VBS VVH All-Hadronic

Improved ABCDNet performance

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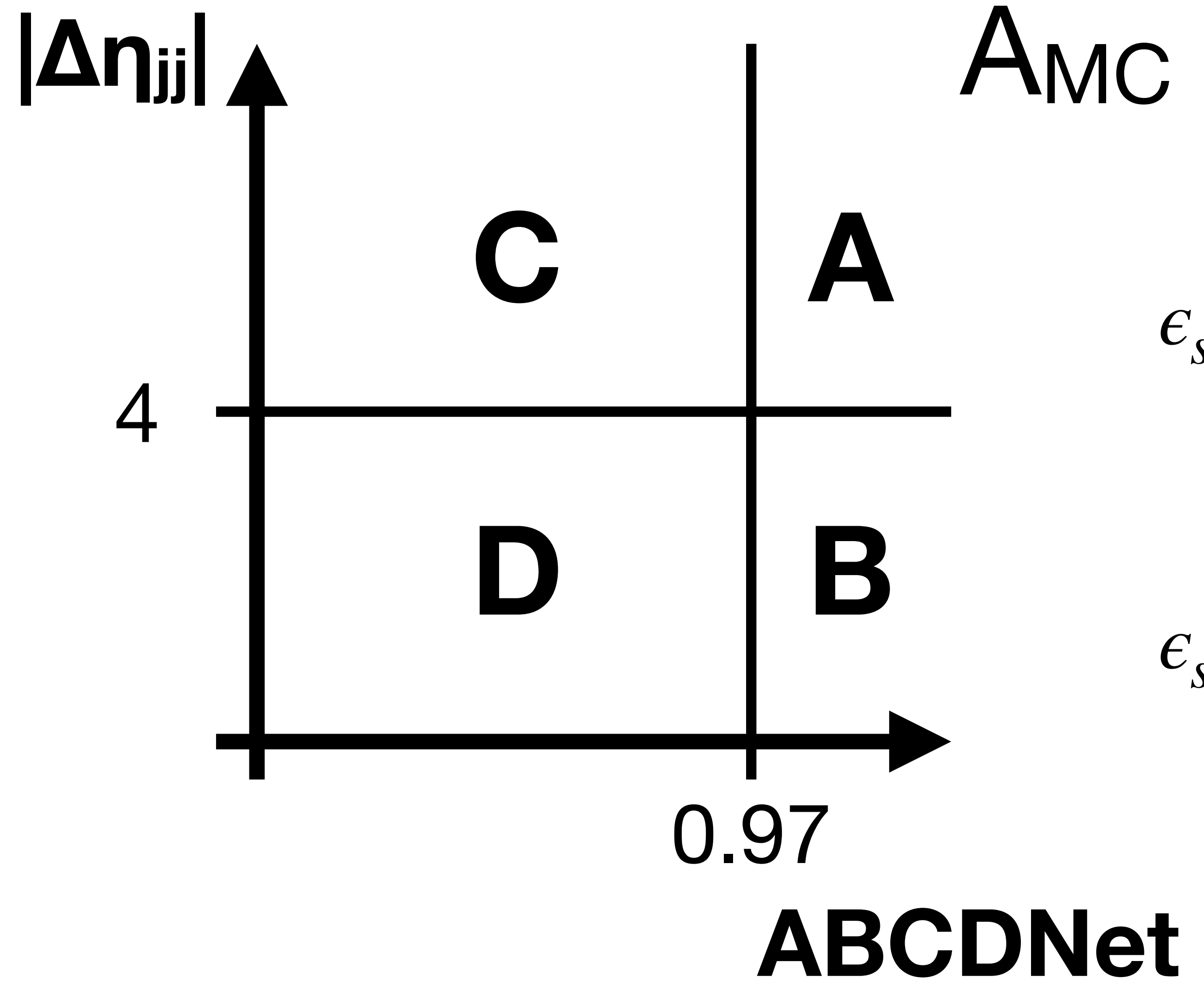
Orig. ABCDNet: λ = 30 DisCo (Leaky ReLU)

Xbb > 0.60 and XWqq > 0.75|0.70 (ld|tr)

Selection	Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
$\lvert\Delta\eta_{jj}\rvert > 4$ and ABCDNet > 0.97	A	1.82	0.57	3.48	0.05	—	—
$\lvert\Delta\eta_{jj}\rvert \leq 4$ and ABCDNet > 0.97	B	5.70	1.25	0.47	0.02	5	2.24
$\lvert\Delta\eta_{jj}\rvert > 4$ and ABCDNet ≤ 0.97	C	292.52	25.89	3.05	0.05	281	16.76
$\lvert\Delta\eta_{jj}\rvert \leq 4$ and ABCDNet ≤ 0.97	D	1011.83	41.07	0.65	0.02	1200	34.64

Fairly performant SR, and closure is within 1σ
(but Region D data/MC is not great)



$$A_{MC} = B_{MC} \times C_{MC} / D_{MC} = \mathbf{1.65 \pm 0.40}$$

$$\epsilon_{syst} = \left| 1 - \frac{A_{MC}^{pred}}{A_{MC}} \right| = \left| 1 - \frac{1.65}{1.82} \right| = 9.4\%$$

$$\epsilon_{stat} = \sqrt{\frac{1}{B_{data}} + \frac{1}{C_{data}} + \frac{1}{D_{data}}} = 45.2\%$$

Original Result

Expected sig. 3.48 ± 0.05

Predicted bkg. 1.17 ± 0.53 ± 0.11

stat. *syst.*

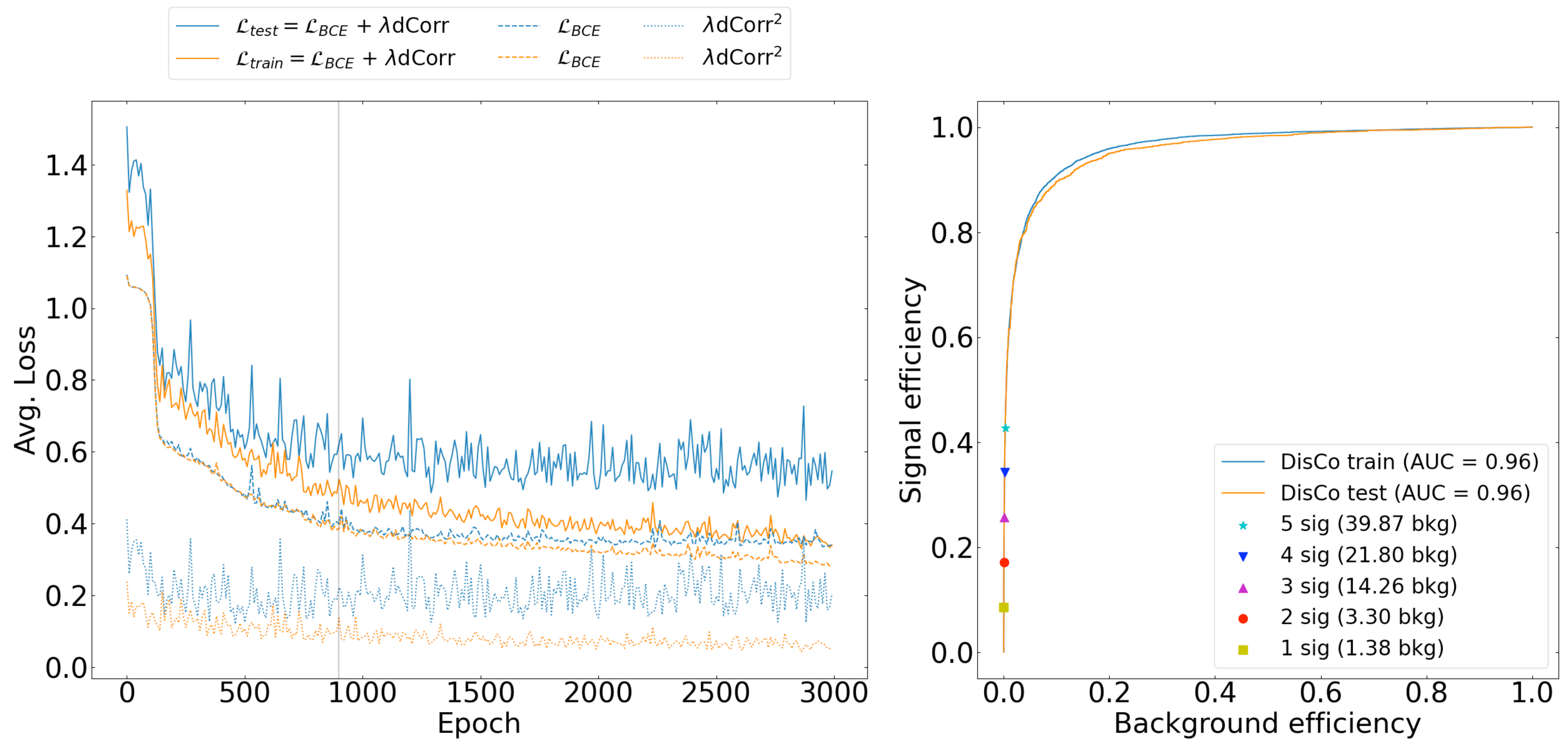
Predicted significance (S/√B) and syst. error improved over previous results

Epoch = 600 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

ABCDNet: λ = 30 DisCo (Leaky ReLU)

$$\mathscr{L} = \mathscr{L}_{BCE}(f(\vec{x}), y) + 30 \times \mathrm{dCorr}_{y=0}(f(\vec{x}), |\Delta\eta_{jj}|)$$

- 3 hidden layers (64 nodes each)
- Preselection:
  - Xbb > 0.5 and XWqq > 0.3
- Input features:
  - H→bb fat jet p4 (i.e. p_T, η, ϕ), M_{PNet}
  - V→qq fat jet p4 (i.e. p_T, η, ϕ), M_{PNet}
  - M_{jj}
- p_T → ln(p_T), others → (x - min)/(max - min)

