ALEPH 92-147
PHYSIC 92-135
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29 Sept-1992

# Fits of 1990/1991 Data with Expostar Including Non Standard Model Extensions

A study of the combined 1990/1991 data sample has been completed with the Expostar fitting program. The analysis is virtually identical to the previously presented work to the 1990 data alone[1], with a few corrections being evaluated more precisely and a more sophisticated treatment of some of the systematic uncertainties being used. As has been previously described, Expostar is a rigourous standard model calculation optimized to fit observable differential and total cross sections. The processes that can be simultaneously calculated, so as to include all the theoretical correlations, are the total hadronic cross section, the differential production cross sections for $\mu^+\mu^-$ and $e^+e^-$ (the latter including t channel exchanges to $\alpha^3$ and $\alpha^4$ leading log), the differential $\tau$ production cross sections for polarized states, and the heavy quark forward backward asymmetries. These all explicitly include double boson exchange diagrams (boxes) which are particularly important for the asymmetries. This has all been described in detail [2], but just as a reminder, the fit parameters in the standard model are the $Z^{\circ}$ mass, the top quark mass (the higgs mass has a degenerate effect on neutral current processes with the exception of the b quark branching ratio), and the factorized QCD corrections. This last variation is accomodated by adjusting the number of colors, which always multiplies these corrections.

The calculations have been extended to include the effects of extended types of models in the way prescribed by Peskin and Takeuchi [3]. This is done by the addition of constants to linear combinations of the various self energy loop integrals and their derivatives, in such a way as to preserve the underlying gauge theory structure (ward identites etc..). As this structure, the so called S, T and U parameters, was originally arrived at by Peskin and Takeuchi in considering the running star scheme[4], it was straight forward to incorporate it into the Expostar program. In fact it had been discussed in earlier work [5].

The data samples used in these fits are straight forward. The total number of hadronic and LCAL events are taken from scanbook. A modified version of the standard common lepton analysis (using a rapidity cut) that divides the common lepton sample into two correlated classes based on the Locci/Clifft Bhabha analysis provides differential distributions of leptons. These samples use the EW group run selection. By analyzing the data in this manner the largest systematic errors in the lepton analyses, $\tau$ misidentification, is overcome. Further, the $\tau$ efficiency within the solid angle is above 94 percent. All of the lepton efficiencies are evaluated as a function of angle. The non collinear photon smearing corrections (and the effect of unmeasured $\nu$ and $\pi^o$) causing errors in the perceived value of $\cos(\theta')$ and rapidity are evaluated at all angles and energies by Monte Carlo (Koralz). The differential $\tau$ polarization measurements have been provided to me by J. Conway. The QCD corrections were constrained by the Aleph value of $\alpha_s(M_z) \equiv 0.125 \pm 0.005$, determined from event shape measurements, in some of the fits. The proton antiproton W measurements are taken from the literature[6].

The expected cross section for the LCAL is evaluated inside the fits as the electroweak parameters are varied. The luminosity is a fit parameter allowing for a nonzero contribution to the overall $\chi^2$ from the LCAL. This smooths out the fit and yields a lower overall $\chi^2$. It also provides a convenient way to include the common luminosity correlation. The effect of the luminosity systematic error is divided into two uncorrelated components and a common component. These are incorporated as constrained fit parameters, rescaling the luminosities. The luminosity treatment was done in conjunction with the group from NBI, many thanks to all concerned. The energy scales are allowed to vary within constraints of 25 and 7 MeV for the 1990 and 1991 data samples. These values are perhaps a bit optimistic. The various nonlinear corrections to the energies have been incorporated.

The table below shows the results of various fits. In all of these the Higgs mass was assumed to be 200 GeV. Changing the Higgs mass to 300 GeV raises the top quark mass by approximately 5 GeV.

| $N_{had}$ | $\frac{dN_{\mu,\tau}}{d\cos\theta'}$ | $\frac{dN_e}{d\cos\theta'}$ | $\alpha_s$ | $\tau_{pol}(\theta')$ | $M_w$ | $M_z$ | $M_{top}$ | $N_{col}$ | $\chi^2/NDF$ |
|---|---|---|---|---|---|---|---|---|---|
| X | $X\|_{-.9}^{.9}$ | $X\|_{-.9}^{.9}$ | - | - | - | $91.190 \pm 0.008$ | $206^{+31}_{-37}$ | $2.998 \pm 0.013$ | 548/552 |
| - | $X\|_{-.9}^{.9}$ | $X\|_{-.9}^{.9}$ | - | - | - | $91.188 \pm 0.016$ | $176 \pm 58$ | $2.99 \pm 0.019$ | 534/537 |
| X | $X\|_{-.9}^{.9}$ | $X\|_{-.9}^{.9}$ | X | - | - | $91.190 \pm 0.008$ | $197^{+27}_{-36}$ | $3.007 \pm 0.004$ | 549/553 |
| X | $X\|_{-.9}^{.9}$ | $X\|_{-.9}^{.9}$ | X | X | - | $91.190 \pm 0.008$ | $181^{+29}_{-34}$ | $3.007 \pm 0.004$ | 554/562 |
| X | $X\|_{-.9}^{.9}$ | $X\|_{-.9}^{.9}$ | X | X | X | $91.190 \pm 0.007$ | $165^{+25}_{-30}$ | $3.008 \pm 0.004$ | 555/563 |

In the second fit it should be noted that while the leptons make up only 10 percent of the data, the accuracy with which the $Z^o$ mass can be determined is only a factor of 2 worse than including the hadronic line shape. This is due to the different energy dependences of the interference terms in the Bhabha and $\mu, \tau$ production cross sections. EXPOSTAR explicitly calculates the full Bhabha matix element, and the t channel photon exchange interference with the s channel $Z^o$ exchange decreases with energy, while the s channel photon exchange interference increases. The simultaneous fitting of these processes constrains $S - M_z^2$. This will be an extremely useful technique when the 1992 data is considered, where there will probably not be as much off peak data.

