AGING EFFECTS ON MONA AND LISA

NATHANIEL LASHLEY-COLTHIRST[1], MICHAEL THOENNESSEN[2], JAMES BROWN[3], PAUL GUEYE[4]

[1]PHYSICS AND ASTRONOMY DEPARTMENT, HOWARD UNIVERSITY, WASHINGTON, DC 20059

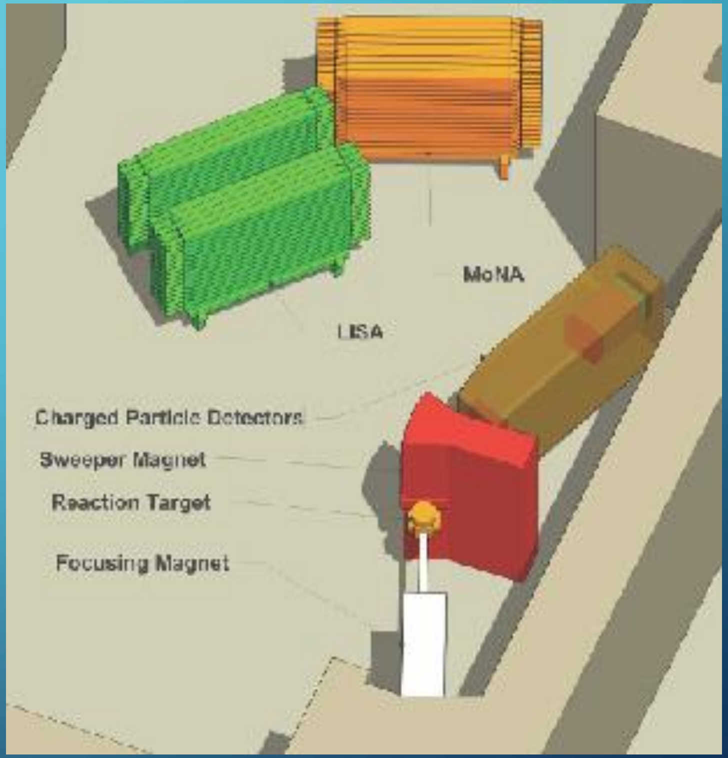
[2]PHYSICS AND ASTRONOMY DEPARTMENT, MICHIGAN STATE UNIVERSITY, EAST LANSING, MI 48223

[3]PHYSICS DEPARTMENT, WABASH UNIVERSITY, CRAWFORDSVILLE, IN 47933

[4]PHYSICS DEPARTMENT, HAMPTON UNIVERSITY, HAMPTON, VA 23668

NUCLEAR PHYSICS EXPERIMENTS AT NSCL

- The National Superconducting Cyclotron Laboratory (NSCl) located at Michigan State University (MSU) houses two neutron detector array systems, the Modular Neutron Array and Large Multi-Institutional Scintillator Array (MoNA-LISA).
- They are used to detect neutrons in order to reconstruct decay energy.



N2 vault at NSCL

BACKGROUND

- MoNA and LISA are comprised of scintillator panels and Photomultiplier Tubes (PMTs).
- The scintillator bars will produce light when a particle passes through it.
- This light is lead to the PMTs which main function is to convert the incoming light into an electrical signal through the use of the photoelectric effect.

MoNA and LISA detectors

MoNA dissembled for reconfiguration in June 2015

RESEARCH QUESTION

- What are the aging effects on the MoNA and LISA detectors at NSCL?

