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ACRONYMS AND ABBREVIATIONS

CS	complete sample
CTW	construction trade worker
GM	geometric mean
GSD	geometric standard deviation
HTO	tritiated water
IREP	Interactive RadioEpidemiological Program
N	total number of individuals in CS
n	total number of individuals in CTW group
NCTW	non-construction trade worker
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH-OCAS Claims Tracking System
OCAS	Office of Compensation Analysis and Support
R2	coefficient of determination for regression line
SRS	Savannah River Site

1.0 INTRODUCTION

Coworker models are used to estimate doses for workers who were not monitored but, in retrospect, perhaps should have been monitored. Coworker models are typically constructed using the data from all monitored workers, but there has been some interest in stratifying the monitored workers into subgroups and constructing separate coworker models for each stratum. Stratification offers potential advantages like more precise estimates of the dose to unmonitored workers in a stratum, but it is not known whether such advantages would be realized in this application. To help answer this question, the annual tritium doses[1] for two strata of workers at the Savannah River Site are analyzed to determine if there are any significant differences in the coworker models constructed from the two strata and the coworker model constructed from the entire dataset.

2.0 METHODS

2.1 THE HTO COWORKER MODEL

There is a population of workers that consists of everyone who received intakes of tritiated water (HTO). It is assumed that some of these workers were monitored and some were not. Thus,

- The workers who received intakes of HTO and were monitored for HTO represent one subgroup of the population (the monitored workers), and

- The workers who received intakes of HTO and were not monitored for HTO represent another subgroup (the unmonitored workers).

The goal of a coworker model is to look at the data available on the monitored workers and estimate the relevant dosimetric parameters for the entire population. For example, the distribution of doses in the population is assumed to be well described by a lognormal probability model. The geometric mean (GM) and geometric standard deviation (GSD) for the population doses are estimated from the monitored worker data. Finally, the doses to the unmonitored workers are estimated using the population dosimetric model. For example, the GM or 95th-percentile population dose might be applied to each of the unmonitored workers.

For this process to be valid one must make an assumption about why the unmonitored workers were not monitored. For example, one could assume that:

1. The occurrence of unmonitored workers in the population occurred completely at random.

2. The unmonitored workers on the average had lower potential for intakes of HTO than did the monitored workers, which is why they were not monitored. This approach is consistent with the graded approach normally applied in radiological protection programs.

3. The unmonitored workers on the average had higher potential for intakes of HTO than did the monitored workers. This approach is inconsistent with applicable regulations and the goals of radiological protection programs.

Assumption 1 will be used here, which allows statistically based conclusions to be reached. In practice, this assumption means that no workers were systematically left off a bioassay program in which they should have participated. Note that none of these assumptions concerning the occurrence of unmonitored workers in the worker population is verifiable in a general way for all sites.

[1] The methodology used to calculate the annual doses from tritium intakes is detailed an Attachment D.

The assumption that unmonitored workers occur at random (Assumption 1) is equivalent to saying the monitored workers can be treated like a simple random sample taken from the population of *all exposed workers.* In ORAUT-OTIB-75 [ORAUT 2009], evidence is presented that supports the assumption that the NIOSH [National Institute for Occupational Safety and Health]-OCAS [Office of Compensation Analysis and Support] Claims Tracking System (NOCTS) dataset is a simple random sample taken from the population of *all monitored workers* (i.e., a random sample taken from a random sample). The net result of this is that the NOCTS dataset is a simple random sample taken from the population of *all exposed workers*. In the remainder of this discussion the *monitored workers* will be referred to as such whether the sample is the dataset of all monitored workers or the NOCTS dataset.

For a typical coworker model the doses for all workers in the sample for each year are plotted on a lognormal probability plot and the GM and GSD are determined from a linear regression on the order statistics. The plotting positions used in the regression are calculated with $i/n - 1/(2n)$ convention (ORAUT 2006). The lognormal parametric model is used because:

- Occupational dose and bioassay data are frequently fit well by a lognormal model.
- The lognormal model is one of the standard options in the probability of causation software IREP, i.e., the geometric mean and geometric standard deviation derived from the coworker model plug directly[2] into the Interactive RadioEpidemiological Program (IREP).

For example, the coworker model for 1954 is shown in Figure 1. For 1954, the GM and GSD of all workers who were exposed to HTO (the population) are estimated from the GM and GSD of a random sample of 122 workers who were exposed to HTO and monitored for HTO (the NOCTS dataset) in 1954. Workers who were not monitored in 1954 (but were exposed to ambient levels of HTO) are assumed to be random samples from a population of workers for whom the estimated GM and GSD are 7.79 mrem and 2.19, respectively.

2.2 STRATIFIED SAMPLING

It is reasonable to postulate that the population of all workers is a conglomeration of a number of smaller subpopulations of workers, where the subpopulations could receive significantly different average doses. For example, the subpopulation of workers who routinely make process line breaks in a heavy-water moderated reactor might be expected to have a significantly different average tritium dose than does the subpopulation of workers who manned the control room of the reactor. In sampling theory these relative homogeneous subpopulations are called *strata*, which are basically the same in this case as the *cohorts* from epidemiology.

Breaking a truly heterogeneous population into a number of relatively homogeneous strata is often desirable because the variance of the estimated parameters will be smaller than the variance of the parameters estimated from a simple random sample (Lohr 2010, p. 74).

However, there are issues associated with stratified sampling. For example, criteria are needed for identifying meaningful strata and assigning workers to the appropriate stratum. The term *meaningful* here is referring to the assumption that there are indeed groups in the population that have significantly different average doses and that we know how to identify these groups. This is important because if there is no real difference in the GM and GSD of the strata, the estimates of the GM and GSD made from the strata will be less precise than those obtained by using all the monitored workers (i.e., from simple random sampling). In addition, stratifying the monitored workers into strata with

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2 If the data from the monitored workers are bioassay data, they must first be converted to dose before going into IREP, but the bioassay data are fit to the lognormal model to begin the process.

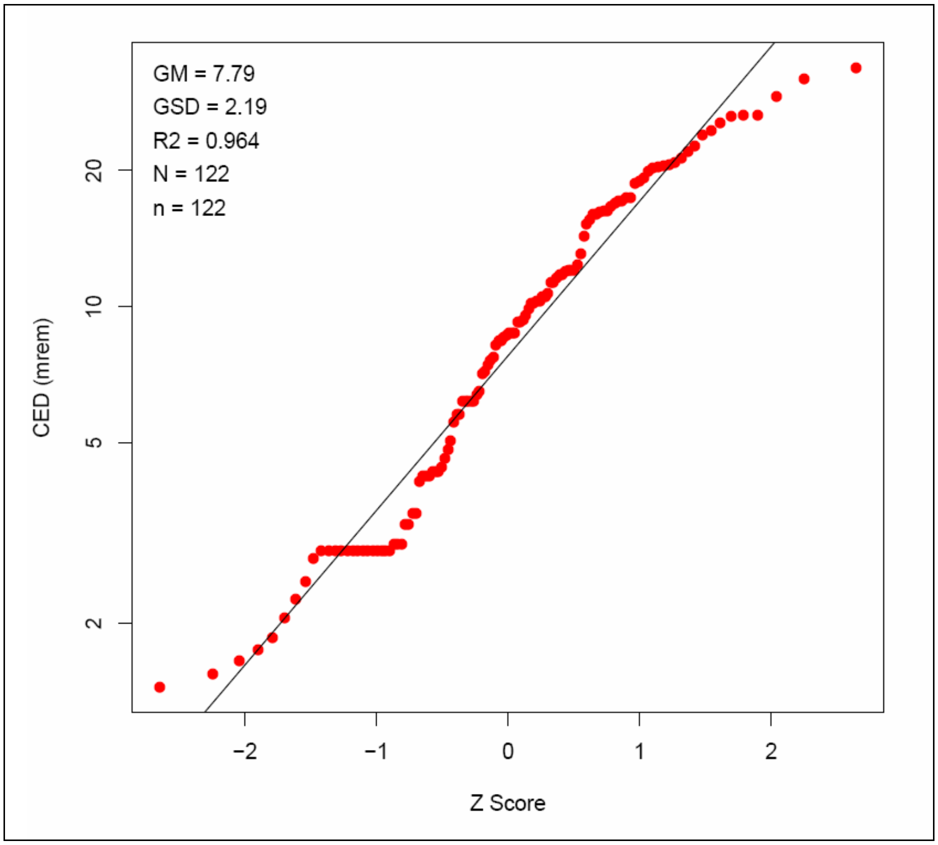

Figure 1. Tritium doses for all monitored workers in 1954.

fewer workers per stratum reduces the precision of the GM and GSD estimated from the strata because the sample is smaller. If the size of the strata become too small it is actually better to leave them combined into one larger sample.

2.3 SIGNIFICANCE OF STRATA

As an example of stratified sampling, assume that the population of all workers exposed to HTO can be meaningfully divided into construction trade worker (CTW) and all other workers (NCTW) strata. The simple random sample of monitored workers who were monitored in 1954 (the complete sample) was poststratified[3] into CTW and NCTW workers and the CTW stratum compared to the complete sample. The coworker model constructed from the CTW stratum is shown in Figure 2. A summary of the statistics for the coworker model constructed from the complete sample (CS) and the coworker model constructed from the CTW stratum is shown in Table 1.

We are interested in deciding if it is of value to stratify the HTO dose data in 1954 as suggested above and use the CTW coworker model rather than the CS coworker model to assign doses to unmonitored CTWs. Part of this decision is based on whether there is any statistically significant difference in the two coworker models. The test discussed below is designed to answer the question of statistical significance. However, even if there is a statistically significant difference in the models, the difference might not be of practical significance.

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[3] Assigned to the appropriate stratum after the sample is collected.

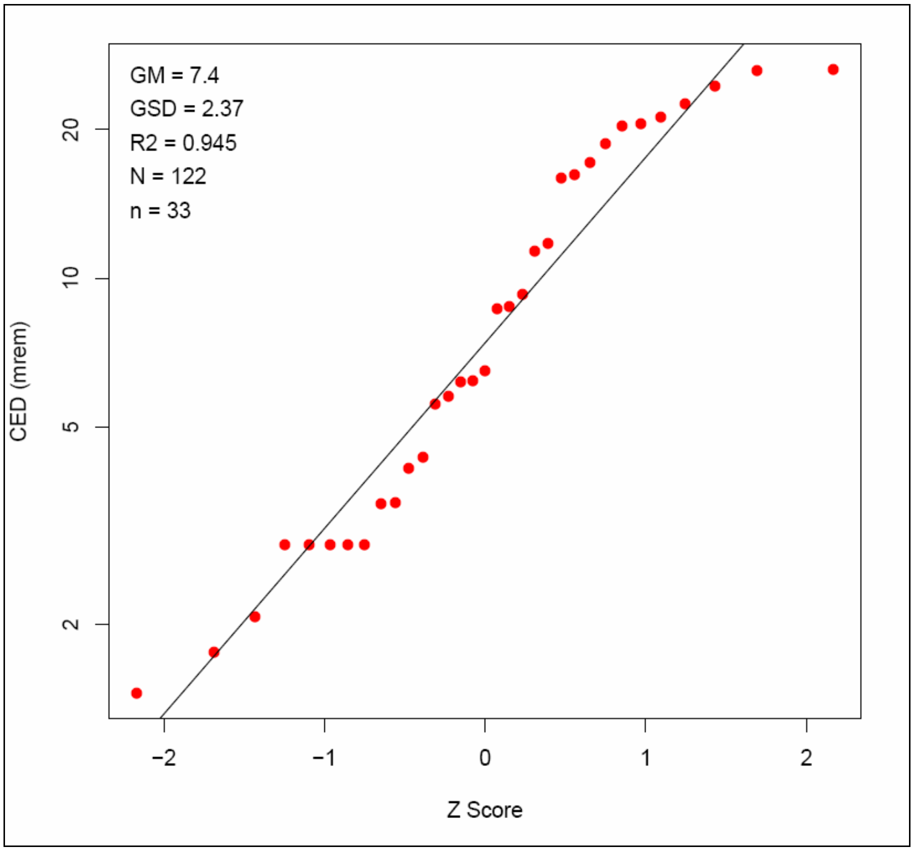

Figure 2. Tritium doses for monitored CTW in 1954.

Table 1. Statistics for the coworker models. N is the number of workers.

	N	GM (mrem)	GSD
CS	122	7.79	2.19
CTW	33	7.40	2.37

3.0 STATEMENT OF TEST

Null Hypothesis H_0:

The coworker model derived from the CTW stratum is a simple random sample from all the coworker models (having the same size as the CTW stratum) that can be derived from the population of monitored workers. In other words, the coworker model derived from the CTW stratum will tend to not be significantly different than the coworker model derived from the population of monitored workers.

Alternate Hypothesis H_A:

Opposite of H_0.

Test Statistic

The coworker model for the HTO consists of the GM and GSD of the lognormal fit to the order statistics for a given year. The test statistics used here are the differences between the GM and GSD from the CTW and CS models:

$$\Delta_{gm} = GM_{CTW} - GM_{CS}$$
$$\Delta_{gsd} = GSD_{CTW} - GSD_{CS}$$

The joint distribution of the Δ_{gm} and Δ_{gsd} under the null hypothesis is calculated using a Monte Carlo simulation that looks at a large number of fits of 33 doses (the number of CTWs) taken at random from 122 doses (number of monitored workers in the complete sample).

Rejection Region

The Δ_{gm} and Δ_{gsd} pairs represents X and Y coordinates of a point on a scatter plot. The Monte Carlo simulation consists of 10,000 such points with a 95% bivariate normal confidence ellipse constructed around the points. If the point defined by the observed Δ_{gm} and Δ_{gsd} falls outside the 95% confidence ellipse, the null hypothesis is rejected.

Conclusion

If the null hypothesis is not rejected at $\alpha = 0.05$, there is nothing here to make us believe that the doses from the CTW stratum are anything other than a random sample from the complete sample.

3.1 DISCUSSION

The GM and GSD of the CTW sample in 1954 is taken to be the best estimate of the GM and GSD of the total CTW population in 1954, and an equivalent statement can be made for the complete sample. Thus, the question here is: Are the GM and GSD of these two samples statistically different and, if so, is the difference of any practical significance?

One way to answer the question of statistical significance begins with an examination of the distribution of the test statistics that can be calculated from all possible samples of $k = 33$ doses taken from $n = 122$ doses. There are:

$$C = \frac{122!}{33!(122-33)!} = 6.889 \cdot 10^{29}$$

equally probable ways of selecting 33 different doses from a population of 122 doses. Each of the *C* combinations of the 33 doses can potentially have its own unique test statistics. Note that only one of these *C* ways (the CTW dataset) was actually observed or realized. In theory, the test statistics for each of the *C* combinations could be calculated, and the ranges where most (95% for example) of the test statistics occurred could be established. The observed test statistics would be considered to be not significantly different than zero if they fell in the range where 95% of the results would be observed.

While theoretically possible, the calculations above are not feasible because of the immense number of samples of size $k = 33$ that can be drawn from the complete dataset. However, the 95% range can be estimated using the following Monte Carlo sampling test[4] (Noreen 1989, p. 43), which looks at a large number of random draws taken from the *C* different combinations:

1. Assume there are *n* doses in the complete dataset and *k* doses in the CTW dataset, where $n > k$ and the CTW dataset is a subset of the complete dataset.

[4] This is also referred to as an “approximate randomization test” and a “Monte Carlo permutation test”.

2. Calculate the slope and intercept of the lognormal fit to the doses for the observed CTW dataset. Do the same for the complete dataset, calculate the differences in GM and GSD, and plot the point defined by them.

3. Randomly draw k = 33 workers without replacement from the complete dataset. Fit a lognormal model to the k doses and calculate the differences in GM and GSD and plot them.

4. Repeat step 3 m times (e.g., m = 10,000 times). Note that each time the experiment is run a new set of k doses are drawn and new differences are calculated and plotted.

5. Calculate a 95% joint confidence ellipse of all m test statistics.

6. Repeat this procedure for each year.

This is a fairly straightforward test, the main technical challenge being to identify an area on the plot in which a large proportion of the points, 95% for example, can be found. If the observed GM and GSD differences fall within this 95% confidence area, the two coworker models are considered to not be statistically different[5]. On the other hand, if the observed differences fall outside the 95% confidence area, the two coworker models are considered to be statistically different. Two different methods were used to generate the 95% confidence area. The first method for generating the 95% confidence area assumes that Δ_{gm} and Δ_{gsd} are drawn from a bivariate normal distribution (probably a good assumption) and generates a confidence ellipse based on this model (Fox 2007, p. 203; Monette 1990). For 1954, one can conclude that there is no reason to believe at the 95% confidence level that the coworker models constructed from the CTW stratum and the complete sample are different (see Figure 3).

The second method uses a bagplot (Rousseeuw, Ruts, and Tukey 1999), which is a nonparametric method that generates a polygon that contains a given fraction of the observed differences. The area defined by 95% confidence ellipse was in general not distinguishable from the ~95% area defined by the bagplot, so the less computationally intensive confidence ellipse is used here in place of the bagplot.

The test statistic presented here is based on the GM and GSD of HTO doses calculated from fits of a linear model to order statistics on a lognormal probability scale. These parameters calculated in this fashion constitute the coworker model. For this reason, we believe that the most relevant statistical tests are those that use the GM and GSD as the test statistics, as we did here.

4.0 OTHER STRATA

A coworker model constructed from the CTW stratum was not expected to be significantly different than the coworker model constructed from the complete sample because there is not an obvious process or health physics-related reason why it should be. A more logical stratum would be that of reactor workers. These workers would be expected to receive higher tritium doses than other workers because they worked in heavy-water reactors that were the primary source of HTO exposures during the years the reactors were operated. For example, compare Figures 4 and 5, where the strata are reactor workers in 1972 and CTWs in 1972, respectively. The coworker model constructed from reactor worker doses is highly significant whereas the coworker model constructed from CTWs is not.

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5 Technically speaking, the null hypothesis that the differences in GM and GSD are equal to zero is not rejected.

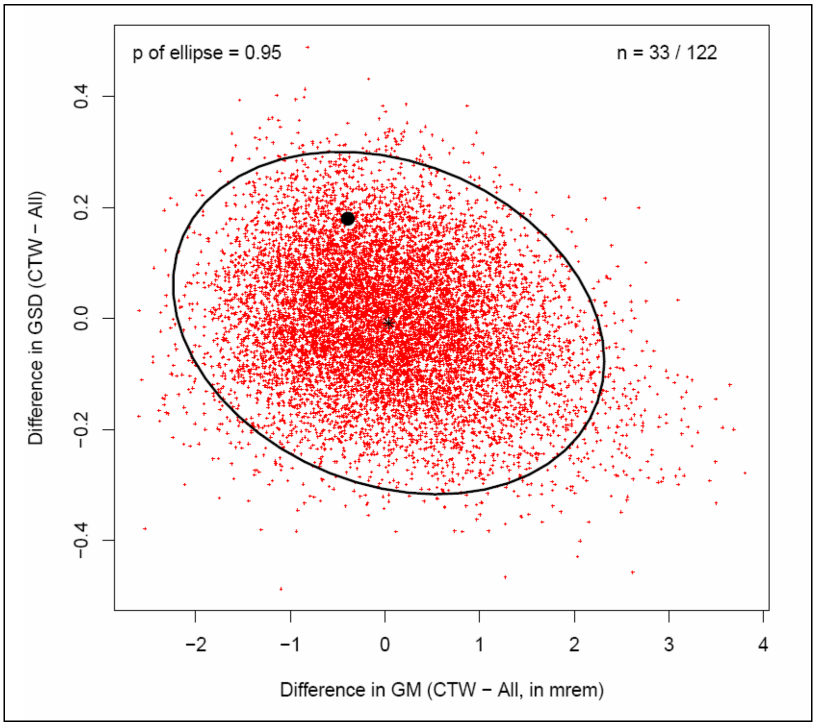

Figure 3. Monte Carlo sampling test of CTW versus CS models for 1954. The black point is the delta GM and delta GSD of the observed CS and CTW models.

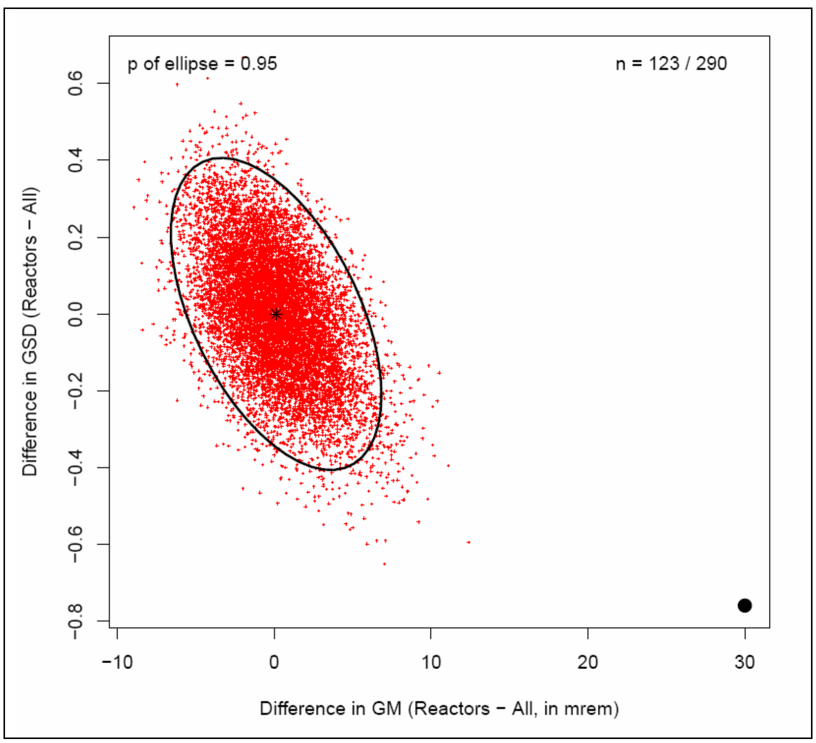

Figure 4. Monte Carlo sampling test of reactor worker versus CS models for 1972. The black point is the delta GM and delta GSD of the observed CS and reactor models.

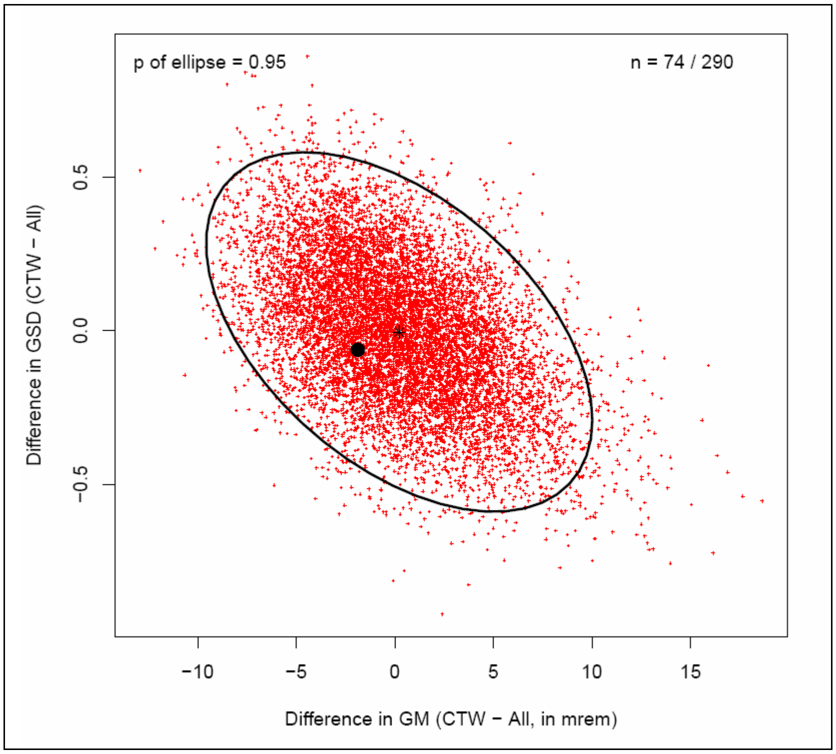

Figure 5. Monte Carlo sampling test of CTW versus CS models for 1972. The black point is the delta GM and delta GSD of the observed CS and CTW models.

Another approach is to create a stratum composed of CTWs who worked in the reactor areas. As discussed in the next section, the coworker models constructed from this stratum tend to be basically the same as the models constructed from the complete sample.

5.0 RESULTS

The complete output of the tests[6] is rather large and is presented in three attachments:

- Attachment A: Comparison of CTW to CS.
- Attachment B: Comparison of reactor workers to CS.
- Attachment C: Comparison of CTW/reactor workers to CS.

A summary of the results of the statistical tests is given in Table 2, where the columns are defined as follows:

- Column 1: Year in which dose was received

- Column 2: Is the coworker model constructed from the CTW stratum statistically different than the coworker model constructed from the complete sample at the 95% confidence level?

- Column 3: Is the coworker model constructed from the reactor worker stratum statistically different than the coworker model constructed from the complete sample at the 95% confidence level?

[6] All calculations were performed with R V2.11.1 [R 2010].

Table 2. Summary of results for statistical tests.

Year	Trade (p < 0.05)	Area (p < 0.05)	Trade/area (p<0.05)
1954	No	No	No
1955	No	No	No
1956	No	Yes	No
1957	No	No	No
1958	No	Yes	No
1959	No	Yes	Yes
1960	No	Yes	No
1961	No	Yes	No
1962	No	Yes	No
1963	No	Yes	No
1964	Yes	Yes	Yes
1965	No	Yes	No
1966	No	Yes	No
1967	No	Yes	No
1968	Yes	No	No
1969	No	Yes	No
1970	No	Yes	No
1971	Yes	Yes	No
1972	No	Yes	Yes
1973	Yes	Yes	No
1974	No	Yes	Yes
1975	No	Yes	No
1976	Yes	Yes	No
1977	Yes	Yes	No
1978	Yes	Yes	No
1979	Yes	Yes	No
1980	Yes	Yes	No
1981	Yes	Yes	No
1982	Yes	No	No
1983	Yes	Yes	No
1984	No	Yes	No
1985	No	No	No
1986	No	Yes	No
1987	No	Yes	No
1988	No	No	No
1989	No	Yes	No
1990	No	No	No

- Column 4: Is the coworker model constructed from the CTW/reactor worker stratum statistically different than the coworker model constructed from the complete sample at the 95% confidence level?

6.0 DISCUSSION

All tests of significance are at $\alpha = 0.05$, which means that there is a 5% chance of concluding that the coworker models were different when in fact they were not. In summary:

- There were 25 years in which there was no significant difference (NO) between the CTW and CS coworker models and 12 years in which there was (YES).

- There were 8 years in which there was no significant difference (NO) between the reactor worker and CS coworker models and 29 years in which there was (YES).

- There were 33 years in which there was no significant difference (NO) between the CTW/reactor worker and CS coworker models and 4 years in which there was (YES).

The absolute magnitude of the differences between a median dose calculated from a stratum and a median dose calculated from all the doses tended to be largest for the reactor worker stratum. When there was a statistically significant difference, the median doses from the reactor stratum were, with the exception of 1956, always larger than the median doses calculated from the complete set of doses. In other words, if there is any statistically significant difference in the models, the use of a coworker model constructed from the complete sample will tend to underestimate the doses to unmonitored reactor workers.

As expected, the absolute magnitude of differences between the median doses calculated from the CTW stratum tended to be smaller than those observed with the reactor stratum and, when there was a statistically significant difference, the median dose of the CTW stratum was, with the exception of 1964, always smaller than the median dose from the complete dataset. In other words, if there is any statistically significant difference in the models, the use of a coworker model constructed from the complete sample will tend to overestimate the doses to unmonitored CTWs.

Both of these conclusions are simply stating that doses derived from an average model (the coworker model constructed from all the data) might underestimate the doses from workers who tended to get higher doses (the reactor workers) and might overestimate doses from workers who tended to get lower doses (the CTWs). In practice, the decision of whether to stratify the doses and construct separate coworker models boils down to the following issues:

- Identification of meaningful strata (i.e., strata that have significantly different median doses) is not always easy to do. Stratification based on classifications that do not strongly influence the dose received by a worker will increase the uncertainty in doses assigned using that stratum (the CTW stratum is a good example).
- Assignment of each worker to a particular stratum might not be possible because the necessary information is not available for that person.
- Statistical significance does not always imply practical significance. For example, the differences in dose observed between the CTW stratum and the complete sample might not be large enough to change the outcome of a probability of causation determination. In such a case, it might not be worth the effort to stratify the coworker models.
- Many datasets are too small to stratify and maintain a reasonable number of doses in each stratum (i.e., 30 doses per stratum).
- Coworker models are generated from *doses* and from *bioassay data*. Doses to individuals (like those from external sources and HTO) are relatively easy to attribute to specific locations and times. This is typically much more difficult to do with bioassay data. For example, a person might be working in Facility A when he submits a positive urine sample for plutonium but the intake that gave rise to the positive result occurred 2 years earlier in a different facility.
- The evaluation of strata that are highly censored (plutonium urine data for example) has not been discussed here, but the evaluations of such datasets will surely be more difficult and the results more uncertain than what we have seen here for the tritium dose data.

7.0 CONCLUSION

There is no advantage in deriving a coworker model based specifically on doses to CTWs at SRS because

- For all but one year there is no statistically significant difference between the coworker model obtained from the CTW stratum and the coworker model obtained from all monitored workers, and
- In the one year when there is a *statistically* significant difference, the median dose for the CTW was 5 mrem more than the median dose to the workers in the complete sample.

A coworker model based specifically on the doses received by workers in the SRS reactor areas is statistically different than the coworker model obtained from all monitored workers for most years. While this difference was expected based on the nature of the work at the SRS reactors versus the work at other facilities, there is little use for a reactor-specific coworker model because it was very unlikely that a reactor worker would be unmonitored. Thus, the net result of creating a reactor-specific coworker model is to lower the doses to non-reactor workers who had a higher likelihood of being unmonitored.

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ATTACHMENT A
COMPARISON OF CTW TO CS

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There are three plots for each year from 1954 through 1990. The first two are lognormal probability plots of the tritium doses for the CS of workers and the CTWs. In these plots the following statistics are presented:

- GM = geometric mean of data (intercept of line)
- GSD = geometric standard deviation of data (slope of line)
- R2 = coefficient of determination for regression line
- N = total number of individuals in CS
- n = total number of individuals in CTW group

The third plot for a given year is a Monte Carlo permutation plot comparing the test statistics of 10,000 random samples from the CS to the observed test statistic for the CTW (the large black dot). An ellipse is constructed that contains 95% of the test statistics. If the observed test statistic for the CTW lies outside the ellipse, the coworker model for the CTW is considered to be different than the coworker model for CS.

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COMPARISON OF CTW TO CS
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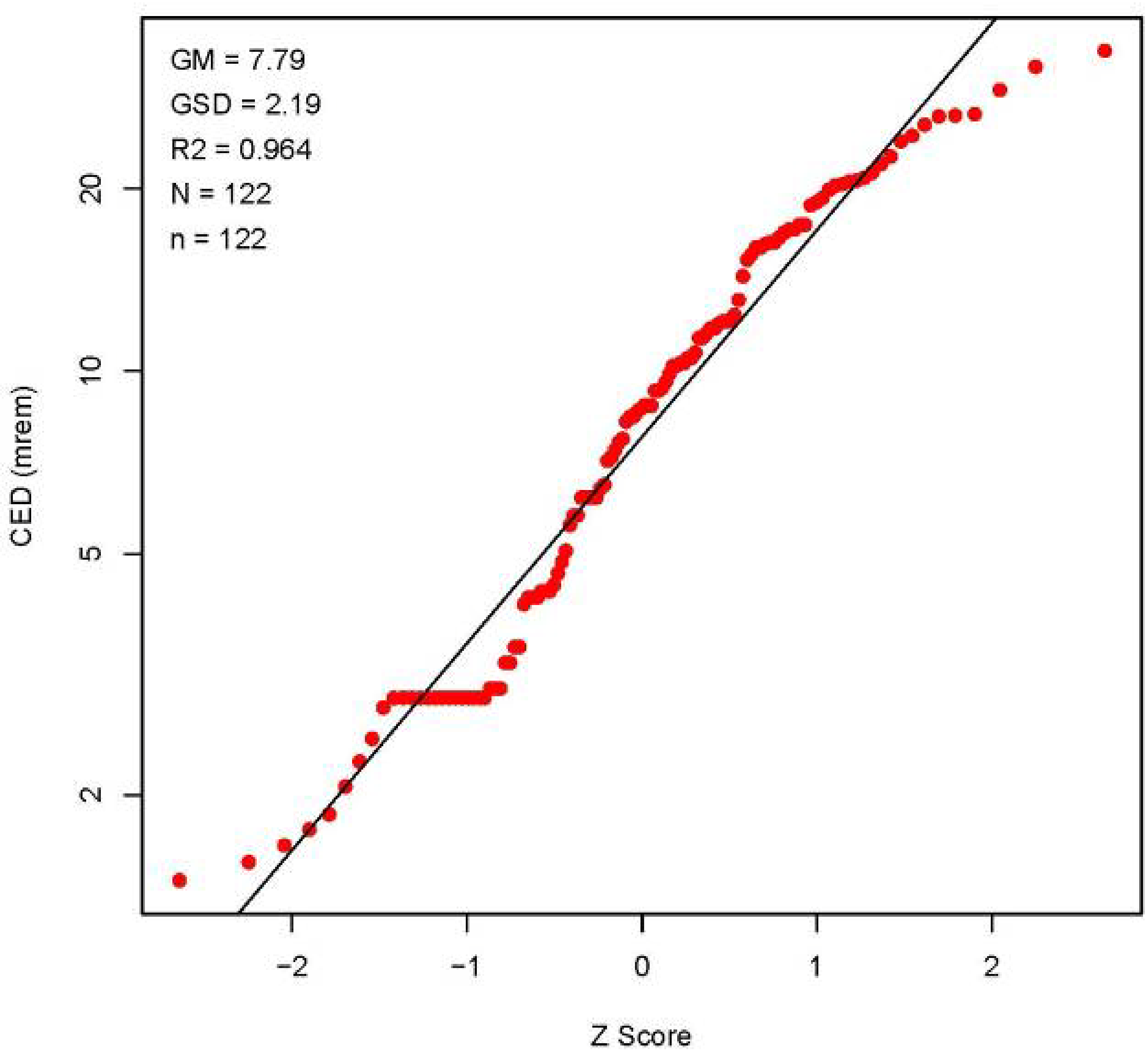

Figure A-1. SRS tritium dose 1954.

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COMPARISON OF CTW TO CS

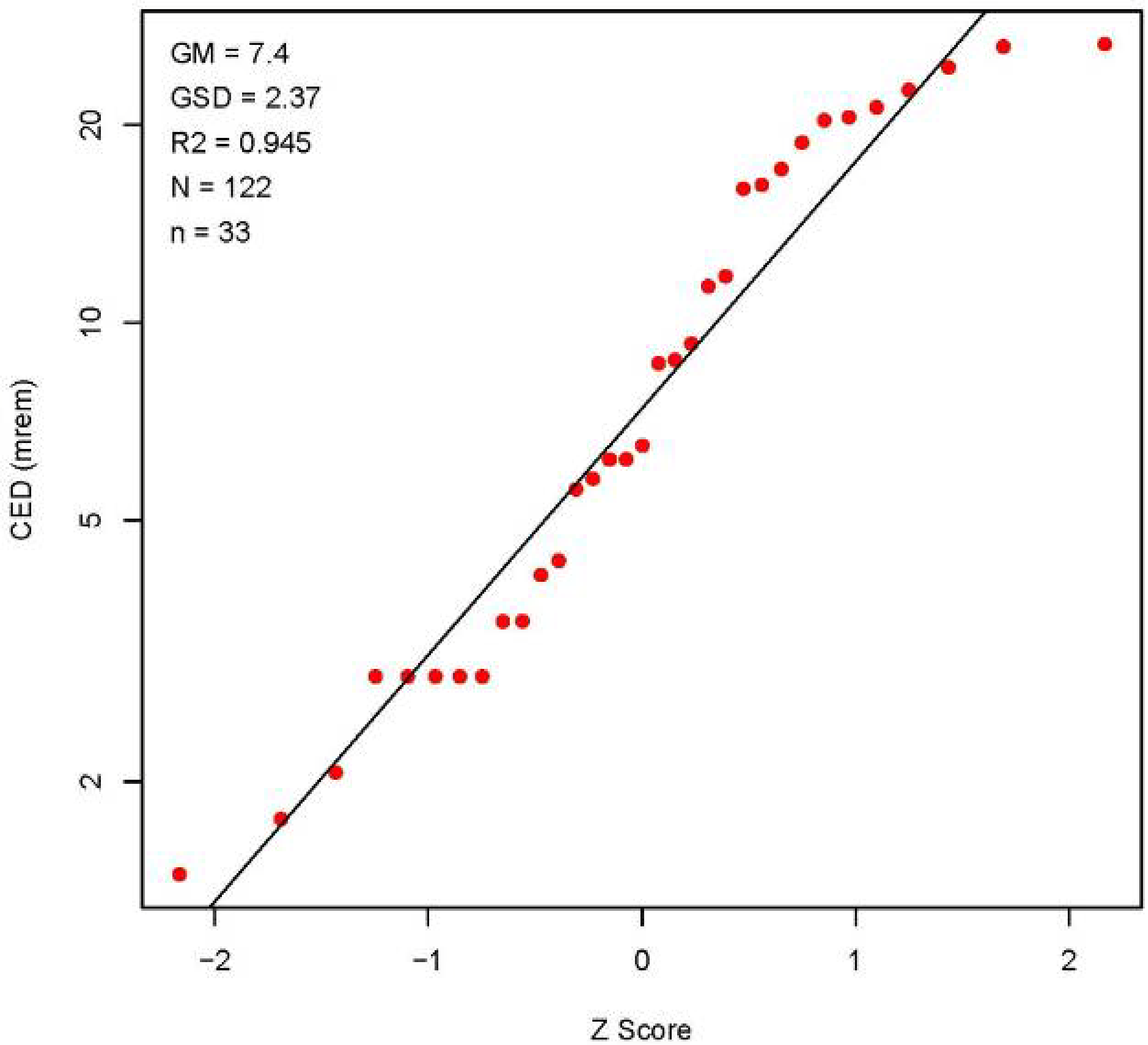

Figure A-2. SRS CTW tritium dose 1954.

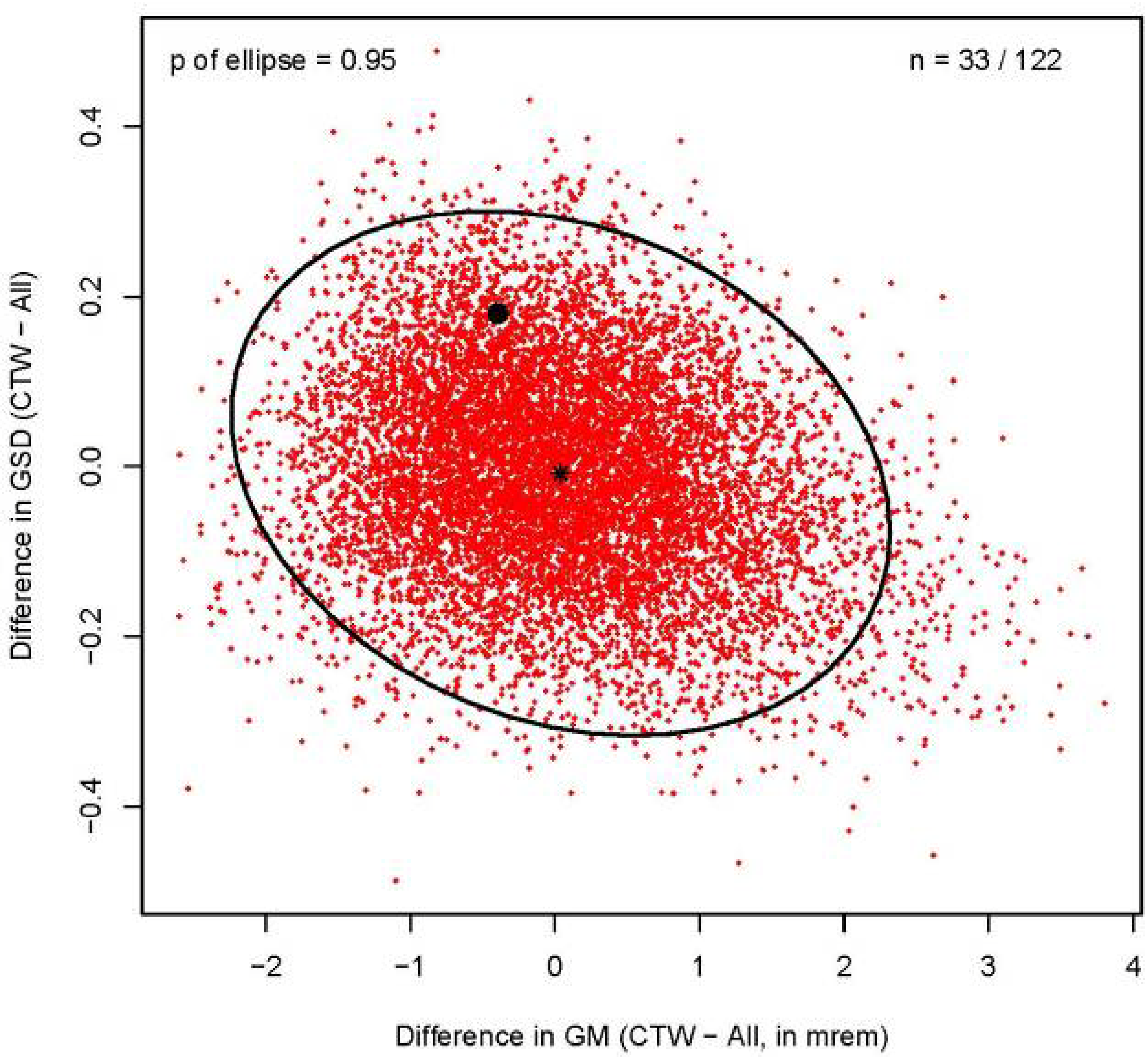

Figure A-3. SRS tritium dose 1954.

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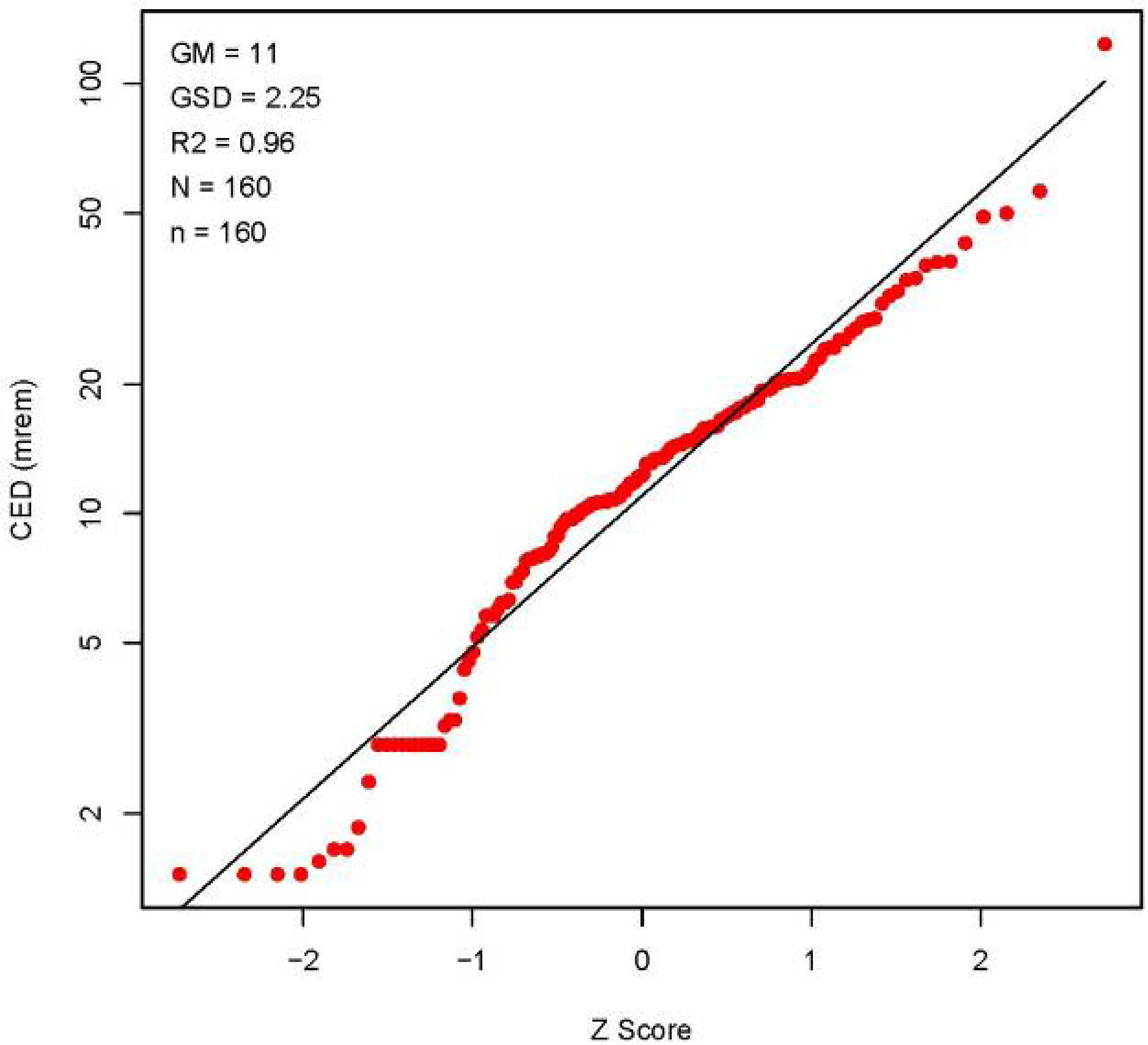

Figure A-4. SRS tritium dose 1955.

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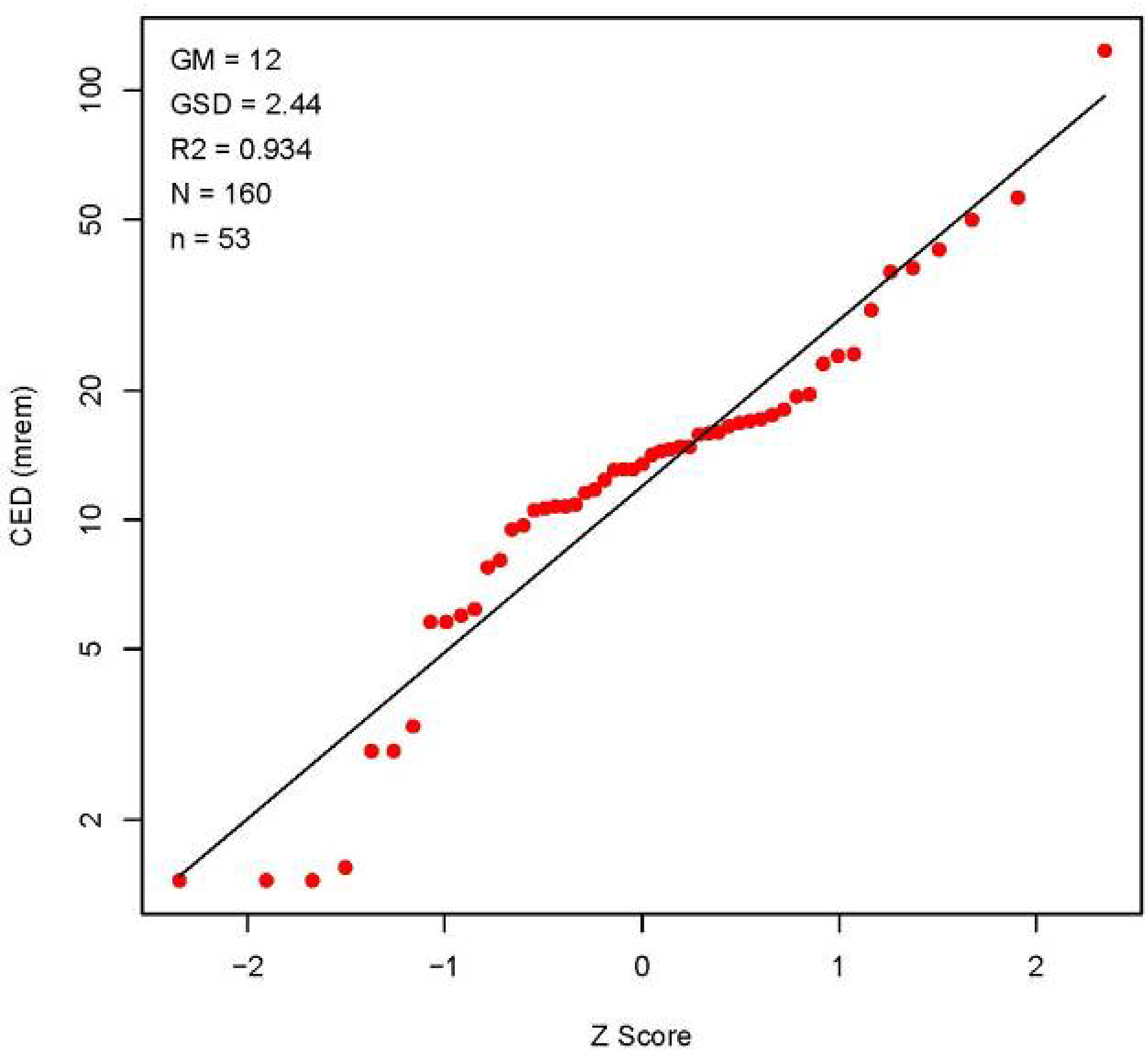

Figure A-5. SRS CTW tritium dose 1955.

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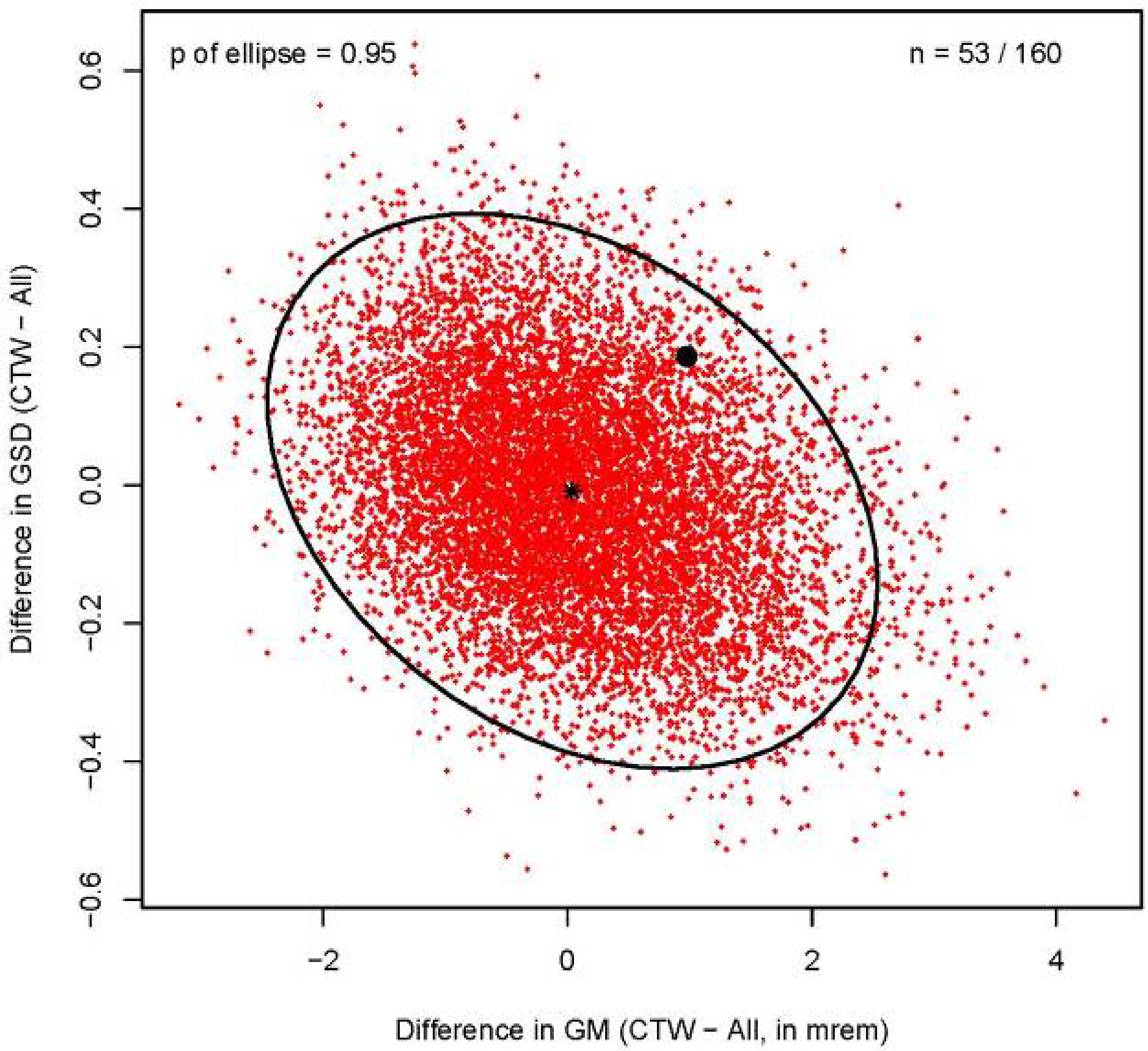

Figure A-6. SRS tritium dose 1955.

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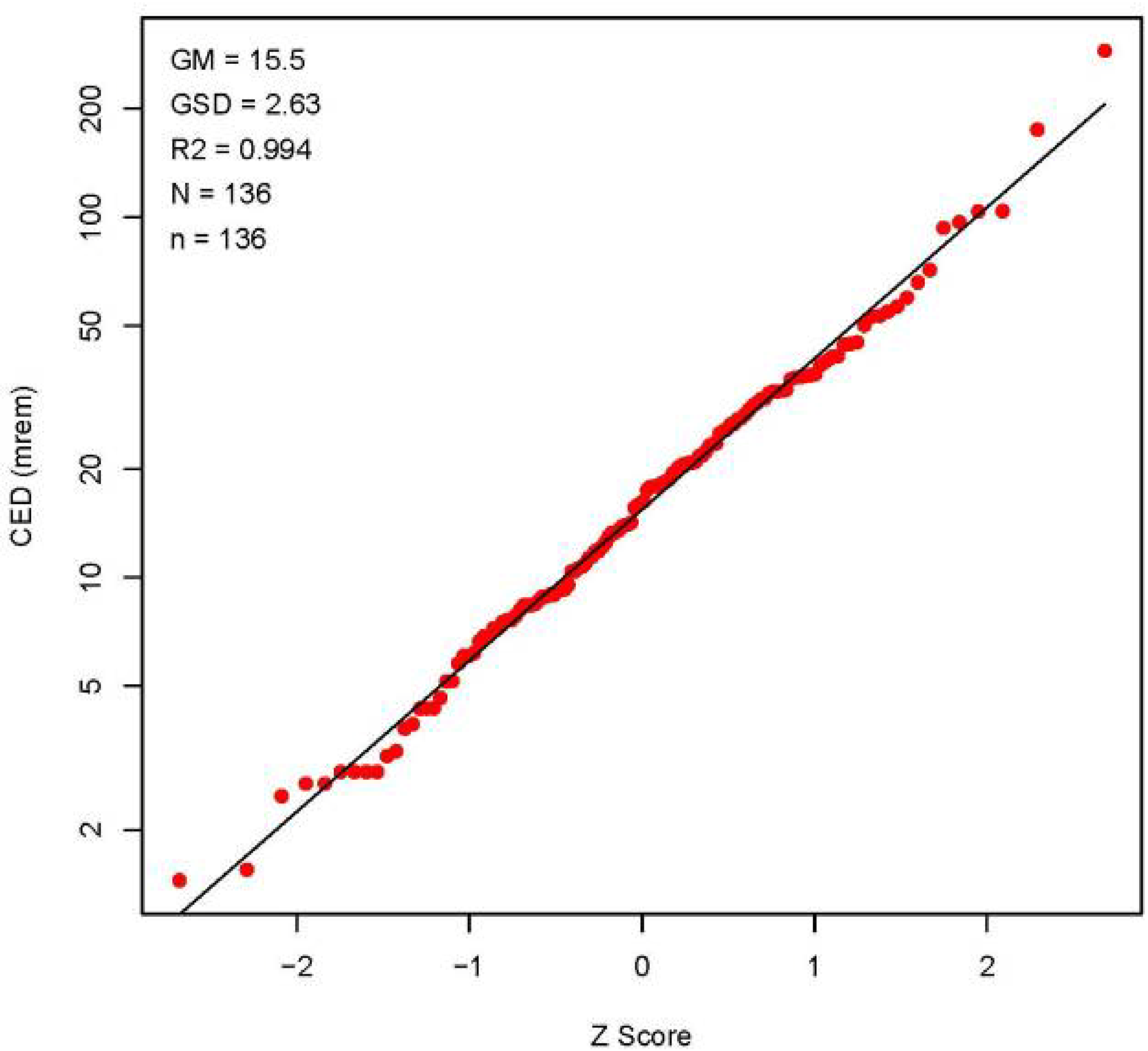

Figure A-7. SRS tritium dose 1956.

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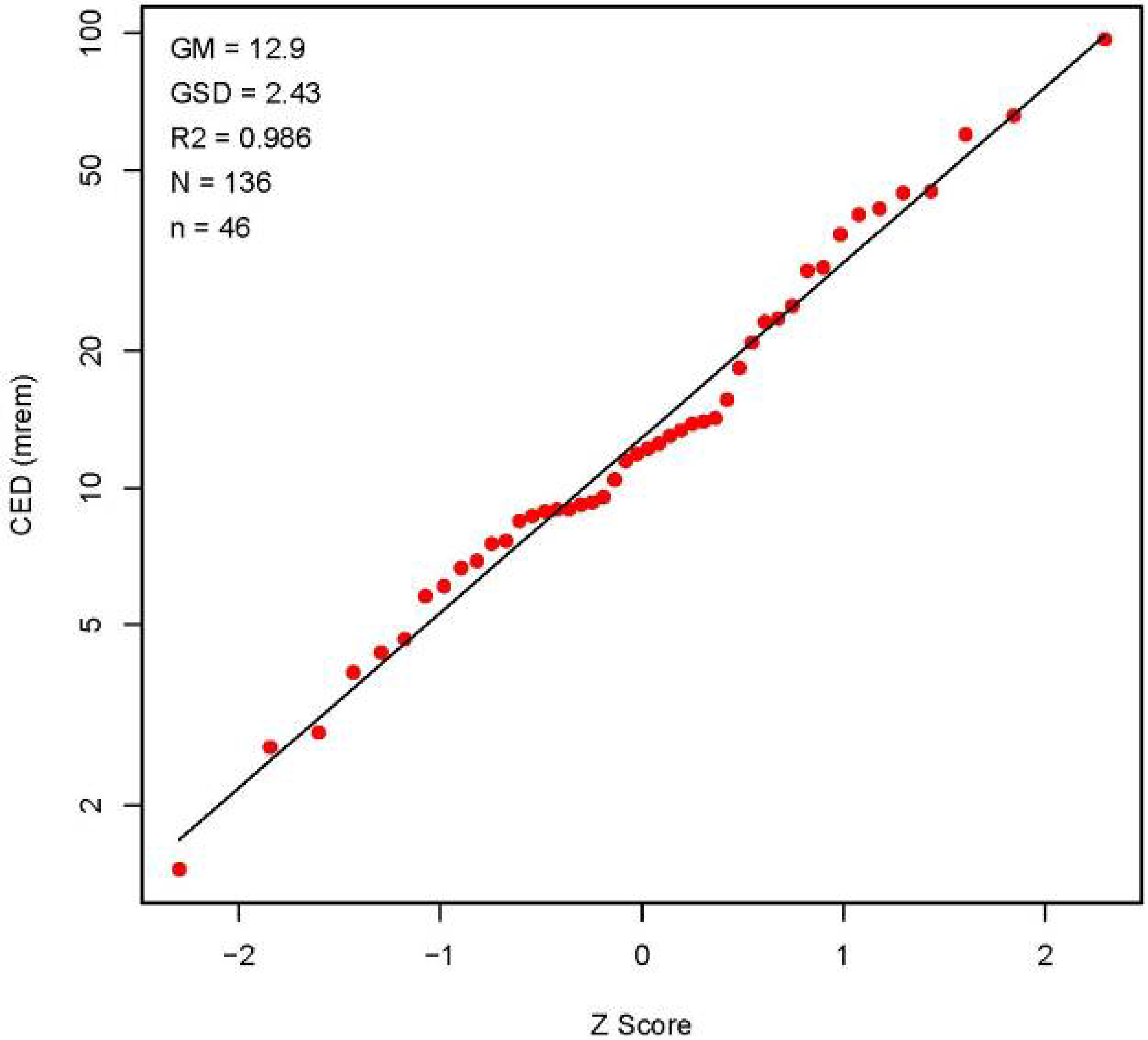

Figure A-8. SRS CTW tritium dose 1956.

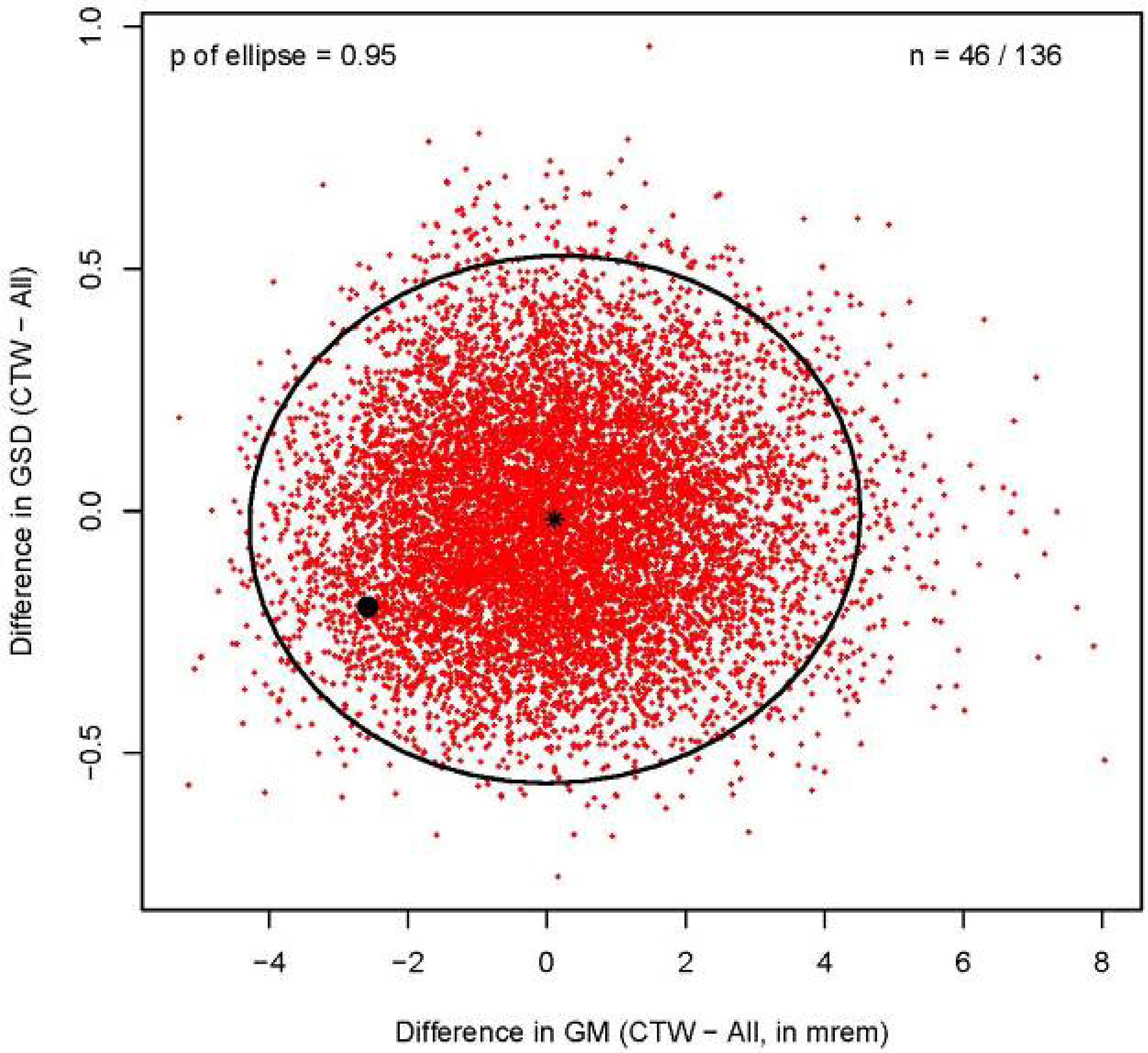

Figure A-9. SRS tritium dose 1956.

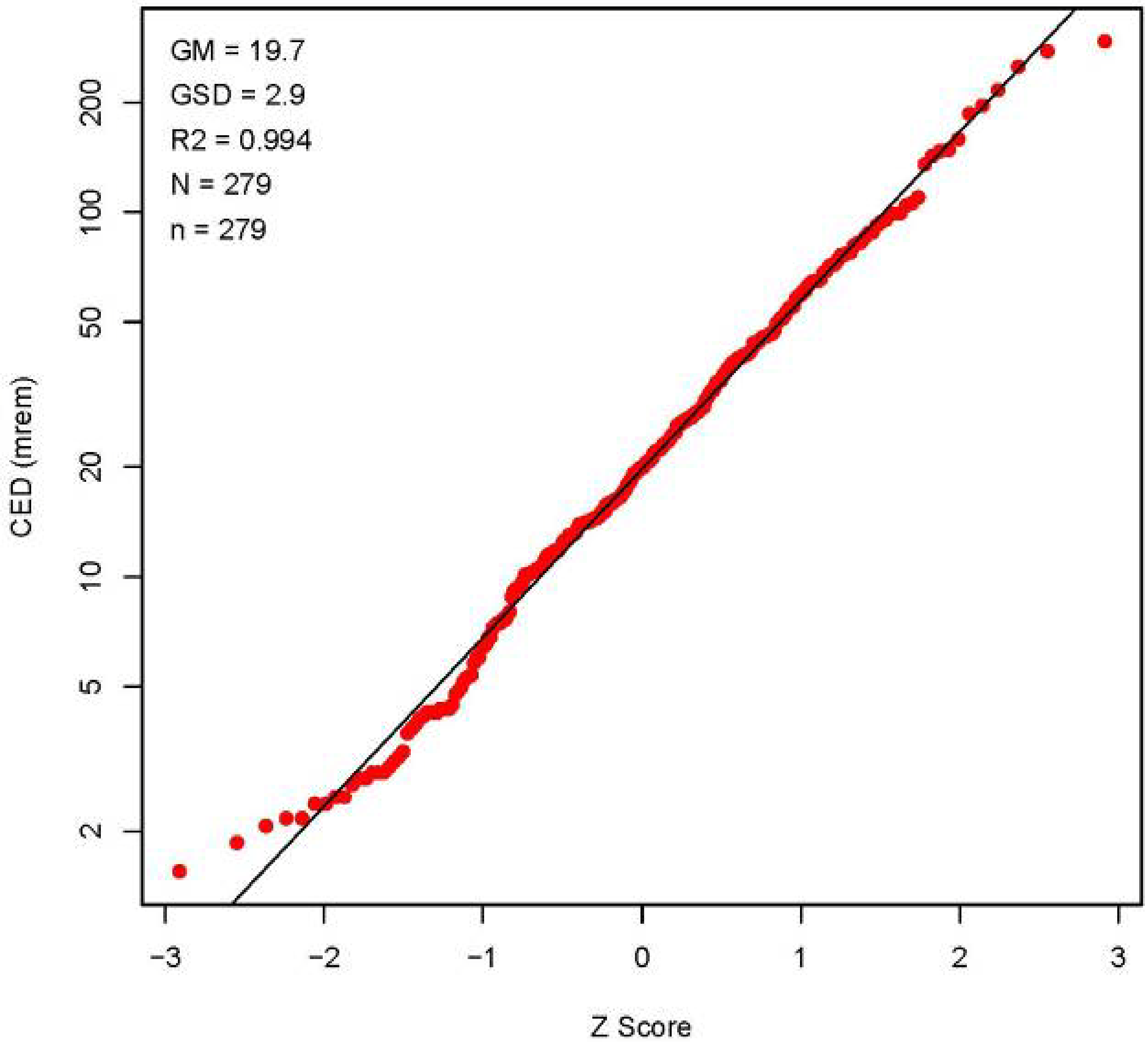

Figure A-10. SRS Tritium dose 1957.

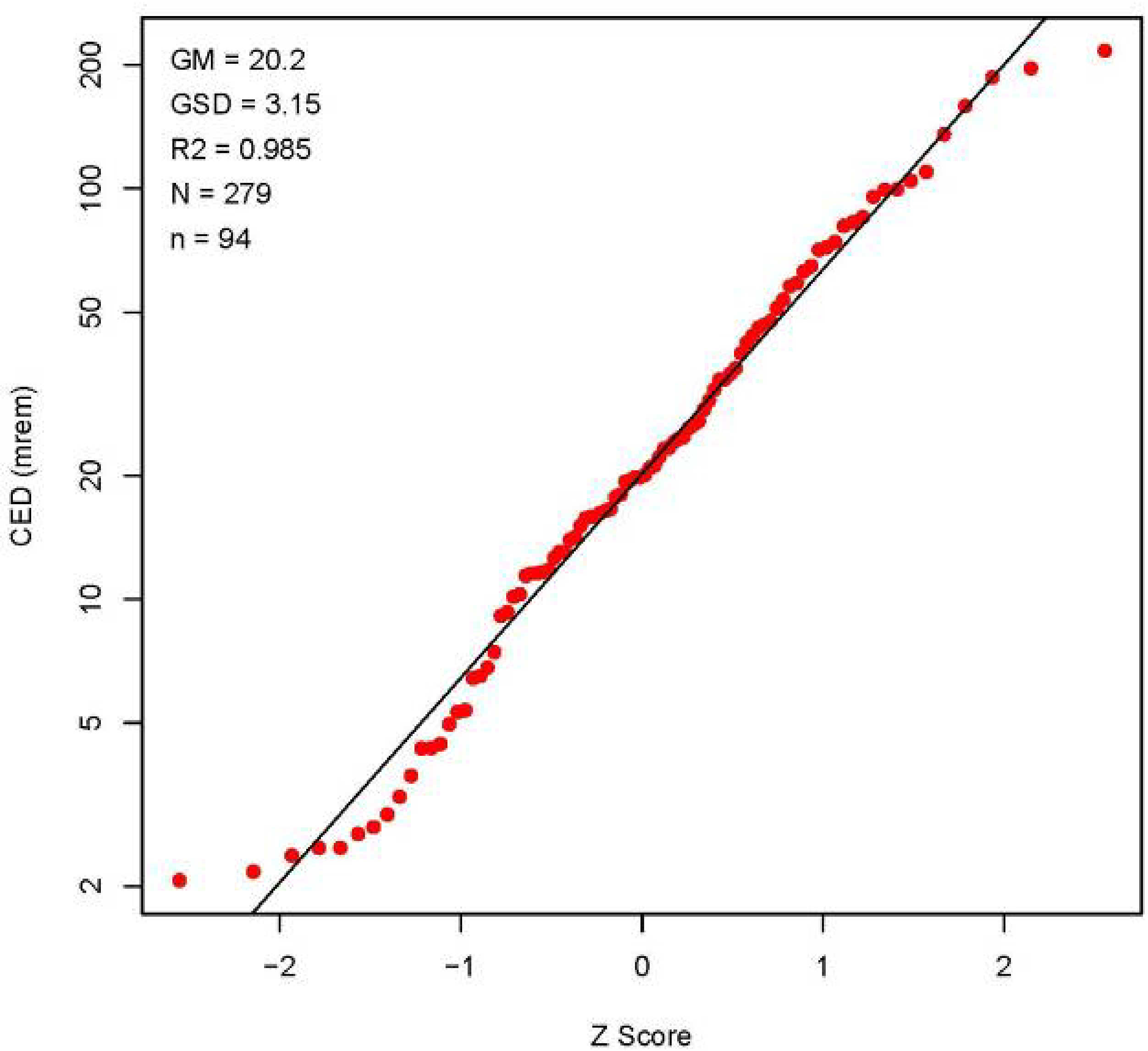

Figure A-11. SRS CTW tritium dose 1957.

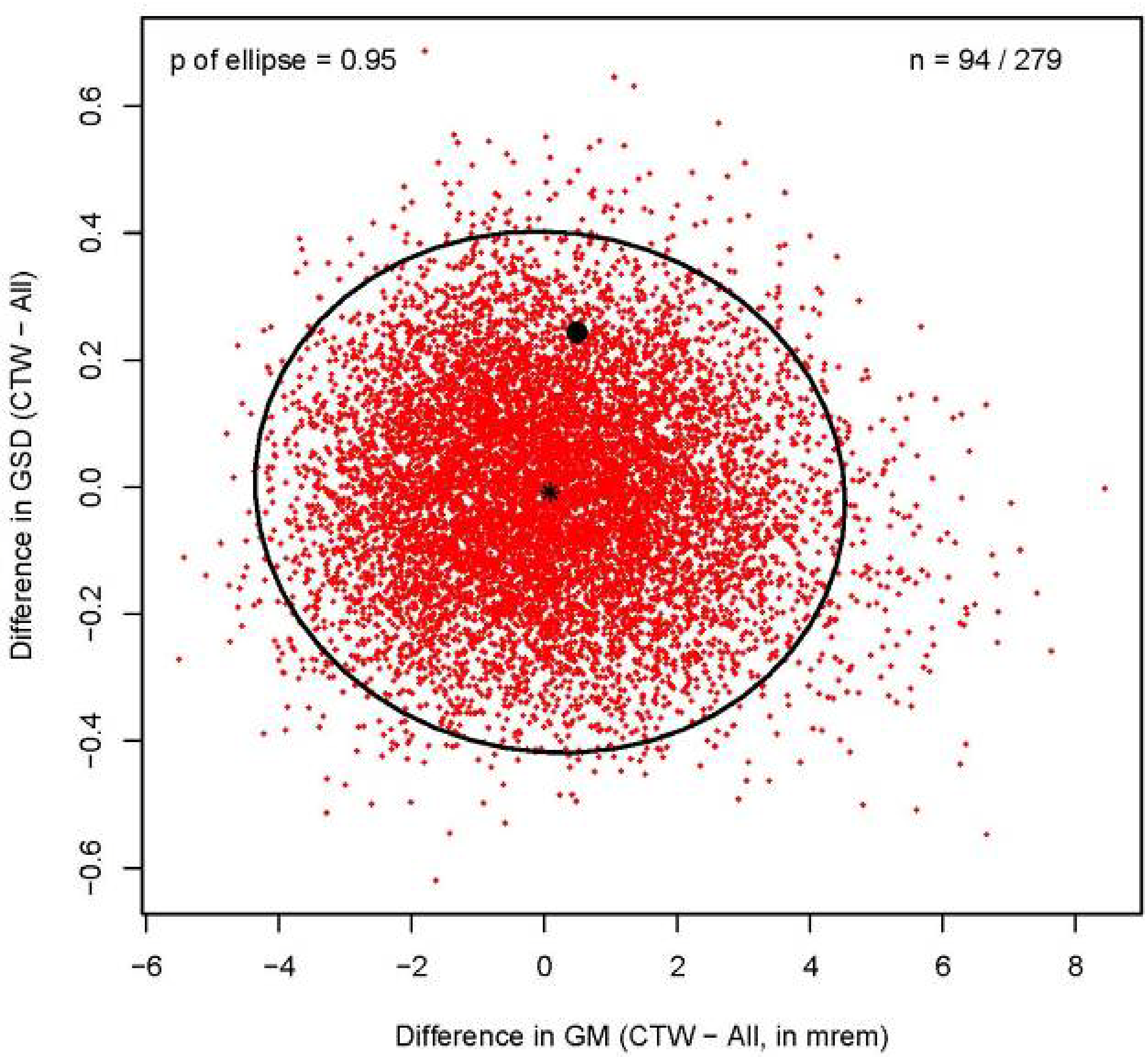

Figure A-12. SRS tritium dose 1957.

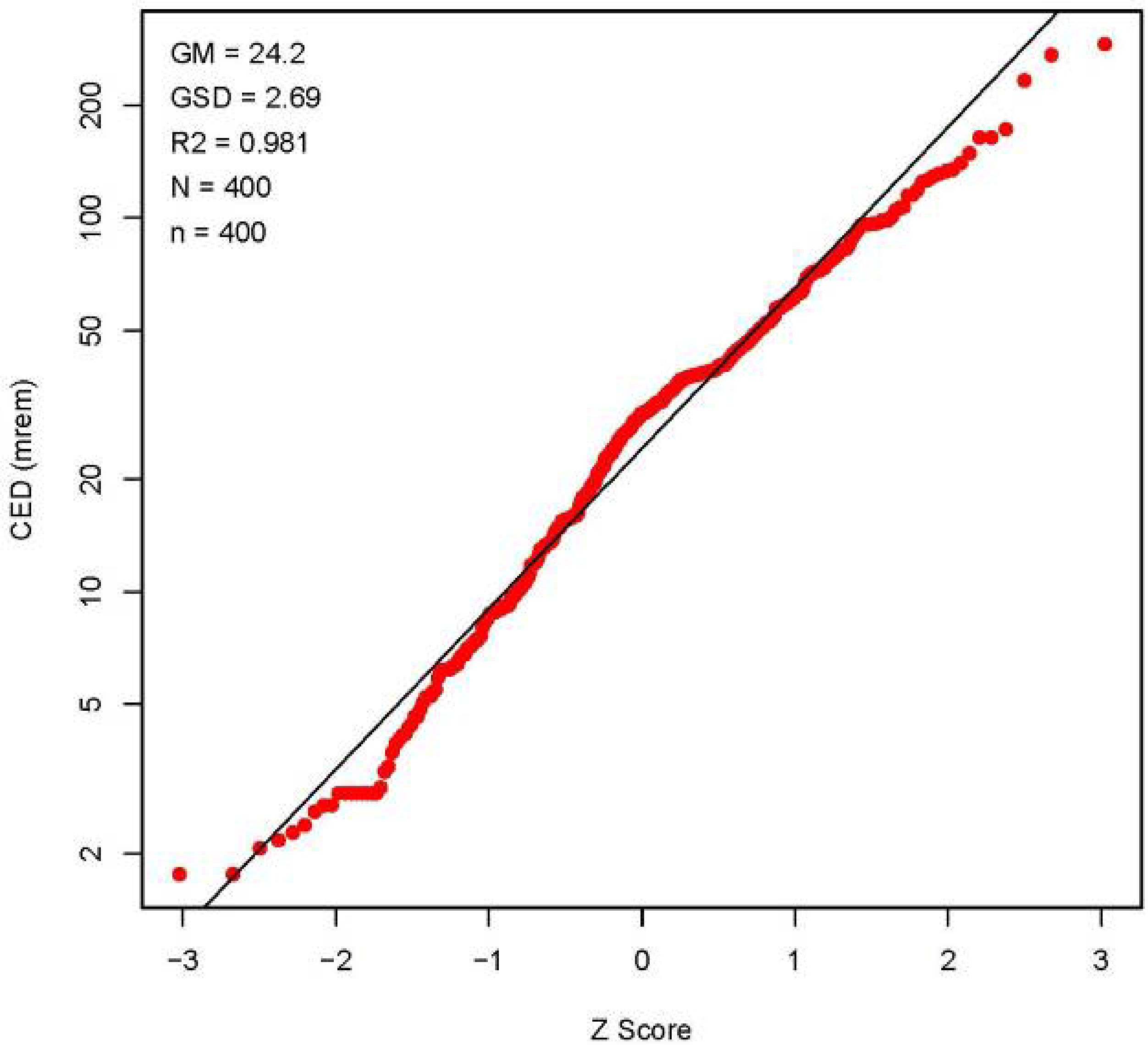

Figure A-13. SRS tritium dose 1958.

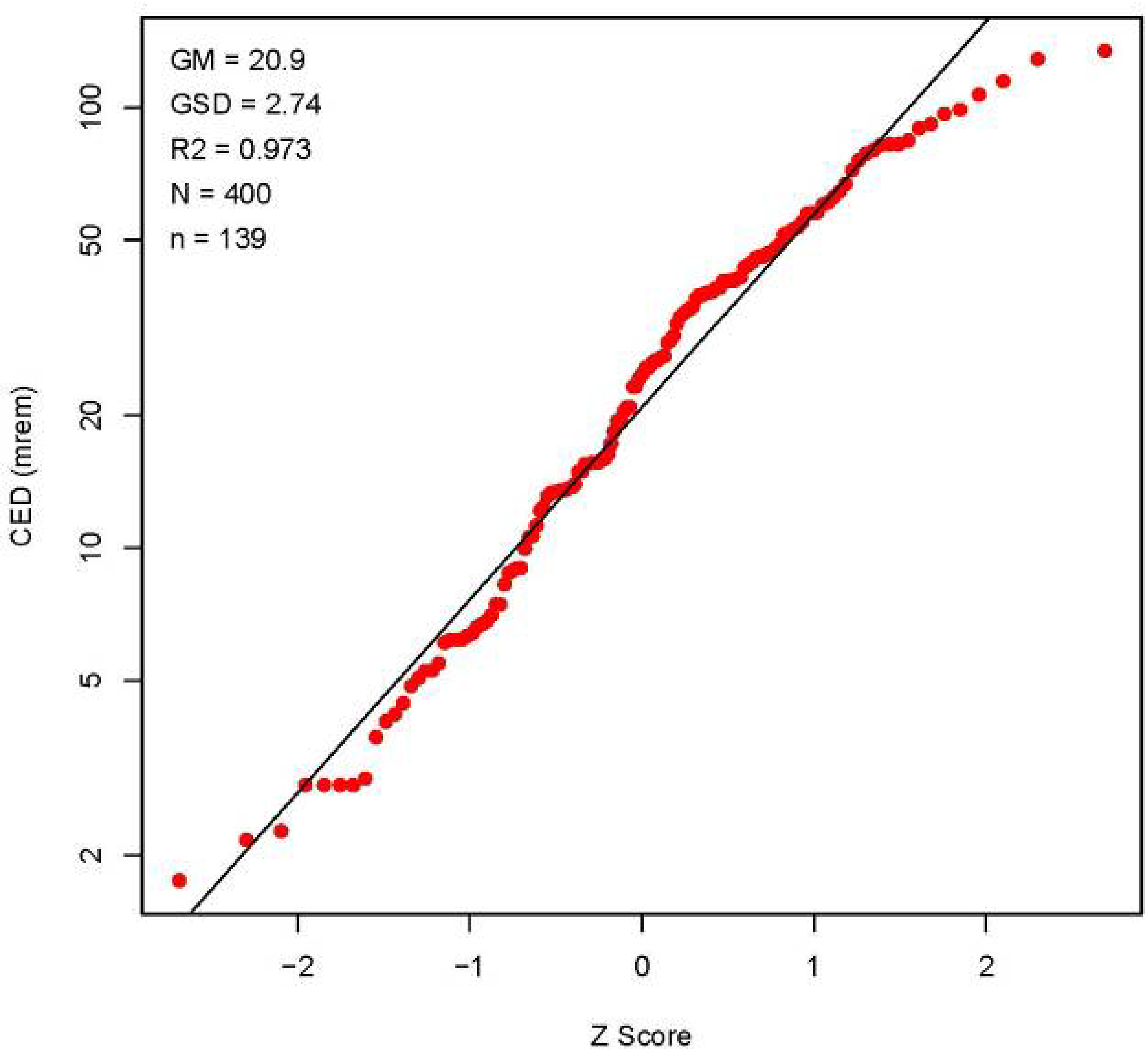

Figure A-14. SRS CTW tritium dose 1958.

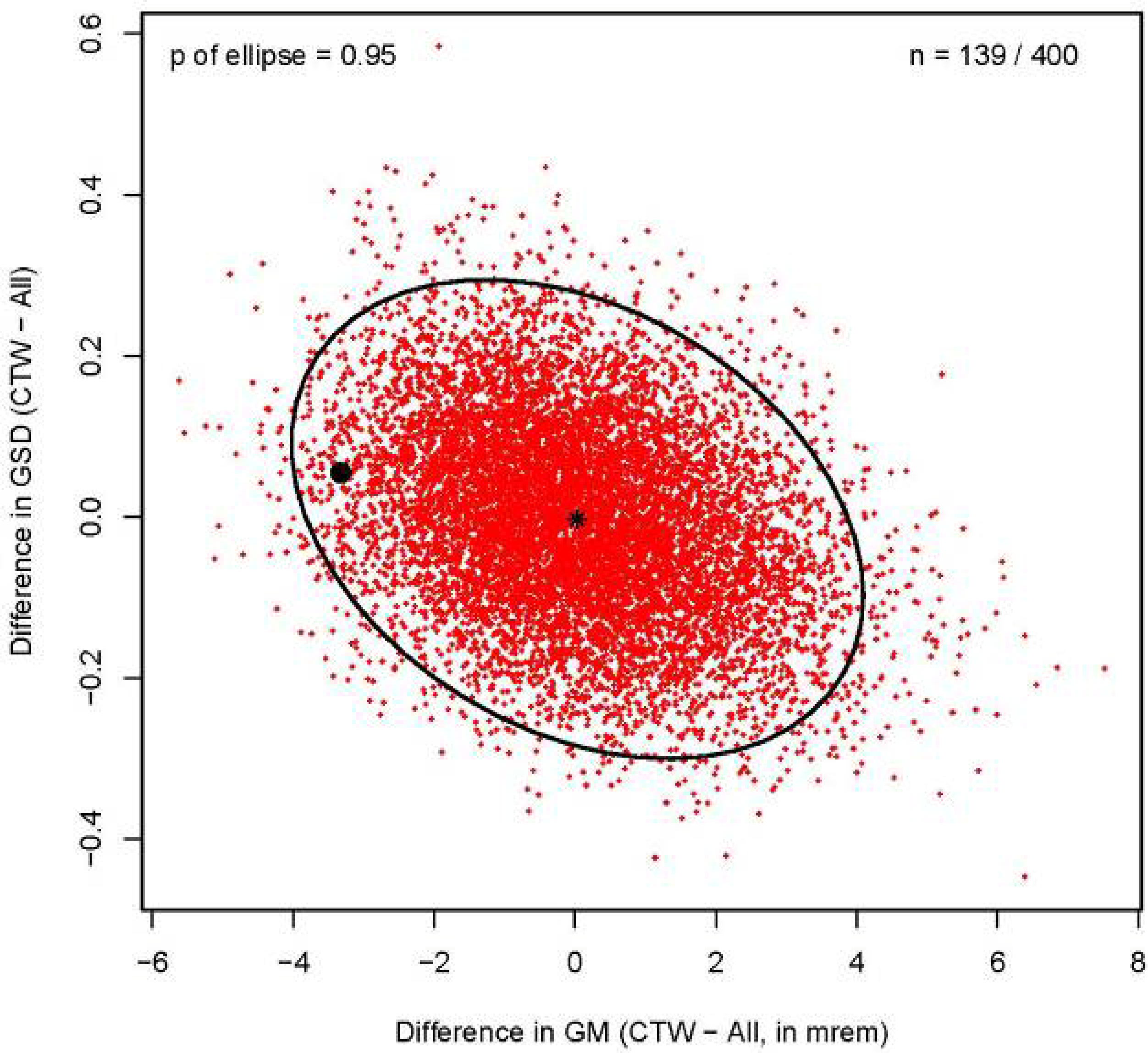

Figure A-15. SRS tritium dose 1958.

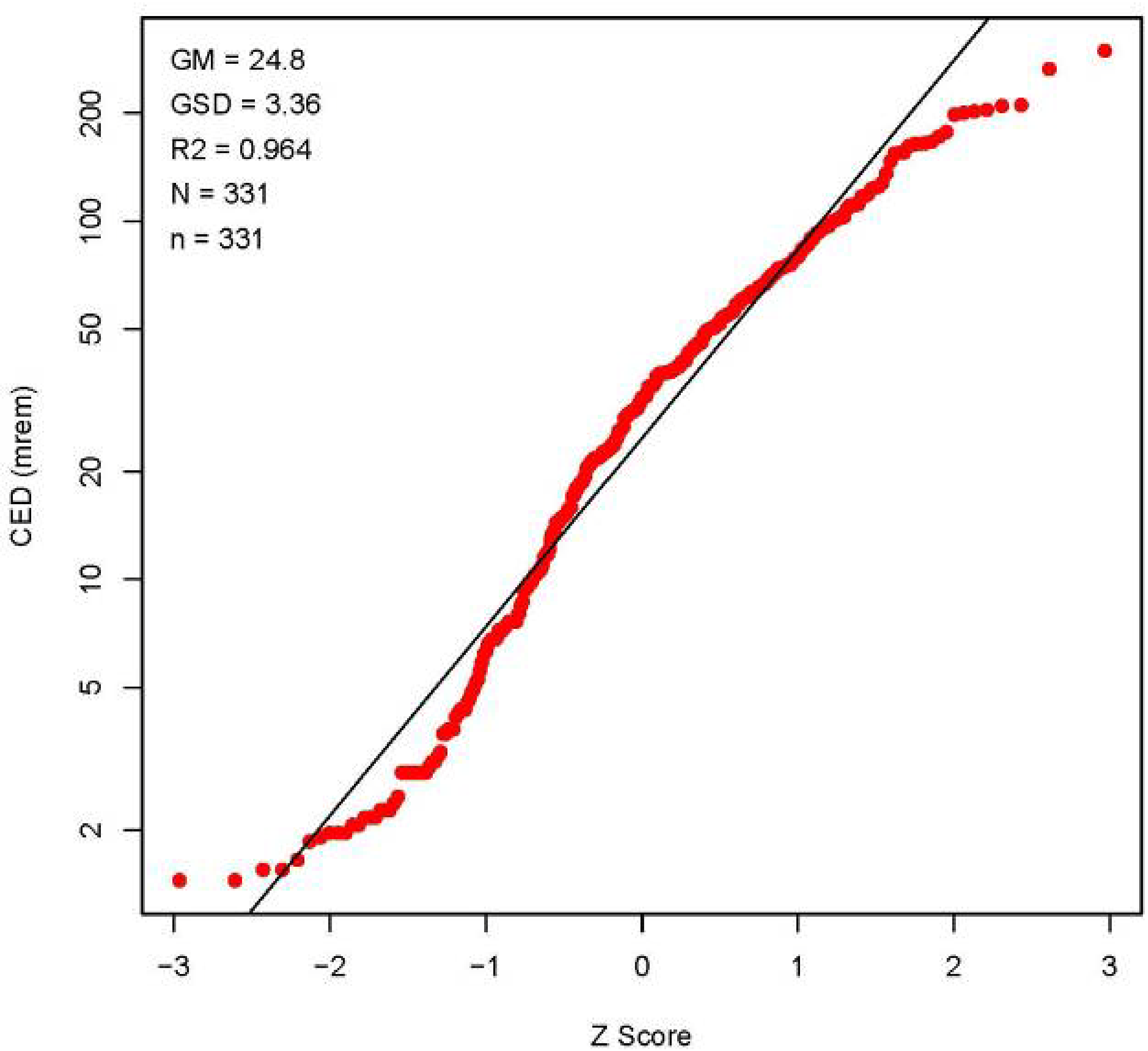

Figure A-16. SRS tritium dose 1959.

ATTACHMENT A
COMPARISON OF CTW TO CS

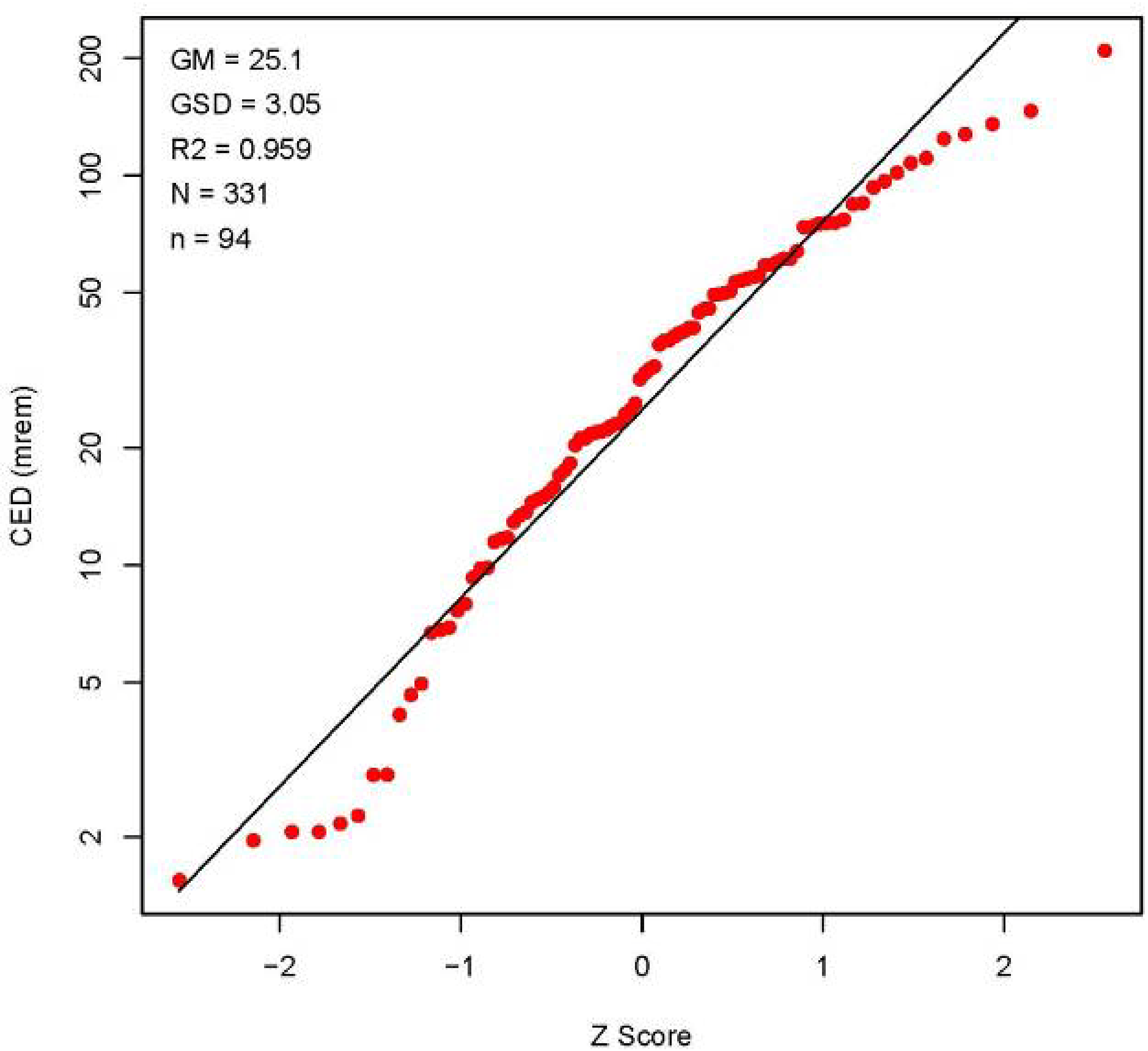

Figure A-17. SRS CTW tritium dose 1959.

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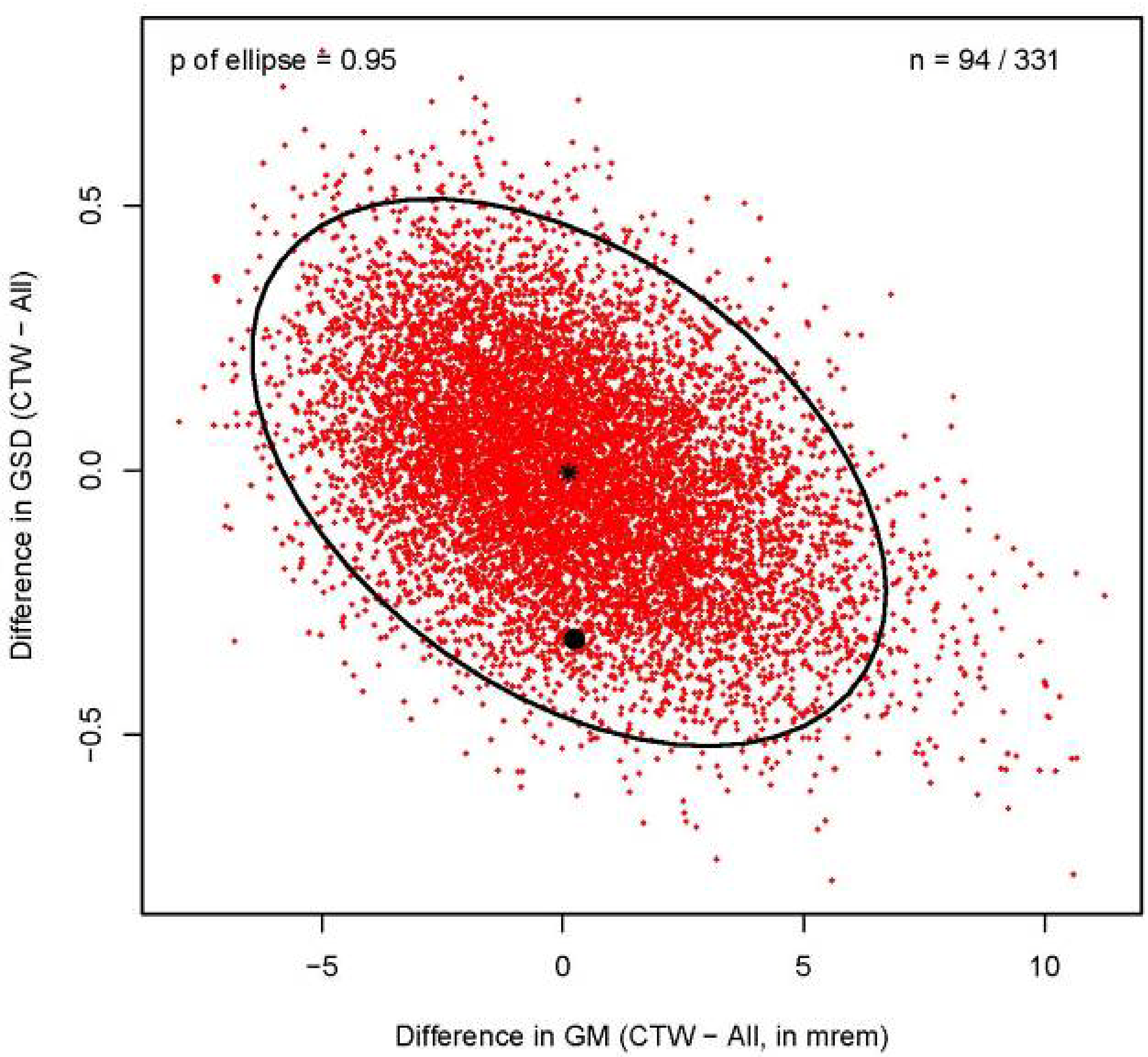

Figure A-18. SRS tritium dose 1959.

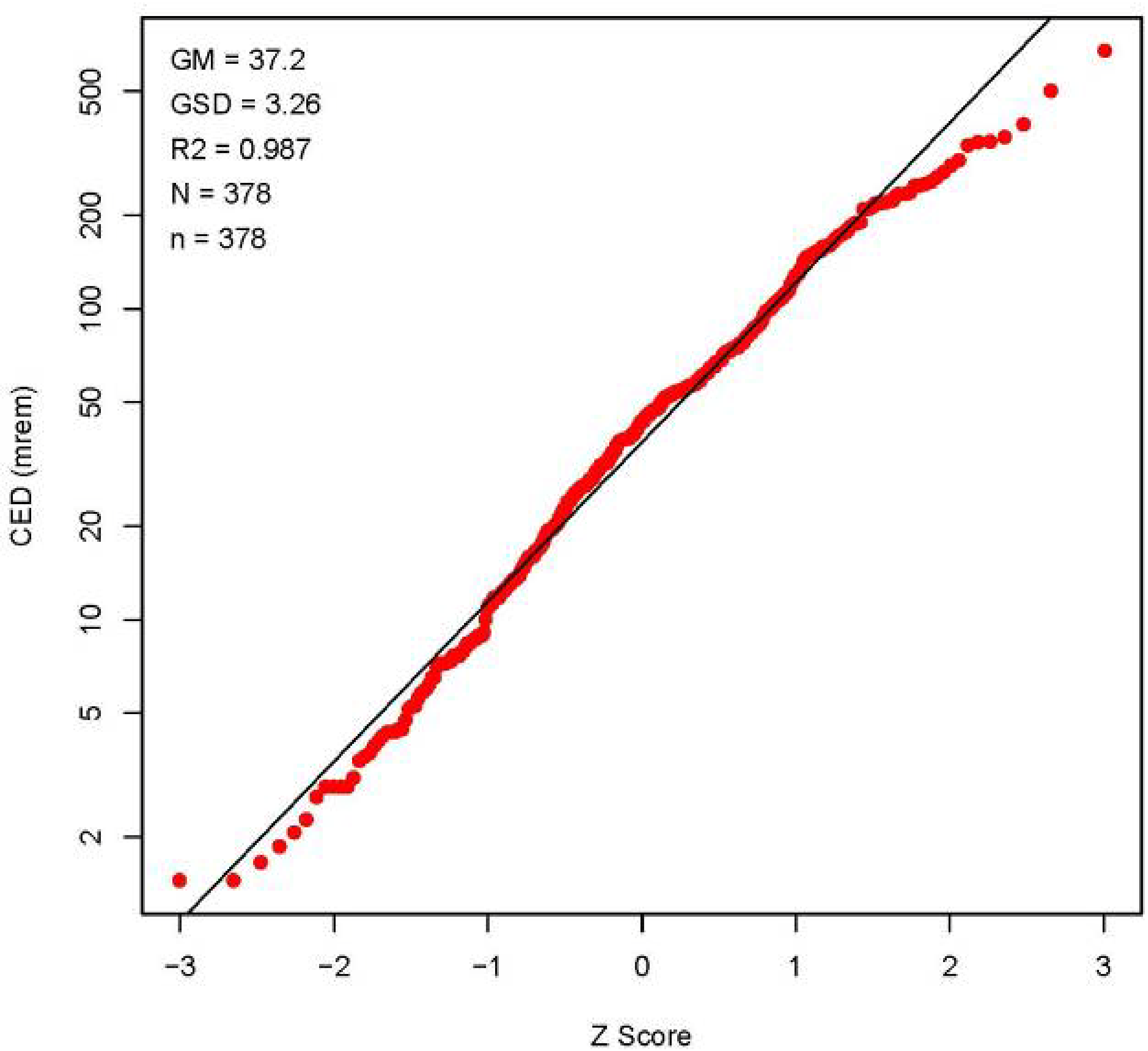

Figure A-19. SRS tritium dose 1960.

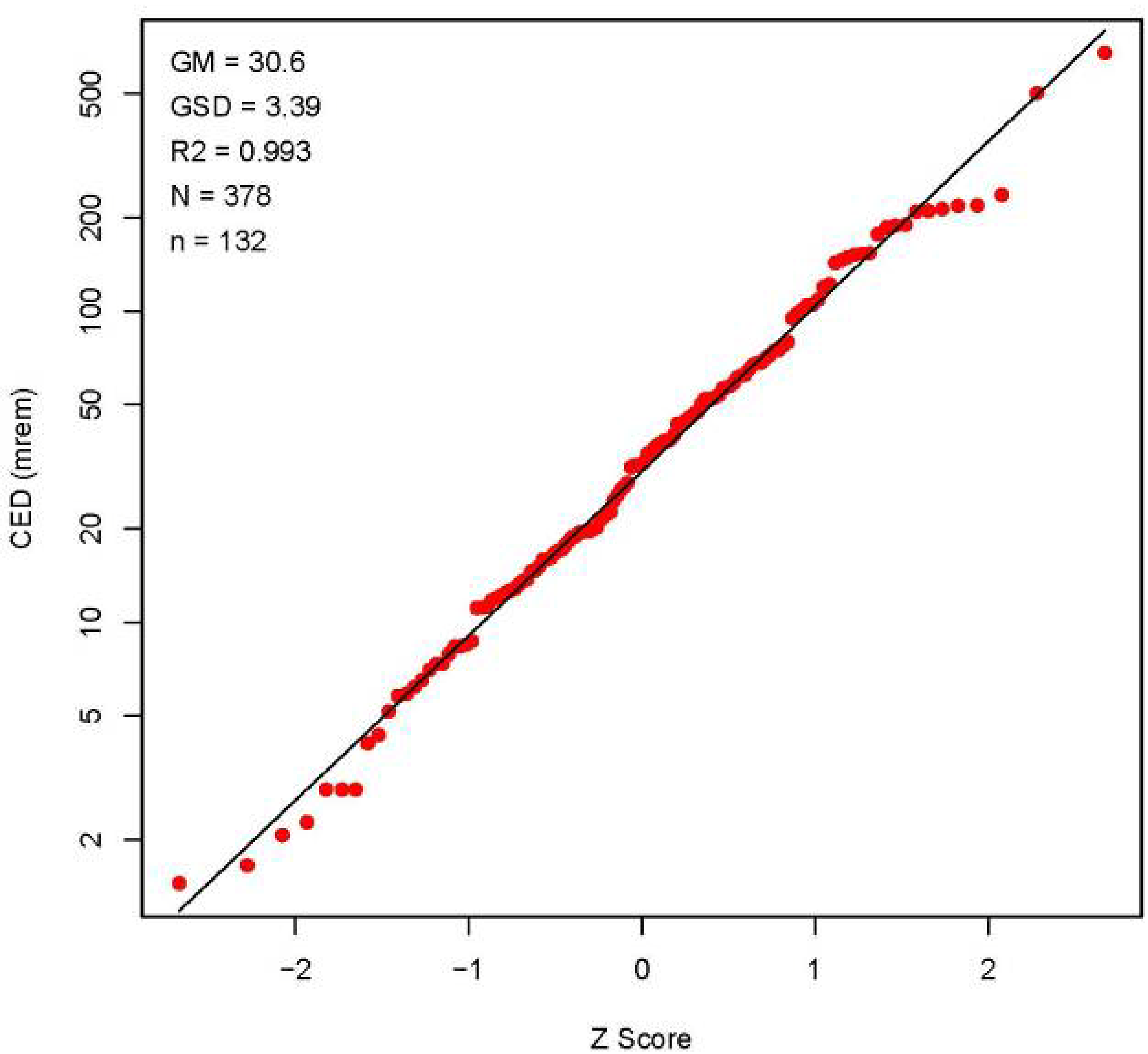

Figure A-20. SRS CTW tritium dose 1960.

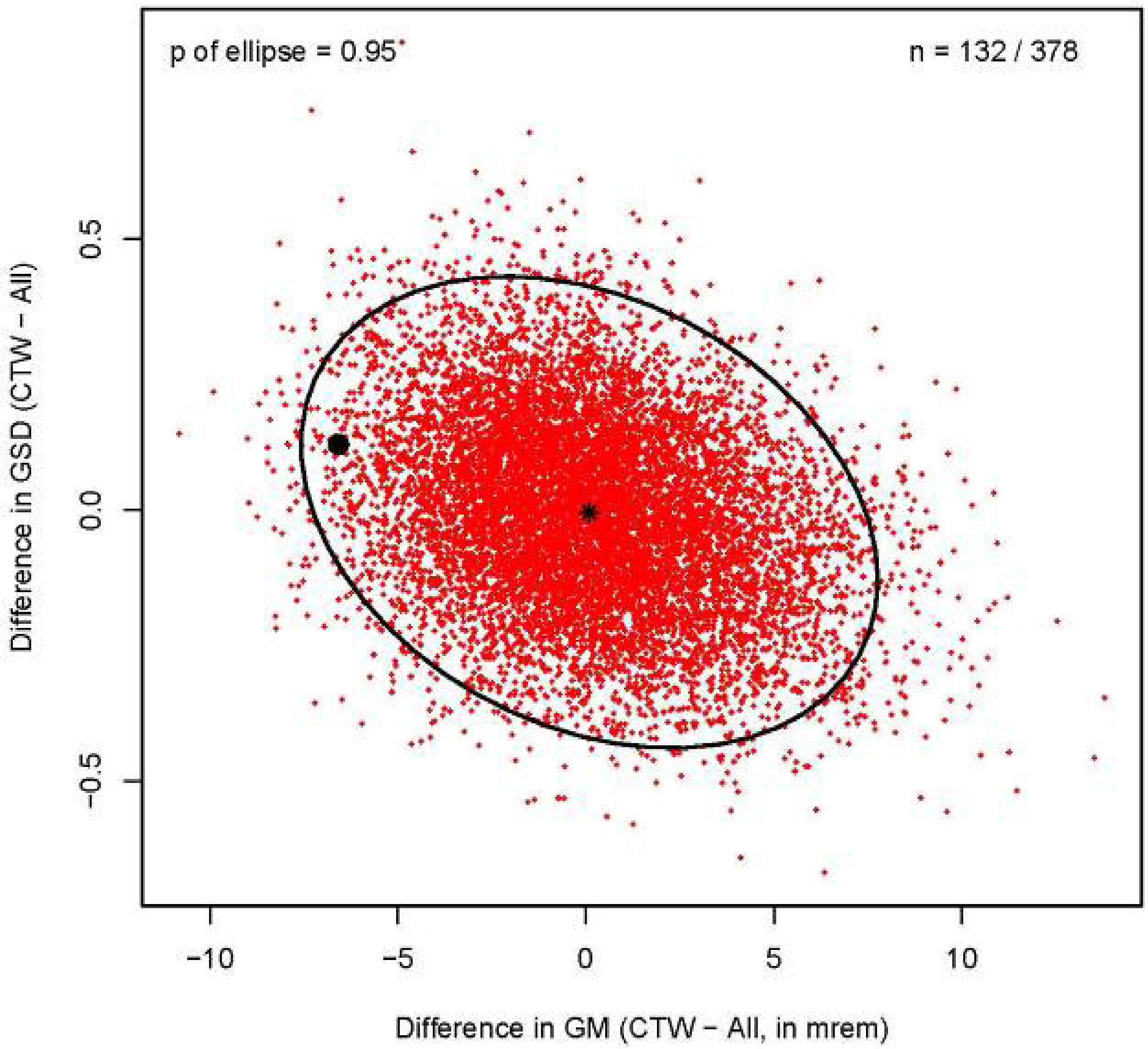

Figure A-21. SRS tritium dose 1960.

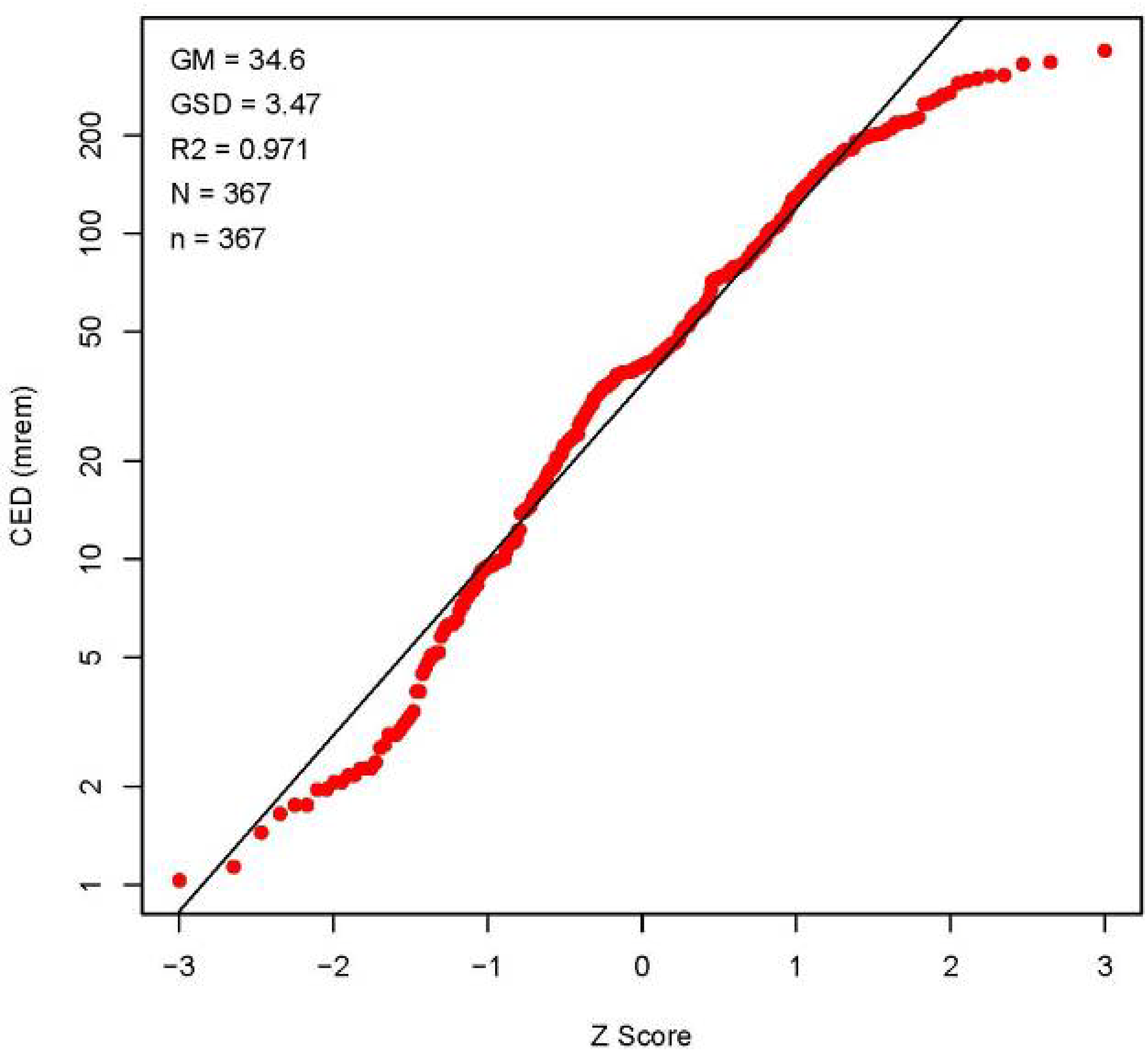

Figure A-22. SRS tritium dose 1961.

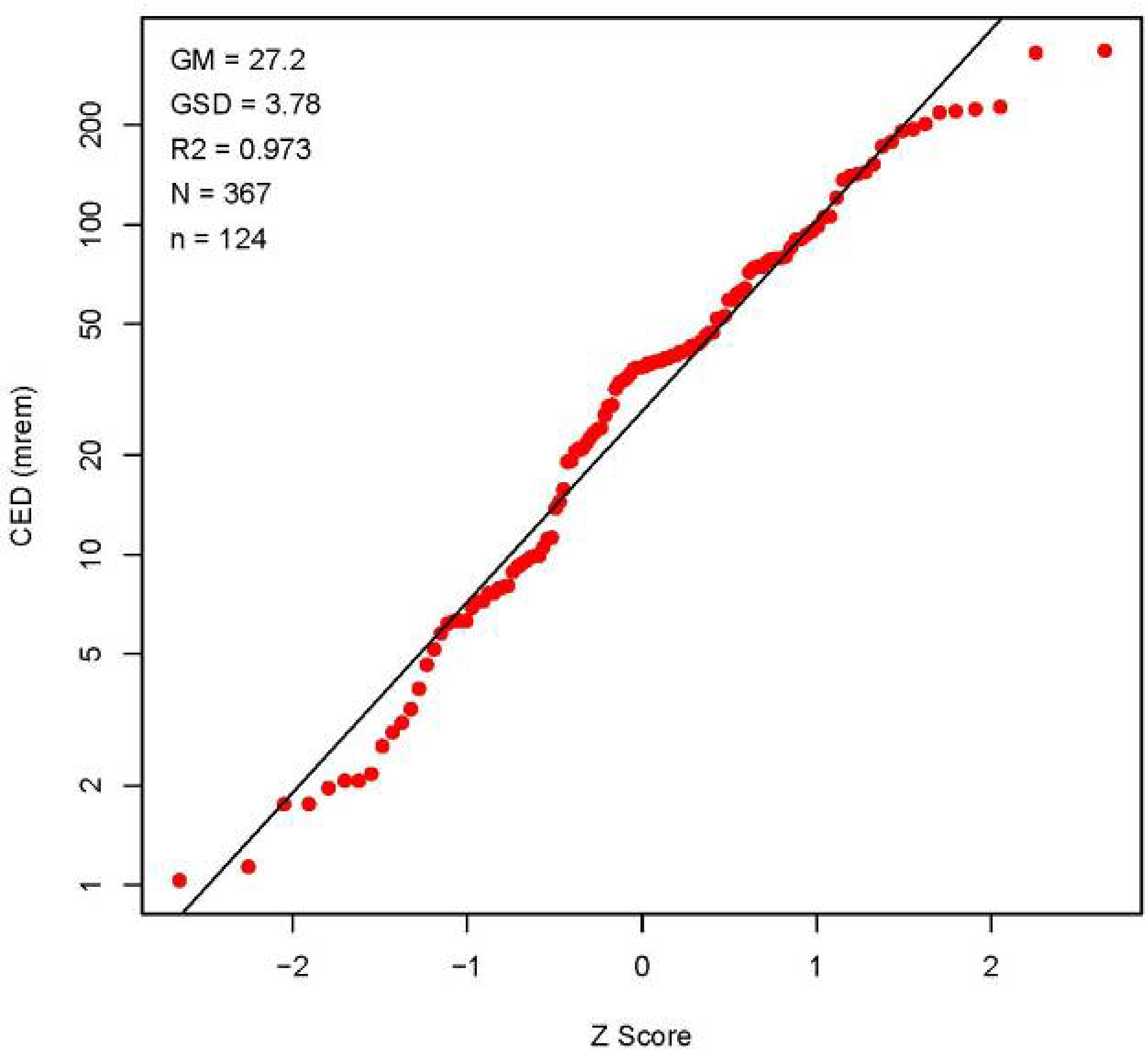

Figure A-23. SRS CTW tritium dose 1961.

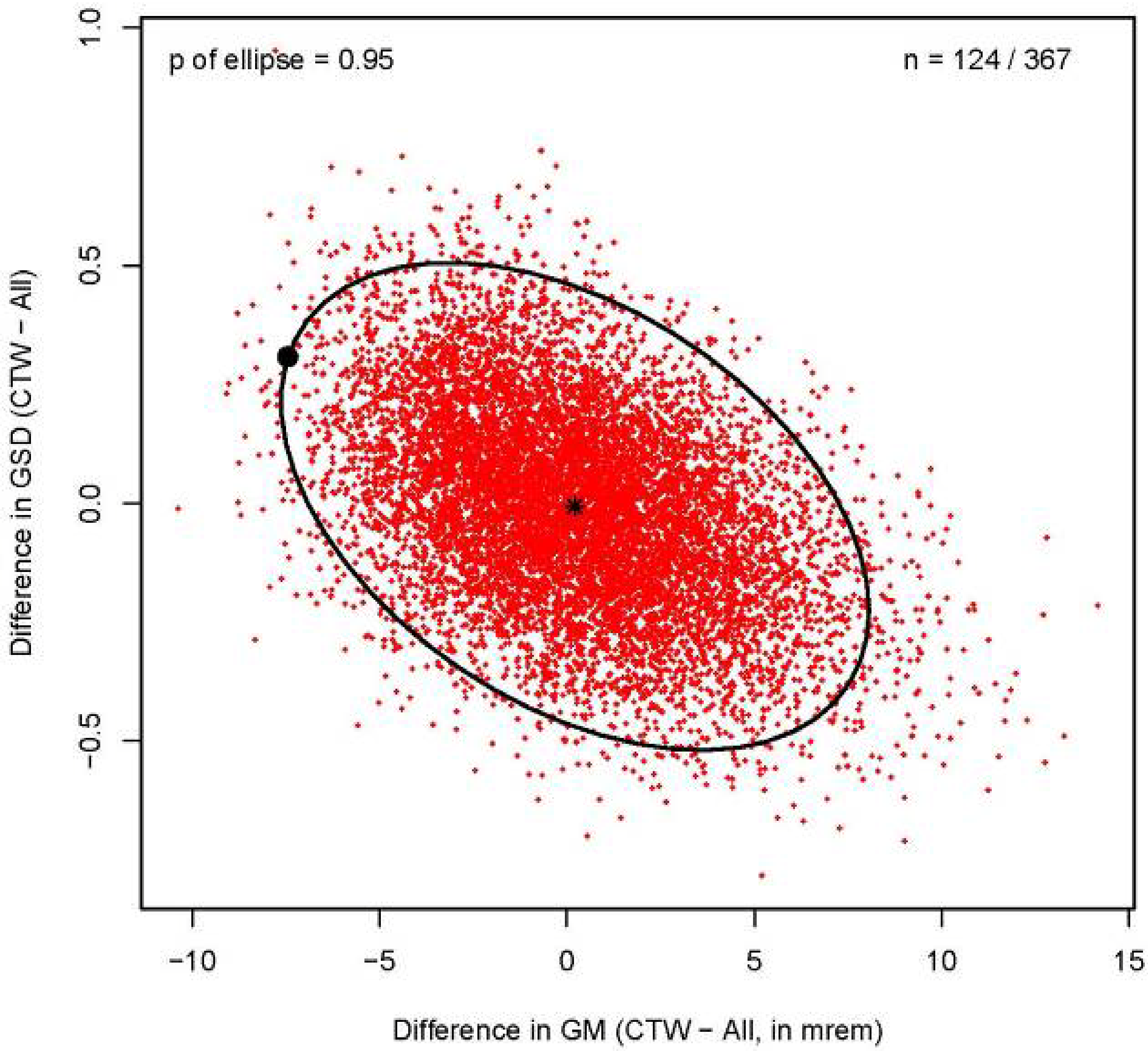

Figure A-24. SRS tritium dose 1961.

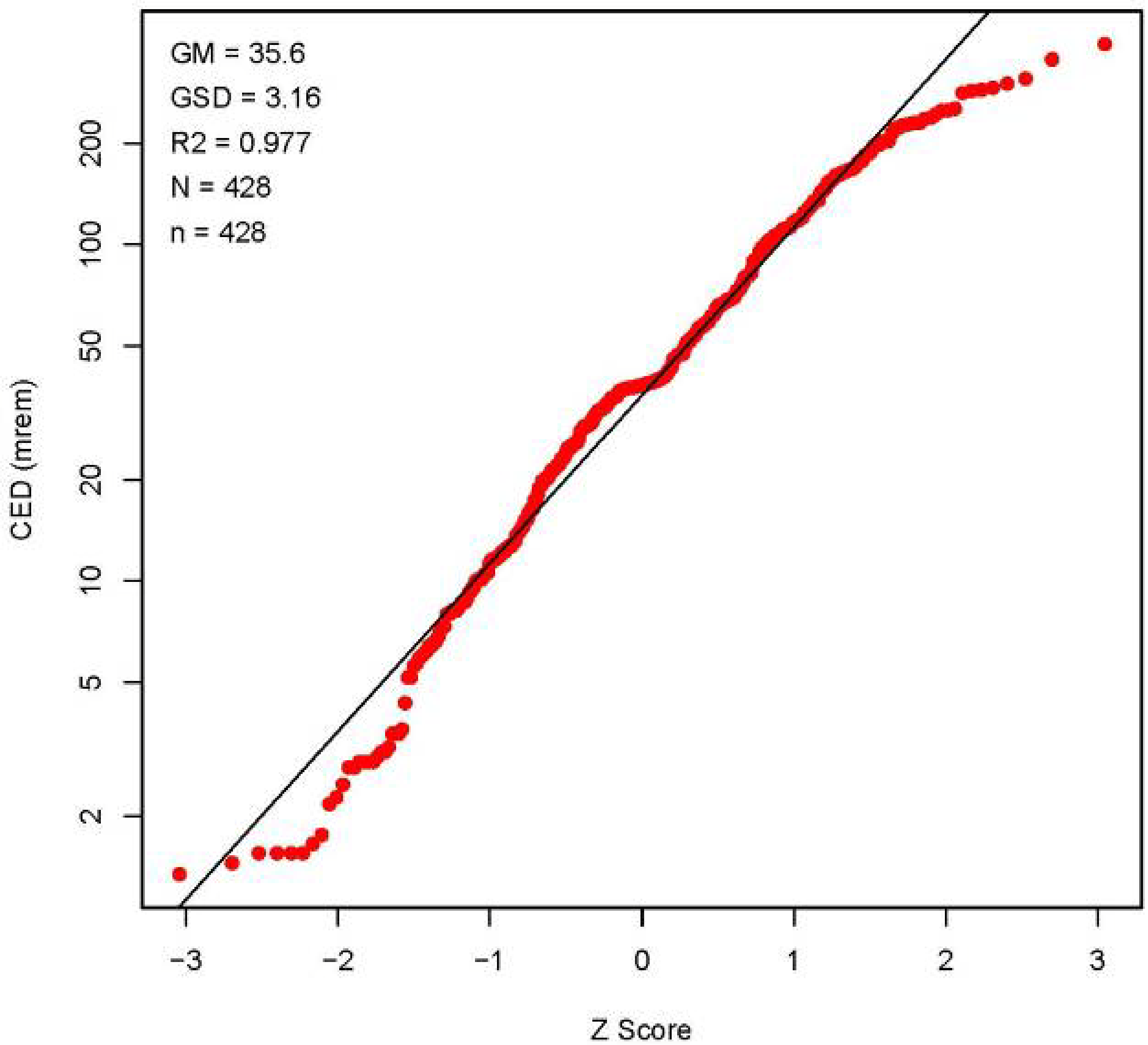

Figure A-25. SRS tritium dose 1962.

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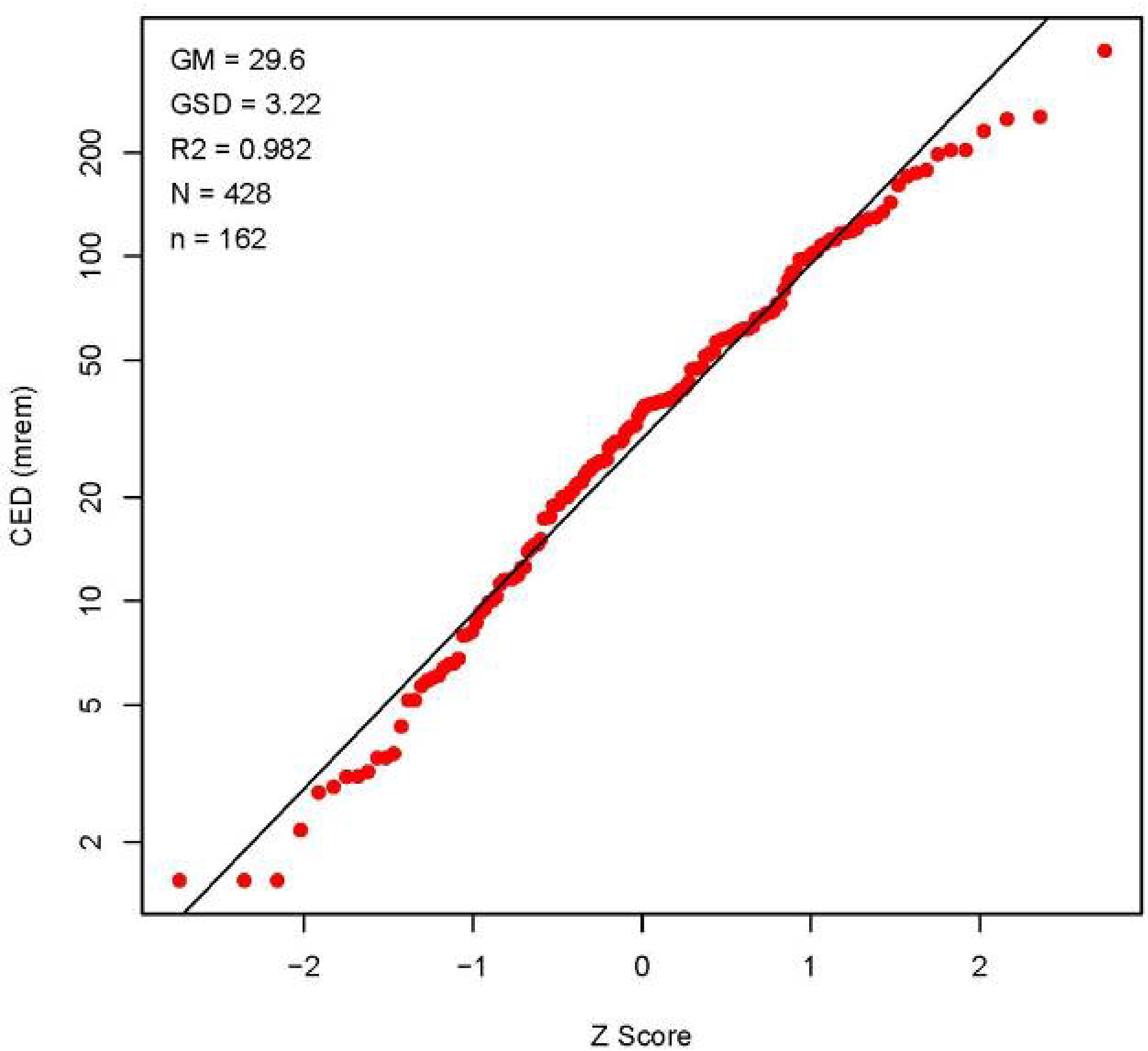

Figure A-26. SRS CTW tritium dose 1962.

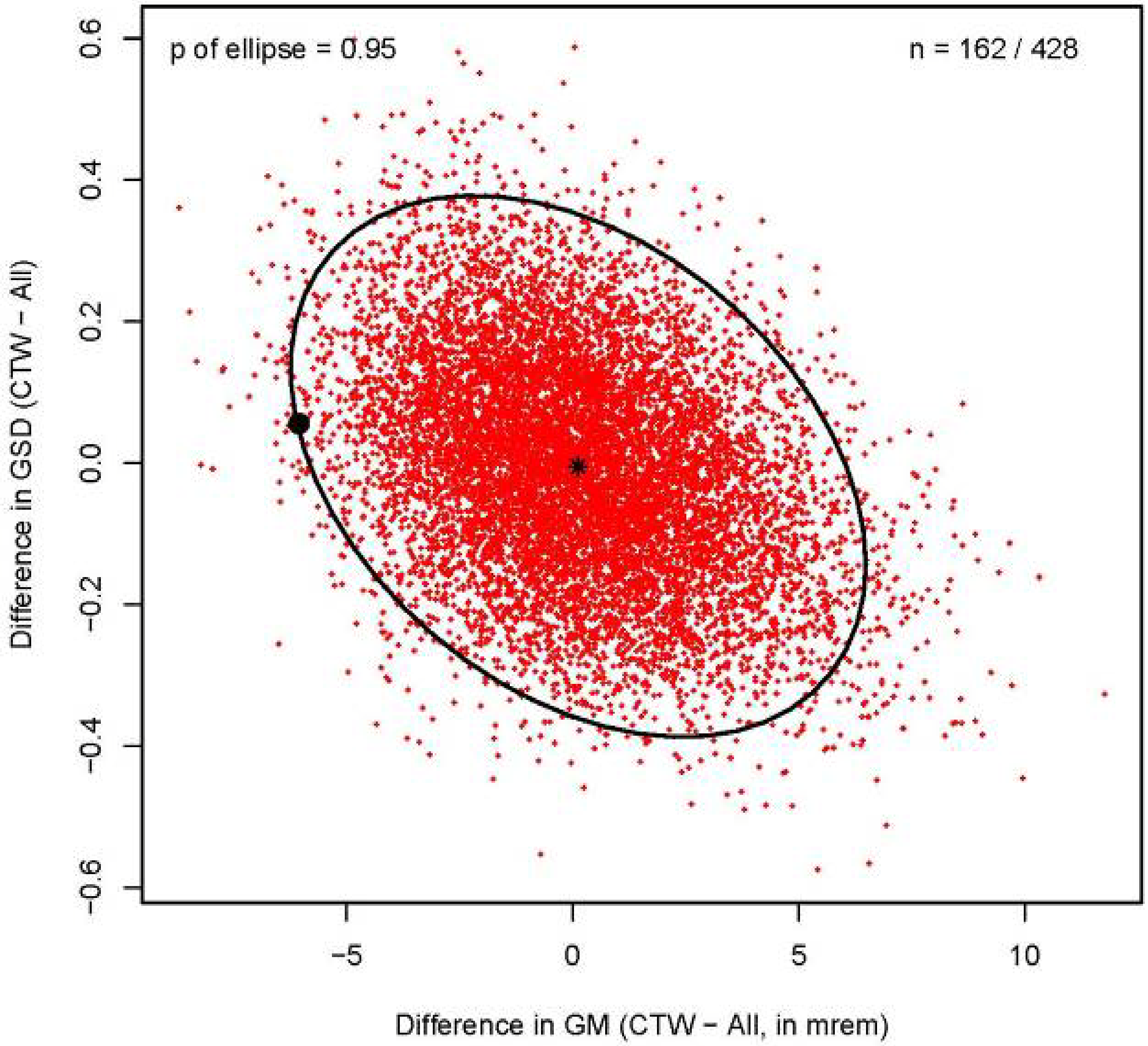

Figure A-27. SRS tritium dose 1962.

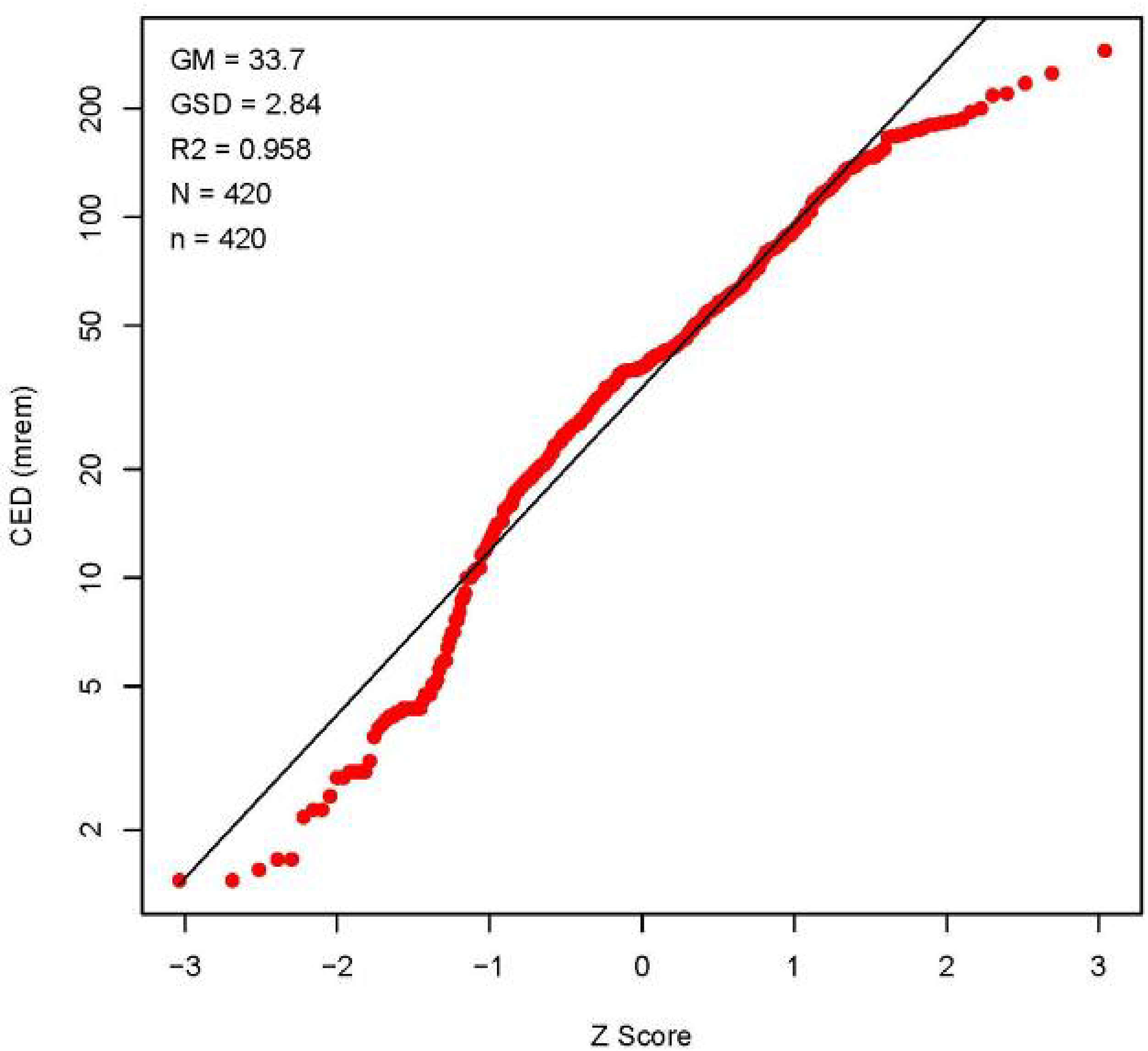

Figure A-28. SRS tritium dose 1963.

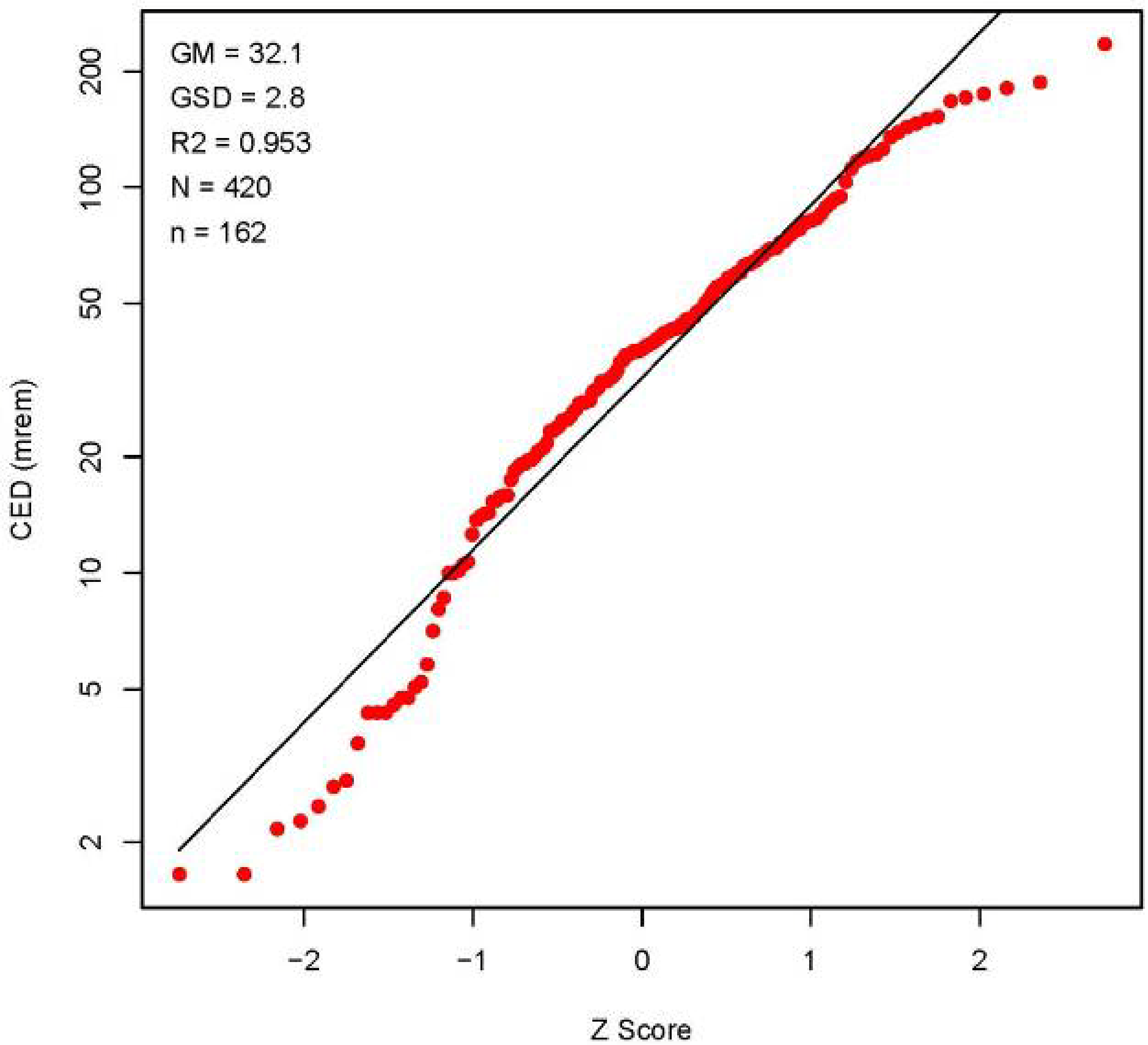

Figure A-29. SRS CTW tritium dose 1963.

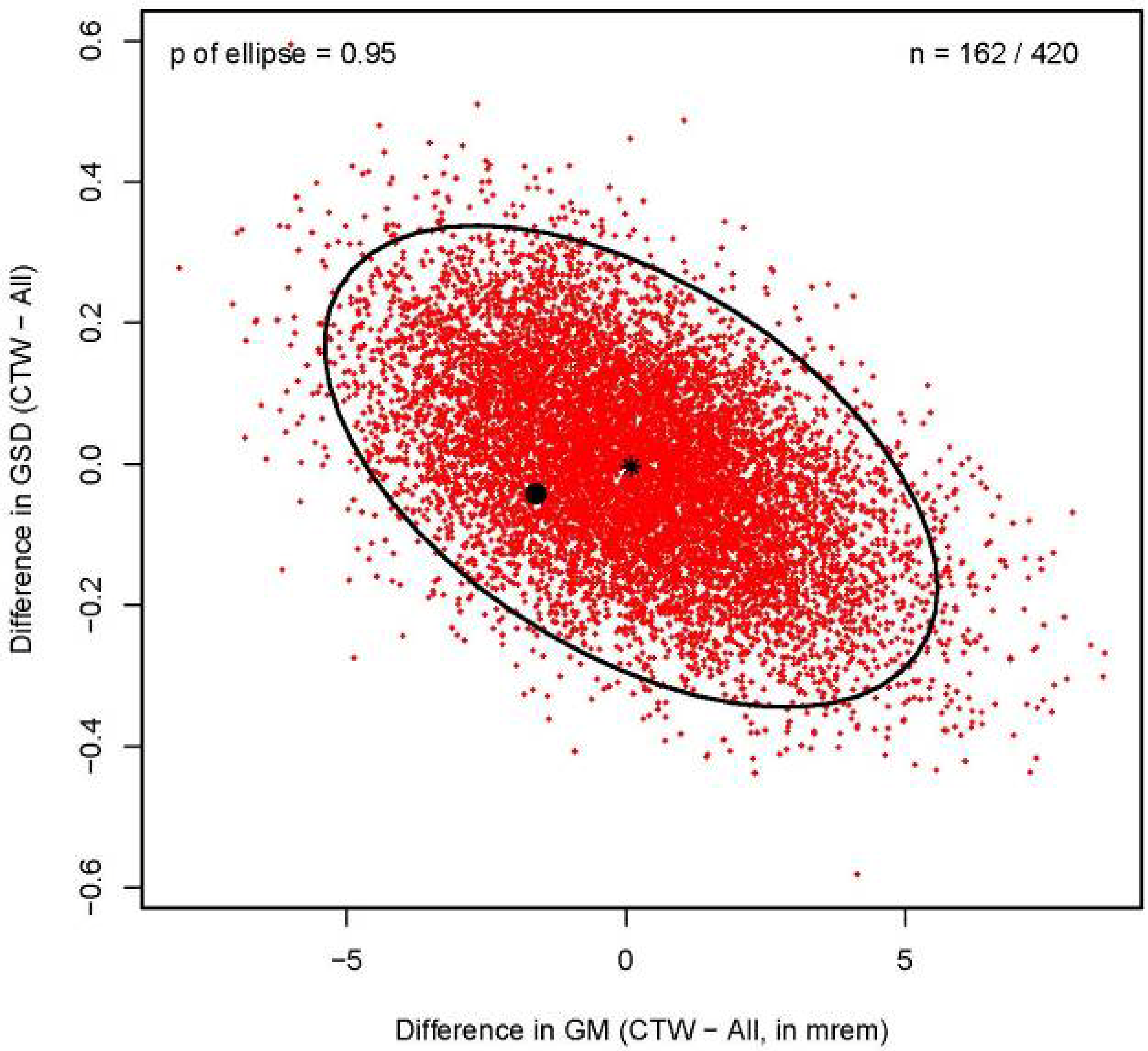

Figure A-30. SRS tritium dose 1963.

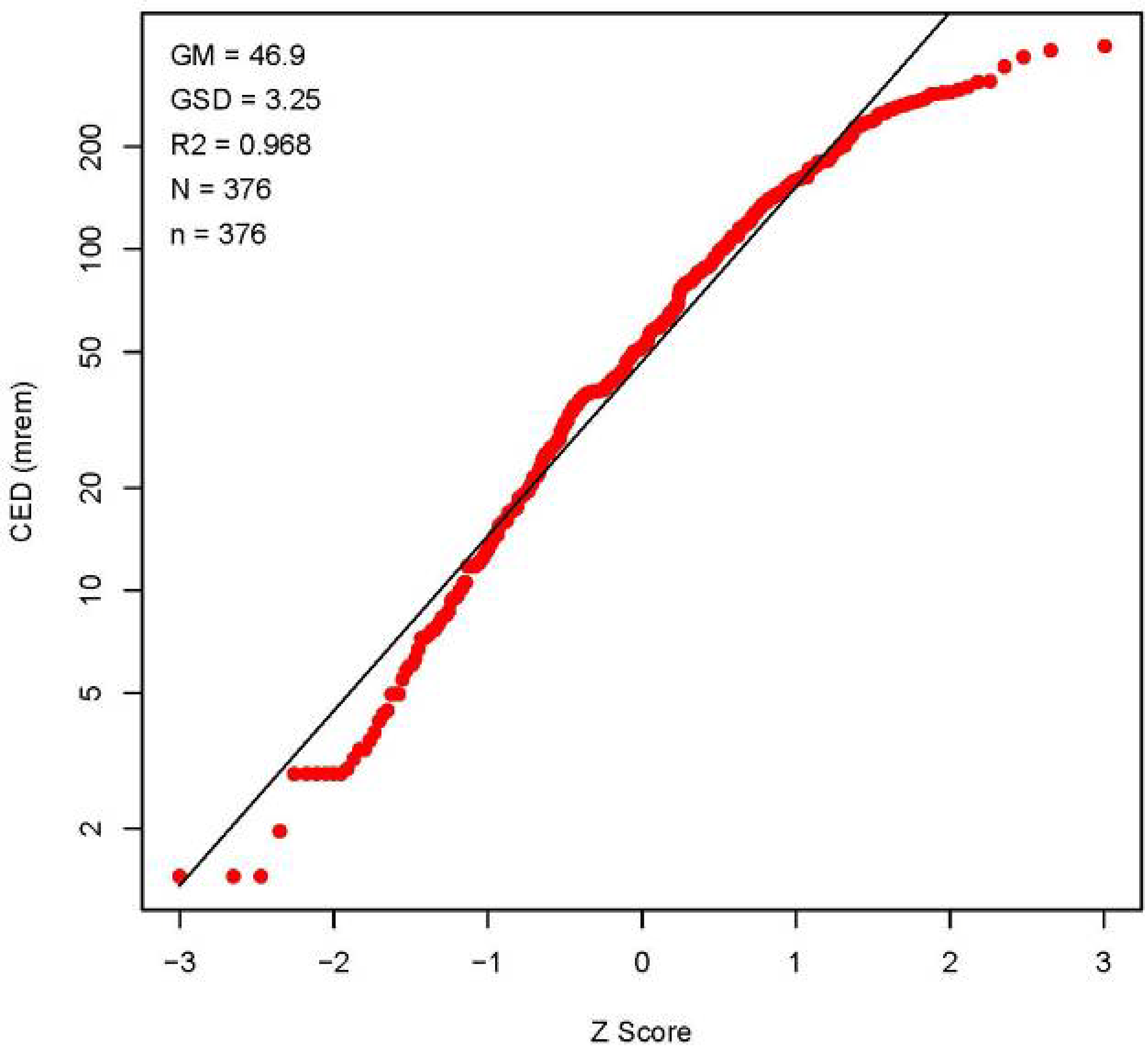

Figure A-31. SRS tritium dose 1964.

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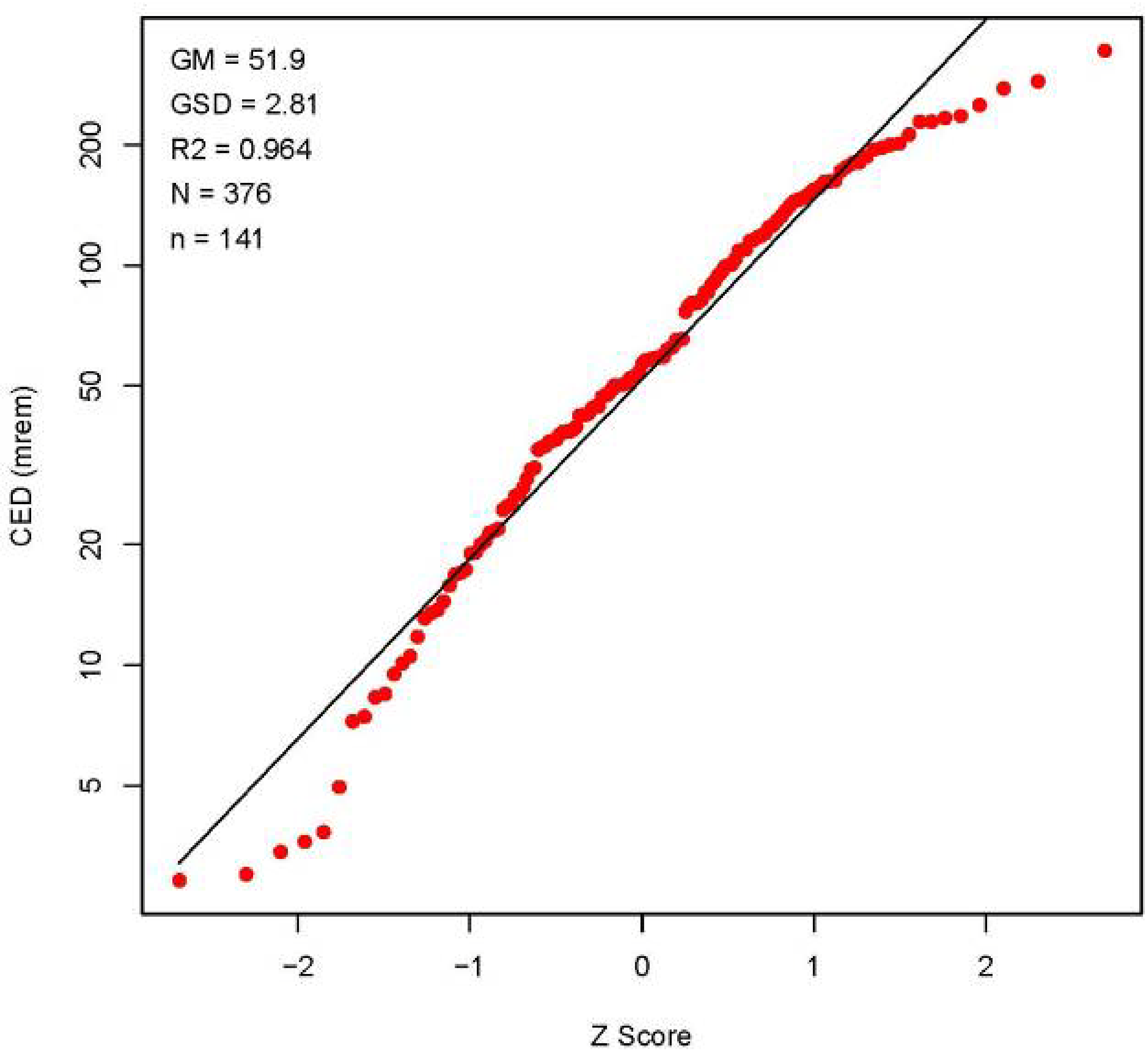

Figure A-32. SRS CTW tritium dose 1964.

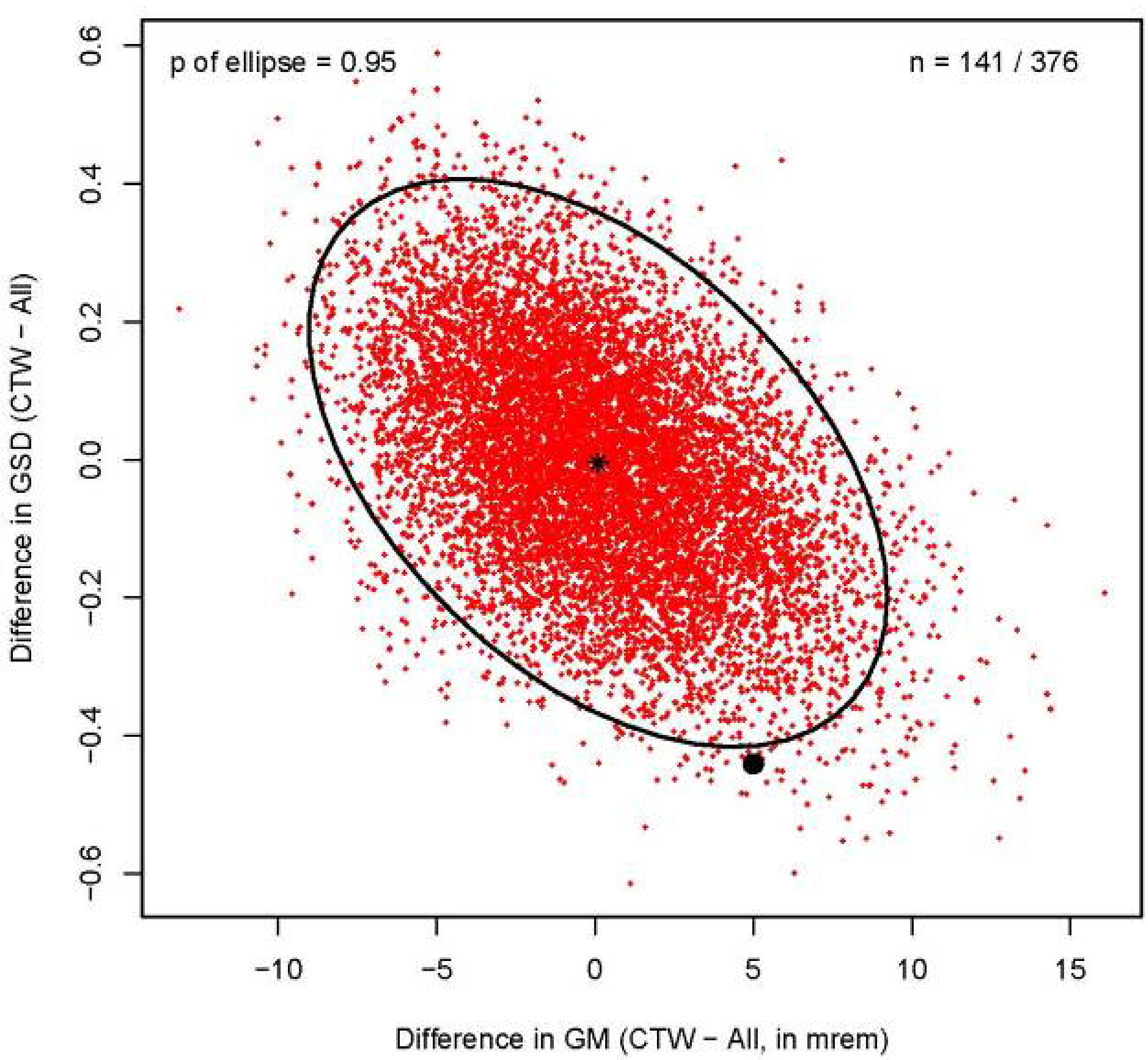

Figure A-33. SRS tritium dose 1964.

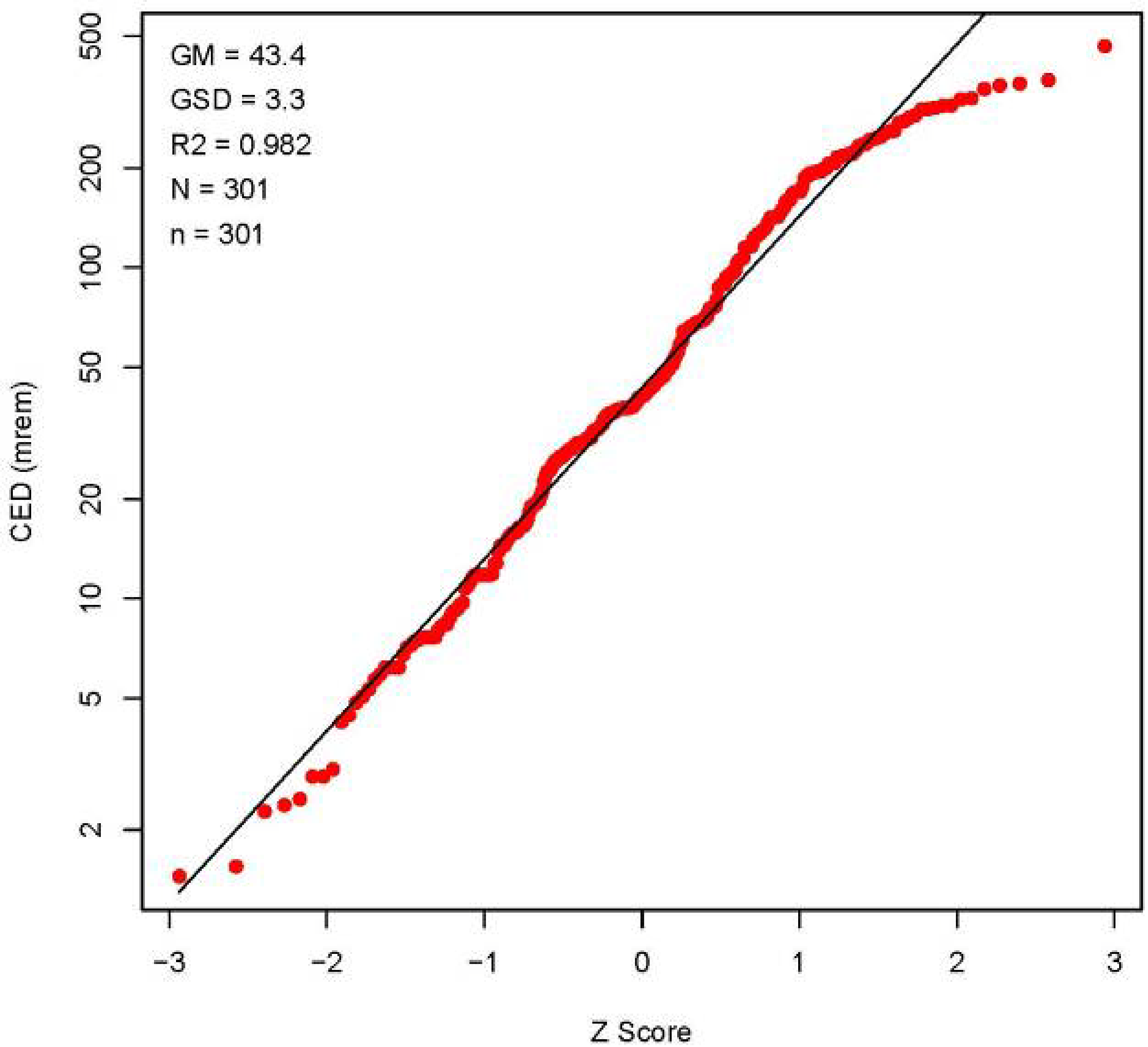

Figure A-34. SRS tritium dose 1965.

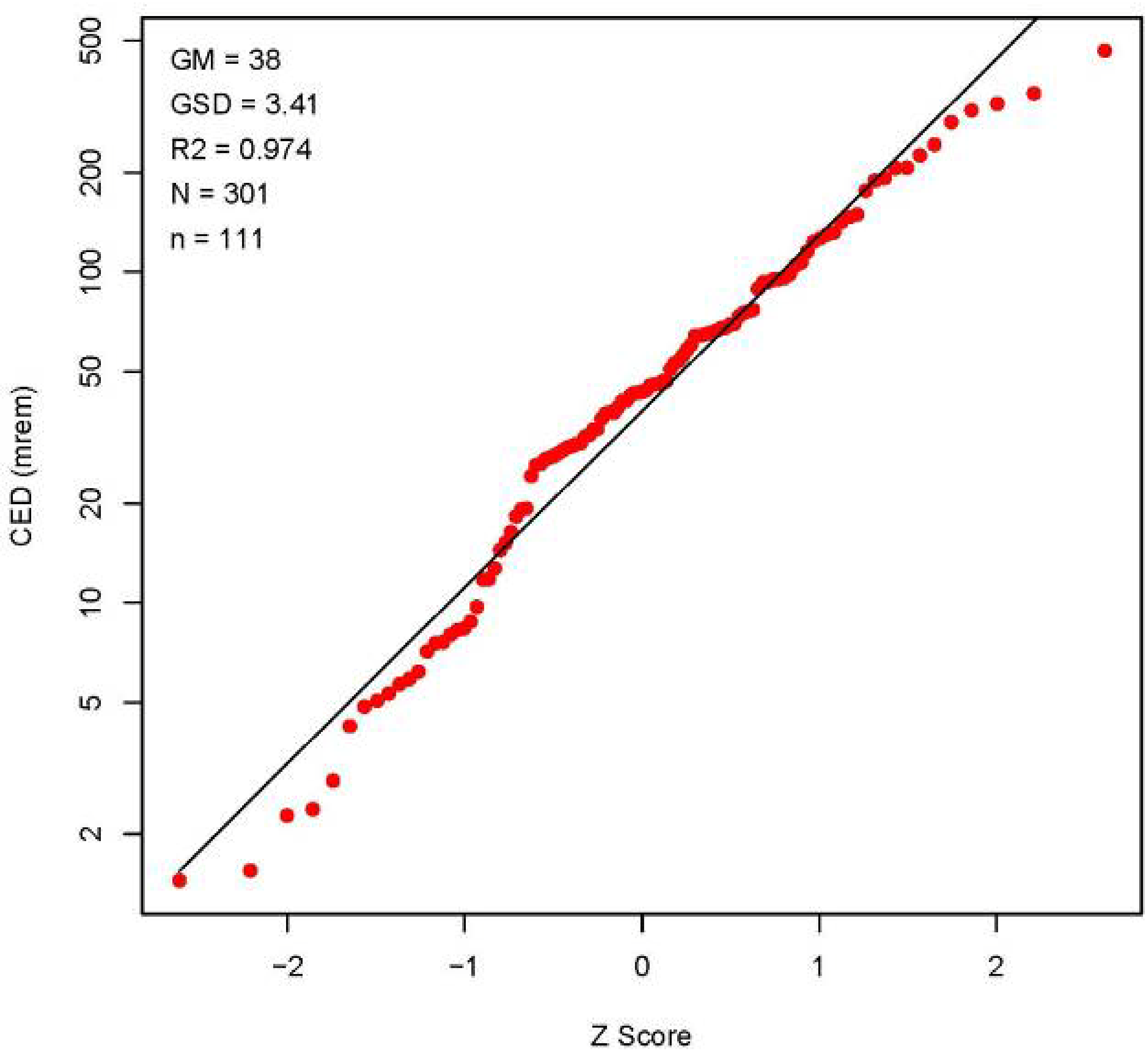

Figure A-35. SRS CTW tritium dose 1965.

