

Full Status for WZ Cross Section in Trilepton+ $\cancel{E}_T$ Signature with 5.3fb^{-1}

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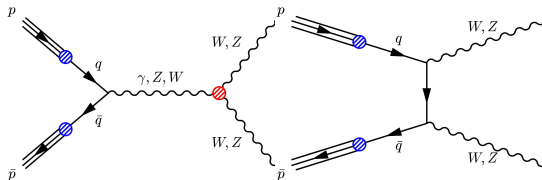
Collider Detector at Fermilab

15 April 2010

Summary

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History of WZ Trileptons



- D0 published 22 June 2006 at $3.98^{+1.91}_{-1.53}$ with 1.1fb^{-1} .
- CDF published WZ diboson discovery on 18 February 2007 at $5.0^{+1.8}_{-1.6} \text{pb}^{-1}$ with 1.1fb^{-1} . (10.1103/PhysRevLett.98.161801, CDF Note 8659)
- Last update: Blessed 10 August 2007, but not published, measuring $4.3^{+1.3}_{-1.0}(\text{stat.}) \pm 0.4(\text{syst.}) \text{pb}$.

Framework

- This measurement uses the $H \rightarrow WW$ group's *Diboson_v17* framework.
- Datasets:
 - ELECTRON_CENTRAL18
 - MUON_CMUP18
 - MUON_CMX18
 - MET_PEM
 - MUON_CMP18_PHI_GAP
- Lepton Reconstruction:
 - Likelihood-based electrons (LBE): recently replaced “tight central electrons” (TCE).
 - PHX, CMUP, CMX
 - CMIOCES, CMIOCES
 - Crack Tracks (CrkTrk)

Signal and Control Regions

Signal Region

- 3 Leptons
- $\cancel{E}_T > 25.0$ GeV
- Any number of jets
- Z-Peak Selection:
 $m_{ll} \in [76.0, 106.0]$ GeV,
where the two leptons
have opposite charge and
same flavor.

Low $\cancel{E}_T$ Control Region

- 3 Leptons
- Any number of jets
- Z-Peak Selection
- $\cancel{E}_T < 20.0$ GeV

Z-Removed Control Region

- 3 Leptons
- Any number of jets
- No $\cancel{E}_T$ cut
- Z-Peak Selected Against:
 $m_{ll} \in \{[0.0, 66.0] \cup [116.0, \infty)\}$ GeV

Backgrounds

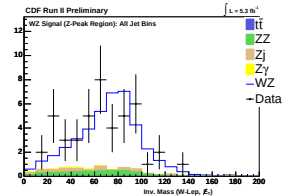
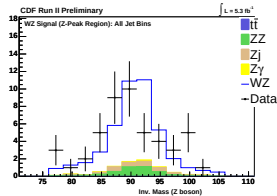
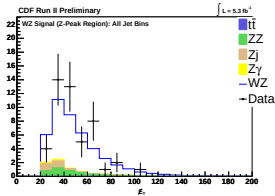
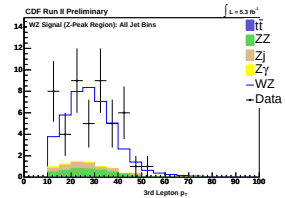
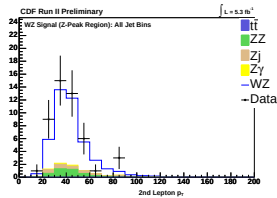
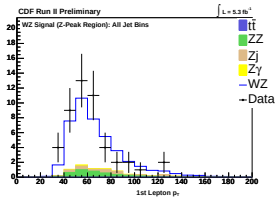
- $ZZ \rightarrow llll$: With a four-lepton topology, some significant portion of events fail to reconstruct one, leaving a Z -lepton pair + 1 more lepton + $\cancel{E}_T$ b/c one is lost. Most difficult to discriminate against.
- $Z\gamma$: Drell-Yan + ISR or FSR, with photon conversion.
- Z +Jets (“Fakes”): Two fully reconstructed leptons + one looser “denominator object” we call a “faked” lepton from a jet. Data-based, not MC.
- $t\bar{t}$: Two W ’s + b -jets, b -jets provide the third lepton signature a small amount of the time. Nearly negligible.

Signal Region

Process	Events		
ZZ	4.42	$\pm$	0.58
$Z + \text{jets}$	2.82	$\pm$	0.69
Z/γ^*	0.65	$\pm$	0.23
$t\bar{t}$	0.04	$\pm$	0.01
Total Background	7.93	$\pm$	0.96
WZ	35.9	$\pm$	3.63
Signal+Background	43.9	$\pm$	4.10
Data	48		

Table: Expected signal (WZ) and background events. The integrated luminosity is 5.3 fb^{-1} . Errors shown are systematic uncertainties only.

