Real-Time, Low-Cost, High Efficiency, In-Situ *High Impact* Radiological Threat Agents Detection with TMFDs

***** 2018 EPA Intl. Decontamination R&D Conference*****

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Greetings from Purdue University – The Boilermakers

Welcome to Sagamore Adams Laboratories, LLC

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A Venture Capital-Purdue University Linked Small Business Company

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Ronald Ragains, COO
Rusi Taleyarkhan, CTO
Brian Archambault, Manager-Technology

Presentation Topics

- Overview of Radiation Related Safety → Nuclear Terrorism; Security-Decon.

- Current Sensor Challenges in Radiological Detection & Decontamination

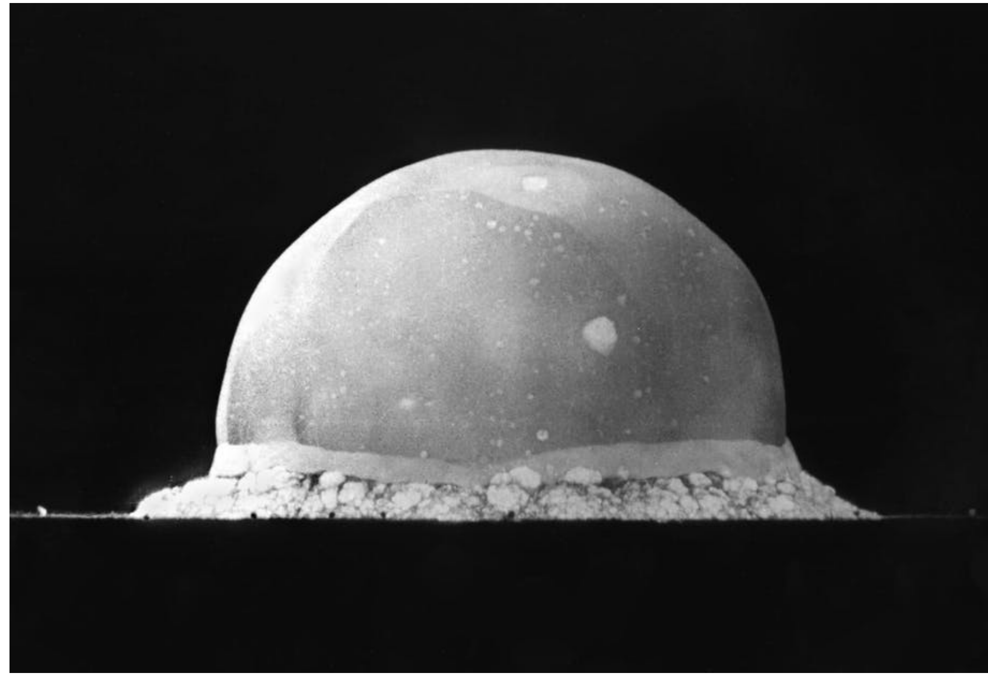
- Overcoming Challenges
    - →Tensioned Metastable Fluid Detector (TMFD) sensors
- TMFD* Applications pertaining to EPA-Homeland Security Mission:

→ Rapid Air-Water-Soil Monitoring for High-Impact Radionuclides
→ Ultra-trace Alpha-Fission Radionuclides (U,Pu,Cm,Rn,Po,..actinides)
→ Trace Neutron Emitter Radionuclide (Pu,U,Fission Product) Identification
→ Passive, reduced dose HEU/Pu/FP monitoring and tracking
→ Active, reduced dose HEU/Pu/FP monitoring and tracking

(*) –Potentially x100 more efficient/sensitive; x10+ lower cost

Nuclear Terrorism
2006 – London,UK

^{210}Po (~5.3 MeV a)
~200x M.Lethal Dose
10 µg (50 ng)
Widespread:
→Confusion (Th)
→Contamination



