

Measuring the W Boson Mass at the Tevatron

XXIInd Rencontres de Blois

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Michiel Sanders

Ludwig-Maximilians-Universität München

For the DØ and CDF Collaborations

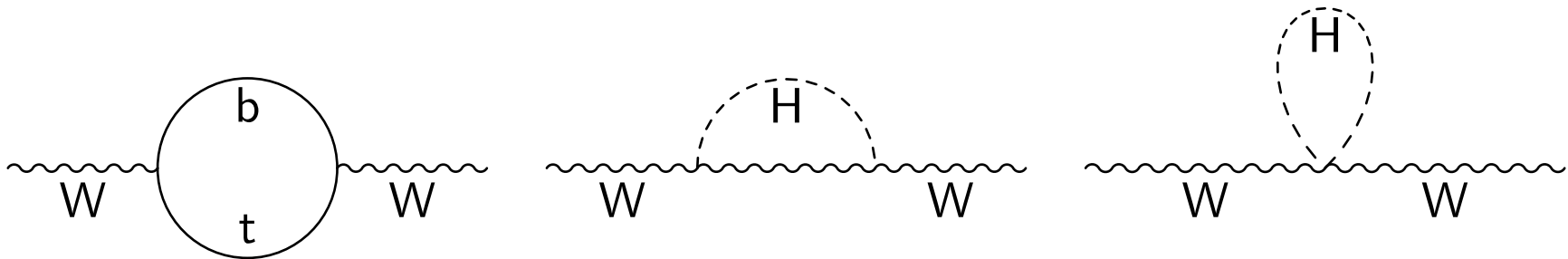
Outline

- Introduction / Motivation
- Tevatron
- Measurement strategy
- Results
- Conclusion & Outlook

Introduction

$$m_W^2 \left(1 - \frac{m_W^2}{m_Z^2} \right) = \frac{\pi\alpha}{\sqrt{2}G_F} \left(\frac{1}{1 - \Delta r} \right)$$

$$\Delta r = \Delta\alpha + \Delta\rho(m_{\text{top}}^2) + \Delta\chi(\ln(m_H))$$



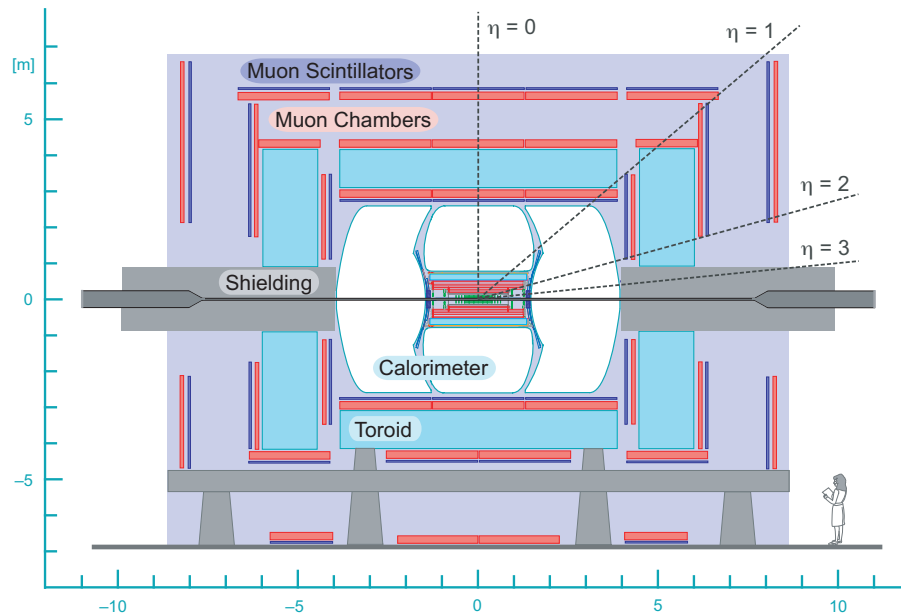
To have equal uncertainty on m_H , $\Delta m_W \approx 0.006 \cdot \Delta m_{\text{top}}$

Current $\Delta m_{\text{top}} = 1.1 \text{ GeV} \Rightarrow \Delta m_W = 7 \text{ MeV}$

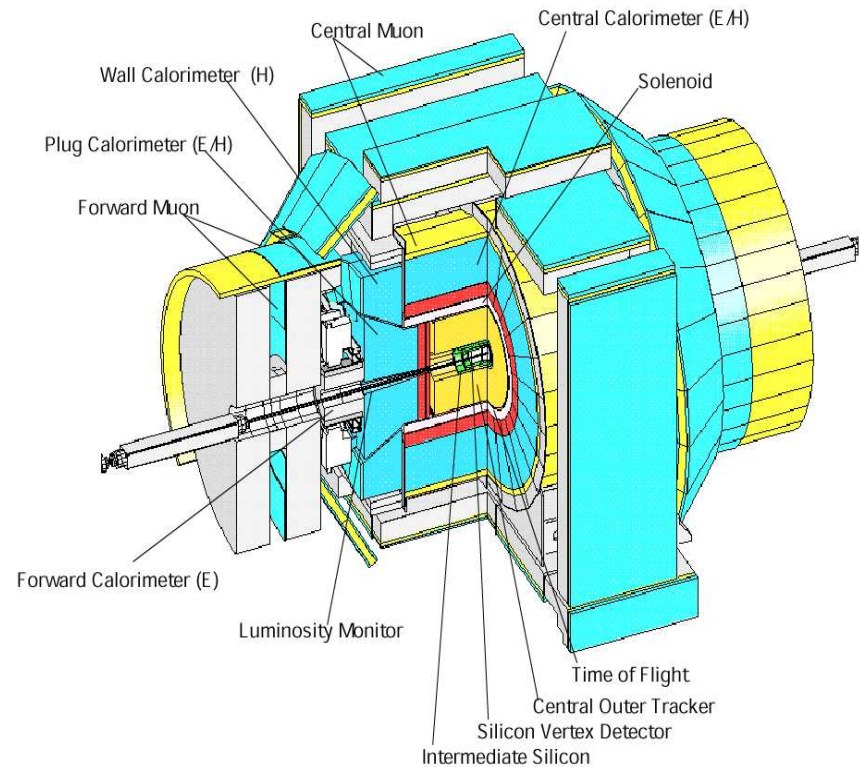
Tevatron

- $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
- Up to now: $\int \mathcal{L} dt > 9 \text{ fb}^{-1}$ delivered / experiment
- Measurement of m_W : 200 pb^{-1} (CDF), 1 fb^{-1} (DØ)

