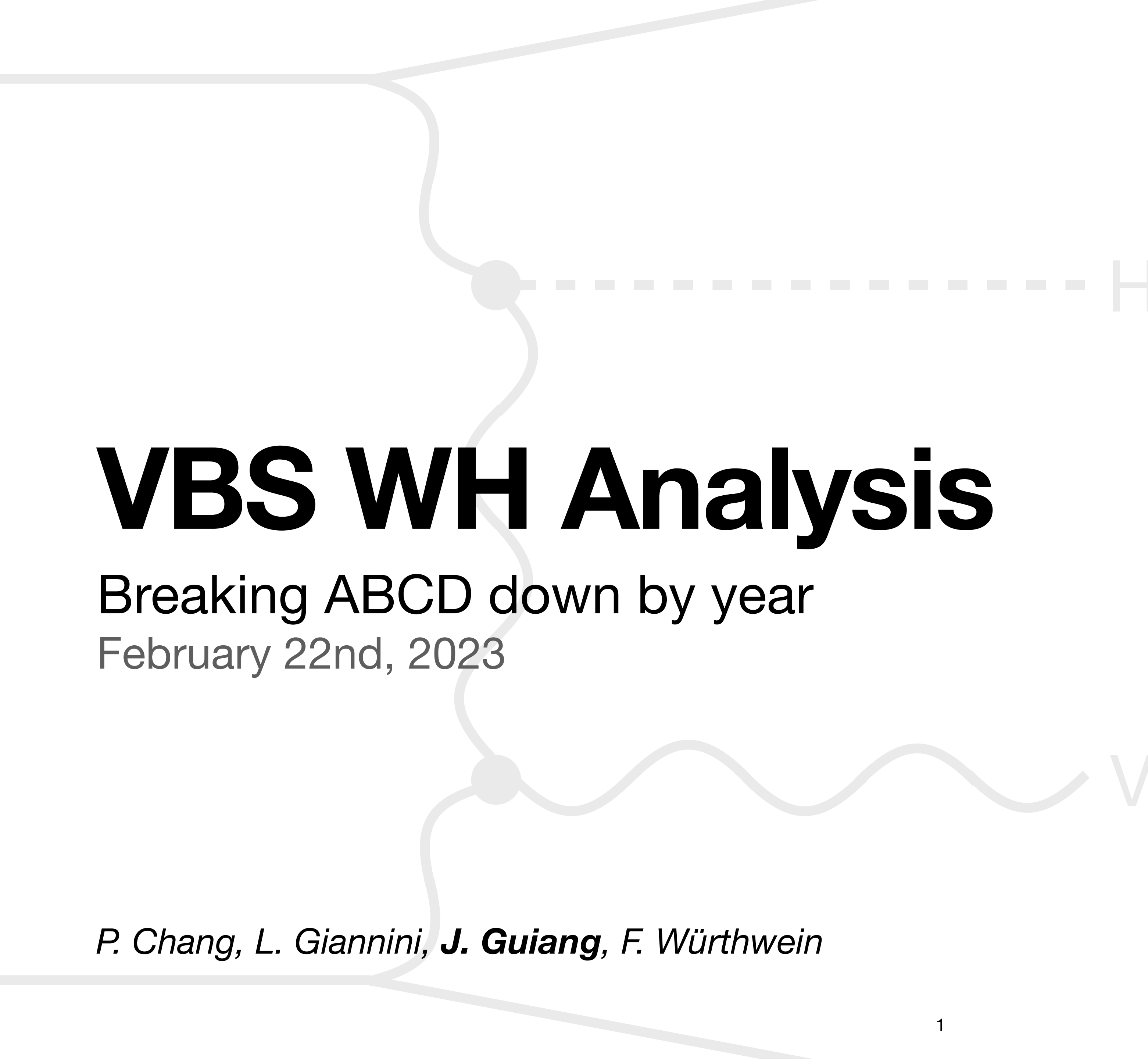


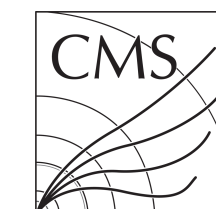


VBS WH Analysis

Breaking ABCD down by year

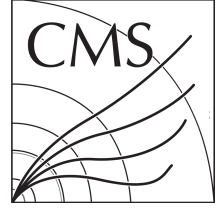
February 22nd, 2023

*P. Chang, L. Giannini, **J. Guiang**, F. Würthwein*

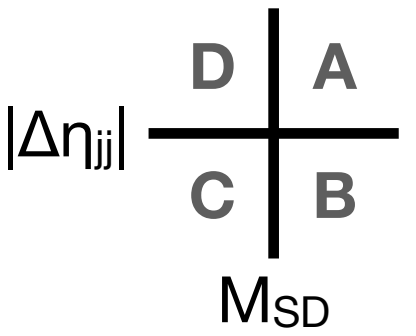


UC San Diego





ABCD: Year-by-year



Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.24	1.06	53.49	1.85	3.28	0.50	36	6.00
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.15	1.00	66.80	1.84	0.26	0.15	55	7.42
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.15	1.02	50.58	2.24	3.33	0.49	31	5.57
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.91	0.82	29.74	1.70	102.95	2.96	—	—

36.33 fb⁻¹

	MC	Data
A/B	0.80 ± 0.04	0.65 ± 0.14
$D_{pred} = C \cdot (A/B)$	40.5 ± 2.53	20.3 ± 5.67
$ 1 - D_{pred}/D_{MC} $	36.2%	—
$D_{pred}/Lumi$	1.11 ± 0.07	0.56 ± 0.16

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2017 ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	—	0.86	49.19	1.62	3.02	0.71	45	6.71
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	—	0.87	66.25	3.05	0.17	0.17	67	8.19
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	—	0.89	50.23	2.22	4.61	0.87	58	7.62
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	—	0.90	37.43	2.32	116.15	4.44	—	—

41.48 fb⁻¹

	MC	Data
A/B	0.74 ± 0.04	0.67 ± 0.13
$D_{pred} = C \cdot (A/B)$	37.3 ± 2.68	39.0 ± 9.08
$ 1 - D_{pred}/D_{MC} $	0.3%	—
$D_{pred}/Lumi$	0.90 ± 0.06	0.94 ± 0.22