MoNA

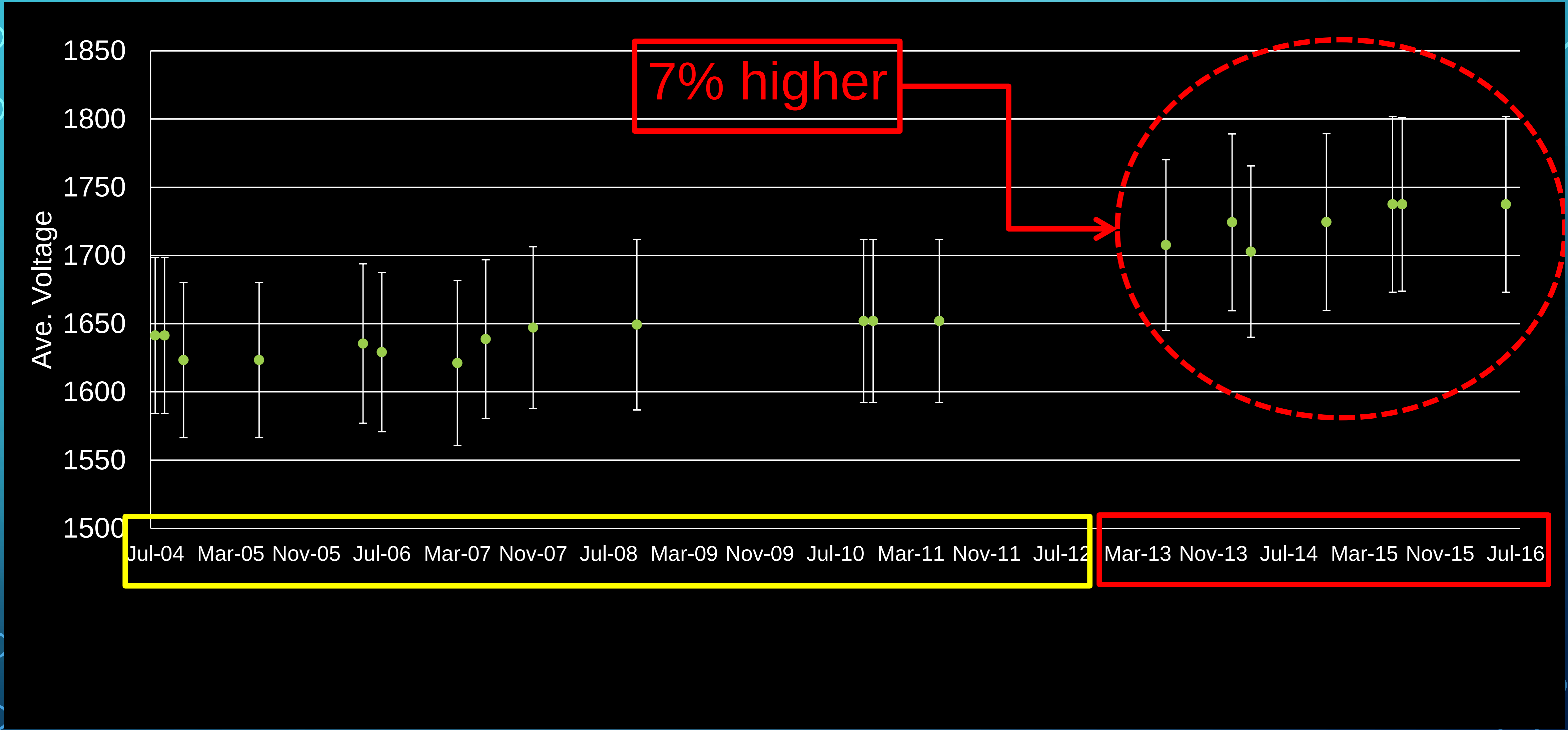
METHODS

- The methods used to determine aging effects on MoNA-LISA were the analysis of the attenuation lengths and mean gain voltages.
  - Mean gain voltage:
    - The average applied voltage and gain of the PMTs.
    - Time evolution of cosmic peak.
  - Attenuation lengths: The length in which the light intensity falls off by a factor of e.

