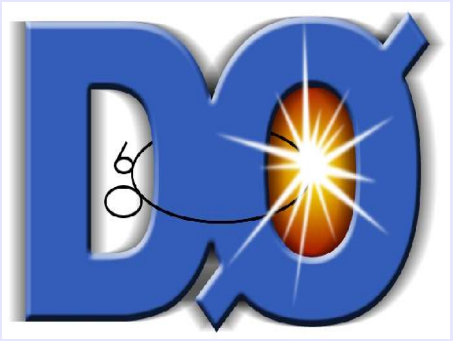
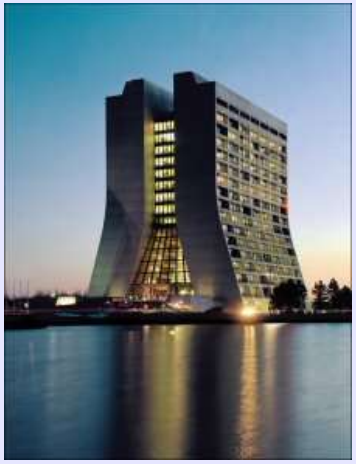




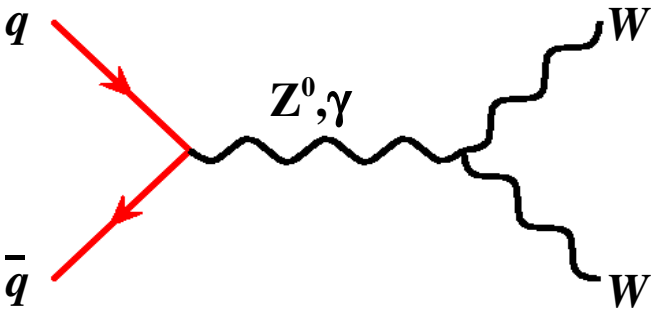
Di-boson Physics: WW, WZ

Jorgen Sjolin
(For the CDF and D0 collaborations)

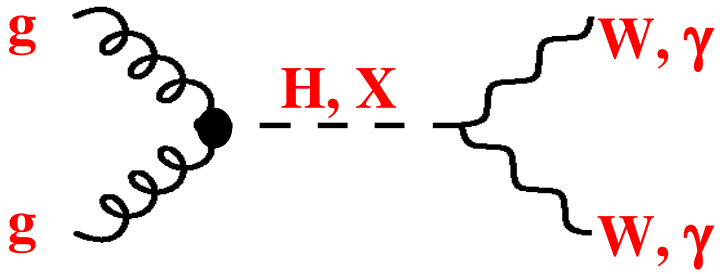
Oxford University,
Niels Bohr Institute

Moriond Electroweak
March 14, 2006

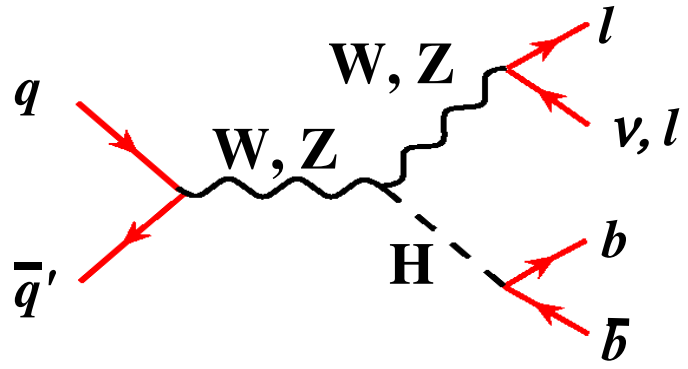
Motivations for the Di-boson final state



- SM tests of the triple gauge vertex.
- Lower statistics than LEP but higher $\hat{s}$.

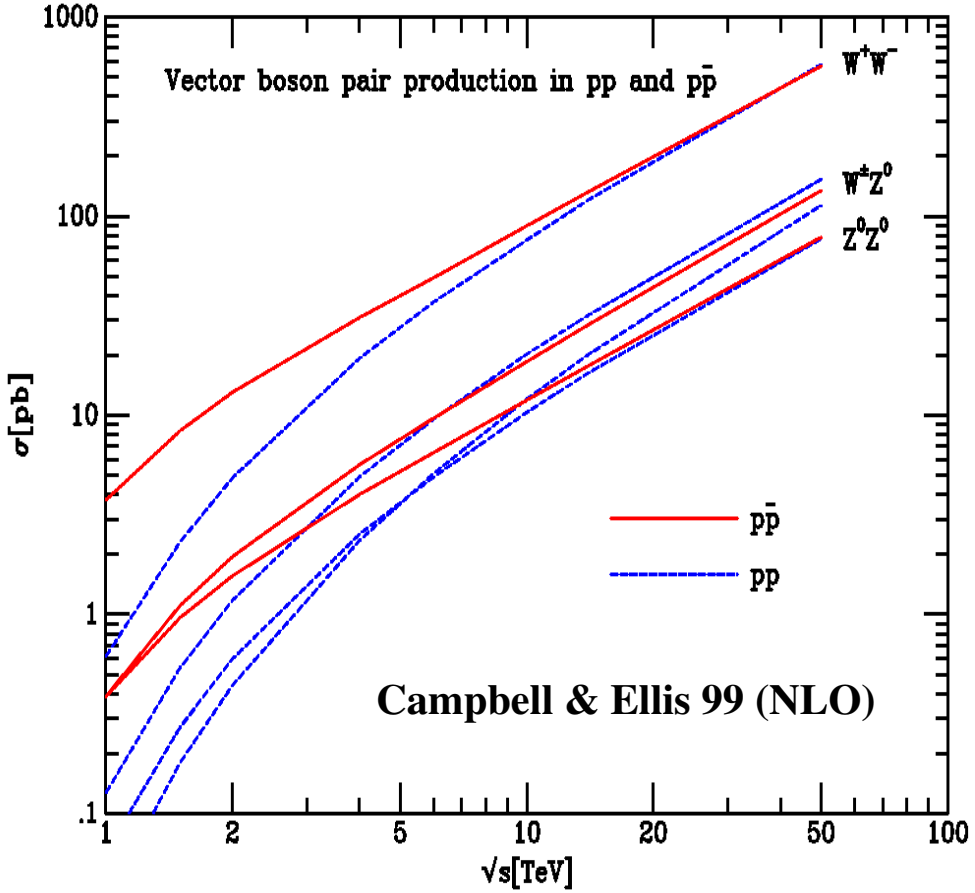


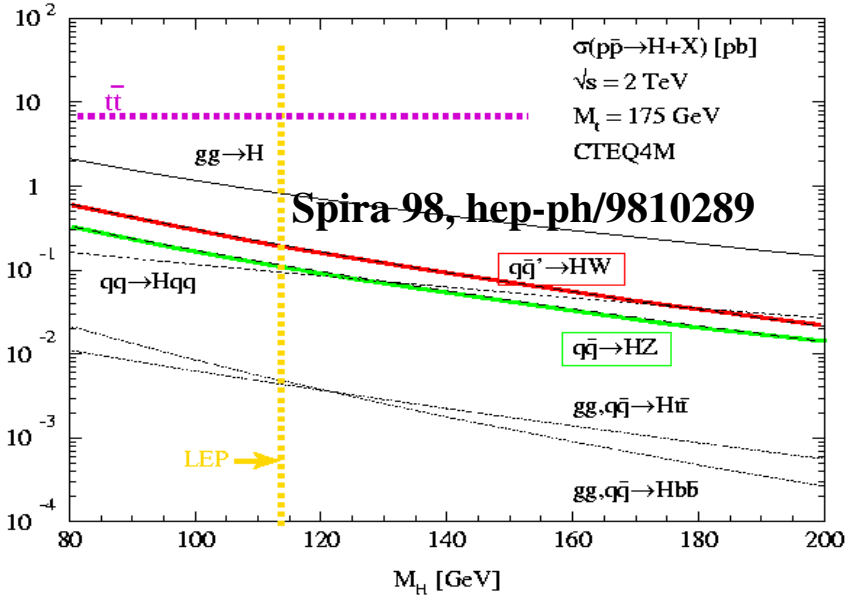
- Searches for heavy resonances. Note however that Di-boson scattering is small compared to LHC.

