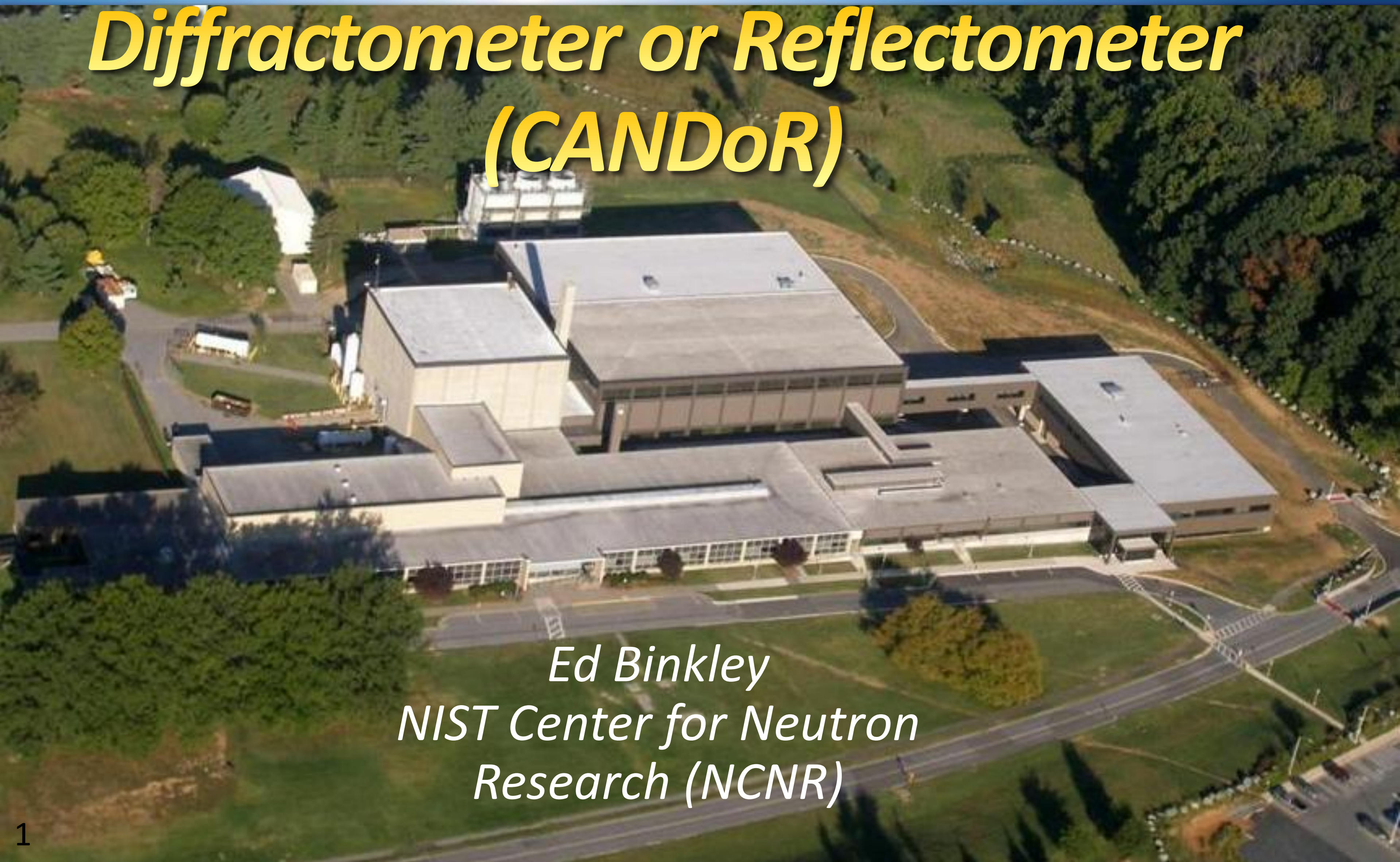
Chromatic Analysis Neutron Diffractometer or Reflectometer (CANDoR)



Ed Binkley
NIST Center for Neutron Research (NCNR)

CANDoR Detector

Overview

- *Candor Detector Array*
- *How a Scintillator works and Challenges*
- *Scintillator Detector Optimization*
  - *Frame design*
  - *Testing*
  - *Compound*
  - *Reflector*
  - *SiPM*
  - *Fiber Loop*