The comparison of the first and third fits illustrates the correlation between the

QCD correction and the deduced top mass. When the QCD correction is constrained by the ALEPH value of $\alpha_s$, it is increased. To compensate for the increase in the effective width, $sin\theta_w$ must increase, requiring a smaller top quark mass. The inclusion of the W mass measurements pulls the top quark mass by almost one $\sigma$. The value of the top quark mass is consistently 10 GeV higher that the official result presented at Dallas.

The consistently higher $Z^\circ$ masses found compared to the official results (3 MeV) is probably due to the fitting of the luminosity, and the ommision on my part of the light pair production from the structure functions. The correlation coefficients between the mass and the luminosities varies between 10% and 25%, and so probably account for the rest. The second factor would lower the mass by 1.3 MeV[7].

A series of fits, like the second to last fit in the above table, were made to study the sensitivity to the higgs mass in a standard model constrained fit. The higgs mass was varied from 50 to 1000 GeV. All of the fits had 562 degrees of freedom. As can be seen from the table below, the ALEPH data alone in fact seems to prefer a higher higgs mass, but with weak statistical significance. The $\chi^2$ is virtually constant between 100 and 500 GeV. This is consistent with the simulated study described in the EXPOSTAR paper[2]. The $b\bar{b}$ data does have some sensitivity, as the top quark dependence of the loops is virtually canceled by the vertex corrections, leaving only higgs mass dependence. It should be noted that all perturbative calculations make little sense for higgs masses above 600 GeV as the higgs sector becomes strongly interacting and perturbative calculations cannot converge.

| $M_{higgs}$ | $50GeV$ | $100GeV$ | $200GeV$ | $300GeV$ | $500GeV$ | $1000GeV$ |
|---|---|---|---|---|---|---|
| $\chi^2$ | 554.28 | 553.96 | 553.73 | 553.71 | 553.49 | 553.35 |

Including the W mass measurements does not change the conclusion as the results were as follows:

| $M_{higgs}$ | $50GeV$ | $100GeV$ | $200GeV$ | $500GeV$ |
|---|---|---|---|---|
| $\chi^2$ | 555.69 | 555.38 | 555.10 | 555.00 |

Thus the 1991/1992 data sample would indicate a higher top quark mass and Higgs mass than had been extracted from the 1990 data alone. As will be shown this can easily be understood in terms of the fits to the extension parameters, S and T.

As usual, an additional fit was performed to see if the data preferred a form different than that predicted by the Standard Model. All of the Aleph measurements discussed were used. The fit variables were $M_Z$, $N_\nu$, $N_c$, and the vector and axial lepton coupling multipliers. These last two parameters rescale the standard model vector and axial couplings for leptons. The results are shown below assuming a top quark mass of 181 GeV and a Higgs mass of 200 GeV.

| $M_Z$ | $N_\nu$ | $N_c$ | $k_v$ | $k_a$ | $\chi^2/N.D.F.$ |
|---|---|---|---|---|---|
| $91.191 \pm 0.008$ | $3.017 \pm 0.05$ | $3.008 \pm 0.005$ | $.930 \pm 0.095$ | $1.0028 \pm 0.0025$ | 552/560 |

These results show that the Standard Model with 3 light neutrinos not only describes the data well, but is the *preferred* solution.

After the standard model parameters have been optimized I considered the ability of these data to constrain the S and T parameters. Thus, these are the values of these constants *beyond* the contributions due to the standard model. The method of analysis is similar to the fit just discussed, which yielded the number of neutrinos and the lepton multipliers. The value of the top mass is frozen at the preferred values of 181 GeV and 165 GeV (when the proton antiproton data is used) and a simultaneous fit to the $Z^\circ$ mass, the number of colors, and S and T is performed. The variation of the QCD correction should not be overlooked as it is correlated to the extension parameters. Minos was also used to evaluate the full error on S and T and these errors were the same as the parabolic errors. The contour plot of the correlated extension parameters is then evaluated within Minuit, but of course the other correlated parameters are not varied.

The significance of this is that the theoretical impact on the parameter S can be evaluated for many types of models (technicolor models for example) without knowledge of the masses of the new particles of those models[5],[3],[8]. As a historical note, the actual fit parameters used are like those discussed in the earliest references[5] and most of the later references[8]. The first two are identically S (called del3tec) and T (called rhotec) and the third, called del1tec, is actually S+U. These names are rather obvious as they are addition to the running coupling correction functions $\Delta_{\rho*}$, $\Delta_{3*}$ and $\Delta_{1*}$, which form the core of the $*$ scheme. The first two functions control the $q^2$ evolution of $\rho^*$ and $G_F^*$. The third can be evaluated from the other two if custodial SU(2) symmetry is correct. This means that the Higgs sector has a global SU(2) symmetry, ie the reason that the tree level $\rho$ parameter is 1. The third function controls the running of the product of $\rho^* G_F^*$, thus is clearly not independent in the MSM.

