Observation of $WW/WZ \to l\nu$ +jets at CDF

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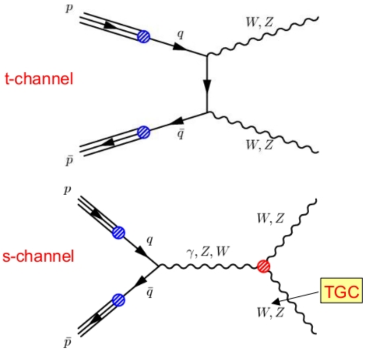
Physics Motivation

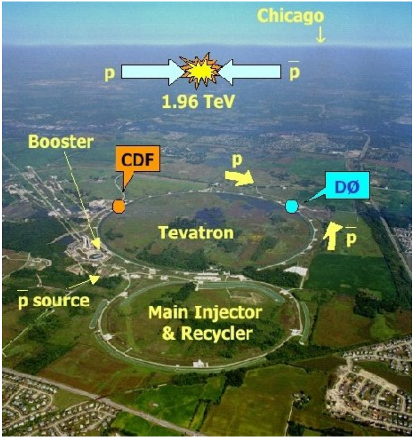


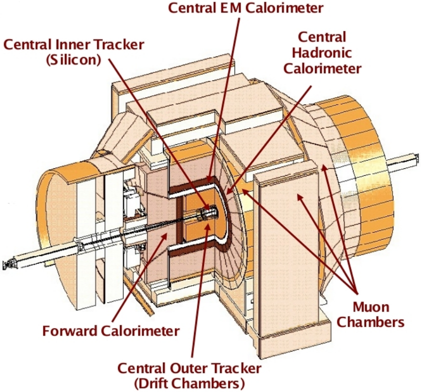
- Why search for Diboson:
  1. Tests the Standard Model predictions
  2. Can be enhanced by new physics (Higgs, SUSY,...)
  3. Has similar topology to SM Higgs production
- Observation and cross section measurement in leptonic modes
  1. $WW \to l\nu l\nu$, $WZ \to l\nu ll$
  2. Consistent with SM so far
- Semi-leptonic modes suffer from large background

Signal: $\sigma(p\bar{p} \to WW/WZ) = 15.9 \pm 0.9$ pb
Background: $\sigma(p\bar{p} \to W + \text{jets}) = 2066$ pb
$\sigma(p\bar{p} \to Z + \text{jets}) = 187$ pb

CDF detector

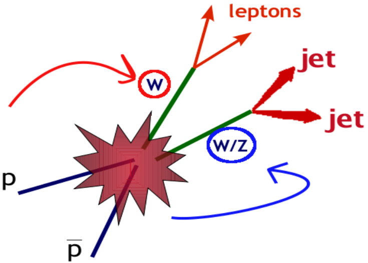
- Proton-antiproton collision at $\sqrt{s} = 1.96$ TeV
- 36 bunches: crossing time = 396 ns
- Peak luminosity $3.76 \cdot 10^{32}$ cm^{-2} s^{-1}





- Data taking efficiency $\sim 85\%$
- About 7 fb^{-1} on tape

Strategy of WW/WZ → lν +jets I



Leptonic W candidate:

- One tight lepton (electron or muon) with $E_T > 20$ GeV.
  1. CEM: electromagnetic calorimeter that cover $|\eta| < 1$
  2. CMUP: muon chambers that cover $|\eta| < 0.6$
  3. CMX: muon chambers that cover $0.6 < |\eta| < 1$
- $\not{E}_T > 25$ GeV
- $M_T(W) > 30$ GeV/c^2 to get rid of large part of the QCD background

Hadronic W/Z candidate:

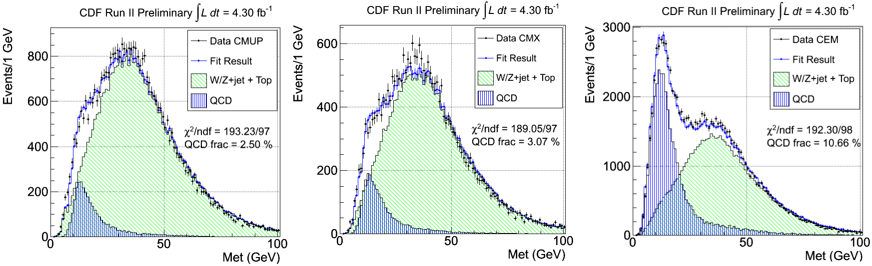
- At least 2 jets (cone based algorithm) with:
  1. $E_T > 20 GeV$ corrected for detector effects.
  2. $|\eta| < 2.4$
  3. $\Delta\eta_{j1,j2} < 2.5$

Strategy of $WW/WZ \to l\nu$ +jets II

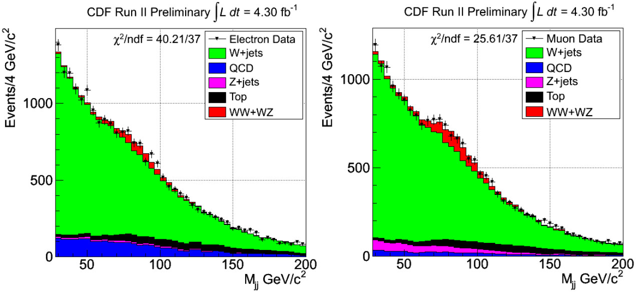
- Use the invariant mass of the two leading jets to search for a di-jet resonance in 4.3 fb^{-1} of data.
- Cannot separate W from Z because of detector smearing
  - WW is dominant (WZ has lower cross section, branching ratio)
- Backgrounds:
  1. $W \to l\nu$ + jets $(l = e, \mu, \tau)$: shape taken from Alpgen MC.
  2. $Z \to ll$ + jets $(l = e, \mu, \tau)$: shape taken from Alpgen MC.
  3. $t\bar{t}$ + single top: shape taken from Pythia MC.
  4. QCD Multijet : shape taken from data.

QCD normalization

- We extract the non W background from data fitting the $\not\!\!E_T$ distribution.
- For the non-W template
  1. In CEM the $\not\!\!E_T$ distribution of isolated "antielectrons" are used.
     - Estimated using the same trigger as central electron and looking for variables that reject fake electrons but do not greatly affect the kinematic properties of the event.
  2. For CMUP and CMX we use $\not\!\!E_T$ of non-isolated muons.
- Then knowing the theoretical cross section of the other processes we obtain the W+jets normalization.



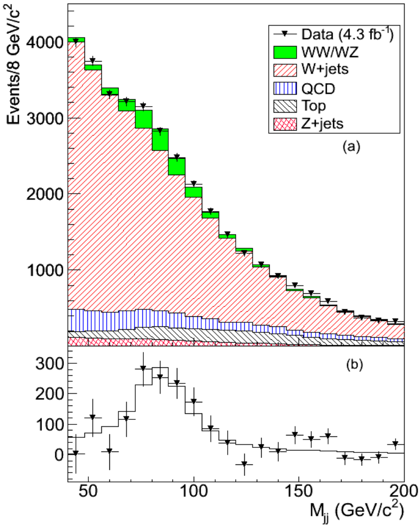
M_{jj} distribution



- Binned fit to the mjj shape taking as templates the histograms:
  1. W+jet $\longrightarrow$ completely free in the fit
  2. SIGNAL (WW and WZ)
  3. QCD $\longrightarrow$ gaussian constraint to the value found in the $\not{E}_T$ fit with 25% width.
  4. Top+single top : constrained to the measured cross section
  5. Z+jet: constrained to the measured cross section
- Fit to the whole shape with $M_{jj} > 28 \mathrm{GeV/c^2}$
- Fit electrons and muons separately

Systematic summary

- Consider two classes of systematics:
  1. systematics affecting signal extraction
  2. systematics affecting signal cross-section
- Dominant Systematic for signal extraction:
  1. Shape of W+jets: evaluated changing the Q^2 of the MonteCarlo generator (6%).
  2. Jet energy scale: evaluated varying the Jet energy scale up and down of 1 σ (6%).
  3. QCD Shape: (4%).
- Dominant Systematic for signal cross-section:
  1. Luminosity 6%
  2. ISR/FSR 2%