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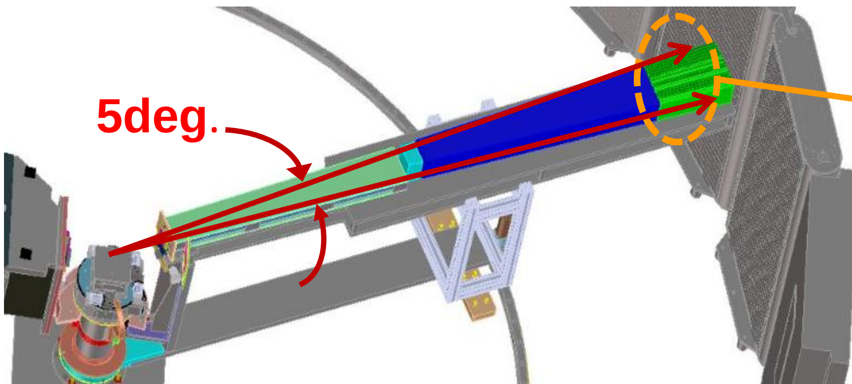
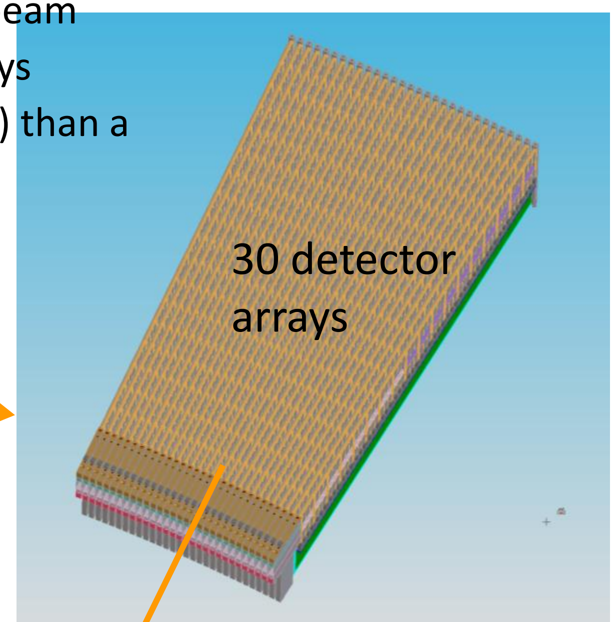
CANDoR Detector Array

- Polychromatic white beam (4 to 6 Angstroms) vs monochromated beam
- Five degree angle analyzed by multiple closely spaced detector arrays
- Equals significantly shorter measurement times (>1000 times faster) than a single detector





54 detectors per array

=1620 detectors total

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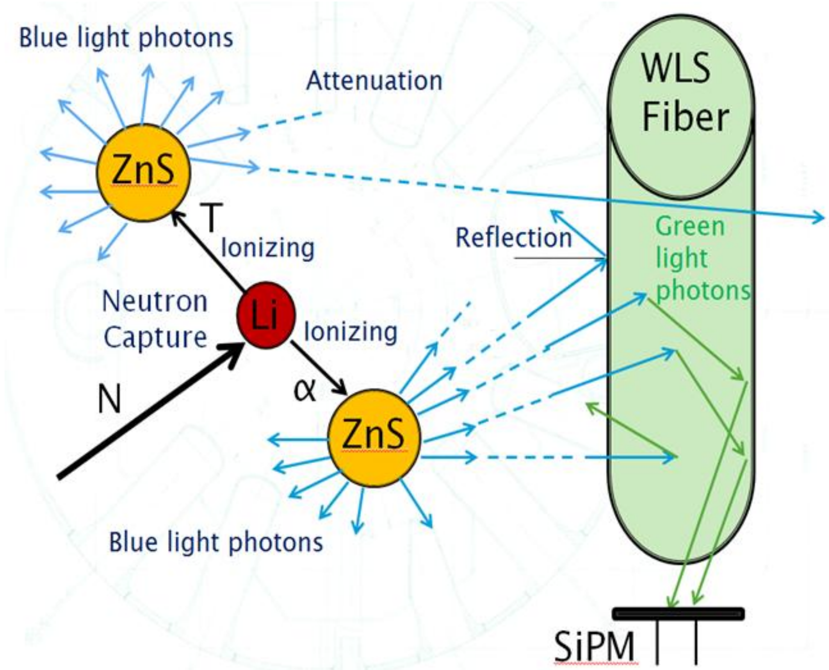
CANDoR How it works

Neutron Detection

6LiF:ZnS(Ag)

- The neutron is captured by 6Li in the scintillator (6Li (n,α) 3H reaction
- The alpha and tritons ionize the ZnS(Ag) and produce blue light photons.
- Blue light photons are then absorbed by the fluorescent dye in the WLS fibers and re-emitted as green light photons, which are then conducted down the fiber to the SiPM.



CANDoR Detector

Challenges or things to be optimized

- Neutron Capture Sensitivity: The likelihood of interaction between an incident neutron and a target nucleus (6Li).
- Stopping power, the ability to stop all the neutrons that it sees.
- Measurable Signal: The scintillator is opaque to its own scintillation light.
- Gamma Rejection: The scintillators are inherently sensitive to gamma ray photons.
- The silicon photomultipliers are subject to thermally induced noise.
- Scintillation decay time (double counting).

