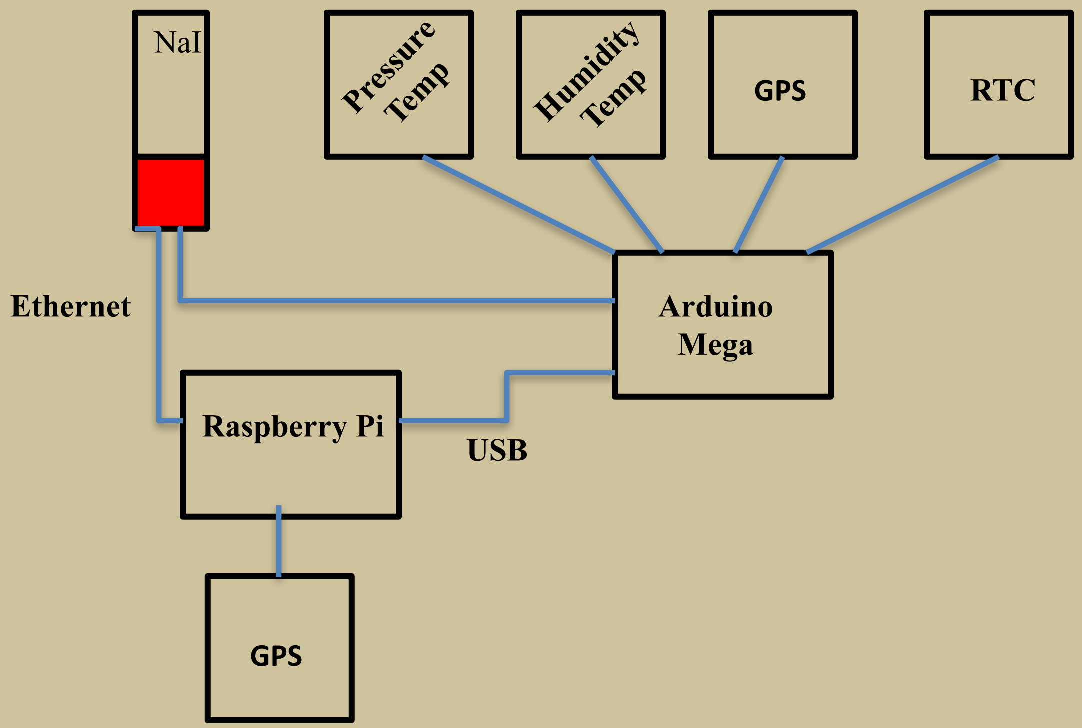
Measurement and Tracking of Ground-level Prompt Photon Showers and Their Connection to Meteorological Parameters

Christopher G. Fasano and the Monmouth College Lightning Research Group

Overview

- Measure High-Energy Photon spectra coming from the atmosphere at ground level
- Connect those measurements to meteorological data
- Measure the evolution of photon-generating systems as they march across the Midwest.
- Research with Undergraduates—outreach to high school students and teachers.

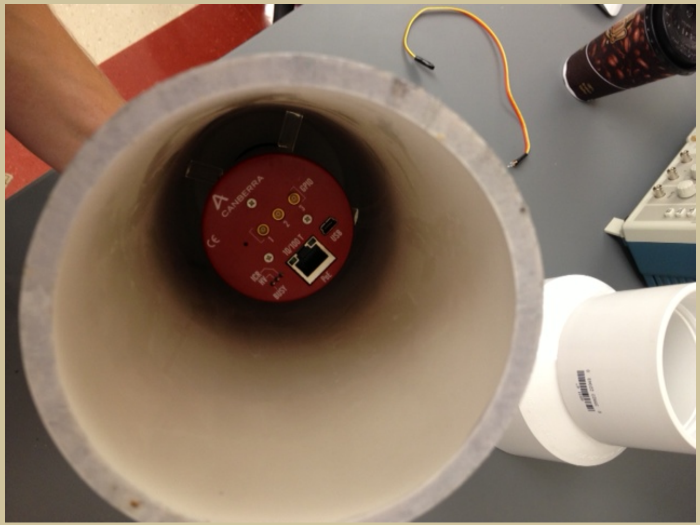
MC Detector Schematic



Monmouth College Detector Package

Packaging

- NaI crystal exposed, but remaining parts sealed
- Ventilation-small fan circulates air up through base and out ventilation tubes



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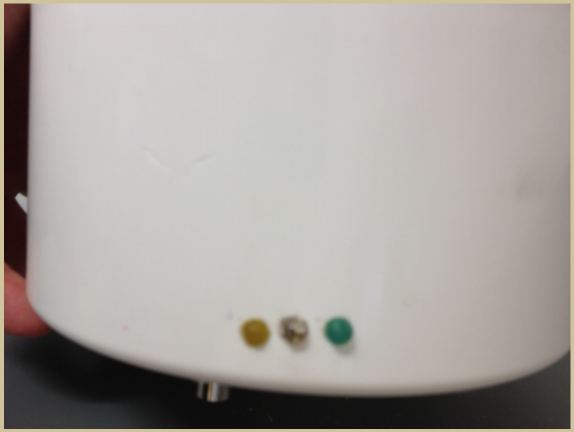
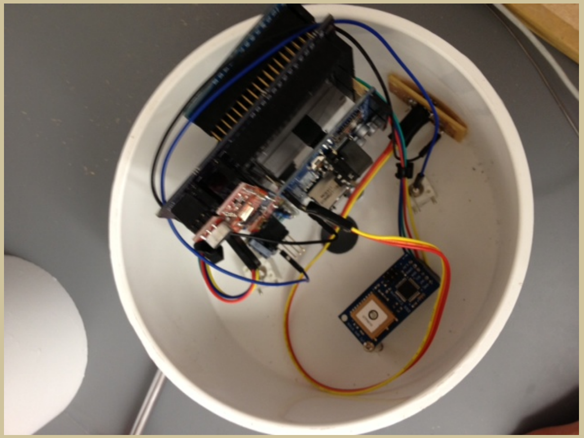
Monmouth College Detector Package

Packaging

- Water-resistant but ventilated
- Easy to Assemble
- Easy to service
- Compact and easy to transport and deploy
- Electronics in removable base cap





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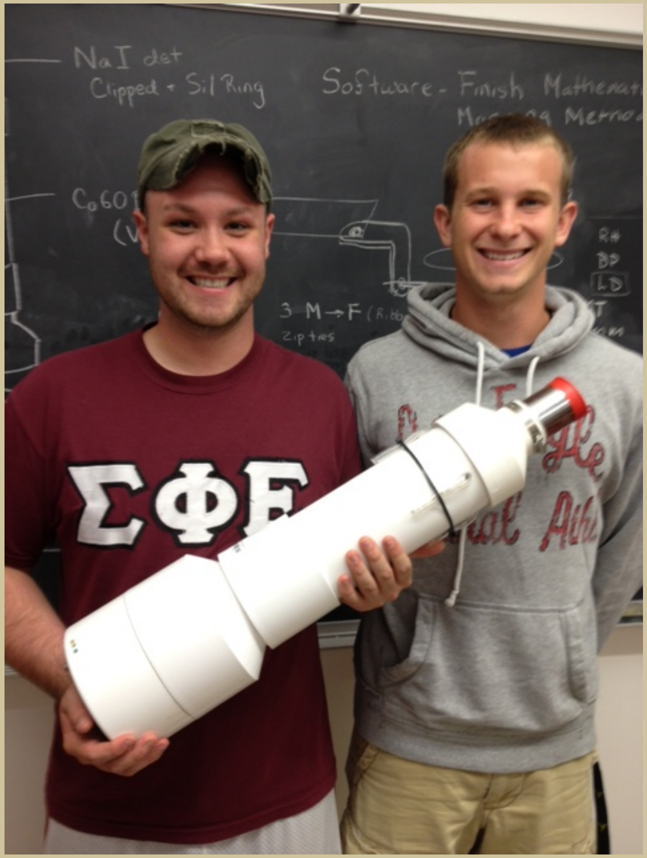
Monmouth College Detector Package

