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More luminosity estimators

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Abstract

This note presents three estimators of the luminosity which are as little dependent as possible on the systematic errors.

1 Introduction

The luminosity can be obtained from:

$$L = \frac{E_{data}}{E_{MC}} \cdot \frac{N_{MC}}{\sigma} \tag{1}$$

where E is the luminosity estimator and N_{MC} is the number of Monte-Carlo events used in estimating σ. The estimator is choosen such that the ratio of E_{MC} to N_{MC} is constant within the statistical error on the Monte-Carlo calculation.

By the number of events in a sample is always meant the number of trigger events minus the predicted number of background events.

There are many contributions to the systematic error of σ.

The measurement errors in the determination of angles of the individual events matters little [1] as these errors enter as small second order effects.

More serious is the dependence on the absolute value of the inner radius.

Other serious errors could come from our limited knowledge of the transverse shower profile and from the theoretical prediction of the distribution of the electron relative to the combined electron photon shower.

The first estimator presented here is best when the combined error of the systematic inner radius error of the calorimeter plus the systematic shower profile error is the smallest. The others are better when it is the combined error of the systematic error in the determination of the inner radius using the track detector plus the systematic uncertainty in the electron distribution which is the smallest.

Our primary data sample consists of events with two electromagnetic showers/clusters with energies above some thresholds. The thresholds are in general not the same for the two showers. There is no attempt in this note to correct for the trigger efficiency.

We have one acceptance region A fully covered by the calorimeter and the track detector, and another acceptance region B at a larger radius fully covered by the calorimeter but not "covered" by the track detector. The track detector extends to a smaller radius than the calorimeter such that the track requirement on A only puts a limit on the outer boundary. One might not use the same angular cuts in the two hemispheres when defining region A and B.

The rate in region A is expected to be about twice that in region B. This means that quantities on which the relative luminosity error is linear, and these errors are the most important [1], should for the track detector be only only be 2/3 of the corresponding calorimeter value to give the smallest systematic error. This is true for an estimate, which uses only region A, The most important "linear" error is the uncertainty in the inner radius of the fiducial area.

The calculated luminosities should not within the quoted errors depend on the estimator nor on the boundary between the regions A and B.

To calculate the estimators we define samples as follows:

- S_0 is the subsample where two showers and two tracks are in A.
- S_1 is the subsample where two tracks are in A but not both showers.
- S_2 is the subsample where two showers are in A but not both electrons.
- S_3 is the subsample where two showers are in A but at most one electron seen.
- S_4 is the subsample where one shower is in A and the other in B or both in B.
- S_1' is the common subset of S_1 and S_4.
- S''_1 is a subset of S_4 which does not have two electrons in A.
- S_2' is a subset of S_2 with one electron in A and the other in B or both in B.
- $S_A = S_0 + S_2 + S_3$.

2 The calorimeter has the smaller systematic error

No information about the tracks will be used in the estimator which is:

$$E = S_A + S_4 \tag{2}$$

The information from the track detector is only used to improve the performance of the calorimeter.

This estimate is the estimate which has the smallest statistical error for given acceptance regions A plus B.

3 The track detector has the smaller systematic error

The second estimate is based on the acceptance region A only.

$$E = (S_0 + S_1) \cdot \frac{S_A}{S_0 + S_2} = S_A \cdot (1 + \frac{S_1 - S_2}{S_0 + S_2}) \tag{3}$$

If events with two showers inside A and with no or only one electron seen are distributed as those with both electrons seen then this estimator is equal to the number of events with two electrons in A corrected for the detection efficiency of the two electrons. However this equality is not used in the calculation of the estimator. The acceptance region for this estimator is mainly determined by the electrons as the ratio of the shower samples depends little on the exact determination of A as done with the showers. Most if not all of the dependence on the efficiency of the track detector is eliminated.

This is the estimator with the largest statistical error for a given acceptance region A.

To reduce the statistical error a third estimate might be formed.

$$\begin{aligned} E &= (S_0 + S_1 + S_2') \cdot \tfrac{S_A}{S_0+S_2} + S"_1 - S_1' \tfrac{S_3}{S_0+S_2} \\ &= S_A \cdot (1 + \tfrac{S_1+S_2'-S_2}{S_0+S_2}) + S"_1 - S_1' \tfrac{S_3}{S_0+S_2} \end{aligned} \tag{4}$$

This estimator is with the same remark as above equal to the number of events with two electrons corrected for efficiency where the electrons fall in a region of A or in the part of B where they should be seen plus an estimate of the number of events which have an electron in this region and another in the remaning part of B or both in the remaining part of B.

This neglects of course any correction for the outer boundary of B.

The minus sign removes events of sample S_1 already corrected for in the first term.

Still it is the estimator that matters and not the interpretation.

References

[1] J. D. Hansen - ALEPH Note 88-30/ PHYSICS 88-10.