Signal Region

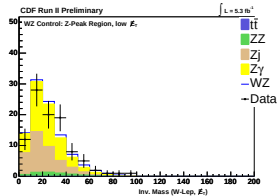
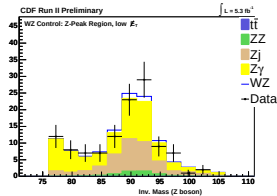
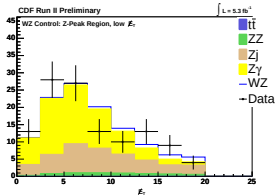
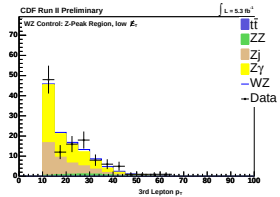
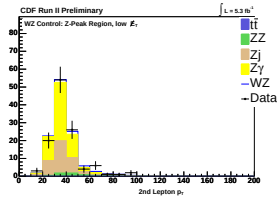
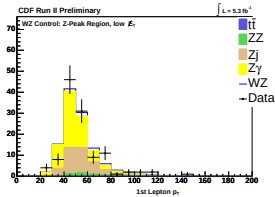


Low $\cancel{E}_T$ Control Region

Process	Events		
ZZ	6.43	$\pm$	0.85
$Z+\text{jets}$	38.9	$\pm$	9.5
$Z\gamma^*$	65.1	$\pm$	22.8
$t\bar{t}$	0.009	$\pm$	0.003
Total Background	110	$\pm$	25
WZ	5.87	$\pm$	0.59
Signal+Background	116	$\pm$	25
Data	117		

Table: Low $\cancel{E}_T$ Control Region

Low E_T Control Region

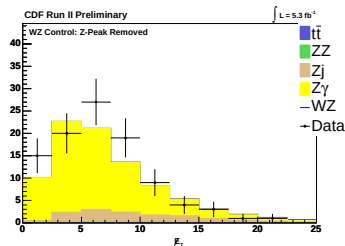
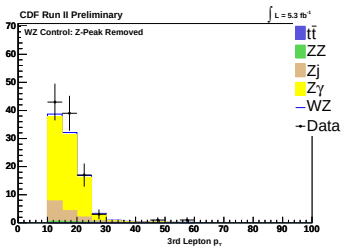
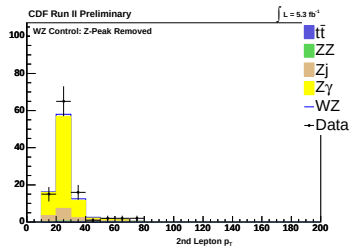
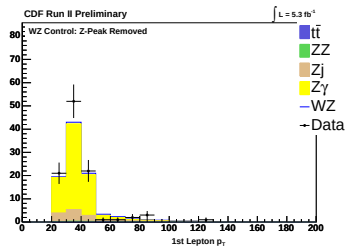


Z-Removed Control Region

Process	Events		
ZZ	1.54	$\pm$	0.20
$Z + \text{jets}$	14.4	$\pm$	3.53
$Z\gamma^*$	74.6	$\pm$	26.1
$t\bar{t}$	0.29	$\pm$	0.09
Total Background	90.8	$\pm$	26.4
WZ	3.15	$\pm$	0.32
Signal+Background	94.0	$\pm$	26.6
Data	104		

Table: Z Peak Removed Region

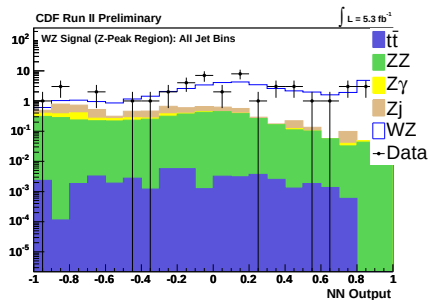
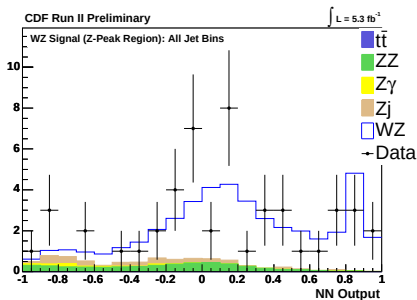
Z-Removed Control Region



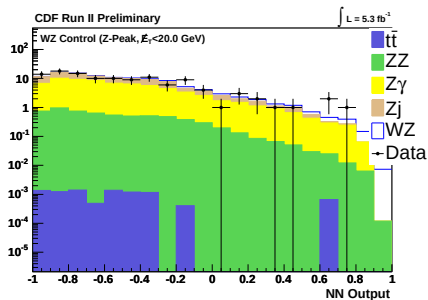
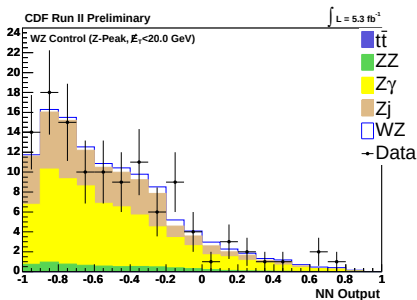
Discriminating Variables

- 1 $\Delta\phi$ (W -Lep., $\cancel{E}_T$)
- 2 m_T (jets), 0-jet events just assigned a value of zero.
- 3 Lepton type combinations: discriminate by whether an event is eee (three electrons), $ee\mu$, $e\mu\mu$, etc.
- 4 $\cancel{E}_T$
- 5 m_T (W -Lep., $\cancel{E}_T$)
- 6 $\Delta\phi$ (2nd Lep. by p_T ., $\cancel{E}_T$)
- 7 H_T
- 8 m_T (All Lep. , $\cancel{E}_T$, Jets)
- 9 m_T (3rd Lep. by p_T , $\cancel{E}_T$)
- 10 $\Delta\phi$ (vector sum of the three leptons, $\cancel{E}_T$)
- 11 m_T (three leptons)
- 12 NJet

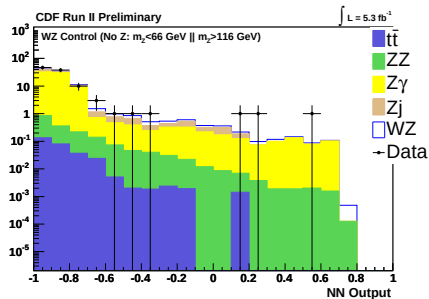
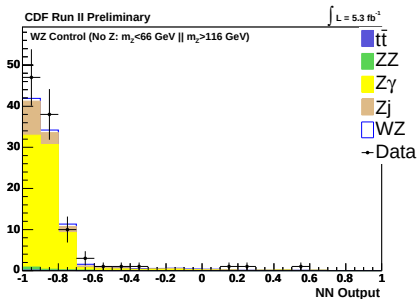
Signal Region NN Score



Low E_T Control NN Score



No Z Control NN Score



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).

