Proton Recoil Event Localization for Fast Neutron Radiography

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THE UNIVERSITY OF TENNESSEE KNOXVILLE

ASNT Research Symposium, Columbus, OH, 26-30 June 2023

Introduction

- Neutron Radiography is important for imaging dense, metallic objects
- Many current neutron radiography systems require:
  - Large-scale user facilities to produce neutrons [1, 2]
  - Low-efficiency thin-film converters to detect fast neutrons [3]

Goal

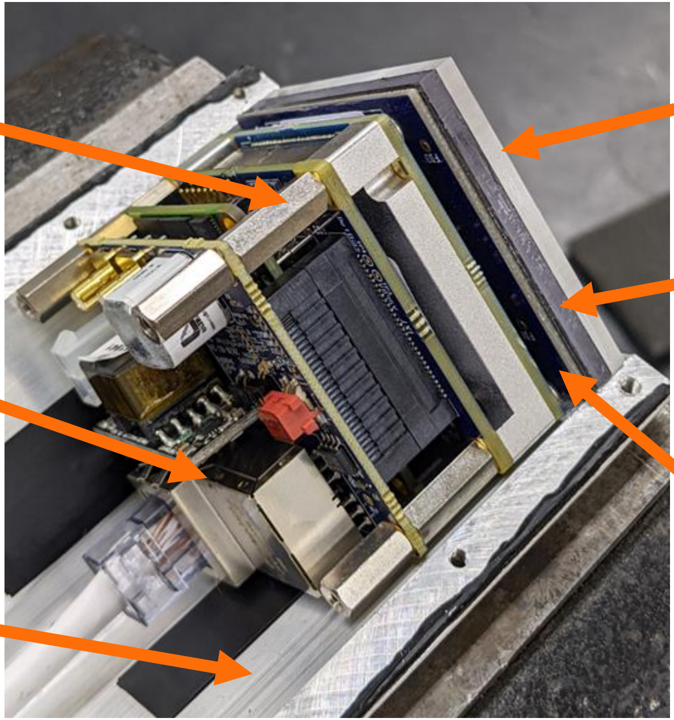
- Develop a fast-neutron radiography panel that is:
  - Portable
  - Modular (easy to scale)
  - Comprised of COTS components
- Panel is designed for transmission radiography using D-D or D-T neutrons