These parameters measure only *deviations* from the MSM. In such terms the contribution to S from a one generation SU(4) technicolor model would be around 1.8, and a double SU(4) technicolor model would be at S of 0.5. These values can be seen on the reproduction of the graph from the second Peskin/Takeuchi paper[3]. The errors of this analysis are considerably smaller than those presented by Peskin and Takeuchi. However the central value has shifted to the upper right hand quadrant, thus explaining the preferred high Higgs mass.

The evaluation of these parameters is unfortunately not entirely unique. In fact one must always subtract off the values evaluated at some reference point. In Peskin and Takeuchis' paper their reference point is defined by a Z mass of 91.174 GeV, a top mass of 150 GeV and a Higgs mass of 1 TeV. Even with this subtraction, the renormalization scheme dependence remains as I tested by evaluating the standard model variations with both the old * scheme (just loops), and the new one (**), which uses also universal boxes and verticies in defining the running couplings. While the errors are large compared to this difference, clearly a scheme could be chosen to produce really any value one likes, the same problem that exists with widths, $sin\theta_{w,*,-}$, etc. The standard model predicts cross sections, given the masses. But proceeding undaunted, the fits using the ALEPH data with and without the W mass measurement yields:

| ALEPH | $M_w$ | $M_Z$ | $N_c$ | $S$ | $T$ | $\chi^2/N.D.F.$ |
|---|---|---|---|---|---|---|
| X | - | $91.191 \pm 0.007$ | $3.007 \pm 0.004$ | $0.794 \pm .723$ | $.531 \pm 0.663$ | 553/561 |
| X | X | $91.191 \pm 0.006$ | $3.007 \pm 0.004$ | $0.737 \pm .603$ | $.687 \pm 0.633$ | 554/562 |

The contour plots from the fits (attached) are in the upper right hand quadrant. (Note that the contour plots have the axes flipped with respect to Peskins') If one looks at the attached graphs copied from reference[3], the reason for the high top and higgs masses are immediately clear. The standard model is an extremely narrow vertical band around $S = 0$. Thus an upper right hand qudrant value will require a high top and Higgs mass. A fit, in general, will yield some value of S, pulling the Higgs mass to its lowest or highest value, with no ability to differentiate in between, as the MSM range is far too narrow to allow a real minimum to exist. If the analysis is done in terms of the usual fit parameters of scheme dependent widths and so on, what you are doing is looking at the intersection in the ST plane of nearly parallel diagonal bands. This is illustrated by the reproduced graphs also taken from referece[3]. The contour plots of T (called rhotec) versus S (del3tec) for the first two extension fits are attached. Thus it is clear that with the inclusion of the 1991 data sample the situation in the ST plane and hence any understanding about the higgs sector has changed substantially.

Fitting to all three of the extension parameters simultaneously using all of the ALEPH data and the $p\bar{p}$ data yields the following after untangling S and U.

| $M_Z$ | $N_c$ | $S$ | $T$ | $U$ | $\chi^2/N.D.F.$ |
|---|---|---|---|---|---|
| $91.191 \pm .007$ | $3.007 \pm .004$ | $.765 \pm .744$ | $.698 \pm .659$ | $-.68 \pm 1.03$ | 554/561 |

The value of U indicates that there is no indication of a custodial SU(2) symmetry breaking.

Just to check, two fits to just the 1990 data were also made, after optimizing the top quark mass to their prefered values of 130 GeV and 137 GeV. For these fits the $\tau$ polarization was not used as the values I have are the sum of the 1990 and 1991 data.

| ALEPH | $M_w$ | $M_Z$ | $N_\nu$ | $S$ | $T$ | $\chi^2/N.D.F.$ |
|---|---|---|---|---|---|---|
| X | - | $91.176 \pm 0.010$ | $3.008 \pm 0.005$ | $-.56 \pm 1.1$ | $-1.13 \pm 1.59$ | 258/255 |
| X | X | $91.176 \pm 0.010$ | $3.009 \pm 0.005$ | $-.36 \pm .88$ | $-.33 \pm 0.98$ | 259/256 |

The value in the lower left quadrant explains the conclusions of the low higgs mass and the lower top mass thanthe current data indicates. While it is unclear as to whether these parameters really have any meaning being RS dependent, they do make the top quark and Higgs mass dependence ofthe data easy to visualize. I suspect that a value in the upper right quadrant may have a bearing on the likelihood of observing supersymmetry at LEP 200. High mass supersymmetry models with no SU(2) breaking exactly duplictate the standard model. It would therfore seem reasonable that a model with low masses would deviate from the standard model in the S T plane by the maximal amount allowed in MSSM. This suspicion was confirmed by a conversation with J. Ellis. I will try to investigate this in the near future, by including true MSSM corrections to loops, verticies and maybe even boxes. This is required if the scheme dependence is to be reasonably contained.