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2018 ONLY)

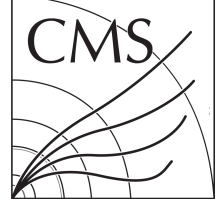
Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.17	—	82.94	2.34	6.27	1.28	65	8.06
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.15	—	109.65	4.66	0.51	0.36	77	8.77
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.12	—	81.47	3.27	8.41	1.49	83	9.11
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	1.11	—	59.74	3.09	191.01	7.10	—	—

59.83 fb⁻¹

	MC	Data
A/B	0.76 ± 0.04	0.84 ± 0.14
$D_{pred} = C \cdot (A/B)$	61.6 ± 4.00	70.1 ± 14.09
$ 1 - D_{pred}/D_{MC} $	3.2%	—
$D_{pred}/Lumi$	1.03 ± 0.07	1.17 ± 0.24

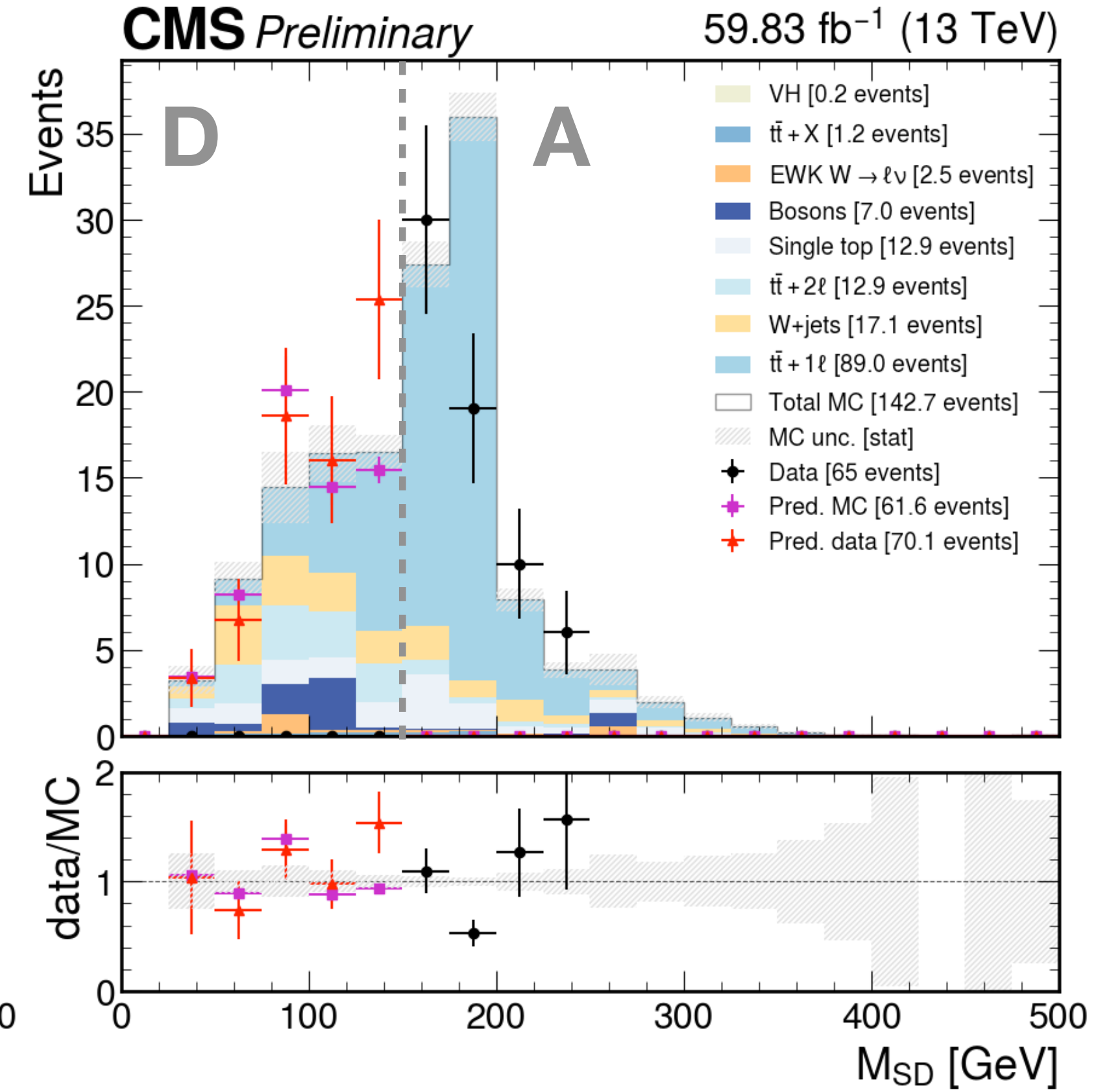
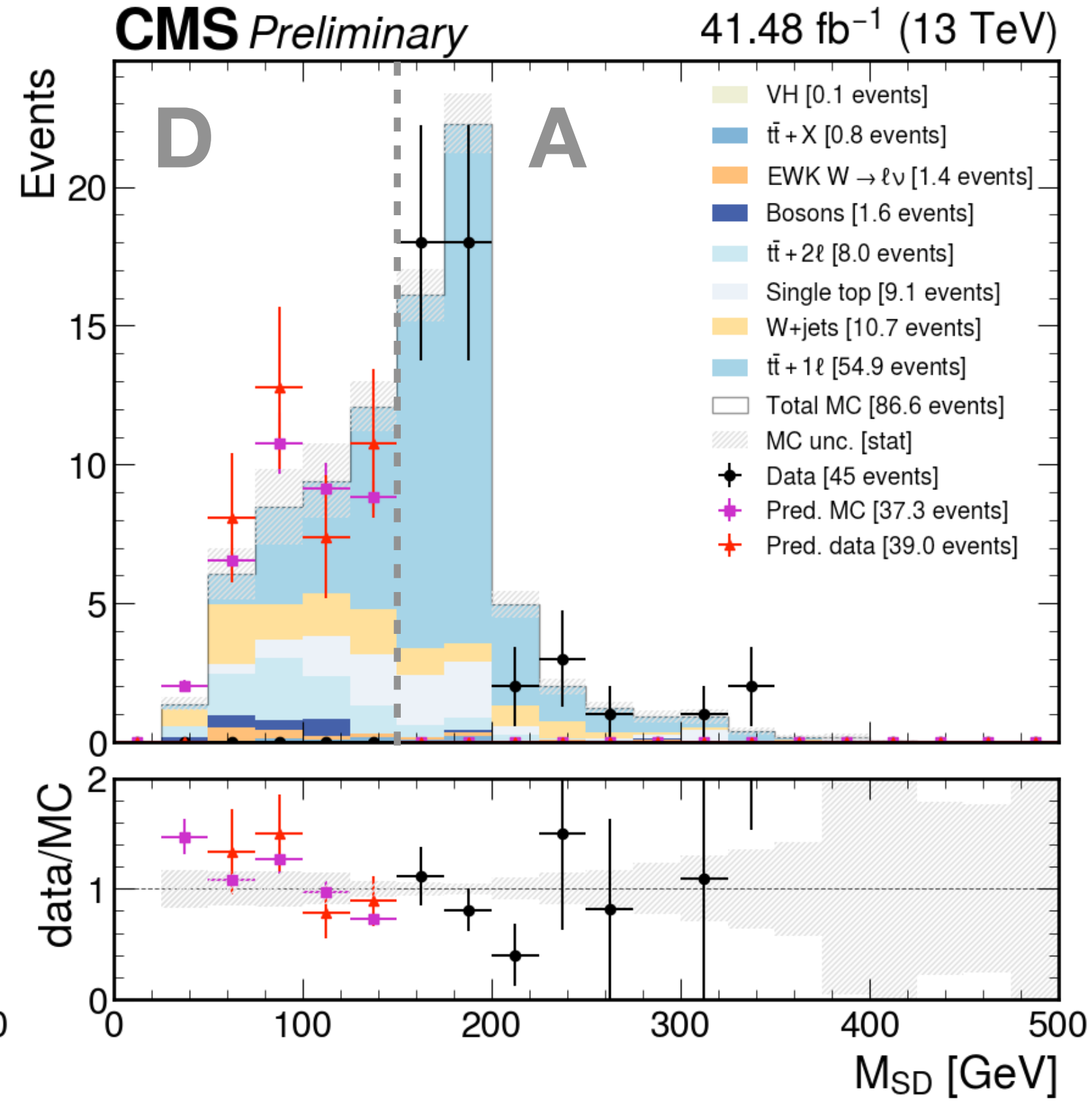
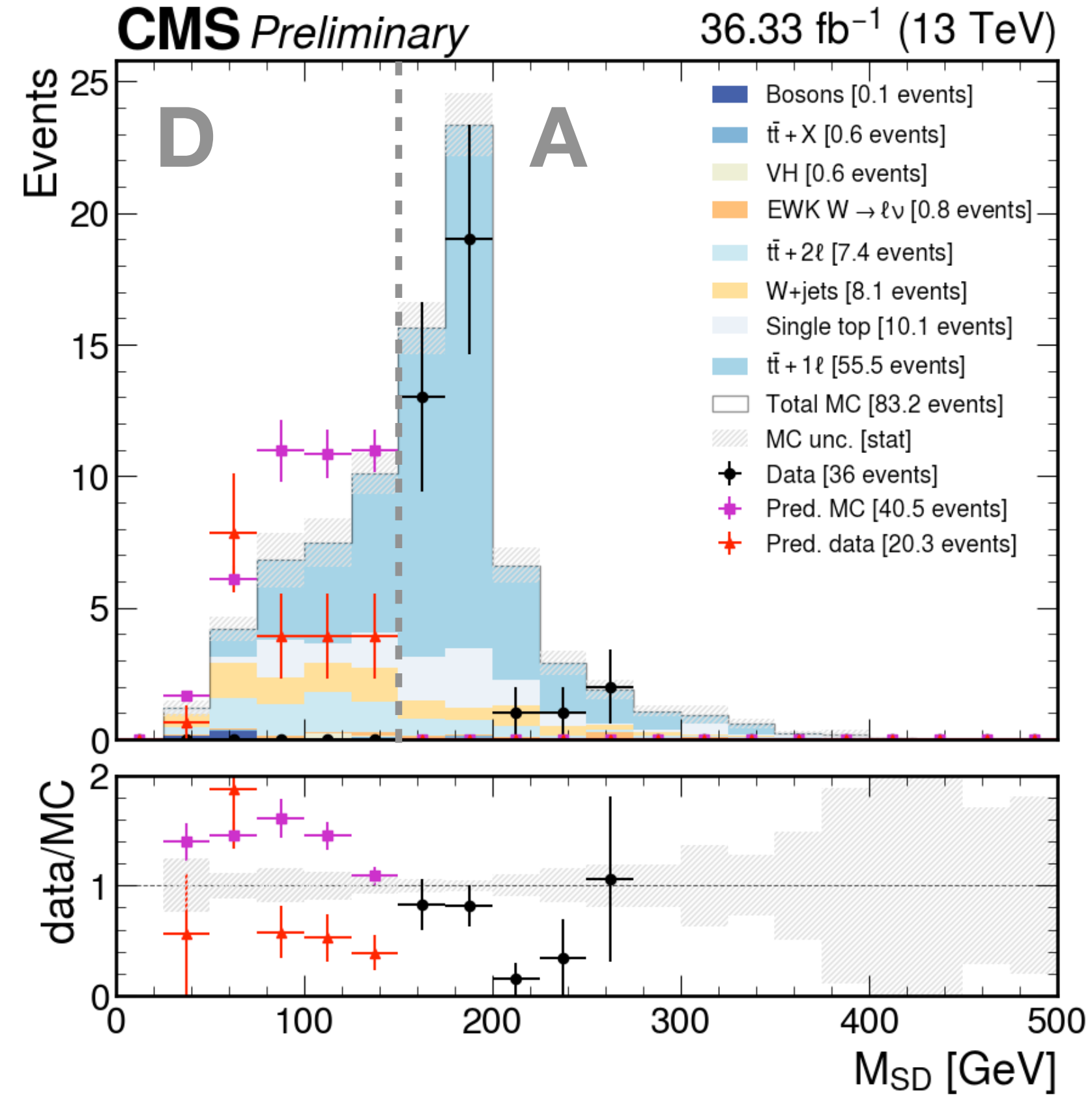
For 2018: Bkg./2017 = ((Bkg. 2018)/59.83)/((Bkg. 2017)/41.48)