Detector Module

ROSSPAD readout module

Power-over-Ethernet Connection

Aluminum housing



3-mm-thick sheet of EJ-200

3-mm-thick sheet of acrylic

8 by 8 board of 6-mm-pitch SiPMs

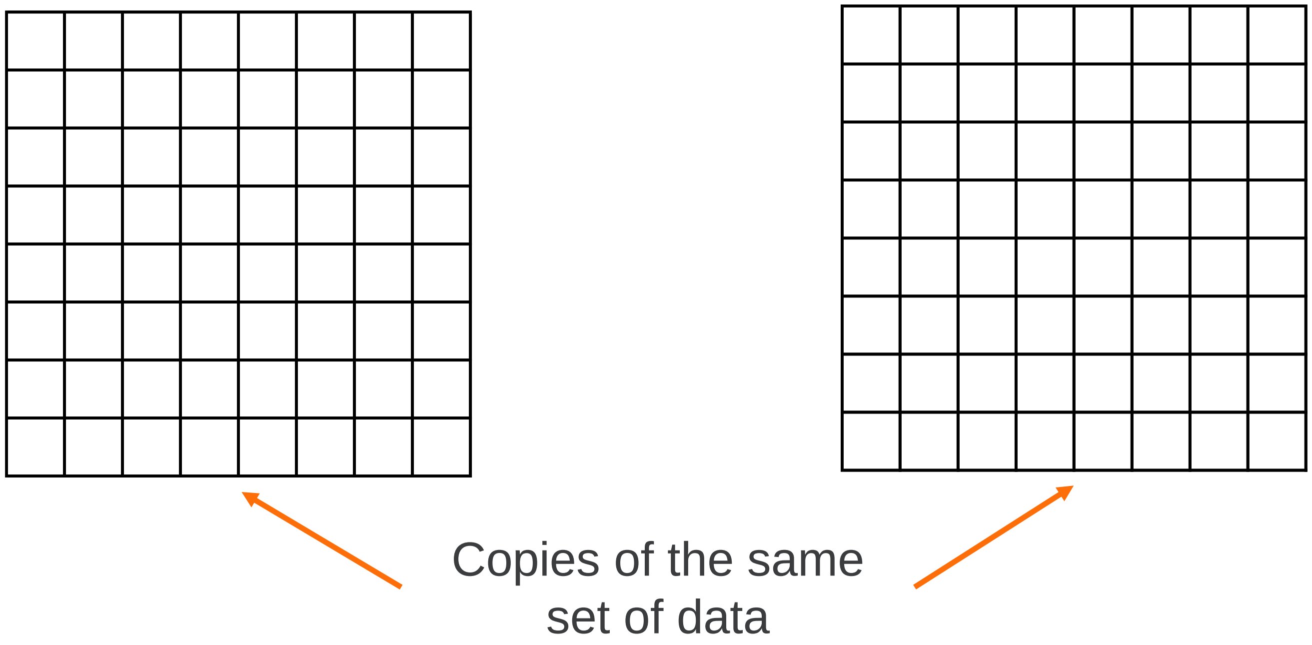
Dynamic Calibration

- SiPMs tend to be noisier than PMTs
- Dynamic calibration allows for:
  - Accurate noise and gain correction for each radiograph
  - SiPM by SiPM calibration

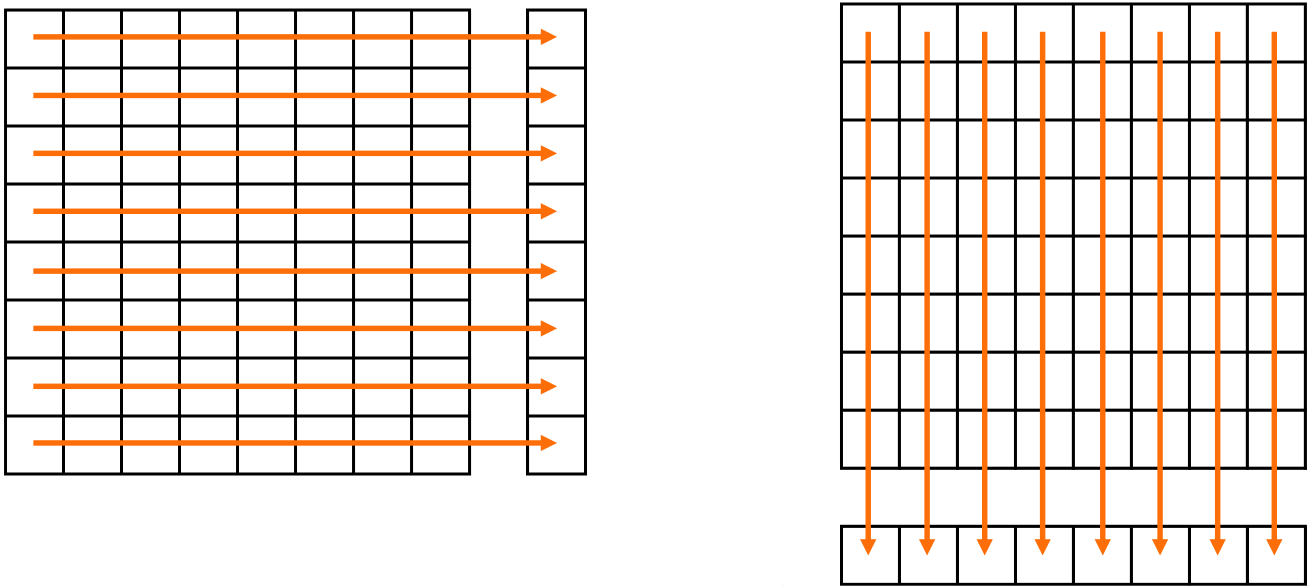
Localization Methods

- Light from EJ-200 scintillator reaches SiPM board
- Signal from single event (on all 64 SiPMs) used to generate sub-SiPM position)
- Two methods in use:
  - Weighted average
  - 2D Gaussian solving

