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Measurement of the WW Cross Section using 0.8fb^{-1}

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Abstract

We present a measurement of the WW cross-section using 800 pb^{-1} of data. We find

$$\sigma = 13.69 \pm 2.32(\mathrm{stat}) \pm 1.56(\mathrm{sys}) \pm 1.19(\mathrm{lum})\ \mathrm{pb},$$

with a sample of 95 events and an expected background of $37.2 \pm 0.9 \pm 4.6$ which is consistent with the Next-to-Leading-Order calculation of the Standard Model WW cross-section, $\sigma_{NLO}^{WW} = 12.4 \pm 0.8 pb$.

Contents

1 Introduction

We present the selection and preliminary measurement of the WW production cross-section, using 800 pb^{-1} as the first step toward a detail measurement of the $WW\gamma$ and WWZ triple gauge couplings. With the large new CDF dataset, the $WW \rightarrow ll\nu\nu$ mode is moving from the regime of low statistics cross-section measurements to a mode in which to make a detailed study of the kinematics of the production mechanism. This analysis quadruples the statistics of the previous CDF WW cross-section measurement [1] which measured a cross-section of

$$\sigma(p\overline{p} \rightarrow WW) = 14.5^{+5.8}_{-5.1}(stat)^{+1.8}_{-3.0}(sys) \pm 0.9(lum)pb \tag{1}$$

with a sample of 17 events and an expected background of $5.1^{+2.1}_{-0.6}$. Here we find

$$\sigma(p\overline{p} \rightarrow WW) = 13.69 \pm 2.32(\mathrm{stat}) \pm 1.56(\mathrm{sys}) \pm 1.19(\mathrm{lum})\ \mathrm{pb}, \tag{2}$$

with a sample of 95 events and an expected background of $37.2 \pm 0.9 \pm 4.6$. Both are consistent with the Next-to-Leading-Order calculation of the Standard Model WW cross-section, $\sigma^{WW}_{NLO} = 12.4 \pm 0.8pb$.

2 Event Selection

We reconstruct the WW events in the $ll + \not{E}_T$ final state. The other significant contributions to this final state are:

- Drell-Yan events with fake $\not{E}_T$ (where $Z \rightarrow \tau\tau$ is a special case in which there is some small expected real $\not{E}_T$),
- W+jets events where the jet produces a fake lepton,
- W+γ events where the γ produces a fake electron,
- $t\bar{t}$ events all have to real Ws,
- WZ events in which a lepton is lost,
- ZZ events in which either a lepton is lost or on Z decays to $\nu\overline{\nu}$.

There are limited handles to suppress these backgrounds while maintaining the signal acceptance. We apply a jet veto to suppress the $t\bar{t}$ contribution and a tighter $\not{E}_T$ requirement in the Z mass region.

This section is describes the datasets and trigger paths used, the selections of the individual low-level objects: leptons, jets, and $\not{E}_T$, and then the event level cuts.

Good run list	$\mathcal{L}$ (pb^{-1})
EM_NOSI	824.5
EM_CMUP_NOSI	803.3
EM_MU_NOSI_CMXIGNORED	747.6
EM_SI	753.9
EM_CMUP_SI	735.1
EM_MU_SI_CMXIGNORED	682.8

Table 1: Luminosity for each of the good run lists used in this analysis. These have been scaled by the factor of 1.019.

2.1 Datasets and Trigger Paths

In order to maximized efficiency, we use four trigger paths which feed three separate data samples. The trigger paths are ELECTRON_CENTRAL_18, MET_PEM, MUON_CMUP_18, MUON_CMX_18. The inclusion of the MET_PEM trigger adds the PHX-PHX and PHX-CMIO categories described below for 1.5% and 4.5% additional acceptance respectively. It also allows us to gain back some fraction of the trigger inefficiency for events that could pass multiple triggers. The detail of the applications of trigger efficiencies are described in Section 4.1.2.

The corresponding datasets are bhel0d/0h, bpel0d/0h, and bhmu0d/0h. We combined all the datasets into one effective dataset, vetoing multiple entries to avoid double counting events that are included more than one of the datasets. We only include runs in the following v10 good run lists:

EM_NOSI	EM_SI
EM_CMUP_NOSI	EM_CMUP_SI
EM_MU_NOSI_CMXIGNORED	EM_MU_SI_CMXIGNORED

The corresponding luminosities are shown in Table 2.1.

2.2 Low-level Objects

Selection begins with construction of categories of identified leptons, reconstruction of jets, and calculation of the $\not\!\!E_T$ in each event. These are described in this section.

2.2.1 Lepton Identification and Categories

We use two categories of electrons and three categories of muons for this analysis. The electrons are TCE and PHX and the muons are CMUP, CMX, and CMIO where CMIO is defined at any things that passes the CMIO cuts, but does not pass the CMUP and CMX cuts. The cut used for each category are shown in Tables 2-4.

	TCE
Region	Central
Fiducial	FidEleSmx ==1
E_T	>= 20
Track p_T	>= 10
Track $\|z_0\|$	<= 60 cm
#Ax SL (5hits)	>= 3
#St SL (5hits)	>= 2
Conversion	! = 1
Had/Em	$<= 0.055 + 0.00045E$
Iso/E_T	<= 0.1
Lshr	<= 0.2
E/P	$< 2.5 + 0.015 * E_T$
Signed CES ΔX	$-3 <= q\Delta X <= 1.5$ cm
$CES\|\Delta Z\|$	< 3 cm
Tracks	BcTrk (Larry's Correction if Data)

Table 2: Selection for central leptons.

We require both leptons to have at least 20 GeV E_T. This choice and the use of standard TCE, CMUP, CMX, and PHX selections means that the trigger efficiencies measured in notes 7939[5], 7956[6], and 7940 [7].

2.2.2 Track Isolation

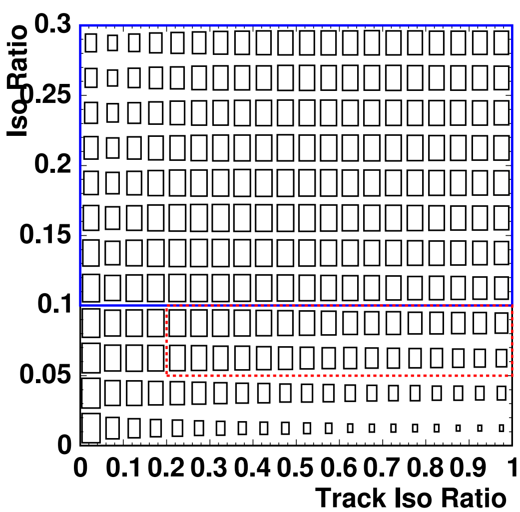
Because of an unexpected background attribued to W+jets in the same sign cross-check region, we have added a cut on the track isolation ratio. The track isolation is defined as the sum of the p_T all the defTrack tracks in a cone of ΔR¡0.4 around each candidate lepton. We choose a cut of $TIso < 0.2$ if $Iso > 0.05$. This 2-d cut was choosen to minimize the loss of efficiency while removing the region populated by the jets in the jet sample and denominators in the electroweak samples. In Figure 1, we show the distributions of denominator objects in the bhel0h and identified leptons (without the isolation cuts) in the Gen5 Zee MC. Both plots have the Z-axis on a log scale so that the cut region is visible. The cut removes $\approx$ 1% of the WW acceptance and $\approx$ 30% of the fake rate (depending on the jet sample). The N-1 efficiencies for this cut are shown in Figure 6.

2.2.3 Jets

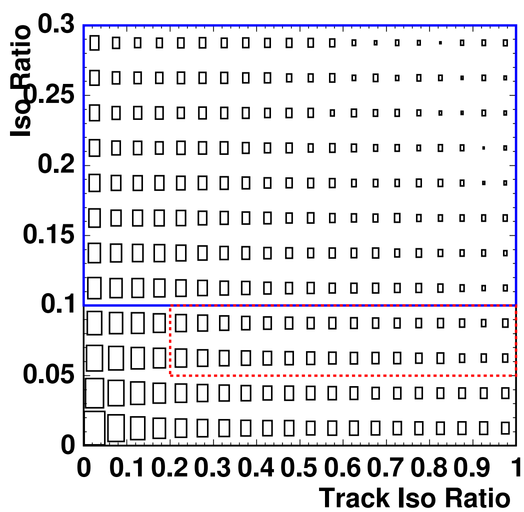
Jets are as part of the $\not\!\!E_T$ correction applied below and for the jet counting used to suppress $t\bar{t}$ background. The jets used in this correction are selected with a cone size of ΔR <0.4 based on the JetClu algorithm. The level 5 corrections used to correct the

	PHX
Region	Plug
Et	20
Pes2DEta	$1.2 < \|\eta\| < 2$
Had/Em	$<= 0.05$
PEM3x3FitTower	true
$PEM3x3\chi^2$	$<= 10$
Pes5x9U	$>= 0.65$
Pes5x9V	$>= 0.65$
Iso/Et	$<= 0.1$
ΔR(Pes,PEM)	$<= 3.0$
PhxMatch	True
NSiHits	$>= 3$
$\|TrackZ0\|$	$<= 60cm$

Table 3: Selection for phoenix electrons



(a) Denominator objects in bhel0h



(b) Identified leptons in Zee MC

Figure 1: Distributions of denominator objects in the bhel0h(left) and identified leptons (without the isolation cuts) in the Gen5 Zee MC(right). The solid (blue) box show the region already excluded by the calorimeter iso cut. The dotted (red) box shows the region exclude by the 2-d cut. Both plots have the z-axis on a log scale.

	Muon
Track p_T	$>= 20$
CMU Fid	x-fid< 0 cm z-fid< 0cm
CMP Fid	x-fid< 0 cm z-fid<-3cm
CMX Fid	x-fid< 0 cm z-fid<-3cm
E_{em}	$<= 2 + max(0, (p - 100) * 0.0115)$
E_{had}	$<= 6 + max(0, (p - 100) * 0.028)$
Iso/Pt	$<= 0.1$
NAxL(5 hits)	$>= 3$
NStL(5 hits)	$>= 2$(3 if CMIO)
Track $\|Z_0\|$	$<= 60cm$
Track $\|D_0\|$	$<= 0.2cm$ (0.02cm if NSiHit> 0)
χ^2/dof	$<= 4$ (3 if run $<= 186598$ or CMIO)
$\|\Delta X_{CMU}\|$	$<= 7cm$
$\|\Delta X_{CMP}\|$	$<= 5cm$
$\|\Delta X_{CMX}\|$	$<= 6cm$
ρ_{exit}	> 140 cm if CMX
$E_{em} + E_{had}$	$> 0.1GeV$ if CMIO
CMP veto	No Bluebeam in CMP for run < 154449
CMX veto	No CMX for run < 150144, No Miniskirt, No Keystone
Arches	Arches only for all run range
	Arches removing wedge 14 on West Side for run > 190697
Tracks	BcTrk (Larry's Correction if Data)

Table 4: Selection for CMUP, CMX, and CMIO muons

	Gen5	Gen6	CDF Note
TCE	0.9620 ± 0.006	0.9766 ± 0.006	7939
PHX	0.910 ± 0.003	0.910 ± 0.003	7940
CMUP	0.8977 ± 0.005	0.9186 ± 0.004	7956
CMX	0.9665 ± 0.004	0.9586 ± 0.004	7956

Table 5: Trigger effieciencies used.

	TCE	CMUP	CMX	CMIO
Gen5 Data	0.9920+-0.0007	0.9989+-0.0005	0.9991+-0.0006	0.9993+-0.0003
Gen5 MC	0.9924+-0.0002	0.9996+-0.0001	0.9994+-0.0001	0.9995+-0.0001
Gen6 Data	0.9913+-0.0007	0.9996+-0.0003	0.9978+-0.0009	0.9992+-0.0003
Gen6 MC	0.9920+-0.0002	0.9997+-0.0001	0.9995+-0.0001	0.9995+-0.0001

Table 6: Track isolation cut N-1 efficiencies.

absolute energy scaled of the jets, but the higher level out of cone and underlying event corrections are not applied in order to avoid double counting or under counting of the energy. For the purposes of jet counting, we eliminate jets which $\Delta R < 0.4$ match our reconstructed leptons.

2.2.4 Missing Transverse Energy ($\not\!\!E_T$)

The $\not\!\!E_T$ calculation used for this analysis starts with the sum of the transverse energy over the entire calorimeter using the highest $\sum p_T$ vertex to define the directions. The $\not\!\!E_T$ is then corrected for the identified muons by subtracting the muons p_T and adding back its calorimeter E_T. Finally the $\not\!\!E_T$ is corrected for jets $E_T > 15$ GeV and $|\eta| < 2.5$ which do not $\Delta R < 0.4$ match any identified leptons in the event, by subtracting the corrected jet E_T and adding back the raw E_T.

