Diboson Cross Sections: A Few Notes

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WZ The Analyses:

- The basic analyses (all approx 200pb^{-1}):
  - $W\gamma/Z\gamma$ (CDF and D0)
  - $WW/WZ \to l\nu jj$ (CDF preliminary)
  - $WW \to ll\nu\nu$ (CDF and D0)
  - $WZ \to lll\nu$ (D0)
  - $WZ/ZZ \to llll$, $lll\nu$, $ll\nu\nu$ (CDF)
- Some rather non-technical observations (we can of course get technical if you want).

WZ Analyses with photons:

- Backgrounds are dominated by j->γ, for Wγ and Zγ.
- CDF and D0 went different ways:
  - CDF: Cut hard, has lower fake rate, quotes higher uncertainty.
  - D0: Cut loose, has higher fake rate, quotes lower uncertainty.
- Get to the same place though:
  - Final systematic errors ended up fairly comparable.
  - With the larger stats, the challenge will be to bring these to heel.

Worth Mentioning: Zγ

- Radiative Zγ production:
  - Backgrounds are low, for BOTH CDF and D0.
  - An opportunity to get real photon efficiencies from data? Cross section may be large enough at LHC to use $M_{ll\gamma}$ to do this.
  - Not enough statistics at Tevatron :(

WZ WW/WZ-> Lepton Channels:

- Both CDF and D0 have published analyses on the WW cross section (and done clean searches in WZ, and WZ/ZZ).
  - Again experiments take different tacks, but...
  - In general, with two or more reconstructed leptons, your backgrounds become more physics and less mis-id (DY, Wγ, ZZ, etc.).
  - Need to know more about detector's resolution to separate.
  - Doing one lepton + stiff track tends to bring you back to having lots of mis-id background.
    - Larger acceptance though...

WZ WW/WZ->lvjj

- Much larger branching fraction than lepton only.
- Extremely small signal on VERY large continuum background (W+jj).
  - Like the most difficult parts of top and EW combined.

WZ Summary

- You can divide these analyses into:
  - Mis-ID backgrounds
    - Photons get hit twice: first by systematics dealing with the efficiencies, and then by the j->g rate in data.
  - Physics backgrounds
    - Theoretical predictions, with data resolutions and efficiencies.
- Taking statistics out of the equation 'pulls the curtain back' on these issues.

WZ BARRIER SLIDE

Here there be dragons….

