Blessing: Trileptons in $H \rightarrow WW$

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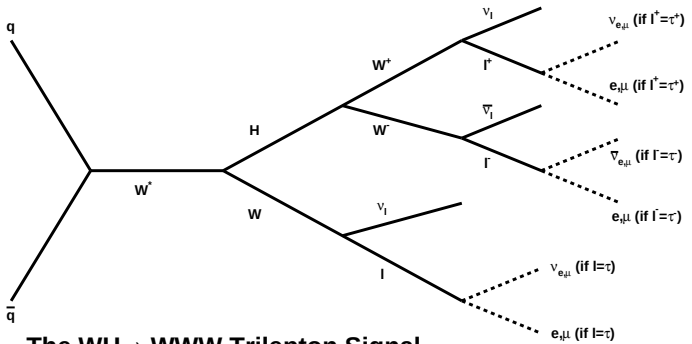
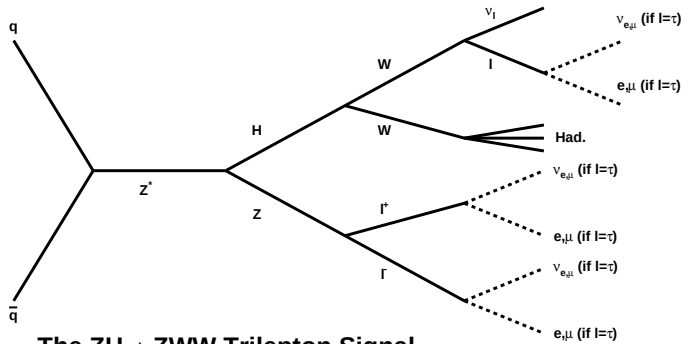
Summary

Trilepton Analysis Review



The WH→ WWW Trilepton Signal



The ZH→ ZWW Trilepton Signal

The $H \rightarrow WW$ group has studied the high mass ($m_H > 135$ GeV) standard model Higgs boson search in exclusively dilepton events. We now introduce the first $H \rightarrow WW$ analysis in trilepton events, focusing on the WH and ZH signals ($gg \rightarrow H$ and VBF are negligible).

Signal Regions Defined

With two new trilepton analyses containing $ZH \rightarrow ZWW$ and $WH \rightarrow WWW$ signals, we define two regions to isolate the signals. Define the ZH signal region as:

- 1^{st} lepton 20.0 GeV, 2^{nd},3^{rd} leptons 10.0 GeV,$\not{E}_T > 10.0$
- 3-lepton events have 3 possible pairings (1^{st},2^{nd}), (1^{st},3^{rd}),(2^{nd},3^{rd})
- Consider events with opposite-sign, same flavor pairs...
- ...with $m_{ll} \in [81.0, 101.0]$ GeV
- Thus, creating a region dominated by ZH over WH ($96\%ZH, 4\%WH$)
- WH Signal Region: The rest of the trilepton events that do not have a dimass near the Z mass.
- creating another region dominated by WH over ZH ($77\%WH, 23\%ZH$)

Backgrounds

Recap: $H \rightarrow WW$ dilepton analysis uses:

- High p_T lepton+Jets data with misidentification rate (e.g. "fake lepton rate") applied to cover W+Jets.
- MC: $t\bar{t}$, Drell Yan, WW, WZ, ZZ, $W\gamma$

Trilepton Analysis: For $VW \rightarrow VWW$ we use slightly different set...

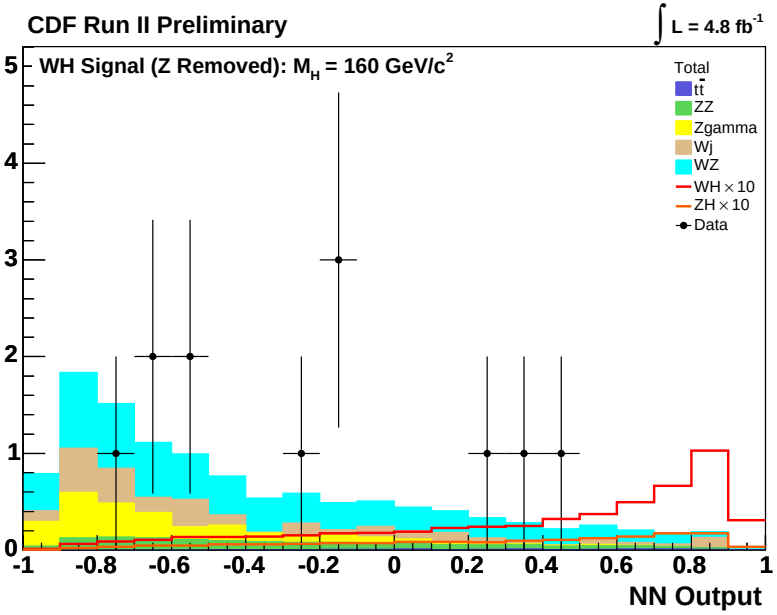
- High p_T lepton+Jets data with misidentification rate (e.g. "fake lepton rate") applied to cover WW+Fake, Z+Fake, W+Fakes, $t\bar{t}$+fake
- MC: WZ, ZZ, $Z\gamma$, $t\bar{t}$
  - $Z\gamma$: Two leptons+photon conversion (ISR or FSR)
  - $t\bar{t}$: Two leptons+b-jet faking isolated lepton–fake rates for b-jets in particular not well-known. [NOTE: Any $t\bar{t}$ covered by Fakes is scaled assuming the light jet fake rate, but b-jets would likely fake a lepton more often than a light jet. So we look in NLep=3 for the standard ntuple (leptons match to gen. lepton or photons) and another $t\bar{t}$ ntuple with leptons matching to gen. leptons, photons, or b-jets. Half the % difference is taken to be the systematic error for overlap (23%).]

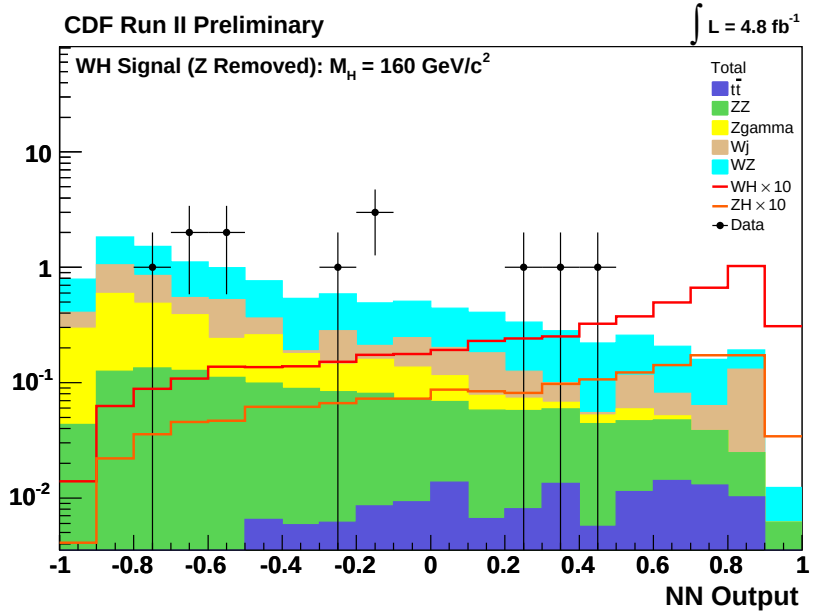
Signal Region Event Count

Process	*WH* (NoZPeak Region)	*ZH* (InZPeak Region)
WZ	$5.92 \pm 0.81_{\text{syst}}$	$7.65 \pm 1.48_{\text{syst}}$
ZZ	$1.28 \pm 0.17_{\text{syst}}$	$3.90 \pm 0.61_{\text{syst}}$
$Z\gamma$	$2.04 \pm 0.36_{\text{syst}}$	$2.51 \pm 0.54_{\text{syst}}$
Fakes (WW, Z+Jets)	$2.28 \pm 0.68_{\text{syst}}$	$6.12 \pm 1.84_{\text{syst}}$
$t\bar{t}$	$0.25 \pm 0.07_{\text{syst}}$	$0.05 \pm 0.01_{\text{syst}}$
*WH*165 Signal	$0.50 \pm 0.07_{\text{syst}}$	$0.02 \pm 0.003_{\text{syst}}$
*ZH*165 Signal	$0.15 \pm 0.02_{\text{syst}}$	$0.51 \pm 0.07_{\text{syst}}$
Background Stack	$11.7 \pm 1.25_{\text{syst}}$	$20.2 \pm 2.96_{\text{syst}}$
data($4.8\ \text{fb}^{-1}$)	12	26

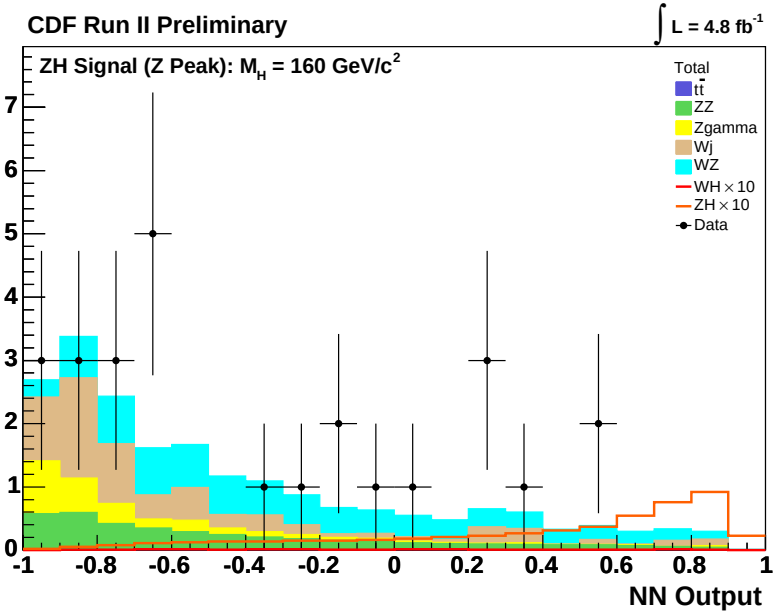
Table: Background and Signal Counts for the *WH* and *ZH* Trilepton Analyses. [For Public Release Blessing]

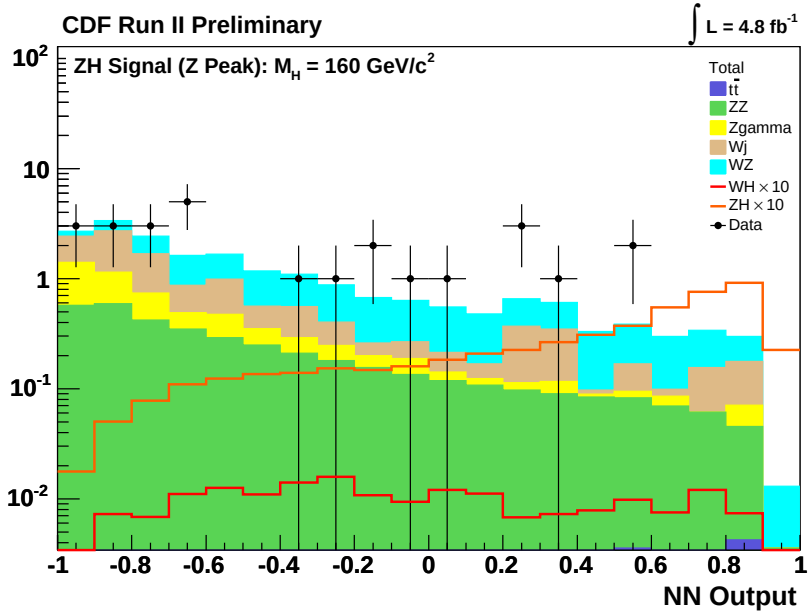
WH NN at $m_H = 160$ GeV





ZH NN at $m_H = 160$ GeV





Jet Energy Scaling

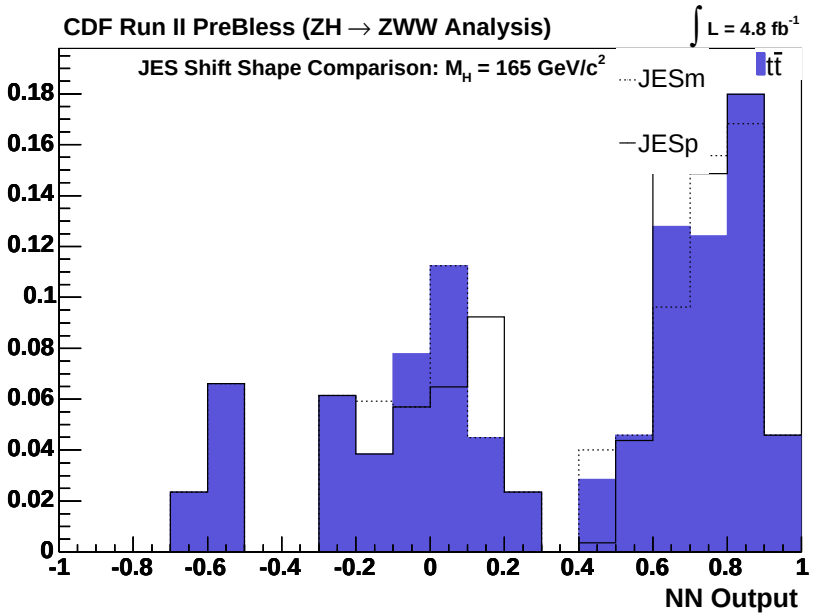
- Recall: Trilepton *ZH* analysis removes the NJet$=$ 0 bin from the signal region and makes it the control region. As such, we must check jet energy scaling within uncertainties to determine:
  - whether background modelling shifts up or down (i.e. *J.E.S. total systematic*)
  - whether background modelling shifts toward or away from the signal region of the NN score (i.e. *J.E.S. shape systematic*)
- *WH* analysis did not remove jet bins, but was checked anyways. No systematics necessary.
- *ZH* Analysis J.E.S. Total Systematic:
  - *WZ*: 0.097
  - *ZZ*: 0.052
  - $Z\gamma$: 0.088
  - *WH*: 0.084
  - *ZH*: 0.011

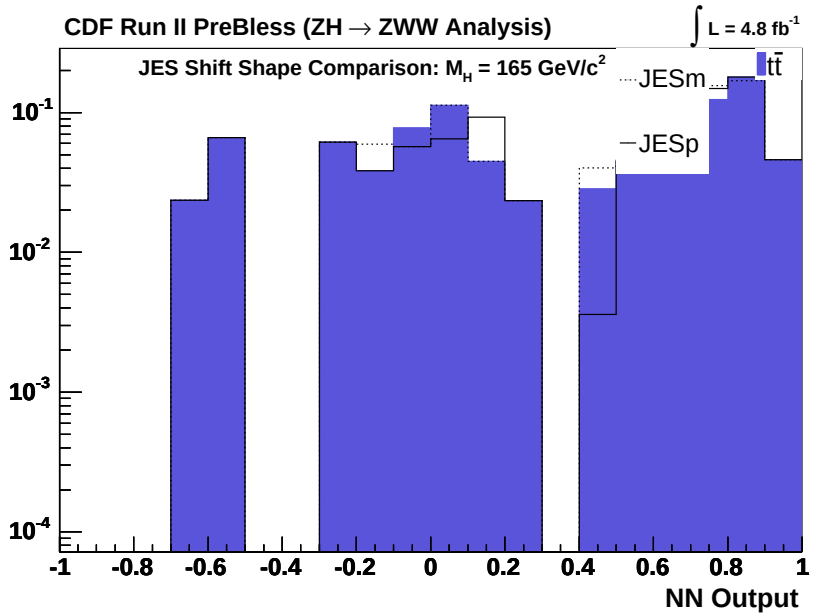
J.E.S. Shape Systematic

Even if the total count of the background does not change, there could be a shift to or from the signal region of the neural nets score, which would affect limit calculations. So we checked the templates for any shift.

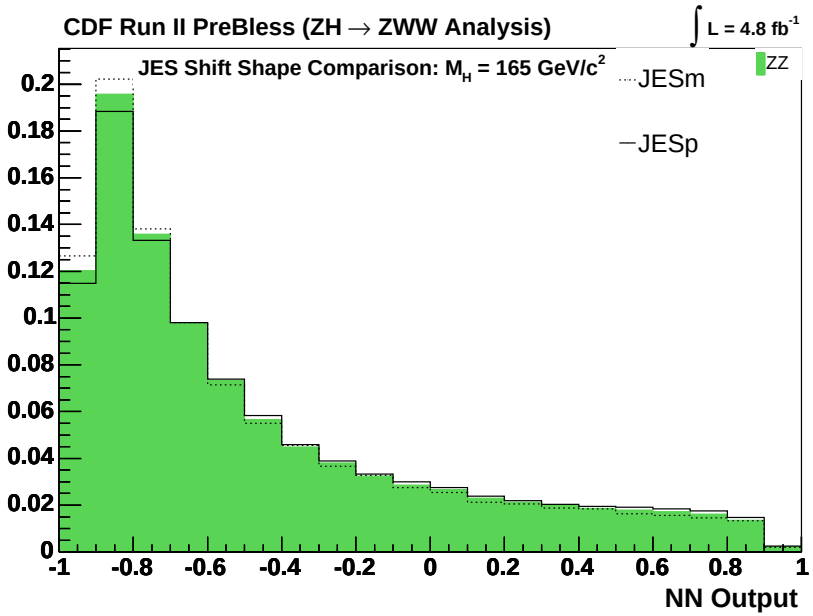
- Check the templates for any shift
- Recalculate the limits using a shape systematic and see if the results change (done here only for $m_H = 165$ GeV).

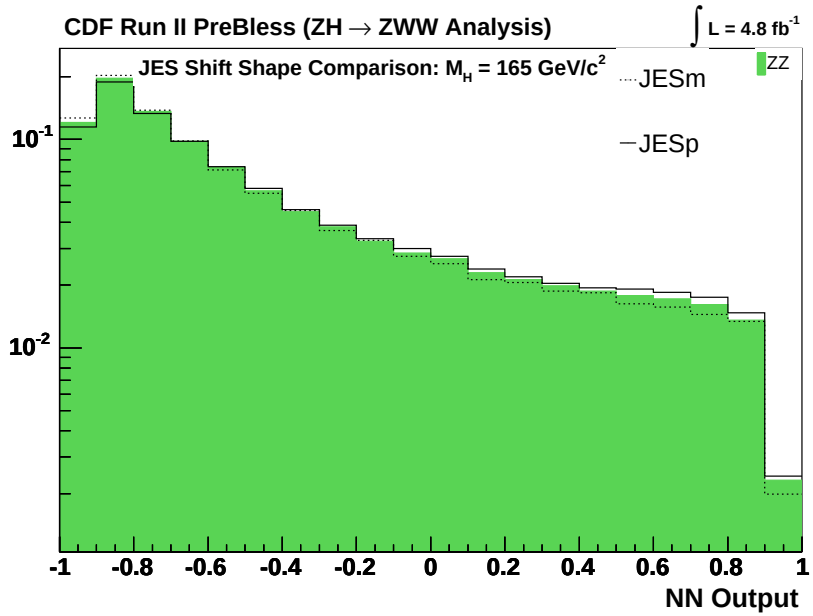
J.E.S. Shape Systematic



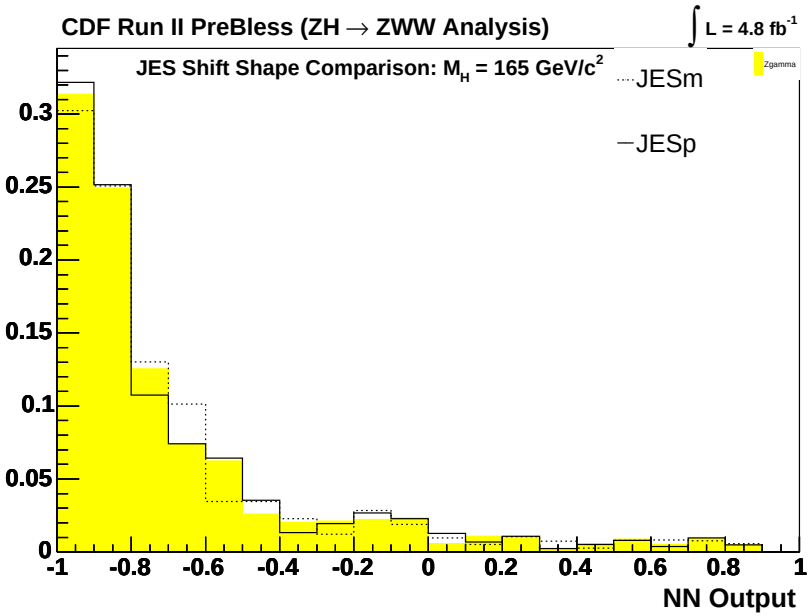


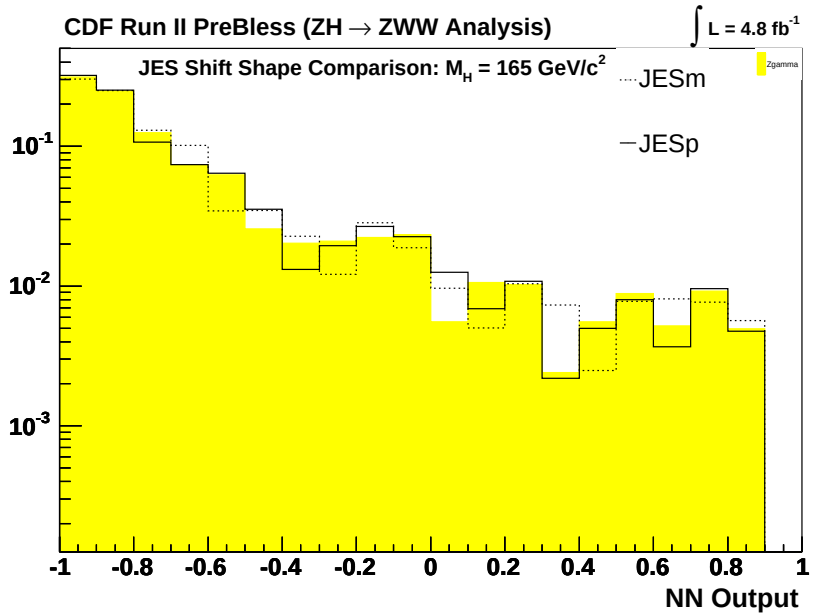
J.E.S. Shape Systematic



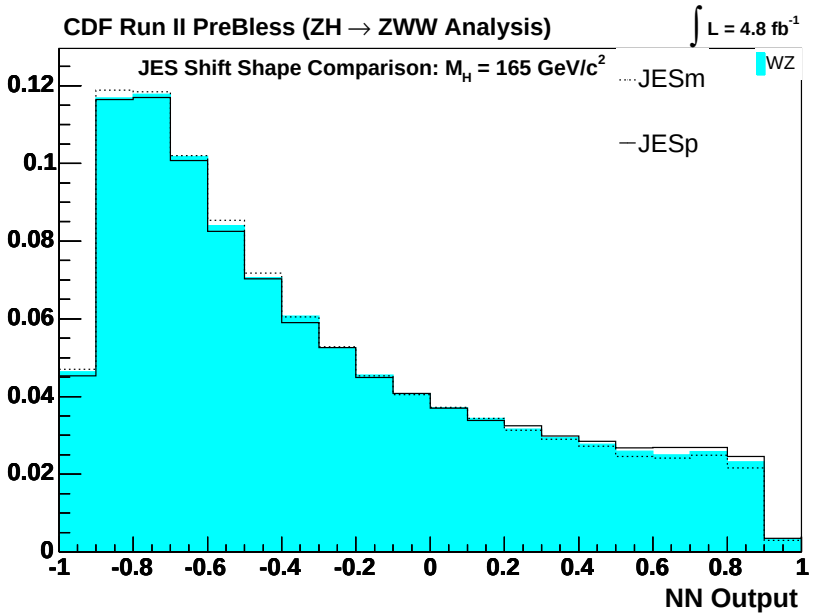


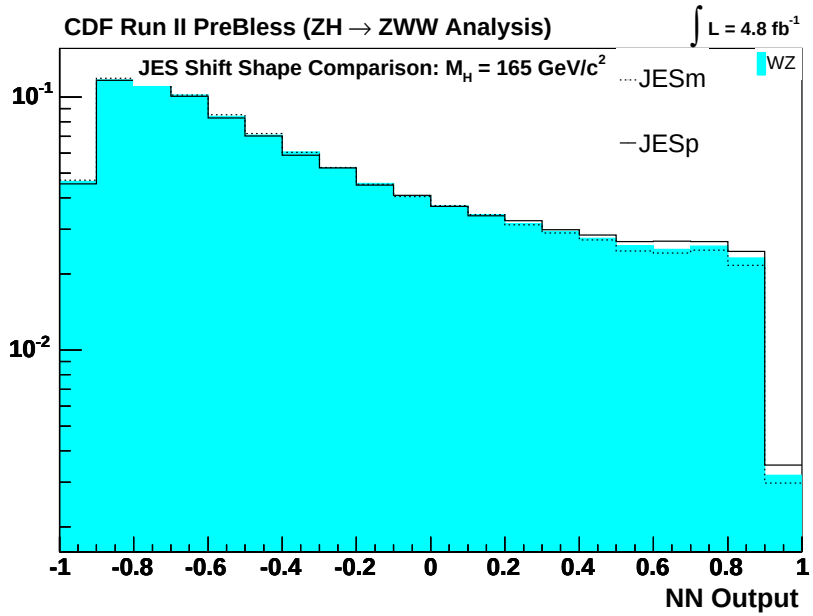
J.E.S. Shape Systematic



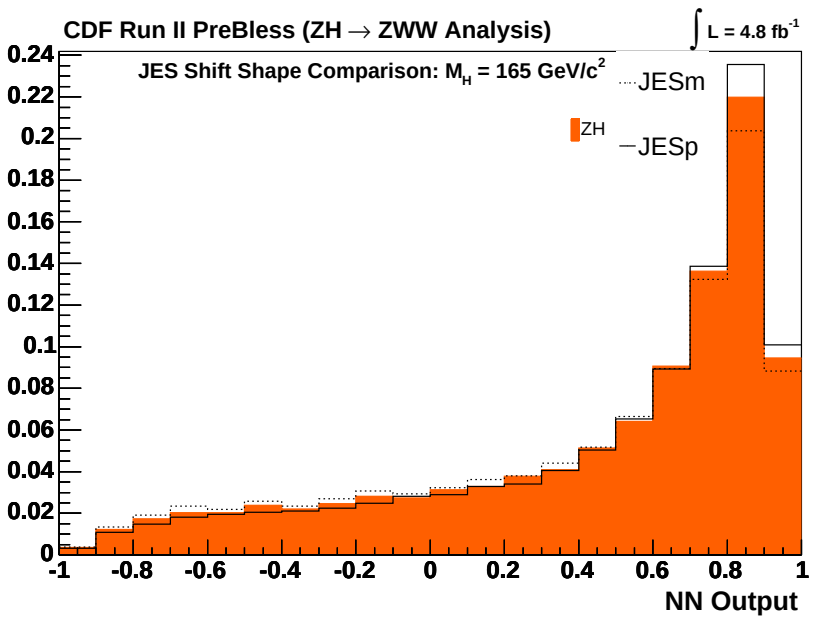


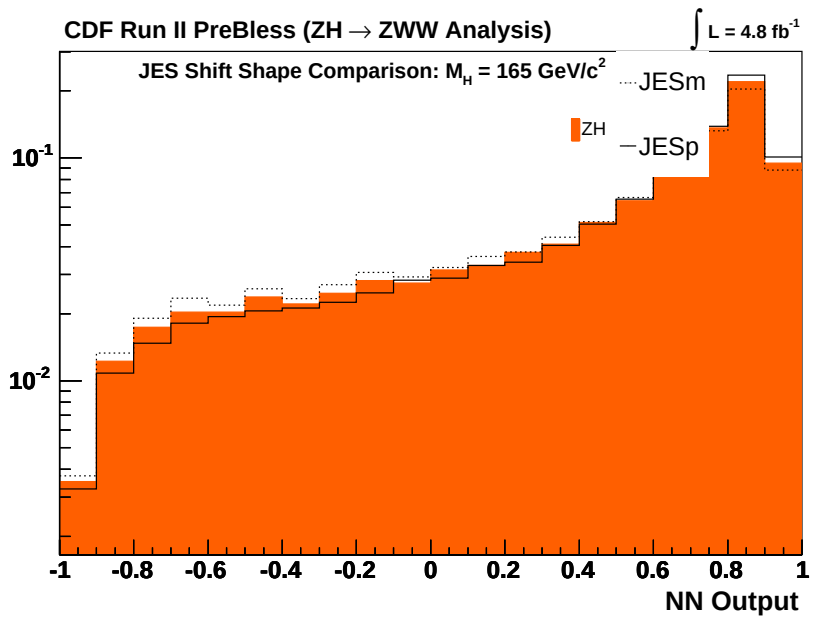
J.E.S. Shape Systematic





J.E.S. Shape Systematic





Do the limits change if we use shape systematics?

$m_H = 165$ GeV bin	Exp. Limit-1σ	Median Exp. Limit	Exp. Limit$+1\sigma$
WH Analysis, JES Shape Syst.	6.7	8.9	12.3
WH Analysis, Standard	6.7	8.8	12.4
ZH Analysis, JES Shape Syst.	9.4	12.5	17.7
ZH Analysis, Standard	9.4	12.5	17.2
Trilepton Analyses, JES Shape Syst.	4.7	6.3	8.9
Trilepton Analyses, Standard	4.7	6.3	8.9

The median expected limits change by only 0.35% or less when the shape systematic is used. Eventually, it must be used, but is not crucial now and the necessary files have been created for all mass points yet.

$gg \rightarrow H$ Signal in Fakes?

Is it possible that a significant amount of $gg \rightarrow H$ signal could fake a third lepton from a jet and contribute to the '2 lepton+1 denominator object' Fakes background sample? Short answer: No. Let's see why:

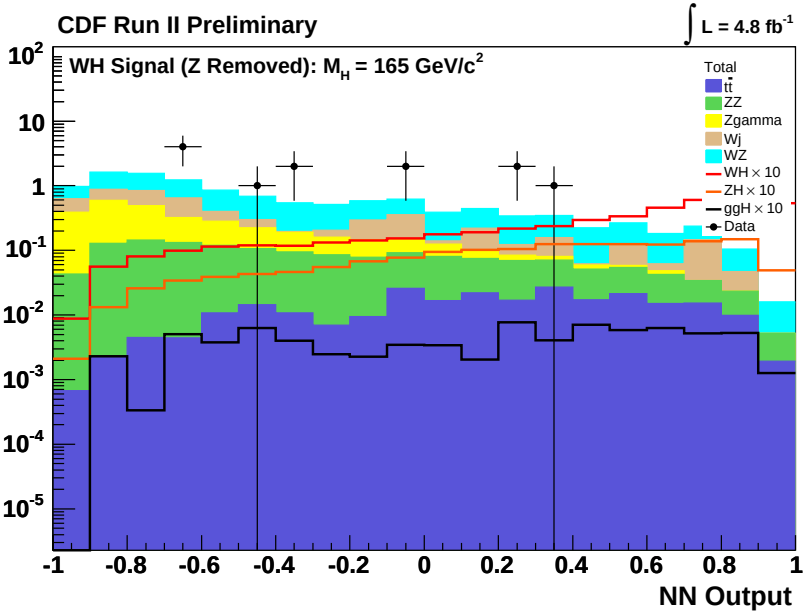
Region	$gg \rightarrow H$ Signal (Count in 4.8fb^{-1})	$\frac{(gg \rightarrow H)\cdot 100}{WH+ZH}$
WH signal region	0.00779	1.1 %
ZH signal region	0.00031	0.062 %
Total Trilepton	0.0081	0.68 %

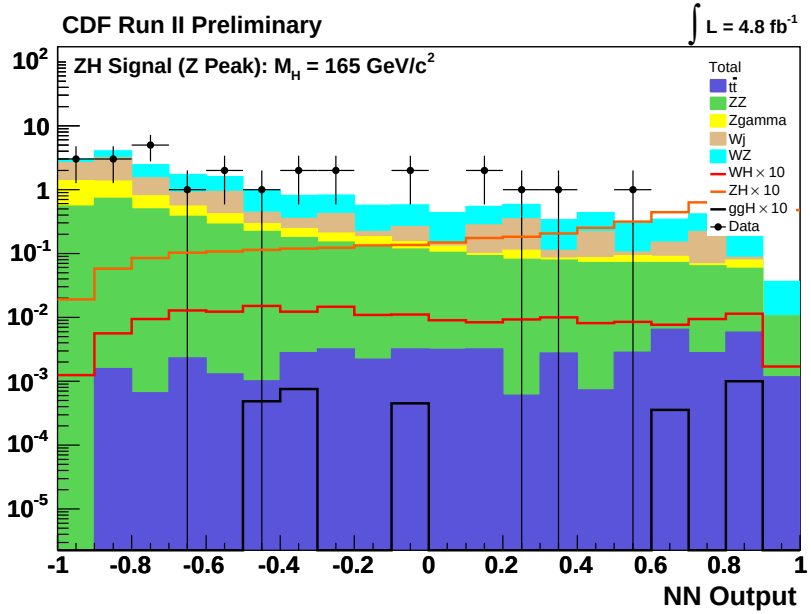
That's pretty small, but could it could affect the limits if the $gg \rightarrow H$ part of Fakes is in the signal region of the neural net score?

