MI-0110

Study of the Long and Short Quadrupoles Strength Match

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June 30, 1994

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In this paper we discuss calculations done to study the effect of mismatch in the strength of the long (100" and 116") quadrupoles to that of the Main Ring 84" quadrupoles. Our analysis shows that a strength of the long quadrupoles should be matched to that of 84" quadrupoles to about 10 units.

I. INTRODUCTION

The Fermilab Main Injector (FMI) will use 128 recycled 84" long quadrupoles from the Main Ring. The FMI will also have newly constructed 100" and 116" quadrupoles of similar design. We are in process of selecting the steel length of the newly constructed quadrupoles. All the focusing and defocusing quadrupoles, irrespective of their length will be powered by one power bus each. Any mismatch in the quadrupole strength will introduce an additional variation in beta function. The long quadrupoles are placed in the zero dispersion regions. Any change in their strength can also effect the dispersion in that region. The dynamical aperture of the FMI depends on the variation in the beta function.

We have assumed that we know the strength of the Main Ring 84" quadrupoles perfectly and the strength variation sigma is 24 units for all the quadrupoles. We have also assumed that we will separate these quadrupole according to their strength as described in MI Note 108 [1].

In this note we have studied the required strength precision for the long quadrupoles using TEAPOT[2]. This precision is required to maximize the dynamical aperture and minimize the variation in Beta function throughout the ring.

*Operated by Universities Research Association under contract with the Department of Energy

. II. Tracking calculations

The study of the required length (strength = gradient*length) precision of the quadrupoles was made by studying the change in the beta function. We are required to minimize the variation in the beta function at injection to control the closed orbit at three local bumps in the lattice and also for a smooth slow extraction of 120 GeV beam.

In order to study the effect of length error, a systematic quadrupole strength of a) +10 units to both 100" and 116" quadrupoles b) +25 units to 100" and +50 units to 116" c) +50 units to both 100" and 116" quadrupoles were added to the long quadrupoles strength as a systematic error. All the other errors described in MI Note 88 [3] were present in the lattice.

Fig. 1,2, and 3 shows the change in beta function, i.e. difference in beta function between before and after the addition of the above systematic strength errors at 8.9 GeV and Fig 4 and 5 at 120 GeV. It is clear from these figures that a systematic strength error introduces additional change in beta function of FMI. A strength error of 10 units in both magnets corresponds to an additional beta function variation of about 0.75%. This is about one fourth of the actual variation due to quadrupole strength variations. In the worst case considered where +50 units of systematic strength was added to both the long magnets, additional beta function variation increases to about 3%. Fig 6,7 and 8 shows the change in dispersion around the ring due to addition of systematic strength in the long quadrupoles. There is a small change in dispersion due to stronger long quadrupoles.

We have also studied the effect of mismatch in the quadrupole strength on the dynamical aperture of the FMI for one seed, Fig 9. There is a 2mm loss of aperture which seems to be independent of the three conditions considered.

. III. Conclusions

If the strength of the long (100" and 116") quadrupoles is matched to existing Main Ring (84") quadrupoles to about 10 Units, we will not introduce significant variation in the FMI beta function and dispersion. This mismatch will not cause a significant loss in the dynamical aperture of the FMI.

At present we donot have good information about the strength of the 84" Main Ring quadrupoles. If we miscalculate the strength of the 84" quadrupole and mismatch in strength between 84" and the long (100" and 116") quadrupoles increases to 20 units, it will not be a serious problem considering that we will know the strength of all the quadrupoles several months before their final placement in the ring.

References

[1] C. S. Mishra," Study of the Main Injector Quadrupole Measurement Precision", MI notes 0108,

[2] L. Schachinger and R. Talman, Particle Accl. 22, 35(1987).

[3] C. S. Mishra and F. A. Harfoush, MI notes 0088.

