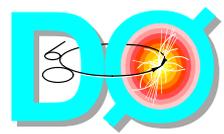


W Mass and Width at the Tevatron

Sarah Eno, University of Maryland



For the DØ Collaboration

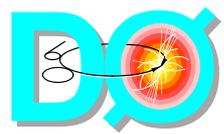


W Mass and Width at the Tevatron

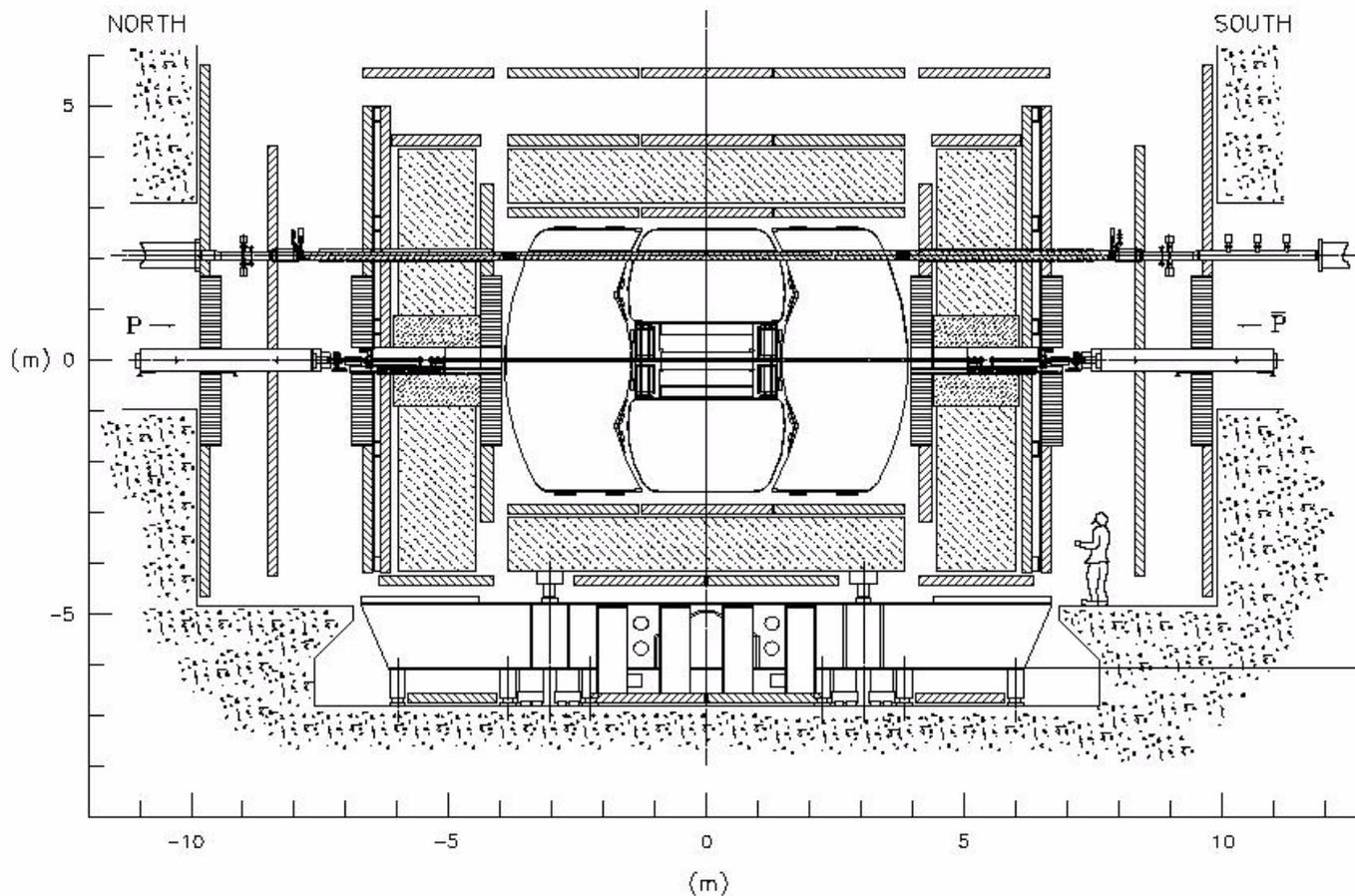


New Results from the Tevatron Run I (1994–1995) Data

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

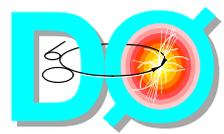


Run I DØ Detector



$p\bar{p}$ collisions
 $\sqrt{s} = 1.8 \text{ TeV}$

Analyses based on $\approx 85 \text{ pb}^{-1}$ taken in 1994–1995.

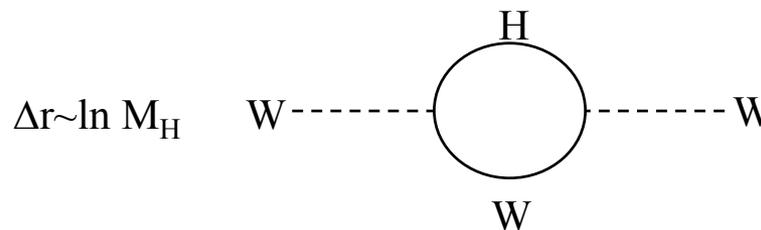
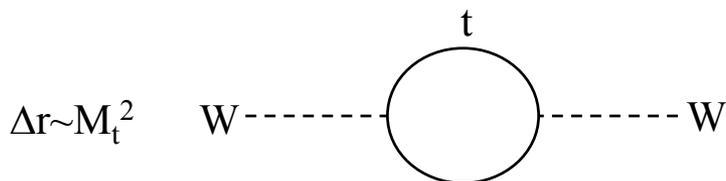


W Mass

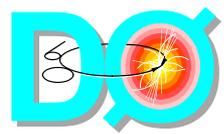


Highest precision measurement from the Tevatron's Collider.

