DOE/NV/25946--971

Prototype Neutron Energy Spectrometer

Stephen Mitchell
Remote Sensing Laboratory–Nellis

June 16, 2010

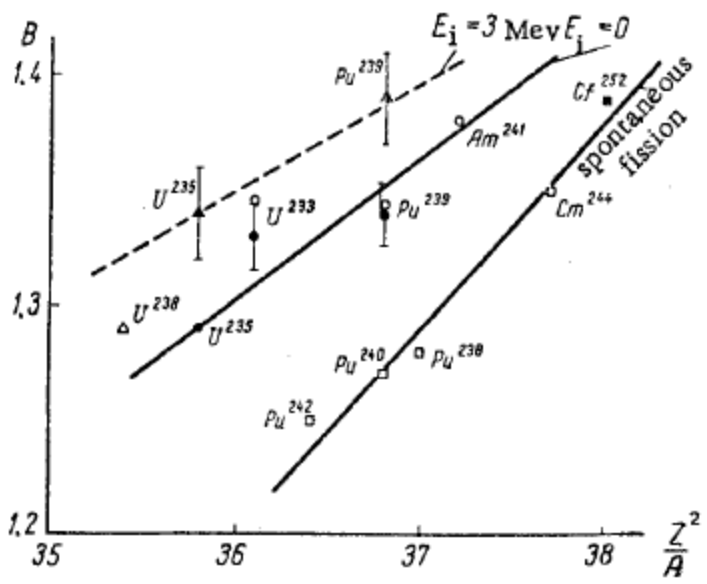
This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06NA25946 with the U.S. Department of Energy.

National Security Technologies LLC
Vision • Service • Partnership

Project Goals

- Use three to five pressurized helium tubes with varying polyethylene moderators to build a neutron energy spectrometer that is most sensitive to the incident neutron energy of interest.
  - Neutron energies that are of particular interest are those from the fission neutrons (typically around 1–2 MeV)
- Neutron Source Identification – Use the neutron energy "selectivity" property as a tool to discriminate against other competing processes by which neutrons are generated (viz. Cosmic ray induced neutron production [ship effect], [a, n] reactions).
- Determine the efficiency as a function of neutron energy (response function) of each of the detectors, and thereby obtain the composite neutron energy spectrum from the detector count rates.
- Far-field data characterization and effectively discerning shielded fission source

Literature Survey



Hardness of fission neutron energy spectrum increases as Z^2/A of the isotopes

- It has been found experimentally that the spectra of fission neutrons from ^{233}U, ^{239}Pu, and ^{252}Cf are harder than the spectrum of ^{235}U and that hardness increases in going from the ^{233}U spectrum to ^{252}Cf spectrum

"Systematics of prompt fission neutron spectra," B. P. Kovalex and V. S. Staviniki

Spectrometer Design Goals

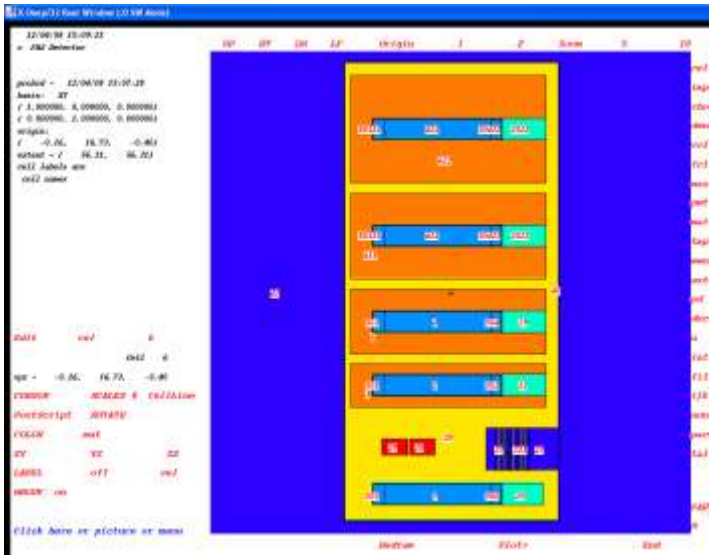
Optimized detector response functions

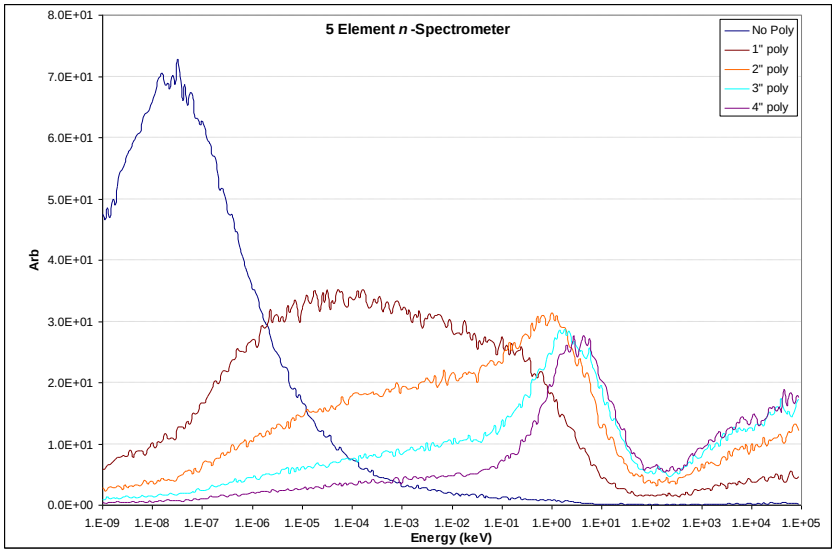
- Moderator
- Shielding
- Absorber
- Geometry

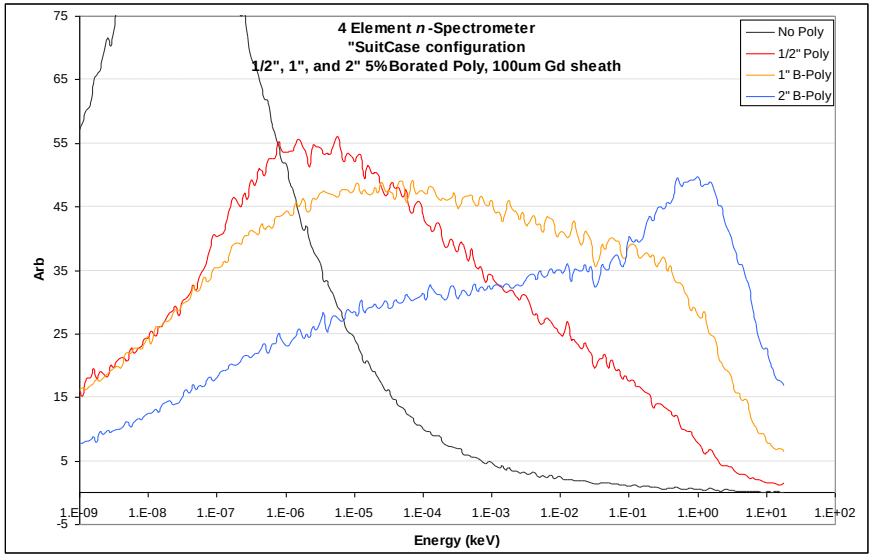
Man portable (<30 pounds)

