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Preliminary Results on Z Production Cross-Sections and Lepton Forward–Backward Asymmetries including the 1990-1995 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 4.6 million Z decays into hadrons and charged leptons accumulated with the ALEPH detector at LEP between 1989 and 1995. The Standard Model fit has been performed using these measurements 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 1995 data taking period ALEPH has accumulated about 35 pb^{-1} of new data from which about 20 pb^{-1} where taken during high precision scan at $\mathrm{E}_{cms} \cong m_{\mathrm{Z}} \pm$ 2 GeV, therefore almost doubling the total statistics of scan data 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 the published ones using the 1990 and 1991 energy scans data ($\mathrm{E}_{cms} \cong m_{\mathrm{Z}} \pm$ 3 GeV), as well as the data collected in 1992 ($\mathrm{E}_{cms} \cong m_{\mathrm{Z}}$). Preliminary results of the 1993 high precision scan ($\mathrm{E}_{cms} \cong m_{\mathrm{Z}} \pm$ 2 GeV) [1] and the high statistics data collected in 1994 ($\mathrm{E}_{cms} \cong m_{\mathrm{Z}}$) have been already presented at previous conferences [2]. As it will be described below we revise here the results of the measurement of the lepton forward-backward asymmetries in 1993 and 1994. 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 scan in 1995. The luminosity systematic errors are detailed in Table 2 [3] and compared with those obtained in previous years. The experimental systematic error is 0.097% for the 1995 analysis and the theoretical one is 0.16% [4].

3 Lepton forward–backward asymmetries

The 1995 lepton forward–backward asymmetries are presented in Table 3. A new set of revised numbers for the 1993 and 1994 data sets is presented in Table 4. Numbers for these data sets had been provided in previous conferences, it has appeared that there was a problem of Bhabha contamination, a few tens of events, in the tau asymmetry for the 1993 data set and that the selection procedures were introducing a bias against the initial state radiation which has a slight impact on the asymmetry. The three years of data have then been analysed in a coherent way for the three leptons. The evaluation of the systematics has been redone taking into account the effects mentioned above.

4 Line-shape and asymmetry parameters

The 1995 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 [5].

In the fits we have user revised LEP energies for 1993, 1994 and 1995. In fact during the 1995 data taking period it was discovered, using newly installed measurement probes, that the dipole field in the LEP magnets drifts during a physics fill. These drifts are caused by parasitic currents generated by electrically powered trains in the Geneva area. Similar drifts had to be present in the past leading to revision also of the 1993 and 1994 energies.

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 measurements of $\sin^2\theta_{\rm eff}^{\rm lept}$ and $R_{\rm b}$, Figure 2 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 [6].
- $R_{\rm b}$: preliminary analysis using mutually exclusive tags [7].
- $R_{\rm c}$: preliminary analysis using exclusive D double tag, exclusive D and soft pion tags and inclusive lepton fit [8].
- $A_{\rm FB}^{0,\rm b}$: preliminary results including jet charge analysis of the 1992-95 data and high p_T lepton analysis using the 1990-95 data [9].
- $A_{\rm FB}^{0,\rm c}$: lepton analysis using the 1990-91 data and preliminary D* analysis using the 1990-94 data [10].
- jet charge asymmetry: results using 1990-94 data [11].

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 are shown in Table 14. A value of $\alpha^{-1}(m_Z^2) = 128.89 \pm 0.09$ [12] has been used and the error is propagated in the fits. The value of m_t resulting from the fit is in very good agreement with the recent measurements from CDF and D0 collaborations [13] of 175±9 GeV.

References

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	statistics	σ (nb)	stat. error (nb)	sys. error (nb)	sys. error (%)
95 peak scan					
$q\bar{q}$	148152	30.615	0.12	0.011	0.067
e^+e^-	5292	1.5042	0.022	0.0	0.47
$\mu^+\mu^-$	5949	1.4646	0.019	0.0	0.25
$\tau^+\tau^-$	5548	1.4642	0.020	0.0012	0.38
95 peak-2					
$q\bar{q}$	81248	10.018	0.040	0.011	0.076
e^+e^-	3007	0.4981	0.012	0.0	1.40
$\mu^+\mu^-$	3299	0.4907	0.0087	0.0	0.306
$\tau^+\tau^-$	3078	0.4904	0.0091	0.0010	0.41
95 peak+2					
$q\bar{q}$	134087	14.348	0.049	0.011	0.076
e^+e^-	4620	0.7022	0.010	0.0	0.39
$\mu^+\mu^-$	5505	0.7132	0.0097	0.0	0.31
$\tau^+\tau^-$	5060	0.7011	0.010	0.0009	0.40