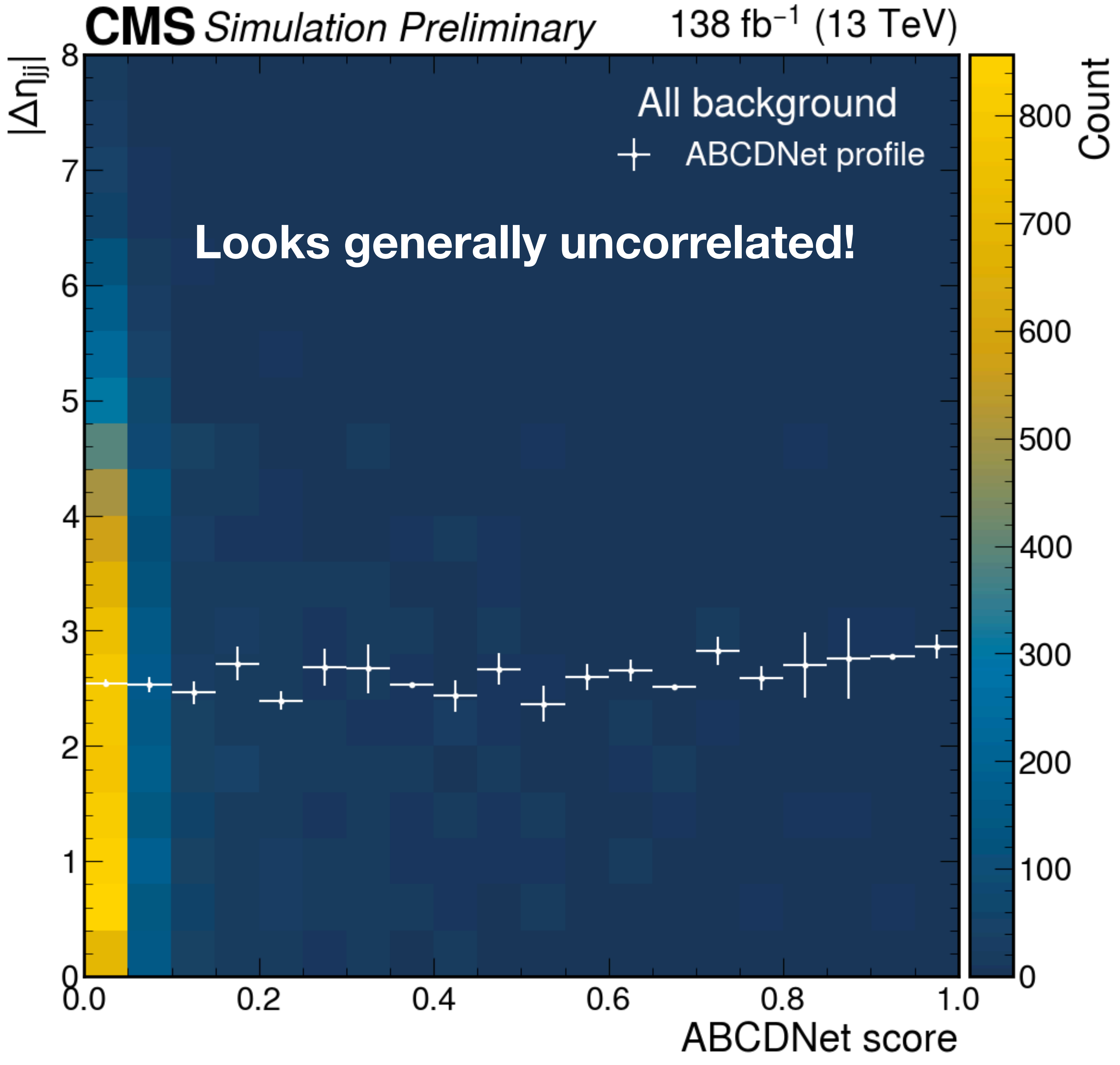


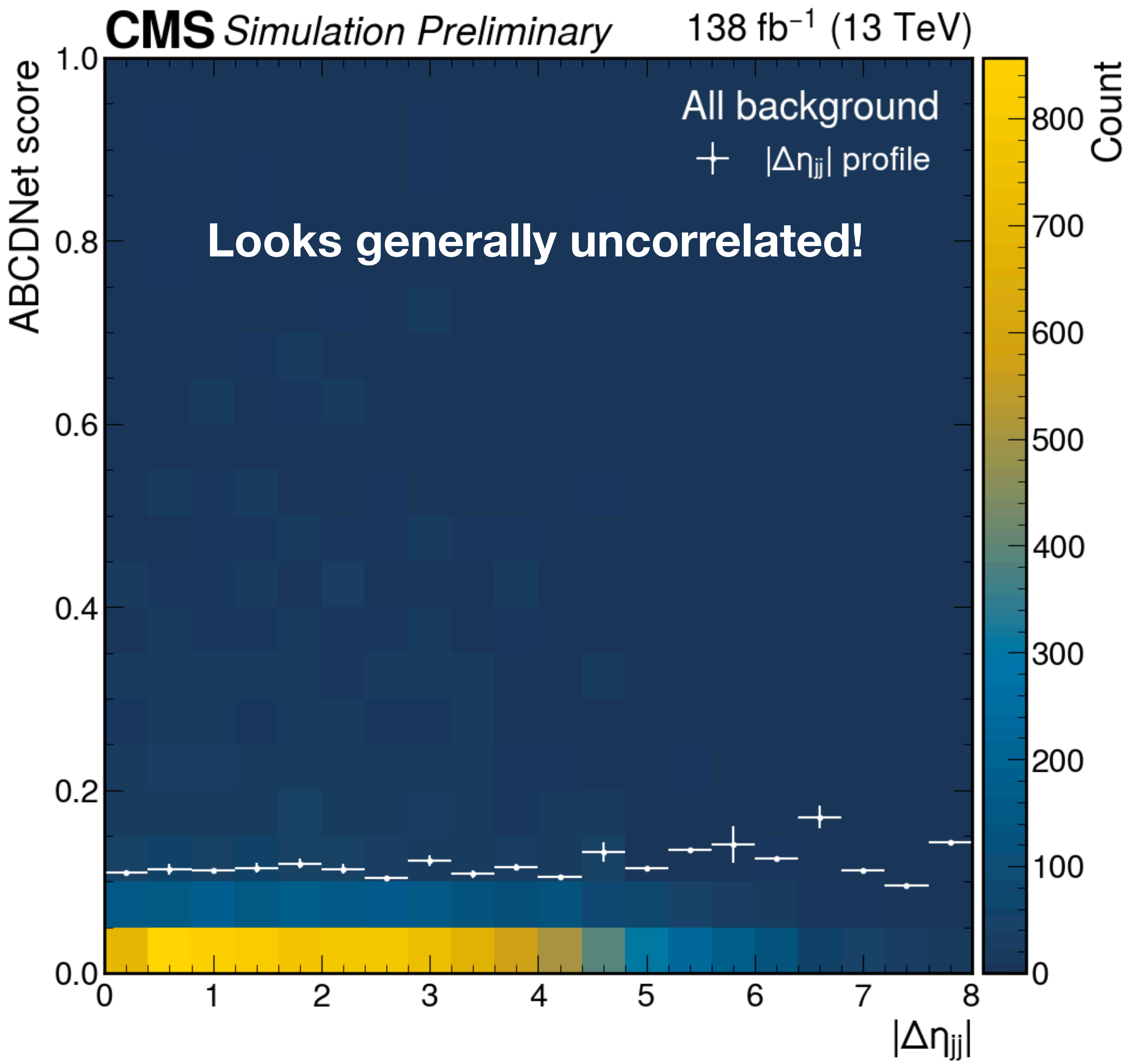
Trained longer than previous model
in order to ensure that we have
the most performant model

Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

ABCDNet: λ = 30 DisCo (Leaky ReLU)

$$\mathscr{L} = \mathscr{L}_{BCE}(f(\vec{x}), y) + 30 \times \mathrm{dCorr}_{y=0}(f(\vec{x}), |\Delta\eta_{jj}|)$$





Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

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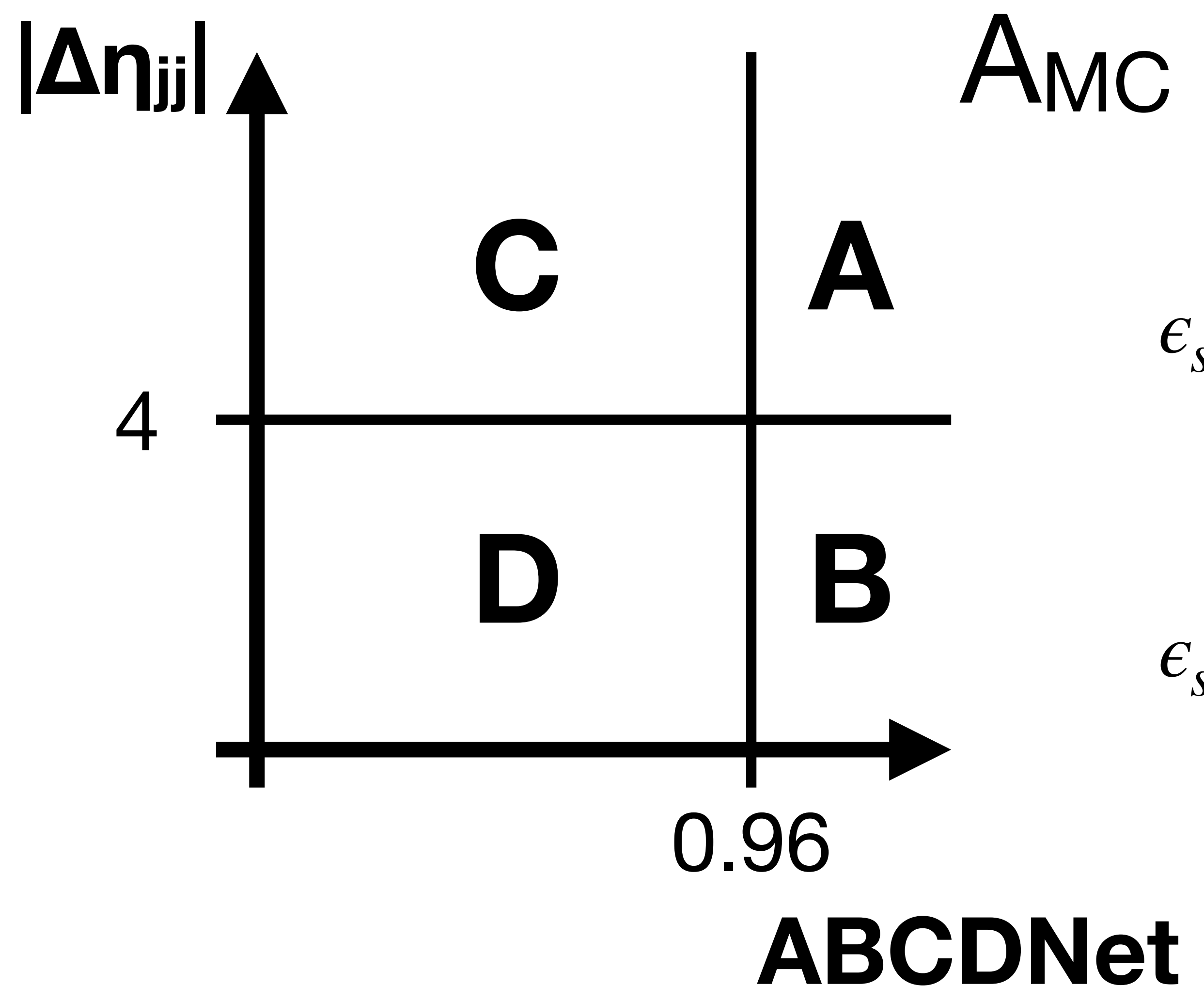
ABCDNet: λ = 30 DisCo (Leaky ReLU)

Xbb > 0.60 and XWqq > 0.75|0.70 (ld|tr)

Selection	Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
$\lvert\Delta\eta_{jj}\rvert > 4$ and ABCDNet > 0.96	A	1.46	0.54	3.73	0.05	–	–
$\lvert\Delta\eta_{jj}\rvert \leq 4$ and ABCDNet > 0.96	B	5.12	1.06	0.48	0.02	4	2.00
$\lvert\Delta\eta_{jj}\rvert > 4$ and ABCDNet ≤ 0.96	C	292.88	25.89	2.80	0.05	280	16.73
$\lvert\Delta\eta_{jj}\rvert \leq 4$ and ABCDNet ≤ 0.96	D	1012.41	41.07	0.63	0.02	1201	34.66

Fairly performant SR, and closure is very good
(but Region D data/MC is not great)



$$A_{MC} = B_{MC} \times C_{MC} / D_{MC} = \mathbf{1.48 \pm 0.34}$$

$$\epsilon_{syst} = \left| 1 - \frac{A_{MC}^{pred}}{A_{MC}} \right| = \left| 1 - \frac{1.48}{1.46} \right| = 1.6\%$$

$$\epsilon_{stat} = \sqrt{\frac{1}{B_{data}} + \frac{1}{C_{data}} + \frac{1}{D_{data}}} = 50.4\%$$

Final Result

Expected sig. 3.73 ± 0.05

Predicted bkg. 0.93 ± 0.47 ± 0.02

stat. *syst.*

Predicted significance (S/√B) slightly improved and MC closure is better

Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

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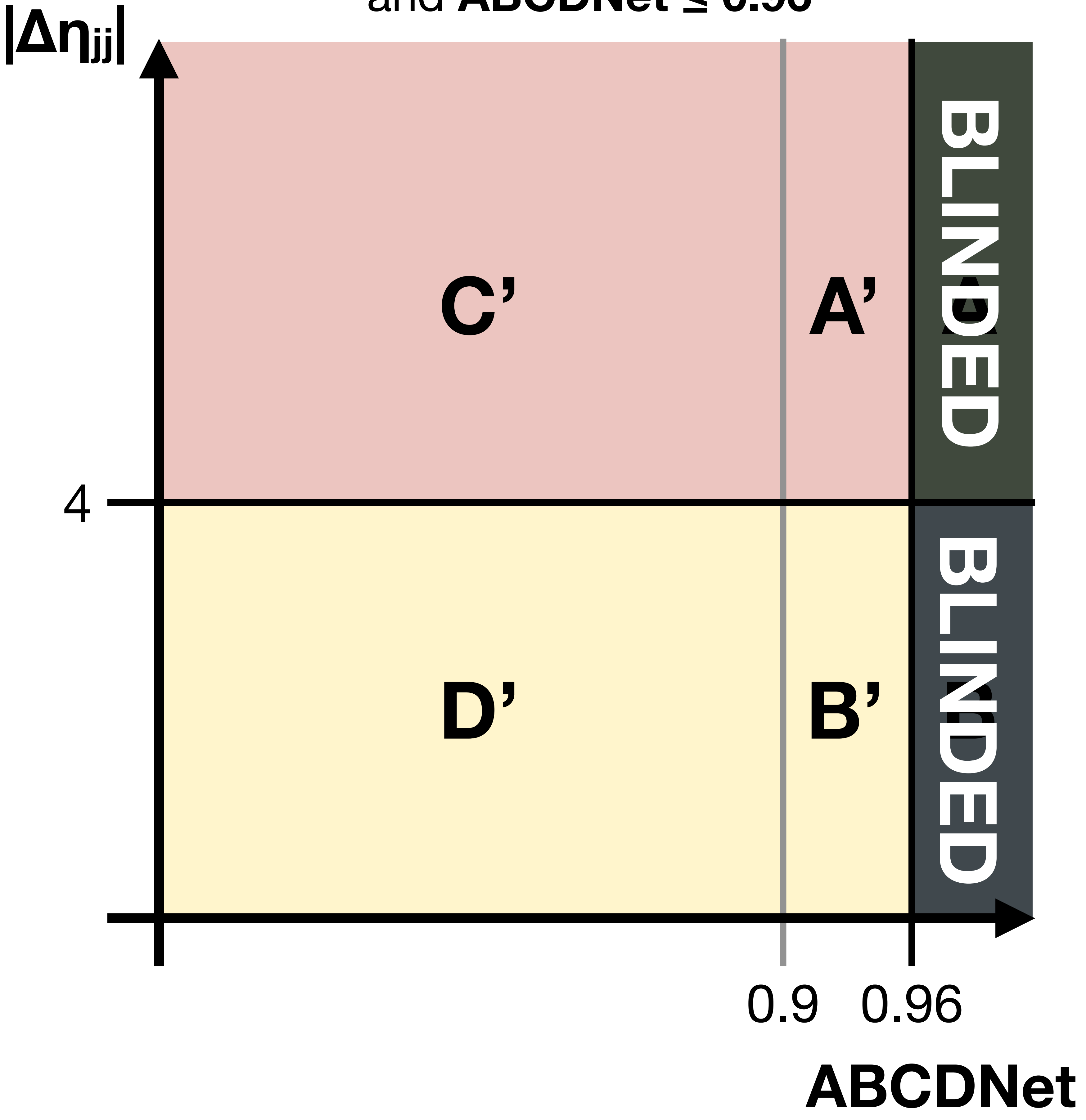
ABCDNet: λ = 30 DisCo (Leaky ReLU)

Xbb > 0.60 and XWqq > 0.75|0.70 (ld|tr)
and **ABCDNet ≤ 0.96**



Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
A’	**1.59**	0.82	0.96	0.03	**2**	1.41
B’	11.62	2.20	0.16	0.01	10	3.16
C’	291.29	25.88	1.84	0.04	278	16.67
D’	1000.8	41.01	0.47	0.02	1191	34.51

$$A^{pred} = B \times \frac{C}{D} = \begin{cases} \mathbf{3.38 \pm 0.72} \ \text{(MC)} \\ \mathbf{2.33 \pm 0.75} \ \text{(Data)} \end{cases}$$

- Blind ABCDNet SR cut
- Perform ABCD (here: A’B’C’D’) to predict number of background in a “near-SR” part of the C+D sideband
- Closer to “real-life” closure test in **data**

ABCD works well with data in sidebands ⇒ method is valid!

Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

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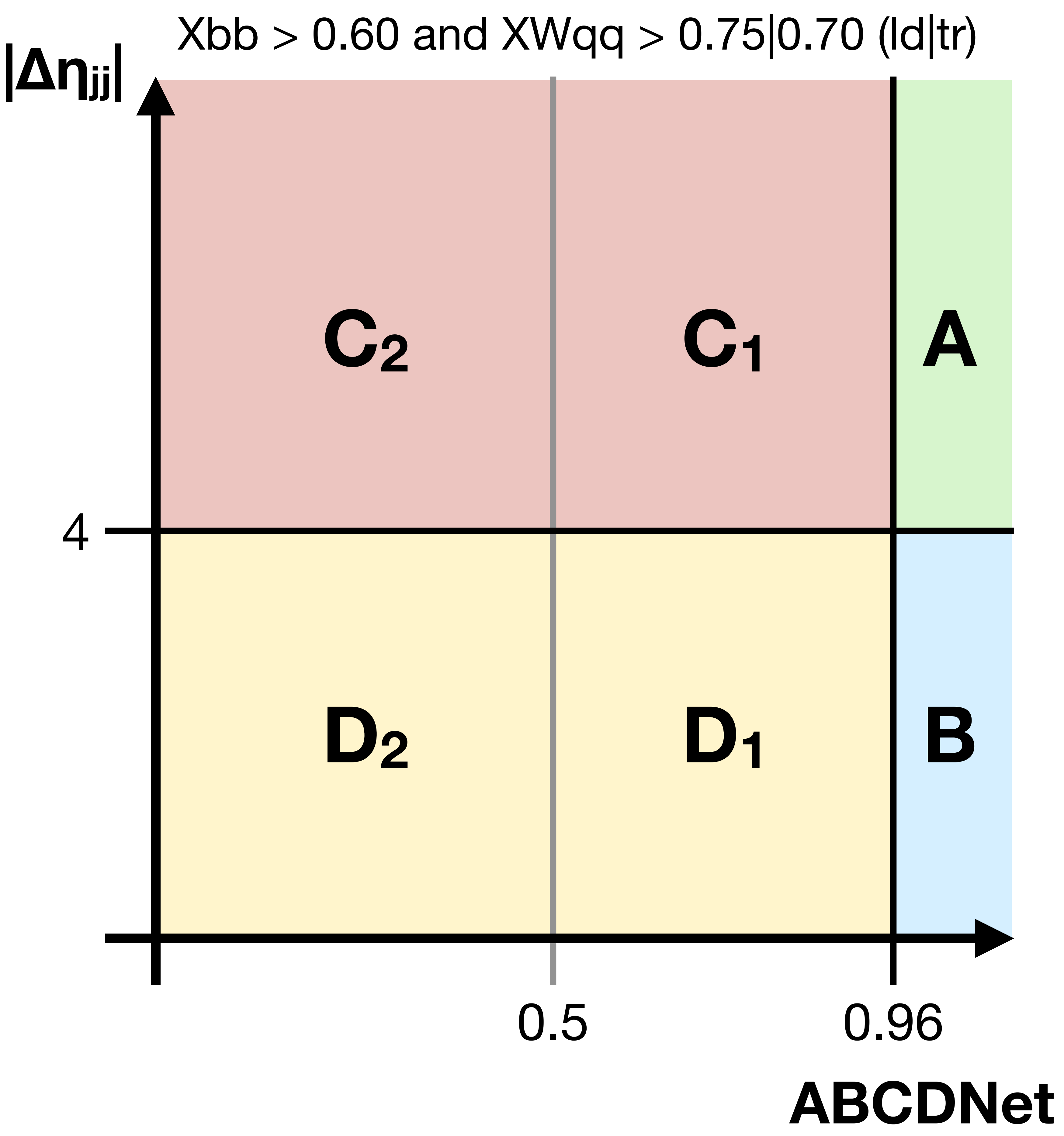
ABCDNet: λ = 30 DisCo (Leaky ReLU)



Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
A	**1.46**	0.54	**3.73**	0.05	–	–
B	5.12	1.06	0.48	0.02	4	2.00
C	292.88	25.89	2.80	0.05	280	16.73
D	1012.4	41.07	0.63	0.02	1201	34.66

$$A^{\text{pred}} = B \times \frac{C}{D} = \begin{cases} 1.48 \pm 0.34 \ \text{(MC)} \\ \mathbf{0.93 \pm 0.47} \ \text{(Data)} \end{cases}$$

✓

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
A	**1.46**	0.54	**3.73**	0.05	–	–
B	5.12	1.06	0.48	0.02	4	2.00
C_1	17.17	2.46	2.29	0.04	16	4.00
D_1	81.2	9.25	0.47	0.02	70	8.37

$$A^{\text{pred}} = B \times \frac{C_1}{D_1} = \begin{cases} 1.08 \pm 0.30 \ \text{(MC)} \\ \mathbf{0.91 \pm 0.52} \ \text{(Data)} \end{cases}$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
C_1	17.17	2.46	2.29	0.04	**16**	4.00
D_1	81.15	9.25	0.47	0.02	70	8.37
C_2	275.71	25.78	0.51	0.02	264	16.25
D_2	931.26	40.02	0.17	0.01	1131	33.63

$$C_1^{\text{pred}} = D_1 \times \frac{C_2}{D_3} = \mathbf{16.34 \pm 2.25} \ \text{(Data)} ✓$$

ABCD works well with data in sidebands ⇒ method is valid!

Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

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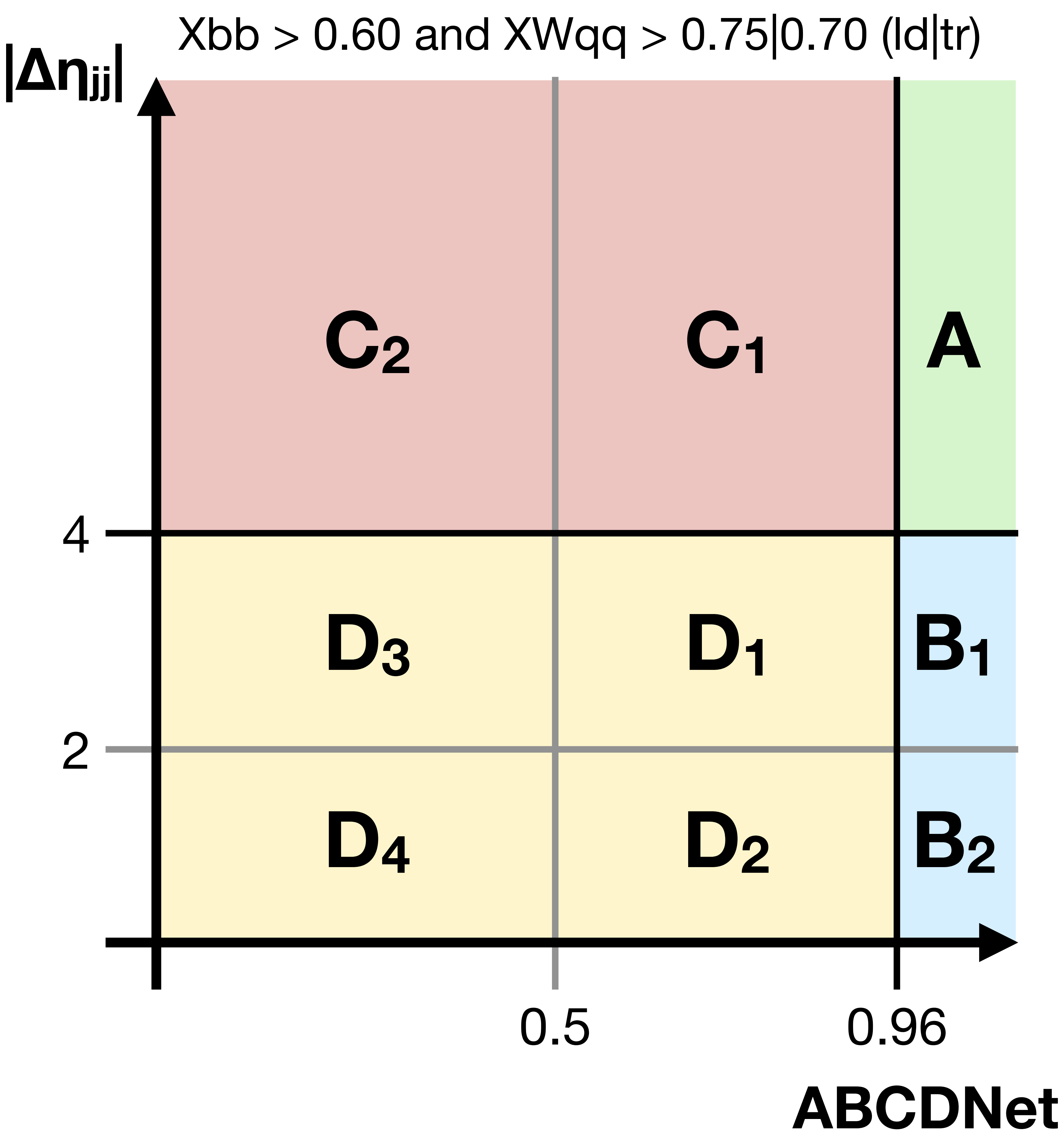
ABCDNet: λ = 30 DisCo (Leaky ReLU)



Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
A	**1.46**	0.54	**3.73**	0.05	–	–
B	5.12	1.06	0.48	0.02	4	2.00
C	292.88	25.89	2.80	0.05	280	16.73
D	1012.4	41.07	0.63	0.02	1201	34.66

$$A^{pred} = B \times \frac{C}{D} = \left[\begin{array}{ll} 1.48 \pm 0.34 & \text{(MC)} \\ \mathbf{0.93 \pm 0.47} & \text{(Data)} \end{array} \right.$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
B_1	2.90	0.81	0.20	0.01	2	1.41
B_2	2.22	0.68	0.28	0.01	2	1.41
D_1	33.28	3.80	0.20	0.01	37	6.08
D_2	47.87	8.44	0.27	0.01	33	5.74

$$B_1^{pred} = B_2 \times \frac{D_1}{D_2} = \mathbf{2.24 \pm 1.67} \text{ (Data) ?}$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
D_1	33.28	3.80	0.20	0.01	37	6.08
D_2	47.87	8.44	0.27	0.01	33	5.74
D_3	441.29	28.47	0.07	0.01	540	23.24
D_4	489.96	28.12	0.10	0.01	591	24.31

$$D_1^{pred} = D_2 \times \frac{D_3}{D_4} = \mathbf{30.15 \pm 5.55} \text{ (Data) ✓}$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
C_1	17.17	2.46	2.29	0.04	16	4.00
D_1	33.28	3.80	0.20	0.01	37	6.08
C_2	275.71	25.78	0.51	0.02	264	16.25
D_3	441.29	28.47	0.07	0.01	540	23.24

$$C_1^{pred} = D_1 \times \frac{C_2}{D_3} = \mathbf{18.09 \pm 3.27} \text{ (Data) ✓}$$

ABCD works well with data in sidebands ⇒ method is valid!

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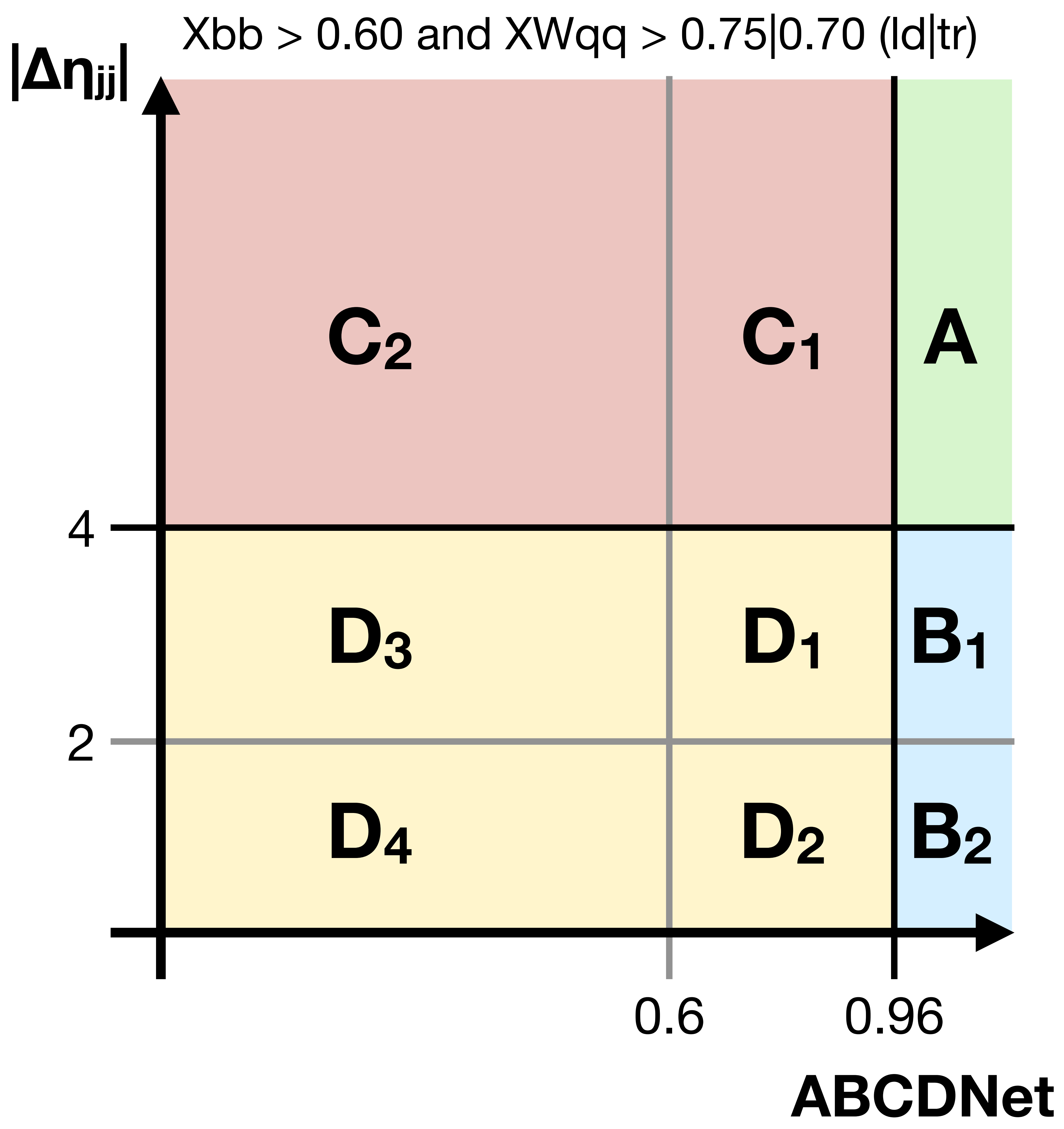
ABCDNet: λ = 30 DisCo (Leaky ReLU)



Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
A	**1.46**	0.54	**3.73**	0.05	–	–
B	5.12	1.06	0.48	0.02	4	2.00
C	292.88	25.89	2.80	0.05	280	16.73
D	1012.4	41.07	0.63	0.02	1201	34.66

$$A^{\text{pred}} = B \times \frac{C}{D} = \left[\begin{array}{l} 1.48 \pm 0.34 \ \text{(MC)} \\ \mathbf{0.93 \pm 0.47} \ \text{(Data)} \end{array} \right.$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
B_1	2.90	0.81	0.20	0.01	2	1.41
B_2	2.22	0.68	0.28	0.01	2	1.41
D_1	27.26	3.48	0.18	0.01	30	5.48
D_2	37.87	8.14	0.24	0.01	26	5.10

$$B_1^{\text{pred}} = B_2 \times \frac{D_1}{D_2} = 2.31 \pm 1.75 \ \text{(Data) ?}$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
D_1	27.26	3.48	0.18	0.01	30	5.48
D_2	37.87	8.14	0.24	0.01	26	5.10
D_3	447.31	28.51	0.09	0.01	547	23.39
D_4	499.96	28.21	0.12	0.01	598	24.45

$$D_1^{\text{pred}} = D_2 \times \frac{D_3}{D_4} = 23.78 \pm 4.87 \ \text{(Data)} \checkmark$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
C_1	14.91	2.33	2.15	0.04	11	3.32
D_1	27.26	3.48	0.18	0.01	30	5.48
C_2	277.97	25.79	0.64	0.02	269	16.40
D_3	447.31	28.51	0.09	0.01	547	23.39

$$C_1^{\text{pred}} = D_1 \times \frac{C_2}{D_3} = 14.75 \pm 2.91 \ \text{(Data)} \checkmark$$

ABCD works well with data in sidebands ⇒ method is valid!

Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

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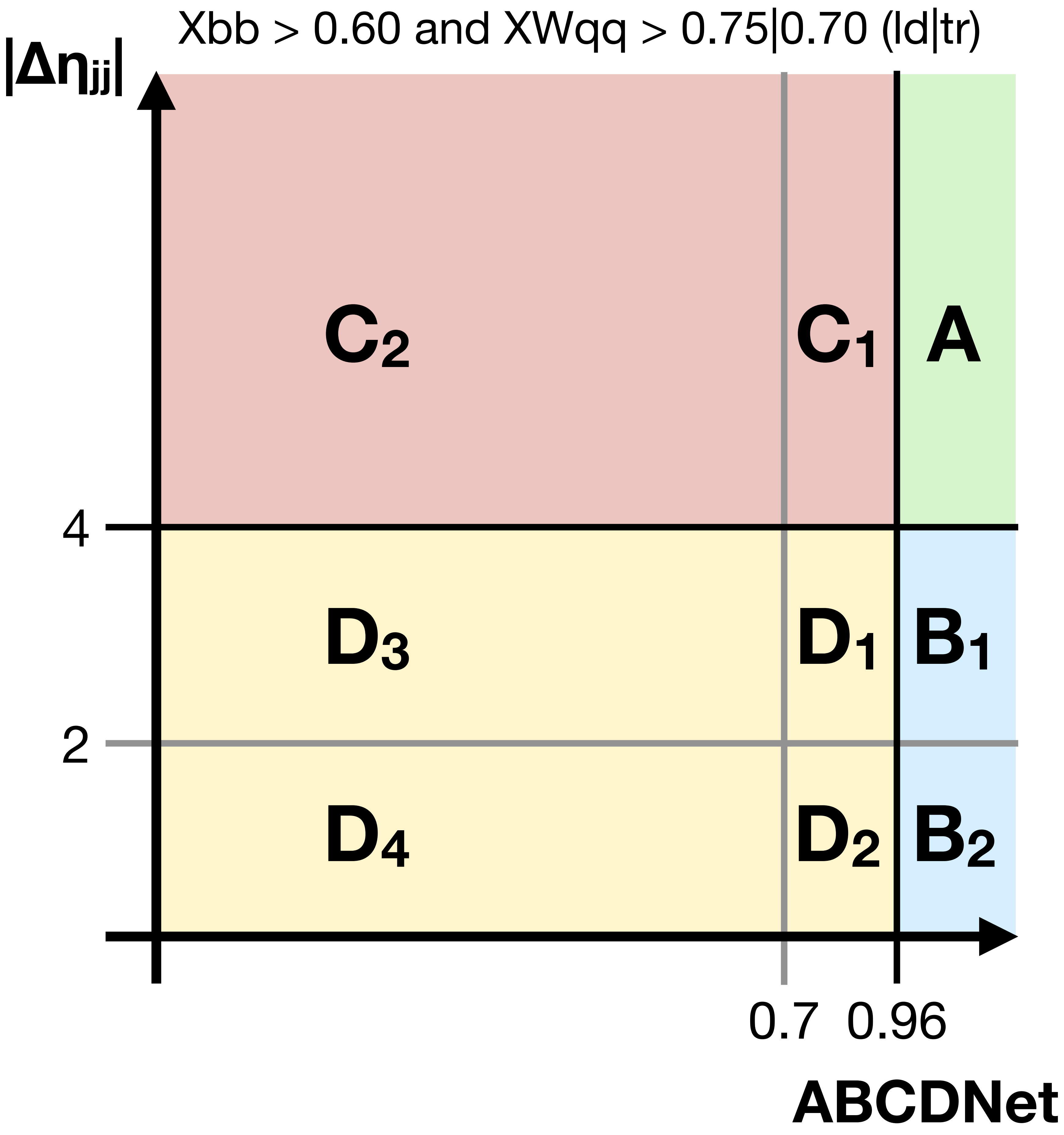
ABCDNet: λ = 30 DisCo (Leaky ReLU)



Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
A	**1.46**	0.54	**3.73**	0.05	—	—
B	5.12	1.06	0.48	0.02	4	2.00
C	292.88	25.89	2.80	0.05	280	16.73
D	1012.4	41.07	0.63	0.02	1201	34.66

$$A^{pred} = B \times \frac{C}{D} = \left[\begin{array}{l} 1.48 \pm 0.34 \text{ (MC)} \\ \mathbf{0.93 \pm 0.47} \text{ (Data)} \end{array}\right.$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
B_1	2.90	0.81	0.20	0.01	2	1.41
B_2	2.22	0.68	0.28	0.01	2	1.41
D_1	21.52	3.10	0.16	0.01	24	4.90
D_2	22.04	3.09	0.21	0.01	17	4.12

$$B_1^{pred} = B_2 \times \frac{D_1}{D_2} = 2.82 \pm 2.19 \text{ (Data) ?}$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
D_1	21.52	3.10	0.16	0.01	24	4.90
D_2	22.04	3.09	0.21	0.01	17	4.12
D_3	453.06	28.56	0.11	0.01	553	23.52
D_4	515.80	29.19	0.15	0.01	607	24.64

$$D_1^{pred} = D_2 \times \frac{D_3}{D_4} = 15.49 \pm 3.87 \text{ (Data) ✓}$$

Region	Bkg	Bkg err	Sig	Sig err	Data	Data err
C_1	8.89	1.71	1.96	0.04	9	3.00
D_1	21.52	3.10	0.16	0.01	24	4.90
C_2	283.99	25.84	0.84	0.03	271	16.46
D_3	453.06	28.56	0.11	0.01	553	23.52

$$C_1^{pred} = D_1 \times \frac{C_2}{D_3} = 11.76 \pm 2.55 \text{ (Data) ✓}$$

ABCD works well with data in sidebands ⇒ method is valid!

Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized

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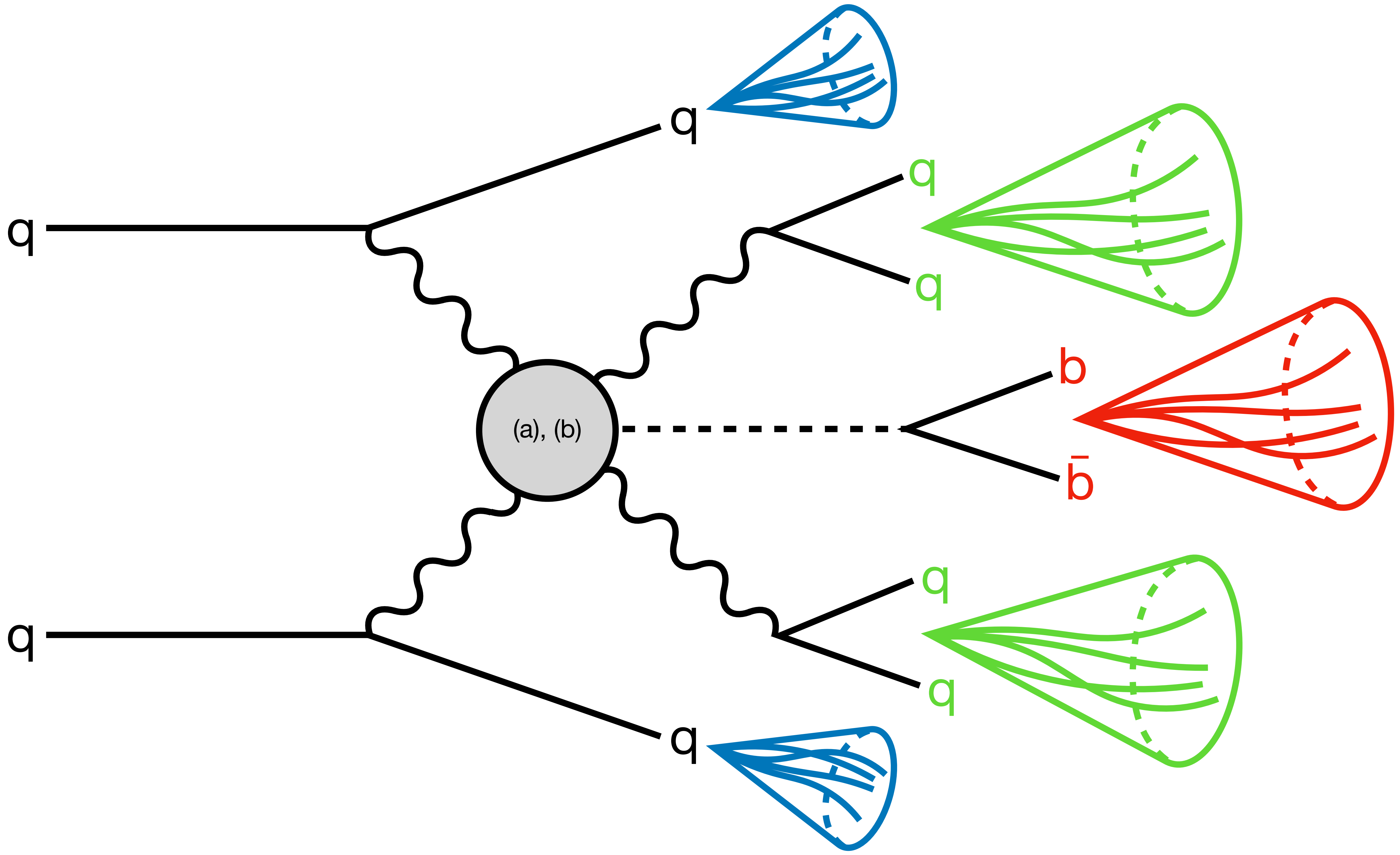
Summary

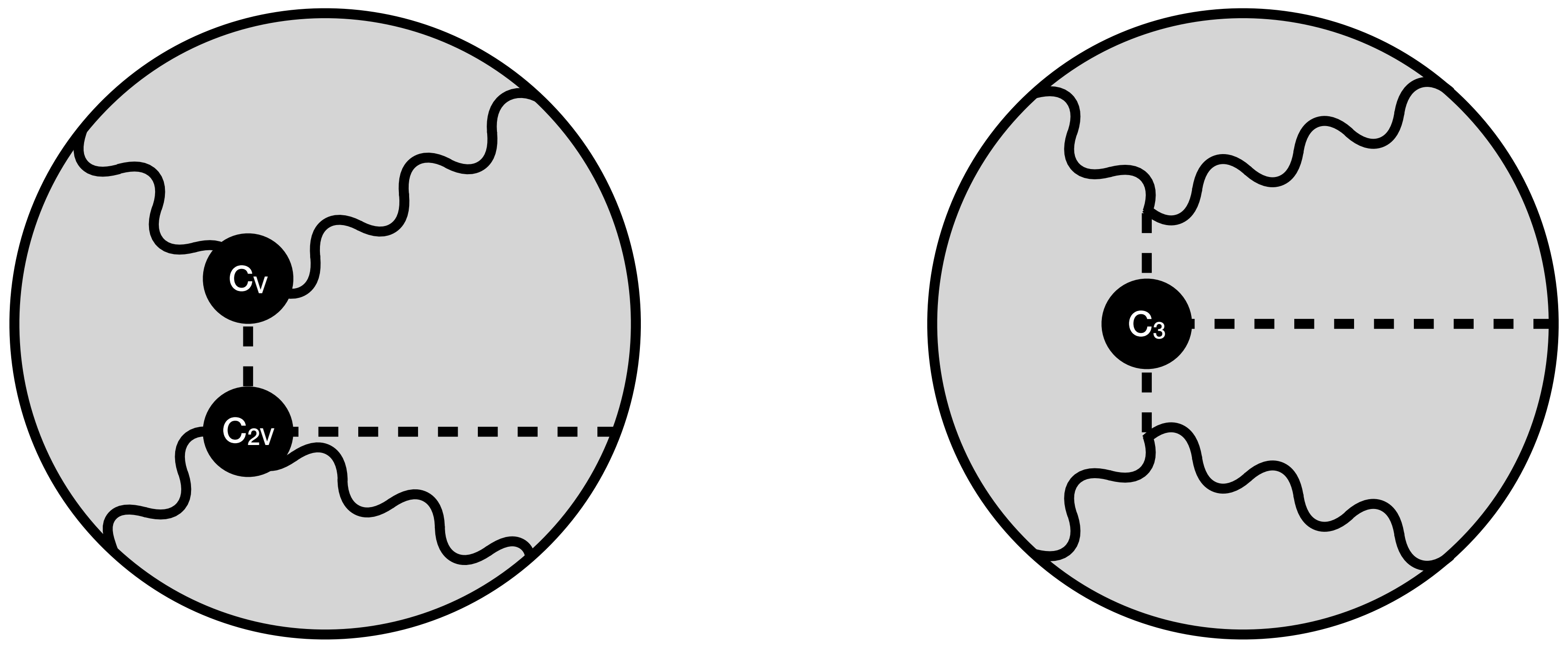
- Settled on ABCDNet training
- Next steps:
  - Strengthen defense for QCD correction
  - Add scale factors, get signal systematics

