Fisica del W e Z al Tevatron

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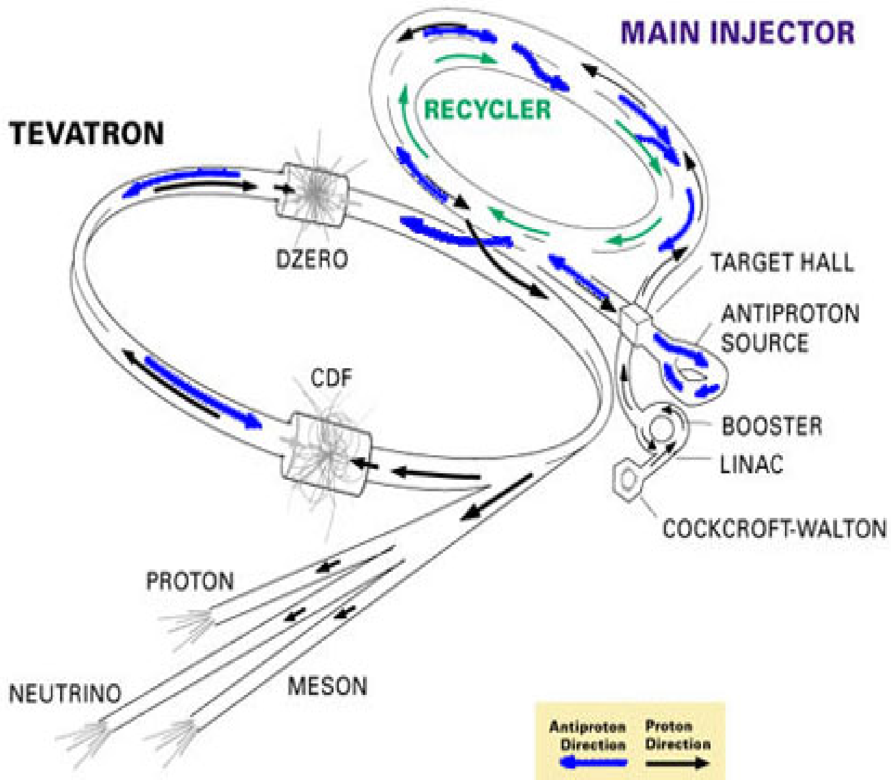
Outline:

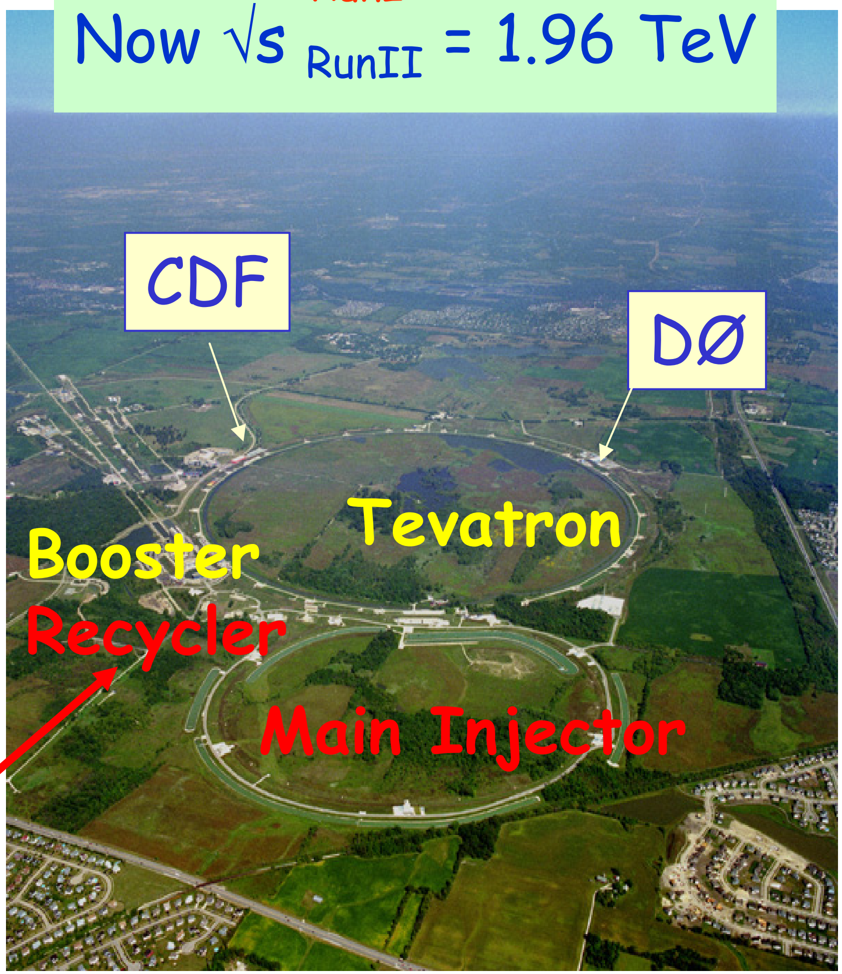
- Tevatron: CDF and DØ detectors
- Baseline Electroweak Measurements
- Electroweak precision measurements
- Towards W Mass measurements

Fermilab Tevatron Upgrade RunII



$\sqrt{s}_{RunI} = 1.8$ TeV

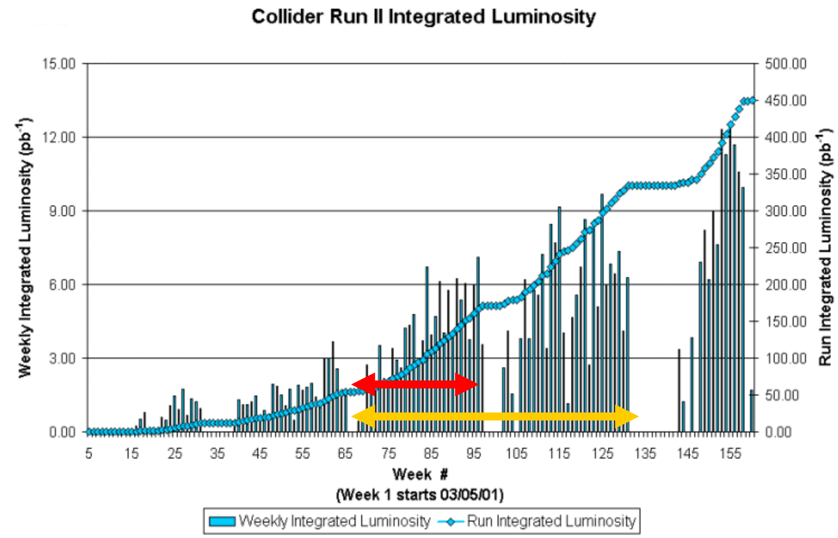
Now $\sqrt{s}_{RunII} = 1.96$ TeV



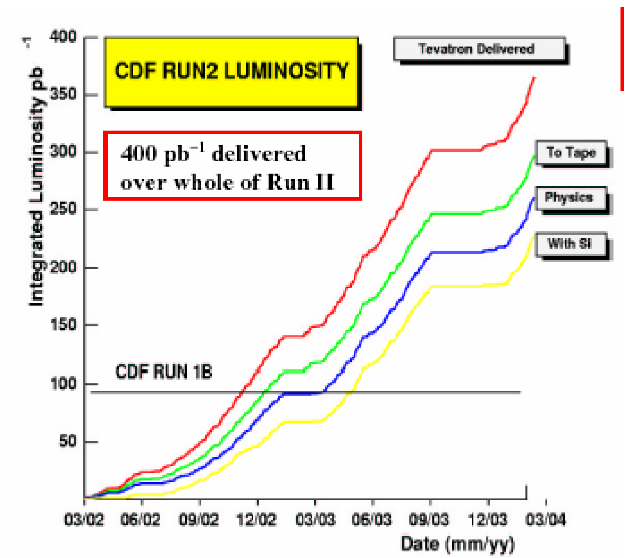
- New Main Injector:
  - Improve p-bar production
- Recycler ring:
  - accumulate p-bars
  - Commissioning

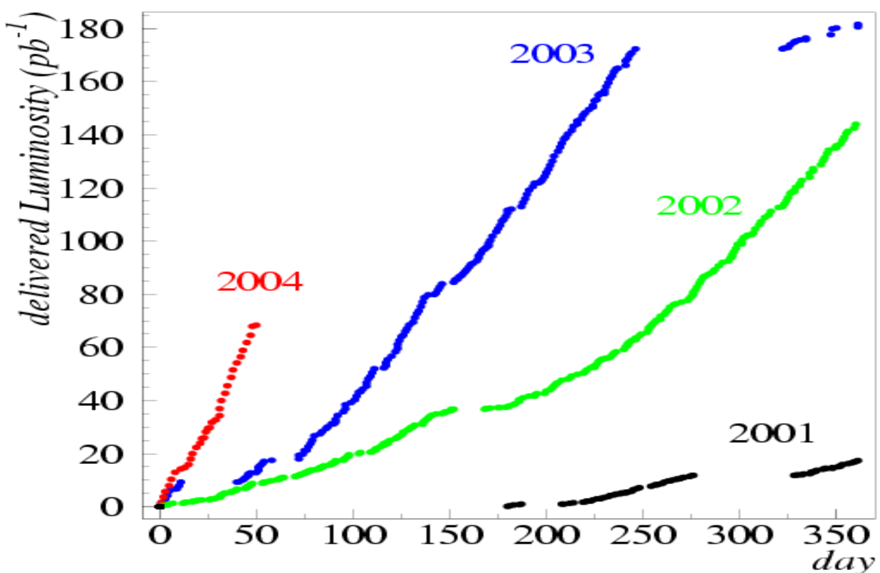
Tevatron: Luminosity

Integrated Luminosity is the key for Tevatron RunII success.
Analysis presented here are based on different integrated luminosity period



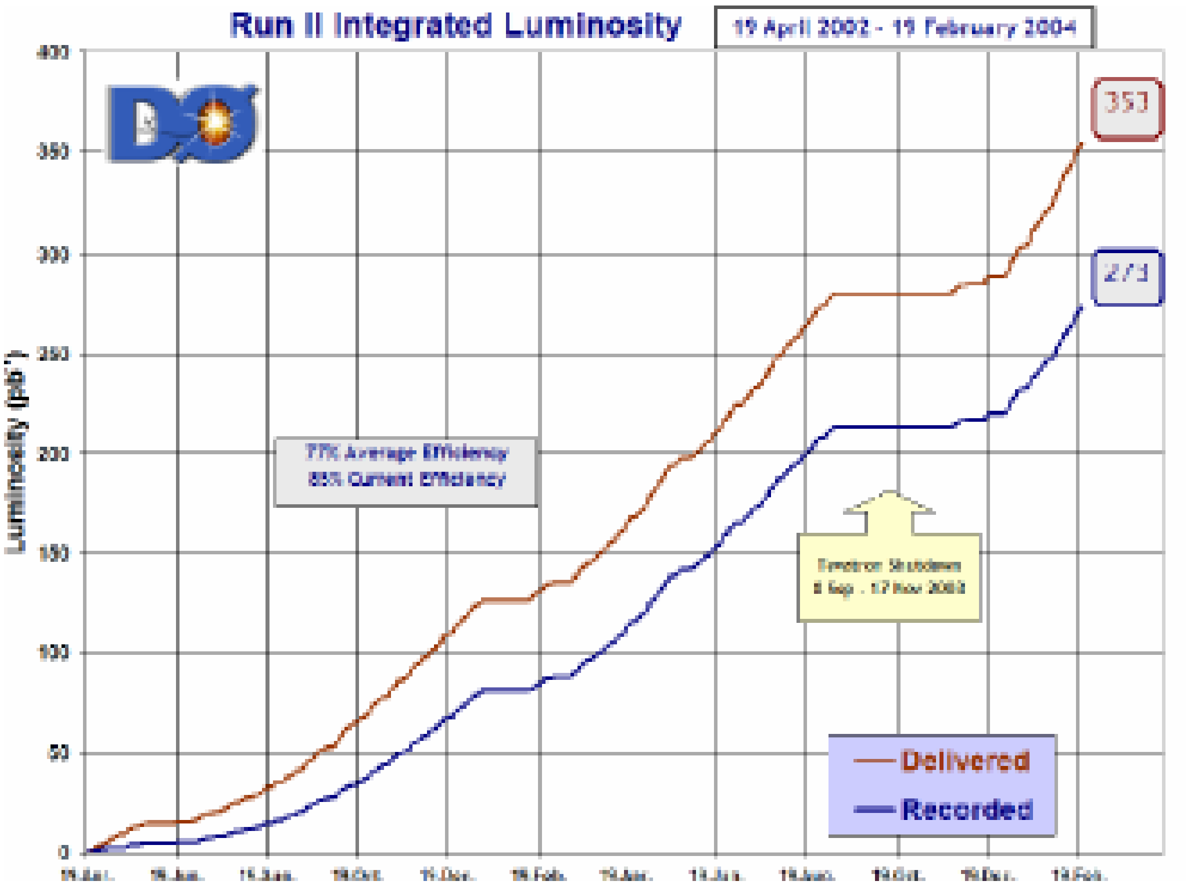
Record Peak Luminosity
(05/02/2004) 6.1×10^{31} cm^{-2} s^{-1}
CDF Takes data at >85%
Silicon integrated most of runs





