2.3 Experimental errors

2.3.1 Scenario: Good results with bad data

Jane is preparing a hands-on exercise for physics students, and plans to make use of old data collected in electron-positron annihilation at LEP-I. Searching in the archives, she discovers that there are two data samples at her disposal: both come from leptonic Z-boson decays, one containing absolute momenta of e^-, and another – of e^+. Unfortunately, due to corruption of the old disk, only a small part of the e^+ sample can be recovered, corresponding to just 4% of the e^- volume. Jane nevertheless decides to go ahead with the exercise, and makes a trivial estimate of Z-boson mass value. To her satisfaction, she finds that the *spread* of both distributions is about the same. With the small e^+ sample, she obtains the positron momentum value of 43.0±10.0 GeV, and the larger e^- sample gives the corresponding momentum value of 45.0 GeV, with much smaller *error*. She ultimately estimates the Z mass at 89.8±3.9 GeV. The students however come with a different result: 88.0±10.2 GeV. Upon close inspection, Jane finds out that the students did not really commit any mistake: they simply did not make use of theoretical knowledge that would help reducing the error.

2.3.2 Literature

1. J. Orear, Notes on Statistics for Physicists (UCRL-8417, 1958)
2. D. J. Hudson, Lectures on Elementary Statistics and Probability (CERN 63-29, 1963)
3. W.T. Eadie et al, Statistical methods in experimental physics (North-Holland, 1971 and Elsevier, 1983)
4. S.L. Meyer, Data Analysis for Scientists and Engineers (Wiley, 1975)
5. S. Brandt, Statistical and computational methods in data analysis (North-Holland, 1976)
6. A. Frodesen et al, Probability and Statistics in Particle Physics (Oxford University Press, 1979)
7. L. Lyons, Statistics for Nuclear and Particle Physicists (Cambridge University Press 1986, reprinted 1989 and 1999)
8. R. Barlow, Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences (Wiley, 1989)
9. B. Roe, Probability and Statistics in Experimental Physics (Springer, 1997)
10. J. Taylor, An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements (University Science Books, 1997)
11. G. Cowan, Statistical Data Analysis (Oxford Science Publications 1998)

2.3.3 Aims of the material

The goal of this material is to familiarize the students with the following aspects of error analysis:

- The meaning of sigma
- Combining errors
- Combining results from different experiments
- Using the error matrix

While not all of the mentioned items are covered by the specific scenario, the students will inevitably encounter them in the reference literature. It is a good idea to provide hints for students as to what to pay attention to when reading the books. It is also useful to mention that different sources may use different terminology, such as “uncertainty” versus “error” etc. In general, literature on this subject is abundant, and the teacher may chose to offer a different list.