VBS WH Analysis

Background extrapolation

August 1st, 2022

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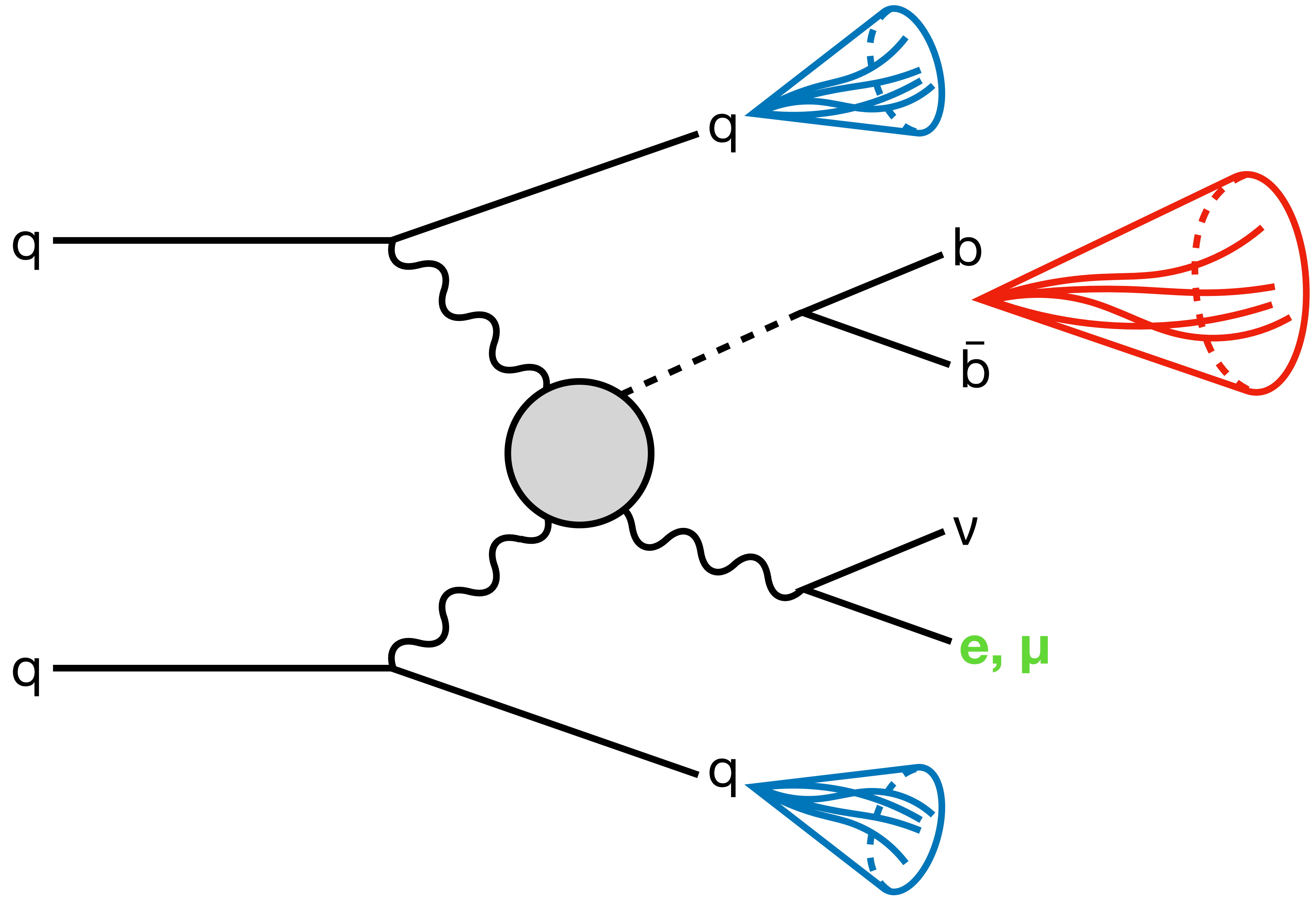
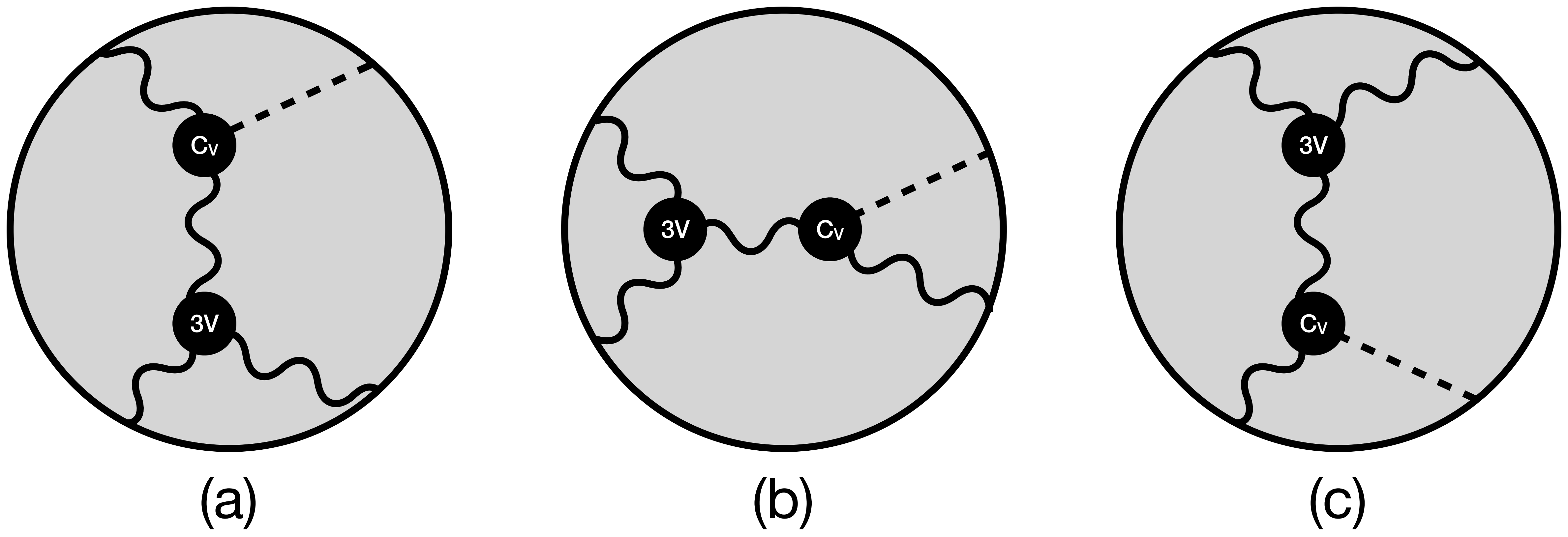
Target Final State

- Targeting **VBS** WH→**ℓ**ν**b$\bar{b}$**
- Sensitive to κ_V → $\lambda_{WZ} = \kappa_Z/\kappa_W$
  - Handle for ruling out $\lambda_{WZ} = -1$ (BSM)
- VBS WH BSM kinematics:
  - High-p_T H and W (high S_T)
  - VBS jets with large $\Delta\eta_{jj}$, M_{jj}





Overview

Yields scaled to lumi×σ, rounded for readability

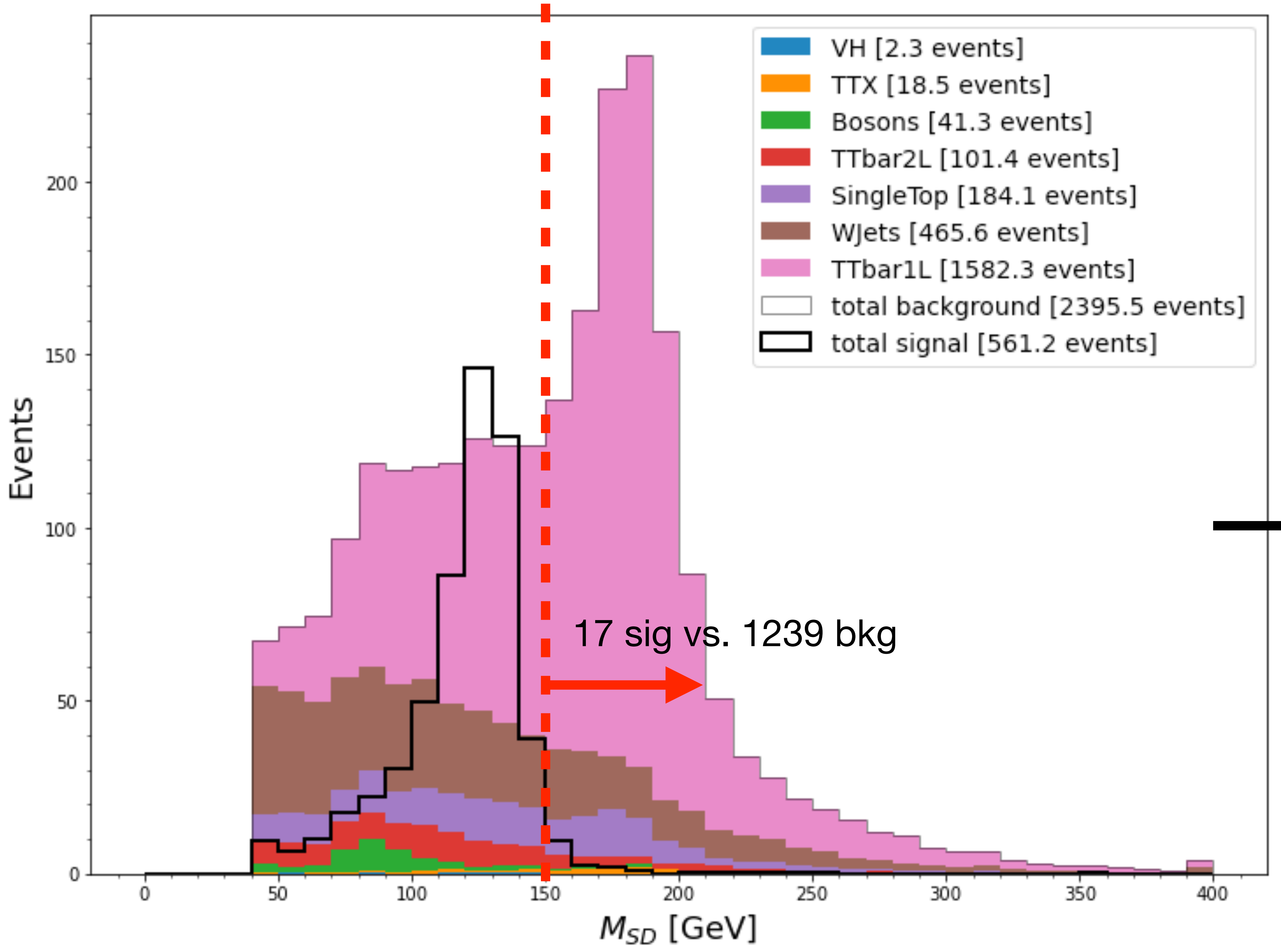
	Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg	Eff.*	VBSWH (κ_W = -1)	Eff.*
	Skim AND Postskim	232	6.5K	122K	7.6K	1K	86K	10K	233K	—	2K	—
	Object Selection	50	2K	47K	4.4K	654	50K	6.3K	111K	52%	1.1K	43%
Presel.	**M_{jj} > 500 GeV AND $\lvert\Delta\eta_{jj}\rvert$ > 3**	7	376	7.7K	994	124	10K	1.4K	21K	81%	920	17%
Presel.	**max(PNet Xbb score) > 0.3**	3	51	587	537	77	5.8K	382	7.4K	64%	608	34%
Presel.	**No b-tagged (med.) AK4 jets**	2	43	484	194	20	1.7K	110	**2.5K**	88%	**579**	37%
SR	**M_{jj} > 1.5 TeV AND $\lvert\Delta\eta_{jj}\rvert$ > 4**	1	5	68	31	3	297	22	**427**	83%	**322**	44%
SR	**S_T > 1.2 TeV**	0	1	11	6	0	25	2	**45**	89%	**139**	57%
SR	**PNet Xbb vs. QCD > 0.9 AND M_{SD} < 150**	0	0	1	0	0	2	1	**4**	91%	**109**	22%

- Reminder: Postskim includes S_T > 800 GeV (full details in backup)
- Explored two background extrapolation strategies:
  - ABCD: $\Delta\eta_{jj}$ vs. M_{SD}
  - MC-based: M_{SD} and/or $\Delta\eta_{jj}$ sideband(s)

