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Preliminary Results on Z Production Cross-Sections and Lepton Forward–Backward Asymmetries using the 1994 Data

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Abstract

Preliminary values of the Z resonance parameters and lepton pair forward–backward asymmetries are measured from a sample of about 3.4 million Z decays into hadrons and charged leptons accumulated with the ALEPH detector at LEP between 1989 and 1994. The Standard Model fit has been performed using these parameters as well as the most recent ALEPH results on τ polarization, R_{b}, R_{c}, b and c quark and hadronic charge asymmetries.

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1 Introduction

During the 1994 data taking period ALEPH has accumulated about 1.4 million Z decays at the center-of-mass (cms) energy of 91.2 GeV, therefore almost doubling the total statistics accumulated so far. Preliminary values of the measured hadronic and leptonic cross-sections and the leptonic forward–backward asymmetries are presented here. These results are combined with those of the 1990 and 1991 energy scans ($E_{cms} \cong m_Z \pm$ 3 GeV), the high statistics data collected in 1992 ($E_{cms} \cong m_Z$), and the preliminary results of the 1993 high precision scan ($E_{cms} \cong m_Z \pm$ 2 GeV) [1]. These combined line-shape analysis results have been used as input to the Standard Model fit, together with the results of the b, c quark and hadronic charge asymmetries, the ratios of the b and c quark partial width to the total hadronic partial width, R_b, R_c, and the τ polarization measurements. The definition of the different variables used in the text can be found in Ref. [1].

2 Cross-section measurements

Table 1 gives the results of the cross-section measurements performed during the high statistics data-taking period in 1994. A luminosity of 42 639 nb^{-1} has been used to extract the cross-section values. The luminosity systematic errors are detailed in Table 2 [2] and compared with those obtained in previous years. The experimental systematic error is 0.116% for the 1994 analysis and the theoretical one is 0.16% [3].

As in previous years [1], the hadronic selection was made using two different techniques based on charged tracks and energy deposition in the calorimeters, respectively. Details of the various contributions to the systematic error for both selections are summarized in Table 3. The combined systematic error on the hadronic selection is 0.073% [4].

3 Lepton forward–backward asymmetries

The 1994 lepton forward–backward asymmetries are presented in Table 4. A larger data sample was used in this analysis (55 077 nb^{-1}) corresponding to the number of events presented in Table 4 for the different leptonic channels.

Details of the cross-section and forward–backward asymmetry analysis can be found in Ref. [4, 5].

4 Line-shape and asymmetry parameters

The 1994 hadronic and lepton pair cross-sections and the lepton forward–backward asymmetries were simultanously fitted with all previously accumulated data using the line shape fitting program MIZA [6]. Table 5 summarizes the statistics used in the analysis while

Table 6 shows the systematic errors for the different event samples. From the fit results we have obtained a set of nine parameters and, assuming lepton universality, a set of five parameters given in Table 7. Tables 8 and 9 show the values of the correlation coefficients, while Table 10 gives the results for other derived quantities.

Figure 1 gives the 68% probability contours in the $A_{\rm FB}^{0,\ell}$-R_ℓ plane, Figure 2 the measurements of $\sin^2\theta_{\rm eff}^{\rm lept}$ and $R_{\rm b}$, Figure 3 the measurements of $\sin^2\theta_{\rm eff}^{\rm lept}$ and $\Gamma_{\ell\ell}$. The Standard Model predictions are shown as well.

5 Standard Model fits

As input to the Standard Model fit we have used the line-shape and lepton forward–backward asymmetry measurements together with the most recent ALEPH results on the τ polarization, τ forward-backward polarization asymmetry (giving $\mathcal{A}_\tau$ and $\mathcal{A}_{\rm e}$), the b and c quark forward–backward asymmetries ($A_{\rm FB}^{0,\,\rm b}$, $A_{\rm FB}^{0,\,\rm c}$), and the ratios of the b and c quark partial width to the total hadronic partial width ($R_{\rm b}$, $R_{\rm c}$). The values of the parameters used in the fits are given in Table 11.