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

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

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 .
- $(N_k^{\text{Exp.}})_i \equiv$ Expected number of events from process k in the i^{th} bin.
- $\alpha_k \equiv$ parameter used to measure the cross section

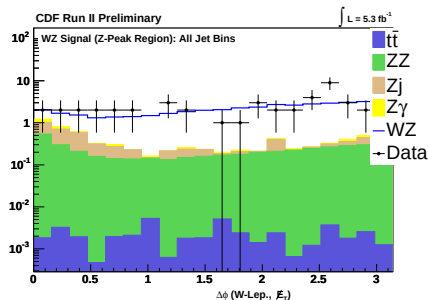
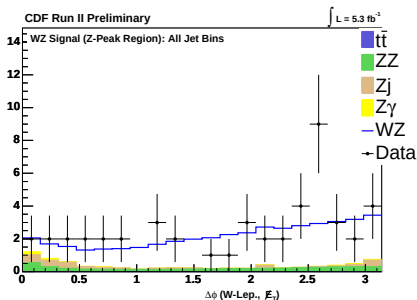
Systematics

Systematic Uncertainty	WZ	ZZ	$Z\gamma$	$t\bar{t}$	Fakes
Diboson Acceptance	0.100	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 Efficiencies	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		
σ_{Diboson}		0.060			
$\sigma_{t\bar{t}}$				0.100	
$\sigma_{Z\gamma}$			0.050		

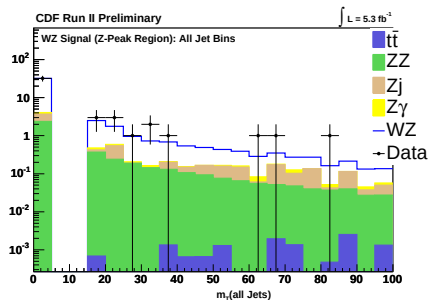
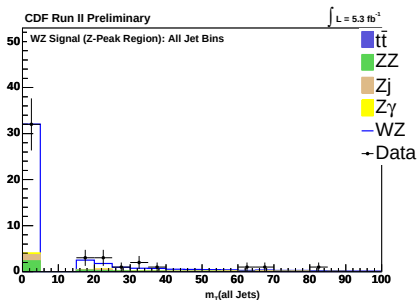
Results

- The fit parameter for the WZ cross section returns as $\alpha_{WZ} = 1.050^{+0.256}_{-0.213}$.
- Yielding WZ cross section:
 $\sigma(p\bar{p} \rightarrow WZ) = 3.63^{+0.68}_{-0.61}|_{\text{stat}}^{+0.57}_{-0.40}|_{\text{syst}}(\text{pb})$
- Or combining errors: $\sigma(p\bar{p} \rightarrow WZ) = 3.63^{+0.89}_{-0.73}(\text{pb})$
- Consistent with theoretical prediction:
 $\sigma_{WZ}^{NLO} = 3.46 \pm 0.21 \text{ pb}$
- And a significant improvement over the last published result: $5.0^{+1.8}_{-1.4}(\text{stat}) \pm 0.4(\text{syst}) \text{ pb}$

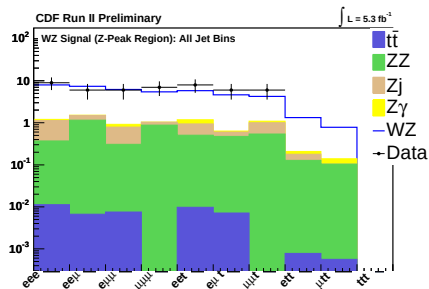
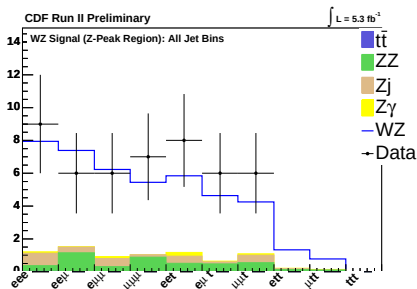
Signal Region Discriminating Variables