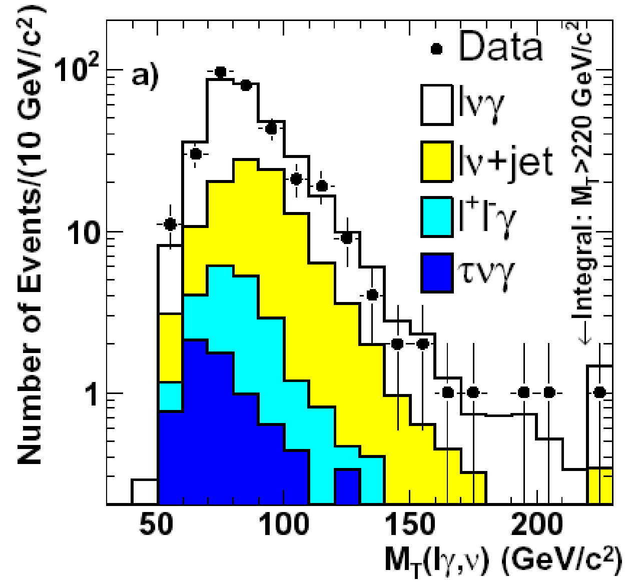
CDF Wγ Cross Section

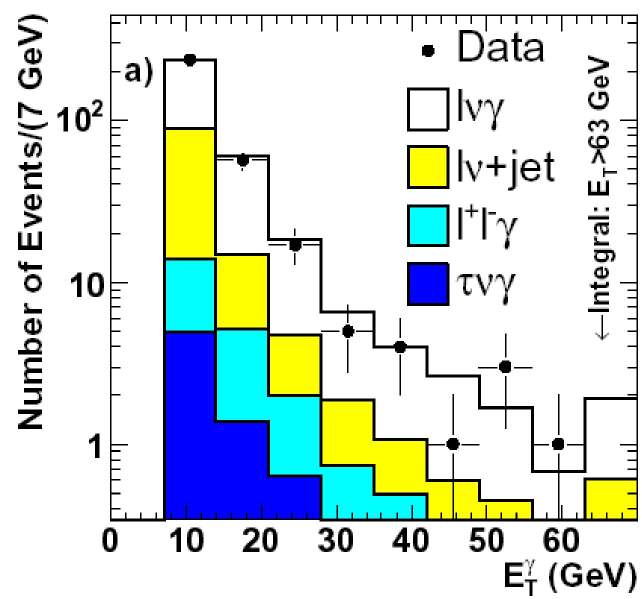
WZ

Channel:	$e\nu\gamma$	$\mu\nu\gamma$
η^l	2.6	1.0
$p_T^{\,l}$	25	20
$\not{E}_T$	25	20
η_γ	1.0	
$p_T^{\,\gamma}$	7	
M_T	$30<M_T<120$	
Lum (pb^{-1})	202	192
Bkg:	67.3±18.1	47.3±7.6
SM exp:	126.8±5.8	95.2±4.9
Observed:	195	128

$\sigma(p\bar{p} \to l\nu\gamma;\ E_T^\gamma>7$ GeV, $dR_{l\gamma}>0.7) = 18.3 \pm 3.1$ pb

PRL 94, 041803 (2005) SM: 19.3 ± 1.4 pb





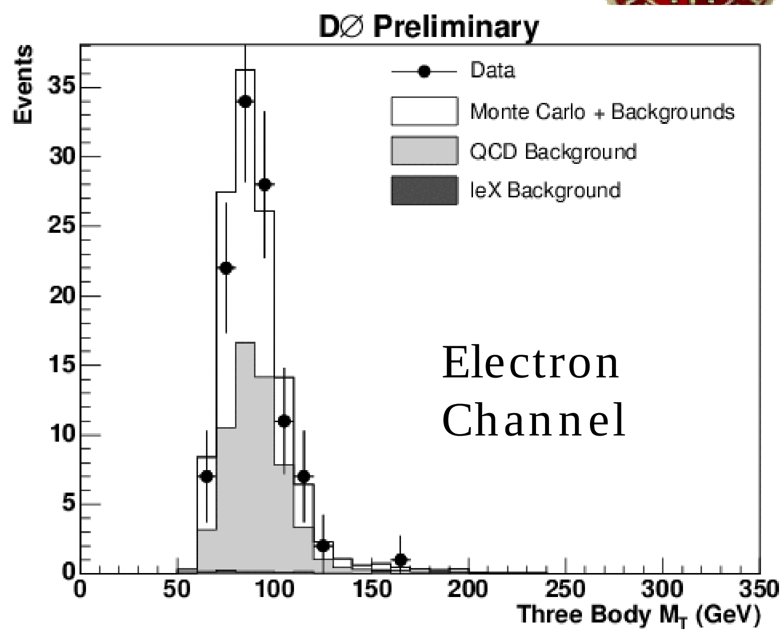
WZ

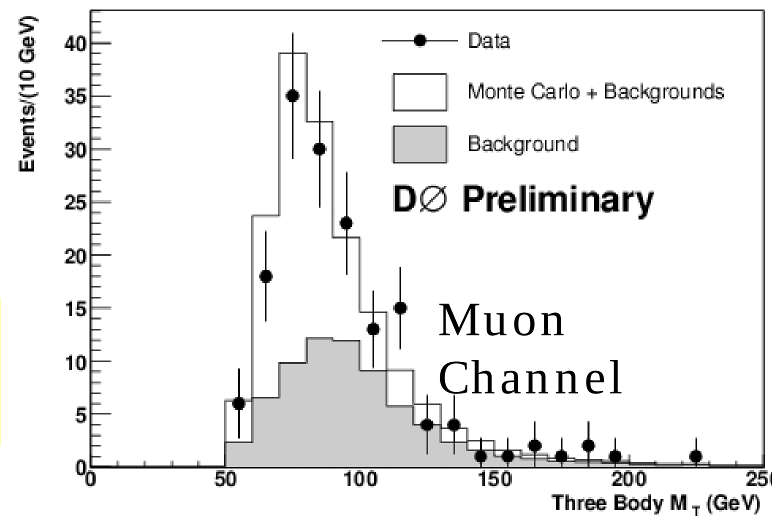
DØ Wγ Cross Section

Channel:	eνγ	μνγ
η^{l}	1.1	2.0
$p_T^{\,l}$	25	20
$\not{E}_T$	25	20
η^{γ}	1.1	
$p_T^{\,\gamma}$	8	
M_T	$40<M_T$	0
Lum (pb^{-1})	162	134
Bkg:	60.8±4.5	71.3±5.2
SM exp:	59.5±5.4	94.0±7.4
Observed:	112	161

$\sigma(p\bar{p} \to l\nu\gamma;\ E_T^{\gamma}>8$ GeV, $dR_{l\gamma}>0.7) = 14.8 \pm 2.1$ pb

