

An Imaging Neutron/ γ -Ray Spectrometer

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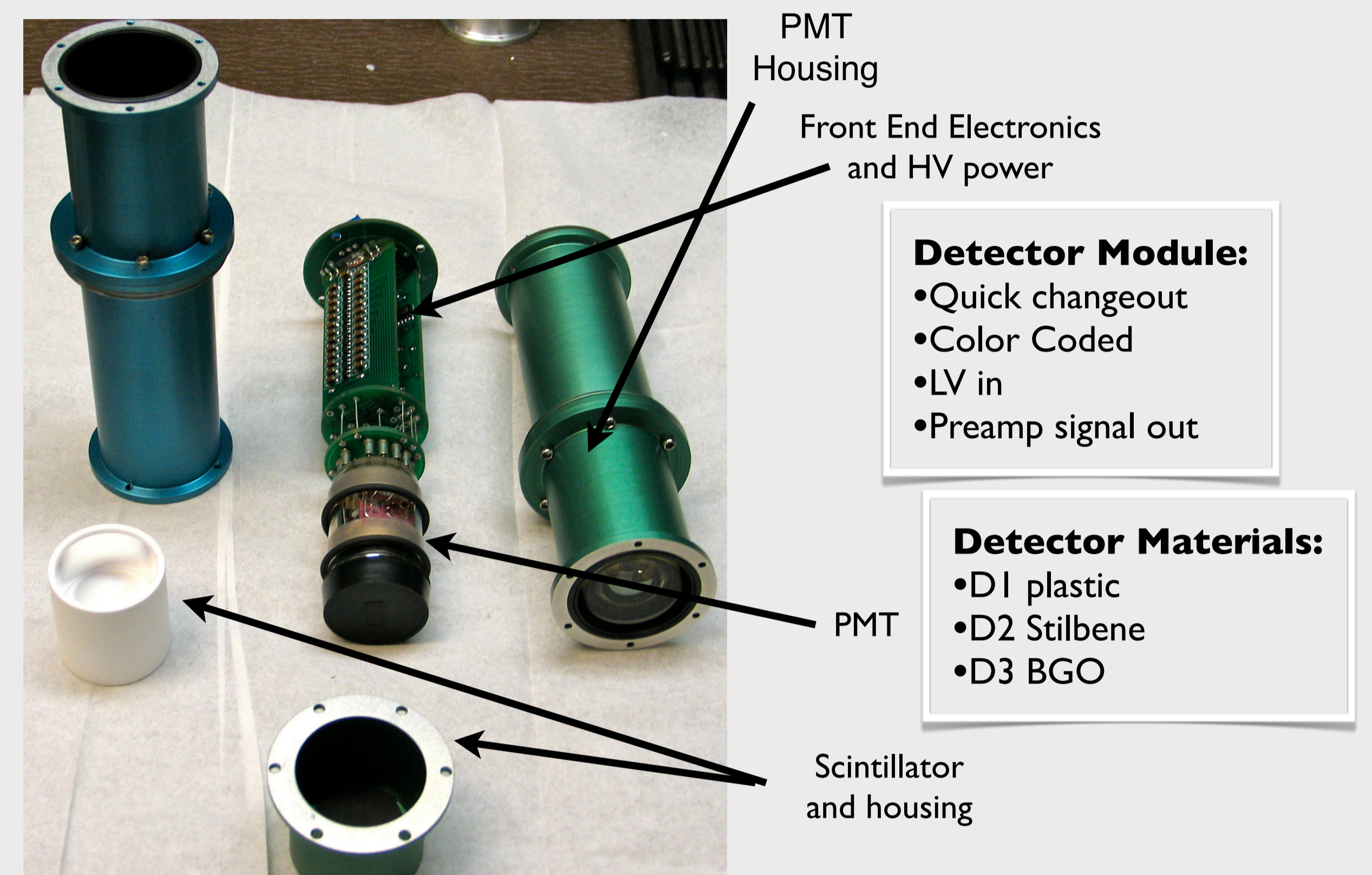
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Abstract

We present the design and development of a dual-species, neutron/ γ -ray imaging spectrometer (NSPECT) for the identification and location of special nuclear materials (SNM). Real-time detection and identification is important for locating fissile materials. These materials, specifically uranium and plutonium, emit neutrons and γ rays via spontaneous or induced fission. Co-located neutron and γ -ray emissions are a sure sign of fissile material, requiring very few spatially correlated events for a significant detection. Our instrument design detects neutrons and γ rays from all sources in its field of view, constructs images of the emission pattern, and reports the spectra for both species. The instrument is optimized for imaging and spectroscopy in the 1-20 MeV range. The detection principle is based upon multiple elastic neutron-proton scatters in organic scintillator for neutrons, and Compton scattering in organic scintillator followed by absorption in inorganic scintillator for γ rays. We have developed and tested a prototype imaging neutron/ γ spectrometer using three scintillator layers, and successfully recorded the images and spectra of both Cs-137 and Cf-252 sources (neutrons and γ 's). We report the initial performance of the prototype in the laboratory and in simple field tests.