Real-time determination of neutron source identity in less than an hour

MCNPX 5-element Spectrometer

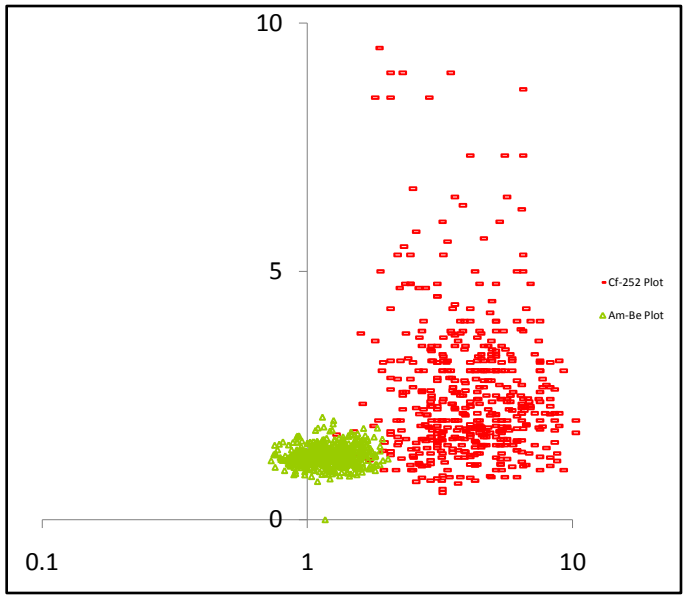




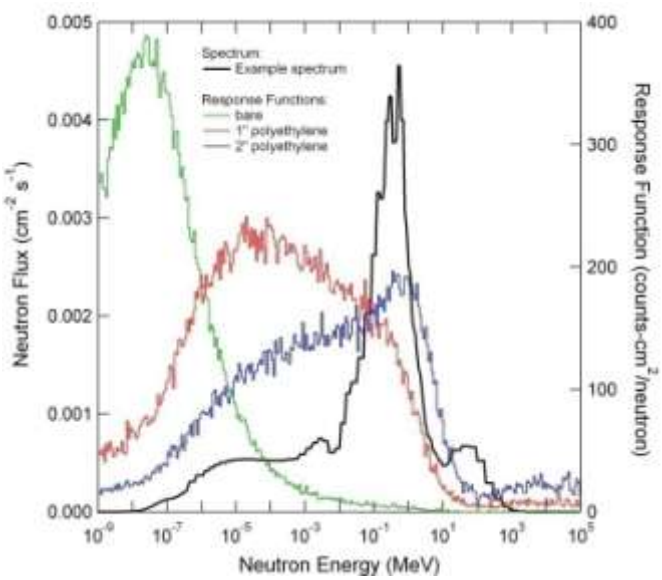


National Security Technologies LLC
Vision • Service • Partnership

4-element Spectrometer



Neutrons of the same energy hardness cluster together in the above plot sample Cf-252 and Am-Be

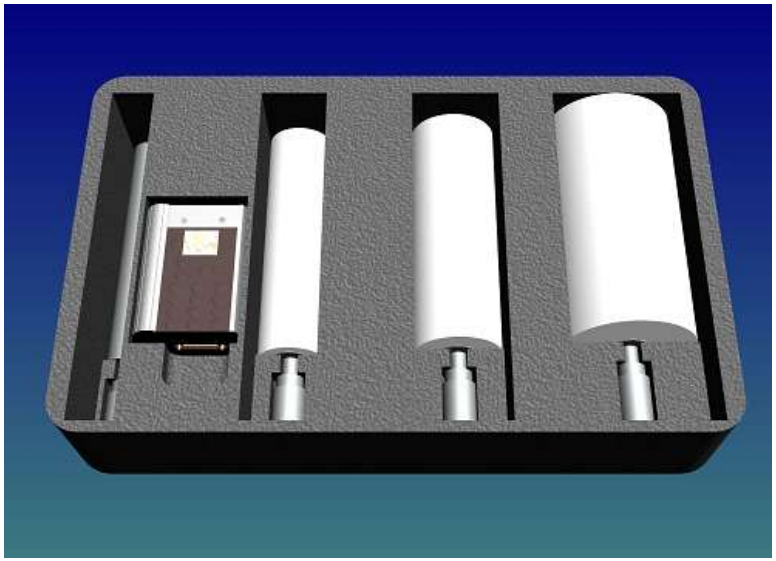


Goldhagen and RSLA work

4-element neutron spectrometer (RSLA)

National Security Technologies LLC
Vision • Service • Partnership

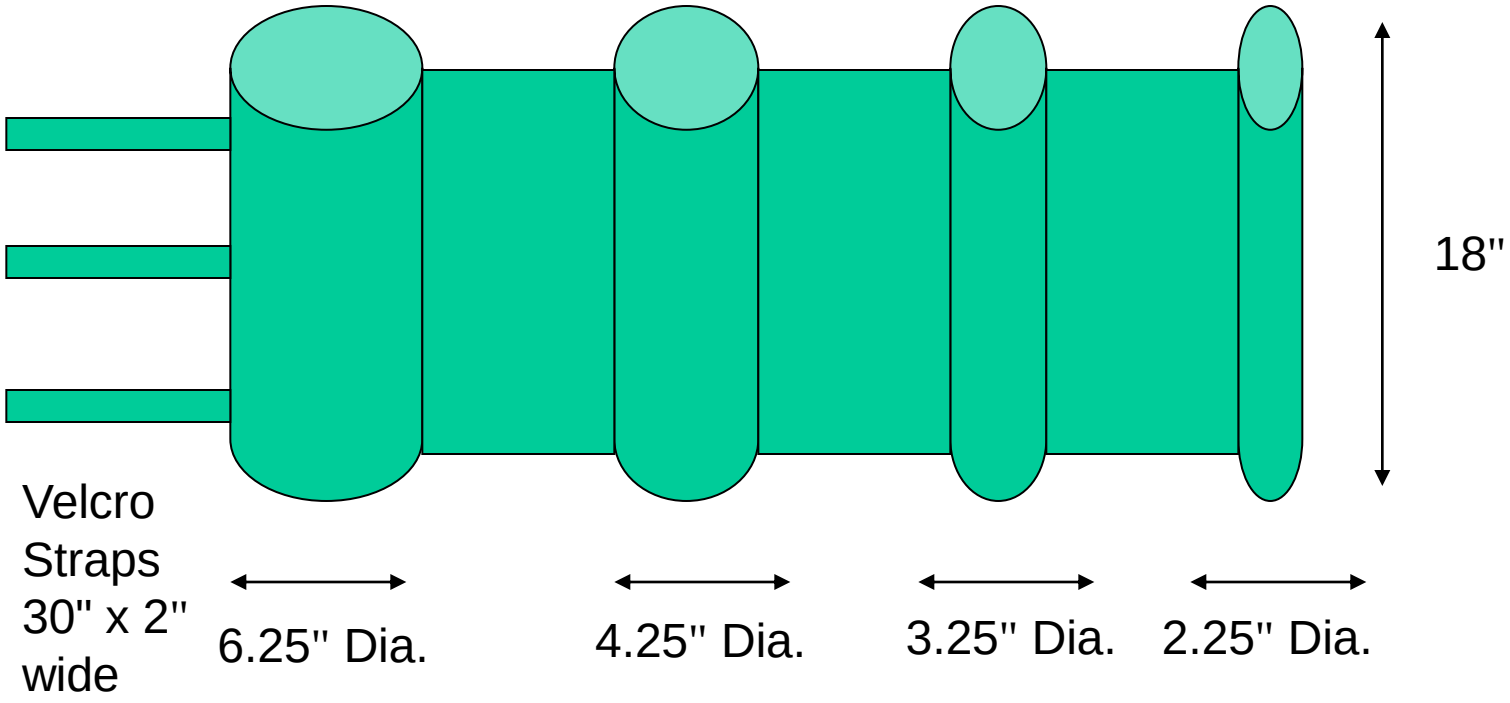
Suitcase Design with 4 Elements



Final Packaging Proposal

Weights & Measures

Suitcase Complete with PDA	42 pounds
Tubes with Poly and electronics	22 pounds
Ballistic Nylon garment	6–8 pounds
Total weight	**28–30 pounds**

