WZ Diboson Cross Section in $5.3fb^{-1}$

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Summary

Intro.

- Reminder [CDF8659]: Previous analysis used 1.1fb^{-1},
  - observed 16 events
  - expected 9.75 *WZ* events
  - expected 2.65 background events
  - measured $5.0^{+1.8}_{-1.6}\mathrm{pb}^{-1}$
- Now we are using 5.3fb^{-1}
- The $H \rightarrow WW$ group's *Diboson_v17* framework is used for this analysis.

WZ Selection

- Number of Leptons: 3
- Number of Jets: Any
- $\not\!\!E_T > 20.0\mathrm{GeV}$
- Z-Peak Region: With three leptons, choose events with any dilepton invariant mass such that $m_{ll} \in [71.0, 111.0]$, and the leptons have opposite charge and same flavor.

Event Count

CDF Run II Public $\int \mathcal{L} = 5.3\ \mathrm{fb}^{-1}$

	WZ Signal Region			*WZ* Control Region		
ZZ	5.64	$\pm$	0.75_{syst}	3.27	$\pm$	0.43_{syst}
$Z\gamma$	1.80	$\pm$	0.63_{syst}	16.6	$\pm$	5.83_{syst}
Fakes (WW,Z+Jets)	5.34	$\pm$	1.31_{syst}	16.2	$\pm$	3.97_{syst}
$t\bar{t}$	0.06	$\pm$	0.019_{syst}	0.004	$\pm$	0.001_{syst}
Total Background	12.9	$\pm$	1.69_{syst}	36.1	$\pm$	7.14_{syst}
WZ	40.5	$\pm$	4.10_{syst}	4.57	$\pm$	0.46_{syst}
Data	60			41		

High Mass

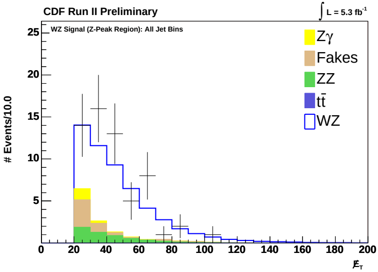
*Systematic errors subject to change

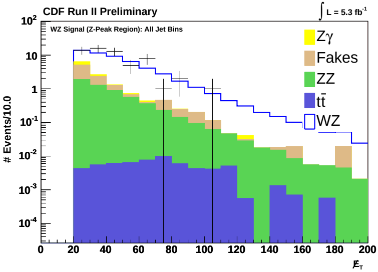
Discriminating Variables

Discriminating Variables, starting with the most significant.

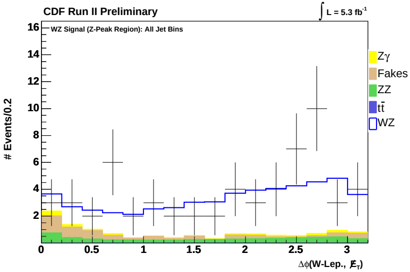
- $\not\!\!E_T$
- $\Delta\phi(WLep, \not\!\!E_T)$
- $m_T(jets)$
- Inv. Mass$(WLep, \not\!\!E_T)$
- $\Delta\phi(2^{\text{nd}}Lep., \not\!\!E_T)$
- m_T(3 leptons)
- H_T
- m_T(3$^{\text{rd}}$ Lep,$\not\!\!E_T$)
- $\Delta\phi$(3 leptons,$\not\!\!E_T$)
- Inv. Mass(3$^{\text{rd}}$ Lep., $\not\!\!E_T$, jets)

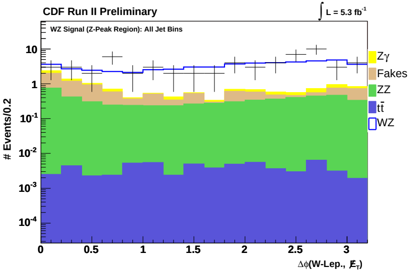
Discriminating Variables: $\not\!\!E_T$



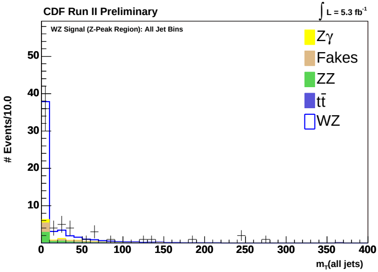


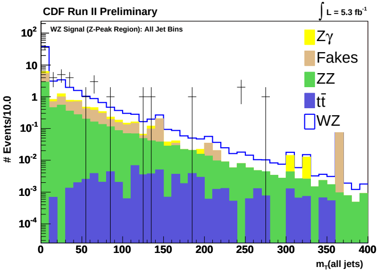
Discriminating Variables: $\Delta\phi(WLep, \not{E}_T)$