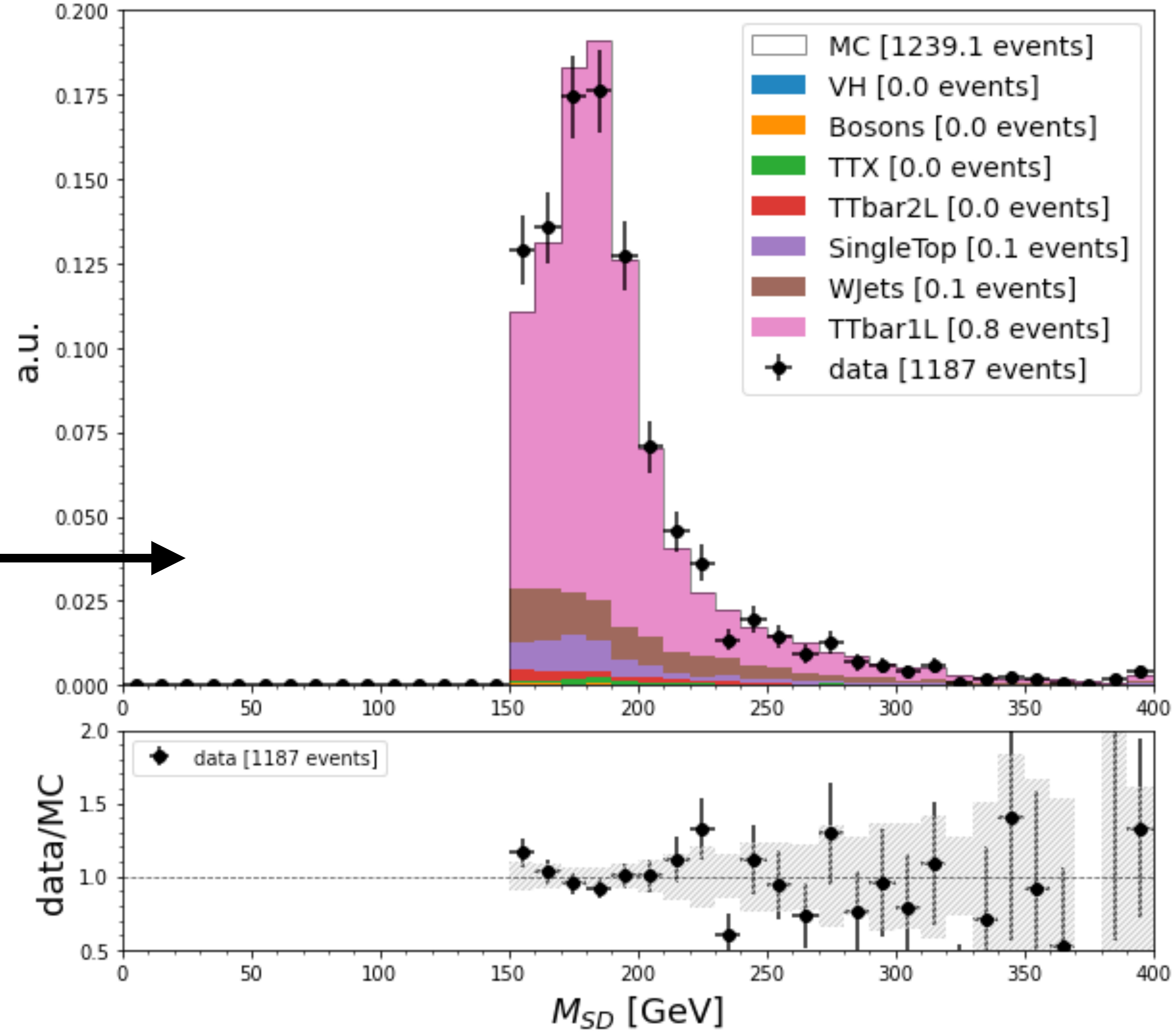
*eff = 1 - after/before

Validation: Hbb Kinematics

Preselection



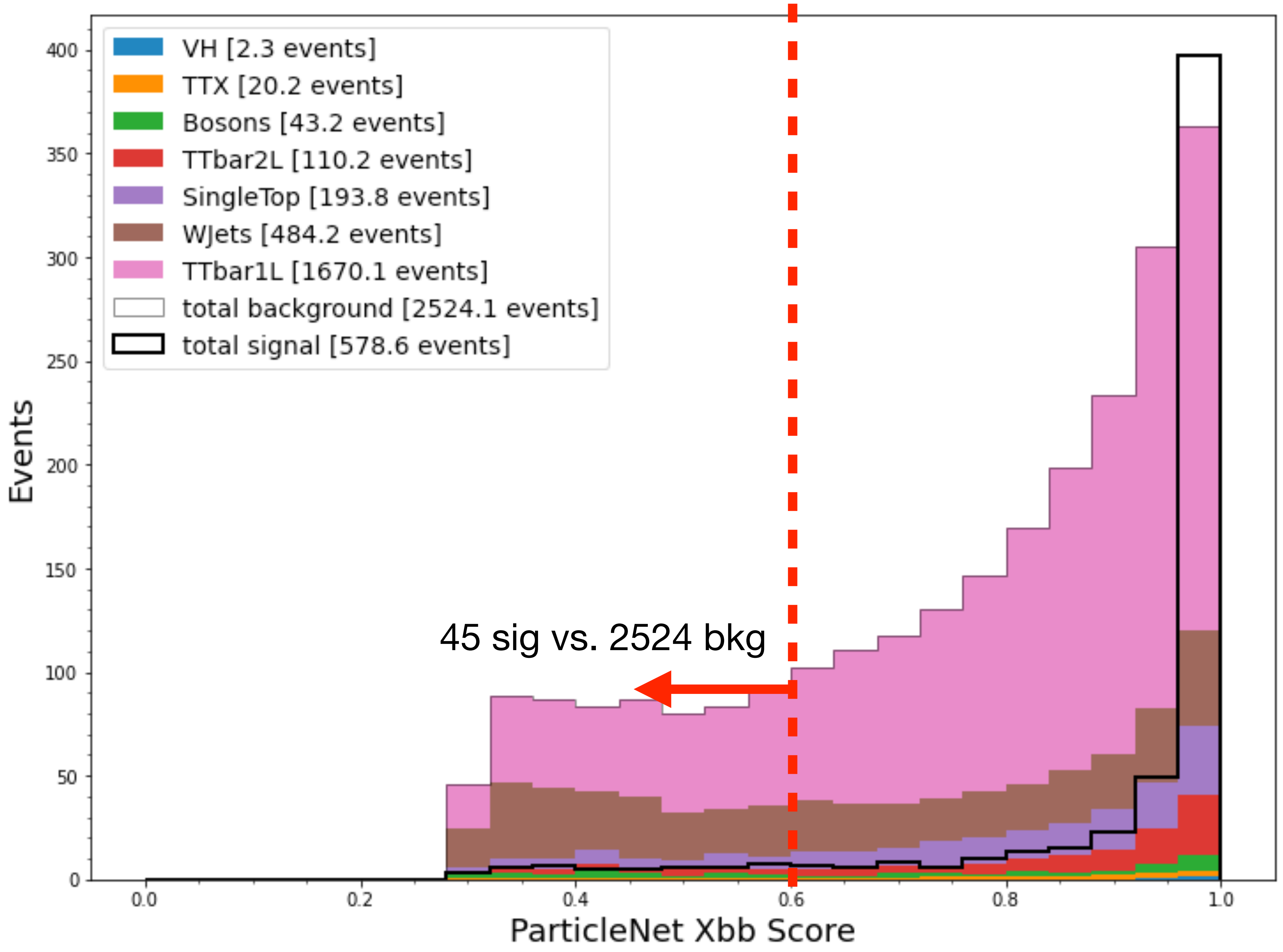
Preselection AND $M_{SD} \geq 150$ GeV



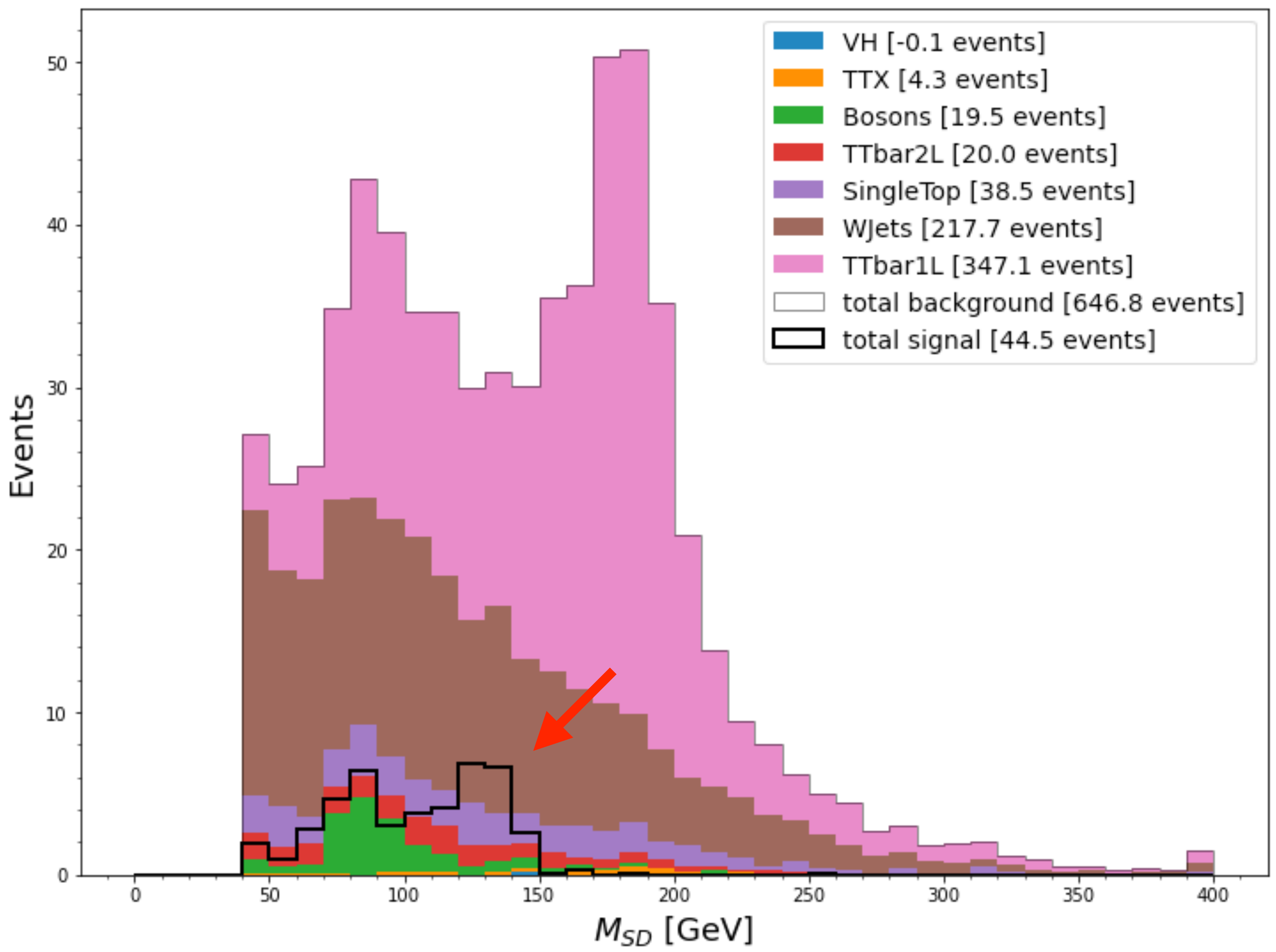
Agreement looks good, more plots in backup

Validation: Hbb Kinematics

Preselection



Preselection AND PNet Xbb < 0.6



PNet Xbb sideband not viable: visible signal bump in M_{SD}

ABCD: $\Delta\eta_{jj}$ vs. M_{SD}

Presel. (w/out $\Delta\eta_{jj}$ cut) AND M_{jj} > 1500 GeV AND PNet Xbb > 0.9
AND S_T > 1200 GeV

Yields scaled to lumi×σ, rounded for readability

Cut	Region	Bkg. (raw)	Bkg. (wgt)	Bkg. Err.*	Sig. (raw)	Sig. (wgt)	Sig. Err.*
$\|\Delta\eta_{jj}\|$ > 4 AND M_{SD} ≥ 150 GeV	A	546	9.29	0.71	17	2.25	0.60
$\|\Delta\eta_{jj}\|$ ≤ 4 AND M_{SD} ≥ 150 GeV	B	1019	8.35	0.58	1	0.26	0.26
$\|\Delta\eta_{jj}\|$ ≤ 4 AND M_{SD} < 150 GeV	C	806	5.12	0.53	9	1.00	0.38
$\|\Delta\eta_{jj}\|$ > 4 AND M_{SD} < 150 GeV (SR)	D	408	3.73	0.39	729	105.63	4.37

⬅
0.728 ±14.7%

D	C
A	B

⬆ 0.613 ±12.4%

0.899 ±10.3%
➡

- Seemed too signal polluted/too low stats to be useful
- Upon closer inspection, maybe the first issue is less important than the second
  - For "sumw2" errors, sig is within 3σ, 1σ, and 2σ for A, B, C respectively
  - If we instead assume bkg MC exactly predicts data, then sig would be within 1σ for every region
    - Taking uncertainty as √(round(bkg MC)) = 3, 2.8, 2.2 for A, B, C
- **Nevertheless, proceeding without the overall S_T > 1200 GeV cut**

*err = $\Sigma_i w_i^2$

ABCD: $\Delta\eta_{jj}$ vs. M_{SD}

Presel. (w/out $\Delta\eta_{jj}$ cut) AND M_{jj} > 1500 GeV AND PNet Xbb > 0.9

Yields scaled to lumi×σ, rounded for readability

Cut	Region	Bkg. (raw)	Bkg. (wgt)	Bkg. Err.*	Sig. (raw)	Sig. (wgt)	Sig. Err.*
$\lvert\Delta\eta_{jj}\rvert$ > 4 AND M_{SD} ≥ 150 GeV	A	2902	79.68	2.02	43	6.30	1.06
$\lvert\Delta\eta_{jj}\rvert$ ≤ 4 AND M_{SD} ≥ 150 GeV	B	2662	45.21	1.42	2	0.50	0.35
$\lvert\Delta\eta_{jj}\rvert$ ≤ 4 AND M_{SD} < 150 GeV	C	2481	28.66	1.21	13	1.57	0.50
$\lvert\Delta\eta_{jj}\rvert$ > 4 AND M_{SD} < 150 GeV (~SR**)	D	2492	50.84	1.65	1658	244.98	6.70

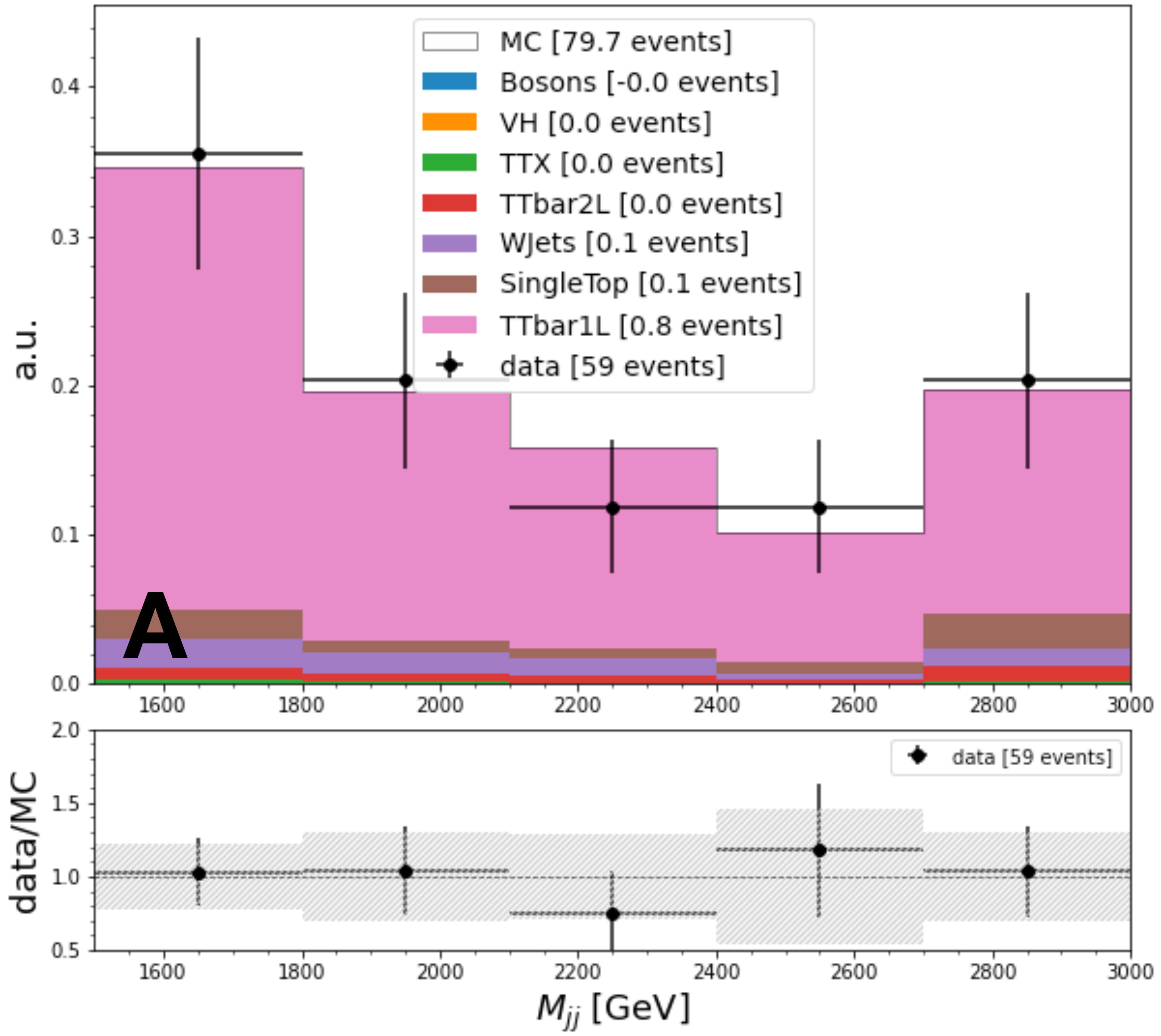
1.774 ±5.3%

D	C
A	B

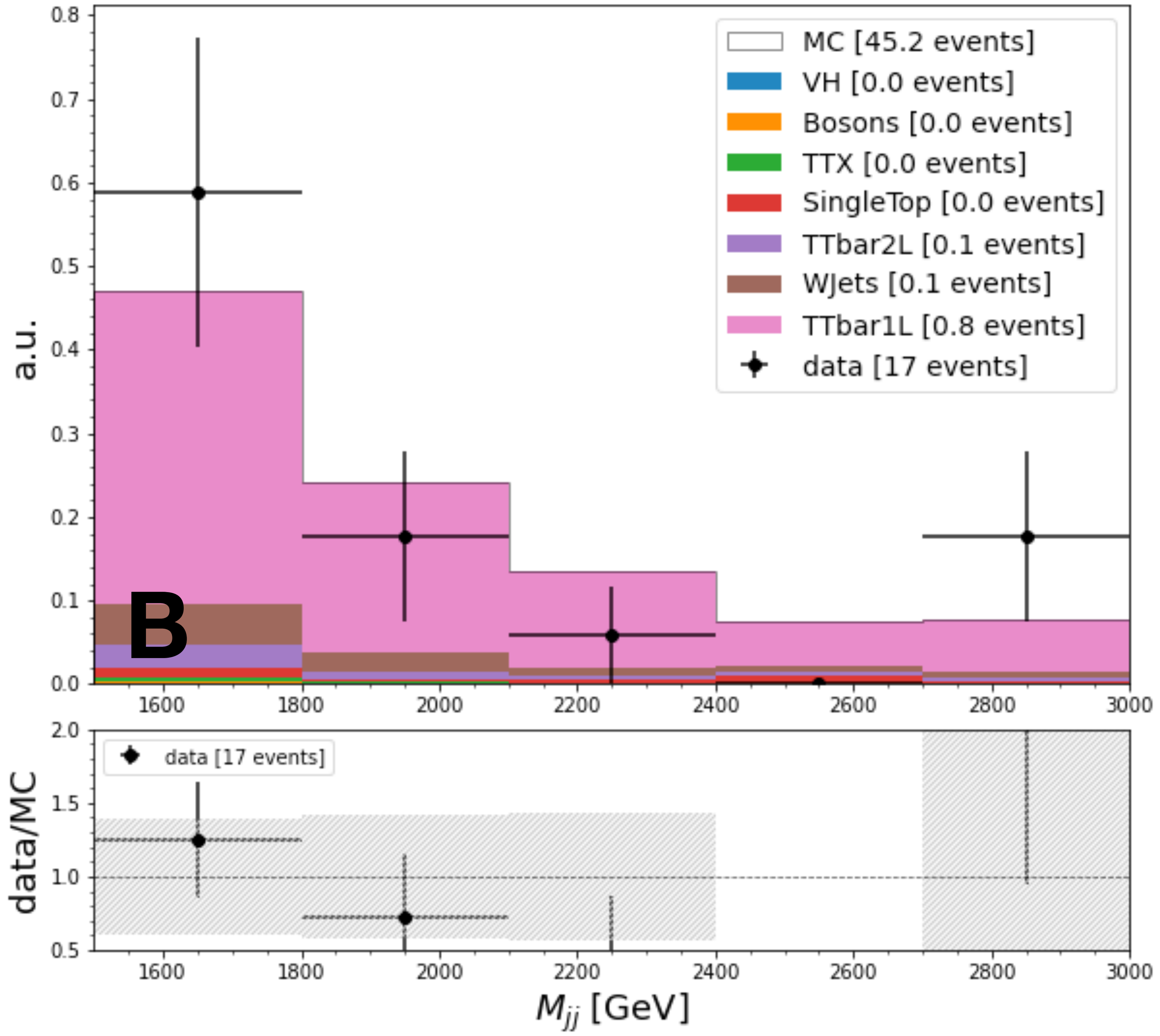
0.634 ±5.3%

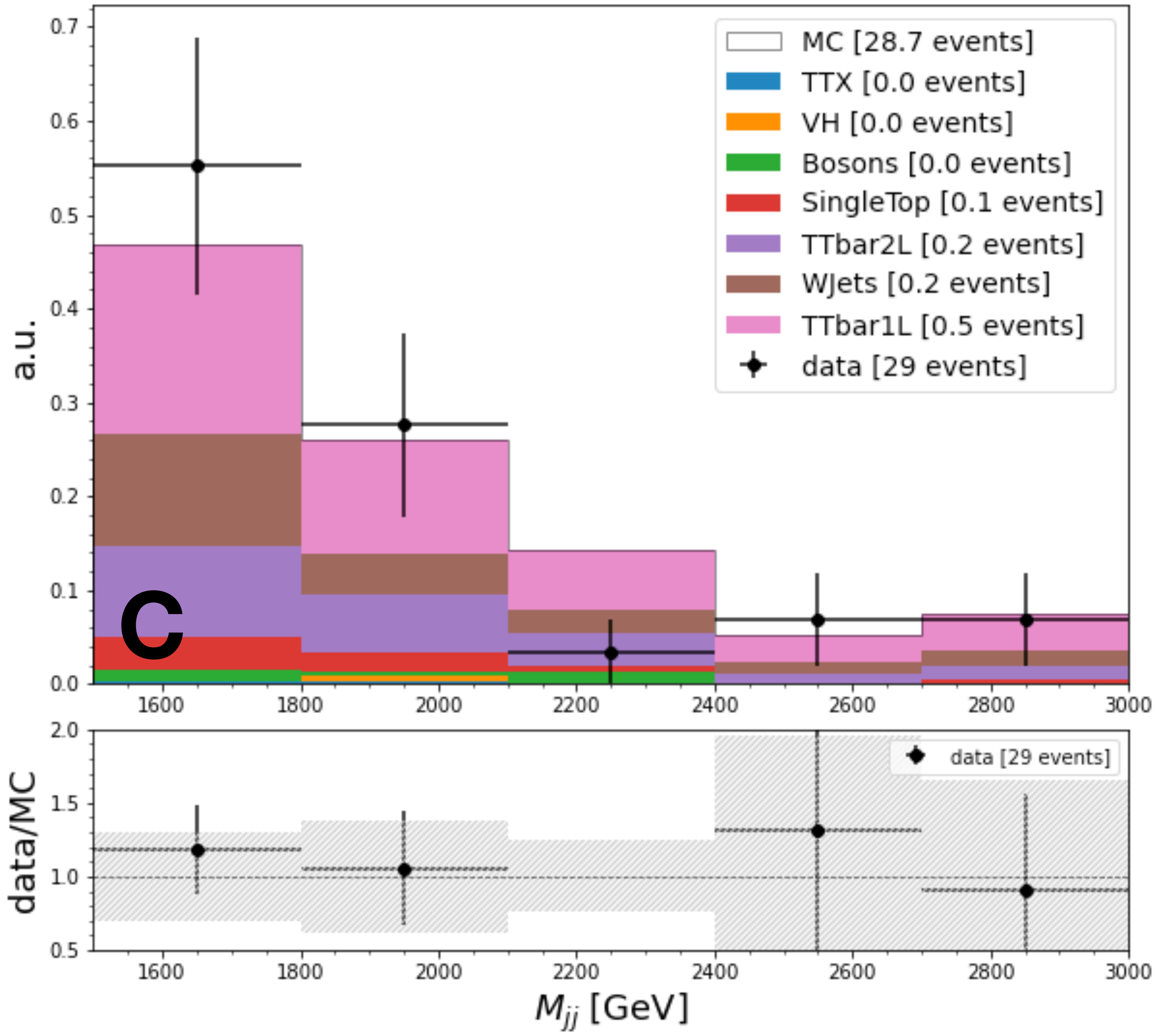
0.567 ±4.0%

59 data vs 80 MC



17 data vs 45 MC





*err = $\sqrt{(\Sigma_i w_i^2)}$
**Specifically, this is the SR with a looser S_T cut (S_T > 800 GeV)