CDF and DØ are collecting 1pb^{-1}/day

Tevatron: Luminosity

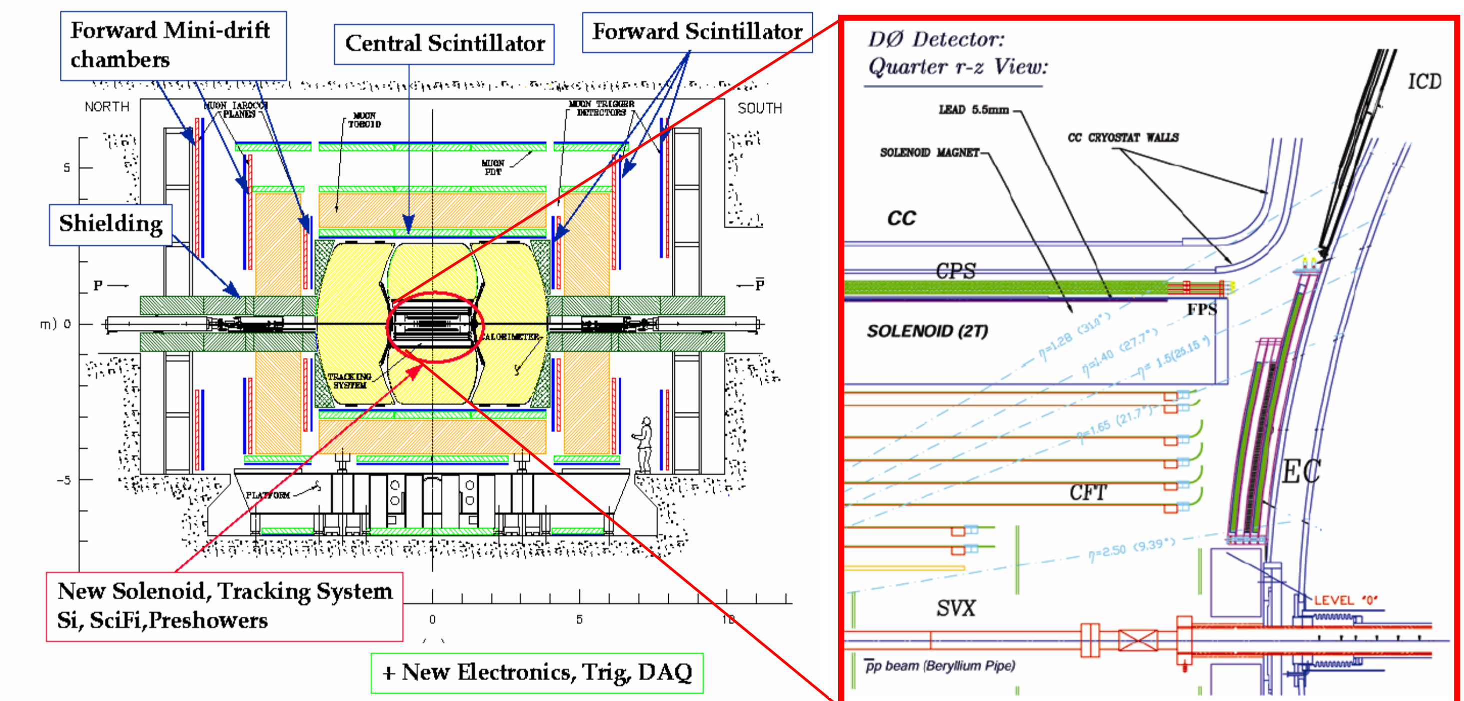


DØ RunII Detector

Many improvements from RunI:

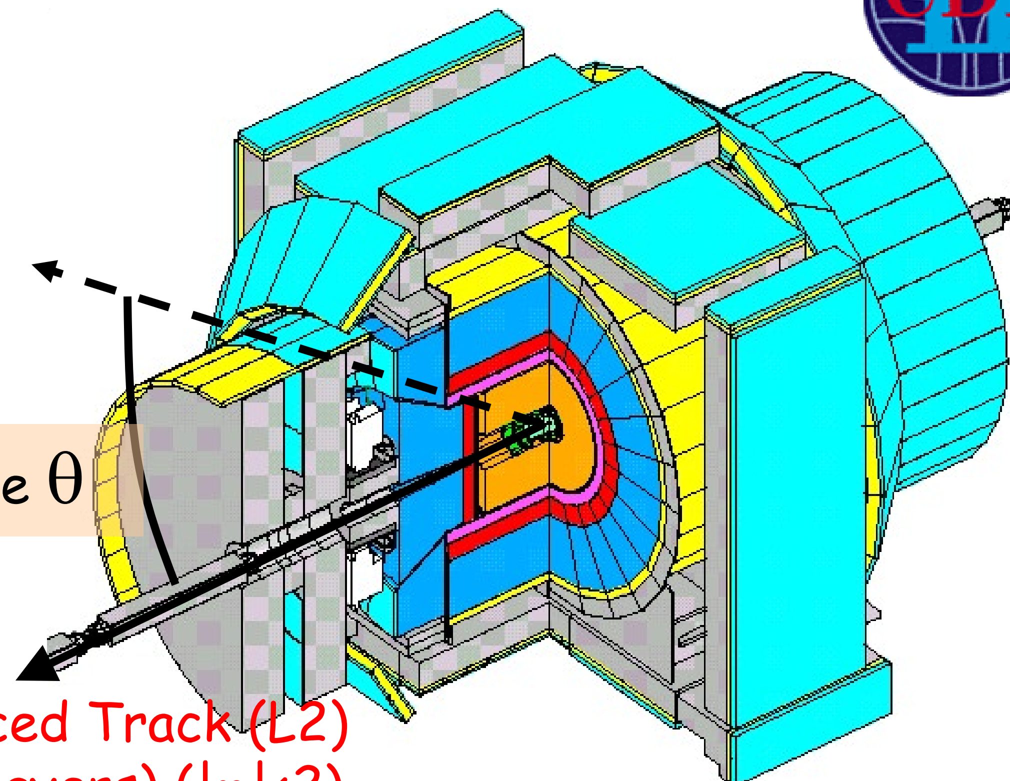
- Solenoid installed for RunII (2T 60cmx2.8m)
  - ->New Tracking system
- Trigger + Electronics and DAQ

Si Tracker: Layers&Disks
8 Layers Fiber Tracker
Preshower



CDF RunII Detector

From RunI:
- Solenoid
- Muon system
- Central Calorimeter



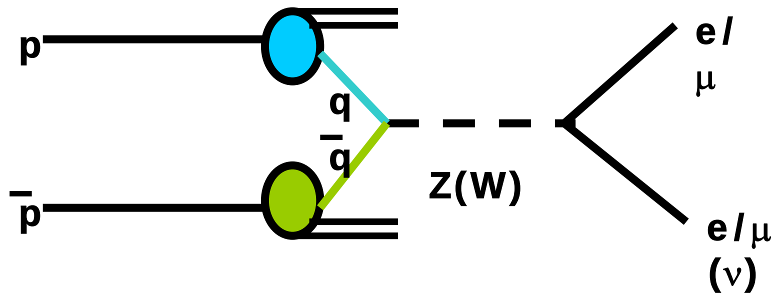
Polar angle θ

For RunII:
- Front-end DAQ
- Trigger
  - Track (L1) and Displaced Track (L2)
- New Silicon Tracker (8 Layers) ($|\eta|<2$)
- Central Outer Tracker
- TOF
- Plug Calorimeters
- Extended Muon Coverage → Lepton Id up to $|\eta|\sim 2$

$$\eta = -\log(\tanh(\theta/2))$$

Lepton ID

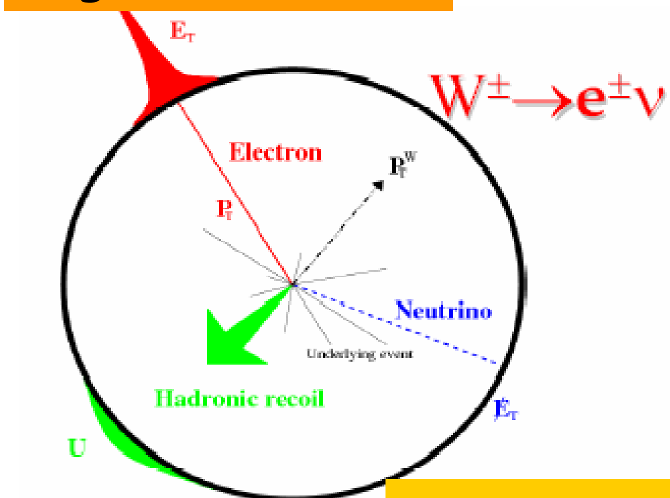
At hadronic collider W and Z bosons: decaying hadronically are overwhelmed by QCD background
-> identification trough leptonic decays

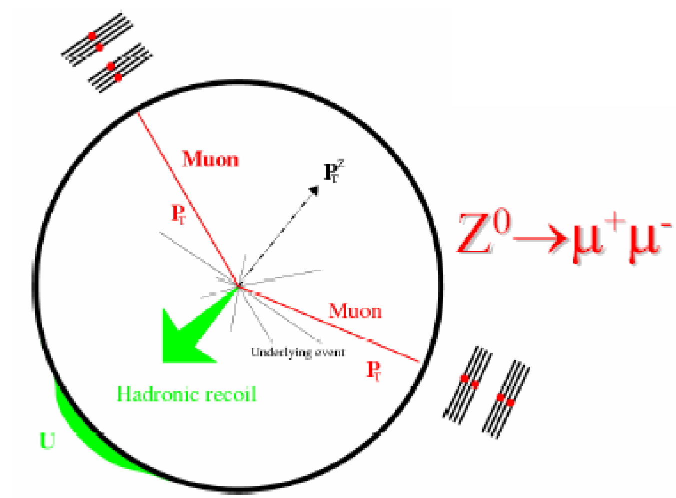


Electron:
EM Calorimeters
High Pt Track

Muons:
Muon Detectors
High P_T Track

Neutrinos:
Large Missing Energy
Only Transverse (Met)



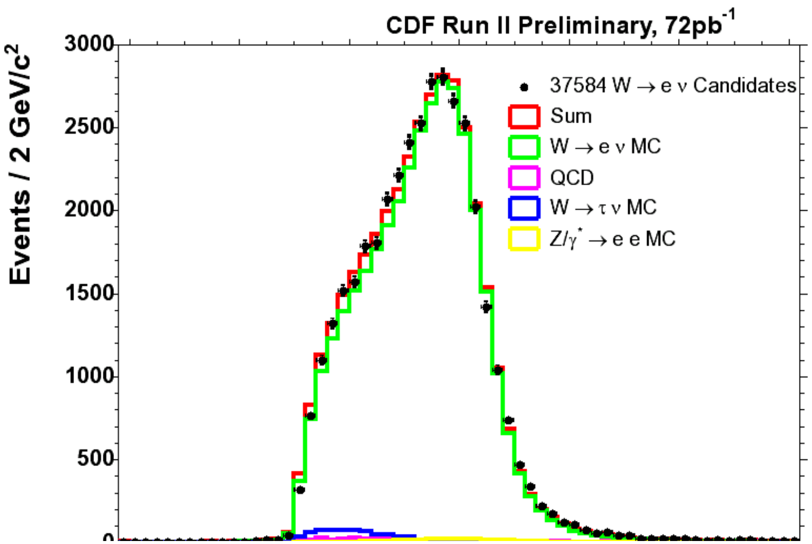


Z Signature: Two Isolated Leptons (opposite charge)

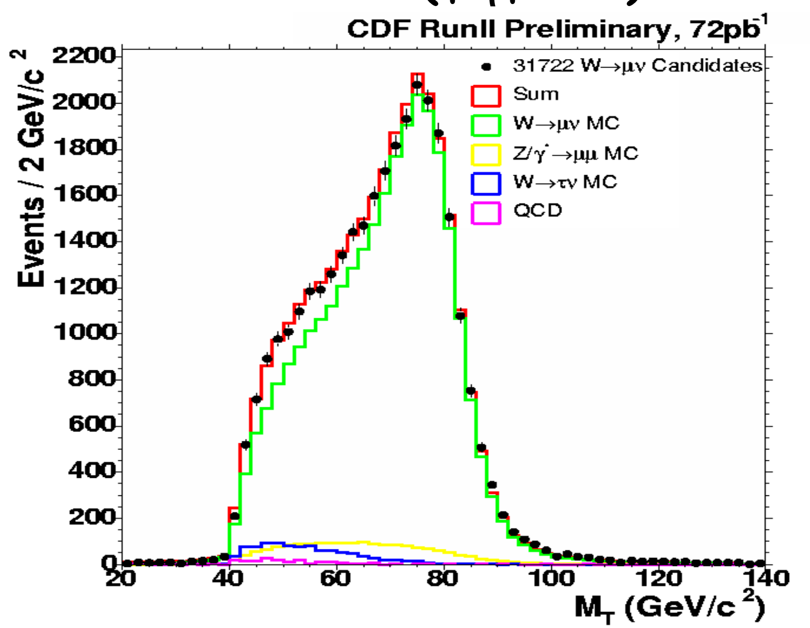
W Signature: Isolated Lepton and MET

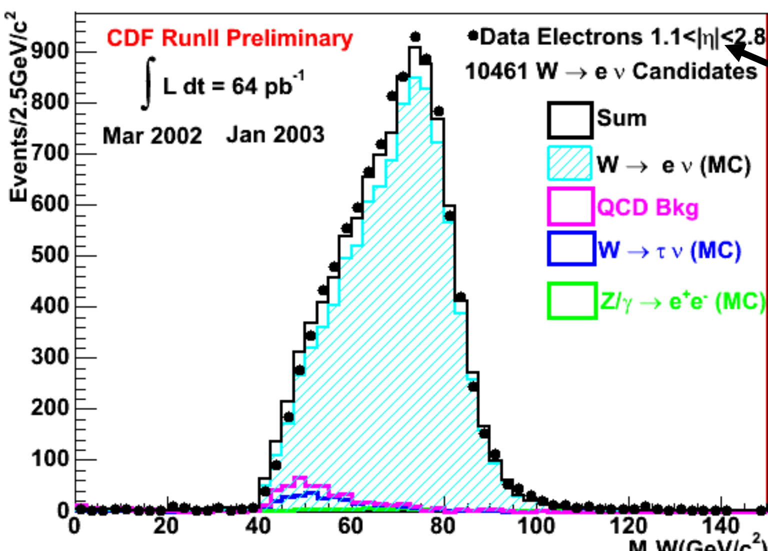
W Cross Sections

Central Electron channel (|η|<1.1)



Muon channel (|η|<1.0)





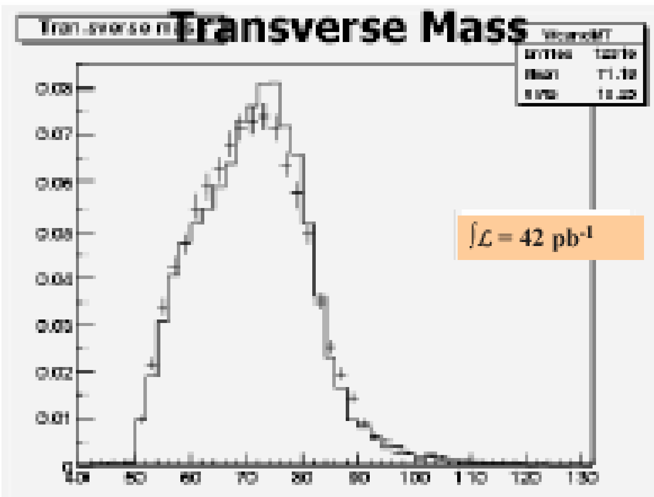
Extended pseudorapidity electron coverage+Forward Tracking $1.1<|\eta|_{Ele}<2.8$