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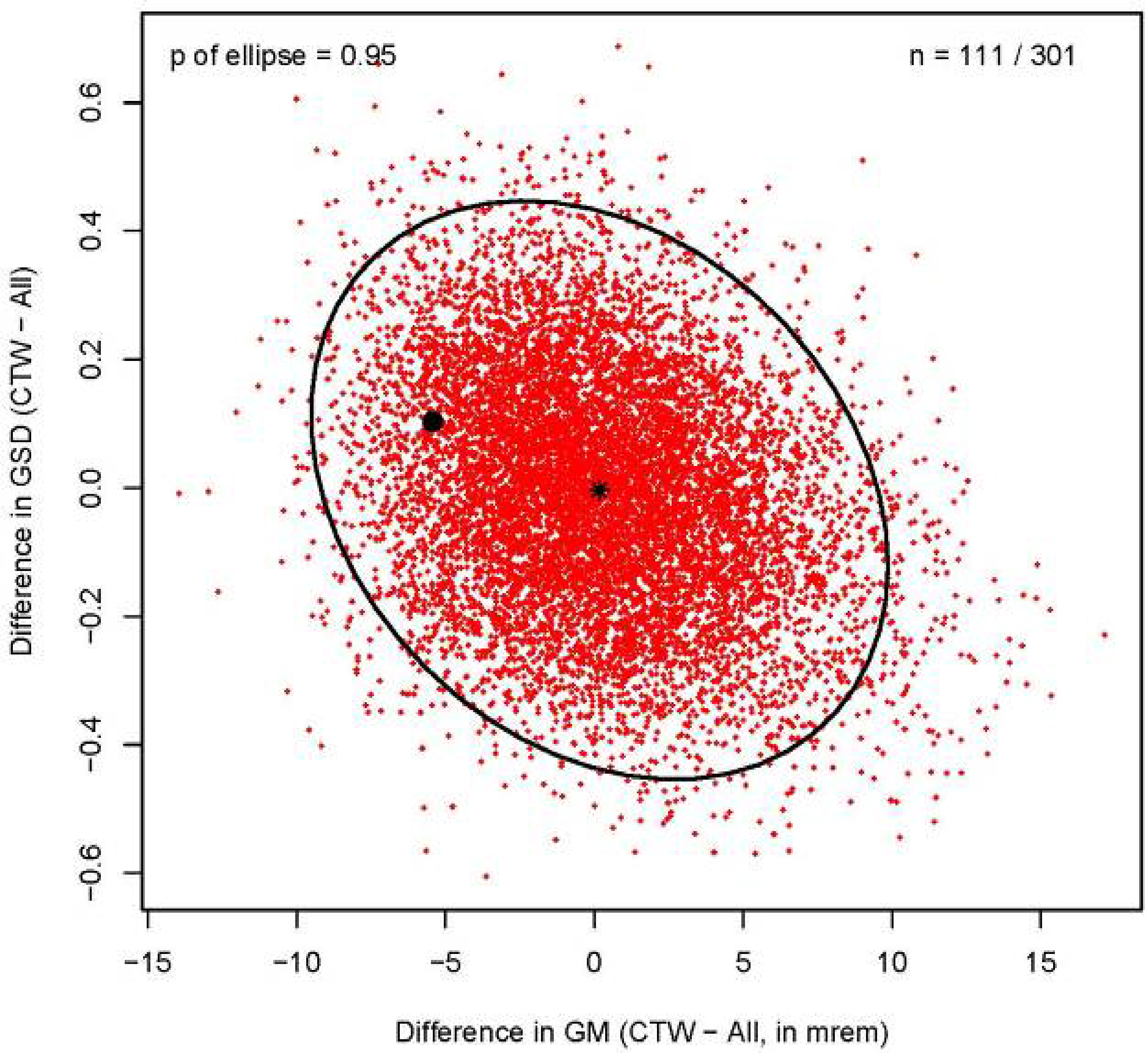

Figure A-36. SRS tritium dose 1965.

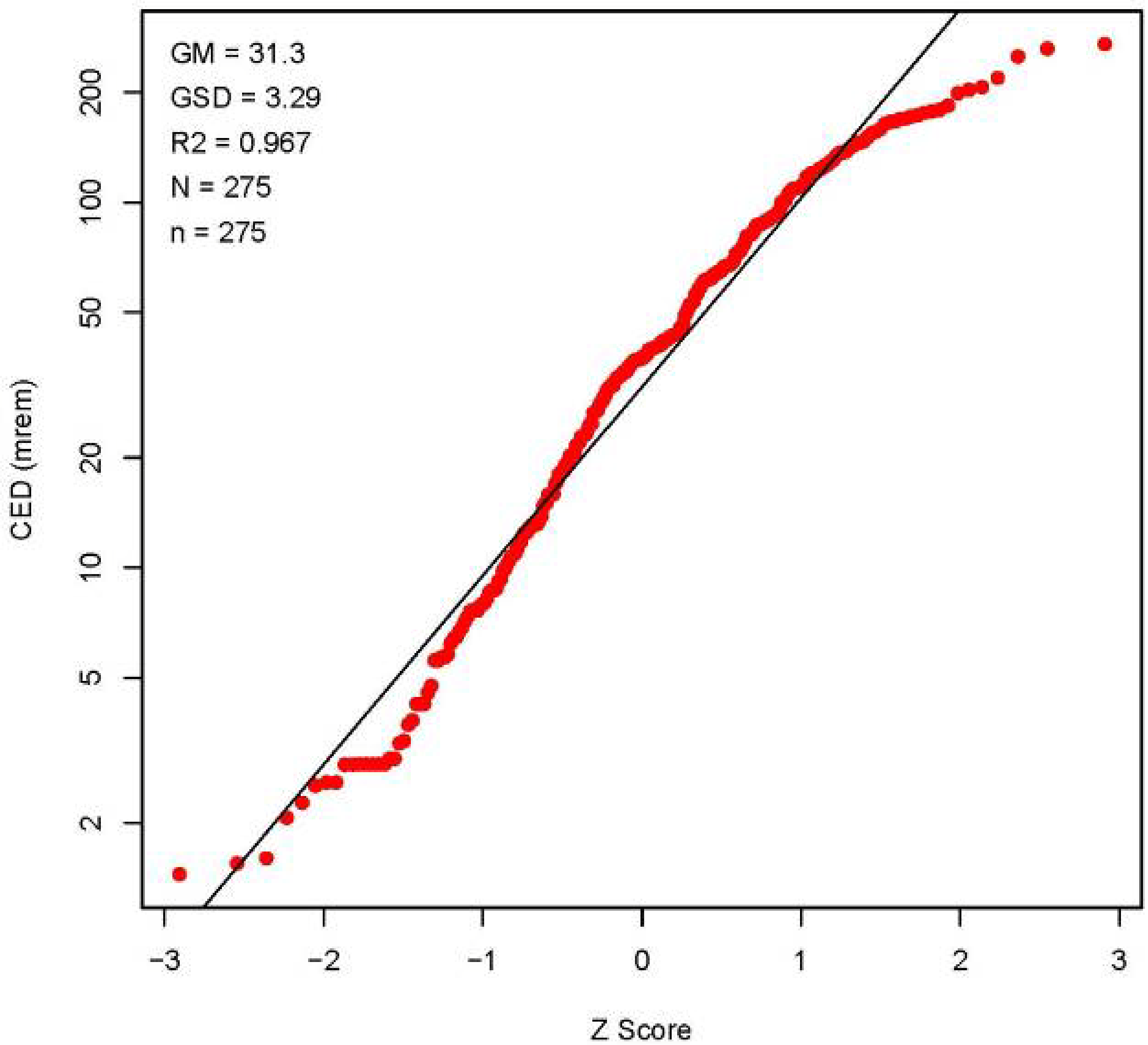

Figure A-37. SRS tritium dose 1966.

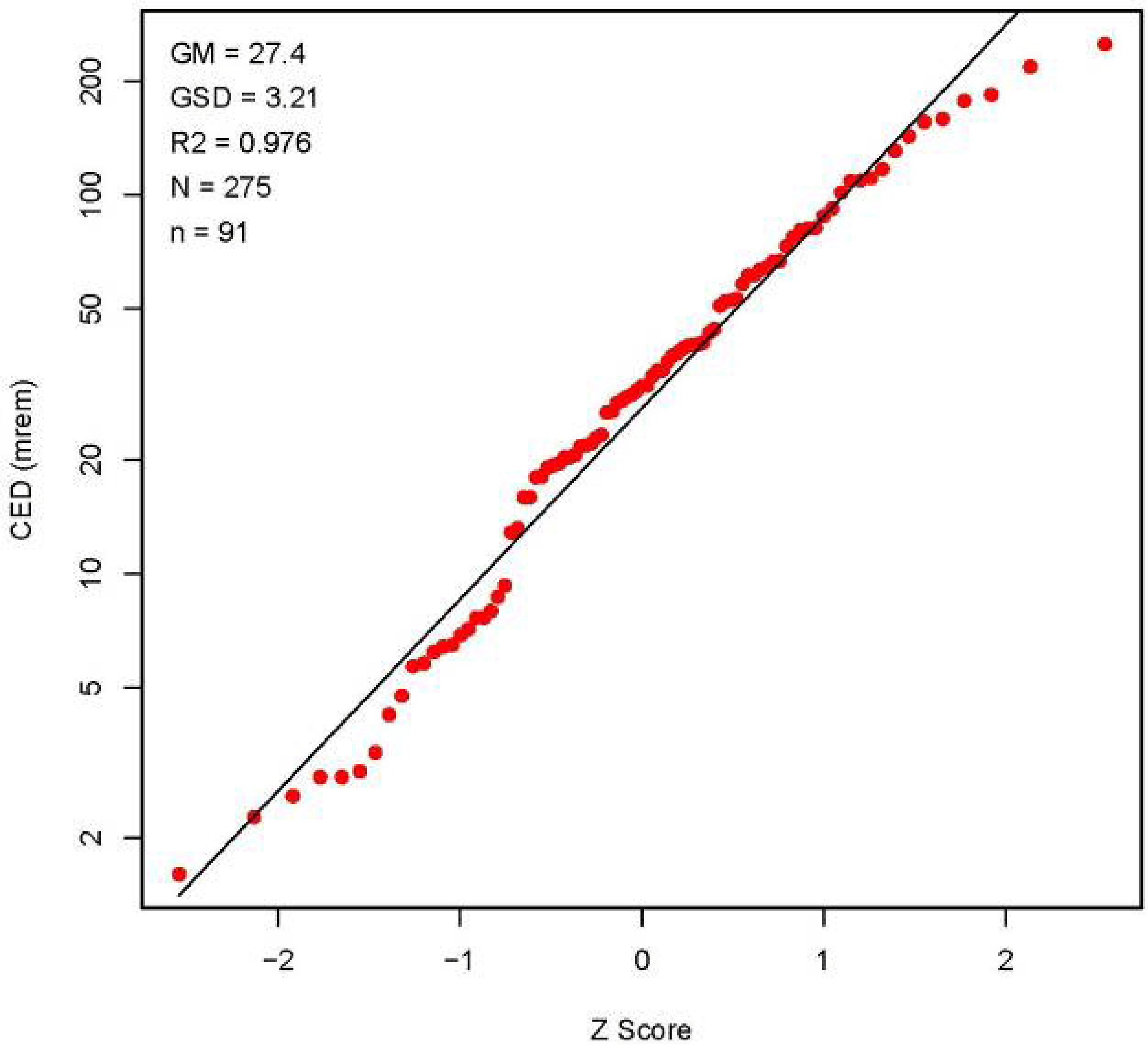

Figure A-38. SRS CTW tritium dose 1966.

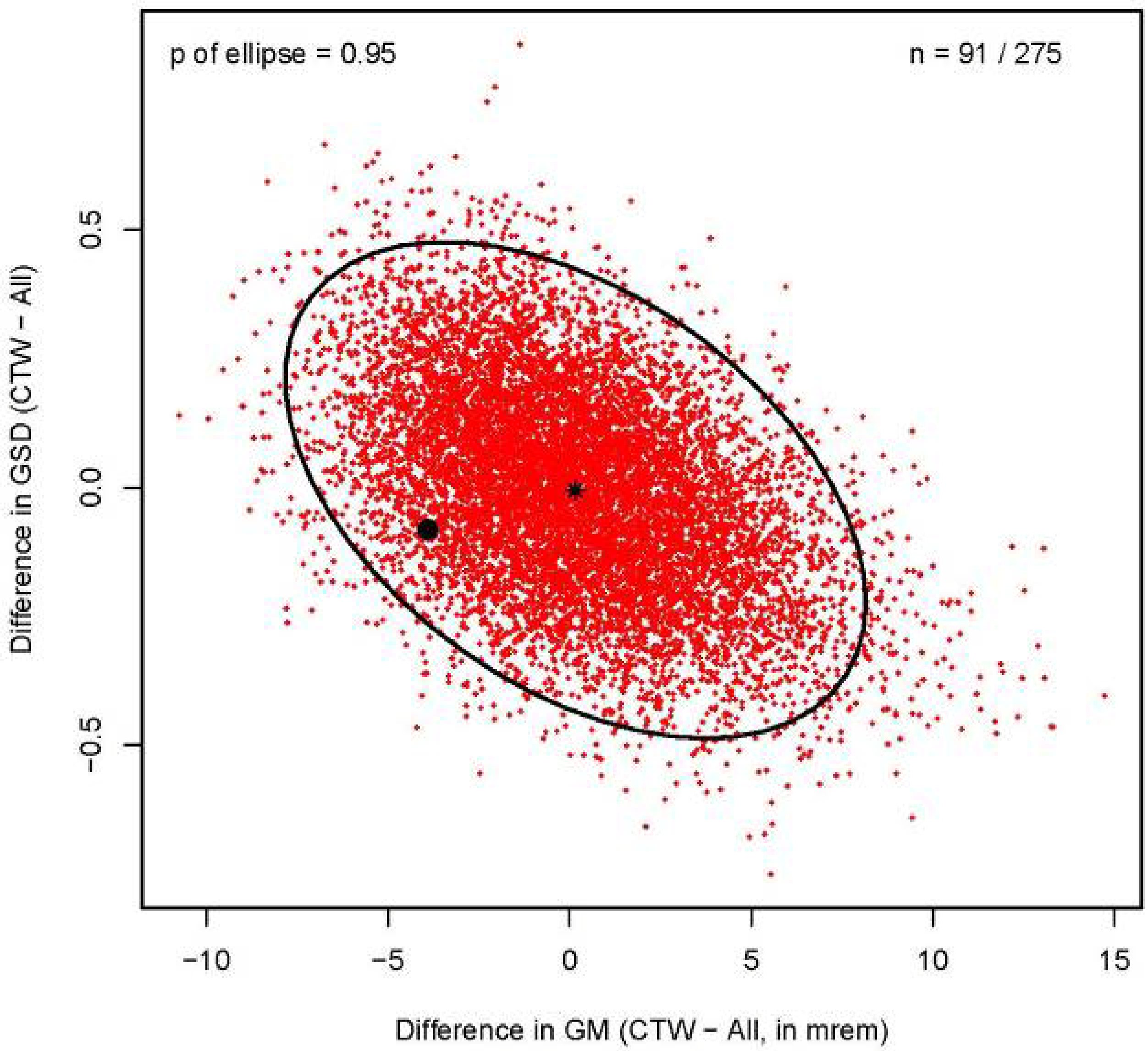

Figure A-39. SRS tritium dose 1966.

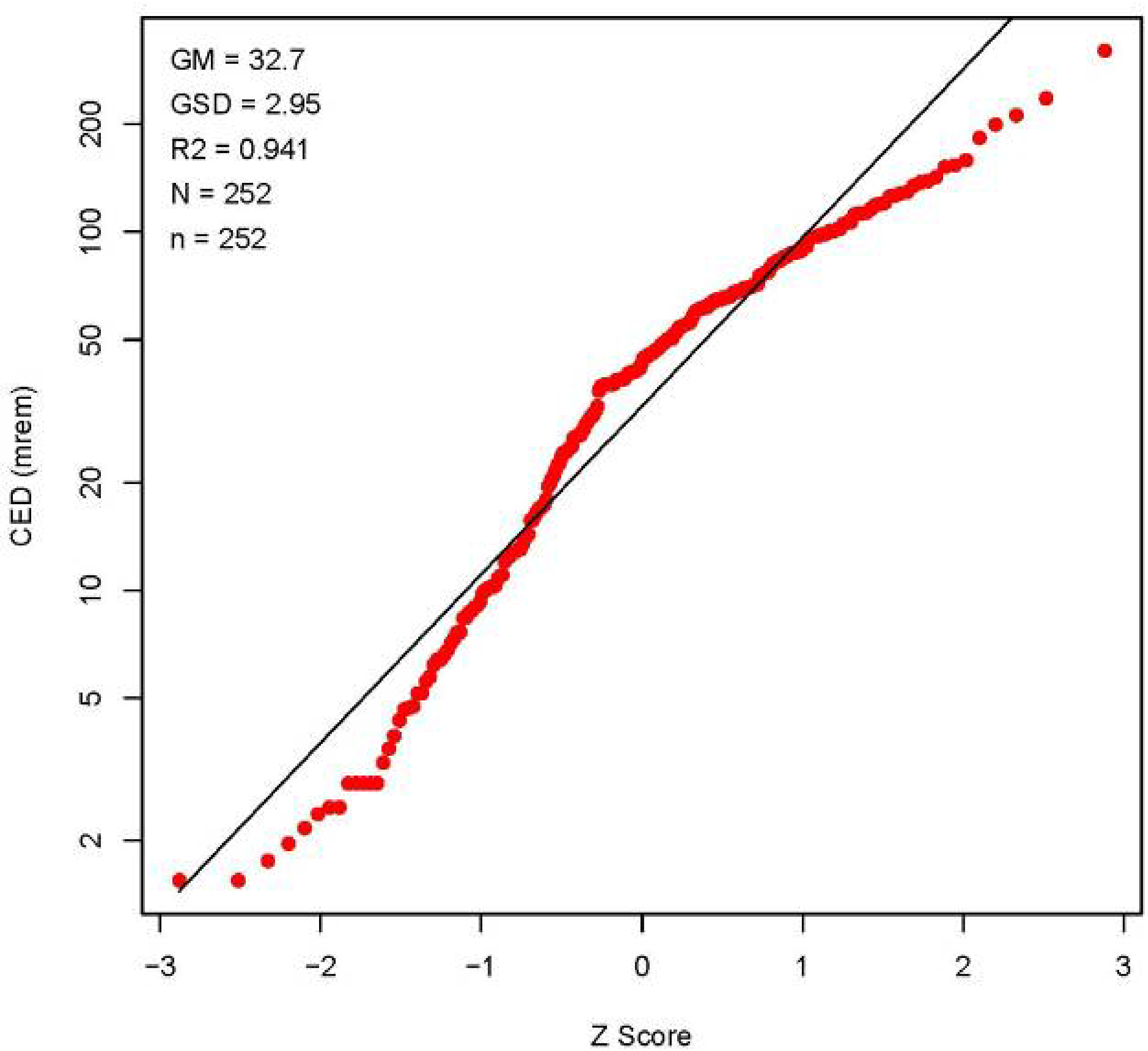

Figure A-40. SRS tritium dose 1967.

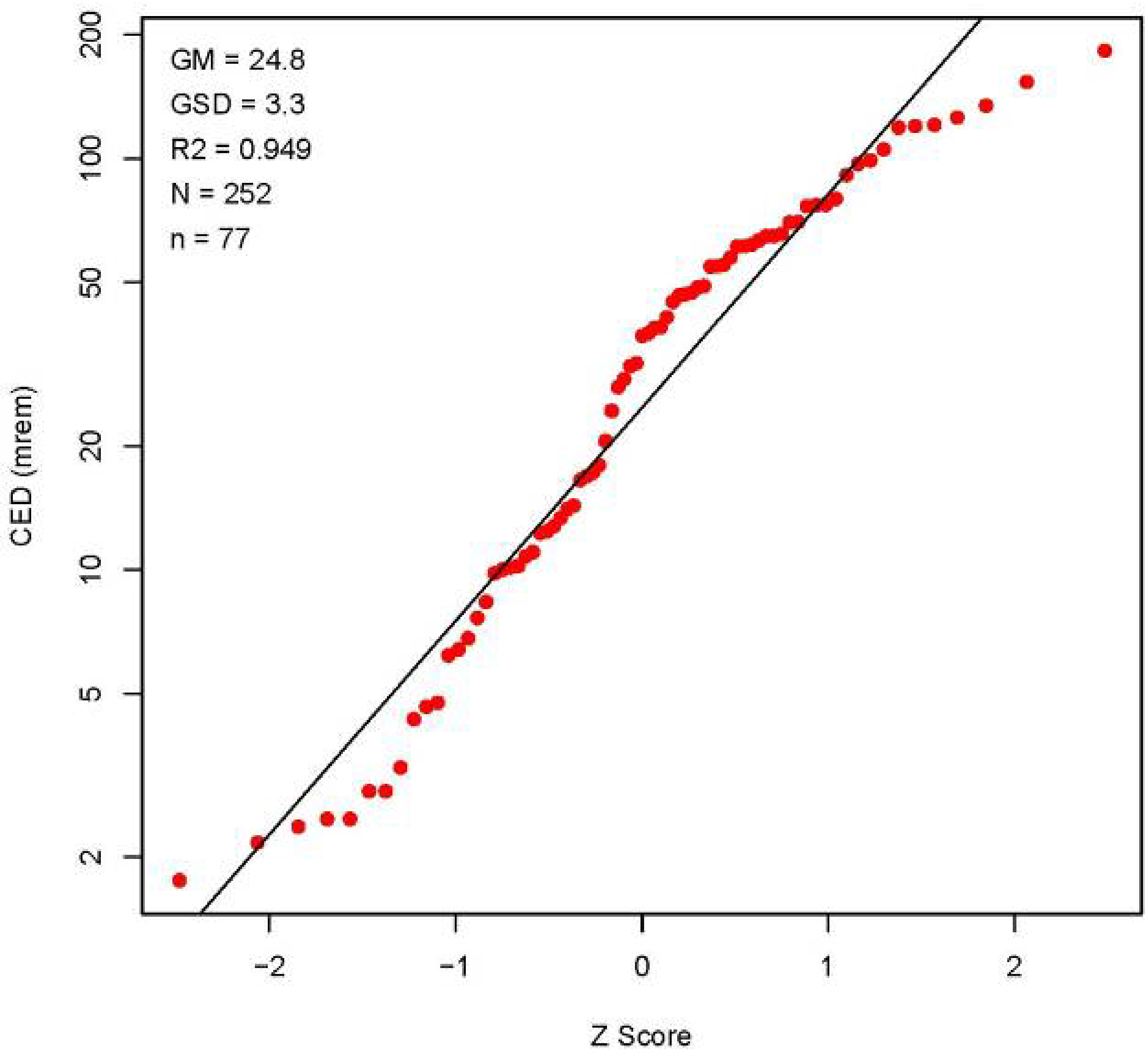

Figure A-41. SRS CTW tritium dose 1967.

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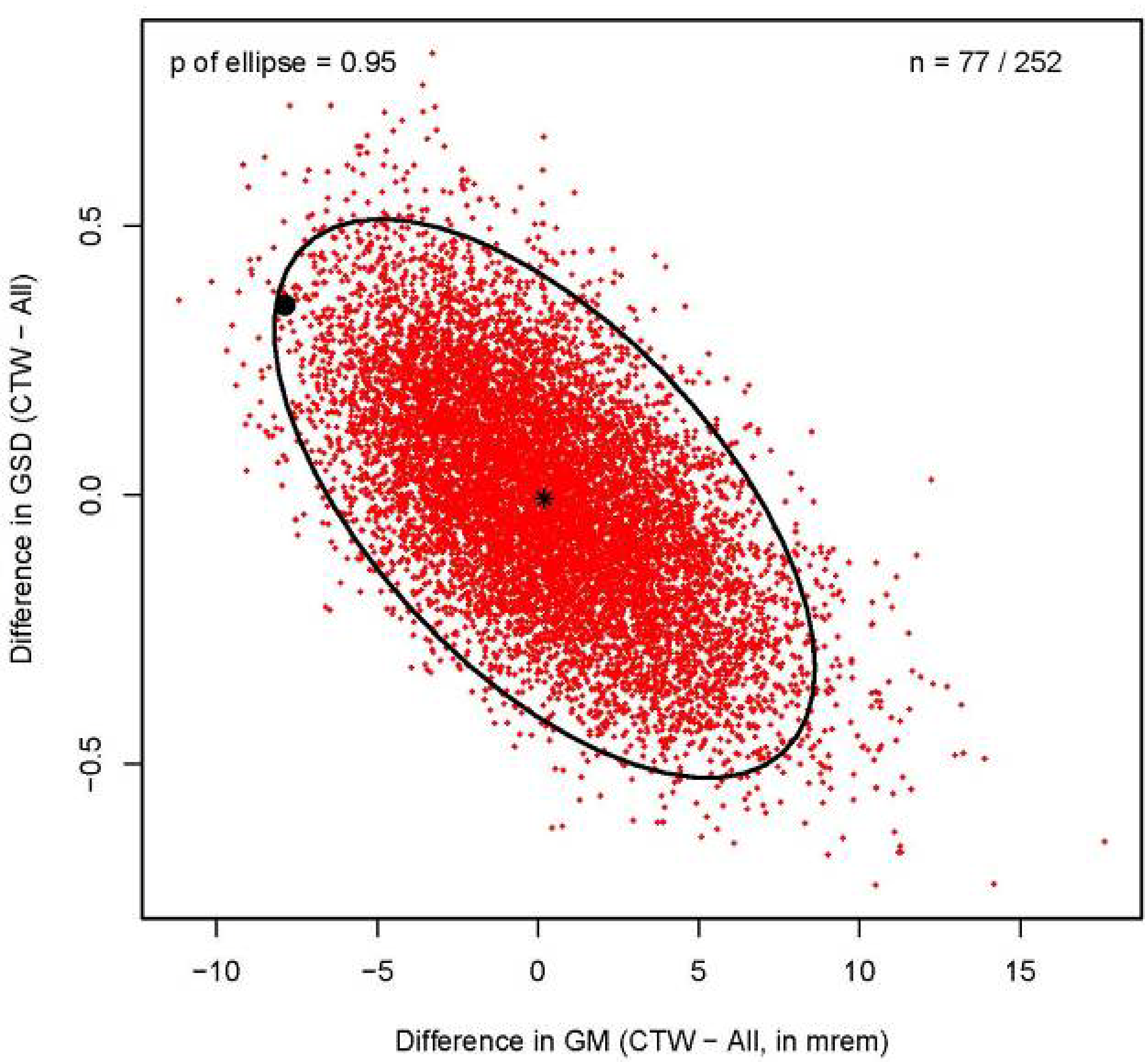

Figure A-42. SRS tritium dose 1967.

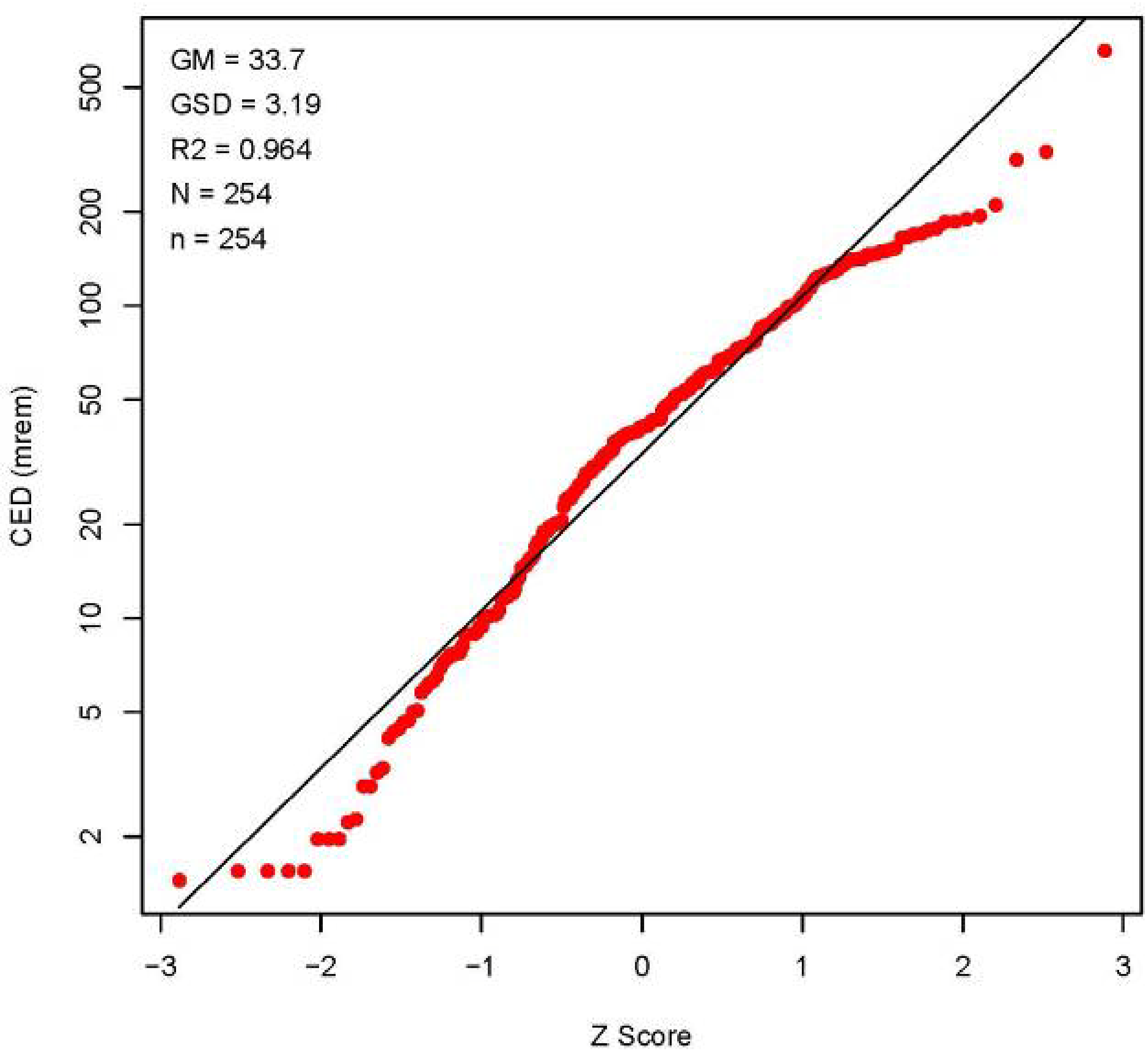

Figure A-43. SRS tritium dose 1968.

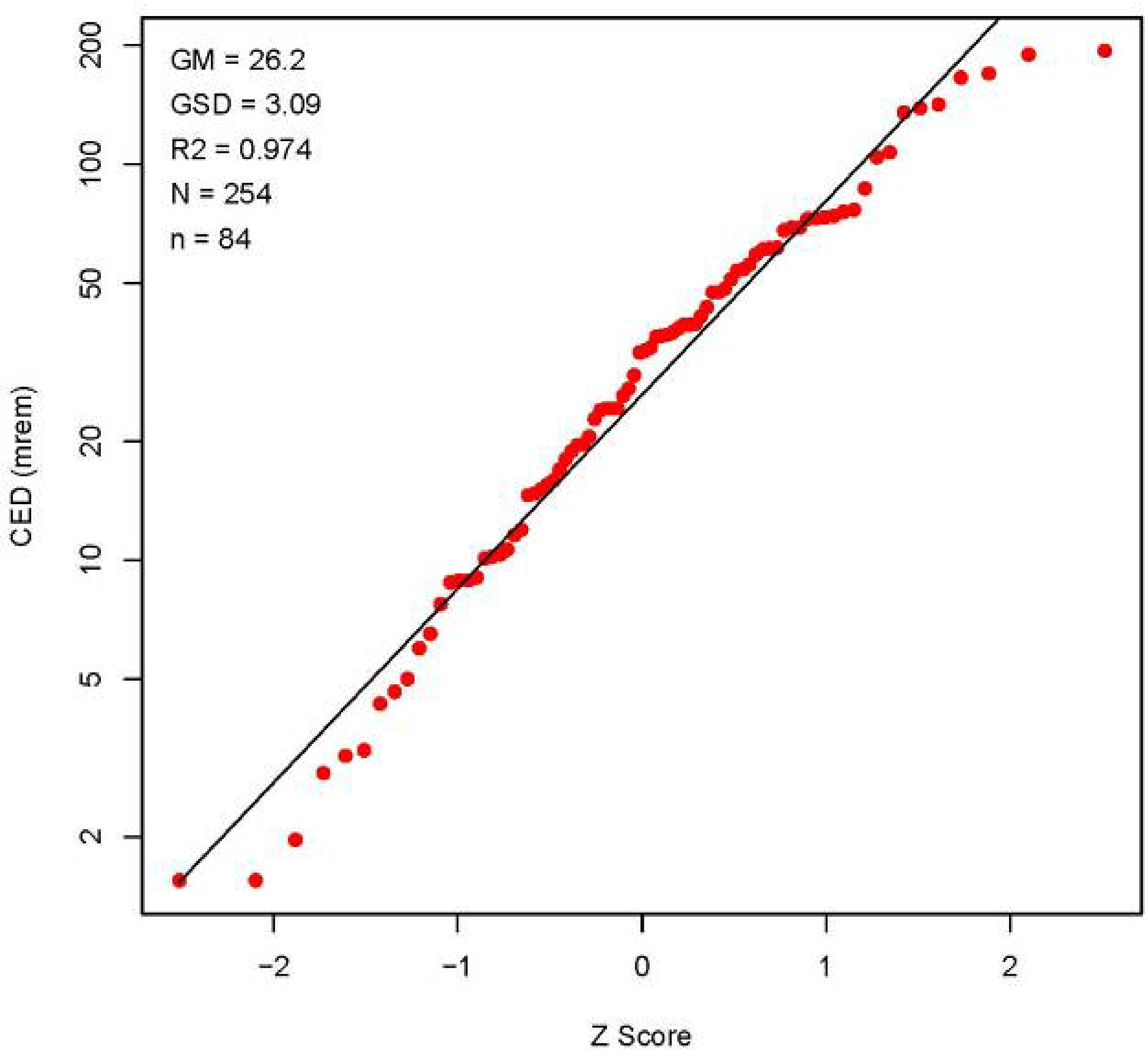

Figure A-44. SRS CTW tritium dose 1968.

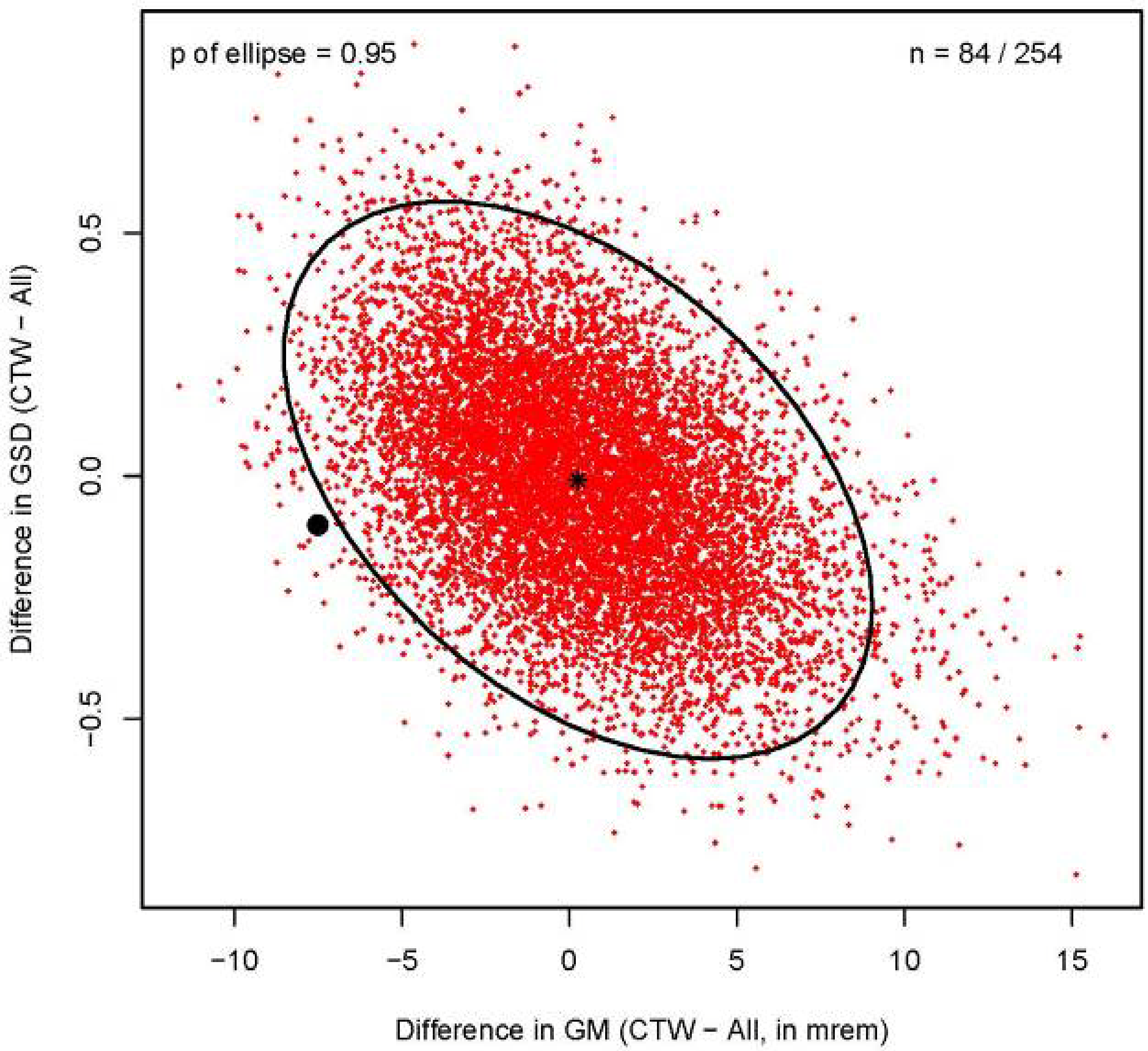

Figure A-45. SRS tritium dose 1968.

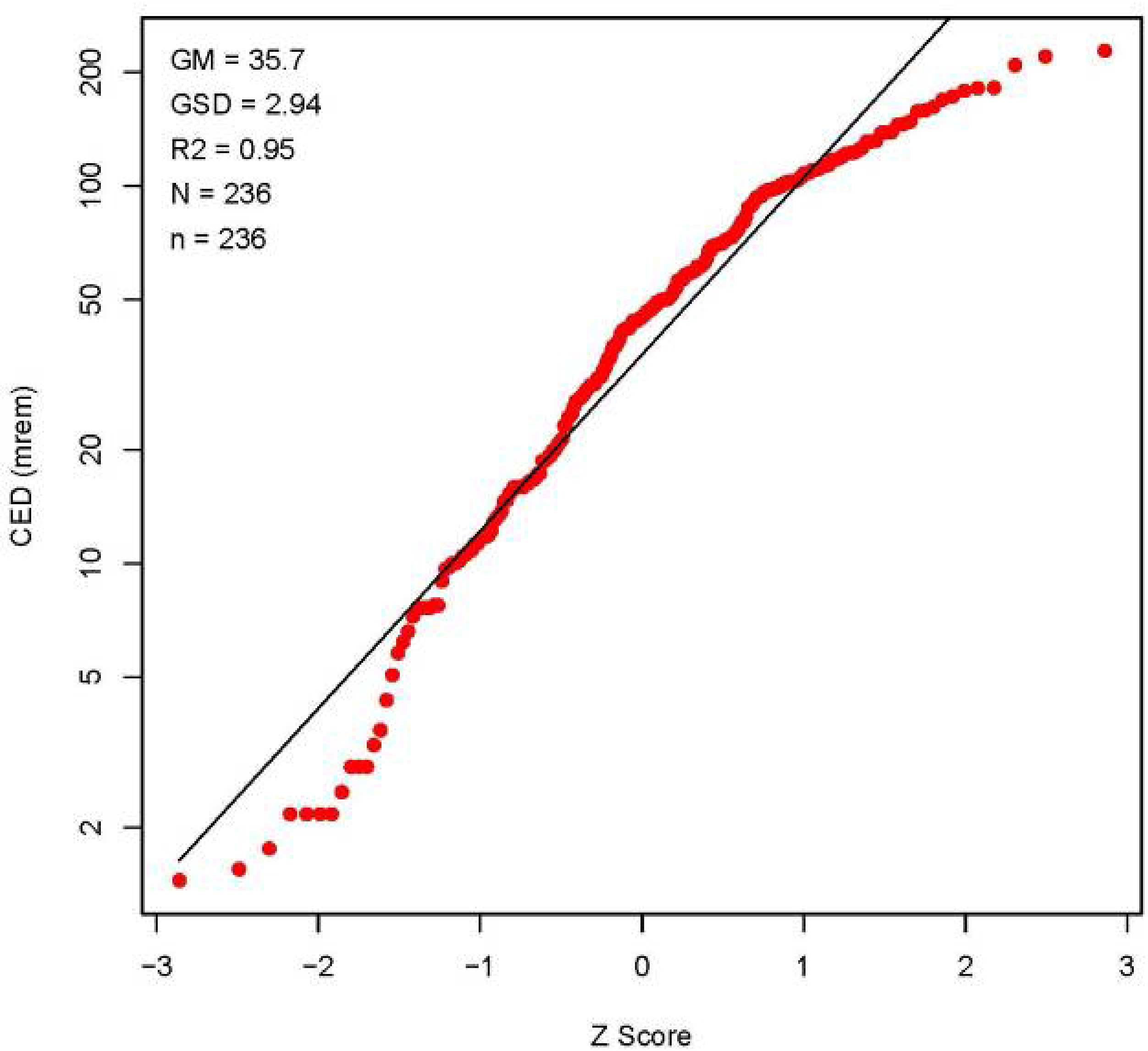

Figure A-46. SRS tritium dose 1969.

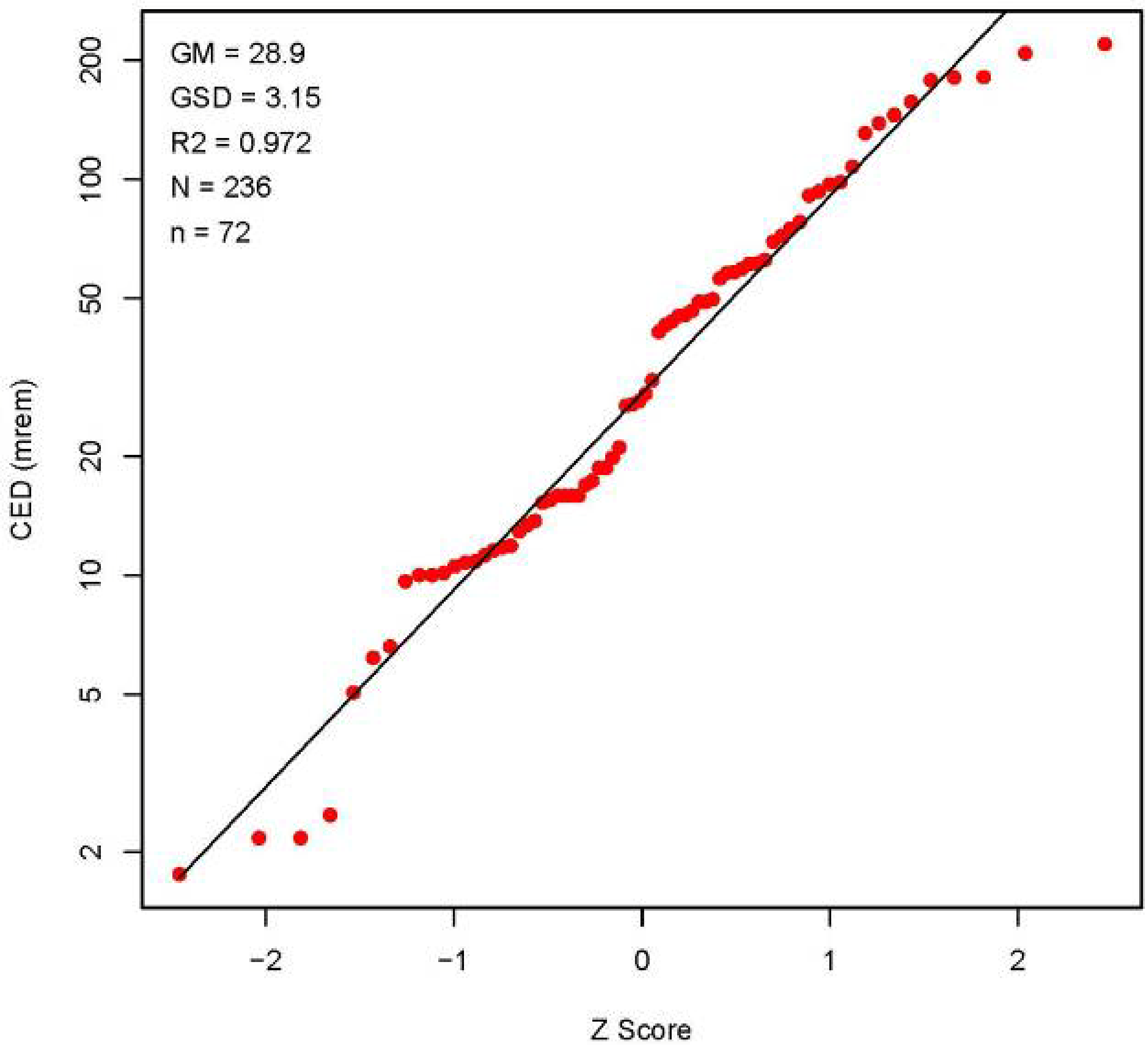

Figure A-47. SRS CTW tritium dose 1969.

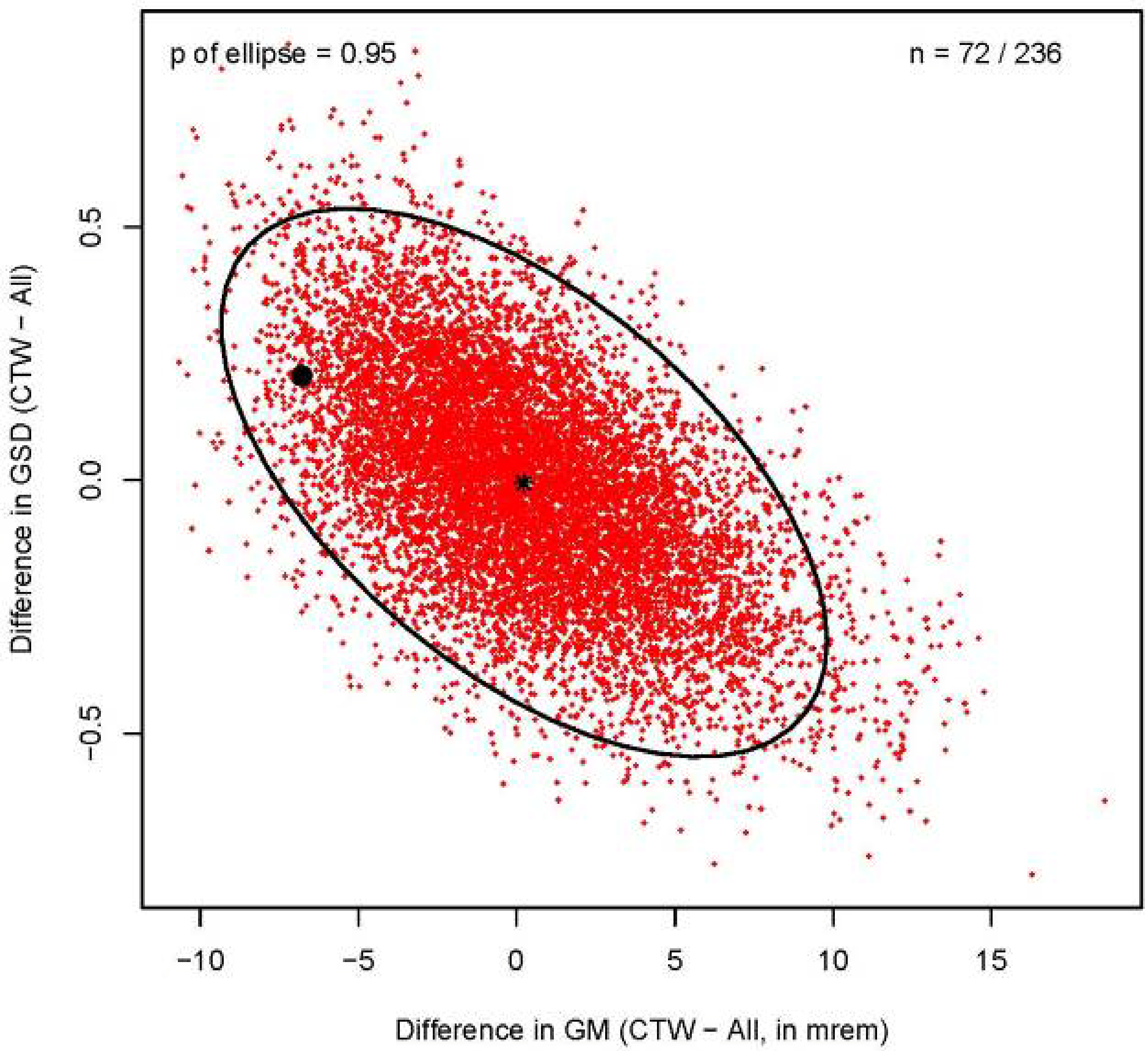

Figure A-48. SRS tritium dose 1969.

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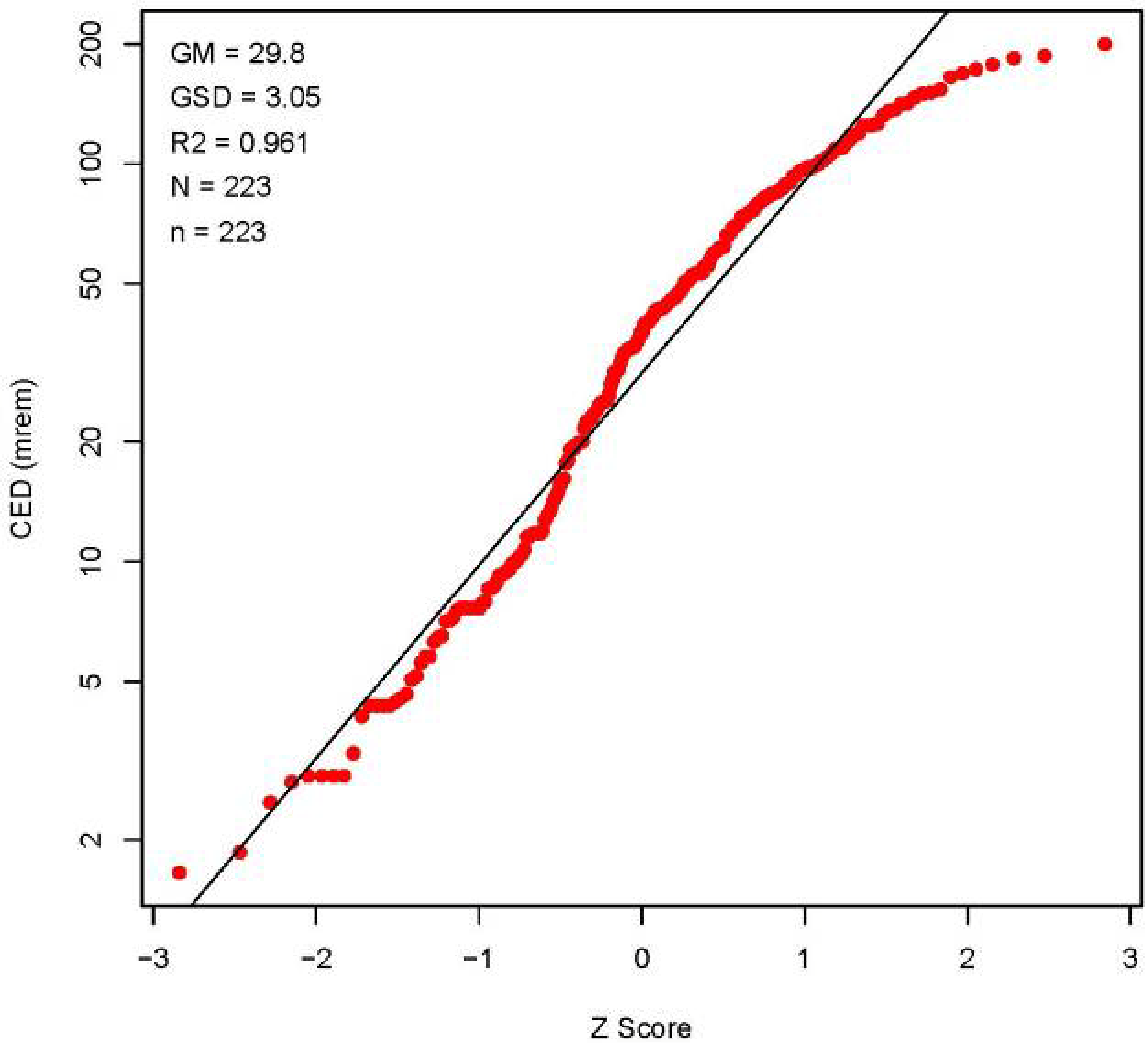

Figure A-49. SRS tritium dose 1970.

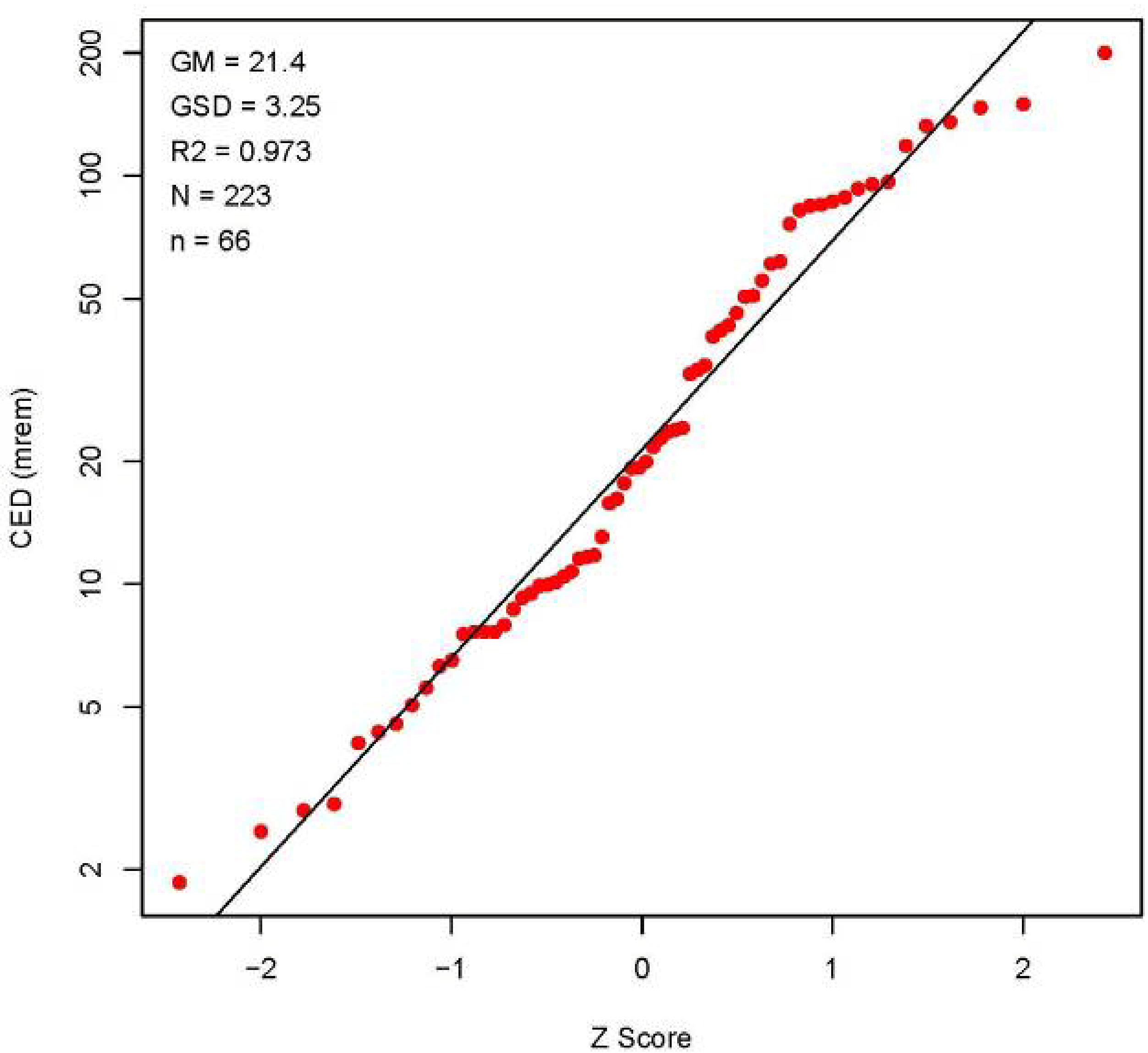

Figure A-50. SRS CTW tritium dose 1970.

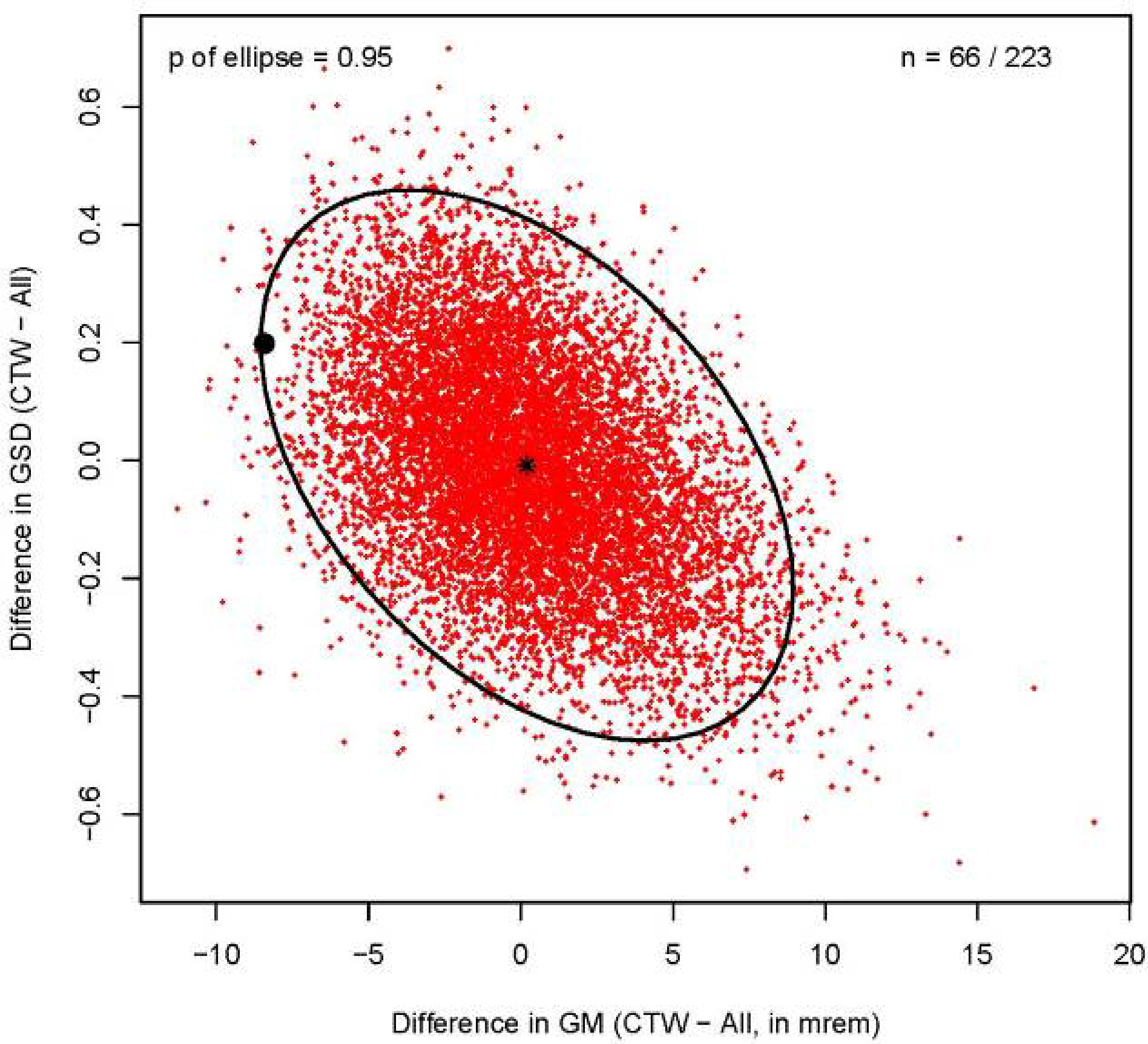

Figure A-51. SRS tritium dose 1970.

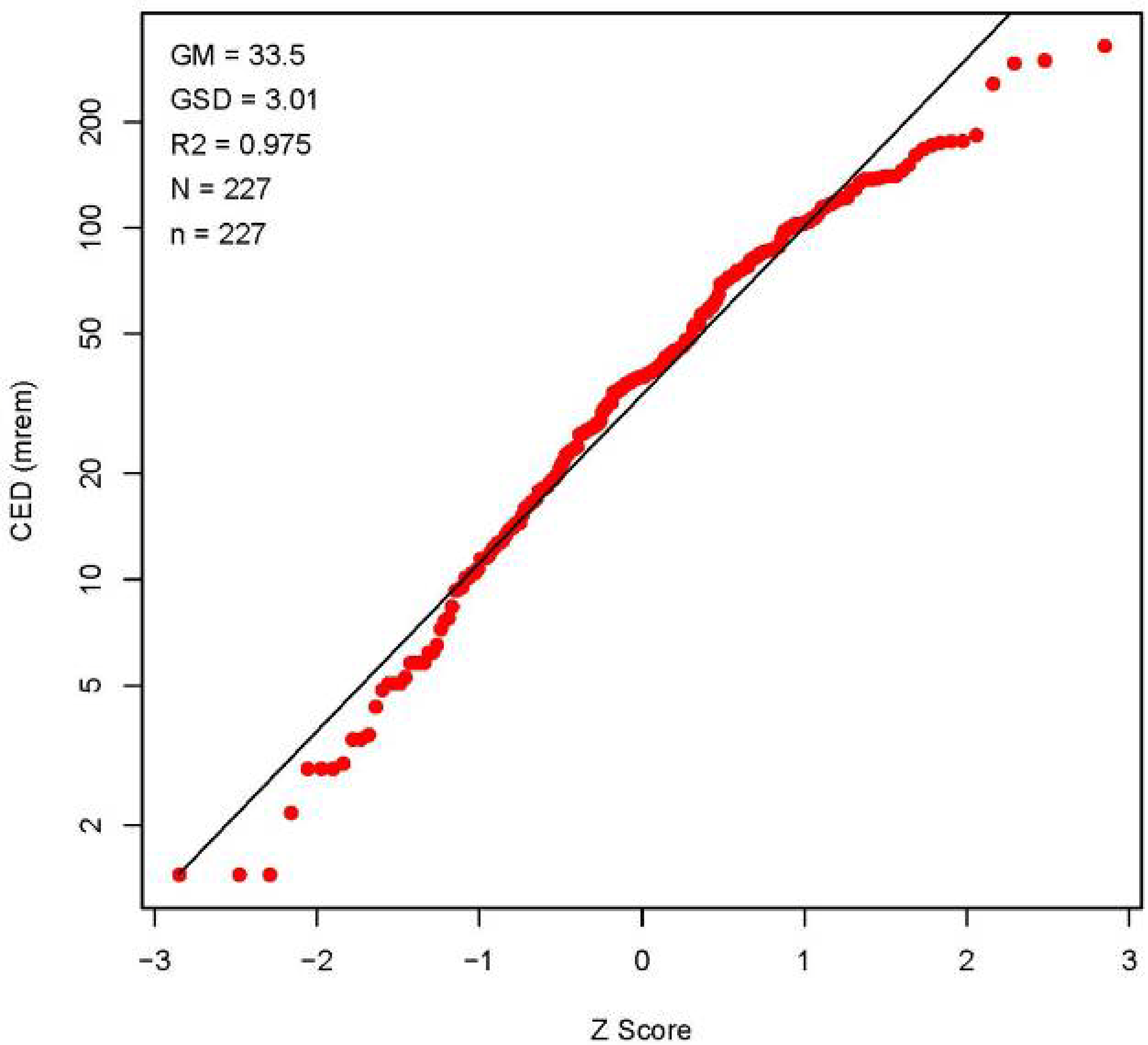

Figure A-52. SRS tritium dose 1971.

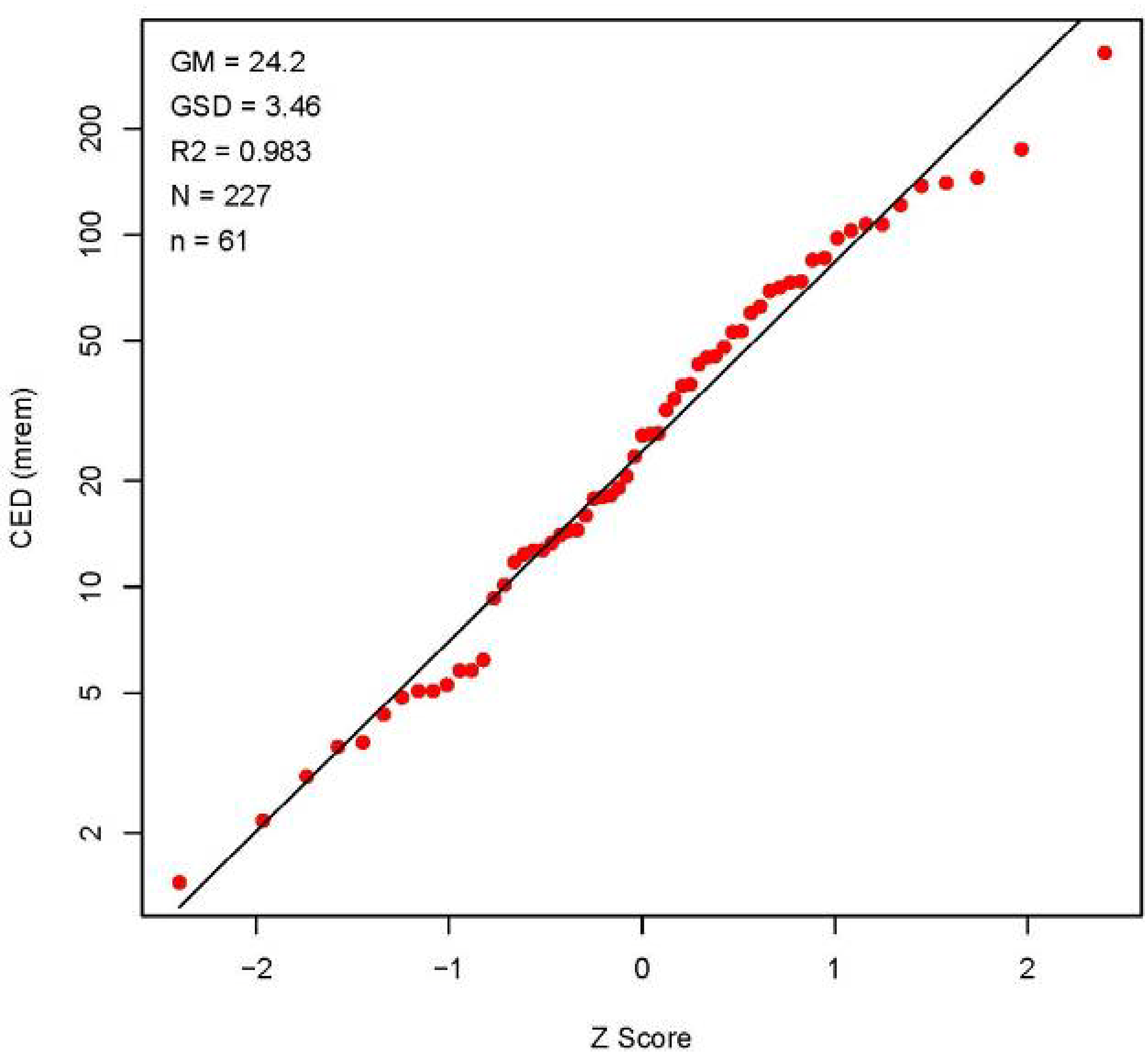

Figure A-53. SRS CTW tritium dose 1971.

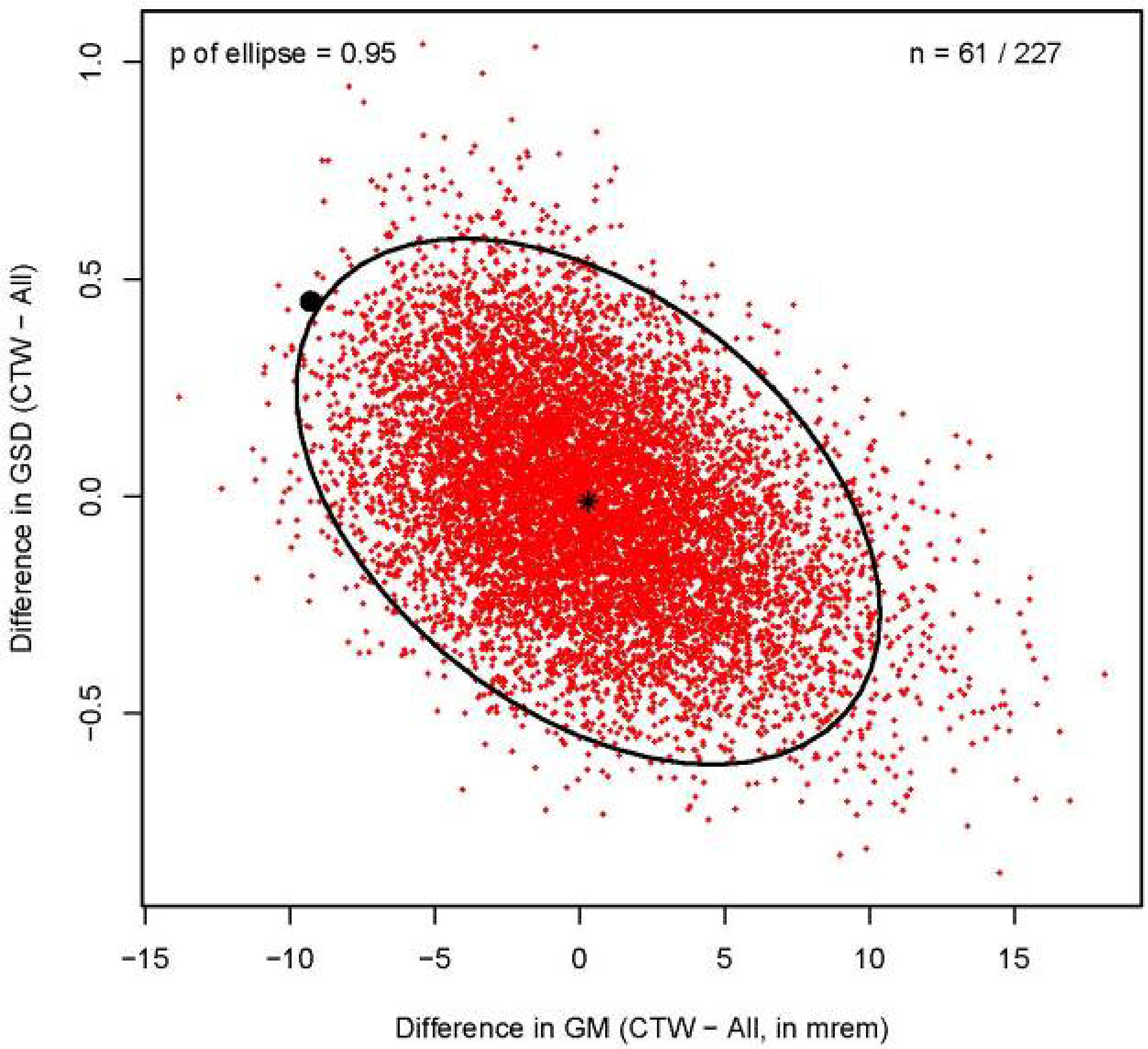

Figure A-54. SRS tritium dose 1971.

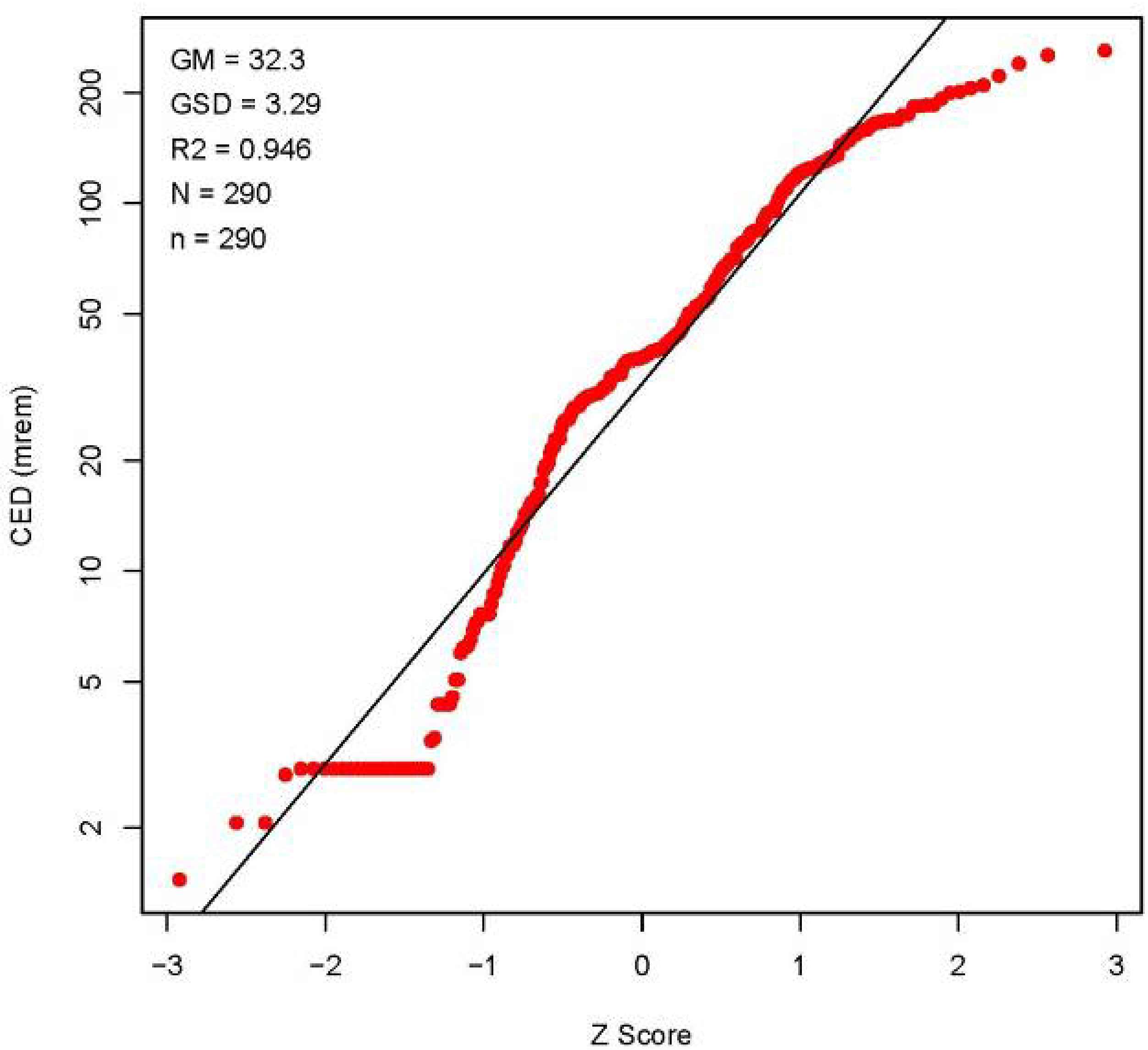

Figure A-55. SRS tritium dose 1972.

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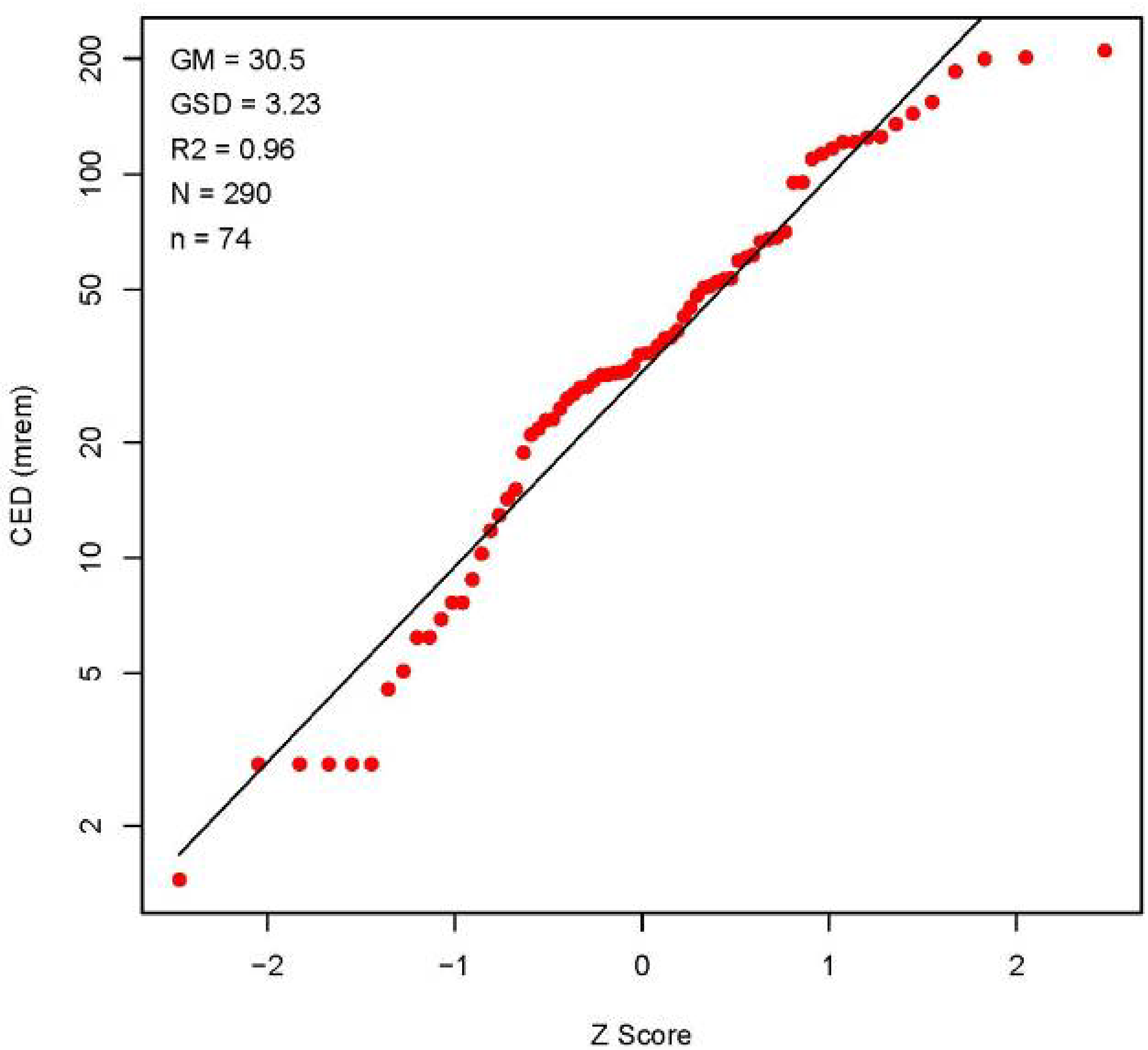

Figure A-56. SRS CTW tritium dose 1972.

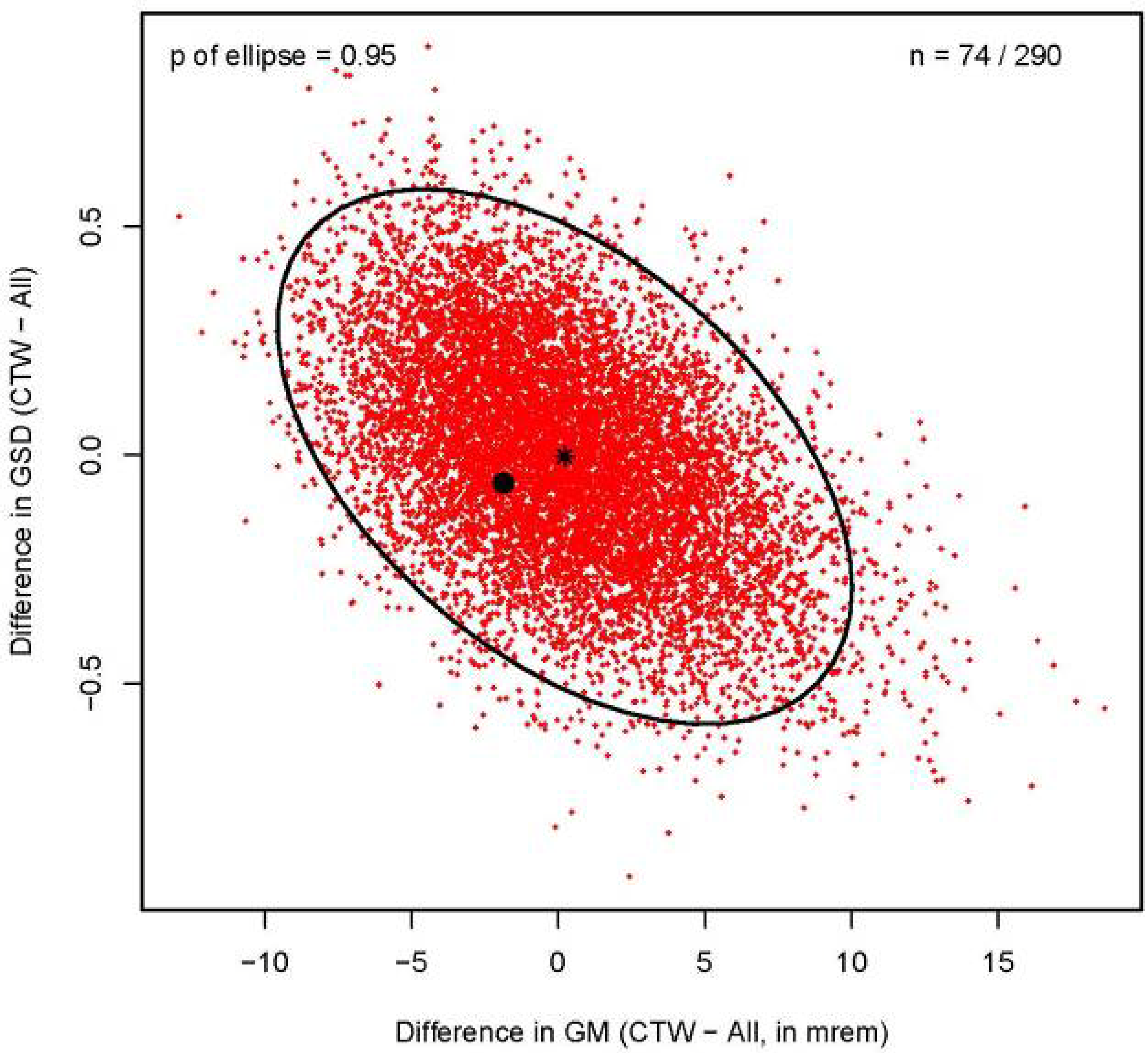

Figure A-57. SRS tritium dose 1972.

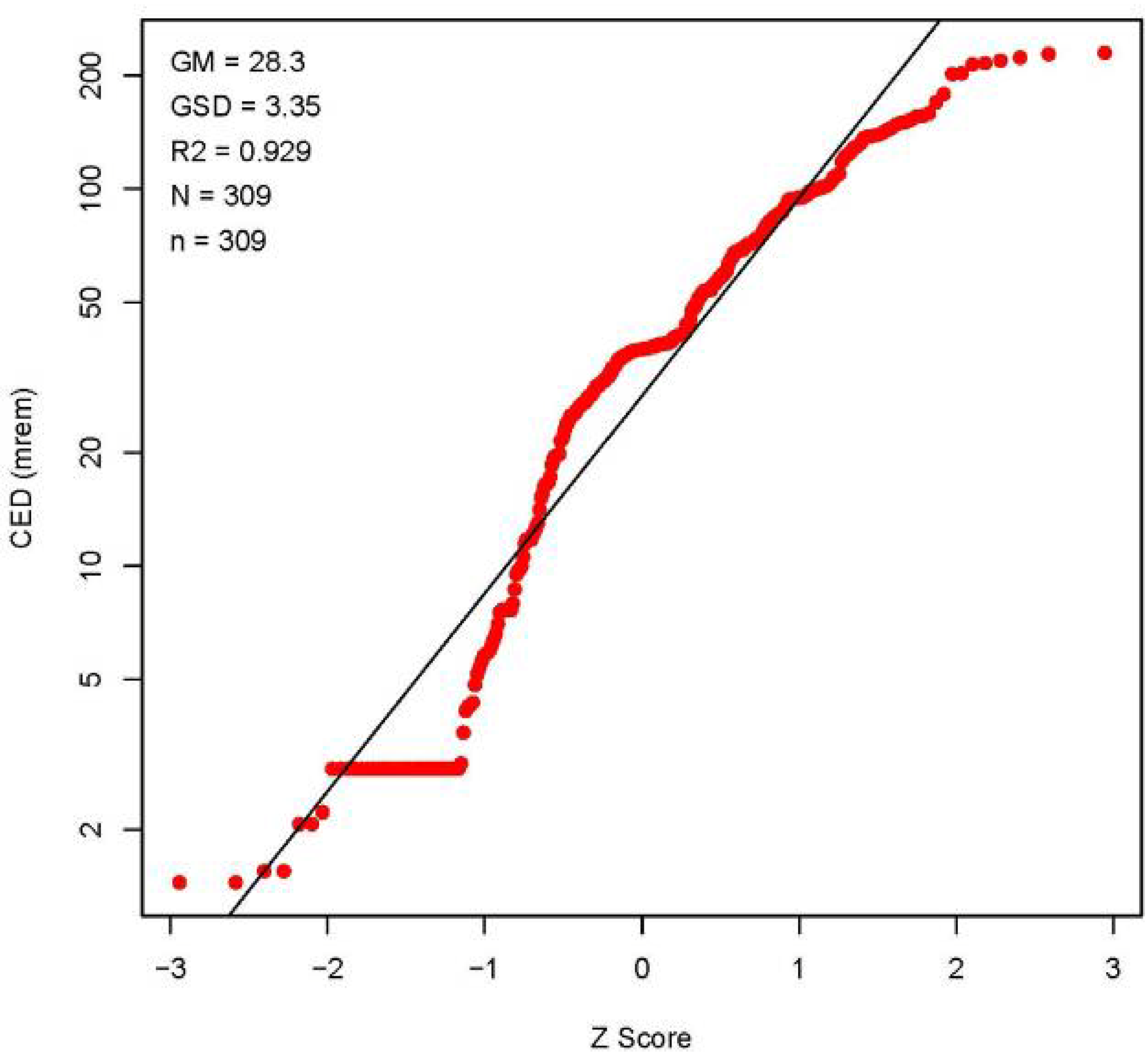

Figure A-58. SRS tritium dose 1973.

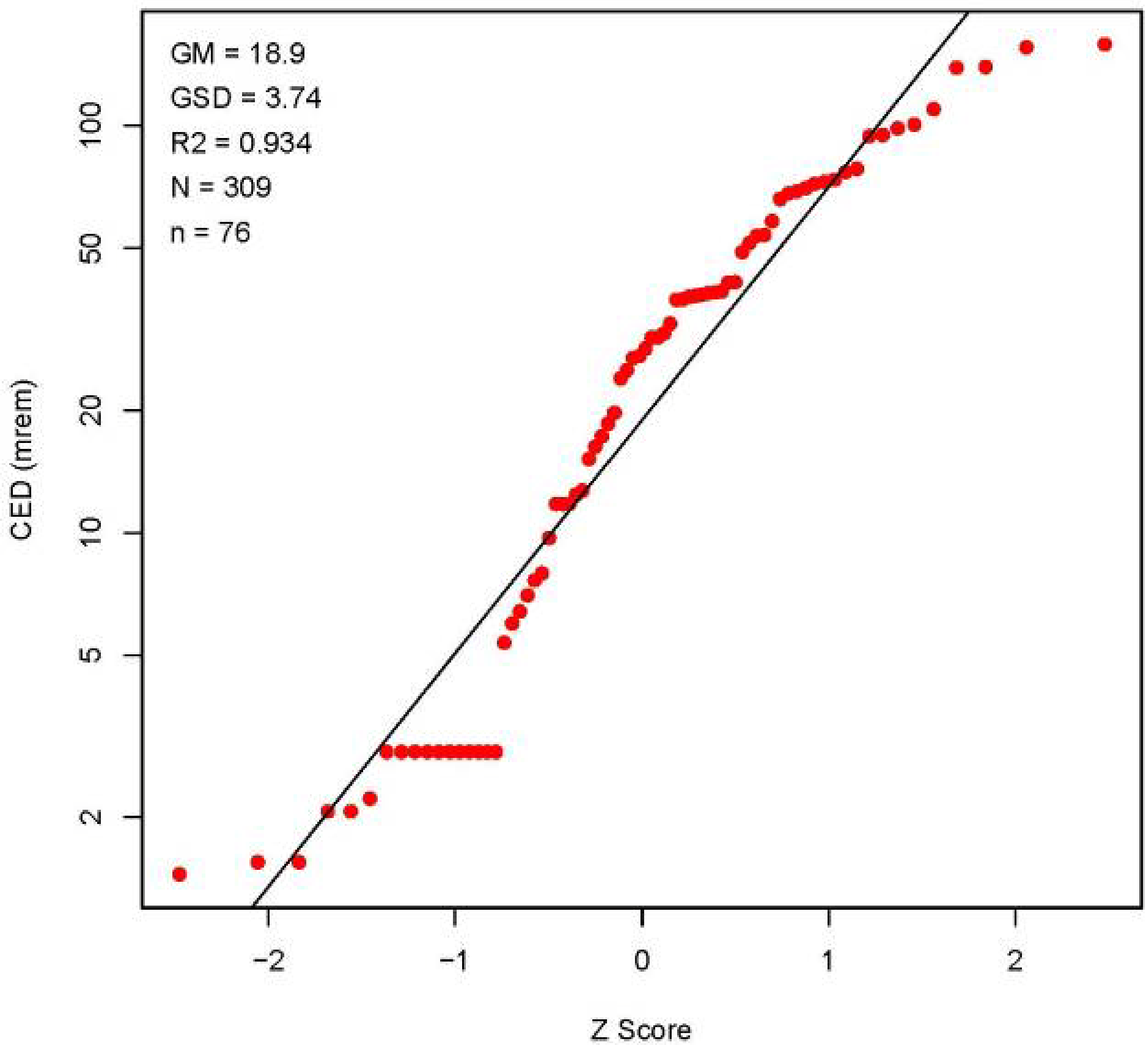

Figure A-59. SRS CTW tritium dose 1973.

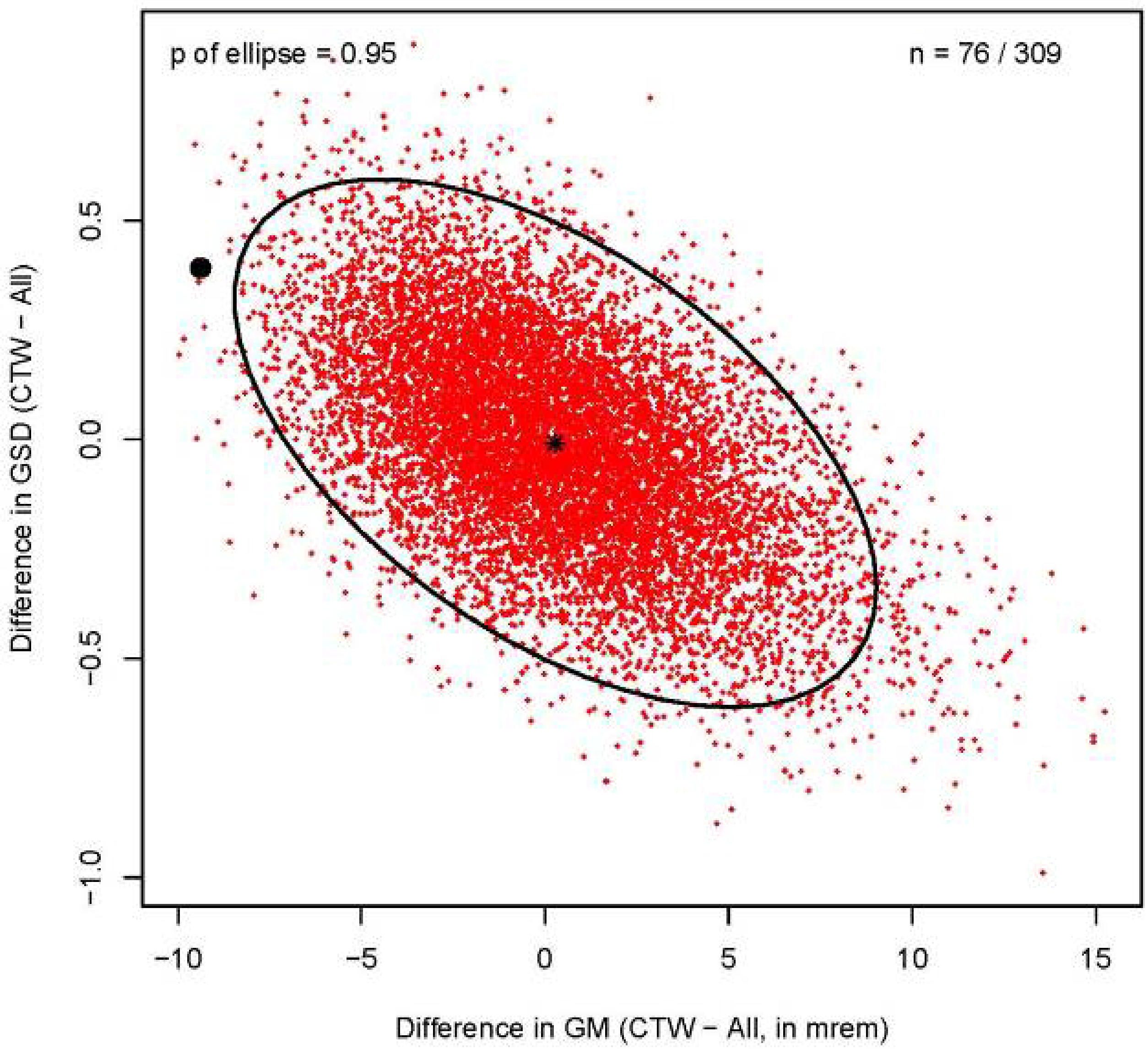

Figure A-60. SRS tritium dose 1973.

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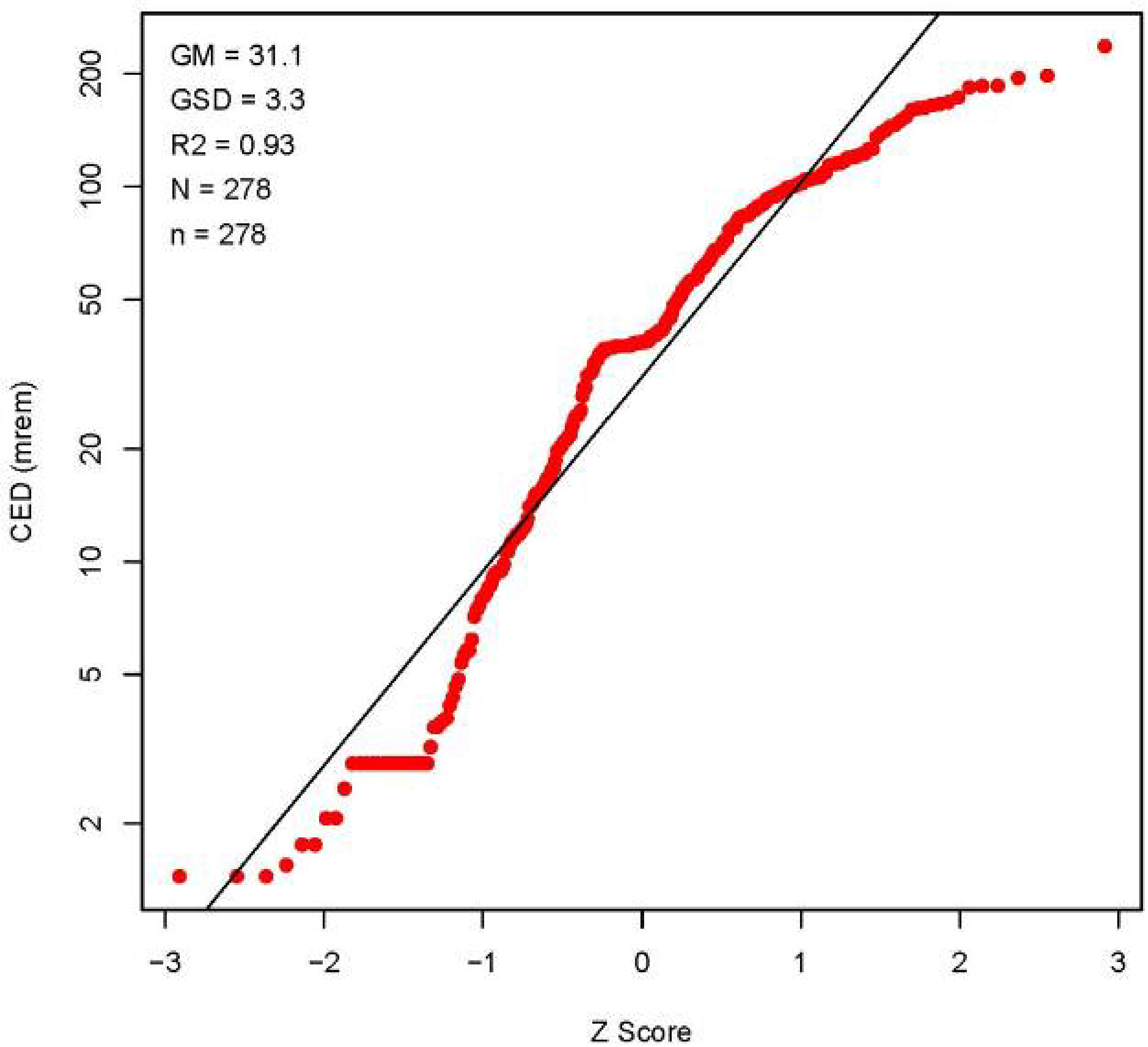

Figure A-61. SRS tritium dose 1974.

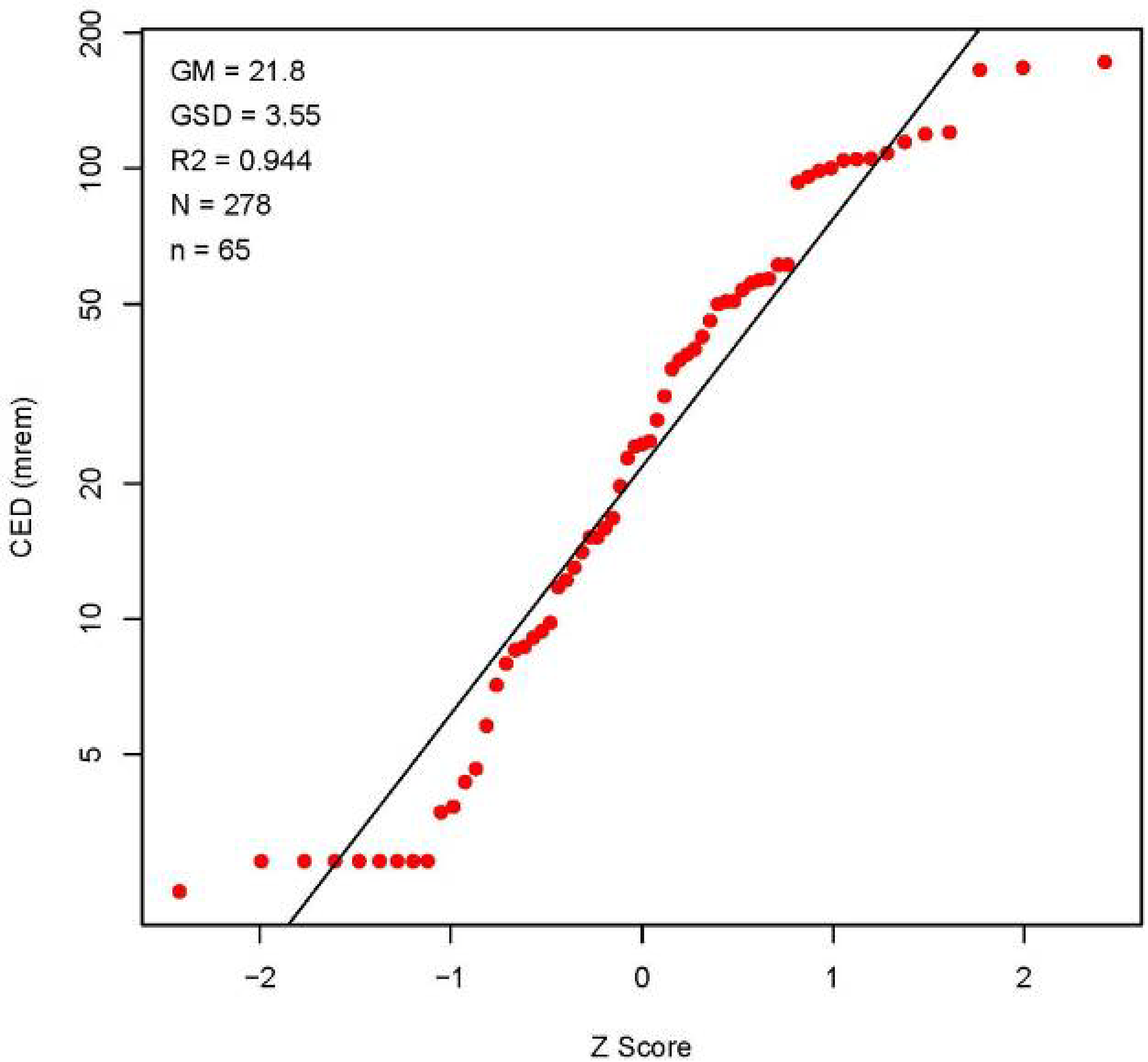

Figure A-62. SRS CTW tritium dose 1974.

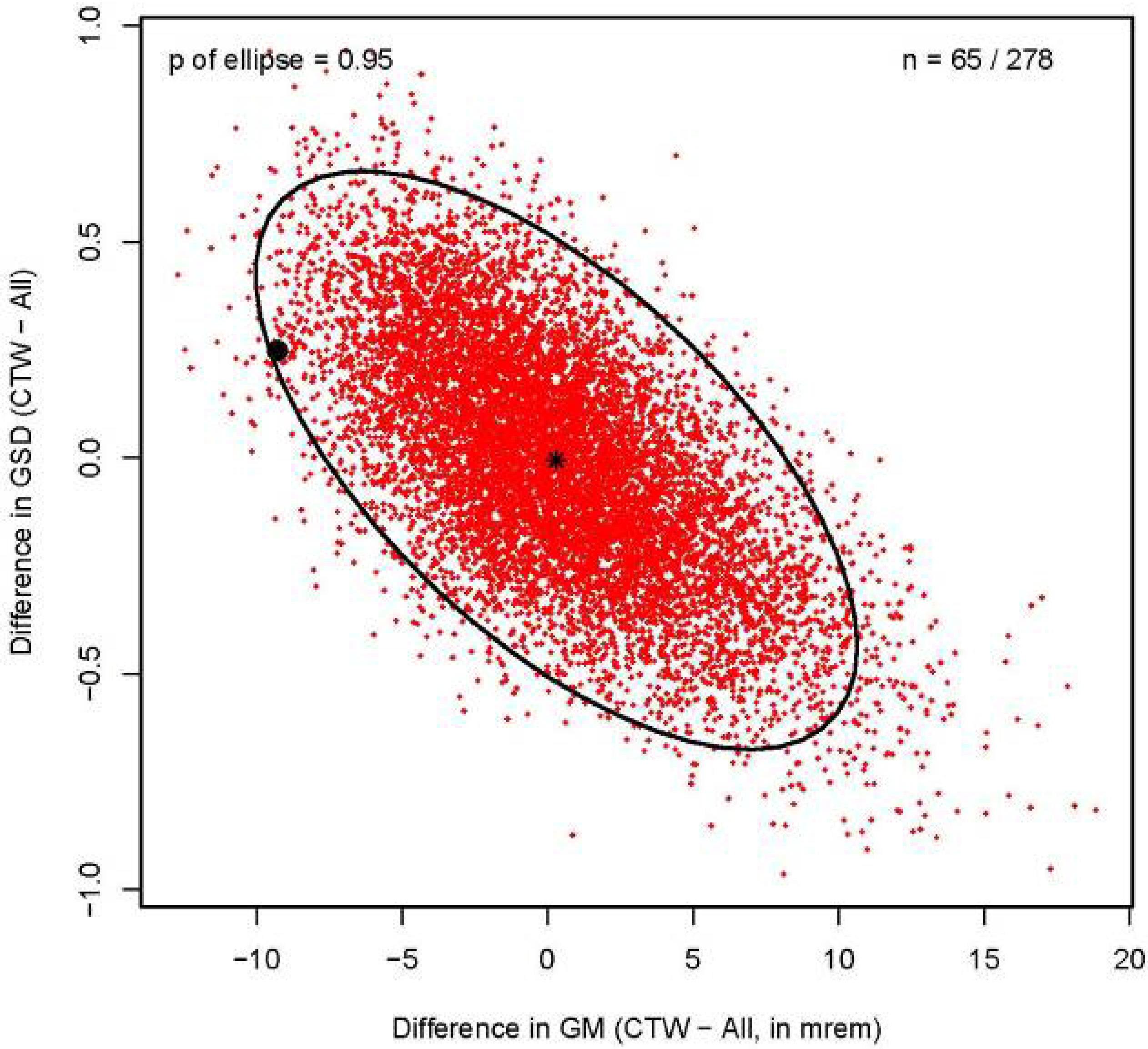

Figure A-63. SRS tritium dose 1974.

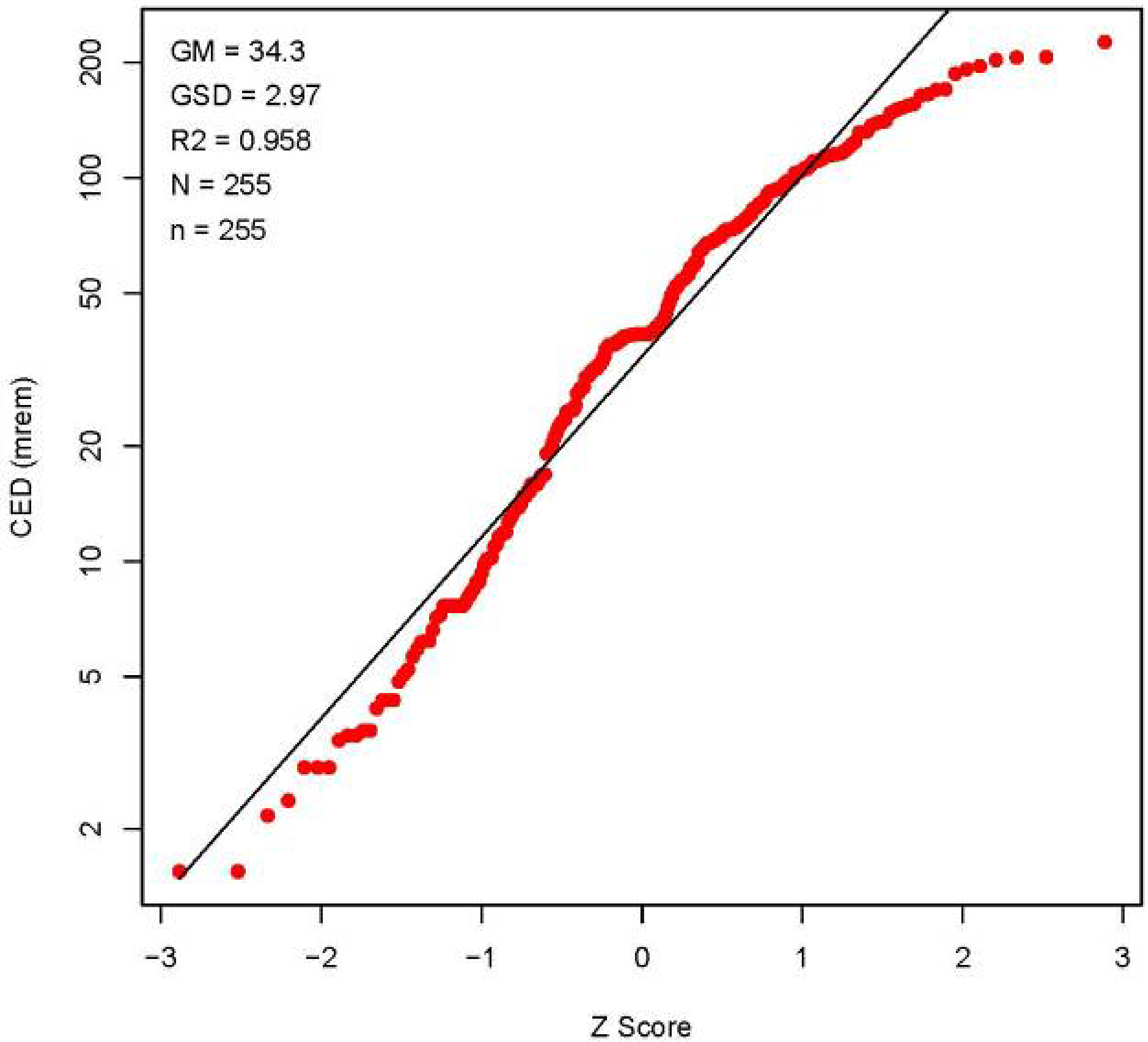

Figure A-64. SRS tritium dose 1975.

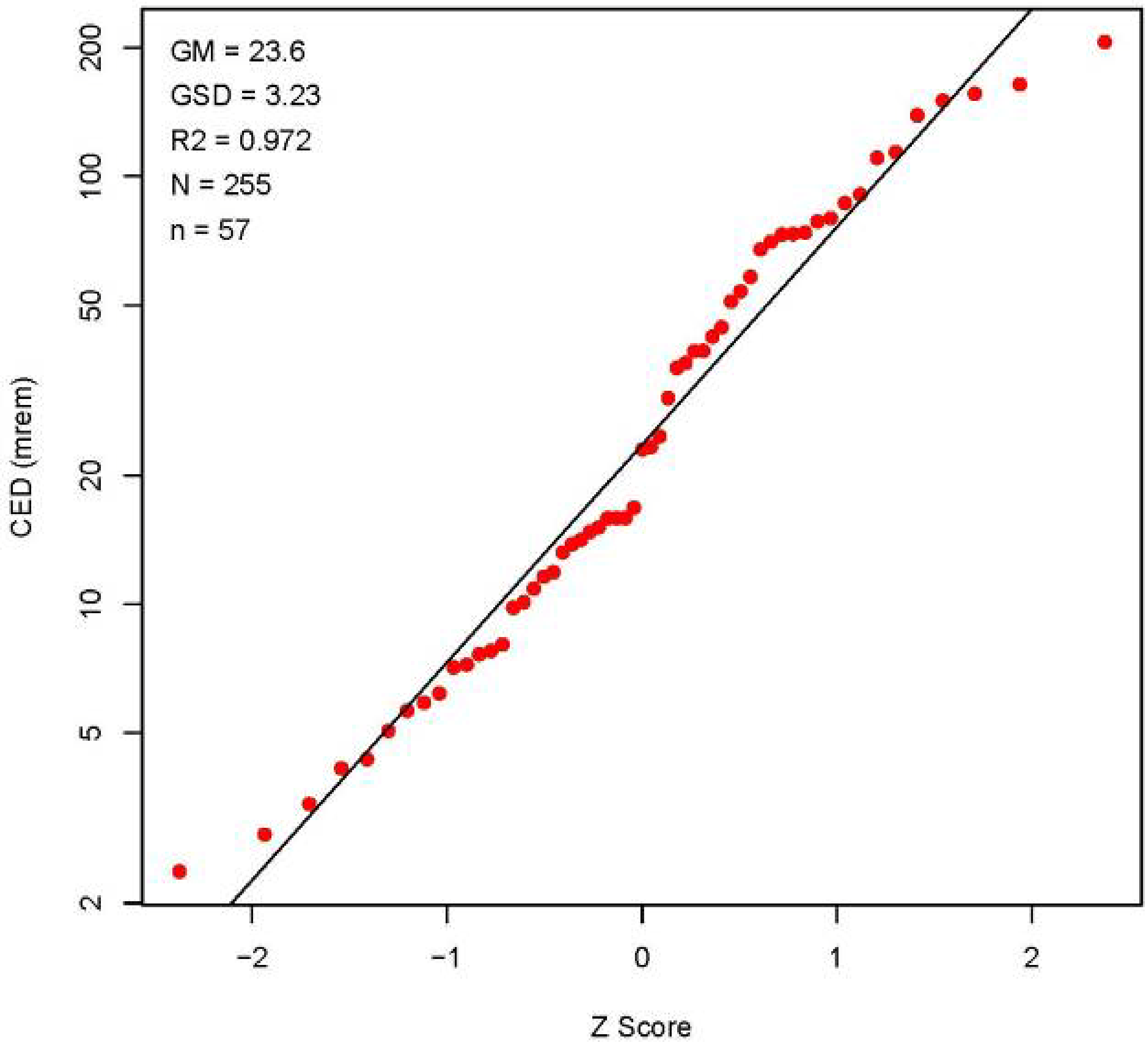

Figure A-65. SRS CTW tritium dose 1975.

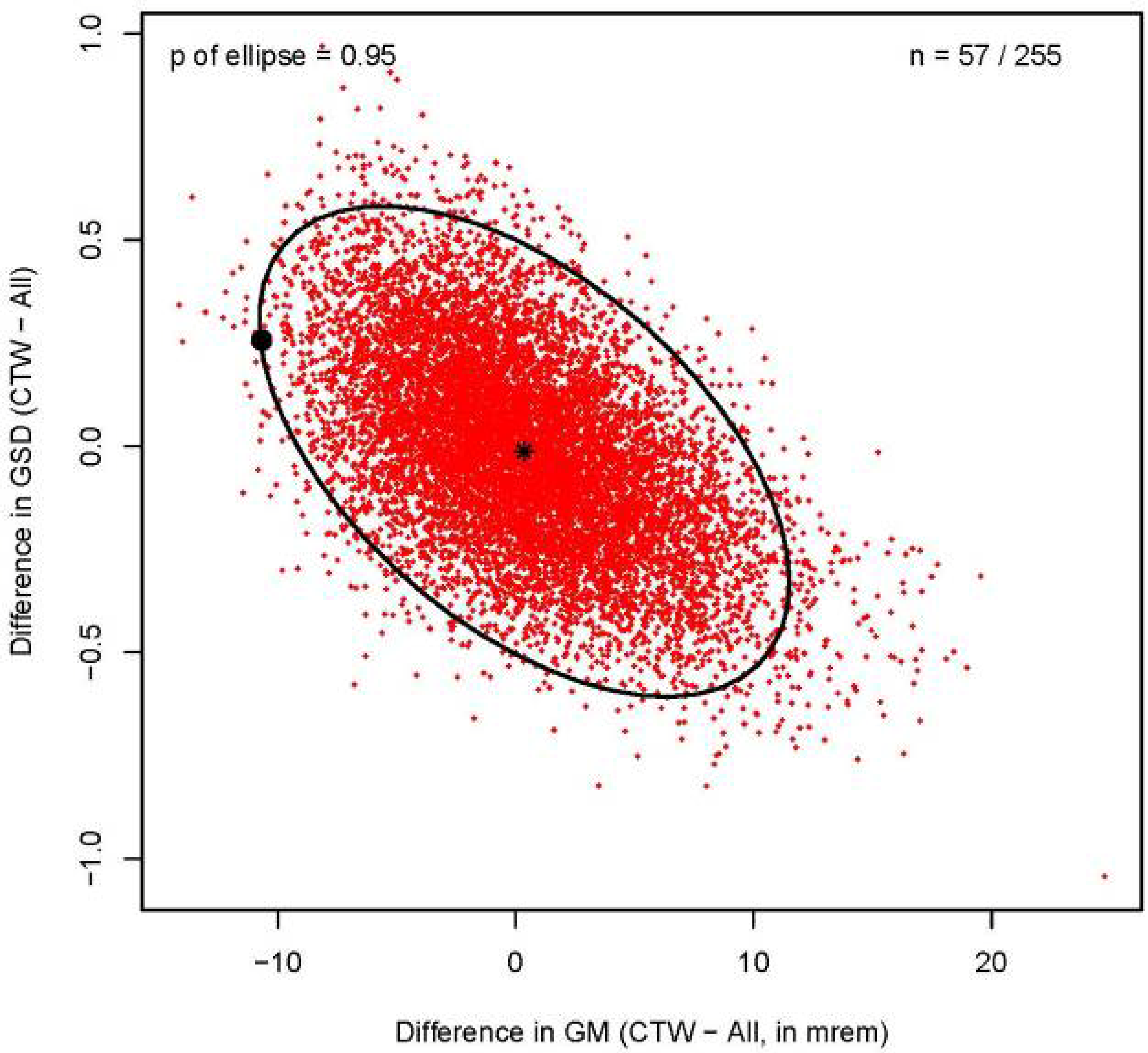

Figure A-66. SRS tritium dose 1975.

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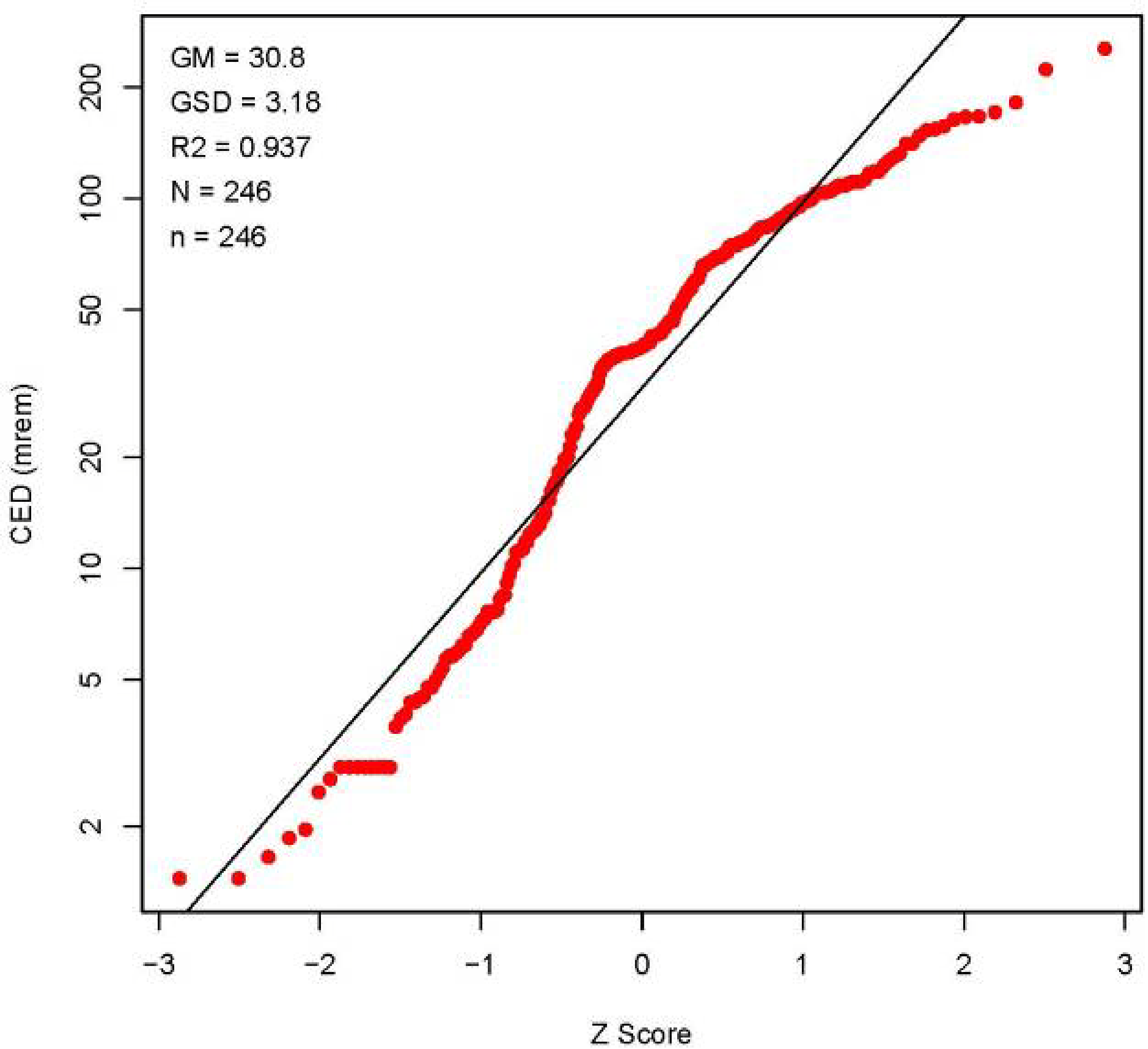

Figure A-67. SRS tritium dose 1976.

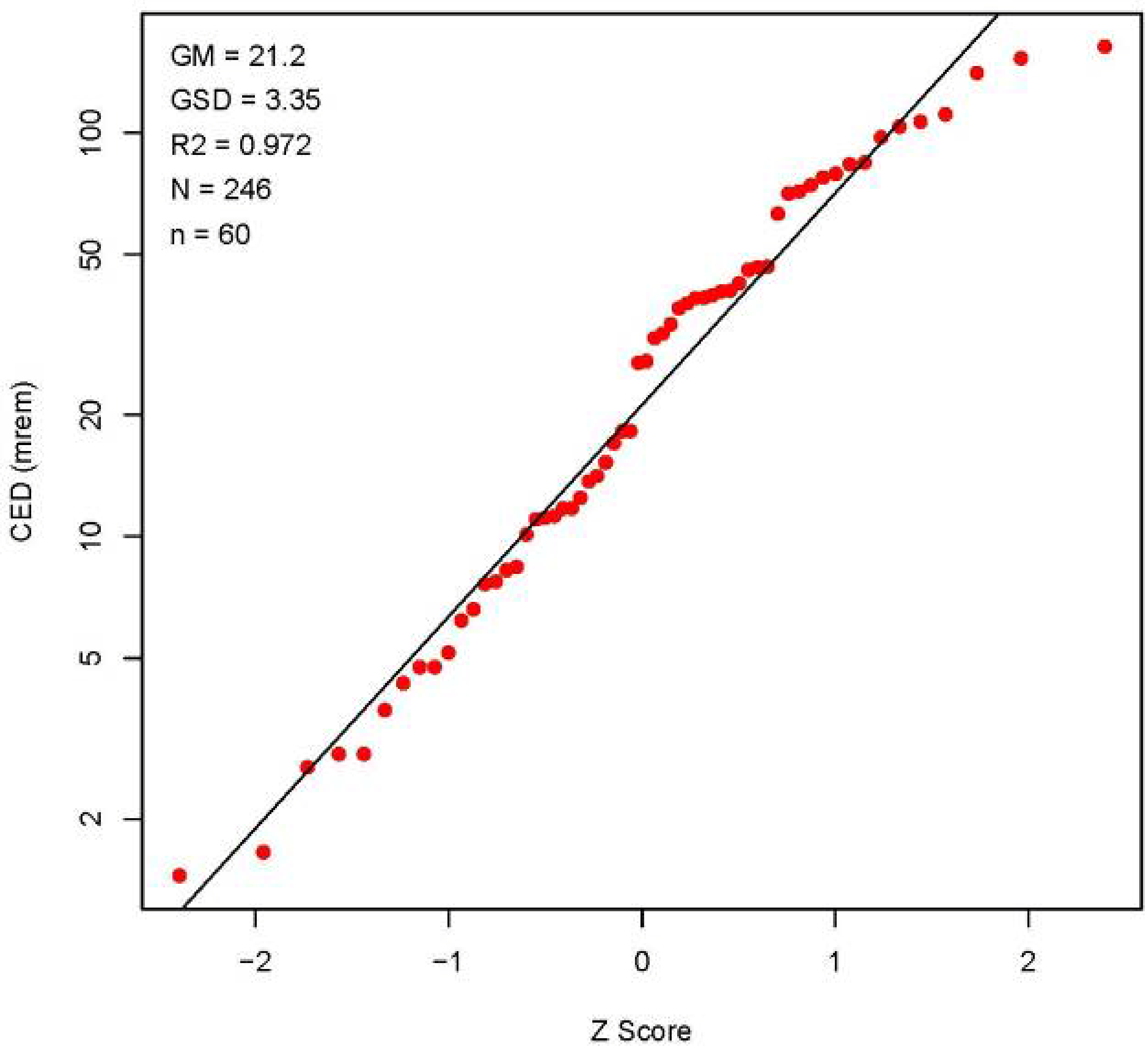

Figure A-68. SRS CTW tritium dose 1976.

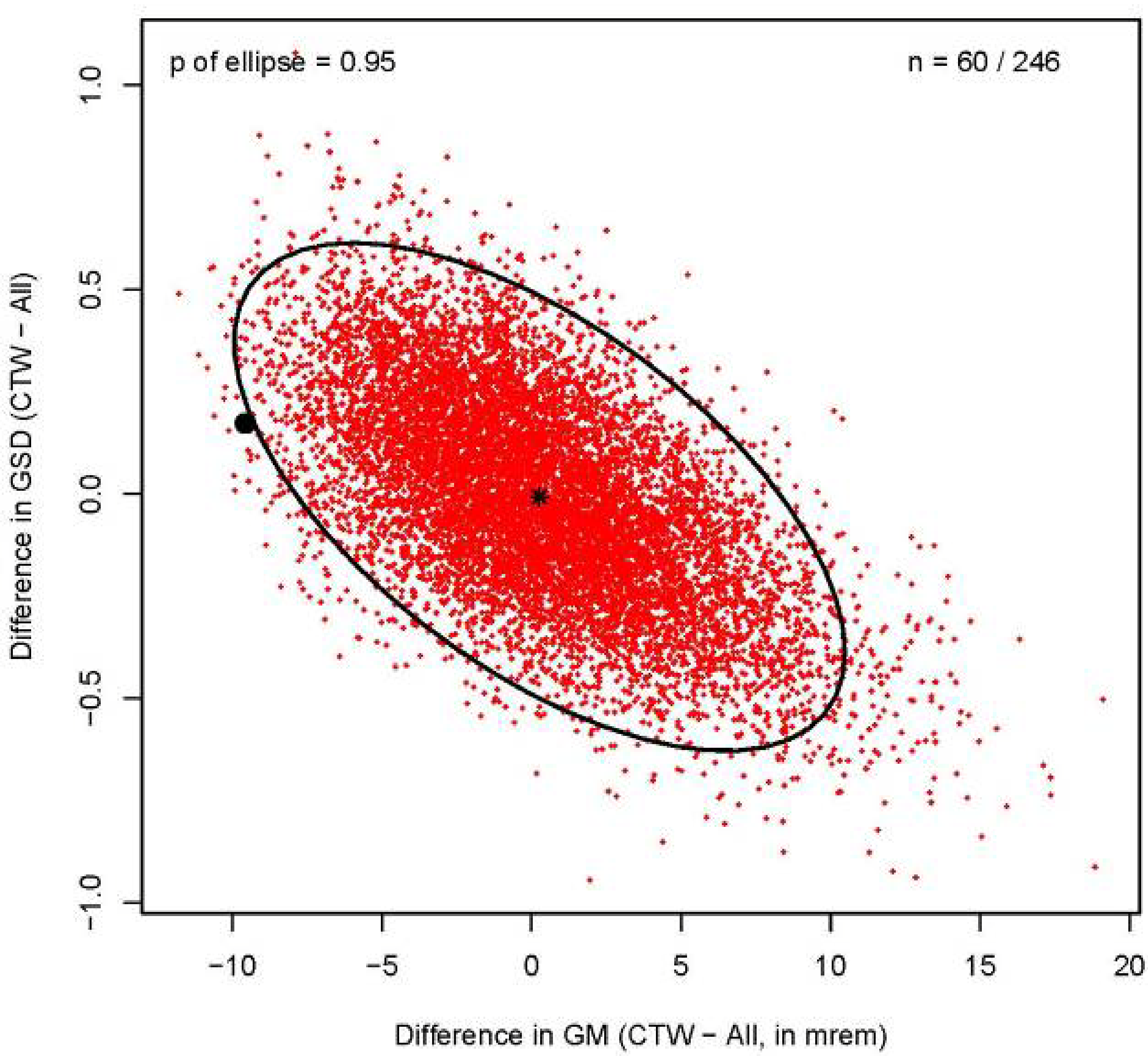

Figure A-69. SRS tritium dose 1976.

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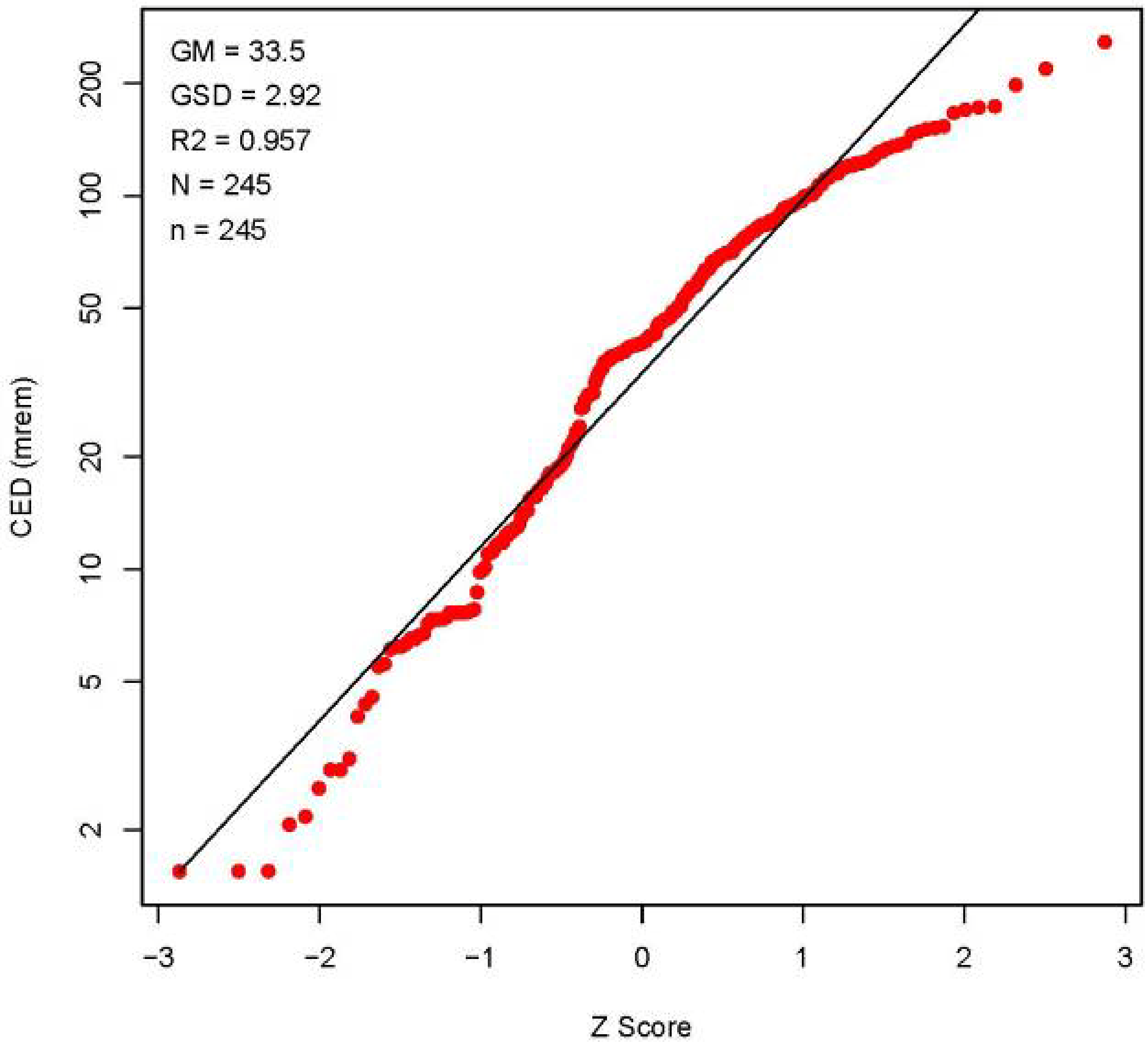

Figure A-70. SRS tritium dose 1977.

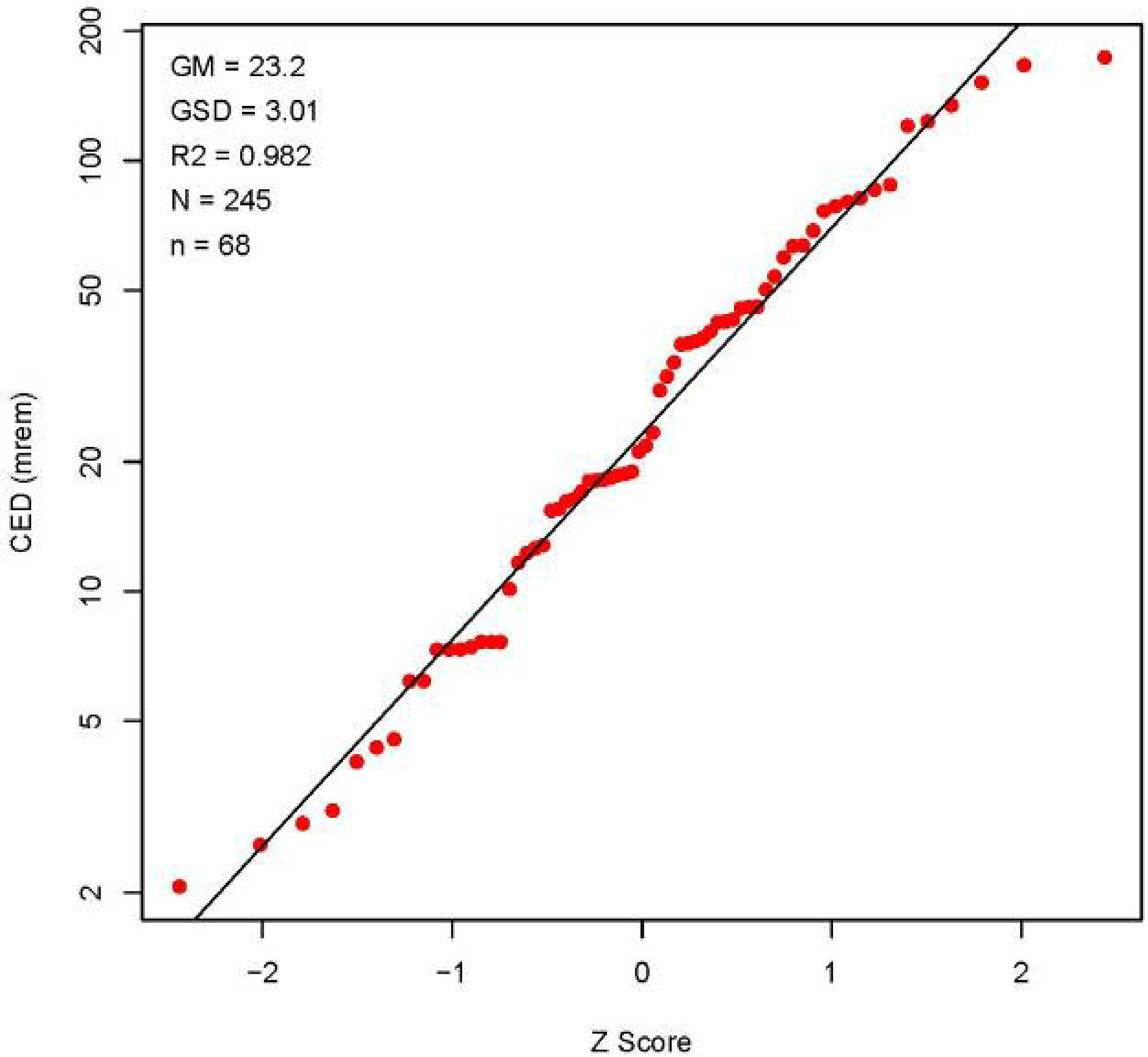

Figure A-71. SRS CTW tritium dose 1977.

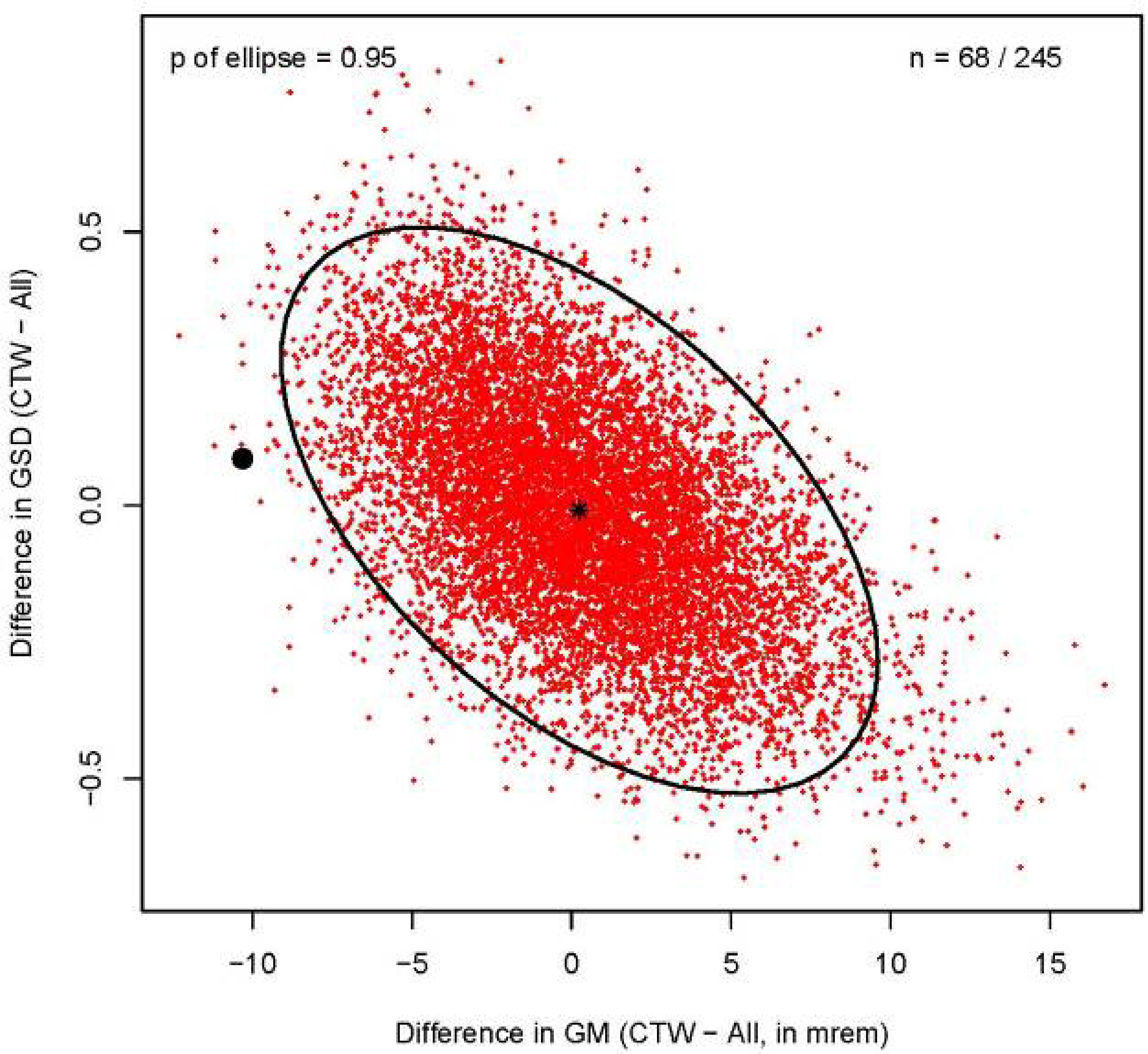

Figure A-72. SRS tritium dose 1977.

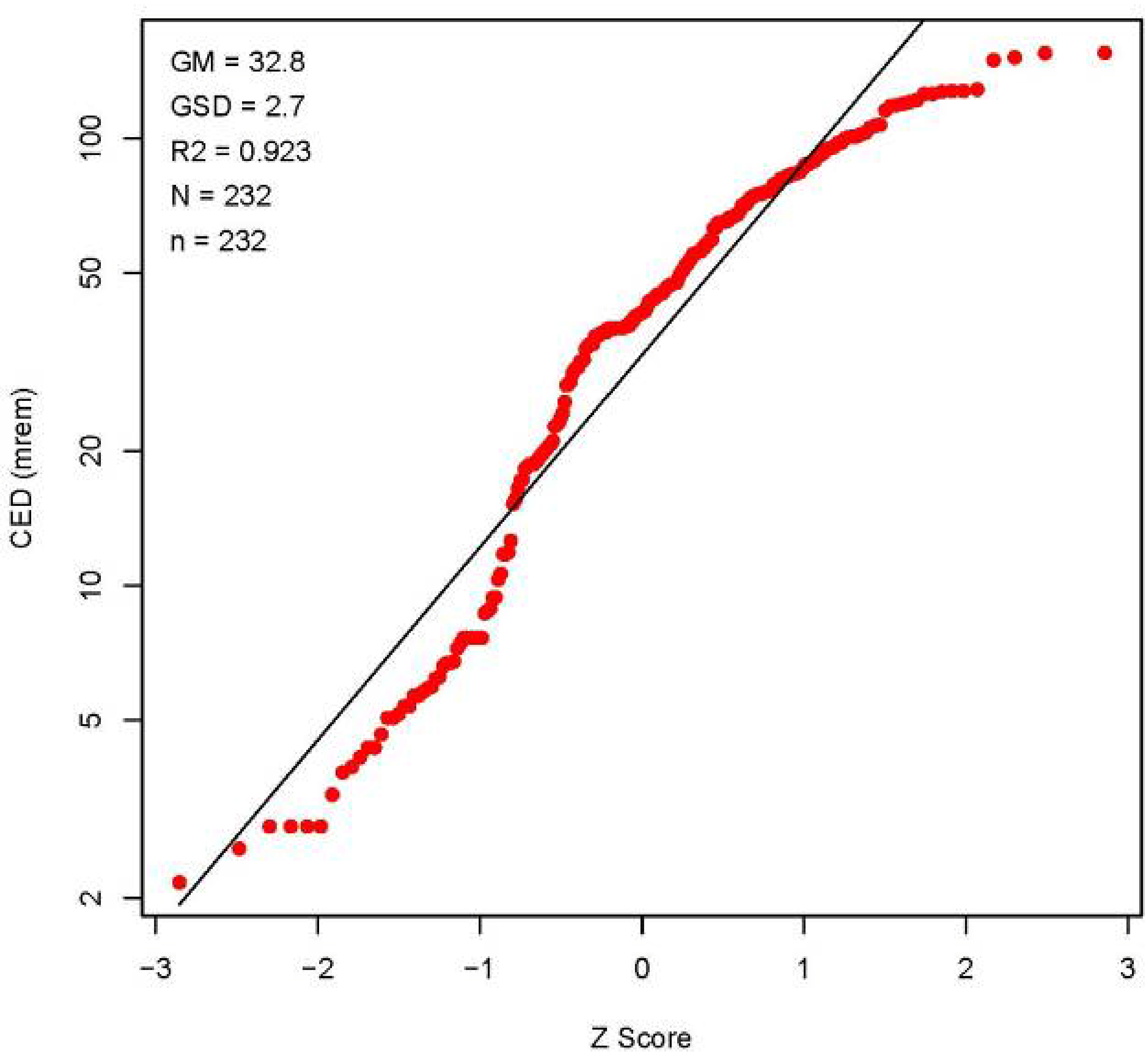

Figure A-73. SRS tritium dose 1978.

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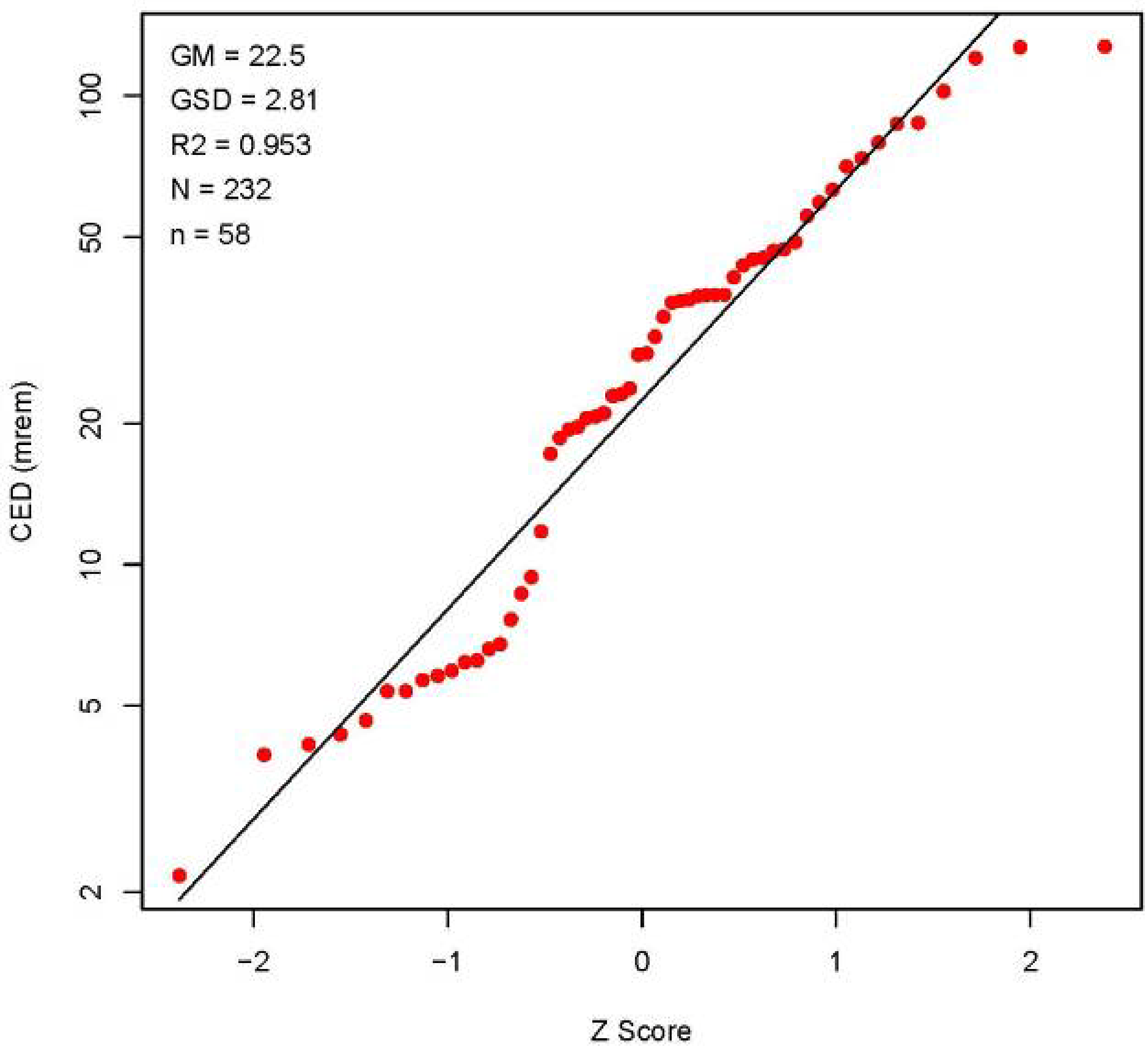

Figure A-74. SRS CTW tritium dose 1978.

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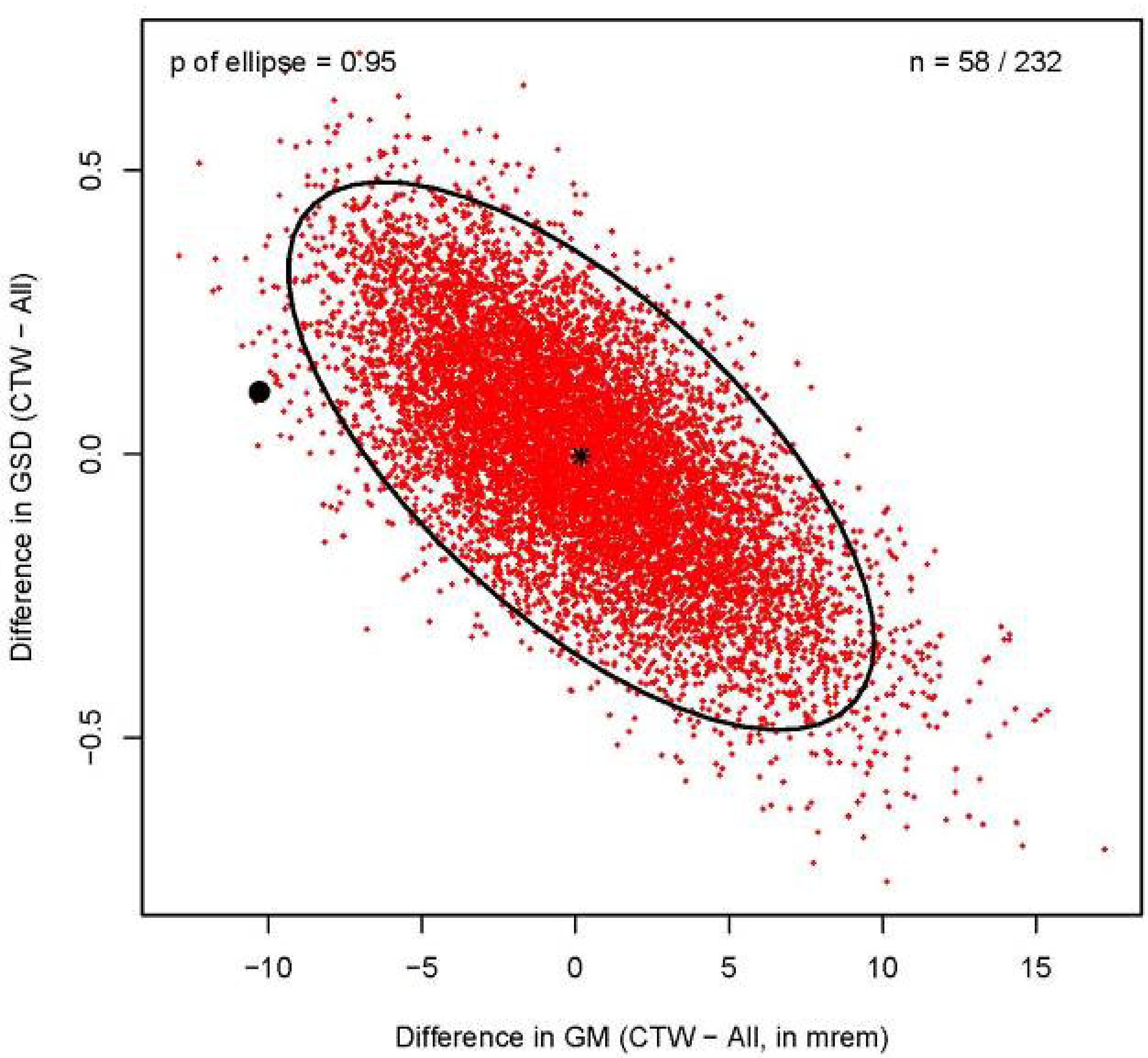

Figure A-75. SRS tritium dose 1978.

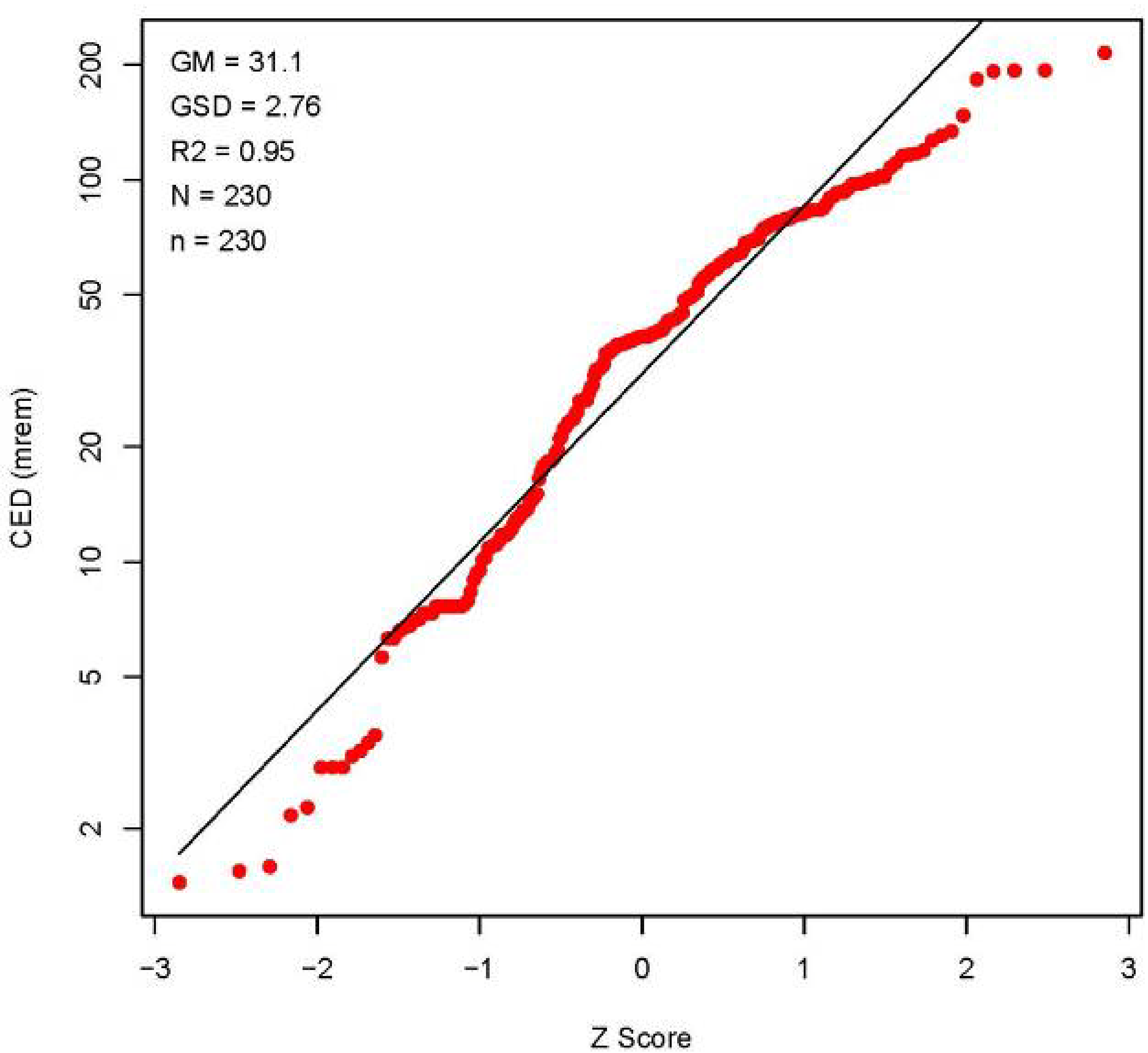

Figure A-76. SRS tritium dose 1979.

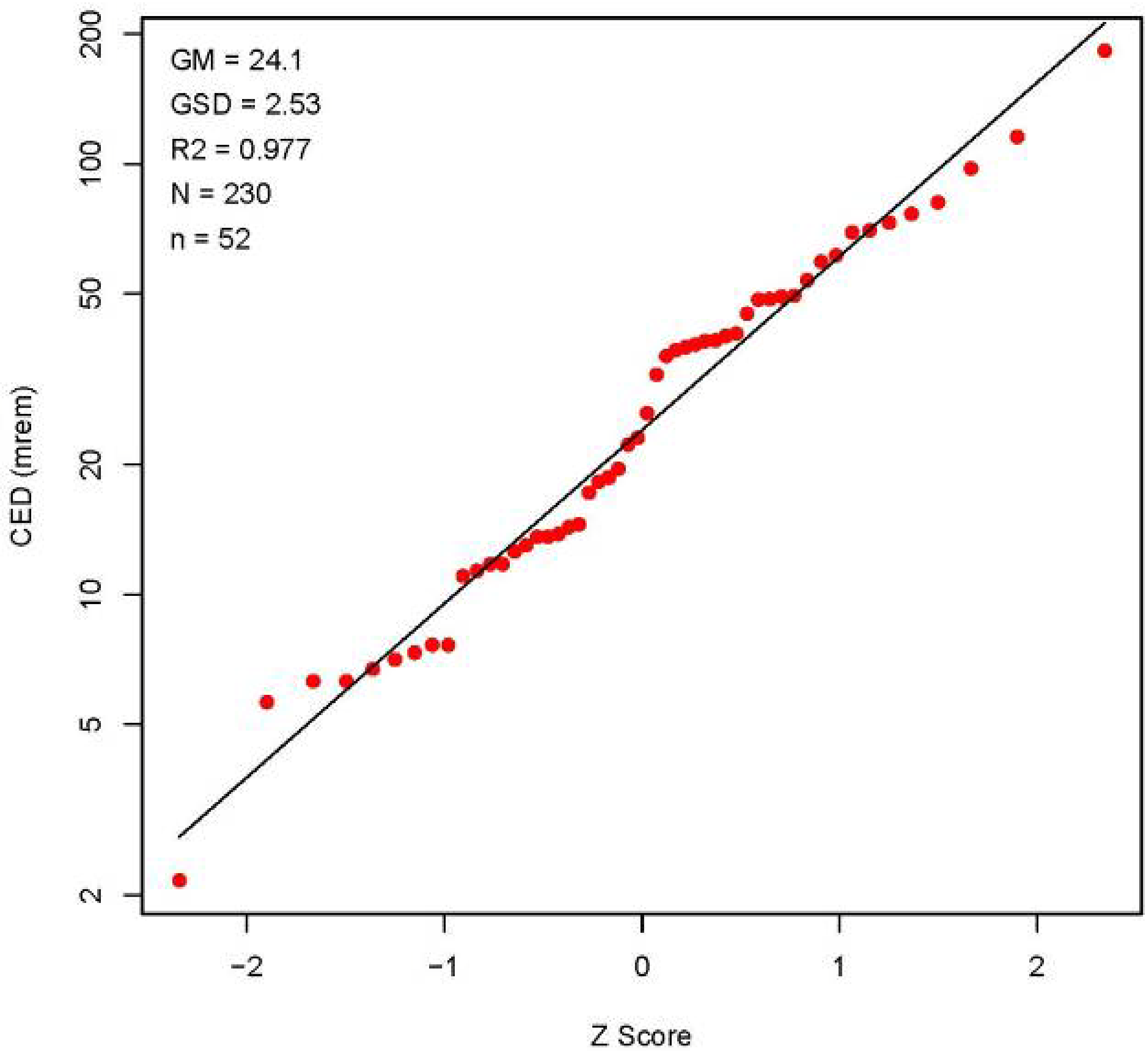

Figure A-77. SRS CTW tritium dose 1979.

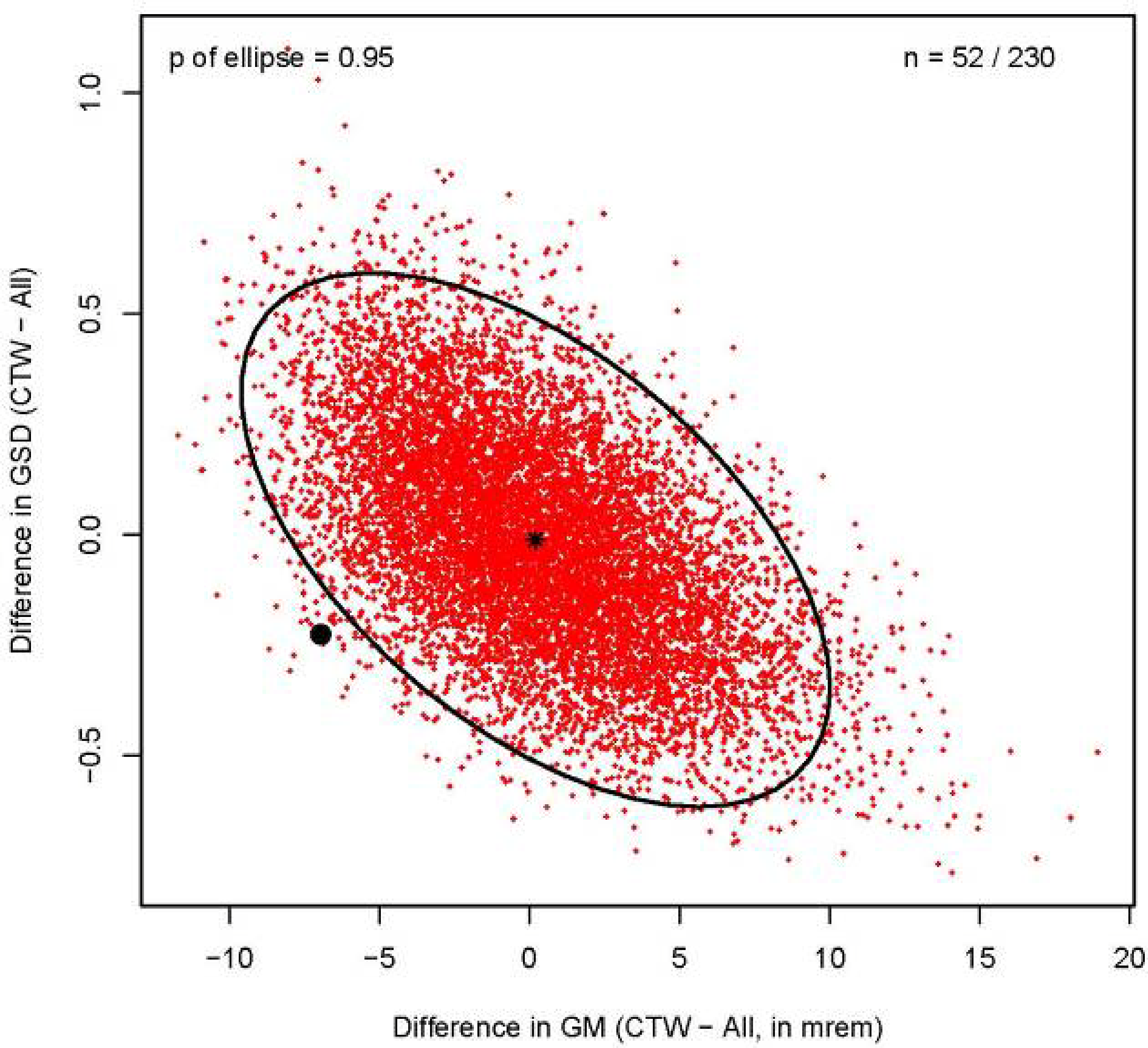

Figure A-78. SRS tritium dose 1979.

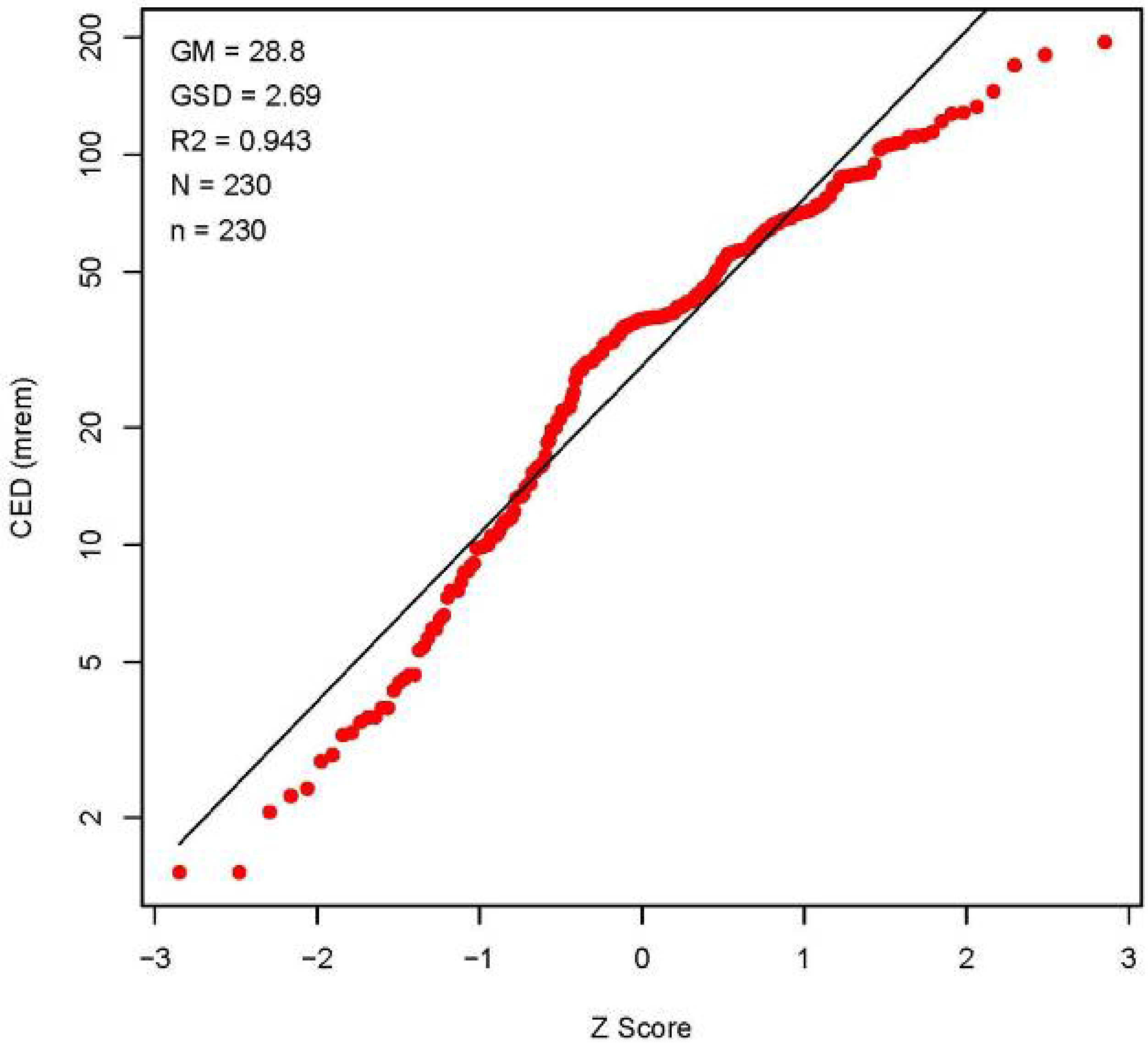

Figure A-79. SRS tritium dose 1980.

