Electroweak Measurements at the Tevatron

Kristian Harder

Les Rencontres de Physique de La Vallée d’Aoste, La Thuile, 7 March 2007
Precision Measurement of the $W$ Boson Mass with CDF

Chris Hays,
University of Oxford

Les Rencontres de Physique
de la Vallee d’Aoste
March 7, 2007
On the Brink of Revelation and Revolution: Electroweak Symmetry Breaking in 2009

Dr. Richard St. Denis
Glasgow University
La Thuile
March 4-10, 2007
Where the fb\(^{-1}\) are coming from

Fermilab’s Tevatron:
2 km diameter \(p\bar{p}\) collider
centre of mass energy 1.96 TeV
Tevatron performance: peak lumi

very close to the (revised) design luminosity!
Tevatron performance: integrated lumi

Integrated lumi still falling short of 55 pb$^{-1}$ per week expectation.
Still problems with antiproton stacking rate!

**BUT:** delivered lumi per experiment growing quickly
Tevatron performance: integrated lumi

Delivered luminosity per experiment: currently \( \approx 2.4 \text{ fb}^{-1} \)

Lumi used in analyses presented today: typically \( \approx 1 \text{ fb}^{-1} \)

Difference explained by:

- \( \approx 1 \) year delay in preparing data for analysis
  (understanding detector effects etc)
- Losses due to hardware and data quality problems

Integrated lumi still falling short of \( 55 \text{ pb}^{-1} \) per week expectation.

Still problems with antiproton stacking rate!

**BUT:** Delivered lumi per experiment growing quickly
Each experiment has collected >2 fb$^{-1}$ of 1.96 TeV $\sqrt{s}$ pp collisions

Current Run II: >15x Run I data set

First Run II W mass measurement uses 200 pb$^{-1}$ of CDF data
$\eta = -\ln(\tan(\theta/2))$

- $\eta = 0$: central muon
- $\eta = 1$: central tracker
- $\eta = 1.7$: central tracker
- $\eta = 2$: forward muon
- $\eta = 3$: forward tracker
- $\eta = 4.2$: calorimeter
DØ tracking detectors

- 8 (+1) layers of silicon strips
- 16 (-2) silicon disks
- 16 scintillating fiber layers
- ≈2 T solenoid

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CDF Run II detector
CDF Detector

High-precision tracking drift chamber
\[ \delta p_T/p_T = 0.05\% \quad p_T : 2\% \text{ for } 40 \text{ GeV } \mu \]

High-precision electromagnetic calorimeter
\[ \delta E_T/E_T = 13.5\%/\sqrt{E_T} \oplus 1.7\% : \]
\[ 3\% \text{ for } 40 \text{ GeV } e \]
CDF inner detectors

- 6–7 layer silicon
- COT: 96 layer
- 1.4 T solenoid
SM cross-section predictions

Tevatron Run II $p\bar{p}$ at $\sqrt{s} = 1.96$ TeV/c$^2$

**Cross-Section [pb]**

$10^4$

$10^3$

$10^2$

$10^1$

$10^{-1}$

$W\, Z\, W\gamma\, Z\gamma\, WW\, WZ\, ZZ\, H\rightarrow WW$

**SM Expectation**

- $W$ cross-section
- $Z$ cross-section
- $W\gamma$ cross-section
- $Z\gamma$ cross-section
- $WW$ cross-section
- $WZ$ cross-section
- $ZZ$ cross-section

**Reconstructed events:**

- $O(100k)$ per fb$^{-1}$ per final state
- $O(1)$ per fb$^{-1}$ per final state

**Note:** this is $\sigma$, not $\sigma \times \text{BR}$

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Electroweak physics 101

Simplest tree-level diagrams to study at hadron colliders:

\[ Z \rightarrow \ell\ell, \ W \rightarrow \ell\nu \] reconstruction can be studied very well:

- clean signature (high \(p_t\) leptons)
- high rate (for single W,Z production)

Electroweak physics = excellent laboratory for precision studies!
- testing the SM beyond leading order
- detecting non-SM contributions
- constraining PDFs

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Tevatron Run I/II W/Z cross-sections

\[ p\bar{p} \rightarrow Z + X \rightarrow \ell\ell + X \]

\[ p\bar{p} \rightarrow W + X \rightarrow \ell\nu + X \]

Total W, Z production cross-sections: good agreement with Standard Model (at current precision!)

