ICHEP02

# W Mass and Width at the Tevatron

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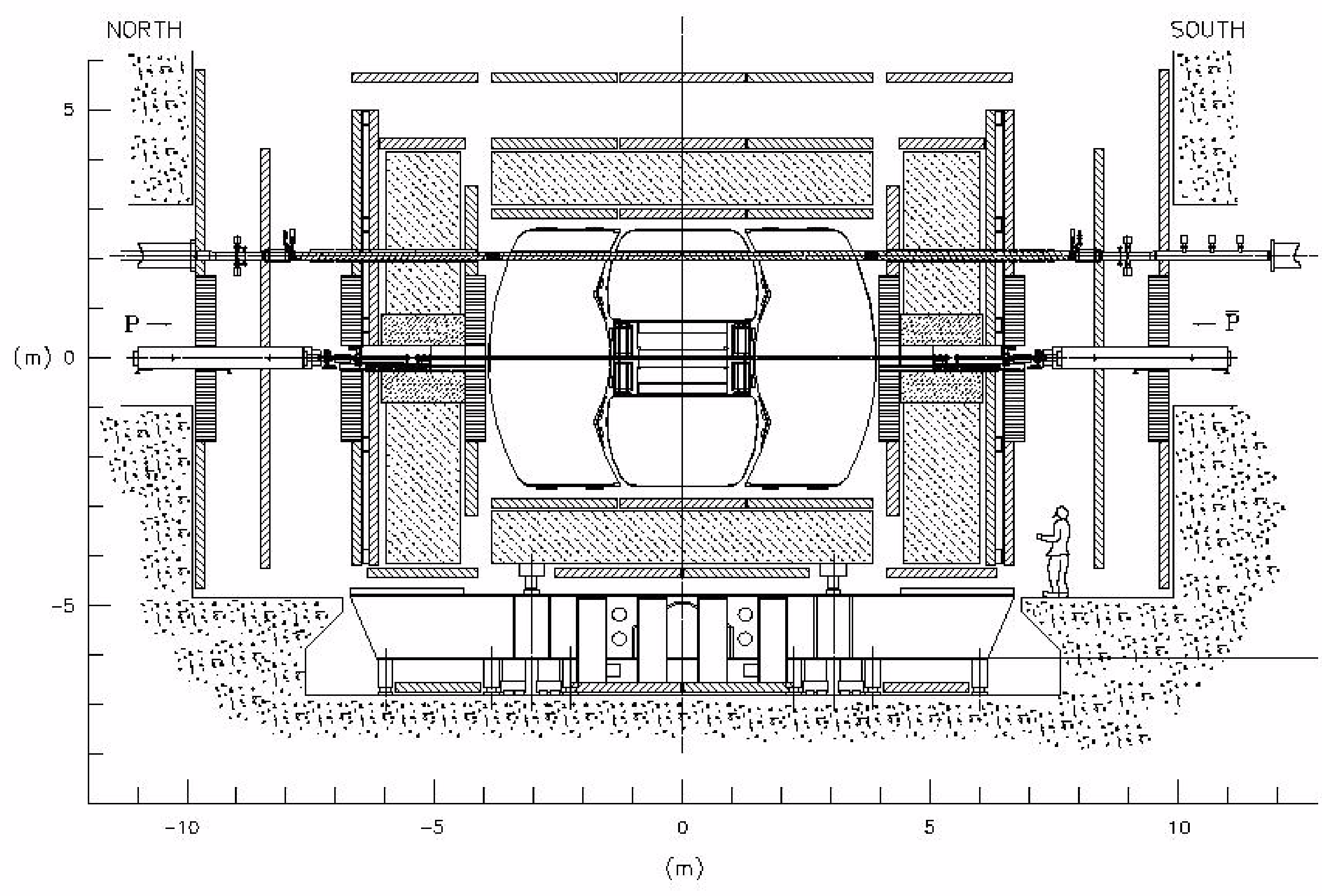
For the DØ Collaboration

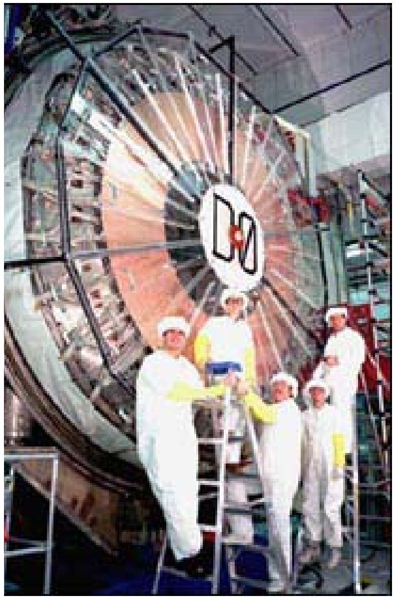
# W Mass and Width at the Tevatron

New Results from the Tevatron Run I (1994–1995) Data

1. A new measurement of the W mass using "edge" electrons from DØ
2. A new "direct" measurement of the W width from DØ

# Run I DØ Detector



$p\bar{p}$ collisions

$\sqrt{s} = 1.8$ TeV

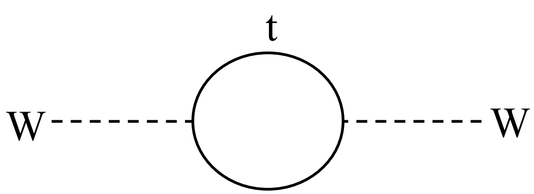
Analyses based on ≈85 $pb^{-1}$ taken in 1994-1995.