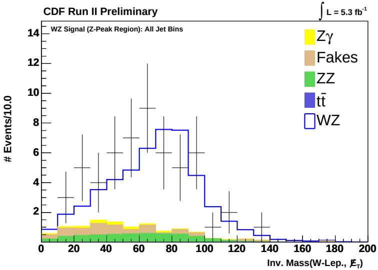


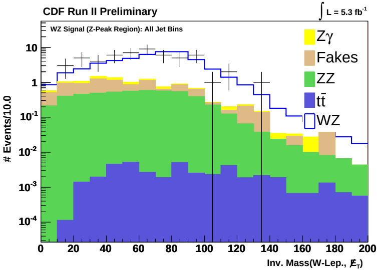
Discriminating Variables: $m_T(jets)$



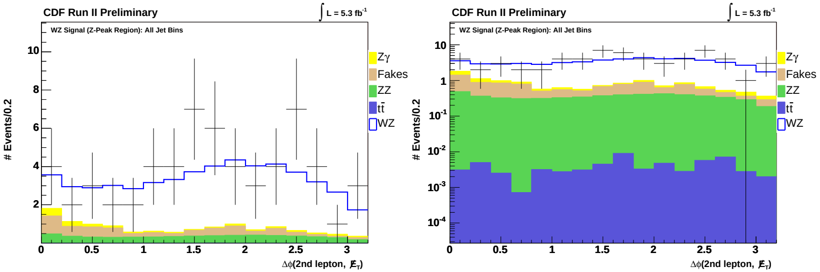


Discriminating Variables: Inv. Mass($WLep, \not{E}_T$)

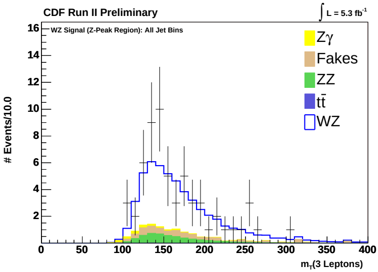


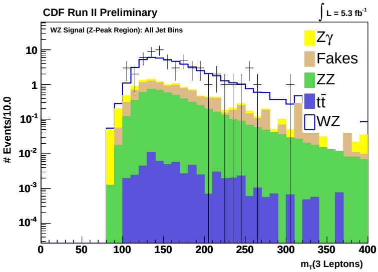


Discriminating Variables: $\Delta\phi(2^{nd} Lep., \not{E}_T)$

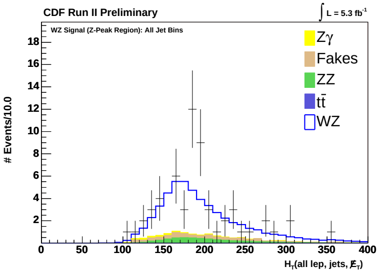


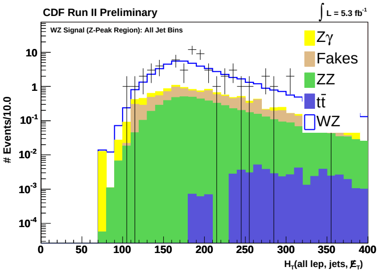
Discriminating Variables: m_T(3 leptons)