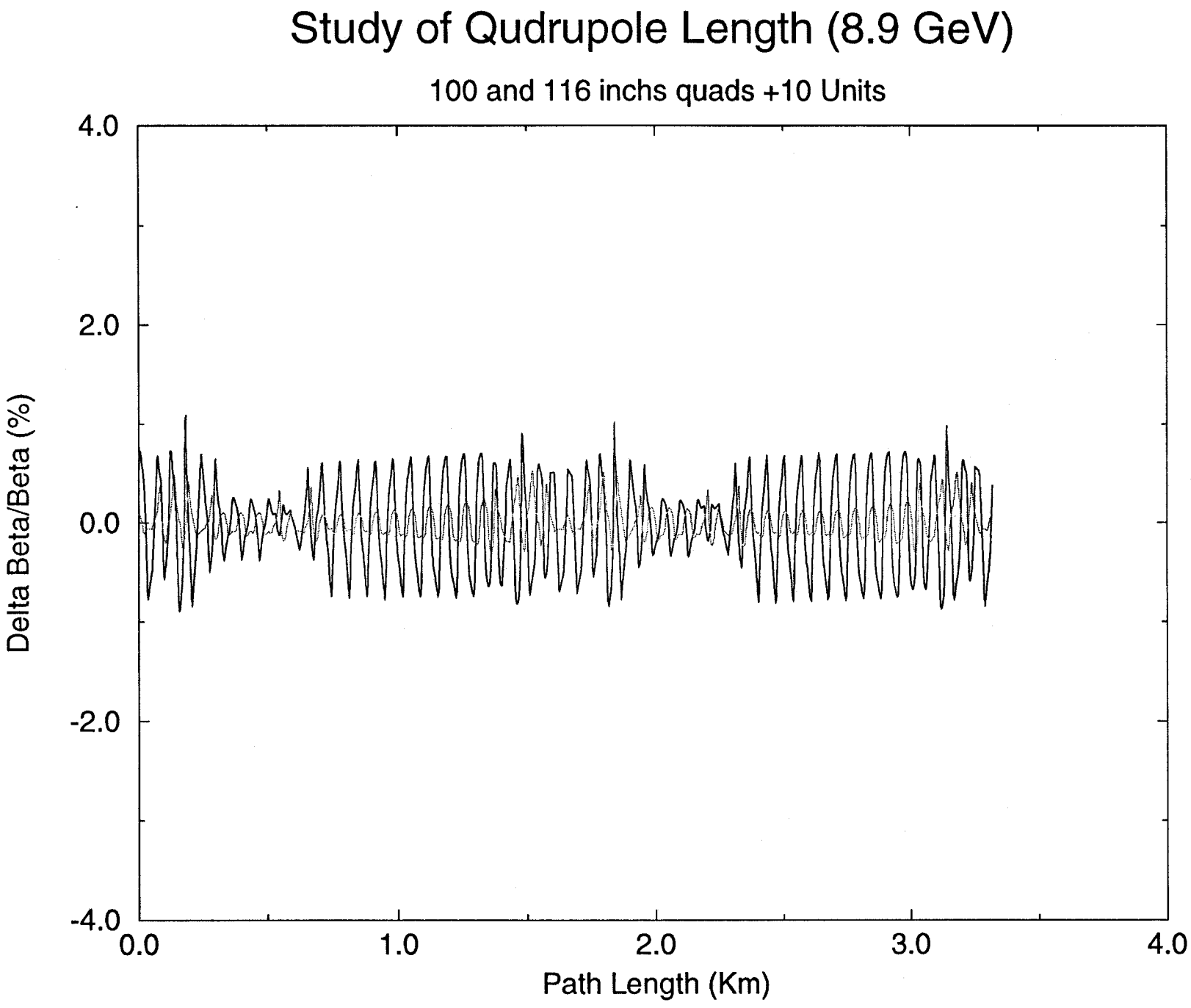
Study of Qudrupole Length (8.9 GeV)
100 and 116 inchs quads +10 Units
4.0
2.0
0.0
-2.0
-4.0
Delta Beta/Beta (%)
0.0
1.0
2.0
3.0
4.0
Path Length (Km)

Fig_1