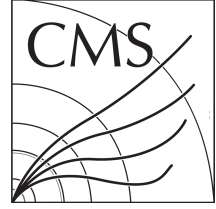
2016 accounts for almost all of the systematic on ABCD method



ABCD: Year-by-year

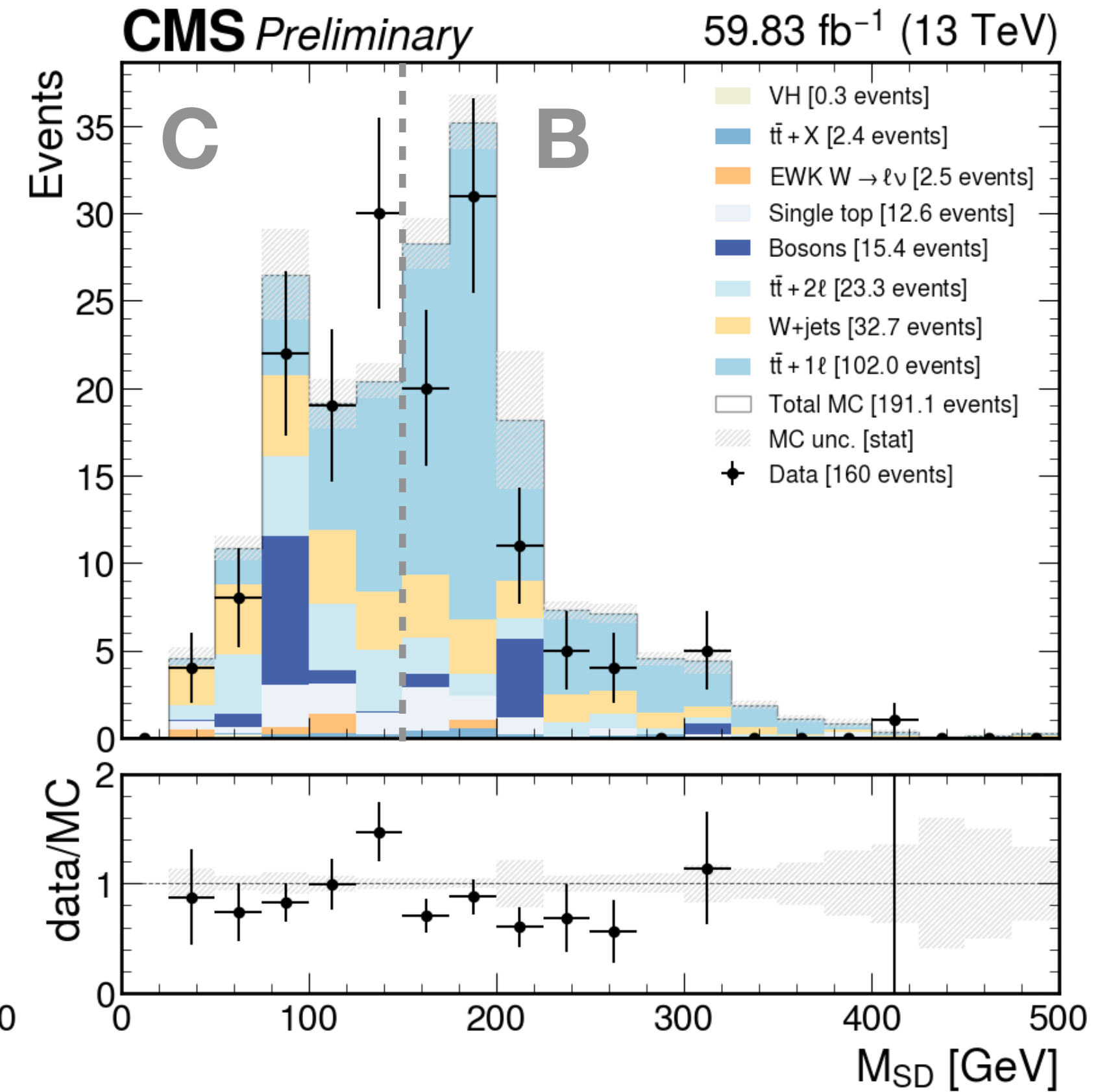