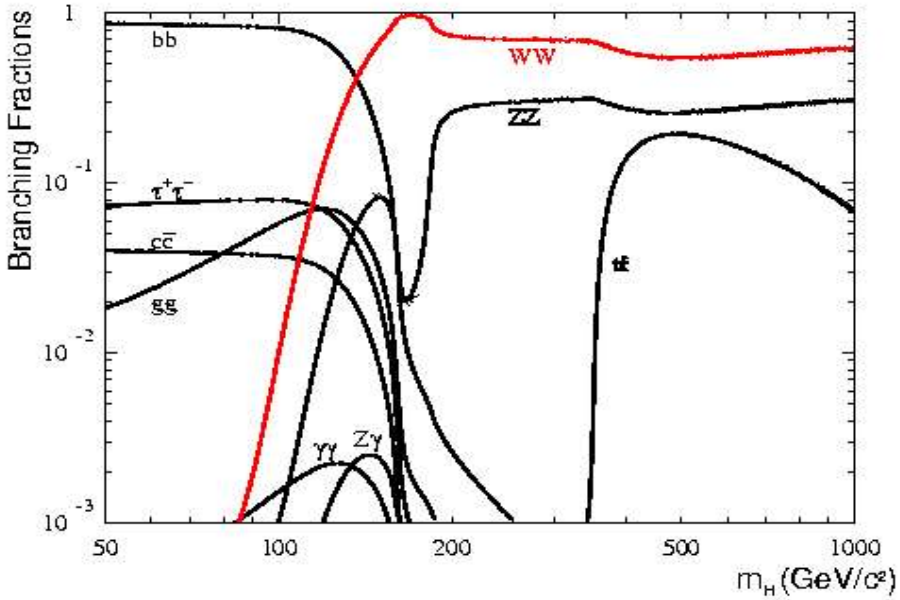


- Searches for light higgs.

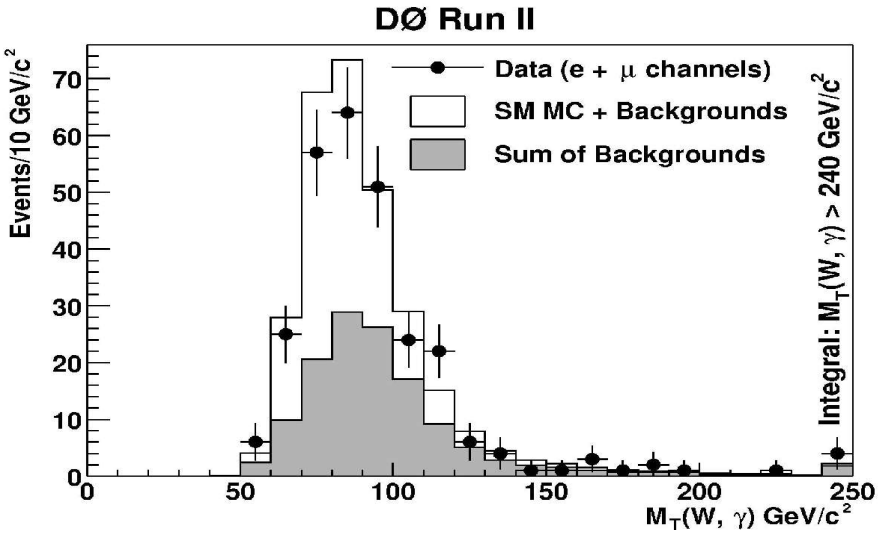
Di-boson theoretical predictions



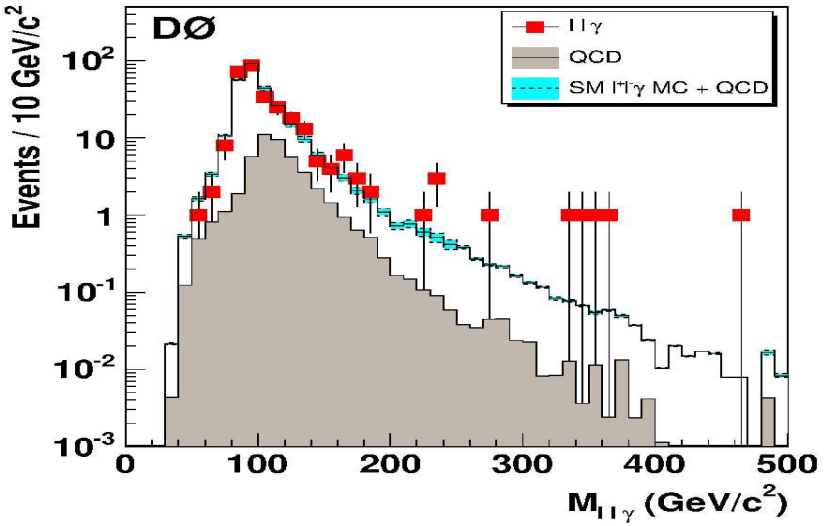




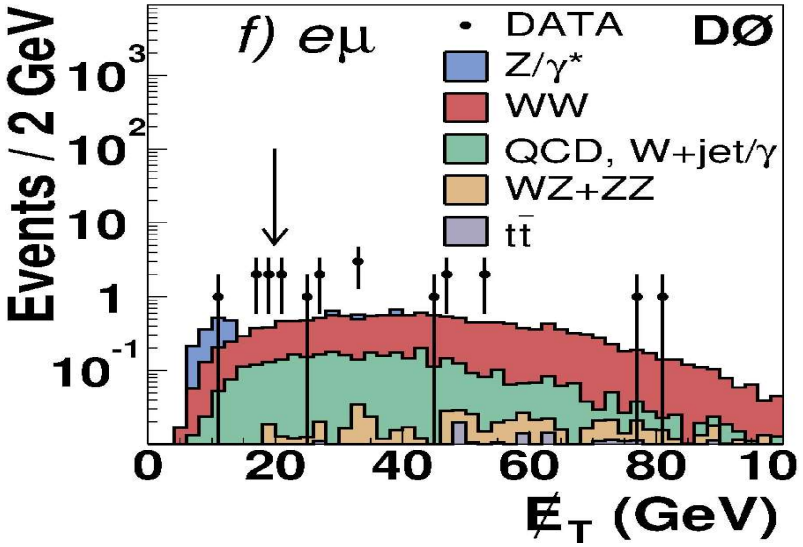
Last year Di-boson measurements



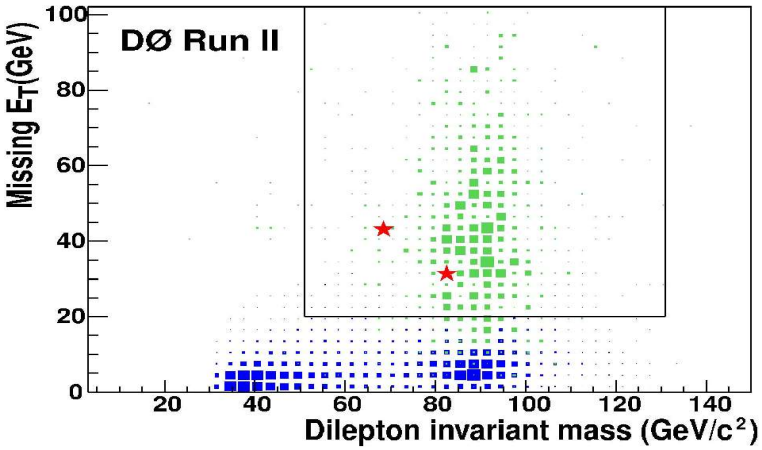
Wγ: D0, 134-165/pb (2005)