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



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



Previous Measurements



Direct

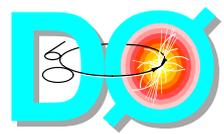
- 80.433 ± 0.079 (CDF)
- 80.447 ± 0.042 (LEP2)
- 80.482 ± 0.091 (DØ)

Indirect

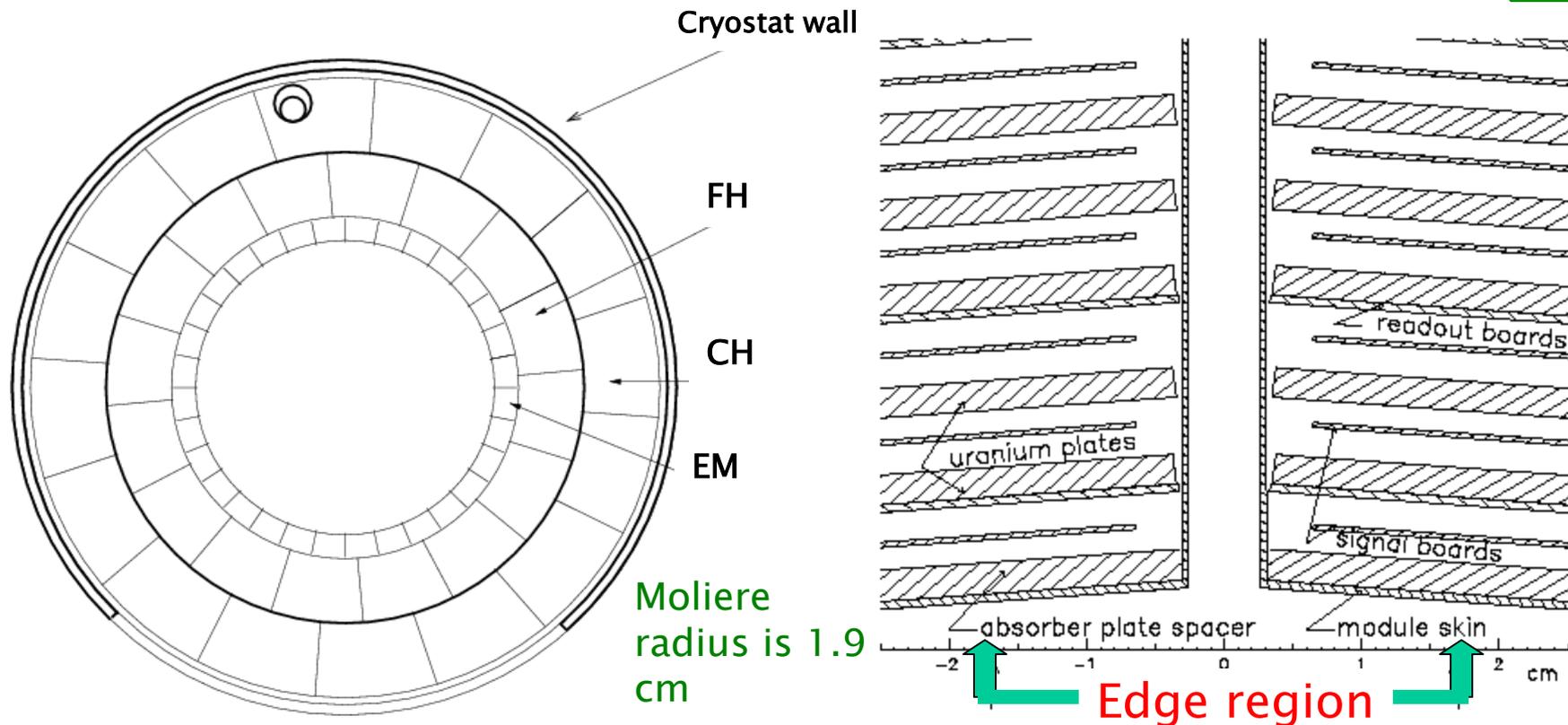
- 80.136 ± 0.084 (NuTeV)
- 80.380 ± 0.023 (LEP1 /SLD/Tevatron top mass)

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

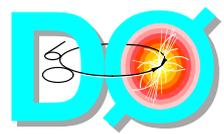
LEP EWK working group Web page, 22 Jul 02



DØ Calorimeter



- 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



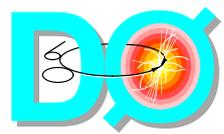
Variable	W boson sample	Z boson sample
$p_T(e \text{ central})$	$\geq 25 \text{ GeV}$	$\geq 25 \text{ GeV}$
$p_T(e \text{ end})$	–	$\geq 30 \text{ GeV}$
$p_T(\nu)$	$\geq 25 \text{ GeV}$	–
$p_T(W)$	$\leq 15 \text{ GeV}$	–
m_{ee}	–	60 – 120 GeV
$ z_{\text{vtx}} $	$\leq 100 \text{ cm}$	$\leq 100 \text{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

