Summary of the Cross Cutting Sessions

Petra Merkel, Fermilab

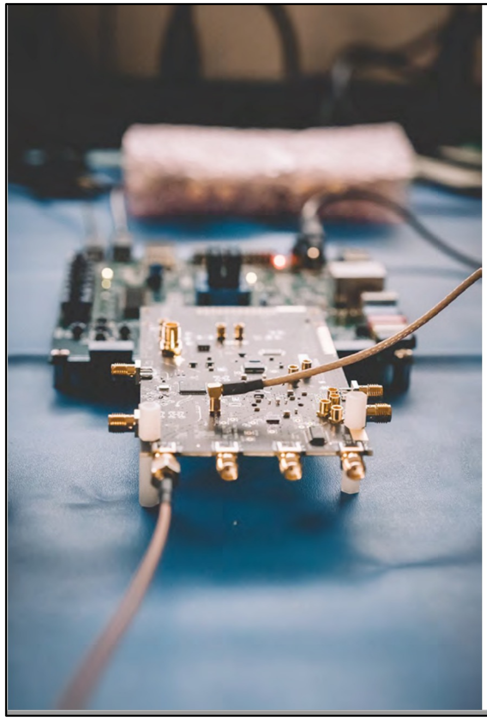
CPAD 2022 Workshop, Stony Brook University

December 2, 2022

Overview

- Very diverse sessions
  - talks were submitted to multiple sessions
  - loosely grouped into themes
- 14 contributions total
  - readout systems and calibrations/quality control
  - use of new materials
  - photon detection
  - low threshold/low noise detectors
  - experimental systems
- Will briefly summarize each presentation instead of presenting overarching themes

Isar Mostafanezhad
(Nalu Scientific, LLC)



NALU SCIENTIFIC
ENABLING INNOVATION

Waveform Digitizing Electronics for Reading out Next Generation Detectors

Nov 29, 2022
Isar Mostafanezhad, Ph.D.
Founder and CEO at Nalu Scientific LLC

Work partially funded by US DOE SBIR Grants:

DE-SC0015231, DE-SC0017833, DE-SC0020457

https://indico.bnl.gov/event/17072/contributions/70717/

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low cost, high channel count, high density, streaming readout capable, waveform sampling ASIC

optimized for use in large future detectors such as GEMs for TPCs, and for tracking and PID detector systems

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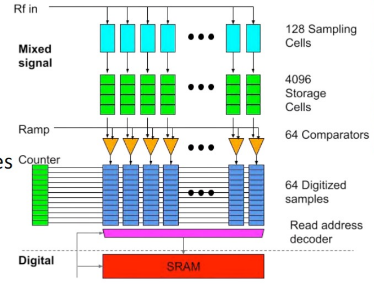
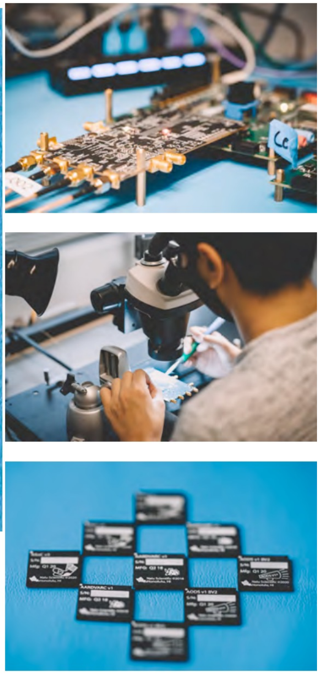
Current SoC-ASIC Projects

Project	Sampling Frequency (GHz)	Input BW (GHz)	Buffer Length (Samples)	Number of Channels	Timing Resolution (ps)	Available Date
ASoC	3-5	0.8	16k	4	35	Rev 3 avail
HDSoC	1-3	0.6	2k	64	80-120	Rev 1 avail
AARDVARC	8-14	2.5	32k	4	10	Rev 3 avail
AODS	1-2	1	8k	1-4	100-200	Rev 2 avail
UDC	8-10	1.5-2	4k	16/32	10	Rev 1 avail

- Waveform digitizing benefits:
  - Pileup, sensor damage
  - Feature extraction
- Readout size and power is constrained
- No one form fits all:
  - Various sensor arrays and densities
  - Analog pre-processing
  - Timing resolution
  - Types of features





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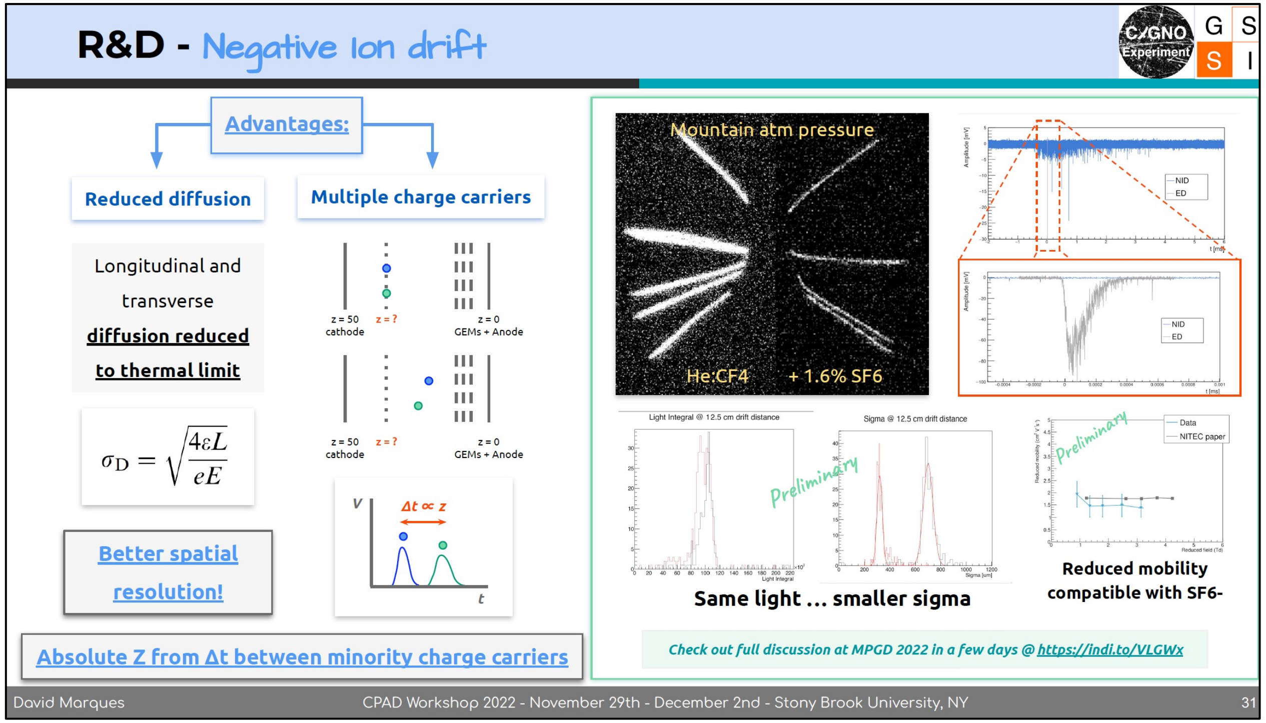
David Marques
(Gran Sasso)

A CYGNus tpc module with Optical readout

Negative ion drift observed for the first time at atmospheric pressure and with PMTs – stay tuned!



