SAND2019-7245PE

BACKUP SLIDES

Single-Volume Neutron Scatter Camera Development
Independent Review
Project Overview

Erik Brubaker

Sandia National Laboratories

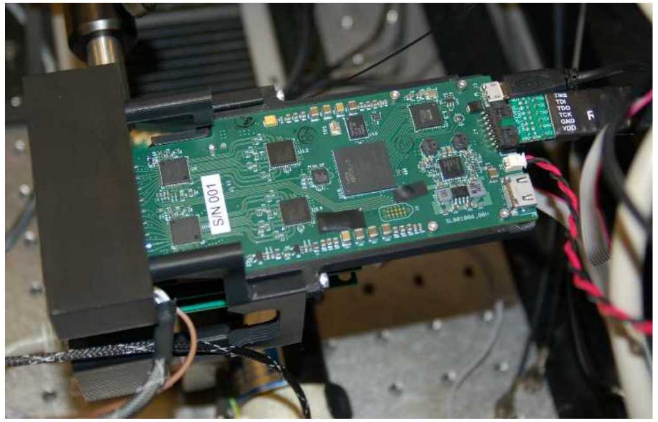
June 25, 2019

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Electronics development

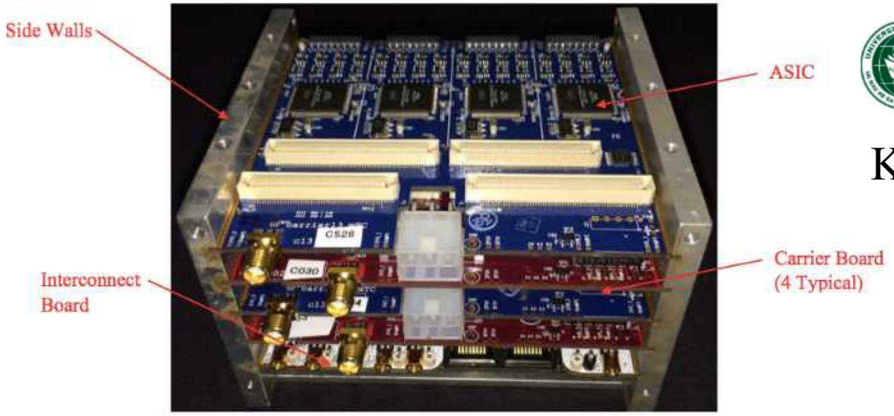
- Need high performance, high channel count, compact electronics
- Sandia Compact Electronics for Modular Acquisition (SCEMA)
  - 16+2 channels
  - 5 GS/s (DRS4)
  - 14 cm x 6 cm
  - Revision in progress
- UH SCROD
  - Full stack, 128 channels
  - 2.7 GS/s (IRS3D)
  - Self-triggering

SCEMA



J. Steele, J. Brown, et al.
2019 *JINST* **14** P0203
doi:10.1088/1748-0221/14/02/P02031

UH electronics



Kurtis Nishimura, et al.

We develop systems for eventual application in a range of scenarios:

Arms control treaty verification

Emergency response

SNM imaging applications

- **High resolution required**
  - **Fine detector segmentation**
- **Multiple or extended sources**

Need imaging for imaging?
Yes.
Check.

We develop systems for eventual application in a range of scenarios:

Standoff detection

Cargo screening

SNM detection/localization

- **Low signal rate**
  - **Need large area detectors!**
- **Low signal to background**
  - **Need background discrimination!**

Need directional information for localization?
Not necessarily, but it sure is helpful.

Need imaging for detection?
This is not a trivial question.
For **detection**, break it into two sub-cases:

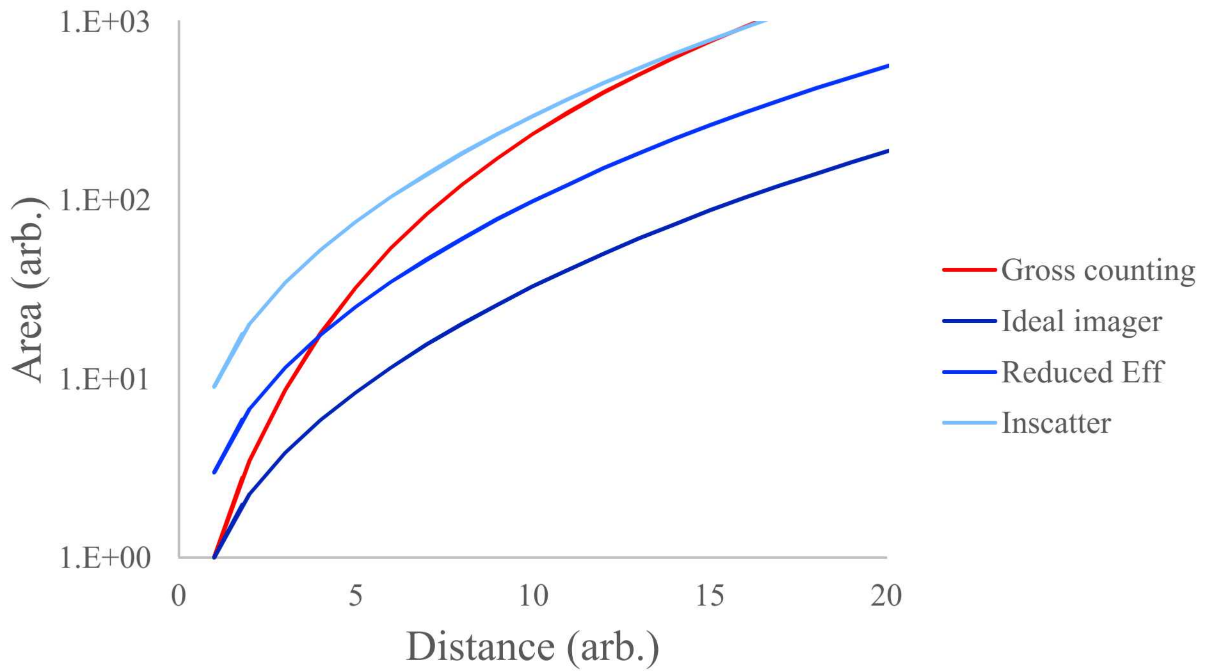
- Background unknown
- Background known

Case: background known

Detection again

- What about when the background is independently known?
  - Example: portal monitor. Effectively have repeated background measurements in between occupancies.
  - Example: building monitoring. Looking for changes in the rad field due to an approaching source.
- Now is there an advantage from imaging?
  - In principle, yes, because background is reduced by directional info.
  - But real imagers have complex directional info (angular resolution).
  - Also generally take a hit on efficiency.

- Study by Paul H (ORNL)
- Look at detection in background-known case
- Understand tradeoff between efficiency and background rejection
- Specific plot below shows how area of detector needs to change as function of distance to the source
- *Punchline: Imager scales better than counter, but has to overcome efficiency reduction—only helps when detector areas are unreasonably large..*

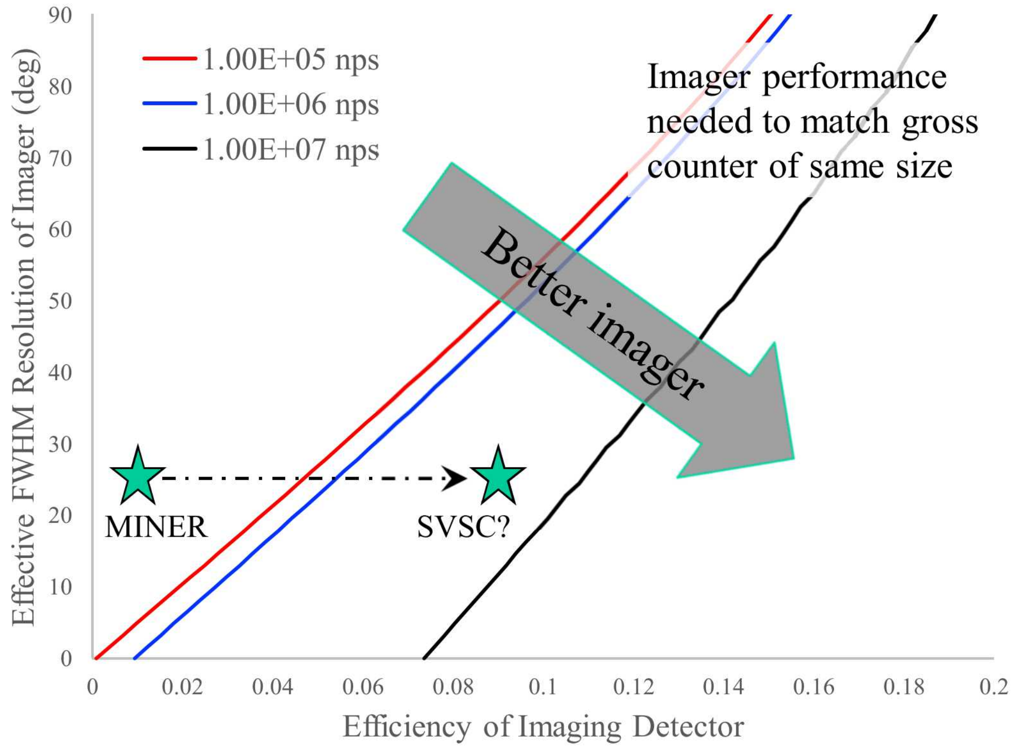


Detection again

Case: background known

- **What about when the background is independently known?**
  - **Example: portal monitor. Effectively have repeated background measurements in between occupancies.**
  - **Example: building monitoring. Looking for changes in the rad field due to an approaching source.**
- **Now is there an advantage from imaging?**
  - **In principle, yes, because background is reduced by directional info.**
  - **But real imagers have complex directional info (angular resolution).**
  - **Also generally take a hit on efficiency.**

- Study by Paul H (ORNL)
- Equal area detectors, background known
- Specific plot below uses one particular set of assumptions (bg rate, exposure time, etc.)
- *Punchline: Difficult to achieve performance to beat gross counter.*