# W Mass

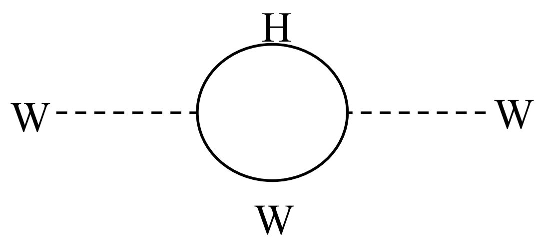
Highest precision measurement from the Tevatron's Collider.

$$M_W^2 = \frac{\pi\alpha(M_Z^2)}{\sqrt{2}\,G_F}\frac{1}{\left(1-(M_W^2/M_Z^2)\right)}\frac{1}{(1-\Delta r)}$$

$\Delta r \sim M_t^2$




$\Delta r \sim \ln M_H$




One of the best ways we have to constraint the Higgs mass before its discovery

# Previous Measurements

Direct

- 80.433 ±0.079 (CDF)
- 80.447 ±0.042 (LEP2)
- 80.482 ±0.091 (DØ)

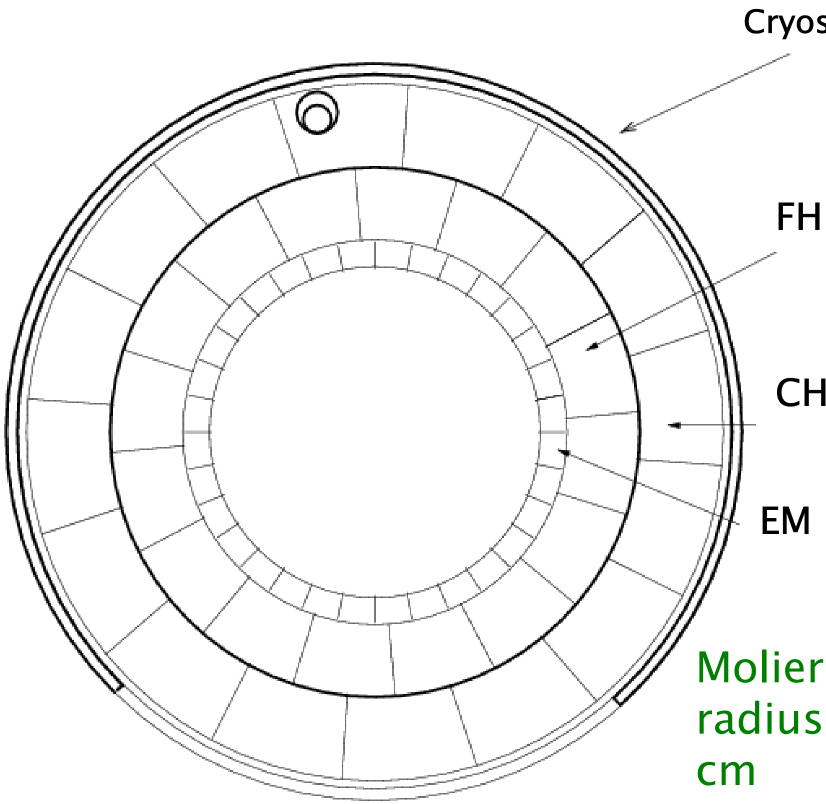
Indirect

- 80.136 ± 0.084 (NuTeV)
- 80.380 ± 0.023 (LEP1/SLD/Tevatron top mass)

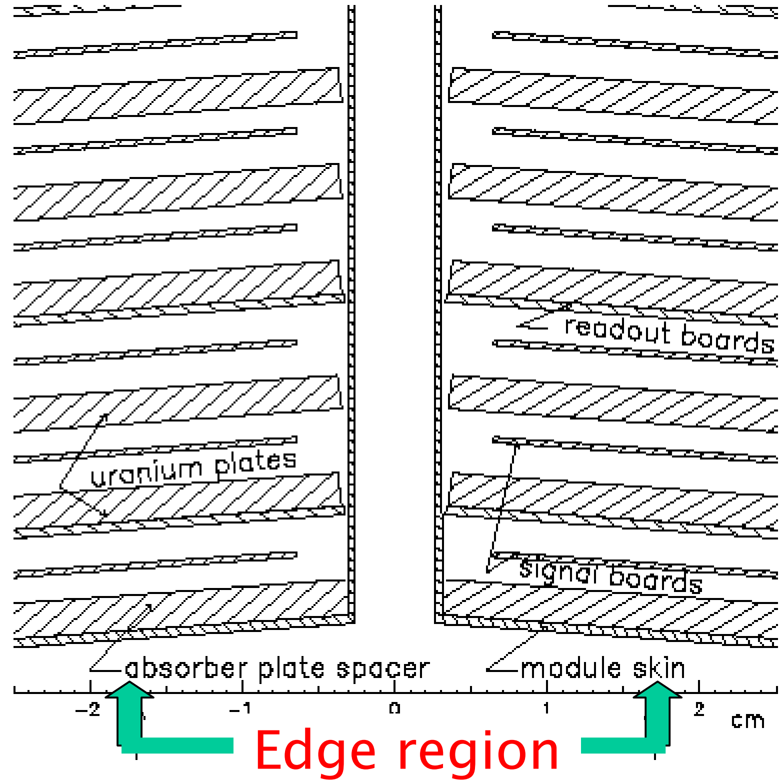
For DØ measurement, W statistical error alone is 60 MeV.
Most systematics are also statistics limited.

LEP EWK working group Web page, 22 Jul 02

# DØ Calorimeter




Moliere radius is 1.9 cm




- most DØ exclude electrons 1.8 cm from module edges (10% of width)
- increase W statistics by 9%
- increase Z statistics by 15% and thus knowledge of energy scale (the leading systematic uncertainty)

# Selection

| Variable | $W$ boson sample | $Z$ boson sample |
|---|---|---|
| $p_T(e\ \text{central})$ | $\geq 25$ GeV | $\geq 25$ GeV |
| $p_T(e\ \text{end})$ | – | $\geq 30$ GeV |
| $p_T(\nu)$ | $\geq 25$ GeV | – |
| $p_T(W)$ | $\leq 15$ GeV | – |
| $m_{ee}$ | – | 60 – 120 GeV |
| $\lvert z_{\text{vtx}} \rvert$ | $\leq 100$ cm | $\leq 100$ cm |

| $W$ boson sample | No. events | $Z$ boson sample | No. events |
|---|---|---|---|
| C | 27,675 | CC | 2,012 |
| $\tilde{\text{C}}$ | 3,853 | $\tilde{\text{C}}$C | 470 |
| E | 11,089 | $\tilde{\text{C}}\tilde{\text{C}}$ | 47 |
| | | CE | 1,265 |
| | | $\tilde{\text{C}}$E | 154 |
| | | EE | 422 |

