Can One Build A Global Neutron Surface Spectrum Map?

ROBERT VALDILLEZ

DR. HANS PIETER MUMM

Outline

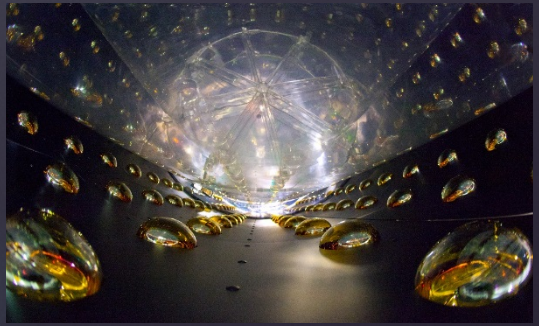
- Background
- Analysis of Previously Gathered Data
- Analytical Function to Predict Neutron Spectra
- Data Collection
- Next Steps
- Conclusion

Outline

- Background
- Analysis of Previously Gathered Data
- Analytical Function to Predict Neutron Spectra
- Data Collection
- Next Steps
- Conclusion

What is a surface neutron spectrum map and why is it useful?

- A tool to determine the neutron background anywhere, anytime
- Usefulness
  - Searches for illicit special nuclear material
  - Radiation Monitoring
  - Fundamental Nuclear Physics Research



Neutron Spectrum

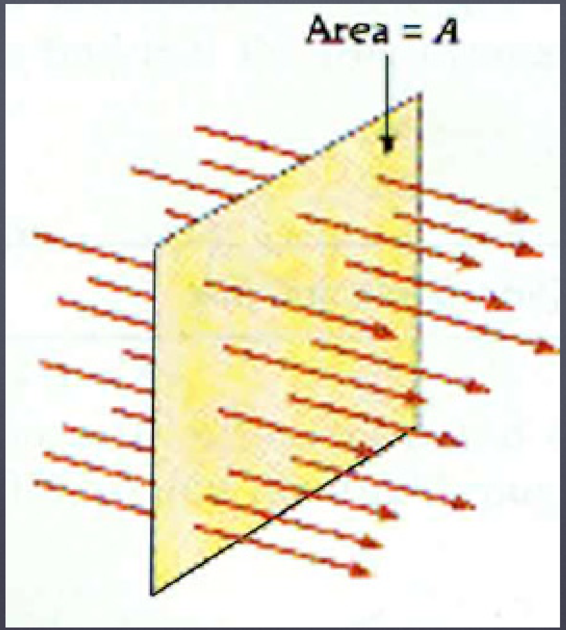
Neutron energy	Energy range
0.0–0.025 eV	Cold neutrons
0.025 eV	Thermal neutrons
0.025–1eV	Epithermal Neutrons
1–10 eV	Slow neutrons
10–300 eV	Resonance neutrons
300 eV–1 MeV	Intermediate neutrons
1–20 MeV	Fast neutrons
> 20 MeV	Ultrafast neutrons

Neutron Spectrum

Neutron energy	Energy range
0.0–0.025 eV	Cold neutrons
0.025 eV	Thermal neutrons
0.025–1eV	Epithermal Neutrons
1–10 eV	Slow neutrons
10–300 eV	Resonance neutrons
300 eV–1 MeV	Intermediate neutrons
1–20 MeV	Fast neutrons
> 20 MeV	Ultrafast neutrons

Neutron Flux

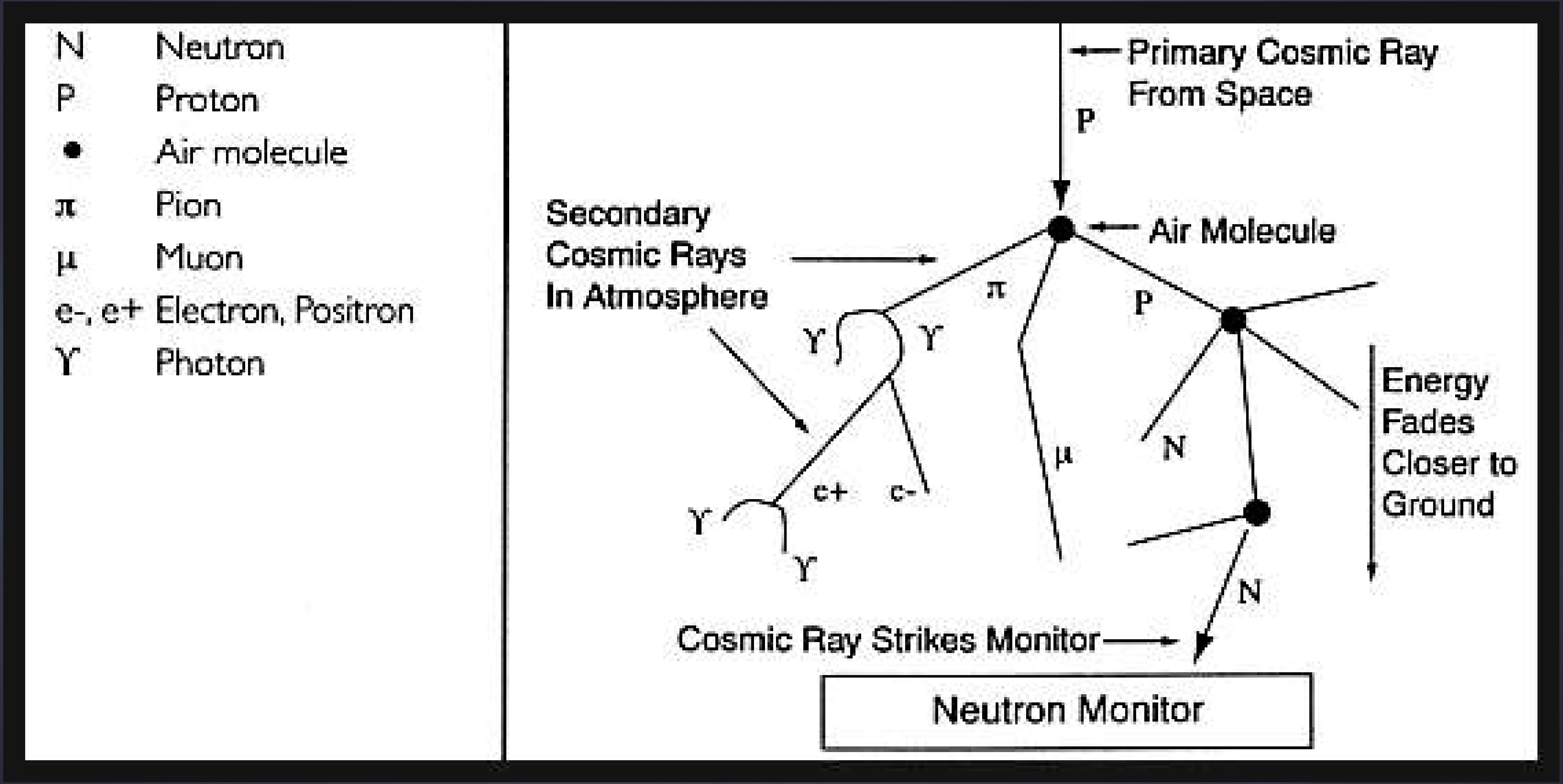
- Number of neutrons passing through a given area in a specified amount of time.
- Usually measured in neutrons per cm^2 per second.