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ABCD: $\Delta\eta_{jj}$ vs. M_{SD}

Presel. (w/out $\Delta\eta_{jj}$ cut) AND M_{jj} > 1500 GeV AND PNet Xbb > 0.9

Yields scaled to lumi×σ, rounded for readability

Cut	Region	Bkg. (raw)	Bkg. (wgt)	Bkg. Err.*	Sig. (raw)	Sig. (wgt)	Sig. Err.*
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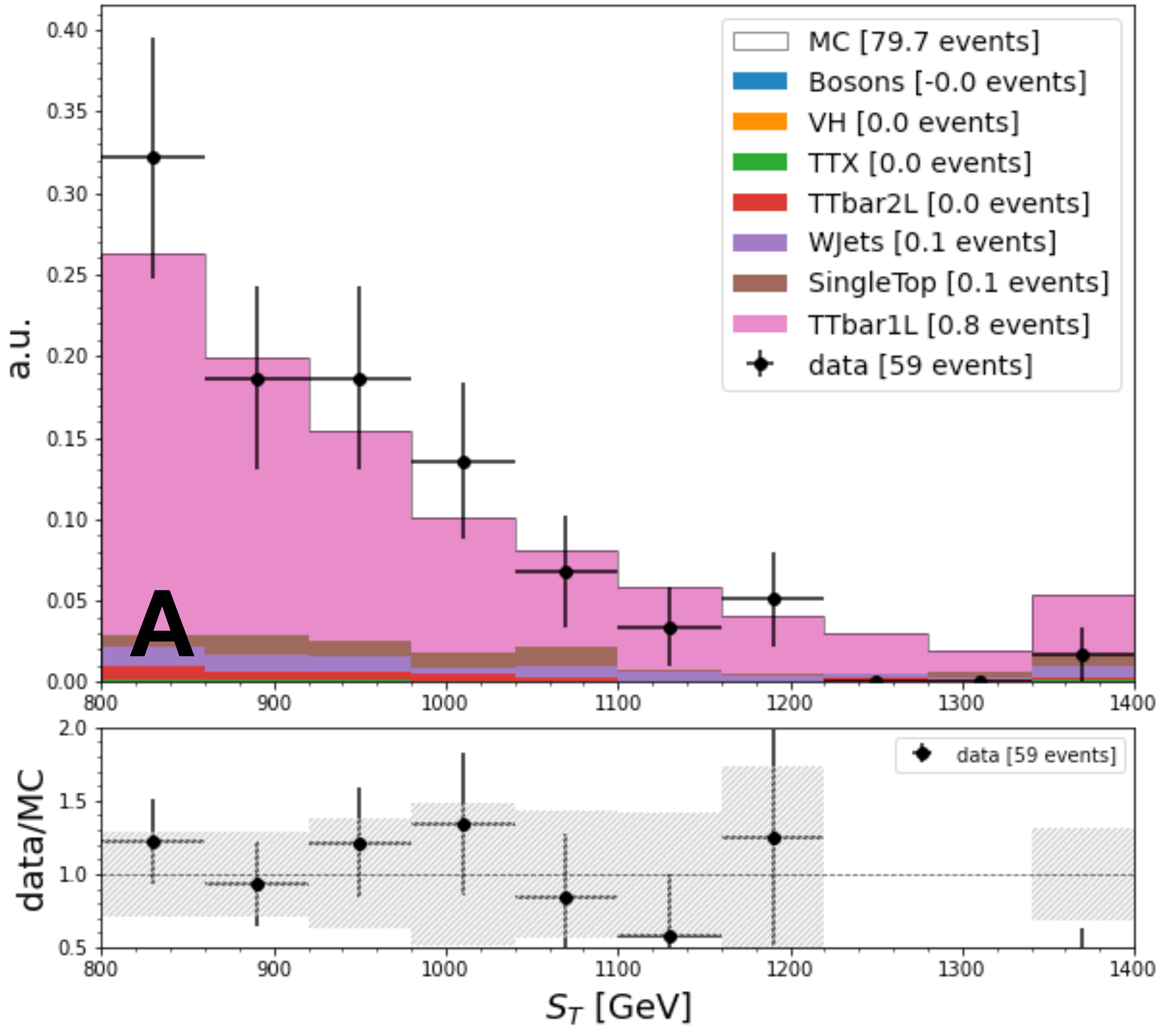

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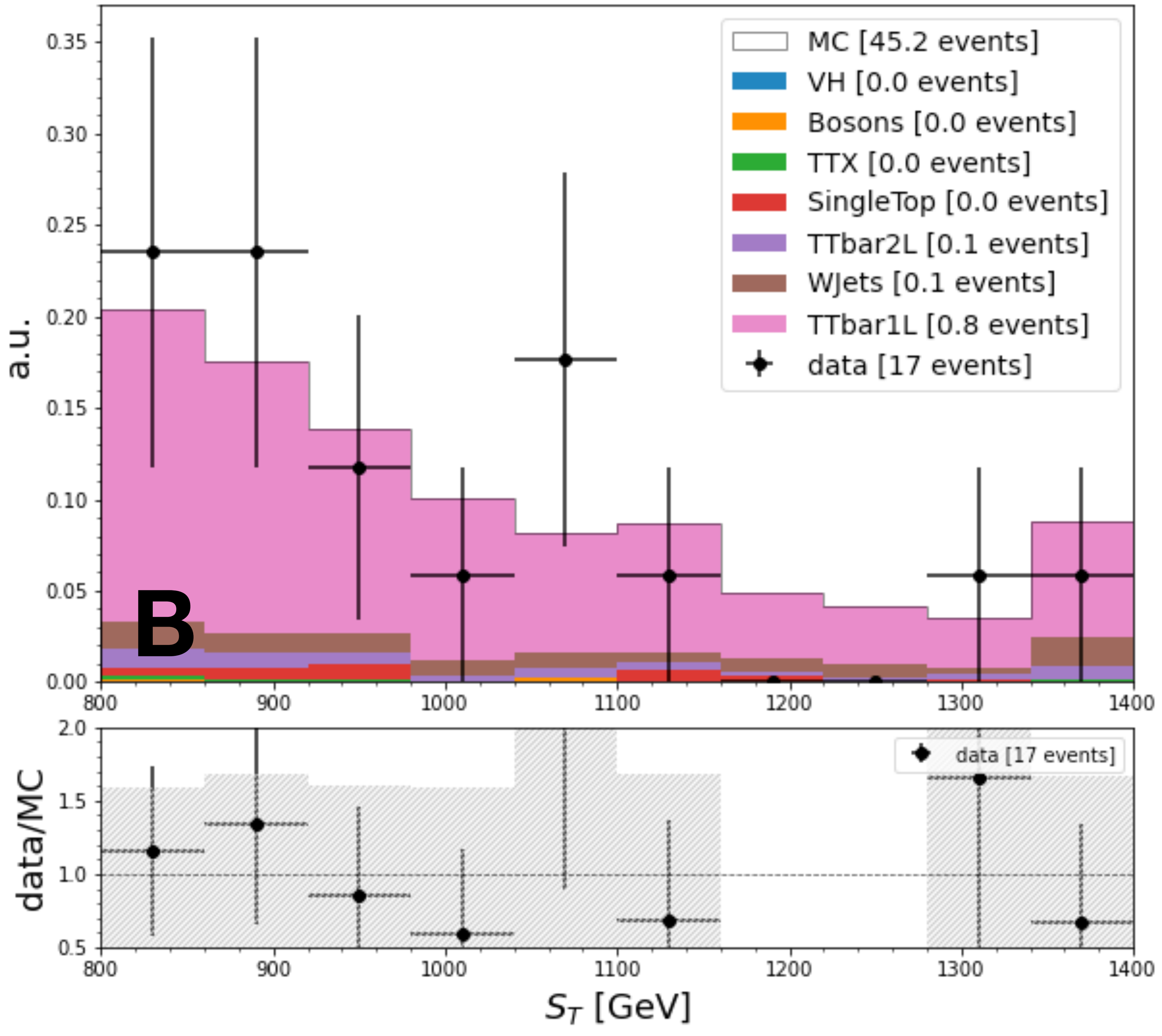

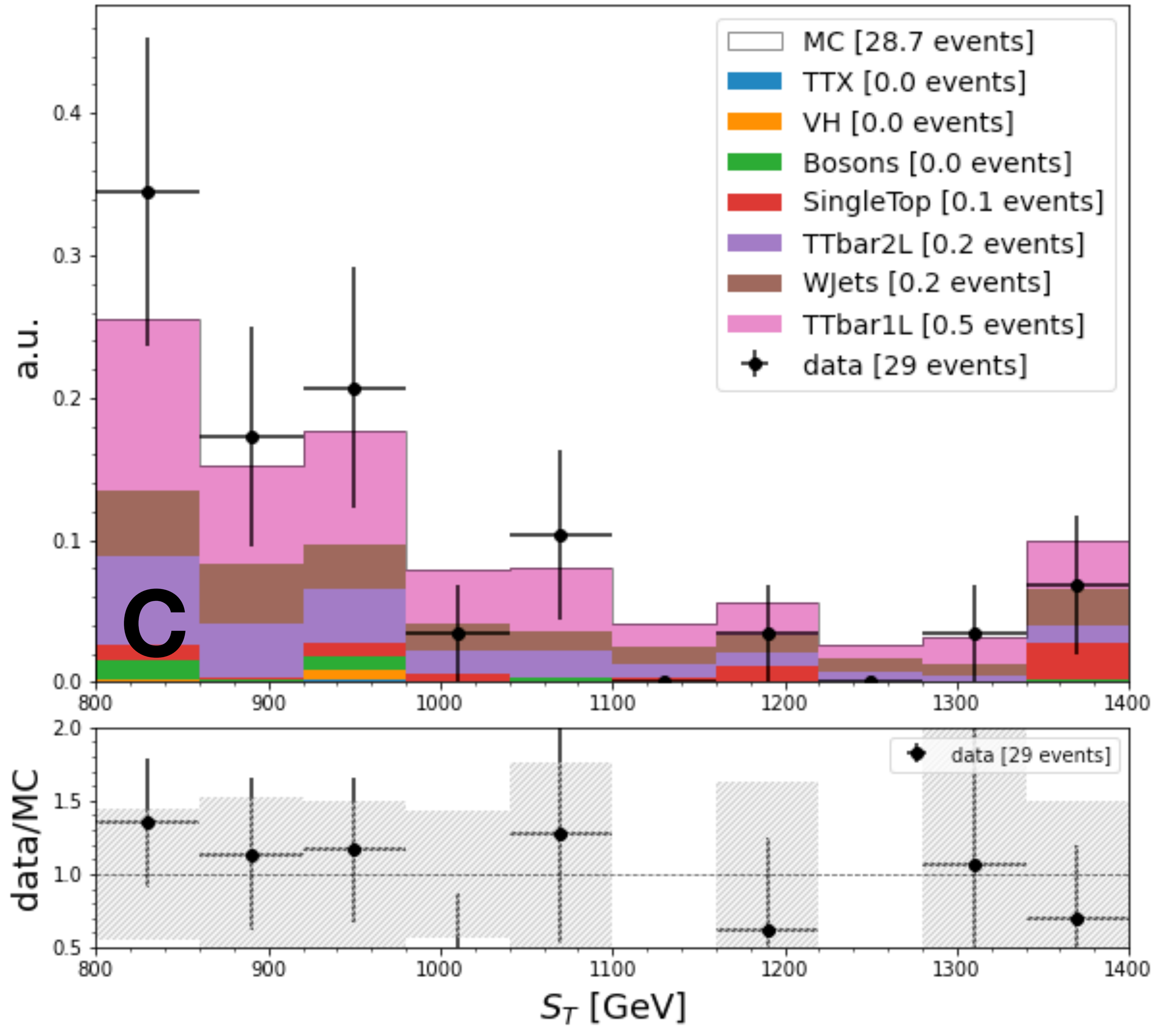

*err = $\Sigma_i w_i^2$

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ABCD: $\Delta\eta_{jj}$ vs. M_{SD}