# References


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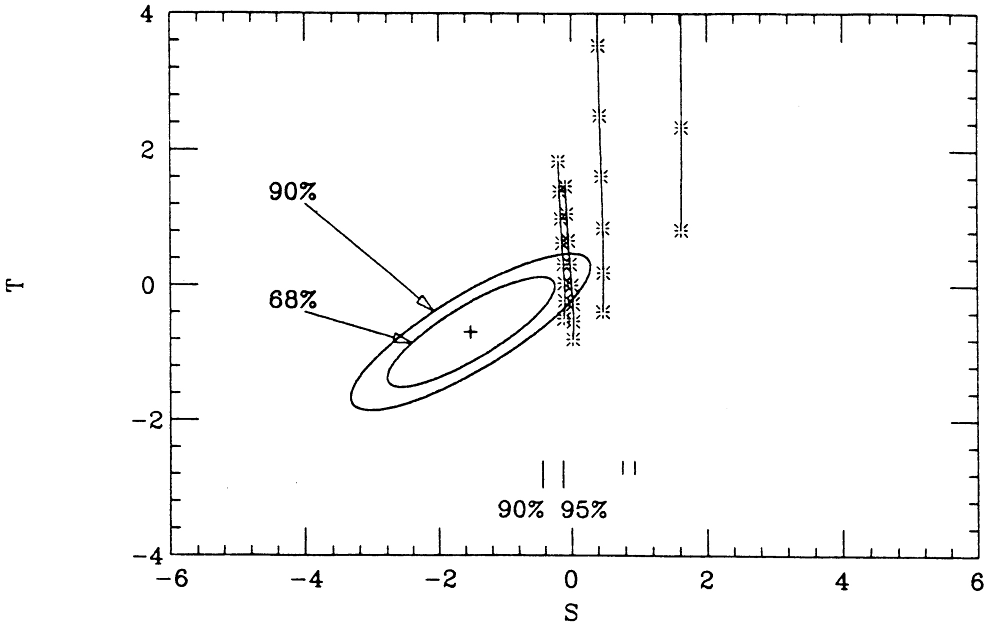


FIG. 15. Contours of the likelihood function of $S$ and $T$ corresponding to 68% and 90% probability, computed from the measurements listed in Table I. The long notches at the bottom of the figure correspond to the 90% and 95% confidence upper limits on $S$ in an unbiased analysis. The shorter notches show the locations of these limits if one imposes *a priori* that $S > 0$.

$m_H = 1$ TeV. For different values of $m_t$ and $m_H$, the position of the likelihood contours on the $S$-$T$ plane will be different. However, the shapes and sizes of these contours would be the same. This gives a convenient way to plot the influence of the reference $m_t$ and $m_H$ on the $S$-$T$ analysis: We simply hold the position of the likelihood contours fixed and plot the relative position of the origin with respect to these contours. As we vary $m_t$, this relative position then sweeps out a contour in the $S$-$T$ plane which roughly follows the displacements (4.4) but gives a more accurate accounting for small values of $m_t$. In Figs. 15 and 16, we have plotted the contours corre-

