Electroweak loops as a Probe of Dimension-six Operators of the SMEFT in $t\bar{t}$ Production

The First Results(Nov 2, 2021)

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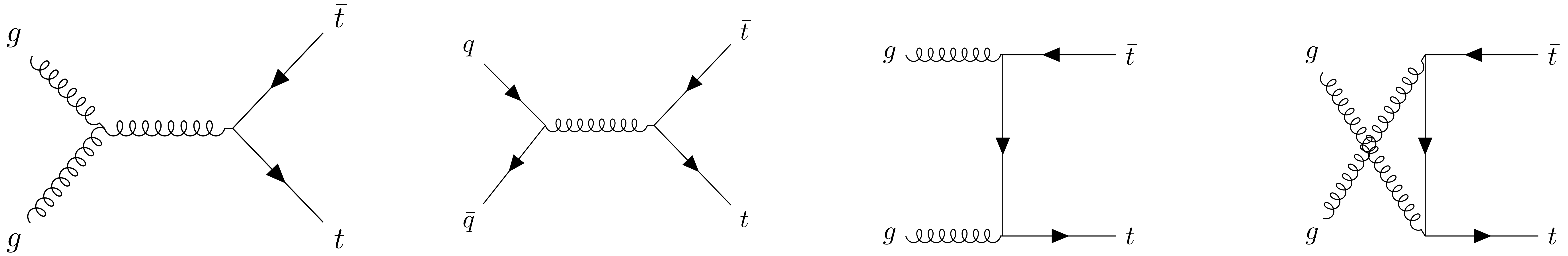
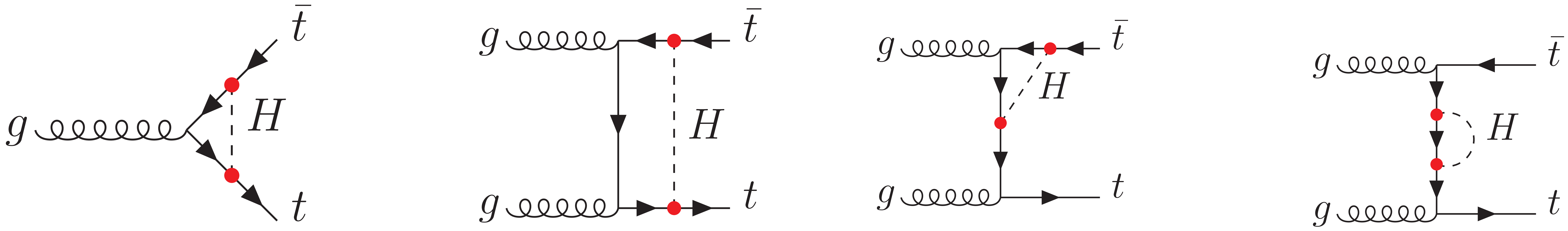
Top Quark Pairs Production



$t\bar{t}$ production at leading order

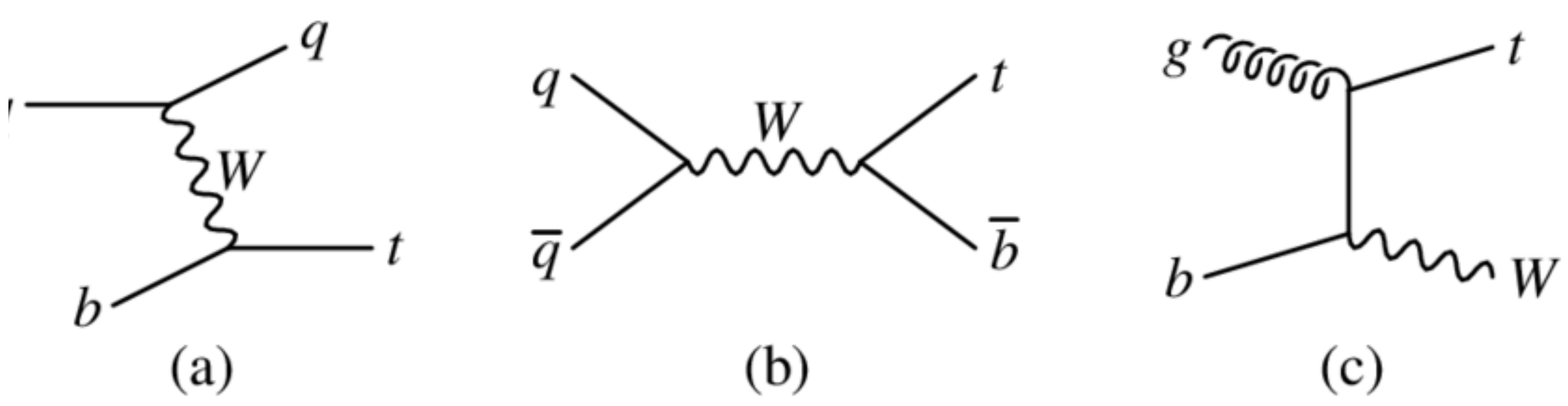
Calculate NLO EW corrections of $t\bar{t}$ production with arbitrary CP mixing:

$$\mathscr{L}(Htt) = -\frac{m_t}{v}\bar{\psi}_t\left(\kappa + i\tilde{\kappa}\gamma_5\right)\psi_t H$$