Table 1: ALEPH preliminary results on Z production cross-sections using the 1995 data. The second column gives the number of events after experimental cuts and before acceptance corrections. The statistical error includes the statistical error of the luminosity measurement. The systematical error is divided into systematical error of the nonresonant background (in nb) and systematical error of the resonant contribution (in %). It does not include the systematical error of the luminosity measurement.

Source of uncertainty	1992 SICAL Period	1993 EW Selection	1994 EW Selection	1995 EW Selection
Trigger efficiency	0.0010%	0.0002%	0.0006%	0.003%
Background estimation:				
- Off momentum e^+ or e^-	0.018%	0.003%	0.0007%	0.0009%
- Physics sources	0.010%	0.010%	0.010%	0.010%
Reconstruction efficiency	0.001%	0.001%	0.001%	0.001%
Event migration from overlays	$< 0.005\%$	nil	0.008%	0.008%
Absolute radial fiducial boundary:				
- Mechanical precision	0.058%	0.029%	0.029%	0.029%
- Beam and module alignments	0.035%	0.030%	0.031%	0.030%
- z position of modules	0.035%	0.035%	0.035%	0.035%
- Asymmetry precision	0.044%	0.025%	0.030%	0.030%
- Simulation precision	0.023%	0.016%	0.016%	0.016%
Energy cuts	0.015%	0.004%	0.015%	0.040%
Acoplanarity cut	0.005%	0.005%	0.005%	0.005%
Box cut related sources:				
- following wagon contamination				0.0006%
- preceding wagon contamination				0.001%
SUBTOTAL	0.095%	0.063%	0.069%	0.077%
Simulation statistics	0.120%	0.060%	0.024%	0.060%
TOTAL experimental error	0.153%	0.087%	0.073%	0.097%
Theoretical error	0.250%	0.16%	0.16%	0.16%
(Improved theor. error)	(0.16%)			
TOTAL LUMI error	0.293%	0.182%	0.176%	0.187%
(Improved theor. error)	(0.221%)			

Table 2: Summary of absolute luminosity measurement systematics. The improvement of the theoretical error for 1992 is given in parentheses ().

	statistics	A_{FB}	stat. error	sys. error
95 peak prescan				
e^+e^-	13228	-0.0024	0.0101	0.0030
$\mu^+\mu^-$	15825	0.0087	0.0077	0.0005
$\tau^+\tau^-$	12049	0.0096	0.0089	0.0007
95 peak scan				
e^+e^-	5292	0.0124	0.0158	0.0028
$\mu^+\mu^-$	6212	0.0026	0.0124	0.0005
$\tau^+\tau^-$	4731	0.0067	0.0144	0.0009
95 peak-2				
e^+e^-	3007	-0.1916	0.030	0.0166
$\mu^+\mu^-$	3014	-0.1554	0.0170	0.0006
$\tau^+\tau^-$	2324	-0.1569	0.0193	0.0009
95 peak+2				
e^+e^-	4620	0.1025	0.0154	0.0013
$\mu^+\mu^-$	5394	0.0964	0.0130	0.0007
$\tau^+\tau^-$	4119	0.1102	0.0148	0.0011

Table 3: ALEPH preliminary results on lepton forward–backward asymmetries using the 1995 data. The second column gives the number of events after experimental cuts and before acceptance corrections.

