DETERMINATION OF NON-LINEAR COMPONENTS IN CORPUSCULAR-OPTICAL ELEMENTS BY INCREMENTAL HALL-PROBE MEASUREMENT TAKING INTO ACCOUNT SYSTEMATIC ERRORS DUE TO LONGITUDINAL FIELD COMPONENTS AND SAG OF THE PROBE ARM

V. Jung

Institut für Experimentelle Kernphysik, Kernforschungszentrum Karlsruhe, Karlsruhe, Germany

ABSTRACT

For determination of non-linear field components along the beam axis of a quadrupole field an incremental Hall-probe measurement is proposed. The small sensitive length of a Hall-probe allows to measure the detailed field distribution needed for high precision beam calculations. Systematic errors due to longitudinal field components and sag of the probe arm can be eliminated.

Beam calculations on the basis of a sharp cut-off-model for magnetic lenses have a result different from that of a calculation incorporating the real field distribution. It is important especially to take into account the distribution of non-linear field fractions along the beam center line[1].

Because of the variation of the axial distance of a particle passing a lens[2] (e. g. in the case: focal length equal length of the lens) and because of the high power n-1 in the increase of non-linear field fractions with the multipole order $p = 2n$ there will be different deflection errors for the same integral value of non-linear field fractions integrated along the beam centerline, but for different distributions of non-linear fractions along this axis.

The deflecting angle of a lens for a particle passing the lens at a certain distance r from the axis shall be α and the deflection error produced by different non-linear field fractions shall be $\Delta\alpha$, NL_n shall be a non-linear field fraction of the order $p = 2n$ which varies along the axis s and is normalized to the field on the aperture circle in the longitudinal central region, r_o is the radius of the aperture circle and g(s) the gradient of the quadrupole field and l its total length. Then the relative deflecting error $\Delta\alpha/\alpha$ is:

$$\frac{\Delta\alpha}{\alpha} = \frac{\sum_{n=3}^{\infty} \int_0^l NL_n(s) \cdot \left(\frac{r(s)}{r_o}\right)^{n-1} \cdot ds}{\int_0^l g(s) \cdot r(s) \cdot ds}$$

As demonstrated in Fig. 1, the measured distribution of non-linear field fractions along the axis in the end field region of a quadrupole depends on the measuring system used.

Rotating coils[3, 4] average the multipole components over a certain longitudinal range, whereas a Hall-plate enables one to measure a short disk type section of the field, which is smaller by one or two orders of magnitude[5].

In order to perform exact beam calculations, needed especially for spectrometer arrangements and energy defining systems[6], an incremental Hall-probe measurement with the transverse field component normal to the Hall-plate and with the probe led on a circle around the field axis is proposed for determination of non-linear field components along the field axis by Fourier analysis of the fluctuation of the field value on circles in planes normal to the field axis[7], as shown in Fig. 2.

The systematic errors caused in the three-dimensional end fields by the plane Hall-effect and sag of the probe arm can be calculated and do not disturb the analysis of the multipole components, respectively[8].

In this way , a more detailed measurement is possible in order to perform a thick lens high order beam calculation.

REFERENCES

1. V. Jung, Nucl. Instr. and Meth. 91 (1971) 195.
2. R. Frosch, SIN Tagung (Brugg/Windisch, Switzerland, 19. Nov. 1971).
3. J. K. Cobb and D. Horrelick, 3rd Intern. Conf. Magnet Technology (Hamburg 1970) F63.
4. K. D. Lohmann, C. Iselin, CERN SI/Note MAE 69-18/Rev. 1(1969).
5. V. Jung, Nucl. Instr. and Meth. 98 (1972) 157.
6. J. Amato et al. LAMPF MP-7-10 (August 1970) "Private Communication".
7. V. Jung, DAS 2 127 044 (25. 5. 1972).
8. V. Jung, Nucl. Instr. and Meth. 101 (1972) 225.

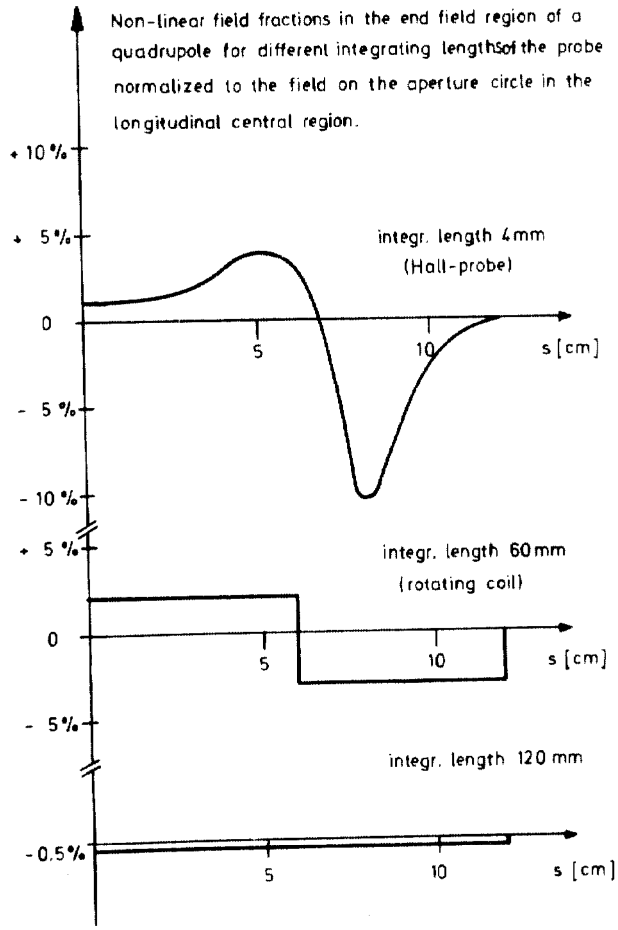
Non-linear field fractions in the end field region of a quadrupole for different integrating lengths of the probe normalized to the field on the aperture circle in the longitudinal central region.
+ 10 %
+ 5 %
0
- 5 %
- 10 %
integr. length 4mm
(Hall-probe)
5
10
s [cm]
+ 5 %
0
- 5 %
integr. length 60mm
(rotating coil)
5
10
s [cm]
integr. length 120 mm
- 0.5 %
5
10
s [cm]

