W/Z Cross Sections at 2 TeV

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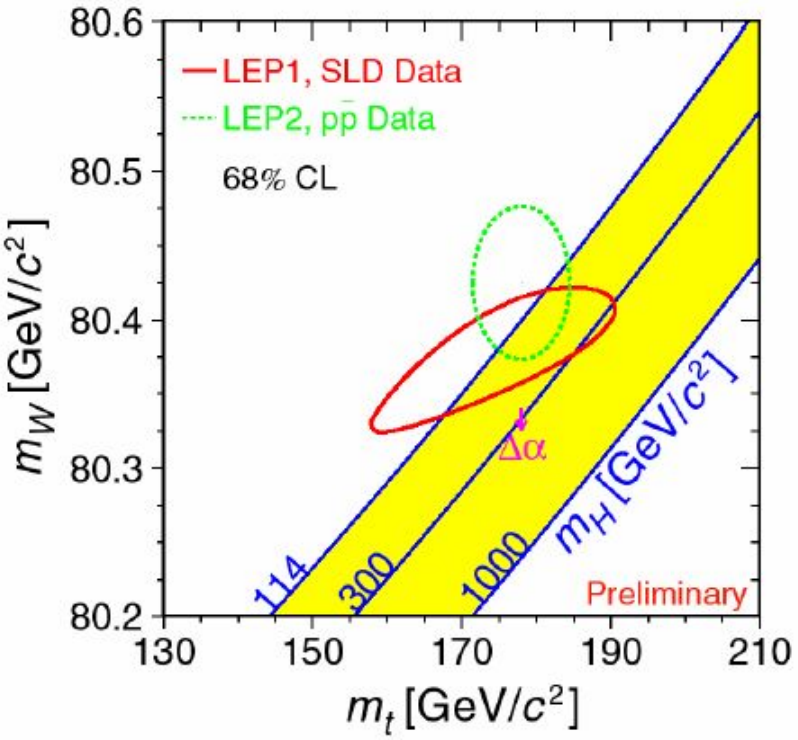
for the CDF and DØ collaborations

Fermilab

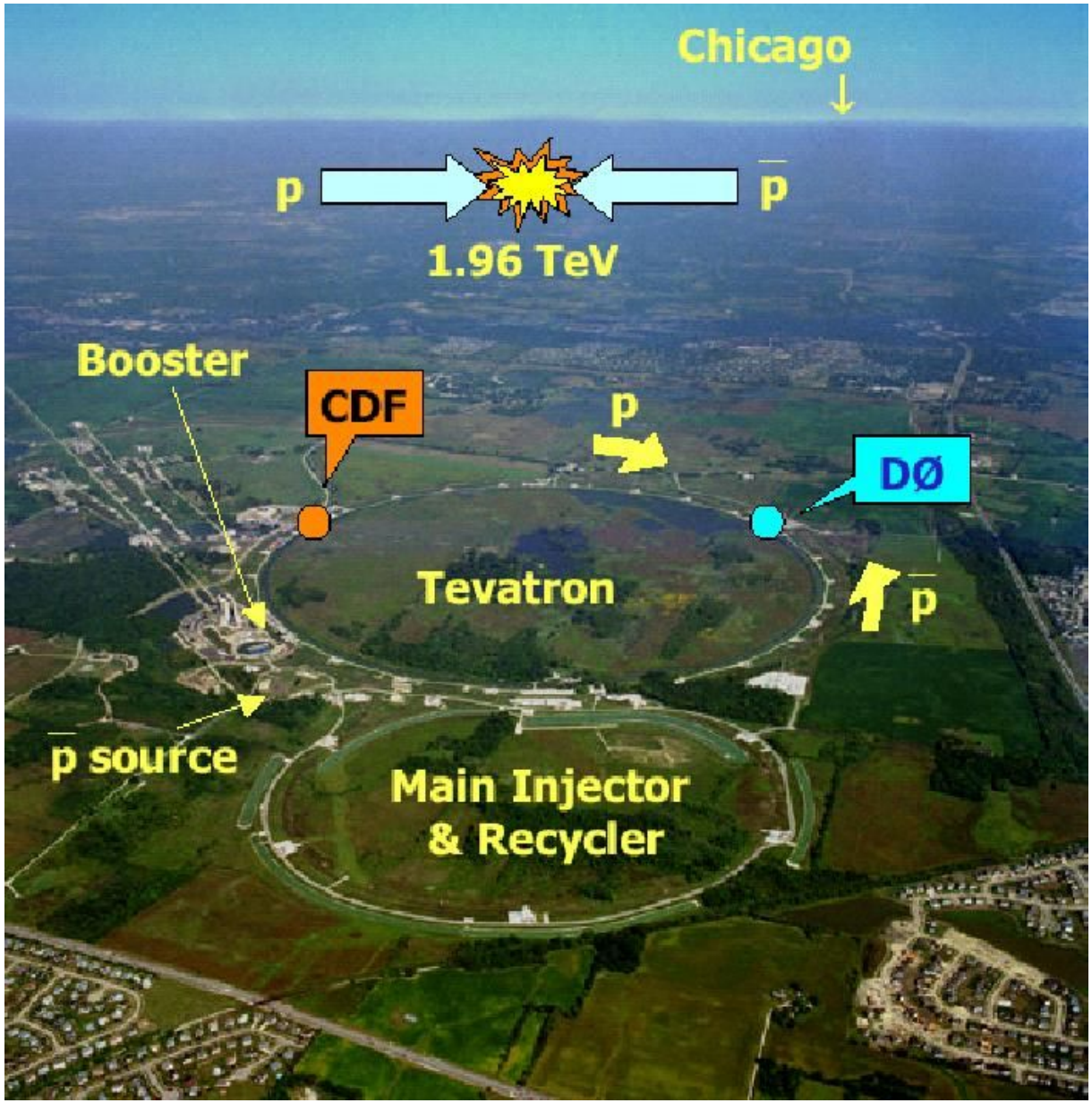
- Motivation
- Experiments and Detectors
- Event topology
- Analysis methods
- Z results
- W results
- Summary

