# Research Updates: High Rate Pixelated Neutron Detector

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Monthly Group Meeting

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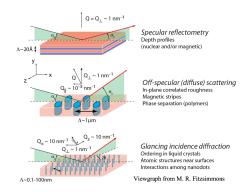
- Introduction
- Prior Work
- Current Work
- **4** Future Work

# **Neutron Reflectometry (NREF)**

Neutron reflectometry is a neutron scattering technique that makes use of the reflection of neutrons to probe and analyze interfacial structure and composition.

#### Capability:

- Specular reflectivity:
   Depth profiles
- Off-specular reflectivity:
   Surface roughness
- Glancing incidence diffraction: Atomic structure near the surface

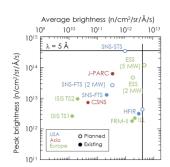


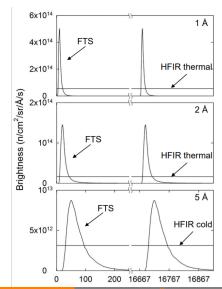
#### **Motivation**

#### Reasons:

Introduction

- Increasing neutron flux in upcoming instruments
- Current detector technology lacks in counting rate capability





## **Project Goals**

The detector requirements for neutron reflectometers at ORNL are summarized here.

The project goal is to aim to satisfy all aspects of the requirements, except the active area of the detector.

Detector Requirement			
Parameter	Desired		
Counting rate	1 MHz/cm <sup>2</sup>		
Detector efficiency	60% (2Å)		
Gamma sensitivity	$1 \times 10^{-6}$		
Spatial resolution	1 - 2 mm		
Active area	$20 \times 20 \text{ cm}^2$		

It is expected that the detector has an active area of 6.4  $\times$  6.4 cm<sup>2</sup>.

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# **Current Detector Prototype**

 $8 \times 8$  array of GS20 (2 × 2 × 2 mm<sup>2</sup>) Scintillator

 $8 \times 8$  array of SiPM (1 mm<sup>2</sup> active area) Photosensor

Independent channel readout for fast signal processing Readout

Signal Processing Pulse height discrimination & Time-Over-Threshold

Custom firmware and software Acquisition

#### **Detector Performance**

Current detector prototype showed satisfactory performance for detection efficiency and spatial resolution.

#### **Evaluation**

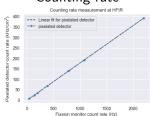
Parameter	Achieved	Goal
Counting rate	400 kHz/cm <sup>2</sup>	1 MHz/cm <sup>2</sup>
Detector efficiency†	74% (1.8Å)	60% (2Å)
	92% (4.2Å)	
Gamma sensitivity <sup>‡</sup>	$1 \times 10^{-4}$	$1 \times 10^{-6}$
Spatial resolution	2 mm	1 - 2 mm
Active area	$1.6  imes 1.6  ext{ cm}^2$	$6.4 \times 6.4 \text{ cm}^2$

 $<sup>^\</sup>dagger$  Detection efficiency relative to a 10-atm  $^3\mathrm{He}$  gas detector.

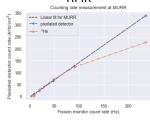
<sup>&</sup>lt;sup>‡</sup> Gamma sensitivity is obtained using <sup>60</sup>Co source.

## **Key Results**

#### Counting rate

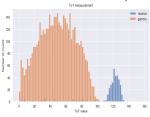


#### HFIR

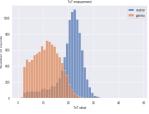


MURR

#### Gamma sensitivity

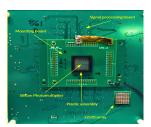


 $6 \times 6 \text{ mm}^2$ 



 $1\times 1~\text{mm}^2~\text{MURR}$ 

Active area



Requires rearrangement of electronic configuration for scale-up without introducing dead space within the active area of the detector

Exploring commercially available SiPM readout systems.

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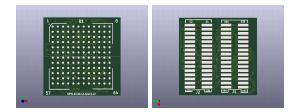
#### **Geant4** simulation

Scintillator studies and literature reviews

# **SiPM Readout System**

Comparison		
Company	CAEN	Petsys
Module Name	A5202 + DT5215	TOF ASIC evaluation kit
ASIC chip	CITIROC-1A (x2)	TOFPET ASIC
Channel/ASIC chip	32	64
Dynamic range	400 pC	1500 pC
Maximum channel hit rate	20 MHz	600 kHz
Max output data rate	6.25 Gb/s	3.2 Gb/s
Acquisition modes	PHA, TOT	PHA, TOT, TOF
Availability	Coming soon	In stock

# **Board Layout**



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#### This Summer

#### Goals:

- Wrap up Geant4 simuation on GS20, and compare results with experimental results
- Once the SiPM readout system is finalized, lay out the connector board that interfaces the SiPMs with the readout system.
- Work on a peer-reviewed journal on the latest work and upgrades on the detector prototype.

#### Possible work:

- Explore other scintillators or photosensors as alternatives
- Explore other signal processing techniques to improve the neutron-gamma discrimination of the detector
- Improve our DAQ software