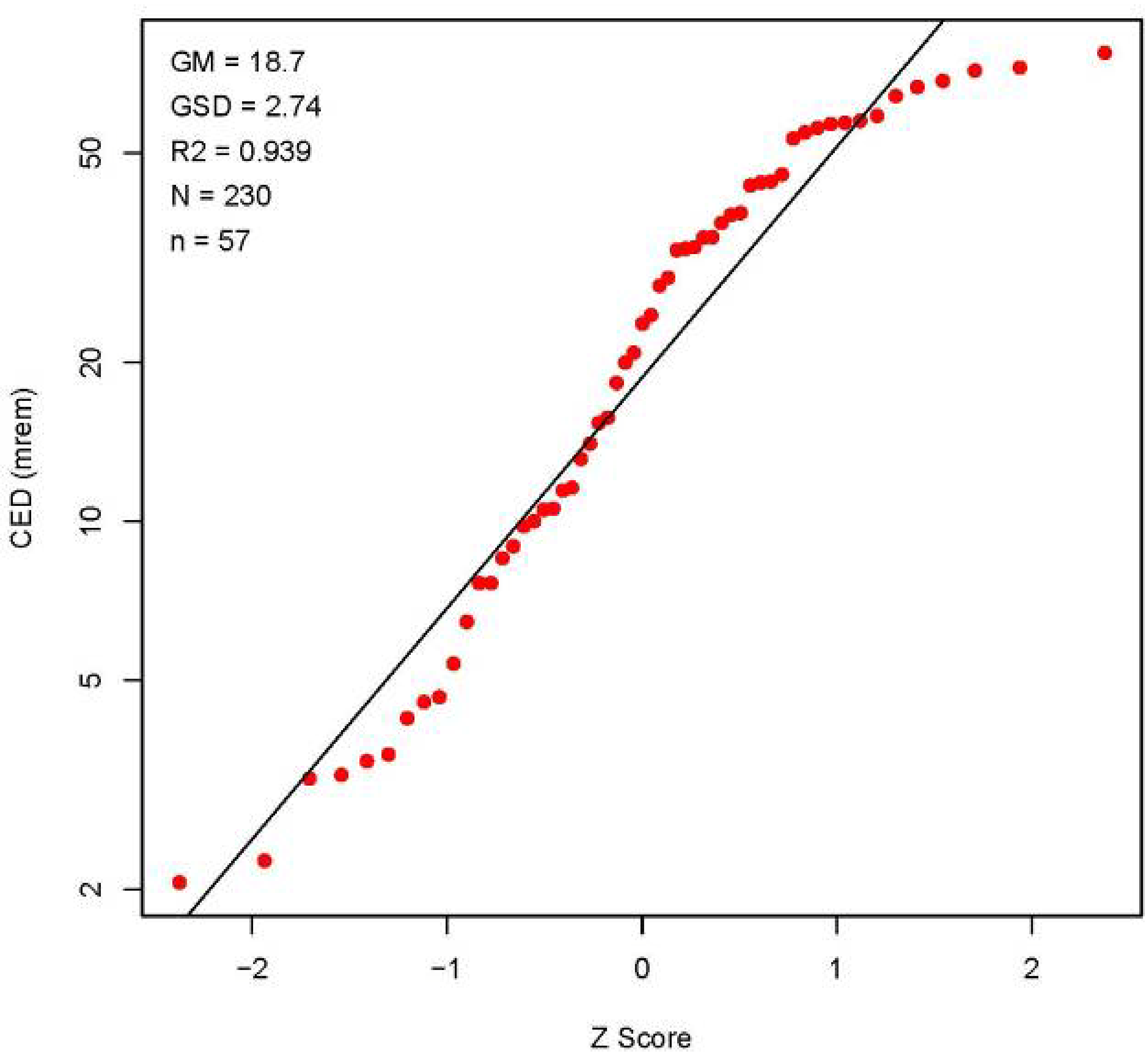

Figure A-80. SRS CTW tritium dose 1980.

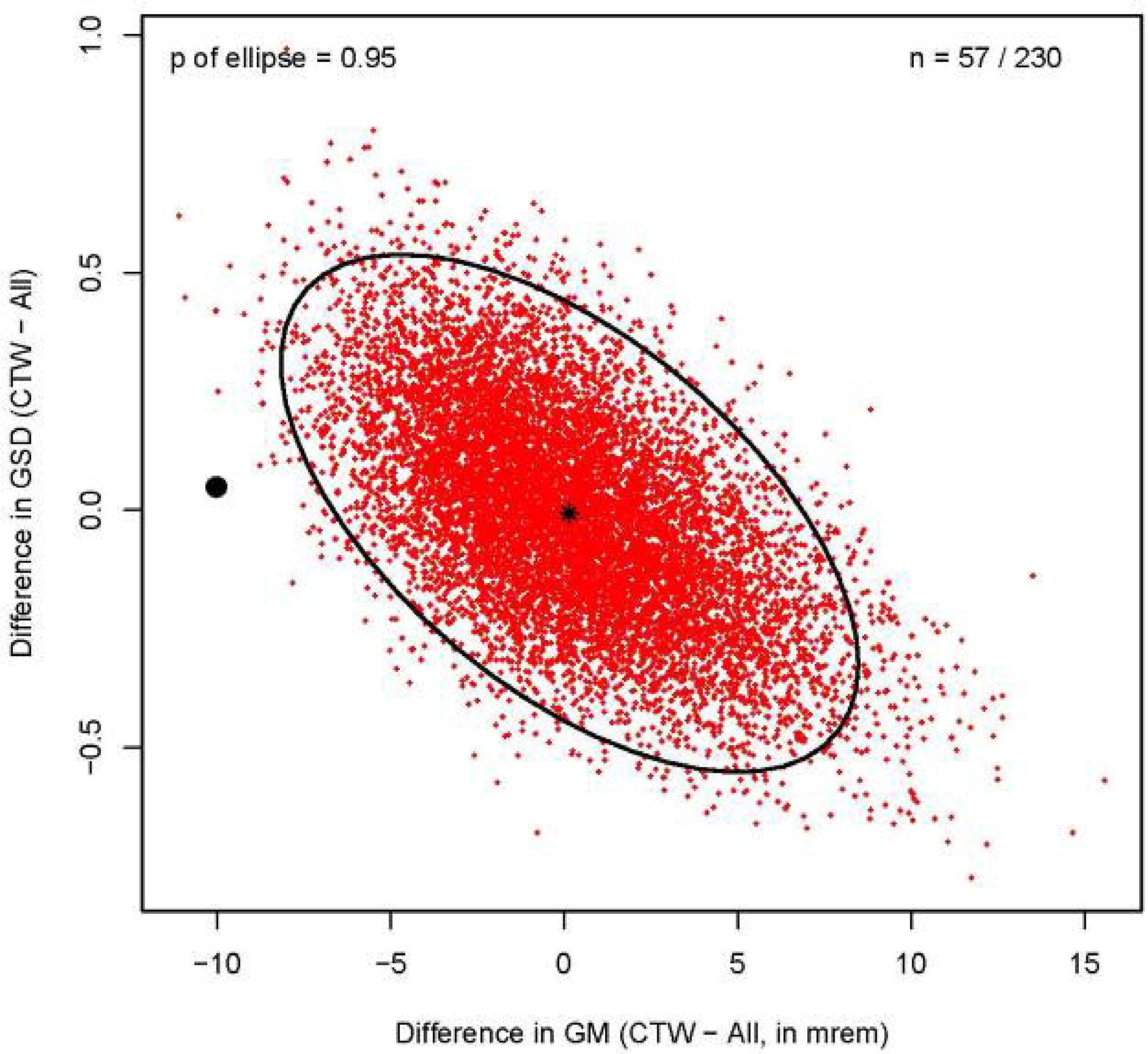

Figure A-81. SRS tritium dose 1980.

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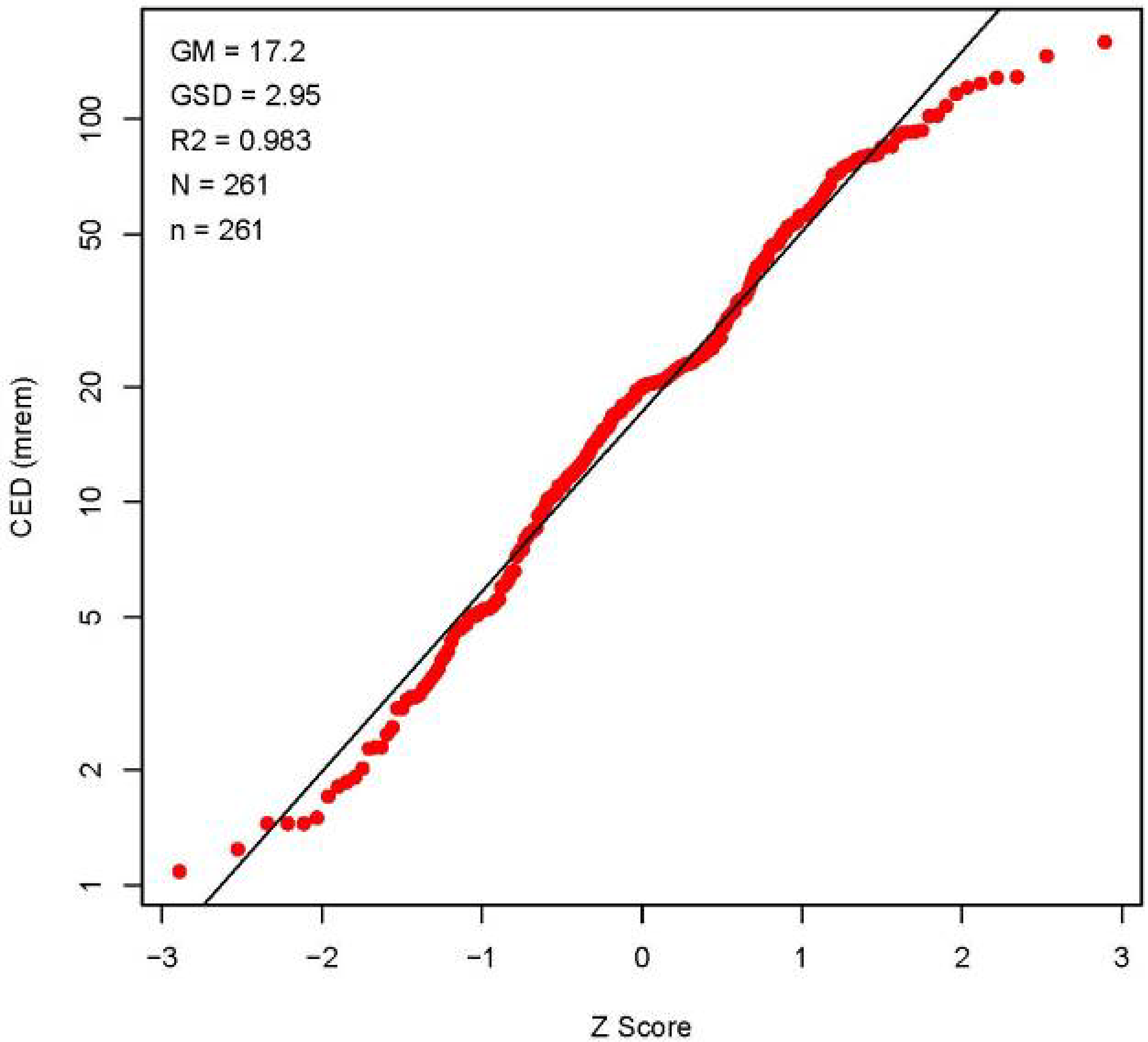

Figure A-82. SRS tritium dose 1981.

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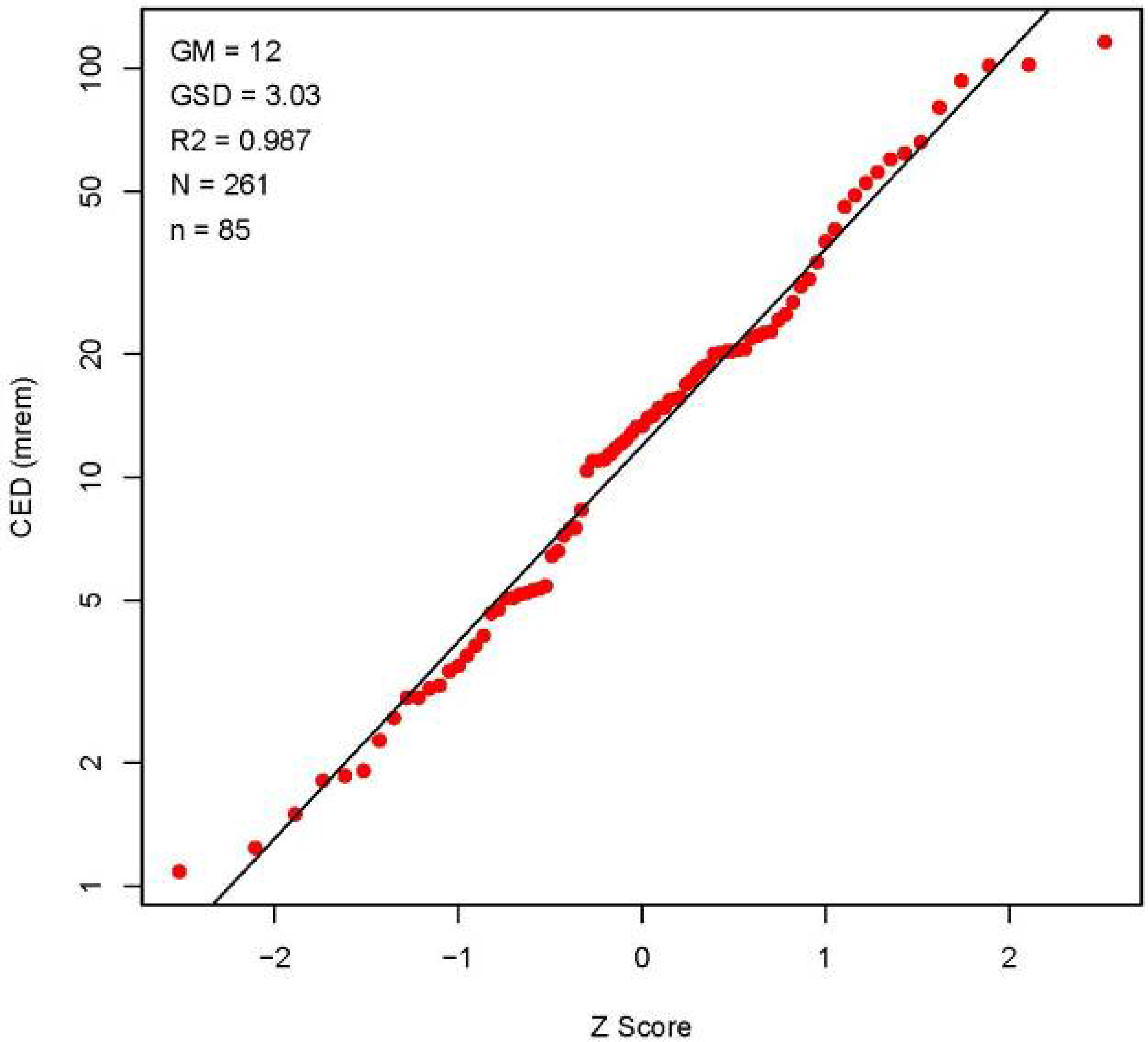

Figure A-83. SRS CTW tritium dose 1981.

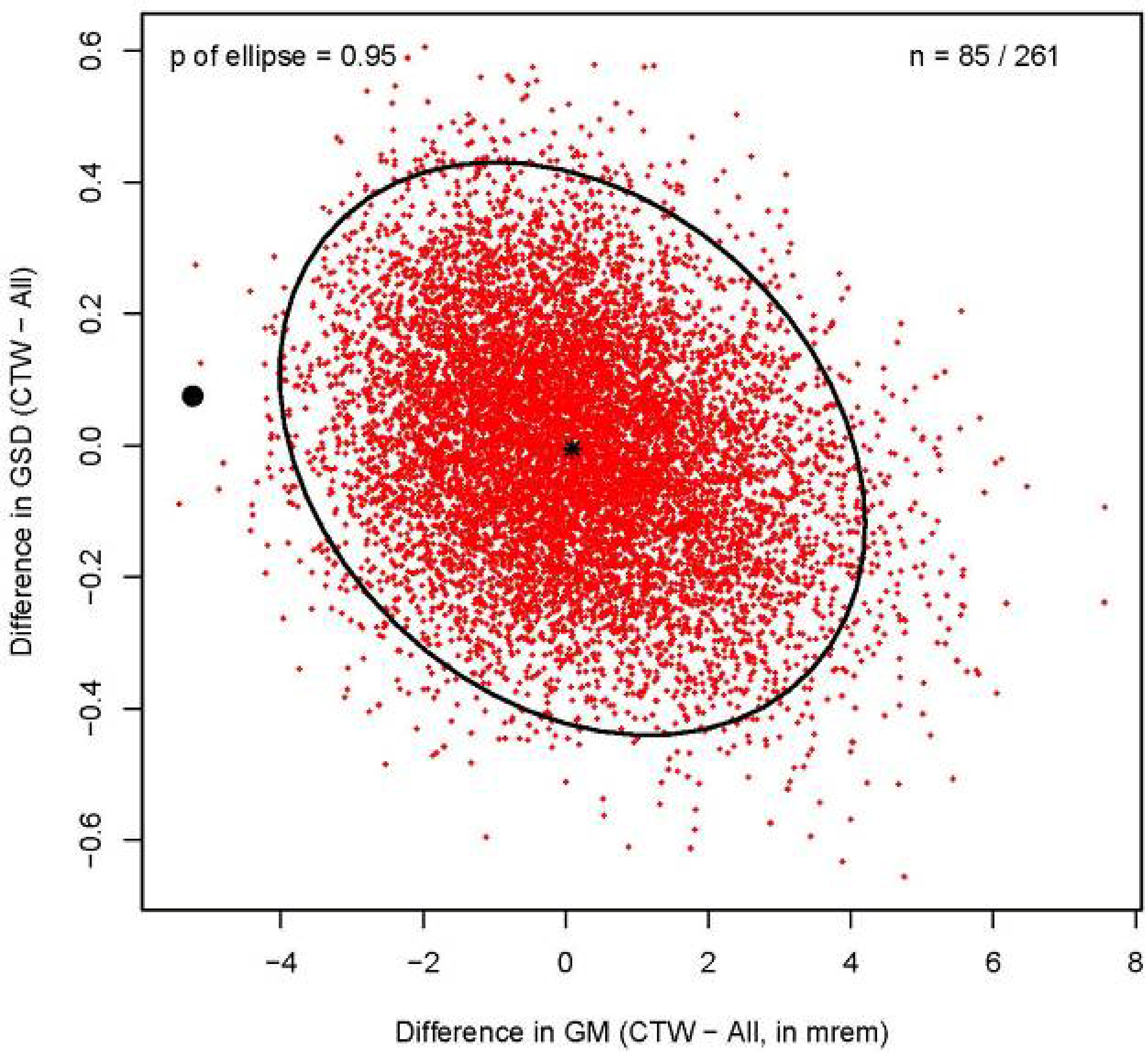

Figure A-84. SRS tritium dose 1981.

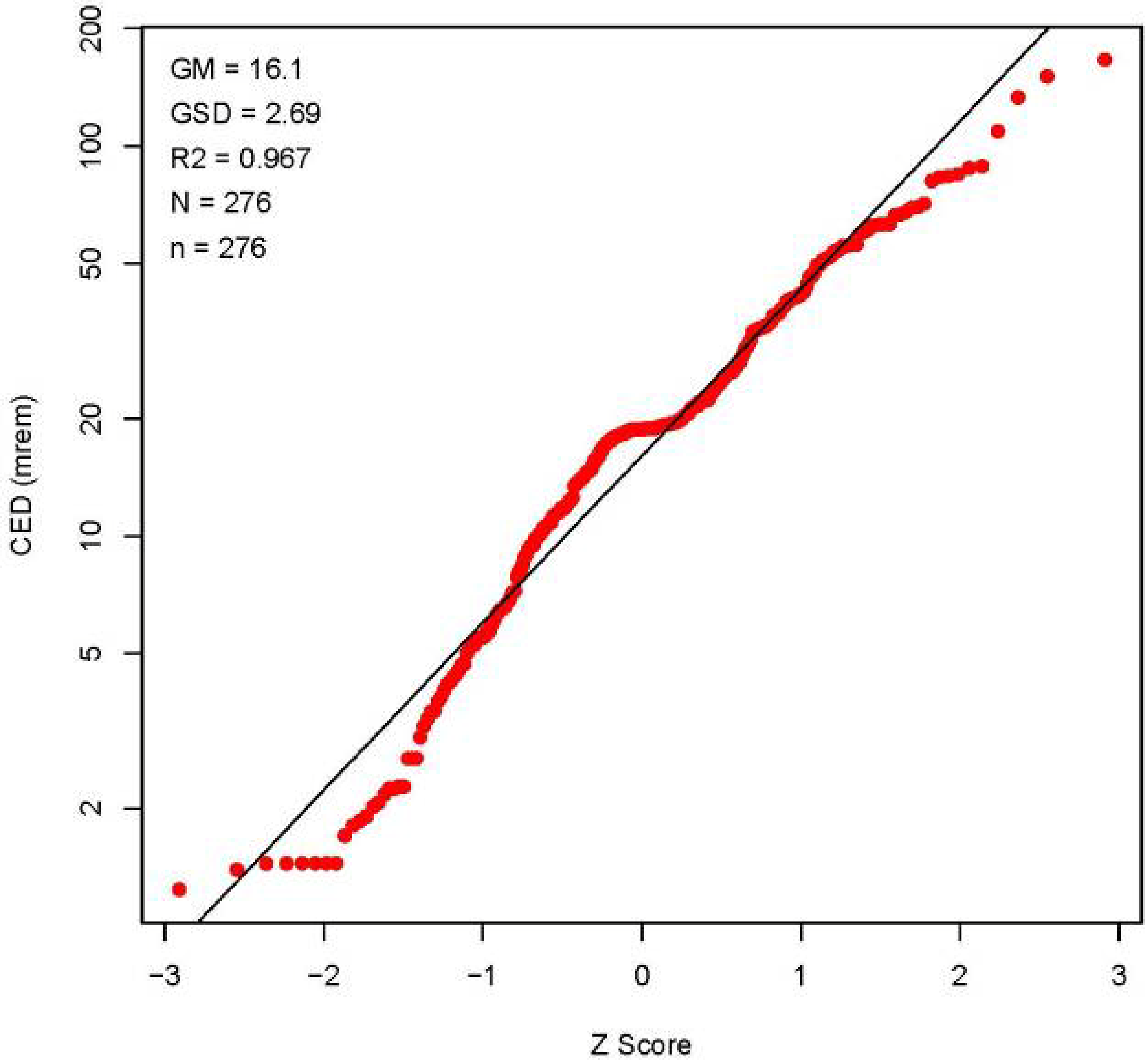

Figure A-85. SRS tritium dose 1982.

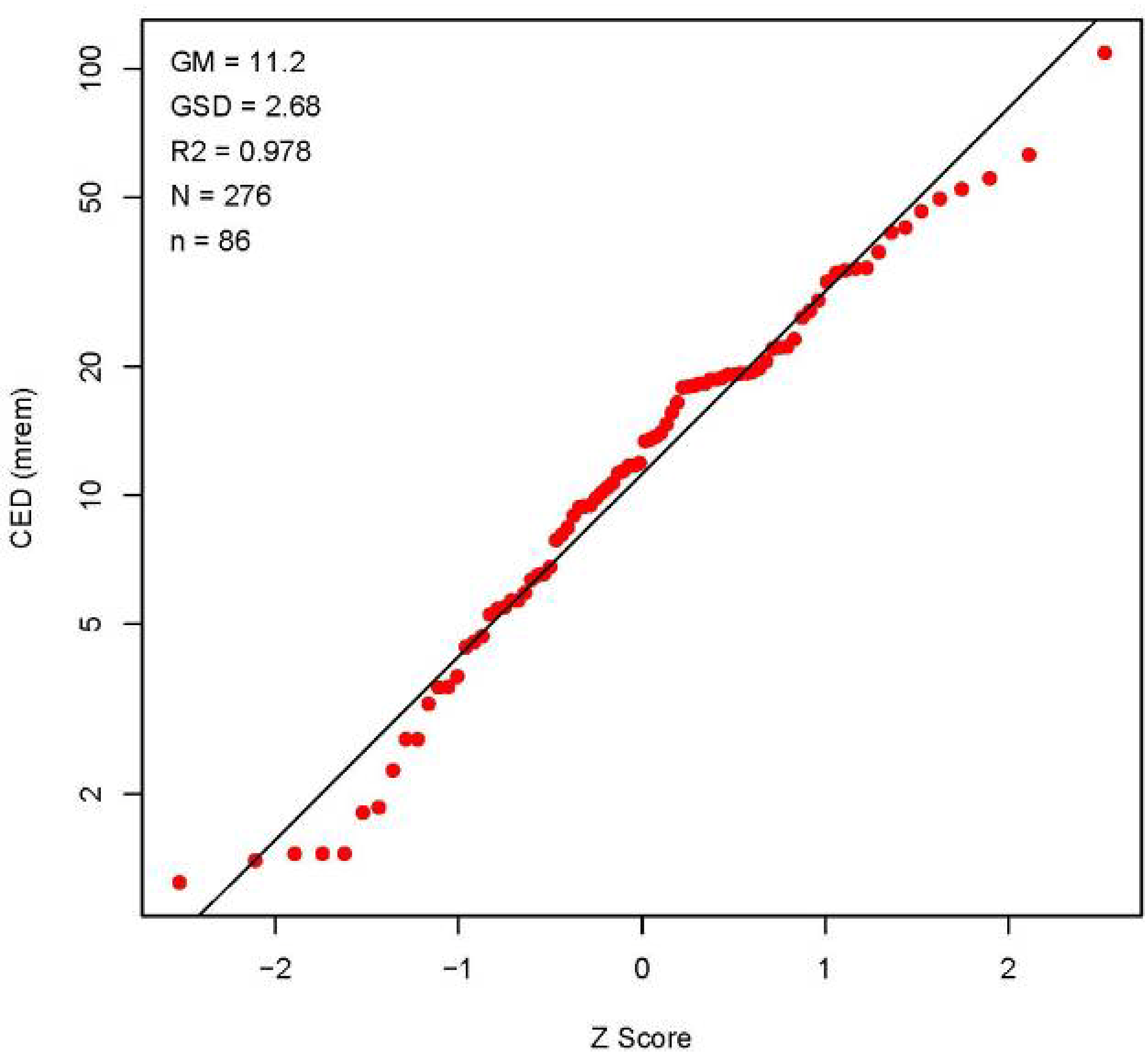

Figure A-86. SRS CTW tritium dose 1982.

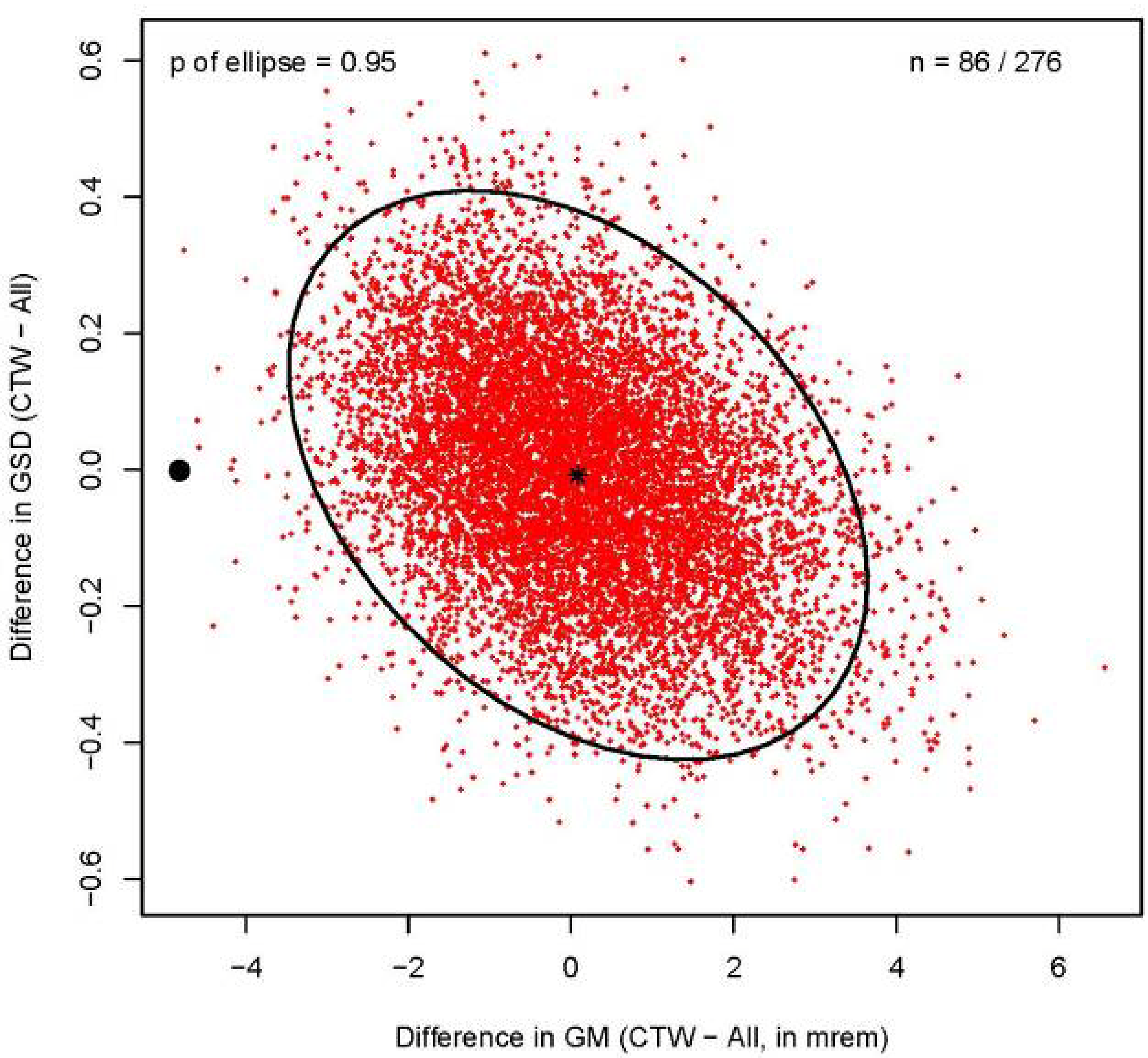

Figure A-87. SRS tritium dose 1982.

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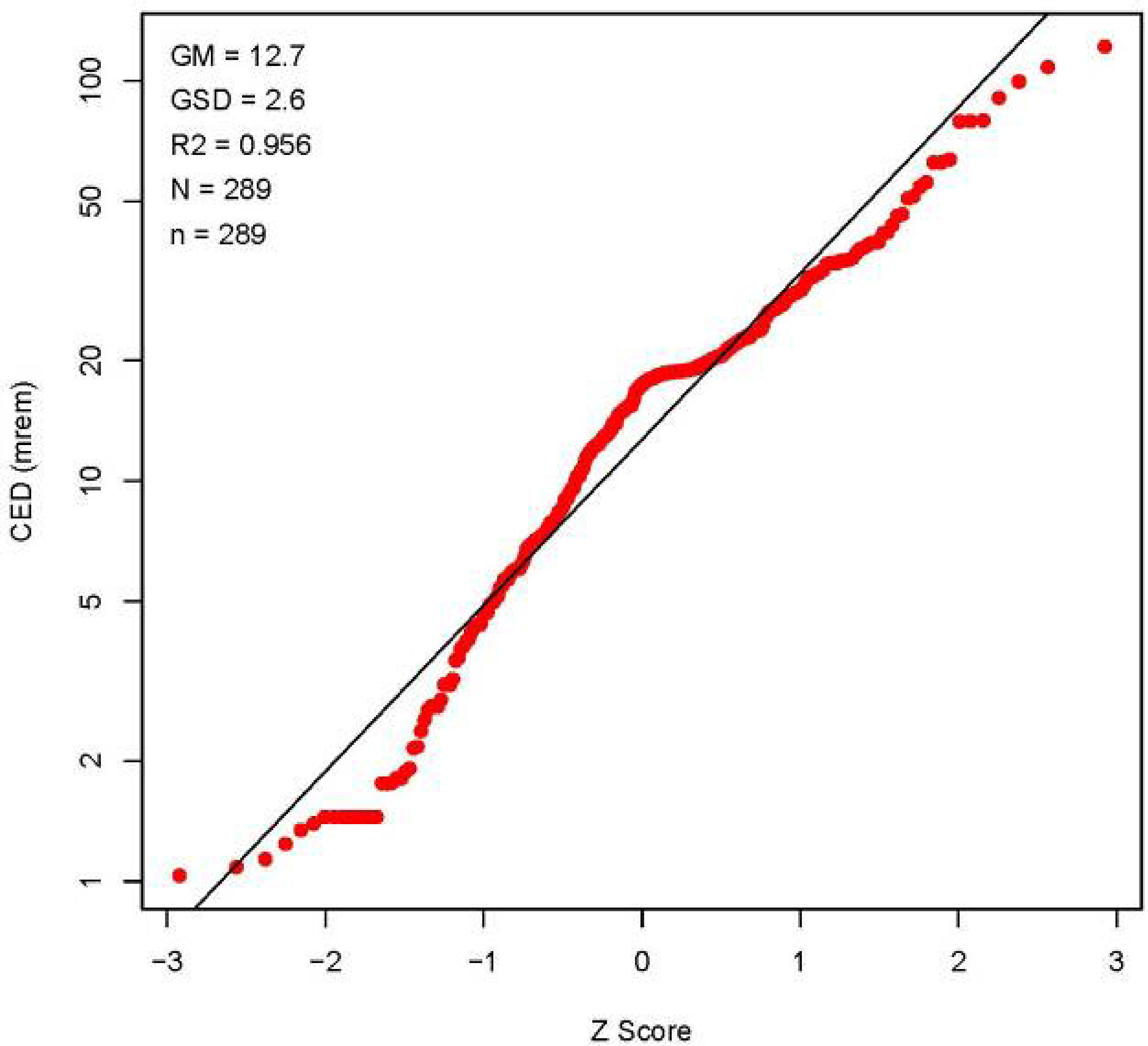

Figure A-88. SRS tritium dose 1983.

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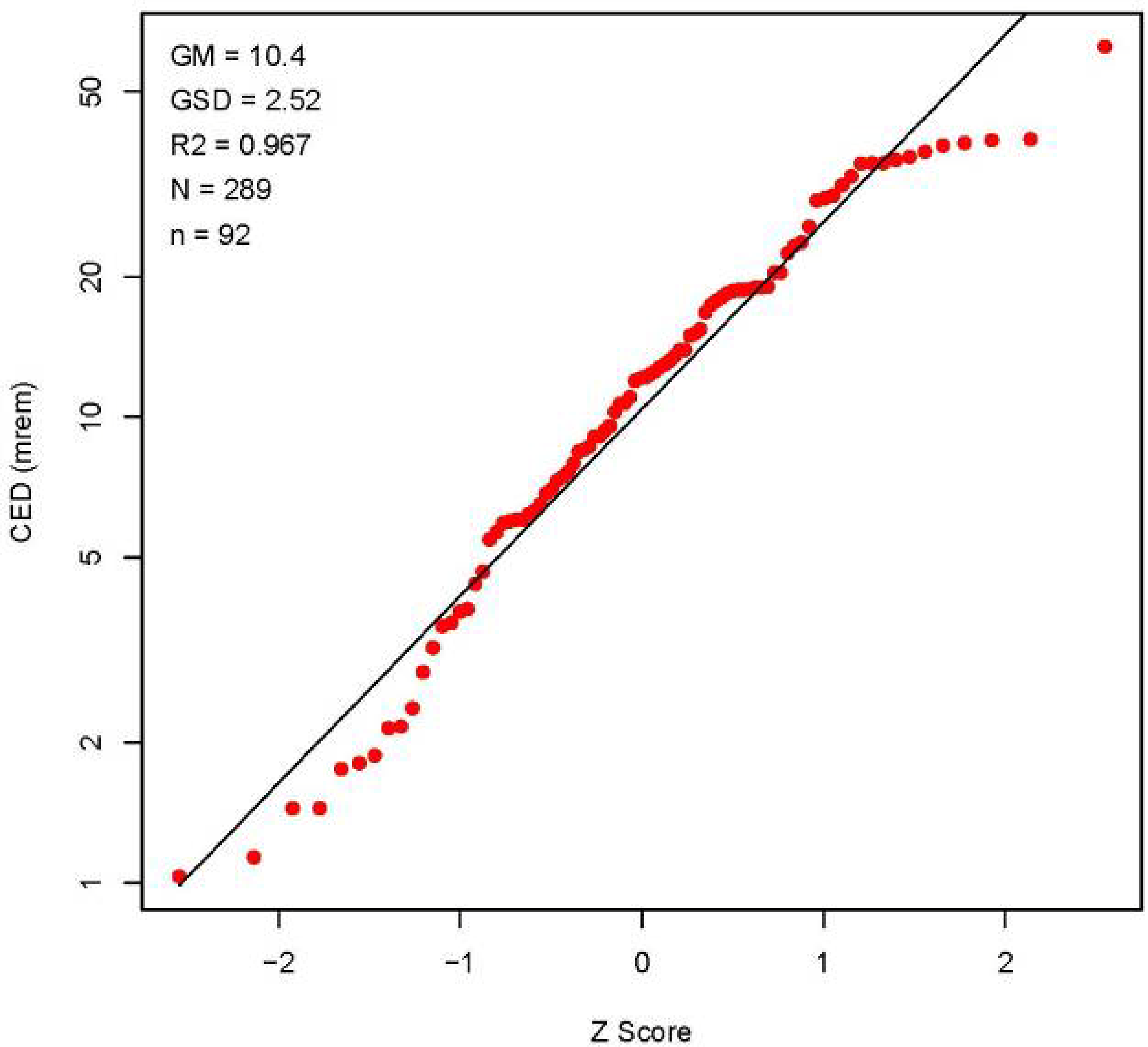

Figure A-89. SRS CTW tritium dose 1983.

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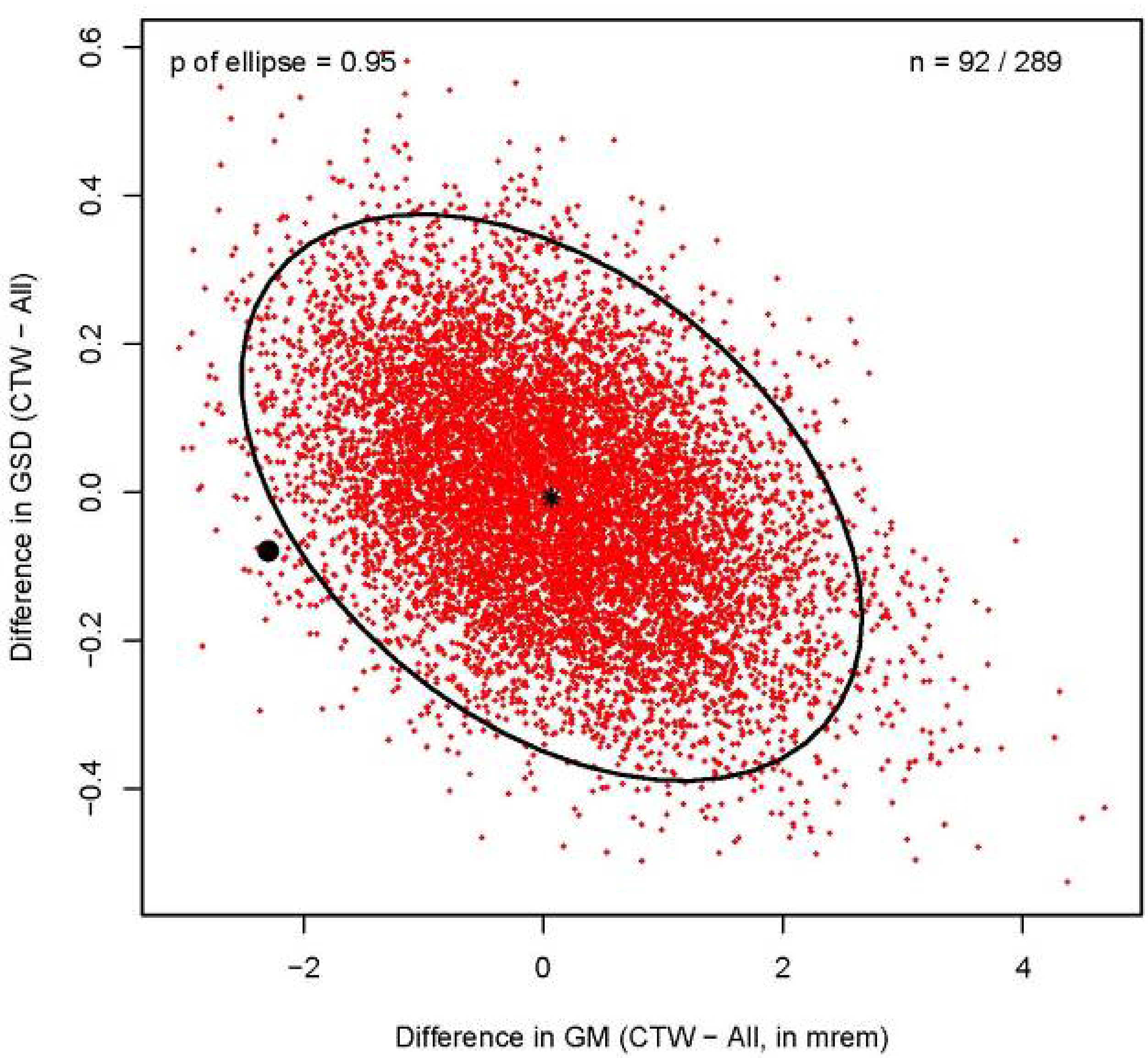

Figure A-90. SRS tritium dose 1983.

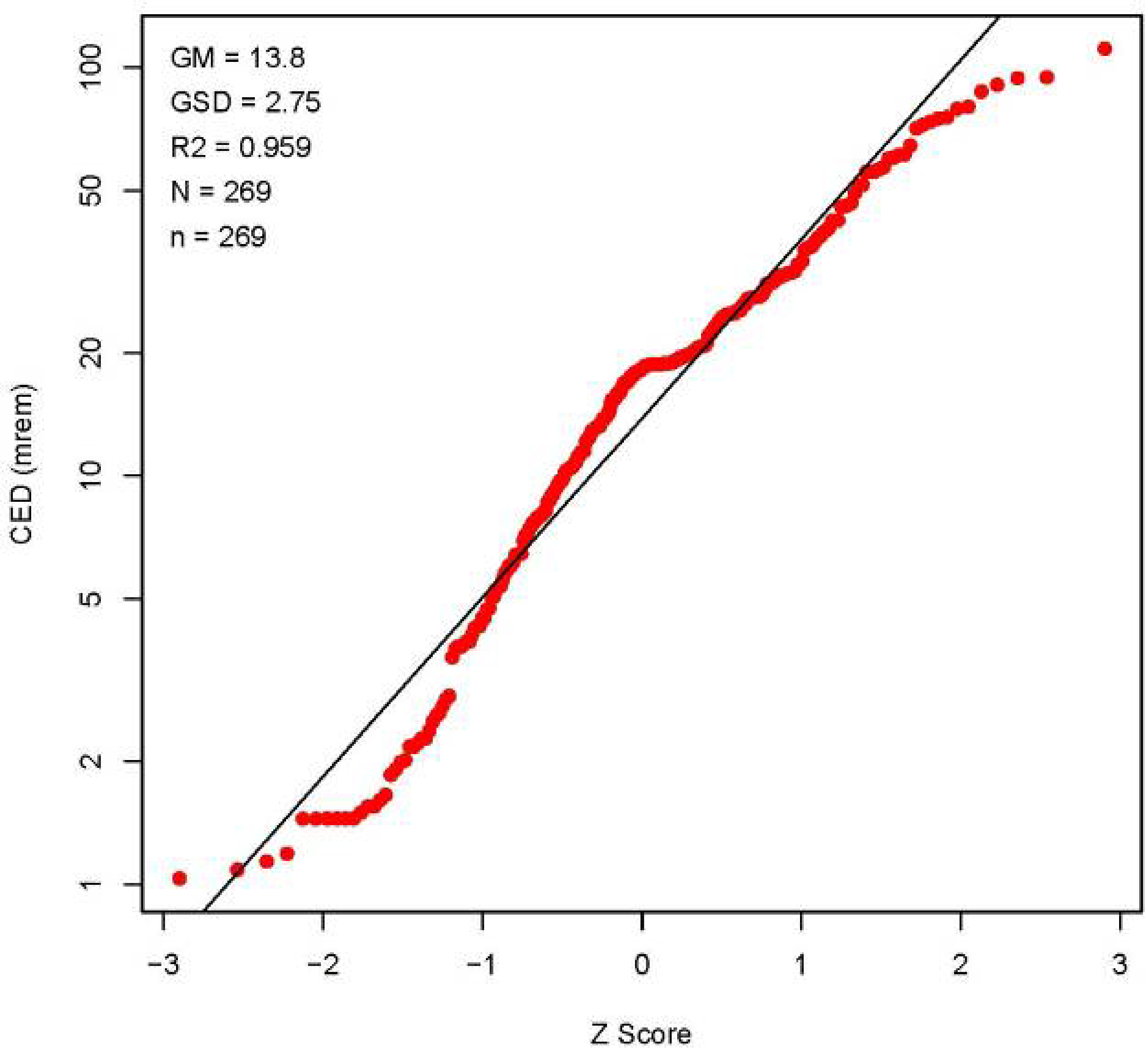

Figure A-91. SRS tritium dose 1984.

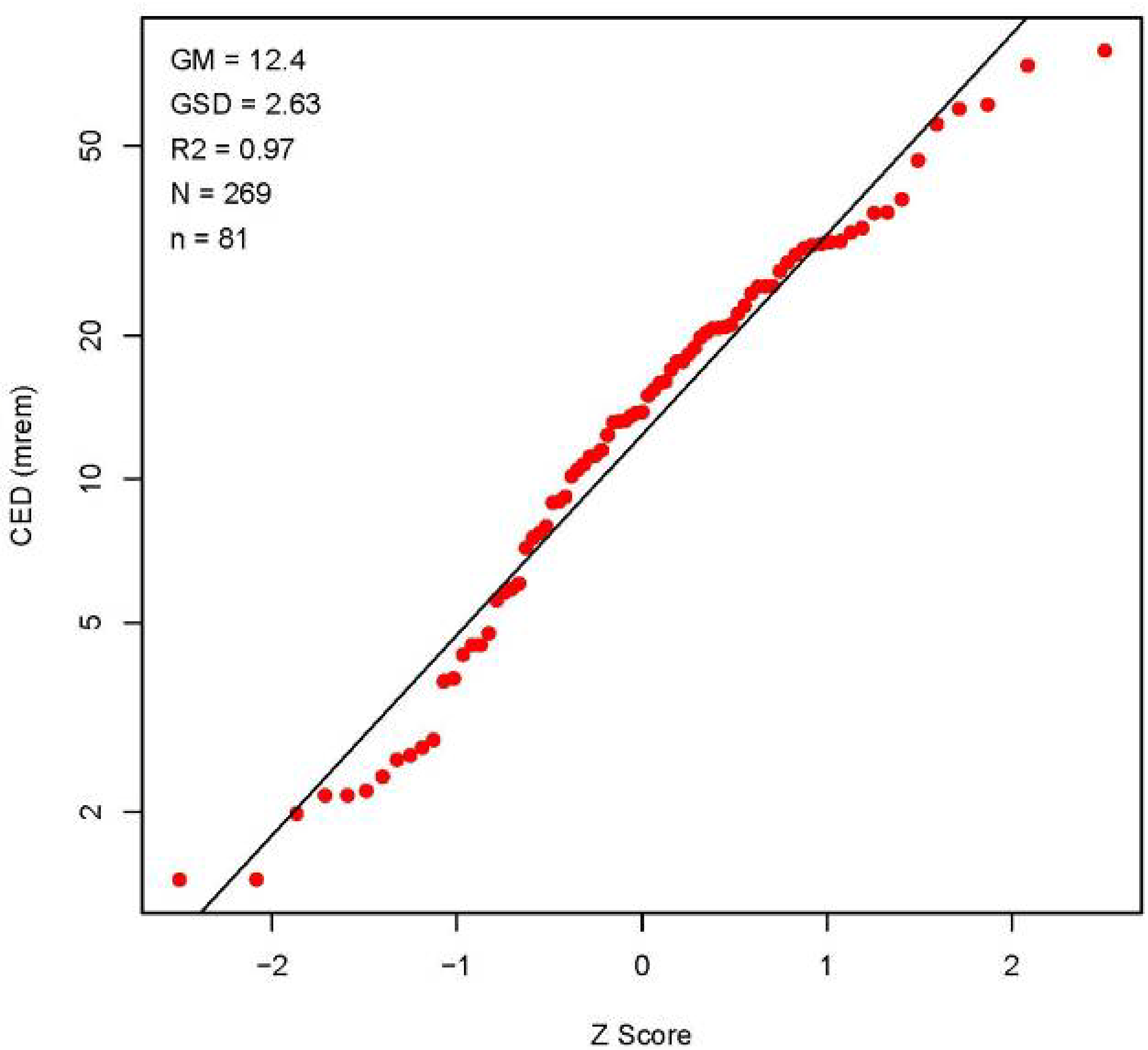

Figure A-92. SRS CTW tritium dose 1984.

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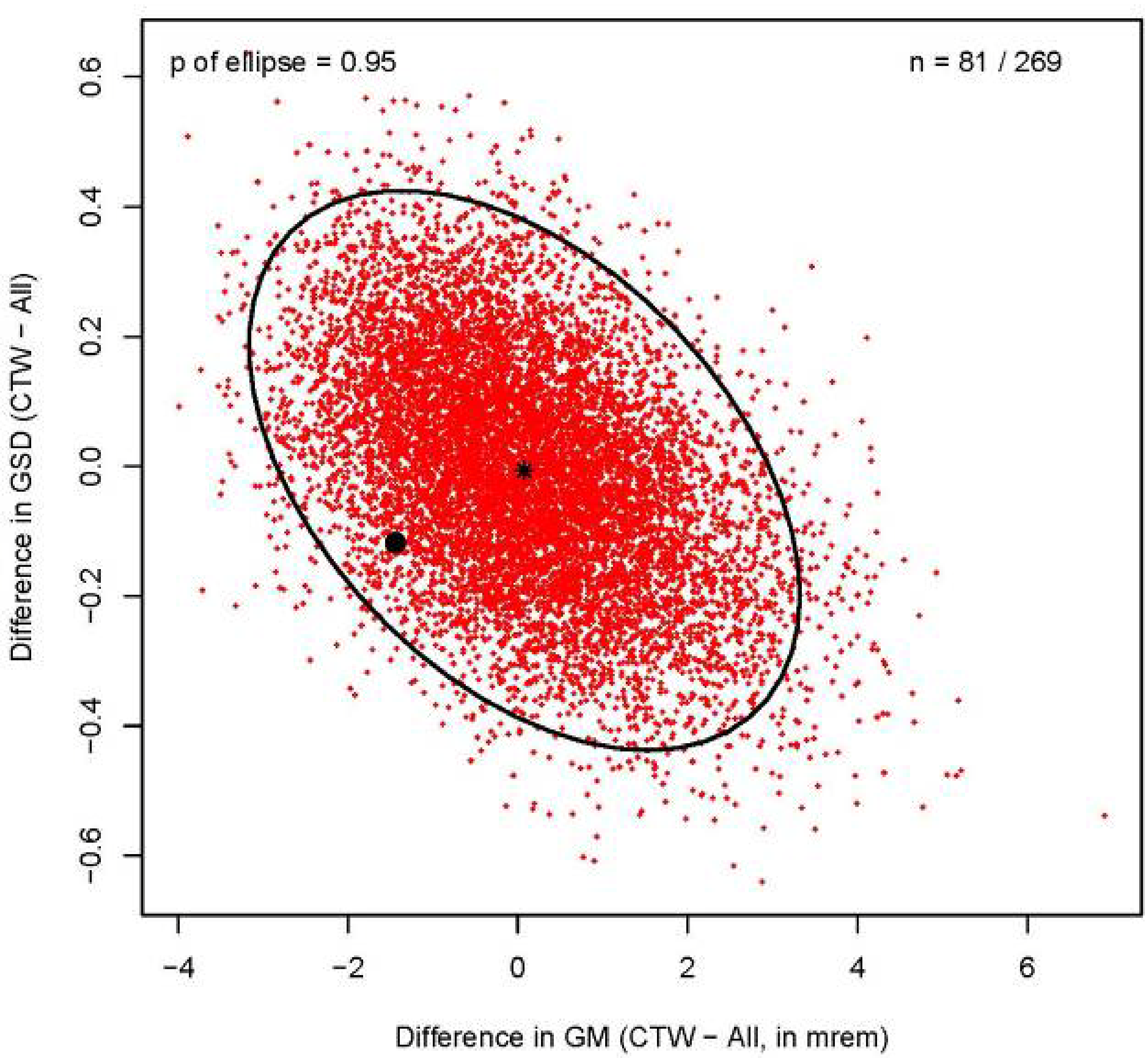

Figure A-93. SRS tritium dose 1984.

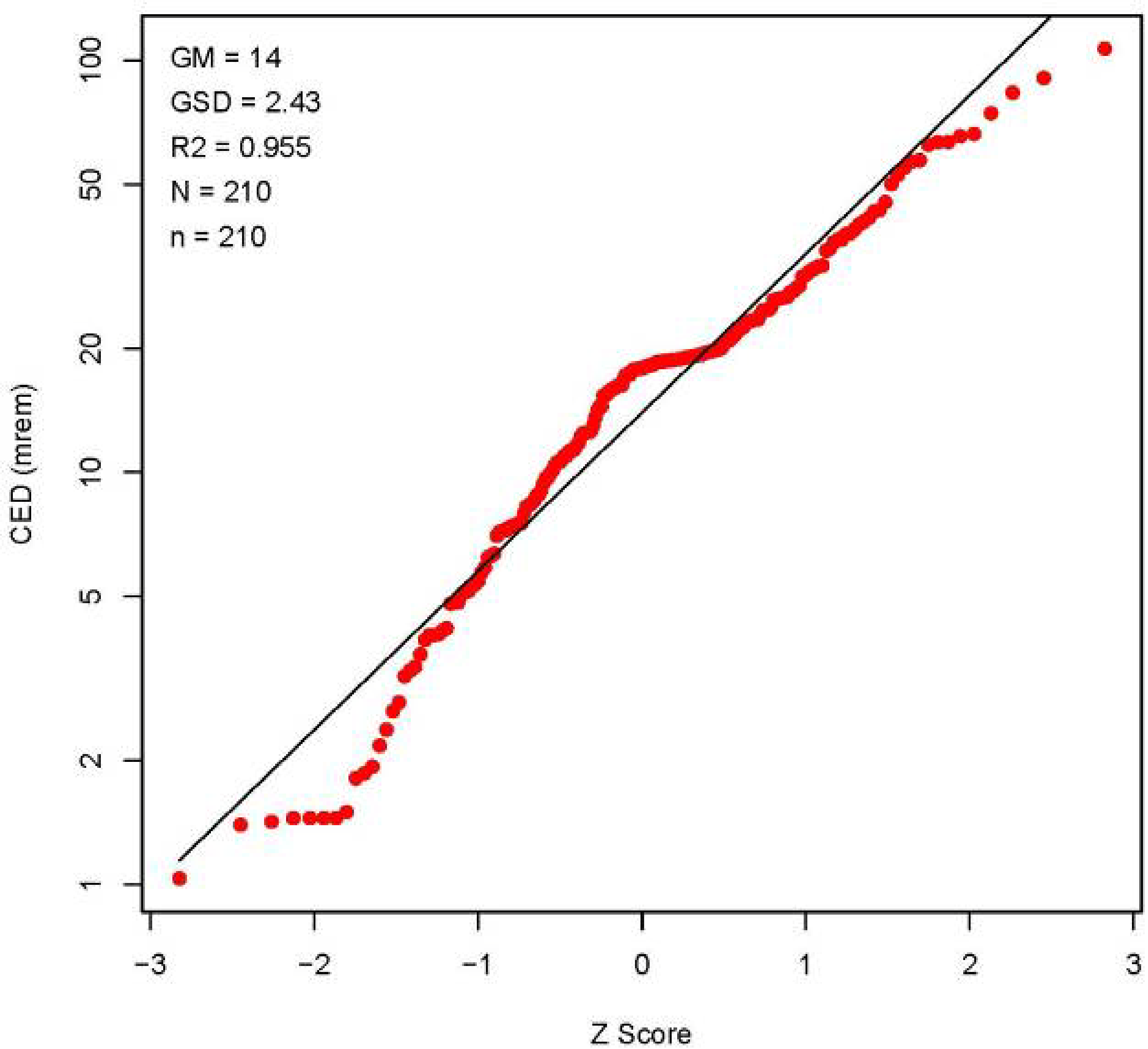

Figure A-94. SRS tritium dose 1985.

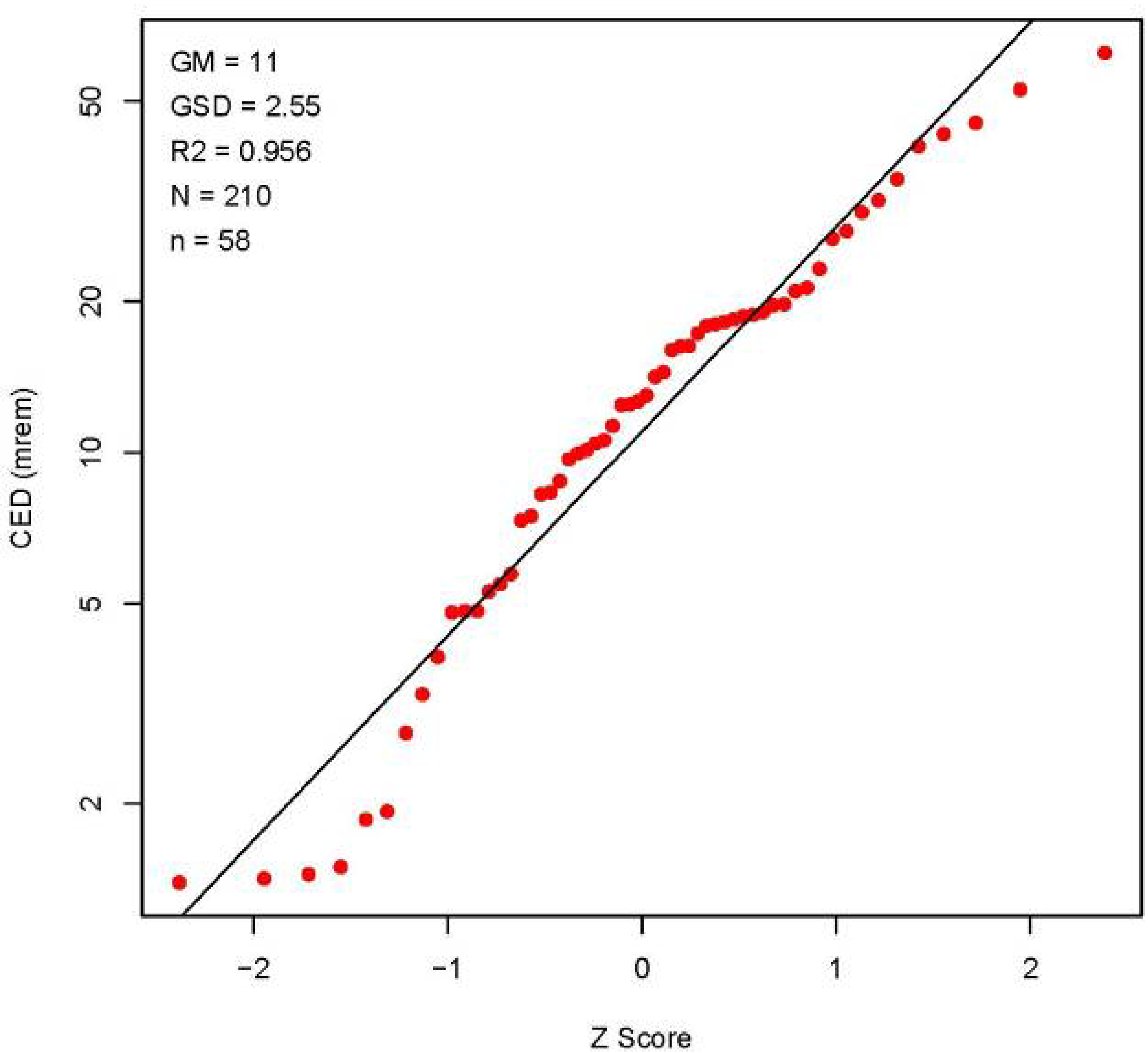

Figure A-95. SRS CTW tritium dose 1985.

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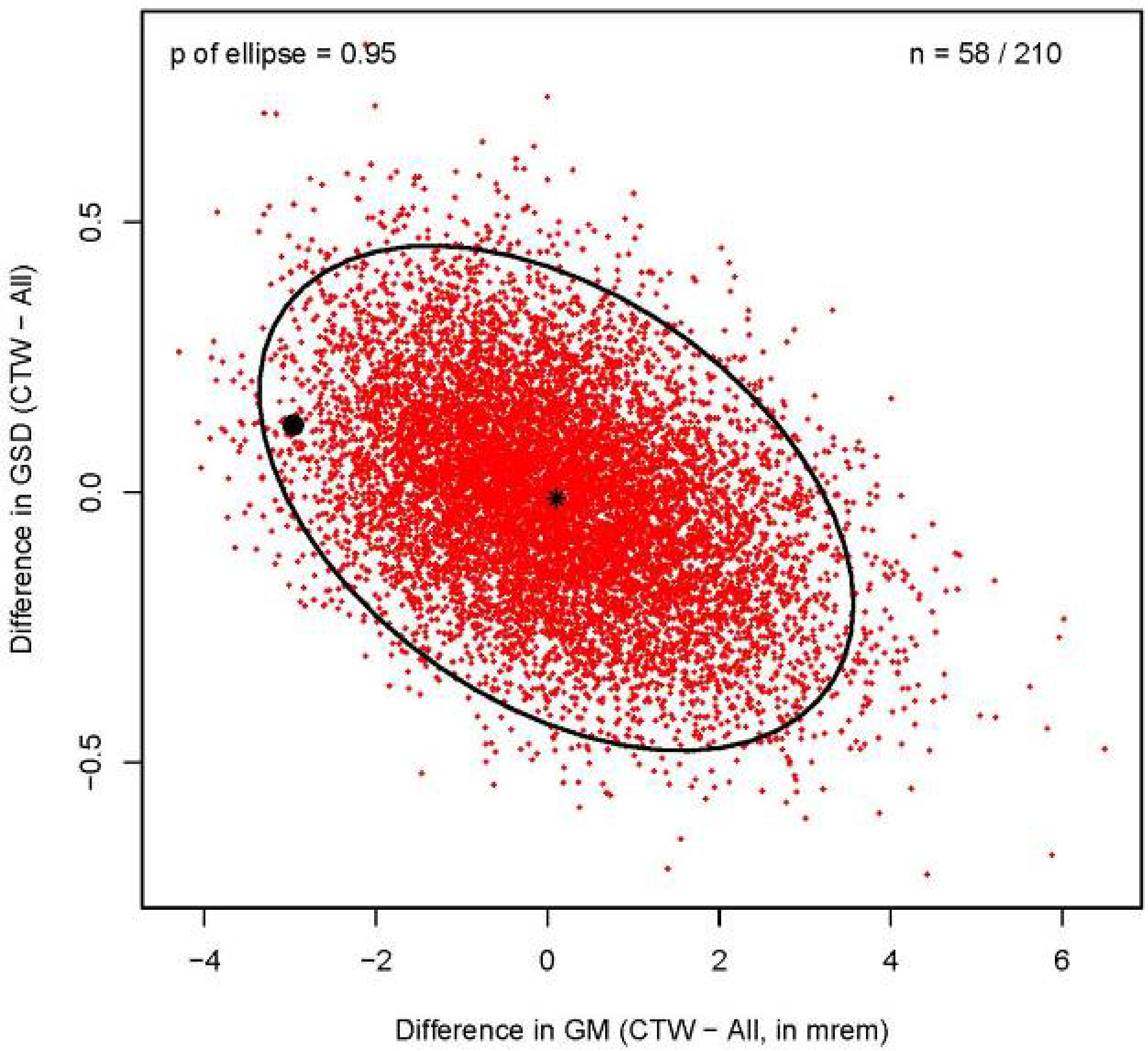

Figure A-96. SRS tritium dose 1985.

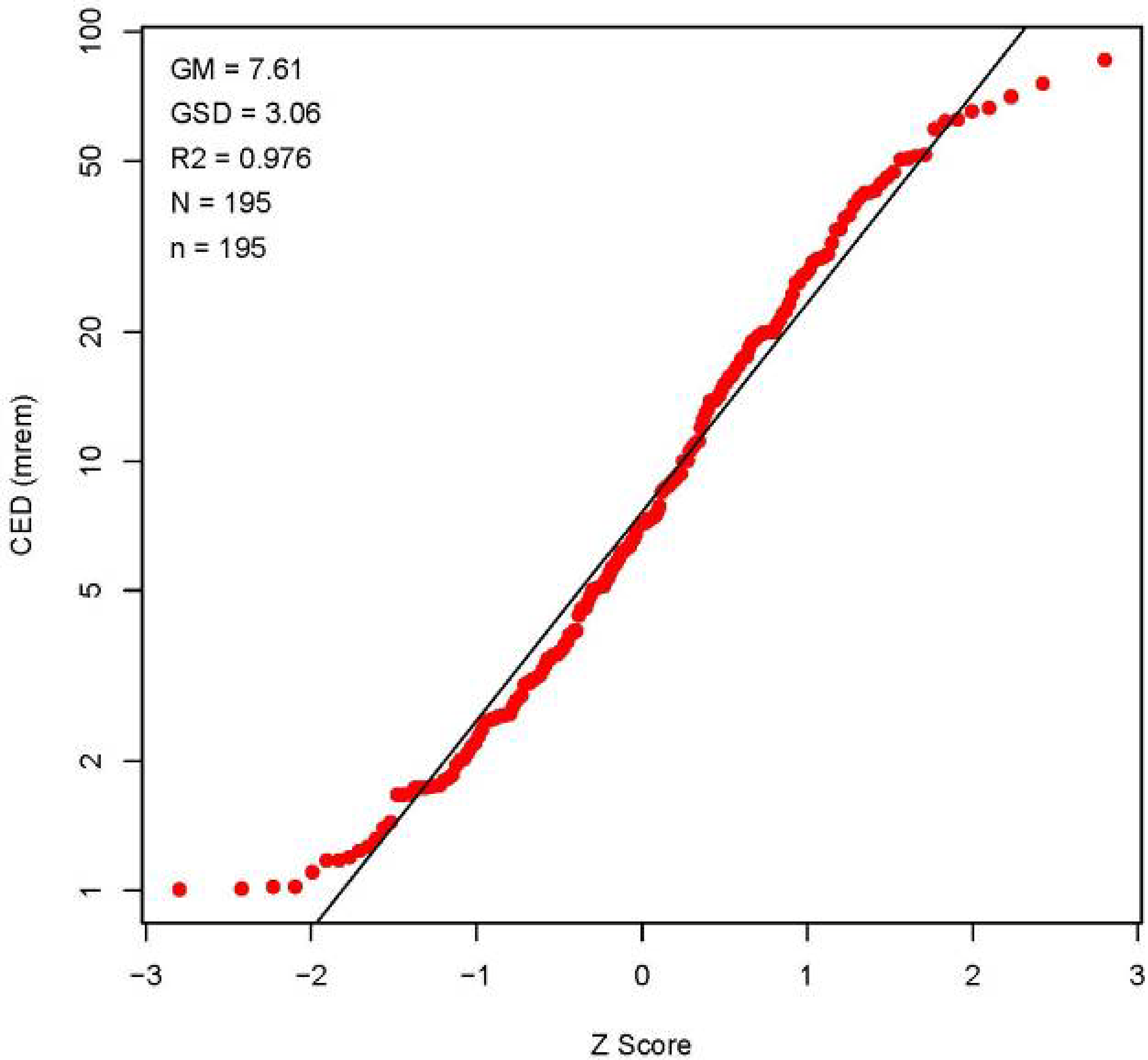

Figure A-97. SRS tritium dose 1986.

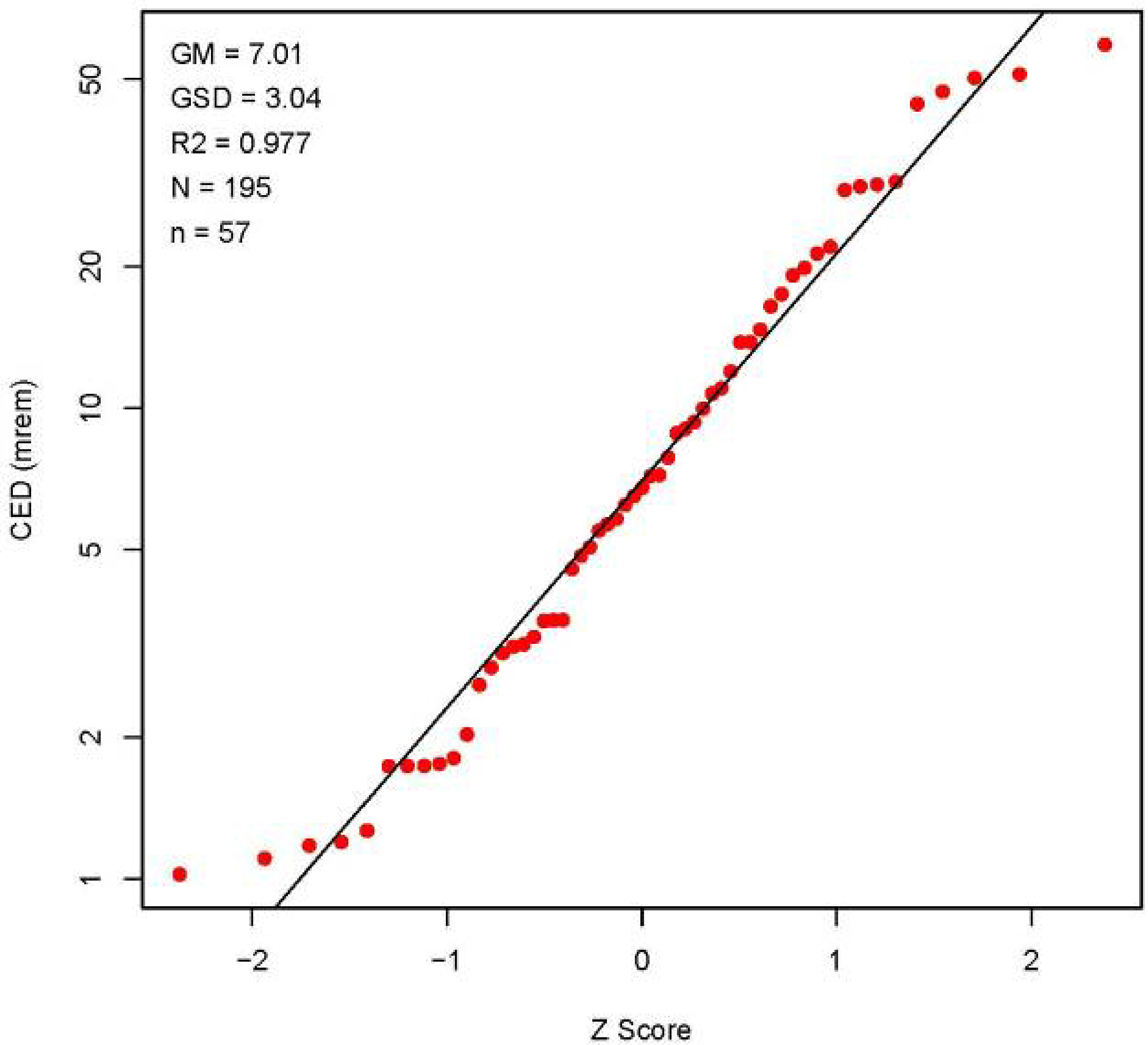

Figure A-98. SRS CTW tritium dose 1986.

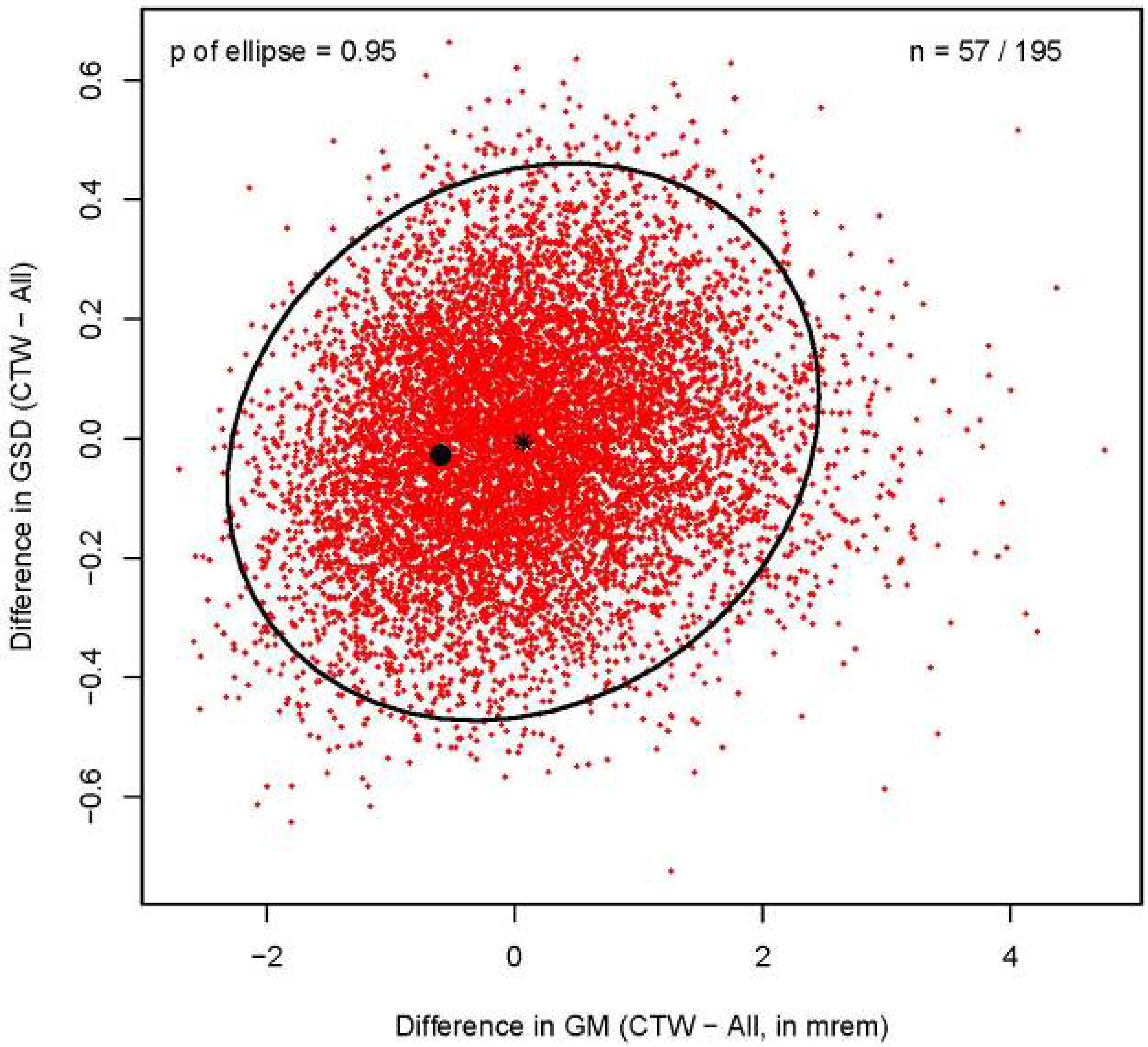

Figure A-99. SRS tritium dose 1986.

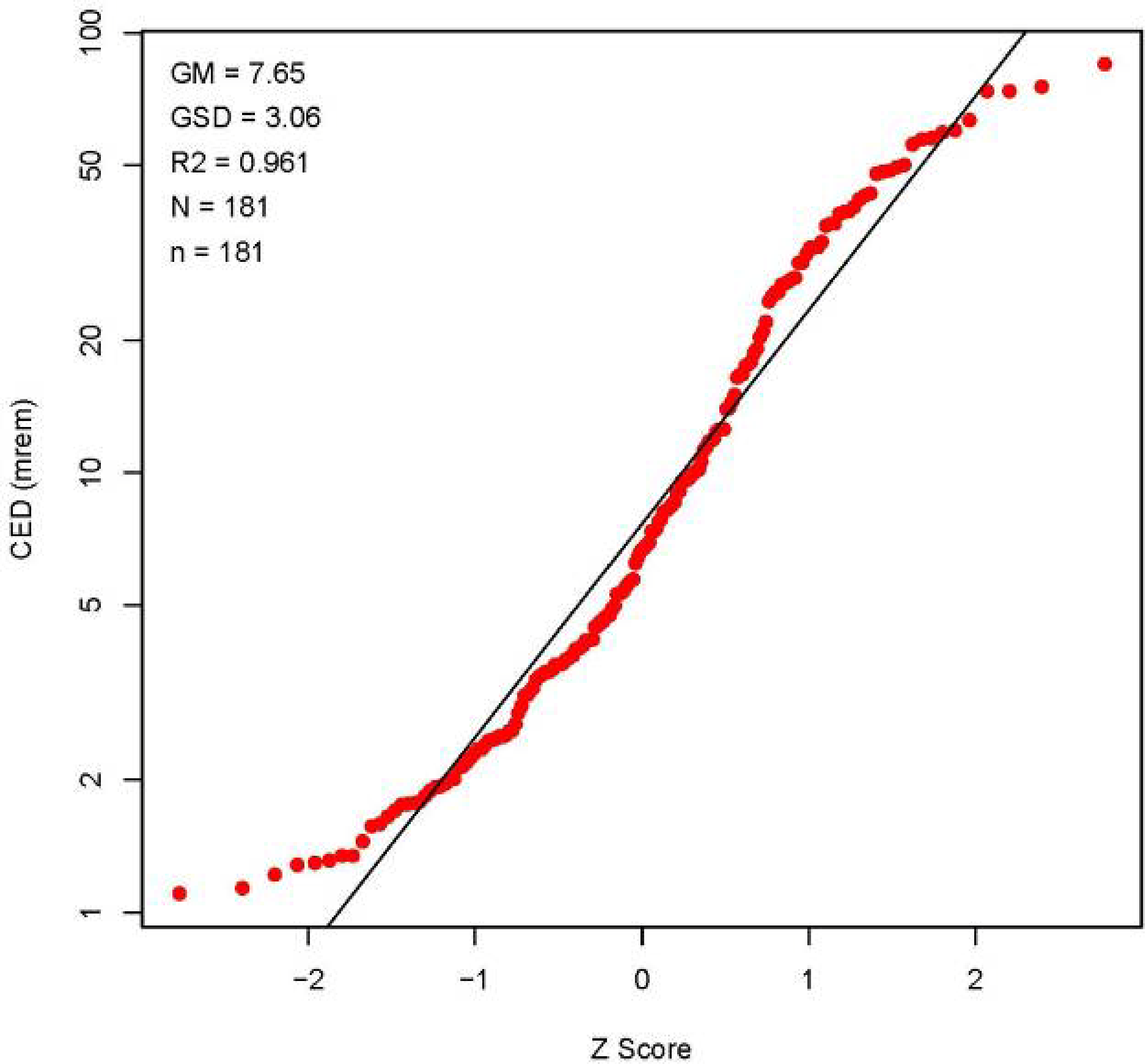

Figure A-100. SRS tritium dose 1987.

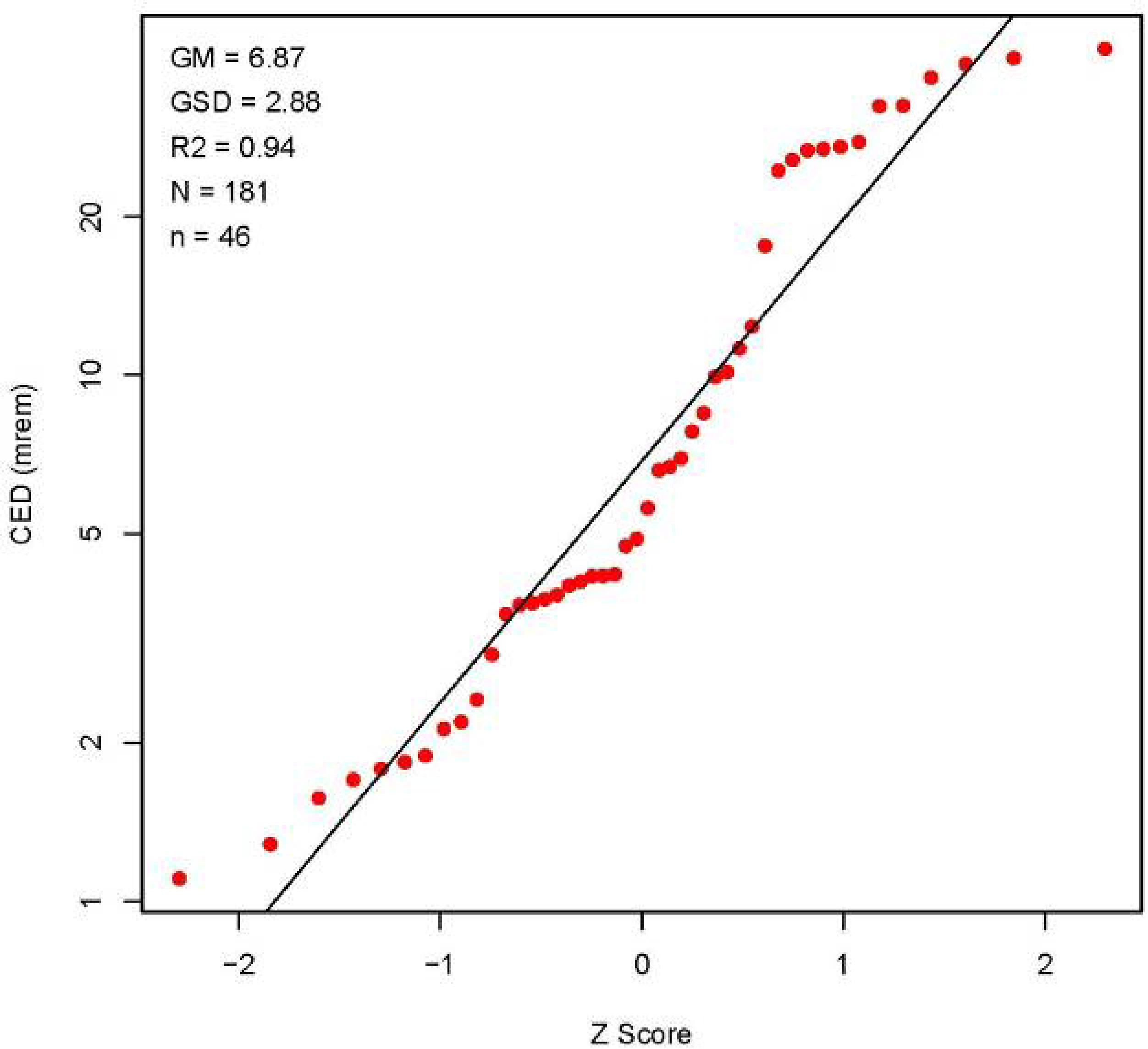

Figure A-101. SRS CTW tritium dose 1987.

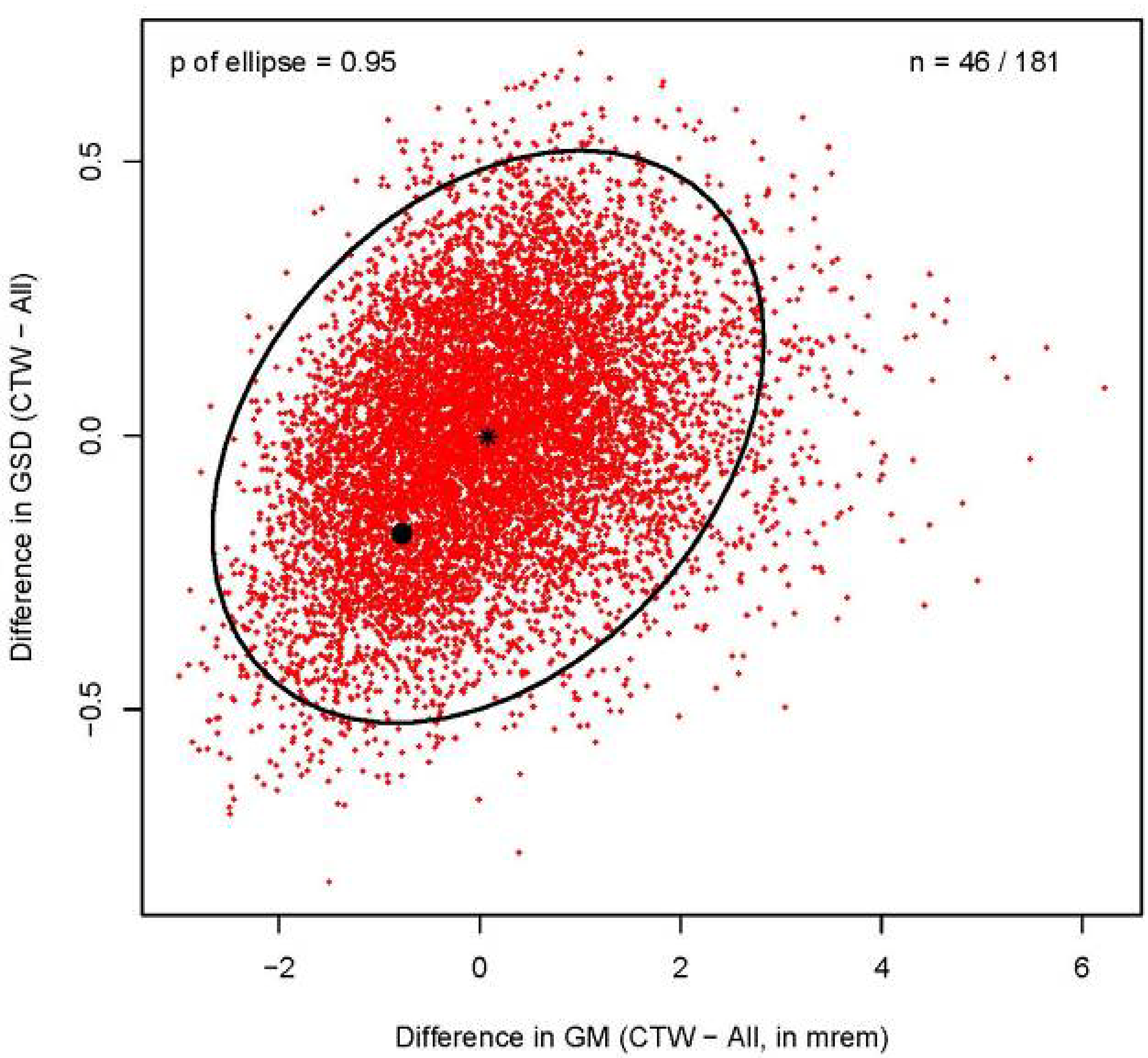

Figure A-102. SRS tritium dose 1987.

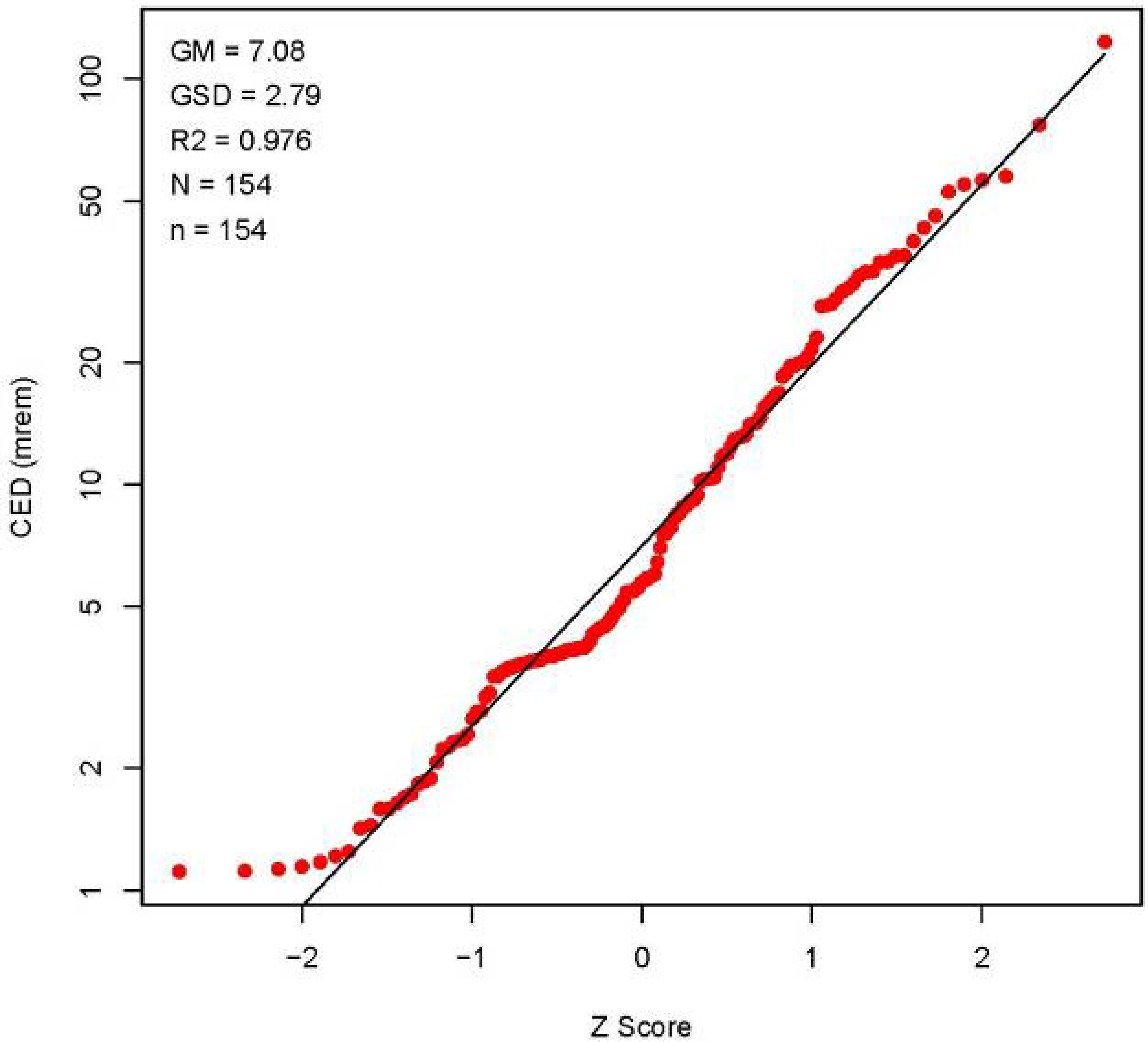

Figure A-103. SRS tritium dose 1988.

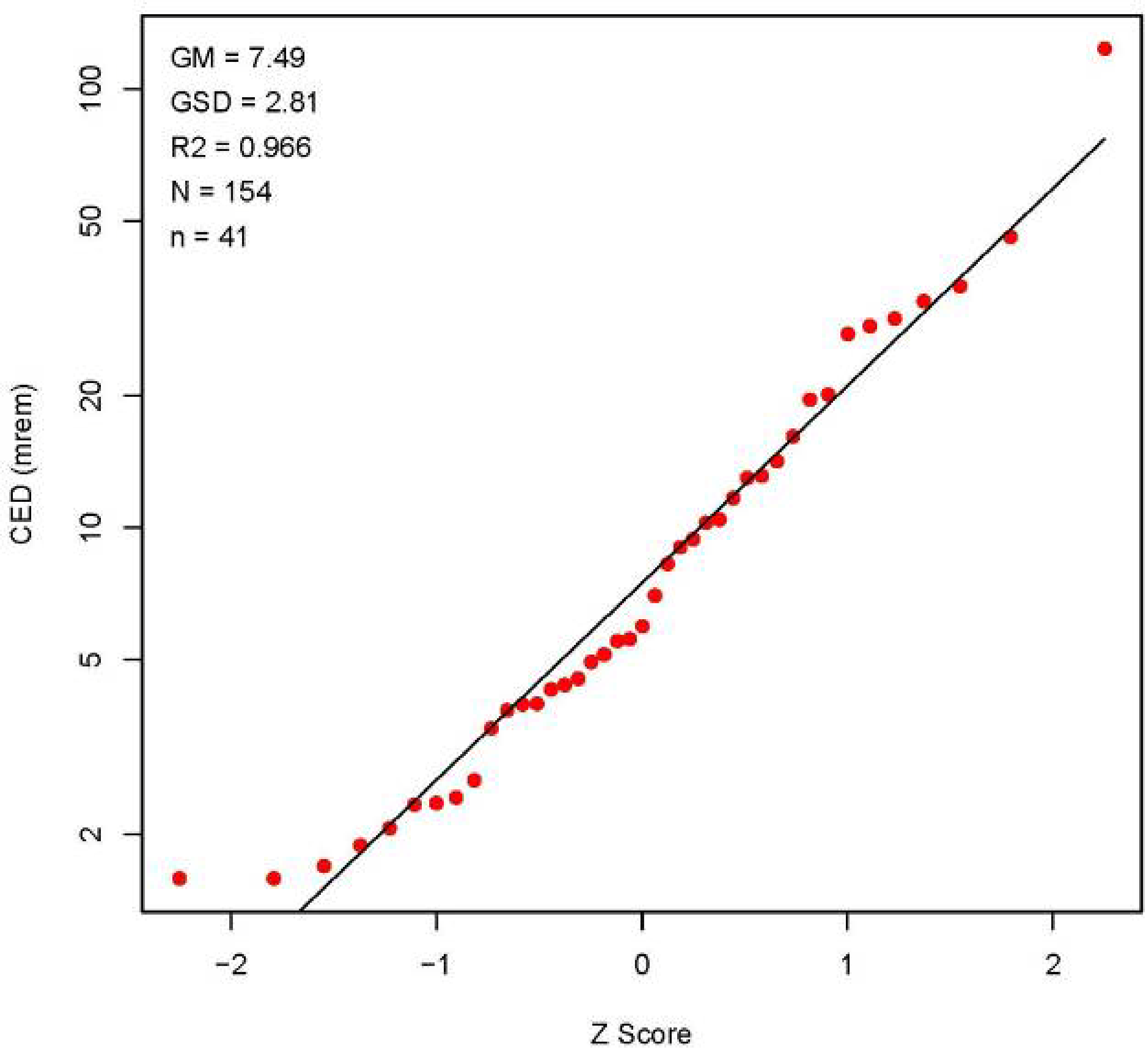

Figure A-104. SRS CTW tritium dose 1988.

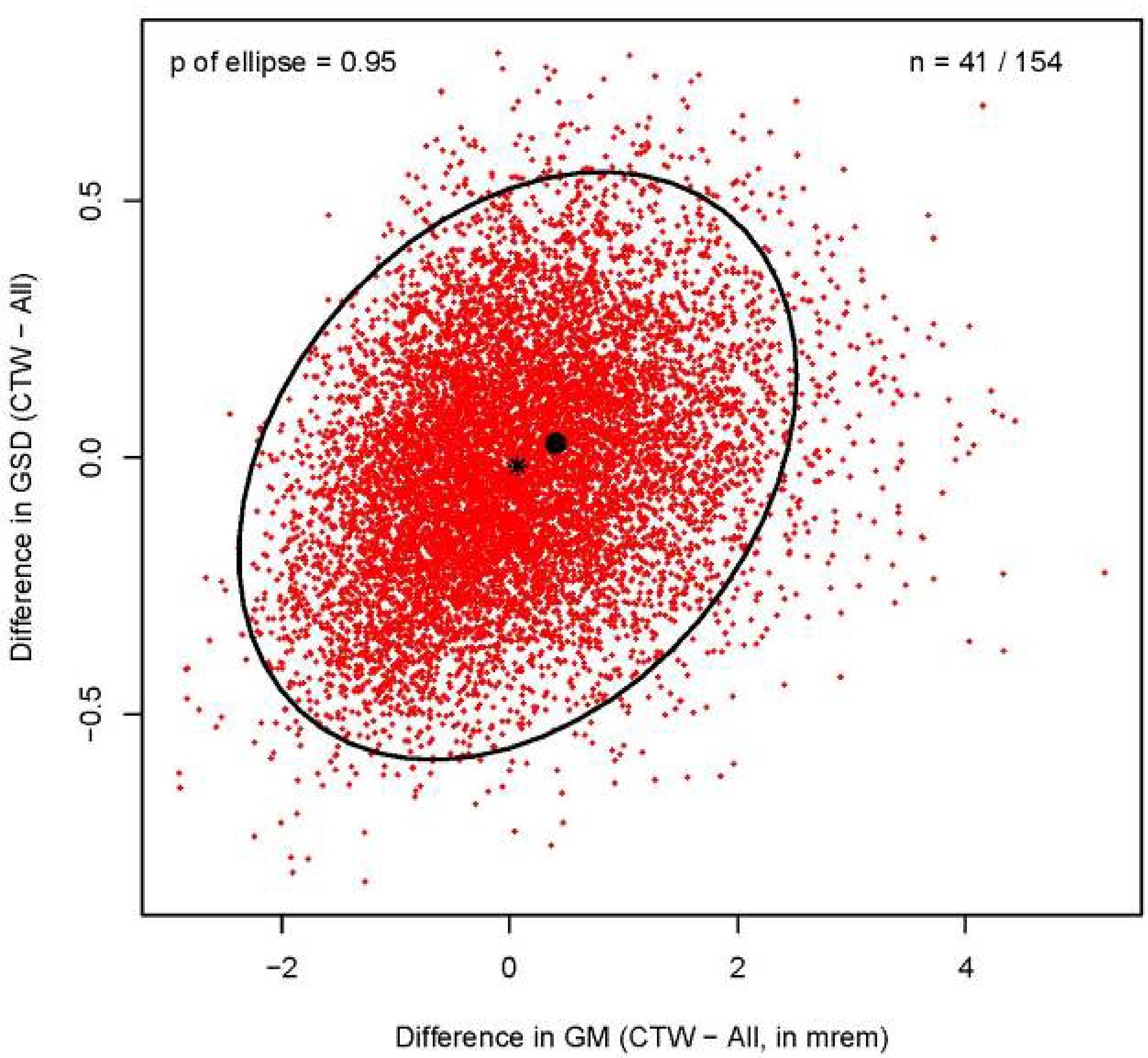

Figure A-105. SRS tritium dose 1988.

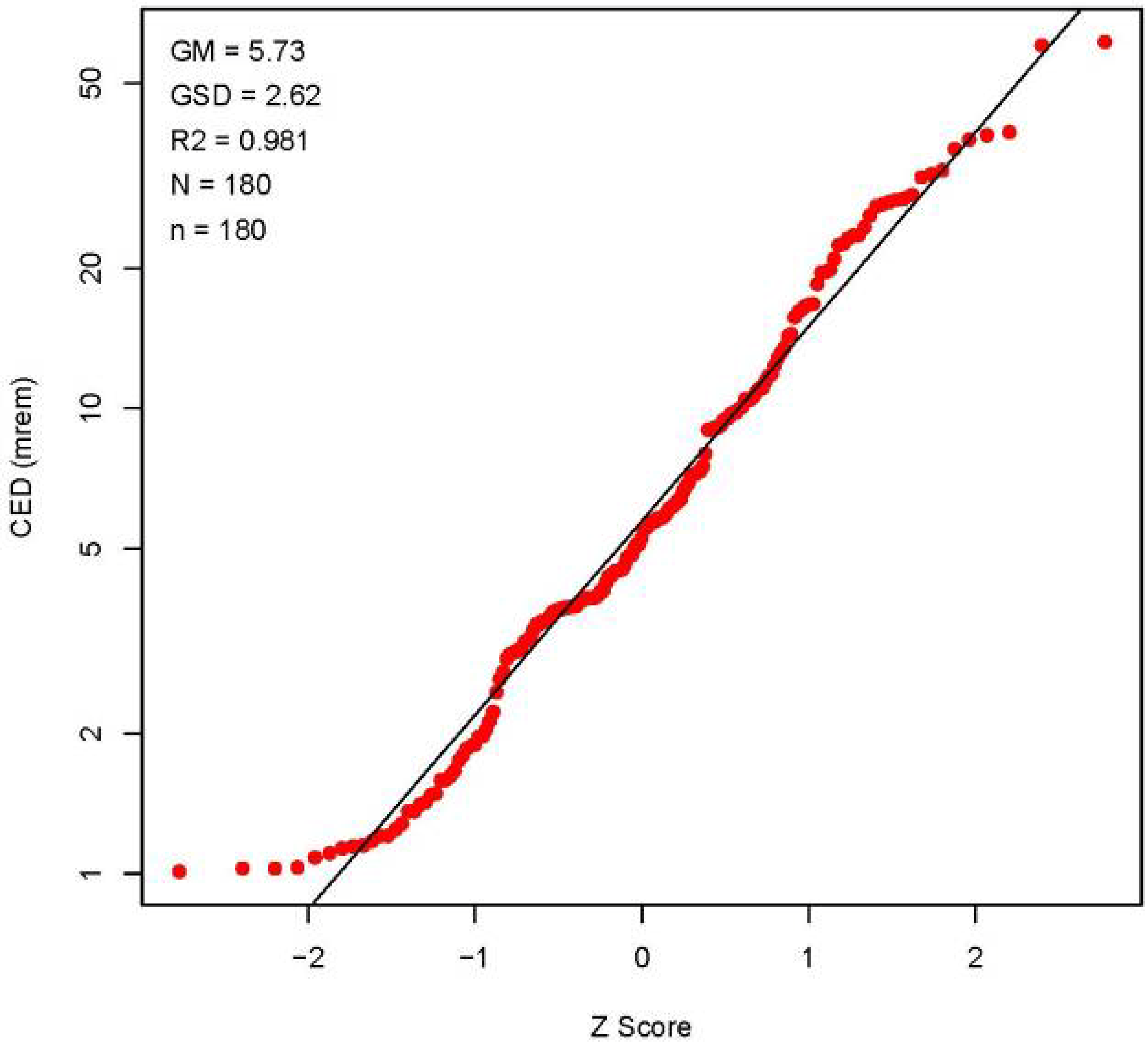

Figure A-106. SRS tritium dose 1989.

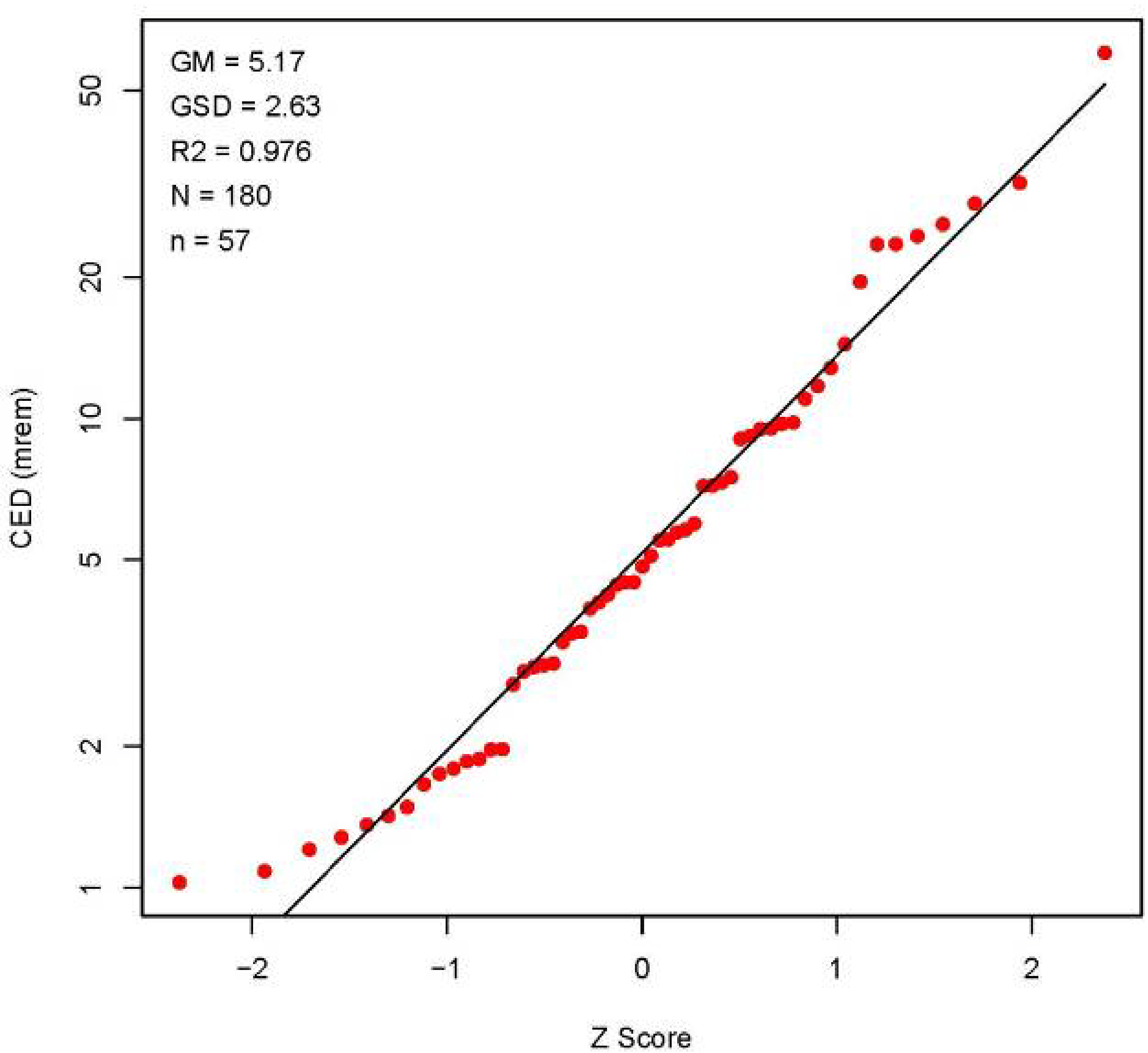

Figure A-107. SRS CTW tritium dose 1989.

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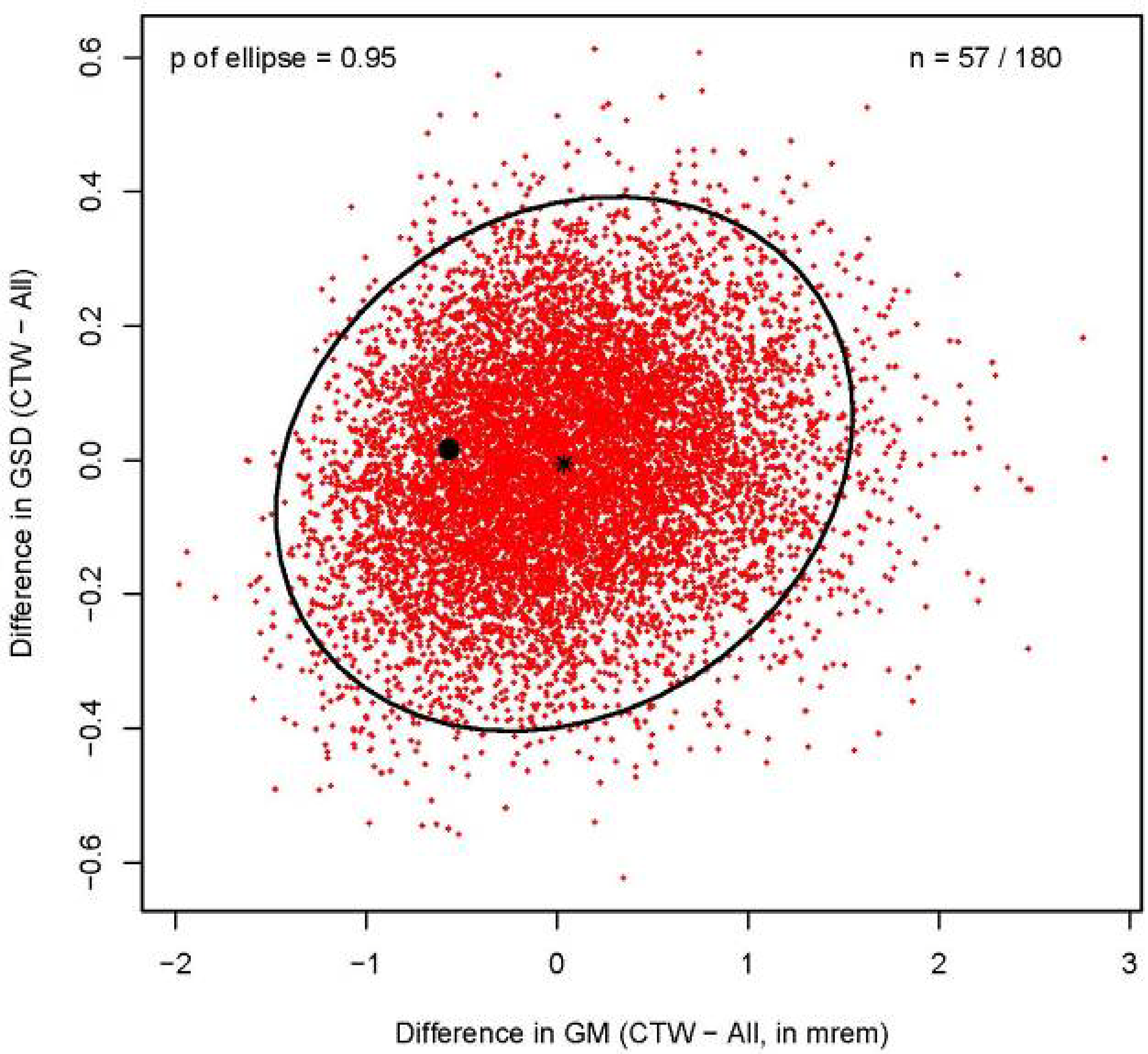

Figure A-108. SRS tritium dose 1989.

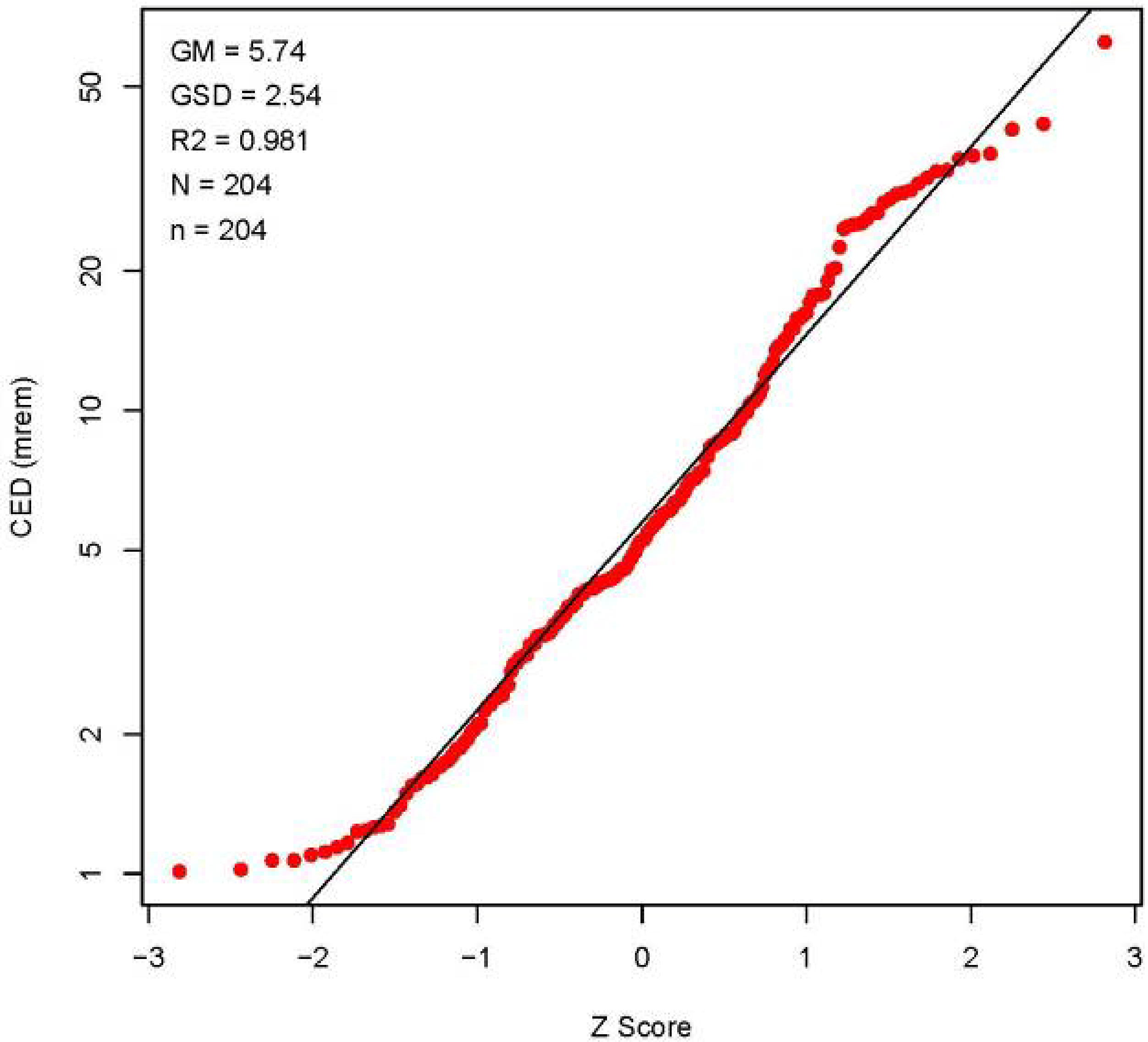

Figure A-109. SRS tritium dose 1990.

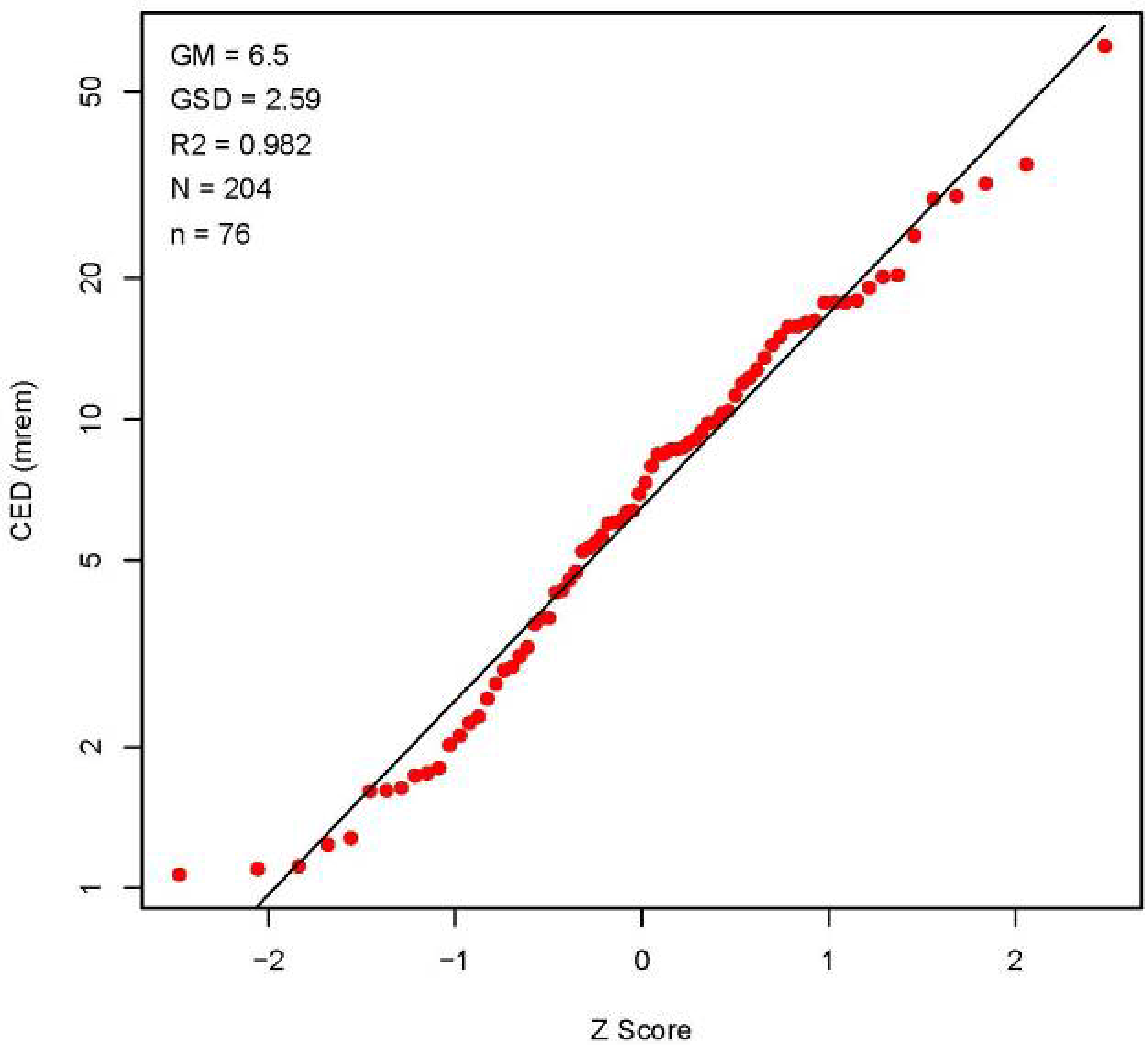

Figure A-110. SRS CTW tritium dose 1990.

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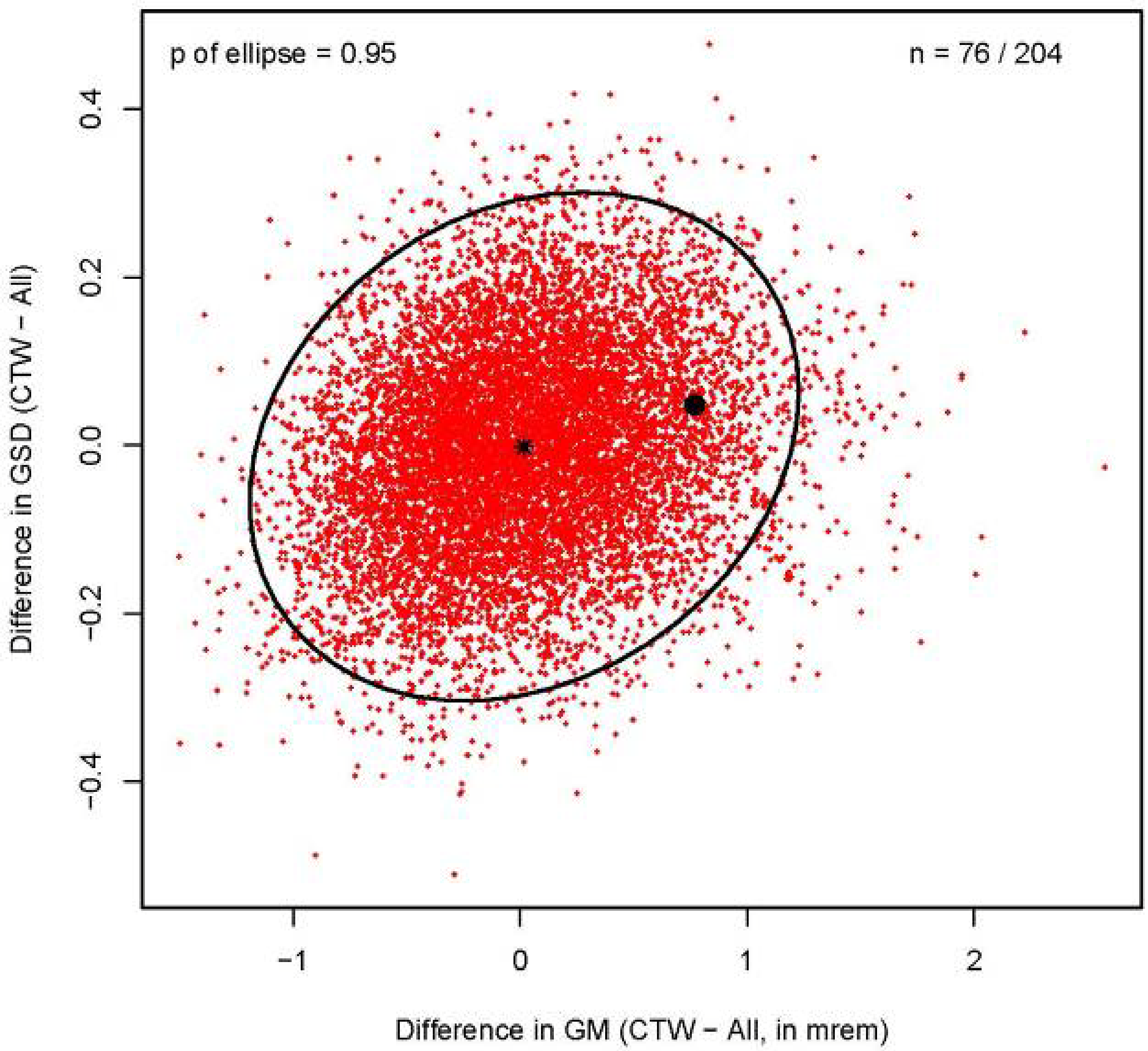

Figure A-111. SRS tritium dose 1990.

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There are three plots for each year from 1954 through 1990. The first two are lognormal probability plots of the tritium doses for the CS of workers and individuals who worked in the reactor areas (reactor workers). In these plots the following statistics are presented:

- GM = geometric mean of data (intercept of line)
- GSD = geometric standard deviation of data (slope of line)
- R2 = coefficient of determination for regression line
- N = total number of individuals in CS
- n = total number of individuals in reactor workers

The third plot for a given year is a Monte Carlo permutation plot comparing the test statistics of 10,000 random samples from the CS to the observed test statistic for the reactor workers (the large black dot). An ellipse is constructed that contains 95% of the test statistics. If the observed test statistic for the reactor workers lies outside the ellipse, the coworker model for the reactor workers is considered to be different than the coworker model for CS.

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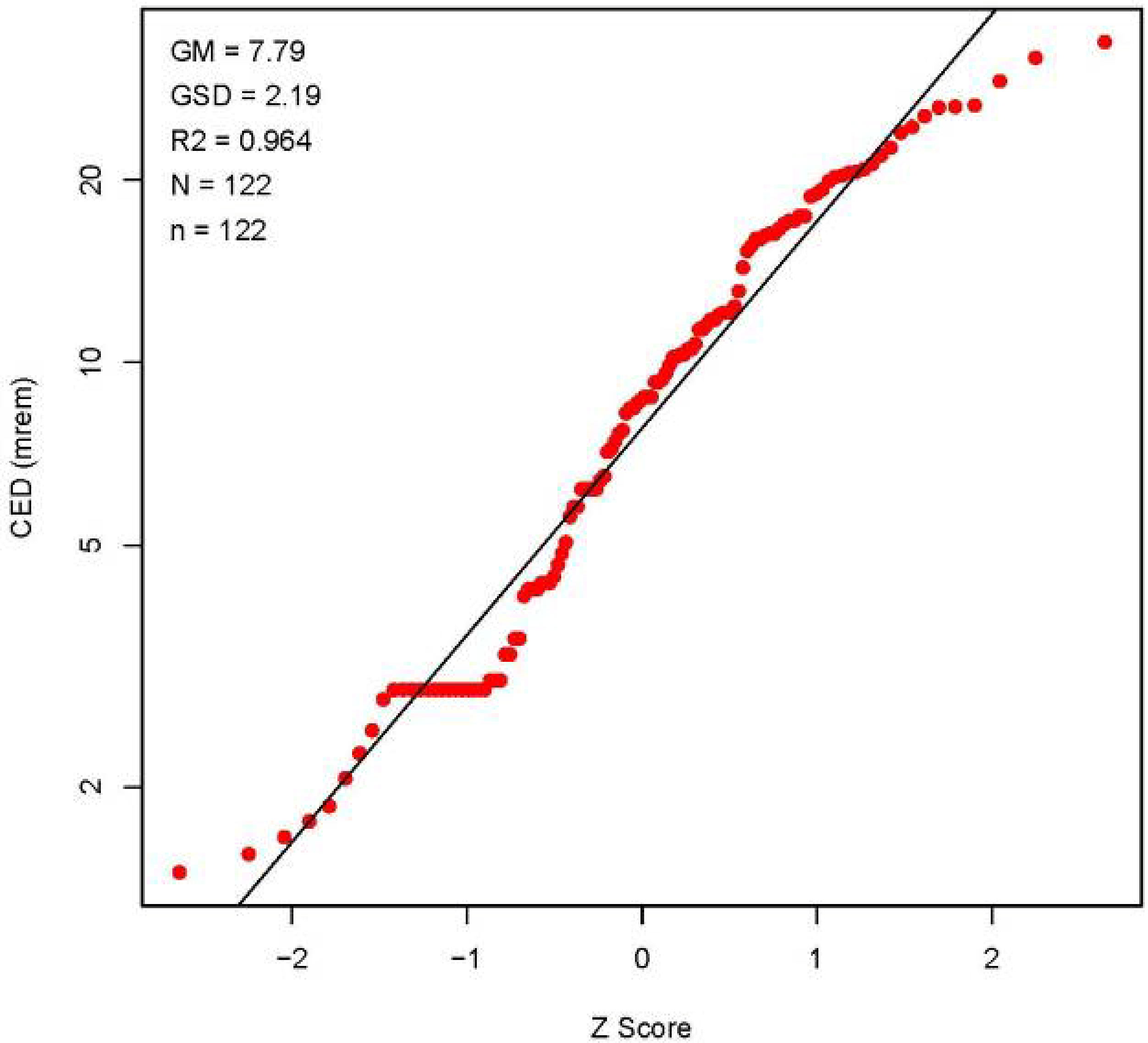

Figure B-1. SRS tritium dose 1954.

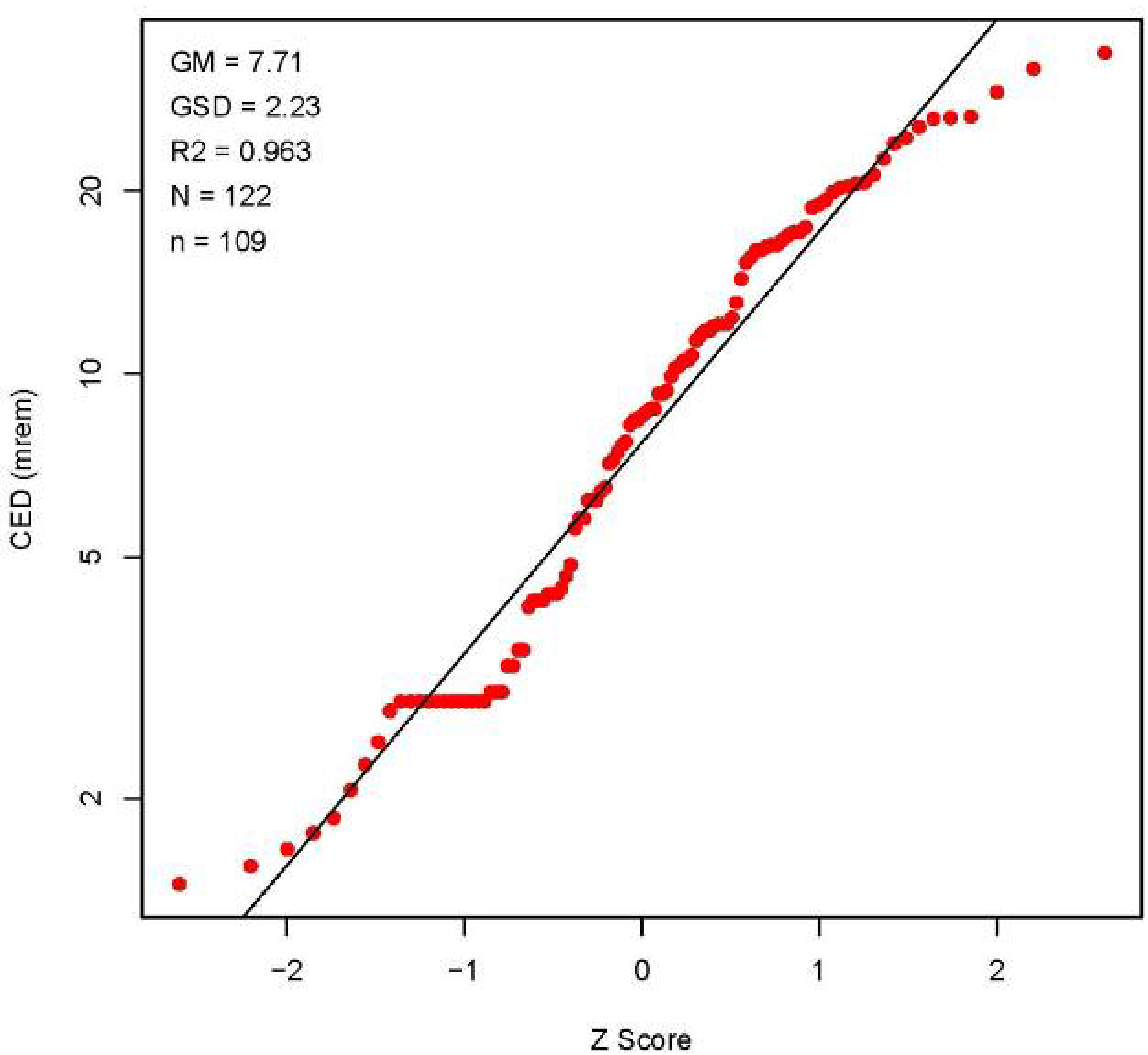

Figure B-2. SRS reactor tritium dose 1954.

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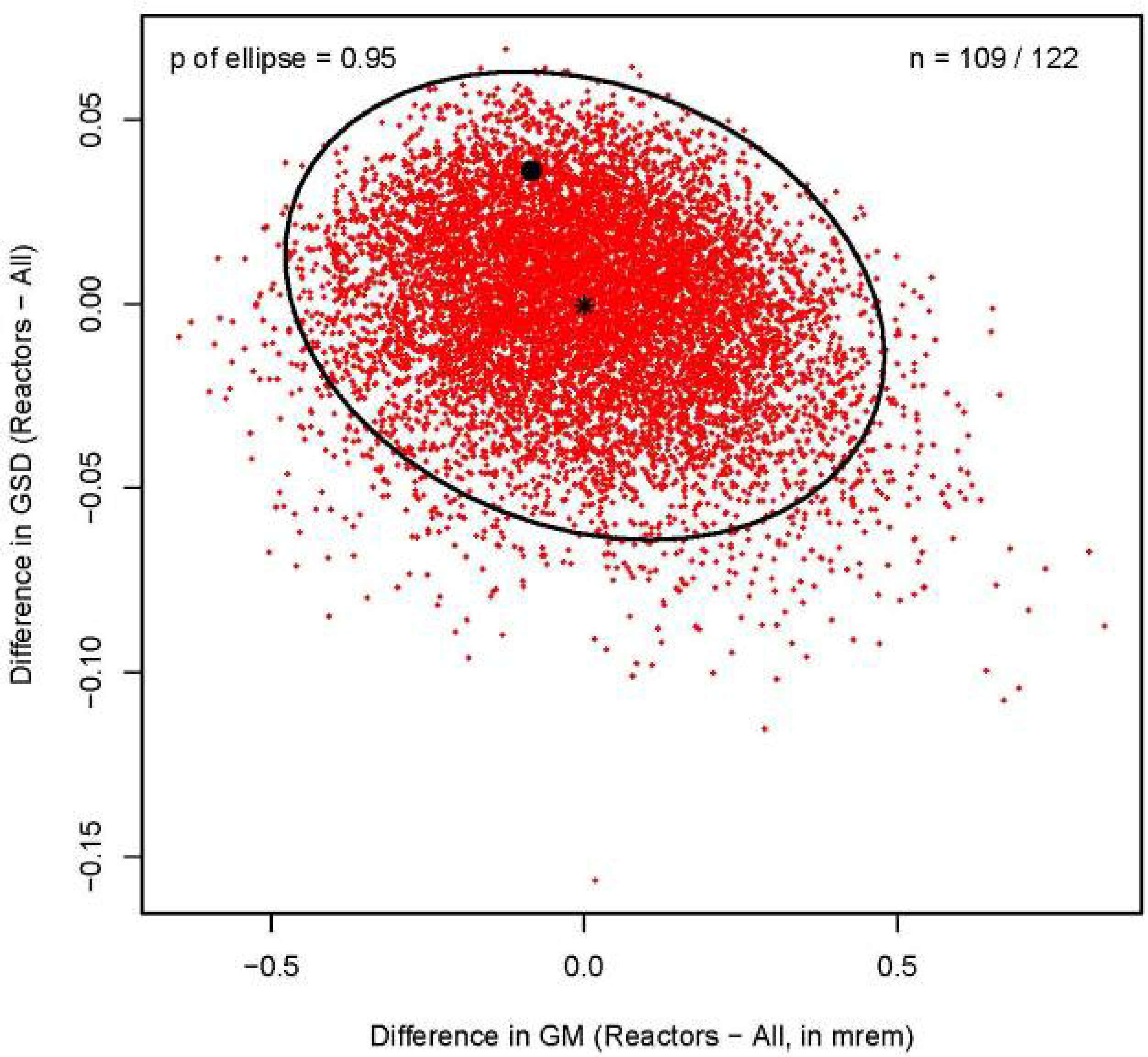

Figure B-3. SRS tritium dose 1954.

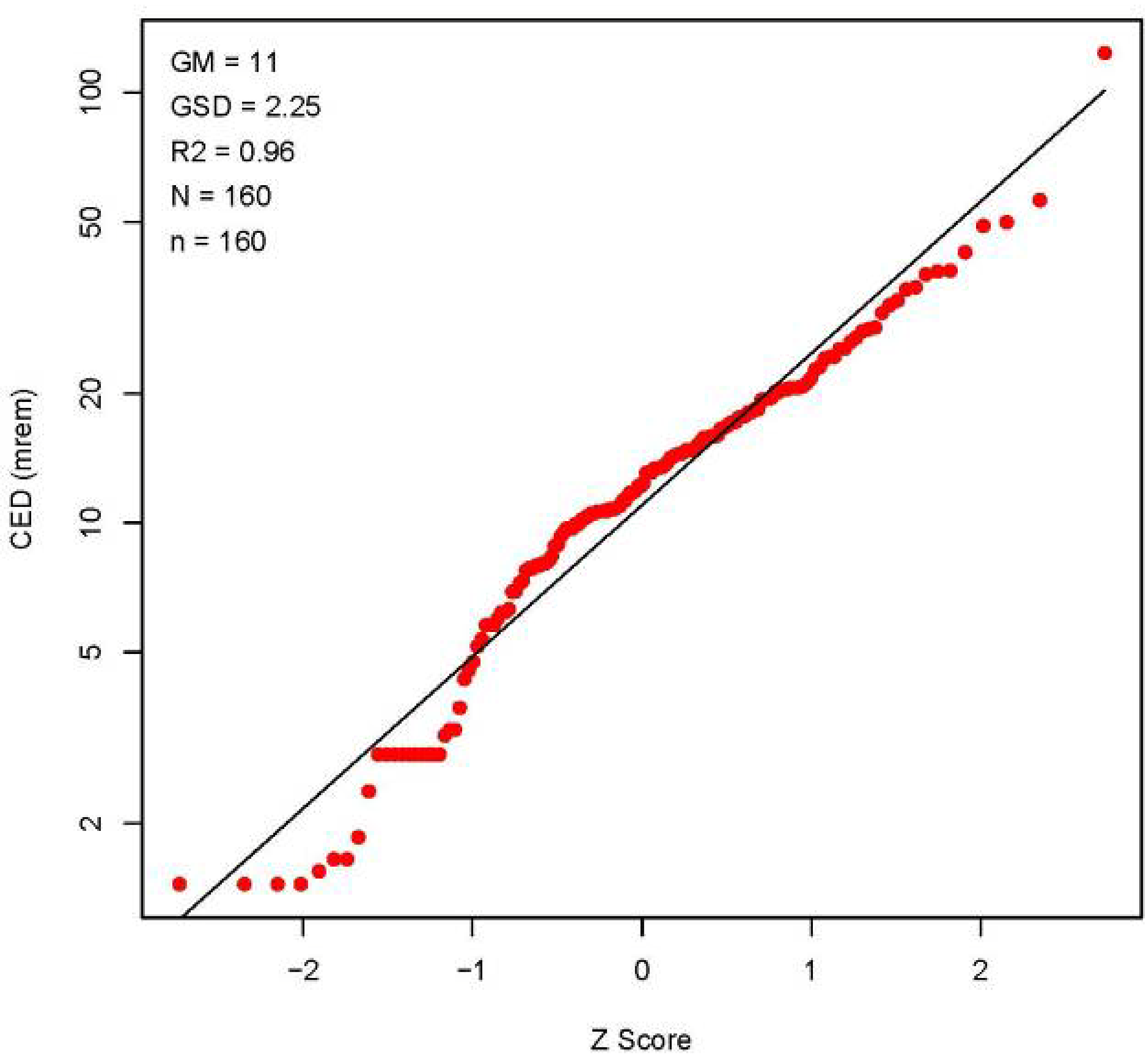

Figure B-4. SRS tritium dose 1955.

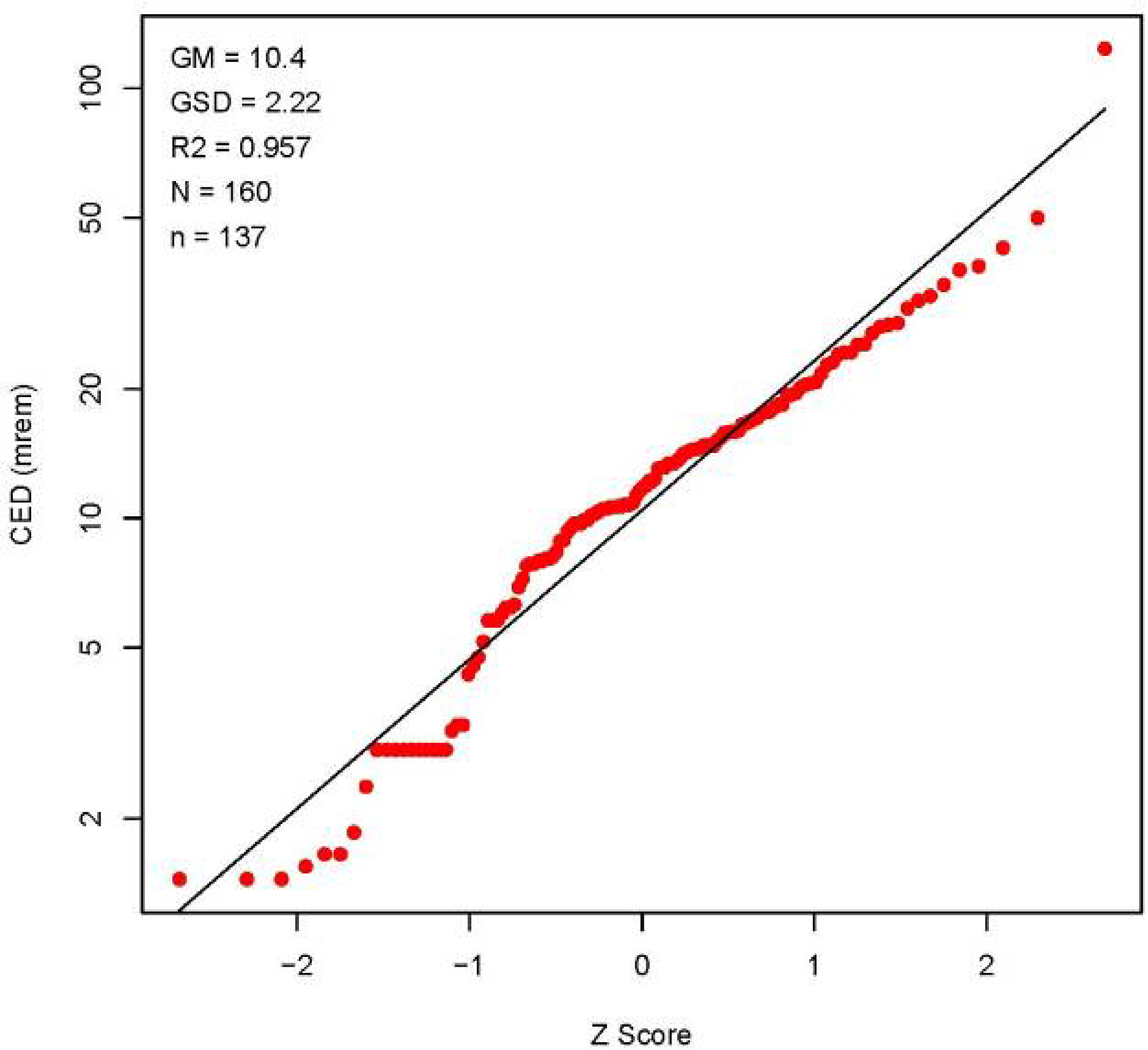

Figure B-5. SRS reactor tritium dose 1955.

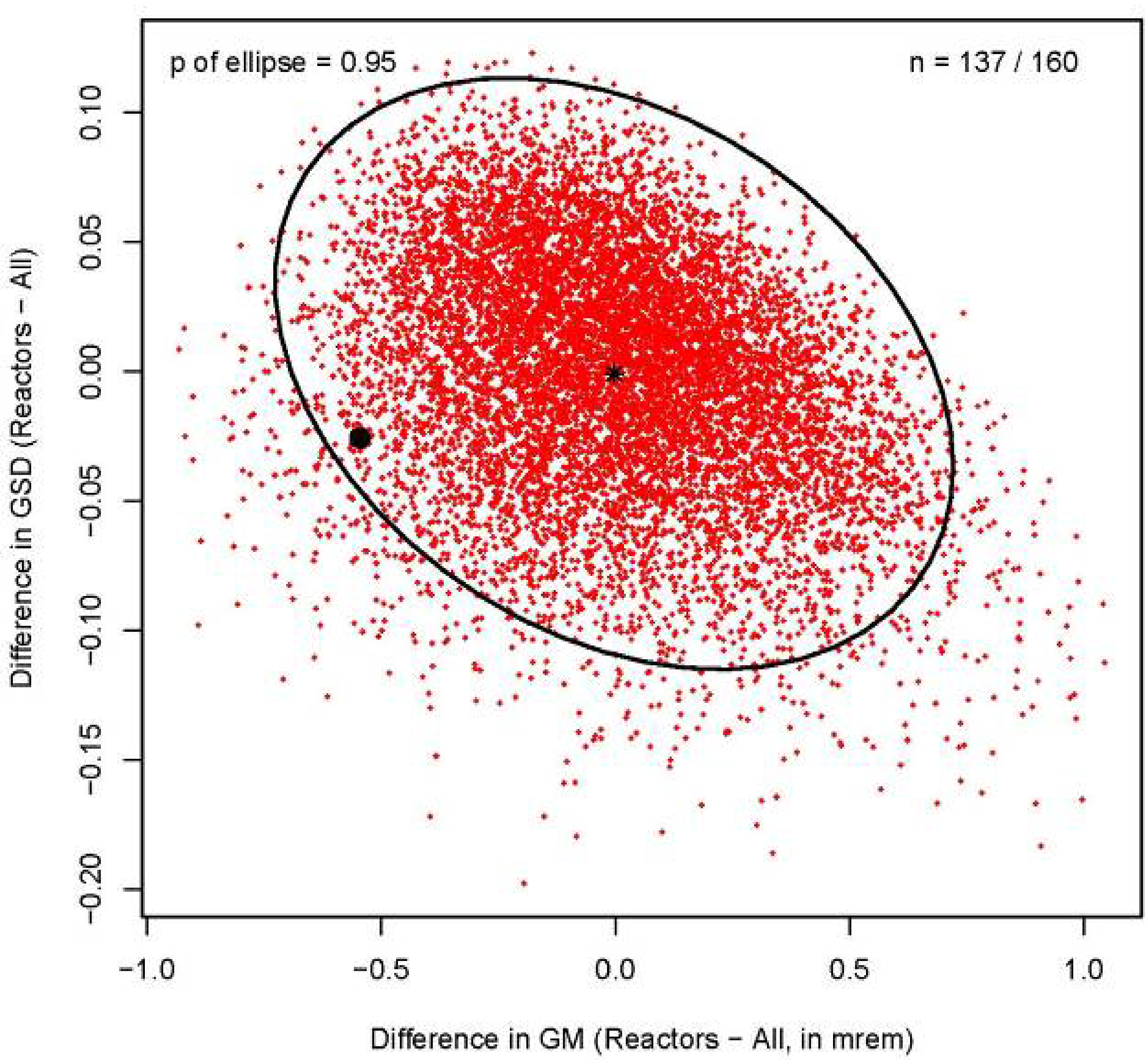

Figure B-6. SRS tritium dose 1955.

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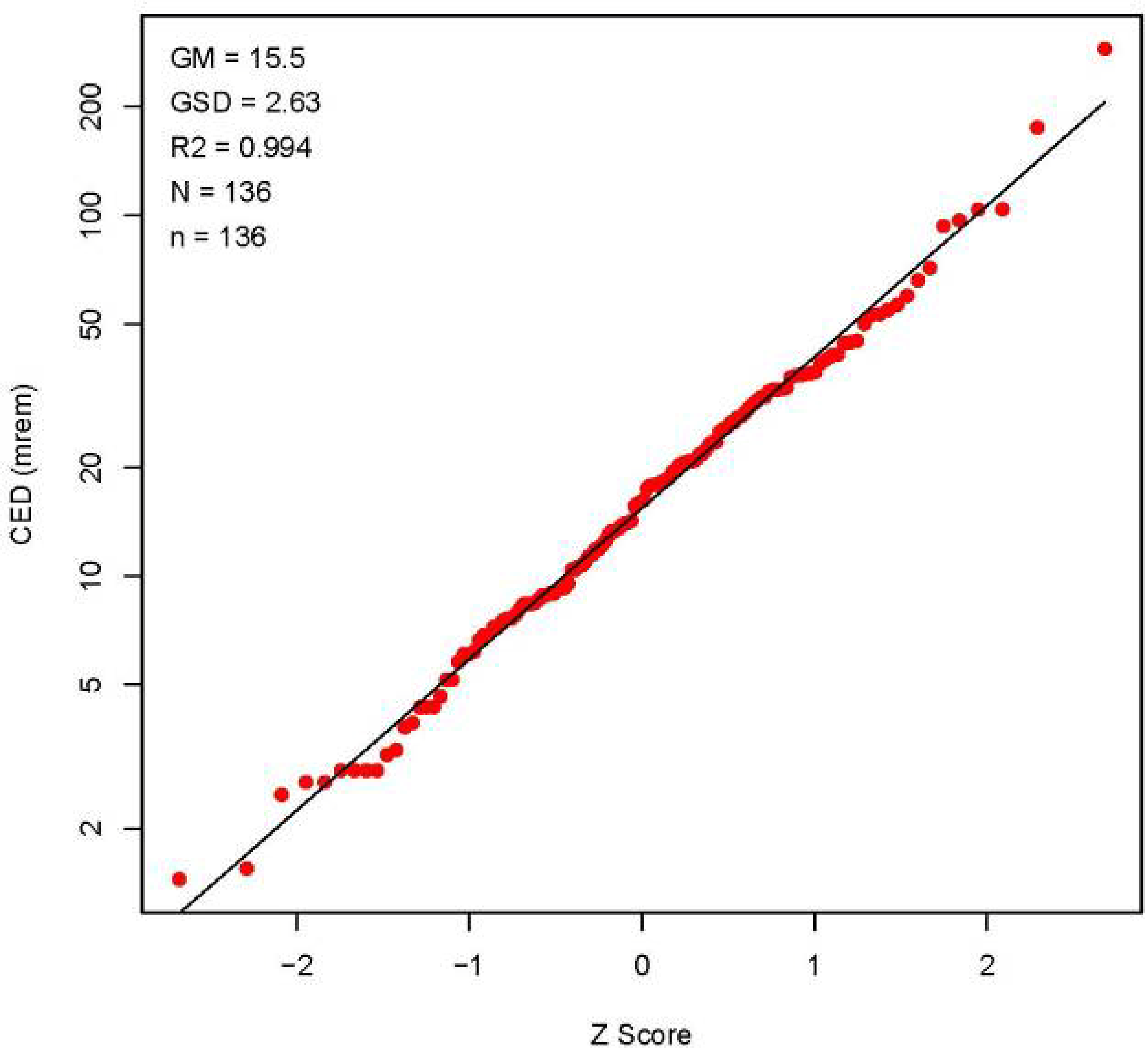

Figure B-7. SRS tritium dose 1956.

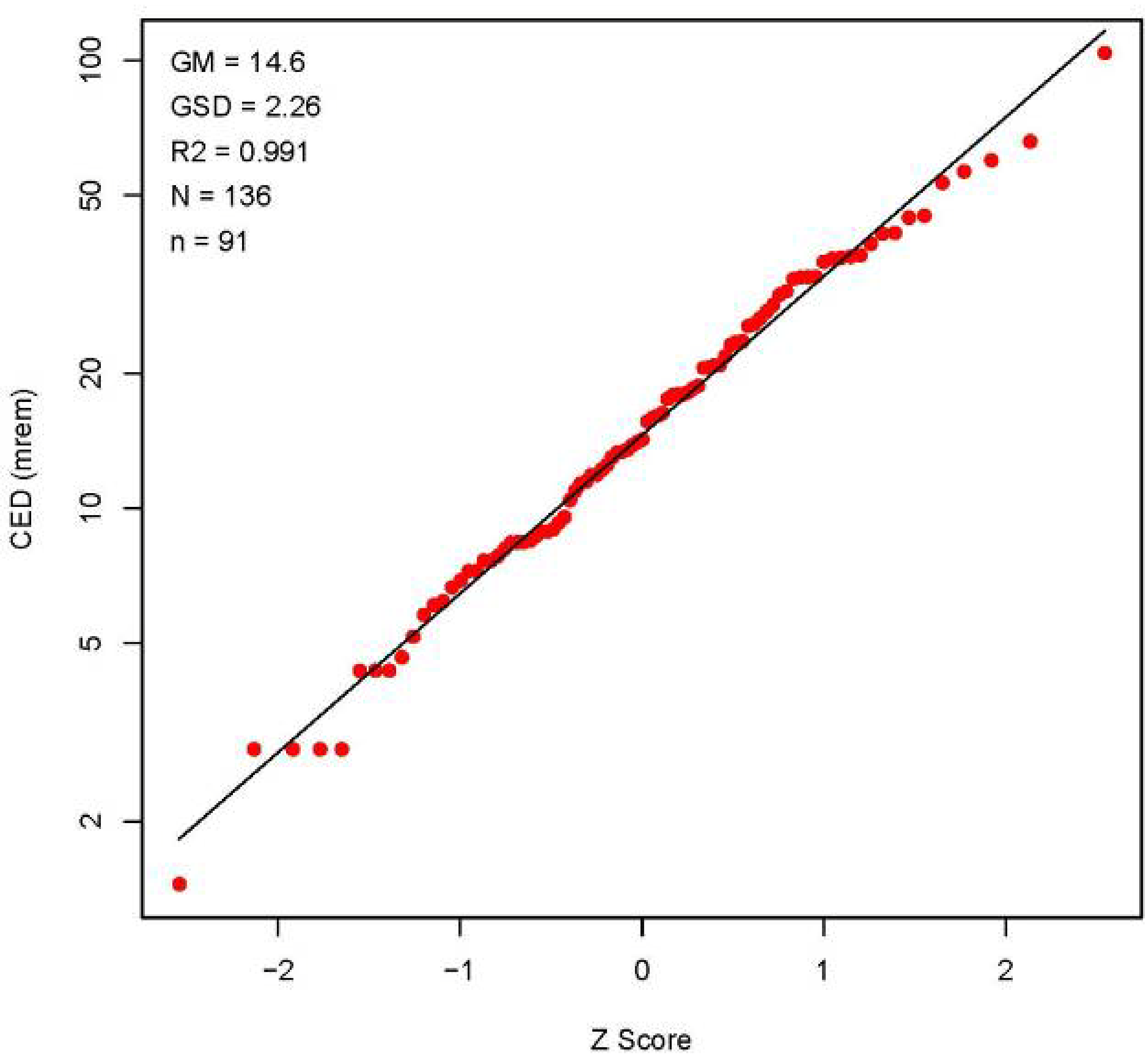

Figure B-8. SRS reactor tritium dose 1956.

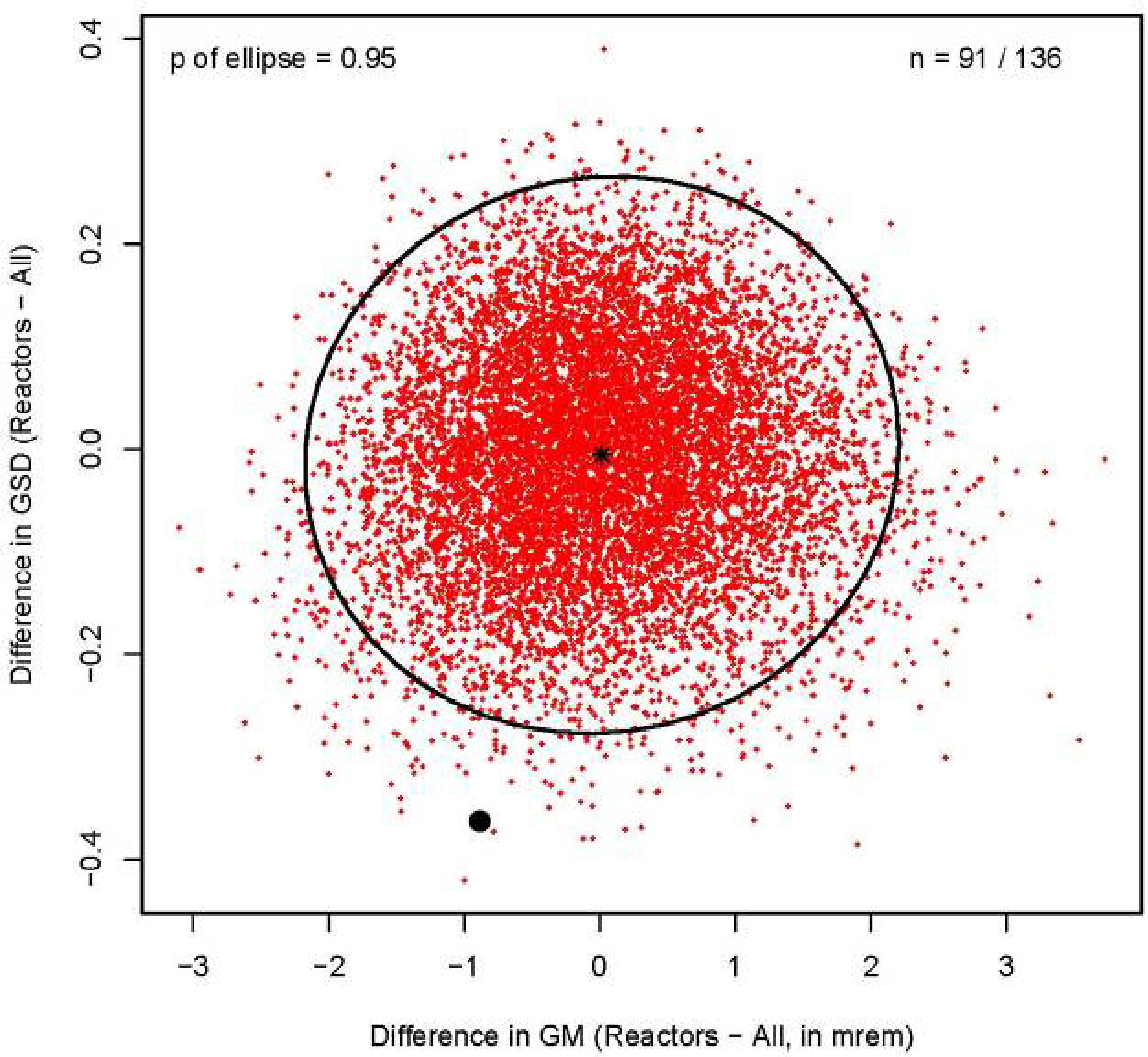

Figure B-9. SRS tritium dose 1956.

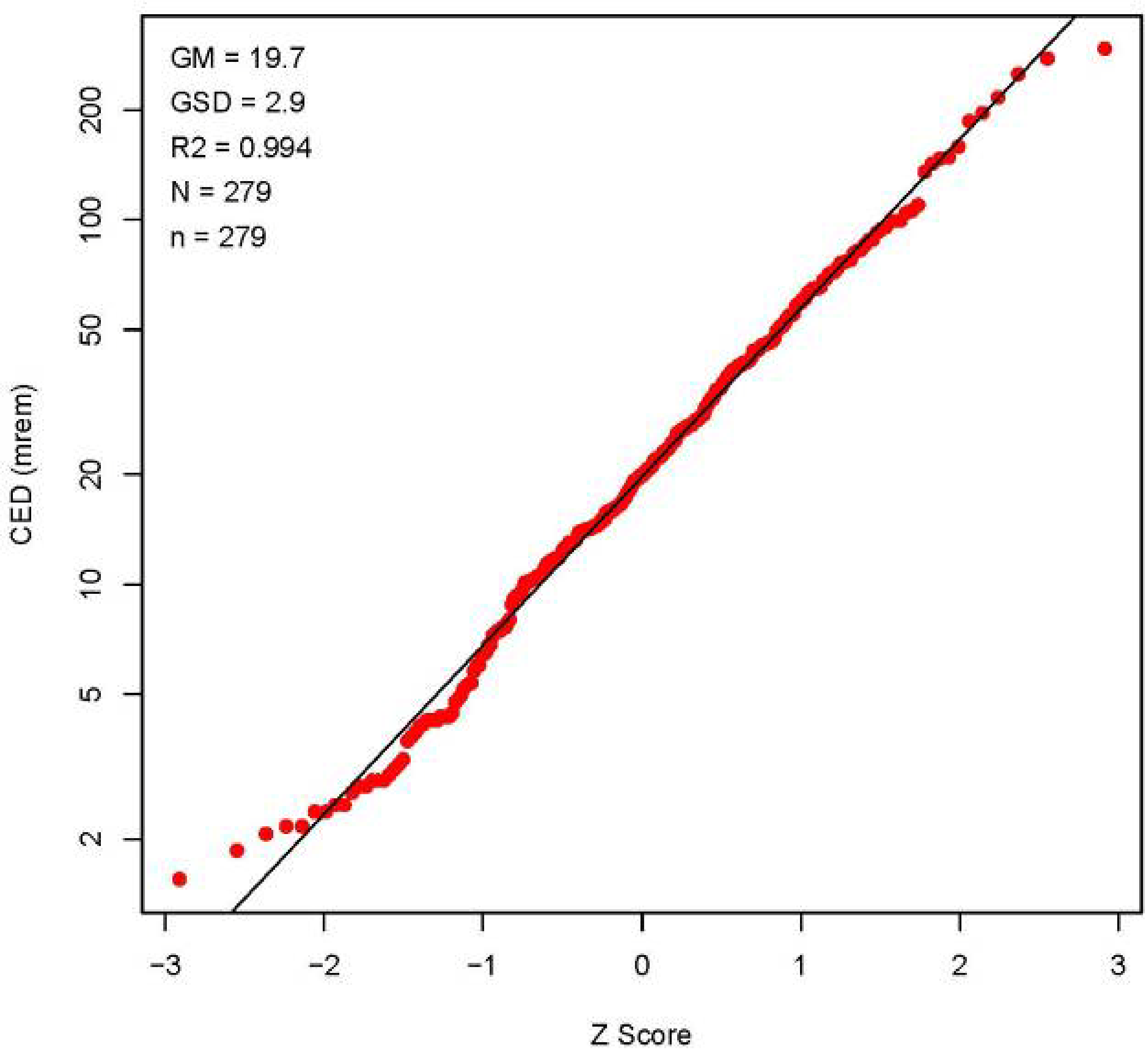

Figure B-10. SRS tritium dose 1957.

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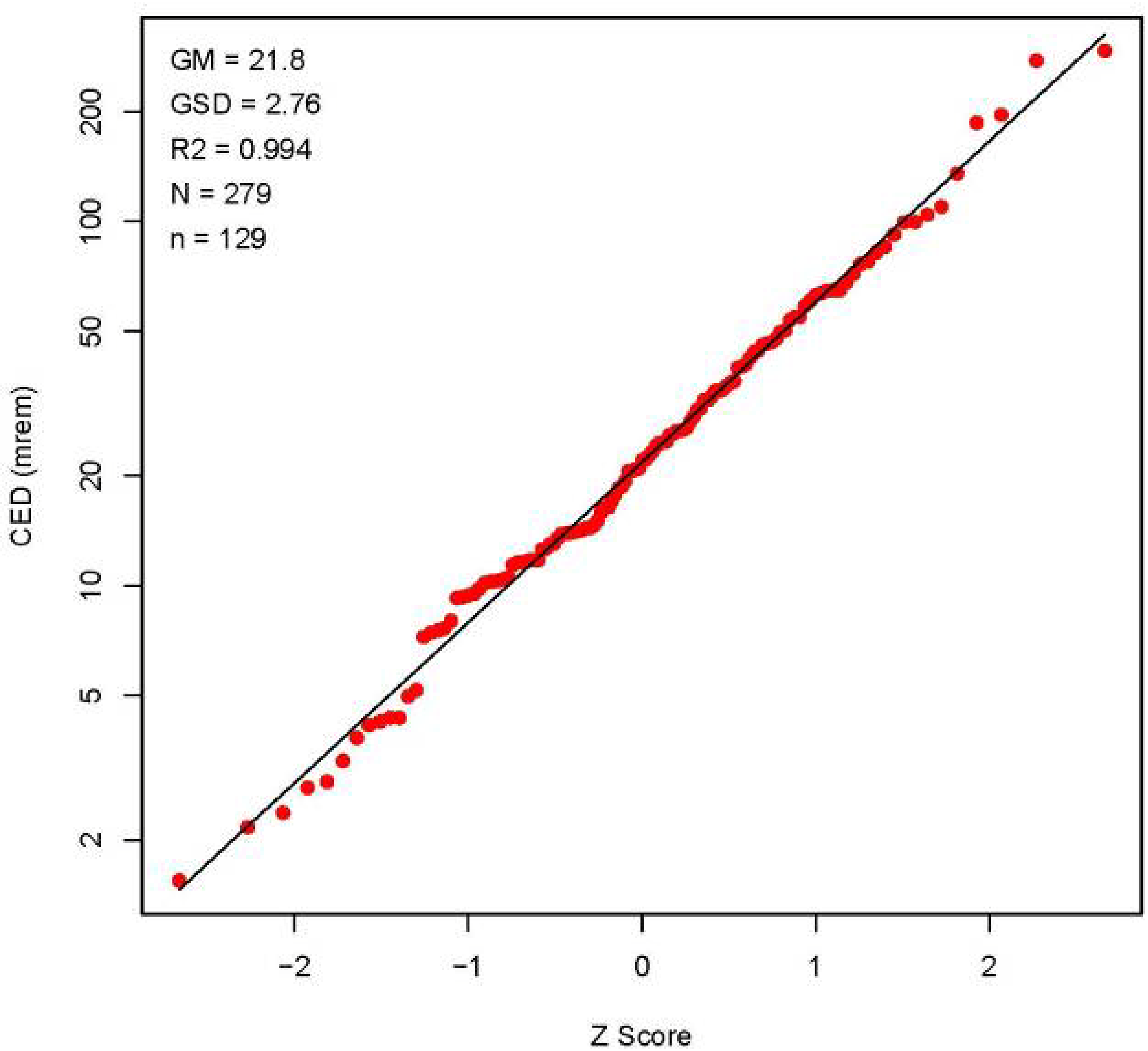

Figure B-11. SRS reactor tritium dose 1957.