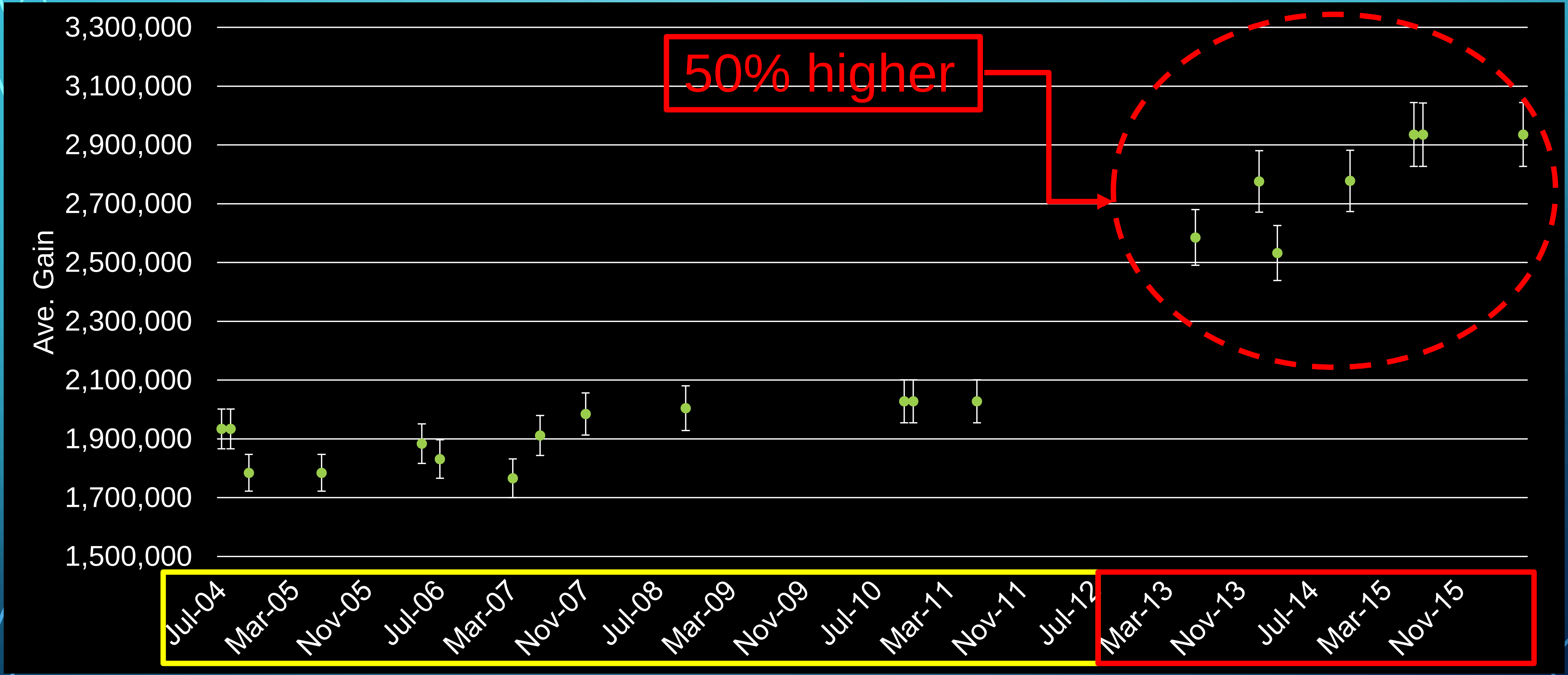
HIGH VOLTAGE GAIN STUDY

- The mean voltage study used the voltage settings stored in the high voltage (HV) files from the selected set of experiments.
- These values were imported and analyzed in Microsoft Excel.
- The mean was calculated and plotted as a function of time.
- The mean voltage was used to calculate the gain of the PMTs.
- The equation for the gain was developed from a log-log chart provided by the manufacturer data sheet.
- $G = 5.3946 \times 10^{-18} \times V^{7.326}$