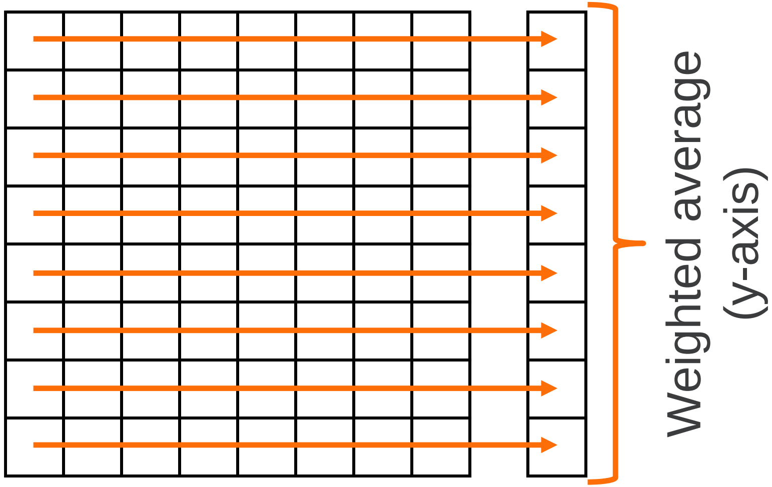
Weighted Average Approach

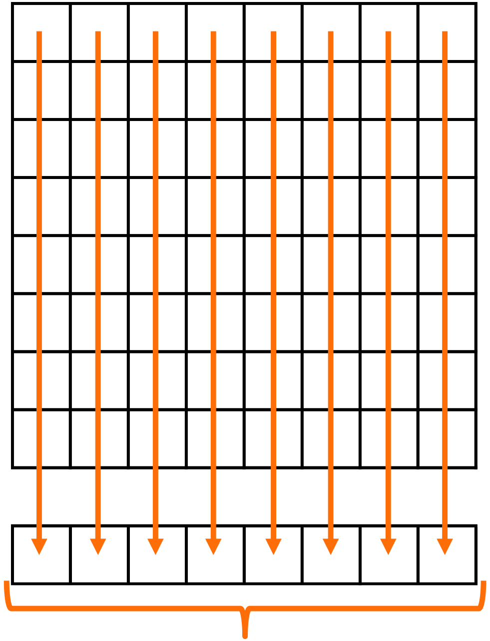


Weighted Average Approach



Weighted Average Approach

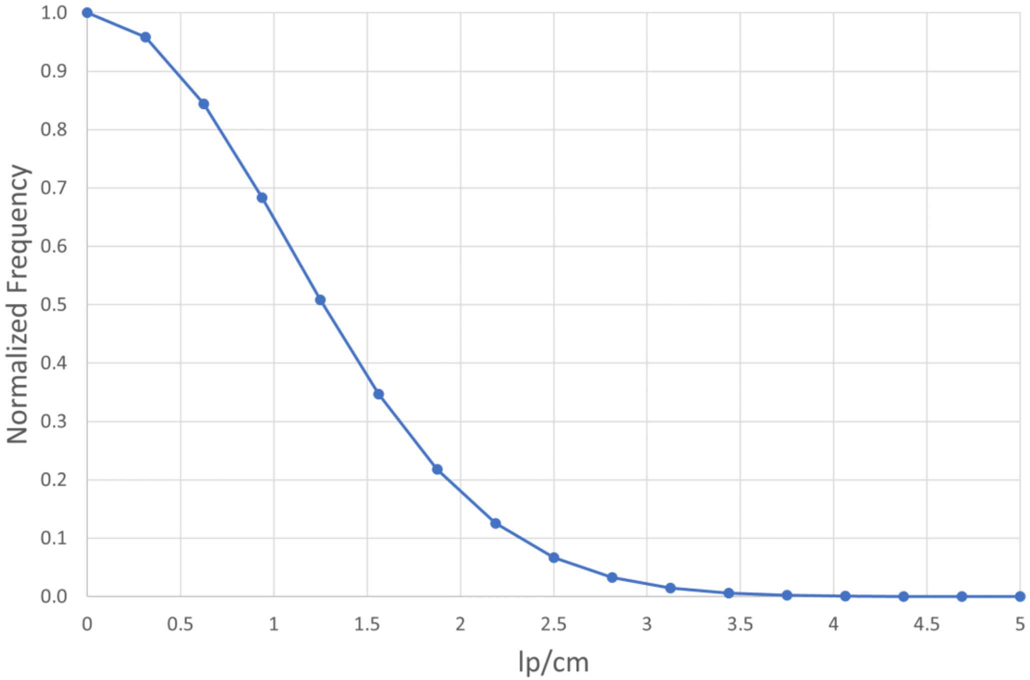




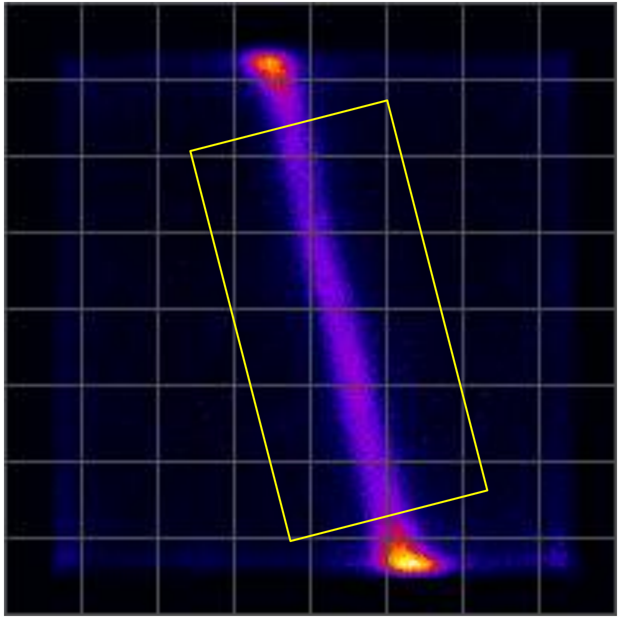
Weighted Average

- Results currently in-review with the Journal of Nondestructive Evaluation