Zγ: D0, 300/pb (2005)



WW: D0, 224-252/pb (2005)

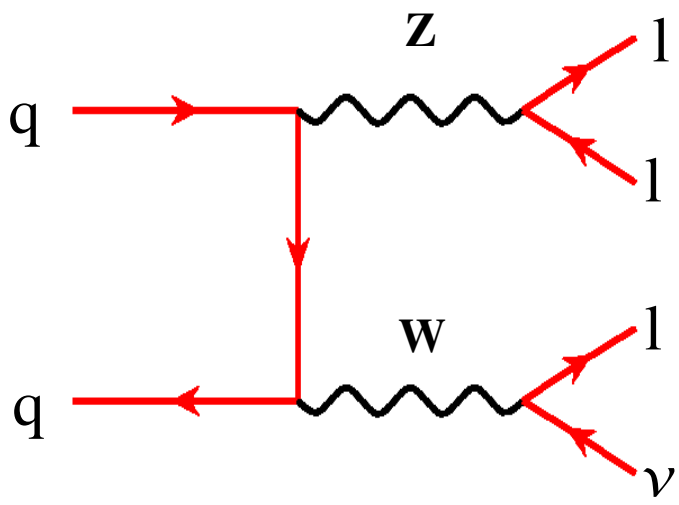


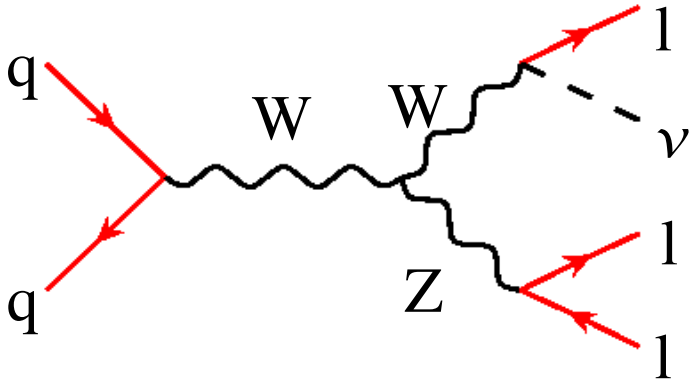
WZ: D0, 285-320/pb (2005)

New Di-boson measurements

- WZ : CDF, 800/pb (2006)
- WW: CDF, 350/pb (2006)

WZ in hadron collisions





- Clean signal.
- Unique handle on the WWZ vertex.

New CDF WZ measurement

l^+l^- : $76 < M(l^+l^-) < 106$ GeV

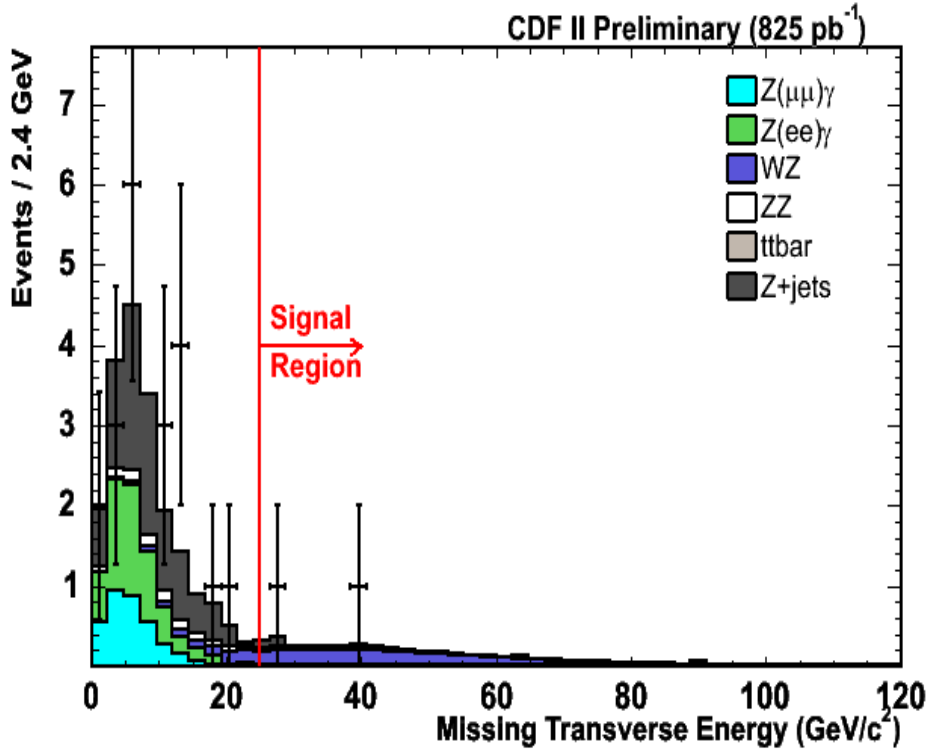
1 lepton > 20 GeV

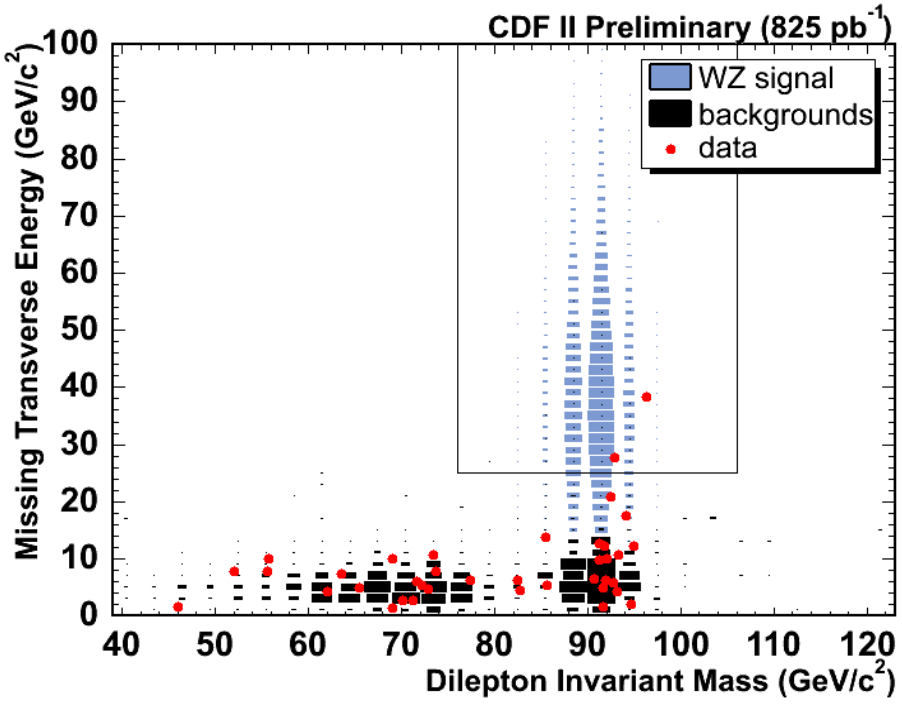
$\not\!\!E_T > 25$ GeV

$\sigma(WZ) < 6.34$ pb (95% C.L.)

