# Design Investigation of a Scalable Fast Neutron Radiography Panel

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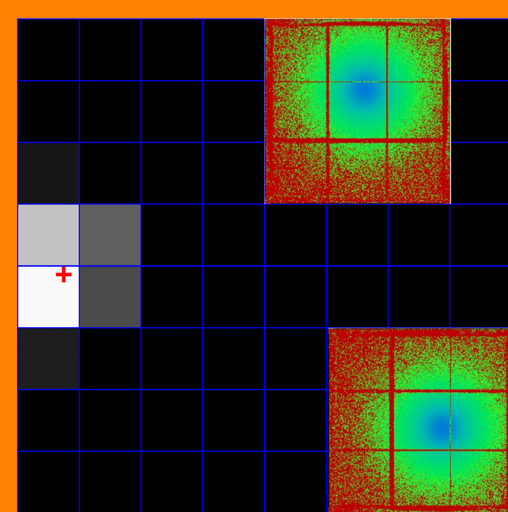
## INTRODUCTION

- Advances in flat-panel radiography device design have increased the use of radiation imaging as a nondestructive evaluation tool
- Neutron radiography offers many advantages compared to photon-based radiography [1]
  - Neutrons penetrate dense, high-Z metals more effectively than photons
- Typical neutron imaging systems [2,3]:
  - Large, immobile neutron facilities
  - Reliant on absorption-based conversion
  - Uses a thin (<1mm) scintillator, mirror, and camera
  - High resolution with cold neutrons
  - Poor image resolution with fast neutrons
- A flat-panel fast-neutron radiography imager must:
  - Have a compact and portable form factor
  - Use proton recoil instead of absorption
  - Use thick (>1mm) higher efficiency scintillators
  - Be comprised of tileable readout modules
  - Achieve millimeter-scale resolution with fast neutrons

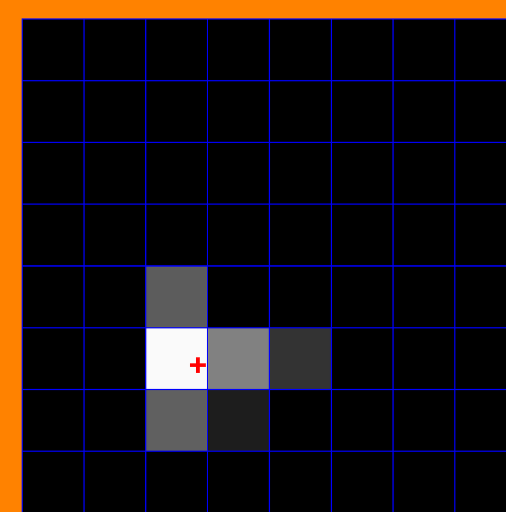
## METHODS

- Zemax simulations were used to simulate scintillation light spread on silicon photomultipliers (SiPMs)
  - Simplified to a 3 x 3 area of SiPMs with Anger logic localization
  - Quantified differences between actual scintillation event position and computed event position with varying light spreader thicknesses
- Tileable detector module assembled using:
  - Ideas ROSSPAD readout module
  - 8 by 8 array of 6 mm SensL MICROFJ-60035-TSV SiPMs
  - 3 mm of Eljen Technologies EJ-200 scintillator
  - Polycarbonate light spreader
- Data collection and processing methods were developed
  - Packet capture data processed and stored in a SQLite database file
  - Using flood field illumination data, background, noise, and gain corrections were generated for each SiPM
  - Scintillation events were localized using a dual 1D Gaussian fitting method
  - Localized events were combined into high-resolution energy weighted and unweighted radiographs
- A fan beam image was generated using a narrowly collimated Cs-137 source
  - The spatial resolution of the system was determined using the full-width half-max (FWHM) and modulation transfer function (MTF) of the fan beam