Haoran Zhao

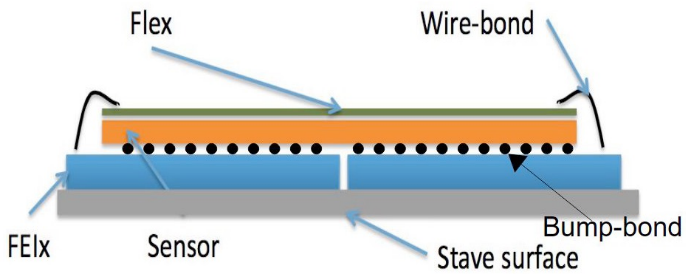
(University of Washington)

Developments of ITkPixV1.1 module Quality Control tools

Haoran Zhao[1], Jay Chan[2,3], Emily Thompson[2], Kehang Bai[2,4], Elisabetta Pianori[2], Timon Heim[2], Lingxin Meng[5], Marija Marjanovic[5], Shih-Chieh Hsu[1] , Scott Hauck[1]

[1] University of Washington
[2] Lawrence berkeley national laboratory
[3] University of Wisconsin-Madison
[4] University of Oregon
[5] CERN

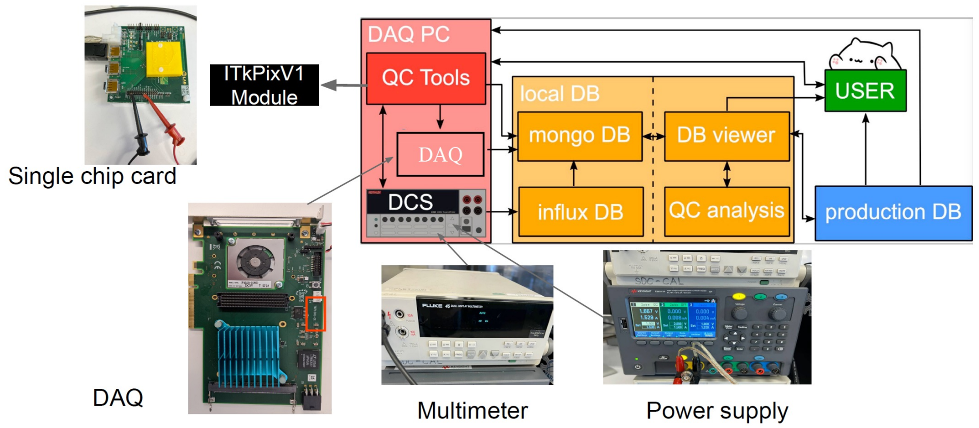
CPAD 2022



ATLAS ITk Pixel module QC developed to be carried out at ~25 institutions

- Calibrate the ADC that digitizes the internal signals from the monitoring block (temperature, total ionizing dose, internal voltages or currents)
- Check the powering behavior of the chip
- Calibrate the injection circuit

Module QC Tools - Schematics



H. Zhao CPAD 2022

Cristina Bernardes Monteiro (University of Coimbra)

The PISA concept: Photon Induced Scintillation Amplifier, an innovative high-gain photosensor for rare event detection

Cristina M.B. Monteiro[1,*]
R.D.P. Mano[1], R.J.C. Roque[1]

[1]*LIBPhys, Physics Department, University of Coimbra, Portugal*

*cristinam@uc.pt

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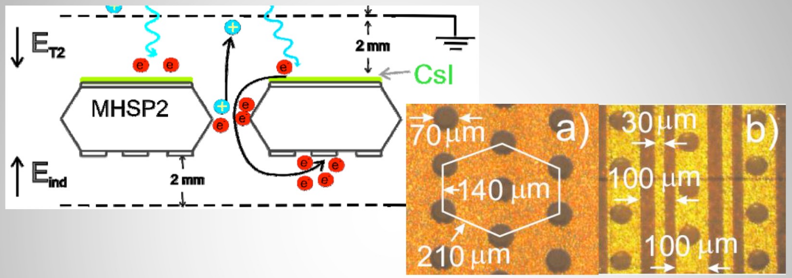
UNIVERSIDADE D COIMBRA

LIBPhys-UC

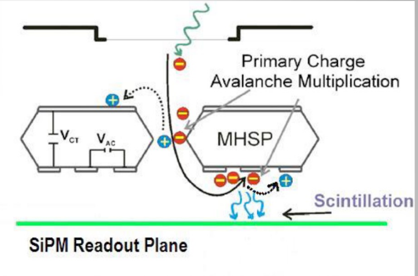
PISA: The MHSP e⁻-multiplier



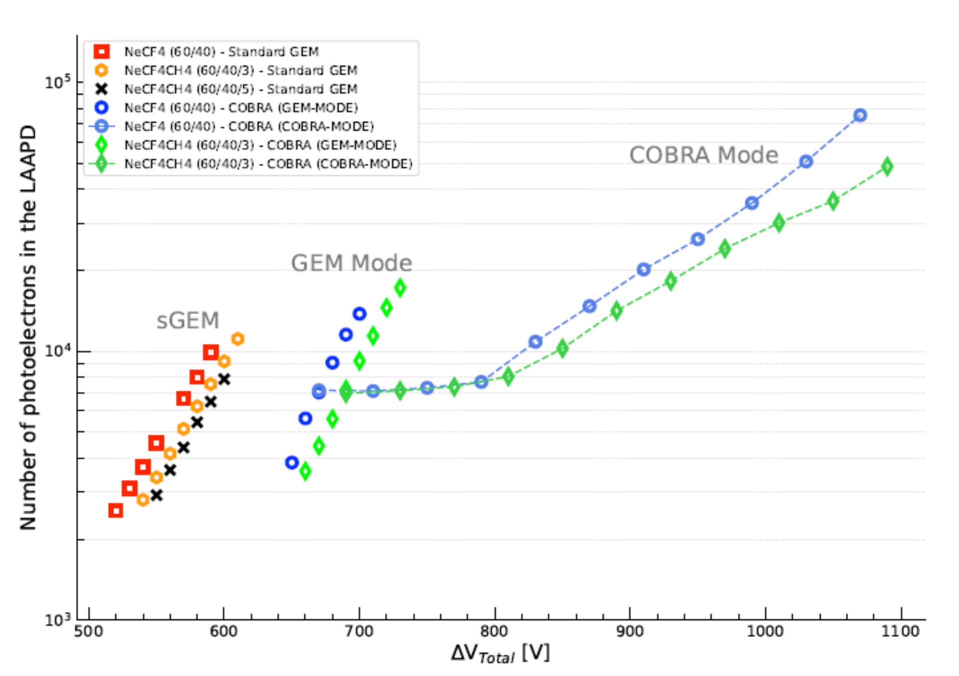
- Element made of Kapton 125 μm thick (robust, radiopure)
- 2 e⁻-avalanche stages in one-single element
- Higher scintillation yield than THGEM

PISA: Advantages

- Compact: only 1 element
- Extra-high gain from SiPMs
- Improved S/N ratio



- Clean Materials: Kapton + Silicon
- Electronics placed far away from the SiPM plane
- Reduced SiPM coverage area.