Backup

All-Hadronic VBS VVH

- Targeting the following final states:
  - VBS WWH → qq qq qq $b\bar{b}$
  - VBS ZZH → qq qq qq $b\bar{b}$
  - VBS WZH → qq qq qq $b\bar{b}$
- Sensitive to C_{2V}, C_3, and C_V in principle
- BSM signature:
  - W/Z/H jets with large p_T
  - VBS jets with large $\Delta\eta_{jj}$, M_{jj}





(a) (b)

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Skim + Triggers + 3 Fat Jet Region

Yields scaled to lumi×σ, rounded for readability

Cut	QCD	$t\bar{t}$+jets	$t\bar{t}+1\ell$	$t\bar{t}$+W	$t\bar{t}$+H	Single top	Bosons	Total Bkg.	Eff.	VBSVVH (C_{2V} = 2)	Eff.
Skim	137,061K	748K	86K	2.6K	1.3K	53K	1,513K	139,464K	—	175	—
HLT + MET Filters	88,702K	575K	70K	2.2K	1.1K	41K	1,120K	90,512K	65%	168	96%
At least 3 fat jets	395K	9.8K	1.4K	110	46	874	13K	421K	0%	32	19%

Object	Skim Selection
Leptons (μ, e)	== 0 veto*
Fat Jets	≥ 2 AK8 jets w/ p_T > 300 GeV AND $\|\eta\|$ < 2.5 AND mass > 50 GeV AND M_{SD} > 40 GeV AND fat jet ID > 0
Jets	≥ 2 AK4 jets w/ p_T > 20 GeV AND passes tight jet ID AND ΔR(jet, fat jet) > 0.8

*Using the ttH lepton ID

Year	HLT path

2016	`HLT_PFHT800`
	`HLT_PFHT900`
	`HLT_AK8PFHT650_TrimR0p1PT0p03Mass50`
	`HLT_AK8PFHT700_TrimR0p1PT0p03Mass50`
	`HLT_AK8PFJet450`
	`HLT_AK8PFJet360_TrimMass30`
	`HLT_AK8DiPFJet280_200_TrimMass30`
	`HLT_AK8DiPFJet280_200_TrimMass30_BTagCSV_p20`

2017	`HLT_PFHT1050`
	`HLT_AK8PFHT800_TrimMass50`
	`HLT_PFJet320`
	`HLT_PFJet500`
	`HLT_AK8PFJet320`
	`HLT_AK8PFJet500`
	`HLT_AK8PFJet400_TrimMass30`
	`HLT_AK8PFJet420_TrimMass30`

2018	`HLT_PFHT1050`
	`HLT_AK8PFHT800_TrimMass50`
	`HLT_PFJet500`
	`HLT_AK8PFJet500`
	`HLT_AK8PFJet400_TrimMass30`
	`HLT_AK8PFJet420_TrimMass30`

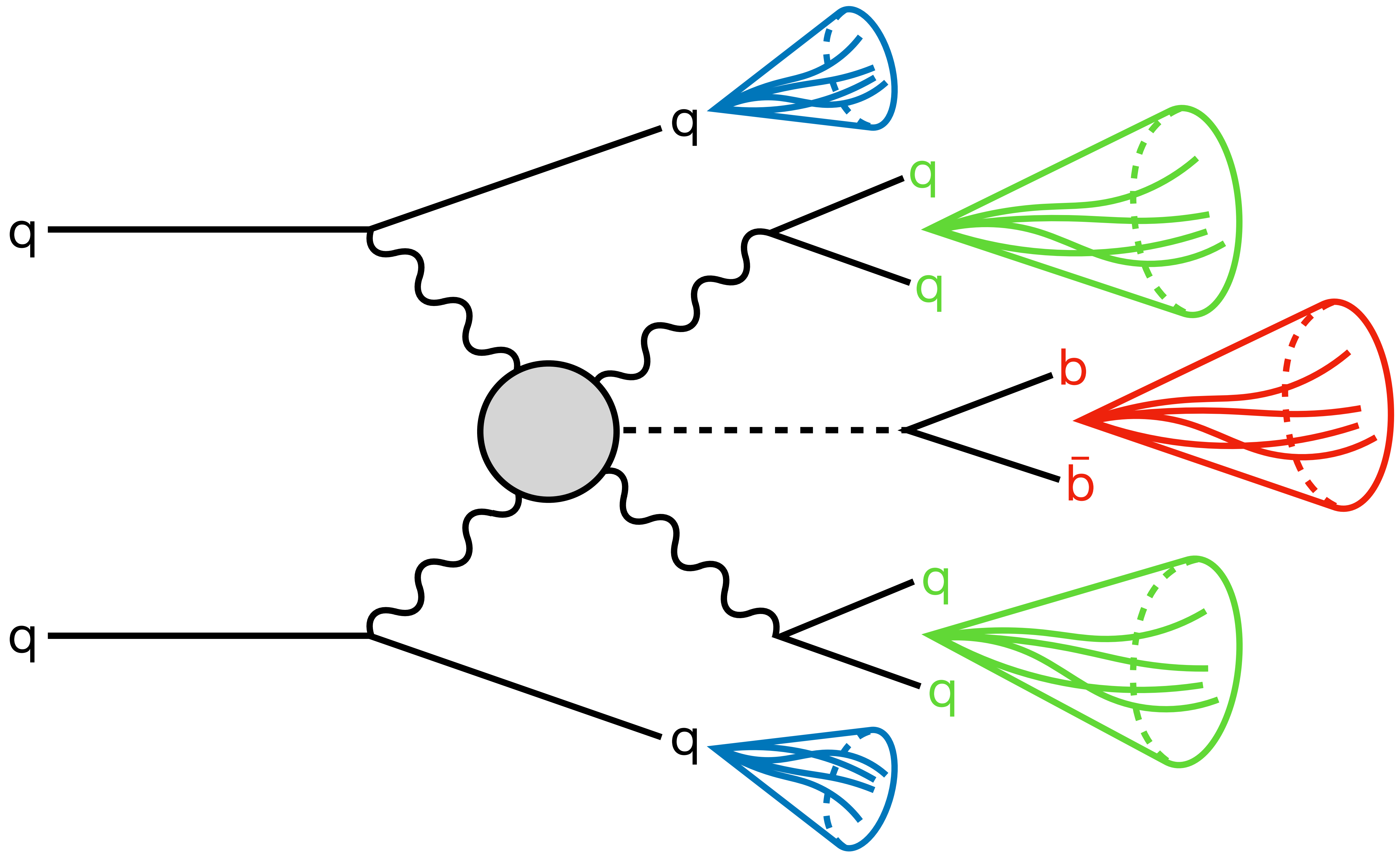
Taken from B2G-21-003

Object Selection

Yields scaled to lumi×σ, rounded for readability

Cut	QCD	$t\bar{t}$+jets	$t\bar{t}+1\ell$	$t\bar{t}$+W	$t\bar{t}$+H	Single top	Bosons	Total Bkg.	Eff.	VBSVVH (C_{2V} = 2)	Eff.
Skim	137,061K	748K	86K	2.6K	1.3K	53K	1,513K	139,464K	—	175	—
HLT + MET Filters	88,702K	575K	70K	2.2K	1.1K	41K	1,120K	90,512K	65%	168	96%
At least 3 fat jets	395K	9.8K	1.4K	110	46	874	13K	421K	0%	32	19%
Object selection	158K	6.2K	855	59	30	478	5.1K	171K	41%	18	56%

Object	Selections
AK8 jets	• Same as skim • max(p_T) > 550 GeV (HLT plateau)
H→b$\bar{b}$ fat jet	• Has max(ParticleNet Xbb)
V→qq fat jets	• Not the H→b$\bar{b}$ candidate • Leading and next-leading in p_T
AK4 jets	• Same as skim
VBS (AK4) jets	• p_T > 30 GeV • For > 2 candidates: • Take pair with maximum $\lvert\Delta\eta_{jj}\rvert$



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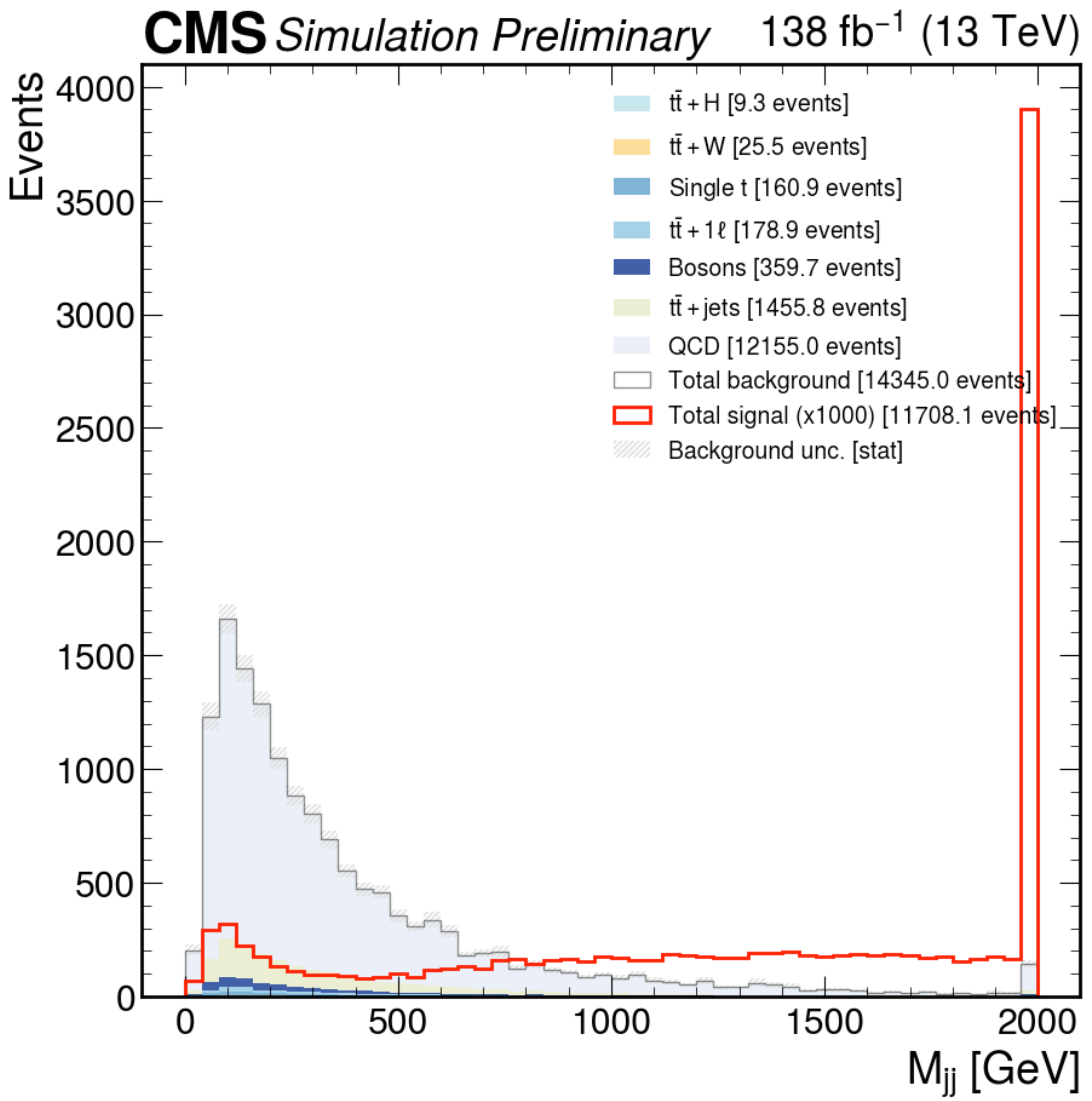
Preselection