Motivation

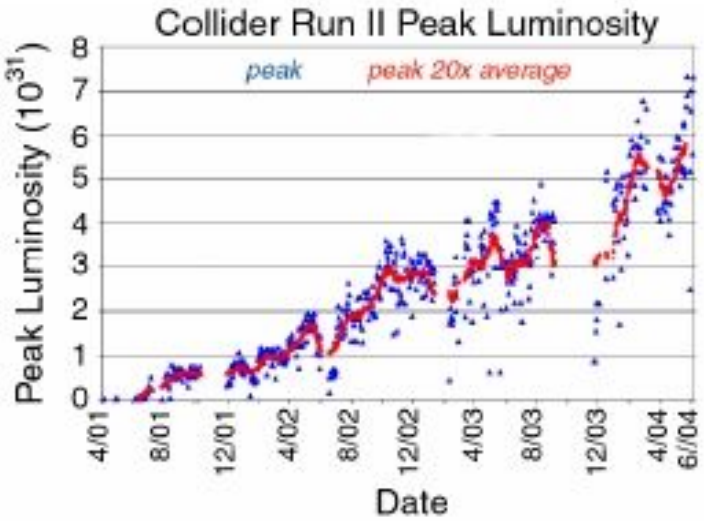
- Ultimate goal is to measure M_W accurately - measuring cross sections is a necessary first step
- M_W , M_t , and M_H are related - constrain one $\rightarrow$ contrains all
- Test standard model couplings
- Study higher order QCD
- Study detector performance and luminosity



Experiments and Detectors

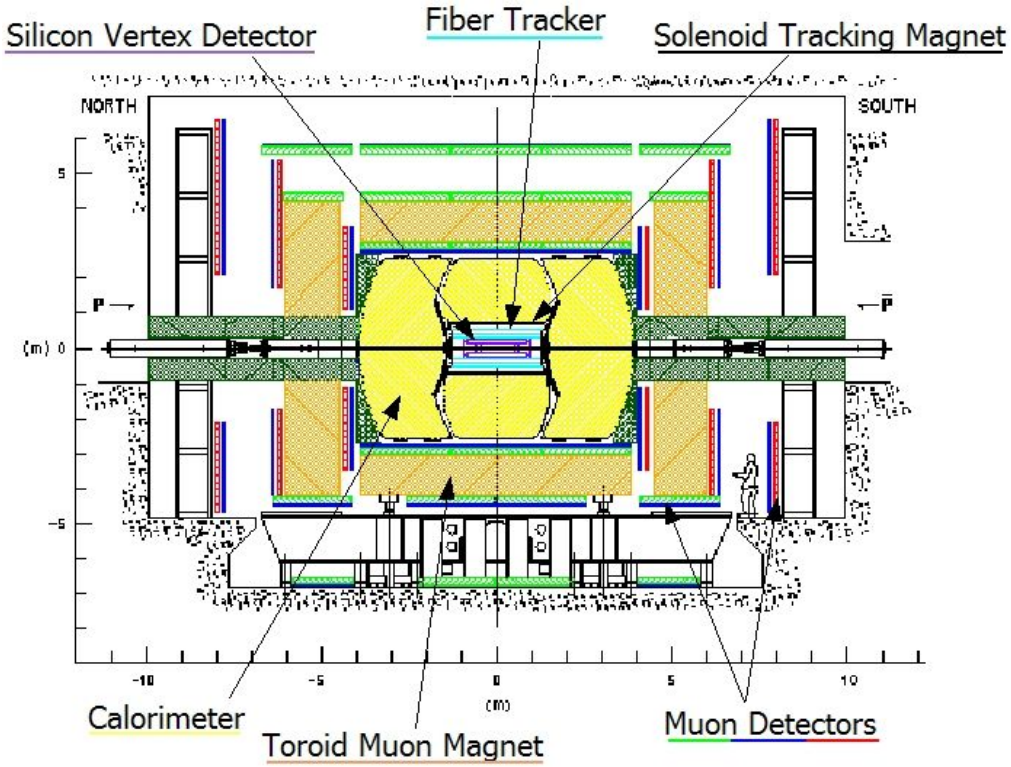


- Experiments are at Fermilab
- Use proton-antiproton collider ("Tevatron")
- Statistics limited
  - ~10^6 W s per fb^{-1}
  - ~10^5 Z s per fb^{-1}