	statistics	A_{FB}	stat. error	sys. error
93 peak prescan				
e^+e^-	5979	-0.0081	0.0154	0.0029
$\mu^+\mu^-$	6654	0.0286	0.0120	0.0005
$\tau^+\tau^-$	5844	0.0187	0.0128	0.0030
93 peak scan				
e^+e^-	10252	0.0220	0.0118	0.0031
$\mu^+\mu^-$	11431	0.0100	0.0092	0.0005
$\tau^+\tau^-$	10103	-0.0004	0.0098	0.0009
93 peak-2				
e^+e^-	4894	-0.1711	0.0298	0.0163
$\mu^+\mu^-$	3224	-0.1790	0.0169	0.0006
$\tau^+\tau^-$	3013	-0.1818	0.0175	0.0036
93 peak+2				
e^+e^-	4009	0.1297	0.0157	0.0013
$\mu^+\mu^-$	4897	0.1198	0.0139	0.0007
$\tau^+\tau^-$	4496	0.1410	0.0144	0.0016
94 peak				
e^+e^-	59784	0.0021	0.0047	0.0031
$\mu^+\mu^-$	68749	0.0020	0.0037	0.0005
$\tau^+\tau^-$	60189	0.0027	0.0040	0.0007

Table 4: ALEPH revised results on lepton forward–backward asymmetries using the 1993 and 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.	1654
	95 prel.	739
	total	4164
l^+l^-	90-91	55
	92	82
	93 prel.	78
	94 prel.	190
	95 prel.	80
	total	485

Table 5: ALEPH event statistics in units of 10^3 used for the analysis of the Z line-shape and lepton forward–backward asymmetries.

	93 prel.	94 prel.	95 prel.
$\mathcal{L}^{\mathrm{exp.}}$	0.087%	0.073%	0.097%
$q\bar{q}$	0.073%	0.073%	0.076%
$\mathrm{e^+e^-}$	0.50%	0.48%	0.47%
$\mu^+\mu^-$	0.25%	0.26%	0.25%
$\tau^+\tau^-$	0.34%	0.32%	0.39%
$A_{\mathrm{FB\ e}}$	0.0031	0.0031	0.0028
$A_{\mathrm{FB}\ \mu}$	0.0005	0.0005	0.0005
$A_{\mathrm{FB}\ \tau}$	0.0009	0.0007	0.0009

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

Parameter	No lepton univ.	lepton univ.
m_{Z} (GeV)	91.1873 ± 0.0030	91.1874 ± 0.0030
Γ_{Z} (GeV)	2.4950 ± 0.0047	2.4948 ± 0.0047
σ^0_{h} (nb)	41.576 ± 0.083	41.578 ± 0.083
R_{e}	20.64 ± 0.092	-
R_{μ}	20.88 ± 0.075	-
R_{τ}	20.78 ± 0.079	-
R_{ℓ}	-	20.766 ± 0.049
$A^{0,\mathrm{e}}_{\mathrm{FB}}$	0.0187 ± 0.0039	-
$A^{0,\mu}_{\mathrm{FB}}$	0.0179 ± 0.0025	-
$A^{0,\tau}_{\mathrm{FB}}$	0.0196 ± 0.0028	-
$A^{0,\ell}_{\mathrm{FB}}$	-	0.0187 ± 0.0017
$\chi^2/d.o.f.$	195/217	200/221