$gg \longrightarrow H$ Signal in Fakes?

Region	$gg \longrightarrow H$ Signal (Count in 4.8fb^{-1})	$\frac{(gg \longrightarrow H)\cdot 100}{WH+ZH}$	Fakes	WH	ZH
WH signal region	0.0012	0.500%	0.14	0.210	0.03
ZH signal region	0.0001	0.045%	0.16	0.002	0.22
Total Trilepton	0.0013	0.281%	0.30	0.212	0.25

Table: Last three bins of the neural net score for $m_H = 165$ GeV. Only $\frac{0.0012+0.0001}{0.0081} = 16\%$ of the $gg \longrightarrow H$ events are found.





Systematic Uncertainty	WZ	ZZ	$Z\gamma$	$t\bar{t}$	Fakes	WH	ZH
Diboson Higher Order Diagrams	0.100	0.100					
$t\bar{t}$ Higher Order Diagrams				0.100			
Higgs Higher Order Diagrams						0.100	0.100
PDF Model	0.027	0.027		0.021		0.012	0.009
Lepton ID Efficiencies	0.020	0.020		0.020		0.020	0.020
Trigger Efficiences	0.021	0.021		0.020		0.021	0.021
Light Jet Fake Rates					0.300		
b-Jet Fake Rate*				0.23			
Luminosity	0.059	0.059		0.059		0.059	0.059
MC Run Dependence			0.050*				
Jet Energy Scale	0.098*[a]	0.053*[a]	0.086*[a]			0.084*[a]	0.011*[a]
$Z\gamma$ Higher Order Diagrams*			0.110*				
$W\gamma$ Scaling			0.120*				
σ_{Diboson}	0.060	0.060					
$\sigma_{t\bar{t}}$				0.100			
σ_{VH}						0.050	0.050
$\sigma_{\text{Z}\gamma}$*			0.050*				

Table: Systematic Uncertainties: Standard values for systematics used in other $H \rightarrow WW$ analyses are used wherever applicable. [For Public Release Blessing]

[a] Only for the ZH analysis (*trilep-InZPeak* region) because the NJet$=0$ bin is removed from the signal region and made a control region.

* New to trilepton analysis, not in dilepton analysis.

WH Final Limits

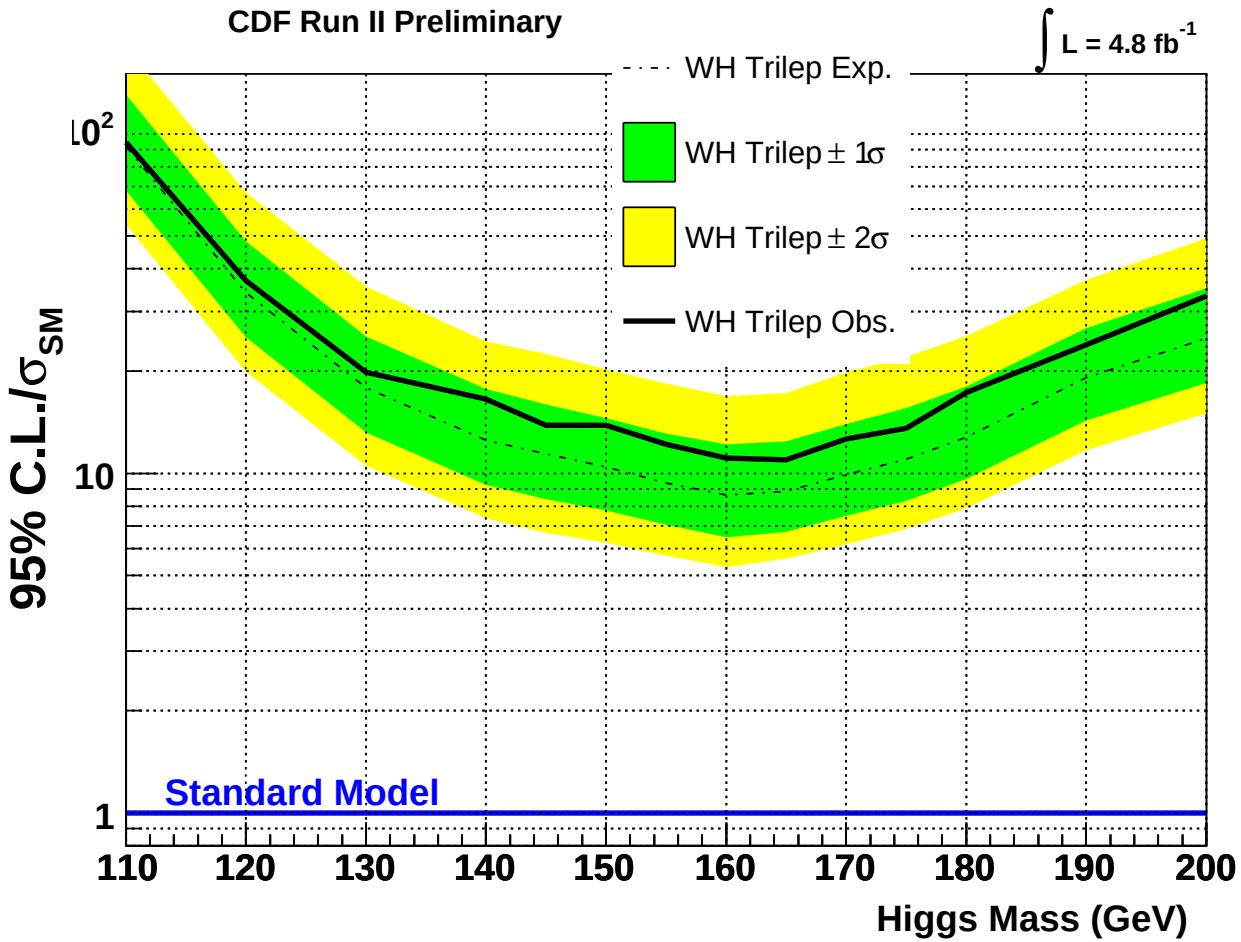


Figure: [For Public Release Blessing]

WH Final Limits

Limits	110	120	130	140	145	150	155
$+2\sigma/\sigma_{SM}$	180	67.2	35.5	24.4	22.5	20.3	18.4
$+1\sigma/\sigma_{SM}$	130	48.3	25.3	17.7	16.0	14.5	13.1
Median$/\sigma_{SM}$	**91.6**	**34.1**	**17.9**	**12.5**	**11.4**	**10.4**	**9.35**
$-1\sigma/\sigma_{SM}$	67.9	25.1	13.2	9.23	8.40	7.76	7.05
$-2\sigma/\sigma_{SM}$	54.0	19.9	10.5	7.36	6.67	6.25	5.72
Observed$/\sigma_{SM}$	**94.4**	**36.9**	**19.9**	**16.5**	**13.9**	**13.8**	**12.2**
Limits	160	165	170	175	180	190	200
$+2\sigma/\sigma_{SM}$	16.9	17.2	19.8	22.1	25.3	27.1	49.3
$+1\sigma/\sigma_{SM}$	12.2	12.4	14.0	15.6	18.0	26.8	35.1
Median$/\sigma_{SM}$	**8.62**	**8.86**	**9.91**	**11.0**	**12.8**	**19.1**	**24.9**
$-1\sigma/\sigma_{SM}$	6.48	6.71	7.49	8.29	9.62	14.3	18.5
$-2\sigma/\sigma_{SM}$	5.29	5.60	6.17	6.85	7.90	11.7	15.0
Observed$/\sigma_{SM}$	**11.1**	**11.0**	**12.6**	**13.6**	**17.3**	**23.9**	**33.3**

Table: *WH* trilepton analysis limits for 4.8fb^{-1}. [For Public Release Blessing]

ZH Final Limits

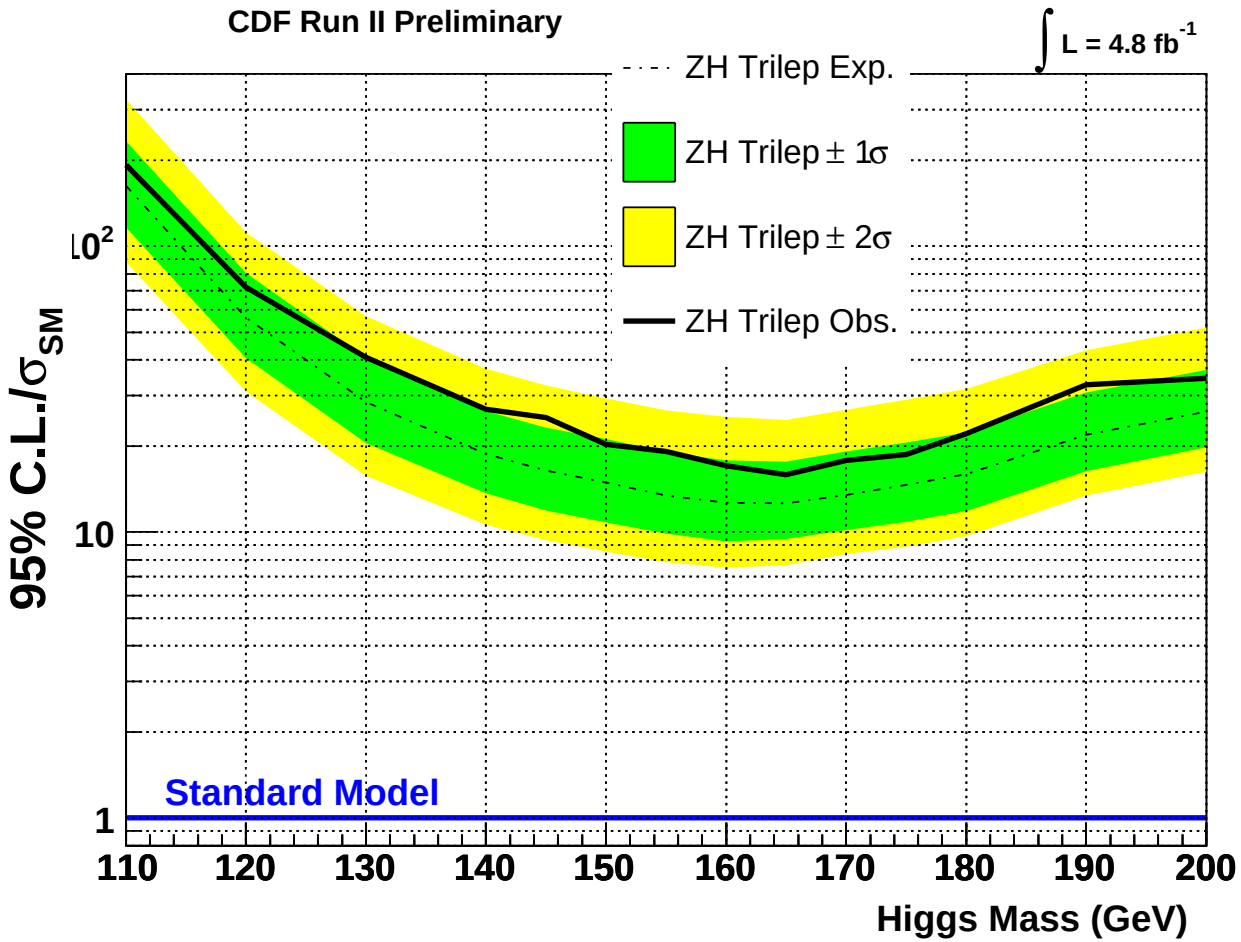


Figure: [For Public Release Blessing]

ZH Final Limits

Limits	110	120	130	140	145	150	155
$+2\sigma/\sigma_{SM}$	327	112	57.0	37.3	32.6	29.7	26.7
$+1\sigma/\sigma_{SM}$	233	80.6	40.6	26.5	23.2	21.1	19.1
Median$/\sigma_{SM}$	**162**	**56.3**	**28.5**	**18.8**	**16.4**	**14.9**	**13.4**
$-1\sigma/\sigma_{SM}$	116	40.6	20.5	13.7	11.9	10.8	9.90
$-2\sigma/\sigma_{SM}$	88.0	31.1	15.7	10.6	9.37	8.54	7.86
Observed$/\sigma_{SM}$	**192**	**71.9**	**40.8**	**27.0**	**25.2**	**20.3**	**19.1**
Limits	160	165	170	175	180	190	200
$+2\sigma/\sigma_{SM}$	25.2	24.6	26.8	29.0	31.7	43.3	52.0
$+1\sigma/\sigma_{SM}$	17.8	17.6	19.1	20.6	22.4	30.8	37.0
Median$/\sigma_{SM}$	**12.6**	**12.6**	**13.5**	**14.6**	**16.0**	**21.9**	**26.4**
$-1\sigma/\sigma_{SM}$	9.27	9.44	10.1	10.9	11.9	16.3	19.8
$-2\sigma/\sigma_{SM}$	7.50	7.65	8.37	8.91	9.68	13.4	16.2
Observed$/\sigma_{SM}$	**17.0**	**15.8**	**17.8**	**18.7**	**22.1**	**32.8**	**34.5**

Table: ZH trilepton analysis limits for 4.8fb^{-1}. [For Public Release Blessing]

Trilepton Final Limits

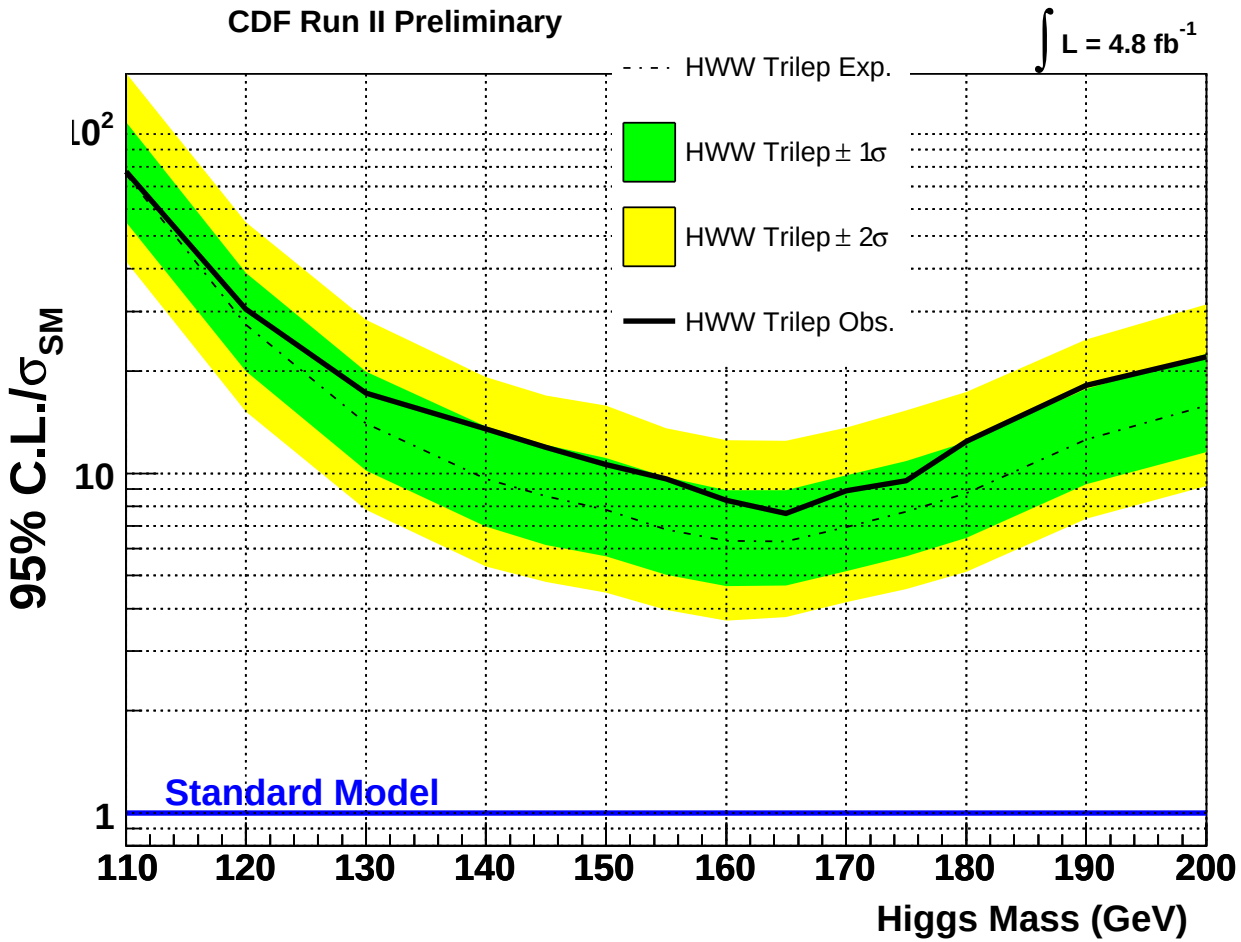


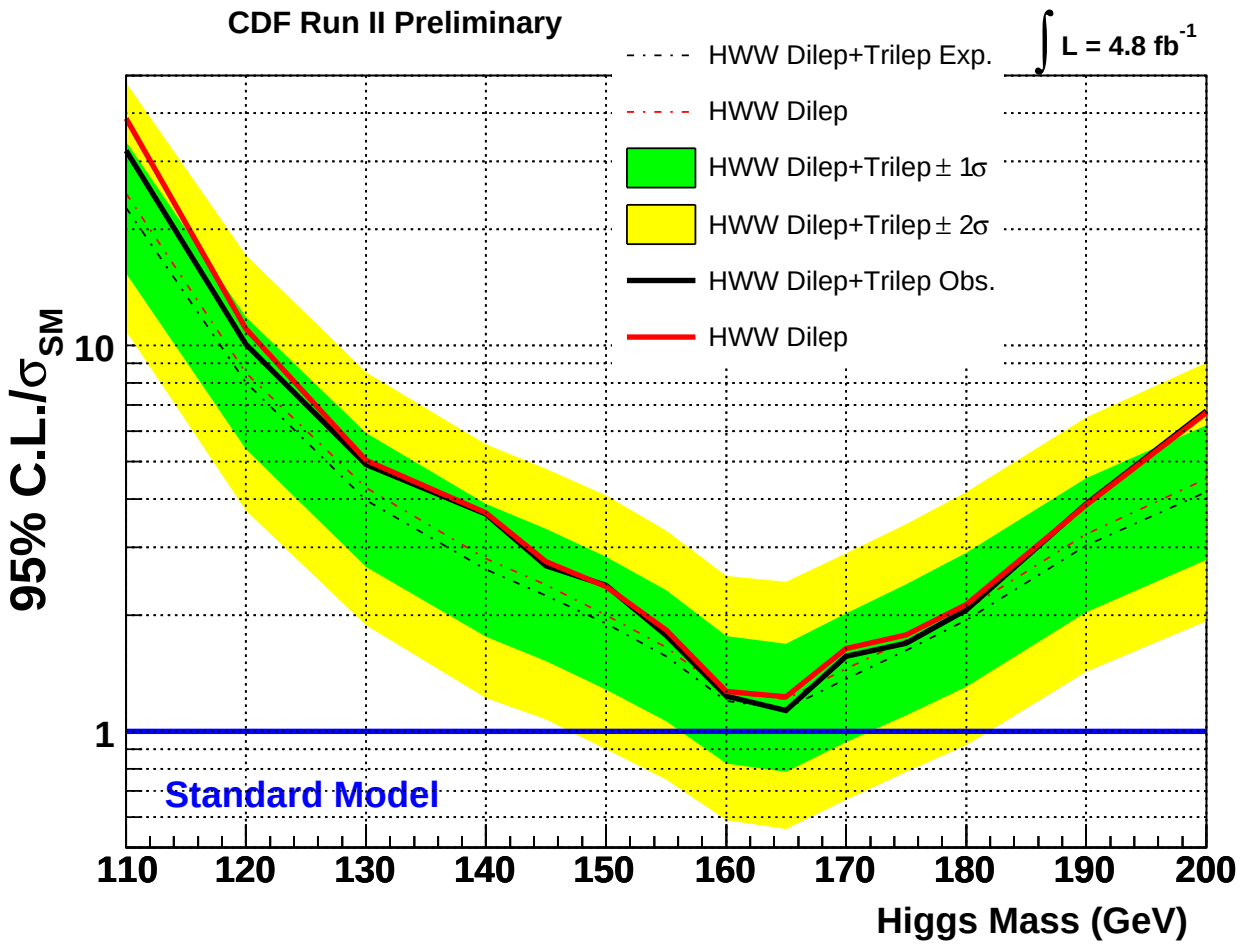
Figure: [For Public Release Blessing]

Trilepton Final Limits

Limits	110	120	130	140	145	150	155
$+2\sigma/\sigma_{SM}$	151	55.0	28.3	19.2	16.9	15.8	13.6
$+1\sigma/\sigma_{SM}$	108	38.9	20.0	13.7	12.1	11.1	9.74
Median$/\sigma_{SM}$	**75.8**	**27.4**	**14.0**	**9.63**	**8.55**	**7.79**	**6.84**
$-1\sigma/\sigma_{SM}$	54.9	20.0	10.2	6.96	6.16	5.69	5.03
$-2\sigma/\sigma_{SM}$	42.0	15.2	7.81	5.31	4.79	4.45	3.97
Observed$/\sigma_{SM}$	**77.4**	**30.5**	**17.2**	**13.5**	**12.0**	**10.6**	**9.64**
Limits	160	165	170	175	180	190	200
$+2\sigma/\sigma_{SM}$	12.5	12.5	13.6	15.3	17.4	24.8	31.5
$+1\sigma/\sigma_{SM}$	8.93	8.91	9.87	10.9	12.4	17.7	22.4
Median$/\sigma_{SM}$	**6.33**	**6.31**	**6.95**	**7.72**	**8.73**	**12.6**	**15.8**
$-1\sigma/\sigma_{SM}$	4.65	4.68	5.16	5.70	6.47	9.27	11.6
$-2\sigma/\sigma_{SM}$	3.69	3.78	4.17	4.57	5.13	7.36	9.17
Observed$/\sigma_{SM}$	**8.33**	**7.61**	**8.90**	**9.52**	**12.4**	**18.1**	**22.0**

Table: Trilepton combined (*WH* and *ZH*) analysis limits for 4.8fb^{-1}. [For Public Release Blessing]

$H \rightarrow WW$ w/ Trileptons (WZ,ZZ,$Z\gamma$ Decorrelated)



$H \to WW$ w/ Trileptons (WZ,ZZ,$Z\gamma$ Decorrelated)

Limits	110	120	130	140	145	150	155
$+2\sigma/\sigma_{SM}$	48.0	17.2	8.52	5.54	4.79	4.08	3.32
$+1\sigma/\sigma_{SM}$	33.8	11.9	5.93	3.89	3.53	2.83	2.32
Median$/\sigma_{SM}$	**22.7**	**8.02**	**3.96**	**2.63**	**2.25**	**1.90**	**1.56**
$-1\sigma/\sigma_{SM}$	15.4	5.39	2.67	1.76	1.52	1.28	1.06
$-2\sigma/\sigma_{SM}$	10.9	3.74	1.88	1.22	1.07	0.90	0.75
Observed$/\sigma_{SM}$	**32.0**	**10.1**	**4.91**	**3.66**	**2.69**	**2.39**	**1.77**
Limits	160	165	170	175	180	190	200
$+2\sigma/\sigma_{SM}$	2.53	2.44	2.89	3.45	4.17	6.50	9.01
$+1\sigma/\sigma_{SM}$	1.76	1.69	2.02	2.41	2.91	4.53	6.21
Median$/\sigma_{SM}$	**1.20**	**1.14**	**1.37**	**1.62**	**1.94**	**3.03**	**4.17**
$-1\sigma/\sigma_{SM}$	0.83	0.78	0.94	1.10	1.31	2.03	2.78
$-2\sigma/\sigma_{SM}$	0.59	0.56	0.67	0.78	0.92	1.43	1.93
Observed$/\sigma_{SM}$	**1.23**	**1.13**	**1.57**	**1.69**	**2.07**	**3.88**	**6.78**

Table: HWW w/ Trileptons (WZ, ZZ, $Z\gamma$ Decorrelated)

$H \rightarrow WW$ w/ Trileptons Final Limits

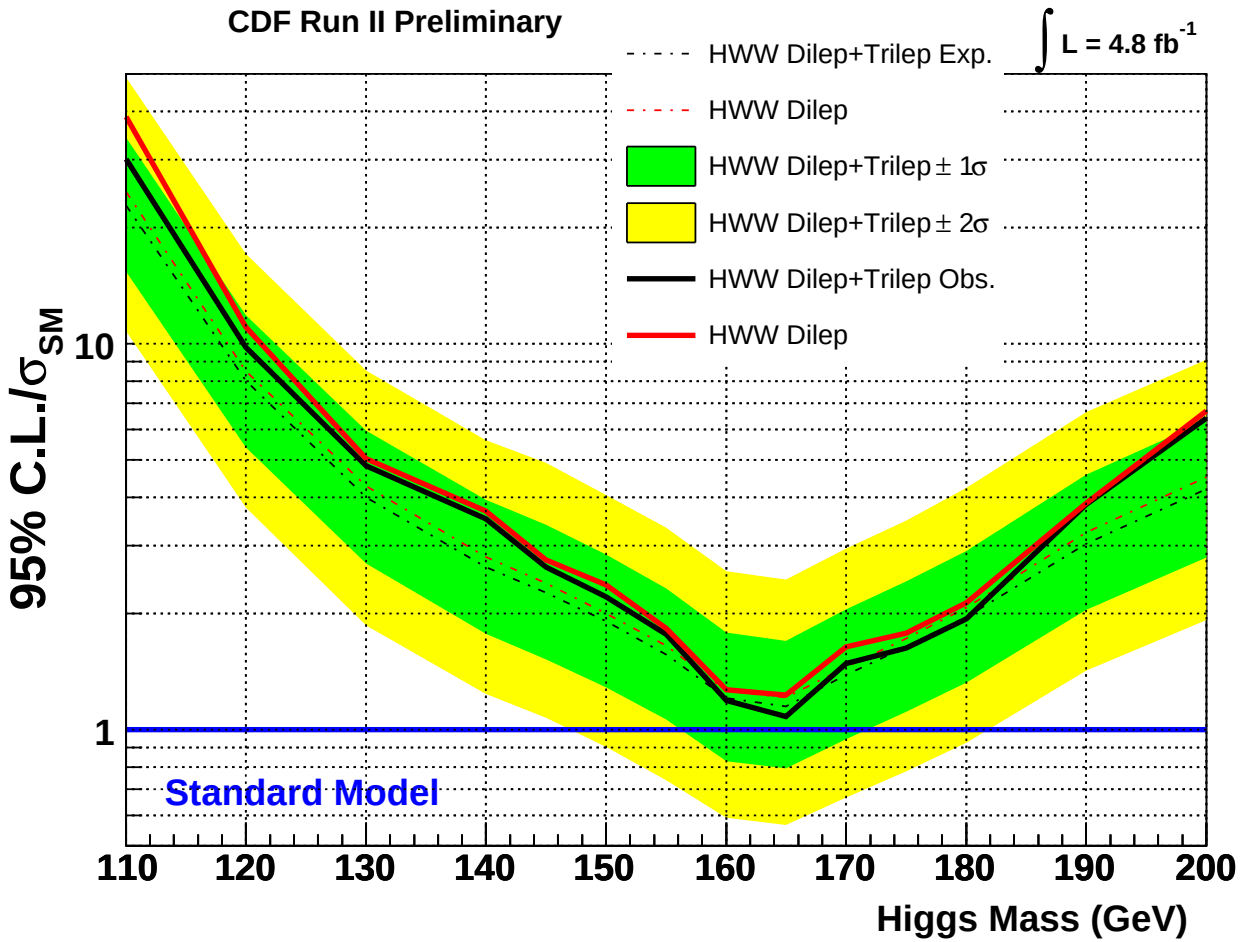


Figure: [For Public Release Blessing]

$H \rightarrow WW$ w/ Trileptons Final Limits

Limits	110	120	130	140	145	150	155
$+2\sigma/\sigma_{SM}$	49.0	17.1	8.52	5.62	4.91	4.06	3.34
$+1\sigma/\sigma_{SM}$	34.2	11.9	5.95	3.94	3.39	2.84	2.32
Median$/\sigma_{SM}$	**22.8**	**8.02**	**4.01**	**2.64**	**2.27**	**1.91**	**1.57**
$-1\sigma/\sigma_{SM}$	15.4	5.39	2.70	1.77	1.52	1.29	1.06
$-2\sigma/\sigma_{SM}$	10.8	3.76	1.86	1.24	1.08	0.90	0.74
Observed$/\sigma_{SM}$	**30.1**	**9.79**	**4.83**	**3.52**	**2.64**	**2.21**	**1.77**
Limits	160	165	170	175	180	190	200
$+2\sigma/\sigma_{SM}$	2.57	2.45	2.95	3.48	4.23	6.65	9.08
$+1\sigma/\sigma_{SM}$	1.79	1.70	2.05	2.42	2.91	4.57	6.33
Median$/\sigma_{SM}$	**1.21**	**1.15**	**1.39**	**1.64**	**1.96**	**3.03**	**4.20**
$-1\sigma/\sigma_{SM}$	0.83	0.79	0.94	1.11	1.32	2.04	2.80
$-2\sigma/\sigma_{SM}$	0.59	0.57	0.67	0.78	0.93	1.42	1.93
Observed$/\sigma_{SM}$	**1.19**	**1.08**	**1.49**	**1.63**	**1.94**	**3.83**	**6.41**

Table: HWW w/ Trileptons Combined Expected Sensitivity. [For Public Release Blessing]

Conclusions

- Limit improvements to note:
  - For $m_H = 165$ GeV, median expected limit improves $1.21 \rightarrow 1.15$.
  - For $m_H = 165$ GeV, median observed limit improves $1.23 \rightarrow 1.08$.
- Shape systematics are still very small, but slated for inclusion for the next iteration.
- Hadronic τ's would improve acceptance.
- Decreasing ΔR limit between leptons would improve acceptance.
- CDF note 10020 to be updated this weekend.
- Upgrade to 5.4fb^{-1} to begin immediately after blessing.

For Public Release

All items in this presentation that are intended for public release are labelled with [For Public Release Blessing]

- Expected background, signal, and data counts. (slide 6)
- Systematic Errors (slide 19)
- *WH* Trilepton analysis limits (slides 20, 21)
- *ZH* Trilepton analysis limits (slides 22, 23)
- Trilepton combined limits (slides 24, 25)
- $H \rightarrow WW$ w/ Trileptons combined limits (slides 28, 29)
- Neural Net scores for all mass bins in the Backup section (slides 32 - 58).
- Discriminating Variables (slides 60 - 90).