Fig. 1

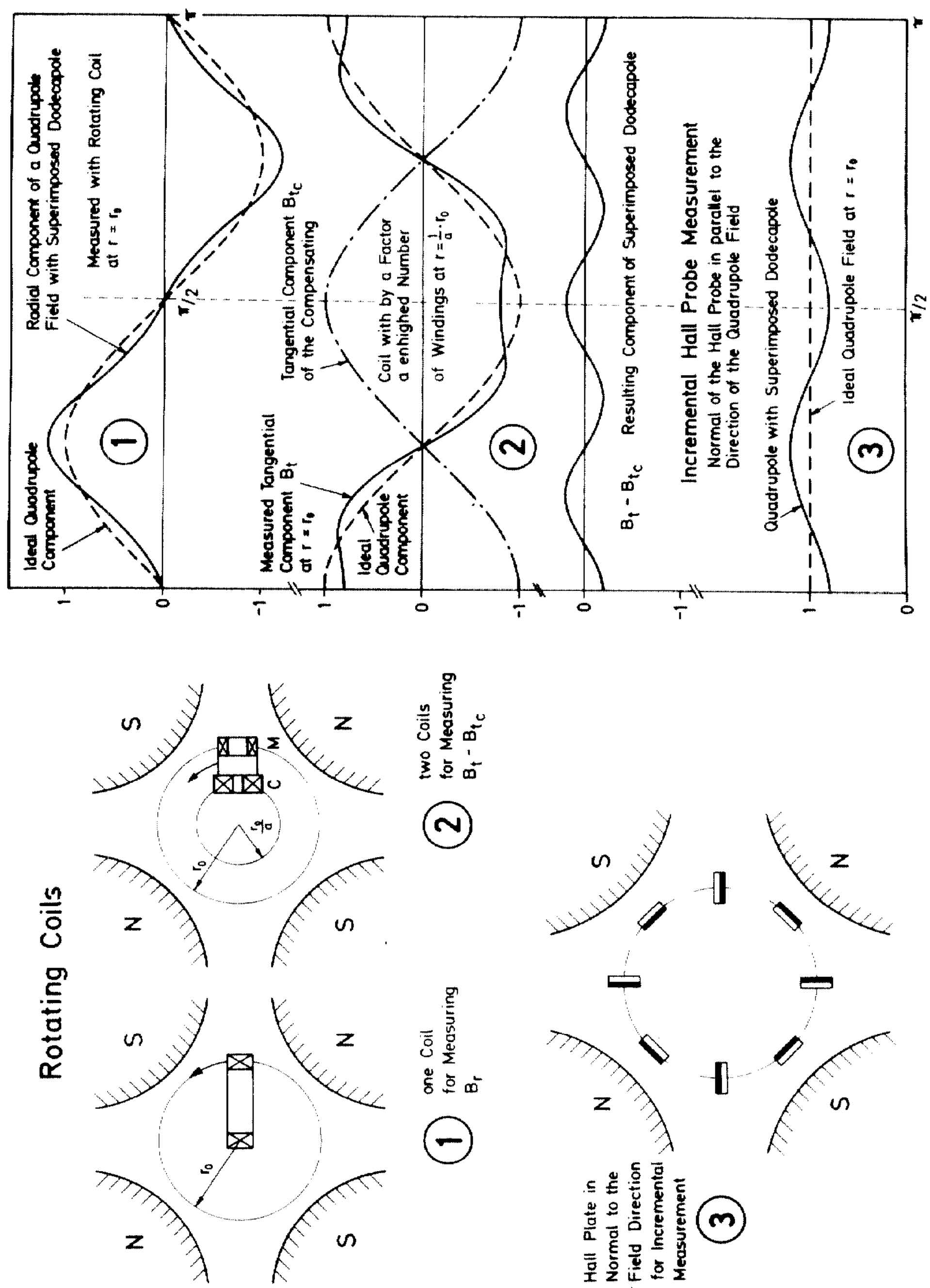

Fig. 2 Comparison of measuring methods for determining non-linear field components in multipole fields