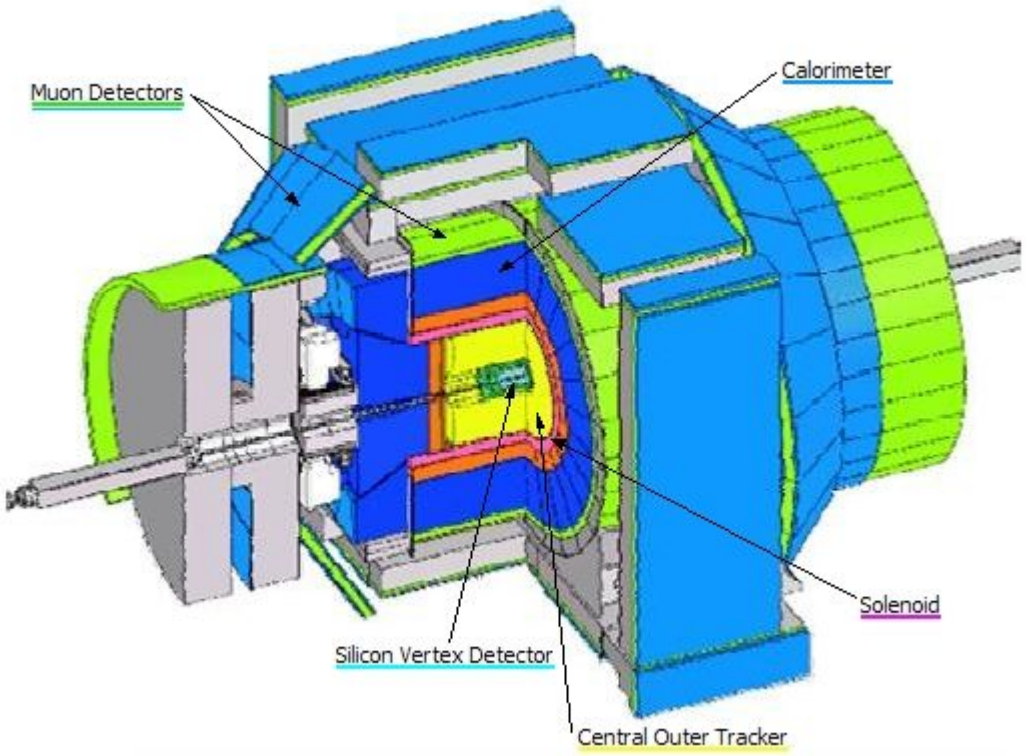
Detectors

DØ detector



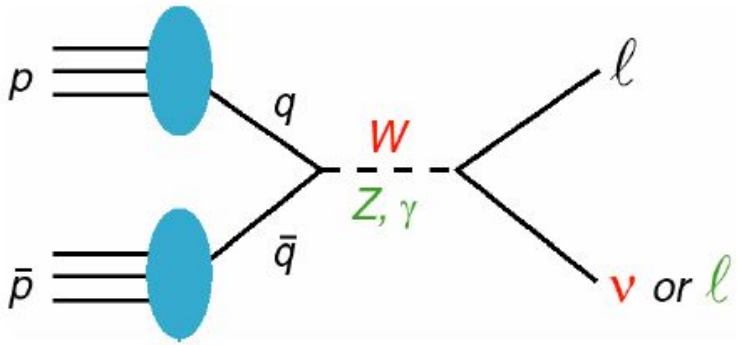
- Energy stored in magnetic field : 5 MJ
- ~500 pb^{-1} on tape; these results use 17-162 pb^{-1}

CDF detector



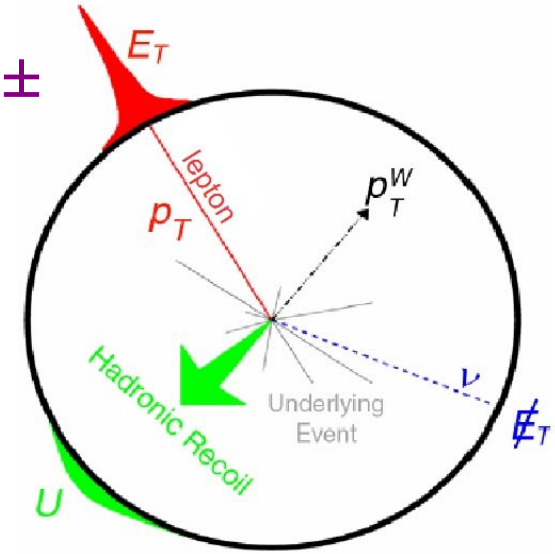
- Energy stored in magnetic field : 30 MJ
- ~500 pb^{-1} on tape; these results use 65-200 pb^{-1}

Event Topology



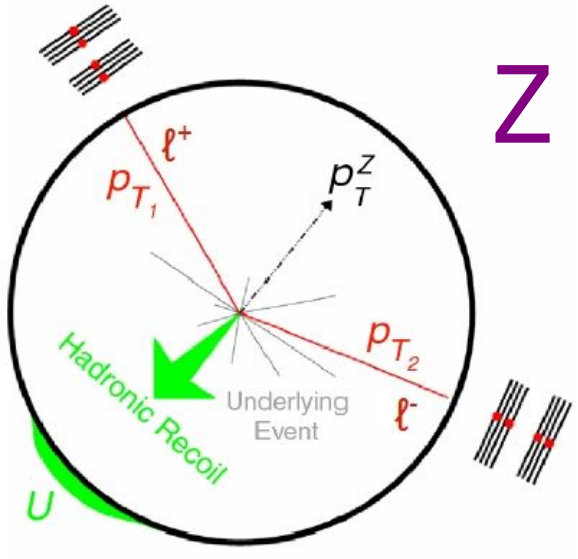
- Use lepton decay channels because they are clean

$W^{\pm}$



- energetic lepton
- missing E_T ("$\not\!\!E_T$")

Z^0



- 2 energetic leptons
- (leptons w/ opposite signs)