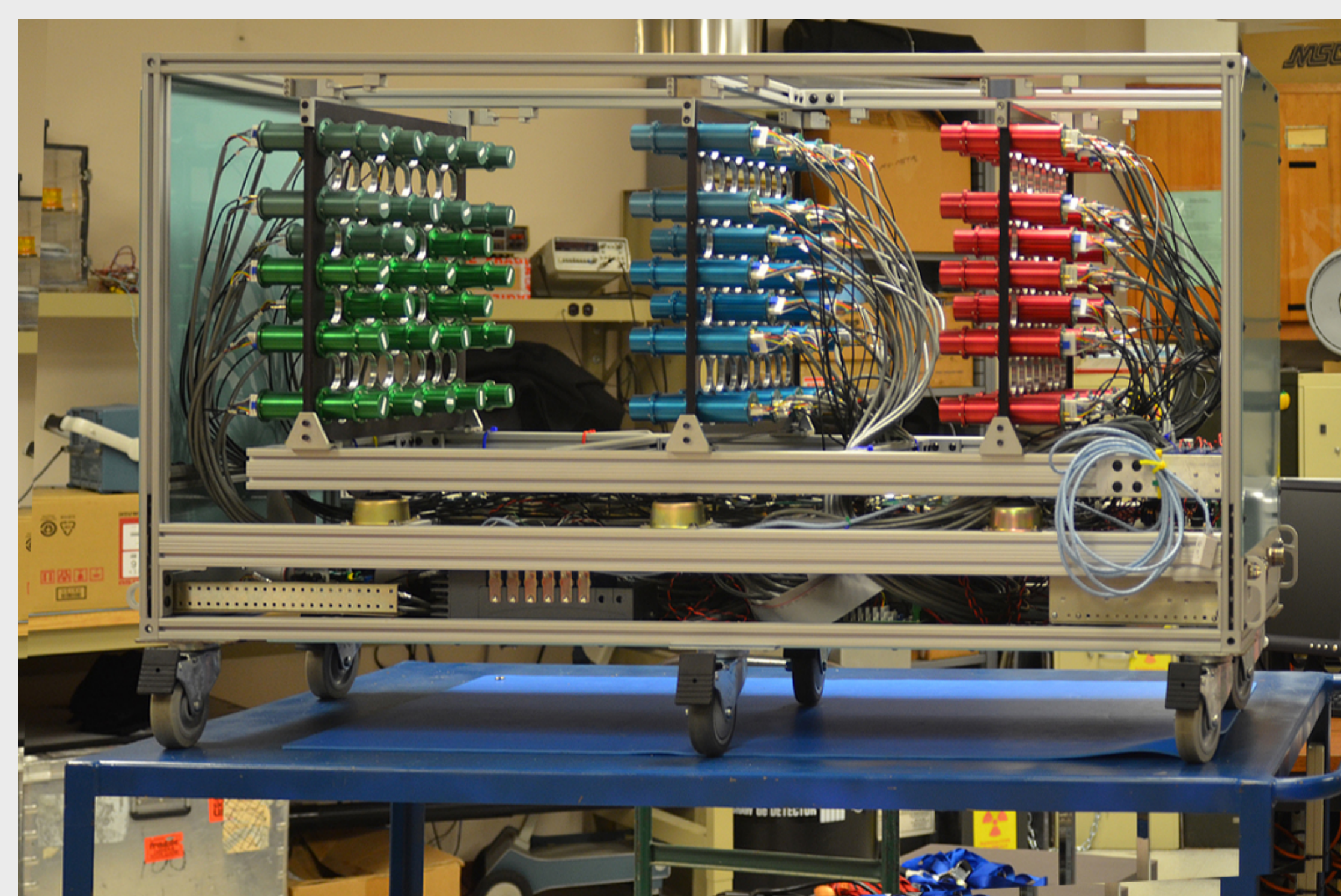
Design and Fabrication



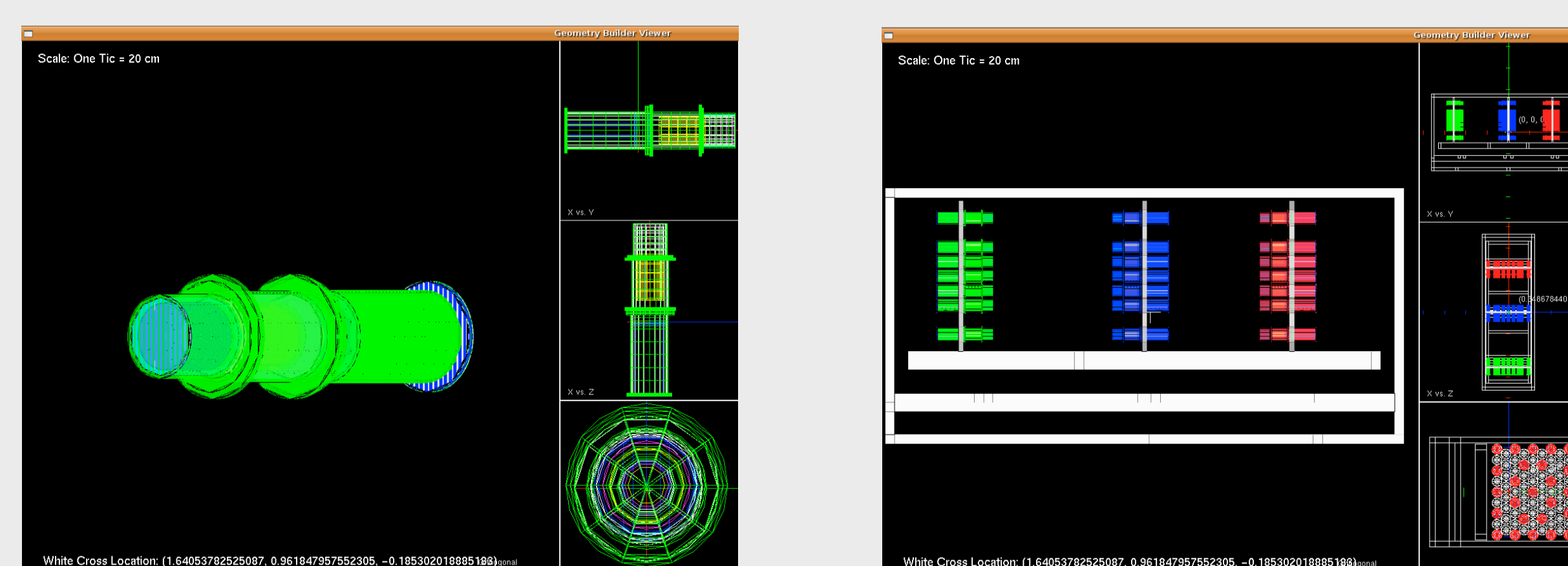
- Field Transportable System with Real Time Feedback
- Draws 25W from on-board battery, external 12 VDC, or 120 VAC
- Operates a minimum of 8 hrs off on-board battery