Proof of principle looks promising, more R&D needed

David Winn
(Fairfield University)

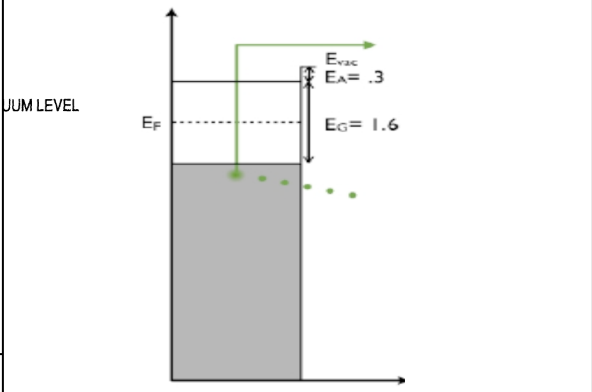
These materials are potentially easier to grow now than when they were first investigated

Some advantages over e.g. Silicon; could operate at room temperature

Cs_3Sb and Ag-O-Cs as Diode Detectors for Low Energy Photon and Particle Detection:
Time Resolution, High Rates, Radiation Resistant

David R Winn - Fairfield University*
Yasar Onel - University of Iowa

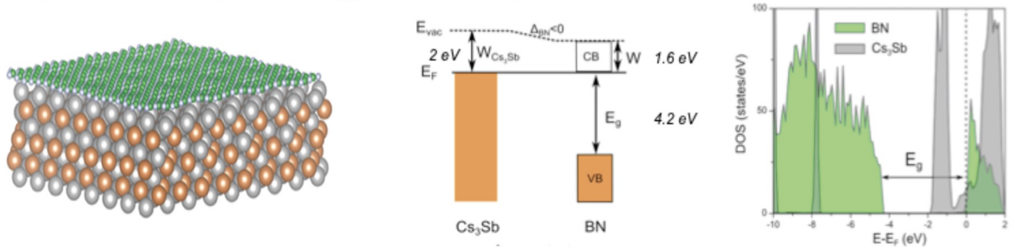
*winn@fairfield.edu



Cs_3Sb (S-11) Cs_3Sb

The Cs_3Sb semi-conductor energy level band diagram – the energy for pair production $E_P \sim Ea+Eg=$ 1.9-2.0 eV, near the vacuum level and like the 2nd class Band Diagram

- Recently it has been shown that one molecular thickness of boron carbide (BN) or one layer of graphene can protect Cs_3Sb from air, important for practical detectors with minimal effects from air.
- Remarkably, the BN layer *lowers* the pair energy from 2 eV to 1.6 eV [], [] whereas graphene layers raise the pair energy to 2.1 eV[].

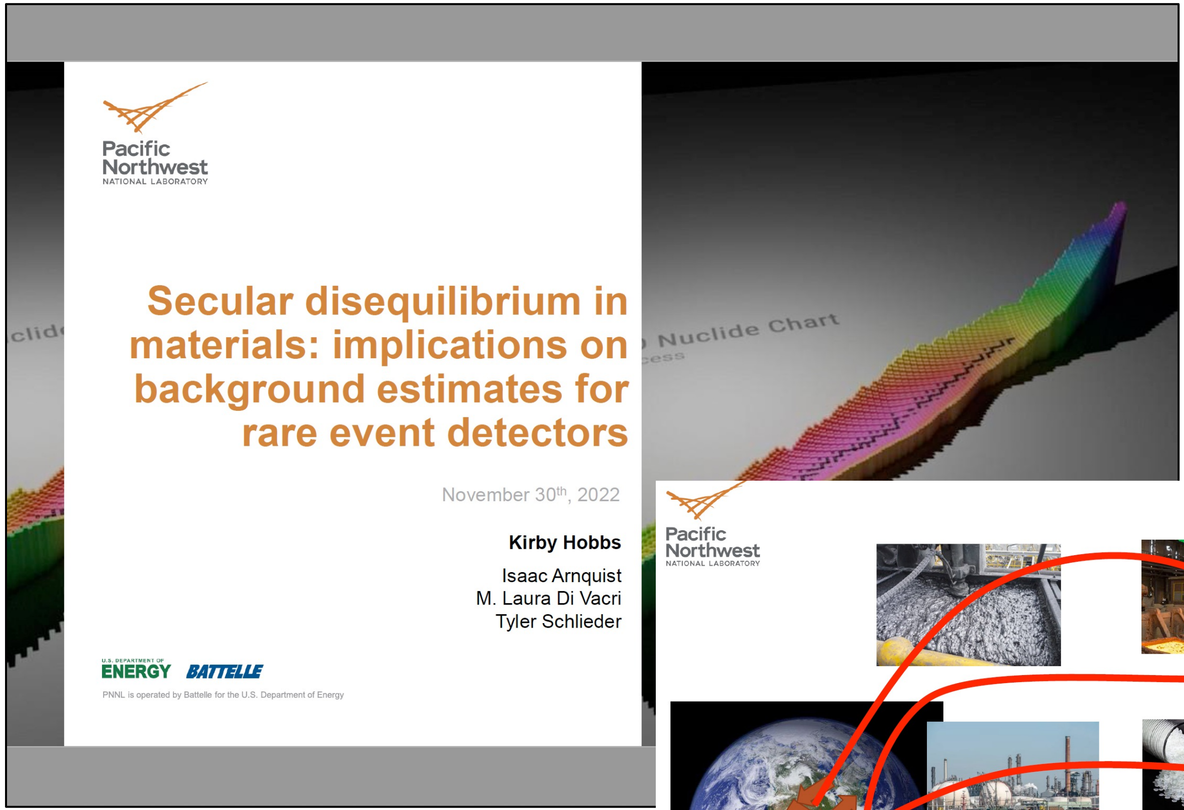


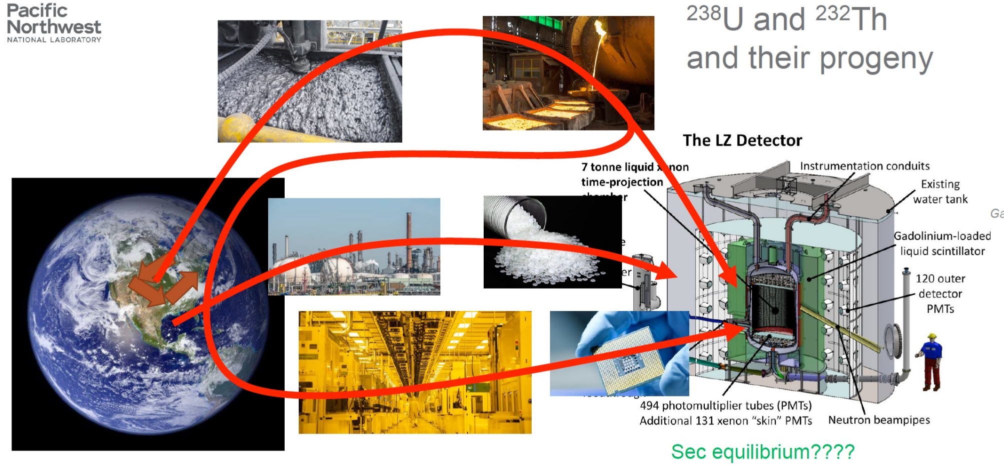
(L): Molecular model of layered Cs_3Sb with a BN (boron nitride; graphene similar) single molecular layer top-side covering. The e-hole pairs could be drifted parallel to the atomic planes in perfect crystals that result from (near)atomic layer assembly. ***(M):*** Remarkably, the implied electrostatic potential *lowers* the work function of Cs_3Sb from 2 eV to 1.6 eV **(R)** Energy bands of Cs_3Sb+BN.

Wang, Yang, Moody and Batista, NPJ 2D Materials and Applications 2, 1-9 (2018)
Wang , Pandey, Moody, Yang, Batista, J. Phys. Chem. C 121, 8399-8408 (2017)
Pavlenko, Liu, Hoffbauer, Moody, and Batista, AIP Adv. **6**, 115008(2016)
BN and graphene atomic layers deposit at T<100°C [].