Brubaker/SVSC

- **Neutron directional information analogous to gamma spectral information for detection.**
  - **Estimate background (systematic).**
  - **Ignore most background (statistical).**

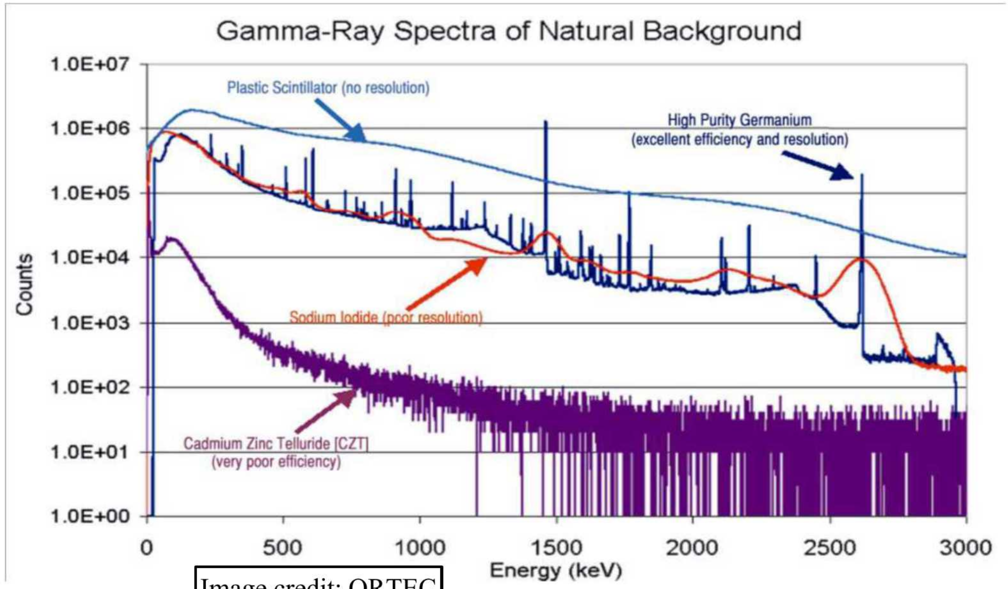


Image credit: ORTEC

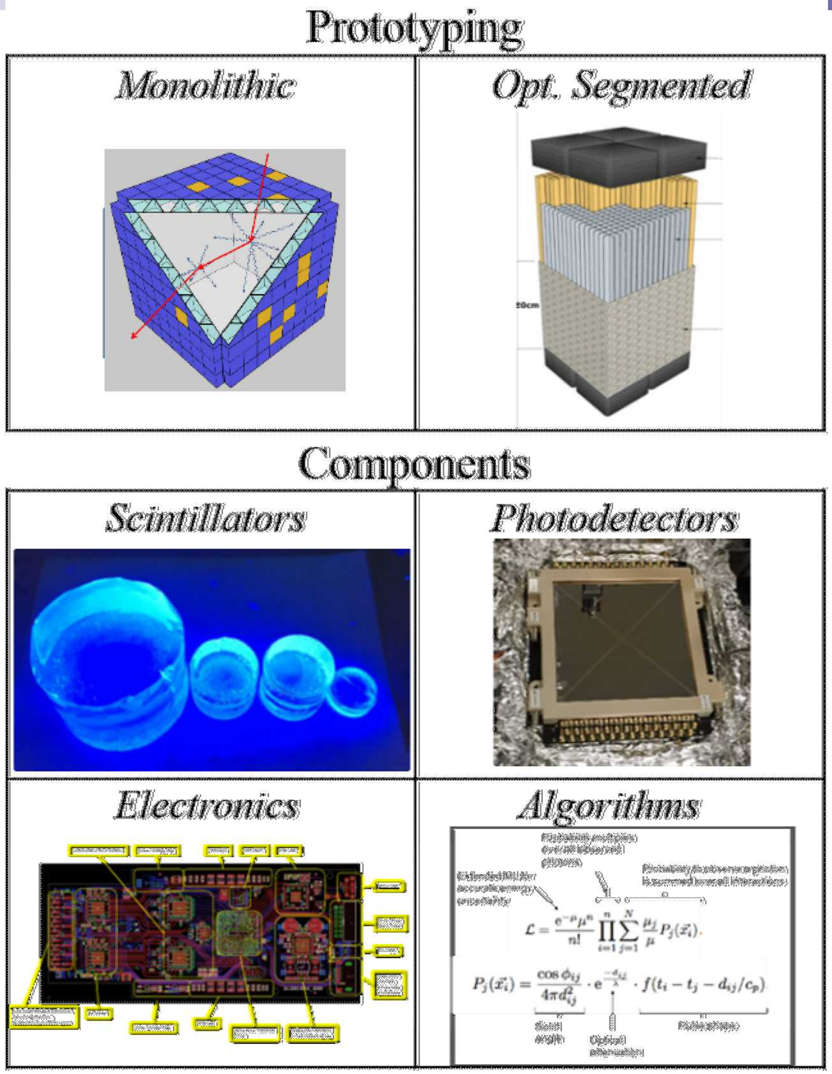
Summary: need imaging?

- **Imaging applications: Yes**
  - **Emergency response diagnostics, Arms control treaty verification**
- **Localization: Yes**
  - **Direction to detected source**
- **Detection, background unknown: Probably**
  - **Long-dwell standoff detection**
- **Detection, background known: Need very high quality imager**
  - **Portal monitor, building monitoring**

SVSC project

We have demonstrated feasibility in simulation—information content is there.

Technical achievability is not guaranteed—need to integrate multiple cutting-edge technologies.



Why is fast timing important?

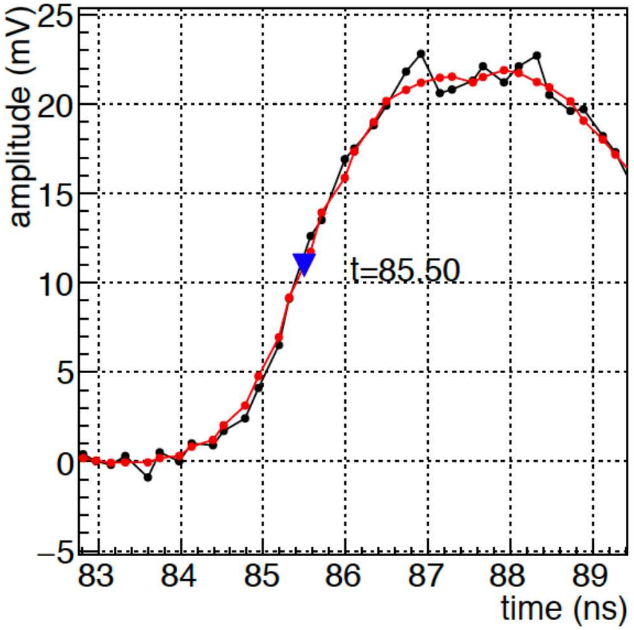
- Distinguish interactions 2 ns & 3 cm apart
- Determine TOF to ~10% → 200 ps
- Correlated with position resolution: c/n = 20 cm/ns → 3 mm ~ 15 ps

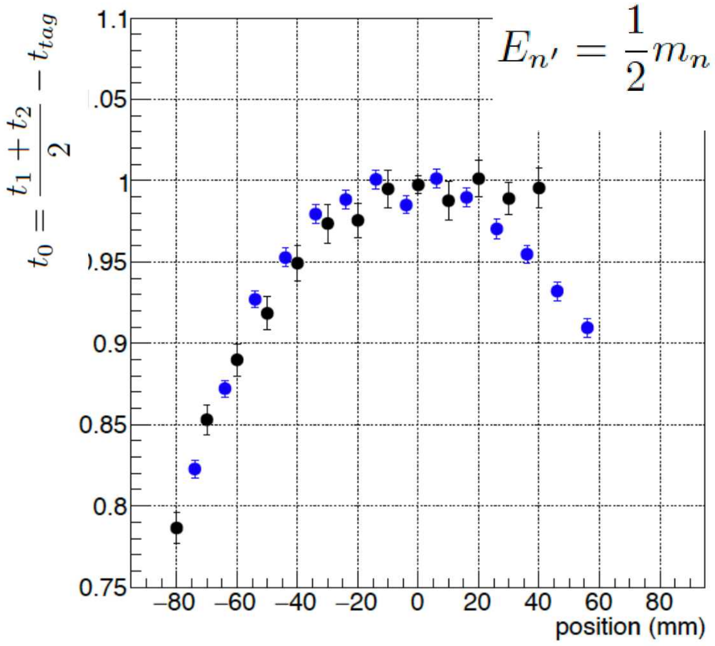
System components:

1. Organic scintillator—fast plastic, O(1 ns) decay time
2. Fast photodetectors—MCP-PMTs, SiPMs, etc. Low tts ~100 ps if possible
3. Fast electronics—sufficient to take advantage of PDs. Must be scalable
4. Algorithms—use all information available

Single Bar Results – Event time

~100ps difference in event time ($t_0 = \frac{t_1 + t_2}{2} - t_{tag}$) for edge/center:



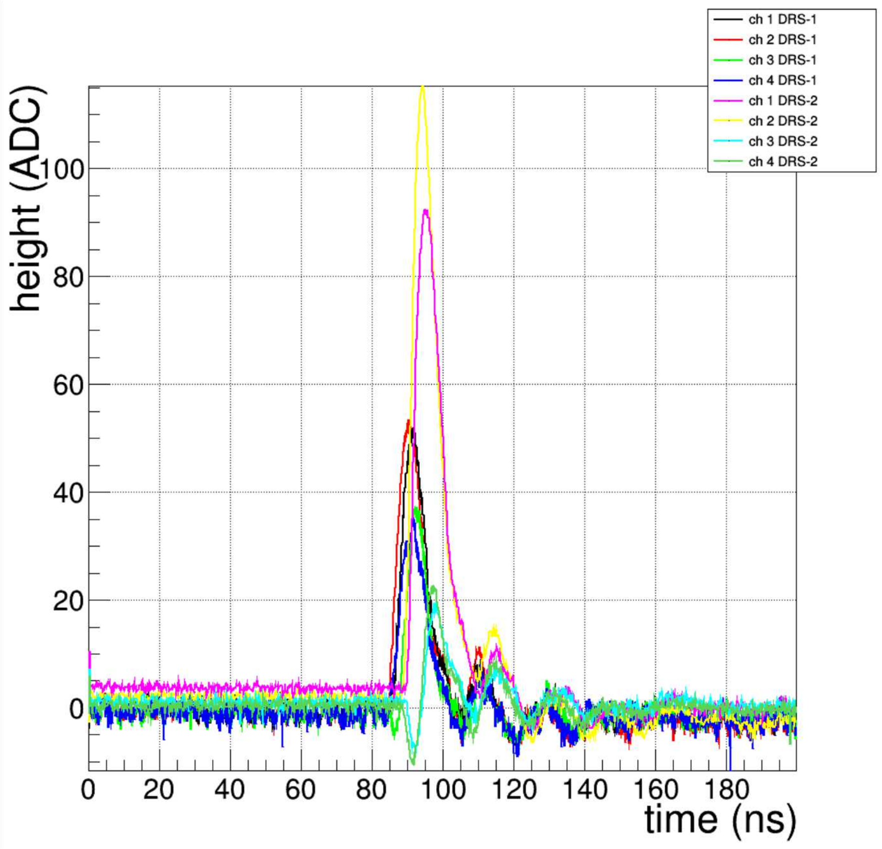


$$E_{n'} = \frac{1}{2} m_n \left(\frac{\Delta d}{\Delta t} \right)^2$$

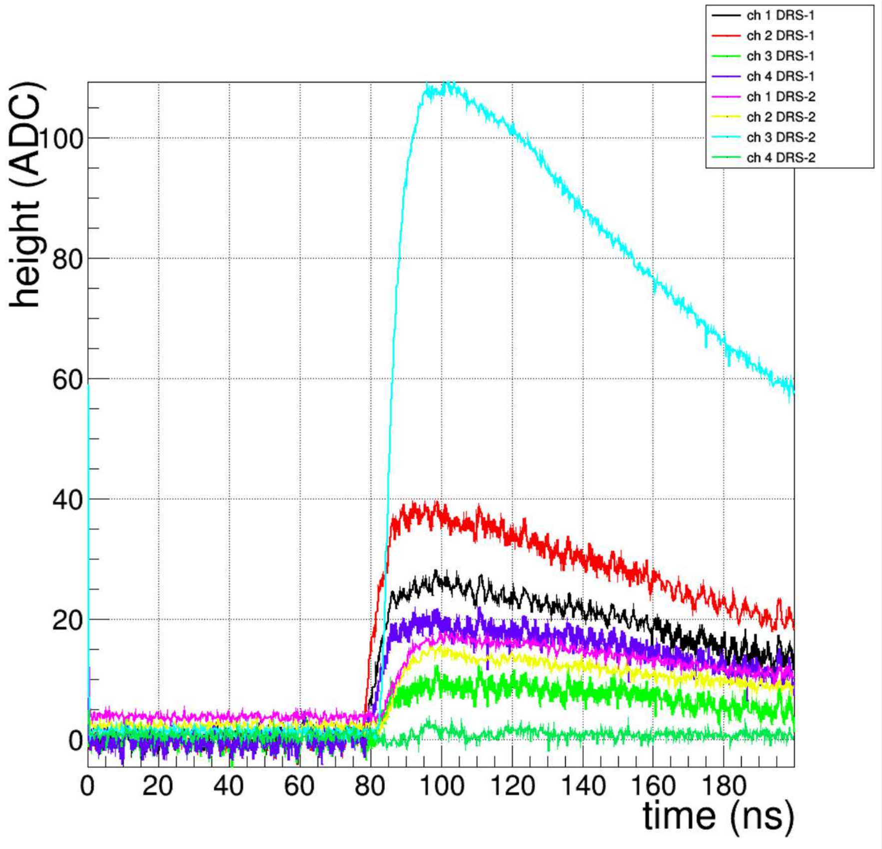
See: M. Sweany, A. Galindo-Tellez, J. Brown, E. Brubaker, R. Dorrill, A. Druetzler, N. Kaneshige, J. Learned, K. Nishimura, and W. Bae. "Interaction position, time, and energy resolution in organic scintillator bars with dual-ended readout" *Nucl. Instr. And Meth. A 927 (2019) 451-462*

