LEP Energy Working Group Memo
31 October 2003

Final LEP 2 centre-of-mass energy values

Abstract

This memo summarises the results of the LEP 2 energy analysis. For all running above the W-pair threshold a small energy dependent offset is calculated with respect to the energy values distributed in the files announced in December 2002. The errors and correlations on the energies are also given. In addition, errors are presented for lower energy running and for the centre-of-mass energy spread.

A paper is in preparation detailing the analysis. The final numbers in this paper are expected to be identical to those presented here. It is advised that experiments reference the published paper and not this memo.

1 Overview

The analysis of the LEP 2 collision energies ($E_{\rm CM}$) has now been completed and a paper is in preparation. This memo summarises the results of the analysis. Also included is a statement on the $E_{\rm CM}$ energy spread.

Note the following:

- The results presented in this memo are referenced to the energy files which were announced in December 2002, and which may be found in:

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  /afs/cern.ch/phys/lep/lepecal/xx/efilexx.data
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  where 'xx' is 96,97,98,99 or 00.

- In the LEP W mass community it has become common to refer to 'the beam energy' and 'the error on the beam energy' when what is really meant is half the collision energy, $E_{\rm CM}/2$, and the uncertainty on this value. In order to prevent confusion, in sections 2 and 3 this memo adopts the same convention, ie. $E_{\rm b} \equiv 0.5 \times E_{\rm CM}$.

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2 Central values and Errors on $E_{\rm b}$ above the W threshold

The data from the flux loop, the spectrometer and the Q_s vs $V_{\rm RF}$ scans provide three independent tests of the NMR based energy model. The data from each method have been analysed and give consistent results. A combination of these results has been performed to give an offset, $\Delta E_{\rm b}$, by which the true beam energy, $E_{\rm b}$, differs from the value provided by the NMR model, $E_{\rm b}^{\rm NMR}$, used in the energy file production:

$$E_{\rm b} \;=\; E_{\rm b}^{\rm NMR} + \Delta E_{\rm b}.$$

The combination yields the following result:

$$\Delta E_{\rm b}\,[\rm MeV] \;=\; -1.5 \,-\, 0.06 \times (E_{\rm b}^{\rm NMR}\,[\rm GeV] \,-\, 100),$$

which is applicable to all LEP 2 high energy running ($E_{\rm CM}$ nominal $\geq$ 161 GeV) for all experiments.

The uncertainty on $E_{\rm b}$ is made up from the error on the NMR part of the model, together with those errors on the other model components, such as those associated with the quadrupole effects and the RF sawtooth. These vary with energy and with year and so a separate assignment has been made for each of the running points of LEP 2. The total errors are shown in table 1, together with the values of $\Delta E_{\rm b}$, at each energy point. In this table the '205 GeV' and '207 GeV' points of 2000 refer to data taken below and above 205.5 GeV respectively. The 2000 errors do not apply to the small fraction of data taken *during* a mini-ramp, for which no energies have been calculated. The significant increase

Year	1996		1997	1998	1999				2000	
E_{CM} nominal [GeV]	161	172	183	189	192	196	200	202	205	207
E_{b} offset (ΔE_{b}) [MeV]	-0.4	-0.7	-1.0	-1.2	-1.3	-1.4	-1.5	-1.6	-1.6	-1.7
Error on E_{b} [Mev]	12.7	13.7	10.2	10.8	10.8	11.6	11.8	11.9	18.5	20.8

Table 1: Offsets in E_{b} referenced to the NMR model, and total errors on E_{b} for the LEP 2 energy points. (Note that the offsets have been evaluated at the luminosity weighted energies calculated by the model, rather than the nominal E_{CM} values displayed.)

in uncertainty for 2000 is associated with the so-called 'Bending Field Spreading': the strategy unique to that year whereby the corrector magnets were powered in a coherent manner so as to boost the beam energy.

The correlation matrix for these uncertainties is given in table 2. The errors can be assumed to be identical and fully correlated between experiments.

E_{CM} nom [GeV]	161	172	183	189	192	196	200	202	205	207
161	1.00	1.00	0.58	0.57	0.58	0.59	0.59	0.60	0.39	0.35
172	1.00	1.00	0.60	0.59	0.59	0.60	0.60	0.61	0.40	0.36
183	0.58	0.60	1.00	0.94	0.95	0.95	0.95	0.94	0.57	0.51
189	0.57	0.59	0.94	1.00	0.94	0.94	0.94	0.93	0.57	0.50
192	0.58	0.59	0.95	0.94	1.00	1.00	1.00	0.99	0.58	0.52
196	0.59	0.60	0.95	0.94	1.00	1.00	1.00	0.99	0.58	0.52
200	0.59	0.60	0.95	0.94	1.00	1.00	1.00	1.00	0.59	0.52
202	0.60	0.61	0.94	0.93	0.99	0.99	1.00	1.00	0.59	0.53
205	0.39	0.40	0.57	0.57	0.58	0.58	0.59	0.59	1.00	0.99
207	0.35	0.36	0.51	0.50	0.52	0.52	0.52	0.53	0.99	1.00

Table 2: Correlation matrix for errors on E_{b} at all nominal energy points.

3 Uncertainty for Z Runs and Lower Energy Data

The uncertainty on E_{b} for the Z running in each year is estimated to be 5 MeV; that for the 130–136 GeV running in 1997 is 10 MeV. No adjustment is required to any of the values found in the energy files for these data.

4 Centre-of-mass Energy Spread

The instantaneous values of the fractional beam energy spreads are as given in the energy files. The corresponding values for the centre-of-mass energy spreads are $\sqrt{2}$ larger. The relative error on the centre-of-mass energy spread is a fully correlated 5% for 1996-1999, and 10% for 2000.