  - Photon 10% MTF: 2.32 line pairs per cm [4]
  - Neutron 10% MTF: 3.35 line pairs per cm [4]
  - Sub-SiPM spatial resolution achieved

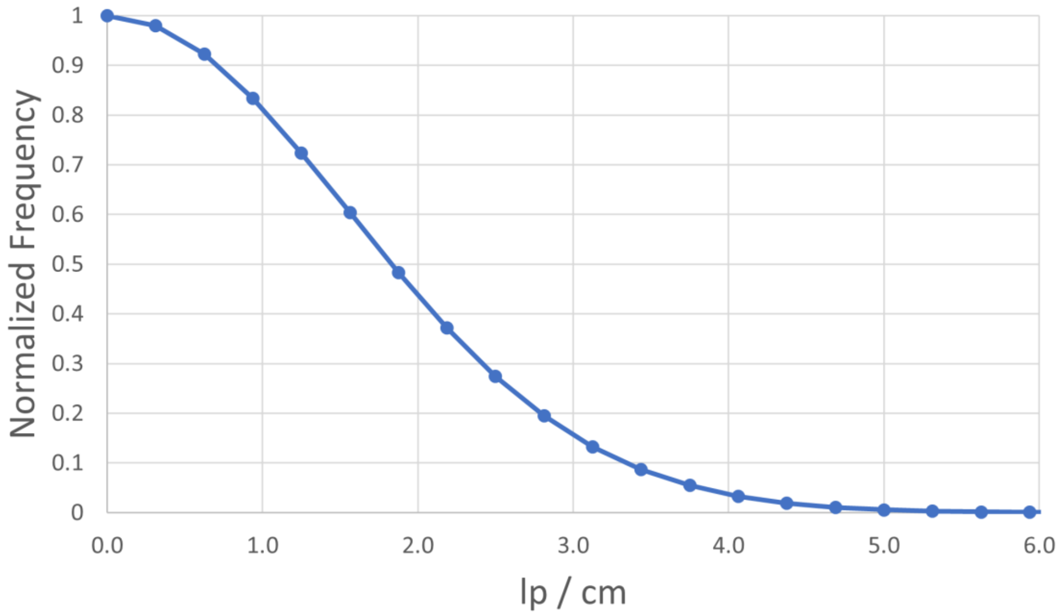
Photons



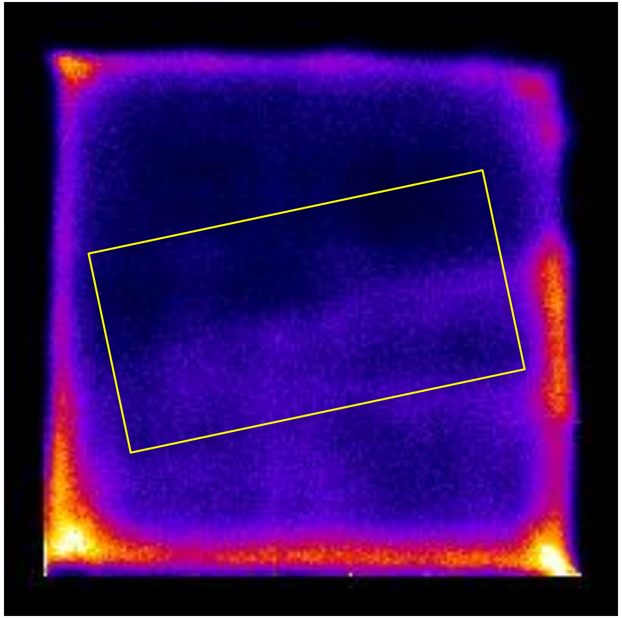
Normalized Frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
lp/cm