Yields scaled to lumi×σ, rounded for readability

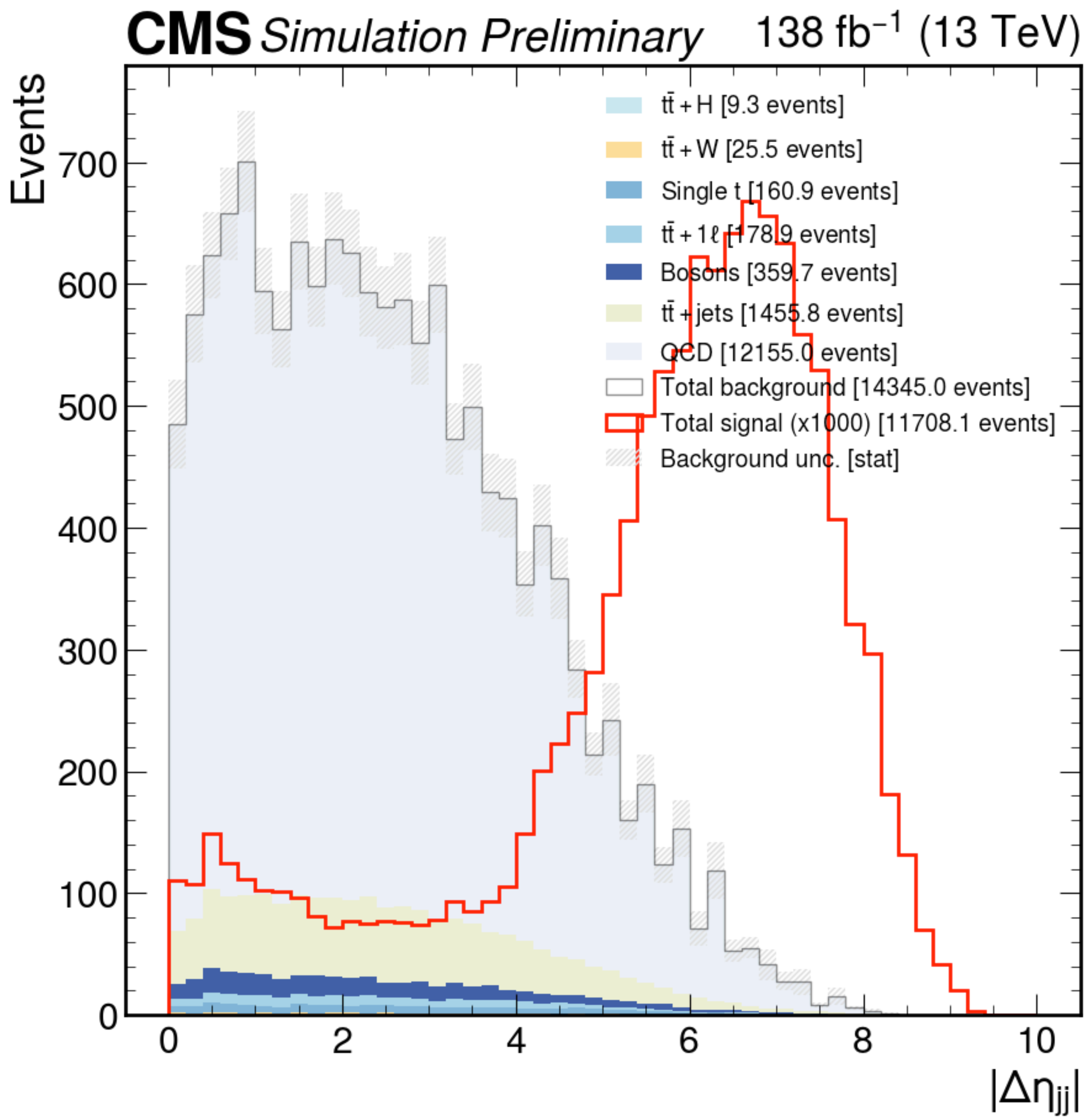
Cut	QCD	$t\bar{t}$+jets	$t\bar{t}$+1ℓ	$t\bar{t}$+W	$t\bar{t}$+H	Single top	Bosons	Total Bkg.	Eff.	VBSVVH (C_{2V} = 2)	Eff.
Skim	137,061K	748K	86K	2.6K	1.3K	53K	1,513K	139,464K	—	175	—
HLT + MET Filters	88,702K	575K	70K	2.2K	1.1K	41K	1,120K	90,512K	65%	168	96%
At least 3 fat jets	395K	9.8K	1.4K	110	46	874	13K	421K	0%	32	19%
Object selection	158K	6.2K	855	59	30	478	5.1K	171K	41%	18	56%
Preselection	12K	1.5K	179	25	9	161	360	14K	8%	12	66%

- Now that data/MC is better, we can trust MC shape more than before
- Make loose selection on ParticleNet scores to walk us slightly closer to a SR
  - Xbb($H \rightarrow b\bar{b}$) > 0.5 and XWqq(ld $V \rightarrow qq$) > 0.3 and XWqq(tr $V \rightarrow qq$) > 0.3
  - Recall: we rescale QCD integral to data - Σ(non-QCD MC)
- **Next:** plot important variables sig. vs. bkg. on next slides

VBS Variables (Preselection)



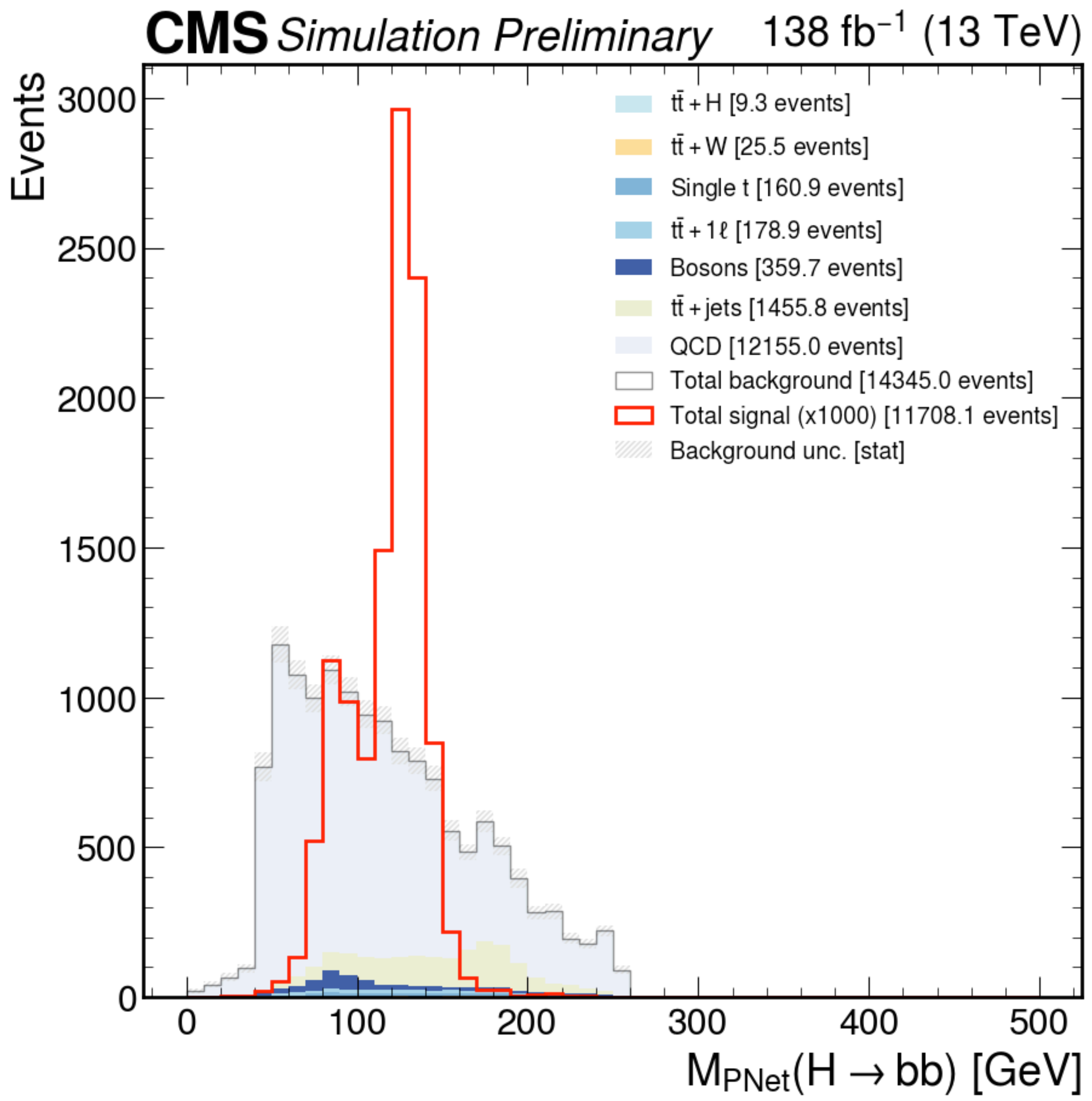
M_{jj} = Mass(ld VBS jet p4 + tr VBS jet p4)



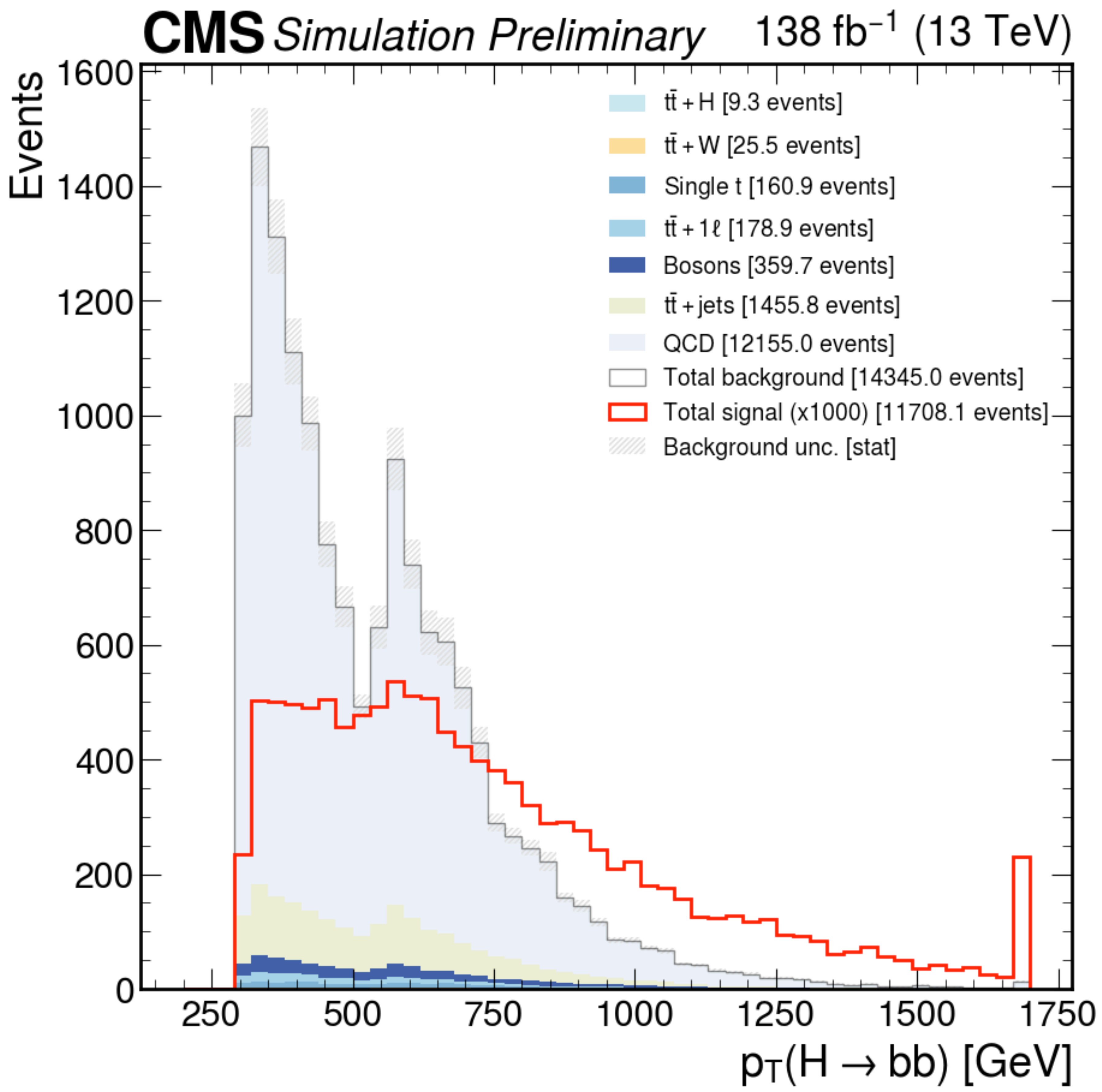
$|\Delta\eta_{jj}|$ = |ld VBS jet η - tr VBS jet η|

Characteristically large $\Delta\eta_{jj}$ and M_{jj} for signal (C_{2V} = 2)

H→bb Variables (Preselection)



