Summary of Low Background / Low Threshold Detectors

Conveners: Juan Estrada and Noah Kurinsky

Phil Barbeau 3/22/2021

Priority Research Directions

- #5: Develop new modalities for signal detection
- #6: Improve understanding of detector microphysics and characterizations
- #14: Advance the state of the art in low-threshold Quantum Calorimeters

My apologies if I missed any that apply

One of they drivers in the related fields is the energy resolution and threshold.

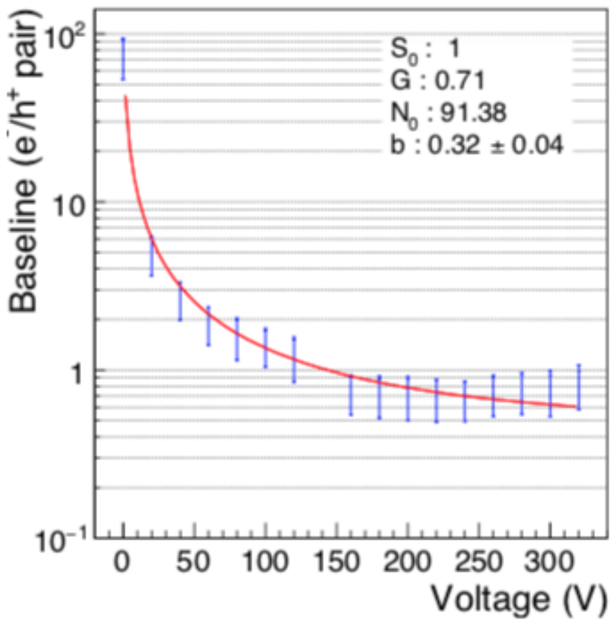
There is an increasing emphasis on background reduction, particularly those caused by instrumentation.

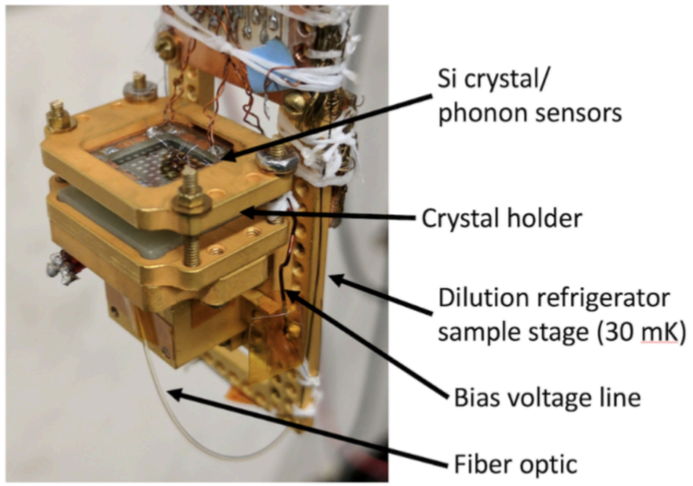
Fundamentally a technology driven field.

Low Threshold SuperCDMS (motivated by CEvNS and light WIMPs)

HVeV Single electron phonon mediated detectors

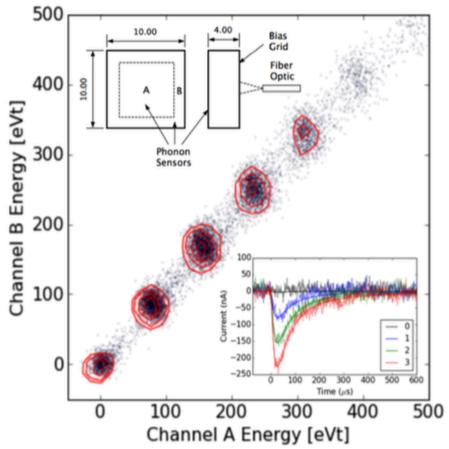
Nader Mirabolfathi

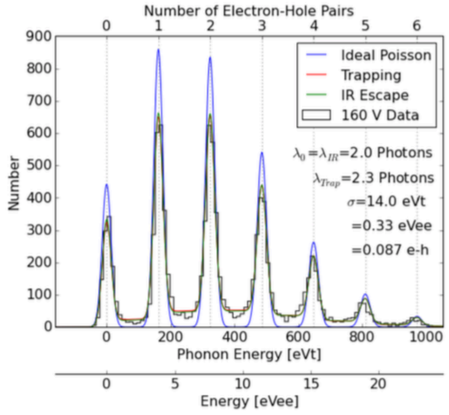




K. K. Romani et al., Appl. Phys. Lett. ***112****, 043501 (2018);*
https://doi.org/10.1063/1.5010699

- Developed in Blas Cabrera group at SU
- Use 1 cm ^{2} 0.4 cm thick Si: ~ 1 g
- Use CDMS QET deisgn T_c~ 35 mK
- CDMS HV technology @ 160 Volts.
- Monochromatic Laser light: 640 nm
- Achieved ~0.1 e-h pair resoltion.
- **Clear single electron resolution!**

