DAΦNE TECHNICAL NOTE

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MULTIPOLAR FIELD EFFECTS ON DAΦNE TRANSFERLINES FOR A $\Delta G/G \leq 10^{-2}$

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Introduction

The effect of magnetic field high order terms on the DAϕNE transferlines has been evaluated in [1] for a $\Delta G/G \leq 2.5 \times 10^{-3}$ in quadrupoles. The specifications for the transferlines have been set to $\Delta G/G \leq 10^{-2}$ in the quad good field region. In this note we check by tracking simulations [2] if this value is acceptable.

1. Gradient error evaluation

The magnetic field in a quadrupole can be expressed by the multipolar expansion

$$B = B_0\rho_0 \sum_{n=1}^{\infty} \frac{k_n}{n\,!} x^n$$

where n indicates the $2(n + 1)$-pole term and $B_0\rho_0$ the magnetic rigidity.

Thus the field error can be easily derived:

$$\frac{\Delta B}{B} = \frac{B - B_1}{B_1} = \sum_{n=2}^{\infty} \frac{k_n}{k_1} \frac{1}{n\,!} x^{n-1}$$

or

$$\frac{\Delta B}{B} = \sum_{n=2}^{\infty} \left(\frac{\Delta B}{B}\right)_n$$

with

$$\left(\frac{\Delta B}{B}\right)_n = \frac{1}{n\,!} \frac{k_n}{k_1} x^{n-1} \qquad (1)$$

We are now able to calculate the quadrupole gradient G

$$G = \frac{\partial B}{\partial x} = B_0 \rho_0 \sum_{n=1}^{\infty} \frac{k_n}{(n-1)!} x^{n-1}$$

and the gradient error:

$$\frac{\Delta G}{G} = \frac{G - G_1}{G_1} = \sum_{n=2}^{\infty} \frac{1}{(n-1)!} \frac{k_n}{k_1} x^{n-1}$$

or using (1)

$$\frac{\Delta G}{G} = \sum_{n=2}^{\infty} n \left(\frac{\Delta B}{B}\right)_n \qquad (2)$$

In a perfectly symmetric quadrupole the only multipolar terms are those caused by the finite dimensions of the poles. The **12-pole** and the **20-pole** components are the most important ones. In real magnets, because the mechanical tolerances other multipolar terms exist. Anyway it is reasonable to think they are negligible compared with the 12 and 20-pole terms. Experimental result [3,4] confirm this consideration and thus in our simulations we assumed the presence of only these two main terms.

From previous magnetic fields calculations and simulations [5] it was possible to decide the relative weight of the terms. Finally using (1) and (2) we calculated the values of the terms k_5 and k_9 in order to have:

$$\Delta G/G = 10^{-2} \qquad @\ x = 3\ cm$$

The x value is representative of the typical good field region dimension of the transferline quadrupoles. The values (normalized to the quadrupolar term) so obtained are:

$$\frac{k_5}{k_1} = -1.91 \times 10^{5}\ m^{-4}$$

$$\frac{k_9}{k_1} = 7.33 \times 10^{15}\ m^{-8}$$

2. Results and conclusions

The tracking simulations have been performed on two parts of the transferline. The 'EOUT' line, from the Accumulator to the Main Rings for the electron beam, and the 'INPO' line, from the Linac to the Accumulator for the positron beam (the nomenclature is the one of [1]).

The EOUT is the longest transferline and it has the largest number of magnets. Anyway the very small emittance (and dimensions) the beam will have inside it, should make the line not very sensitive versus the multipolar terms in the quadrupoles (with the condition the beam passes through the quad along its magnetic axis). This situation has been confirmed by the results of the simulations. Fig. 1 shows that no significant variation on the beam envelope is caused by the multipolar components.

On the contrary, the positron beam inside the INPO line will have a very large emittance. The beam transverse dimensions will be large and the transferline should be more sensitive to the action of the multipolar fields. Several runs have been done with different values of the multipolar components and they showed that no significantly change in the beam envelope and lose particles number along the line are if the gradient error is $\leq 10^{-2}$. Fig. 2 shows this situation for the INPO line.

Remark. In the runs with the gradient error the values of the multipolar terms used in the dipoles magnets are the ones specified in [1].