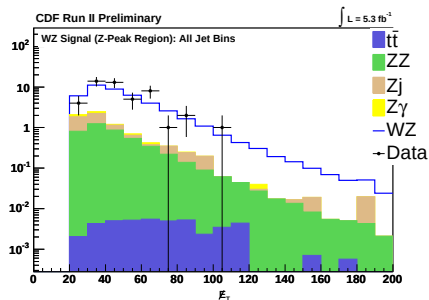
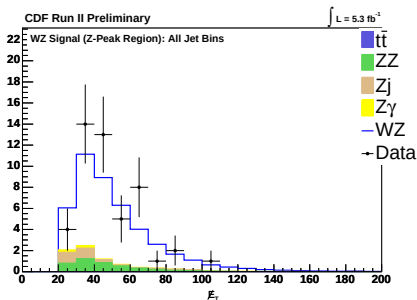
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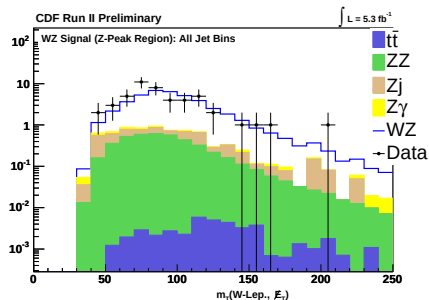
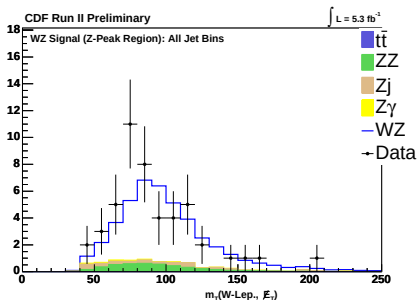
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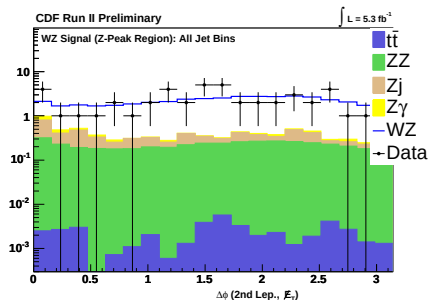
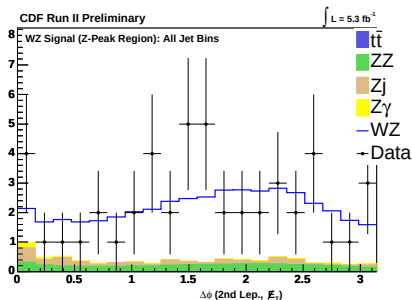
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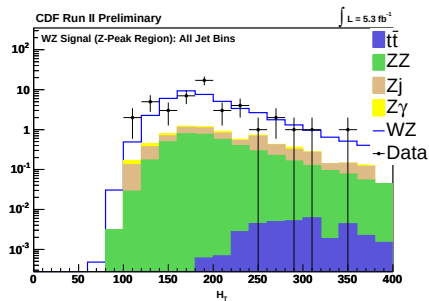
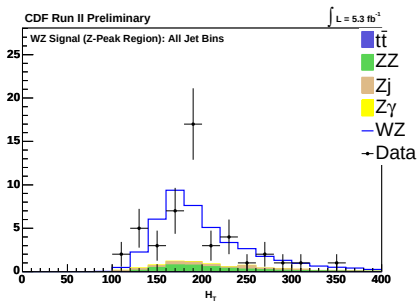
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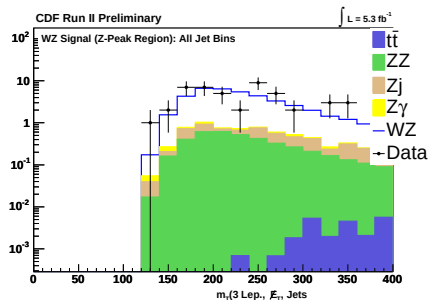
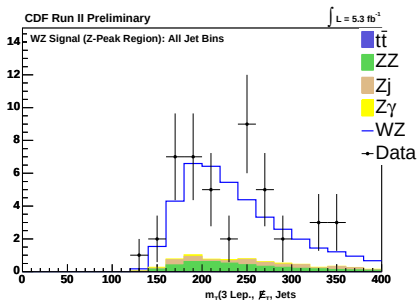
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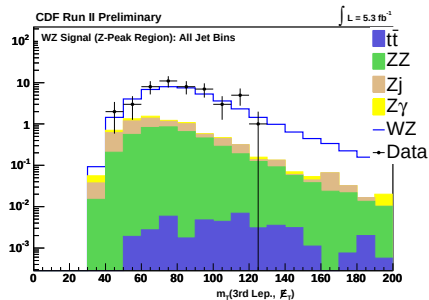
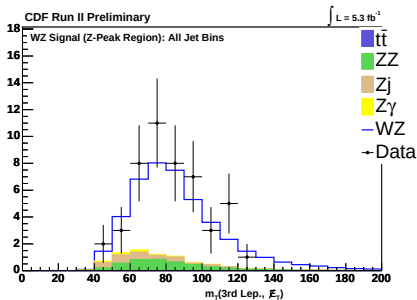
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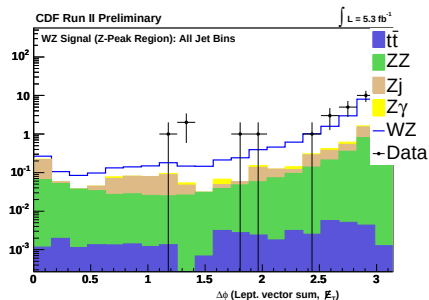
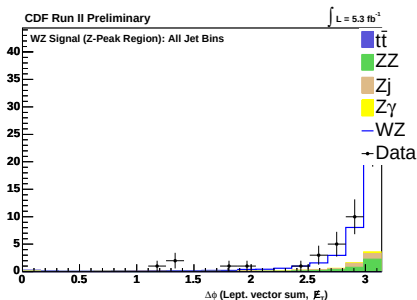
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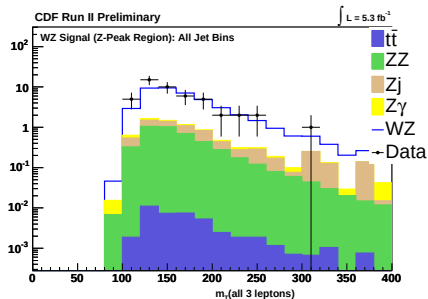
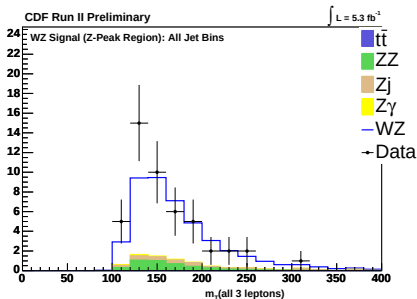
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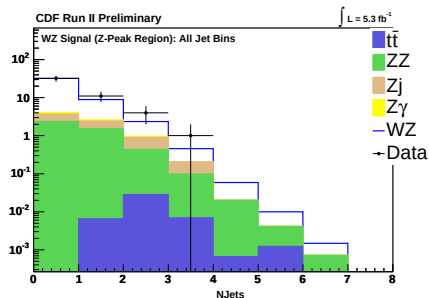
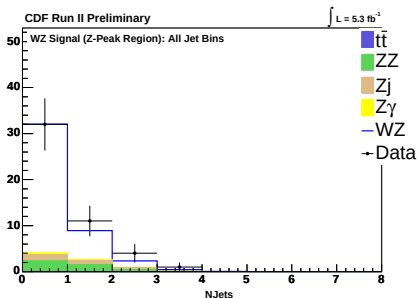
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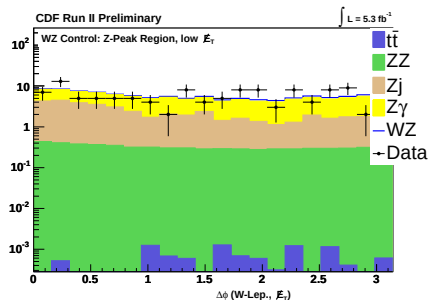
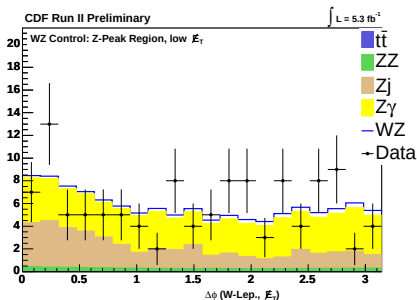
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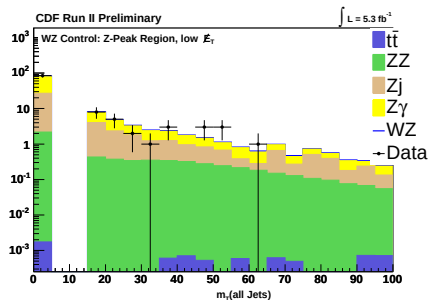
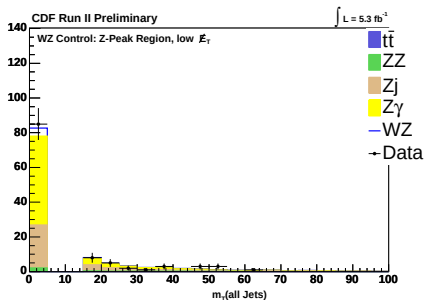
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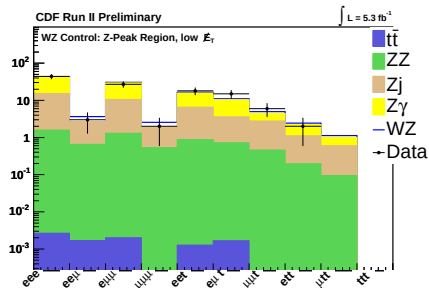
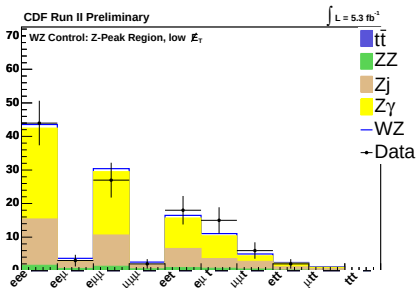
Low $\cancel{E}_T$ Control Region Discriminating Variables