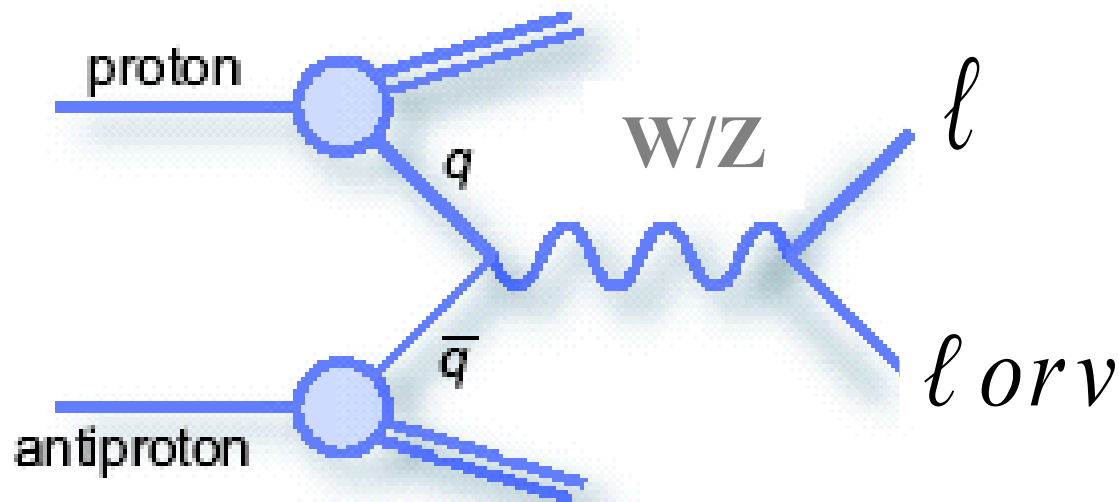
DØ



CDF

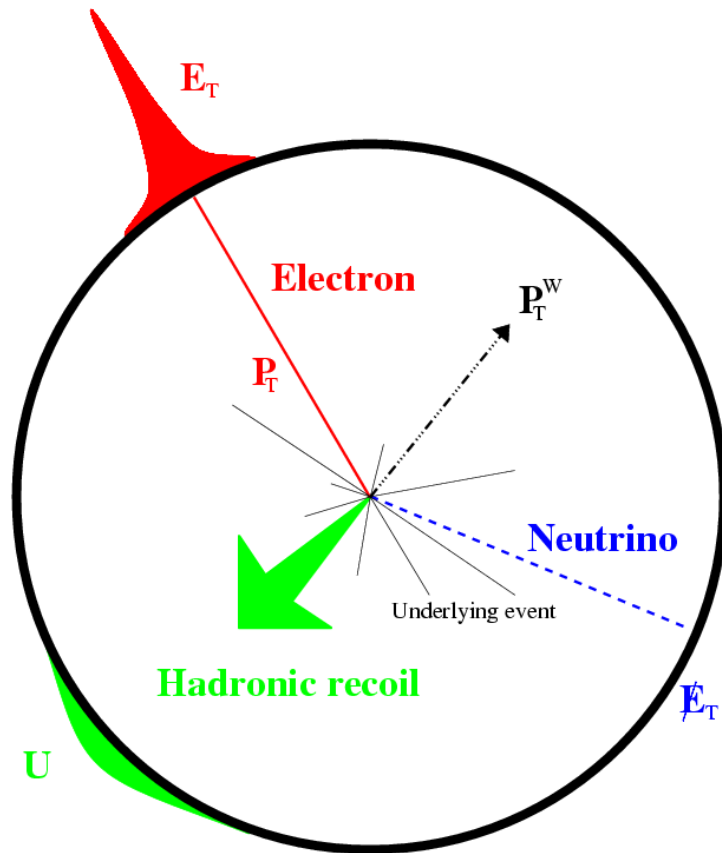


W (& Z) Signature



- High momentum lepton, $|\eta| \lesssim 1$
DØ: $p_T(e) > 25 \text{ GeV}$; CDF: $p_T(\ell) > 30 \text{ GeV}$
- High momentum neutrino $\rightarrow$ Large $\cancel{E}_T$
DØ: $\cancel{E}_T > 25 \text{ GeV}$; CDF: $\cancel{E}_T > 30 \text{ GeV}$
- Small-ish recoil: $u_T < 15 \text{ GeV}$

