

Proposed EQ irradiation analysis methods

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Variability

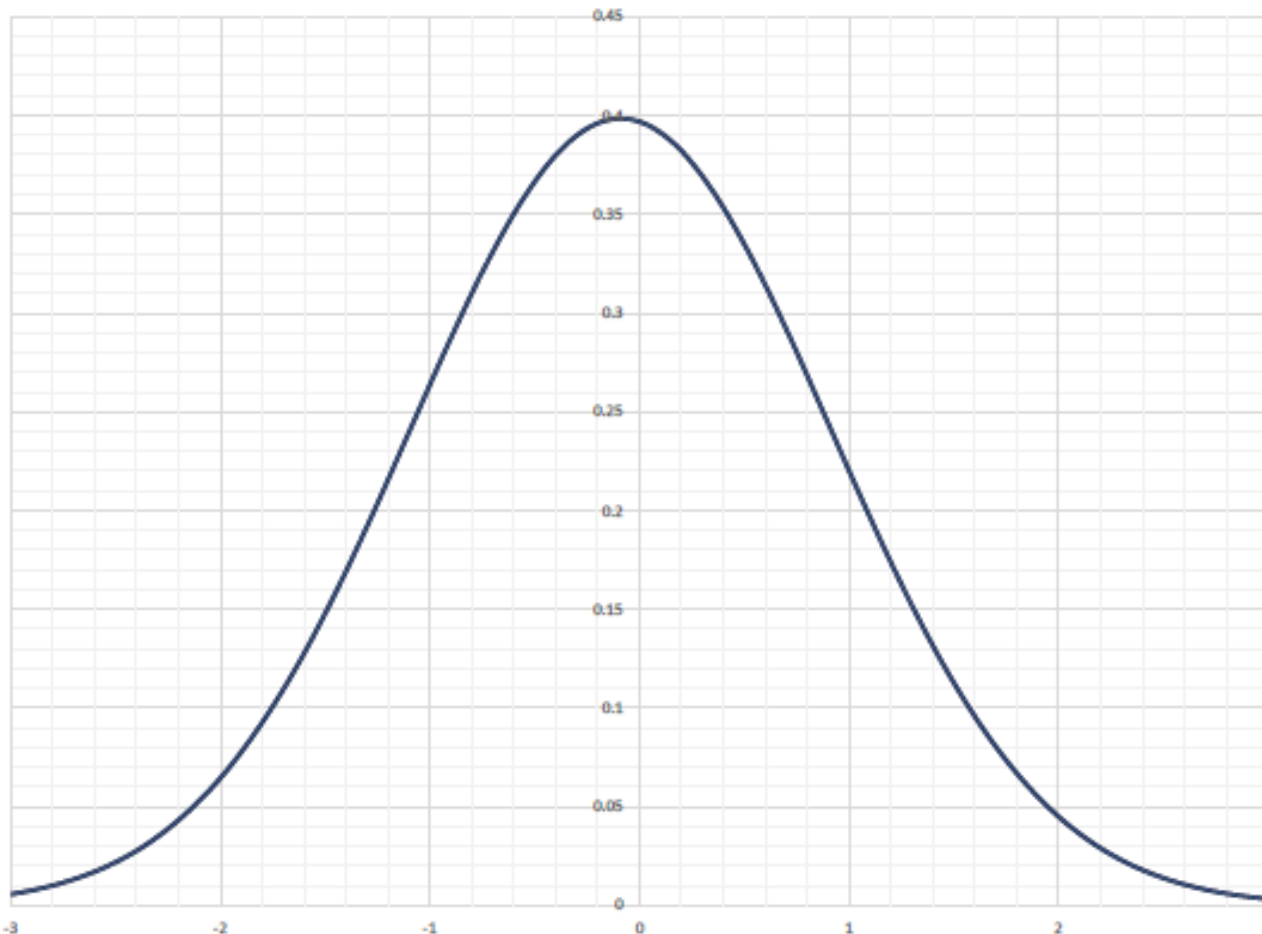
- Density
- Dosimetry
- Intercomparison (only applies to the ceiling zone)
- Source decay (not a variability, rather, a translation)
- Others.....?

