37	-15.98	bbH	0.299M
						tHbj	0.4M
						tHW	0.208M
$2(l+\tau_{had})$	4.37	4.39	6.20	38.96	-16.38		
VBFH	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)		
$1l+jets$	0.98	7.96	8.12	0.97	-0.52		
$1\tau_{had}+jets$	0.71	7.06	7.19	0.92	-0.72		
$2(l+\tau_{had})$	0.70	6.11	6.21	1.19	-1.12		
WmH	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)		
$1l+jets$	0.83	5.78	6.11	2.77	-3.20		
$1\tau_{had}+jets$	0.78	5.94	6.25	3.88	-3.33		
$2(l+\tau_{had})$	1.02	4.83	5.05	1.87	-3.37		
WpH	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)		
$1l+jets$	0.86	4.99	5.32	2.45	-3.08		
$1\tau_{had}+jets$	0.78	5.11	5.46	2.89	-3.09		
$2(l+\tau_{had})$	1.17	4.26	4.57	5.16	-4.12	2	

Single higgs

qqZH	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)
$1l + jets$	0.88	6.08	6.40	3.64	-3.68
$1\tau_{had} + jets$	0.84	6.02	6.35	3.88	-3.55
$2(l + \tau_{had})$	1.00	5.78	6.09	4.67	-3.91
ggZH	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)
$1l + jets$	1.14	3.08	3.29	25.83	-19.45
$1\tau_{had} + jets$	1.07	2.98	3.17	25.64	-19.34
$2(l + \tau_{had})$	1.03	2.97	3.15	25.77	-19.41
ttH	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)
$1l + jets$	2.00	5.21	5.68	7.39	-9.51
$1\tau_{had} + jets$	1.99	5.14	5.61	6.29	-9.41
$2(l + \tau_{had})$	1.92	4.87	5.32	6.63	-9.59

Prod. Mode	Events in AOD
ggH	18.3M
VBF	7M
W^+H	0.6M
W^-H	0.6M
$qq \rightarrow ZH$	1.5M
$gg \rightarrow ZH$	0.15M
ttH	7.8M
bbH	0.299M
tHbj	0.4M
tHW	0.208M

Single higgs

- bbH don't store the theory sys weight
- tHbj/tHW don't store the α_s , and they store the PDF MC sets.(not the hessian sets.)

PDF Uncertainties:

$$\delta^{\text{pdf}}\sigma = \sqrt{\frac{1}{N_{\text{mem}} - 1} \sum_{k=1}^{N_{\text{mem}}} (\sigma^{(k)} - \langle \sigma \rangle)^2}$$

Different way to calculate

Prod. Mode	Events in AOD
ggH	18.3M
VBF	7M
W^+H	0.6M
W^-H	0.6M
$qq \rightarrow ZH$	1.5M
$gg \rightarrow ZH$	0.15M
ttH	7.8M
bbH	0.299M
tHbj	0.4M
tHW	0.208M

tHbj	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)
$1l + jets$	0.00	17.01	17.01	8.38	-8.63
$1\tau_{had} + jets$	0.00	19.96	19.96	10.92	-9.84
$2(l + \tau_{had})$	0.00	30.57	30.57	9.91	-8.77
tHW	$\alpha_s(\%)$	PDF(%)	PDF+ $\alpha_s(\%)$	QCD_up(%)	QCD_down(%)
$1l + jets$	0.00	8.30	8.30	2.51	-2.02
$1\tau_{had} + jets$	0.00	11.63	11.63	2.46	-1.82
$2(l + \tau_{had})$	0.00	8.07	8.07	5.45	-6.46

Fit

- 1l0tau(without Single Higgs theoretical uncertainty)
- Upper Limit: 27.38

- 0l1tau(without Single Higgs theoretical uncertainty)
- Upper Limit: 50.94
- 2l not finished. Expected final combined result: 15->16~17

