R.P.NOTE 114

SUMMARY OF BADGE SPIKING AT FERMILAB FOR 1993

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Elaine Marshall

INTRODUCTION

For some time, Fermilab has conducted a program of testing film badges supplied by the vendor. This program, the Personnel Dosimetry Testing Program, or informally the badge spiking program, was continued when the site moved from film to thermoluminescent dosimeters (TLDs) and track-etch foils (CR-39). The Personnel Dosimetry Testing Program provides a method for an in-house evaluation of the dosimetry results reported by the contracted vendor. For 1993, the contracted vendor was Siemens Gammasonics, Inc. Studies to better understand dosimetry response to external conditions, such as high temperature, high humidity, and laundote 123.re also included in this program. This program serves as part of Fermilab's quality assurance program.

A group of eighteen (18) badges is used for the spiking each quarter. As each badge has been assigned data similar to that provided for other permanently badged employees (name, date of birth, identification number, and Social Security Number), the vendor is unaware of which badges are part of the test group.

For each quarter, a test was designed to evaluate the response to gammas, betas, neutrons, or some combination of the above. In addition to the four quarterly tests, one additional irradiation was conducted to further investigate badge response to neutrons.

QUALITATIVE COMPARISON

One of the easiest ways to qualitatively compare the expected results to those reported is through a bar or column graph. Figures 1 - 6 show graphs of the expected values of the dose given to the badges during the irradiation versus the value measured and reported by Siemens for each quarter of 1993. Figure 7 displays this comparison for the additional test that was performed during the fourth quarter of 1993. Note that the scales vary from one graph to the next.

With the exception of the April 1993 spiking, the measured gamma values are consistently lower than the expected values. This assessment confirms the notable discrepancies between the pocket dosimeter readings and the reported dose. Throughout the year, exposure investigations have been performed to reconcile the significantly higher pocket dosimeter readings with the reported doses to no avail.

The reported neutron doses were erratic. The test group was exposed to neutrons during the first and third quarters. The special test group was exposed solely to neutrons. The reported results for the first quarter are varied. It was postulated by the vendor that somehow the CR-39 foils for the group had become mixed up, which may explain why those not exposed exhibited a measurable dose and those that were exposed indicated minimal exposure. This, however, would not explain the two readings that were significantly greater than any administered dose. The third quarter report from the vendor showed minimal exposures for the badges contained in the group that was exposed to well above the "minimal dose" as declared by the vendor. A later conversation with one of the vendor's technical experts revealed that two of the badges had received 40 mrem of neutron exposure, but as this was below the 50 mrem threshold, the dose was reported as minimal. The other two showed no indication of exposure to neutron fields. As a matter of record, all of the technical specifications provided to us by the vendor list 30 mrem as the threshold for neutron doses (Specification Sheet SLD 760). The vendor raised the threshold verbally after several meetings regarding the peculiar neutron readings from the first quarter. The reported values for the special neutron irradiation are consistently lower that the administered doses. This graph also leads one to question the threshold for neutron doses. No badge exposed to 25 mrem had a reported exposure; only one badge exposed to 50 mrem had a corresponding measured value; and only three of the five in the group exposed to 75 mrem had corresponding measured values.

No conclusion can be made regarding the reported shallow doses. Only the third quarter involved irradiations to low energy x-rays and betas. Both subgroups exposed to the low energy x-rays from a Fe-55 source seem to indicate that the TLD is unable to respond to this radiation. This could be due to the TLD having a threshold of about 15 - 20 keV and the iron-55 x-ray having an energy of 6 keV. Another possibility is that the TLD is not being uniformly irradiated and a dose can not be extrapolated. (Telephone conversation with E. Deneau of Siemens) There were two subgroups that were exposed to a Sr-90/Y-90 source. Only one badge in the first subgroup registered any beta dose, although they were exposed to 50 mrem, well above the 10 mrem threshold. The second subgroup was exposed to both the x-ray source and the beta source. The doses reported for this subgroup agree well with the beta dose given.

QUANTITATIVE COMPARISON

Applying the methodology employed by D. Boehnlein in RP Note #97, the expected and measured values were quantitatively compared by calculating the fractional difference. The fractional differences are plotted against the administered doses in Figures 8 - 10. Figures 8 and 9 also illustrate the best fit curve for the data as determined by CA-Cricket Graph III. No curve was provided for the beta doses because of small data set.

The fractional differences were determined in the following manner. The measured values of gammas, neutrons, and betas were averaged for each subset of badges. These average values were assigned an error equal to the standard deviation of the sample. The fractional difference is given by:

$$f = \frac{(E - M)}{E},$$

where E is the expected value and M is the average measured value for the subset. The scaled error is given by:

$$\sigma_f = \frac{\sigma}{E},$$

where σ is the standard deviation of M.

In the absence of any systematic error in the dose measurements, one would expect the fractional differences to be random in nature. The fractional differences for gamma vary not only with the dose given, but also the quarter in which the badges were irradiated. Figure 9 indicates a dose dependence until the badges have been exposed to a minimum of 100 mrem, and then a relatively constant fractional difference of approximately 0.35. Both of the graphs imply that there are systematic errors involved in addition to the expected random error. The fractional uncertainties are greater for the smaller doses than for the larger doses, as predicted. No comments can be made regarding the fractional differences associated with the beta exposures.

CONCLUSIONS

A definitive statement on the reliability of the measured dose values returned by Siemens is somewhat difficult to make as the actual errors associated with the measured values are not known. The errors associated with the expected values have been estimated and are about 10% for neutron doses and range between 1 and 5% for gamma doses. Theses estimations are included as part of the Fermilab Badge Spiking Logbook. The data seem to indicate that there are significant systematic errors associated with the measured values in addition to the random errors expected with any monitoring system. In this case, it would appear that the systematic errors dominate the results reported by the vendor.