DØ Preliminary — SM: 16.0 ± 0.4 pb



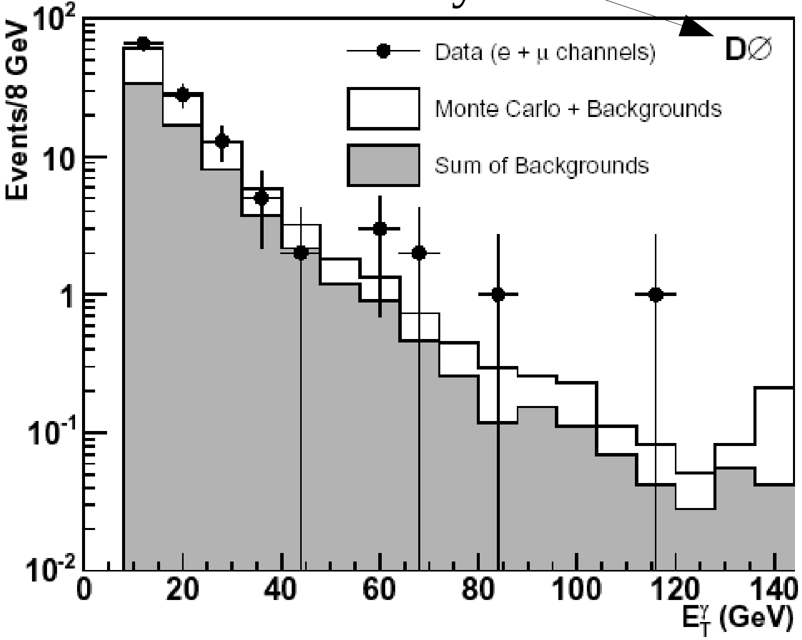


WZ

Wγ Anomalous Couplings

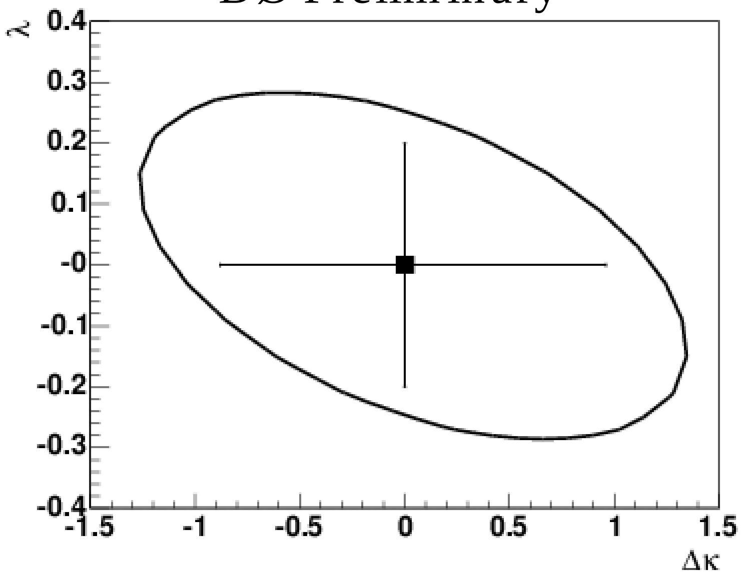
E_T^γ Combined Channels:

DØ Preliminary



- Photon E_T agrees w/ S.M. (last is overflow bin).
- Form a binned-likelihood based on E_T^γ in a λ_γ vs. $\Delta\kappa_\gamma$ grid (including bkgd) on events w/ M_{T3}>90 GeV/c^2.

DØ Preliminary



$-0.88<\Delta\kappa_\gamma < 0.96$

$-0.20<\lambda_\gamma<0.20$

DØ Preliminary

1D limits @95% C.L.