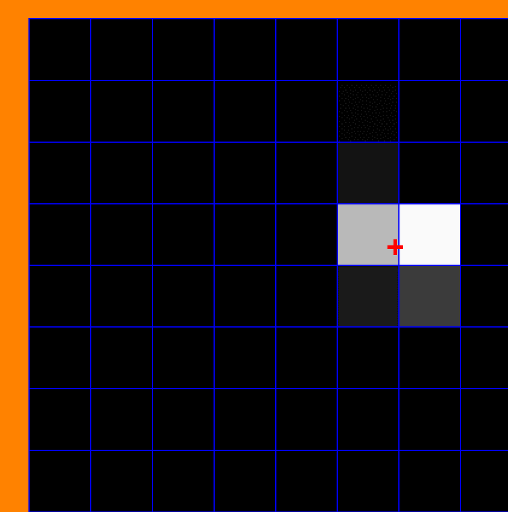
# Proper calibration and scintillation event localization yield sub-SiPM spatial resolution.



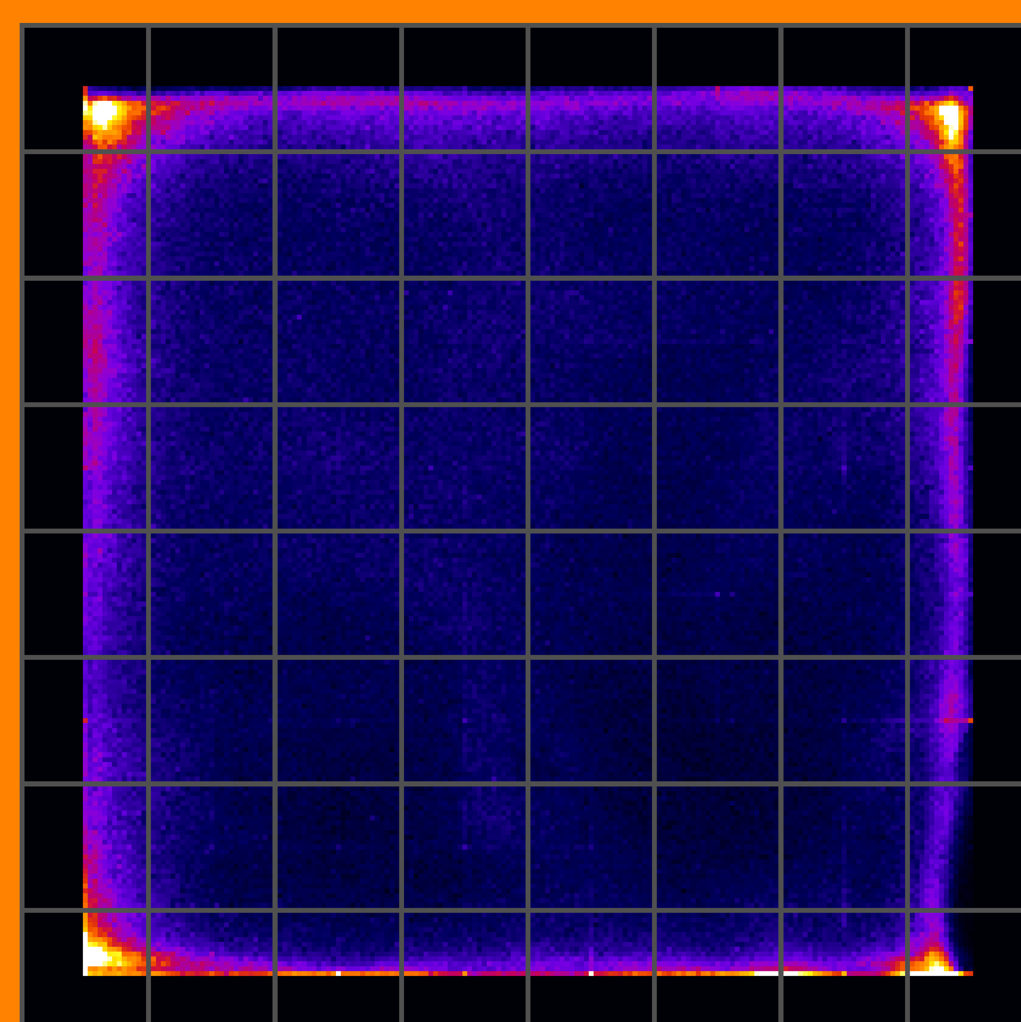
**Example Simulated Light Spreads & Event #2**