Measurement Strategy

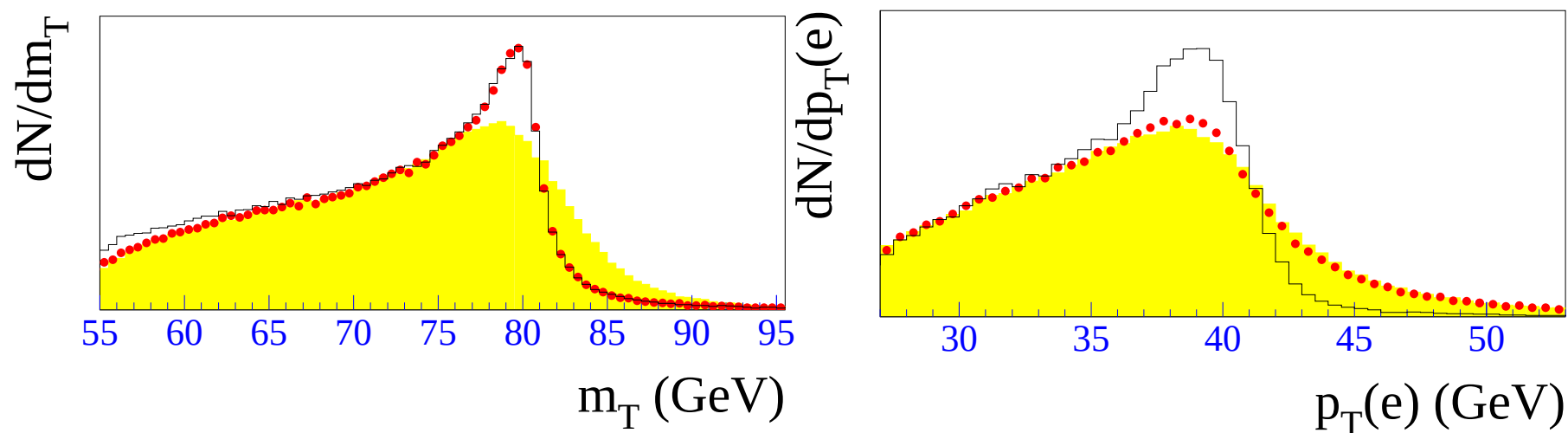


$$\vec{p}_T(\nu) = -\vec{p}_T(\ell) - \vec{u}_T$$

$$m_T^2 = 2p_T(\ell)p_T(\nu)(1 - \cos \Delta\phi_{\ell\nu})$$

- Template fits on parametric simulation of m_T , $p_T(\ell)$ and $p_T(\nu)$
- Precision on $p_T(\ell)$: 10^{-4} level; precision on u_T : %o-level;

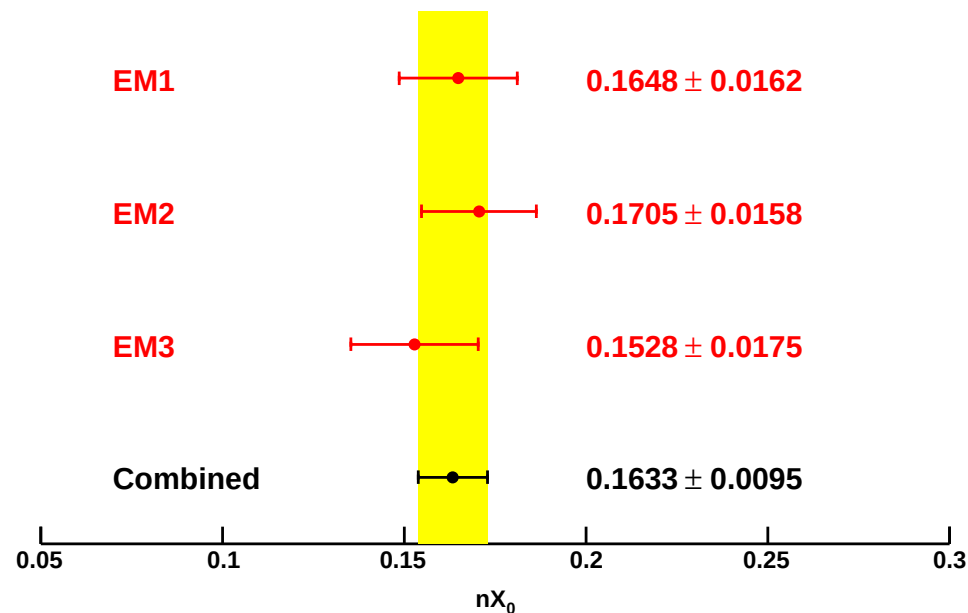
W Production



- Production/decay model: RESBOS, PHOTOS/WGRAD
- Dominant uncertainties:
 - * PDF: ≈ 10 MeV
 - * Photon radiation: ≈ 11 MeV (CDF), ≈ 7 MeV (DØ)

Electron Energy Scale (DØ)

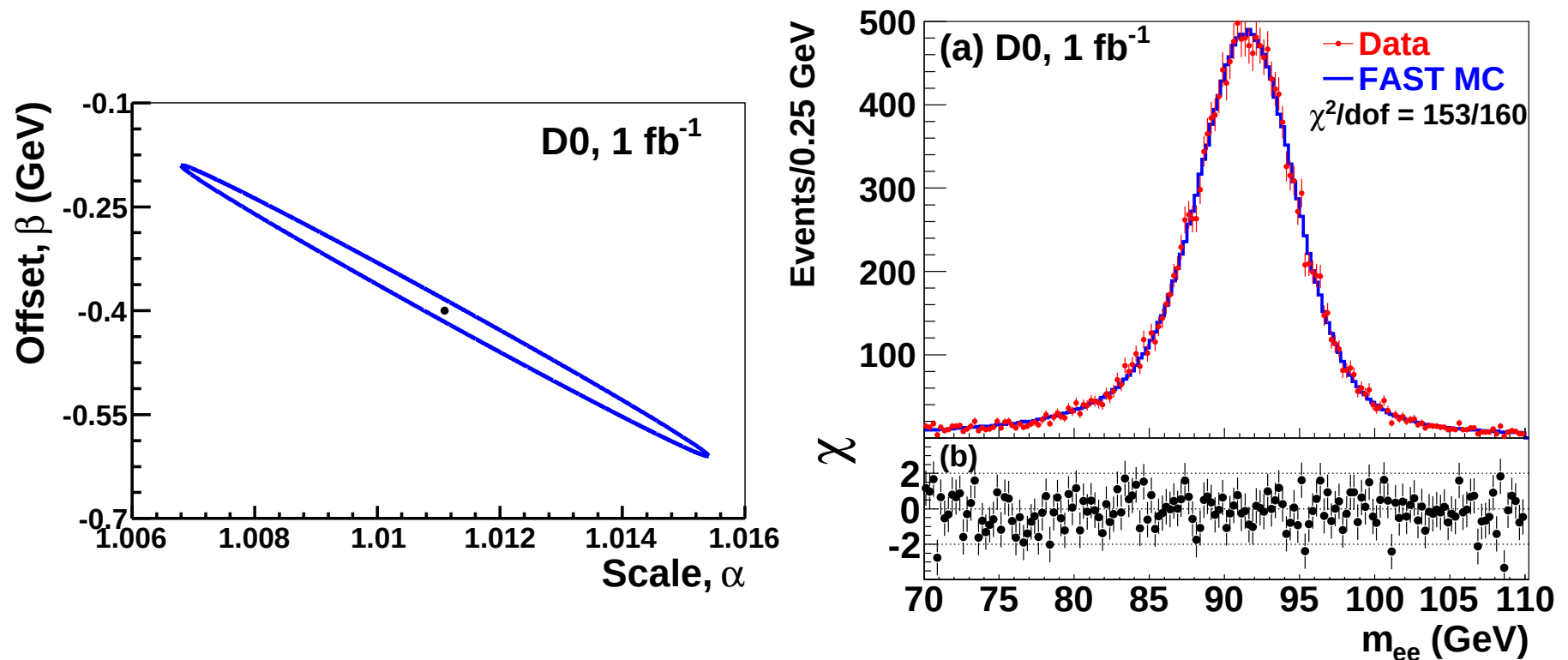
- Calorimeter calibration
 - Corrections for energy-loss in uninstrumented regions
 - * Detailed GEANT simulation
 - * Material tuning with 4×15 fractional energy distributions
- ⇒ E and η dependent parameterization of response and resolution