2.3 Event Selection

2.3.1 Lepton Pair Selection

We select opposite sign charged-lepton pairs where both leptons have $E_T > 20$ GeV. With the 5 lepton types described above there are 14 triggerable combinations:

$e-e$	$e-\mu$		$\mu-\mu$	
TCE-TCE	TCE-CMUP	PHX-CMUP	CMUP-CMUP	CMX-CMX
TCE-PHX	TCE-CMX	PHX-CMX	CMUP-CMX	CMX-CMIO
PHX-PHX	TCE-CMIO	PHX-CMIO	CMUP-CMIO	

The tracks of the leptons are further required to be coincident in z, $|\Delta z_0| < 4$ cm.

2.4 Missing Energy and N_{jets} Requirements

We further make three selection requirements to separate WW events from Drell-Yan events:

- $\not\!\!E_T > 25$ GeV,

- $\min \Delta\phi(\not{E}_T, l) > 20^\circ$ if $\not{E}_T < 50$ GeV,
- if $76\ GeV < M_{ll} < 106\ GeV$ then we require $\not{E}_{T\mathrm{sig}} \equiv \frac{\not{E}_T}{\sqrt{\sum E_T}} > 3.0\ GeV^{1/2}$,
- no jets $E_T > 15$ GeV and $|\eta| < 2.5$ in the event ($N_{\mathrm{jets}} = 0$).

2.5 Cosmic Veto

The events which satisfy the *HasCosmic* selection described in CDF Note 6100 [8] are vetoed as cosmics.

3 Monte Carlo Samples

The acceptance and several of the backgrounds are estimated using Monte Carlo samples. Table 7 lists all the samples used. Here we give brief notes on the samples.

3.1 Heavy dibosons: WW, WZ, ZZ

The WW, WZ, and ZZ samples used are all PYTHIA based. The WW sample had both Ws required to decay to e, μ, or τ. The WZ samples is decayed with the Z decaying to a pair e, μ, or τ, and the W decaying inclusively, which is then filtered for two leptons above 1 GeV. The ZZ sample is constructed with both Zs decaying inclusively and then then filters for two leptons above 1 GeV. The ZZ Monte Carlo has a γ^* component in it and has an $M_{ll} > 15$ GeV generator level requirement.

3.2 $W\gamma$

The $W\gamma$ Monte Carlo used for this analysis uses the Baur matrix element generator [4] which is passed to PYTHIA via the LesHouchesModule. Because of indecision over the proper settings for the PYTHIA QED radiation settings the Gen5 sample has the QED turned off and the Gen6 sample has it turned on. The two settings correspond to slightly over estimating the lepton id efficiency and double counting at order α_{EM} the hard radiation, respectively. Neither of these effects should be significant for this analysis, relative to the conversion find efficiency and K-factor uncertainties. It should also be noted that the $W\gamma$ cross-section has been measured at CDF [10] and D0 [11].

3.3 $t\bar{t}$

The $t\bar{t}$ sample is generated at a mass of 175 GeV, uses Gen5 for the full run range and has no minbias in the events.

mode	Gen	Dataset	$\sigma \times \mathcal{B}$	K-factor[a]	Filter Eff
$W\gamma \to e\nu\gamma$	5	rewk06	21.48	1.34	1.0
$W\gamma \to \mu\nu\gamma$	5	rewk07	21.47	1.34	1.0
$W\gamma \to e\nu\gamma$	6	rewk08	21.48	1.34	1.0
$W\gamma \to \mu\nu\gamma$	6	rewk09	21.47	1.34	1.0
WW	5	sewkcd	1.27	1.0	1.0
WW	6	wewk5d	1.27	1.0	1.0
$t\bar{t}$	5	tewk0z	6.7	1.0	1.0
$t\bar{t}$	6	tewk1z	6.7	1.0	1.0
WZ	5	wewk6d	0.365	1.0	0.76
WZ	6	wewk6d	0.365	1.0	0.76
ZZ	5	wewk7d	2.01	1.0	0.23
ZZ	6	wewk7d	2.01	1.0	0.23
$Z \to ee$	5	sewkdd	355.3[b]	1.4	1.0
$Z \to ee$	6	zewk6d	355.3[b]	1.4	1.0
$Z \to \mu\mu$	5	zewk6m	355.3[b]	1.4	1.0
$Z \to \mu\mu$	6	zewk6m	355.3[b]	1.4	1.0
$Z \to \tau\tau$	5	zewk8t	237.8[b]	1.4	1.0
$Z \to \tau\tau$	6	zewk9t	237.8[b]	1.4	1.0

[a] If cross-section is NLO then K-factor is one.
[b] The difference between the $Z \to ee$ and $Z \to \mu\mu$ samples and the $Z \to \tau\tau$ sample is that the first two are generated with $m_{ll} > 20$ GeV and the second is generated with $m_{ll} > 30$ GeV.

Table 7: Monte Carlo samples used in this analysis

3.4 $Z \to \tau\tau$

The $Z \to \tau\tau$ sample is generated with a 30 GeV minimum dilepton mass, uses Gen5 for the full run range and has no minbias in the events.

3.5 $Z \to ee$ and $Z \to \mu\mu$

The $Z \to ee$ and $Z \to \mu\mu$ samples are generated with a 20 GeV minimum dilepton mass. They use Gen5 for the 0d run range and Gen6 for the 0h run range. They have a full luminosity dependent addition of minbias in the events.

4 Acceptance

4.1 Baseline

The Monte Carlo sample used to estimate the WW acceptance is described in Section 3. The baseline estimate of the efficiency is made separately for each of the lepton pair category described in Section 2.3.1. Each category is corrected for the lepton identification scale factors and trigger efficiencies that are relevant to that specific pair and for the relative luminosity of applicable good run list to the em_nosi good run list. The master formula is then

$$A_i \;=\; \frac{N_i^{\rm reco}}{N_i^{\rm gen}(|Z_0|<60\ {\rm cm})} \times \epsilon_i^{trg} \times s_i^{lep} \times \epsilon_{vtx} \times \frac{\mathcal{L}_i}{\mathcal{L}_{\rm em\_nosi}} \tag{3}$$

where A_i is the acceptance times the efficiency and

- $N_{\rm reco}$ is the number of reconstructed WW events passing the full selection,
- $N_{\rm gen}(|Z_0| < 60\ {\rm cm})$ is the number of generated events within 60 cm of the interaction point
- ϵ_{trg} is the effective trigger efficiency for the category (see below),
- s_{lep} is the effective lepton id scale factor (see below),
- ϵ_{vtx} is $0.9555 \pm 0.0004(stat) \pm 0.0031(sys)$ from CDF note 7935, and
- $\frac{\mathcal{L}_i}{\mathcal{L}_{\rm em\_nosi}}$ accounts for the relative amount of the applicable good run list.

Once calculated, the summary acceptances for the ee, $e\mu$, and $\mu\mu$ categories are shown in Table 8. The acceptances defined with the luminosity ratios are truly comparable in terms of predicting expected events and converting an observed number of events to a cross-section. The number is normalized to the total WW rate, so it includes the W branching fractions, possible τ branching fractions, and detector acceptance and reconstruction efficiency. This the same normalization as the previous Run 2 WW analysis [1], so the acceptances are comparable and in fact are very similar.

4.1.1 Application of the Lepton Id Scale Factors

The lepton id scale factors for this analysis are summarized in Table 9. They are discussed in detail in CDF Note 8093 [2]. These are applied by simply multiplying together the scale factor for each lepton type assuming that they are completely uncorrelated.

Cut	ee $(A \times 10^{-2}\%)$		$e\mu$ $(A \times 10^{-2}\%)$		$\mu\mu$ $(A \times 10^{-2}\%)$		ll $(A \times 10^{-2}\%)$	
Trig	25.5 ± 0.1	100.0	53.2 ± 0.1	100.0	20.8 ± 0.1	100.0	99.4 ± 0.2	100.0
Cosmic	25.5 ± 0.1	100.0	53.2 ± 0.1	100.0	20.8 ± 0.1	100.0	99.4 ± 0.2	100.0
ZVeto	22.2 ± 0.1	87.0	53.2 ± 0.1	100.0	18.0 ± 0.1	86.7	93.3 ± 0.2	93.9
Met	17.5 ± 0.1	78.7	38.6 ± 0.1	72.5	13.9 ± 0.1	77.2	69.9 ± 0.1	74.9
dPhi	16.8 ± 0.1	96.5	37.0 ± 0.1	96.0	13.4 ± 0.1	96.6	67.3 ± 0.1	96.2
OS	15.9 ± 0.1	94.4	35.9 ± 0.1	97.0	13.4 ± 0.1	100.0	65.3 ± 0.1	97.0
0jet	12.5 ± 0.1	78.9	28.2 ± 0.1	78.5	10.5 ± 0.0	78.0	51.2 ± 0.1	78.5
1jet	2.7 ± 0.0	21.2	6.1 ± 0.0	21.6	2.3 ± 0.0	22.0	11.1 ± 0.0	21.6

Table 8: WW acceptance as the cuts are applied. The number is normalized to the total WW rate, so it includes the W branching fractions. The second column is the fractional acceptance of that cut relative to the previous cut.

	Gen5	Gen6
TCE	0.9944	0.9926
PHX	0.9366	0.9223
CMUP	0.9334	0.9327
CMX	1.0078	1.0138
CMIO	1.0020	0.9916

Table 9: Lepton Id Scale Factors Used.

4.1.2 Application of the Trigger Efficiencies

All the data is combined into one dataset with repetitions removed. This means that events with two triggerable leptons are given two chances to trigger. We use this formula to combine trigger efficiencies

$$\epsilon_{trg} \quad = \quad 1 - (1 - \epsilon_{trg}^{\text{leg 1}}) \times (1 - \epsilon_{trg}^{\text{leg 2}}) \tag{4}$$

where $\epsilon_{trg}^{\text{leg 1,2}}$ are the trigger efficiencies for each leg. If one leg is not triggerable then its efficiency is set to zero.

4.2 Trigger Efficiency and Lepton Id Scale Factor Systematics

The statistical uncertainty on the scale factors is approximately 0.5% per leg, so a systematic of 1% is assigned for the total. The statistical uncertainty on the trigger efficiencies have been assessed to be between 1 and 2 percent, so a 2% systematic is assigned.

4.3 PHX charge mis-ID scale

In CDF Note 8093, we described a measurement the PHX charge mis-id scale factor. For both Gen5 and Gen6 this is approximately 2%. We do not correct the acceptance for this effect. Instead we apply this as a systematic. Approximately 13% of our acceptance uses PHX electrons so we apply a $0.13 \times 0.02 \approx 0.3\%$ systematic.

4.4 $\not\!\!E_T$ and $\sum E_T$ Systematics

The uncertainty due to modeling of the $\not\!\!E_T$ and $\sum E_T$ enters the acceptance calculation through the $\not\!\!E_T$ and $\not\!\!E_{T\text{sig}}$ cuts. The accuracy of the Monte Carlo in modeling these distributions can be assessed through level of agreement in the Drell-Yan $\not\!\!E_T$ and $\sum E_T$ distributions. It should be noted that the acceptance is sensitive to the core of this distribution, while the backgrounds discussed in the next section are sensitive to the tails of this distribution.

A quantitative estimate of the uncertainty is made by separately reweighting the WW Monte Carlo events by the data over Monte Carlo ratio of $\not\!\!E_T$ and $\sum E_T$ distributions. For the $\not\!\!E_T$ the resulting fractional uncertainty is

$$\frac{\dfrac{N^{\text{rw}}_{\text{all cuts}}}{N^{\text{rw}}_{\text{no }\not\!\!E_T\text{ cut}}}}{\dfrac{N_{\text{all cuts}}}{N_{\text{no }\not\!\!E_T\text{ cut}}}} - 1. \tag{5}$$

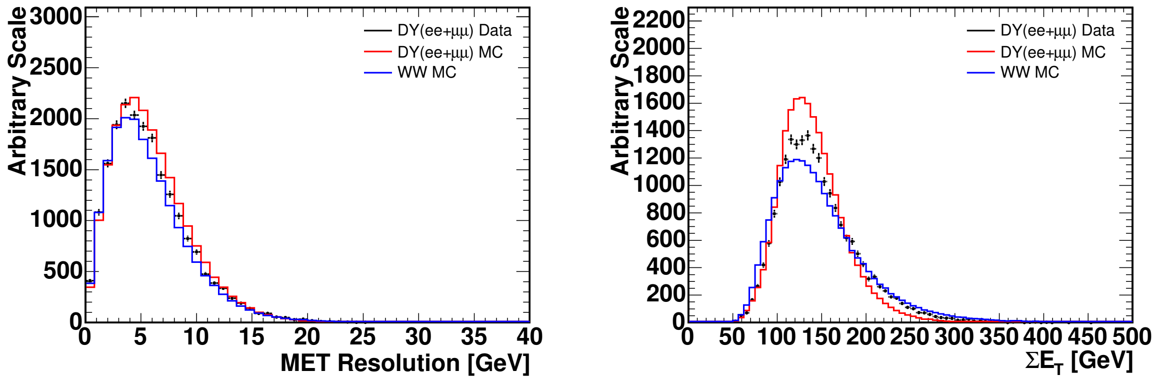


Figure 2: Distributions used for $\not{E}_T$ (left) and $\sum E_T$ (right) acceptance systematics.

where the weight used is

$$w = \frac{\mathcal{D}^{DY}_{\text{data}}(|\vec{\not{E}}^{\,WW}_{T\text{reco}} - \vec{\not{E}}^{\,WW}_{T\text{gen}}|)}{\mathcal{D}^{DY}_{\text{MC}}(|\vec{\not{E}}^{\,WW}_{T\text{reco}} - \vec{\not{E}}^{\,WW}_{T\text{gen}}|)} \tag{6}$$

where $\mathcal{D}_{\text{data}}$ and $\mathcal{D}_{\text{MC}}$ are the data and Monte Carlo Drell-Yan $\not{E}_T$ distributions shown in Figure 2. Also shown in Figure 2 is the distributions of the $\not{E}_T$ resolution $|\vec{\not{E}}^{\,WW}_{T\text{reco}} - \vec{\not{E}}^{\,WW}_{T\text{gen}}|$ for the WW Monte Carlo. To restate, the WW Monte Carlo resolution is reweighted by the weight that would take the Drell-Yan Monte Carlo to the data. No attempt to correct the data distributions for contributions other than Drell-Yan is made as the other contributions are very small. All cuts except for the $\not{E}_T$ and Z-veto cuts are applied to these distributions. The results are shown in Table 10.

