Latest Electroweak Results from CDF

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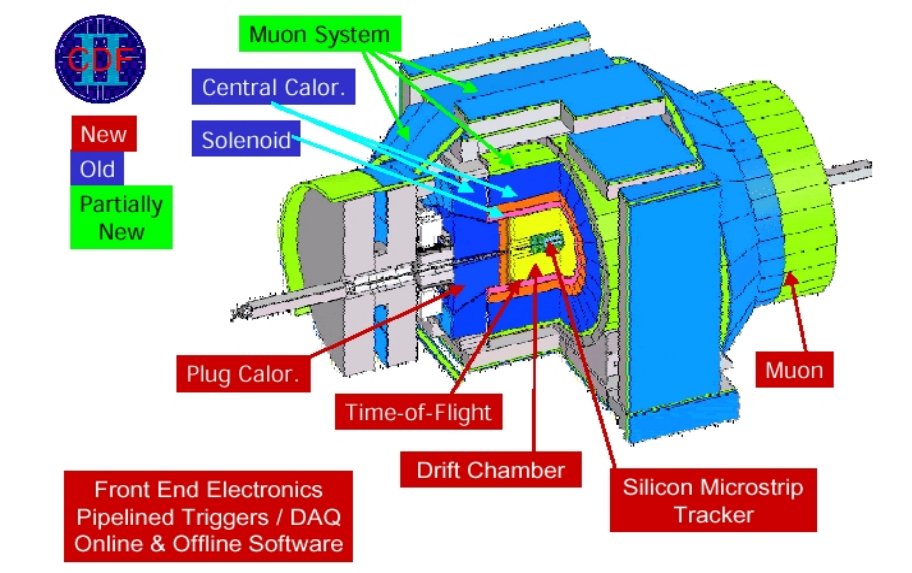
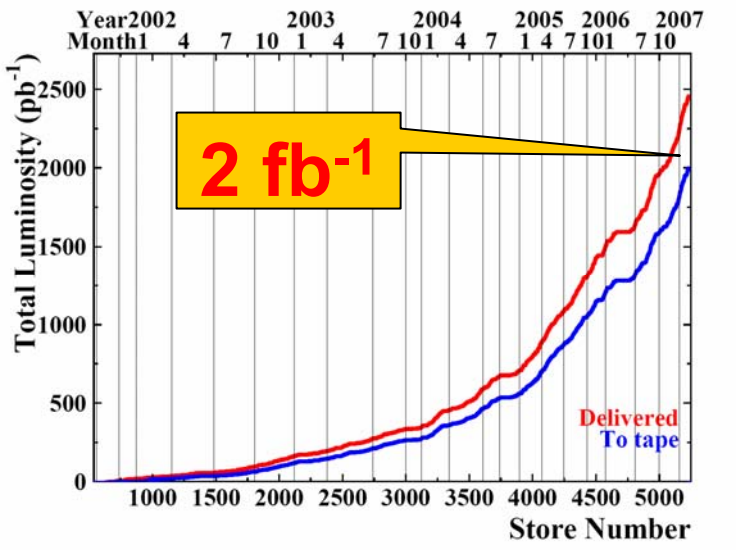
Detector and Performance



- Pp-bar collisions
- E(cm)=1.96 TeV

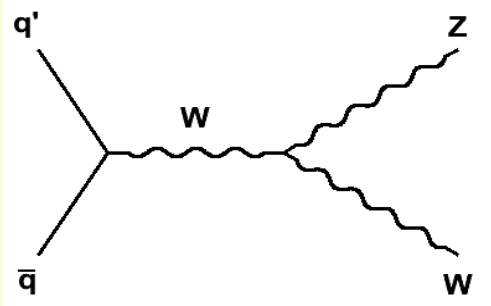
- Just hit 2 fb^{-1} "to tape"
- Steady data taking