C is central, non-edge
E is endcap
$\tilde{\text{C}}$ is central, edge

# Basic Methodology

common to all DØ W mass measurements

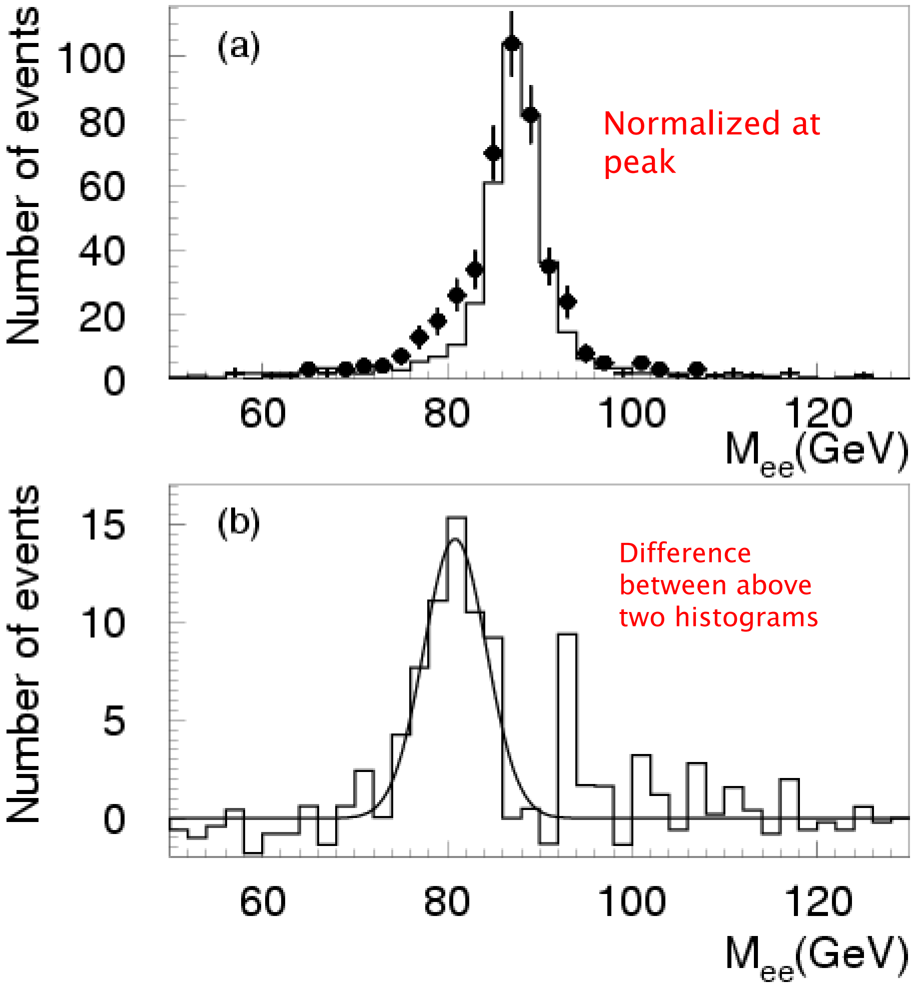
- Fast Monte Carlo with parameterizations of the electron, MET response used to produce distributions of measured $P_T(e)$, $P_T(\nu)$, $M_T$ as a function of M(W)

$$m_T = \sqrt{2 p_T(e) p_T(\nu)[1 - \cos(\phi_e - \phi_\nu)]}$$

- smearing functions determined mostly from $Z \rightarrow e^+e^-$ data (and other data)
- Mass and statistical error are determined from a binned maximum likelihood fit

# Parameterization of Resolution

Points: Z's with 2 central e's, one edge.
Histogram: Z's without edge




Key to using these "edge" electrons is understanding their response function

Z's with an edge electron look like those without for most of the events. However, some fraction produce a low edge tail

# Response

Model: shower process is unaffected by module edge. But, for some fraction f, the electronic response is lowered due to smaller electric drift field (and thus resolution is also worsened)

f=0.346±0.076

scale = 0.912 ±0.018

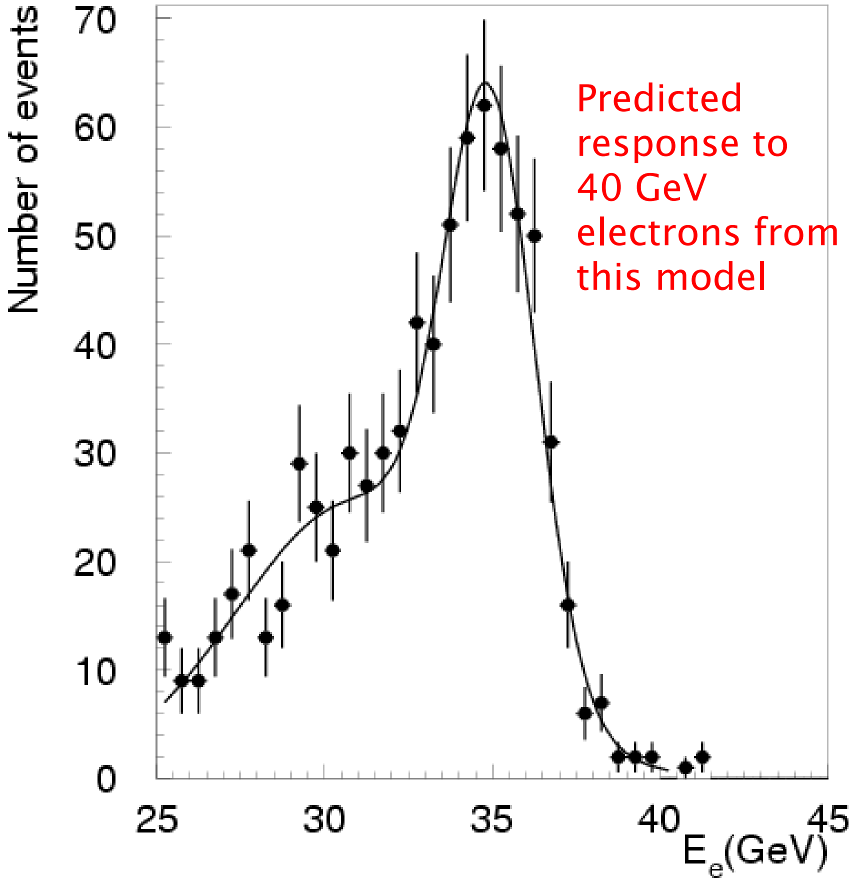
constant term = $0.101^{+0.028}_{-0.018}$

