Minutes of the 147th Energy Calibration Meeting held on 16 January 1998

1 NMR/flux-loop comparison

Joerg Wenninger showed the latest comparison of NMR, flux-loop (FL) and polarisation data.

For the very first look at NMR vs. polarisation in previous meetings, the relationship was assumed to be ("naive" normalisation):

$$E_{pol} = C \times B_{NMR}^{P-2}$$

More recent fits by Guy Wilkinson and Peter Renton assume

$$E_{pol} = A \times B_{NMR} + D$$

which can be evaluated for any fills with two or more energy points. This is called "line" normalisation in Joerg's presentation.

The residual deviations from either of these fits can be expressed in terms of the parameters describing the lines.

The NMR/FL comparison also uses a "line" normalisation, with the additional feature that the B field of the flux loop at minimum excitation current, B_0 is not precisely known. It is in the region of 80 Gauss. Joerg fits

$$B_{NMR} = \alpha B_{FL} + \delta$$

and the unknown B_0 is absorbed into δ.

The slopes of the NMR/pol fit and the NMR/FL fits are expected to be strongly correlated from octant-to-octant and probe-to-probe. They should both reflect how the field at a particular point in a magnet compares to the total integrated bending field. This comparison has now been made, with some care to use only good quality flux loop and pol data. Unfortunately, there are no good flux loop measurements within 10 days of a polarisation fill. A good correlation is indeed seen. The error bars are the RMS of the slopes over all the fills used, and each point corresponds to one NMR probe. The RMS spread corresponds to a 2×10^{-4} relative error.

Comparing the slopes fitted in the restricted region 40–55 GeV, one expects the slopes to be the same if both polarisation and fluxloop are a good measure of the total bending field. The average ratio of local slopes is 0.98 ± 0.04, consistent with 1.

To test the extrapolation to high energy, the NMR's are normalised to the flux loop in the 40–55 GeV region. The NMR's can then be used to predict the flux-loop B field at high energy, and this prediction can be compared with the measured flux-loop field. A plot is shown with this exercise for fill 4000. There is a spread of deviations of magnetic field over the 16 NMR's.

In the following figures, the mean and RMS of this deviation is plotted for each flux-loop measurement (i.e. the mean NMR deviation and the RMS over the working NMR's). The different symbols indicate the different fills, and the shift in B field has been converted to an equivalent shift in MeV. The shifts are in the range –10 to +20 MeV, with an RMS of about 40 MeV. These shifts are not related to missing octants in the flux loop. There seems to be some time dependence of the shifts – two flux loops a few hours apart show exactly the same behaviour. There are also some systematic features of the flux loop measured field related to the steps between measurements.

In summary, if the flux loop gave an exact measurement of the change in total bending field between the 40-55 GeV region and the physics energy, then the bias from using the NMR's would be –10 to +20 MeV (the range reflects different fills) with an RMS of 40 MeV (where this is the RMS over working NMR's). However, we do not have enough information to know if this bias is coming from the NMR's or from the flux loop, so at this stage we will not make a correction based on the flux loop, but will use this information in assessing the systematic error.

2 NMR calibration and extrapolation uncertainty

Pete Renton (not present) and Guy Wilkinson have continued to study the scatter of NMR's and the spread of extrapolated energies, comparing the NMR's with the polarisation measurements.

Peter finds he needs to add an uncertainty of about 2MeV to the energy measured by an NMR to have a reasonable χ^2 for fits to the NMR-polarisation data. This scatter is evaluated by looking at the value from one NMR compared to the average of the other 15 NMR's. It was suggested to time average the NMR's over a longer interval to reduce the noise (given that the polarisation data at the same energy point are all averaged).

A two parameter fit is made for each NMR to:

$$E_{pol} = a + bB_{NMR}$$

Peter only uses the fills with four polarisation measurements so as to be able to check the χ^2. Guy uses all fills with two or more points. Peter and Guy's results are consistent.

In Peter's analysis, fill 4242 gives an average NMR value of 91567 MeV for the energy at 91.5, and using fill 4279 gives a mean value of 91555 MeV. In each case the rms scatter is about 40 MeV, corresponding to an extrapolation error of 12 MeV for the 11 working probes.

For Guy, using all fills together, the mean is 91557 MeV (corresponding to a BOF energy in this case) and RMS of 41 MeV, leading to an error of 10 MeV for 16 probes.

Plotting $E_{pol} - E_{NMR}$ as a function of beam energy, the residuals for the two fills with four energies measured have a significant banana shape when averaging all NMR's together.

Peter also checked the effect of forcing the fit to go through zero for each NMR. The χ^2 of the fits is worse, and the scatter of extrapolated energies increases to about 60 MeV.

3 Update of NMR checks from Nading Qi

After the meeting, Nading Qi provided the fill numbers whose energies are away from the average:

- fill 3932, 3936, 3938 and 3939 are in the left(lower energy region)
- fill 4143 is in the right(higher energy region).

Updated plots of NMR behaviour vs. time are also included in the minutes. These plots zoom in on the interesting energy region.

4 Summary of inputs to error calculation

In the following table, the available tests of extrapolation error are listed, with the measured bias and rms. The third column gives a not-even-preliminary indication of the size of resulting extrapolation uncertainty. These "interpretations" have NOT been discussed within the group, but are offered as a basis for future iteration.

Source	Size [MeV]	Resulting Error [MeV]
Extrapolation measured with flux loop		
(a) Range over fills	– 10 to +20	15
(b) RMS over working NMR's (up to 16 NMR's)	± 30 to 40	10
Extrapolations from NMR–polarisation only		
(c) RMS for two parameter fit (11 or 16 NMR's)	40	10
(d) RMS for one parameter fit	60	–
(e) 3.5 % of field not measured by flux-loop with eg. 1 % uncertainty over 55 to 90 GeV (i.e. 1% of 3.5% of 35 GeV)	12	12
Total extrapolation error	–	24

This assumes item (d) is a cross check, rather than giving additional information. It also shows that discussions of which errors are double counted and how to interpret the NMR/flux-loop bias are critical for assigning the error. The consistency of the (local) slopes for NMR/FL and NMR/pol are the main validity test of the method.

Also, the 1% uncertainty on the fringe fields and injection dipoles quoted here is an assumption and must be justified from existing measurements at this stage (eg. original work on flux-loop effective length and calibration curves of the "nice steel" injection dipoles). It will be investigated more carefully in future years.

Additional uncertainties (time variation in a fill, fill to fill normalisation, RF corrections etc.) should be under control at the 5 to 10 MeV level, by analogy with the 1996 analysis.

5 Time scales

After discussion it was agreed to aim to produce energy files by mid February, using the NMR two parameter fits to the polarisation data for the central values. Missing ingredients are treatment of the optics difference, possible horizontal corrector information and the RF corrections for the IP's. However, these should be in hand for producing (preliminary) files on this timescale.

The present information should be sufficient to estimate a reasonable preliminary error for the spring conferences.

6 Next Meeting

The next meeting will be on Friday 6 February at 14:00 in the Pavillon.

Pippa Wells, 19 January 1997