**BUT:** not the most sensitive observable to look at for SM checks!

**anyone awake yet?**

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Electroweak topics of the day

Analyses presented in this talk:

- differential Z cross sections (rapidity, transverse momentum)
- better distinction of production mechanisms
- diboson production ($WW, WZ, ZZ, W\gamma, Z\gamma$)
- unknown loop contributions?
- anomalous triple gauge couplings?
- high mass particles decaying to two bosons? (Higgs?)

All these require a lot more integrated luminosity to study than $\sigma_{tot}(p\bar{p} \to W+X)$ and $\sigma_{tot}(p\bar{p} \to Z+X)$.
lepton identification

**Electrons**
- $E_t$ above $\approx 20$ GeV
- shower shape criteria
- isolation requirement
- $|\eta|$ coverage CDF $< 1.1$ (central), $1.2 - 2.0$ (forward)
- DØ $< 1.1$ (central), $1.5 - 2.5$ (forward)

**Muons**
- $p_t$ above $\approx 20$ GeV
- isolation requirement
- $|\eta|$ coverage CDF $< 1.1/1.2$ (central)
- DØ $< 1$ (central), $1 - 2$ (forward)

**Tau** not treated separately. $\tau \rightarrow e, \tau \rightarrow \mu$ included in $e, \mu$ channels

**Neutrinos**
- missing $E_t$ above $\approx 20$ GeV
- CDF: isolation requirement (angular distance)
Z rapidity

**forward region probes PDF**
at low $x +$ large $Q^2$, and at large $x$

**use $Z\rightarrow ee$ events: best $\eta$ range —**
DØ: $|\eta| < 3.2$, CDF: $|\eta| < 2.8$

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**Z transverse momentum**

- **boson** $p_t$ can be non-zero for NLO
- **$p_t$ shape predicted by resummation**
- $> 1$ model for small $x$ (\(=\)large rapidity)
  \(\rightarrow\) forward region very interesting!

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**tricky analysis:**
- sensitive to electron energy scale
- $p_t$ dependence of lepton ID

**improving model sensitivity:**
- more data
- plot in bins of Z rapidity
  \(\rightarrow\) updated version due soon
$Z\gamma$ production

no LO $ZZ\gamma$ and $Z\gamma\gamma$ vertices in SM $\rightarrow$ $Z\gamma$ production only as ISR or FSR

new physics could be found as additional $ZZ\gamma$ or $Z\gamma\gamma$ contribution potentially with high $E_t$ photons

CDF and DØ analyses: $Z \rightarrow ee$ selection photon with $E_t > 7$ GeV (angular separation)

two-body vs three-body mass

CDF Run II Preliminary, 1.1fb$^{-1}$

$E_t$ spectrum

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Z$\gamma$ results

| candidates | $Z\gamma$ cross section $\times$ BR | SM prediction |
|------------|-----------------------------------|---------------|
| DØ 387    | $4.51\pm0.37(\text{stat+syst})\pm0.27(\text{lum})$ pb | $4.2\pm0.2$ pb |
| CDF 390   | $4.9\pm0.3(\text{stat})\pm0.3(\text{syst})\pm0.3(\text{lum})$ pb | $4.7\pm0.4$ pb |

NB: different SM predictions due to different kinematic region
good agreement with Standard Model!

two-body vs three-body mass

photon $E_t$ spectrum

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Now with LO diagrams:

Similar analysis to $Z\gamma$, but $W \rightarrow \mu \nu$ (CDF+DØ), $W \rightarrow e\nu$ (DØ)

CDF RunII Preliminary 1/fb

\begin{align*}
\text{Number of Events/(7GeV)} & \quad 10^{-1} \quad 10 \quad 10^2 \quad 10^3 \\
\text{Photon } E_T \text{ (GeV)} & \quad 0 \quad 20 \quad 40 \quad 60 \quad 80 \quad 100 \quad 120 \quad 140 \quad 160
\end{align*}