M_{PNet} = ParticleNet regressed mass

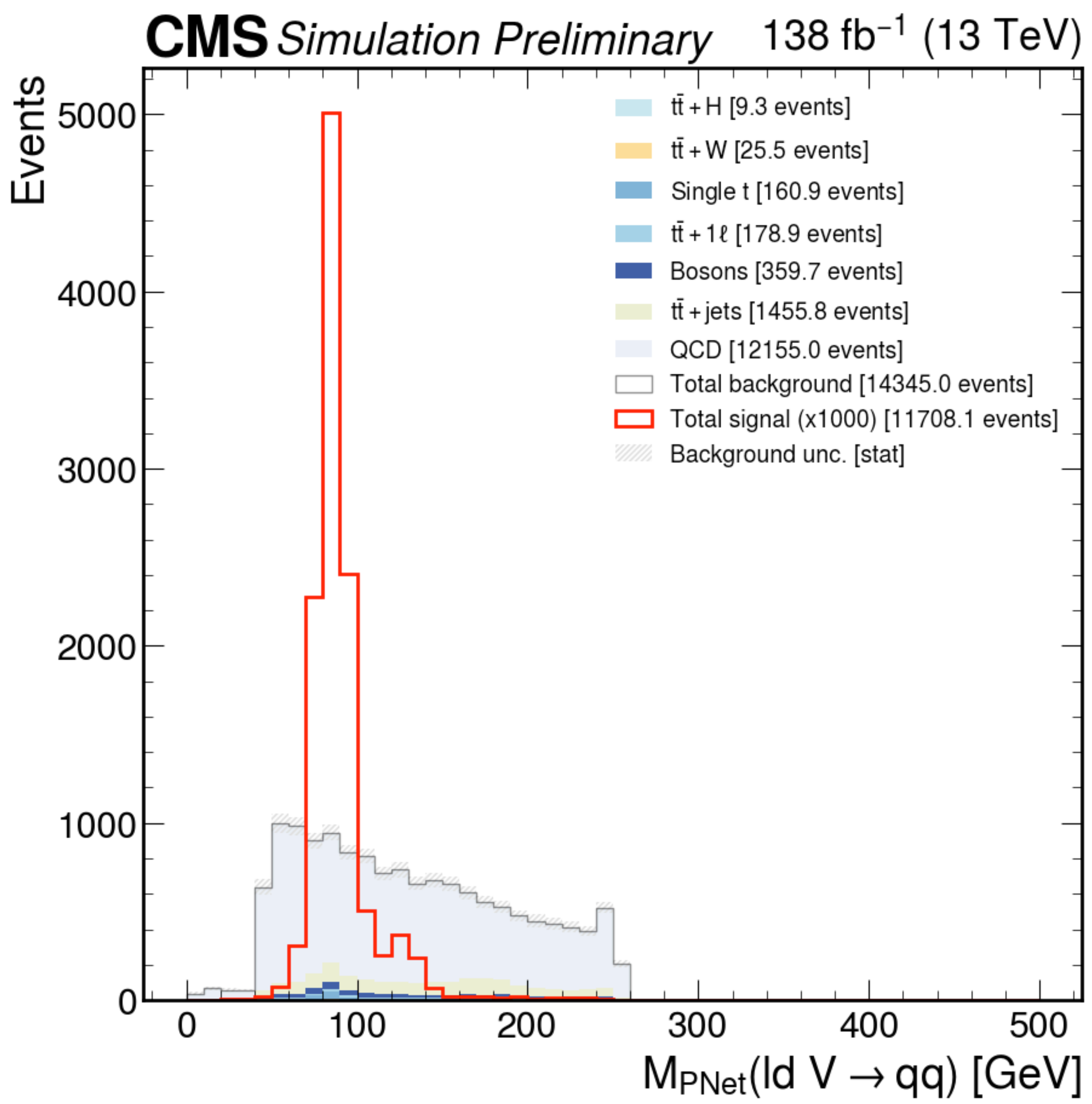


Spike at 500 GeV due to HLT threshold cut

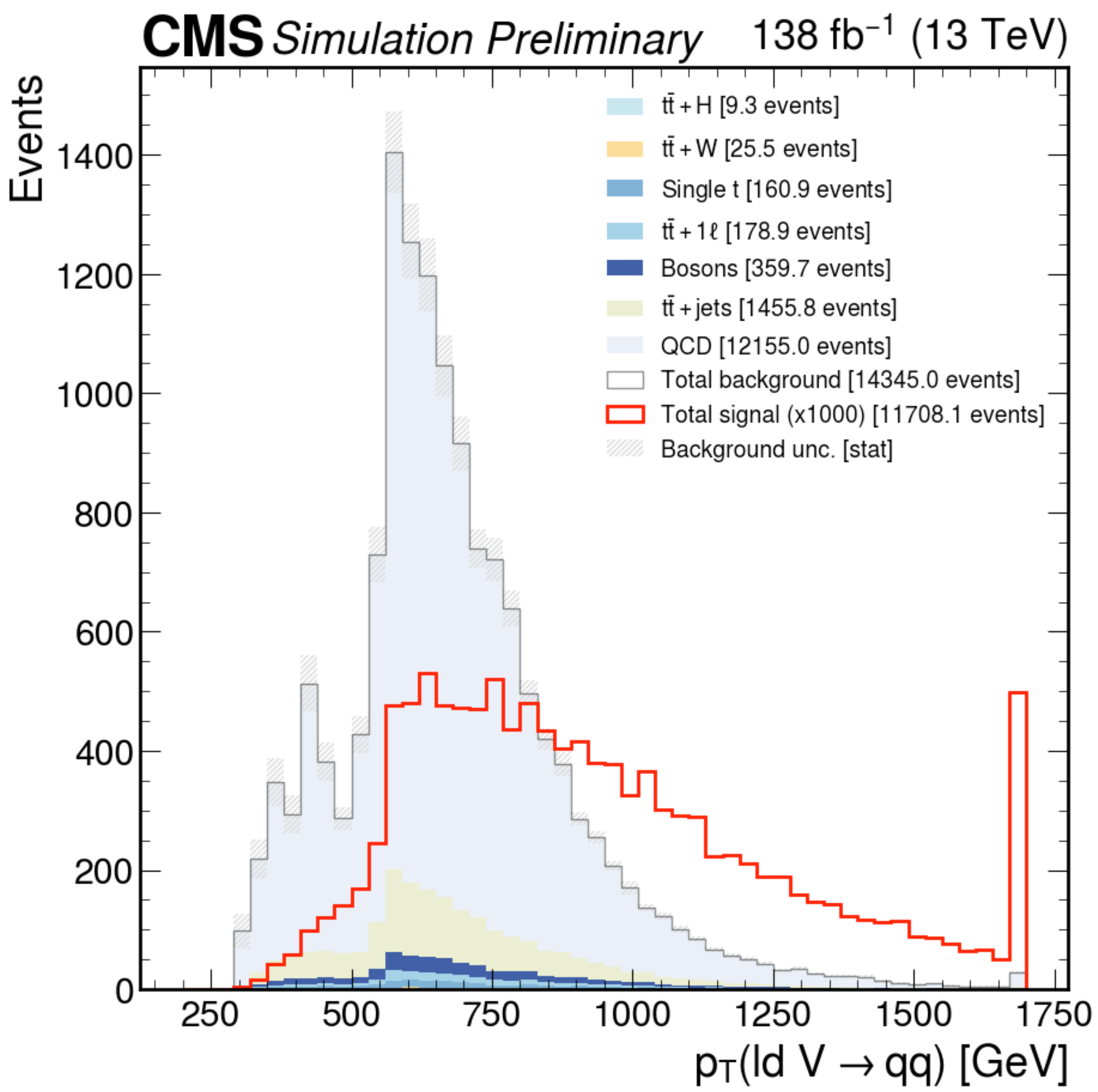
Higgs peak in regressed mass + large p_T for signal (C2V = 2)

UC San Diego

V→qq Variables (Preselection)



M_{PNet} = ParticleNet regressed mass

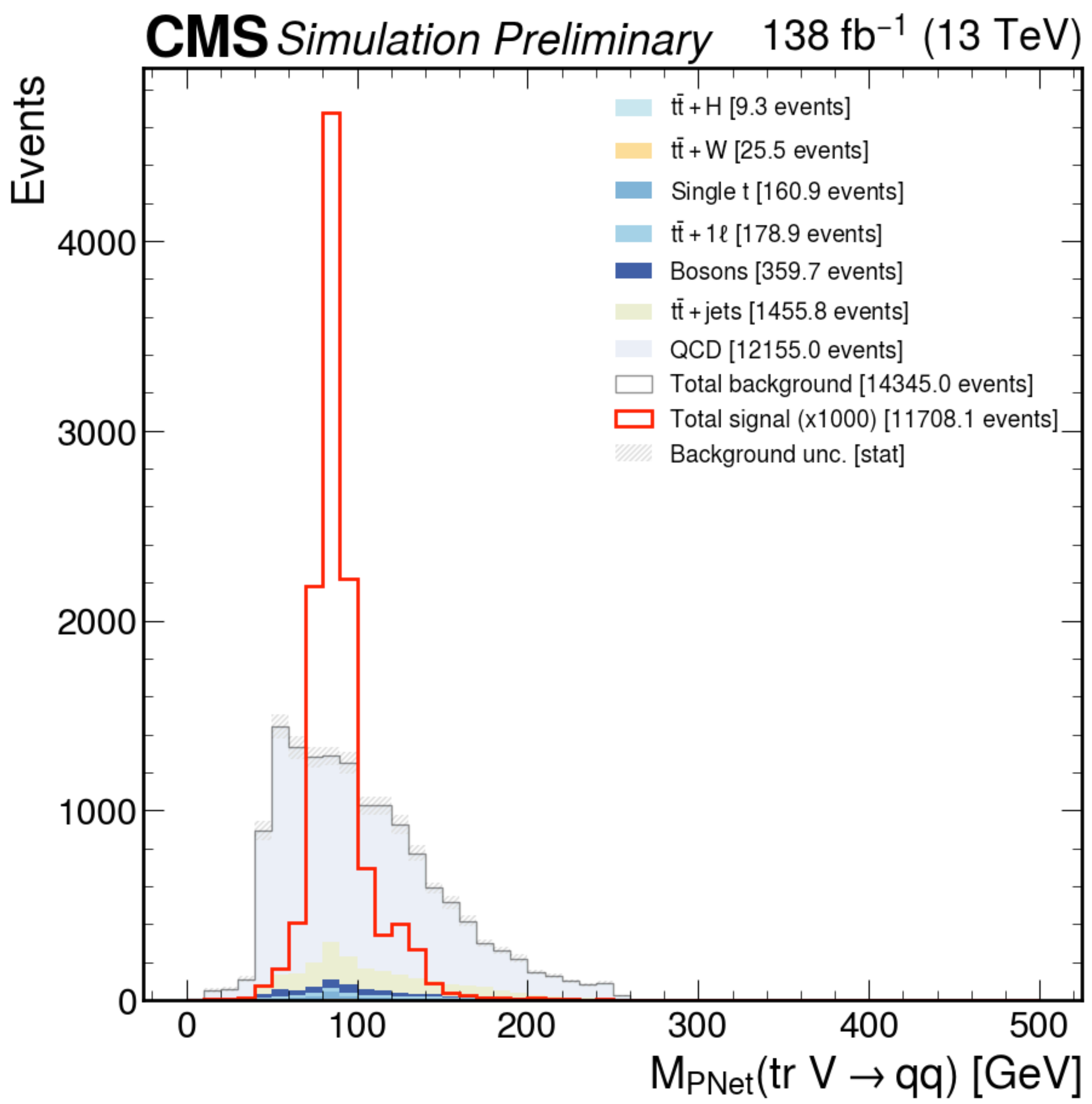


Spike at 500 GeV due to HLT threshold cut

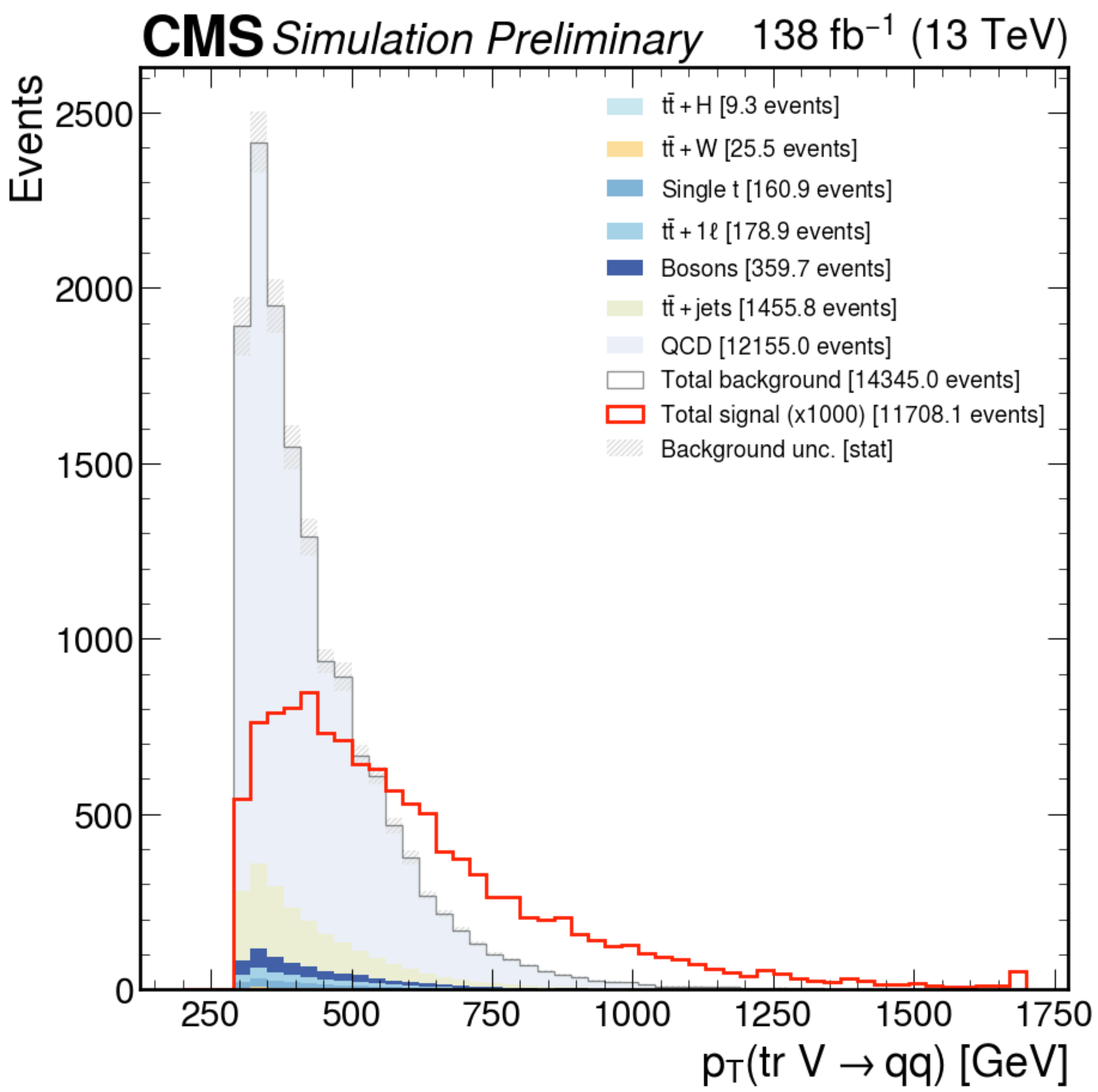
W/Z peak in regressed mass + large p_T for signal (C2V = 2)

UC San Diego

V→qq Variables (Preselection)