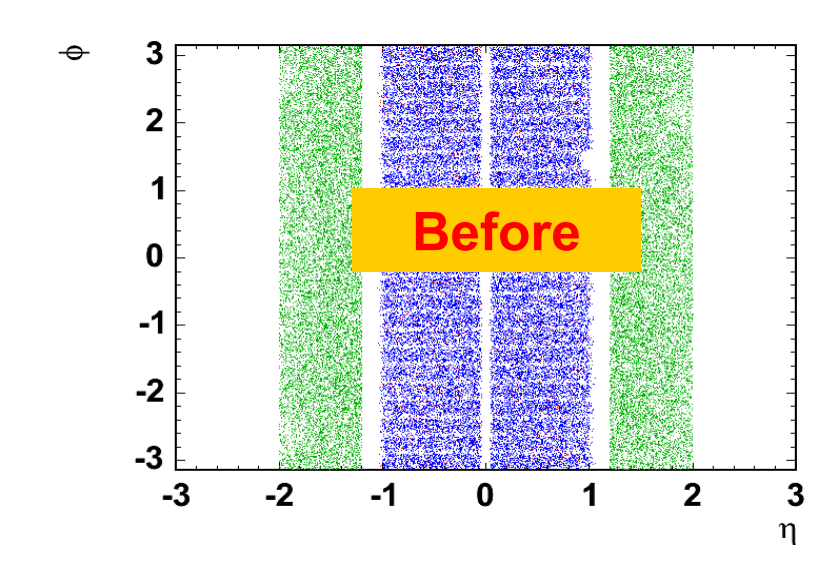
Electroweak Physics at CDF

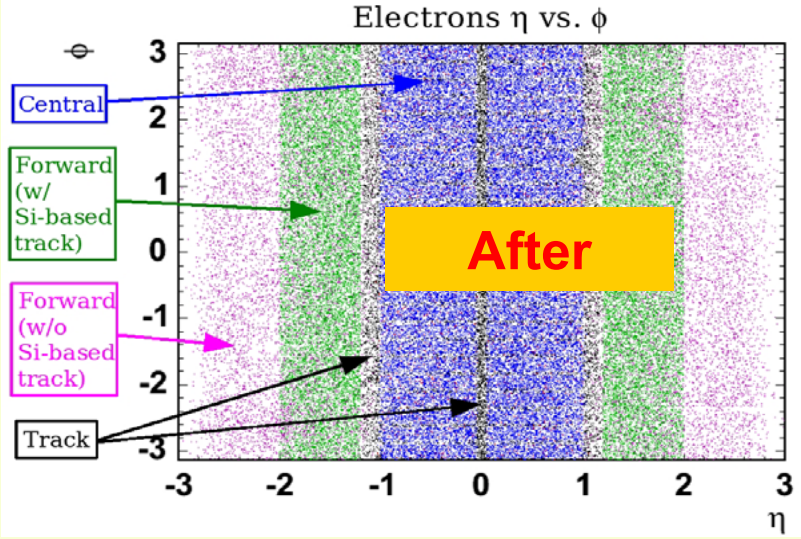
- **Main thrusts of the CDF electroweak program:**
  - W mass
    - Important connection to higgs– see talk later this evening!
  - Diboson production
    - √ WZ observation
    - √ $Z\gamma$ and $W\gamma$ cross-sections
    - Probes trilinear coupling
  - W and Z cross-section measurements
    - Early measurements in electron and muon channels
    - √ Recent addition: $Z \rightarrow \tau\tau$
  - W/Z asymmetry:
    - Constrain PDF functions

WZ Production



- Sensitive to trilinear coupling
  - Direct verification of the SM gauge structure
- New analysis (1.1 fb^{-1}): x2.5 larger acceptance:
  - New lepton categories provide additional gains in partly instrumented regions
  - Similar improvement in muon channel (not shown)