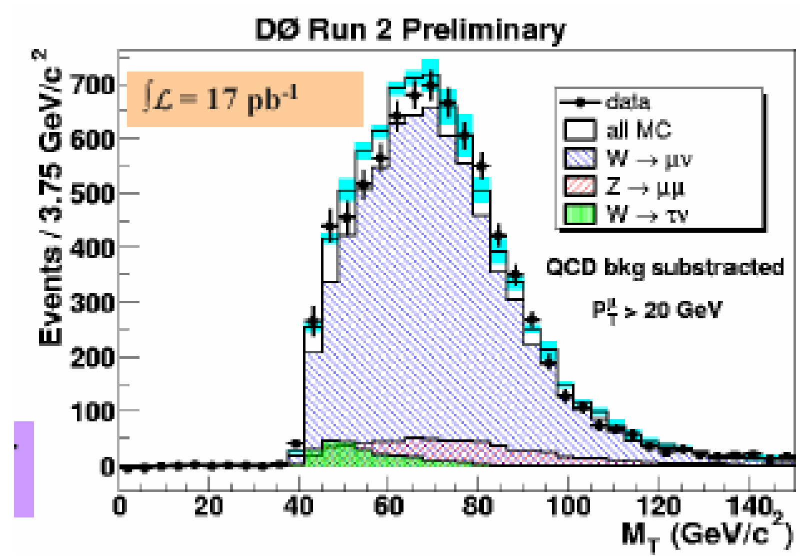
Small background contamination (QCD, $W\to\tau\nu$, $Z\to ee$) (~6% e, ~11 % μ)

Systematics from PDF, energy scales, material description

W Cross Sections

$W \rightarrow \mu\nu$
One isolated muon with Pt>20 GeV/c $|\eta|$<1.6
$\not{E}_T$>20 GeV
8305 Candidate
~12 % background contamination
(mainly $W \rightarrow \tau\nu$, $Z \rightarrow \mu\mu$)

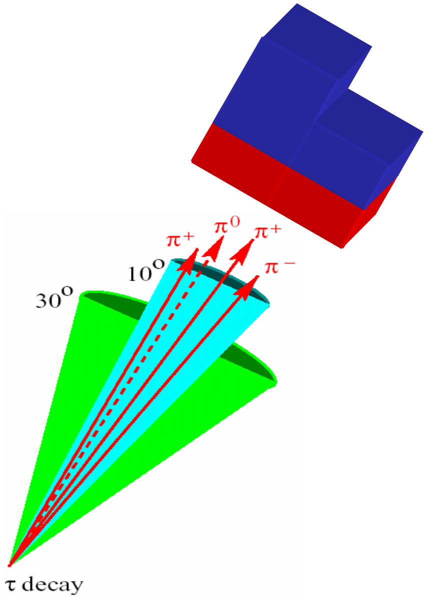




$W \rightarrow e\nu$
One isolated electron with
Et>25 GeV $|\eta|$<1.1
$\not{E}_T$>25 GeV
27370 Candidates

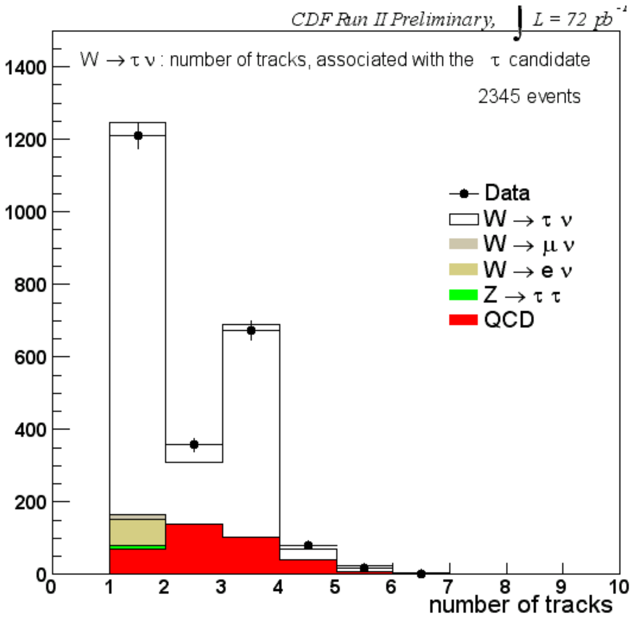
Bosons decaying to Tau

Both CDF and DØ in RunII can identify taus.
CDF has a specific trigger identifying tau decaying hadronically conbining calorimetry and tracking.



- Tau reconstruction@CDF:
  - Count tracks in 10^o τ -cone and veto tracks in 30^o isolation cone
  - Reconstruct π^0 candidates in Shower Max detector
  - Combined mass < m(τ)

$W \rightarrow \tau\nu_\tau$: 2345 in ~72 pb^{-1}
Background ~ 26 % (dominated by QCD)



W cross section measurements

CDF and DØ $\sigma(pp \rightarrow W) \times BF(W \rightarrow l\nu_l)$ Measurements(pb)

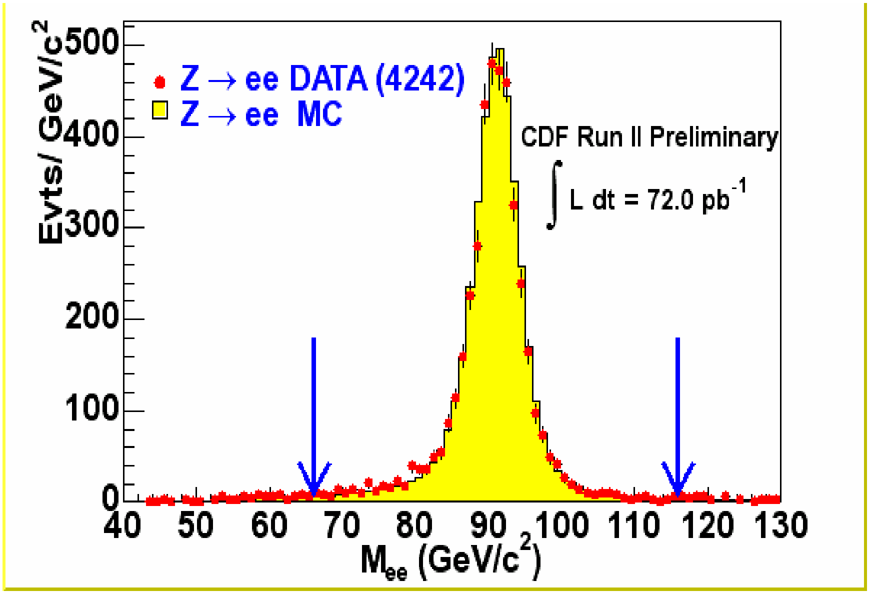
Channel	Central Value	Uncertainties			$\int \mathcal{L} dt$ (pb^{-1})
		stat	syst	Lum	
CDF e $\lvert\eta\rvert<1.1$	2782	14	+61/-56	167	72
CDF e $1.1<\lvert\eta\rvert<2.8$	2874	34	167	172	64
D0 e $\lvert\eta\rvert<1.1$	2844	21	128	284	42
CDF μ $\lvert\eta\rvert<1.1$	2772	16	+64/-60	166	72
D0 μ $\lvert\eta\rvert<1.1$	3226	128	100	322	17
CDF τ $\lvert\eta\rvert<1.1$	2620	70	210	160	72
CDF Combined	2777	10	52	167	72

Theory (Stirling NNLO): 2731 ± 10 pb

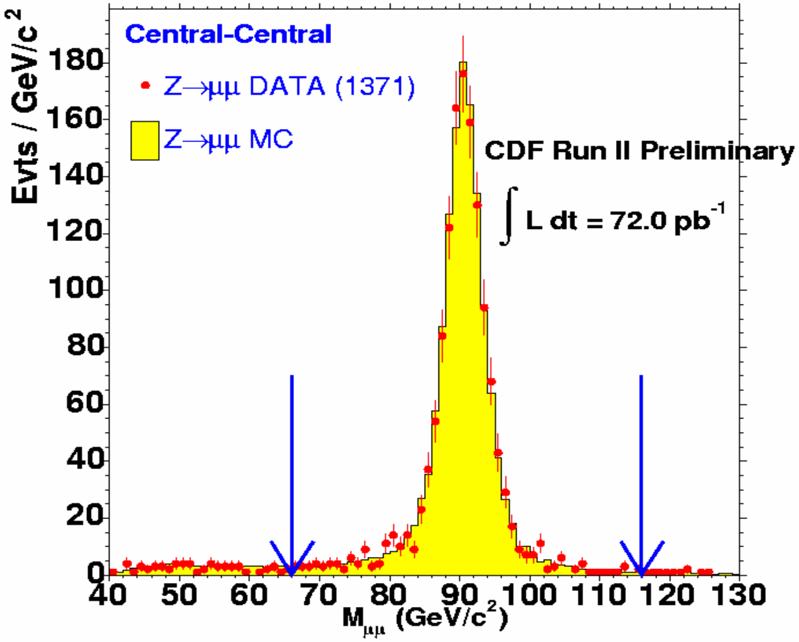
Z Boson Cross Section

Z-> ee Invariant mass distribution

Central Central (CC) + Central Plug (CP)



Z->μμ Invariant Mass Distributions



$|\eta(1^{st}\ e)| < 1.0$

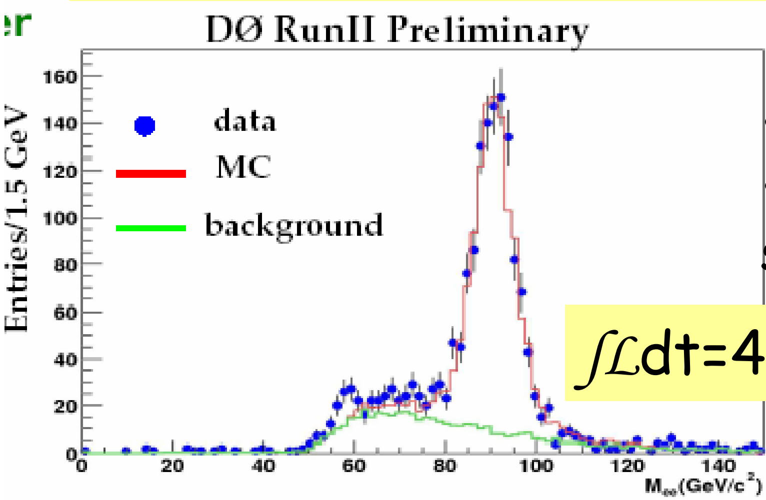
$|\eta(2^{nd}\ e)| < 2.8$

Extended coverage in the forward $|\eta| < 2.8$

Small backgrounds :

QCD, Z/W → τ, cosmics (μ) < 1.5%

Z Boson Cross Sections

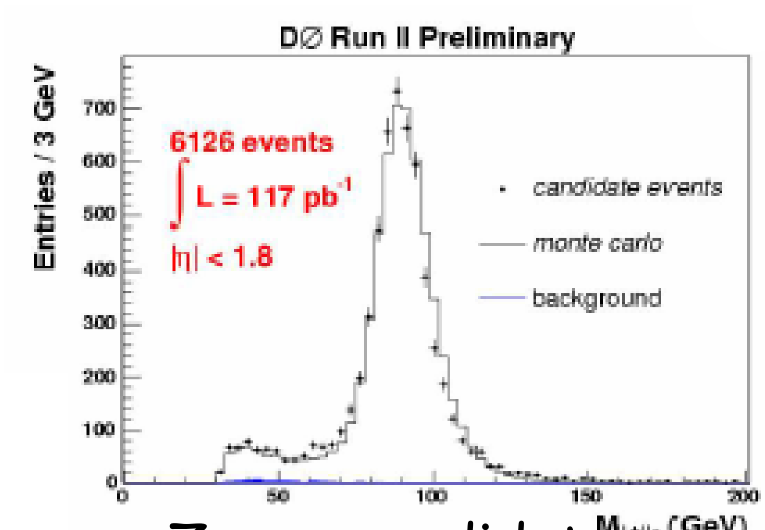


- QCD Bkg contamination ~2.3%
- 1139 candidates after bkg substraction

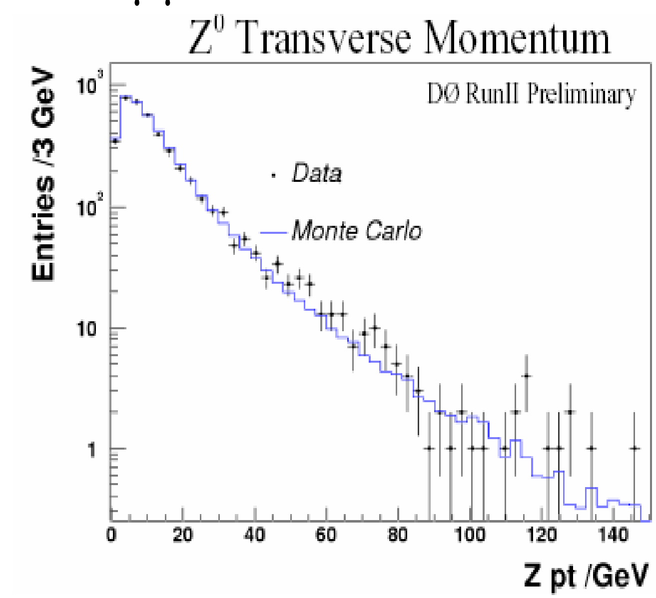
$\int \mathcal{L} dt = 42\ pb^{-1}$

Z→ee candidates

Z Boson P_T reconstructed from Z→μμ candidates



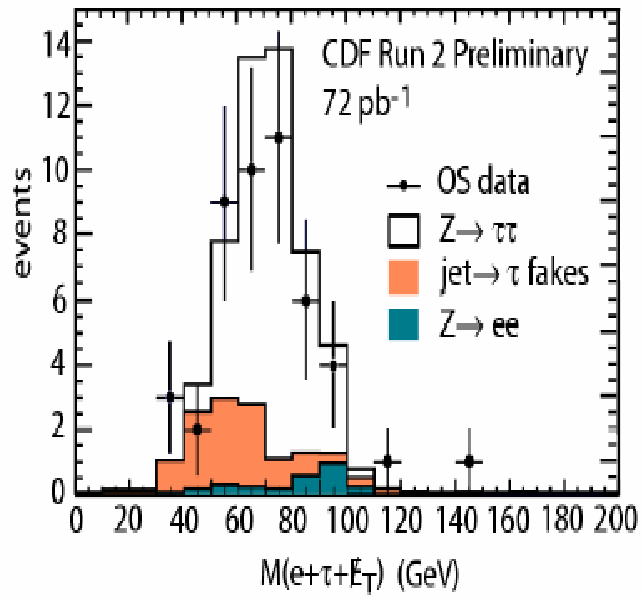
Z→μμ candidates



QCD Bkg Contamination <1%

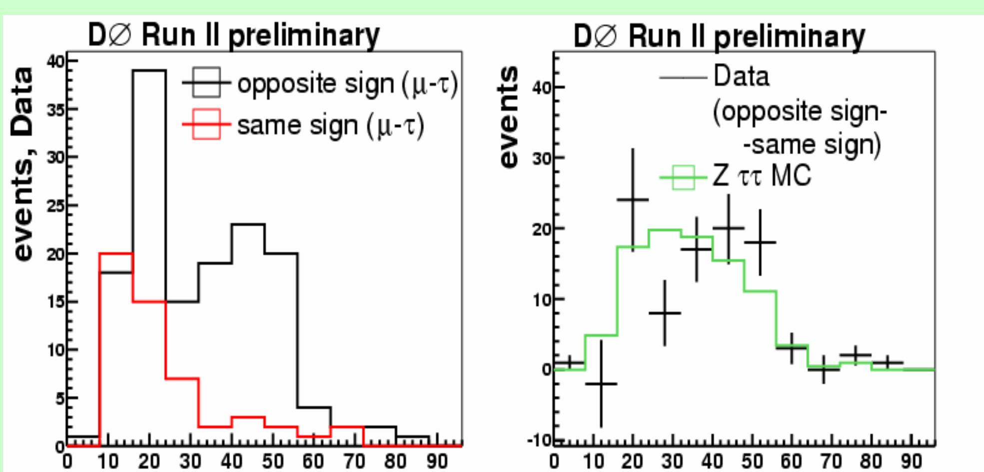
$Z \to \tau\tau$

$Z \to \tau_h^+ \tau_\ell^-$: first look !