CDF uses tight FSR veto: $M_t(W\gamma) > 110$ GeV

|          | cands | $Z\gamma$ cross section $\times$ BR | SM prediction |
|----------|-------|-------------------------------------|--------------|
| CDF $\mu$ | 855   | $19.11 \pm 1.04 \text{(stat)} \pm 2.40 \text{(syst)} \pm 1.11 \text{(lum)}$ pb | $19.3 \pm 1.4$ pb |
| DØ $\mu$  | 245   | $3.21 \pm 0.49 \text{(stat+syst)} \pm 0.20 \text{(lum)}$ pb | $3.21 \pm 0.08$ pb |
| DØ $e$    | 389   | $3.12 \pm 0.49 \text{(stat+syst)} \pm 0.19 \text{(lum)}$ pb | $3.21 \pm 0.08$ pb |
increased sensitivity to anomalous couplings through charge-signed rapidity difference:

interference between tree-level diagrams

dip in \( Q_\ell \times [y(\gamma) - y(\ell)] \)

prediction (SM vs example anom TGC)

good agreement with Standard Model

...and with many other scenarios...

clearly need more data for this measurement!
WW (SM: $12.4 \pm 0.8$ pb)

WZ (SM: $3.7 \pm 0.3$ pb)

ZZ (SM: $1.4 \pm 0.1$ pb)
**CDF WW with 0.8 fb$^{-1}$**

\[ WW \rightarrow \ell\ell\nu\nu \text{ with } \ell\ell = ee, e\mu, \mu\mu \]

\[ \approx \text{std lepton selection, missing } E_t, \text{jet veto, opposite charge, } |\Delta z| < \pm 4 \text{ cm} \]

**95 events, cross section** 13.6$\pm$2.3(stat)$\pm$1.6(syst)$\pm$1.2(lumi) pb,

**SM prediction** 12.4$\pm$0.8 pb

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WZ → ℓℓℓν, with eee, eem, emm, mmμ (total BR ≈ 1.5%) again, standard lepton and missing $E_t$ selection. require two leptons in Z mass window.

**selection results:**

|     | candidates | background     | signal significance |
|-----|------------|----------------|---------------------|
| DØ  | 12         | 3.61±0.20      | 3.34σ               |
| CDF | 16         | 2.65±0.28±0.33±0.09 | 6.0σ               |

**Z mass**

background composition similar, just overall worse S/B ratio for DØ
WZ cross section

|          | measured                        | predicted   |
|----------|---------------------------------|-------------|
| CDF      | $5.0^{+1.8}_{-1.4} \text{(stat)} \pm 0.4 \text{(syst) pb}$ | $3.7 \pm 0.3 \text{ pb}$ |
| DØ       | $4.0^{+1.9}_{-1.5} \text{(stat+syst) pb}$               | $3.7 \pm 0.3 \text{ pb}$ |

CDF Run II Preliminary \[ \int L \, dt = 1.1 \text{ fb}^{-1} \]

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How about events with 4 leptons? SM predicts $\approx 2$ events in 1 fb$^{-1}$...

Here is a candidate.

The only one so far.

$\sigma(ZZ) < 3.8$ pb
(95% C.L.)

(SM: $1.4 \pm 0.1$ pb)

With 4–8 fb$^{-1}$, this could become another first observation.

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DØ+CDF data samples increase quickly
understanding of detector response improving as well
bringing electroweak precision physics to the next next-to-next level!

Precision physics playground
established signals —
more data should help to improve those!
promising searches
acts of desperation $\rightarrow$ LHC?
**W Boson Mass**

Given precise measurements of $m_Z$ and $\alpha_{EM}(m_Z)$, we can predict $m_W$:

$$m_W^2 = \frac{\pi \alpha_{EM}}{\sqrt{2} G_F (1 - m_W^2/m_Z^2)(1 - \Delta r)}$$

(“on-shell scheme”)

$\Delta r$: O(3%) radiative corrections dominated by $tb$ and Higgs loops

$\Delta m_W \propto m_t^2$

$\Delta m_W \propto \ln (m_H/m_Z)$

C. Hays, University of Oxford
Predicted Higgs mass from global electroweak data:

\[ m_H = 85^{+39}_{-28} \text{ GeV} \ (\text{at } 95\% \text{ CL}) \]