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

	m_{Z}	Γ_{Z}	σ^0_{h}	R_{ℓ}	$A^{0,\ell}_{\mathrm{FB}}$
m_{Z}	1.00	0.07	0.07	0.02	0.12
Γ_{Z}		1.00	-0.23	0.00	0.00
σ^0_{h}			1.00	0.16	0.02
R_{ℓ}				1.00	0.01
$A^{0,\ell}_{\mathrm{FB}}$					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	0.07	0.07	0.03	0.00	0.00	0.05	0.09	0.08
Γ_Z		1.00	-0.23	-0.02	0.01	0.00	0.01	0.00	0.00
σ_h^0			1.00	0.09	0.10	0.09	0.01	0.01	0.01
R_e				1.00	0.04	0.04	0.00	0.00	0.00
R_μ					1.00	0.05	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	0.03
$A_{FB}^{0,\tau}$									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)	-	1744.7 ± 4.0
$\Gamma_{\ell\ell}$ (MeV)	-	84.02 ± 0.18
Γ_{inv} (MeV)	-	498.2 ± 3.1
$\Gamma_{inv}/\Gamma_{\ell\ell}$	-	5.930 ± 0.035
Γ_{ee} (MeV)	84.28 ± 0.24	-
$\Gamma_{\mu\mu}$ (MeV)	83.31 ± 0.37	-
$\Gamma_{\tau\tau}$ (MeV)	83.73 ± 0.39	-
$BR(\mathrm{Z} \to \mathrm{q\bar{q}})$ (%)	-	69.93 ± 0.12
$BR(\mathrm{Z} \to \ell^+\ell^-)$ (%)	-	3.3677 ± 0.0048
$BR(\mathrm{Z} \to \mathrm{e^+e^-})$ (%)	3.378 ± 0.008	-
$BR(\mathrm{Z} \to \mu^+\mu^-)$ (%)	3.339 ± 0.014	-
$BR(\mathrm{Z} \to \tau^+\tau^-)$ (%)	3.356 ± 0.015	-
$\sigma_{\ell\ell}^0$ (nb)	-	2.0022 ± 0.0057
σ_{ee}^0 (nb)	2.015 ± 0.010	-
$\sigma_{\mu\mu}^0$ (nb)	1.991 ± 0.008	-
$\sigma_{\tau\tau}^0$ (nb)	2.001 ± 0.008	-
α_s from R_ℓ	-	0.122 ± 0.007
$g_{V\ell}$	-	$-0.0398^{+0.0019}_{-0.0018}$
$g_{A\ell}$	-	-0.50122 ± 0.00057
$g_{V\mathrm{e}}$	$-0.0399^{+0.0044}_{-0.0040}$	-
$g_{A\mathrm{e}}$	-0.5020 ± 0.0008	-
$g_{V\mu}$	$-0.0380^{+0.0062}_{-0.0072}$	-
$g_{A\mu}$	-0.4992 ± 0.0012	-
$g_{V\tau}$	$-0.0418^{+0.0068}_{-0.0080}$	-
$g_{A\tau}$	-0.5008 ± 0.0013	-
N_ν		2.977 ± 0.018

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]	91.1874 ± 0.0030	91.1863	0.4
Γ_{Z} [GeV]	2.4948 ± 0.0047	2.4949	0.0
σ_{h}^{0} [nb]	41.578 ± 0.083	41.477	1.2
R_{ℓ}	20.766 ± 0.049	20.739	0.6
$A_{\mathrm{FB}}^{0,\ell}$	0.0187 ± 0.0017	0.0155	1.9
τ polarization:			
$\mathcal{A}_{\tau}$	0.136 ± 0.015	0.144	0.5
$\mathcal{A}_{\mathrm{e}}$	0.129 ± 0.017	0.144	0.9
b and c quark results:			
$R_{\mathrm{b}} = \Gamma_{\mathrm{b\bar{b}}}/\Gamma_{\mathrm{had}}$	0.2158 ± 0.0014	0.2156	0.2
$R_{\mathrm{c}} = \Gamma_{\mathrm{c\bar{c}}}/\Gamma_{\mathrm{had}}$	0.1683 ± 0.0091	0.172	0.4
$A_{\mathrm{FB}}^{0,\mathrm{b}}$	0.0968 ± 0.0037	0.1008	1.1
$A_{\mathrm{FB}}^{0,\mathrm{c}}$	0.081 ± 0.013	0.0719	0.7
$\mathrm{q\bar{q}}$ charge asymmetry:			
$\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$ from $\langle \mathrm{Q_{FB}} \rangle$	0.2322 ± 0.0013	0.2319	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 $m_{\mathrm{H}} = 300$ GeV.

Derived parameter	
$g_{V\mathrm{e}}$	$0.0378^{+0.0029}_{-0.0028}$
$g_{V\mu}$	$0.0399^{+0.0061}_{-0.0066}$
$g_{V\tau}$	0.0369 ± 0.0033

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

	$\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$
$A_{\mathrm{FB}}^{0,\ell}$	0.2302 ± 0.0009
$\mathcal{A}_{\tau}$	0.2329 ± 0.0019
$\mathcal{A}_{\mathrm{e}}$	0.2338 ± 0.0021
$A_{\mathrm{FB}}^{0,\mathrm{b}}$	0.2327 ± 0.0007
$A_{\mathrm{FB}}^{0,\mathrm{c}}$	0.2299 ± 0.0030
$\langle \mathrm{Q_{FB}} \rangle$	0.2322 ± 0.0013
Average	0.2319 ± 0.0005

Table 13: Summary of ALEPH measurements of $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$ from asymmetries. The $\chi^2/d.o.f.$ of the average is 6.5/5.