It is of interest to ask what effect these errors might have on a person's dose measurements. The actual doses normally received at Fermilab are considerably smaller than those which are given to the spiked badges. In 1992, greater than 95% of all permanently badged individuals received less than 100 mrem for the calendar year. For the purposes of this exercise, it is assumed that the "average individual" received 100 mrem cumulative gamma exposure for the year as reported by the vendor.

As a result of the variance in the fractional differences between the quarters and for the administered doses, the measured values for the three administered doses closest to 100 mrem were used to estimate the effect on the "average individual's" annual dose. The average administered dose was 97.4 mrem with a standard deviation of 77.3 mrem. The average measured dose was 82.2 mrem with a standard deviation of 70.8 mrem. The average fractional difference of these three points is 0.18 with a standard deviation of 0.07. The following equation was used to estimate the effect on the "average individual's" dose:

$$\frac{M_{ave}}{1-f_{ave}} = E_{ave}$$

where M_{ave} is the average measured dose, f_{ave} is the average fractional difference and E_{ave} is the average expected value. Thus, the average expected value is 100.2 mrem, an underestimation of the individual's dose by 18 mrem.

Current policy states that dose adjustments should not be made unless the change is greater than 50 mrem and greater than 10% of the reported dose (FRCM). Therefore, dose adjustments should only be considered for individuals that have received greater than 250 mrem measured dose. Lastly, assuming an underestimate of an individual's dose by approximately 20%, no individual permanently badged at Fermilab during 1993 would have exceeded any administrative control levels or legal limits.

REFERENCES

1. D. Boehnlein. RP Note #97 A Summary of Film Badge Spiking at Fermilab for 1991, dated May 11, 1992.
2. Fermilab Radiological Control Manual, Article 573.9.
3. Siemens Gammasonics, Inc. Dosimetry Service Specification Sheet SLD 760.
4. Personal conversation with E. Deneau, Siemens Gammasonics, 12/93.
5. Fermilab Badge Spiking Logbook.