Direct search from LEP II: \( m_H > 114.4 \text{ GeV} \) at 95\% CL

C. Hays, University of Oxford
W Mass Prediction and Measurement

W mass uncertainty from input parameters:

| Parameter Shift | $m_W$ Shift (MeV/$c^2$) |
|-----------------|--------------------------|
| $\Delta m_H = +100$ GeV/$c^2$ | -41.3                   |
| $\Delta m_t = +2.1$ GeV/$c^2$ | 12.8                    |
| $\Delta m_Z = +2.1$ MeV/$c^2$ | 2.6                     |
| $\Delta \alpha_{EM} = +0.00013$ | -2.3                   |

Direct W mass measurement

| W-Boson Mass [GeV] | |
|--------------------|--|
| TEVATRON            | 80.452 ± 0.059 |
| LEP2               | 80.376 ± 0.033 |
| Average            | 80.392 ± 0.029 |

W mass predicted much more precisely (13 MeV) than measured (29 MeV)

Need to reduce $\delta m_W$ to further constrain $m_H$ and other new physics

C. Hays, University of Oxford
Weak Boson Physics

Z boson parameters measured precisely by LEP:
* 17 million measured Z candidates: $\delta m_Z = 2.1$ MeV, $\delta \Gamma_Z = 2.3$ MeV

Tevatron goal:
* World's most precise W boson measurements
* Expect 15 million measured W candidates
W & Z Boson Production and Decay

Dominant production mechanism: $q\bar{q}^{'(\gamma)}$ annihilation

$\sigma(W \rightarrow l\nu) = 2775 \text{ pb}$

After event selection
$(l, \nu E_T > 30 \text{ GeV})$:
51,128 $W \rightarrow \mu\nu$ candidates
63,964 $W \rightarrow e\nu$ candidates

$\sigma(Z \rightarrow ll) = 254.9 \text{ pb}$

After event selection
$(l E_T > 30 \text{ GeV})$:
4,960 $Z \rightarrow \mu\mu$ candidates
2,919 $Z \rightarrow ee$ candidates
**Measurement Strategy**

Calibrate $l^\pm$ track momentum with mass measurements of $J/\psi$ and $Y$ decays to $\mu$

Calibrate calorimeter energy using track momentum of $e$ from $W$ decays

*Cross-check with $Z$ mass measurement, then add $Z$'s as a calibration point*

Calibrate recoil measurement with $Z$ decays to $e, \mu$

*Cross-check with $W$ recoil distributions*

Combine information into transverse mass:

$$m_T = \sqrt{E_T^e E_T^\mu (1 - \cos \Delta \phi)}$$

**Statistically most powerful quantity for $m_W$ fit**
Momentum Scale Calibration

Magnetic field along z-axis causes curvature in transverse plane:

\[ \frac{mv^2}{R} = evB, \]
\[ p_T = eBR \]

CDF: Insufficient precision on \( B \) and \( R \) for \( W \) mass measurement

**In-situ calibration:**
(1) Apply relative alignment of drift chamber wires

(2) Determine momentum scales such that \( J/\psi, Y, \) and \( Z \) mass measurements result in the world-average values

Combine results to obtain scale for \( m_W \) measurement
Alignment and Corrections

Align tracker using cosmic-ray data
Determine track-level corrections from electron-positron differences
Use ratio of calorimeter energy to track momentum

*Curvature biases affect* $e^+$, $e^-$ differently, but calorimeter measurement independent of charge

Statistical uncertainty of track-level corrections leads to $\delta m_w = 6$ MeV
Tracker Alignment

Central Outer Tracker: Open-cell drift chamber
Wires strung under tension between two endplates

Model endplate distortions and constructional variations using a cell-to-cell endplate alignment

Determine individual cell tilts & shifts using cosmic-ray data
Fit a single 'dicosmic' to track segments on opposite sides of the chamber
Measure cell displacement

C. Hays, University of Oxford

(Kotwal, Gerberich, Hays, NIM A 506, 110 (2003))
Alignment Example

Inner 'Superlayer:'

Before alignment

After alignment

CDF Run II preliminary

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Wire Alignment

Wire shape along z-axis determined by:
- Gravitational sag
- Electrostatic effects