Electron Energy Scale (DØ)

$$E_{\text{meas}} = \alpha E_{\text{true}} + \beta \Rightarrow \text{fit for } \alpha \text{ and } \beta \text{ in } E_e \text{ bins}$$

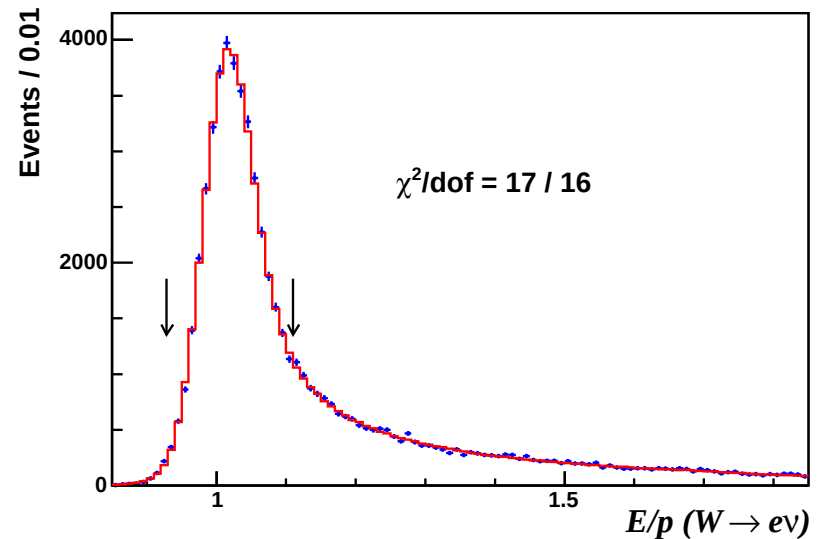
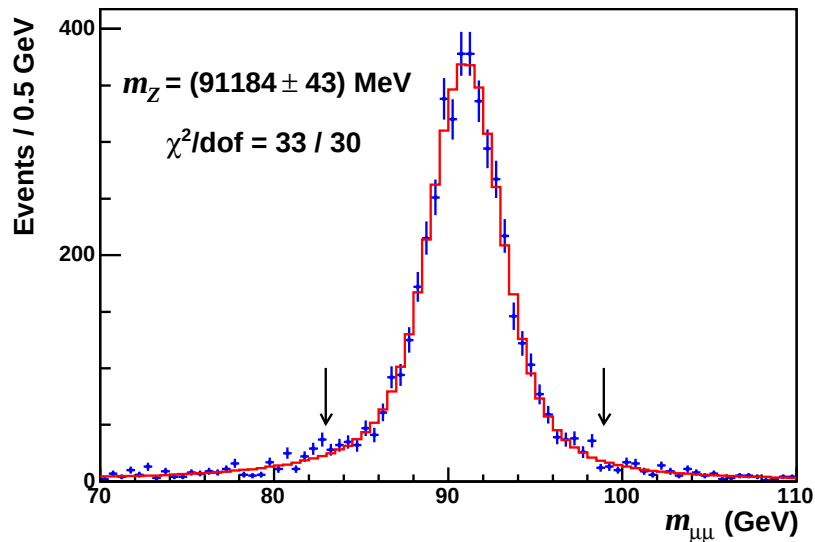
Use m_Z (LEP) and 18.7k $Z \rightarrow e^+e^-$ events



$\Rightarrow$ Largest uncertainty on m_W : 34 MeV

Lepton Momentum Scale (CDF)

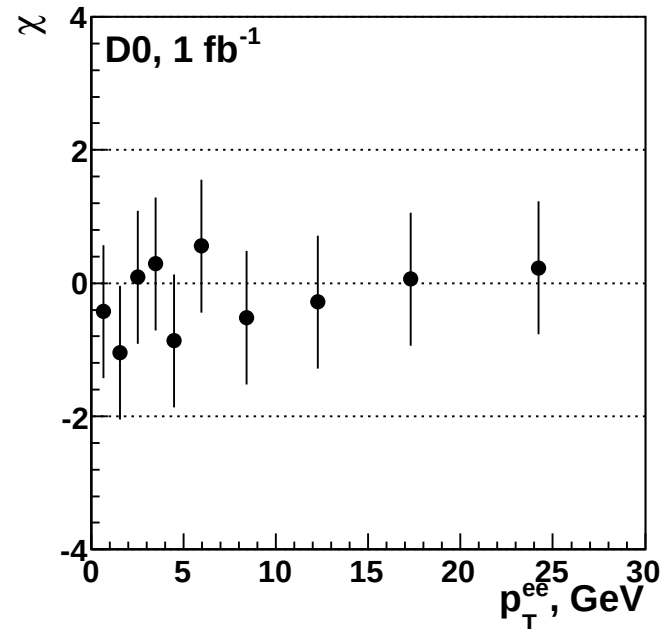
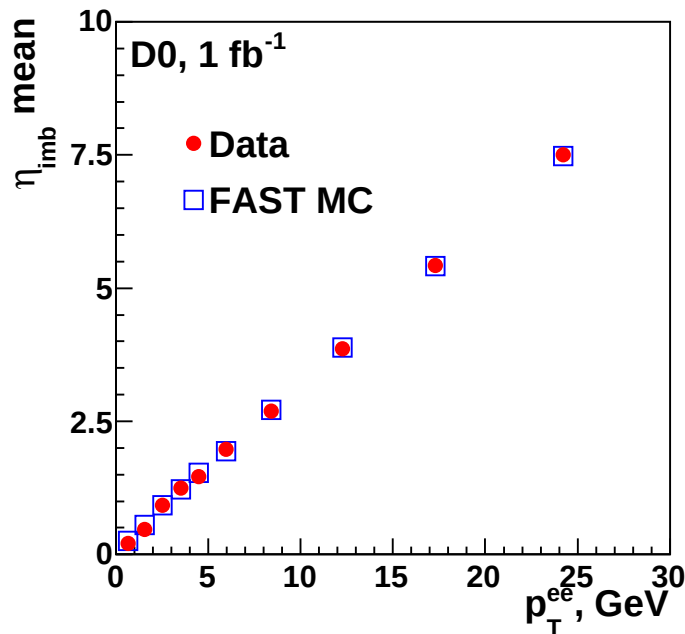
- Tracker calibration $\Rightarrow$ precise tracker simulation
- Alignment using cosmics
- Momentum scale
 - * Set by fits to 600k J/ψ events
 - * In bins of $1/p_T(\mu)$ and $\cot \theta_\mu$