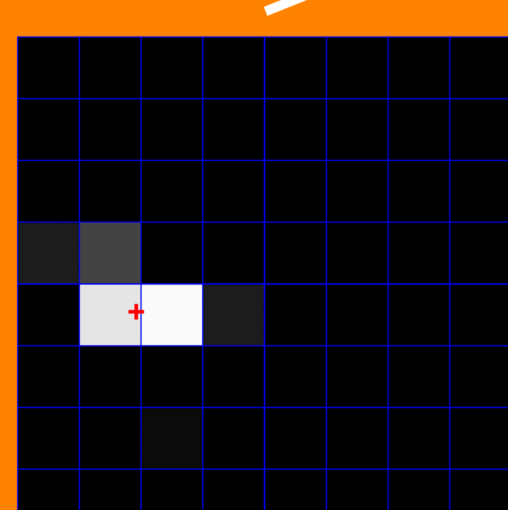
**Event #50**



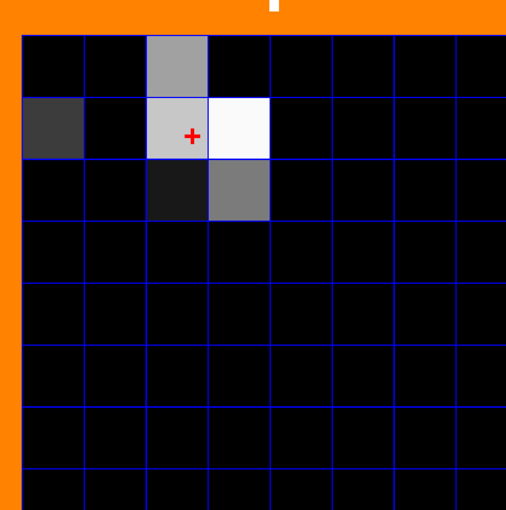
**Event #60**



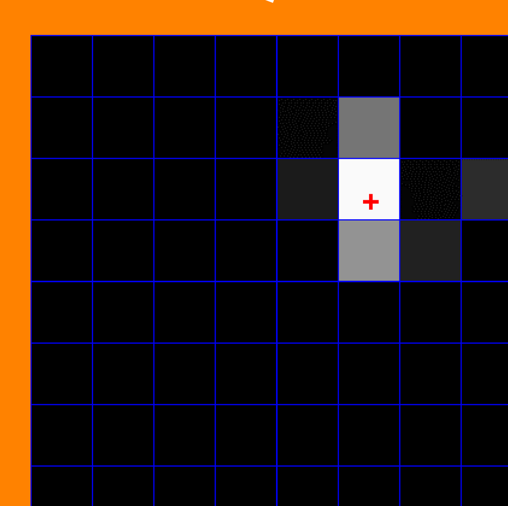
**Cs-137 Flood Field (n = 1.3 x $10^6$)**