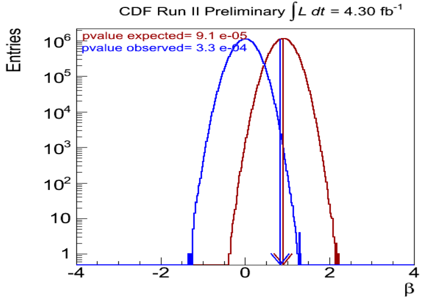


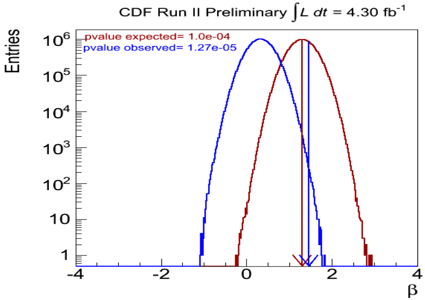
- In a data sample corresponding to 4.3 fb^{-1} we estimate: 1582 $\pm$ 275 (stat.) $\pm$ 107 (syst) $WW/WZ \to l\nu jj$ events
- Finally, we measure:

$$\sigma_{WW/WZ} = 18.1 \pm 3.3(stat.) \pm 2.5(syst.)$$

- Compatible with SM cross section (15.9 $\pm$ 0.9 pb)

Significance estimation





- Generate one toy for each combination of the N_{syst} i.e. in each sample some of the systematic are varied.
- For each sample evaluate how many times the toy results exceeds the value observed in data and choose the worst
- The combined p-value is $8.56 * e^{-08}$
- 5.24 σ found where 5.09σ was expected

Conclusion

- Measured the cross section of WW/WZ $\rightarrow l\nu$ +jets
  - Opens the way to diboson studies with jets
- PRL published on march 2010: Phys. Rev. Lett. 104, 101801 (2010)
- By the end of 2011 more than double the statistic!
- Future:
  1. Focus on trilinear gauge couplings
  2. Next step on the way to Higgs: $WZ \rightarrow l\nu+$ bjets ($\sigma = 0.12\text{pb}$)

Backup slides

QCD

- QCD multijet event have high cross section so even if the configurations are kinematically unlikely configurations can form a significant background: three jet event in which one of the jet manages to pass all lepton cuts and simultaneously, the energies are so badly measured that it give a large missing Et.
- One way to estimate :Met vs Iso based on the assumption that the electron isolation shoul be uncorrelated with the missing E_T in the event. Not true so it doesn't work!
- Estimated using the same trigger as central electron and looking for variables that reject fake electrons but do not greatly affect the kinematic properties of the event.
- Five "non-kinematic" cuts: $E_{had}/E_{em}, \chi^2_{strip}$. $Lshr, Q \cdot \Delta x$, and $|\Delta Z|$.

Systematic

- Consider two classes of systematics:
  1. systematics affecting signal extraction
  2. systematics affecting signal cross-section
- Estimate the systematics on the signal extraction by generating pseudo-experiment using an alternative template model for each systematic source. The pseudo-experiments are then fitted using the templates used in the main fit on data.
- The difference between the central value of the fit on data and the mean of the estimator of the signal content on the alternative pseudo-experiment is taken as systematics on the corresponding source.

Systematic summary

	Source	e %	μ %
Signal Extraction	QCD shape	4.5%	3.9 %
	Q2 up (EWK shape)	+6.2%	+6.1%
	Q2 down (EWK shape)	-6.2%	-6.1%
	JES up	+6.3%	+5.1%
	JES down	-6.3%	-5.1%
	JER	2.9%	1.4 %
TOTAL		10.3 %	9.0 %
Cross section	Luminosity	6%	6%
	Lepton Acceptance	2%	2%
	ISR more	1.8%	1.4%
	ISR less	-1.8%	-1.4%
	FSR more	0.7%	2.6%
	FSR less	-0.7%	-2.6%
	PDF	2.0%	2.0 %
TOTAL		12.4 %	11.6%