One τ decays in hadrons, the other decays in leptons
Main Background from QCD

Taus from Z and W are a starting point:
Will use them for SUSY searches, top physics, etc…



Z Cross Sections Measurements

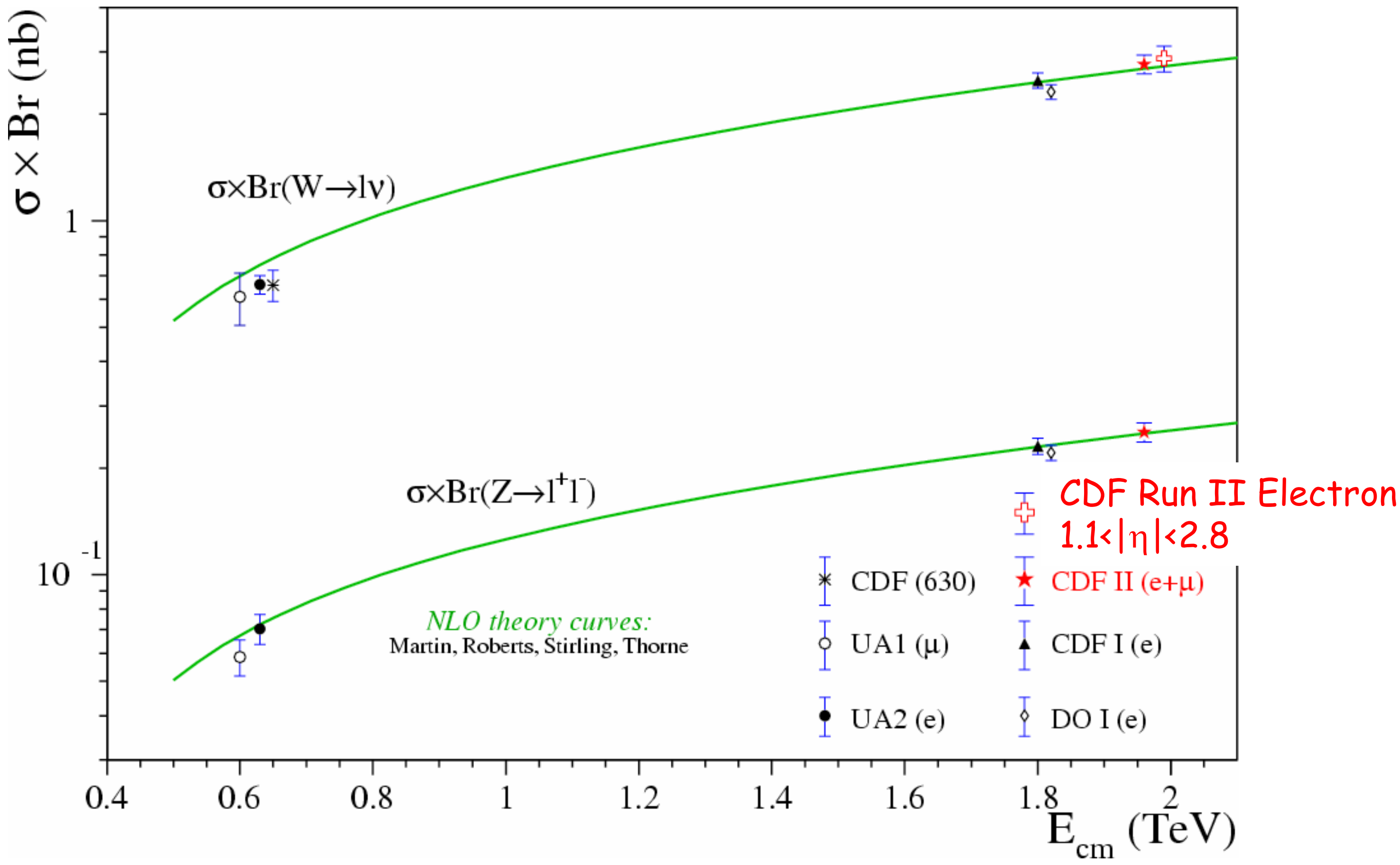
CDF and DØ $\sigma(pp \rightarrow Z) \times BF(Z \rightarrow ll)$ Measurements (pb)

Mass Range 66 GeV/c^2 < M_{ll}<116 GeV/c^2

Channel	Central Value	Uncertainties stat	syst	Lum	$\int \mathcal{L} dt$ (pb^{-1})
CDF e	255.2	3.9	+5.5/-5.4	15.3	72
DØ e	275	9	9	28	42
CDF μ	248.5	5.9	+7.0/-6.2	14.9	72
DØ μ	261.8	5.0	8.9	26.2	117
CDF Combined	254.3	3.3	4.3	15.2	72

Theory (Stirling NNLO): 252 ± 9 pb

W and Z Cross Section



20 years of W and Z at hadronic colliders!

From R to W width Measurement

Measuring Ratio R of σ x BF

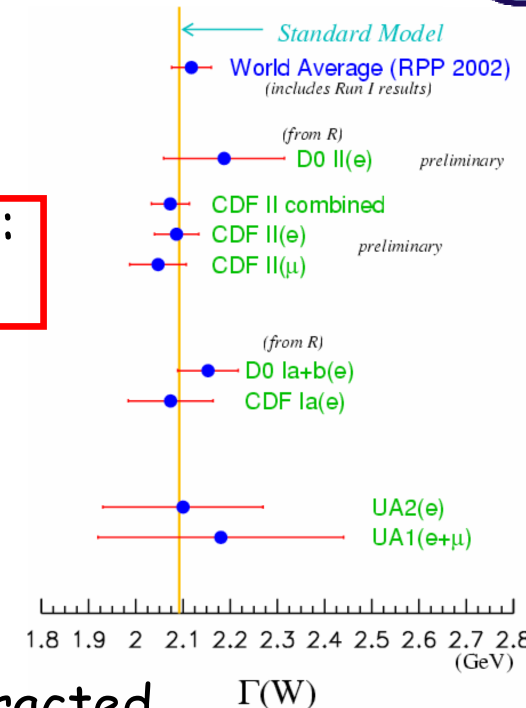
$$R = \frac{\sigma \times BF(p\bar{p} \to W \to l\nu)}{\sigma \times BF(p\bar{p} \to Z \to l^+l^-)}$$

$$= \frac{\sigma(p\bar{p} \to W)}{\sigma(p\bar{p} \to Z)} \times \frac{\Gamma(Z)}{\Gamma(Z \to ll)} \times \frac{\Gamma(W \to l\nu_l)}{\Gamma(W)}$$

From Theory: Van Neerven

From LEP

From Theory: Rosner et al.



Γ(W) can be extracted indirectly.

R Measurements:

	CDF	DØ	Theory
R e-channel:	10.86±0.18 ±0.16	10.34±0.59	10.66 ±0.05
R μ-channel:	11.10±0.27 ±0.17	11.32±0.76	
R Combined	10.94±0.15±0.13		
Γ(W)(MeV)	2071 ±40	2187±128	

World Average	LEP Direct
2092 ± 40	2150 ± 90

Lepton Universality

From W decaying in e and μ:

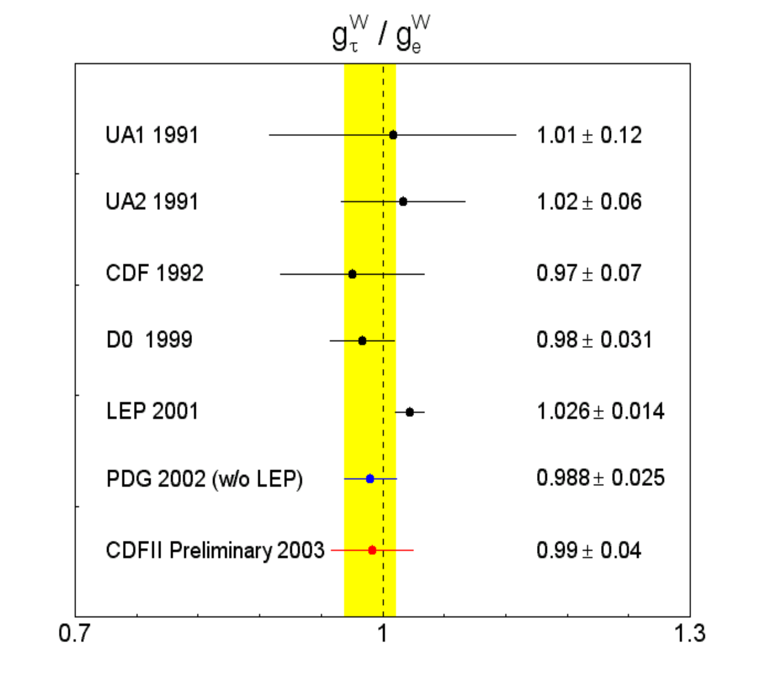
$$U = \frac{R_\mu}{R_e} = \frac{\Gamma(W \to \mu\nu)}{\Gamma(W \to e\nu)} = \frac{g_{W\mu}^2}{g_{We}^2}$$

g_μ/g_e	
CDF measurement	1.011±0.018
World Average	0.993±0.025

From W decaying in τ:

$$U = \frac{R_\tau}{R_e} = \frac{\Gamma(W \to \tau\nu)}{\Gamma(W \to e\nu)} = \frac{g_{W\tau}^2}{g_{We}^2}$$

g_τ/g_e	
CDF measurement	0.99±0.04±0.07



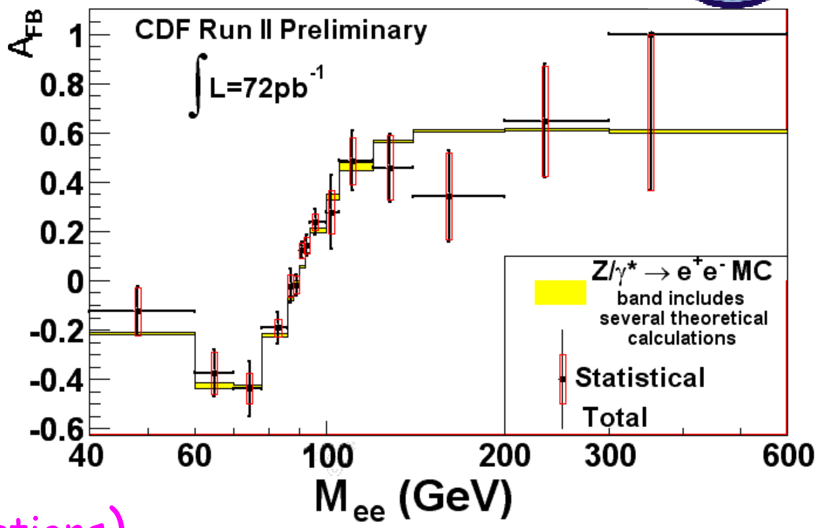
Z Forward Backward Asymmetry

$$A_{FB} = \frac{d\sigma(\cos\theta > 0) - d\sigma(\cos\theta < 0)}{d\sigma(\cos\theta > 0) + d\sigma(\cos\theta < 0)}$$

$$= A(1+\cos^2\theta) + B\cos\theta + \ldots$$

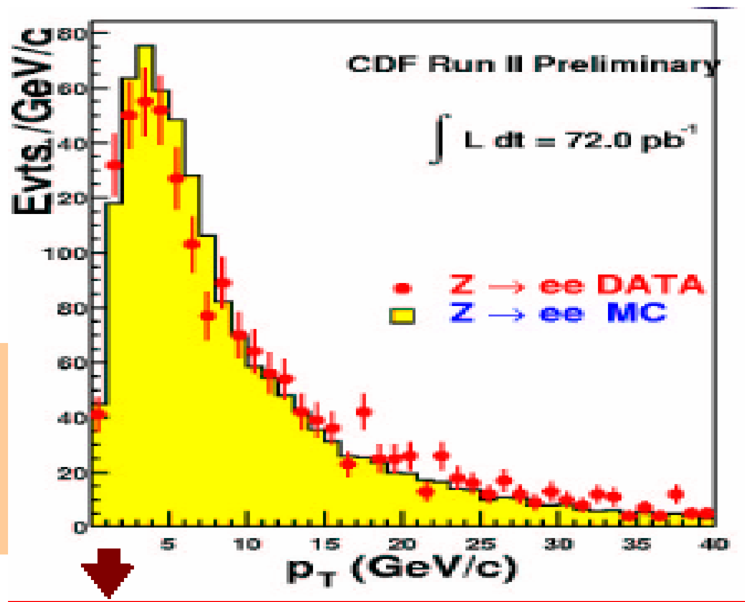
SM Contributions

Beyond SM(Z',New Interactions)



Probing (Unique at Tevatron):

• Z/γ* Interference in High Invariant Mass Region (far from Z-pole)