M_{PNet} = ParticleNet regressed mass

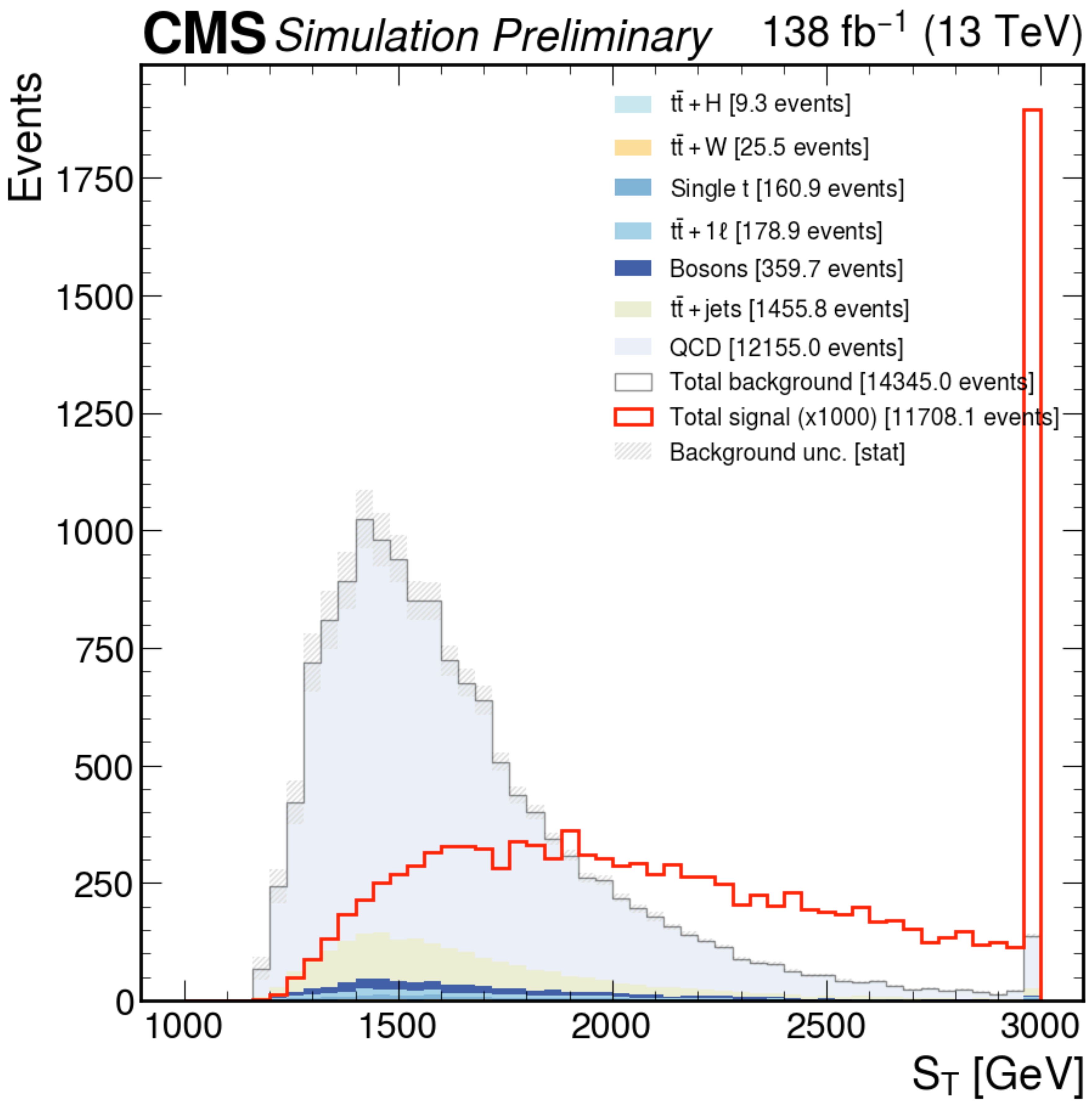


Trailing (tr) in p_T ⇒ no spike at 500 GeV from cut

W/Z peak in regressed mass + large p_T for signal (C2V = 2)

UC San Diego

Other Variables (Preselection)



$S_T = p_T(H\rightarrow bb) + p_T(\text{ld } V\rightarrow qq) + p_T(\text{tr } V\rightarrow qq)$

Expectedly large S_T for signal (C2V = 2)

Cutflow

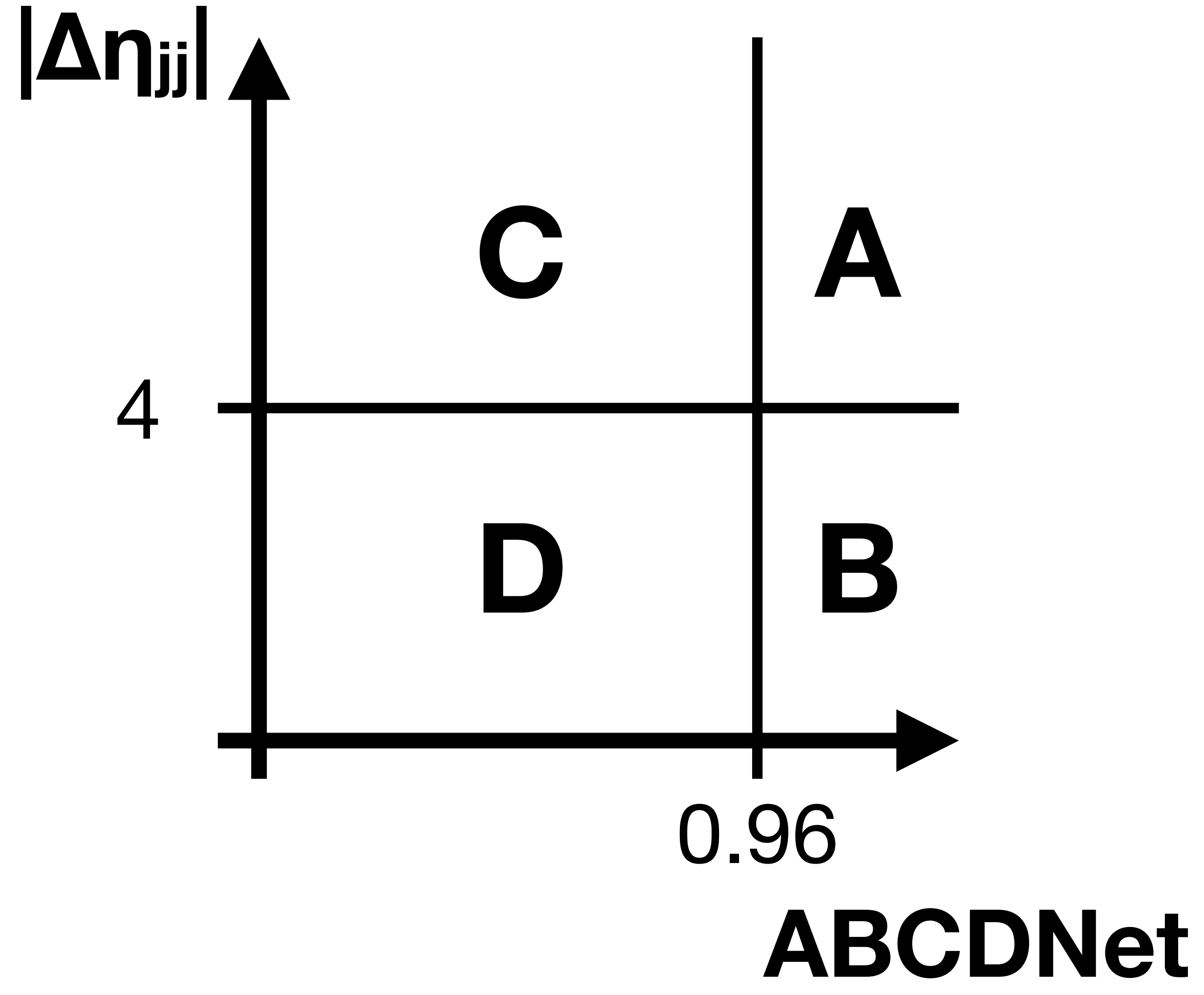
	QCD		TTHad		TT1L		TTW		TTH		SingleTop		Bosons		TotalBkg		VBSVVH	
cut	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt
Bookkeeping	23348898	137060539.91	11563843	748039.60	1952781	85549.20	291342	2574.92	1457254	1341.75	801492	53435.60	18001906	1512567.11	57417516	139464048.10	323711	175.15
SaveSystWeights	23348898	137060539.91	11563843	748039.60	1952781	85549.20	291342	2574.92	1457254	1341.75	801492	53435.60	18001906	1512567.11	57417516	139464048.10	323711	175.15
PassesEventFilters	23228634	136865407.91	11539080	746478.00	1946259	85267.20	290178	2566.97	1452921	1337.93	799328	53280.13	17946508	1508632.44	57202908	139262970.58	320310	173.33
PassesTriggers	19971141	88702387.12	8948283	574638.30	1610549	70244.26	261105	2236.23	1270751	1142.71	620348	41251.69	15012150	1120027.71	47694327	90511928.03	314509	168.32
SelectLeptons	19971141	88702387.12	8948283	574638.30	1610549	70244.26	261105	2236.23	1270751	1142.71	620348	41251.69	15012150	1120027.71	47694327	90511928.03	314509	168.32
NoLeptons	19971141	88702387.12	8948283	574638.30	1610549	70244.26	261105	2236.23	1270751	1142.71	620348	41251.69	15012150	1120027.71	47694327	90511928.03	314509	168.32
SelectFatJets	19971141	88702387.12	8948283	574638.30	1610549	70244.26	261105	2236.23	1270751	1142.71	620348	41251.69	15012150	1120027.71	47694327	90511928.03	314509	168.32
TriggerPlateauCuts	11032313	17507476.58	2402330	151403.21	577399	24859.33	117668	951.51	477636	414.98	178184	12210.73	4786171	331011.06	19571701	18028327.40	240732	129.81
Geq3FatJets	625880	395252.58	147659	9753.17	30742	1372.63	18012	110.44	50985	45.99	9319	873.52	211979	13105.95	1094576	420514.28	58085	31.64
AllMerged_ReplacePNetsQCD	625880	395252.58	147659	9753.17	30742	1372.63	18012	110.44	50985	45.99	9319	873.52	211979	13105.95	1094576	420514.28	58085	31.64
AllMerged_SelectVVHFatJets	625880	395252.58	147659	9753.17	30742	1372.63	18012	110.44	50985	45.99	9319	873.52	211979	13105.95	1094576	420514.28	58085	31.64
AllMerged_SetPtSortedFatJetVariables	625880	395252.58	147659	9753.17	30742	1372.63	18012	110.44	50985	45.99	9319	873.52	211979	13105.95	1094576	420514.28	58085	31.64
AllMerged_SelectJets	625880	393124.82	147659	9689.05	30742	1363.65	18012	109.84	50985	45.68	9319	868.00	211979	13042.54	1094576	418243.58	58085	31.24
AllMerged_SelectVBSJets	300296	158240.71	94313	6171.85	19389	854.93	11634	58.85	32458	30.18	5298	477.98	85560	5146.20	548948	170980.70	32951	17.71
AllMerged_SaveVariables	300296	158240.71	94313	6171.85	19389	854.93	11634	58.85	32458	30.18	5298	477.98	85560	5146.20	548948	170980.70	32951	17.71
AllMerged_MjjGt500	81337	36481.09	23578	1512.52	5146	223.48	2229	13.20	7651	7.00	1675	150.36	19854	1179.31	141470	39566.96	27420	14.71
AllMerged_detajjGt3	63871	31003.64	19862	1269.03	4331	187.52	1882	10.62	6538	5.94	1413	126.67	16215	959.46	114112	33562.87	27201	14.59
AllMerged_XbbGt0p9	3698	1872.43	6683	427.79	1700	73.28	688	3.72	3624	2.75	449	44.77	2074	83.07	18916	2507.80	18272	9.56
AllMerged_XVqqGt0p9	12	8.13	59	3.78	7	0.33	65	0.28	80	0.07	12	1.70	75	0.93	310	15.20	5717	3.09
AllMerged_STGt1300	12	8.13	54	3.45	6	0.28	61	0.27	71	0.06	12	1.70	74	0.86	290	14.75	5677	3.06
AllMerged_HbbMSDLt150	8	6.89	26	1.61	5	0.24	38	0.24	49	0.03	7	1.05	66	0.56	199	10.63	5567	3.01
AllMerged_VqqMSDLt120	3	5.56	13	0.71	2	0.08	19	0.04	13	0.01	3	0.47	44	0.30	97	7.18	5170	2.83

ABCDNet: λ = 30 DisCo (Leaky ReLU)

Xbb > 0.60 and XWqq > 0.75|0.70 (ld|tr)

Region	Bosons	err.	%	QCD	err.	%	Single top	err.	%	$t\bar{t}+1\ell$	err.	%	$t\bar{t}$+H	err.	%	$t\bar{t}$+jets	err.	%	$t\bar{t}$+W	err.	%	Total	err.
A	**0.43**	0.16	30%	**0.67**	0.48	46%	**0.15**	0.15	10%	**0.14**	0.08	9%	**0.00**	0.00	0%	**0.07**	0.07	5%	**0.00**	0.00	0%	1.46	0.57
B	**0.68**	0.23	13%	**3.33**	0.98	65%	**0.57**	0.29	11%	**0.00**	0.00	0%	**0.01**	0.00	0%	**0.52**	0.20	10%	**0.01**	0.00	0%	5.12	1.25
C	**10.1**	1.07	3%	**214.0**	25.8	73%	**13.1**	1.37	4%	**5.63**	0.52	2%	**0.42**	0.03	0%	**48.4**	1.84	17%	**1.30**	0.35	0%	292.9	25.9
D	**44.0**	2.01	4%	**730.7**	40.8	72%	**32.8**	2.17	3%	**21.8**	1.02	2%	**1.63**	0.05	0%	**176.9**	3.54	17%	**4.51**	0.76	0%	1012.4	41.1

	Bosons	QCD	Single top	$t\bar{t}+1\ell$	$t\bar{t}$+H	$t\bar{t}$+jets	$t\bar{t}$+W	Total
C/D	**0.23** ± 0.03	**0.29** ± 0.04	**0.40** ± 0.05	**0.26** ± 0.03	**0.26** ±0.02	**0.27** ±0.01	**0.29** ± 0.09	**0.29** ± 0.03



- **SR matches Preselection composition better than BDT SR**
- Many of the percentages above have large error bars:

Region	Bosons	QCD	Single top	$t\bar{t}+1\ell$	$t\bar{t}$+H	$t\bar{t}$+jets	$t\bar{t}$+W
A	30% ± 56%	46% ± 91%	10% ± 22%	9% ± 18%	0% ± 1%	5% ± 10%	0% ± 0%
B	13% ± 13%	65% ± 62%	11% ± 12%	0% ± 0%	0% ± 0%	10% ± 10%	0% ± 0%
C	3% ± 1%	73% ± 27%	4% ± 2%	2% ± 1%	0% ± 0%	17% ± 6%	0% ± 0%
D	4% ± 1%	72% ± 15%	3% ± 1%	2% ± 0%	0% ± 0%	17% ± 4%	0% ± 0%

$$\epsilon_{\%QCD} = (\%\text{QCD}) \times \sqrt{2\times\left(\frac{\epsilon_{QCD}}{A_{QCD}}\right)^2 + \left(\frac{\epsilon_{Bosons}}{A_{Bosons}}\right)^2 + \ldots + \left(\frac{\epsilon_{t\bar{t}+W}}{A_{t\bar{t}+W}}\right)^2}$$

$$\epsilon_{\%Bosons} = (\%\text{Bosons}) \times \sqrt{\left(\frac{\epsilon_{QCD}}{D_{QCD}}\right)^2 + 2\times\left(\frac{\epsilon_{Bosons}}{D_{Bosons}}\right)^2 + \ldots + \left(\frac{\epsilon_{t\bar{t}+W}}{D_{t\bar{t}+W}}\right)^2}$$

Epoch = 900 | LR = 0.001 (constant) | λ = 30 | QCD norm | All features normalized