

Research Updates: High Rate Pixelated Neutron Detector

Su-Ann Chong

Monthly Group Meeting

June 5th, 2020

Outline

① Introduction

② Prior Work

③ Current Work

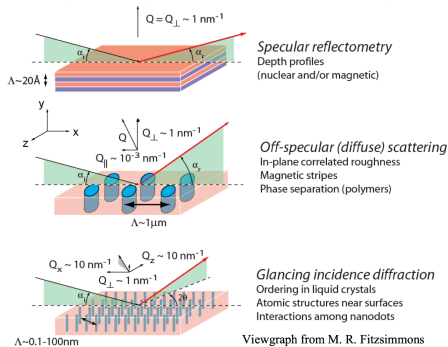
④ Future Work

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:

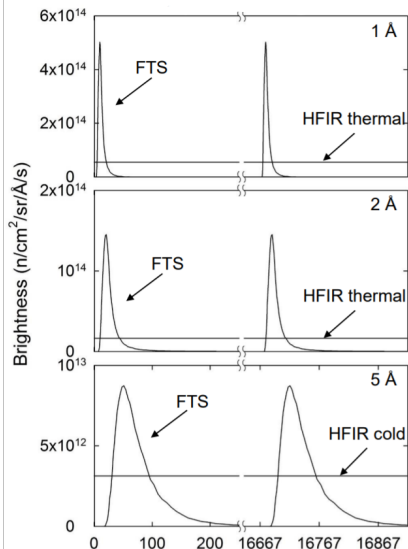
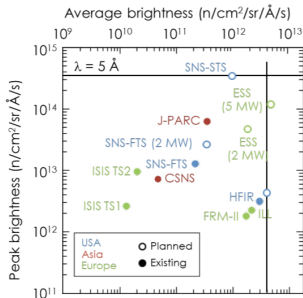
- Specular reflectivity:
Depth profiles
- Off-specular reflectivity:
Surface roughness
- Glancing incidence diffraction:
Atomic structure near the surface



Motivation

Reasons:

- 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 ²
Detector efficiency	60% (2Å)
Gamma sensitivity	1×10^{-6}
Spatial resolution	1 - 2 mm
Active area	20 × 20 cm ²

It is expected that the detector has an active area of 6.4×6.4 cm².

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Current Detector Prototype

Scintillator	8×8 array of GS20 ($2 \times 2 \times 2 \text{ mm}^2$)
Photosensor	8×8 array of SiPM (1 mm^2 active area)
Readout	Independent channel readout for fast signal processing
Signal Processing	Pulse height discrimination & Time-Over-Threshold
Acquisition	Custom firmware and software

Detector Performance

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

Evaluation

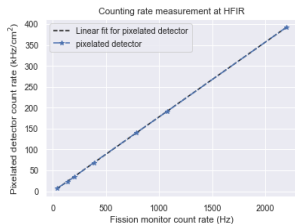
Parameter	Achieved	Goal
Counting rate	400 kHz/cm ²	1 MHz/cm ²
Detector efficiency [†]	74% (1.8Å) 92% (4.2Å)	60% (2Å)
Gamma sensitivity [‡]	1×10^{-4}	1×10^{-6}
Spatial resolution	2 mm	1 - 2 mm
Active area	$1.6 \times 1.6 \text{ cm}^2$	$6.4 \times 6.4 \text{ cm}^2$

[†] Detection efficiency relative to a 10-atm ³He gas detector.

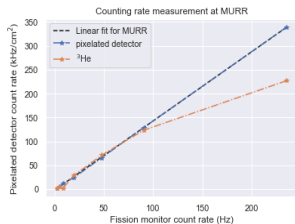
[‡] Gamma sensitivity is obtained using ⁶⁰Co source.

Key Results

Counting rate

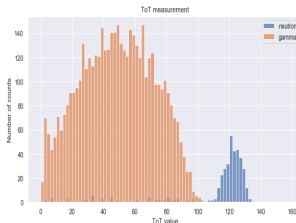


HFIR

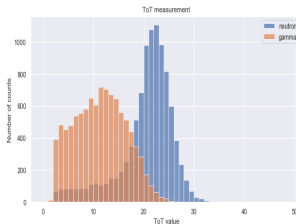


MURR

Gamma sensitivity

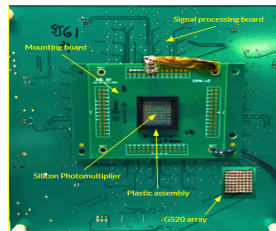


$6 \times 6 \text{ mm}^2$



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

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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- ➌ **Current Work**
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Geant4 simulation

Scintillator studies and literature reviews

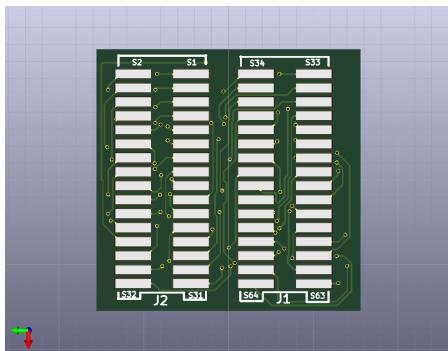
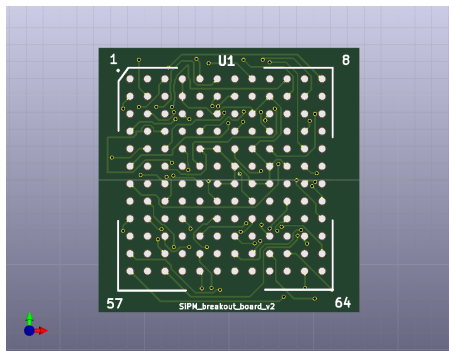
SiPM Readout System

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

Printed circuit board (PCB) layout for SiPM connector. Some SiPM comes with a connector, some comes with ball grid array (BGA).



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This Summer

Goals:

- Wrap up Geant4 simulation 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

Thank you for your time!