The following results have been used:

- τ polarization: final analysis of the 1990-92 period [7].
- $R_{\rm b}$: published results including the lifetime tag analysis of the 1992 data, event shape analysis and lepton analysis using the 1990-91 data [8].
- $R_{\rm c}$: published results of the lepton analysis using the 1990-91 data[9].
- $A_{\rm FB}^{0,\,\rm b}$: published results including jet charge analysis of the 1991-93 data [10] and preliminary high p_T lepton analysis using the 1990-93 data [10].
- $A_{\rm FB}^{0,\,\rm c}$: lepton analysis using the 1990-91 data [9] and preliminary D* analysis using the 1990-94 data [11].
- jet charge asymmetry: preliminary results using 1990-93 data [12].

Table 12 shows the improved results on the effective couplings obtained by using the ALEPH measurements of the couplings of the τ and electron from the τ polarization measurements as constraints.

The ALEPH measurements of $\sin^2\theta_{\rm eff}^{\rm lept}$ are given in Table 13.

Results of the Standard Model Fits to the ALEPH data, giving $m_{\rm t}$ and α_s values, are shown in Table 14. A value of $\alpha^{-1}(m_Z^2) = 128.89 \pm 0.09$ [13] has been used and the error is propagated in the fits. The value of $m_{\rm t}$ resulting from the fit is in very good agreement with the recent determination from CDF [14] and D0 [15] collaborations.

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	statistics	σ (nb)	stat. error (nb)	sys. error (nb)	sys. error (%)
$q\bar{q}$	1281418	30.385	0.0305	0.022	0.073
e^+e^-	52363	1.5052	0.0075	0.0073	0.48
$\mu^+\mu^-$	52802	1.4792	0.0064	0.0039	0.26
$\tau^+\tau^-$	49604	1.4702	0.0067	0.0047	0.32

Table 1: ALEPH preliminary results on Z production cross-sections using the 1994 data. The second column gives the number of events after experimental cuts and before acceptance corrections.

Source of uncertainty	1992 SICAL Period	1993 Data	1994 Data Preliminary
Trigger efficiency	0.0010%	0.0002%	0.0005%
Background estimation:			
- Off momentum e^+ or e^-	0.018%	0.003%	0.0007%
- Physics sources	0.010%	0.010%	0.010%
Reconstruction efficiency	0.001%	0.001%	0.001%
Event migration from overlays	$< 0.005\%$	nil	0.008%
Absolute radial fiducial boundary:			
- Mechanical precision	0.058%	0.029%	0.029%
- Beam and module alignments	0.035%	0.030%	0.031%
- z position of modules	0.035%	0.035%	0.035%
- Asymmetry precision	0.044%	0.025%	0.064%
- Simulation precision	0.023%	0.016%	0.016%
Energy cuts	0.015%	0.004%	0.015%
Acoplanarity cut	0.005%	0.005%	0.005%
SUBTOTAL	0.095%	0.063%	0.089%
Simulation statistics	0.120%	0.060%	0.075%
TOTAL experimental error	0.153%	0.087%	0.116%
Theoretical error	0.250%	0.16%	0.16%
(Improved theor. error)	(0.16%)		
TOTAL LUMI error	0.293%	0.182%	0.198%
(Improved theor. error)	(0.221%)		

Table 2: Summary of absolute luminosity measurement systematics as defined in Ref. [2]. The improvement of the theoretical error for 1992 is given in parentheses.

	Hadronic selection	
	Charged track	Calorimeter
Efficiency	97.49%	99.07%
Background:		
$\tau^+\tau^-$	0.32%	0.45%
$\gamma\gamma$ (pb)	78 ± 12	71 ± 16
e^+e^- (pb)	negl.	(a)
Source of systematics		
detector response	0.02%	0.09%
modeling	0.063%	negl.
MC statistics	0.02%	0.02%
background:		
$\tau^+\tau^-$	0.03%	0.06%
$\gamma\gamma$	0.04%	0.05%
e^+e^-	negl	(a)
Total systematics	0.087%	0.121%
combined	0.073%	

Table 3: Efficiency, background and systematic errors for hadronic selections at $\sqrt{s} = 91.2$ GeV.
(a) The e^+e^- contribution is already included in the $\gamma\gamma$ cross-section.

	statistics	A_{FB}	stat. error	sys. error
e^+e^-	66953	0.0002	0.0048	0.0031
$\mu^+\mu^-$	68095	0.0027	0.0038	0.0011
$\tau^+\tau^-$	61630	0.0046	0.0039	0.0040

Table 4: ALEPH preliminary results on lepton forward–backward asymmetries using the 1994 data. The second column gives the number of events after experimental cuts and before acceptance corrections.

	year	statistics
$q\bar{q}$	90-91	451
	92	680
	93 prel.	640
	94 prel.	1281
	total	3052
l^+l^-	90-91	55
	92	82
	93 prel.	78
	94 prel.	[a] 155
	total	370

Table 5: ALEPH event statistics in units of 10^3 used for the analysis of the Z line-shape and lepton forward–backward asymmetries.
[a]Statistics used in the measurement of the lepton cross-section measurements. The statistics used in the lepton forward–backward asymmetries was about 27% higher.