Signal and Background Expectations (825 pb^{-1})

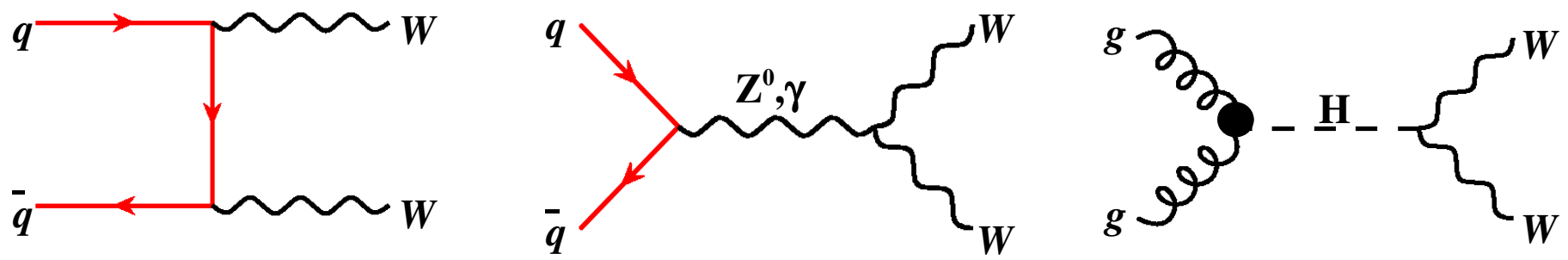
Signal:					
WZ:	3.72	± 0.02	(stat.)	± 0.15	(syst.)
Backgrounds:					
ZZ:	0.498	± 0.007	(stat.)	± 0.050	(syst.)
Zγ:	0.025	± 0.011	(stat.)	± 0.005	(syst.)
ttbar:	0.047	± 0.010	(stat.)	± 0.005	(syst.)
Z+jets (fakes):	0.34	± 0.07	(stat.)	$^{+0.15}_{-0.09}$	(syst.)
Total:	0.91	± 0.07	(stat.)	$^{+0.16}_{-0.10}$	(syst.)



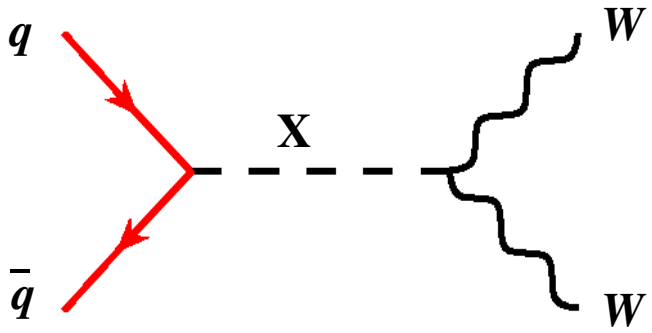


WW in hadron collisions

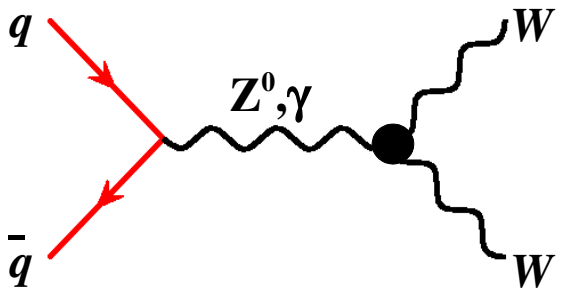
SM:



Resonance searches:

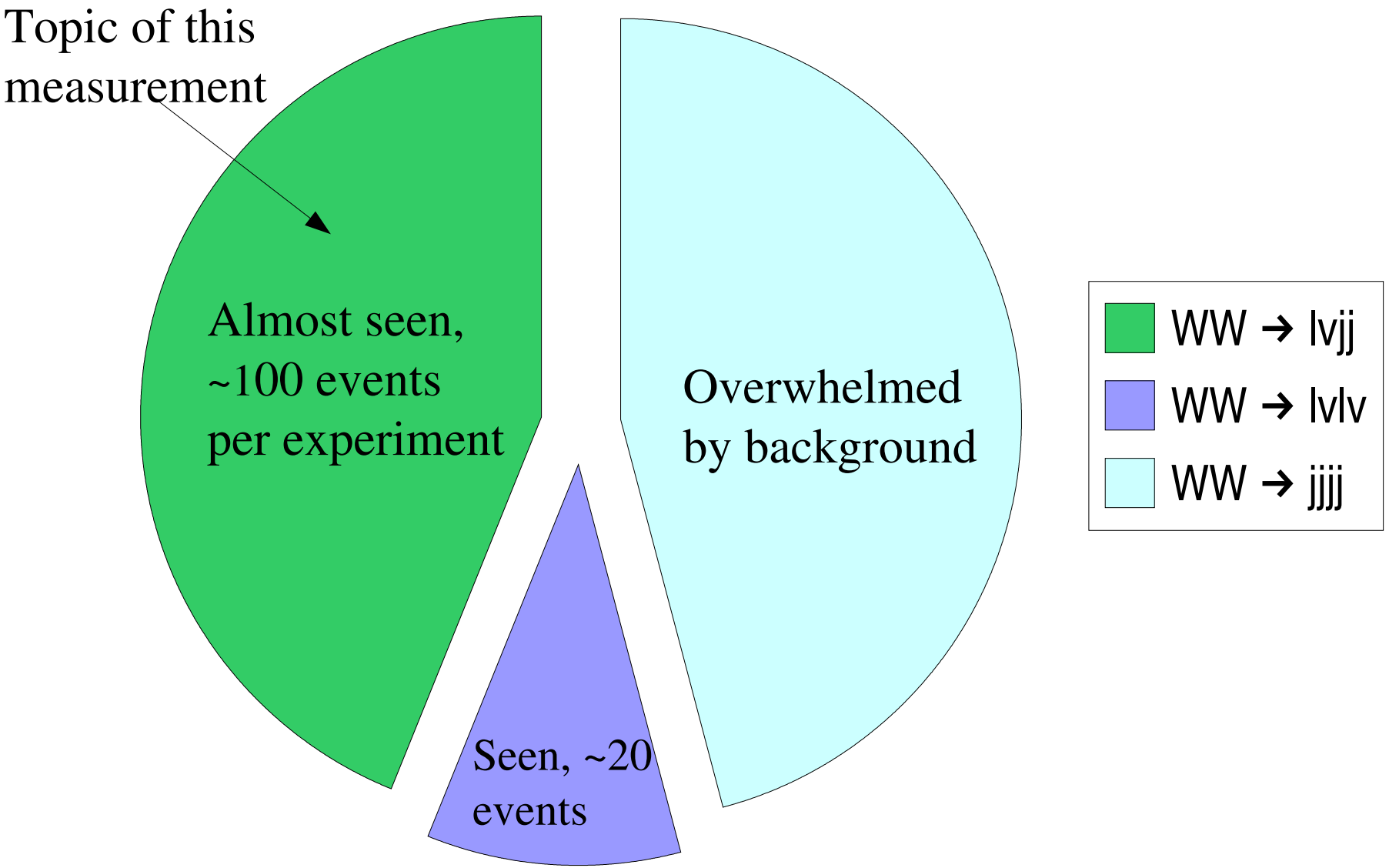


Anomalous couplings:

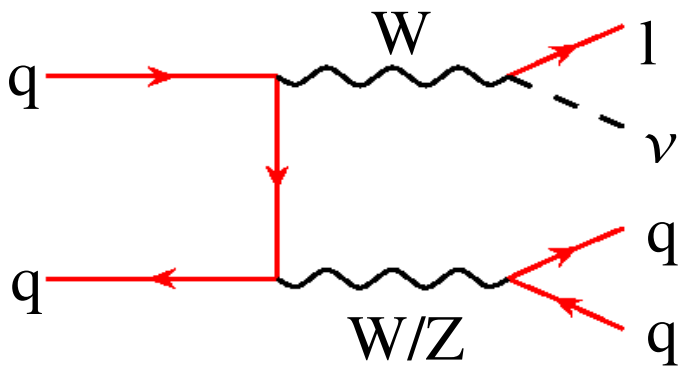


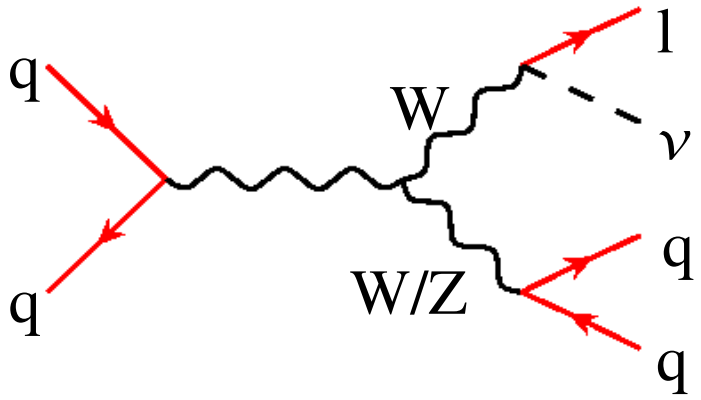
- First seen during Tevatron Run I: $\sigma(WW) = 10.2^{+6.3}_{-5.1} \pm 1.6$ pb
- The signature important as signal but also as background to other searches.

