L3 Note # 1731
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L3 Electroweak Update for 1995 La Thuile/Moriond

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The L3 Collaboration[1]

I. L3 Data

(a) Events

Details of the events used for this update are given below.

Table 1

	No. of Evts 1990 + 91	No. of Evts 1992	No. of Evts 1993	No. of Evts 1994
Data type	7 point scan	Peak only	3 point scan	Peak only
Luminosity (pb^{-1})	18.4	22.4	32	45
$q\overline{q}$	416 K	678 K	658 K	1362 K
e^+e^-	16 K	22 K	26 K	47 K
$\mu^+\mu^-$	14 K	21 K	21 K	41 K
$\tau^+\tau^-$	10 K	15 K	15 K	–

(b) Systematic Errors on Cross sections (%):

Table 2

	1990	1991	1992	1993	1994
$q\overline{q}$	0.3	0.15	0.15	0.11-0.14	0.2
e^+e^-	0.4	0.3	0.3	0.30-0.34	0.4
$\mu^+\mu^-$	0.8	0.5	0.5	0.29-0.34	–
$\tau^+\tau^-$	0.9	0.7	0.7	0.63-1.37	–

[1]Lineshape group members are:
G. Ambrosi, G.Bobbink, A.Bohm, D.Bourilkov, S.Dutta, J.Field, F.Filthaut, S.N.Ganguli, S.Gentile, D.Goujon, M.Gruenewald, A.Gurtu, M.Kienzle-Focacci, E.Koffeman, H.Kuijten, W.Lu, L.Malgeri, M.Merk, J.Mnich, G.Passaleva, C.Paus, A.Robohm, S.Roth, C.Schäfer, J.Weber, U.Uwer, S.Wynhoff, J.You

(c) Systematic Errors on lepton asymmetries:

Table 3

	1990	1991	1992	1993	1994
e^+e^-	0.004	0.0042	0.0023	0.004	0.004
$\mu^+\mu^-$	0.005	0.002	0.002	0.001	0.004
$\tau^+\tau^-$	0.005	0.005	0.003	0.004	–

(d) Systematic Errors on Luminosity:
Systematic errors on luminosity are determined to be 0.6% for 1990-1992, 0.2% for 1993 and 0.22% for 1994. For 1993 and 1994 these include a theoretical systematic error of 0.16%.

II. LEP Energy Errors

The LEP Energy Group has come out with a final determination of the uncertainties in LEP energy for the year 1993 (R. Assmann et al, CERN-PPE/95-10, CERN-SL/95-02, dated January 20, 1995, submitted for publication to Z. Phys. C).

(a) the LEP energy covariance matrix for the 1993 scan is provided. The average error on the determination of M_Z and Γ_Z due to LEP energy uncertainties are estimated as 1.4 and 1.5 MeV respectively for 1993 data. **Using only 1993 L3 data we have carried out fits switching on/off the LEP errors and confirm that the errors on M_Z and Γ_Z due to LEP energy uncertainties are 1.5 and 1.7 MeV respectively.**

(b) the average value of the beam energy spread is determined to be 55 ± 5 MeV for 1993. This value was $51\pm\sim5$ MeV for the 1991 data (L. Arnaudon et al, CERN-PPE/92-125, CERN-SL/92-37(DI), dated July 31, 1992). Using L3 data we have carried out fits using values of beam energy spread increased/decreased by 5 MeV. **We find that this ±5 MeV error results in an additional error on Γ_Z of ±1 MeV.**

(c) Assmann et al confirm that the LEP energy errors for the years 1990-1992 stay as they were and furthermore they are UNCORRELATED with the 1993 LEP errors during the energy scan. (To recapitulate: the overall LEP energy errors are: i) 26 MeV for 1990, ii) 18 MeV for 1991 data prior to Aug 14, 1991, 5 MeV for 1991 data thereafter, iii) 18 MeV for the 1992 data and iv) 18 MeV for the first 1993 run on the peak which is uncorrelated with all other data)

(d) For the 1994 run preliminary estimate of the overall LEP energy error from the LEP Energy Group is 4 MeV; it is to be taken as UNCORRELATED with the earlier LEP energy errors.

III Change in M_{top}

We now use the value of 175 GeV for M_{top} to calculate the (t+i) effects in the e^+e^- final state instead of 150 GeV used earlier. This has only a very minor effect on the 'model independent' fits.