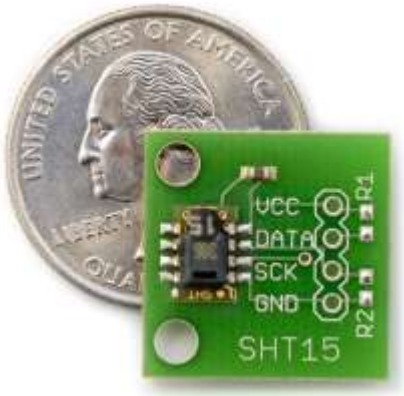


Material: Ballistic Nylon; closed on bottom, velcro cover on top

National Security Technologies LLC
Vision • Service • Partnership

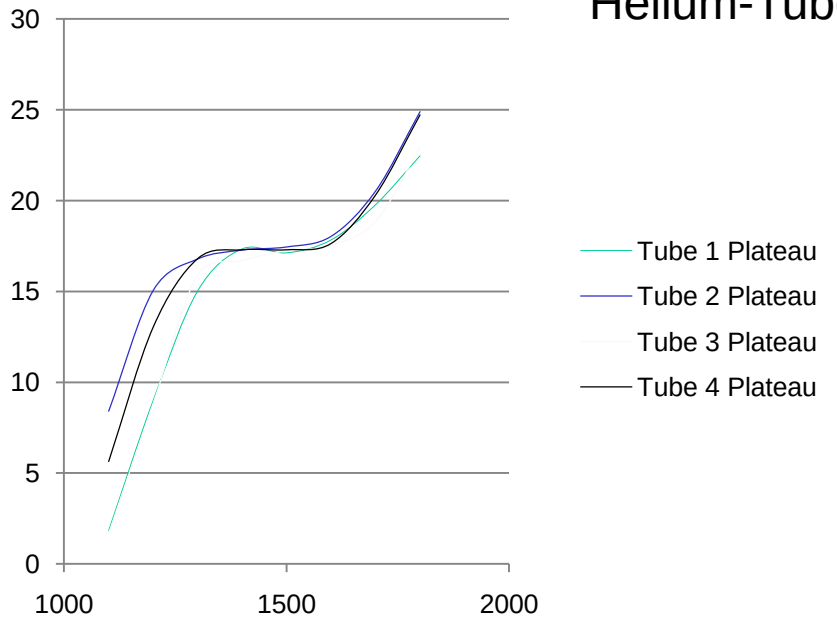
Other Measurements

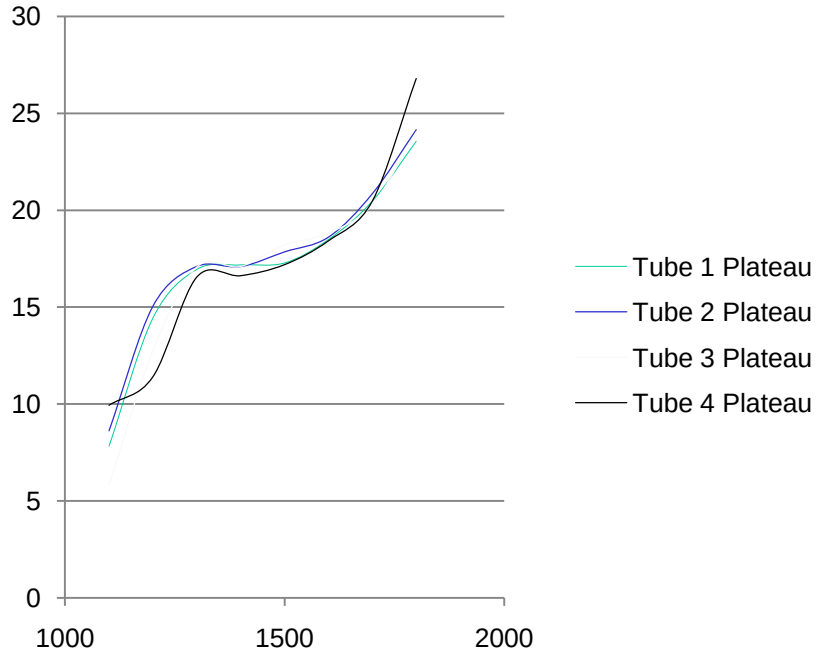
- Humidity
- Pressure
- Temperature
- GPS
- Real-time Clock
- Battery State



