# PHY3004W2025 Lab02 Poisson Counting Statistics

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## 1 Abstract

This report explores the statistics of the Poisson distribution through the data produced by counting radioactive decays from a Caesium-137 source.

## 2 Introduction

## 3 Method

### 3.1 Data Collection

The detecting apparatus includes a NaI detector connected to a UCS30 acquisition unit. This will count and report the energy of high energy photons it interacts with. The source of the high-energy photons is a sample of Caesium-137. The distance between the sample and the detector can be adjusted to allow for different detection rates. The spectrum is taken, and adjusted so that the 0.662 MeV peak is in an optimal spot. The spectrum is restricted 50 channels either side of the peak. The MCS mode counts how many detections fall within this window in a set of time intervals. The length of the time intervals is changed to further adjust the mean.

### 3.2 Data Processing

Data analysis is done in Python, using the Numpy, Scipy, and Matplotlib packages. Please refer to the code.

## 4 Analyses

### 4.1 Cumulative Average

Refer to Figures 3 to 10 in Appendix 1.

### 4.2 Mean and Standard Deviation

Refer to tables 1 and 2 in Appendix 1. For each relevant distance and time interval combination, the time scaled count from the restricted spectrum falls within a standard deviation of the mean of the data collected using MCS mode.

### 4.3 Histograms and Poisson Distributions

Refer to Figures 11 to 19 in Appendix 1. For all datasets, the histogram and Poisson distribution approximately match, but not exactly within the error bars.

### 4.4 Data Point with Highest Deviation

The dataset with the lowest mean has a mean of 1.0, and is produced by the setup with a 195mm distance to the source, and a time interval of 20ms. It also has a standard deviation of 1.03. Refer to Figure 6. There is a time interval that recorded 6 counts. This is a deviation of 5.0 from the mean, or 4.85 standard deviations. According to the Poisson distribution with mean 1, the frequency of 6 counts is expected to be 0.0005. For an experiment with 1024 time intervals, the expected number of time intervals to have recorded 6 counts is 0.5232. This can be approximately thought of as running the experiment multiple times and getting a interval with 6 counts every second experiment. This means we should not discard this data point.

### 4.5 Gaussian Distribution

The following setups produce datasets that can be approximated by a Gaussian distribution: 10mm, 40ms; 10mm, 60ms; 10mm, 100ms; 10mm, 200ms.

### 4.6 Rate of Decay Uncertainty Budget

## 5 Conclusion

## 6 References

## 7 Bibliography

## 8 External Links

I have stored files in my UCT OneDrive and GitHub. The UCT OneDrive folder is viewable by anyone with a UCT email address. The GitHub repository is viewable by the public. Please use these if you wish to see my code, or higher quality images.

https://uctcloud-my.sharepoint.com/:f:/g/personal/ellror001_myuct_ac_za1/ErMFe5n_uiBCvbp4BVYqKCQBnQg
e=b5gp5F

https://github.com/ellr16/20250324_Lab02_PoissonCounting

## 9 Appendix 1: Tables and Figures

| Distance | Time(s) | Counts | per 1s | per 20ms | per 40ms | per 60ms | per 100ms | per 200ms |
|---|---|---|---|---|---|---|---|---|
| 10mm | 600.65 | 814815 | 1356.56 | 27.13 | 54.26 | 81.39 | 135.66 | 271.31 |
| 35mm | 600.51 | 303203 | 504.915 | 10.10 | | | | |
| 73mm | 600.56 | 119285 | 198.62 | 3.97 | | | | |
| 195mm | 615.22 | 30475 | 49.54 | 0.99 | | | | |

Table 1: Counts from restricted spectrum data, scaled to relevant time intervals

| Distance | Time Interval | Mean | Standard Deviation | Uncertainty of Mean |
|---|---|---|---|---|
| 10mm | 20ms | 26.83 | 4.92 | 0.15 |
| 35mm | 20ms | 10.06 | 3.19 | 0.10 |
| 73mm | 20ms | 4.00 | 1.97 | 0.06 |
| 195mm | 20ms | 1.00 | 1.03 | 0.03 |
| 10mm | 40ms | 54.98 | 7.48 | 0.23 |
| 10mm | 60ms | 82.55 | 8.89 | 0.28 |
| 10mm | 100ms | 137.36 | 12.01 | 0.38 |
| 10mm | 200ms | 273.93 | 16.51 | 0.52 |

Table 2: Mean, Standard Deviation, and Uncertainty of the Mean for each MCS dataset