IV Results

(a) Fits to cross section data alone

Table 4

Parameter	Fitted/derived Value*	July 1994 (Glasgow)
M_Z	91193.4 ±3.7	91190 ± 5.4
Γ_Z	2503.8 ± 5.3	2504 ± 5.8
R_e	20.911 ± 0.117	
R_μ	20.847 ± 0.125	
R_τ	20.725 ± 0.171	
σ°_{had}	41.41 ± 0.11	
Γ_{ee}	83.87 ± 0.29	83.84 ± 0.34
Γ_μ	84.12 ± 0.56	83.93 ± 0.64
Γ_τ	84.62 ± 0.74	84.75 ± 0.76
Γ_{hadron}	1753.7 ± 6.4	1755.6 ± 7.3
R_l	20.842 ± 0.081	
Γ_{lepton}	84.01 ± 0.23	83.99 ± 0.27
Γ_{hadron}	1750.9 ± 5.4	1752.6 ± 6.1
$\Gamma_{invisible}$	501.1 ± 4.6	499.6 ± 5.4
N_ν	2.995 ± 0.025	2.981 ± 0.031

* Units are MeV for mass and widths, nano barn for cross section

(b) Fits to cross section plus lepton F/B asymmetry data

Table 5

Parameter	Fitted/derived Value*	July 1994 (Glasgow)
M_Z	91193.5 ± 3.7	91190 ± 5.4
Γ_Z	2.5040 ± 5.3	2504.0 ± 5.8
σ°_{had}	41.411 ± 0.11	41.45 ± 0.15
R_e	20.911 ± 0.117	20.94 ± 0.13
R_μ	20.851 ± 0.124	20.93 ± 0.14
R_τ	20.712 ± 0.171	20.70 ± 0.17
$A^{\circ,e}_{FB}$	.0125 ± 0.0070	.0109 ± 0.0081
$A^{\circ,\mu}_{FB}$	.0164 ± 0.0041	.0132 ± 0.0048
$A^{\circ,\tau}_{FB}$	.0305 ± 0.0073	.0299 ± 0.0073
g^e_A	-0.5012 ±0.0010	
g^μ_A	-0.5012 ±0.0022	
g^τ_A	-0.4978 ±0.0058	
g^e_V	-0.032 ±0.01	
g^μ_V	$-0.043^{+.013}_{-.031}$	
g^τ_V	$-0.083^{+.026}_{-.064}$	
R_l	20.836 ± 0.080	20.859 ± 0.088
$A^{\circ,l}_{FB}$	0.0183 ± 0.0032	0.0168 ± 0.0036
g^l_A	−0.5012 ± 0.0007	-0.5013 ± 0.00085
g^l_V	−0.0395 ± 0.0034	$-0.0374^{+.0043}_{-.0039}$
ρ	1.005 ± 0.0029	
$\sin^2\theta^{eff}_w$	0.2303 ±0.0017	.2313 ± 0.0020

* Units are MeV for mass and widths, nano barn for cross section

Correlation matrix for 5 parameter fit with
M_Z,Γ_Z,σ°_{had},R_l,$A^{\circ,l}_{FB}$

Table 6

	1	2	3	4	5
1	1.000	.055	−.063	−0.010	.078
2	.055	1.000	−.254	.011	.001
3	−.063	−.254	1.000	.186	.006
4	−.010	.011	.186	1.000	−.010
5	.078	.001	.006	−.010	1.000

Correlation matrix for 9 parameter fit with
$M_Z, \Gamma_Z, \sigma^\circ_{had}, R_e, R_\mu, R_\tau, A^{\circ,e}_{FB}, A^{\circ,\mu}_{FB}, A^{\circ,\tau}_{FB}$

Table 7

	1	2	3	4	5	6	7	8	9
1	1.000	.056	-.062	-.023	.006	-.001	.053	.057	.025
2	.056	1.000	-.253	-.010	.019	.017	-.003	.003	.003
3	-.062	-.253	1.000	.109	.131	.094	.032	-.007	-.004
4	-.023	-.010	.109	1.000	.072	.052	-.106	.015	.012
5	.006	.019	.131	.072	1.000	.051	-.001	.017	.000
6	-.001	.017	.094	.052	.051	1.000	-.001	.000	.012
7	.053	-.003	.032	-.106	-.001	-.001	1.000	-.005	-.005
8	.057	.003	-.007	.015	.017	.000	-.005	1.000	.008
9	.025	.003	-.004	.012	.000	.012	-.005	.008	1.000