WH Neural Net ($m_H = 110$ GeV)

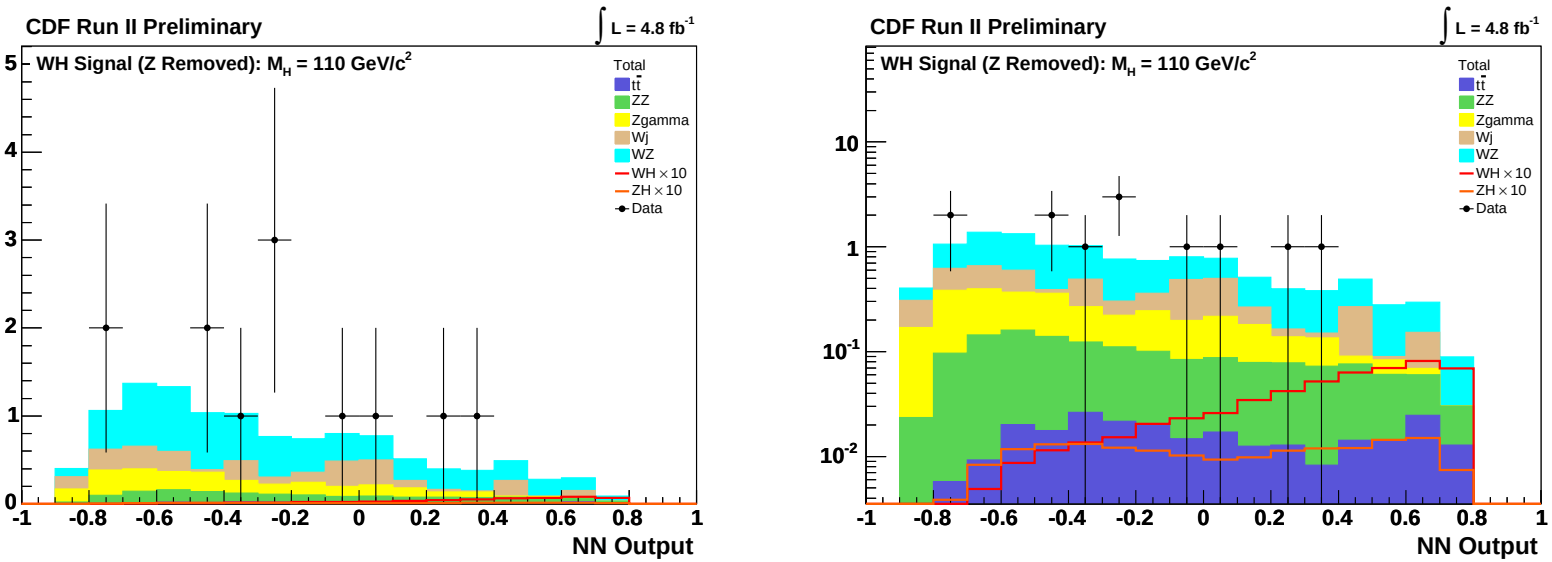


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 120$ GeV)

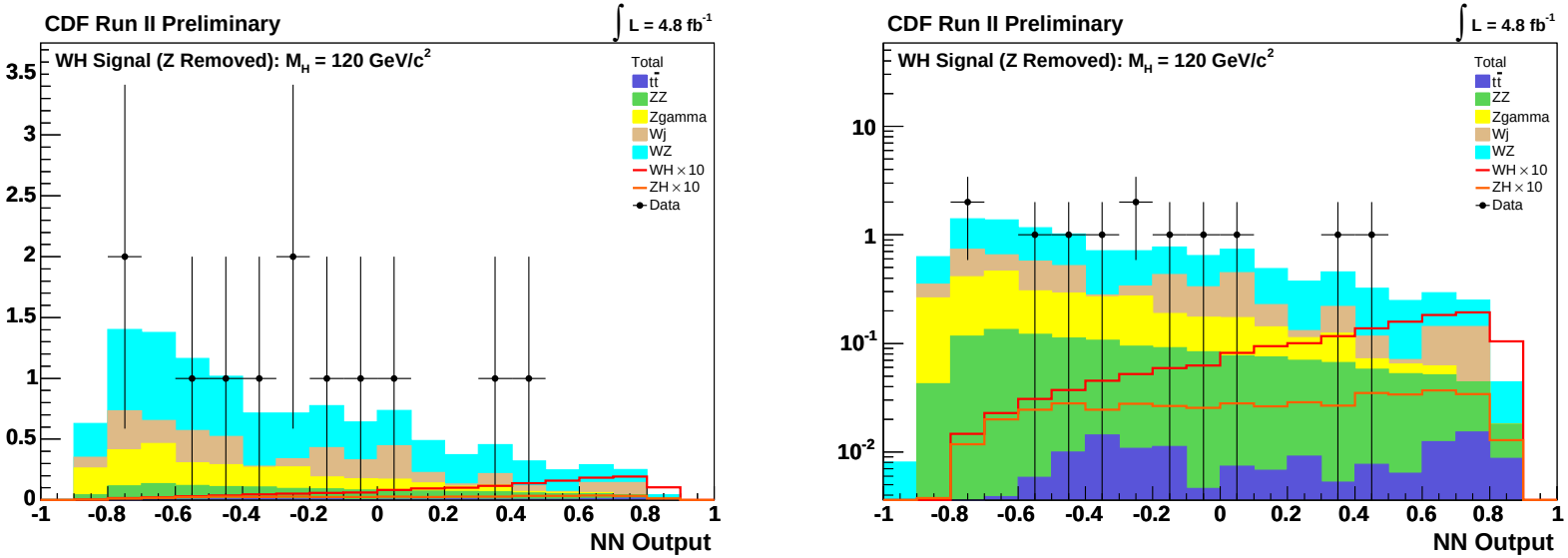


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 130$ GeV)

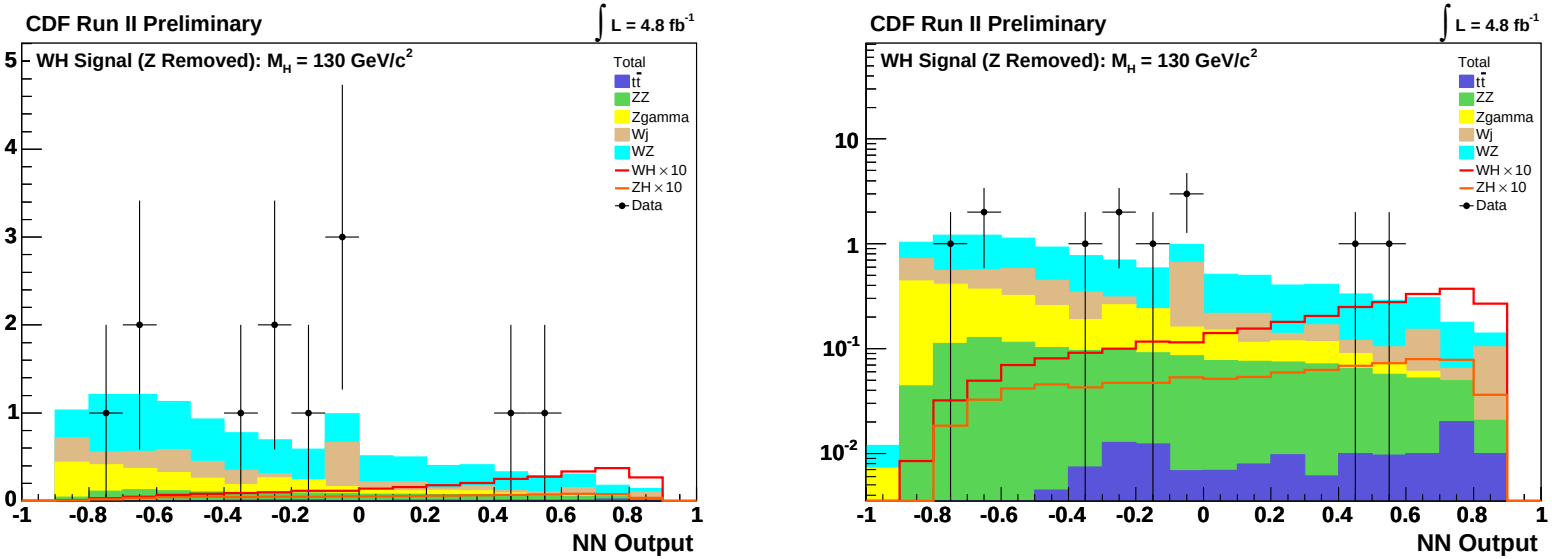


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 140$ GeV)

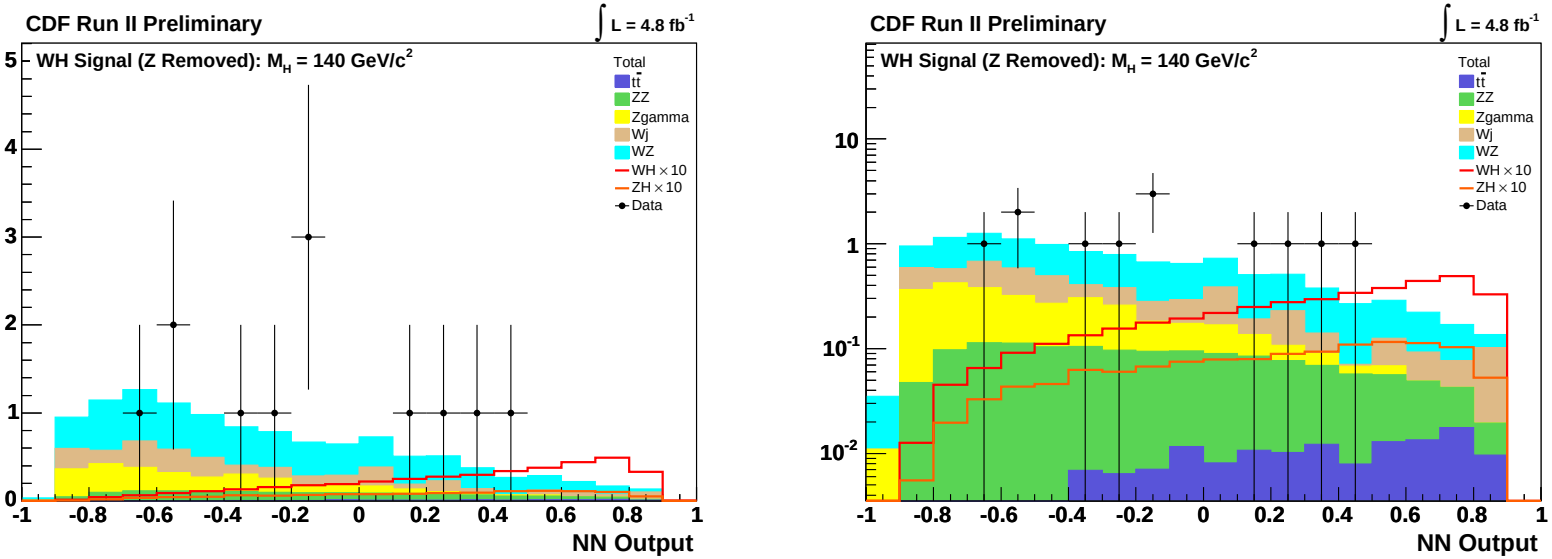


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 145$ GeV)

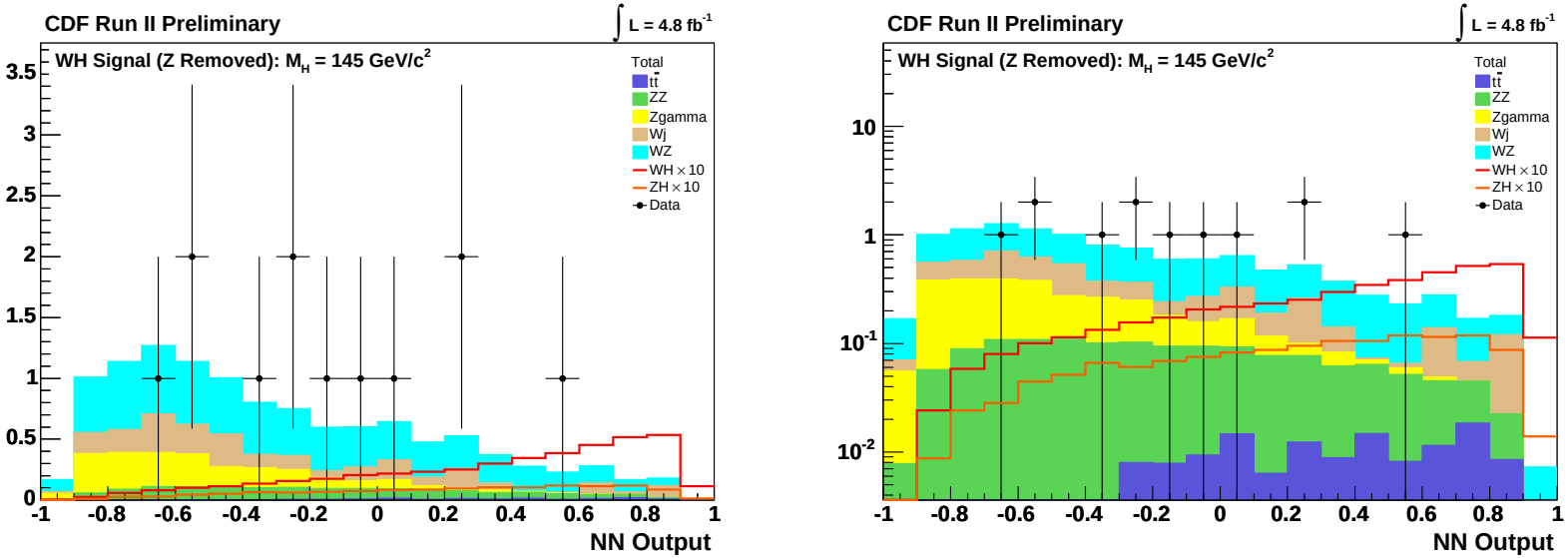


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 150$ GeV)

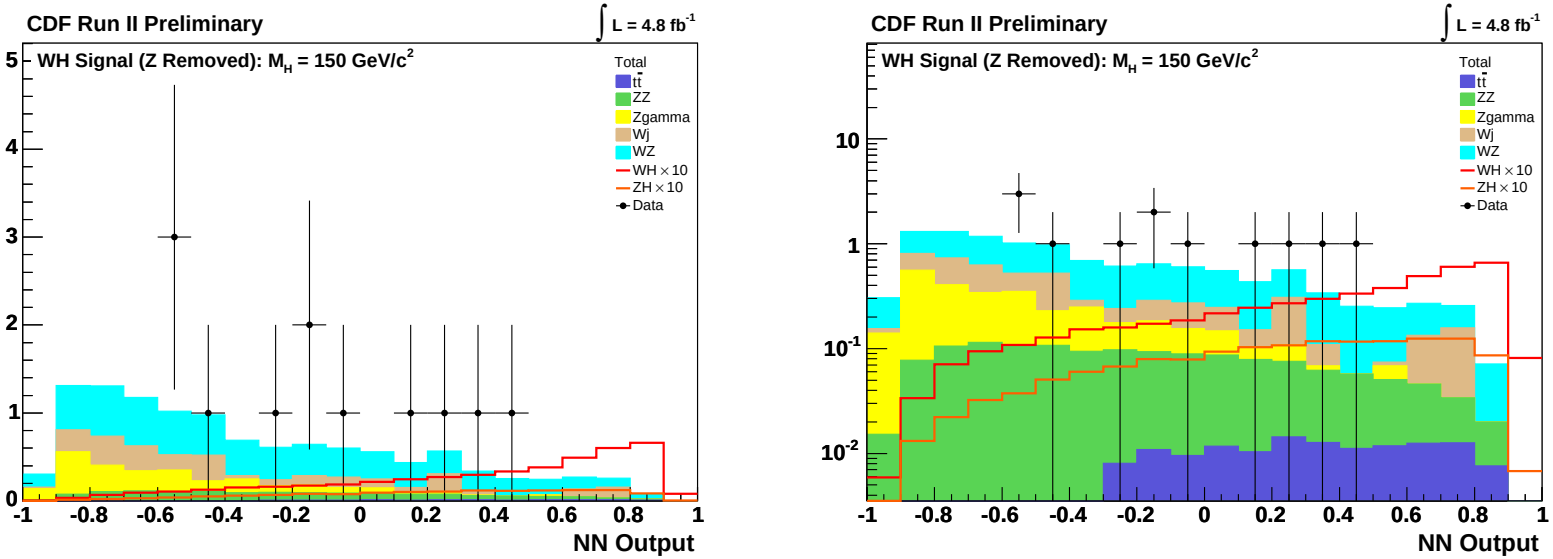


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 155$ GeV)

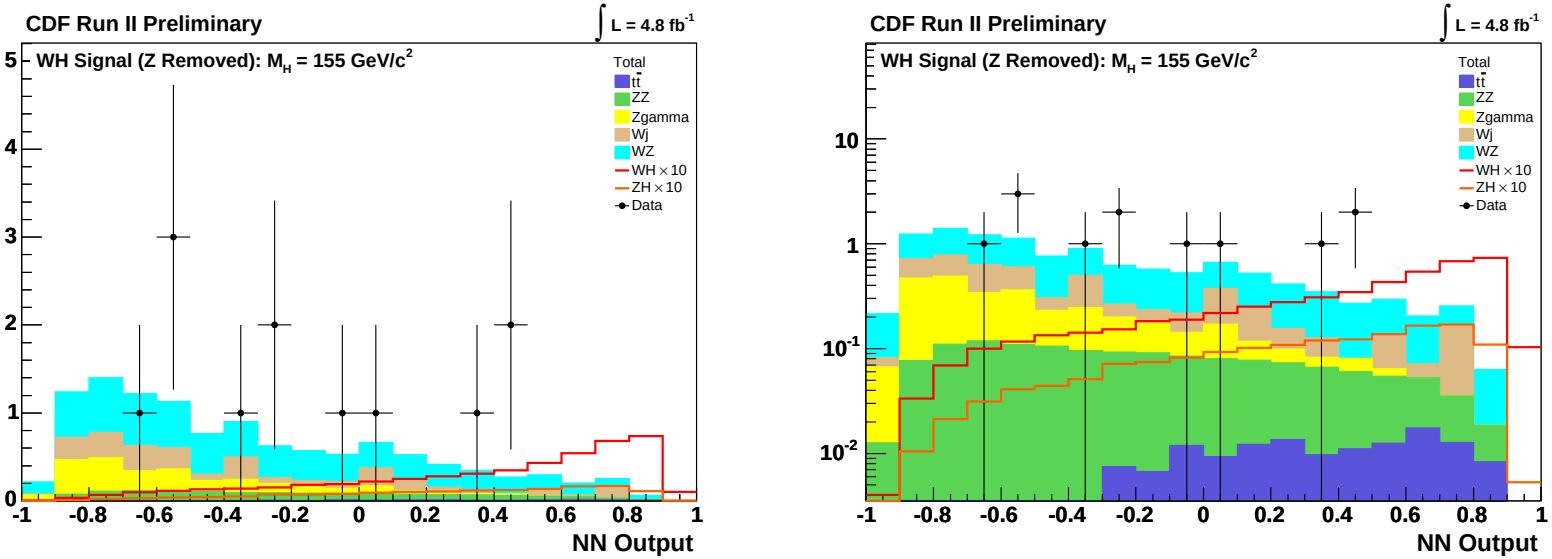


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 160$ GeV)

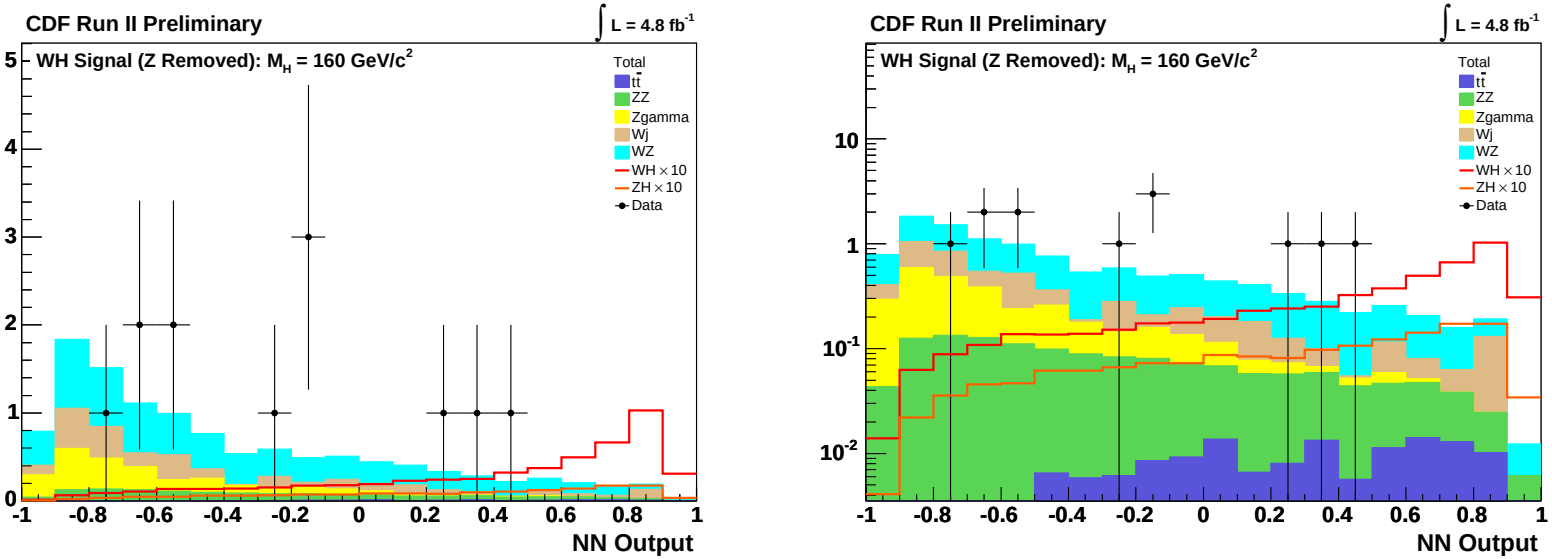


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 165$ GeV)

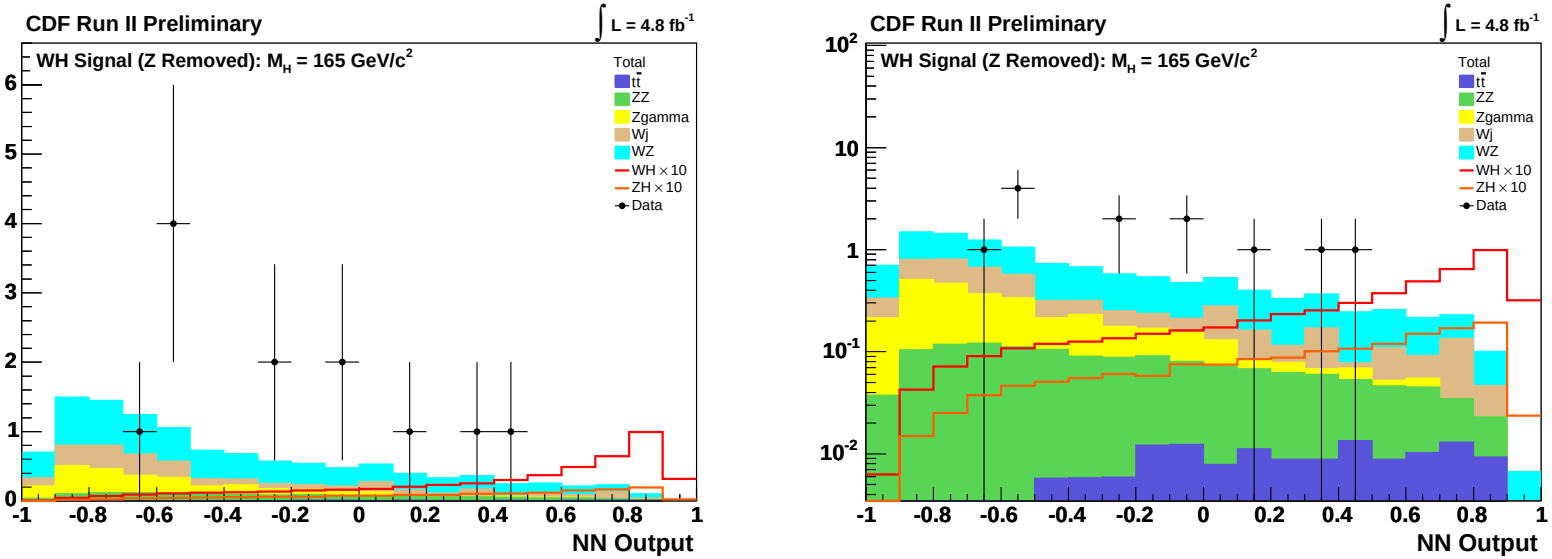


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 170$ GeV)

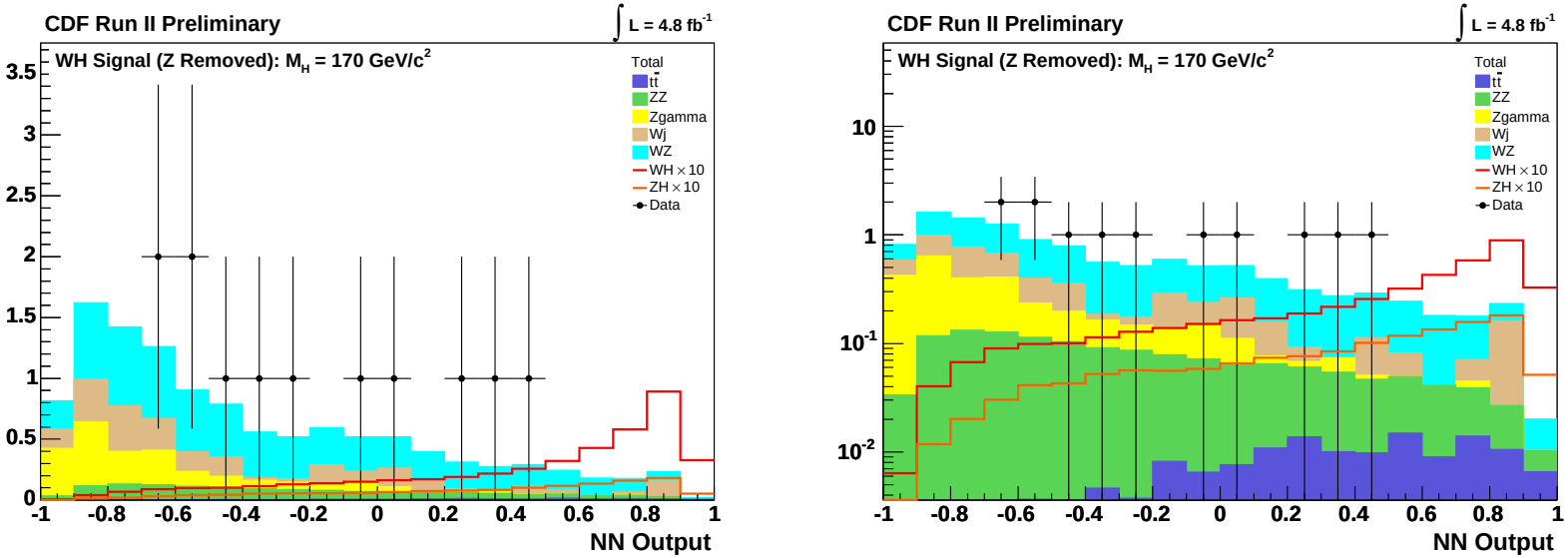


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 175$ GeV)

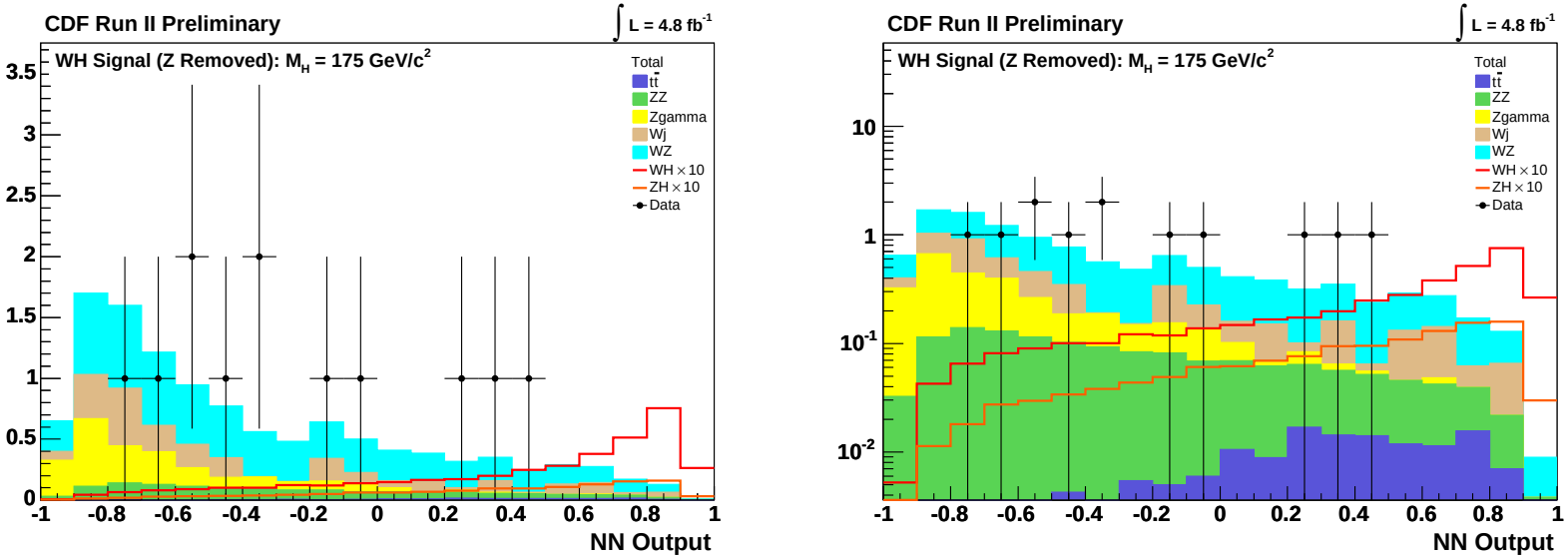


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 180$ GeV)

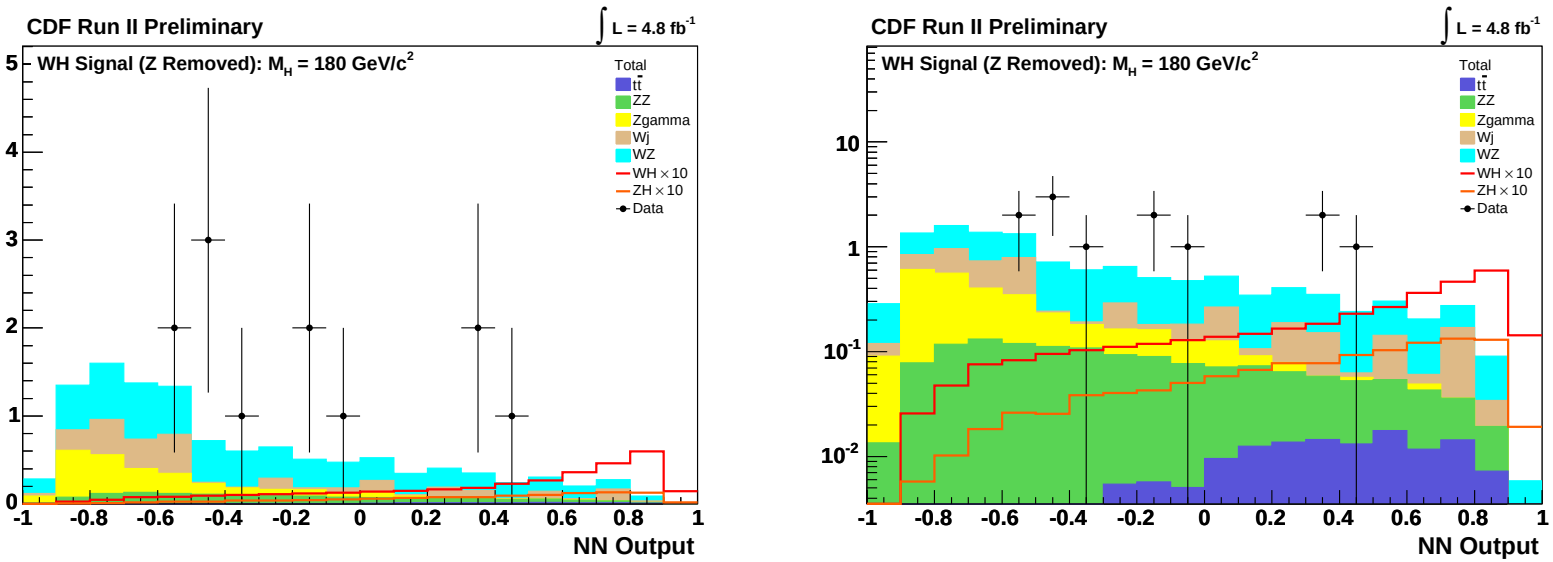


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 190$ GeV)