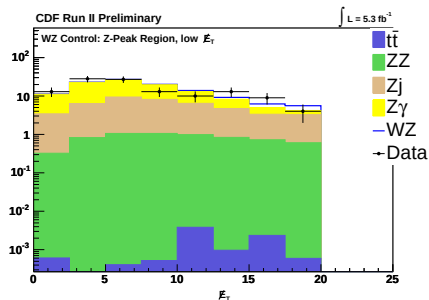
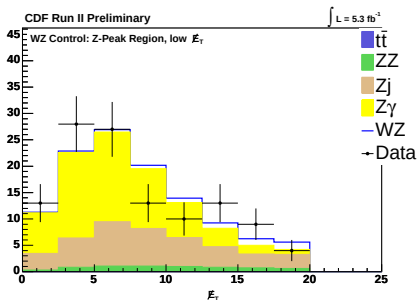
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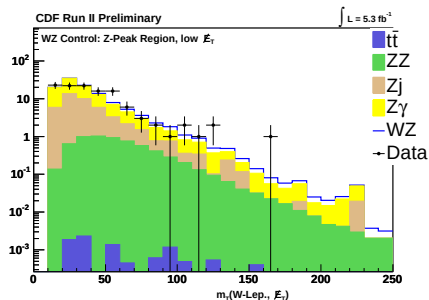
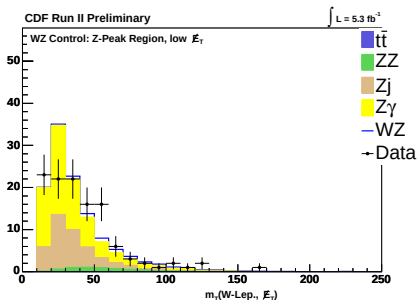
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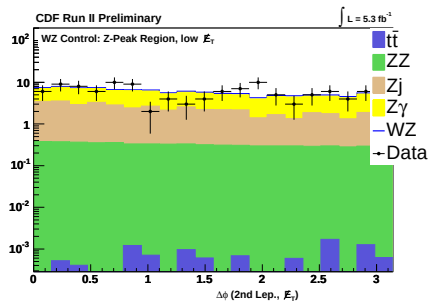
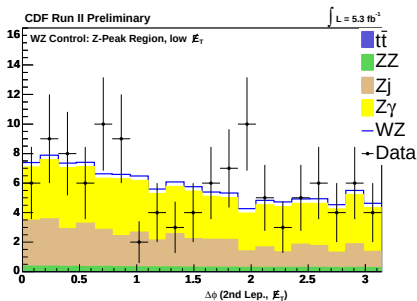
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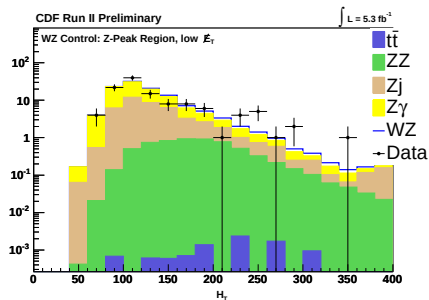
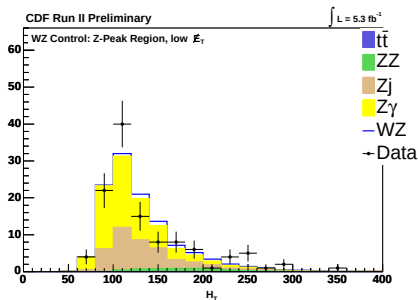
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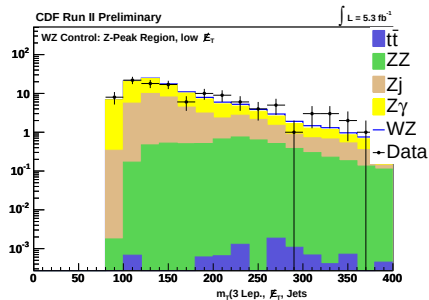
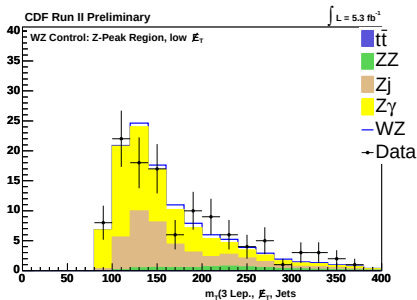
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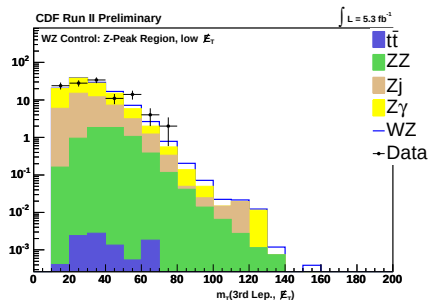
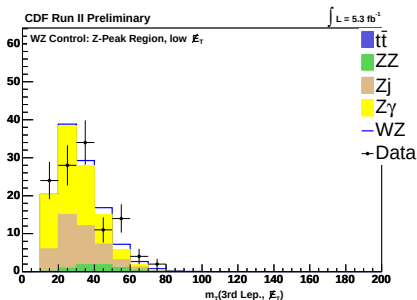
Low $\cancel{E}_T$ Control Region Discriminating Variables