Technical Details

Instrument Parameter	Neutron Mode	Gamma Mode
Detector Modules	25/D1; 25/D2	25/D2; 25/D3
Detector Dimensions	1" ϕ x 1" right circular cylinders	
Plane Separation	30 cm	30 cm
Energy Resolution @ 1 MeV	100 keV	150 keV
Angular Resolution (FWHM) @ 1 MeV	10° (53 cm @ 3 m)	9° (48 cm @ 3 m)
ToF Resolution @ 1 MeV	~ 900 ps	~ 1000 ps
Field of View (FHHM)	90°	60°
Instrument Mass and Power	63 kg / 25 W	
Instrument Dimensions	1500 x 50 x 85 cm	
Instrument Control and DA	via local or remote laptop	



(Above) The chassis, frame and detectors of the NSPECT prototype. Each layer contains 25 detector modules. The electronics and power lie beneath the mounting plates for the detectors.

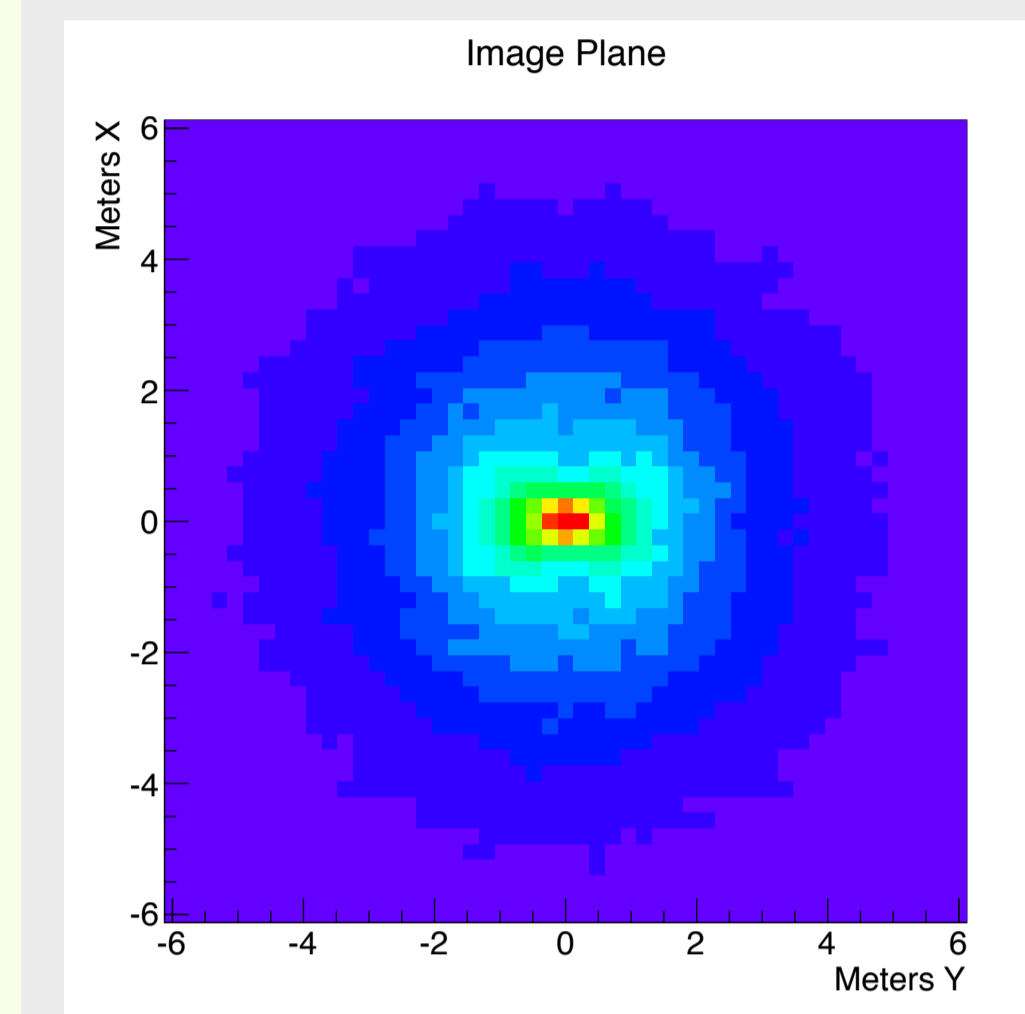


Instrument modeling is performed using the SWORD package. Shown is the SWORD mass model of a detector module (left) and top view of NSPECT (right) with each plane populated with 25 detector modules