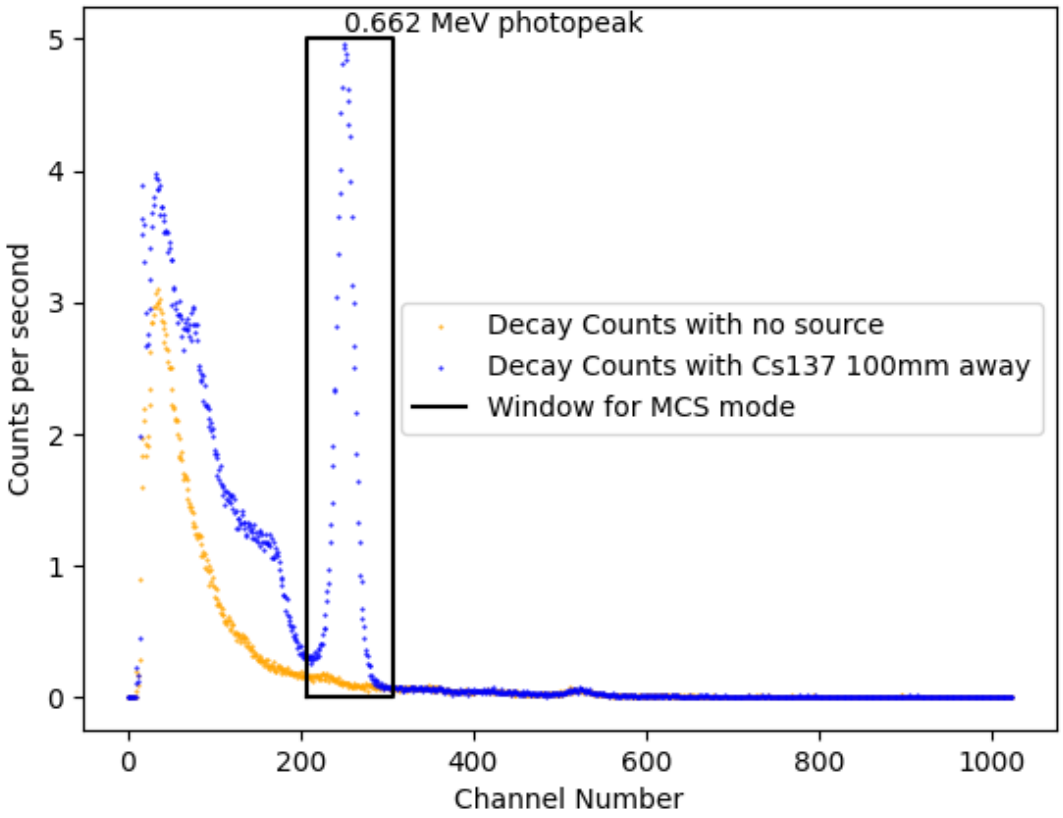


Figure 1: Time scaled spectrum of source 100mm away and background

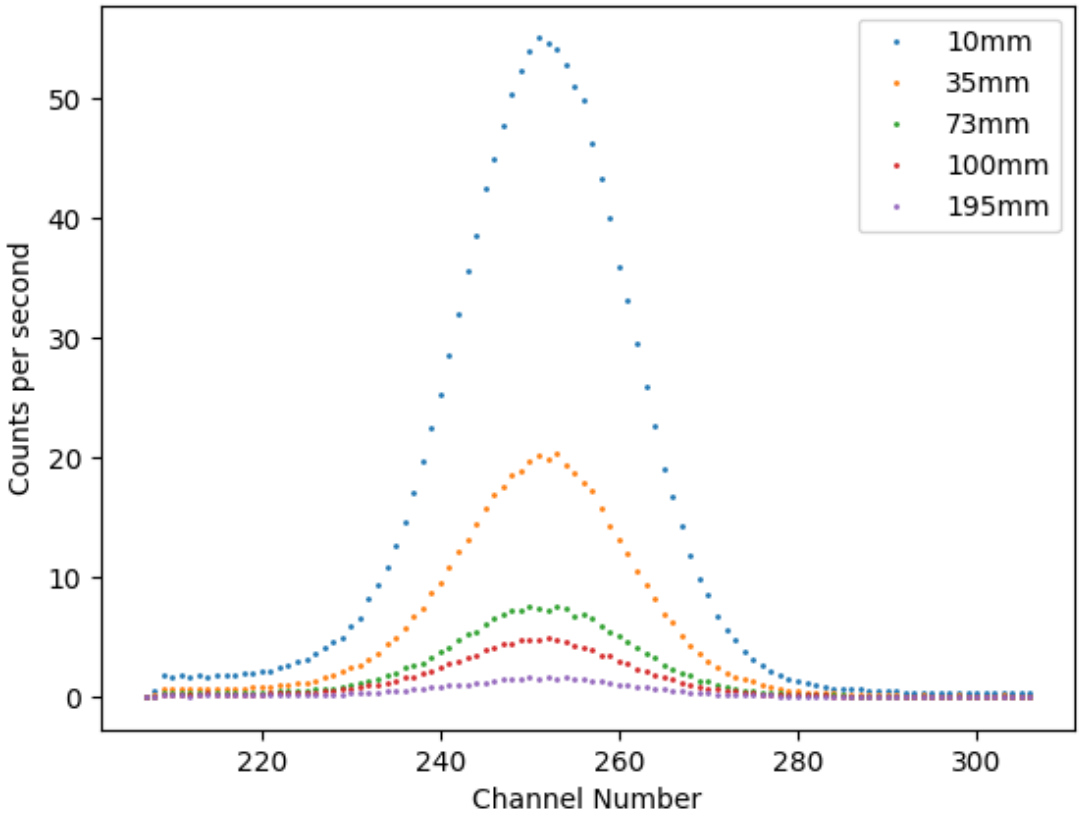


Figure 2: Time scaled spectrum of source at set distances

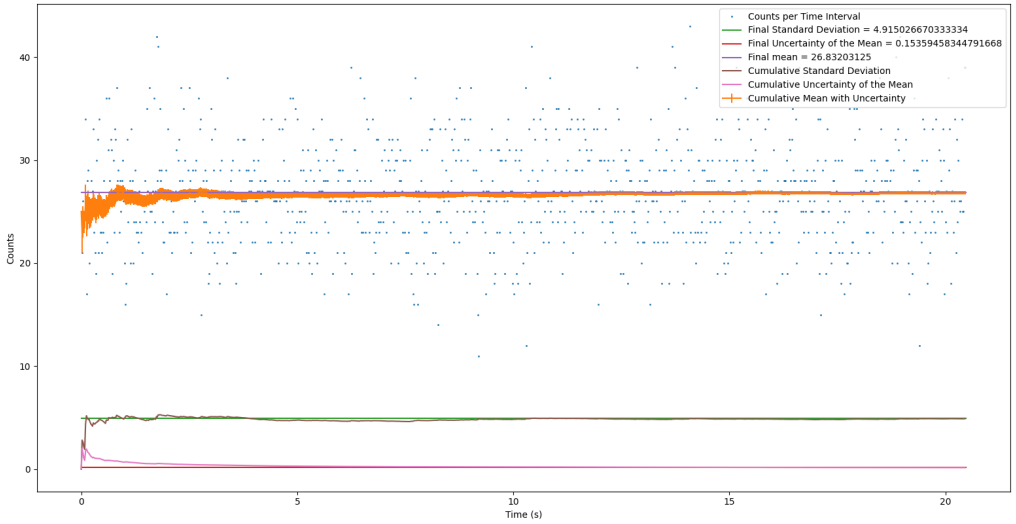


Figure 3: Cumulative mean of source 10mm away with 20ms time intervals