Sources of Neutrons

- Cosmic Rays
  - Galactic Cosmic Rays
    - Supernovae
    - Quasars
    - Gamma-ray bursts
  - Solar Energetic Particles
- Terrestrial
  - Natural Radioactivity of Spontaneously Fissionable Elements in the Earth’s Crust
  - NIST

How cosmic rays produce neutrons



What affects neutron flux?

- Dominant Effects
  - Barometric Pressure
  - Changes in Cosmic Ray Flux
  - Soil Moisture Content
- Other Effects
  - The Ship-Effect
  - Column Water Vapor
  - Humidity

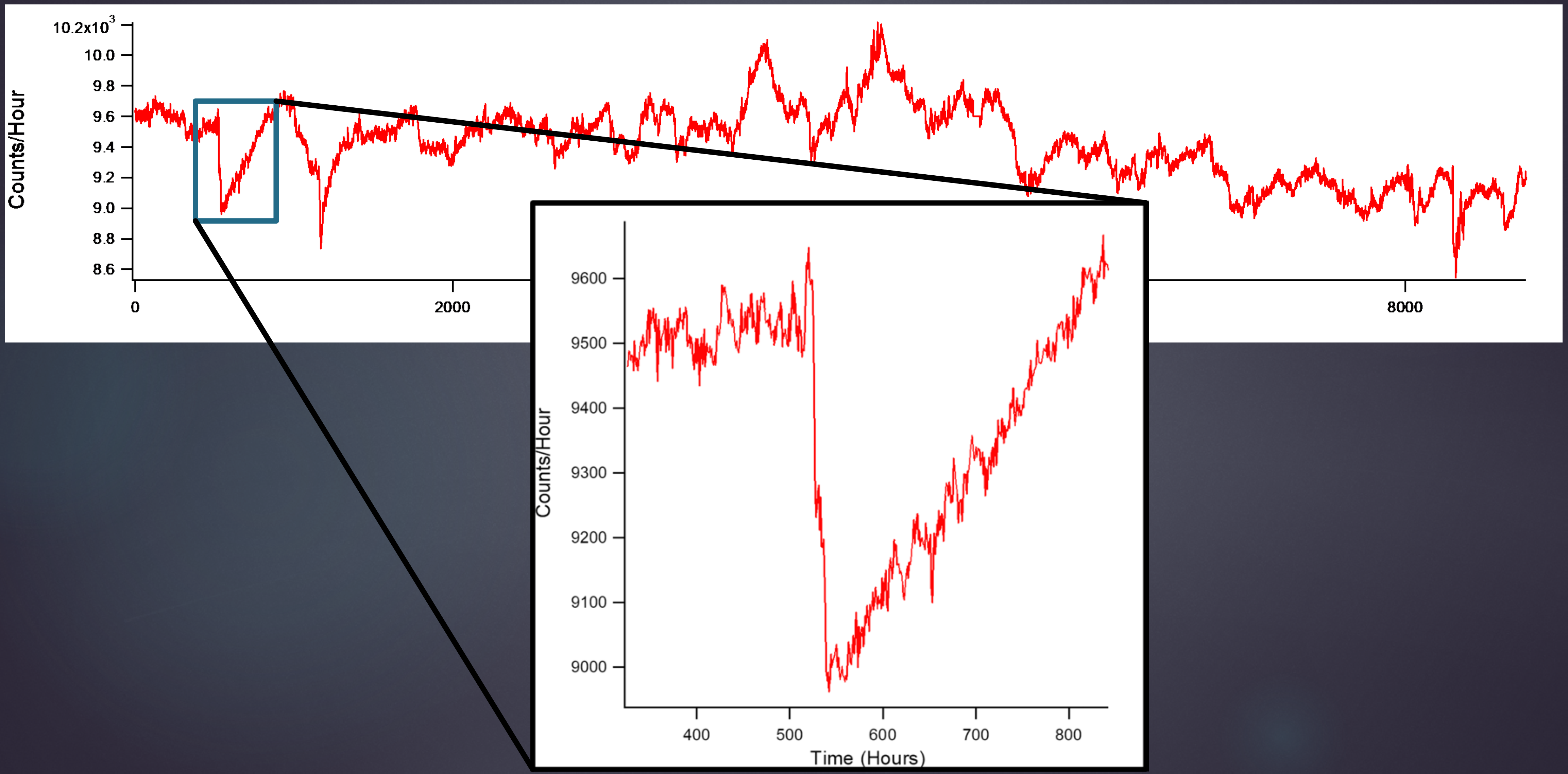
Outline

- Background
- Analysis of Previously Gathered Data
- Analytical Function to Predict Neutron Spectra
- Data Collection
- Next Steps
- Conclusion