Completed Detector



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Typical Deployments

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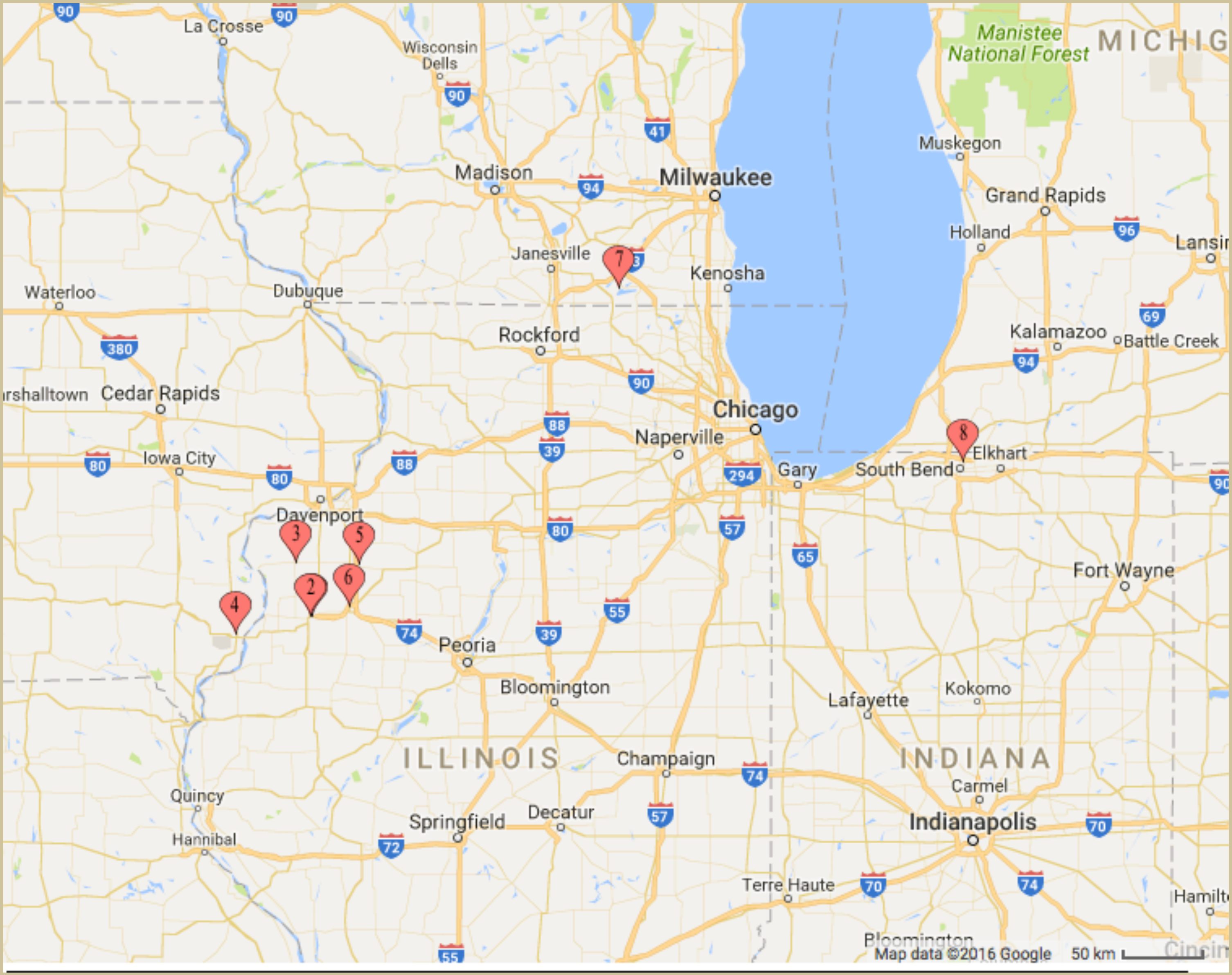

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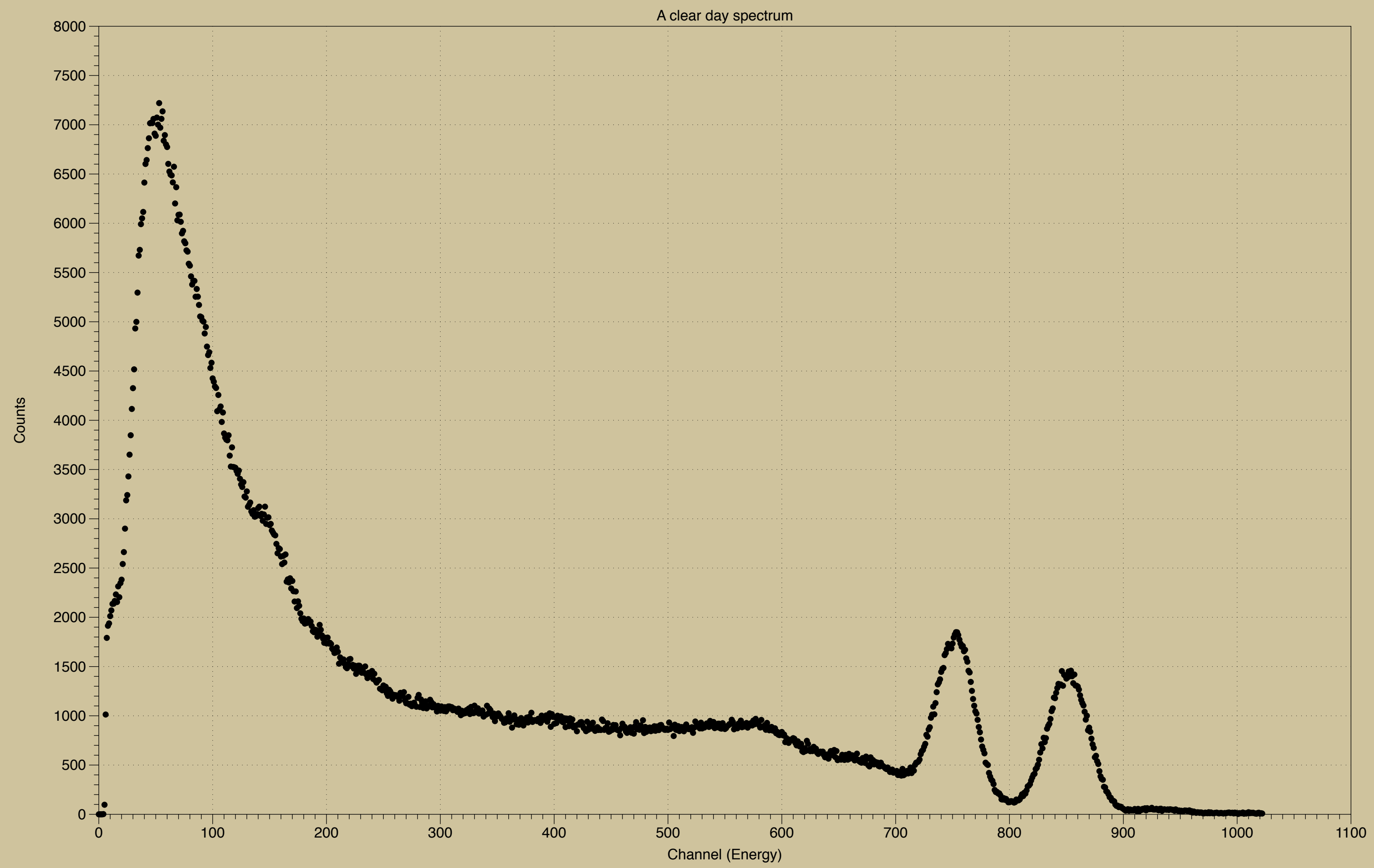
Clear Air Spectrum Example