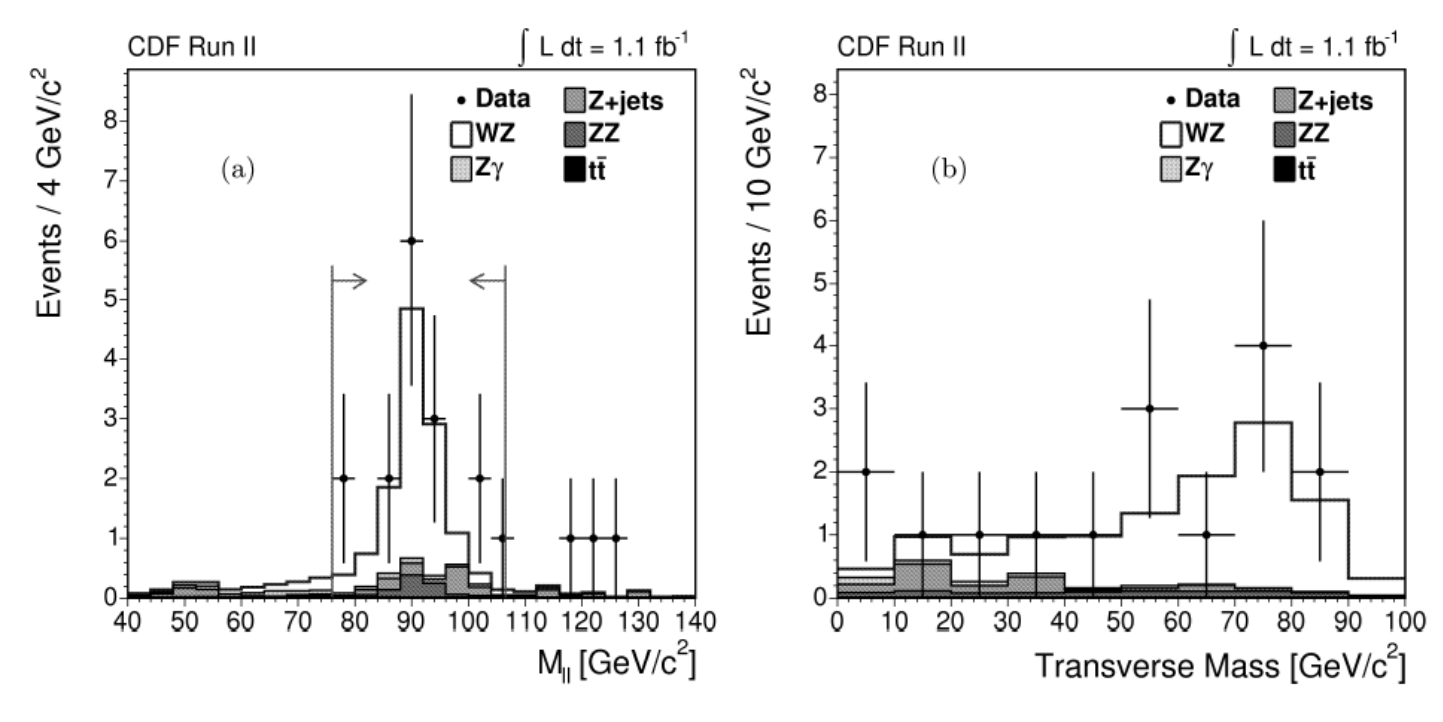




WZ: Candidate Events

- **Kinematics of selected events consistent with the WZ hypothesis**

Source	Expectation ± Stat ± Syst ± Lumi
Z+jets	1.22 ± 0.27 ± 0.28 ± -
ZZ	0.89 ± 0.01 ± 0.09 ± 0.05
$Z\gamma$	0.48 ± 0.06 ± 0.15 ± 0.03
$t\bar{t}$	0.12 ± 0.01 ± 0.01 ± 0.01
WZ	9.79 ± 0.03 ± 0.31 ± 0.59
Total Background	2.70 ± 0.28 ± 0.33 ± 0.09
Total Expected	12.50 ± 0.28 ± 0.46 ± 0.68
Observed	**16**

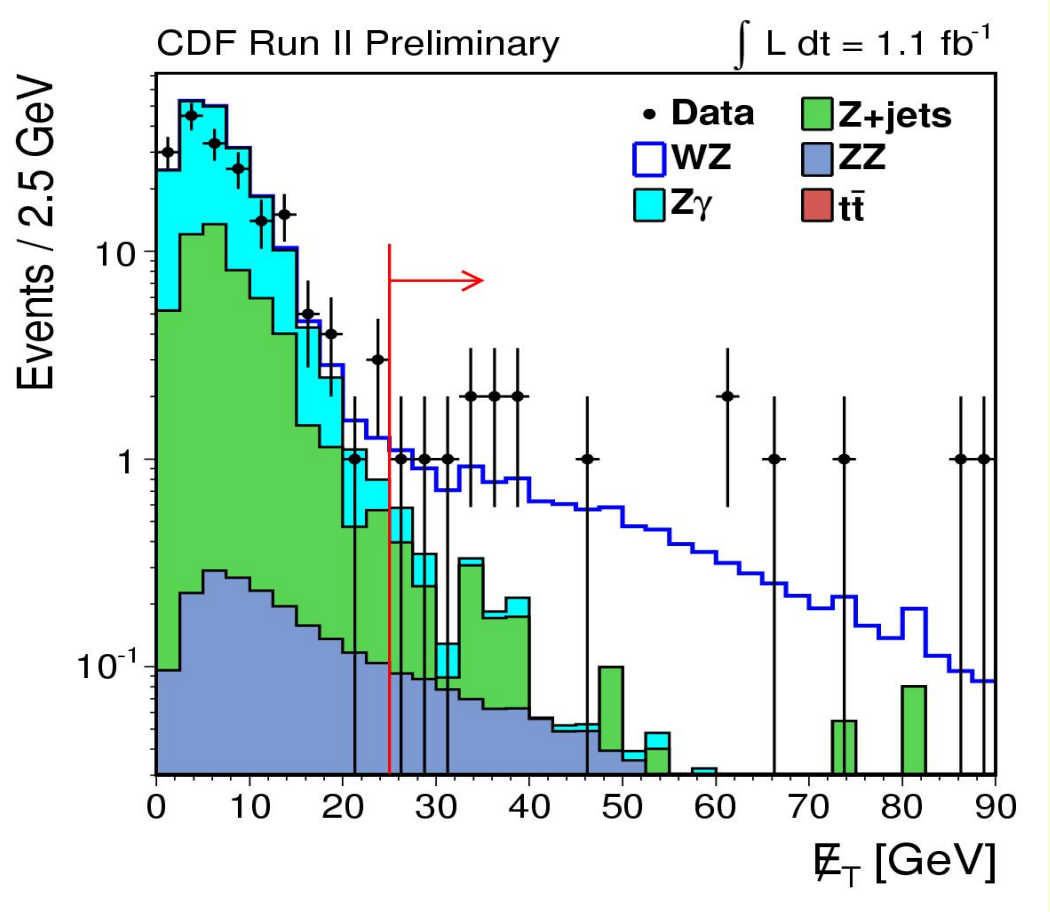


WZ Production

- Significance of the excess: about 6σ using a 2-bin fit in MET
- First observation of WZ production
- Measured cross-section:

$$\sigma(WZ) = 5.0^{+1.8}_{-1.6} \quad pb$$

- SM: 3.7±0.3 pb

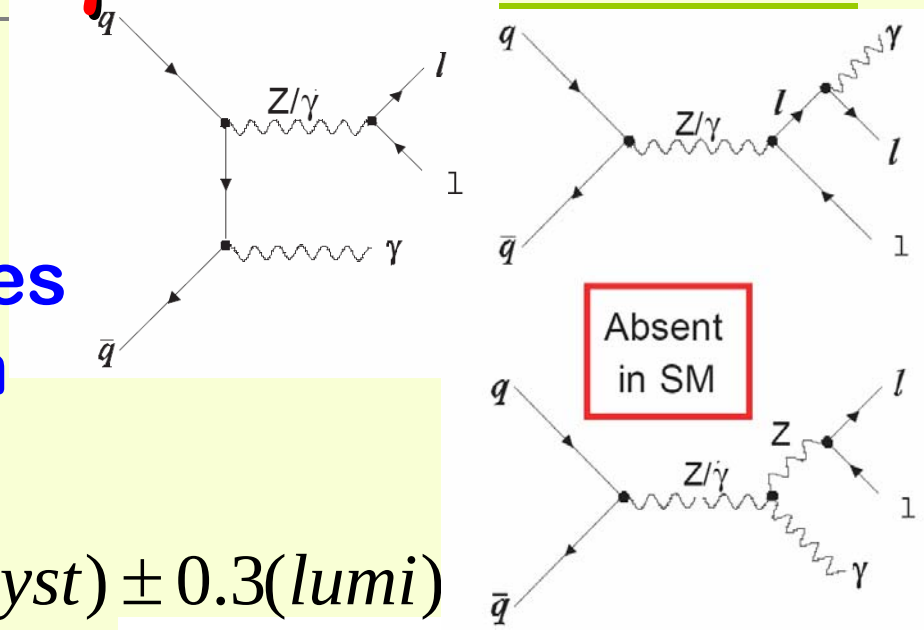


Measurement of Zγ Cross-Section

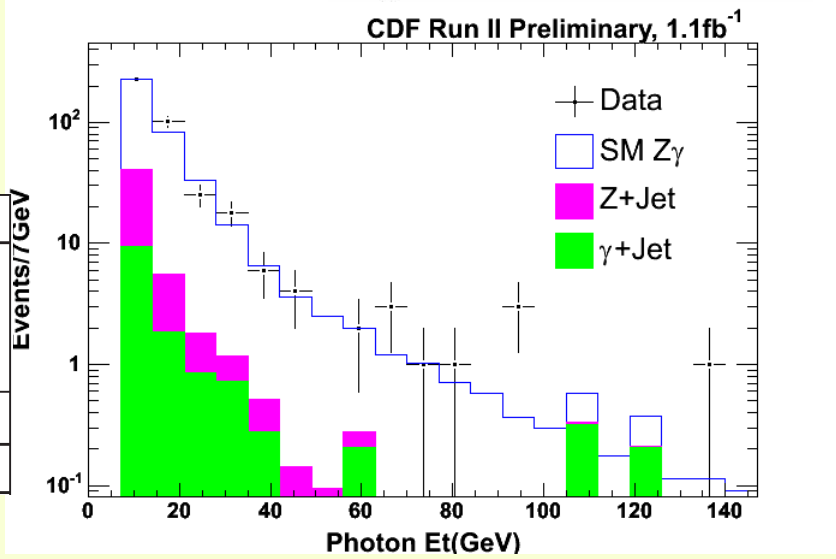
- **Not only full x-section, but also can play with M(ll) and M(llγ): enhances one or another diagram**
- **Result:**

$$\sigma(Z\gamma) = 4.9 \pm 0.3(stat) \pm 0.3(syst) \pm 0.3(lumi)$$

- **Theory: 4.7±0.4**

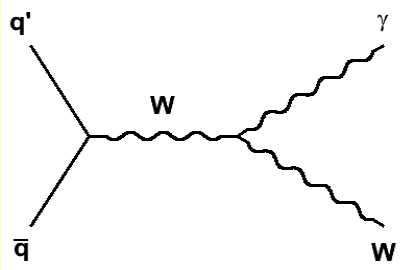


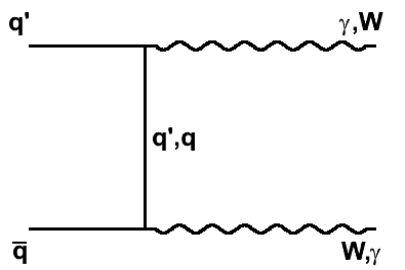
Zee type	CC	CP	CC + CP
$N^{bkg}_{\gamma+Jet}$	1.8 ± 1.2	12.1 ± 5.4	13.9 ± 6.5
N^{bkg}_{Z+Jet}	11.5 ± 4.3	25.6 ± 9.9	37.1 ± 14.3
N^{exp}_{SM}	142.6 ± 7.7	181.2 ± 10.0	323.8 ± 17.3
$N^{exp}_{SM} + N^{bkg}_{QCD}$	155.9 ± 8.9	218.9 ± 15.1	374.8 ± 23.4
N^{obs}	183	207	390