Variability

- Two components to variability
 - The percent variability
 - The confidence level that variability is based upon
- Example: Dosimeters have a 6.5% variability with 95% confidence level

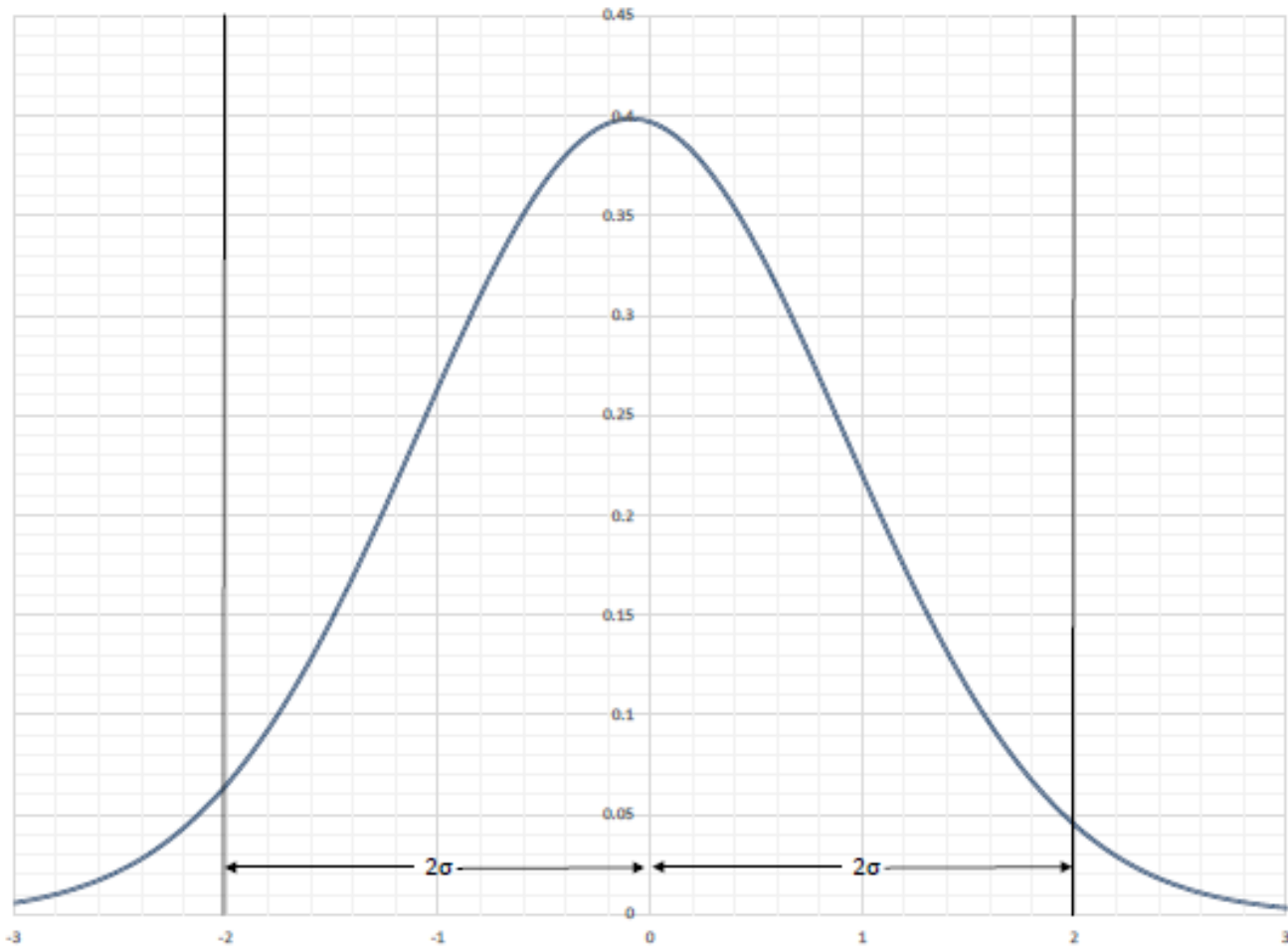
Normal Distribution

- 95% confidence can be viewed in two ways in terms of the # of standard deviations (σ) from the mean (μ)