Signals with DRS4 daisy chain

- Fast-output

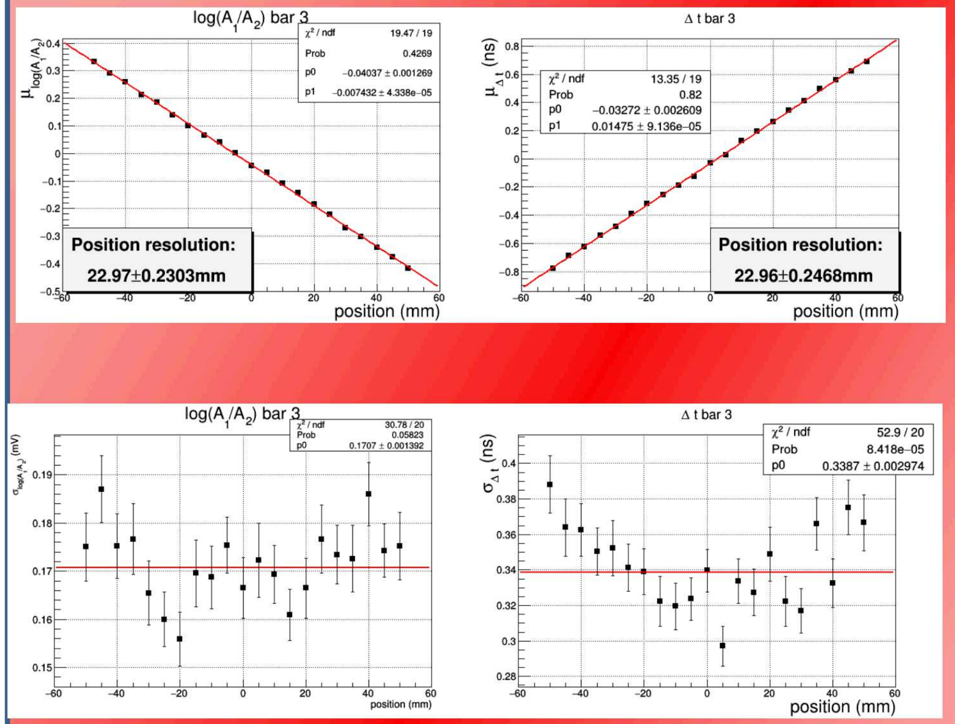


- Standard-output

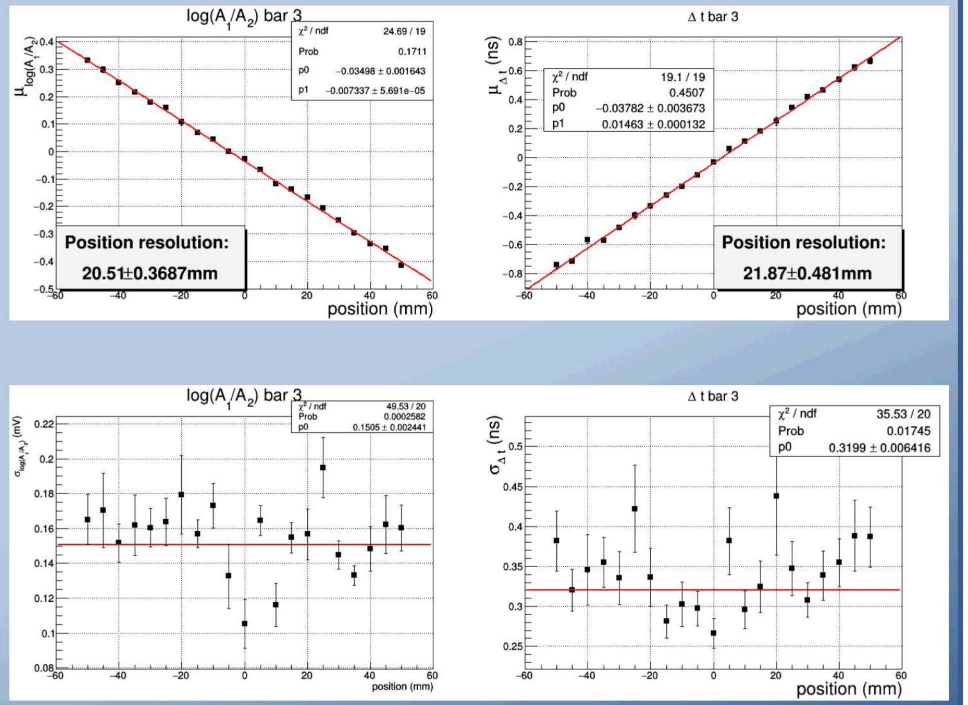


Position resolution. Fast-output. Energy cut 300-400 keV

- Near channels configuration

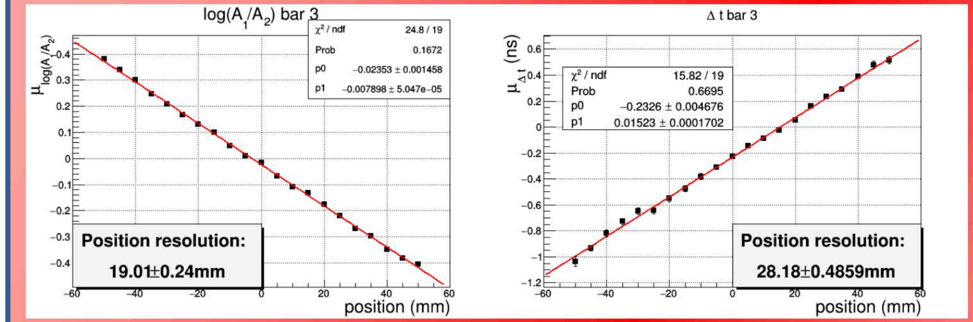


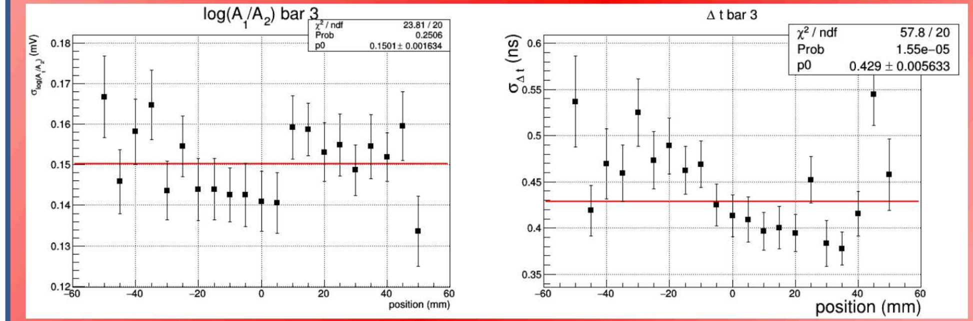
- Far channels configuration



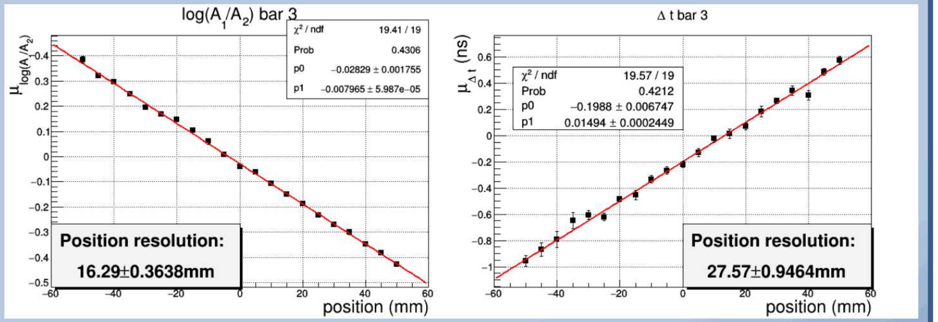
Position resolution. Standard-output. Energy cut 300-400 keV

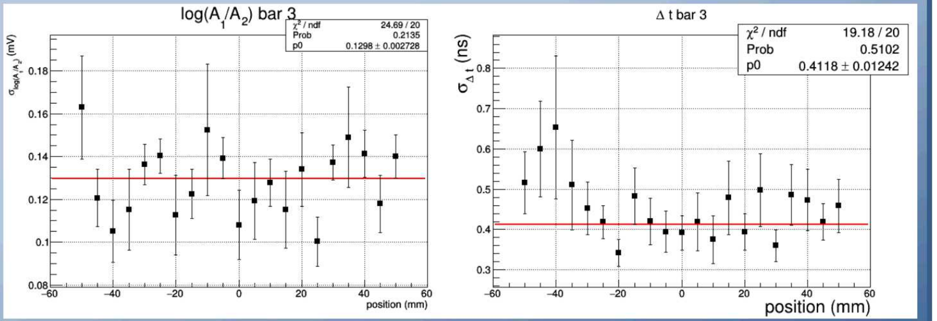
- Near channels configuration





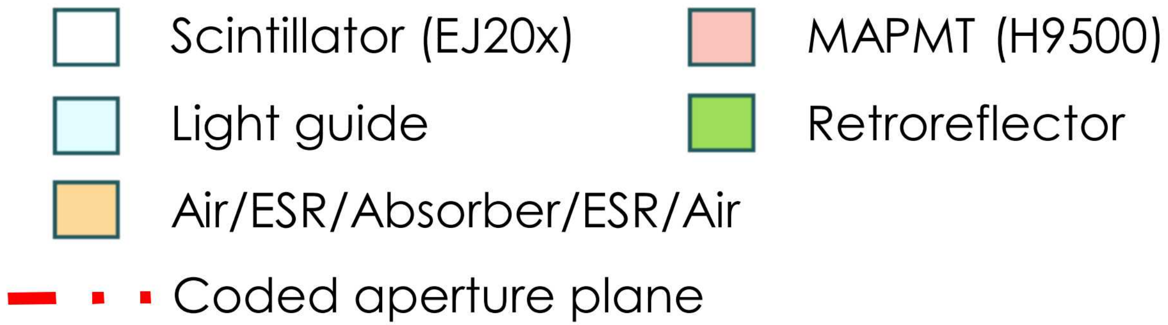
- Far channel configuration

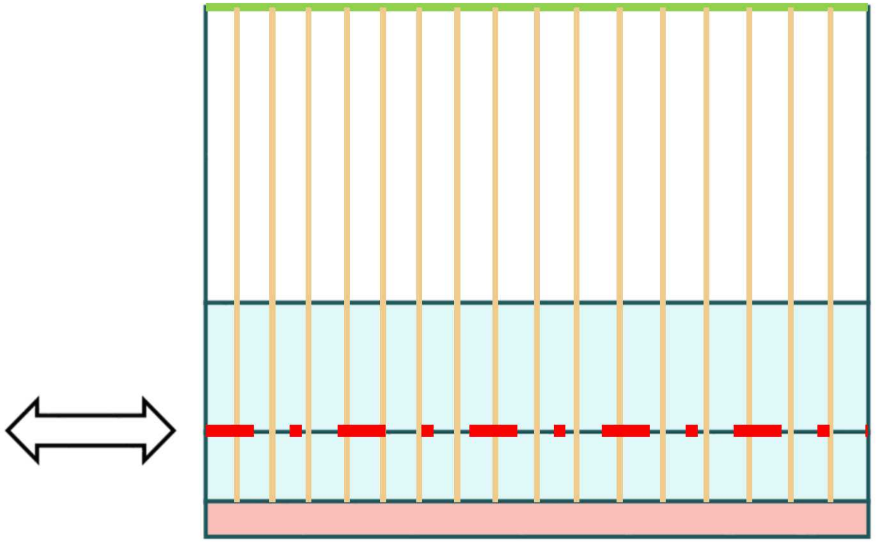




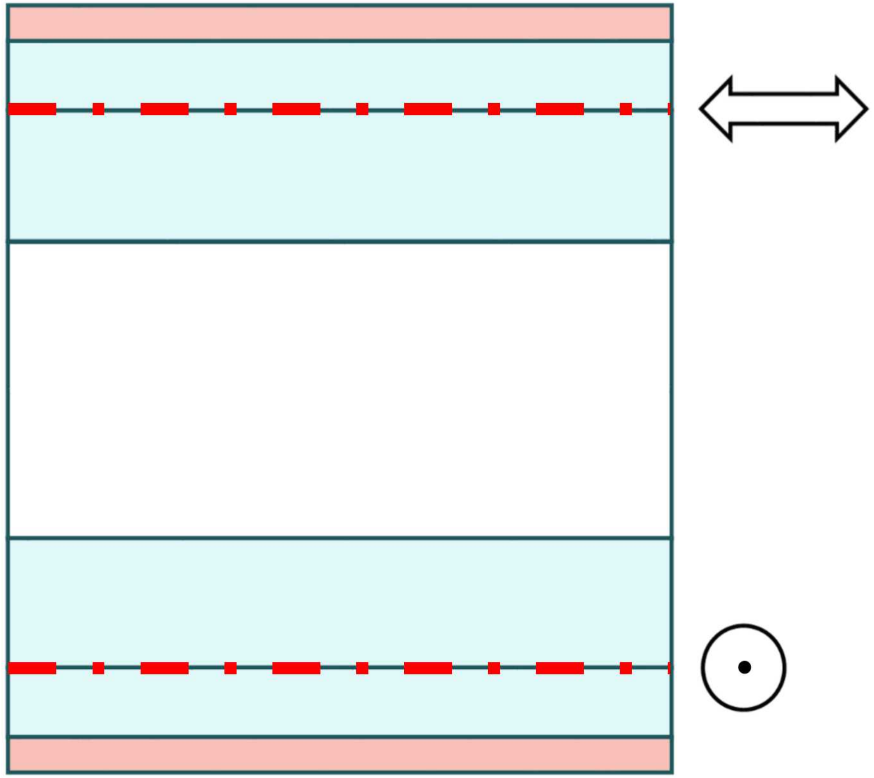
OCA Design

- 2 designs
- Modeled using Geant4
- Require different approaches to reconstruction





