ALEPH 93-06
PHYSIC 93-03
T. Fearnely et al.
18.1.1993

Luminosity Errors - Again

T.A.Fearnley, J.D.Hansen, J.R.Hansen,
P.H.Hansen and R.Møllerud

January 15, 1993

This note is an attempt to finalize the values of the systematic errors on the LCAL luminosity measurement for the period until the installation of SICAL. It also gives a preliminary estimate for the period after, and the correlation with SICAL. The analysis covers the data sets collected in '90, '91 and '92. Description of the luminosity determination and the Monte Carlo generator BABAMC can be found in our publication on the measurement of the absolute luminosity [1]. All errors referred to in this note are in %.

There are several contributions to the systematic error on the LCAL measurement of the luminosity. Some of these are estimated from variations of the analysis cuts. These variations are chosen so that they check the different cuts applied to the data. We have so far as the error used the largest observed difference, ignoring the statistical errors and possible contributions from other error sources.

Now we have four high statistics measurements of the luminosity, and hence better error estimates are possible using consistency assumptions between the measurements.

As an example we look at the fiducial side cut error, which is the biggest error. This comes from the difference between method 9 and 8, as we are free to choose between the two methods. The results in % are:

1992 BHLUMI :	+ 0.09	± 0.15(stat)	± 0.01(uncor.)	± 0.04(cor)
1991 BHLUMI :	+ 0.32	± 0.15	± 0.01	± 0.04
1991 BABAMC :	+ 0.12	± 0.15	± 0.01	± 0.04
1990 BABAMC :	- 0.38	± 0.19	± 0.02	± 0.04

The statistical errors on the 1991 measurements have contributions from the Monte Carlo generators and the common experimental data. The latter gives a correlated error of 0.11. The label "uncor" refers to the uncorrelated contribution from the "external alignment and construction". Similarly "cor" is the corresponding correlated contribution. If the boundary is shifted, then the luminosity will change as the angular dependence in that case is not correctly simulated. This gives an error "error-ext" which is already included in the set of errors, but it also gives a contribution to the error under study, which can be approximated by error = "error-ext"$\cdot dr/r_9$, where dr is the padsize and r_9 the minimum radius of method 9. The actual values can be deduced from table 1 in our publication on the measurement of the absolute luminosity.

The fits described in the following use all three errors.

[1] D.Decamp et al.
Measurement of the absolute luminosity with the ALEPH detector.
Z.Phys.C -53, 375-390 (1992)

First we assume that there is a common value of the difference between method 9 and 8 for all the measurements. The result is a chisquared of 8.76 for 3 degrees of freedom and a value of 0.05 $\pm$ 0.10, consistent with the "cor"-errors above.

In our luminosity paper the theoretical expectation for BABAMC was given as -0.08 $\pm$ 0.03, which is believed to come from higher order corrections not included. However, they are included in BHLUMI, so we assume that the theoretical expectation in this case is 0.00. We have until now never accounted for these expectations in our published error estimates.

Including these expectations we get a chisquared of 6.51 for 3 degrees of freedom and a value of 0.08 $\pm$ 0.10, again consistent with the "cor"-errors above.

Alternatively we might assume that the difference for BABAMC (BHLUMI still 0.0) is the one preferred by data, or equivalently that the mean difference, i.e. the fit parameters, are independent for the two Monte Carlo generators. This gives a fit with a chisquared of 4.58 for 2 degrees of freedom with parameters equal to 0.16 (BHLUMI) and -0.09 (BABAMC). This fit has as before a low probability.

All the fits described above have a ratio of chisquared to degrees of freedom larger than 2, thus suggesting an additional error.

We will in the following decribe four alternative ways of estimating the fiducial side error using different consistency arguments. The first three estimates assume the theoretical expectations, while the fourth uses the value preferred by data.

Estimate 1

Estimate 1 assumes that each year has its own value. A fit gives a chisquared of 0.72 for 1 degree of freedom. The values are for 1992 +0.09 $\pm$ 0.15, for 1991 +0.26 $\pm$ 0.11 and for 1990 -0.30 $\pm$ 0.20.

The errors to be used for this estimate are the absolute value of these numbers.

We note that if the theoretical expectations are not included then the fit gives a chisquared of 2.00 for 1 degree of freedom.

Estimate 2

However, there is no obvious reason why the values should vary significantly from year to year, as it is suggested in estimate 1. But we have already seen that a common value for all years gives a low probability.

Estimate 2 therefore assumes that the year which differs the most from the others, i.e. 1990, has its own value, whereas the others have a common value.

We then get for 1991/1992 0.19 $\pm$ 0.11 and for 1990 -0.30 $\pm$ 0.20, with a chisquared of 1.86 for 2 degree of freedom. The source of the change from 1990 to 1991/1992 is unexplained.