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

C is central, non-edge

E is endcap

\tilde{C} is central, edge



Basic Methodology

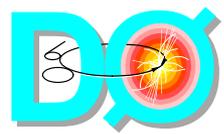


common to all DØ W mass measurements

- 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 $M(W)$

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

- 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

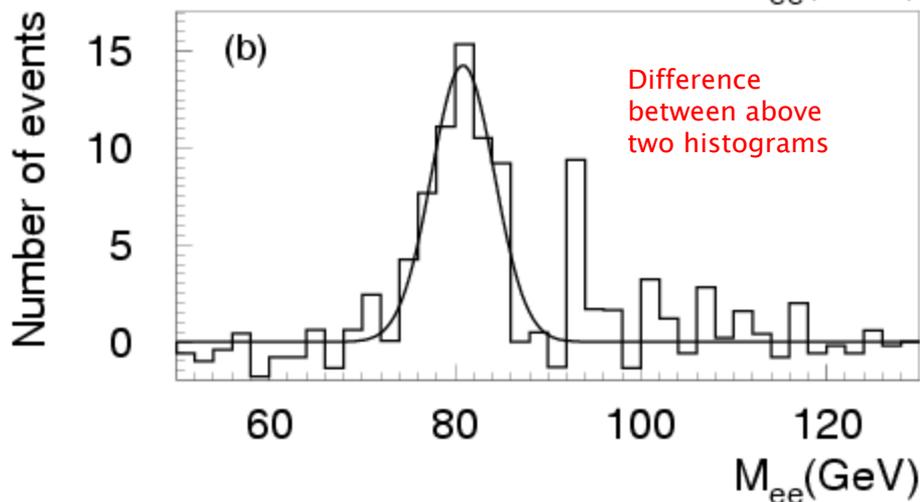
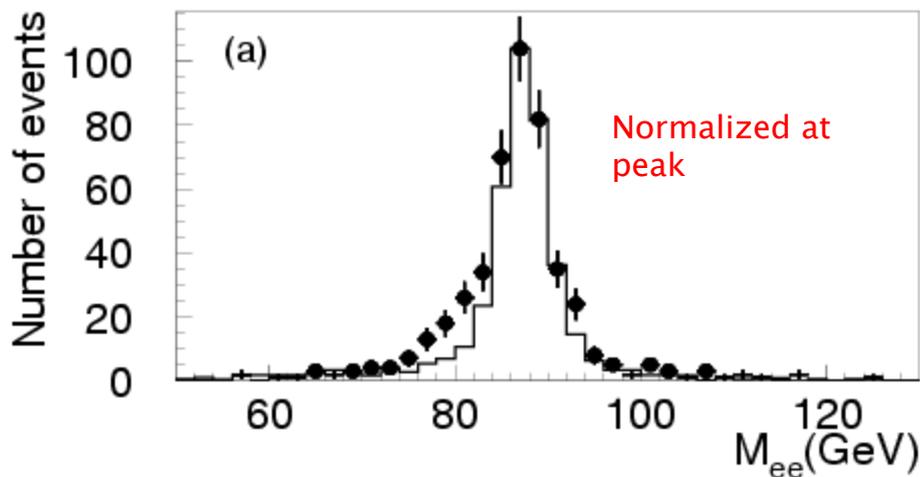


Parameterization of Resolution



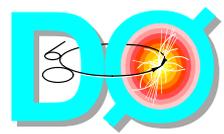
Points: Z's with 2 central e's, one edge.

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)

$$f = 0.346 \pm 0.076$$

$$\text{scale} = 0.912 \pm 0.018$$

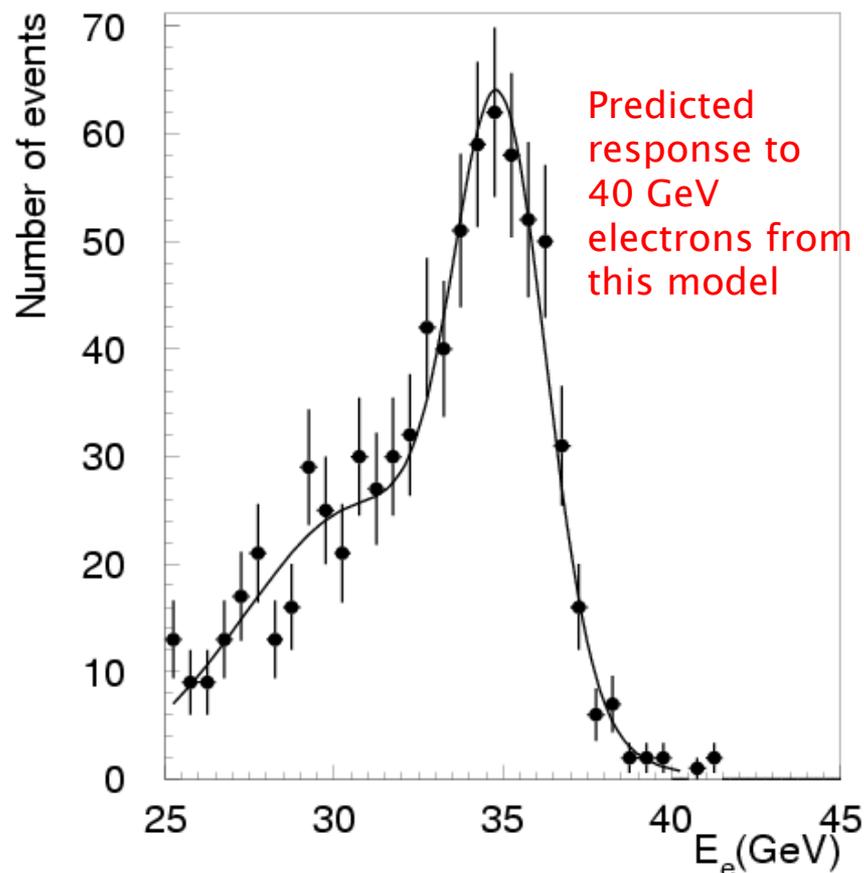
$$\text{constant term} = 0.101^{+0.028}_{-0.018}$$