The $\sum E_T$ systematic is made in an analogous way. The fractional uncertainty is then

$$\frac{\dfrac{N^{\text{rw}}_{\text{all cuts}}}{N^{\text{rw}}_{\text{no Z-veto}}}}{\dfrac{N_{\text{all cuts}}}{N_{\text{no Z-veto}}}} - 1. \tag{7}$$

with the weight

$$w = \frac{\mathcal{D}^{DY}_{\text{data}}(\sum E_T)}{\mathcal{D}^{DY}_{\text{MC}}(\sum E_T)}. \tag{8}$$

Again the distributions are shown in Figure 2 and the results in Table 10.

Category	$\frac{\Delta A}{A}$ $\not\!\!E_T$	$\frac{\Delta A}{A}$ $\sum E_T$
TCE-TCE	-0.42	0.73
TCE-PHX	-0.24	0.38
PHX-PHX	-0.08	0.18
TCE-CMUP	-0.28	0.00
TCE-CMX	-0.44	0.00
TCE-CMIO	-0.44	0.00
PHX-CMUP	-0.13	0.00
PHX-CMX	0.22	0.00
PHX-CMIO	-0.15	0.00
CMUP-CMUP	-0.27	0.64
CMUP-CMX	-0.18	0.40
CMUP-CMIO	-0.18	0.67
CMX-CMX	0.48	0.41
CMX-CMIO	-0.13	0.27
Total	-0.28	0.26

Table 10: Systematic uncertainties on the acceptance due to $\not\!\!E_T$ and $\sum E_T$. Note that the Z-veto is not applied to the $e\mu$ categories so the change in acceptance for those modes is zero.

4.5 Jet Counting Systematics

This systematic has not yet been calculated, for now we combine the ISR (6%), parton shower(4%), and jet energy scale(3%) uncertainties from the previous WW analysis [1] in to a jet counting systematic. The combined uncertainty is then 7.8%.

4.6 PDF Systematic

A set of variations of the CTEQ6M PDF are available which can be used to assess the uncertainty in the PDF shape. The WW Monte Carlo sample, however, was generated with the CTEQ5L PDF. Since this is not a large systematic, an expedient and conservative estimate was made by first reweighting the sample from the CTEQ5L to CTEQ6M PDF, and then applying the eigenvector variations. The reweighting function is

$$\text{weight} \quad = \quad \frac{\text{CTEQ6M}_\text{i}(x_1,q)\text{CTEQ6M}_\text{i}(x_2,q)}{\text{CTEQ5L}(x_1,q)\text{CTEQ5L}(x_2,q)} \tag{9}$$

where x_1, x_2, and q are extracted from the HEPG banks and CTEQ6M_i refers either to the CTEQ6M central value or one of the variations. For each eigenvector we get two shifts $\Delta A^i_\uparrow$ and $\Delta A^i_\downarrow$. These are combined following the prescription used for the Drell-Yan cross-section PRD [9], which results in the asymmetric errors shown 11. These uncertainties

Type	CTEQ6M-CTEQ5L ($\frac{\Delta A}{A}$)	CTEQ6M variations ($\frac{\Delta A}{A}$)	Combined ($\frac{\Delta A}{A}$)
ee	-0.57	$^{+0.39}_{-0.47}$	$^{+0.69}_{-0.73}$
$e\mu$	-1.48	$^{+0.56}_{-0.64}$	$^{+1.58}_{-1.61}$
$\mu\mu$	-2.60	$^{+1.00}_{-1.18}$	$^{+2.78}_{-2.85}$
all	-1.44	$^{+0.57}_{-0.61}$	$^{+1.55}_{-1.57}$

Table 11: Lepton Id Scale Factors Used.

Source	Uncertainty
Lepton Id	1.0%
Trigger Efficiency	2.0%
PHX Charge Mis-Id	0.3%
$\not\!\!E_T$ Modeling	0.3%
$\sum E_T$ Modeling	0.3%
Jet Counting	7.8%
PDF	1.6%
Sum	8.3%

Table 12: Summary of Acceptance Systematics

are combined with the shift from CTEQ5L to CTEQ6M. We use the mean systematic accounting for the relative production rates of ee, $e\mu$, and $\mu\mu$ which is a symetric 1.6%.

4.7 Acceptance Summary

A summary of all the acceptance systematics is shown Table 12. The systematics are combined in quadrature to get the final number

$$A = (50.9 \pm 0.1 \pm 4.23) \times 10^{-4} \tag{10}$$

5 Background Estimate

5.1 Drell-Yan + Fake $\not\!\!E_T$

The Drell-Yan background contribution is assessed with Monte Carlo. Figures 3, shows qualitatively good agreement, with the possible exception of the ee channel in Gen5. In order to make a quantitative systematic uncertainty estimate, we use the region $\not\!\!E_{T\mathrm{sig}} < 3\mathrm{GeV}^{\frac{1}{2}}$, $\not\!\!E_T > 25$ GeV. We use the same background estimation methods as for the signal region. We find 19 events with an expectation of 15.2 ± 0.8 which is a 0.95σ difference. We take the stastical uncertainty of this test as the systematic uncertainty on the Drell-Yan background in the signal region, $26\% = \sqrt{15.2 + 0.8^2}/15.2$. The results are shown in Table 16 with the channel-by-channel results shown in Table 20.

5.2 Fake Lepton

The background due to W+jets where the jet fakes a lepton is estimated using a fake rate method. We define a set of denominator objects and select all events with one tight lepton and a denominator object. Each of these is weight by the corresponding fake rate measured in jet data. The fake rates and procedures are described in detail in CDF Note [2].

This procedure misses the part of the total fake background in which the fake lepton caused the trigger. In this analysis there is only one category of nontriggering lepton: CMIO. In order to estimate this background, we apply scale factor derived from inclusive W Monte Carlo (the sample used is wewk7m),

$$\begin{aligned} f_{\frac{\mathrm{CMIO}}{\mathrm{CMUP+CMX}}} &= \frac{N(\mathrm{CMIO} - \mathrm{denominator})}{N(\mathrm{CMUP} - \mathrm{denominator}) + N(\mathrm{CMX} - \mathrm{denominator})} \\ &= 0.897 \pm 0.034, \end{aligned} \quad (11)$$

to the fake lepton background estimated with the triggered leptons. The estimated CMIO+fake lepton background is

$$Bkg_{\mathrm{CMIO+fake}} = f_{\frac{\mathrm{CMIO}}{\mathrm{CMUP+CMX}}} \times Bkg_{(\mathrm{CMUP\ or\ CMX})+(\mathrm{triggerable\ fake})}, \quad (12)$$

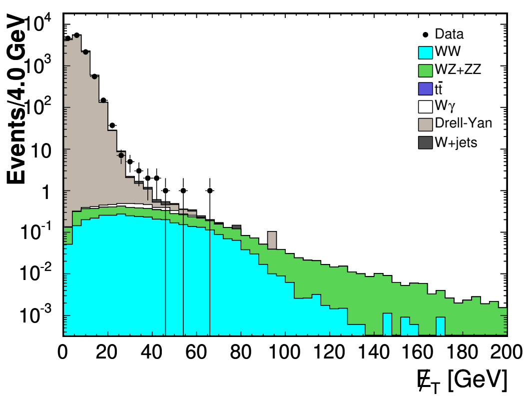
where the $Bkg_{(\mathrm{CMUP\ or\ CMX})+(\mathrm{triggerable\ fake})}$ is the background estimate for a real CMUP or CMX plus triggerable fake (TCE, PHX, CMUP, CMX).

As described in CDF note [2], the systematic uncertainty on the fake background is estimated from the scatter of the fake rates in the jet sample. Those uncertainties are propagated to this analysis by simply raising or lowering the entire fake rate by one systematic "σ". (We previously handled PHX specially because of poor agreement in the jet Monte Carlo to electroweak Monte Carlo fake rate extraction, this was traced to a failure to veto ISR which is already counted in the $W\gamma$ Monte Carlo). The resulting background estimate with systematic uncertainty is $17.59 \pm 0.7^{+8.24}_{-4.74}$ events.

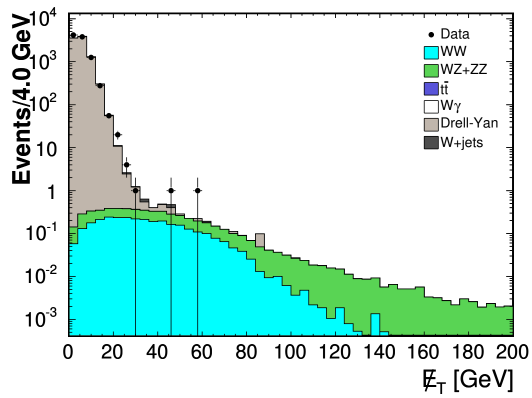
A cross-check of the fake rate calculation and procedure is given in the WZ note [2]. The region 3 leptons with out $\not{E}_T$ is predicted and measured. This region is dominated by fake leptons and $Z\gamma$ and hence provides a good check of two of the largest backgrounds in this analysis.

5.3 Wγ

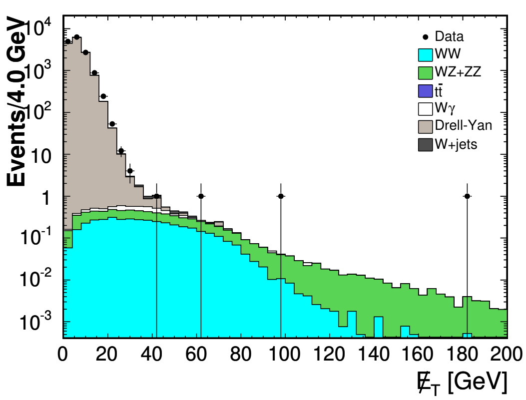
The Wγ mode enters the selection when the photon is reconstructed as an electron. This is usually due to a conversion. In the TCE selection, we explicitly veto conversions, but



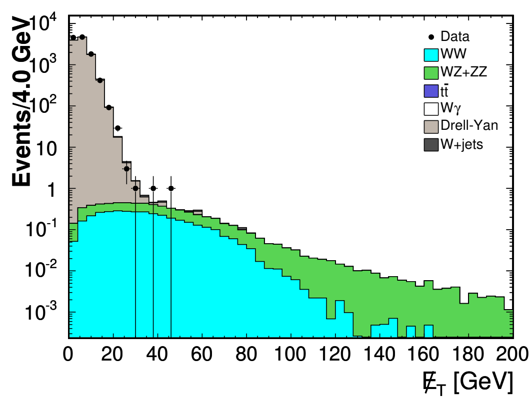
(a) $\not\!\!E_T$ in Gen5 e^+e^- Category