Apply additional correction based on cosmic ray study
- Compare parameters of incoming and outgoing tracks from a cosmic ray muon

Final correction removes $z$-dependent curvature biases
Mass Measurements

Template mass fits to $J/\psi$, $Y$, $Z$ resonances in muon decay channels

Fast detector simulation models relevant physical processes
- internal bremsstrahlung
- ionization energy loss
- multiple scattering

Simulation includes event reconstruction and selection

Detector material model
- Map energy loss and radiation lengths in each detector layer

One material parameter determined from data:
- Overall material scale
Y Mass Measurement

$\lambda = 200 \text{ pb}^{-1}$  CDF Run II Preliminary

$\Delta p / p = (-1.38 \pm 0.06) \times 10^3$

$\chi^2 / \text{dof} = 26 / 18$

Tracks with beam constraint

34,618 $Y \rightarrow \mu\mu$ candidates

Short lifetime allows a track constraint to the beam line

Improves resolution by a factor of $\approx 3$

Test beam constraint by measuring mass using unconstrained tracks

Correct by half the difference between fits

Take correction as a systematic uncertainty

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Momentum Scale Calibration

Constrain tracks to originate from the beam line
Improves resolution by a factor of $\approx 3$

Use calibrated momentum scale to measure $Z$ mass

$606,701 \ J/\psi \to \mu\mu$ candidates

Fit mass as a function of mean inverse $p_T$

Slope affected by energy loss modelling

Scale detector material by 0.94 to remove slope

$M_Z = (91184 \pm 43) \text{ MeV}$

$\chi^2/\text{dof} = 32 / 30$
Electron Track Model Validation

Fit Z mass reconstructed from electron track momenta

$\mathcal{L} = 200 \text{ pb}^{-1}$  CDF Run II Preliminary

Measured value consistent with world average value (91188 MeV)
Calorimeter Energy Calibration

Calibrate electron energy using electron track momentum
First step: validate model of electrons in tracker

Additional physical effects beyond those associated with muons:
Photon radiation and conversion in tracker
Full Electron Simulation

- Response and resolution in EM calorimeter
- Energy loss into hadronic calorimeter
- Track reconstruction in outer tracker
- Energy loss in solenoid
- Bremstrahlung and conversions in silicon

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Use GEANT to parametrize energy loss in solenoid and hadronic calorimeter

Energy loss in hadronic calorimeter:
Energy Scale Calibration

Calibrate calorimeter energy with peak of $W$ electron $E/p$ distribution

One free parameter for $X_0$ scale (set with high $E/p$ region)

Material scale: $1.004 \pm 0.009$

Energy scale uncertainty: 0.034%

CDF Run II Preliminary

Calorimeter Energy < Track Momentum:
Energy loss in hadronic calorimeter

Calorimeter Energy > Track Momentum:
Energy loss in tracker

Energy Scale Calibration
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Apply energy-dependent scale to each simulated electron and photon.

Determine energy dependence from $E/p$ fits as functions of electron $E_T$.

Scale:

$$1 + (6 \pm 7) \times 10^{-5} \left[ \frac{E_T}{\text{GeV}} - 39 \right]$$

($\delta m_W = 23$ MeV)

Most energy dependence implicitly accounted for by detector model.
Fit Z mass using scale from $E/p$ calibration

$\mathcal{L} = 200 \text{ pb}^{-1}$  CDF Run II Preliminary

$m_Z = (91190 \pm 67) \text{ MeV}$

$\chi^2/\text{dof} = 34/38$

Measured value consistent with world average value (91188 MeV)

Incorporate mass fit into calibration to reduce scale uncertainty

$\delta m_W = 30 \text{ MeV}$

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Boson $p_T$ Model

Model boson $p_T$ using RESBOS generator with tunable non-perturbative parameters

“$g_2$” parameter determines position of peak in $p_T$ distribution

Measure $g_2$ with Z boson data (other parameters have negligible effect on $W$ mass)

\[ g_2 = 0.685 \pm 0.048; \delta m_W = 3 \text{ MeV} \]
Recoil Measurement

Calculate recoil by summing over calorimeter towers, excluding:
- Towers with lepton energy deposits
- Towers near the beam line