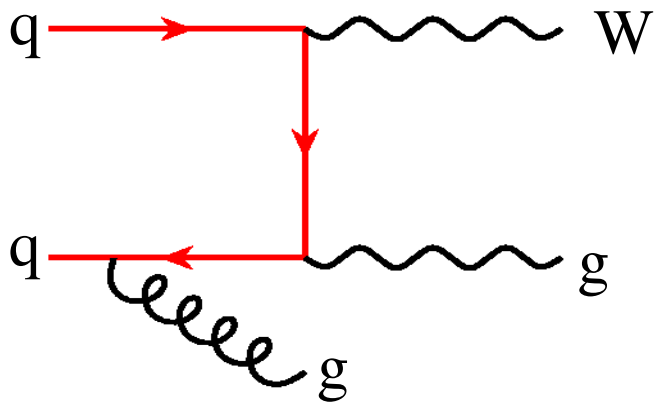
WW@Tevatron


Topic of this measurement
Almost seen, ~100 events per experiment
Seen, ~20 events
Overwhelmed by background
WW → lνjj
WW → lνlν
WW → jjjj

WW/WZ → lνjj







- W + 2 jets has O(100) diagrams.

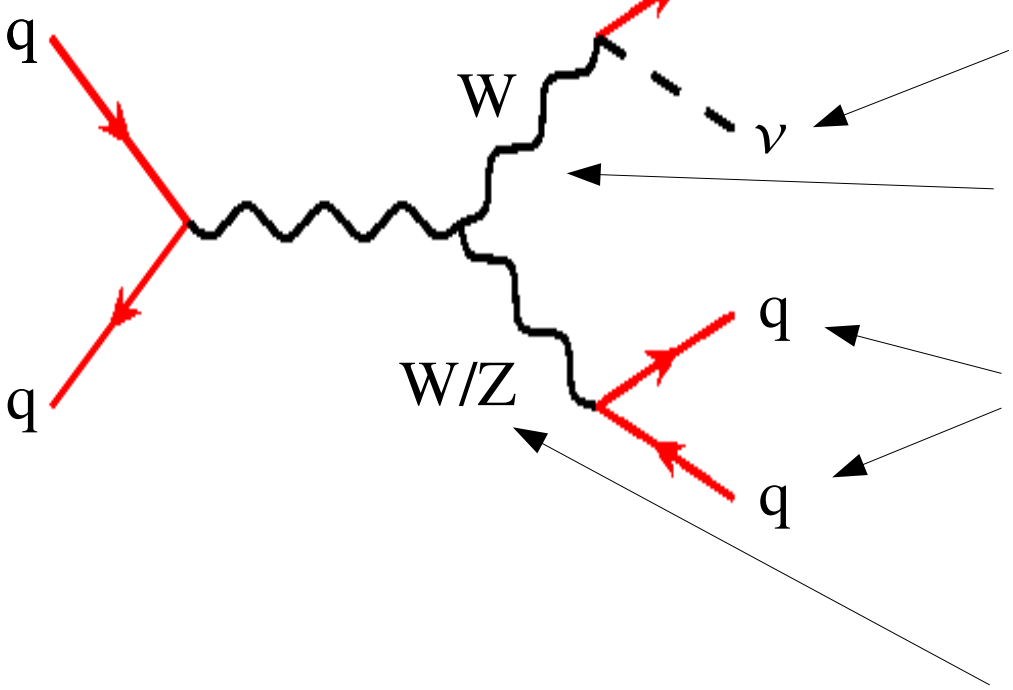
\+ Much higher yield than lvlv.

\- Low jet-jet mass resolution (~10%), large jet energy scale uncertainty.

\- Gluon/jet tagging very limited.

→ Challenging!