(c) Fits to cross section plus lepton F/B asymmetry data plus P_τ plus P_τ asymmetry data

Table 8

Parameter	Fitted/derived Value*	July 1994 (Glasgow)
g^e_A	-0.5008 ±0.0009	-0.5009 ± 0.0010
g^μ_A	-0.5017 ±0.0018	-0.5016 ± 0.0020
g^τ_A	-0.5030 ±0.0022	-0.5034 ± 0.0023
g^e_V	-0.0395 ±0.0041	-0.0391 ± 0.0045
g^μ_V	-0.0349 ±0.0095	-0.0273 ± 0.0108
g^τ_V	-0.0397 ±0.0040	-0.0392 ± 0.0048
g^l_A	–0.5012 ±0.0007	-0.5013 ± 0.0008
g^l_V	–0.0388 ±0.0024	-0.0375 ± 0.0028
ρ	1.0049 ± 0.0028	
$\sin^2\theta^{eff}_w$	0.2306 ± 0.0012	

(d) L3 Summary on $\sin^2\theta^{eff}_w$ using various data

Table 9

Using	Derived $\sin^2\theta^{eff}_w$	July 1994 (Glasgow)
$A^{\circ,l}_{FB}$	0.2303 ± 0.0017	0.2313 ± 0.0020
$A_e + A_\tau$	0.2309 ± 0.0016	0.2312 ± 0.0019
$A^{\circ,b}_{FB}$	0.2335 ± 0.0021	0.2335 ± 0.0021
Average	0.2313 ± 0.0010	0.2319 ± 0.0011

V S-Matrix Approach

A simple SM-independent ansatz to determine the properties of the Z boson is given by the S-Matrix formalism[1]. This ansatz allows to vary the photon/Z interference terms for cross sections and asymmetries independently from the couplings describing the pure Z exchange.

We use the program SMATASY 48[2] to perform S-Matrix fits to the L3 data set.

Not assuming lepton universality, the results are:

Table 10

Parameter	Value	Error
M_Z	91.158	.013
Γ_Z	2.5031	.0058
$JTXS_{el}$	.015	.064
$JTXS_{mu}$	.008	.057
$JTXS_{ta}$	.072	.063
$JTXS_{ha}$	.22	.70
$JAFB_{el}$	.71	.10
$JAFB_{mu}$	.823	.066
$JAFB_{ta}$	.697	.089
$RTXS_{el}$	.1428	.0011
$RTXS_{mu}$	.1431	.0011
$RTXS_{ta}$	.1442	.0013
$RTXS_{ha}$	2.986	.014
$RAFB_{el}$	.0021	.0015
$RAFB_{mu}$	.00297	.00081
$RAFB_{ta}$	.0055	.0014

Assuming lepton universality, the results are:

Table 11

Parameter	Value	Error
M_Z	91.159	.013
Γ_Z	2.5028	.0058
$JTXS_{el}$	.028	.043
$JTXS_{ha}$	.19	.67
$JAFB_{el}$	.760	.047
$RTXS_{el}$	.14320	.00083
$RTXS_{ha}$	2.985	.014
$RAFB_{el}$	.00323	.00064

(Mass and width in GeV, all other parameters are dimensionless).

With Correlation Coeffs

Table 12

1.00	-.38	-.52	-.56	-.50	-.95	-.02	.00	.00	-.17	-.22	-.16	-.33	.13	.20	.08
-.38	1.00	.18	.23	.22	.40	.00	.04	.02	.52	.53	.41	.83	-.05	-.05	-.01
-.52	.18	1.00	.30	.26	.50	.17	.00	.00	.10	.09	.07	.14	-.06	-.10	-.04
-.56	.23	.30	1.00	.29	.55	.01	-.05	.00	.11	.22	.10	.20	-.07	-.09	-.05
-.50	.22	.26	.29	1.00	.49	.01	.00	-.03	.11	.13	.21	.19	-.06	-.10	-.02
-.95	.40	.50	.55	.49	1.00	.02	.01	.00	.20	.23	.17	.35	-.12	-.19	-.08
-.02	.00	.17	.01	.01	.02	1.00	.00	.00	-.03	.00	.00	-.01	.04	.00	.00
.00	.04	.00	-.05	.00	.01	.00	1.00	.00	.03	.08	.02	.04	.00	.21	.00
.00	.02	.00	.00	-.03	.00	.00	.00	1.00	.01	.02	.06	.03	.00	.00	.16
-.17	.52	.10	.11	.11	.20	-.03	.03	.01	1.00	.37	.29	.58	.08	-.04	-.01
-.22	.53	.09	.22	.13	.23	.00	.08	.02	.37	1.00	.29	.57	-.02	-.01	-.01
-.16	.41	.07	.10	.21	.17	.00	.02	.06	.29	.29	1.00	.45	-.01	-.02	.03
-.33	.83	.14	.20	.19	.35	-.01	.04	.03	.58	.57	.45	1.00	-.03	-.04	-.01
.13	-.05	-.06	-.07	-.06	-.12	.04	.00	.00	.08	-.02	-.01	-.03	1.00	.01	.00
.20	-.05	-.10	-.09	-.10	-.19	.00	.21	.00	-.04	-.01	-.02	-.04	.01	1.00	.03
.08	-.01	-.04	-.05	-.02	-.08	.00	.00	.16	-.01	-.01	.03	-.01	.00	.03	1.00