Figure 1: Jan 93 Gamma

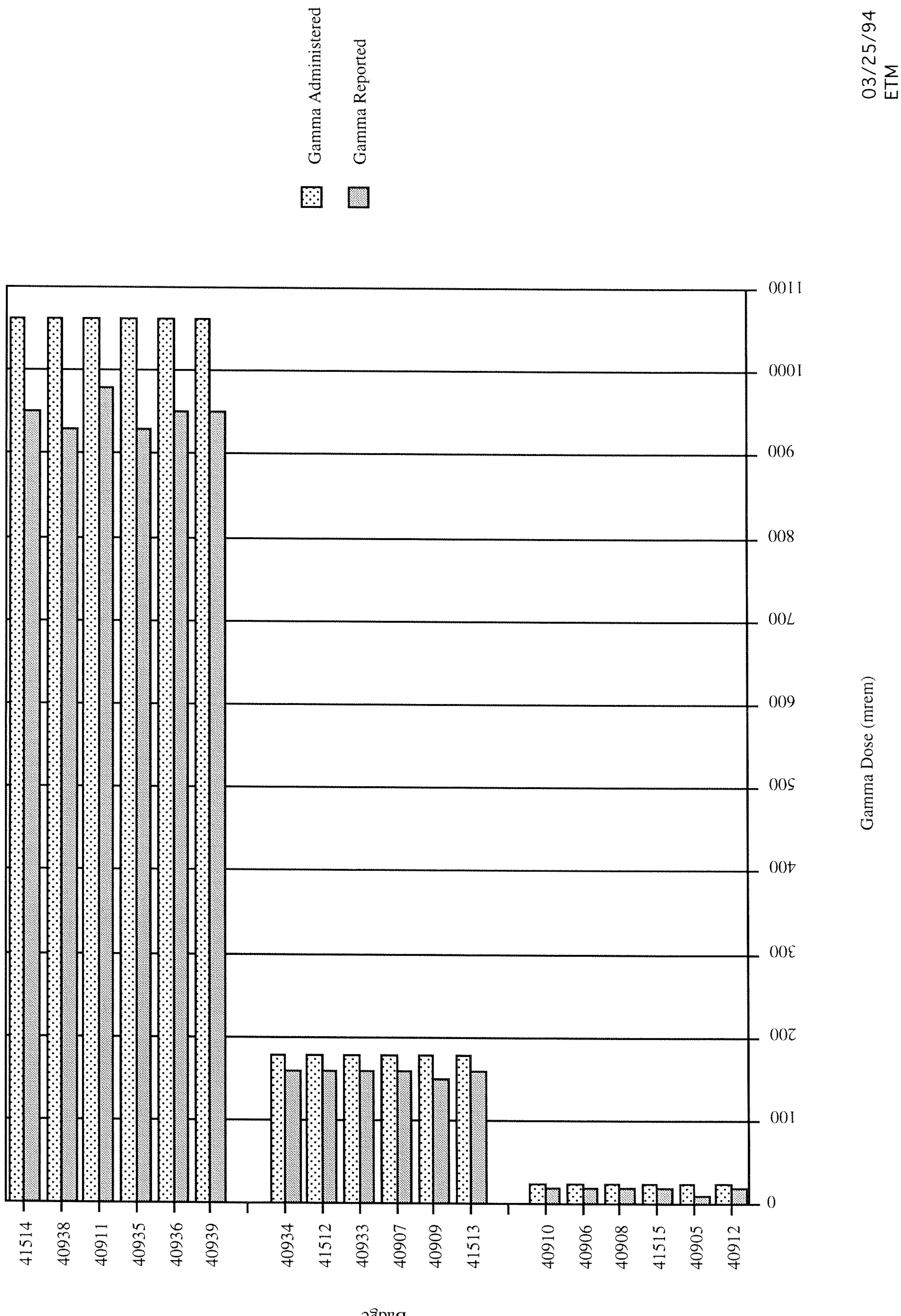

Figure 2: Jan 93 Neutron

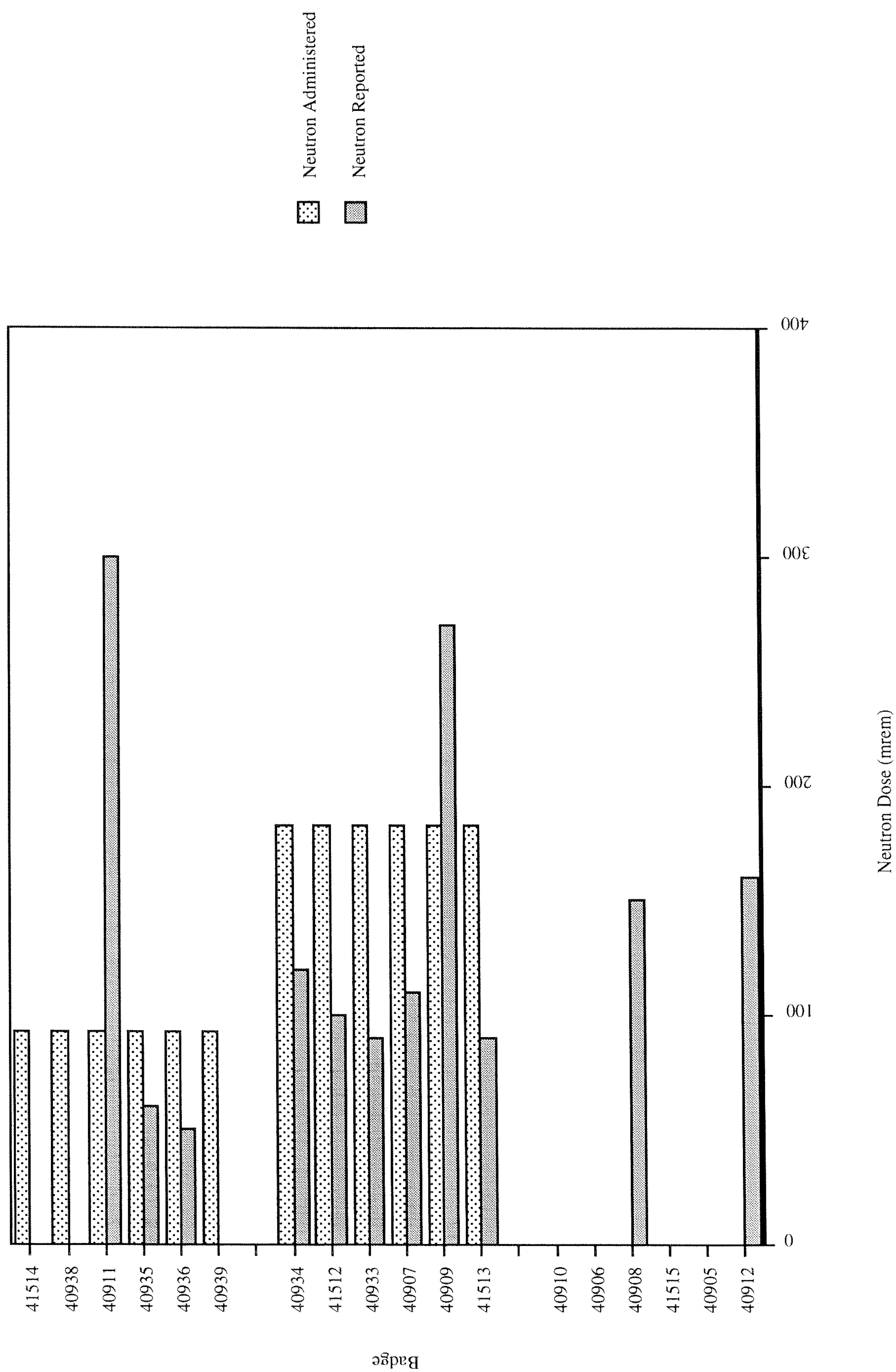