VOLTAGE RESULTS



GAIN RESULTS



ATTENUATION LENGTH STUDY

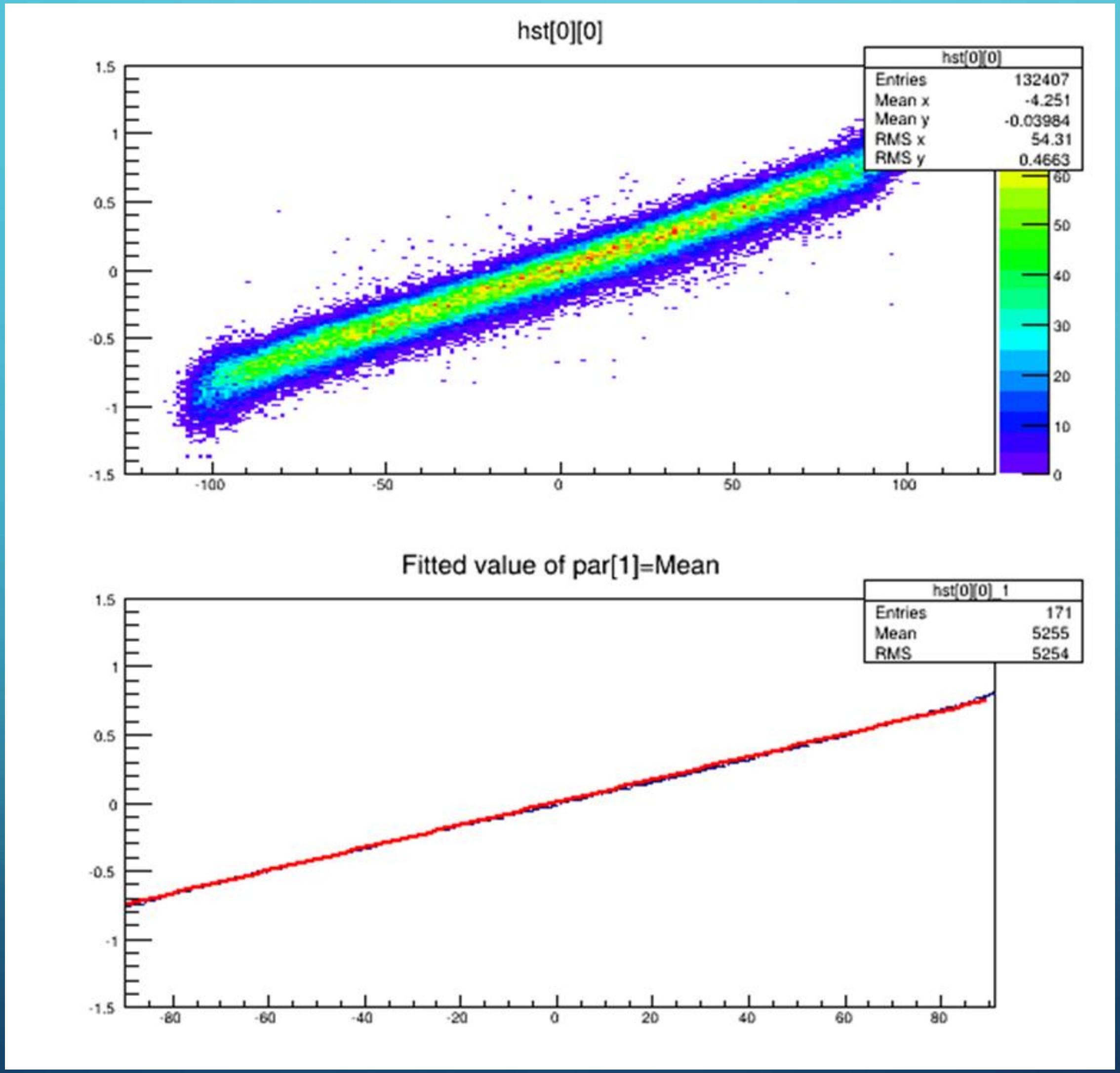
The attenuation lengths study was performed using the Root analysis software and consisted of eight steps:

- Step 1: Load the root file containing calibrated data from a cosmic run in the Root environment.
- Step 2: Create arrays for the charge collected on the left and right PMTs to store the data.
- Step 3: Fill the array with the data from the root file.
- Step 4: Create 2D histograms for each bar showing the ratio of the log of the charge from the left and right ends of the scintillator bars as a function of the position within the bar.

ATTENUATION LENGTH STUDY

- Step 5: Applied vertical slices to the histograms creating a projections onto the x-axis, which were then fitted with straight lines.
- Step 6: Record the slope (A) and intercept (B) of the fitted line for each bar.
- Step 7: Calculate the average slope ($\bar{A}$).
- Step 8: Calculate the attenuation lengths (λ) by taking two divided by the average slope and the associated error from the attenuation length multiplied by the ratio of the error in the average slope to the average slope.