$\Rightarrow$ Uncertainty on m_W : 17/30 MeV (muon/electron)

Recoil Momentum Scale

$$\vec{u}_T = \vec{u}_T^{\text{hard}} + \vec{u}_T^{\text{soft}} + \vec{u}_T^{\text{electron}} \quad \text{Scale set by } \eta_{\text{imb}} \text{ in } Z \rightarrow \ell\ell \text{ events}$$

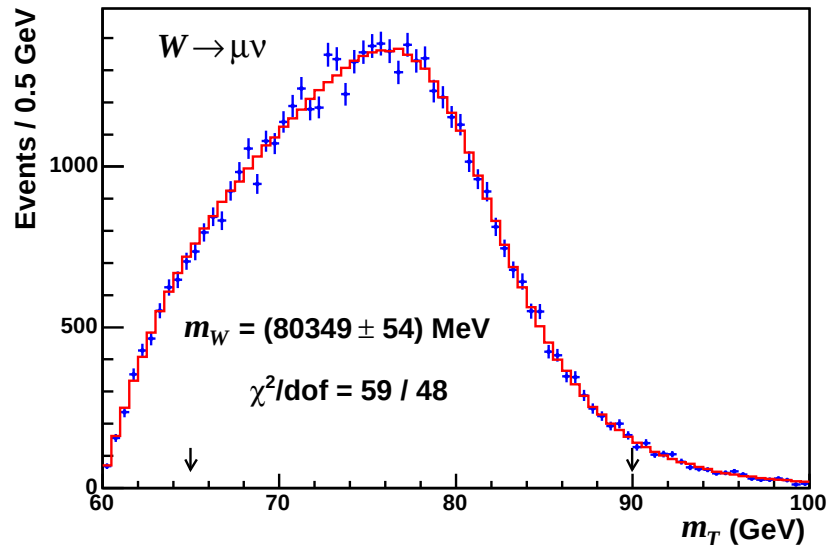


Uncertainty on m_W :

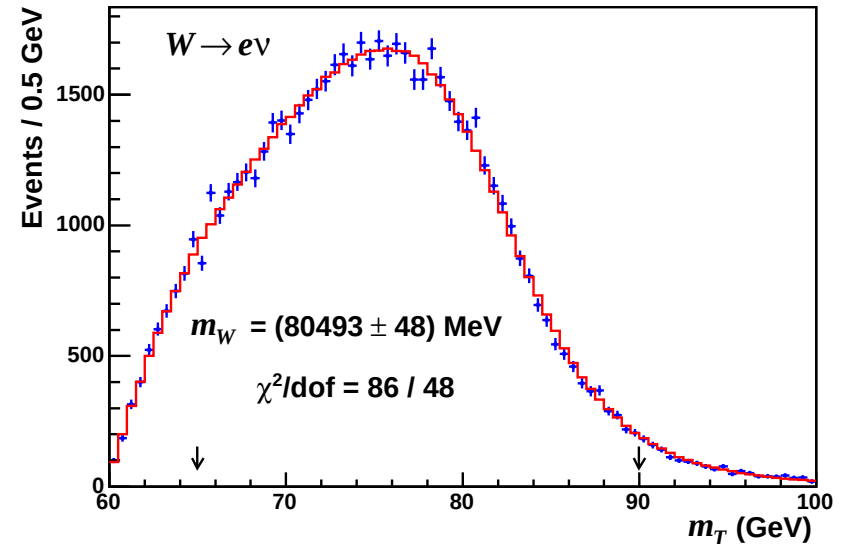
- DØ: 6 MeV (m_T), 12 MeV (p_T), 20 MeV (E_T)
- CDF: 9 MeV (m_T), 17 MeV (p_T), 30 MeV (E_T)

Results (CDF)