Table 13

1.00	-.37	-.73	-.95	-.01	-.25	-.33	.24
-.37	1.00	.29	.40	.04	.67	.83	-.07
-.73	.29	1.00	.71	.01	.24	.25	-.16
-.95	.40	.71	1.00	.01	.27	.36	-.23
-.01	.04	.01	.01	1.00	.06	.04	.16
-.25	.67	.24	.27	.06	1.00	.73	-.01
-.33	.83	.25	.36	.04	.73	1.00	-.05
.24	-.07	-.16	-.23	.16	-.01	-.05	1.00

Remarks:

1) The S-Matrix ansatz uses a constant Z width in the Breit-Wigner propagator. Thus, results for the mass and total width of the Z Boson must be shifted by +34 MeV and + 1MeV, respectively, in order to compare them to the results of the other fits.

2) The hadronic photon/Z interference term for the total cross section (parameter $JTXS_{ha}$) is strongly anti-correlated with the Z Mass. As the Z mass is essentially determined by the hadronic lineshape, the error on the Z mass is increased in fits where this parameter is left free. The Standard-Model expectation for $JTXS_{ha}$ is 0.21.

3) The energy dependence of the leptonic forward/backward asymmetries is described by the parameter JAFB. The Standard-Model expectation for $JAFB_{leptons}$ is 0.80.

V Standard Model based Fits

We carry out fits in the standard model framework to determine best values of M_{top}, α_s and M_{Higgs}. The ZFITTER4.8 package is used for this purpose. The fits given below use the value of

$$1/\alpha(M_z^2) = 128.896 \pm 0.090$$

as now used by the LEP Electroweak Working Group based on a recent paper by Eidelman and Jegerlehner[3]. The 0.09 error on this results in an additional ~5 GeV error on M_{top} and corresponding increased error on M_{Higgs}.

The input data for these standard model fits consists of the 5 parameter fit results (lepton universality) given in tables 5 and 6, the L3 values of A_e= 0.157±0.021, A_τ= 0.150±0.016, R_b= 0.222±0.008 and the $\sin^2\theta_w^{eff}$= 0.2335±0.0021 from $A_{FB}^{o,b}$.

1. Allowing both M_{top} and α_s to be free parameters we obtain:

$$M_{top} = 186^{+17}_{-19} \pm 16\ GeV, \quad \alpha_s = 0.132 \pm 0.008 \pm 0.002$$

   the central value corresponding to M_{Higgs}= 300 GeV and the second error being due to variation of M_{Higgs} from 60 to 1000 GeV

2. To obtain best value of M_{top} we constrain α_s to be 0.123 ± 0.006, from event shape measurements. We obtain:

$$M_{top} = 191^{+16}_{-17} \pm 17\ GeV$$

   and the various derived parameters to be

$$\begin{aligned} \Delta r &= 0.032 \pm 0.007 \pm 0.001 \\ M_w &= 80.44 \pm 0.12\ ^{+0.02}_{-0.01} \\ sin^2\theta_w &= 0.2220 \pm 0.0021\ ^{+0.0001}_{-0.0003} \\ sin^2\theta_w^{eff} &= 0.2313 \pm 0.0007\ ^{+0.0001}_{-0.0002} \end{aligned}$$

3. Allowing M_{top} and M_{Higgs} to vary simultaneously a fit to L3 data leads to

$$\begin{aligned} M_{top} &= 174^{+34}_{-20}\ \ GeV \\ M_{Higgs} &= 61^{+814}_{-..}\ \ GeV \end{aligned}$$

   If we include the CDF and D0 values of M_{top}: 176±13 GeV and 199±30 GeV in the fit, we obtain

$$\begin{aligned} M_{top} &= 179 \pm 11\ \ GeV \\ M_{Higgs} &= 83^{+307}_{-23}\ \ GeV \end{aligned}$$

   where the negative error on M_{Higgs} comes from the lower limit on M_{Higgs} set by the direct searches at LEP

References:

1. SMatrix:
A.Leike, T.Riemann, J.Rose, Phys.Lett. B273 (1991) 513; T.Riemann, Phys.Lett. B293 (1992) 451; and references therein.