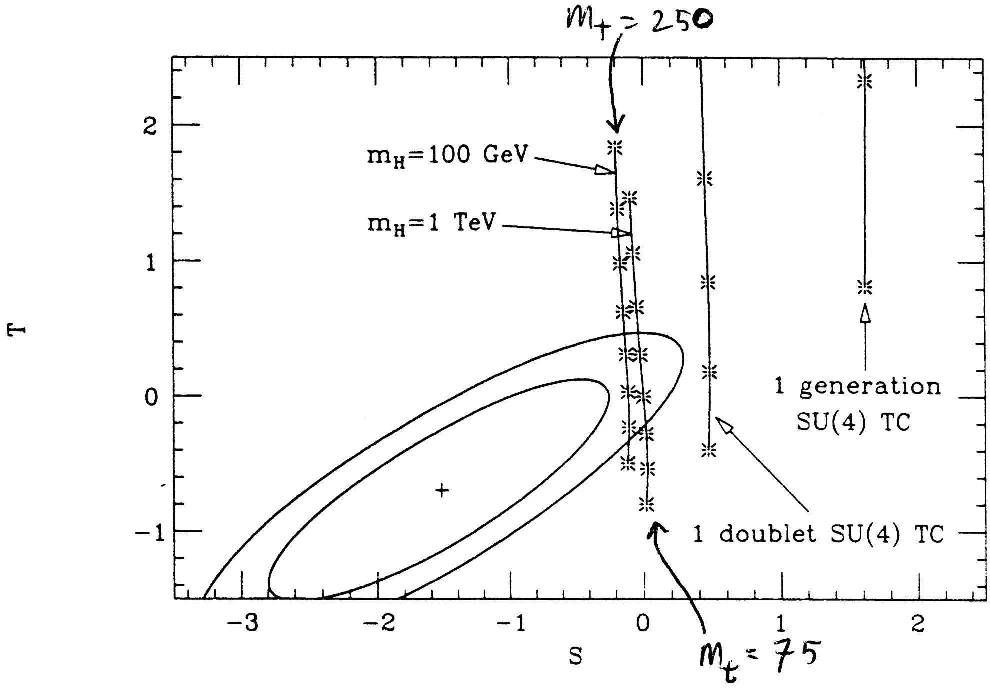


FIG. 16. Enlarged version of Fig. 15, showing the comparison of the region preferred by the fit with the predictions of the minimal standard model and two technicolor models. The values of $S$ and $T$ for the minimal standard model are computed as described in the text, for Higgs-boson masses for 100 GeV and 1 TeV, as a function of the top-quark mass. The stars denote values of $m_t$ from 75 to 250 GeV in 25 GeV steps. The values of $S$ in technicolor models are the values for $N_{TC} = 4$ from Sec. VII. The values of $T$ due to technicolor are computed from (8.2), as an indication of the possible size of this effect. Again, the stars denote values of $m_t$ increasing from 75 GeV in steps of 25 GeV.

```
FCN=   552.6972     FROM MINOS     STATUS=SUCCESSFUL    427 CALLS      1367 TOTAL
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 EXT PARAMETER                      PARABOLIC         MINOS ERRORS
 NO.   NAME          VALUE            ERROR       NEGATIVE        POSITIVE
  1  ZMASS          91.191          0.62367E-02
  3  NUM_COL        3.0071          0.45265E-02
 10  RHOTEC        0.53267          0.66095
 11  DEL3TEC       0.79487          0.74882       -0.75105         0.75720
 13  HADNORM       0.99941          0.28672E-02
 14  ABSNORM       0.99994          0.21848E-02
 15  LEPNORM        1.0003          0.25206E-02
 16  BHASYS         1.0001          0.10671E-03
 18  ESCALE90       1.0001          0.93401E-04
 19  ESCALE91      0.99999          0.46064E-04
 20  ABSNORM90      1.0058          0.32687E-02
 21  ABSNORM91     0.99860          0.18633E-02
 22  LUMIN_1        480.26           4.1805
 23  LUMIN_2        517.74           4.2222
 24  LUMIN_3        446.94           3.4457
 25  LUMIN_4        3609.6           11.718
 26  LUMIN_5        551.38           3.6143
 27  LUMIN_6        590.03           4.3295
 28  LUMIN_7        633.07           4.8826
 29  LUMIN_8        677.14           4.9017
 30  LUMIN_9        800.98           5.3031
 31  LUMIN_10       755.14           4.7809
 32  LUMIN_11       4620.5           13.558
 33  LUMIN_12       697.08           4.0378
 34  LUMIN_13       677.63           4.5276
 35  LUMIN_14       769.03           5.1490
 36  LUMIN_15       2952.8           9.6639


 **********
 Y-AXIS: PARAMETER  11: DEL3TEC
                    X=0
   2.233      7  6  55 44*33    222
   2.113     77 66 55 44 33   222 22
   1.993     7 66 55:44 33  222    2
   1.873      66 55 44 33* 22      2
   1.753      6  5  4  3 *22      22
   1.634     66 55 44 33 22        2  3
   1.514     6 55 44:33 22  111    2  3
   1.394      55 44 33 22*111 1  22 33
   1.274      5 44 33 22 11    1  2 33
   1.154     55 4  3:22 11   11 22 3 4
   1.034     5 44 33:2 11*   1 22 33 4
  0.9147      44 33 22 1 *  11 2 33 44
  0.7949     *4*33*22*11***11*22*3*44*
  0.6751     44 3  2:11   * 1 22 33 4 5
  0.5552     4 33 22:1    *11 2 33 44 5
  0.4354       3 22 11    11 2233 44 55
  0.3156      33 2  1   11 22 3 44 55
  0.1958     33 22  1 111*22 3344 55 6
  0.7600E-01 3  2   111  22 33 4 55 66
 -0.4381E-01 3--2---+---22-33-4455-66-
 -0.1636       22   :  22*33 44 5 66 7
 -0.2834       2    :222 33 44 5566 77
 -0.4032       2    22  33 44 55 6 77
 -0.5231       222222  33*44 55 6677 8
 -0.6429        22  : 33 44 55 6677 88
             I           I           I
       -0.7892                    1.855
                      0.5327
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 FUNCTION VALUES: F(I)=   552.7     +   1.000     *I**2
```