Estimate 3

The difference between 1991 and 1992 is, however, not much smaller than the difference between 1990 and 1992, when the theoretical expectations are taken into account. Therefore estimate 3 does not single out 1990. Instead, it is assumed that there is a common difference for all years, but that the results fluctuate around this value with a sigma equal to the square root of the sum of the square of the errors given in the above table, **plus** an extra contribution.

This extra uncorrelated error must be chosen to be 0.208 for a fit to give a chisquared of 3 for 3 degrees of freedom. The fitted common difference is 0.04 $\pm$ 0.16, in agreement with the 0.04 "cor"-error above. The source of this additional error is unexplained. However, such an error could come from a combination of different alignments, backgrounds, amplifier fluctuations, etc.

Estimate 4

Assuming again, as in estimate 3, that the uncorrelated error is the same over the years, but that the mean expected difference for the two Monte Carlos could be different, gives a two-parameter fit with a chisquared of 2 for two degrees of freedom when the uncorrelated error is set to 0.183. The result of the fit is that the mean value for BHLUMI is 0.12 $\pm$ 0.16 and for BABAMC -0.12 $\pm$ 0.16. These values are correlated errors when BHLUMI and BABAMC are used respectively. These together with the uncorrelated error of 0.183 give a total error of 0.22 for both generators.

Estimate 4 gives roughly the same errors as estimate 3, but it gives a larger correlation amongst years with the same generator. Also the fit values agree within errors with the theoretical expectations. But we prefer estimate 3 over 4 because it uses the theoretical expectations in order to minimize the number of "free" parameters.

Estimate 1 is not preferred, as it does not exploit the fact that we expect to have similar errors every year, which reduces the effect of the statistical errors.

Our own preference is estimate 3, which treats the years equally and uses the theoretical expectations.

Still we choose to give below the errors and correlations for the two estimates 2 and 3 in order to demonstrate the differences.

In the calculation of the errors we exclude the additional "safety" error, which was introduced to increase the combined errors to the nearest integer - or later half integer - permille. The theoretical error for BHLUMI is taken to be 0.28, which is the most recent value for LCAL.

Some of the smaller errors can also be given a similar consistency treatment. As the main difference is expected to come from the two Monte Carlo generators and the statistics, we leave 1990 unchanged, and take an average between 1991 and 1992, where the results do agree within statistics. For the non-fiducial side error we use 0.11 instead of 0.13 (1991) and 0.09 (1992), respectively. For the $\Delta\phi$ error we use 0.03 instead of 0.05 and 0.01, while we for the energy error use 0.10 instead of 0.08 and 0.12.

The 1991 and 1992 errors are this way the same, except for the socalled relative error, which was introduced to compensate for the fact that we have ignored the correlation between the statistical errors when using the relative luminosity in 1991.

The errors from estimate 2 / 3 are given with the old value in parenthesis. For 1992 it is the value we would have given if the old method of estimating the error was used.

	1990		1991		1992 pre SICAL	
Exp.	0.52 / 0.47	(0.60)	0.37 / 0.38	(0.45)	0.36 / 0.37	(0.32)
Theo.	0.30	(0.30)	0.28	(0.30)	0.28	(0.28)
Total	0.60 / 0.56	(0.70)	0.46 / 0.47	(0.55)	0.46 / 0.46	(0.43)

The values and errors on the mass, width and cross sections depend on the luminosity taken at the various energies, on the systematic errors and their correlations.

Correlations between the years in the systematic error on the relative LCAL cross section are estimated using the previous error estimates and assuming that the errors in 1992 are the same before and after the installation of SICAL, except for the error due to the presence of SICAL. This latter error is in the following without justification set to 0.1. Future studies might change this number.

The theoretical BHLUMI and BABAMC errors are taken to be correlated only through the electroweak correction error. The "inadequate approximation of the energy dependence" is obviously uncorrelated between the years. The same is true for the contribution from the "relative" luminosity, so far only in 1991. We have assumed for the non-fiducial side cut, the dphi cut and the energy error, that the smallest error is equal to the correlated part of the error, meaning that the rest is uncorrelated.

As usual the errors listed below are in %.

Estimate 2:

	1990	1991	1992 (pre SICAL)	1992 (post SICAL)
Total errors	0.60	0.46	0.46	0.46
External alignment errors	0.12	0.07	0.07	0.07
Fiducial side cut	0.30	0.19 [-]	0.19 [-]	0.19 [-]
Non-fiducial side cut	0.10	-	-	-
Dphi cut	0.10	-	-	-
Energy	0.21	-	-	-
Approx. of energy dep.	0.10	-	-	-
Monte Carlo statistics	0.19	0.14	0.14	0.14
"Relative" error	-	0.10	-	-
Error due to SICAL	-	-	-	0.10
Theoretical errors	0.28	0.26 [-]	0.26 [-]	0.26 [-]
Total uncorrelated errors	0.54	0.37	0.36	0.37
		0.19	0.16	0.19
Total correlated errors	0.26	0.27	0.29	0.27
		0.42	0.43	0.42
Ratio correlated/total	0.43	0.59	0.63	0.59
		0.91	0.93	0.89

The numbers in brackets are used when calculating the correlation between luminosities based on BHLUMI, with the results given in the second line. Since we have only used BABAMC for the publications in 1990 (and 1989) then the first line is used when evaluating correlations between 1990 (and 1989) and the following years, while the second line is used for correlations between the following years.