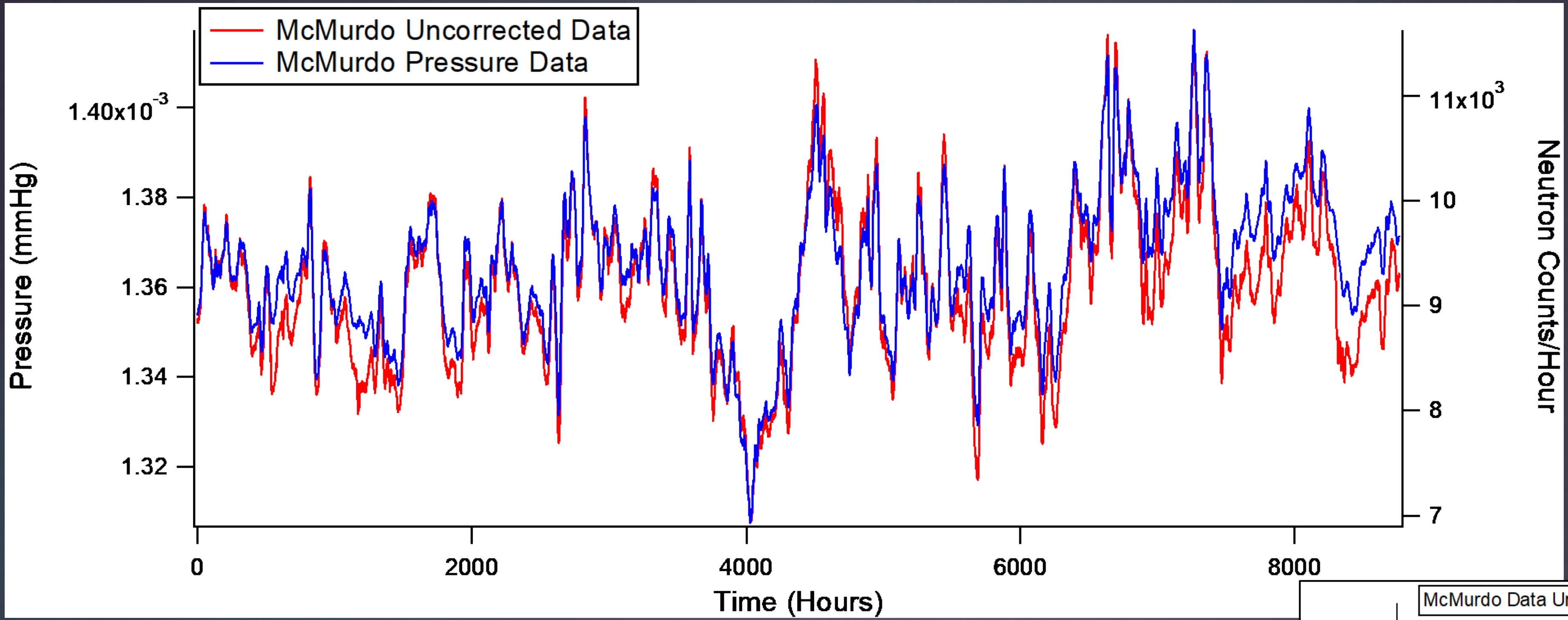
University of Delaware
Bartol Research Institute
Neutron Monitor Program

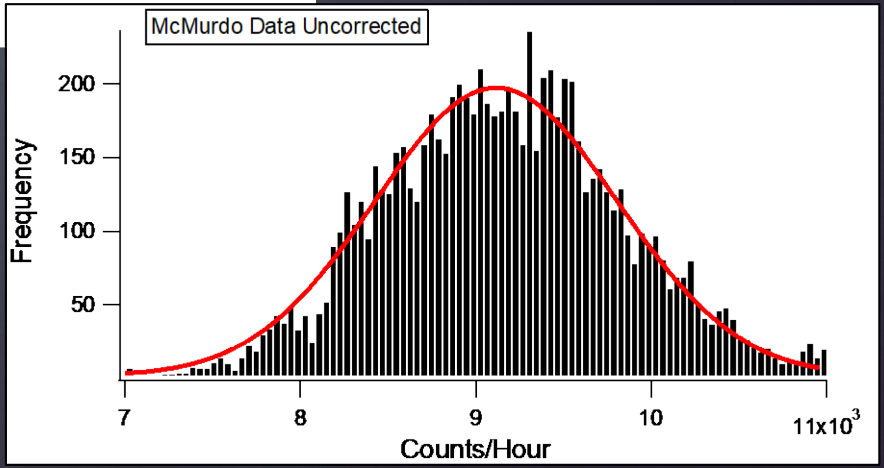
- Neutron Flux data from four sites around the world
  - Newark, Delaware
  - McMurdo, Antarctica
  - South Pole, Antarctica
  - Thule, Greenland
- Uncorrected Data
- Corrected Data
- Pressure Data