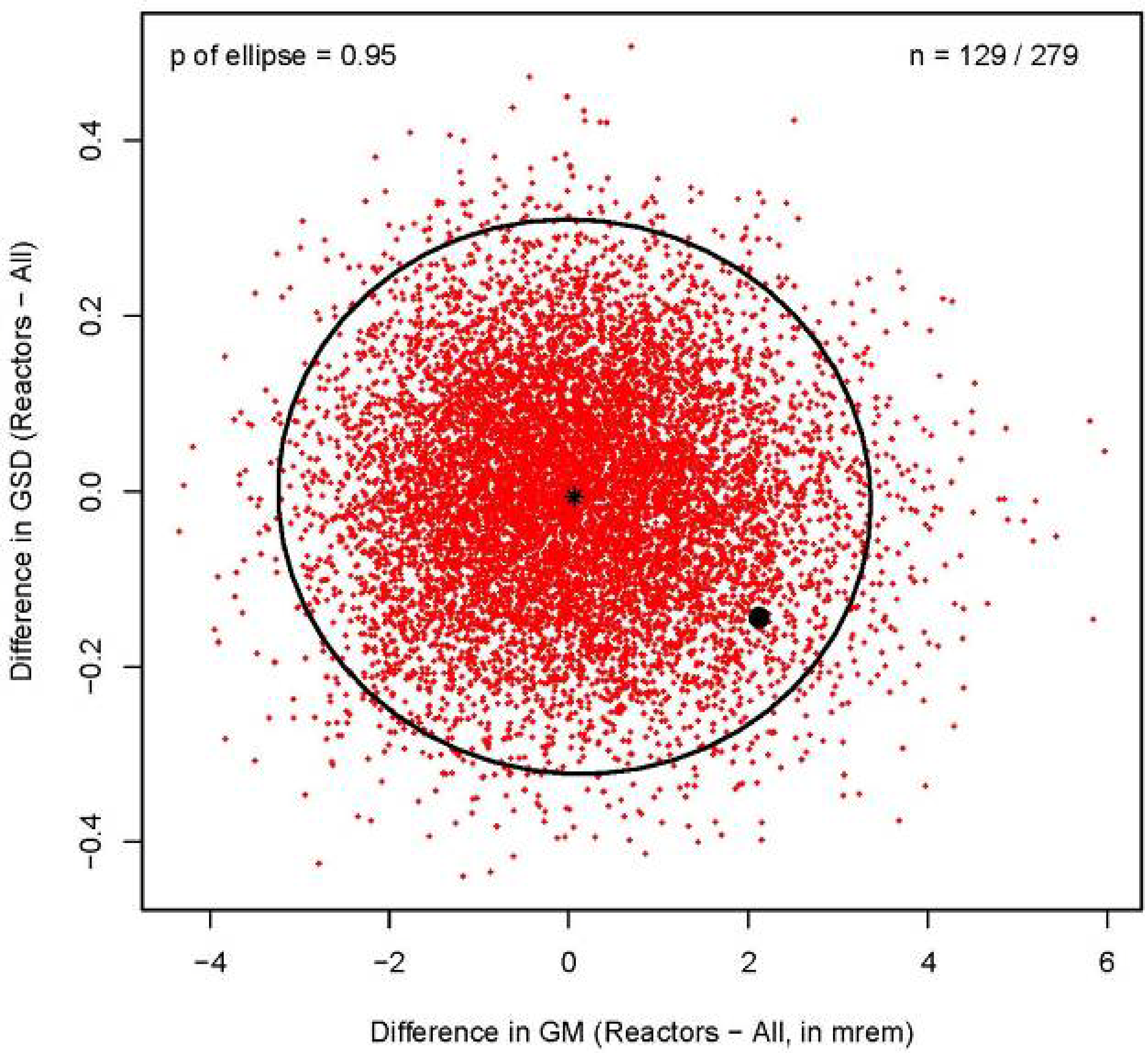

Figure B-12. SRS tritium dose 1957.

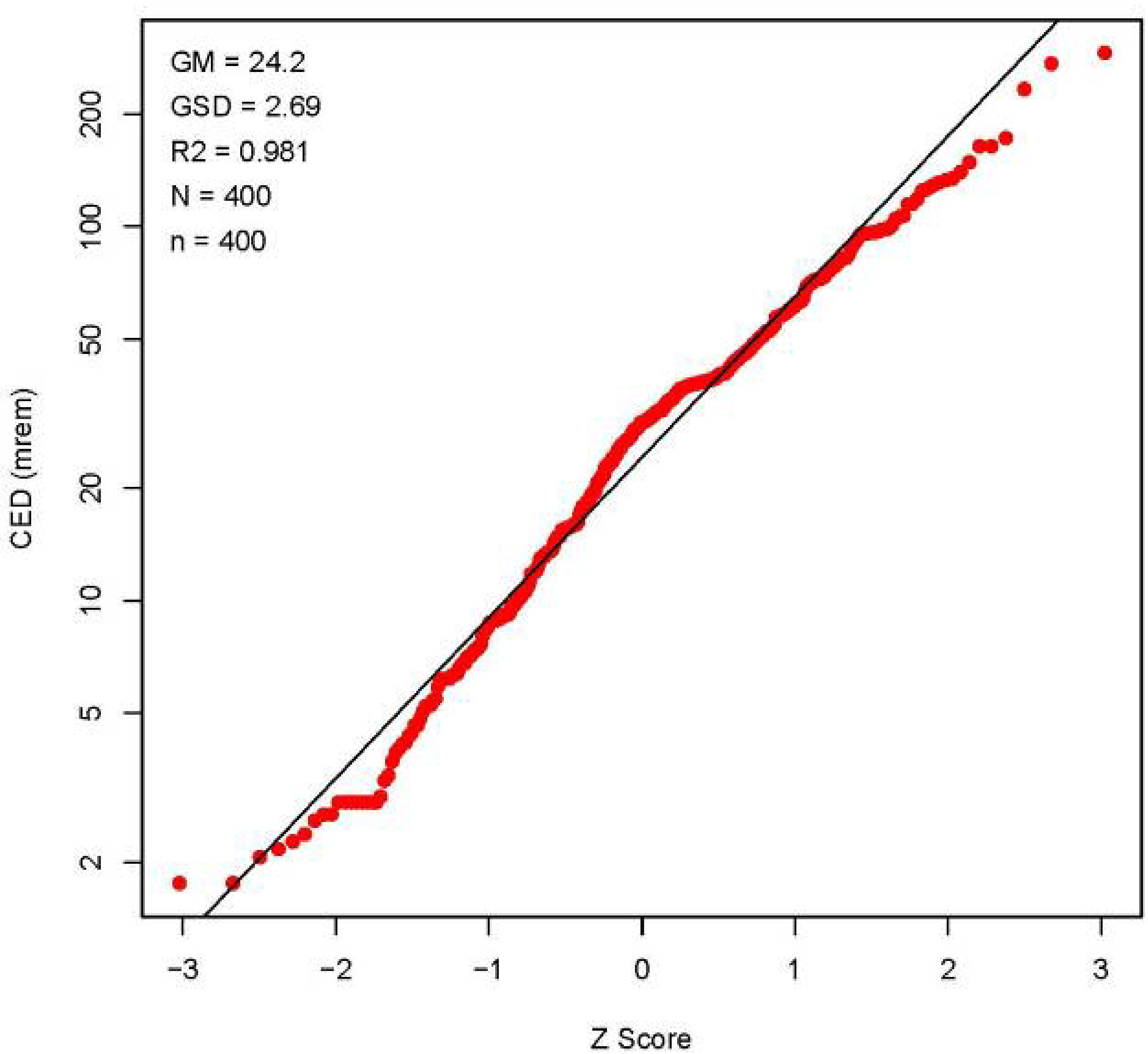

Figure B-13. SRS tritium dose 1958.

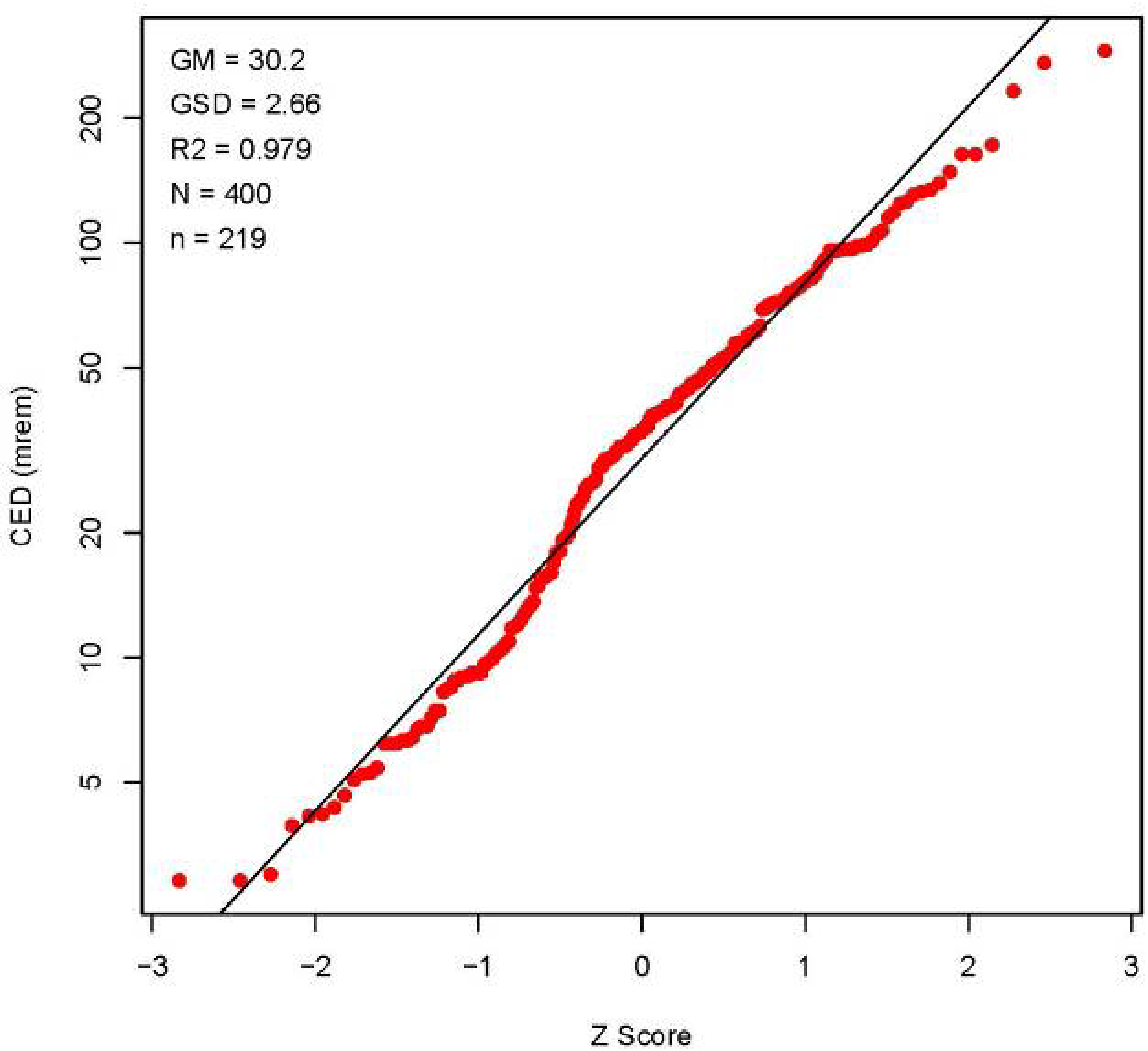

Figure B-14. SRS reactor tritium dose 1958.

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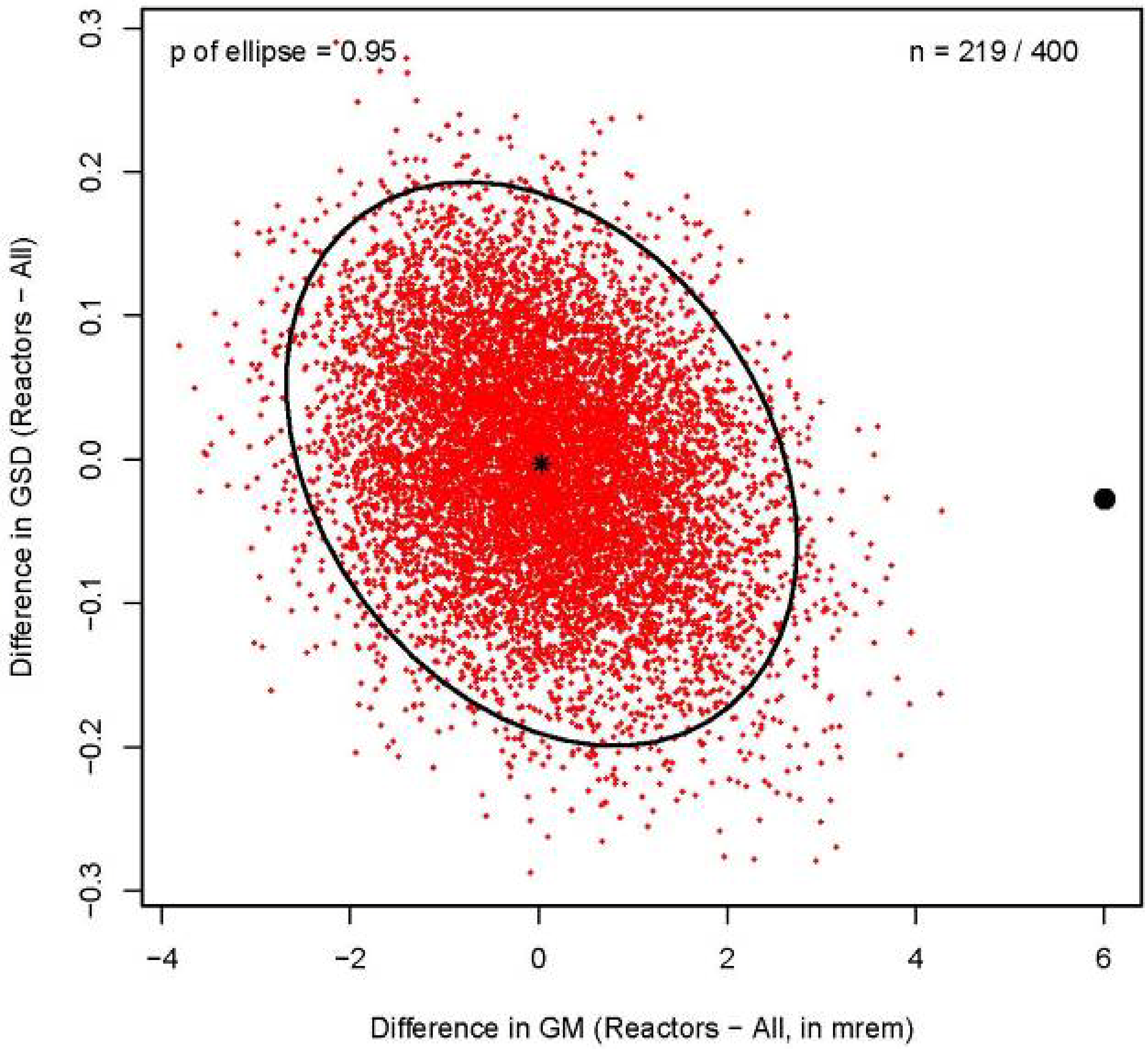

Figure B-15. SRS tritium dose 1958.

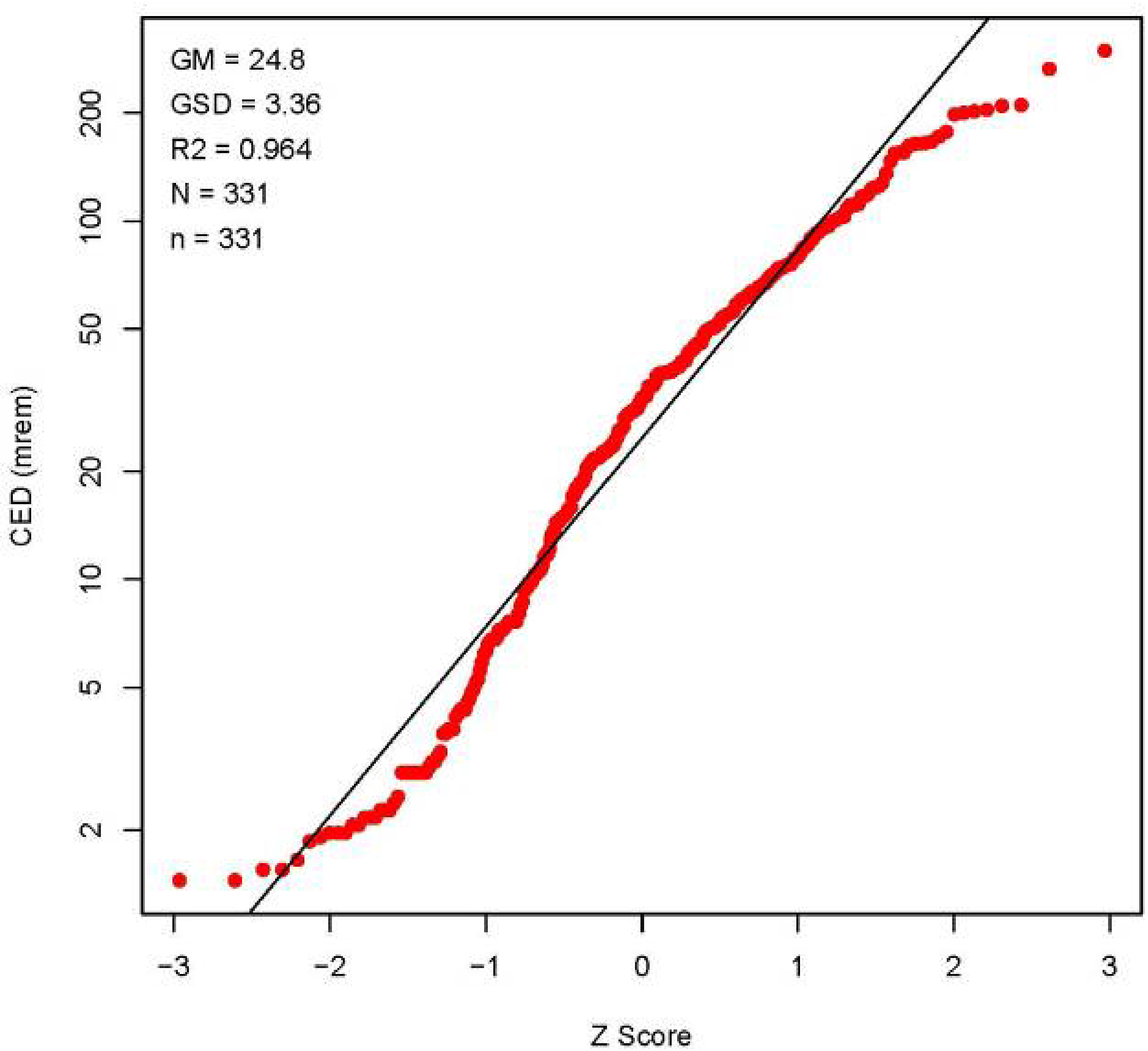

Figure B-16. SRS tritium dose 1959.

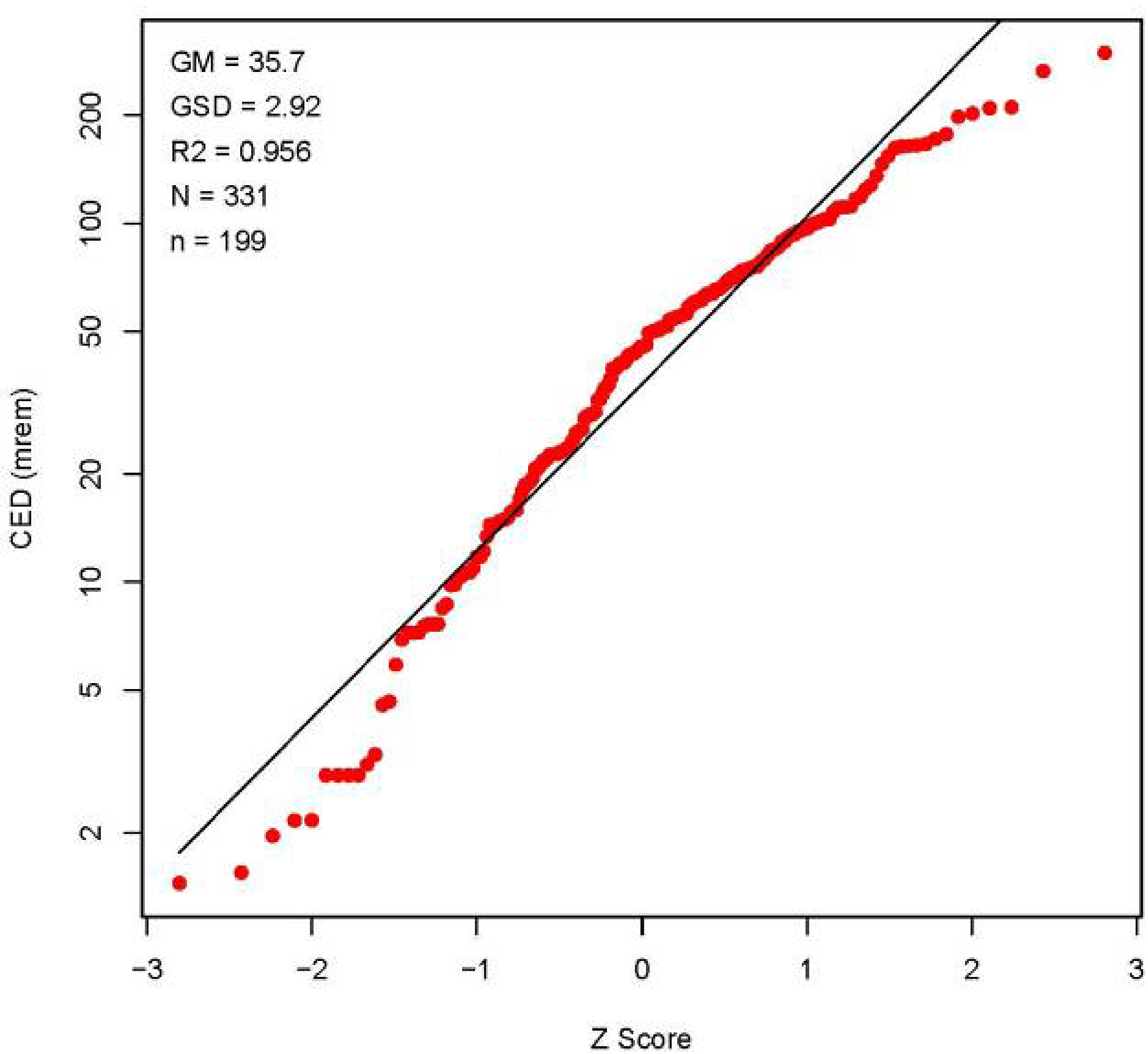

Figure B-17. SRS reactor tritium dose 1959.

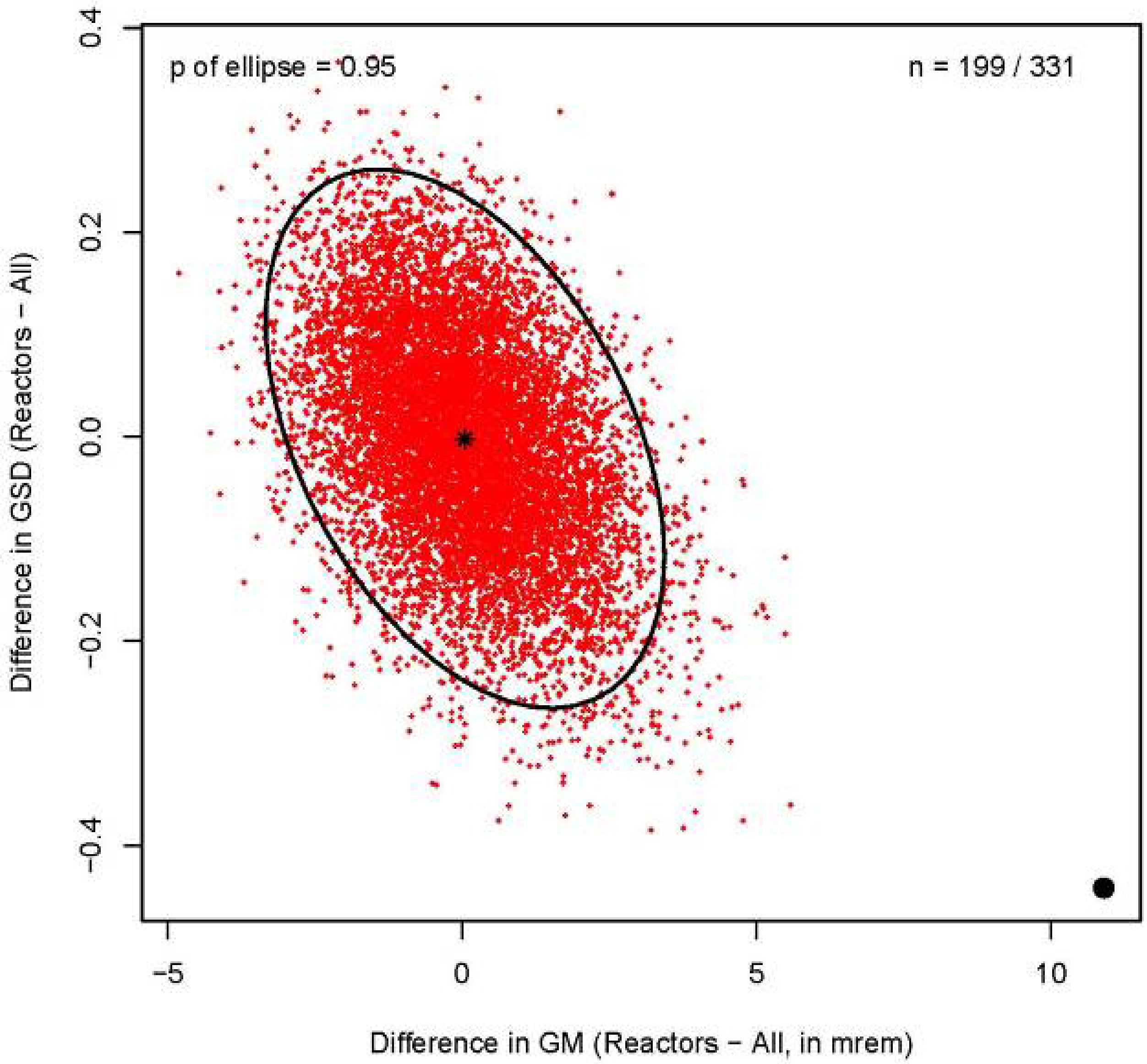

Figure B-18. SRS tritium dose 1959.

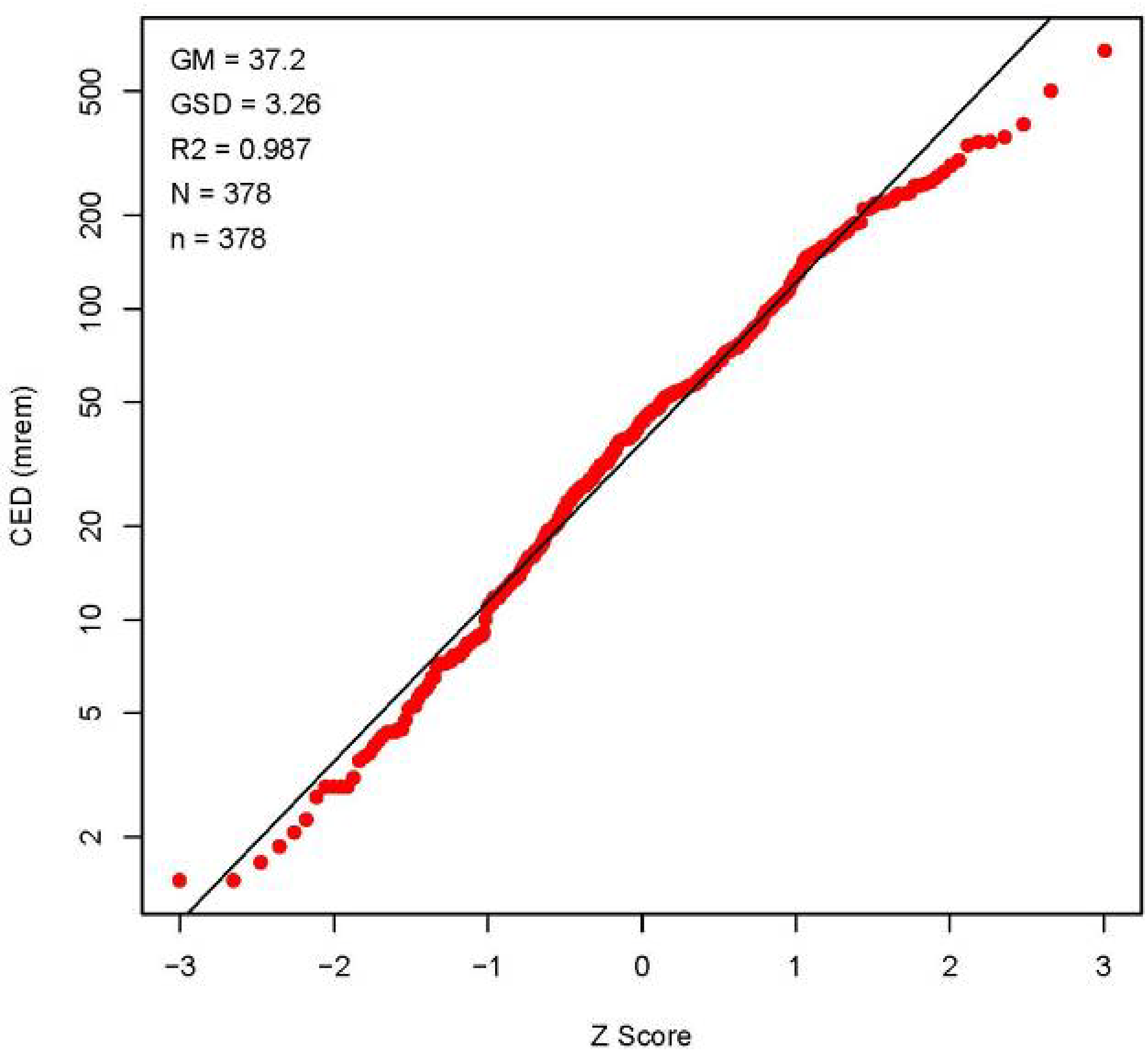

Figure B-19. SRS tritium dose 1960.

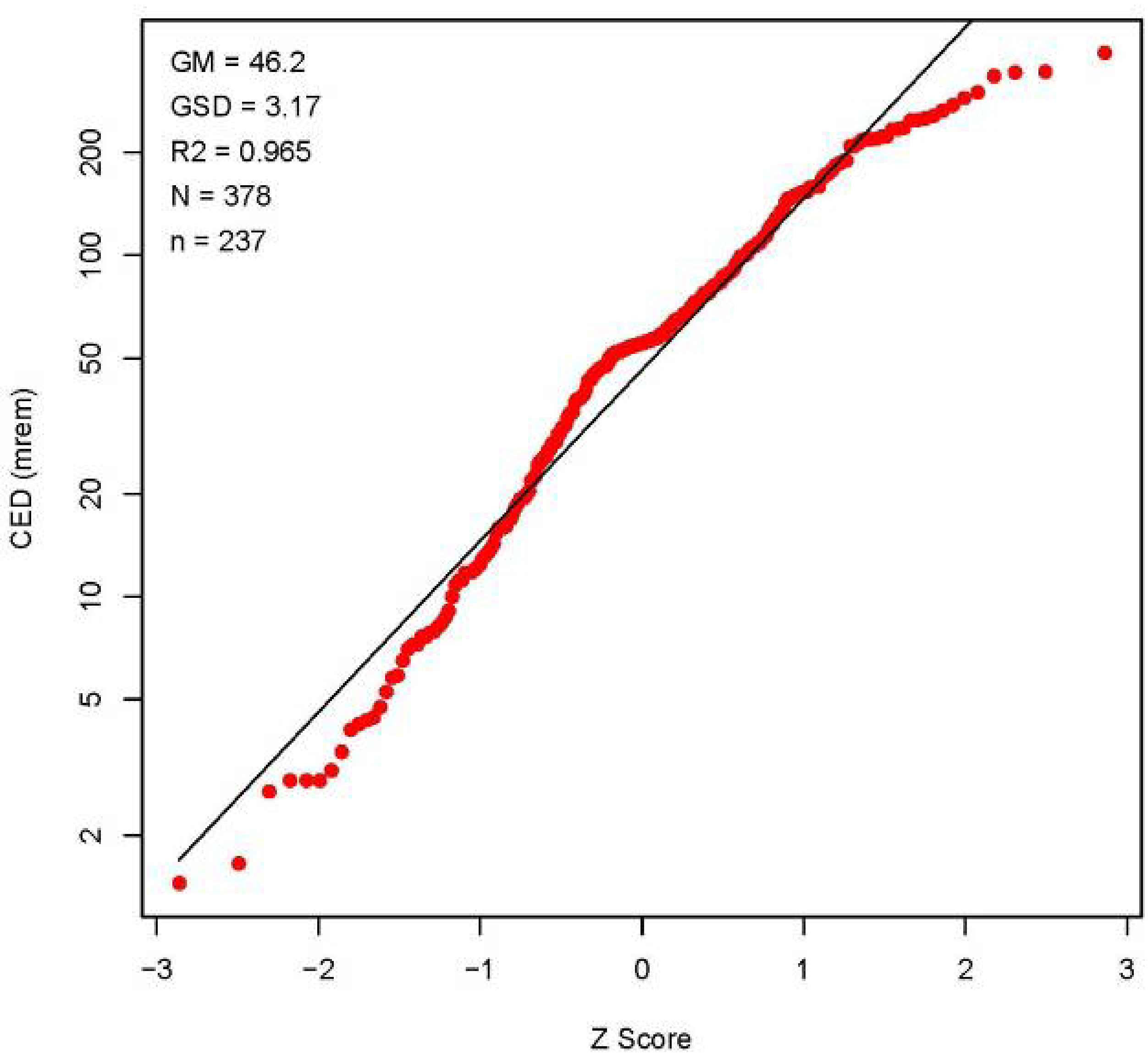

Figure B-20. SRS reactor tritium dose 1960.

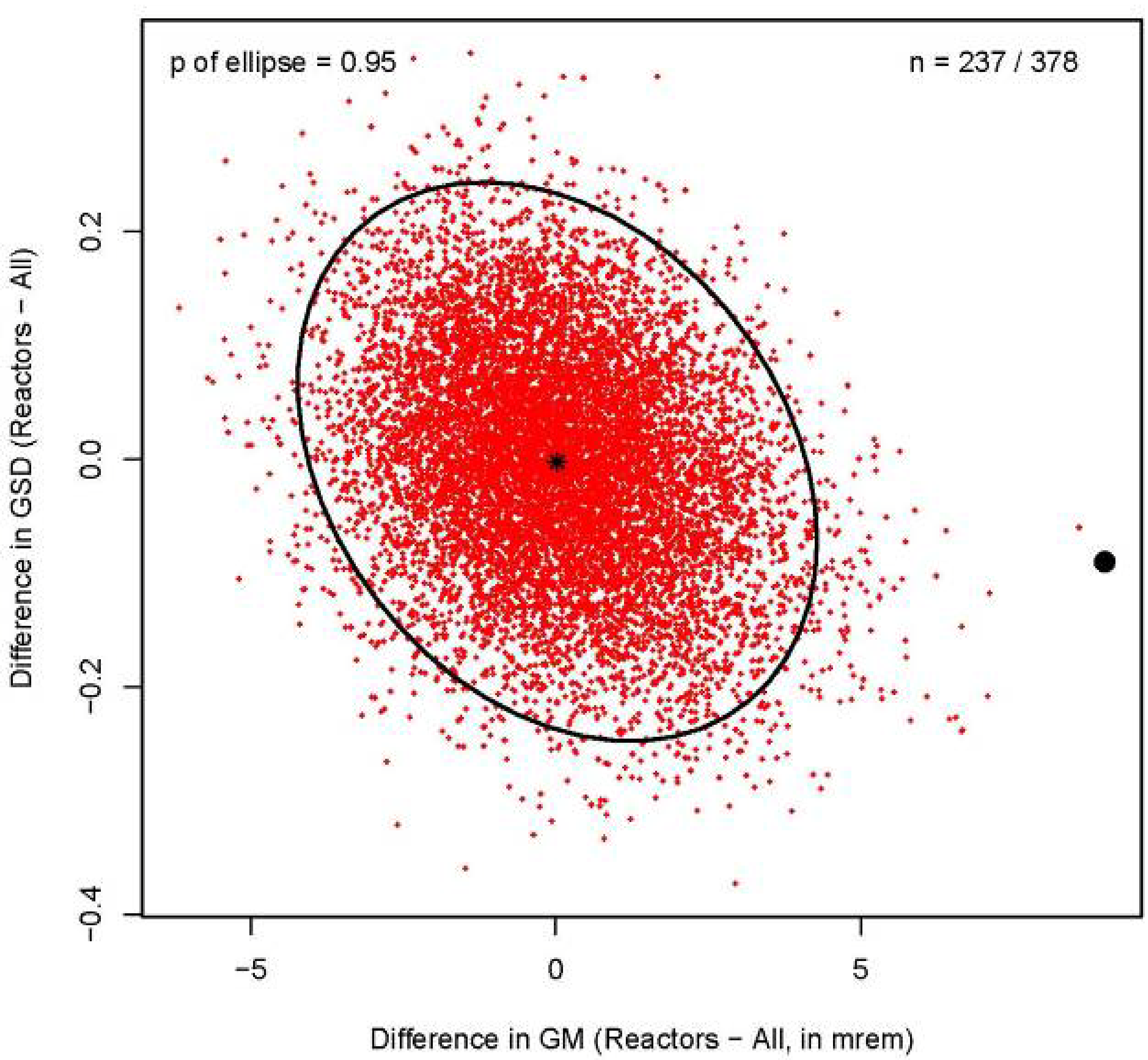

Figure B-21. SRS tritium dose 1960.

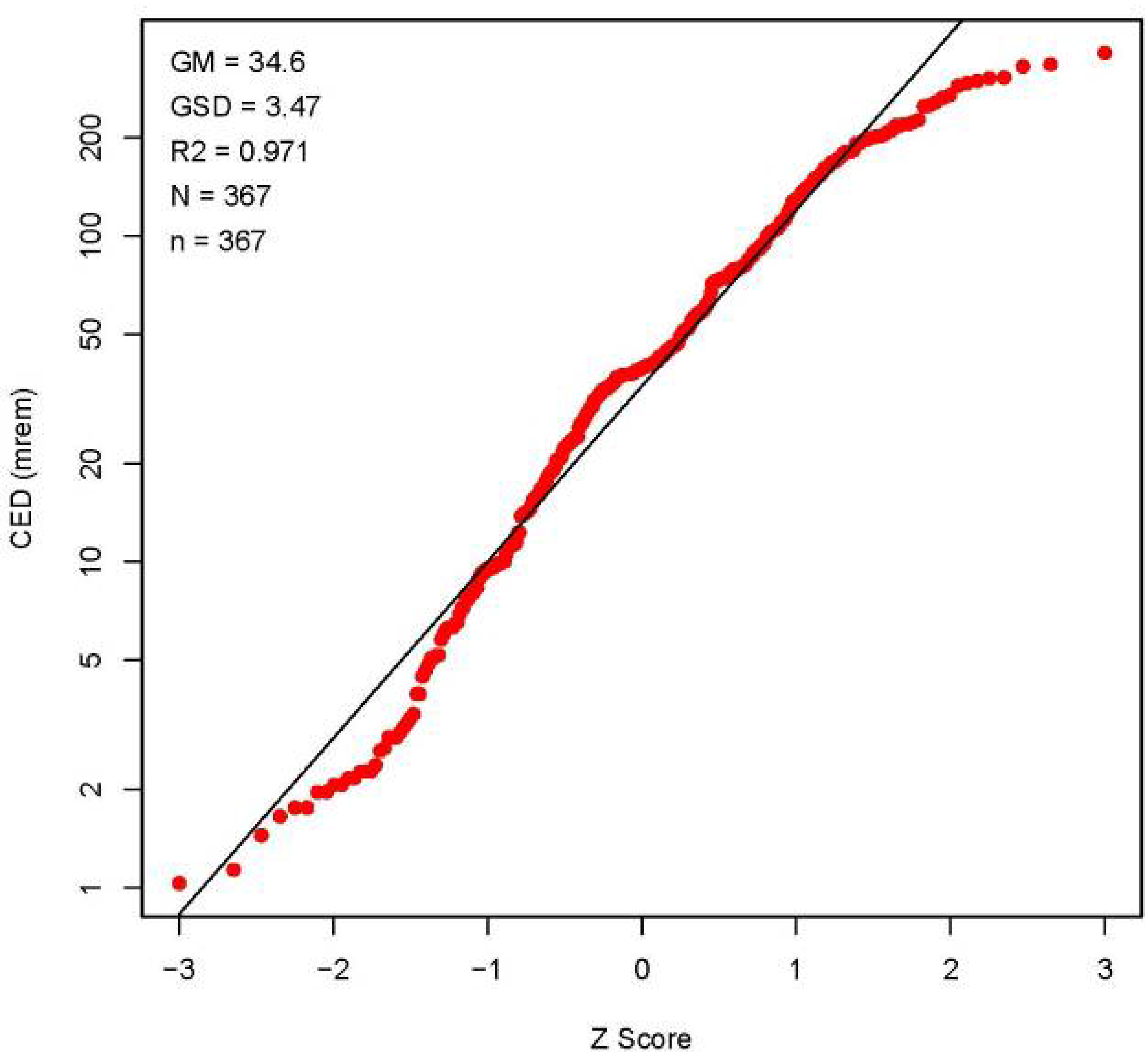

Figure B-22. SRS tritium dose 1961.

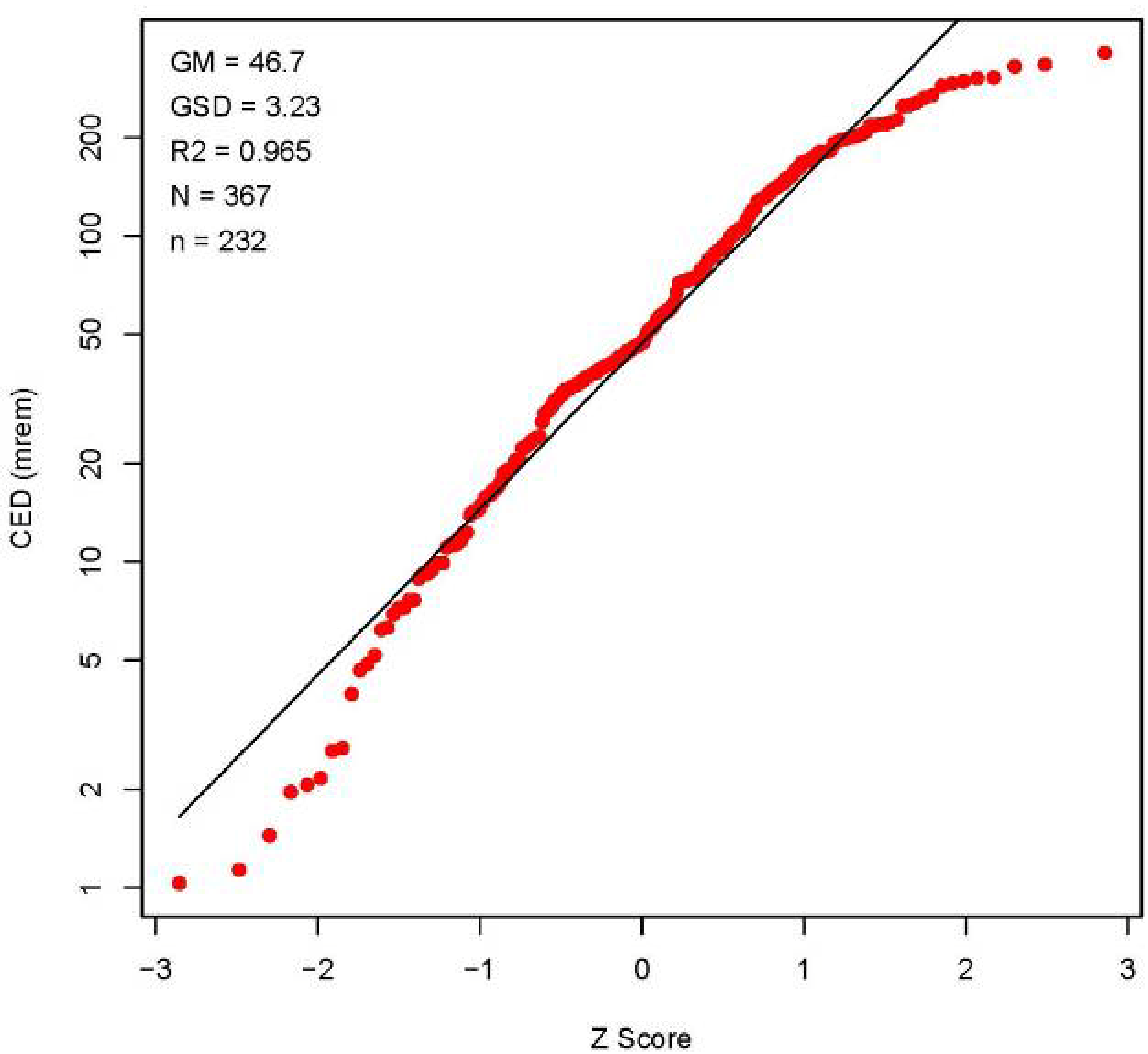

Figure B-23. SRS reactor tritium dose 1961.

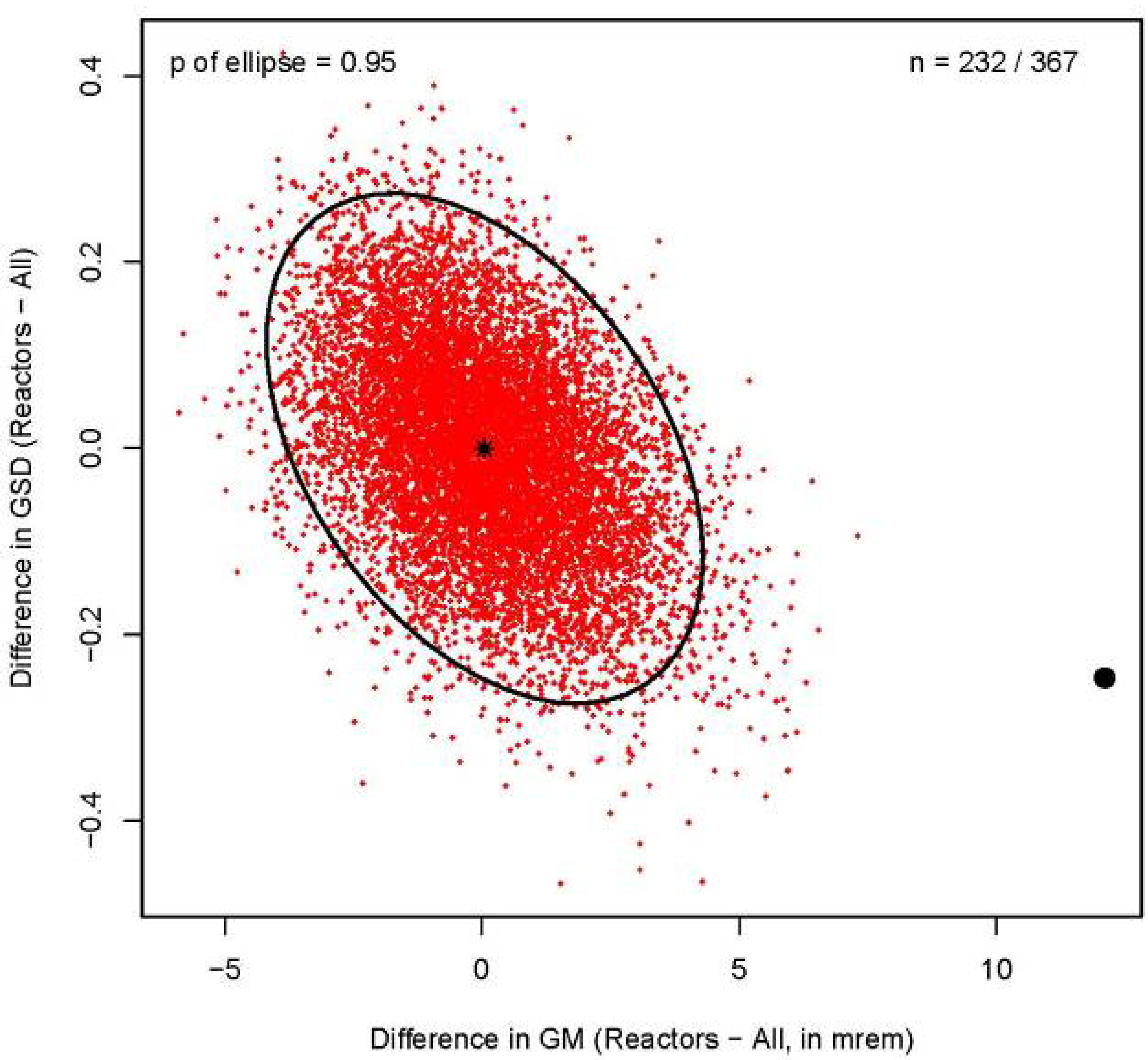

Figure B-24. SRS tritium dose 1961.

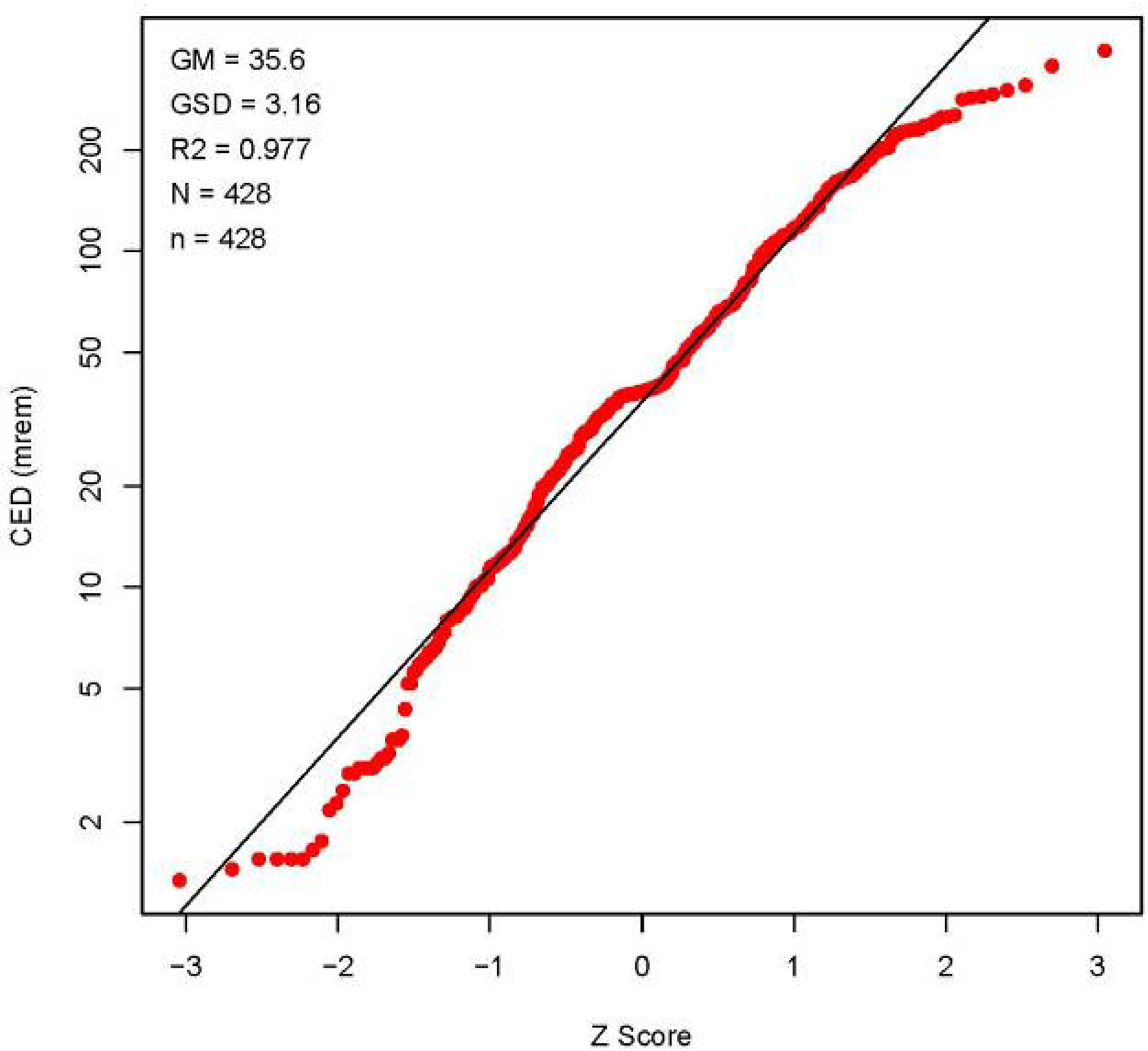

Figure B-25. SRS tritium dose 1962.

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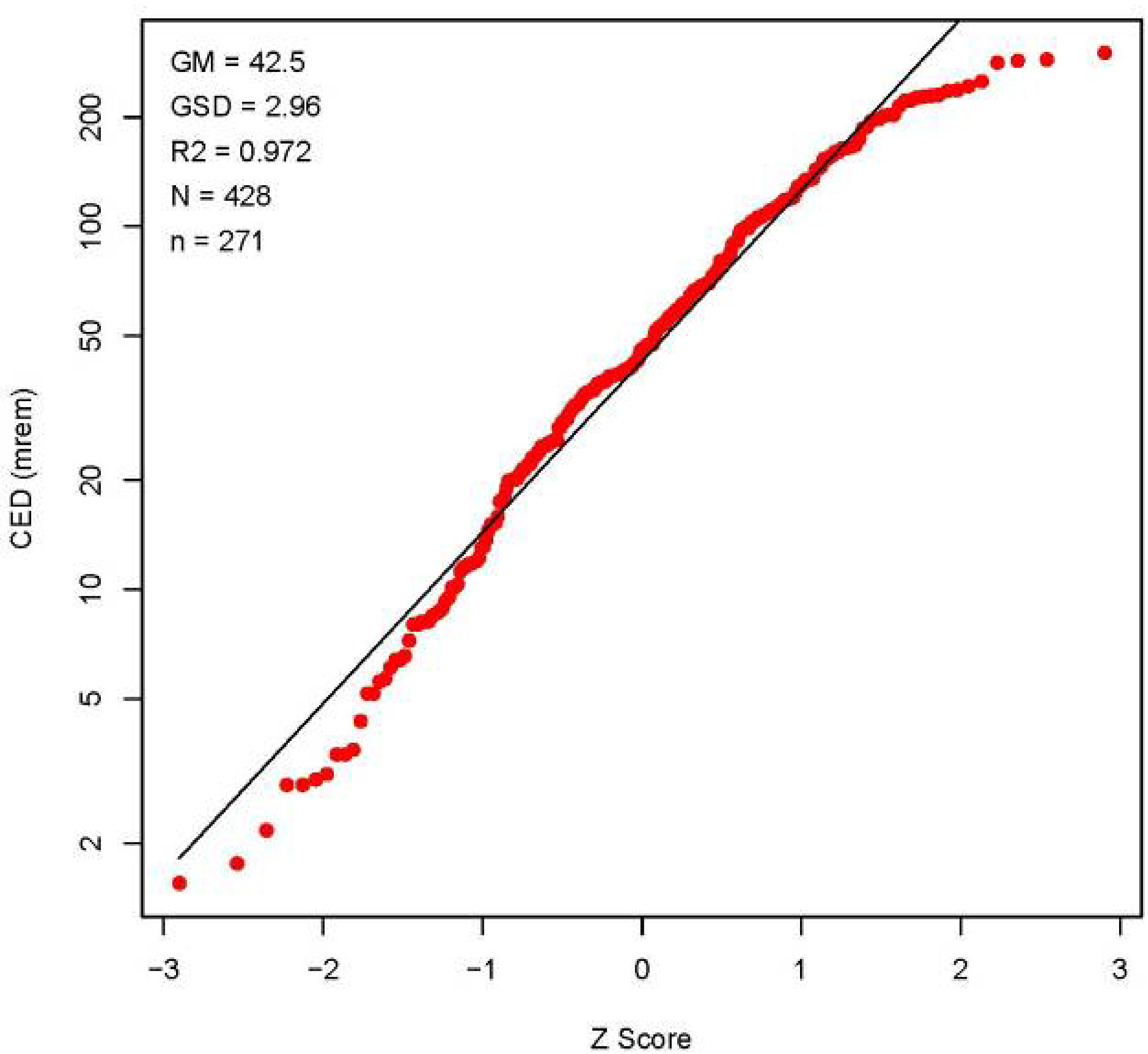

Figure B-26. SRS reactor tritium dose 1962.

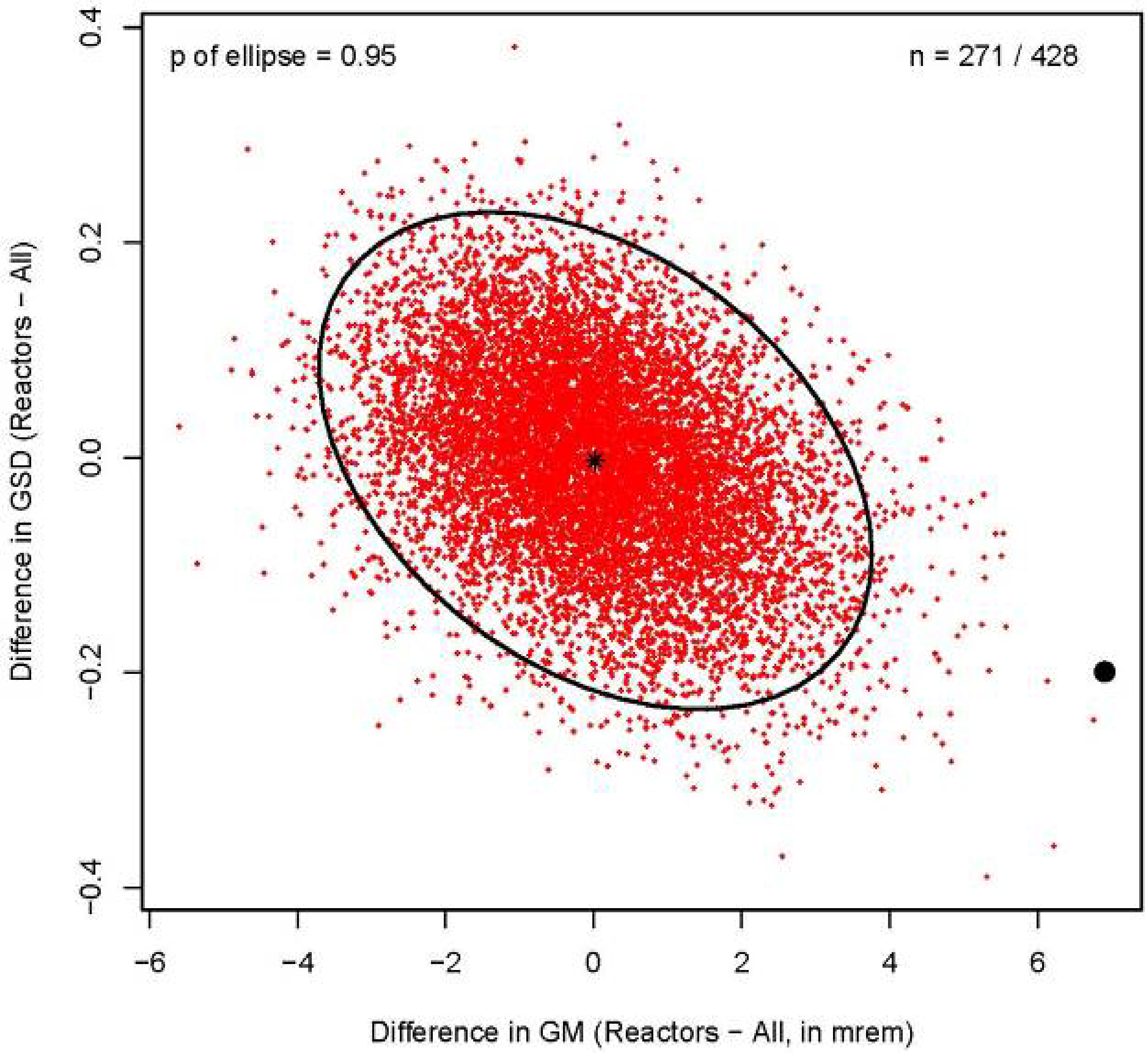

Figure B-27. SRS tritium dose 1962.

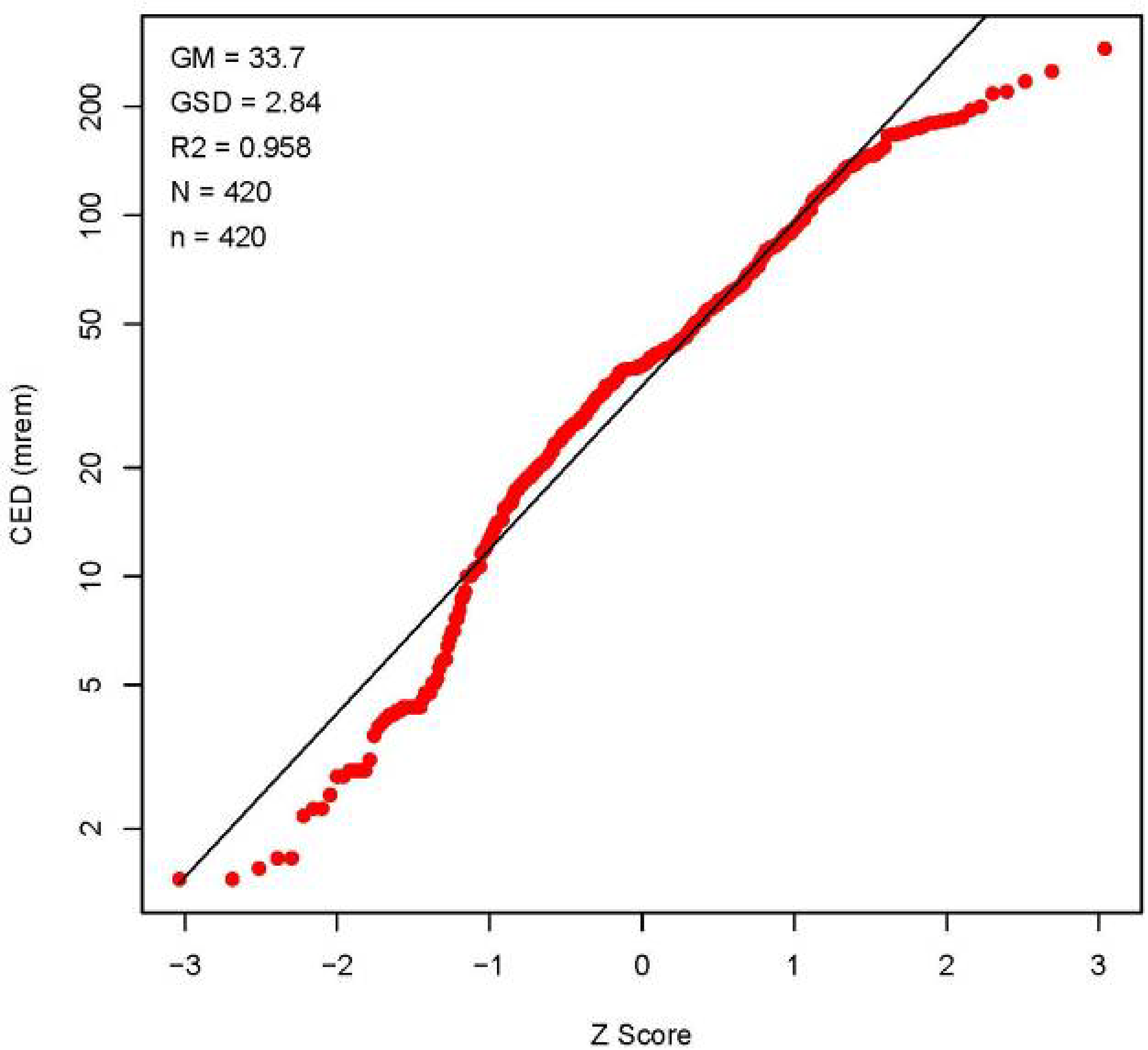

Figure B-28. SRS tritium dose 1963.

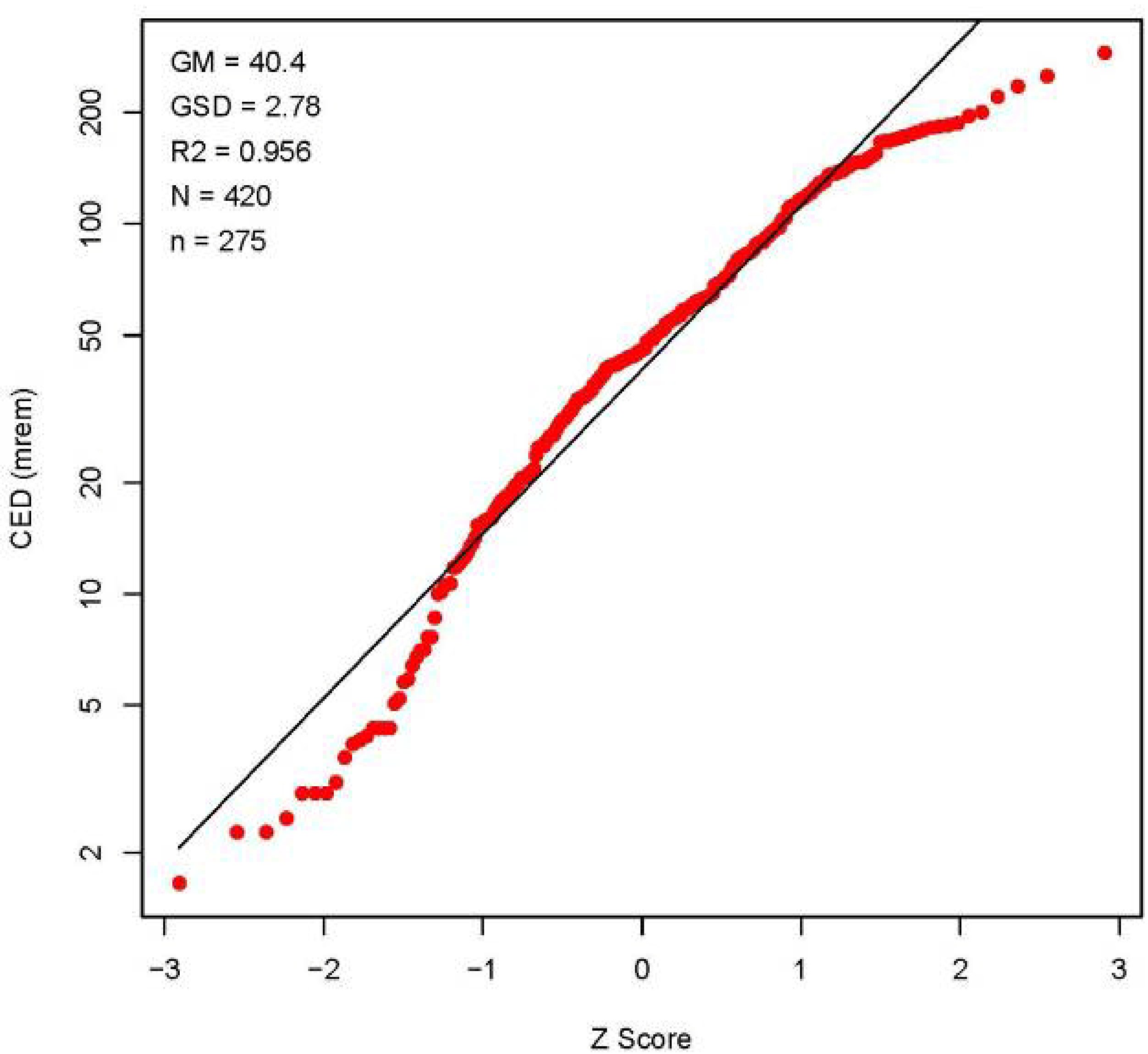

Figure B-29. SRS reactor tritium dose 1963.

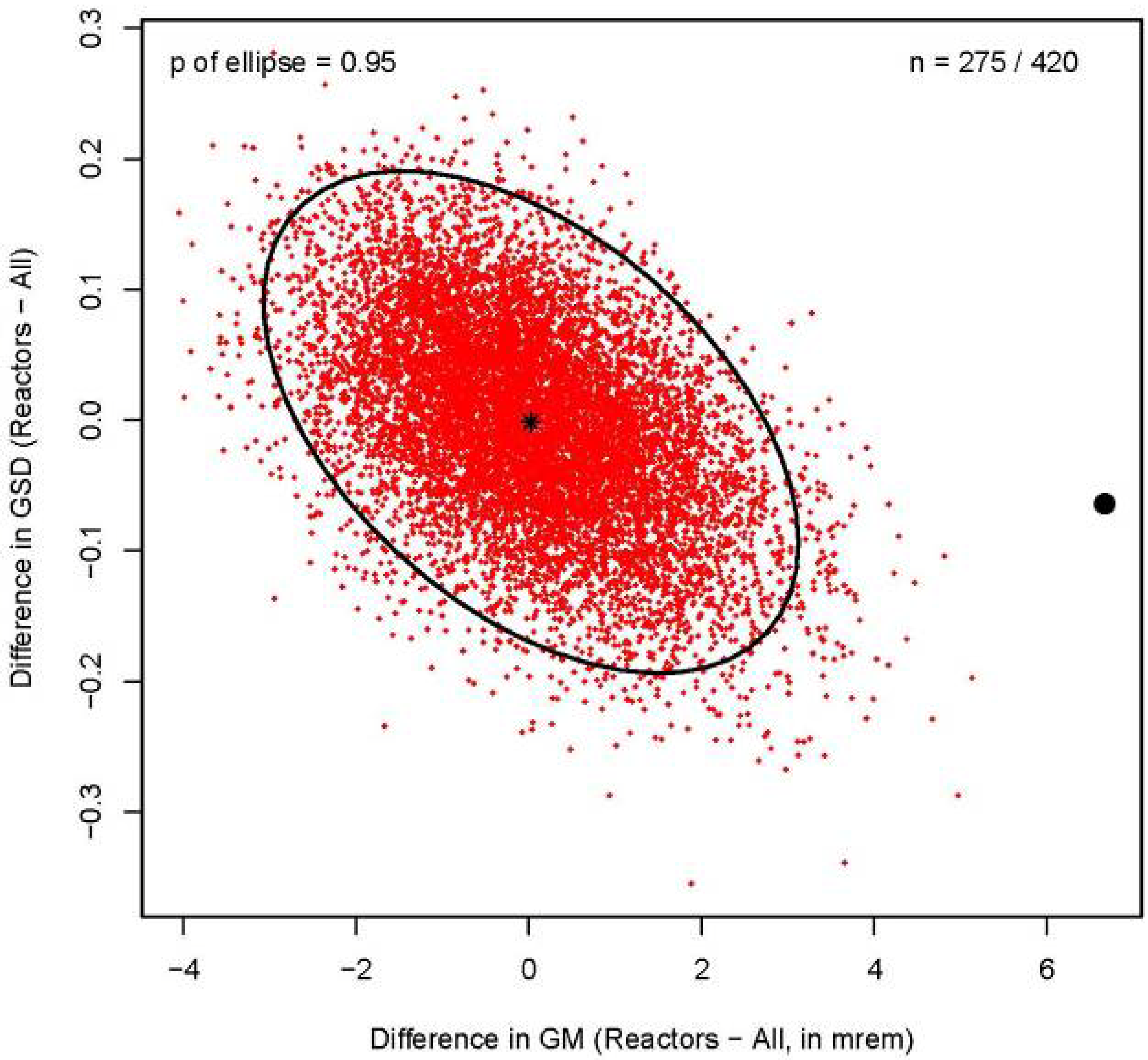

Figure B-30. SRS tritium dose 1963.

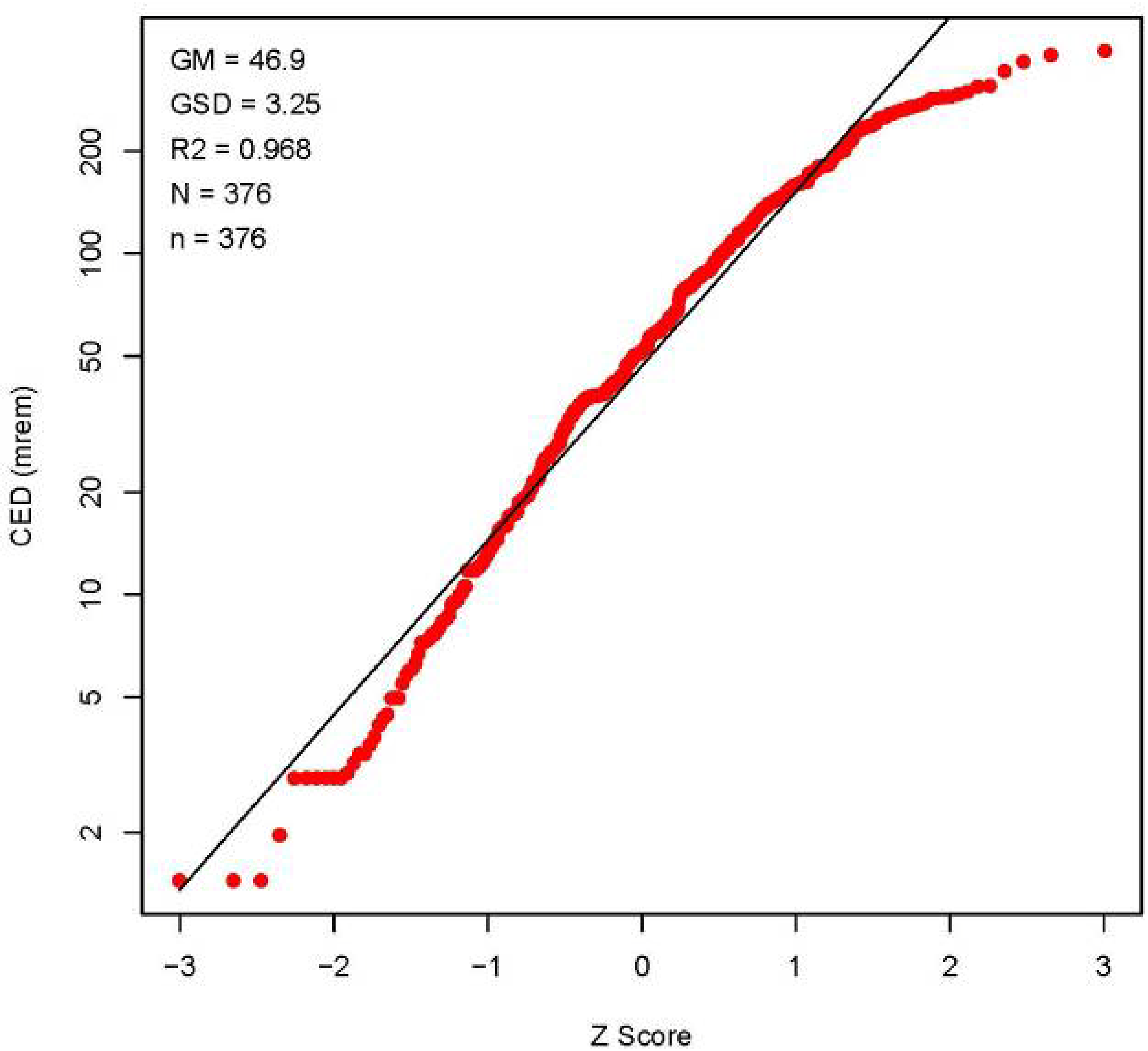

Figure B-31. SRS tritium dose 1964.

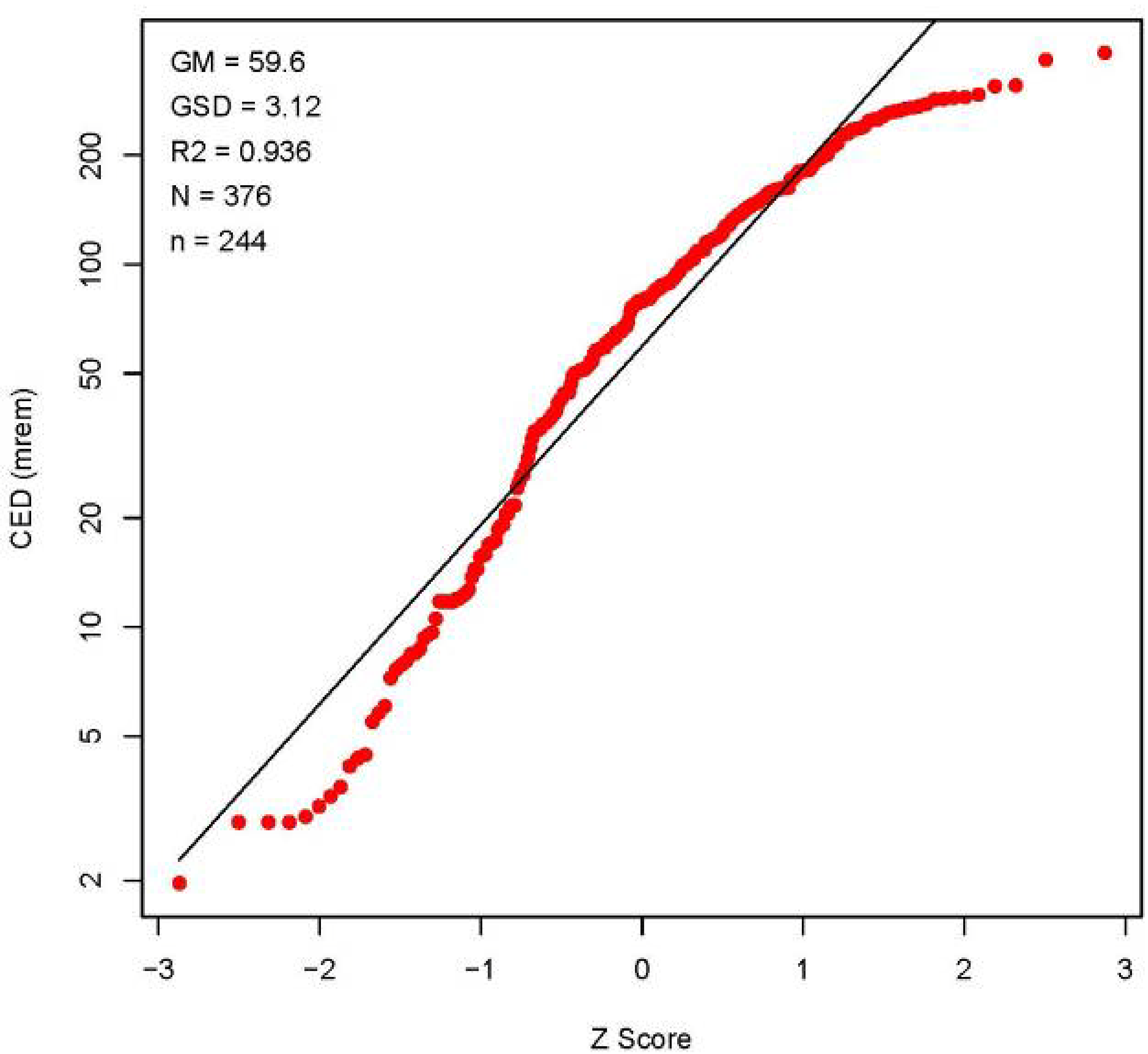

Figure B-32. SRS reactor tritium dose 1964.

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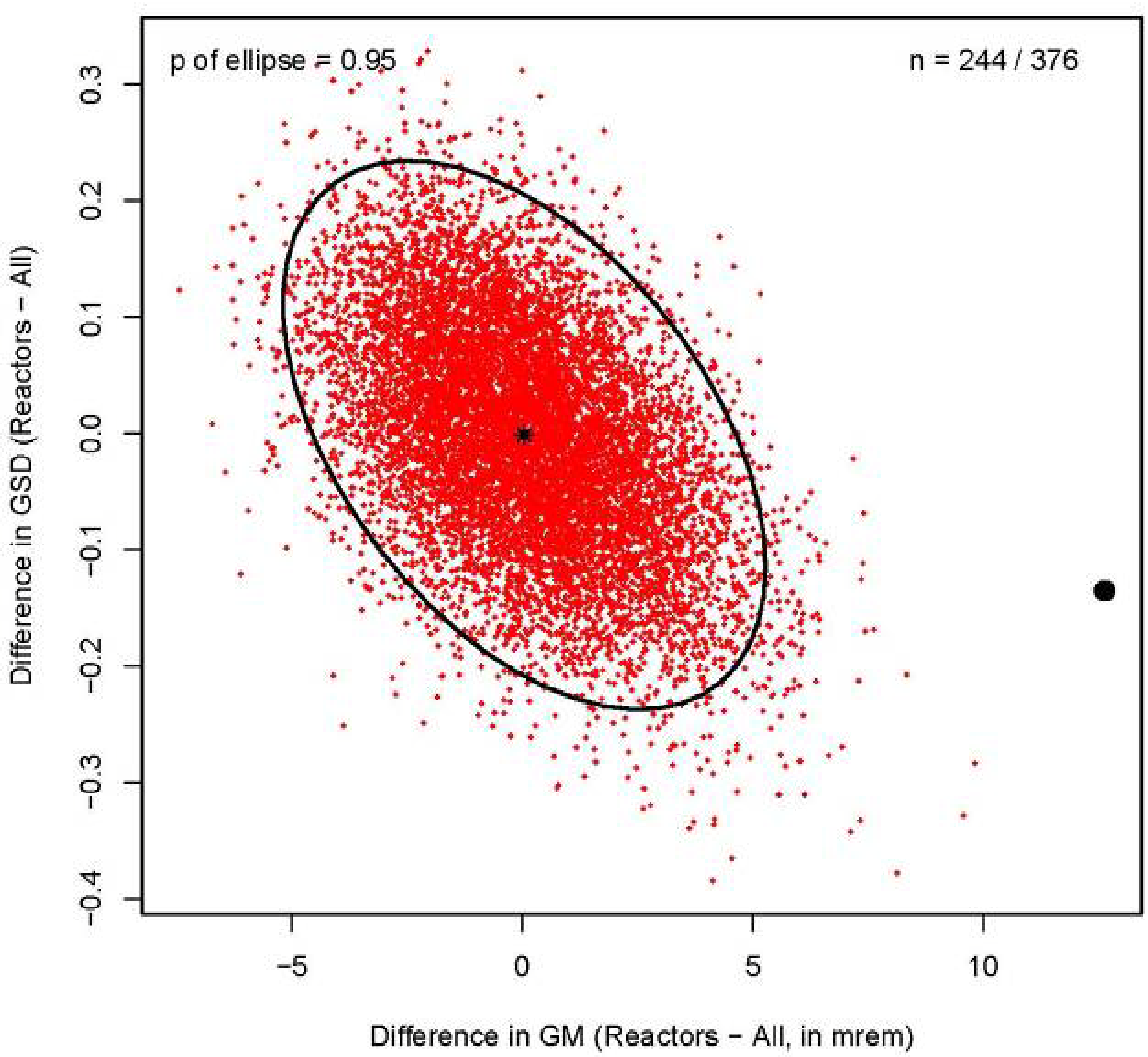

Figure B-33. SRS tritium dose 1964.

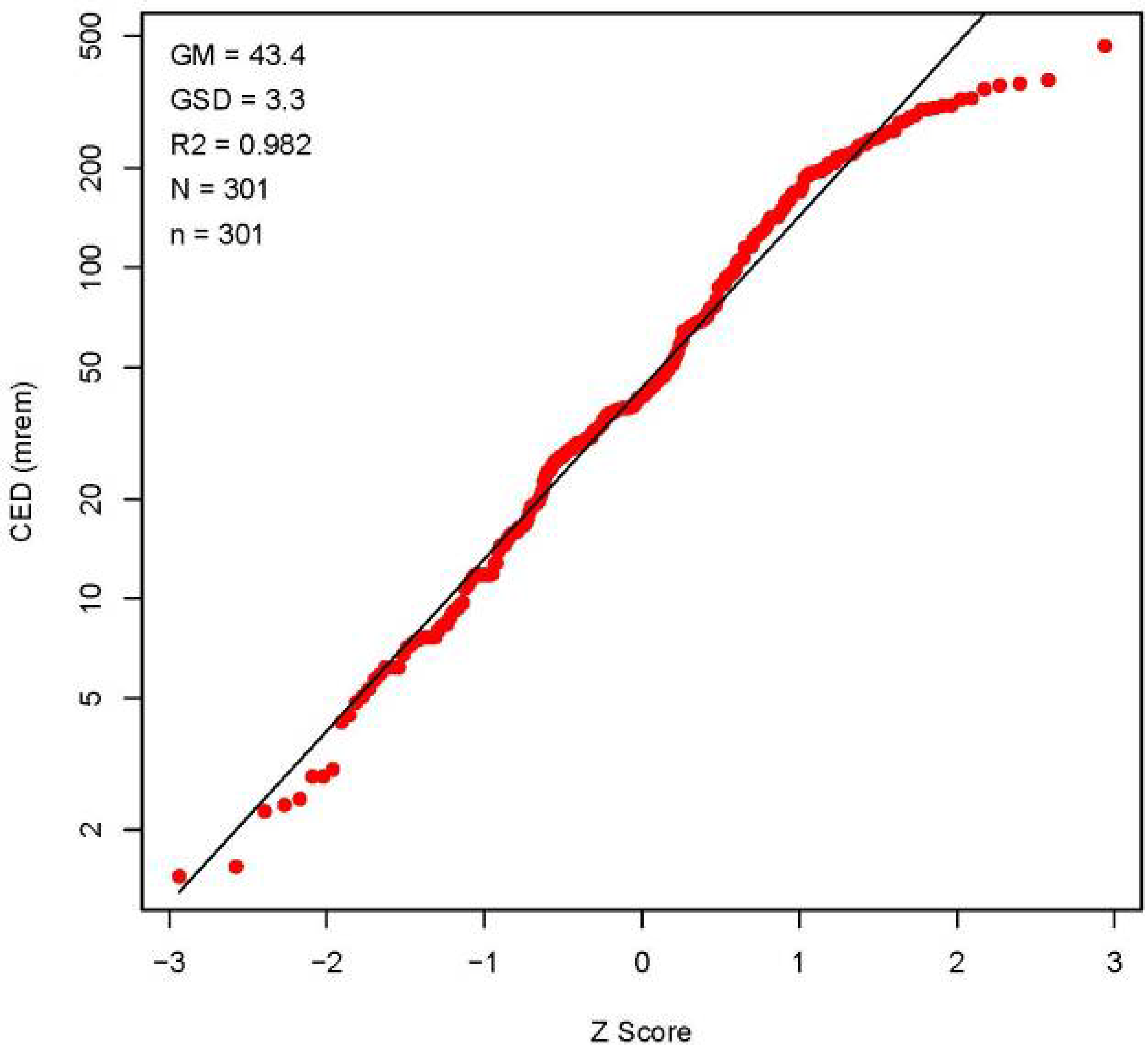

Figure B-34. SRS tritium dose 1965.

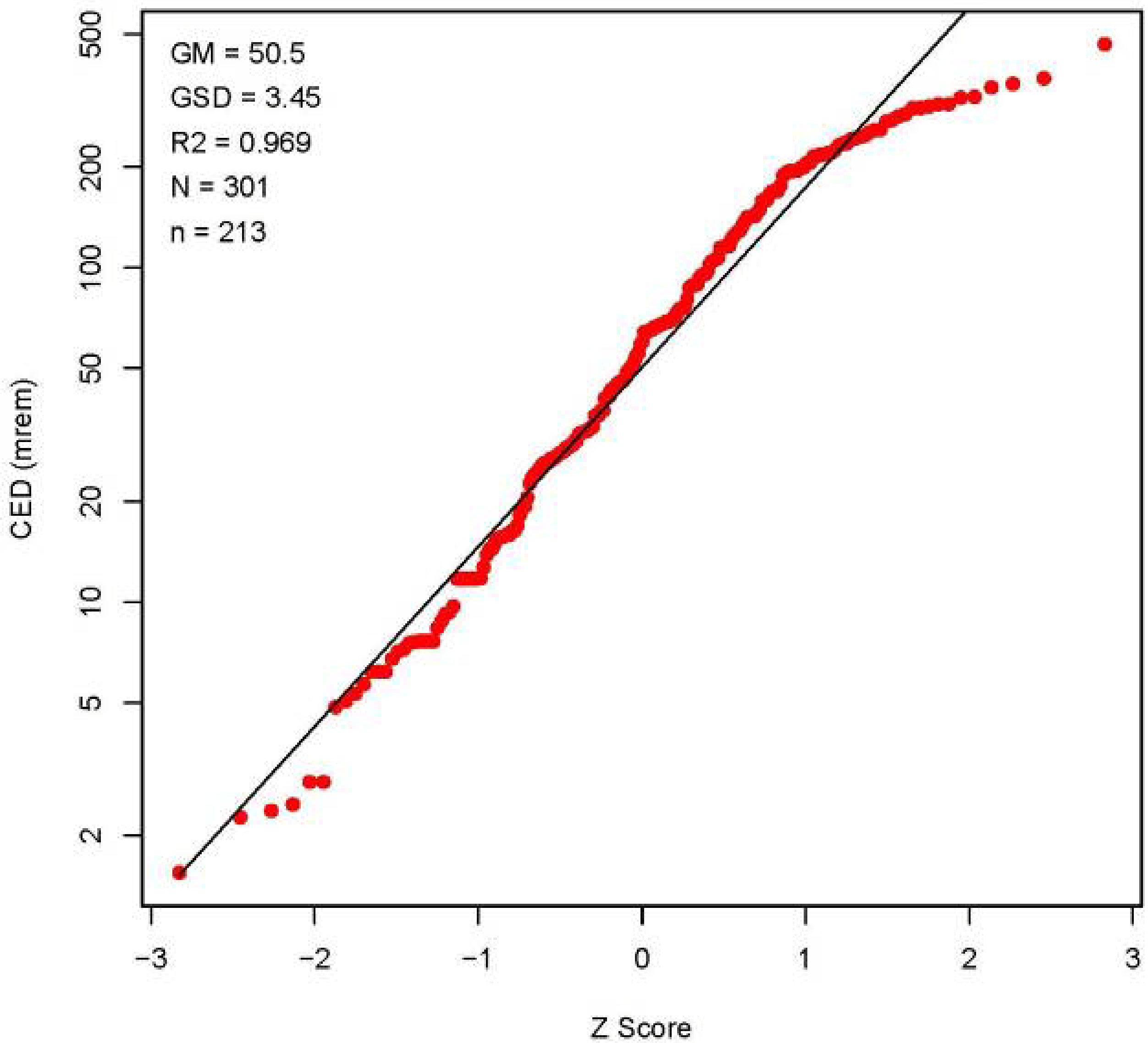

Figure B-35. SRS reactor tritium dose 1965.

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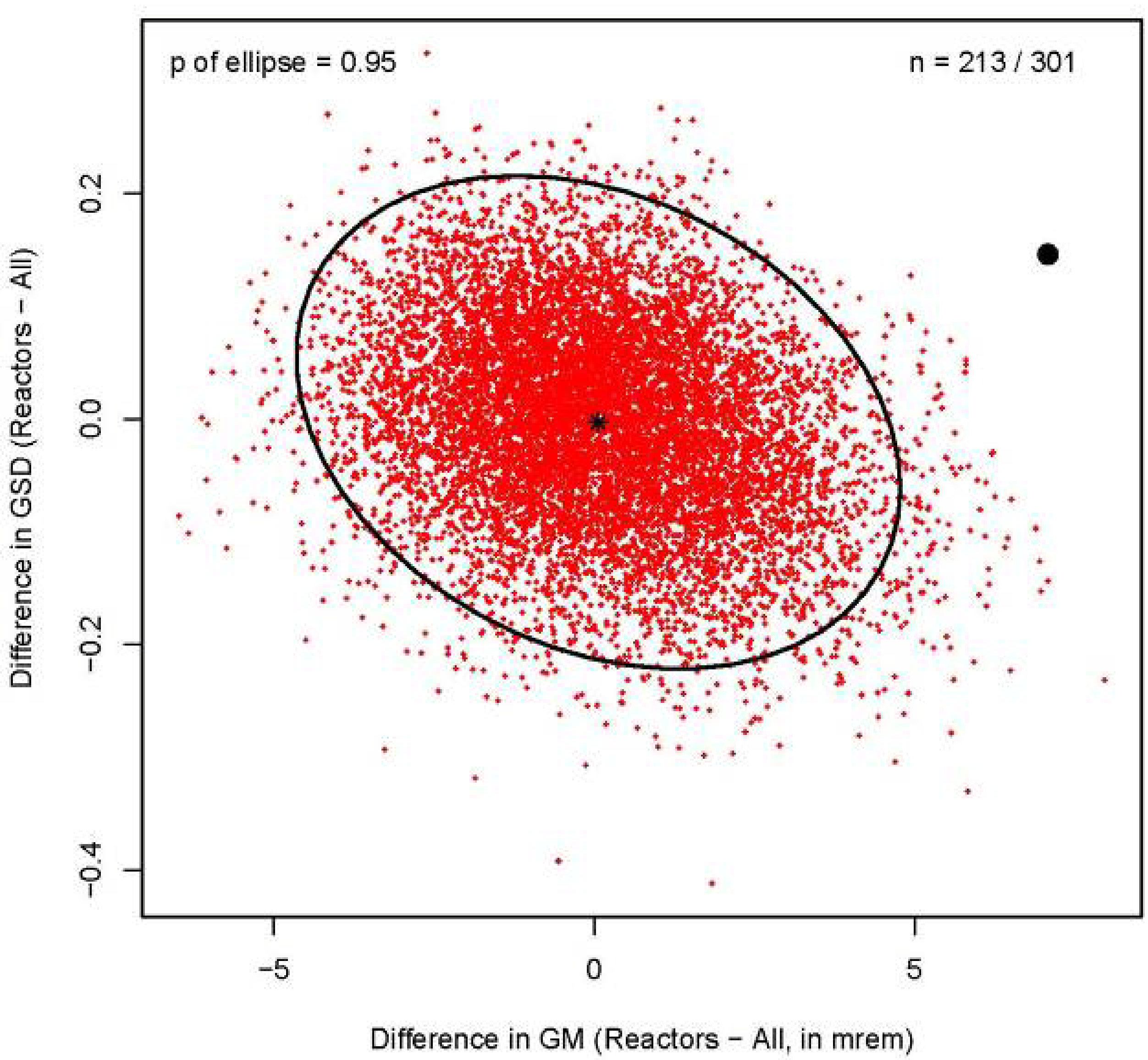

Figure B-36. SRS tritium dose 1965.

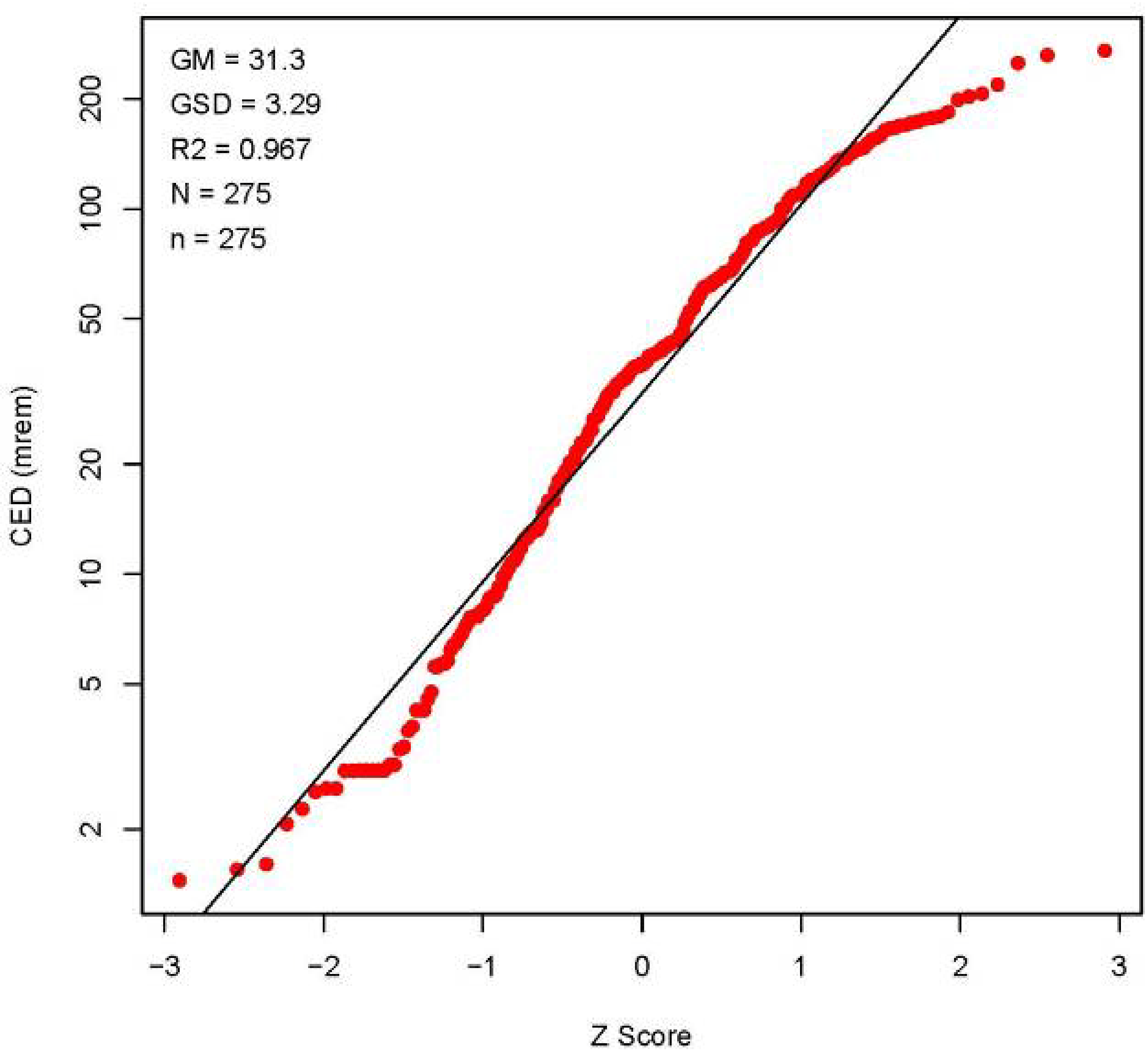

Figure B-37. SRS tritium dose 1966.

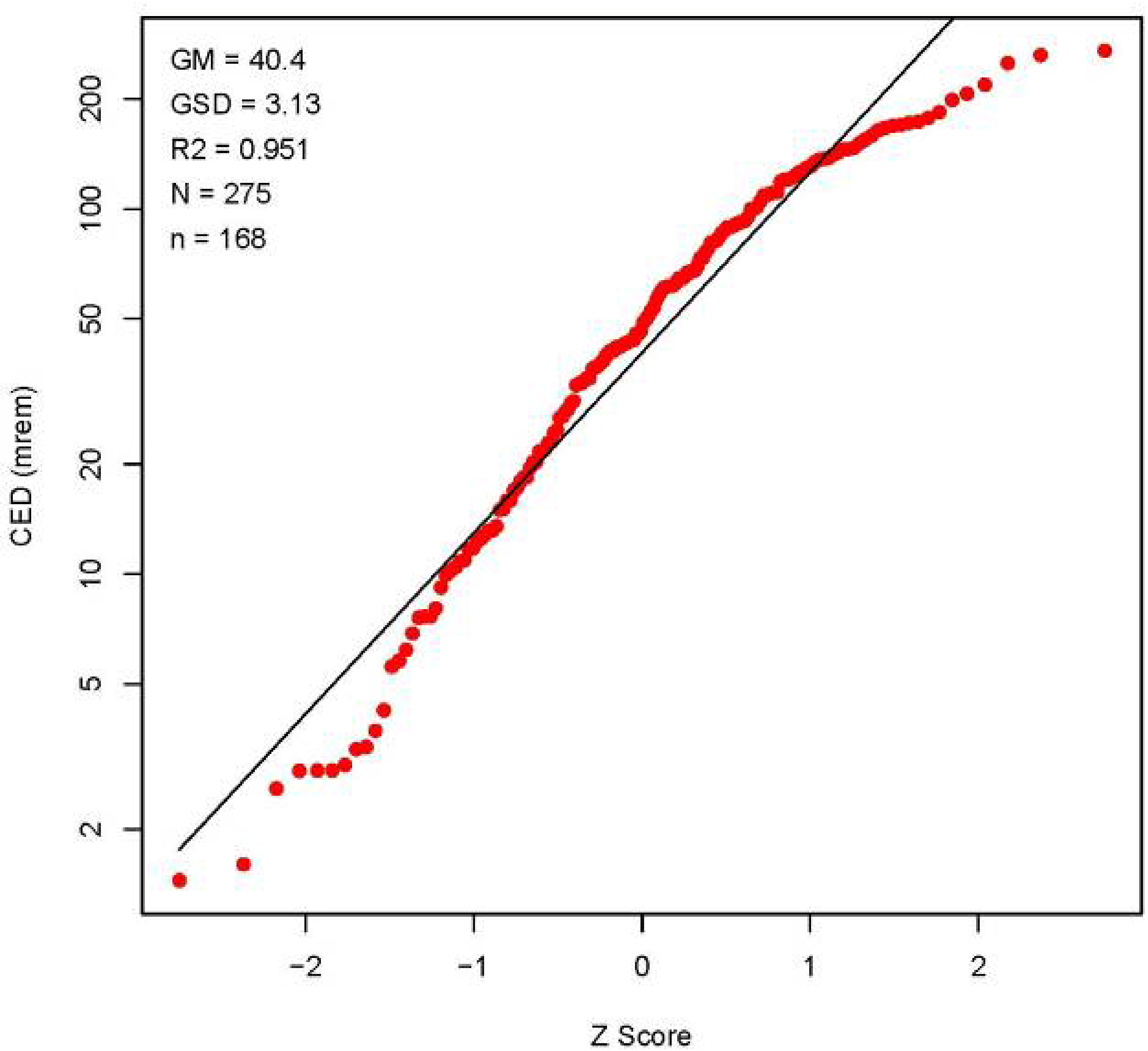

Figure B-38. SRS reactor tritium dose 1966.

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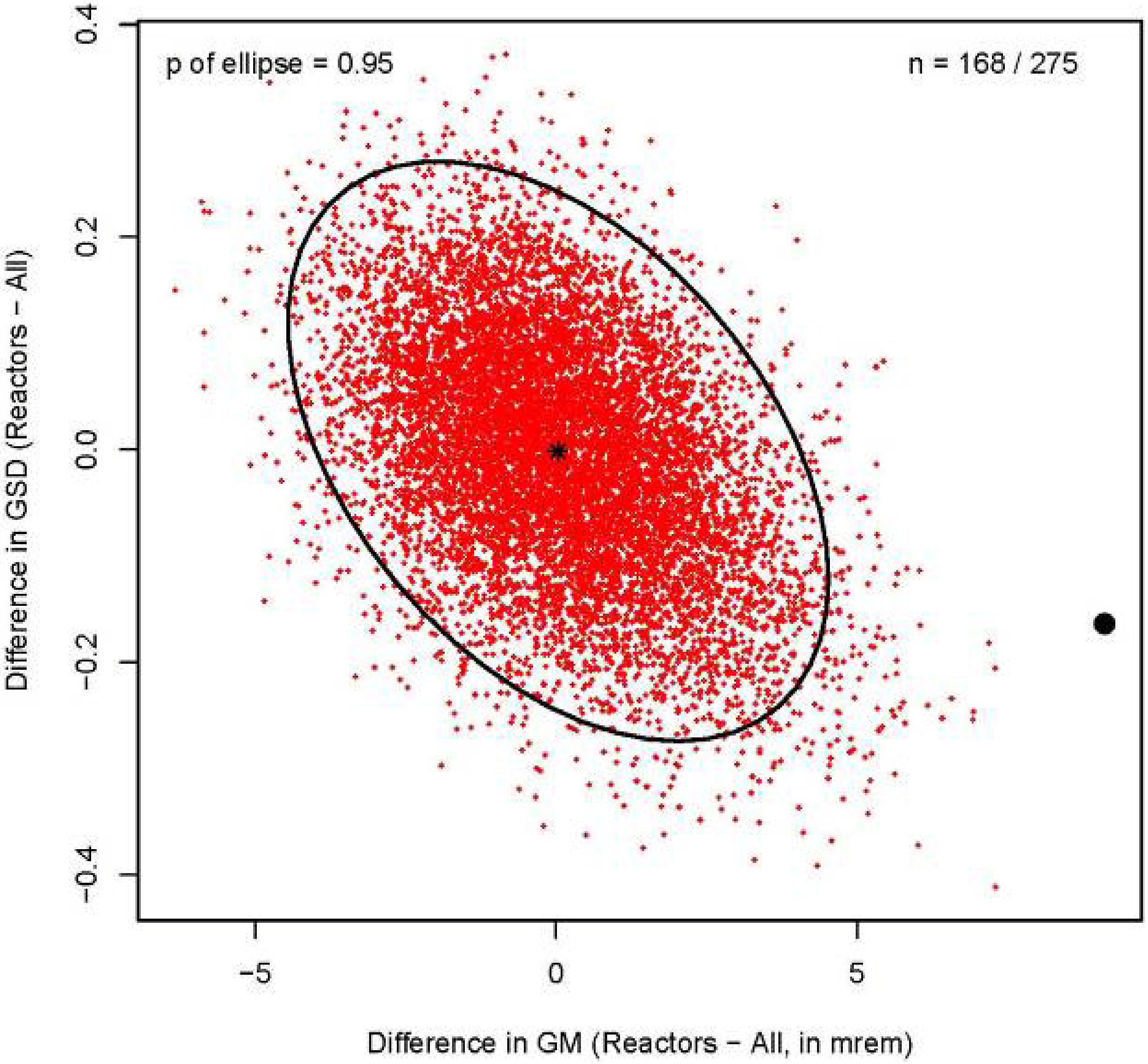

Figure B-39. SRS tritium dose 1966.

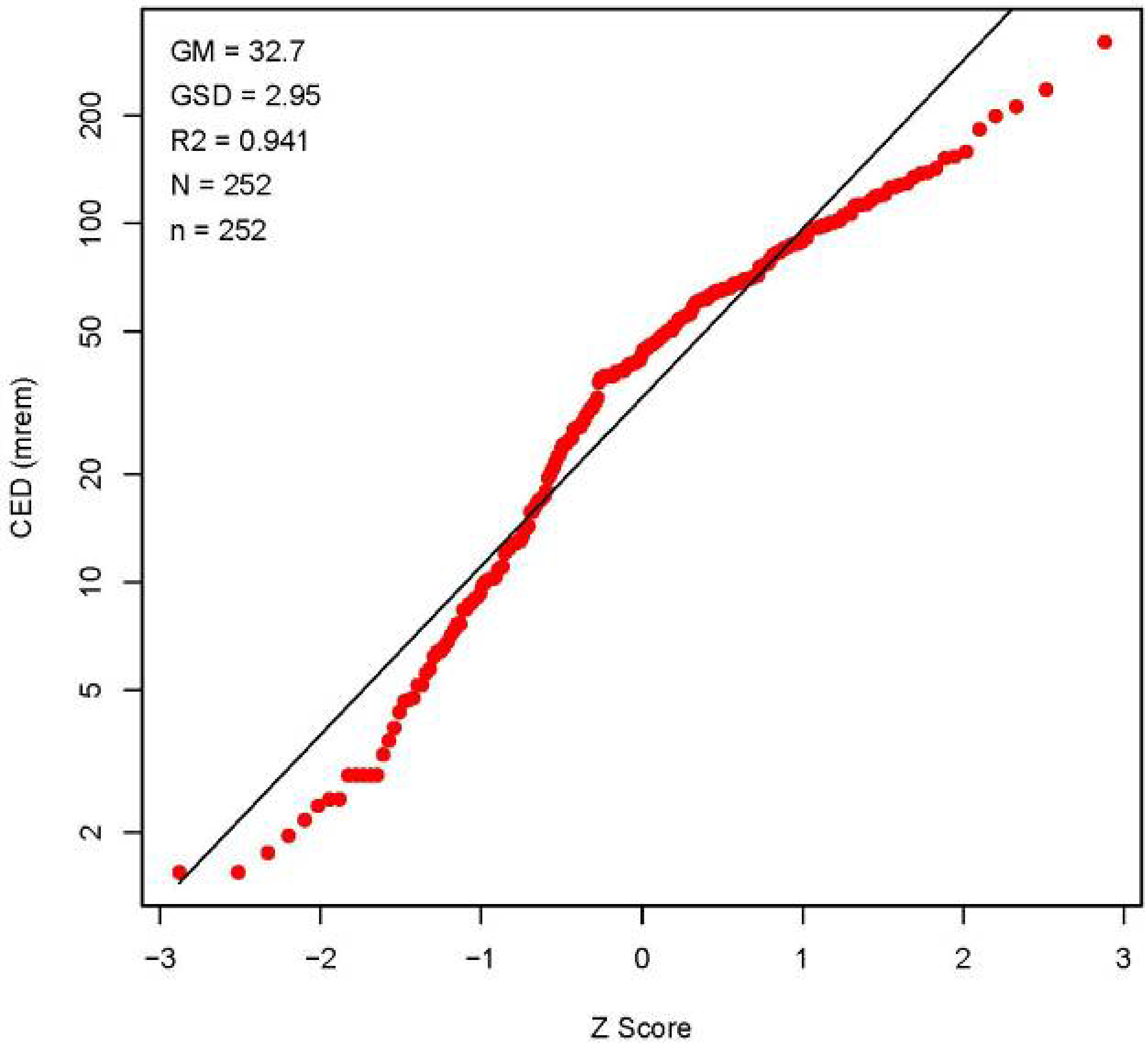

Figure B-40. SRS tritium dose 1967.

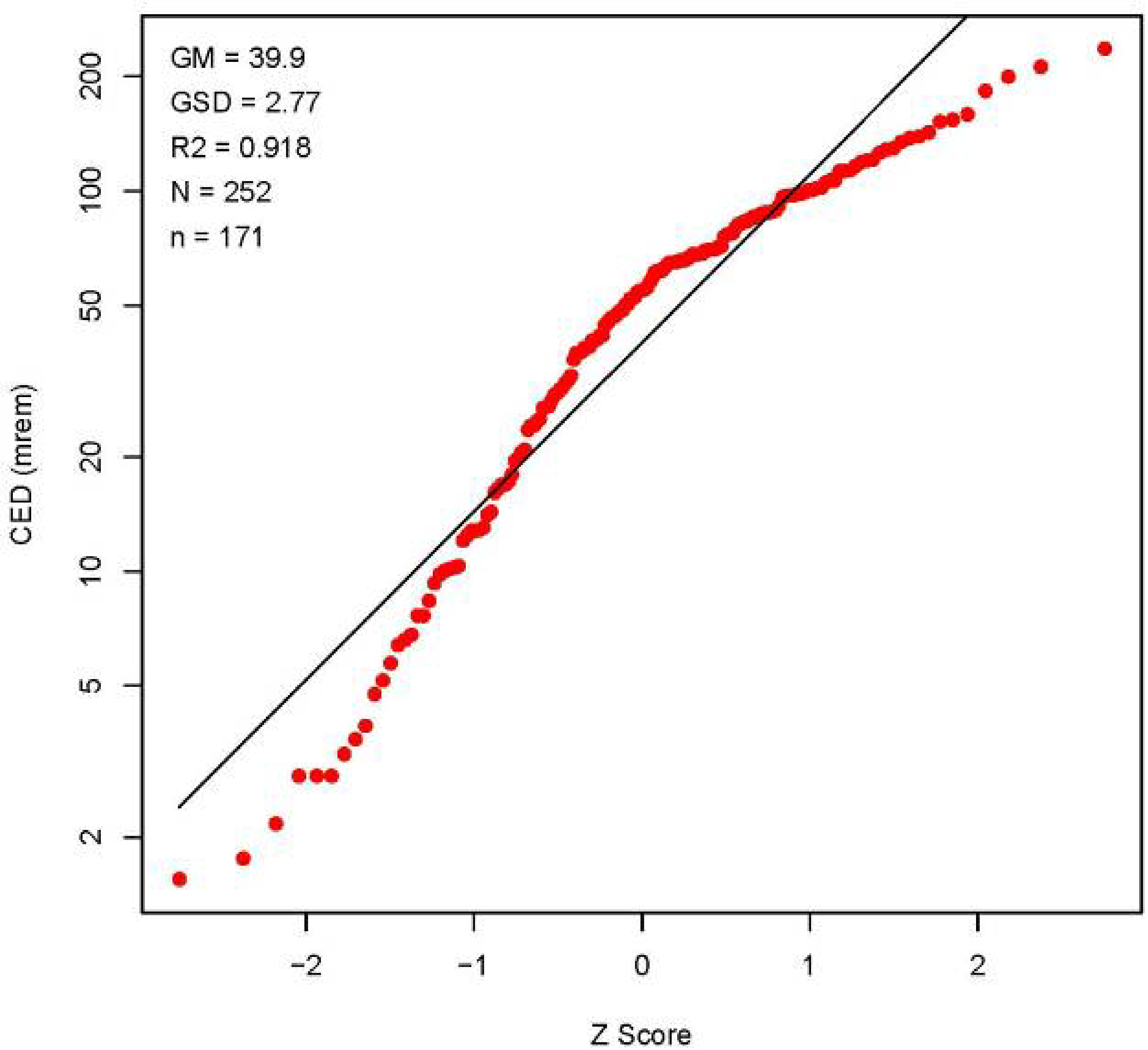

Figure B-41. SRS reactor tritium dose 1967.

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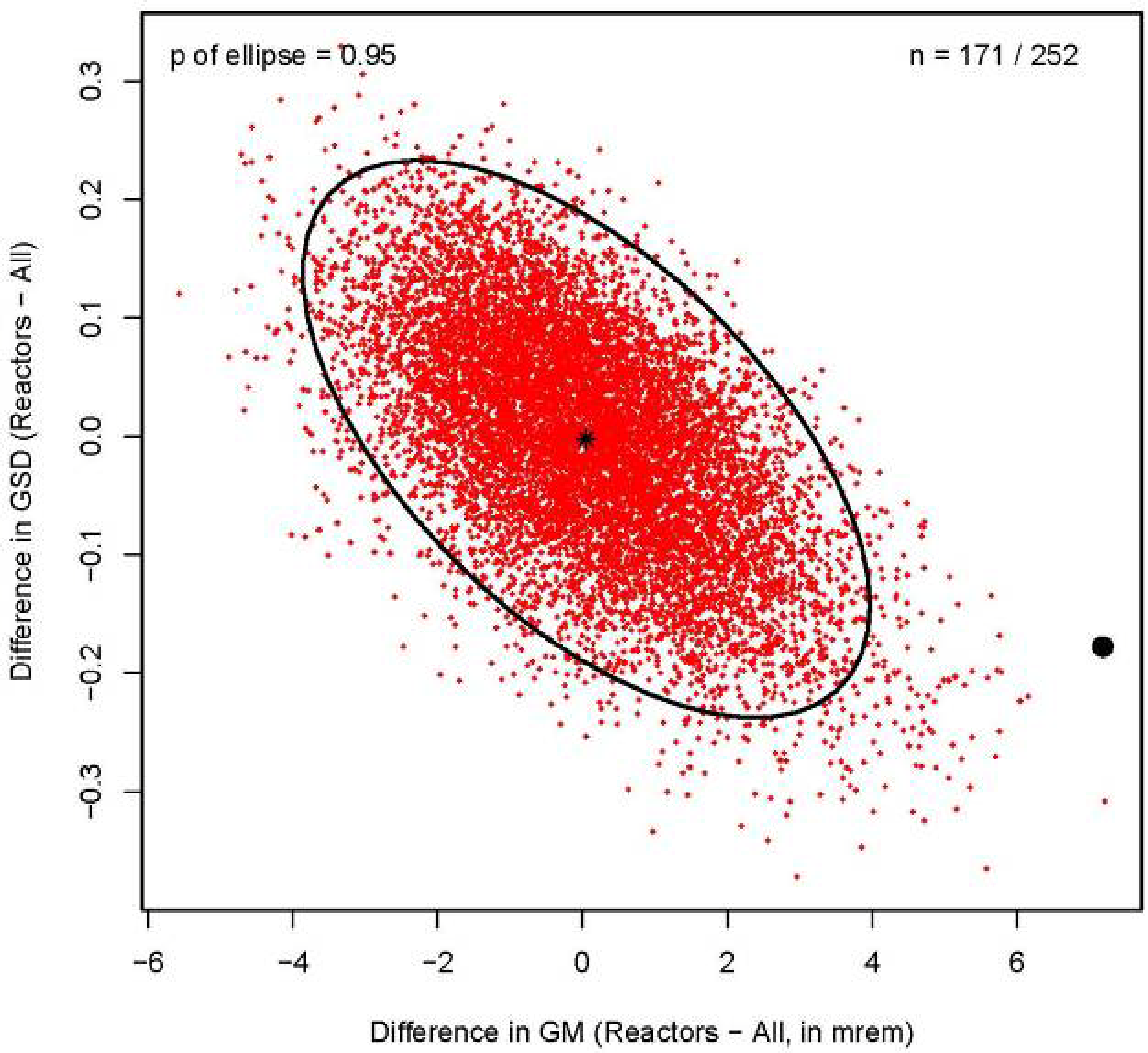

Figure B-42. SRS tritium dose 1967.

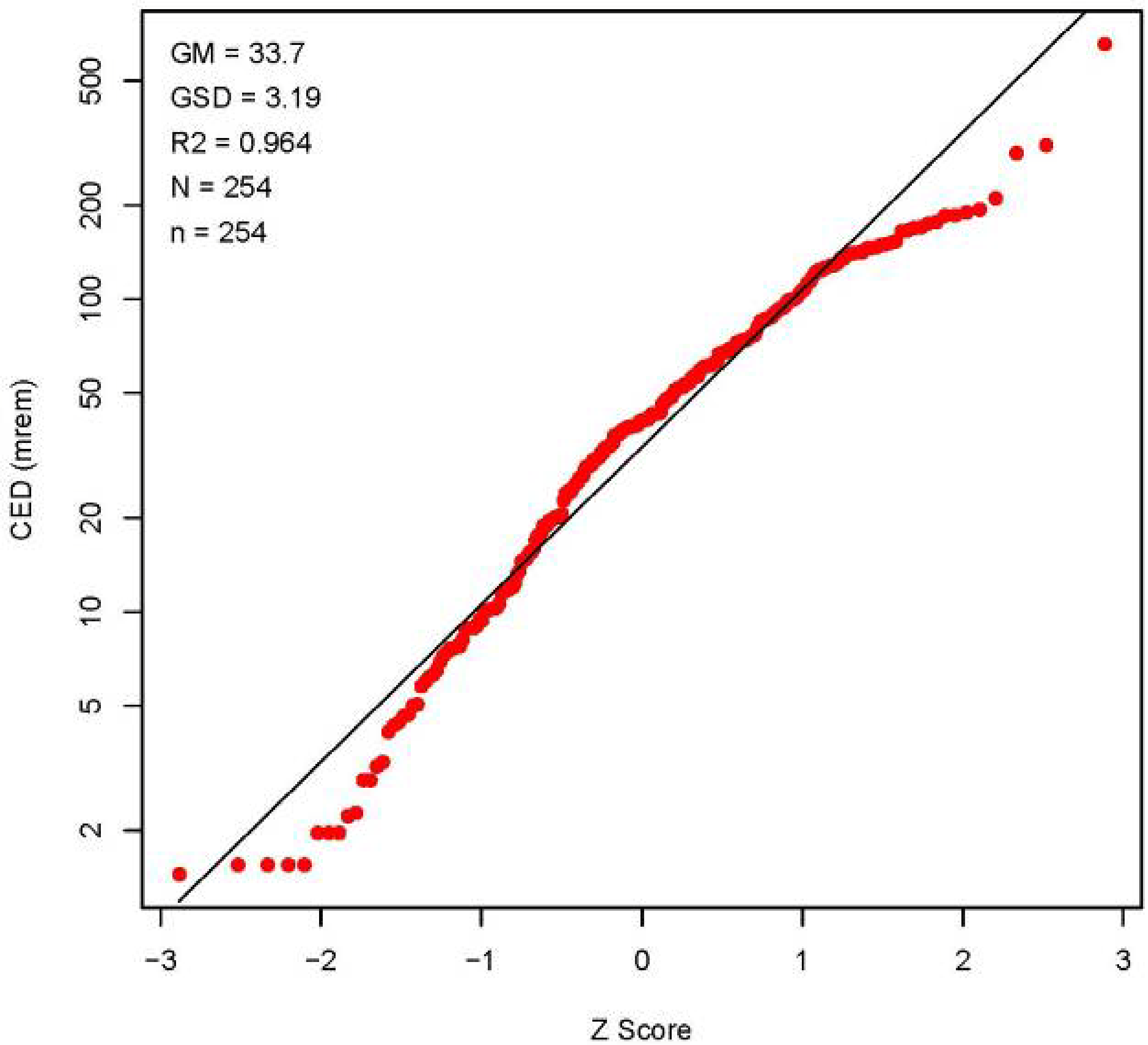

Figure B-43. SRS tritium dose 1968.

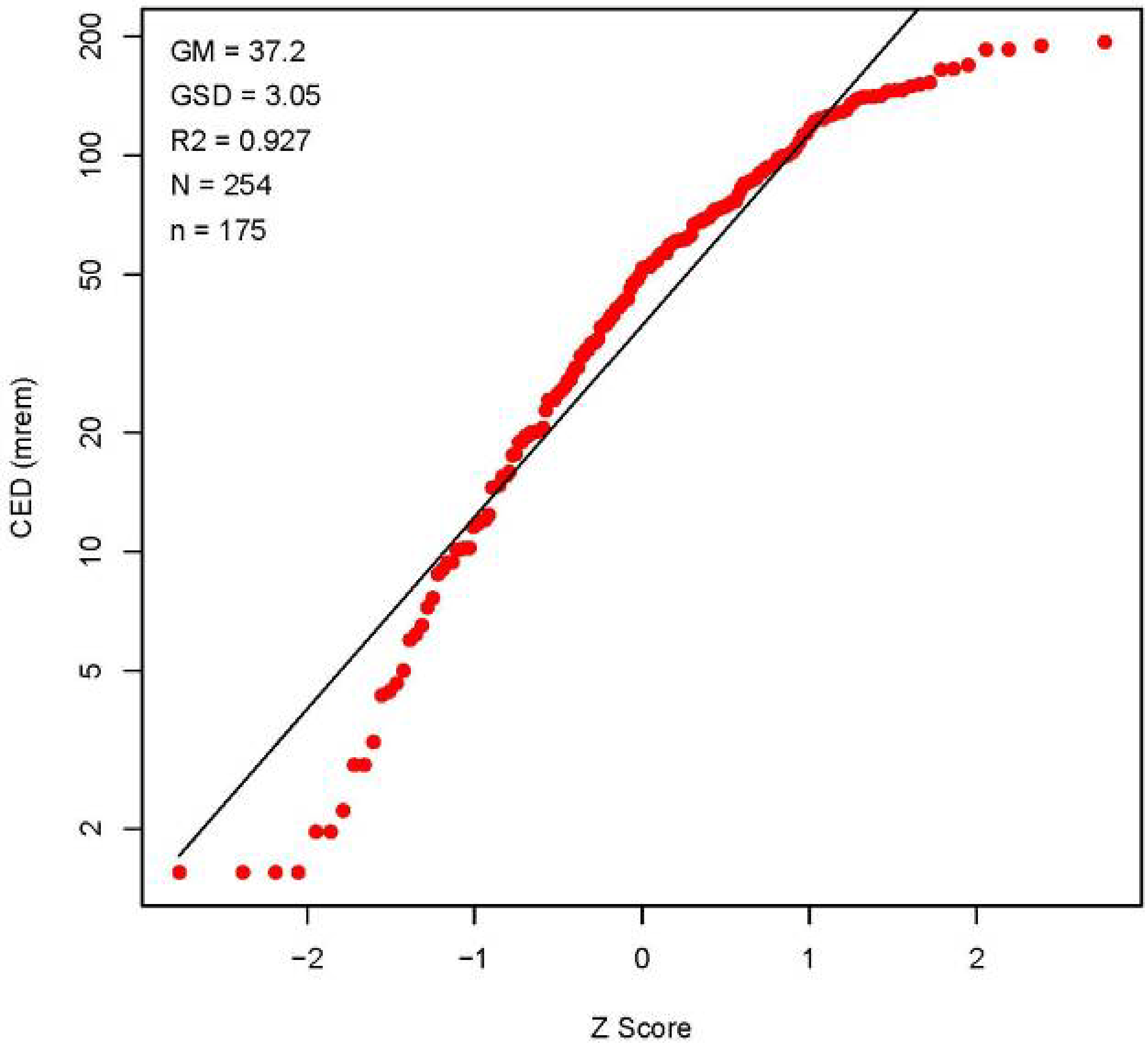

Figure B-44. SRS reactor tritium dose 1968.

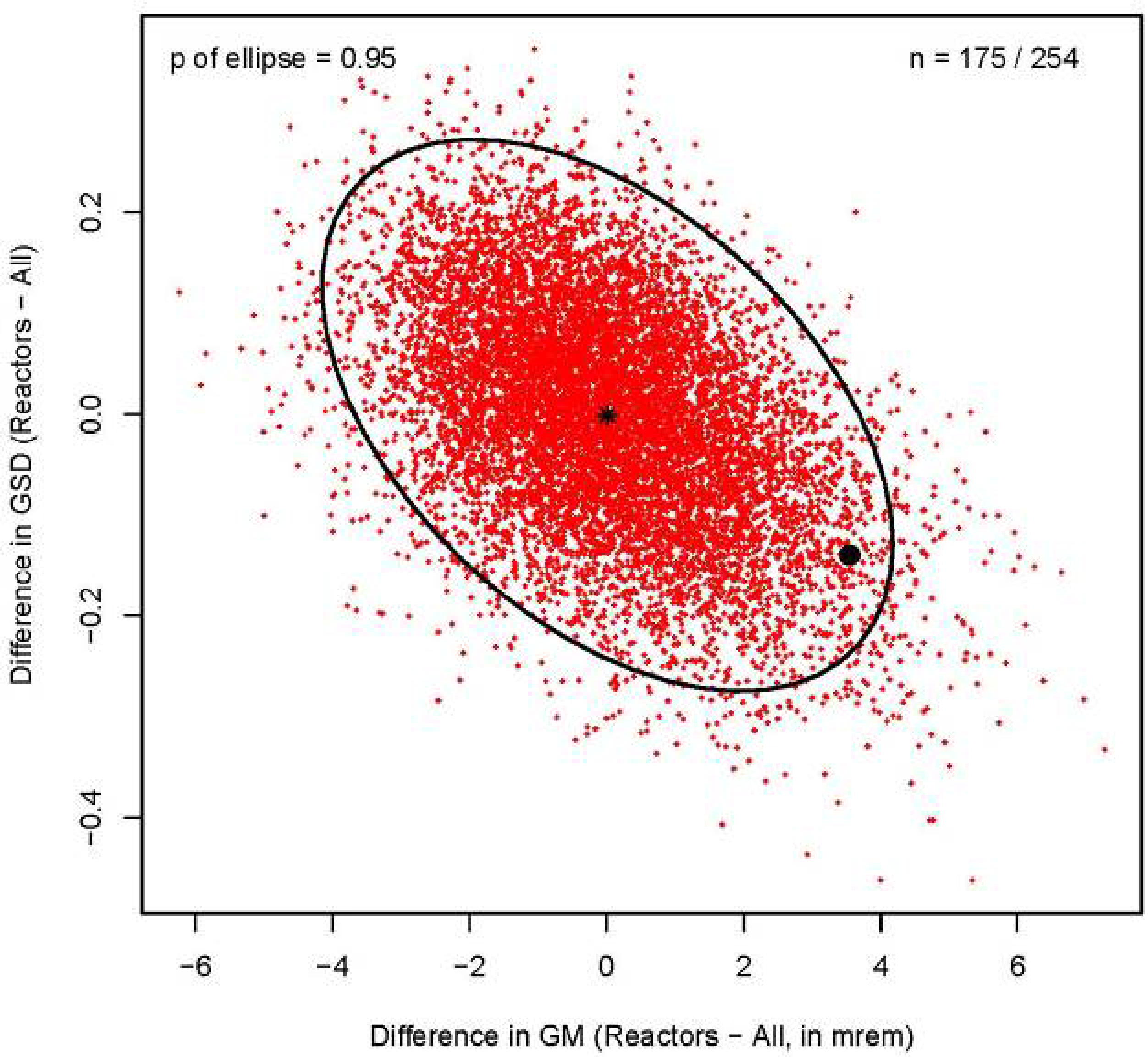

Figure B-45. SRS tritium dose 1968.

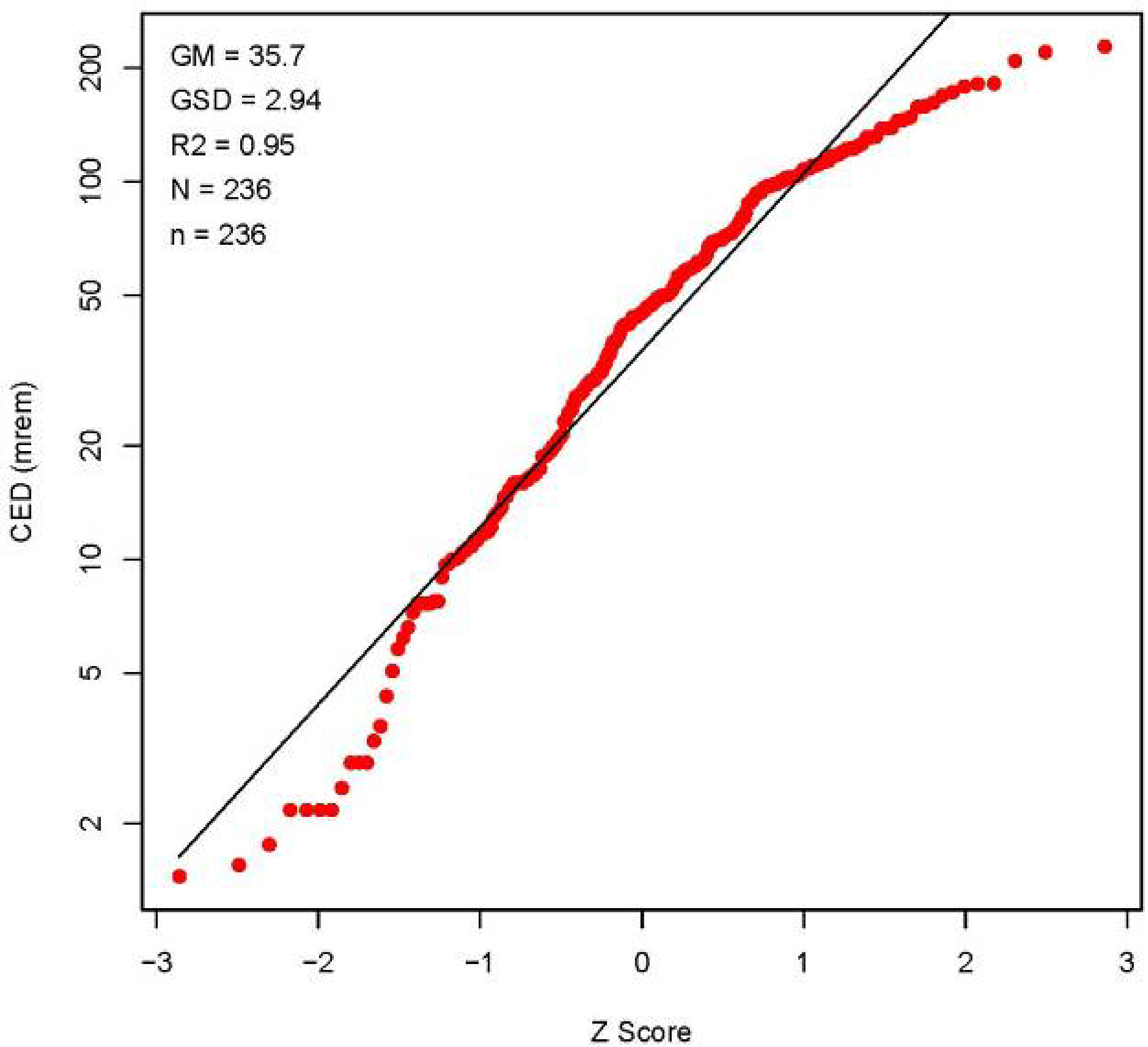

Figure B-46. SRS tritium dose 1969.

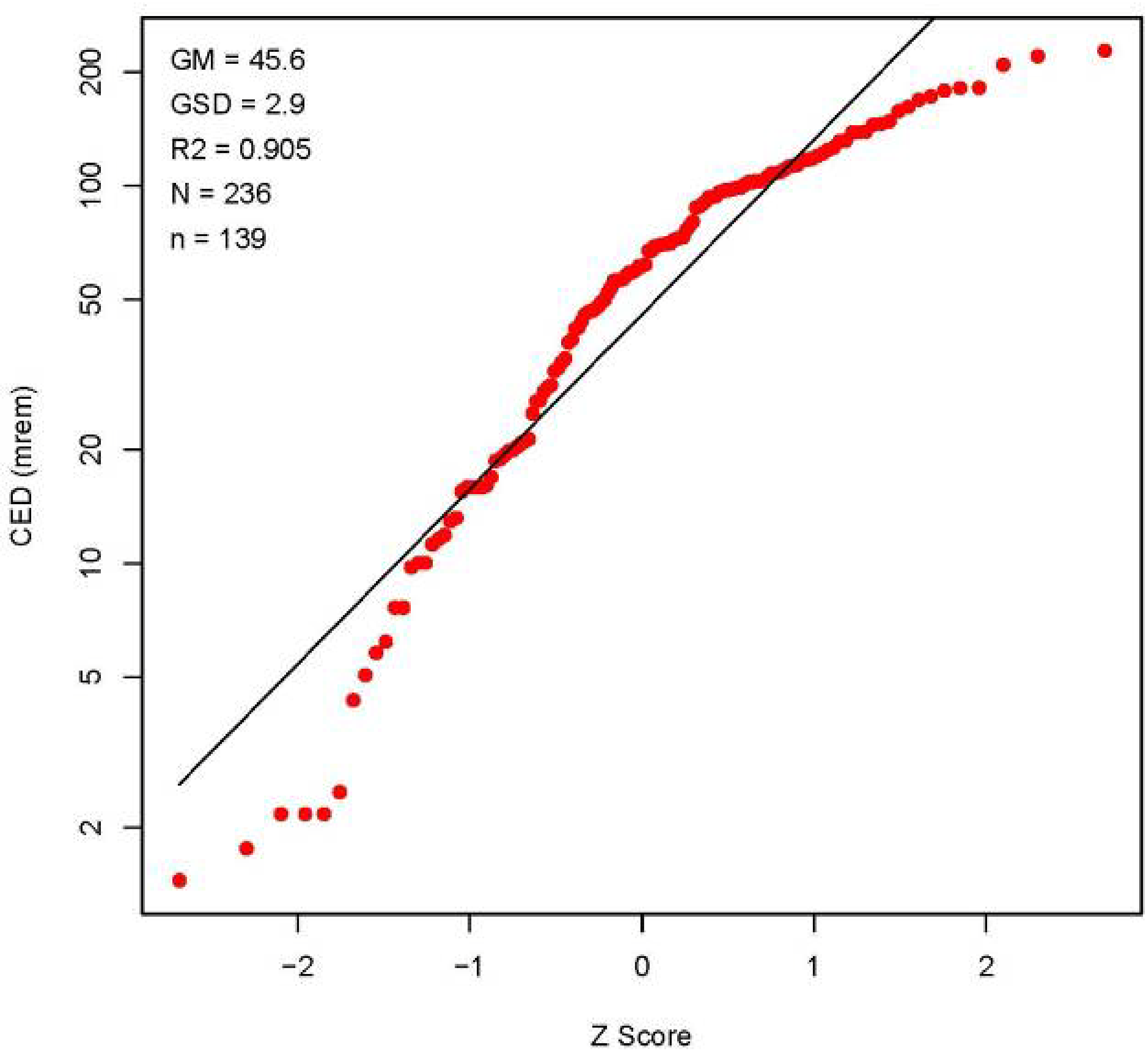

Figure B-47. SRS reactor tritium dose 1969.

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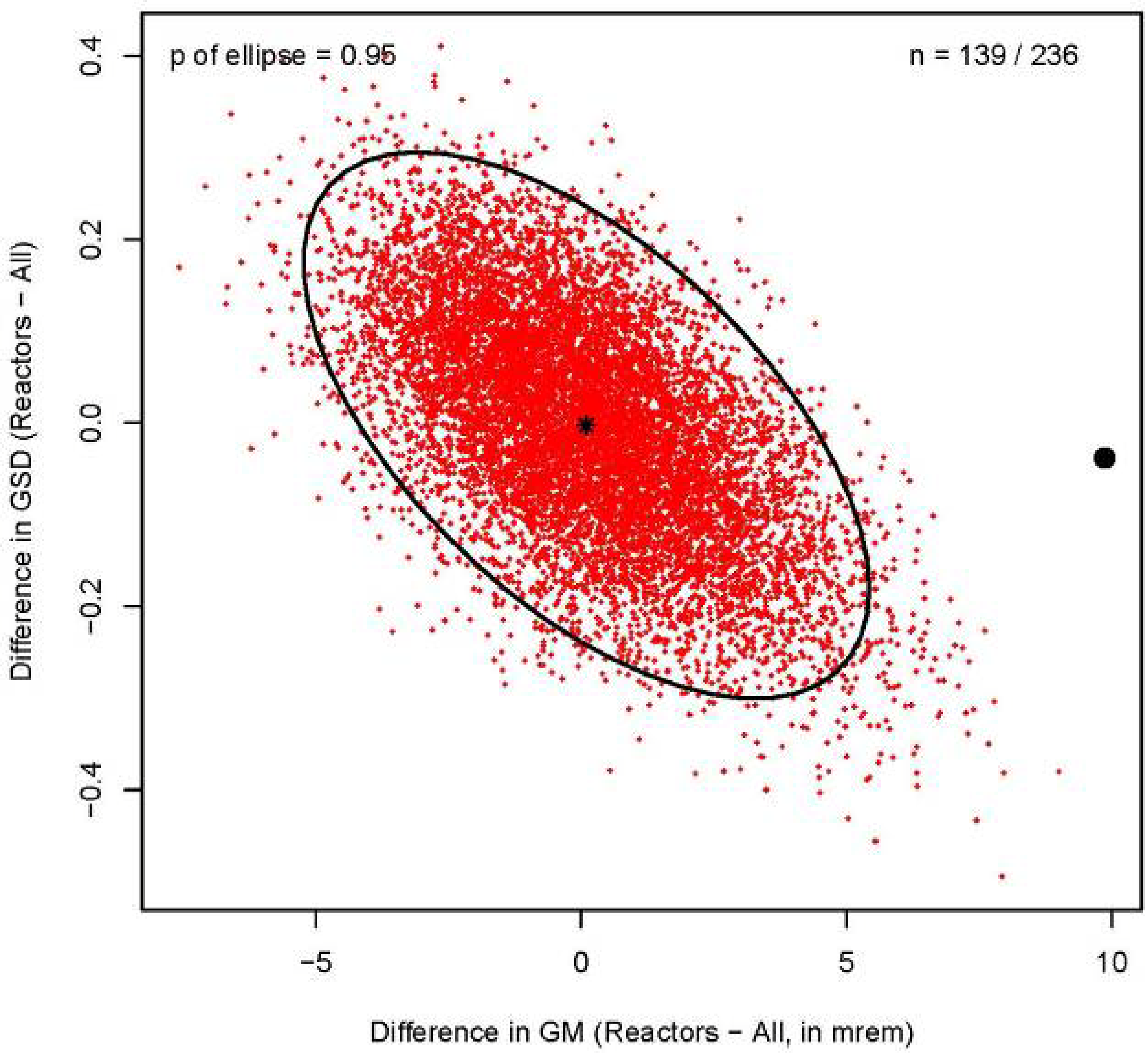

Figure B-48. SRS tritium dose 1969.

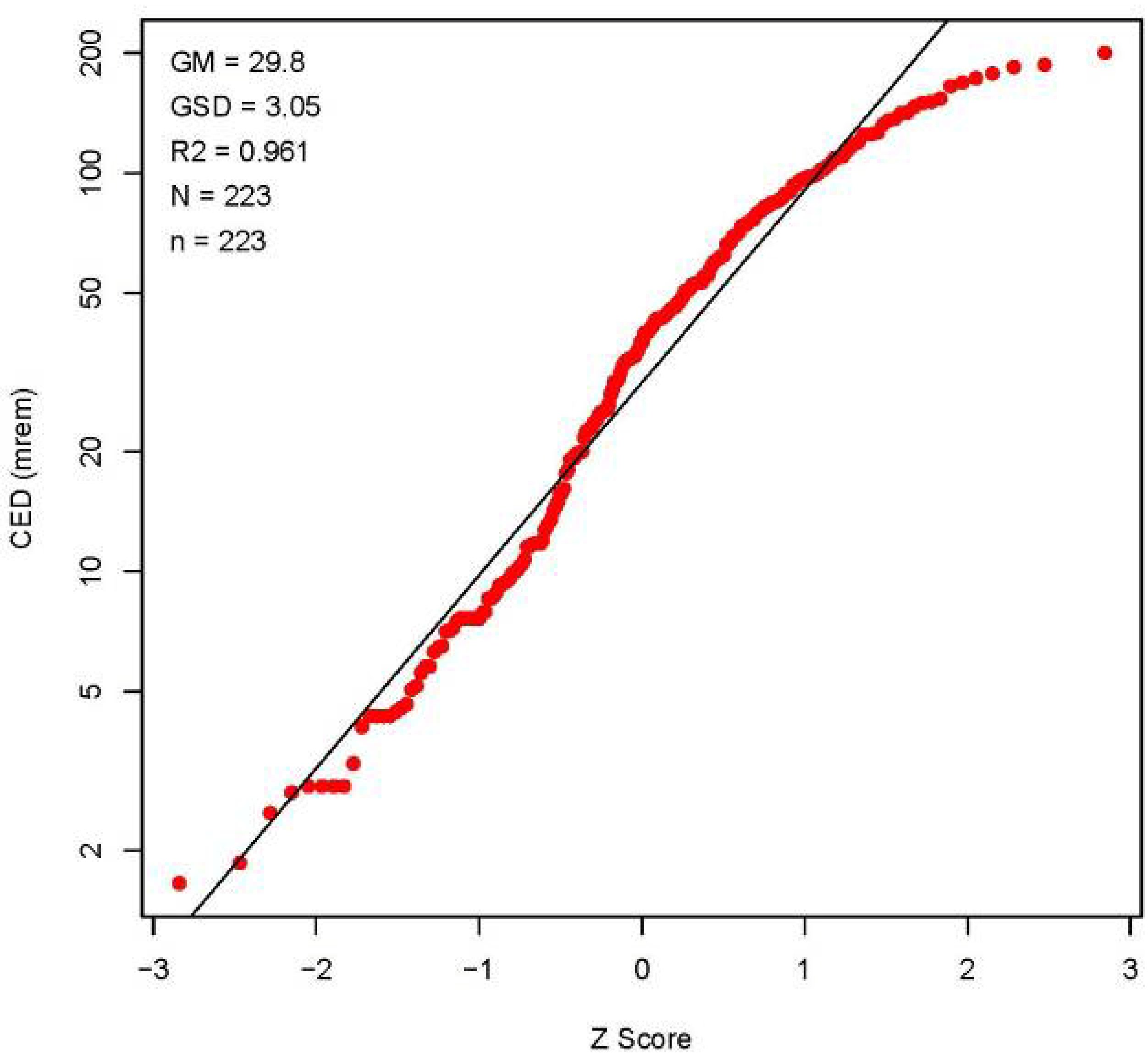

Figure B-49. SRS tritium dose 1970.

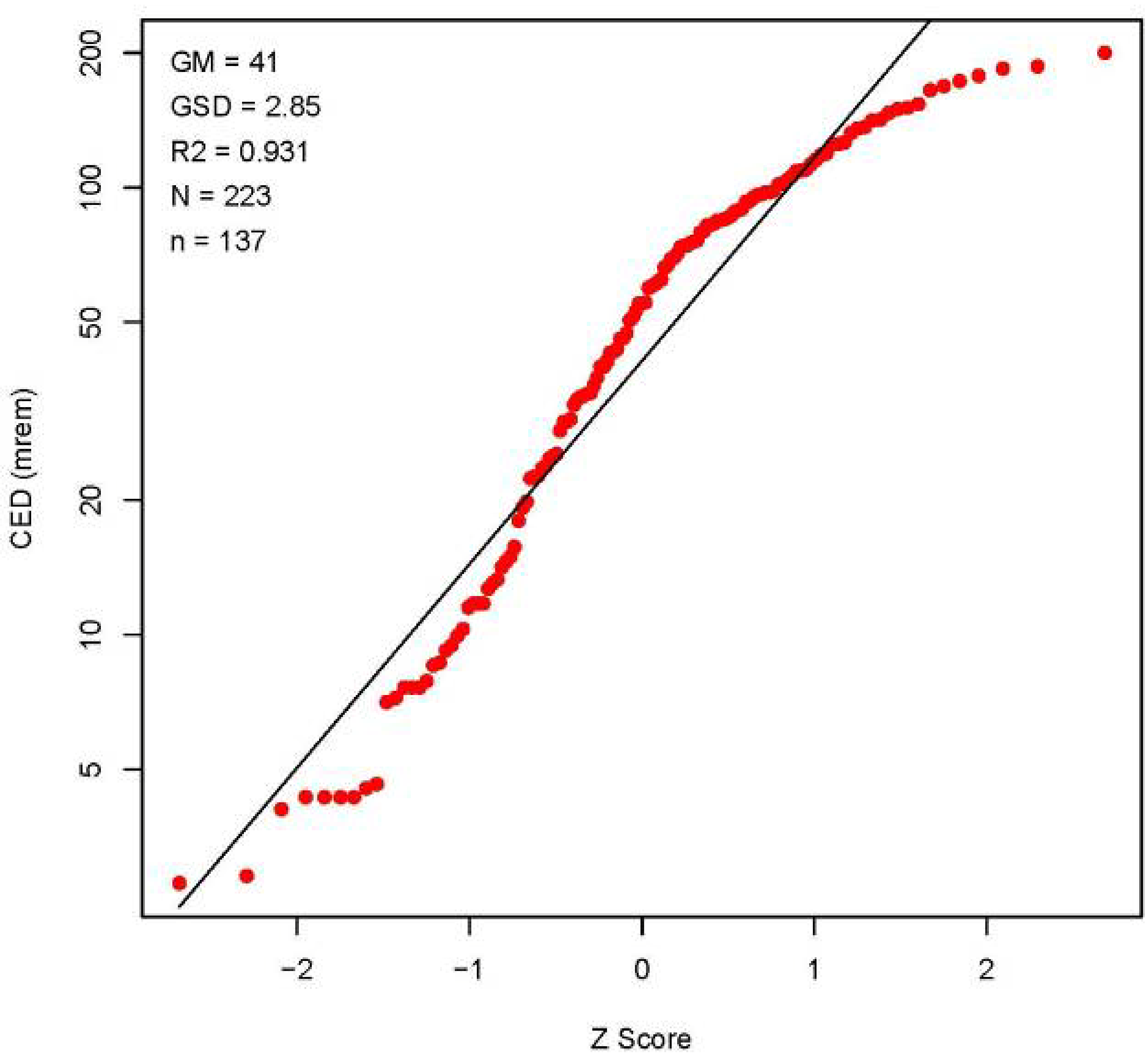

Figure B-50. SRS reactor tritium dose 1970.

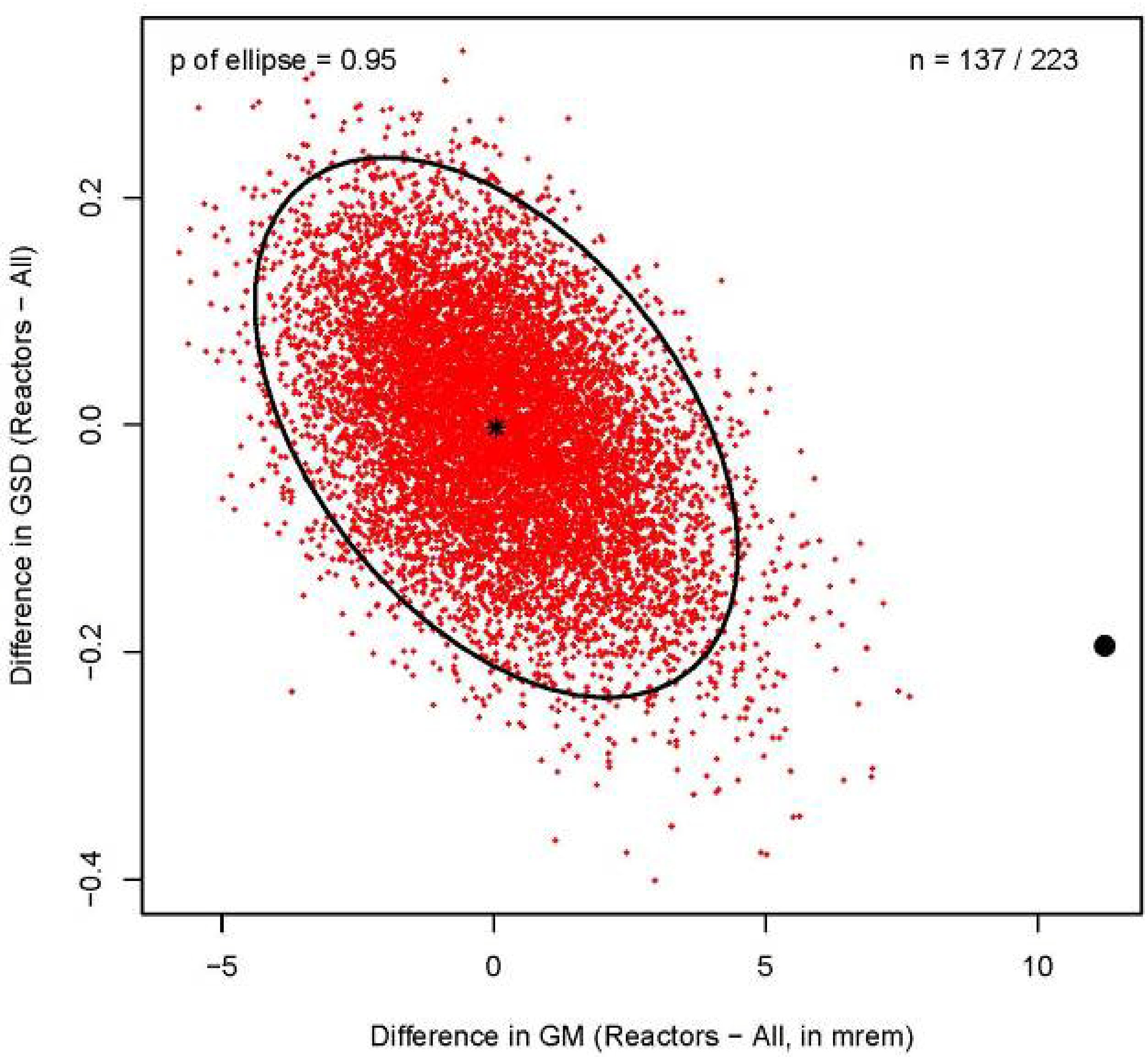

Figure B-51. SRS tritium dose 1970.

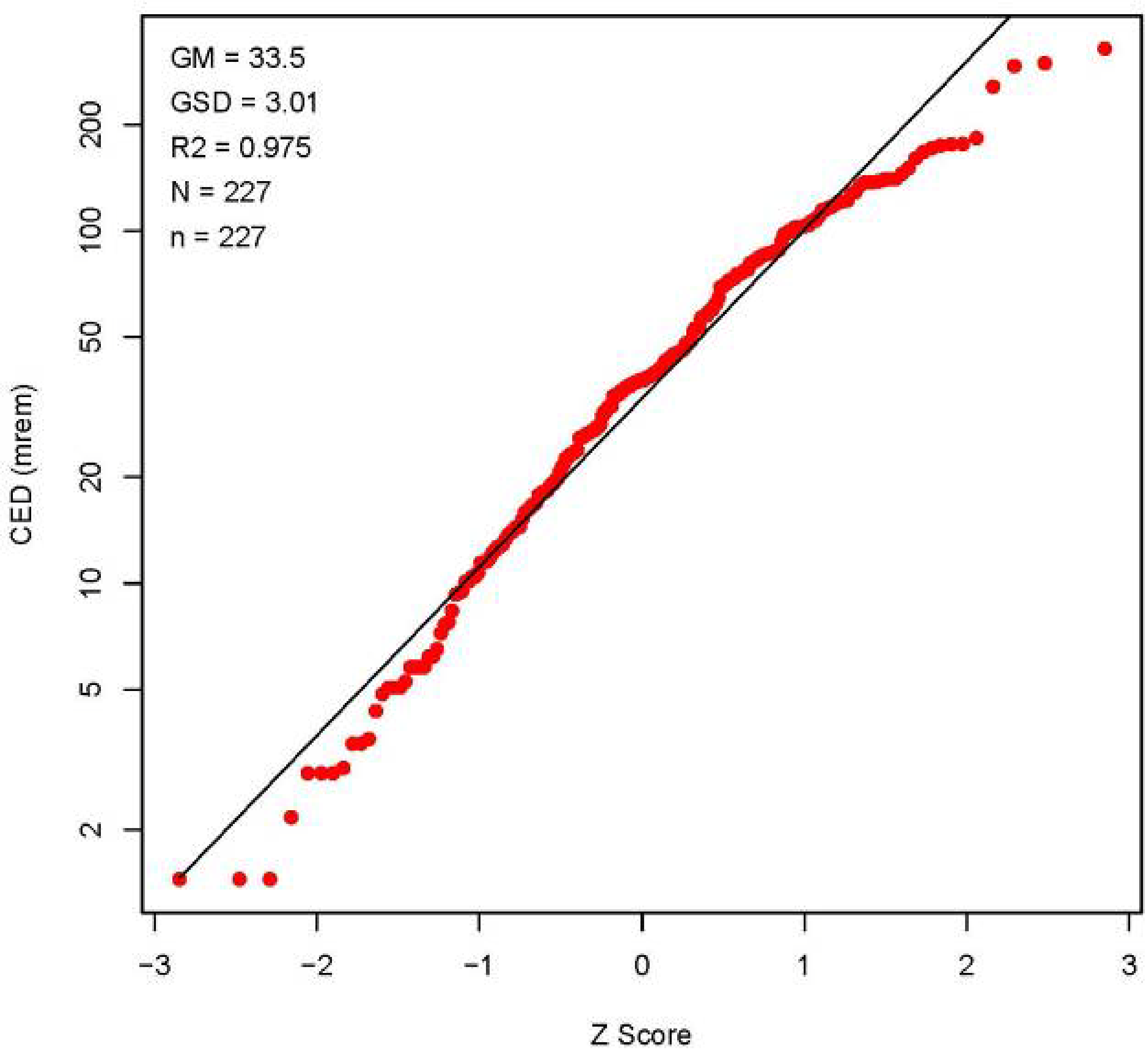

Figure B-52. SRS tritium dose 1971.

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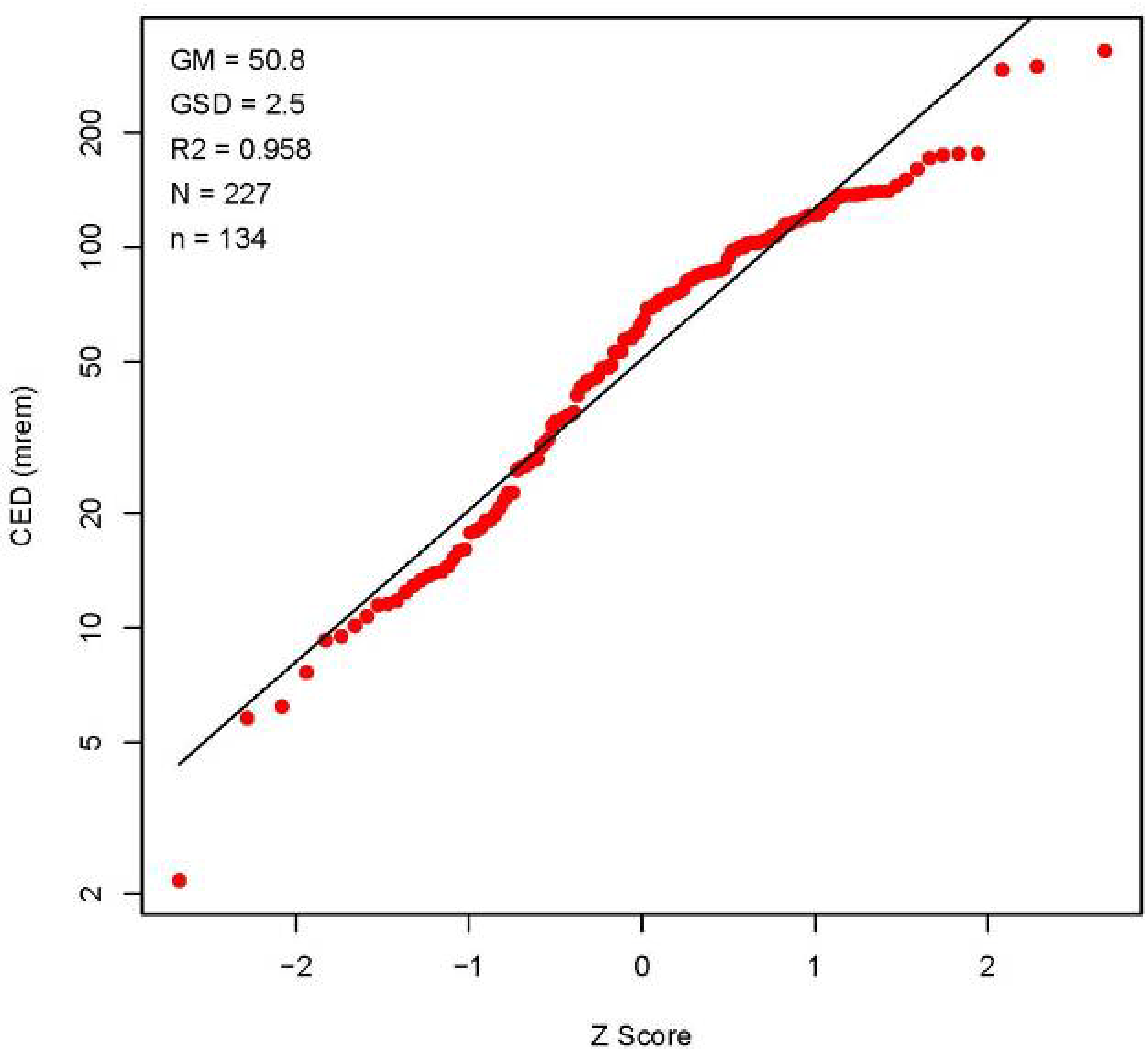

Figure B-53. SRS reactor tritium dose 1971.

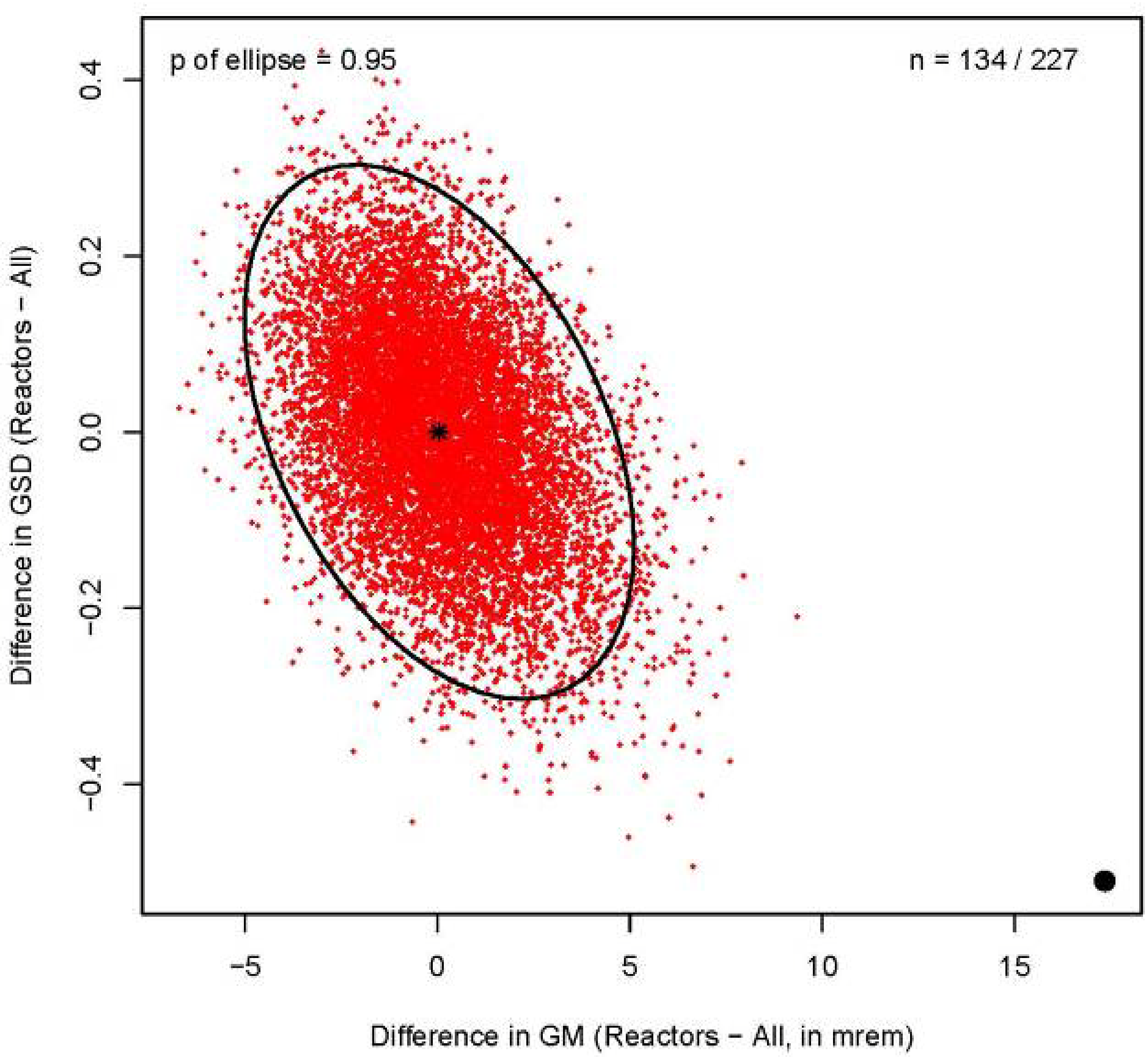

Figure B-54. SRS tritium dose 1971.

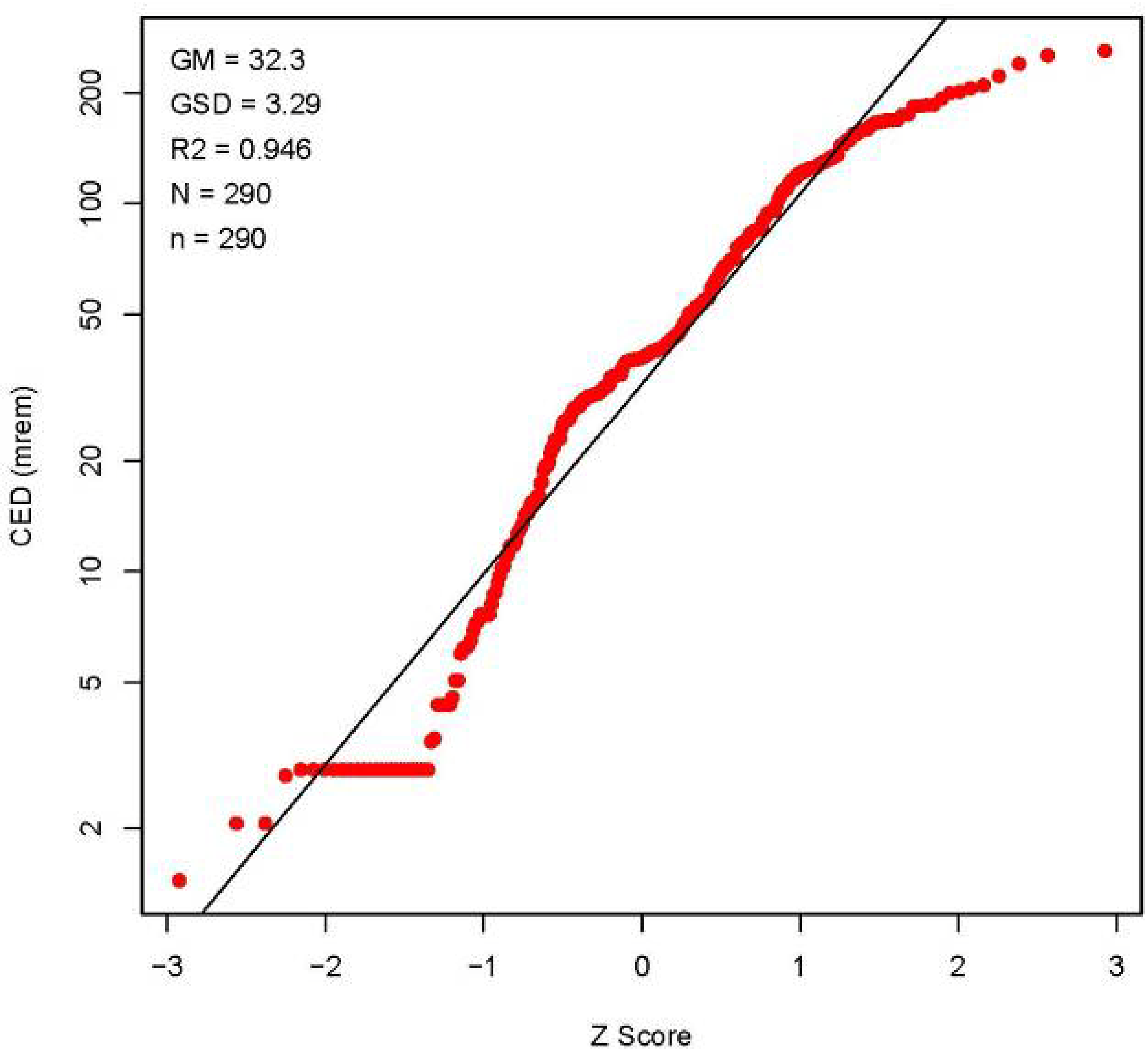

Figure B-55. SRS tritium dose 1972.