(b) $\not\!\!E_T$ in Gen5 $\mu^+\mu^-$ Category

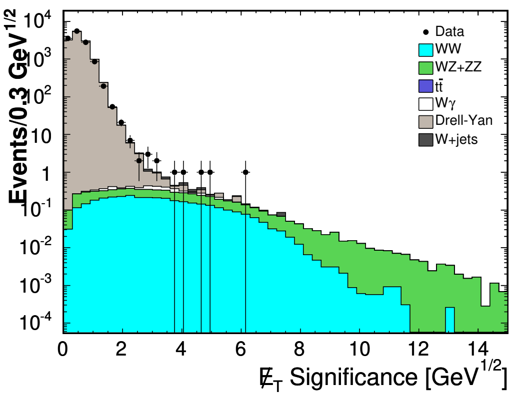


(c) $\not\!\!E_T$ in Gen6 e^+e^- Category

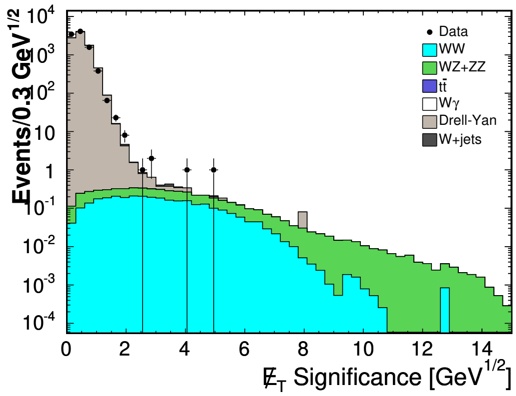


(d) $\not\!\!E_T$ in Gen6 $\mu^+\mu^-$ Category

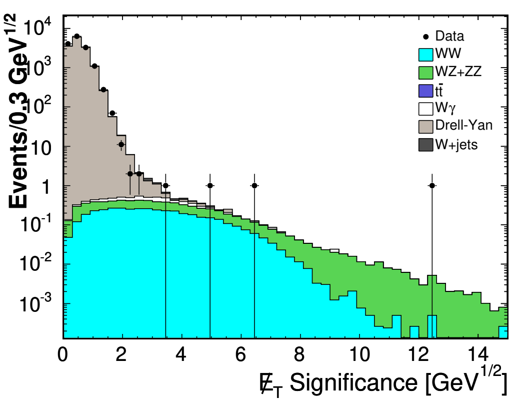
Figure 3: $\not\!\!E_T$ Distribution in Z Mass window $76 < M(ll) < 106$



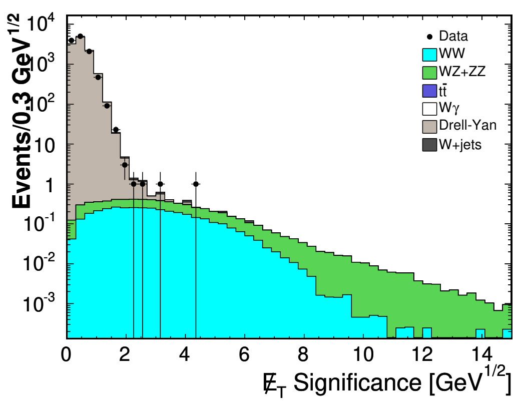
(a) $\not\!\!E_T$ in Gen5 e^+e^- Category



(b) $\not\!\!E_T$ in Gen5 $\mu^+\mu^-$ Category



(c) $\not\!\!E_T$ in Gen6 e^+e^- Category



(d) $\not\!\!E_T$ in Gen6 $\mu^+\mu^-$ Category

Figure 4: $\not\!\!E_{T\mathrm{sig}}$ Distribution in Z Mass window $76 < M(ll) < 106$

the efficiency of this veto may not be well modeled in the Monte Carlo. In CDF Note 8073[12] Attal et al. measure a conversion veto scale factor by identifying conversions using the CES and then determining the rate at which they are vetoed. For the energy range $E_T > 20$ GeV, they find an scale factor of $\approx 1.2 \pm 0.1$. In the plug region, the conversion rate is sensitive to the material description in the Monte Carlo which is not tuned perfectly.

Finally there is an overall uncertainty on the production rate. The $W\gamma$ cross-section has been measured at CDF [10] and D0 [11]. These measurements are in a kinematic range different from those relevant to this analysis, but are in agreement with the NLO predictions. The uncertainty on these measurements is $\approx 15\%$.

Based on the conversion veto scale factor, we scale the $W\gamma$ up by 1.2. A similar scale factor was applied in the WZ low $\not\!\!E_T$ control region described above. Combining the conversion scale factor, material uncertainty, and normalization uncertainty, we apply a 20% uncertainty.

5.4 WZ and ZZ

These are assessed with Monte Carlo using the cross-sections and k-factors listed in Table 7. These are moderate sized background where the main uncertainty comes from the cross-section prediction. We apply a systematic of 20% to the normalization which is approximately half the difference between the leading order and next to leading order cross-sections.

5.5 $t\bar{t}$ and $Z \to \tau\tau$

In the zero-jet bin used for this measurement, $t\bar{t}$ is very small background so no systematic is applied. The $Z \to \tau\tau$ background is also small. In the summary table with systematics, it is added to the Drell-Yan background.

5.6 Summary of Backgrounds

Table 13 shows the summary of all the backgrounds described above and Table 14 shows the estimate of the systematic uncertainty for each background and their combination.

6 Cross Checks

6.1 Drell-Yan Cross-section Calculation

As a cross-check of our acceptance calculation, data handling procedures and implementation, we simply remove the $\not\!\!E_T$, $\not\!\!E_{T\mathrm{sig}}$, and $\min \Delta\phi(\not\!\!E_T, l)$ cuts and apply a $66 < M_Z < 116$ GeV cut. The resulting acceptance calculation, data yield, and cross-sections are shown

Gen5	ee	$e\mu$	$\mu\mu$	ll
WW	6.03 ± 0.04	13.33 ± 0.06	4.87 ± 0.04	24.23 ± 0.08
$Z \to ee$	2.66 ± 0.41	0.70 ± 0.21	0.00 ± 0.00	3.36 ± 0.46
$Z \to \mu\mu$	0.00 ± 0.00	1.01 ± 0.23	1.00 ± 0.23	2.01 ± 0.32
$Z \to \tau\tau$	0.07 ± 0.03	0.13 ± 0.04	0.06 ± 0.03	0.26 ± 0.06
$t\bar{t}$	0.02 ± 0.00	0.05 ± 0.01	0.02 ± 0.00	0.09 ± 0.01
$W\gamma \to e\nu\gamma$	1.53 ± 0.08	0.06 ± 0.02	0.00 ± 0.00	1.59 ± 0.08
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	1.43 ± 0.08	0.01 ± 0.01	1.45 ± 0.08
WZ	0.54 ± 0.01	0.37 ± 0.00	0.56 ± 0.01	1.48 ± 0.01
ZZ	1.19 ± 0.01	0.07 ± 0.00	1.02 ± 0.01	2.27 ± 0.02
Fake Lepton	1.56 ± 0.17	2.70 ± 0.26	0.70 ± 0.13	4.96 ± 0.34
Background Sum	7.57 ± 0.45	6.52 ± 0.42	3.37 ± 0.27	17.47 ± 0.67
Total Expected	14± 0.45	20± 0.42	8± 0.27	42± 0.67
Data	14	18	10	42
Gen6	ee	$e\mu$	$\mu\mu$	ll
WW	6.79 ± 0.04	15.49 ± 0.06	5.85 ± 0.04	28.13 ± 0.08
$Z \to ee$	2.09 ± 0.32	0.85 ± 0.21	0.00 ± 0.00	2.94 ± 0.38
$Z \to \mu\mu$	0.00 ± 0.00	0.87 ± 0.20	1.76 ± 0.29	2.63 ± 0.35
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.03 ± 0.00	0.05 ± 0.01	0.02 ± 0.00	0.11 ± 0.01
$W\gamma \to e\nu\gamma$	2.04 ± 0.09	0.06 ± 0.01	0.00 ± 0.00	2.09 ± 0.09
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	1.70 ± 0.07	0.01 ± 0.00	1.70 ± 0.07
WZ	0.60 ± 0.01	0.42 ± 0.00	0.67 ± 0.01	1.69 ± 0.01
ZZ	1.28 ± 0.01	0.07 ± 0.00	1.14 ± 0.01	2.49 ± 0.01
Fake Lepton	1.40 ± 0.15	3.99 ± 0.32	0.63 ± 0.12	6.03 ± 0.37
Background Sum	7.44 ± 0.36	8.01 ± 0.44	4.23 ± 0.31	19.68 ± 0.65
Total Expected	14± 0.37	24± 0.44	10± 0.32	48± 0.65
Data	15	29	9	53
All	ee	$e\mu$	$\mu\mu$	ll
WW	12.82 ± 0.06	28.82 ± 0.09	10.71 ± 0.05	52.36 ± 0.12
$Z \to ee$	4.76 ± 0.52	1.55 ± 0.30	0.00 ± 0.00	6.31 ± 0.60
$Z \to \mu\mu$	0.00 ± 0.00	1.88 ± 0.30	2.76 ± 0.37	4.64 ± 0.48
$Z \to \tau\tau$	0.07 ± 0.03	0.13 ± 0.04	0.06 ± 0.03	0.26 ± 0.06
$t\bar{t}$	0.05 ± 0.01	0.11 ± 0.01	0.04 ± 0.01	0.20 ± 0.01
$W\gamma \to e\nu\gamma$	3.57 ± 0.12	0.12 ± 0.02	0.00 ± 0.00	3.68 ± 0.12
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	3.13 ± 0.10	0.02 ± 0.01	3.15 ± 0.10
WZ	1.15 ± 0.01	0.79 ± 0.01	1.23 ± 0.01	3.16 ± 0.01
ZZ	2.47 ± 0.02	0.14 ± 0.00	2.16 ± 0.01	4.77 ± 0.02
Fake Lepton	2.96 ± 0.23	6.69 ± 0.41	1.33 ± 0.17	10.99 ± 0.50
Background Sum	15.03 ± 0.58	14.54 ± 0.60	7.60 ± 0.41	37.16 ± 0.93
Total Expected	28± 0.59	43± 0.61	18± 0.41	90± 0.94
Data	29	47	19	95

Table 13: Grand summary of backgrounds and signal expectation.

Mode	ee	$e\mu$	$\mu\mu$	ll
WW	12.82 ± 0.06 ± 1.06	28.82 ± 0.09 ± 2.39	10.71 ± 0.05 ± 0.89	52.36 ± 0.12 ± 4.35
Drell-Yan	4.83 ± 0.52 ± 1.26	3.56 ± 0.43 ± 0.93	2.82 ± 0.37 ± 0.73	11.21 ± 0.77 ± 2.91
$t\bar{t}$	0.05 ± 0.01 ± 0.01	0.11 ± 0.01 ± 0.01	0.04 ± 0.01 ± 0.00	0.20 ± 0.01 ± 0.02
$WZ+ZZ$	3.62 ± 0.02 ± 0.36	0.93 ± 0.01 ± 0.09	3.39 ± 0.01 ± 0.34	7.93 ± 0.02 ± 0.79
$W\gamma$	3.57 ± 0.12 ± 0.71	3.25 ± 0.10 ± 0.65	0.02 ± 0.01 ± 0.00	6.83 ± 0.16 ± 1.37
W+jets	2.96 ± 0.23 ± 0.71	6.69 ± 0.41 ± 1.98	1.33 ± 0.17 ± 0.53	10.99 ± 0.50 ± 3.20
Sum Bkg	15.03 ± 0.58 ± 1.65	14.54 ± 0.60 ± 2.28	7.60 ± 0.41 ± 0.97	37.16 ± 0.93 ± 4.61
Expected	28± 0.59 ± 1.96	43± 0.61 ± 3.31	18± 0.41 ± 1.31	90± 0.94 ± 6.33
Data	29	47	19	95

Table 14: Estimated background with systematic uncertainties

Cut	ee ($A\%$)		$\mu\mu$ ($A\%$)	
Trig	17.9 ± 0.0	100.0	12.8 ± 0.0	100.0
Cosmic	17.9 ± 0.0	100.0	12.8 ± 0.0	100.0
ZVeto	17.0 ± 0.0	94.8	12.0 ± 0.0	93.6
OS	16.0 ± 0.0	94.4	12.0 ± 0.0	100.0
0jet	12.9 ± 0.0	80.4	9.5 ± 0.0	79.6
1jet	2.6 ± 0.0	20.1	2.0 ± 0.0	21.1
Data	34243		26259	
$\sigma\mathcal{B}$	259.0 ± 1.4 *pb*		265.9 ± 1.7 *pb*	

Table 15: Z Cross-section Check. A detailed channel-by-channel result is in Appendix A.

in Table 15. The agreement with the recent CDF $Z \to \mu\mu$ cross-section [13] is within uncertainties. Figure 5 shows invariant mass distribution in full Gen5 and Gen6 data.