2. SMATASY:
S.Kirsch, T.Riemann, Preprint DESY 94-125 (hep-ph9408365).

3. S. Eidelman and F. Jegerlehner, Preprint PSI-PR-95-1, BudkerINP 95-5, January 1995.

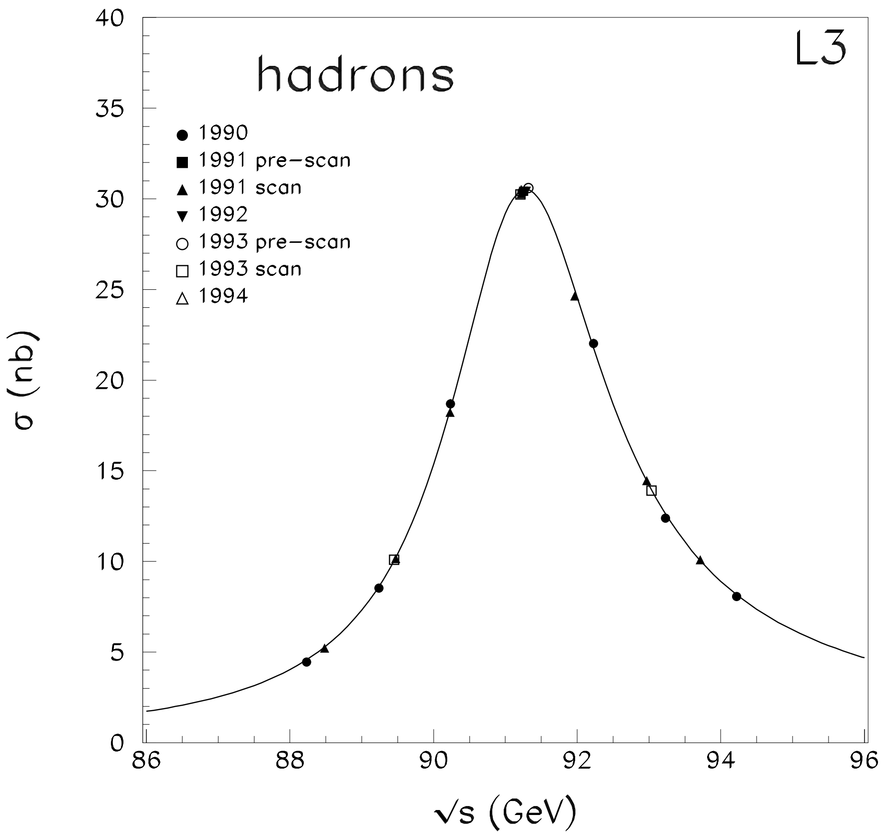

Figure 1: Hadron lineshape with lepton universality fit superimposed