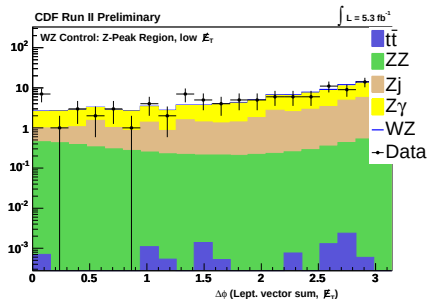
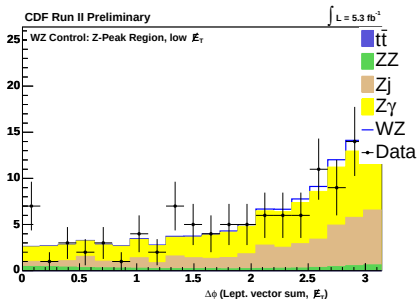
Low $\cancel{E}_T$ Control Region Discriminating Variables



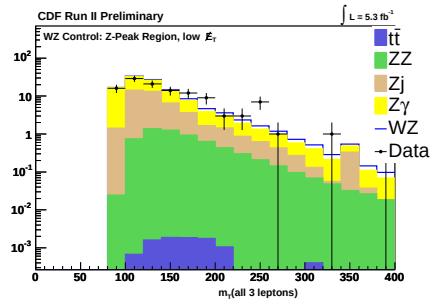
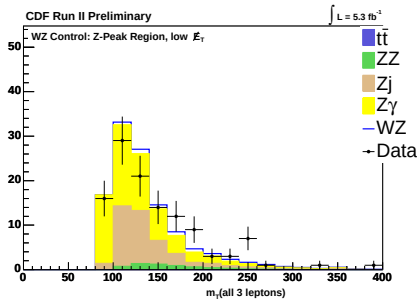
Low $\cancel{E}_T$ Control Region Discriminating Variables