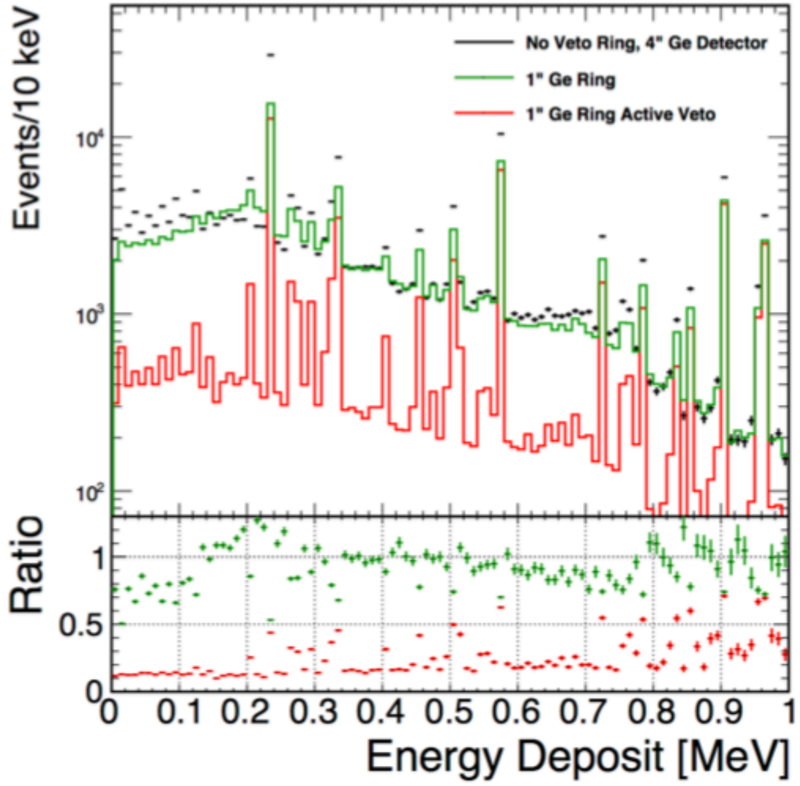


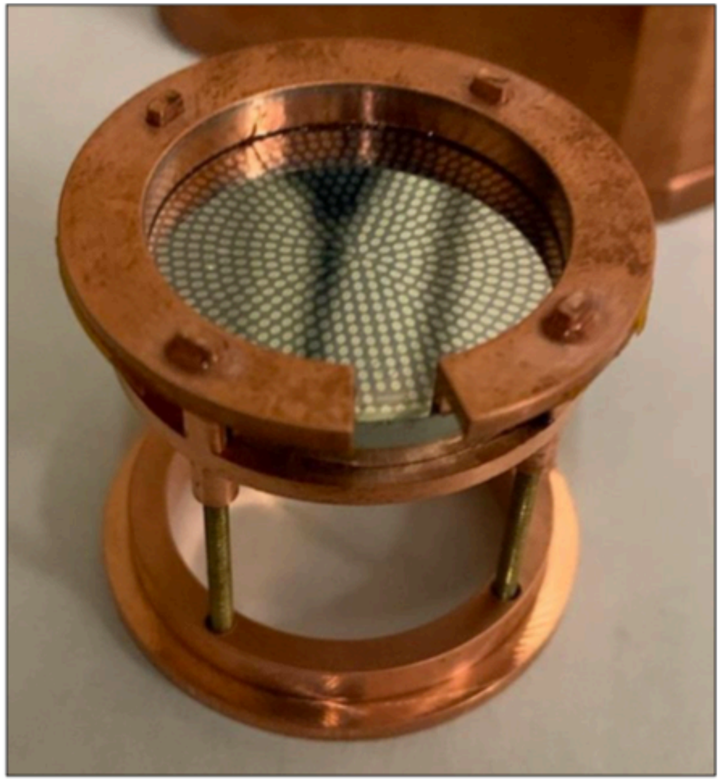


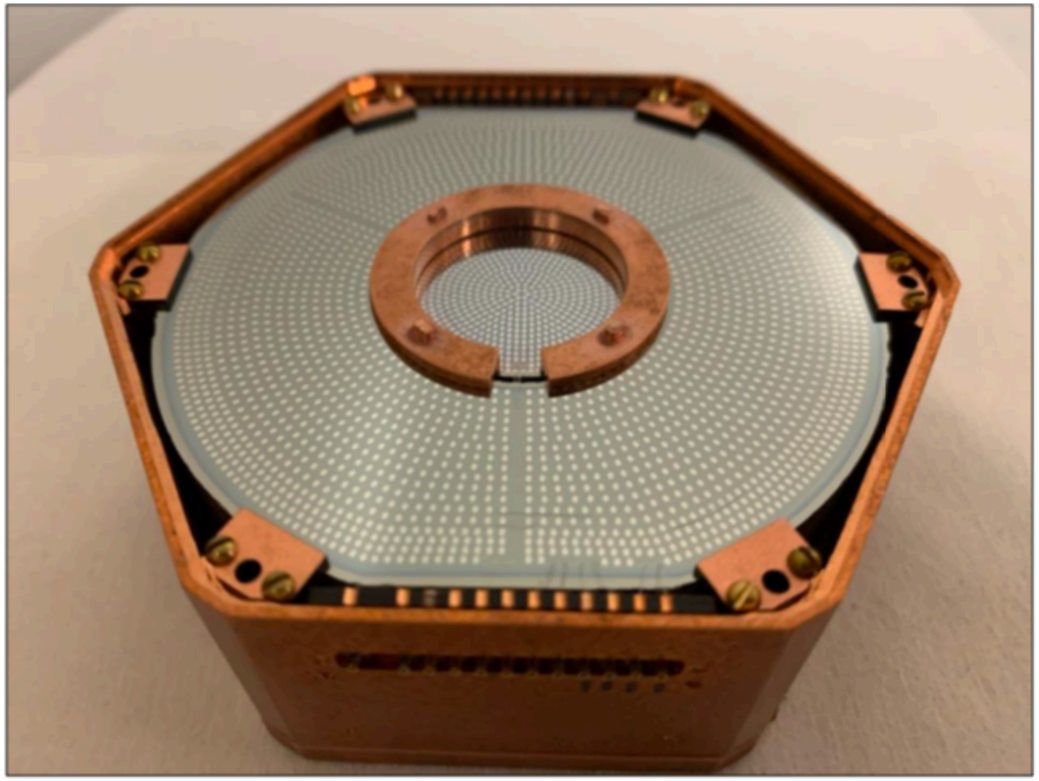
Low Threshold SuperCDMS (motivated by CEvNS and light WIMPs)

Andrew Jastram

25mm Diameter (4mm thick) Inner Detector



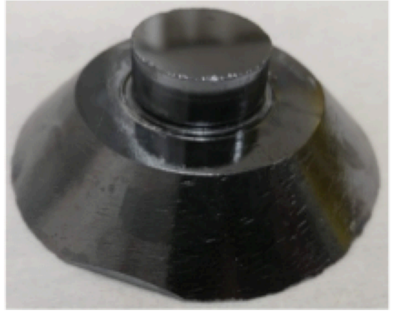


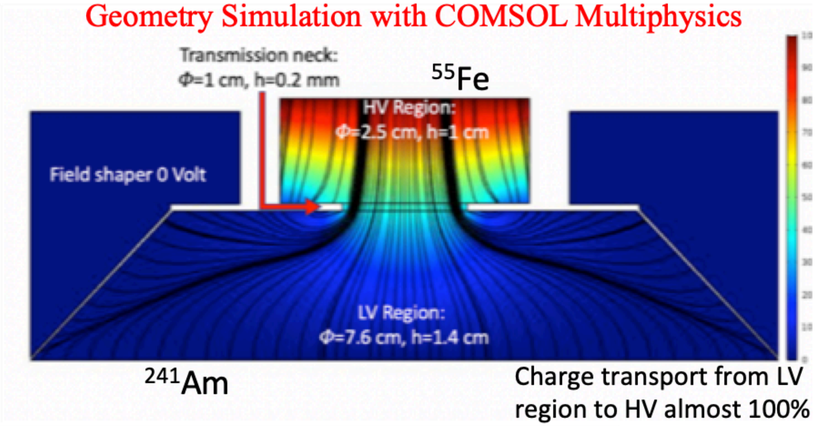


Low Threshold SuperCDMS (motivated by CEvNS and light WIMPs)