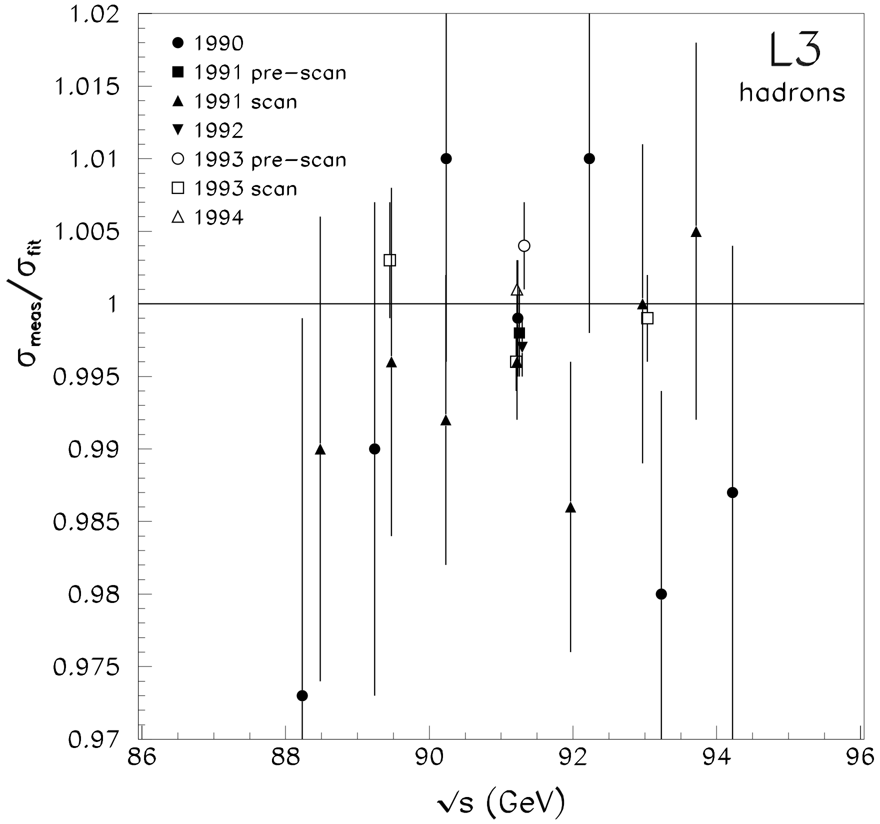

Figure 2: $\sigma_{\text{meas}}/\sigma_{\text{fit}}$ corresponding to fig 1

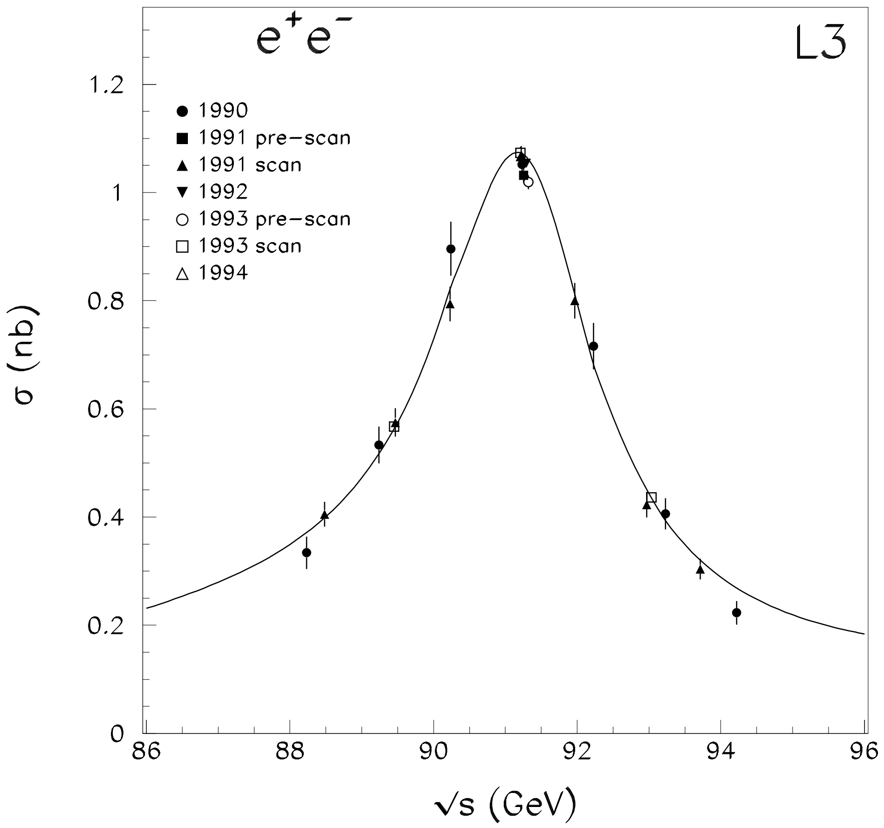

Figure 3: Electron lineshape with lepton universality fit superimposed

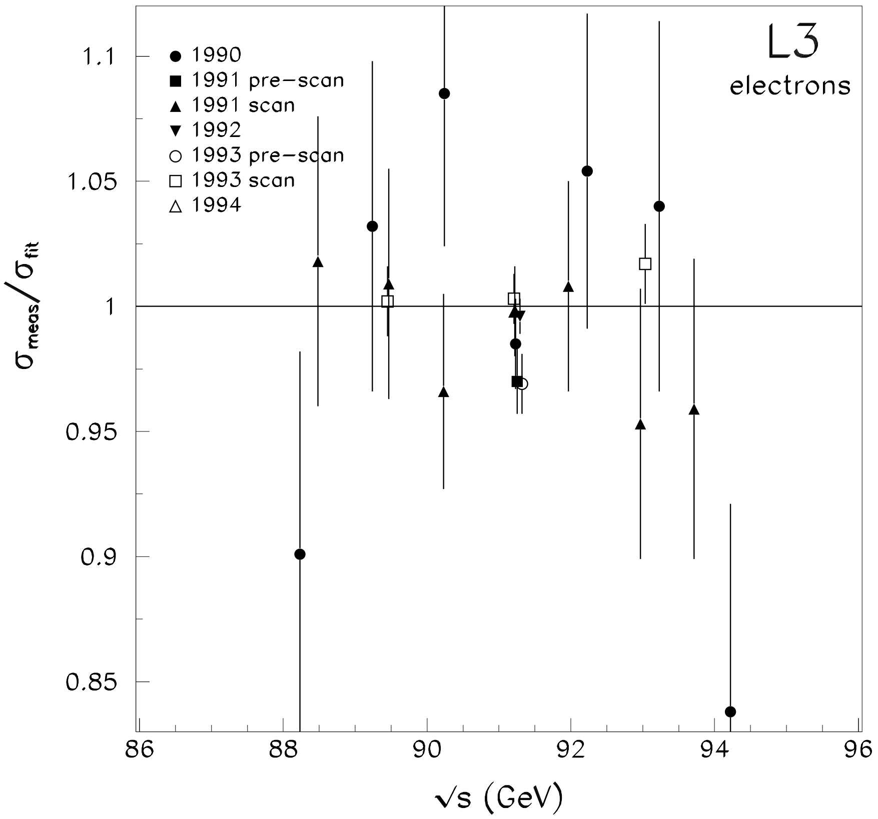