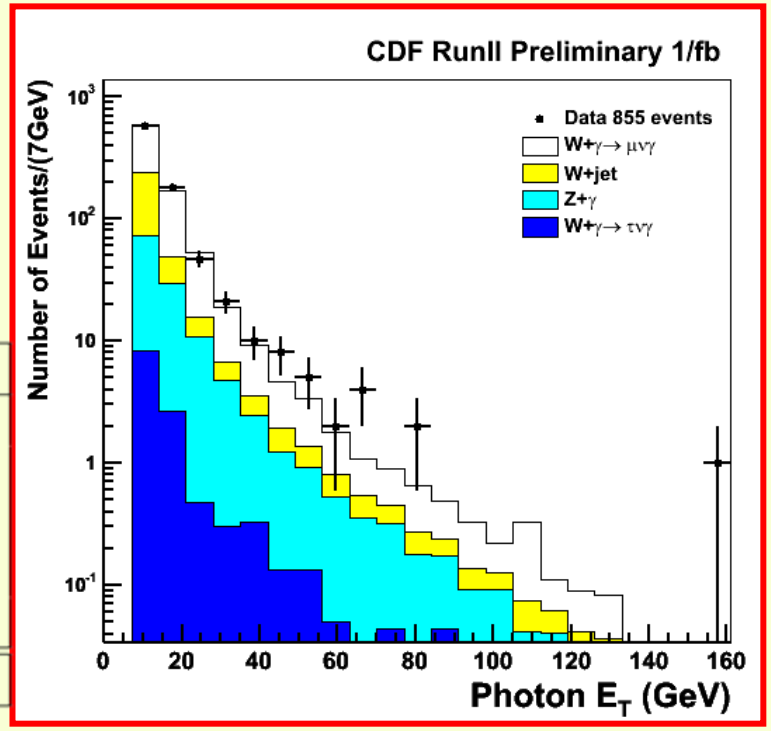
Measurement of Wγ Cross-Section

High-statistics sample allows precise cross section measurement





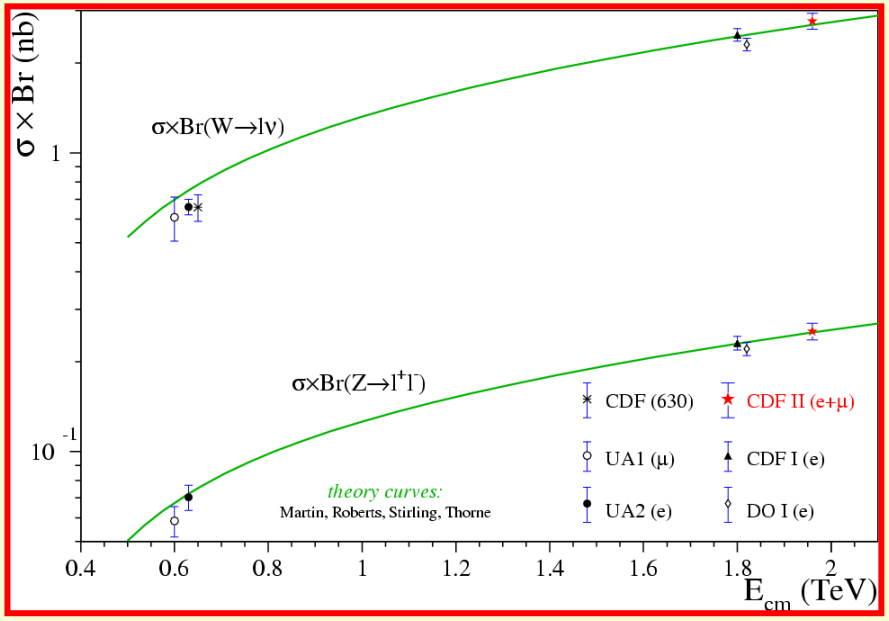
	Number of Events
$W\gamma$	541.7±4.02(stat.)±1.57(sys.)
W+jet	194.3±0.15(stat.)±66.91(sys.)
$Z\gamma$	112.0±0.39(stat.)±0.32(sys.)
$W\gamma(\tau)$	12.4±0.60(stat.)±0.04(sys.)
Number of Total	860.4±29.25(stat.)±66.95(sys.)
Number of Observed	855



- **CDF:** $\sigma(W\gamma) = 19.1 \pm 1.0(stat) \pm 2.4(syst) \pm 1.1(lumi)$
- **Theory: 19.3±1.4**

W/Z Production and Properties

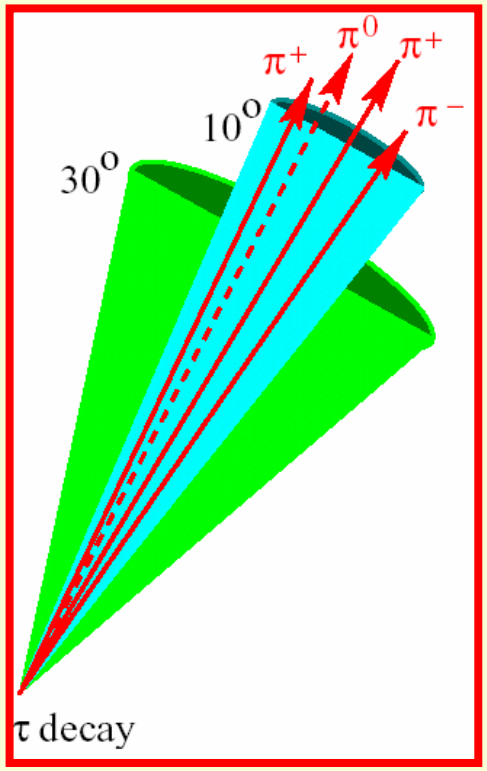
- Measurements of the Z and W cross sections in e and μ channels - one of the first CDF EW results in Run II
- Good agreement with SM