Consistent with SM

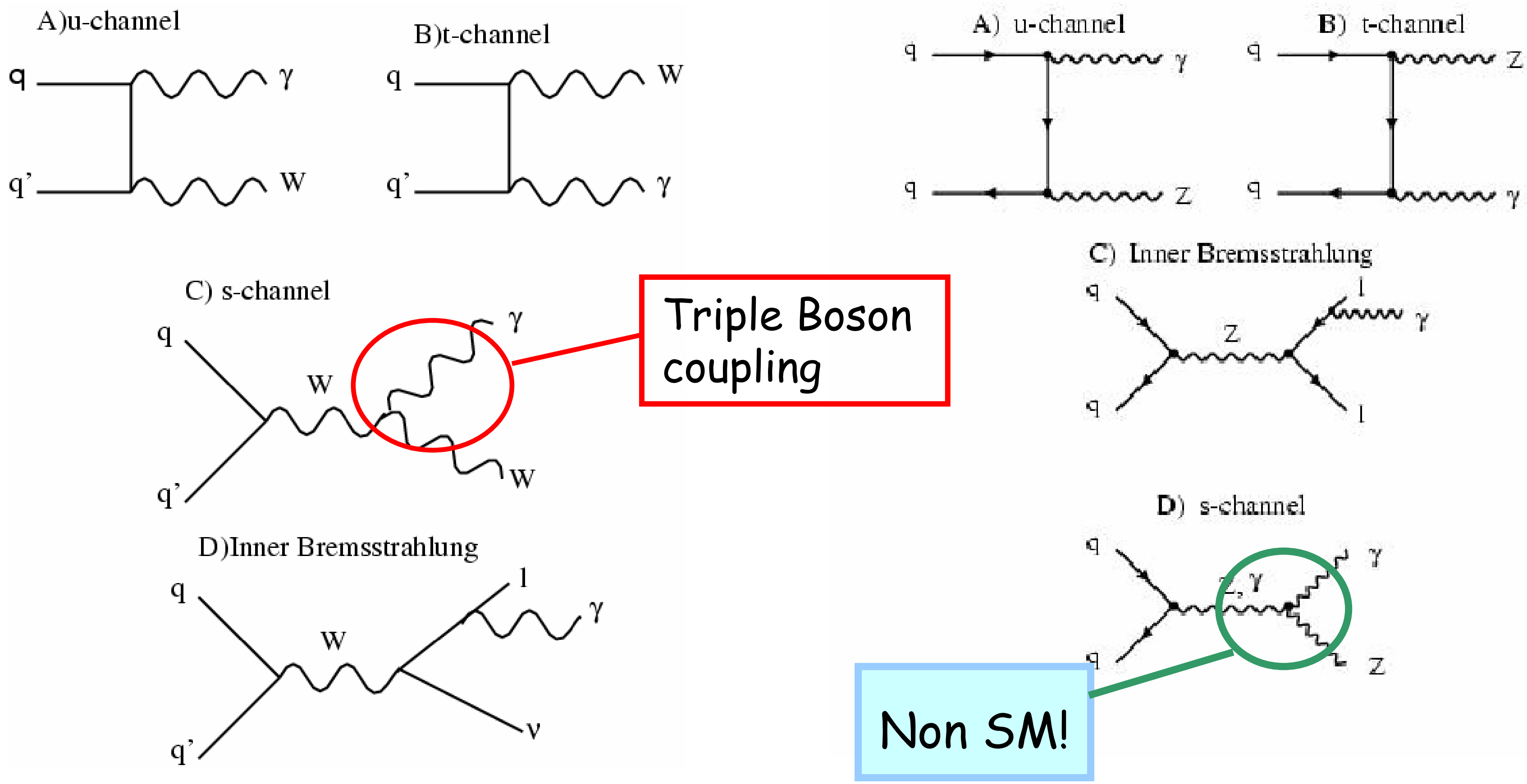
Constraints on non-SM Z Couplings soon!

DiBoson Production

- DiBoson Coupling Measurements:
- Probe ewk boson self-coupling
- Sensitivity to physics BSM(Anomalous Couplings)

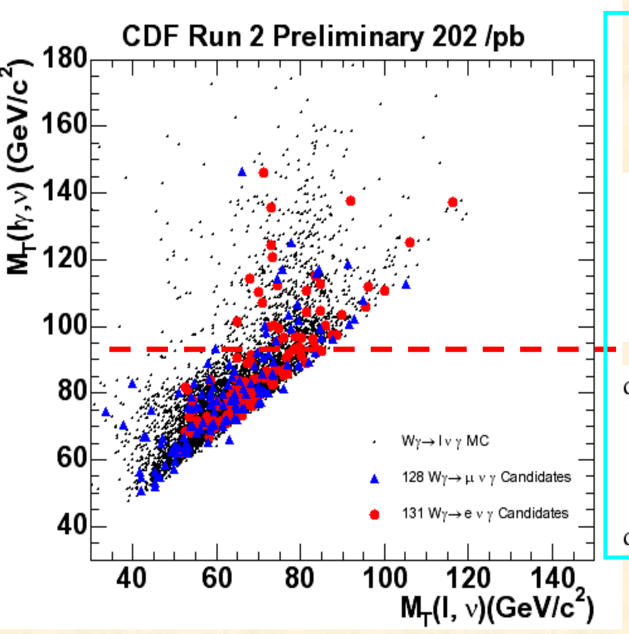
W gamma

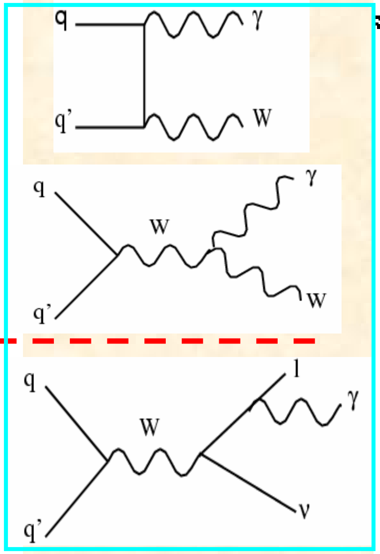
Z gamma



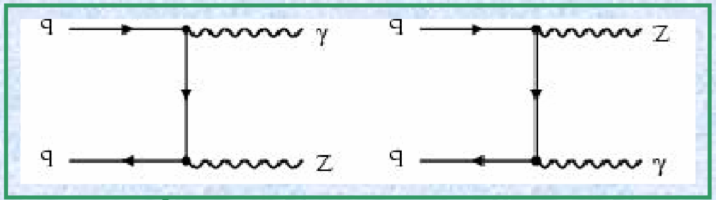
DiBoson Production

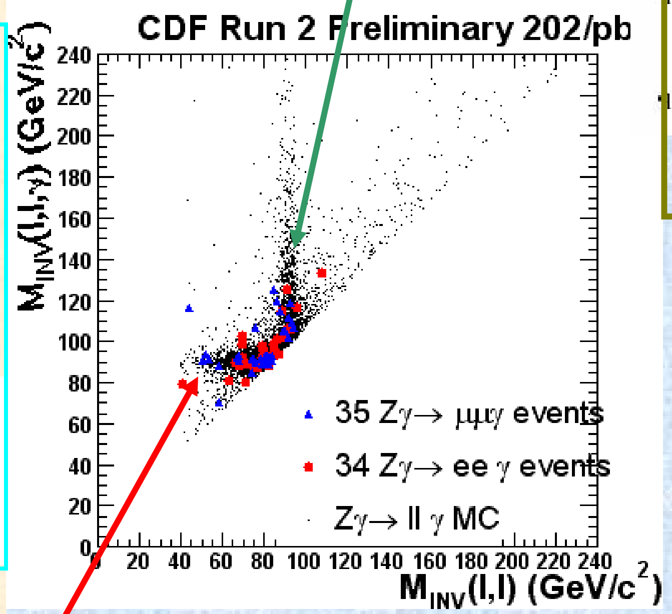
W-γ

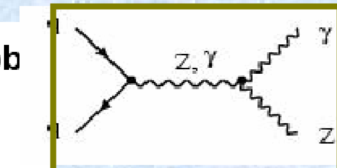




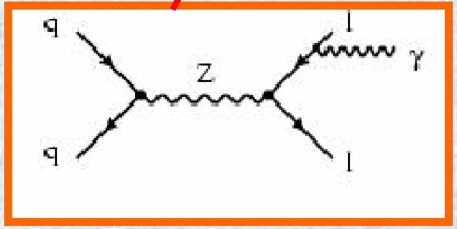
Z-γ







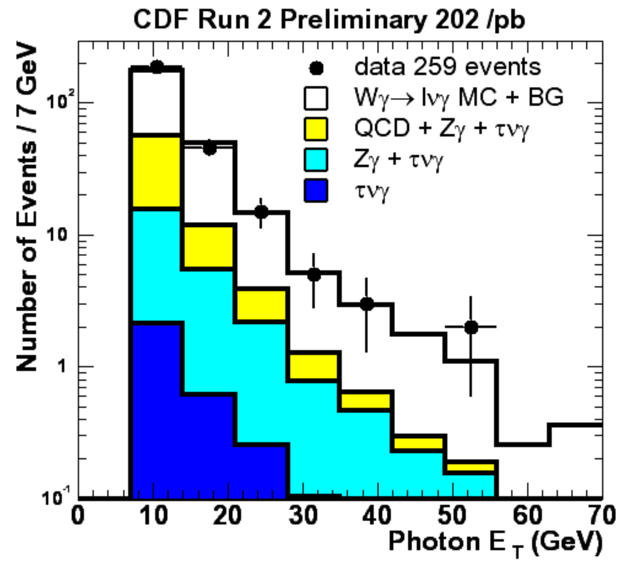
Non SM



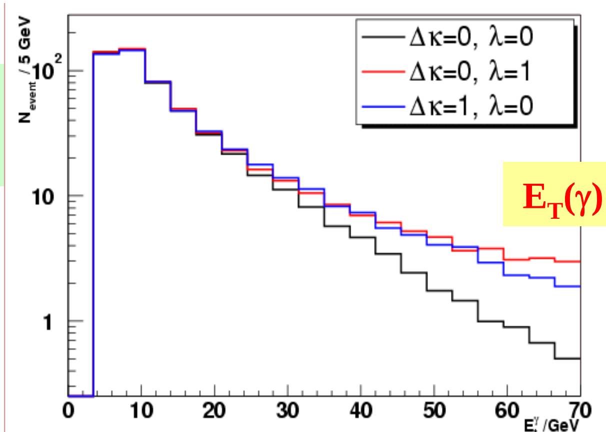
W-gamma

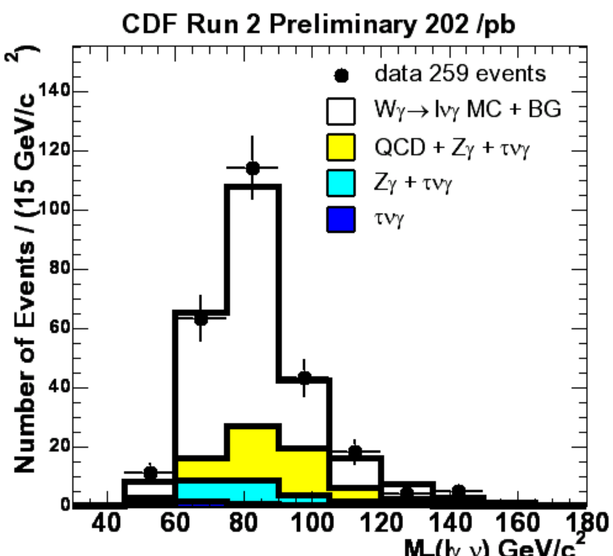
Selection Cuts

- One High-P_T lepton(e,μ)
- One Photon($\Delta R_{(\gamma,l)}$>0.7)
- Large Missing E_T



probing anomalous couplings



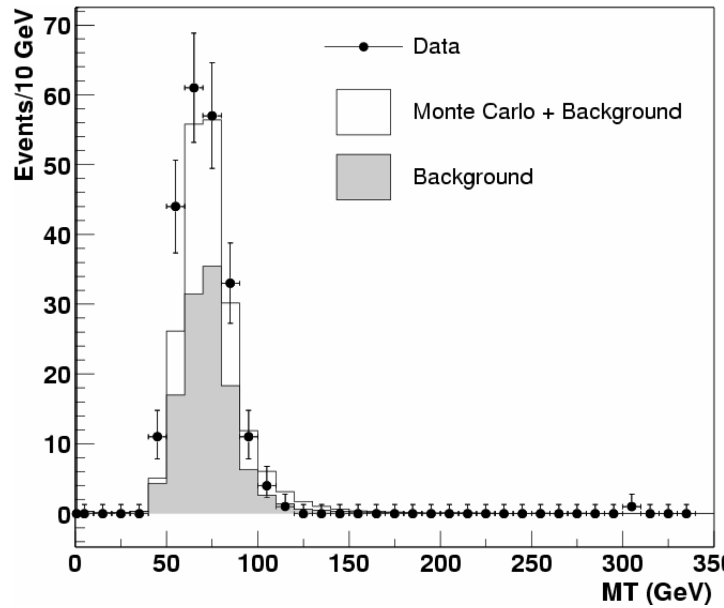


Consistent with SM

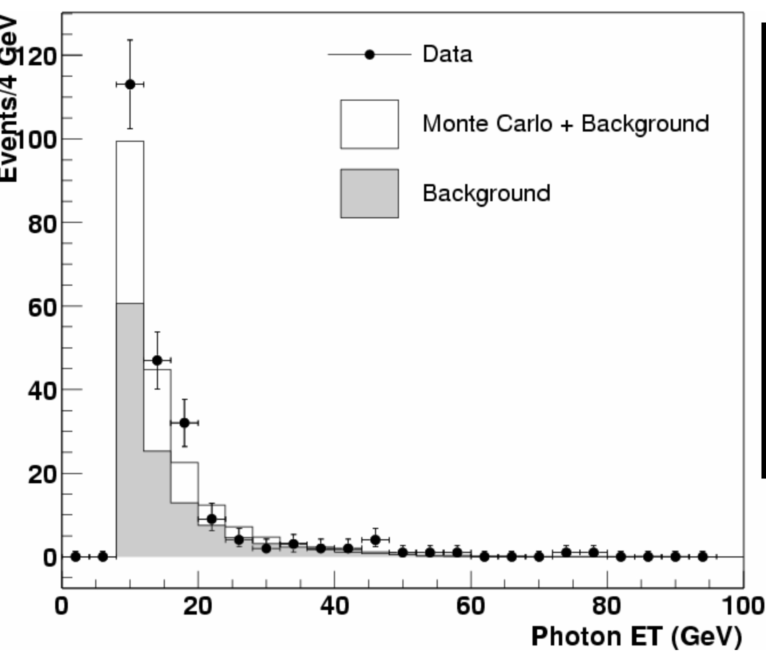
	Events	Back	σ•B(Wγ→lνγ) (pb)
e+μ	259	29%	**19.7**$\pm 1.7_{stat} \pm 2.0_{sys} \pm 1.1_{lum}$
SM @$\sqrt{s}$=1.96TeV			19.3 ± 1.4