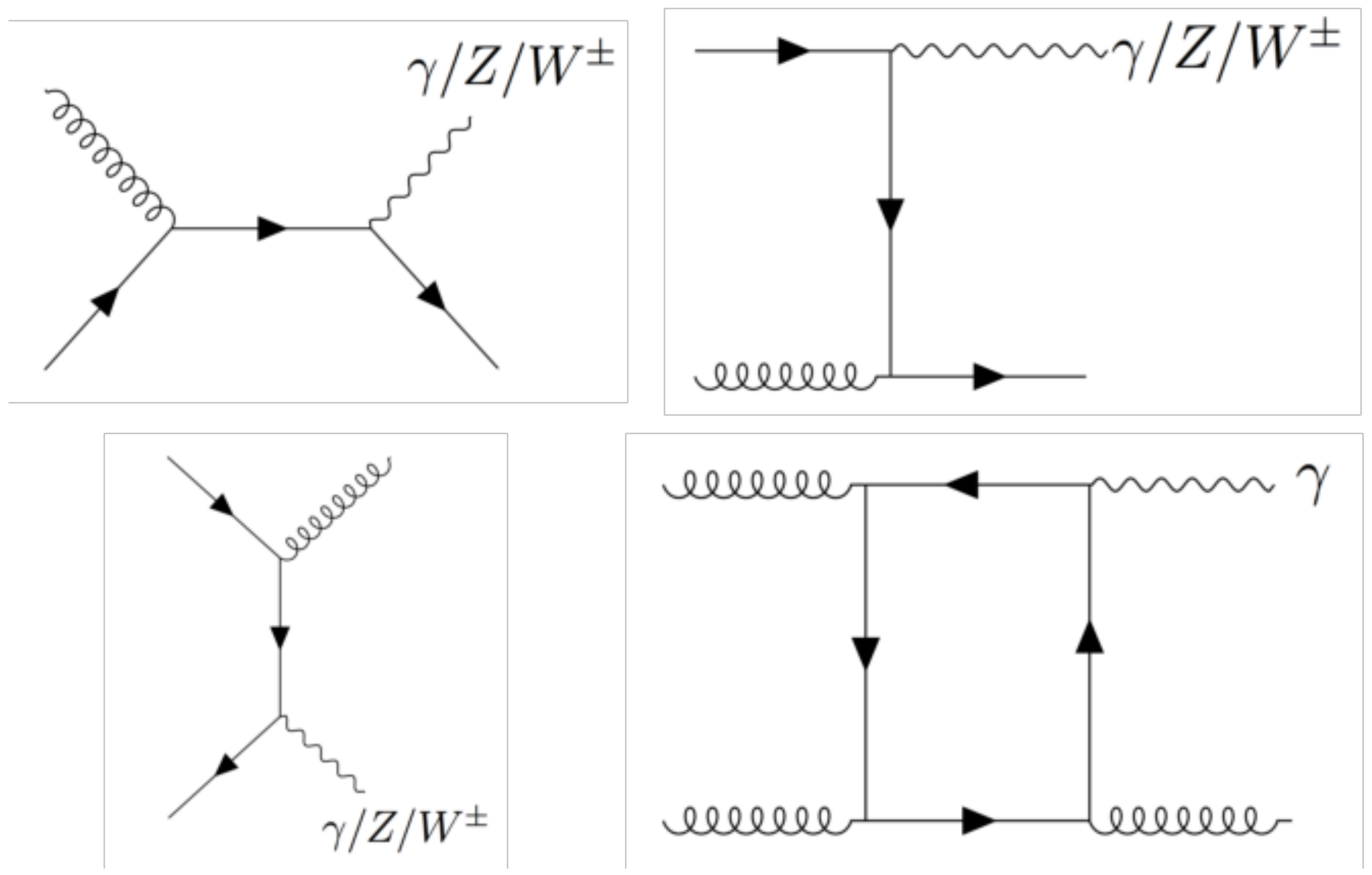


Typical Feynman diagrams of NLO EW Corrections

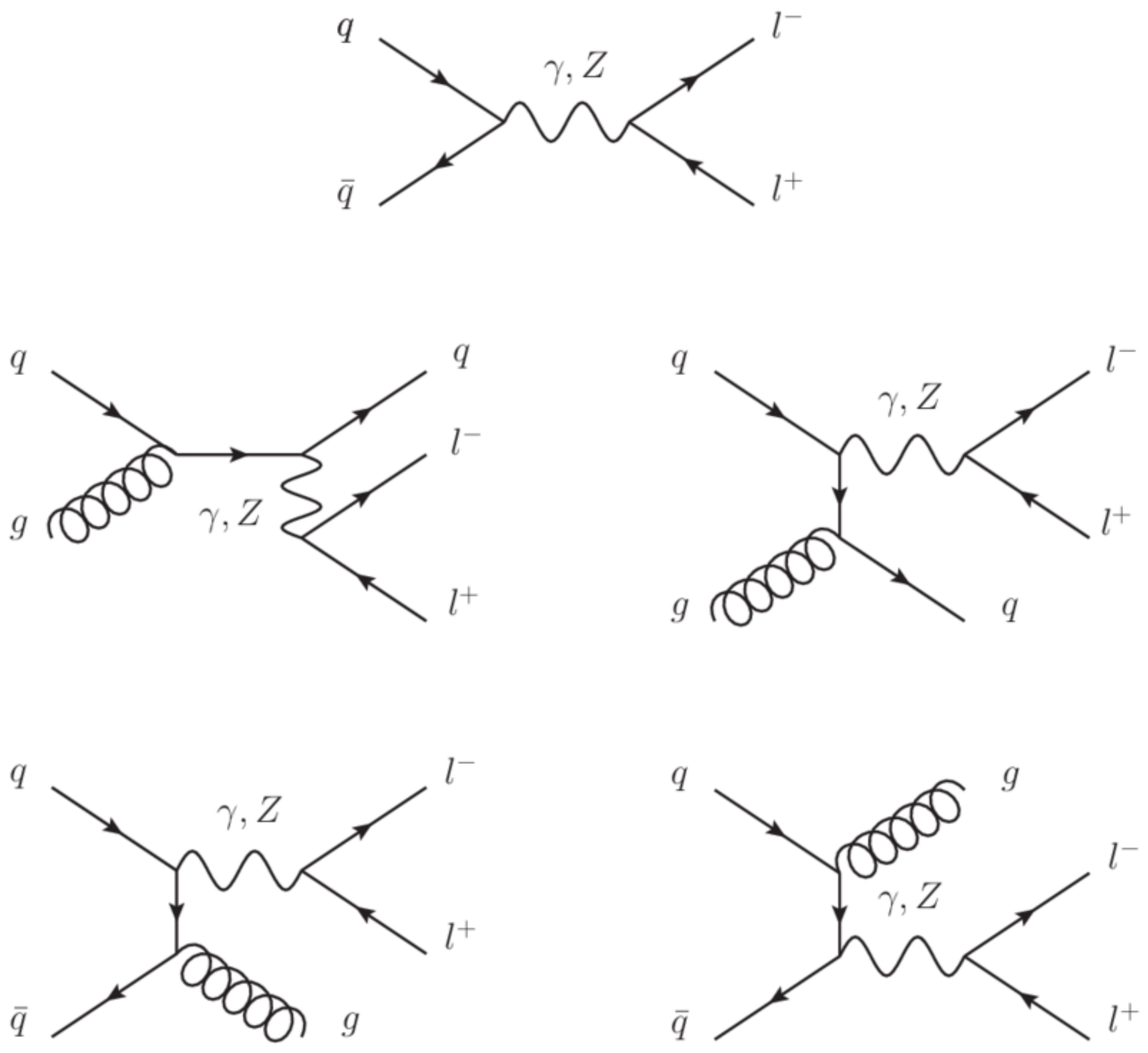
Single Top, V+jets and Drell-Yan



Single Top

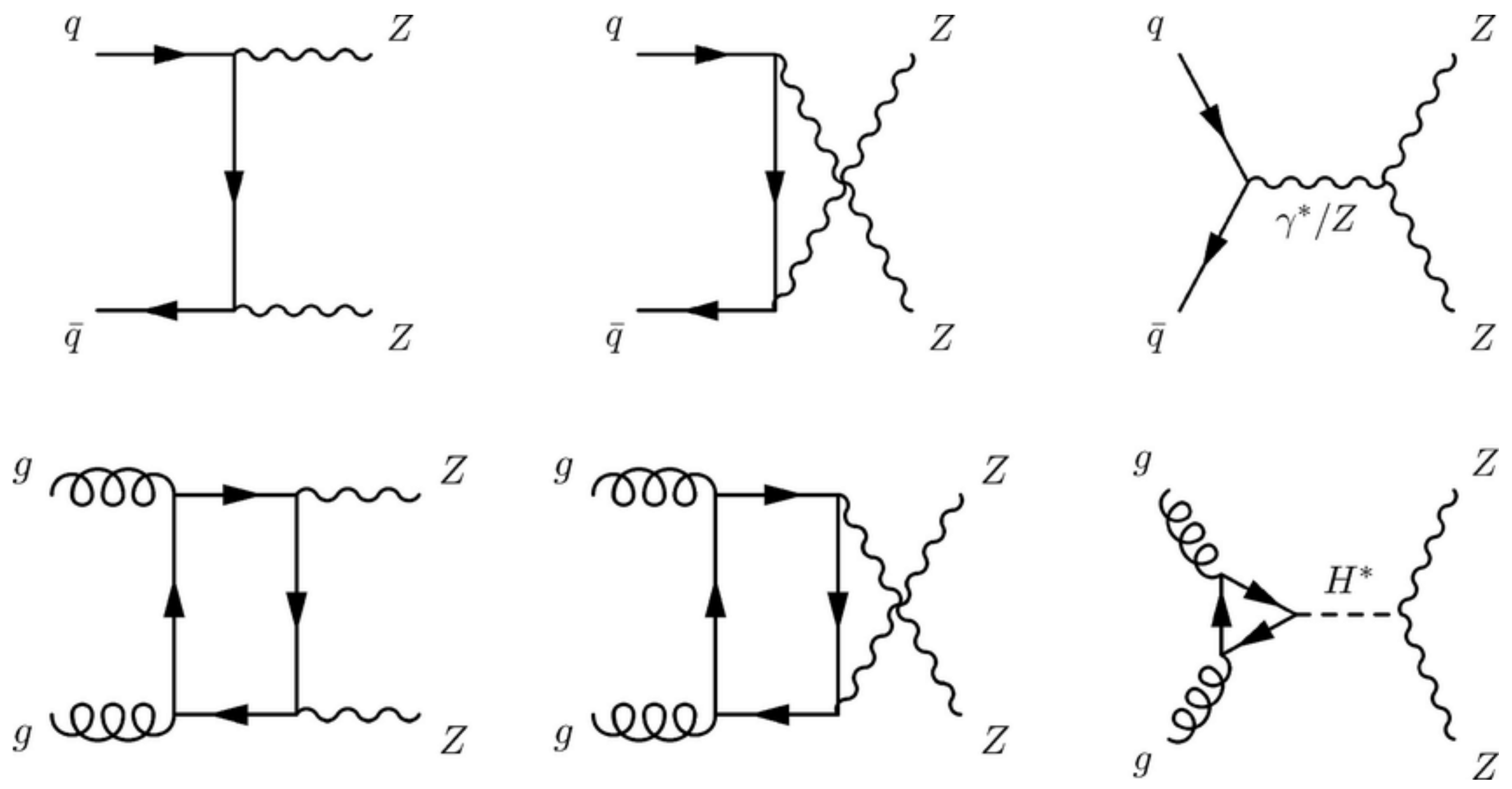


V+jets

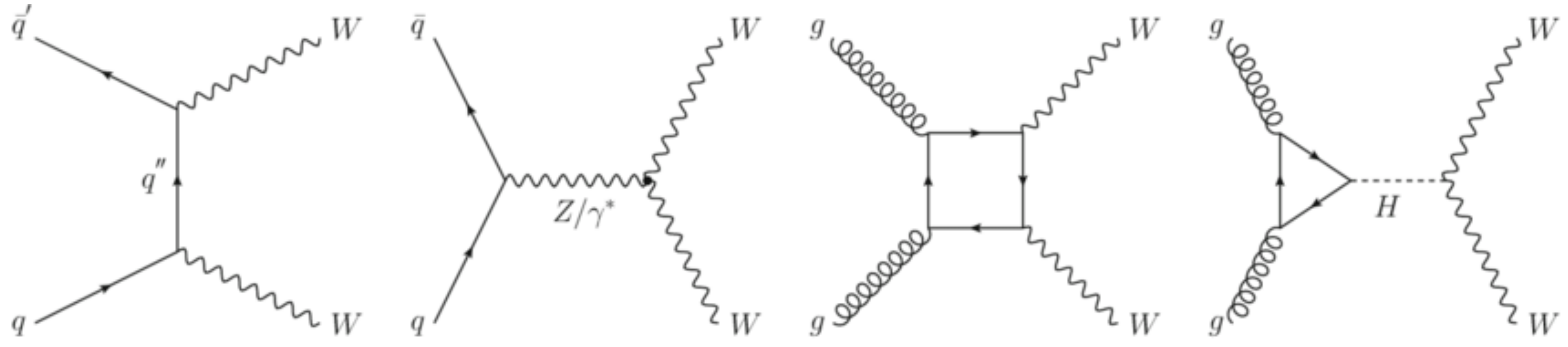


Drell-Yan

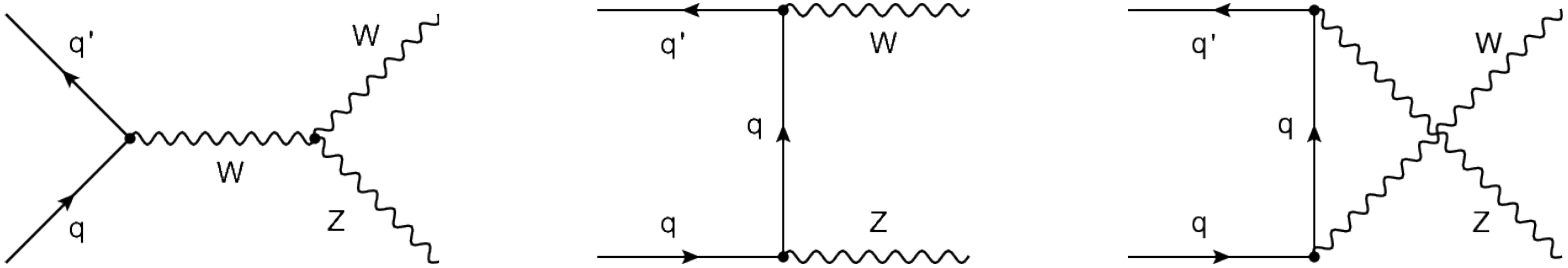
VV Production



ZZ



WW

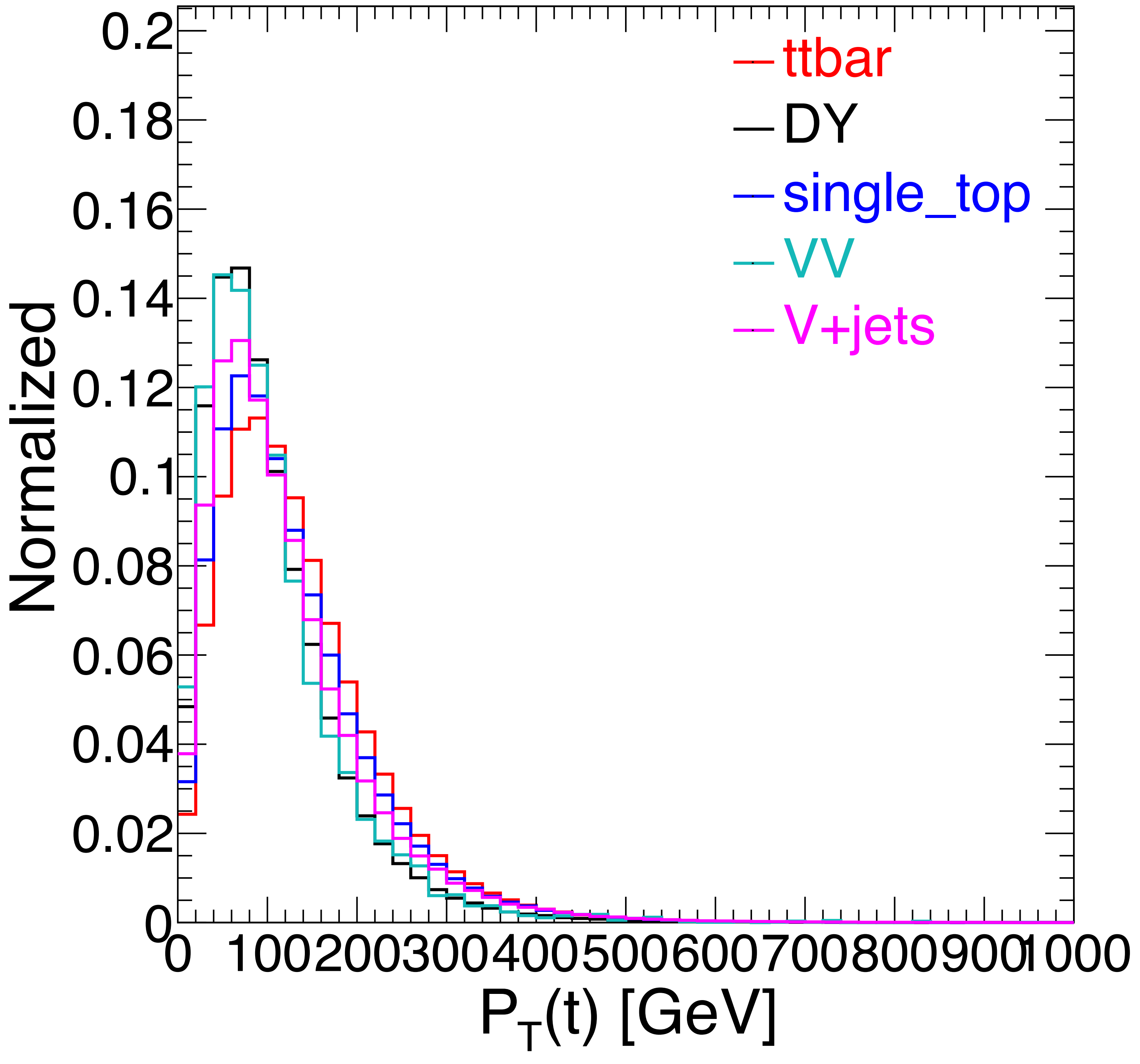


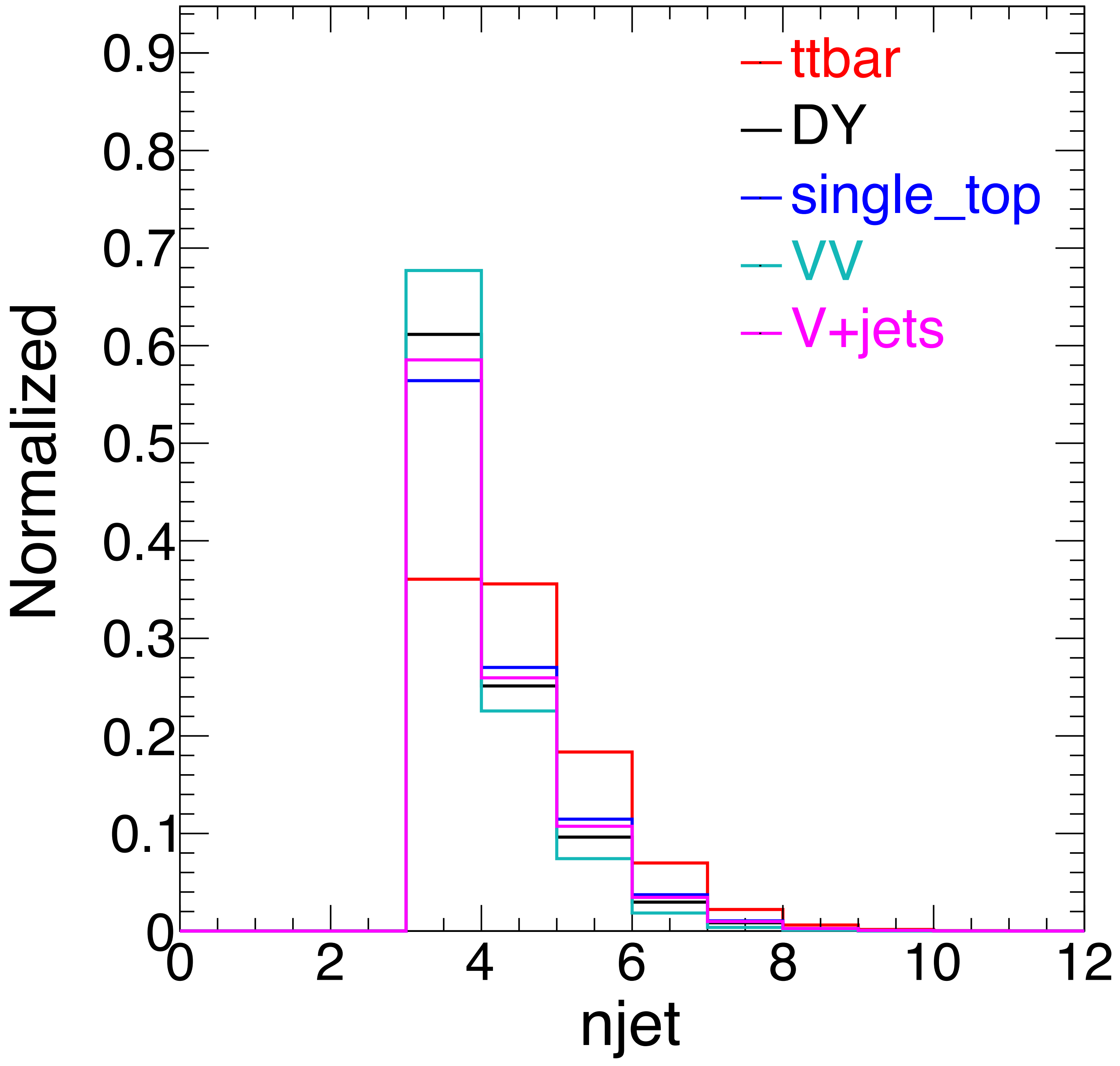
ZW

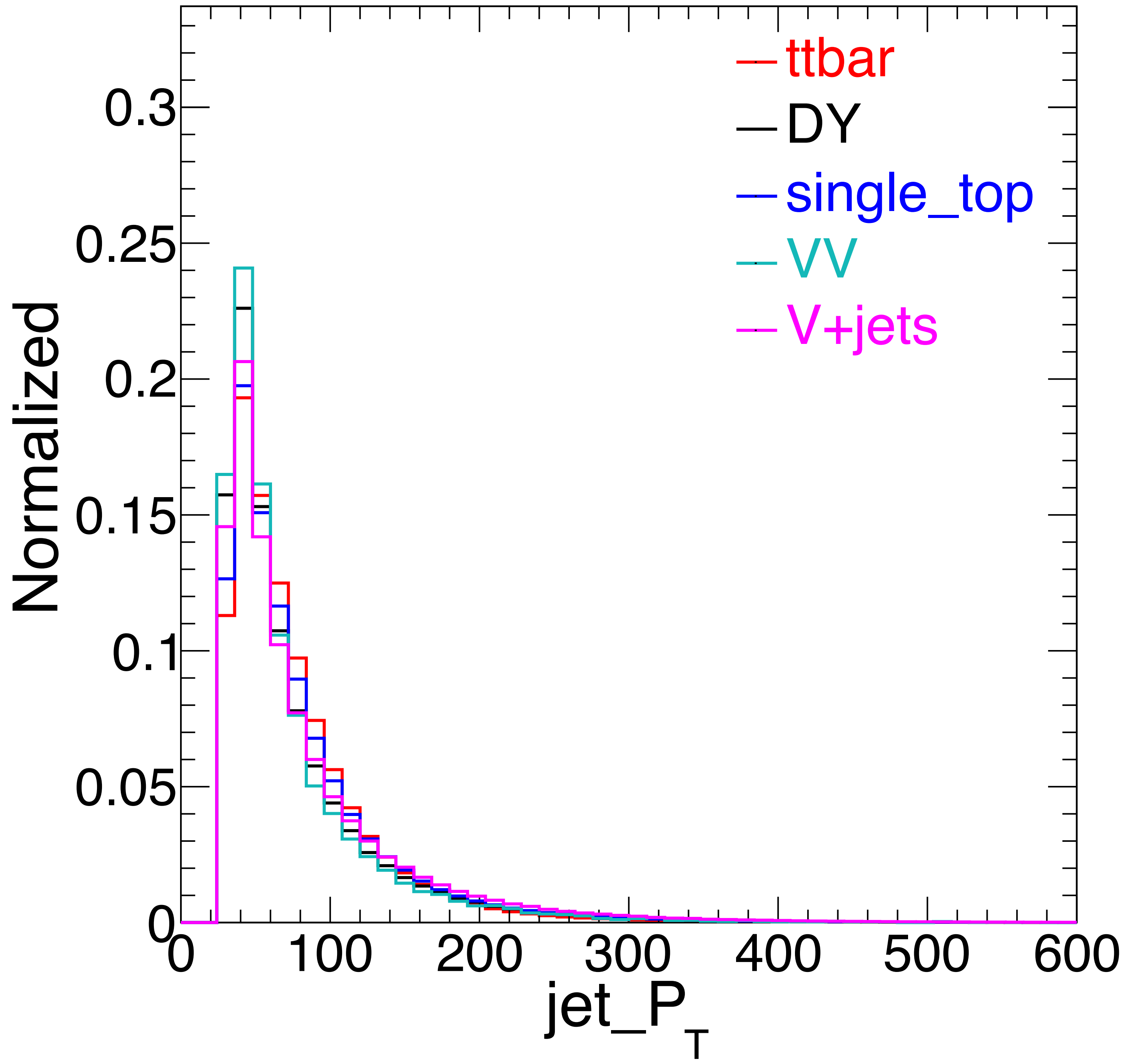
Selection without likelihood cuts				
process	cross_section	efficiency(%)	efficiency(>=4jets)(%)	efficiency(3jets)(%)
TTToSemiLeptonic	366.91	9.998	6.696	3.302
TTTo2L2Nu	89.05	5.934	2.532	3.403
TTToHadronic	377.96	0.019	0.015	0.004

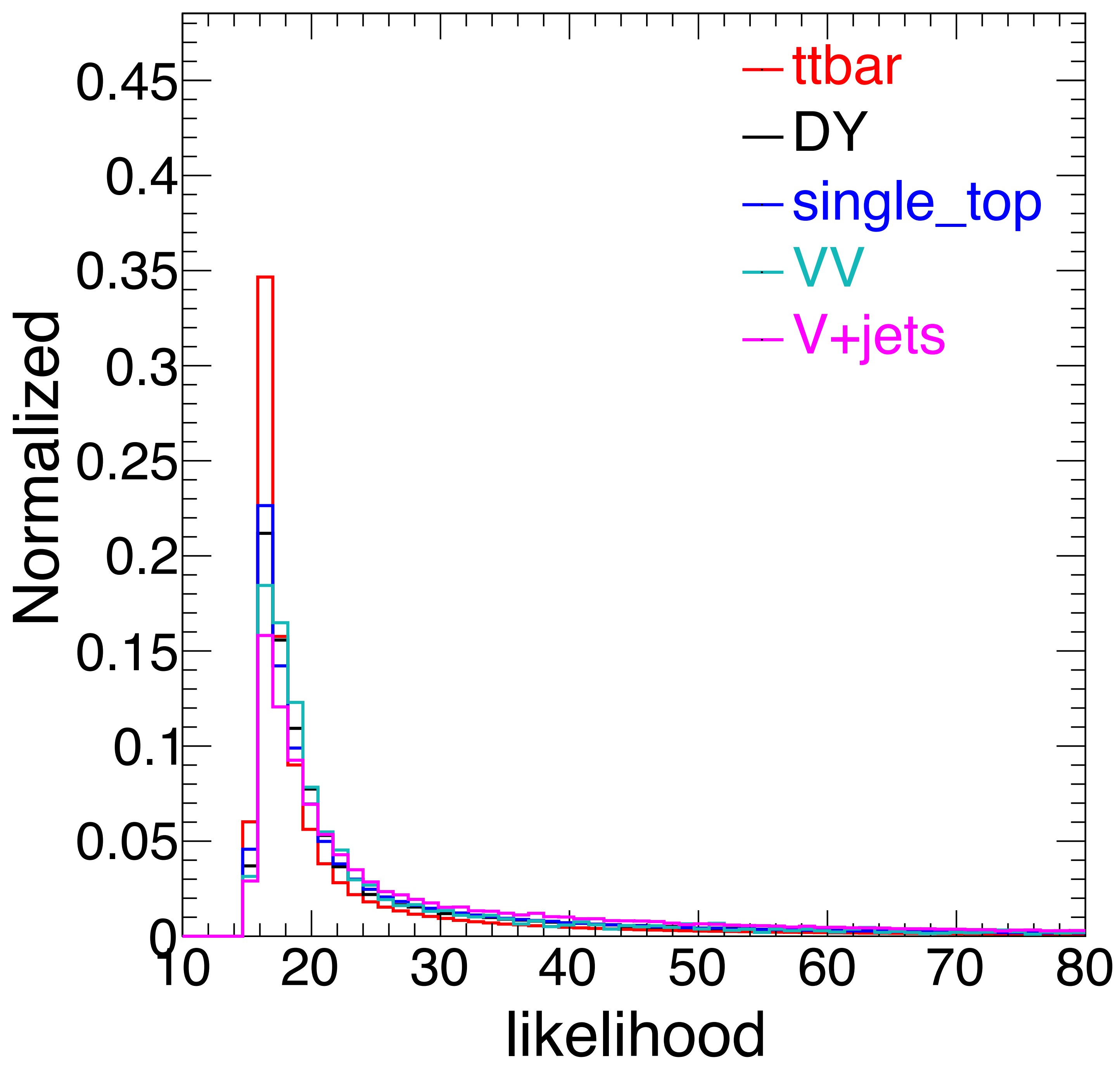
The expected number of events of SM processes				
process	cross_section	semiletonic (%)	>=4jets(%)	3jets(%)
ttbar	833.92	5763897.00	3685229.50	2078667.75
DY	366.18	31871.79	12374.74	19497.04
single_top	291.53	327332.28	142642.81	184689.47
VV	182.30	5446.95	1759.13	3687.82
V+Jets	1773.23	125730.52	52102.05	73628.48
QCD		629345.56	88258.48	541087.12
Total		6883624.10	3982366.71	2901257.68