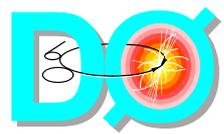
(1-f) with non-edge values

$$\text{scale} = 0.9540 \pm 0.008$$

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

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

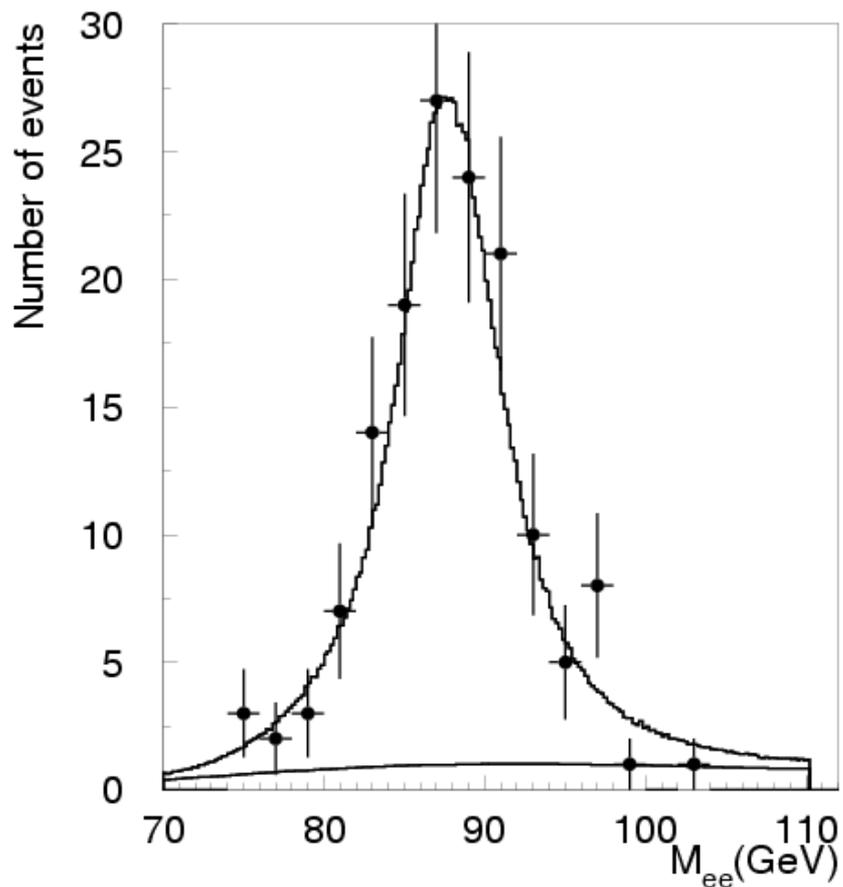




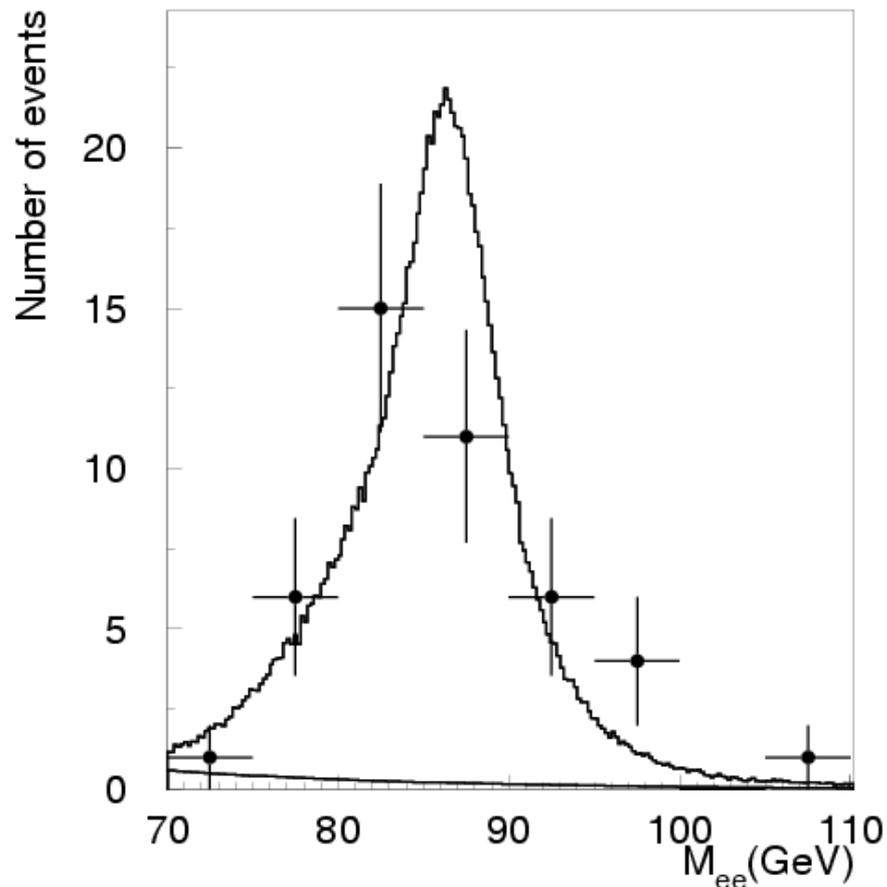
Systematic Tests

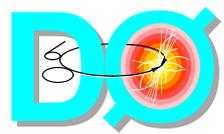


Z's with one edge,
one endcap electron

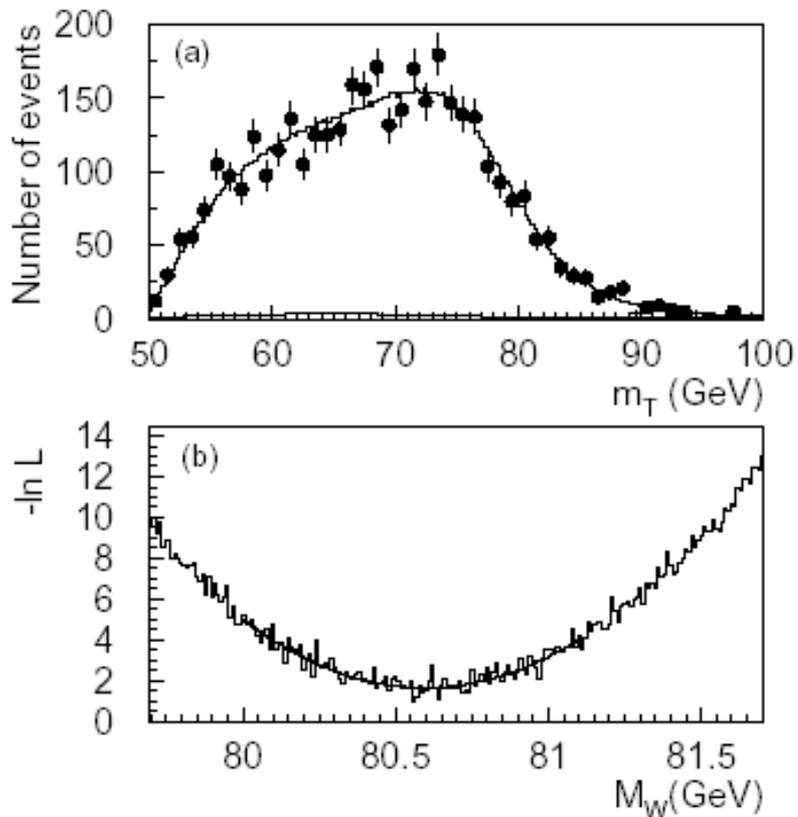


Z's with two edge
electrons



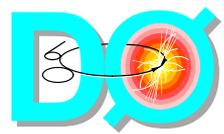


Results using only the edge electrons



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

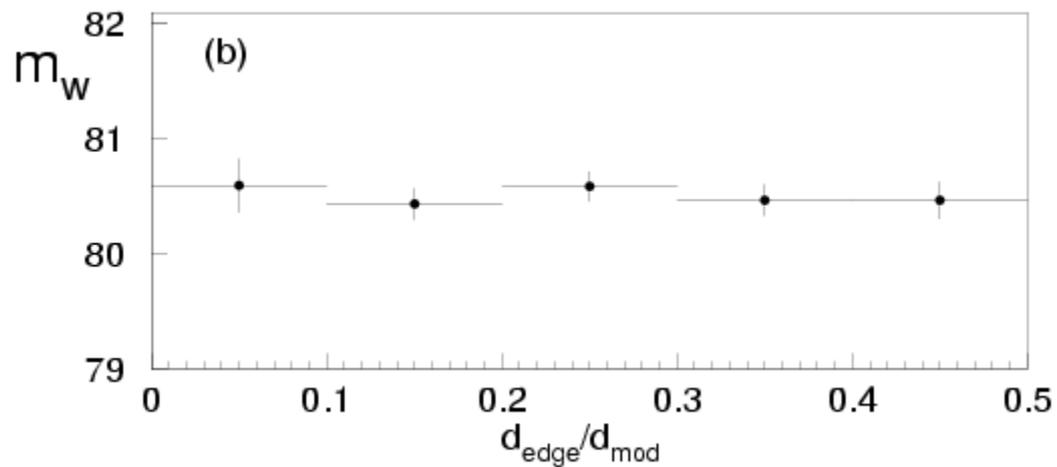
$$M_W = 80.574 \pm 0.405 \text{ GeV}$$

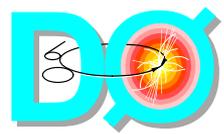


Systematic Tests



Fitted W mass as function of distance from the crack





Combined Analysis



W-Boson Mass [GeV]