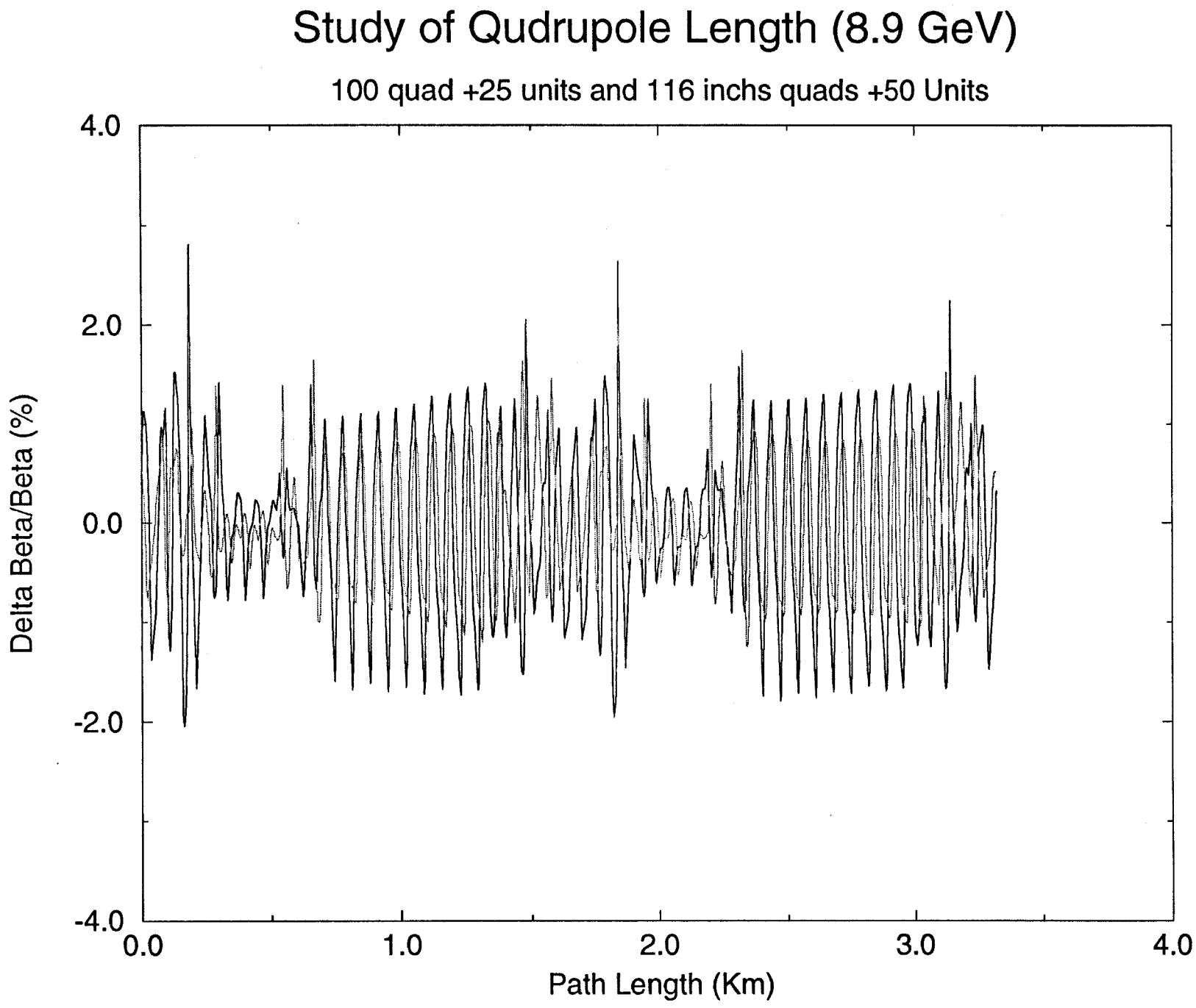
Study of Qudrupole Length (8.9 GeV)
100 quad +25 units and 116 inchs quads +50 Units
4.0
2.0
0.0
-2.0
-4.0
Delta Beta/Beta (%)
0.0
1.0
2.0
3.0
4.0
Path Length (Km)