(1-f) with non-edge values

scale = 0.9540 ±0.008

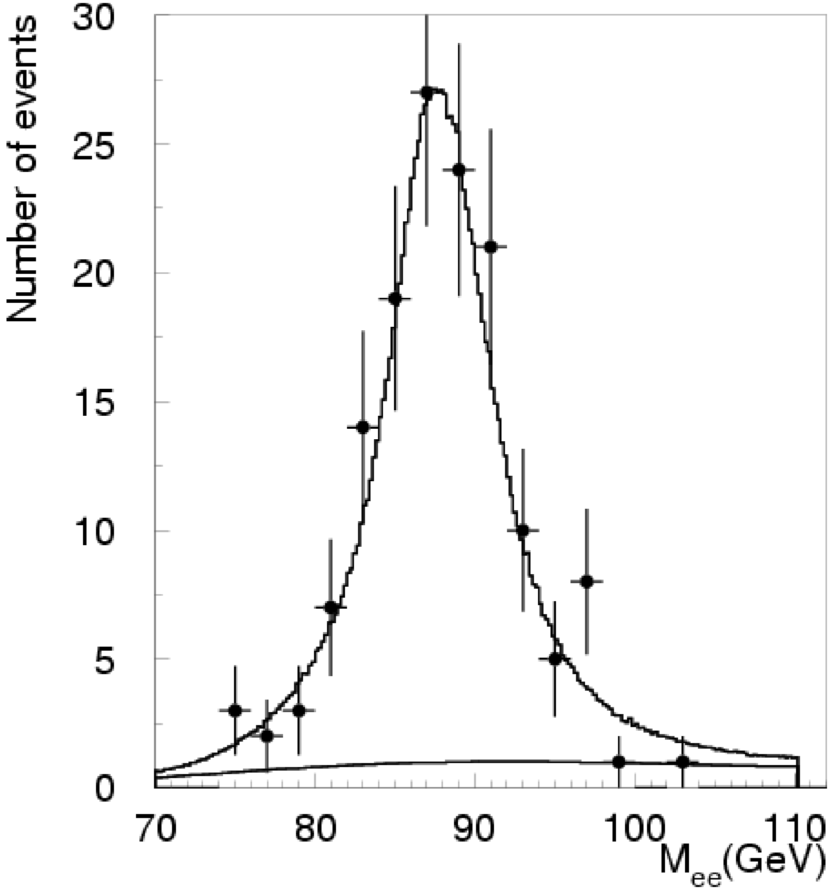
constant term = $0.0115^{+0.0027}_{-0.0036}$