	93 prel.	94 prel.
$\mathcal{L}^{\rm exp.}$	0.087%	0.116%
$q\bar{q}$	0.073%	0.073%
$\rm e^+e^-$	0.50%	0.48%
$\mu^+\mu^-$	0.25%	0.26%
$\tau^+\tau^-$	0.34%	0.32%
$A_{\rm FB\ e}$	0.003	0.0031
$A_{\rm FB\ \mu}$	0.001	0.0011
$A_{\rm FB\ \tau}$	0.0040	0.0040

Table 6: The ALEPH experimental systematic errors for the analysis of the Z line-shape and lepton forward–backward asymmetries.

Parameter	No lepton univ.	lepton univ.
$m_{\rm Z}$ (GeV)	91.1924 ± 0.0037	91.1924 ± 0.0037
$\Gamma_{\rm Z}$ (GeV)	2.4954 ± 0.0056	2.4951 ± 0.0055
$\sigma^0_{\rm h}$ (nb)	41.56 ± 0.09	41.56 ± 0.09
$R_{\rm e}$	20.54 ± 0.11	-
R_μ	20.88 ± 0.09	-
R_τ	20.77 ± 0.10	-
R_ℓ	-	20.739 ± 0.060
$A^{0,\rm e}_{\rm FB}$	0.0196 ± 0.0044	-
$A^{0,\mu}_{\rm FB}$	0.0189 ± 0.0029	-
$A^{0,\tau}_{\rm FB}$	0.0206 ± 0.0039	-
$A^{0,\ell}_{\rm FB}$	-	0.0195 ± 0.0021
$\chi^2/d.o.f.$	181/185	187/189

Table 7: Line shape and asymmetry results from nine and five parameter fits to all ALEPH data.

	m_Z	Γ_Z	σ_h^0	R_ℓ	$A_{FB}^{0,\ell}$
m_Z	1.00	0.03	0.10	0.02	0.13
Γ_Z		1.00	-0.24	-0.01	0.00
σ_h^0			1.00	0.19	0.02
R_ℓ				1.00	0.01
$A_{FB}^{0,\ell}$					1.00

Table 8: Correlation coefficients for the five parameter fit to the Z line shape assuming lepton universality.

	m_Z	Γ_Z	σ_h^0	R_e	R_μ	R_τ	$A_{FB}^{0,e}$	$A_{FB}^{0,\mu}$	$A_{FB}^{0,\tau}$
m_Z	1.00	0.028	0.10	0.03	0.00	0.01	0.06	0.10	0.07
Γ_Z		1.00	-0.24	-0.03	0.01	-0.01	0.00	0.00	0.00
σ_h^0			1.00	0.11	0.11	0.12	0.01	0.01	0.01
R_e				1.00	0.05	0.05	0.00	0.00	0.00
R_μ					1.00	0.06	0.00	0.01	0.00
R_τ						1.00	0.00	0.00	0.01
$A_{FB}^{0,e}$							1.00	0.02	0.03
$A_{FB}^{0,\mu}$								1.00	0.02
$A_{FB}^{0,\tau}$									1.00

Table 9: Correlation coefficients for the nine parameter fit to the Z line shape.