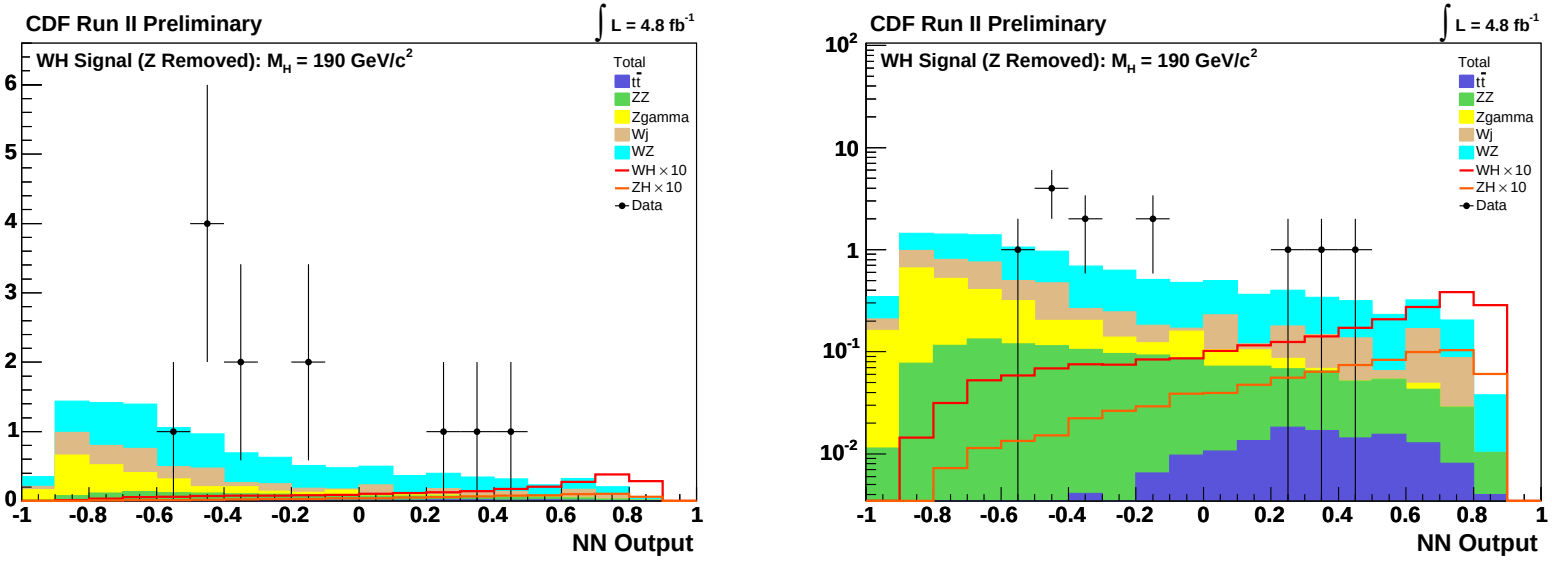


Figure: [For Public Release Blessing]

WH Neural Net ($m_H = 200$ GeV)

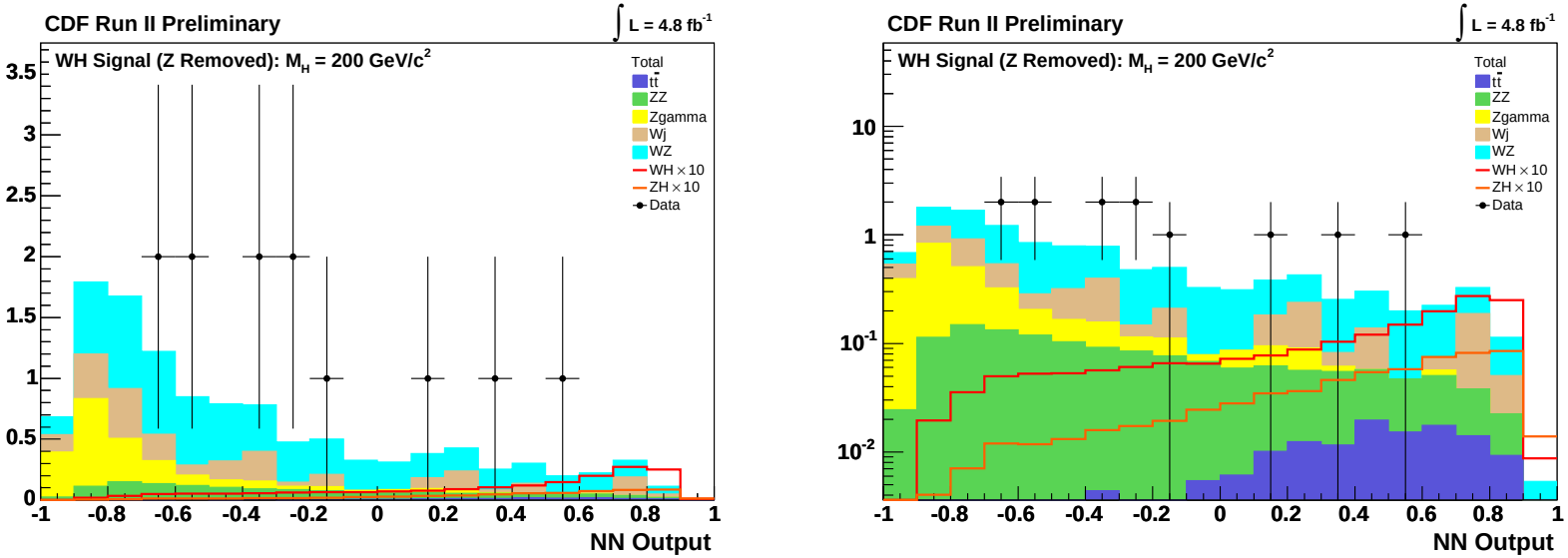


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 110$ GeV)

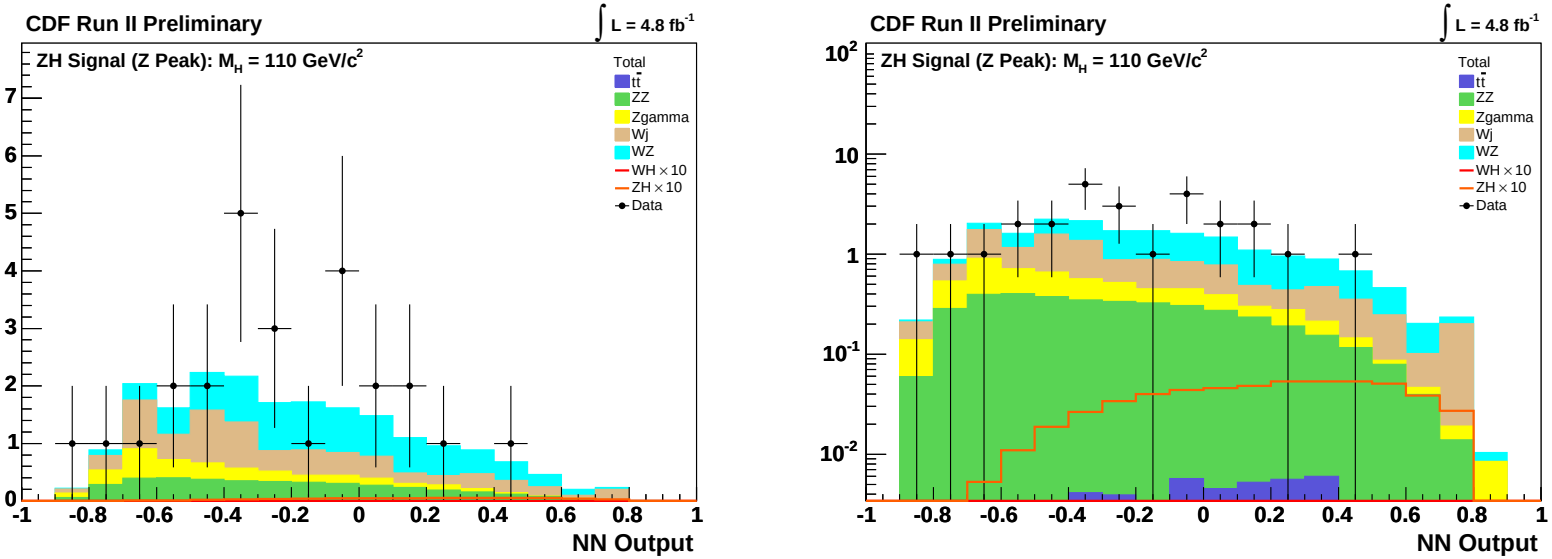
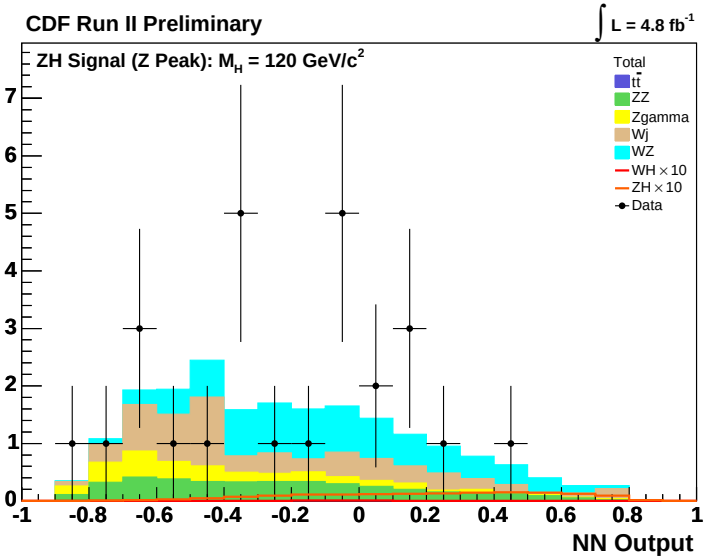


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 120$ GeV)



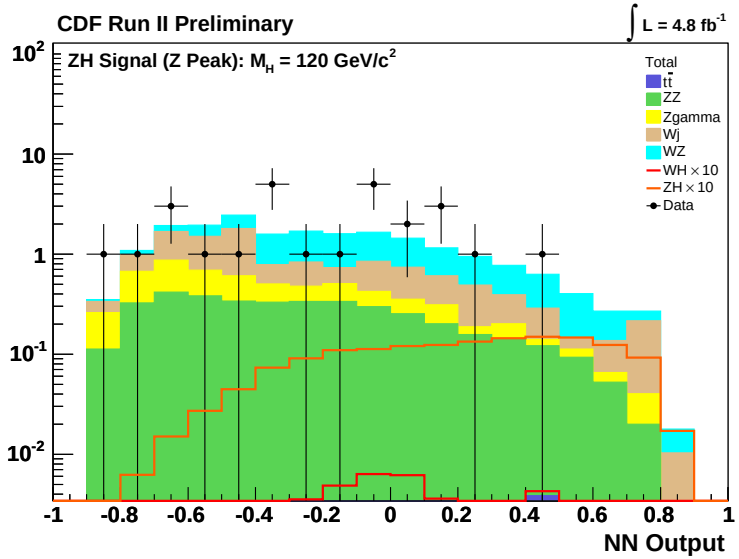


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 130$ GeV)

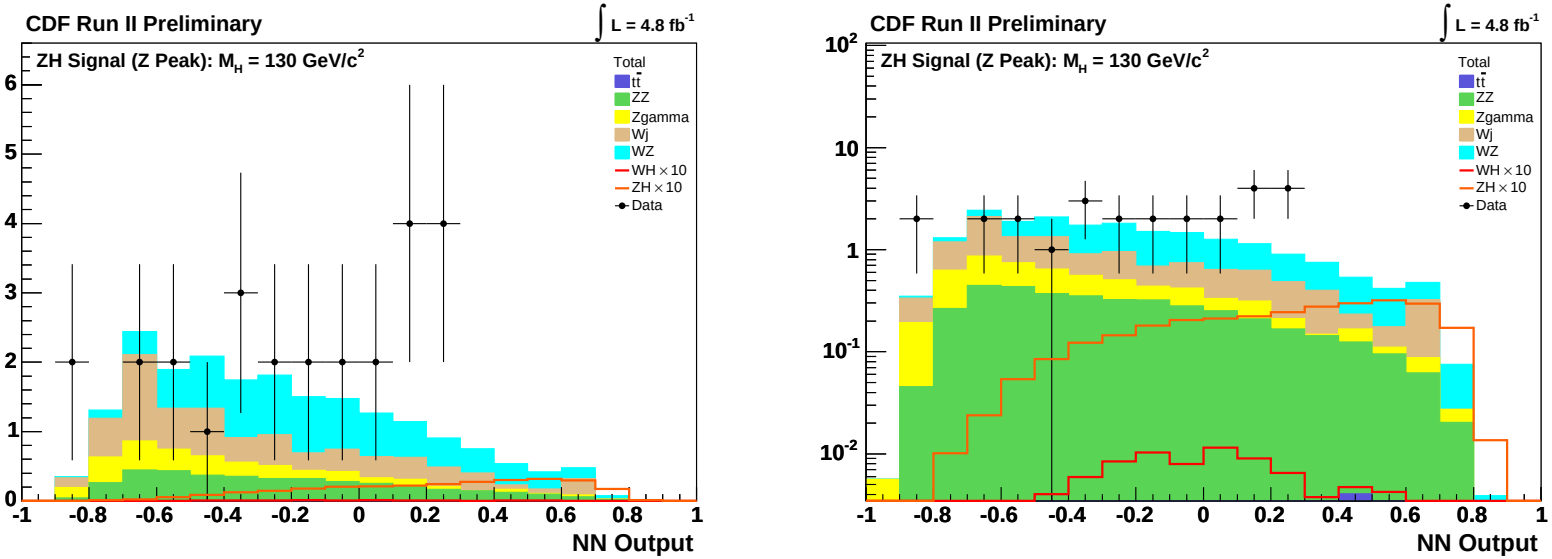


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 140$ GeV)

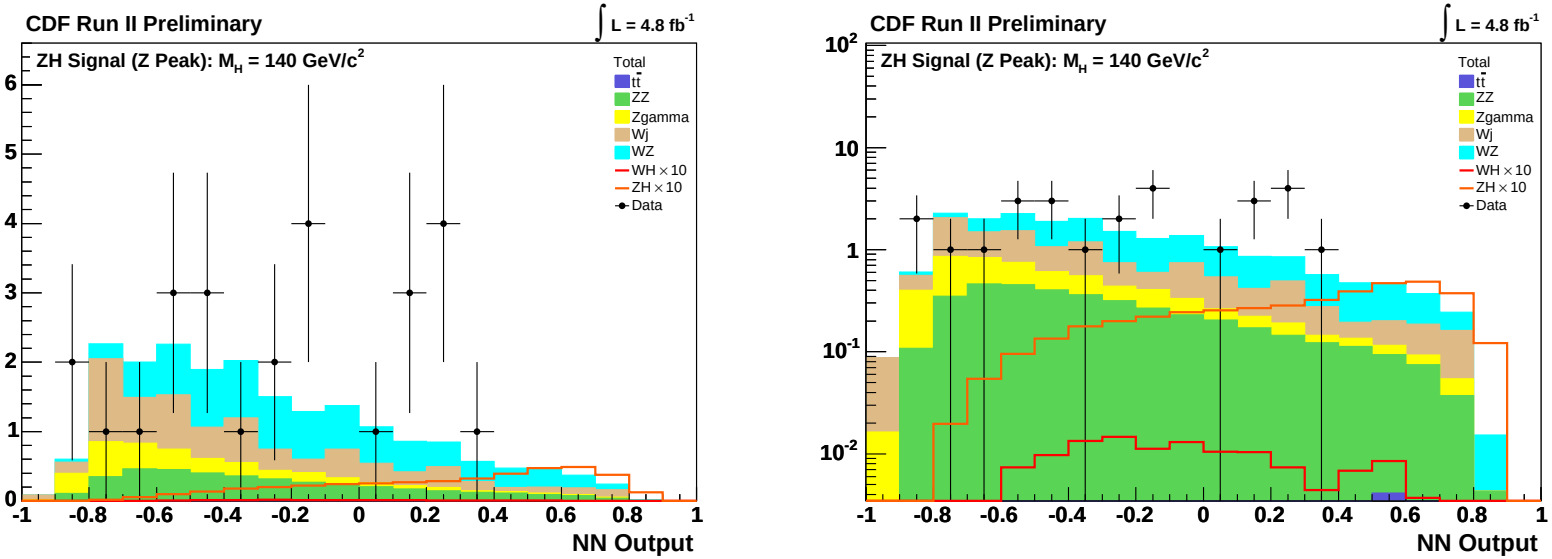


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 145$ GeV)

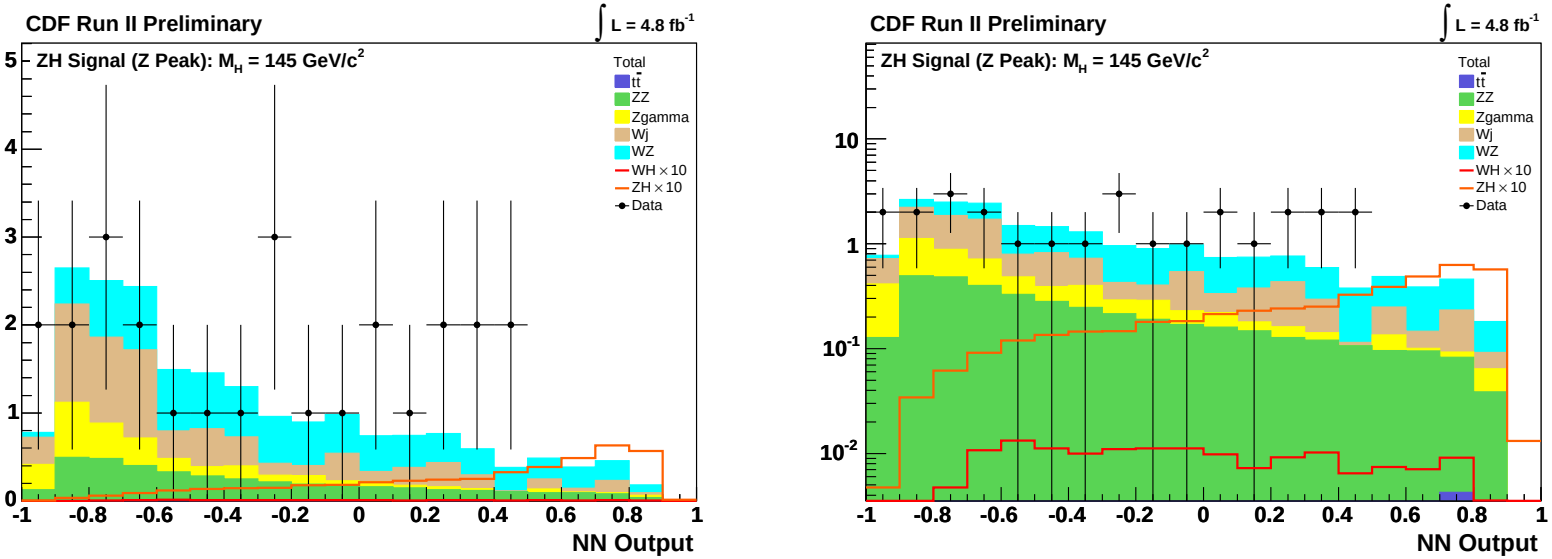


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 150$ GeV)

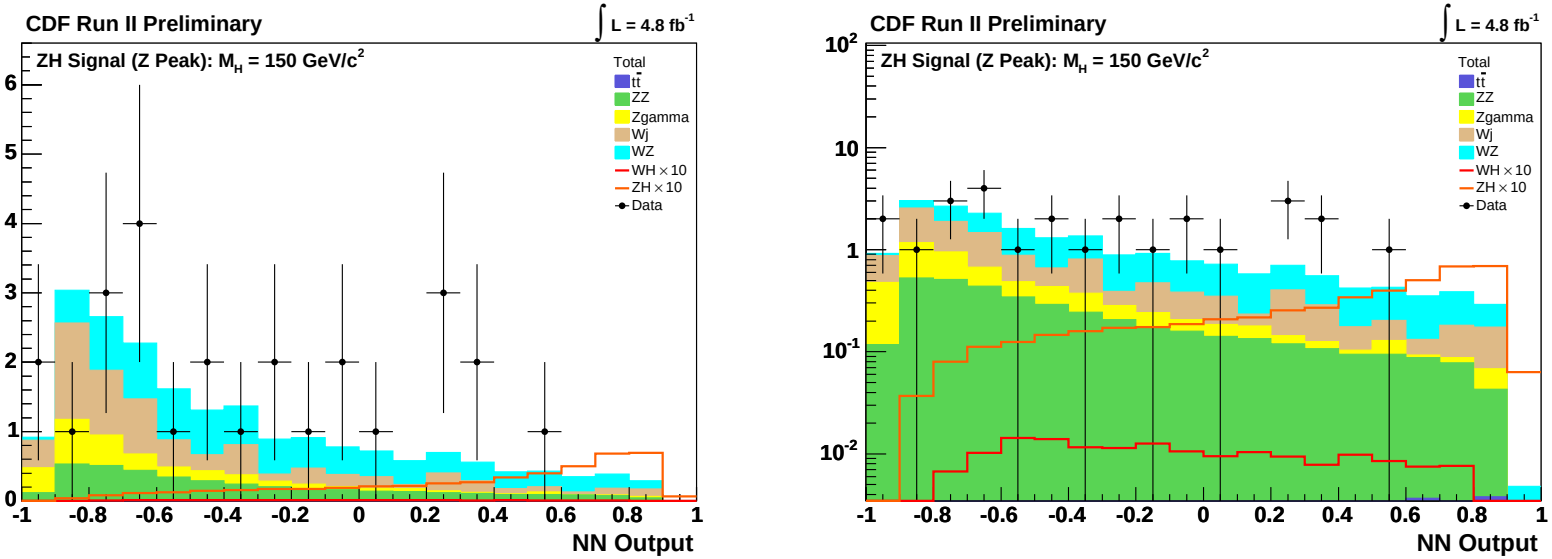


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 155$ GeV)

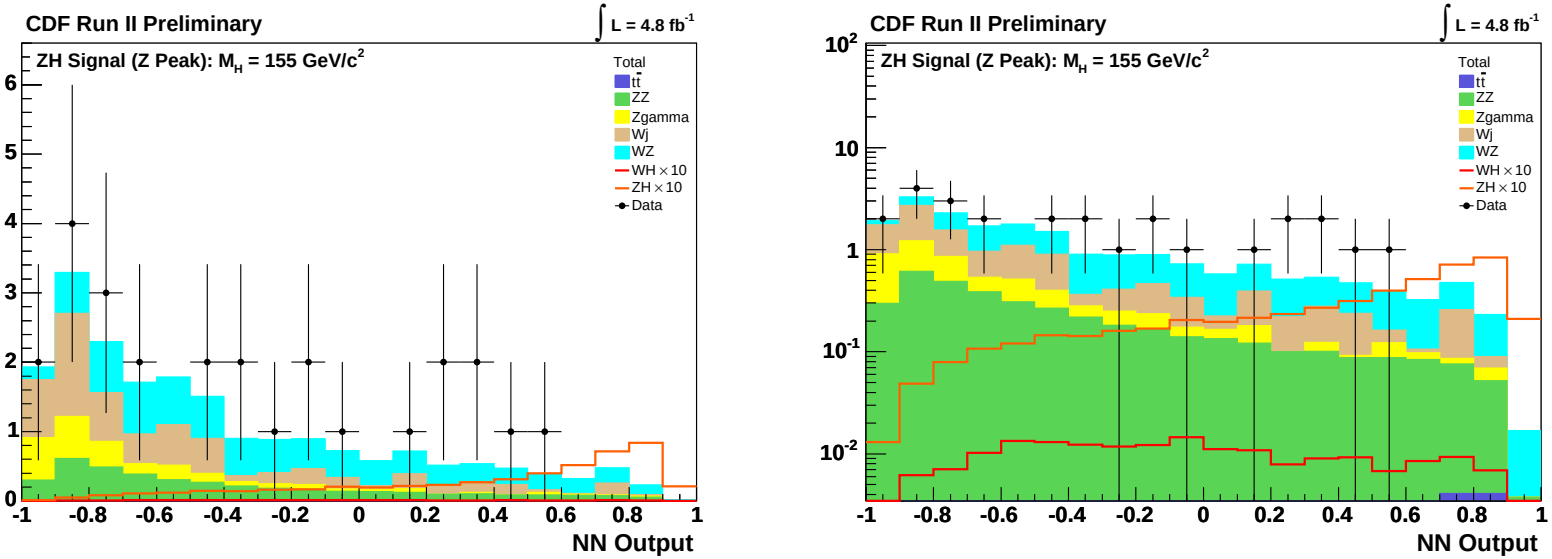


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 160$ GeV)

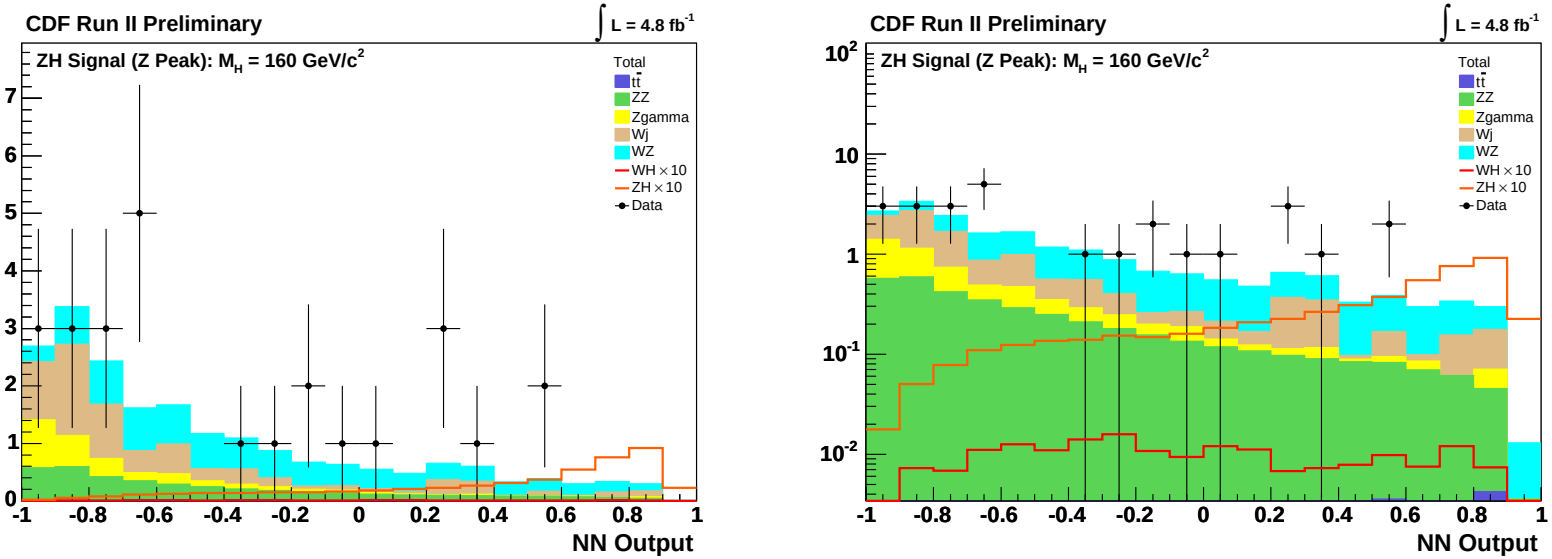


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 165$ GeV)

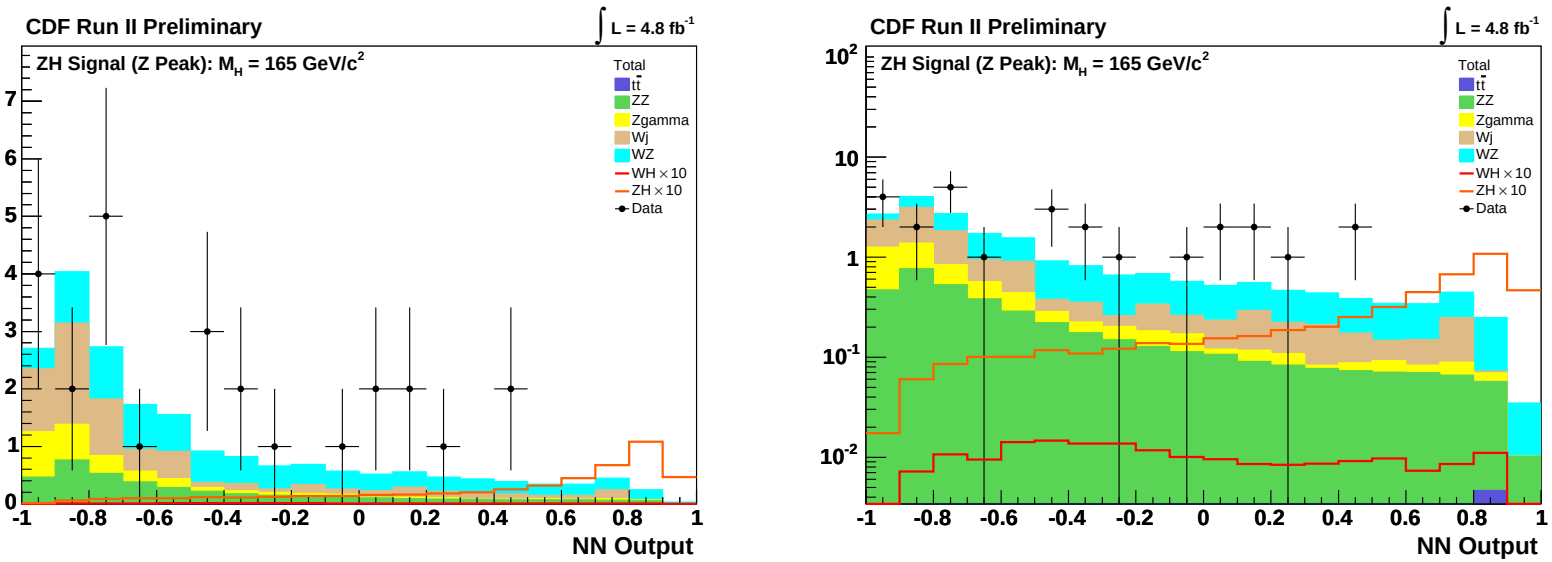


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 170$ GeV)