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

$$80.482 \pm 0.091 \\ \rightarrow 80.481 \pm 0.085$$

Add edge electron W's $\rightarrow 80.482 \pm 0.084$

Combine with CDF, LEP2 $\rightarrow 80.450 \pm 0.034$

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

$p\bar{p}$ -colliders

LEP2

Average

NuTeV

LEP1/SLD

LEP1/SLD/ m_t



$$80.454 \pm 0.059$$



$$80.447 \pm 0.042$$



$$80.450 \pm 0.034$$

$$\chi^2/\text{DoF}: 0.0 / 1$$



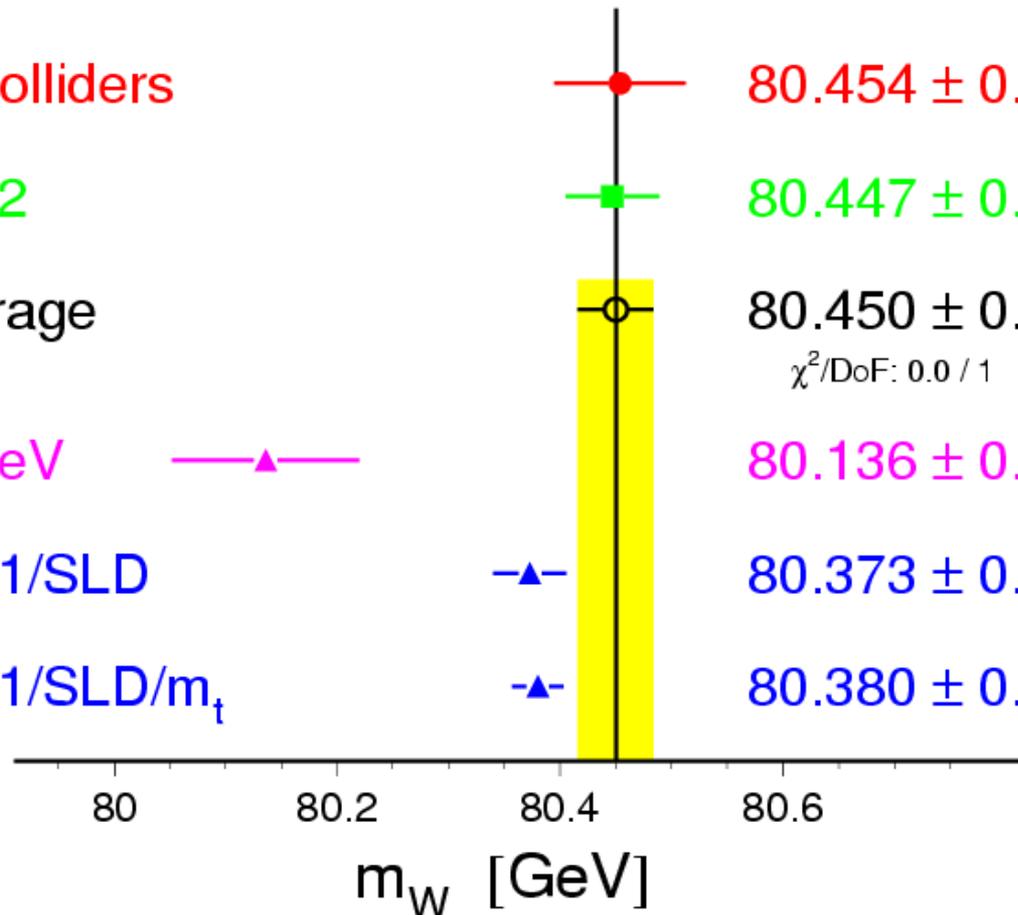