Analysis Methods

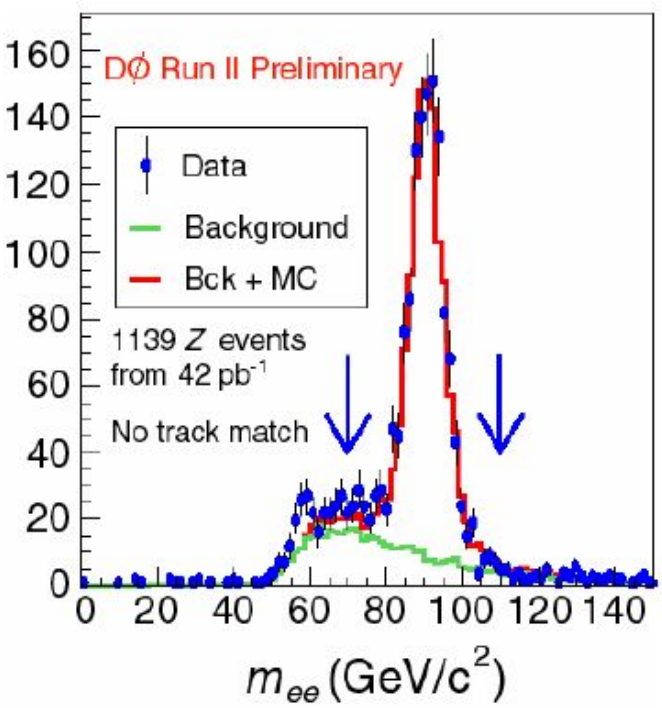
- CDF and DØ use similar analysis strategies
- Trigger criteria
  - DØ:
    - calorimeter activity for e
    - muon system track for μ
  - CDF: track in central for both
- Selection criteria
  - lepton + $\not\!\!E_T \Rightarrow$ W
  - 2 (opp. sign) leptons $\Rightarrow$ Z
- Measure ID efficiencies with Z s
- Measure backgrounds with QCD dijet events
- Limiting systematic uncertainties:
  - luminosity (~6%)
  - PDF (1-2%)
  - lepton ID (~1%)

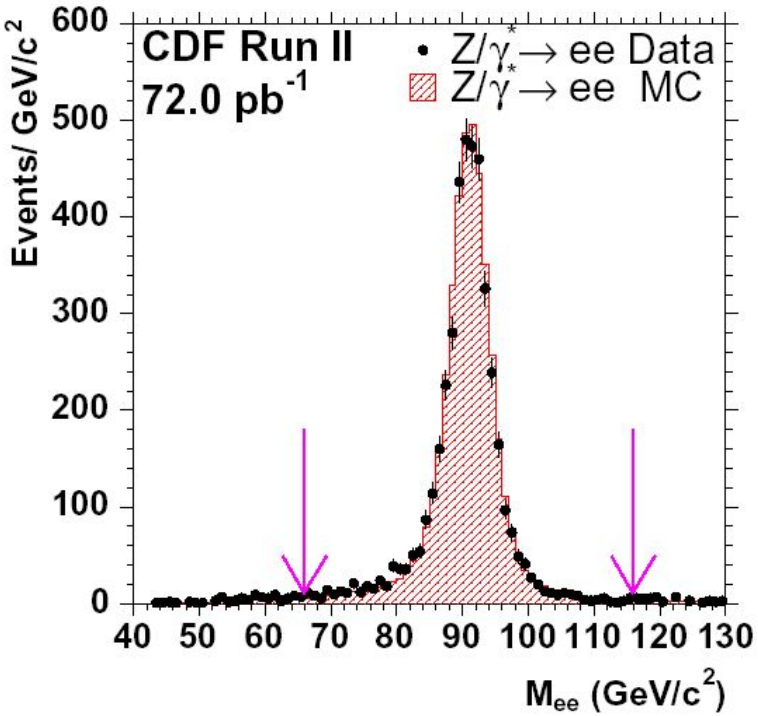
Analysis Methods - cont.

- Electron requirements
  - EM-type calorimeter system cluster
  - cluster is isolated
  - track pointing to cluster
- Muon requirements
  - track matched to calorimeter MIP or muon system track
  - appropriate timing coincidence and impact parameter
  - track and calorimeter isolation
- Tau requirements
  - 1 or 3 tracks plus reconstructible π^0s
  - narrow jet in calorimeter
  - isolated track(s)
  - hadronic products recontruct to τ mass

Z Results - Z→ee cross section

- 2 EM objects with p_T > 25 GeV/c
- Small backgrounds: QCD, Z→ττ





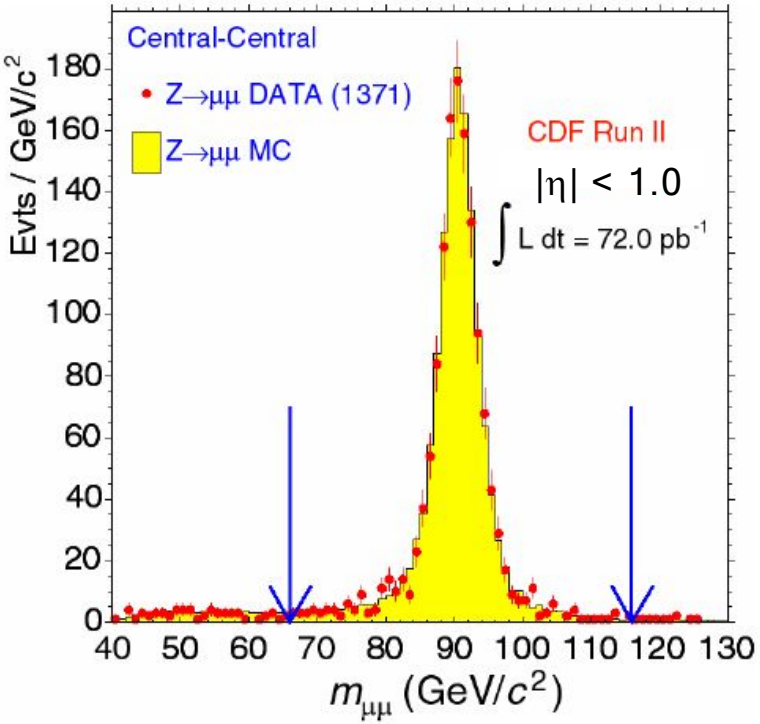
- |η| range:
  - CDF: central + plug cal. (|η|<2.8)
  - DØ: central cal. only (|η|<1.1)