Figure 4: $\sigma_{\mathrm{meas}}/\sigma_{\mathrm{fit}}$ corresponding to fig 3

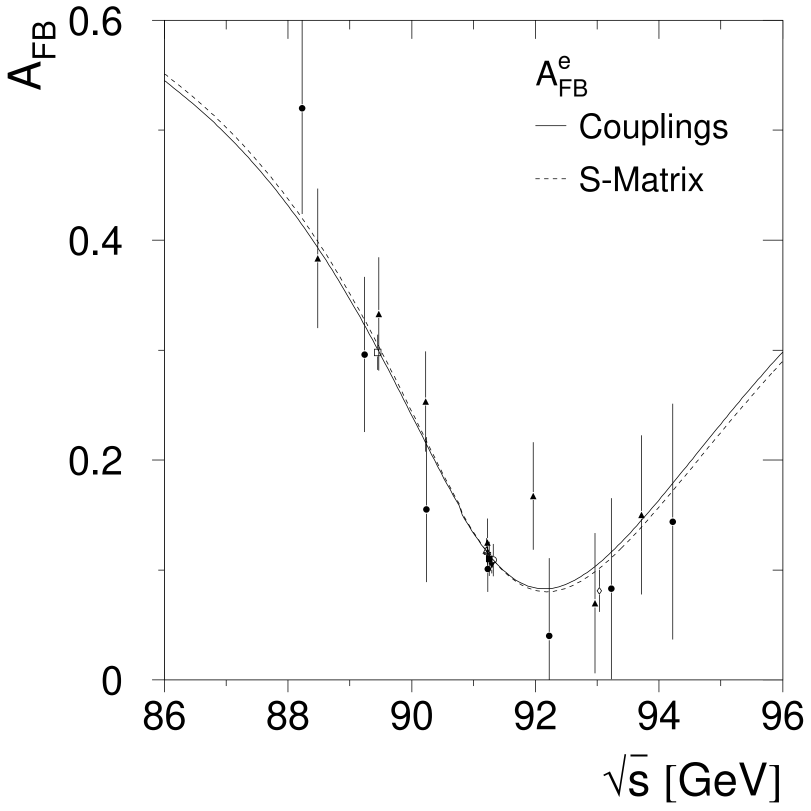

Figure 5: Electron A_{FB} with superposition of Couplings (Breit-Wigner) fit and S-Matrix fit assuming lepton universality