$$80.136 \pm 0.084$$

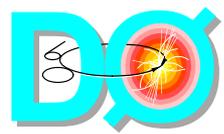


$$80.373 \pm 0.033$$

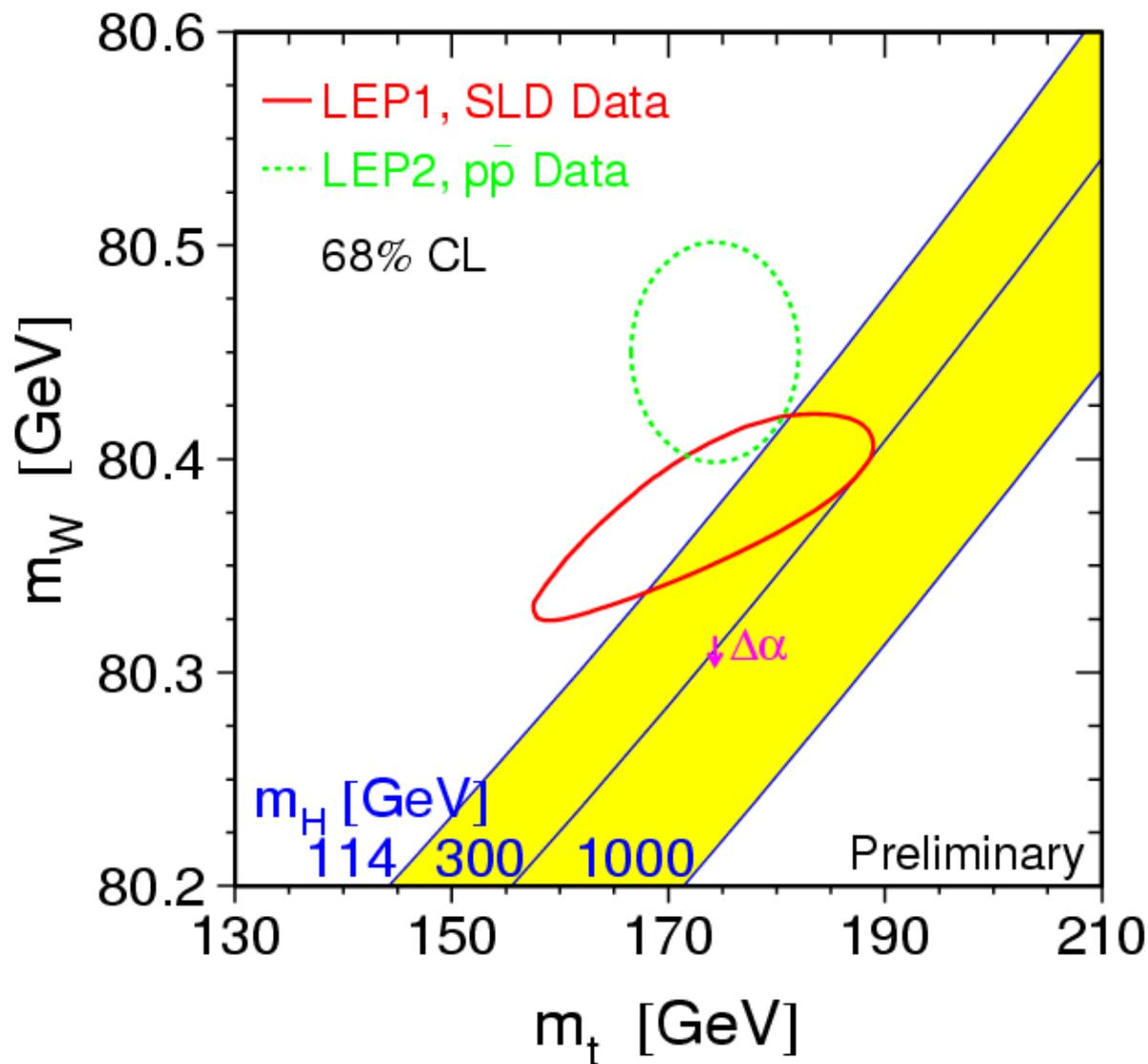


$$80.380 \pm 0.023$$

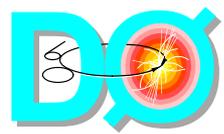




Higgs Mass



LEP EWK
working
group web
page



W Width



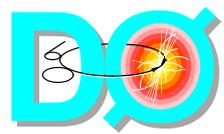
Standard Model Prediction depends on:

- 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

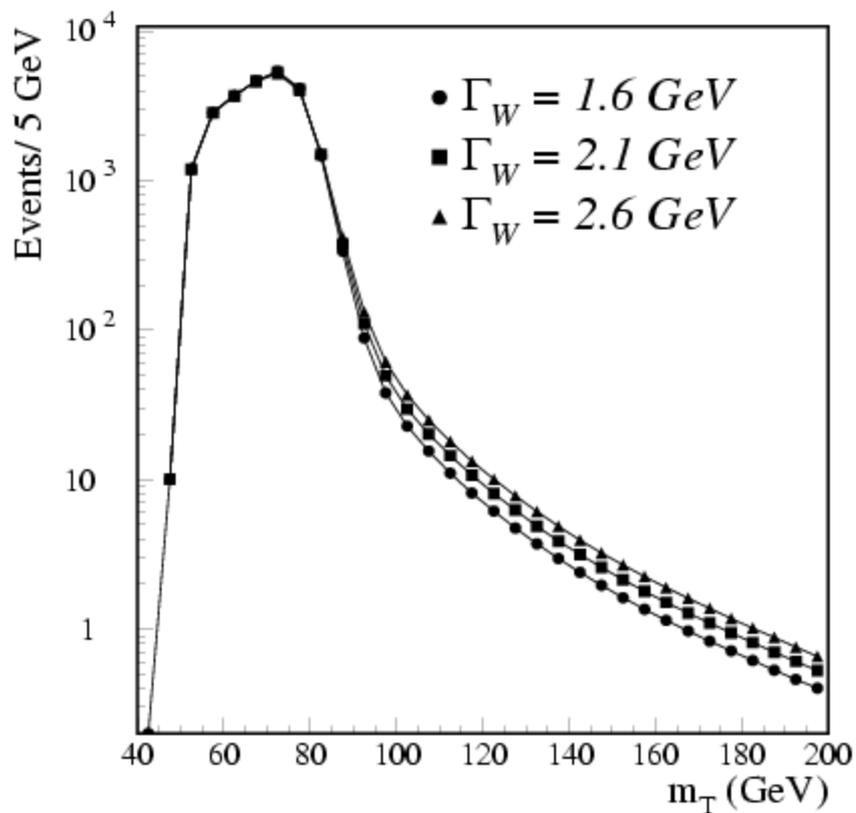
$\Gamma(W) = 2.0921 \pm 0.0025$ GeV (0.12% uncertainty!)