Equipment Characteristics

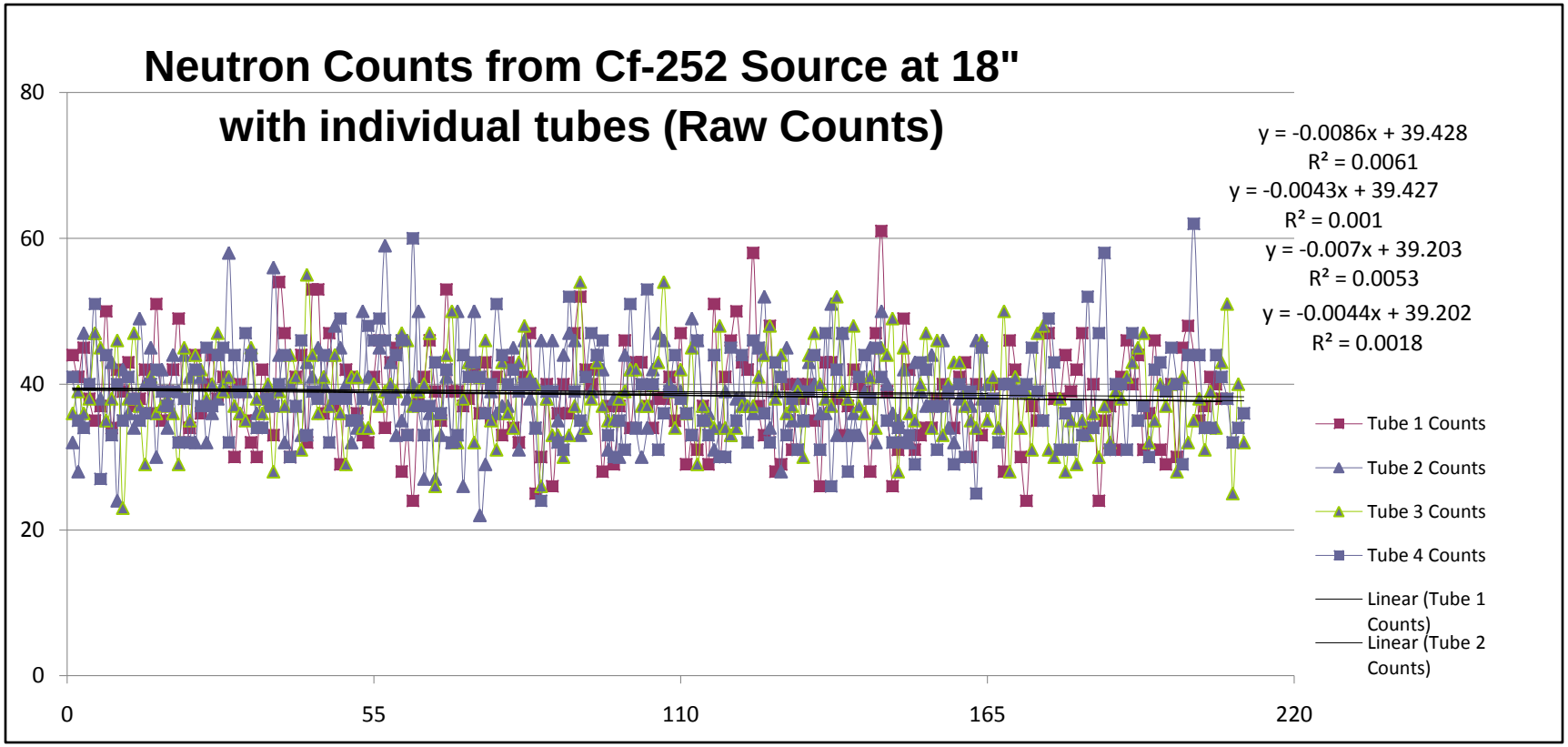
Helium-Tube Plateauing



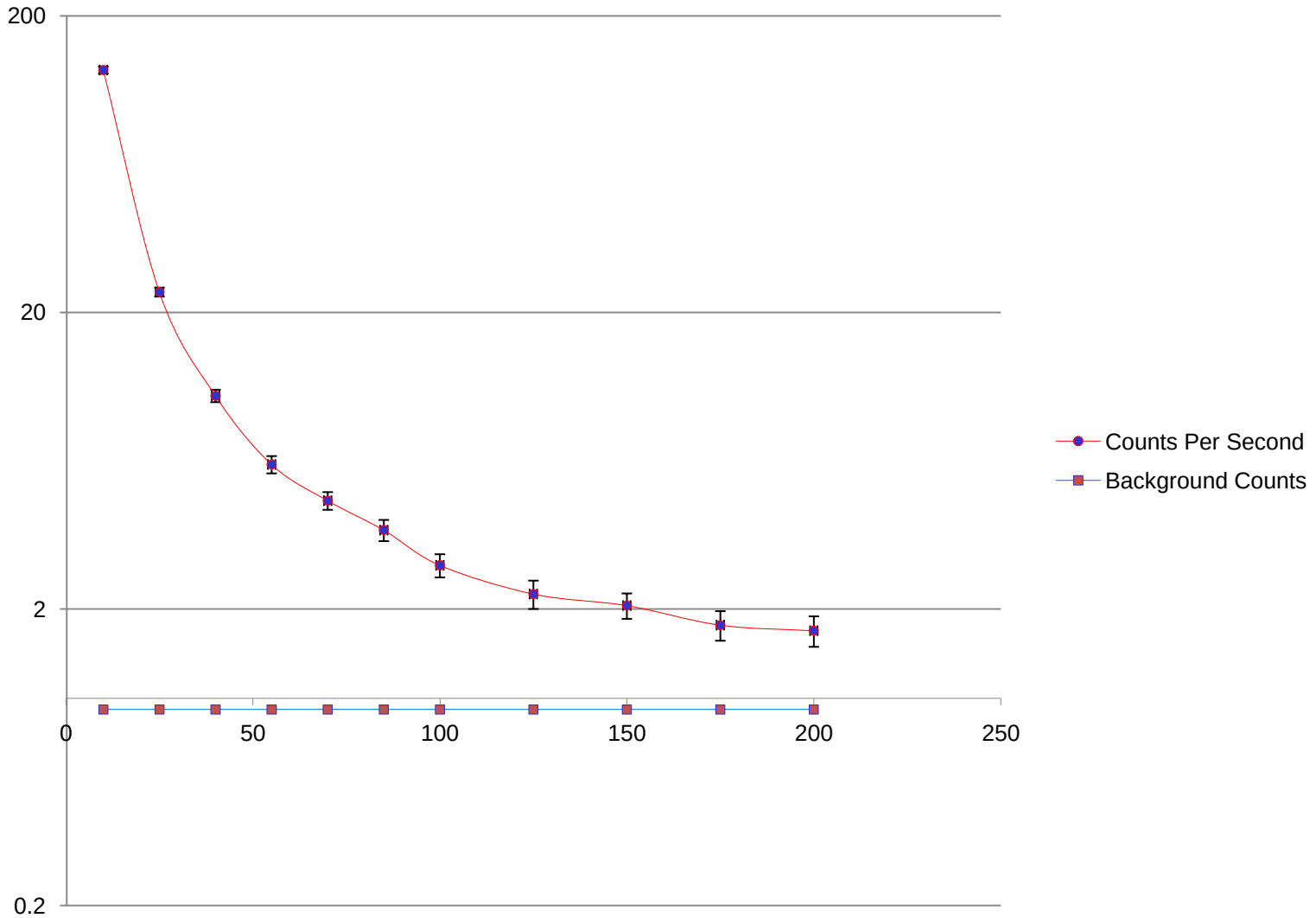


Equipment Characteristics

Source Counting by Individual Tube (Cross Calibration)



Sensitivity Plot



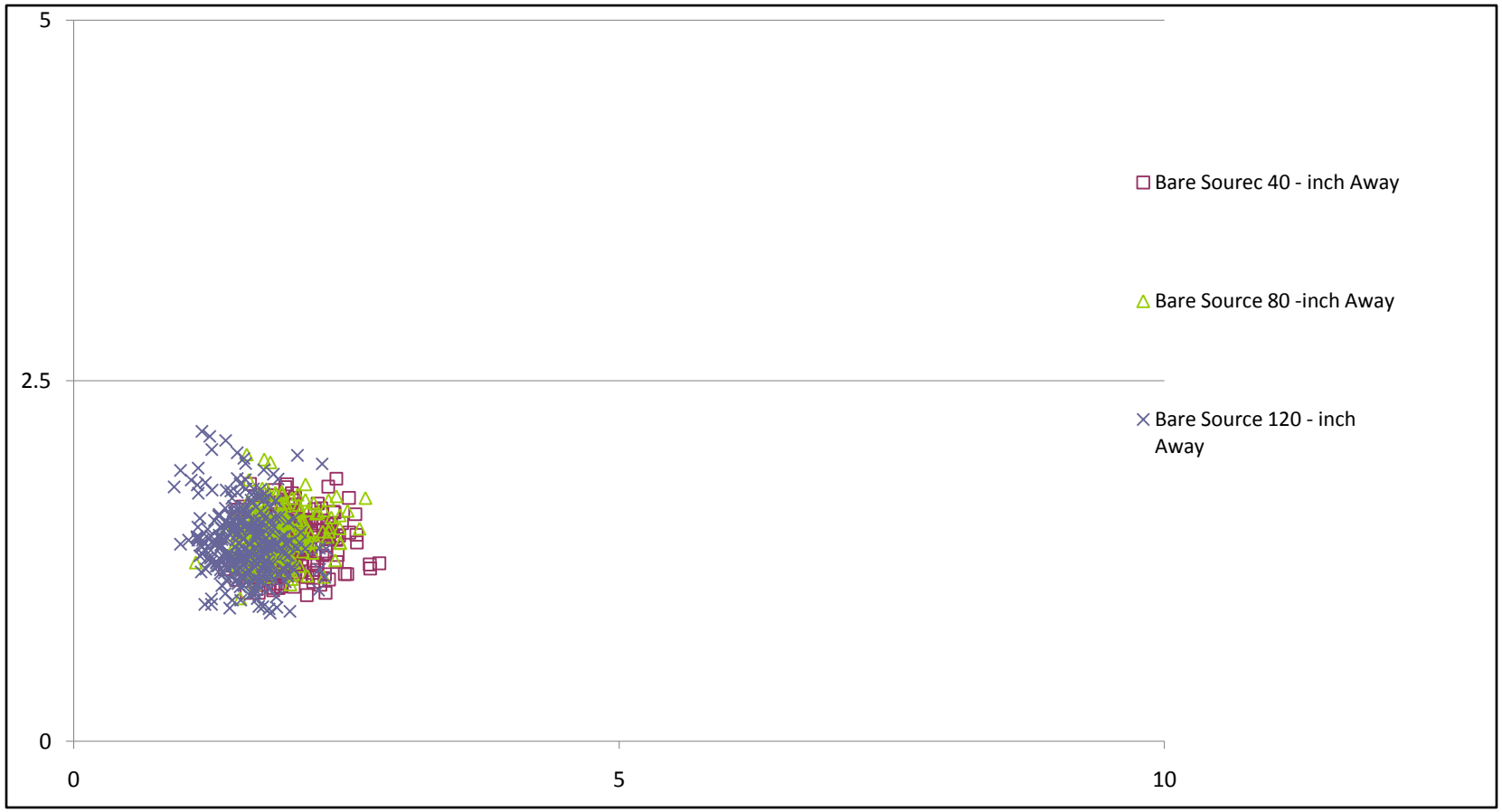
National Security Technologies LLC
Vision • Service • Partnership