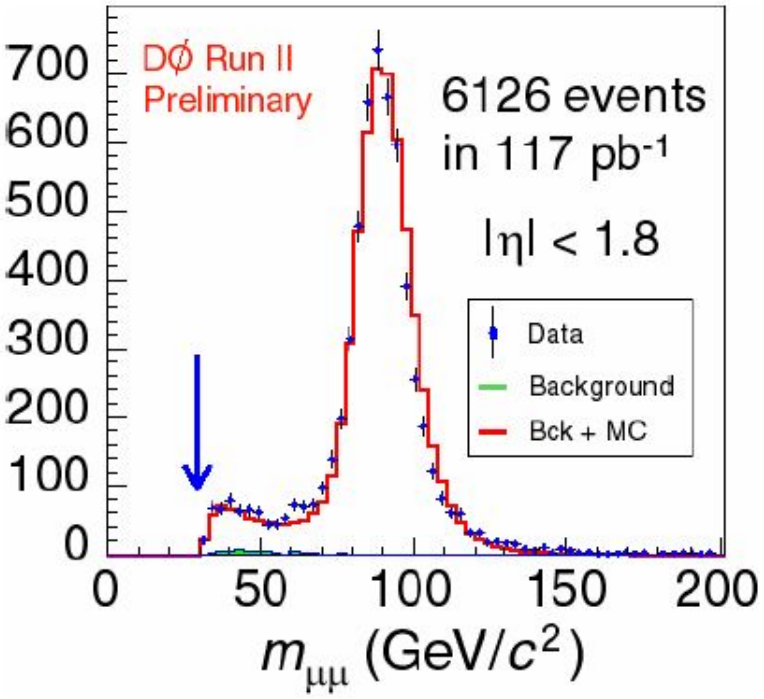
DØ: σ x BR(Z→ee)= 275.2 ±9$_{stat}$ ±9$_{sys}$ ±28$_{lum}$ pb

CDF: σ x BR(pp→γ* / Z→ee)= 255.8 ±3.9$_{stat}$ ±5.5$_{sys}$ ±15.4$_{lum}$ pb

Z Results - Z→μμ cross section

- 2 objects with p_T > 15-20 GeV/c
- Small backgrounds: QCD, Z→ττ





- DØ applies Drell-Yann corrections
- CDF result is published

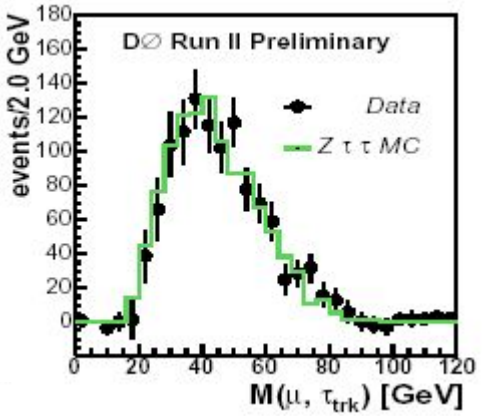
DØ: σ x BR(Z→μμ)= 261.8 ±5.0$_{stat}$ ±8.9$_{sys}$ ±26.2$_{lum}$ pb

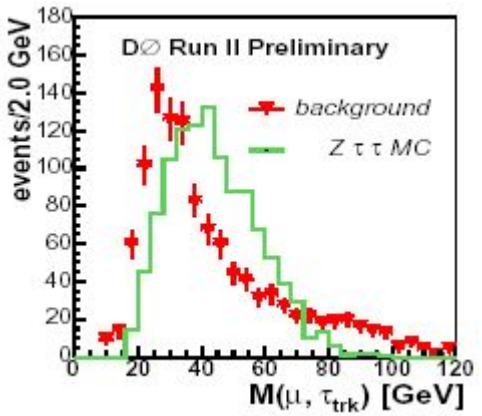
CDF: σ x BR(pp→γ* / Z→μμ)= 248.0 ±5.9$_{stat}$ ±7.6$_{sys}$ ±14.9$_{lum}$ pb

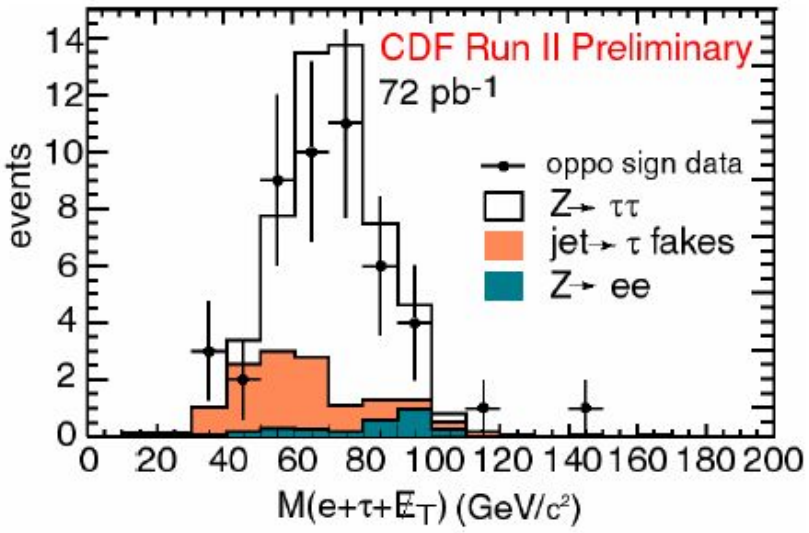
Z Results - $Z \rightarrow \tau\tau$ cross section

- Look for 1 prong decays
- Look for other τ via e or μ

$$Z^0 \rightarrow \tau\tau \rightarrow (e \text{ or } \mu)\nu\nu$$
$$\rightarrow \pi^{\pm}\nu + N\pi^0$$