Fig. 2

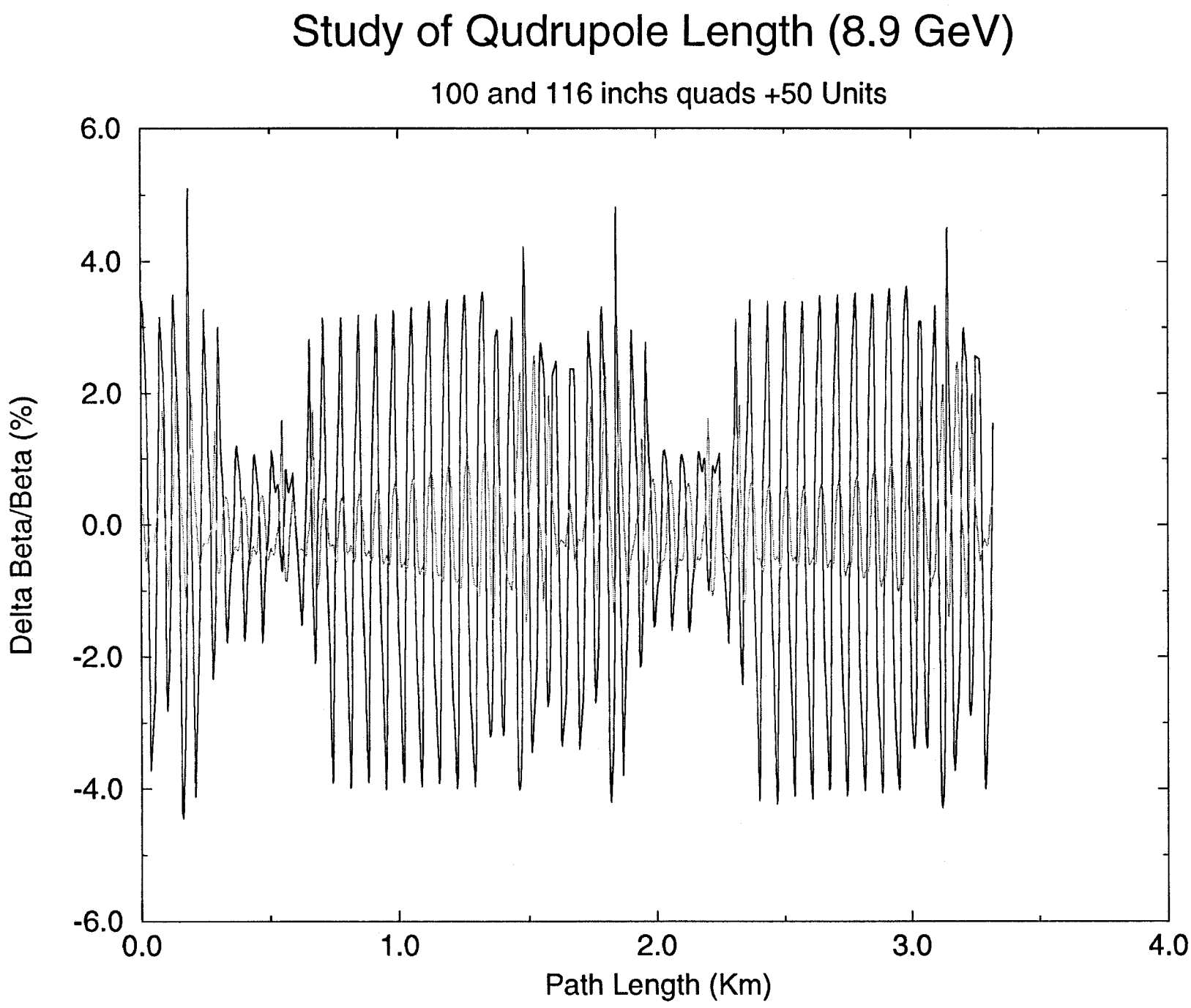
Study of Qudrupole Length (8.9 GeV)
100 and 116 inchs quads +50 Units
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
Delta Beta/Beta (%)
0.0
1.0
2.0
3.0
4.0
Path Length (Km)