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Figure 3: Apr 93 Gamma

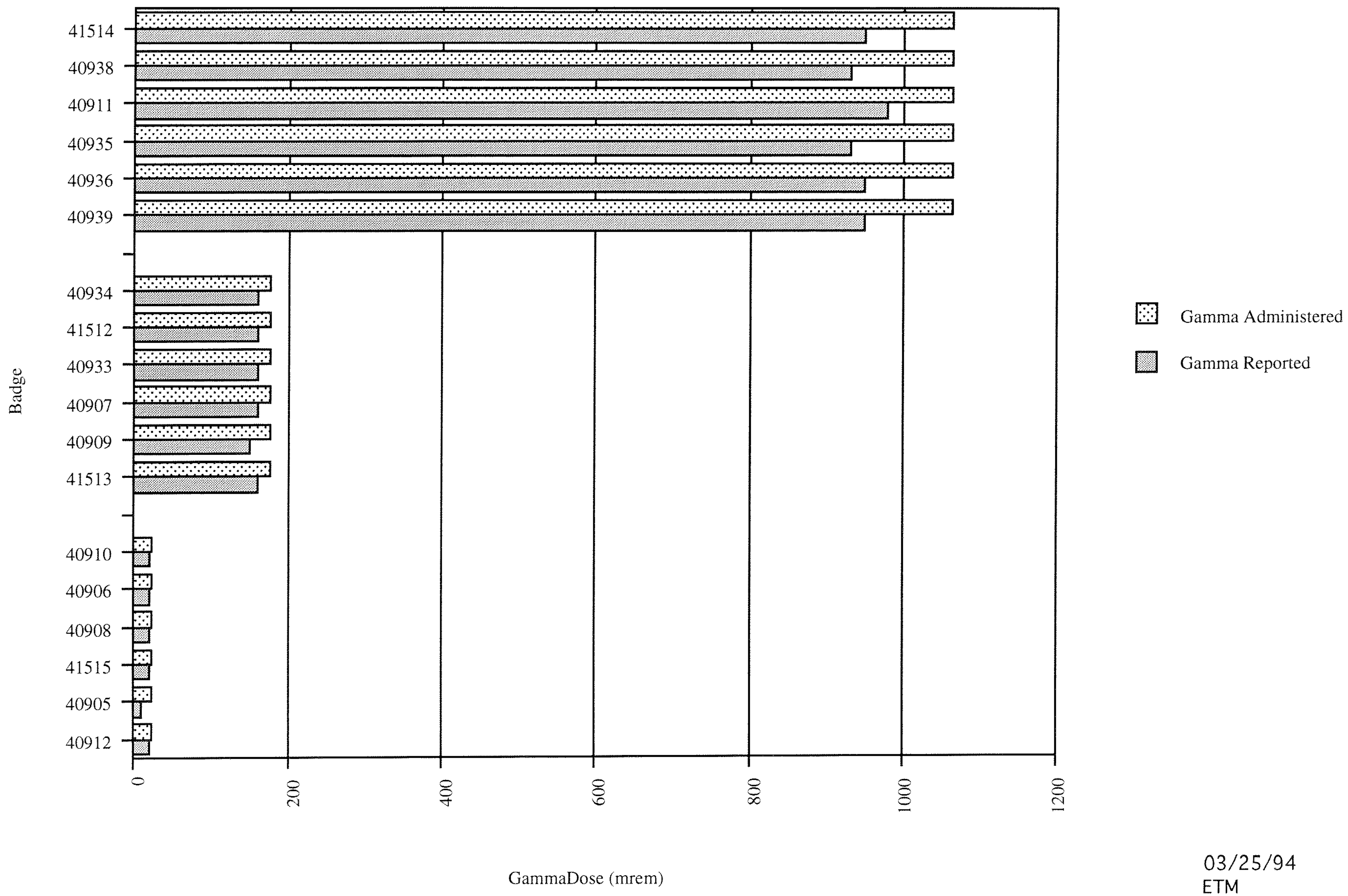