Λ=2TeV

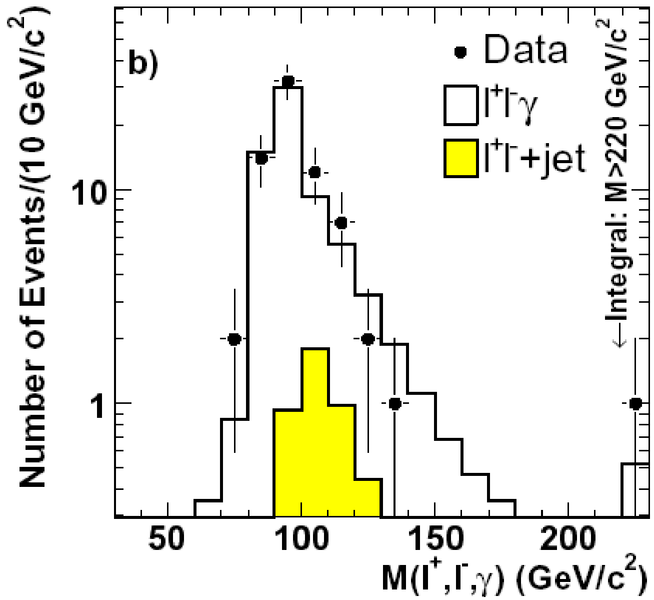
WZ

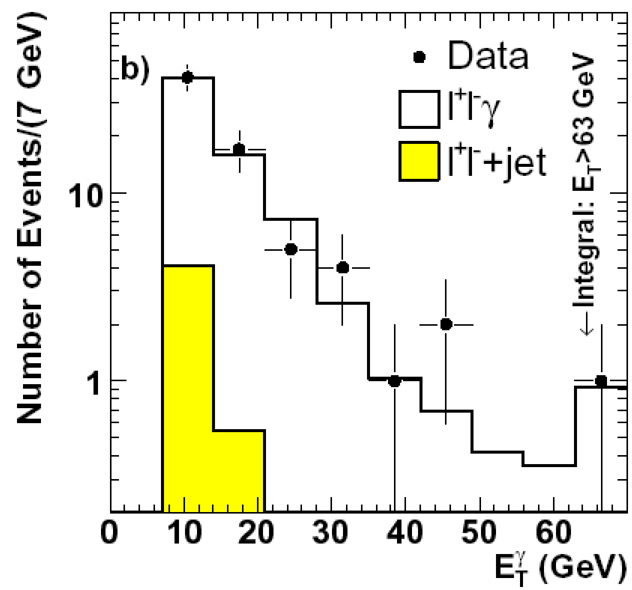
CDF Zγ Cross Section

Channel:	eeγ	μμγ
η^l	2.6	1.0
$p_T^{\,l}$	25	20
η^γ	1.0	
$p_T^{\,\gamma}$	7	
M_{ll}	$40<M_{ll}<130$	
Lum (pb^{-1})	202	192
Bkg:	2.8±0.9	2.1±0.6
SM exp:	31.3±1.6	33.6±1.5
Observed:	36	35

$\sigma(p\bar{p} \to ll\gamma;\ E_T^\gamma>7$ GeV, $dR_{l\gamma}>0.7) = 4.6 \pm 0.6$ pb

