NORMALIZATION

G. Coignet
Convener of the Working Group

The luminosity monitors of the four LEP experiments have been initially designed to determine the luminosity with an absolute error $(\Delta L/L)_{abs} \leq 2\%$. For this purpose each experiment has built a "standard" Small Angle Tagger (SAT) to detect Bhabha events with a minimum scattering angle $\theta_{min} \geq 30$-50 mrad depending on the experiment. Working at the Z energy with the nominal luminosity $L \approx 10^{31}$ cm^{-2} s^{-1}, each SAT is expected to reach a statistical precision of about 2% on a run (fill) to run (fill) basis. The uncertainty in the absolute luminosity will finally be dominated by other run independent errors : theoretical uncertainty on the Bhabha cross section, manufacturing tolerances and positioning of the detectors, etc. Run-dependent errors may arise from uncertainties in estimating the effects of machine backgrounds on detection efficiencies.

To reduce the statistical error to a negligible level, most experiments have designed a very small angle luminosity monitor (called VSAT, SALM or FFD) to measure Bhabha events at an angle of 5 to 7 mrad. A very high rate detector to measure the photons emitted at zero degrees in the reaction $e^+e^- \rightarrow e^+e^-\gamma$ has also been proposed. This detector would also provide information on beam divergence over a reduced angular acceptance region.

With polarized beams, in the four bunch scheme proposed for LEP by A. Blondel, the left-right asymmetry A_{LR} could be measured with a precision ΔA_{LR} which can be expressed as :

$$\Delta A_{LR} = \sqrt{\frac{(1 + 1/\gamma)\ (1 + \rho)^2}{P^2\ N} + \frac{1 + \rho^2}{4\ P^2} \left(\Delta\left(\frac{Li}{Lj}\right)_{syst}\right)^2 + A_{LR}^2 \left(\frac{\Delta P}{P}\right)^2_{syst}}$$

with

P : beam polarization

N : total number of Z events

$$\gamma = \frac{Bi}{Ni}\Big|_{i = 1,\,4}$$: ratio of Bhabha events to Z events

$$\rho = \frac{A_{LR}\left(\frac{1}{P} - P\right)}{1 - A^2_{LR}\,P^2} = \frac{N_3 + N_4}{N_1 + N_2}$$

$\Delta\left(\frac{Li}{Lj}\right)_{syst}$: systematic error on the relative bunch i to bunch j luminosity measurement

$\left(\frac{\Delta P}{P}\right)_{syst}$: systematic error on polarization measurement

Table 1 shows an estimate of the total number of Z events, as a function of γ and for different values of $\Delta(\frac{Li}{Lj})_{syst}$, needed to measure $A_{LR} = 0.15$ with an error $\Delta A_{LR} = 3°/_{\circ\circ}$. Two values of beam polarization P, assumed to be determined with $(\frac{\Delta P}{P})_{syst} = 3°/_{\circ\circ}$, are considered.

Table 1

Estimated number of 10^6 Z events

needed to measure A_{LR} with $\Delta A_{LR} = 3°/_{\circ\circ}$

P (%)	$\Delta(\frac{Li}{Lj})_{syst}$ ($°/_{\circ\circ}$)	$\gamma = 1$	$\gamma = 4$	$\gamma = 15$
50	1.0	1.6	1.0	0.8
	1.5	1.9	1.2	1.0
	2.0	2.7	1.7	1.5
30	0.5	6.2	3.9	3.3
	1.0	9.3	5.8	4.9
	1.5	48.0	30.0	25.5

Since run-independent errors will cancel out, the systematic errors affecting the relative luminosity measurement $\Delta(\frac{Li}{Lj})_{syst}$ will be due to systematic differences between various bunches circulating in the machine. The following sources of systematic errors have been considered :

i) shape and position of the luminosity region,

ii) beam divergence and tilt at the interaction region,

iii) machine backgrounds,

iv) physics backgrounds.

The sensitivity of the SAT and of the VSAT measurements to the effects i) and ii) have been investigated by Monte Carlo simulation. Typical values of beam position and angle, which will be monitored by the LEP instrumentation and independently by the central detector and the SAT detector of each experiment, have been assumed. Two types of machine background have been taken into account : the photons from synchrotron radiation and the off-momentum electrons (positrons) due to beam gas bremsstrahlung. It is hoped that these parasitic fluxes will be sufficiently reduced by a set of collimators implemented in the LEP main ring. It is planned to measure the off momentum electrons due to beam gas interactions and then to subtract them statistically. The synchrotron radiation will add energy rather homogeneously and hence only change the effective trigger thresholds. Finally the physics background, mainly two photon physics event, has been estimated to be negligible.

From this study, the following conclusions can be drawn :

- The relative luminosity measurement, with the accuracy required to carry out polarized beam experiments, relies on the monitoring of the beam position and divergence and of machine background. It appears that the beam parameters can be measured with the necessary precision by LEP instrumentation and also by the experiments themselves. The effects due to off-momentum electrons and to synchrotron radiation are expected to be negligible on the relative bunch to bunch luminosity measurement.

- The SAT detector measurements are stable against variations of the beam at the interaction point. Under the assumptions considered, the required systematic precision accuracy on the relative bunch to bunch luminosity measurements should be achievable with these luminosity detectors. Their main limitation comes from their counting rate.

- The VSAT detector measurements can provide high statistical accuracy but are more sensitive to variations of the interaction parameters, and especially to horizontal divergence and position changes. These variations cause systematic errors which render the use of these detectors more difficult; a good position measurement would certainly improve the situation. At present, there is no general agreement that these detectors can be used to measure the relative luminosity with the accuracy needed in the case of polarized beam experiments.

- The proposal based on the measurement of the single bremsstrahlung photons emitted around zero degrees offers the possibility to monitor certain parameter changes in the luminous region very quickly. Its main limitation, for the purpose discussed here, comes from its limited angular acceptance. However, it could be considered as a first part of a device to measure the longitudinal polarization.

- After some running time at LEP (without polarization) has occurred, information on monitor behavior and LEP instrumentation performances will be obtained. Realistic conditions will then be available to reassess the present conclusions. It appears anyway from this study that a reduction of the beam pipe radius (to 6 cm or less) would allow for coverage of the $\approx$ 25 to $\approx$ 60 mrad angular region, which is the best region for normalization as far as systematic and statistical errors are concerned. Except for the L3 experiment which already has a luminosity monitor covering this angular region, the other experiments would need to construct new luminosity detectors.

Contributors to the Normalization Working Group :

G. Alexander, A. Blondel, L. Bugge, T. Buran, H. Burkhardt, M. Chen, G. Coignet, M. Dallavalle, M. Dam, G. De Zorzi, G. Diambrini-Palazzi, A. Di Domenico, E. Fernandez, L. Garrido, J.D. Hansen, P.R. Hobson, G. Jarlskog, R.G. Kellog, D.J. Miller, R. Mollerud, J.A. Perlas, D.E. Plane, A.L. Read, C. Rippich, G. Rinaudo, D. Treille, G. Von Holtey.