Derived parameter	No lepton univ.	lepton univ.
Γ_{had} (MeV)	-	1743.5 ± 4.8
$\Gamma_{\ell\ell}$ (MeV)	-	84.07 ± 0.22
Γ_{inv} (MeV)	-	499.6 ± 3.7
$\Gamma_{\mathrm{inv}}/\Gamma_{\ell\ell}$	-	5.943 ± 0.039
Γ_{ee} (MeV)	84.48 ± 0.30	-
$\Gamma_{\mu\mu}$ (MeV)	83.12 ± 0.46	-
$\Gamma_{\tau\tau}$ (MeV)	83.57 ± 0.48	-
$BR(\mathrm{Z} \rightarrow q\overline{q})$ (%)	-	69.88 ± 0.14
$BR(\mathrm{Z} \rightarrow \ell^+\ell^-)$ (%)	-	3.3693 ± 0.0055
$BR(\mathrm{Z} \rightarrow \mathrm{e}^+\mathrm{e}^-)$ (%)	3.385 ± 0.010	-
$BR(\mathrm{Z} \rightarrow \mu^+\mu^-)$ (%)	3.331 ± 0.017	-
$BR(\mathrm{Z} \rightarrow \tau^+\tau^-)$ (%)	3.349 ± 0.018	-
$\sigma^0_{\ell\ell}$ (nb)	-	2.0038 ± 0.0066
σ^0_{ee} (nb)	2.023 ± 0.012	-
$\sigma^0_{\mu\mu}$ (nb)	1.990 ± 0.009	-
$\sigma^0_{\tau\tau}$ (nb)	2.001 ± 0.010	-
α_s from R_ℓ	-	0.117 ± 0.010
$g_{V\ell}$	-	$-0.0407^{+0.0023}_{-0.0021}$
$g_{A\ell}$	-	-0.50126 ± 0.00067
$g_{V\mathrm{e}}$	$-0.0408^{+0.0049}_{-0.0044}$	-
$g_{A\mathrm{e}}$	-0.5025 ± 0.0010	-
$g_{V\mu}$	$-0.0392^{+0.0069}_{-0.0081}$	-
$g_{A\mu}$	-0.4985 ± 0.0015	-
$g_{V\tau}$	$-0.0429^{+0.0089}_{-0.010}$	-
$g_{A\tau}$	-0.5001 ± 0.0017	-
N_ν		2.983 ± 0.020

Table 10: Derived quantities from fit results to all the ALEPH accumulated data.

	measurement	Standard Model fit	pull
line-shape and lepton asymmetries:			
m_Z [GeV]	91.1924 ± 0.0037	91.1910	0.4
Γ_Z [GeV]	2.4951 ± 0.0055	2.4933	0.3
σ_h^0 [nb]	41.56 ± 0.09	41.48	0.8
R_ℓ	20.739 ± 0.060	20.726	0.2
$A_{FB}^{0,\ell}$	0.0195 ± 0.0021	0.0154	2.0
τ polarization:			
$\mathcal{A}_\tau$	0.136 ± 0.015	0.143	0.5
$\mathcal{A}_e$	0.129 ± 0.017	0.143	0.8
b and c quark results:			
$R_b = \Gamma_{b\bar{b}}/\Gamma_{had}$	0.2206 ± 0.0031	0.2157	1.6
$R_c = \Gamma_{c\bar{c}}/\Gamma_{had}$	0.165 ± 0.021	0.172	0.3
$A_{FB}^{0,b}$	0.0922 ± 0.0057	0.1002	1.4
$A_{FB}^{0,c}$	0.081 ± 0.013	0.071	0.7
$q\bar{q}$ charge asymmetry:			
$\sin^2\theta_{eff}^{lept}$ from $\langle Q_{FB}\rangle$	0.2323 ± 0.0014	0.2320	0.2

Table 11: Summary of ALEPH measurements included in the combined analysis of Standard Model parameters. The Standard Model fit result in column 3 and the pulls in column 4 are derived from the fit for a fixed value of $m_H = 300$ GeV.

Derived parameter	No lepton univ.
g_{Ve}	$0.0375^{+0.0032}_{-0.0031}$
$g_{V\mu}$	$0.0425^{+0.0072}_{-0.0078}$
$g_{V\tau}$	0.0361 ± 0.0035

Table 12: Effective vector coupling constants from fit results for all the Aleph accumulated data using the added constraint of τ polarization .

	$\sin^2\theta_{eff}^{lept}$
$A_{FB}^{0,\ell}$	0.2297 ± 0.0011
$\mathcal{A}_\tau$	0.2329 ± 0.0019
$\mathcal{A}_e$	0.2338 ± 0.0021
$A_{FB}^{0,b}$	0.2335 ± 0.0010
$A_{FB}^{0,c}$	0.2299 ± 0.0030
$\langle Q_{FB}\rangle$	0.2323 ± 0.0014
Average	0.2321 ± 0.0006

Table 13: Summary of ALEPH measurements of $\sin^2\theta_{eff}^{lept}$ from asymmetries. The $\chi^2/d.o.f.$ of the average is 8.1/5.