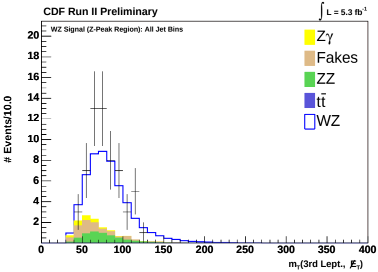


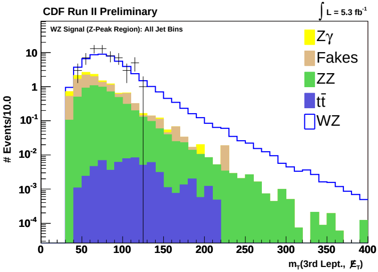
Discriminating Variables: H_T



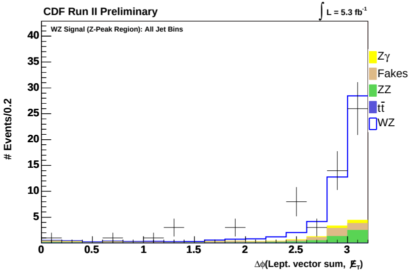


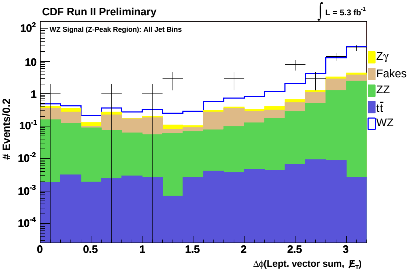
Discriminating Variables: $m_T(3^{rd}\ \text{Lep}, \not\!\!E_T)$



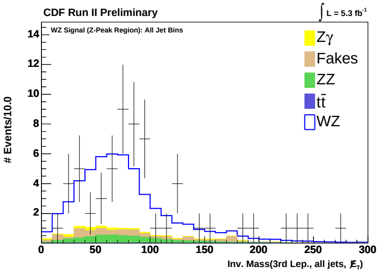


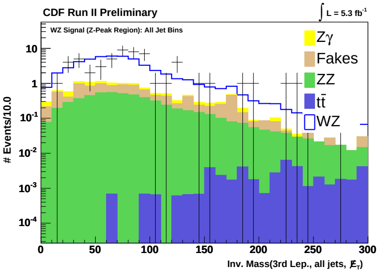
Discriminating Variables: $\Delta\phi$(3 leptons,$\not{E}_T$)



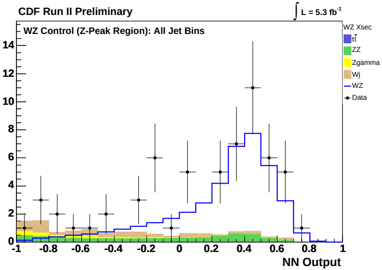


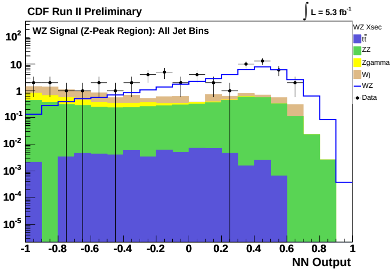
Discriminating Variables: Inv. Mass(3rd Lep., $\not{E}_T$, jets)





NN Score


CDF Run II Preliminary
∫ L = 5.3 fb-1
WZ Control (Z-Peak Region): All Jet Bins
WZ Xsec
tt̄
ZZ
Zgamma
Wj
WZ
Data
NN Output


CDF Run II Preliminary
∫ L = 5.3 fb-1
WZ Signal (Z-Peak Region): All Jet Bins
WZ Xsec
tt̄
ZZ
Zgamma
Wj
WZ
Data
NN Output

Systematics

Systematic Uncertainty	WZ	ZZ	$Z\gamma$	$t\bar{t}$	Fakes
Diboson Higher Order Diagrams		0.100			
$t\bar{t}$ Higher Order Diagrams				0.100	
PDF Model	0.027	0.027		0.021	
Lepton ID Efficiencies	0.020	0.020		0.020	
Trigger Efficiences	0.021	0.021		0.020	
Light Jet Fake Rates					0.245*
b-Jet Fake Rate*				0.23	
Luminosity	0.059	0.059		0.059	
MC Run Dependence			0.050		
Jet Energy Scale			0.012*		
$Z\gamma$ Higher Order Diagrams*			0.110		
$Z\gamma$ Conversion			$0.20^{\dagger}$		
σ_{Diboson}		0.060			
$\sigma_{t\bar{t}}$				0.100	
$\sigma_{Z\gamma}$*			0.050		

Table:

* New to *WZ* analysis.

† Replaces the '$W\gamma$ scale' systematic, $Z\gamma$ no longer scaled down.