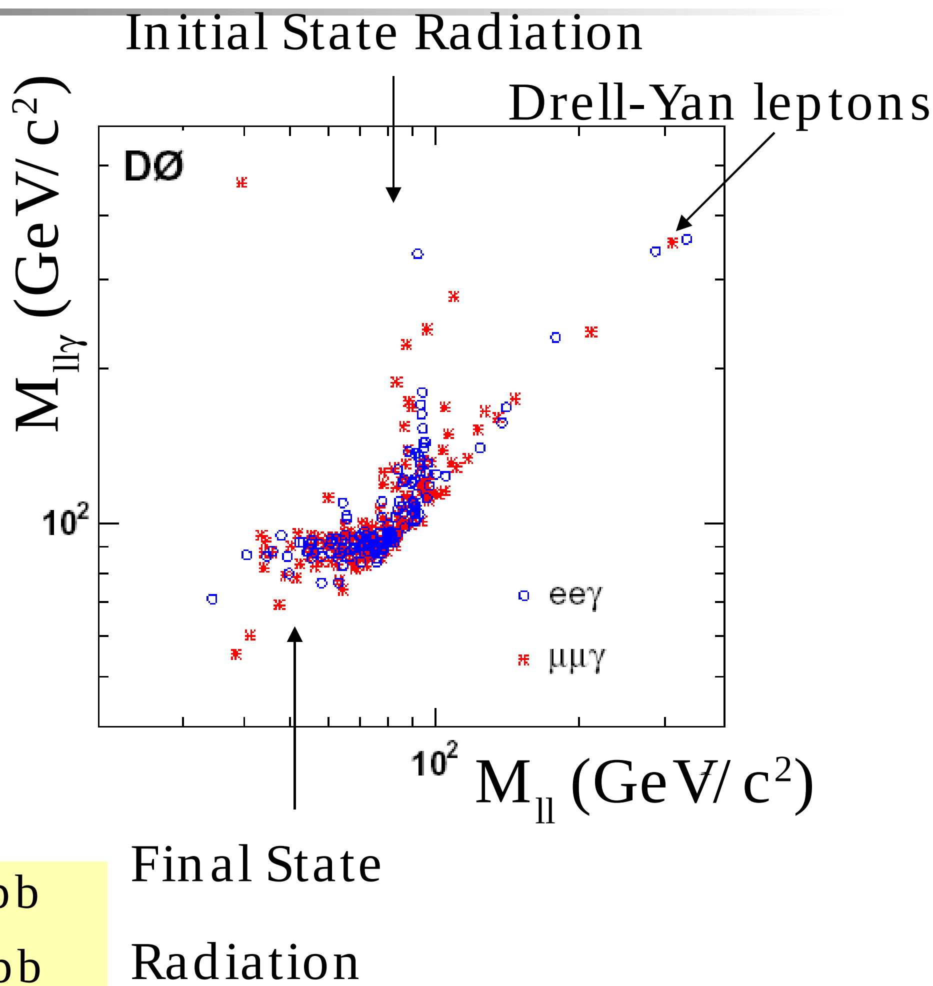
PRL 94, 041803 (2005) SM: 4.5 ± 0.3 pb





DØ Zγ Cross Section

Channel:	eeγ	μμγ
η^{l}	1.1 (2.5)	2.0
p_T^{l}	25	15
η^{γ}	1.1	
p_T^{γ}	8	
M_{ll}	$30<M_{ll}$	
Lum (pb^{-1})	320	290
Bkg:	23.6±2.3	22.4±3.0
SM exp:	95.3±4.9	126.0±7.8
Observed:	138	152

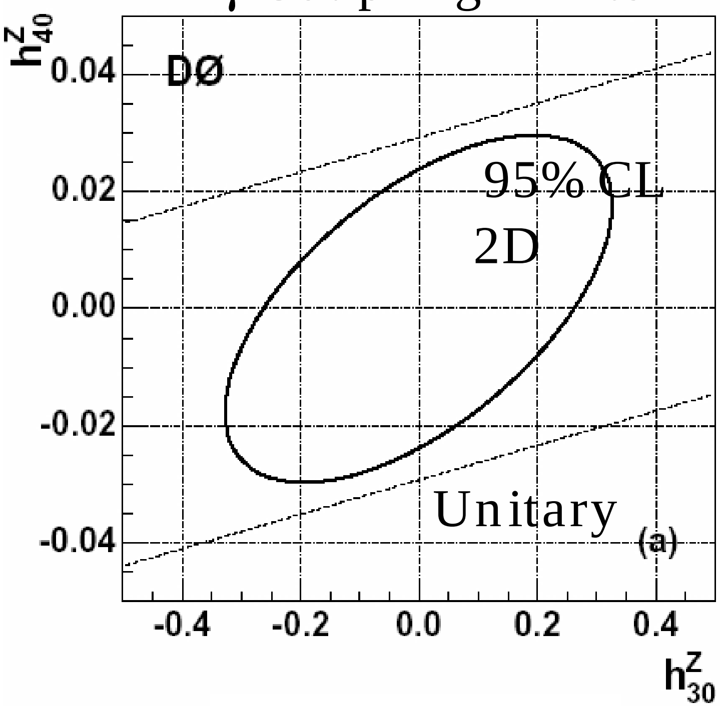


$\sigma(p\bar{p} \to ll\gamma; E_T^{\gamma}>8$ GeV, $dR_{l\gamma}>0.7) = 4.2 \pm 0.5$ pb
hep-ex/0502036 SM: 3.9 ± 0.2 pb