Presel. (w/out $\Delta\eta_{jj}$ cut) AND M_{jj} > 1500 GeV AND PNet Xbb > 0.9

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Cut	Region	Bkg. (raw)	Bkg. (wgt)	Bkg. Err.*	Sig. (raw)	Sig. (wgt)	Sig. Err.*
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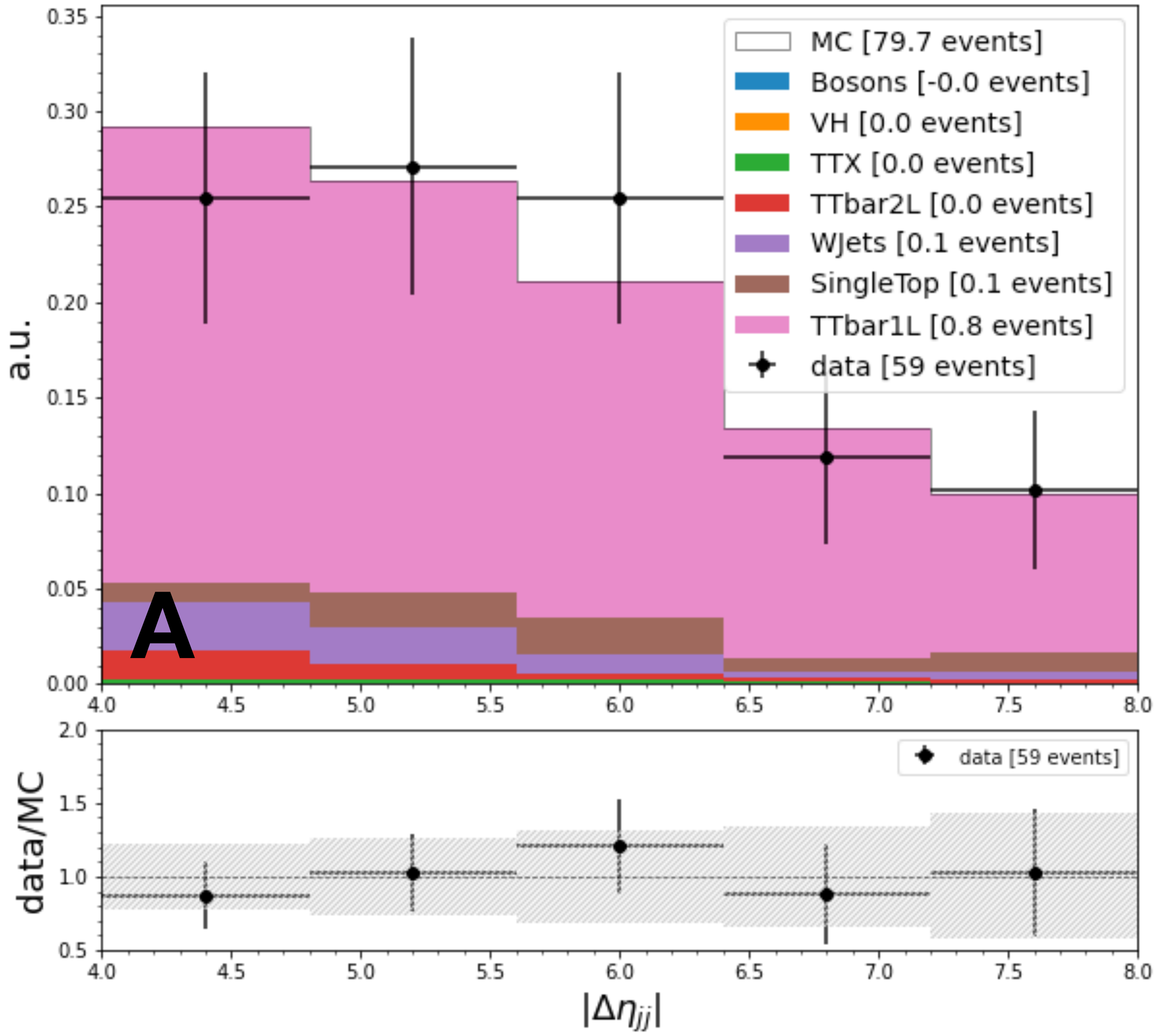
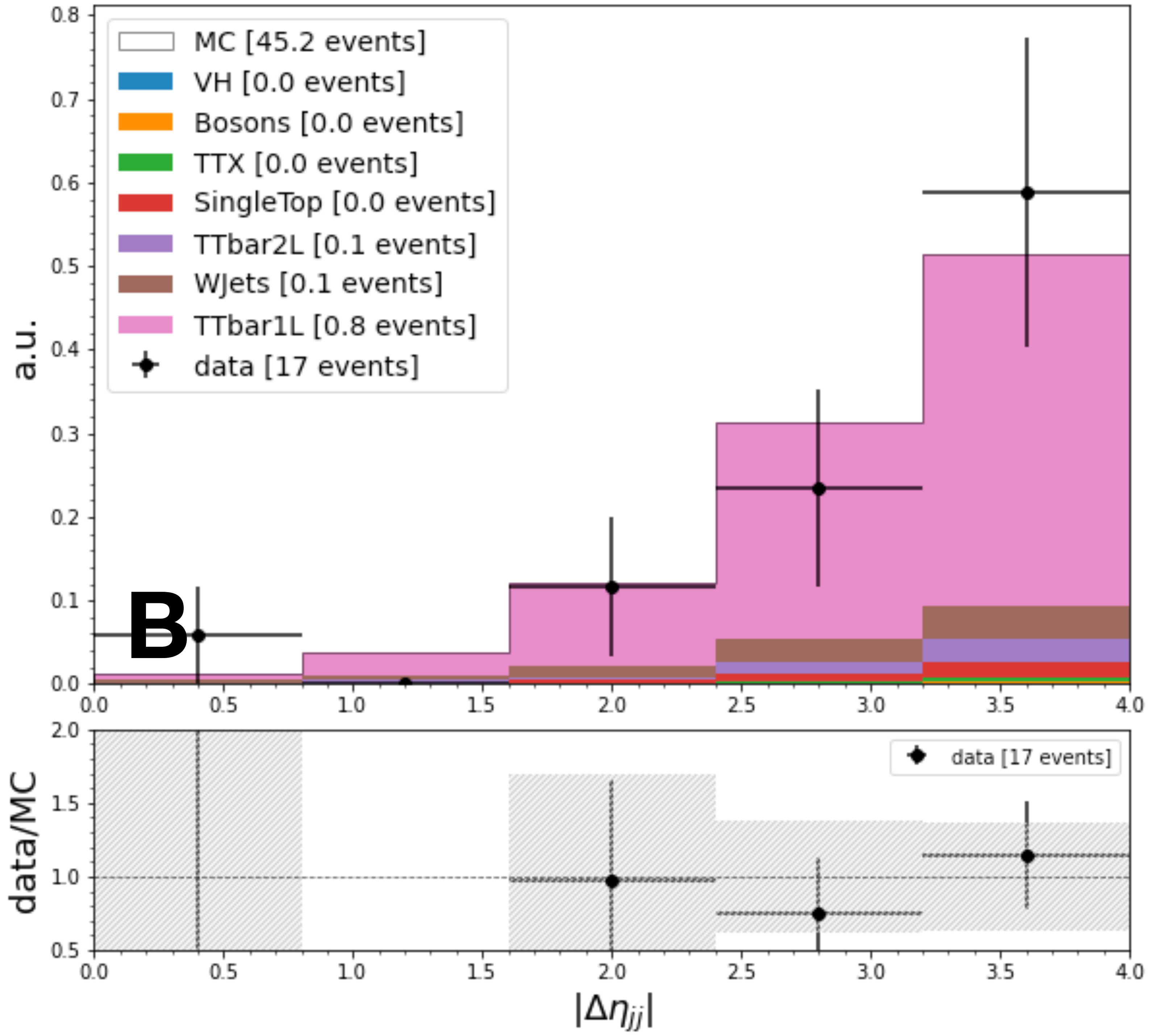
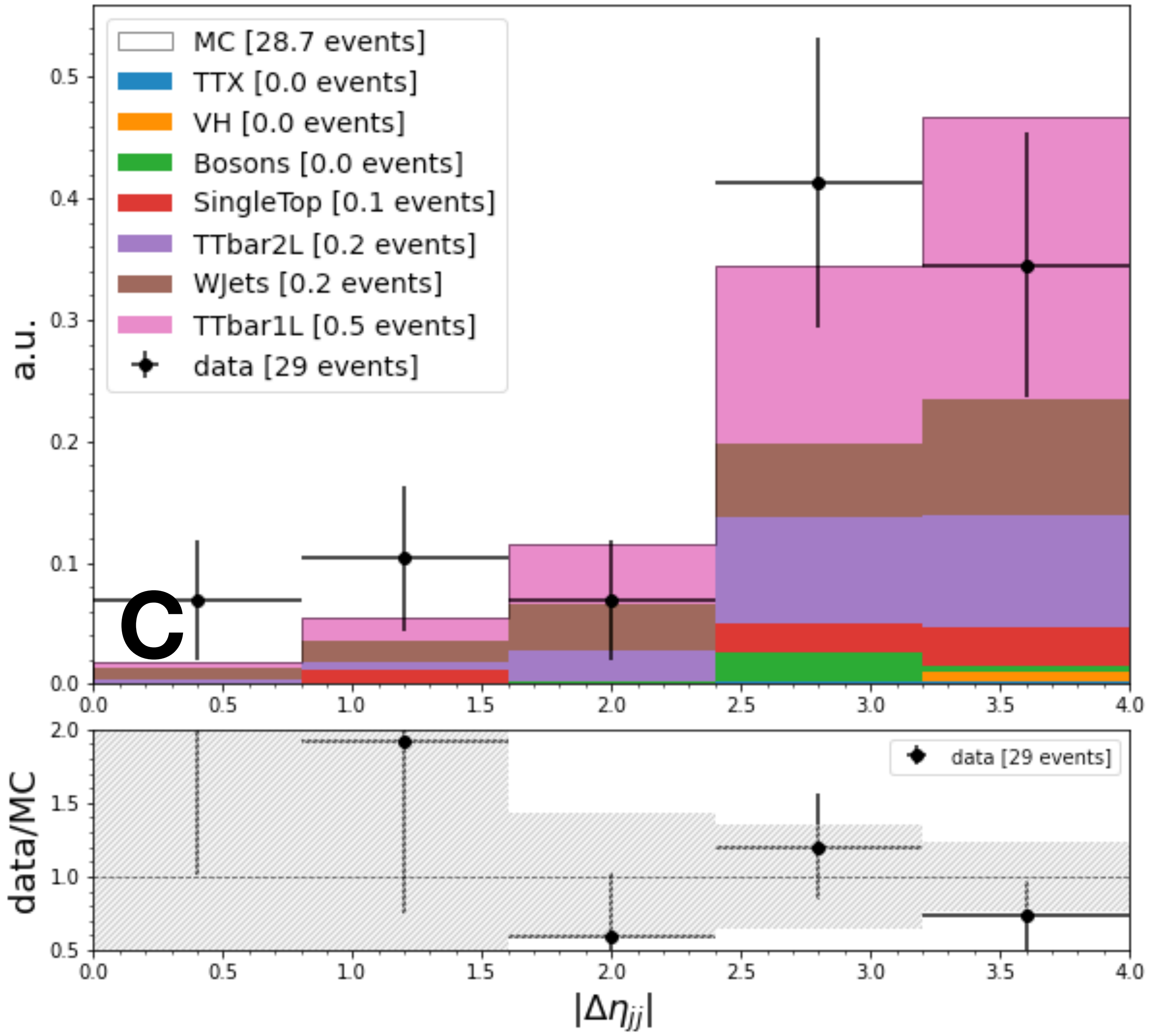


17 data vs 45 MC





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Yields scaled to lumi×σ, rounded for readability

Cut	Region	Bkg. (raw)	Bkg. (wgt)	Bkg. Err.*	Sig. (raw)	Sig. (wgt)	Sig. Err.*
$\|\Delta\eta_{jj}\| > 4$ AND $M_{SD} \geq 150$ GeV	A	2902	79.68	2.02	43	6.30	1.06
$\|\Delta\eta_{jj}\| \leq 4$ AND $M_{SD} \geq 150$ GeV	B	2662	45.21	1.42	2	0.50	0.35
$\|\Delta\eta_{jj}\| \leq 4$ AND $M_{SD} < 150$ GeV	C	2481	28.66	1.21	13	1.57	0.50
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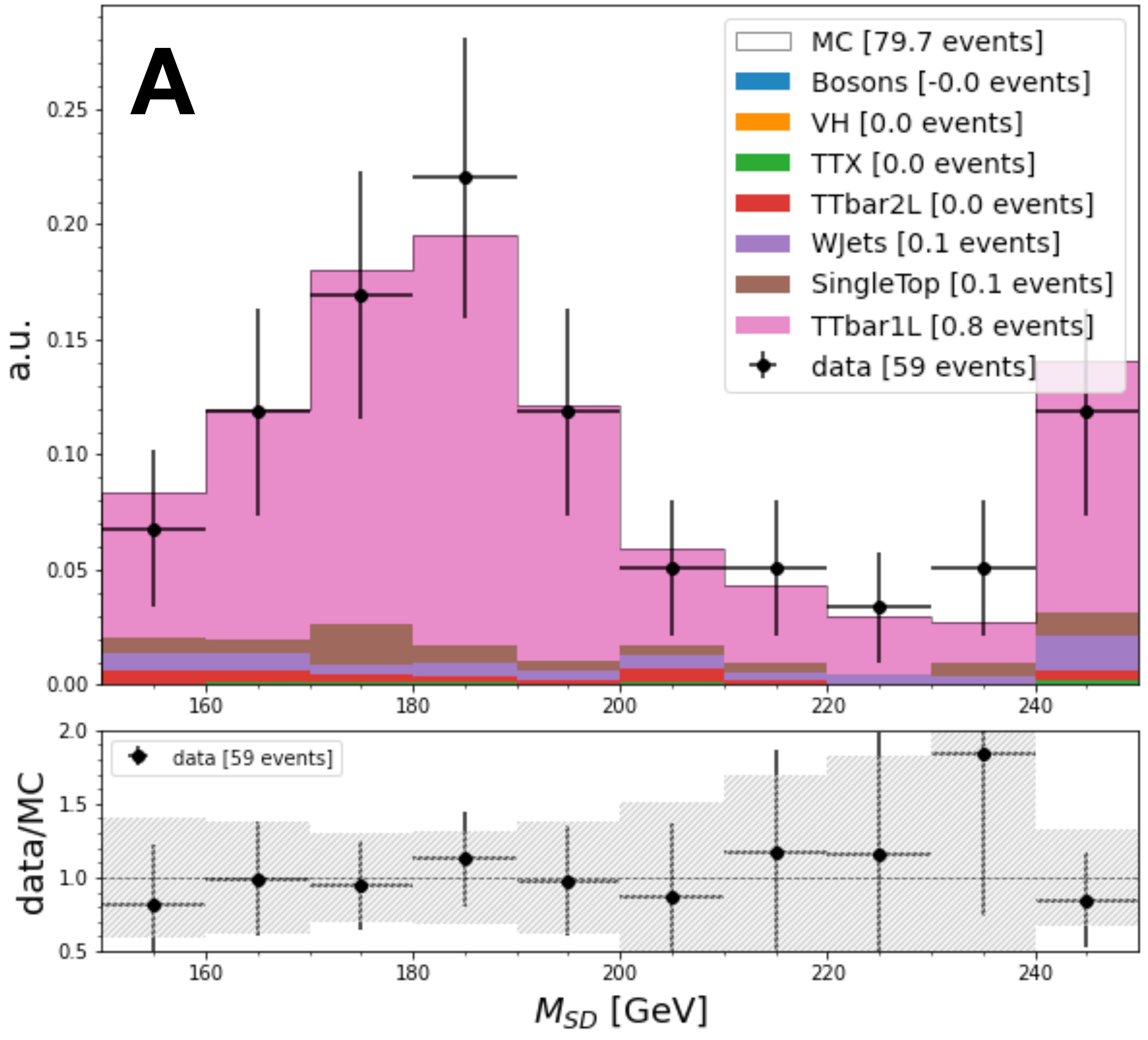

