

FERMI NATIONAL ACCELERATOR LABORATORY

TEVEWWG/WZ 2010/01
FERMILAB-TM-2460-E
CDF Note 10103
D0 Note 6041
March 12, 2010

Combination of CDF and D0 Results on the Width of the W boson

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Abstract

We summarize and combine direct measurements of the width of the W boson in data collected by the Tevatron experiments CDF and D0 at Fermilab. Results from CDF and D0 Run-I (1992-1995) have been combined with the CDF 200 pb⁻¹ results from the first period of Run-II (2001-2004) and the recent 1 fb⁻¹ result in the electron channel from D0 (2002-2006). The results are corrected for any inconsistencies in parton distribution functions and assumptions about electroweak parameters used in the different analyses. The resulting Tevatron average for the width of the W boson is $\Gamma_W = 2,046 \pm 49$ MeV.

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1 Introduction

The CDF and D0 experiments at the Tevatron $\bar{p}p$ collider, located at the Fermi National Accelerator Laboratory, have directly measured the total decay width of the W boson, Γ_W , in both the $e\nu$ and $\mu\nu$ decay modes.

Previous measurements of Γ_W were published by CDF using Run-I [1, 2] and Run-II [3] data and by D0 [4] in Run-I. These earlier results have been combined by this group and appear in reference [5]. The present note includes a more recent 2009 D0 measurement using 1 fb^{-1} of data from Run-II in the $e\nu$ decay mode [6] and supersedes the previous Tevatron combinations [5, 7, 8]. The measurements are combined using the analytic BLUE method [9, 10]. This procedure takes account of both statistical and systematic uncertainties as well as the correlations among them.

As in the July 2008 combined analysis of the mass and width in reference [5] and the 2009 analysis of the mass measurements [11], there are three significant changes relative to previous combinations of W boson results by the TEVEWWG:

- The individual measurement channels of Γ_W for CDF Run-Ia and Run-Ib are now combined for each run period using the BLUE method to achieve a consistent statistical treatment of all results.
- The older central values of Γ_W , based upon very old parton distribution function (PDF) sets, are corrected to use the PDFs from the CTEQ6M [12] PDF set with uncertainty estimates from the CTEQ6M, CTEQ6.1M [13] and MRST2003 [14] sets. The new D0 Run-II measurement uses CTEQ6.1M while the CDF Run II measurement used CTEQ6M. The difference in the width extracted using these PDF sets is found to be $\Gamma_W(\text{CTEQ6.1M}) - \Gamma_W(\text{CTEQ6M}) = 3 \pm 9 \text{ MeV}$, significantly less than the 20 MeV PDF systematic uncertainty, and therefore no correction is applied for this difference.
- In addition, in this combined measurement we have revisited the uncertainty on Γ_W resulting from changes in the assumed value of M_W in different measurements. The revised uncertainties are described when they are used in section 4.

2 New data from D0 on Γ_W

The width, Γ_W of the W boson determined by D0 in Run-II [6], using $W \rightarrow e\nu$ decays observed in 1 fb^{-1} of data at $\sqrt{s} = 1960 \text{ GeV}$, is extracted from fits to the transverse mass distribution in the range $100 \leq m_T \leq 200 \text{ GeV}$. The central value of Γ_W is $2,028 \pm 72 \text{ MeV}$. The measurement procedure differs somewhat from the 2009 D0 Run-II measurement [15] of M_W as the effects of hadrons recoiling against the W boson in the measurement of Γ_W are modeled using a library of recoil kinematics derived from detected Z bosons [16] rather than through simulation, as in the measurement of the W boson mass. The M_W measurement used the transverse mass range $65 \leq m_T \leq 90 \text{ GeV}$, in addition to fits to the $p_T^e \geq 25 \text{ GeV}$ and $p_T^\nu \geq 25 \text{ GeV}$ distributions, and, as a result, the W event samples used in the Γ_W and M_W measurements are effectively statistically independent. The two measurements share electron response, resolution and models of detector efficiencies, and the same production models and electroweak radiative corrections.

Table 1 summarizes the uncertainties on the new measurement of Γ_W by D0 and the correlation of sources of systematic uncertainties with previous results.