REFERENCES

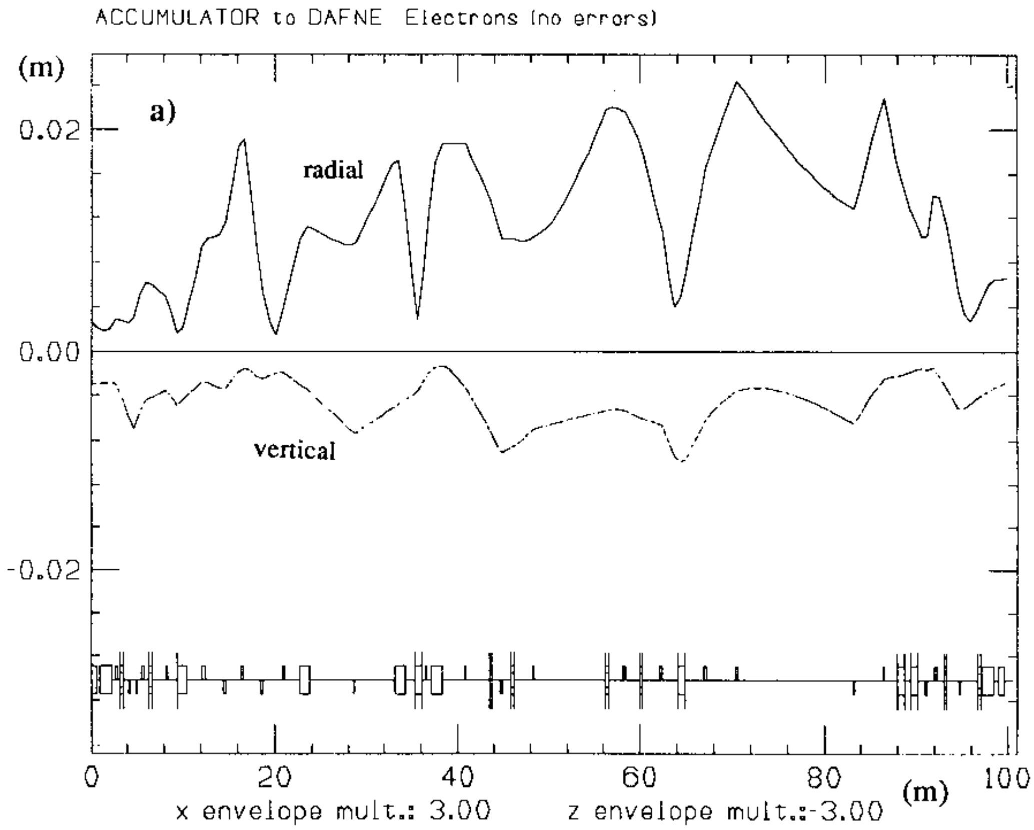
[1] C. Biscari, F. Sannibale *Tolerances and correction scheme in* .... Daϕne Technical Note I-10, June 18, 1992.

[2] F. Sannibale *MULTITRANS Code* Unpublished.

[3] J. Tanabe et al. *Summary of prototype magnetic measurements* LBL Engineering Note AL0312 M6787 December 14, 1988.

[4] PEP Insertion Quads magnetic measurements. *1-2 GeV Synchrotron Radiation Source*. Conceptual Design Report - July 1986. LBL Pub-5172 Rev. Appendix C.

[5] G. Qiao Unpublished work.