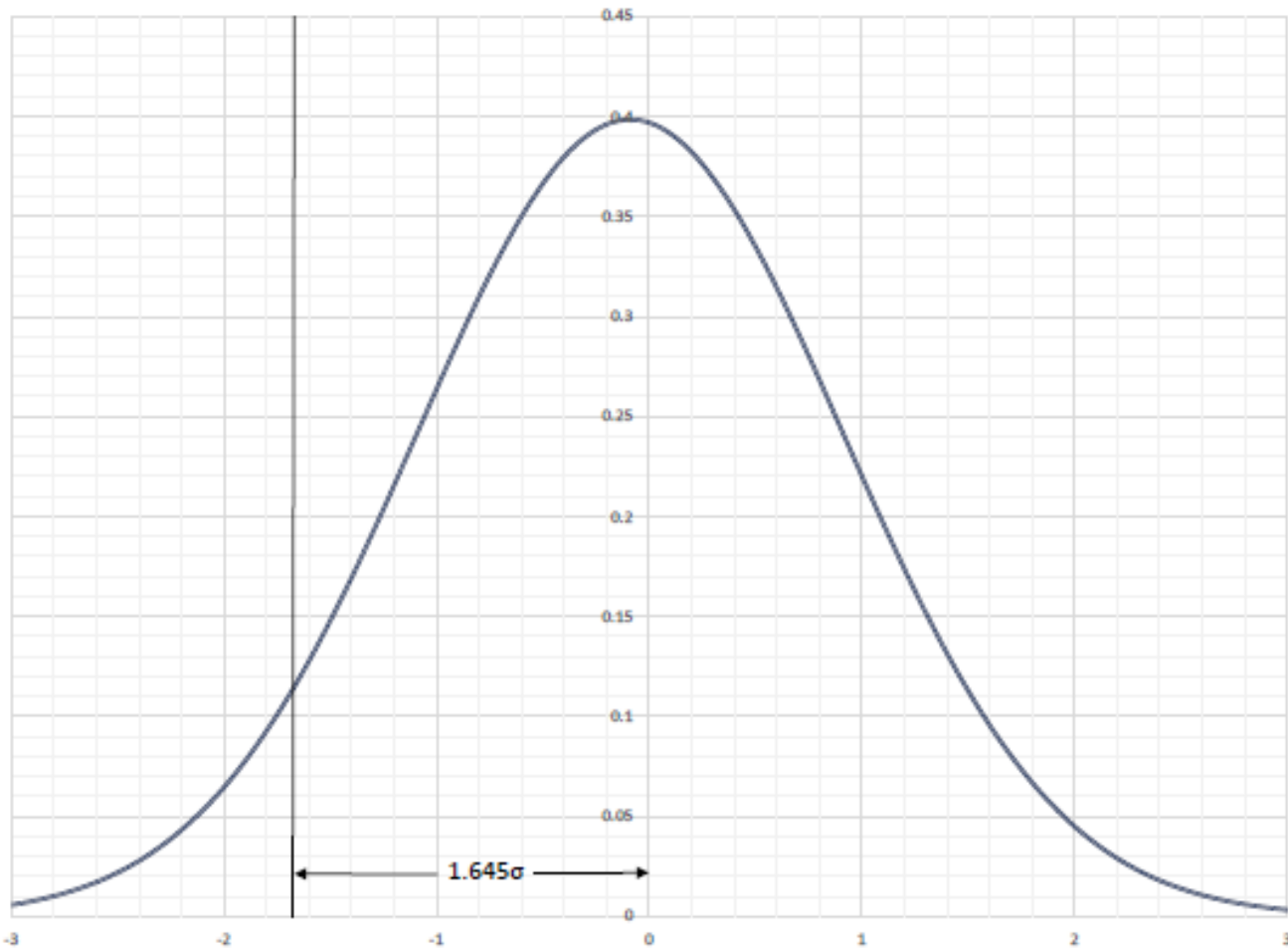
Normal Distribution

- 2 standard deviations(σ) from both sides of the mean(μ)
 - Yields 95% confidence that the dose received is within two σ 's of the reported dose



Normal Distribution

- 1.645 standard deviations(σ) from left side of the mean(μ)
 - Yields 95% confidence that the dose received is equal to or greater than the dose reported



Central Limit Theorem

- The standard deviation (σ) of a normal distribution of the sample mean can be calculated from the formula for the variance of the sum of independent random variables. It is equal to σ/\sqrt{n} , where n is the number of data points in the sample.

Density variability

- A single dose rate study is used to extrapolate the amount of time in the hot cell to reach the reported total integrated dose (TID)
- Since a single dose rate study is used, then averaging does not occur and the central limit theorem does not apply

Density variability

- Three methods for determining the density variability
 - Representative experiment
 - Statistical analysis of historical dose rate studies
 - Analysis of procedures and carrier product densities

Density variability

- Three methods for determining the density variability
 - **Representative experiment**
 - Must be replicative of an actual dose rate study
 - # of batches irradiated per dose rate study
 - Dosimeters used (else dosimeter variability is excluded)
 - Sample population size must yield a 95% confidence level
 - Statistical analysis of historical dose rate studies
 - Analysis of procedures and carrier product densities

Density variability

- Three methods for determining the density variability
 - Representative experiment
 - **Statistical analysis of historical dose rate studies**
 - Plot dose rate studies vs. time and perform a regression based on the exponential decay of a Co-60 source
 - The standard error from the regression is equal to the standard deviation of the combined density and dosimeter variability