WZ

Zγ Anomalous Couplings

ZZγ Coupling Limits



$|h^Z_{10,30}| < 0.23$

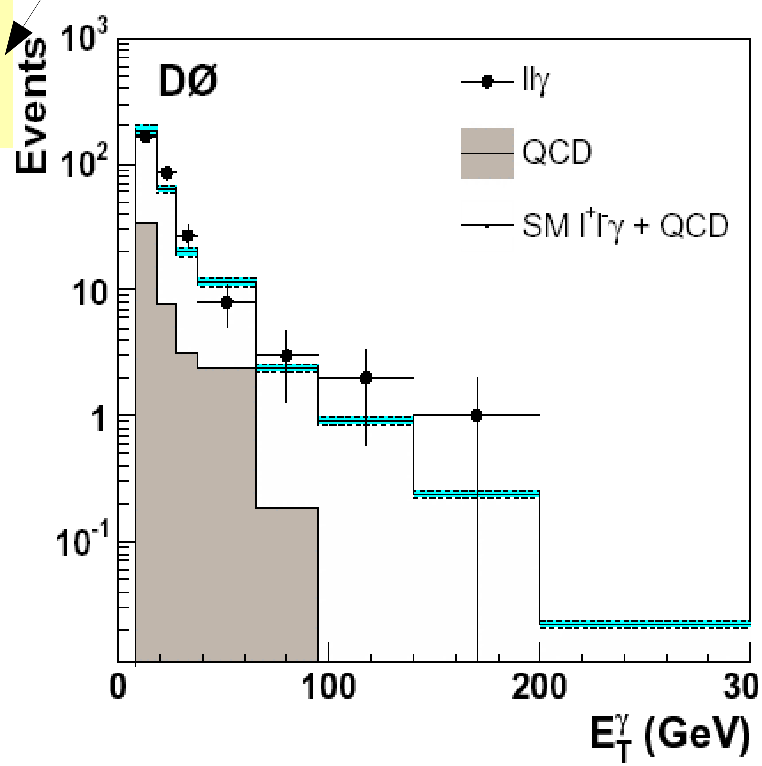
$|h^Z_{20,40}| < 0.020$

$|h^\gamma_{10,30}| < 0.23$

$|h^\gamma_{20,40}| < 0.019$

Most stringent limits to date.

hep-ex/0502036



$\Lambda = 1000$ GeV

The ZZγ and Zγγ

AC contours are similar.

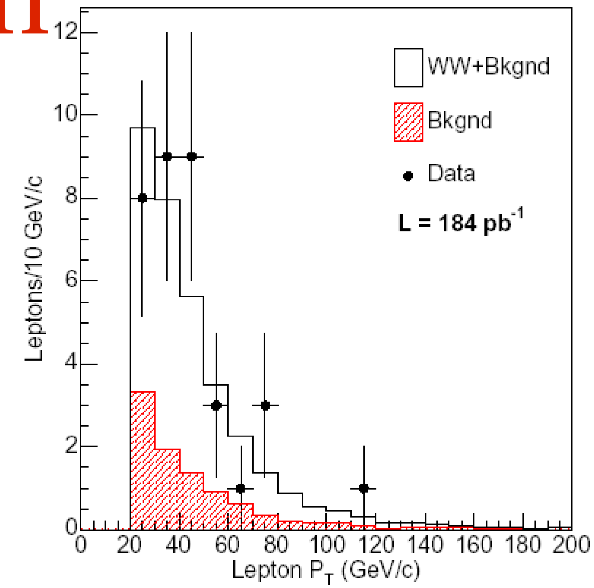
WZ

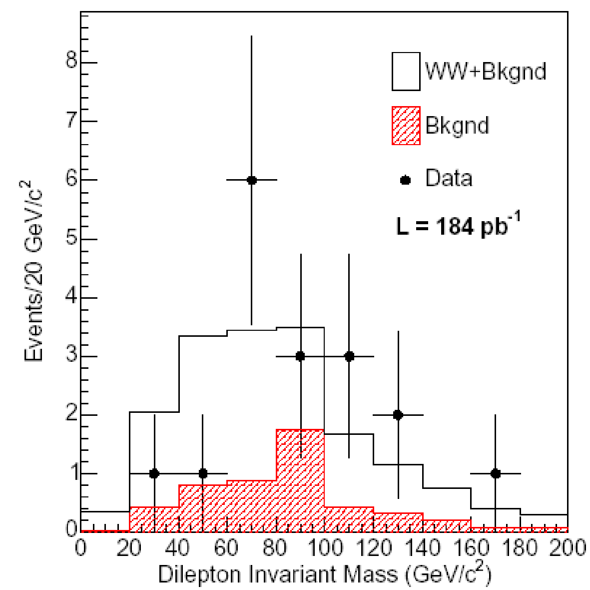
CDF WW Cross Section

Channel:	ee	eμ	μμ
η^l	2	2(1)	1
$p_T^{\,l}$		20	
$\not{E}_T$		25 ($\Delta\phi_{ll} > 20°$ if $E_T<50$)	
$\not{E}_T^{\,sig}$		3	
Jet Veto		$E_T > 15$, $\lvert\eta\rvert<2.5$	
Lum	184	184	184
Bkg:	$4.5^{+1.4}_{-0.5}$	1.9 ± 0.4	$1.3^{+1.6}_{-0.5}$
SM exp:	$4.5^{+1.4}_{-0.5}$	7.0 ± 0.8	$3.8^{+1.6}_{-0.5}$
Observed:	6	5	6