Slab design

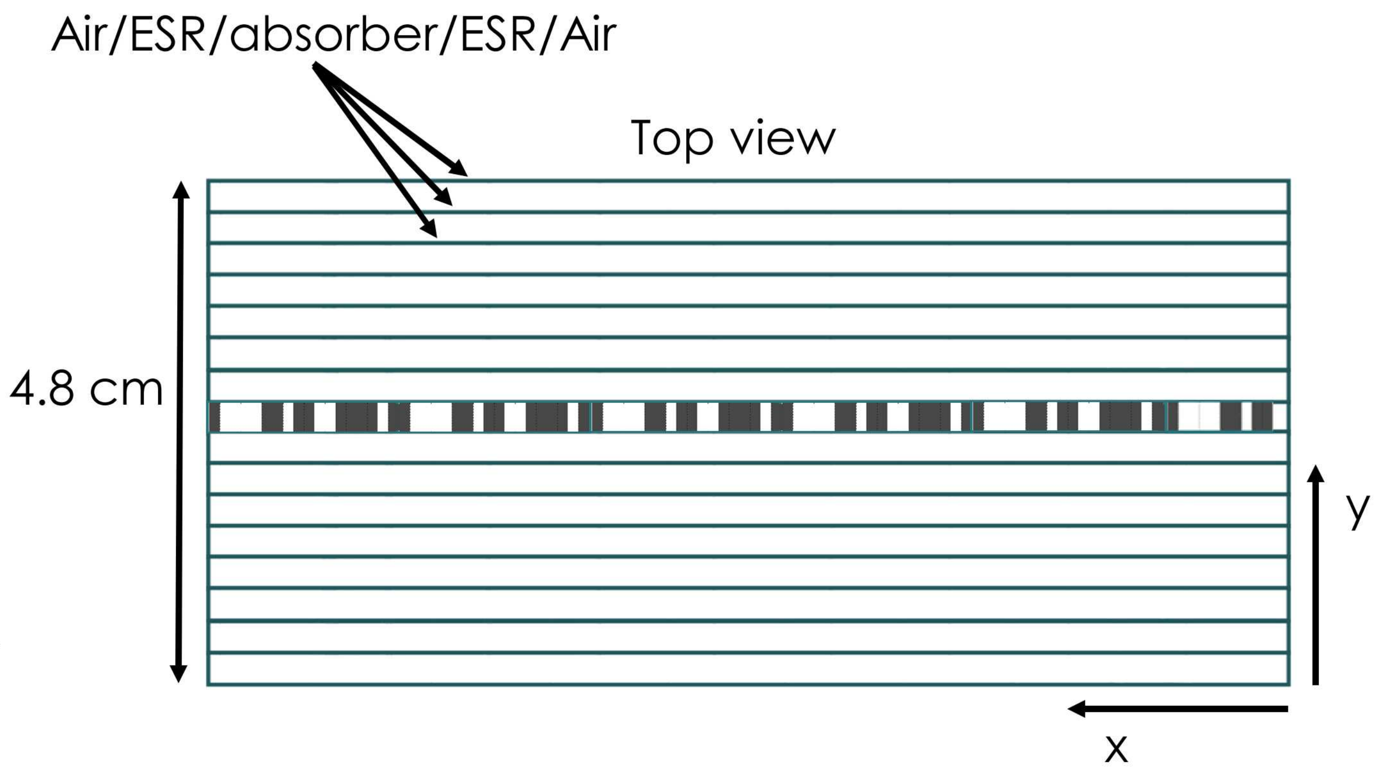


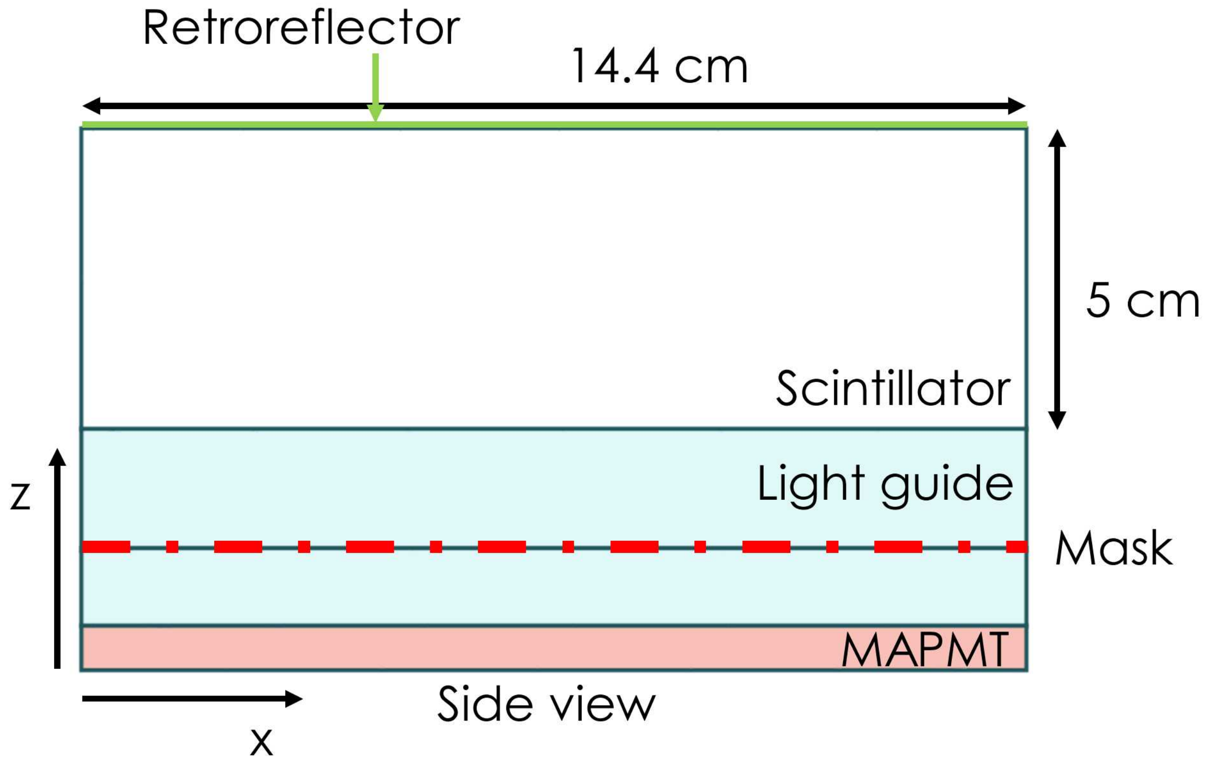
Orthogonal 1D design

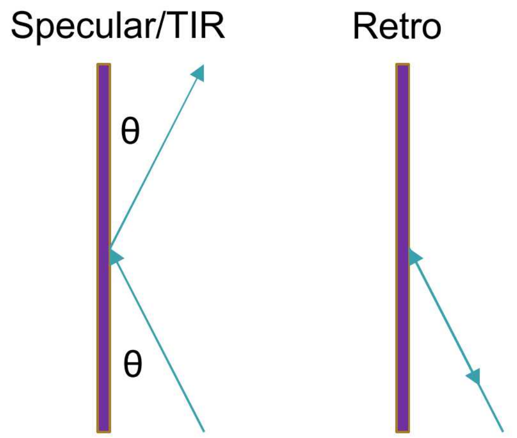
OAK RIDGE National Laboratory

OCA Design: Slabs

- Building slab design prototype

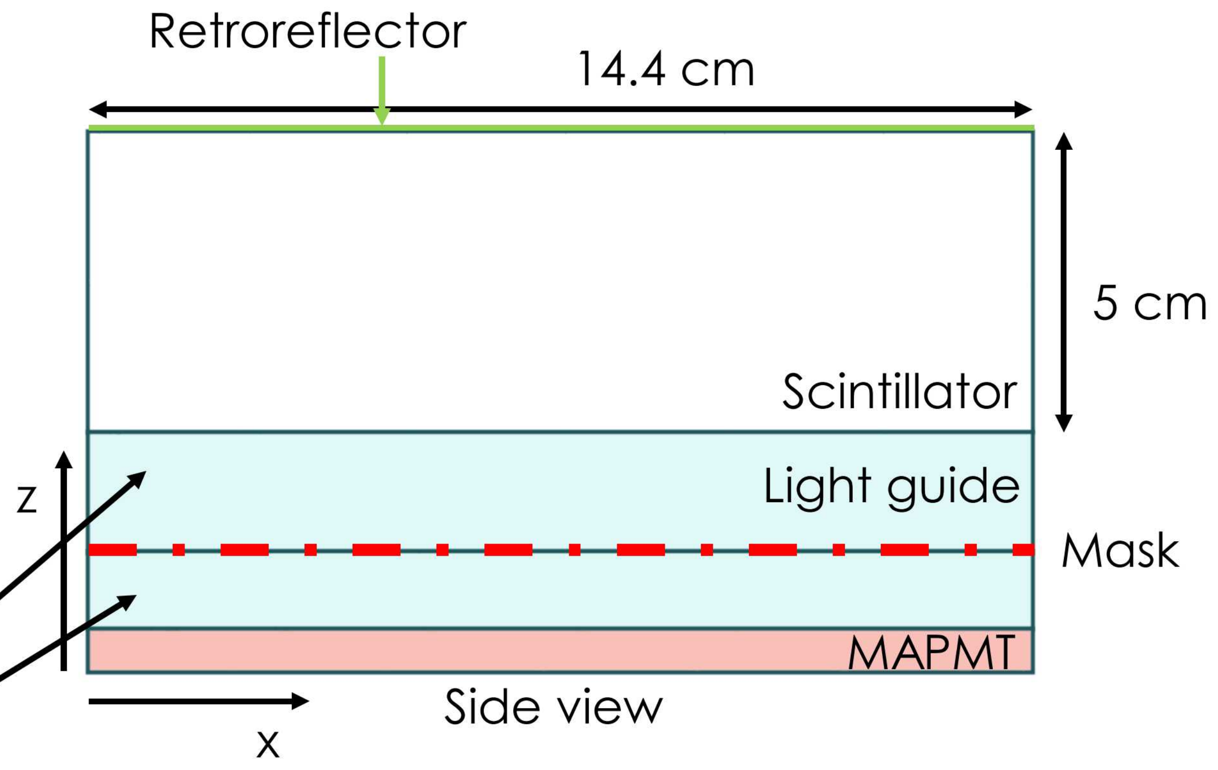






OCA Design: Slabs

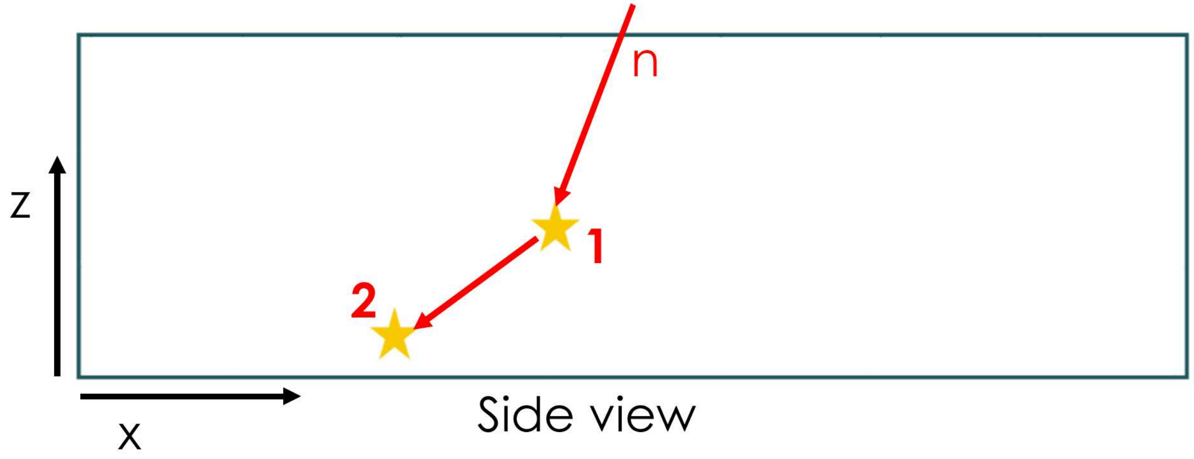
- 3 mm, rank 11 mask, detector, and slab pixel sizes
- EJ200
- 14.4 cm (3 photodetectors) long
- 5 cm tall
- 2 cm gap light guide
- 1 cm focal length