51k $W \rightarrow \mu\nu$ events



64k $W \rightarrow e\nu$ events



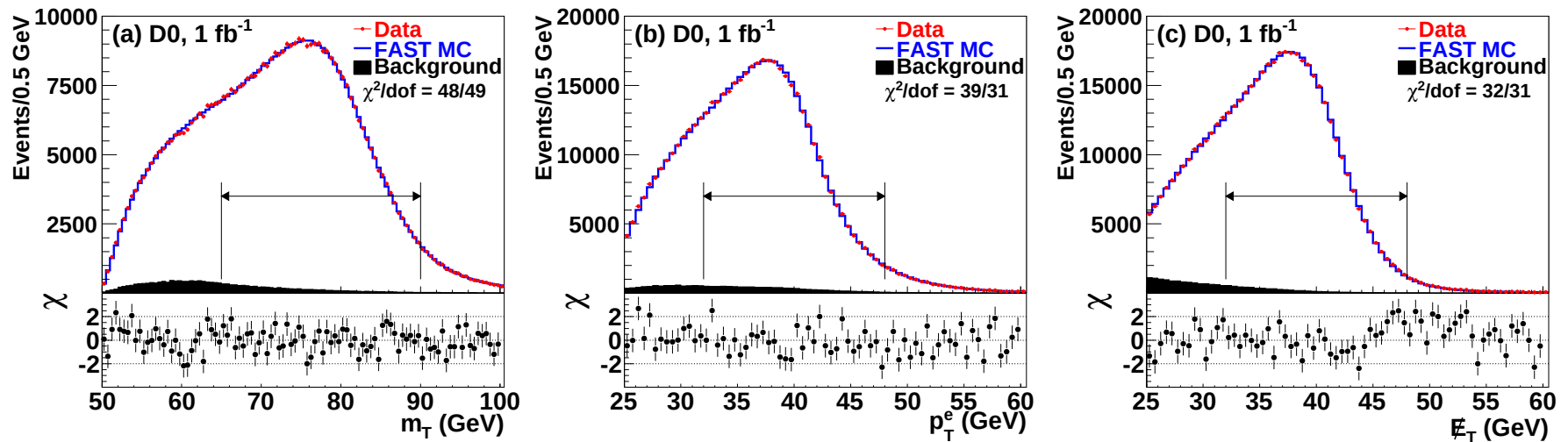
Combination of six measurements:

$$m_W = 80.413 \pm 0.034_{\text{stat}} \pm 0.034_{\text{syst}} \text{ GeV}$$

$$m_W = 80.413 \pm 0.048 \text{ GeV (200 pb}^{-1}\text{)}$$

Results (DØ)

500k $W \rightarrow e\nu$ events



$$80.401 \pm 0.023 \text{ GeV}$$

$$80.400 \pm 0.027 \text{ GeV}$$

$$80.402 \pm 0.023 \text{ GeV}$$

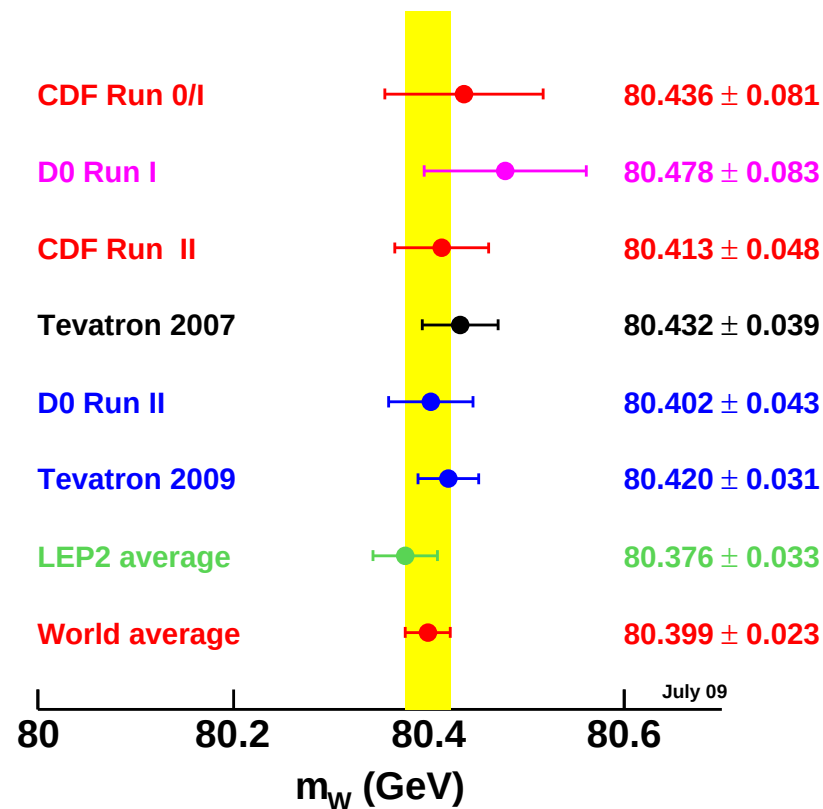
Combination of three measurements:

$$m_W = 80.401 \pm 0.021_{\text{stat}} \pm 0.038_{\text{syst}} \text{ GeV}$$

$$m_W = 80.401 \pm 0.043 \text{ GeV (1 fb}^{-1}\text{)}$$

Combination

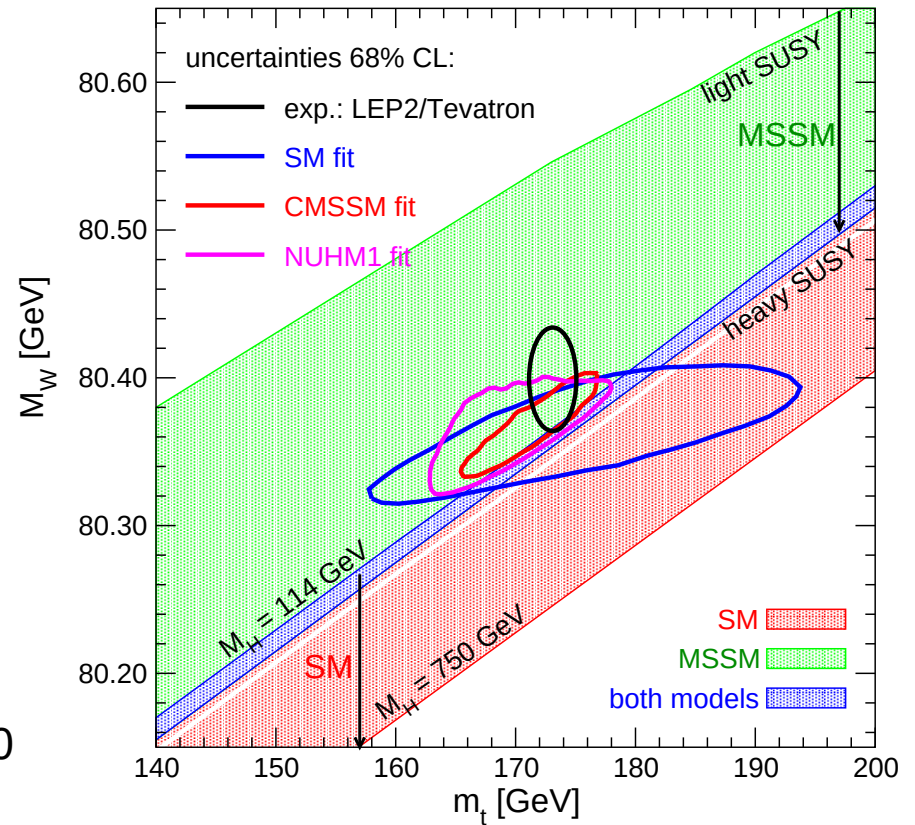
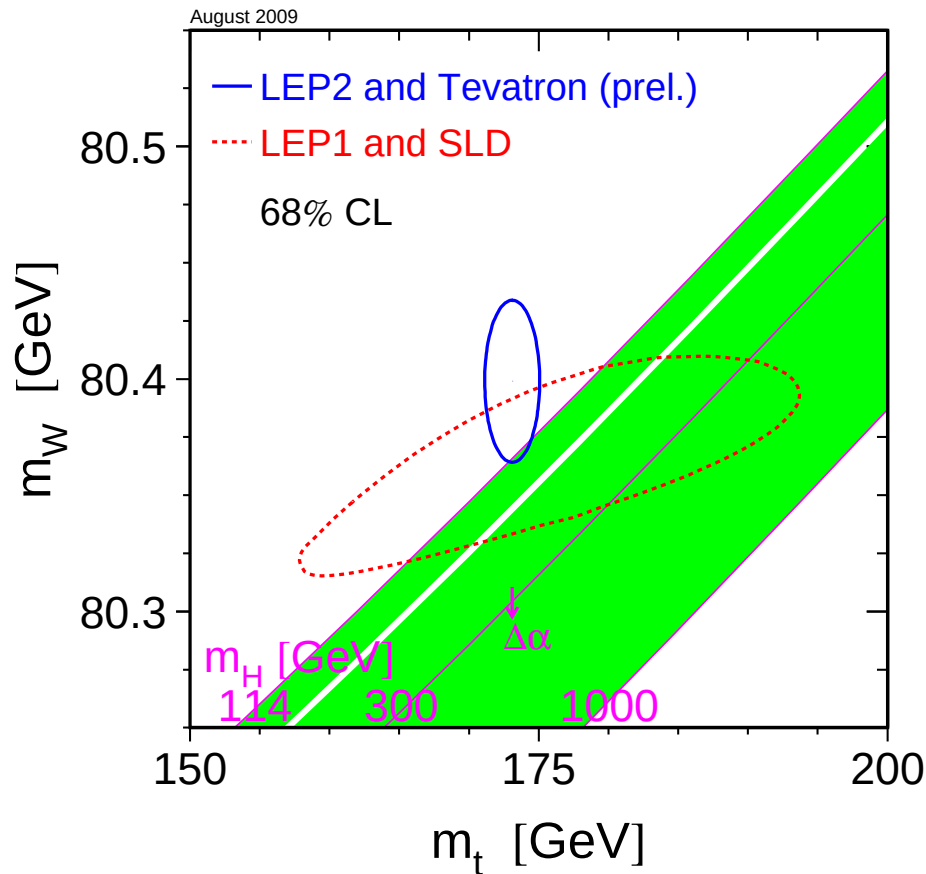
- Correct old CDF measurements to modern PDF
- Correct to the same Γ_W value
- PDF, QED, Γ_W uncertainties correlated



Interpretation

Standard Model LEPEWWG

SUSY PRD 81, 035009 (2010)



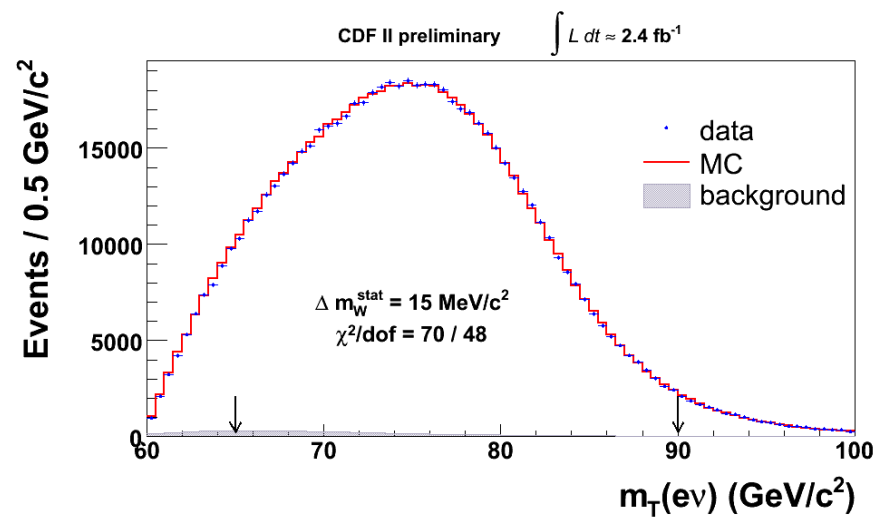
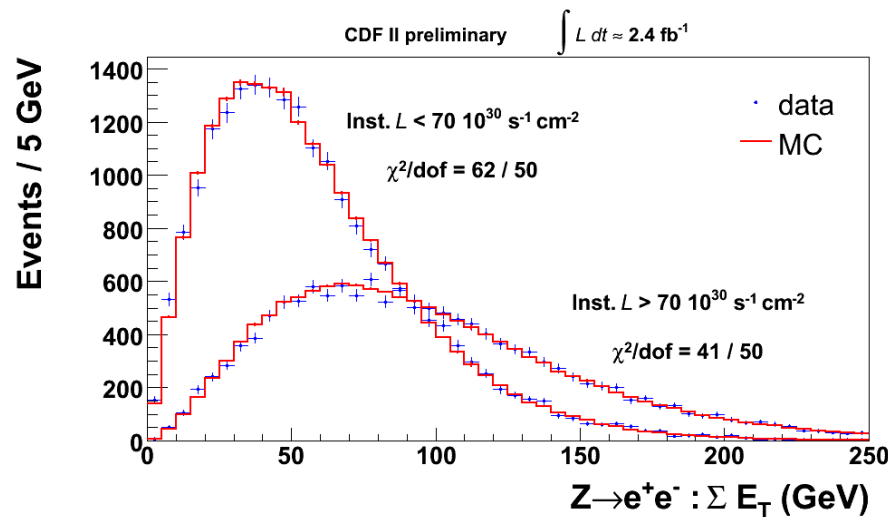
Using $m_{\text{top}} = 173.1 \pm 1.3$ GeV

$$\Rightarrow m_H = 87^{+35}_{-26} \text{ GeV}$$

Future

More data, at higher $\mathcal{L}$

- Smaller statistical uncertainty
- Better determination of momentum scale
- Better constraints on production model
- More energy in the detector