Fig. 3

Study of Qudrupole Length (120 GeV)

100 and 116 inchs quads +10 Units

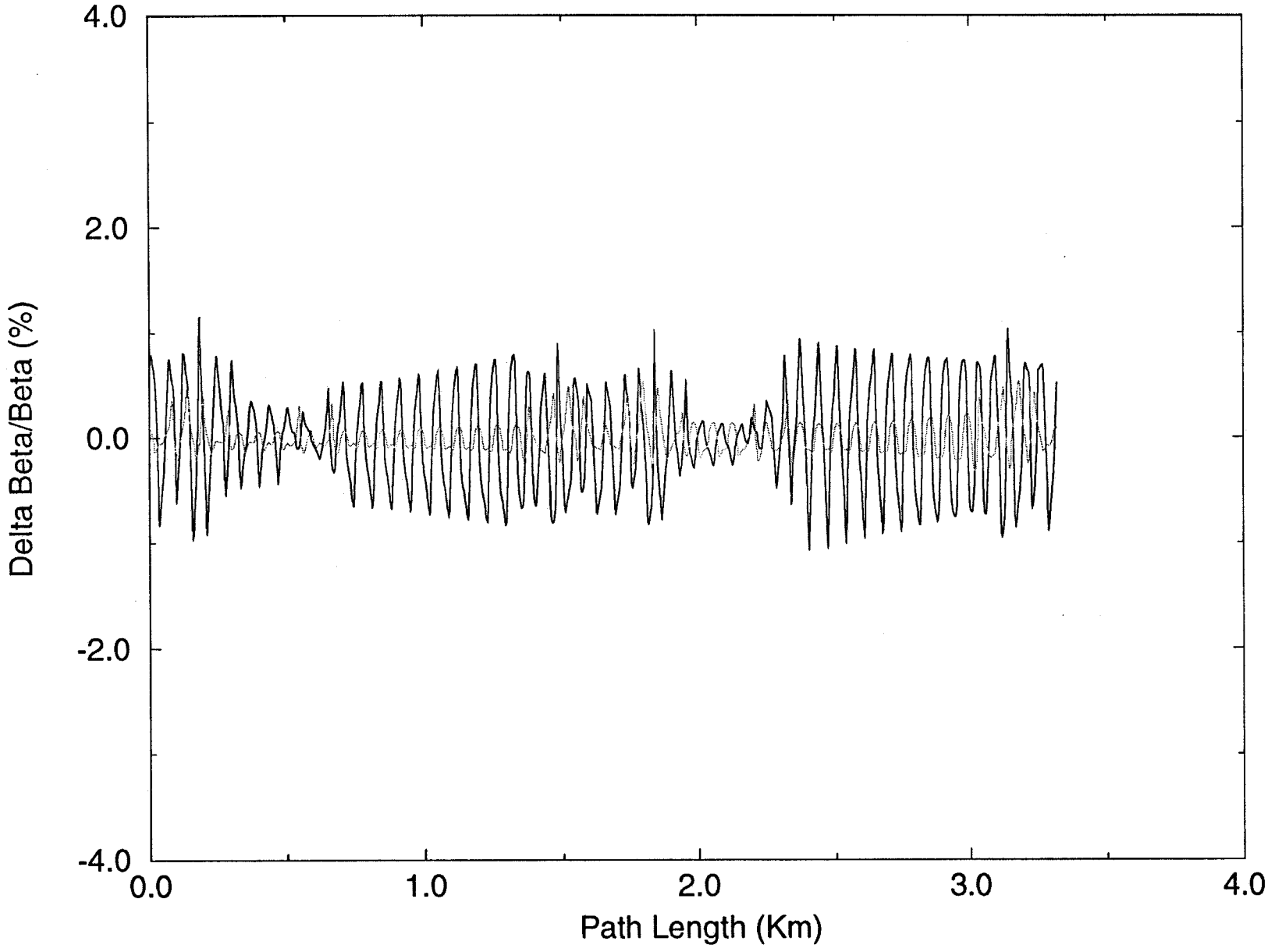

Fig. 4

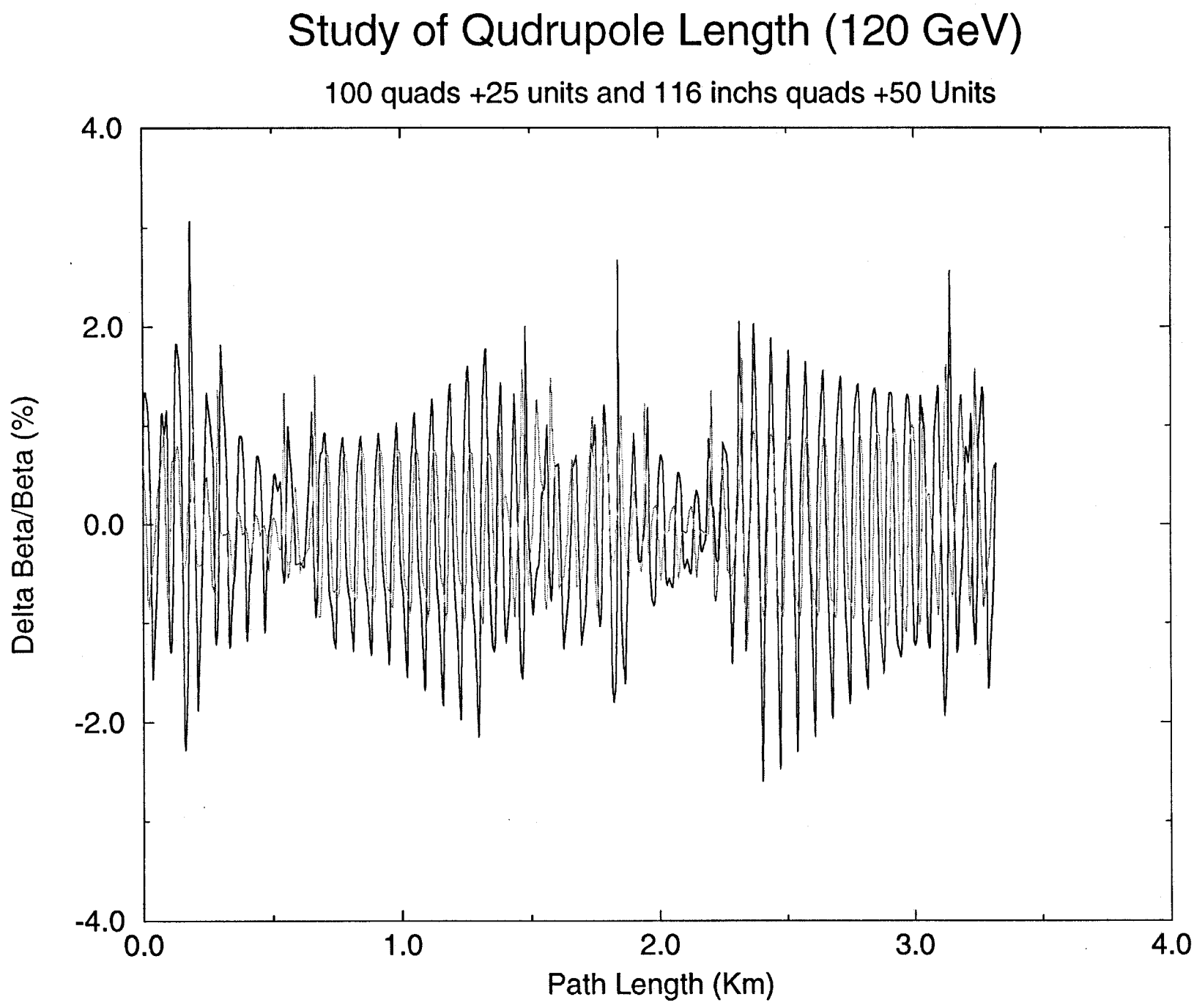
Study of Qudrupole Length (120 GeV)
100 quads +25 units and 116 inchs quads +50 Units
4.0
2.0
0.0
-2.0
-4.0
Delta Beta/Beta (%)
0.0
1.0
2.0
3.0
4.0
Path Length (Km)