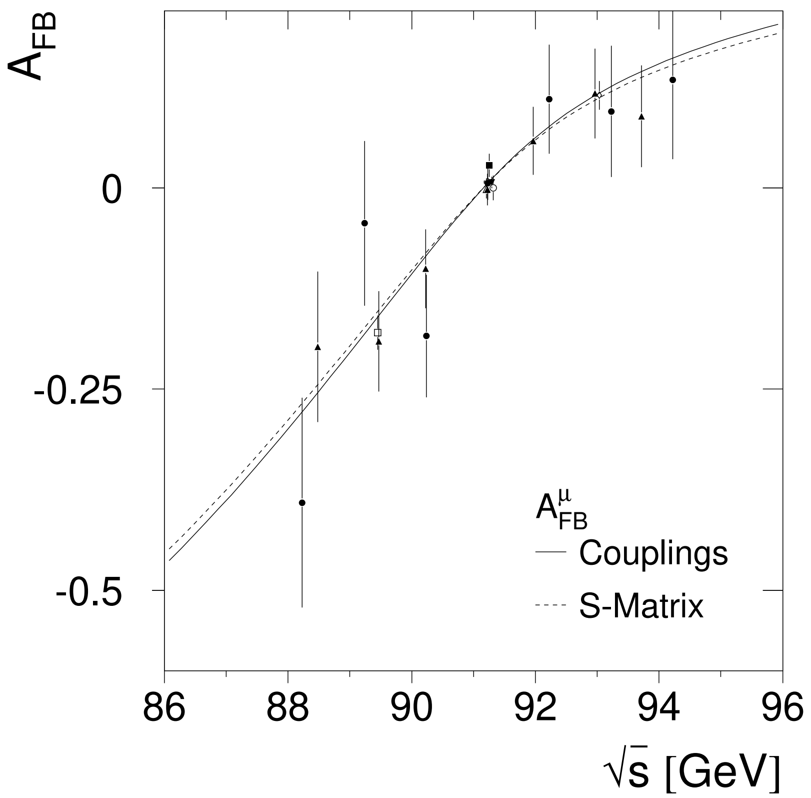

Figure 6: Muon A_{FB} with superposition of Couplings (Breit-Wigner) fit and S-Matrix fit assuming lepton universality

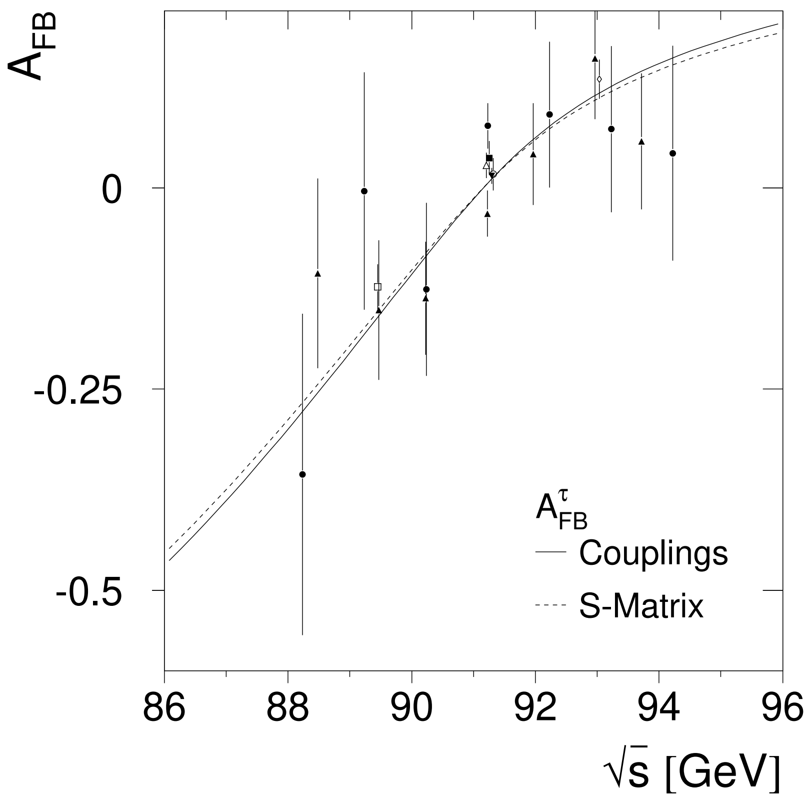

Figure 7: Tau A_{FB} with superposition of Couplings (Breit-Wigner) fit and S-Matrix fit assuming lepton universality