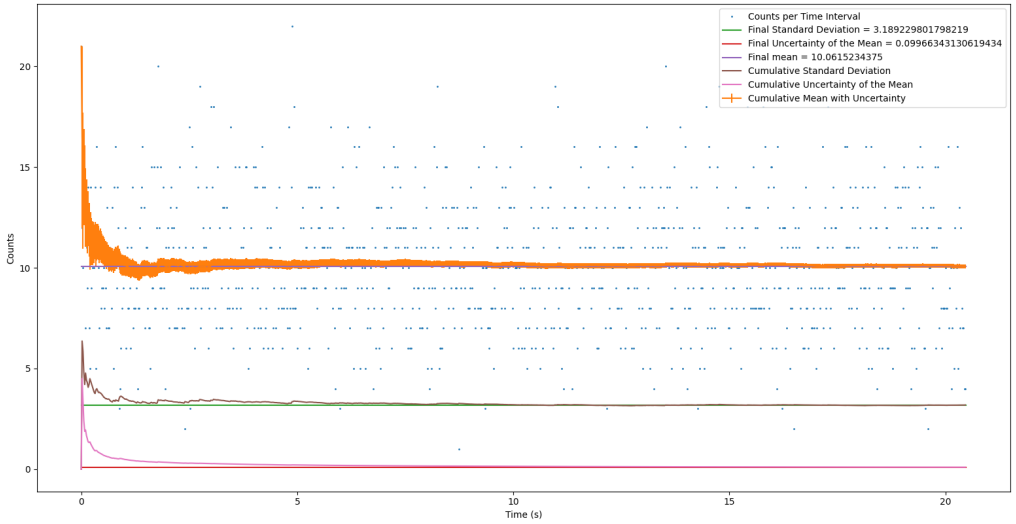


Figure 4: Cumulative mean of source 35mm away with 20ms time intervals

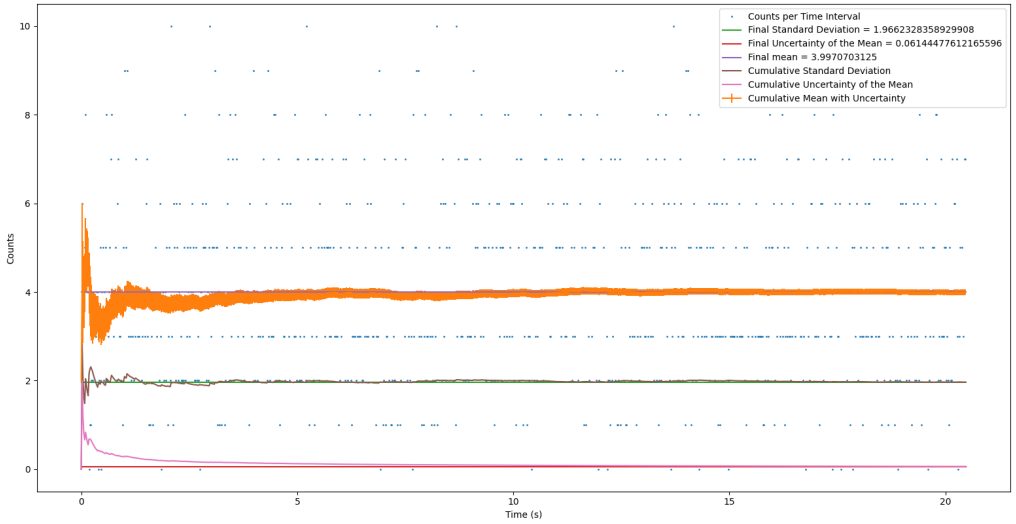


Figure 5: Cumulative mean of source 73mm away with 20ms time intervals

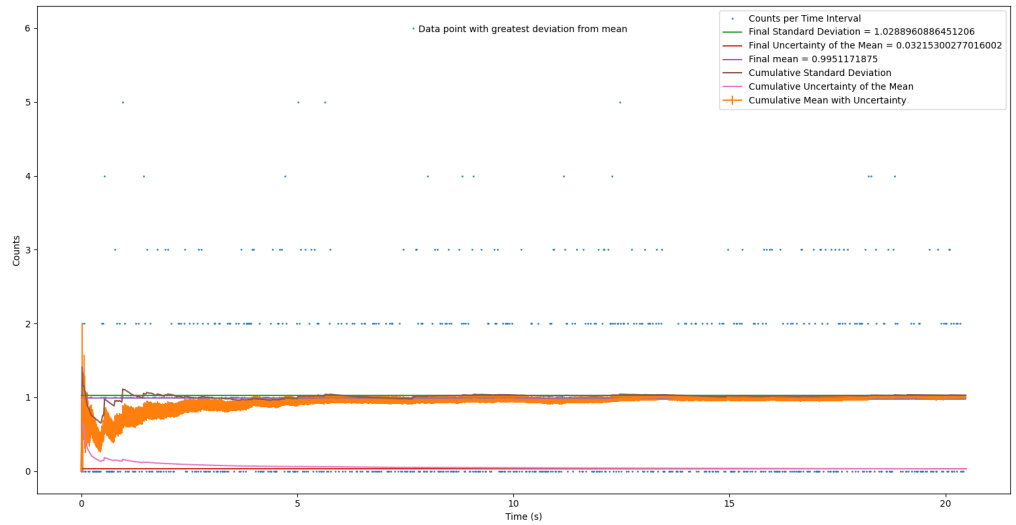