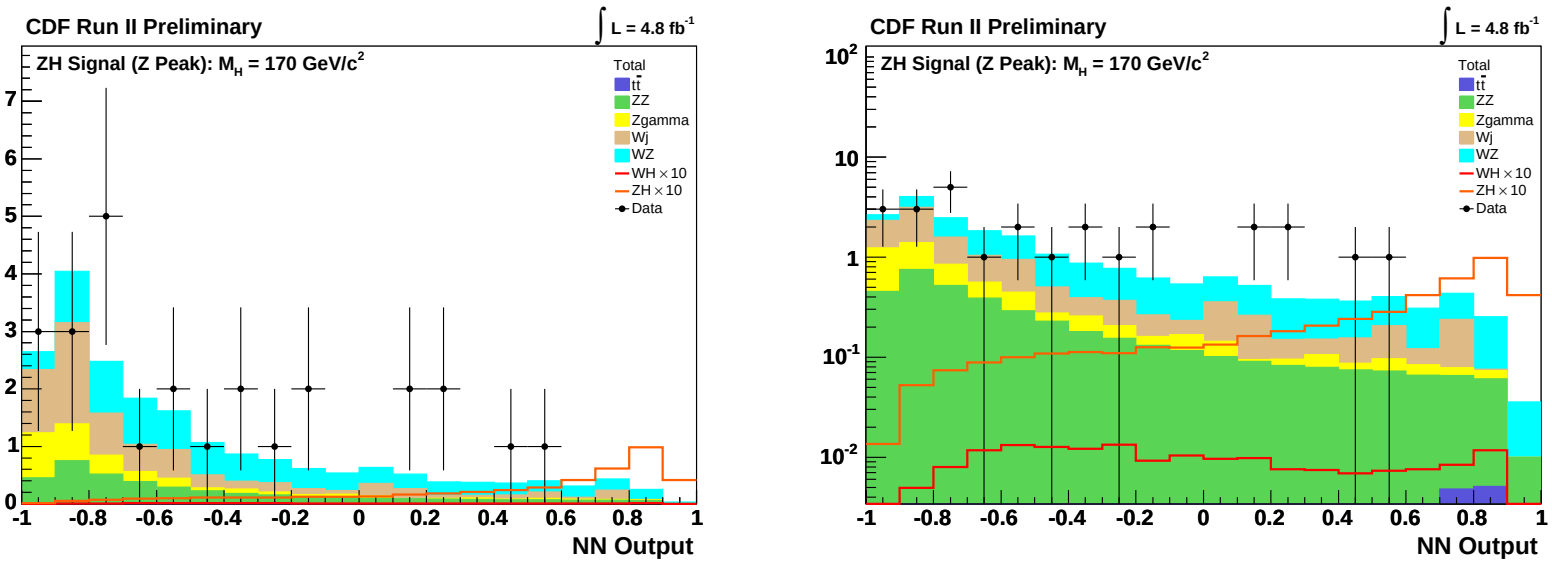


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 175$ GeV)

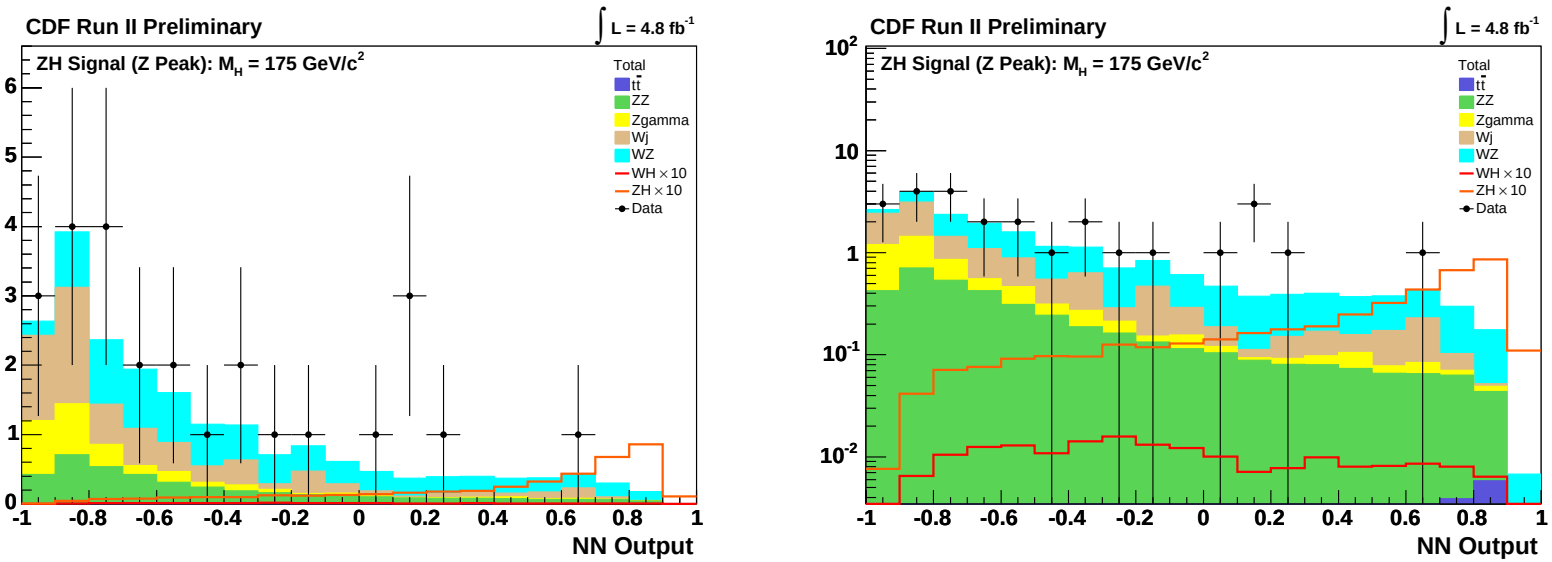


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 180$ GeV)

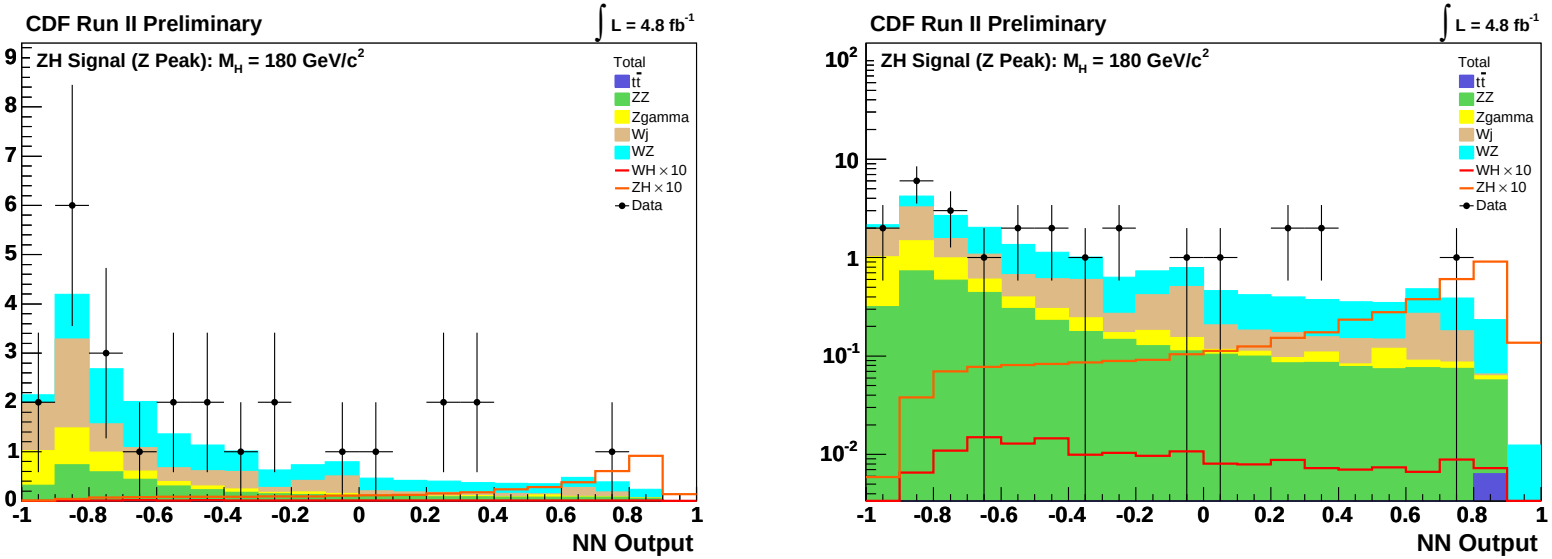


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 190$ GeV)

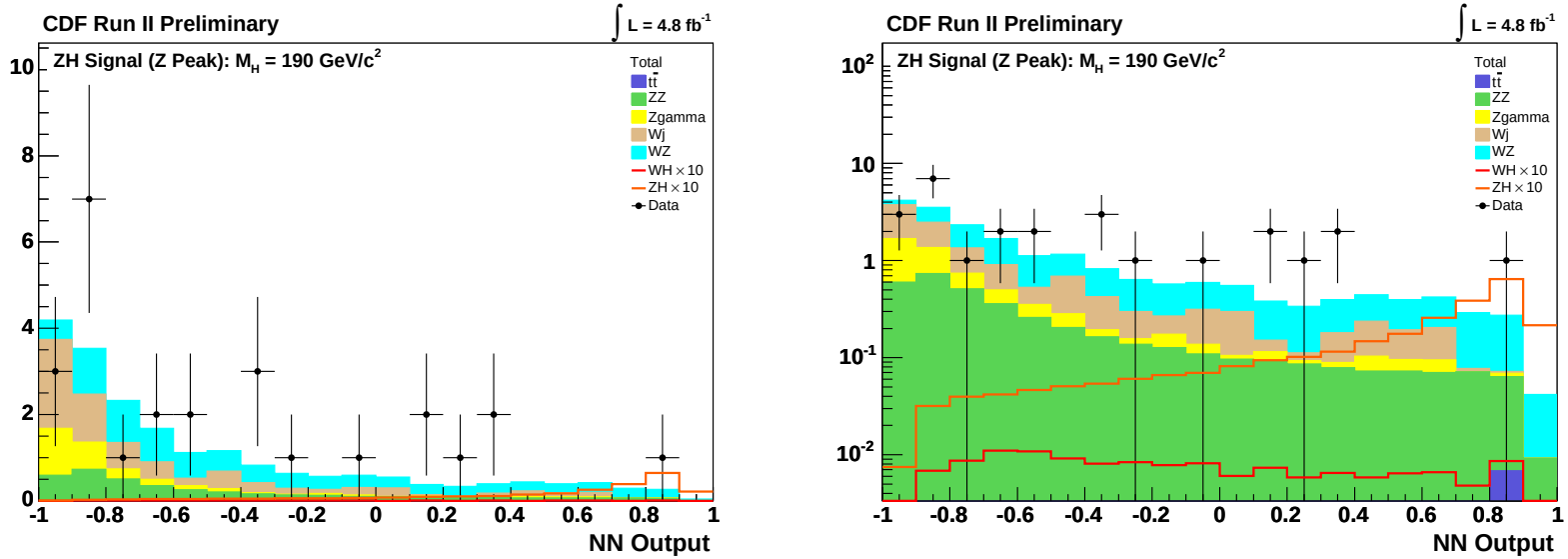


Figure: [For Public Release Blessing]

ZH Neural Net ($m_H = 200$ GeV)

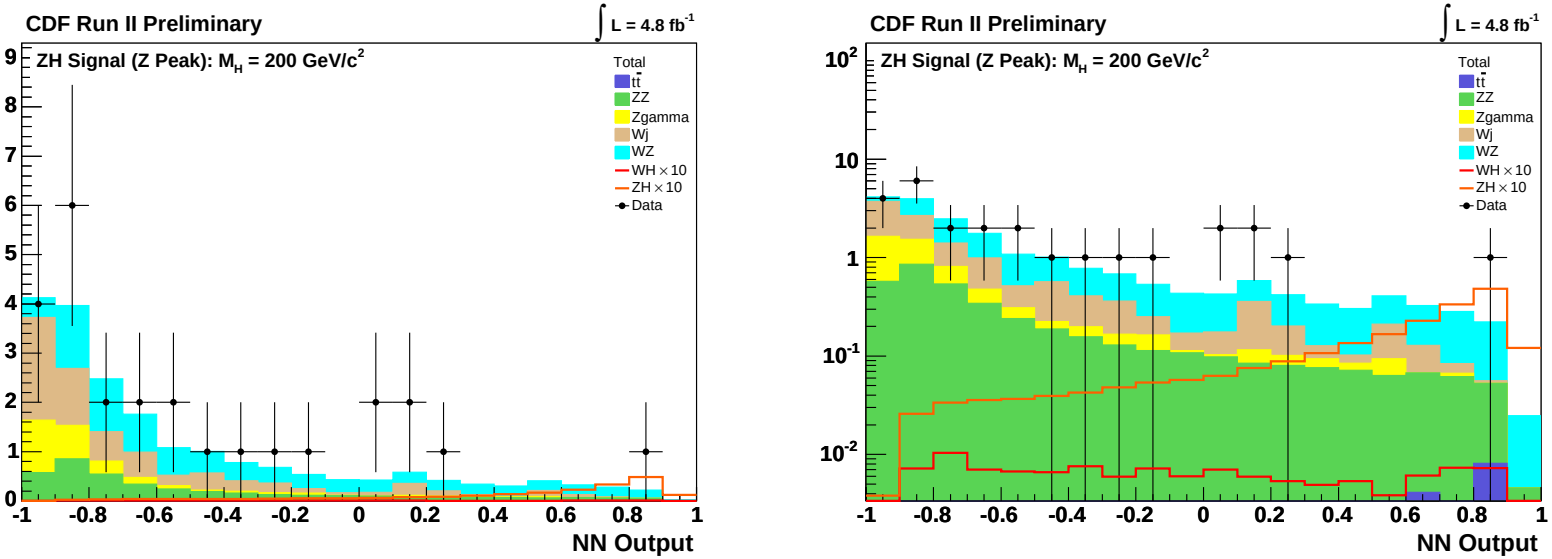


Figure: [For Public Release Blessing]

Full Disc. Variable Lists

Ordered by significance for $m_H = 160$ GeV.

ZH Variables

- NJet
- $\not\!\!E_T$
- Lead Jet E_T
- ΔR(*W*-Lep, Lead Jet)
- $\Delta\phi$(Leptons,$\not\!\!E_T$)
- m_T(Leptons,$\not\!\!E_T$,Jets)
- $\Delta\phi$(Lep2,$\not\!\!E_T$)
- ΔR b/w Opp. Sign Close Lept.
- Trilepton Inv. Mass
- Inv. Mass(Lep3,$\not\!\!E_T$,Jets)
- H_T(Leptons,$\not\!\!E_T$,Jets)
- m_T Jets
- Dimass(*W*-Lep,$\not\!\!E_T$)
- m_T(*W*-Lep,$\not\!\!E_T$)
- ΔR Opp. Sign Far Lept.
- $\Delta\phi$(*Z*-Leptons,*W*-Lepton)

WH Variables

- ΔR b/w Opp. Sign Close Lept.
- $\not\!\!E_T$
- Dimass b/w Opp. Sign Close by ϕ
- H_T
- $\Delta\phi$(Lep2,$\not\!\!E_T$)
- m_T(Leptons,$\not\!\!E_T$,Jets)
- p_T 2$^{\text{nd}}$ Lepton
- Inv. Mass(Lep3,$\not\!\!E_T$,Jets)
- ΔR Opp. Sign Far Lept.
- NJet
- m_T Trilepton Mass
- m_T (Lep3, $\not\!\!E_T$)
- Inv. Mass(Lep1,Lep2,$\not\!\!E_T$)

WH Signal: ΔR Opp. Sign Close

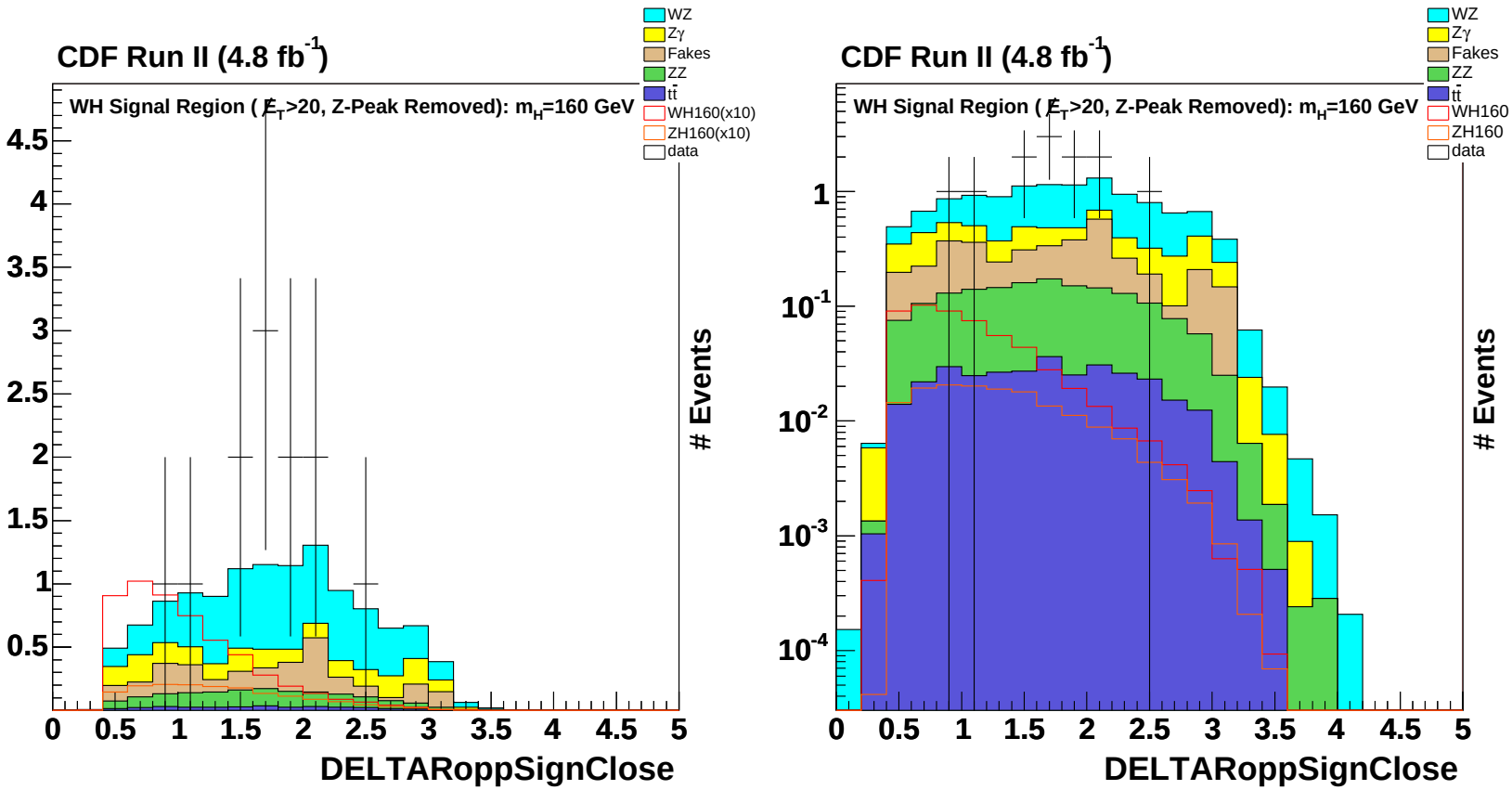


Figure: [For Public Release Blessing]

WH Signal: $\not\!\!E_T$

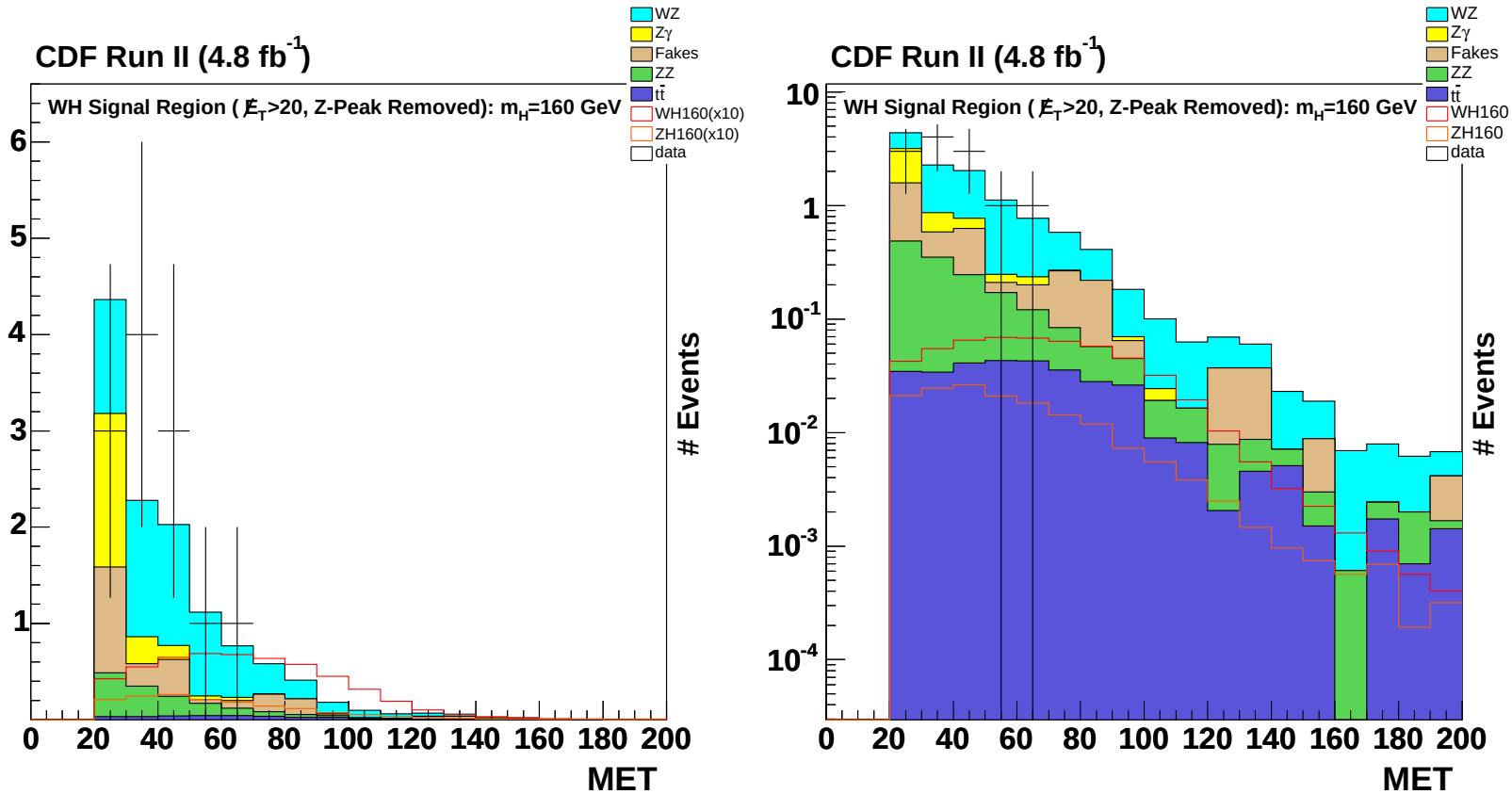


Figure: [For Public Release Blessing]

WH Signal: H_T

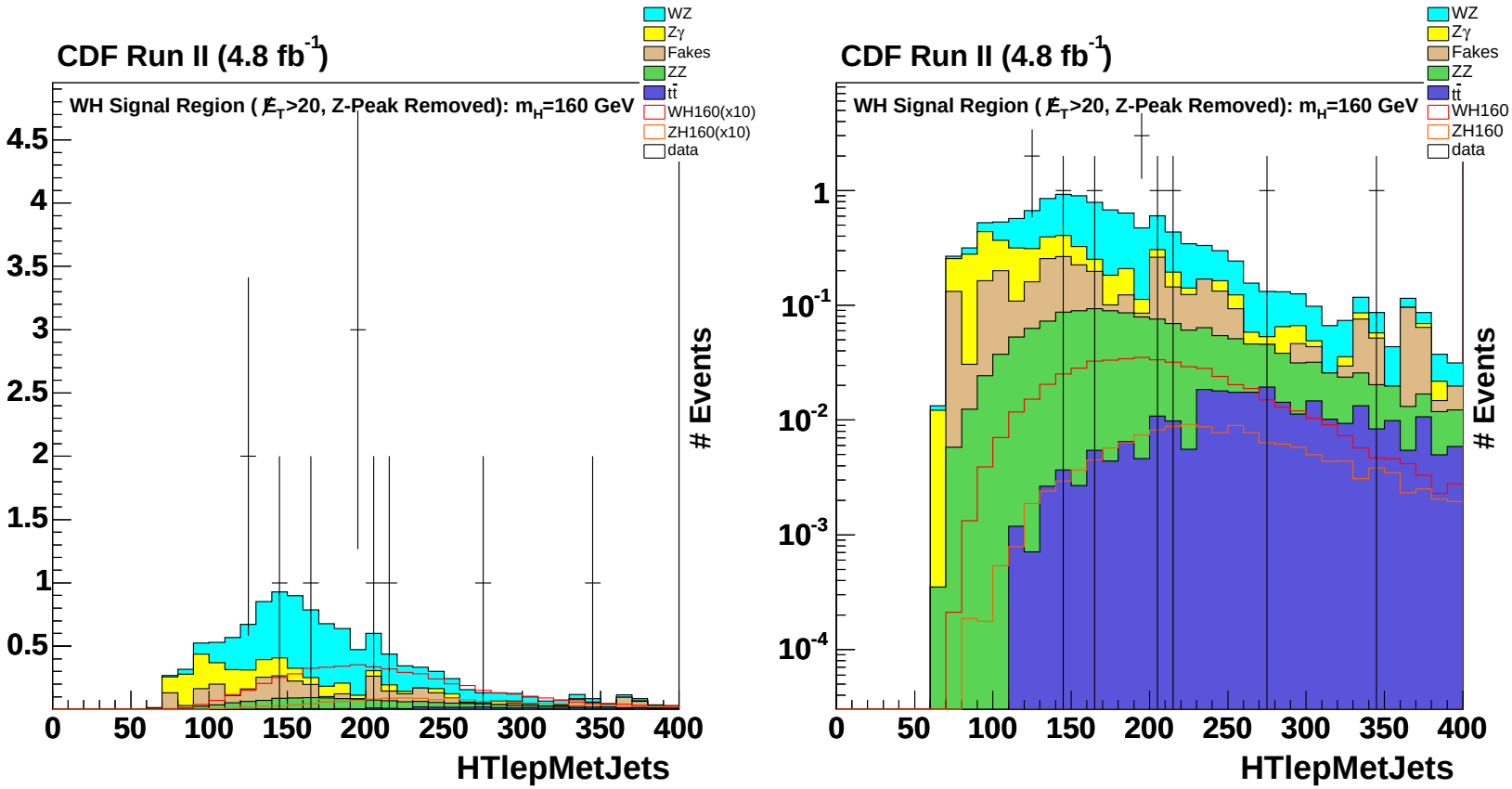


Figure: [For Public Release Blessing]

WH Signal: Dimass Opp. Sign Lepton (closer by ϕ)

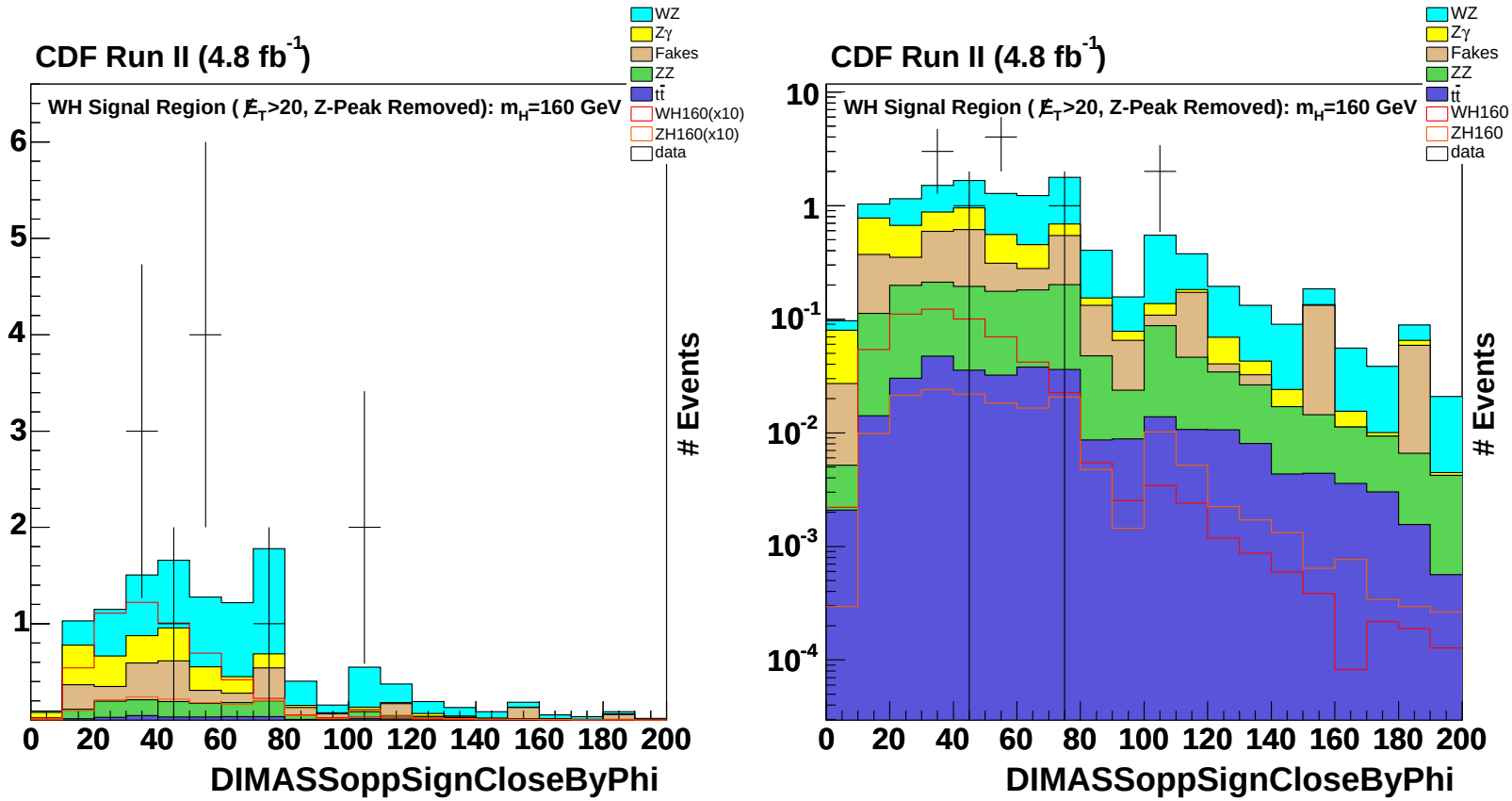


Figure: [For Public Release Blessing]

WH Signal: $\Delta\phi$ (2nd Lep, $\not\!\!E_T$)