Source	Uncertainty in MeV	Correlation coefficient with previous results
Experimental uncertainties		
W Statistics	39	0
Electron response model	33	0
Electron resolution model	10	0
Hadronic recoil model	41	0
Electron efficiencies	19	0
Backgrounds	6	0
Production uncertainties		
PDFs	20	1.0
EWK radiative corrections	7	1.0
Boson p_T	1	0
M_W	5	1.0

Table 1: Contributions (in MeV) to the uncertainty on the measurement of Γ_W in D0 data from Run-II .

3 Correlation of the D0 Run II result with other measurements

Experimental uncertainties on the new D0 measurement of Γ_W are dominated by the statistical uncertainty on the number of W events found in the high mass region sensitive to the width, and by uncertainties in the energy response of the D0 detector. Energy response functions are derived from events containing Z bosons and their uncertainties are almost purely statistical. All of the experimental uncertainties in the new D0 measurement of Γ_W are assumed to be uncorrelated with previous measurements.

Three systematic uncertainties from the production of W and Z bosons are assumed to be fully correlated among all Tevatron measurements, namely (i) the parton distribution functions (PDFs), (ii) the mass of the W boson (M_W) and (iii) the electroweak radiative corrections (EWK RC).

The D0 measurement also includes an uncertainty in the models of the W and Z boson p_T distributions, which is derived from a global fit to deep-inelastic scattering and hadron collider data [17]. In previous analyses, this source of uncertainty is treated differently, and it is therefore regarded as uncorrelated with the earlier measurements.

Current estimates of uncertainties from radiative corrections include a significant statistical component. The WGRAD/ZGRAD [18] and PHOTOS [19] models are used in the different measurements and yield results consistent within the statistical uncertainties. We assume that the effects of radiative corrections are 100% correlated between all measurements because the models used are very similar.

4 Combination of Widths of the W Boson

4.1 Corrections for changes in M_W

As in the case of the combined mass analysis, we have applied corrections to achieve consistency across all input results. The CDF Run-Ib results have been recombined using the BLUE method, and all results are corrected so that Γ_W is evaluated assuming the world-averaged (December 2009) mean value of $M_W = 80,399 \pm 23$ MeV [20]. We correct for the M_W assumptions in the initial publications using the relation $\Delta\Gamma_W = (-0.3 \pm 0.1) \times \Delta M_W$. This is the average of the shift in Γ_W empirically determined by CDF and

	Run-I			Run-II	
	CDF-Ia	CDF-Ib	D0-Ib	CDF	D0
Γ_W (published)	2,110	2,042.5	2,231	2,032	2,028.3
Total uncertainty (published)	329	138.3	172.8	72.4	72
M_W used in publication	80,140	80,400	80,436	80,403	80,419
Correction to Γ_W from M_W	-78	0.3	11.1	1.2	6.0
Γ_W (corrected)	2,032	2,042.8	2,242.1	2,033.2	2,034.3
Total uncertainty(corrected)	329.3	138.3	172.4	72.4	71.9
Uncorrelated uncertainty (corrected)	327.6	136.8	167.4	68.7	68.5
PDF uncertainty(published)	0	15	39	20	20
PDF uncertainty (this analysis)	15	15	39	20	20
EWK RC uncertainty	28	10	10	6	7
M_W uncertainty (published)	0	10	15	9	5
M_W uncertainty (this analysis)	7	7	7	7	7
M_W extrapolation	26	0	4	0	2

Table 2: Summary of the five measurements of Γ_W performed by CDF and D0. All numbers are in MeV. The published values and the corrected values (assuming M_W is the 2009 world average of $80,399 \pm 23$ MeV) used in the average are shown. The three sources of correlated systematic uncertainty (PDF, EWK RC, M_W) are given explicitly.

D0 when M_W is varied. We include an uncertainty of $0.1 \Delta M_W$, for this correction. In addition, we have re-evaluated the uncertainties on Γ_W due to the uncertainty in M_W . The world average uncertainty of 23 MeV in M_W yields an uncertainty in Γ_W of 7 MeV which replaces the M_W uncertainty assumed in the original publications. In most cases, our improved knowledge of M_W has decreased the estimated uncertainty from the input M_W .

5 Results

The combined Tevatron value for Γ_W is:

$$\Gamma_W = 2,046 \pm 49 \text{ MeV}$$

The combined Tevatron result has a χ^2 of 1.4 for 4 degrees of freedom, corresponding to a probability of 84%. All measurements are in good agreement with each other as can be seen in Figure 1, where the individual results and this combination are shown.