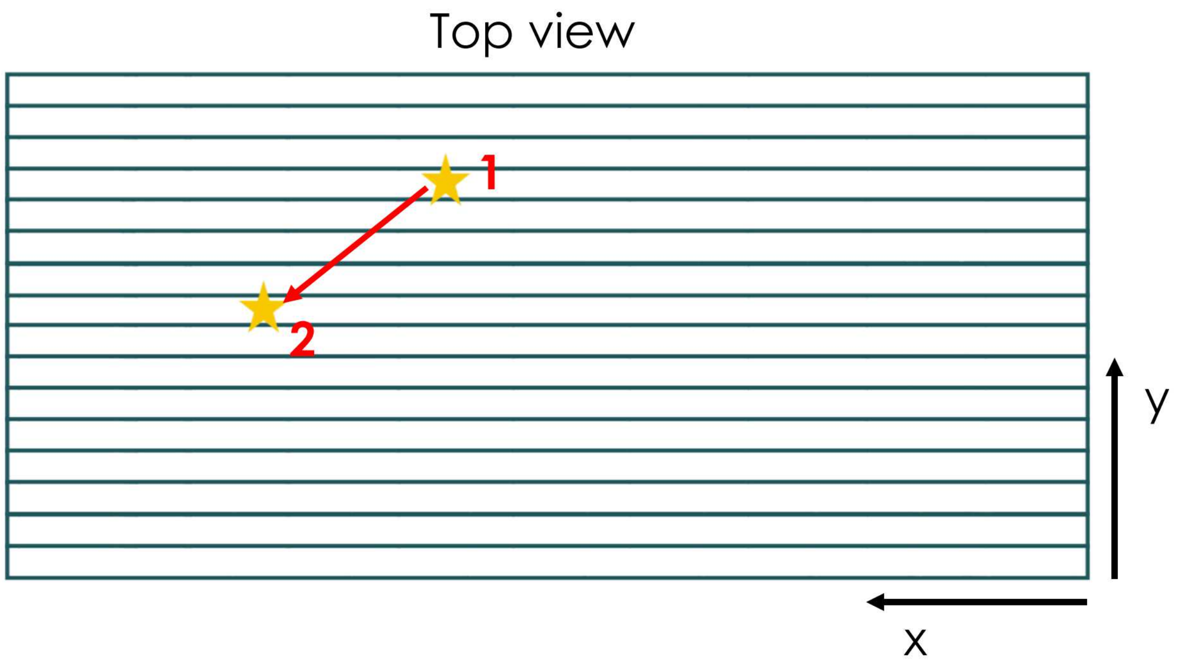


- Air/reflector/absorber/reflector/air in gaps between slabs
- Narrow edges black
- Retroreflector on top

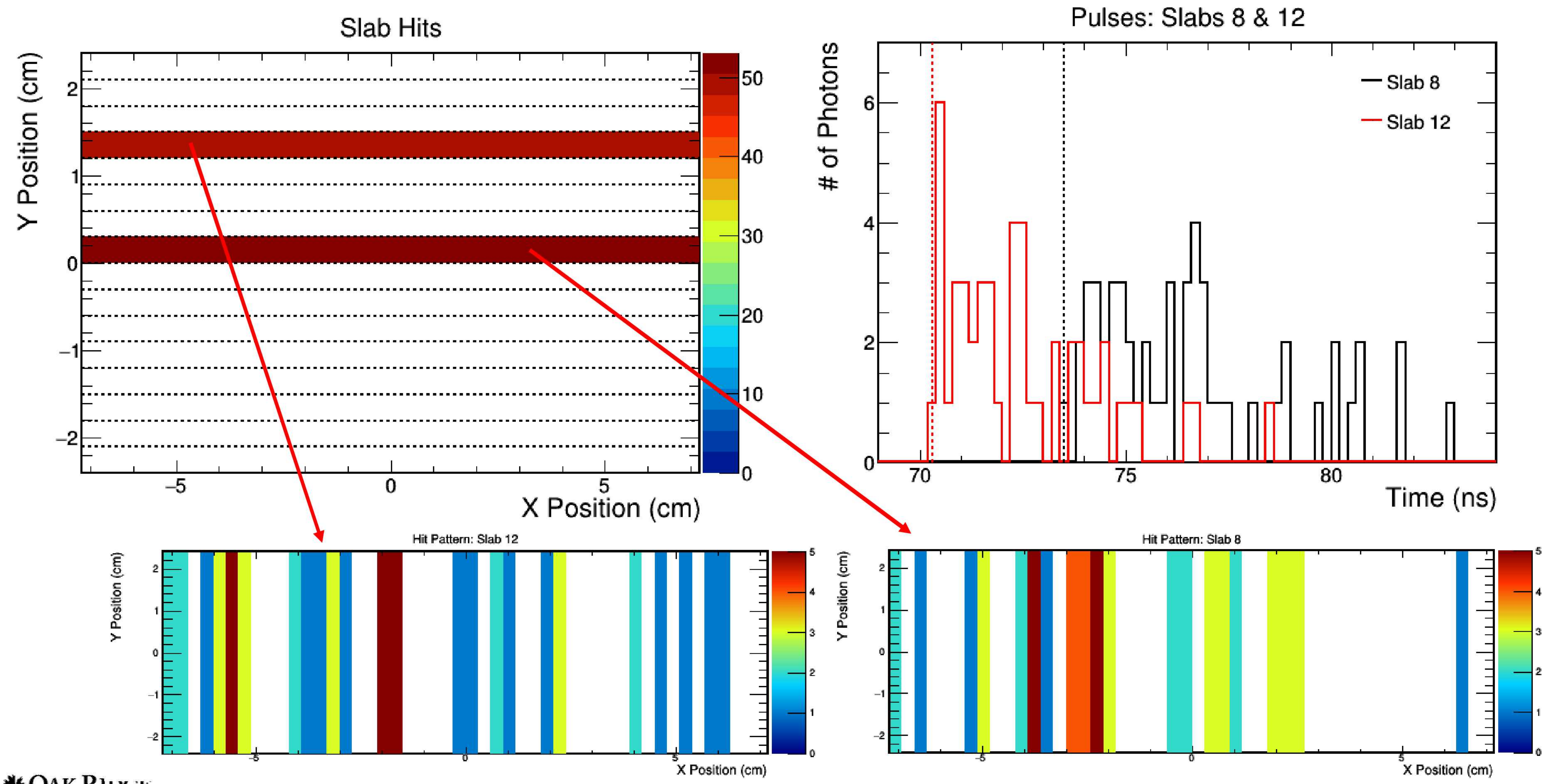
OCA Event Reconstruction: Sample Event

- Random two-scatter event from simulation
- Recoil 1: 675 keV deposited
  - 49 photons detected in slab 12
- Recoil 2: 544 keV deposited
  - 53 photons detected in slab 8