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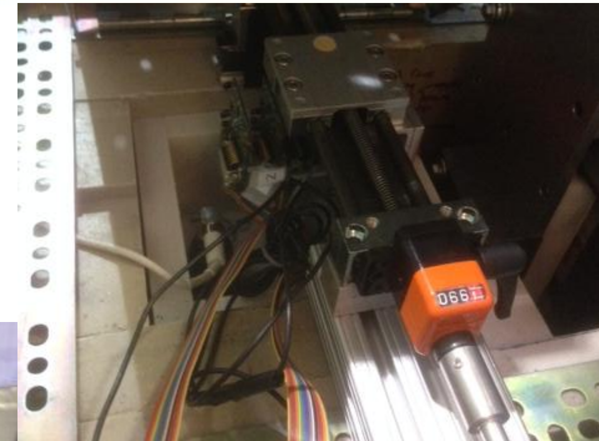
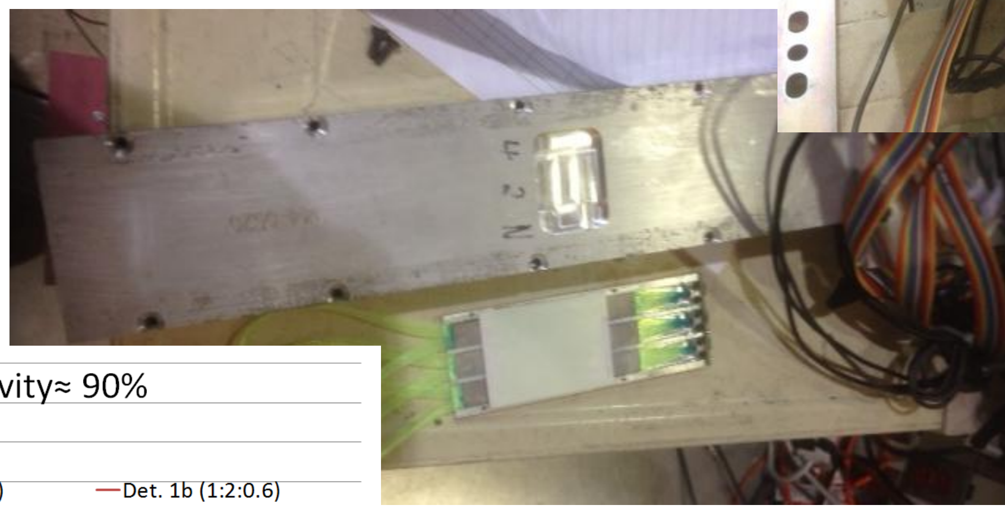
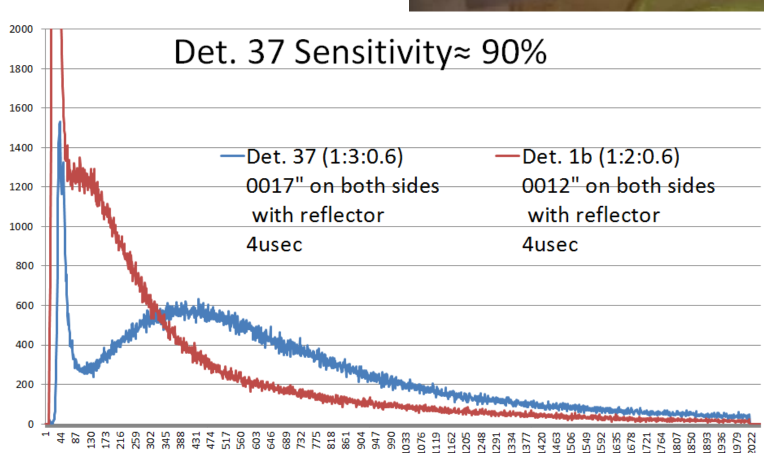
CANDOR Scintillator Testing

<u>All testing relative to HE3</u>

- Stopping power-Neutrons stopped
- Sensitivity- Neutrons counted
- Light spectrum- the brightness of events counted