WZ-Fit

"The likelihood function is formed from a product of Poisson probabilities for each bin" in the neural net output and constrained by each systematic error s_c with a Gaussian distribution (CDF note 9763).

$$\mathcal{L} = \underbrace{\left[\prod_i \frac{\mu_i^{n_i} e^{-\mu_i}}{n_i!}\right]}_{\text{Poisson prob. over bins } i} \cdot \underbrace{\prod_c e^{\frac{s_c^2}{2}}}_{\text{Gaussian Dists. for Systematics}}$$

$$\mu_i = \sum_k \alpha_k \left[\prod_c (1 + f_k^c s_c)\right] \left(N_k^{\text{Exp.}}\right)_i$$

MINUIT minimizes the *negative* log likelihood and MINOS extracts the error on the minimization. We tell the fit program to keep the cross sections of backgrounds fixed to theoretical values while WZ is allowed to float. It then returns $\alpha_{WZ} = \frac{\sigma_{WZ}^{\text{measured}}}{\sigma_{WZ}^{\text{NLO}}}$.

- $\mu_i \equiv$ Total expectation of the i^{th} bin.
- $n_i \equiv$ Number of data events in the i^{th} bin.
- $f_k^c \equiv$ fractional uncertainty associated with systematic s_c and process k.
- $\left(N_k^{\text{Exp.}}\right)_i \equiv$ Expected number of events from process k in the i^{th} bin.
- $\alpha_k \equiv$ parameter used to measure the cross section

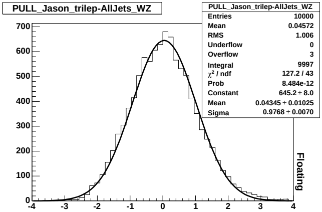
Obs. Cross Section

Define the “pull” for assymmetric errors as

$$\frac{\tau_g - \tau_m}{|\sigma_m^+|} \qquad \text{for } \tau_m \leq \tau_g$$

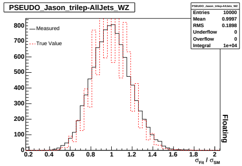
$$\frac{\tau_m - \tau_g}{|\sigma_m^-|} \qquad \text{for } \tau_m > \tau_g$$

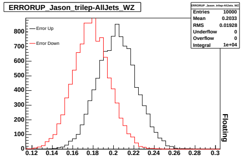
where τ_g is the generated value, τ_m is the measured value, and $\sigma_m^{\pm}$ are the positive and negative errors. The mean of the Gaussian fit to the fit distribution could be displaced from zero, indicating a fit bias on the value α_{WZ}. “To check for fit bias, we plot the distribution of differences, $\tau_g - \tau_m$, and fit it to a Gaussian. The mean of this Gaussian gives the fit bias.”

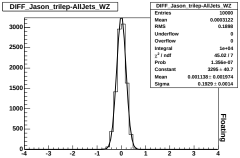


Obs. Cross Section

- With 10,000 pseudoexperiments, the fit result is $\alpha_{WZ} = 1.1363^{+0.2185}_{-0.1923}$, corresponding to $\sigma_{WZ,\text{obs.}} = 4.18^{0.81}_{0.71}$ pb, assuming and consistent with a theoretical cross section $\sigma_{WZ,\text{SM}} = 3.68 \pm 0.25$ pb.
- But the pull yields a mean of 0.04345 ± 0.01025, so does this constitute a significant bias? We check the corresponding *_Diff distribution to see how much it affects α_{WZ}, and therefore the cross section measurement.
- The *_Diff distribution yields a mean 0.001138 ± 0.001974, corresponding to a cross section deviation on the order of $4.1856 - 4.1816 = 0.0040$ pb, insignificant compared to the measured errors.







Obs. Cross Section

This study measures the WZ diboson cross section at $\sigma_{WZ,\text{obs.}} = 4.18^{0.81}_{0.71}$ pb with 5.3fb^{-1}, compared to the previously observed cross section with 1.1fb^{-1} $\sigma_{WZ,\text{obs.}} = 5.0^{1.8}_{1.6}$ pb and a predicted cross section $\sigma_{WZ,\text{SM}} = 3.68 \pm 0.25$ pb