W-gamma

Process:
$p\bar{p} \to W\gamma \to l\nu_l\gamma$



- One High-P_T lepton(e,μ)
- One Photon($\Delta R_{(\gamma,l)}$>0.7)
- Large Missing E_T(E_T>8 GeV)



	Events	Back	$\sigma \cdot B(W\gamma \to l\nu\gamma)$ (pb)	$\int \mathcal{L} dt$
e	146	12%	**17.8**$\pm 3.6_{stat} \pm 5.3_{sys} \pm 1.1_{lum}$	162±11
μ	77	17%	**22.0**$\pm 4.2_{stat} \pm 7.3_{sys} \pm 1.4_{lum}$	82±5
e+μ	223	13%	**19.3**$\pm 4.2_{stat} \pm 5.2_{sys} \pm 1.2_{lum}$	

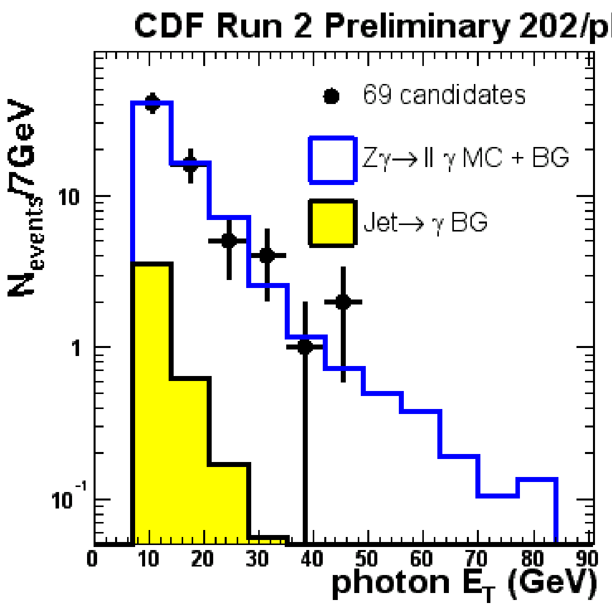
SM @$\sqrt{s}$=1.96TeV 16.4 ± 0.4

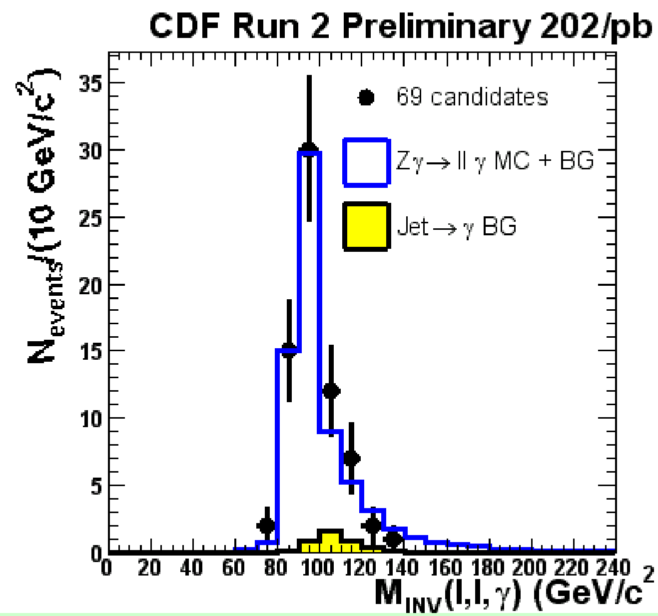
Consistent with SM

Z-gamma

Process:

$p\bar{p} \rightarrow Z\gamma \rightarrow ll\gamma$





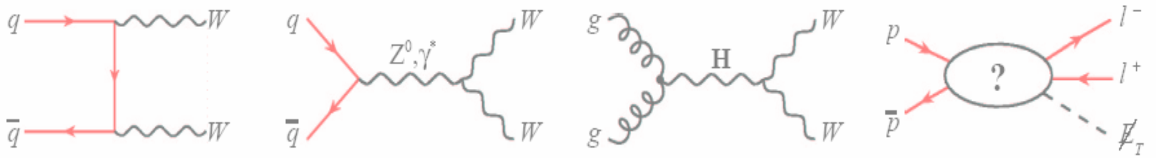
- Two High-P_T Leptons(Opposite sign)
- One Photon ($\Delta R_{(l,\gamma)}$ >0.7)

	Events	Back.	$\sigma \cdot B(Z\gamma \to ll\gamma)$ (pb)
e+μ	69	6.8%	**5.5**$\pm 1.7_{stat} \pm 0.6_{sys} \pm 0.3_{lum}$

$\sigma \cdot B(Z\gamma \to ll\gamma)_{SM} = 5.4 \pm 0.3$ pb

Consistent with SM

WW Production



- Sensitive to WWγ and WWZ vertex
- Higgs discovery channel
- Right place to look for new Physics

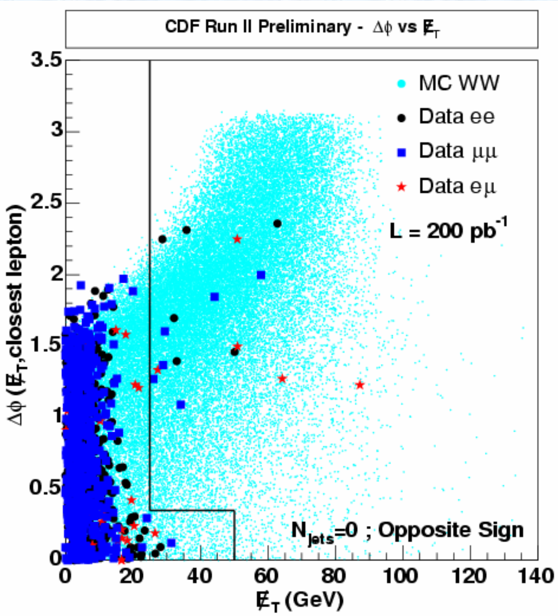
$\int\mathcal{L}dt$=200pb-1

$\sigma\bullet BR(WW\rightarrow\ell^+\ell^-\nu\nu)_{Th}$ = 12.5±0.8pb(NLO)

Two complementary approaches:

Dilepton selection (l^+l^-)
(small yield and background)

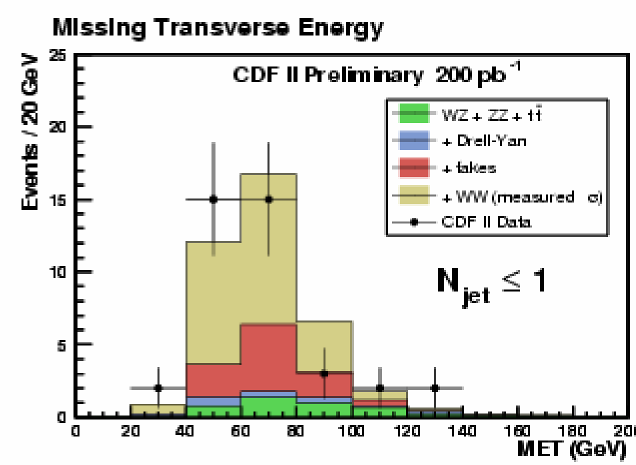
$14.3\ ^{+5.6}_{-4.9}$ (stat) ± 1.6 (sys) ± 0.9(lum) pb



Data	17
WW signal	11.3 ± 1.3
Bkg	4.8 ±0.8

Tight Lepton + Isolated Track selection
(larger yield and background)

19.1 ± 5.0 (stat) ± 3.6 (sys) ± 1.1(lum) pb

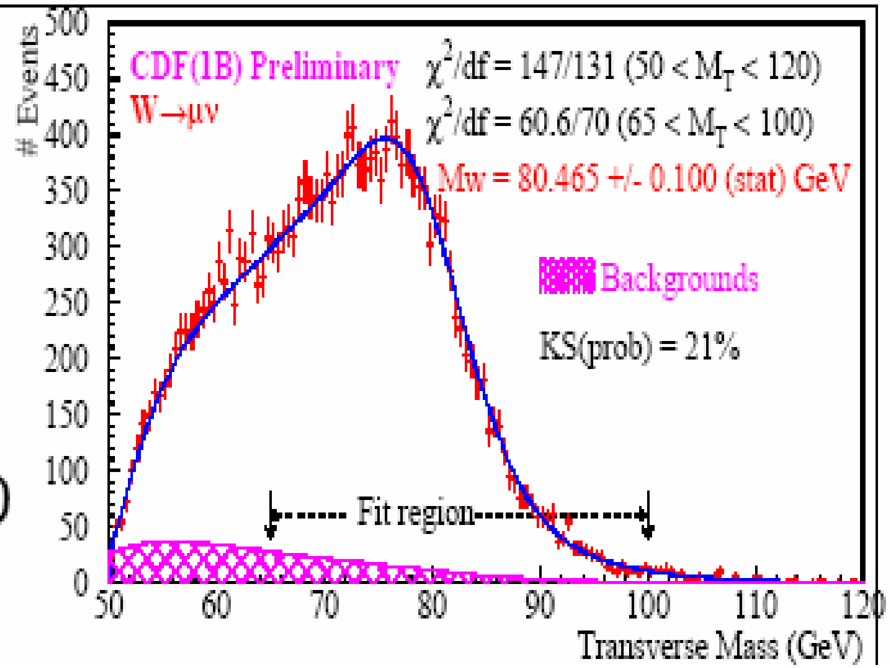


Data	39
WW signal	16.3 ± 0.4
Bkg	15.27±3.55

Consistent with SM

W Mass measurement: RunI

The Tevatron Run 1 combined W mass measurement was ready six years after end of RunI



Method: fit Transverse Mass distributions to MC varying M_W, including:

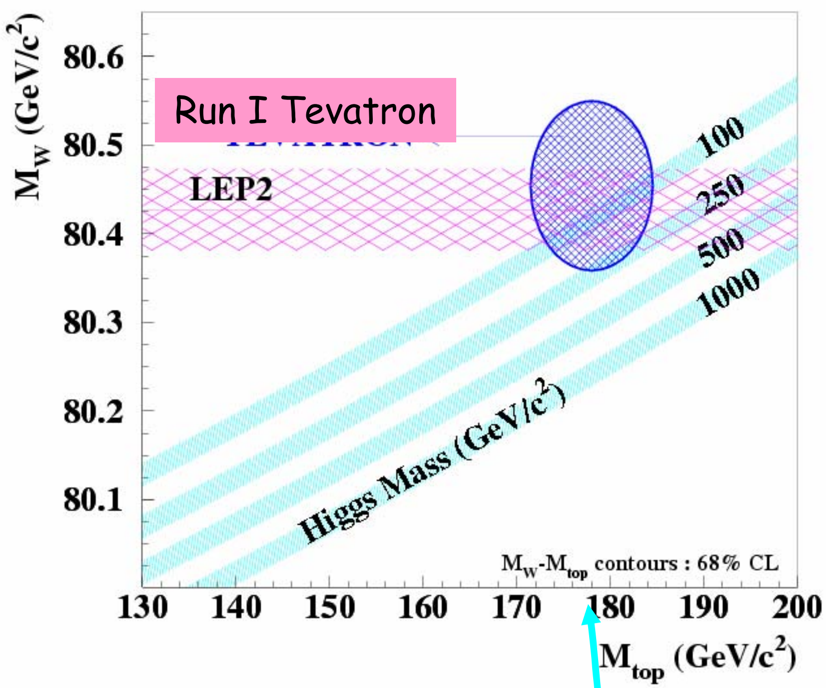
- detectors effects,
- W decay
- W production model

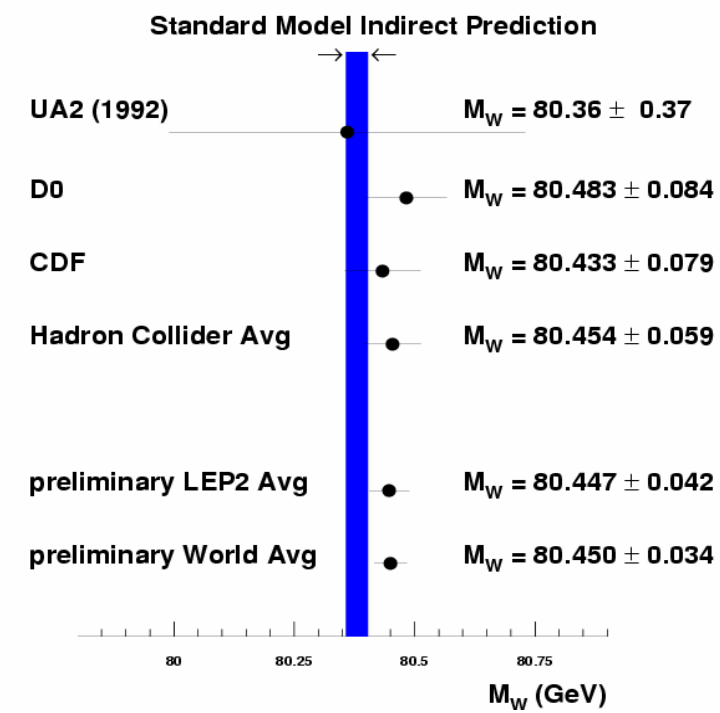
In Run I larger uncertainties coming from:

- Statistics
- Detector Energy response
- W Transverse Momentum
- PDF (correlated between experiments)

W Mass measurement: RunI

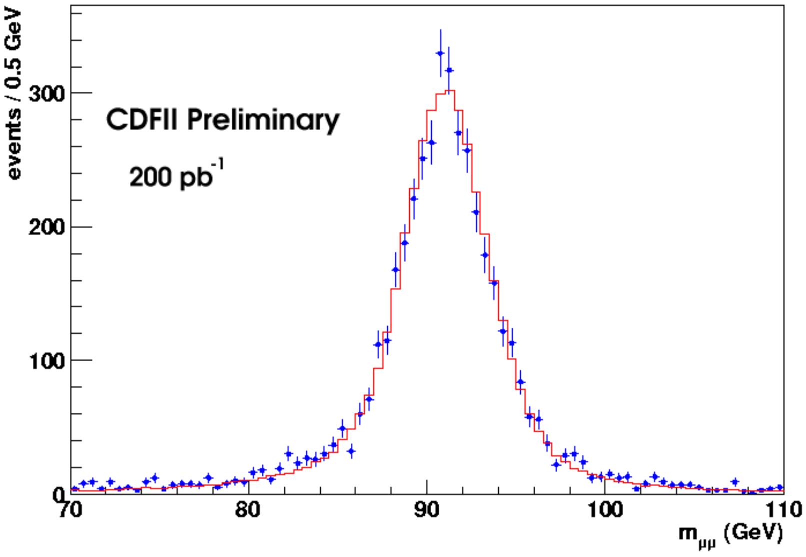
W Boson mass SM key parameter and for SM Higgs mass constraints