S

T

```
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  3   NUM_COL        3.0069          0.44417E-02
 10   RHOTEC        0.68887          0.64421
 11   DEL3TEC       0.73751          0.61382      -0.61519        0.61550
 13   HADNORM       0.99919          0.28948E-02
 14   ABSNORM       0.99987          0.21871E-02
 15   LEPNORM        1.0005          0.24835E-02
 16   BHASYS         1.0001          0.10604E-03
 18   ESCALE90       1.0001          0.94632E-04
 19   ESCALE91      0.99999          0.45812E-04
 20   ABSNORM90      1.0057          0.32977E-02
 21   ABSNORM91     0.99856          0.18655E-02
 22   LUMIN_1        480.38           4.1795
 23   LUMIN_2        517.88           4.2192
 24   LUMIN_3        447.06           3.4568
 25   LUMIN_4        3610.6           11.735
 26   LUMIN_5        551.54           3.6628
 27   LUMIN_6        590.19           4.3540
 28   LUMIN_7        633.24           4.8870
 29   LUMIN_8        677.30           4.8875
 30   LUMIN_9        801.17           5.2643
 31   LUMIN_10       755.32           4.7361
 32   LUMIN_11       4621.8           13.550
 33   LUMIN_12       697.28           4.0716
 34   LUMIN_13       677.81           4.5638
 35   LUMIN_14       769.23           5.1791
 36   LUMIN_15       2953.6           9.6506

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   1.916    8 77 66 55 44 33
   1.818     77 66 55 44*33  22222
   1.720    77 66:55 44 33  22    2
   1.621    7 66 55 44 33 222     2
   1.523    7 6 55 44 33*22       2  3
   1.425     66 5:44 33 22        2  3
   1.327    66 55:4 33 22  11    22 33
   1.229    6 55 4433 22* 1111  2  3
   1.130     55 44 3 22 111 11 22 33
   1.032     5 44:33 2 11   1  2 33 4
  0.9339    55 4 33 22 1*   1 22 3 44
  0.8357    5 4433 22 11*  11 2 33 4
  0.7375    *44*3*22*11***11*2233*445
  0.6393    44 33:2 11  *11 22 3 44 5
  0.5411    4  3 22 1   *1 22 3344 55
  0.4429    4 33 2  1   1122 33 4 55
  0.3447     33 22 11 111 2 33 4455 6
  0.2465     3  2: 1111 *2233 44 5 66
  0.1482    33 22:  11  22 3 44 5566
  0.5003E-01 3  2 :     22 3344 55 6 7
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 -0.1464       2 :  22  33 4 55 6677
 -0.2446       2 :222  33 4455 66 7 8
 -0.3428       2222   33*4455 66 7788
 -0.4410         :  333 44 5 66 77 8
            I           I           I
       -0.5995                    1.977
                    0.6889
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| 3 | NUM_COL | 3.0069 | 0.48178E-02 | -0.39161E-06 | -0.52495E-01 |
| 10 | RHOTEC | 0.69815 | 0.65917 | -0.15747E-03 | 0.55786E-03 |
| 11 | DEL3TEC | 0.76544 | 0.74484 | 0.12068E-03 | 0.12243E-02 |
| 12 | DEL1TEC | 0.84648E-01 | 1.2523 | -0.44378E-03 | -0.70367E-03 |
| 13 | HADNORM | 0.99919 | 0.28975E-02 | 0.19072E-05 | -0.69295 |
| 14 | ABSNORM | 0.99988 | 0.21964E-02 | 0.38131E-05 | 0.37386 |
| 15 | LEPNORM | 1.0005 | 0.25740E-02 | -0.21985E-05 | -0.37567 |
| 16 | BHASYS | 1.0001 | 0.10729E-03 | 0.19018E-06 | 7.9805 |
| 18 | ESCALE90 | 1.0001 | 0.96972E-04 | -0.10887E-07 | -3.5433 |
| 19 | ESCALE91 | 0.99999 | 0.43624E-04 | 0.27876E-07 | -12.496 |
| 20 | ABSNORM90 | 1.0057 | 0.32840E-02 | -0.86728E-06 | 0.11187 |
| 21 | ABSNORM91 | 0.99856 | 0.19000E-02 | -0.14972E-05 | 0.63768 |
| 22 | LUMIN_1 | 480.38 | 4.1702 | -0.84270E-06 | -0.50382 |
| 23 | LUMIN_2 | 517.88 | 4.2353 | 0.27544E-07 | -0.31022 |
| 24 | LUMIN_3 | 447.06 | 3.5394 | 0.89126E-06 | -0.25153 |
| 25 | LUMIN_4 | 3610.6 | 11.760 | -0.43506E-06 | 0.23763 |
| 26 | LUMIN_5 | 551.54 | 3.7634 | -0.99224E-06 | 0.63439 |
| 27 | LUMIN_6 | 590.20 | 4.3362 | 0.46320E-07 | 1.0630 |
| 28 | LUMIN_7 | 633.25 | 4.8890 | -0.32916E-06 | 0.31729 |
| 29 | LUMIN_8 | 677.30 | 4.8892 | -0.86280E-06 | -0.71209 |
| 30 | LUMIN_9 | 801.17 | 5.3066 | 0.56685E-06 | -0.13552 |
| 31 | LUMIN_10 | 755.33 | 4.7406 | 0.10762E-05 | -0.69349E-01 |
| 32 | LUMIN_11 | 4621.9 | 13.627 | -0.92173E-06 | -0.66211 |
| 33 | LUMIN_12 | 697.29 | 3.9185 | -0.65274E-07 | 0.92053 |
| 34 | LUMIN_13 | 677.82 | 4.4408 | 0.49014E-06 | 1.0003 |
| 35 | LUMIN_14 | 769.23 | 5.1301 | 0.12728E-06 | 0.49071 |
| 36 | LUMIN_15 | 2953.6 | 9.6993 | -0.66938E-06 | -0.64889 |