One Year of Data from Single Site

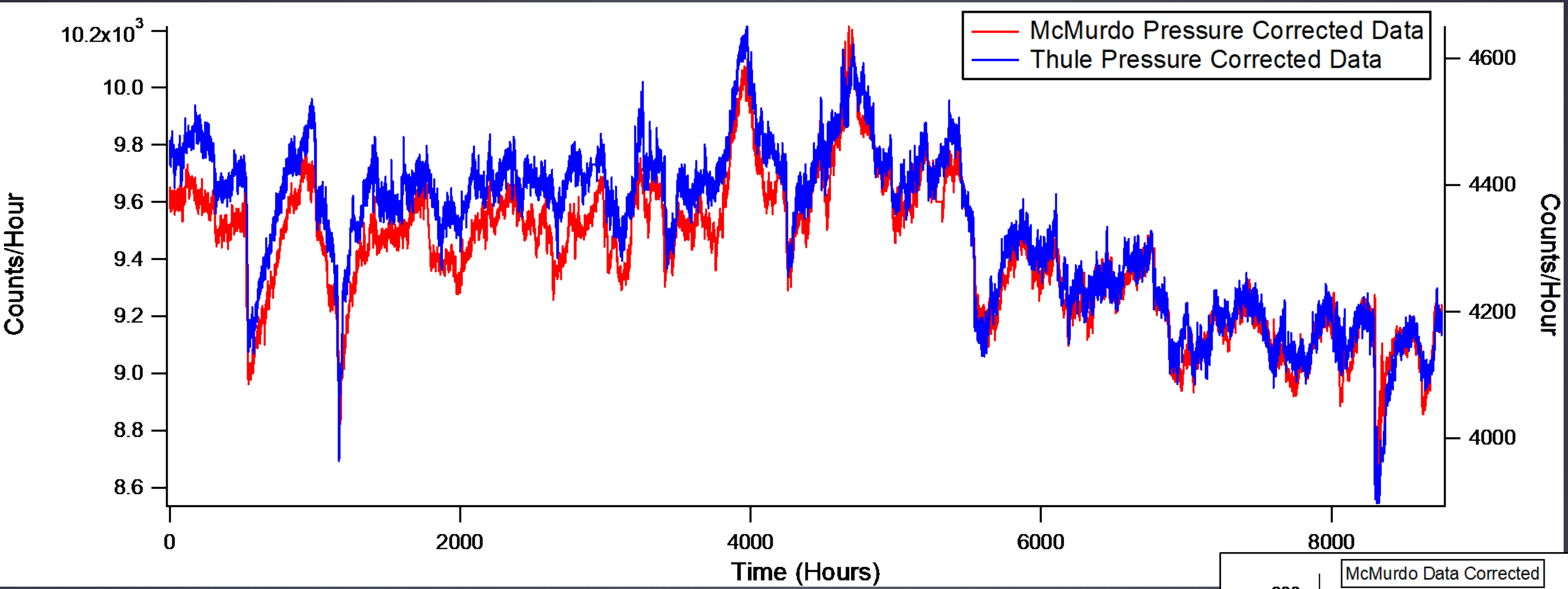


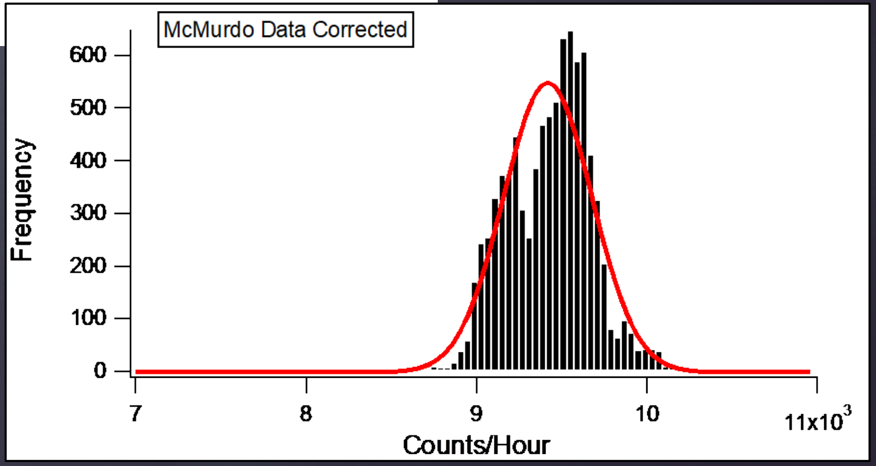
Pressure Effect About 25%



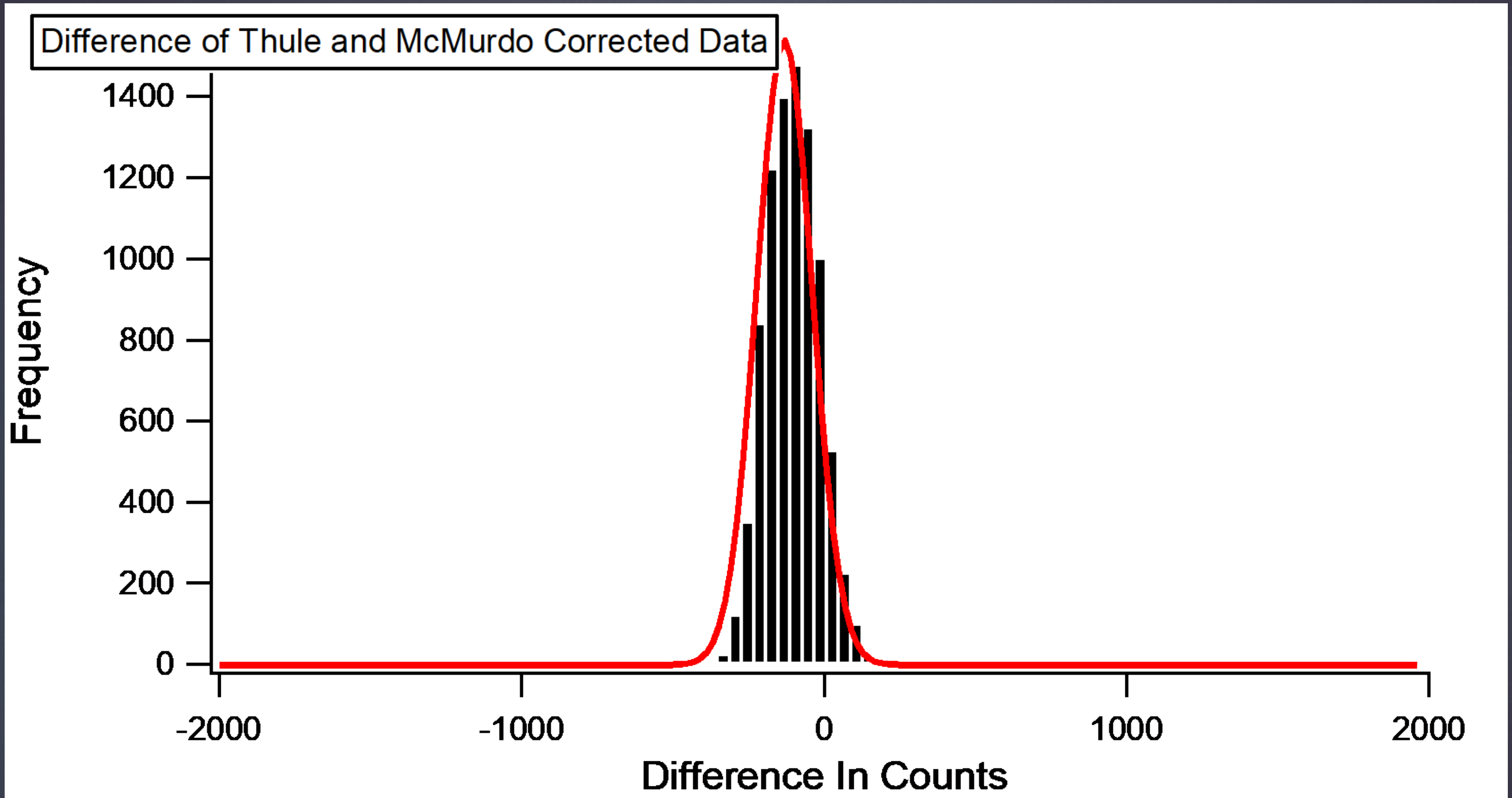


Solar Effect About 6%





All Other Effects About 1.5%



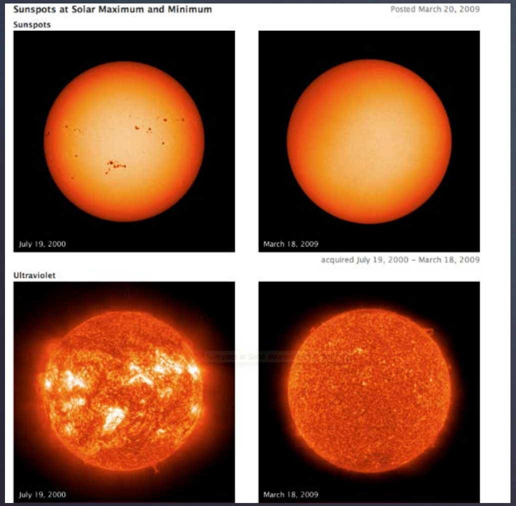
Outline

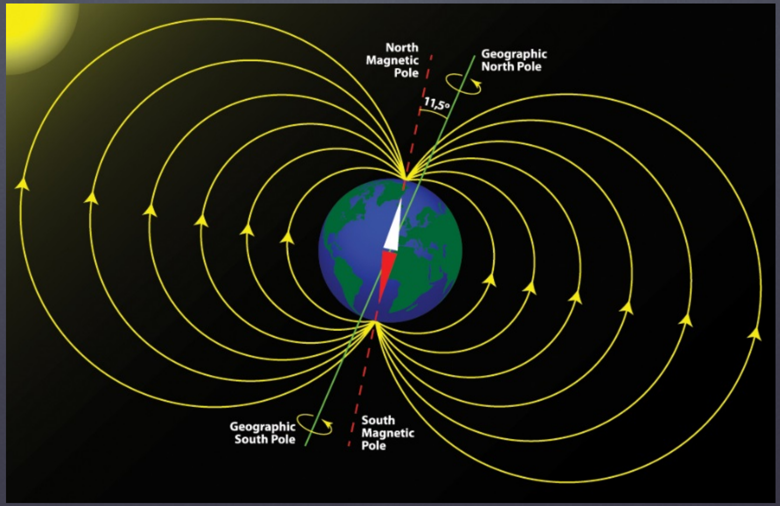
- Background
- Analysis of Previously Gathered Data