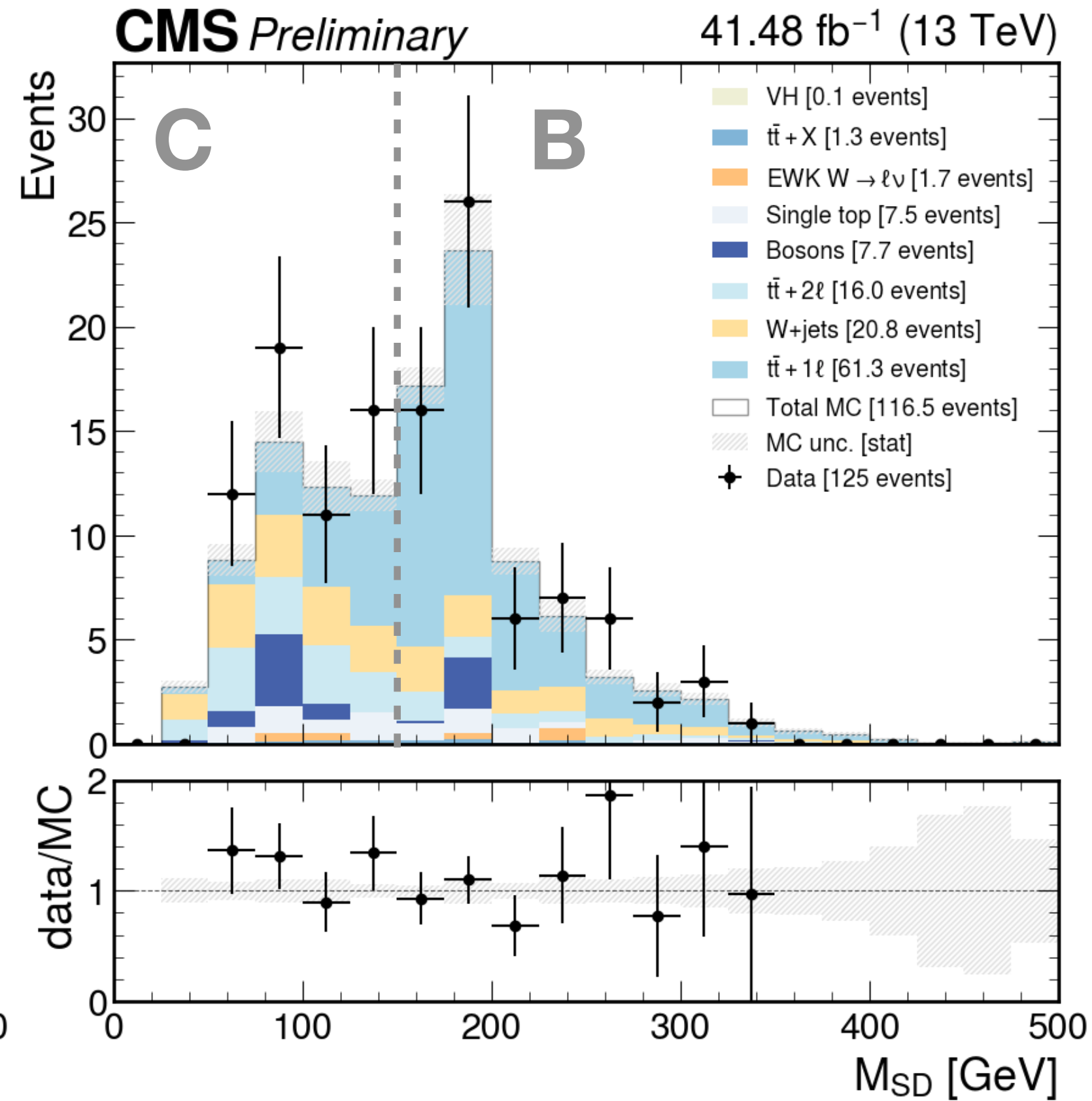
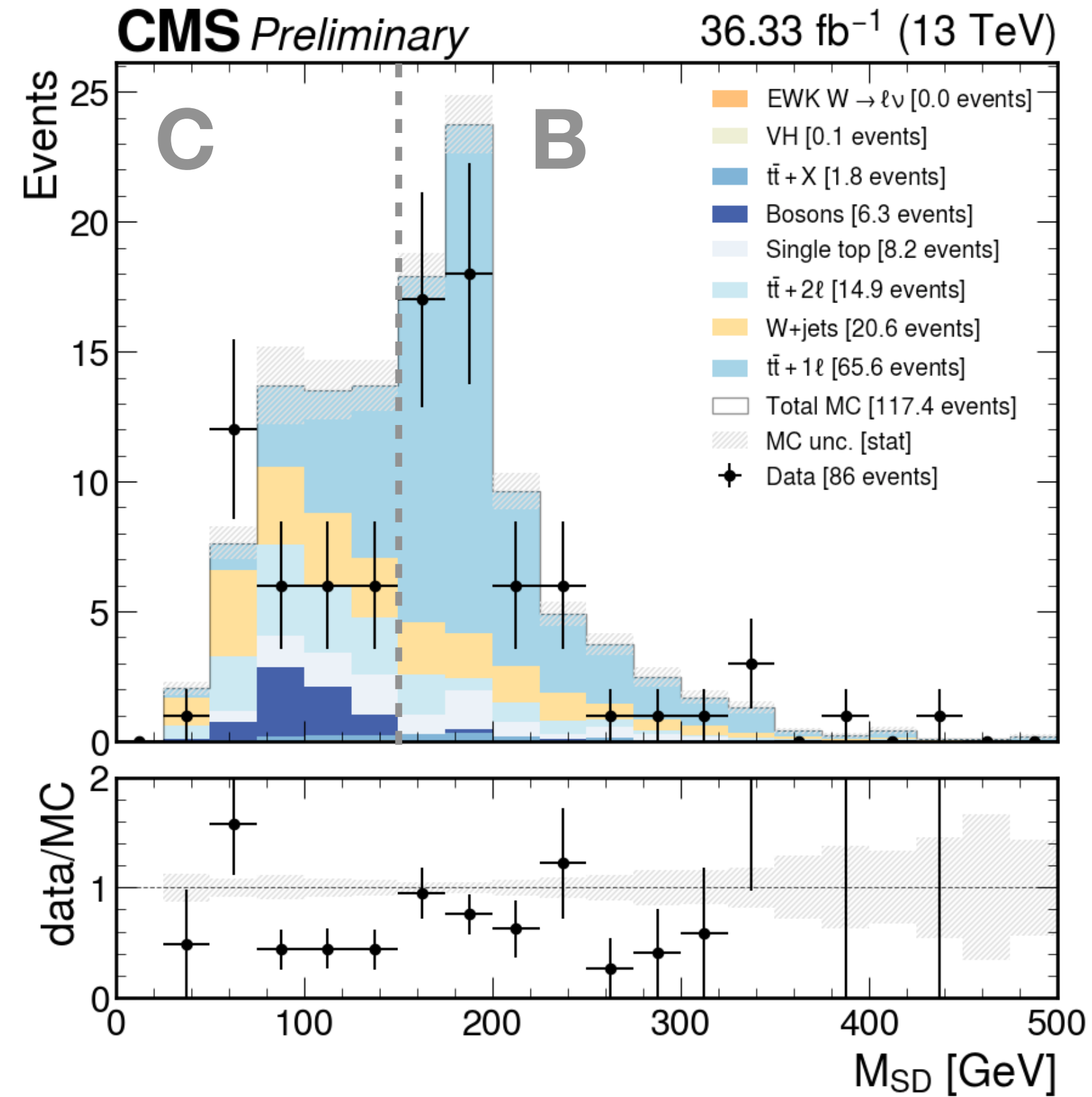
$$|\Delta\eta_{ij}| \begin{array}{c|c} \text{D} & \text{A} \\ \hline \text{C} & \text{B} \end{array} M_{SD}$$