$\sigma(p\bar{p}\to W^+W^-)=14.6^{+5.8}_{-5.1}(stat)^{+1.8}_{-3.0}(sys)\pm0.6(lum)$ pb

hep-ex/0501050 SM: 12.4 ± 0.8 pb





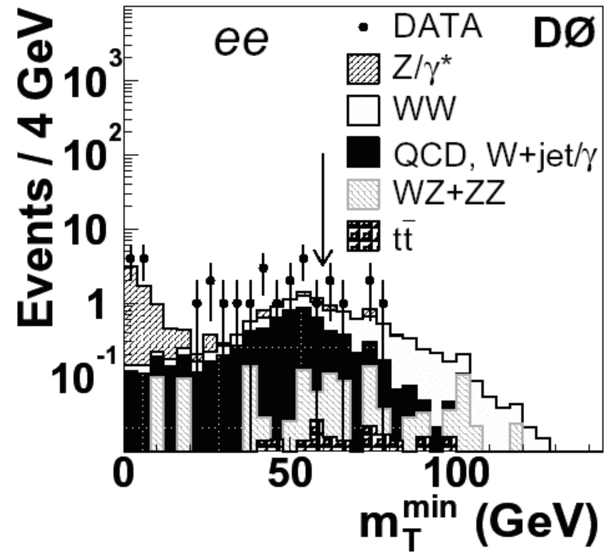
WZ

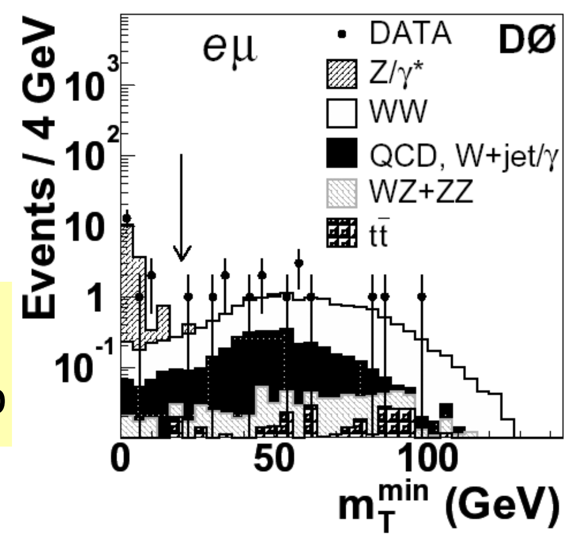
DØ WW Cross Section

Channel:	ee	eμ	μμ
η^l	3	3(2)	2
$p_T^{\,l}$		20(15)	
$\not{E}_T$	30	20	40
$\not{E}_T^{\,sc}$	15	15	----
$H_{T\,E_T > 20,\ \lvert\eta\rvert<2.5}$	50	50	100
Lum	252	235	224
Bkg:	2.30±0.21	3.81±0.17	1.95±0.41
SM exp:	3.42±0.05	11.10±0.10	2.10±0.05
Observed:	6	15	4

$\sigma(p\bar{p} \to W^+W^-) = 13.8^{+4.3}_{-3.8}(\text{stat})^{+1.2}_{-0.9}(\text{sys}) \pm 0.9(\text{lum})$ pb