- Analytical Function to Predict Neutron Spectra
- Data Collection
- Next Steps
- Conclusion

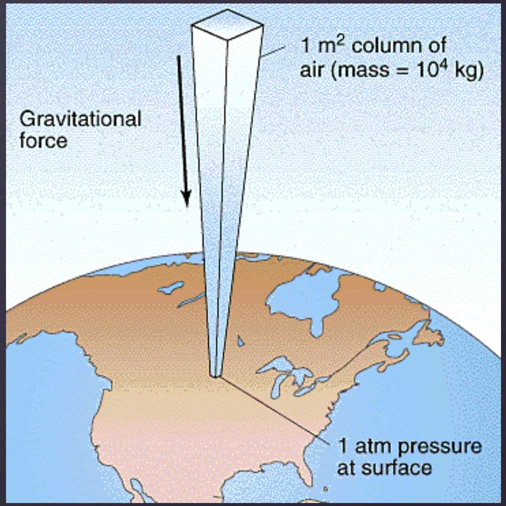
Input Variables

- Solar Modulation Potential (Sunspot Number)
  - Influences energy spectrum of primary cosmic rays
- Vertical Cut-off Rigidity

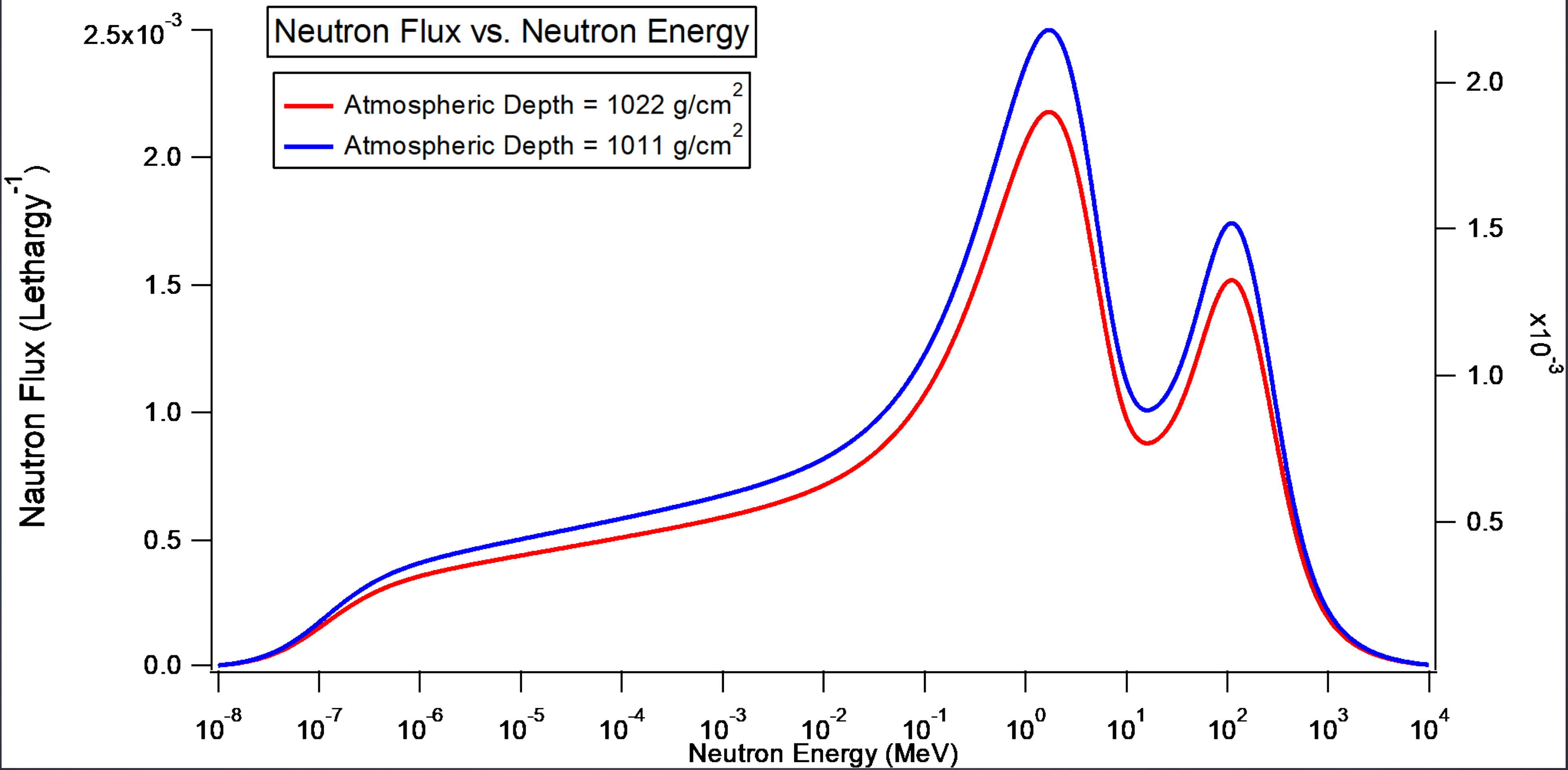
  A measure of the shielding provided by the earth’s magnetic field
- Atmospheric Depth (Barometric Pressure)