$$\frac{\sigma_E}{E} = \frac{s}{\sqrt{E}} \oplus c \oplus \frac{n}{E}$$

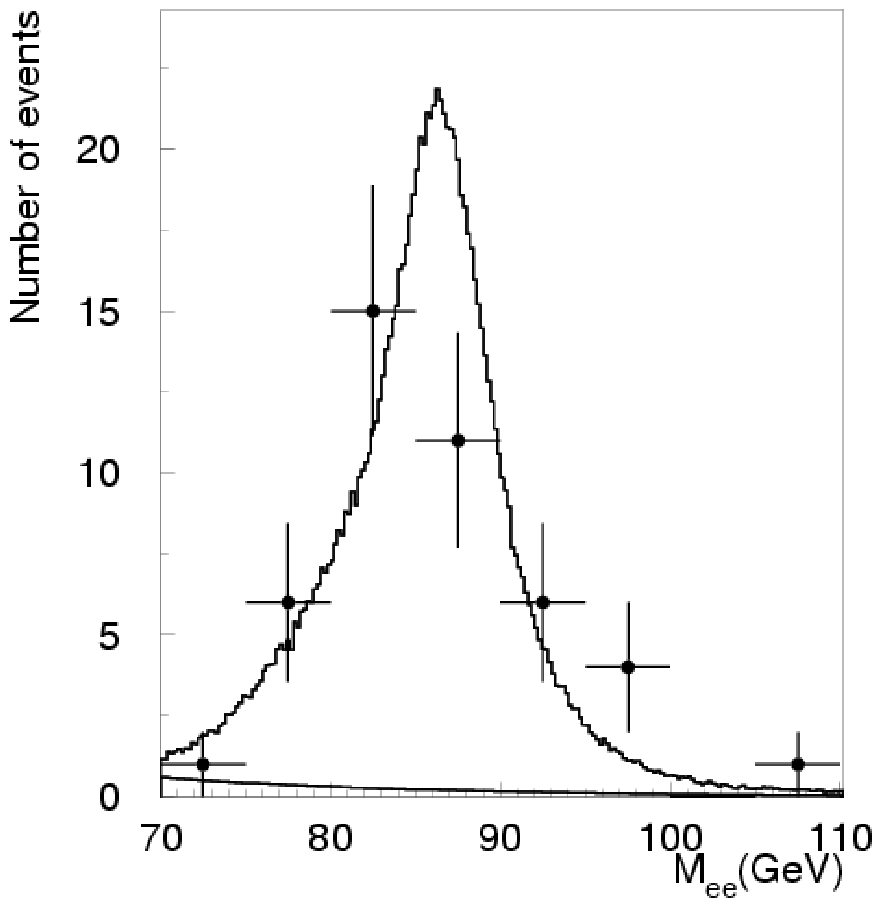


# Systematic Tests

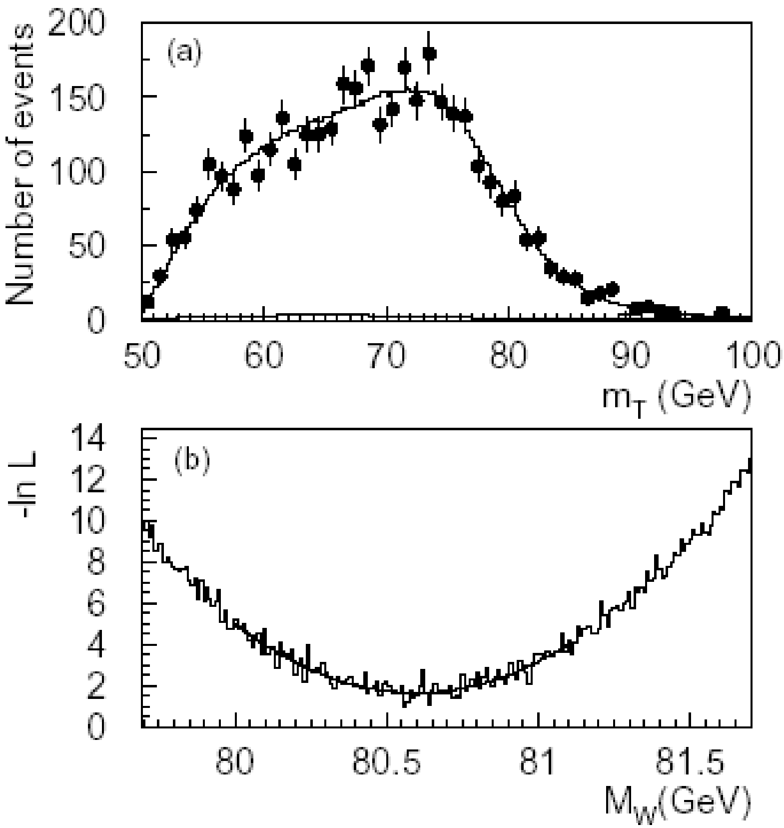
Z's with one edge, one endcap electron




Z's with two edge electrons



# Results using only the edge electrons

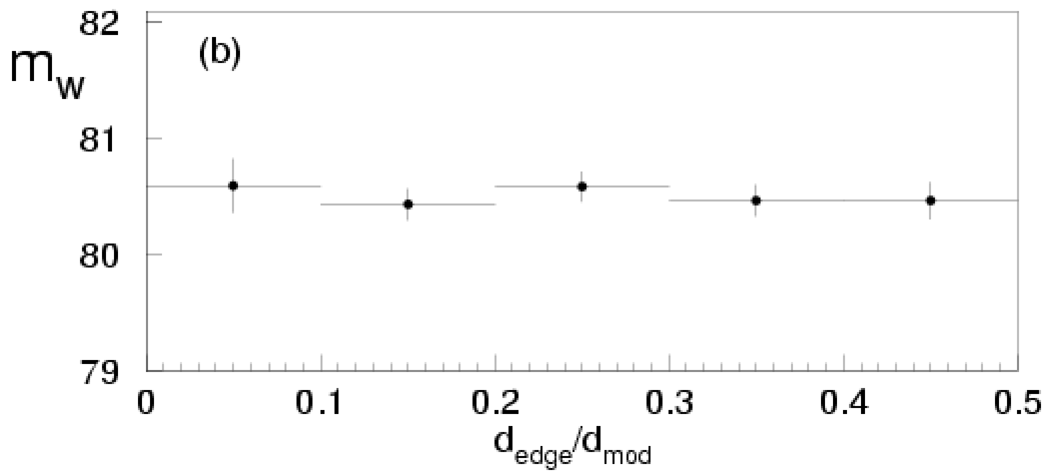



Uncertainty dominated by statistics and uncertainty in constant term in resolution and in energy scale (all around 230 MeV)

$M_W$=80.574±0.405 GeV

# Systematic Tests

Fitted W mass as function of distance from the crack



# Combined Analysis

Use Z's with edge electrons to improve understanding of scale in non-edge regions