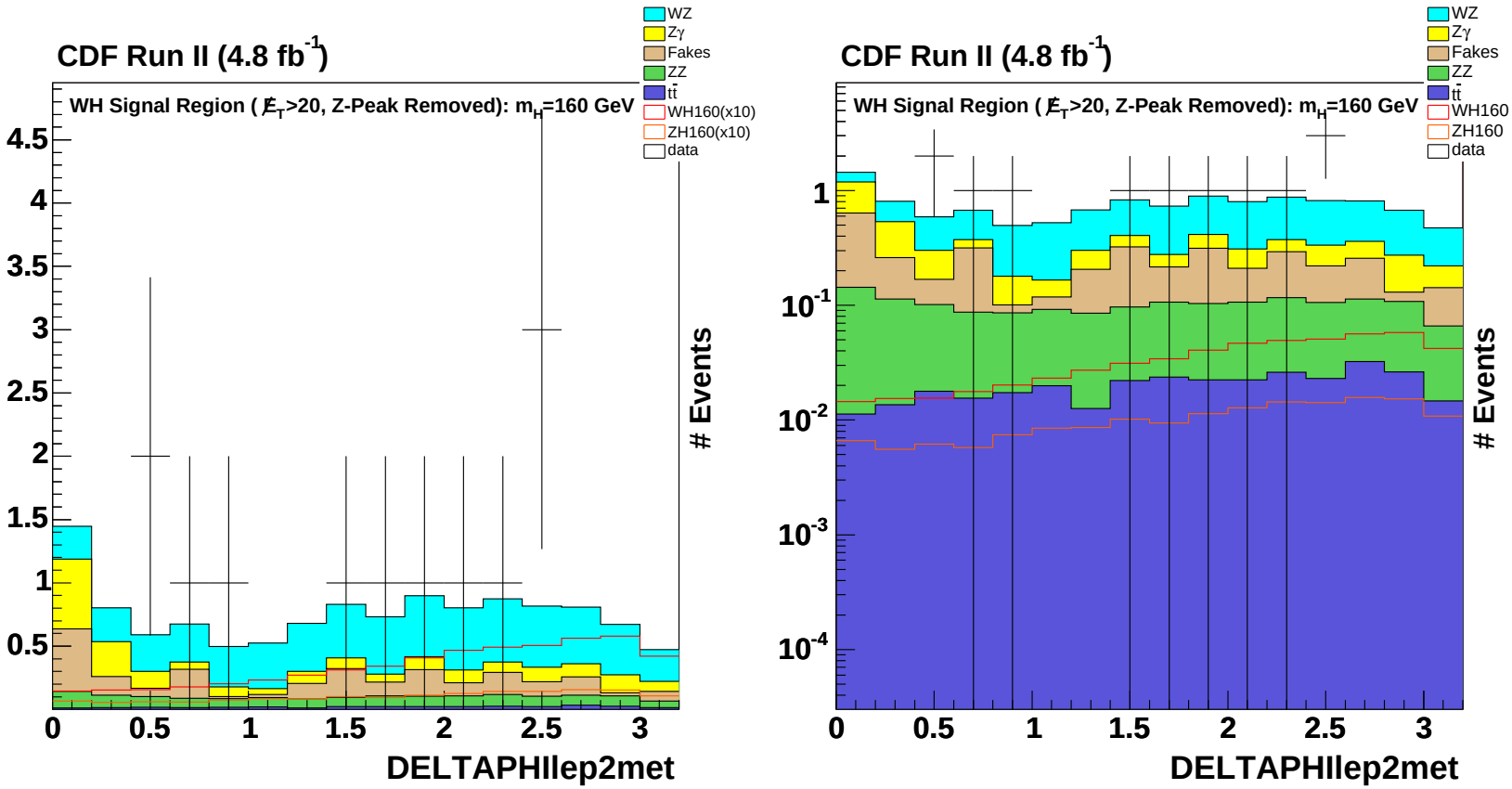


Figure: [For Public Release Blessing]

WH Signal: Inv. Mass(3rd Lep, $\not\!\!E_T$, Jets)

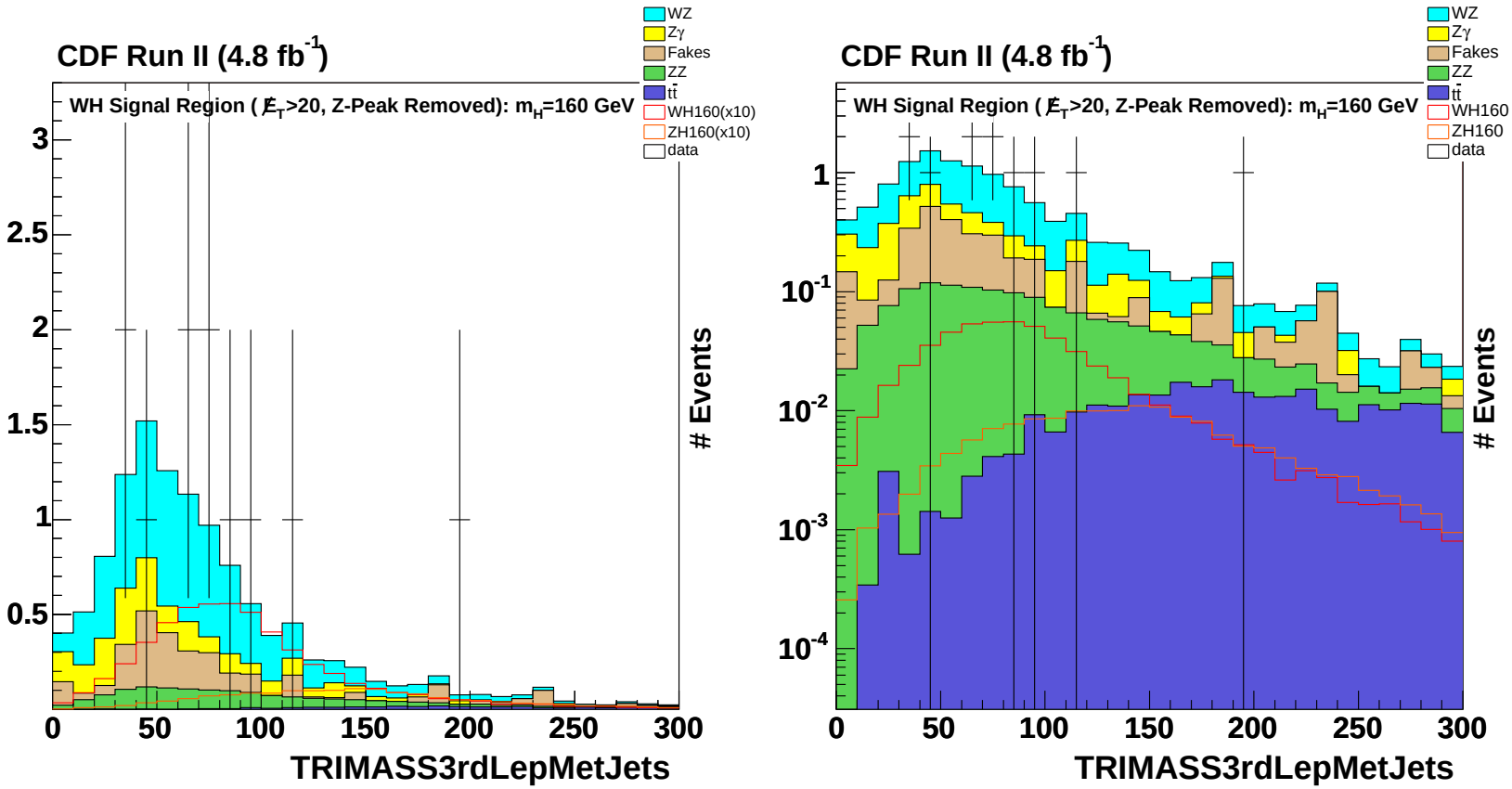


Figure: [For Public Release Blessing]

WH Signal: m_T(all Lep.,$\not\!\!E_T$, Jets)

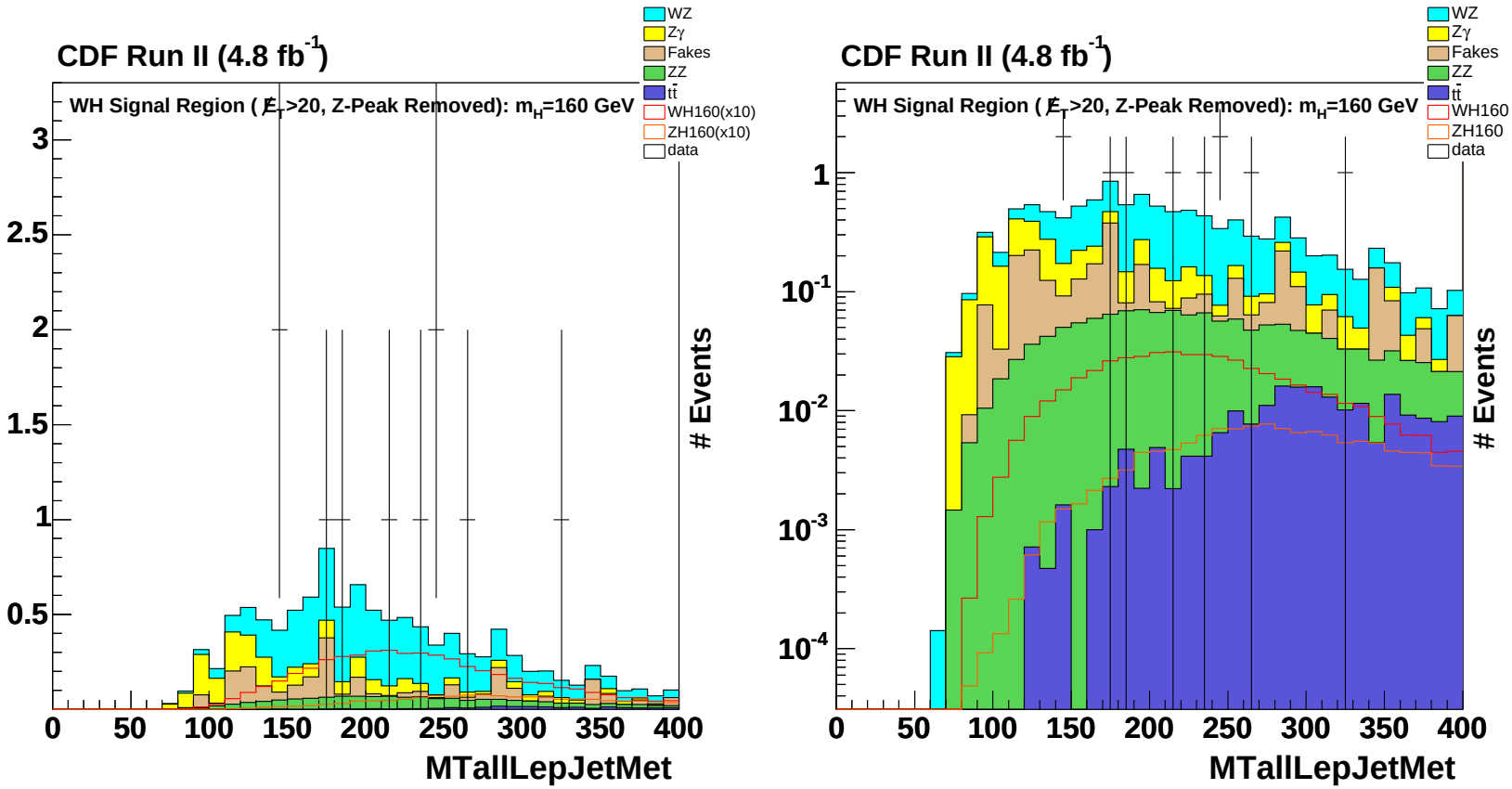


Figure: [For Public Release Blessing]

WH Signal: 2nd Lepton p_T

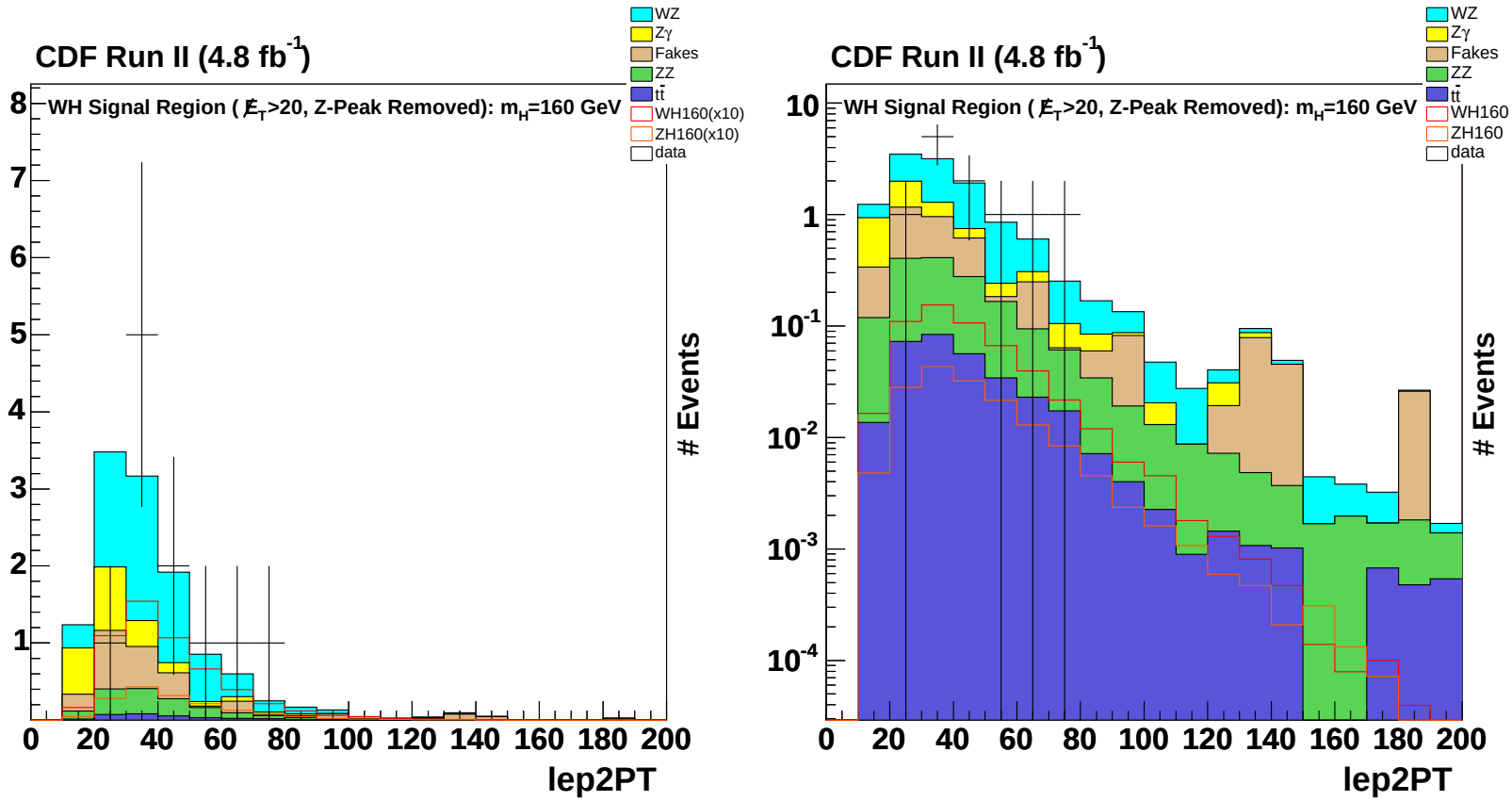


Figure: [For Public Release Blessing]

WH Signal: ΔR Opp. Sign. Leptons Far

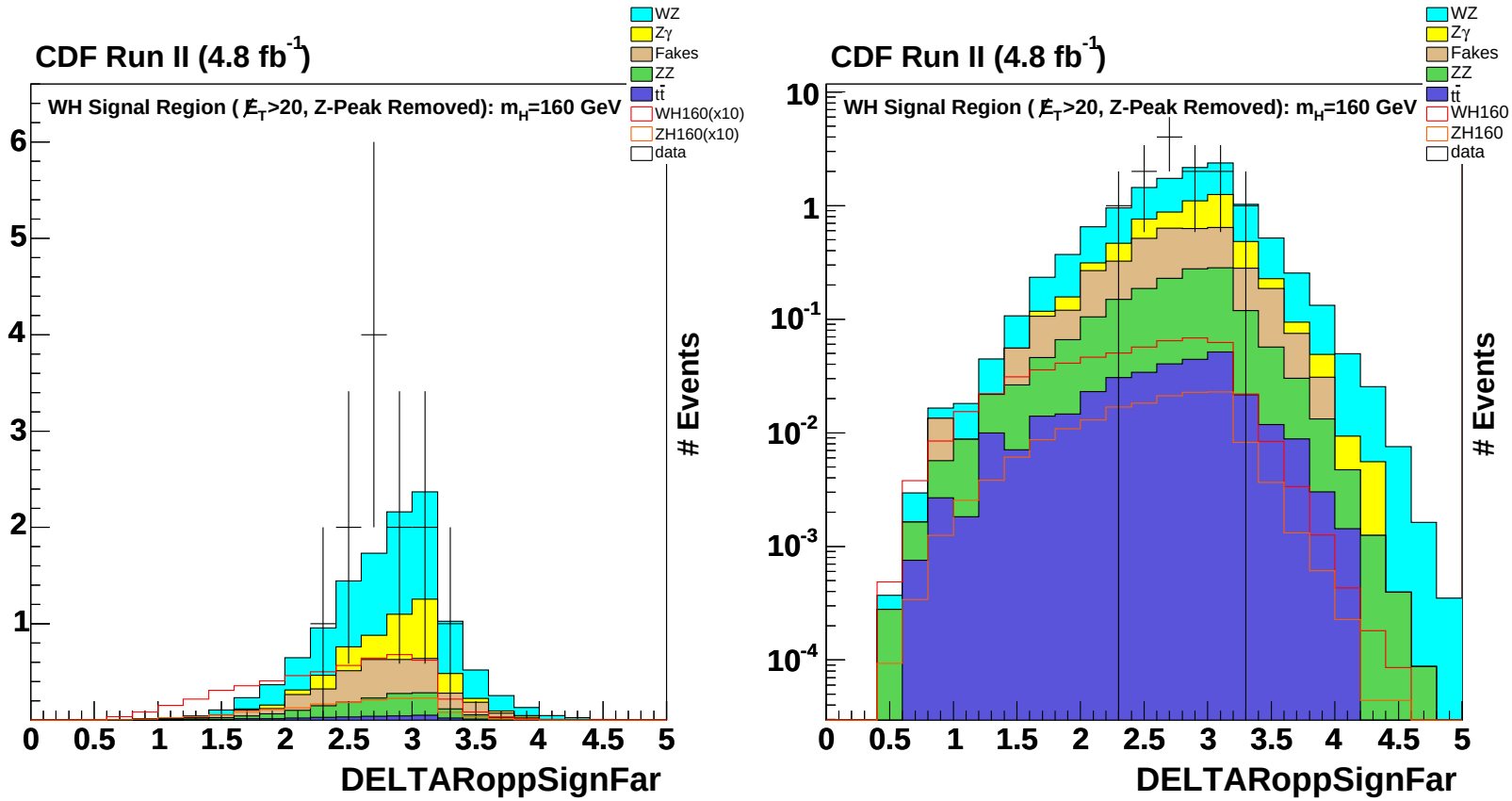


Figure: [For Public Release Blessing]

WH Signal: m_T trimass

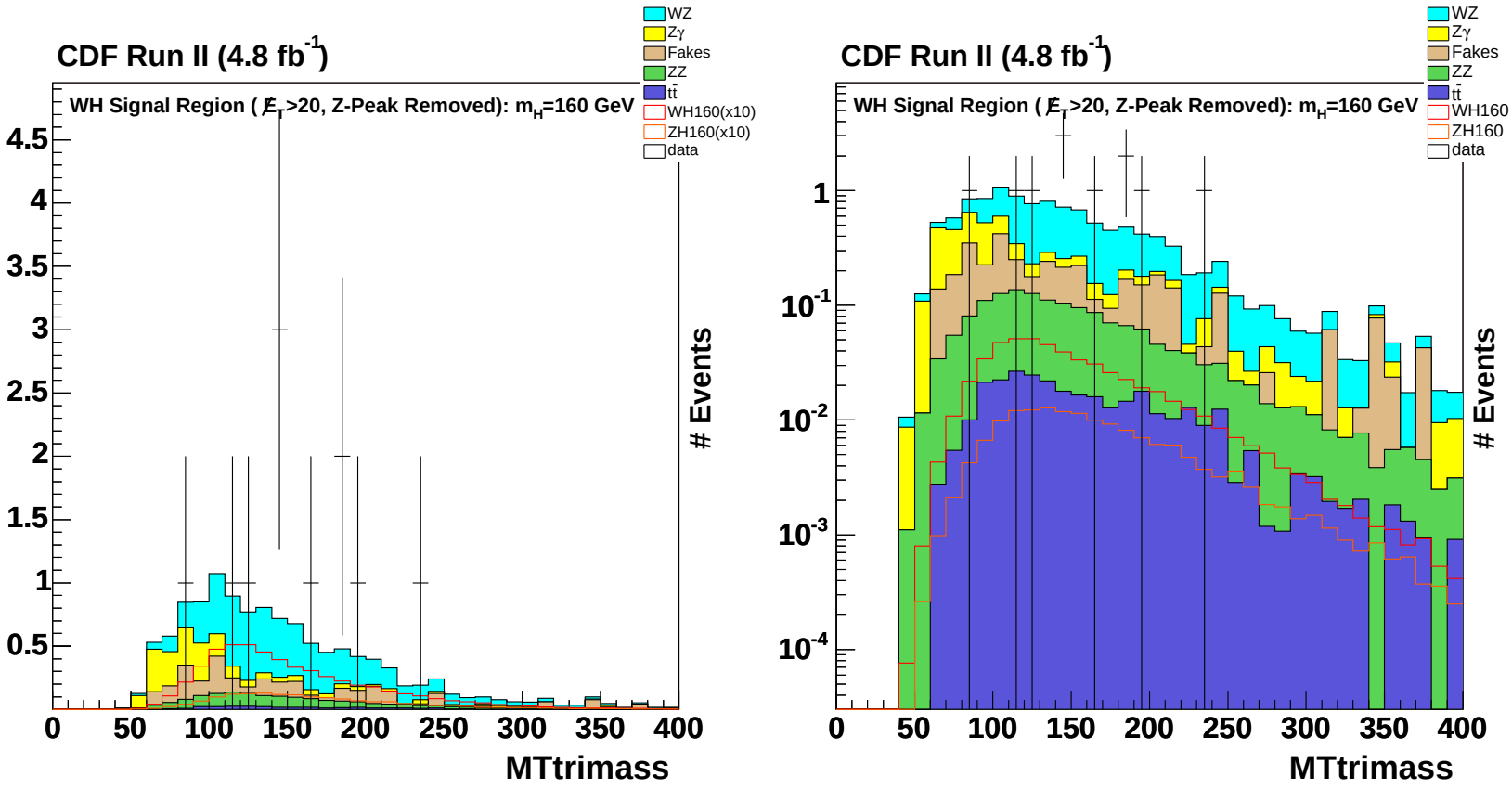


Figure: [For Public Release Blessing]

WH Signal: NJet

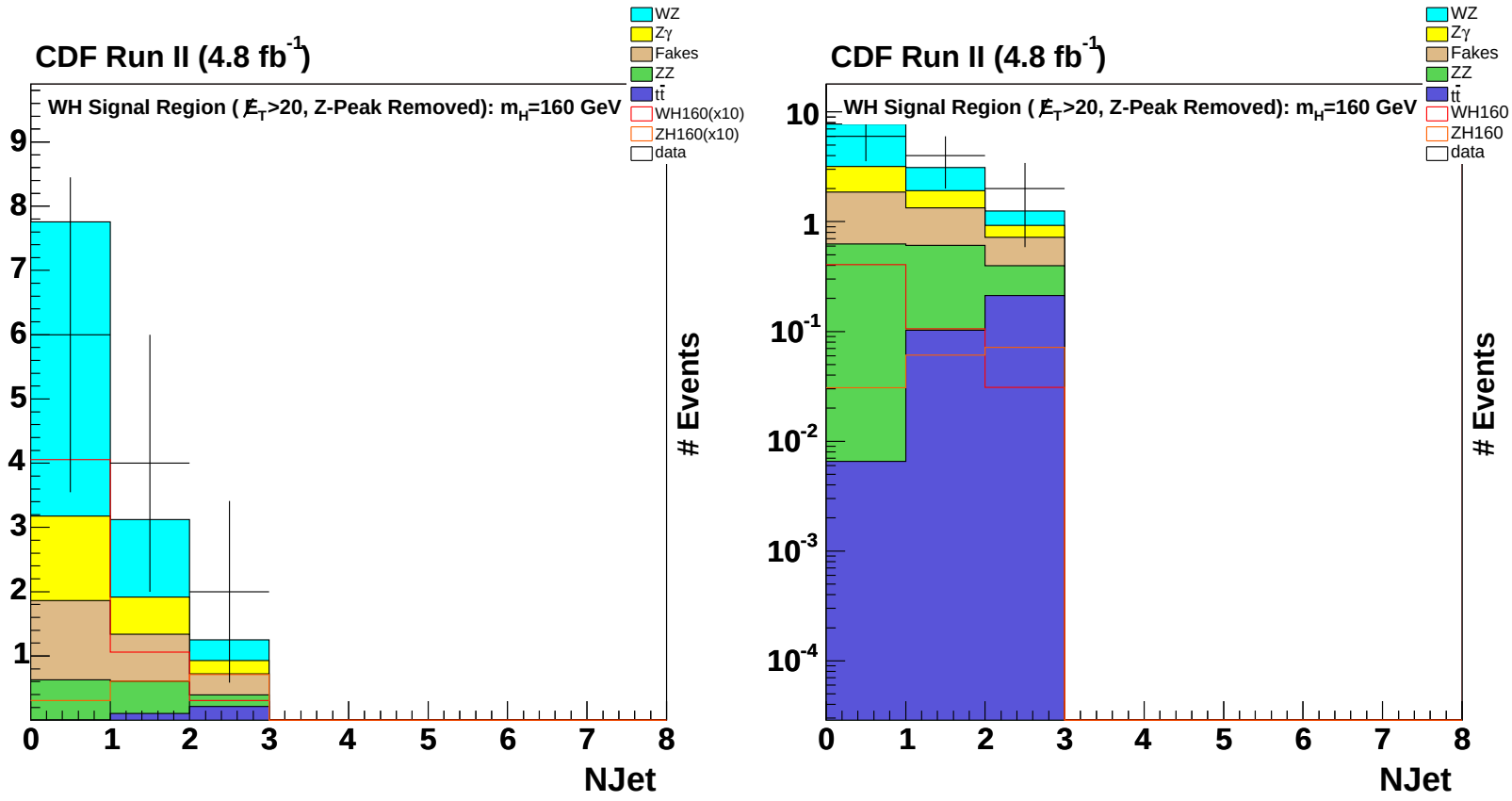


Figure: [For Public Release Blessing]

WH Signal: m_T (3rd Lep.,$\not\!\!E_T$)

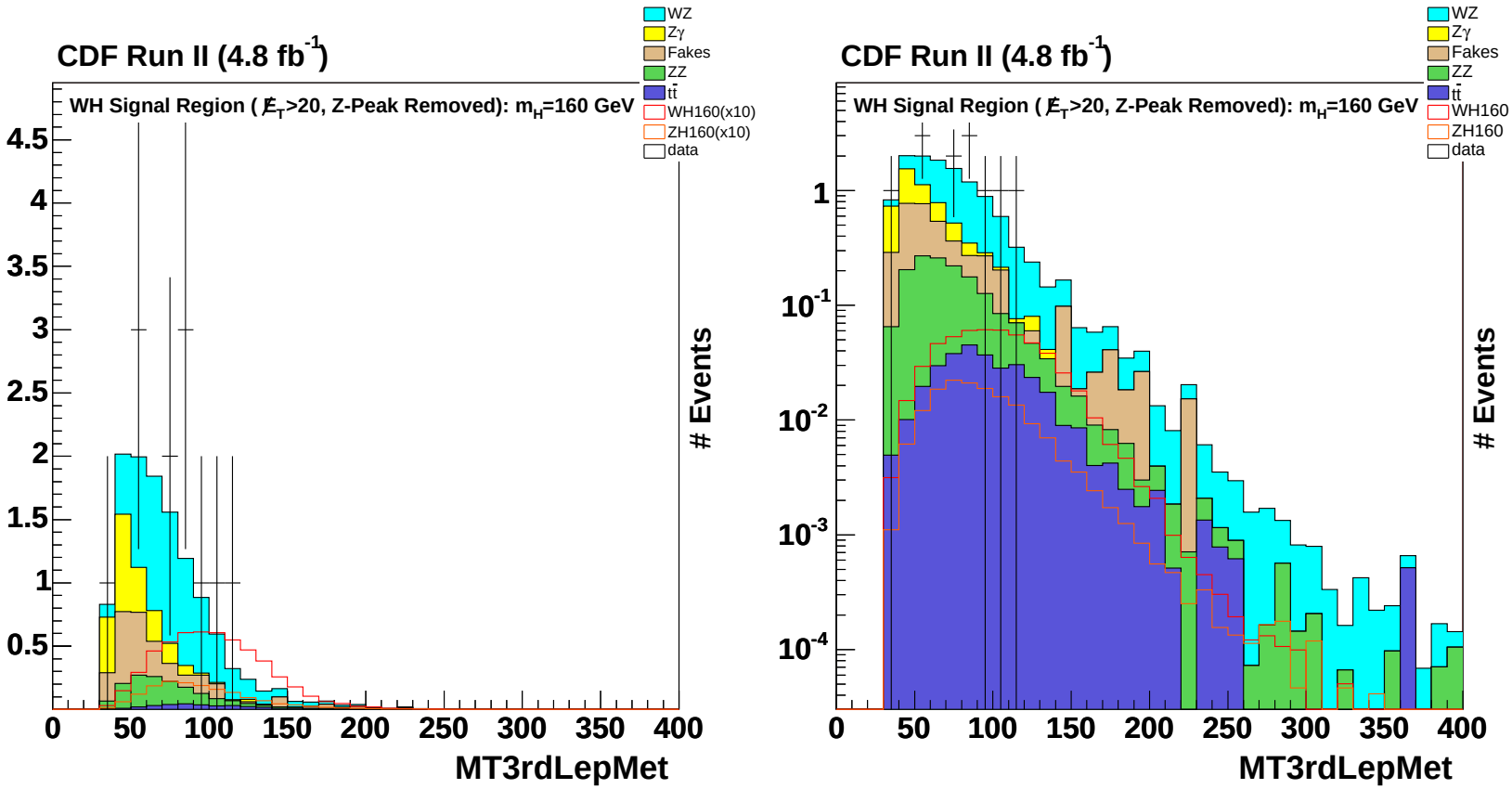


Figure: [For Public Release Blessing]

WH Signal: Inv. Mass(1st Lep., 2nd Lep., $\not\!\!E_T$)

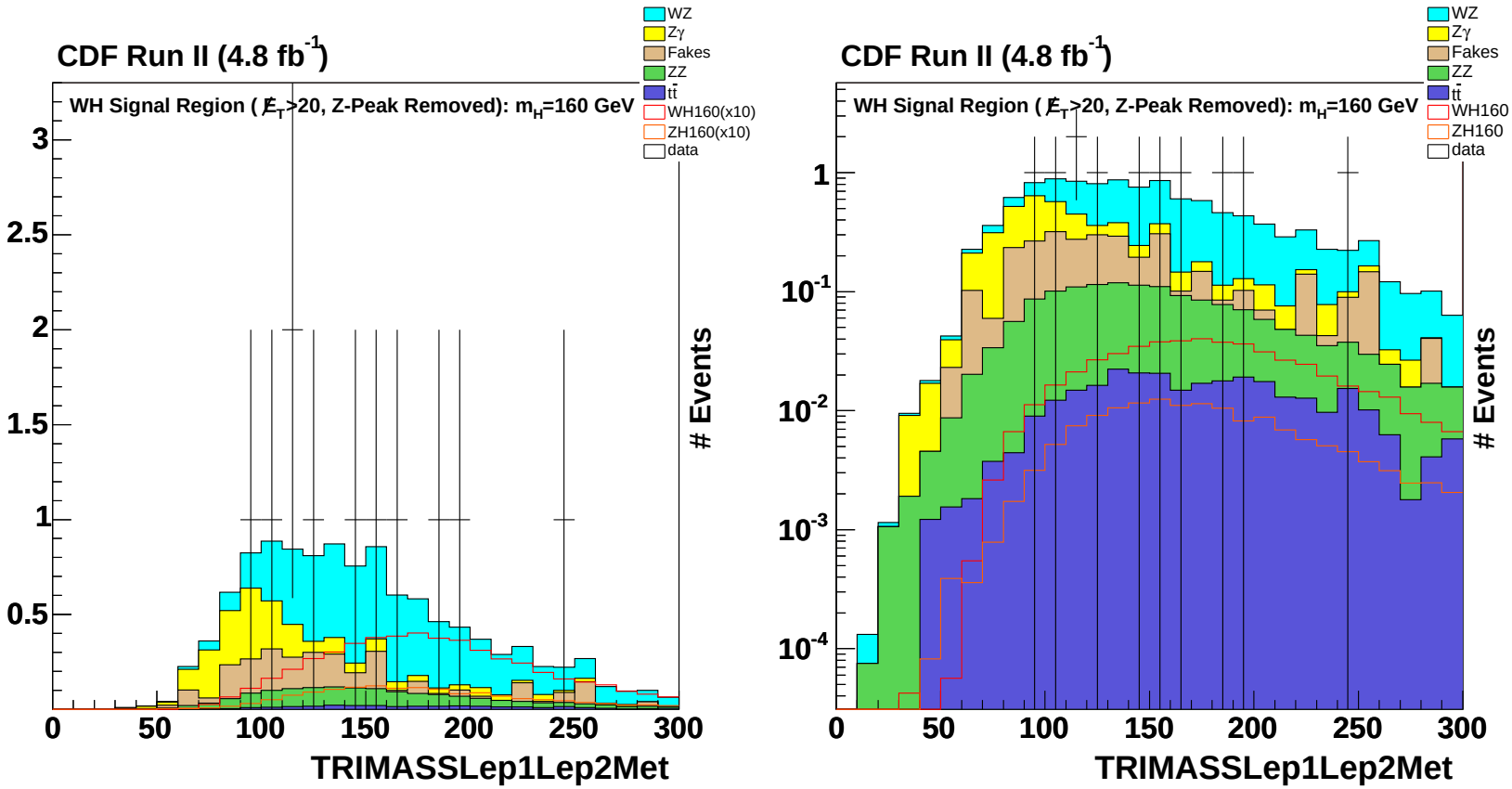


Figure: [For Public Release Blessing]