Figure 6: Cumulative mean of source 195mm away with 20ms time intervals

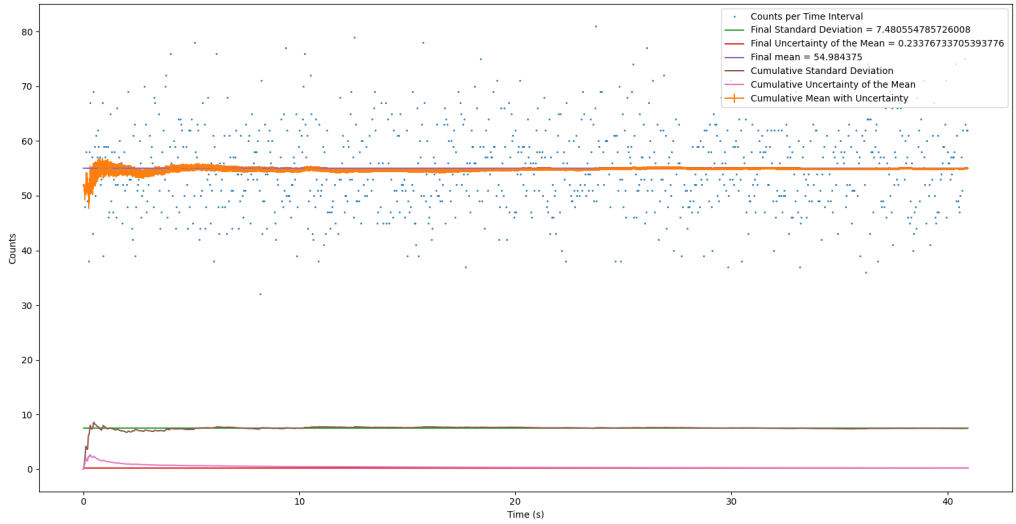


Figure 7: Cumulative mean of source 10mm away with 40ms time intervals

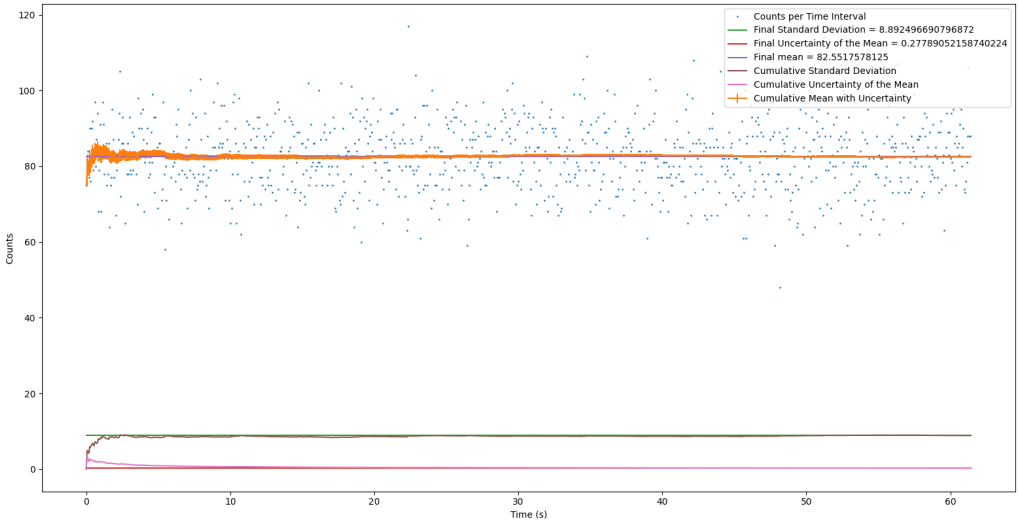


Figure 8: Cumulative mean of source 10mm away with 60ms time intervals

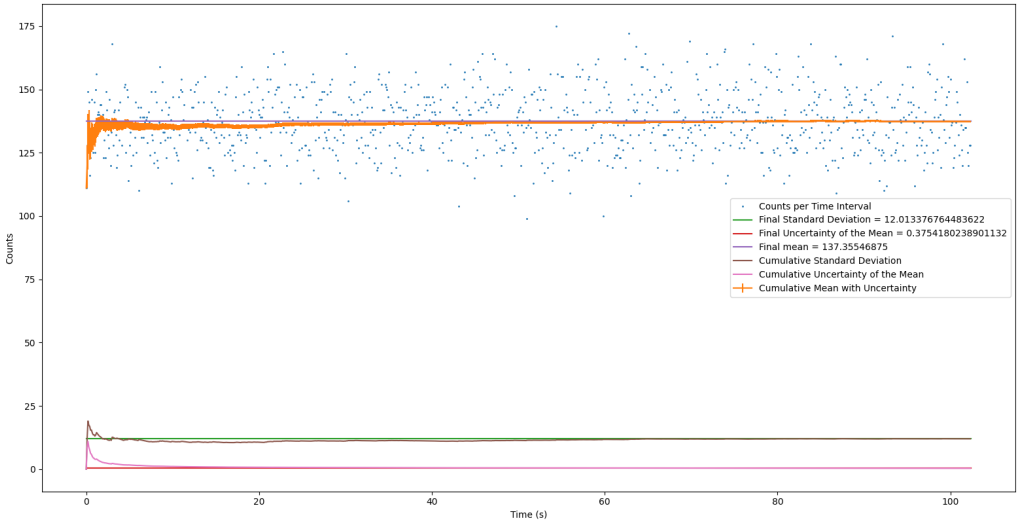