Data Display and Interpretation

- We have defined a 2-dimensional (2-D) space with two orthogonal axes (without unit) that represents the ratio of counts (N4/N1) as x-axis and (N3/N2) as y-axis where N1, N2, N3, and N4 are count rates in bare, ½", 1", and 2"–polyethylene moderated Helium-3 tubes.
- Neutrons originated from similar mechanism (a, n), cosmic, fission, spallation, tend to cluster in definite fixed region in this 2-D space. By noting the extent of these clusters, we can identify neutron sources singly.
- The display unit will have a bunch of pixels in a cluster designated for a different neutron source; in operation, one of these clusters will start to grow brighter and brighter in color, signifying the presence of a particular neutron source.

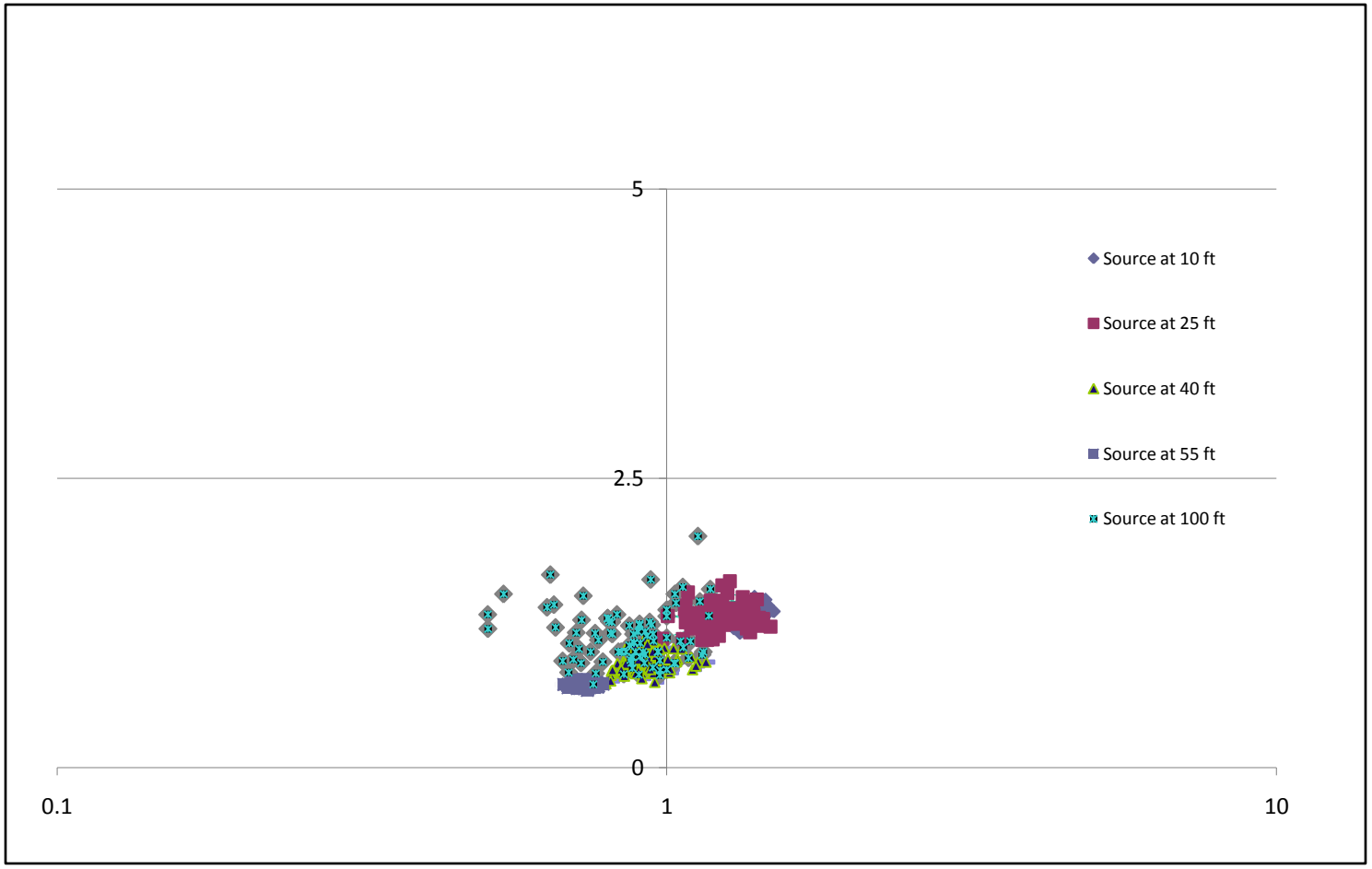
Equipment Characteristics

Ratio Plot remains steady as the field strength due to single source varies



National Security Technologies LLC
Vision • Service • Partnership

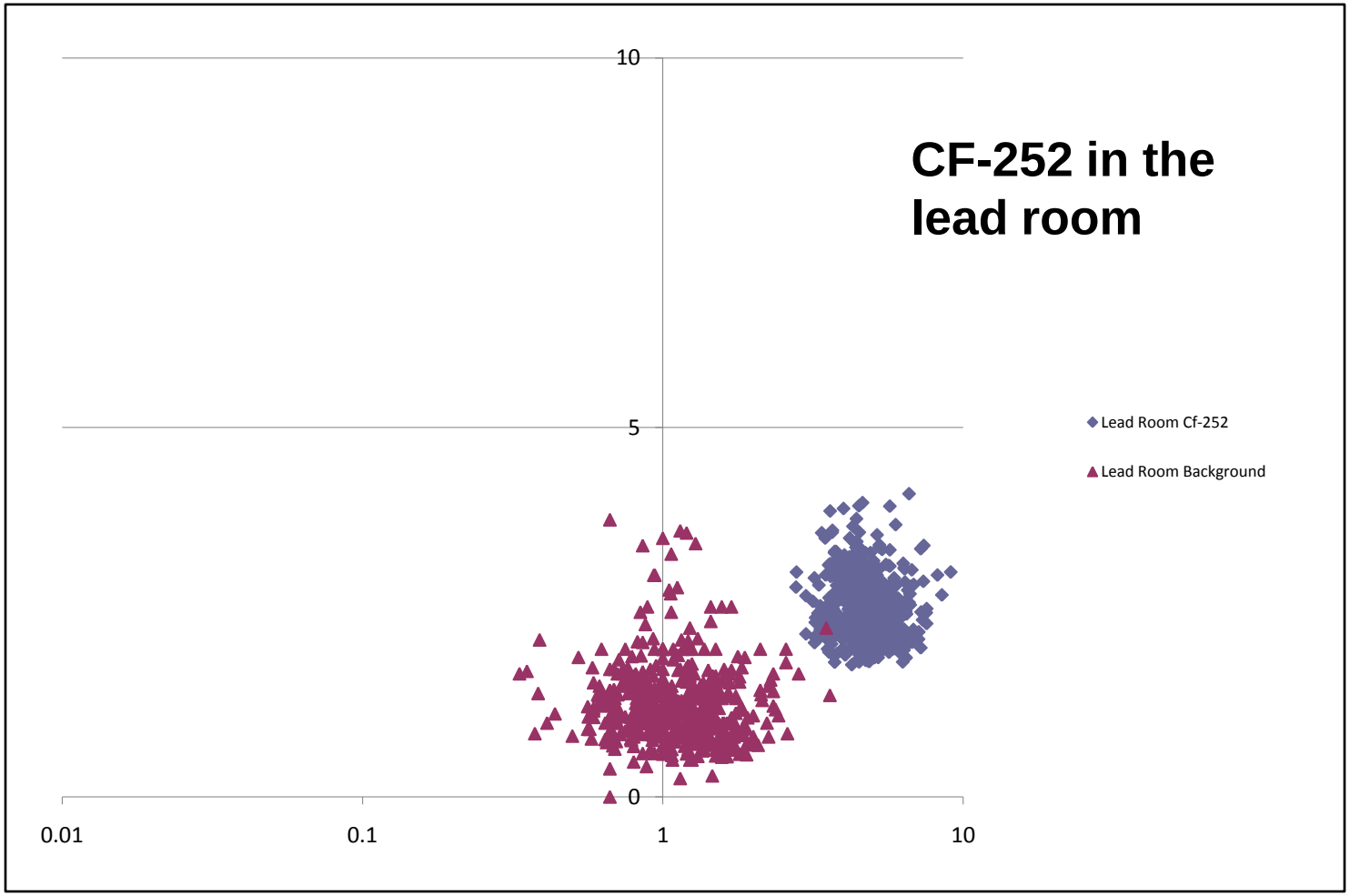
Far Field Measurements



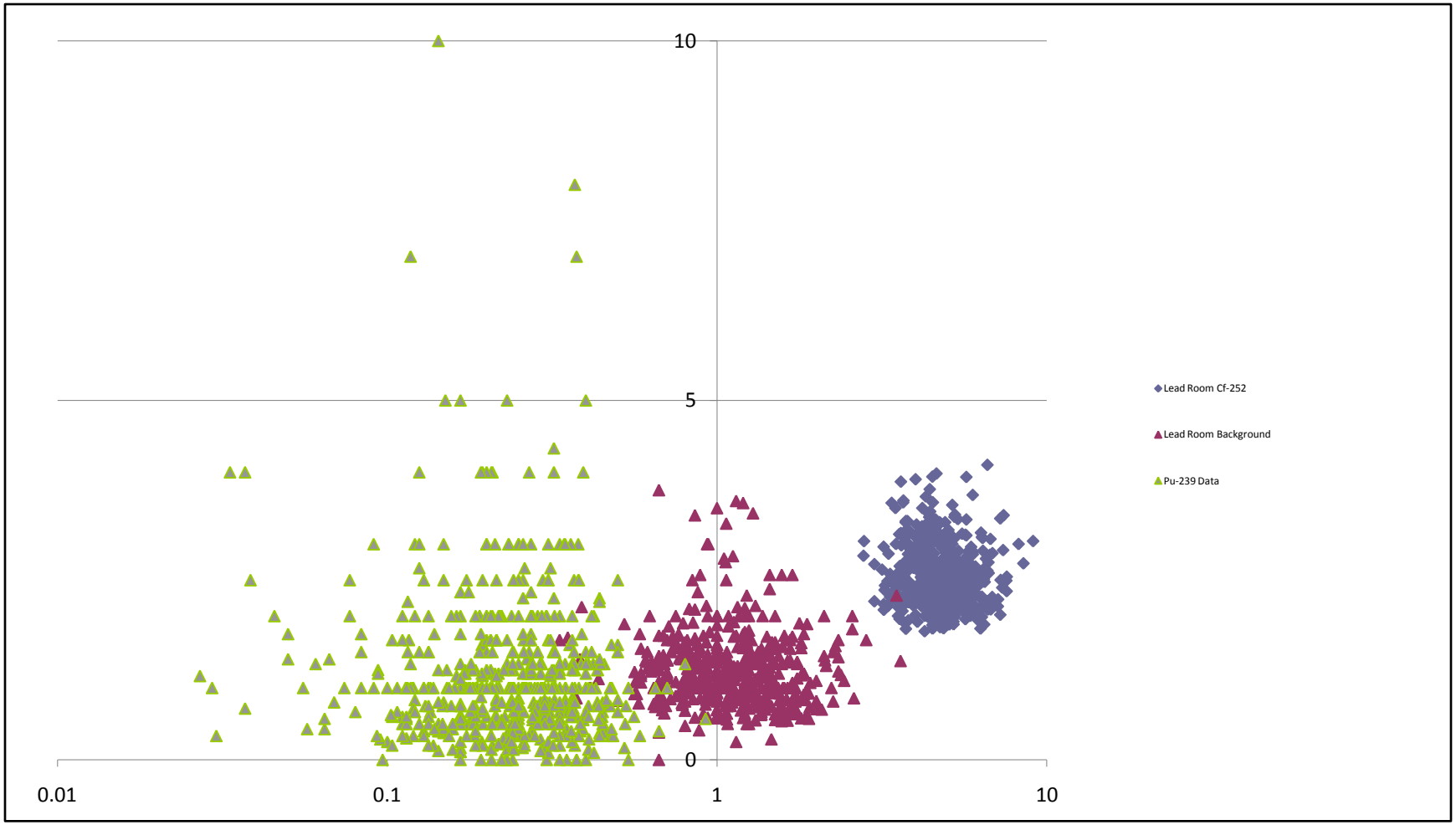
^{252}Cf cluster does not move till about 30 ft Source ~200 mCi