Kirby Hobbs
(PNNL)

investigate procedures that promote *favorable* secular disequilibria and leverage these procedures to reduce backgrounds in ULB detectors

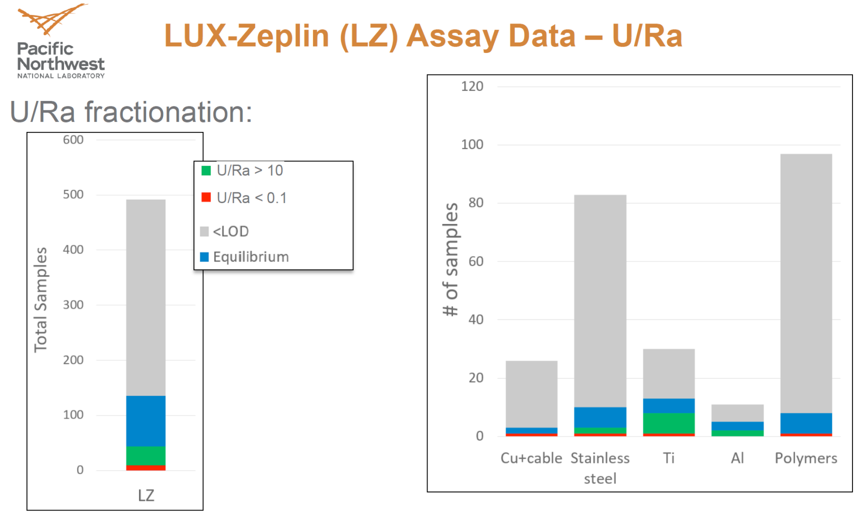




^{238}U and ^{232}Th and their progeny

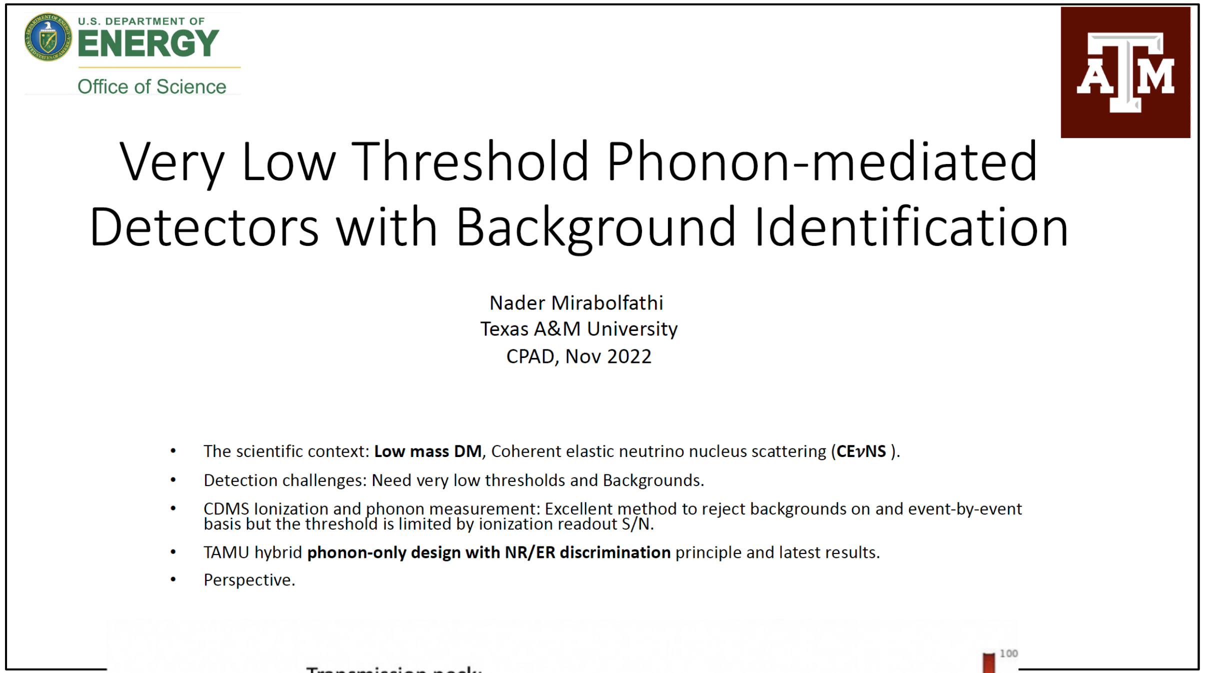
Sec equilibrium, *sans* radon

Sec equilibrium????



Garnered from D.S. Akerib et al. 2020

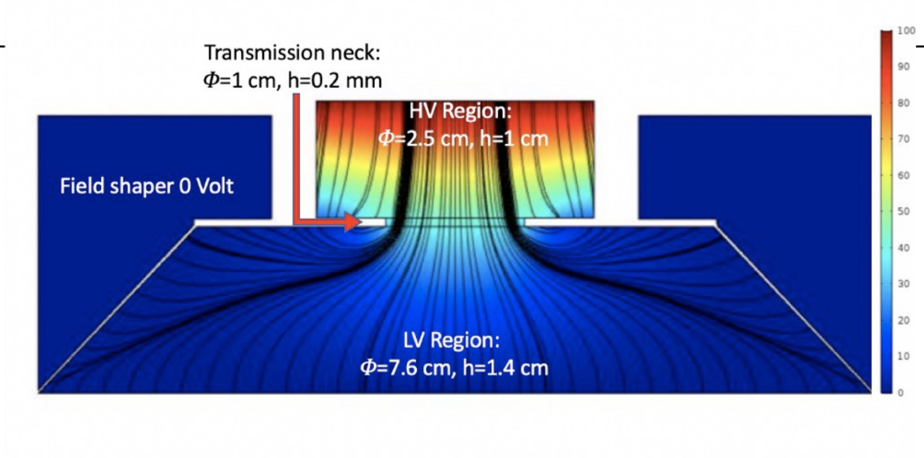
Nader Mirabolfathi (TAMU)