Figure 4: July 93 Shallow Dose

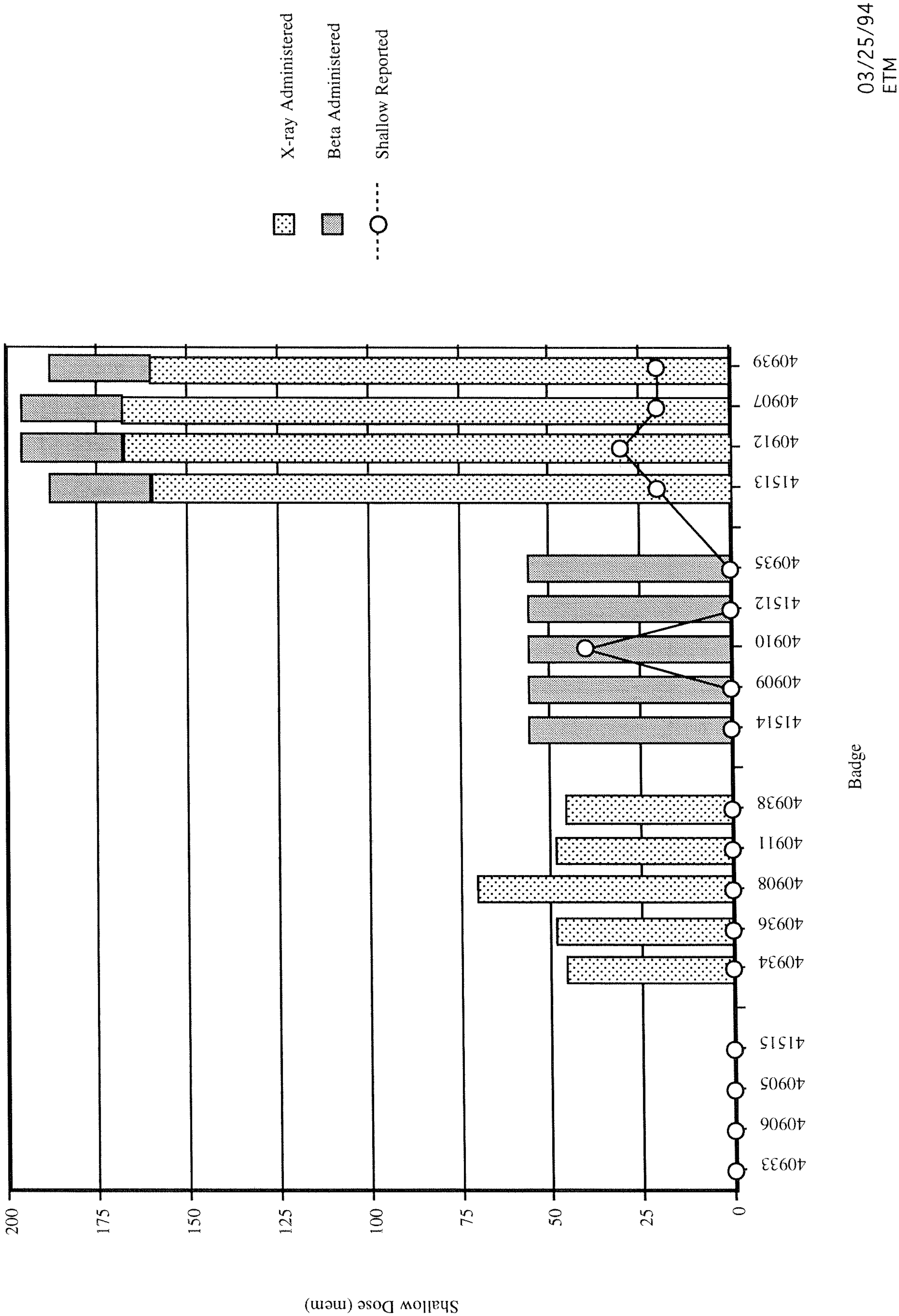
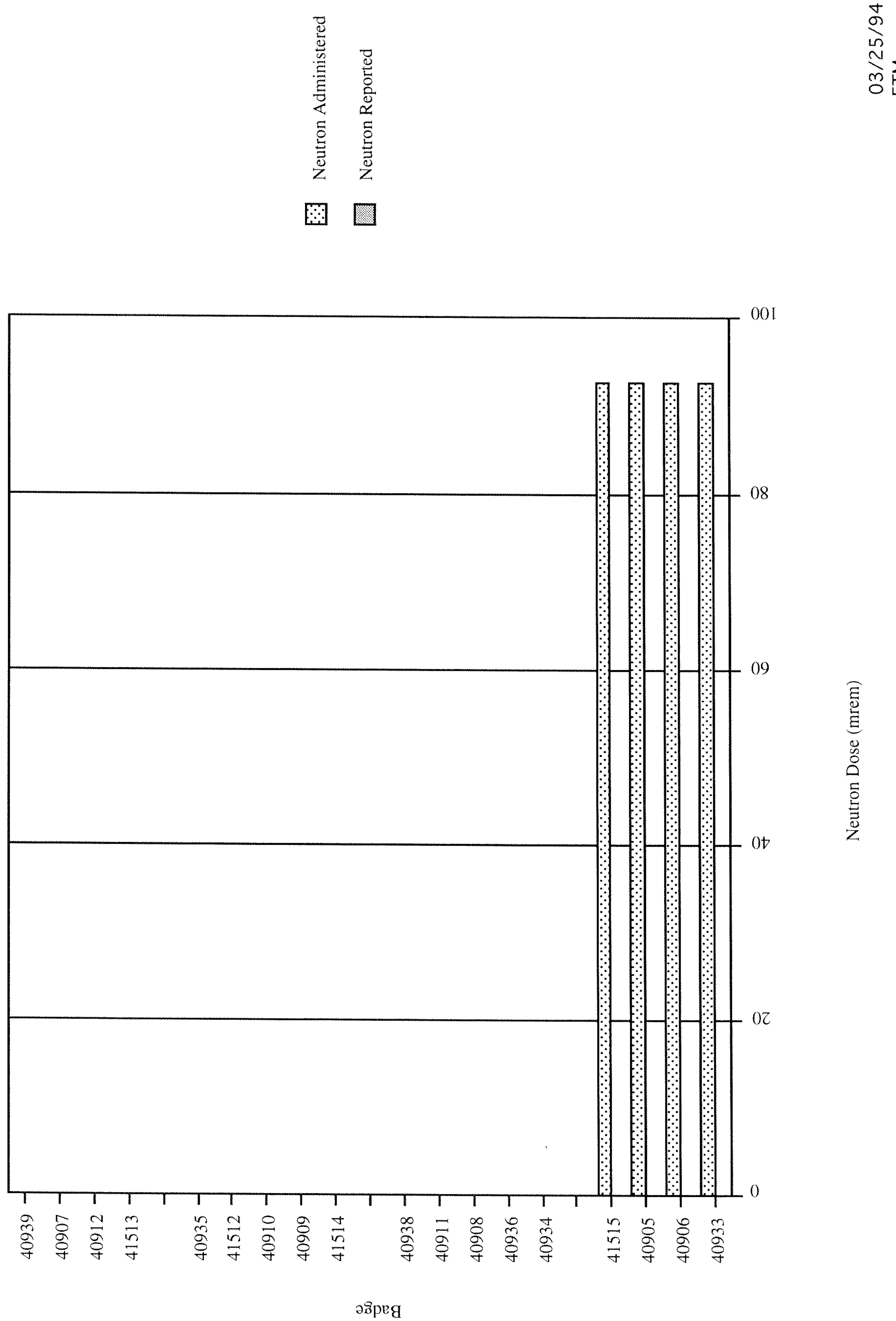