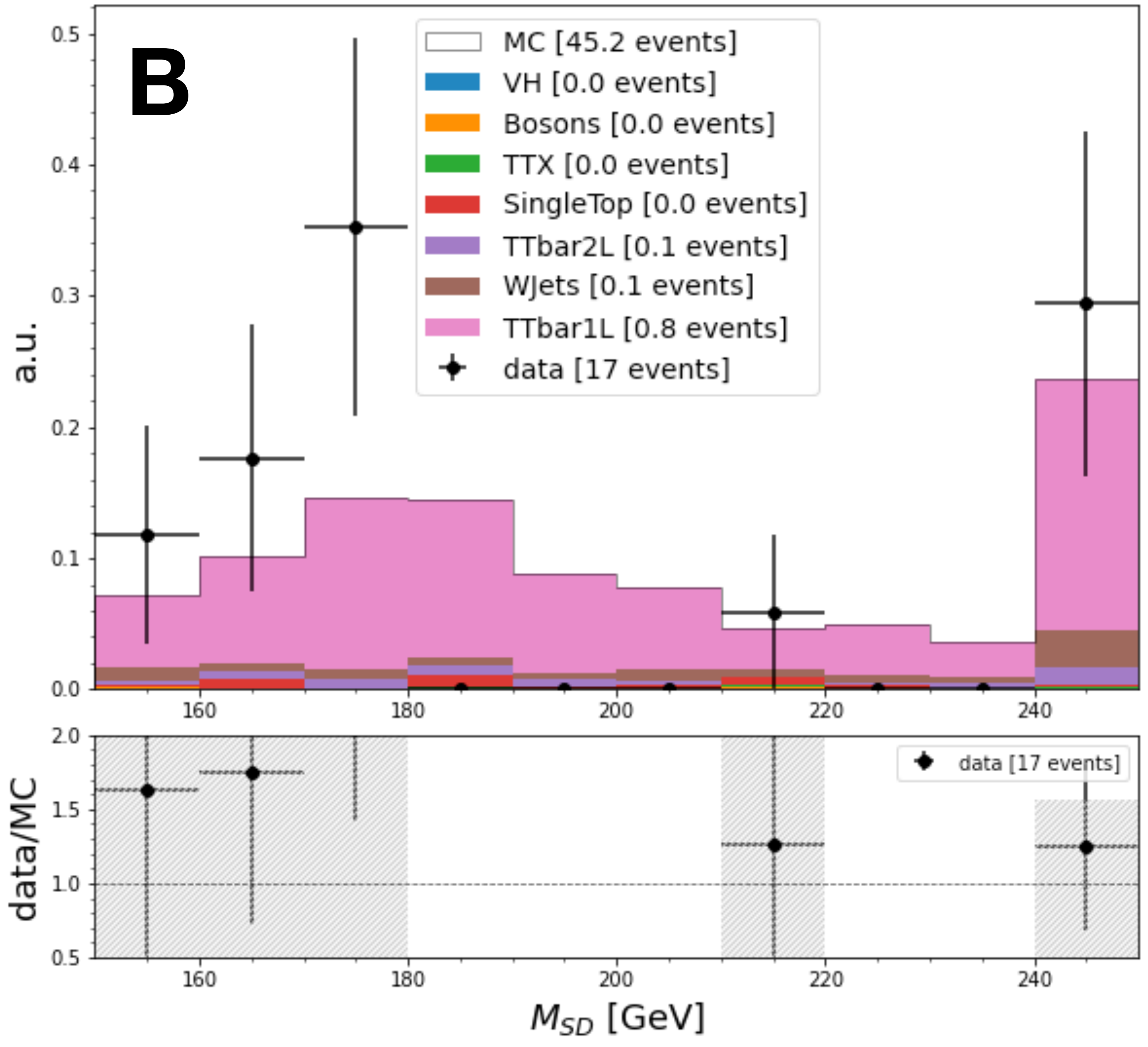

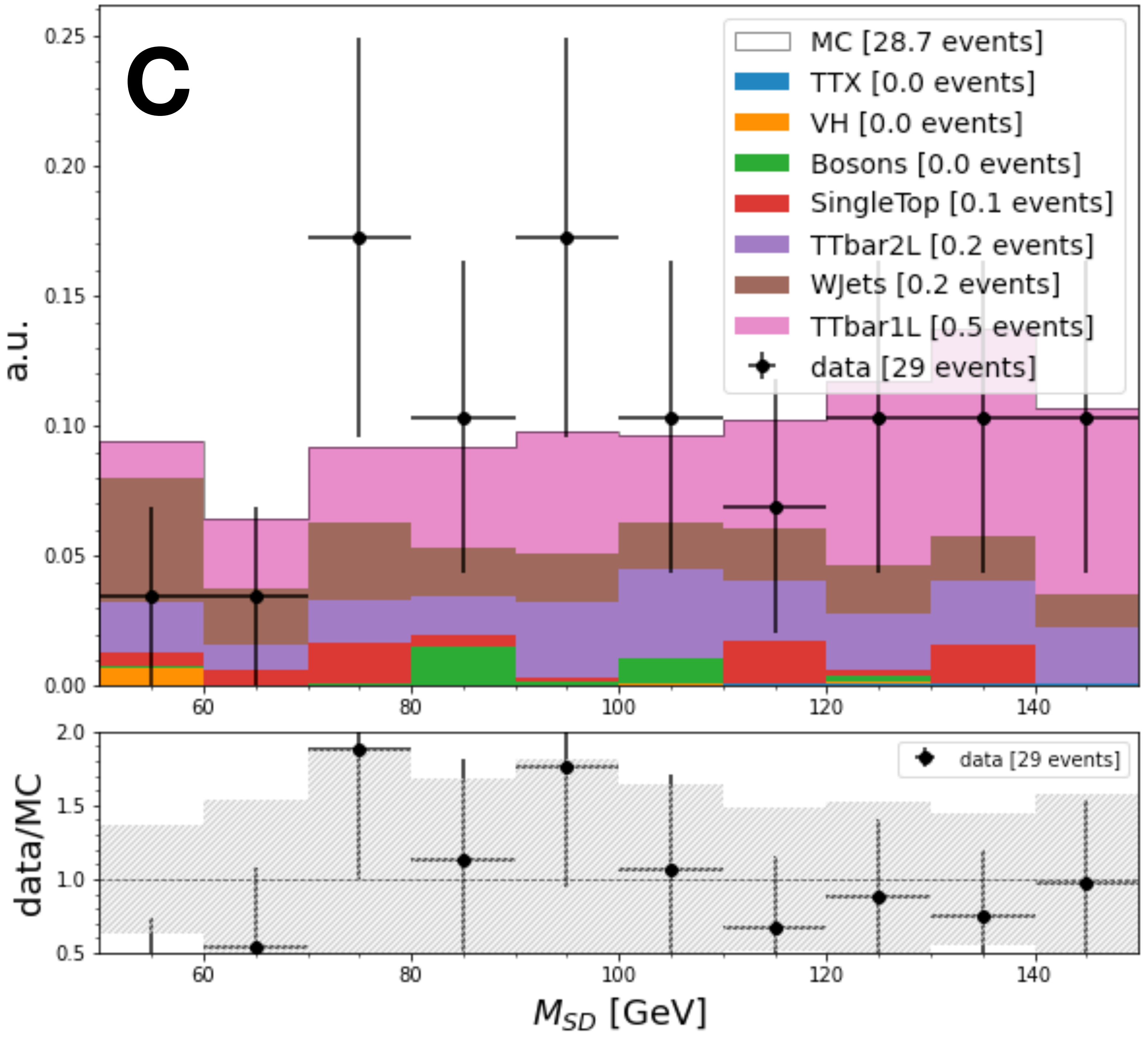

*err = $\Sigma_i w_i^2$

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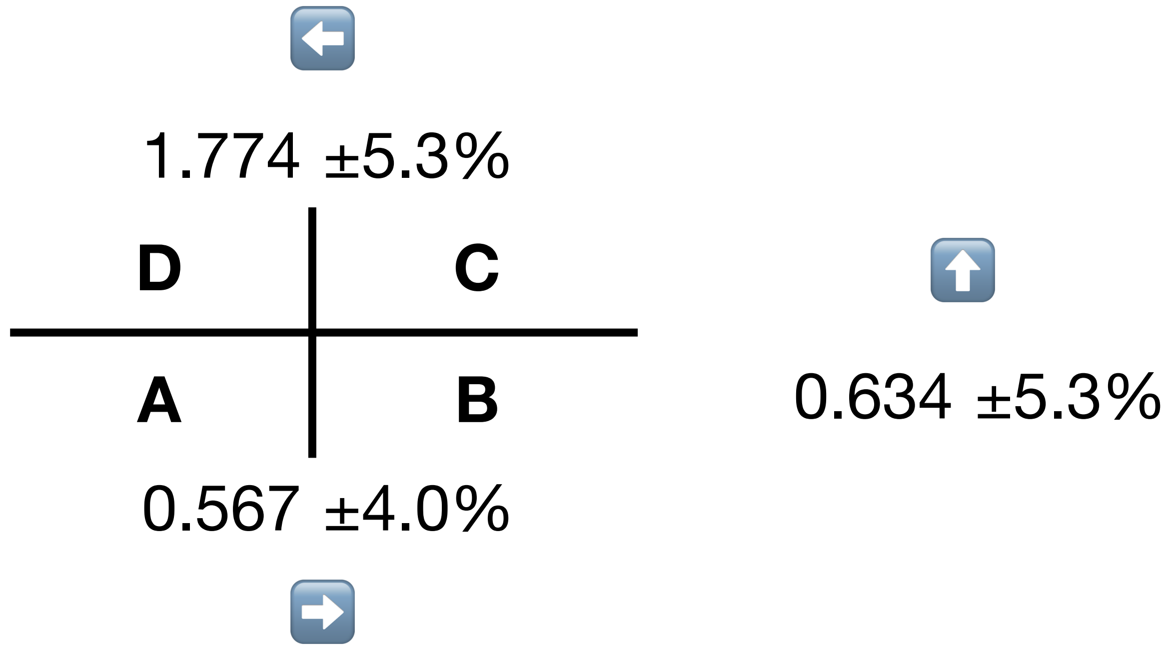

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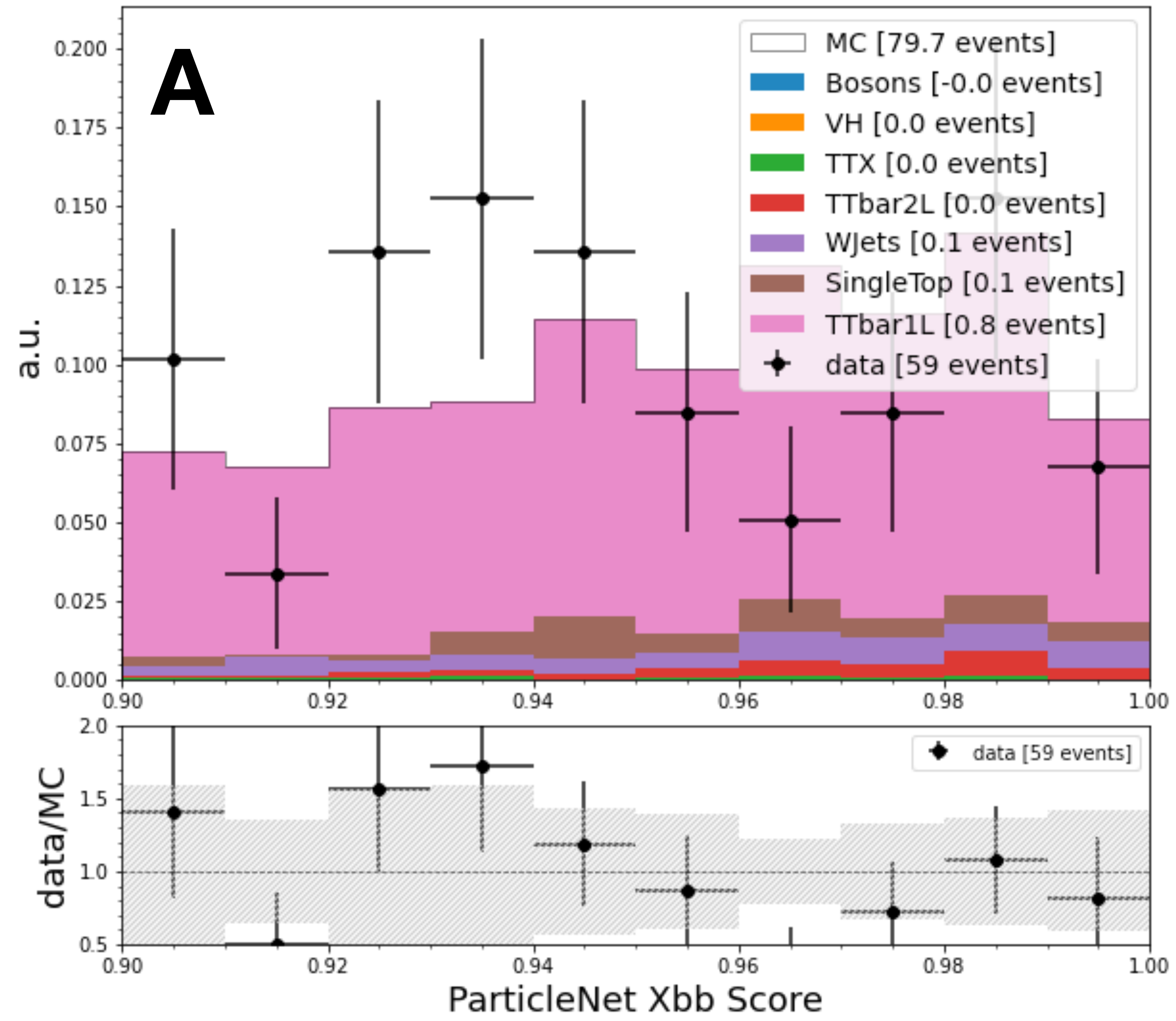

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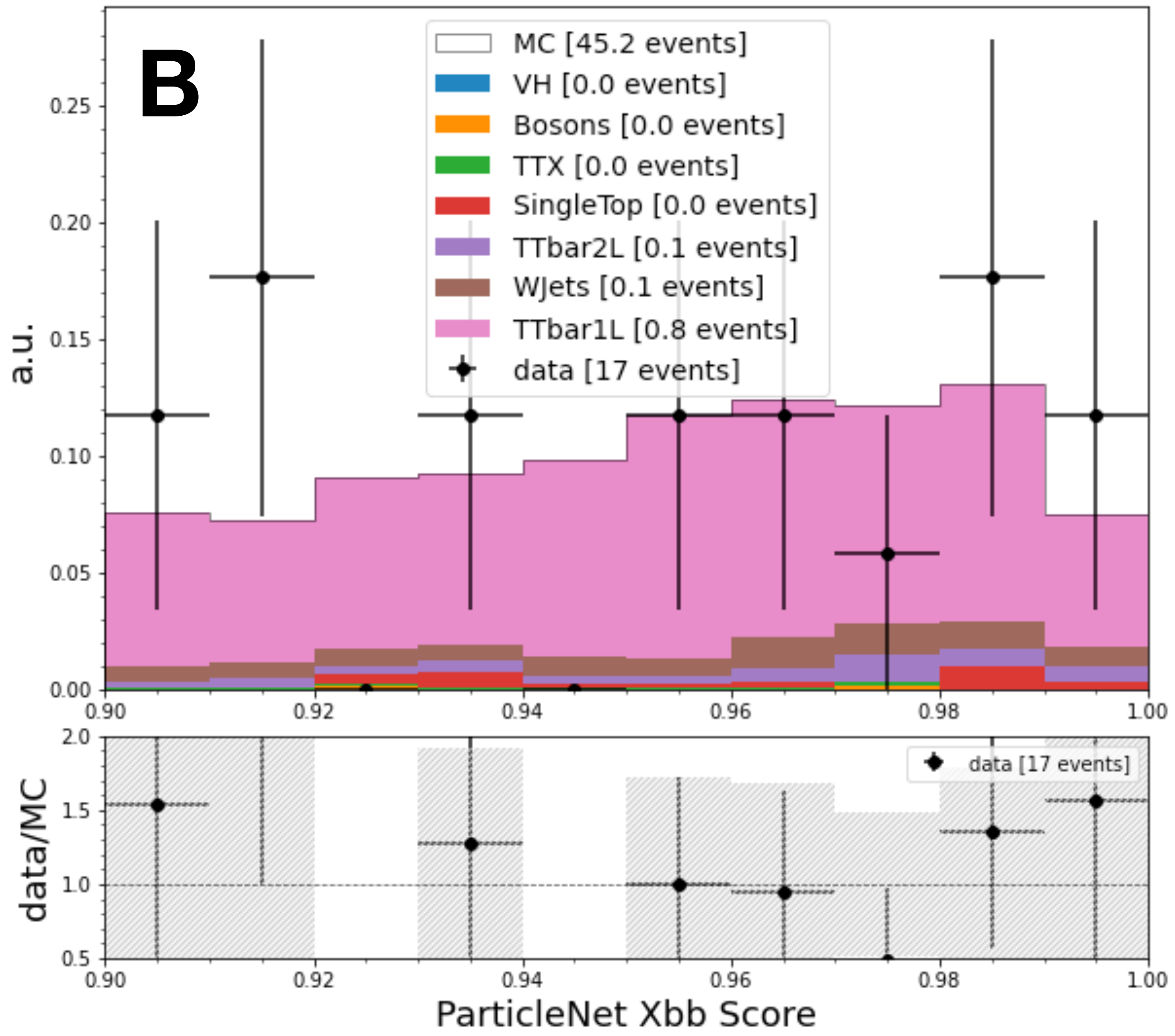

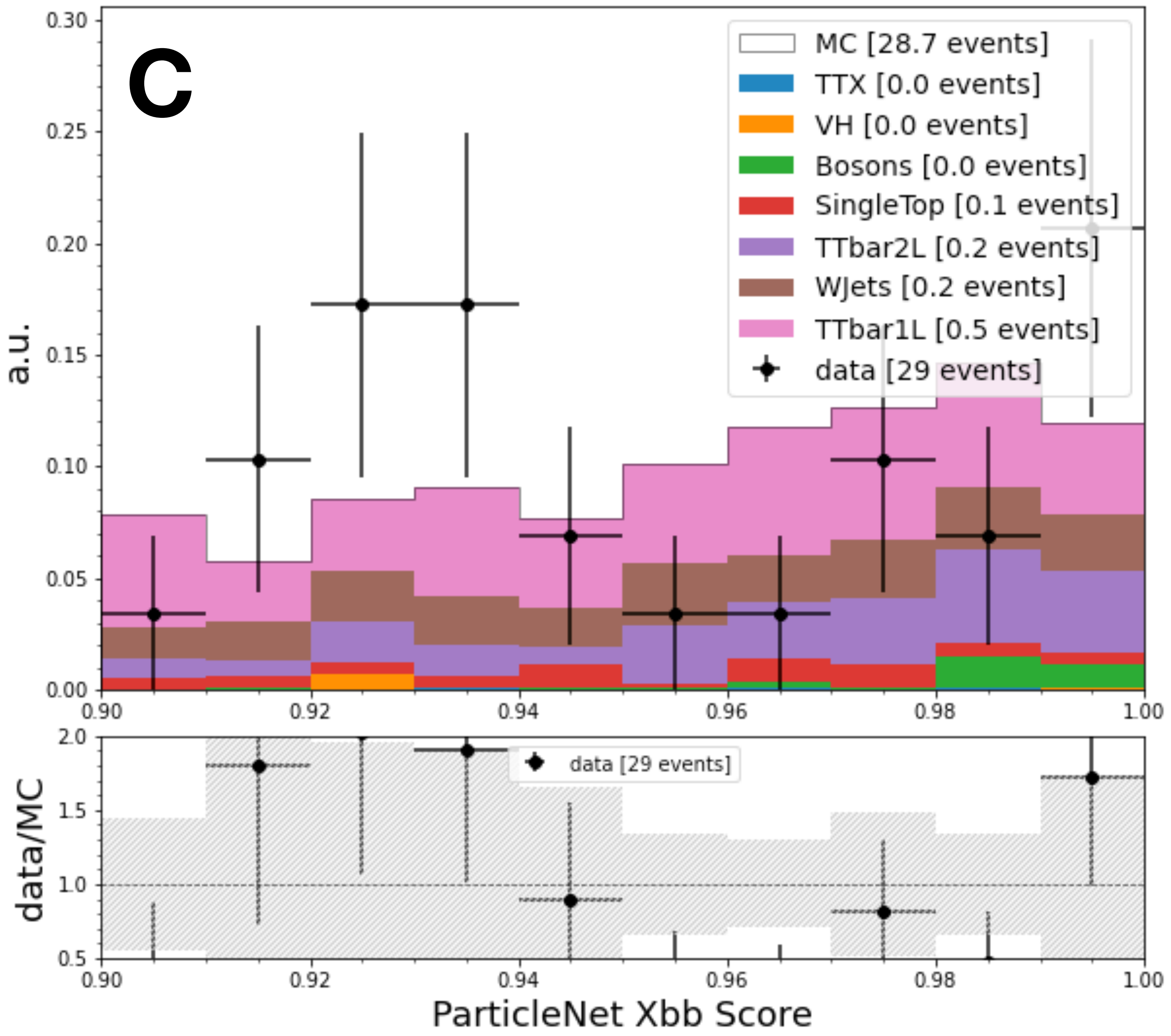

*err = $\Sigma_i w_i^2$

**Specifically, this is the SR with a looser S_T cut (S_T > 800 GeV)

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MC-Based

Yields scaled to lumi×σ, rounded for readability

Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg	Eff.*	VBSWH (κ_W = -1)	Eff.*
Preselection	2	43	484	194	20	1.7K	110	**2.5K**	—	**579**	—
Signal Region	0	0	1	0	0	2	1	**4**	100%	**109**	81%

	Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg		VBSWH (κ_W = -1)	S/B
	Preselection (w/out $\Delta\eta_{jj}$ cut) AND M_{jj} > 1.5 TeV AND S_T > 1.2 TeV	0.0	0.1	4.9	2.3	0.4	17.7	2.5	**27.8**		**112.4**	—
Sidebands	**M_{SD} ≥ 150 GeV AND $\lvert\Delta\eta_{jj}\rvert$ > 4**	0.0	0.0	0.9	1.0	0.2	7.2	0.5	**9.8**		**2.3**	24%
Sidebands	**M_{SD} < 150 AND $\lvert\Delta\eta_{jj}\rvert$ ≤ 4**	0.0	0.1	1.3	0.9	0.1	2.1	0.9	**5.3**		**1.0**	19%
Sidebands	**M_{SD} ≥ 150 GeV AND $\lvert\Delta\eta_{jj}\rvert$ ≤ 4**	0.0	0.0	1.4	0.2	0.1	6.5	0.6	**8.8**		**0.3**	3%
Sidebands	**M_{SD} ≥ 150 GeV OR $\lvert\Delta\eta_{jj}\rvert$ ≤ 4**	0.0	0.1	3.6	2.1	0.4	15.7	2.0	**23.8**		**3.6**	15%

	Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg		VBSWH (κ_W = -1)	S/B
	Same presel. as table above	0.0	0.1	4.9	2.3	0.4	17.7	2.5	**27.8**		**112.4**	—
VRs	**M_{SD} ≥ 150 GeV ($\Delta\eta_{jj}$ VR)**	0.0	0.0	0.9	1.0	0.2	7.2	0.5	**9.8**		**2.3**	24%
VRs	**$\lvert\Delta\eta_{jj}\rvert$ ≤ 4 (M_{SD} VR)**	0.0	0.1	2.7	1.1	0.2	8.5	1.5	**14.1**		**1.3**	9%

- Sidebands to consider: M_{SD}-only, $\Delta\eta_{jj}$-only, and M_{SD} AND/OR $\Delta\eta_{jj}$
- Low stats in most regions shown above (including validation regions)

*eff = 1 - after/before

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MC-Based

Yields scaled to lumi×σ, rounded for readability

Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg	Eff.*	VBSWH ($\kappa_W = -1$)	Eff.*
Preselection	2	43	484	194	20	1.7K	110	**2.5K**	—	**579**	—
Signal Region	0	0	1	0	0	2	1	**4**	100%	**109**	81%

	Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg		VBSWH ($\kappa_W = -1$)	S/B
	Preselection (w/out $\Delta\eta_{jj}$ cut) AND M_{jj} > 1.5 TeV AND S_T > 1.2 TeV	0.8	2.0	25.2	12.5	2.0	152.4	20.4	**215.2**		**260.9**	—
Sidebands	**$M_{SD} \geq 150$ GeV AND $\|\Delta\eta_{jj}\| > 4$**	0.0	-0.0	5.2	5.5	0.8	70.1	2.5	**84.0**		**6.5**	8%
Sidebands	**$M_{SD} < 150$ AND $\|\Delta\eta_{jj}\| \leq 4$**	0.3	0.9	6.6	1.9	0.2	13.6	6.6	**30.0**		**1.6**	5%
Sidebands	**$M_{SD} \geq 150$ GeV AND $\|\Delta\eta_{jj}\| \leq 4$**	0.0	0.2	4.3	1.4	0.5	38.5	2.6	**47.4**		**0.5**	1%
Sidebands	**$M_{SD} \geq 150$ GeV OR $\|\Delta\eta_{jj}\| \leq 4$**	0.3	1.0	16.0	8.8	1.5	122.1	11.8	**161.5**		**8.6**	5%

	Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg		VBSWH ($\kappa_W = -1$)	S/B
	Same presel. as table above	0.0	0.1	4.9	2.3	0.4	17.7	2.5	**27.8**		**112.4**	—
VRs	**$M_{SD} \geq 150$ GeV ($\Delta\eta_{jj}$ VR)**	0.0	0.2	9.4	6.9	1.3	108.5	5.1	**131.4**		**7.0**	5%
VRs	**$\|\Delta\eta_{jj}\| \leq 4$ (M_{SD} VR)**	0.3	1.1	10.9	3.4	0.7	52.0	9.2	**77.5**		**2.1**	3%

- Sidebands to consider: M_{SD}-only, $\Delta\eta_{jj}$-only, and M_{SD} AND/OR $\Delta\eta_{jj}$
- Better stats here, as in ABCD shown earlier

*eff = 1 - after/before

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Conclusions

- Poor data/MC agreement for regions A, B of ABCD strategy shown
- Considering a number of sidebands for doing a MC-based extrapolation
  - Would need to validate MC well to do these, but VRs have low stats
  - Unsure which regions are pure enough in bkg. to be viable
  - Better stats if S_T cut is loosened in sidebands/VRs

Backup

*Professor
†Post-doc
‡Graduate Student
§Undergraduate Student

Who is involved?

- UC San Diego:
  A. Arora‡, P. Chang†, L. Giannini†, J. Guiang‡, F. Würthwein*, Y. Xiang‡, A. Yagil*

- U. Nebraska:
  F. Golf*

- Boston University:
  D. Spitzbart†, I. Suarez*

- UC Santa Barbara:
  C. Campagnari*

BSM Signal Models

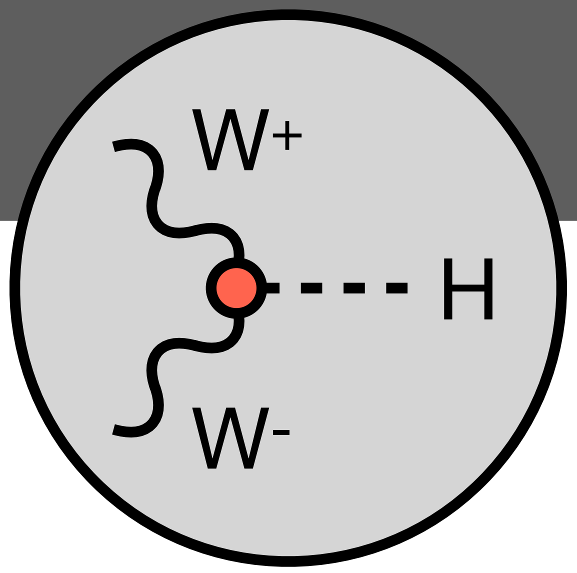
$\kappa_W = -1$

models/sm/couplings.py

```
GC_72 = Coupling(name = 'GC_72',
                 value = '(ee**2*complex(0,1)*vev)/(2.*sw**2)',
                 value = '-((ee**2*complex(0,1)*vev)/(2.*sw**2))',
                 order = {'QED':1})
```

models/sm/vertices.py

```
V_52 = Vertex(name = 'V_52',
              particles = [ P.W__minus__, P.W__plus__, P.H ],
              color = [ '1' ],
              lorentz = [ L.VVS1 ],
              couplings = {(0,0):C.GC_72})
```



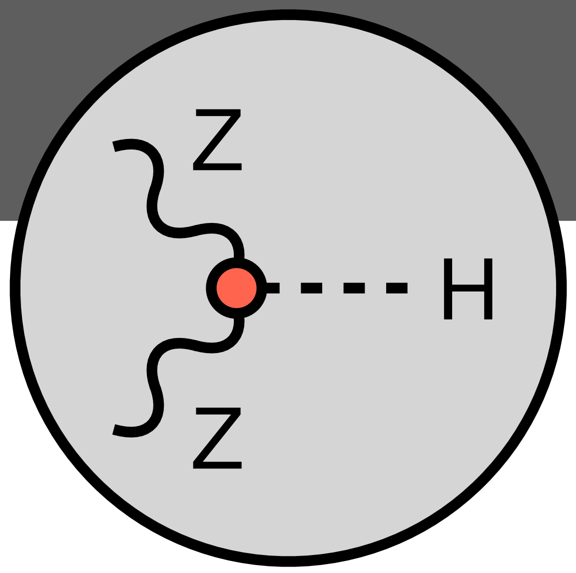
$\kappa_Z = -1$

models/sm/couplings.py

```
GC_81 = Coupling(name = 'GC_81',
                 value = 'ee**2*complex(0,1)*vev + …',
                 value = '-(ee**2*complex(0,1)*vev + … )',
                 order = {'QED':1})
```

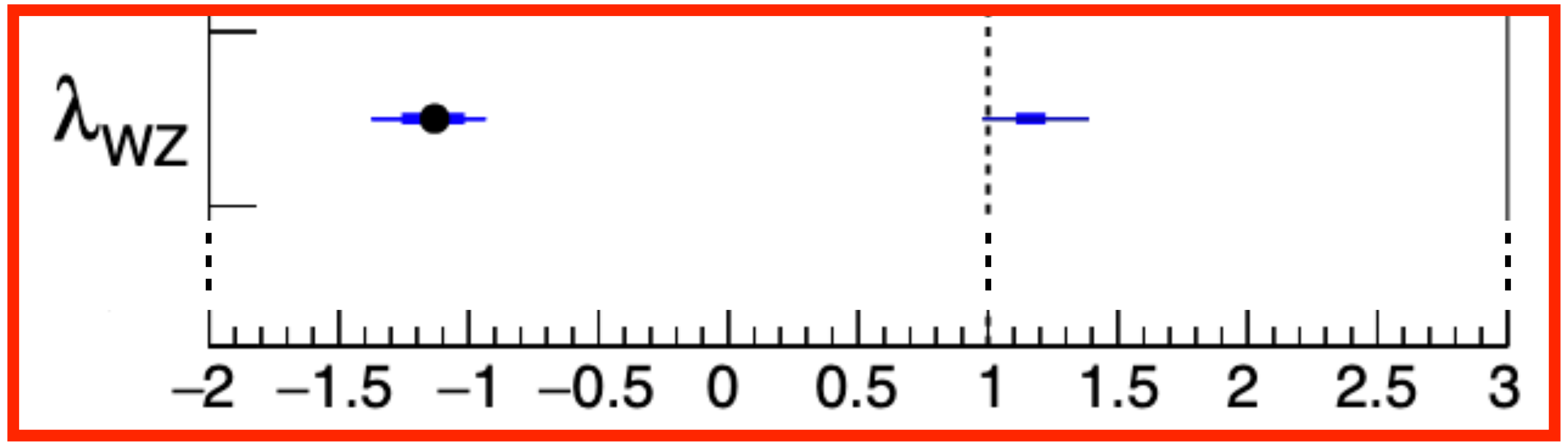
models/sm/vertices.py

```
V_69 = Vertex(name = 'V_69',
              particles = [ P.Z, P.Z, P.H ],
              color = [ '1' ],
              lorentz = [ L.VVS1 ],
              couplings = {(0,0):C.GC_81})
```



Only changed one line in SM Madgraph model!

Current CMS Result



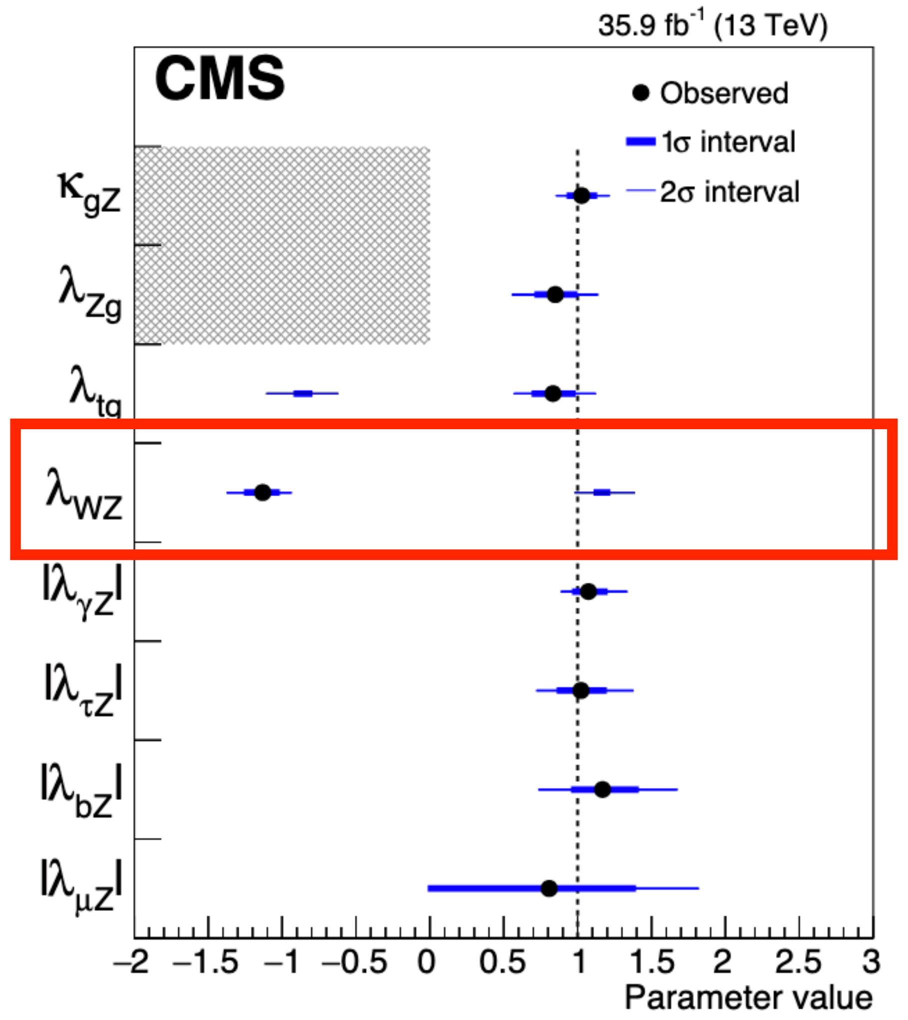


Figure 16: Summary of the model with coupling ratios and effective couplings for the ggH and H $\rightarrow \gamma\gamma$ loops. The points indicate the best fit values while the thick and thin horizontal bars show the 1σ and 2σ CL intervals, respectively. For this model, both positive and negative values of λ_{WZ} and λ_{tg} are considered.

- From 35.9 fb^{-1} Higgs combination: best fit hints at λ_{WZ} = -1 (BSM)
  - https://arxiv.org/pdf/1809.10733.pdf
- **With the handles we have on BSM λ_{WZ} via VBS WH, we can rigorously explore this!**

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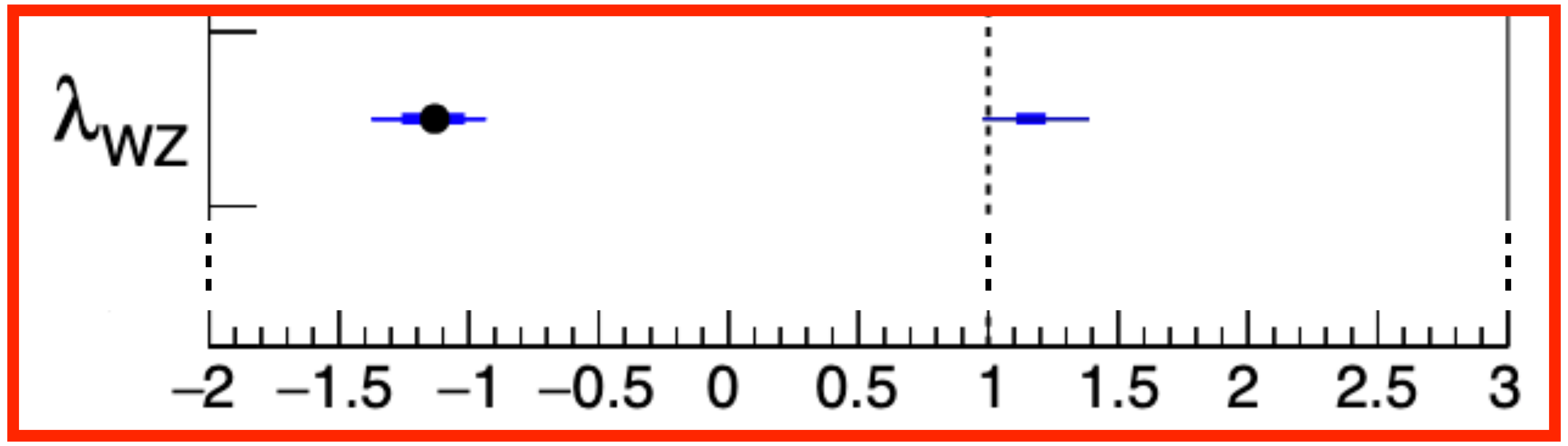
Current CMS Result



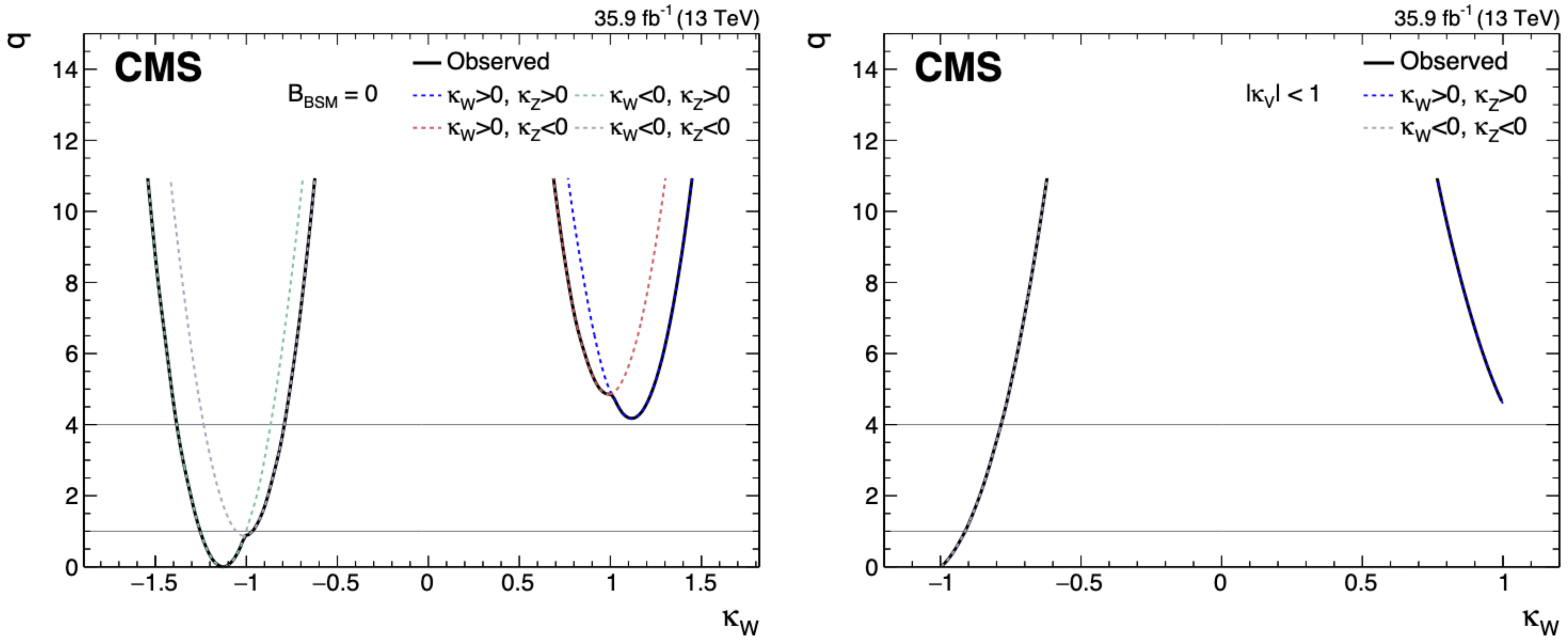


Figure 13: Scan of the test statistic q as a function of κ_W in the generic κ model assuming $\mathcal{B}_{BSM} = 0$ (left) and allowing $\mathcal{B}_{inv}$ and $\mathcal{B}_{undet}$ to float (right). The different colored lines indicate the value of q for different combinations of signs for κ_W and κ_Z. The solid black line shows the minimum value of $q(\kappa_W)$ in each case and is used to determine the best fit point and the 1σ and 2σ CL regions. The scan in the right figure is truncated because of the constraints of $|\kappa_W| \leq 1$ and $|\kappa_Z| \leq 1$, which are imposed in this model.