80.482±0.091

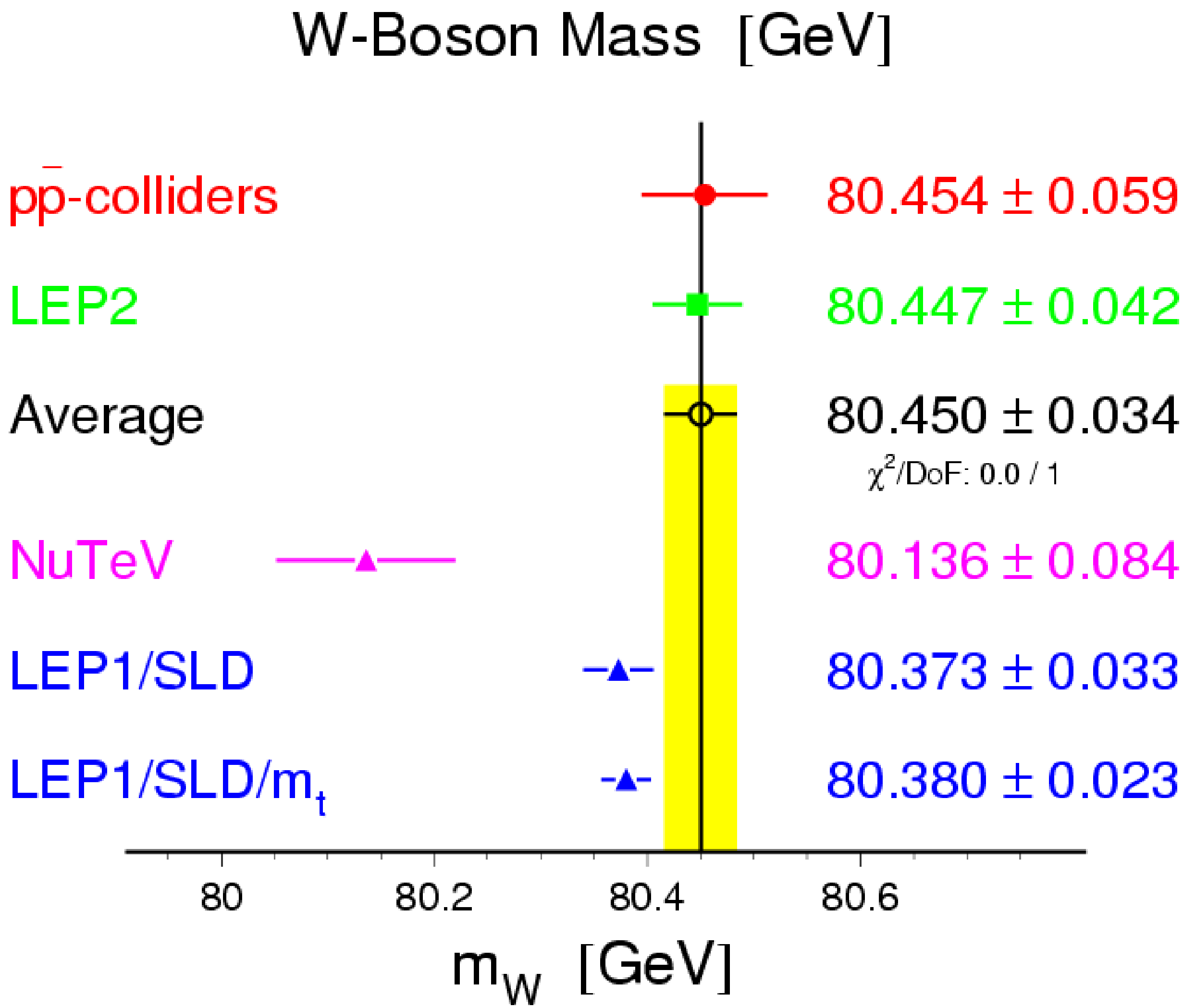
→80.481 ±0.085

Add edge electron W's

→80.482 ±0.084

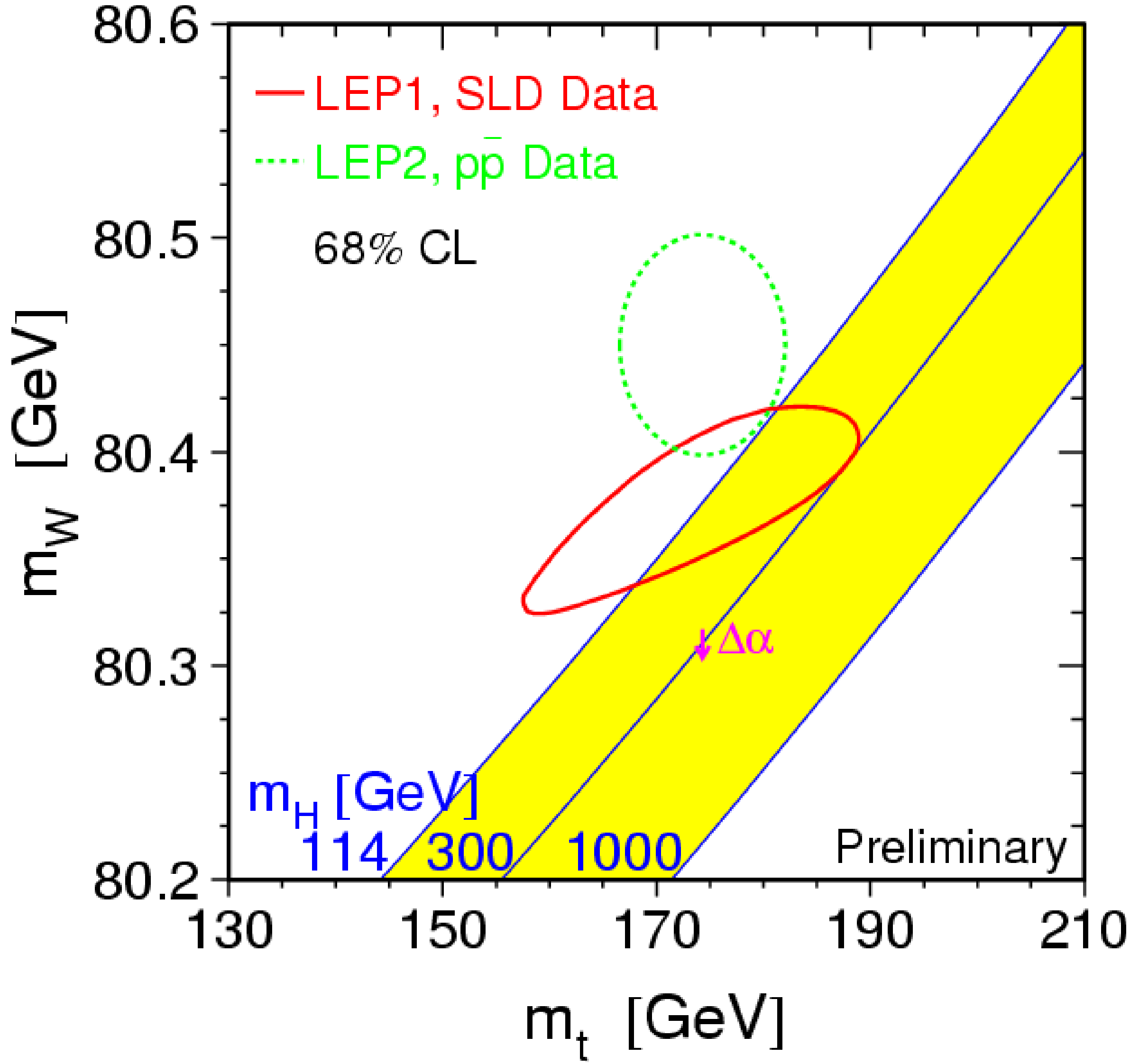
Combine with CDF, LEP2

→ 80.450±0.034




Numbers from LEP EWK working group web page, 22 Jul 02

# Higgs Mass




LEP EWK working group web page

# W Width

Standard Model Prediction depends on:

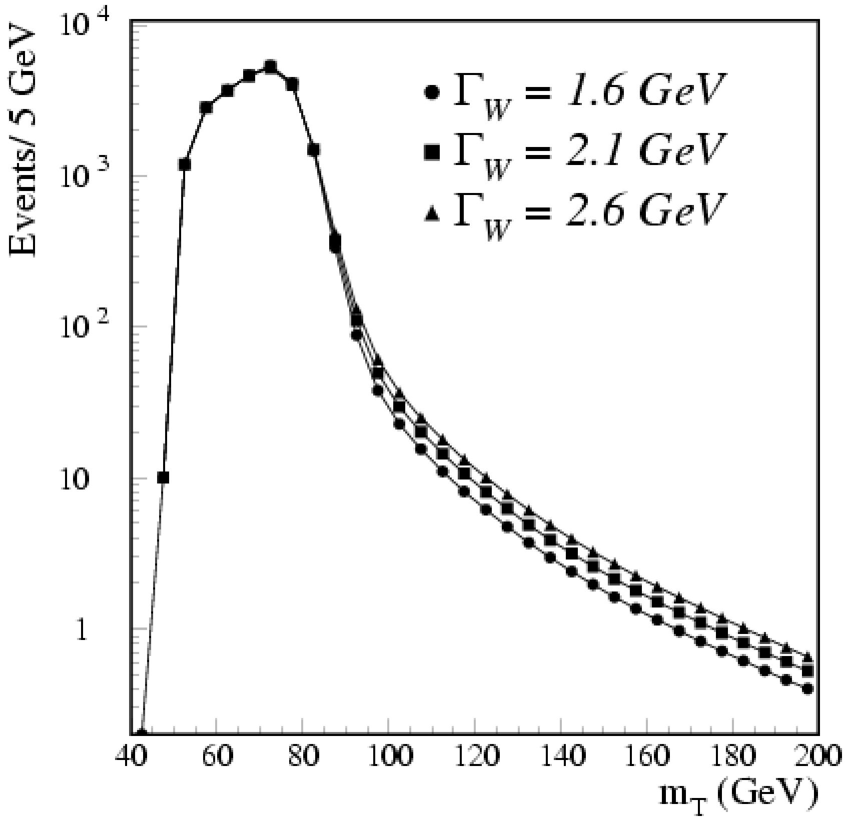
- Number of decay modes available to the W
- coupling of W to the EWK doublets
- EWK corrections to these couplings
- QCD corrections to these couplings
- W mass