The total uncertainty on the combined Tevatron Γ_W is 49 MeV and consists of the following components: an uncorrelated uncertainty of 44 MeV and correlated systematic contributions from parton distribution functions of 20 MeV, electroweak radiative corrections of 7.4 MeV, and input W -boson mass of 7.4 MeV, for a total correlated systematic uncertainty of 23 MeV. The global correlation matrix of the five Tevatron measurements is shown in Table 4.

A combination with the latest LEP-2 average value, $\Gamma_W = 2,196 \pm 83$ MeV [20], assuming no correlation between the Tevatron and LEP-2 measurements, gives a preliminary world average of $\Gamma_W = 2,085 \pm 42$ MeV with a χ^2 of 2.4 for one degree of freedom. This world average value is in agreement with the SM prediction of $\Gamma_W = 2,093 \pm 2$ MeV [21].

6 Summary

Combinations of the direct CDF and D0 measurements of the total decay width of the W boson are presented. Corrections have been made to achieve a consistent treatment across published Tevatron measurements, corrected for inconsistencies in Standard Model parameters. The Tevatron average result is $\Gamma_W = 2,046 \pm 49$ MeV, and a preliminary world average including both the Tevatron and LEP2 is $\Gamma_W = 2,085 \pm 42$ MeV.

	Relative Weights in %
CDF Ia	1.6
CDF Ib	10.8
D0 I	5.4
CDF II	41.2
D0 II	41.2

Table 3: Relative weights of the individual contributions in %.

	Run-I			Run-II	
	CDF-Ia	CDF-Ib	D0-Ib	CDF	D0
CDF-Ia	1.00	0.02	0.02	0.03	0.03
CDF-Ib		1.00	0.03	0.04	0.04
D0-I			1.00	0.07	0.07
CDF-II				1.00	0.09
D0-II					1.00

Table 4: Matrix of global correlation coefficients among the 5 measurements of Table 2.

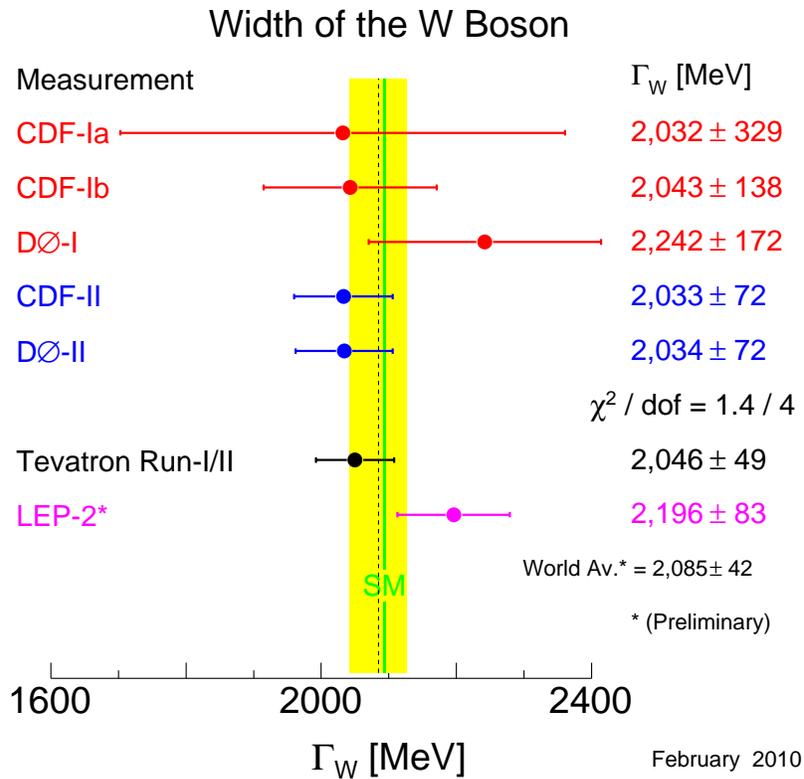


Figure 1: Comparison of measurements of the width of the W -boson and their average. The most recent preliminary result from LEP-2 [20] and the Standard Model prediction are also shown. The Tevatron values are corrected for small inconsistencies in theoretical assumptions among the original publications .

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