WW/WZ → lνjj event selection

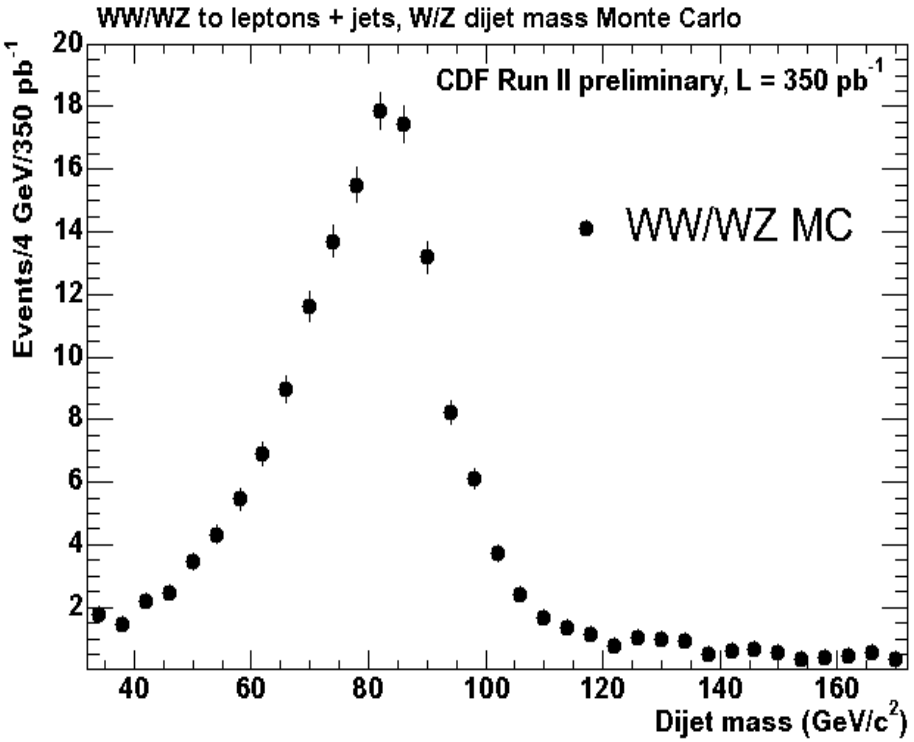


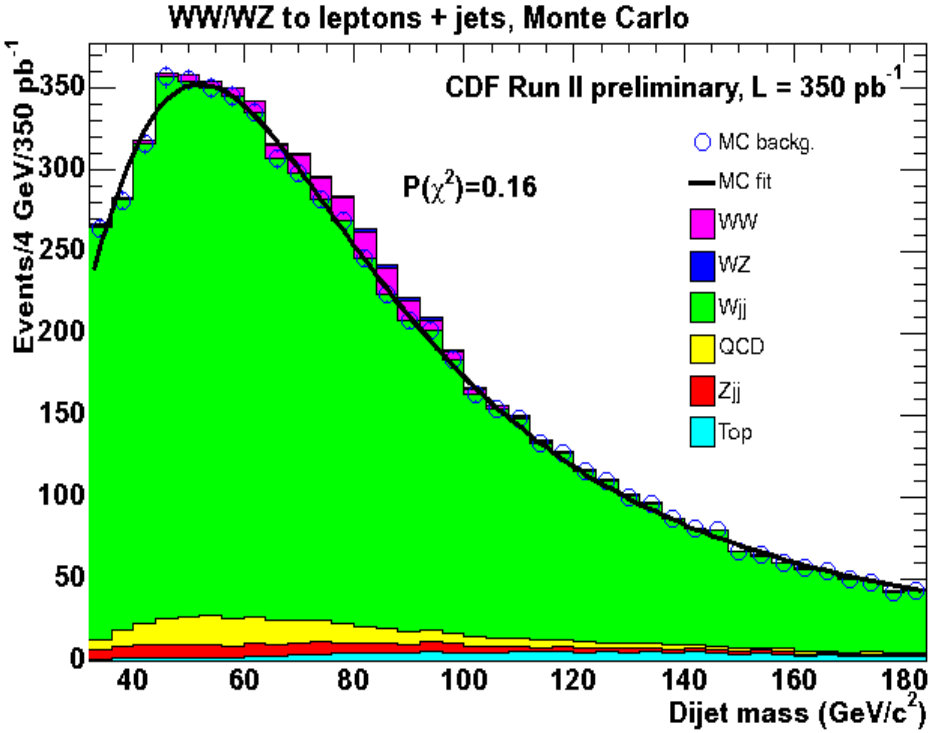
- Trigger on the charged lepton. 350/pb of electron and muon data.
- Require missing transverse energy.
- Get a sample of inclusive W.
- Look for at least two jets and form the invariant mass.
- Fit the expected W/Z and background dijet mass shape to data to extract the Di-boson fraction.

WW/WZ → lνjj expectations

- Lepton $E_T > 25$ GeV, $|\eta| < 1$
- $\not\!\!E_T > 25$ GeV.
- At least 2 jets $E_T > 15$ GeV
- Dijet mass 32-184 GeV

Process	Uncert.(%)	Electrons	Muons	Total
WW	15	79.9	62.1	142
WZ	15	11.3	6.9	18.2
W+jets	20	3537	2724	6261
tt, QCD,Z+jets	20-40	438	354	792





WW/WZ → lνjj systematics

Large potential systematics:

- W + 2jets cross-section ~20% uncertainty (~3*signal!).
- LO W + 2jets sensitive to renormalization scale.
- Jet energy scale.

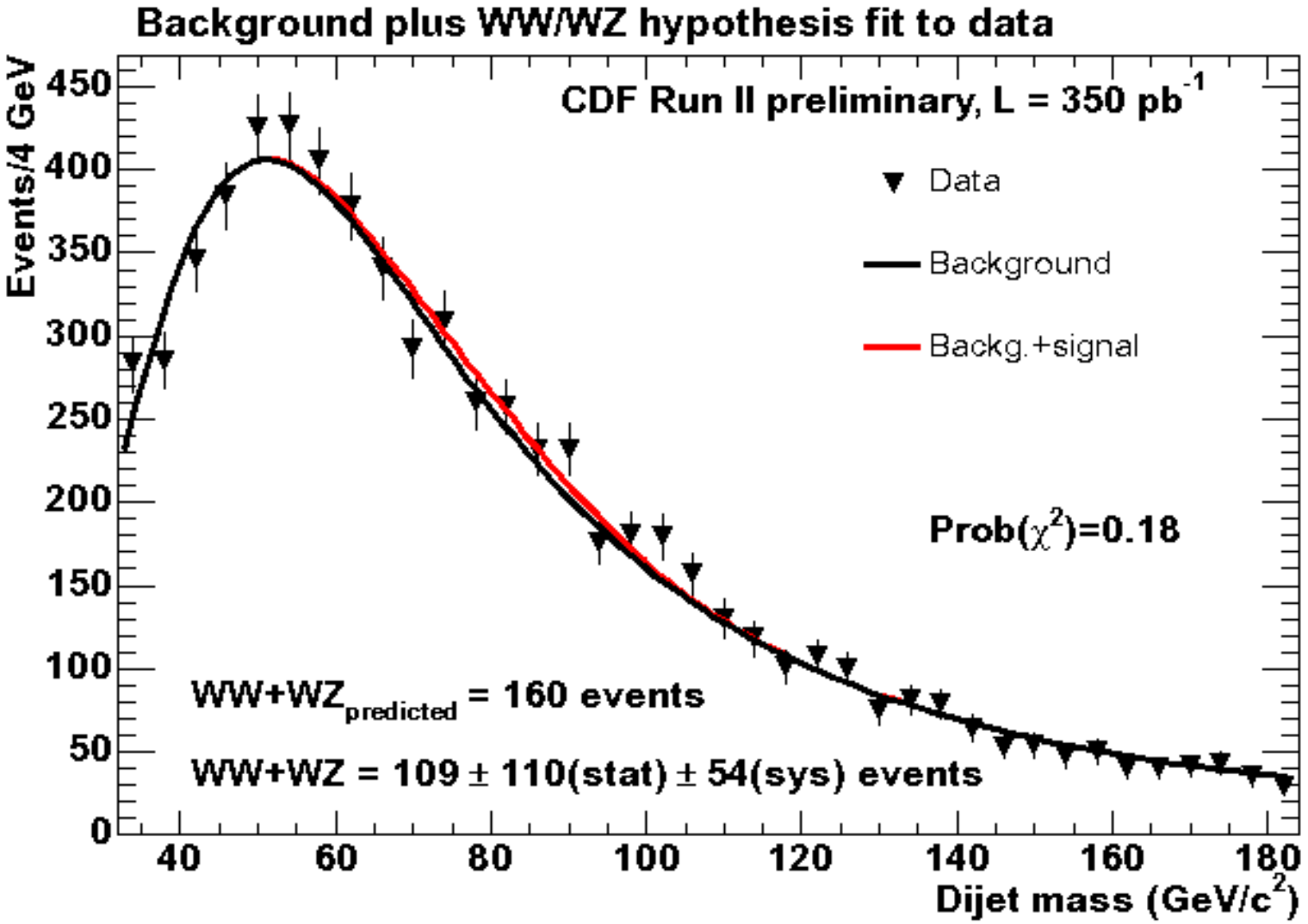
Several methods evaluated for optimal performance, this is what we finally use in the measurement:

- Fit signal and background shape to data.
- Vary MC and cross-check with data sideband.

Source	3-par fit(%)
Statistics	69
Jet resolution	19
Jet energy scale	16
Non-W background	16
ISR/FSR	10
Signal shape	10
Q^2 uncertainty	8
Luminosity	6
Leptonic W	3

WW/WZ → lνjj cross-section

- Fit signal and background di-jet mass shape to data.



WW/WZ → lνjj cross-section

- Expected events and uncertainties based on pseudo experiments assuming SM cross-section σ(WW+WZ)=16 pb:

  WW+WZ events = 160 ± 113(stat) ± 34(sys)