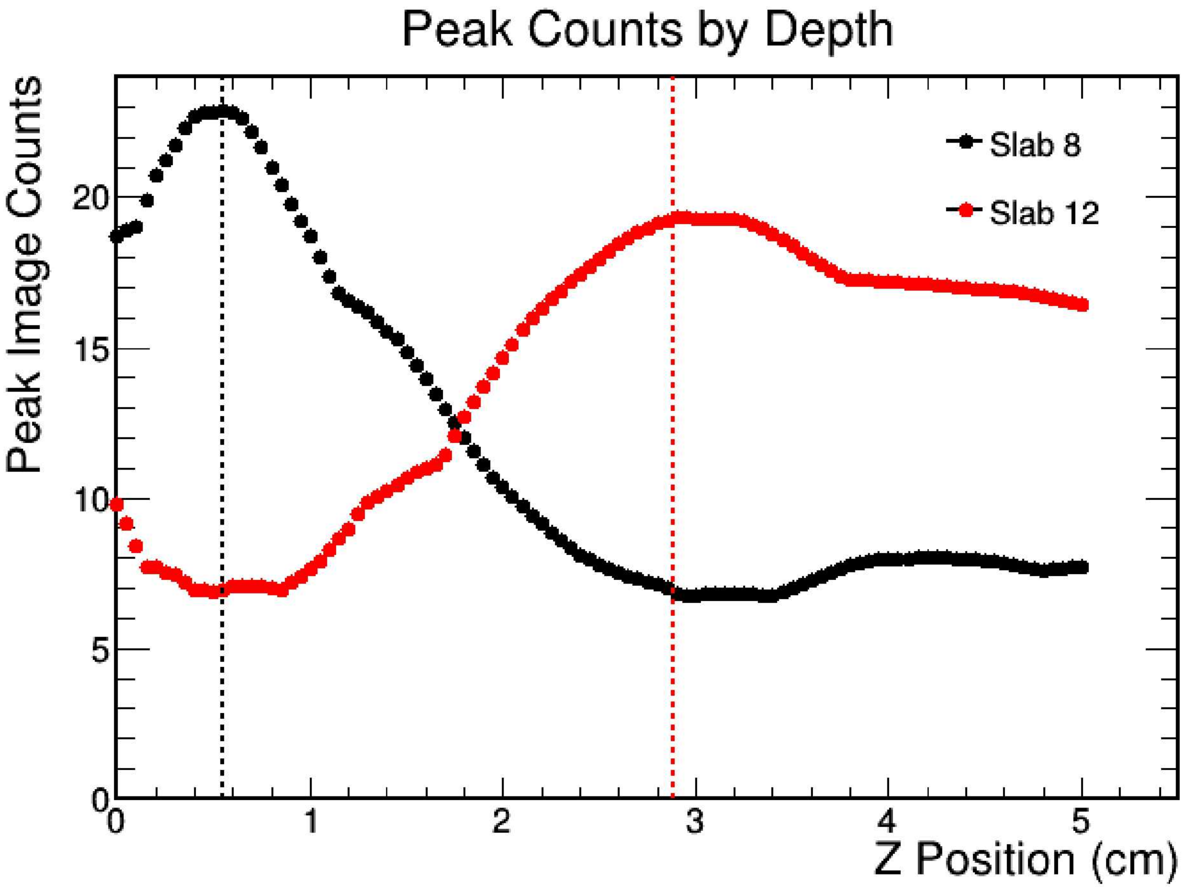


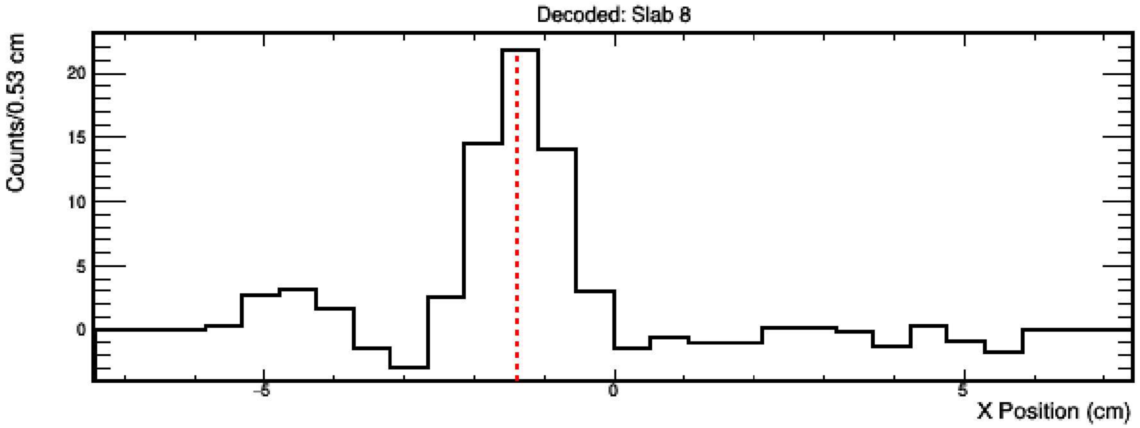


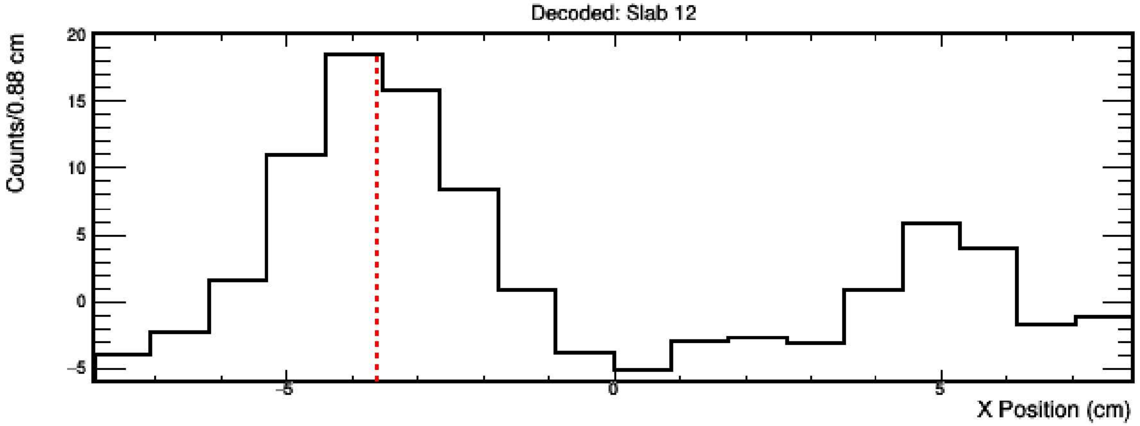
OCA Event Reconstruction: Sample Event



OCA Event Reconstruction: Sample Event





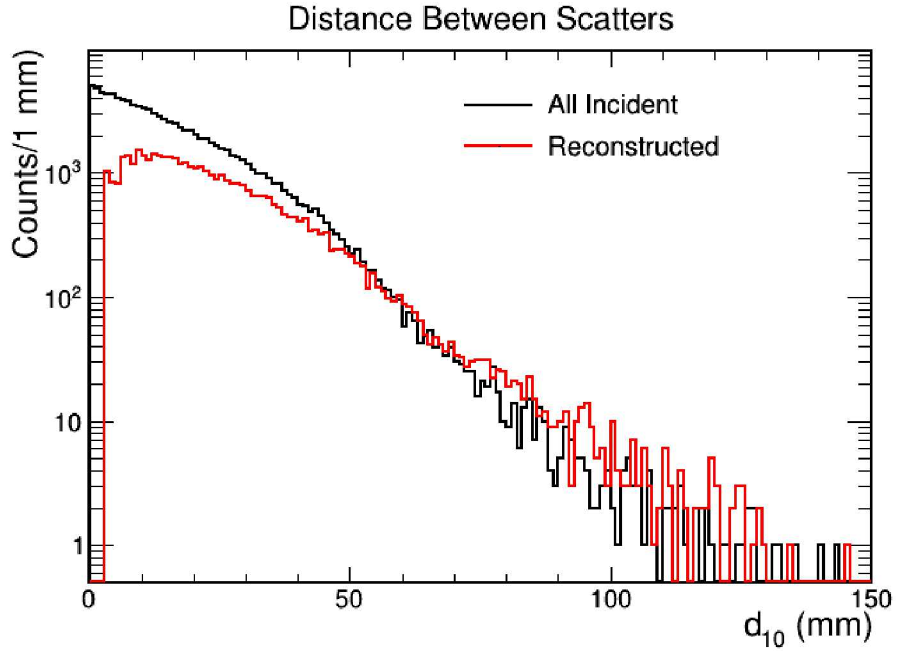


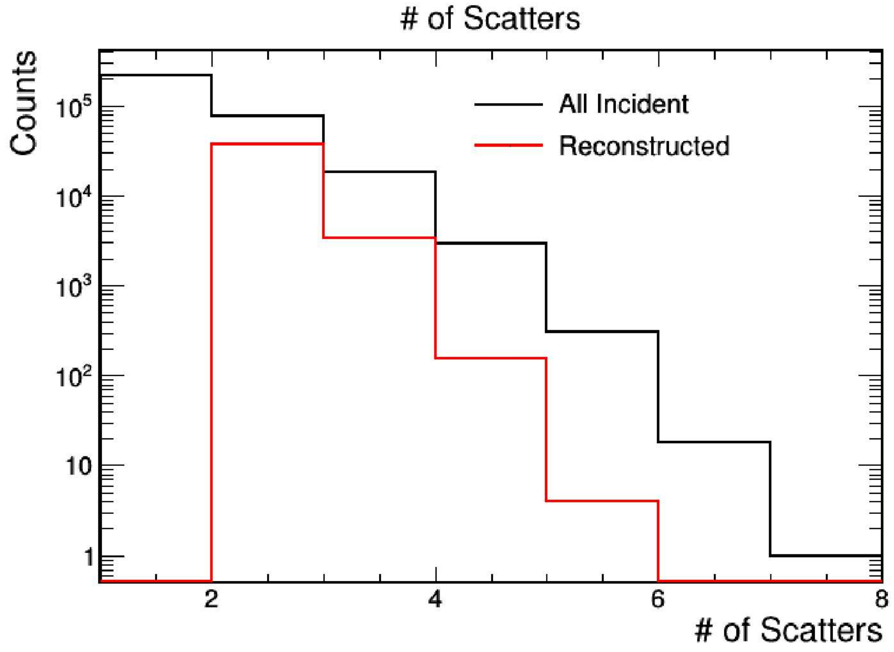
OAK RIDGE National Laboratory

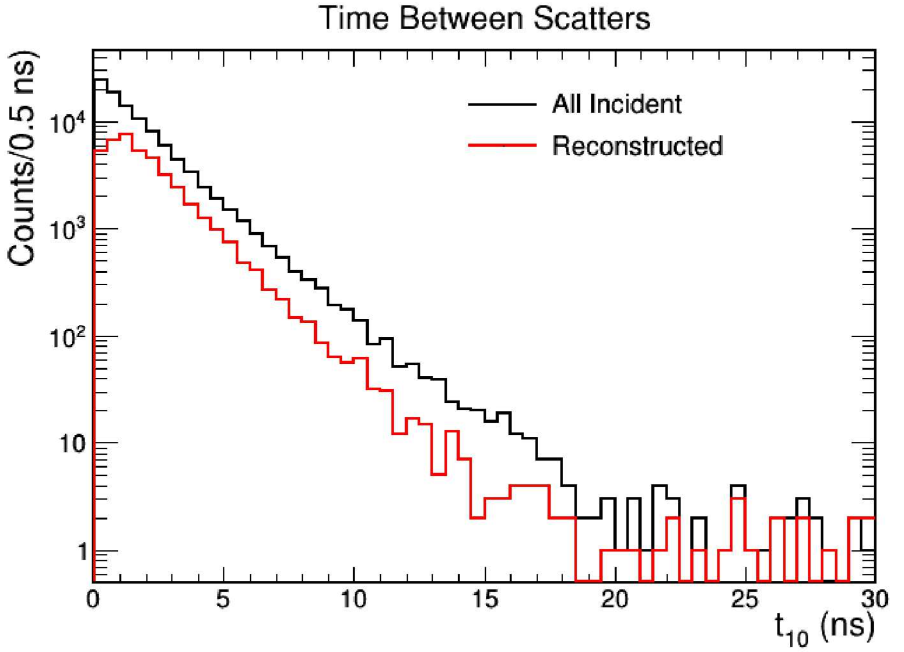
Results

- ^{252}Cf point source 1 m away (+z)
- 320k recoils total
- 41796 recon'd

- Select events in which 2+ slabs trigger with > 10 photons each



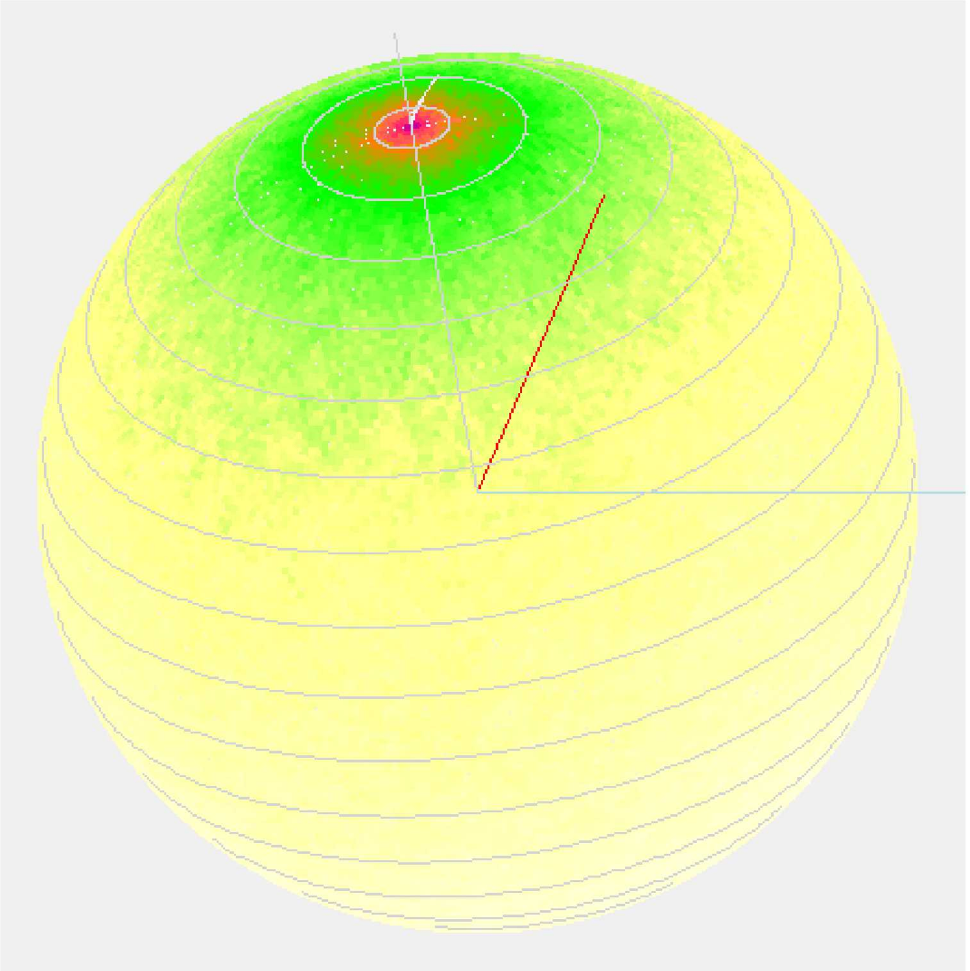




OAK RIDGE National Laboratory

Results Summary

- Image created using simple back-projection
- 41.7k events
- ~25° FWHM



	ΔX (mm)	ΔZ (mm)	E_p (keV)	Δt (ps)	E_n (keV)	$Δd_{10}$ (mm)	$Δt_{10}$ (ps)	Δθ (rad)
σ	2.67	3.87	72.8	259	412	4.34	425	0.197
FWHM	3.77	5.83	145	595	479	6.86	846	0.220

Oak Ridge National Laboratory

Parameter Study Results

	ΔX (mm)	ΔZ (mm)	E_p (keV)	Δt (ps)	E_n (keV)	Δd_{10} (mm)	Δt_{10} (ps)	Δθ (rad)
Base	3.77	5.83	145	595	479	6.86	846	0.220
6 mm pixels	10.9	12.9	175	644	719	14.9	945	0.330
2.5 cm tall	3.68	3.73	130	594	419	4.79	798	0.220
7.5 cm tall	5.82	7.89	170	594	620	9.89	895	0.240
10 cm tall	6.86	14.9	190	644	778	13.9	945	0.280