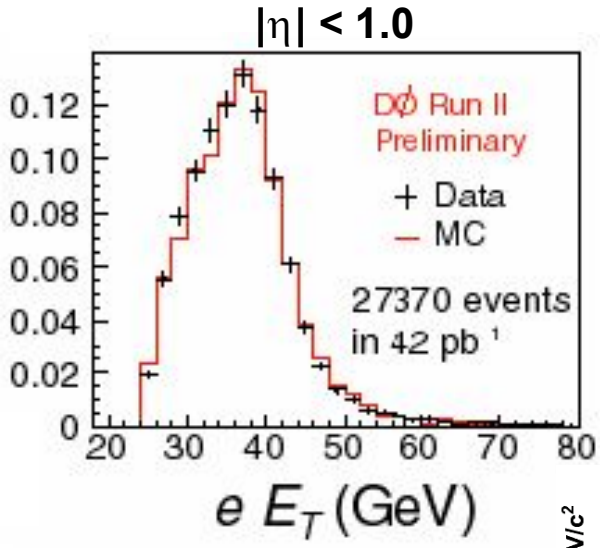
- Important channel for searches
- Proof that $\tau\tau$ resonances are seen at the Tevatron

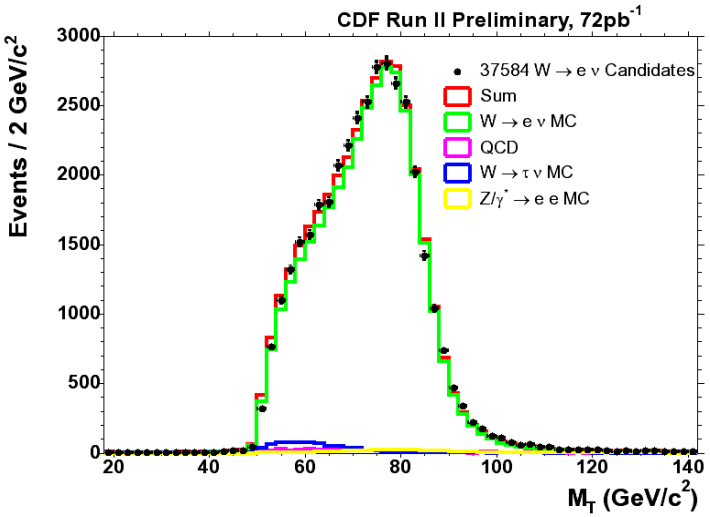
DØ: σ x BR($Z \rightarrow \tau\tau$)= 256 $\pm 16_{stat} \pm 17_{sys} \pm 16_{lum}$ pb

CDF: σ x BR($p\bar{p} \rightarrow \gamma^*$ / $Z \rightarrow \tau\tau$)= 242 $\pm 48_{stat} \pm 26_{sys} \pm 15_{lum}$ pb

W Results - W→eν cross section

- Require
  - E_T(e) > 25 GeV
  - $\not\!\!E_T$ > 25 GeV
  - track match
- Backgrounds:
  QCD, W→τν, Z→ee

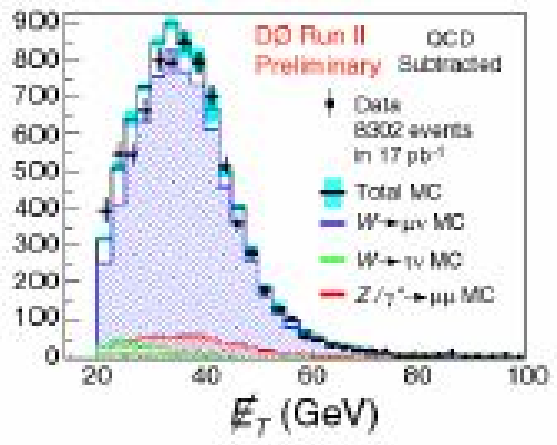




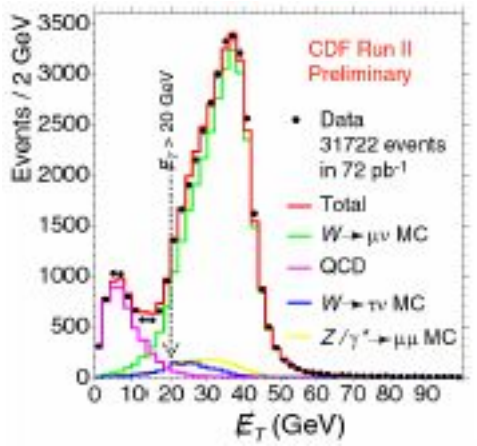
DØ: σ x BR(W→eν)= 2844 ±21$_{stat}$ ±128$_{sys}$ ±284$_{lum}$ pb

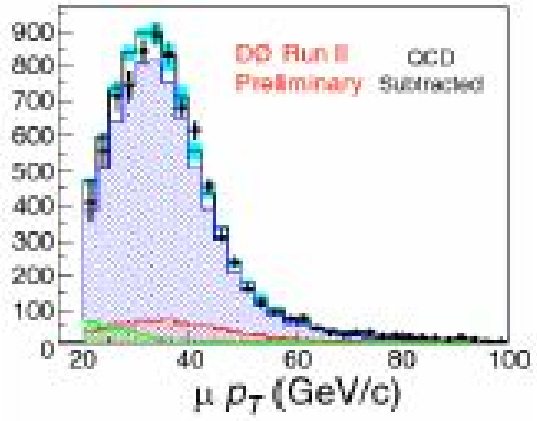
CDF: σ x BR(W→eν)= 2780 ±14$_{stat}$ ±60$_{sys}$ ±167$_{lum}$ pb