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

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

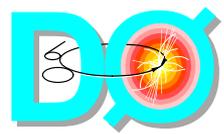


Direct Measurement



Shape of transverse mass distribution for $m_T < 90 \text{ GeV}$ is affected by the W width

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



Selection

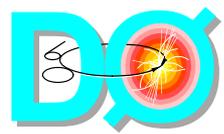


$$P_T(e) > 25 \text{ GeV}$$

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

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

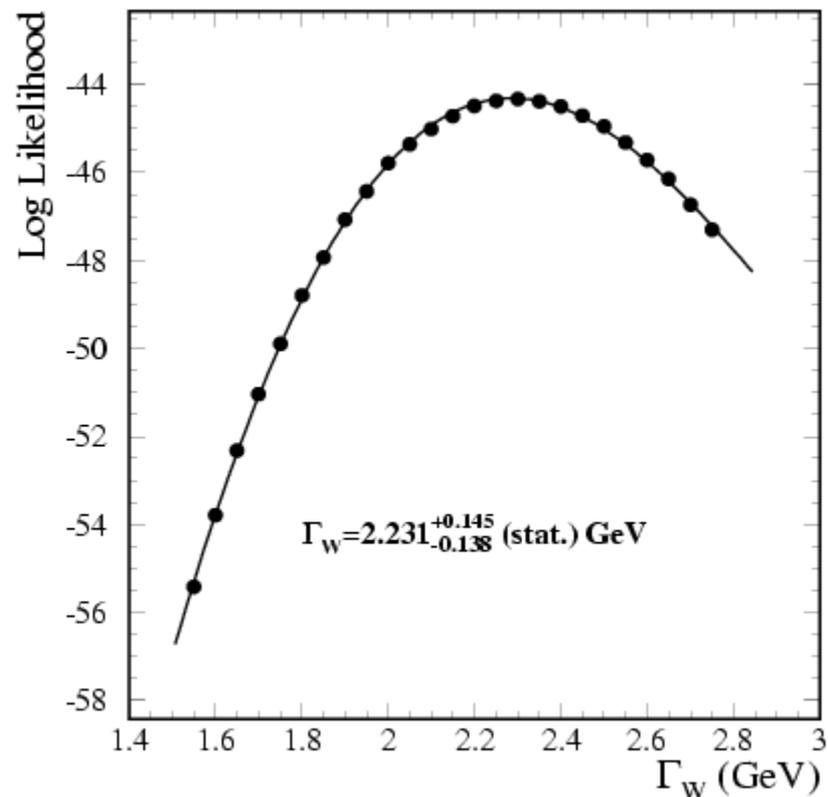
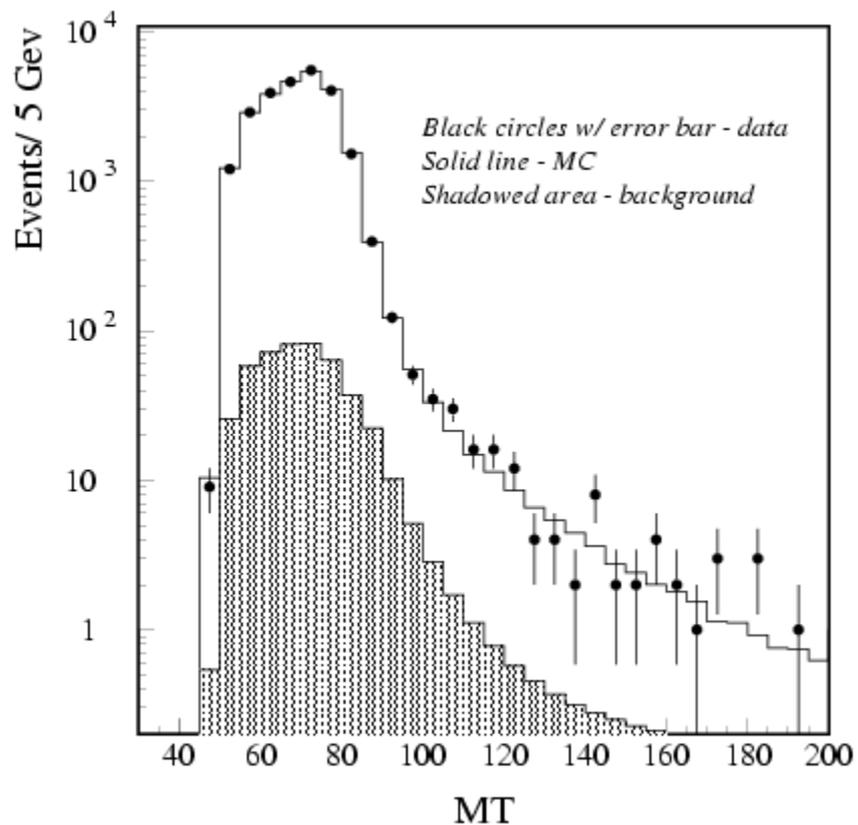
e in central calorimeter (non edge)