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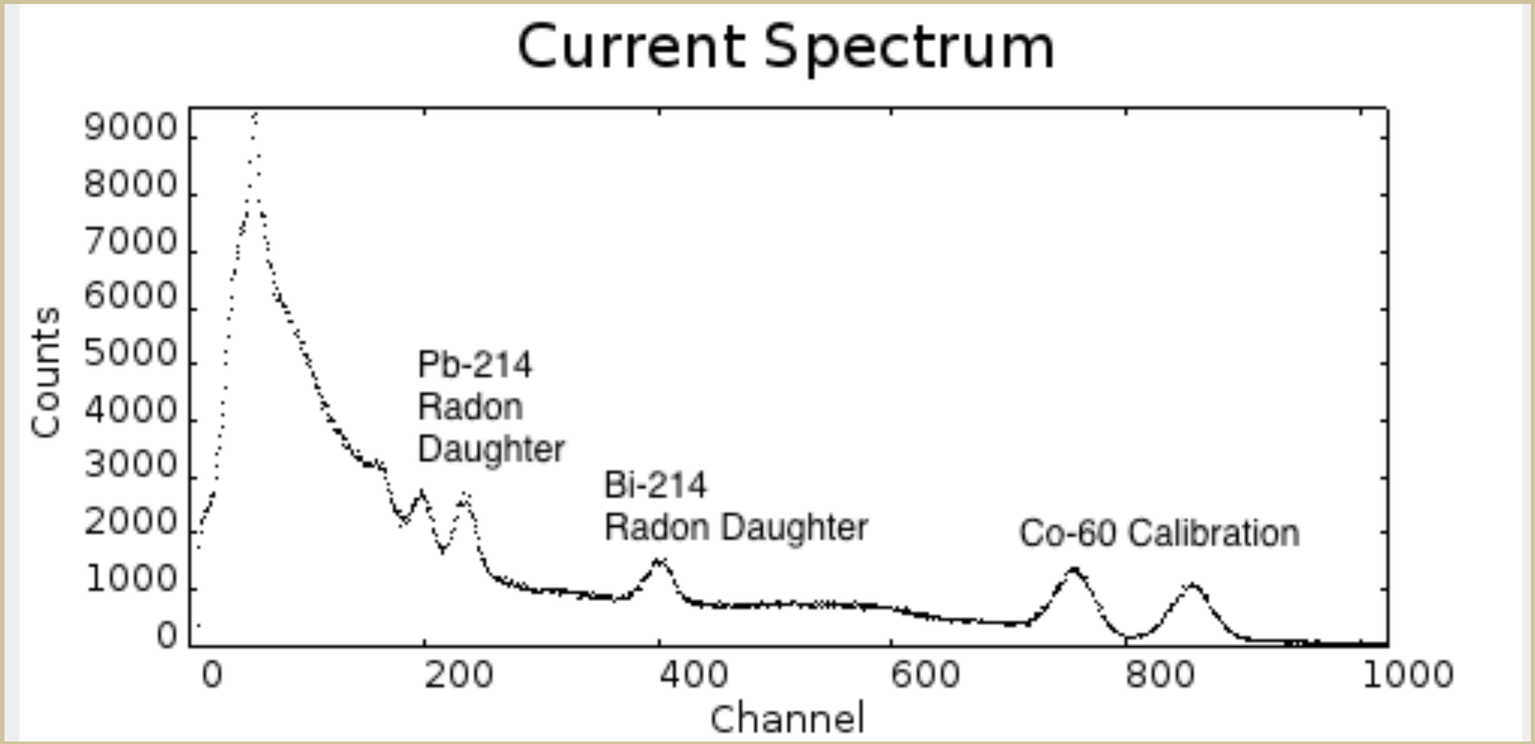
Rainy Day Spectrum



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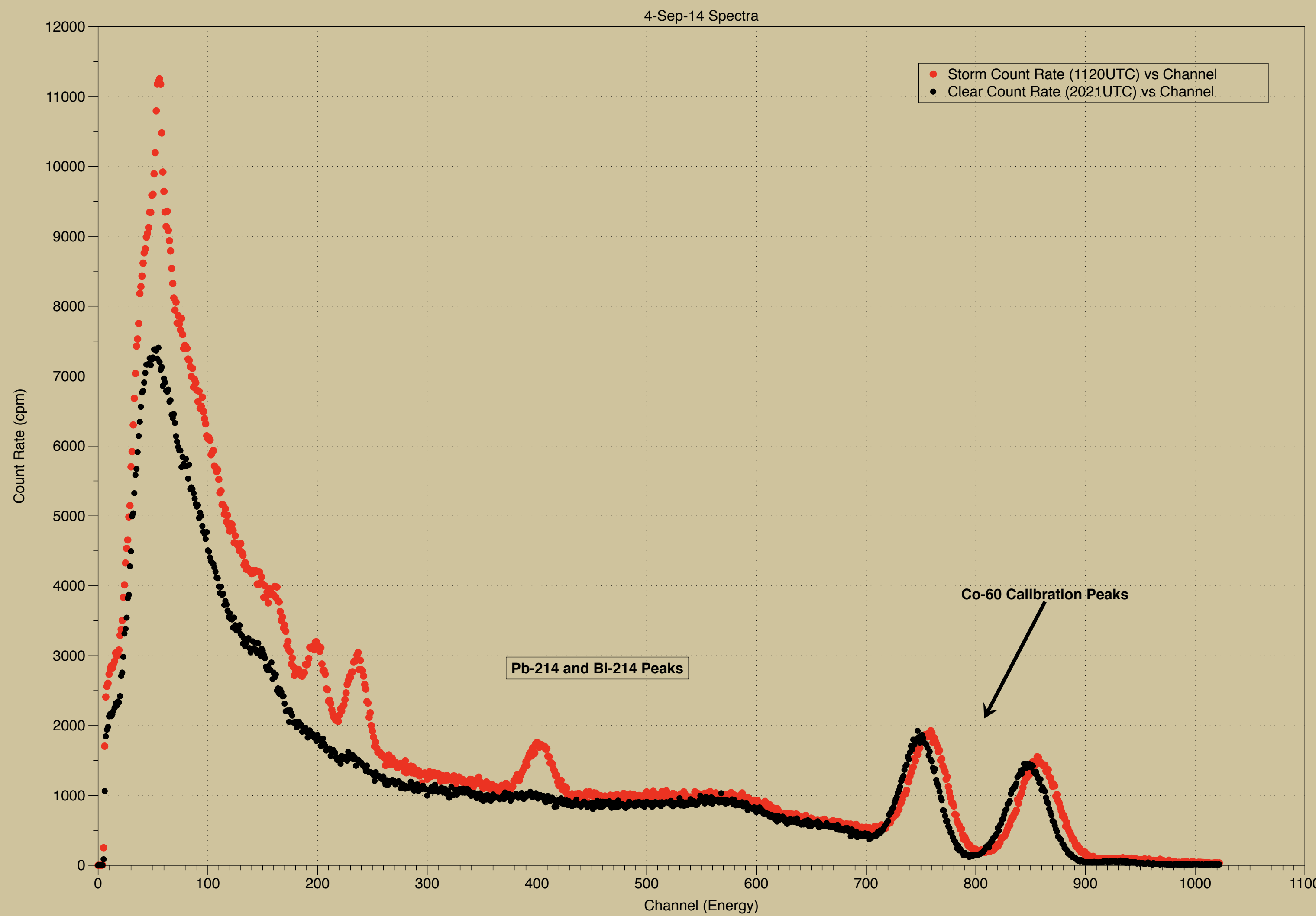
Clear vs. Rainy Day Spectra Compared