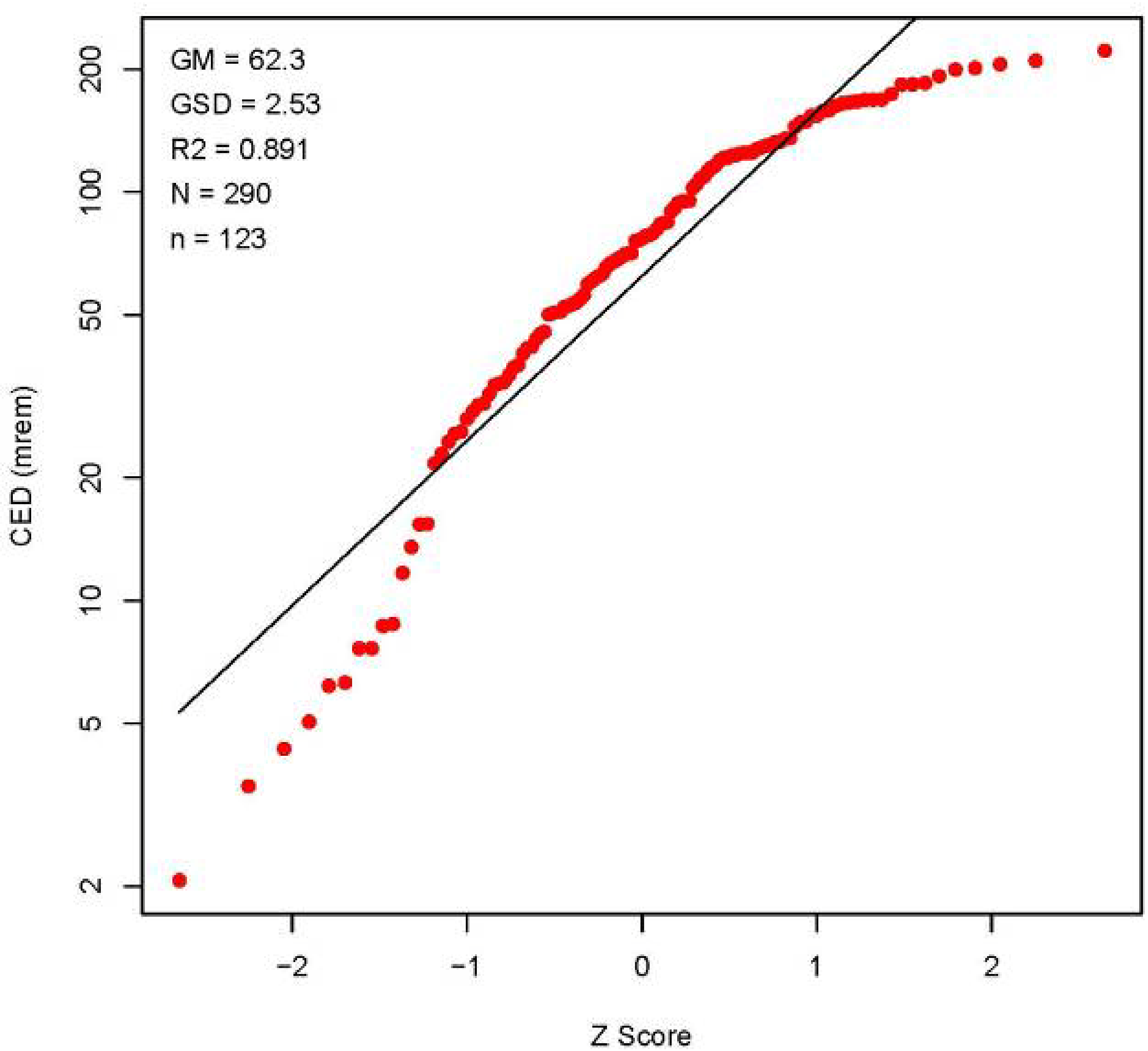

Figure B-56. SRS reactor tritium dose 1972.

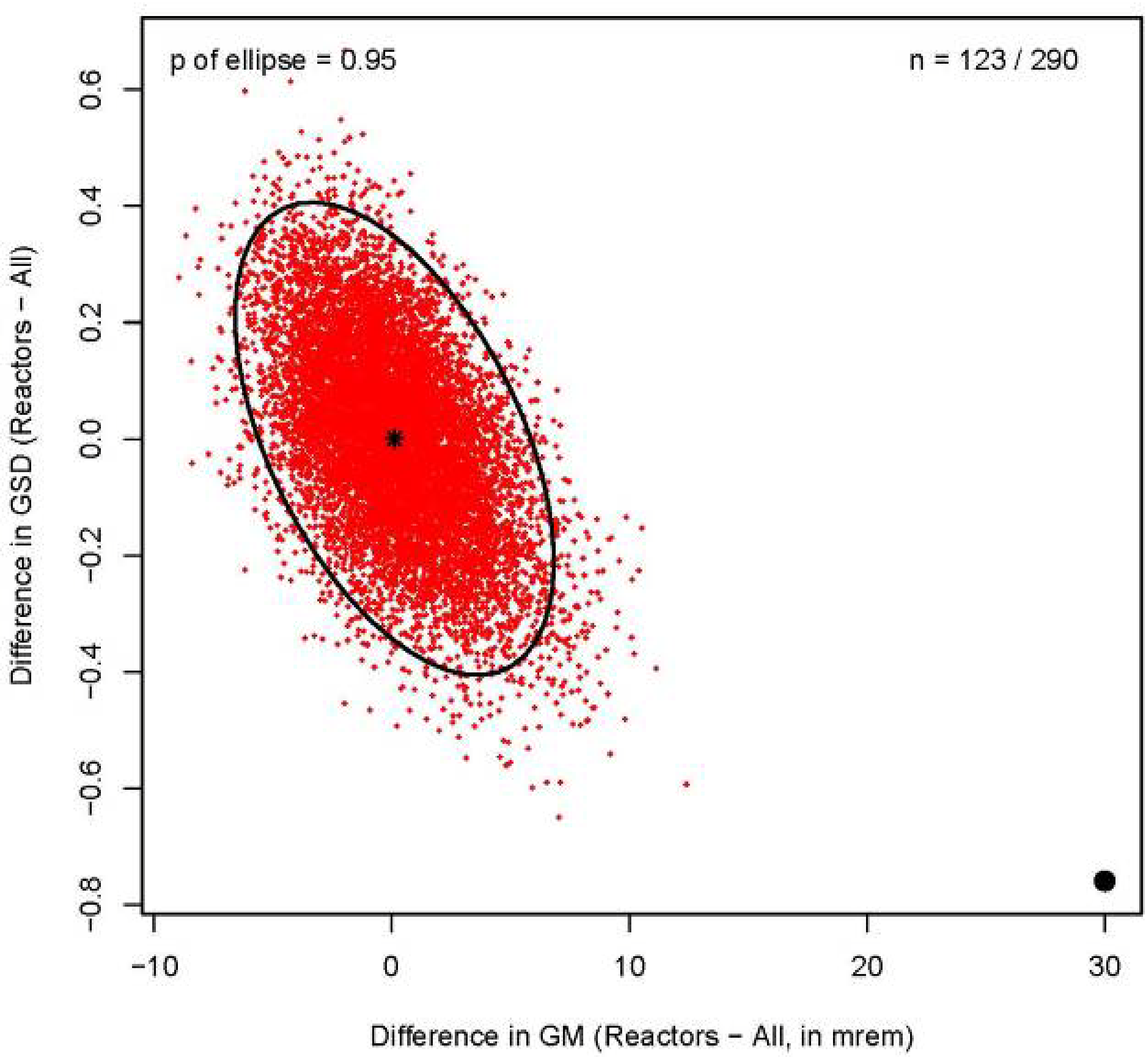

Figure B-57. SRS tritium dose 1972.

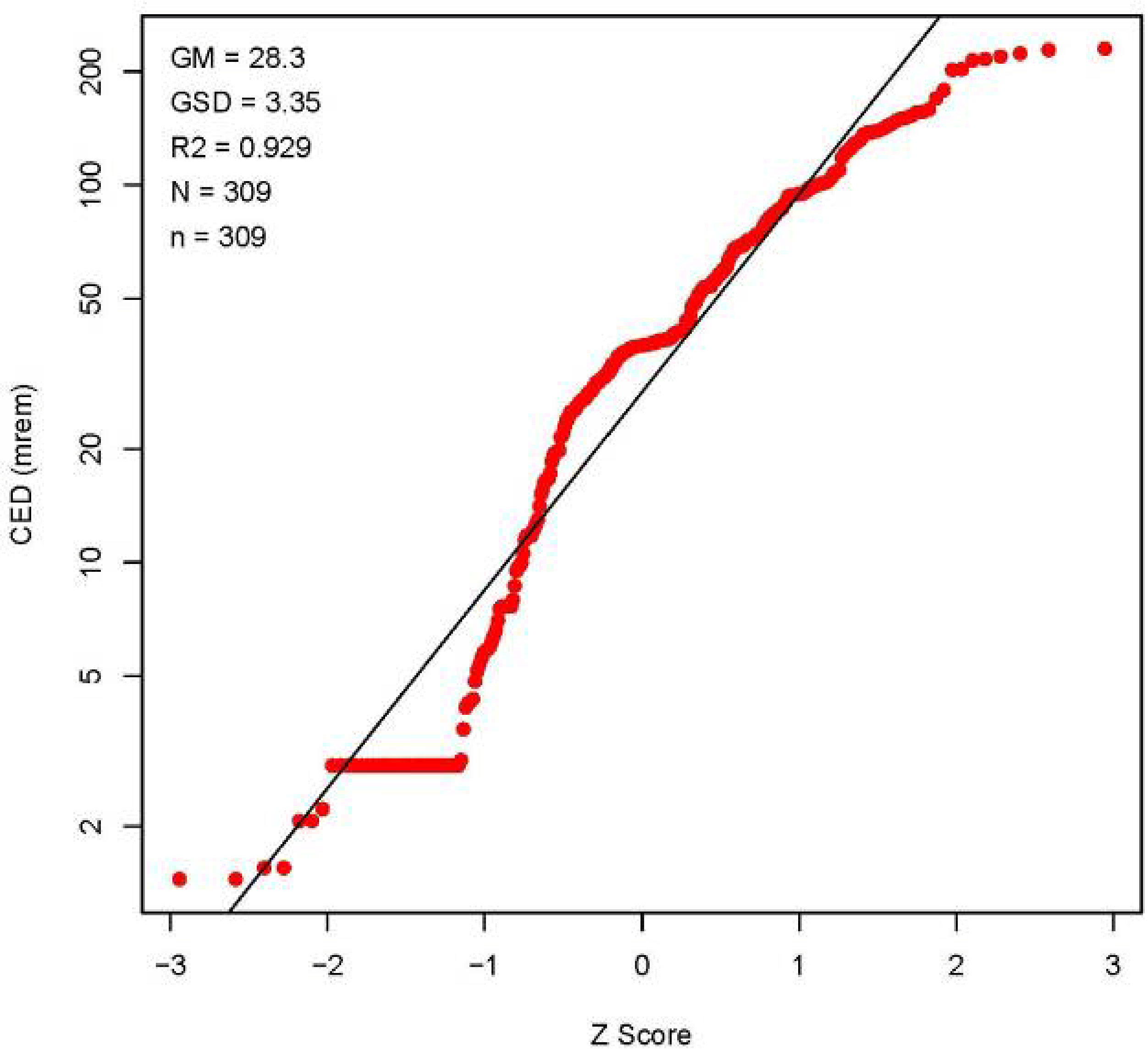

Figure B-58. SRS tritium dose 1973.

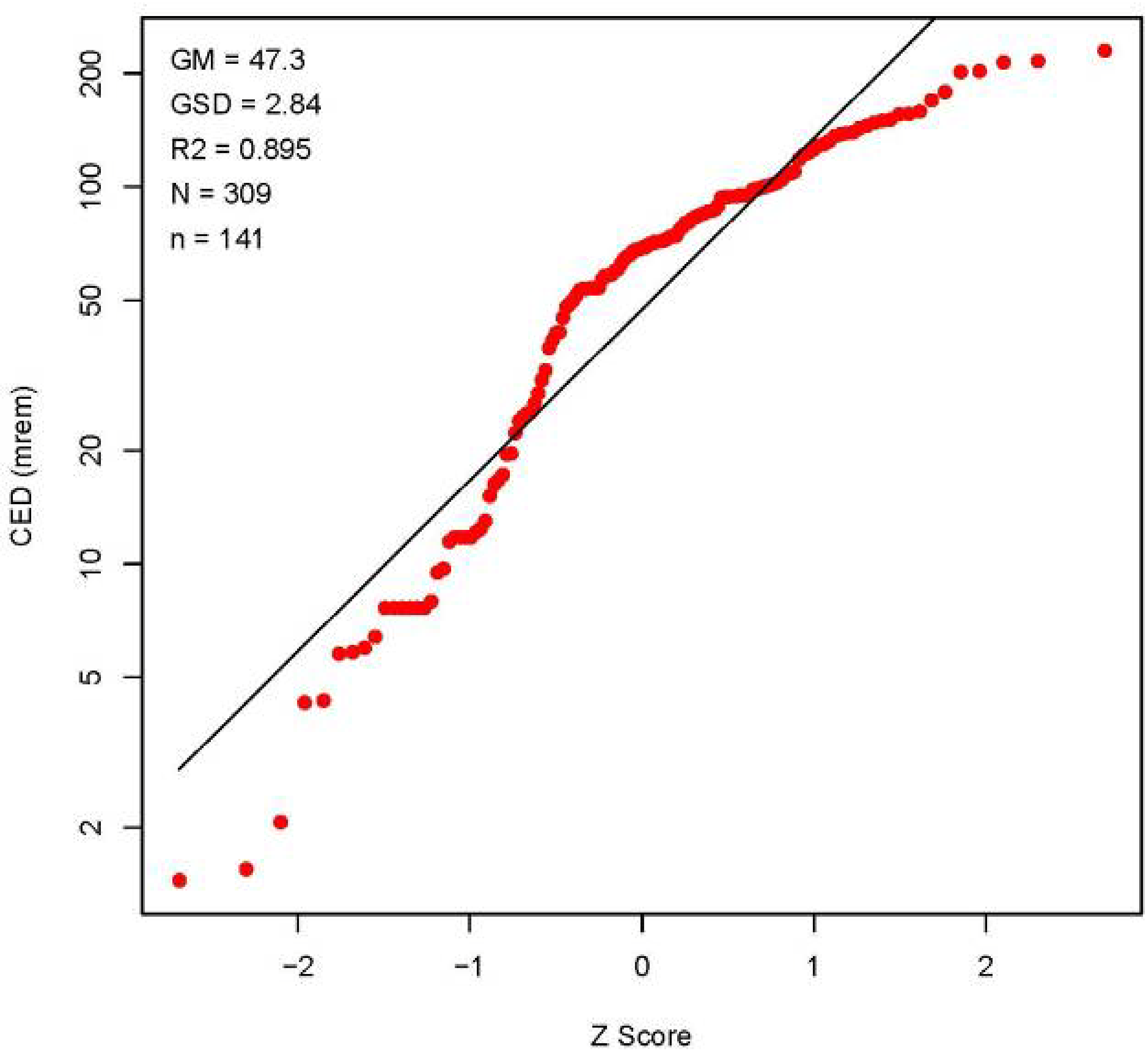

Figure B-59. SRS reactor tritium dose 1973.

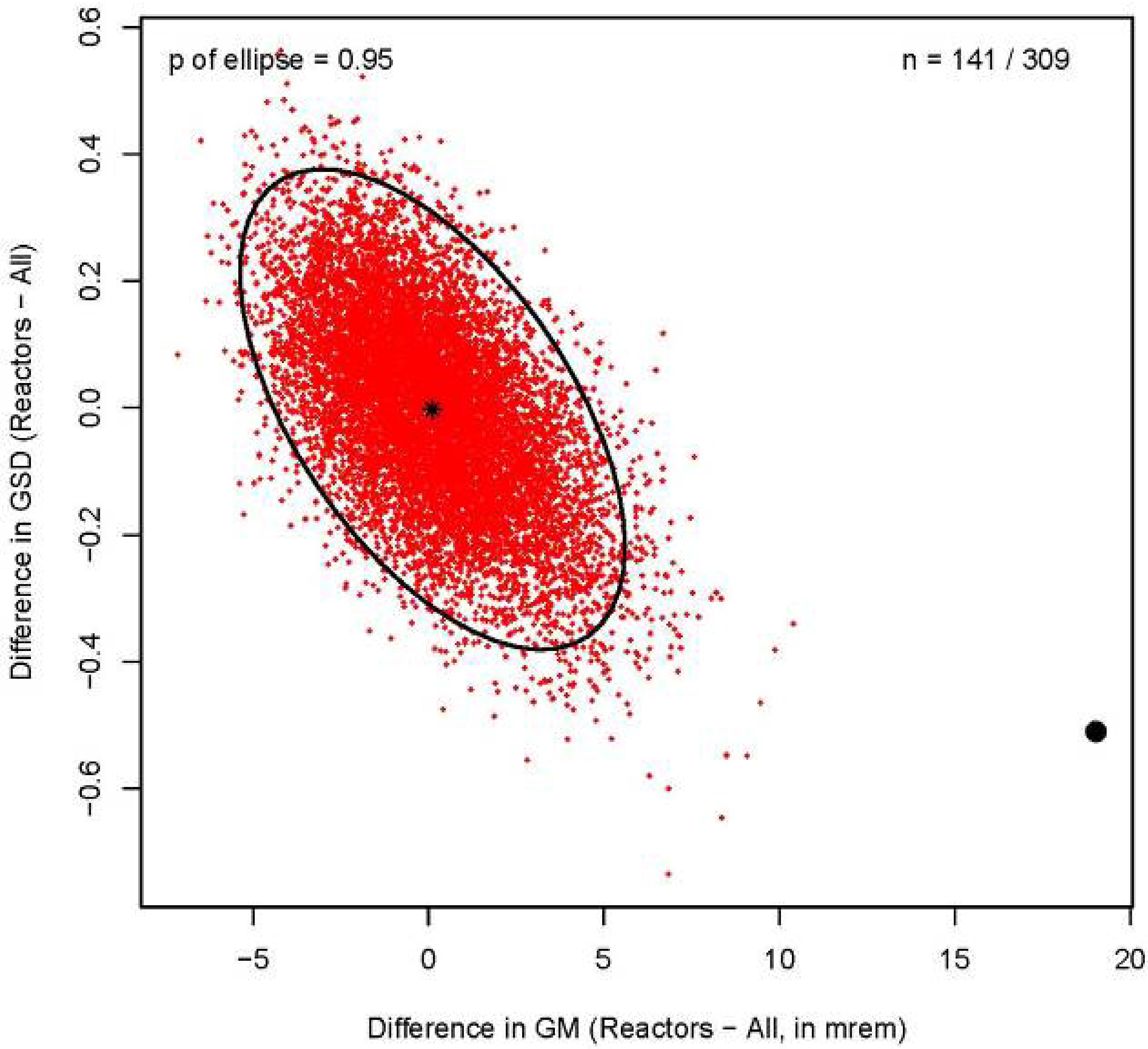

Figure B-60. SRS tritium dose 1973.

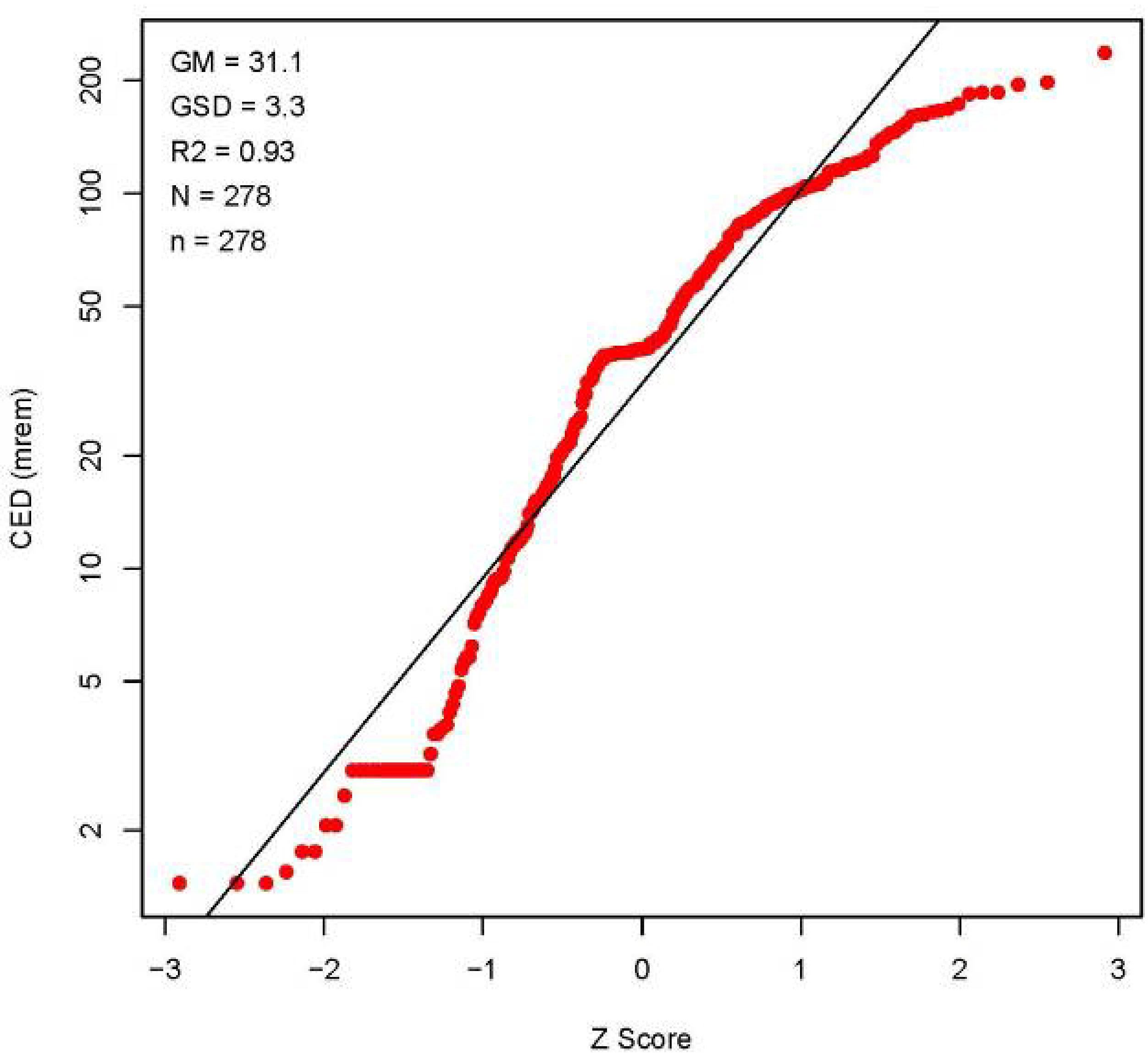

Figure B-61. SRS tritium dose 1974.

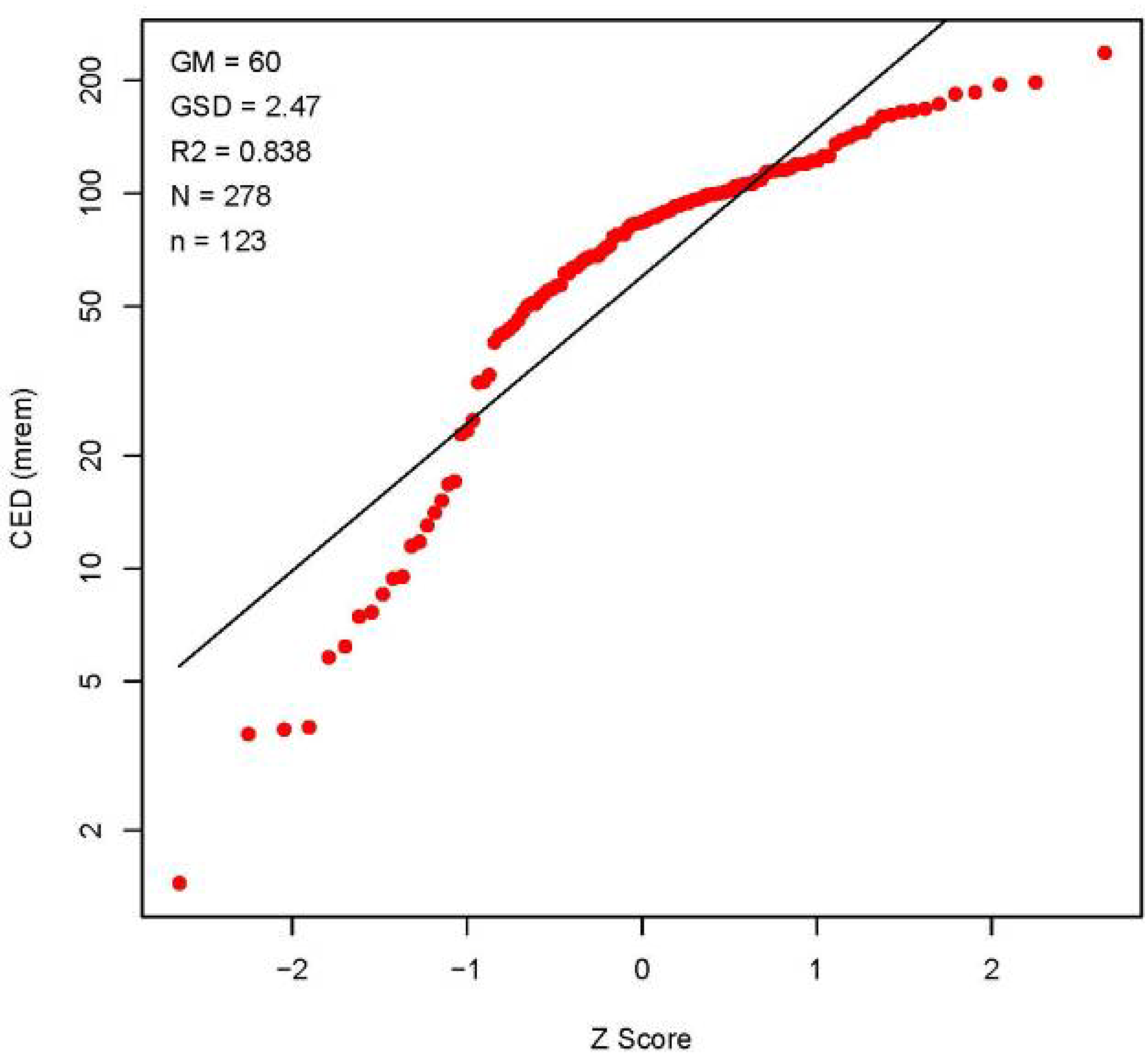

Figure B-62. SRS reactor tritium dose 1974.

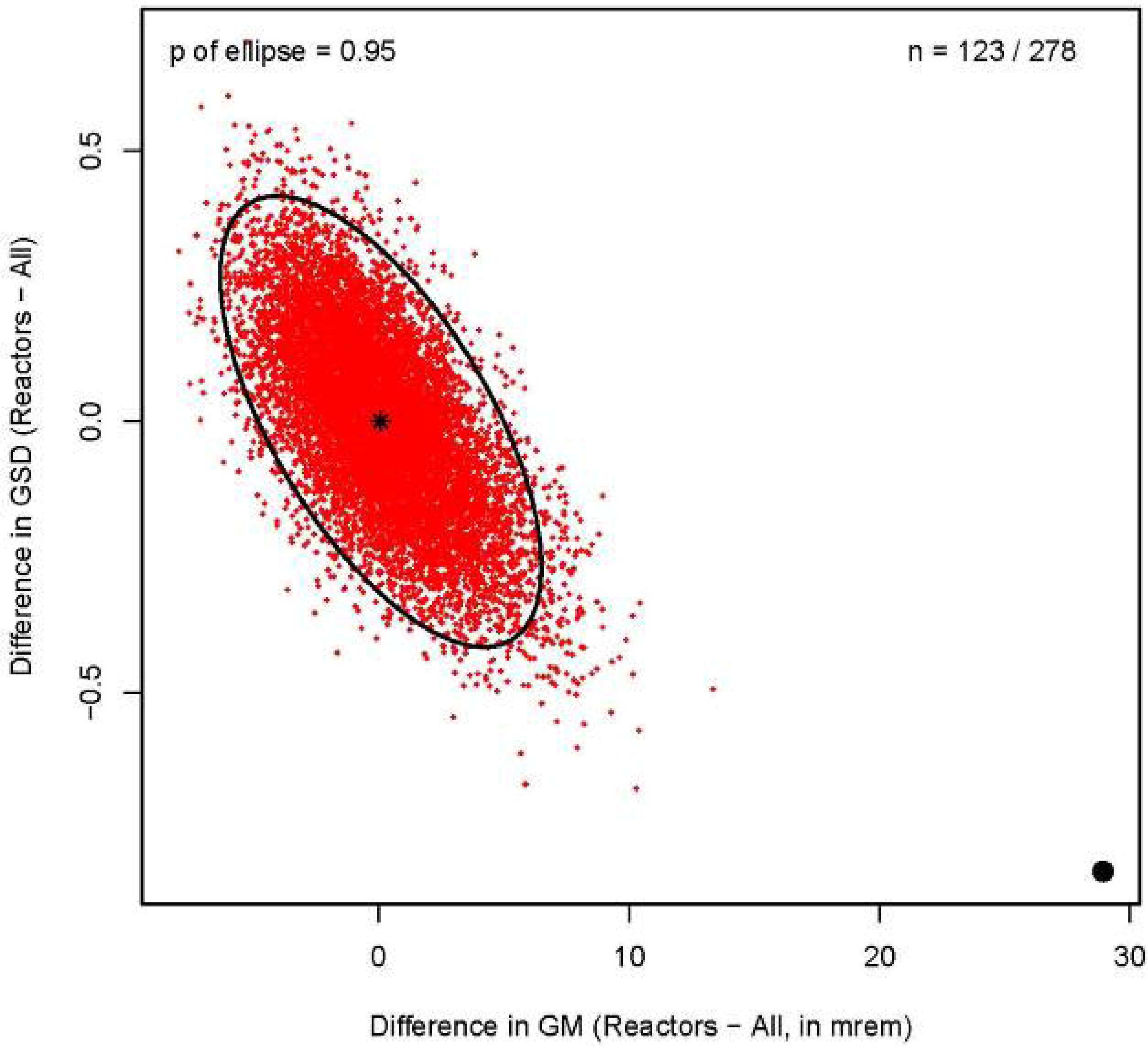

Figure B-63. SRS tritium dose 1974.

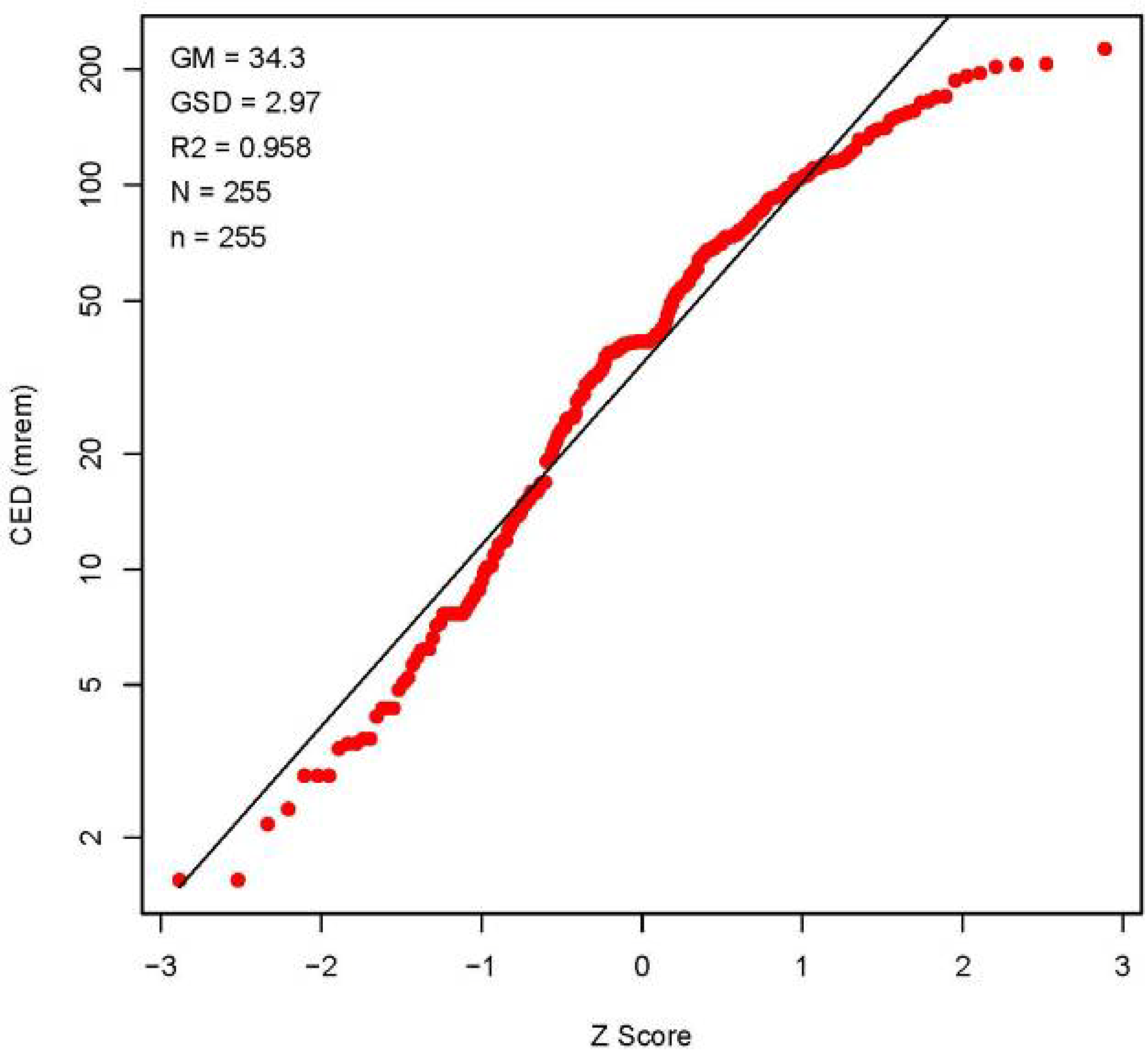

Figure B-64. SRS tritium dose 1975.

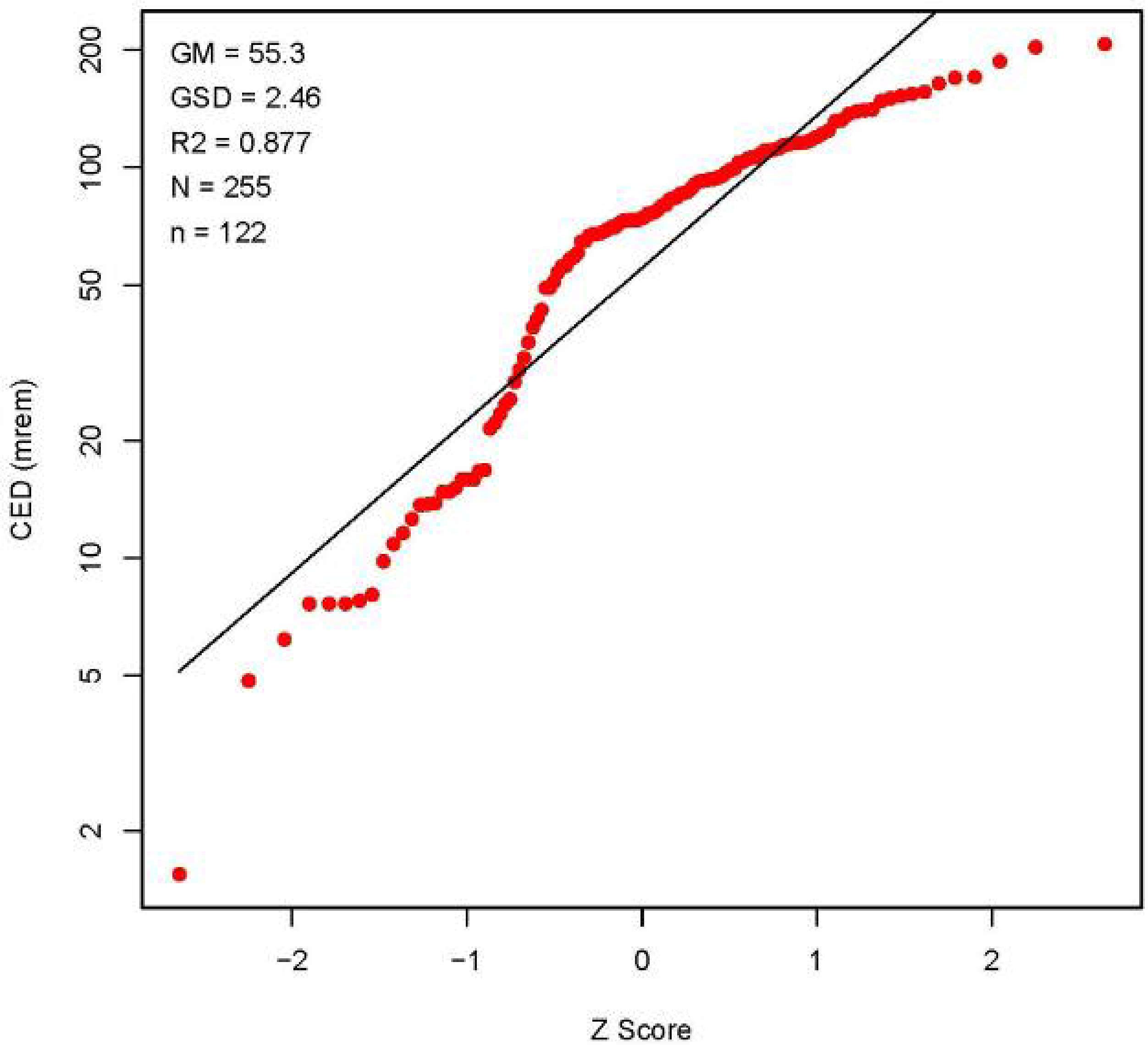

Figure B-65. SRS reactor tritium dose 1975.

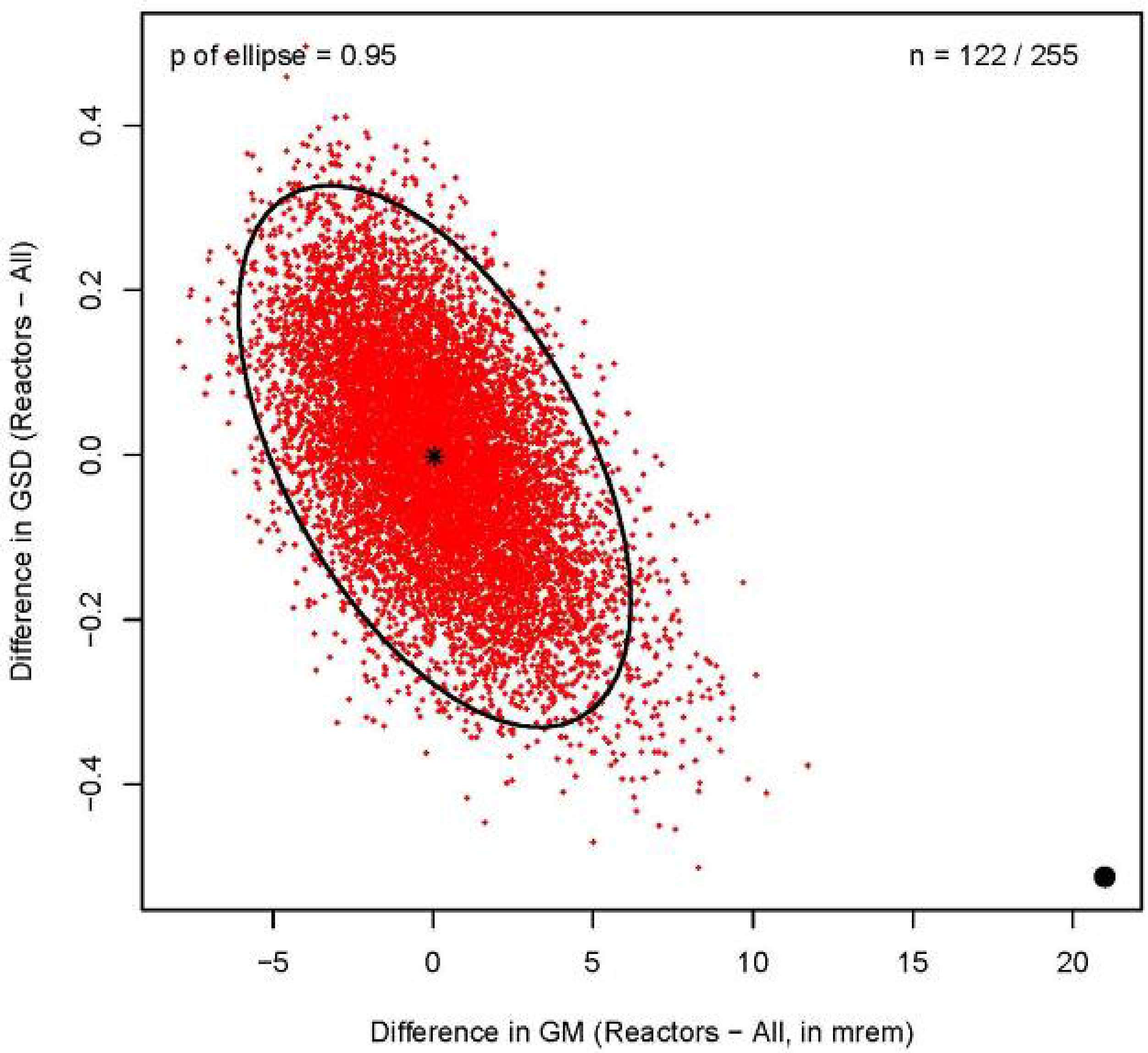

Figure B-66. SRS tritium dose 1975.

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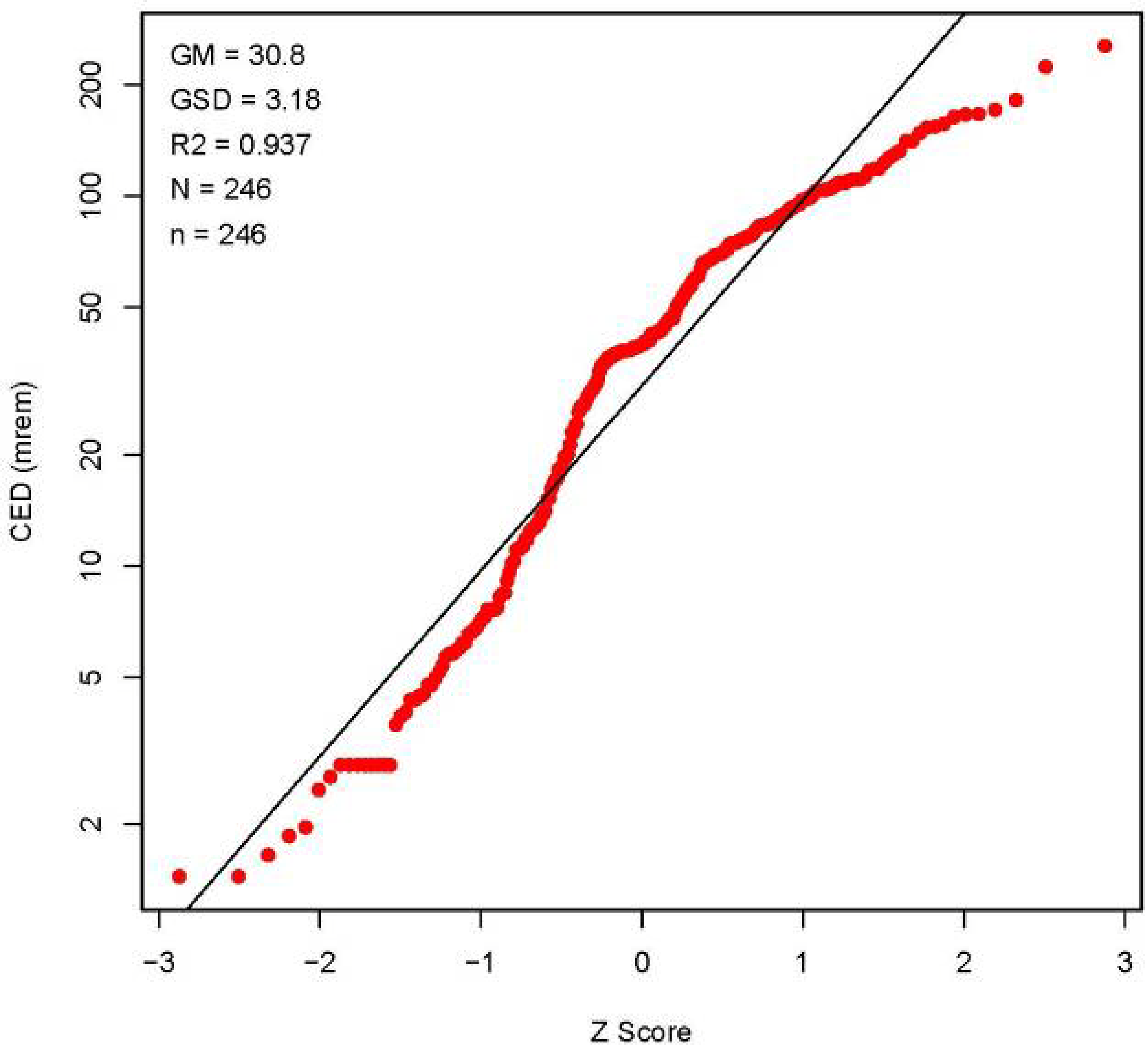

Figure B-67. SRS tritium dose 1976.

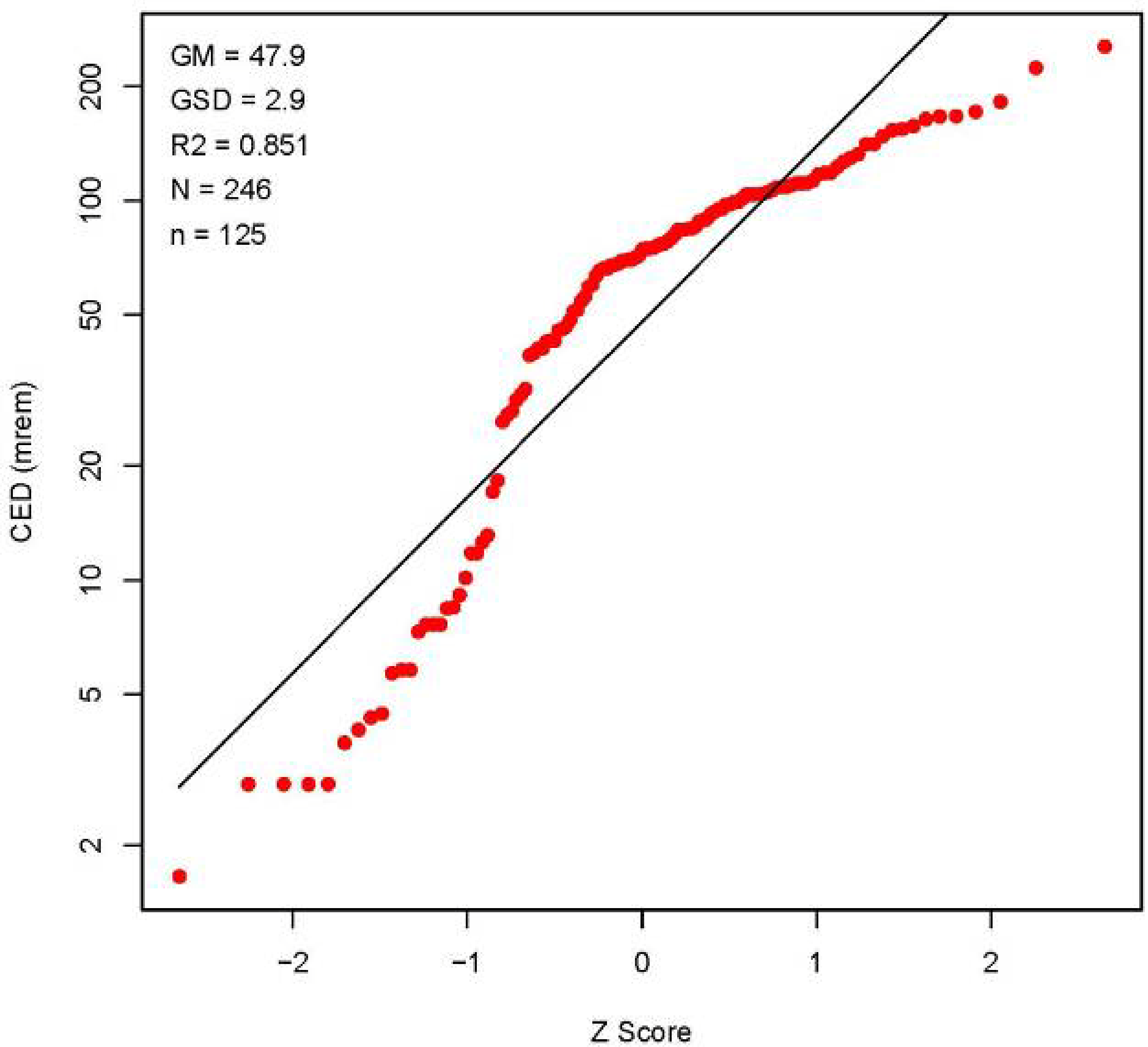

Figure B-68. SRS reactor tritium dose 1976.

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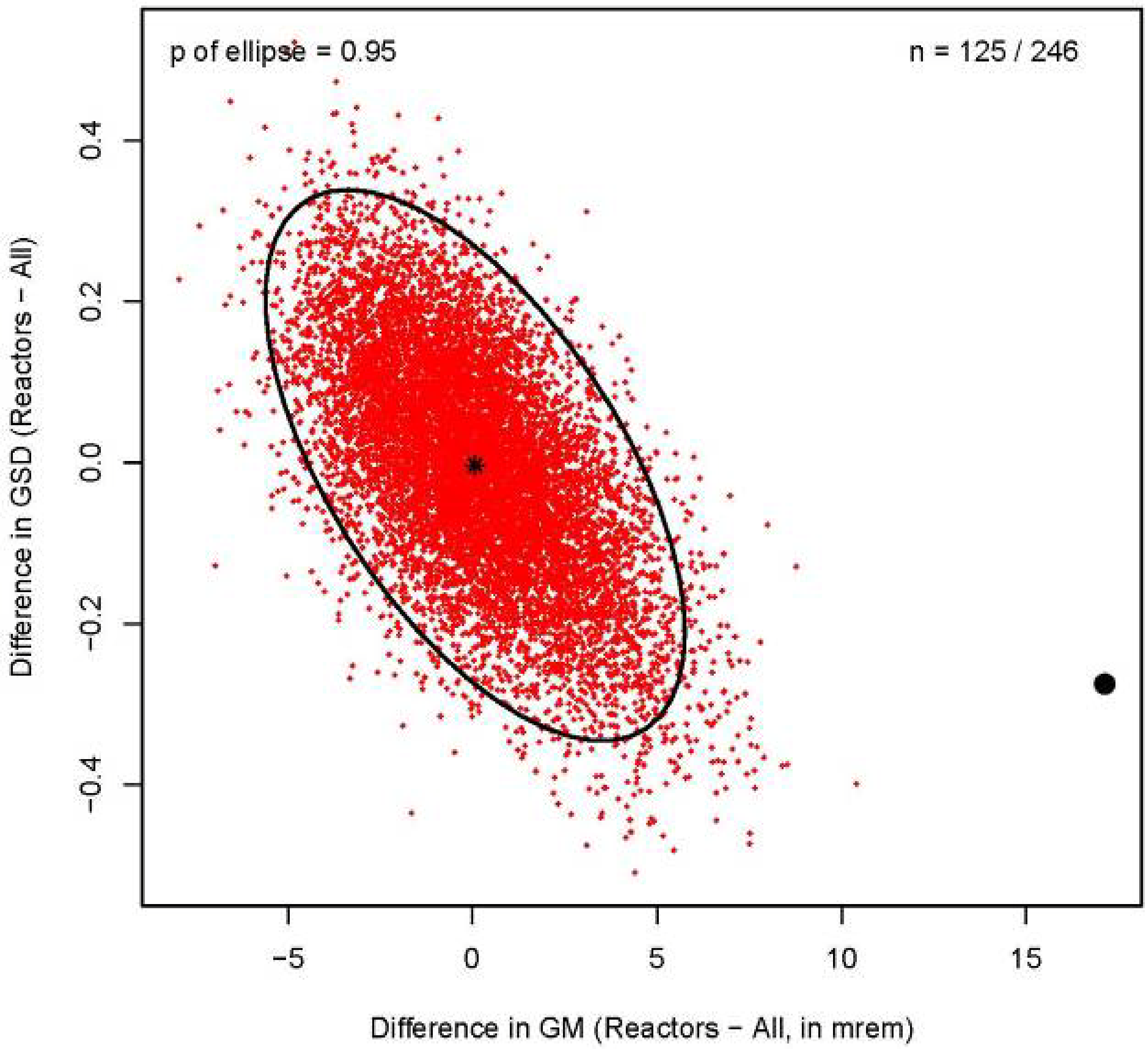

Figure B-69. SRS tritium dose 1976.

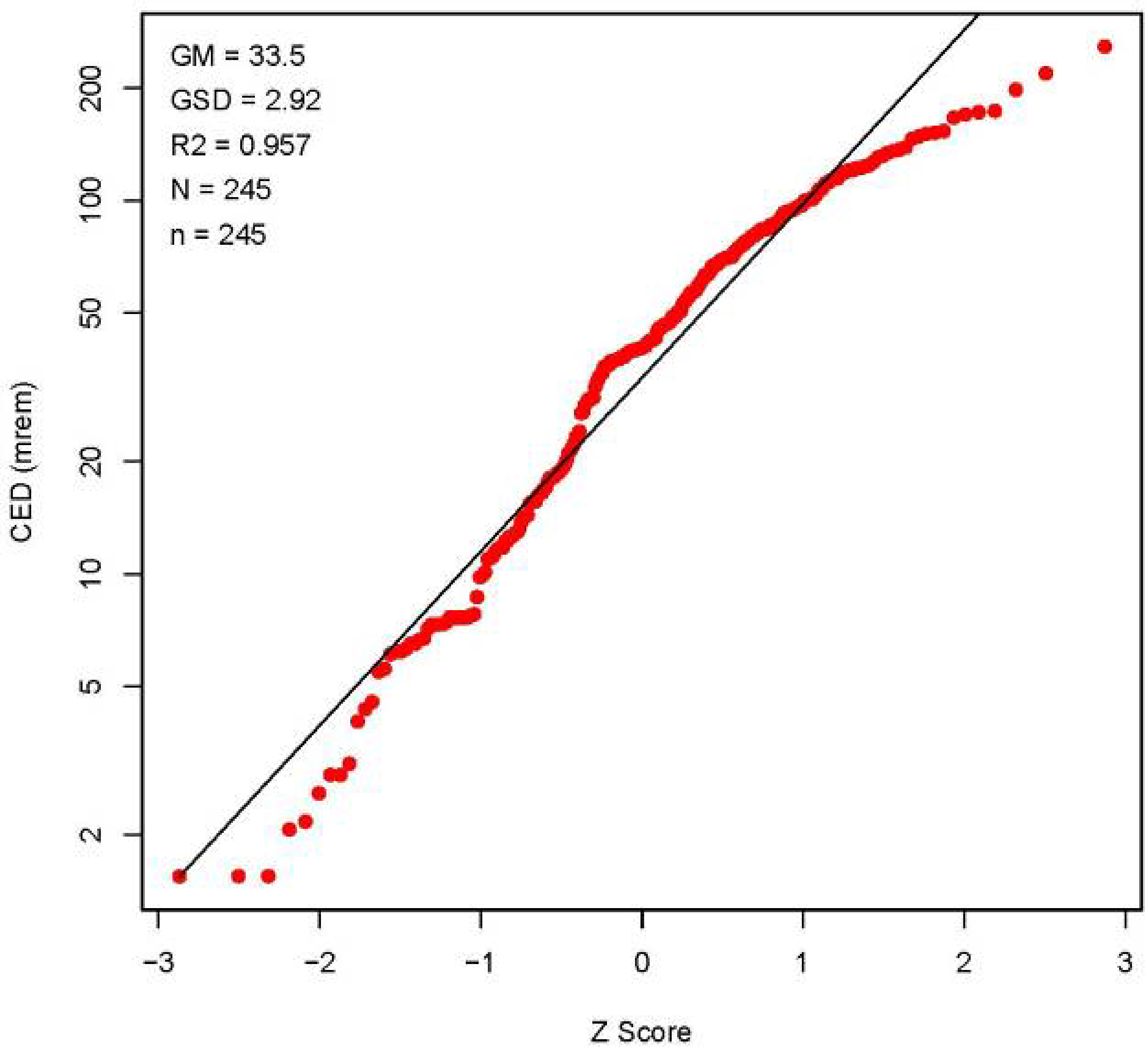

Figure B-70. SRS tritium dose 1977.

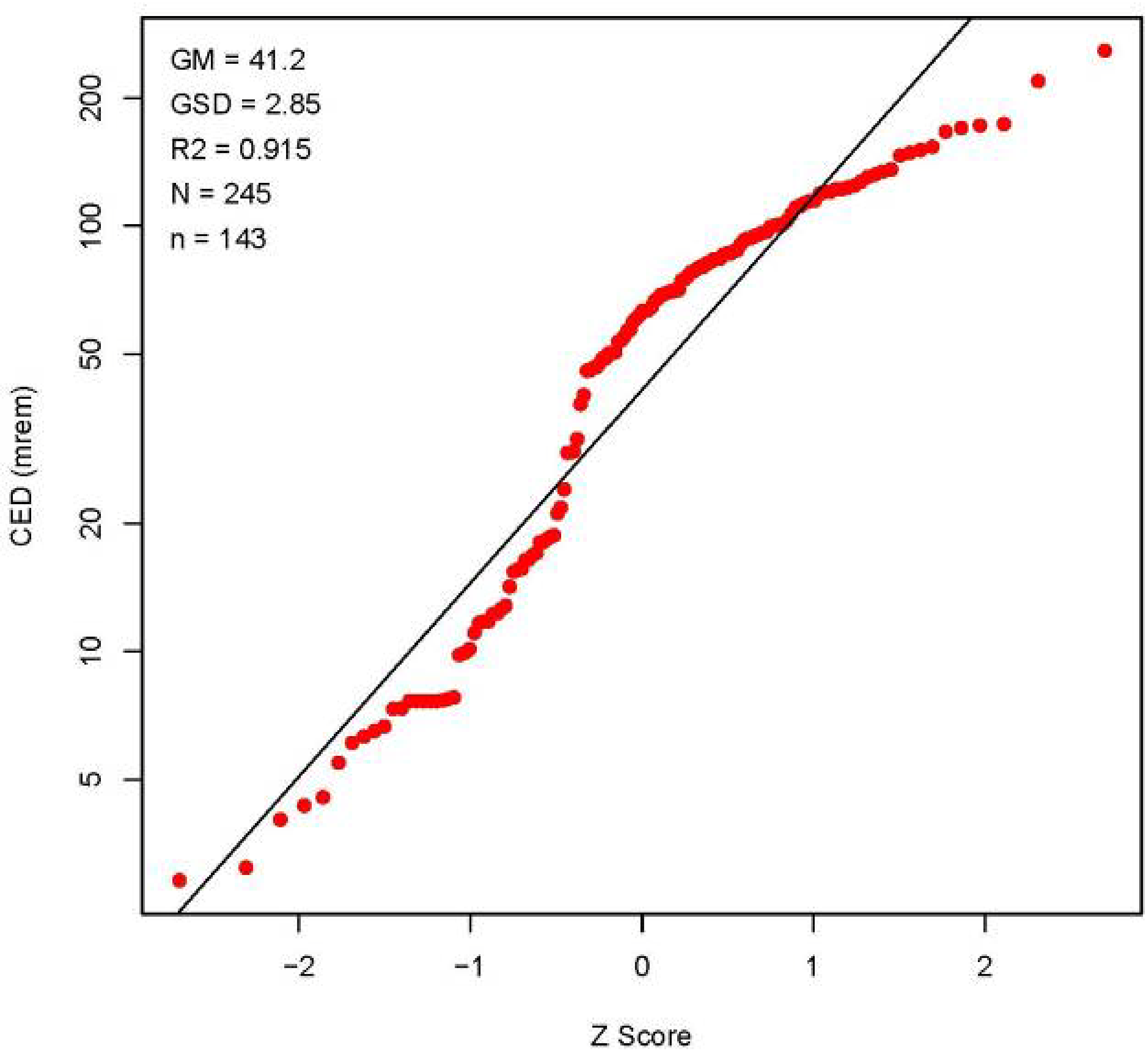

Figure B-71. SRS reactor tritium dose 1977.

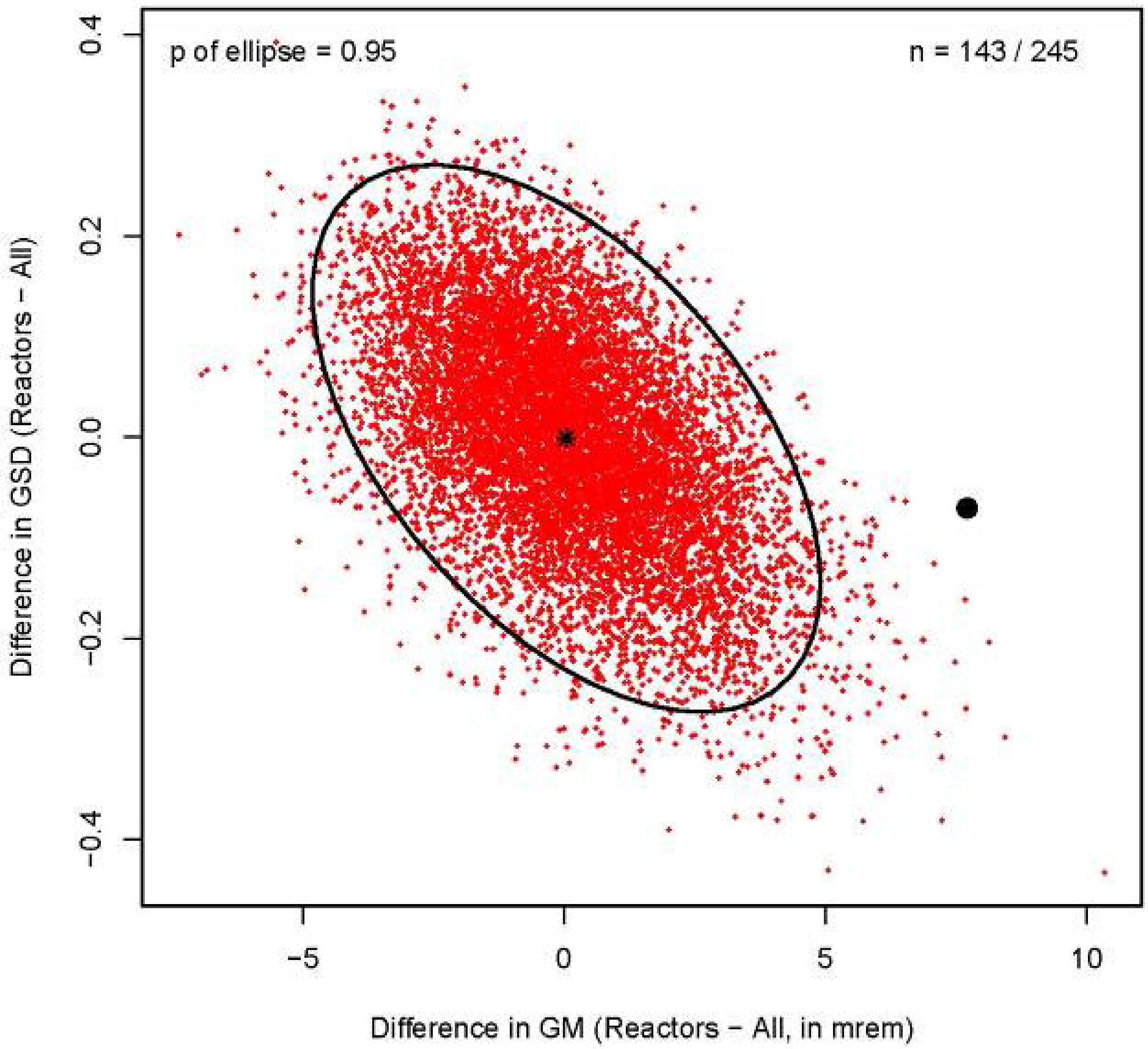

Figure B-72. SRS tritium dose 1977.

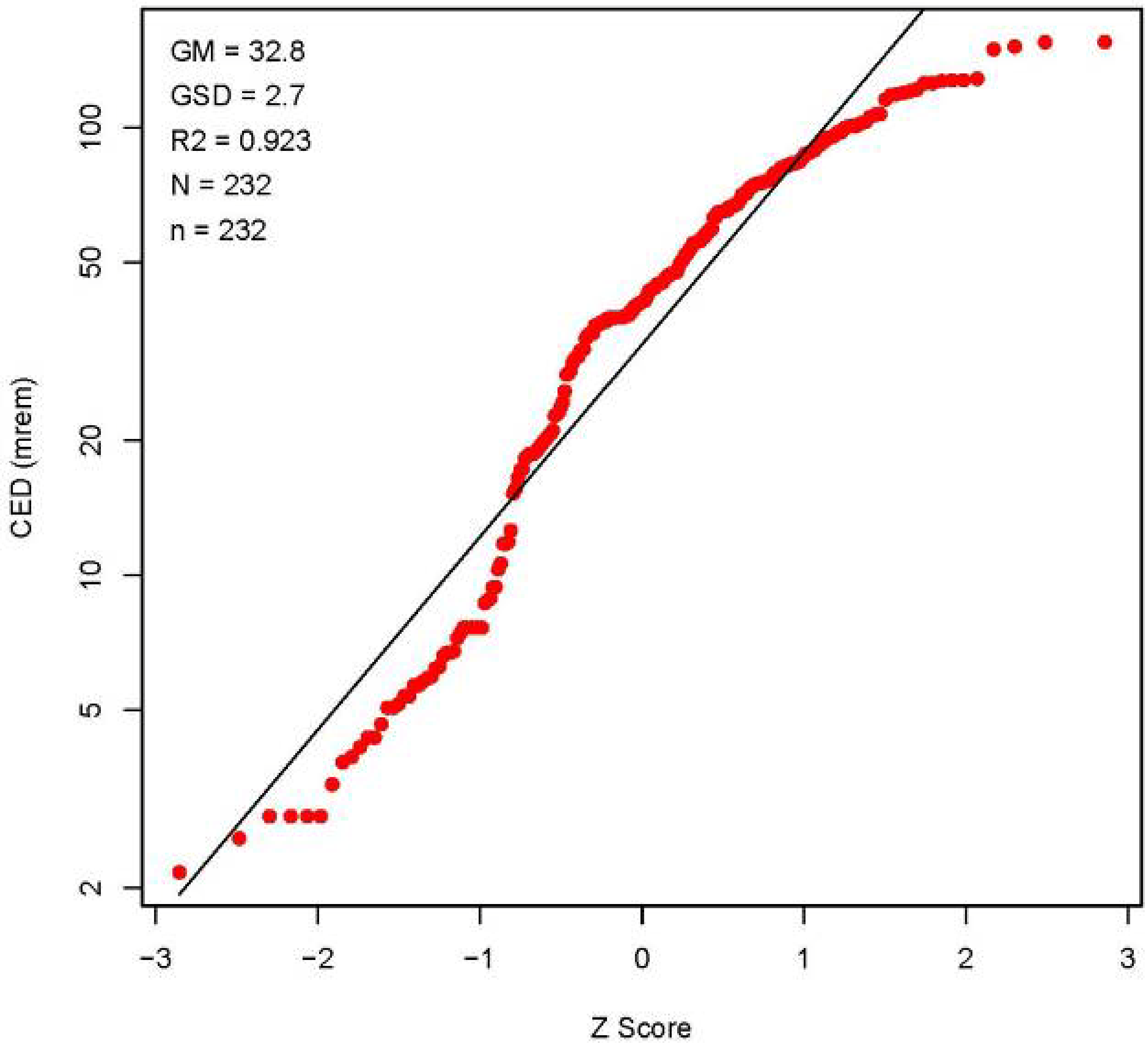

Figure B-73. SRS tritium dose 1978.

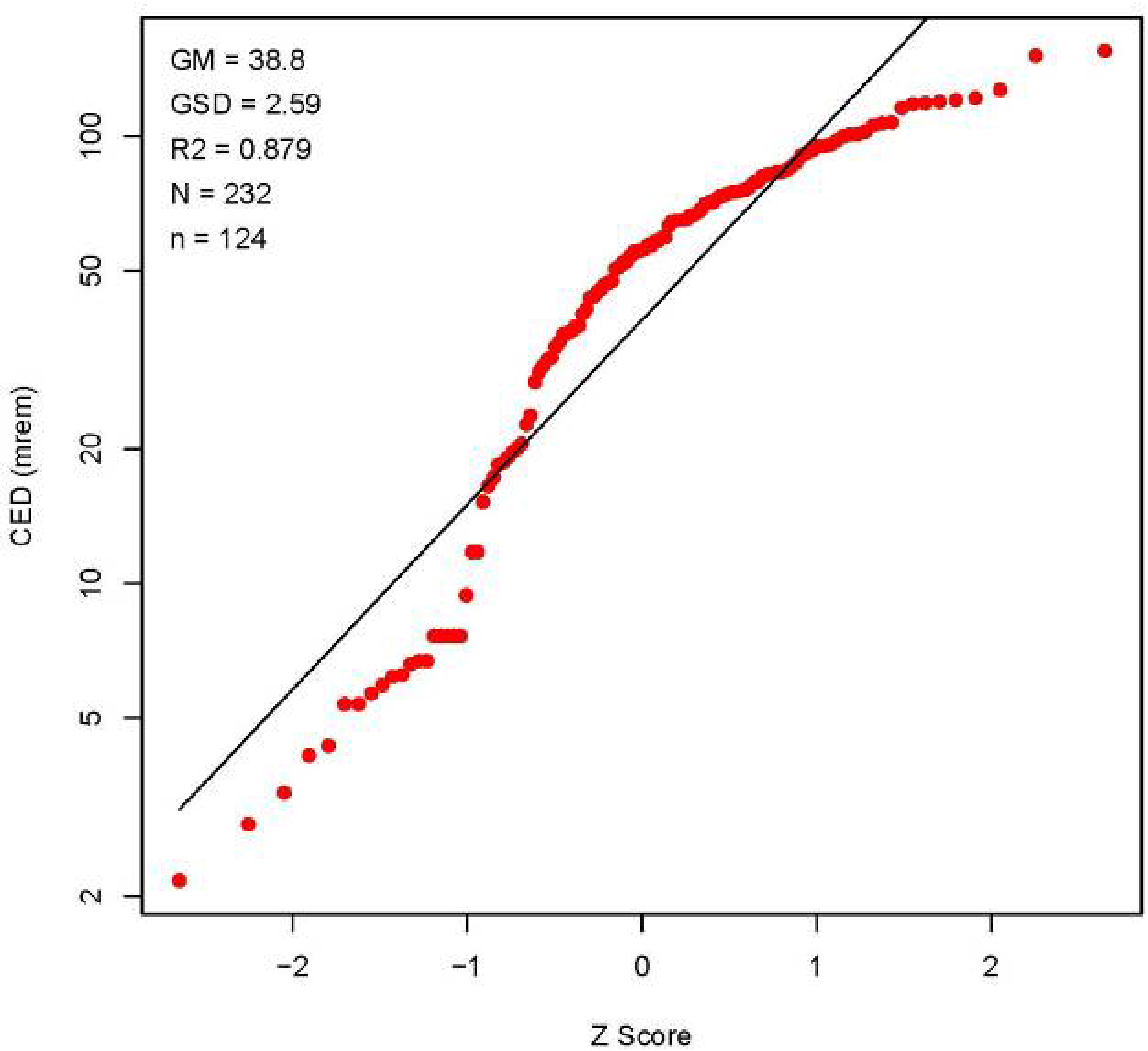

Figure B-74. SRS reactor tritium dose 1978.

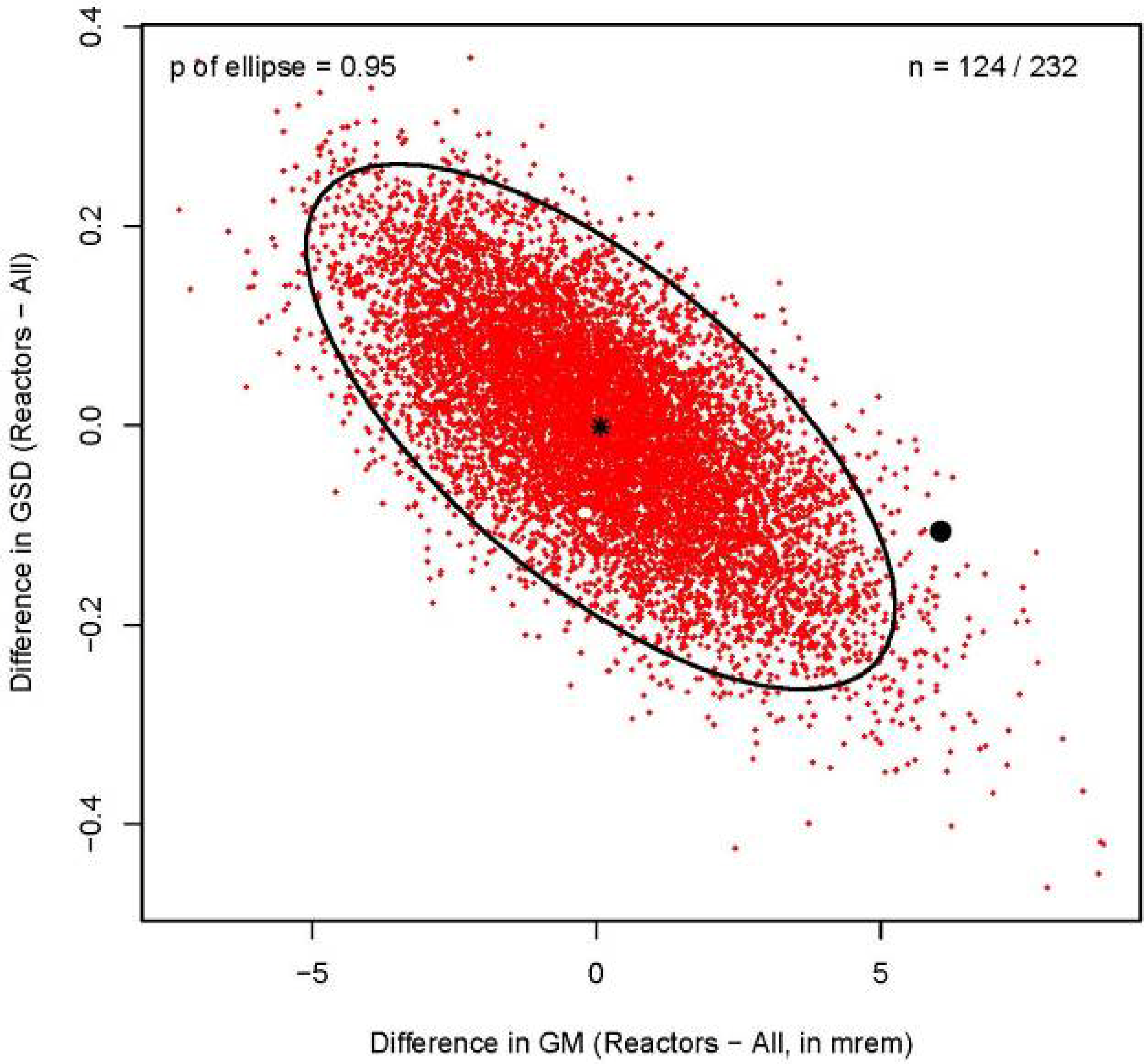

Figure B-75. SRS tritium dose 1978.

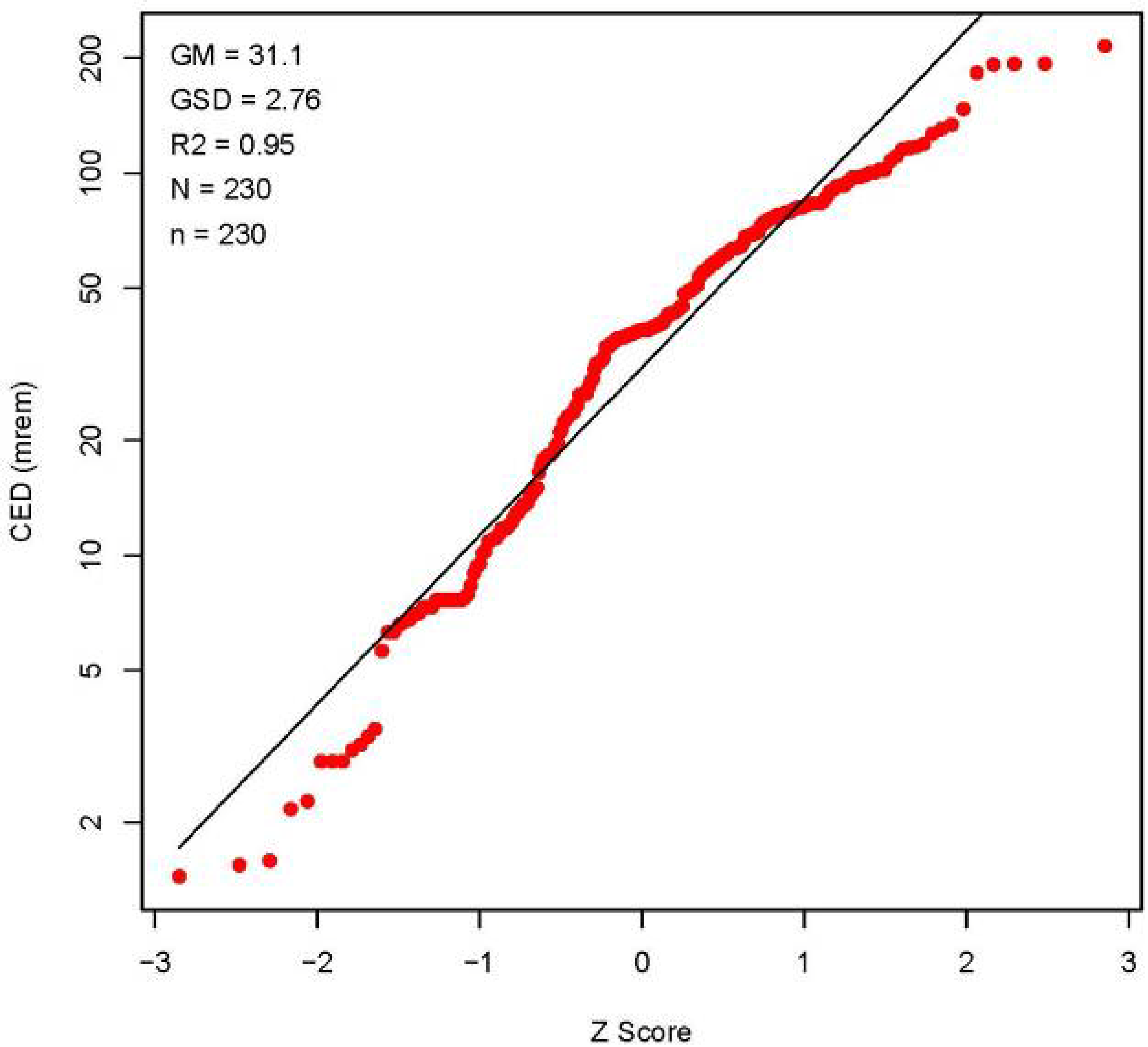

Figure B-76. SRS tritium dose 1979.

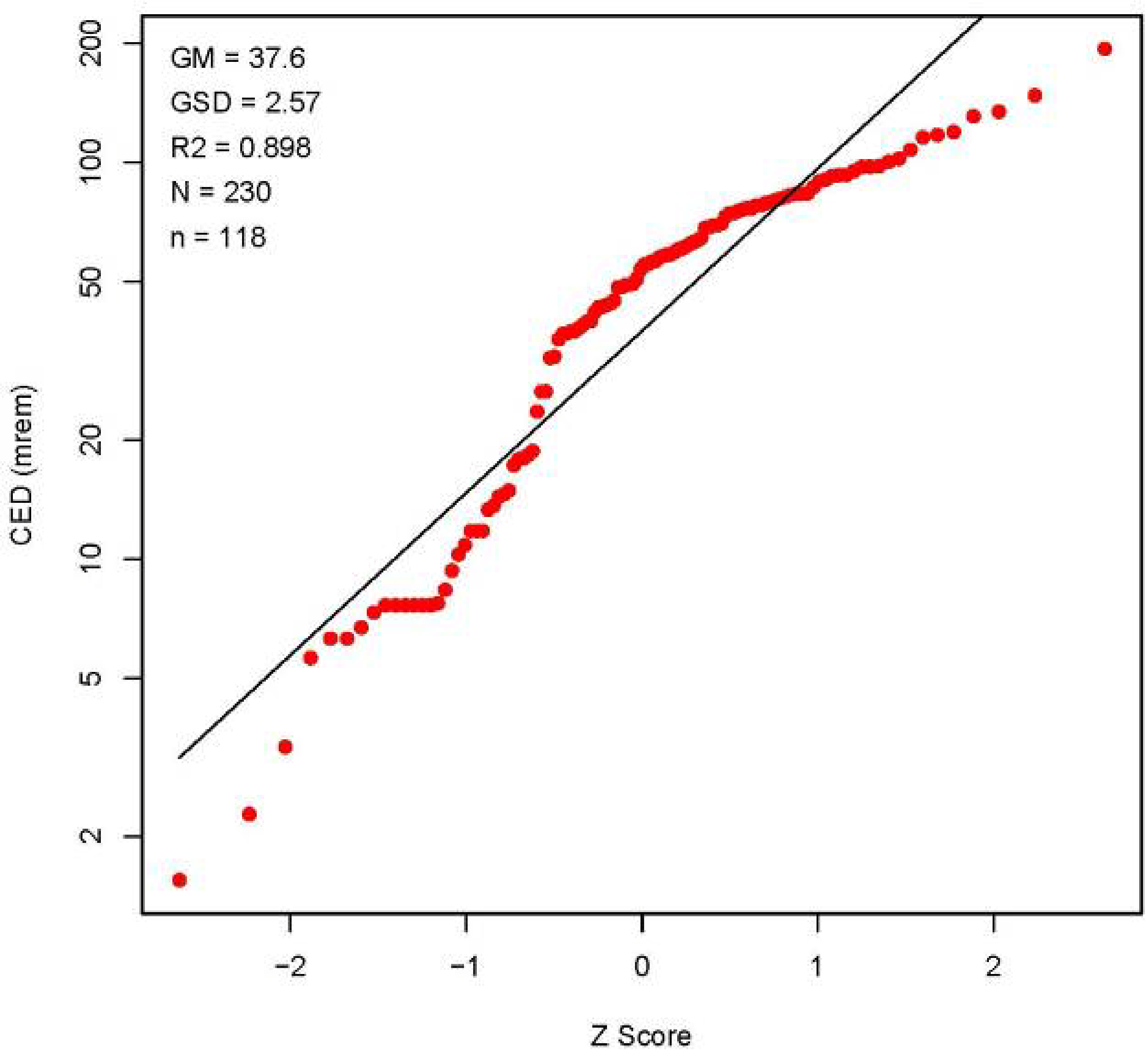

Figure B-77. SRS reactor tritium dose 1979.

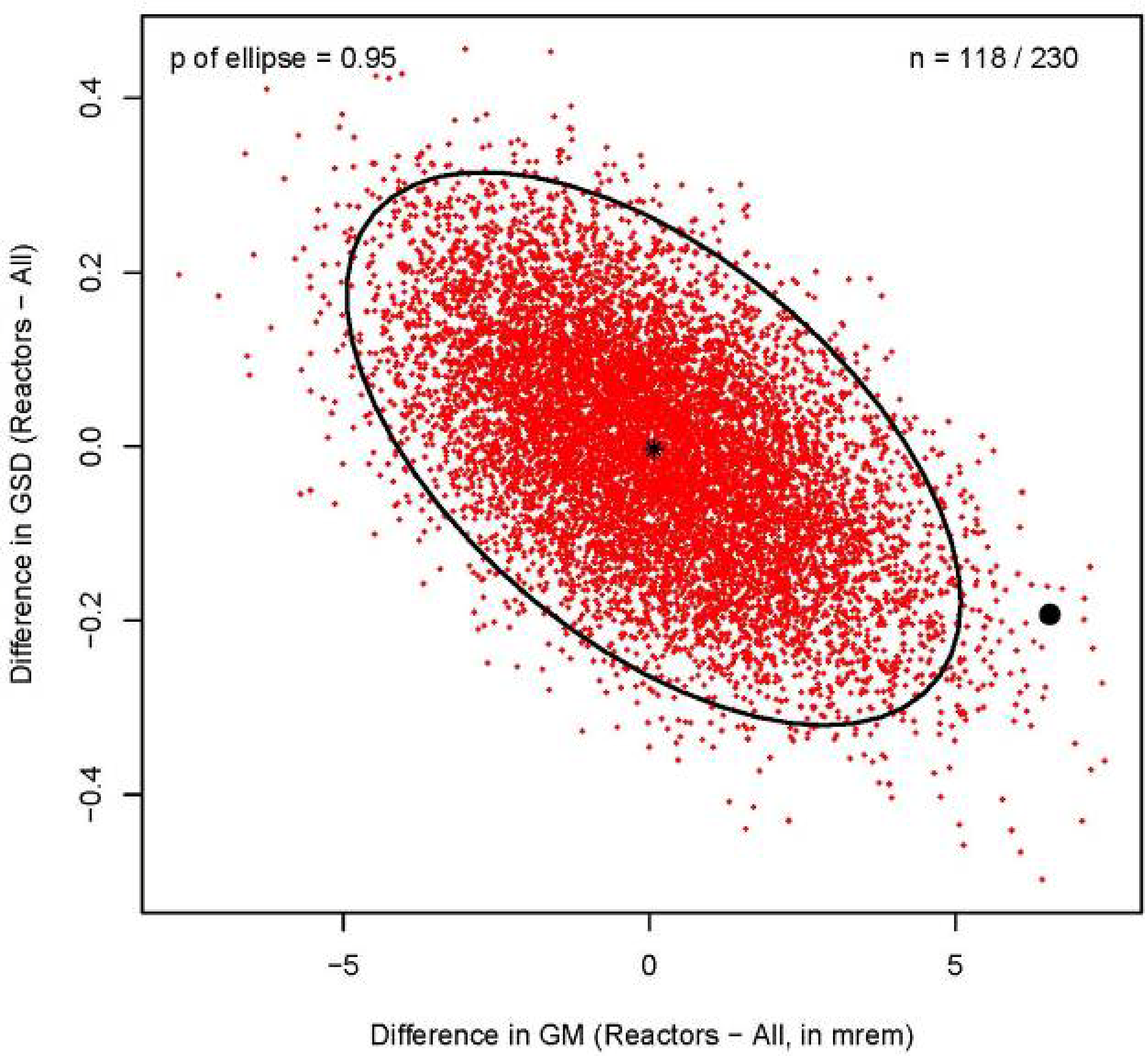

Figure B-78. SRS tritium dose 1979.

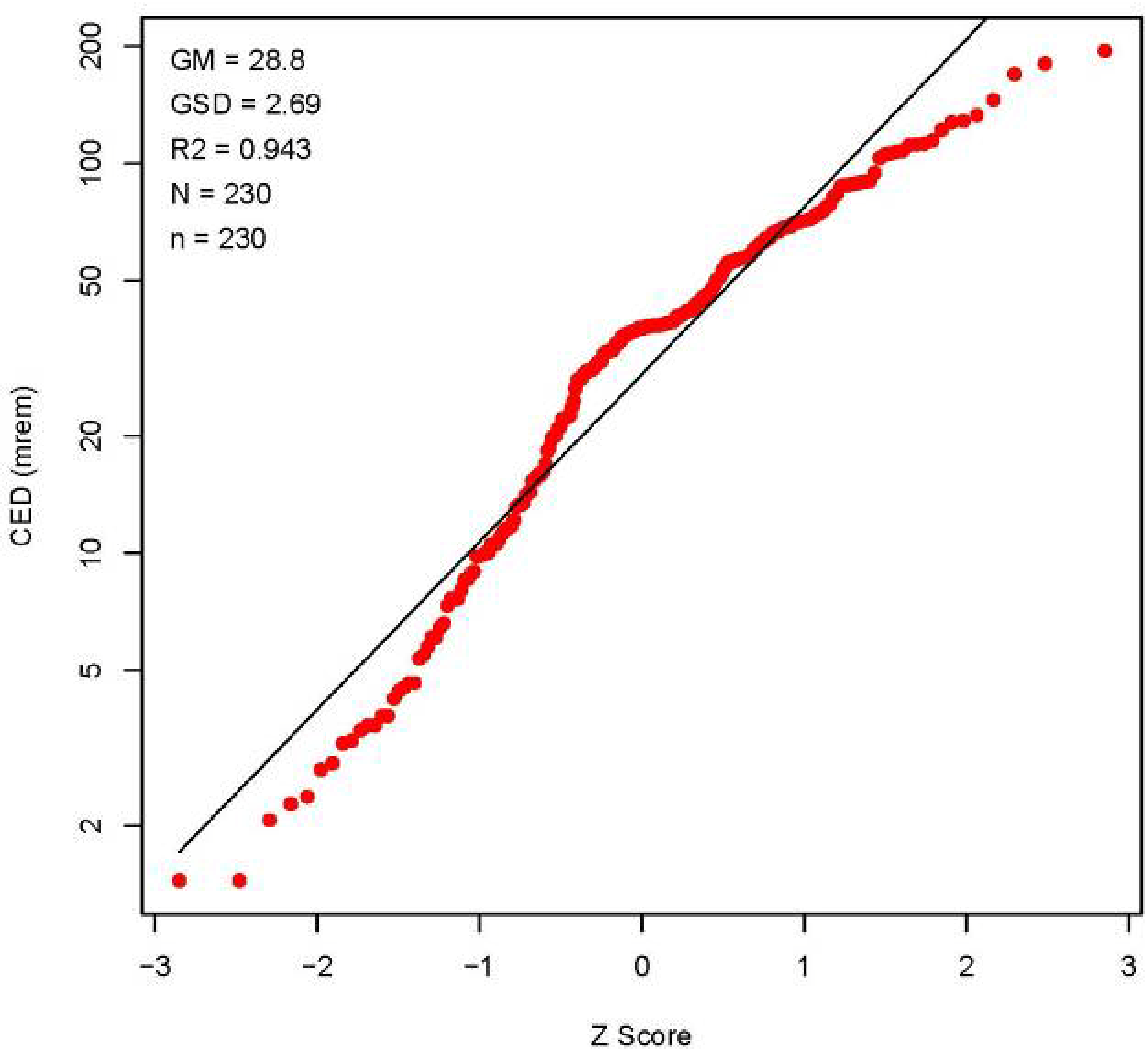

Figure B-79. SRS tritium dose 1980.

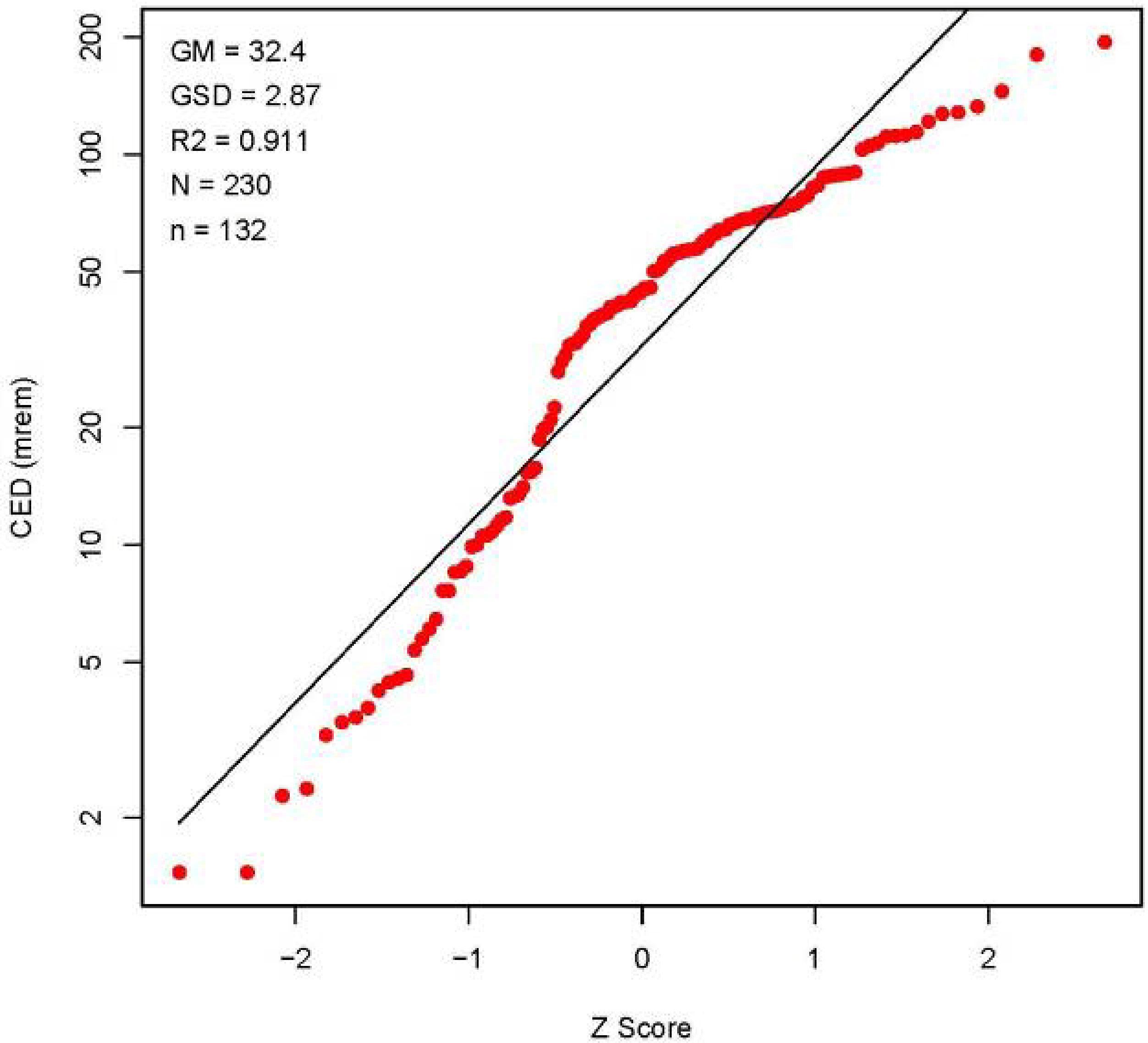

Figure B-80. SRS reactor tritium dose 1980.

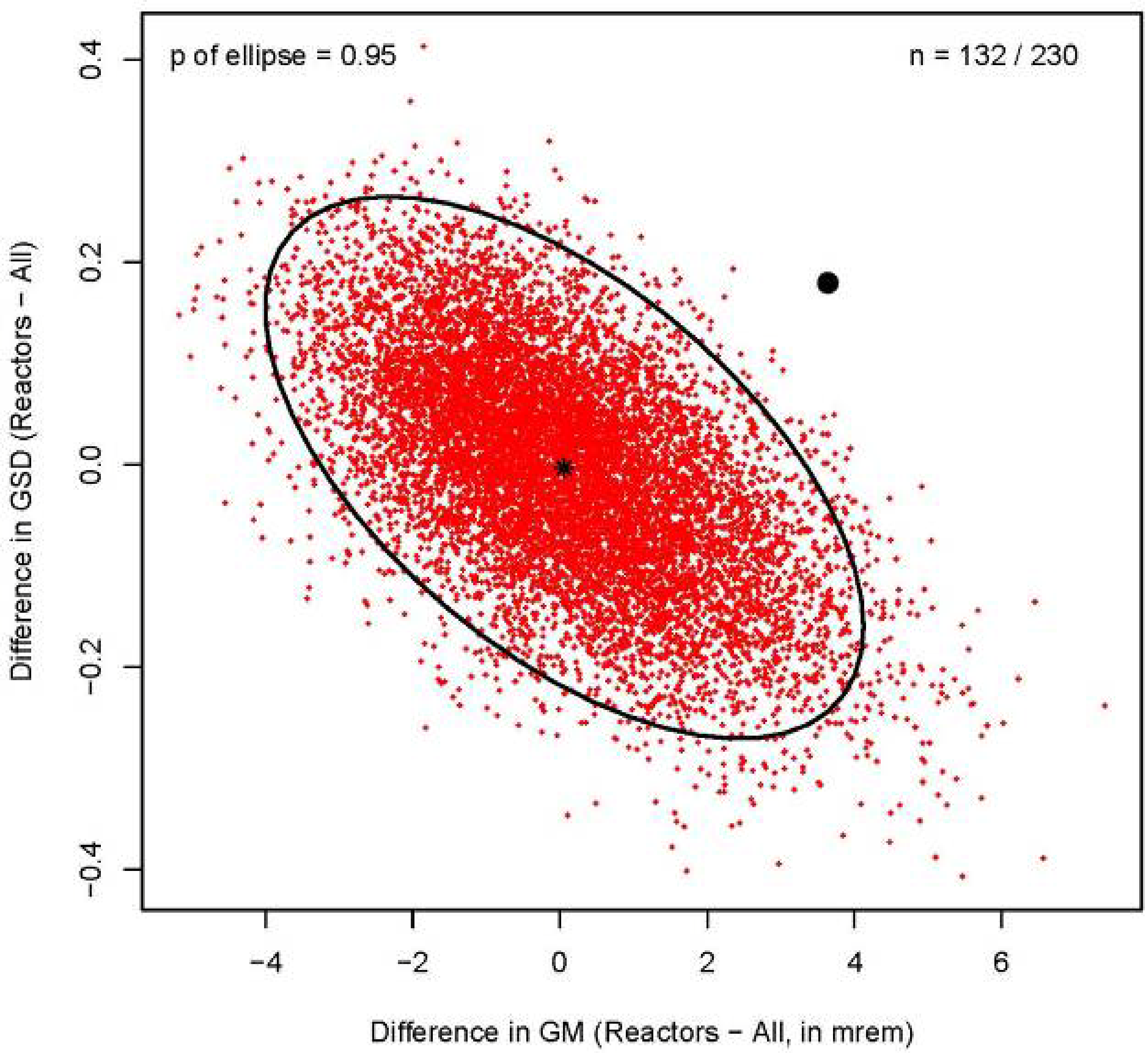

Figure B-81. SRS tritium dose 1980.

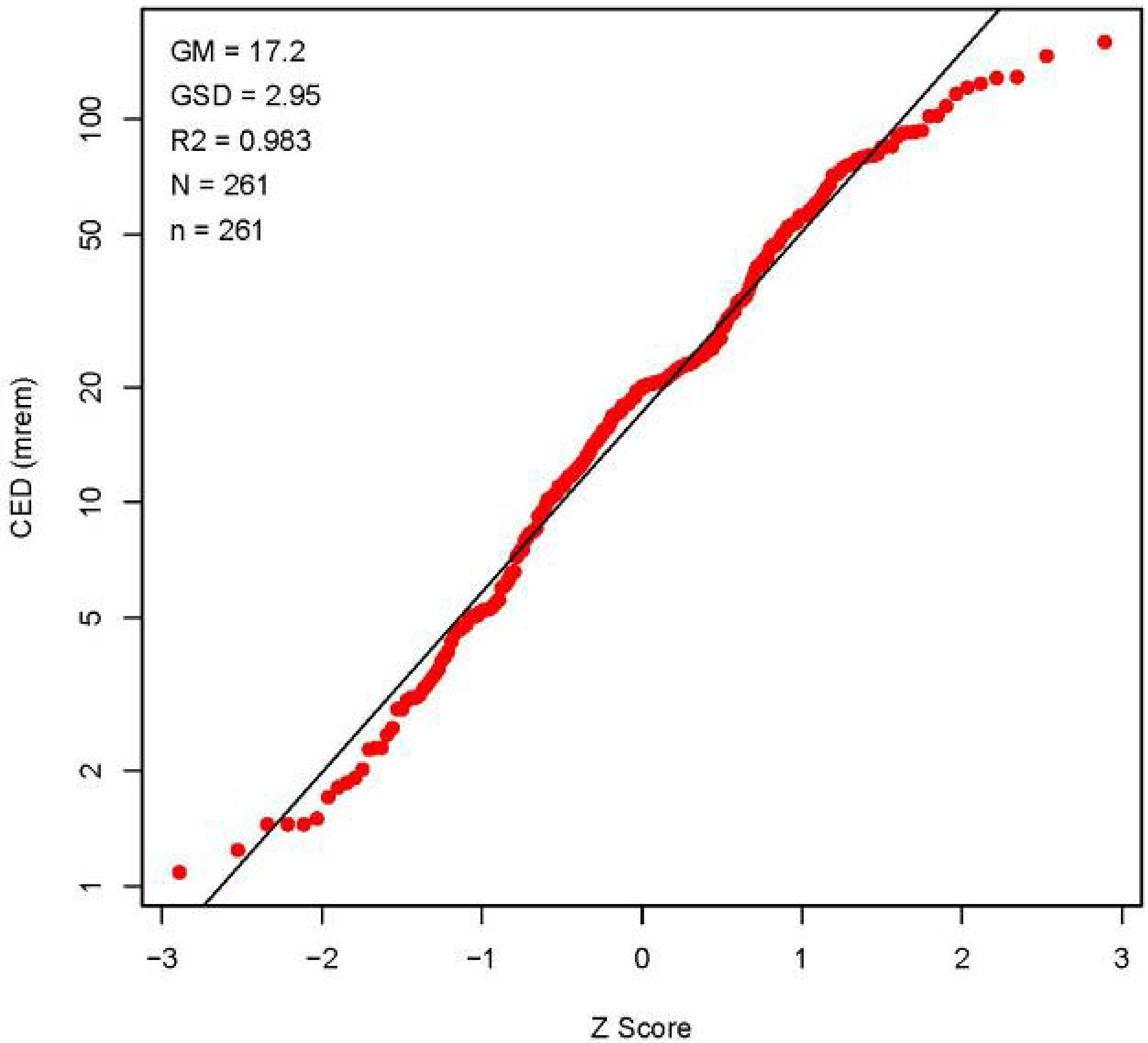

Figure B-82. SRS tritium dose 1981.

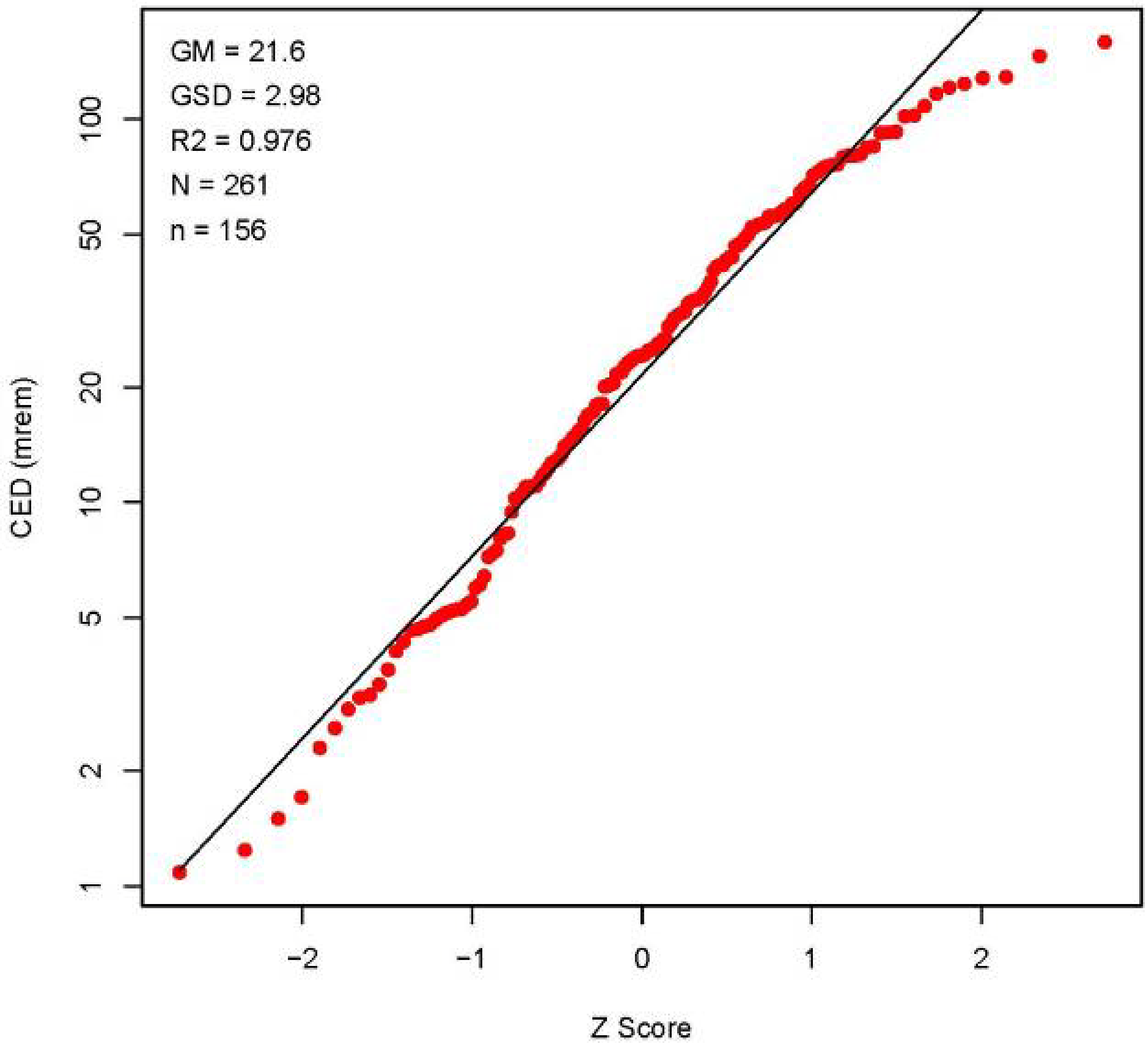

Figure B-83. SRS reactor tritium dose 1981.

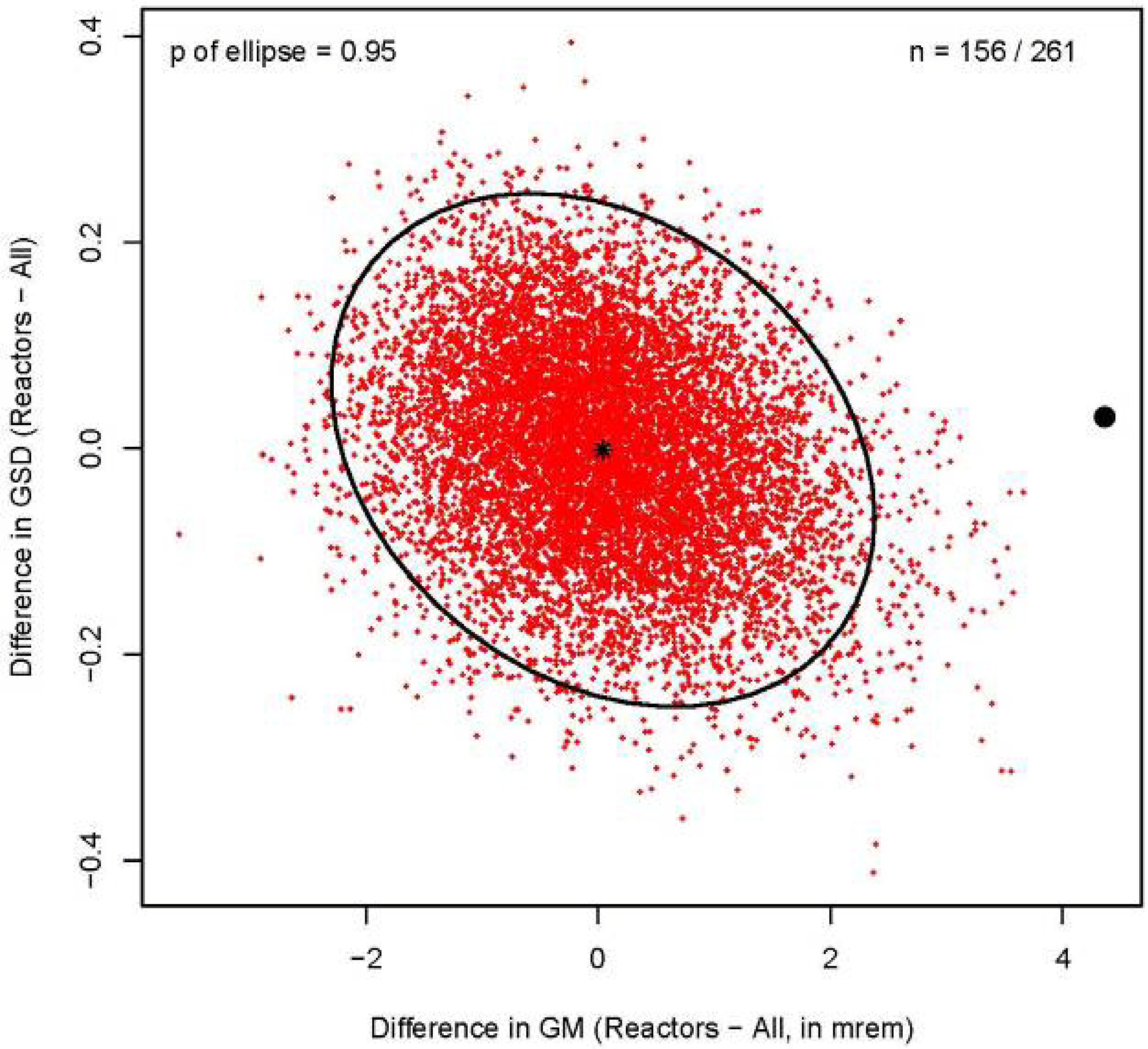

Figure B-84. SRS tritium dose 1981.

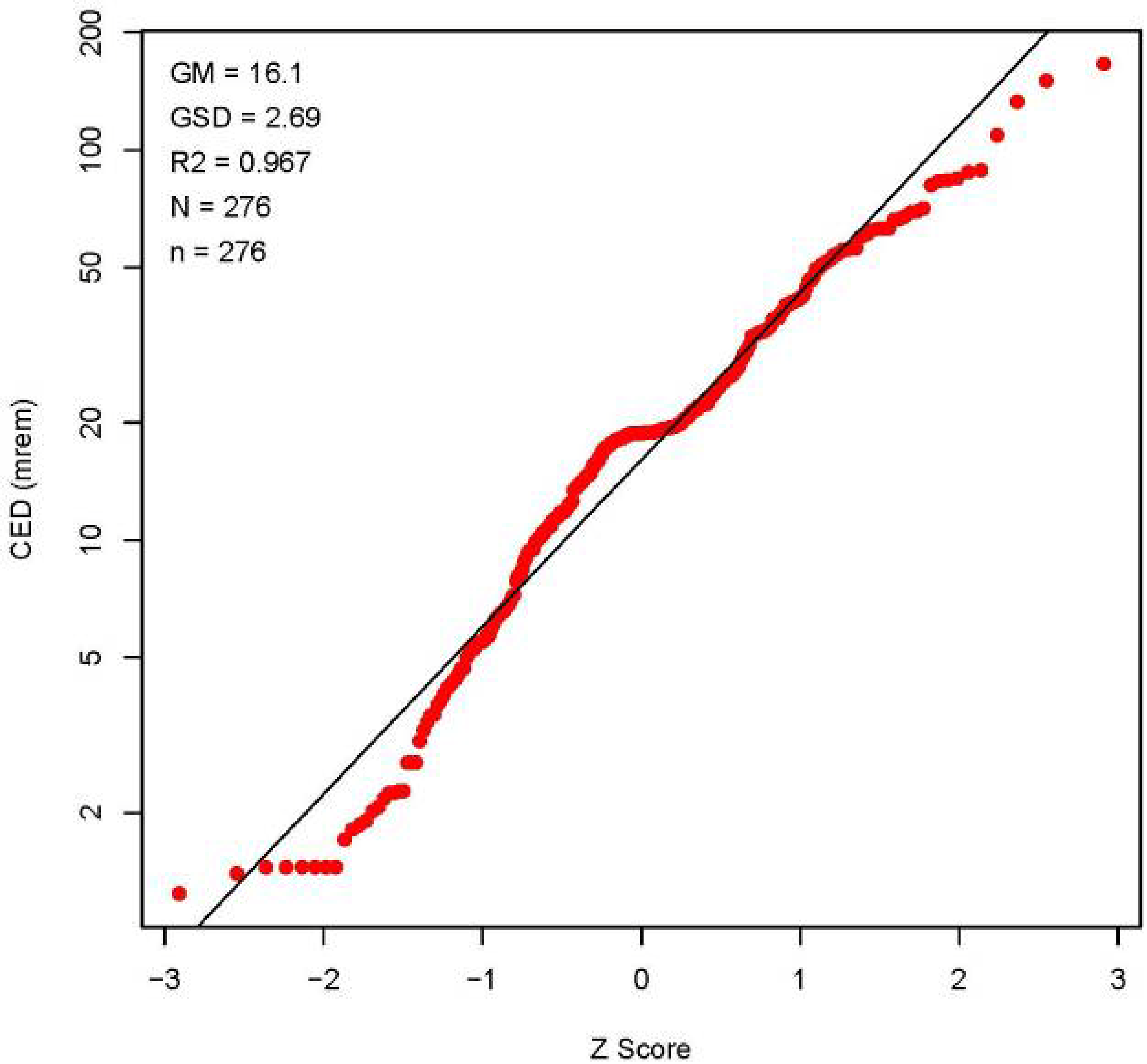

Figure B-85. SRS tritium dose 1982.

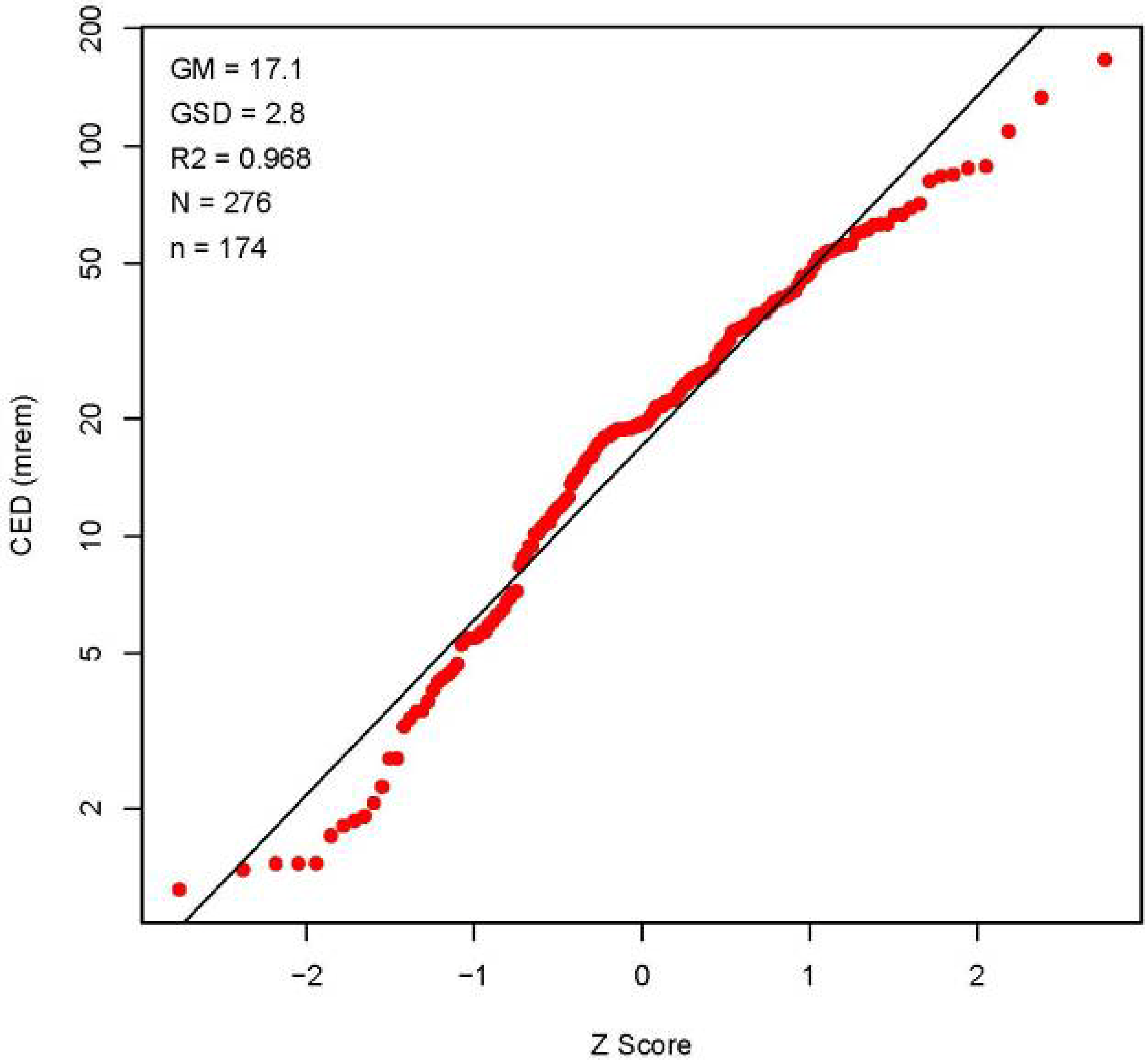

Figure B-86. SRS reactor tritium dose 1982.

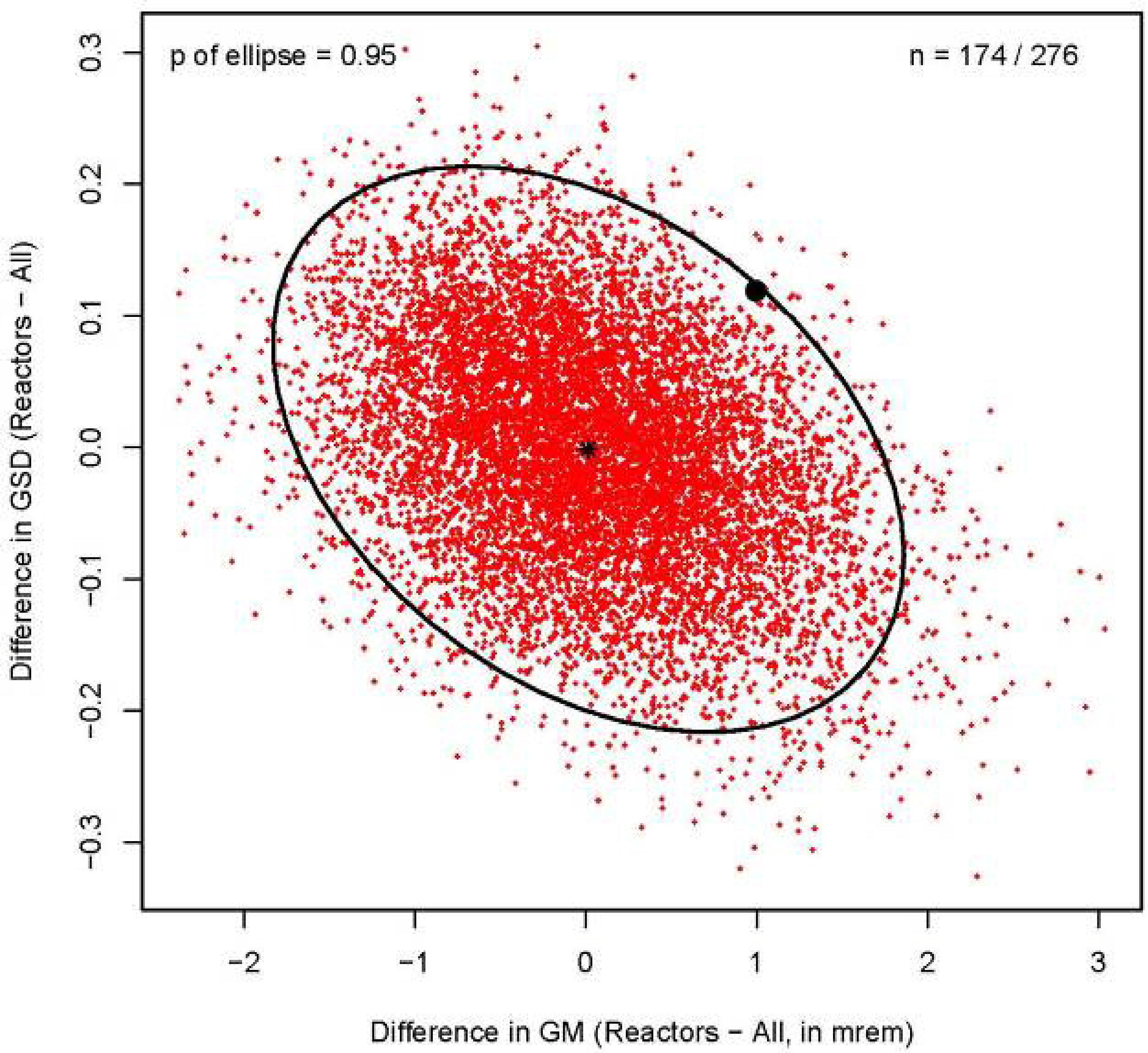

Figure B-87. SRS tritium dose 1982.

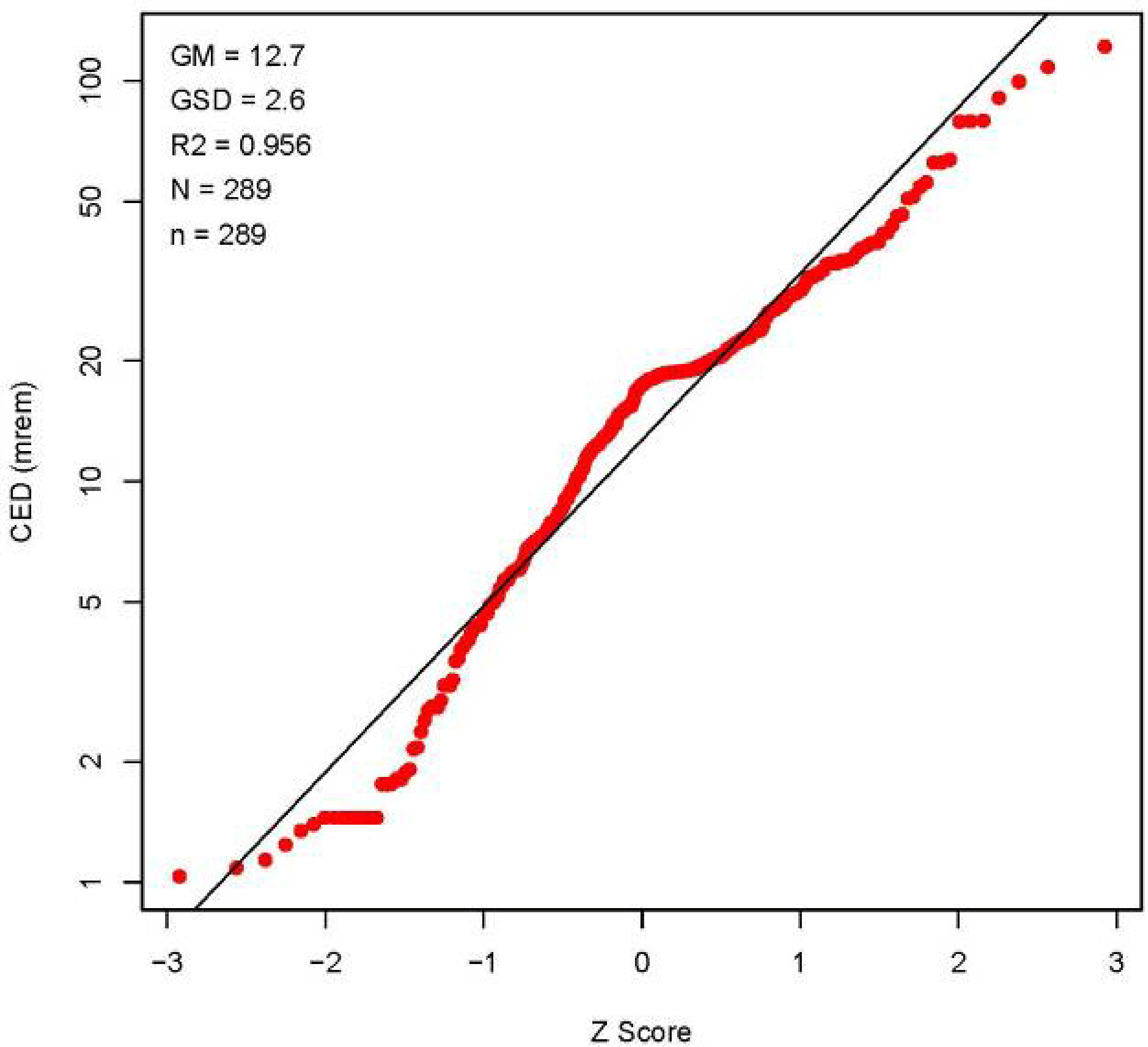

Figure B-88. SRS tritium dose 1983.

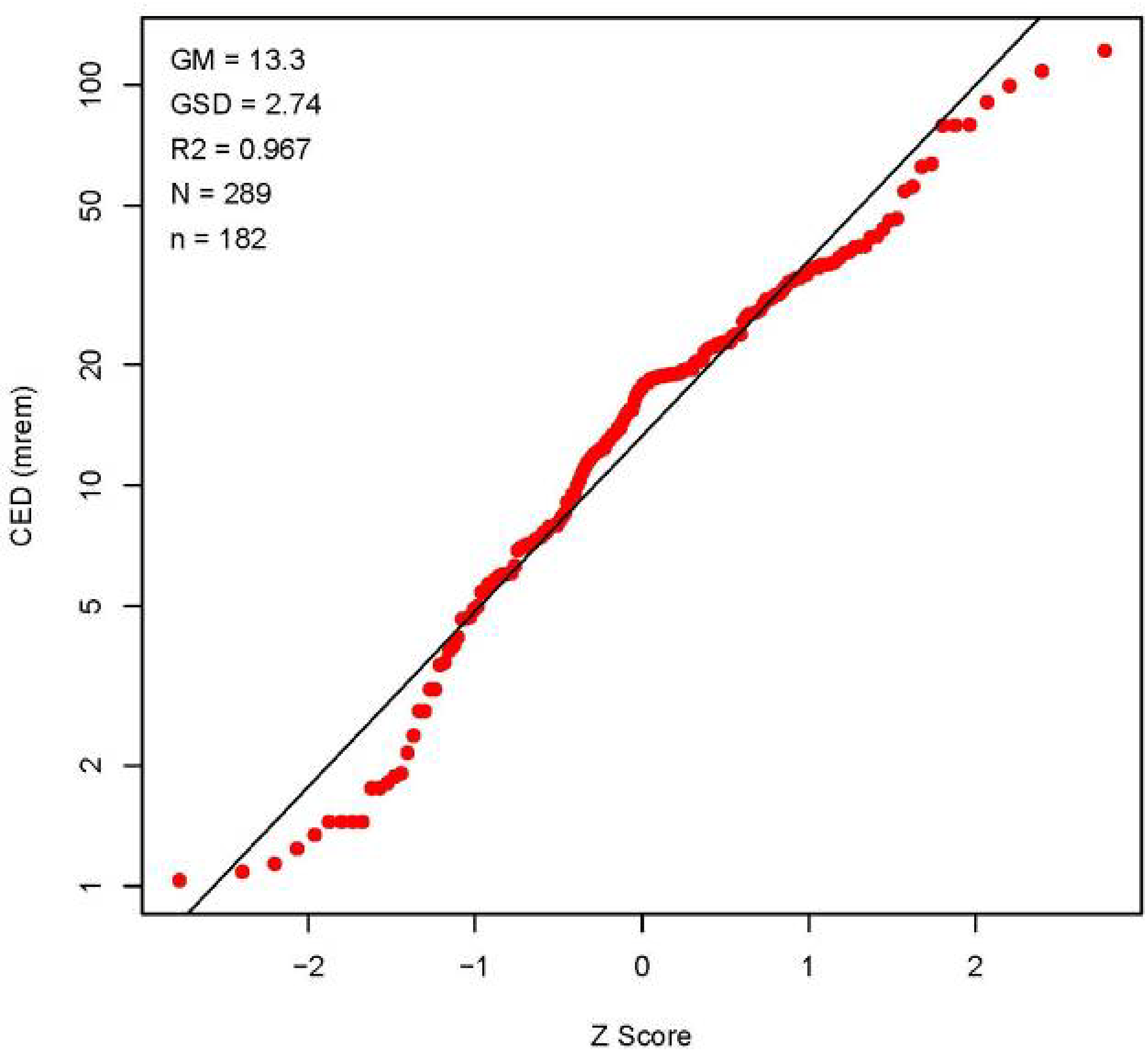

Figure B-89. SRS reactor tritium dose 1983.

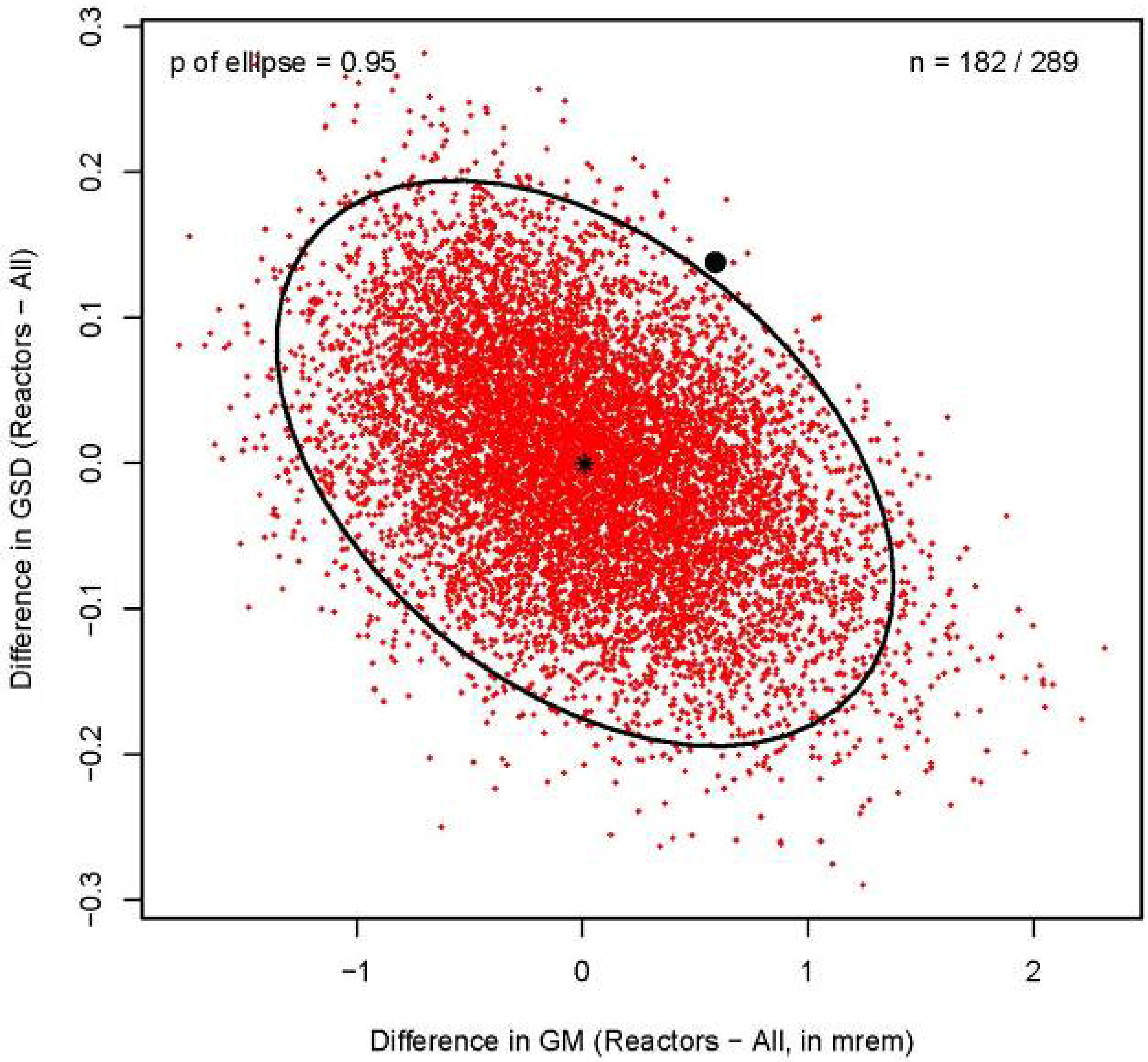

Figure B-90. SRS tritium dose 1983.

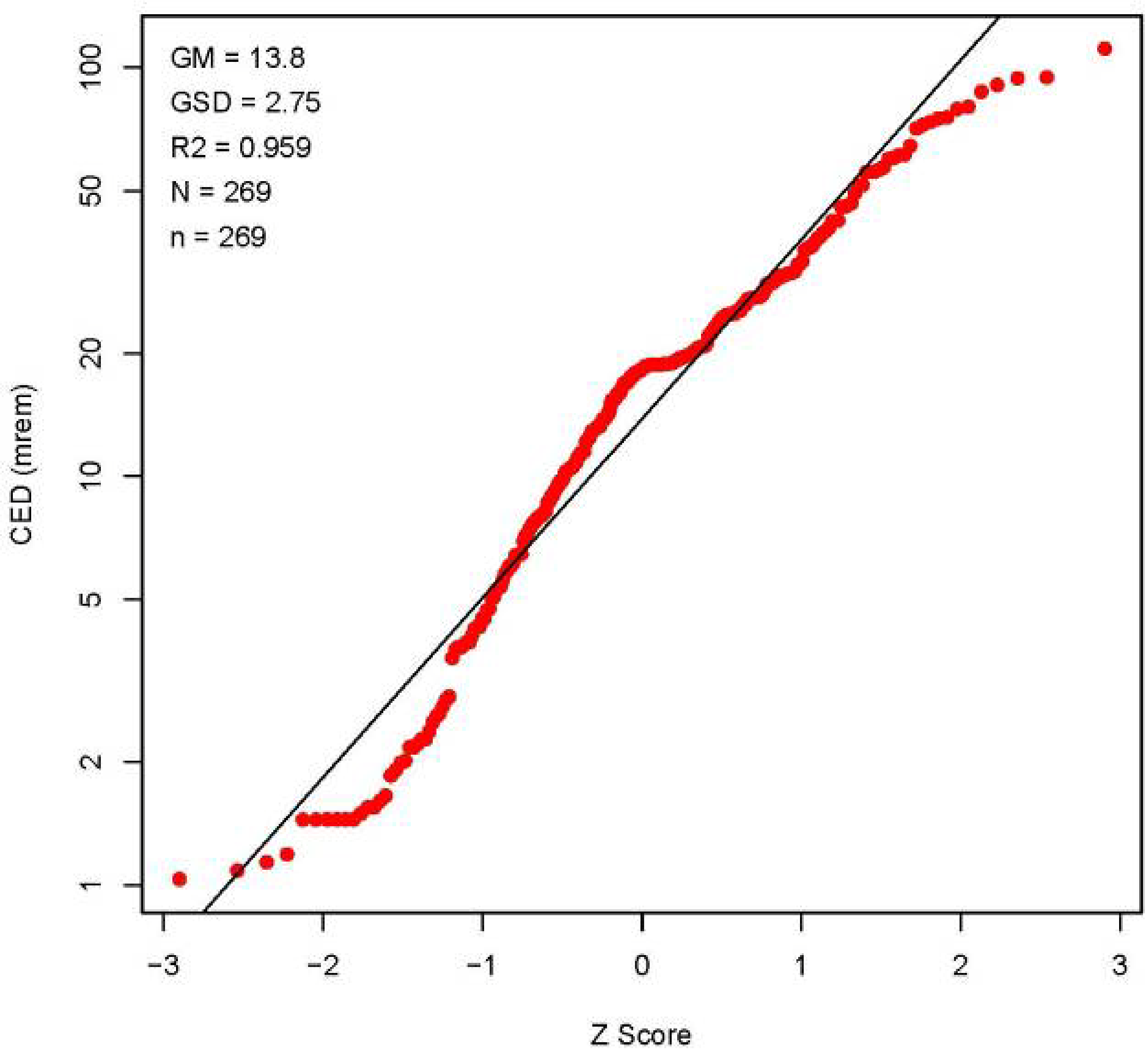

Figure B-91. SRS tritium dose 1984.

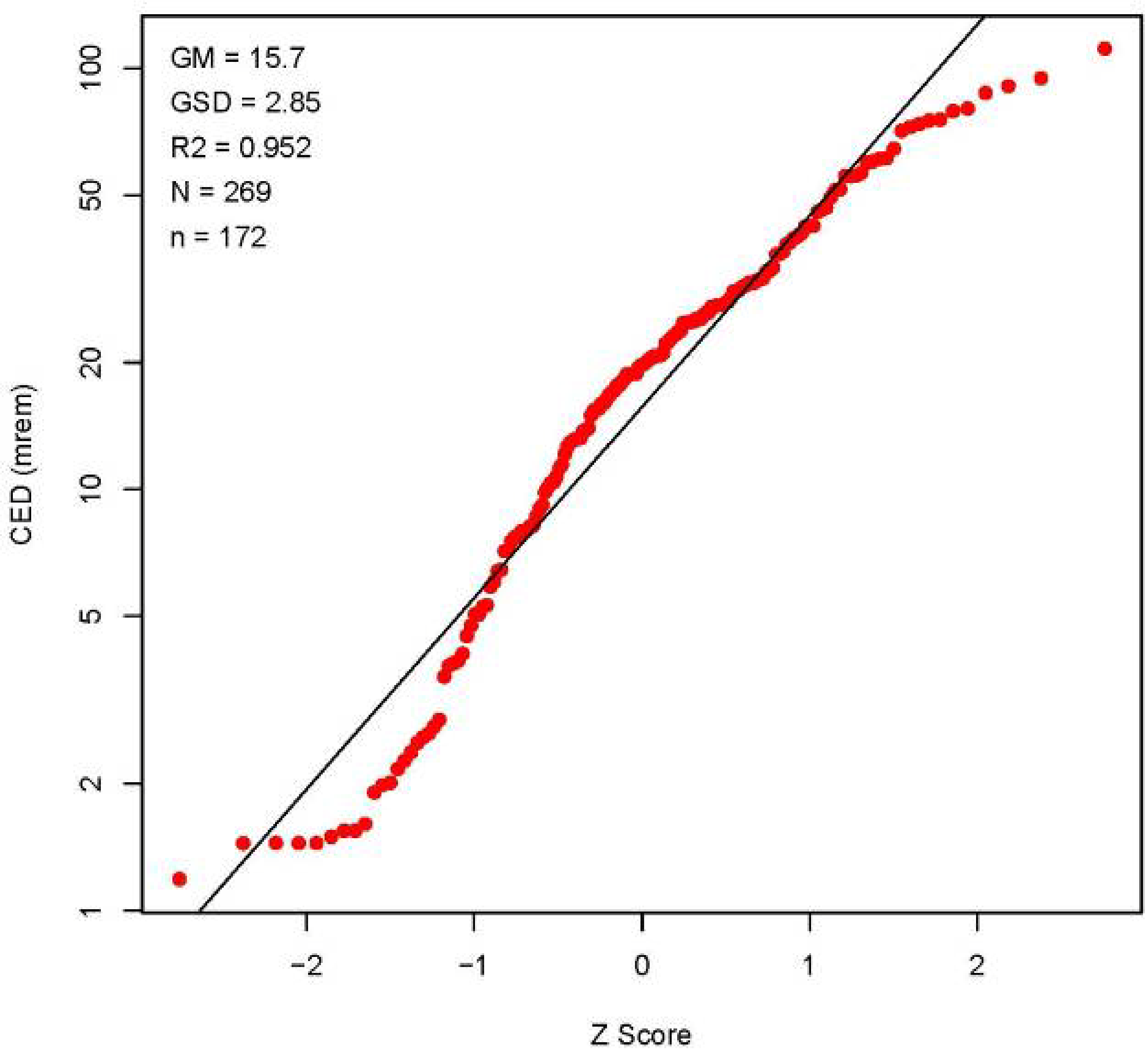

Figure B-92. SRS reactor tritium dose 1984.

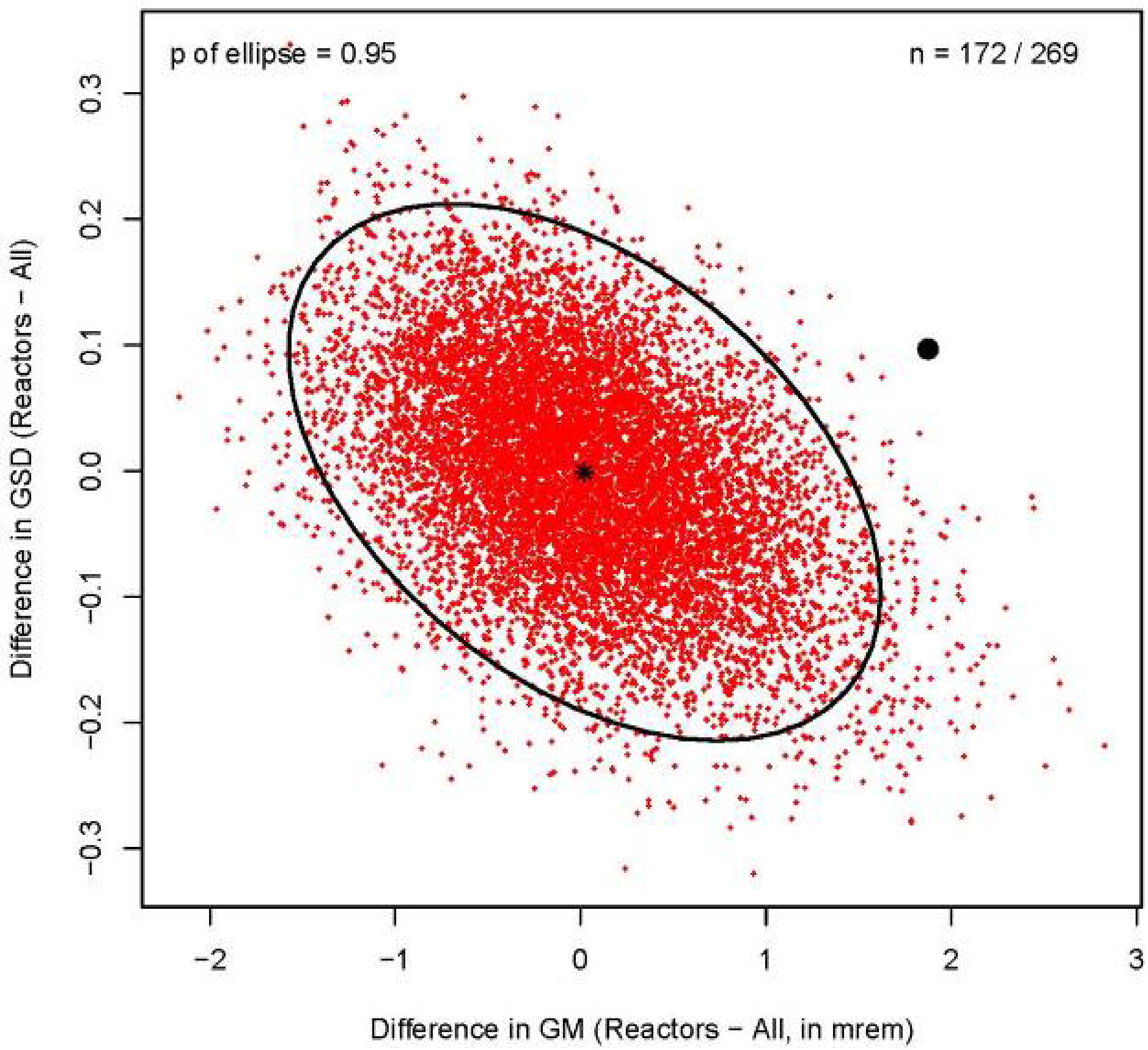

Figure B-93. SRS tritium dose 1984.

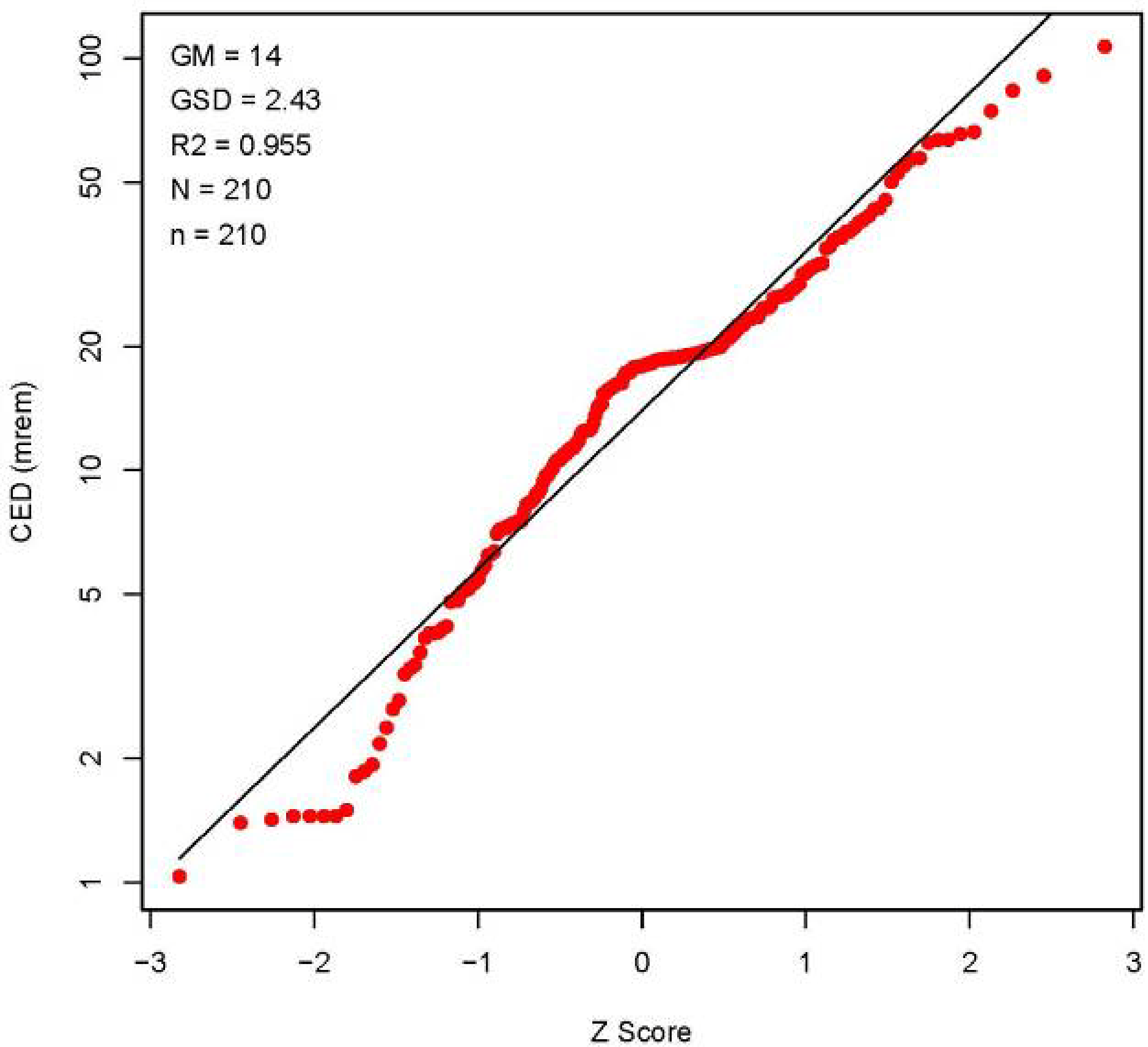

Figure B-94. SRS tritium dose 1985.

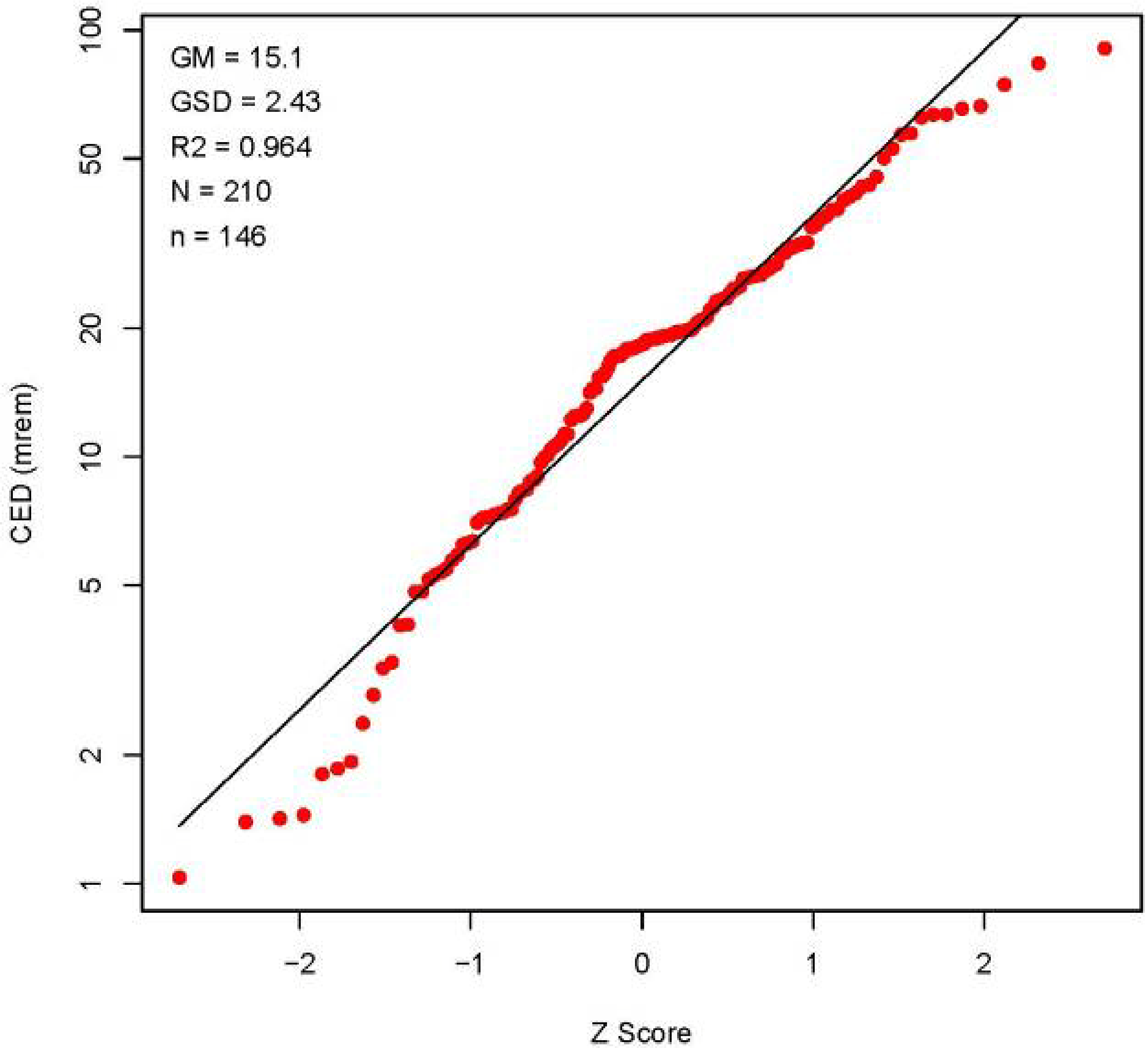

Figure B-95. SRS reactor tritium dose 1985.

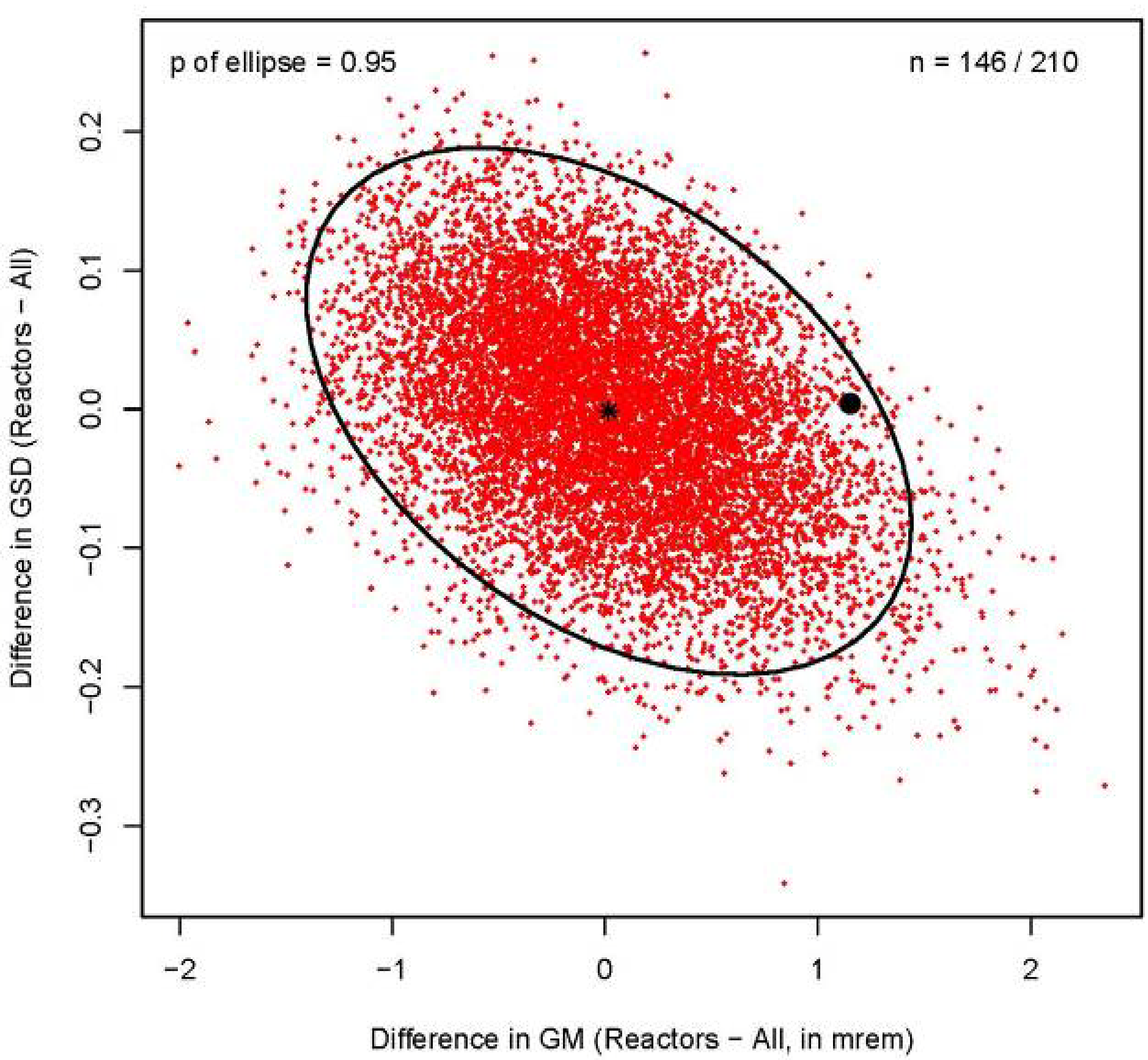

Figure B-96. SRS tritium dose 1985.

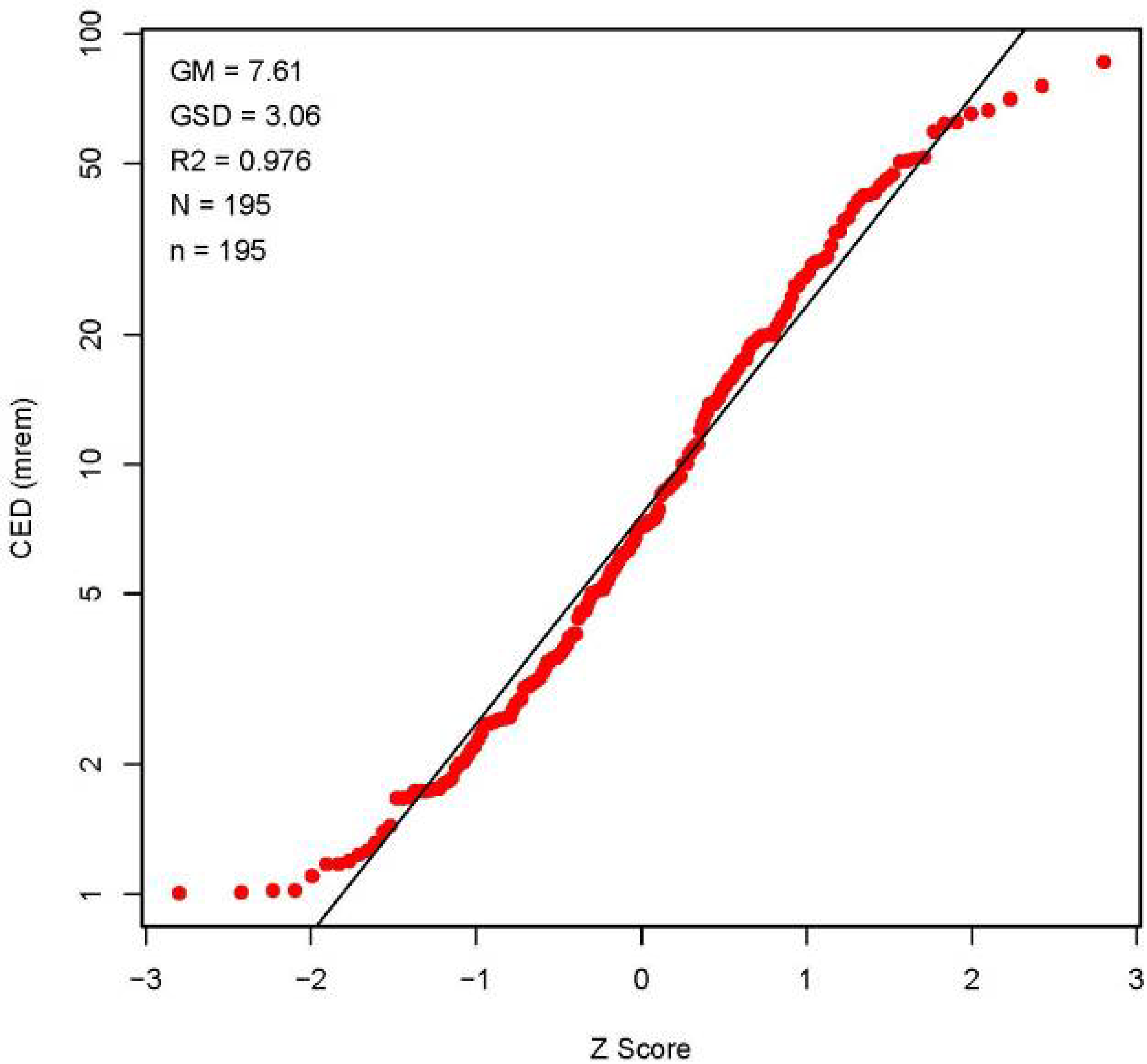

Figure B-97. SRS tritium dose 1986.

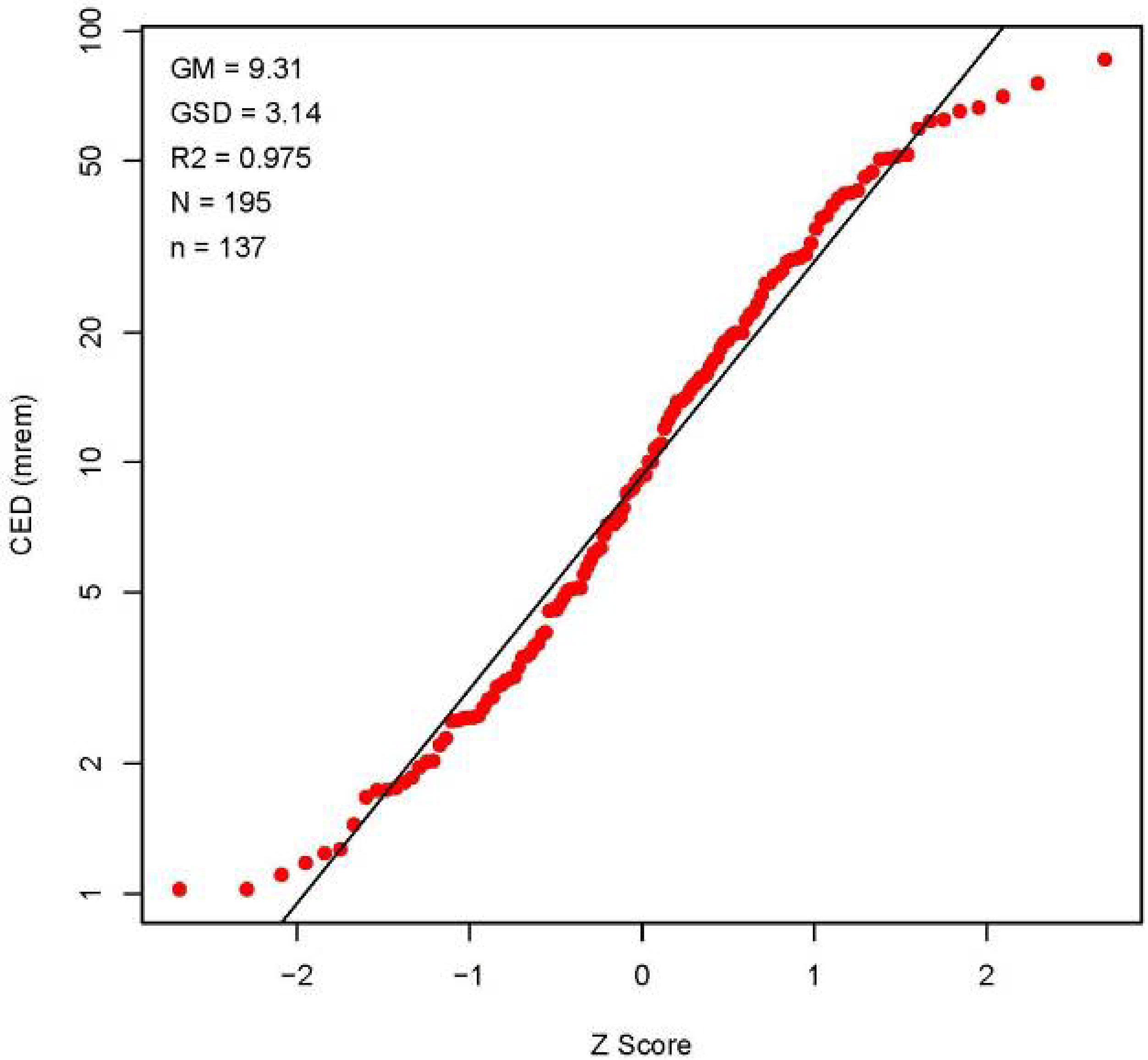

Figure B-98. SRS reactor tritium dose 1986.