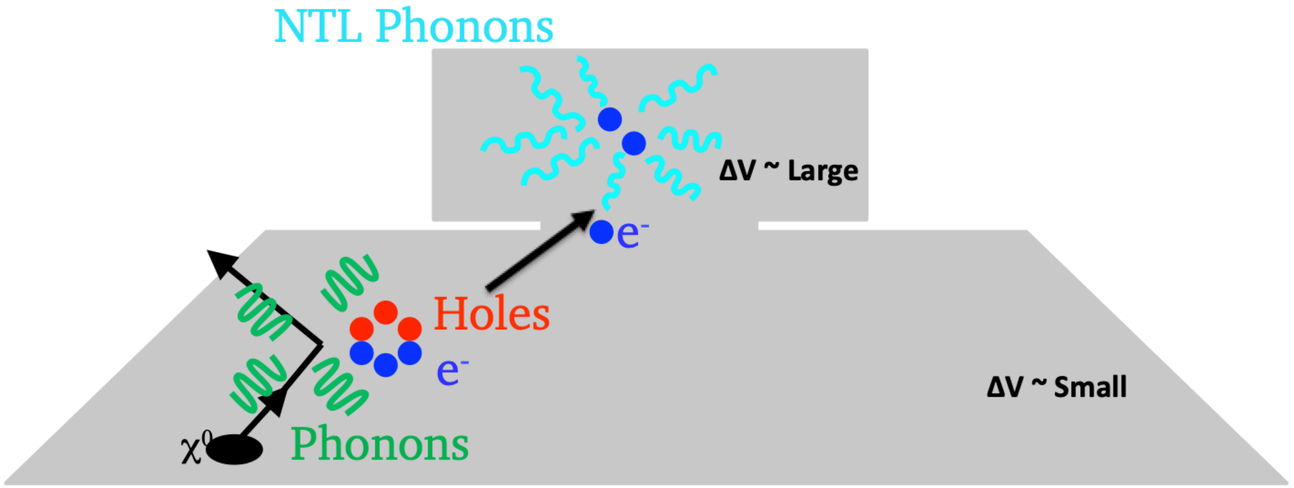
Rupak Mahapatra

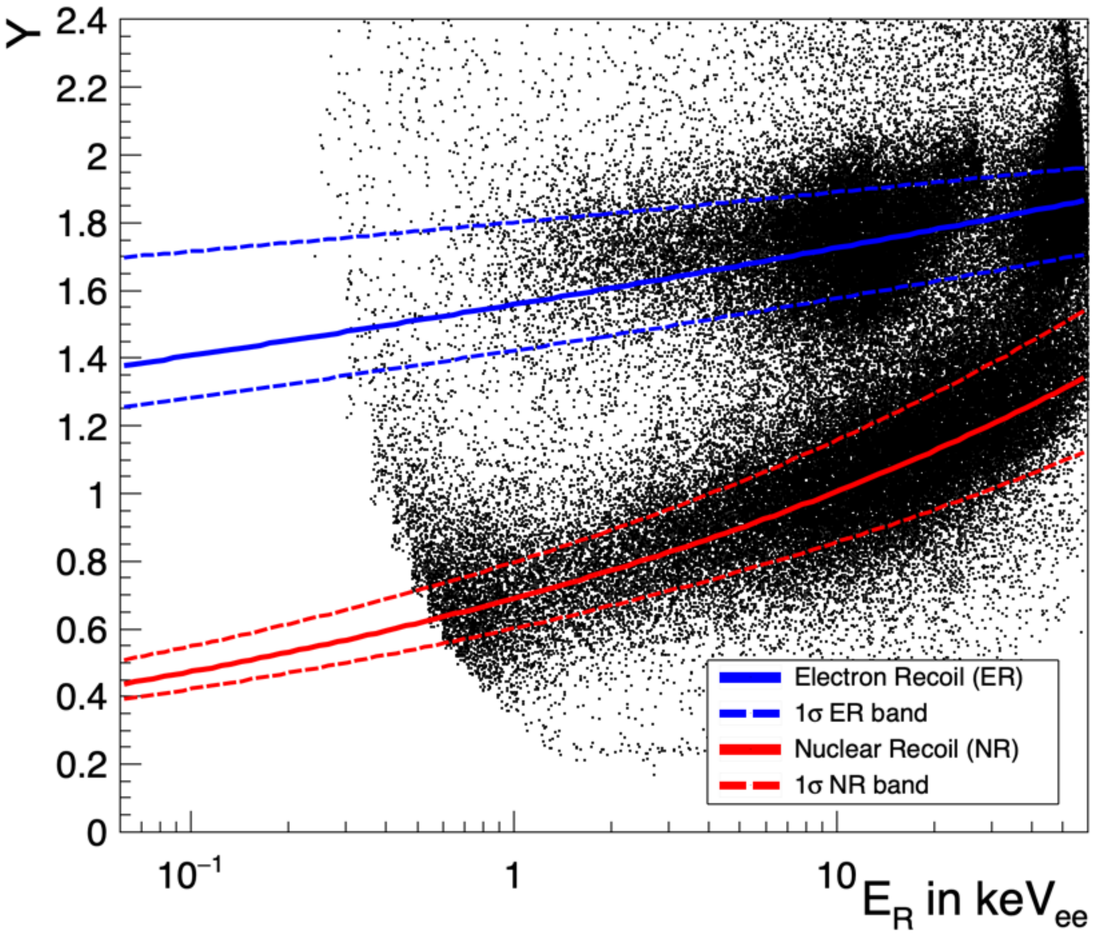
Hybrid HV Detector Principle





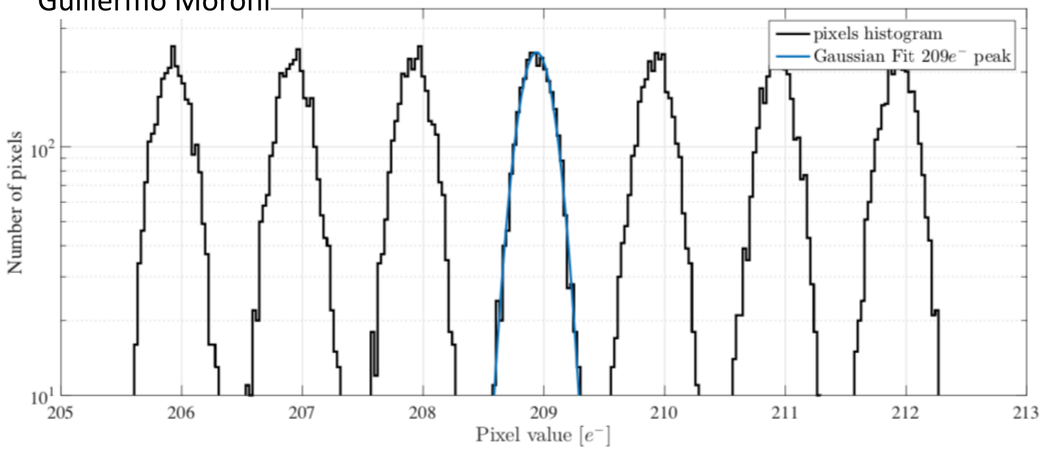
Main idea: Monolithic detector with a low voltage (LV) and high voltage (HV) sides: LV to measure primary phonons like ZIP and HV to measure NTL phonons. Minimize HV to LV NTL phonon pollution using geometric suppression at the neck