- Missing part – taus:
  - High jet fake rates lead to very high backgrounds
  - Low statistics makes it difficult to understand efficiencies
    - Lower acceptance as visible tau decay products are soft
  - Strong motivation from NP models (SUSY at high tanβ, higgs)

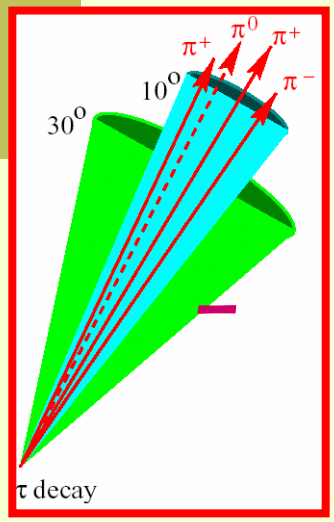
$Z \rightarrow \tau\tau$ Analysis

- **Tau decays:**
  - Leptonic modes $B(\tau \rightarrow e/\mu)=17\%$
  - Hadronic: $B(\tau \rightarrow \tau_h)= 64\%$
    - Mostly 1 or 3 charged particles plus neutrals
- **Di-tau Phenomenology:**
  - $\tau_h\tau_h$ – too high backgrounds
  - $ee, \mu\mu, e\mu$ – low branching, soft
  - $e\tau_h$, $\mu\tau_h$ – best option
- **Lepton+Tau Triggers:**
  - Electron or muon p_T>8 GeV
  - Track w/ p_T>5 GeV isolated in the tau style
    - No tracks p_T>1 GeV between cones 10-30 degrees



Tau Identification

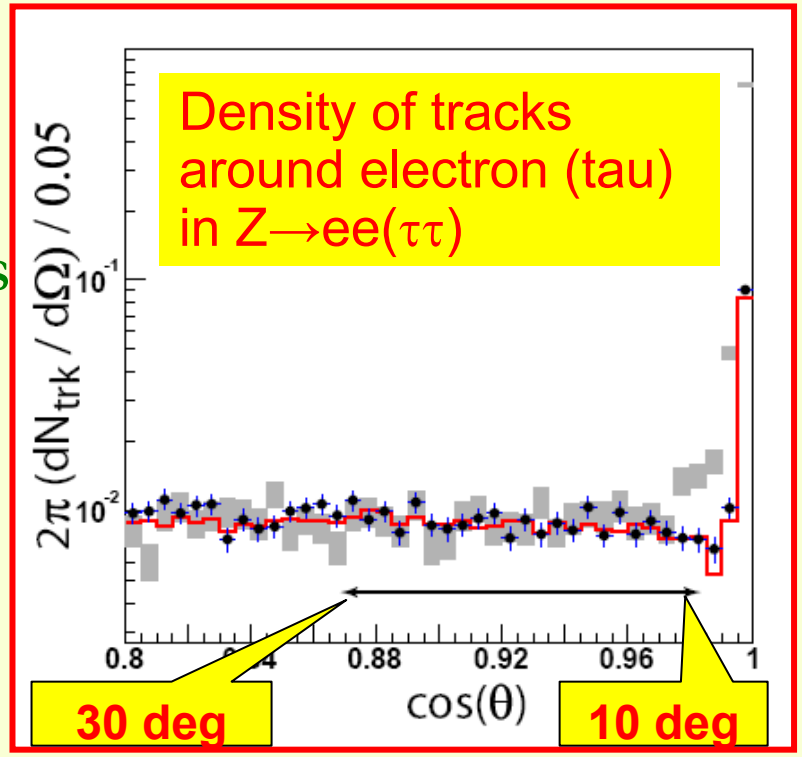
- **Isolation - dominant role in tau ID:**
  - Cannot study directly as no good source of taus of acceptable purity
  - Workaround:
    - Use Z→ee(μμ) events
    - Taus have similar isolation properties to those of e/μ as long as one does not look close to the lepton:



Taus in MC

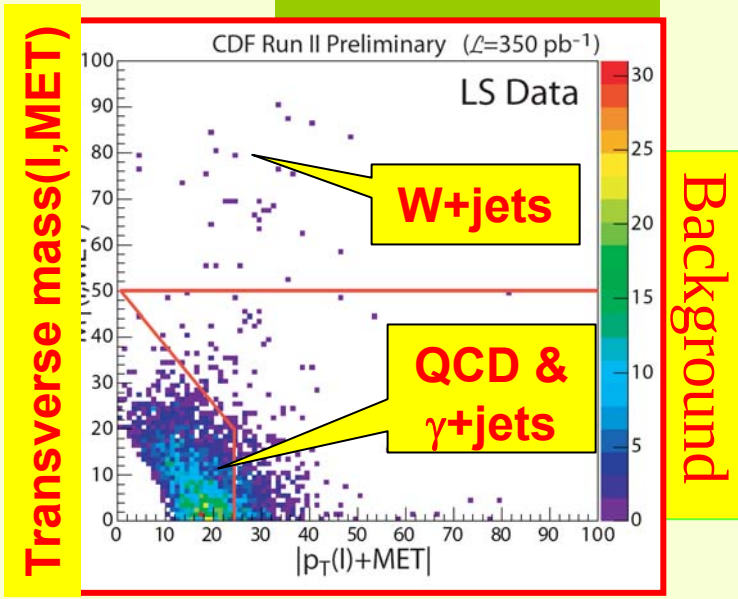
Electrons in data

Electrons in MC

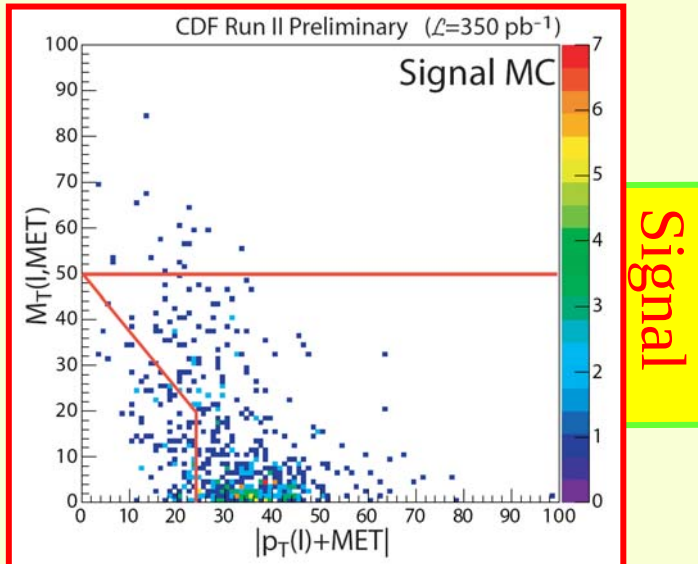


Event Selection

- **Electron+track trigger**
- **Selections:**
  - Central electron: $p_T(\ell)$>10 GeV
  - Had. tau candidate: $p_T(\tau)$>15 GeV
  - Apply electron and tau ID



- **Kinematical cuts:**
  - Z→ee and conversions removal
  - Optimized 2D cut (plot)
    - Suppresses multi-jet events and W+jets
  - This is SIGNAL region



Signal Extraction

- **Strategy:**
  - Define complementary regions enriched with main backgrounds:
    - QCD multi-jets: events with poorly isolated electron
    - W+jet: high $M_T(e,MET)$ events
    - γ+jet: Like Sign (LS) events with $Q(e)Q(\tau)=+1$
  - Measure shapes of each background (mostly from data)
  - Fit the number of events in each region to the sum of the background and signal shapes
  - Extract the number of events in the SIGNAL region
  - Multiply this number by acceptance to get x-section

$Q(e)Q(\tau)= -1$

IsoTrk (GeV)		
8	QCD 465	W+j 12
2		
1	Signal+…504	W+j 105
0		

0 50 $M_T(e,E_T)$

$Q(e)Q(\tau)= +1$

IsoTrk (GeV)		
8	QCD 386	W+j 2
2		
1	QCD/γ+j 150	W+j 33
0		

0 50 M_T(GeV)

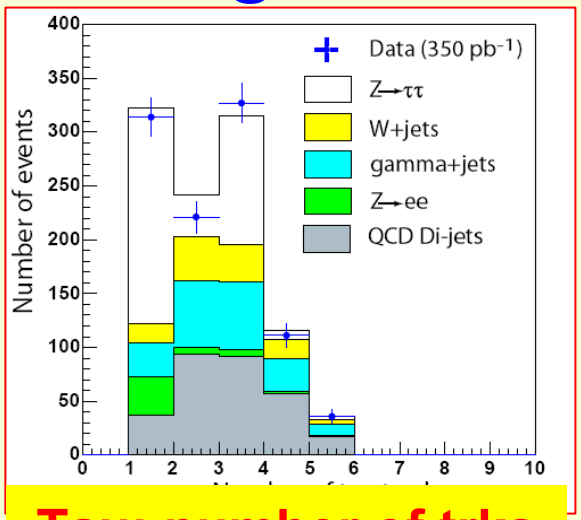
- **Result: ~316 events out of 504 in the SIGNAL region are $Z\rightarrow\tau\tau$ events**