National Security Technologies LLC
Vision • Service • Partnership

Neutron Source Separation

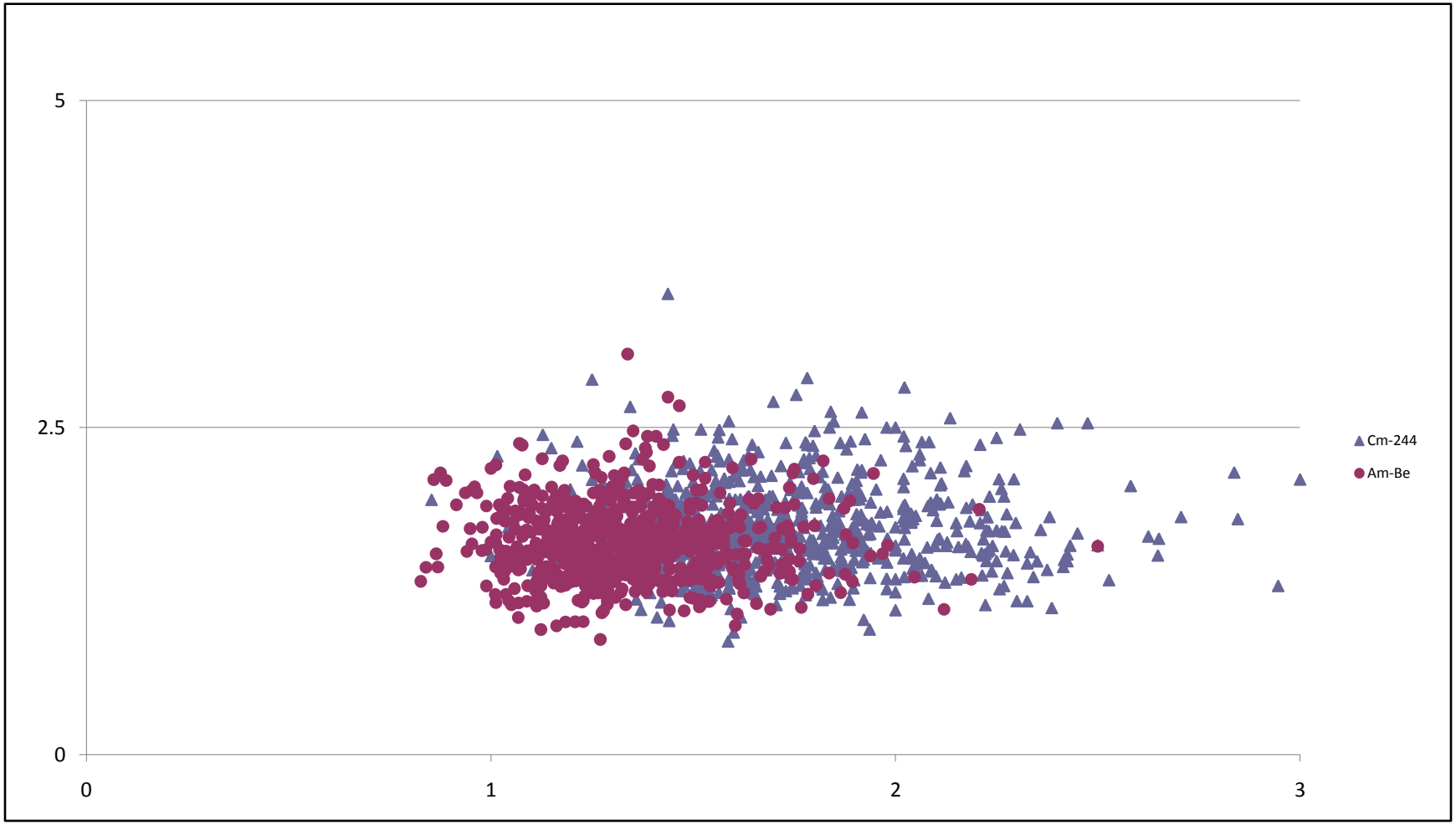


Pu-239, Lead Background, and Cf-252



National Security Technologies LLC
Vision • Service • Partnership

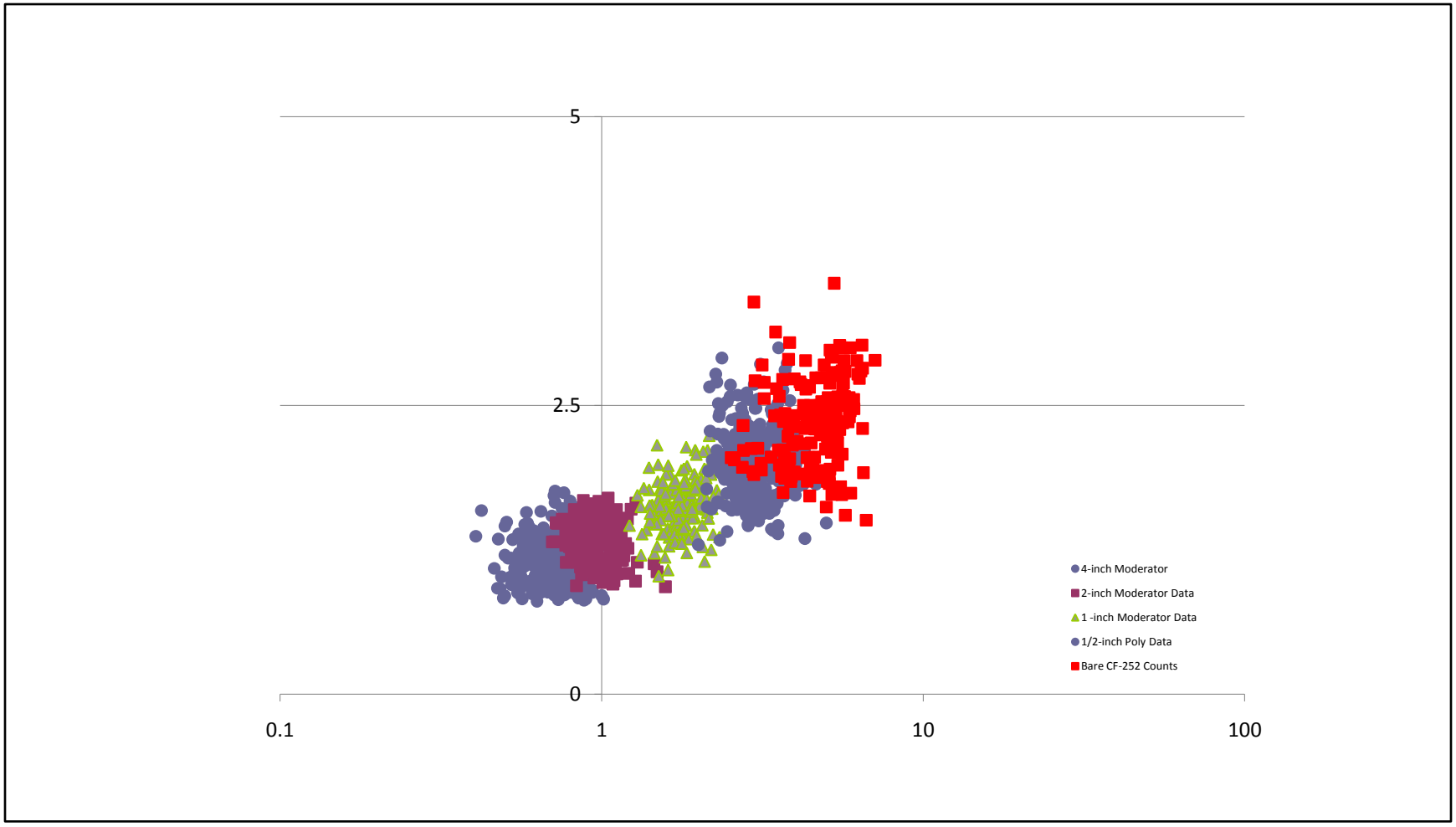
Am-Be and Cm-244 – Same Origin



National Security Technologies LLC
Vision • Service • Partnership

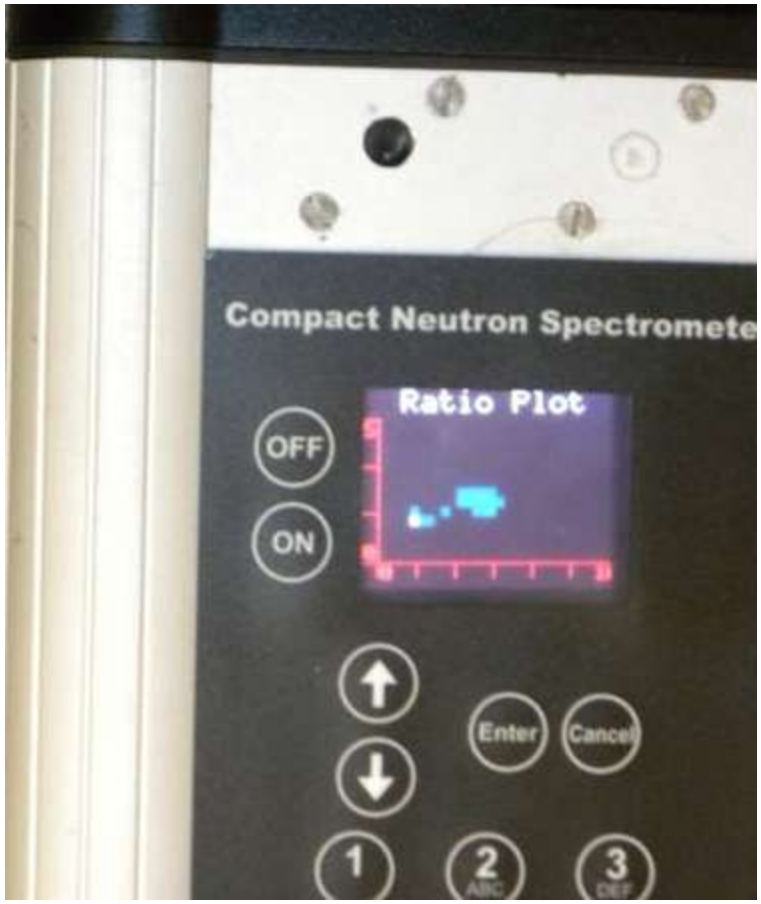
Moderated Cf-252 Source

Shielded Sources Could be recognized

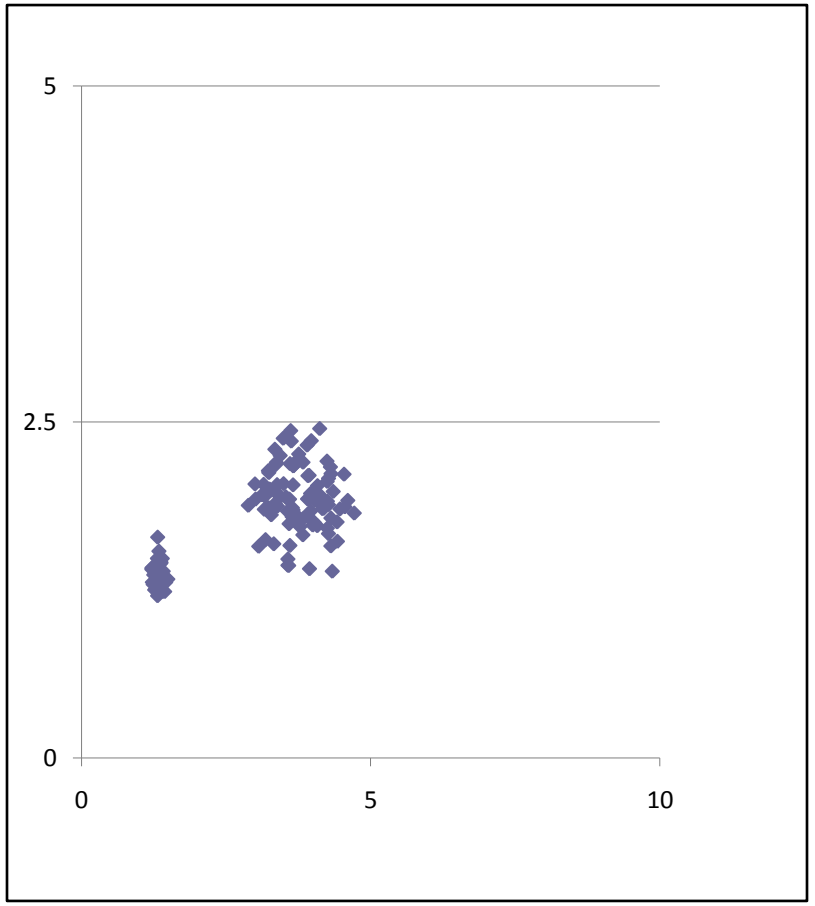


National Security Technologies LLC
Vision • Service • Partnership

Separation of Cf-252 and Am-Be

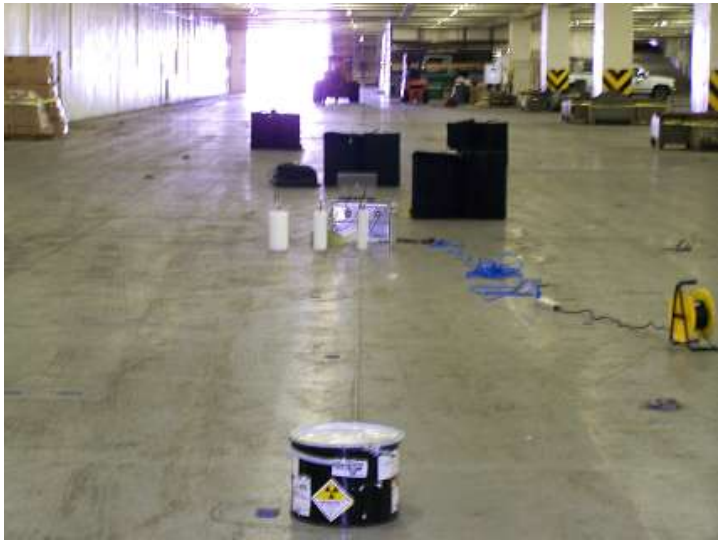


Real-time data



Data during source transition removed

Shipboard Measurement



Summary

- A light weight simple form factor compact neutron energy spectrometer ready to be used in maritime missions has been built.
- Under laboratory conditions, individual Single Neutron Source Identification is possible within 30 minutes.
- Sources belonging to the same type of origin viz., (a, n), fission, cosmic cluster in the same place in the 2-D plot shown.
- Isotopes belonging to the same source origin like Cm-Be, Am-Be (a, n) or Pu-239, U-235 (fission) do have some overlap in the 2-D plot.

Questions To Be Answered

- At what signal-to-noise ratio will the group blur together?
- Will this work when the source is inside the container?
- Will this still work when the cargo is no longer containerized?
- What is the effect of local source moderation?
- What is the optimal configuration for such a diagnostic tool?