The expected composition of SM processes				
process	cross_section	semiletonic (%)	>=4jets(%)	3jets(%)
ttbar	833.92	83.73	92.54	71.65
DY	366.18	0.46	0.31	0.67
single_top	291.53	4.76	3.58	6.37
VV	182.30	0.08	0.04	0.13
V+Jets	1773.23	1.83	1.31	2.54
QCD		9.14	2.22	18.65

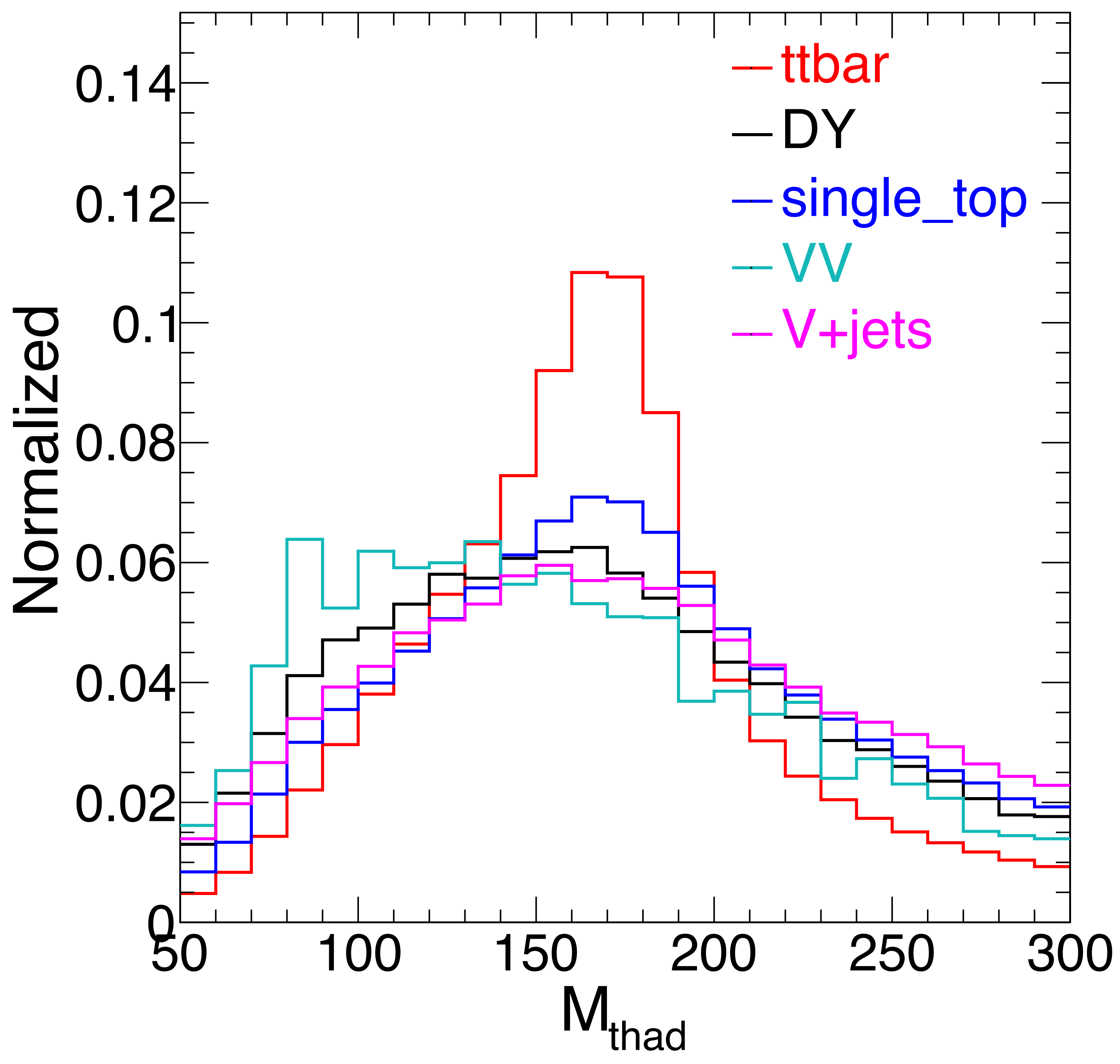

ttbar
DY
single_top
VV
V+jets
Normalized
$P_T(t)$ [GeV]


ttbar
DY
single_top
VV
V+jets
Normalized
njet

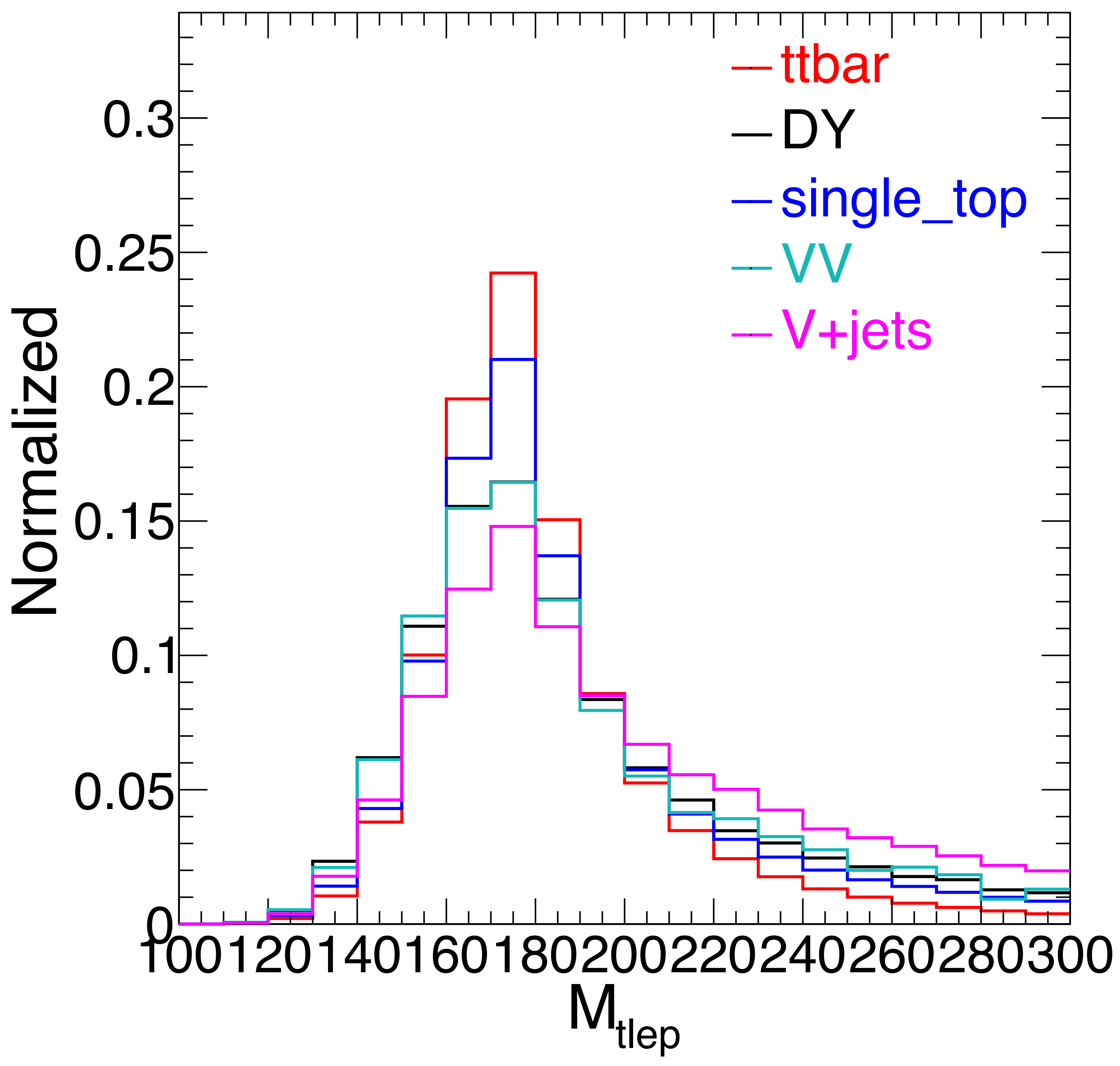

ttbar
DY
single_top
VV
V+jets
Normalized
jet_P_T



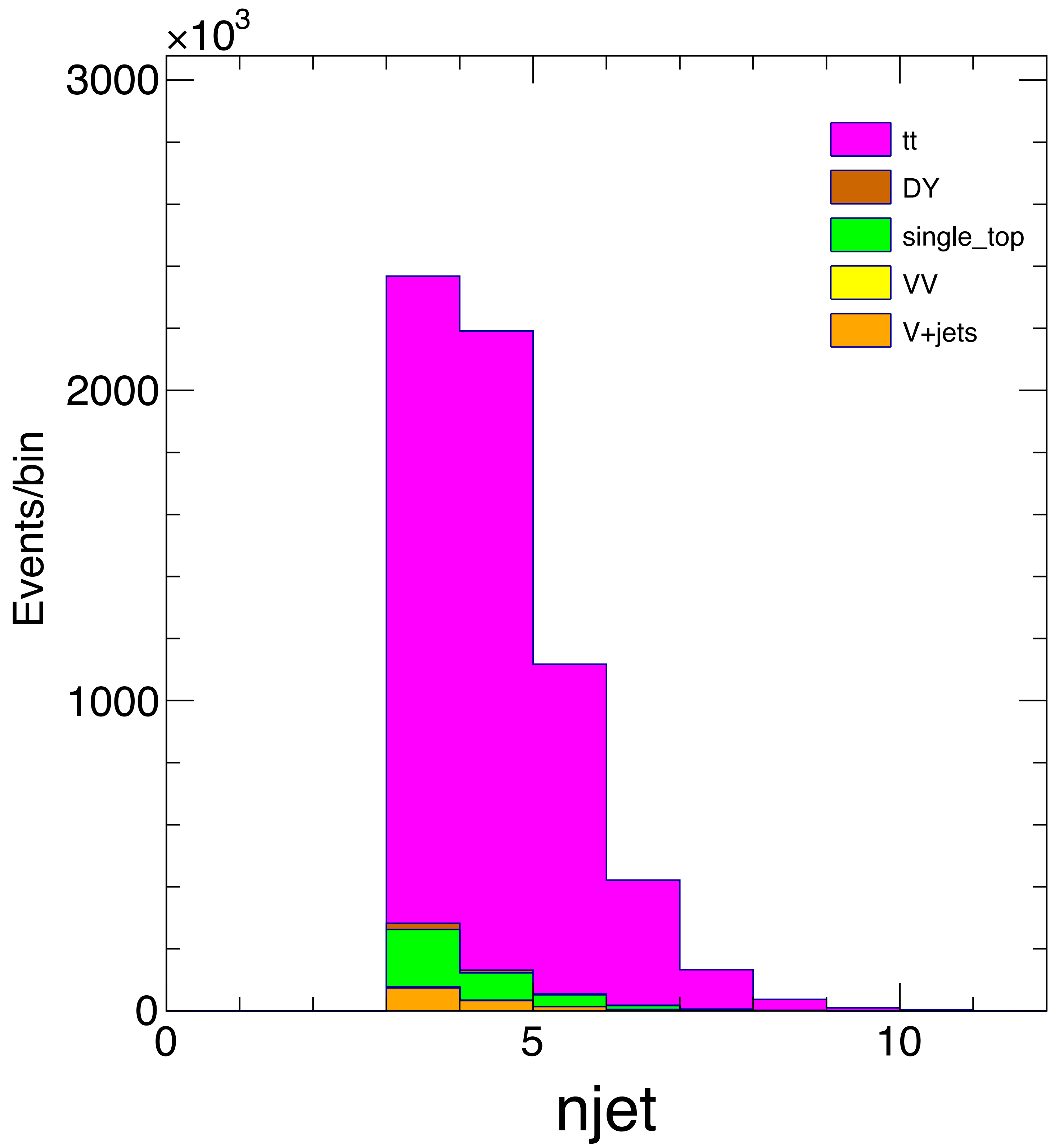
ttbar
DY
single_top
VV
V+jets
Normalized
likelihood