Fission Nuke Radioactivity
α,n,γ,β,FF

Long-Lived Contamination/…
****Not Enough $$ After Boom****

Nuclear Radiation Safety – Primer

DOSES FROM: Alpha, β/γ, Neutrons, Fission Products

→ Alpha/FPs: **~10^{6+}** Rem/Ci **** ~500 Rem → Lethal ****
→ Neutron: **~10^{4+}** Rem/Ci
→ Gamma/Beta: **~10^{3}** Rem/Ci

Nuclear Emergency Safety Relevance:

-If Ingested/inhaled: Alpha/FP radiation most harmful
-External exposure: Neutrons/Gamma/Beta radiation most harmful

→ **Detection Difficulty: Highest (n); High (α); Low (β/γ)**

Desirable Characteristics- (n,α,f) Radiation Monitors*

- Real-Time Functionality (Reduced dose to responders/public)
- High Detection Efficiency → Major ALARA Impacts
- Spectroscopic ("Nuke" or Not?)
- Blind to Common Background Radiation (gamma-beta)
- SNM Tracking Capability – Real Time
- Ultra-Trace Level Monitoring (esp. alpha sources)
- One Unit for Key Radiation Types/Uses (α,n,FF)
- Lower Cost (x10+)
- Light-weight (Portability); Robust; Field Worthy
- Intuitive, Readily Deployable-Understandable
- "Smell-Sip" the air/water for SNM/FP/Actinide "odors" ???

(*) – Present day systems: Costly ($50K-$500K); Inefficient; Bulky; Off-Site Forensics

Why TMFD Technology?
– For Neutron, Alpha, Fission Detection/Spectroscopy

- 100% gamma-beta-muon blindness (to 700+ R/h fields)
- Thermal (eV) and Fast (1-100 MeV) Neutron Detection
- ~60-80% intrinsic detection efficiency (neutrons)
- ~95%+ intrinsic efficiency (alpha/fission); x100 below LS
- ~1.4 keV energy resolution
- Spectroscopy; Distinguish between (α,n);fission; cosmics
- On-Off within seconds to microseconds
- 10^{-9}s to 10^{-12}s event timing and multiplicity possibilities
- Directionality/Source positioning with 1/2 TMFD units
- Low-cost sensing material (<< 0.1$/g)
- SNMs/actinides/neutrons from air/fluid borne (Am/Pu vs Rn)
- Active and Passive Interrogation
- Tech. Transfer to Fielding - by Purdue via SALabs,LLC

1st Prize Paper Award – Nov.2016 IEEE SENSORS Intl.Conf. (*) – Demo Units For Viewing at Tech. Cafe

Paper No. 1287

Live Demonstration:

Femto- to-Macro Scale Interdisciplinary Sensing with Tensioned Metastable Fluid Detectors

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Abstract—*Live interaction, interdisciplinary multi-physics demonstrations using the tensioned metastable fluid detector (TMFD) sensor systems are proposed. TMFDs utilize centrifugal-acoustic forcing to place ordinary liquids like water into sub-zero (i.e., below vacuum) pressure states of metastability such that interacting subatomic scale particles, or even eV photons can be detected via visible-audible transient bubbles that nucleate from nm scales growing to visible mm scales. Interactive experiments will cover diverse areas such as: nuclear physics (detecting neutrons – tell-tale signal from U/Pu fission using a unique NRC-licensed public use neutron source, study of cosmic rays); health-nuclear medicine (measuring of lung-cancer causing Radon in air at ultra-trace 1 part in 10^{17}); Optics (monitoring and tracking a nanosecond pulsed laser beam); Acoustics-Piezoelectrics-Fluidics-Heat Transfer-.Mechanics.*