```
Y-AXIS: PARAMETER  11: DEL3TEC
                            X=0
   2.196        6666   555 :  4444
   2.076       66  5555   4444
   1.957          555   4444    33333333
   1.838        555   444  : 3333
   1.719       55   444   3333
   1.600          444   333:    222222
   1.480        444  3333  :22222    222
   1.361       44   33   2222          2
   1.242          333  222 :           2
   1.123        333  222   1111111    22
   1.004       33   22   111     1     2
  0.8846       3  222  111 :    11    22
  0.7654       **22***11*******11***22**
  0.6463        22   11    : 111  222  3
  0.5271        2    1     111   22  333
  0.4079       22    1111111   222  33
  0.2887       2           : 222  333  4
  0.1696       22         2222  333  444
  0.5039E-01  -22222222222+--333--444--
 -0.6879E-01              3333  444   5
 -0.1880                3333   444   555
 -0.3071       3  3333333  : 444  5555
 -0.4263       3333       4444  555   66
 -0.5455              44444:  555   666
 -0.6647       44444444    5555  6666  7
               I           I           I
           -2.420                    2.589
                       0.8465E-01
        X-AXIS: PARAMETER 12: DEL1TEC     ONE COLUMN=  0.2004
FUNCTION VALUES: F(I)=    553.8     +   1.000     *I**2
```

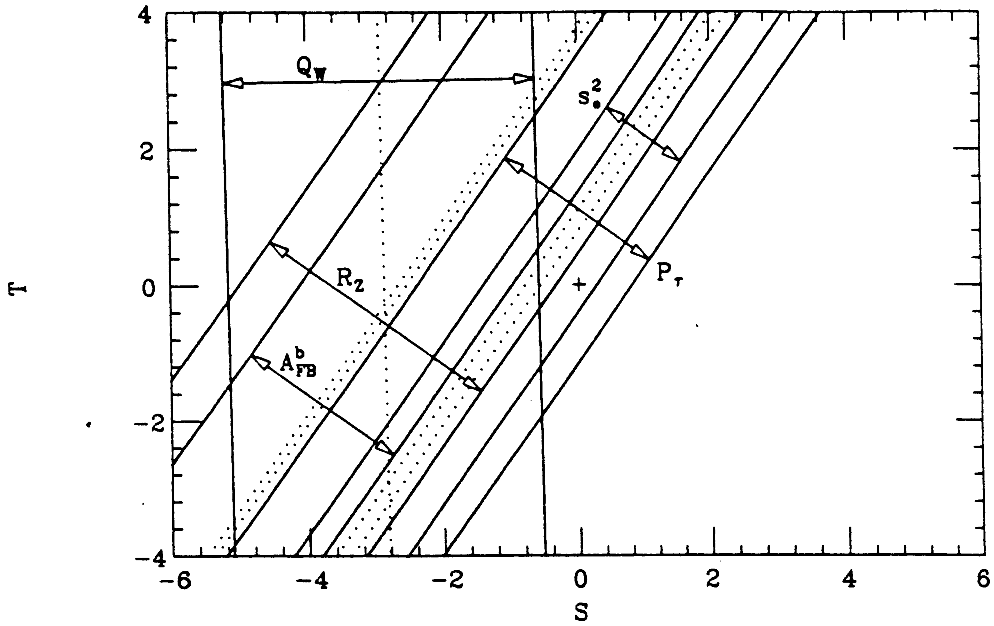


FIG. 14. Bands in the $S$-$T$ plane allowed, within $1\sigma$ errors, by the last five measurements listed in Table I. These observables belong to the second and third classes discussed in the text.

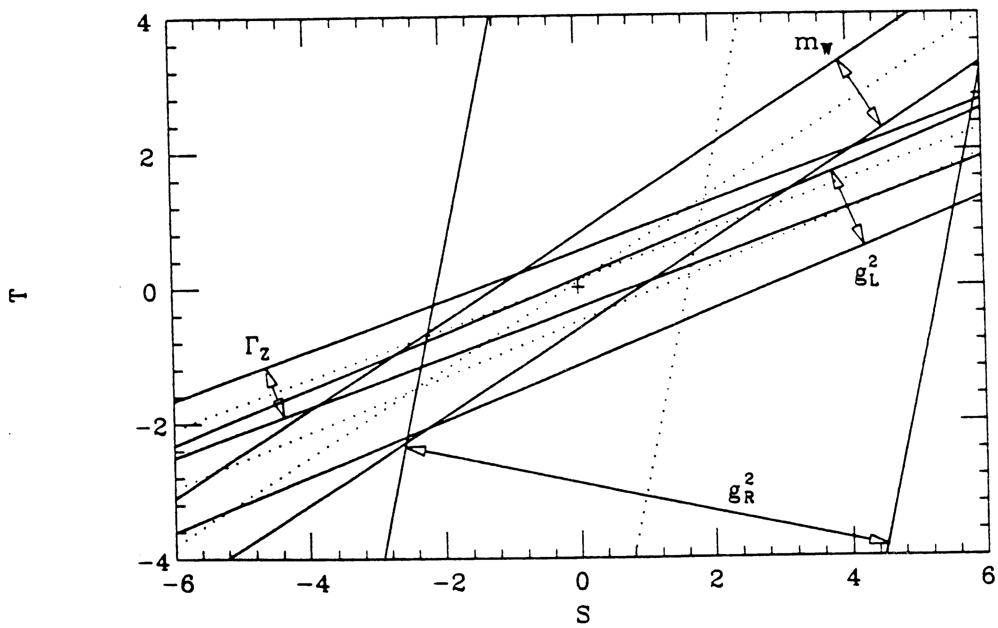


FIG. 13. Bands in the $S$-$T$ plane allowed, within the $1\sigma$ errors, by the first four measurements listed in Table I. These obesrvables belong to the first class discussed in the text.

1990 aleph only

```
FCN=   257.8940      FROM MINOS     STATUS=SUCCESSFUL    437 CALLS      1061 TOTAL
                     EDM=  0.24E-05    STRATEGY= 1      ERROR MATRIX ACCURATE

 EXT PARAMETER                        PARABOLIC          MINOS ERRORS
 NO.   NAME            VALUE            ERROR        NEGATIVE       POSITIVE
  1   ZMASS            91.176         0.99328E-02
  3   NUM_COL          3.0084         0.50153E-02
 10   RHOTEC         -0.55530          1.1046
 11   DEL3TEC         -1.1266          1.5859        -1.5257          1.6756
 13   HADNORM          1.0021         0.40503E-02
 14   ABSNORM         0.99997         0.24151E-02
 15   LEPNORM         0.99936         0.28229E-02
 16   BHASYS           1.0000         0.11519E-03
 20   ABSNORM90        1.0020         0.40099E-02
 22   LUMIN_1          481.50          4.3545
 23   LUMIN_2          519.26          4.5420
 24   LUMIN_3          447.73          3.8724
 25   LUMIN_4          3611.4          12.255
 26   LUMIN_5          553.69          4.1635
 27   LUMIN_6          592.67          4.7913
 28   LUMIN_7          636.22          5.1908