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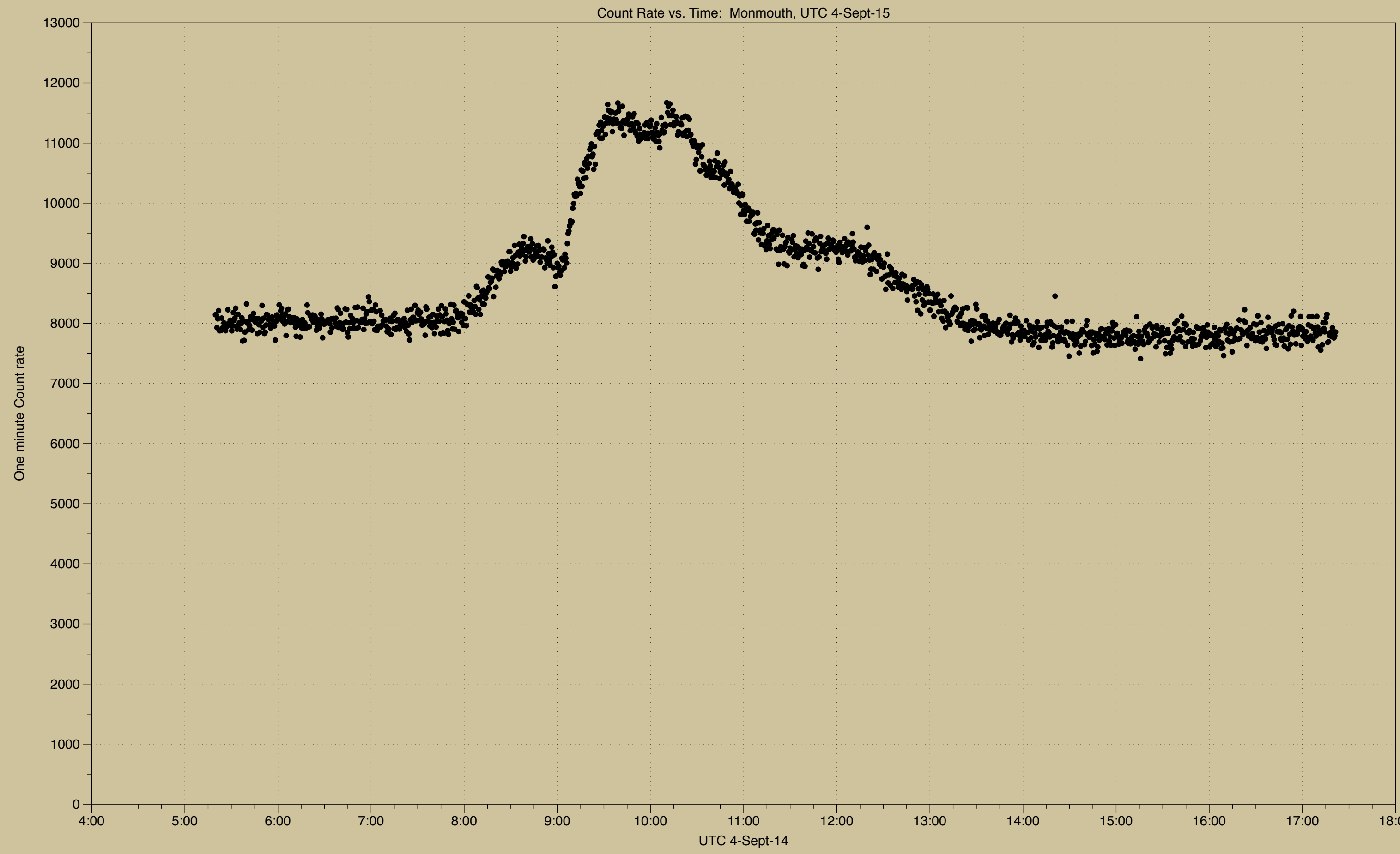
Rainy Day Count Rate

Rise in Count rate

Decay to background over hours.

Characteristic of Uranium Daughter Rainout



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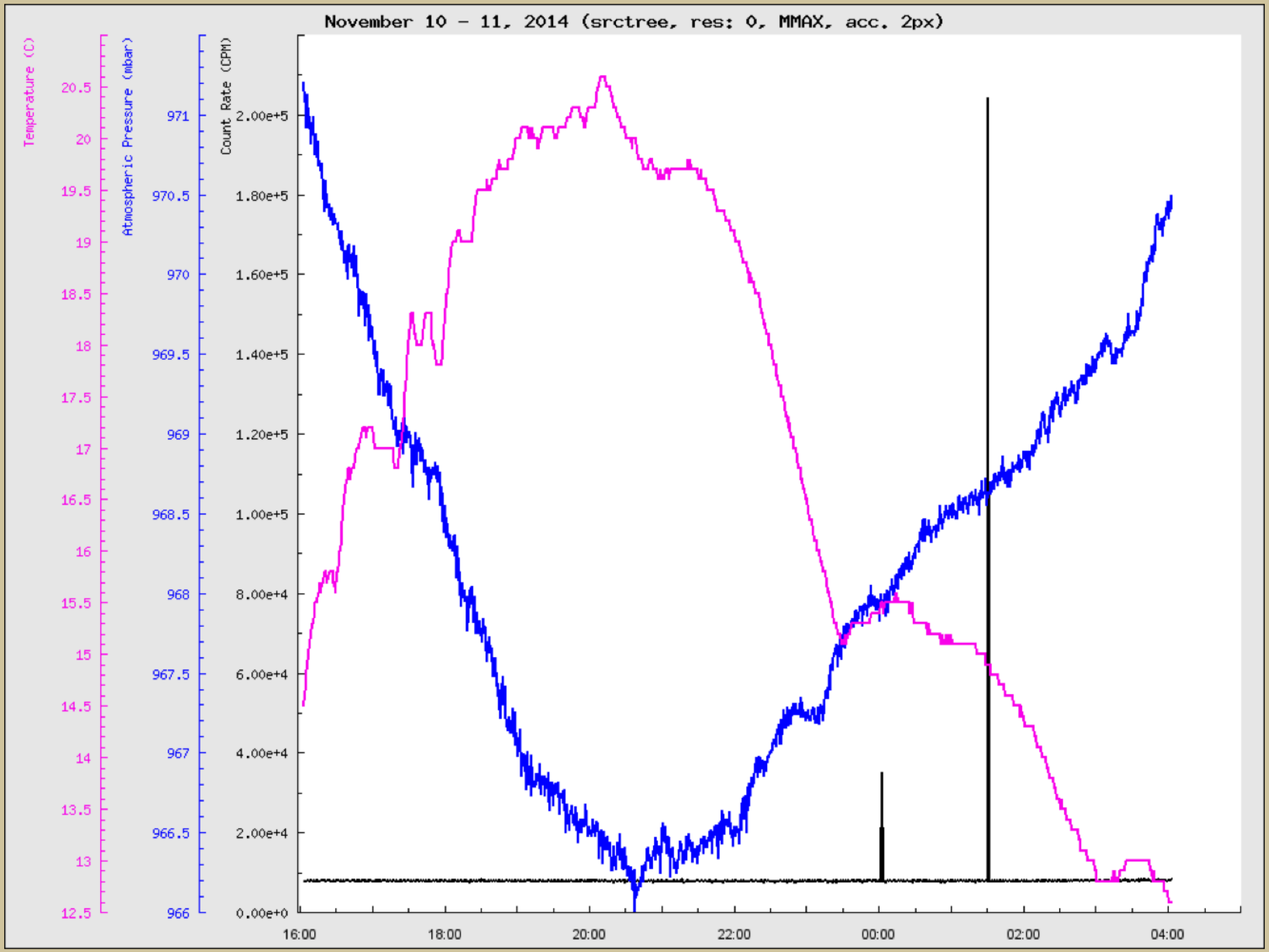
Event Detection Techniques

- Count rate
- Distribution of spectra in bins
- Time structure
- Spectra
- Background Subtraction.