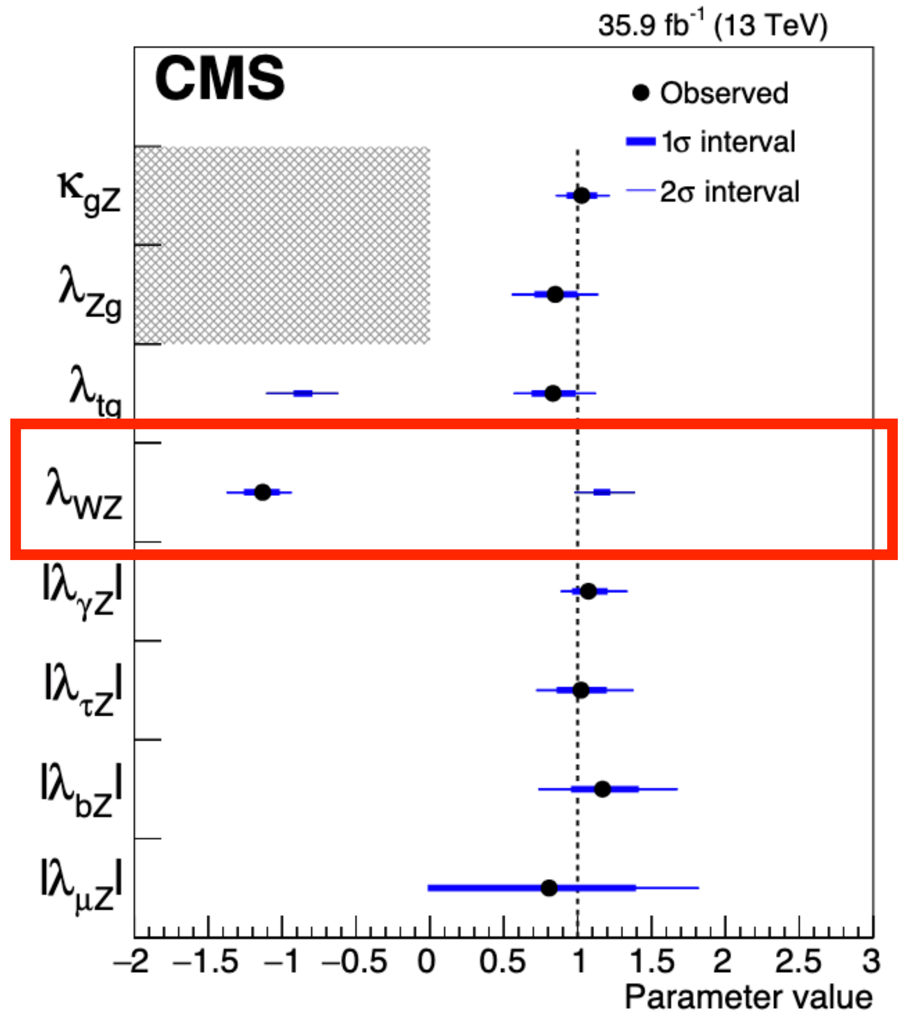


Figure 16: Summary of the model with coupling ratios and effective couplings for the ggH and $H \to \gamma\gamma$ loops. The points indicate the best fit values while the thick and thin horizontal bars show the 1σ and 2σ CL intervals, respectively. For this model, both positive and negative values of λ_{WZ} and λ_{tg} are considered.

https://arxiv.org/pdf/1809.10733.pdf

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VBS WH Cross Sections

Model	σ [pb]
$\kappa_W = \kappa_Z = +1$ (SM)	0.075
$\kappa_W = -1$	0.433
$\kappa_Z = -1$	0.433

×6

- Setting $\kappa_W = -1$ or $\kappa_Z = -1$ equivalently enhances cross section by a factor of 6
- These numbers are taken from MadGraph*: `generate p p > w h j j QCD=0`
  - Includes gen-level filters (e.g. jet $p_T > 10$ GeV)
  - Generated 10,000 events for each to obtain xsec value
- **Optimizing for $\kappa_W = -1$** (kinematics are equivalent to $\kappa_Z = -1$)
  - Generated 100k UL NanoAOD events for 2016 pre-VFP, 2016 post-VFP, 2017, and 2018

*More details in backup

Analysis Skim

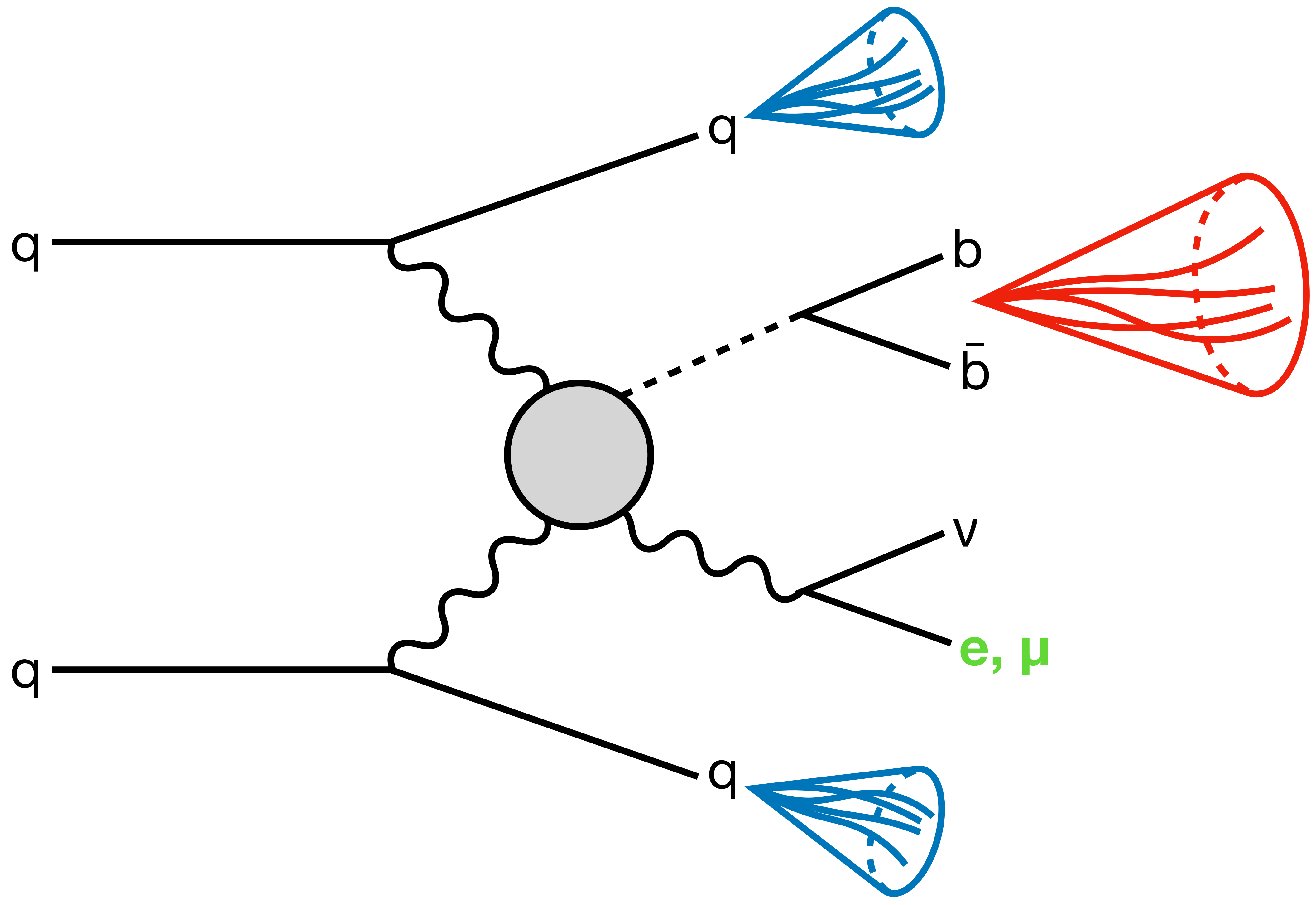
Yields scaled to lumi×σ, rounded for readability

Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg	Eff.*	VBSWH (κ_W = -1)	Eff.*
Skim AND Postskim	232	6.5K	122K	7.6K	1K	86K	10K	233K	—	2K	—

Object	Primary Skim	Postskim
Leptons (μ, e)	≥ 1 veto*	== 1 loose AND == 1 tight*
Fat Jets	≥ 1 w/ p_T > 200 GeV AND mass > 10 GeV AND M_{SD} > 10 GeV AND ΔR(fat jet, any veto lepton) > 0.8	≥ 1 w/ p_T > 250 GeV AND mass > 50 GeV AND M_{SD} > 40 GeV AND ΔR(fat jet, tight lepton) > 0.8
Jets	≥ 1 w/ p_T > 20 GeV AND ΔR(jet, any veto lepton) > 0.4	—
Other	—	S_T > 800 GeV

*Using the ttH lepton ID

VBS WH Objects



Object	Selections
One **Lepton** (loose veto in postskim)	• Passes ttH tight ID • p_T > 40 GeV
One **Hbb** Ak8 Jet	• ΔR(Ak8 jet, any veto lep) > 0.8 • p_T > 250 GeV • mass > 50 GeV • M_{SD}* > 40 GeV • Has max(PNet Xbb vs. QCD score) • PNet Xbb vs. QCD score > 0.3

Two **VBS** Ak4 jets	• ΔR(Ak4 jet, any veto lep) > 0.4
	• ΔR(Ak4 jet, Hbb Ak8 jet) > 0.8
	• p_T > 30 GeV
	• For > 2 candidates**:
	  • All in same η-hemisphere: leading/trailing (in P) jets
	  • Else: leading (in P) jet from each η-hemisphere

*M_{SD} = soft drop mass
**Hereafter referred to as the “Max-E” selection

Overview

Yields scaled to lumi×σ, rounded for readability

	Cut	VH	VV/VVV/VBSWZ	W+Jets	SingleTop	TTbar+X	TTbar1L	TTbar2L	TotalBkg	Eff.*	VBSWH (κ_W = -1)	Eff.*
	Skim AND Postskim	232	6.5K	122K	7.6K	1K	86K	10K	233K	—	2K	—
Preselection	**$p_T(\ell)$ > 40 GeV**	220	5.9K	110K	6.9K	910	78K	8.8K	211K	10%	1.8K	5%
Preselection	**Passes single-lepton triggers**	181	5.3K	98K	6.2K	773	68K	7.6K	186K	12%	1.6K	14%
Preselection	**≥ 1 AK8 jet w/ p_T > 250 GeV AND mass > 50 GeV AND M_{SD} > 40 GeV**	181	5.3K	98K	6.2K	767	68K	7.4K	186K	0%	1.6K	0%
Preselection	**2 VBS jets (max E)**	50	2K	47K	4.4K	654	50K	6.3K	111K	40%	1.1K	30%
Preselection	**M_{jj} > 500 GeV AND $\|\Delta\eta_{jj}\|$ > 3**	7	376	7.7K	994	124	10K	1.4K	21K	81%	920	17%
Preselection	**max(PNet Xbb score) > 0.3**	3	51	587	537	77	5.8K	382	7.4K	64%	608	34%
Preselection	**No b-tagged (med.) AK4 jets**	2	43	484	194	20	1.7K	110	**2.5K**	88%	**579**	37%
SR	**M_{jj} > 1.5 TeV AND $\|\Delta\eta_{jj}\|$ > 4**	1	5	68	31	3	297	22	**427**	83%	**322**	44%
SR	**S_T > 1.2 TeV**	0	1	11	6	0	25	2	**45**	89%	**139**	57%
SR	**PNet Xbb vs. QCD > 0.9 AND M_{SD} < 150**	0	0	1	0	0	2	1	**4**	91%	**109**	22%

- Using ParticleNet Xbb (mass-decorrelated) tagger
- Global b-veto for suppressing ttbar bkg: discard if there are *any* “good” b-tagged AK4s

*eff = 1 - after/before

VBS WH Cutflow

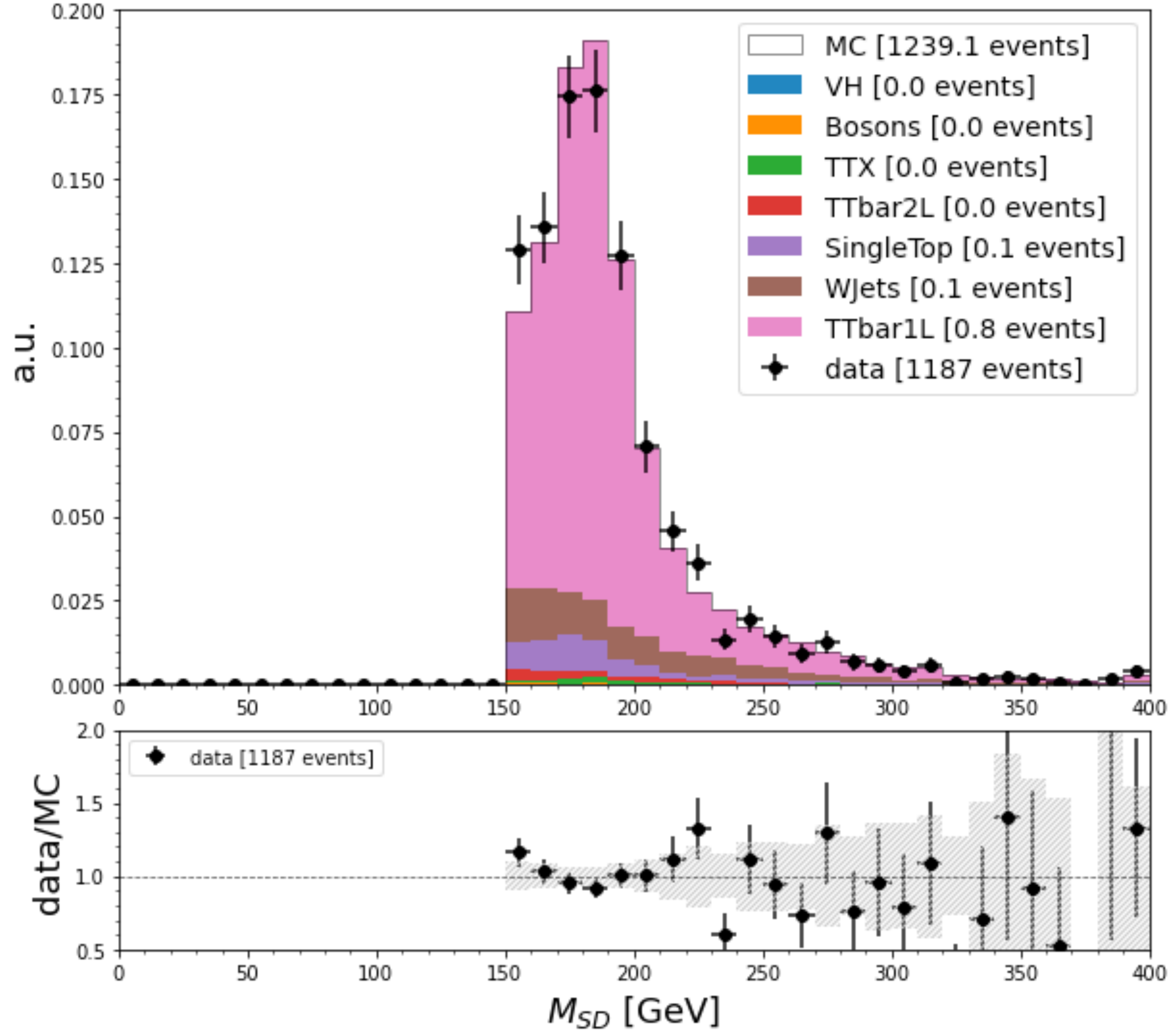
Weighted yields ("wgt") scaled to lumi×σ