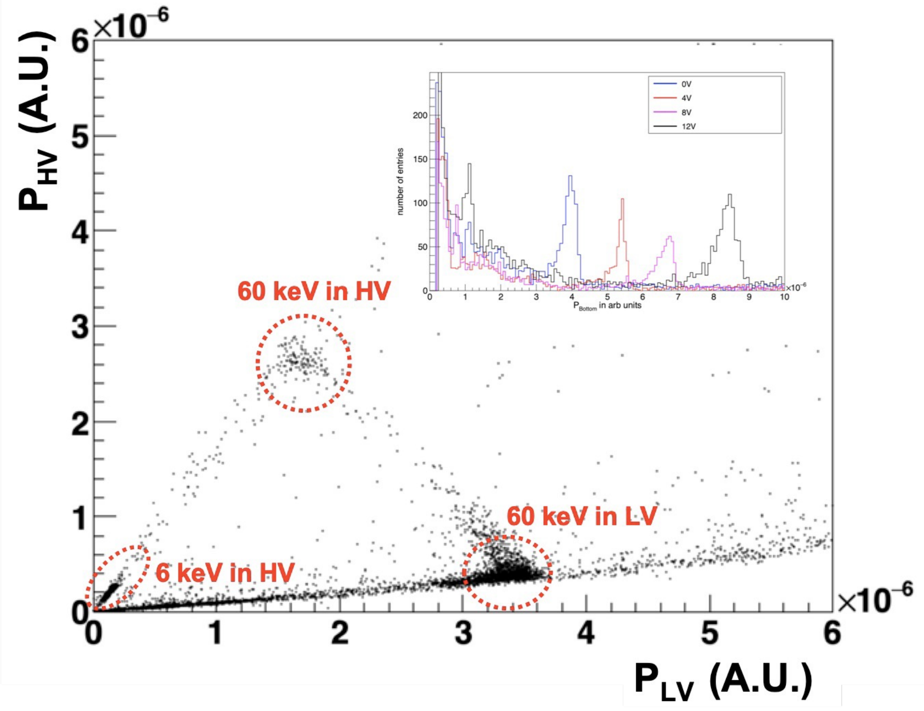

U.S. DEPARTMENT OF ENERGY
Office of Science

Very Low Threshold Phonon-mediated Detectors with Background Identification

Nader Mirabolfathi
Texas A&M University
CPAD, Nov 2022

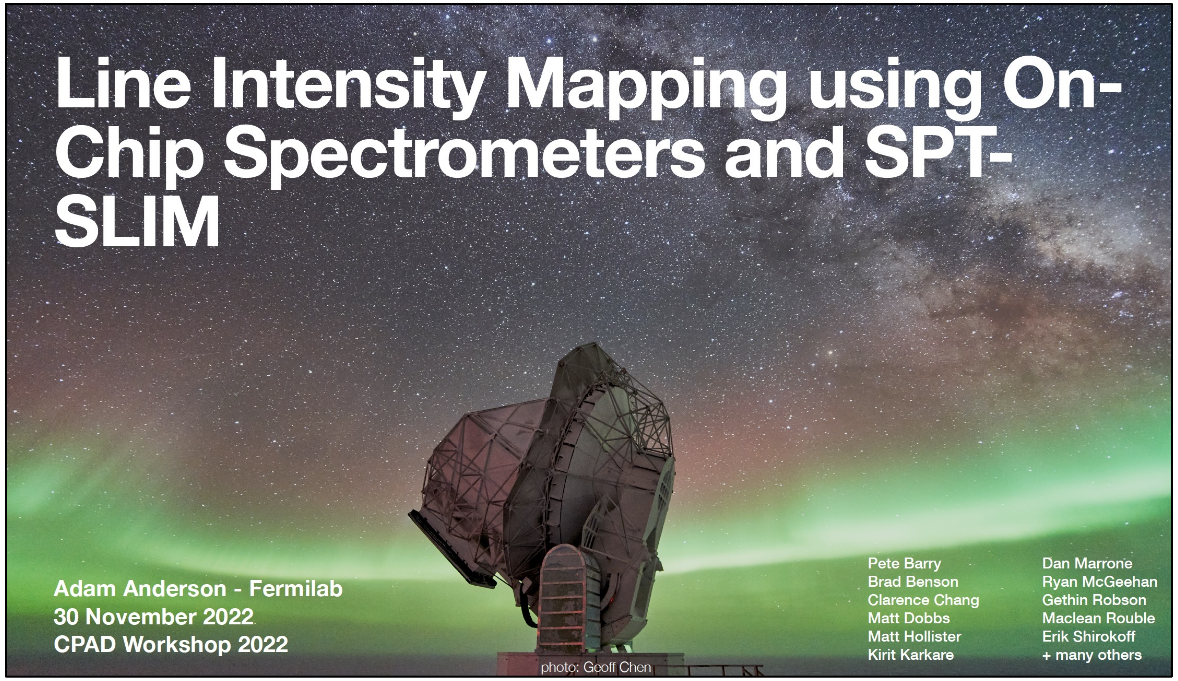
- The scientific context: **Low mass DM**, Coherent elastic neutrino nucleus scattering (**CEνNS**).
- Detection challenges: Need very low thresholds and Backgrounds.
- CDMS Ionization and phonon measurement: Excellent method to reject backgrounds on and event-by-event basis but the threshold is limited by ionization readout S/N.
- TAMU hybrid **phonon-only design with NR/ER discrimination** principle and latest results.
- Perspective.



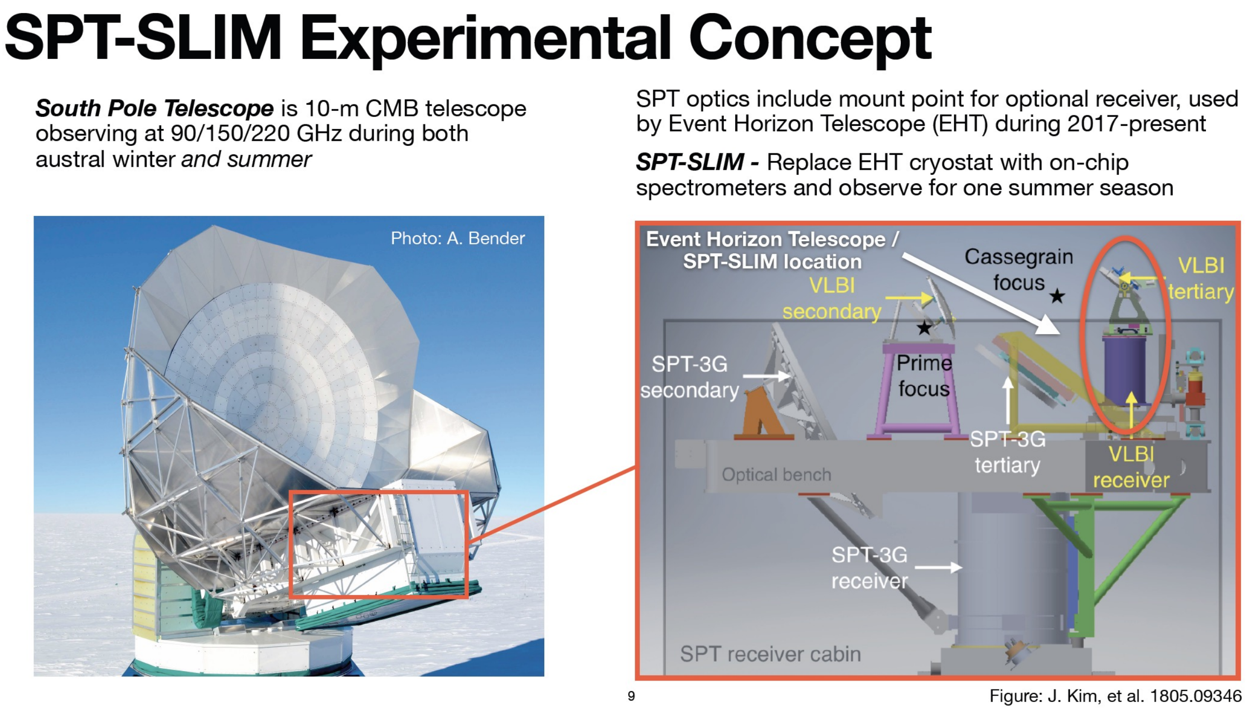


This detector is actively in use for CEνNS searches in the MINER experiment and once the R&D is complete, it can be a candidate for future low background DM searches, notably SuperCDMS at SNOLAB.

Adam Anderson
(FNAL)