November 10-11, 2014: Prompt Photon Event



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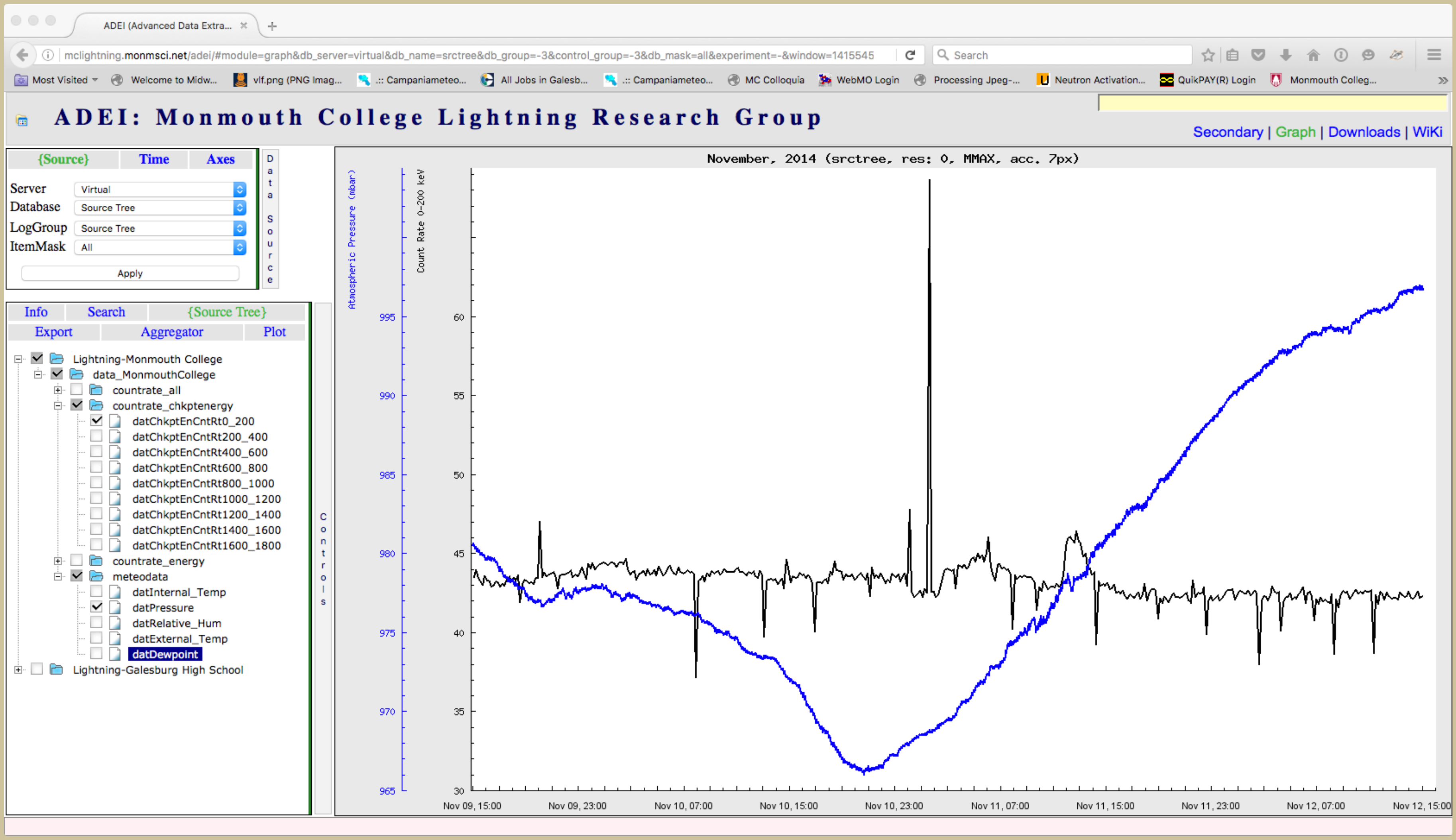
November 10-11, 2014: Prompt Photon Event



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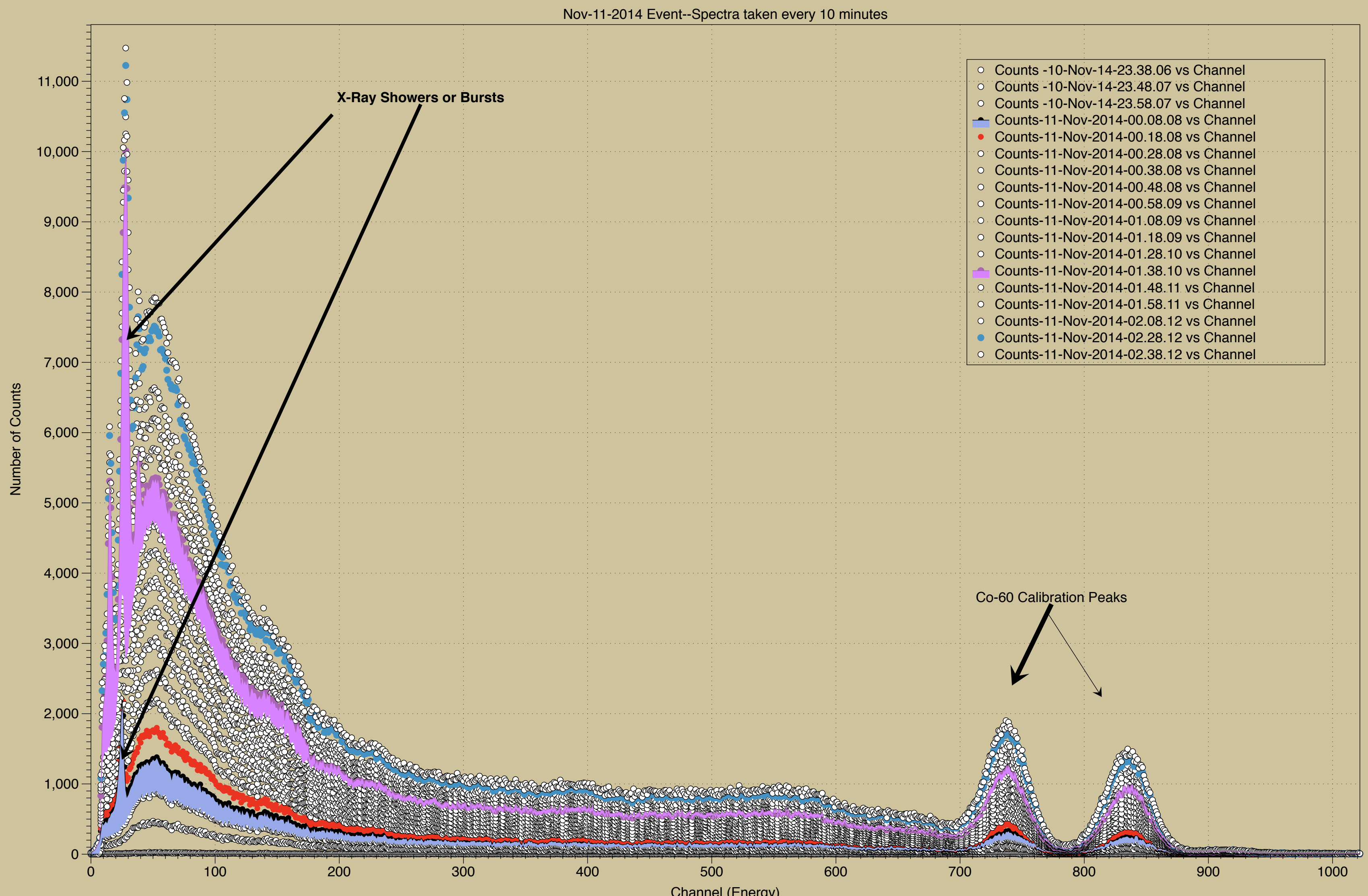

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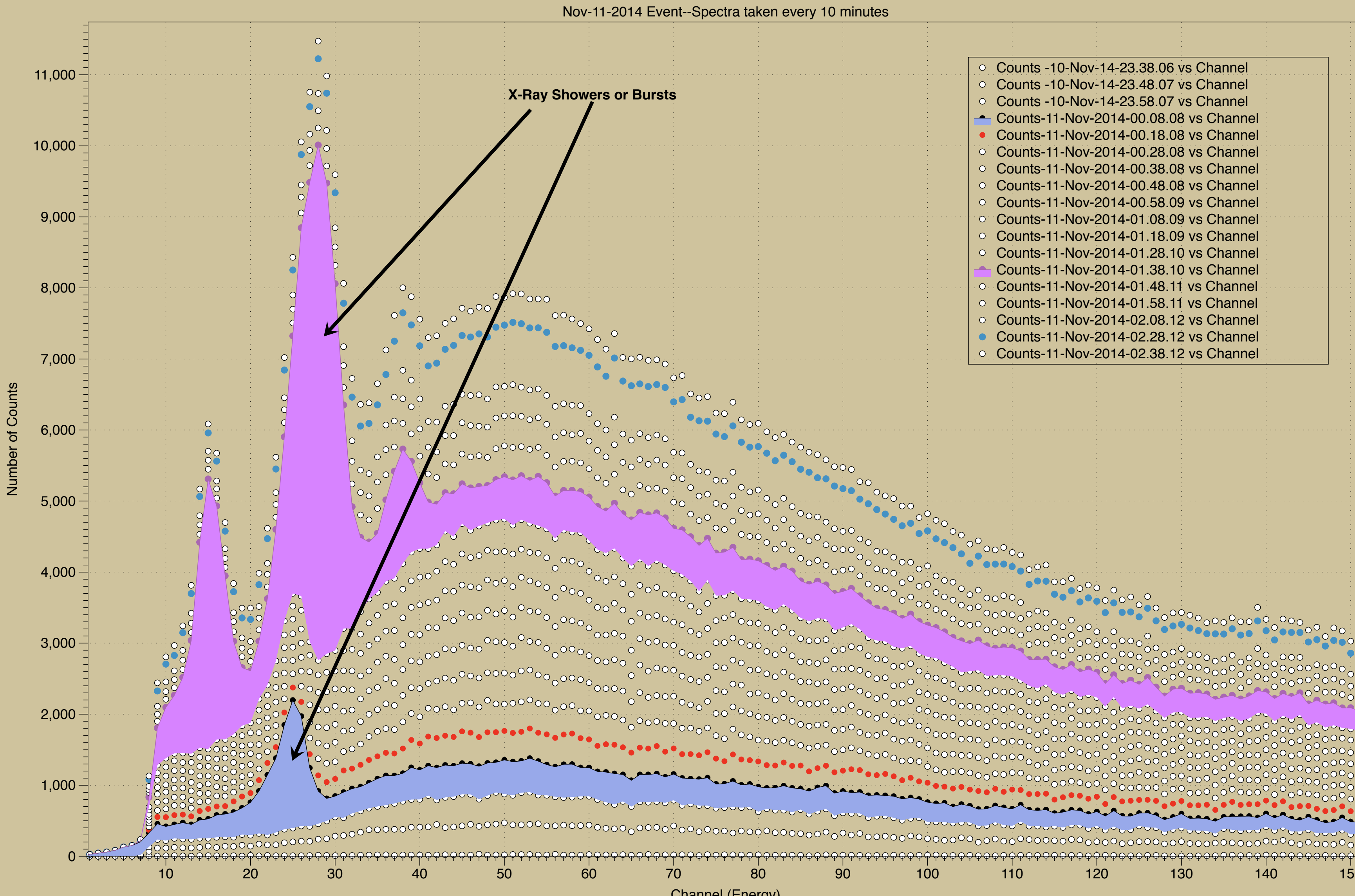