ZH Signal: NJet

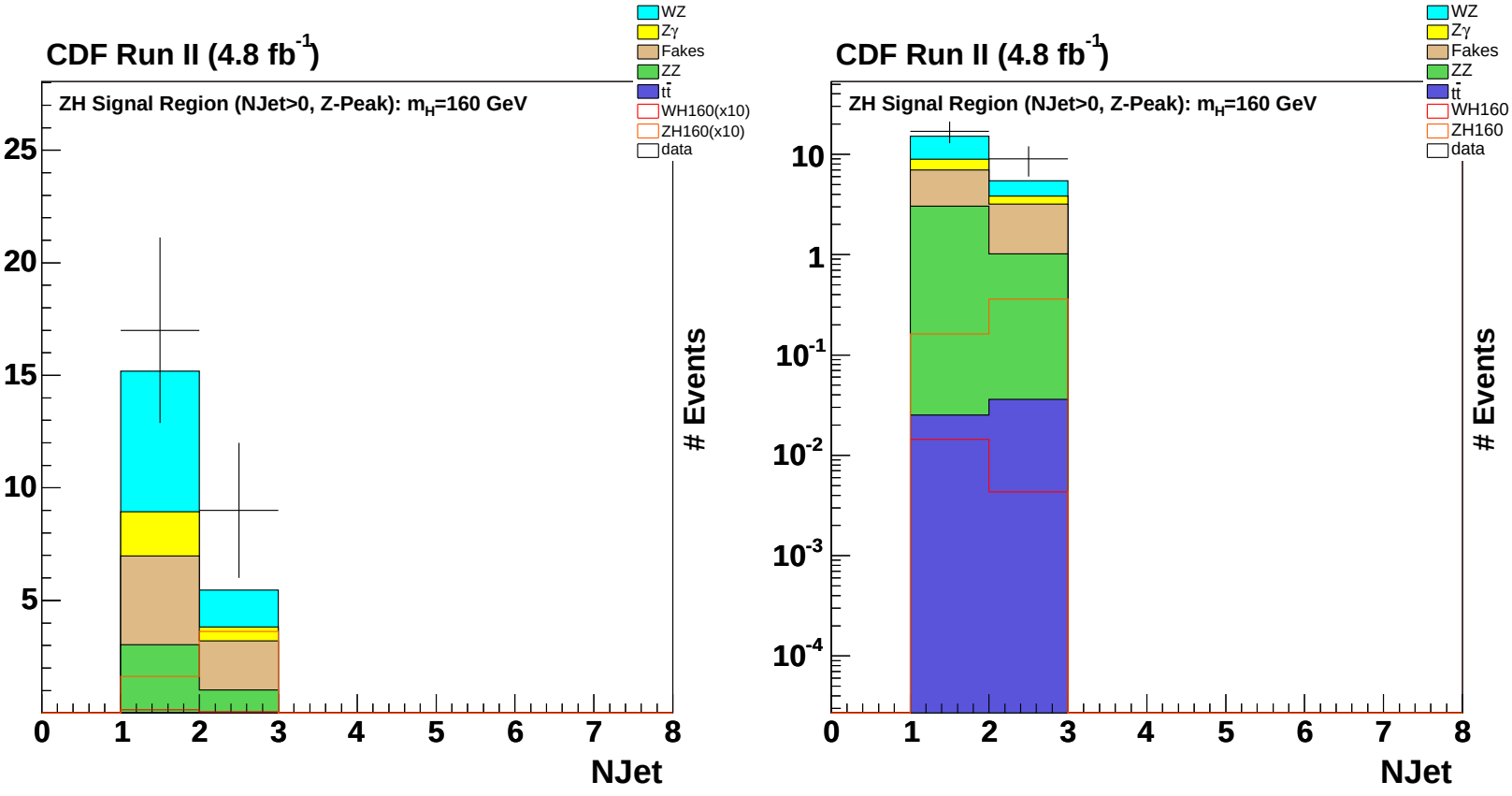


Figure: [For Public Release Blessing]

ZH Signal: $\not\!\!E_T$

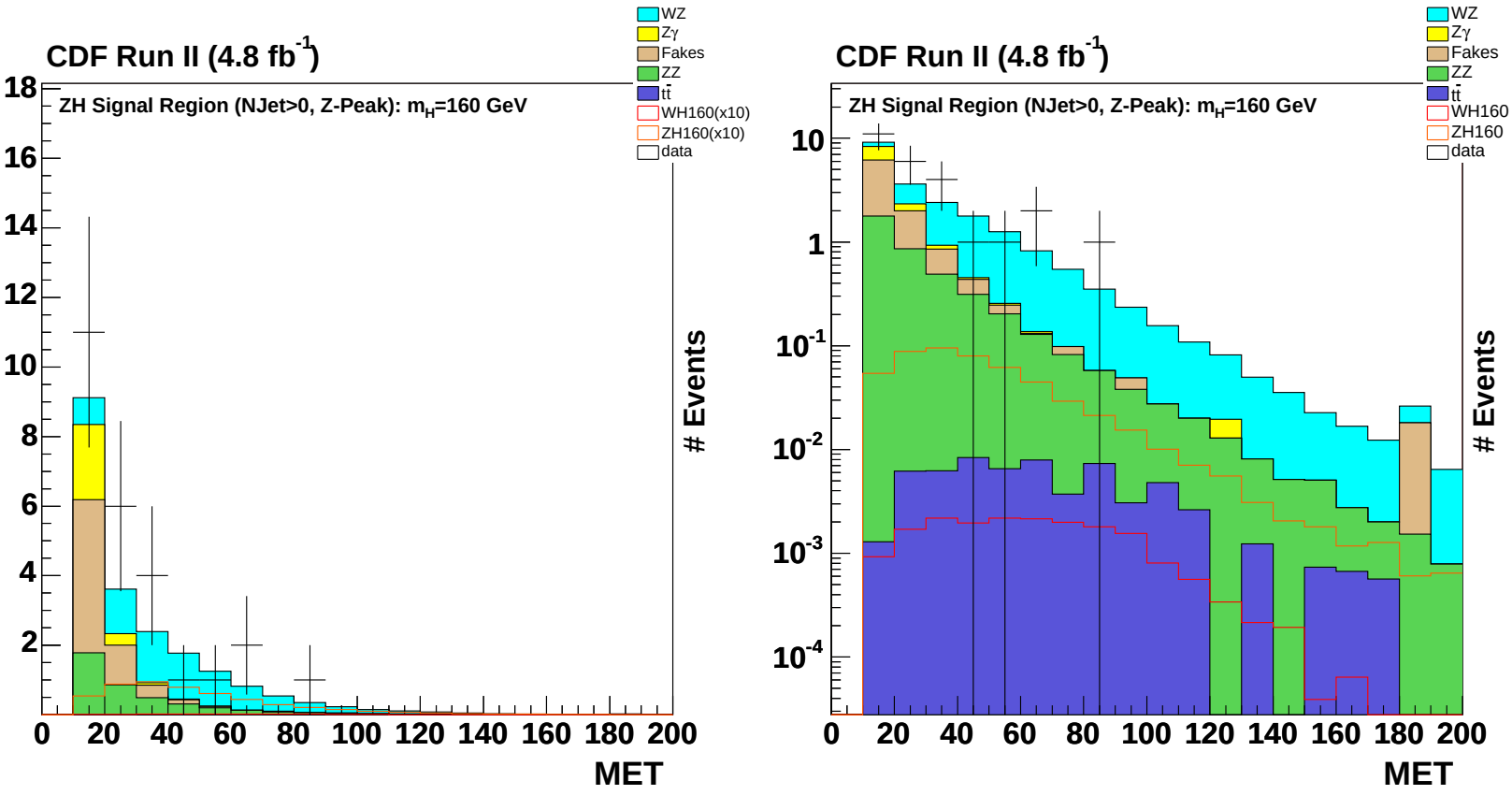


Figure: [For Public Release Blessing]

ZH Signal: Lead Jet E_T

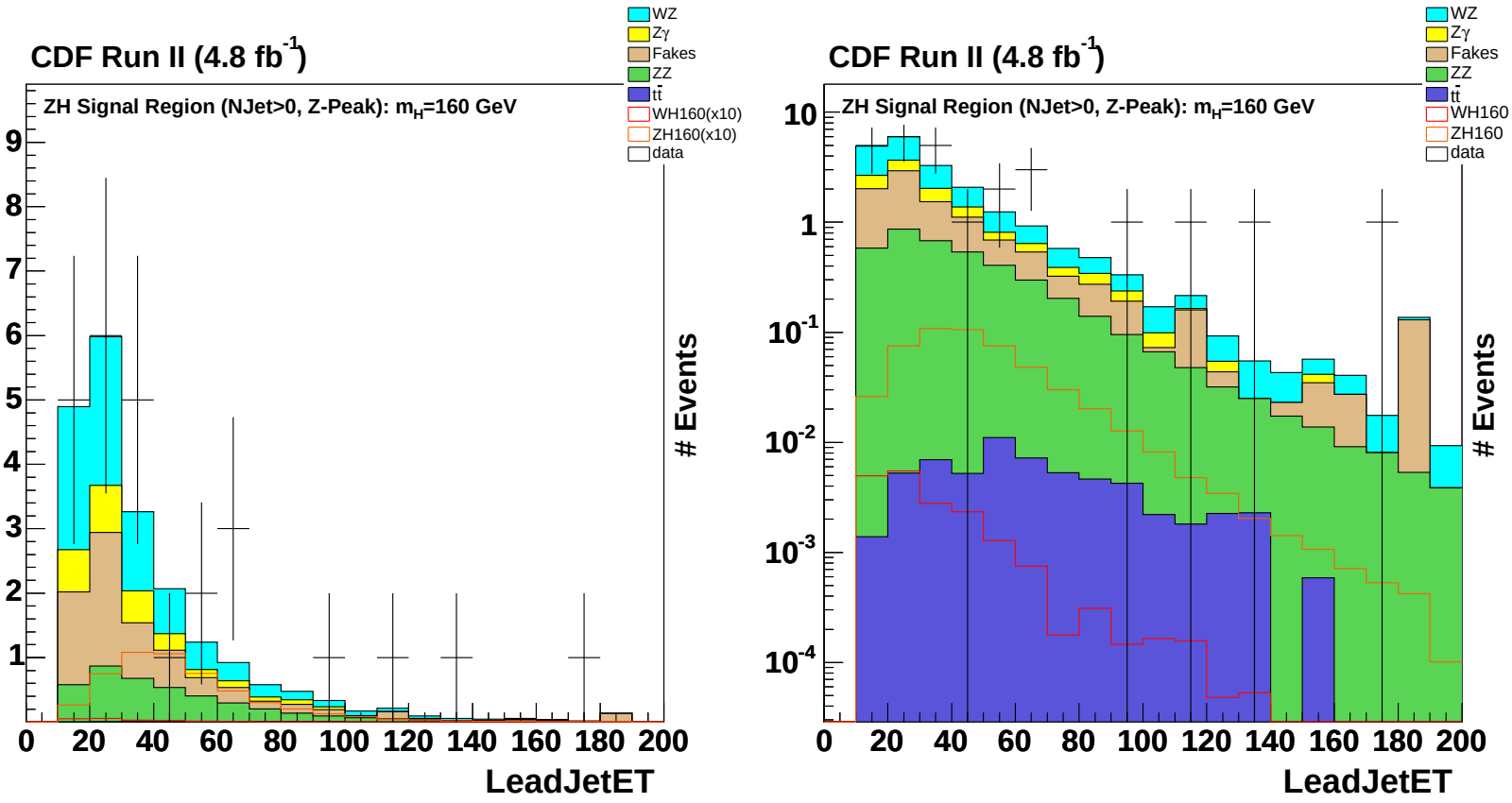


Figure: [For Public Release Blessing]

ZH Signal: ΔR(*W*-Lep.,Lead Jet)

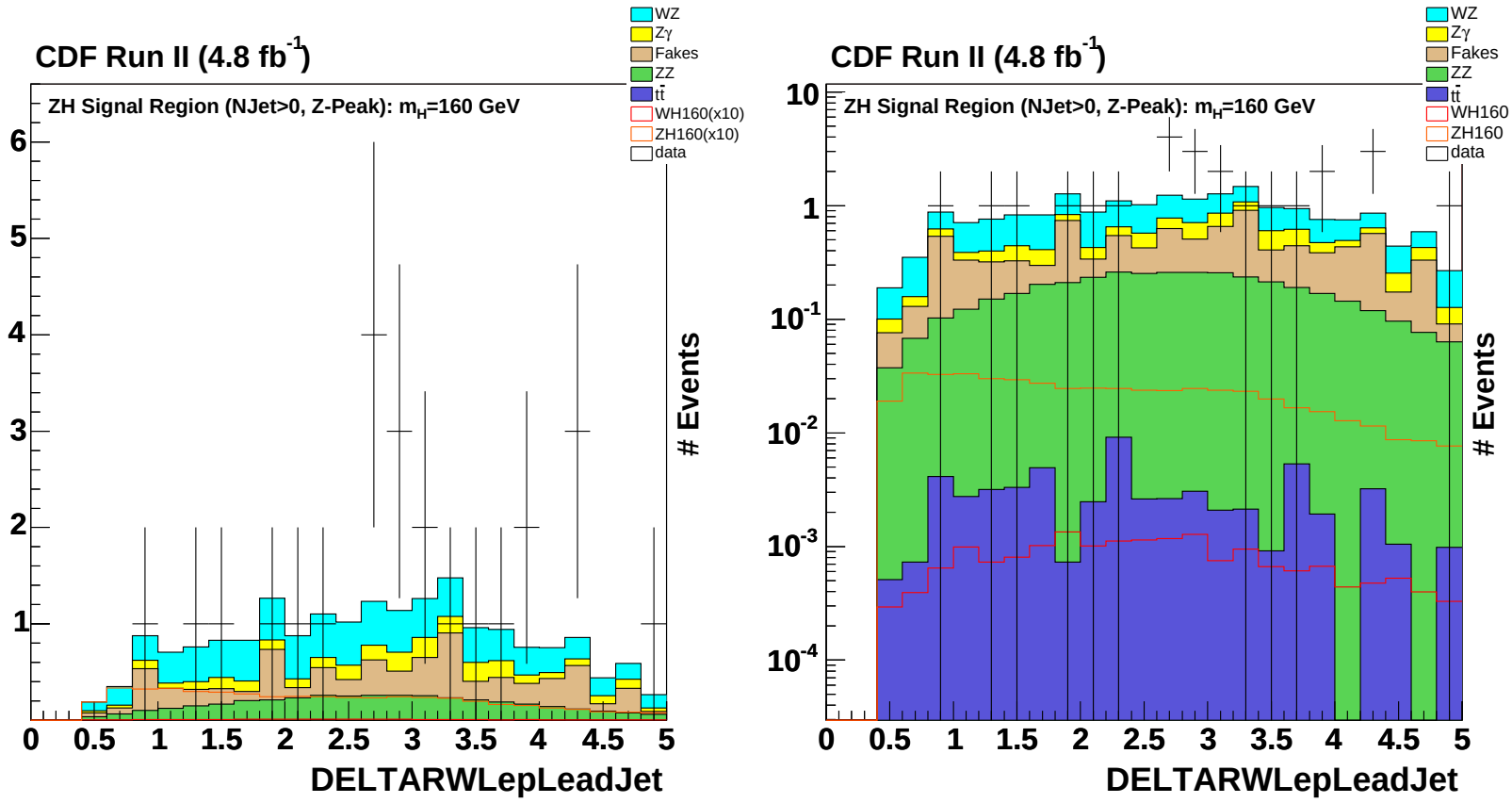


Figure: [For Public Release Blessing]

ZH Signal: $\Delta\phi$(all Lep., $\not\!\!E_T$)

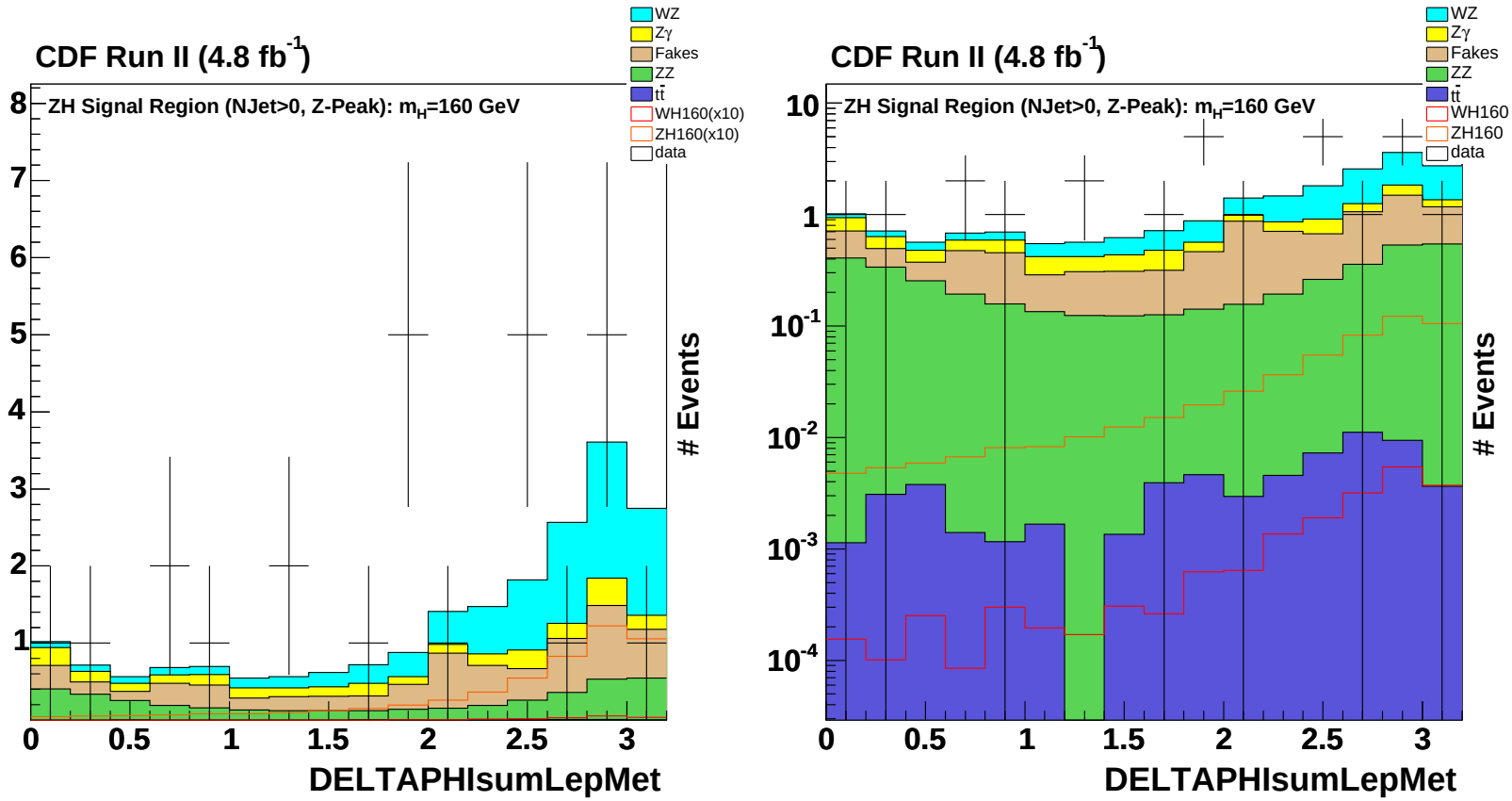


Figure: [For Public Release Blessing]

ZH Signal: H_T

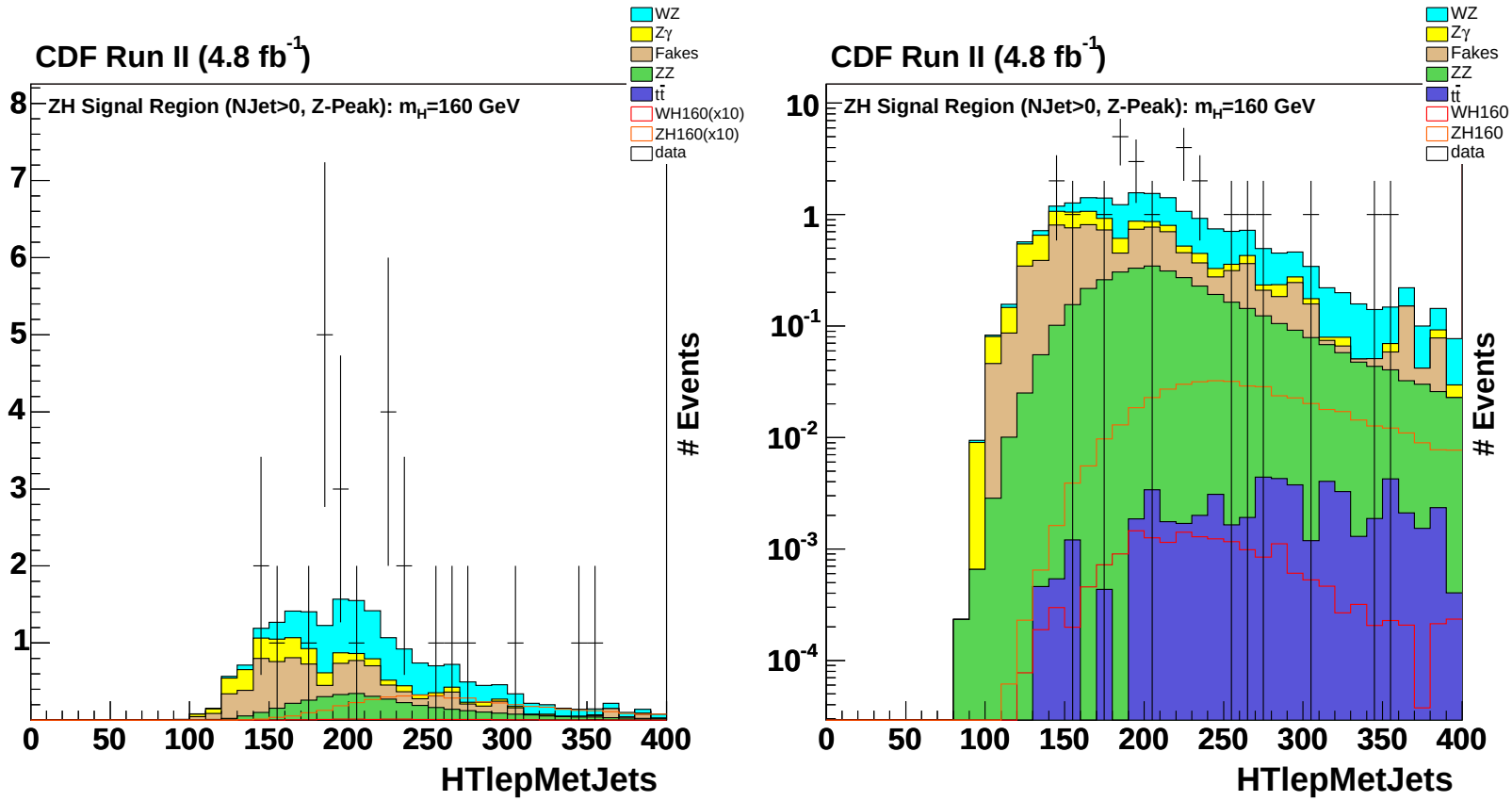


Figure: [For Public Release Blessing]

ZH Signal: m_T(all Lep.,$\not\!\!E_T$,Jets)

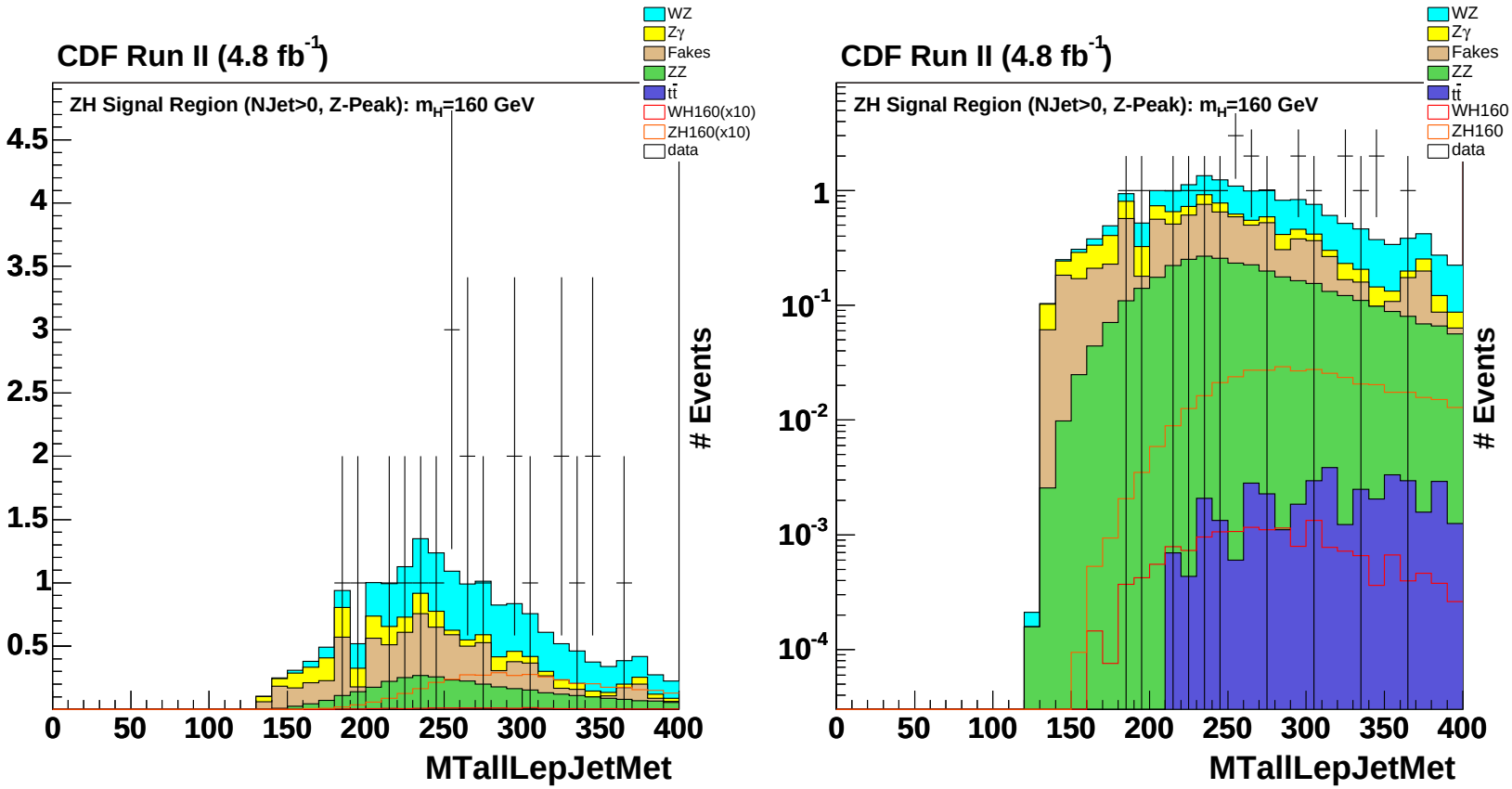


Figure: [For Public Release Blessing]

ZH Signal: $\Delta\phi$ (2^{nd} Lep.,$\not\!\!E_T$)

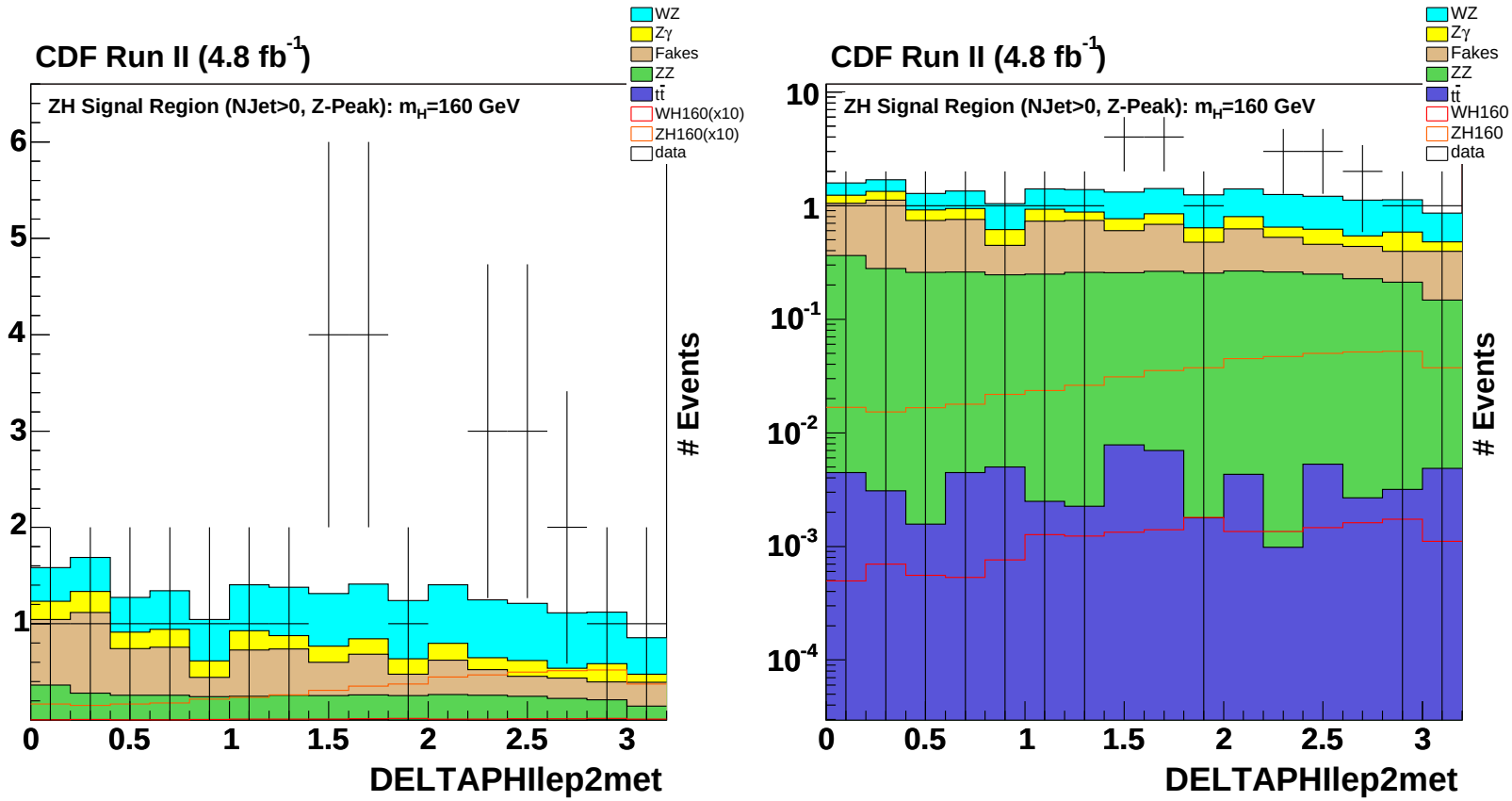


Figure: [For Public Release Blessing]