6.2 $\not{E}_T$ control region

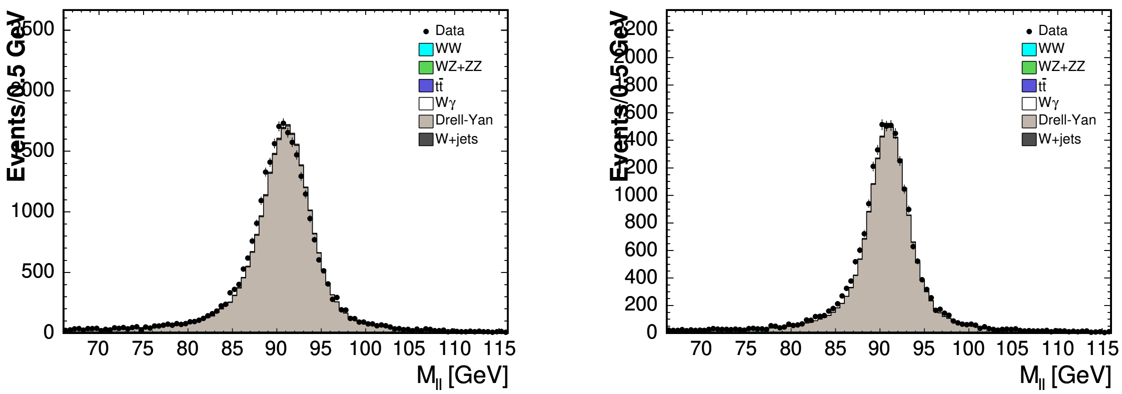
As a cross check of the $\not{E}_T$ simulation and in order to assess a systematic on the Drell-Yan background, we analyses the low $\not{E}_{T\mathrm{sig}}$, high $\not{E}_T$ region. We find that a moderate excess of events in the Gen5 data and very consistent results in the Gen6 data, see Table 16. The predictions for the two datasets from the Monte Carlo scale with the luminosity. The Gen5 $Z \to ee$ events have been scanned and do not cluster in run number, η, or ϕ of the leptons or $\not{E}_T$. We also look in the $\not{E}_{T\mathrm{sig}} > 3.0$ GeV$^{\frac{1}{2}}$, $\not{E}_T < 25$ GeV region but find zero events with a prediction of zero events (the region is in principle accessible). The $\not{E}_T$ distribution of these events is shown in Figure 6.

Gen5	ee	$e\mu$	$\mu\mu$	ll
WW	0.36 ± 0.01	0.00 ± 0.00	0.31 ± 0.01	0.67 ± 0.01
$Z \to ee$	3.39 ± 0.46	0.00 ± 0.00	0.00 ± 0.00	3.39 ± 0.46
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	1.45 ± 0.27	1.45 ± 0.27
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.10 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.02
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.12 ± 0.00	0.00 ± 0.00	0.11 ± 0.00	0.23 ± 0.00
ZZ	0.23 ± 0.00	0.00 ± 0.00	0.19 ± 0.00	0.42 ± 0.01
Fake Lepton	0.34 ± 0.07	0.00 ± 0.00	0.07 ± 0.04	0.41 ± 0.08
Background Sum	4.54 ± 0.47	0.00 ± 0.00	2.13 ± 0.27	6.67 ± 0.54
Data	9	0	4	13

Gen6	ee	$e\mu$	$\mu\mu$	ll
WW	0.48 ± 0.01	0.00 ± 0.00	0.43 ± 0.01	0.90 ± 0.01
$Z \to ee$	4.45 ± 0.46	0.00 ± 0.00	0.00 ± 0.00	4.45 ± 0.46
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	2.33 ± 0.33	2.33 ± 0.33
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.17 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.17 ± 0.03
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.16 ± 0.00	0.00 ± 0.00	0.14 ± 0.00	0.30 ± 0.00
ZZ	0.29 ± 0.01	0.00 ± 0.00	0.26 ± 0.00	0.55 ± 0.01
Fake Lepton	0.33 ± 0.07	0.00 ± 0.00	0.10 ± 0.04	0.43 ± 0.09
Background Sum	5.88 ± 0.47	0.00 ± 0.00	3.26 ± 0.33	9.13 ± 0.57
Data	4	0	3	7

All	ee	$e\mu$	$\mu\mu$	ll
WW	0.84 ± 0.02	0.00 ± 0.00	0.73 ± 0.01	1.57 ± 0.02
$Z \to ee$	7.84 ± 0.65	0.00 ± 0.00	0.00 ± 0.00	7.84 ± 0.65
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	3.78 ± 0.43	3.78 ± 0.43
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.27 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.27 ± 0.03
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.28 ± 0.00	0.00 ± 0.00	0.25 ± 0.00	0.53 ± 0.01
ZZ	0.52 ± 0.01	0.00 ± 0.00	0.45 ± 0.01	0.97 ± 0.01
Fake Lepton	0.67 ± 0.10	0.00 ± 0.00	0.18 ± 0.06	0.84 ± 0.12
Background Sum	10.42 ± 0.66	0.00 ± 0.00	5.39 ± 0.43	15.80 ± 0.79
Data	13	0	7	20

Table 16: $\not\!\!E_{T\mathrm{sig}} < 3.0$ GeV$^{\frac{1}{2}}$, $\not\!\!E_T > 25$ GeV control region.



(a) $Z \to e^+e^-$ invariant mass distribution

(b) $Z \to \mu^+\mu^-$ invariant mass distribution

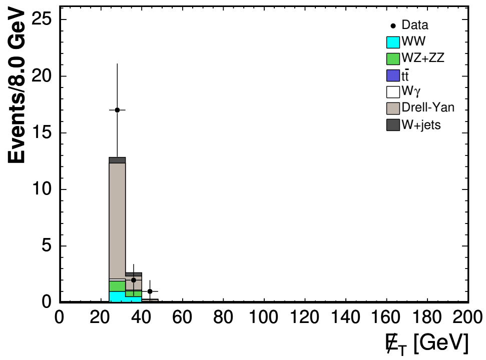
Figure 5: Drell Yan invariant mass distribution in $800pb^{-1}$

6.3 Same sign control region

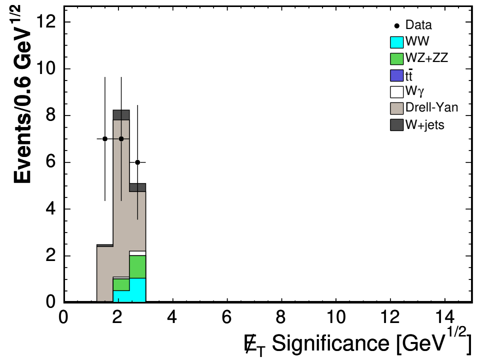
As a check of the W+jets and $W\gamma$ fake backgrounds, we look at the data in the signal region with full selection, but with the opposite sign lepton requirement reversed. This region is dominated by fake leptons, either from jets or photons. The PHX categories also have significant contributions from charge mis-id.

6.4 Fake Rate Issues with Same Sign

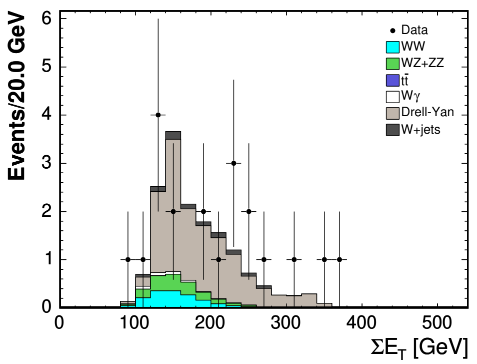
After the original posting of this note, we were asked to do a this same sign cross-check of the fake rate. We found a moderate excess in the TCE-TCE channel, 6 events expecting 1.6. After inspection of these events we added the 2-d track iso ¡ 0.2 if iso ¿ 0.05 cut. If we sum all the TCE+X modes together before the application of this cut we expected 13.5 events, 7.5 of which were fake leptons and saw 18. After the application of this cut we expect 10.1 events, 4.2 of which are fake leptons, and see 13. On the whole the shift in the results is not inconsistent with the fake background model, however the precut TCE-TCE channel was suspicious.



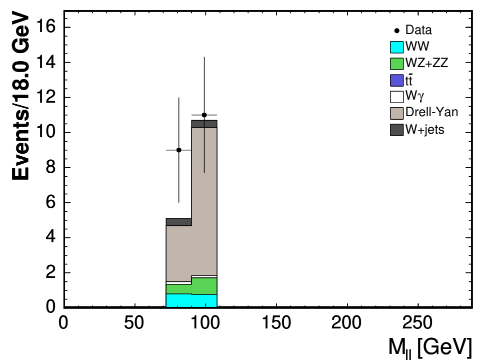
(a) $\not{E}_T$



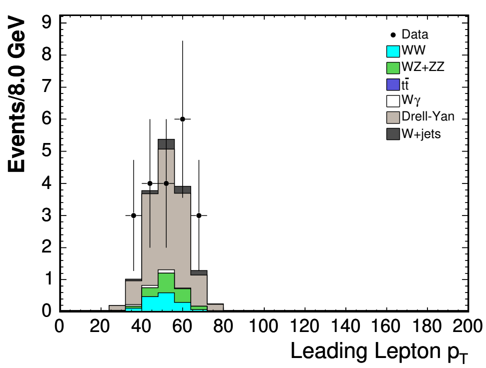
(b) $\not{E}_{T\mathrm{sig}}$



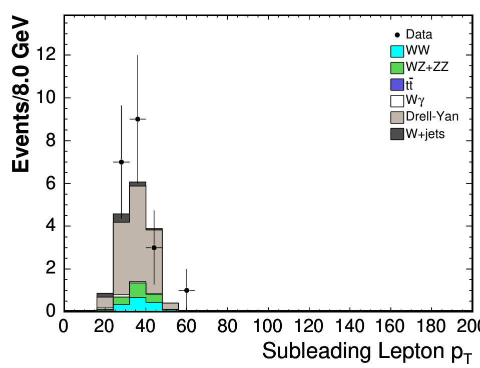
(c) $\sum E_T$



(d) M_{ll}



(e) Leading Lepton p_T

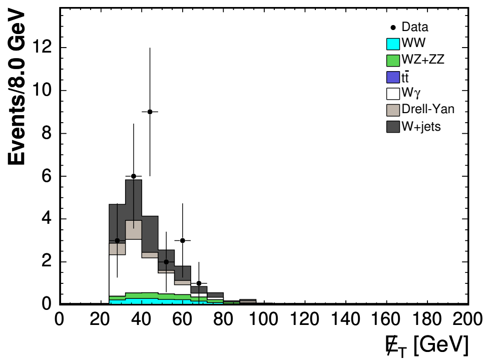


(f) Secondary Lepton p_T

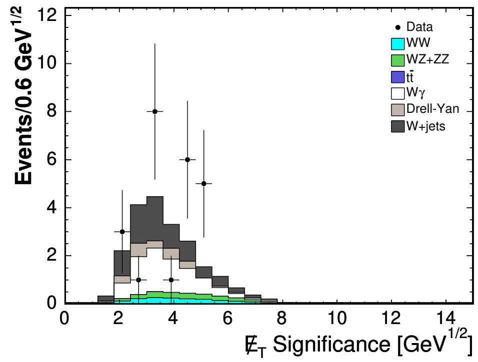
Figure 6: Distributions in $\not{E}_T > 25 GeV$ and $\not{E}_{T\mathrm{sig}} < 3$ Region.

Gen5	ee	$e\mu$	$\mu\mu$	ll
WW	0.35 ± 0.01	0.40 ± 0.01	0.00 ± 0.00	0.75 ± 0.01
$Z \to ee$	0.18 ± 0.10	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.10
$Z \to \mu\mu$	0.00 ± 0.00	0.98 ± 0.23	0.00 ± 0.00	0.98 ± 0.23
$Z \to \tau\tau$	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	1.70 ± 0.08	0.04 ± 0.01	0.00 ± 0.00	1.73 ± 0.08
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	1.70 ± 0.08	0.01 ± 0.01	1.71 ± 0.08
WZ	0.10 ± 0.00	0.36 ± 0.00	0.19 ± 0.00	0.65 ± 0.01
ZZ	0.07 ± 0.00	0.03 ± 0.00	0.04 ± 0.00	0.13 ± 0.00
Fake Lepton	1.34 ± 0.16	1.90 ± 0.24	0.35 ± 0.10	3.59 ± 0.31
Background Sum	3.75 ± 0.21	5.41 ± 0.34	0.59 ± 0.10	9.73 ± 0.41
Data	6	5	1	12
Gen6	ee	$e\mu$	$\mu\mu$	ll
WW	0.43 ± 0.01	0.48 ± 0.01	0.00 ± 0.00	0.91 ± 0.01
$Z \to ee$	0.05 ± 0.05	0.10 ± 0.07	0.00 ± 0.00	0.15 ± 0.08
$Z \to \mu\mu$	0.00 ± 0.00	0.78 ± 0.19	0.05 ± 0.05	0.83 ± 0.20
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	2.37 ± 0.09	0.06 ± 0.02	0.00 ± 0.00	2.44 ± 0.10
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	2.05 ± 0.08	0.01 ± 0.01	2.06 ± 0.08
WZ	0.11 ± 0.00	0.42 ± 0.00	0.24 ± 0.00	0.77 ± 0.01
ZZ	0.08 ± 0.00	0.03 ± 0.00	0.04 ± 0.00	0.15 ± 0.00
Fake Lepton	1.50 ± 0.17	2.32 ± 0.26	0.37 ± 0.10	4.18 ± 0.33
Background Sum	4.54 ± 0.20	6.24 ± 0.34	0.71 ± 0.11	11.49 ± 0.41
Data	8	5	0	13
All	ee	$e\mu$	$\mu\mu$	ll
WW	0.78 ± 0.01	0.88 ± 0.01	0.00 ± 0.00	1.66 ± 0.02
$Z \to ee$	0.22 ± 0.11	0.10 ± 0.07	0.00 ± 0.00	0.32 ± 0.13
$Z \to \mu\mu$	0.00 ± 0.00	1.76 ± 0.29	0.05 ± 0.05	1.81 ± 0.30
$Z \to \tau\tau$	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01
$t\bar{t}$	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00
$W\gamma \to e\nu\gamma$	4.07 ± 0.13	0.10 ± 0.02	0.00 ± 0.00	4.17 ± 0.13
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	3.74 ± 0.12	0.02 ± 0.01	3.77 ± 0.12
WZ	0.21 ± 0.00	0.78 ± 0.01	0.43 ± 0.00	1.42 ± 0.01
ZZ	0.15 ± 0.00	0.06 ± 0.00	0.08 ± 0.00	0.28 ± 0.01
Fake Lepton	2.84 ± 0.24	4.21 ± 0.36	0.72 ± 0.14	7.77 ± 0.45
Background Sum	8.28 ± 0.29	11.64 ± 0.48	1.30 ± 0.15	21.22 ± 0.58
Data	14	10	1	25