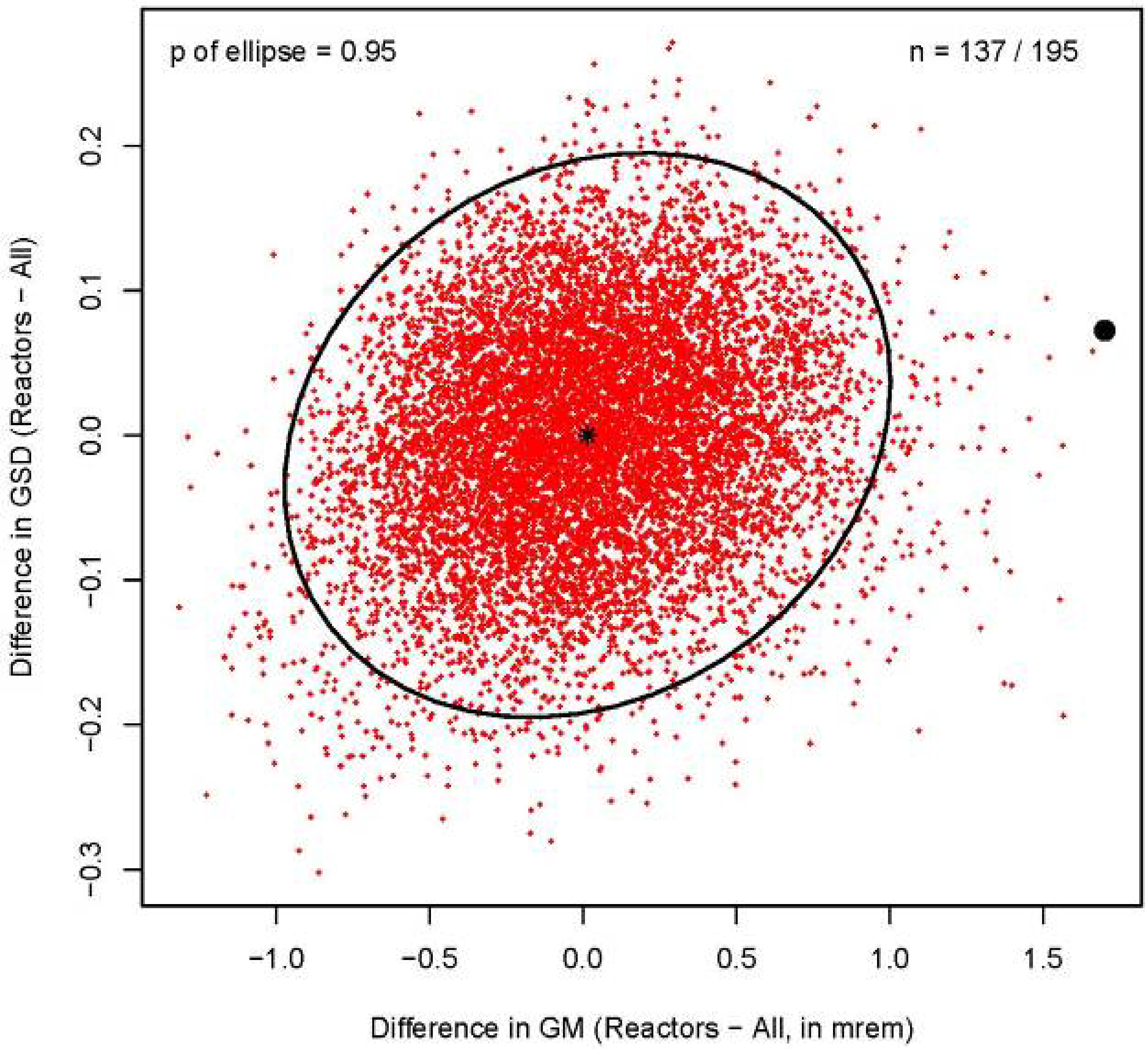

Figure B-99. SRS tritium dose 1986.

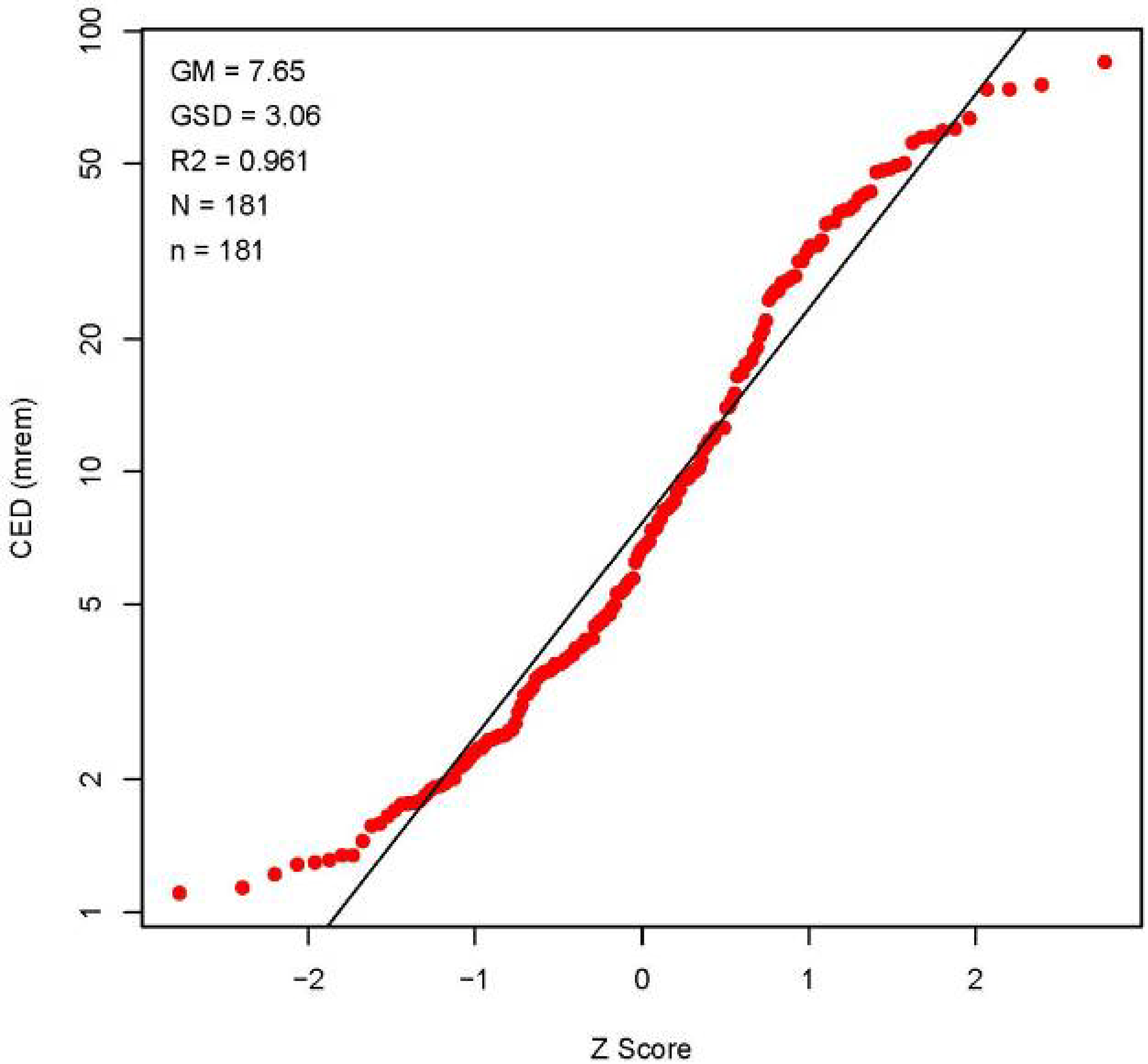

Figure B-100. SRS tritium dose 1987.

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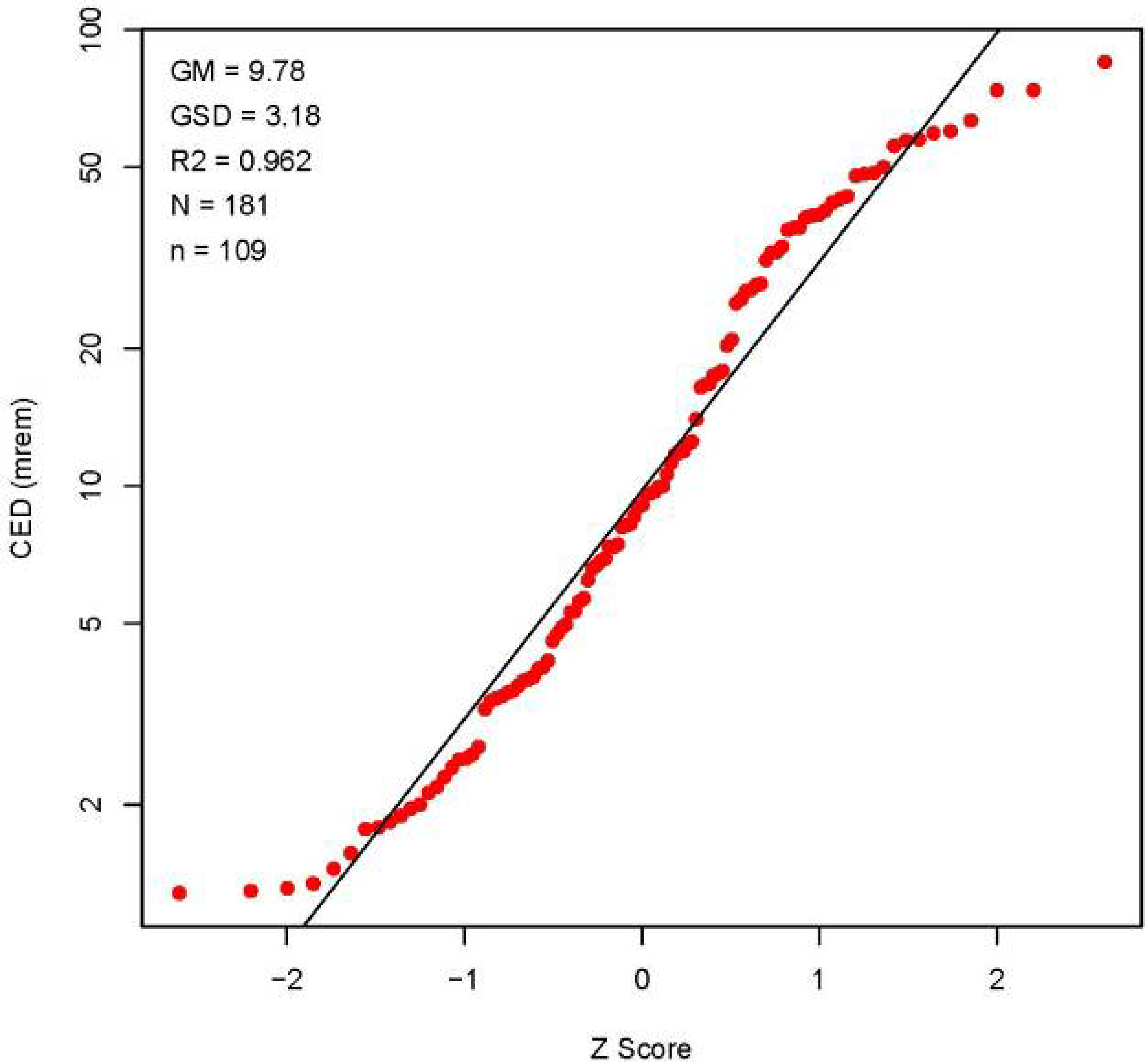

Figure B-101. SRS reactor tritium dose 1987.

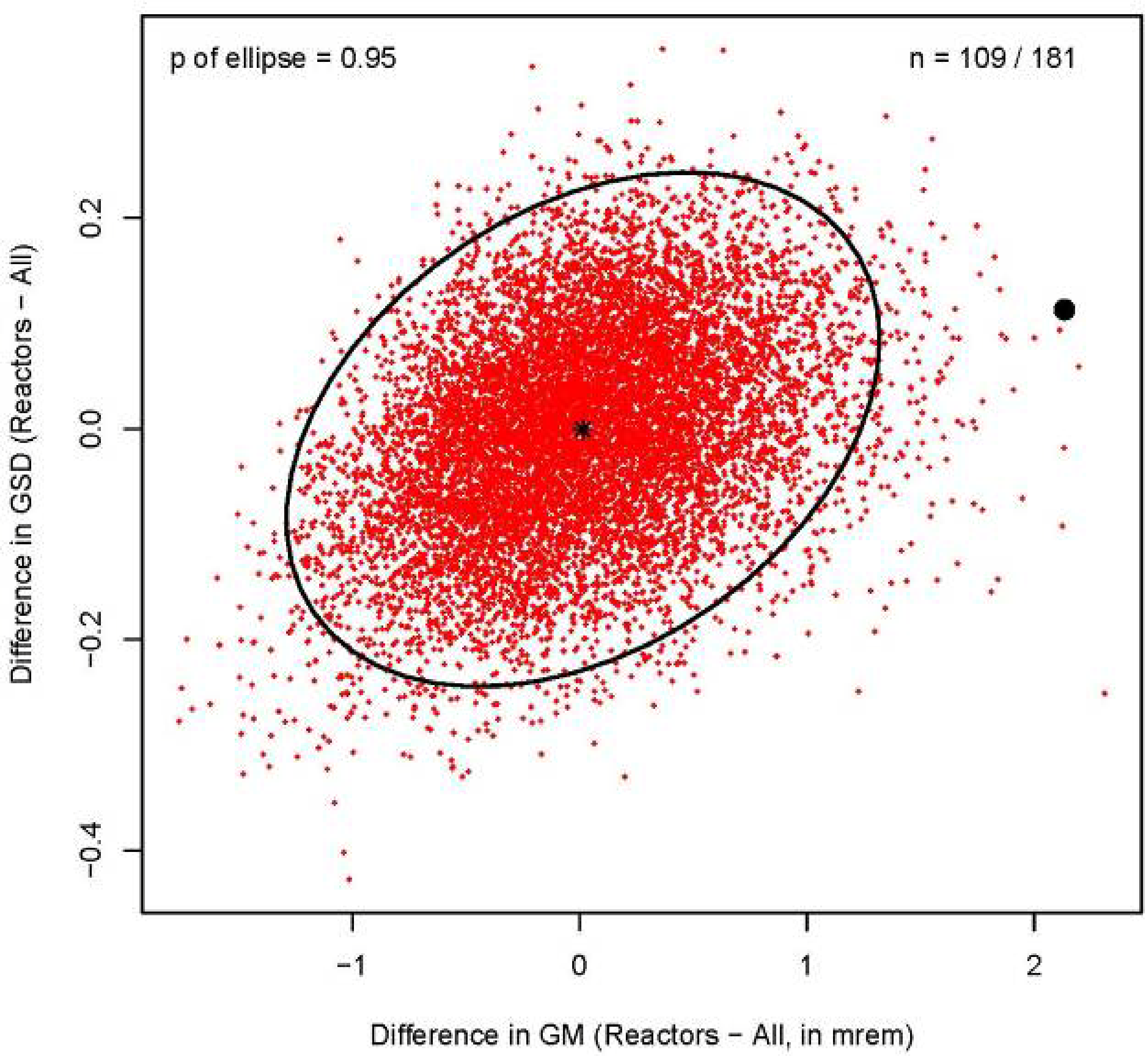

Figure B-102. SRS tritium dose 1987.

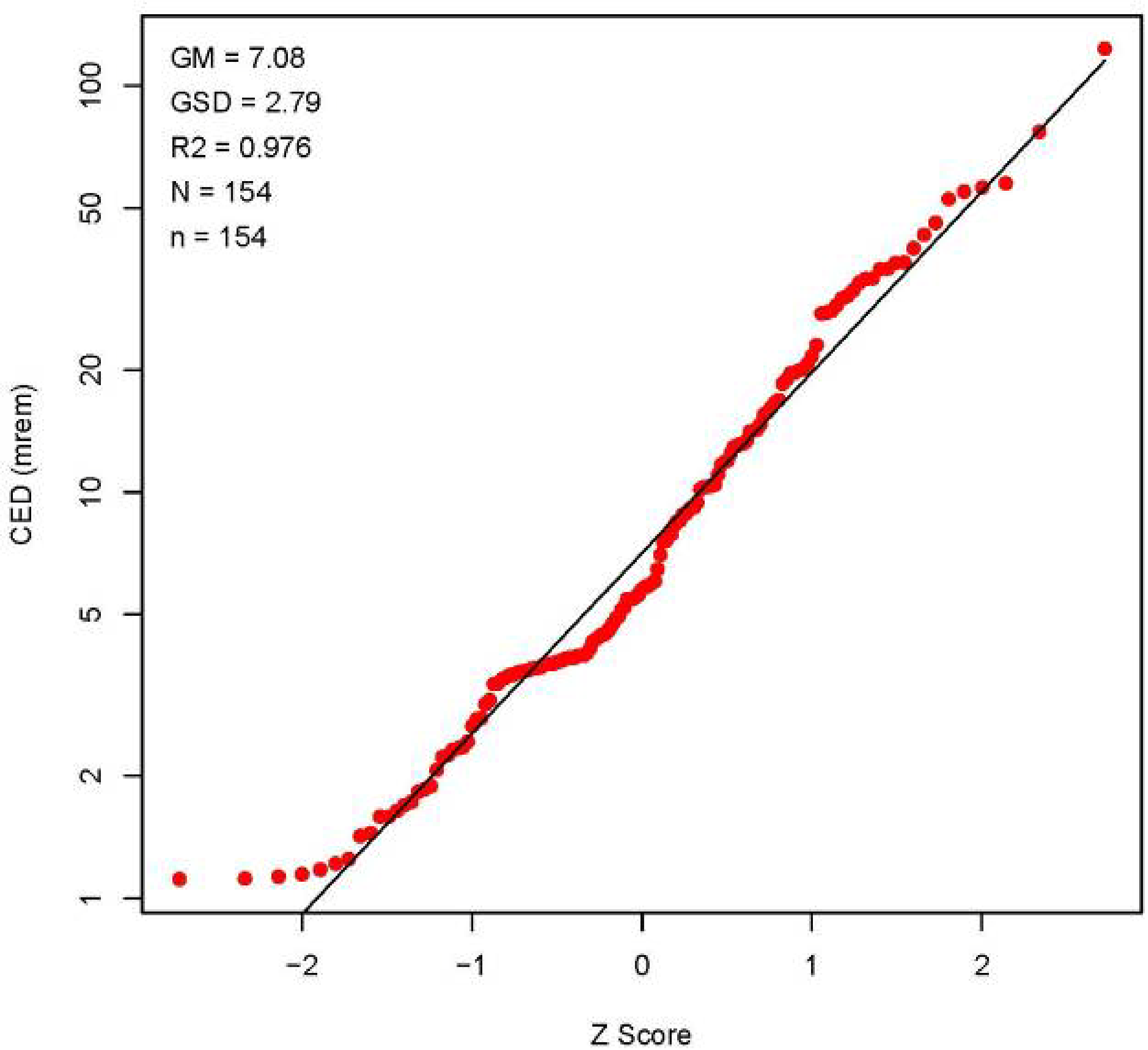

Figure B-103. SRS tritium dose 1988.

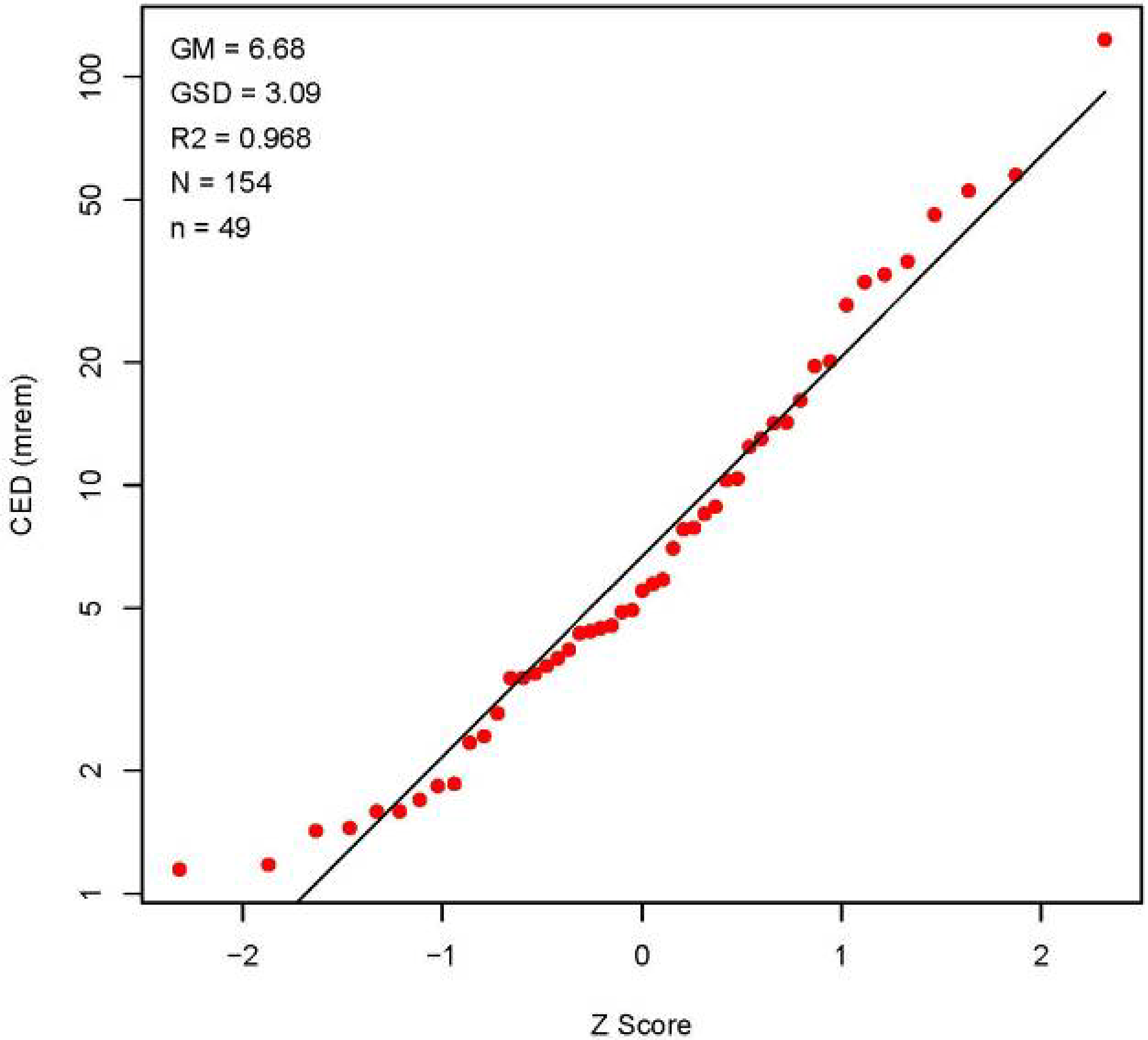

Figure B-104. SRS reactor tritium dose 1988.

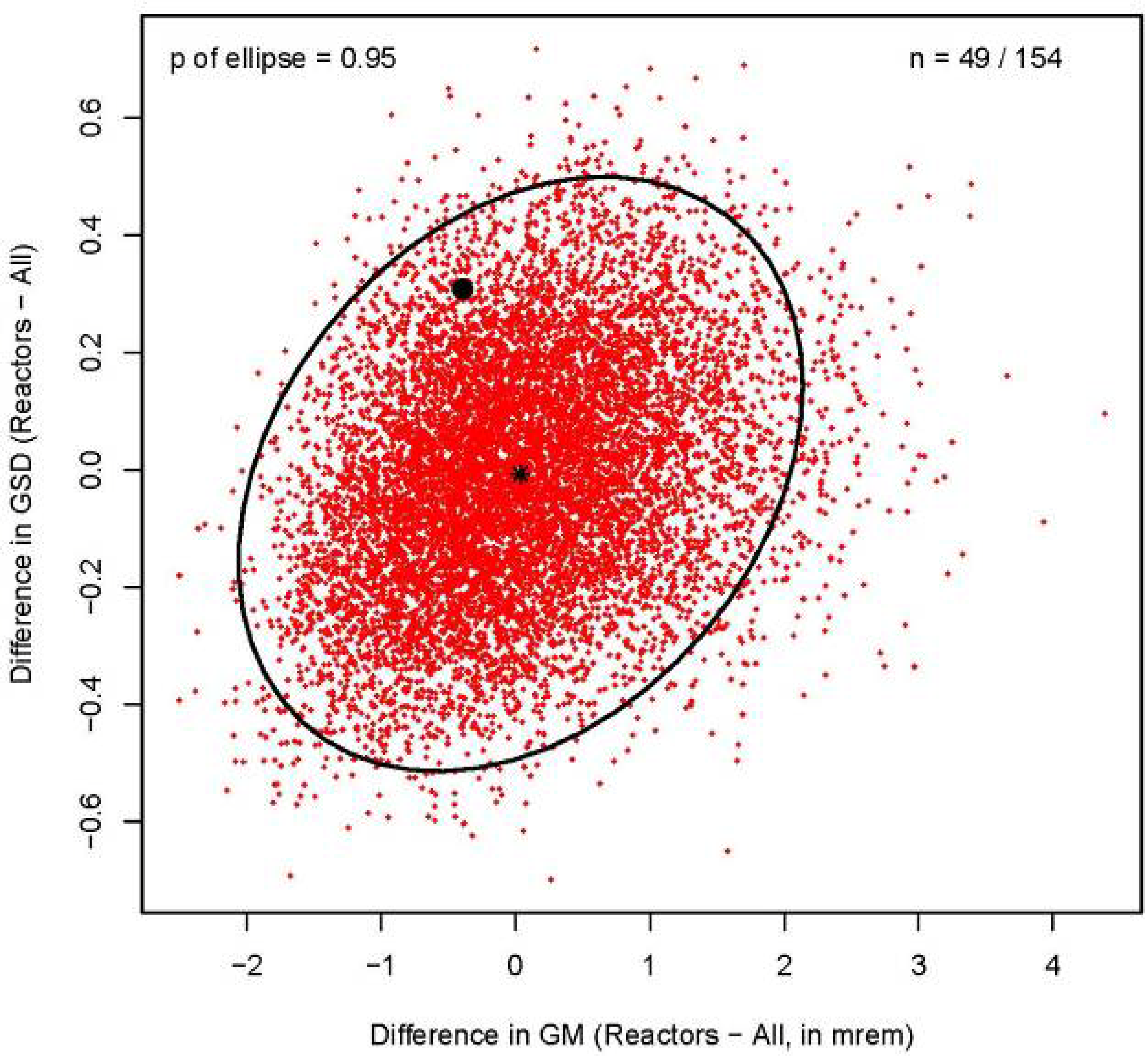

Figure B-105. SRS tritium dose 1988.

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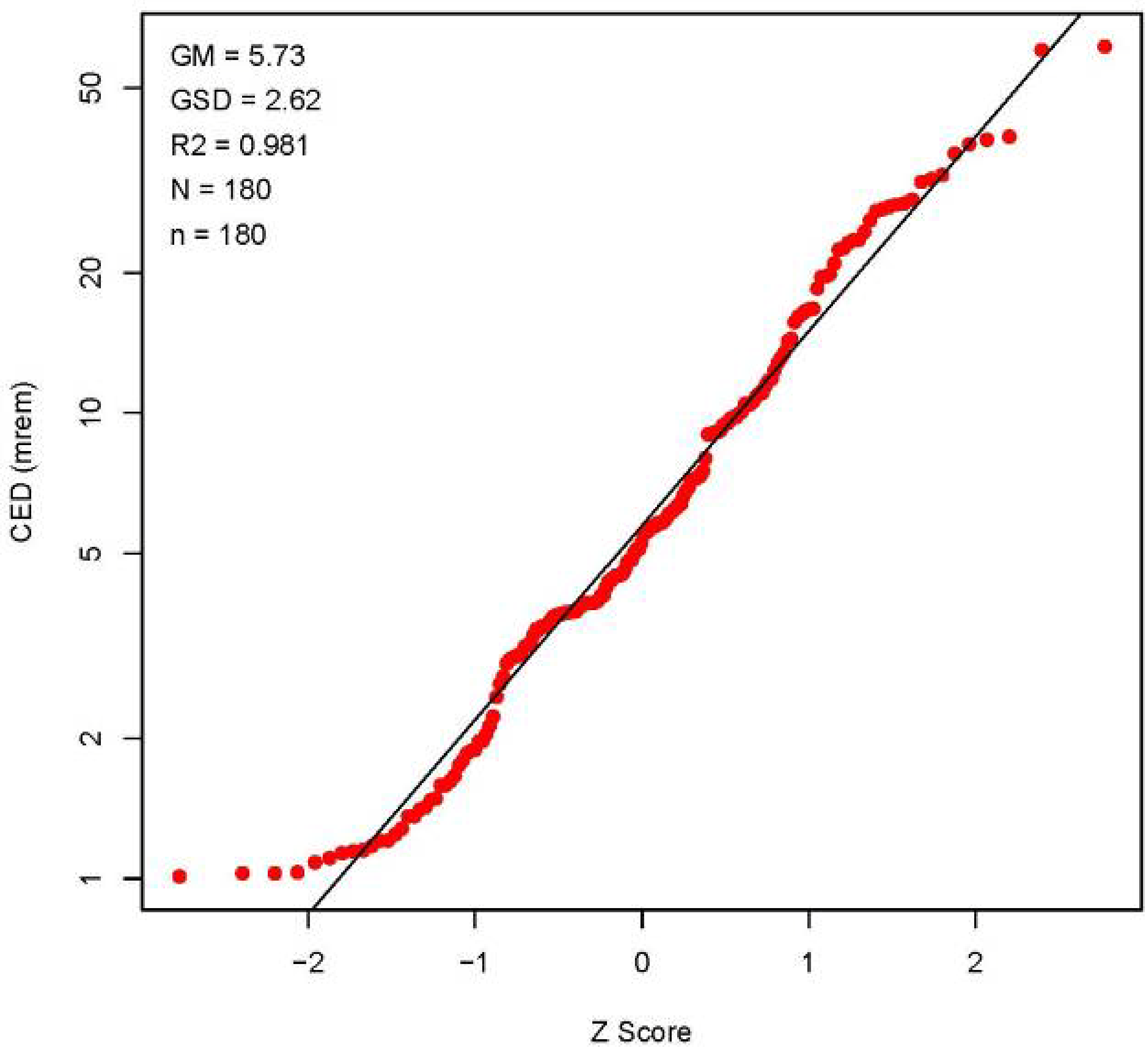

Figure B-106. SRS tritium dose 1989.

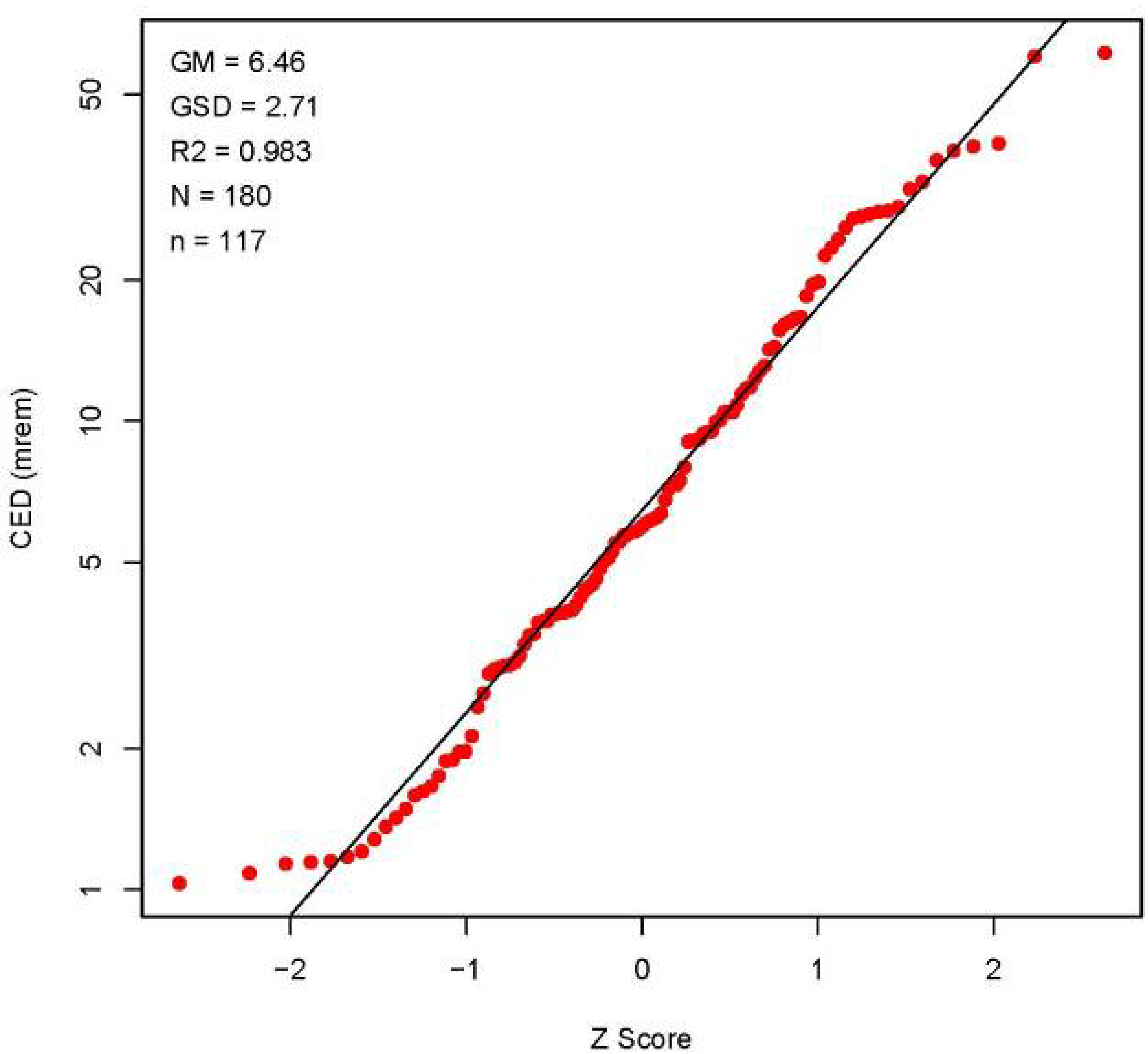

Figure B-107. SRS reactor tritium dose 1989.

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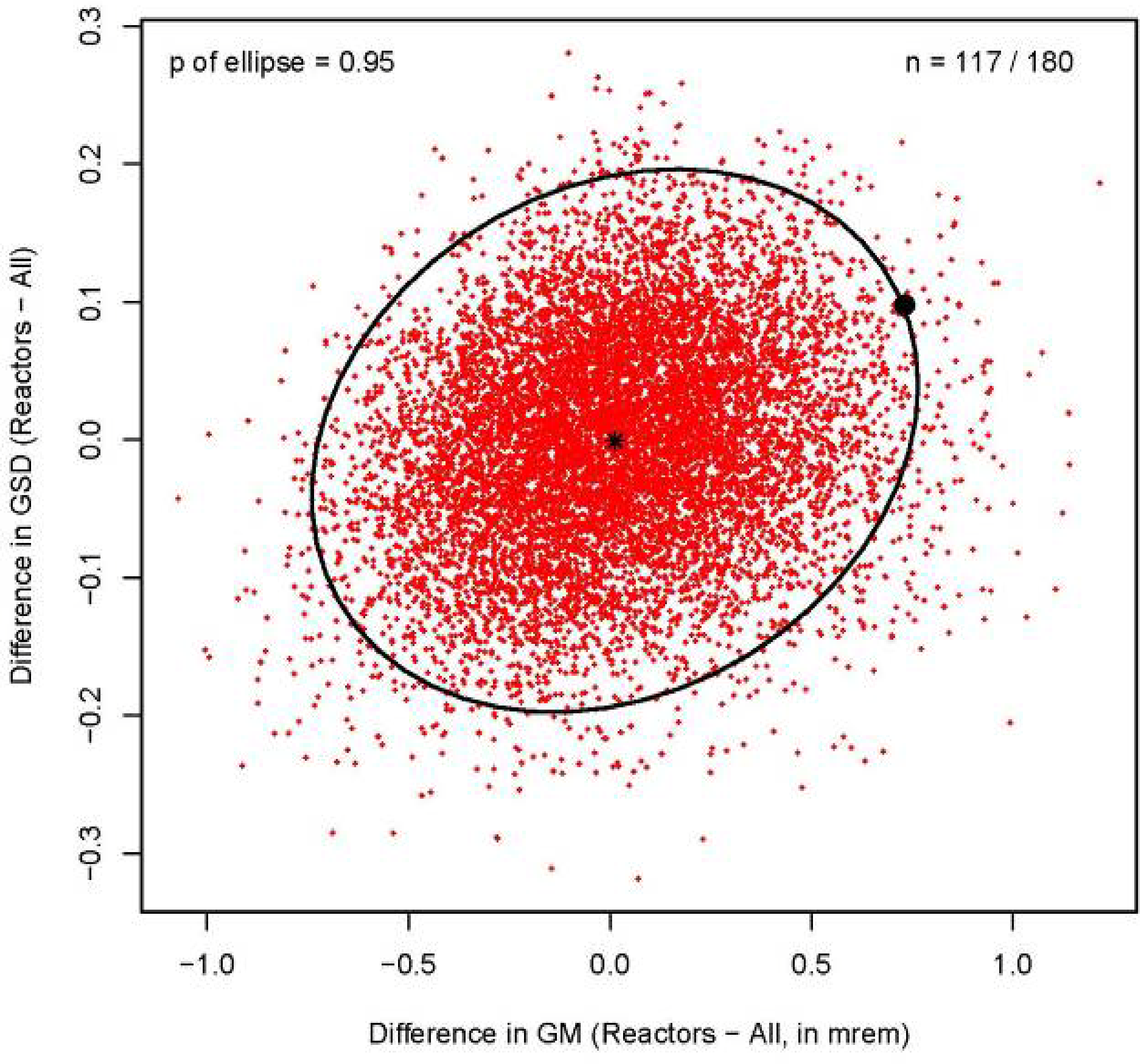

Figure B-108. SRS tritium dose 1989.

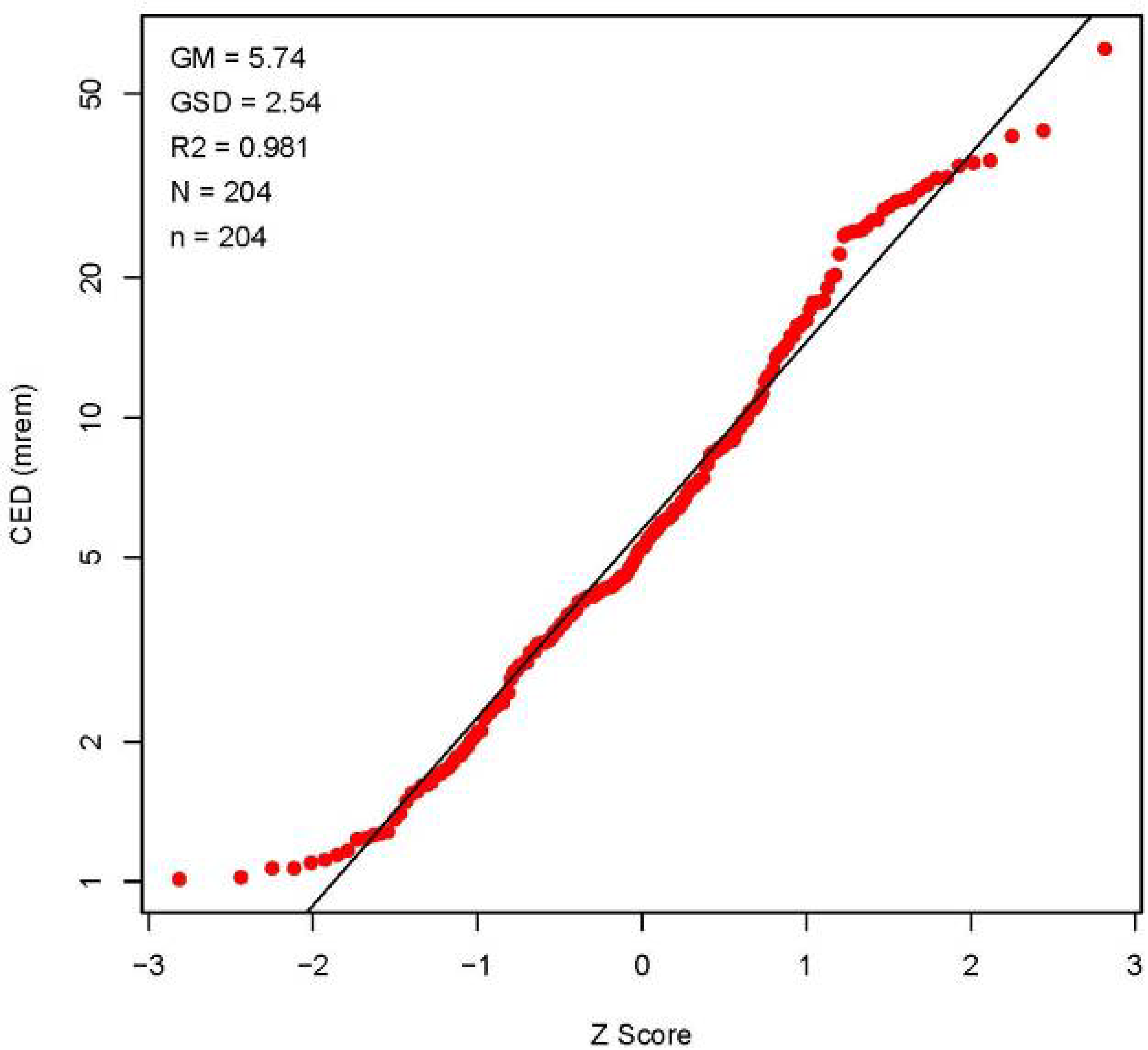

Figure B-109. SRS tritium dose 1990.

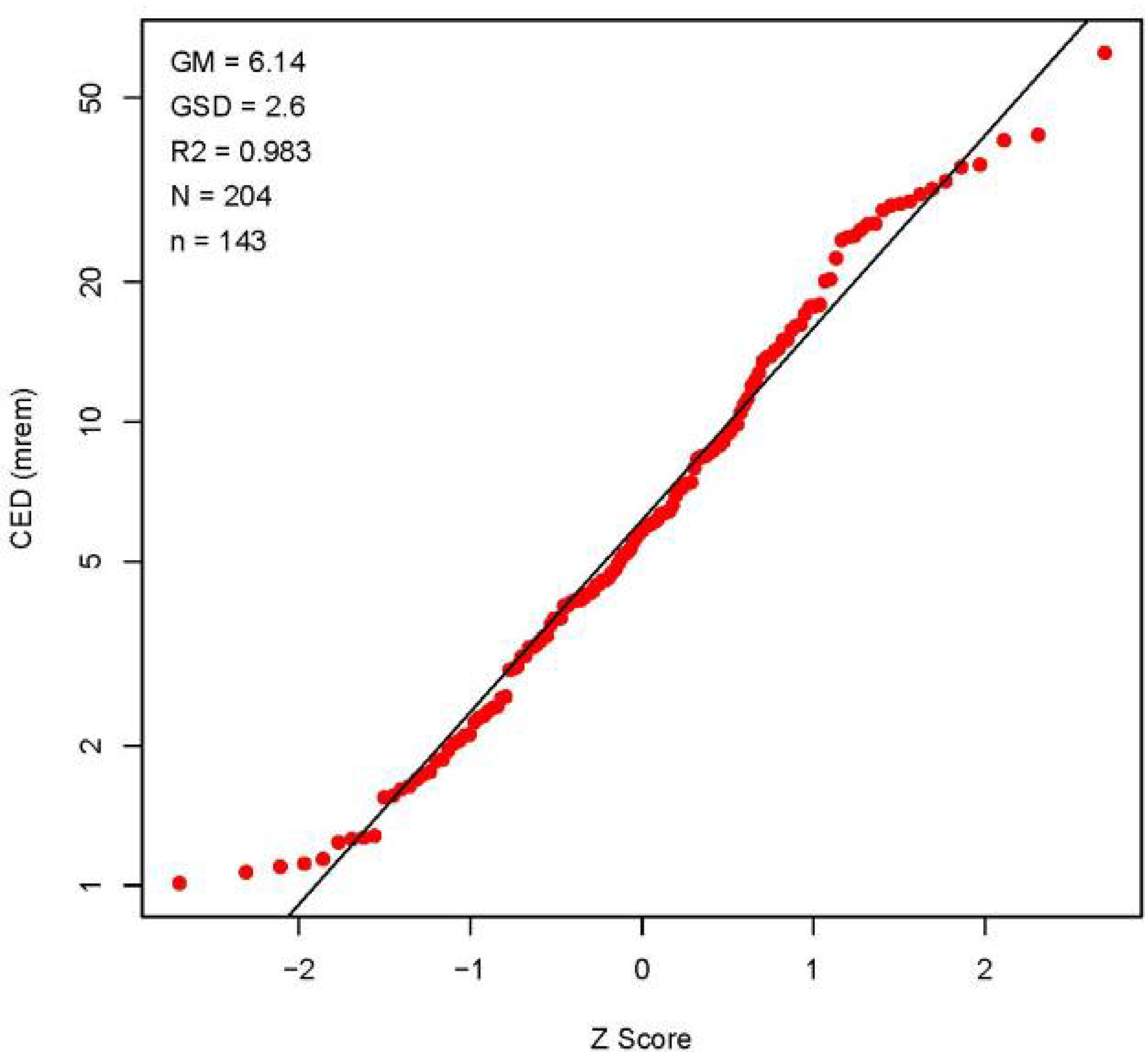

Figure B-110. SRS reactor tritium dose 1990.

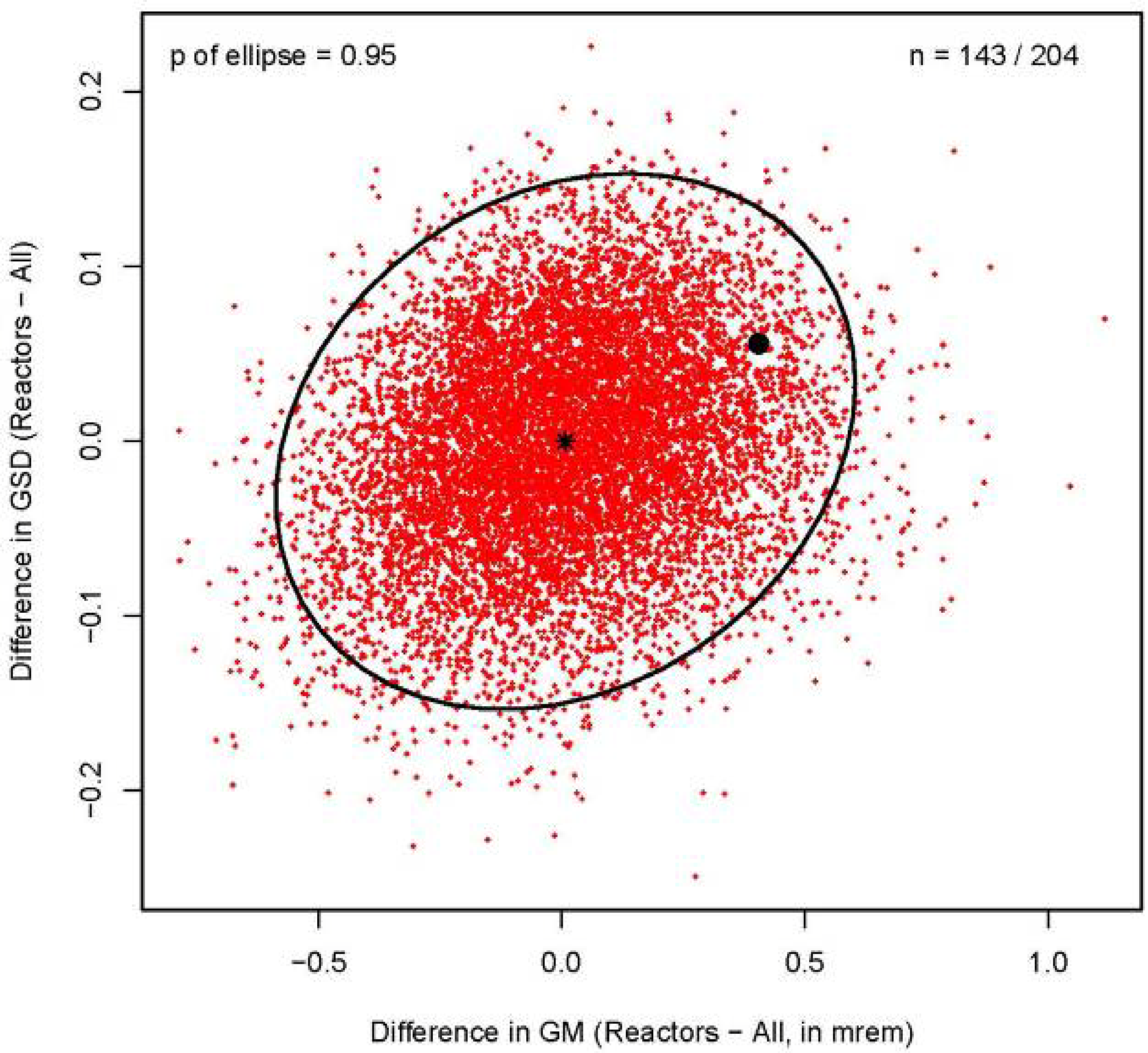

Figure B-111. SRS tritium dose 1990.

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There are three plots for each year from 1954 through 1990. The first two are lognormal probability plots of the tritium doses for the CS of workers and the CTWs who worked in the reactor areas (CTW/reactor). In these plots the following statistics are presented:

- GM = geometric mean of data (intercept of line)
- GSD = geometric standard deviation of data (slope of line)
- R2 = coefficient of determination for regression line
- N = total number of individuals in CS
- n = total number of individuals in CTW/reactor group

The third plot for a given year is a Monte Carlo permutation plot comparing the test statistics of 10,000 random samples from the CS to the observed test statistic for the CTW/reactor (the large black dot). An ellipse is constructed that contains 95% of the test statistics. If the observed test statistic for the CTW/reactor lies outside the ellipse, the coworker model for the CTW/reactor is considered to be different than the coworker model for CS.

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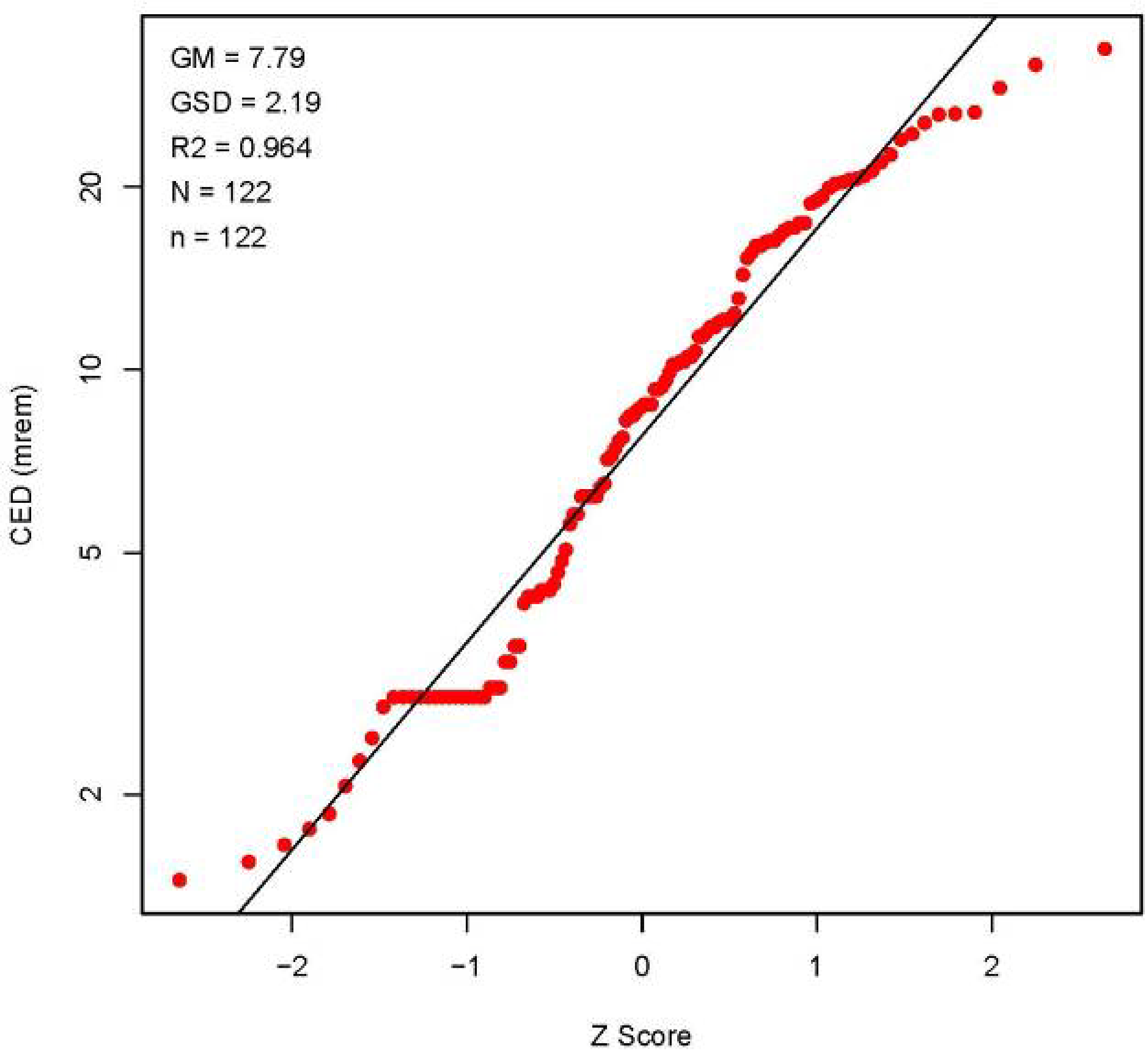

Figure C-1. SRS tritium dose 1954.

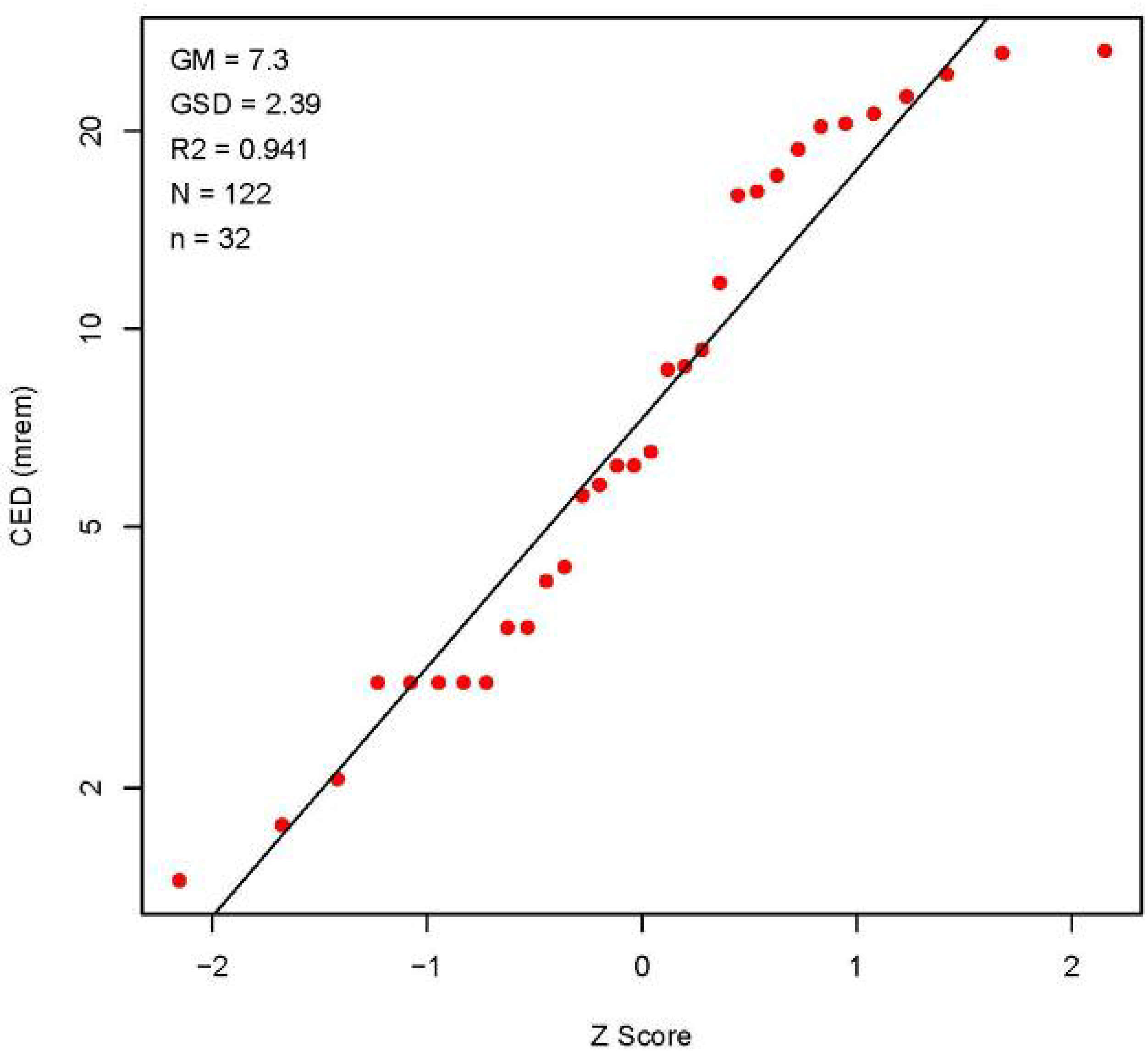

Figure C-2. SRS reactor/CTW tritium dose 1954.

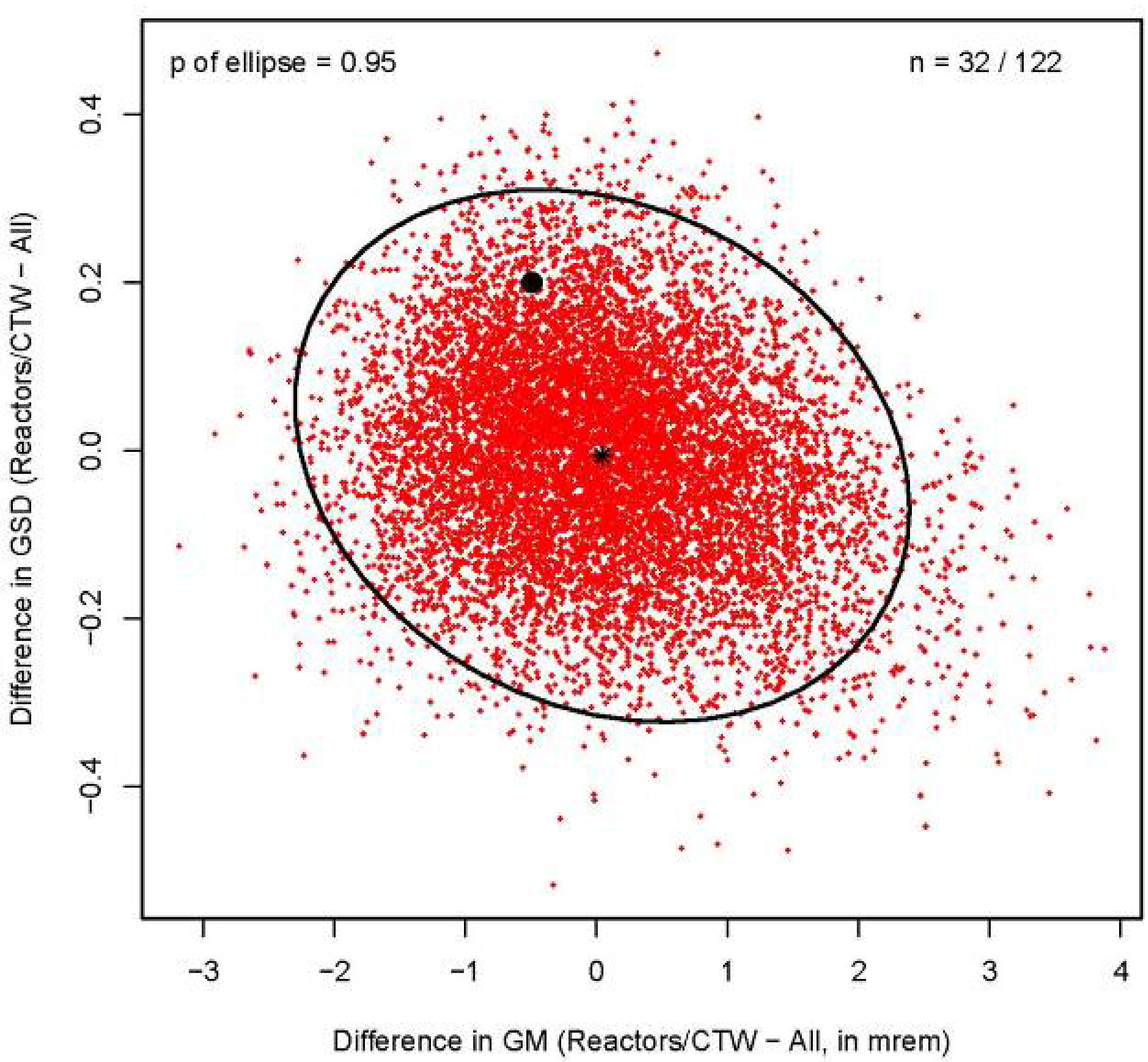

Figure C-3. SRS tritium dose 1954.

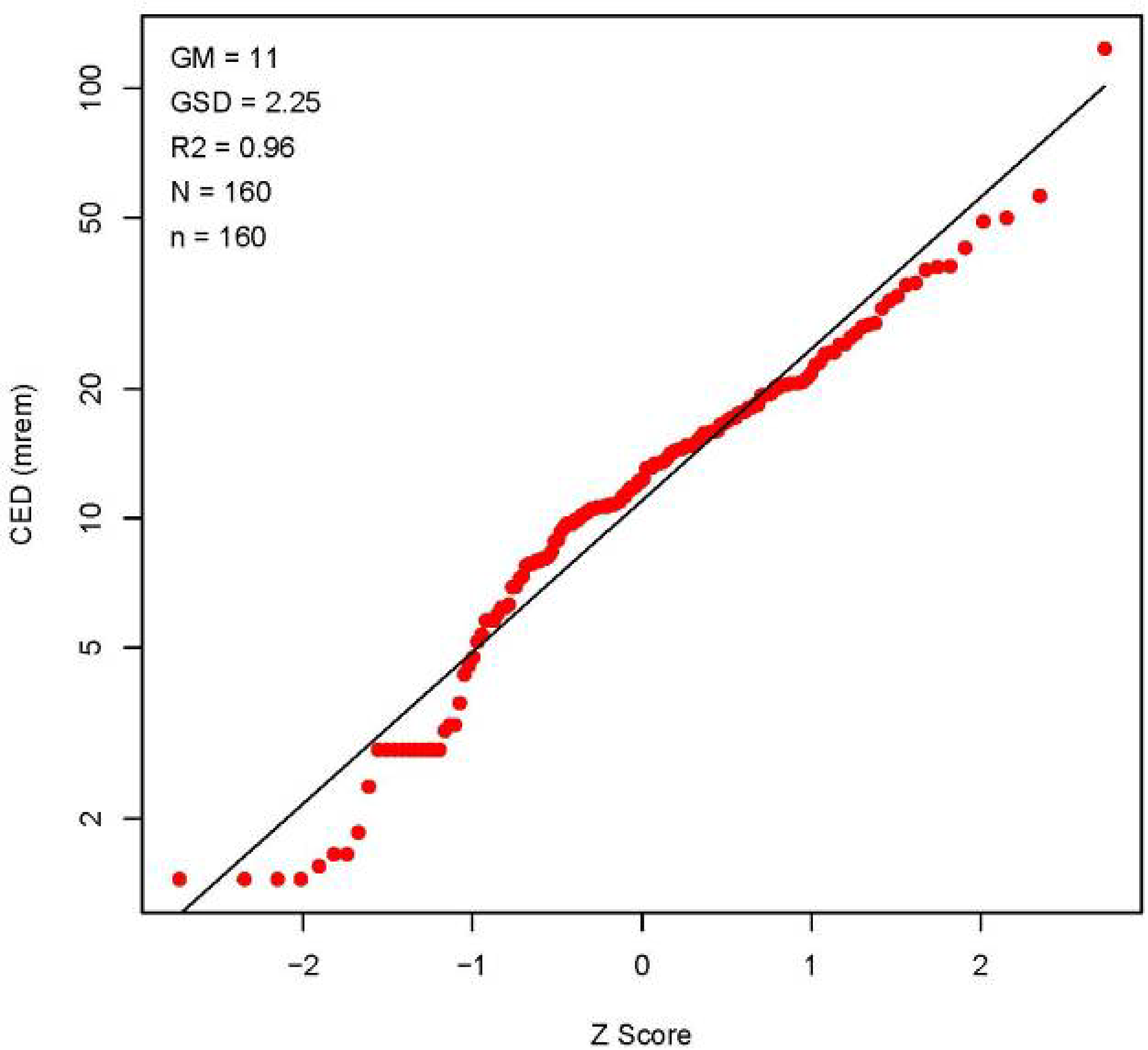

Figure C-4. SRS tritium dose 1955.

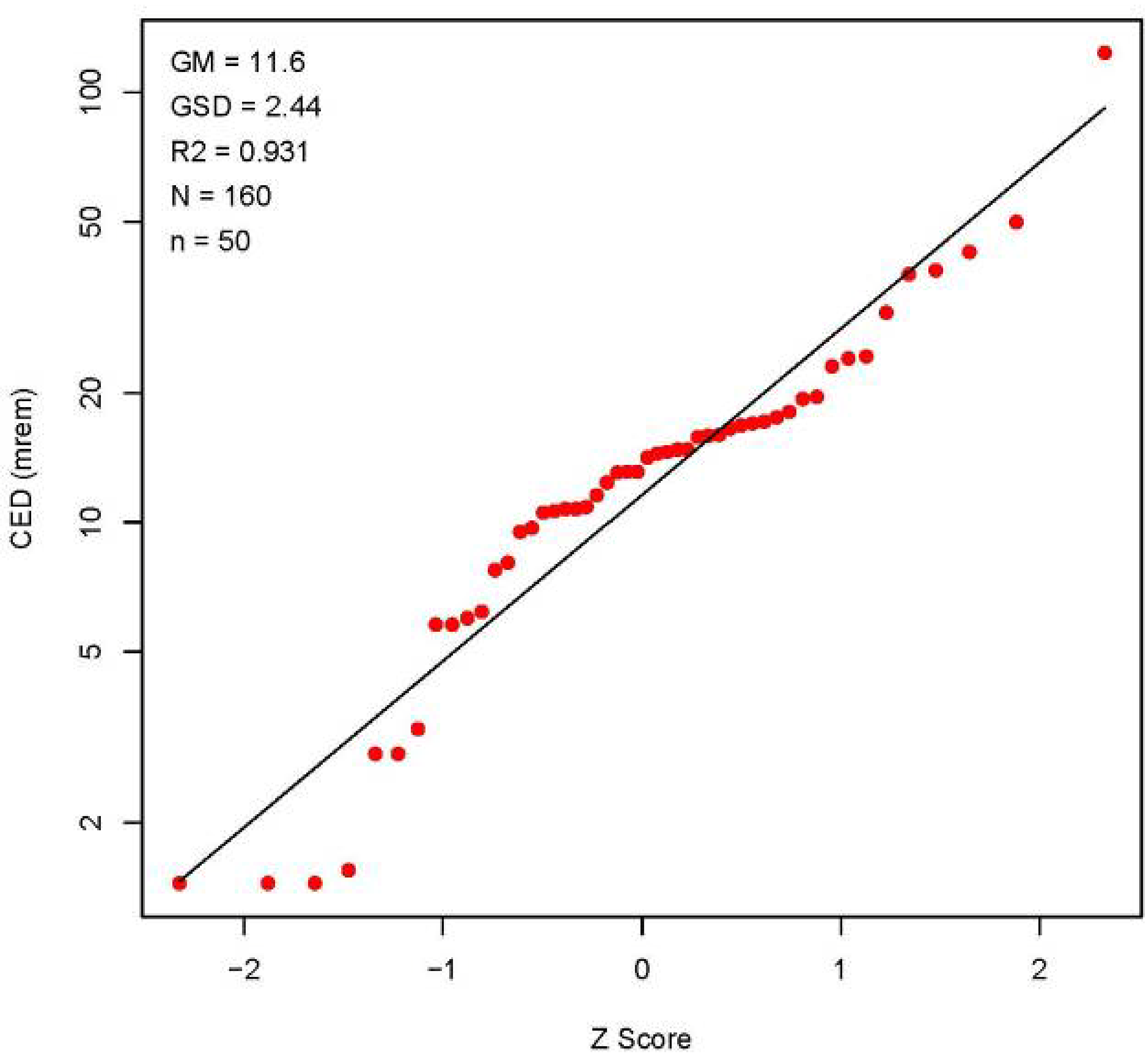

Figure C-5. SRS reactor/CTW tritium dose 1955.

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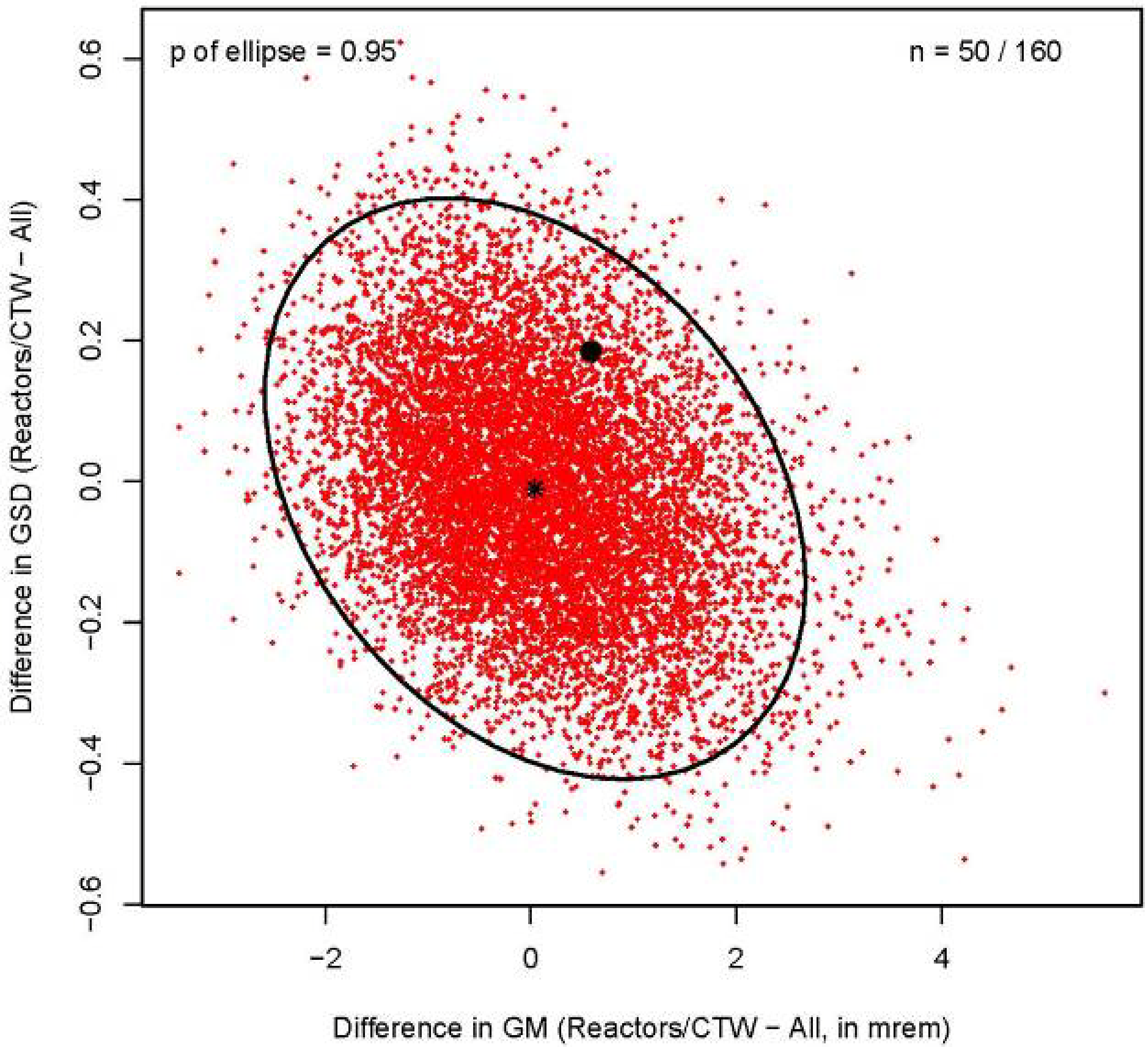

Figure C-6. SRS tritium dose 1955.

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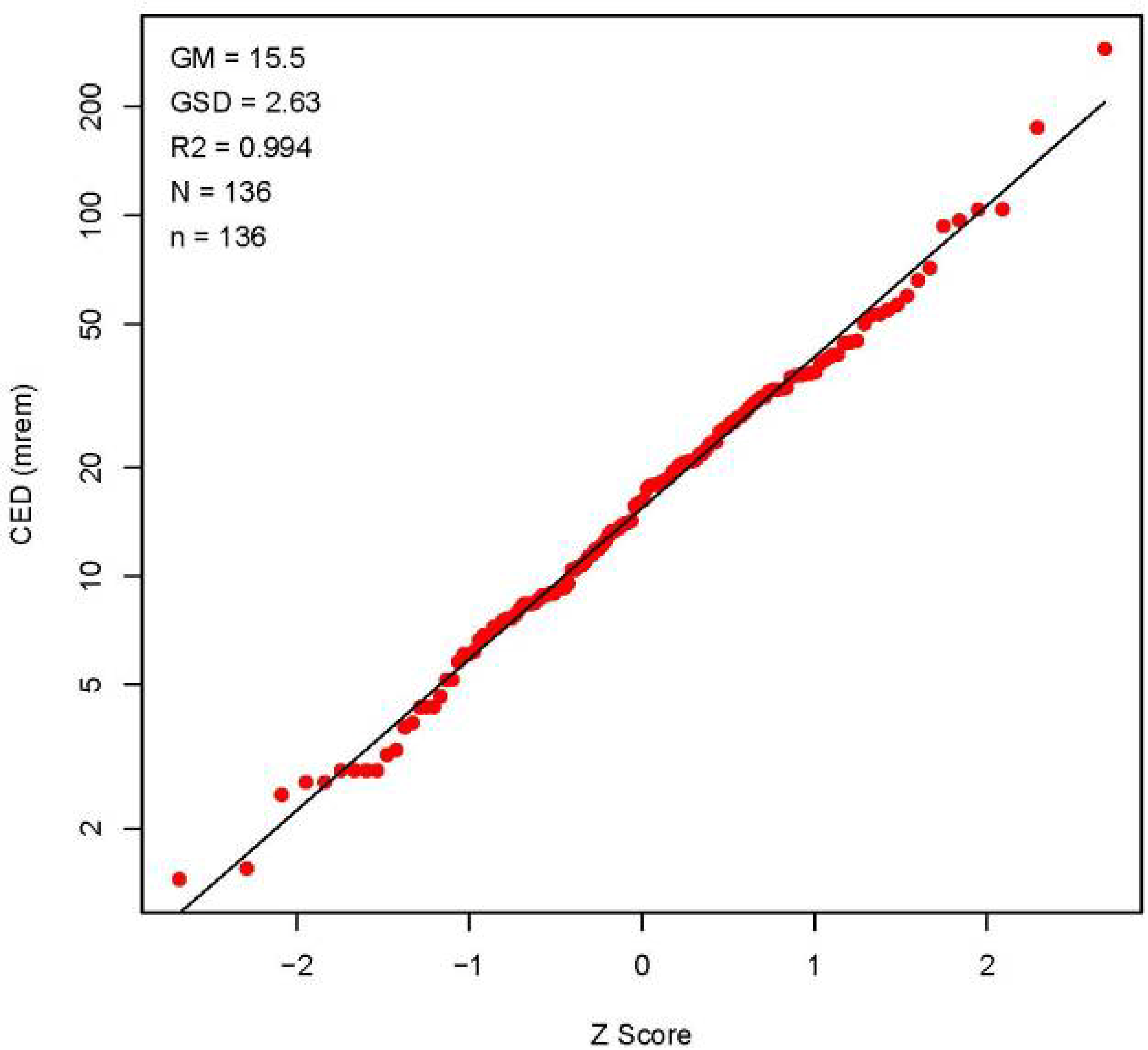

Figure C-7. SRS tritium dose 1956.

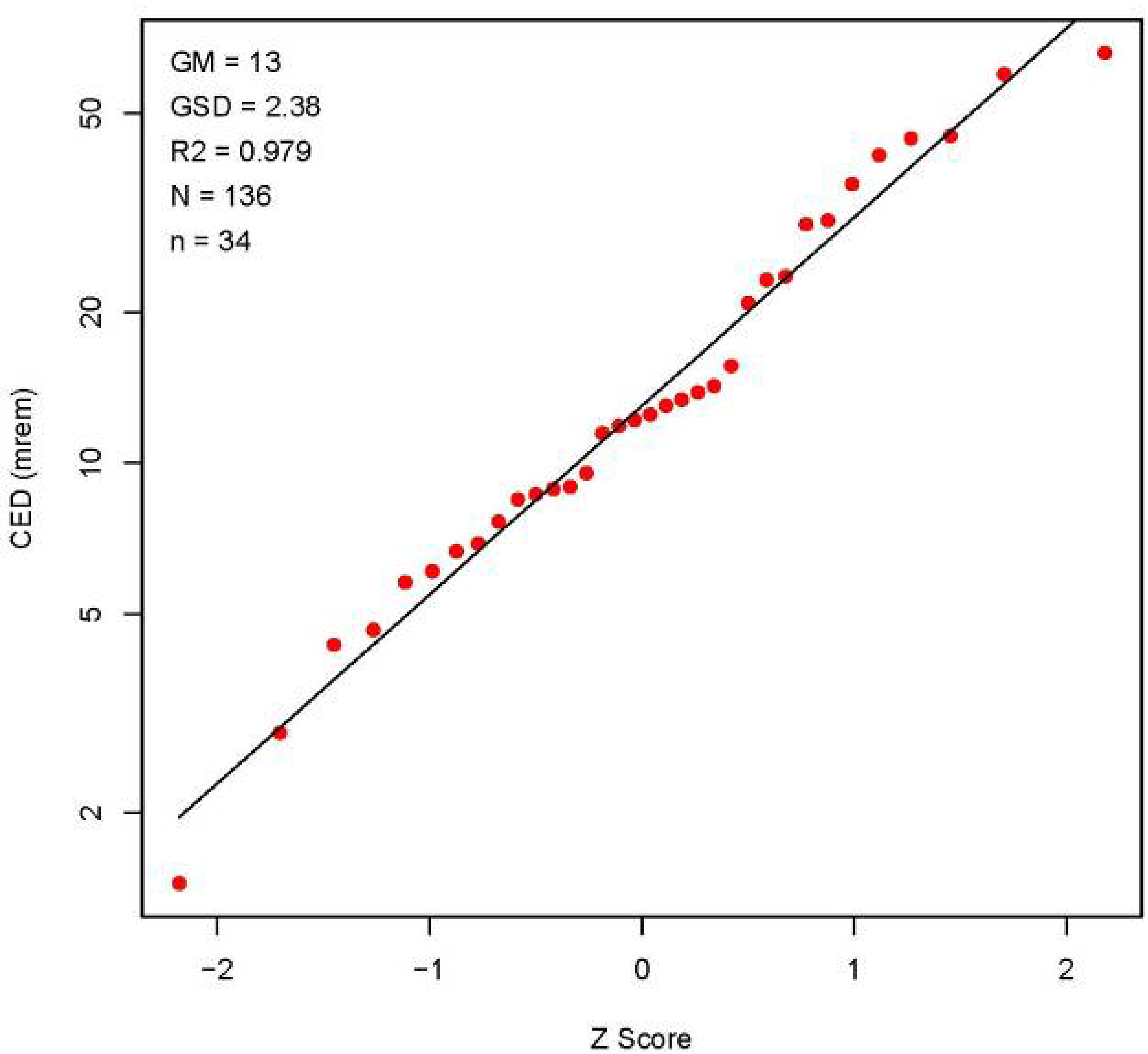

Figure C-8. SRS reactor/CTW tritium dose 1956.

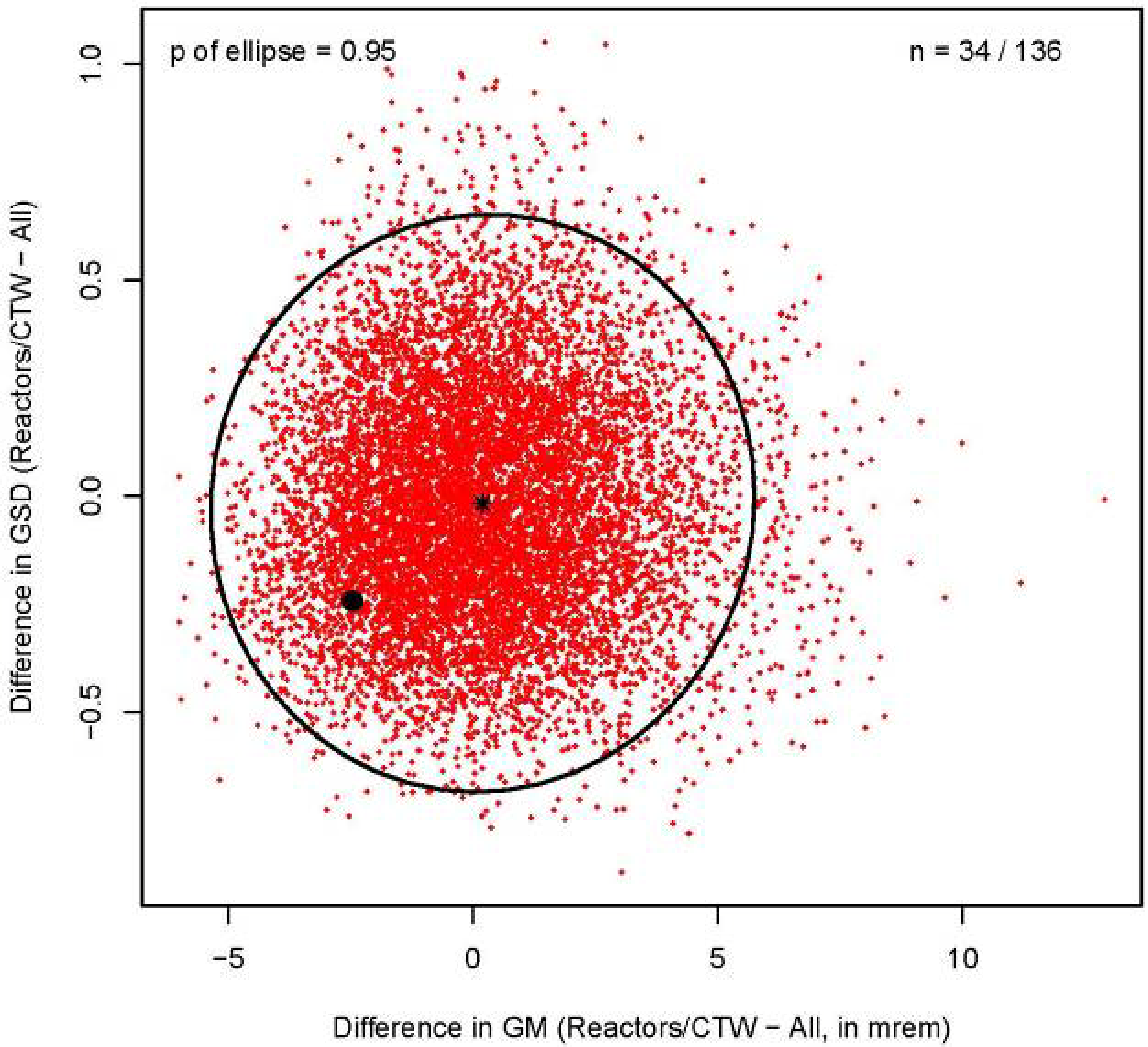

Figure C-9. SRS tritium dose 1956.

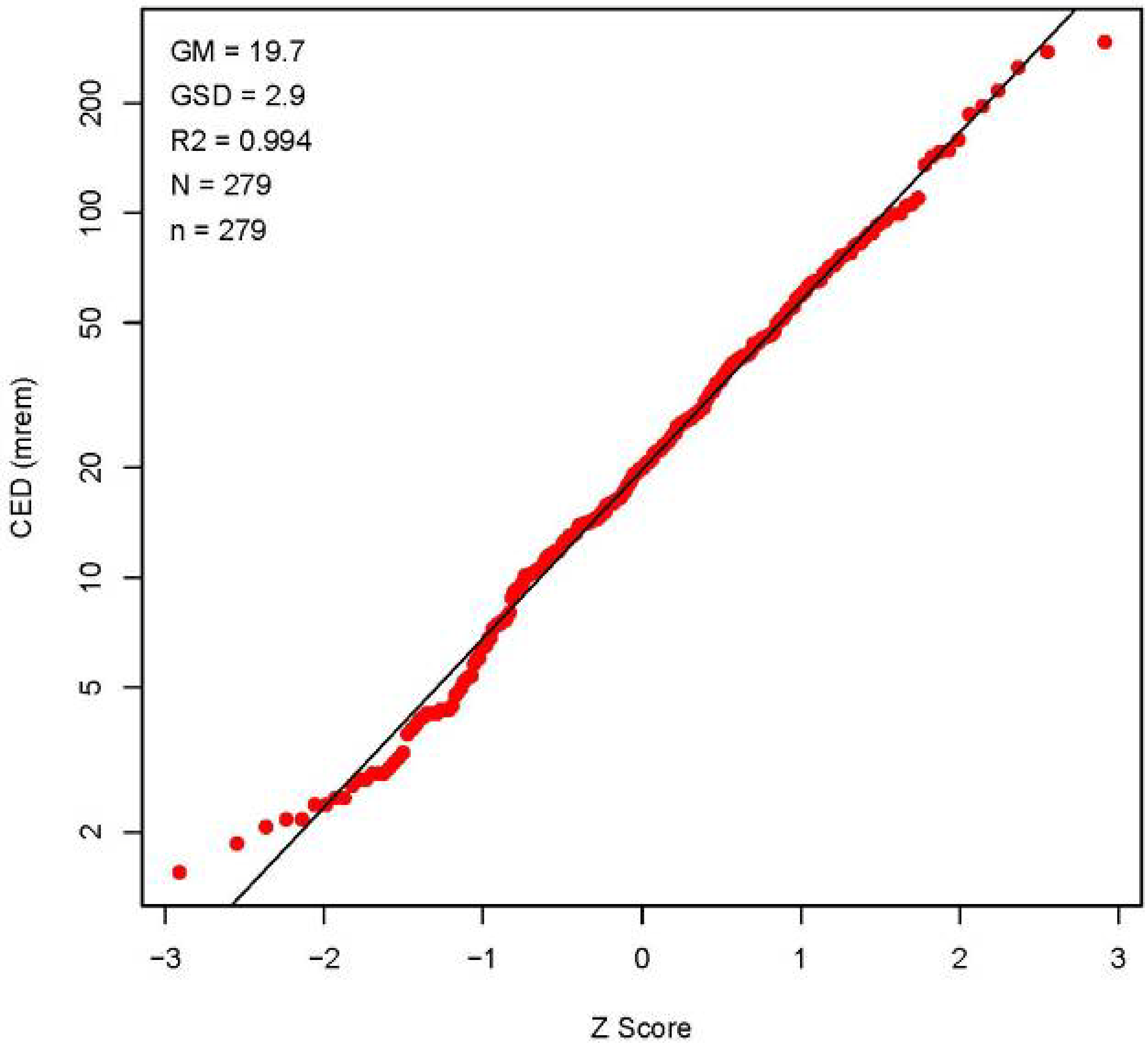

Figure C-10. SRS tritium dose 1957.

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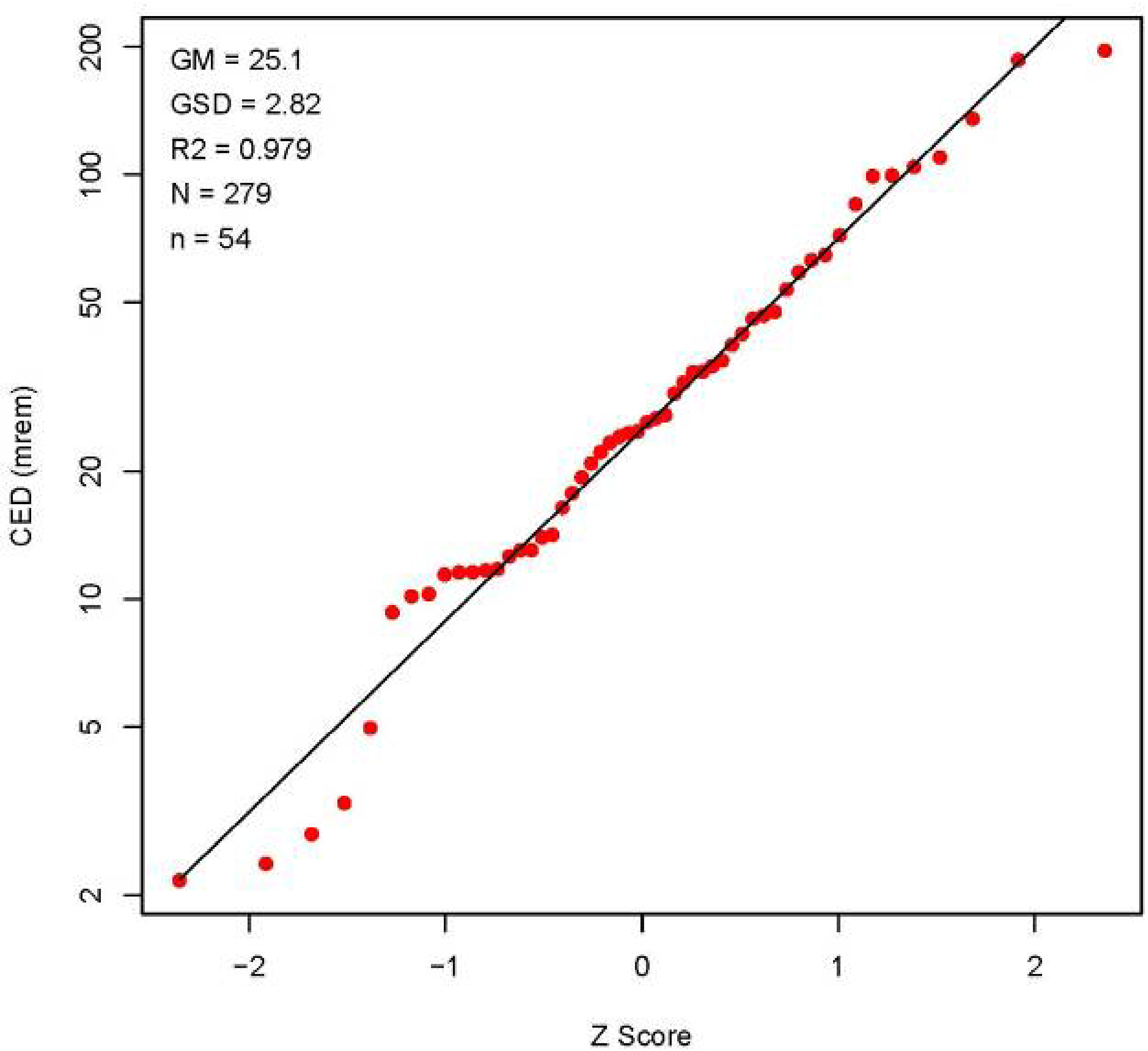

Figure C-11. SRS reactor/CTW tritium dose 1957.

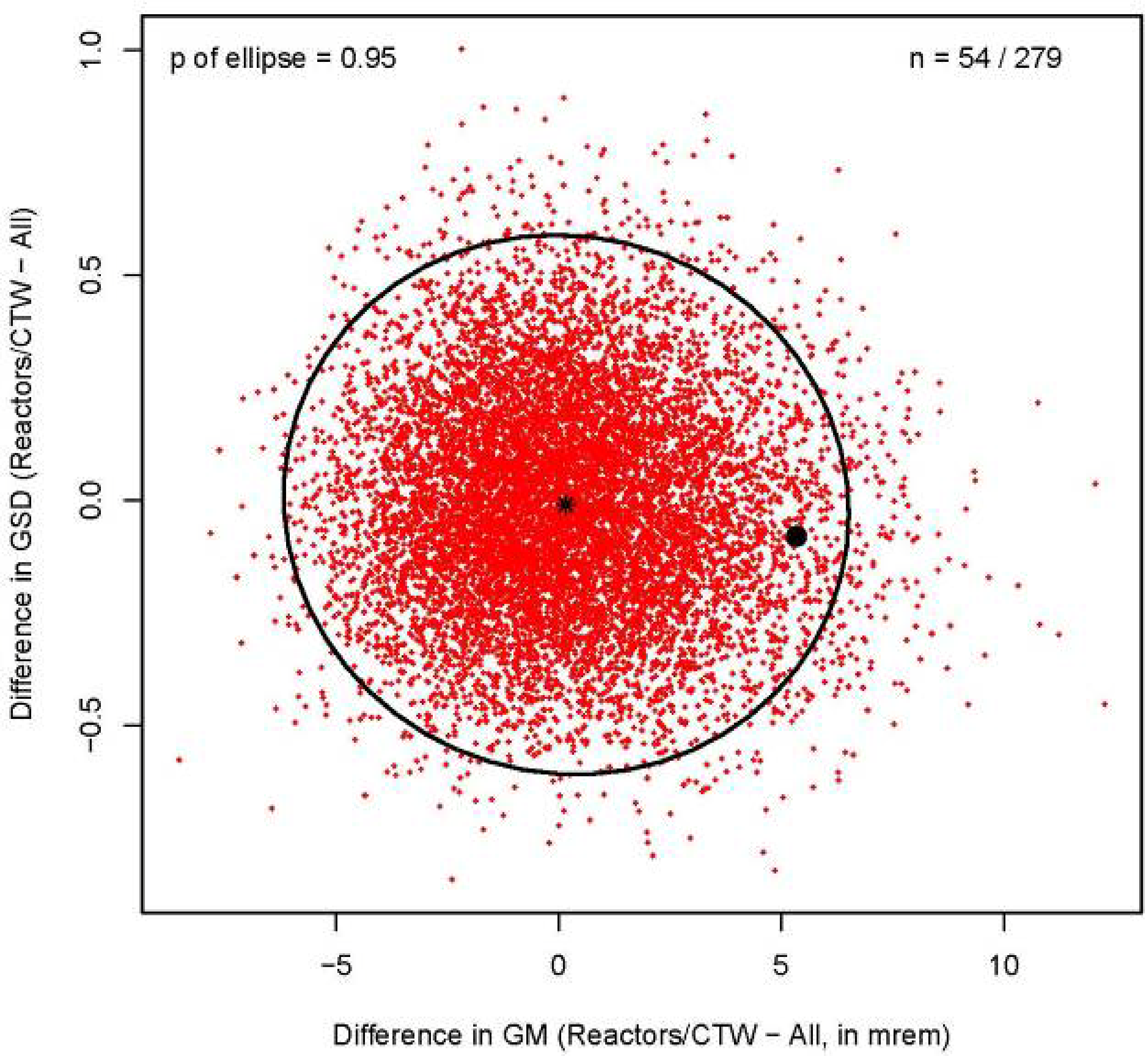

Figure C-12. SRS tritium dose 1957.

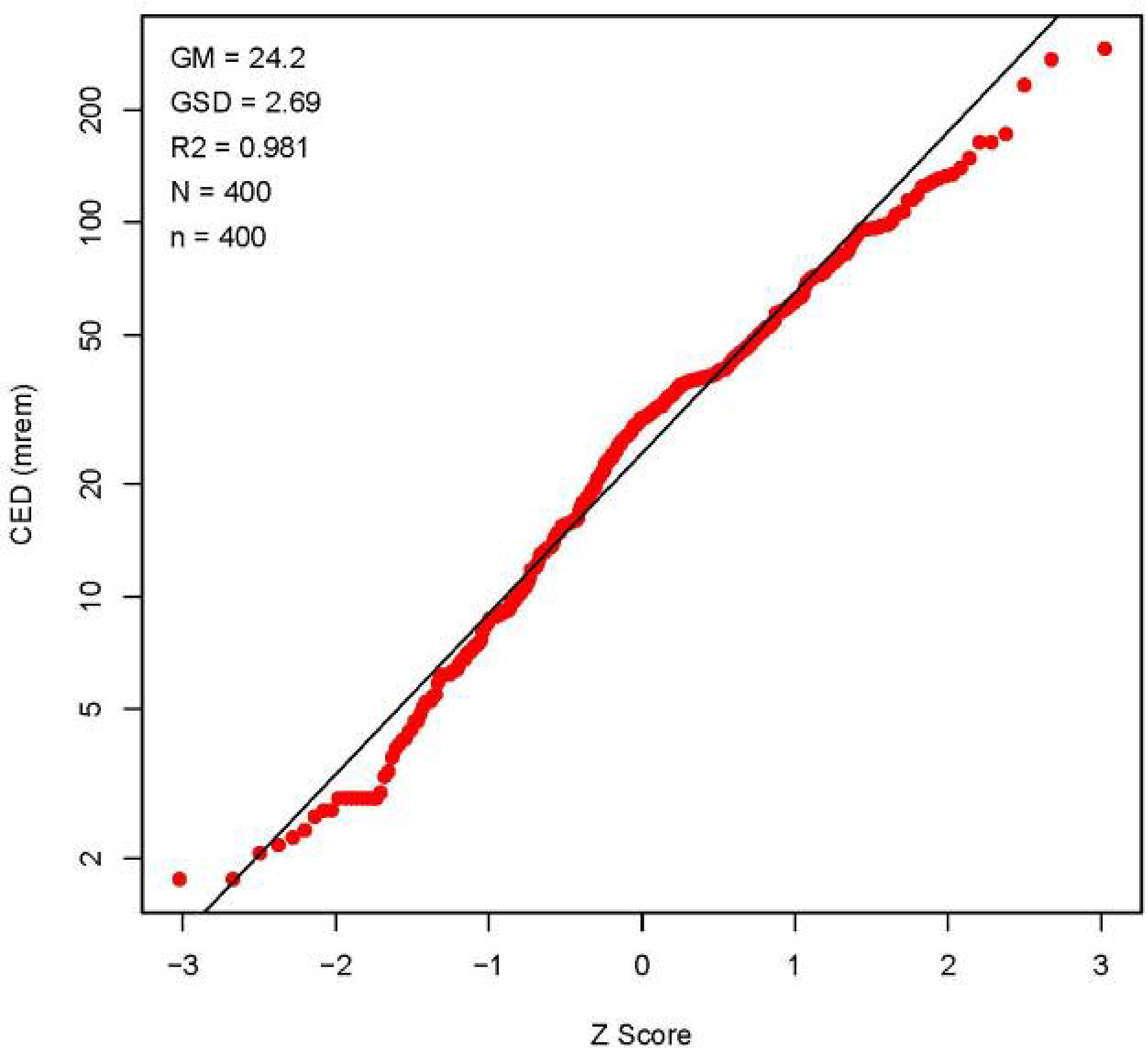

Figure C-13. SRS tritium dose 1958.

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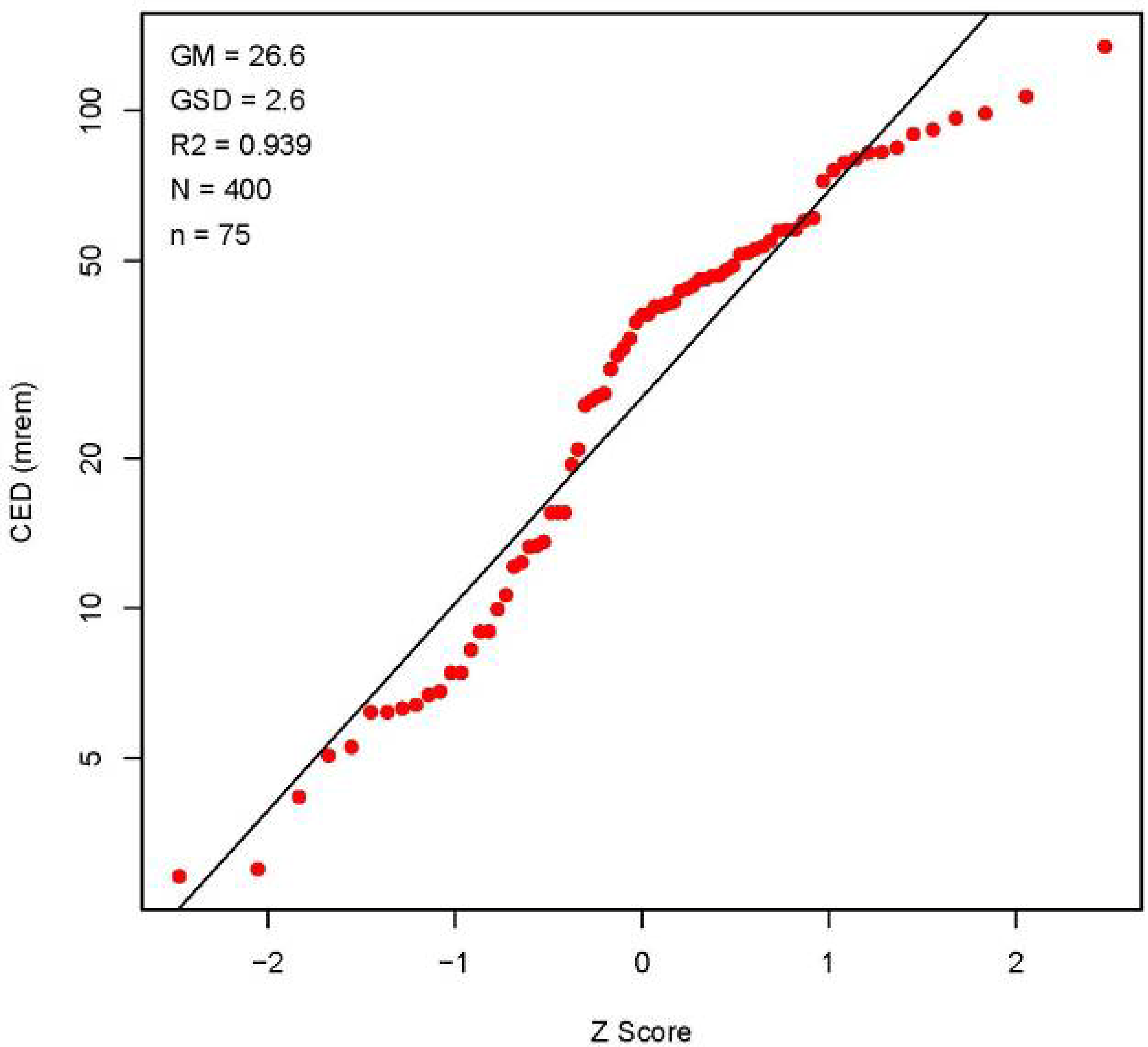

Figure C-14. SRS reactor/CTW tritium dose 1958.

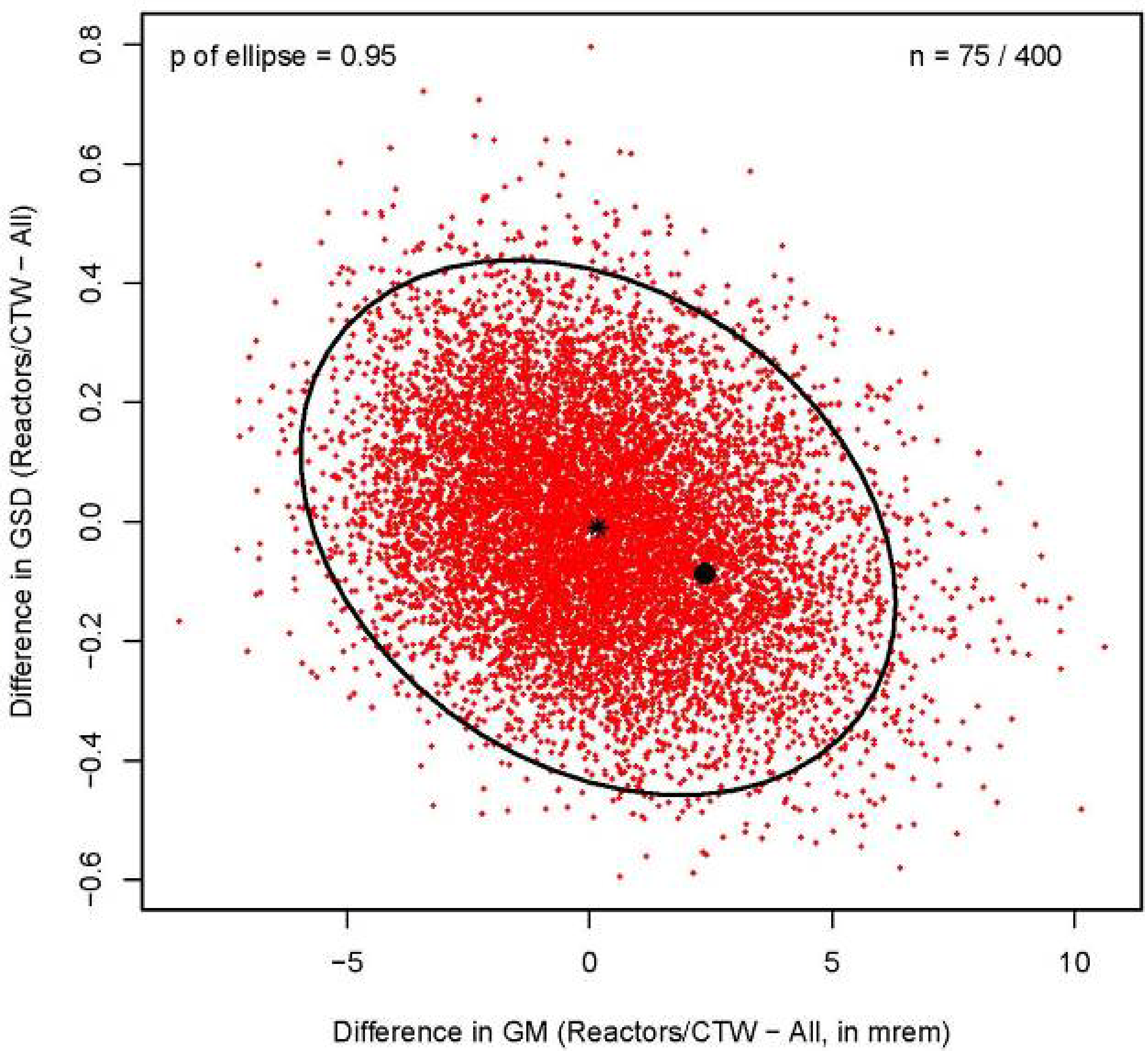

Figure C-15. SRS tritium dose 1958.

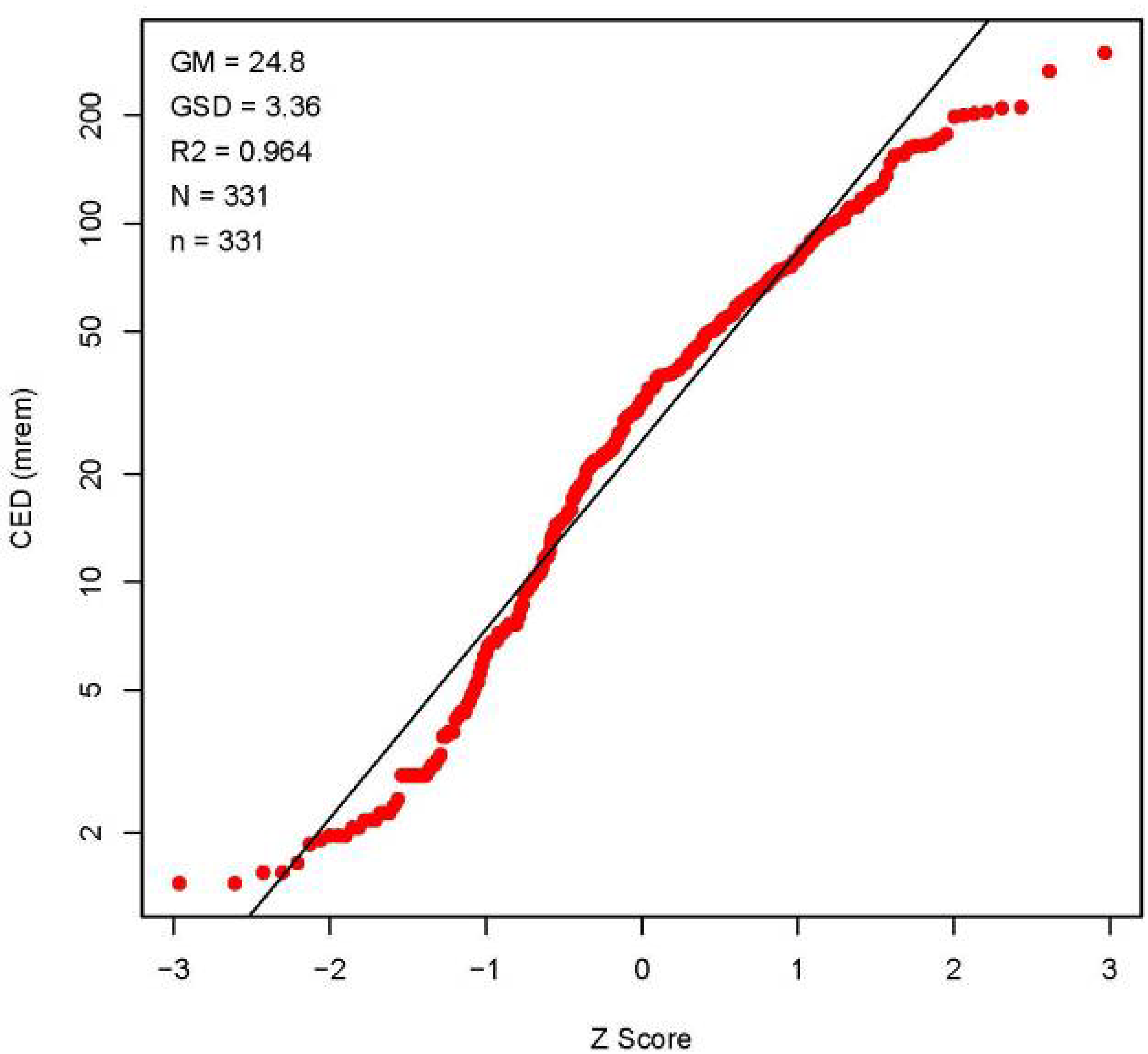

Figure C-16. SRS tritium dose 1959.

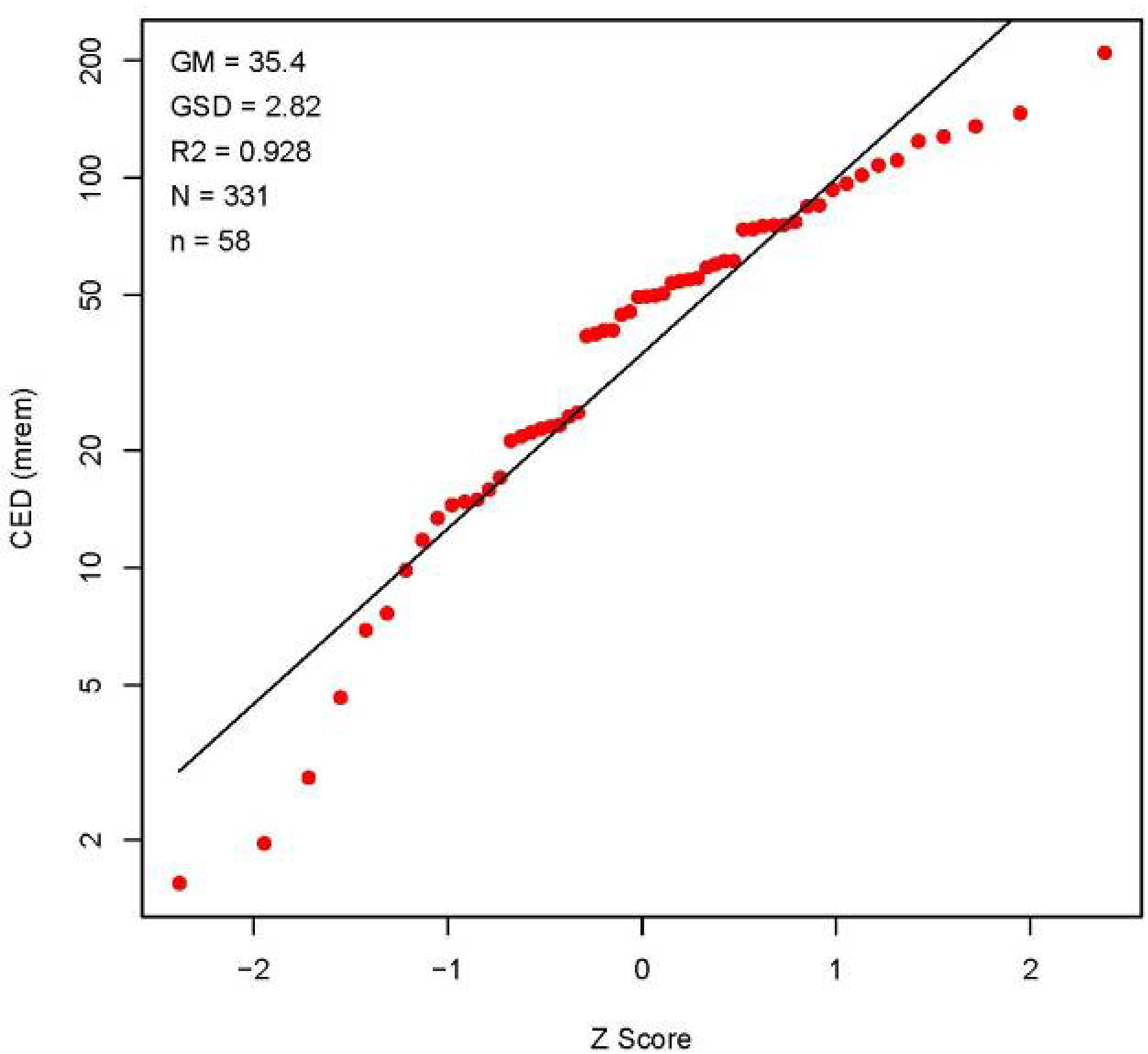

Figure C-17. SRS reactor/CTW tritium dose 1959.

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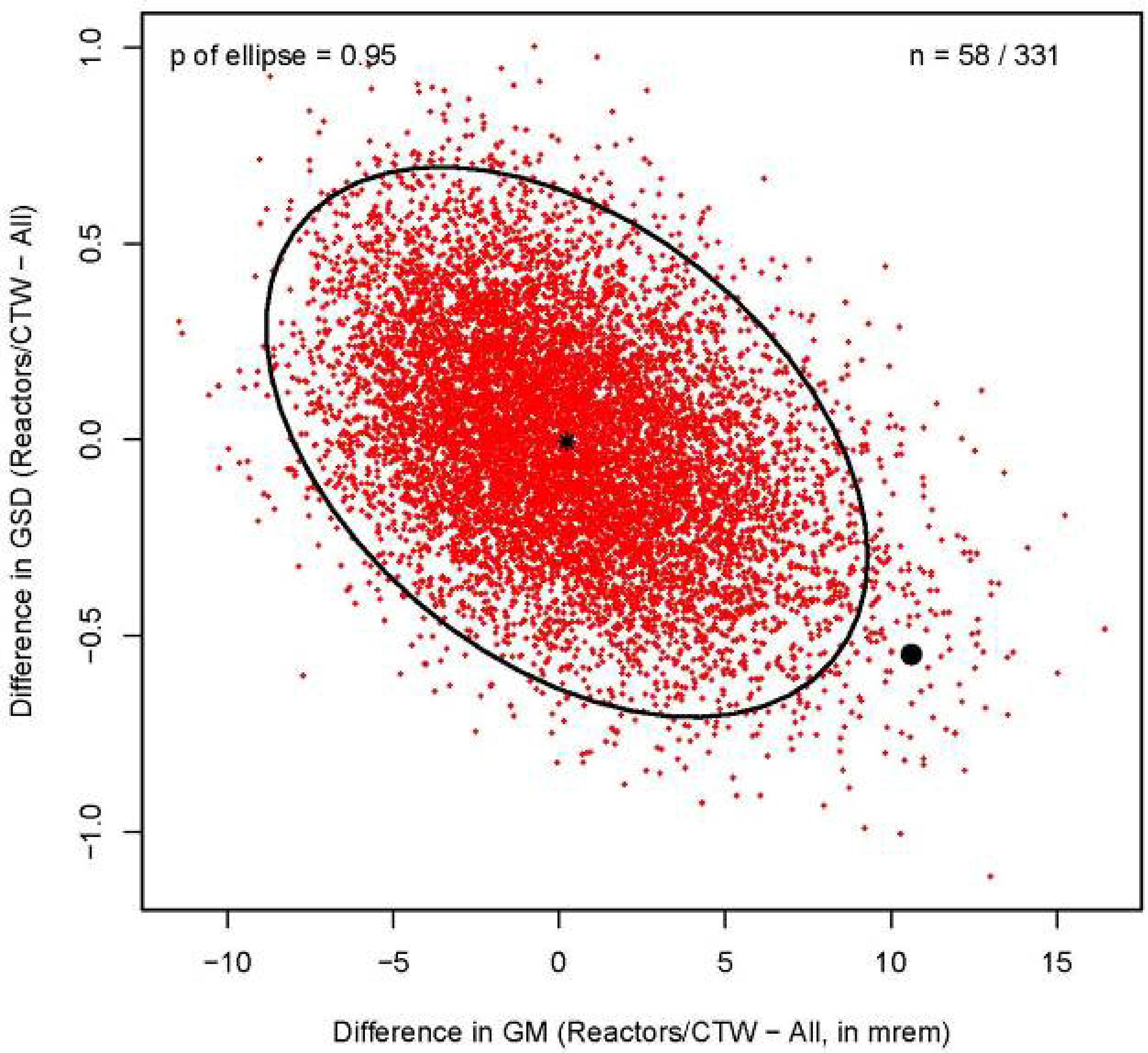

Figure C-18. SRS tritium dose 1959.

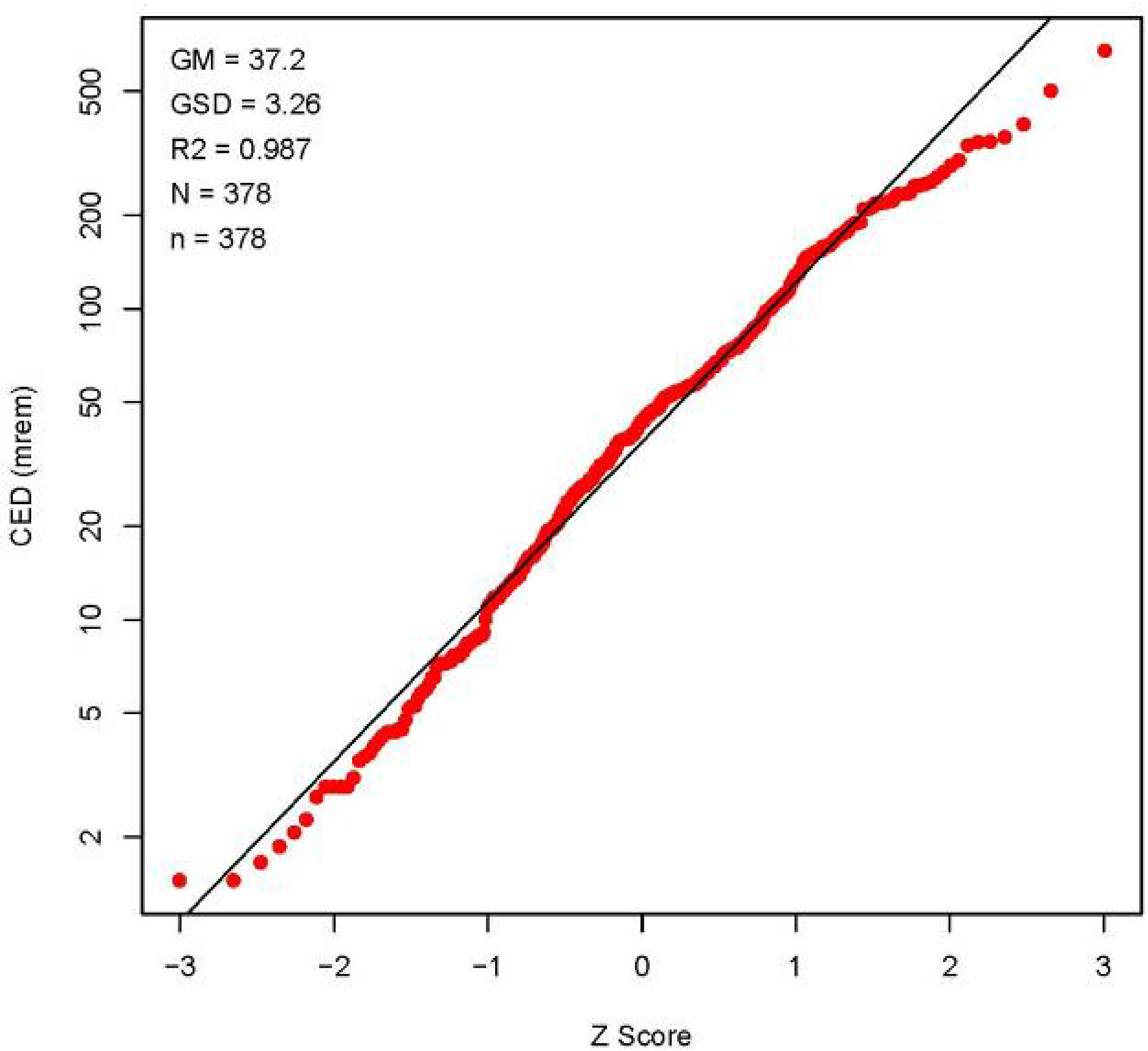

Figure C-19. SRS tritium dose 1960.

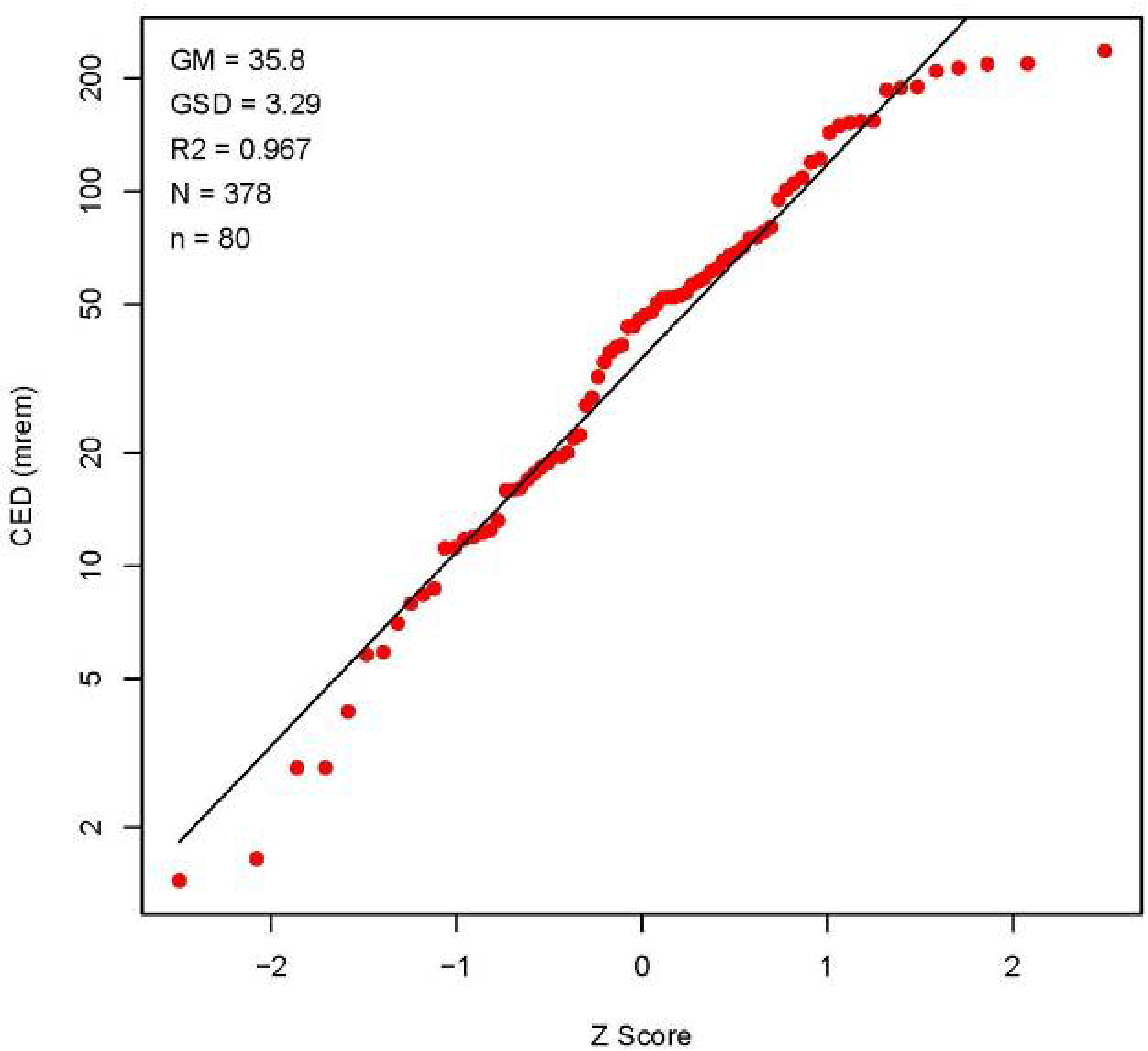

Figure C-20. SRS reactor/CTW tritium dose 1960.

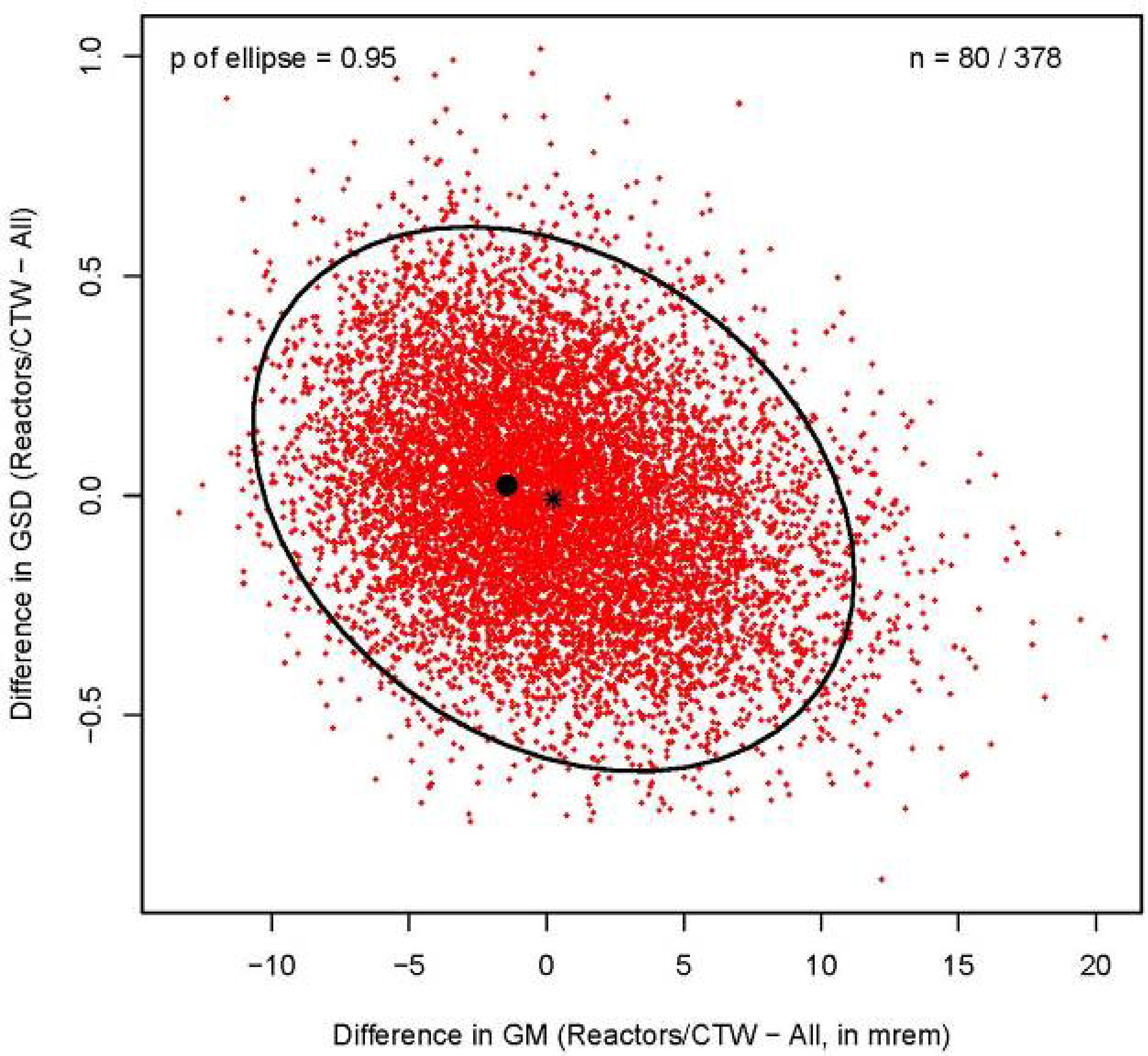

Figure C-21. SRS tritium dose 1960.

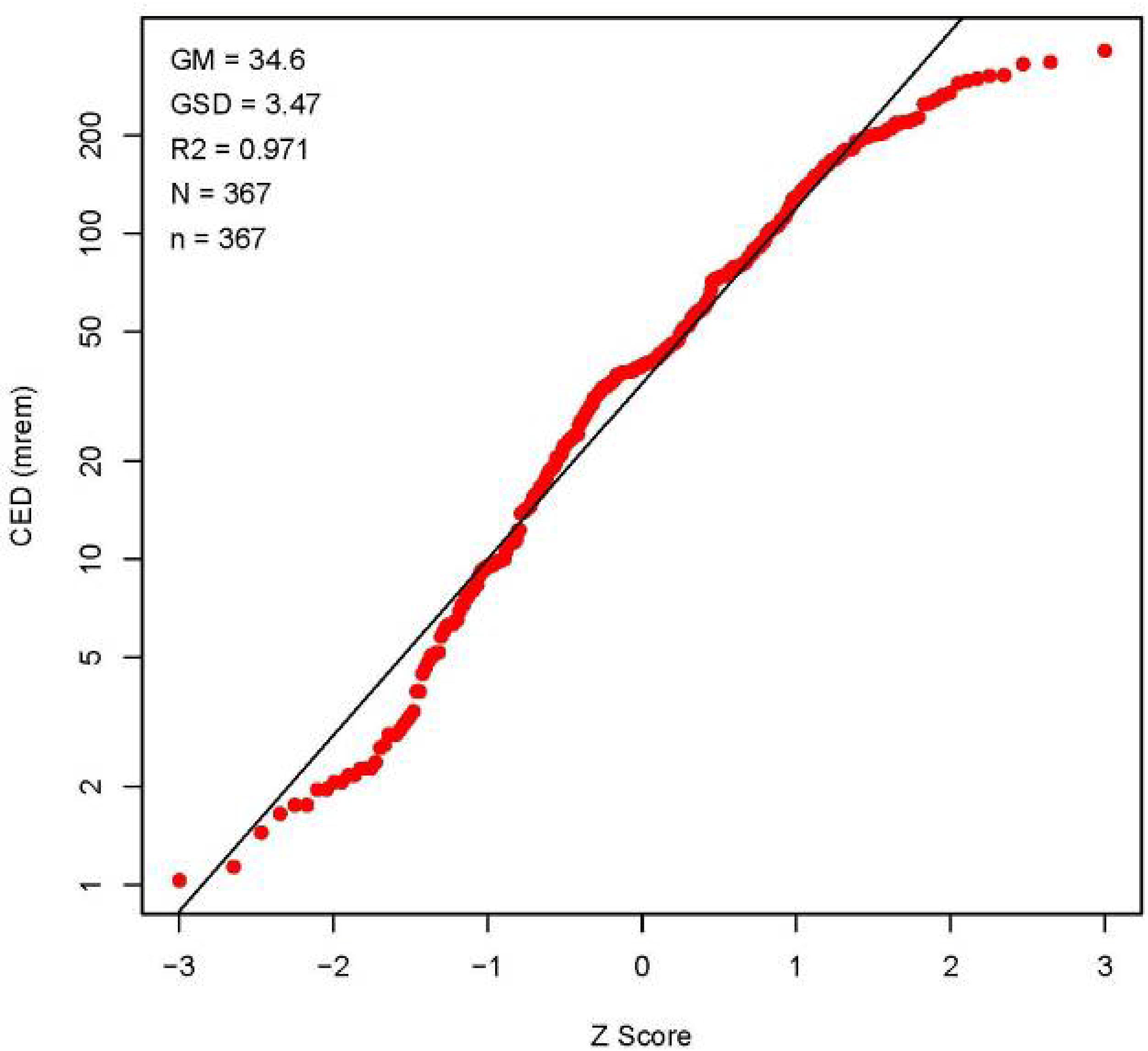

Figure C-22. SRS tritium dose 1961.

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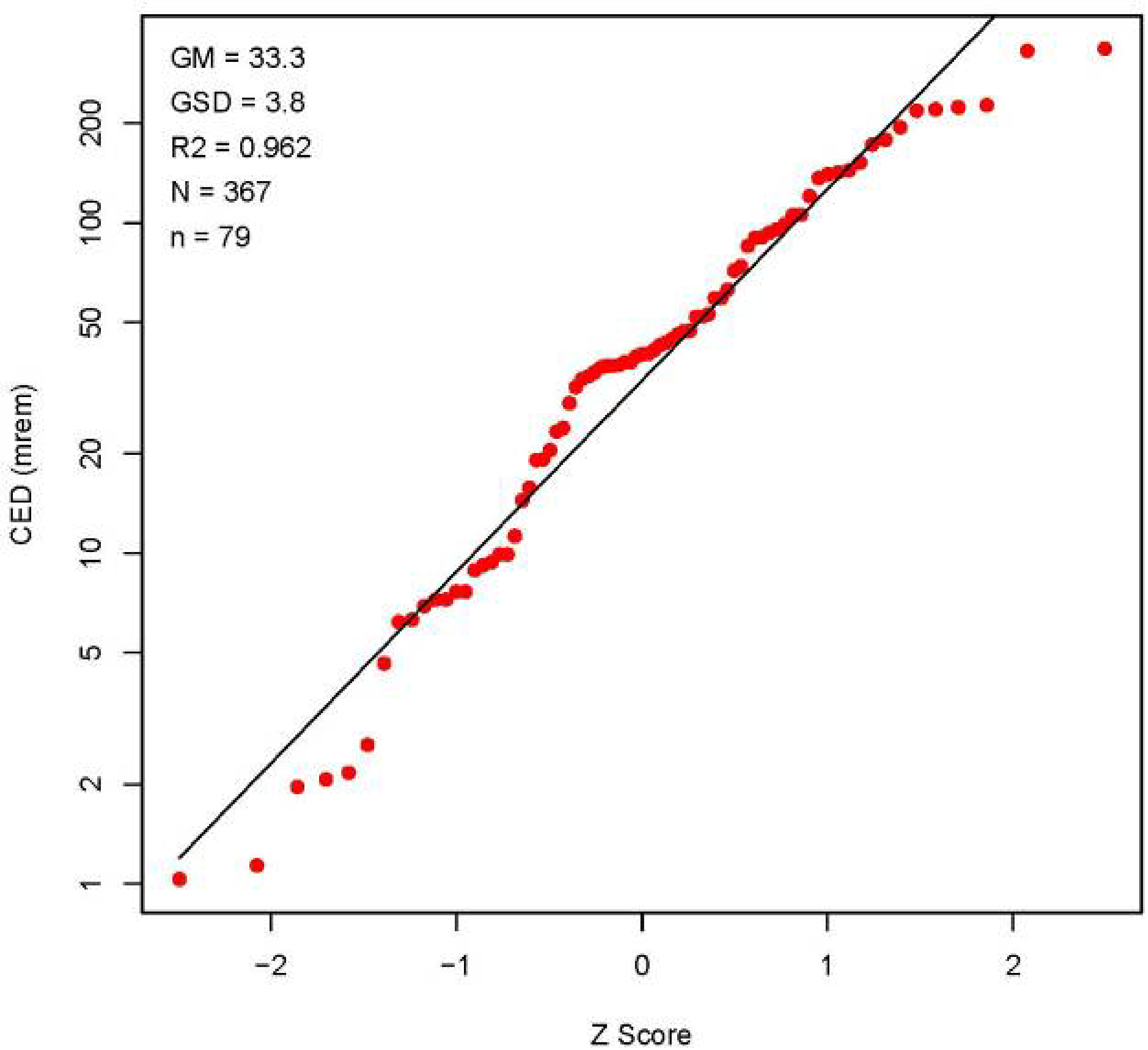

Figure C-23. SRS reactor/CTW tritium dose 1961.

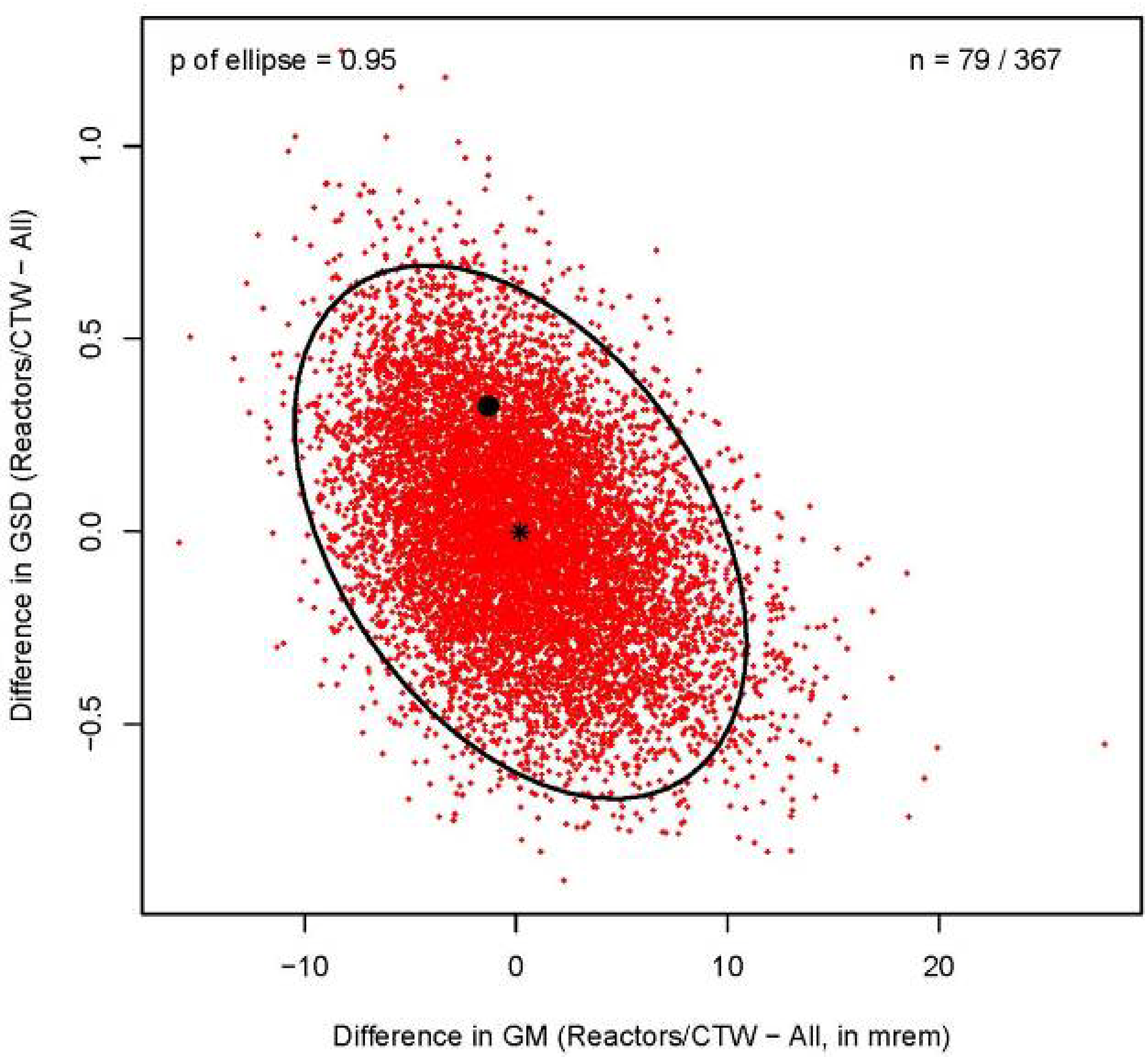

Figure C-24. SRS tritium dose 1961.

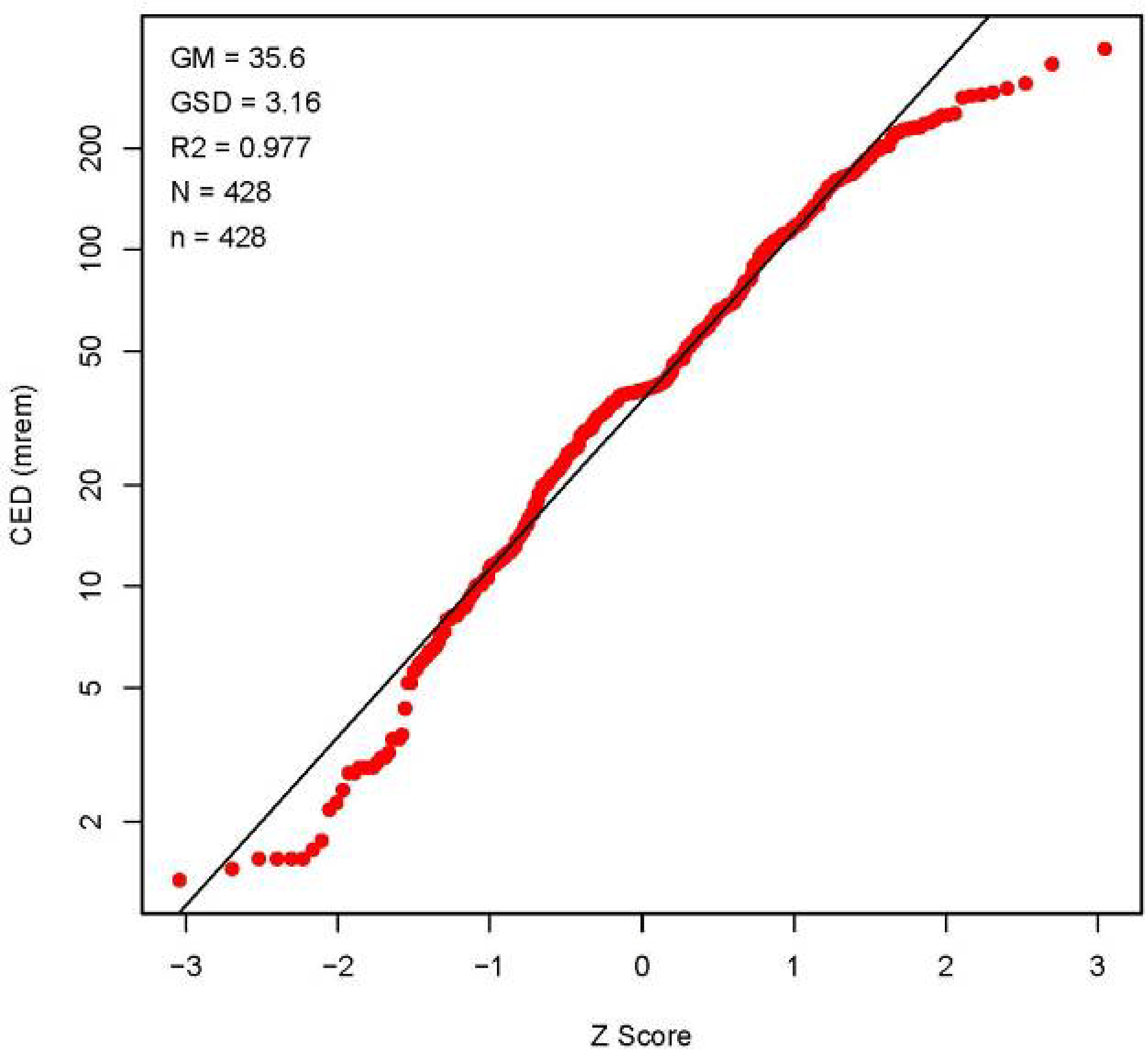

Figure C-25. SRS tritium dose 1962.

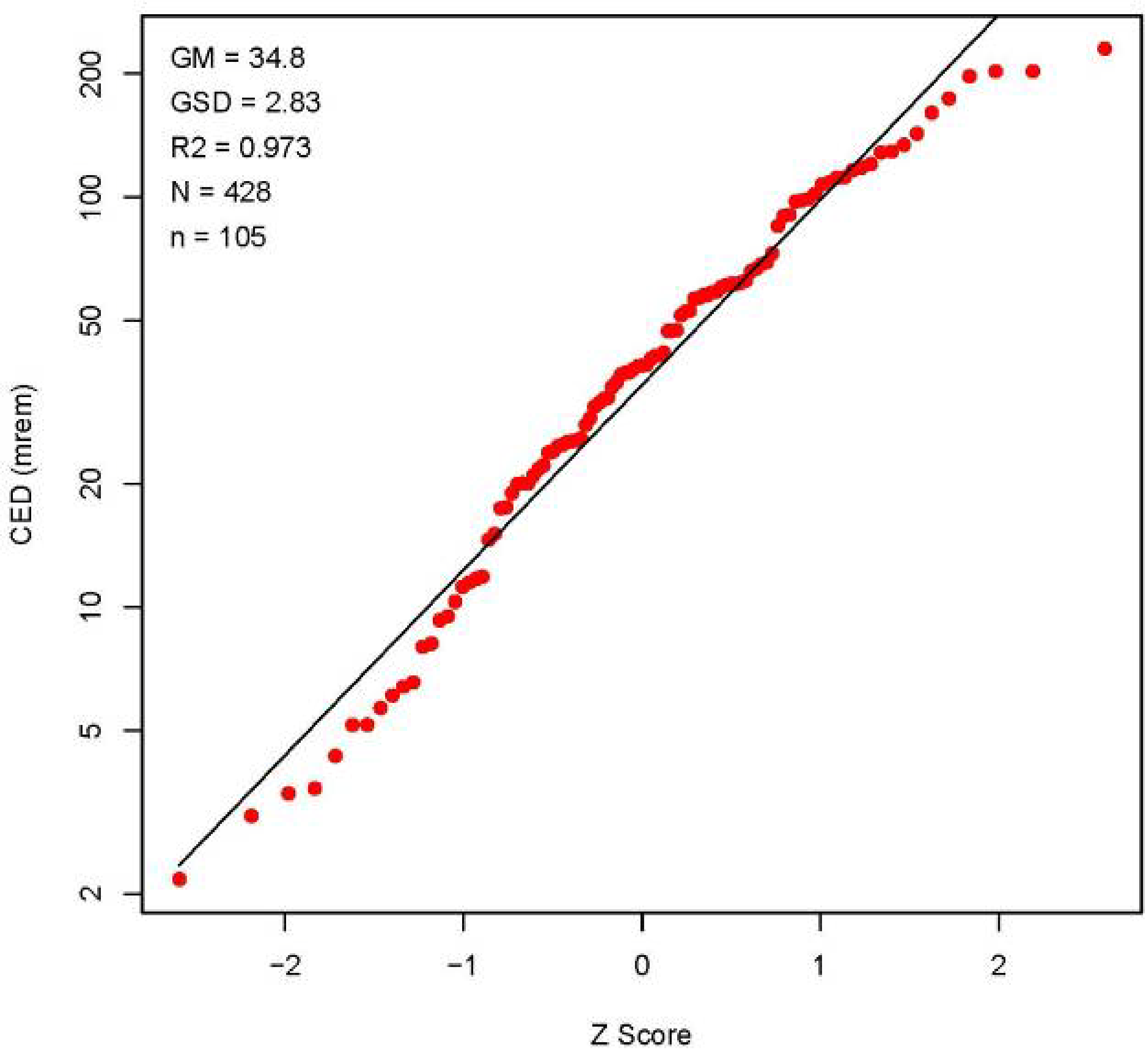

Figure C-26. SRS reactor/CTW tritium dose 1962.

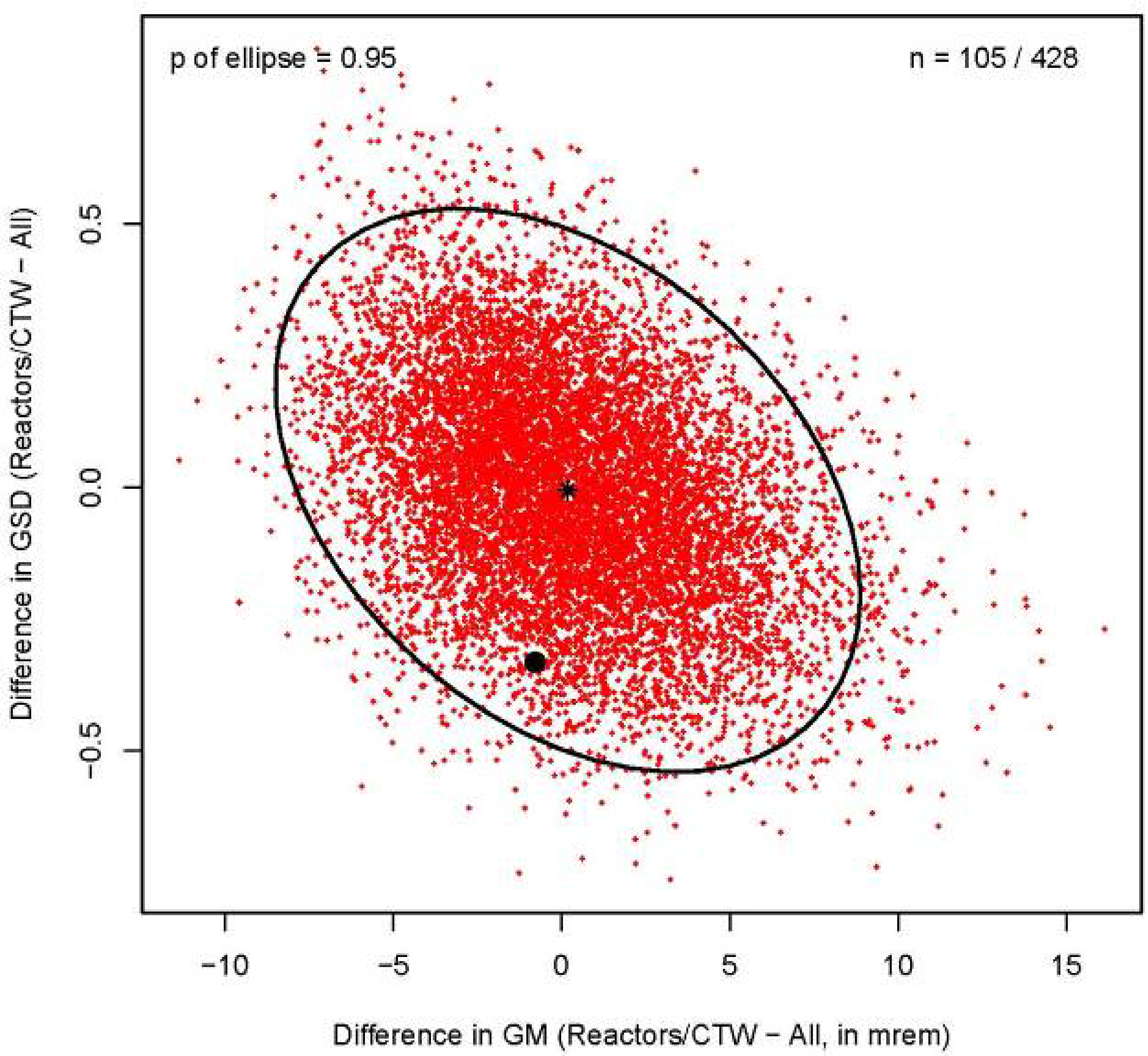

Figure C-27. SRS tritium dose 1962.

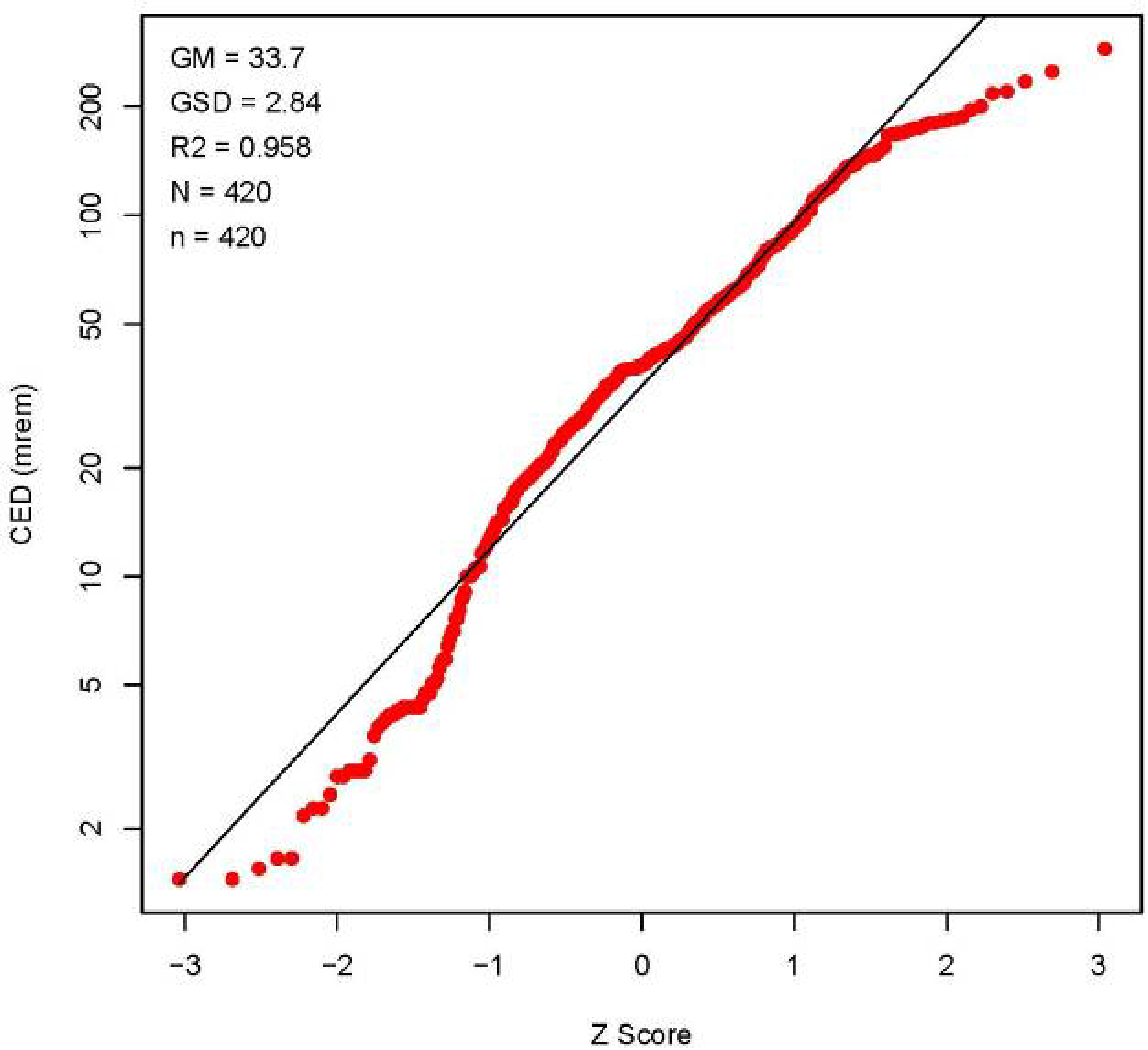

Figure C-28. SRS tritium dose 1963.

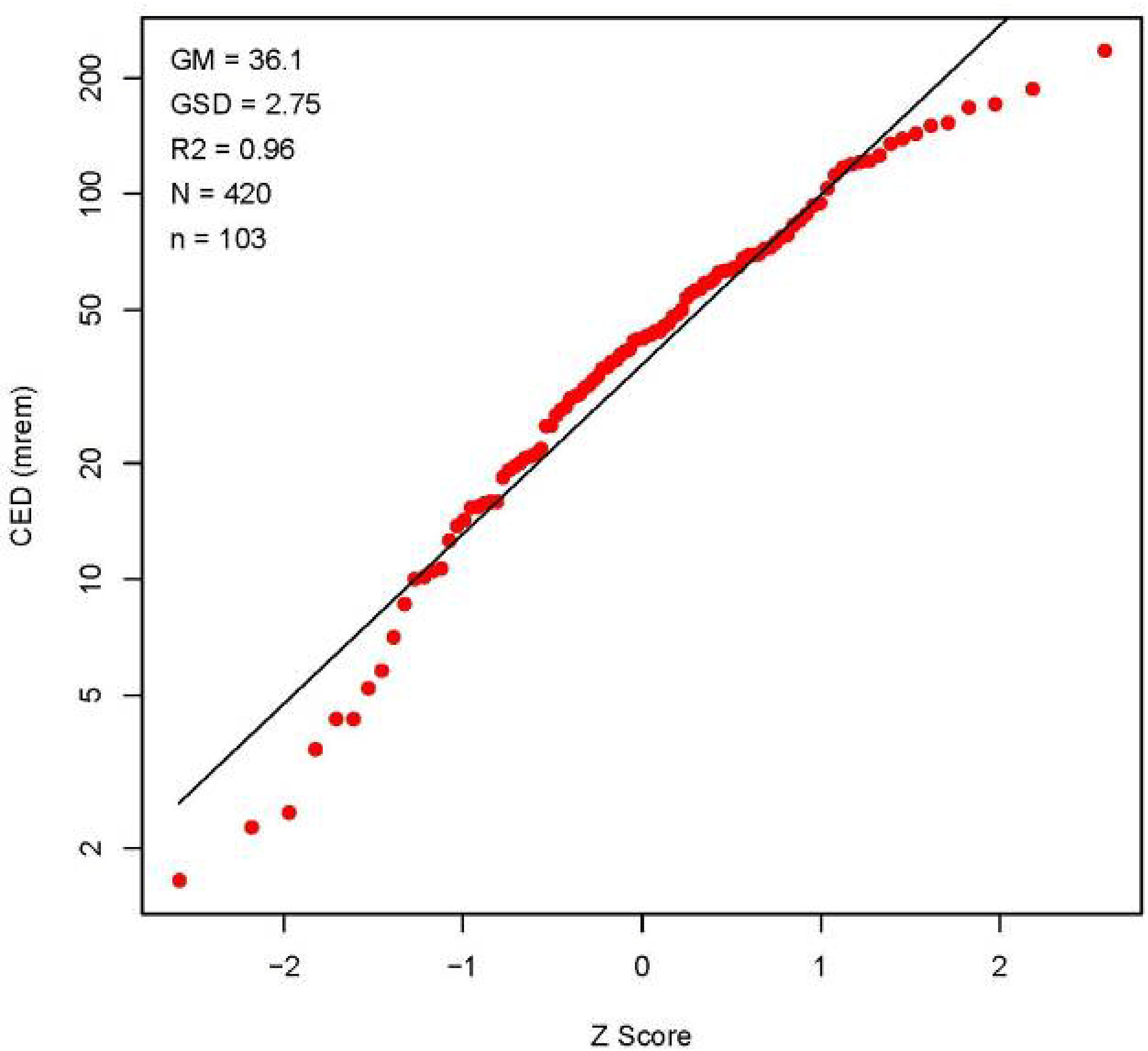

Figure C-29. SRS reactor/CTW tritium dose 1963.

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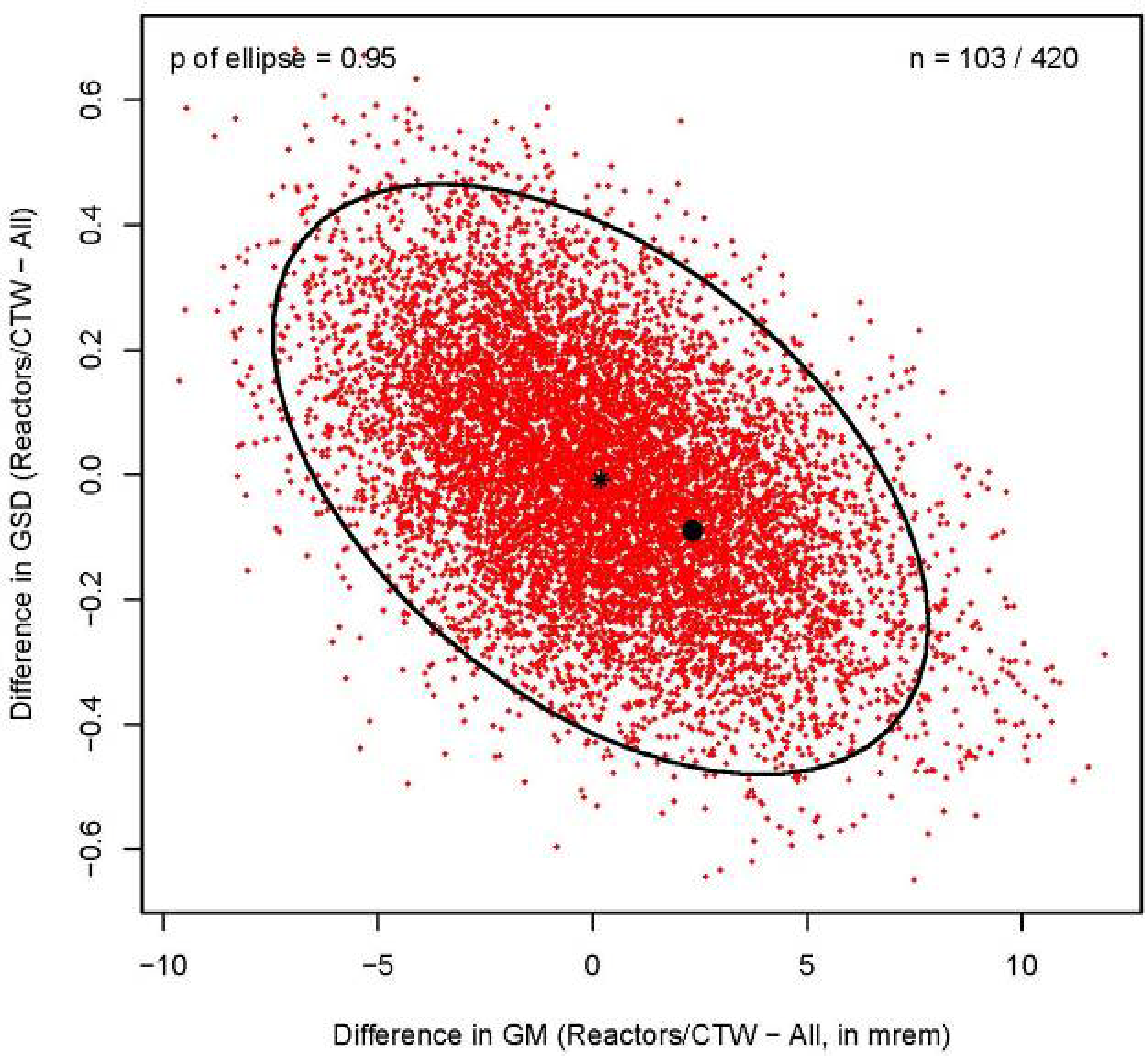

Figure C-30. SRS tritium dose 1963.

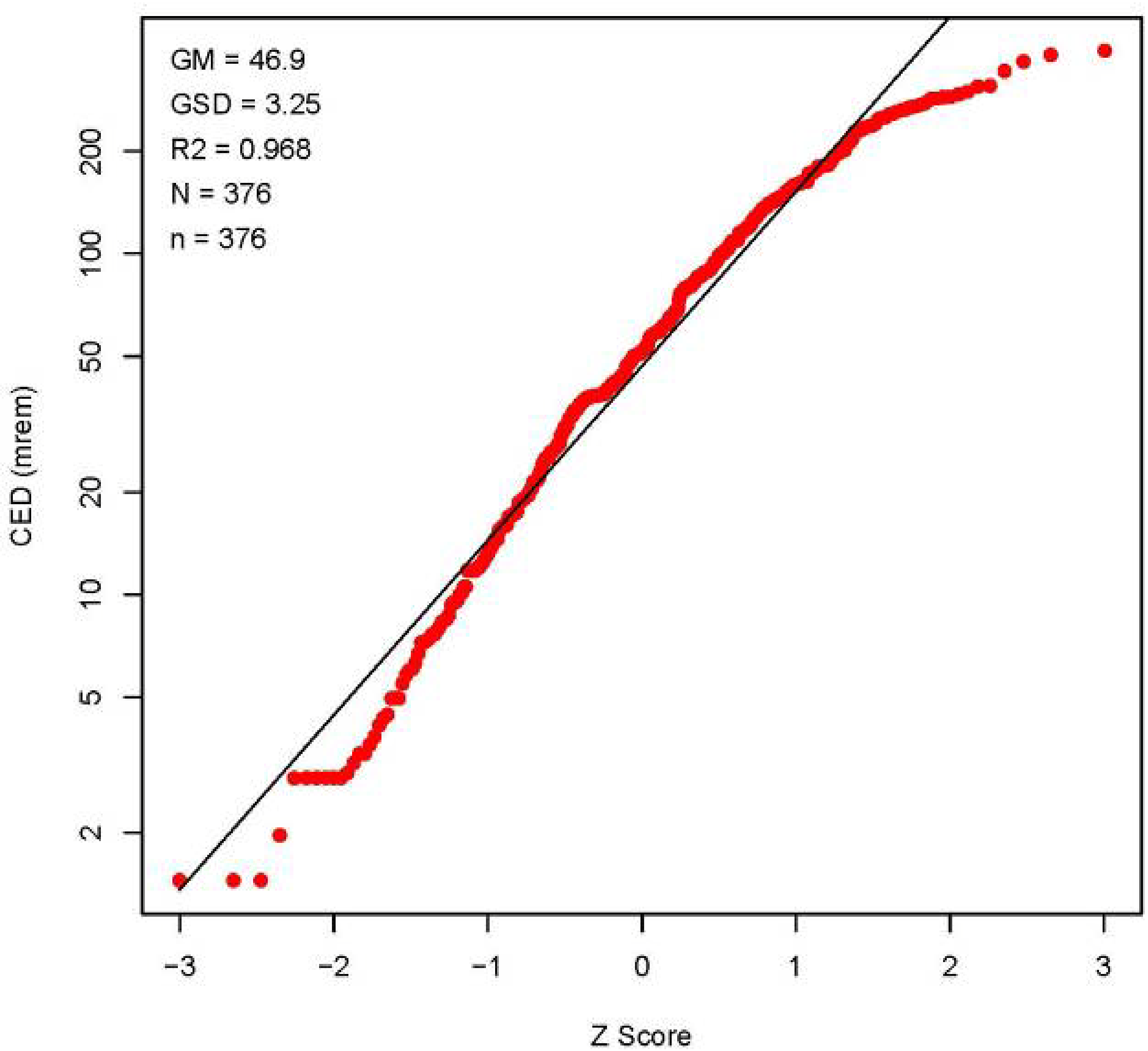

Figure C-31. SRS tritium dose 1964.