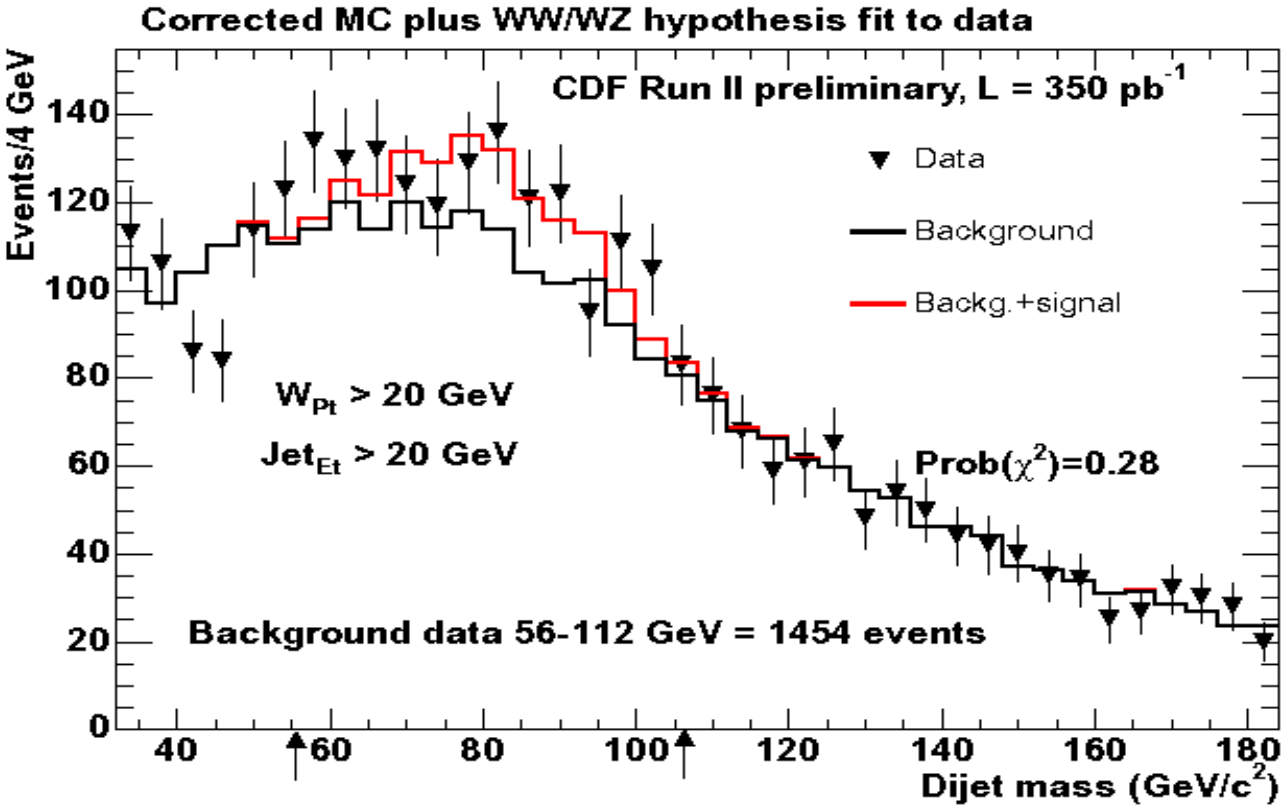
- Measured from 350/pb of data:

  WW+WZ events = 109 ± 110(stat) ± 34(sys)

σ(WW+WZ) < 36 pb (95% C.L.)

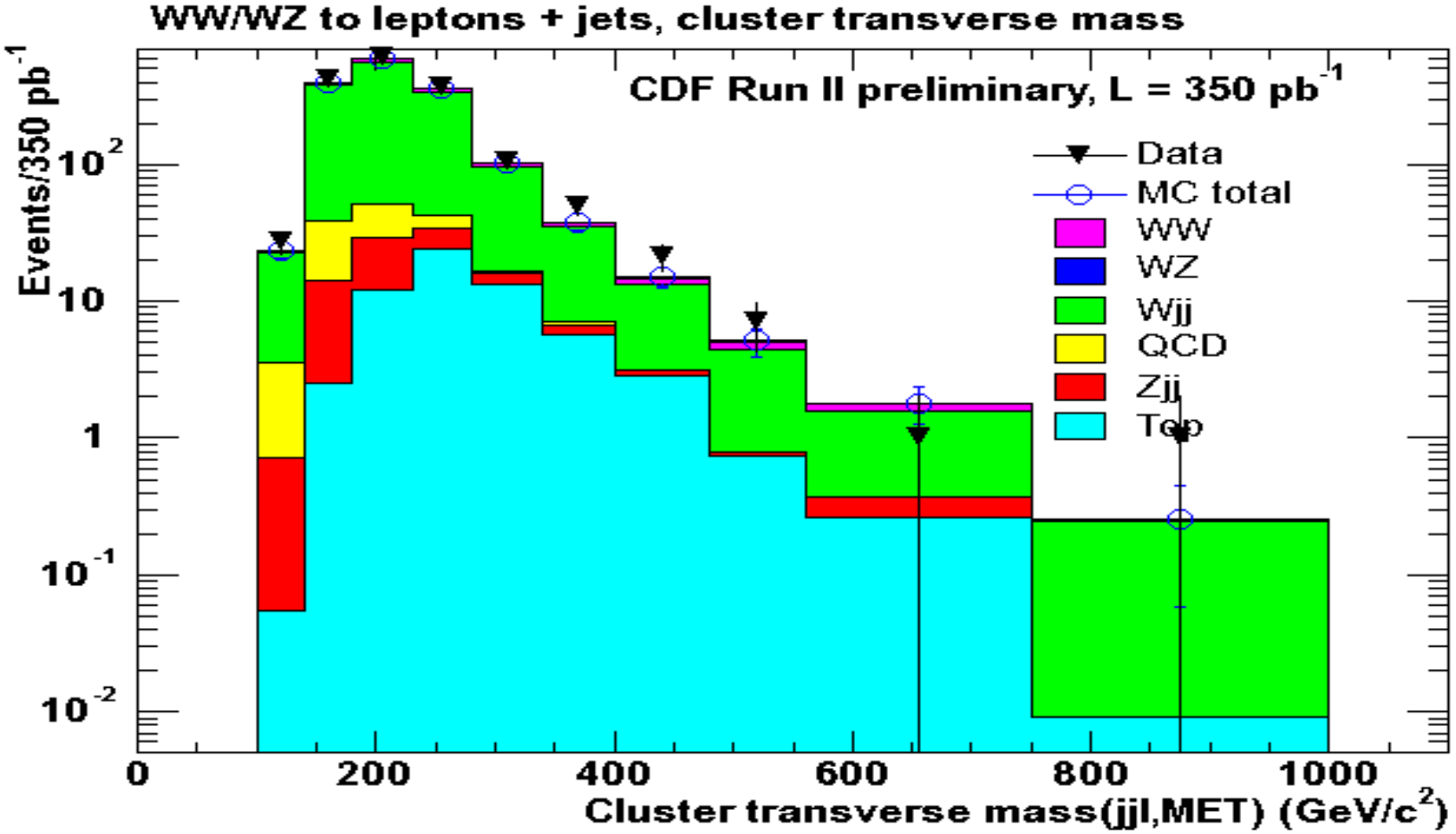
WW/WZ → lνjj anomalous couplings

- Most sensitivity in the high energy tail.
- Increase jet Et > 20 GeV and W Pt > 20 GeV.
- Fit for the background in the region 32-184 GeV.
- Then test a AC hypothesis in the dijet signal region 56-112 GeV using the most sensitive kinematic distribution.