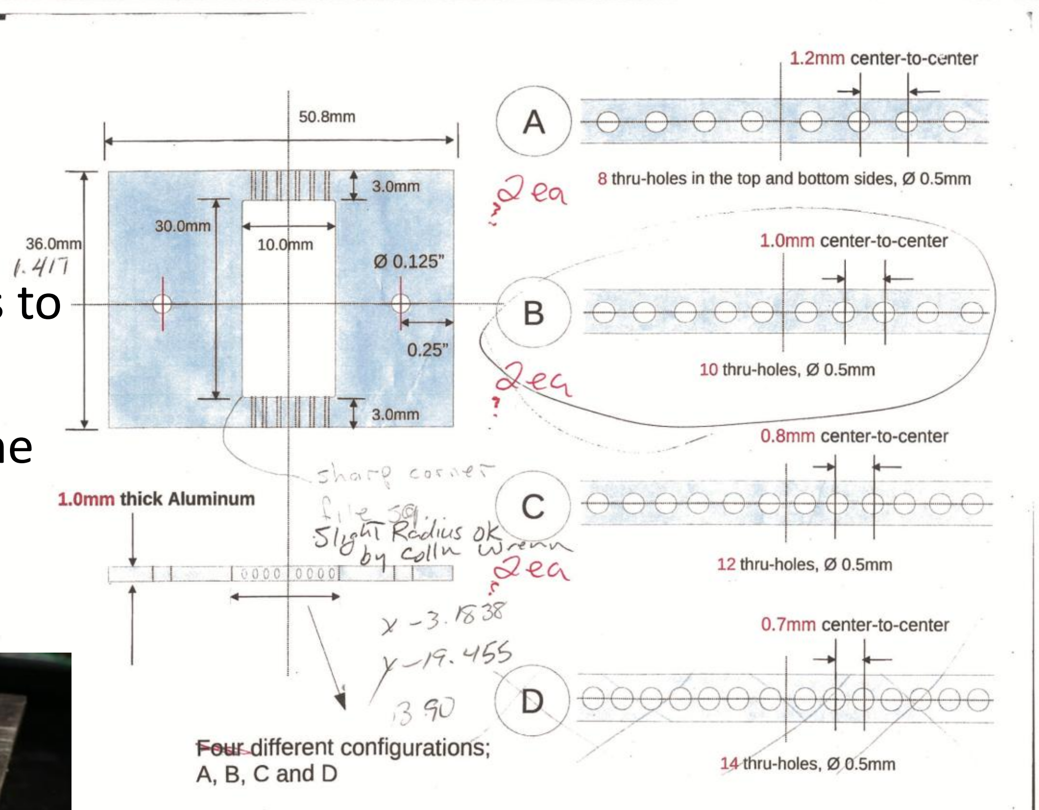


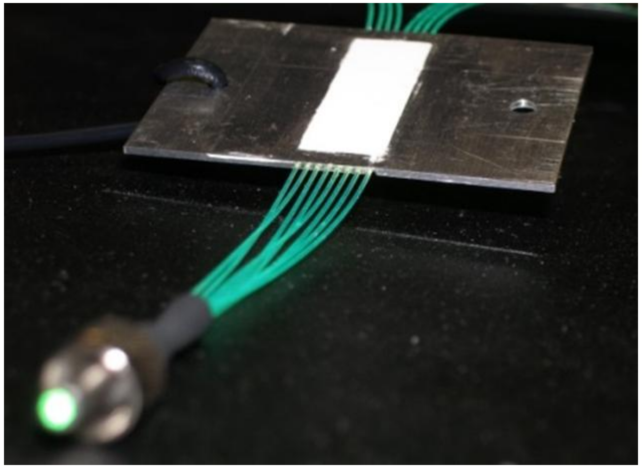


CANDoR Detector Development

Frame Design

- First frames had few fibers with spacing between fibers.
- These were complicated frames to produce.
- And labor intensive to thread the fibers.
- Poor sensitivity

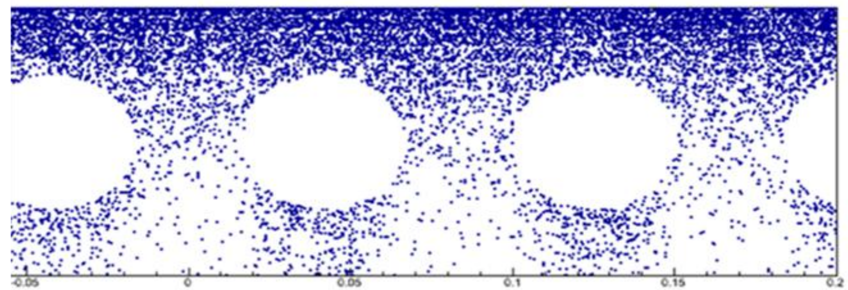


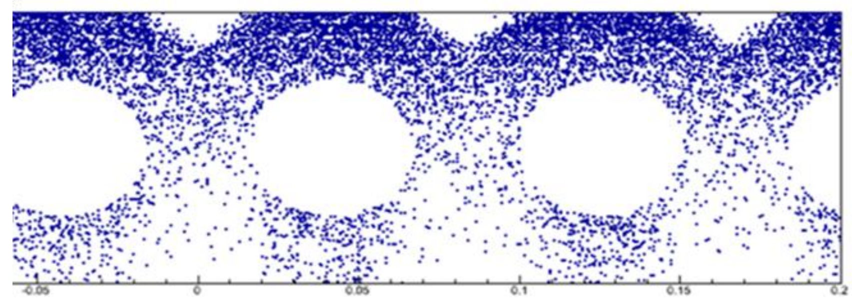


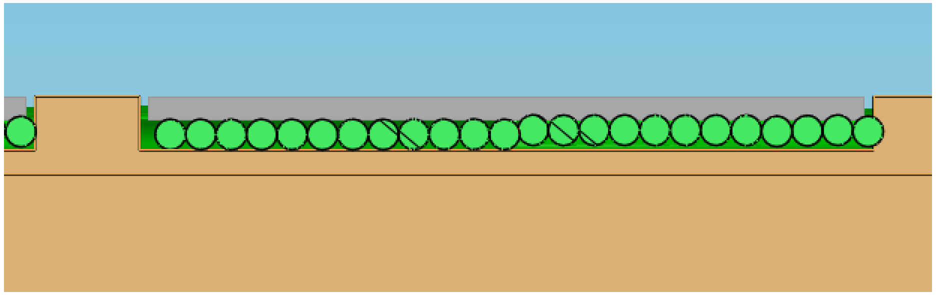
CANDoR Detector Development

Fiber Spacing Changes Light Collection

- Neutron events happen most near the surface of the detector.
- Due to the opaqueness of the compound some of these events are unlikely to be captured.
- We are losing events in area where they happen MOST!







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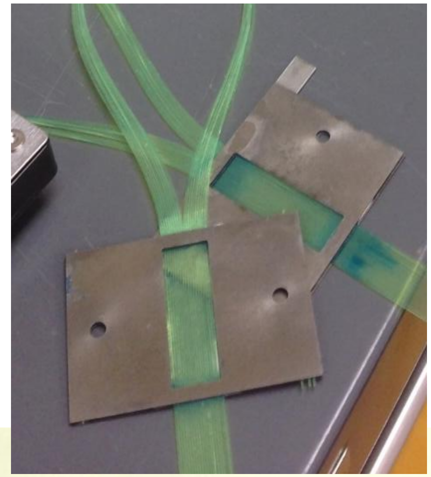
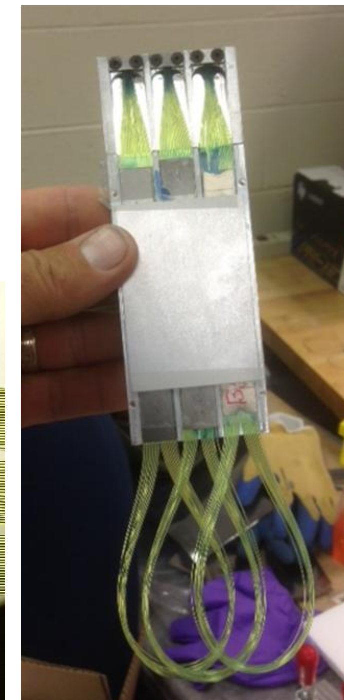
CANDoR Detector Development