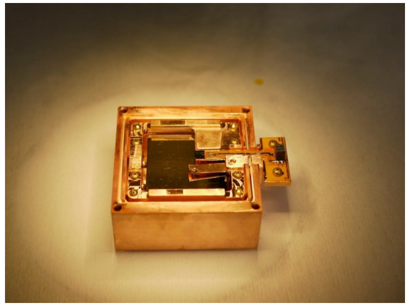


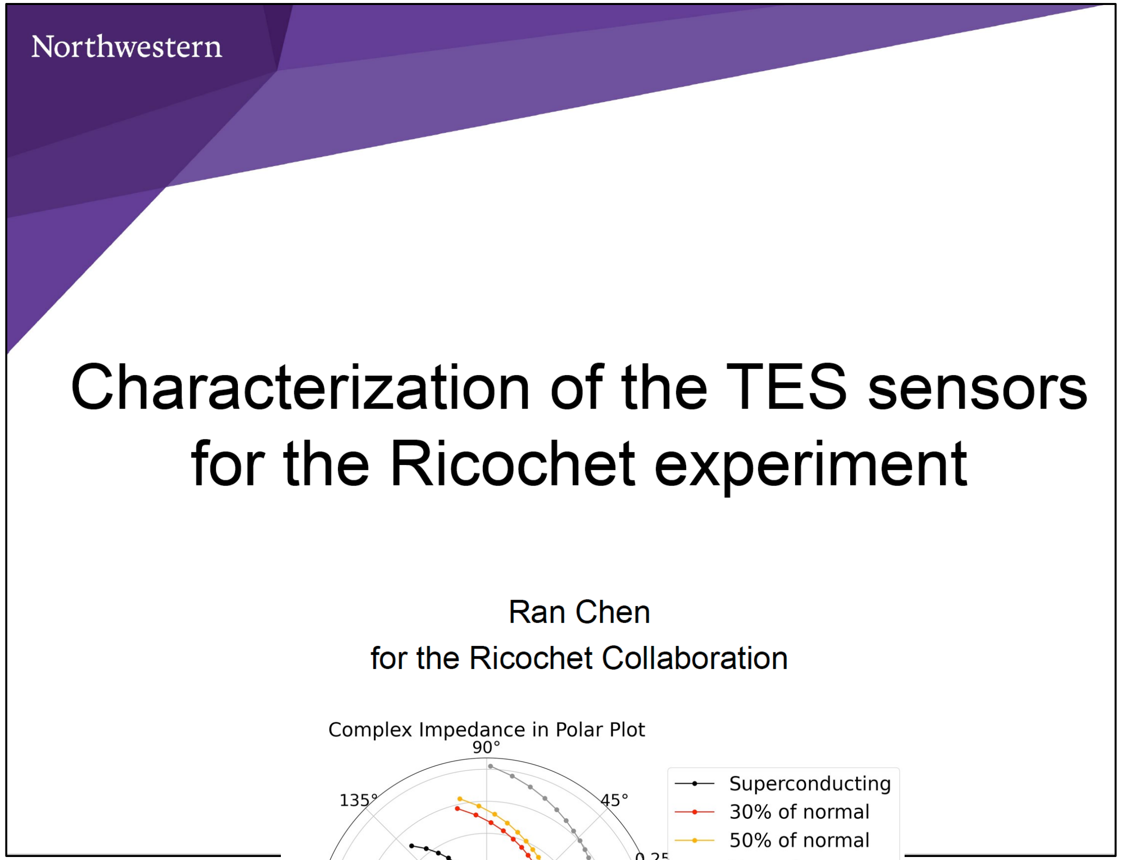
High-significance detection of CO power spectrum is possible even with a small technology demonstrator

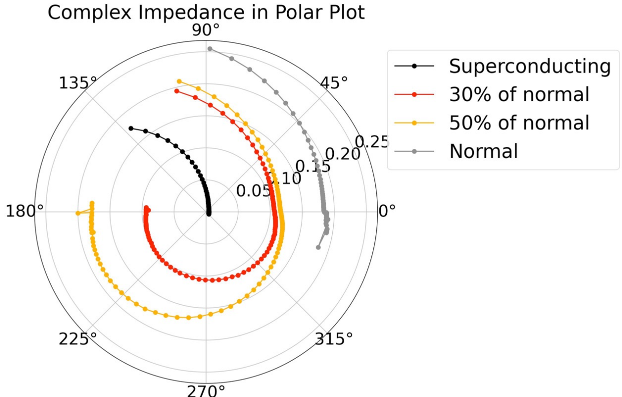


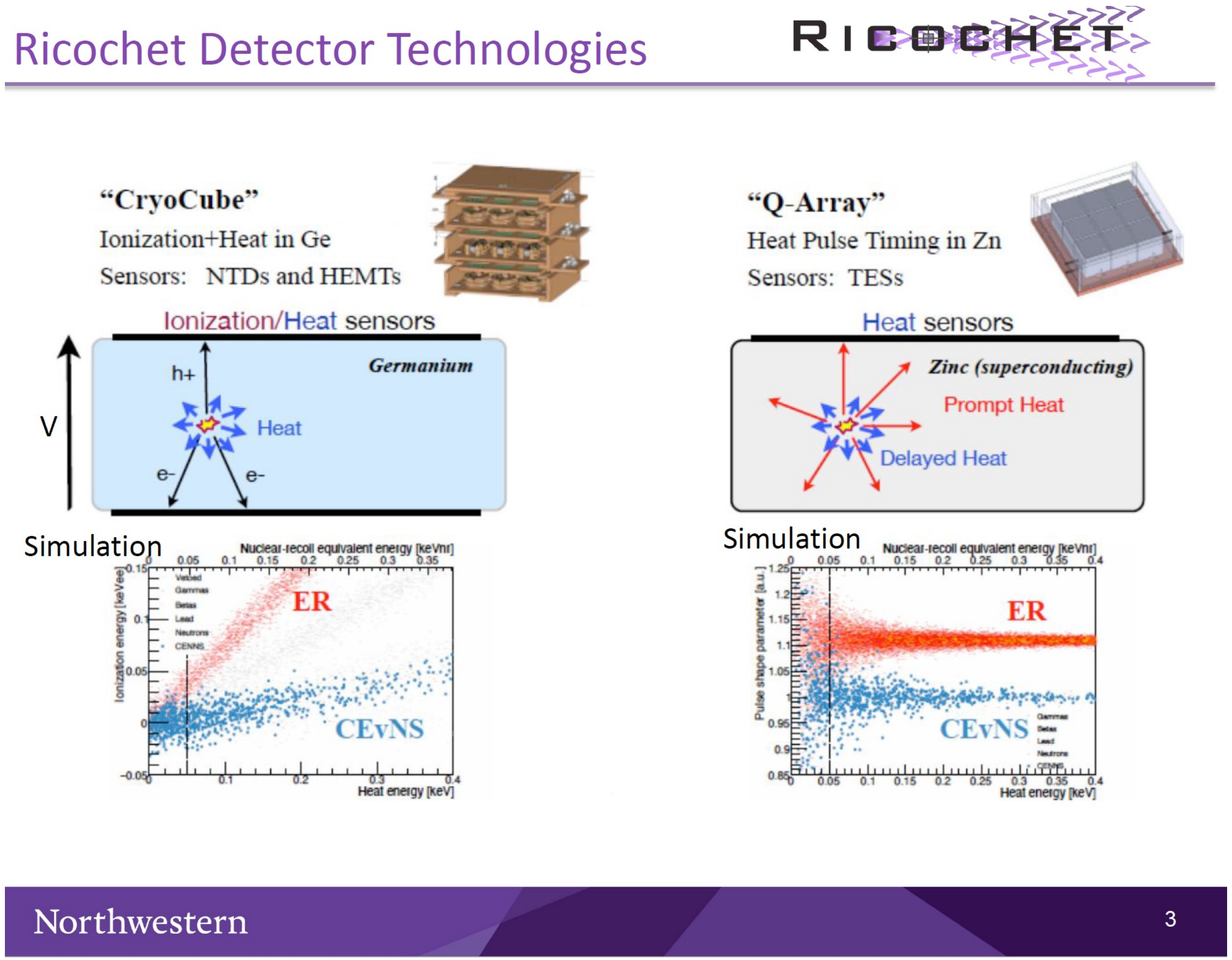
Ran Chen
(Northwestern University)

Complex impedance measurements ongoing. Working on simulation.