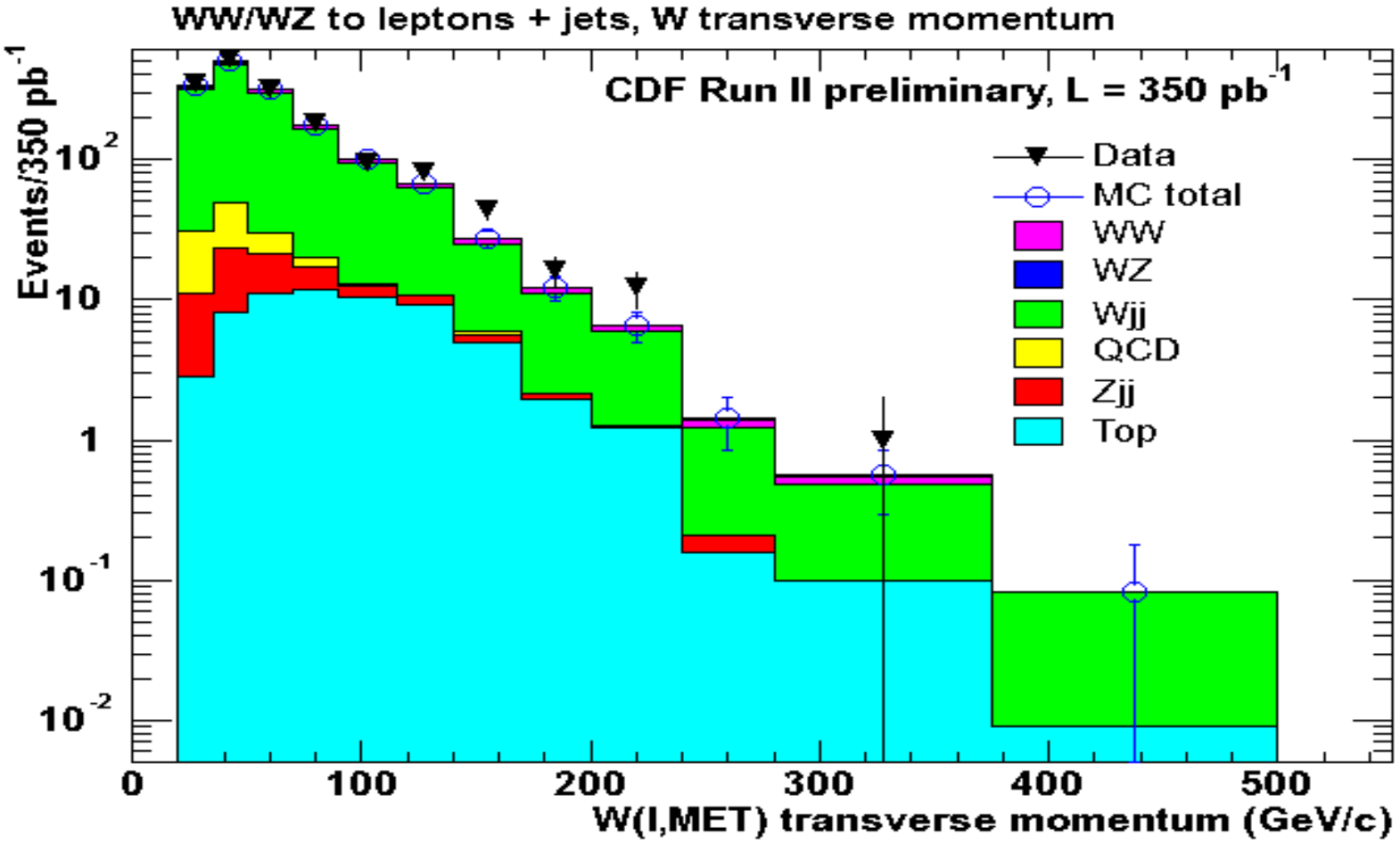
Cluster transverse mass

$$\mathrm{CTM}^2(\mathrm{ljj}, \not\!\!E_T) = ((m^2_{\mathrm{ljj}} + |p_{T_\mathrm{l}} + p_{T_{\mathrm{j}1}} + p_{T_{\mathrm{j}2}}|^2)^{1/2} + \not\!\!E_T)^2 + -|p_{T_\mathrm{l}} + p_{T_{\mathrm{j}1}} + p_{T_{\mathrm{j}2}} + \not\!\!E_T|^2.$$



- CTM peaks near ŝ.
- Mass resolution ~ 15%.
- Sensitive to resonances: X -> W + Y

W transverse momentum



- Strongest observable found for anomalous couplings.
- Full spectrum fitted for the AC hypothesis and used for setting the limits.

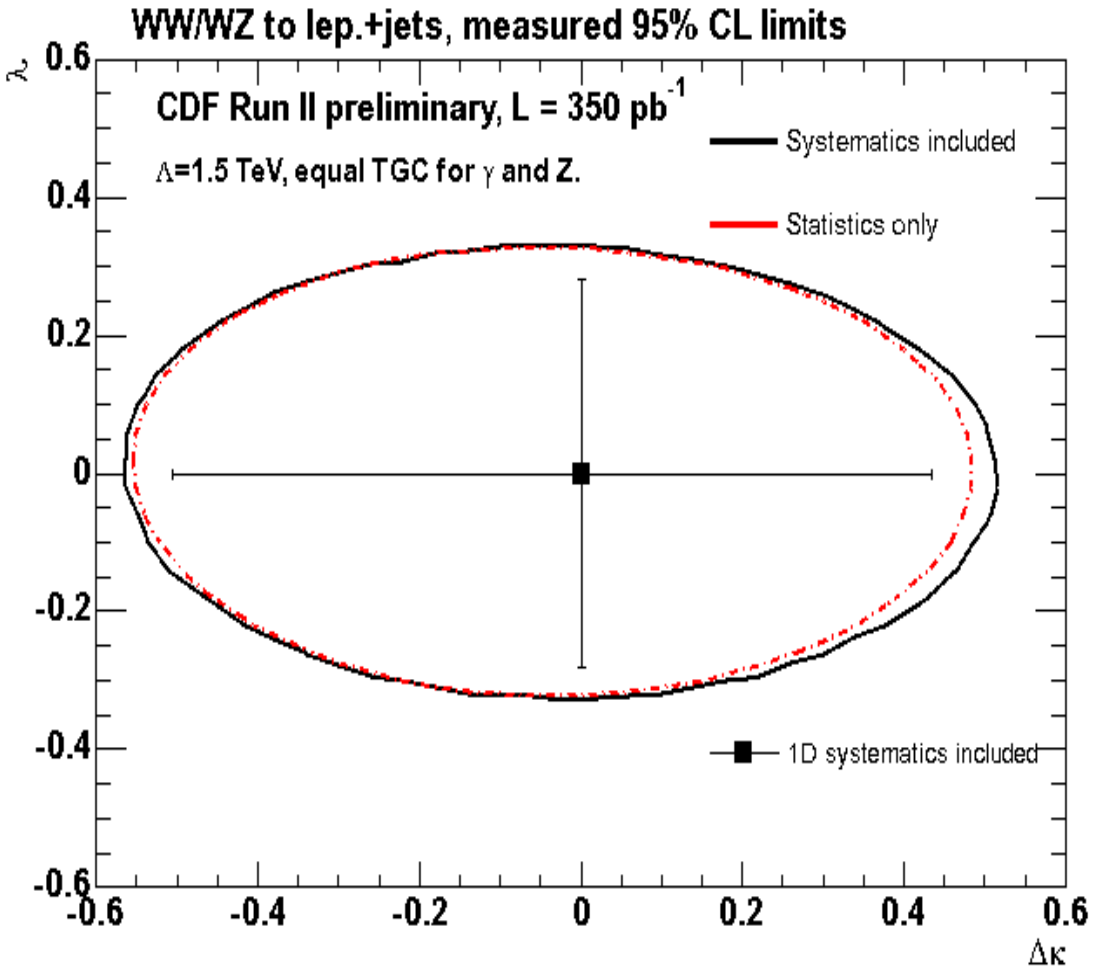
WW/WZ → lνjj ATGC limits

Measured 1D 95% C.L. limits:

$(\Delta\kappa,\lambda)$=([-0.51,0.44],[0.28,0.28])

Previous from Tevatron Run I:

$(\Delta\kappa,\lambda)$=([-0.56,0.75],[0.42,0.44])



W magnetic dipole moment: $\mu_W=(e/2M_W)(2+\Delta\kappa+\lambda)$,

W electric quadrupole moment: $Q_W=-(e/M^2_W)(1+\Delta\kappa-\lambda)$

Summary

From the Tevatron (CDF) we have new limits on:

- WW+WZ to lepton, MET + jets. With a SM expectation of 16 pb the limit on the total cross-section is set to < 36 pb (95% C.L.).

- WZ to leptons. With a SM expectation of 3.65 pb the limit on the total cross-section is set to < 6.34 pb (95% C.L.).

- 1D (95% C.L.) limits on the anomalous triple gauge couplings (lvjj), assuming Lambda=1.5 TeV and equal Z and gamma couplings are set to

$$(\Delta\kappa,\lambda)=([-0.51,0.44],[-0.28,0.28])$$

- Expect likely observation of WZ in the next round of data. In the one after that possibly the same for WW to lepton, MET + jets.