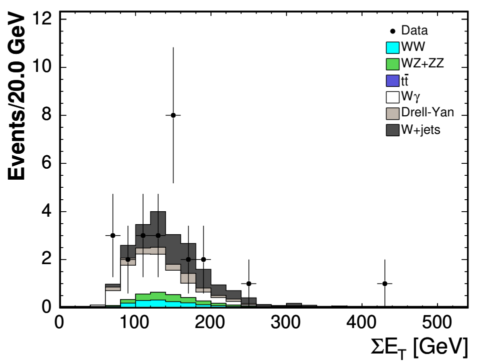
Table 17: Full WW selection except with a same sign requirement.



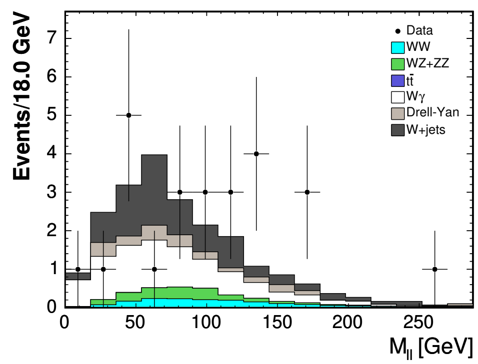
(a) $\not{E}_T$



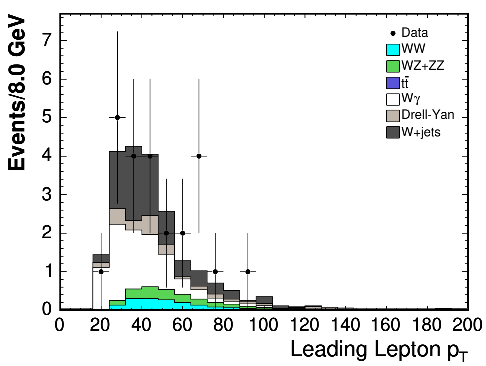
(b) $\not{E}_{T\,\mathrm{sig}}$



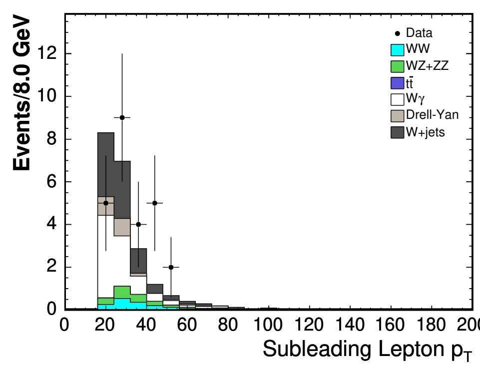
(c) $\sum E_T$



(d) M_{ll}



(e) Leading Lepton p_T



(f) Secondary Lepton p_T

Figure 7: Distributions for same sign region.

7 Results

7.1 Data Results

We find 95 events expecting a signal of $N_{\rm sig} = 52.4 \pm 0.1 \pm 4.4$ events, with a background of $N_{\rm Bkg} = 37.2 \pm 0.9 \pm 4.6$. The signal expectation corresponds to an acceptance of $A = (51.2 \pm 0.1 \pm 4.2) \times 10^{-4}$ where this acceptance includes all efficiency factors and branching fractions. The equation used to extract the final cross-section is

$$\sigma = \frac{N_{\rm Data} - N_{\rm Bkg}}{A\ \mathcal{L}}, \tag{13}$$

where $N_{\rm Data}$ is the observed yield in data and $\mathcal{L}$ is the luminosity. The luminosity uncertainty is applied to both the denominator and the luminosity dependant background, $N_{\rm BkgLumDep} = 26.2$ (all except fakes). The formula for this is

$$(\Delta\sigma)_{\mathcal{L}} = \sigma\frac{\Delta\mathcal{L}}{\mathcal{L}}(1 + \frac{N_{\rm BkgLumDep}}{N_{\rm Data} - N_{\rm Bkg}}). \tag{14}$$

This yields the final cross-section

$$\sigma(p\overline{p} \to WW) = 13.69 \pm 2.32({\rm stat}) \pm 1.56({\rm sys}) \pm 1.19({\rm lum})\ {\rm pb} \tag{15}$$

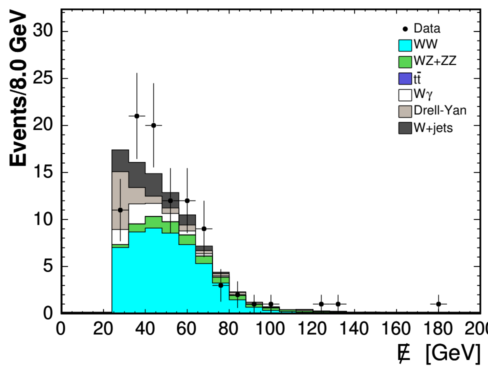
The distributions for the signal region are shown in Figures 8 and 9. A full summary of the contributions to the systematics scaled to be as a percent of the cross-section is shown in Table 18.

8 Conclusion

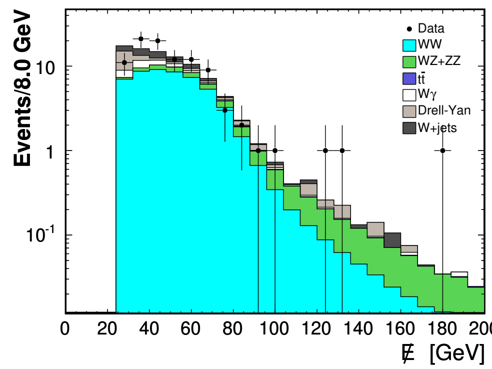
We have measured the WW cross-section in the final state $ll + \not{E}_T$ to be

$$\sigma(p\overline{p} \to WW) = 13.69 \pm 2.32({\rm stat}) \pm 1.56({\rm sys}) \pm 1.19({\rm lum})\ {\rm pb}, \tag{16}$$

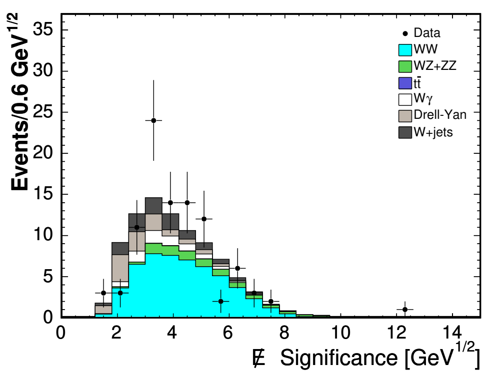
which is consistent with the standard model expectation $\sigma^{WW}_{NLO} = 12.4 \pm 0.8pb$.



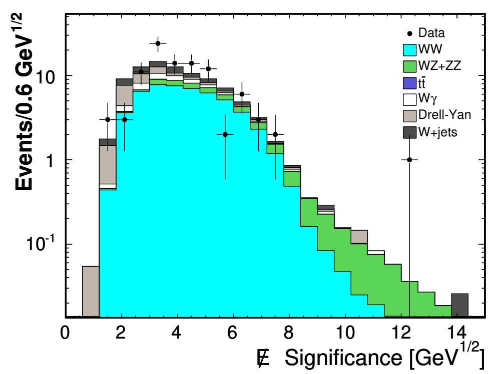
(a) $\not\!\!E_T$



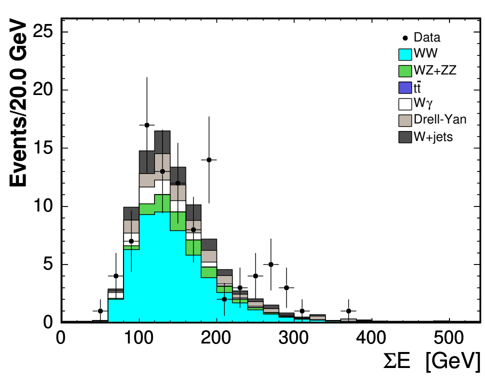
(b) $\not\!\!E_T$



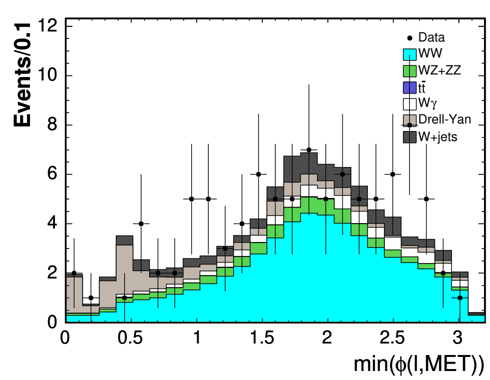
(c) $\not\!\!E_{T\,\mathrm{sig}}$



(d) $\not\!\!E_{T\,\mathrm{sig}}$

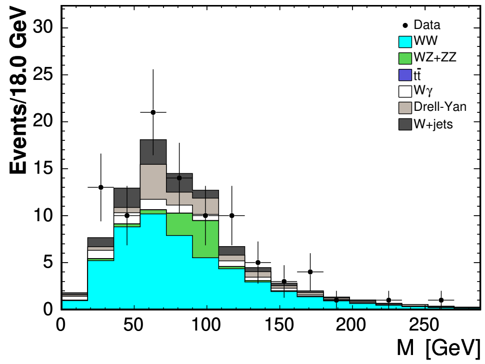


(e) $\sum E_T$

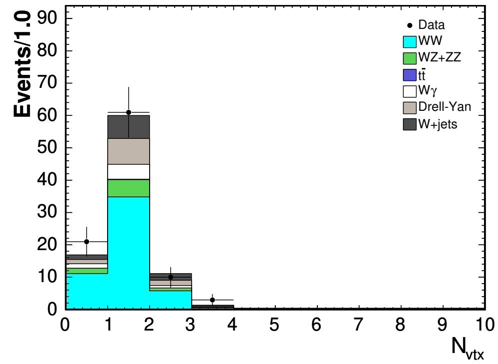


(f) $\min \Delta\phi(\not\!\!E_T, l)$

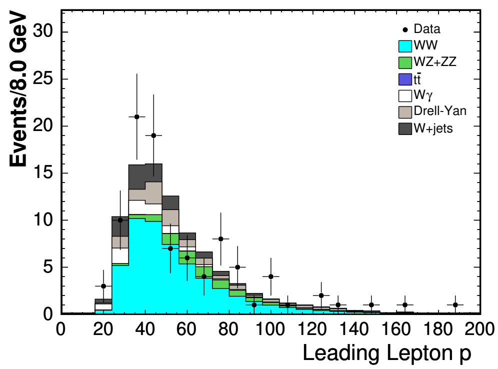
Figure 8: Data distributions for the signal region.