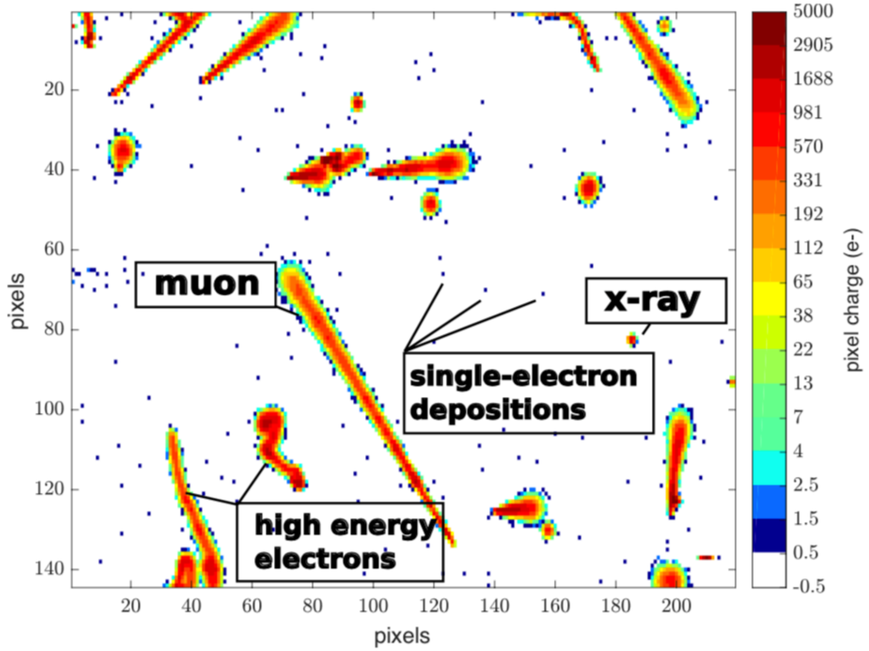




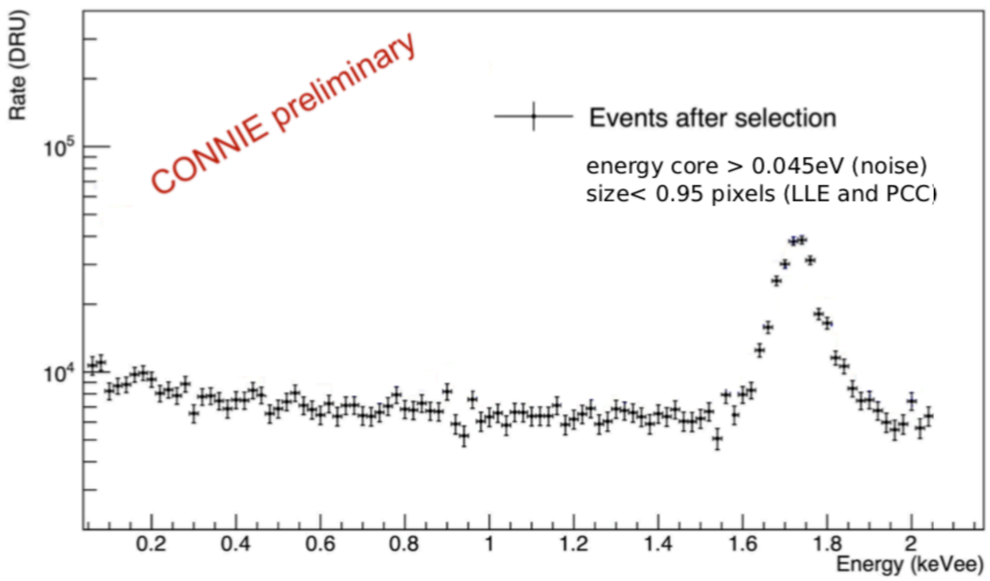
Skipper CCDs: CONNIE's non-destructive, multiple charge measurements

Guillermo Moroni





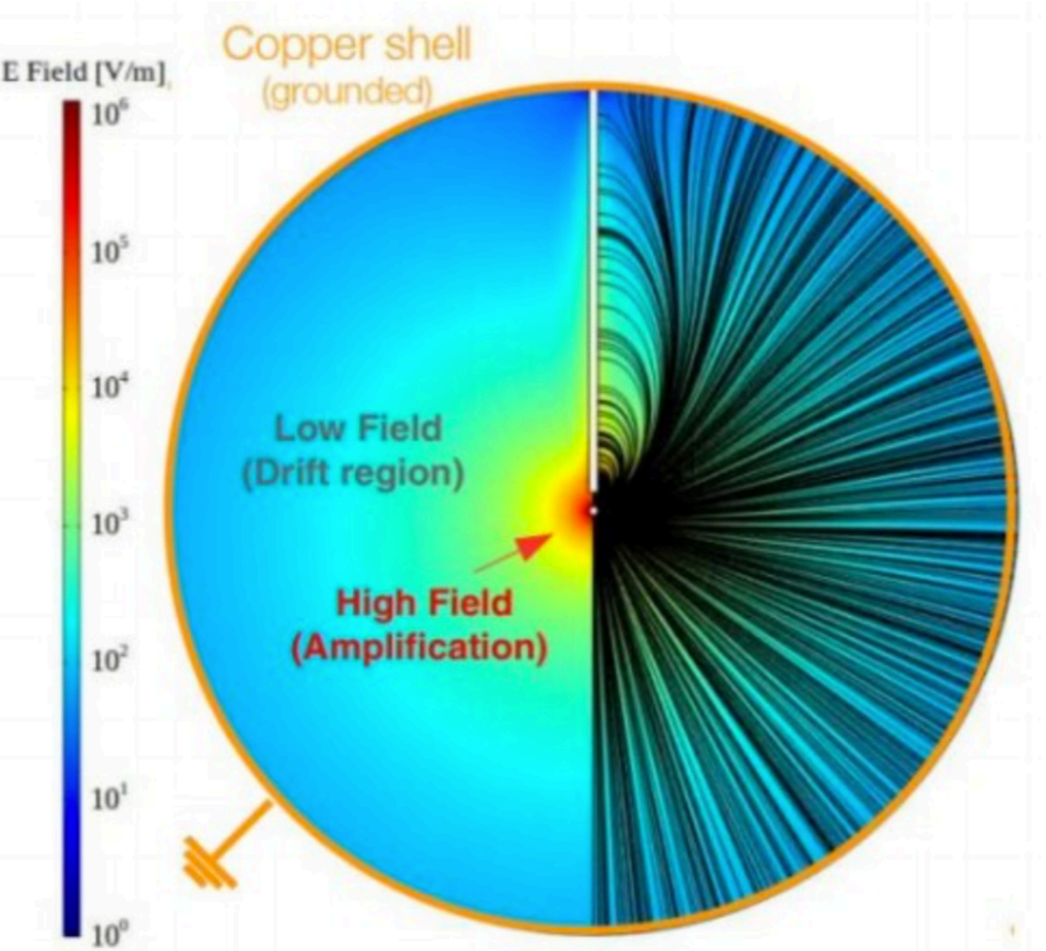
Reactor OFF low energy spectrum after selection cuts



- Event selection criteria using the reactor OFF data:
  - Reject noise events: energy core > 0.045 eVee.
  - Reject LLE events and optimally size of events < 0.95 pixels.
- After this selection we can open.