Figure 5: July 93 Neutron



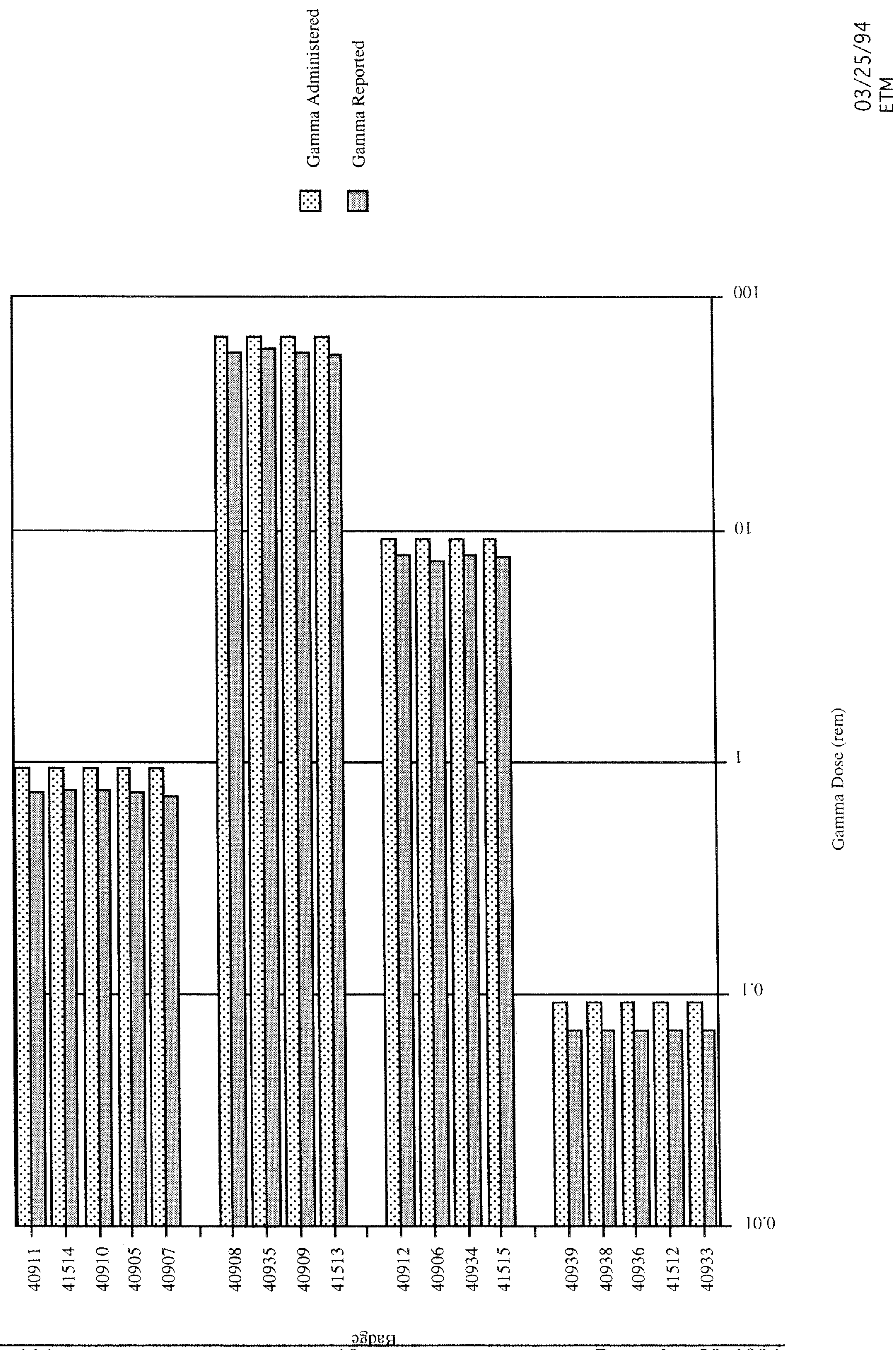


Figure 6: Oct 93 Gamma

Figure 7: 93 Neutron

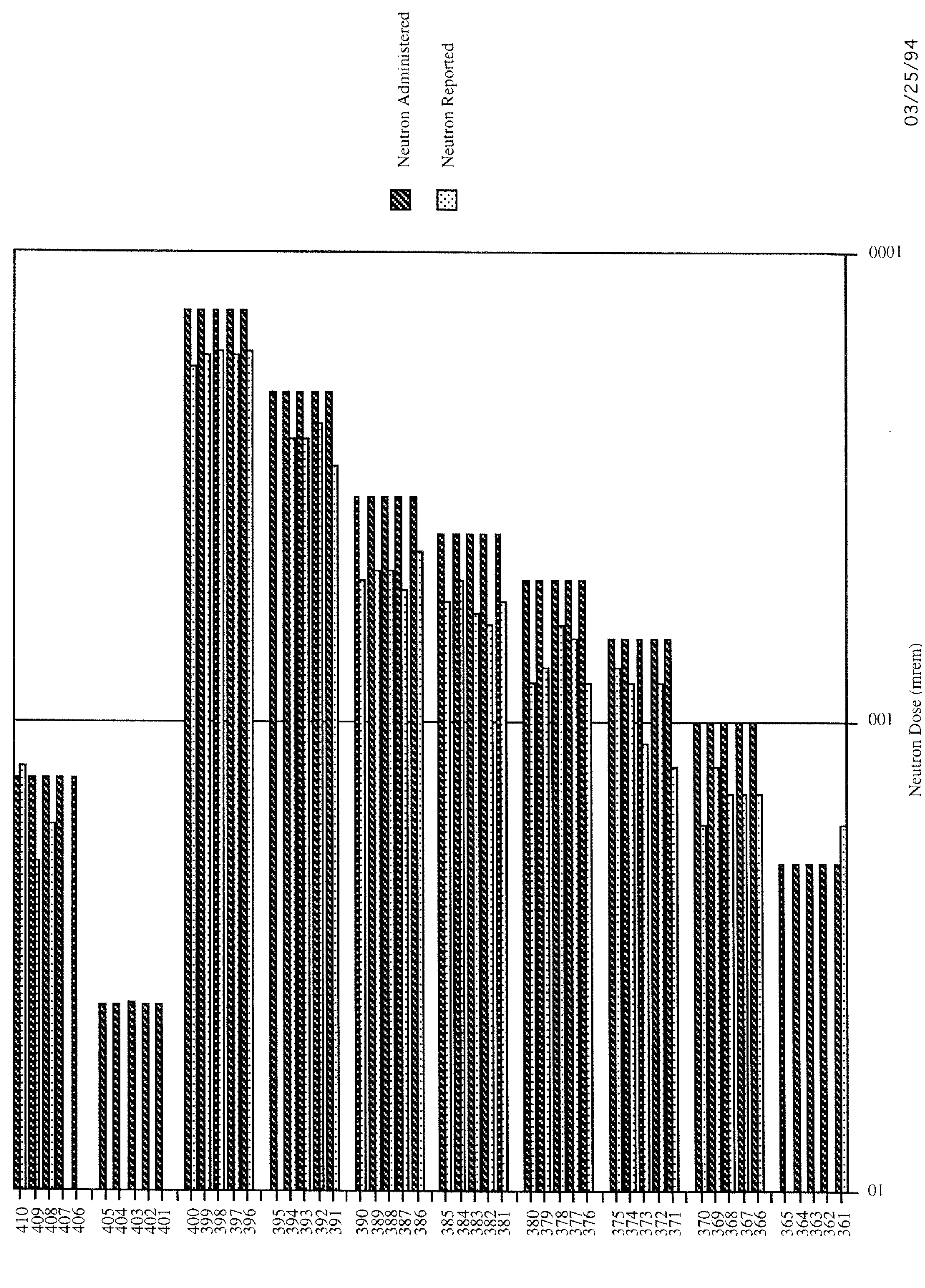