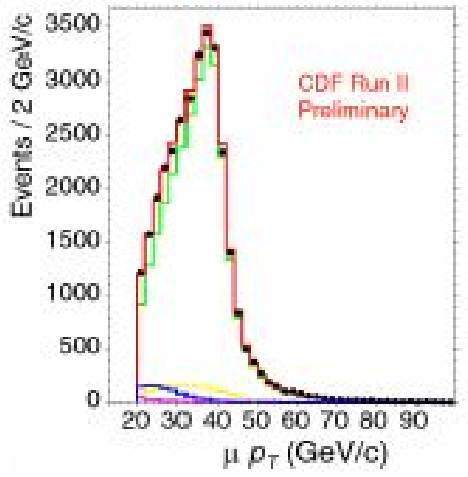
W Results - W→μν cross section



- Require
  - $p_T(\mu) > 20$ GeV
  - $\not\!\!E_T > 20$ GeV
- Backgrounds:
  - $Z \rightarrow \mu\mu$
  - $W \rightarrow \tau\nu$
  - QCD (b-jets)







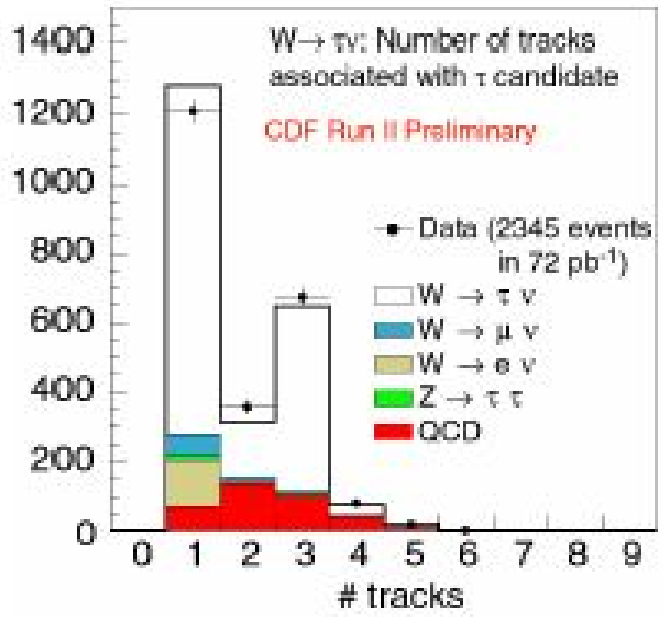
CDF: σ x BR(W→μν)= 2768 ±16$_{stat}$ ± 64$_{sys}$ ±166$_{lum}$ pb

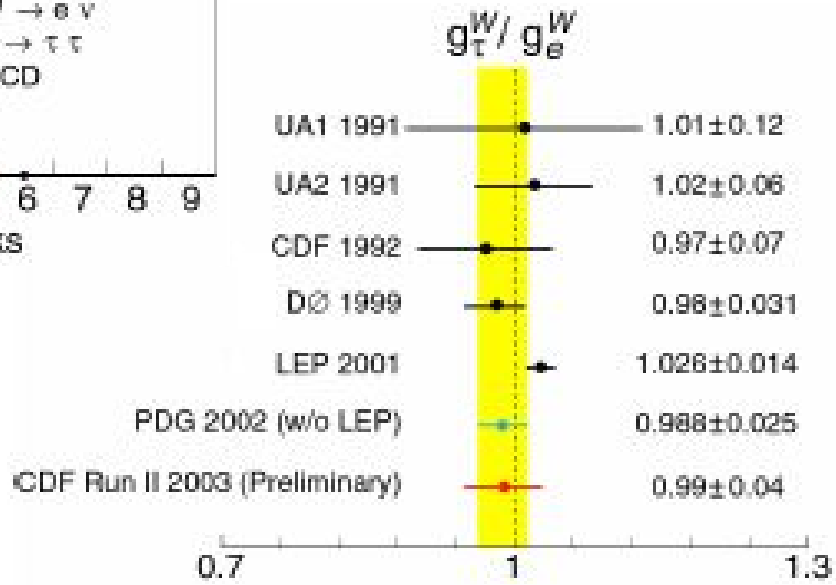
DØ: σ x BR(W→μν)= 3226 ±128$_{stat}$ ±100$_{sys}$ ±322$_{lum}$ pb

W Results - W→τν cross section

- Require
  - $E_T(\tau) > 25$ GeV
  - $\not\!\!E_T > 25$ GeV
  - no other jets above 5 GeV

- $g_\tau / g_e = \sqrt{\frac{BR(W \to \tau \nu)}{BR(W \to e \nu)}}$





σ x BR(W→τν)= 2620 ±70$_{stat}$ ±210$_{sys}$ ±160$_{lum}$ pb

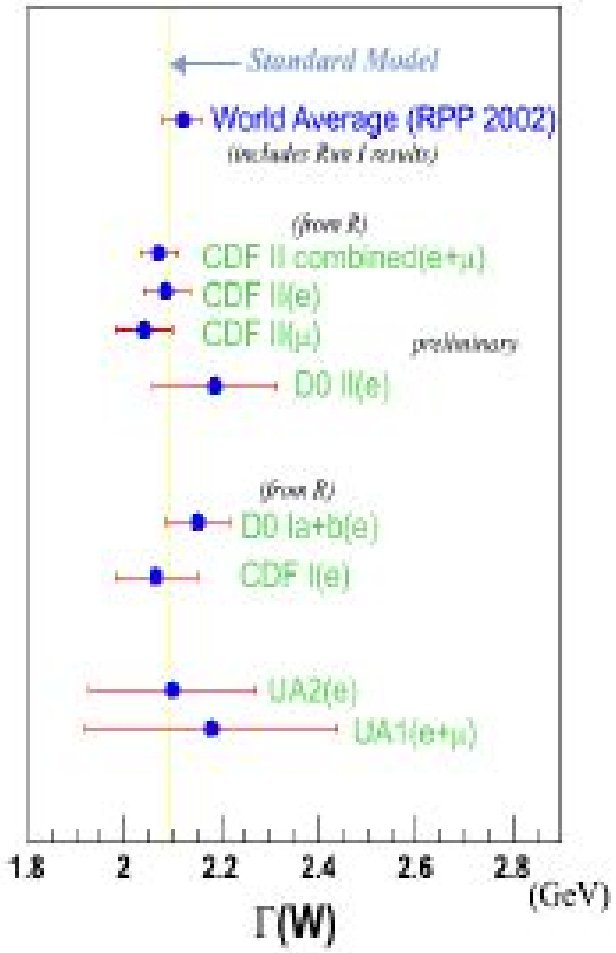
g_τ / g_e = 0.99 ±0.02$_{stat}$ ±0.04$_{sys}$