ZH Signal: ΔR Opp. Sign Closer Leptons

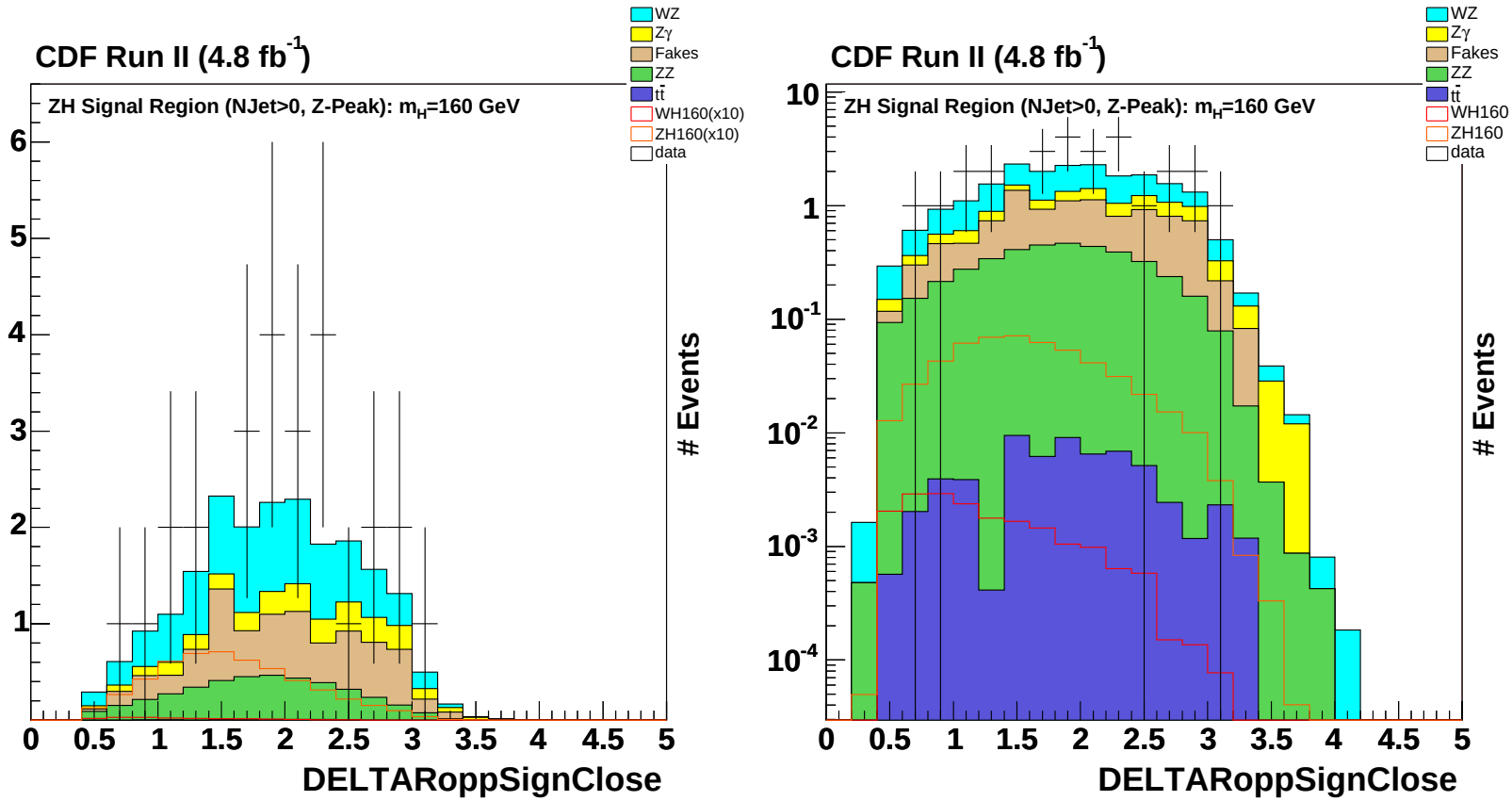


Figure: [For Public Release Blessing]

ZH Signal: Trilepton Inv. Mass

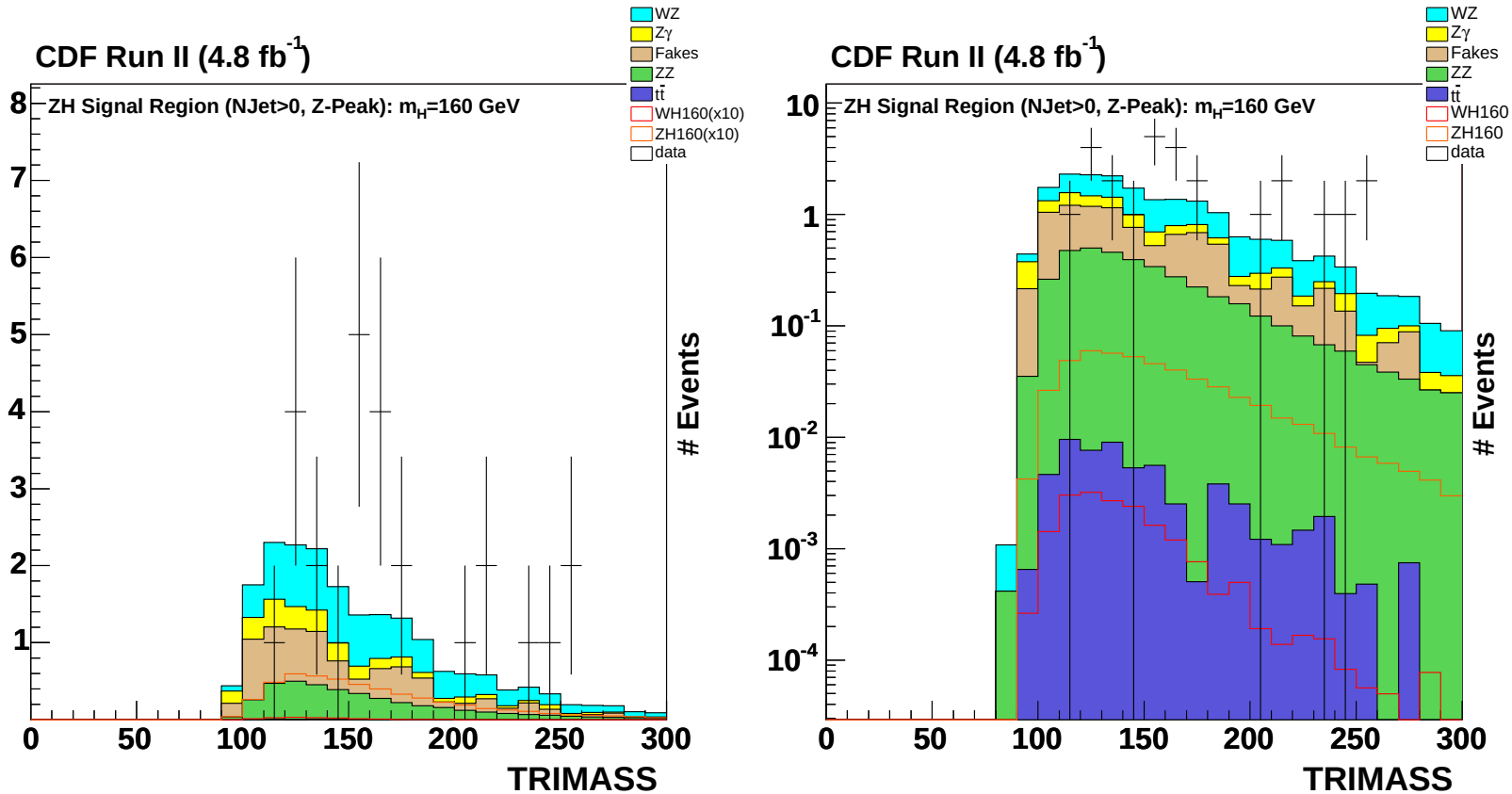


Figure: [For Public Release Blessing]

ZH Signal: Inv. Mass(3rd Lep.,$\not\!\!E_T$, Jets)

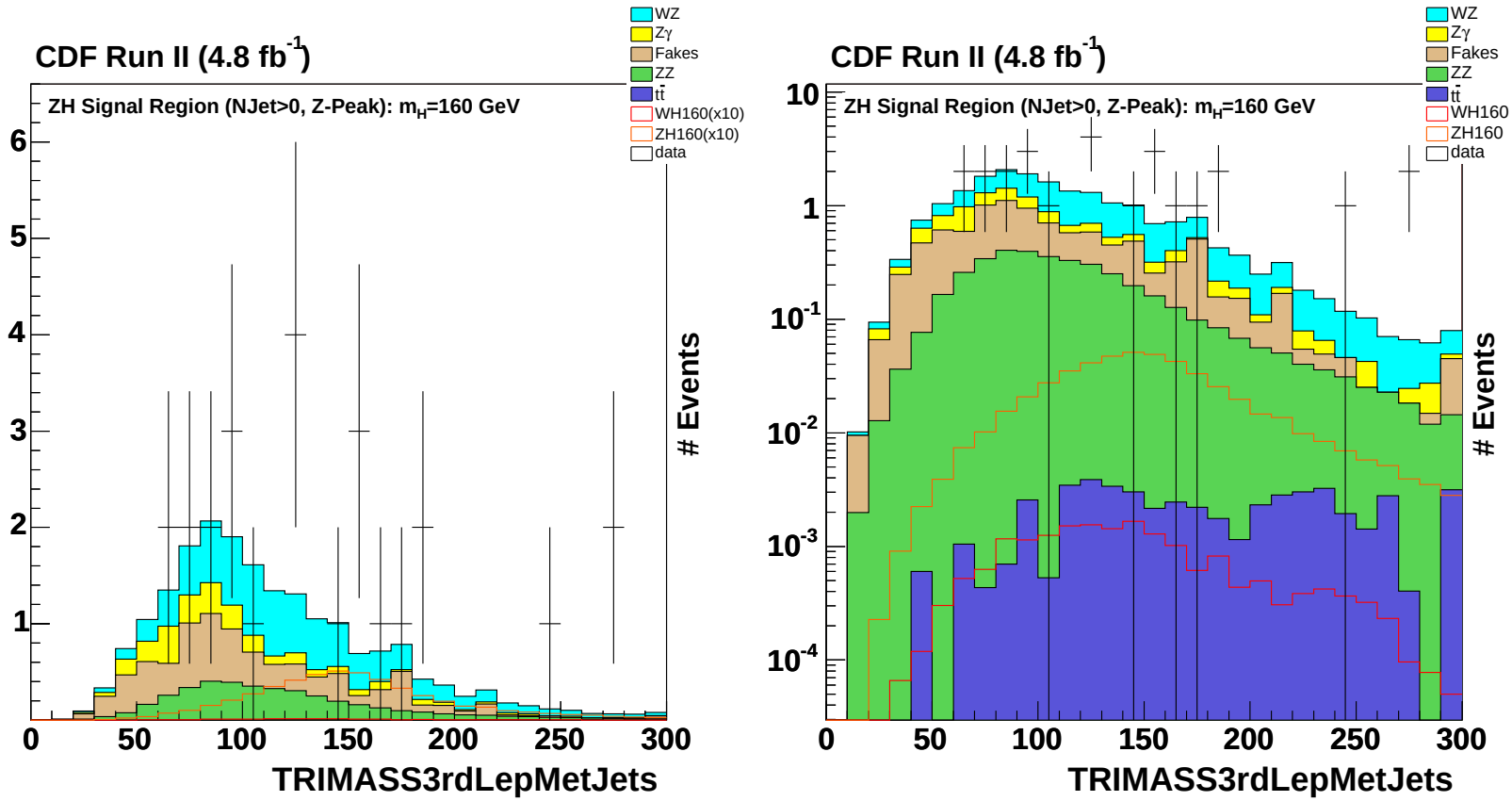


Figure: [For Public Release Blessing]

ZH Signal: Dimass (W-Lep., $\not\!\!E_T$)

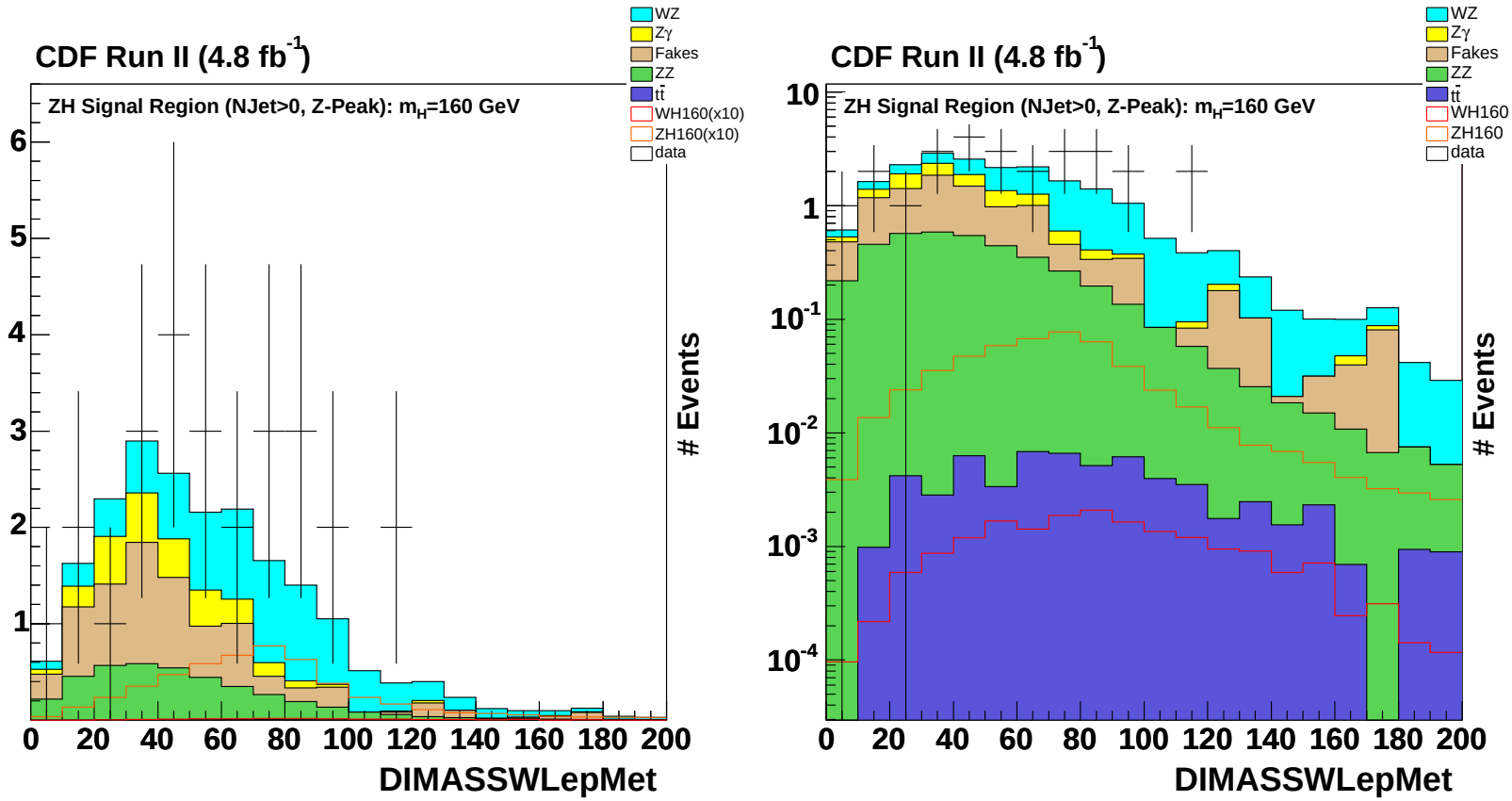


Figure: [For Public Release Blessing]

ZH Signal: m_T all Jets

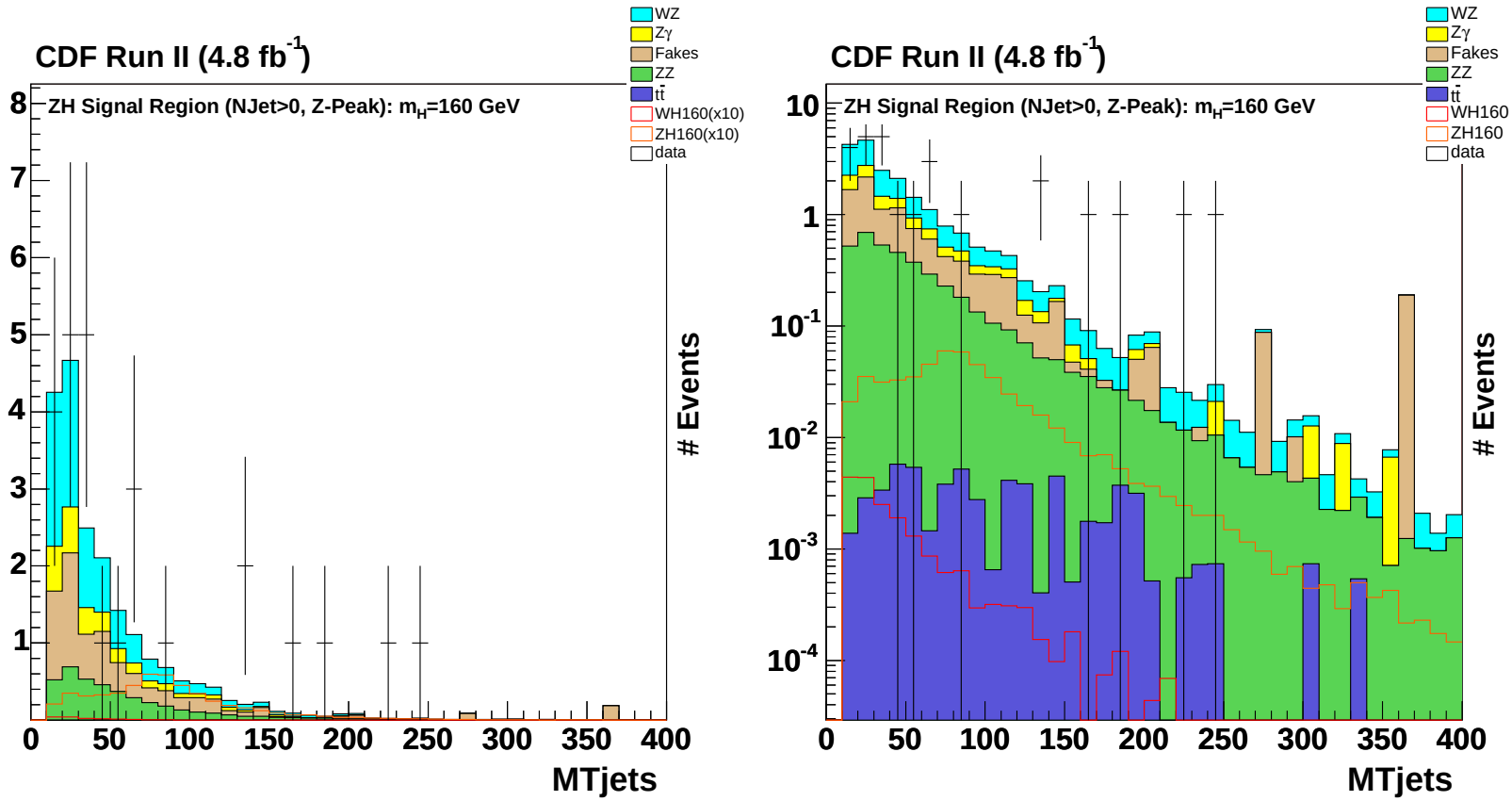


Figure: [For Public Release Blessing]

ZH Signal: $m_T(W\text{-Lep.}, \not\!\!E_T)$

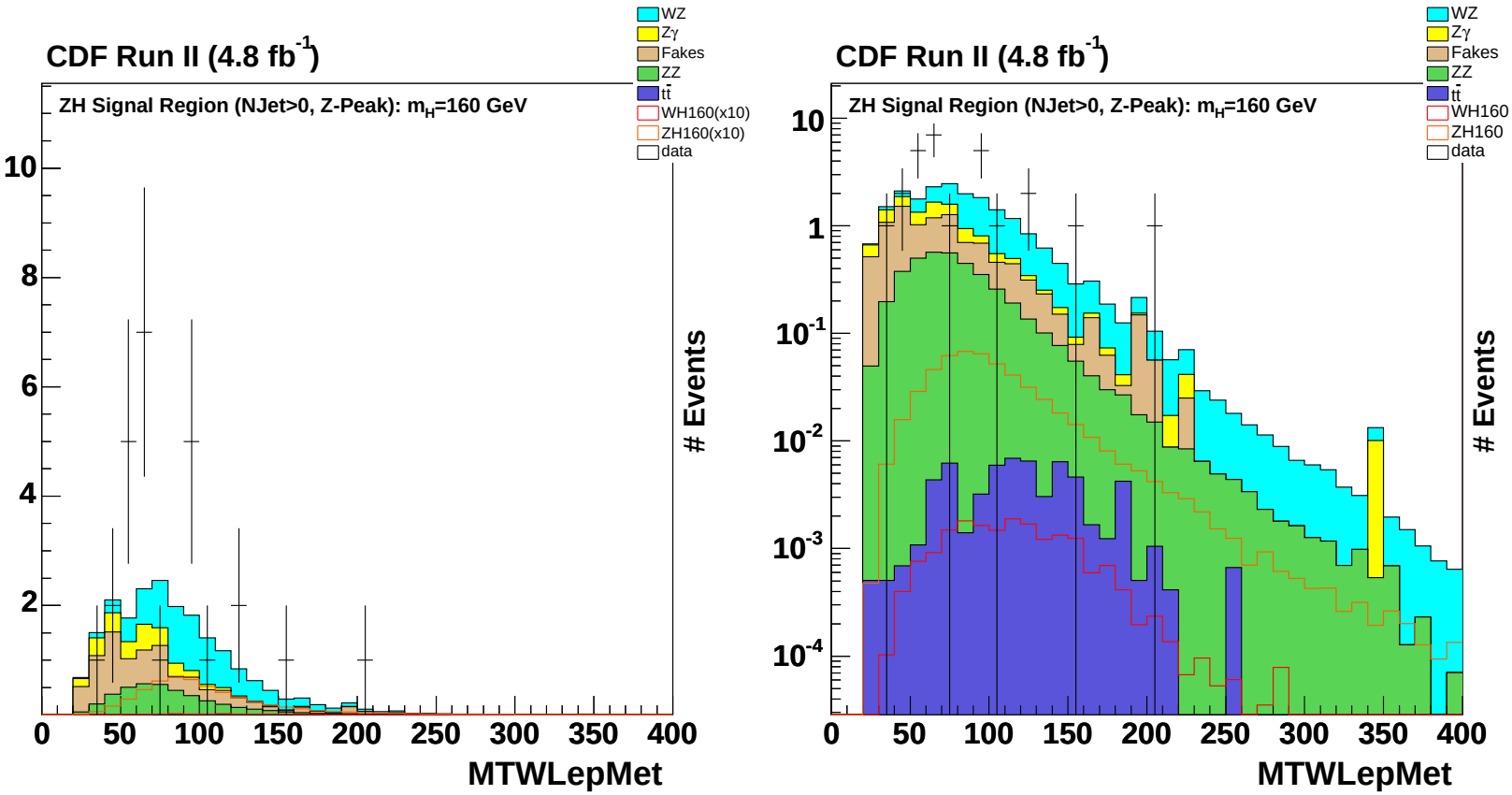


Figure: [For Public Release Blessing]

ZH Signal: $\Delta\phi$ (Sum O.S. Lep's Near *Z*-mass,3rd Lep)

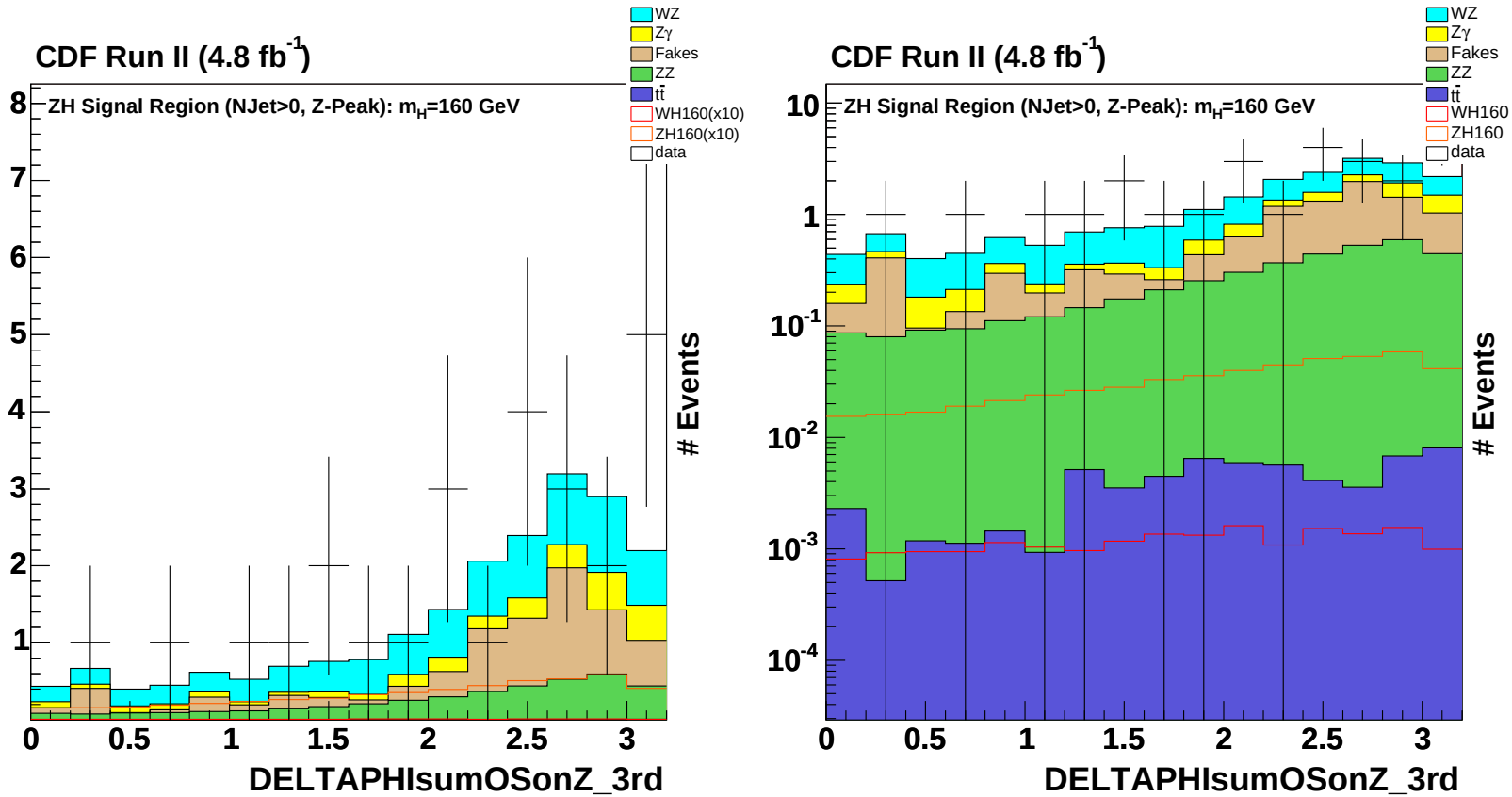


Figure: [For Public Release Blessing]

ZH Signal: ΔR Opp. Sign Leptons (far)

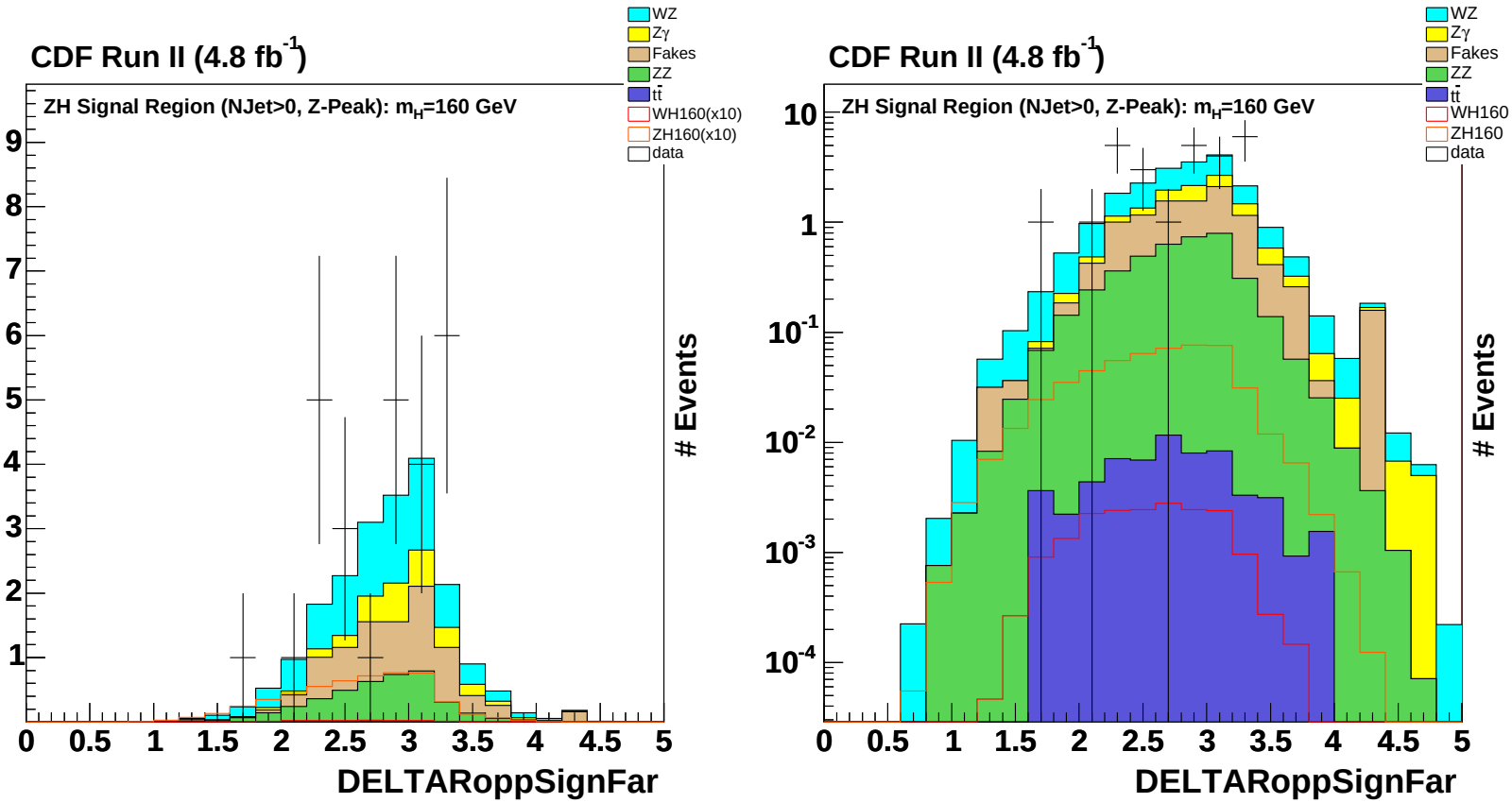


Figure: [For Public Release Blessing]