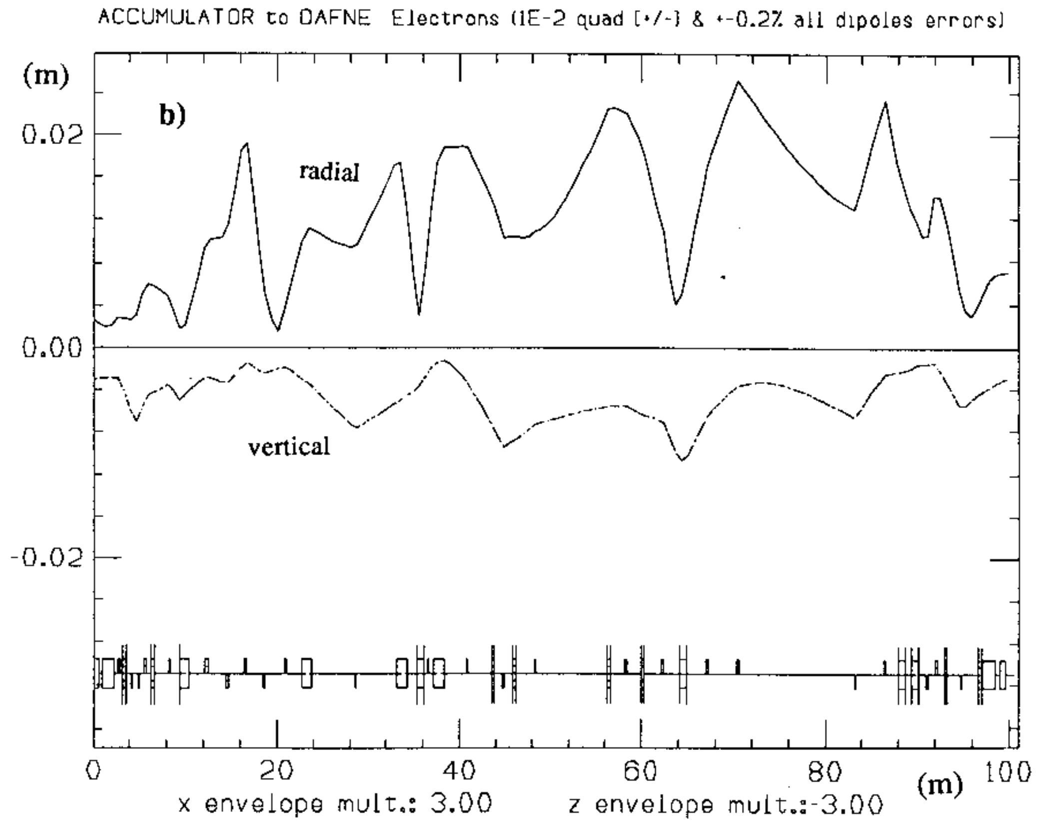


Fig. 1 EOUT transferline: a) without b) with multipole terms.

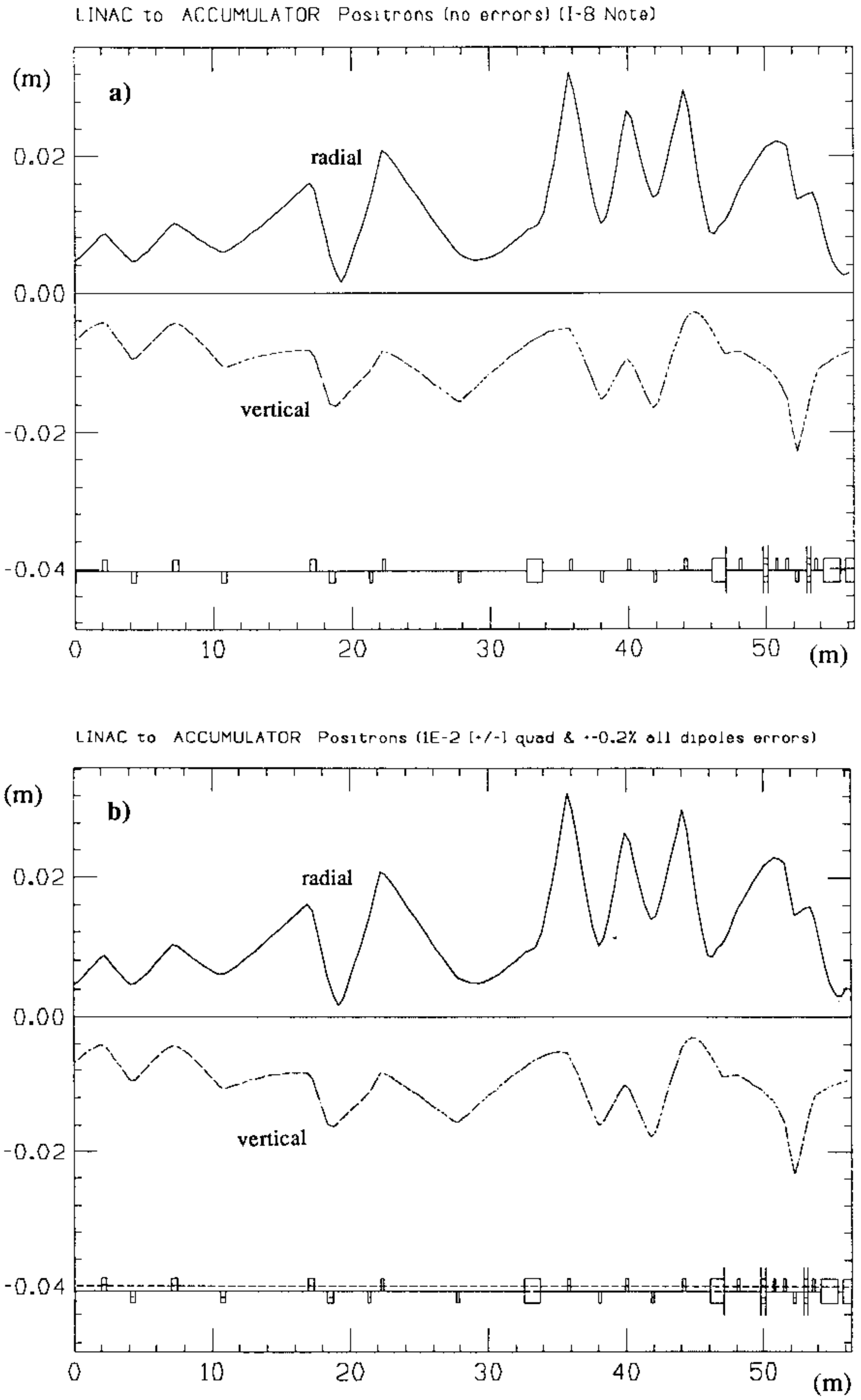


Fig. 2 INPO transferline: a) without b) with multipole terms.