Fig. 5

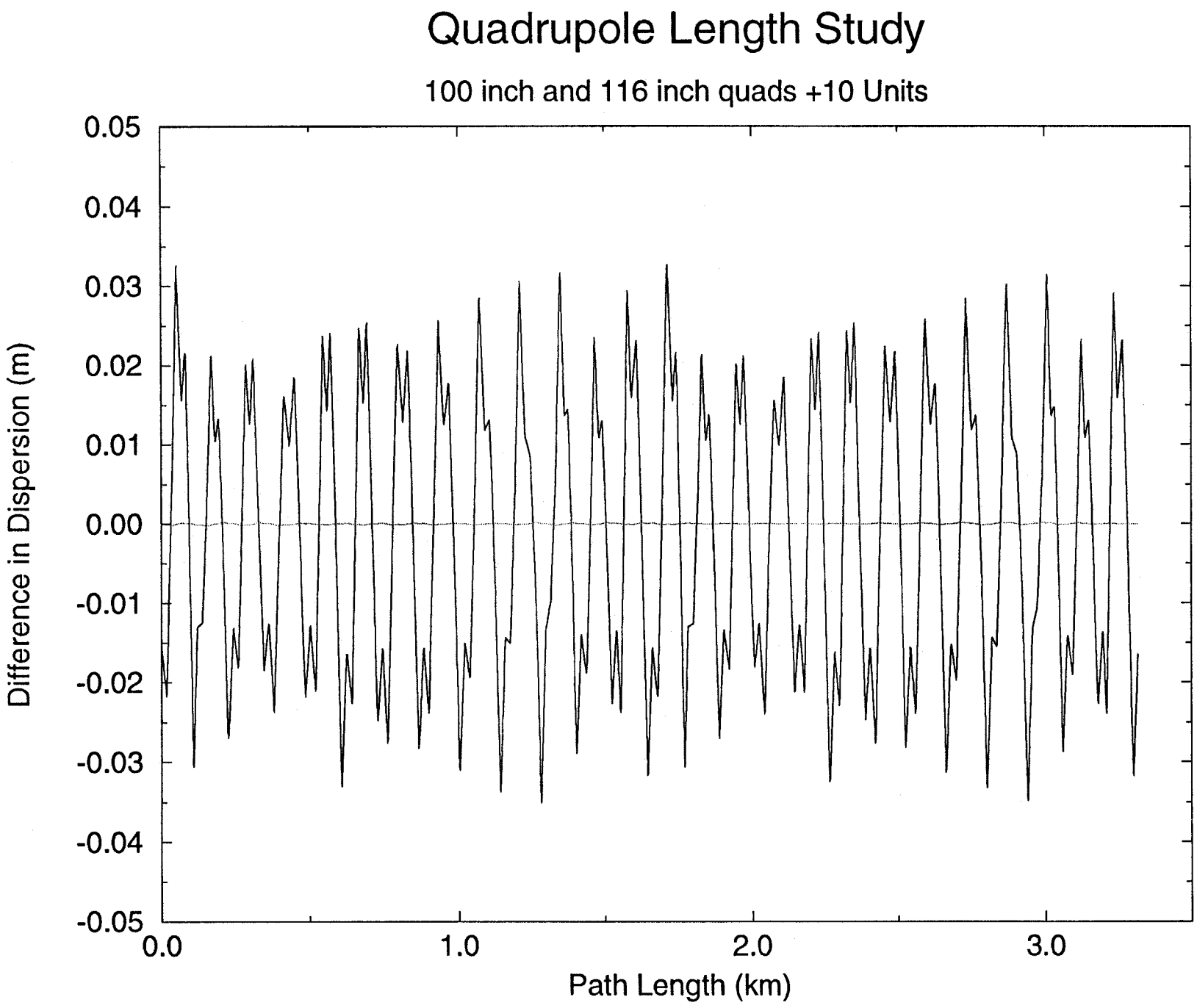
Quadrupole Length Study
100 inch and 116 inch quads +10 Units
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
Difference in Dispersion (m)
0.0
1.0
2.0
3.0
Path Length (km)