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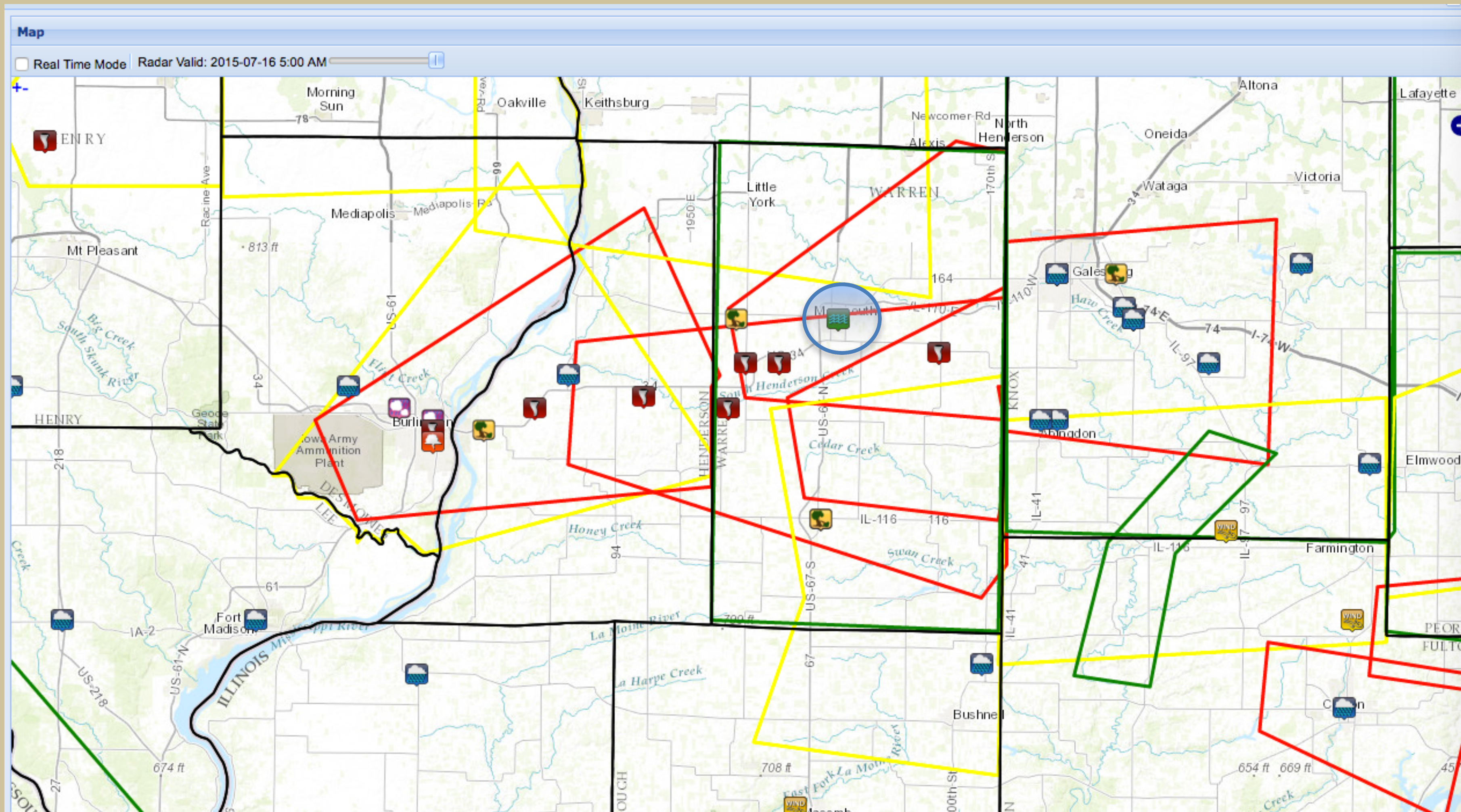
Where did this come from?

- No lightning
- Dramatic Pressure Drop
- Passage of weather front—winter storm
- Prompt - Photon Shower

July 16-17 2015– Tornadic Storms Pass Near Detector



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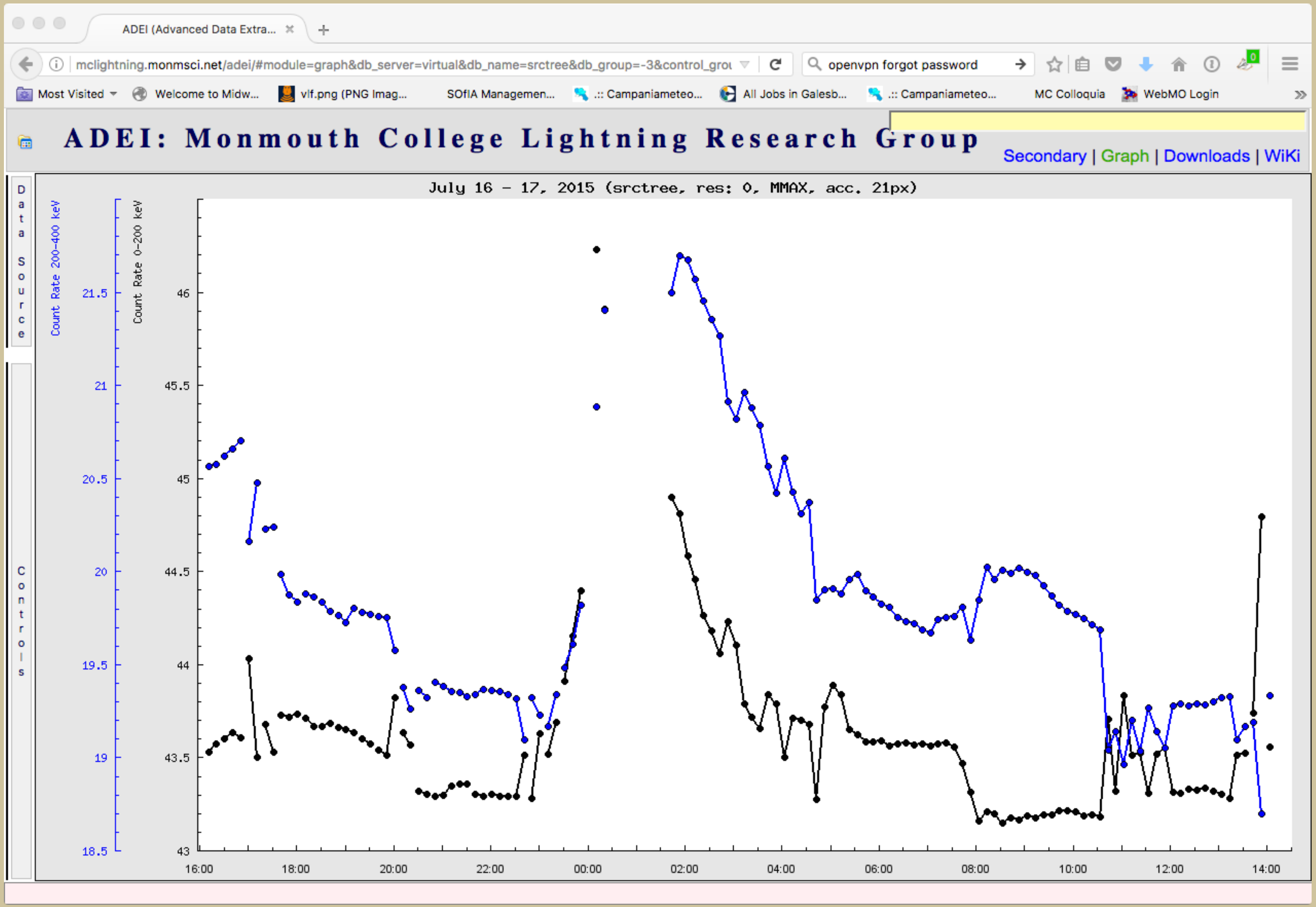