Figure 9: Cumulative mean of source 10mm away with 100ms time intervals

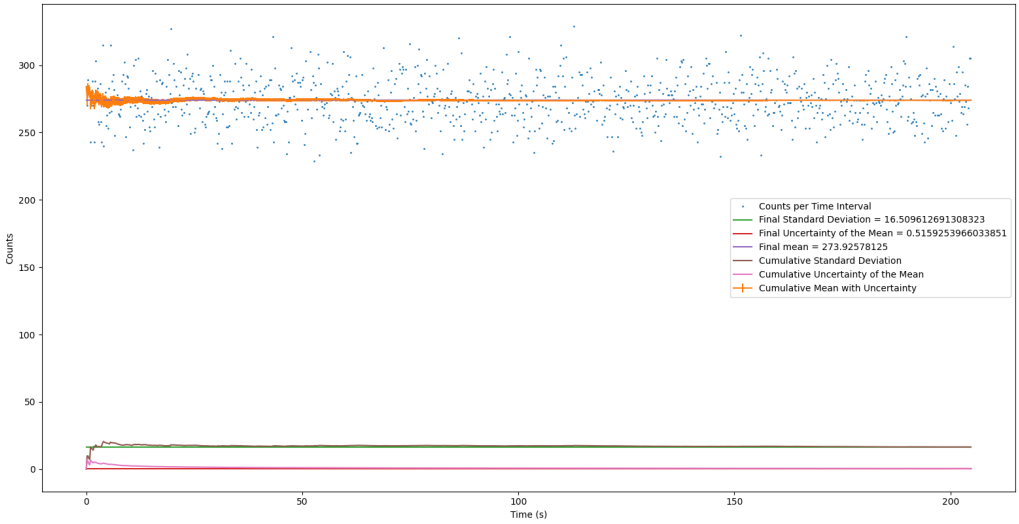


Figure 10: Cumulative mean of source 10mm away with 200ms time intervals

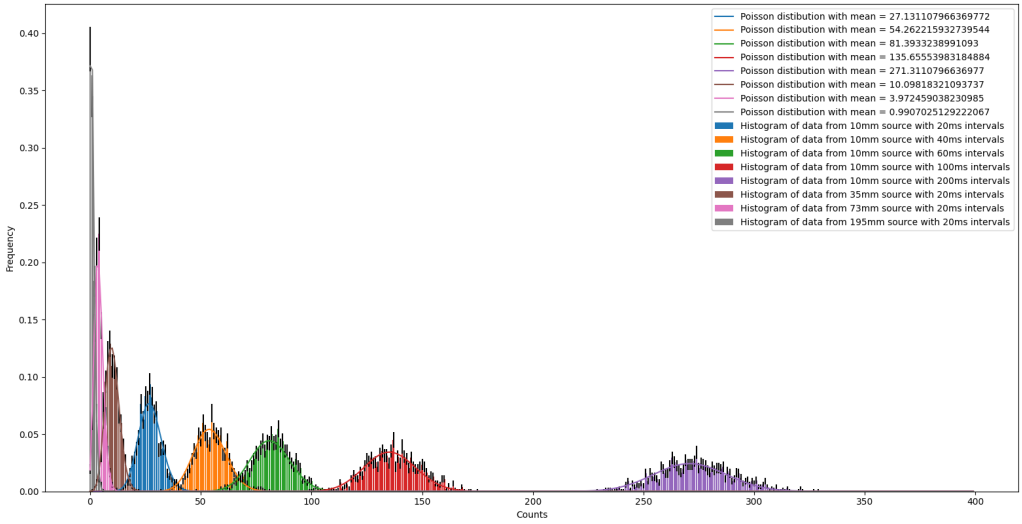


Figure 11: Histograms and Poisson Distribution fittings of all datasets