Fig. 6

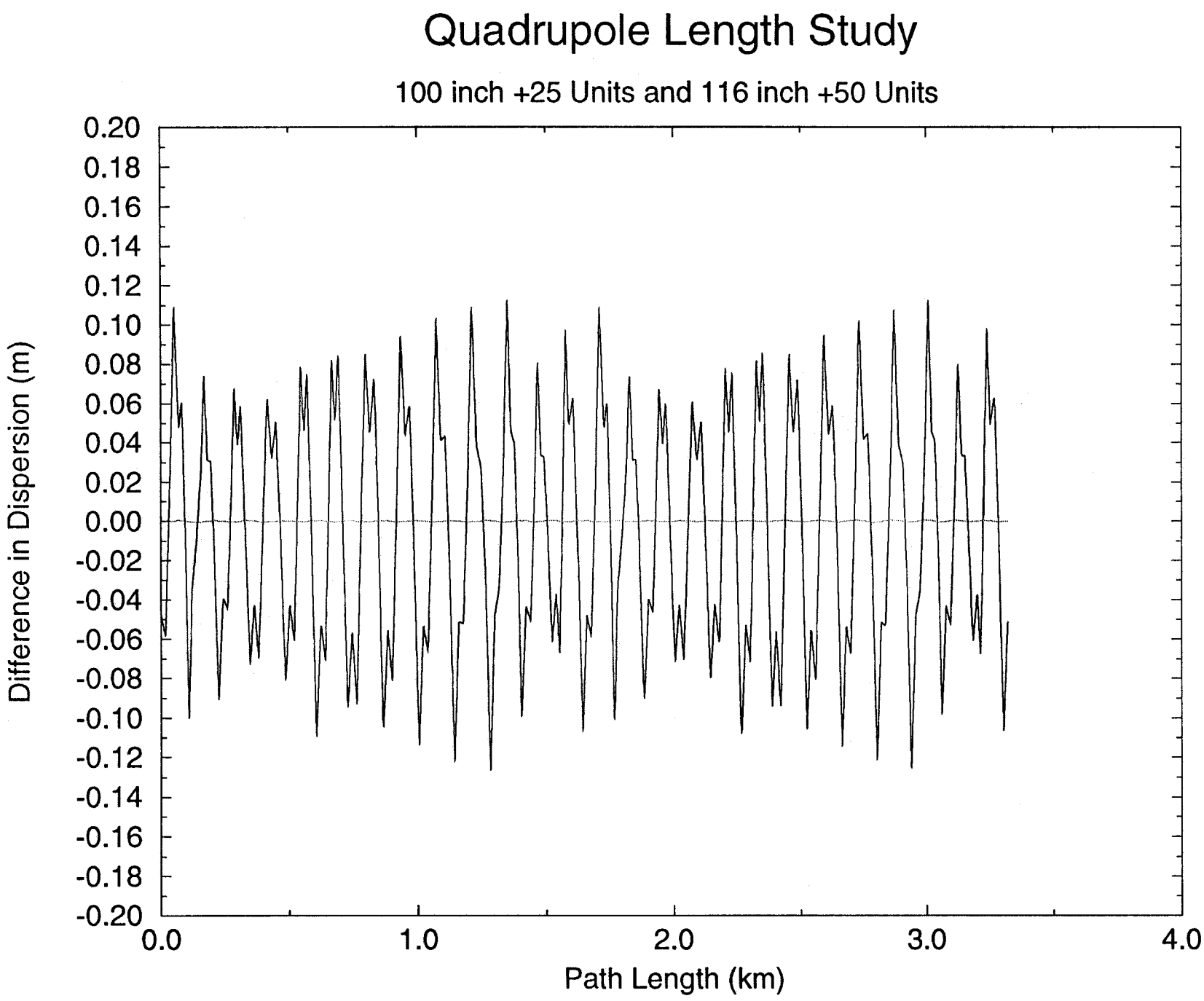
Quadrupole Length Study
100 inch +25 Units and 116 inch +50 Units
Difference in Dispersion (m)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
0.0
1.0
2.0
3.0
4.0
Path Length (km)