NEWS-G: New Low Energy Calibration Facility

Jean-Francois Caron



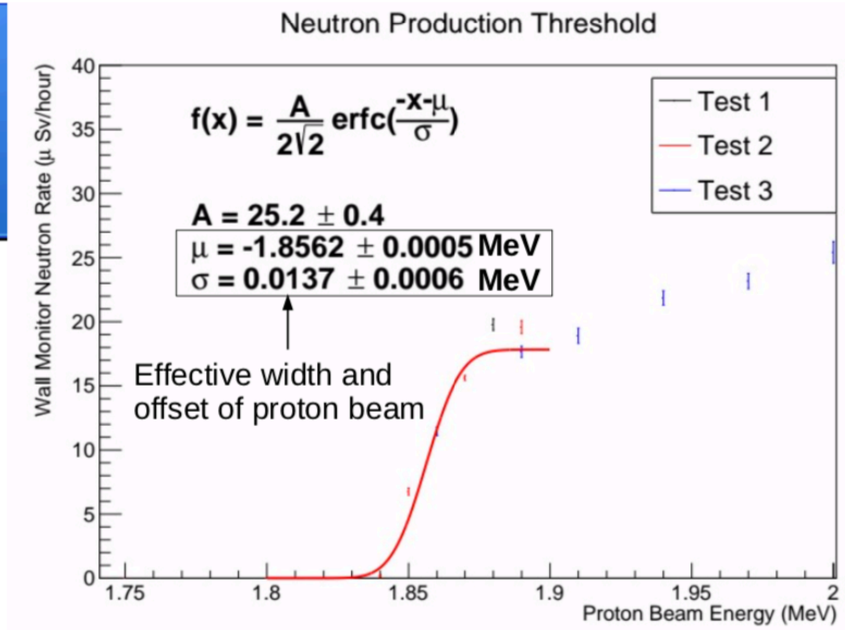
2019 Results

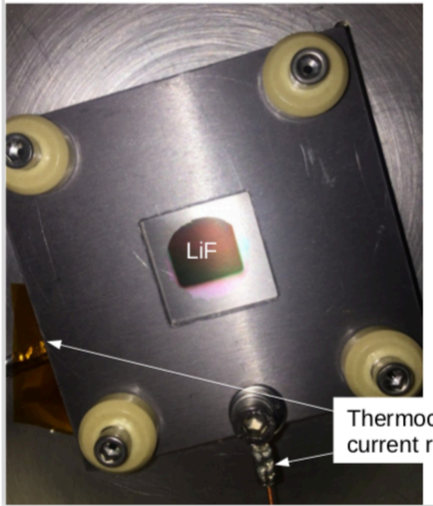
Lessons: need to reduce smearing from:

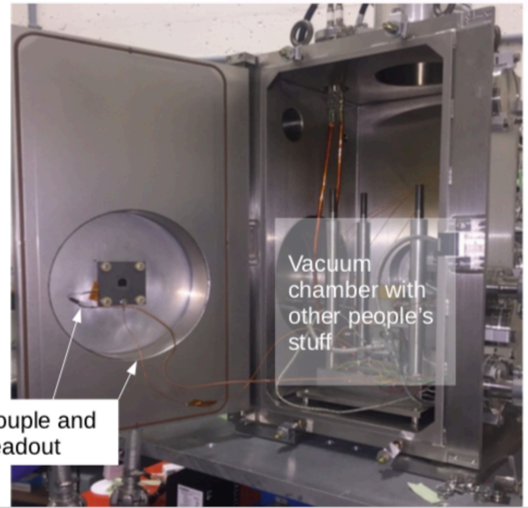
- LiF target itself (~1 μm)
- cooling system (~cm H_2O, Al)
- detection of reflected neutrons

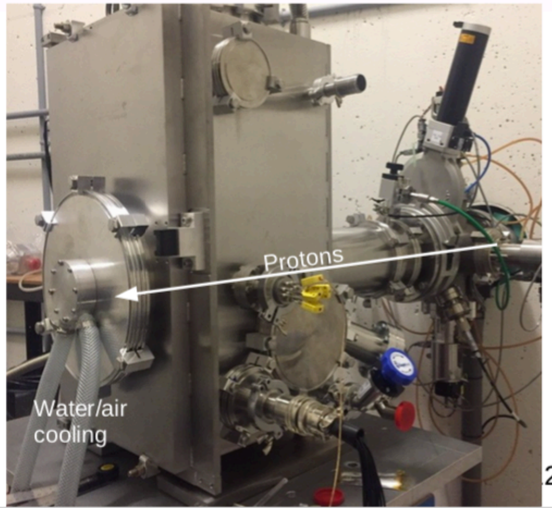
Inconclusive results with:

- angular distribution of neutrons
- neutron spectrum









Low Work Function Semiconductors: improve threshold and resolutions

David Winn

Fairfield UNIVERSITY

University of Iowa

	Z	ρ(g/cc)	Egap(eV)	E_{pair}	μ_e, μ_{hole} $cm^2/V/s$
Ge	32	5.3	0.7	2.98	≤3900, ≤1900
Si	14	2.3	1.1	3.6	≤1400, ≤450
GaAs	31,33	5.3	1.4	4.4	≤8500, ≤400
Cs_3Sb (S-11)	55,51	4.6	1.6	2.0	10,000-10^6
Ag-O-Cs (S-1)	55,47,8	7.1	<0.3	0.4-0.7	Predicted ~5,000

Summary:

- Low Workfunction Semiconductors normally used as photocathodes: potential as low energy calorimetric diode or drifted ionization detectors

- Cs_3Sb has potential to be a room temperature alternative to Si diodes or even Si APD. A "Cs_3SbPM" alternative to SiPM would not need much cooling in many applications.

- Cs_3Sb and Ag-O-Cs have potential to be higher rate detectors than Si due to the high mobility and nearly equal electron and hole mobilities.

- Ag-O-Cs may offer sub-eV energy deposition detection.

- Cs_3Sb and Ag-O-Cs - in thin film photocathodes – are radiation resistant.

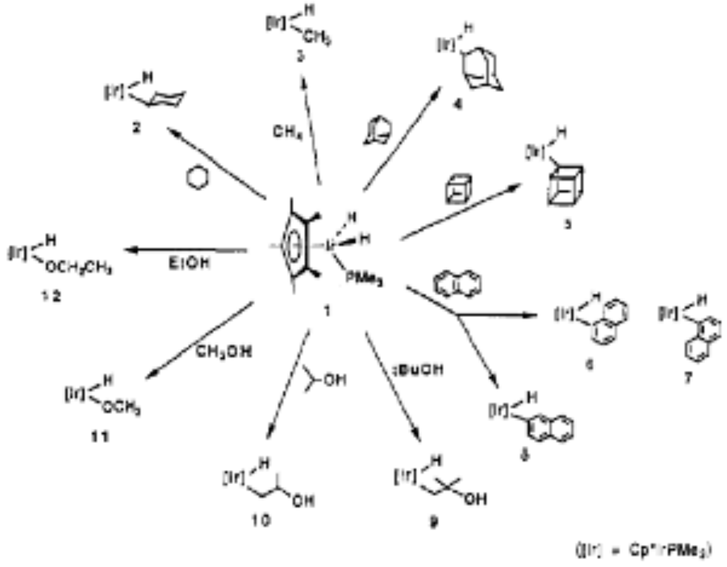
Backgrounds from energy accumulation, clustering and relaxation