ABCD: Year-by-year

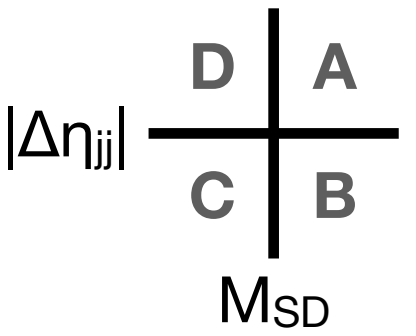
$$|\Delta\eta_{ij}| \begin{array}{c|c} \text{D} & \text{A} \\ \hline \text{C} & \text{B} \end{array} M_{SD}$$



Backup



ABCD: Year-by-year



Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 pre-VFP ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.24	1.06	28.67	1.35	1.87	0.40	17	4.12
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.09	0.95	34.04	1.29	0.26	0.15	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.17	1.04	27.62	1.67	1.63	0.35	19	4.36
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.90	0.81	15.84	1.17	55.21	2.17	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 post-VFP ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.25	1.07	24.82	1.27	1.41	0.31	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.22	1.06	32.77	1.31	0.00	0.00	36	6.00
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.13	1.00	22.96	1.49	1.71	0.35	12	3.46
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.92	0.83	13.91	1.24	47.74	2.01	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2017 ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	—	0.86	49.19	1.62	3.02	0.71	45	6.71
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	—	0.87	66.25	3.05	0.17	0.17	67	8.19
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	—	0.89	50.23	2.22	4.61	0.87	58	7.62
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	—	0.90	37.43	2.32	116.15	4.44	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2018 ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.17	—	82.94	2.34	6.27	1.28	65	8.06
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.15	—	109.65	4.66	0.51	0.36	77	8.77
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.12	—	81.47	3.27	8.41	1.49	83	9.11
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	1.11	—	59.74	3.09	191.01	7.10	—	—

19.52 fb⁻¹

	MC	Data
A/B	0.84 ± 0.05	0.89 ± 0.30
$D_{\text{pred}} = C \cdot (A/B)$	23.3 ± 1.99	17.0 ± 6.89
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	46.9%	—
$D_{\text{pred}}/\text{Lumi}$	1.19 ± 0.10	0.87 ± 0.35

16.81 fb⁻¹

	MC	Data
A/B	0.76 ± 0.05	0.53 ± 0.15
$D_{\text{pred}} = C \cdot (A/B)$	17.4 ± 1.59	6.3 ± 2.56
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	25.1%	—
$D_{\text{pred}}/\text{Lumi}$	1.03 ± 0.09	0.38 ± 0.15

41.48 fb⁻¹

	MC	Data
A/B	0.74 ± 0.04	0.67 ± 0.13
$D_{\text{pred}} = C \cdot (A/B)$	37.3 ± 2.68	39.0 ± 9.08
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	0.3%	—
$D_{\text{pred}}/\text{Lumi}$	0.90 ± 0.06	0.94 ± 0.22

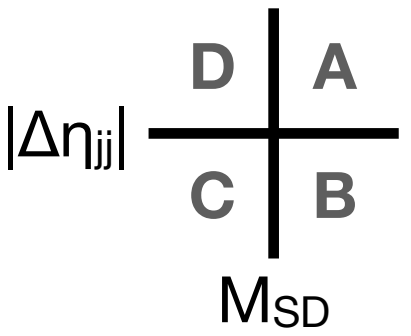
59.83 fb⁻¹

	MC	Data
A/B	0.76 ± 0.04	0.84 ± 0.14
$D_{\text{pred}} = C \cdot (A/B)$	61.6 ± 4.00	70.1 ± 14.09
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	3.2%	—
$D_{\text{pred}}/\text{Lumi}$	1.03 ± 0.07	1.17 ± 0.24

For 2018: Bkg./2017 = ((Bkg. 2018)/59.83)/((Bkg. 2017)/41.48)



ABCD: Year-by-year



Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 pre-VFP, $t\bar{t}+1\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.26	1.07	22.91	1.11	1.87	0.40	17	4.12
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.19	1.04	25.32	1.15	0.26	0.15	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.20	1.01	9.03	0.68	1.63	0.35	19	4.36
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	1.01	1.02	7.70	0.65	55.21	2.17	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 post-VFP, $t\bar{t}+1\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.19	1.01	18.62	0.99	1.41	0.31	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.33	1.16	24.33	1.10	0.00	0.00	36	6.00
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.06	0.89	6.88	0.58	1.71	0.35	12	3.46
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.96	0.96	6.28	0.57	47.74	2.01	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2017, $t\bar{t}+1\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	—	0.85	38.67	1.35	3.02	0.71	45	6.71
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	—	0.88	45.26	1.39	0.17	0.17	67	8.19
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	—	0.84	16.05	0.83	4.61	0.87	58	7.62
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	—	1.01	16.21	0.87	116.15	4.44	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2018, $t\bar{t}+1\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.18	—	65.79	1.85	6.27	1.28	65	8.06
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.14	—	74.45	1.91	0.51	0.36	77	8.77
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.19	—	27.53	1.18	8.41	1.49	83	9.11
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.99	—	23.22	1.10	191.01	7.10	—	—

For 2018: Bkg./2017 = ((Bkg. 2018)/59.83)/((Bkg. 2017)/41.48)

19.52 fb⁻¹

	MC	Data
A/B	0.91 ± 0.06	0.89 ± 0.30
$D_{\text{pred}} = C \cdot (A/B)$	8.2 ± 0.82	17.0 ± 6.89
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	6.2%	—
$D_{\text{pred}}/\text{Lumi}$	0.42 ± 0.04	0.87 ± 0.35

16.81 fb⁻¹

	MC	Data
A/B	0.77 ± 0.05	0.53 ± 0.15
$D_{\text{pred}} = C \cdot (A/B)$	5.3 ± 0.58	6.3 ± 2.56
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	16.2%	—
$D_{\text{pred}}/\text{Lumi}$	0.31 ± 0.03	0.38 ± 0.15