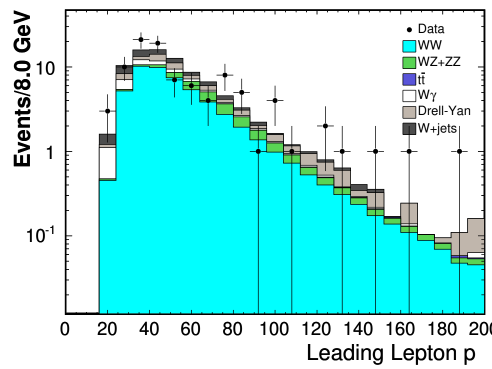
(a) M_{ll}



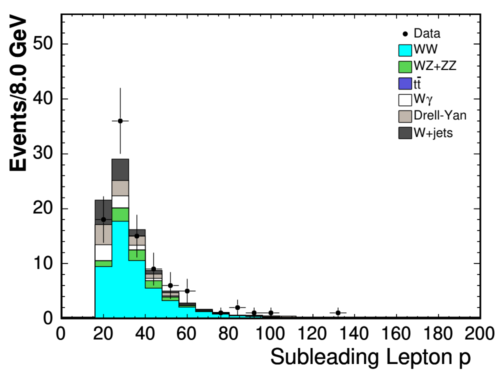
(b) N_{vtx}



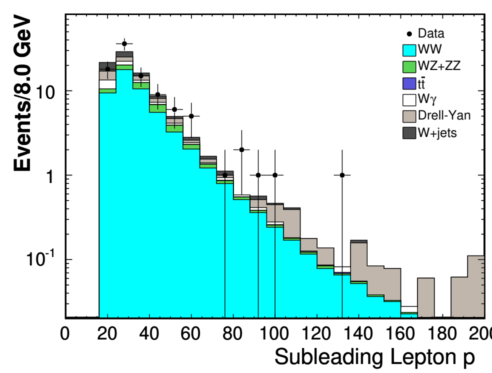
(c) Leading Lepton p_T



(d) Leading Lepton p_T



(e) Secondary Lepton p_T



(f) Secondary Lepton p_T

Figure 9: Data distributions for the signal region (con't).

Source	Uncertainty
Lepton Id	1.0%
Trigger Efficiency	2.0%
PHX Charge Mis-Id	0.3%
$\not\!\!E_T$ Modeling	0.3%
$\sum E_T$ Modeling	0.3%
Jet Counting	7.8%
PDF	1.6%
Acceptance Sum	8.3%
Drell-Yan	5.0%
$t\bar{t}$	0.0%
$WZ + ZZ$	1.4%
$W\gamma$	2.5%
W+jets	5.5%
Background Sum	8.0%
Full Sum	11.5%

Table 18: Summary of all systematics scaled to be as a percent of the cross-section, except luminosity

A Channel-by-Channel Tables

References

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[4]

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[13] W. David Dagenhart, “Measurement of the Z Production Cross Section”, CDF Note 7865

Cut	TCETCE	TCEPHX	CMUPCMUP	CMUPCMX	CMXCMX	CMXCMIO	CMUPCMIO
Trig	9.0 ± 0.1 %	9.2 ± 0.1 %	2.0 ± 0.0 %	1.7 ± 0.0 %	0.5 ± 0.0 %	2.6 ± 0.1 %	5.6 ± 0.1 %
Cosmic	9.0 ± 0.1 %	9.2 ± 0.1 %	2.0 ± 0.0 %	1.7 ± 0.0 %	0.5 ± 0.0 %	2.6 ± 0.1 %	5.6 ± 0.1 %
ZVeto	8.4 ± 0.1 %	8.8 ± 0.1 %	1.9 ± 0.0 %	1.6 ± 0.0 %	0.5 ± 0.0 %	2.4 ± 0.0 %	5.3 ± 0.1 %
OS	8.4 ± 0.1 %	7.9 ± 0.1 %	1.9 ± 0.0 %	1.6 ± 0.0 %	0.5 ± 0.0 %	2.4 ± 0.0 %	5.3 ± 0.1 %
0jet	6.7 ± 0.1 %	6.4 ± 0.1 %	1.5 ± 0.0 %	1.3 ± 0.0 %	0.4 ± 0.0 %	1.9 ± 0.0 %	4.2 ± 0.1 %
1jet	1.4 ± 0.0 %	1.2 ± 0.0 %	0.3 ± 0.0 %	0.3 ± 0.0 %	0.1 ± 0.0 %	0.4 ± 0.0 %	0.9 ± 0.0 %
Data	8125	7587	1846	1667	506	2471	5373
$\sigma\mathcal{B}$	251.0 ± 3.9 pb	250.1 ± 4.0 pb	256.7 ± 8.5 pb	265.0 ± 9.3 pb	272.6 ± 17.4 pb	266.7 ± 7.7 pb	265.4 ± 5.2 pb
Cut	TCETCE	TCEPHX	CMUPCMUP	CMUPCMX	CMXCMX	CMXCMIO	CMUPCMIO
Trig	8.6 ± 0.1 %	9.1 ± 0.1 %	2.1 ± 0.0 %	1.9 ± 0.0 %	0.5 ± 0.0 %	2.8 ± 0.0 %	5.9 ± 0.1 %
Cosmic	8.6 ± 0.1 %	9.1 ± 0.1 %	2.1 ± 0.0 %	1.9 ± 0.0 %	0.5 ± 0.0 %	2.8 ± 0.0 %	5.9 ± 0.1 %
ZVeto	8.1 ± 0.1 %	8.7 ± 0.1 %	1.9 ± 0.0 %	1.7 ± 0.0 %	0.5 ± 0.0 %	2.6 ± 0.0 %	5.5 ± 0.1 %
OS	8.1 ± 0.1 %	7.7 ± 0.1 %	1.9 ± 0.0 %	1.7 ± 0.0 %	0.5 ± 0.0 %	2.6 ± 0.0 %	5.5 ± 0.1 %
0jet	6.5 ± 0.1 %	6.3 ± 0.1 %	1.5 ± 0.0 %	1.4 ± 0.0 %	0.4 ± 0.0 %	2.1 ± 0.0 %	4.4 ± 0.1 %
1jet	1.3 ± 0.0 %	1.2 ± 0.0 %	0.3 ± 0.0 %	0.3 ± 0.0 %	0.1 ± 0.0 %	0.4 ± 0.0 %	0.9 ± 0.0 %
Data	9434	8956	2213	2047	510	2979	6647
$\sigma\mathcal{B}$	265.0 ± 3.9 pb	264.0 ± 4.0 pb	260.9 ± 7.9 pb	266.0 ± 8.4 pb	247.7 ± 15.4 pb	261.6 ± 6.8 pb	273.9 ± 4.8 pb
Cut	TCETCE	TCEPHX	CMUPCMUP	CMUPCMX	CMXCMX	CMXCMIO	CMUPCMIO
Trig	8.8 ± 0.1 %	9.1 ± 0.1 %	2.0 ± 0.0 %	1.8 ± 0.0 %	0.5 ± 0.0 %	2.7 ± 0.0 %	5.8 ± 0.1 %
Cosmic	8.8 ± 0.1 %	9.1 ± 0.1 %	2.0 ± 0.0 %	1.8 ± 0.0 %	0.5 ± 0.0 %	2.7 ± 0.0 %	5.8 ± 0.1 %
ZVeto	8.3 ± 0.1 %	8.7 ± 0.1 %	1.9 ± 0.0 %	1.7 ± 0.0 %	0.5 ± 0.0 %	2.5 ± 0.0 %	5.4 ± 0.1 %
OS	8.2 ± 0.1 %	7.8 ± 0.1 %	1.9 ± 0.0 %	1.7 ± 0.0 %	0.5 ± 0.0 %	2.5 ± 0.0 %	5.4 ± 0.1 %
0jet	6.6 ± 0.1 %	6.3 ± 0.1 %	1.5 ± 0.0 %	1.3 ± 0.0 %	0.4 ± 0.0 %	2.0 ± 0.0 %	4.3 ± 0.0 %
1jet	1.4 ± 0.0 %	1.2 ± 0.0 %	0.3 ± 0.0 %	0.3 ± 0.0 %	0.1 ± 0.0 %	0.4 ± 0.0 %	0.9 ± 0.0 %
Data	17559	16543	4059	3714	1016	5450	12020
$\sigma\mathcal{B}$	258.3 ± 2.8 pb	257.4 ± 2.8 pb	259.0 ± 5.8 pb	265.6 ± 6.2 pb	259.5 ± 11.6 pb	263.9 ± 5.1 pb	270.0 ± 3.5 pb

Table 19: Z Cross-section Check, channel-by-channel.

Gen5	TCETCE	TCEPHX	PHXPHX	TCECMUP	TCECMX	TCECMIO	PHXCMUP
WW	0.23 ± 0.00	0.11 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to ee$	2.09 ± 0.00	1.04 ± 0.00	0.27 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.02 ± 0.00	0.08 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.07 ± 0.00	0.04 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
ZZ	0.13 ± 0.00	0.07 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Fake Lepton	0.13 ± 0.04	0.21 ± 0.07	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Background Sum	2.67 ± 0.04	1.55 ± 0.07	0.32 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Data	5	4	0	0	0	0	0

Gen6	TCETCE	TCEPHX	PHXPHX	TCECMUP	TCECMX	TCECMIO	PHXCMUP
WW	0.29 ± 0.00	0.16 ± 0.00	0.03 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to ee$	1.80 ± 0.00	2.35 ± 0.00	0.30 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.02 ± 0.00	0.14 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.09 ± 0.00	0.05 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
ZZ	0.17 ± 0.00	0.10 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Fake Lepton	0.11 ± 0.03	0.18 ± 0.06	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Background Sum	2.48 ± 0.03	2.98 ± 0.06	0.40 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Data	0	4	0	0	0	0	0

All	TCETCE	TCEPHX	PHXPHX	TCECMUP	TCECMX	TCECMIO	PHXCMUP
WW	0.52 ± 0.00	0.27 ± 0.00	0.05 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to ee$	3.88 ± 0.00	3.39 ± 0.00	0.57 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.04 ± 0.00	0.23 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.16 ± 0.00	0.10 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
ZZ	0.31 ± 0.00	0.17 ± 0.00	0.04 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Fake Lepton	0.24 ± 0.05	0.39 ± 0.09	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Background Sum	5.15 ± 0.05	4.55 ± 0.09	0.72 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Data	5	8	0	0	0	0	0

Table 20: $\not{E}_{T_{\mathrm{sig}}} < 3.0$ GeV$^{\frac{1}{2}}$, $\not{E}_T > 25$ GeV control region, channel-by-channel.

Gen5	PHXCMX	PHXCMIO	CMUPCMUP	CMUPCMX	CMUPCMIO	CMXCMX	CMXCMIO
WW	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.00	0.04 ± 0.00	0.14 ± 0.00	0.01 ± 0.00	0.06 ± 0.00
$Z \to ee$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.26 ± 0.00	0.11 ± 0.00	0.75 ± 0.00	0.00 ± 0.00	0.34 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.05 ± 0.00	0.00 ± 0.00	0.02 ± 0.00
ZZ	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.00	0.03 ± 0.00	0.08 ± 0.00	0.01 ± 0.00	0.04 ± 0.00
Fake Lepton	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.03	0.02 ± 0.02	0.03 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
Background Sum	0.00 ± 0.00	0.00 ± 0.00	0.40 ± 0.03	0.22 ± 0.02	1.05 ± 0.02	0.02 ± 0.00	0.46 ± 0.00
Data	0	0	1	1	1	0	1

Gen6	PHXCMX	PHXCMIO	CMUPCMUP	CMUPCMX	CMUPCMIO	CMXCMX	CMXCMIO
WW	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.00	0.06 ± 0.00	0.19 ± 0.00	0.01 ± 0.00	0.08 ± 0.00
$Z \to ee$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.54 ± 0.00	0.34 ± 0.00	0.77 ± 0.00	0.00 ± 0.00	0.67 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.06 ± 0.00	0.00 ± 0.00	0.03 ± 0.00
ZZ	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.00	0.04 ± 0.00	0.12 ± 0.00	0.01 ± 0.00	0.05 ± 0.00
Fake Lepton	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.03	0.06 ± 0.03	0.00 ± 0.00	0.02 ± 0.02
Background Sum	0.00 ± 0.00	0.00 ± 0.00	0.70 ± 0.00	0.49 ± 0.03	1.20 ± 0.03	0.02 ± 0.00	0.85 ± 0.02
Data	0	0	0	0	2	0	1

All	PHXCMX	PHXCMIO	CMUPCMUP	CMUPCMX	CMUPCMIO	CMXCMX	CMXCMIO
WW	0.00 ± 0.00	0.00 ± 0.00	0.13 ± 0.00	0.11 ± 0.00	0.33 ± 0.00	0.02 ± 0.00	0.15 ± 0.00
$Z \to ee$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.80 ± 0.00	0.45 ± 0.00	1.53 ± 0.00	0.00 ± 0.00	1.00 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.00	0.03 ± 0.00	0.11 ± 0.00	0.01 ± 0.00	0.05 ± 0.00
ZZ	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.00	0.06 ± 0.00	0.20 ± 0.00	0.01 ± 0.00	0.09 ± 0.00
Fake Lepton	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.03	0.05 ± 0.03	0.08 ± 0.04	0.00 ± 0.00	0.02 ± 0.02
Background Sum	0.00 ± 0.00	0.00 ± 0.00	1.09 ± 0.03	0.70 ± 0.03	2.25 ± 0.04	0.04 ± 0.00	1.31 ± 0.02
Data	0	0	1	1	3	0	2

Table 21: $\not{E}_{T\mathrm{sig}} < 3.0$ GeV$^{\frac{1}{2}}$, $\not{E}_T > 25$ GeV control region, channel-by-channel (con't).