Neutrons

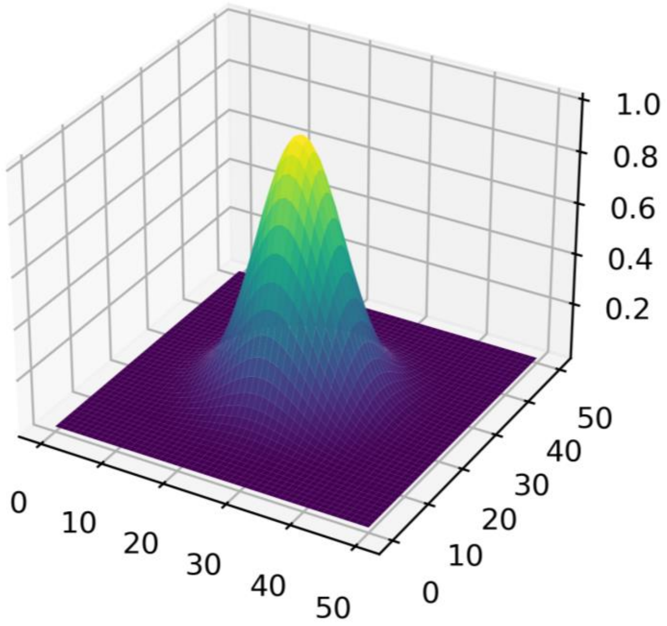


Normalized Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
lp / cm



2D Gaussian Approach

- Looking for a better localization method
  - Fault-tolerant
  - Possibly localize between gaps
- Assume light distribution follows a 2D Gaussian shape



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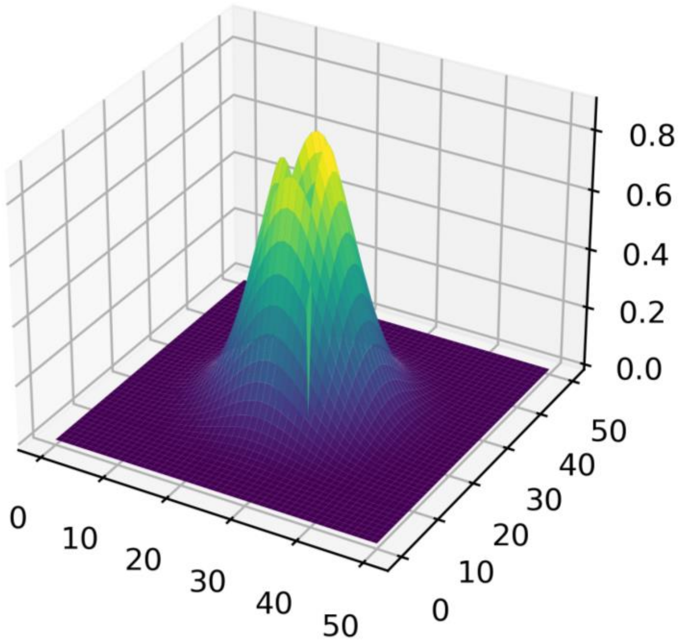

2D Gaussian Approach

- Simple method has been implemented, but:
  - Requires parallel search to achieve reasonable (<30 minutes) processing time
  - Optimization of edge cases and gaps is needed
- Fault correction may be possible with little or no additional code
- Results to be published soon

Towards the Future

- Eventual 6 by 6 array of detector modules
- Full sheet of EJ-200 + light spreader
- All ROSSPADs connected via PoE switch
- Working, portable flat-panel detector

Conclusion

- Single-ROSSPAD neutron radiography is possible
- Advanced localization techniques make multi-ROSSPAD detection simple and effective
- A full panel is in the works
  - Estimated completion by end-of-summer

Citations

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[4] C. Young, C. Browning, R. Thurber, M. Smalley, M. Liesenfelt, J. Hayward, N. McFarlane, and J. Preston, “Scalable Detector Design for a High-Resolution Fast-Neutron Radiography Panel,” Preprint. [Online]. Available: https://www.researchsquare.com/article/rs-2688845/v1

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