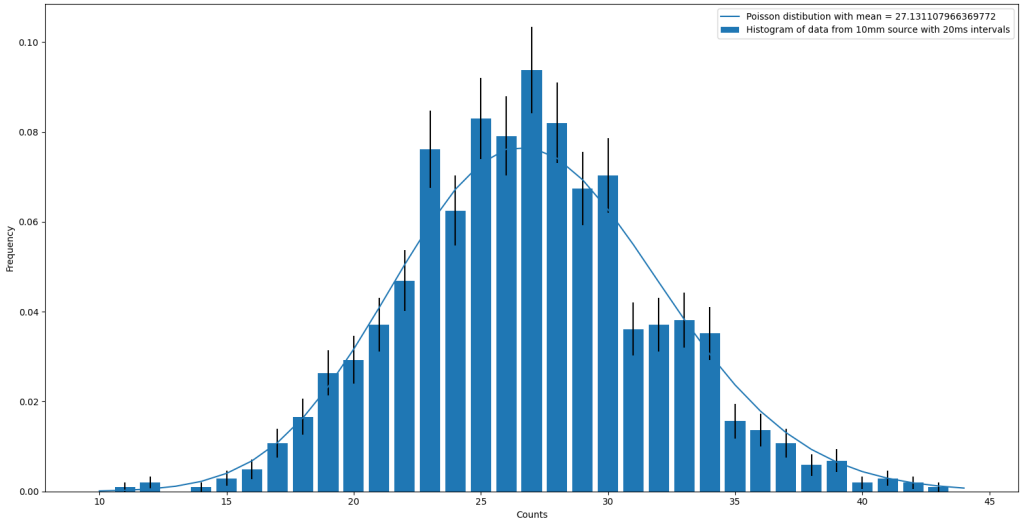


Figure 12: Histogram and Poisson Distribution fitting data from source 10mm away with 20ms time intervals

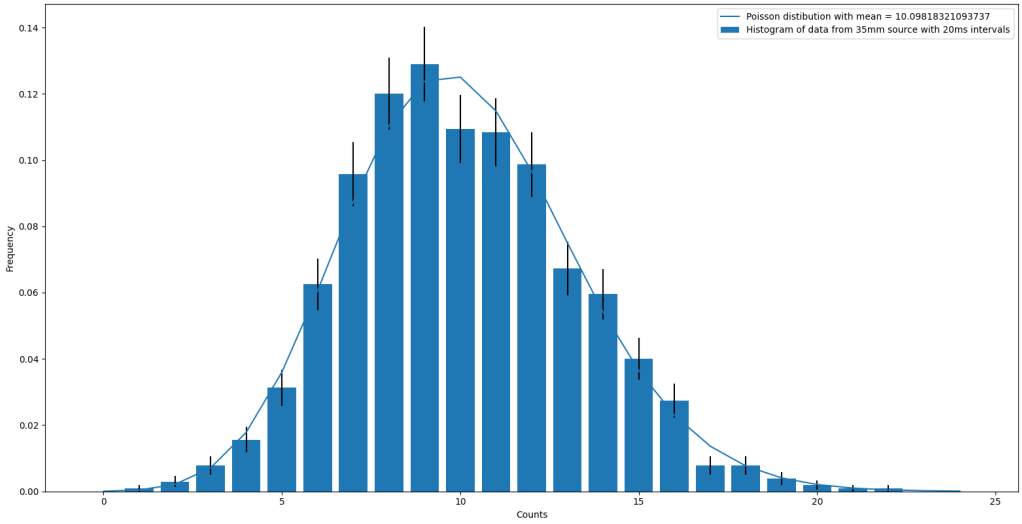


Figure 13: Histogram and Poisson Distribution fitting data from source 35mm away with 20ms time intervals