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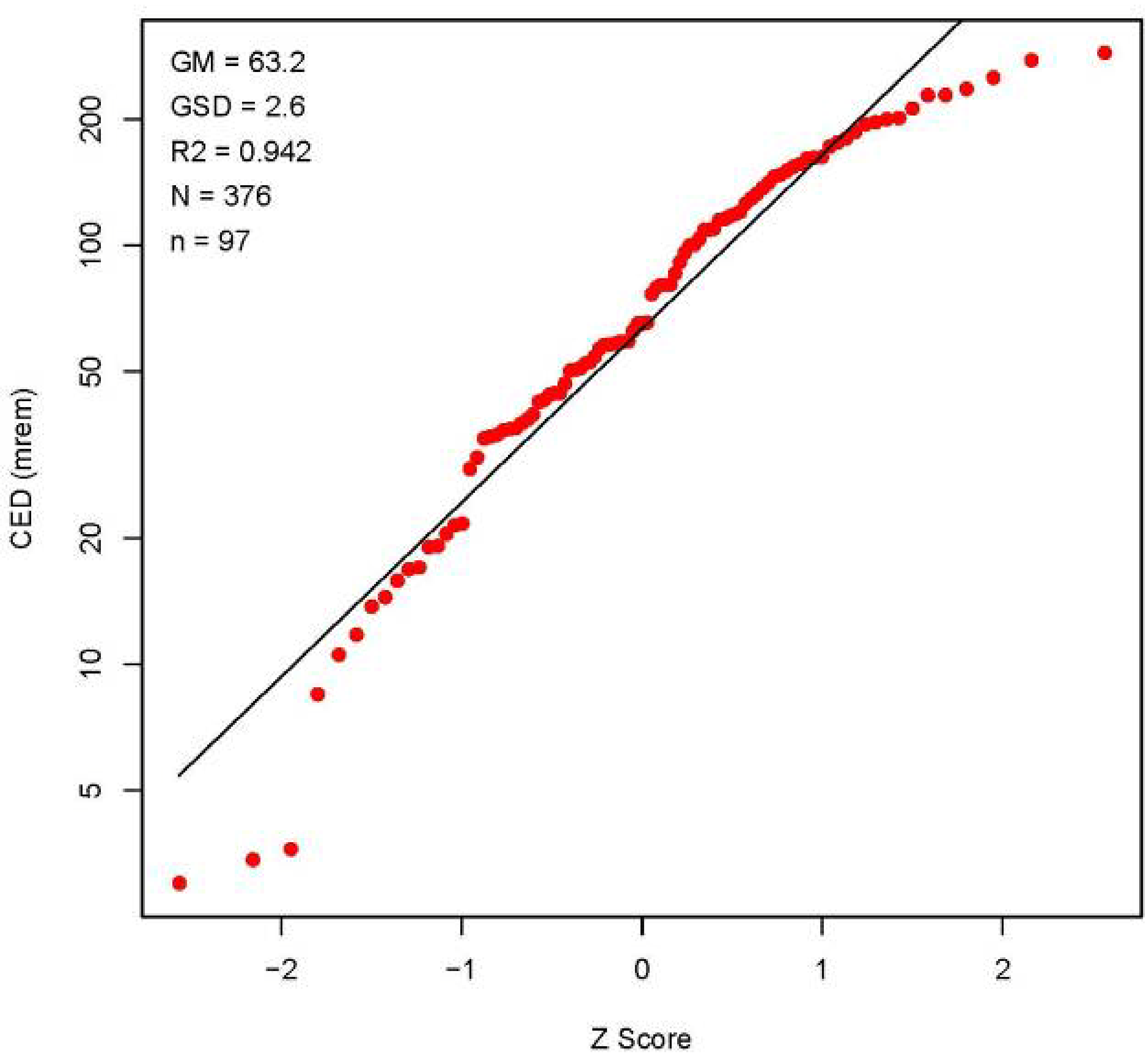

Figure C-32. SRS reactor/CTW tritium dose 1964.

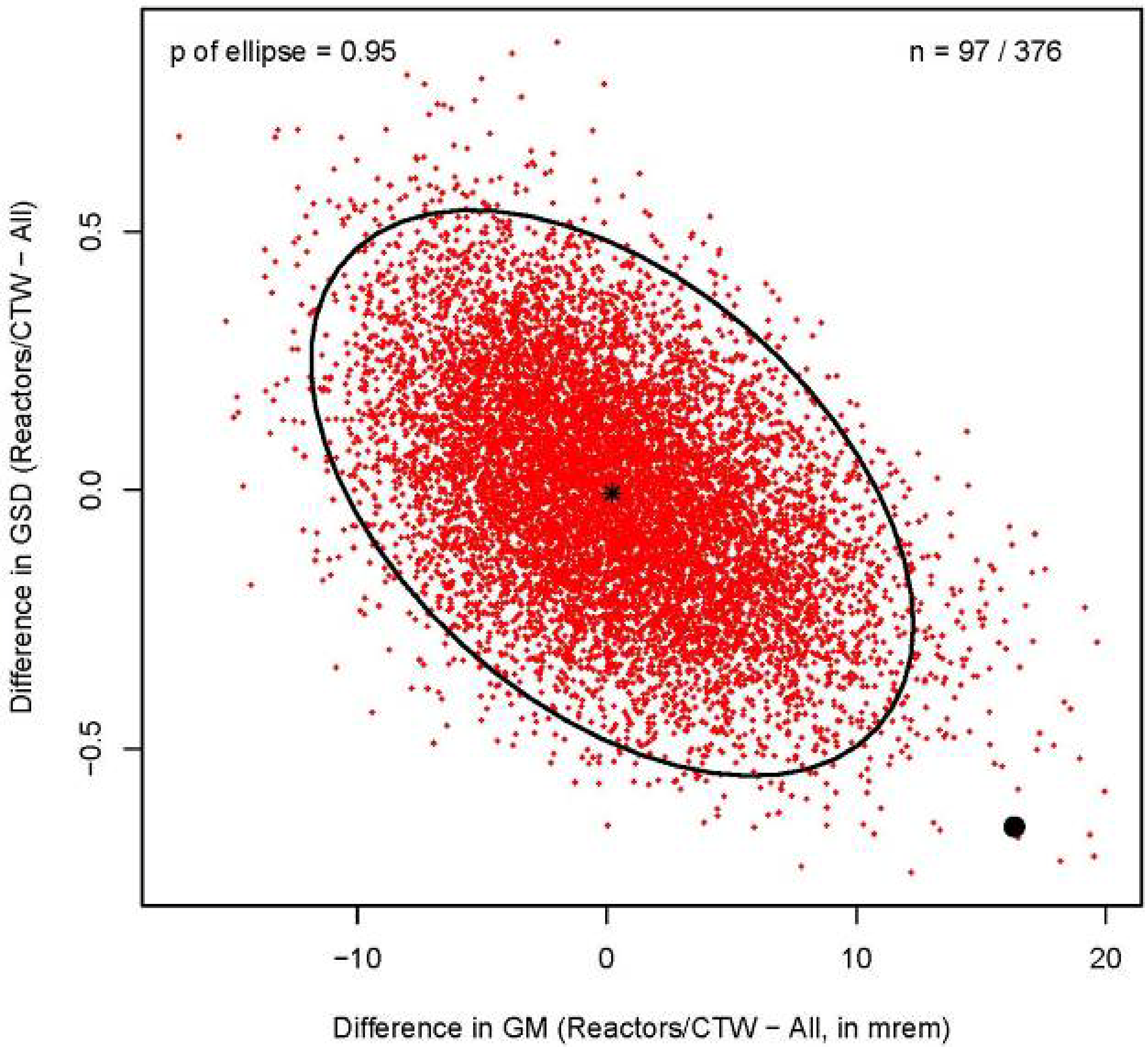

Figure C-33. SRS tritium dose 1964.

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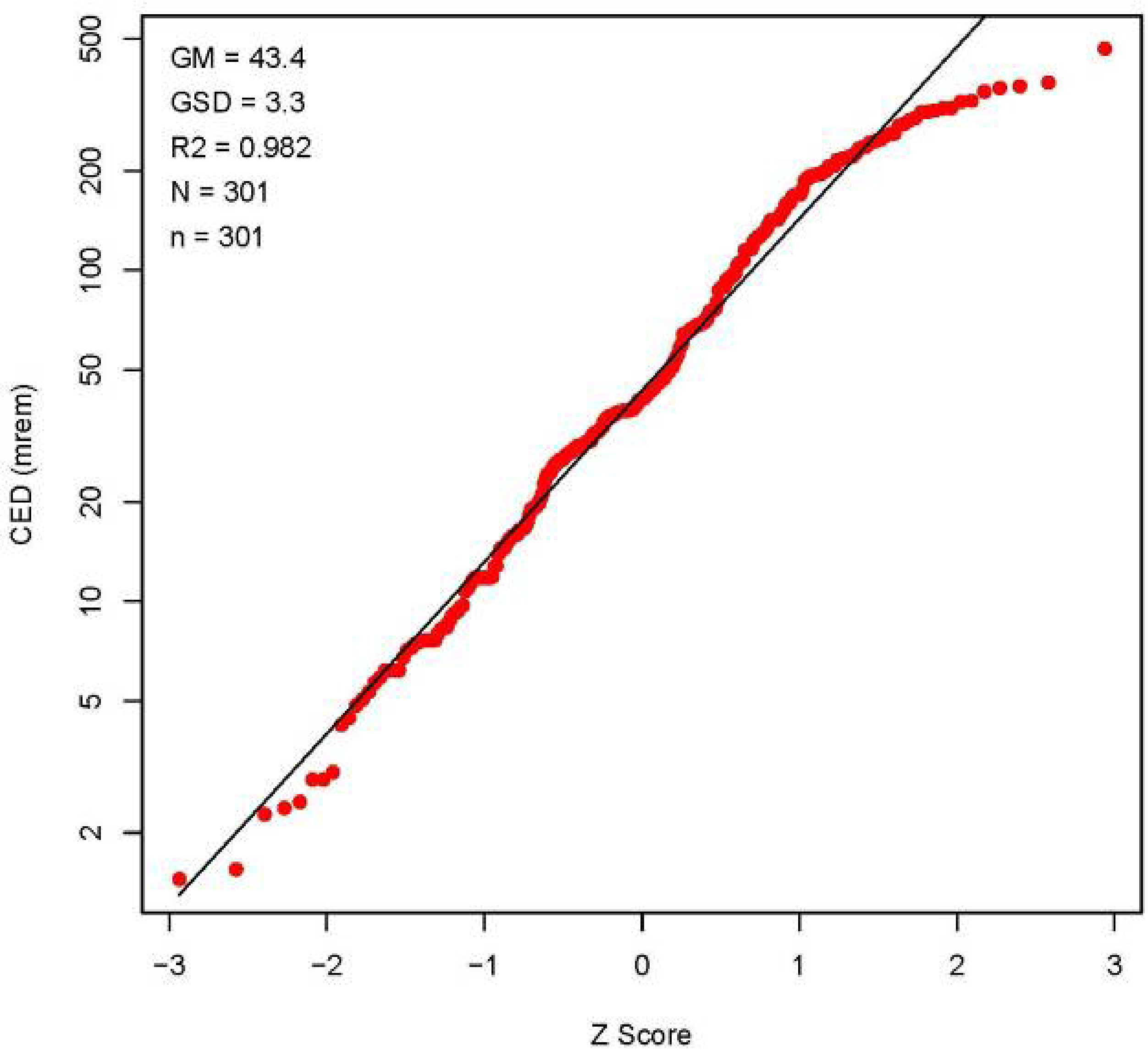

Figure C-34. SRS tritium dose 1965.

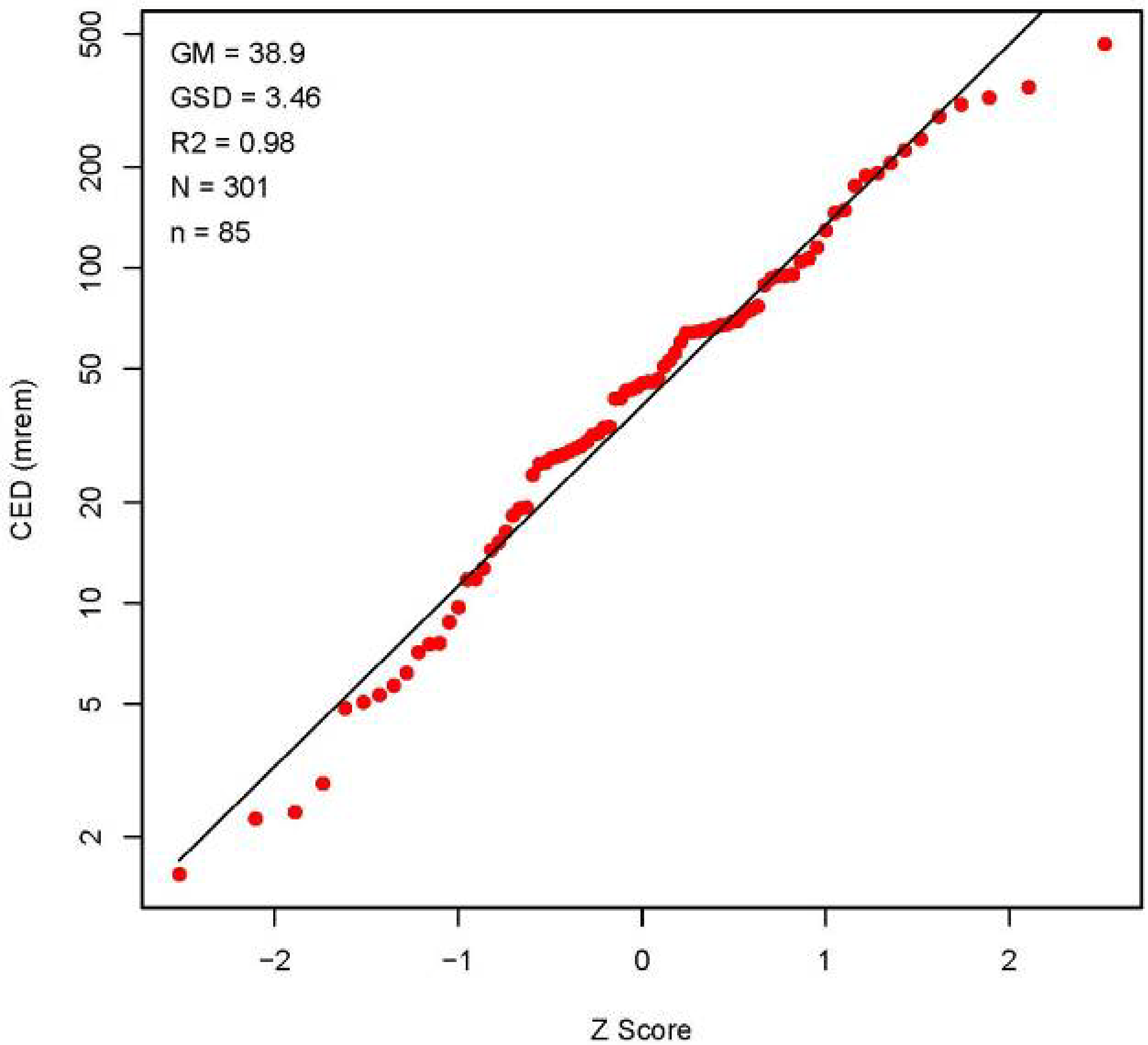

Figure C-35. SRS reactor/CTW tritium dose 1965.

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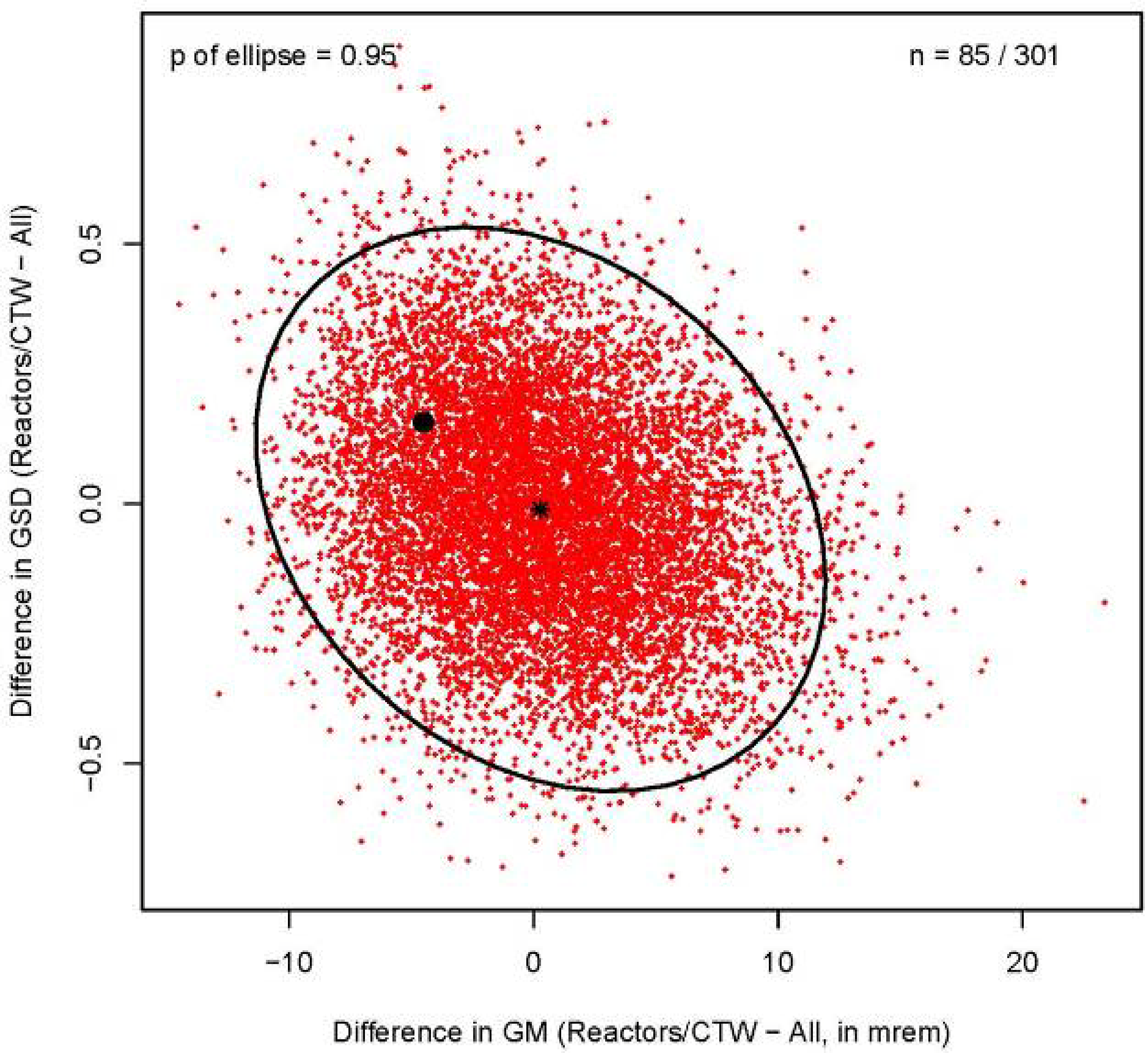

Figure C-36. SRS tritium dose 1965.

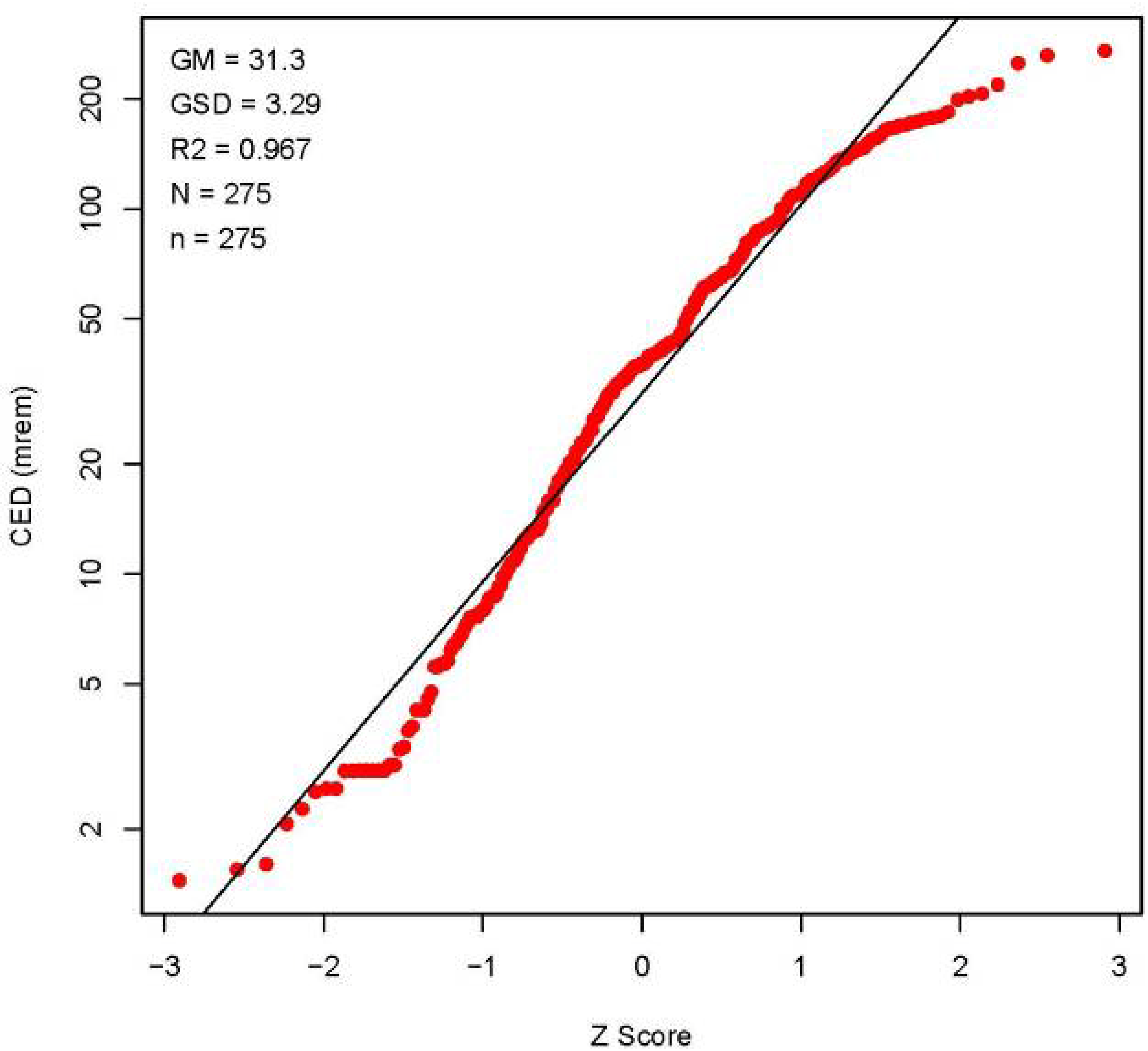

Figure C-37. SRS tritium dose 1966.

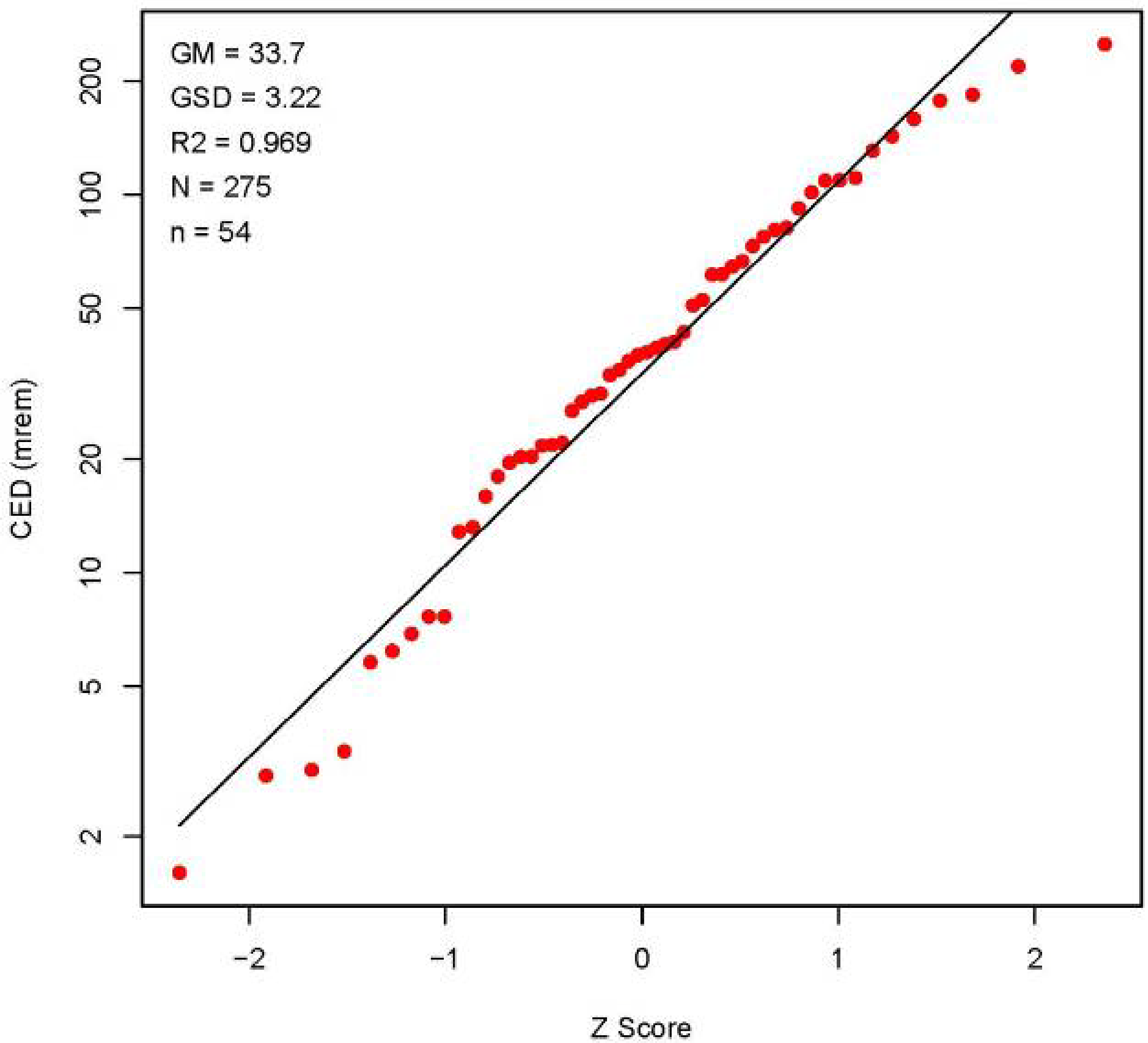

Figure C-38. SRS reactor/CTW tritium dose 1966.

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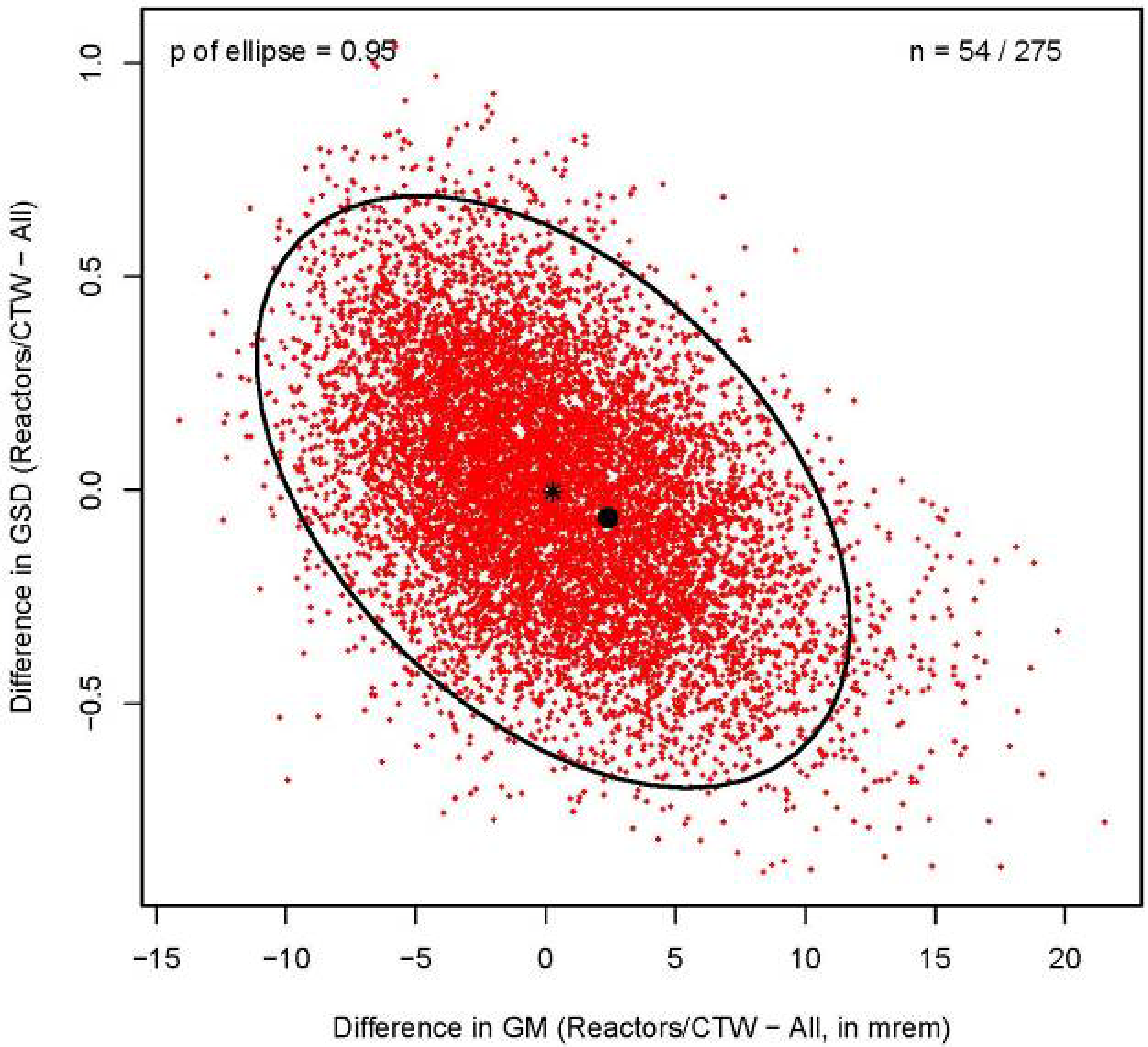

Figure C-39. SRS tritium dose 1966.

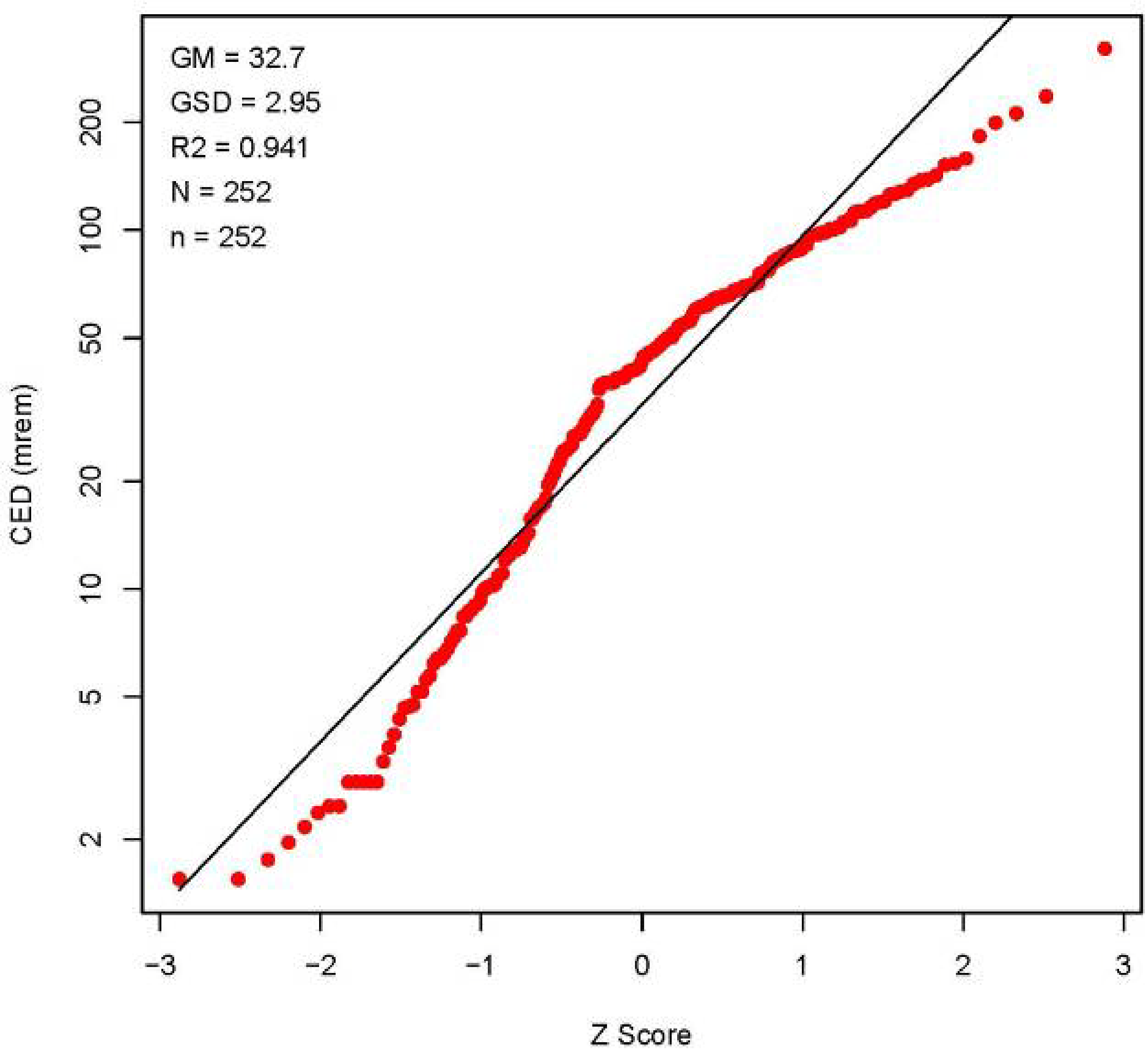

Figure C-40. SRS tritium dose 1967.

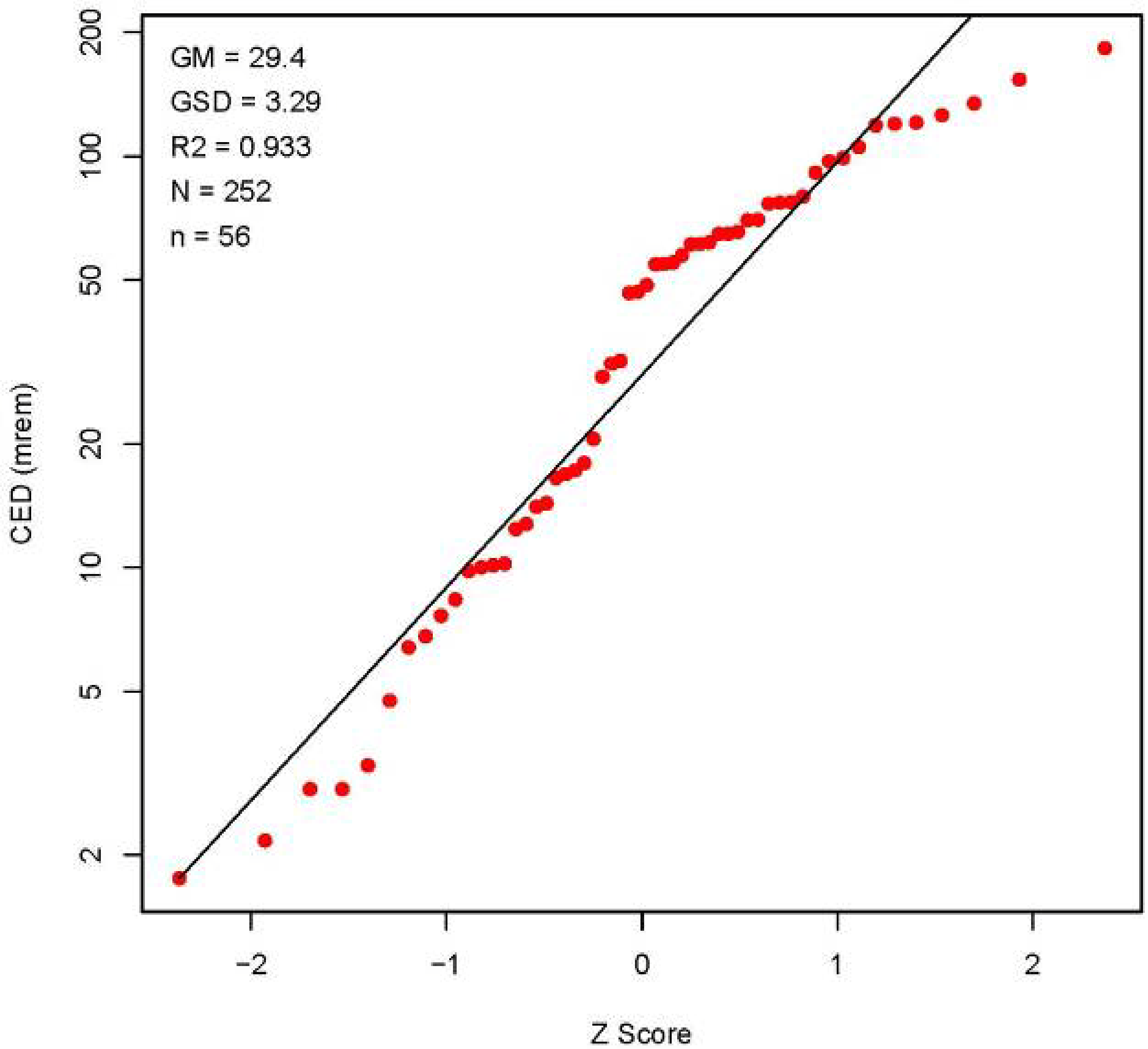

Figure C-41. SRS reactor/CTW tritium dose 1967.

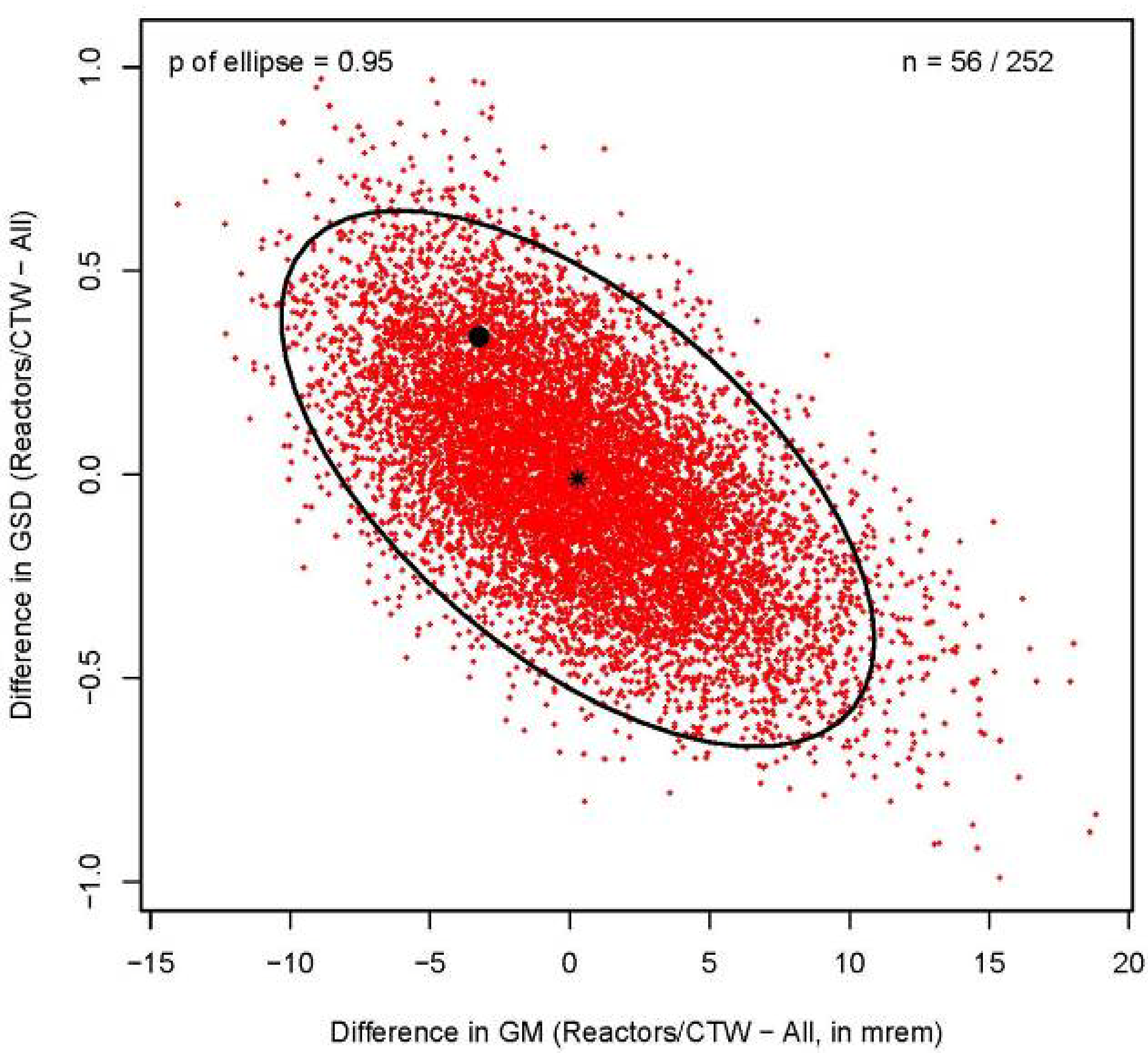

Figure C-42. SRS tritium dose 1967.

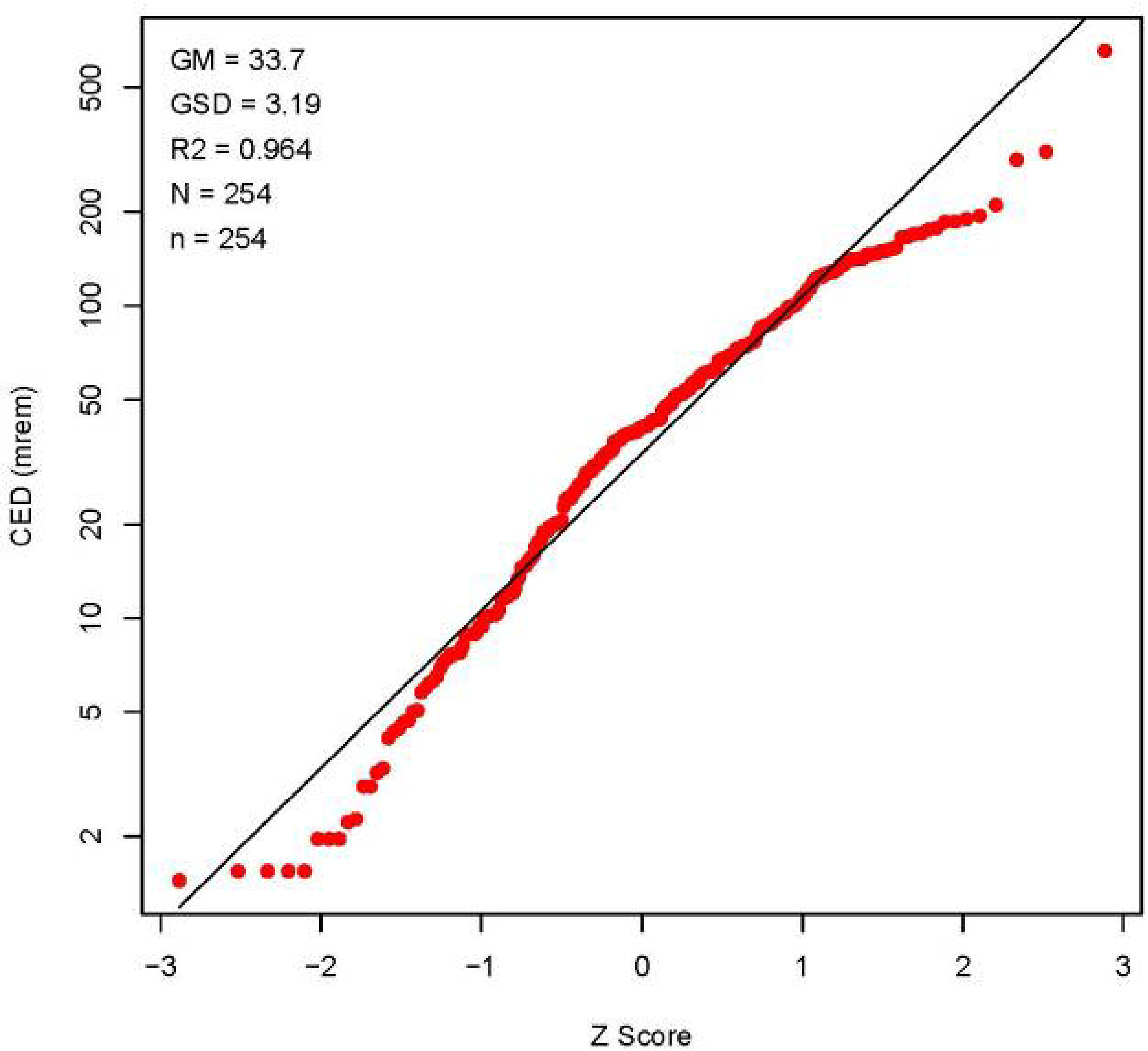

Figure C-43. SRS tritium dose 1968.

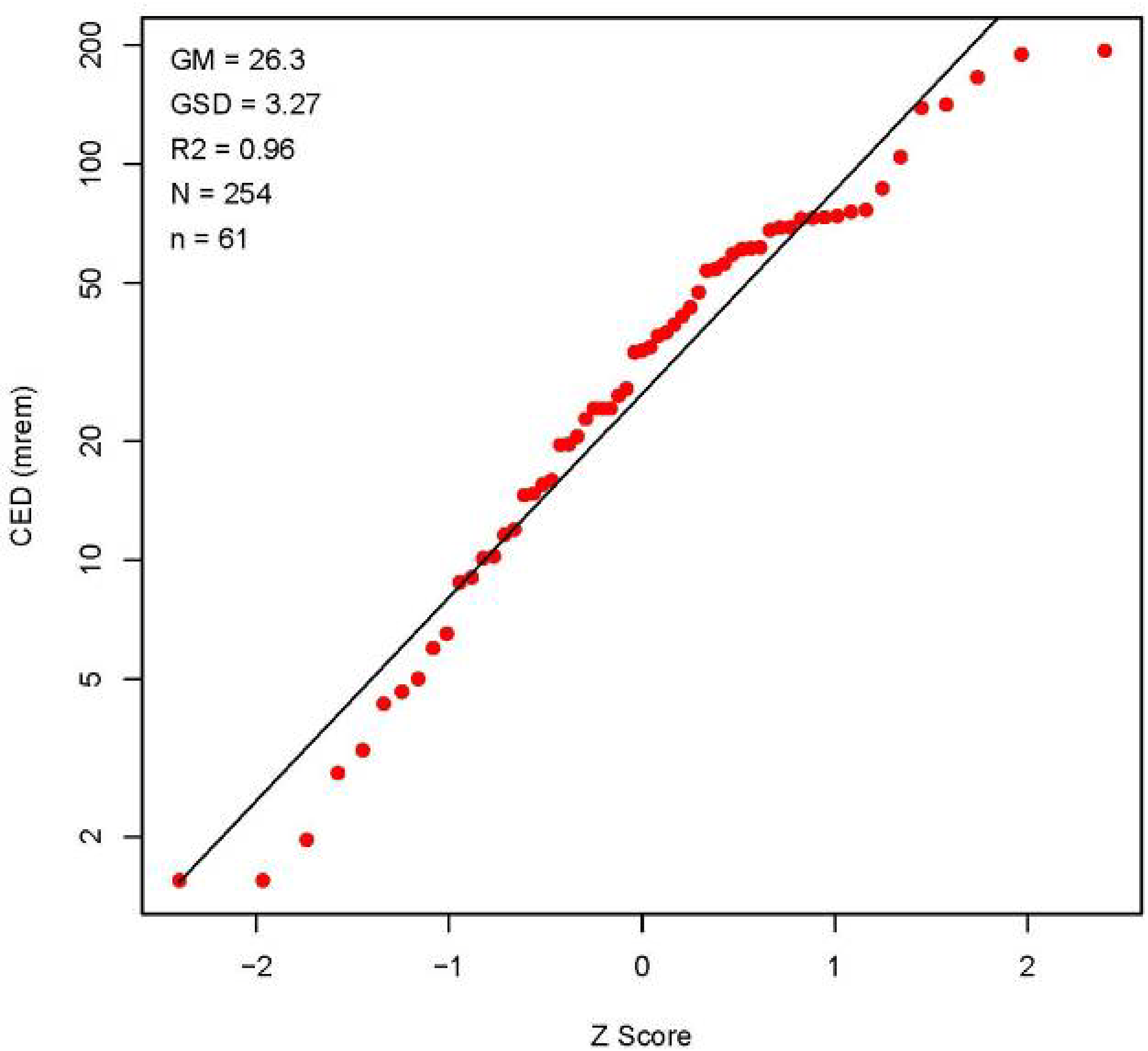

Figure C-44. SRS reactor/CTW tritium dose 1968.

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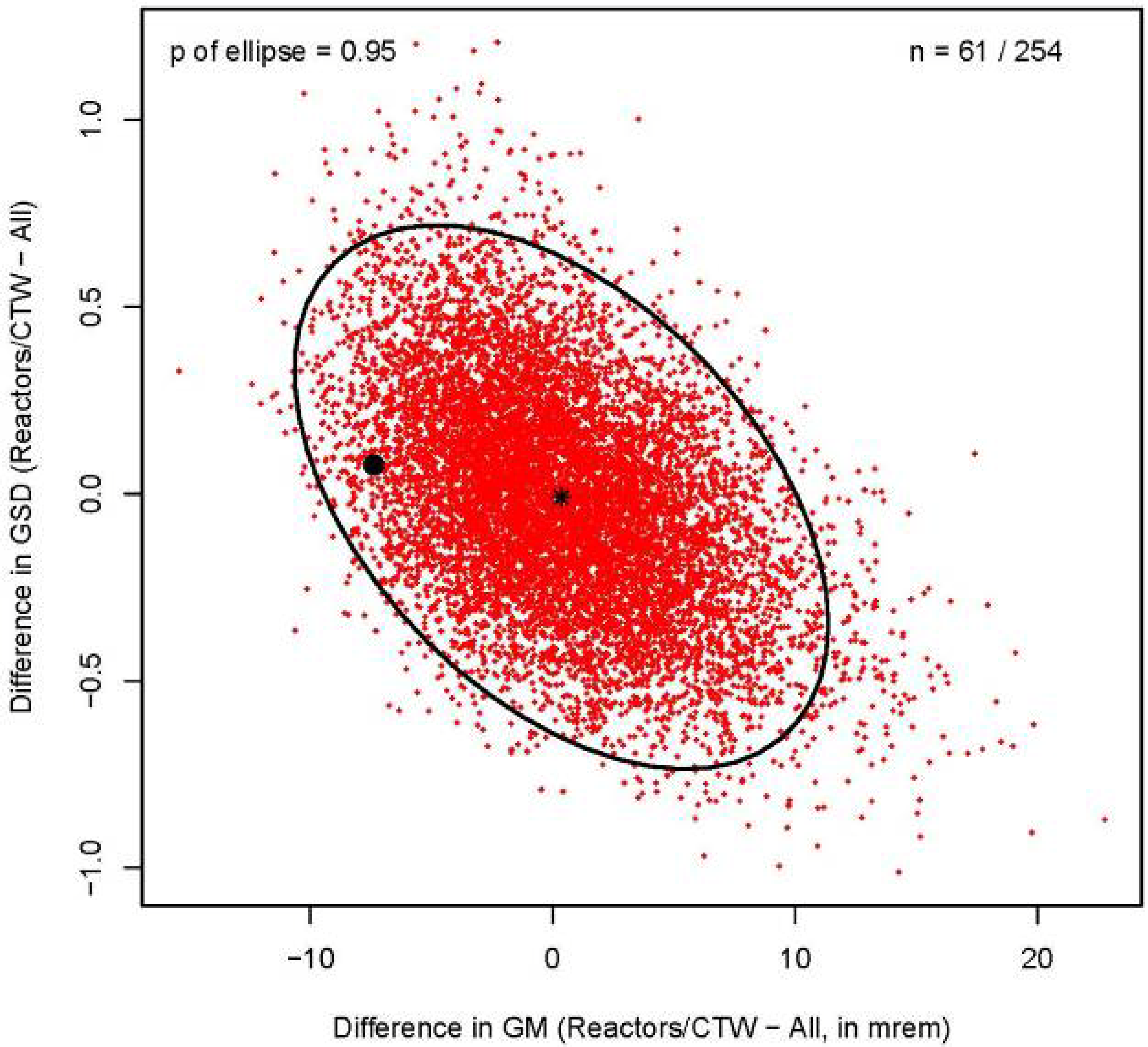

Figure C-45. SRS tritium dose 1968.

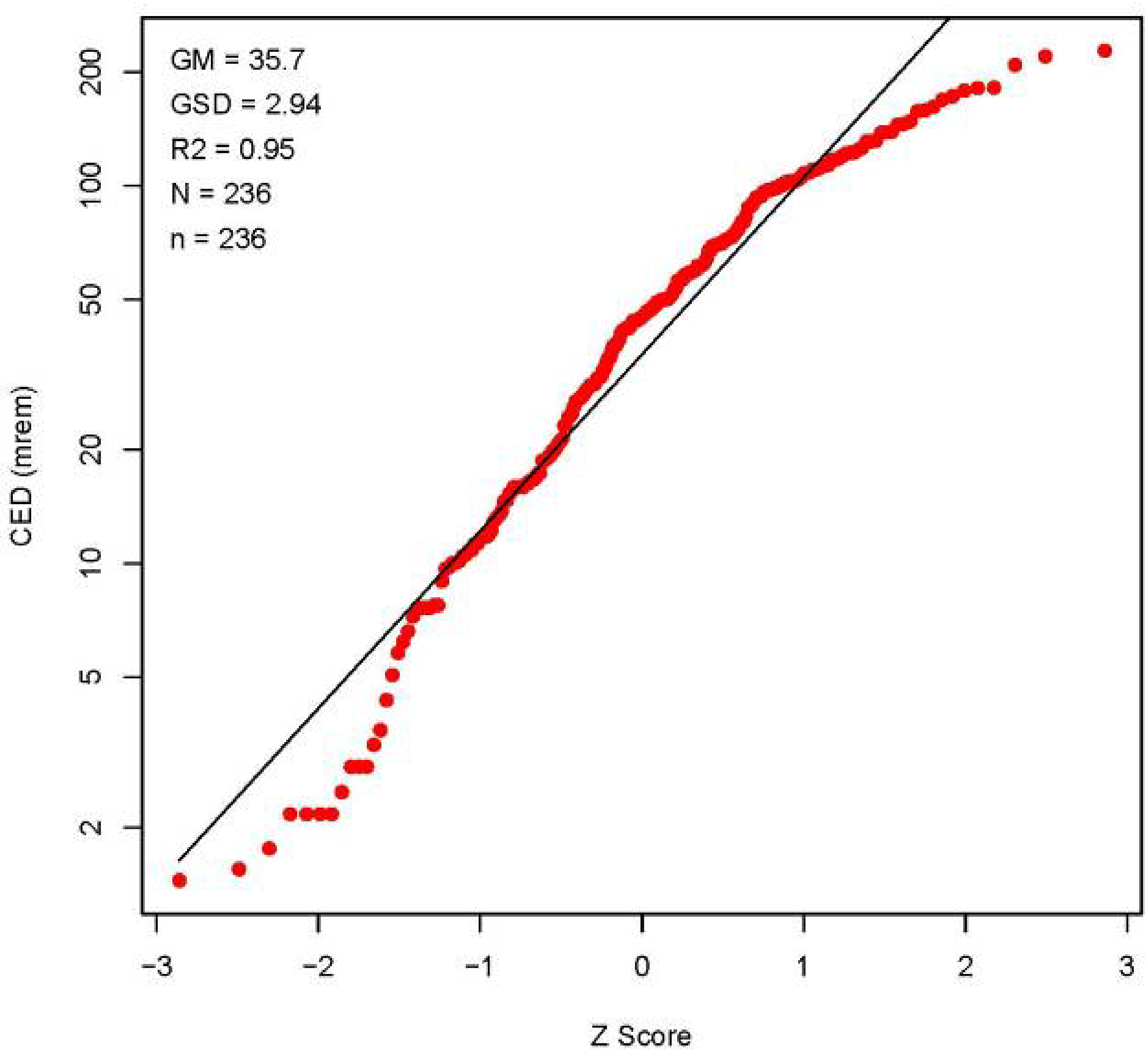

Figure C-46. SRS tritium dose 1969.

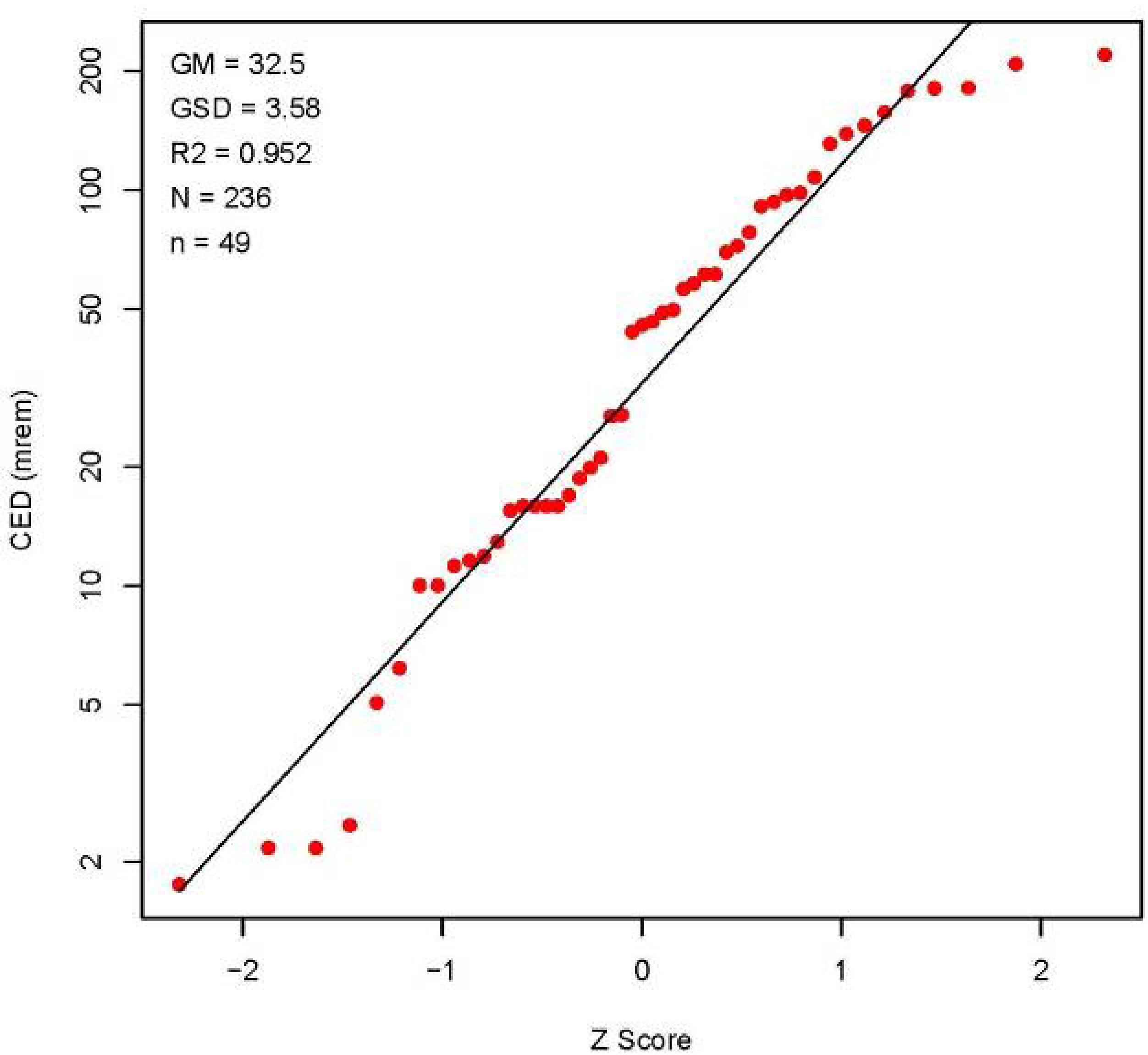

Figure C-47. SRS reactor/CTW tritium dose 1969.

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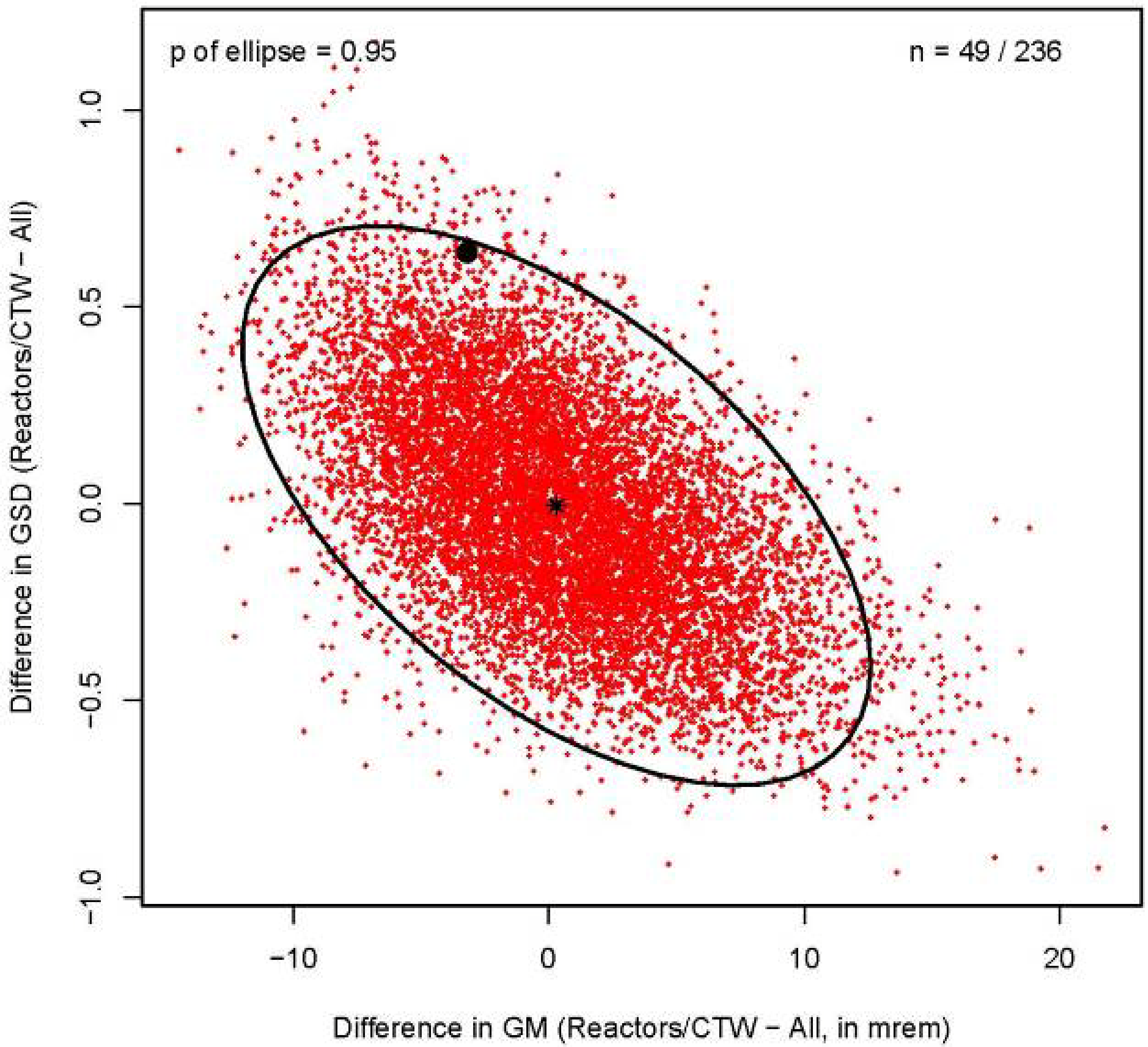

Figure C-48. SRS tritium dose 1969.

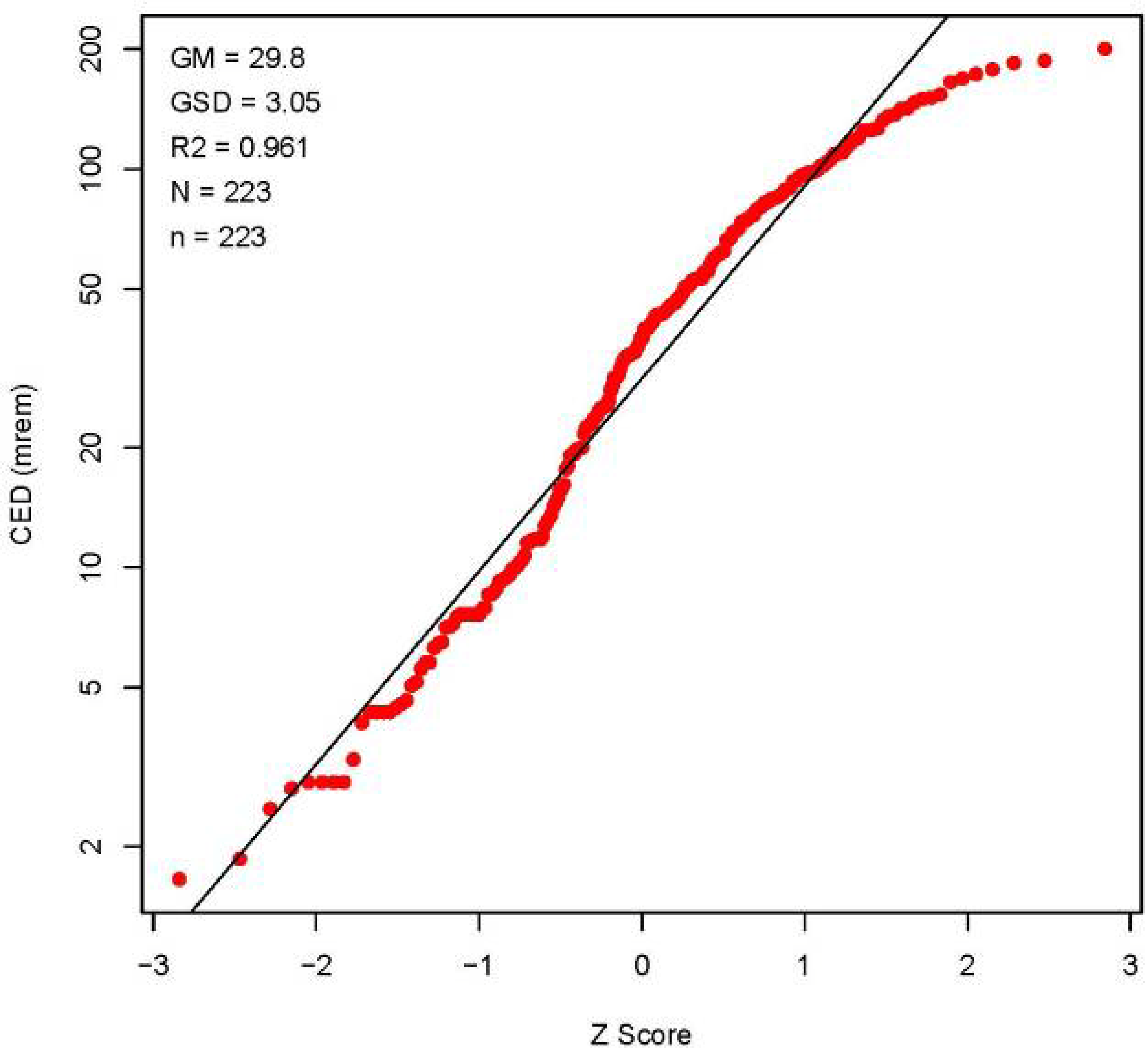

Figure C-49. SRS tritium dose 1970.

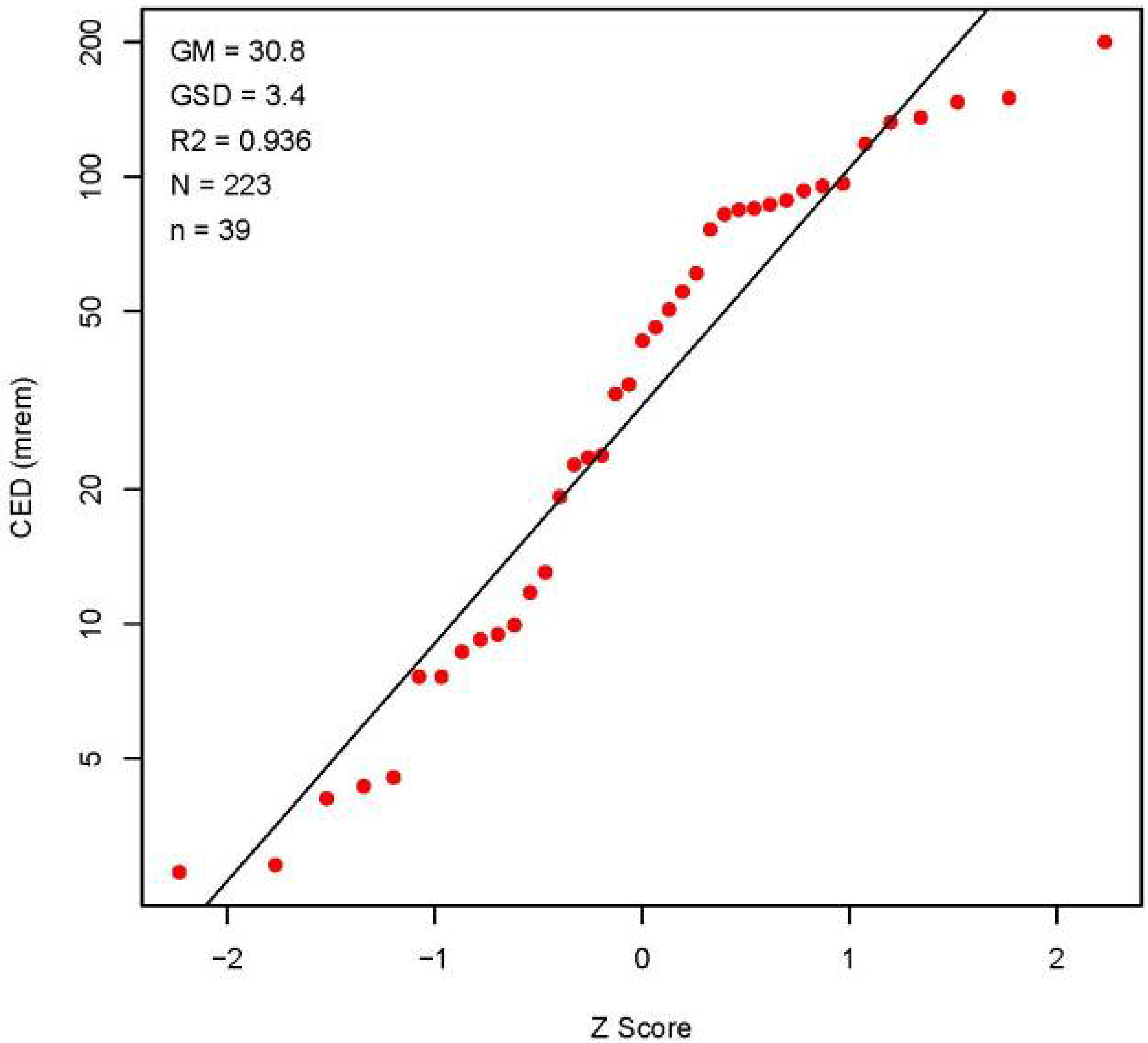

Figure C-50. SRS reactor/CTW tritium dose 1970.

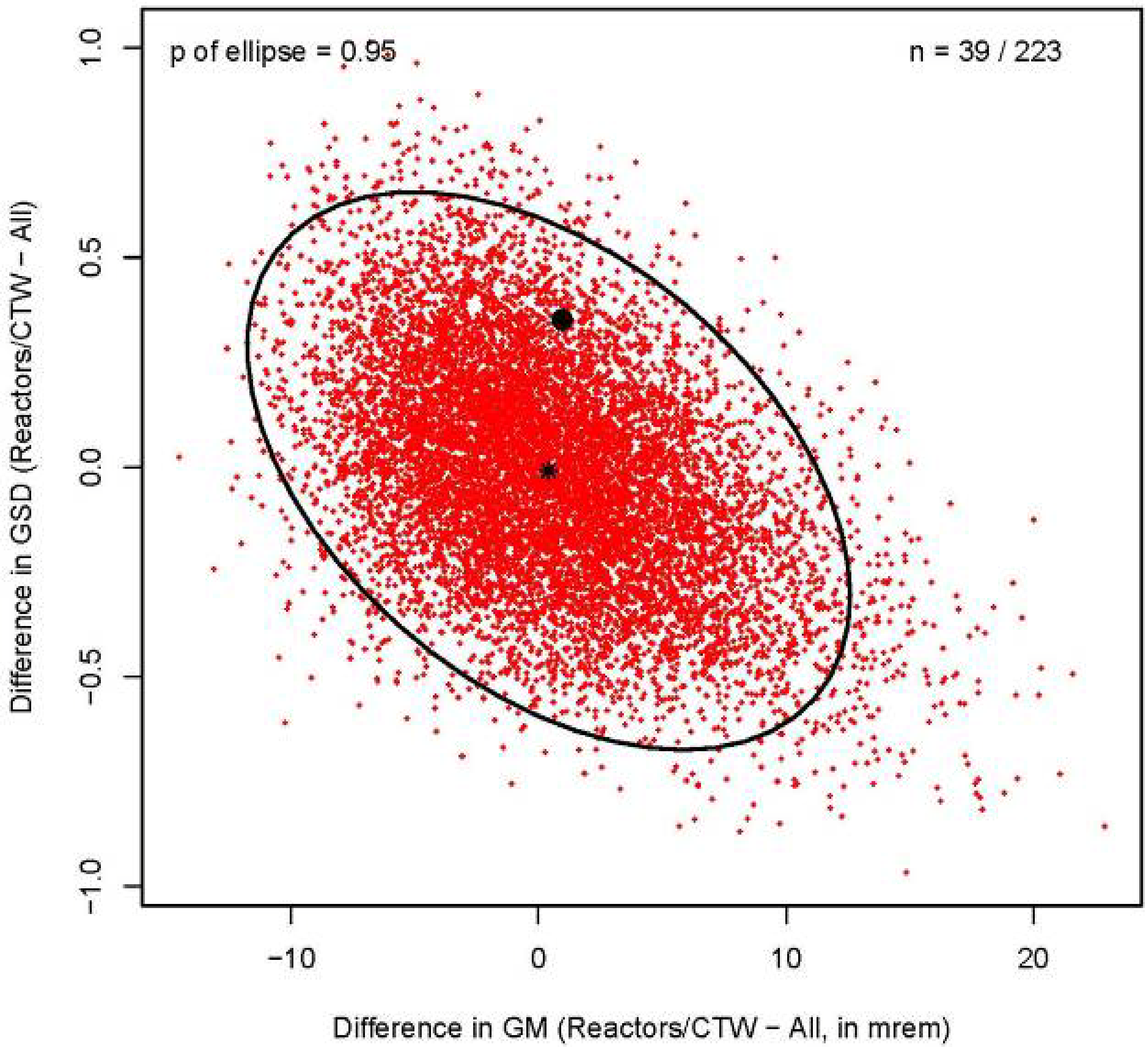

Figure C-51. SRS tritium dose 1970.

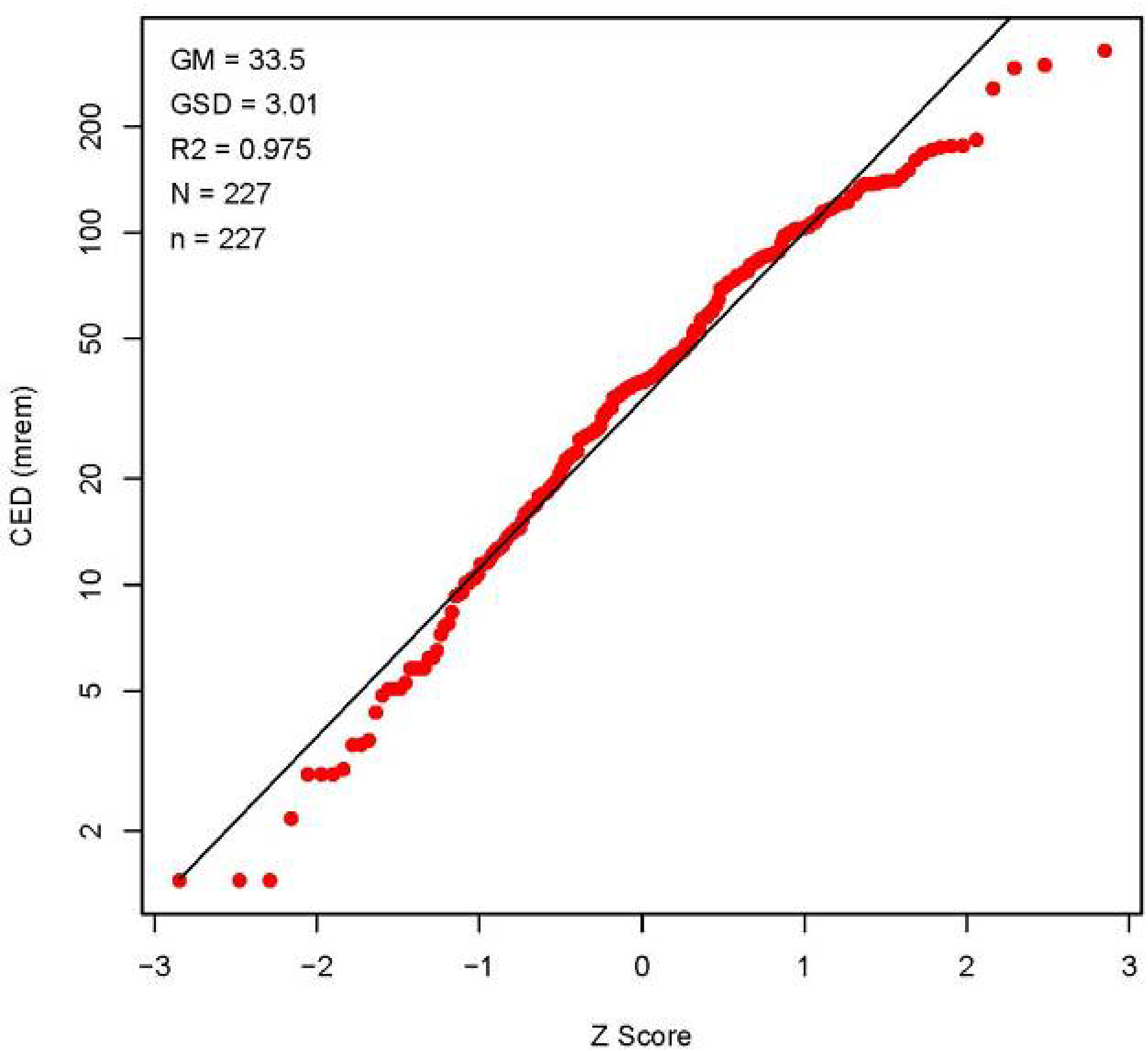

Figure C-52. SRS tritium dose 1971.

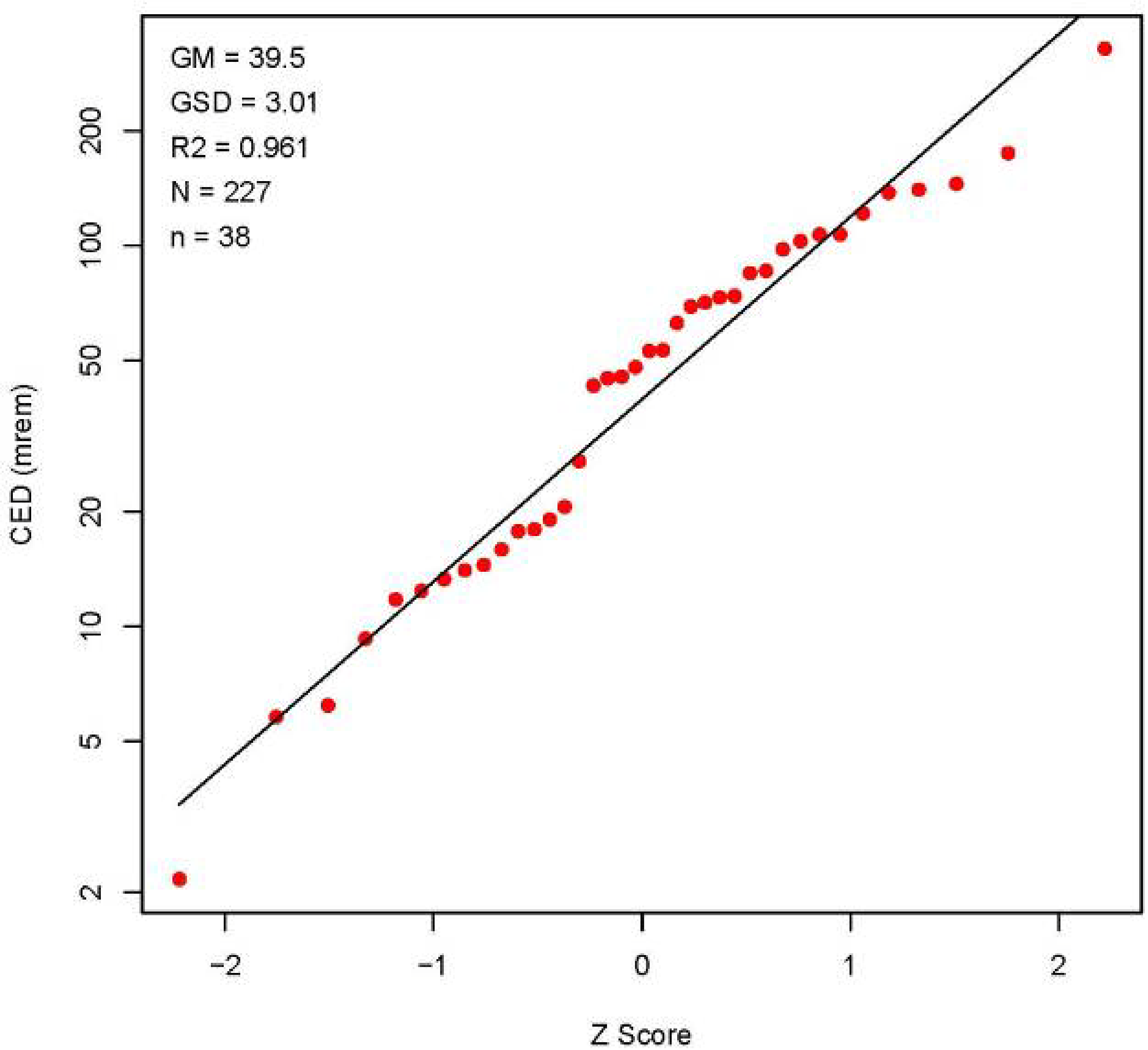

Figure C-53. SRS reactor/CTW tritium dose 1971.

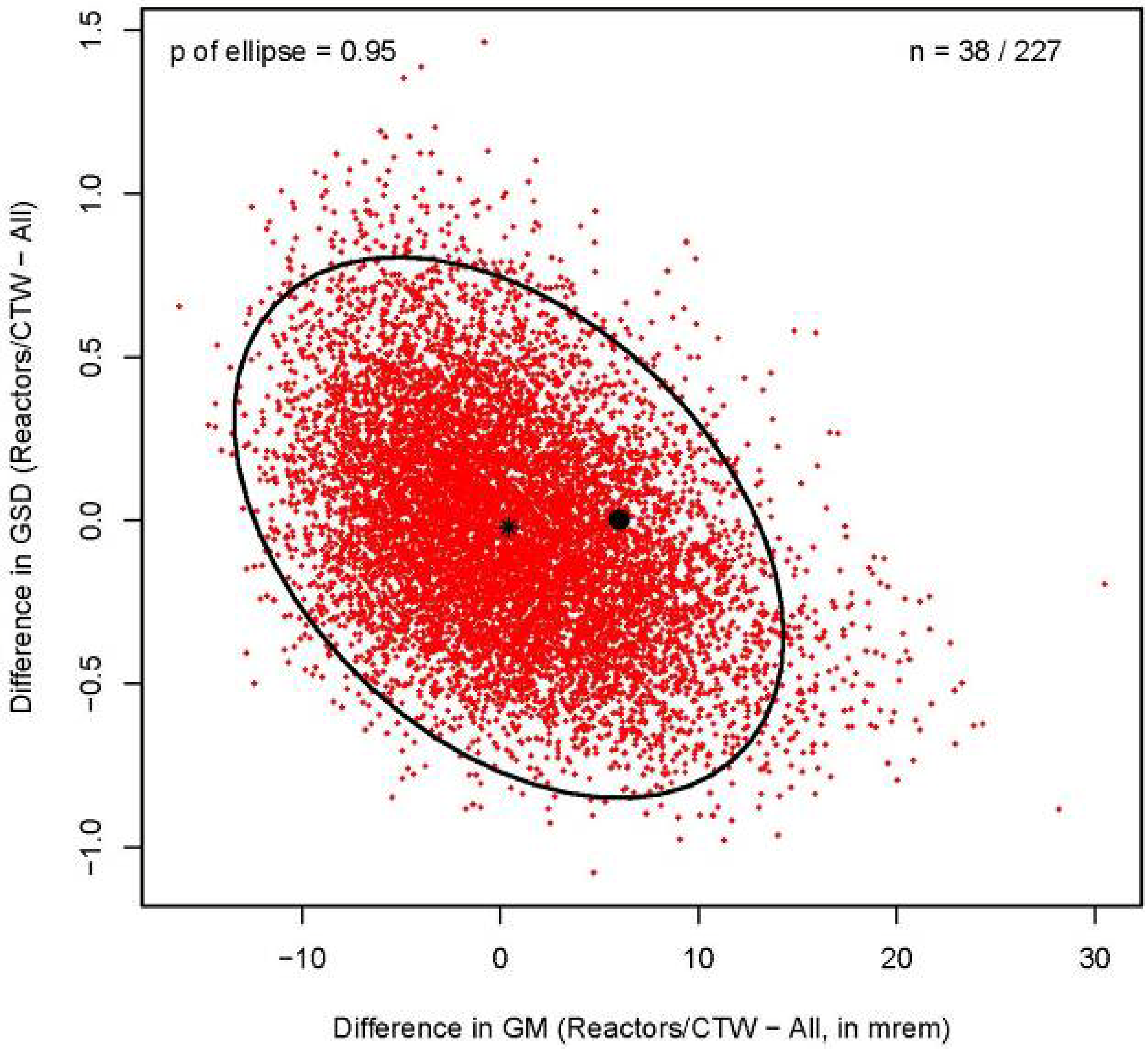

Figure C-54. SRS tritium dose 1971.

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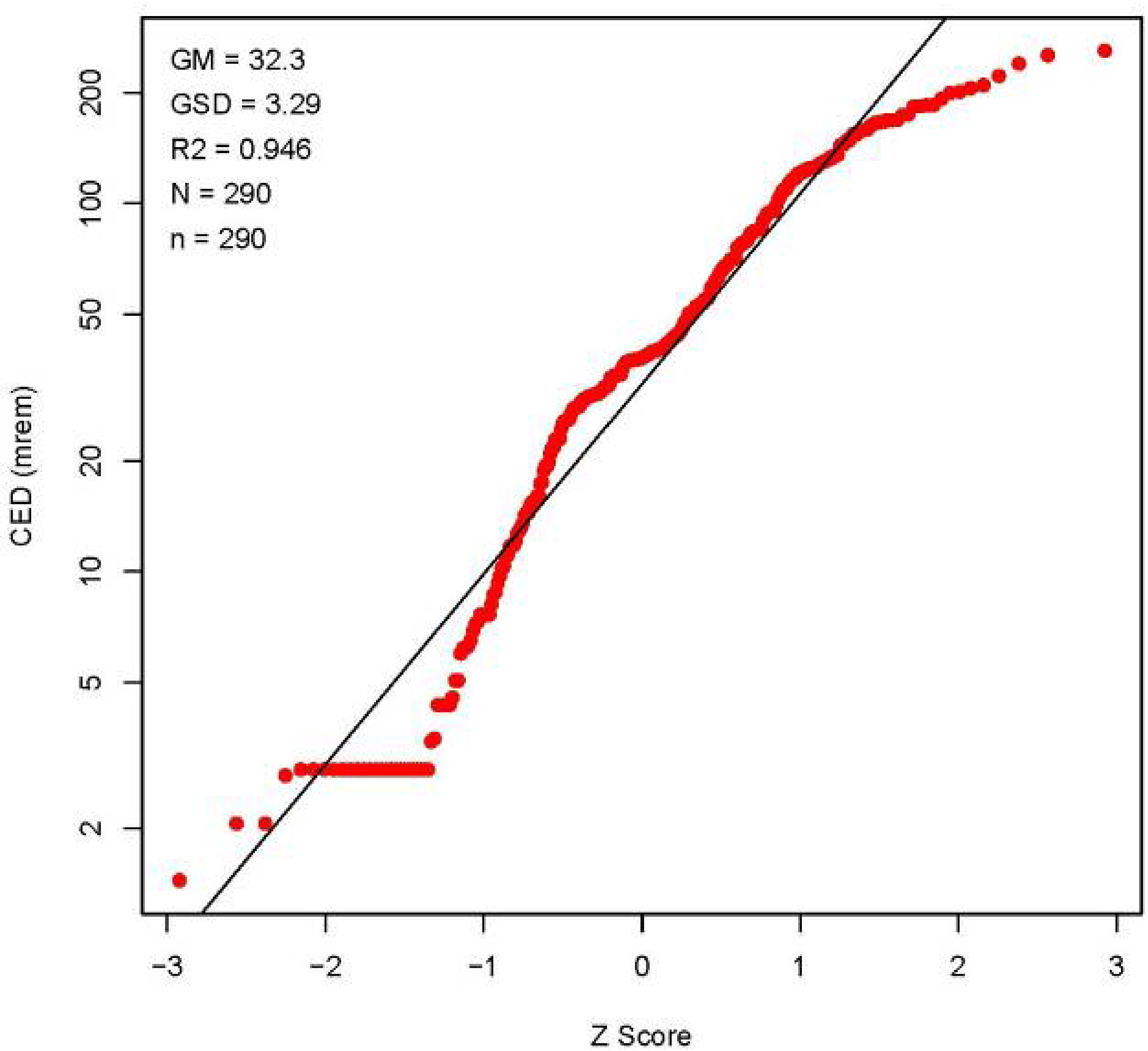

Figure C-55. SRS tritium dose 1972.

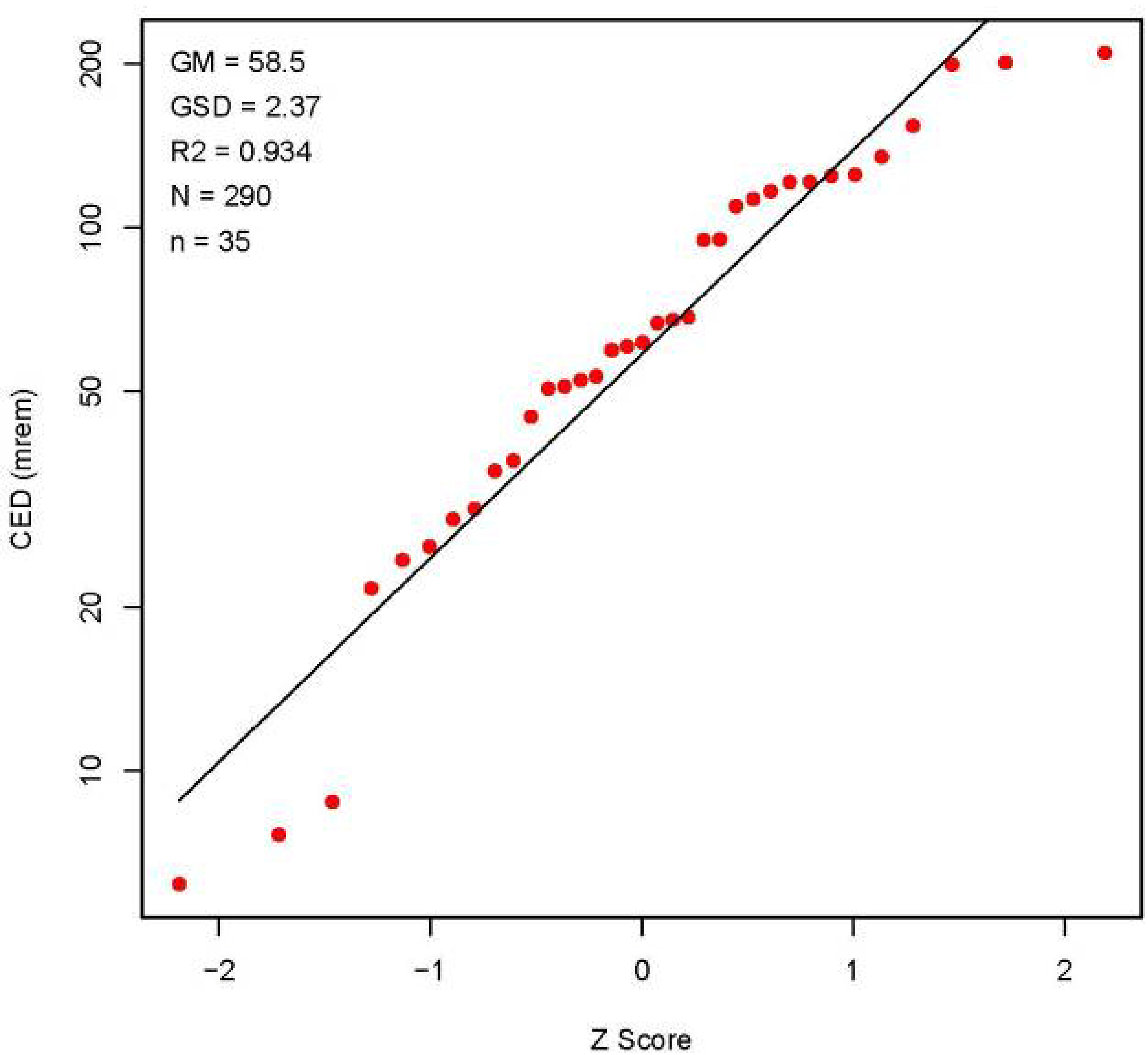

Figure C-56. SRS reactor/CTW tritium dose 1972.

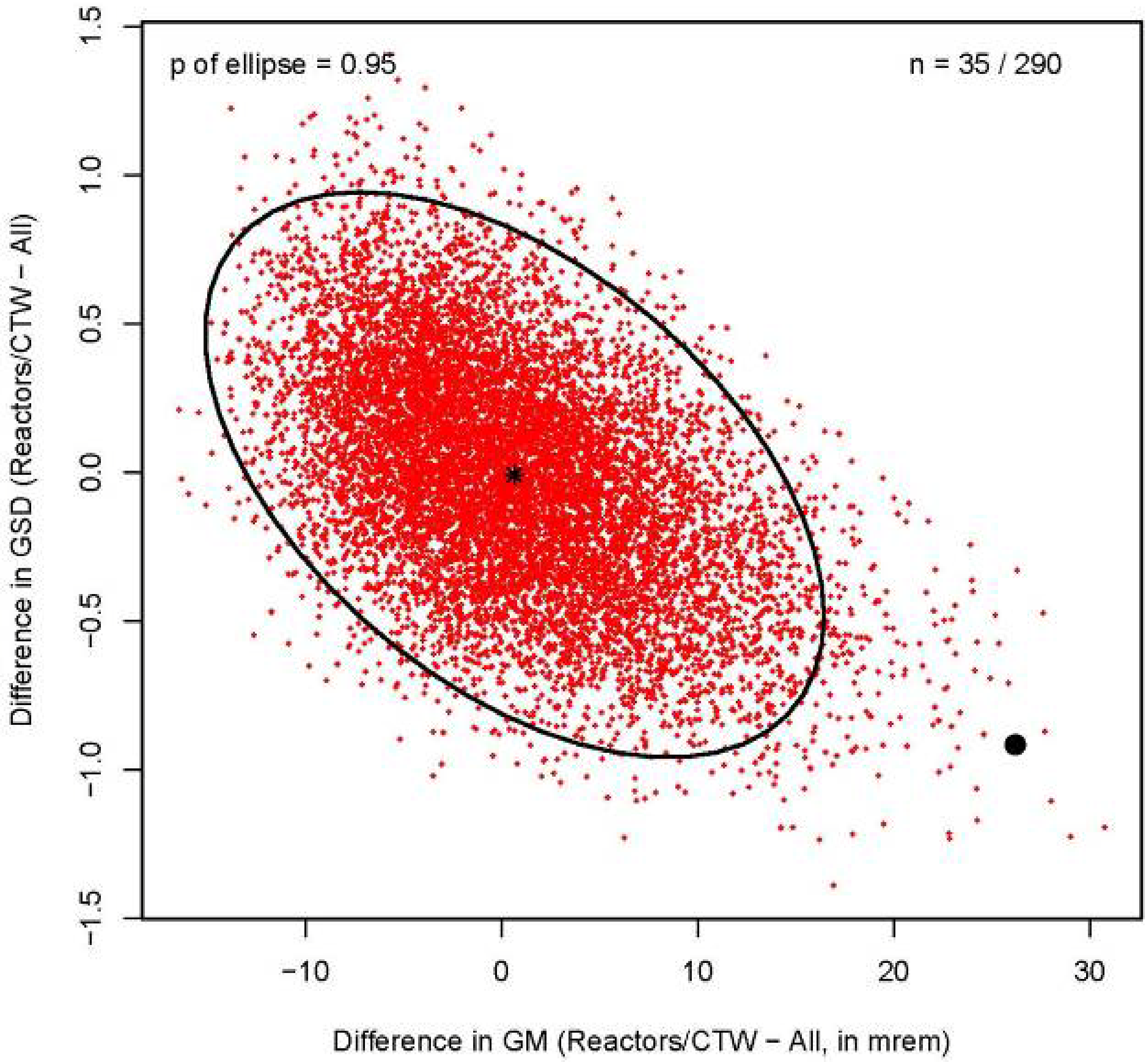

Figure C-57. SRS tritium dose 1972.

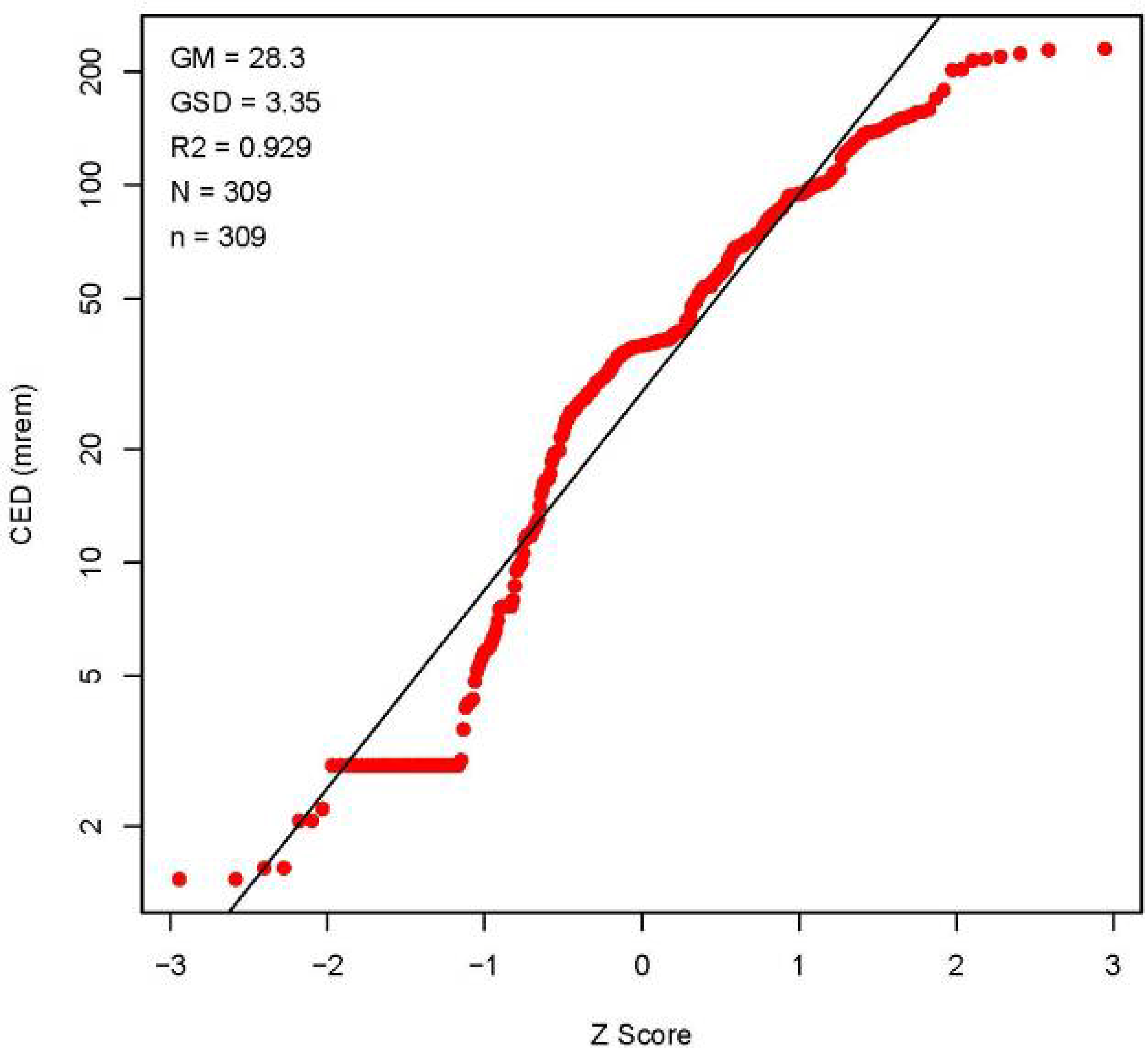

Figure C-58. SRS tritium dose 1973.

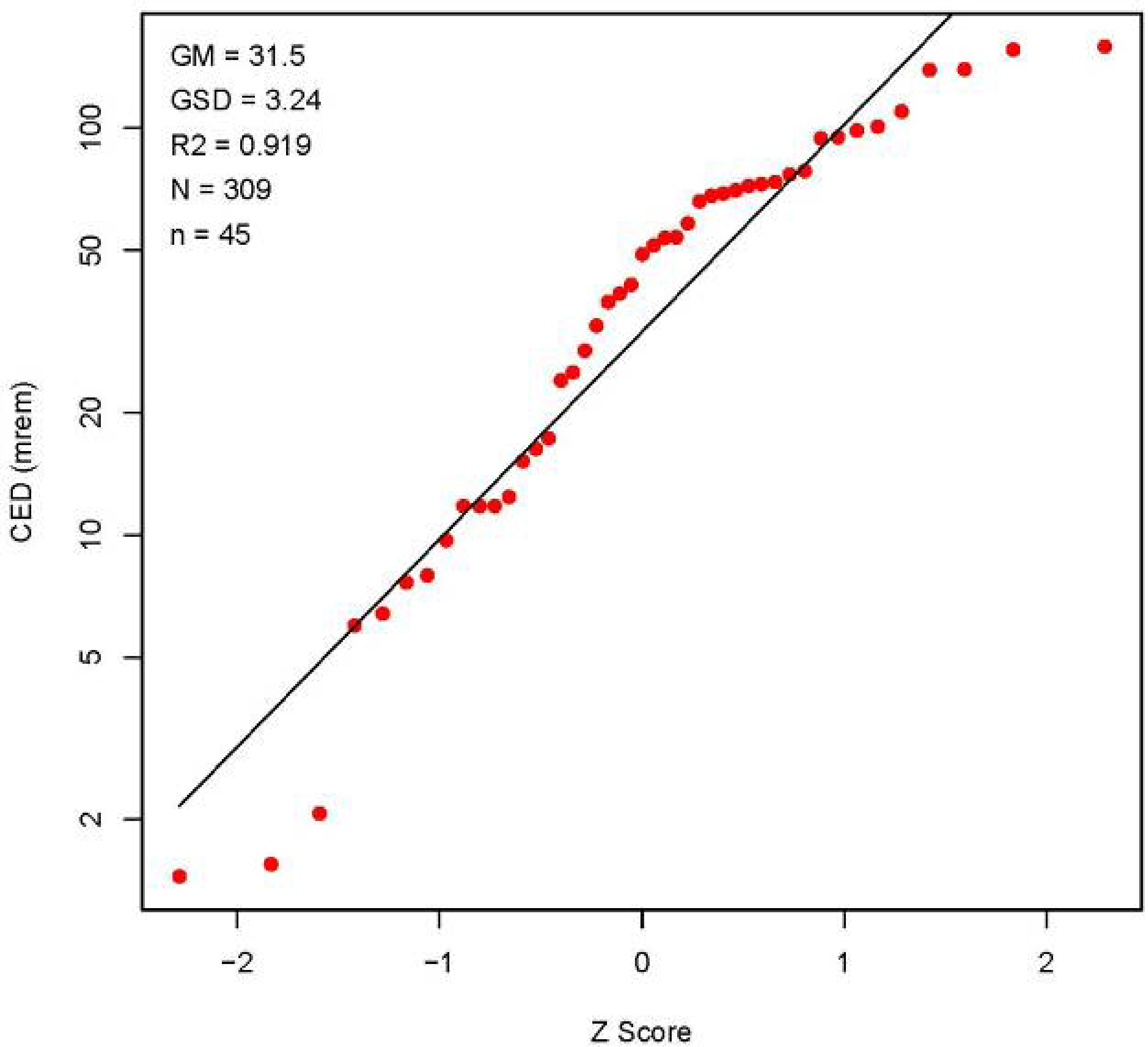

Figure C-59. SRS reactor/CTW tritium dose 1973.

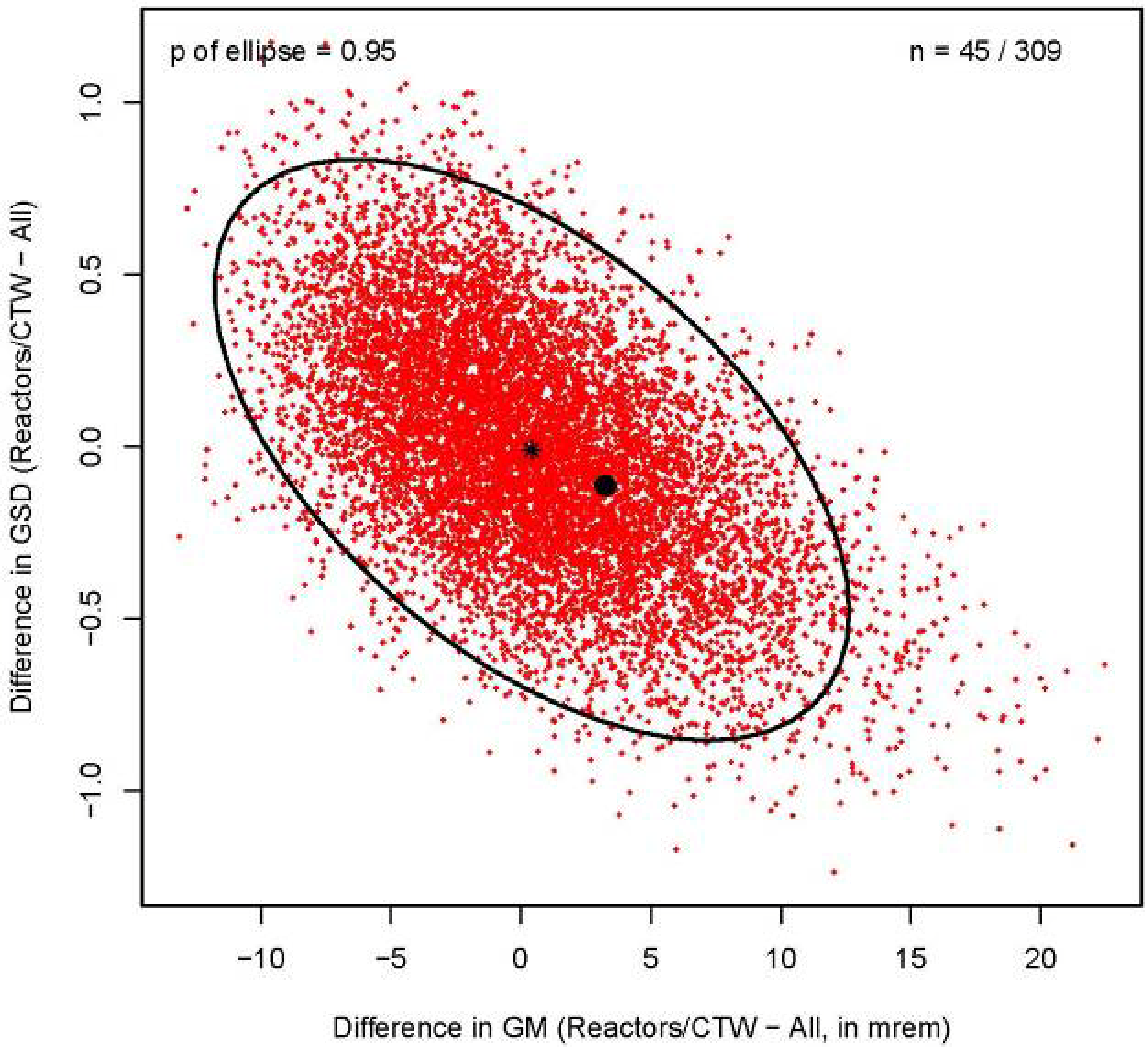

Figure C-60. SRS tritium dose 1973.

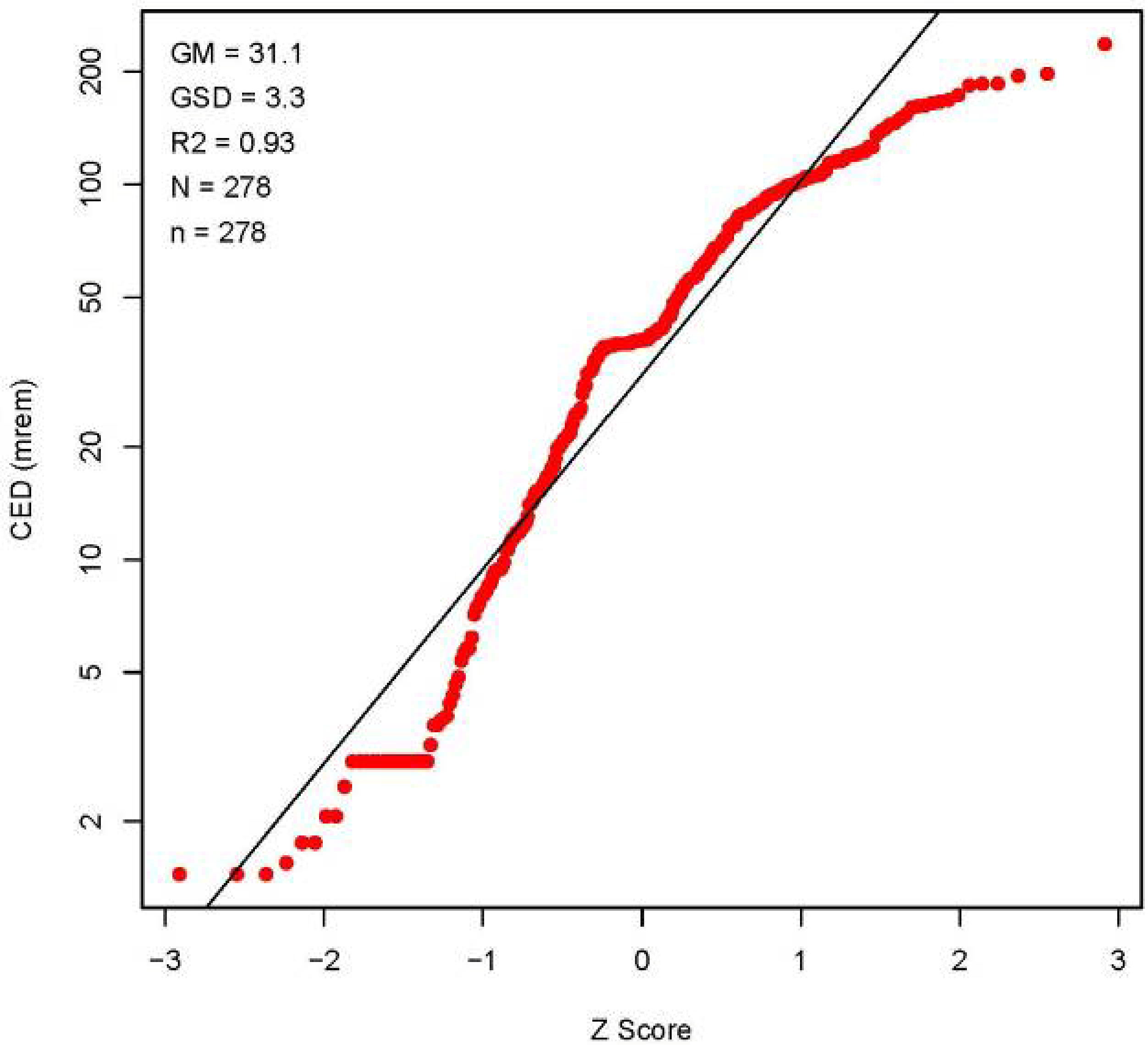

Figure C-61. SRS tritium dose 1974.

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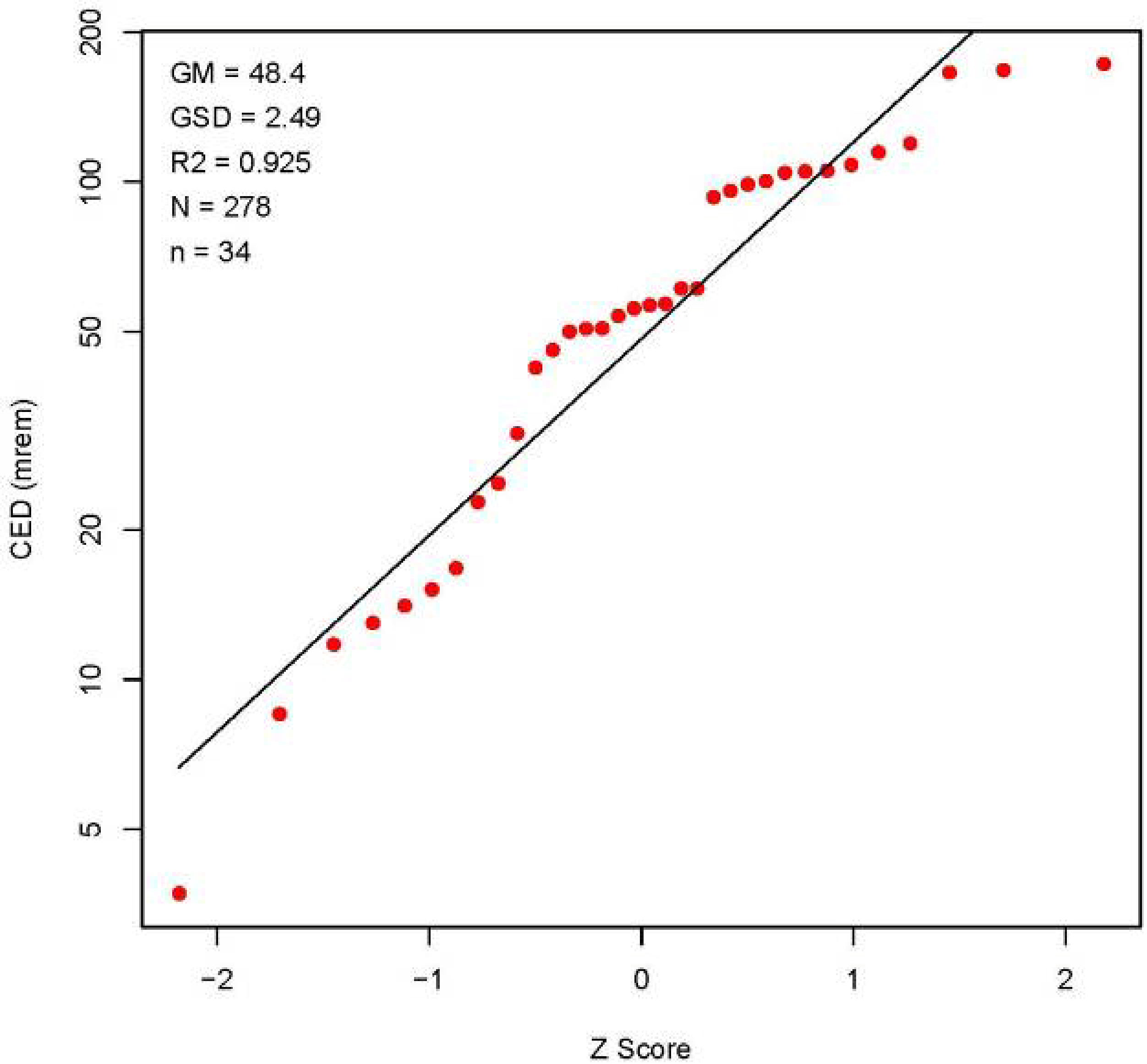

Figure C-62. SRS reactor/CTW tritium dose 1974.

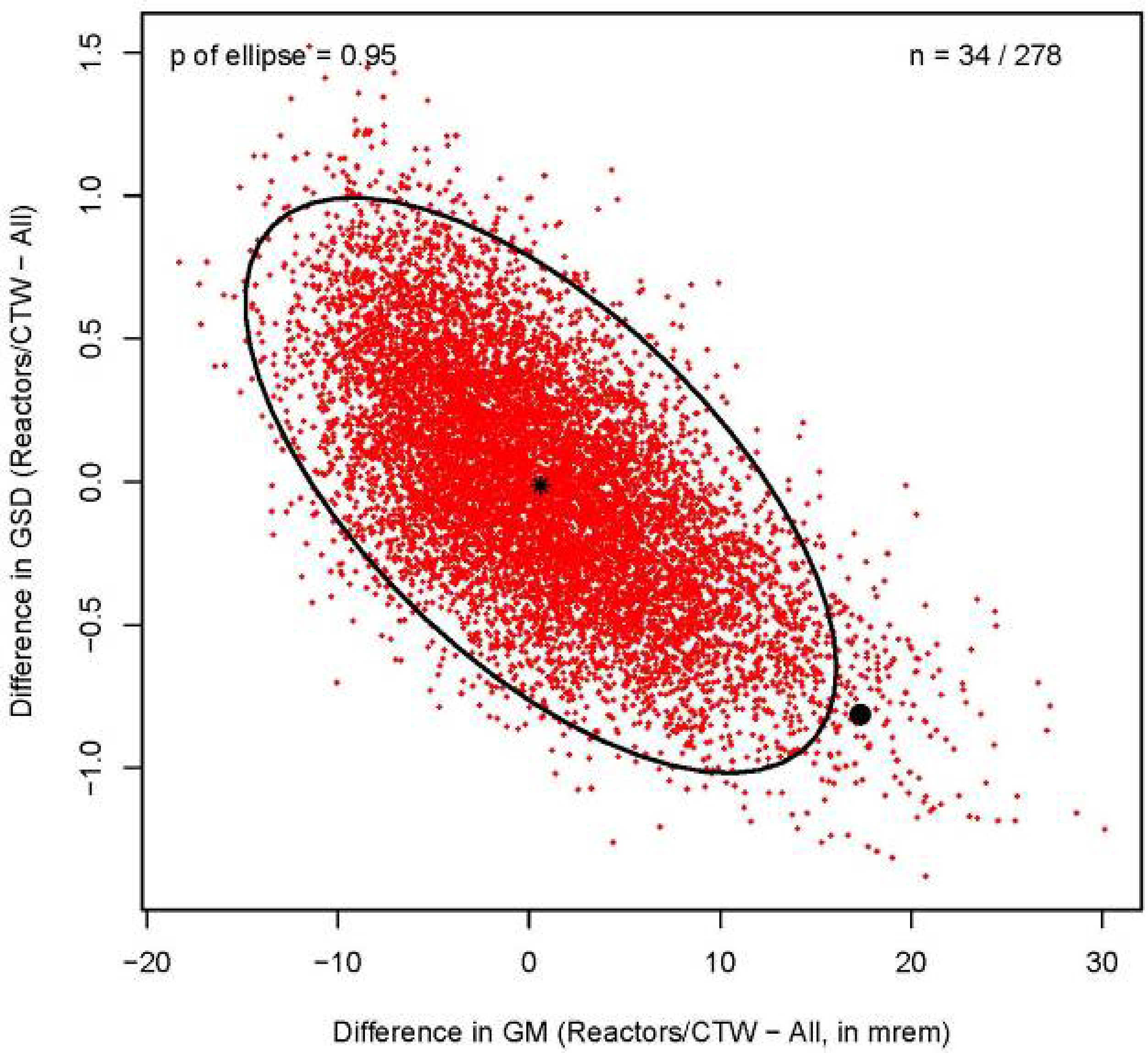

Figure C-63. SRS tritium dose 1974.

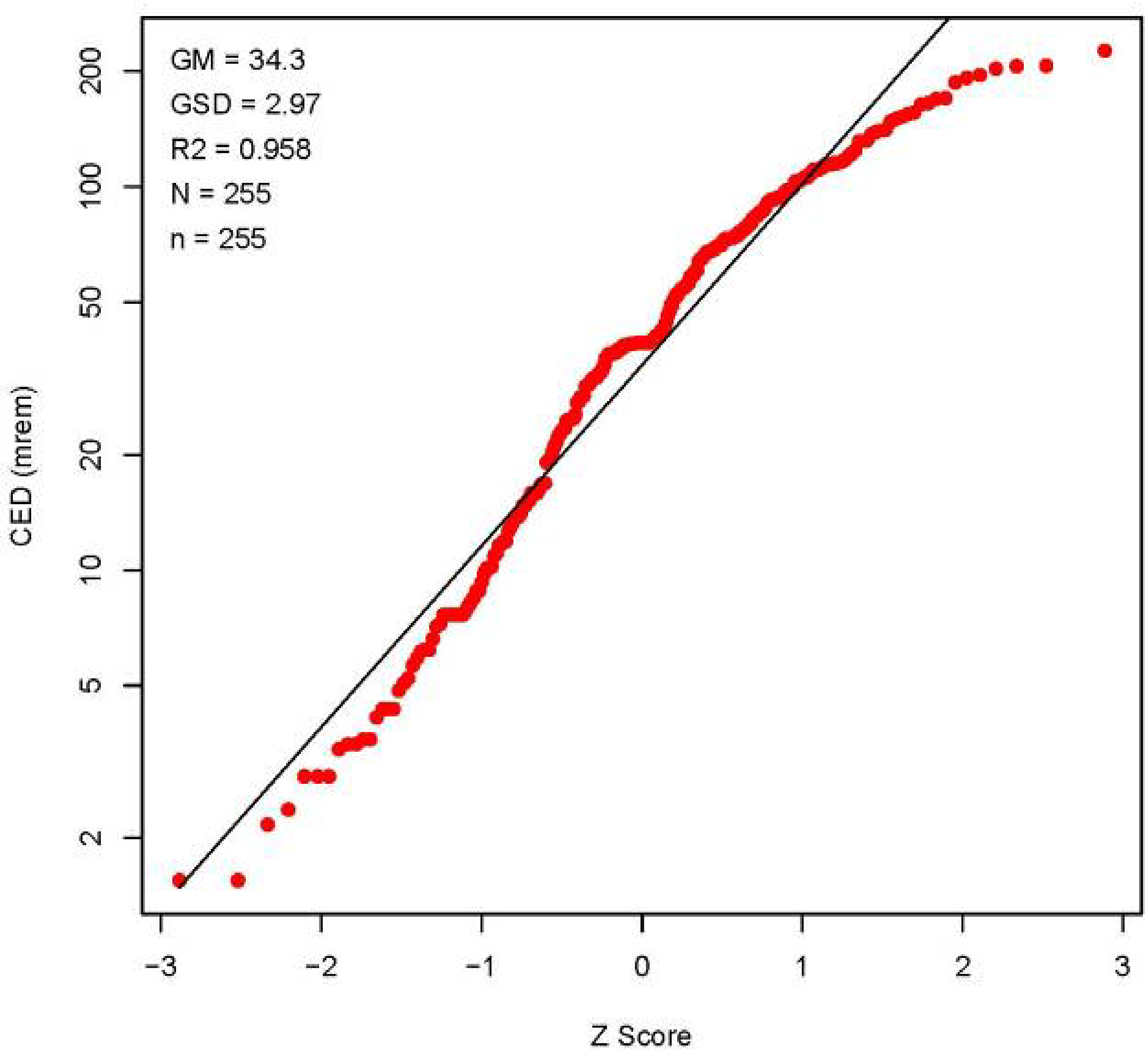

Figure C-64. SRS tritium dose 1975.

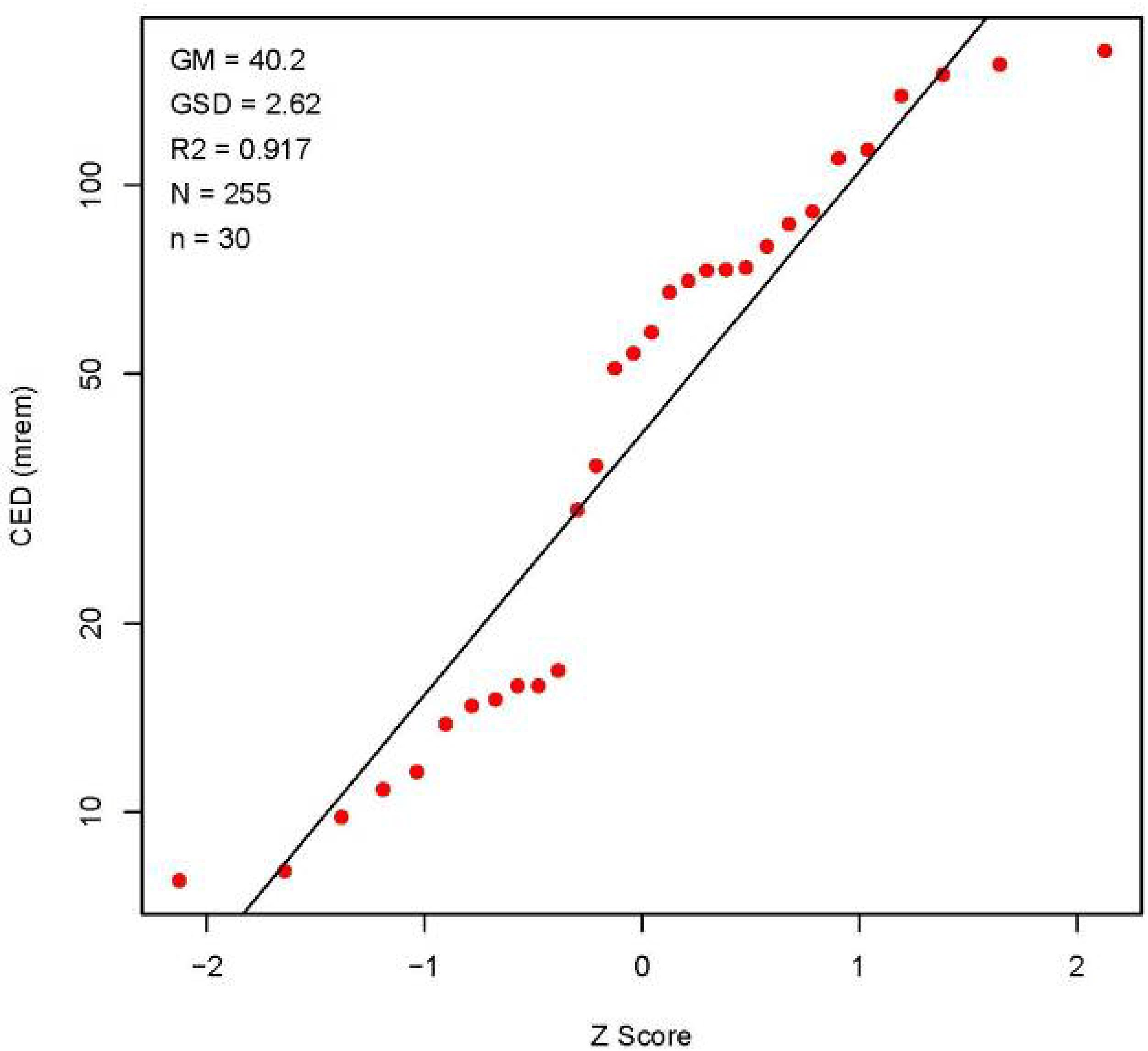

Figure C-65. SRS reactor/CTW tritium dose 1975.

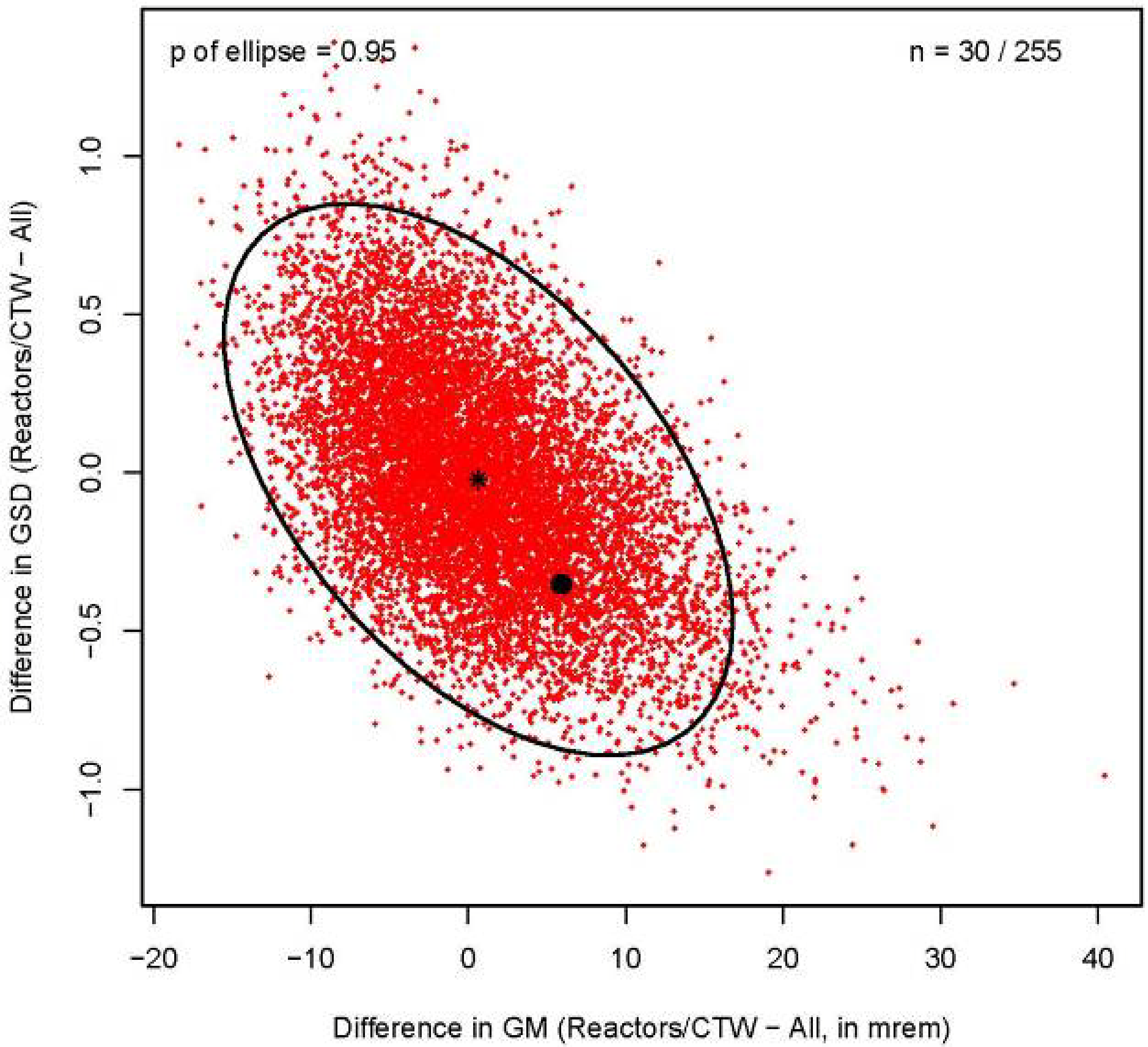

Figure C-66. SRS tritium dose 1975.

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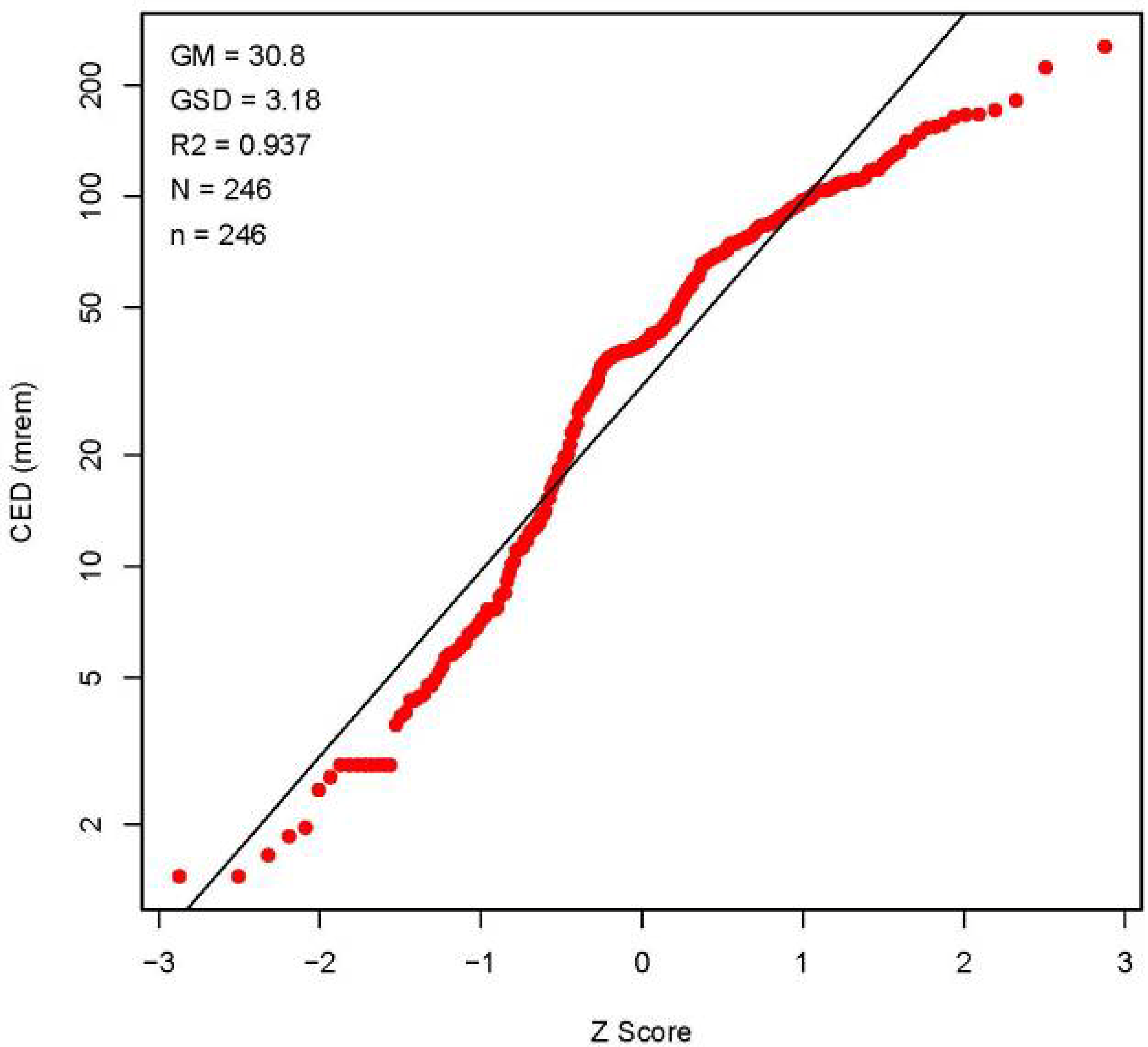

Figure C-67. SRS tritium dose 1976.

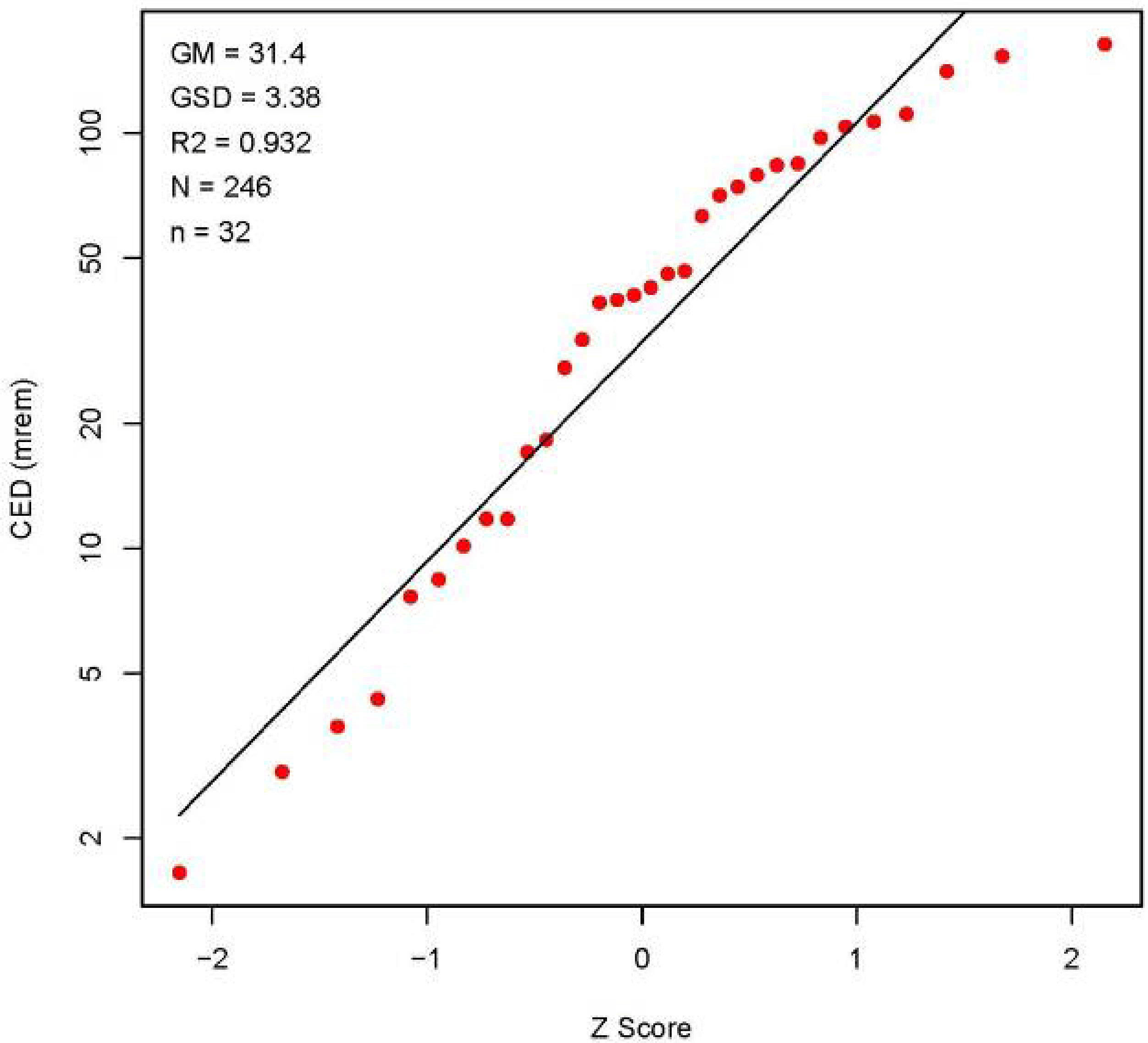

Figure C-68. SRS reactor/CTW tritium dose 1976.

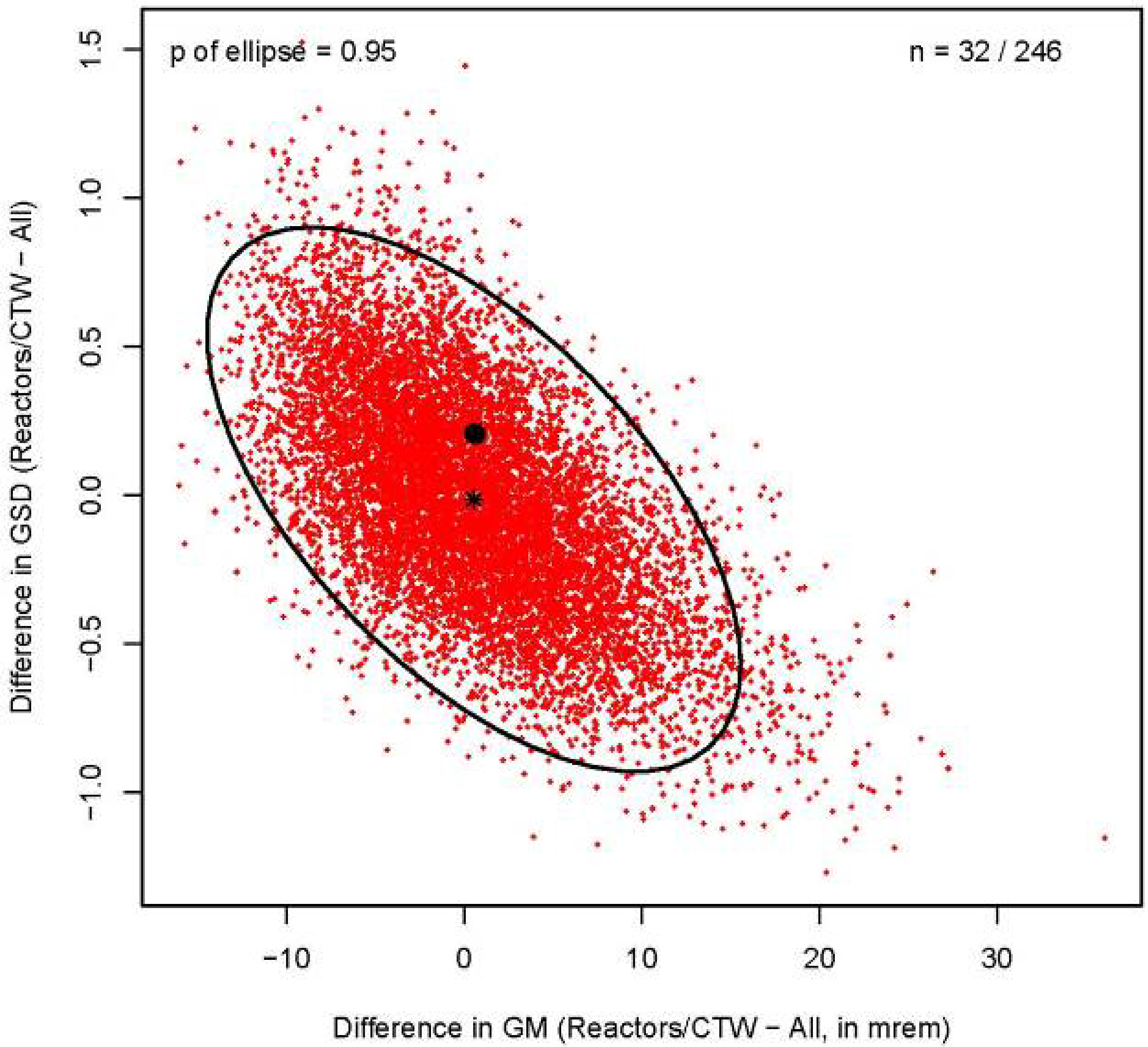

Figure C-69. SRS tritium dose 1976.

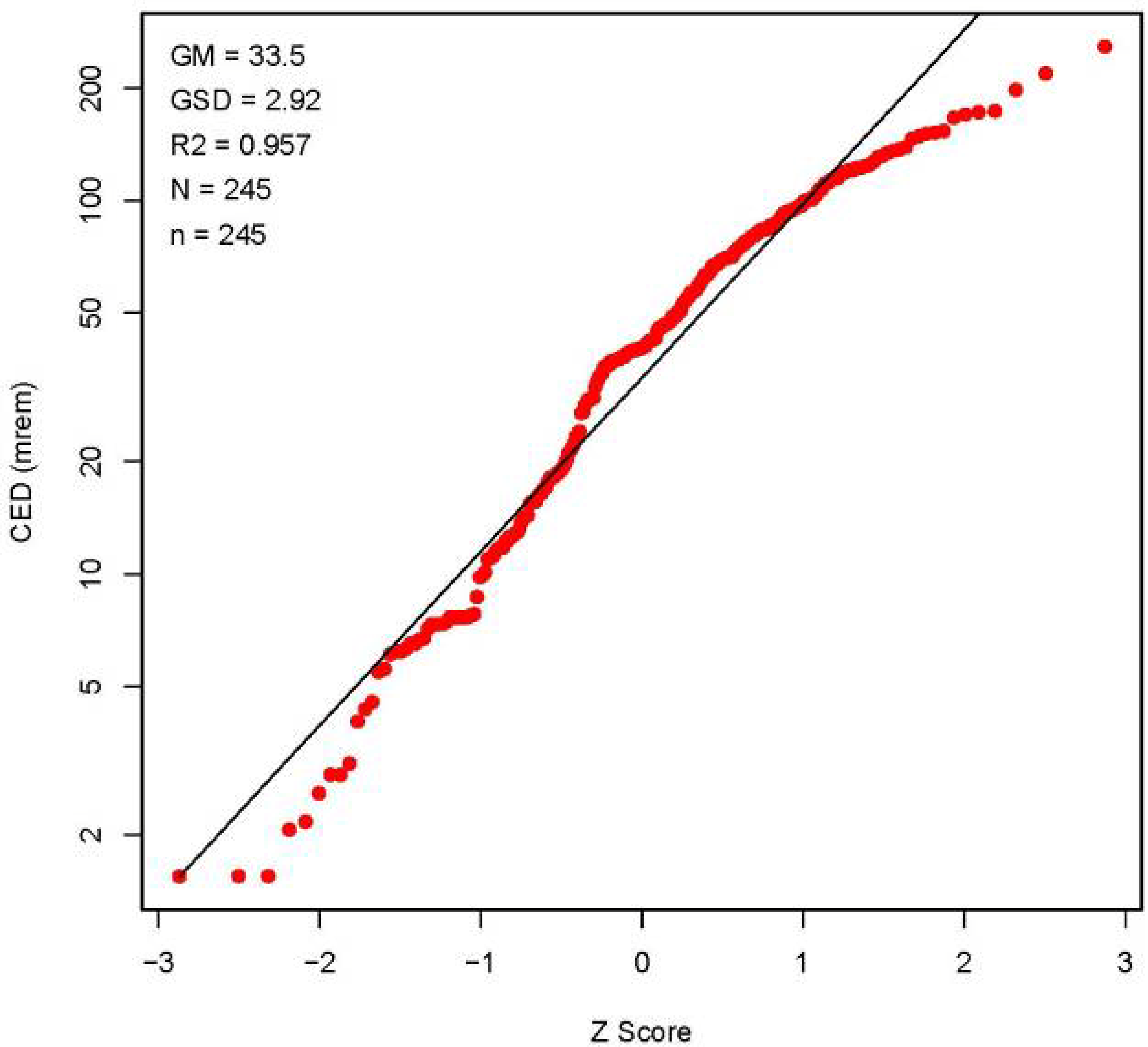

Figure C-70. SRS tritium dose 1977.

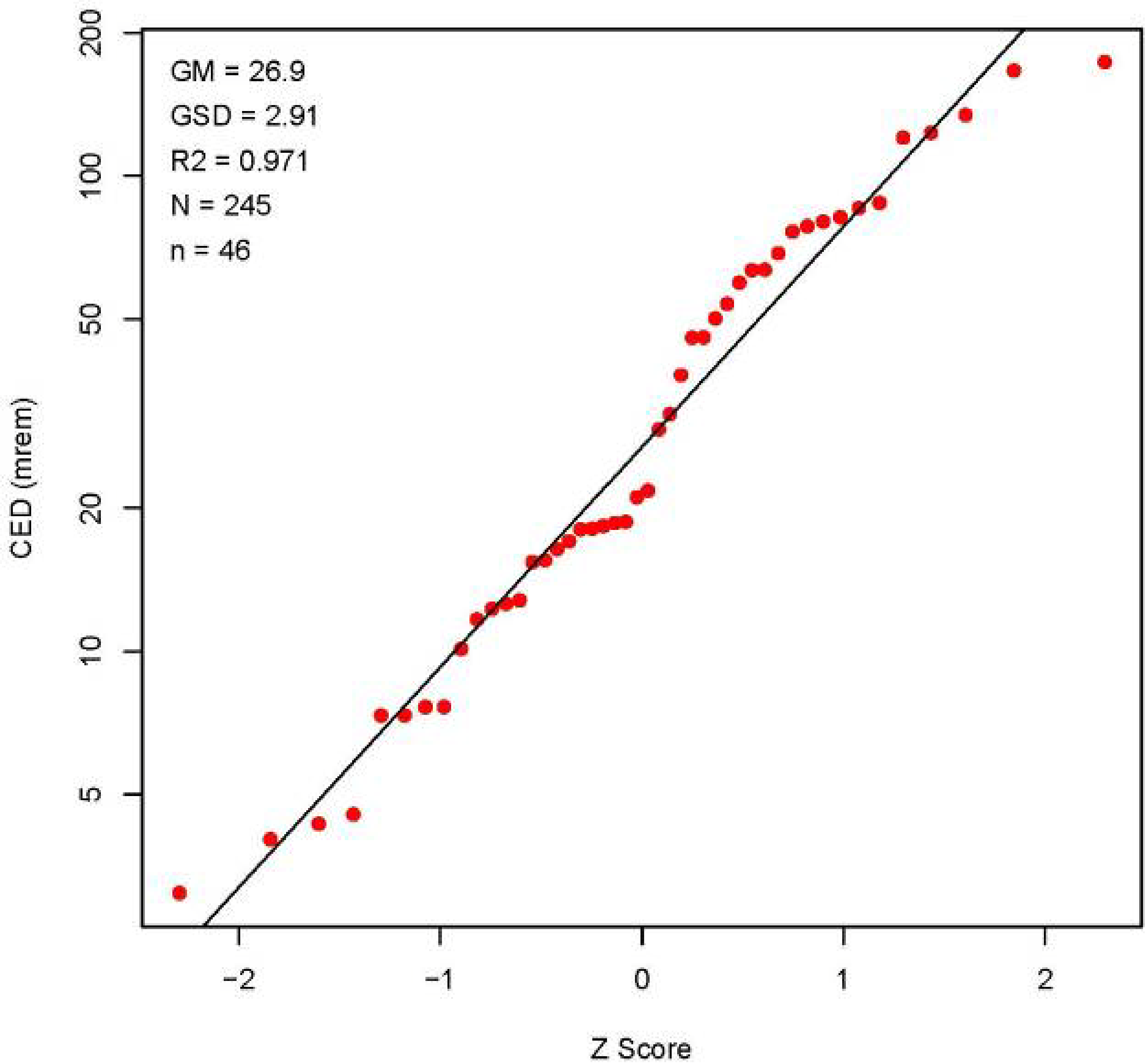

Figure C-71. SRS reactor/CTW tritium dose 1977.

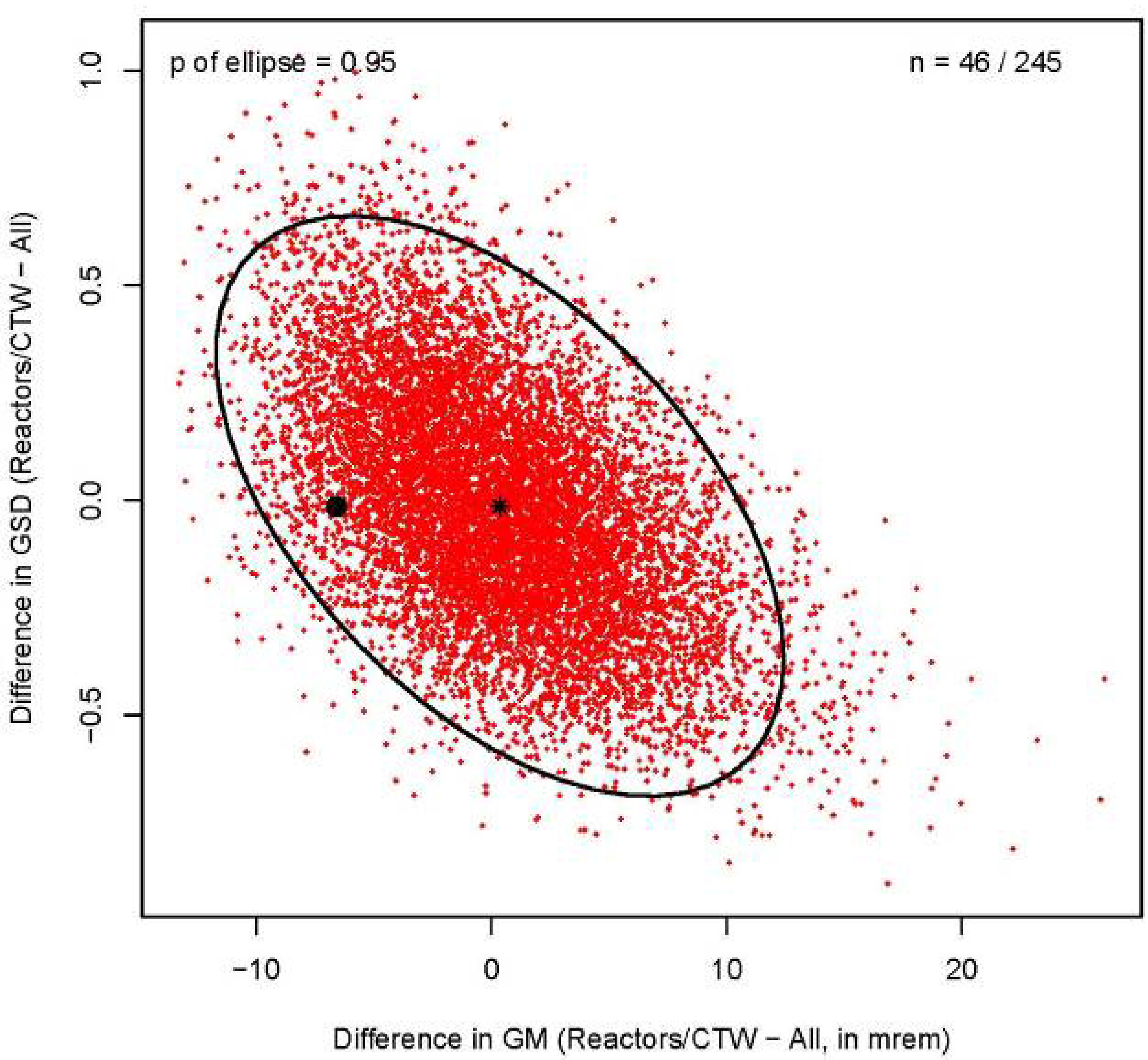

Figure C-72. SRS tritium dose 1977.

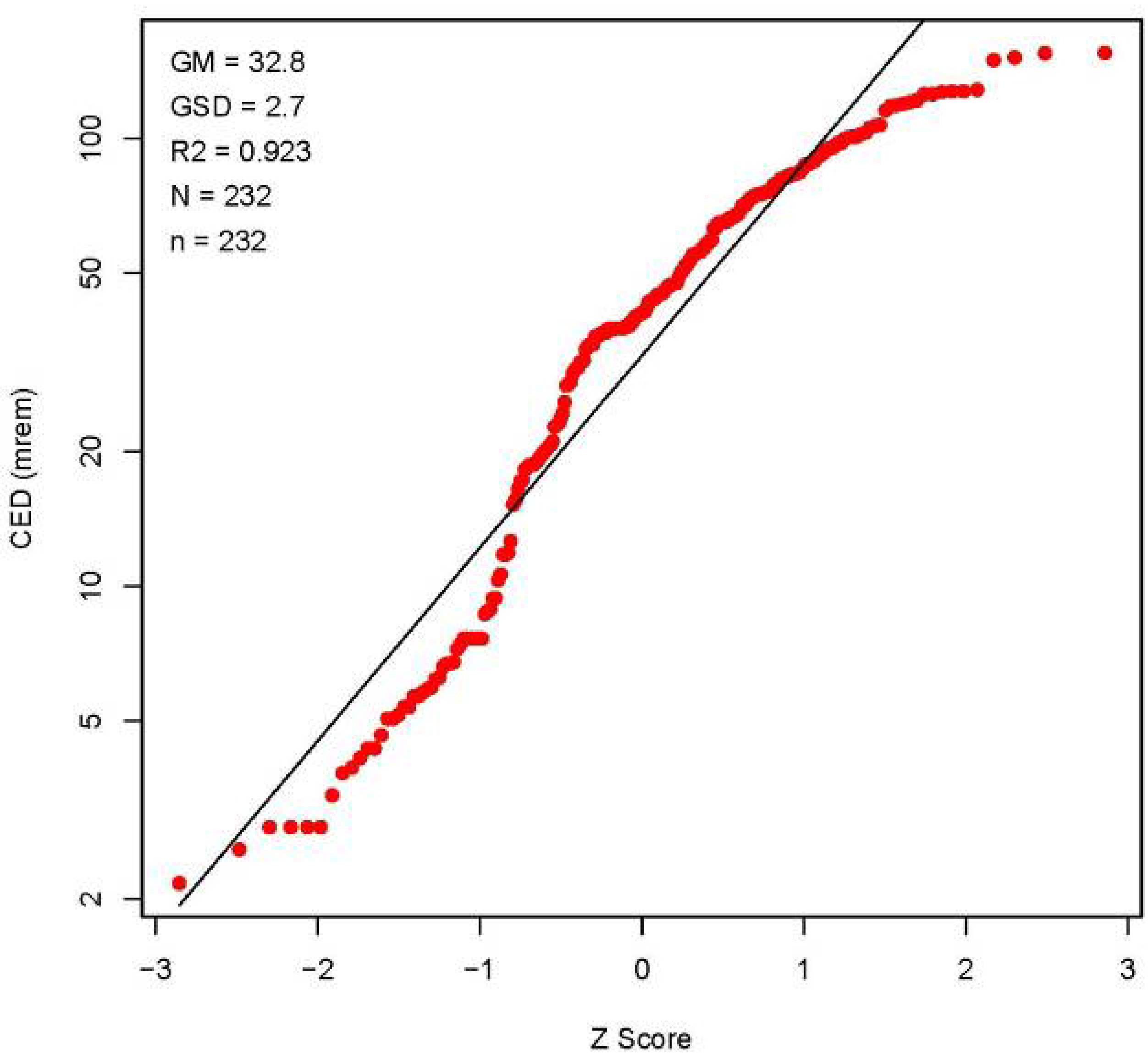

Figure C-73. SRS tritium dose 1978.

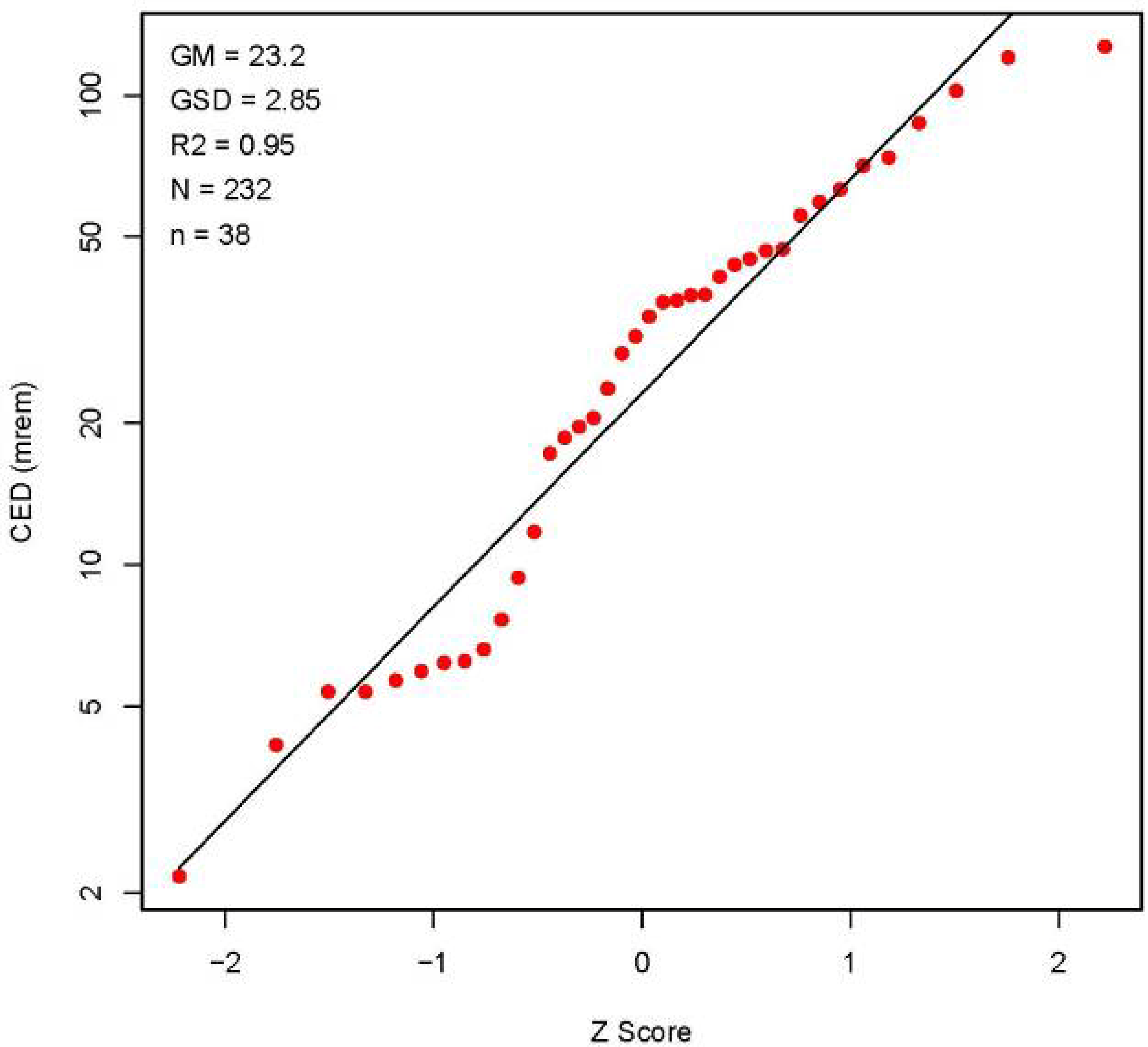

Figure C-74. SRS reactor/CTW tritium dose 1978.