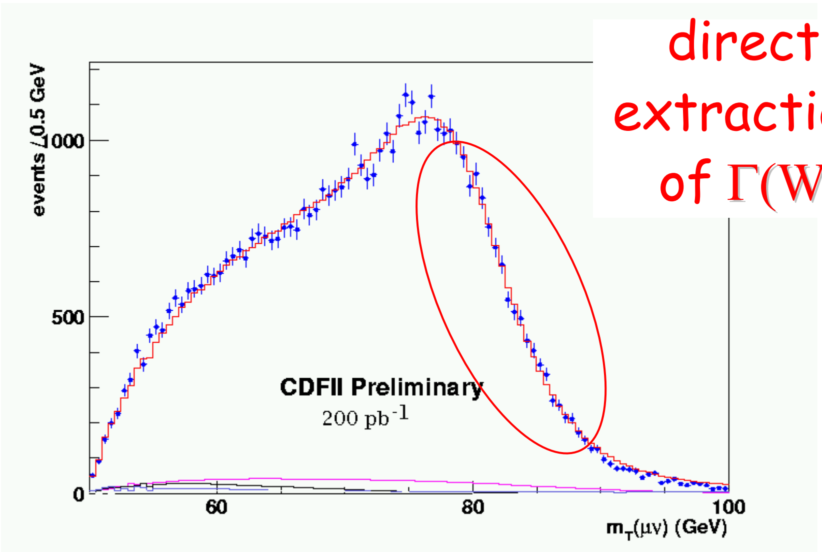


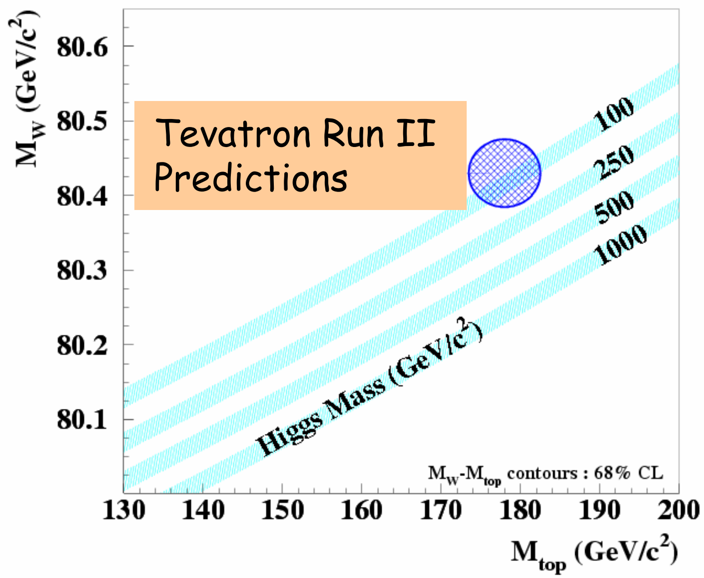


New Run I Top Mass Combined Measurement

W Mass measurement: Run II Prospects







Almost all systematic uncertainties will decreas with statistics(control samples)

Goal for Run II (with 250 pb^{-1})

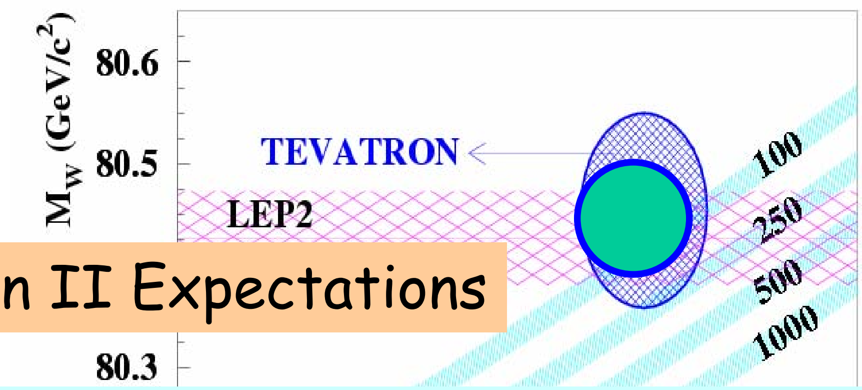
CDF Run II estimate (μ): = X±55(stat)±80(sys) MeV/c^2

We need to improve uncertainties:

- Radiative corrections (electrons)
- QCD effects in W/Z production

Conclusions

CDF and DØ Detectors are taking data
Baseline EWK Measurements well established
Analyzing twice the integrated luminosity of Run I

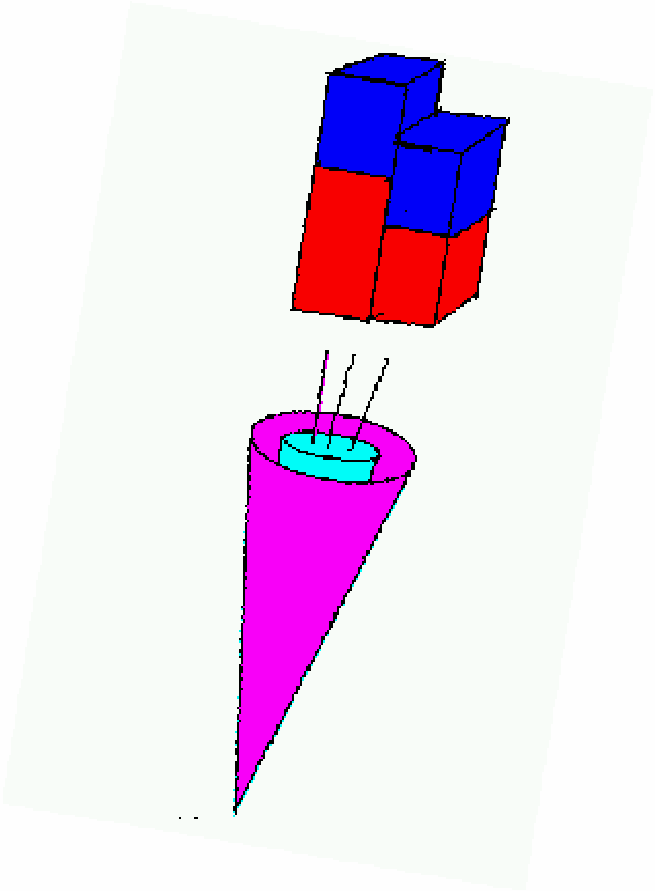


Run II Expectations

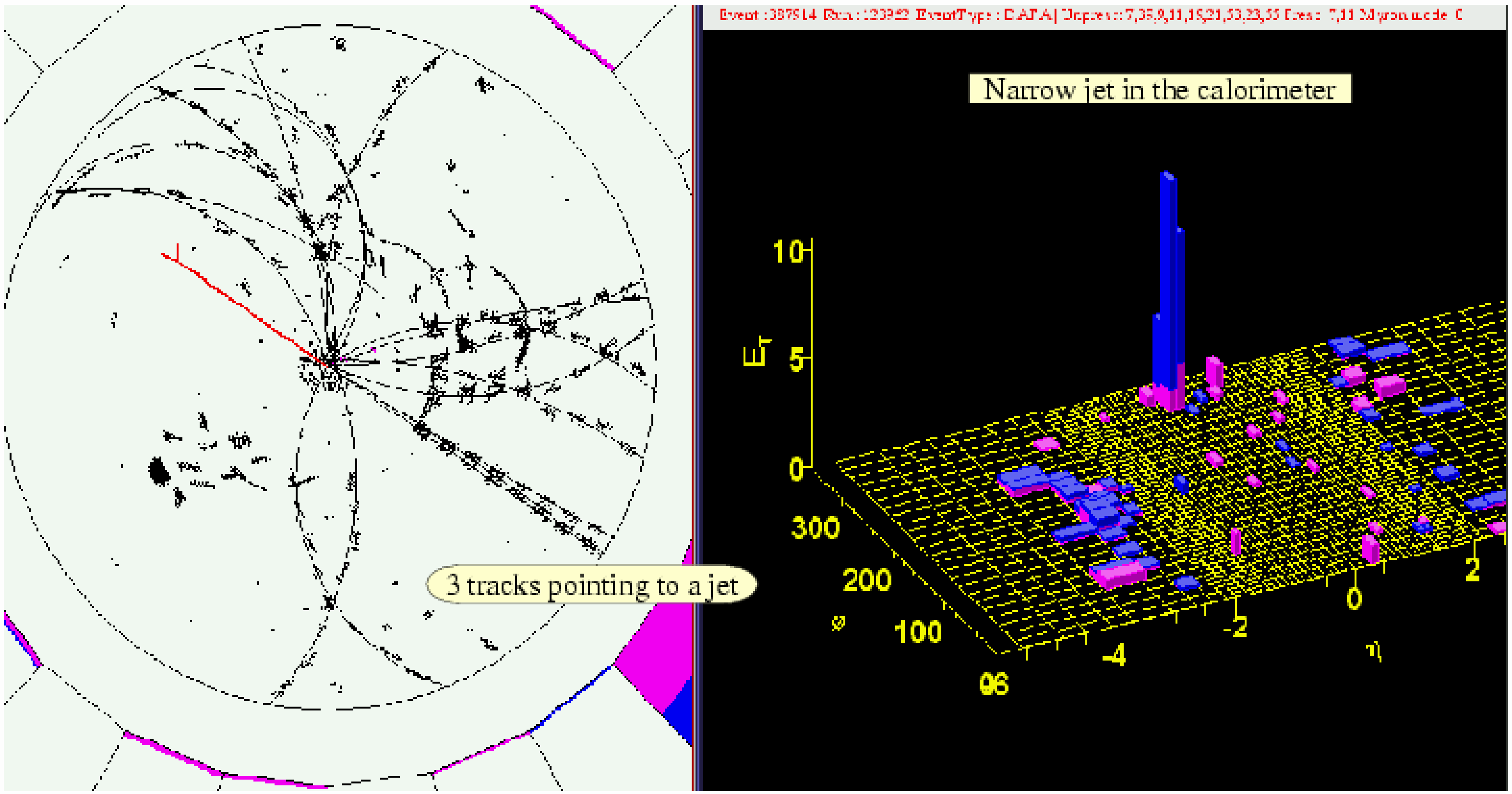
Goals for Summer 2004:
~500 pb^{-1} integrated luminosity per experiment.
Measuring:
- Differential cross sections
- W Mass, Direct $\Gamma(W)$
- Constraints on TGC and Physics Beyond SM

Tau Reconstruction at CDF

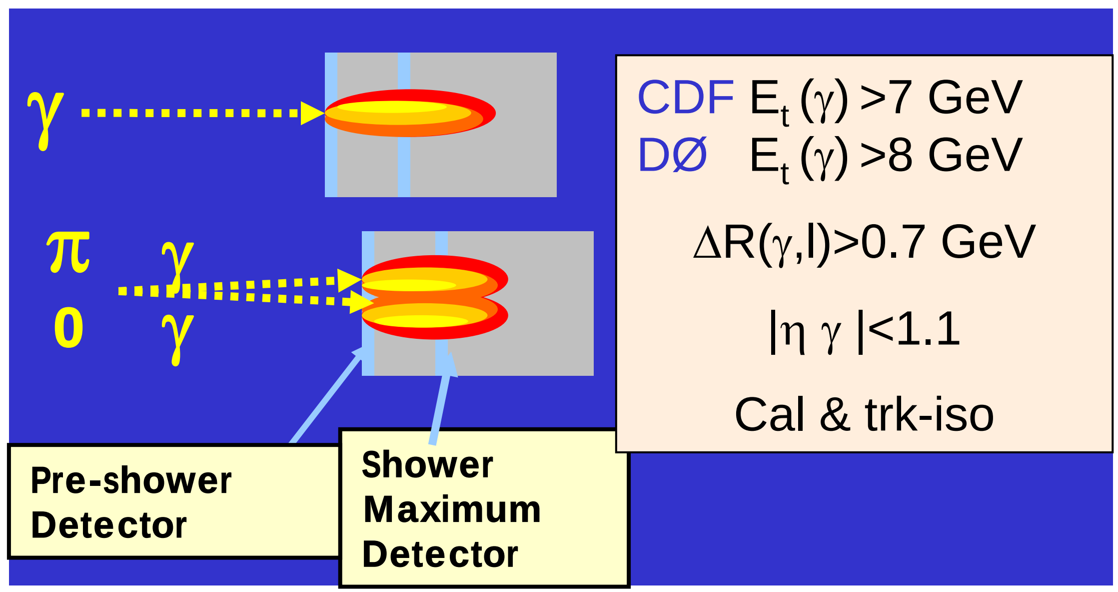
- Start from narrow cluster in the central calorimeter
- Search for an energetic track pointing to it
- Define 2 cones - 10 degrees (cyan) and 30 degrees (pink) - around the seed track
- Allow more tracks within cyan cone
- Disregard the candidate if there are tracks in between the pink and cyan cones
- Reconstruct energy clusters in shower max detector and make π^0 candidates out of them
- Require effective mass of all the tracks and π^0's inside the 10° cone to be < 1.8 GeV (tau mass plus resolution)
- Expect E(cal) = sum(P)(tracks+π^0)