	VH		VV/VVV/VBSWZ		W+Jets		SingleTop		TTbar+X		TTbar1L		TTbar2L		TotalBkg		VBSWH (kW < 0)	
cut	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt	raw	wgt
Bookkeeping	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372794	233443.4	399990	59598.1
FindLeptons	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372794	233443.4	399990	59598.1
Geq1VetoLep	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372794	233443.4	129280	19148.8
Geq2Jets	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372794	233443.4	128653	19057.0
Geq1FatJetNoVetoLepOverlap	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372794	233443.4	52537	7773.7
Exactly1TightLep	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372794	233443.4	31748	4734.4
Geq1FatJetNoTightLepOverlap	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372794	233443.4	24525	3653.0
STgt800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8372792	233443.3	13122	1950.0
SelectLeptons	63165	231.7	484277	6482.0	4603393	121610.6	76733	7558.5	939478	1042.8	1943369	86381.3	262377	10136.4	8372792	233443.3	13122	1950.0
Has1TightLep	63165	231.7	484277	6482.0	4603393	121610.6	76733	7558.5	939478	1042.8	1943369	86381.3	262377	10136.4	8372792	233443.3	13122	1950.0
LepPtGt40	60944	220.0	435912	5900.1	3889493	109822.4	68935	6915.5	817993	910.4	1761239	78242.7	227019	8754.4	7261535	210765.4	12416	1848.4
Passes1LepTriggers	54536	180.9	386803	5342.0	3325103	97557.5	61557	6223.5	700889	772.5	1535810	68294.5	197780	7636.6	6262478	186007.5	10736	1591.5
SelectFatJets	54536	180.9	386803	5342.0	3325103	97557.5	61557	6223.5	700889	772.5	1535810	68294.5	197780	7636.6	6262478	186007.5	10736	1591.5
Geq1FatJet	54470	181.1	384920	5337.1	3323420	97531.5	61404	6201.8	695035	767.0	1534845	68250.4	190755	7367.7	6244849	185636.6	10726	1590.3
SelectHbbFatJet	54470	181.1	384920	5337.1	3323420	97531.5	61404	6201.8	695035	767.0	1534845	68250.4	190755	7367.7	6244849	185636.6	10726	1590.3
SelectJetsNoHbbOverlap	54470	181.1	384920	5337.1	3323420	97531.5	61404	6201.8	695035	767.0	1534845	68250.4	190755	7367.7	6244849	185636.6	10726	1590.3
SaveAk4GlobalBVeto	54470	181.1	384920	5337.1	3323420	97531.5	61404	6201.8	695035	767.0	1534845	68250.4	190755	7367.7	6244849	185636.6	10726	1590.3
SelectVBSJetsMaxE	17662	50.3	251204	2035.9	2399176	47338.8	43921	4372.3	593328	654.0	1126440	50406.5	161098	6253.2	4592829	111110.9	7458	1113.0
MjjGt500_detajjGt3	3039	7.2	44926	376.4	393418	7744.0	10903	994.0	111929	124.2	231383	10337.4	35368	1371.5	830966	20954.6	6167	920.1
XbbGt0p3	2020	3.1	8633	50.8	34602	586.9	5486	537.0	71857	77.0	131324	5803.3	10113	382.3	264035	7440.3	4084	608.2
ApplyAk4GlobalBVeto	1627	2.4	6912	43.2	26699	484.2	1848	193.8	19216	20.2	37379	1670.1	2908	110.2	96589	2524.1	3877	578.6
MjjGt1500_detajjGt4	208	0.5	1127	4.6	5649	68.2	344	31.3	3046	3.5	6592	296.9	590	22.5	17556	427.5	2126	322.2
STGt1200	27	0.0	263	0.6	2244	11.3	56	6.1	500	0.5	565	24.7	49	1.8	3704	45.0	931	138.8
XbbScoreGt0p9_MSDLt150	23	0.0	65	0.0	217	1.3	1	0.2	44	0.0	45	2.0	13	0.5	408	4.0	729	108.8

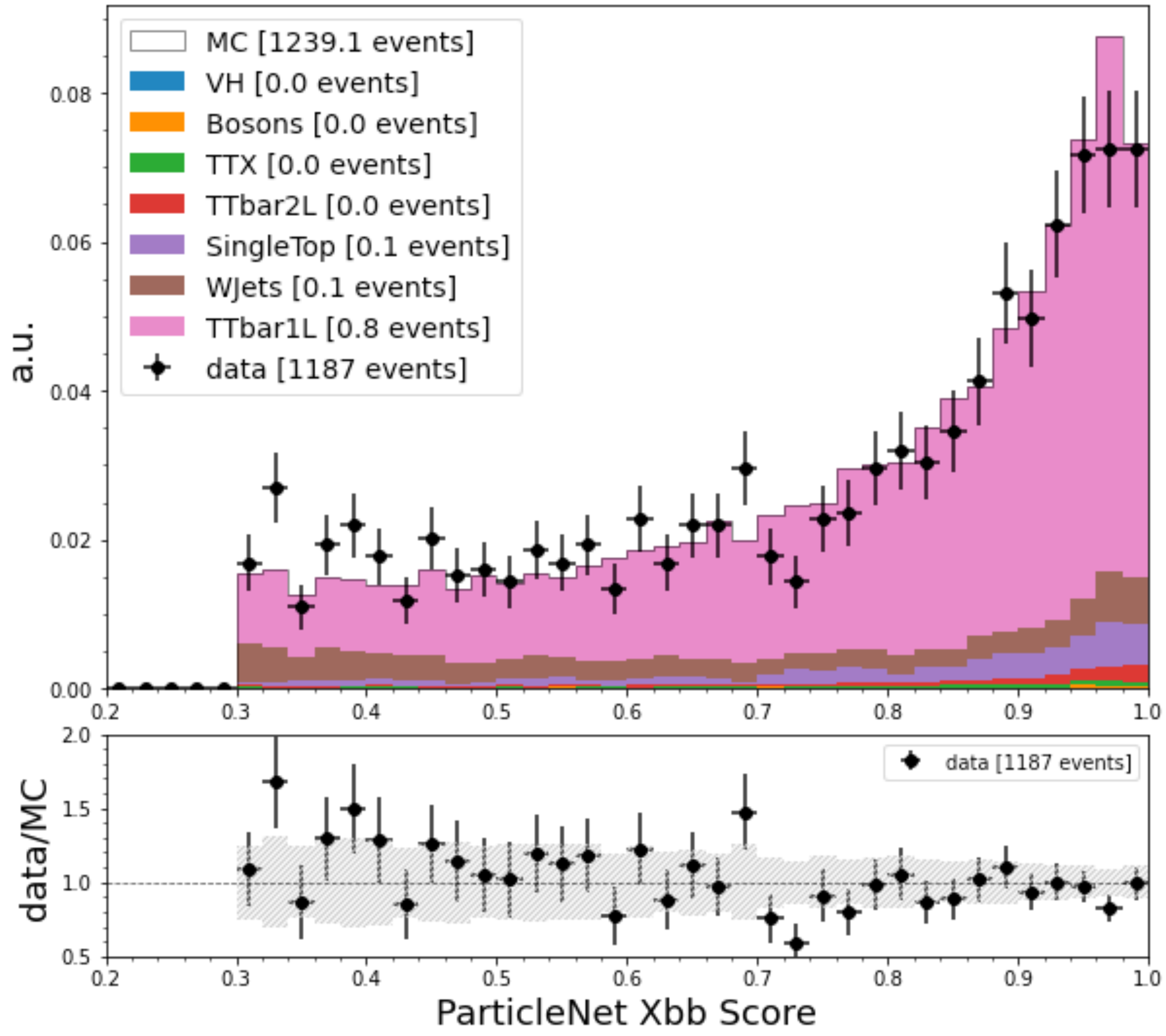
Skim & Postskim already applied!

Validation: Hbb Kinematics

Preselection AND $M_{SD} \geq 150$ GeV

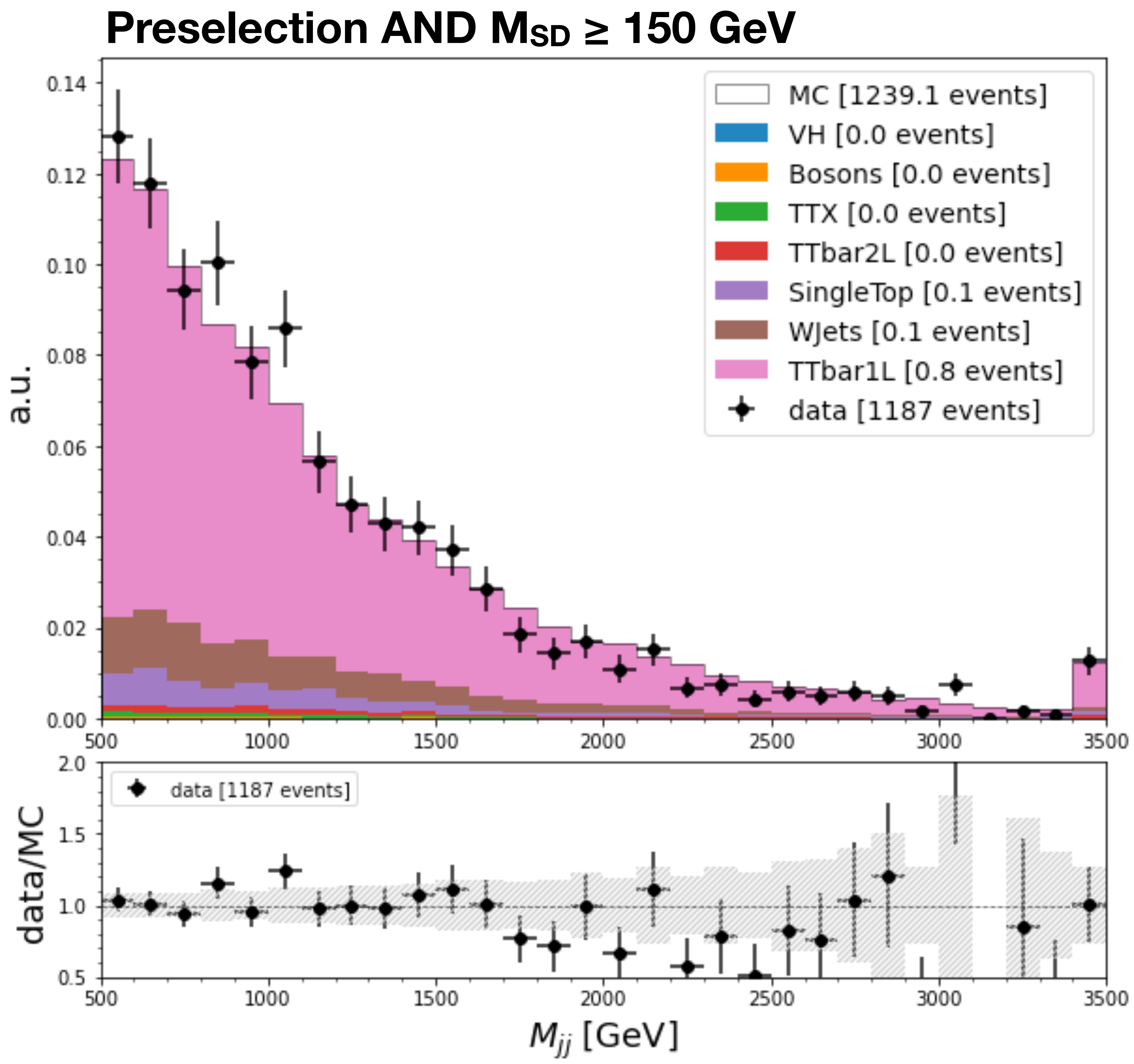


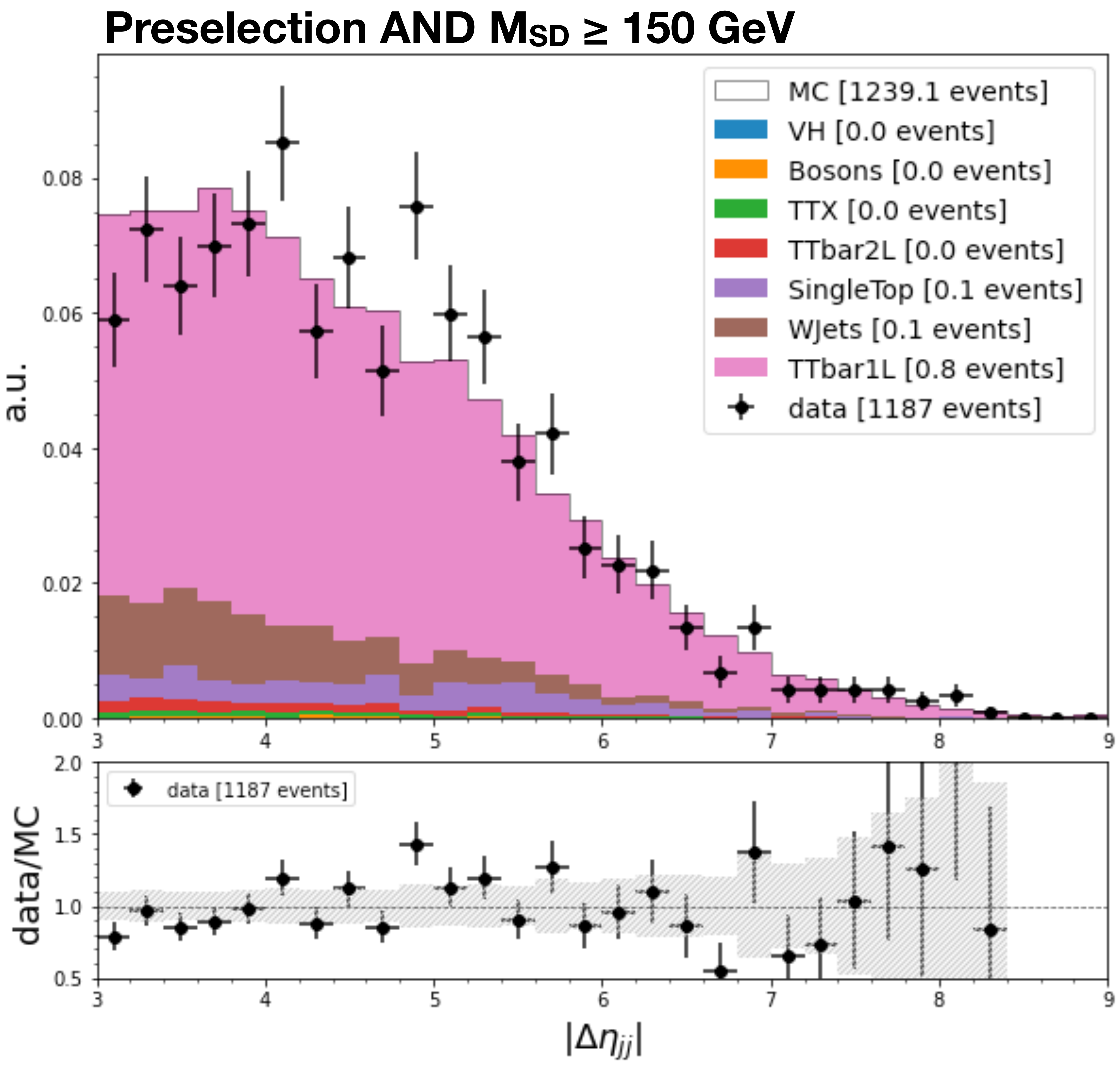
Preselection AND $M_{SD} \geq 150$ GeV



Missing sfs for: Xbb, DeepJet (for b-veto?), triggers

Validation: VBS Kinematics

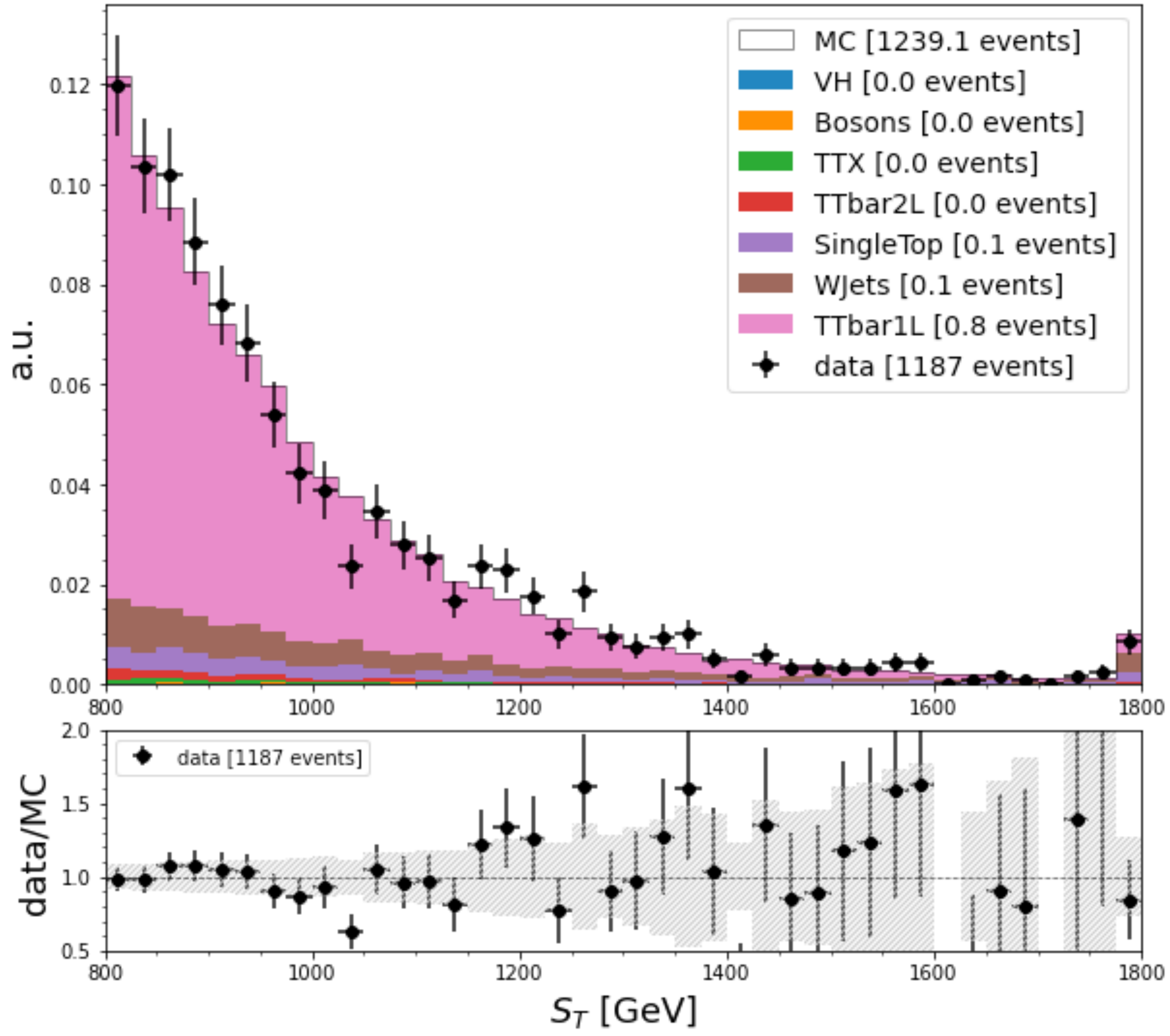




Missing sfs for: Xbb, DeepJet (for b-veto?), triggers

Validation: VBS Kinematics

Preselection AND $M_{SD} \geq 150$ GeV



Missing sfs for: Xbb, DeepJet (for b-veto?), triggers