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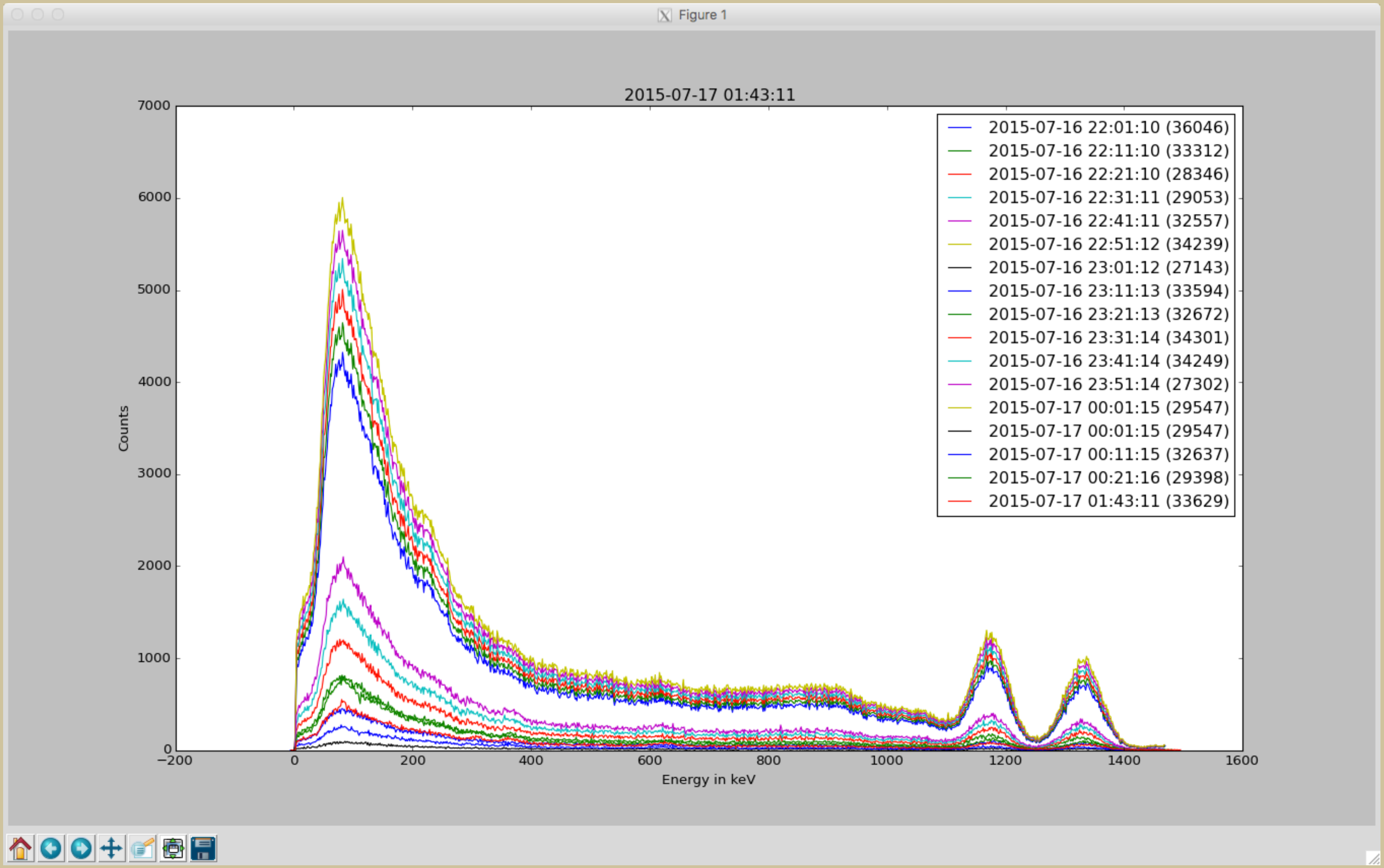

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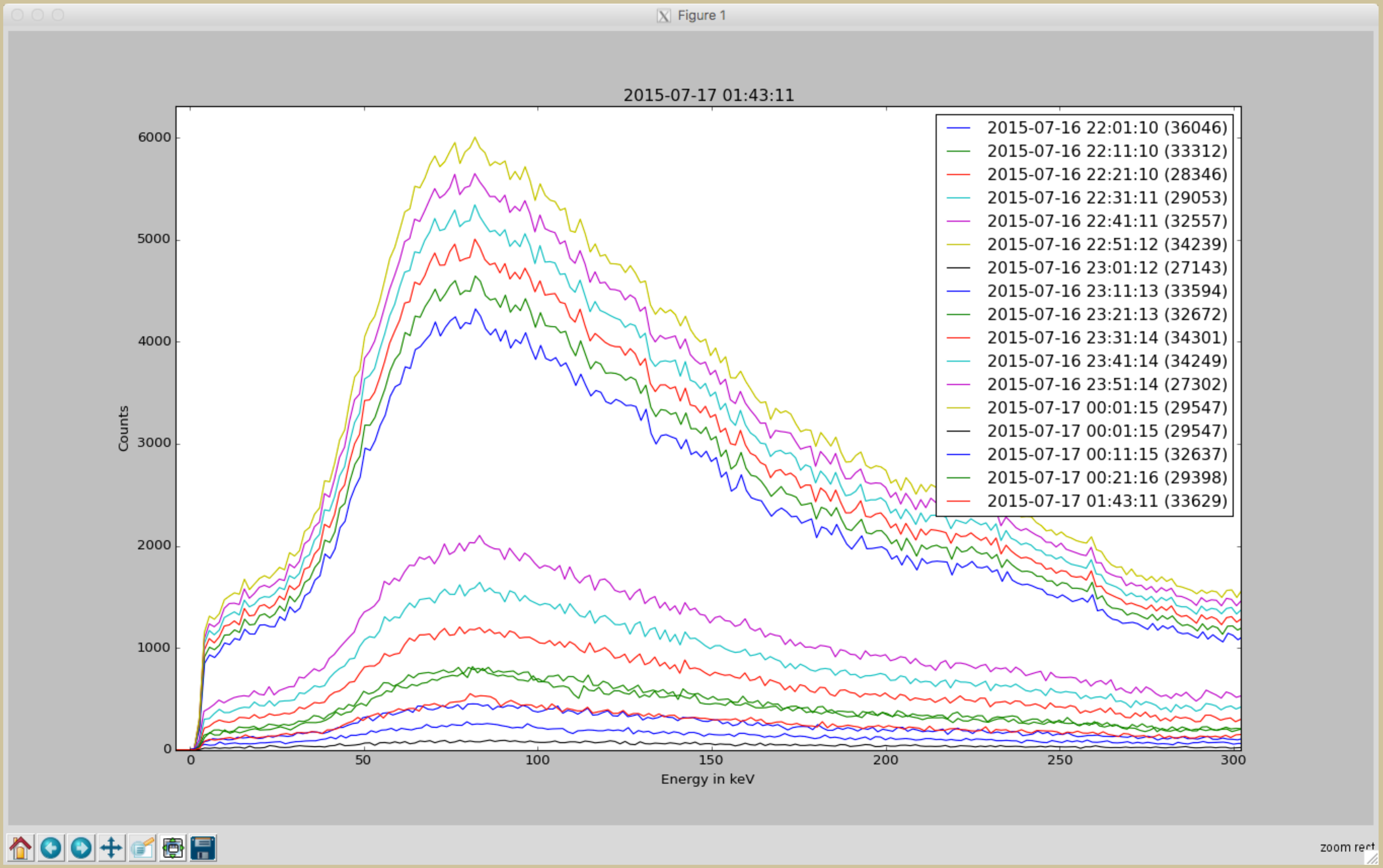

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July 16-17 2015– Tornadic Storms Pass Near Detector

What can we say about this event:

- There is no “dramatic signal” or photon shower
- A subtle signal may be present, but we need to do background subtraction to dig it out if it’s there.
- The pressure drop at our site was not dramatic (~975 mb)
- Rotation in the storm was visible
- Confirmed tornado within approximately 1 mile (EF-2)
- Working on extracting data from other stations (Burlington and Galesburg).