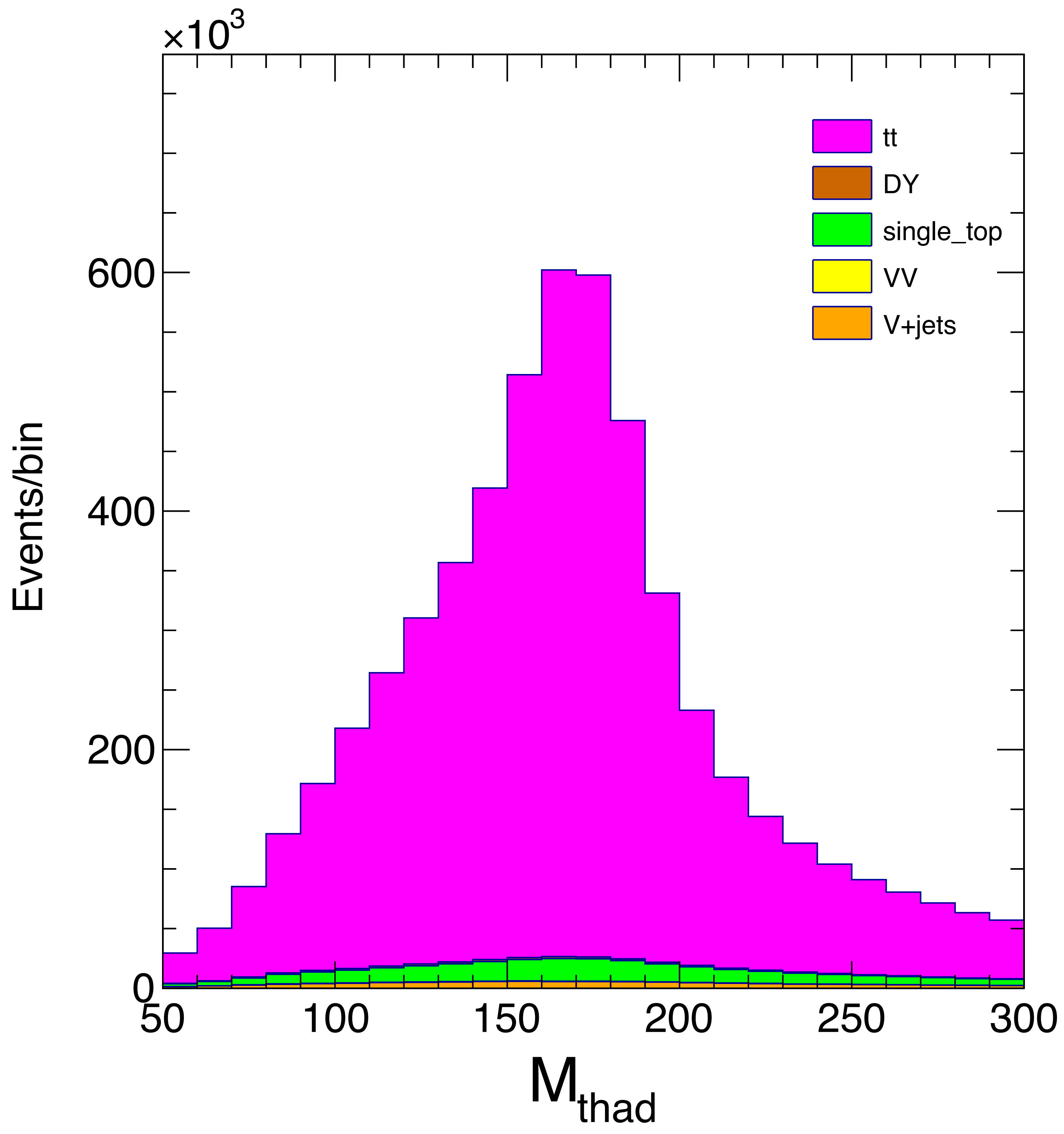


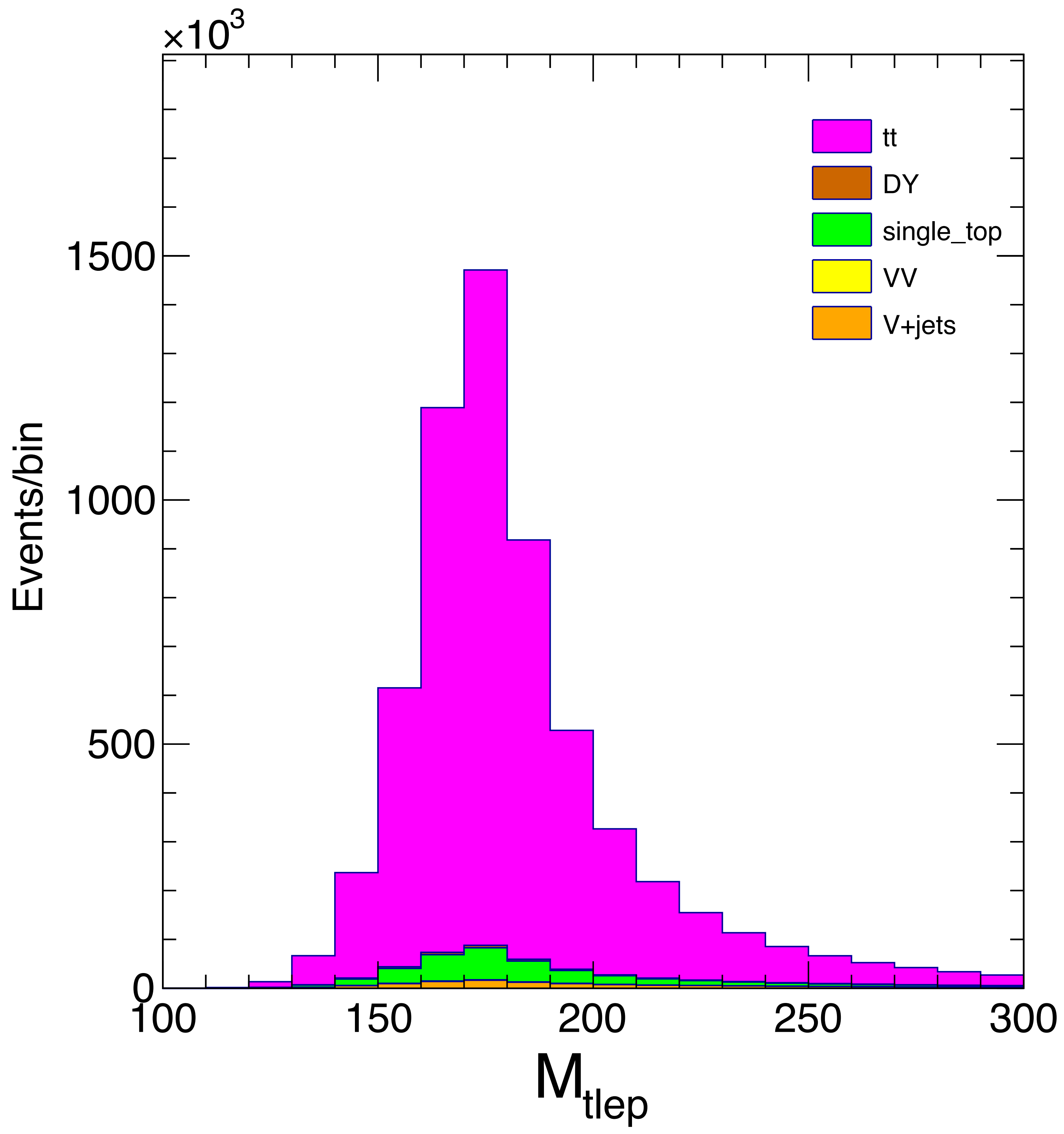
ttbar
DY
single_top
VV
V+jets
Normalized
M_{thad}

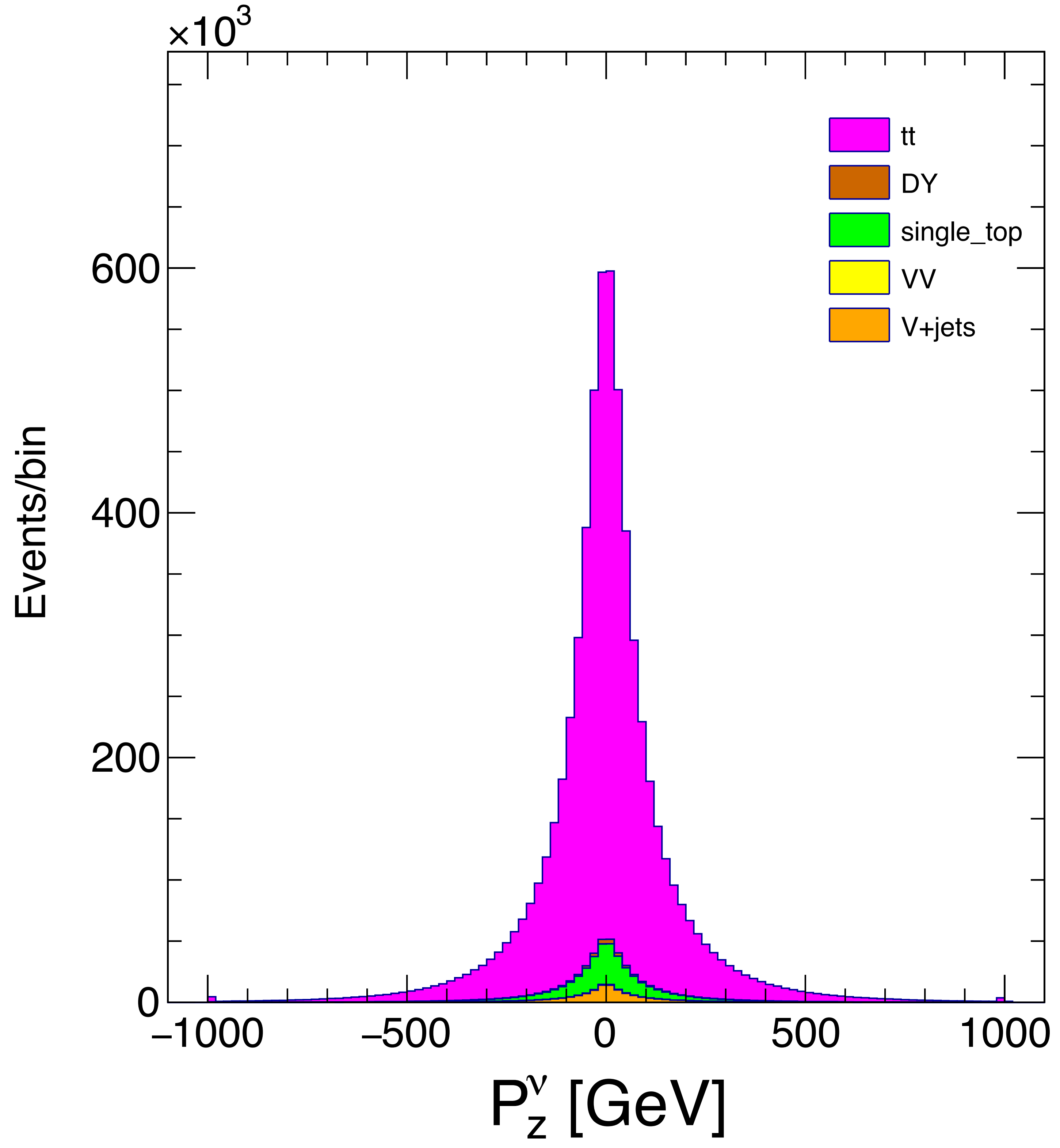


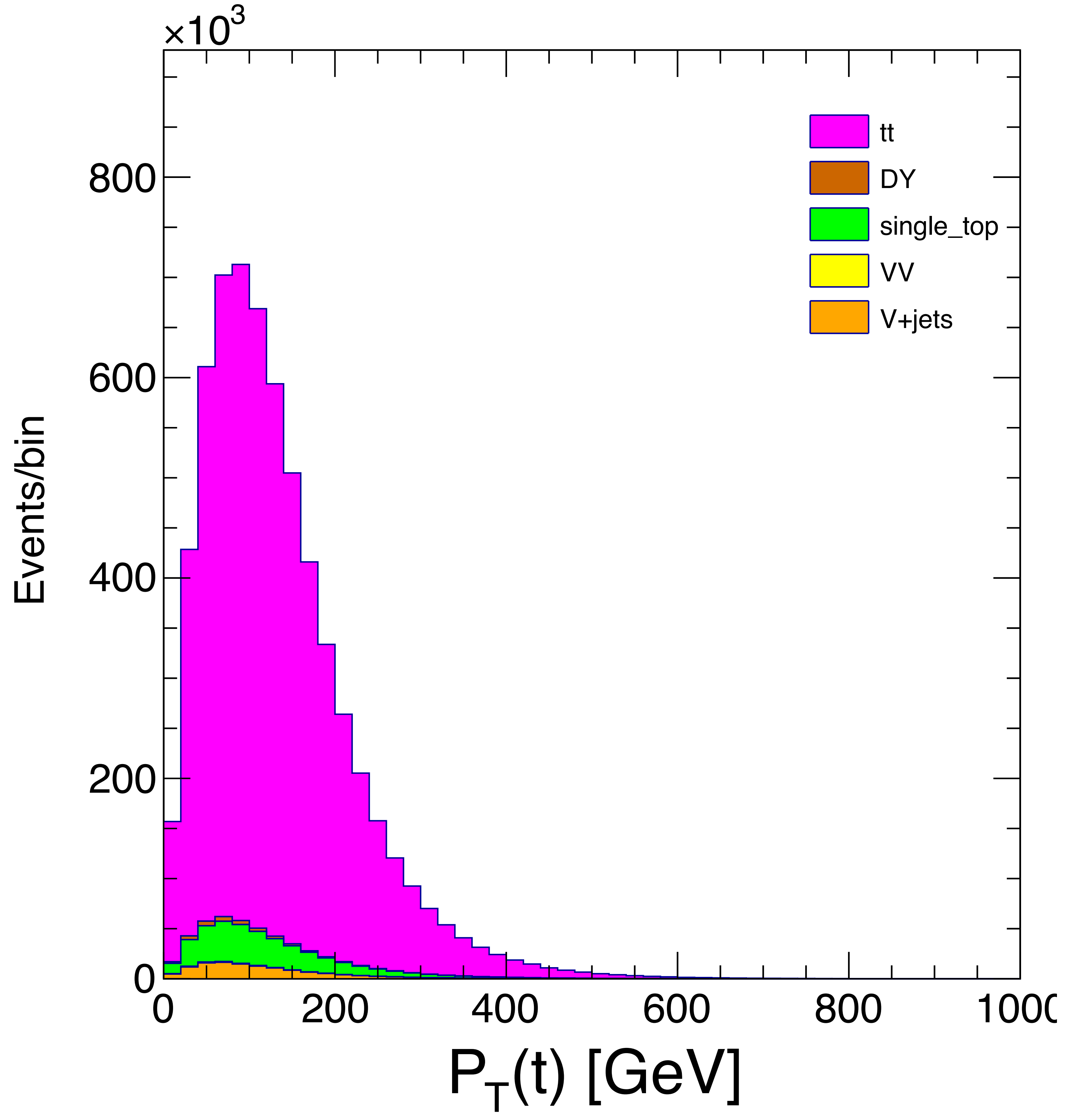
ttbar
DY
single_top
VV
V+jets
Normalized
M_{tlep}