Mohammad Nizam
(UCSC)

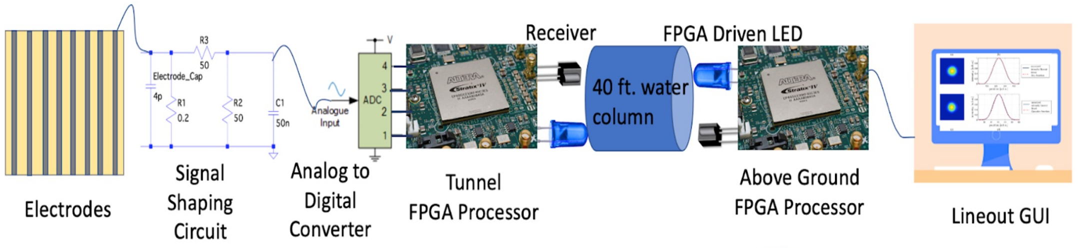
SCIPP
SANTA CRUZ INSTITUTE FOR PARTICLE PHYSICS
UC SANTA CRUZ

Use of Diamond Sensors for High Radiation, Flux and Repetition Rate Applications

Mohammad Nizam
(Postdoc with Prof. Bruce Schumm at SCIPP, UCSC)
(On behalf of the Advanced Accelerator Diagnostic (AAD) Collaboration)

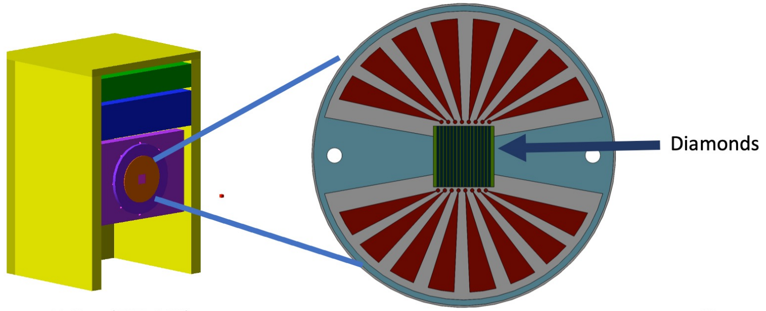
December 1st 2022
CPAD Workshop 2022
Stony Brook University

SWIM Overview



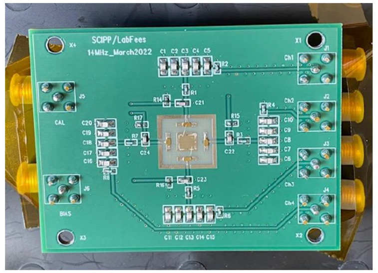
Diamond array is 1.2x1.2 cm^2 strip array with a pitch of 800 um, with two views (total 30 channels)

Blue = Shielding
Green = Electronics
Pink = Diamond PM
Yellow = Iron Carrier
Red = Beam Stop



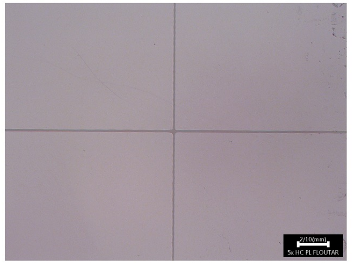
50-MHz POSITION & INTENSITY PASS-THROUGH DIAGNOSTIC

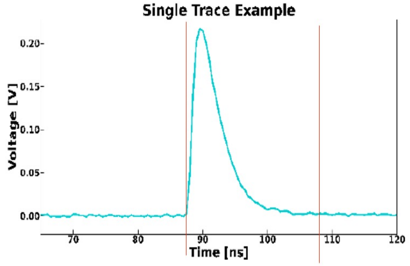
- A pass-through diagnostic that measures intensity and position of the circulating beam at every pass for Cavity-based X-ray free electron laser (CBFEL) .
- A new readout system capable of achieving repetition rates up to 50 MHz was built at SCIPP.
- Use of a 43 µm thin planar diamond sensor to reduce the beam absorption and wave-front distortion.
- 8 parallel 0.2 µF capacitors to provide signal return path that bypasses the voltage supply.



4-channel readout board

4x4 mm^2 quadrant sensor





Fernando Amaro
(Universidade de Coimbra)

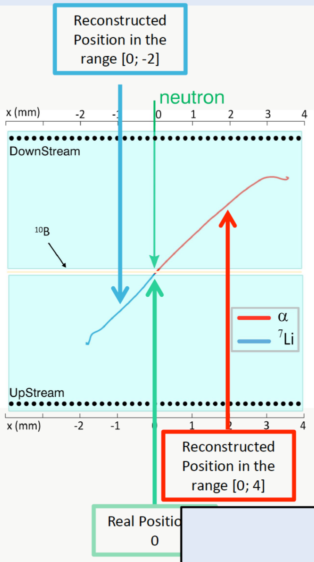
Neutron Imaging Detectors using Ultra-Thin Converter Layers

LIBPhys-UC

F. D. Amaro

LIBPhys – Physics Department, University of Coimbra, 3004-516 Coimbra, Portugal

NeuThin concept



Two position sensitive gaseous detectors, instrumenting both sides of the converter foil, are required.

The information provided by them is averaged in order to determine the position where the neutron interacted with the ^{10}B atom:

$$X_{NeuThin} = \frac{X_{DownStream} + X_{UpStream}}{2}$$

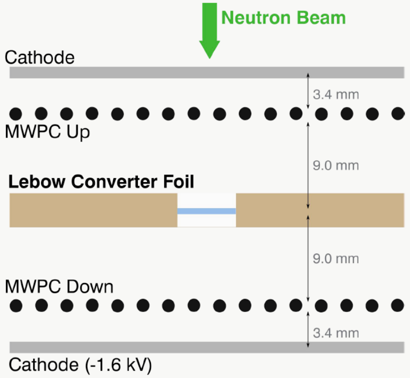
Important Requirements:

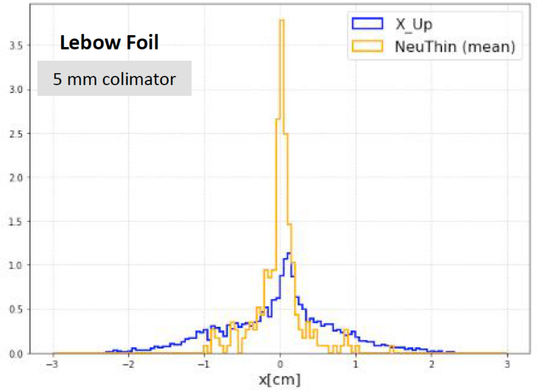
- thin ^{10}B layers (nm scale)
- deposited in a material "transparent" to the ^{7}Li and alpha particle

? Efficiency

NeuThin Results

Converter Foils				
Produced at	Substrate	Coating		Area
		Material	**Thickness***	
International Iberian Nanotechnology Laboratory (INL-Braga), Portugal	Mylar (0.9 μm)	nat. Boron	2 layers (500 nm)	10×10 cm^2
Lebow, USA	**---**	**nat. Boron**	**1 μm**	**ø 1 cm**
Paul Scherrer Institute (PSI), Switzerland	Mylar (0.9 μm)	$^{10}B_4C$	2 layers (≥ 500 nm)	3×3 cm^2





Duncan Adams
(Stony Brook University)

Discovering the Migdal Effect with Neutrons

Duncan Adams
Rouven Essig
B. Lenardo, J. Lin, R. Mannino, J. Xu (Xe)
D. Baxter, H. Day, Y. Kahn (Si)

Xe experiment at LLNL under way

Cross Cu

Experimental Strategy - Backing Detectors

- Tag scattering angle of the outgoing neutron
- Comparison with predicted migdal signal at fixed angle
- Ionization from both the nuclear recoil (quenching), and the Migdal electron
- Tried and true methods for ionization calibration, need to optimize for Migdal