$m_{\rm t}$ (GeV)	$178\ ^{+12}_{-12}\ ^{+17}_{-19}$
$\alpha_s(m_{\rm Z}^2)$	$0.119 \pm 0.005\ \pm 0.002$
χ^2/d.o.f.	8.2/9
$\sin^2\theta_{\rm eff}^{\rm lept}$	$0.2318 \pm 0.0004\ ^{+0.0001}_{-0.0002}$
$m_{\rm W}$(GeV)	$80.34 \pm 0.07\ ^{+0.01}_{-0.02}$

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 $m_{\rm W}$.

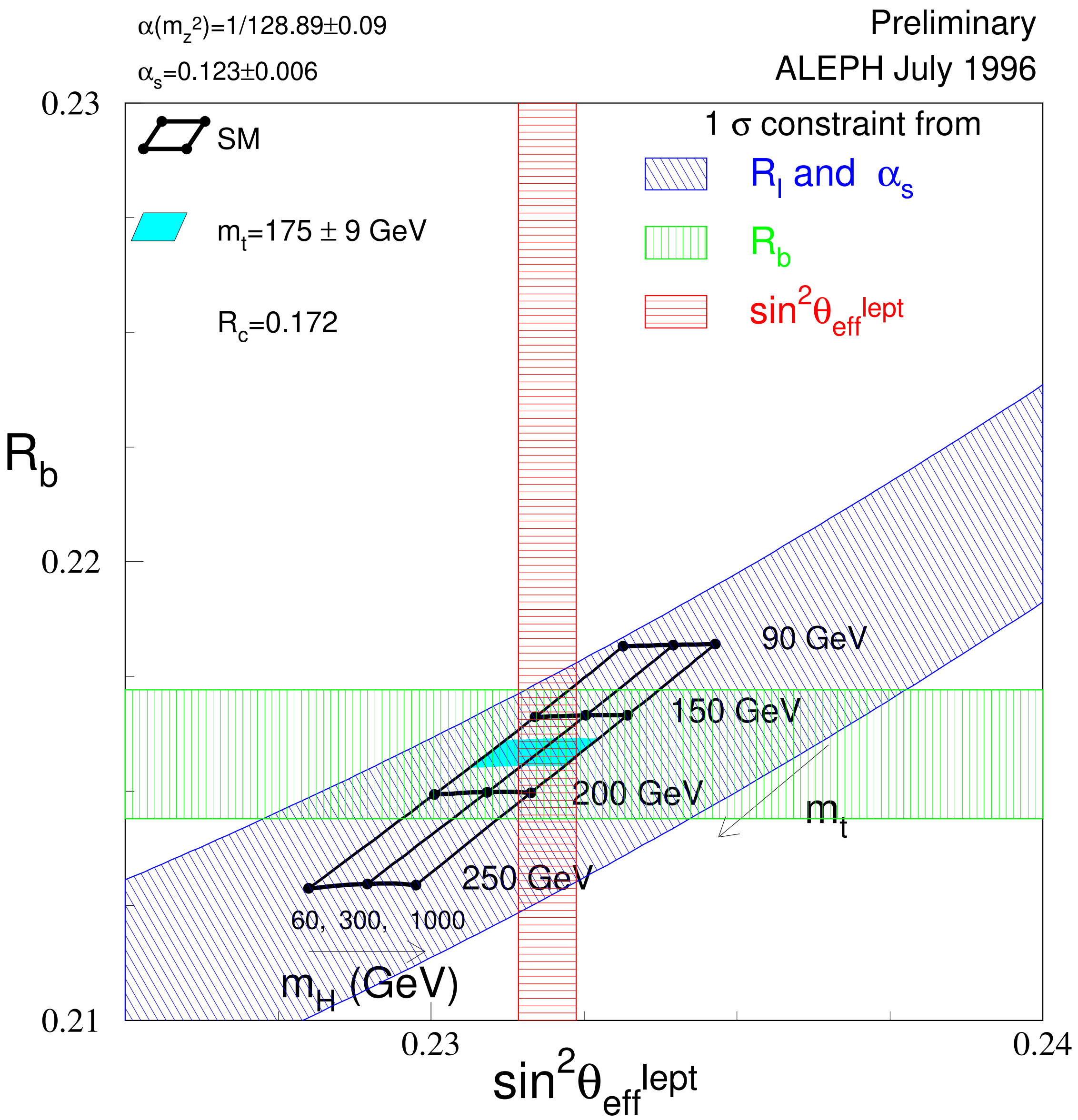

Figure 1: The measurements of $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$ and R_{b} compared to the Standard Model prediction.