Sergey Pereverzev

Xe (Ar) detectors – trace impurities photo-synthesis reactors

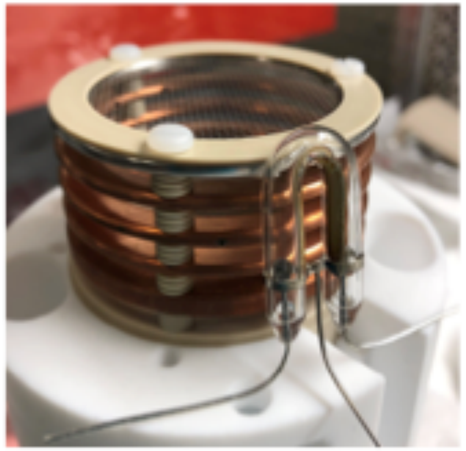
Liquid Xe – media for functional group replacement and photochemical synthesis

Scheme I. Products Formed on Irradiation of Solutions of 1 and the Indicated Organic Molecules in Liquid Xenon at −60 to −75 °C



6842 J. Am. Chem. Soc., Vol. 111, No. 17, 1989

- Impurities in liquid gases can make molecular aggregates and radicals that are not existing in gas phase.
- Molecules which will react in exothermal reaction in gas can form a low energy hydrogen bond - form a stable complex with excessive chemical energy*
- **Our hypothesis: in liquid Xe (Ar) impurities and radicals can form metastable clusters with chemical energy to release several electrons and photons (nano-explosives).**



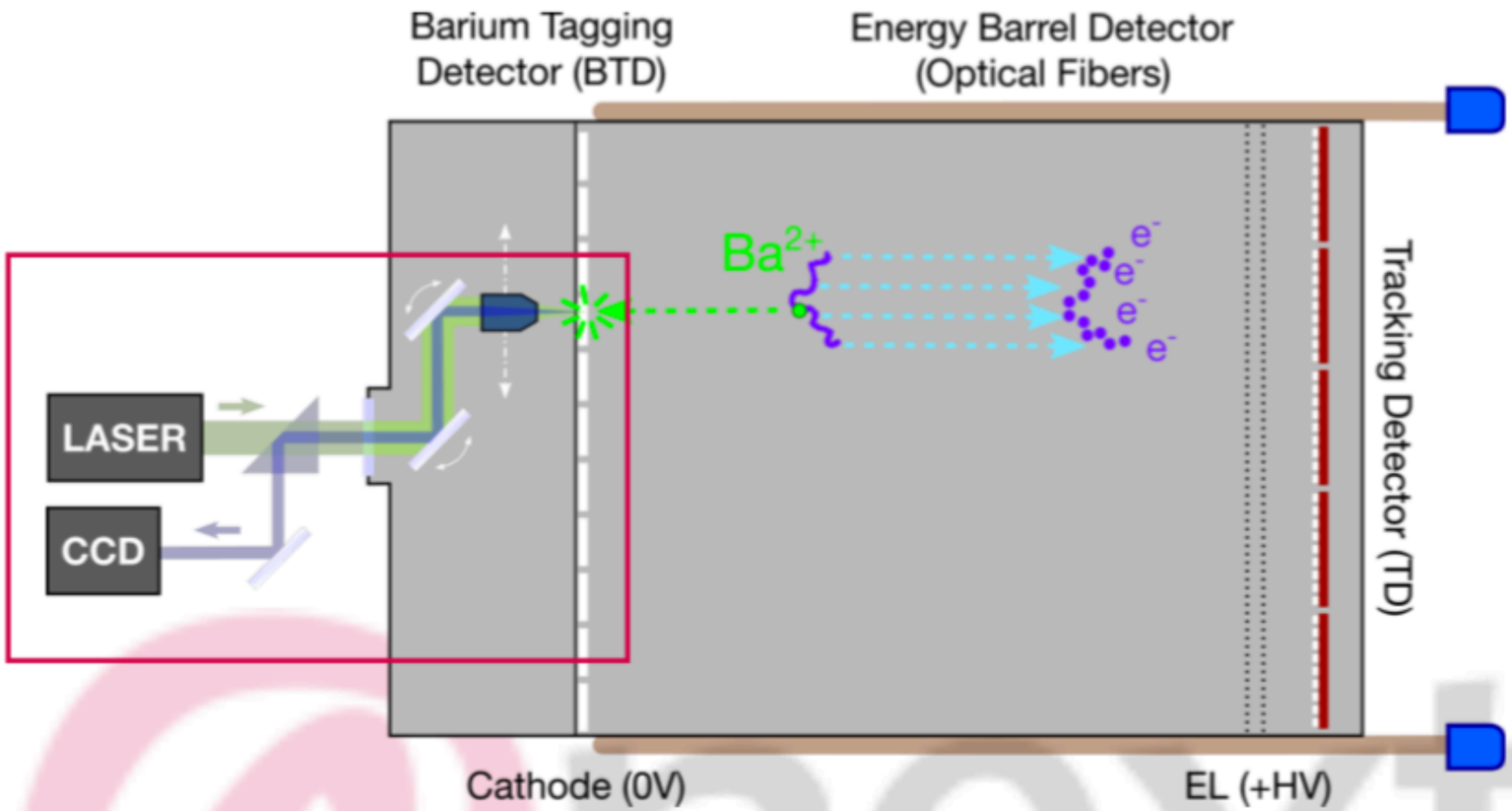
*) "Spectroscopy of molecules and molecular complexes dissolved in liquid gases: Structure and reactivity", published in Russian Chemical Reviews, 57 (8), 1988

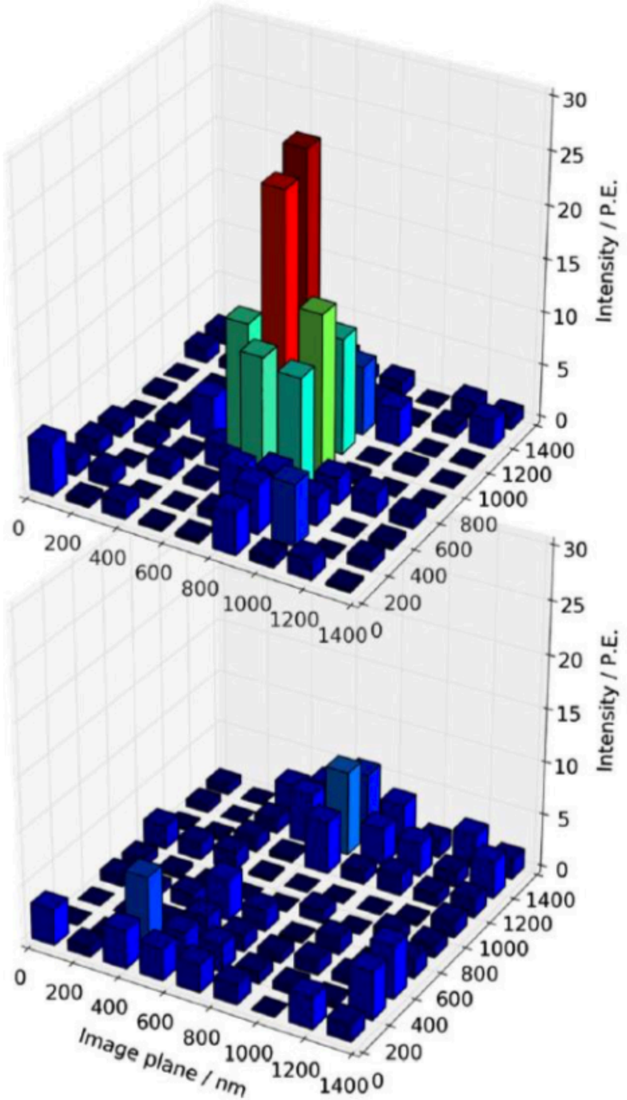
NEXT: Background reduction by tagging daughter Ba daughter