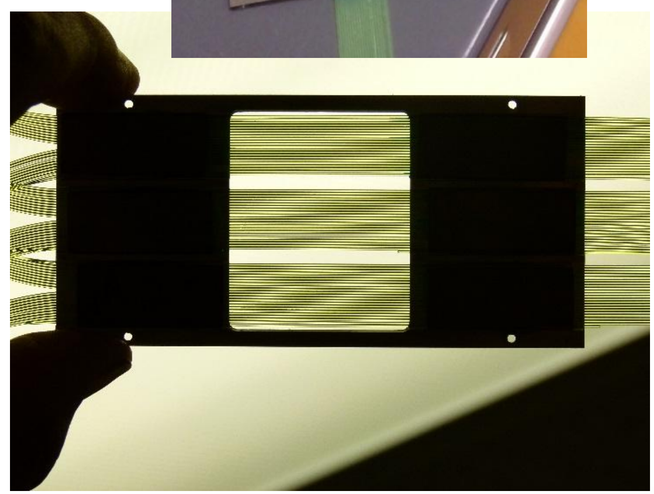
Solution-

More Fibers More Light

- We eliminate the dead spots by filling the frame with fibers
- Win-Win-Frames are easier to produce and no more fiber threading thru small holes
- Labor is easier for the detector
- Fibers are relatively cheap







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CANDOR Scintillator Compound

Scintillation Compound

- Three components- ^{6}LiF, ZnS(Ag), & binder
- High stopping power with ^{6}Li density
- High Light output with ZnS(Ag) density
- Binder is transparent
- Grain Size of the ZnS(Ag)
- Clustering of ZnS(Ag)
- Ratio of components to one another
- 1:2:0.6 vs 1:3:0.6

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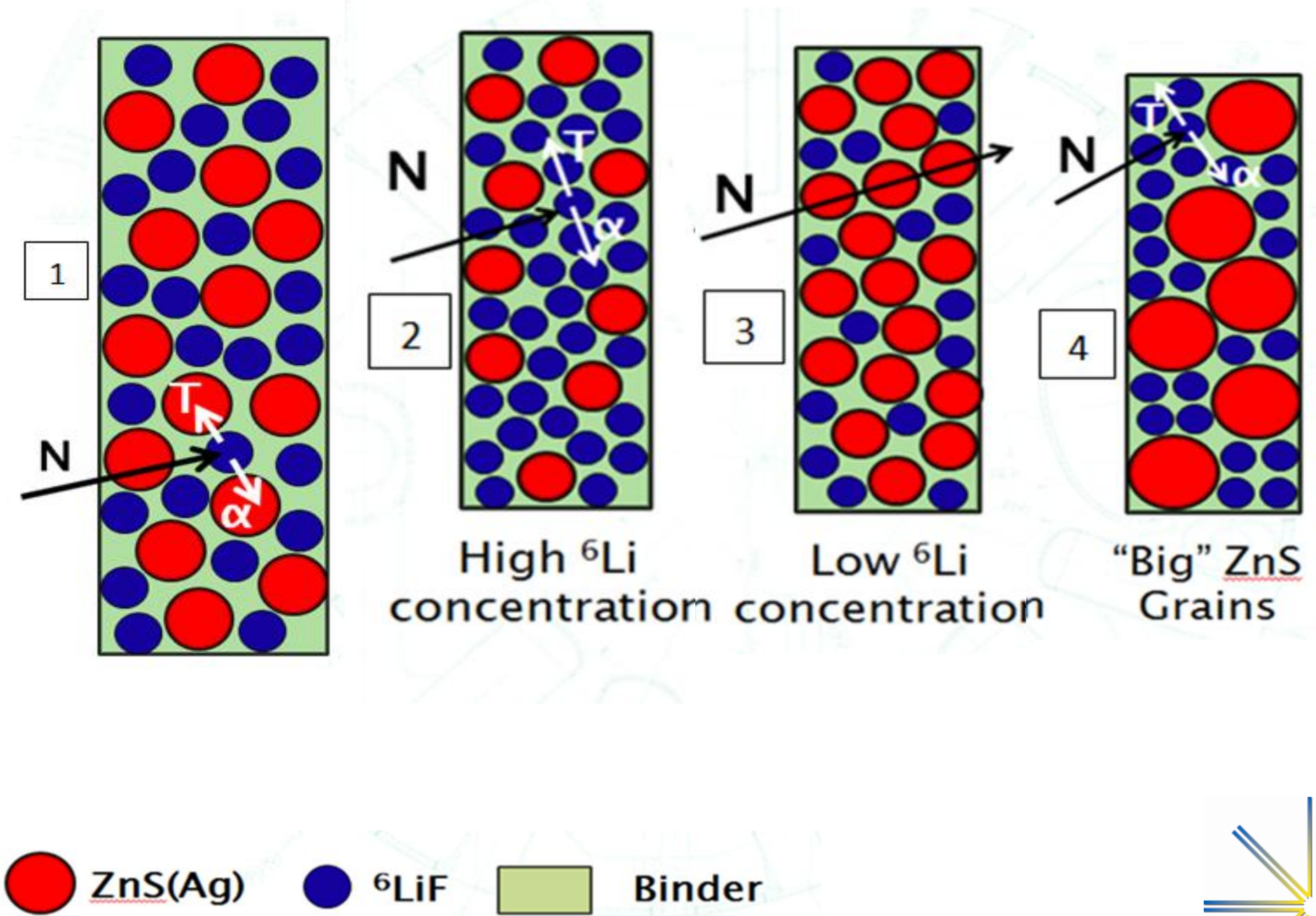
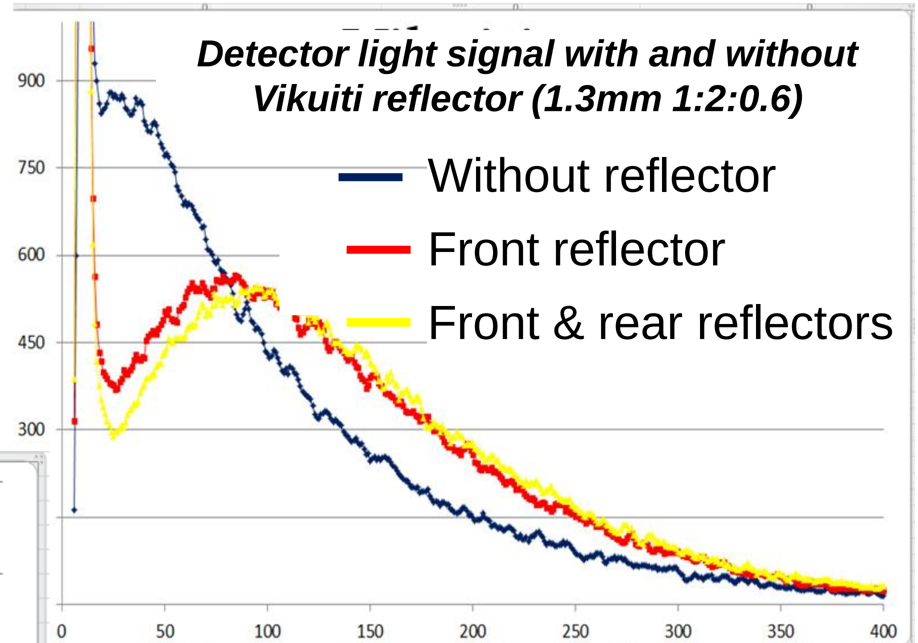
CANDOR Scintillator Compound