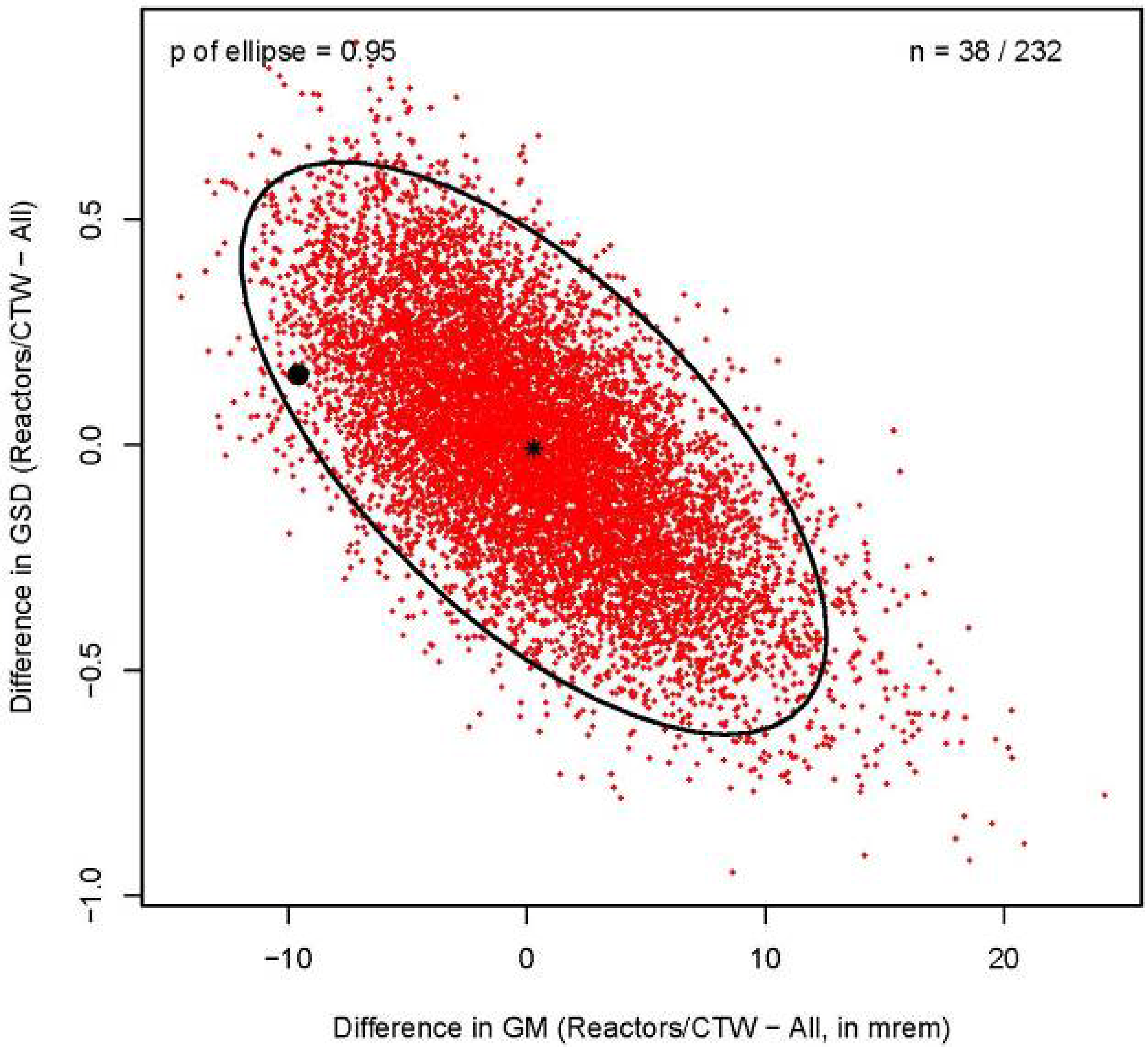

Figure C-75. SRS tritium dose 1978.

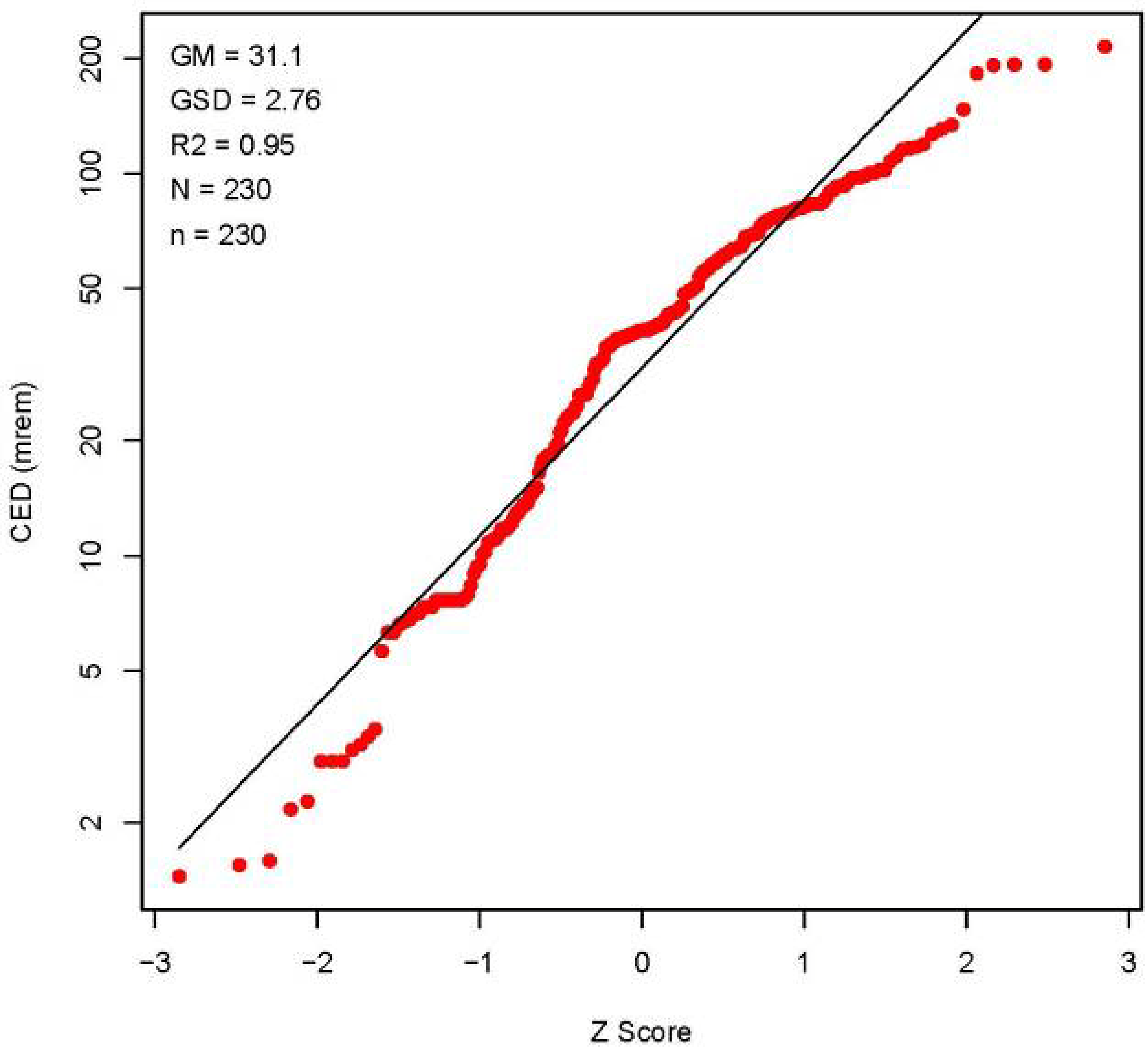

Figure C-76. SRS tritium dose 1979.

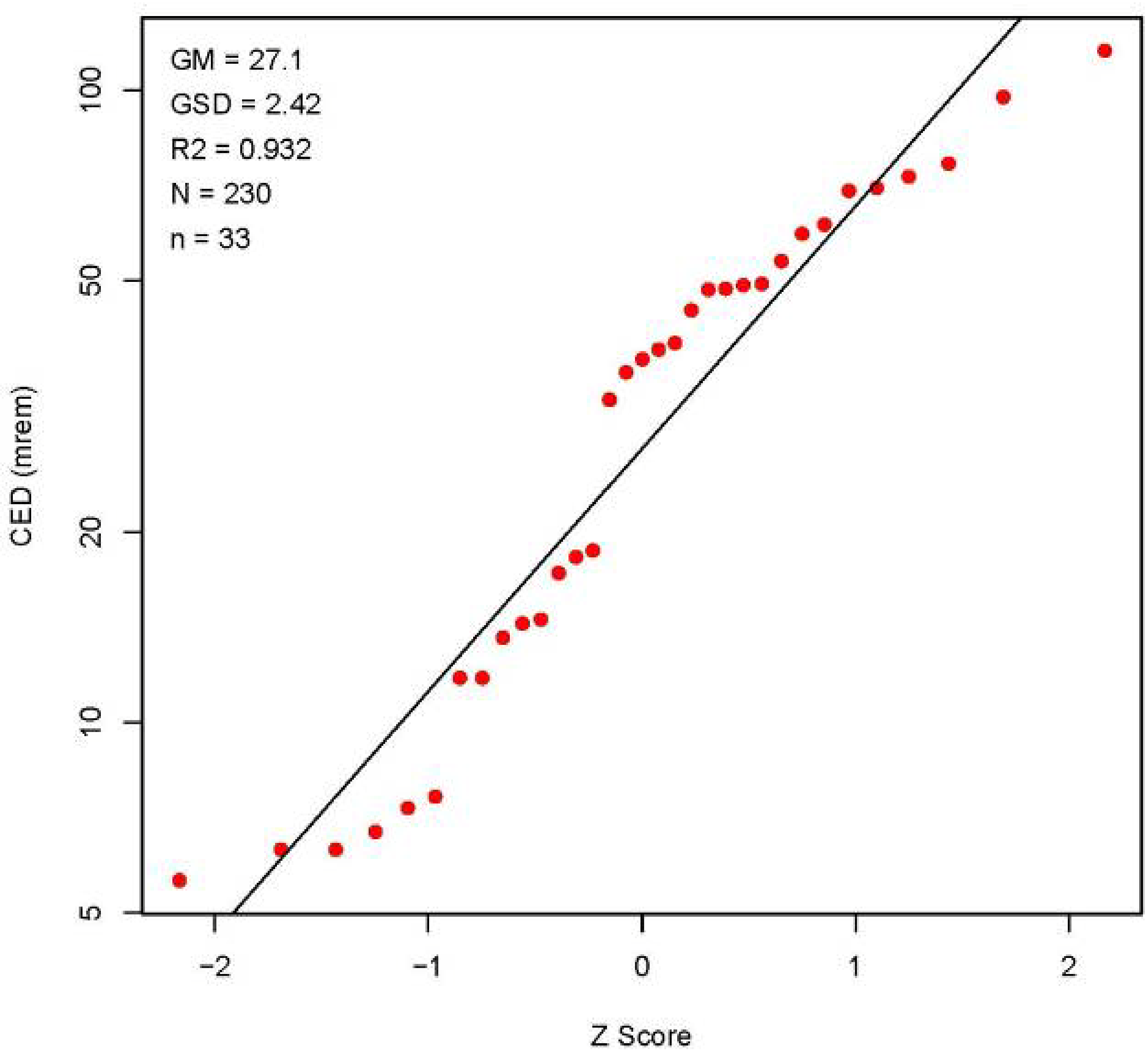

Figure C-77. SRS reactor/CTW tritium dose 1979.

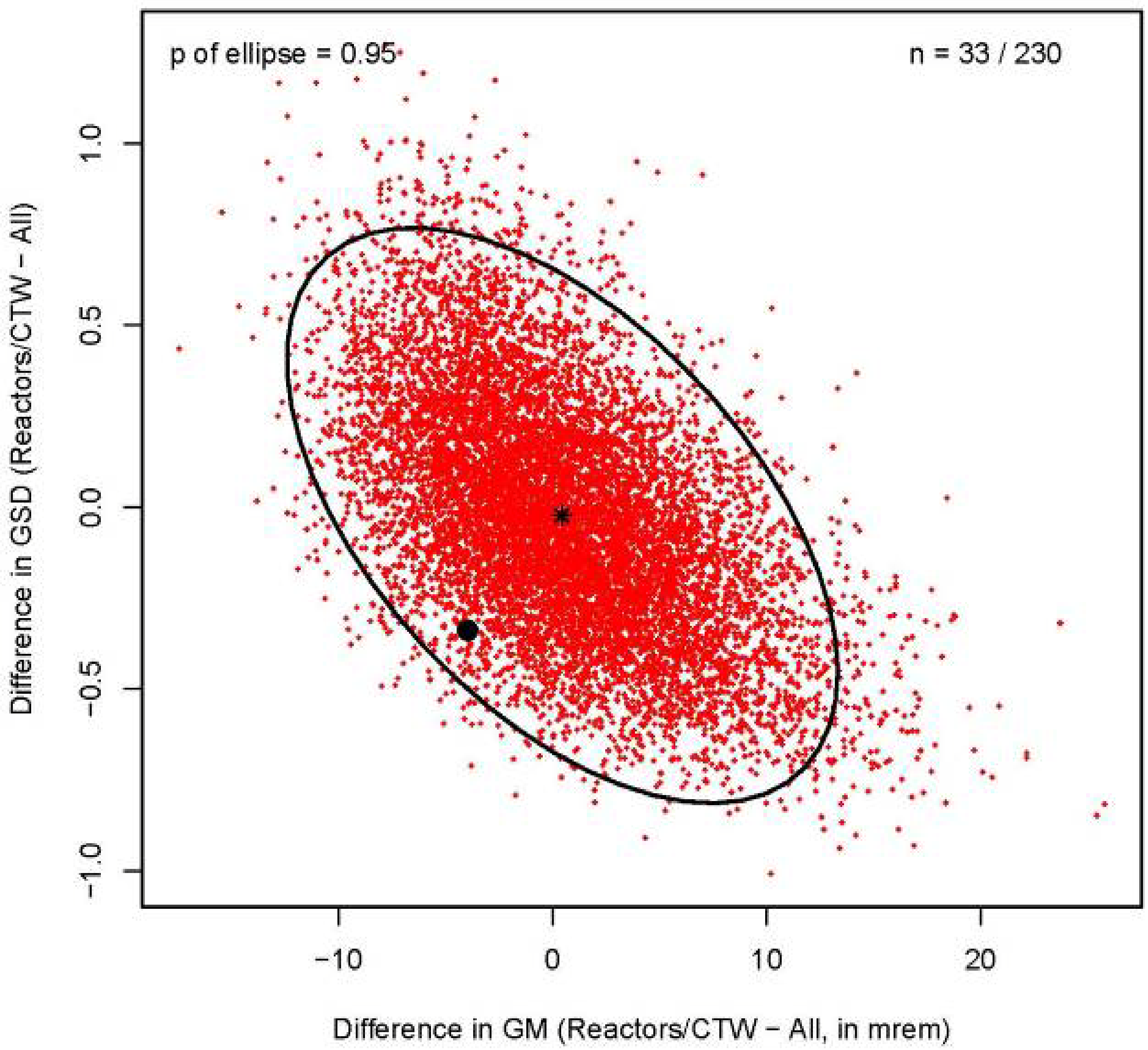

Figure C-78. SRS tritium dose 1979.

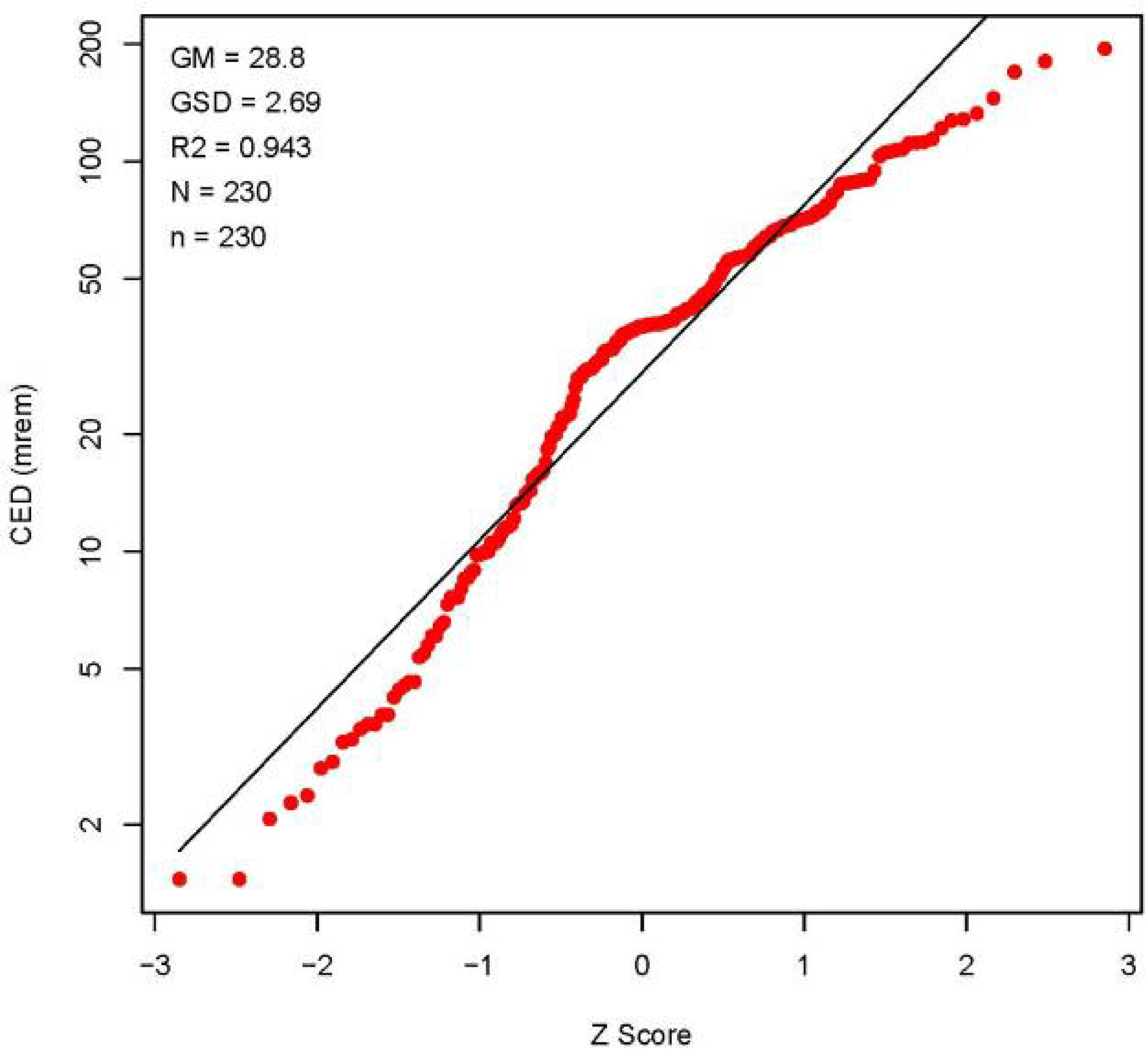

Figure C-79. SRS tritium dose 1980.

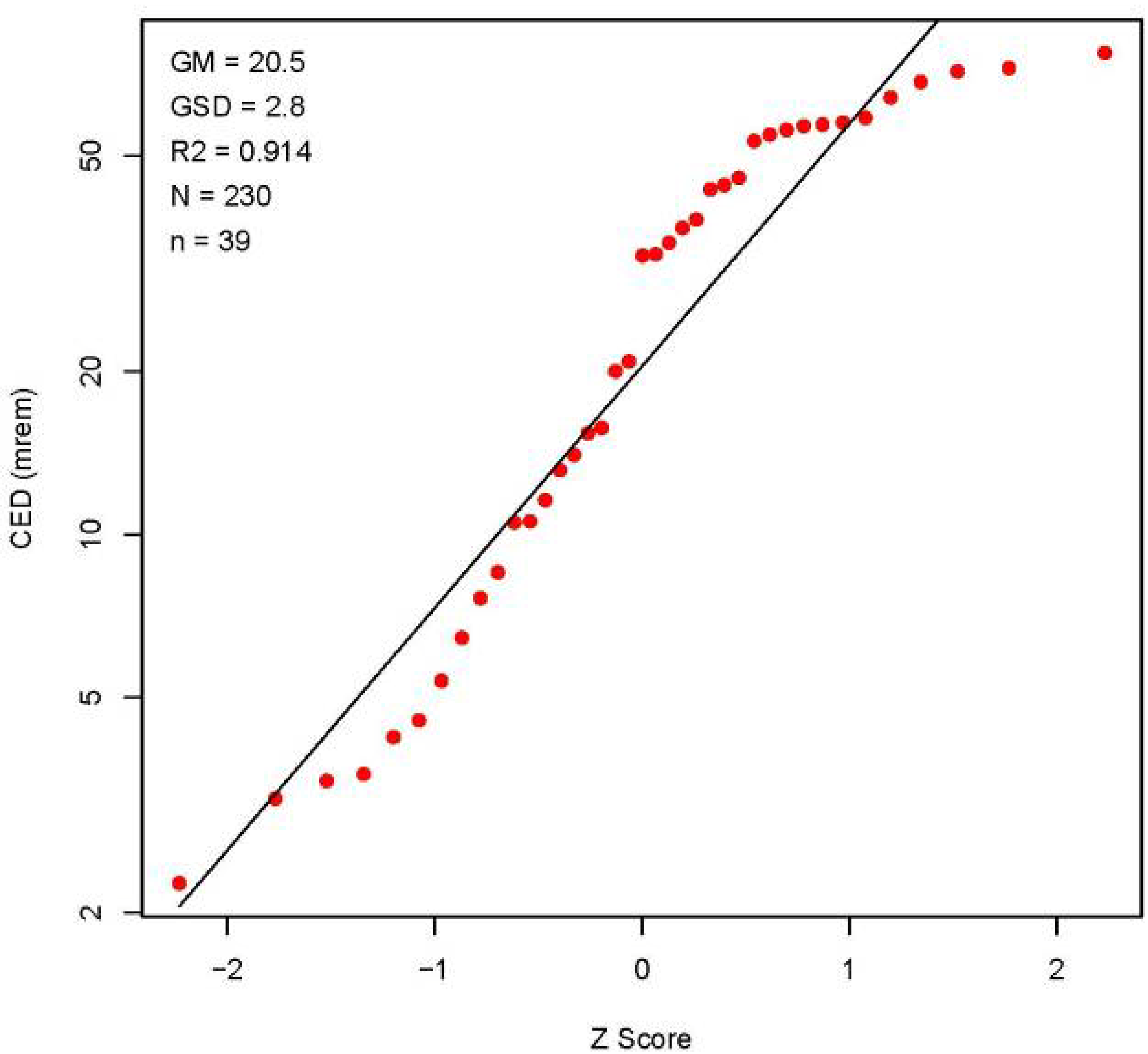

Figure C-80. SRS reactor/CTW tritium dose 1980.

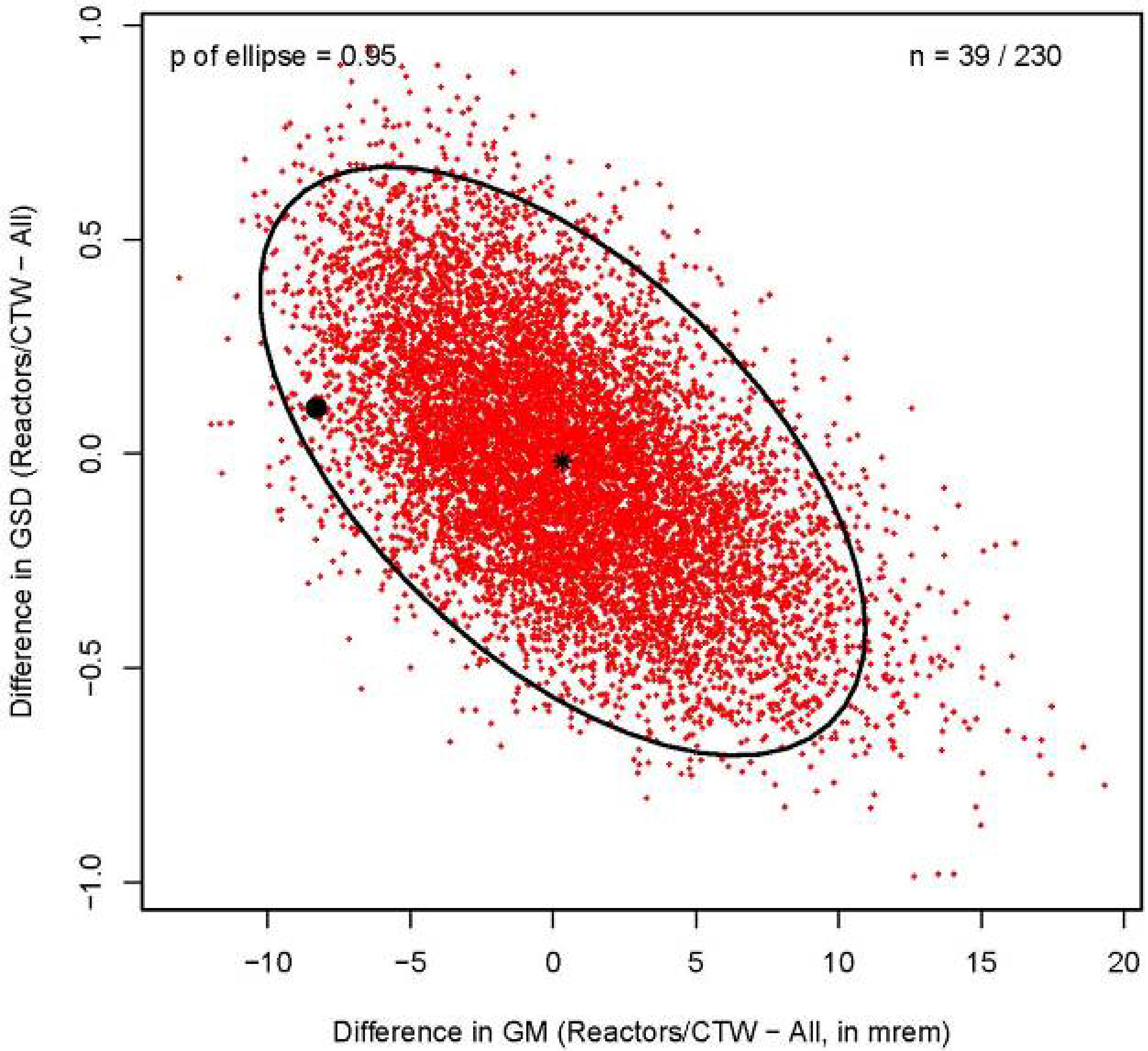

Figure C-81. SRS tritium dose 1980.

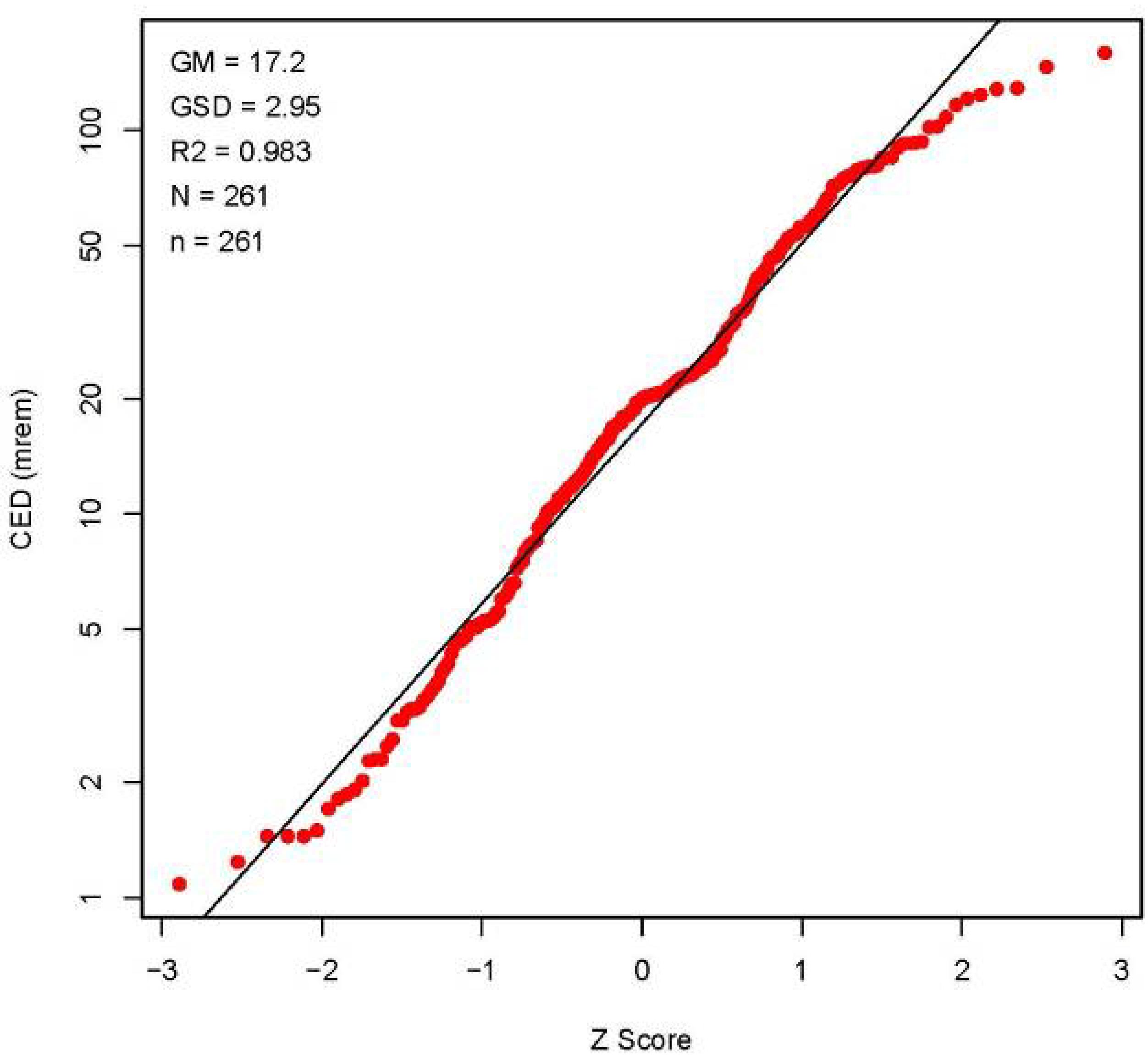

Figure C-82. SRS tritium dose 1981.

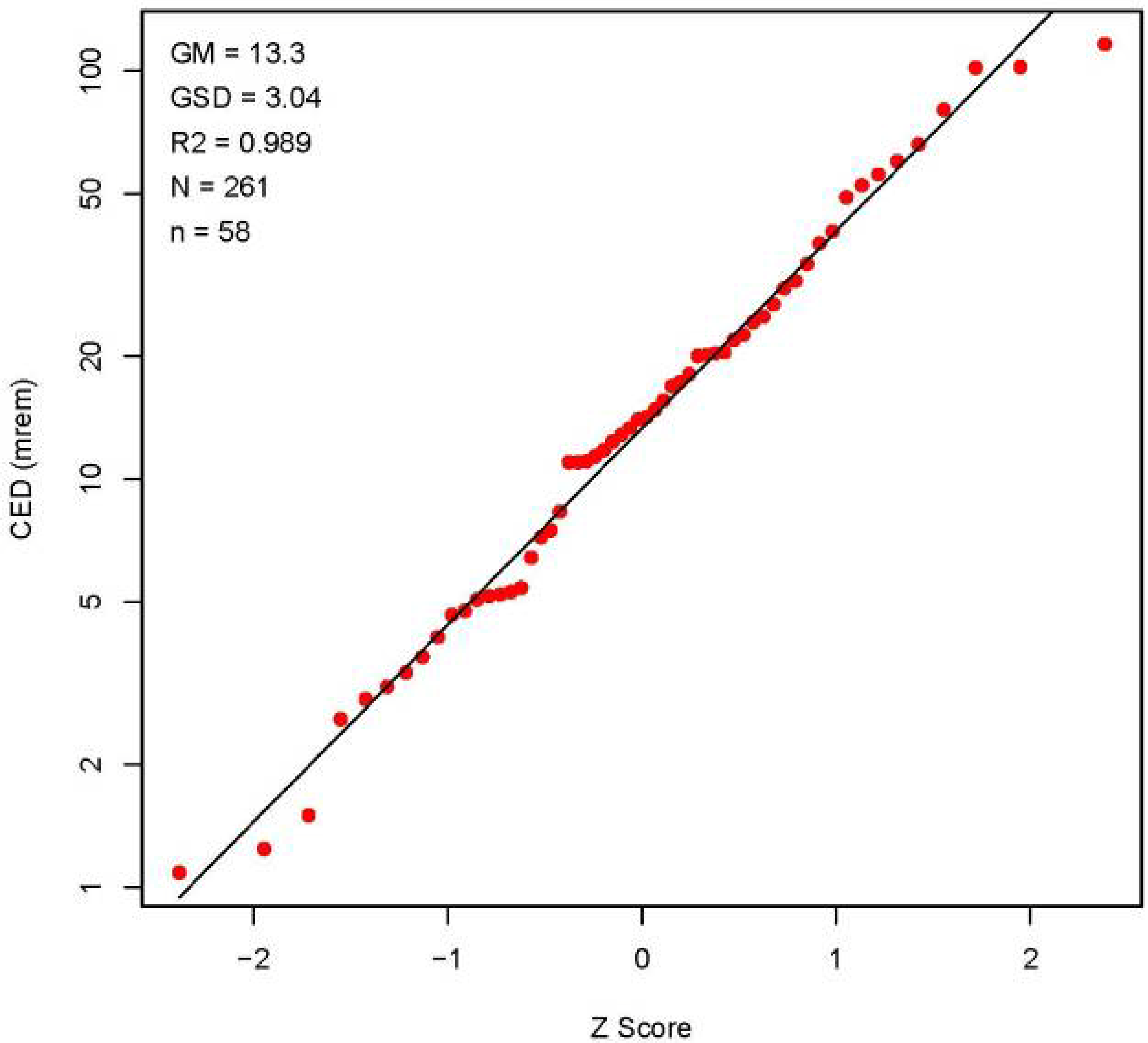

Figure C-83. SRS reactor/CTW tritium dose 1981.

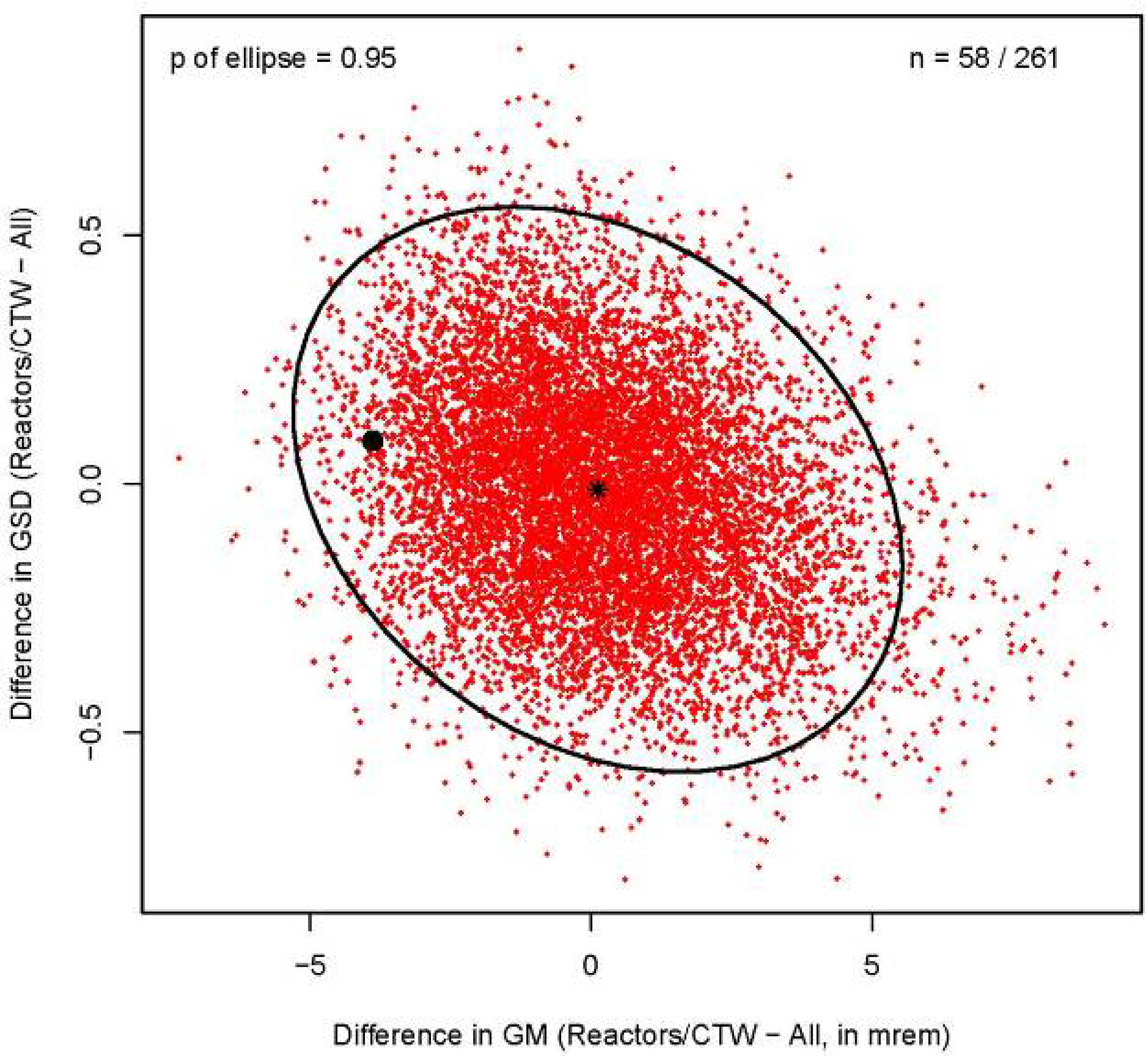

Figure C-84. SRS tritium dose 1981.

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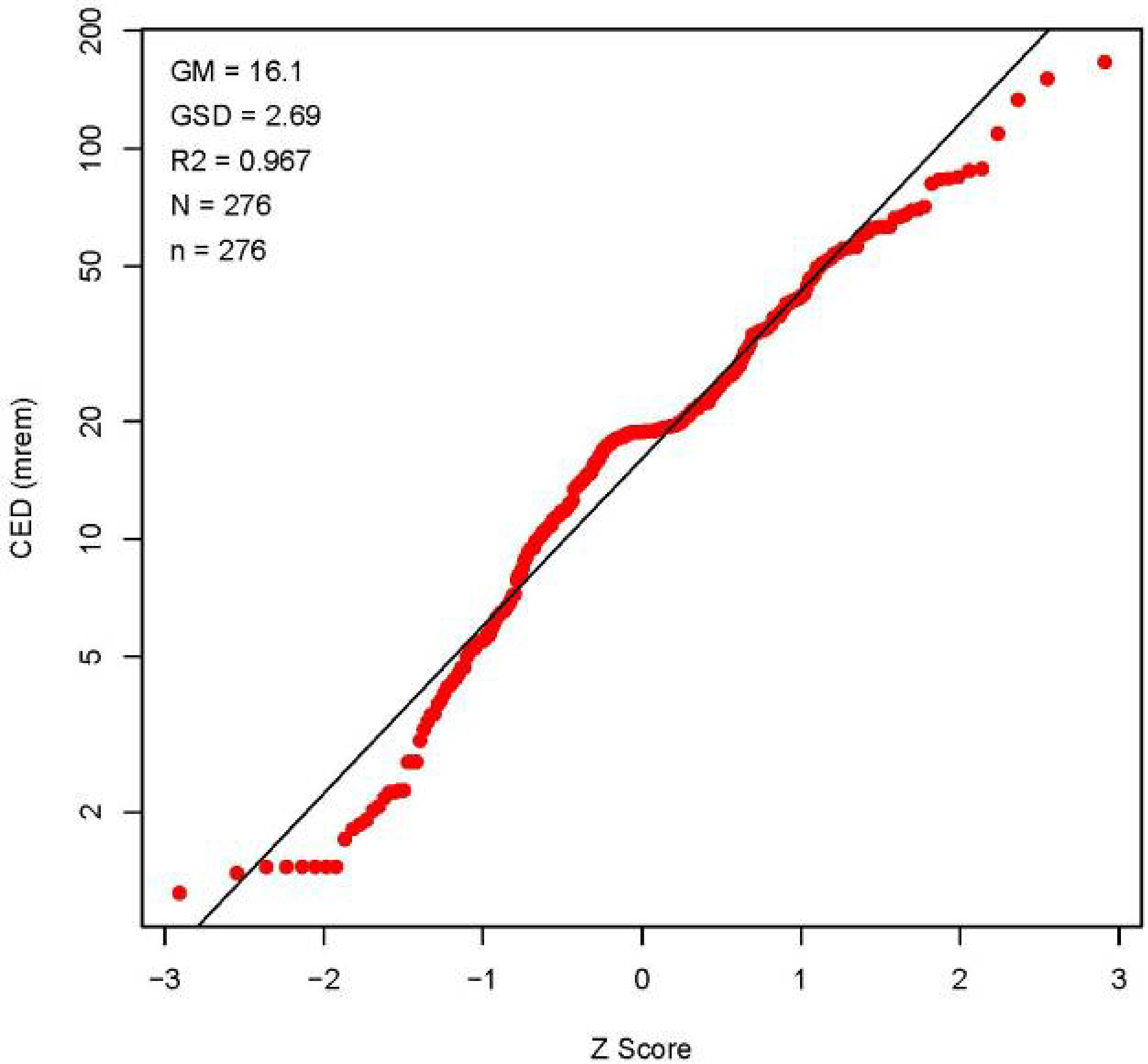

Figure C-85. SRS tritium dose 1982.

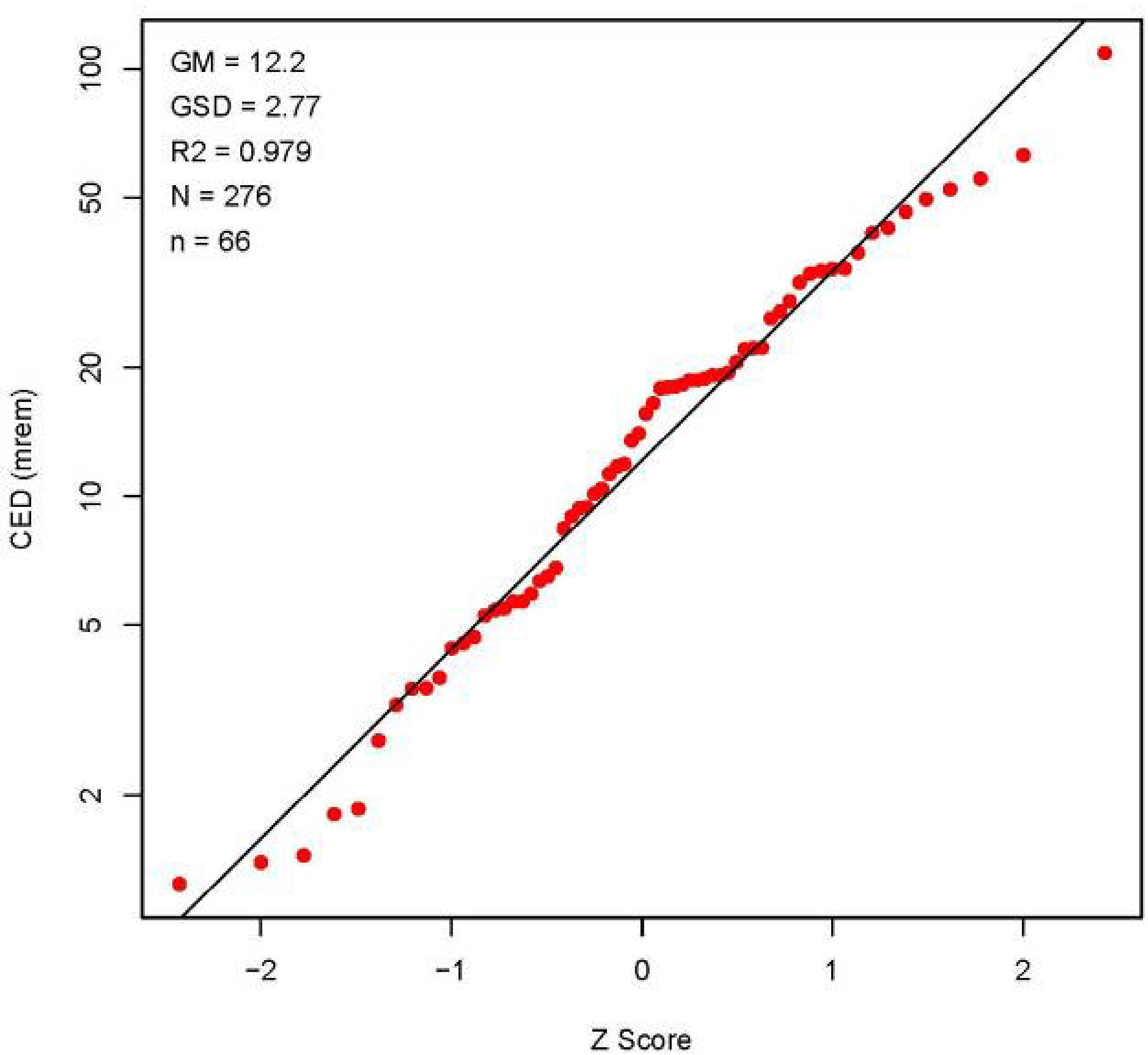

Figure C-86. SRS reactor/CTW tritium dose 1982.

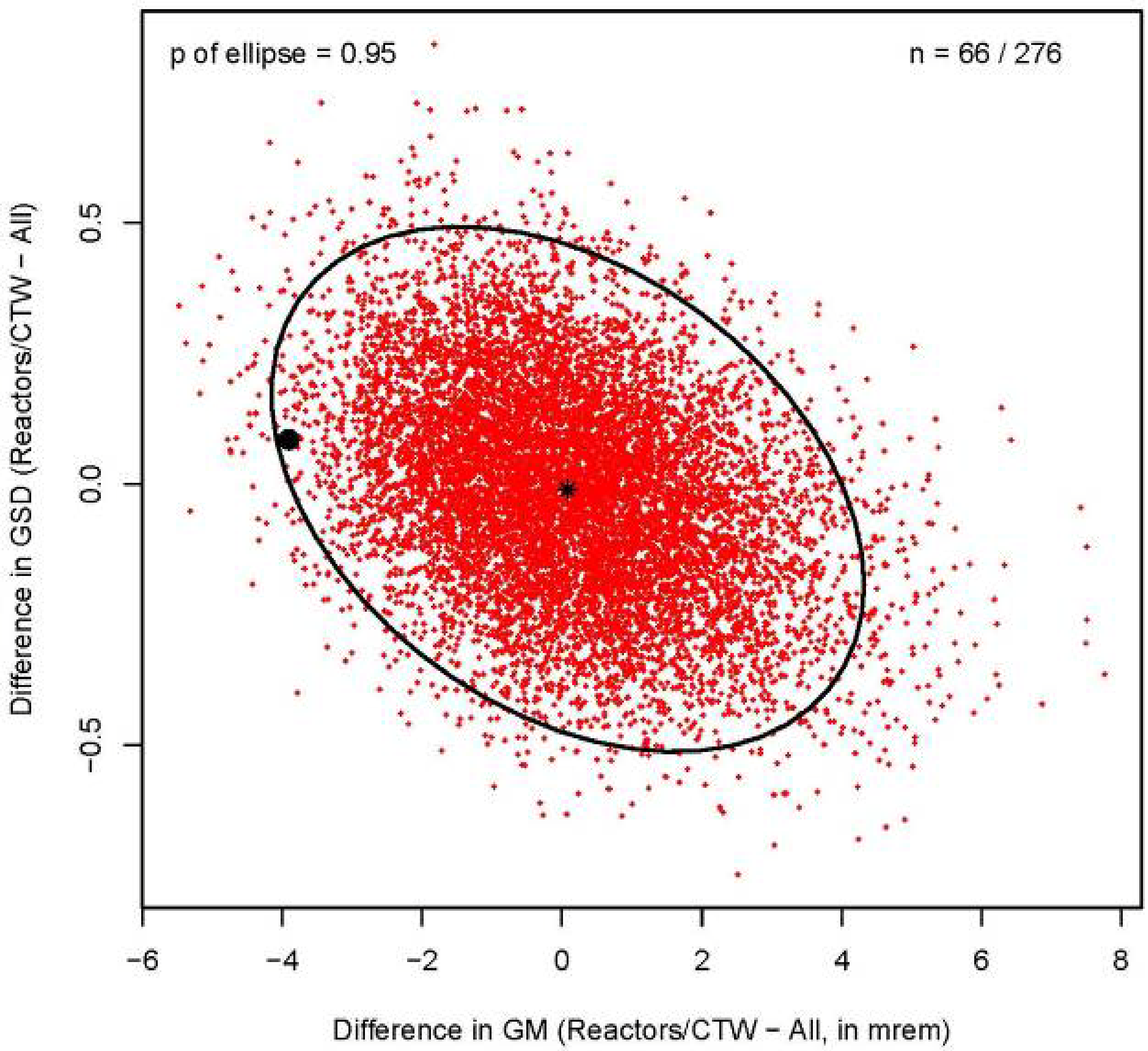

Figure C-87. SRS tritium dose 1982.

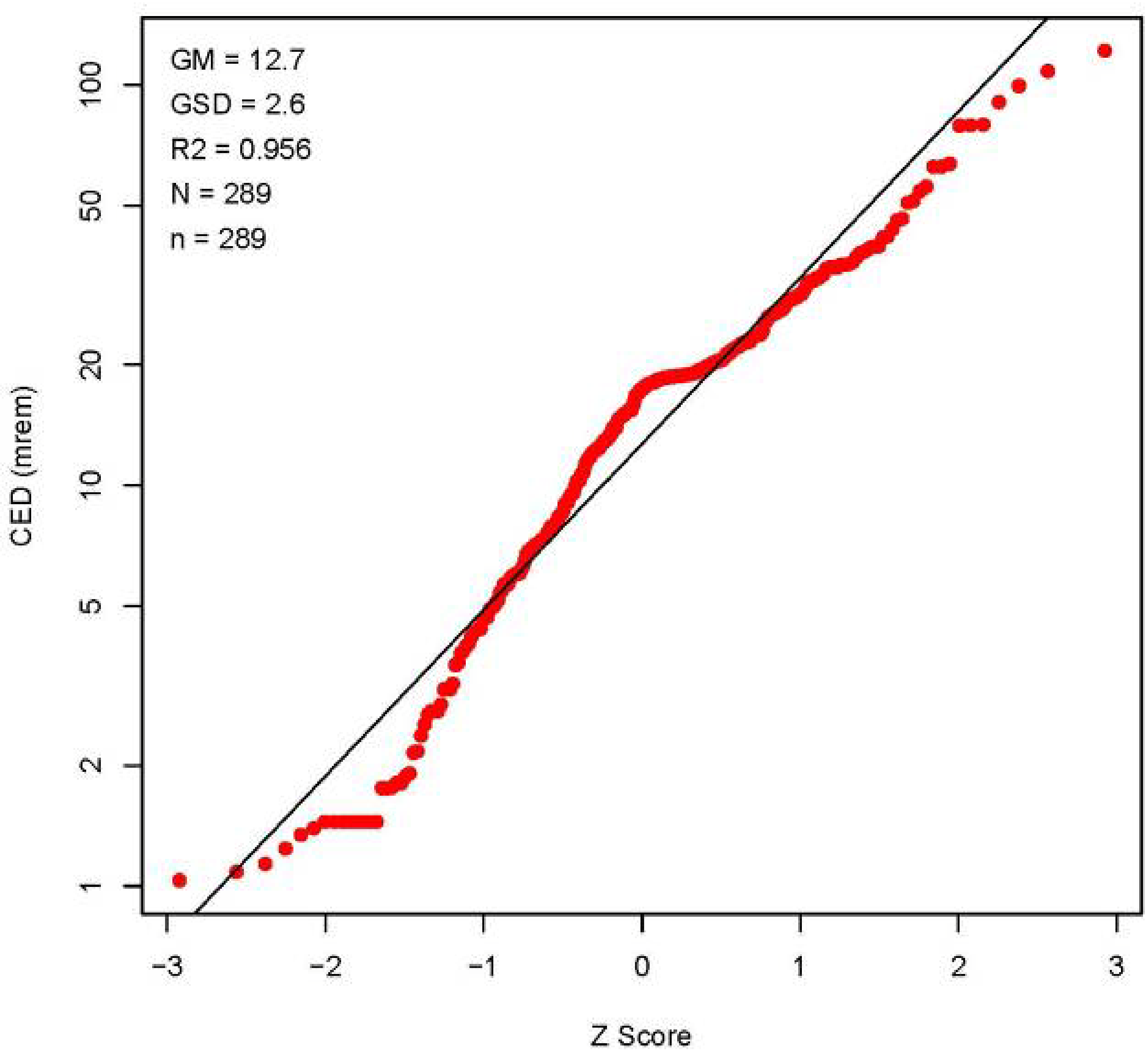

Figure C-88. SRS tritium dose 1983.

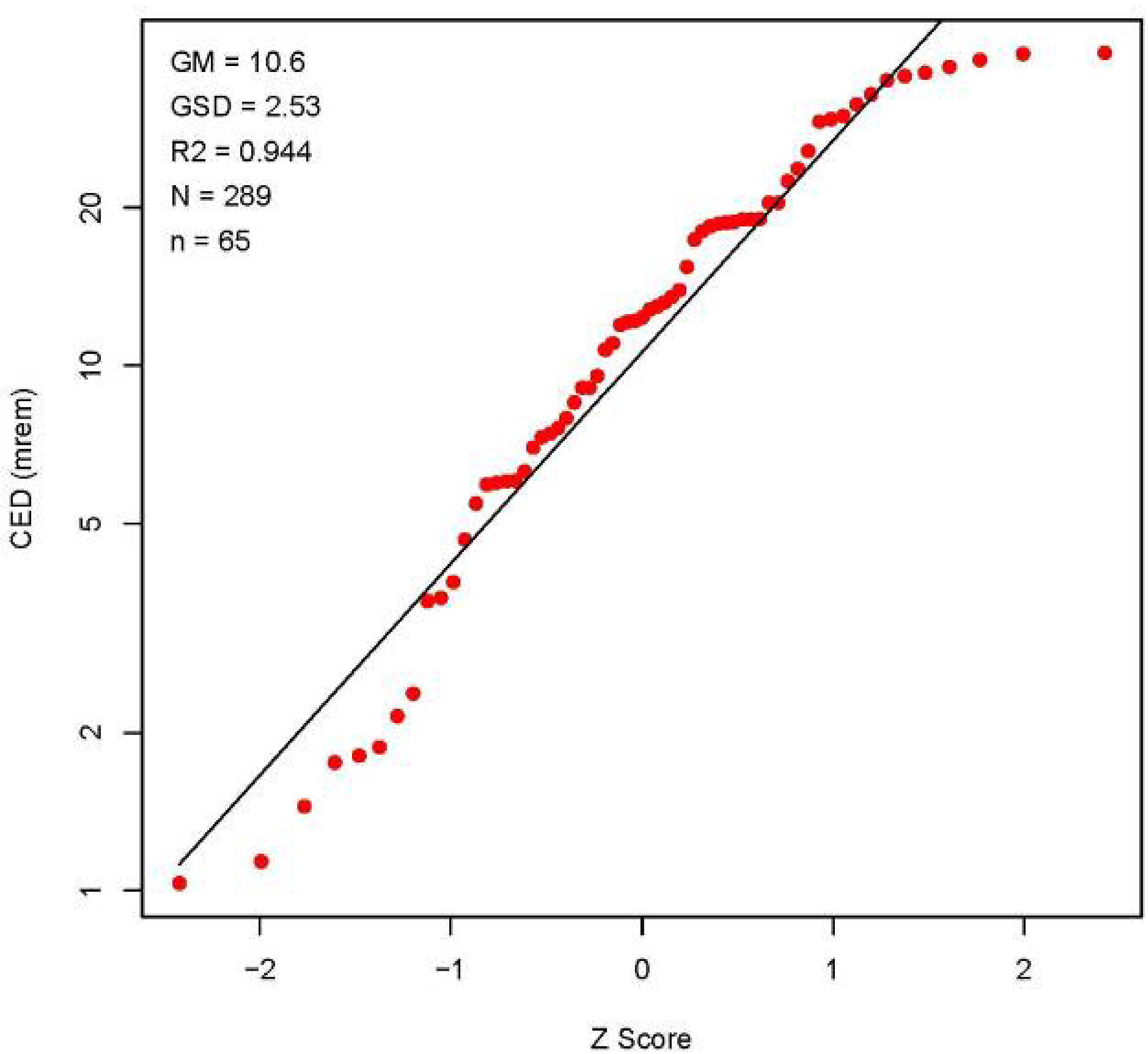

Figure C-89. SRS reactor/CTW tritium dose 1983.

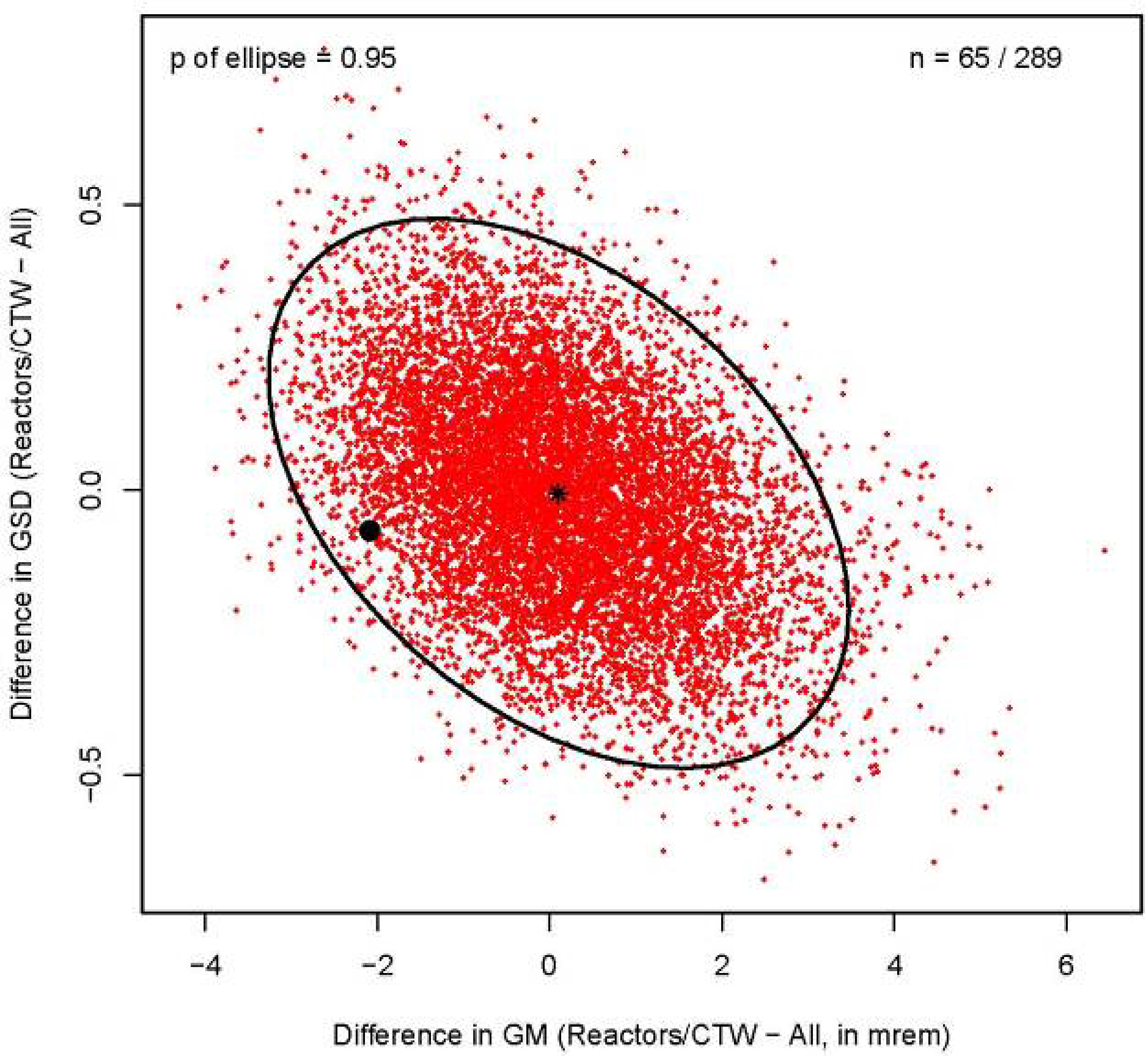

Figure C-90. SRS tritium dose 1983.

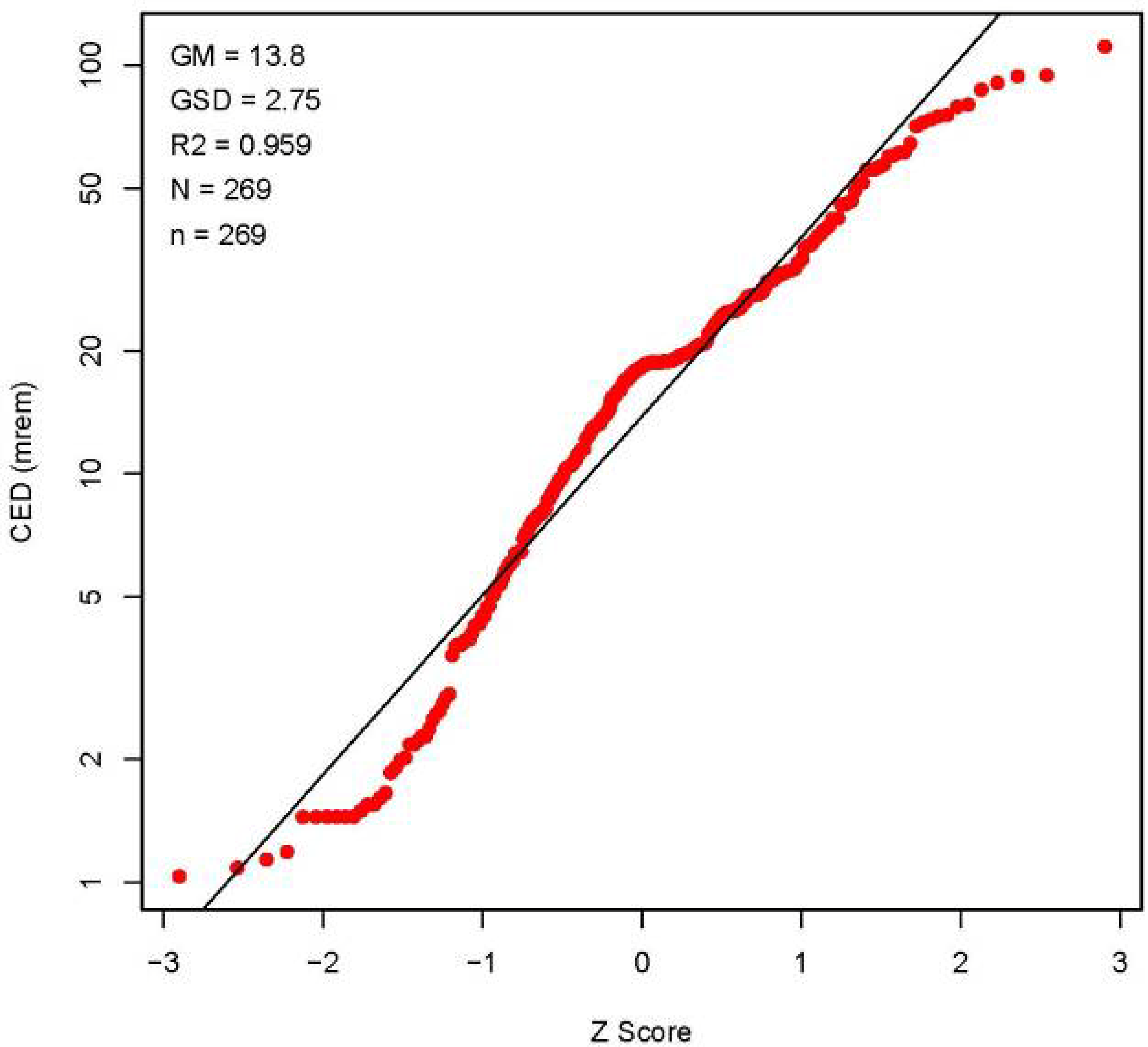

Figure C-91. SRS tritium dose 1984.

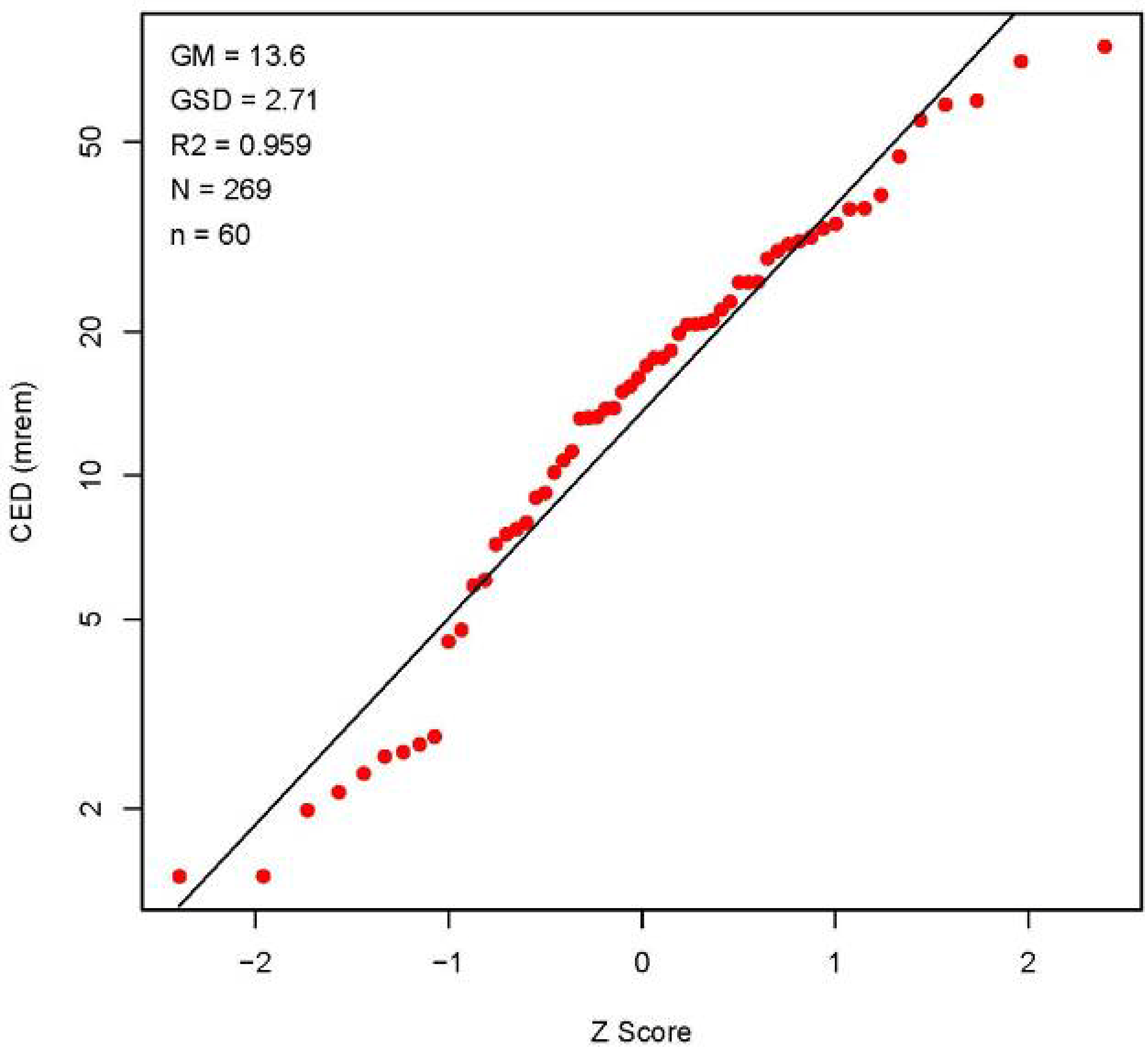

Figure C-92. SRS reactor/CTW tritium dose 1984.

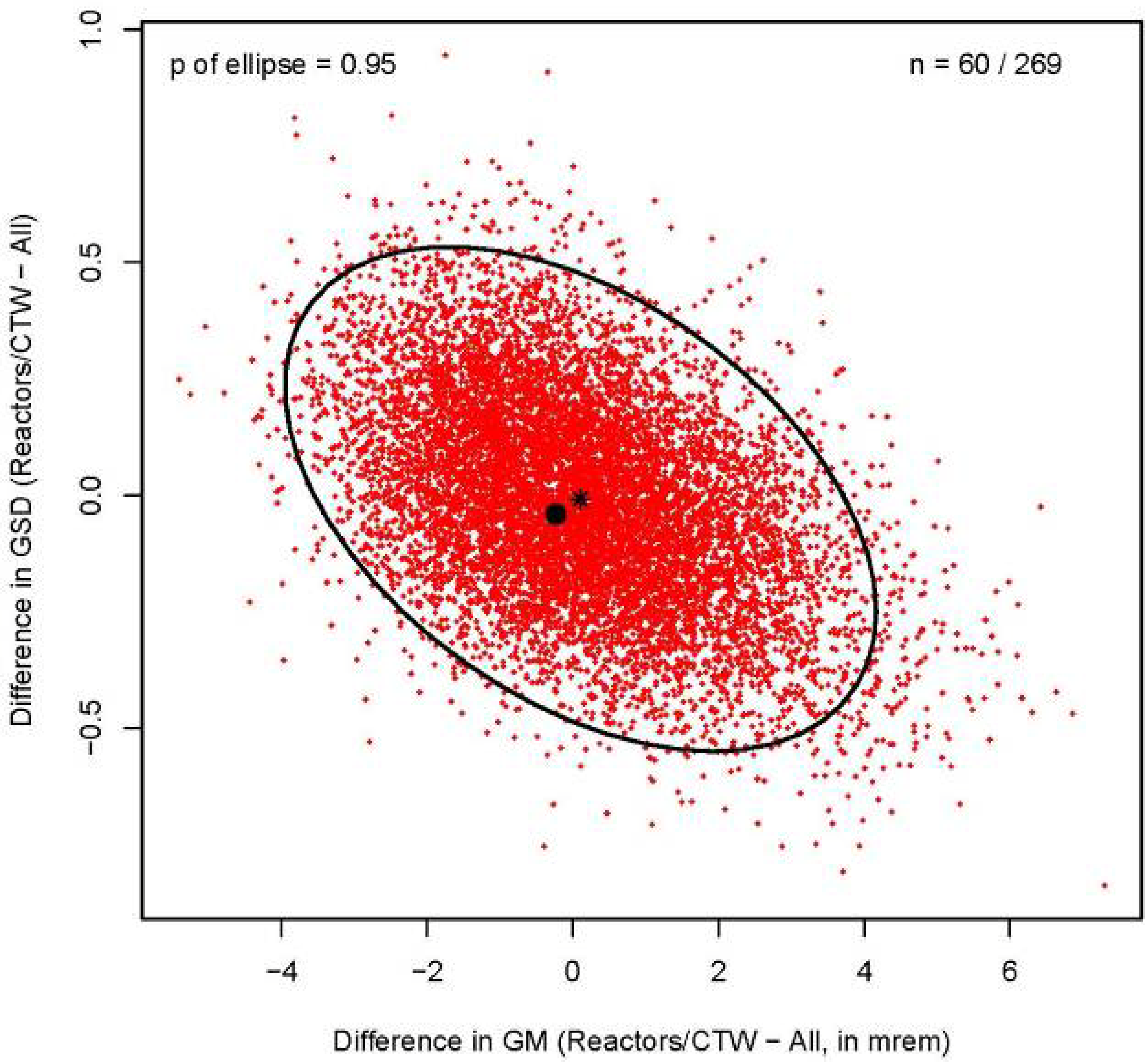

Figure C-93. SRS tritium dose 1984.

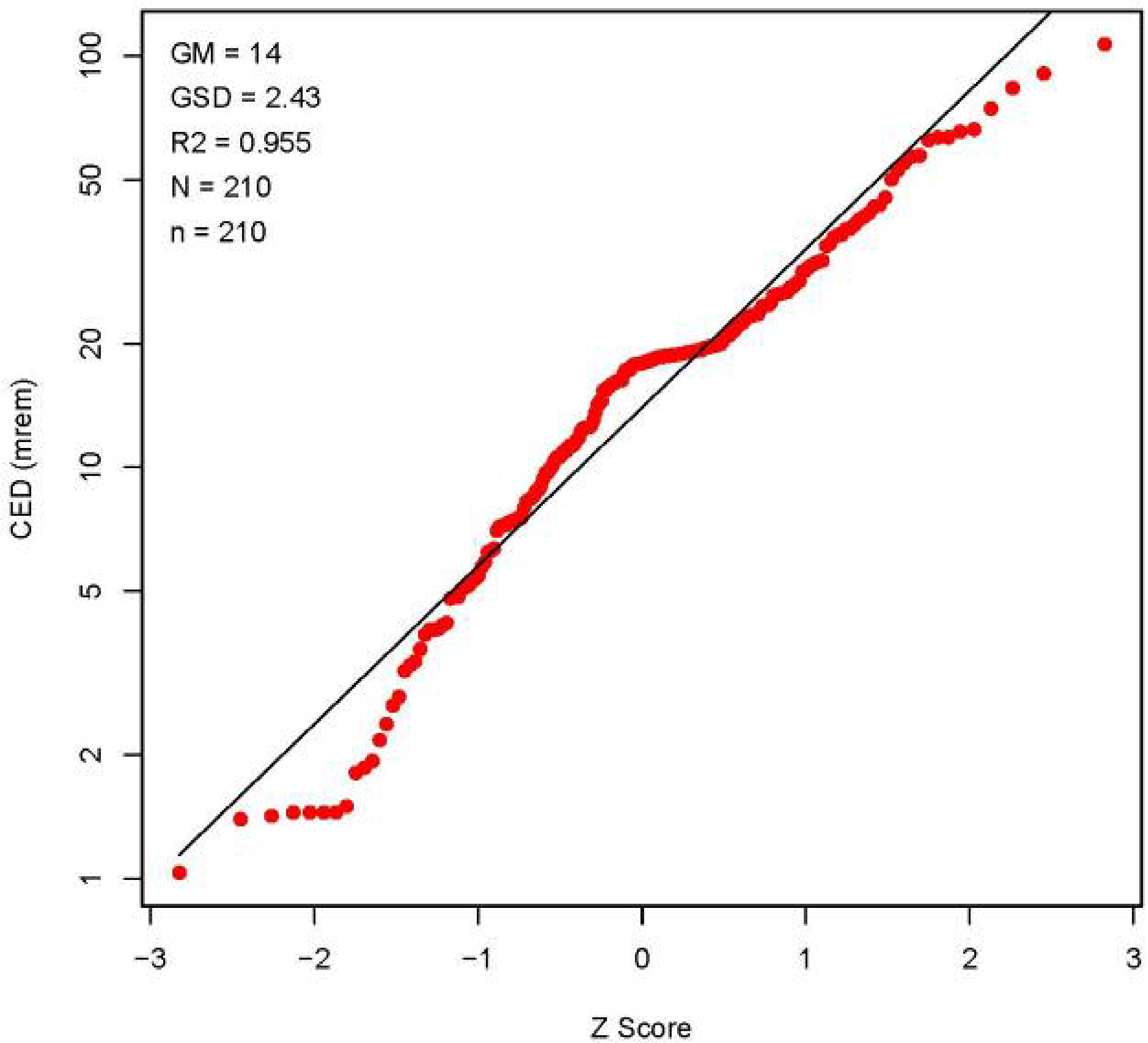

Figure C-94. SRS tritium dose 1985.

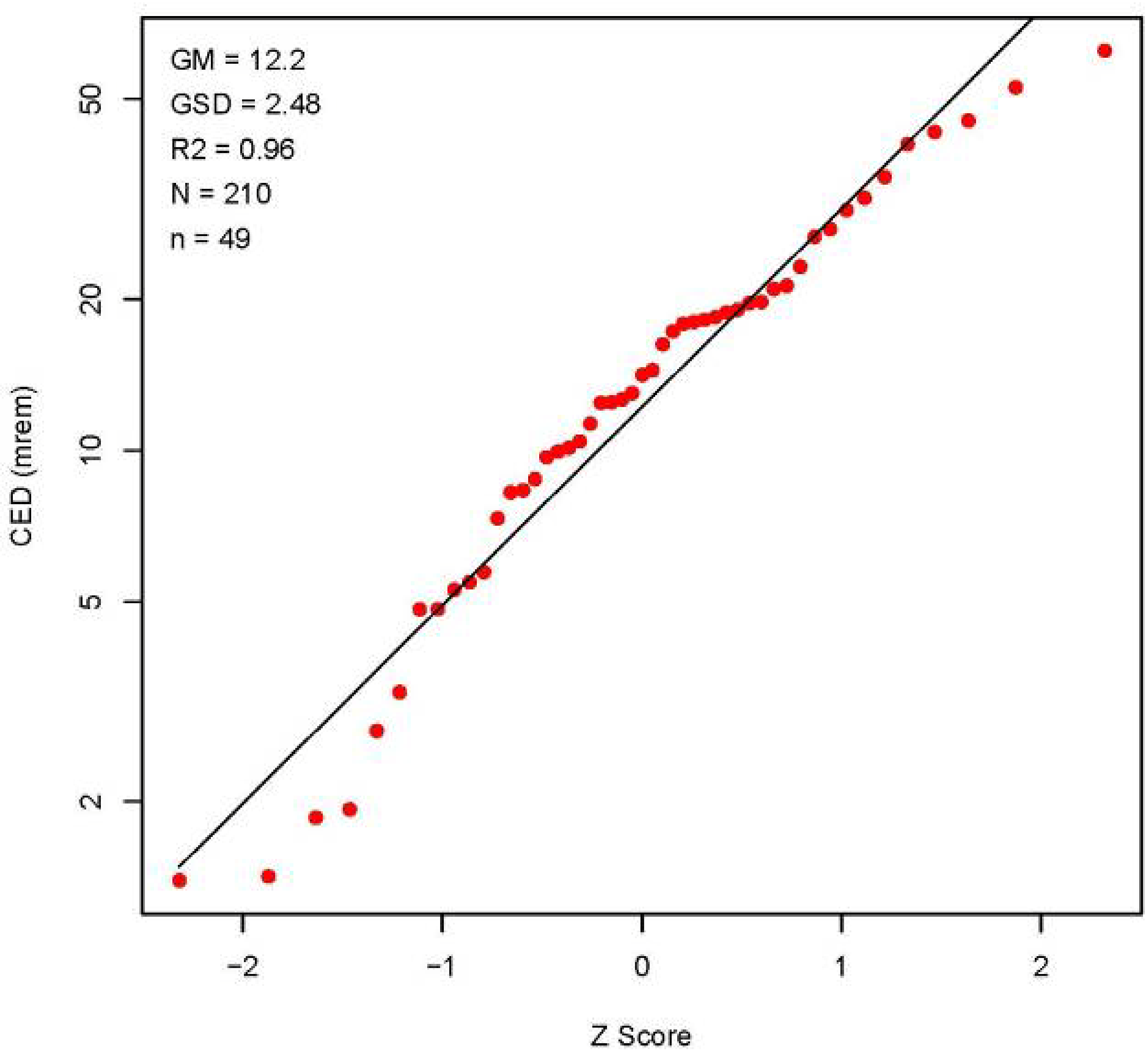

Figure C-95. SRS reactor/CTW tritium dose 1985.

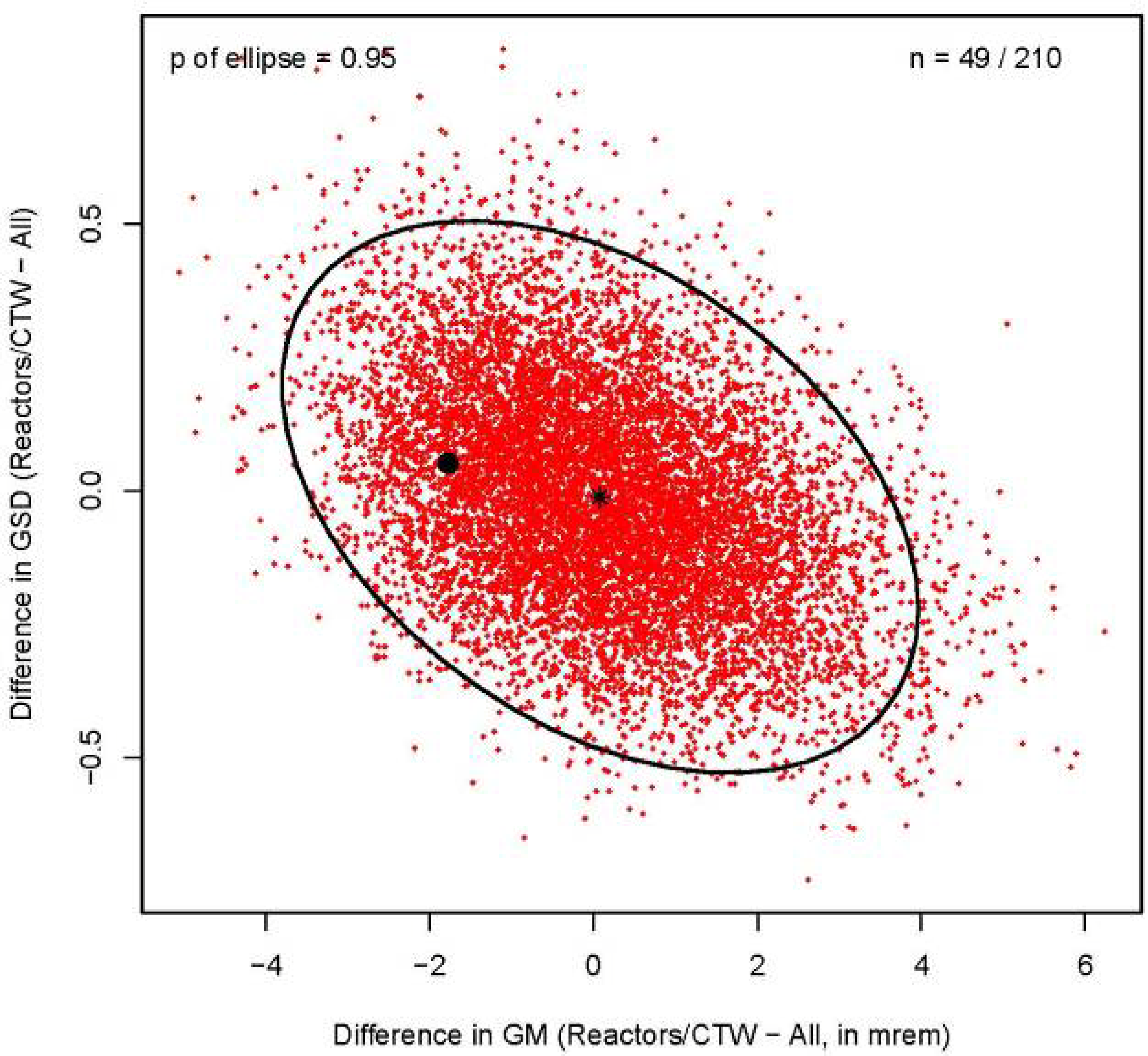

Figure C-96. SRS tritium dose 1985.

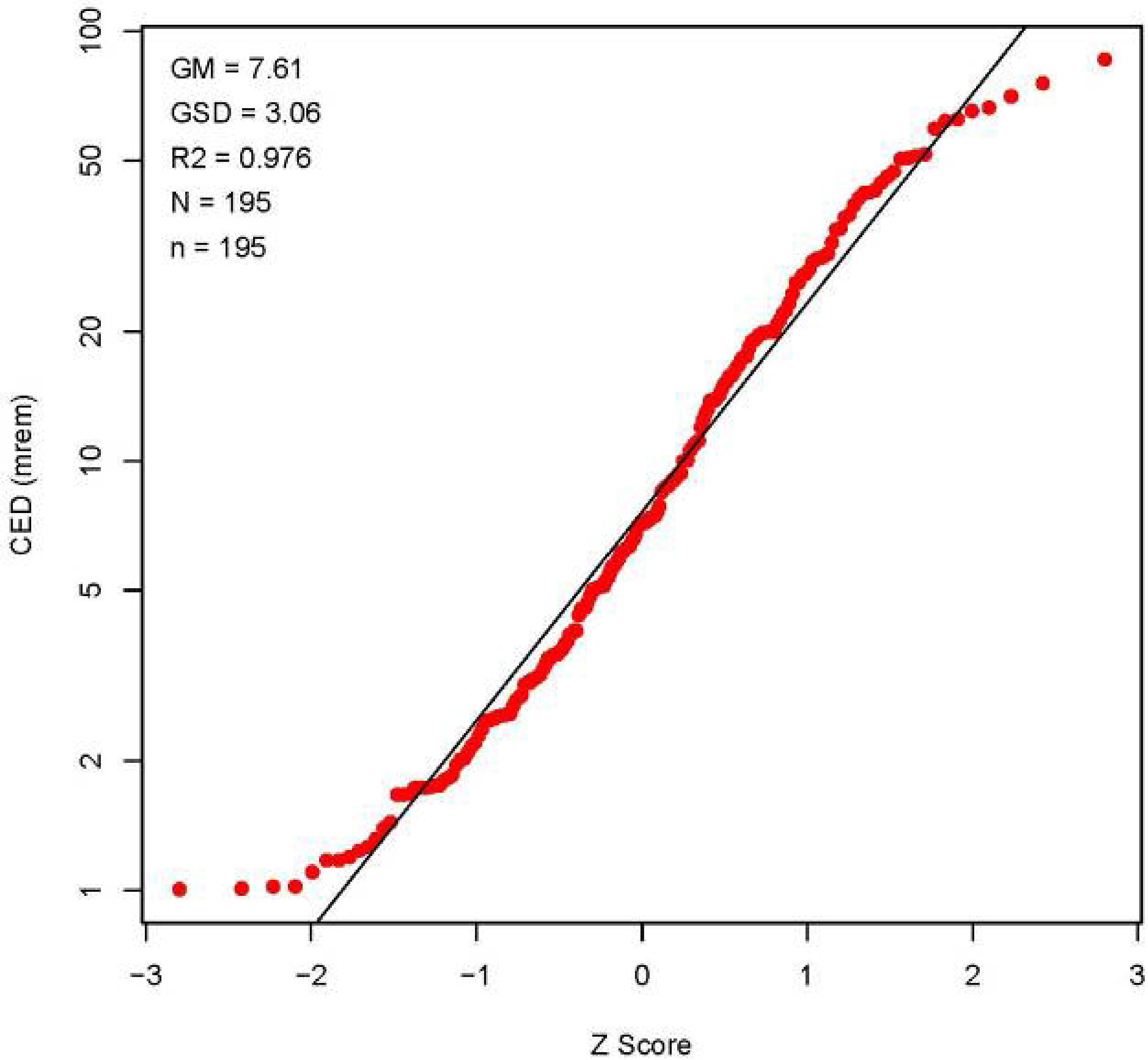

Figure C-97. SRS tritium dose 1986.

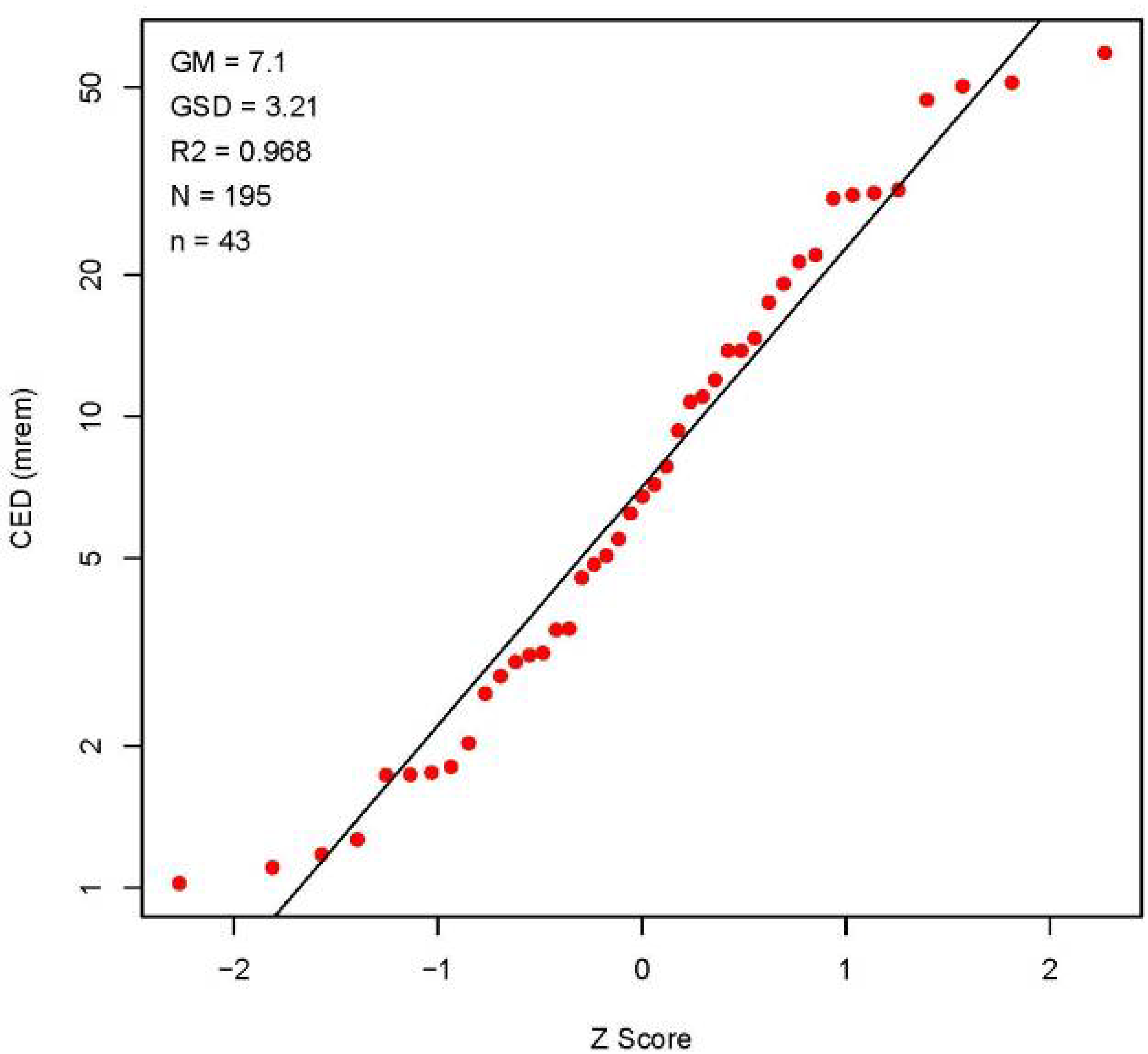

Figure C-98. SRS reactor/CTW tritium dose 1986.

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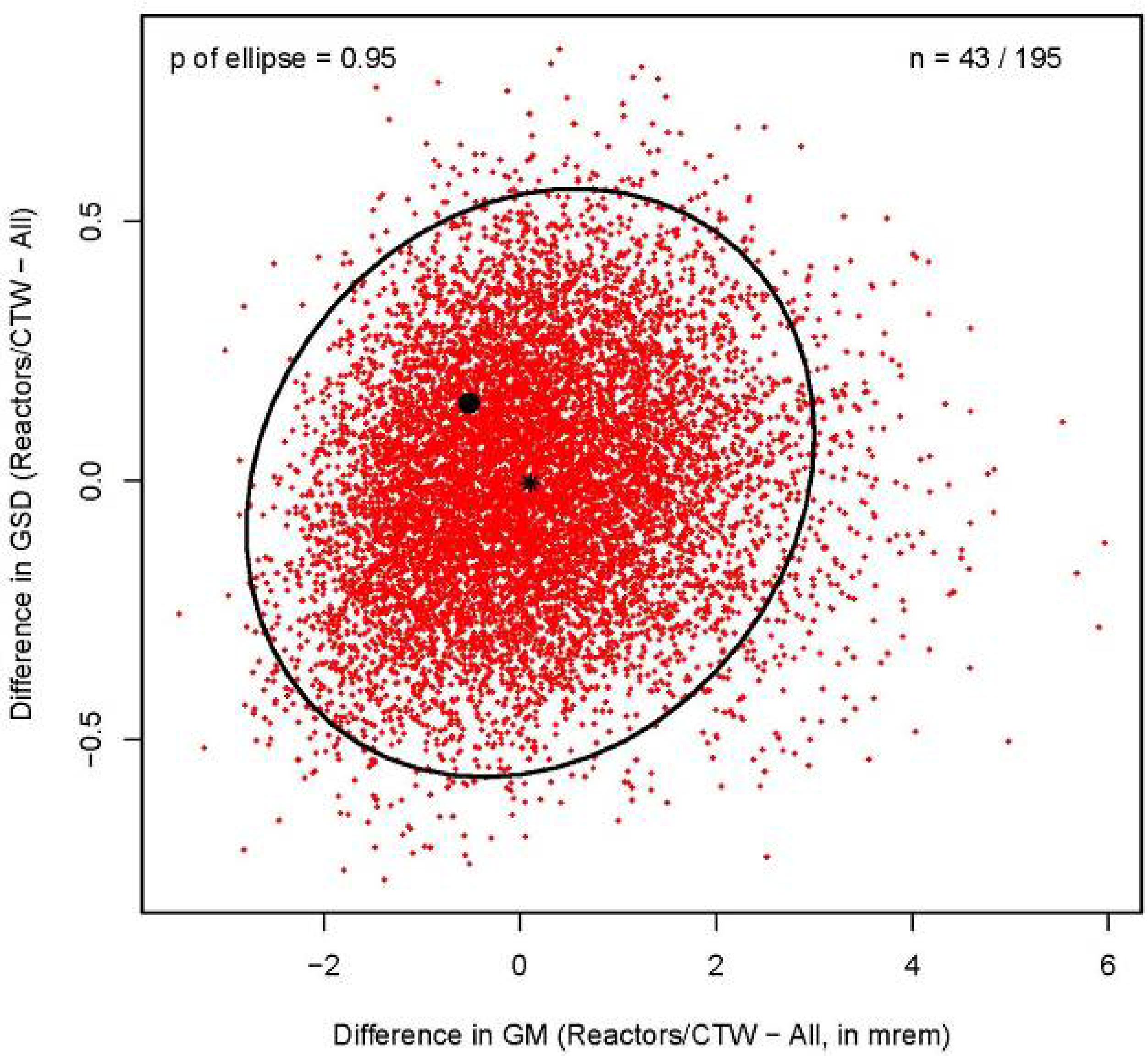

Figure C-99. SRS tritium dose 1986.

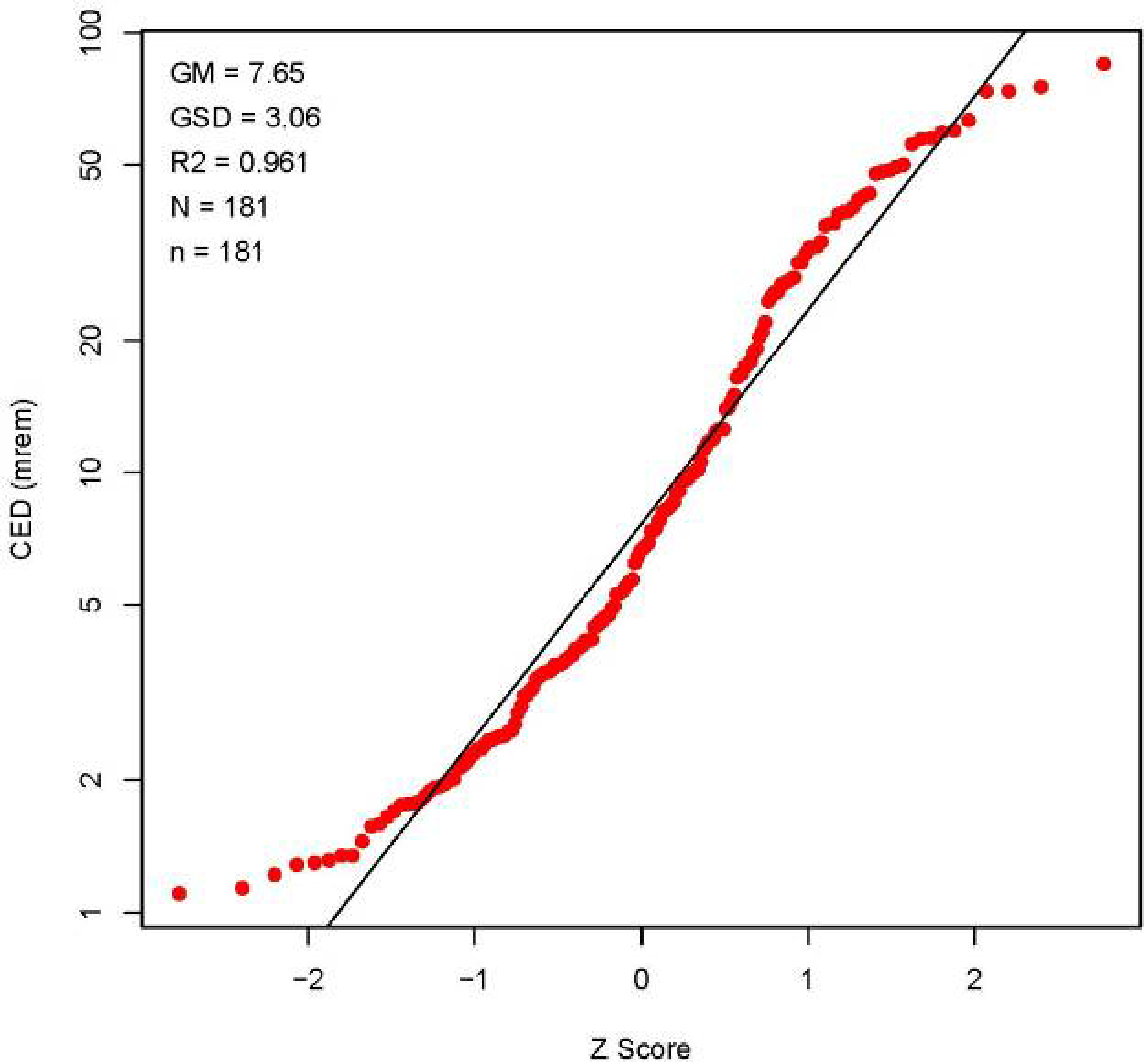

Figure C-100. SRS tritium dose 1987.

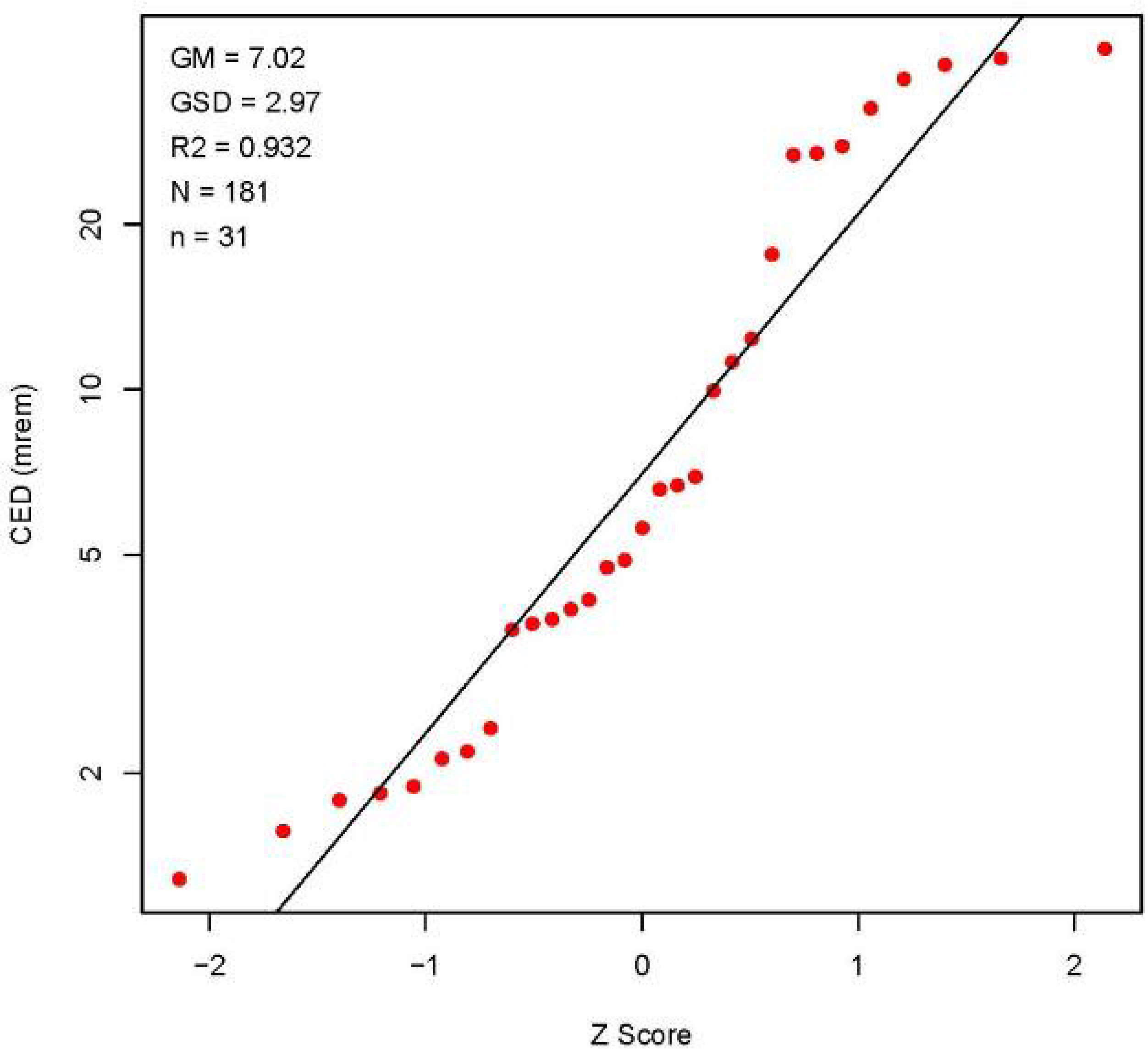

Figure C-101. SRS reactor/CTW tritium dose 1987.

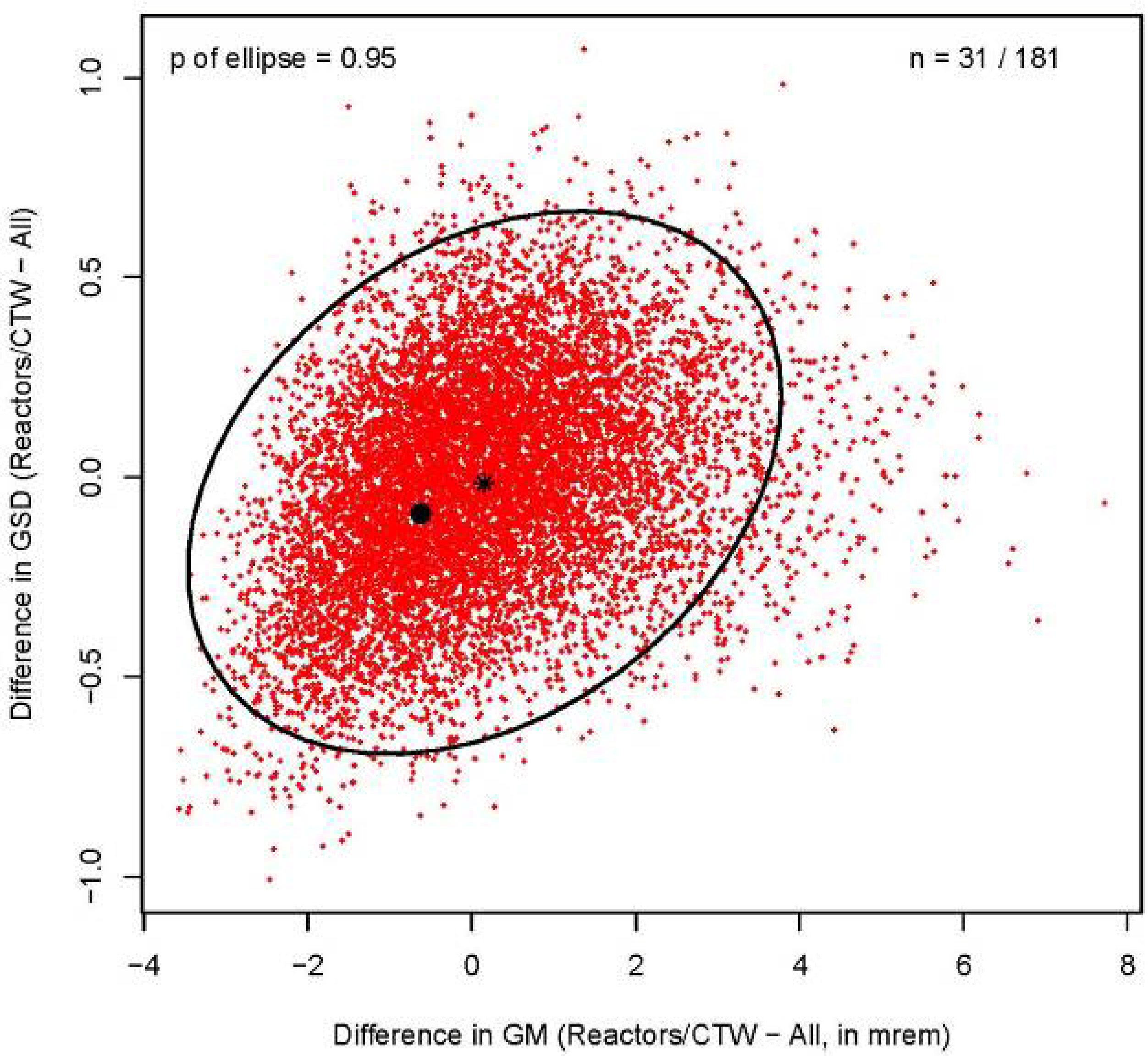

Figure C-102. SRS tritium dose 1987.

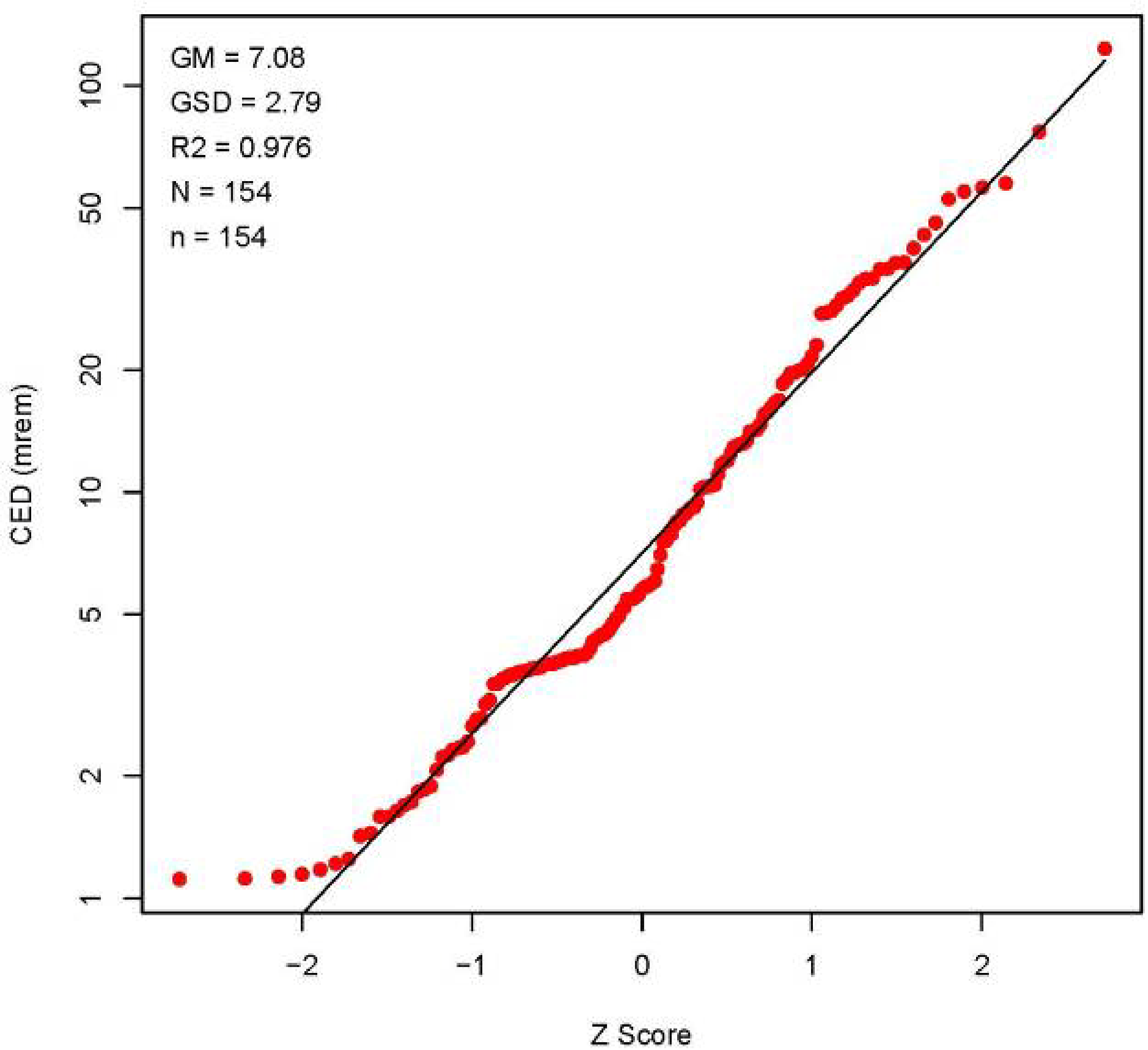

Figure C-103. SRS tritium dose 1988.

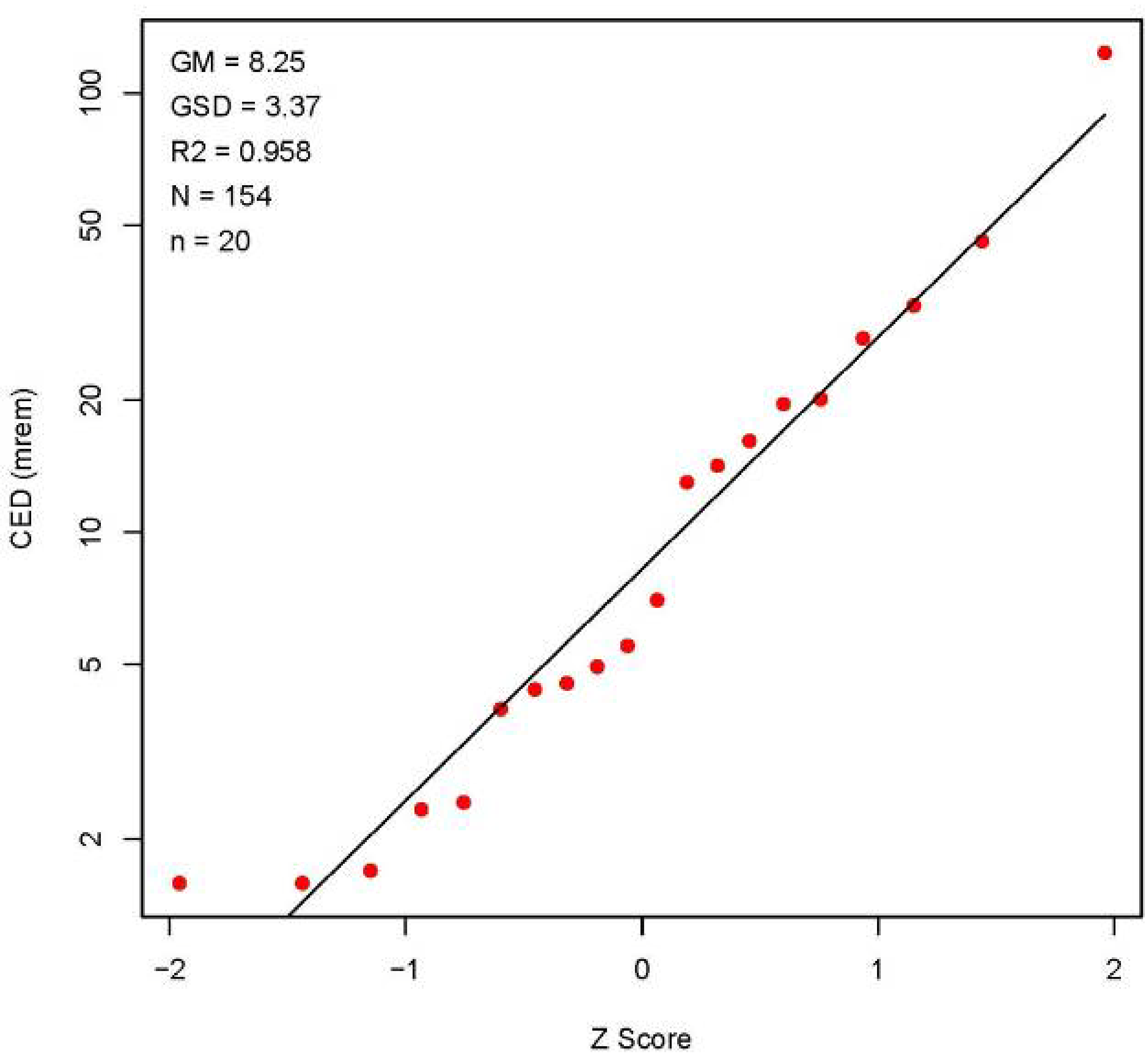

Figure C-104. SRS reactor/CTW tritium dose 1988.

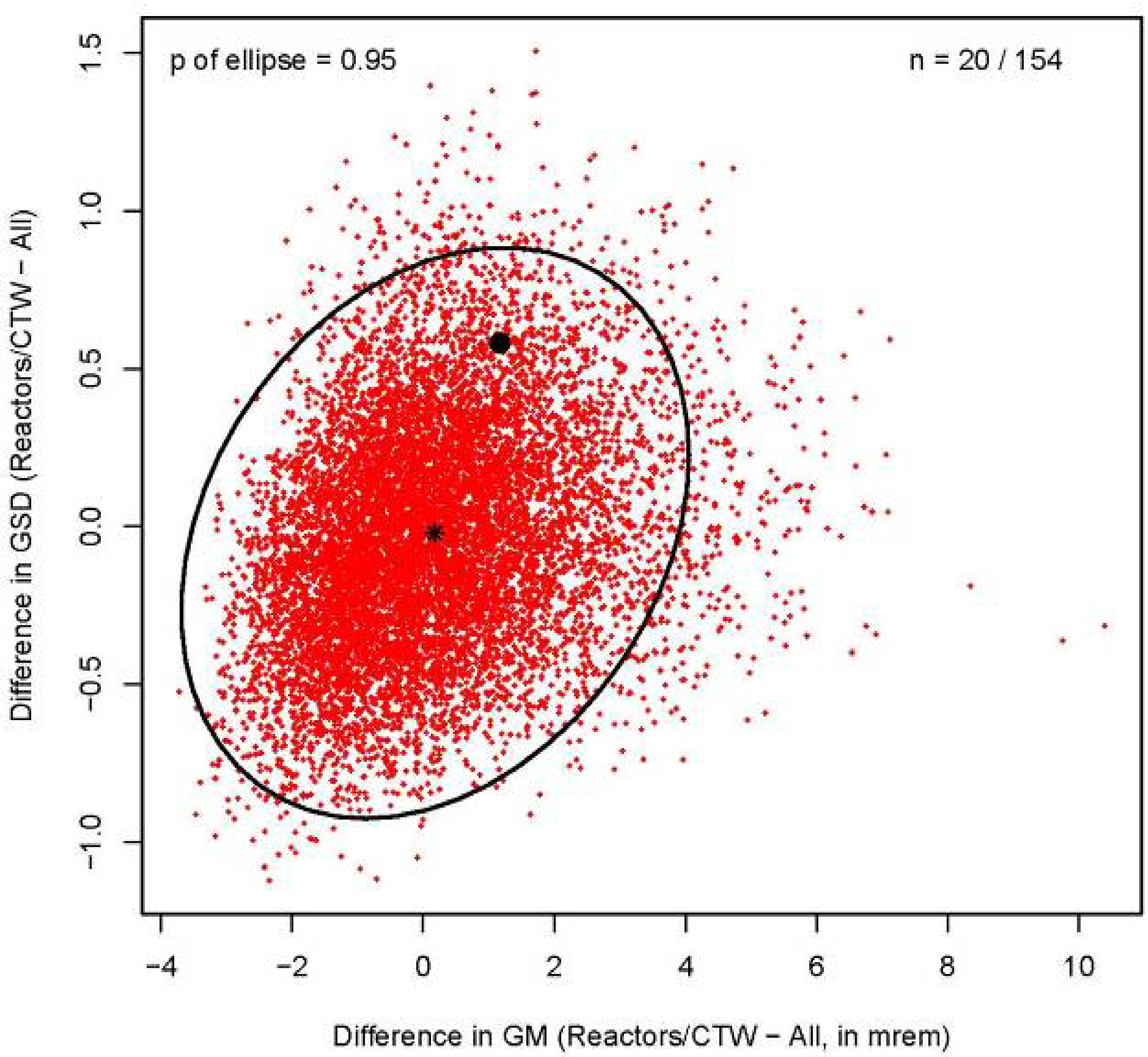

Figure C-105. SRS tritium dose 1988.

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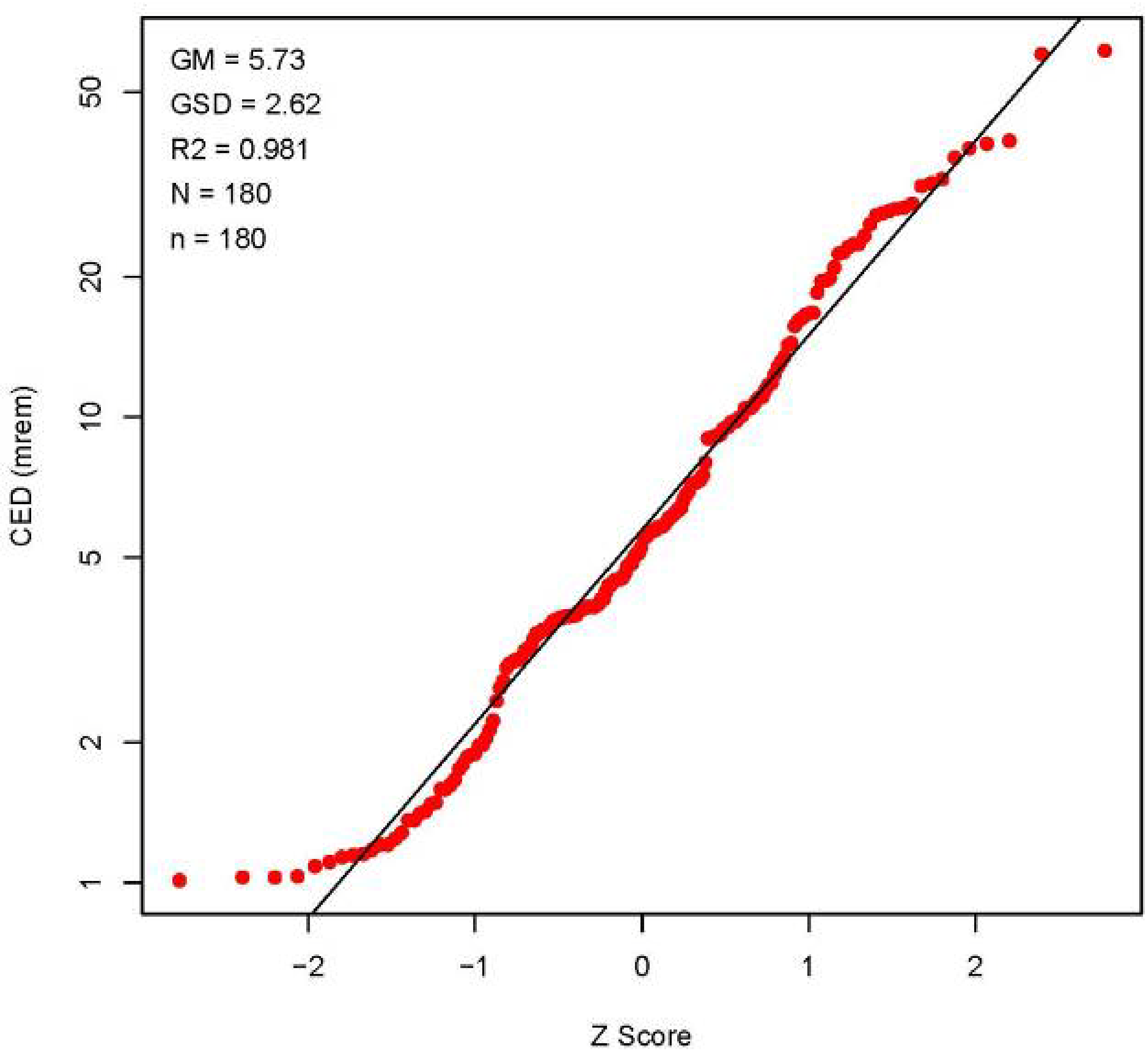

Figure C-106. SRS tritium dose 1989.

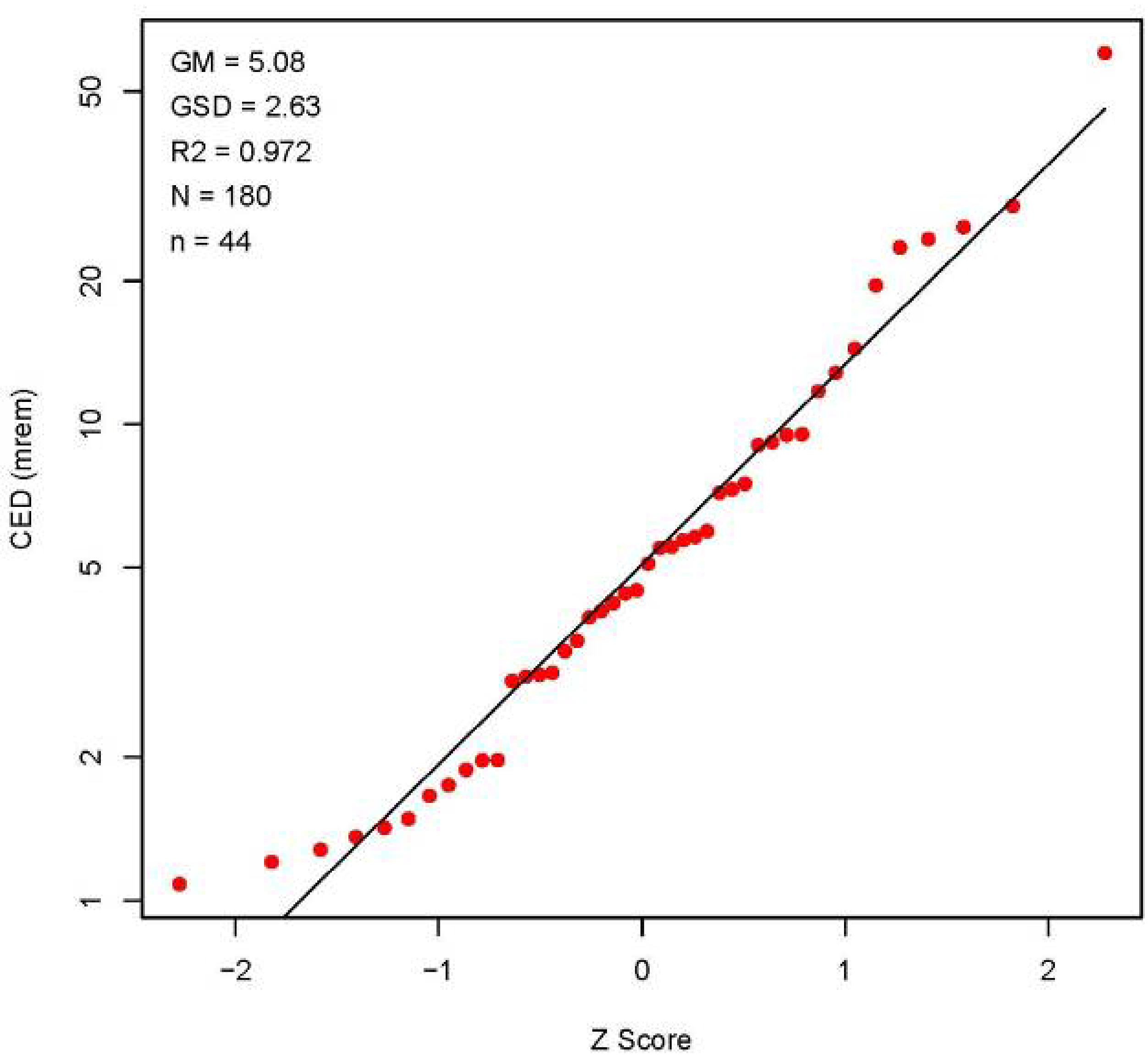

Figure C-107. SRS reactor/CTW tritium dose 1989.

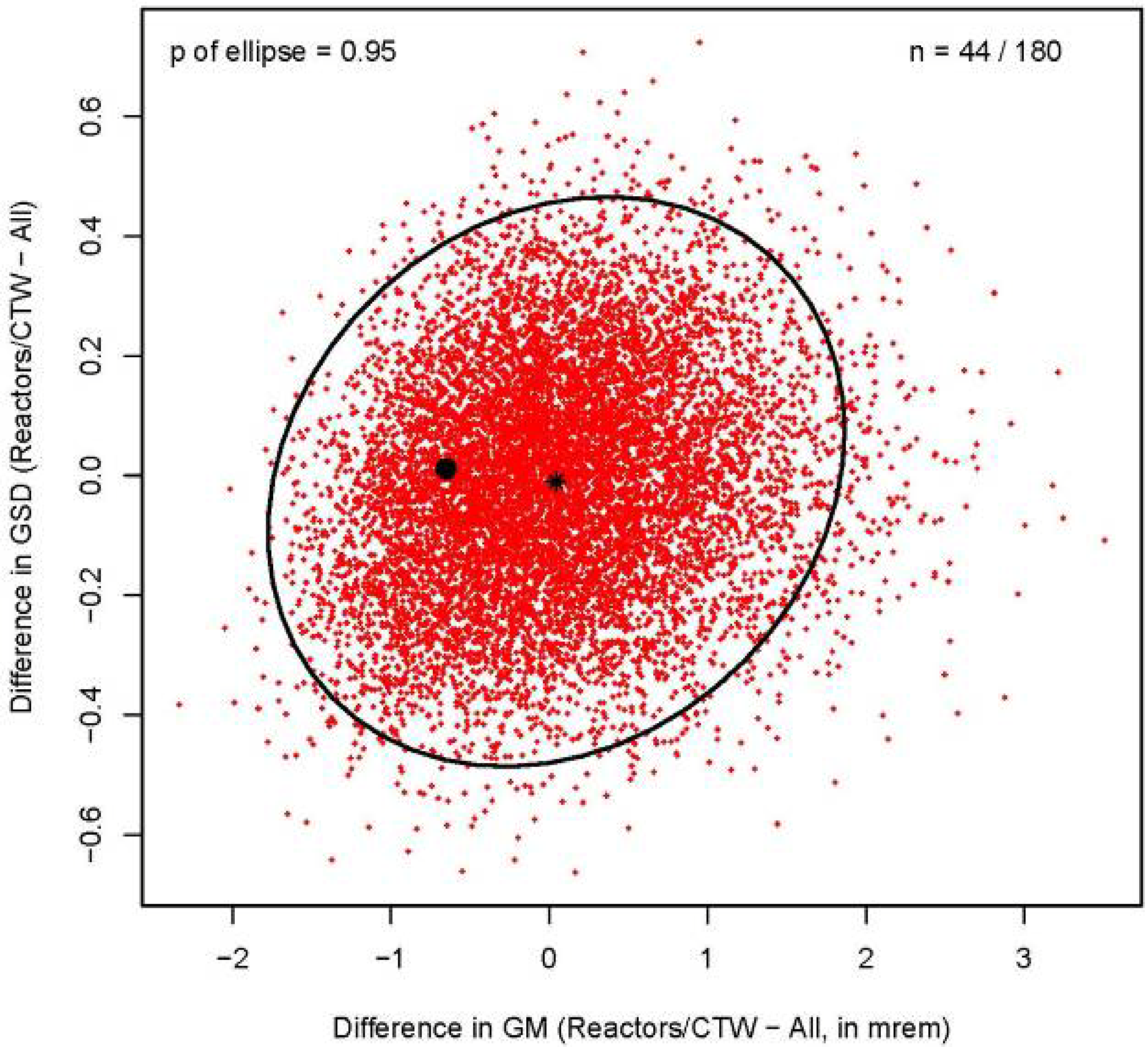

Figure C-108. SRS tritium dose 1989.

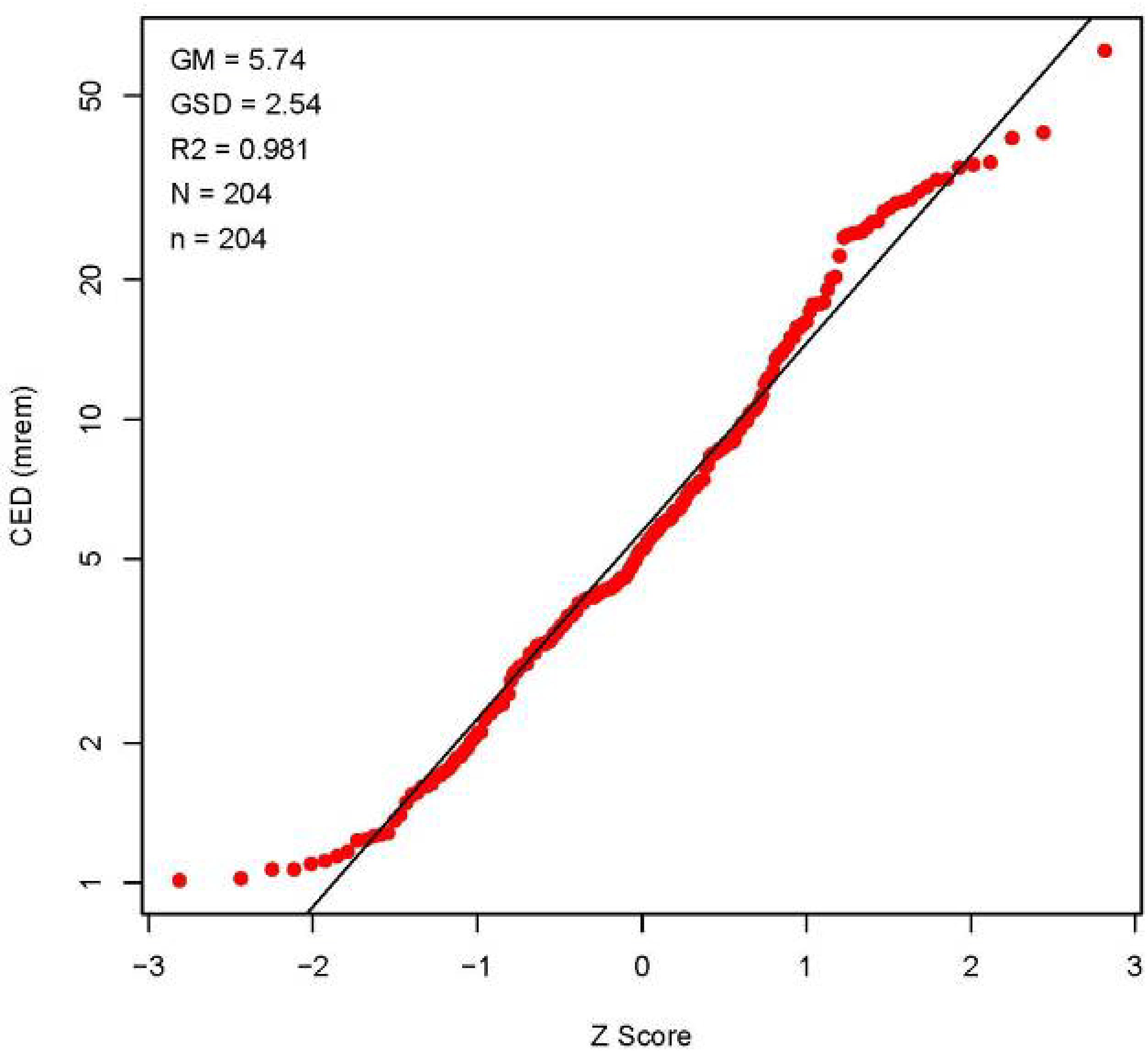

Figure C-109. SRS tritium dose 1990.

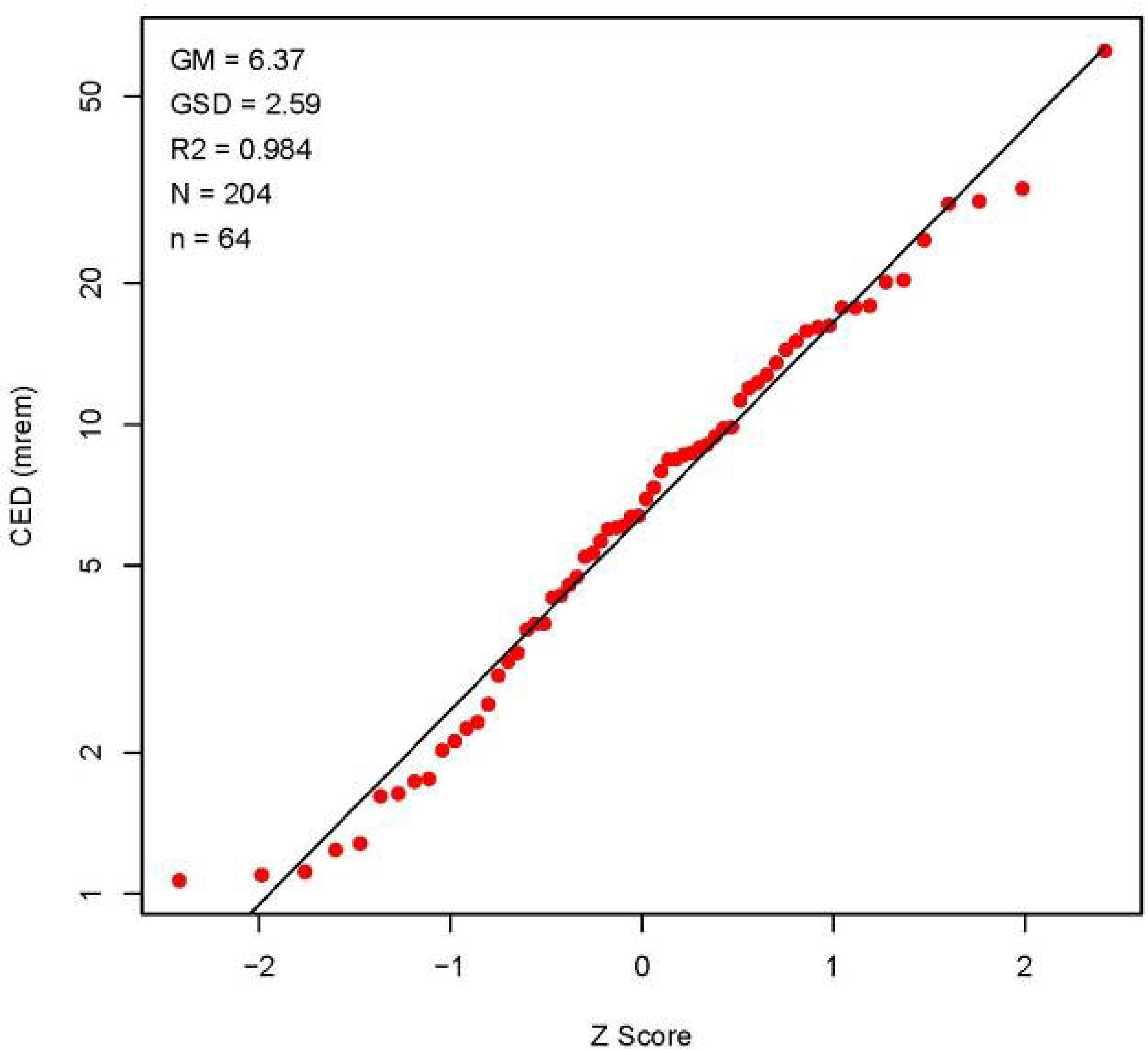

Figure C-110. SRS reactor/CTW tritium dose 1990.

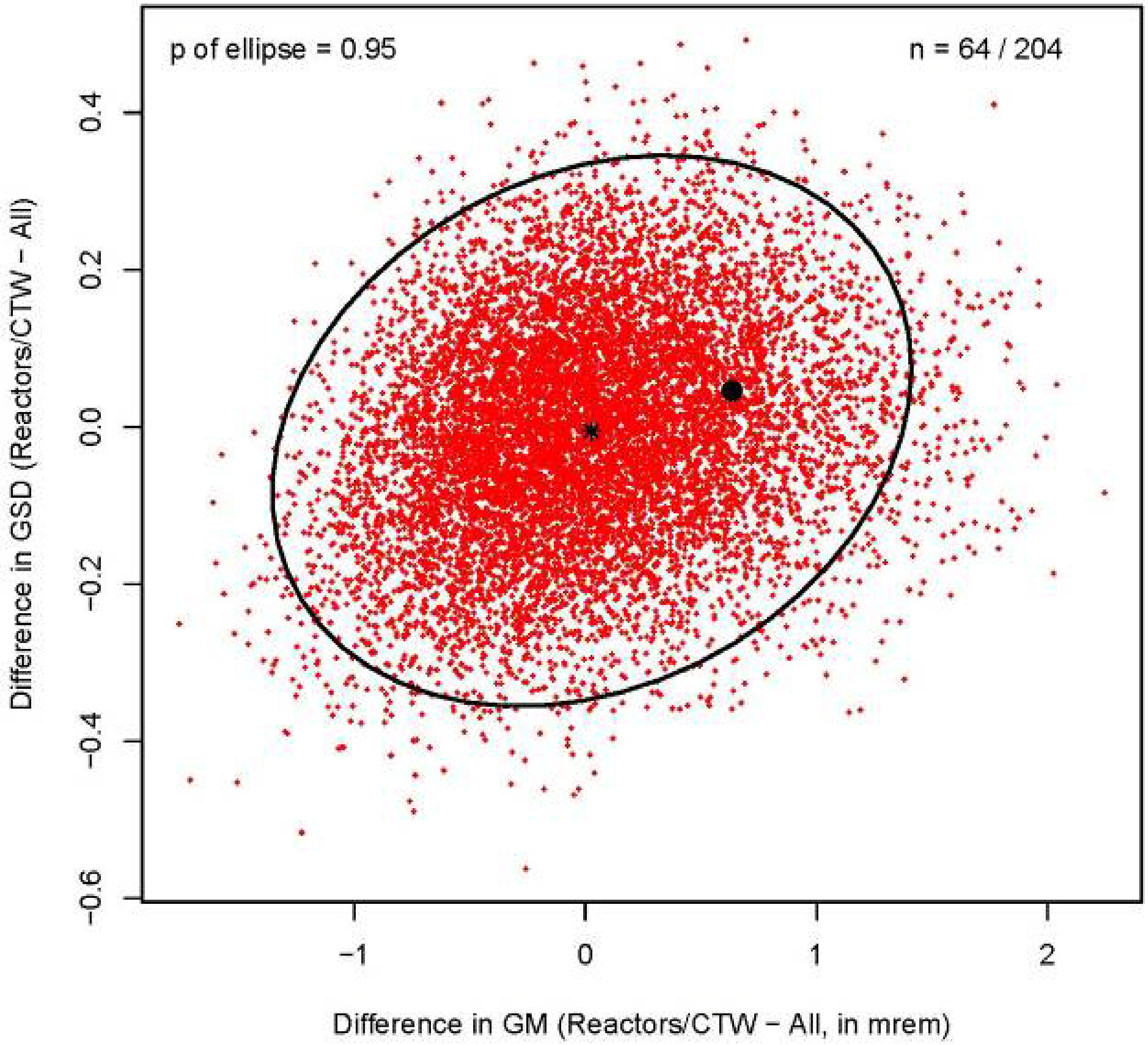

Figure C-111. SRS tritium dose 1990.

ATTACHMENT D
TRITIUM BIOASSAY DATABASE

The Savannah River Site Tritium portion of the coworker study was created by entering claimant tritium data from NOCTS prior to 1991 into a Microsoft Excel spreadsheet and then converting to a Microsoft Access database. This resulted in 260,278 lines of data. Sampling by Attributes Military Standard 105E (ANSI/A SQC Z1.4, ISO 2859) was used to perform a quality assurance check on the SRS tritium database. The procedure for a lot size of 150,001 to 500,000 items is to randomly sample 800 items. For an Acceptance Quality Level (AQL) of 1%, 14 or less errors are acceptable. For an AQL of 1.5%, 21 or less errors are acceptable. 15 of the 800 lines were identified with errors resulting in an AQL of 1.5%. The identified errors were corrected. The Access database was dumped to the following csv text file:

"QC Copy of SRS NOCTS Tritium_52710 RolledUp Area.csv"

Details of Data and Codes used for Calculations
All calculations were performed with R [R 2010].

SRSTritium-Prep.r
This code reads from the NOCTS data file

"QC Copy of SRS NOCTS Tritium_52710 RolledUp Area.csv"

which is a comma-separate value (CSV) text file discussed above. All bioassay results are reported in units of μCi/L, and the only change made to the data file itself was to change "μCi" to "uCi". NOCTS tritium urine bioassay data for 1954-1990 was obtained from this dataset, which contained 260,262 bioassay results for samples submitted by 1447 workers between 1954 and 1990. The tritium data were manipulated and written to

"TritiumBio.csv"

SRSTritium-Dose.r
This code reads in "TritiumBio.csv" and further manipulates the urine bioassay data in preparation for the dose calculation. This step takes a number of hours (~6) to run and the following intermediate bioassay file is generated

"TritiumBio2.csv"

If the dose calculations need to be repeated, starting with this file will greatly speed up the process.

Finally, the urine bioassay data is used to calculate the annual doses for each worker. Any person who had only a single urine result of <MDA μCi/L for a given year was not included in the calculations of the dose distribution for that year because he was not considered part of the routine monitoring program. All remaining concentrations of <MDA μCi/L were replaced with one-half of the appropriate MDA. Any person with a single measurement in a year was assigned a second measurement 40 days later of one-half of the MDA of the first measurement.

The protocol given in [ORAUT 2004] was used to calculate the dose for each individual with the following rules concerning the elapsed time between consecutive samples:

- Type 1 calculations were performed for samples separated by 40 or fewer days.

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TRITIUM BIOASSAY DATABASE

- Type 3 calculations were performed if there were no other samples within 90 days of a sample.
- Type 2 calculations were performed in all other situations.

The annual doses for all workers are given in

"TritiumDose.csv".

A dose of 0 mrem in a given year indicates that the worker either was not monitored in that year or was monitored and assigned a dose of 0 mrem. Each worker was classified as a construction trade worker (CTW) or non-construction trade worker (NCTW). This classification is read from

"NOCTS__SRS_Data_06162010.csv"

and merged with the annual doses along with the NOCTS identification number. Annual doses that were calculated only with samples identified as coming from the reactors areas were classified as "Reactor". All other annual doses are referred to as "Other". The final dose dataset was written to

"TritiumDose2.csv".

The columns in this file are:

ID – NOCTS ID of individual
Year – year in which dose is assigned
Dose – effective dose in mrem
N.Area – number of different areas in which the person submitted urine samples
Area.Name – area to which dose is assigned[7]
CTW – TRUE if individual was identified as a construction trade worker
Male – TRUE is individual was a male

A summary of the number of annual doses (in mrem) by area are shown in the table below

Area	Number of annual doses
Reactors	5,816
H Area	1,810
Not unique	1,292
D Area	327
BLANK	246
F Area	58
Other	150

SRSTritium-Probs2.r
The statistical tests discussed in the body of this report are performed in "SRSTritium-Probs2.r" using the "TritiumDose2.csv" dataset described above. Note that doses of 0 mrem are not used in the analysis.

[7] If urine samples were submitted in more than one area during the year the area is identified as "Not Unique".

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Classification of Samples by Area
The *Area* field in the TritiumBio2.csv file contains one of 9 possible choices:

- A Area
- Central Shops
- D Area
- F Area
- H Area
- M Area
- Other
- Reactors
- Null value

The number of urine bioassay results by area is shown in the table below. The second column in the table lists the raw number of results and the third column the number of results remaining after

- Deleting isolated samples (the only one submitted in a year) that are <MDA, and
- Adding a single ½ MDA result 40 days after an isolated sample if the isolated sample is >MDA.

Area	A Number of samples	B Number of samples
Reactors	166,249	165,799
H Area	58,729	58,395
BLANK	19,402	19,350
D Area	8,709	8,651
Central Shops	3,229	3,207
Other	1,635	1,597
F Area	1,624	1,571
A Area	588	512
M Area	97	51
Sum	260,262	259,133

The values of the *Area* field were determined by checking the value of the *Area* field in the data-coded file (data entered from SRS NOCTS claim records). Assignments were done using the following logic:

- If Data-coded:Area included any location in A Area then TritiumBio2.csv:Area set to “A Area”
- If Data-coded:Area = “CS” then TritiumBio2.csv:Area set to “Central Shops”
- If Data-coded:Area included any location in D Area then TritiumBio2.csv:Area set to “D Area”
- If Data-coded:Area included any location in F Area then TritiumBio2.csv:Area set to “F Area”
- If Data-coded:Area included “Burual Ground” then TritiumBio2.csv:Area set to “F Area”
- If Data-coded:Area = “G” then TritiumBio2.csv:Area set to “Other”
- If Data-coded:Area included any location in H Area then TritiumBio2.csv:Area set to “H Area”
- If Data-coded:Area included any location in M Area then TritiumBio2.csv:Area set to “M Area”
- If Data-coded:Area included “100” then TritiumBio2.csv:Area set to “Reactors”
- If Data-coded:Area = “C” then TritiumBio2.csv:Area set to “Reactors”
- If Data-coded:Area = “K” then TritiumBio2.csv:Area set to “Reactors”
- If Data-coded:Area = “L” then TritiumBio2.csv:Area set to “Reactors”

- If Data-coded:Area included "P" then TritiumBio2.csv:Area set to "Reactors"
- If Data-coded:Area included "R" then TritiumBio2.csv:Area set to "Reactors"
- If Data-coded:Area = "U" then TritiumBio2.csv:Area set to "Reactors"

The value of TritiumBio2.csv: Area of any remaining record was left equal to null.

Classification of Worker Trade

A subjective method was used to assign NOCTS claimants as construction trade workers (CTW). The process started by querying all SRS Claims from NOCTS (through claim number 31058). For each of these claims the following information was extracted from NOCTS:

- NOCTS ID
- SSN
- Last Name
- Position (text containing all values of stated jobs/positions during SRS claimant employment)
- Earliest employment start date
- Latest employment end date
- ICD 9 codes of up to two primary cancers
- Sex

In addition, Yes/No indicators for whether a claim record contains external monitoring and internal monitoring data were merged with each of the queried records.

The contents of the position field for each queried record were checked for construction trade and maintenance job descriptions (other than for management positions). Records found to contain one of the construction trade and maintenance job descriptions were marked "Y" as being CTW. Note that a claimant would be denoted as CTW regardless of when the claimant may have worked in the corresponding job. Due to multiple spelling/abbreviations of NOCTS position values, there are multiple occurrences of some job titles. A file of the resulting NOCTS complete Position values is given in the next section.

Job Titles Used with CTW

Position
Analyst, construction, power equipment operator
Apprentice painter; F3563 painter
Apprentice pipefitter/welder quality control inspector
Apprentice, journeyman; ironworker-welder, ironworker structural, foreman
Area mechanics, maint. mechanic
Asbestos journeyman; asbestos worker; asbestos worker/insulator; journeyman/asbestos worker
Asbestos worker
Asbestos Worker and Insulator
Asbestos worker, mechanic
Asbestos worker; insulator
Asbestosis worker/journeyman
Automotive repair, building radiator maintenance, diesel generator repair

Position

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Boiler maker
Boiler maker helper, boiler maker, general foreman; assistant mechanical superintendent, craft supervisor, construction coordinator, construction engineer
Boiler maker, clean-up work
Boiler maker, machinist, job steward
Boiler maker, mechanic
Boiler maker/mechanic
Boiler operator, sr. operator, dispatcher, foreman, supervisor, sr. supervisor
Boiler operator, supervisor
Boilermaker
Boilermaker apprentice
Boilermaker foreman
Boilermaker, pipefitter, plumber
Boilermaker, truck driver
Boilermaker, welder
Boilermaker/repaired boilers
Boilermaker/welder
Cable repairman
Carpenter
Carpenter and foreman
Carpenter and sheet metal
Carpenter foreman
Carpenter helper
Carpenter then transferred to mechanic
Carpenter, maintenance mechanic, and first line supervisor
Carpenter, millwright
Carpenter, millwright, and sheet metal worker
Carpenter/foreman
Carpenter/operator
Carpenter/draftsman
Carpenter/foreman
Carpenter/laborer
Carpenter/millwright
Carpenter/welder/electrician
Carpenter; construction
Carpenter; operator
Carpenter; truck driver
Carpentry work
Cement finisher
Cement mason
Concrete batch plant operator, mechanic
Concrete consultant; senior engineer
Concrete finisher
Concrete worker
Concrete-mixing truck driver/maintenance mechanic
Construction supervisor

Position
Construction
Construction–fabricator

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TRITIUM BIOASSAY DATABASE

Construction–maintenance
Construction and control room operator
Construction and operations; design liaison
Construction/truck driver
Construction and security worker, reactor worker, foreman and shift supervisor; Individual Consultant
Construction and worked in areas of reactors
Construction discipline engineer (CDE); lead operations specialist; sheet metal worker
Construction electrician
Construction electrician, unknown
Construction engineer
Construction engineer/supervisor; welding/welding supervisor; chief technical engineer (worked w/construction trades)
Construction engineer; pipe fitter
Construction engineering
Construction engineer/scheduler; sr. construction engineer; sr. construction scheduler
Construction field engineer
Construction forces mgr.; lead tech. specialist; senior telecom engineer
Construction foreman
Construction foreman, electrician
Construction insulator
Construction IWE department
Construction laborer
Construction laborer, ground maintenance
Construction laborer, janitor, laundry worker, painter utility mechanic, maintenance mechanic
Construction laborer; laborer and laborer foreman
Construction laborer-worked in tank farm, burial grounds, Reactors 100-K and 100-L and Area 3/700.
Construction machinist
Construction operations
Construction operations operator
Construction operations, petro chemicals driver
Construction painter
Construction pipefitter
Construction sheet metal worker
Construction site manager
Construction specialist
Construction supervisor
Construction supervisor, construction electrician, quality control inspector, QA engineer, training specialist, welder
Construction truck driver
Construction under Carpenter's Union and millwright
Construction worker
Construction worker/journeyman
Construction worker/laborer
Construction worker, apprentice pipefitter in central shops at SRS
Construction worker, laborer

Position
Construction worker, laundry worker; truck driver
Construction worker, pipefitter
Construction worker, production operator

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TRITIUM BIOASSAY DATABASE
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Position
Construction worker, receiving and storage dispatcher
Construction worker/carpenter
Construction worker/janitor
Construction worker/truck driver
Construction worker; welder
Construction, area and civil engineer
Construction, auto mechanic, welder
Construction, boilermaker
Construction, carpenter
Construction, chemical engineer-civil work, estimator
Construction, electrical lineman
Construction, electrician
Construction, fire department, operations, T&T
Construction, foreman for contract work installing pond liners
Construction, heavy equipment operator
Construction, HP work
Construction, laborer, truck driver
Construction, laborer/driver/other jobs in operations
Construction, operational supervisor
Construction, operations
Construction, operator
Construction, operator, millwright
Construction, production operator
Construction, project start-up eng, start-up eng spec, start-up office, supervisor
Construction, quality control engineer
Construction, security guard, security patrol man
Construction, separations
Construction, serviced heavy equipment
Construction, supervisor and trainer
Construction, tritium worker, QA
Construction. operation (clerk), pipe welding dept.
Construction. painter
Construction/asbestos worker
Construction/chemical operator
Construction/fire dept.
Construction/carpentry
Construction/construction purchasing
Construction/electrical
Construction/electrician
Construction/insulator
Construction/iron worker
Construction/machine operator
Construction/maint.
Construction/millwright
Construction/security
Construction/sheet metal worker
Construction/warehouse superintendent
Construction; construction grading; construction supervisor

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TRITIUM BIOASSAY DATABASE
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Construction; construction work
Construction; lab tech
Construction; operator; patrolman
Construction; power equipment operator; operator; sample operator; machine oiler; air compressor
Construction; production operator
Construction-electrical
Construction-electrician
Construction-maintenance mechanic
Diesel maintenance mechanic
E&I mechanic
E&I mechanic supervisor
E&I mechanic, patrolman, radio repairman
E&I mechanic, project assistant
E&I mechanic, supervisor, manager
E&I mechanic, trainer, (computers firearms, and security system)
E&I mechanic and electrician
E&I lab technician, electrician
E&I maintenance, equipment engineer, instrumentation mechanic, engineering assistant, senior engineer
E&I mechanic
E&I mechanic and QA inspector
E&I mechanic, project assistant
E&I mechanic/project asst. (Last 5 yrs.)
E&I mechanic
E&I technician
E&I mechanic
Electrical
Electrical and instrument mechanic
Electrical and instrumental mechanic
Electrical and instrumentation mechanic
Electrical and instruments dept. of production, 100 and 300 Areas; electrician
Electrical /instrumentation mechanic, first line supervisor, cranes/elevators
Electrical and instrument mechanic
Electrical and instrument repair
Electrical and instrumentation mechanic
Electrical apprentice
Electrical construction electrician
Electrical foreman
Electrical foreman, superintendent (CATI)
Electrical instrument mechanic
Electrical journeyman, foreman, general foreman, asst. craft superintendent in 100R, 100K,100C,100L Areas for part of the time
Electrical mechanic
Electrical mechanic, instrumental mechanic, supervisor

Position
Electrical work
Electrical worker
Electrician, machinist
Electrician
Electrician (based on CATI)

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TRITIUM BIOASSAY DATABASE
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Electrician/instrument mechanic
Electrician/mechanic
Electrician and E&D mechanic
Electrician and Foreman
Electrician foreman
Electrician helper/apprentice
Electrician in central shops
Electrician welder/electrician
Electrician, construction
Electrician, electrical and Instrument mechanic, procedure writer
Electrician, electrician foreman
Electrician, engineer, engineer Instrumentation and controls
Electrician, engineer, planner for HB line
Electrician, foreman
Electrician, maintenance
Electrician, maintenance and construction of electrical equipment
Electrician, welder
Electrician, wireman and lineman
Electrician, worker in E&I department, worker in projects department
Electrician, project engineer asst.
Electrician/E and I mechanic
Electrician/escort
Electrician/instrumentation mechanic
Electrician/EI mechanic
Electrician/foreman/superintendent
Electrician/journeyman
Electrician/power lineman
Electrician/video technician/assistant estimator
Electrician; electrician, electrician foreman
Electrician; electrician, electrician foreman; journeyman electrician
Electrician; escort (part time employment equals 17 months of full time employment)
Electrician; iron worker, welder, foreman
Electrician; journeyman
Electrician; journeyman wireman
Electrician; operator, supervisor
Electrician; welder, electrician
Electrician; welder/electrician
Electrician; woreman, journeyman
Electronic mechanic
Foreman, carpenter, instructor
General craft supervisor; machinist
General maint.

Position
General maintenance mechanic, machinist, and supervisor of the maintenance department
Glazer/painter
Heavy duty equipment mechanic
Heavy duty mechanic
Heavy equipment field mechanic
Heavy equipment mechanic

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TRITIUM BIOASSAY DATABASE

Heavy equipment mechanic; heavy equipment operator
Heavy equipment/maint.
Heavy equipment/construction
Helper/sheet metal worker
Instrument mechanic
Instrument mechanic and E&I supv.
Instrument mechanic, p; project assistant
Instrument mechanic, project assistant
Instrument mechanic, project assistant, building engineer in experimental physics/technical division
Instrument mechanic/electrician
Instrument mechanic/electric
Instrument repairman/electrician
Instrument technician
Insulation and asbestos worker
Insulation apprentice
Insulation installer
Insulation installer/asbestos worker
Insulation worker
Insulator
Insulator, asbestos worker, asbestos worker foreman
Insulator, asbestos worker; insulator, journeyman and asbestos worker
Insulator, asbestos worker
Insulator/mechanic
Insulator/pipefitter
Insulator; asbestos worker
Insulator; insulator workers foreman
Iron worker
Iron worker (foreman)
Iron worker/reactor operator/supervisor
Iron worker/steel detailer; operator; health physic inspector; draftsman
Iron worker/welder
Iron worker; welder; welder/emp for one day
Ironworker
Iron-worker
Ironworker supervisor
Ironworker, laborer
Ironworker, safety Inspector, clerk, contract administrator, contract specialist
Ironworker/welder
Ironworker/welder
Ironworker/welder/craft coordinator; supervisor of ironworkers/welders; construction superintendent
Ironworker; shop steward

Position
Ironworker-foreman
Janitor and maintenance mechanic; laborer and maintenance mechanic
Janitor, maintenance
Janitor, operator, elect. and instrument mechanic, supervisor, QA spec., QA engineer, maintenance spec. and decommissioning and demolition spec.; quality assurance manager
Journeyman electrician
Journeyman electrician/supervisor/planning engineer

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Journeyman sheet metal worker to foreman
Journeyman wireman
Journeyman, foreman and steamfitter
Journeyman/pipefitter
Journeyman; pipefitter; steamfitter
Laborer
Laborer (concrete and building), Rodman-survey, Levelman-survey
Laborer and electrical, instrumentation mechanic
Laborer, lab tech, maintenance mechanic, E&I mechanic, project technician
Laborer, maintenance
Laborer, maintenance mech and supv
Laborer, mechanic
Laborer, mechanic's helper, operator
Laborer, operations, janitor, painter, mechanic
Laborer/carpenter apprentice
Laborer; maintenance mechanic
Laborer-construction
Machinist mechanic
Machinist, maintenance supervisor, manager in training
Machinist, welder, general maintenance work
Mail clerk/maint. mechanic
Maint. engineer
Maint. mechanic
Maint. mechanic, supervisor
Maint. mechanic, welding inspector/maint. instructor and maint. supv.
Maint. operations
Maint. Supv.
Maint. worker
Maint./operations
Maintenance
Maintenance and painter
Maintenance and utility mechanic
Maintenance coordinator
Maintenance coordinator, quality controller
Maintenance electrician
Maintenance engineer
Maintenance foreman
Maintenance inspector
Maintenance man
Maintenance manager

Position
Maintenance mech; painter; utility mech; power auxiliary operator
Maintenance mechanic
Maintenance mechanic (a, b, and c), maintenance foreman
Maintenance mechanic (EE-3)
Maintenance mechanic and supervisor
Maintenance mechanic and welder
Maintenance mechanic consultant/management/NA
Maintenance mechanic ii

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Maintenance mechanic, first line maintenance manager; fire protection tester, first line maintenance manager
Maintenance mechanic, foreman, pipefitter
Maintenance mechanic, instrument mechanic, electrician
Maintenance mechanic, mechanic
Maintenance mechanic, millwright worker, foreman, unit manager, welder, pipefitter
Maintenance mechanic, painter and coal handler
Maintenance mechanic, welder
Maintenance mechanic/pipefitter
Maintenance mechanic/project assistant
Maintenance mechanic/welder
Maintenance mechanic; sheet metal worker
Maintenance mechanical
Maintenance operator, janitor, patrolman, production operator
Maintenance supervisor
Maintenance supervisor; supervisor
Maintenance support
Maintenance utility mechanic
Maintenance worker
Maintenance Worker in reactor area
Maintenance, laborer
Maintenance, pipe fitter
Maintenance, supervisor
Maintenance/patrol/security
Maintenance/welder
Maintenance; heavy equipment operator; power equipment operator; crane, derrick and dragline; tractor and motor crane driver; end loader and dozer operator; crane operator
Maintenance; security inspector, sergeant central alarm station
Master electrician/supervisor
Mechanic
Mechanic–repair of heavy equipment
Mechanic/foreman
Mechanic A
Mechanic A/mechanic B
Mechanic and foreman
Mechanic and rigger
Mechanic and welder
Mechanic, drill hand, well driller
Mechanic, electrician, surveyor
Mechanic, foreman, engineer, area supervisor

Position
Mechanic, foreman, insulator
Mechanic, foreman-traffic and transportation
Mechanic, Maintenance foreman
Mechanic, maintenance supervisor
Mechanic, project assistant and wash court operator
Mechanic, project assistant, foreman
Mechanic, reactor operator
Mechanic, welder
Mechanic, Works engineering supervisor

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Position
Mechanic, supv.
Mechanic/maintenance, mechanic/machinist
Mechanic/foreman
Mechanic/welder
Mechanic/welding/diesel svcs
Mechanical maint.
Mechanical maintenance
Metal worker
Millwright
Millwright and Machinist
Millwright apprentice, millwright journeyman
Millwright, operator, draftsman
Millwright/carpenter
Millwright/machinist
Millwright/maintenance
Millwright/welder
Oiler
Painter
Painter apprentice/supervisor
Painter, area mechanic
Painter, carpenter
Painter, construction
Painter, engraver
Painter, glazer, sandblaster
Painter, maintenance man
Painter, millwright; security guard
Painter, supervisor
Painter, maint. mechanic
Painter/insulator
Painter/coding CDE: civil engineer
Painter/supervisor
Painter/utility/maintenance
Pipe fitter
Pipe fitter and welder
Pipe fitter, expeditor
Pipe fitter/welder
Pipe welder
Pipe welder, welding inspector
Pipe welder; welding engineer
Pipe welder-inspector
Pipefitter
Pipefitter (subcontractor)
Pipefitter and fire control
Pipefitter apprentice/construction; pipefitter; production operator
Pipefitter for B F Shaw
Pipefitter and training coordinator
Pipefitter, ITP supervisor
Pipefitter, rigger, laboratory work, construction rigger, rigger foreman, traffic and transportation, iron worker

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Pipefitter, steamfitter
Pipefitter, supervisor
Pipefitter, welder
Pipefitter, welder, construction worker
Pipefitter, welder, engineer
Pipefitter/welder
Pipefitter/area mechanic
Pipefitter/construction
Pipefitter/maintenance mechanic/health physics inspector
Pipefitter/plumber
Pipe-fitter/sprinkler fitter
Pipefitter/steamfitter
Pipefitter/welder
Pipefitter/welder ; telephone technician
Pipefitter; steamfitter; ironworker; plumber
Pipe welder
Pipe welder/apprentice; journeyman/welder
Pipefitter
Plumber
Plumber and pipefitter
Plumber, pipe fitter, welder; general supervisor of the engineering dept.
Plumber, pipefitter
Plumber/pipefitter
Plumber/pipefitter
Plumber/steamfitter
Plumber/welder/pipefitter
Power house maintenance
Replacing and repairing ducts
Rodbuster, welder
Roofer
Roving maintenance crew, pipefitter, welder
Security officer, maintenance worker
Service installation/technician
Sheet metal mech
Sheet metal supervisor
Sheet metal worker
Sheet metal worker, foreman

Position
Sheet metal worker, Sr. general foreman
Sheet metal worker, trainer
Sheet metal worker; construction supervisor
Sheet metal
Sheet metal worker
Sheet metal/foreman
Steam fitter/foreman
Steamfitter
Steamfitter, welder
Steamfitter/plumber
Steamfitter/plumber/pipefitter

Steel worker
Structural ironworker, foreman
Subcontracted pipefitter
Supervisor, maintenance mechanic
Truck driver, maintenance, welding
Truck driver/construction
Truck driver/mechanic
Waste handler/filter changer
Welder
Welder and maintenance
Welder and maintenance worker
Welder and machine shop foreman
Welder and mechanic
Welder, boiler maker craft, metal fabrication, foreman/supervisor for boiler maker crafters
Welder, iron worker
Welder, ironworker
Welder, maintenance mechanic
Welder, millwright, assistant superintendent
Welder, pipefitter
Welder, pipefitter, control operator, steamfitter
Welder, pipefitter, welding inspector, welding supervisor, welding consultant
Welder, sheet metal worker
Welder, steamfitter, pipefitter
Welder/electrician
Welder/foreman
Welder/mechanic
Welder/pipefitter
Welder/steamfitter
Welder; ironworker/journeyman
Welder; pipefitter
Welder; project manager
Welder; torch cutter, "cut-man"

ATTACHMENT D
TRITIUM BIOASSAY DATABASE

REFERENCES

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