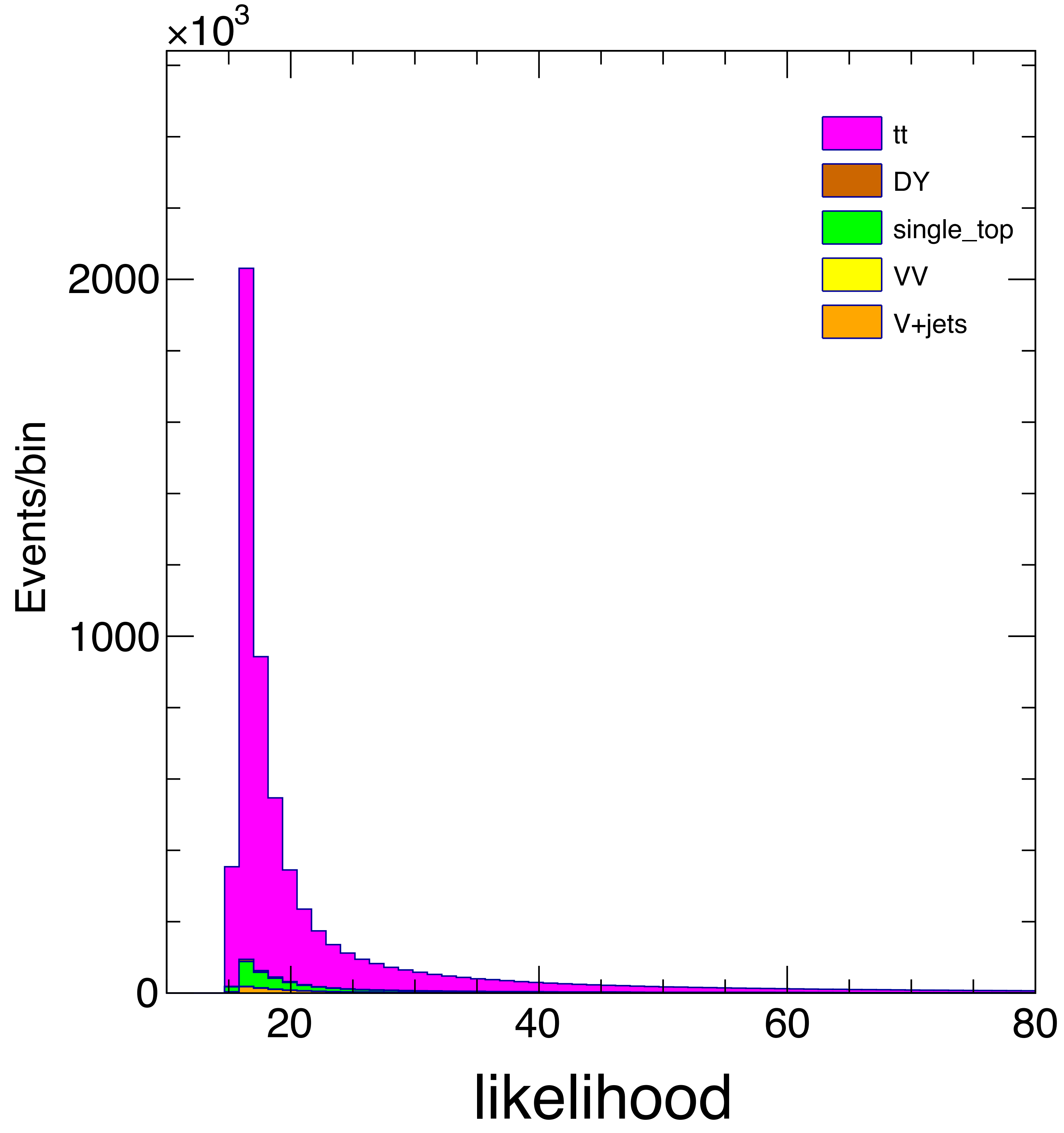

×10^3
3000
2000
1000
0
Events/bin
0
5
10
njet
tt
DY
single_top
VV
V+jets

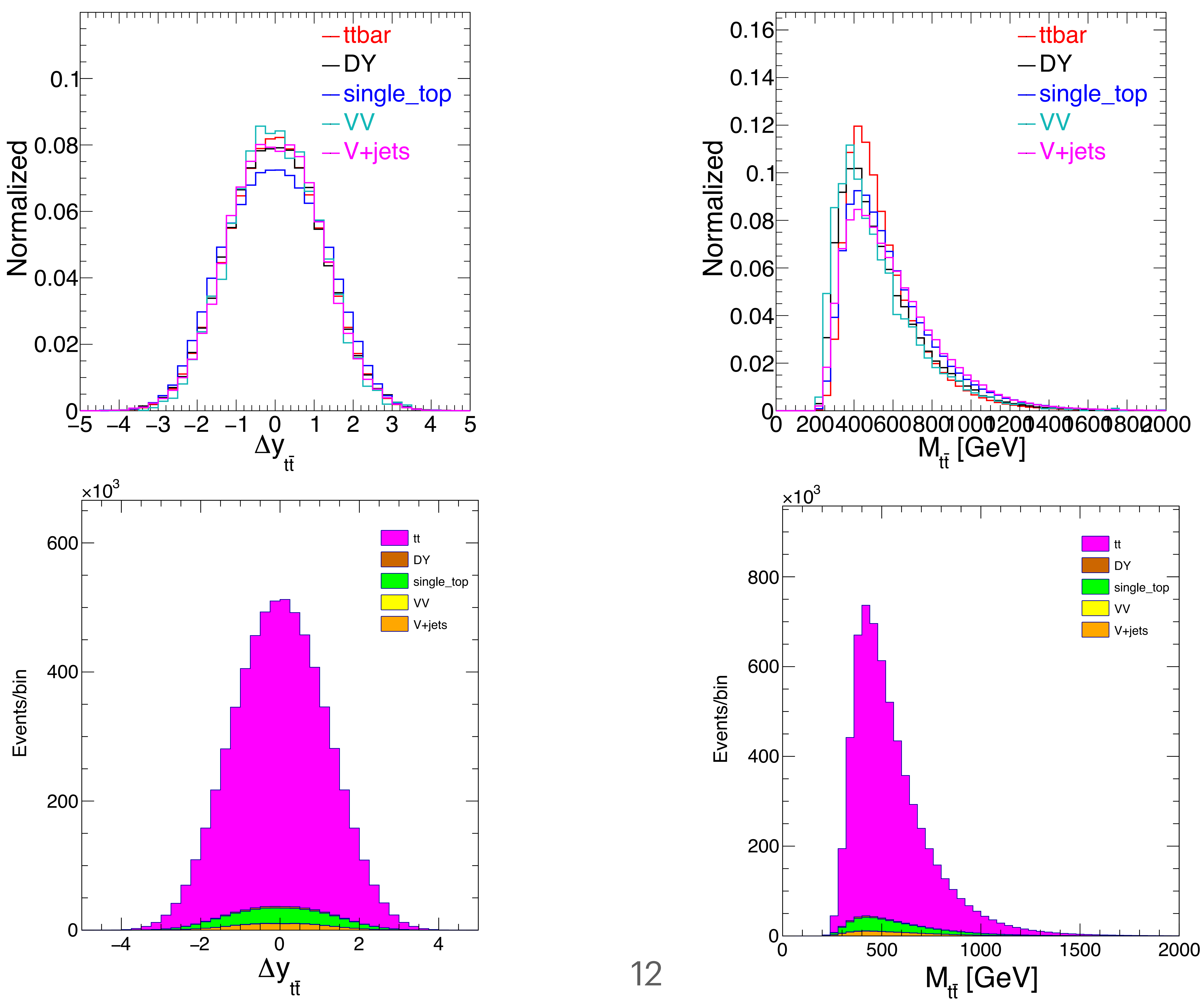

×10^3
600
400
200
0
Events/bin
50
100
150
200
250
300
M_thad
tt
DY
single_top
VV
V+jets


×10^3
1500
1000
500
0
Events/bin
100
150
200
250
300
M_tlep
tt
DY
single_top
VV
V+jets


×10^3
tt
DY
single_top
VV
V+jets
Events/bin
600
400
200
0
−1000
−500
0
500
1000
P_z^ν [GeV]


×10^3
tt
DY
single_top
VV
V+jets
Events/bin
800
600
400
200
0
0
200
400
600
800
1000
$P_T(t)$ [GeV]


×10^3
tt
DY
single_top
VV
V+jets
Events/bin
2000
1000
0
20
40
60
80
likelihood


ttbar
DY
single_top
VV
V+jets
Normalized
$\Delta y_{t\bar{t}}$
$M_{t\bar{t}}$ [GeV]
$\times 10^3$
tt
DY
single_top
VV
V+jets
Events/bin
$\Delta y_{t\bar{t}}$
$M_{t\bar{t}}$ [GeV]

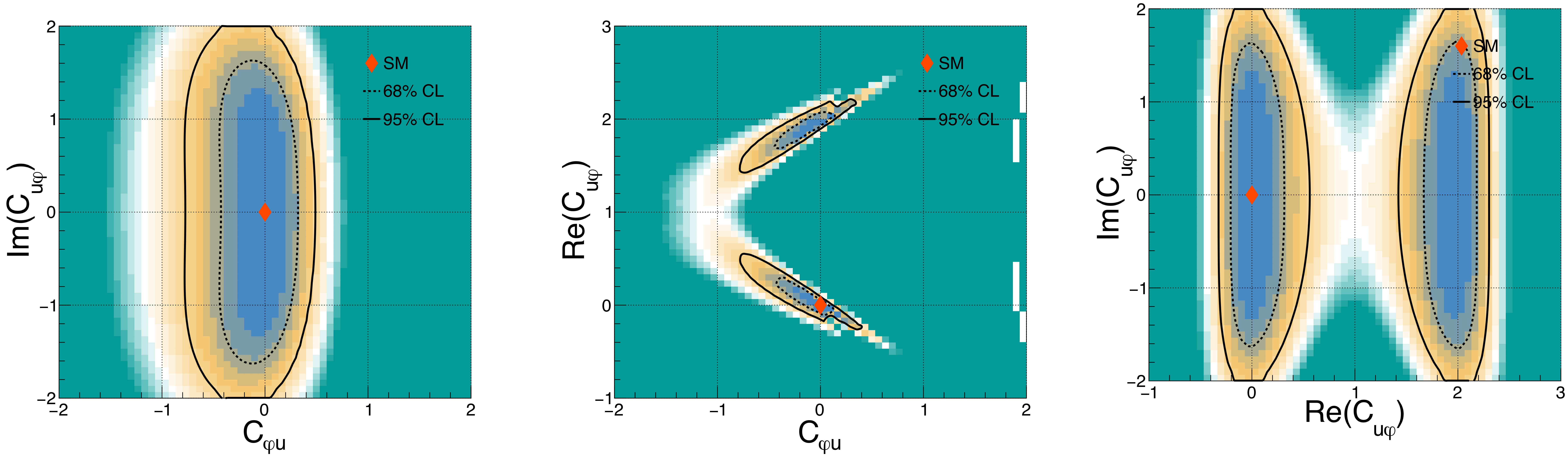
Profile Likelihood

$$L(data\,|\,\mu s(\theta)+b(\theta)) = \prod Poisson(N_i\,|\,\mu S_i(\theta)+B_i(\theta))L(\theta)$$

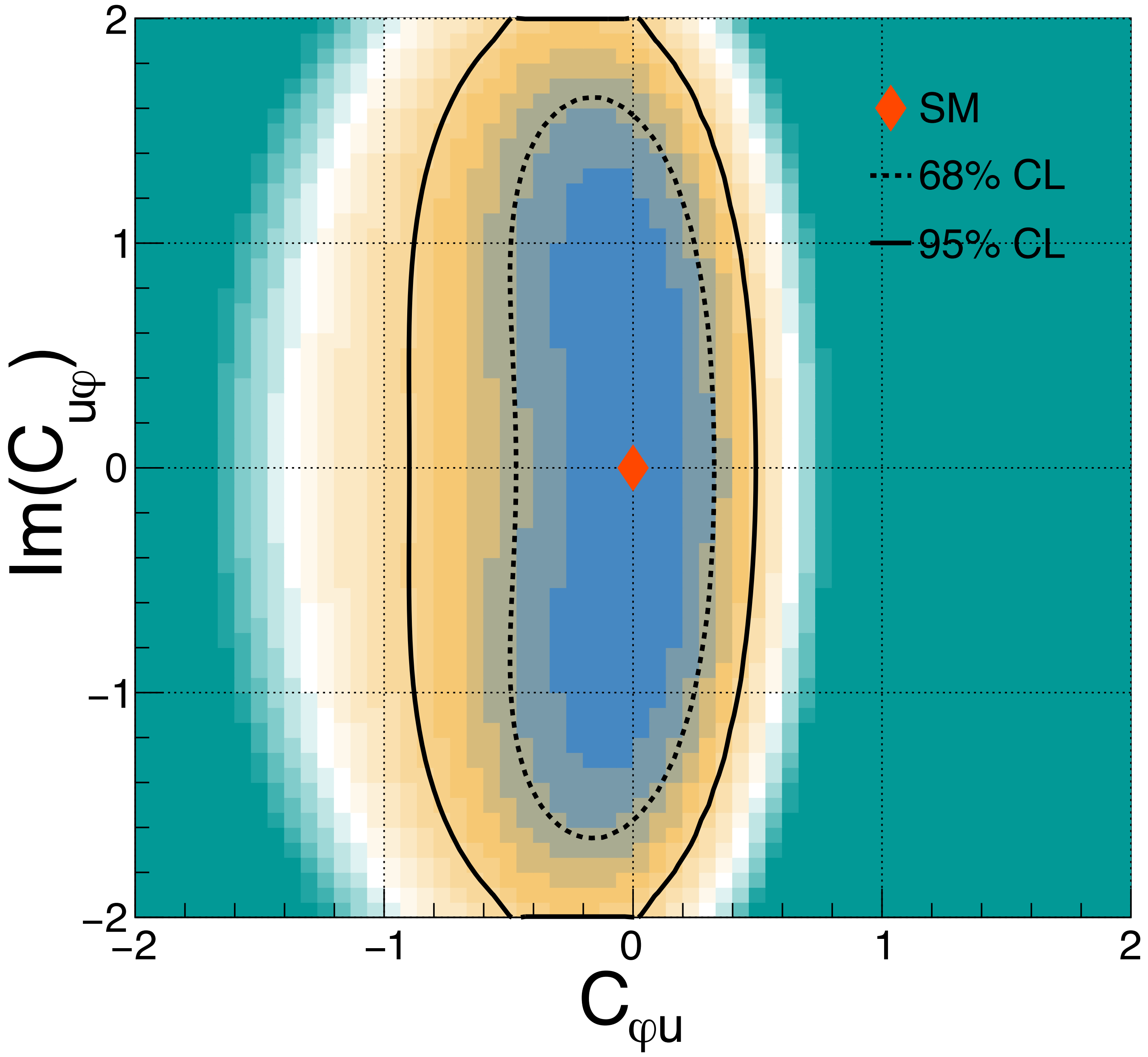
$$q = -2\times\frac{L(data\,|\,\mu s(\theta)+b(\theta))}{L(data\,|\,\hat{\mu}s(\hat{\theta})+b(\hat{\theta}))}$$

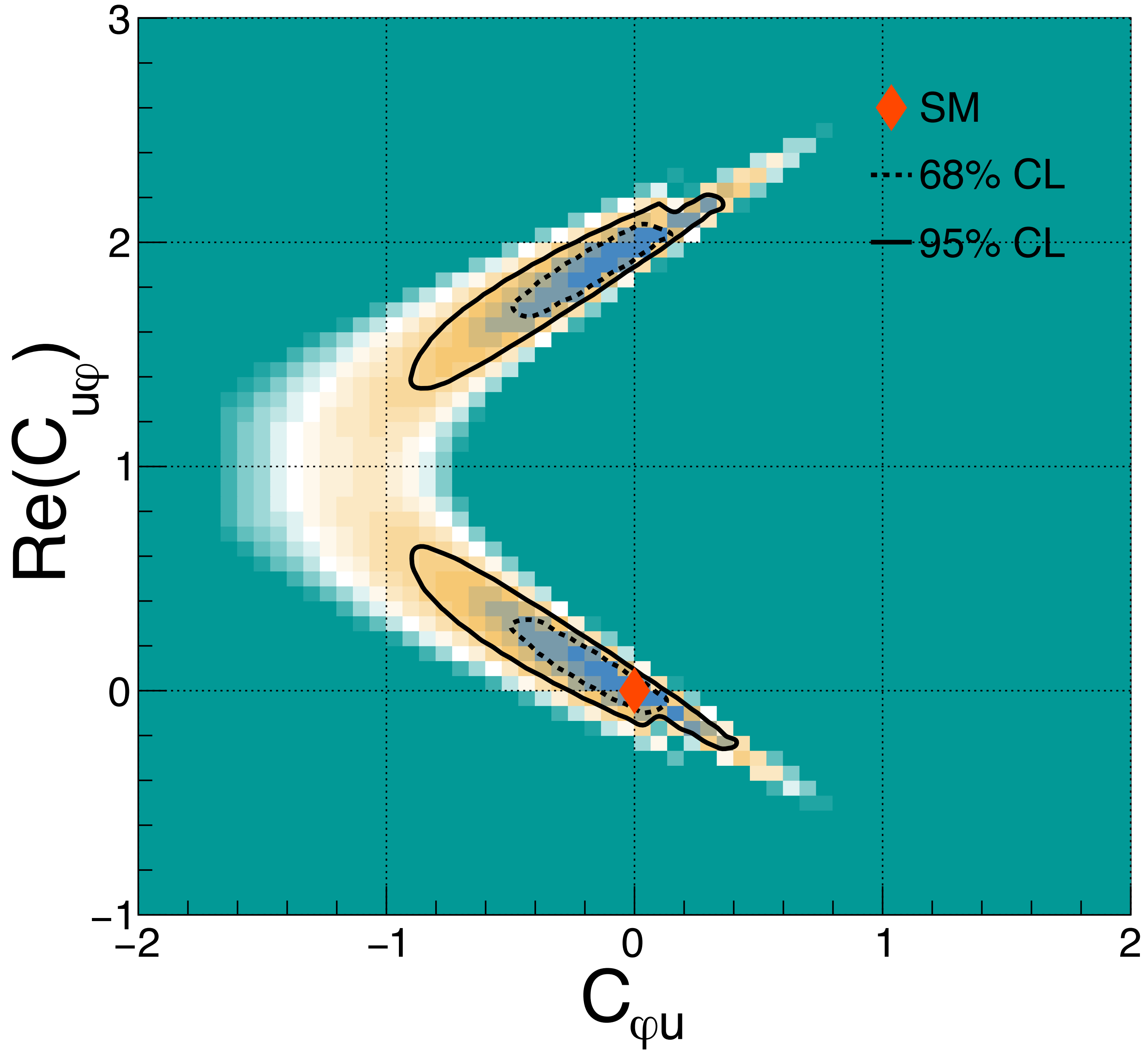
- **μ function of POI**
- **POI:** $C^{\varphi u},\ Im[C^{u\varphi}],\ Re[C^{u\varphi}]$
- $C^{\varphi q3} \to 0$