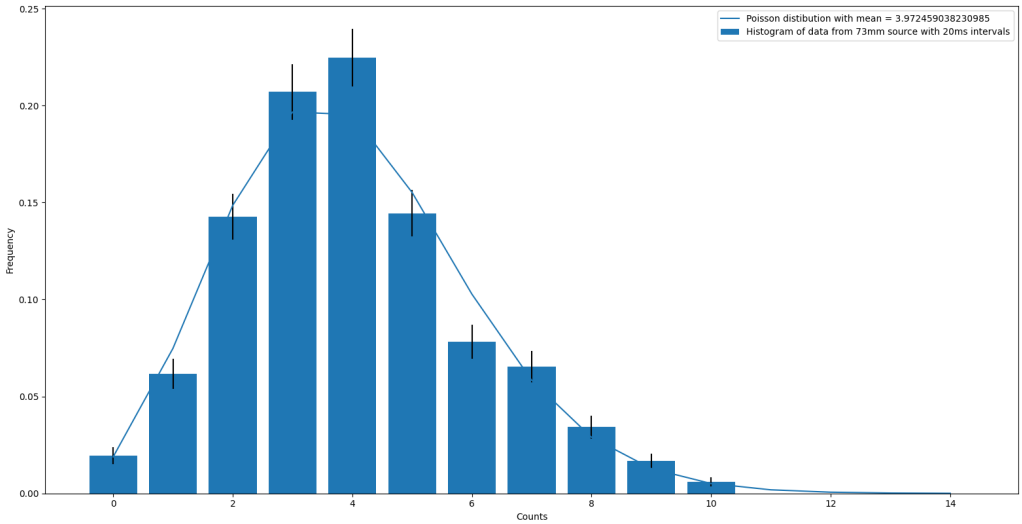


Figure 14: Histogram and Poisson Distribution fitting data from source 73mm away with 20ms time intervals

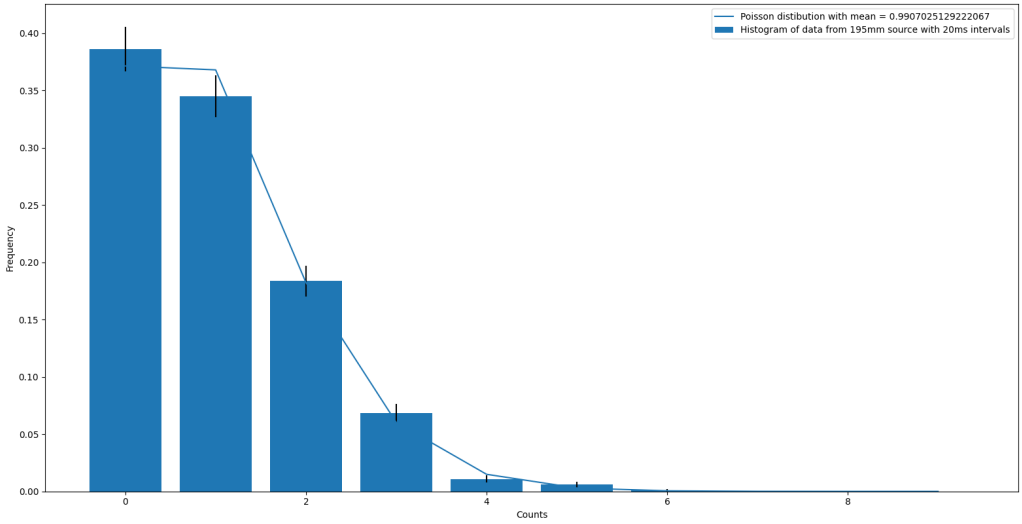


Figure 15: Histogram and Poisson Distribution fitting data from source 195mm away with 20ms time intervals

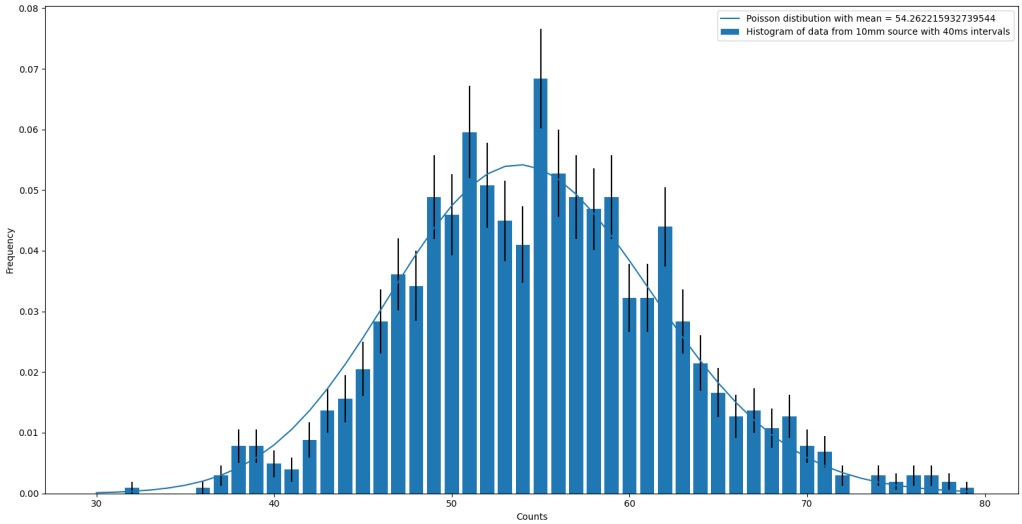


Figure 16: Histogram and Poisson Distribution fitting data from source 10mm away with 40ms time intervals