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Challenges in Running Detectors

- Corrosion
- No Internet Access at high schools (detectors must be standalone)
- Maintenance—Keeping things running and Weather
  - Field repair
  - Move to a modular model for elements that fail often (RH/Temp, GPS)
  - Depot repair

- A roof is a hostile place—continuing safety protocols
- Lots of Data—Data flow
- Managing a large and disparate group over a large geographic area
- Keeping the high schools students engaged as real participants

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Conclusions and Future Work

- We have seen prompt photon showers and they were not connected with lightning but rather with a strong winter storm.
- We have observed a tornadic storm it did not produce an dramatic and easily observable signal.
- We are prepared to see more subtle events via a variety of event detection techniques.
- We are accumulating data and watching evolution of photon producing systems.

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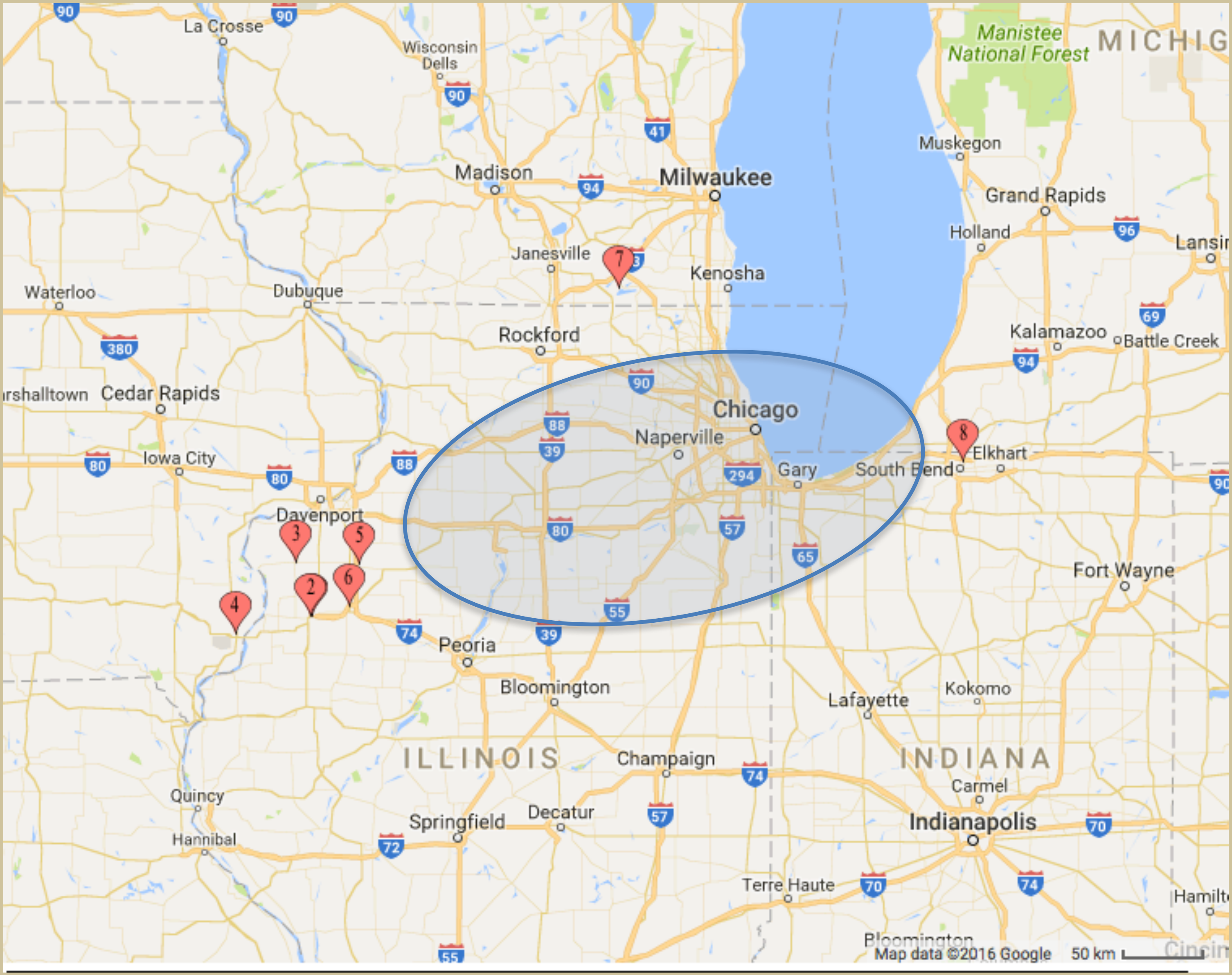
Conclusions and Future Work

- More stations to fill the geographic “hole”…and we have ideas on managing over a large area
- Modeling events
- Upgrade existing stations to make data processing easier and faster (RPi 1 to RPi 3)
- Upgrade software to make it more intelligent—change the acquisition timing based on events observed
- Need additional sensors to add to the package (windspeed, rainfall rate, camera)
- Continue work on improving repair, uptime and fighting corrosion



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Acknowledgements

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- Physics Department, University of Notre Dame (P. Fasano)

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Measuring High Energy Photons

Cole et al. estimated that it would be possible to detect X-rays at relatively large distances from the lightning stroke (in their case in an aircraft at an altitude of 10 km and 2 km from the main beam)

Parks et al. and McCarthy and Parks performed searches for lightning produced X-rays using aircraft based detectors.

"significant quantities of 3 keV to >12 keV X-rays are produced within thunderstorm clouds which support lightning discharge activity"

…statistically significant increases in X-Ray flux in the 5 keV to 110 keV range …observations were consistent with bremsstrahlung produced by electrons "in a region with a length scale of 1 km."

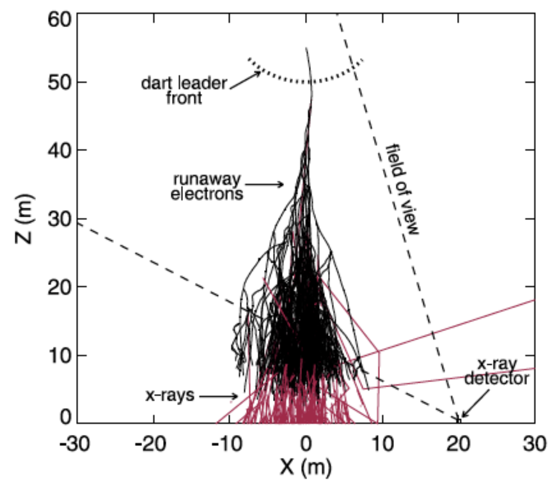

Figure 2. Monte Carlo simulation of the RREA model of runaway breakdown, showing runaway electrons (black trajectories) and x-rays (red trajectories) for the configuration observed by *Dwyer et al.* [2004a]. The simulation is run until all x-rays and electrons either hit the ground or are absorbed. However, in order to show the spray of x-rays at the bottom, the electrons are only plotted for the first 1.5×10^{-7} s of the avalanche. The field of view of the lowest two collimated detectors described by *Dwyer et al.* [2004a] is also shown. These two detectors had the biggest x-ray signals for all the events observed.

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