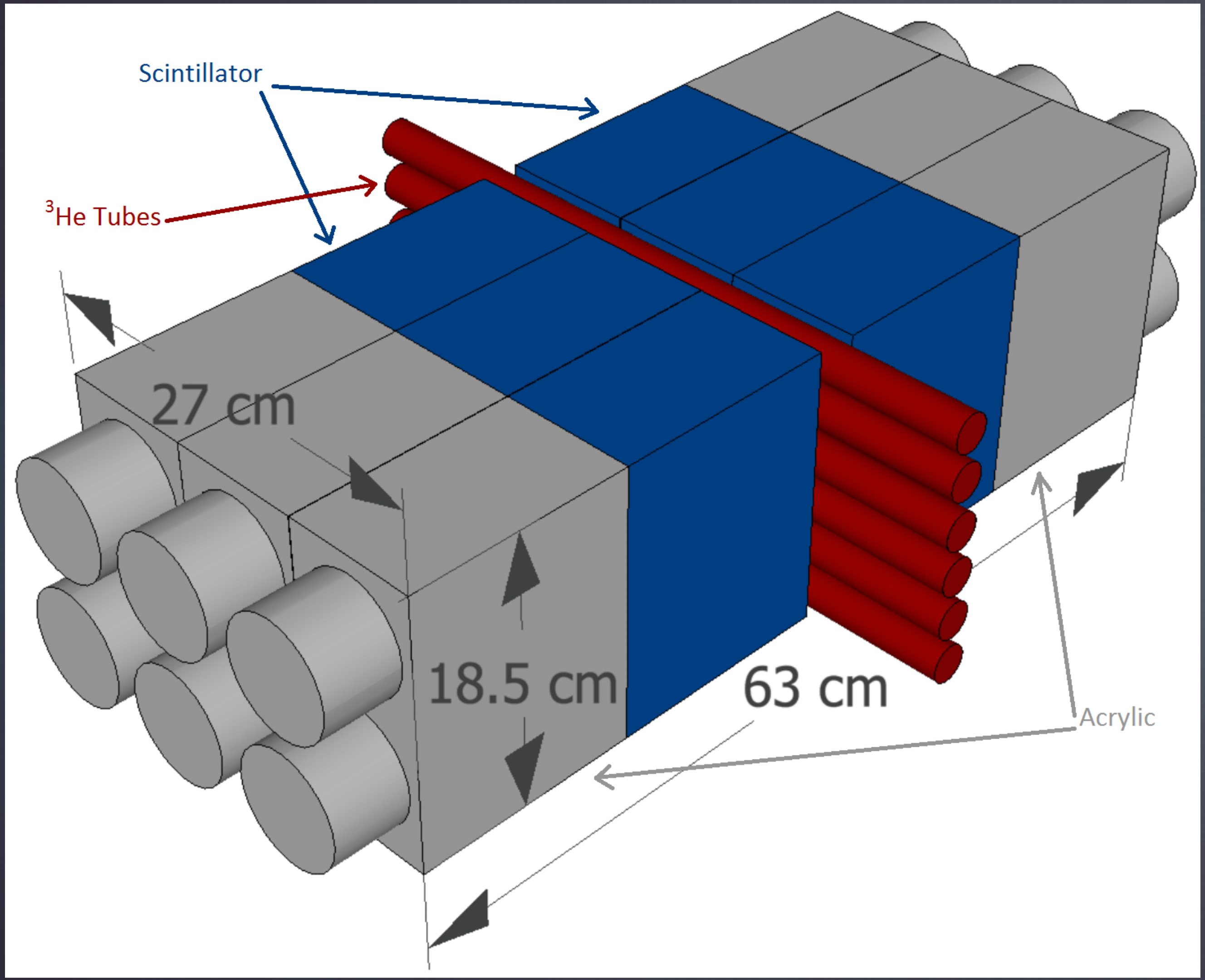
Spectrum at Two Pressures Recorded During One Weekend[1]