Figure 8: Fractional Difference Gamma

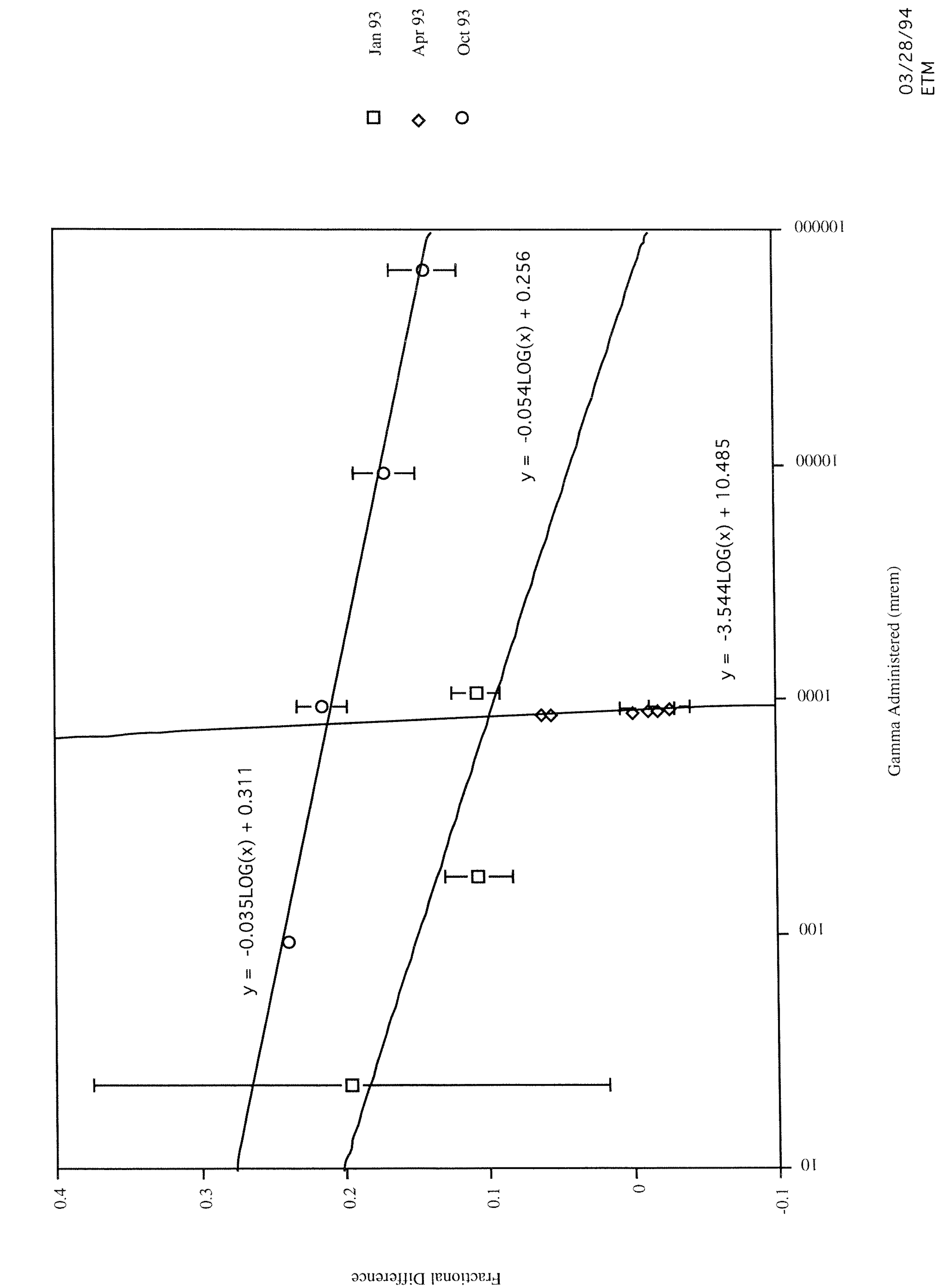


Figure 9: Fractional Difference Neutron

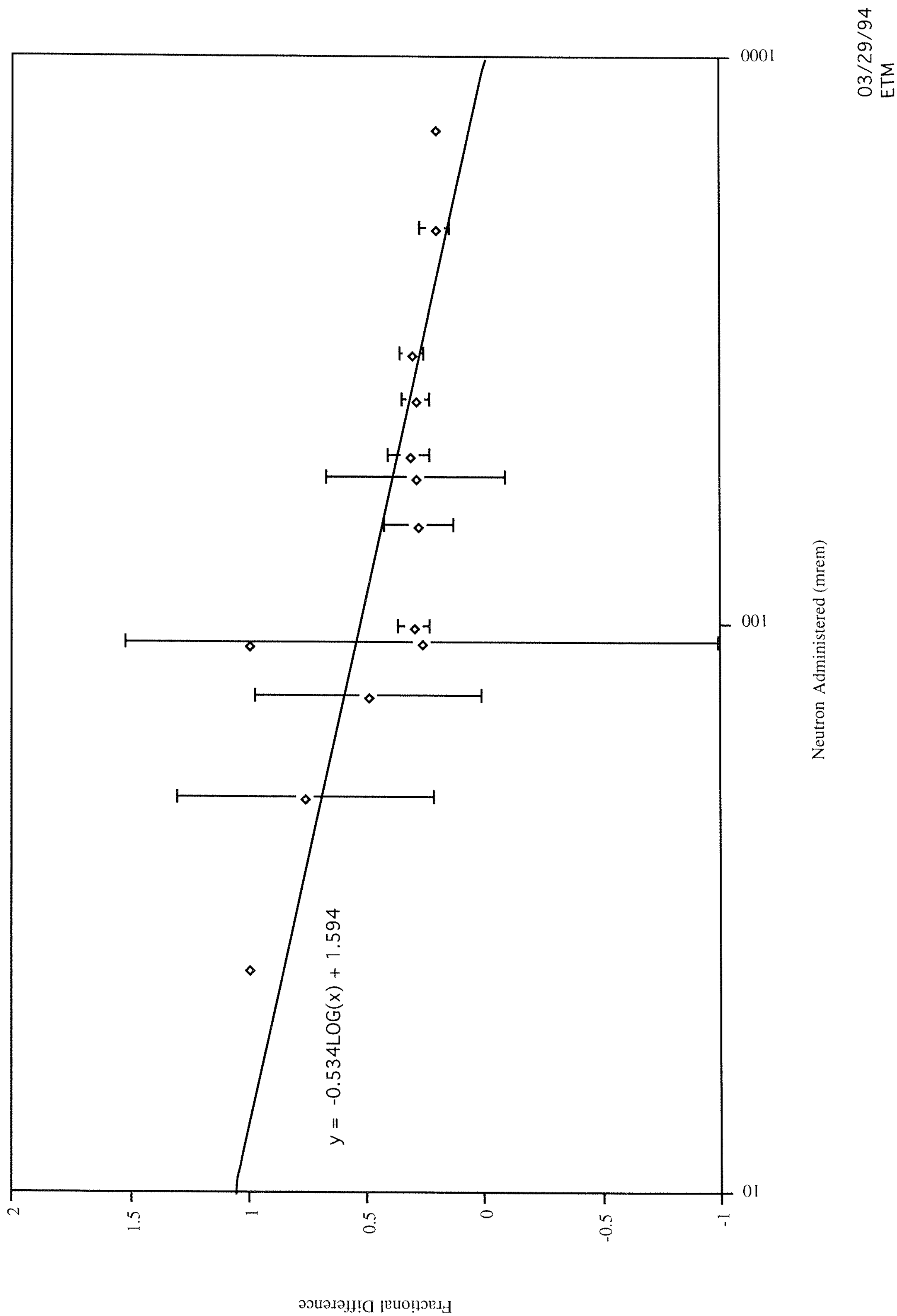