☝(W) = 2.0921±0.0025 GeV (0.12% uncertainty!)

$$\Gamma(W \to e\nu) = \frac{G_F M_W^3}{6\sqrt{2}\pi}(1+\delta_{SM}) \quad \delta_{\mathrm{SM}} < 1/2\%$$

$$\frac{\Gamma(W \to e\nu)}{\Gamma(W)} = 1/(3+6(1+\alpha_S(M_W)/\pi + O(\alpha_s^2)))$$

# Direct Measurement




Shape of transverse mass distribution for $m_T$□90 GeV is affected by the W width

$$m_T = \sqrt{2 p_T(e) p_T(\nu)[1 - \cos(\phi_e - \phi_\nu)]}$$

# Selection

$P_T(e) > 25$ GeV

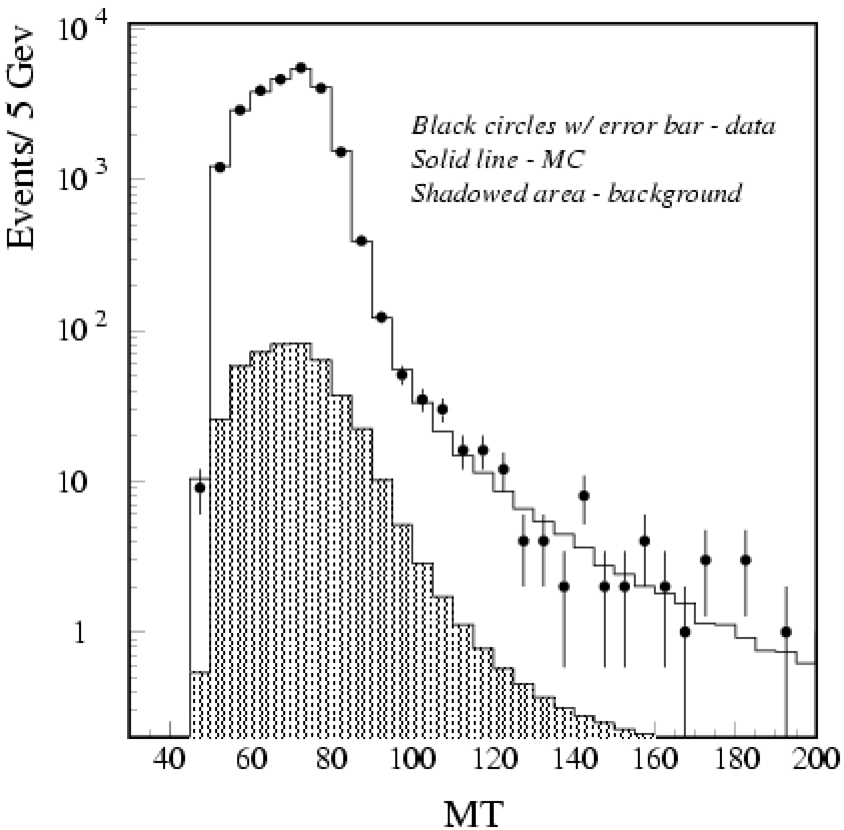
$\mathrm{P_T}(\nu) > 25$ GeV

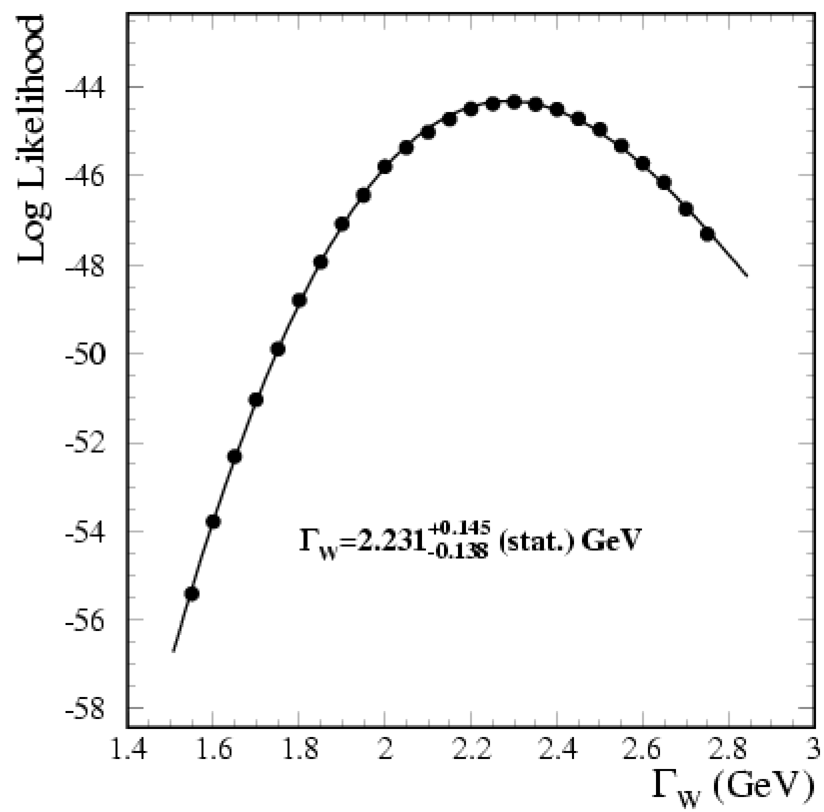
$\mathrm{P_T}(\mathrm{W}) < 15$ GeV

e in central calorimeter (non edge)

# Method

Basically, same method as W mass. Maximum likelihood fit to templates generated using a parameterization of the detector response. Fit range is 90 GeV $< m_T <$ 200 GeV