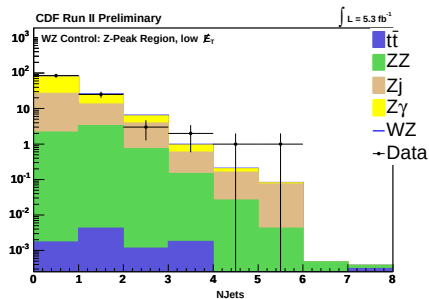
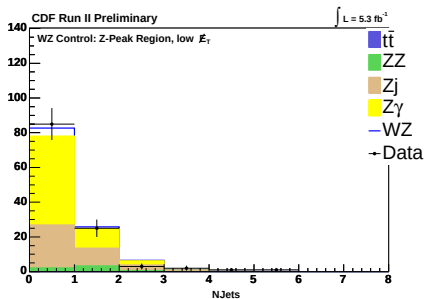
Low $\cancel{E}_T$ Control Region Discriminating Variables



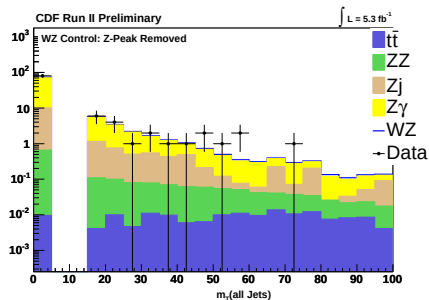
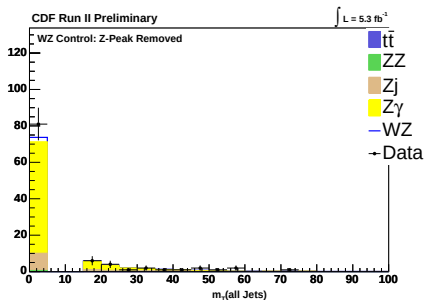
Low $\cancel{E}_T$ Control Region Discriminating Variables



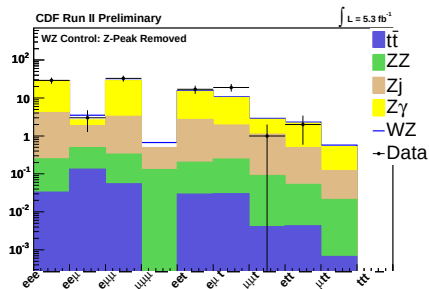
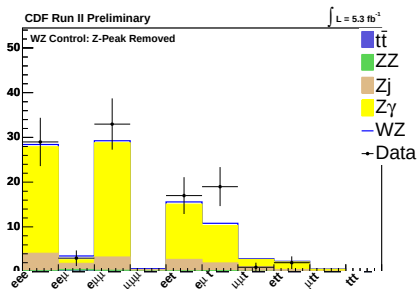
Low $\cancel{E}_T$ Control Region Discriminating Variables



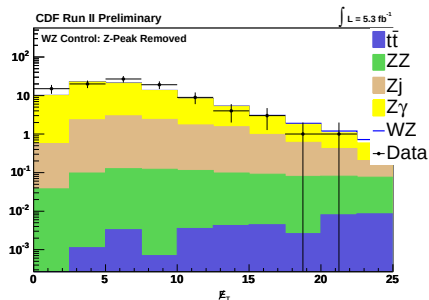
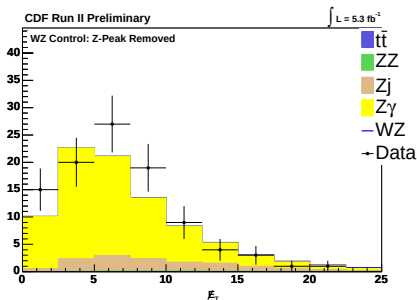
Z Removed Control Region Discriminating Variables