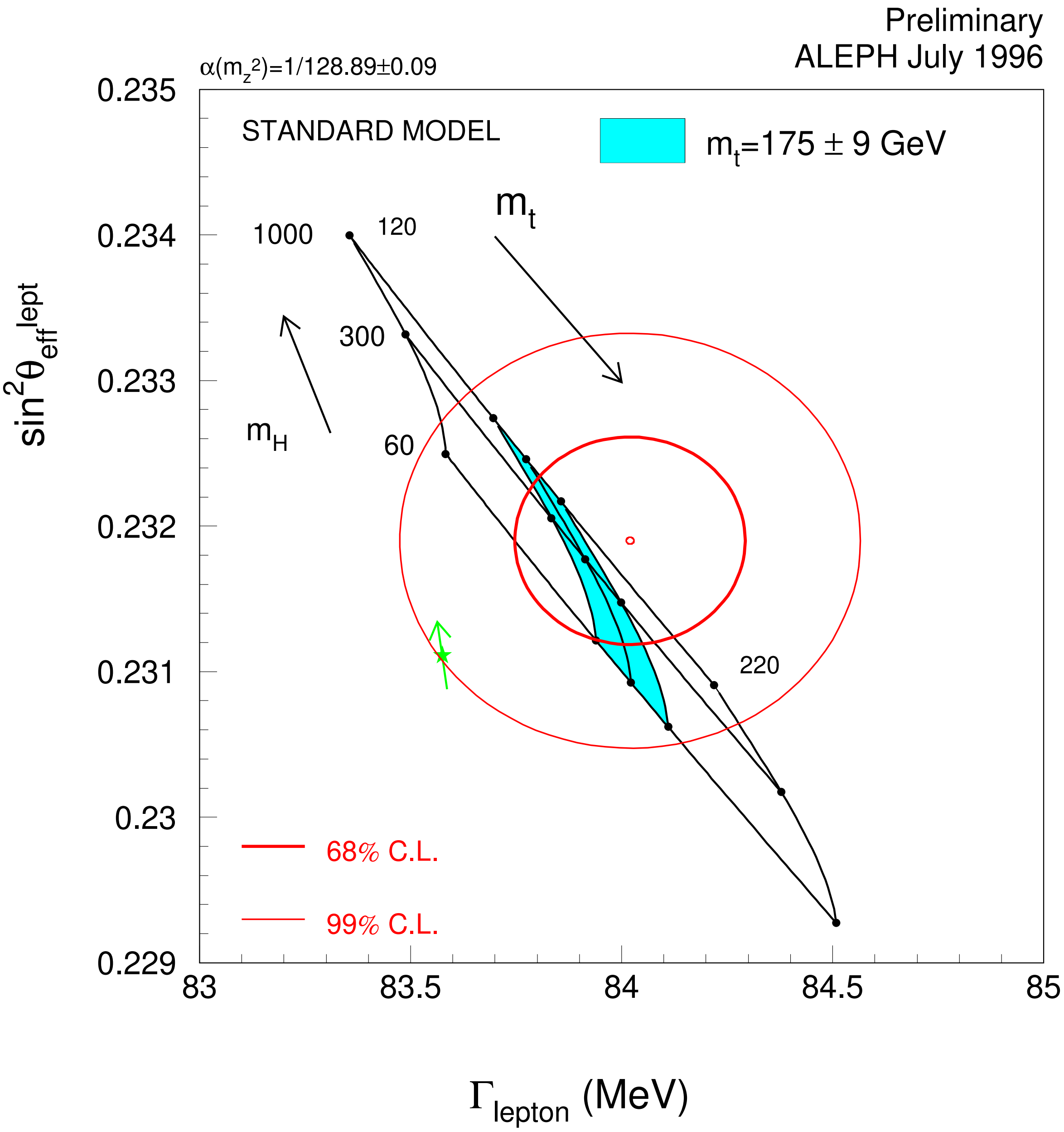

Figure 2: The measurements of $\sin^2\theta_{\rm eff}^{\rm lept}$ and $\Gamma_{\ell\ell}$ compared to the Standard Model prediction.