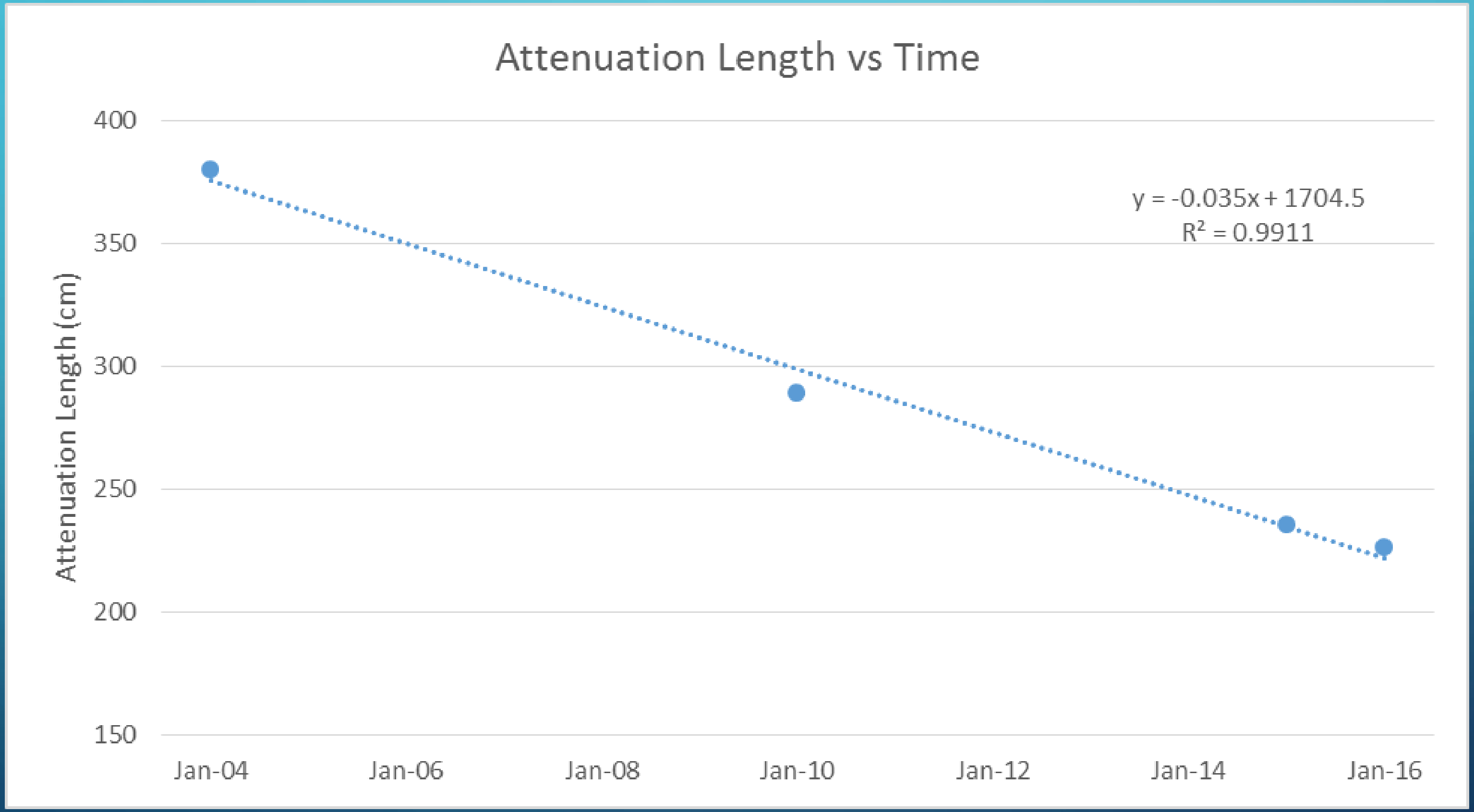
EXAMPLE OUTPUT HISTOGRAM



ATTENUATION LENGTH RESULTS

- Results for the attenuation lengths show a decrease over time.
- The original attenuation length at the time the scintillator bars were manufactured was given to be 3.8 m.
- The experimentally calculated attenuation lengths for 2010, 2015 and 2016 were 2.9 m, 2.32 m and 2.26 m, respectively. This shows an average decrease of 1.54 m, a 40.52% decrease in the attenuation length.

ATTENUATION LENGTH RESULTS



DISCUSSION

- The increase in the average voltage, and in turn the gain, is a potential sign of aging.
- The significance of the voltage increase may have been tied to a need to adjust the reconstructed location of the signal distribution.
- This was analyzed by studying cosmic data and extracting the locations of the cosmic peaks then adjusting the background noise also known as the pedestal.

DISCUSSION

- Data shows the peak moving between 2008 and 2016 by about 10%.
- This correlates well with the observed change in the average high voltage, where an increase of about 7% after 2012 was observed.
- Therefore, the intentional change of the voltage settings needs to be further studied from the pedestals.

DISCUSSION

- MoNA has been the focus of the study currently as it is the oldest of the two neutron detector array: it has been in service since 2004, while LISA has only been in service since 2011.
- Replacing MoNA may become necessary as the attenuation length approaches 2 meters as the bars in MoNA are 2 meters long and would lead to a decrease in its efficiency to detect neutrons.

SOCIAL IMPLICATIONS

- Knowing the aging properties of these detectors help correct experimental data.
- Accuracy in knowledge being added to the scientific body.
- Graduate students use these detectors in experiments for their thesis.
- These detectors are used in various other fields and applications.

➢ i.e. Medical field with MRI and CAT scans.

CONCLUSION AND FUTURE WORK

- The increasing trend in the evolution of the voltage and gain, is a strong indication of signs of aging of the arrays or possibly signs that the electronics involved in these experiments need to be studied.
- The attenuation lengths of the MoNA bars have decreased drastically and may warrant replacing MoNA in future years.
- For the duration of MoNA-LISA the attenuation length will likely have to be periodically studied to track when it may reach the 2 meter threshold and a replacement becomes necessary.

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- Nathaniel Lashley-Colthirst
- Nathaniel.lashley@gmail.com