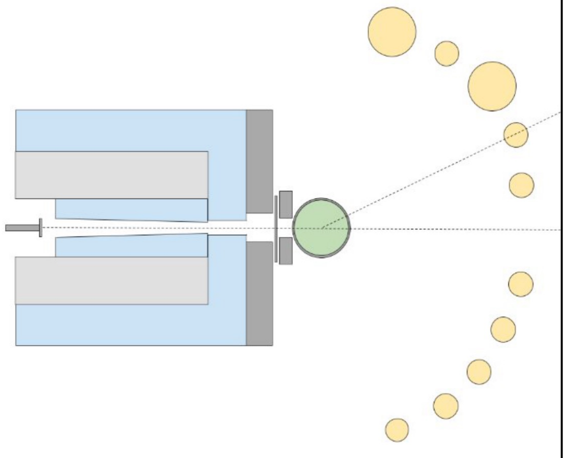
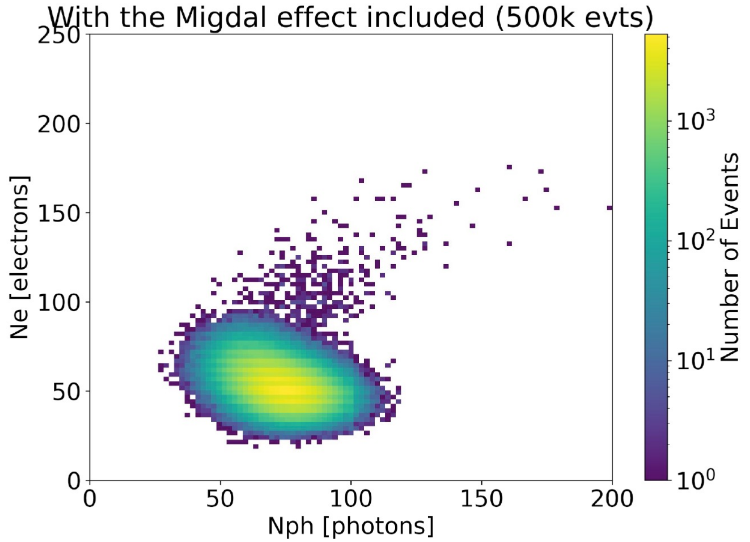


Fig: A cartoon of a backing array setup used in calibration (Lenardo et al: 1908.00518)

Results in Xe @ 14MeV, 17°



* NEST: a comprehensive model for scintillation yield in liquid xenon, http://iopscience.iop.org/article/10.1088/1748-0221/6/10/P10002/meta
* Noble Element Simulation Technique, https://zenodo.org/badge/latestdoi/96344242

Plots courtesy of Brian Lenardo

Pratyush Kumar Patel
(University of Massachusetts)

Progress towards sub-keV *Nuclear* Recoil calibration

Pratyush Patel (University of Massachusetts, Amherst)

For the SPICE/HeRALD Collaboration

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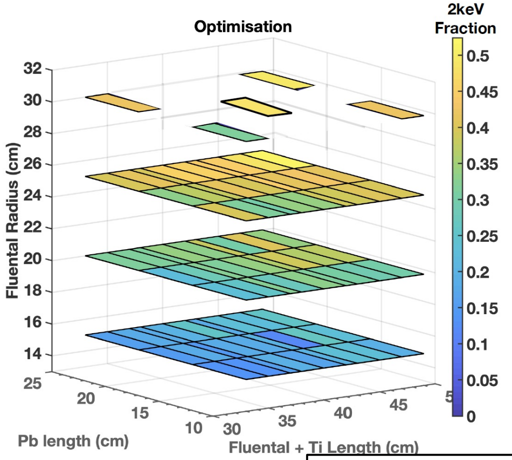
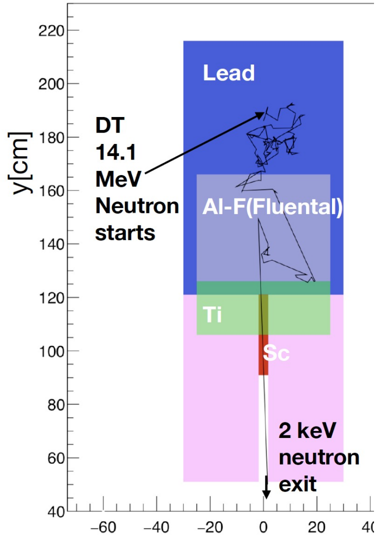
Pulsed 2 keV neutrons from Sc filtered DT neutron

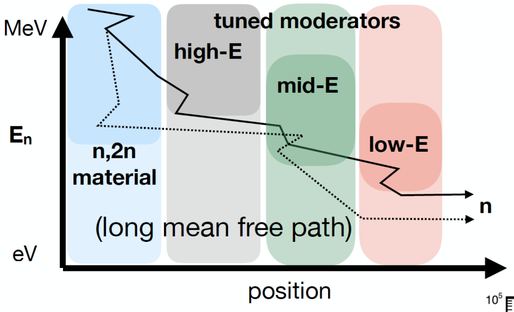
Performed optimisation on:
- Fluental Radius
- Pb length
- Fluental+Ti Length



2keV neutron event in geant4

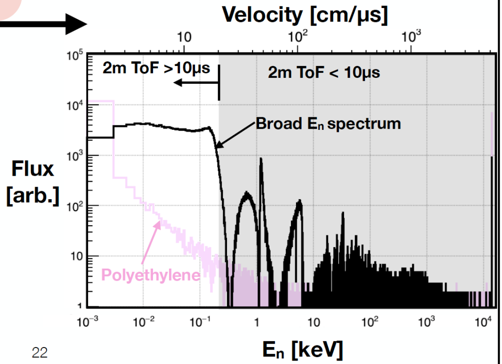


Further lowering NR calibration threshold



- Concept: replace the Sc filter with additional tuned moderators (including Titanium, Manganese)
- Result: broad E_n spectrum, mostly <200eV

For 1µs timing resolution on backing detetctor, we expect to resolve neutrons based on ToF at a distance of ~2m.



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Sushrut Karmarkar
(Purdue University)

CPAD22: CPAD Workshop 2022

PURDUE UNIVERSITY

Measurement of material performance under incremental radiation dose for LHC – Phase II High Luminosity Upgrade

01 December 2022

Purdue University

Sushrut Karmarkar, Souvik Das, Benjamin R. Denos, Andreas Jung, Vikas Tomar

Jack Gulley, Hannyi Lee, Peter Hong

On behalf of CMS Partially supported by NSF

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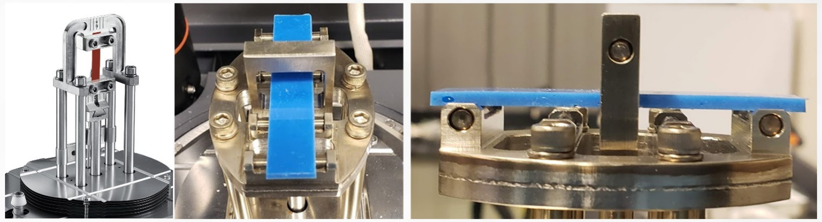
CPAD22: CPAD Workshop 2022

PURDUE UNIVERSITY

1. Mechanical testing of irradiated structural materials - Introduction to Dynamic Mechanical Analysis (DMA)

- Conventional testing – Large Sample Size and destructive testing
- DMA – Small sample size (60 mmx 12 mm)
- Sometimes samples can be recovered for other tests

- Conventional testing – at least 4 inches (100 mm) of gauge length



TA Q800 DMA, Film tension and 3-point bend fixture

 5

Material	Cured at	Direction	Measured Value Pre-irradiation	Measured Value Post-irradiation
K13D2U / EX1515	10% graphite, 7 bar [0 / 90 / 0…]	k_{zz}	**2.12 ± 0.06 W/mK** (TC23)	**2.5 ± 0.13 W/mK** (TC23)
		k_{xx}, k_{yy}	**173 ± 4 W/mK** (INPL21)	**147 ± 3.4 W/mK** (INPL21)

Detailed results are in the public domain and made available on the website – https://www.physics.purdue.edu/cmsfpix/ThermalMeasurements/