Electron: Remove 7 towers (shower)
Muon: Remove 3 towers (MIP)

Model tower removal in simulation
\[ \delta m_W = 8 \pm 5 \text{ MeV for } \mu \]
Recoil Model

Components:

Recoil scale \((R = \frac{u_{\text{meas}}}{u_{\text{true}}})\)

Recoil resolution

Spectator and additional interactions (contribute to resolution)

Calibrate scale with momentum balance along bisector axis \((\eta)\)

Calibrate models of recoil resolution and spectator interactions using momentum resolution along both axes

\[ \delta m_W = 11 \text{ MeV} \]
Recoil Model Checks

Apply model to $W$ boson sample, test consistency with data

Recoil distribution
- Sensitive to scale, resolution, boson $p_T$

$u_{||}$ distribution
- Sensitive to lepton removal, efficiency model, scale, resolution, $W$ decay
- Directly affects $m_T$, fit result
Production, Decay, Background

Boson $p_z$ determined by parton distribution functions

\[ \text{Vary PDFs according to uncertainties} \]

\[ \delta m_W = 11 \text{ MeV} \]

Bremstrahlung reduces charged lepton $p_T$

\[ \text{Predict using NLO QED calculation, apply NNLO correction} \]

\[ \delta m_W = 11 \ (12) \text{ MeV for } e \ (\mu) \]

Background affects fit distributions

\[ \text{QCD: Measure with data} \]

\[ \text{Electroweak: Predict with MC} \]

\[ \delta m_W = 8 \ (9) \text{ MeV for } e \ (\mu) \]

| Background            | % ($\mu$)   | % ($e$)   |
|-----------------------|-------------|-----------|
| Hadronc Jets          | 0.1 ± 0.1   | 0.25 ± 0.15 |
| Decays in Flight      | 0.3 ± 0.2   | -         |
| Cosmic Rays           | 0.05 ± 0.05 | -         |
| $Z \rightarrow ll$    | 6.6 ± 0.3   | 0.24 ± 0.04 |
| $W \rightarrow \tau\nu$ | 0.89 ± 0.02 | 0.93 ± 0.03 |

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Transverse Mass Distribution

Distribution peaks just below $m_W$ and falls sharply just above $m_W$

$\ m_W = 80 \text{ GeV} $ $ \ m_W = 81 \text{ GeV} $
Mass fit results blinded with [-100,100] MeV offset throughout analysis. Upon completion, offset removed to determine final result.

**Transverse mass fits:**

\[
M_W = (80417 \pm 48 \text{ stat + sys}) \text{ MeV}
\]

for \(e + \mu\) combination \((P(\chi^2) = 7\%)\)

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**W Mass Fits**

Fit $E_T$, $E_T^*$ distributions and combine with $m_T$ to extract most precise result

**Electron $E_T$ fit:**

CDF II preliminary $\int L \, dt \approx 200 \, pb^{-1}$

\[
M_W = (80451 \pm 58_{\text{stat}}) \, \text{MeV}
\]

$\chi^2/dof = 63/62$

**Muon $p_T$ fit:**

CDF II preliminary $\int L \, dt \approx 200 \, pb^{-1}$

\[
M_W = (80321 \pm 66_{\text{stat}}) \, \text{MeV}
\]

$\chi^2/dof = 72/62$

\[
m_W = 80388 \pm 59 \, \text{MeV (stat + sys)}
\]

for lepton $p_T \, e + \mu$ combination ($P(\chi^2) = 18\%$)

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$m_W = 80434 \pm 65 \text{ MeV (stat + sys)}$

for neutrino $p_T e + \mu$ combination ($P(\chi^2) = 43\%$)

Electron $E_T$ fit:

Muon $E_T$ fit:

$m_W = 80413 \pm 48 \text{ MeV (stat + sys)}$

for six-fit combination ($P(\chi^2) = 44\%$)
# W Mass Uncertainties

| $m_T$ Uncertainty [MeV] | Electrons | Muons | Common |
|-------------------------|-----------|-------|--------|
| Lepton Scale            | 30        | 17    | 17     |
| Lepton Resolution       | 9         | 3     | 0      |
| Recoil Scale            | 9         | 9     | 9      |
| Recoil Resolution       | 7         | 7     | 7      |
| $u_\|=\| Efficiency     | 3         | 1     | 0      |
| Lepton Removal          | 8         | 5     | 5      |
| Backgrounds             | 8         | 9     | 0      |
| $p_T(W)$                | 3         | 3     | 3      |
| PDF                     | 11        | 11    | 11     |
| QED                     | 11        | 12    | 11     |
| **Total Systematic**    | **39**    | **27**| **26** |
| **Statistical**         | **48**    | **54**| **0**  |
| **Total**               | **62**    | **60**| **26** |

CDF II preliminary, $L = 200 \text{ pb}^{-1}$

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W Mass Result

New CDF result is world's most precise single measurement

Central value increases: 80392 to 80398 MeV
World average uncertainty reduced ~15% (29 to 25 MeV)
Previous Higgs Mass Prediction

Predicted Higgs mass from global electroweak data:

\[ m_H = 85^{+39}_{-28} \text{ GeV} \quad (< 166 \text{ GeV at 95% CL}) \]

Direct search from LEP II: \( m_H > 114.4 \text{ GeV at 95% CL} \)
Predicted Higgs mass from global electroweak data:

\[ m_H = 80^{+36}_{-26} \text{ GeV} \ (< 153 \text{ GeV at 95\% CL}) \]

Direct search from LEP II: \[ m_H > 114.4 \text{ GeV at 95\% CL} \]

C. Hays, University of Oxford
Additional space-time symmetry (Supersymmetry) would affect the $W$ mass

Previous world average:

![Graph showing $M_W$ vs $m_t$ with various models and experimental errors marked.](image-url)
Effect on New Physics Models

Supersymmetry now preferred at 1σ level...

New world average:

![Graph showing theoretical and experimental errors at the 68% confidence level](image)

- **M_{WW} = 114 GeV**
- **M_{WW} = 400 GeV**
- **M_{WW} = 80.7 GeV**

- LEP2/Tevatron (today)
- light SUSY
- heavy SUSY
- SM
- MSSM
- both models

Heinemeyer, Hollik, Stockinger, Weber, Weiglein '06

C. Hays, University of Oxford
Effect on New Physics Models

Supersymmetry now preferred at 1σ level...

New world average:
Previous $W$ Mass Projections

Previously projected Tevatron precision as a function of luminosity:

Projection with 2 $fb^{-1}$ of data:

$\delta m_W = 40$ MeV per experiment
New W Mass Projections

New projected Tevatron precision as a function of luminosity:

**New projection with 1.5 fb\(^{-1}\) of data:**
\[ \delta m_W < 25 \text{ MeV with CDF} \]

C. Hays, University of Oxford
Filling in the Pieces

Precision electroweak data will continue to guide us to the next physics

**Today:** $\delta m_W = 25$ MeV, $m_H < 153$ GeV at 95% CL

After Higgs: $\delta m_W = 15$ MeV, SUSY predicted at 95% CL?

After SUSY: $\delta m_W = 10$ MeV, more new physics?
Summary

W mass excellent probe for new particles coupling to the electroweak sector

CDF has made the single most precise W mass measurement

\[ m_W = 80413 \pm 34 \text{ MeV (stat)} \pm 34 \text{ MeV (sys)} \]
\[ = 80413 \pm 48 \text{ MeV (stat + sys)} \]

New SM Higgs mass prediction: \[ m_H = 80^{+36}_{-26} \text{ GeV} \]

Mass has moved further into LEP-excluded region

Expect CDF \( \delta m_W < 25 \text{ MeV with } 1.5 \text{ fb}^{-1} \text{ already collected} \)

Will squeeze SM in conjunction with Tevatron Higgs results

Electroweak data will probe more new physics after the Higgs
Projections on Virtual

\[ \delta M_t = 1.2 \text{ GeV}, \]
\[ \delta M_w = 24 \text{ MeV}, \text{ world avg} \]

\[ (\text{LEP2} + \delta M_w = 30 \text{ MeV(Tevatron)}, \]
\[ \text{no LEP/TeV correlations}) \]