Ruben Gonzalez-Moreno

Ba-tagging on next: BOLD

"BOLD" concept with fully active cathode, SiPM-based tracking and Energy Barrel Detector





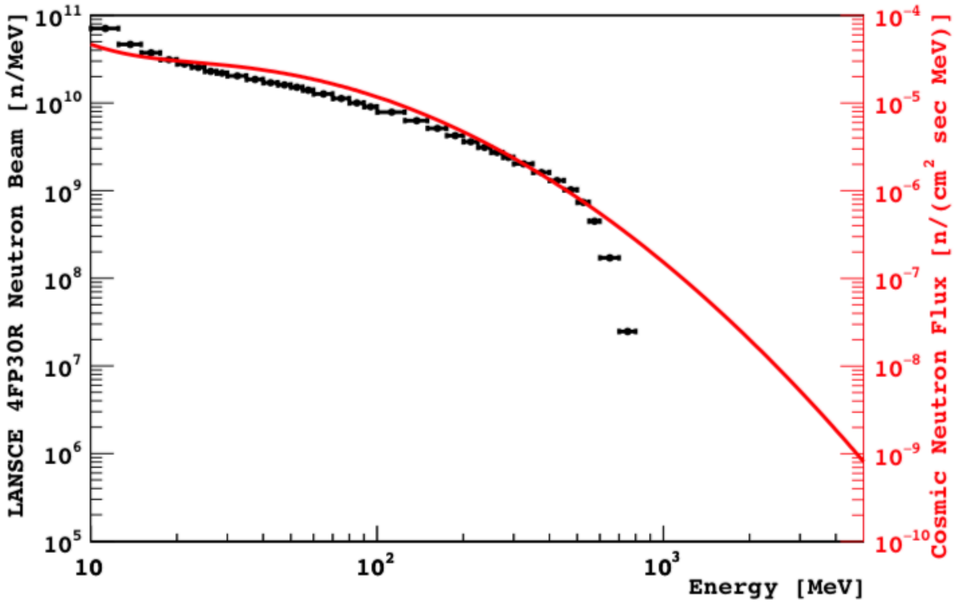
Cosmogenic Activation Measurements for Active Detector Materials

Richard Saldanha

Pacific Northwest NATIONAL LABORATORY

LANSCE ICE-HOUSE Neutron Beam

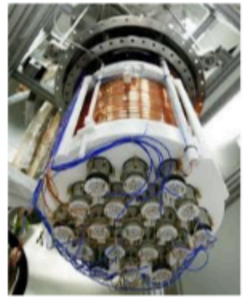
Los Alamos Neutron Science Center (LANSCE) Weapons Neutron Research (WNR) Facility has a neutron beam (4FP30R ICE-HOUSE II) that is very similar in spectral shape to the cosmic ray spectrum



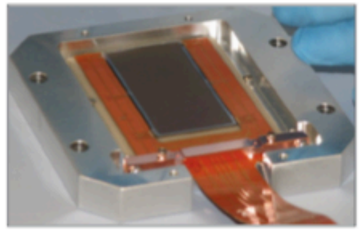
The good agreement in spectral shape between 10–500 MeV allows for low-uncertainty extrapolations to cosmic ray activation rates

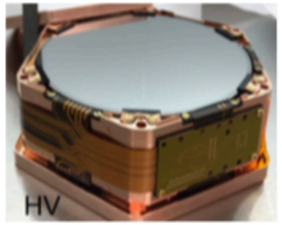
The neutron flux is roughly **5x10^8 times larger** than the sea-level cosmic neutron flux

1 second on beam
~ 16 years on the surface


DarkSide 50

DEAP 3600


DAMIC



SuperCDMS

COSINE

SABRE

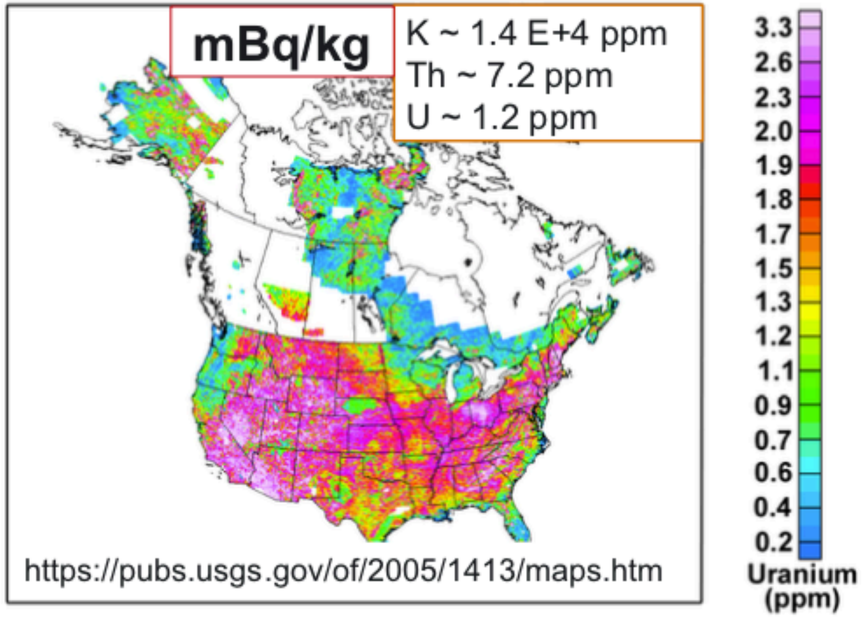
Ultra-Low Background Surface Contamination from Dust (Dedicated Testing Facility at PNNL)

Maria di Vacri

Pacific Northwest NATIONAL LABORATORY

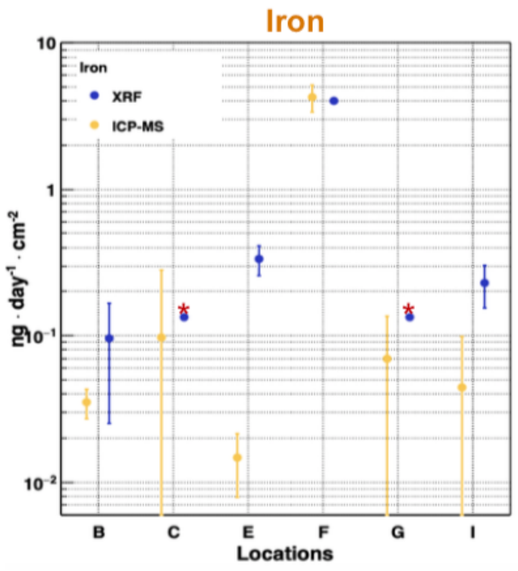
Material selection: a critical challenging task