41.48 fb⁻¹

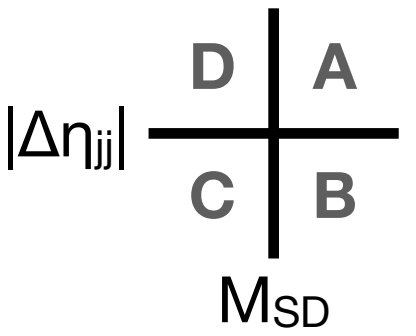
	MC	Data
A/B	0.85 ± 0.04	0.67 ± 0.13
$D_{\text{pred}} = C \cdot (A/B)$	13.7 ± 0.95	39.0 ± 9.08
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	15.4%	—
$D_{\text{pred}}/\text{Lumi}$	0.33 ± 0.02	0.94 ± 0.22

59.83 fb⁻¹

	MC	Data
A/B	0.88 ± 0.03	0.84 ± 0.14
$D_{\text{pred}} = C \cdot (A/B)$	24.3 ± 1.39	70.1 ± 14.09
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	4.7%	—
$D_{\text{pred}}/\text{Lumi}$	0.41 ± 0.02	1.17 ± 0.24



ABCD: Year-by-year



Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 pre-VFP, $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{ij} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.89	1.70	1.14	0.22	1.87	0.40	17	4.12
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.02	0.93	2.18	0.30	0.26	0.15	19	4.36
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.16	1.20	6.29	0.52	1.63	0.35	19	4.36
$ \Delta\eta_{ij} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.94	0.84	2.97	0.36	55.21	2.17	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 post-VFP, $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{ij} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.79	1.61	0.93	0.19	1.41	0.31	19	4.36
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	0.93	0.84	1.71	0.27	0.00	0.00	36	6.00
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.01	1.05	4.72	0.43	1.71	0.35	12	3.46
$ \Delta\eta_{ij} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.87	0.78	2.36	0.32	47.74	2.01	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2017, $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{ij} > 4$ AND $M_{SD} \geq 150$ GeV	A	—	0.90	1.28	0.21	3.02	0.71	45	6.71
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	—	0.91	4.53	0.38	0.17	0.17	67	8.19
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} < 150$ GeV	C	—	1.03	11.50	0.62	4.61	0.87	58	7.62
$ \Delta\eta_{ij} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	—	0.90	6.71	0.50	116.15	4.44	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2018, $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{ij} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.11	—	2.05	0.27	6.27	1.28	65	8.06
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.10	—	7.21	0.51	0.51	0.36	77	8.77
$ \Delta\eta_{ij} \leq 4$ AND $M_{SD} < 150$ GeV	C	0.97	—	16.05	0.80	8.41	1.49	83	9.11
$ \Delta\eta_{ij} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	1.12	—	10.81	0.68	191.01	7.10	—	—

For 2018: Bkg./2017 = ((Bkg. 2018)/59.83)/((Bkg. 2017)/41.48)

19.52 fb⁻¹

	MC	Data
A/B	0.52 ± 0.12	0.89 ± 0.30
$D_{\text{pred}} = C \cdot (A/B)$	3.3 ± 0.82	17.0 ± 6.89
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	10.6%	—
$D_{\text{pred}}/\text{Lumi}$	0.17 ± 0.04	0.87 ± 0.35

16.81 fb⁻¹

	MC	Data
A/B	0.54 ± 0.14	0.53 ± 0.15
$D_{\text{pred}} = C \cdot (A/B)$	2.6 ± 0.70	6.3 ± 2.56
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	8.4%	—
$D_{\text{pred}}/\text{Lumi}$	0.15 ± 0.04	0.38 ± 0.15

41.48 fb⁻¹

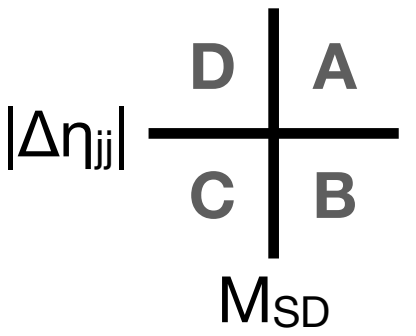
	MC	Data
A/B	0.28 ± 0.05	0.67 ± 0.13
$D_{\text{pred}} = C \cdot (A/B)$	3.2 ± 0.62	39.0 ± 9.08
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	51.7%	—
$D_{\text{pred}}/\text{Lumi}$	0.08 ± 0.01	0.94 ± 0.22

59.83 fb⁻¹

	MC	Data
A/B	0.28 ± 0.04	0.84 ± 0.14
$D_{\text{pred}} = C \cdot (A/B)$	4.6 ± 0.72	70.1 ± 14.09
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	57.7%	—
$D_{\text{pred}}/\text{Lumi}$	0.08 ± 0.01	1.17 ± 0.24



ABCD: Year-by-year



Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 pre-VFP, $t\bar{t}+1\ell$ or $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.28	1.09	24.05	1.13	1.87	0.40	17	4.12
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.17	1.03	27.49	1.19	0.26	0.15	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.18	1.08	15.31	0.86	1.63	0.35	19	4.36
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.99	0.96	10.66	0.75	55.21	2.17	—	—

19.52 fb⁻¹

	MC	Data
A/B	0.87 ± 0.06	0.89 ± 0.30
$D_{\text{pred}} = C \cdot (A/B)$	13.4 ± 1.14	17.0 ± 6.89
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	25.6%	—
$D_{\text{pred}}/\text{Lumi}$	0.69 ± 0.06	0.87 ± 0.35

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 post-VFP, $t\bar{t}+1\ell$ or $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.21	1.03	19.55	1.00	1.41	0.31	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.29	1.14	26.04	1.13	0.00	0.00	36	6.00
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.04	0.95	11.60	0.72	1.71	0.35	12	3.46
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.93	0.90	8.64	0.66	47.74	2.01	—	—