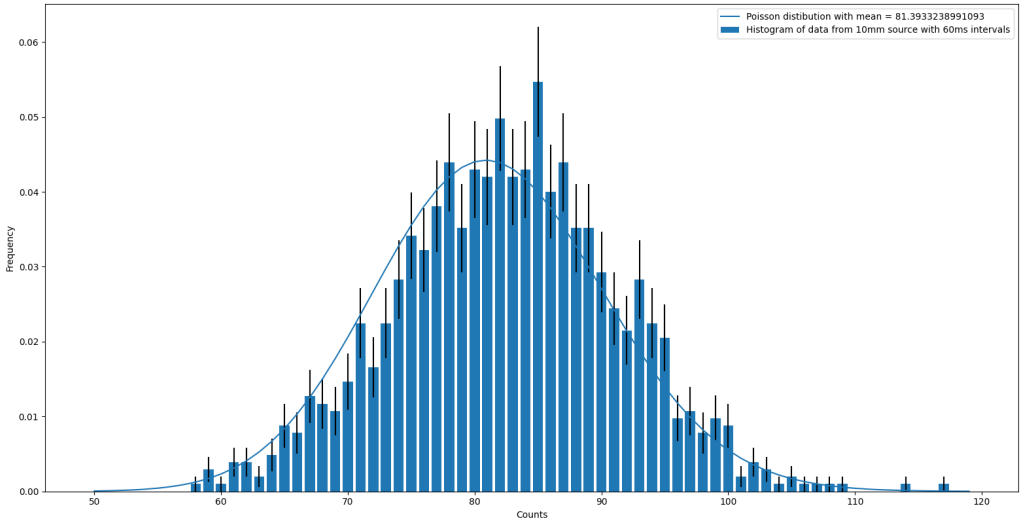


Figure 17: Histogram and Poisson Distribution fitting data from source 10mm away with 60ms time intervals

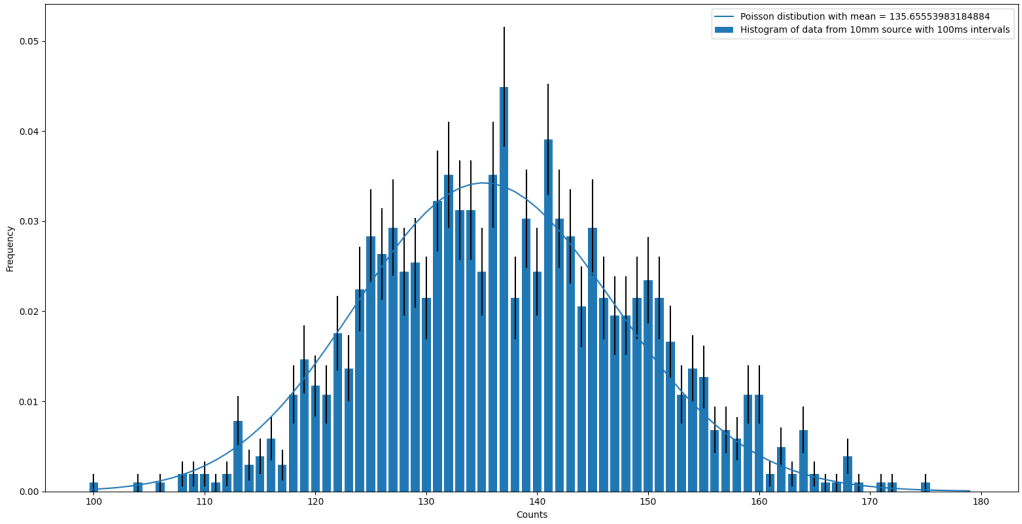


Figure 18: Histogram and Poisson Distribution fitting data from source 10mm away with 100ms time intervals

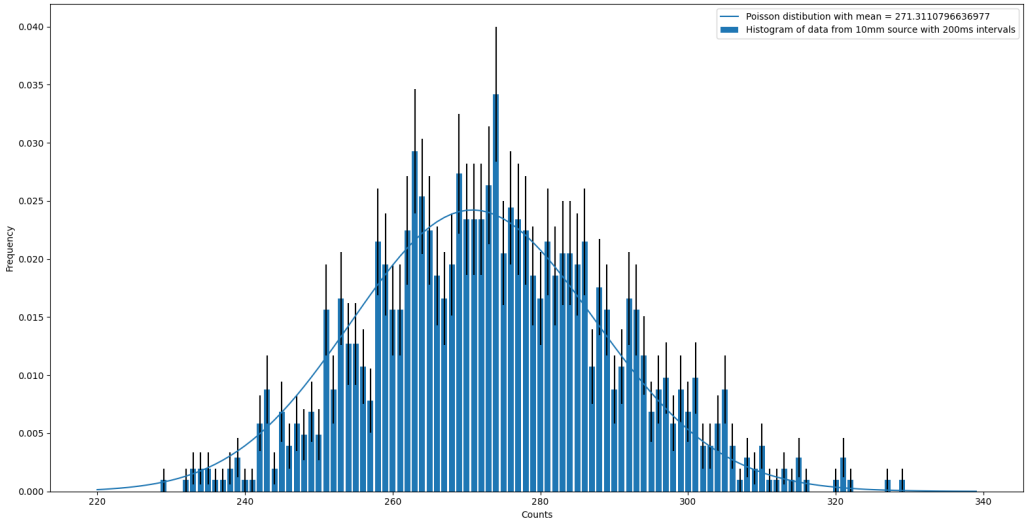


Figure 19: Histogram and Poisson Distribution fitting data from source 10mm away with 200ms time intervals