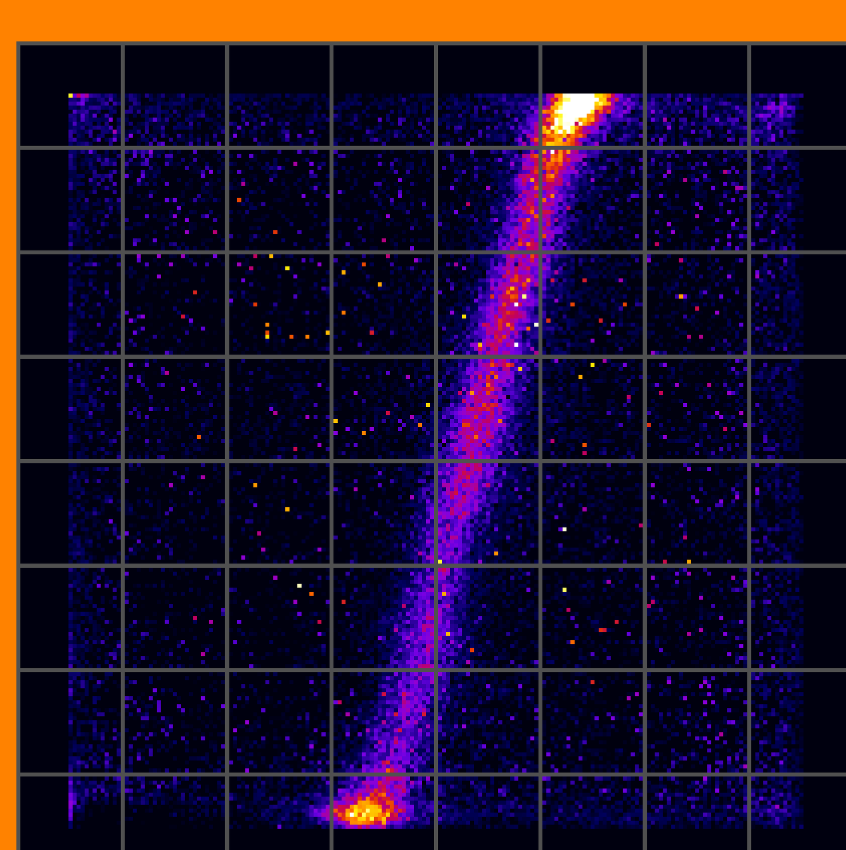
**Event #77**



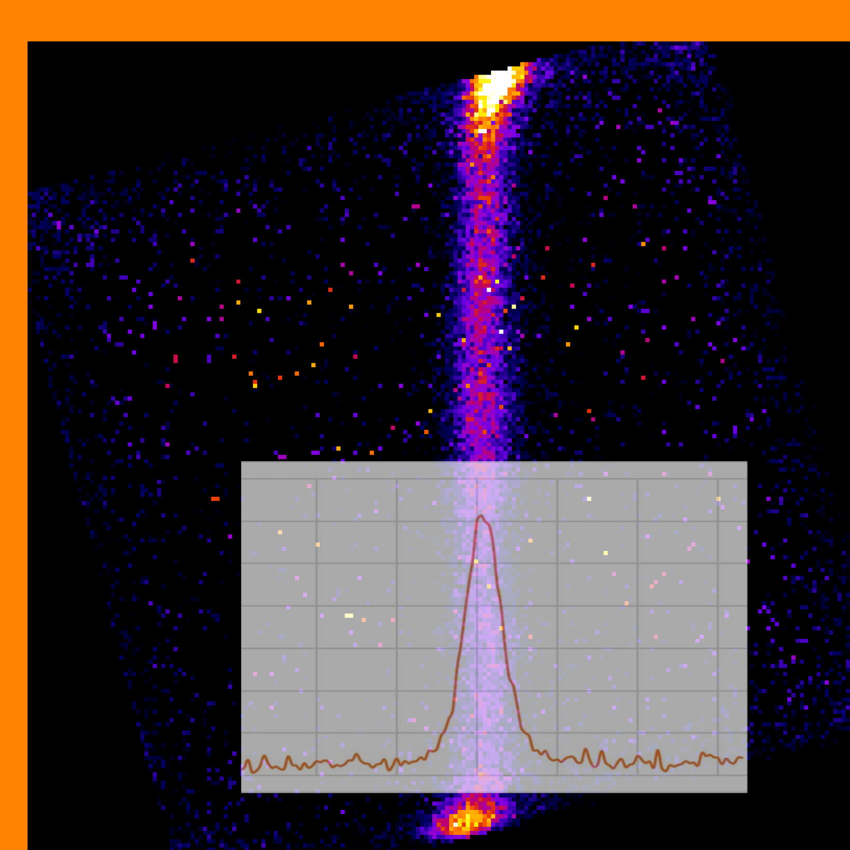
**Event #14**



**Event #94**



**Cs-137 Fan Beam (n = 6.0 x $10^4$)**



**FWHM = 2.75 mm**
**MTF(0.1) = 2.25 mm**

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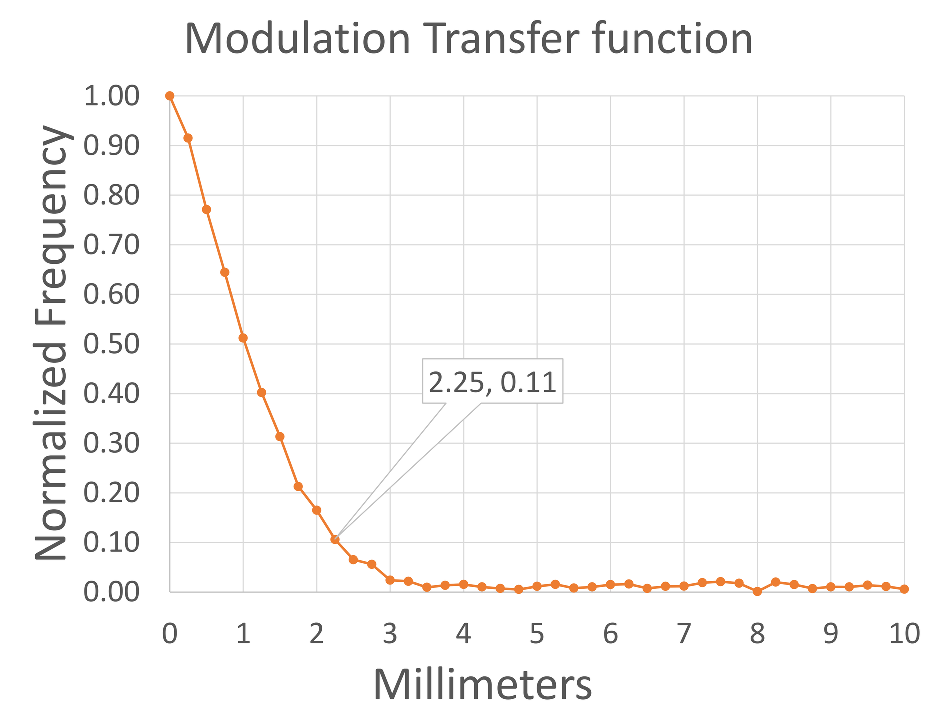
## RESULTS

- 3 mm thick light spreader allows for the best localization based on Anger logic methods
- Gaussian localization methods provide better continuous event localization compared to nearest neighbor Anger logic localization
- Precise background, noise, and gain correction drastically improves localization accuracy within the detector
- Fan beam measurements using Cs-137 show a spatial resolution of 2.25 mm
  - Spatial resolution is approximately 1/3 the pitch of the SiPMs, effectively turning every SiPM into 9 pixels
  - Goal of sub-SiPM resolution achieved




## FUTURE WORK

- Edge correction to spread events to edge of the ROSSPAD
- Characterize spatial resolution using neutrons
- Build a prototype flat-panel neutron radiography imager
- Improve localization methods to span across multiple adjacent ROSSPAD readout modules
- Develop and characterize thicker, segmented scintillator blocks
- Increase spatial resolution to 1.25 - 1.00 mm (1/4 - 1/6 SiPM pitch)

## REFERENCES

[1] J. S. Brzosko, B. V. Robouch, L. Ingrosso, A. Bortolotti and V. Nardi, "Advantages and limits of 14-MeV neutron radiography," Nuclear Instruments and Methods in Physics Research B, vol. 72, pp. 119-131, 1992.
[2] D. L. Williams, C. M. Brown, D. Tong, A. Sulyman and C. K. Gary, "A Fast Neutron Radiography System Using a High Yield Portable DT Neutron Source," Journal of Imaging, vol. 6, no. 12, p. 128, 2020. [3] J. S. Brzosko, B. V. Robouch, L. Ingrosso, A. Bortolotti and V.
[3] S. Bishnoi, P. S. Sarkar, R. G. Thomas, T. Patel, M. Pal, P. S. Adhikari, A. Sinha, A. Saxena and S. C. Gadkari, "Preliminary Experimentation of Fast Neutron Radiography with D-T Neutron Generator at BARC," Journal of Nondestructive Evaluation, vol. 38, 2018.



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