Fig. 7

Quadrupole Length Study

100 inch and 116 inch quads +50 Units

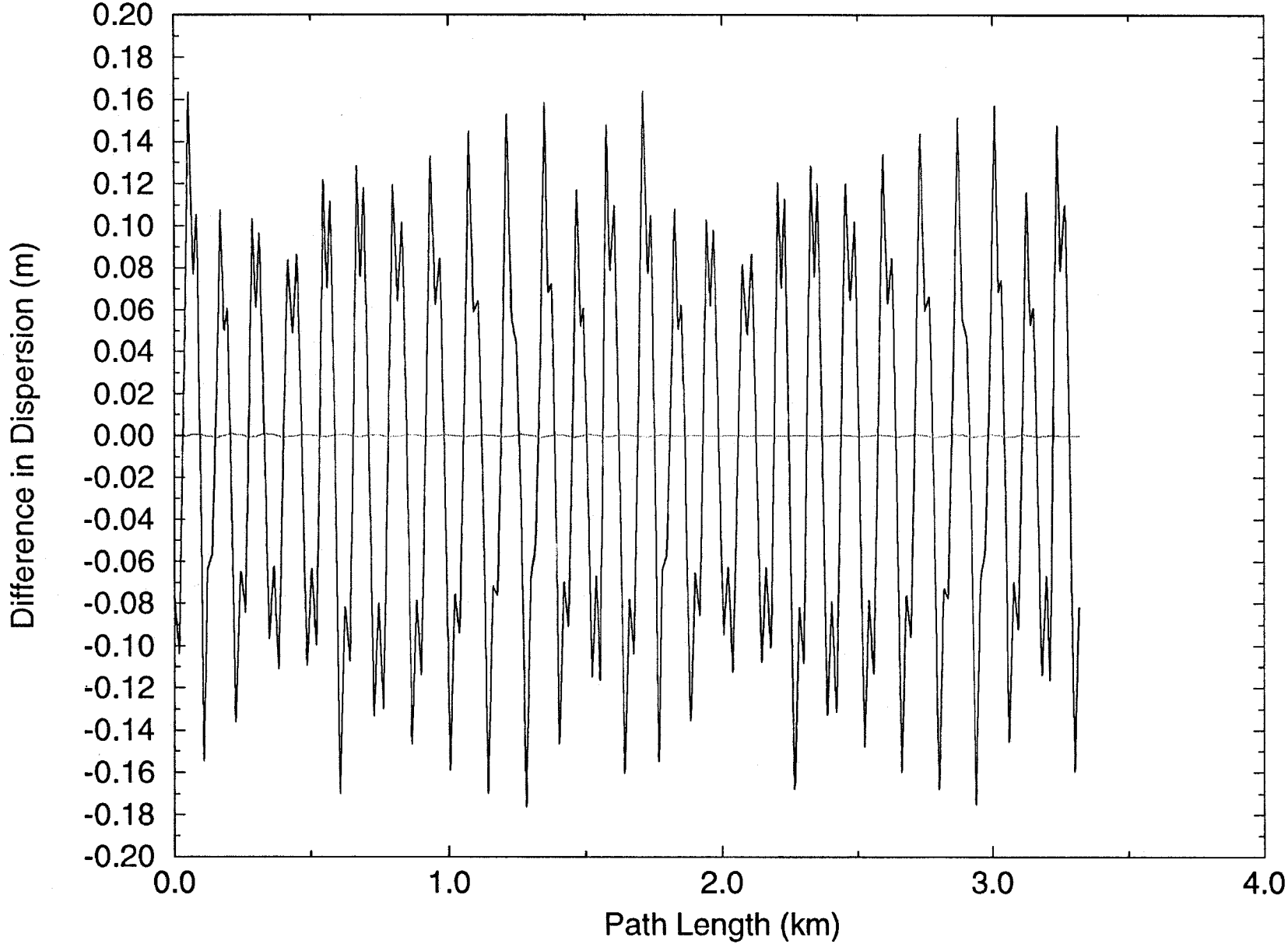

Fig. 8

Study of the effect of quadrupole length

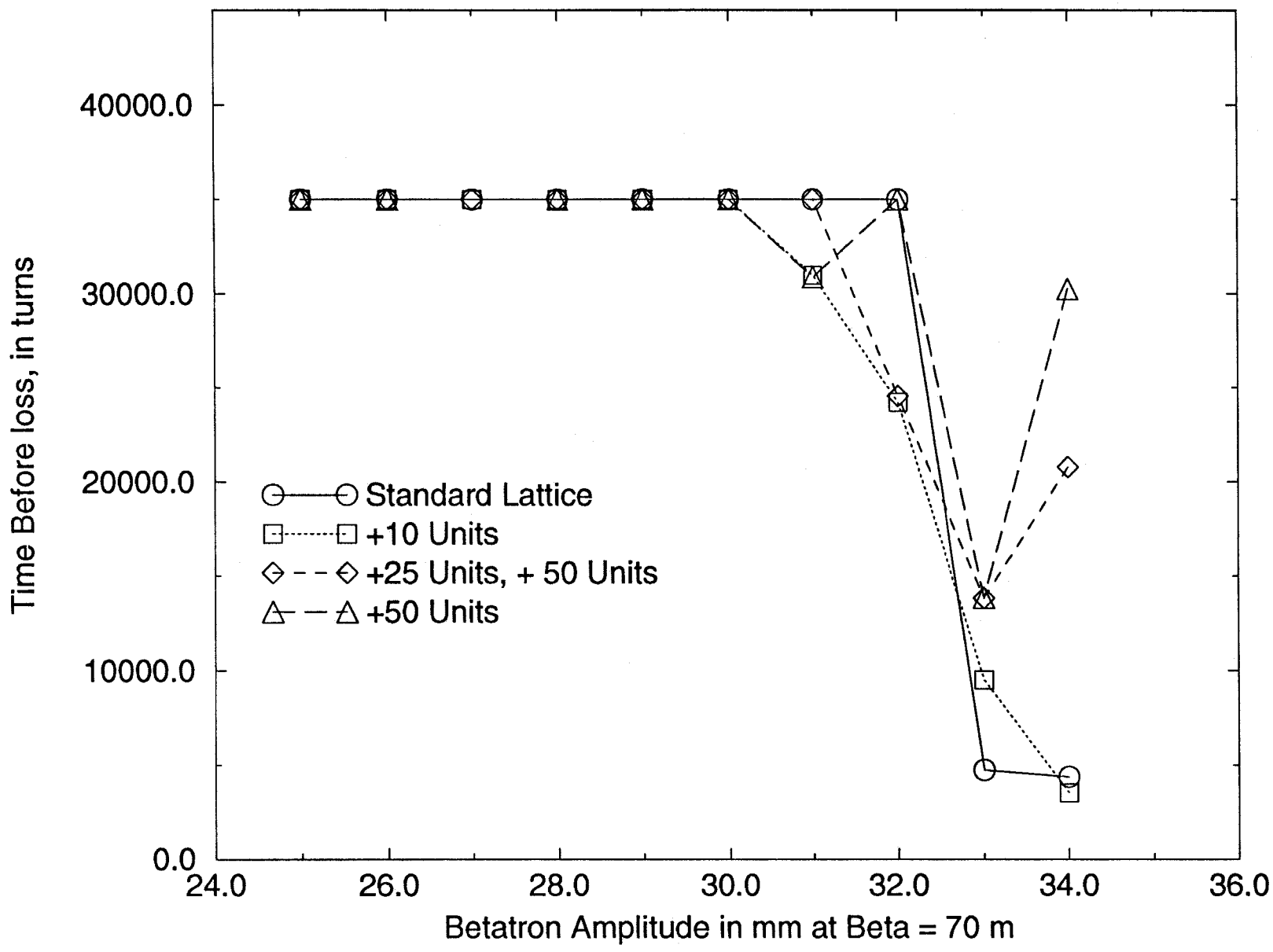

Fig. 9