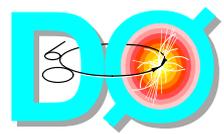


Method



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



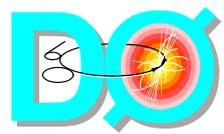


Results



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

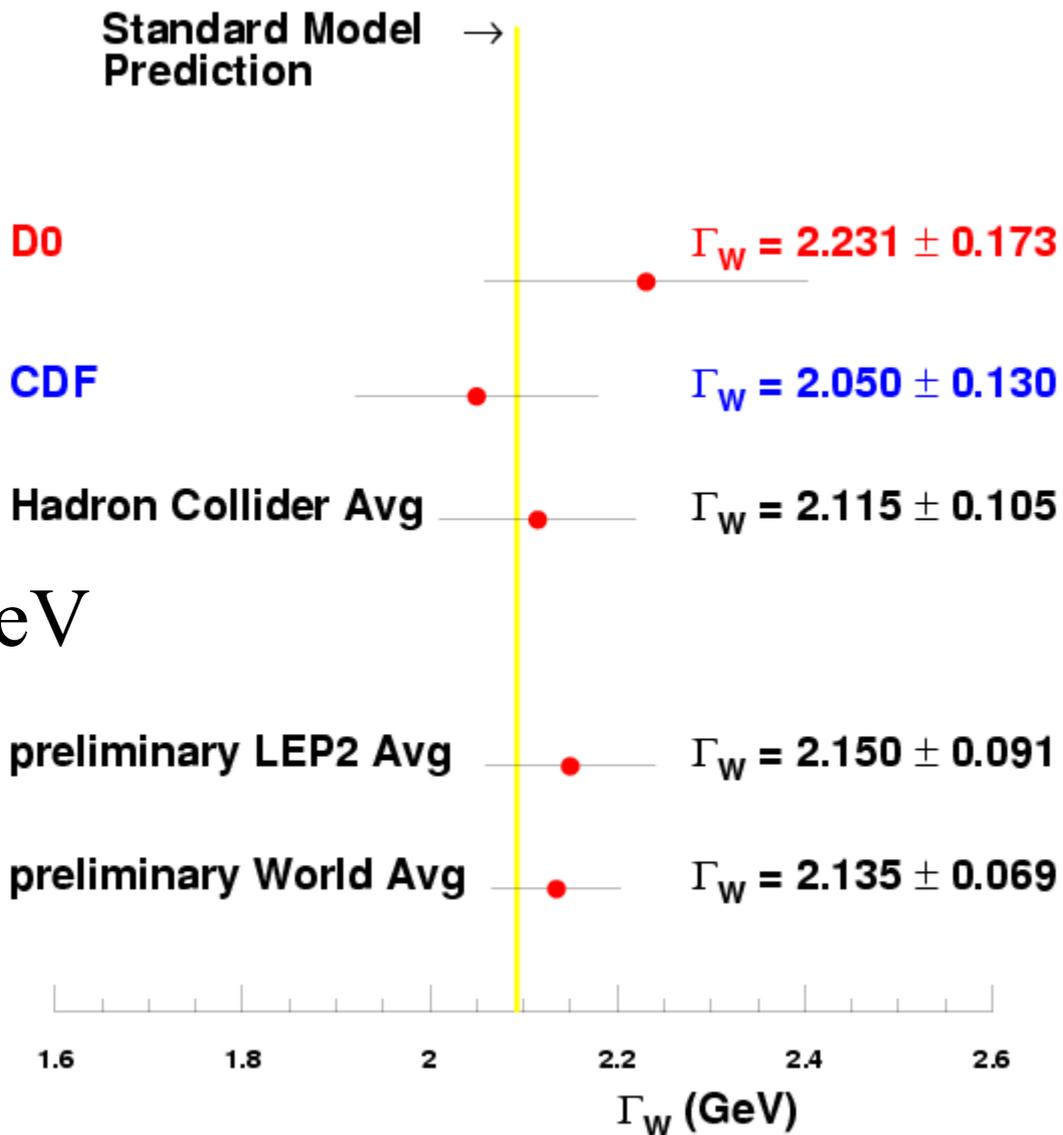
Source	$\delta\Gamma(W)$ (MeV)
Hadronic energy resolution	55
EM energy scale	41
Background ensembles studies	39
Luminosity slope dependence	28
EM energy resolution	27
PDF	27
Hadronic energy scale	22
Background normalization	15
W boson mass	15
Production model	12
Radiative correction	10
Selection bias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



Results



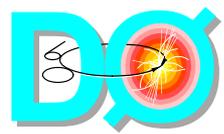
Combine with LEP2 and CDF “direct” results



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

Numbers from FERMILAB-FN-716

May '02



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



In SM, depends on:

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

$$\Gamma(W \rightarrow e\nu) = 226.5 \pm 0.3 \text{ MeV (0.13\%)}$$

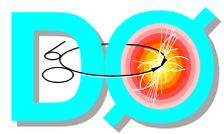
Can get this from our $\Gamma(W)$ measurement along with

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

This just in!!

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

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



$\Gamma(W \rightarrow e\nu)$



In SM, depends on:

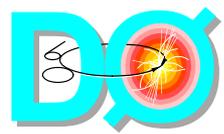
- Couplings of W to EWK doublets
- EWK corrections $\approx 1/2\%$

$$\Gamma(W \rightarrow e\nu) = 226.5 \pm 0.3 \text{ MeV (0.13\%)}$$

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

↑ 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
 ← Just measured this

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



Summary



New Measurements from DØ

$$M(W) = 80.574 \pm 0.405 \text{ GeV}$$

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

New Combined DØ Results

$$M(W) = 80.483 \pm 0.084 \text{ GeV}$$

New Tevatron Results

$$M(W) = 80.456 \pm 0.059 \text{ GeV}$$

$$\Gamma(W) = 21.60 \pm 0.047 \text{ GeV}$$

New World Results

$$M(W) = 80.451 \pm 0.032 \text{ GeV}$$

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