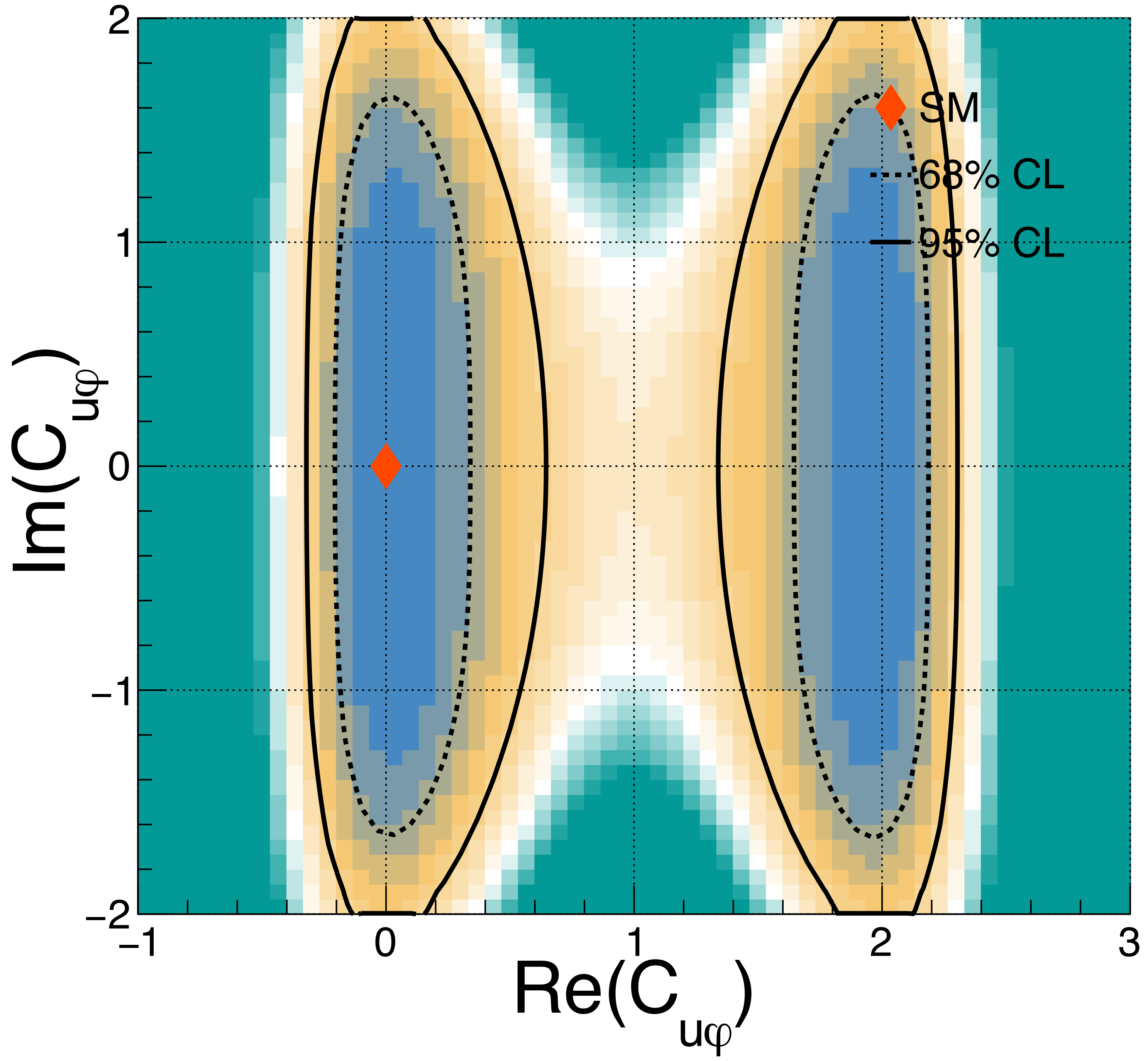
Without Likelihood cut



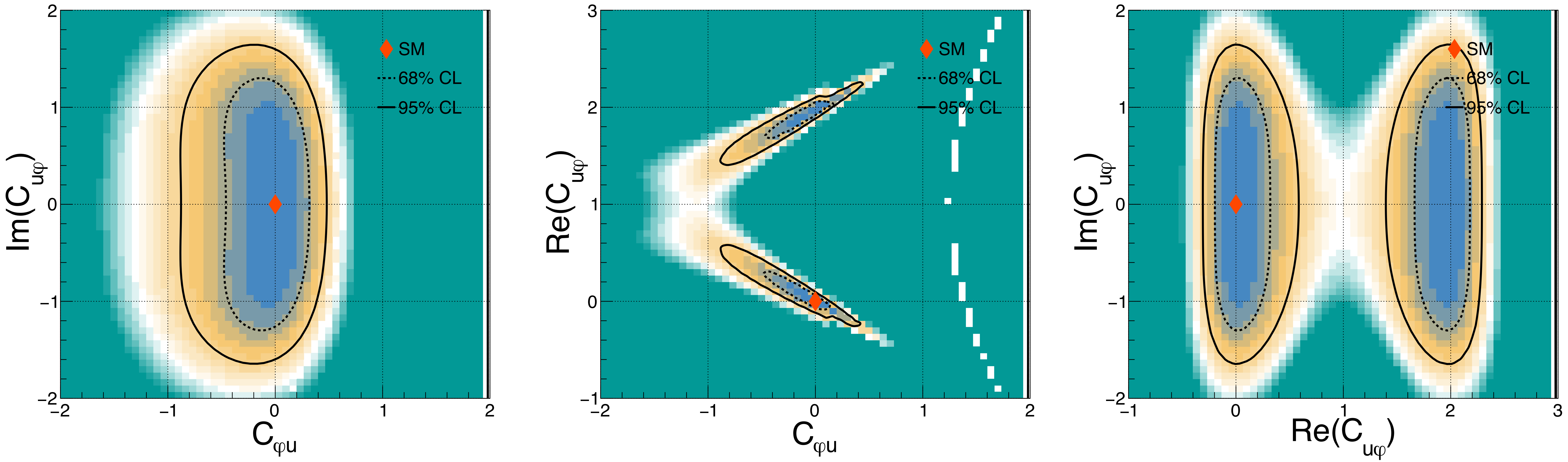
Likelihood <20.0



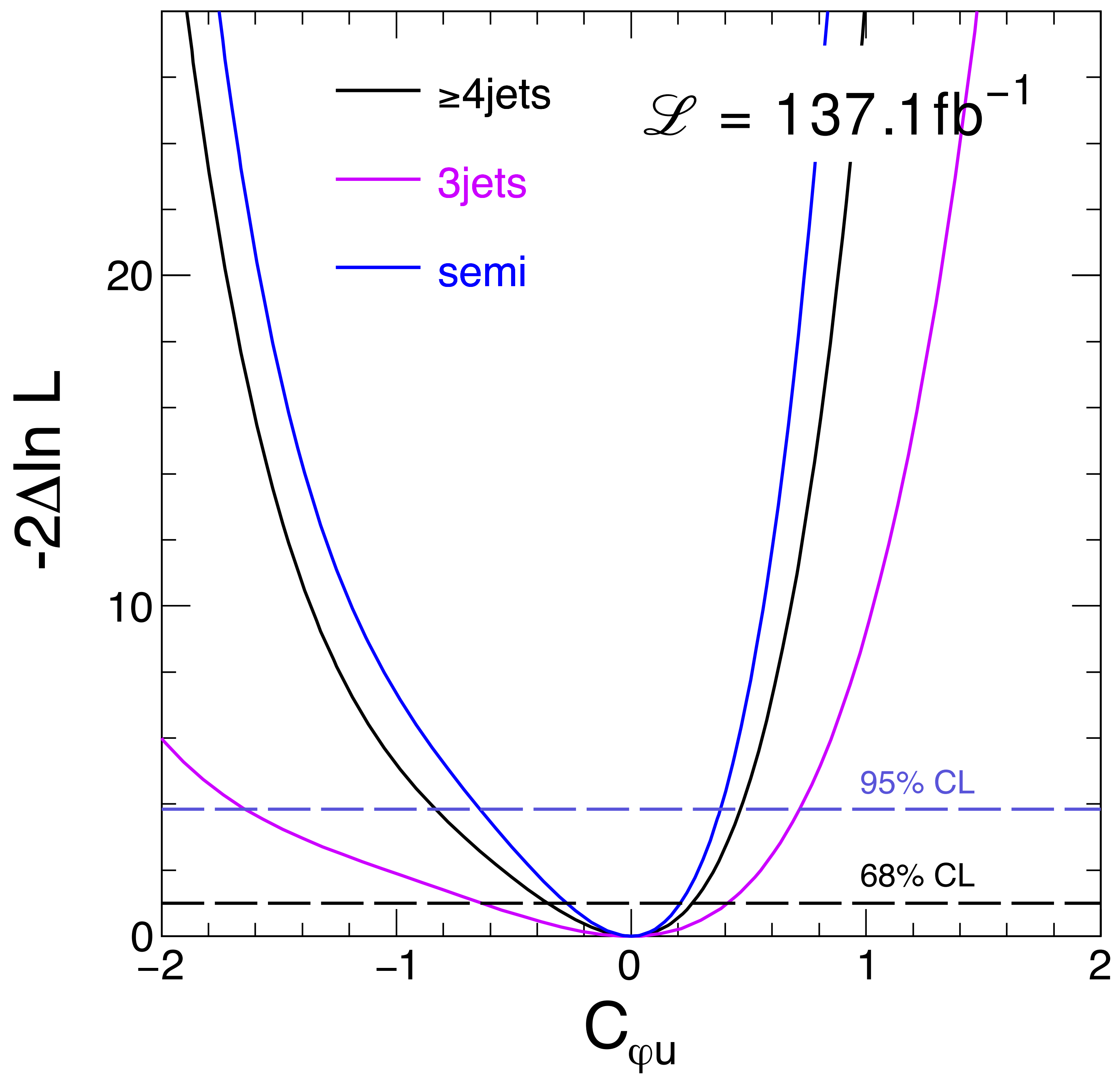


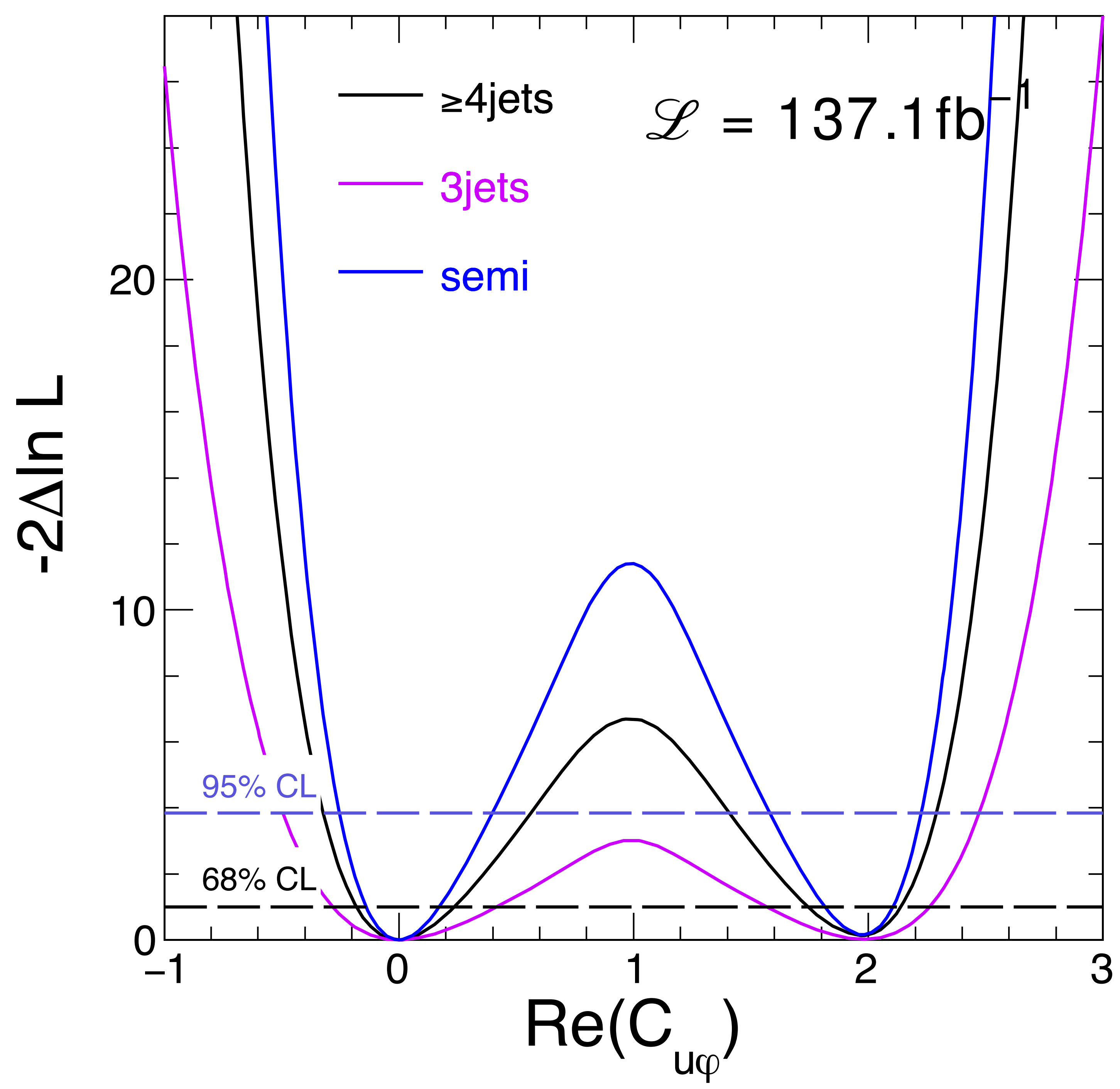


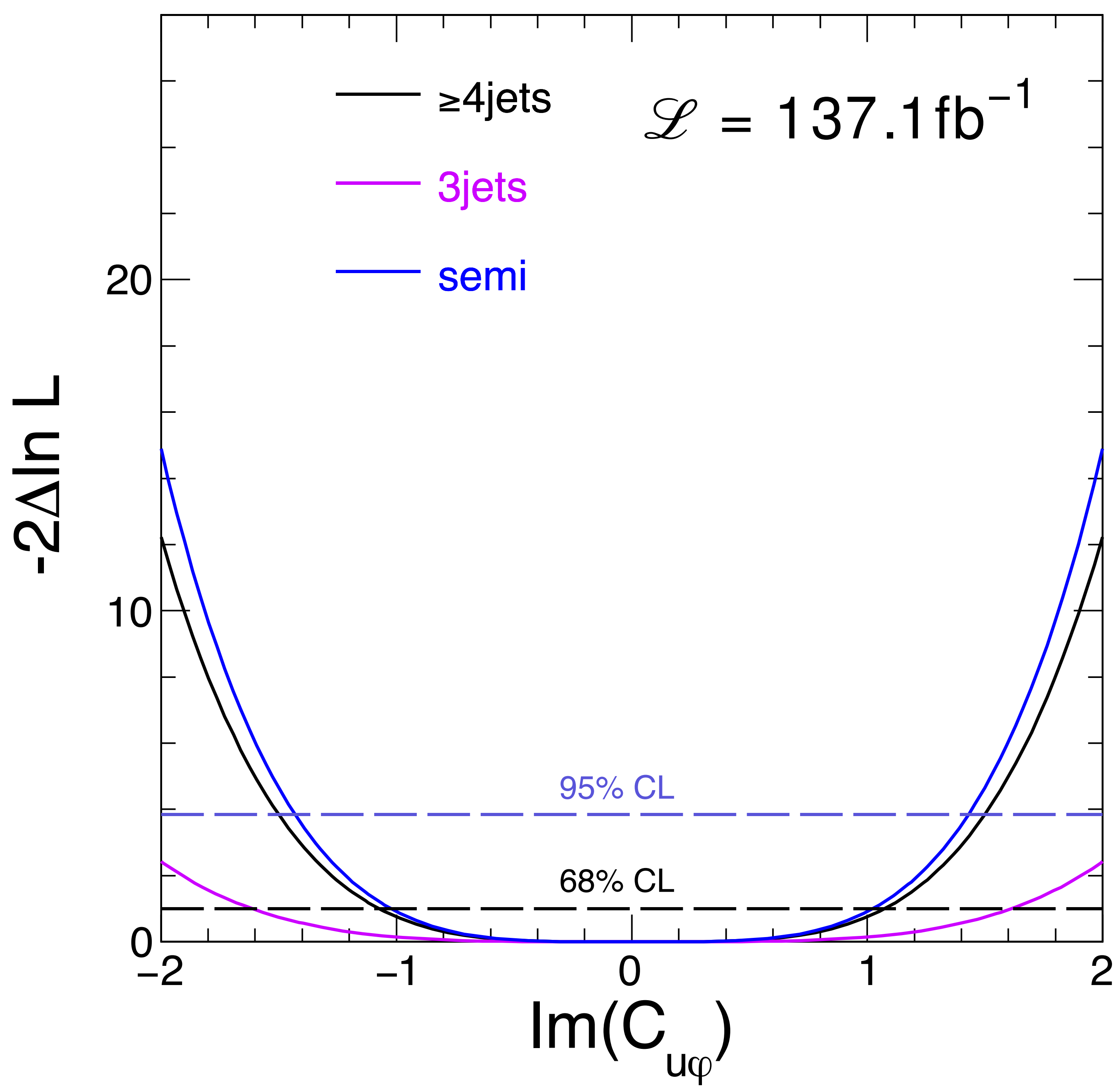
Likelihood <19.0



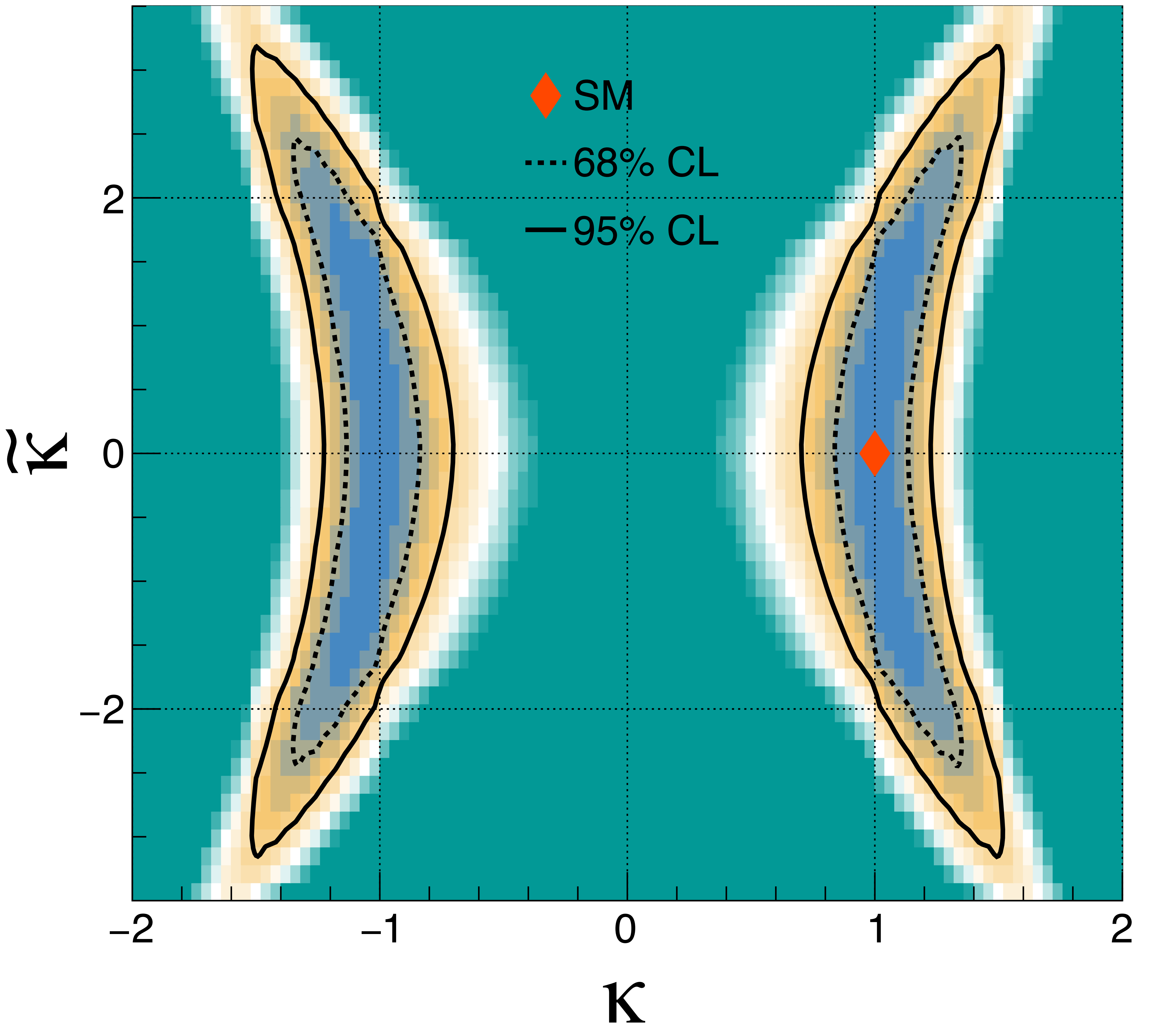
Likelihood < 19.0

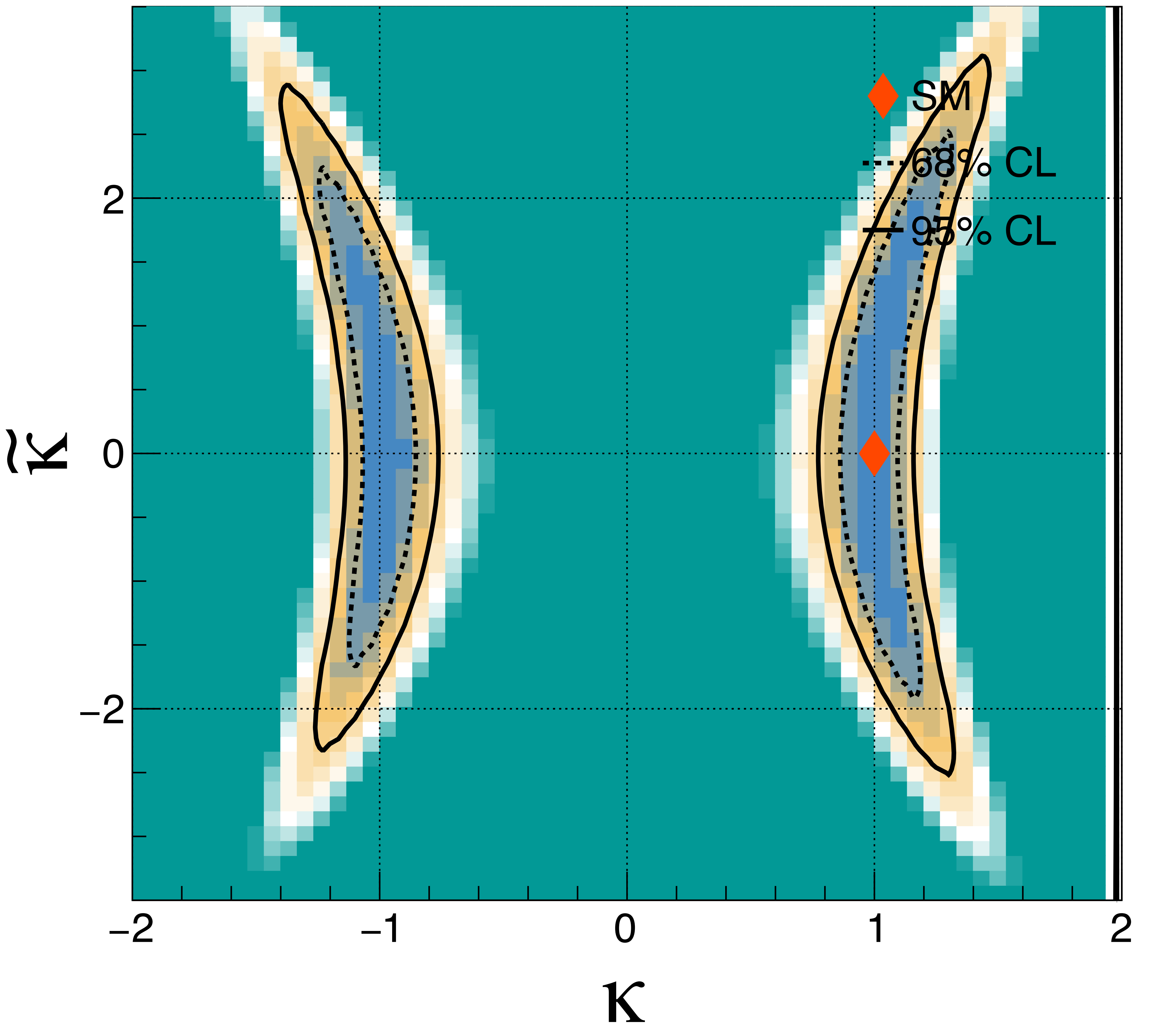






Previous


SM
68% CL
95% CL
2
0
−2
−2
−1
0
1
2
$\tilde{\kappa}$
κ


SM
68% CL
95% CL
2
0
−2
−2
−1
0
1
2
$\tilde{\kappa}$
κ

```
     Number of events is negative or error @ params=(bkg_norm = 9326.01 +/- 0.48291,k = 0.348583 +/- 3.66609,n_exp_binttbar_3jets_proc_DYJets = 12102,n_exp_binttbar_3jets_proc_VV = 2121.13,sig_norm = -396.499 +
/- 0.202688,y = 1.99153 +/- 0.196905,z = -0.79661 +/- 0.146683)
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
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2 +/- 0.202688,y = 1.99153 +/- 0.196905,z = -0.118644 +/- 0.146683)
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[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
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[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
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     Number of events is negative or error @ params=(bkg_norm = 15590.7 +/- 0.48291,k = 0.694555 +/- 3.66609,n_exp_binttbar_3jets_proc_DYJets = 12102,n_exp_binttbar_3jets_proc_VV = 2121.13,sig_norm = -811.71 +/
- 0.202688,y = 1.99153 +/- 0.196905,z = 2.79661 +/- 0.146683)
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[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
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/- 0.202688,y = 2.07627 +/- 0.196905,z = -1 +/- 0.146683)