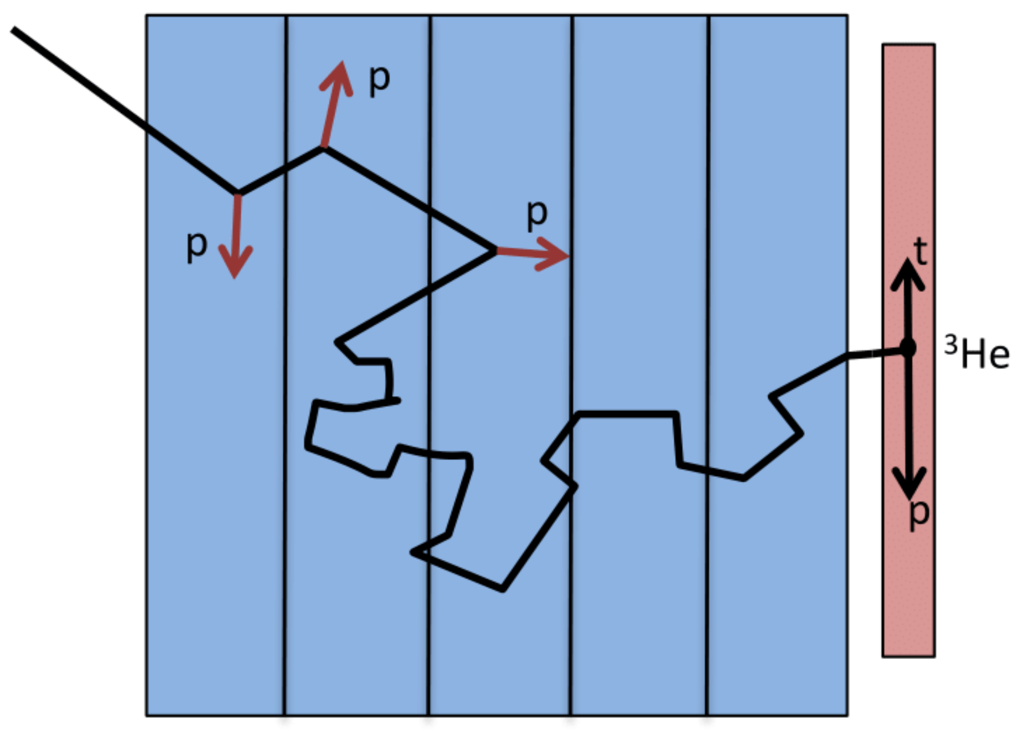


Outline

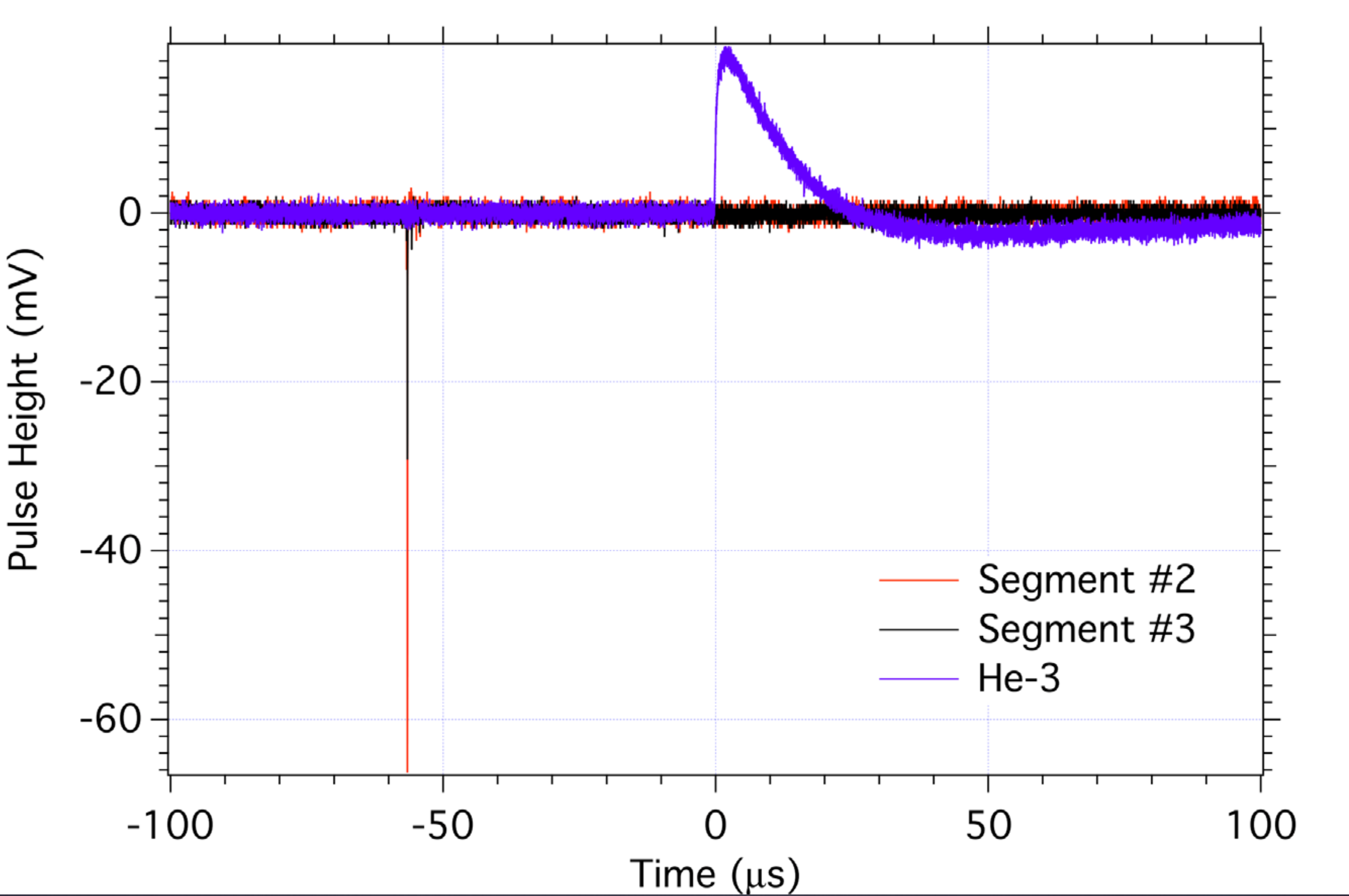
- Background
- Analysis of Previously Gathered Data
- Analytical Function to Predict Neutron Spectra
- Data Collection
- Next Steps
- Conclusion