16.81 fb⁻¹

	MC	Data
A/B	0.75 ± 0.05	0.53 ± 0.15
$D_{\text{pred}} = C \cdot (A/B)$	8.7 ± 0.80	6.3 ± 2.56
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	0.7%	—
$D_{\text{pred}}/\text{Lumi}$	0.52 ± 0.05	0.38 ± 0.15

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2017, $t\bar{t}+1\ell$ or $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	—	0.85	39.95	1.36	3.02	0.71	45	6.71
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	—	0.88	49.79	1.44	0.17	0.17	67	8.19
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	—	0.91	27.55	1.04	4.61	0.87	58	7.62
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	—	0.97	22.92	1.00	116.15	4.44	—	—

41.48 fb⁻¹

	MC	Data
A/B	0.80 ± 0.04	0.67 ± 0.13
$D_{\text{pred}} = C \cdot (A/B)$	22.1 ± 1.29	39.0 ± 9.08
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	3.6%	—
$D_{\text{pred}}/\text{Lumi}$	0.53 ± 0.03	0.94 ± 0.22

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2018, $t\bar{t}+1\ell$ or $t\bar{t}+2\ell$ ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.18	—	67.84	1.87	6.27	1.28	65	8.06
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.14	—	81.66	1.98	0.51	0.36	77	8.77
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.10	—	43.58	1.42	8.41	1.49	83	9.11
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	1.03	—	34.03	1.30	191.01	7.10	—	—

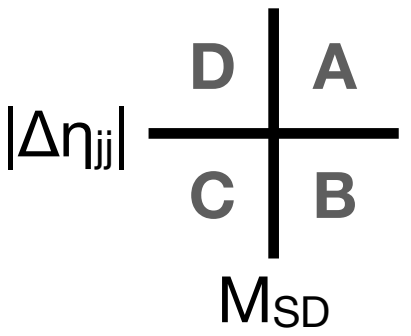
59.83 fb⁻¹

	MC	Data
A/B	0.83 ± 0.03	0.84 ± 0.14
$D_{\text{pred}} = C \cdot (A/B)$	36.2 ± 1.78	70.1 ± 14.09
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	6.4%	—
$D_{\text{pred}}/\text{Lumi}$	0.61 ± 0.03	1.17 ± 0.24

For 2018: Bkg./2017 = ((Bkg. 2018)/59.83)/((Bkg. 2017)/41.48)



ABCD: Year-by-year



Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 pre-VFP, NOT ($t\bar{t}+1\ell$ or $t\bar{t}+2\ell$) ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.06	0.94	4.62	0.73	1.87	0.40	17	4.12
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	0.85	0.72	6.54	0.50	0.26	0.15	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.15	1.00	12.31	1.44	1.63	0.35	19	4.36
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.76	0.62	5.17	0.90	55.21	2.17	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2016 post-VFP, NOT ($t\bar{t}+1\ell$ or $t\bar{t}+2\ell$) ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.41	1.24	5.27	0.78	1.41	0.31	19	4.36
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.01	0.85	6.72	0.66	0.00	0.00	36	6.00
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.24	1.07	11.36	1.30	1.71	0.35	12	3.46
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	0.90	0.73	5.26	1.05	47.74	2.01	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2017, NOT ($t\bar{t}+1\ell$ or $t\bar{t}+2\ell$) ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	—	0.88	9.24	0.88	3.02	0.71	45	6.71
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	—	0.85	16.46	2.68	0.17	0.17	67	8.19
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	—	0.86	22.68	1.96	4.61	0.87	58	7.62
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	—	0.81	14.51	2.10	116.15	4.44	—	—

Preselection AND $M_{jj} > 600$ GeV AND $S_T > 900$ GeV AND PNet Xbb > 0.9 (2018, NOT ($t\bar{t}+1\ell$ or $t\bar{t}+2\ell$) ONLY)

Cut	Region	Bkg./2017	Bkg./2018	Bkg. (wgt)	Bkg. Err.*	Sig. (wgt)	Sig. Err.*	Data	Data Err.*
$ \Delta\eta_{jj} > 4$ AND $M_{SD} \geq 150$ GeV	A	1.13	—	15.10	1.41	6.27	1.28	65	8.06
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} \geq 150$ GeV	B	1.18	—	27.98	4.21	0.51	0.36	77	8.77
$ \Delta\eta_{jj} \leq 4$ AND $M_{SD} < 150$ GeV	C	1.16	—	37.89	2.94	8.41	1.49	83	9.11
$ \Delta\eta_{jj} > 4$ AND $M_{SD} < 150$ GeV (SR)	D	1.23	—	25.71	2.81	191.01	7.10	—	—

For 2018: Bkg./2017 = ((Bkg. 2018)/59.83)/((Bkg. 2017)/41.48)

19.52 fb⁻¹

	MC	Data
A/B	0.71 ± 0.12	0.89 ± 0.30
$D_{\text{pred}} = C \cdot (A/B)$	8.7 ± 1.83	17.0 ± 6.89
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	67.8%	—
$D_{\text{pred}}/\text{Lumi}$	0.44 ± 0.09	0.87 ± 0.35

16.81 fb⁻¹

	MC	Data
A/B	0.78 ± 0.14	0.53 ± 0.15
$D_{\text{pred}} = C \cdot (A/B)$	8.9 ± 1.88	6.3 ± 2.56
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	69.4%	—
$D_{\text{pred}}/\text{Lumi}$	0.53 ± 0.11	0.38 ± 0.15

41.48 fb⁻¹

	MC	Data
A/B	0.56 ± 0.11	0.67 ± 0.13
$D_{\text{pred}} = C \cdot (A/B)$	12.7 ± 2.65	39.0 ± 9.08
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	12.2%	—
$D_{\text{pred}}/\text{Lumi}$	0.31 ± 0.06	0.94 ± 0.22

59.83 fb⁻¹

	MC	Data
A/B	0.54 ± 0.10	0.84 ± 0.14
$D_{\text{pred}} = C \cdot (A/B)$	20.4 ± 3.95	70.1 ± 14.09
$ 1 - D_{\text{pred}}/D_{\text{MC}} $	20.5%	—
$D_{\text{pred}}/\text{Lumi}$	0.34 ± 0.07	1.17 ± 0.24