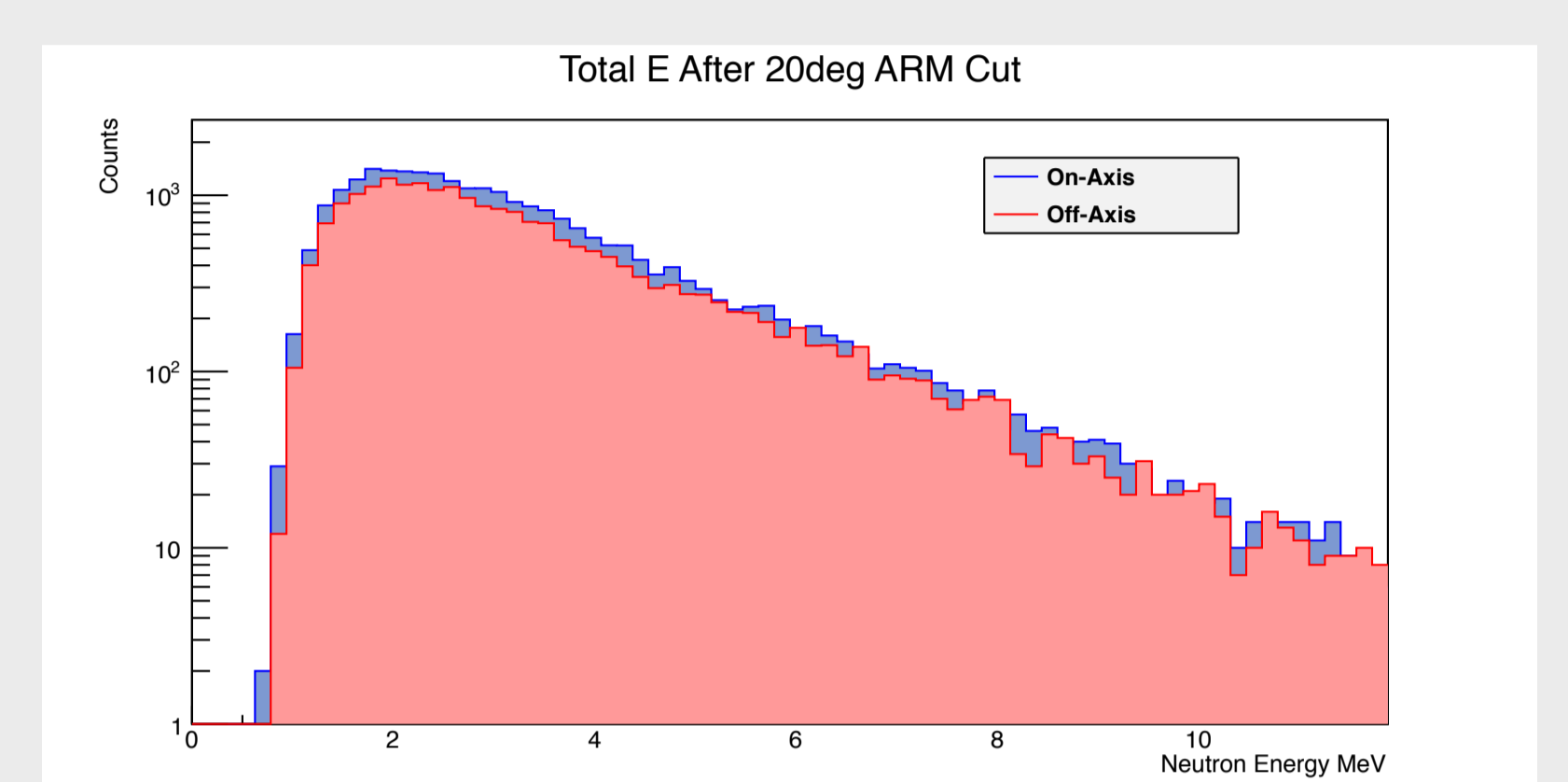
Performance

Neutron Imaging and Spectroscopy

Neutron image of ²⁵²Cf @ 2 m, on-axis:

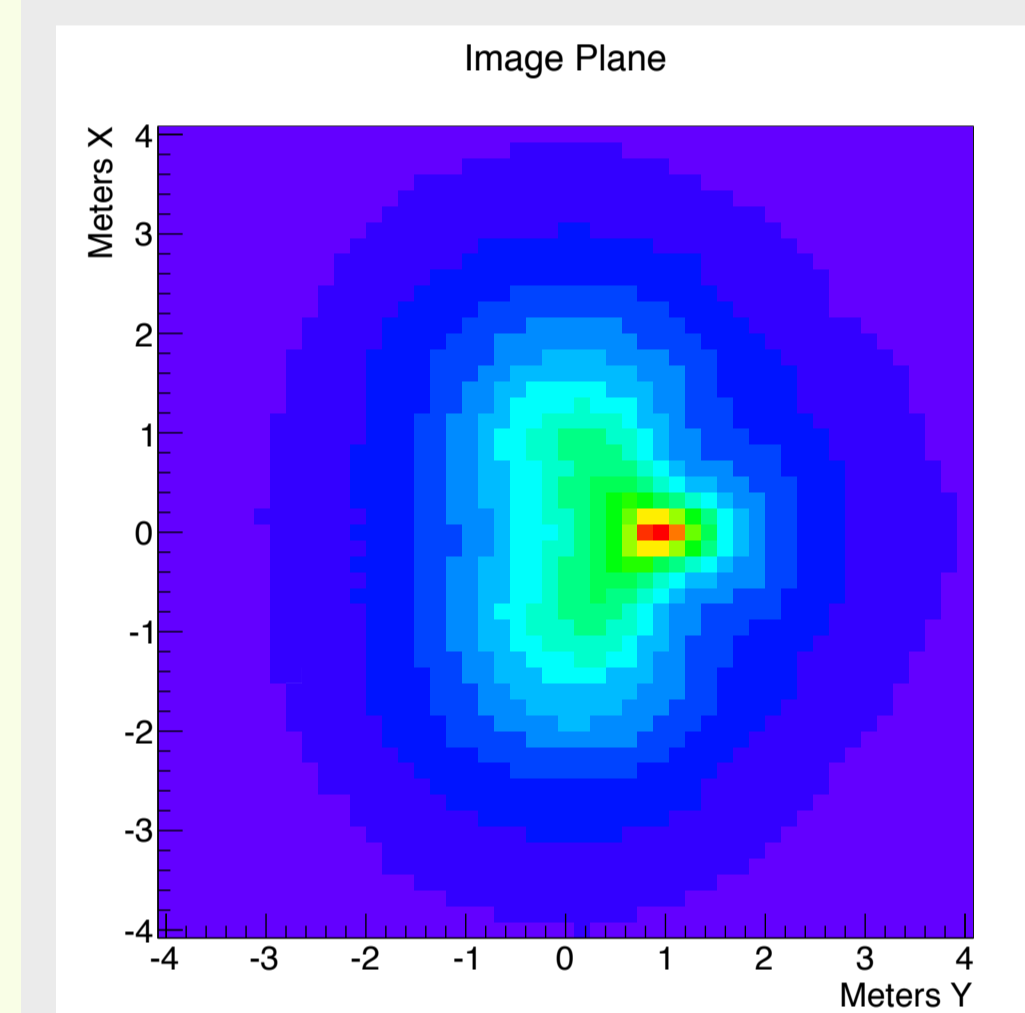


²⁵²Cf neutron count spectrum from on-axis and 1 m off-axis:

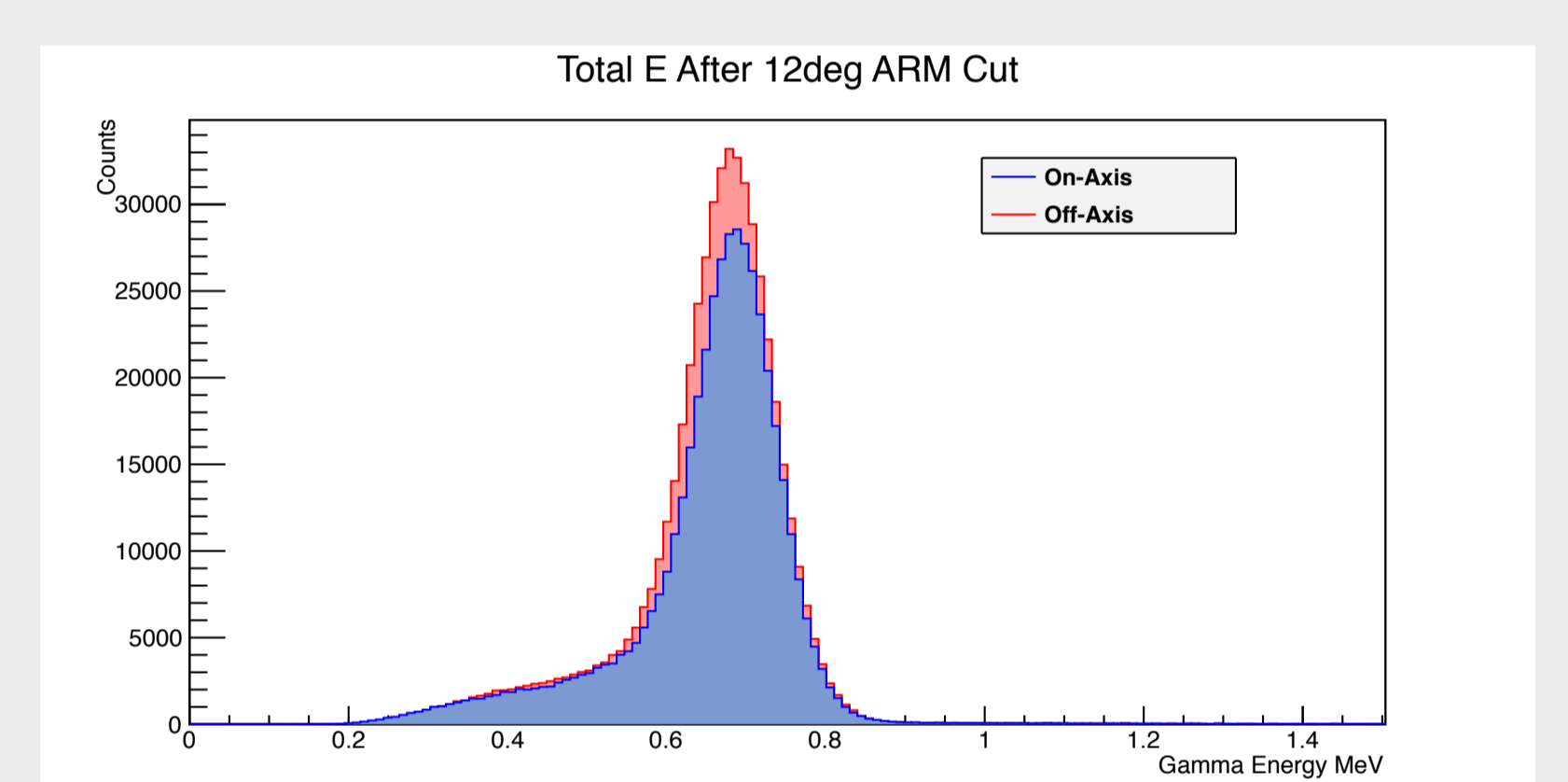


γ -Ray Imaging and Spectroscopy

γ image of ¹³⁷Cs @ 2 m, 1 m off-axis:

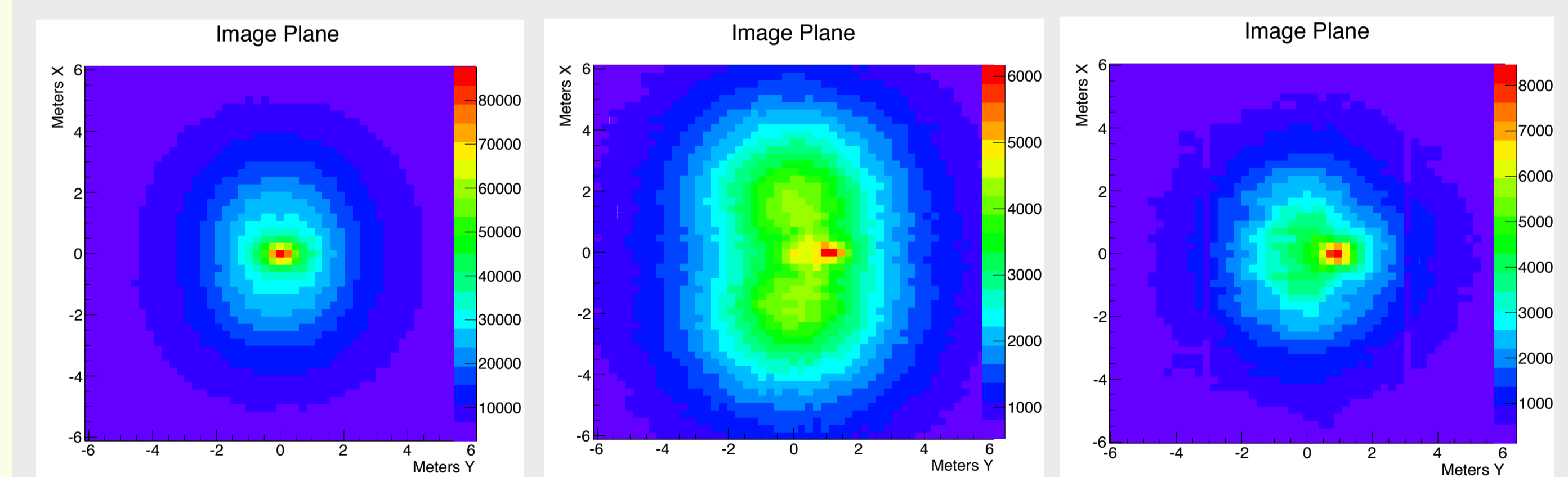


¹³⁷Cs γ count spectrum from on-axis and 1 m off-axis:



Dual Species Imaging and Spectroscopy

A ¹³⁷Cs source was placed on-axis and a ²⁵²Cf source 1 m off-axis. The neutron and γ signals from each were isolated using PSD, ToF, and energy cuts:



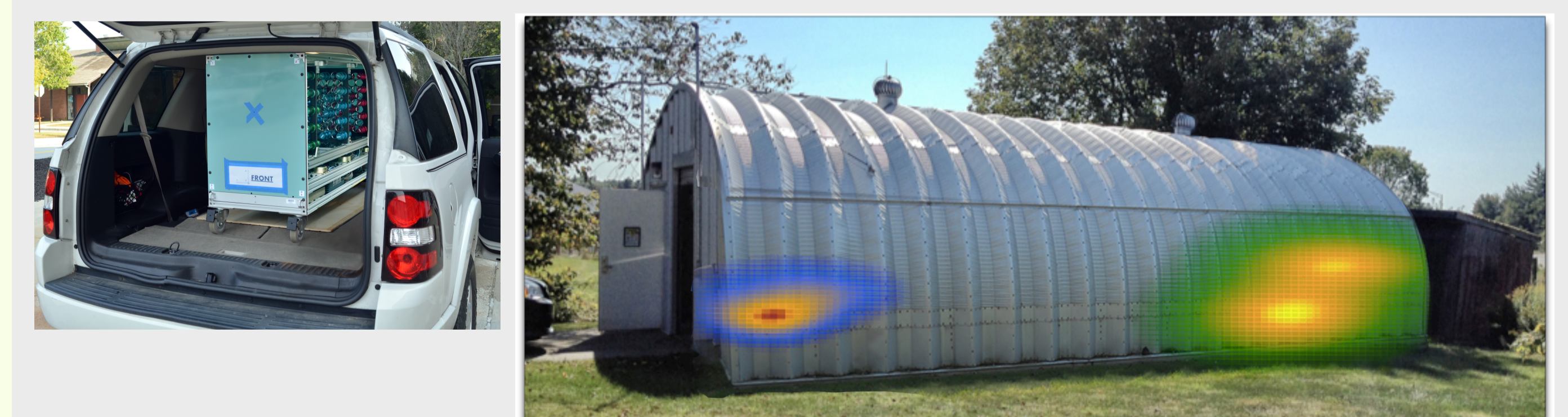
γ image around 662 keV

γ image excluding 662 keV

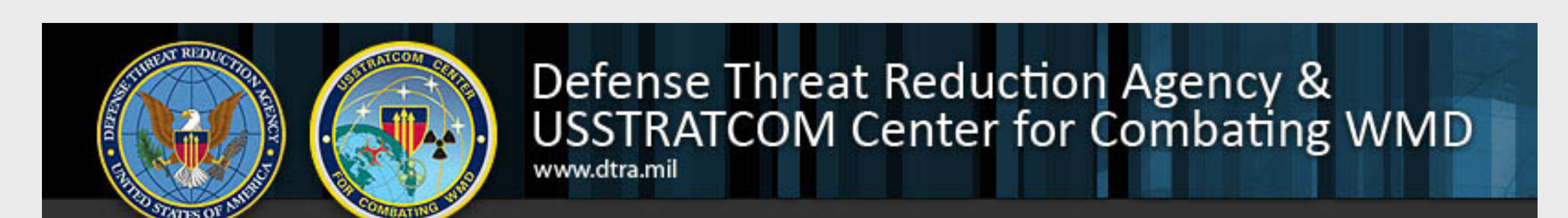
Neutron image

Field Test: Imaging Sources in a Building

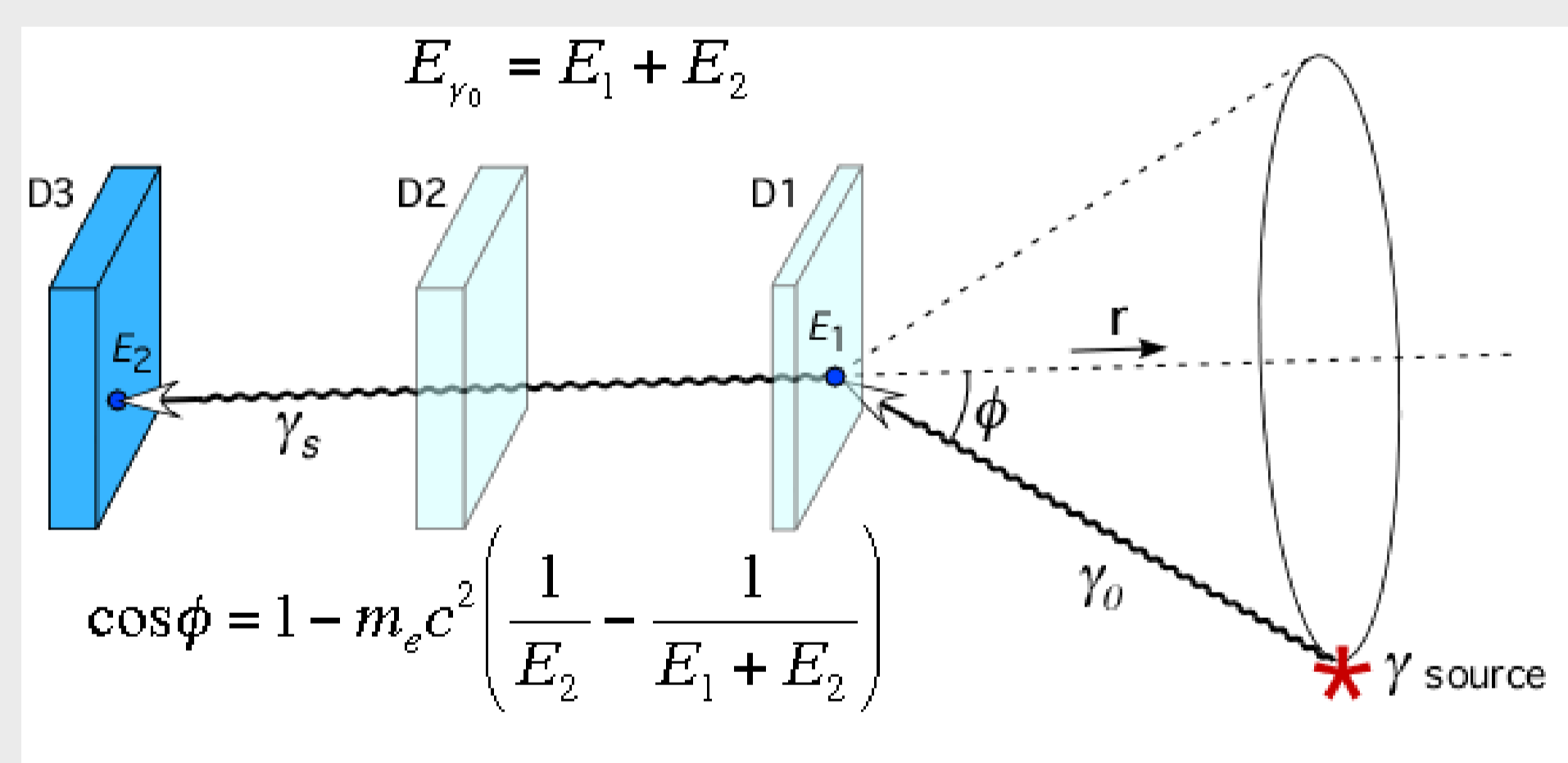
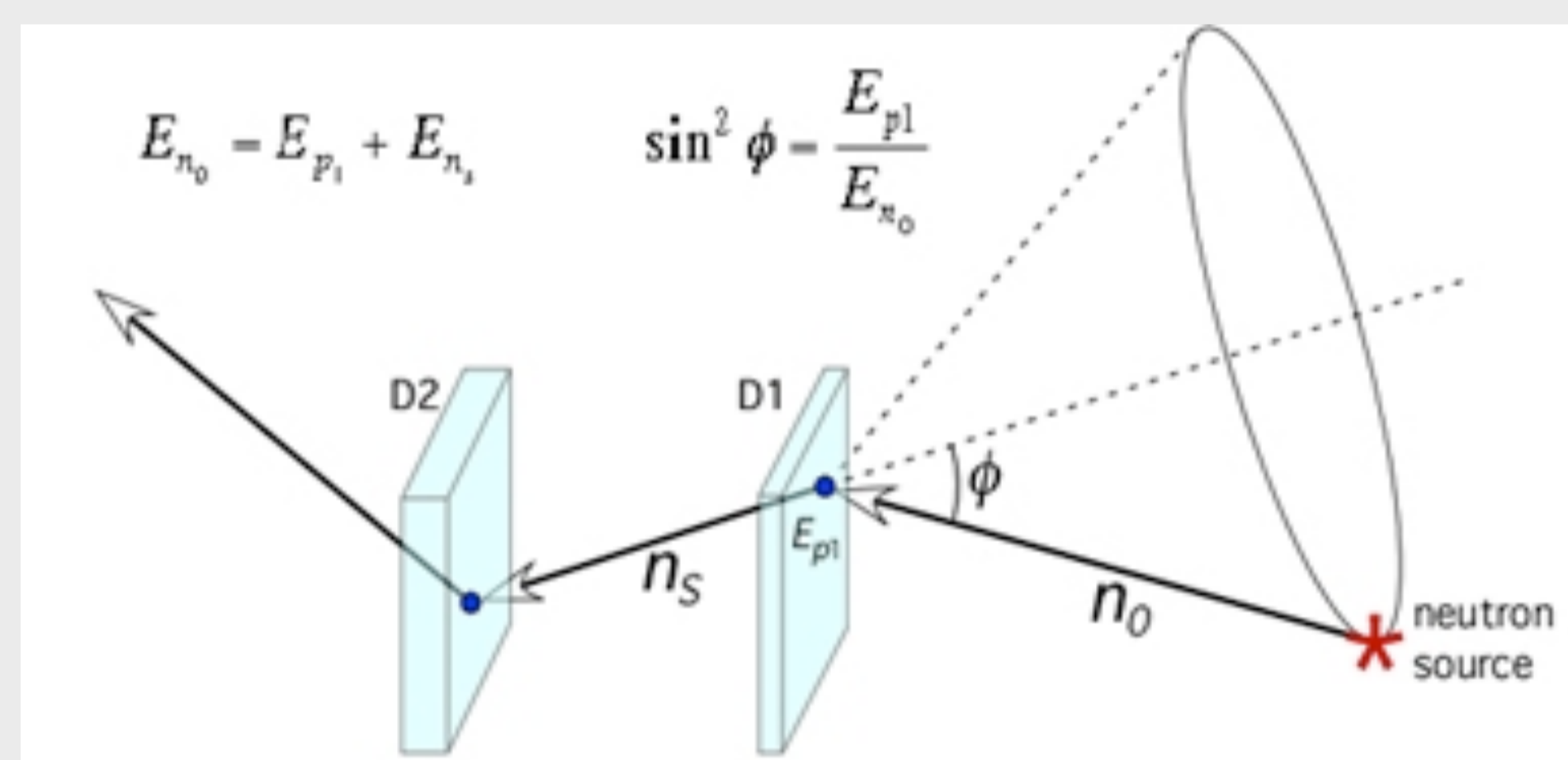
The NSPECT prototype was placed in the back of an SUV (right). The ¹³⁷Cs and ²⁵²Cf sources were placed in a quonset hut on the UNH campus. From a position parked several meters away, NSPECT was able to detect, locate, and identify both sources (left).



Acknowledgements



Detection Physics



A three-layer instrument measures and images neutron and γ sources. Neutrons are scattered between D1 and D2, while γ rays preferentially scatter between D2 (or D1 as shown) and D3. The scattering takes the form and obeys the kinematics shown in the above two figures. The embodiment of this concept is schematically shown below with arrays of detector cells filling the planes.