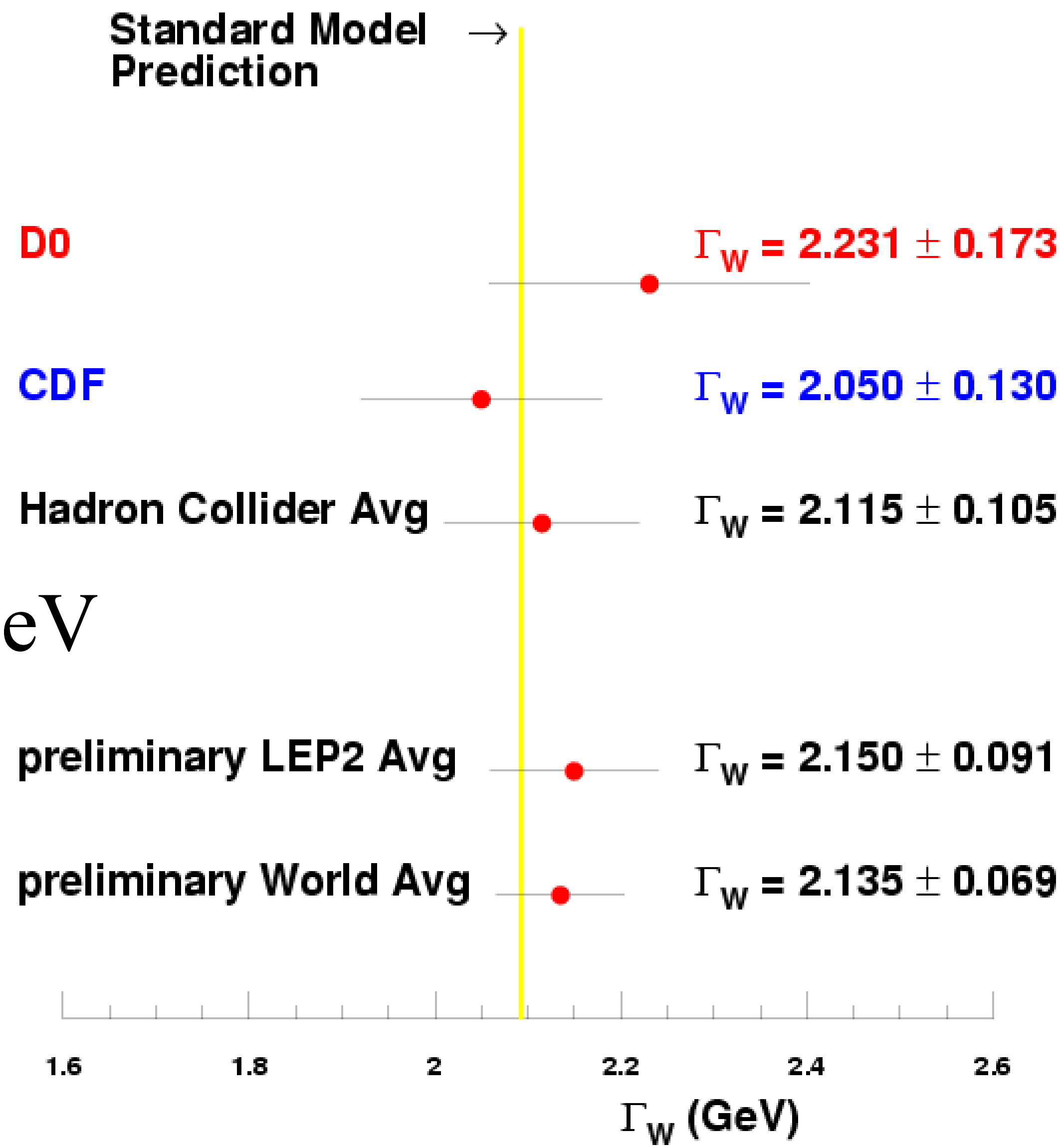
# Results

$$\Gamma(W) = 2.23^{+0.15}_{-0.14}(stat) \pm 0.01(sys)\ \text{GeV}$$

| Source | $\delta\Gamma$(W) (MeV) |
|---|---|
| Hadronic energy resolution | 55 |
| EM energy scale | 41 |
| Background ensesmble studies | 39 |
| Luminosity slope dependence | 28 |
| EM energy resolution | 27 |
| PDF | 27 |
| Hadronic energy scale | 22 |
| Background normalization | 15 |
| W boson mass | 15 |
| Production model | 12 |
| Radiative correction | 10 |
| Selection bias | 10 |
| Angular calibration of e trajectory | 9 |
| Total systematic uncertainty | 99 |
| Total statistical uncertainty | +145 |
| | -138 |
| Total uncertainty | +176 |
| | -170 |

# Results

Combine with LEP2 and CDF "direct" results




$$\Gamma(W) = 2.158 \pm 0.042 \text{ GeV}$$

Numbers from FERMILAB-FN-716

May '02

# $\Gamma(W \rightarrow l\nu)$

In SM, depends on:

- Couplings of W to EWK doublets
- EWK corrections $\approx 1/2\%$

$\Gamma(W \rightarrow e\nu)$ = 226.5±0.3 MeV (0.13%)

Can get this from our $\Gamma(W)$ measurement along with

$$R = \frac{\sigma(\bar{p}p \rightarrow W \rightarrow l\nu)}{\sigma(\bar{p}p \rightarrow Z \rightarrow ll)} = 10.42 \pm 0.18$$

This just in!!

$$R(\sqrt{s} = 1960\ \text{GeV}) = 13.66 \pm .94^{+1.08}_{-1.16}\ \text{CDF}(\mu)$$

$$10.0 \pm 0.8 \pm 1.3\ \text{D0(e)}$$

# $\Gamma(W \to e\nu)$

In SM, depends on:

- Couplings of W to EWK doublets
- EWK corrections ≈1/2%

$\Gamma(W \to e\nu)$ = 226.5±0.3 MeV (0.13%)

$$R = \frac{\sigma(p\bar{p} \to W \to e\nu)}{\sigma(p\bar{p} \to Z \to ee)} = \frac{\sigma(p\bar{p} \to W)}{\sigma(p\bar{p} \to Z)} \bullet \frac{\Gamma(W)}{B(Z \to ee)}$$

$\Gamma(W \to e\nu)$ — Just measured this

Previously measured 10.42±0.18

From theory. Depends on quark couplings to W/Z and QCD corrections. Many uncertainties cancel in ratio

LEP I

$$\Gamma(W \to e\nu) = 220.6 \pm 12.2 \text{ MeV}$$

# Summary

## New Measurements from DØ

M(W)=80.574±0.405 GeV

$$\Gamma(W) = 2.23^{+0.15}_{-0.14}(stat) \pm 0.01(sys)\ \text{GeV}$$

## New Combined DØ Results

M(W)=80.483 ±0.084 GeV

## New Tevatron Results

M(W)=80.456 ±0.059 GeV

Γ(W)=21.60 ±0.047 GeV

## New World Results

M(W)=80.451 ±0.032 GeV

Γ(W)=2.158 ±0.042 GeV