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/- 0.202688,y = 2.07627 +/- 0.196905,z = -1 +/- 0.146683)
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[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
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/- 0.202688,y = 2.07627 +/- 0.196905,z = 3 +/- 0.146683)
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[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
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[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
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[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
[repan@lxplus7107 condor]$
```
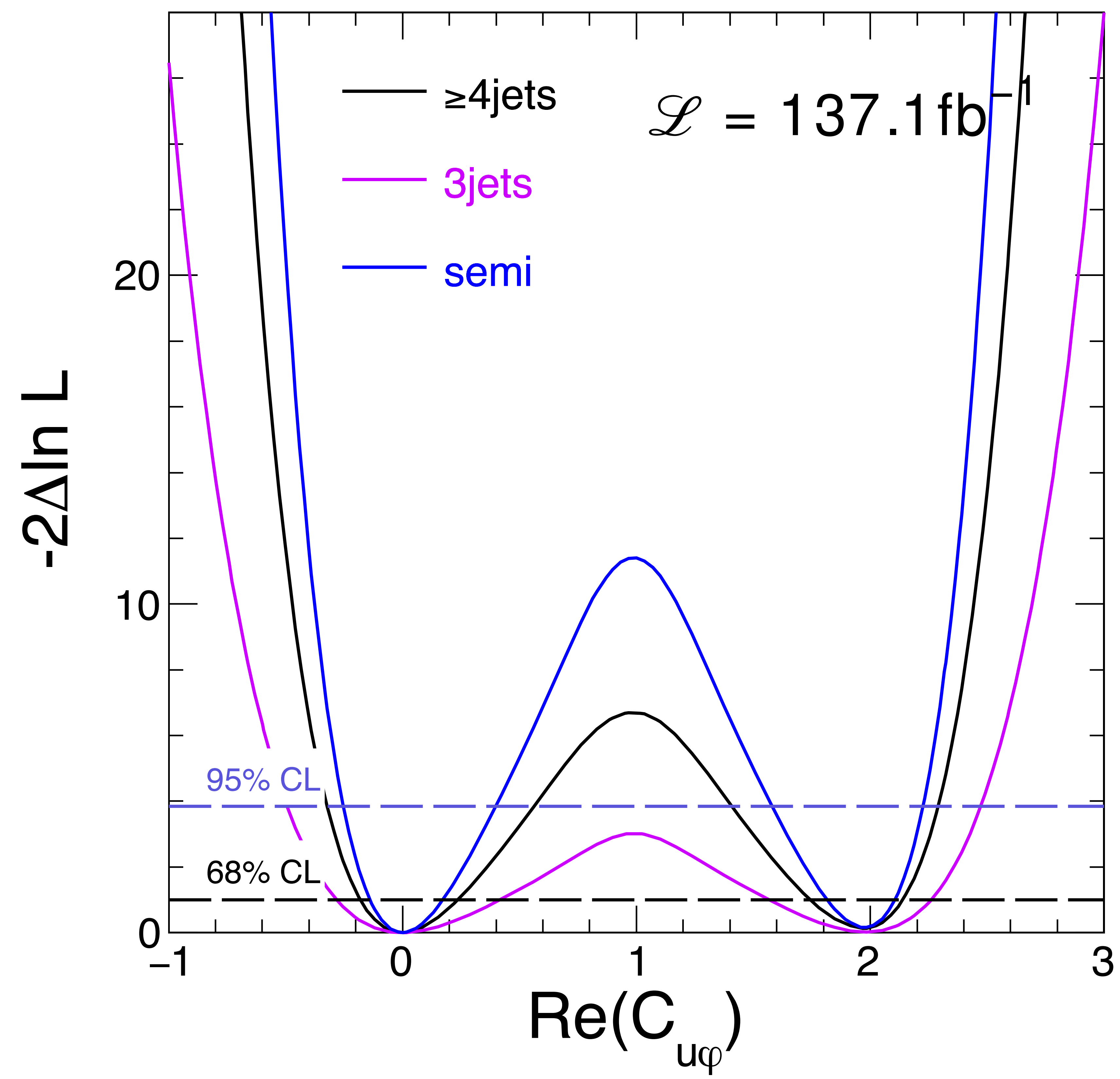

The Selection efficiency of SM processes（Previous）				
source	cross section	semileptonic	>=4 jets	3 jets
tt	833.9	2.4	1.5	0.9
single top	291.5	0.3	0.1	0.2
V+jets	1773.2	0.0	0.0	0.0

The Selection efficiency of SM processes（without cut）				
process	cross_section	semiletonic	>=4jets	3jets
ttbar	833.9	5.0	3.2	1.8
DY	366.2	0.1	0.0	0.0
single top	291.5	0.8	0.4	0.5
VV	182.3	0.0	0.0	0.0
V+Jets	1773.2	0.1	0.0	0.0

The expected composition of SM processes at Run2 (Previous)			
source	semileptonic(%)	>=4 jets(%)	3 jets(%)
tt	91.21	95.36	84.98
single top	3.99	2.83	5.75
V+jets	1.84	1.13	2.89
QCD multijet	2.96	0.68	6.38
MC sum	100.00	100.00	100.00

The expected composition of SM processes at Run2			
process	semiletonic (%)	>=4jets(%)	3jets(%)
ttbar	83.73	92.54	71.65
DY	0.46	0.31	0.67
single top	4.76	3.58	6.37
VV	0.08	0.04	0.13
V+Jets	1.83	1.31	2.54
QCD	9.14	2.22	18.65



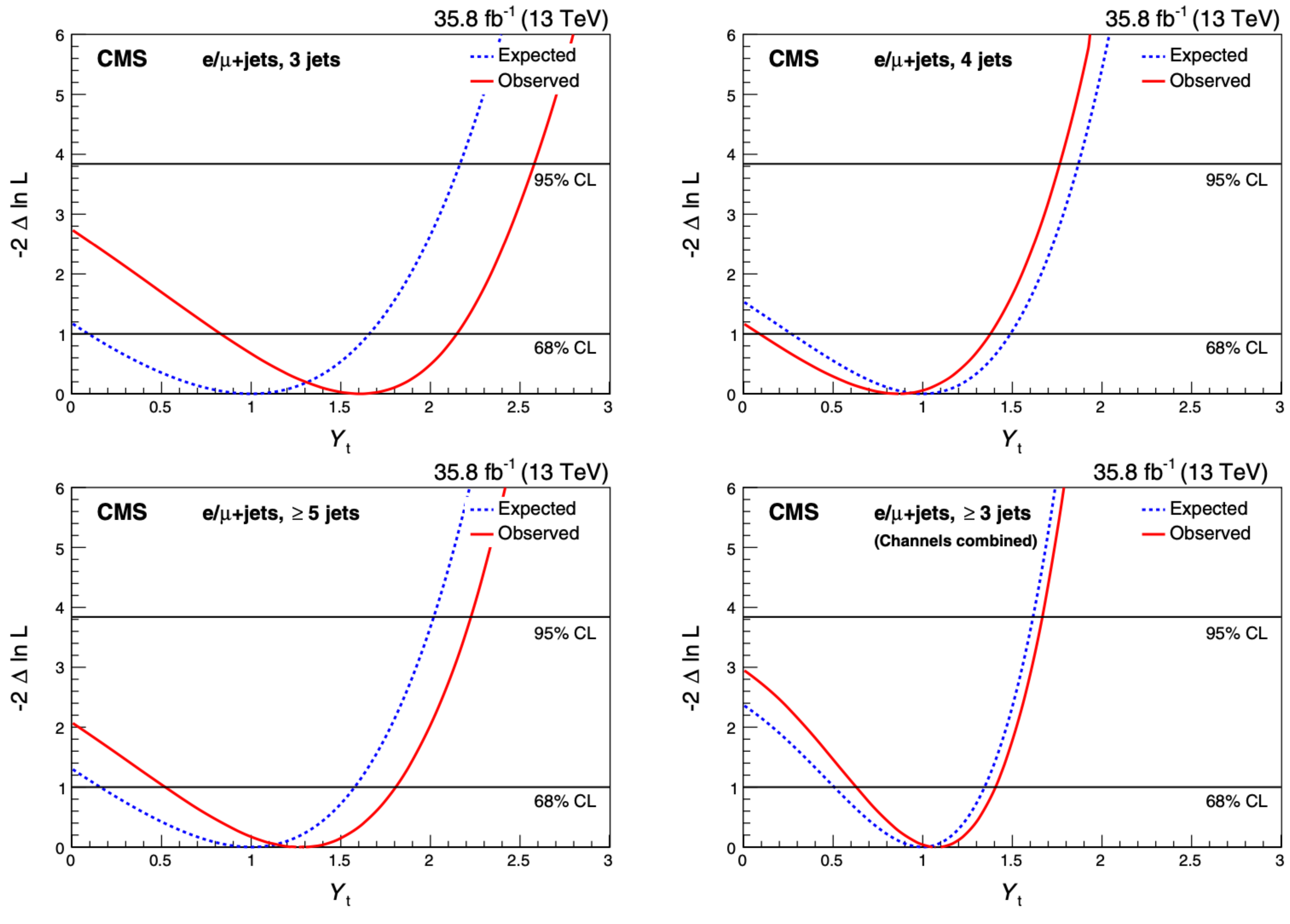
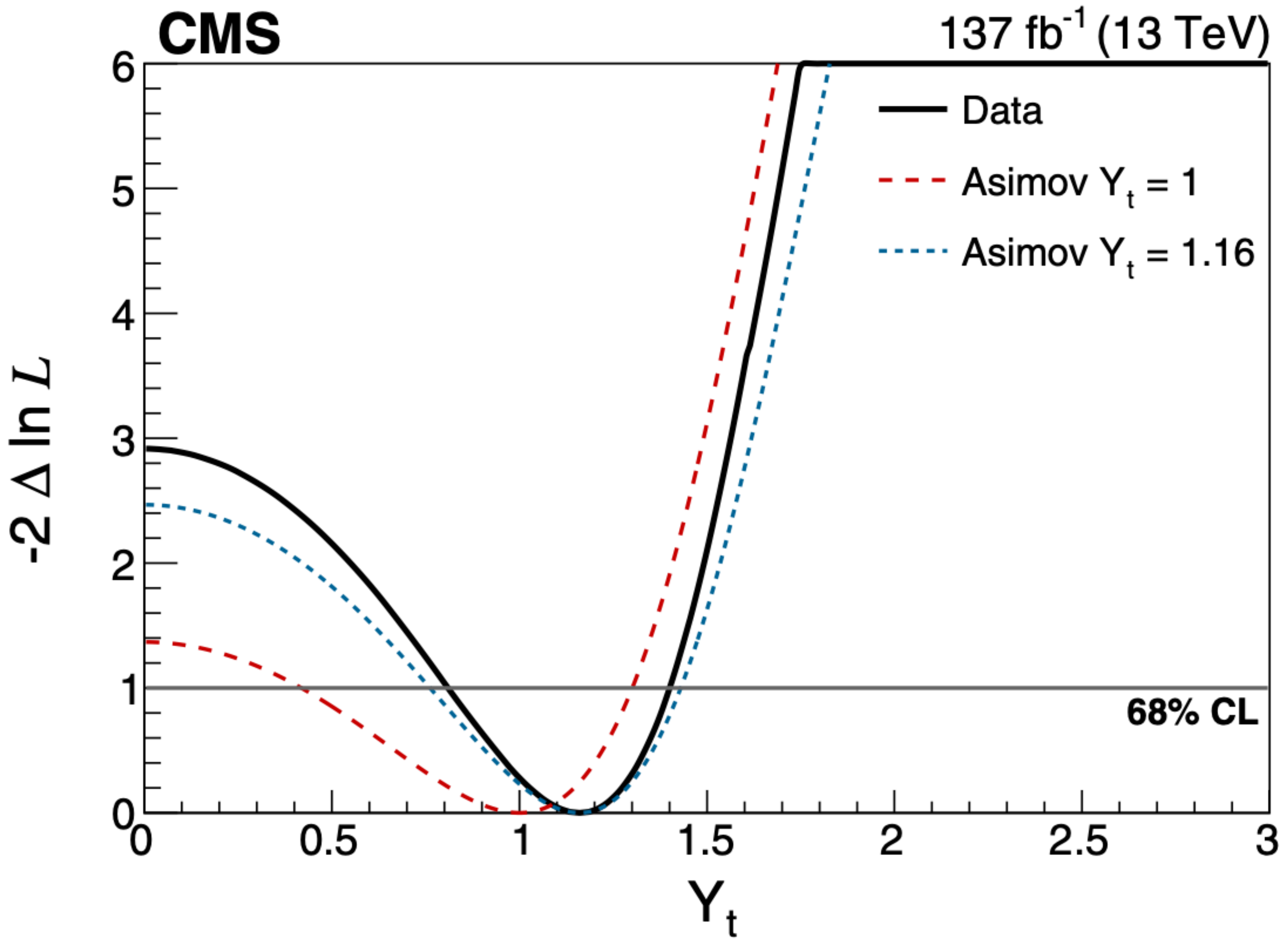


