Energy calibration requirements for 2000

The LEP energy calibration group has considered what machine measurements are necessary in the year 2000 in order to ensure an acceptable beam energy uncertainty for the W mass measurements.

1 Choice of optics

The 101/45 optics commissioned in 1999 was a great success, giving high polarisation levels, allowing the beam to be ramped to physics energies, and being similar to physics optics. We propose to adopt this optics for all measurements in 2000. In 2000 this optics could be re-commissioned rapidly, in a single 8 hour shift.

We note that operation with the 60/60 optics would be necessary for searching for polarisation above 60 GeV with high Q_s or making measurements with minimal uncertainty from tide or ring distortion corrections. These are however not part of our baseline proposal.

2 k-modulation

16 hours would be needed to take a useful set of k-modulation data. This would be done with two beams, and two bunches per beam.

3 NMR extrapolation procedure

A combined analysis of 1997-1999 polarisation data shows excellent stability of the NMR calibration between years (better than 5×10^{-5}). Therefore it is not necessary to request polarisation measurements specifically for this method, on the assumption that those data accumulated for the spectrometer will be sufficient to cross-check the NMR calibration. The structure of the model residuals against energy (the 'banana') shows similar reproducibility, and therefore further very long 4 and 5 point fills are not required. It is suggested, however, that any polarisations which are made for the spectrometer should explore the regions *between* the usual 41.2, 44.8. 50.0, 55.3 & 60.6 GeV points.

4 Spectrometer measurements

In 1999, after the commissioning of the BPM electronics, seven useful polarisation fills were recorded. These included six multipoint fills (19 points in total with 13 energy intervals), necessary for cross-checking systematics, and three successful ramps to high energy, necessary for measuring the energy scale in the physics regime. It is hoped that a similar number of multi-point measurements will be sufficient in 2000, but more ramps to high energy are certainly necessary. This assumes an improvement in procedure, with an online measurement of the bend angle, and care taken to adjust the conditions at each energy point to minimise systematics. Rapid analysis will ensure the quality of the data.

- 6 two-point fills with 41 + x, where x will not always be the same energy. Each fill will conclude with ramp to high energy. Assume 12 hours on average per fill.
- 2 three point fills, scheduled later in the run when polarisation is well established, with ramp to high energy. Assume 16 hours per fill.

In addition it is noted that increased statistics on the spectrometer measurements at high energy can be obtained *without* polarisation measurements. A short fill on physics optics with a bend angle measurement at low energy, and then ramp to high energy and similar measurement, in principle calibrates the physics energy scale, as the NMR model can be used to normalise the measurement at low energy. Such measurements would only take 3-4 hours, and could be included in weeks where no polarisation was scheduled. These fills could be also used for important systematic checks, for instance the two-beam measurement, necessary for checking the RF model.

Clearly the high energy point chosen for the final ramp need not be at year 2000 physics energy (anywhere within $5 - 10$ GeV of this would be sufficient), and so the proposed measurements can take advantage of periods with RF problems. Varying the chosen energy point from fill to fill, or taking several points within a fill, might provide interesting data.

5 Energy boost from horizontal correctors

The approved scheme to increase the LEP energy through redistributing the dipole energy in the correctors will have to be accounted for in the energy model. This can in principle be done with the spectrometer, by measuring the change in bend angle when these correctors are turned on. A few hours should be set aside for this measurement.

6 $\mathrm{Q_s}$ vs $\mathrm{V_{RF}}$ method

The $\mathrm{Q_s}$ based energy calibration method requires machine time in 2000 both to make the measurement itself, and to reduce associated systematic errors. The mininum requirement would be as follows:

- 2 standard measurements, involving 3 low energy points and then 2 or 3 high energy points. These would require 8 hours each.
- A measurement involving several energies between 40 and 65 GeV, and several high energy points, necessary to fix the inverse bending radius, an important uncertainty in the analysis. This would take maybe 10 hours.

An additional standard measurement with fewer points would be rather quick ($\sim$ 4 hours) and be very worthwhile.

7 Flux loop measurements

18 flux loop cycles were performed in both 1998 and 1999, most done at the end of polarisation fills, or when physics was not possible. These data have been used to set the uncertainty on the NMR extrapolation. It is very important that a significant number of cycles (~ 10 ?) are taken in 2000 in order to monitor the stability of this comparison.

8 Summary

The above requests, and their estimated demands on machine time, are here summarised:

- **Optics commissioning** – 8 hours.
- **k modulation** – 16 hours.
- **Spectrometer polarisation measurements** – 6×12 hours + 2×16 hours.
- **Spectrometer measurements without polarisation** – 5×4 hours with physics optics and solenoids on.
- **Horizontal corrector energy boost measurement** – 3 hours.
- Q_s vs V_{RF} **measurements** – 2×8 hours, 1×4 hours and 1×10 hours.
- **Flux loop measurements** – cycles to be taken throughout year when no physics is possible.

In total this amounts to 181 hours, or 7.5 days. It is hoped that as in 1999, most of these measurements can be performed when no high energy physics operation is possible.

Guy Wilkinson, 10 December 1999.