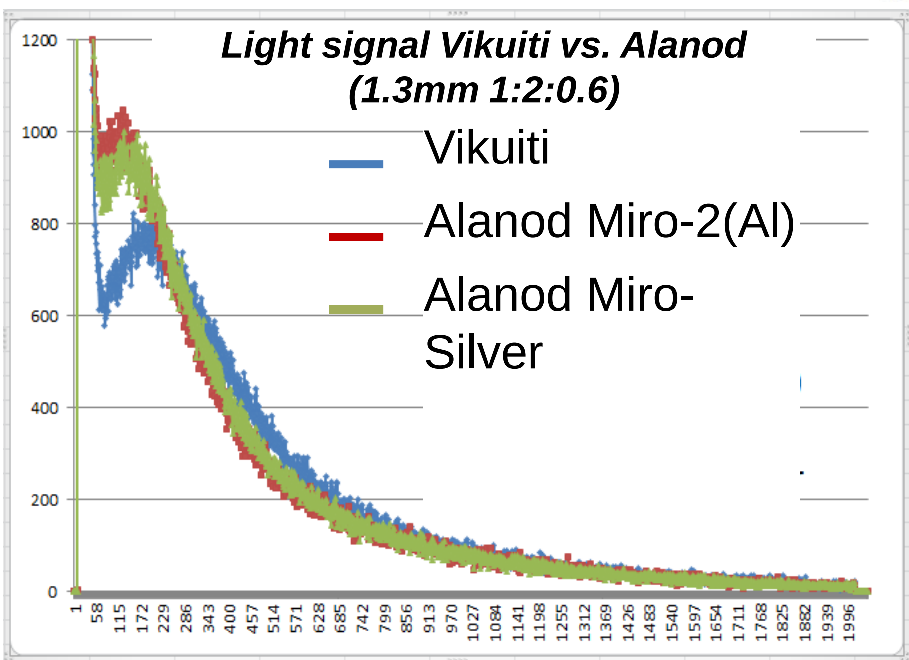


CANDOR Detector Reflectors

Reflectors increase the light energy

But the Type of reflector matters





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CANDOR Scintillator

SiPM Silicone Photo-Multipliers

- Dark noise Rate- High dark count becomes harder to distinguish between the tail and noise
- PDE-Photo Detection Efficiency
- Recovery time
- Rise time
- After Pulsing, Delay Cross Talk, Cross Talk

Luckily Sensl and Hamamatsu as well as other manufactures are improving these properties for us.