hep-ex/0410066 (accepted by PRL) SM: 12.4 ± 0.8 pb





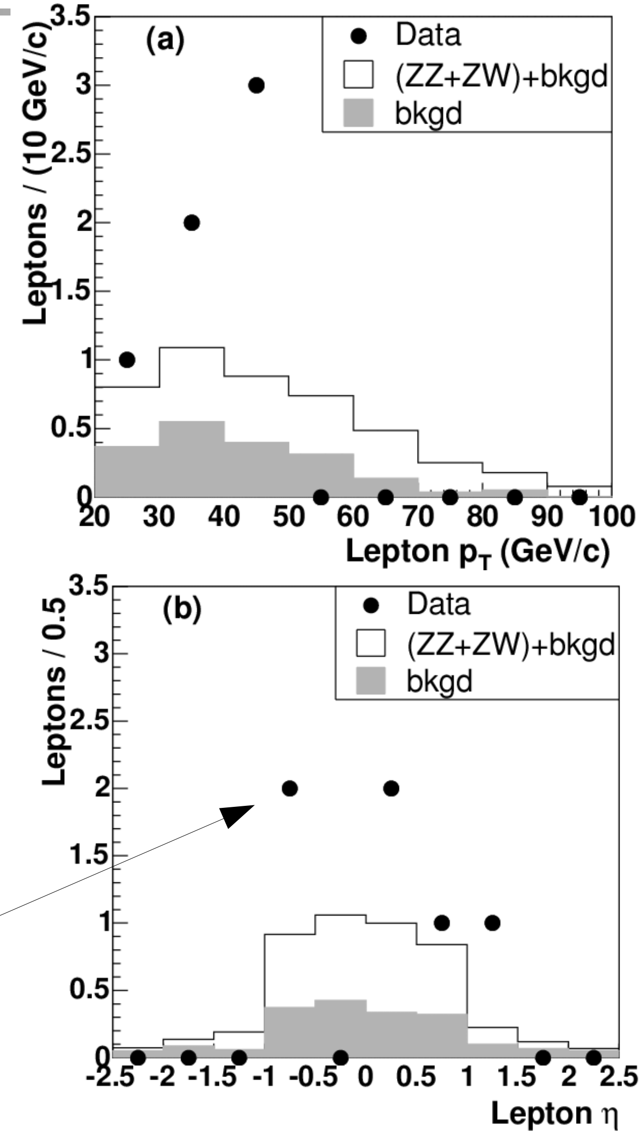
CDF WZ/ZZ Limit

WZ

Channel:	ee	μμ
η^l	2.5	1.0
p_T^l	20	20
M_{ll}	$76<M_{ll}<106$	
Lum (pb^{-1})	194	194
Bkg:	1.02±0.24	
SM exp:	2.31±0.29	
Observed:	2	1

All observed events are in $ll\not{E}_T$ channel.

$\sigma(\bar{p}p \rightarrow ZW/ZZ) < 15.2$ pb
hep-ex/0501021 SM: 5.0 ± 0.4 pb



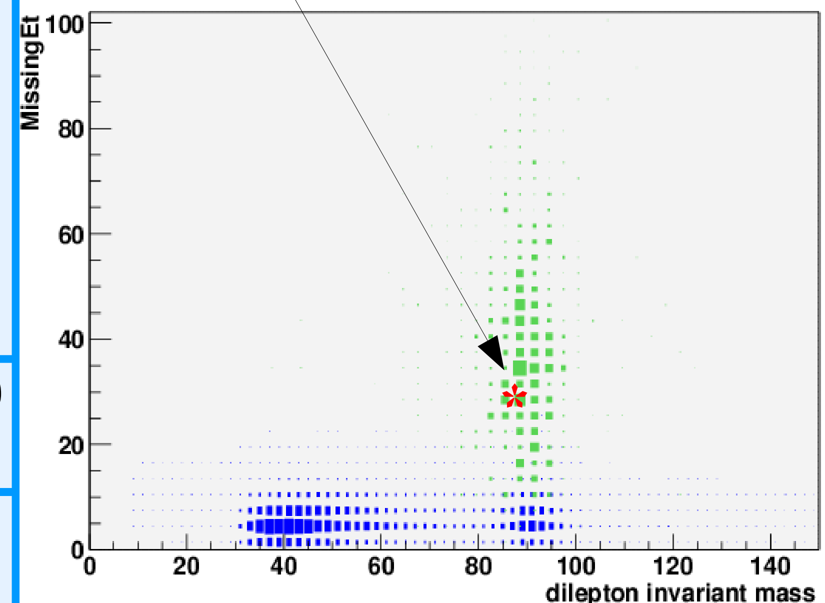
Error bars omitted for clarity.

WZ

DØ WZ Analysis

Tri-electron candidate

Channel:	eee	eeμ	μμe	μμμ
η^l	2.5	2.5(2)	2.5(2)	2
$p_T^{\,l}$	15			
$\not{E}_T$	20			
M_{ll}	$71 < M_{ee} < 111$		$51 < M_{\mu\mu} < 131$	
E_{THAD}	50			
Lum	320	292	285	289
Bkg:	0.71±0.08			
SM exp:	2.04±0.13			
Observed:	1	0	0	2



$\sigma(p\bar{p} \to WZ) < 13.3$ pb

or, interpreted as cross section: $\sigma(p\bar{p} \to WZ) = 4.5^{+3.8}_{-2.6}$ pb

DØ Preliminary SM: 3.7 ± 0.1 pb

Probability of background to fluctuate up to 3 events: 3.5%

WZ Anomalous Couplings

WZ

$\Lambda = 1.0$ TeV	DØ Preliminary	$\Lambda = 1.5$ GeV
$-0.53 < \lambda_Z < 0.56$		$-0.48 < \lambda_Z < 0.48$
$-0.57 < \Delta g_1^Z < 0.76$	95% C.L.	$-0.49 < \Delta g_1^Z < 0.66$
$-2.0 < \Delta\kappa_Z < 2.4$		-

- Inner contours: 2D limits. Outer contours are from unitarity.
- Best limits in WZ final states.
- First 2D limits in $\Delta\kappa_Z$ vs. λ_Z using WZ.
- Best limits available on Δg_1^Z, $\Delta\kappa_Z$, and λ_Z from direct, model-independent measurements.
- The DØ Run II 1D limits are ~ factor of 3 better Run I limits.