The error ratios give the correlation:

0.25	for 1990	/1991,
0.27	for 1990	/1992(pre SICAL)
0.25	for 1990	/1992(post SICAL)
0.85	for 1991	/1992(pre SICAL)
0.83	for 1991	/1992(post SICAL)
0.85	for 1992(pre SICAL)	/1992(post SICAL)

There is a correlation with SICAL through the common theoretical error, however with BABAMC only through the electroweak correction. Taking the SICAL theoretical error to be 0.25 and the SICAL experimental error to be 0.10 gives:

0.02	for 1990	/SICAL
0.57	for 1991	/SICAL
0.57	for 1992(pre SICAL)	/SICAL
0.57	for 1992(post SICAL)	/SICAL

Using that the correlation is inversely proportional to the total error allows a rescaling with another experimental error.

Estimate 3:

	1990	1991	1992 (pre SICAL)	1992 (post SICAL)
Total errors	0.56	0.47	0.46	0.47
External alignment errors	0.12	0.07	0.07	0.07
Fiducial side cut	0.21	0.21	0.21	0.21
Non-fiducial side cut	0.10	-	-	-
Dphi cut	0.10	-	-	-
Energy	0.21	-	-	-
Approx. of energy dep.	0.10	-	-	-
Monte Carlo statistics	0.19	0.14	0.14	0.14
"Relative" error	-	0.10	-	-
Error due to SICAL	-	-	-	0.10
Theoretical errors	0.28	0.26 [-]	0.26 [-]	0.26 [-]
Total uncorrelated errors	0.50	0.38	0.37	0.38
		0.28	0.26	0.28
Total correlated errors	0.25	0.28	0.27	0.28
		0.38	0.38	0.38
Ratio correlated/total	0.45	0.60	0.59	0.60
		0.81	0.83	0.81

The error ratios give the correlation:

0.27	for 1990	/1991,
0.27	for 1990	/1992(pre SICAL)
0.27	for 1990	/1992(post SICAL)
0.67	for 1991	/1992(pre SICAL)
0.66	for 1991	/1992(post SICAL)
0.67	for 1992(pre SICAL)	/1992(post SICAL)

The correlation with SICAL will be:

0.02	for 1990	/SICAL
0.55	for 1991	/SICAL
0.57	for 1992(pre SICAL)	/SICAL
0.55	for 1992(post SICAL)	/SICAL

The correlations of estimate 2 and 3 fall into three groups with small spreads, and one which depends somewhat on the estimate:

0.27	LCAL 1990	/ LCAL 1991 and after
0.84 - 0.67	LCAL 1991 and after	/ LCAL 1992 and after
0.02	LCAL 1990	/ SICAL
0.56	LCAL 1991 and after	/ SICAL

Conclusion

It has been shown that it is not possible to give a consistent value over the years for the difference between method 9 and 8 by simply taking into account statistics and using the effect of the other error sources, not even if the two Monte Carlo generators are allowed to have different mean values. This means that there must be at least one additional error source. Estimate 1, 2, and 3 all assume that the difference between BHLUMI and BABAMC is given by the theory. Estimate 1 is otherwise the standard method, except that an average is taken between the two measurements in 1991. Estimate no. 2 assumes that 1990 is different from 1991 and 1992 for some unknown reason. Estimates no. 3 and 4 assume that there is an additional error of statistical nature with the same mean value each year. Estimate no. 4 uses a fitted value for the difference between BHLUMI and BABAMC. We have deduced new systematic LCAL errors and correlations between them, for the two estimates number 2 and 3.

Our own preference is estimate 3, which treats the years equally and uses the theoretical expectations. Estimate 3 implies that there is on the average no difference in the luminosity when using method 8, as done until now, or 9, as we will do after the installation of SICAL. But the yearly variations are larger than expected from statistics and other error sources. This increase is taken as an uncorrelated fiducial side cut error.

The estimate preferred by ALEPH should be used in **all** future fits. The experimental cross sections are not changed, so we suggest only to mention that the systematic errors have been reduced due to improved knowledge from more running.

We recommend that "final" pre-SICAL fits are performed with these errors and correlations as soon as the luminosity for the pre-SICAL period of 1992 is available. In the meantime a fit to the data recently published should be performed to see the effect of the new errors and correlations.