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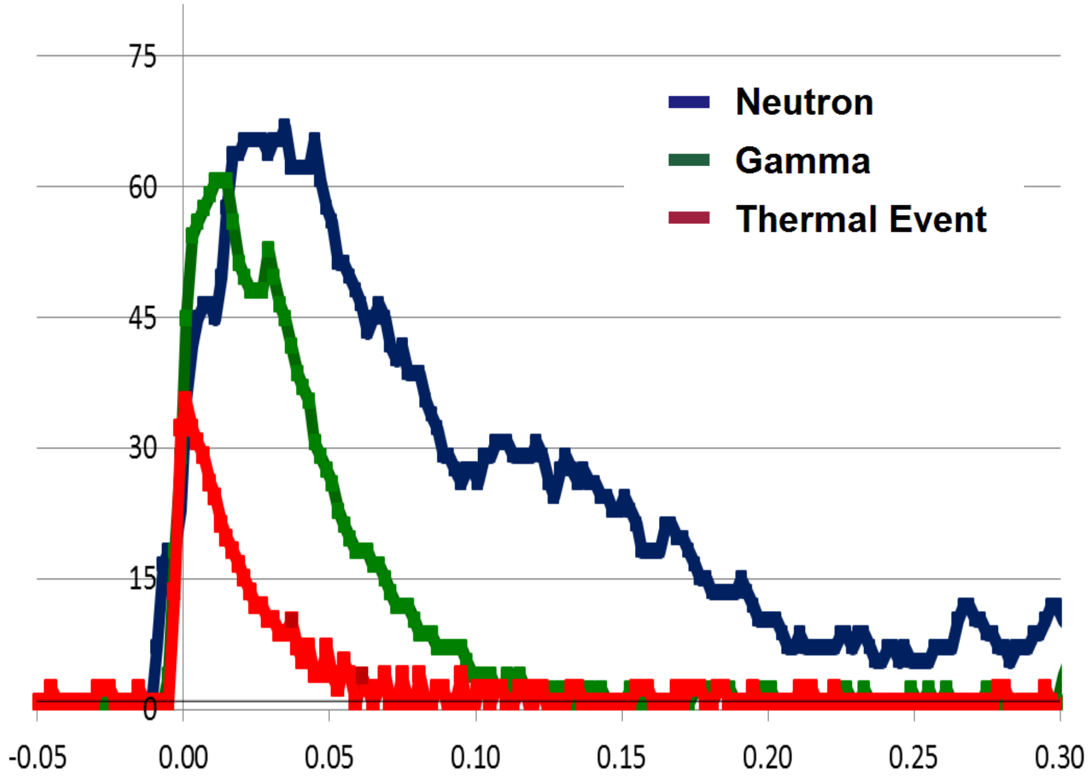
CANDOR Scintillator

Discriminators

Using the Pulse shape vs the pulse peak



Typical waveform events measured with a short recovery time diode

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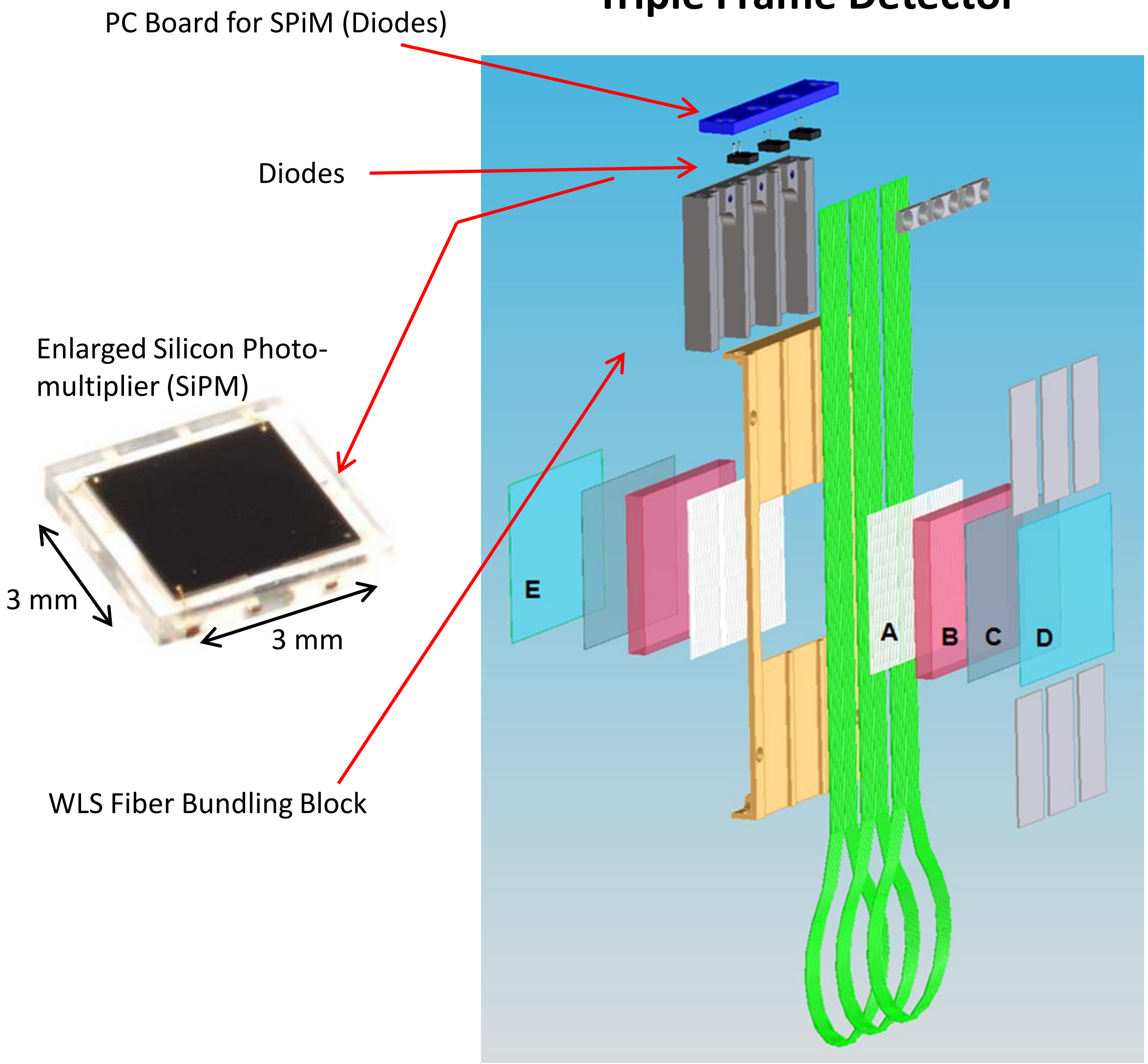
CANDOR Scintillator