$m_{\rm t}$ (GeV)	$174\ ^{+15}_{-16}\ ^{+18}_{-20}$
$\alpha_s(m_{\rm Z}^2)$	$0.116 \pm 0.006\ \pm 0.002$
χ^2/d.o.f.	11.1/9
$\sin^2\theta_{\rm eff}^{\rm lept}$	$0.2319 \pm 0.0005\ ^{+0.0001}_{-0.0002}$
$m_{\rm W}$(GeV)	$80.32 \pm 0.10\ ^{+0.01}_{-0.02}$

Table 14: Fit results of all ALEPH data for $m_{\rm t}$ and α_s. The central values are obtained fixing $m_{\rm H}$ =300 GeV. The second errors correspond to a change in the Higgs mass in the range [60, 1000] GeV. The bottom part of the table gives the derived values for $\sin^2\theta_{\rm eff}^{\rm lept}$ and $m_{\rm W}$.

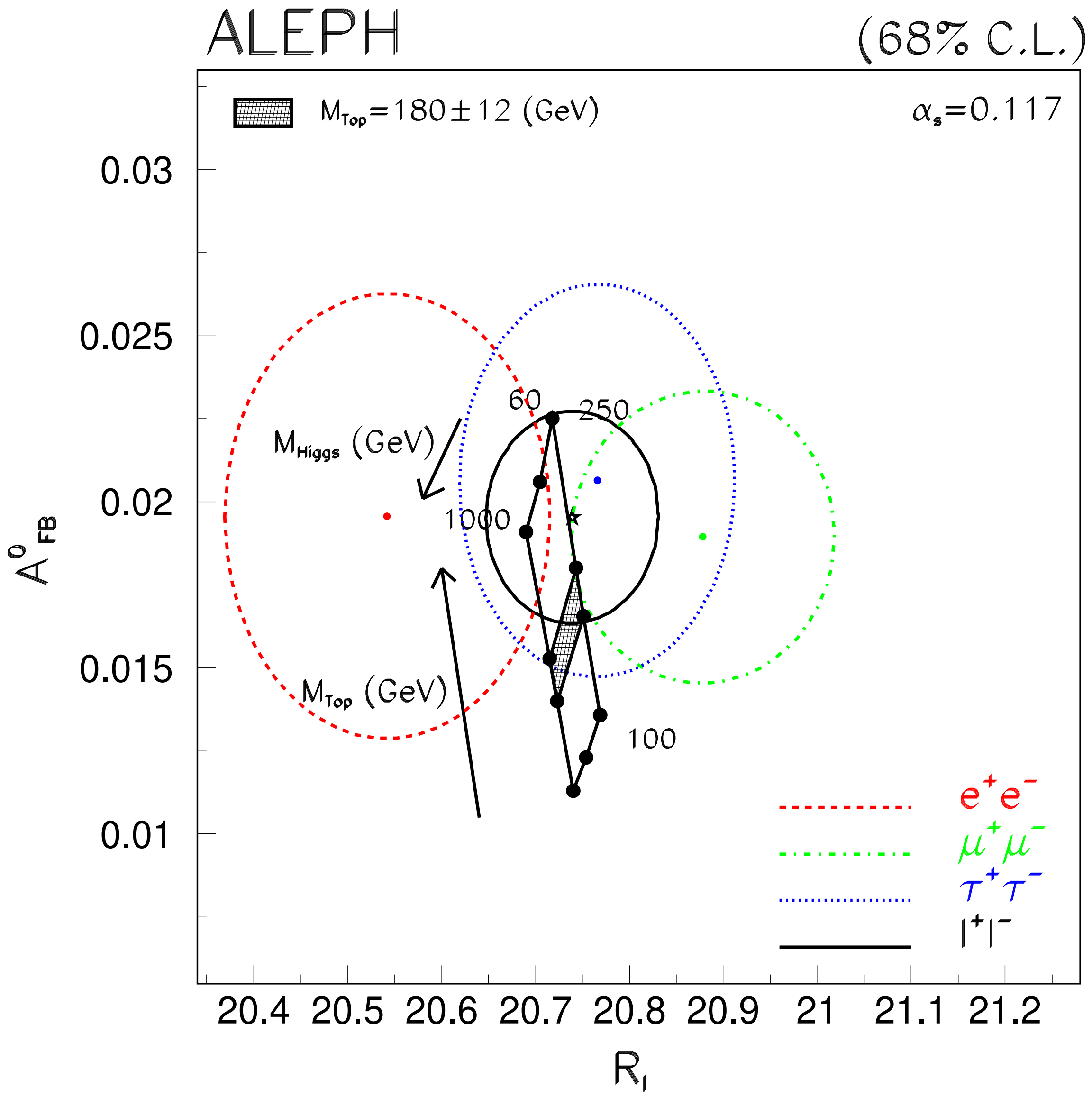

Figure 1: The 68% probability contours in the $A_{\rm FB}^{0,\ell}$-R_ℓ plane and Standard Model prediction.