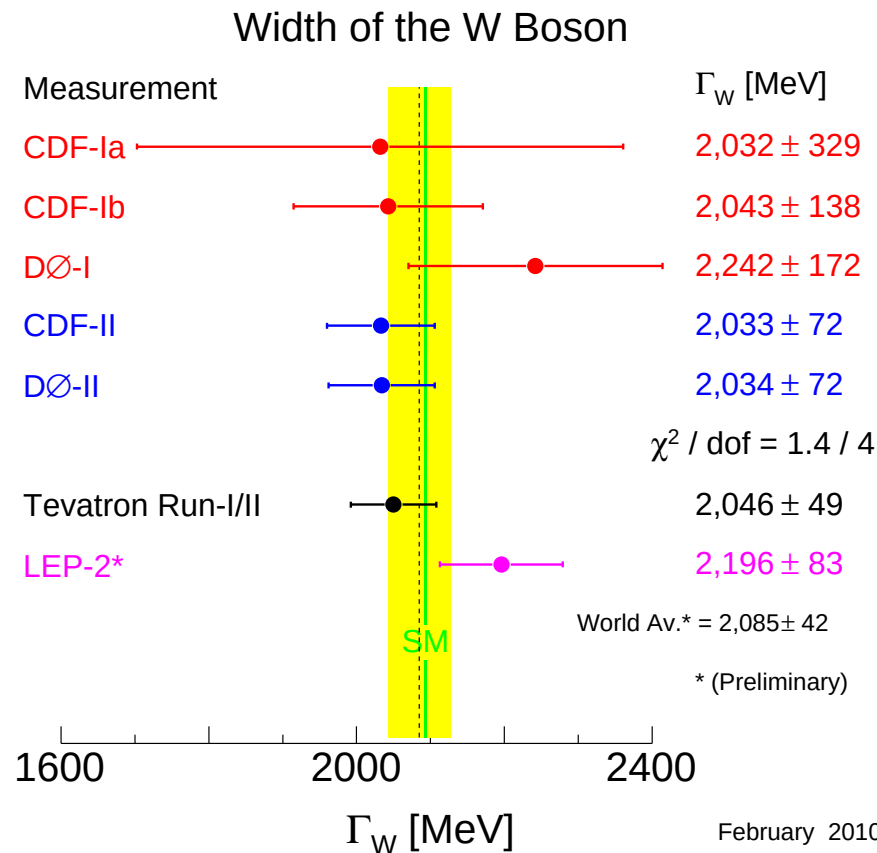
Conclusion

- $m_W = 80.420 \pm 0.031$ GeV (Tevatron)
 $m_W = 80.399 \pm 0.023$ GeV (Tevatron & LEP)
- Precision from Tevatron better than LEP
- Goal: get down to 15 MeV uncertainty
- Find the Higgs boson . . .

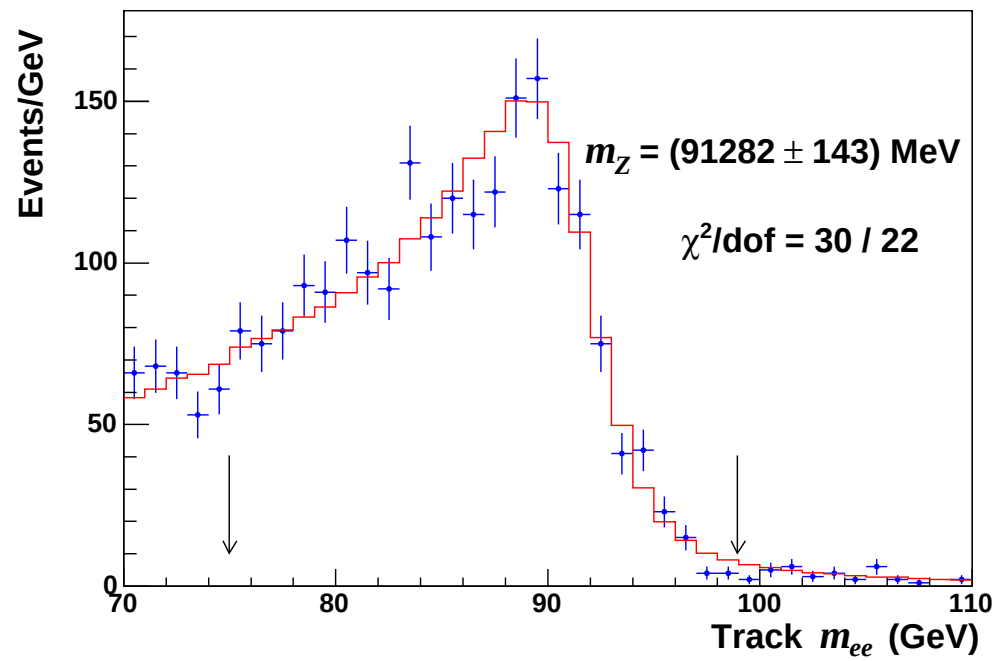
W Boson Width

Sensitive to decays to non-SM particles

New Tevatron combination: $\Gamma_W = 2.046 \pm 0.049$ GeV



CDF Electron Tracking



Selection & Background

Very small background

$$W \rightarrow \tau \nu_\tau$$

$$Z \rightarrow \ell\ell$$

Electron/muon-like jets

$D\emptyset \leq 6$ MeV selection, ≤ 5 MeV background

CDF ≈ 9 MeV background (large $Z \rightarrow \mu\mu$ contribution)