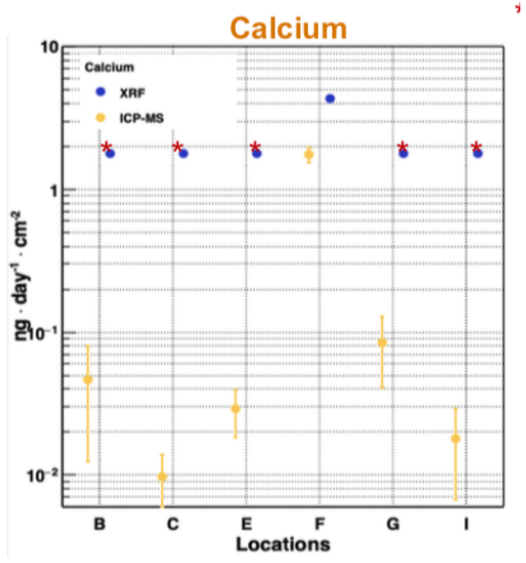
- Radiopurity requirements
  - **μBq/kg** range or lower
- Extensive assay campaigns
  - Selection of the most-radiopure materials
- Ultrasensitive analytical techniques
- Ultraclean analytical procedures and material handling



https://pubs.usgs.gov/of/2005/1413/maps.htm

For reference:
1 ppt Th = 4.1 μBq ^{232}Th/kg
1 ppt U =12.4 μBq ^{238}U/kg
1 ppb ^{nat}K = 30.5 μBq ^{40}K/kg





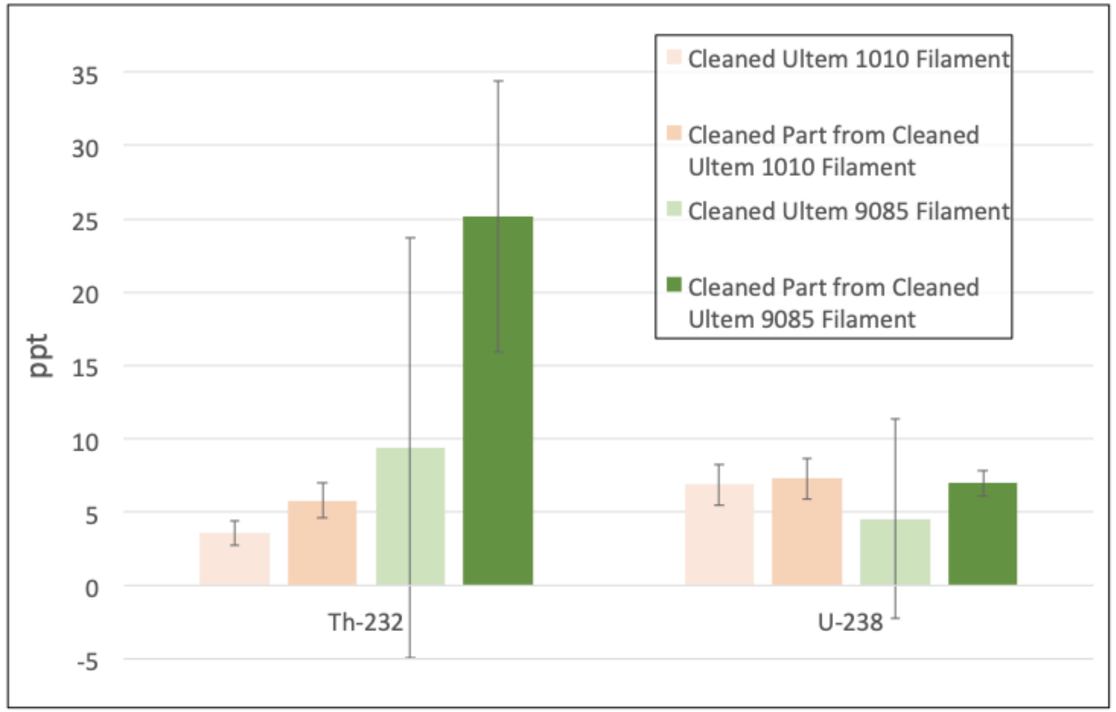
Low Background 3D Printed Materials

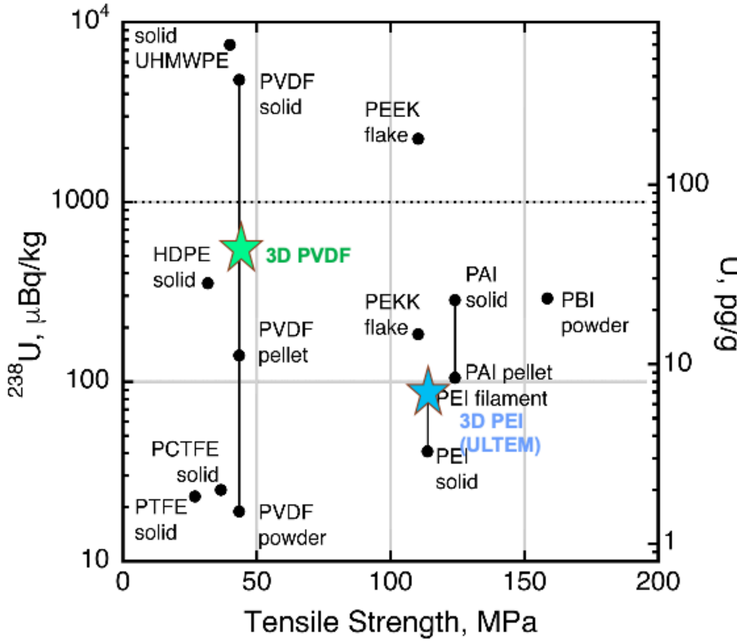
Isaac Arnquis

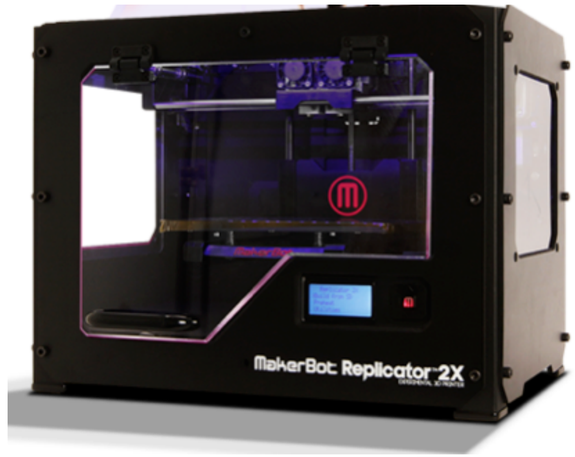
Pacific Northwest NATIONAL LABORATORY

3D Printing ULTEM – Complex Part (Spring Clip)

Spring Clip
(designed for ULB proportional counter)
- Printed on rafts for support during AM







Two different types of ULTEM (polyetherimide) were explored. Cleaned filaments and cleaned parts.

PPS is not clean (not shown): ~300-700 ppt Th, U

ULTEM 1010 looks to be the cleanest finished part yet, which agrees with previous data