Results and Outlook

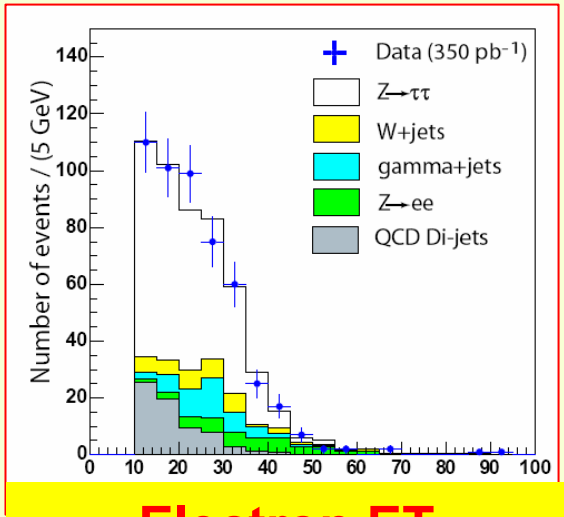
$\sigma(pp \to \gamma^*/Z \to \tau\tau)$=263±23stat±14syst±15lumi pb

- **Systematics is comparable to that in ee, μμ cases (2-3%)**
- **Note the level of background control**

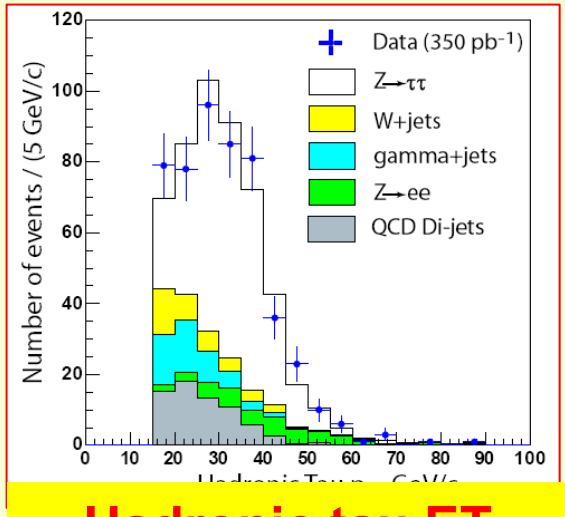
Systematic Uncertainty	[%]
Geometrical and kinematic acceptance (incl. PDFs)	2.7
Electron ID	1.9
Tau ID	3.0
Electron Trigger Efficiency	1.0
Tau Trigger Efficiency	1.0
Topology cuts	0.4
Background estimation	2.2
Total:	5.2



Tau: number of trks



Electron ET



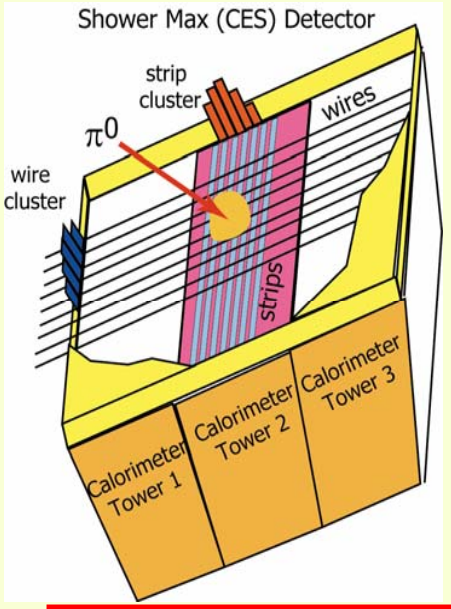
Hadronic tau ET

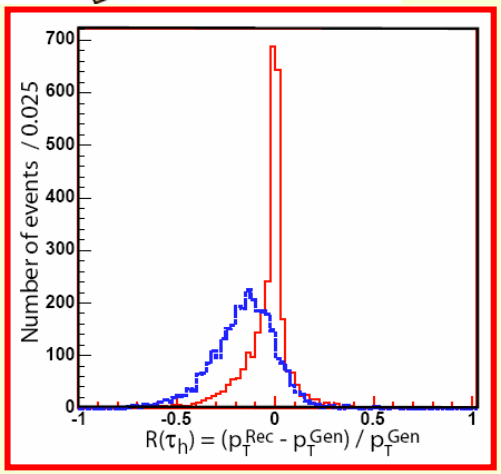
Conclusions

- CDF in a steady regime collecting data
- Just hit the 2 fb^{-1} "to tape" mark
- Healthy program of electroweak studies at CDF:
  - Recent 6σ observation of WZ production
    - A good example of utilizing more elaborate and optimized techniques by CDF
  - $W\gamma$ and $Z\gamma$: improved sensitivity with more data
  - Previously difficult areas such as taus come into play
  - Results on asymmetries provide important constraints to PDFs
- Existing results show agreement with the SM expectations
  - Still a lot of data to come...

Tau Reconstruction

- **Charged particles (+/- pions)** OK: have excellent tracking
- **Neutral pions are more tricky: two potential sources of information:**
  - Calorimeter (energy) clusters:
    - Segmentation ($\Delta\eta$=0.1) x ($\Delta\varphi$=15^0)
      - Typical tau size: α~5-10^0
    - Poor spatial resolution
    - √ Good EM energy resolution, hadronic - poor
  - Shower Position Detector (CES)
    - strip/wire chamber inside EM calorimeter
    - √ Spatial resolution ~few mm
    - Poor energy resolution





- **Be smart and use best of both worlds:**
  - Reconstruct π^0s position using CES
  - Assign energy from EM calorimeter