FaNS-1 – Schematic

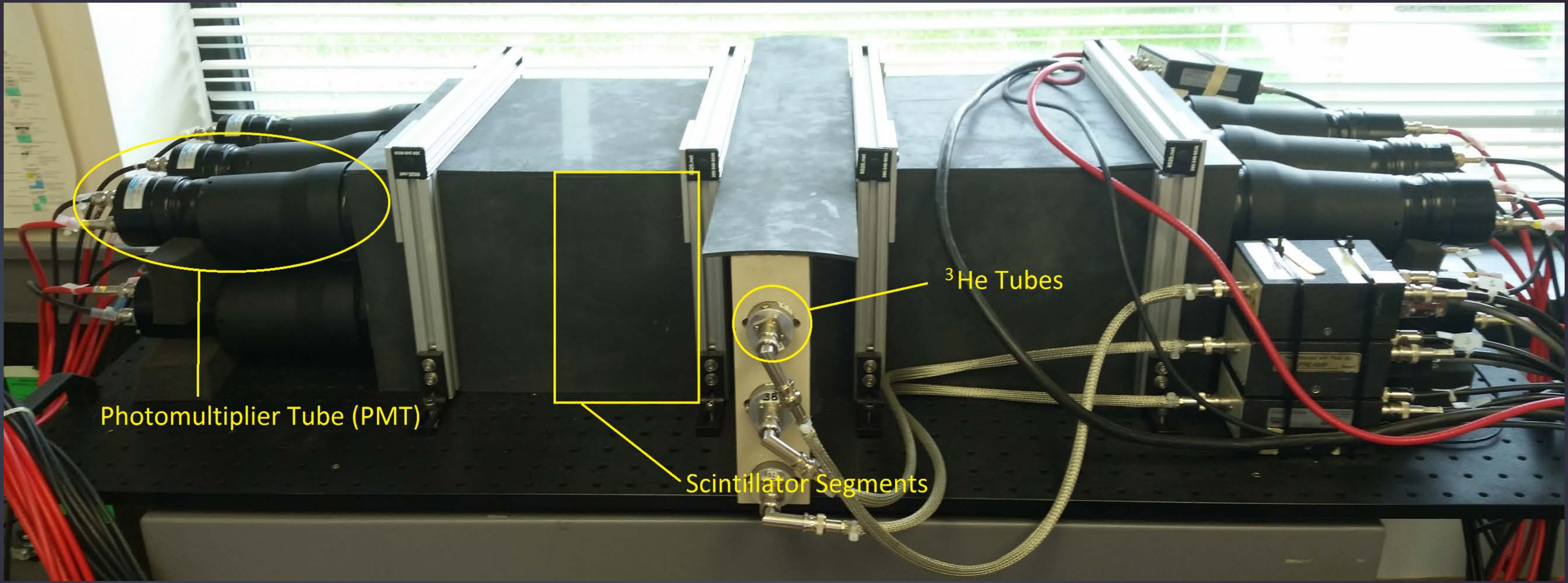




FaNS-1 – Output Signal



FaNS-1 – Picture



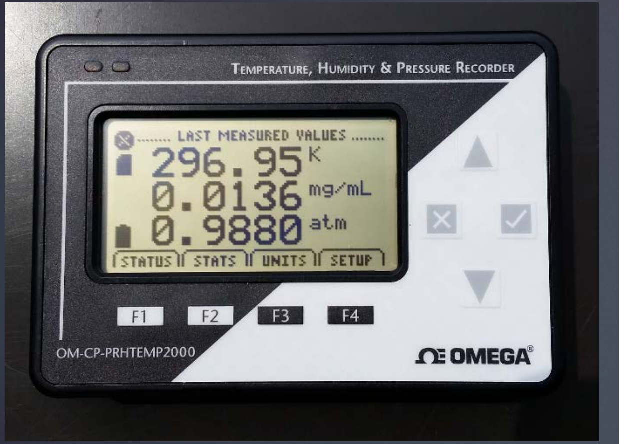
Fixing the Detector

PMTs were coming loose from the scintillator blocks

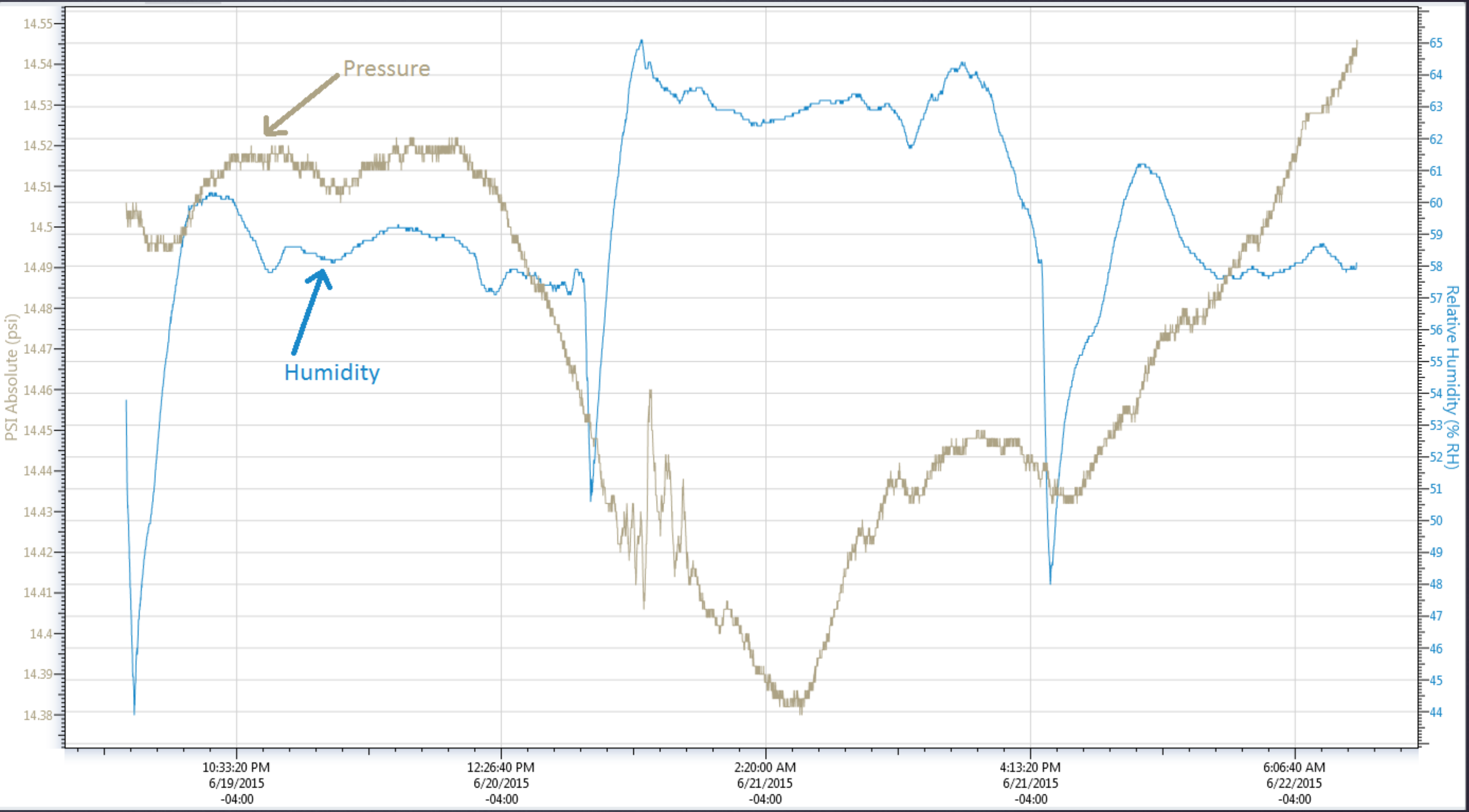
Silicone adhesive used to bond them together

Tape used to make them light tight

Data Logger



TEMPERATURE, HUMIDITY & PRESSURE RECORDER
LAST MEASURED VALUES
296.95 K
0.0136 mg/mL
0.9880 atm
STATUS
STATS
UNITS
SETUP
F1
F2
F3
F4
OM-CP-PRHTEMP2000
OMEGA



Pressure
Humidity
PSI Absolute (psi)
Relative Humidity (% RH)
14.55
14.54
14.53
14.52
14.51
14.5
14.49
14.48
14.47
14.46
14.45
14.44
14.43
14.42
14.41
14.4
14.39
14.38
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
10:33:20 PM 6/19/2015 -04:00
12:26:40 PM 6/20/2015 -04:00
2:20:00 AM 6/21/2015 -04:00
4:13:20 PM 6/21/2015 -04:00
6:06:40 AM 6/22/2015 -04:00

Outline

- Background
- Analysis of Previously Gathered Data
- Analytical Function to Predict Neutron Spectra
- Data Collection
- Next Steps
- Conclusion

What are the next steps in the project?

- Take long term data with FaNS-1 and the data logger
- Take data a different locations and during different weather conditions
- Compare these data with the function output
- Collect sources of global real-time data for pressure, sunspot number, and other effects
- Create a web tool that will predict the spectrum at any location and time

Outline

- Background
- Analysis of Previously Gathered Data
- Analytical Function to Predict Neutron Spectra
- Data Collection
- Next Steps
- Conclusion

Conclusions

- Based on the Bartol data it is feasible to create a neutron surface spectrum map with fairly high precision
- Previous work with an analytical function can predict neutron flux throughout the spectrum
- Neutron flux lends well to a web tool and/or an app that anyone can use that would like to know the background neutron spectrum at their location in near real-time

Acknowledgements

- Dr. Hans Pieter Mumm
- Dr. Paul Huffman
- NIST SURF Program
- NCNR
- NSF
- DoE

References

- 1. Sato, T., & Niita, K. (2006). Analytical functions to predict cosmic-ray neutron spectra in the atmosphere. *Radiation research*, *166*(3), 544-555.

Questions?

SURF NIST

PML
PHYSICAL MEASUREMENT LABORATORY

NIST Center for Neutron Research