W Results - Preliminary Width

- Use measured W and Z cross sections, and "R "

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

- Measured values (CDF preliminary)
  - $R_e = 10.86 \pm 0.18_{stat} \pm 0.16_{sys}$
  - $R_\mu = 11.10 \pm 0.27_{stat} \pm 0.17_{sys}$
- Theoretical values (NNLO,PDG)
  - $\sigma(\, p\bar{p}\to W\,) / \sigma(\, p\bar{p}\to Z\,) = 3.368 \pm 0.024$
  - $BR(W\to \ell\nu) = 0.1093 \pm 0.0021$
- LEP : $\Gamma(Z\to \ell\ell) / \Gamma(Z) = (\, 3.366 \pm 0.0002)\%$
- **$\Gamma(W) = 2071 \pm 40$ MeV**



Summary - cross section comparison

Experiment	Channel	# events	Purity	Lum.(pb^{-1})	$\varepsilon \cdot A$	$\lvert\eta\rvert$ coverage
CDF	$W \to e\nu$	48045	94.0%	72	23.1%	2.8
DØ	$W \to e\nu$	27370	95.7%	42	18.4%	1.1
CDF	$W \to \mu\nu$	31722	90.0%	72	14.4%	1.0
DØ	$W \to \mu\nu$	8302	88.0%	17	13.2%	1.6
CDF	$Z \to ee$	4242	98.5%	72	22.7%	2.8
DØ	$Z \to ee$	831*	98.3%	42	10.0%	1.1
CDF	$Z \to \mu\mu$	1785	98.5%	72	10.2%	1.0
DØ	$Z \to \mu\mu$	1139	98.9%	117	16.4%	1.8

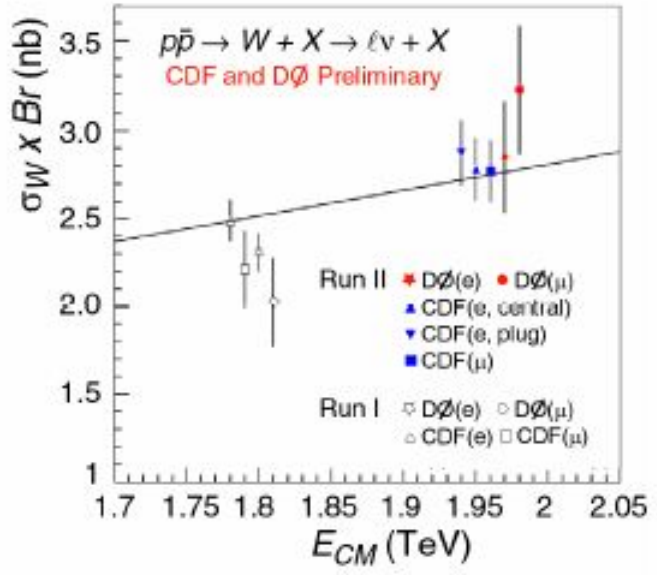
* track match on both electrons required

- DØ and CDF analyses similar except in $\lvert\eta\rvert$ coverage
  - DØ uses forward muon system for far μ coverage
  - CDF uses plug calorimeter for far e coverage
- the greater the angular coverage the better!

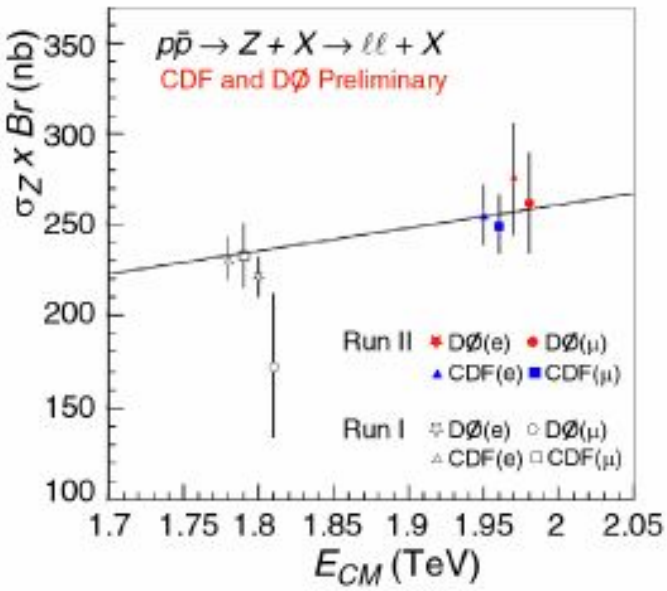
$$\sigma \cdot \boldsymbol{Br} = \frac{N - N_{bkg}}{\epsilon \cdot A \cdot \int L\,dt}$$

Summary

- Preliminary results are consistent with Standard Model



("fit" lines are NNLO theory from Hamberg, van Neerven, Matsuura)



- Many analyses are published or nearing publication
- Further analyses will contain more data (expect >500 pb^{-1} on tape by end of summer)
- Preliminary W mass measurements soon