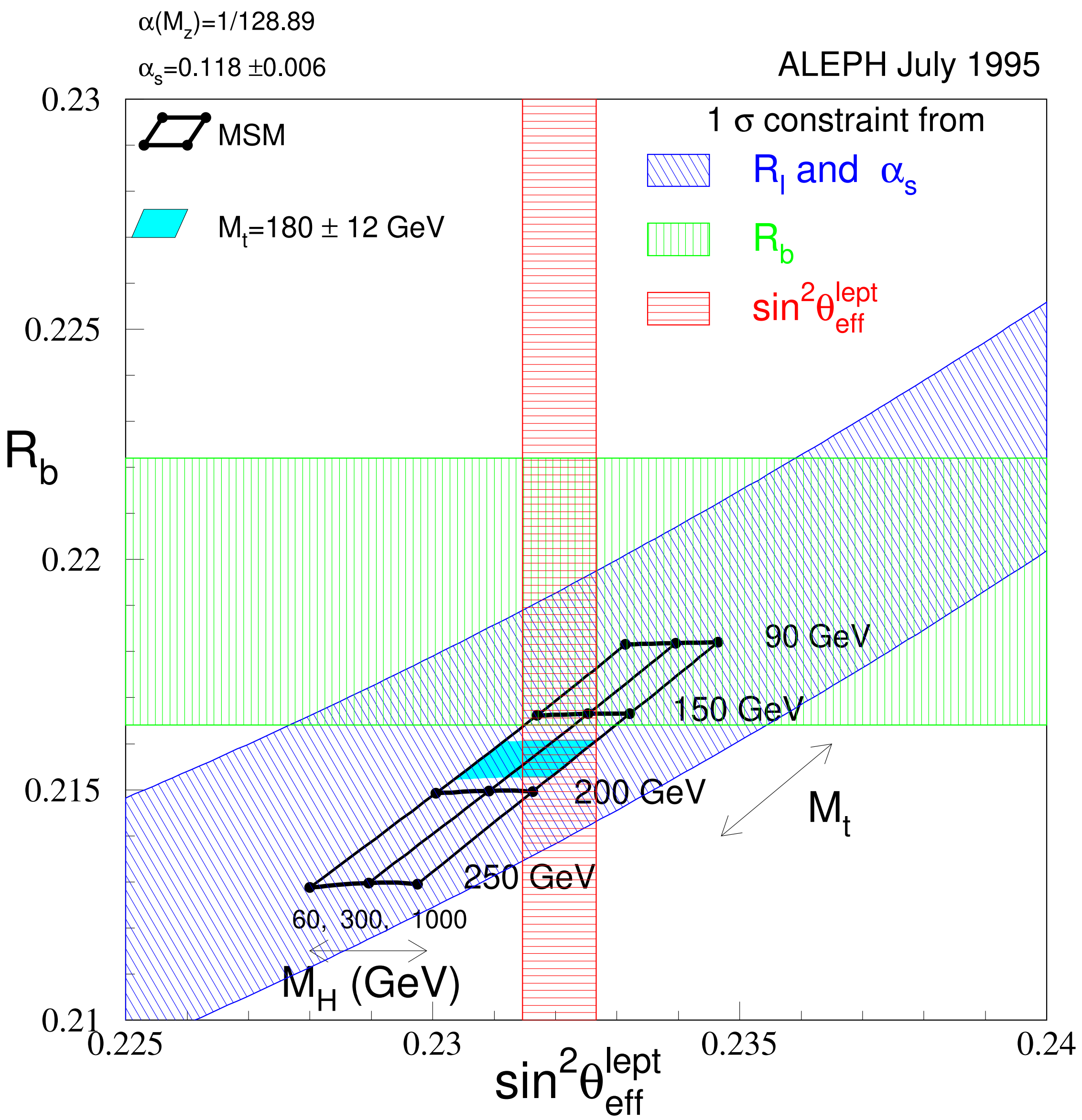

Figure 2: The measurements of $\sin^2\theta_{\rm eff}^{\rm lept}$ and $R_{\rm b}$ compared to the Standard Model prediction.