No airgap	4.80	5.86	220	595	658	7.87	845	0.410
Edge reflector	5.81	5.86	99.6	694	419	8.91	995	0.300
2.5 mm gap guide	14.9	15.9	165	594	778	20.9	847	0.460
5 mm gap guide	7.88	8.89	155	644	538	11.9	896	0.270
15 mm gap guide	3.66	4.78	150	595	458	4.79	845	0.200
0.5 cm focal	3.64	2.73	130	594	439	4.77	895	0.200
1.5 cm focal	3.73	4.80	145	595	458	5.80	846	0.210
2.5 cm focal	4.79	6.85	155	643	499	7.87	847	0.229
No retroreflector	4.77	5.83	205	594	659	6.86	797	0.240

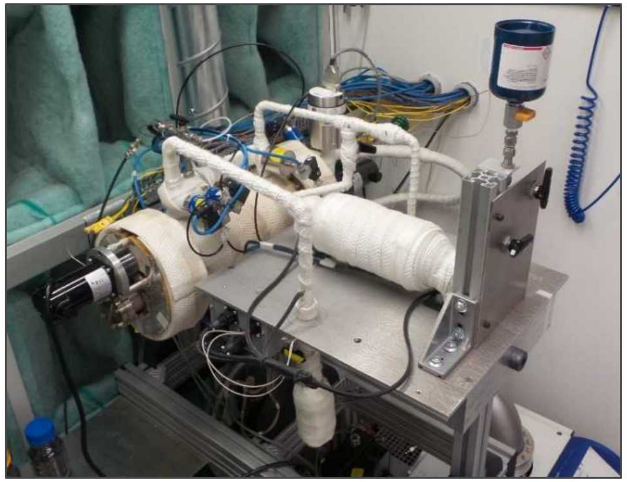
Cross-Flow ALD reactor with In-situ QCM/QMS/FTIR

QMS QCM FTIR

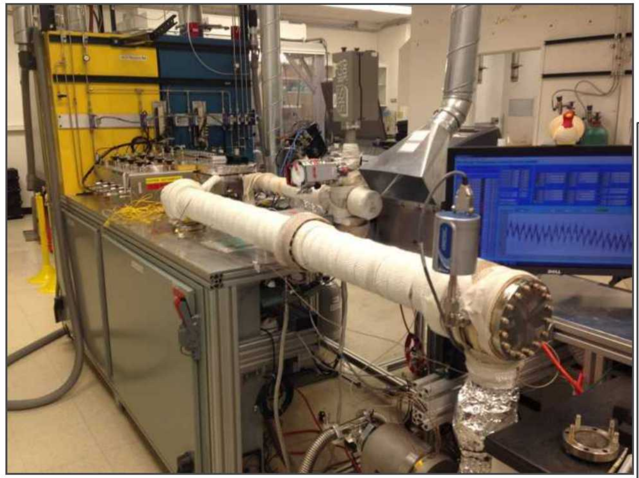
ALD Capabilities at AMD

Substrate size (2”x18”), **in situ QCM, QMS, FTIR, I-V**

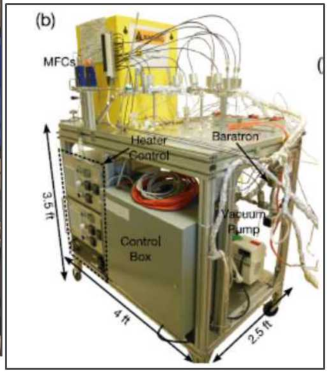
(ALD powder coater 1 kg)

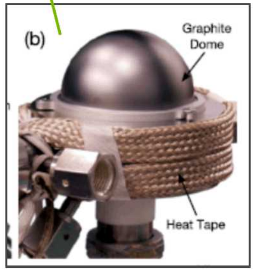


60” L x 6” dia. long tube ALD



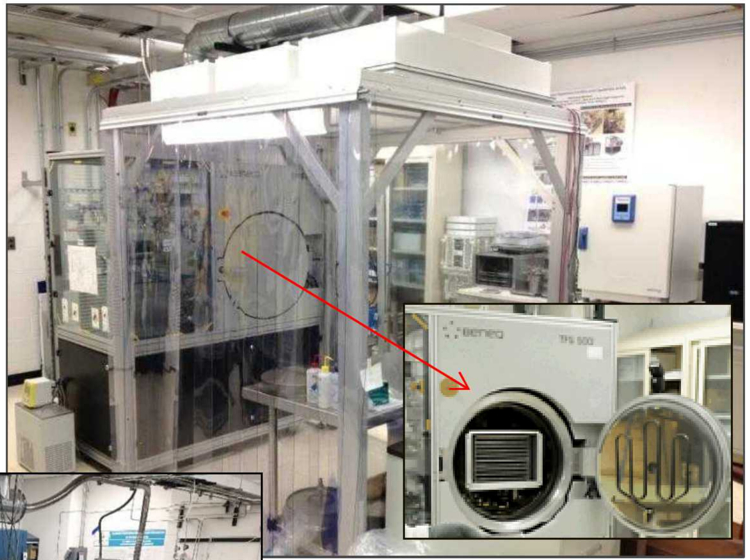
Portable ALD – in situ synchrotron X-ray studies





ALD Capabilities at AMD

Beneq TFS500 –3D chamber, large substrates, scale-up, batch coating (15 x 300mm wafers)



Oxford FlexAL PEALD, 8” wafers, auto-load, in situ ellipsometry and emission spectrometry

WBG semiconductor
GaN, AlN, β-Ga_2O_3, etc.

Glove box system for air sensitive substrates (Li-metal) and films