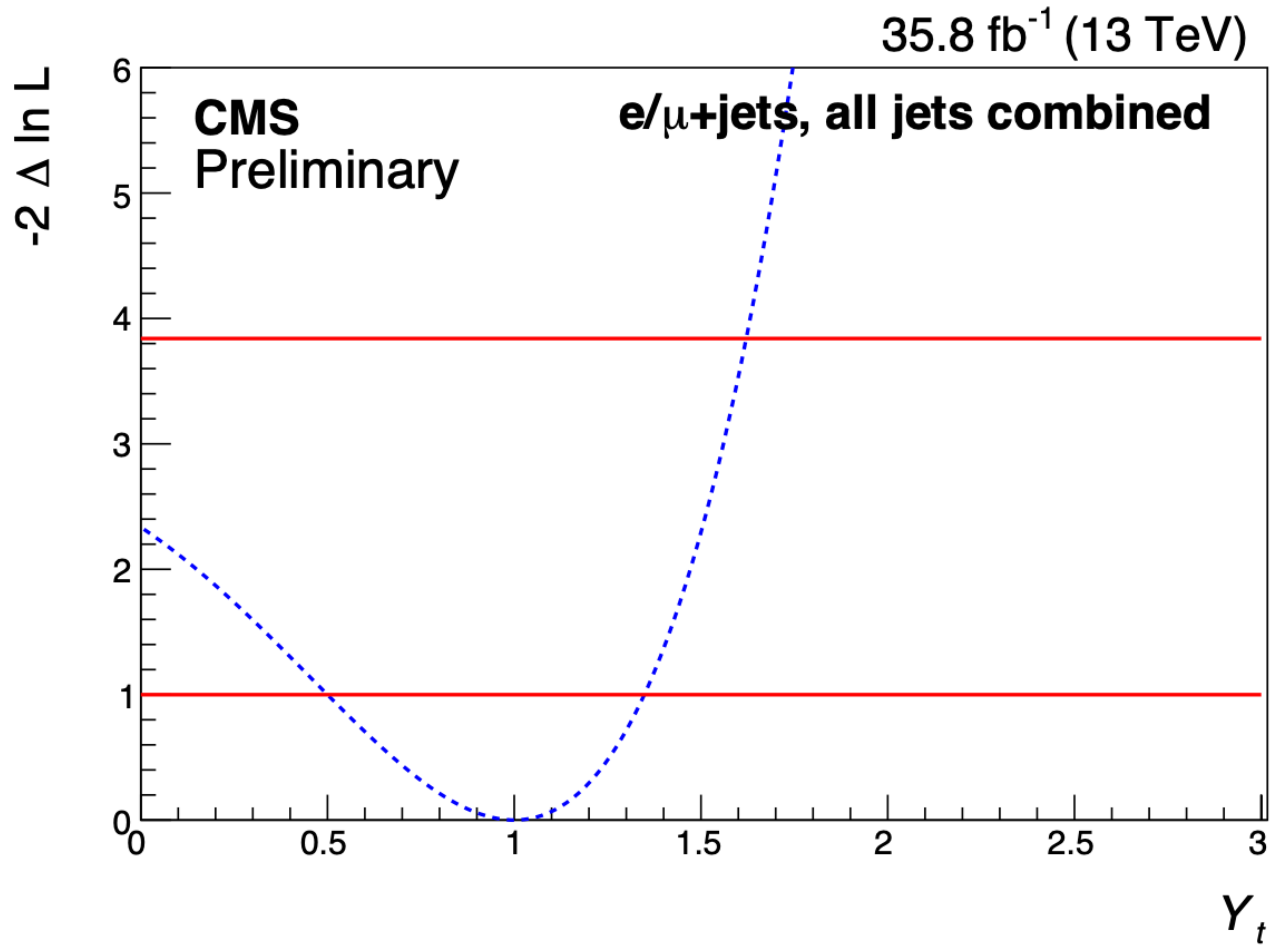
TABLE III. The expected and observed best fit values and 95% CL upper limits on Y_t.

	Best fit Y_t		95% CL upper limit	
Channel	Expected	Observed	Expected	Observed
3 jets	$1.00^{+0.66}_{-0.90}$	$1.62^{+0.53}_{-0.78}$	<2.17	<2.59
4 jets	$1.00^{+0.50}_{-0.72}$	$0.87^{+0.51}_{-0.77}$	<1.88	<1.77
≥5 jets	$1.00^{+0.59}_{-0.83}$	$1.27^{+0.55}_{-0.74}$	<2.03	<2.23
Combined	$1.00^{+0.35}_{-0.48}$	$1.07^{+0.34}_{-0.43}$	<1.62	<1.67

Previous



Previous, dilepton



Previous, semileptonic

TABLE II. Summary of the sources of systematic uncertainty, their effects and magnitudes on signal and backgrounds. If the uncertainty shows a shape dependence in the $M_{t\bar{t}}$ and $\Delta y_{t\bar{t}}$ distributions, it is treated as such in the likelihood. Only the luminosity, background normalization, and ISR uncertainties are not considered as shape uncertainties.

Uncertainty	$t\bar{t}$	Single t	V + jets	QCD multijet
Integrated luminosity	2.5%	2.5%	2.5%	2.5%
Pileup	0–1%	0–1%	...	...
Lepton identification/trigger	1.9%	1.9%	1.9%	...
JEC	0–5%	0–5%	...	...
JER	0–0.6%	...	...	...
b tag scale factor	3%	3%	2–3%	...
b mistag scale factor	0.5%	1%	3–6%	...
Background normalization	...	15%	30%	30%
QCD multijet CR definition	...	...	...	0–60%
Factorization and renormalization scales	0–6%	2–5%	0–15%	...
PDF	0.5–1.5%	0.5–1.5%	...	...
$\alpha_S(m_Z)$ in PDFs	1%	1.5%	...	...
Top quark mass	1–5%	...	...	...
Top quark p_T modeling	0–0.5%	...	...	...
Parton shower				
-NLO shower matching	1.5–5%	...	...	...
-ISR	2–3%	...	...	...
-FSR	0–9%	0–12%	...	...
-Color reconnection	0–3%	...	...	...
-b jet fragmentation	0–3%	0–5%	...	...
-b hadron branching fraction	3%	2.5–3%	...	...
Weak correction $\delta_{QCD}\delta_W$	0–0.2% ($Y_t = 2$)	...	...	...

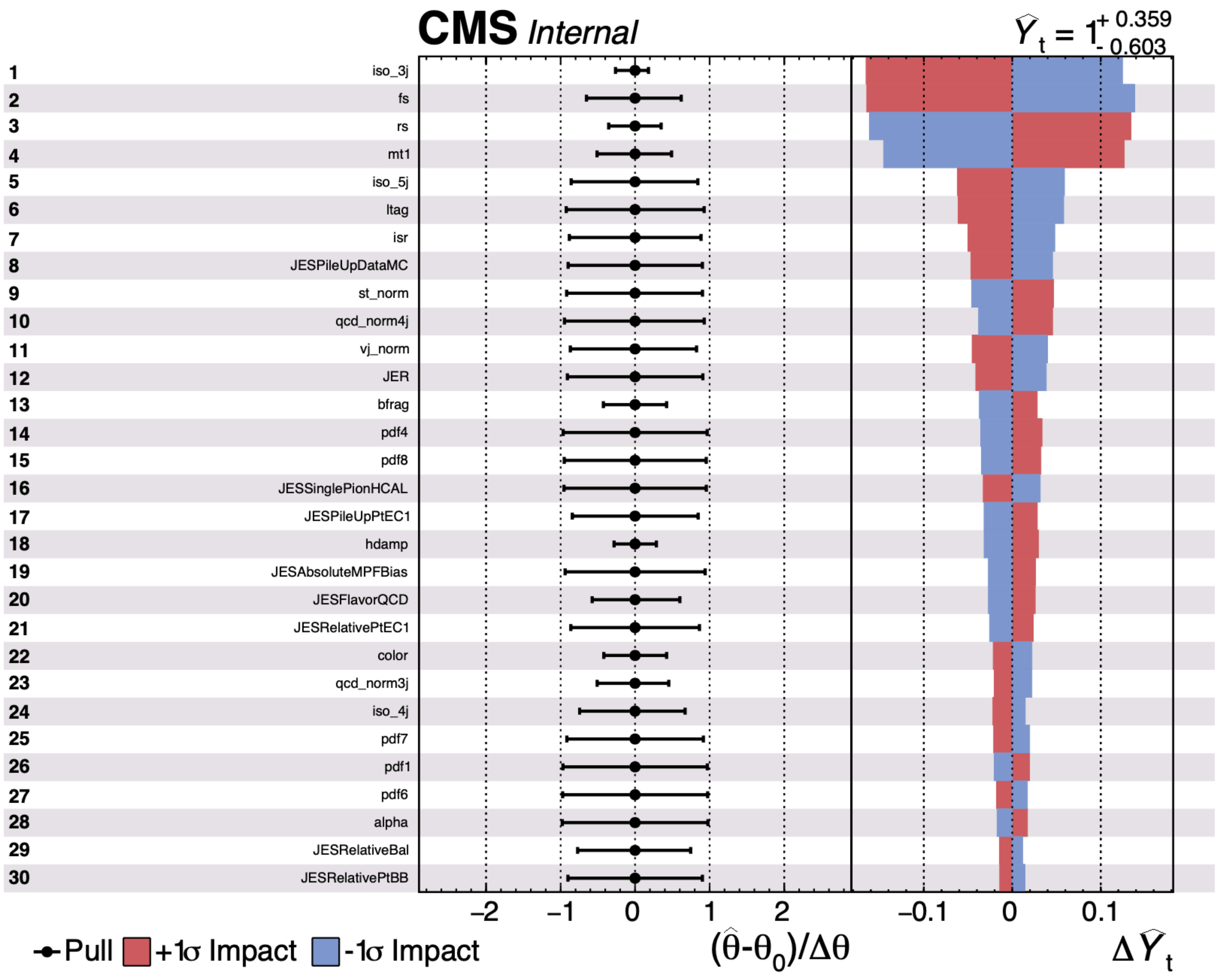
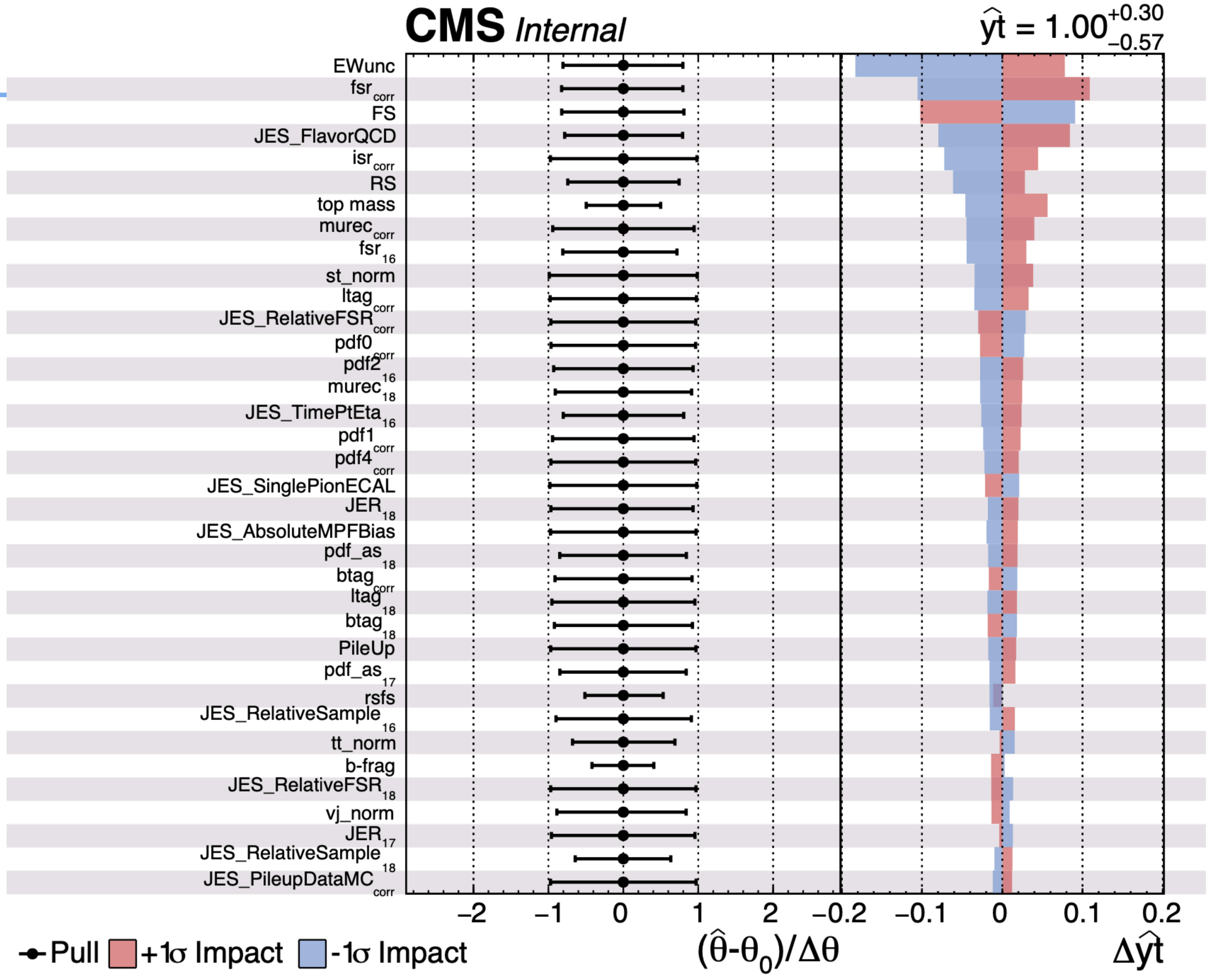


Figure 52: The post fit (Asimov dataset) nuisances and their impacts for all jets combined (bottom plot). The impact of a nuisance is defined as the shift of Y_t that is induced as this nuisance is brought to its up and down 1σ post-fit values.



arxiv: 2108.02803,

arxiv: 2009.07123

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