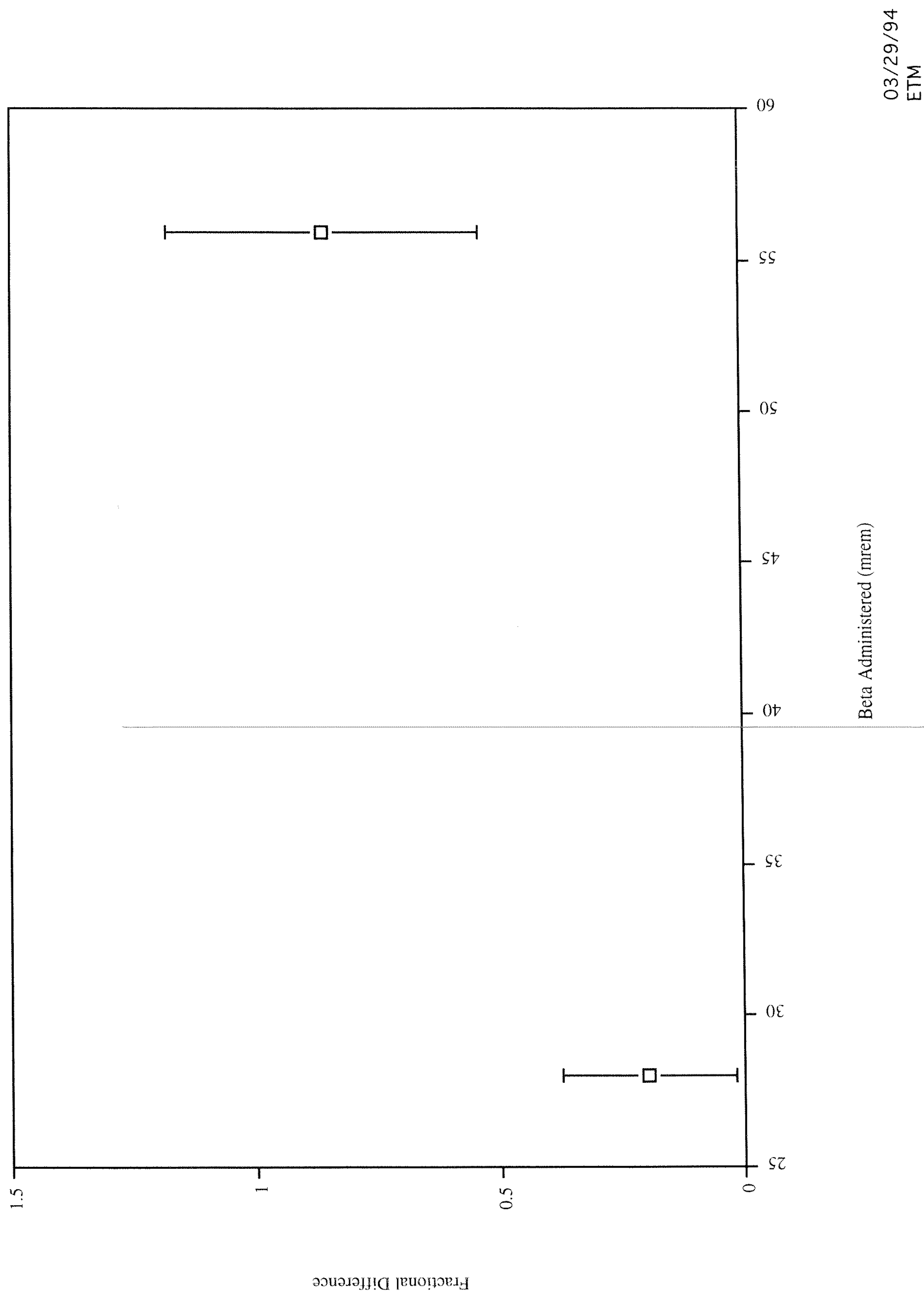


Figure 10: Fractional Difference Beta



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