 - Sample population size must yield a 95% confidence level
- Analysis of procedures and carrier product densities

Density variability

- Three methods for determining the density variability
 - Representative experiment
 - Statistical analysis of historical dose rate studies
 - **Analysis of procedures and carrier product densities**
 - Carrier product densities are believed to be well documented and follow Steris procedures

Dosimetry variability

- The central limit theorem applies if and only if all of the following conditions are met:
 - Multiple dosimeters were used during the dose rate study
 - The dosimeters were within close proximity of one another
 - Each dosimeter was within the bounds of the calibrated zone where the samples were irradiated
 - Dosimetry distribution is normally distributed
 - The dosimeters and samples were irradiated in air
- ... then each measurement is independent and random and assumes to follow a normal distribution with a variability of 6.5% which correlates to a 95% confidence level for a single dosimeter measurement.

Dosimetry variability

- For example:
 - The variability of dosimetry measurements can be reduced by the square root of the number of dosimeters used during the study. For example, if four dosimeters were used, then the variability around the mean of the four dosimeter measurements is equal to $6.5\%/\sqrt{4}$ or 3.25% which correlates to a 95% confidence level for a sample set of four dosimeters.

Intercomparison

- Intercomparison studies are analogous to calibration of the off carrier irradiation zones for dosimetry measurements
- There are 4 zones
- Typically performed quarterly
- This variability only applies to the ceiling zone

Source decay

- Not a variability, rather, a translation of the distribution
- For Co-60 the source decays $\sim .5\%$ per month

Conclusion

- Density variability has not been definitively determined
- History of dose rate studies is probably best way to determine the historical density variability

QUESTIONS