Triple Frame Detector



A. Primer Layer –ZnS w/Nickel Killer
B. Compound Layer
C. ZnS (no Li)
D. Reflector Alonad
E. Reflector Vikuiti

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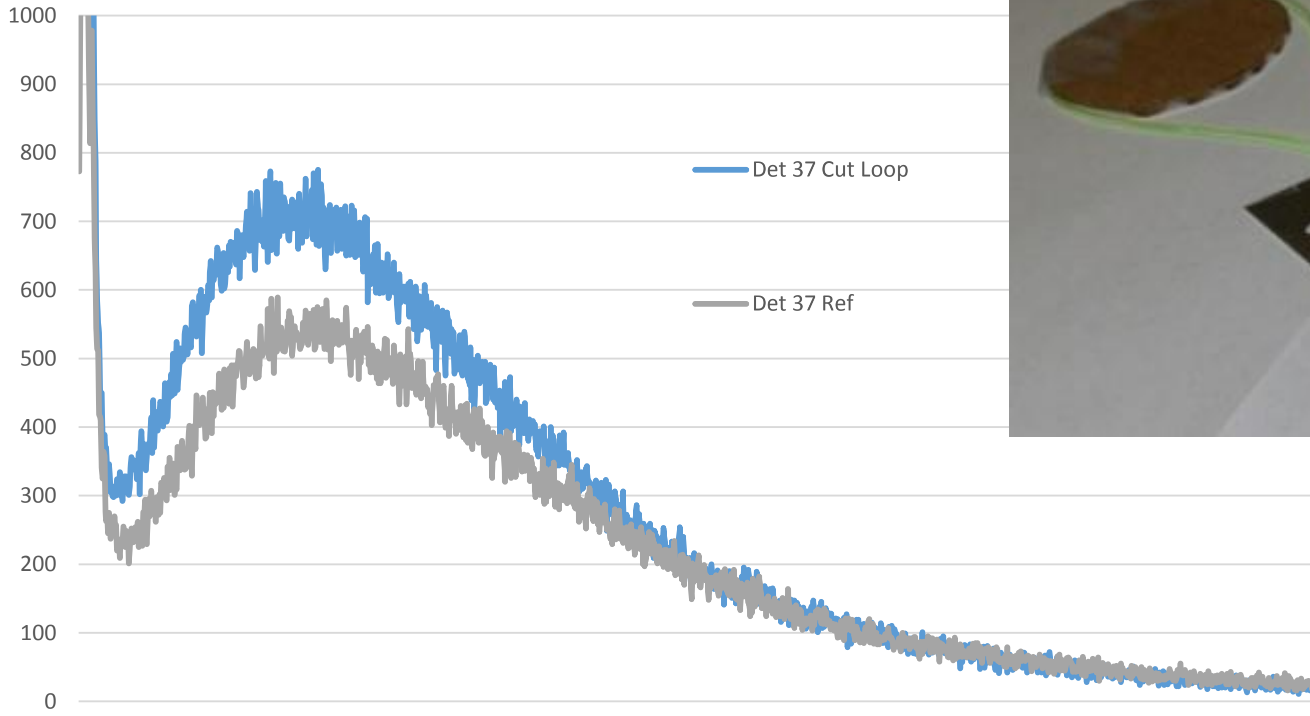
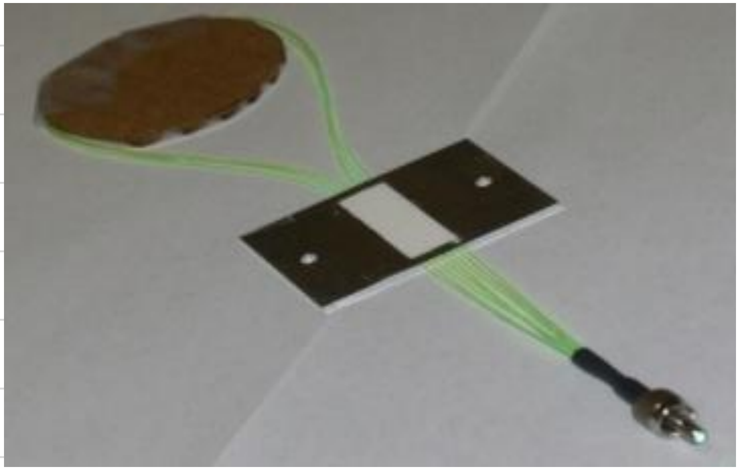
CANDOR Detector

The Final Step

Cutting the Fiber loop





CANDOR Scintillator

Conclusions

- Mechanical design, more fibers more light
- Optimal thickness for the correct compound
- Compound advances
- Discriminator improvement using Pulse shape
- Addition of reflectors to keep light in detector
- Ease of manufacturing
- Now producing >90% vs 45% last year

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THANK YOU

QUESTIONS?

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