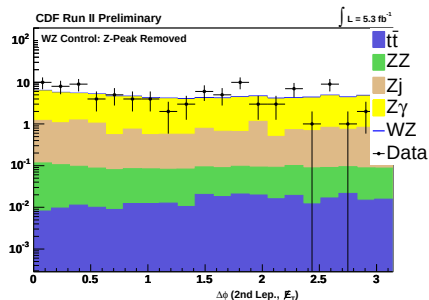
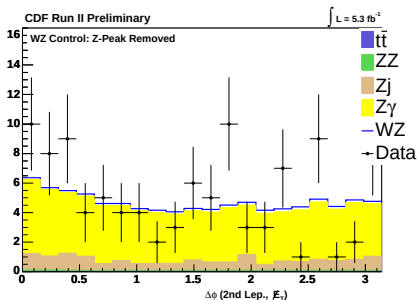
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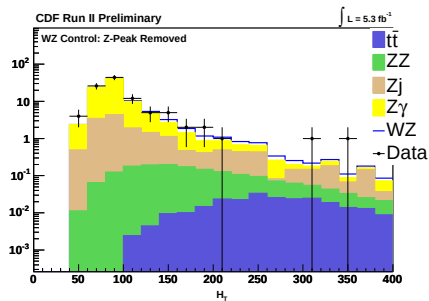
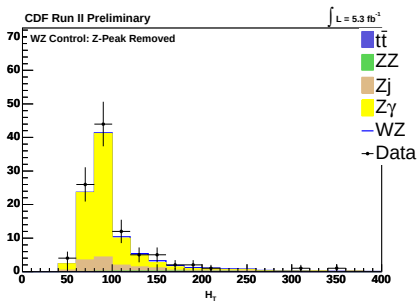
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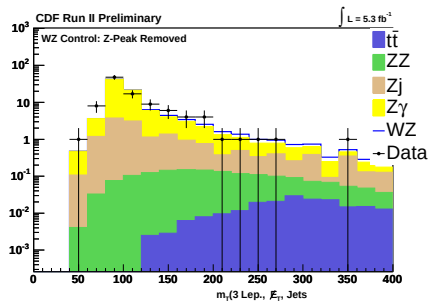
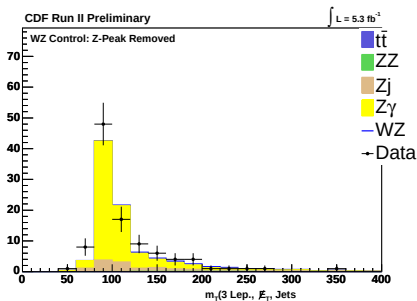
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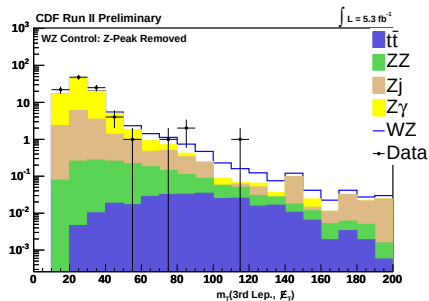
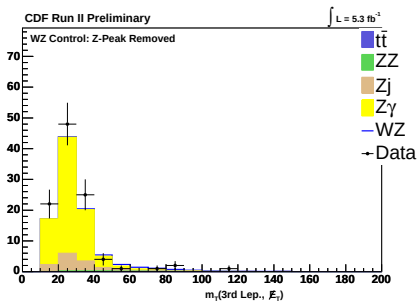
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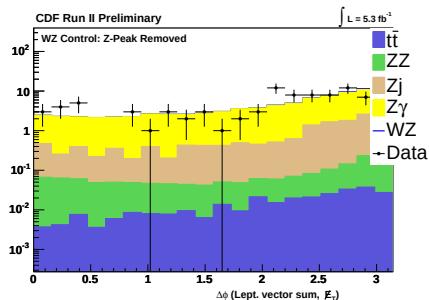
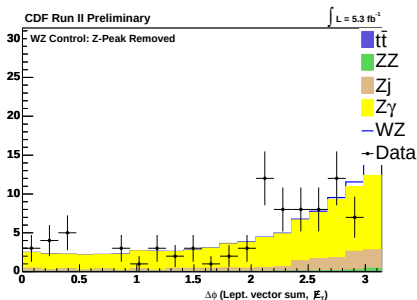
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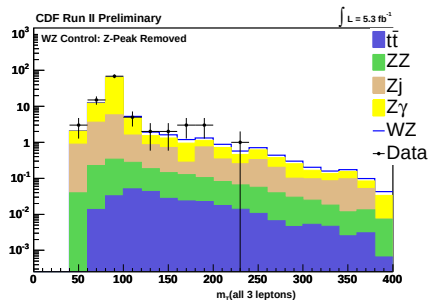
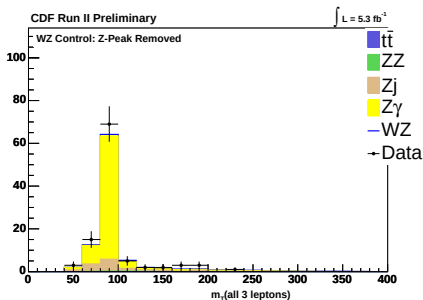
Z Removed Control Region Discriminating Variables



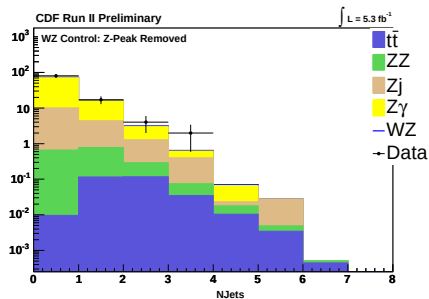
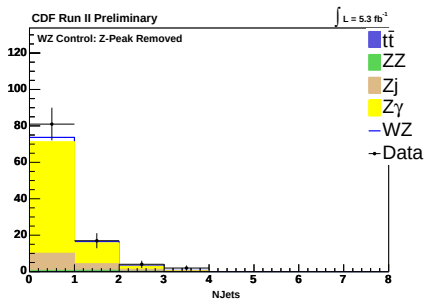
Z Removed Control Region Discriminating Variables



Z Removed Control Region Discriminating Variables



Z Removed Control Region Discriminating Variables



Individual Systematic Effects

Systematic	α_{WZ}	Positive Error	Negative Error
No Syst.	1.0662884	0.1970546	0.1768465
ZgConv	1.0662481	0.1970654	0.1768553
DiboAcc	1.0582665	0.2382274	0.2212017
ttAcc	1.0662884	0.1970547	0.1768465
PDF	1.0655171	0.2003392	0.1789047
ID	1.0658904	0.1988512	0.1779732
Trig	1.0658159	0.1990489	0.1781011
Fake	1.0632795	0.1970638	0.1779794
Lumi	1.0634136	0.2117762	0.1866827
MCDep	1.0662859	0.1970553	0.1768470
XSDibo	1.0659908	0.1971662	0.1769471
XStt	1.0662884	0.1970547	0.1768465
XSZg	1.0662859	0.1970553	0.1768470
bfake	1.0662884	0.1970548	0.1768466
ZgAcc	1.0662762	0.1970579	0.1768492
JES	1.0662883	0.1970547	0.1768465
All Syst.	1.0499676	0.2564898	0.2126826

Table: Results from fit to data when using only the systematic given.