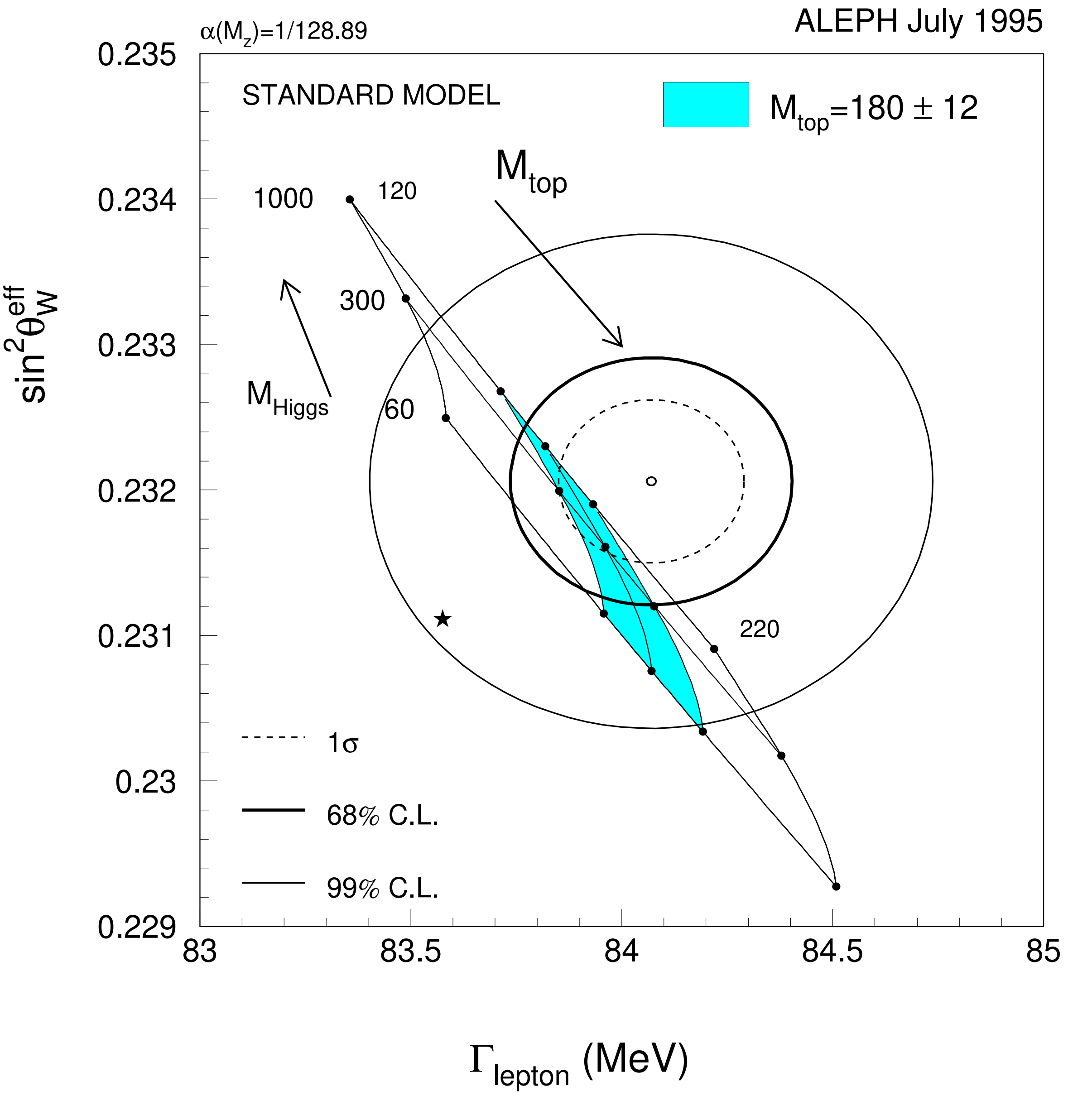

Figure 3: The measurements of $\sin^2\theta_{\rm eff}^{\rm lept}$ and $\Gamma_{\ell\ell}$ compared to the Standard Model prediction.