Gen5	TCETCE	TCEPHX	PHXPHX	TCECMUP	TCECMX	TCECMIO	PHXCMUP
WW	0.00 ± 0.00	0.24 ± 0.00	0.10 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.13 ± 0.00
$Z \to ee$	0.07 ± 0.00	0.06 ± 0.00	0.05 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.06 ± 0.00	0.23 ± 0.00	0.15 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.17 ± 0.00	1.00 ± 0.00	0.53 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.12 ± 0.00	0.05 ± 0.00	0.22 ± 0.00	0.45 ± 0.00
WZ	0.03 ± 0.00	0.05 ± 0.00	0.02 ± 0.00	0.08 ± 0.00	0.04 ± 0.00	0.13 ± 0.00	0.04 ± 0.00
ZZ	0.00 ± 0.00	0.05 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00
Fake Lepton	0.29 ± 0.06	0.75 ± 0.13	0.30 ± 0.08	0.34 ± 0.08	0.23 ± 0.06	0.14 ± 0.04	0.75 ± 0.18
Background Sum	0.56 ± 0.06	2.15 ± 0.13	1.03 ± 0.08	0.55 ± 0.08	0.38 ± 0.06	0.75 ± 0.04	1.52 ± 0.18
Data	1	3	2	0	0	3	0

Gen6	TCETCE	TCEPHX	PHXPHX	TCECMUP	TCECMX	TCECMIO	PHXCMUP
WW	0.01 ± 0.00	0.31 ± 0.00	0.11 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.17 ± 0.00
$Z \to ee$	0.00 ± 0.00	0.05 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.15 ± 0.00	0.00 ± 0.00	0.10 ± 0.00	0.04 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.28 ± 0.00	1.41 ± 0.00	0.68 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.14 ± 0.00	0.07 ± 0.00	0.26 ± 0.00	0.56 ± 0.00
WZ	0.03 ± 0.00	0.06 ± 0.00	0.02 ± 0.00	0.10 ± 0.00	0.05 ± 0.00	0.15 ± 0.00	0.05 ± 0.00
ZZ	0.00 ± 0.00	0.06 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00
Fake Lepton	0.28 ± 0.06	0.80 ± 0.13	0.42 ± 0.10	0.50 ± 0.11	0.34 ± 0.07	0.18 ± 0.05	0.70 ± 0.17
Background Sum	0.60 ± 0.06	2.69 ± 0.13	1.25 ± 0.10	0.90 ± 0.11	0.46 ± 0.07	0.84 ± 0.05	1.52 ± 0.17
Data	1	4	3	1	0	0	1

All	TCETCE	TCEPHX	PHXPHX	TCECMUP	TCECMX	TCECMIO	PHXCMUP
WW	0.01 ± 0.00	0.55 ± 0.00	0.22 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.30 ± 0.00
$Z \to ee$	0.07 ± 0.00	0.10 ± 0.00	0.05 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.15 ± 0.00	0.06 ± 0.00	0.33 ± 0.00	0.19 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.45 ± 0.00	2.42 ± 0.00	1.20 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.26 ± 0.00	0.11 ± 0.00	0.48 ± 0.00	1.01 ± 0.00
WZ	0.07 ± 0.00	0.11 ± 0.00	0.03 ± 0.00	0.18 ± 0.00	0.08 ± 0.00	0.28 ± 0.00	0.09 ± 0.00
ZZ	0.01 ± 0.00	0.10 ± 0.00	0.04 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.01 ± 0.00
Fake Lepton	0.57 ± 0.08	1.55 ± 0.18	0.72 ± 0.13	0.84 ± 0.13	0.56 ± 0.10	0.32 ± 0.07	1.45 ± 0.25
Background Sum	1.18 ± 0.08	4.83 ± 0.18	2.27 ± 0.13	1.45 ± 0.13	0.82 ± 0.10	1.58 ± 0.07	3.05 ± 0.25
Data	2	7	5	1	0	3	1

Table 22: Full WW selection except with a same sign requirement, channel-by-channel.

Gen5	PHXCMX	PHXCMIO	CMUPCMUP	CMUPCMX	CMUPCMIO	CMXCMX	CMXCMIO
WW	0.07 ± 0.00	0.19 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to ee$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.21 ± 0.00	0.34 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.00 ± 0.00	0.03 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.20 ± 0.00	0.66 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.02 ± 0.00	0.05 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.09 ± 0.00	0.01 ± 0.00	0.04 ± 0.00
ZZ	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.01 ± 0.00
Fake Lepton	0.36 ± 0.12	0.09 ± 0.04	0.20 ± 0.08	0.02 ± 0.02	0.08 ± 0.03	0.02 ± 0.02	0.04 ± 0.03
Background Sum	0.86 ± 0.12	1.37 ± 0.04	0.24 ± 0.08	0.05 ± 0.02	0.20 ± 0.03	0.03 ± 0.02	0.09 ± 0.03
Data	1	1	0	0	0	1	0

Gen6	PHXCMX	PHXCMIO	CMUPCMUP	CMUPCMX	CMUPCMIO	CMXCMX	CMXCMIO
WW	0.08 ± 0.00	0.22 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to ee$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.05 ± 0.00	0.44 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.00 ± 0.00	0.04 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.21 ± 0.00	0.81 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.02 ± 0.00	0.06 ± 0.00	0.03 ± 0.00	0.04 ± 0.00	0.11 ± 0.00	0.01 ± 0.00	0.05 ± 0.00
ZZ	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.01 ± 0.00
Fake Lepton	0.45 ± 0.14	0.15 ± 0.05	0.12 ± 0.06	0.12 ± 0.06	0.09 ± 0.04	0.00 ± 0.00	0.04 ± 0.02
Background Sum	0.81 ± 0.14	1.72 ± 0.05	0.16 ± 0.06	0.17 ± 0.06	0.23 ± 0.04	0.01 ± 0.00	0.15 ± 0.02
Data	1	2	0	0	0	0	0

All	PHXCMX	PHXCMIO	CMUPCMUP	CMUPCMX	CMUPCMIO	CMXCMX	CMXCMIO
WW	0.15 ± 0.00	0.41 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to ee$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.25 ± 0.00	0.78 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.00
$Z \to \tau\tau$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to e\nu\gamma$	0.00 ± 0.00	0.06 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.41 ± 0.00	1.47 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WZ	0.03 ± 0.00	0.11 ± 0.00	0.06 ± 0.00	0.06 ± 0.00	0.19 ± 0.00	0.01 ± 0.00	0.09 ± 0.00
ZZ	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.03 ± 0.00	0.00 ± 0.00	0.02 ± 0.00
Fake Lepton	0.80 ± 0.19	0.24 ± 0.06	0.32 ± 0.11	0.14 ± 0.07	0.16 ± 0.05	0.02 ± 0.02	0.08 ± 0.03
Background Sum	1.64 ± 0.19	3.08 ± 0.06	0.39 ± 0.11	0.21 ± 0.07	0.40 ± 0.05	0.03 ± 0.02	0.24 ± 0.03
Data	2	3	0	0	0	1	0

Table 23: Full WW selection except with a same sign requirement, channel-by-channel (con't).

All	TCETCE	TCEPHX	PHXPHX	TCECMUP	TCECMX	TCECMIO	PHXCMUP
WW	7.46 ± 0.00	4.58 ± 0.00	0.77 ± 0.00	7.89 ± 0.00	3.18 ± 0.00	11.19 ± 0.00	2.34 ± 0.00
$Z \to ee$	3.53 ± 0.00	1.11 ± 0.00	0.11 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.40 ± 0.00	0.00 ± 0.00
$Z \to \mu\mu$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.46 ± 0.00	0.00 ± 0.00	0.33 ± 0.00	0.33 ± 0.00
$Z \to \tau\tau$	0.01 ± 0.00	0.05 ± 0.00	0.00 ± 0.00	0.08 ± 0.00	0.00 ± 0.00	0.05 ± 0.00	0.00 ± 0.00
$t\bar{t}$	0.03 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.04 ± 0.00	0.01 ± 0.00	0.04 ± 0.00	0.01 ± 0.00
$W\gamma \to e\nu\gamma$	0.57 ± 0.00	2.26 ± 0.00	0.74 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.00	0.00 ± 0.00
$W\gamma \to \mu\nu\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.29 ± 0.00	0.10 ± 0.00	0.37 ± 0.00	0.94 ± 0.00
WZ	0.63 ± 0.00	0.44 ± 0.00	0.07 ± 0.00	0.18 ± 0.00	0.08 ± 0.00	0.29 ± 0.00	0.08 ± 0.00
ZZ	1.50 ± 0.00	0.83 ± 0.00	0.14 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.08 ± 0.00	0.01 ± 0.00
Fake Lepton	0.92 ± 0.10	1.30 ± 0.16	0.73 ± 0.13	1.65 ± 0.17	0.74 ± 0.11	1.26 ± 0.14	1.74 ± 0.27
Sum Bkg	7.19 ± 0.10	6.00 ± 0.16	1.79 ± 0.13	2.72 ± 0.17	0.94 ± 0.11	3.90 ± 0.14	3.11 ± 0.27
All Expected	14.65± 0.10	10.58± 0.16	2.56± 0.13	10.61± 0.17	4.12± 0.11	15.09± 0.14	5.45± 0.27
All Data	16	13	0	9	6	17	7
Gen5 Expected	7.34± 0.06	4.95± 0.12	1.30± 0.10	4.77± 0.10	1.82± 0.07	6.97± 0.08	2.60± 0.18
Gen5 Data	7	7	0	4	2	9	0
Gen6 Expected	7.32± 0.07	5.64± 0.10	1.26± 0.09	5.83± 0.14	2.30± 0.09	8.12± 0.11	2.83± 0.20
Gen6 Data	9	6	0	5	4	8	7

Table 24: WW expectations and yield, channel-by-channel.

All	PHXCMX	PHXCMIO	CMUPCMUP	CMUPCMX	CMUPCMIO	CMXCMX	CMXCMIO
WW	1.03 $\pm$ 0.00	3.19 $\pm$ 0.00	1.87 $\pm$ 0.00	1.52 $\pm$ 0.00	4.95 $\pm$ 0.00	0.30 $\pm$ 0.00	2.07 $\pm$ 0.00
$Z \to ee$	0.00 $\pm$ 0.00	0.15 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$Z \to \mu\mu$	0.20 $\pm$ 0.00	0.56 $\pm$ 0.00	0.48 $\pm$ 0.00	0.29 $\pm$ 0.00	1.08 $\pm$ 0.00	0.16 $\pm$ 0.00	0.75 $\pm$ 0.00
$Z \to \tau\tau$	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.02 $\pm$ 0.00	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.01 $\pm$ 0.00	0.01 $\pm$ 0.00
$t\bar{t}$	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.01 $\pm$ 0.00	0.01 $\pm$ 0.00	0.02 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$W\gamma \to e\nu\gamma$	0.00 $\pm$ 0.00	0.03 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$W\gamma \to \mu\nu\gamma$	0.45 $\pm$ 0.00	0.98 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
WZ	0.03 $\pm$ 0.00	0.12 $\pm$ 0.00	0.20 $\pm$ 0.00	0.18 $\pm$ 0.00	0.56 $\pm$ 0.00	0.04 $\pm$ 0.00	0.25 $\pm$ 0.00
ZZ	0.00 $\pm$ 0.00	0.02 $\pm$ 0.00	0.40 $\pm$ 0.00	0.31 $\pm$ 0.00	0.98 $\pm$ 0.00	0.06 $\pm$ 0.00	0.41 $\pm$ 0.00
Fake Lepton	0.72 $\pm$ 0.17	0.59 $\pm$ 0.09	0.45 $\pm$ 0.12	0.22 $\pm$ 0.07	0.47 $\pm$ 0.08	0.00 $\pm$ 0.00	0.20 $\pm$ 0.05
Sum Bkg	1.40 $\pm$ 0.17	2.46 $\pm$ 0.09	1.56 $\pm$ 0.12	1.01 $\pm$ 0.07	3.13 $\pm$ 0.08	0.27 $\pm$ 0.00	1.62 $\pm$ 0.05
All Expected	2.43$\pm$ 0.17	5.65$\pm$ 0.09	3.43$\pm$ 0.12	2.53$\pm$ 0.07	8.08$\pm$ 0.08	0.57$\pm$ 0.00	3.69$\pm$ 0.05
All Data	1	7	4	3	10	0	2
Gen5 Expected	1.11$\pm$ 0.11	2.56$\pm$ 0.06	1.60$\pm$ 0.09	1.00$\pm$ 0.04	3.64$\pm$ 0.07	0.26$\pm$ 0.00	1.72$\pm$ 0.03
Gen5 Data	0	3	2	1	7	0	0
Gen6 Expected	1.33$\pm$ 0.13	3.09$\pm$ 0.07	1.82$\pm$ 0.08	1.52$\pm$ 0.06	4.44$\pm$ 0.05	0.31$\pm$ 0.00	1.97$\pm$ 0.04
Gen6 Data	1	4	2	2	3	0	2

Table 25: WW expectations and yield, channel-by-channel (con't).