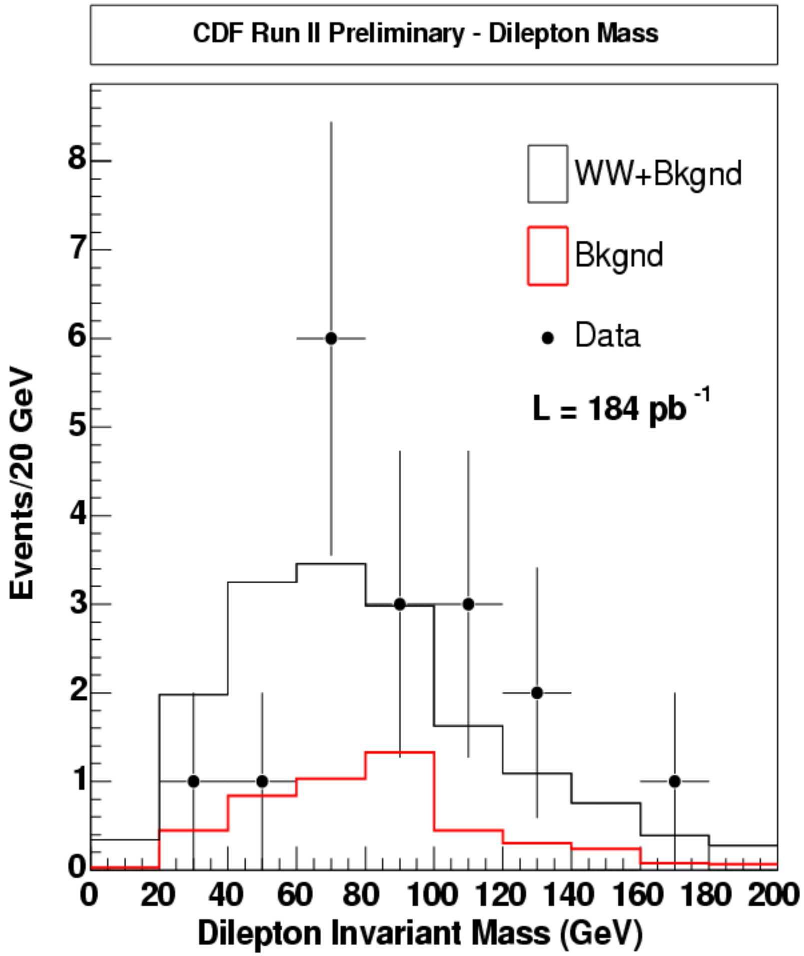
A typical W->$\tau\nu$ candidate event

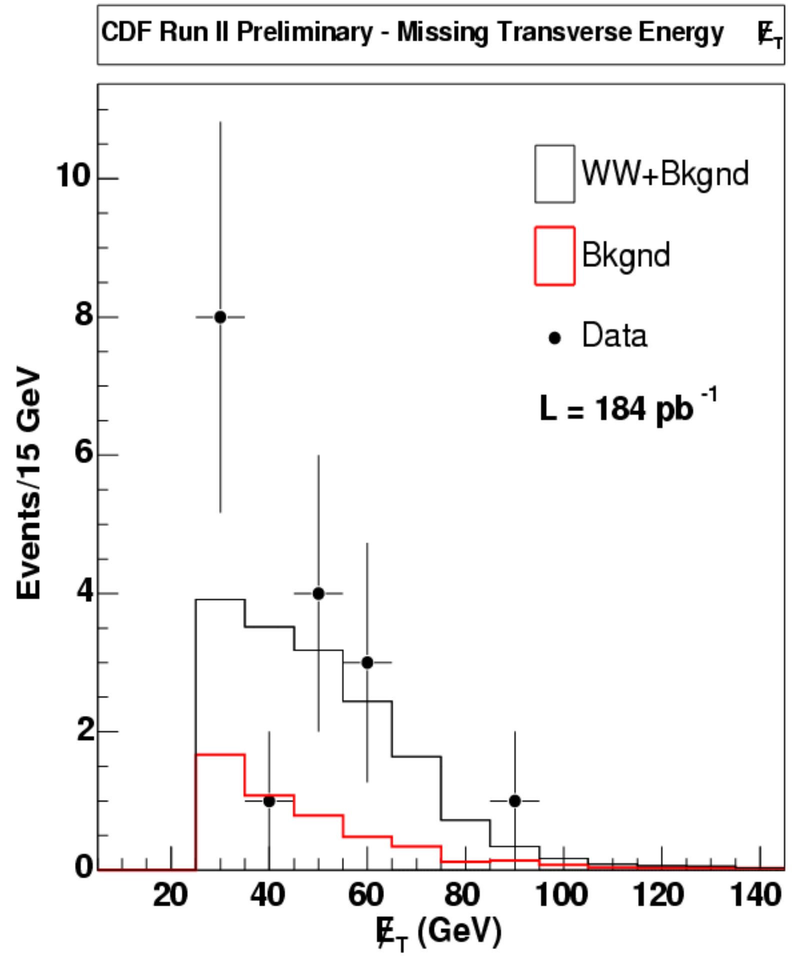


Photons at CDF

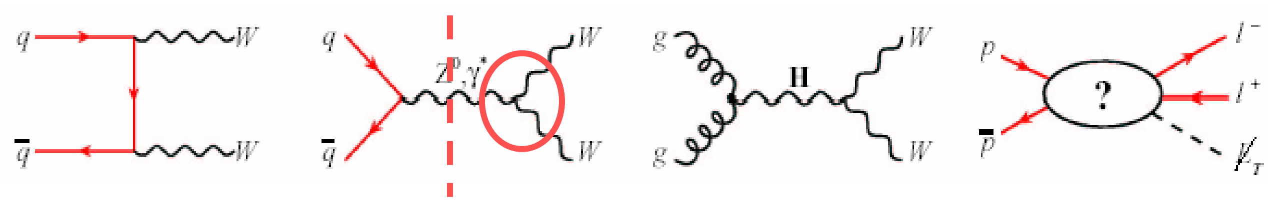


CDF: WW (III)


CDF Run II Preliminary - Dilepton Mass
WW+Bkgnd
Bkgnd
Data
L = 184 pb -1
Events/20 GeV
0
1
2
3
4
5
6
7
8
0
20
40
60
80
100
120
140
160
180
200
Dilepton Invariant Mass (GeV)

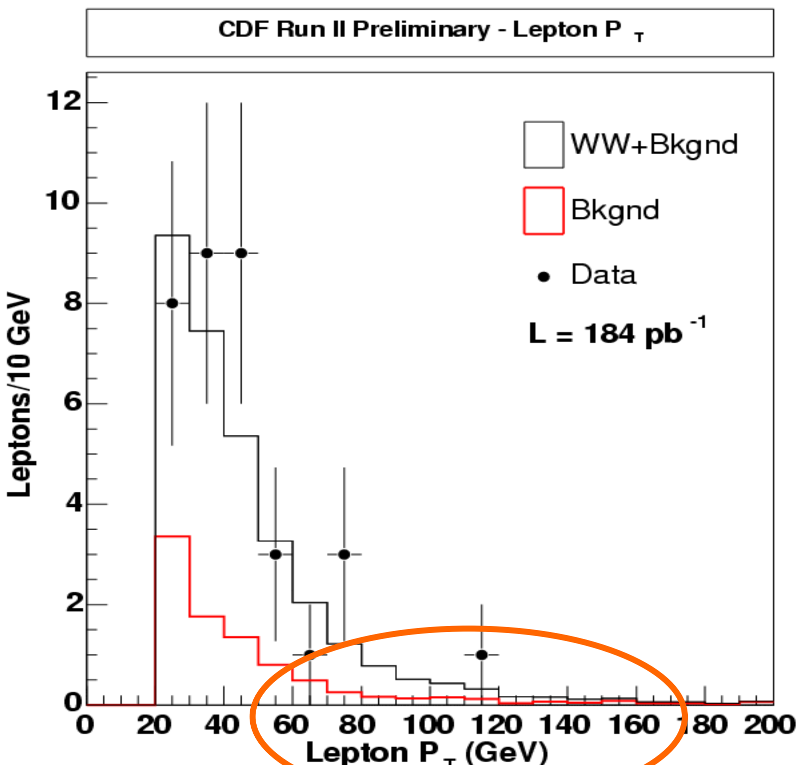

CDF Run II Preliminary - Missing Transverse Energy $\not{E}_T$
WW+Bkgnd
Bkgnd
Data
L = 184 pb -1
Events/15 GeV
0
2
4
6
8
10
20
40
60
80
100
120
140
$\not{E}_T$ (GeV)

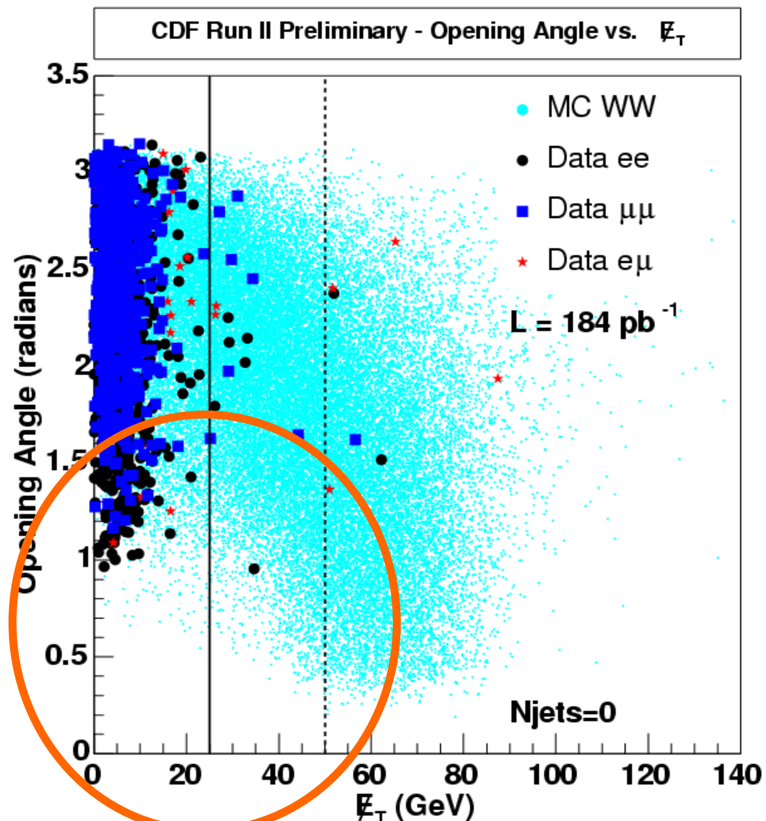
CDF: WW Beyond SM



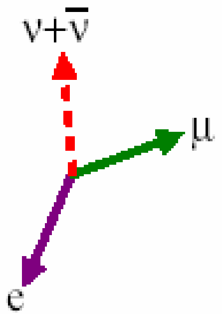
Anoumalous TGC WWZ/WWγ

gg→H→WW 140<M_H<180GeV/c^2

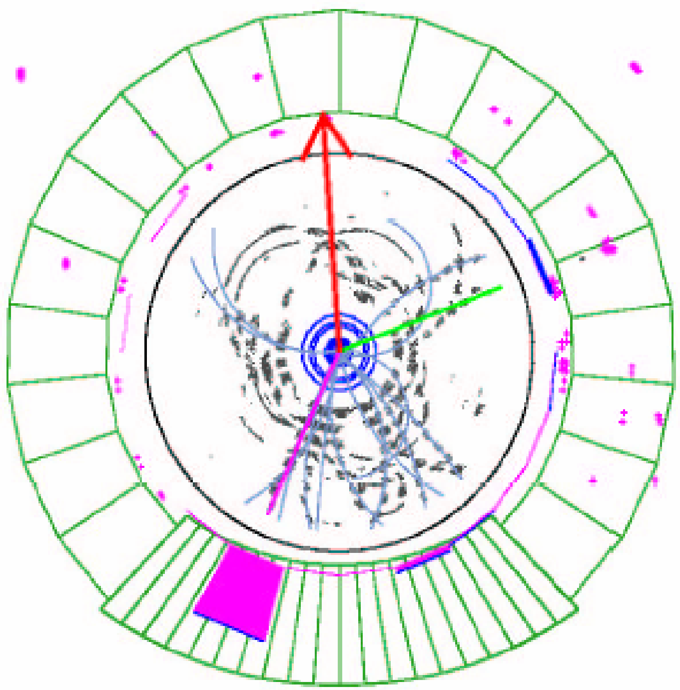




CDF: WW →eμνν candidate



- eμ channel has little Standard Model background
- Signal/Background ≈ 4

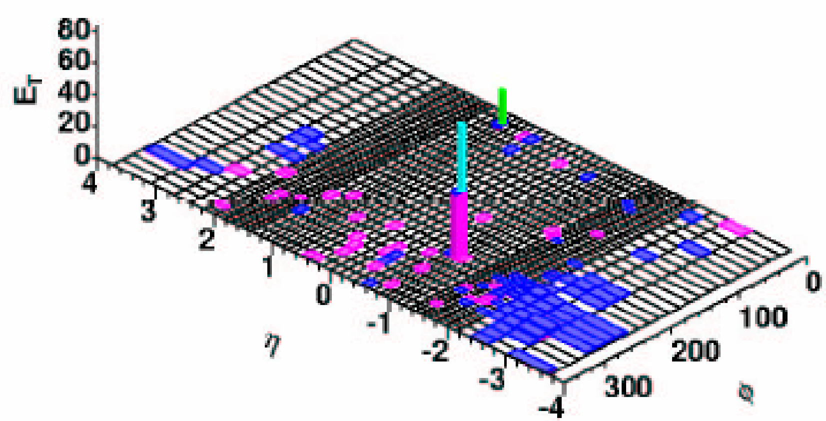


Run 155364 Event 3494901 : $WW \to e^+\nu_e\mu^-\bar{\nu}_\mu$ Candidate

$p_T(e) = 42.0$ GeV/c; $p_T(\mu) = 20.0$ GeV/c; $M_{e\mu} = 81.5$ GeV

$\not{E}_T = 64.8$ GeV; $\Phi(\not{E}_T) = 1.6$

$\Delta\Phi(\not{E}_T, \text{lepton}) = 1.3$; $\Delta\Phi(e,\mu) = 2.4$; Opening-Angle(e,μ)=2.6



W Mass measurement: RunI Systematics

Uncorrelated Uncertainties (MeV/c^2) for W boson mass

Source	**CDF μ**	**CDF e**	**DØ e**
W Statistics	100	65	60
Lepton Scale	85	75	56
Lepton Resolution	20	25	19
PT(W)	20	25	15
Recoil Model	35	37	35
Selection Bias	18	-	12
Bkg	25	5	9

Correlated Uncertainties (MeV/c^2) for W bson mass

Source	**CDF**	**DØ**
PDF and Parton Luminosity	15	$7 \oplus 4$
Radiative Corrections	11	12
$\Gamma(W)$	10	10

COT aging issues

Drift chamber aging:

- Decline in operating performances with time
- Loss of gains
- Caused by organic deposits on wires
- Investigating the causes…

Aging is detected:

- Less charge collected, shorter pulse widths
- Decrease of COT hit widths, smaller COT efficiency (impacts trigger XFT as well)
- Smaller event yields($D^0 \rightarrow K\pi$ down 36%)
- Worse P_T resolution($D0 \rightarrow K\pi$ invariant mass resolution ($15 \rightarrow 20$ MeV/c^2)

References:

http://www-cdf.fnal.gov/internal/upgrades/cot/cot_aging.html