Y-AXIS: PARAMETER  11: DEL3TEC
                              X=0
   1.918      77 66  5  44*33: 222   2
   1.665      7  6  55 44 33 :22     2
   1.411      7 66 55 44 33  22     22
   1.157        6  5  4  3* 22      2
  0.9034       66 55 44 33*22:      2
  0.6496      66 55 44 33 22 :     22 3
  0.3959      6 55 44 33 22  111   2  3
  0.1421      6 5  4 33 22* 11 1  22 33
 -0.1116      -55-44-3-22-111+-1--2-33-
 -0.3654      55 44 33 2 11  :11 22 3 4
 -0.6191      5 44 33 22 1*  :1 22 3344
 -0.8729      5 4 33 22 1100 11 2 33 4
  -1.127      *44*3*22*1100011*2233*445
  -1.380      44 33 2 11 0011:2233 4455
  -1.634      4 33 22 1   11 22 3 4455
  -1.888      4 3 22 11  11 22 3344 5 6
  -2.142       33 2  1  11*22:3344 5566
  -2.395      33 22  1111 22 3344 55667
  -2.649      3  2   11  22 3344 556677
  -2.903      3 22      2233344 556677
  -3.157        2     22233 44 556677 8
  -3.410        2    22 33*445556677 88
  -3.664        2  222 33 4455 6677 889
  -3.918        2222 33344455:6677 8899
  -4.172            33 44 55 667788899A
              I           I           I
          -2.764                    1.654
                      -0.5553
        X-AXIS: PARAMETER 10: RHOTEC      ONE COLUMN=  0.1767
FUNCTION VALUES: F(I)=    257.9       +    1.000      *I**2
```

T

```
FCN=   259.1442      FROM MINOS     STATUS=SUCCESSFUL    126 CALLS       753 TOTAL
                     EDM=  0.29E-05    STRATEGY= 1      ERROR MATRIX ACCURATE

 EXT PARAMETER                        PARABOLIC          MINOS ERRORS
 NO.   NAME            VALUE            ERROR        NEGATIVE       POSITIVE
  1   ZMASS            91.176         0.99310E-02
  3   NUM_COL          3.0086         0.50060E-02
 10   RHOTEC         -0.32516         0.98245
```

| | | | | | |
|---|---|---|---|---|---|
| 11 | DEL3TEC | -0.36085 | 0.88391 | -0.88396 | 0.88404 |
| 13 | HADNORM | 1.0020 | 0.40408E-02 | | |
| 14 | ABSNORM | 1.0002 | 0.23955E-02 | | |
| 15 | LEPNORM | 0.99916 | 0.28068E-02 | | |
| 16 | BHASYS | 1.0000 | 0.11516E-03 | | |
| 20 | ABSNORM90 | 1.0019 | 0.40011E-02 | | |
| 22 | LUMIN_1 | 481.55 | 4.3505 | | |
| 23 | LUMIN_2 | 519.31 | 4.5370 | | |
| 24 | LUMIN_3 | 447.78 | 3.8658 | | |
| 25 | LUMIN_4 | 3612.1 | 12.049 | | |
| 26 | LUMIN_5 | 553.85 | 4.1460 | | |
| 27 | LUMIN_6 | 592.84 | 4.7738 | | |
| 28 | LUMIN_7 | 636.39 | 5.1741 | | |

```
 Y-AXIS: PARAMETER  11: DEL3TEC
                           X=0
    1.336      88 7 66 55 44 :33
    1.195      8 77 6 55 44*333  2222
    1.053       77 66 5 44 33: 222  2
   0.9120      77 66 5544 33 :22    2
   0.7706      7 66 55 4 33* 22     2  3
   0.6291       66 55 44 3 222      2  3
   0.4877       6 55 44 3322 :     22 33
   0.3463      6655 44 33 2* 1111  2 33
S  0.2048      6 5 44 33 22*11 11 22 3 4
   0.6342E-01 -55-4-33-22-11+-1--2-33-4
  -0.7800E-01 55 4433 22 11 :11 22 3 44
  -0.2194      5 44 3 22 11* :1 22 3344
  -0.3609      544*33*2*11***11*2*33*4*5
  -0.5023       4 33 22 1  *11 2233 4455
  -0.6437      44 3 22 11  11:22 3 4455
  -0.7851      4 33 2  1  11 22 3344 5 6
  -0.9266       33 22 11 11*22 3344 5566
   -1.068       3  2  1111 22:33 4 5566
   -1.209      33 22      22 33 4455 6 7
   -1.351      3  2      22*33 4455 6677
   -1.492      3  2     22 33:4455 6677
   -1.634         2    22 33 44 5 66 7 8
   -1.775         2  222 33*44 5566 7788
   -1.917         2222  33 44:5566 7788
   -2.058              33 44 5566 7788 9
               I           I           I
           -2.290                    1.640
                     -0.3252
       X-AXIS: PARAMETER 10: RHOTEC      ONE COLUMN=  0.1572
 FUNCTION VALUES: F(I)=   259.1     +   1.000     *I**2
```

T