Keywords—TMFD, Fluidics, Acoustics, Radiation, Optics

I. Introduction & Background

Ordinary fluids like water at room temperature can indeed be placed under tension, even negative (Pneg) pressures (yes – even below perfect vacuum) as scientifically confirmed only a few decades ago leading to the novel TMFD sensor class [1]. Briefly, tensioned fluids are in state of metastability; their intermolecular bonds weakened such that, select stimuli types can "poke" holes into them to create transient bubbles that can rapidly (within μs) grow to states that are visible-audible to humans. Amazingly, conventionally hard to detect sub-atomic neutral particles like neutrons or ions (tell-tale signatures from U/Pu nuclear fission) can be now detected with unparalleled intrinsic efficiency [1-2]. Stimuli types may also include ordinary UV-IR photons. The scientific principles and potential transformational uses have been published elsewhere [e.g., 1-2]. Unlike complex/expensive conventional sensors for radiation-photon detection which rely on extensive electronc trains, PMTs, scintillators, etc., TMFDs are based on intuitive, centrifugal force as from common rotary tools, and/or resonant mode acoustic vibrations from piezo-electric elements. Two distinct forms of hand portable, table-top systems: C(Centrifugal)-TMFDs and Acoustic(A)-TMFD systems will be used for demonstrations and hands-on experiences.

Table-top CTMFD and ATMFD sensor setups are shown in Figs. 1a, 1b, respectively – AC/DC powered.

Figure 1a. Centrifugal Tensioned Metastable Fluid Detector Setup/Operation **movie clip** http://web.ics.purdue.edu/~ahagen/link_1.mp4	Figure 1b. Acoustically Tensioned Metastable Fluid Detector Setup/Operation **movie clip** http://web.ics.purdue.edu/~ahagen/link_2.mp4

Sponsors: U.S. (DoE, DoD,DHS, NSF); SALabs.,LLC,, Purdue Univ.

II. Interactive Demonstrations

A. Special Nuclear Material (SNM) Identification

Imagine a sub-atomic 10^{-27} kg (almost mass-less) particle with only ~10^{-12} J making a liquid boil on demand in space-time, without any superheat at ~20C!!! Merely, by changing the Pneg tensioned fluid state. Such sensing capability is unparalleled. Using USNRC's first of kind license to Purdue, now for the first time enables our small (~10cc) on-ff source of neutrons for public demonstrations- we will show that state-of-art sensors are ineffective. Then, we demonstrate how the simple macro-scale TMFD apparatus allows a lay-person to spectroscopically detect, in-effect visibly see/hear neutrons via recordable bubble pops. (http://web.ics.purdue.edu/~ahagen/link_1.mp4) - **movie clip.**

B. Tracking a laser beam with directionality and intensity

Imagine studying optical phenomena via fluidics and heat transfer to also sense and map transient pressure profiles [1,3] in non-contact mode!!! Ref. 1 (Fig. 9) shows a track of bubbles delineating the directional characterization of a common ns UV pulse(~0.3 mJ) at only 1bar below vacuum (-10^5 Pa). (http://web.ics.purdue.edu/~ahagen/link_3.mp4) - **movie clip.**.

C. Real-time Radon in air detection with TMFDs

Radon is a gas that enters homes/dwellings at ultra trace quantities (1:10^{17}) but which, according to the EPA, causes 25,000 lung cancer deaths in the USA alone. Conventional (~$10K+) Rn sensors are complex, unaffordable, and require days/weeks to provide reliable estimates. Live demonstration will be given using CTMFDs (http://web.ics.purdue.edu/~ahagen/link_1.mp4-- **movie clip**) on how Rn in air may also be detected in near real time.

III. Visitor Experience

Visitors will handle TMFDs hands-on, learn novel sensing for wide-ranging arenas: terrorism; portal screening; medicine; energy; interdisciplinary engineering sensing applications.

References

[1] R. P. Taleyarkhan, J. Lapinskas, Y. Xu, "Tensioned metastable fluids and nanoscale interactions with external stimuli.." Nucl. Engr. Des., 238 (2008) 1820-1827.

[2] B. Archambault et al., "Transformational Nuclear Sensors – Real-time monitoring of WMDs, Risk Assessment and Response," IEEE HST-2010 978-1-4244-6046/10 (2010) 421-427.

[3] A. Hagen et al.,, "Characterization and optimization of a tensioned metastable fluid nuclear particle sensor using laser based profilometry," ASME Journal of Nuclear Engineering and Radiation Sci 1 (4), 041004-1-10 (2015).

Gold Standard (^3He) vs TMFD Technology

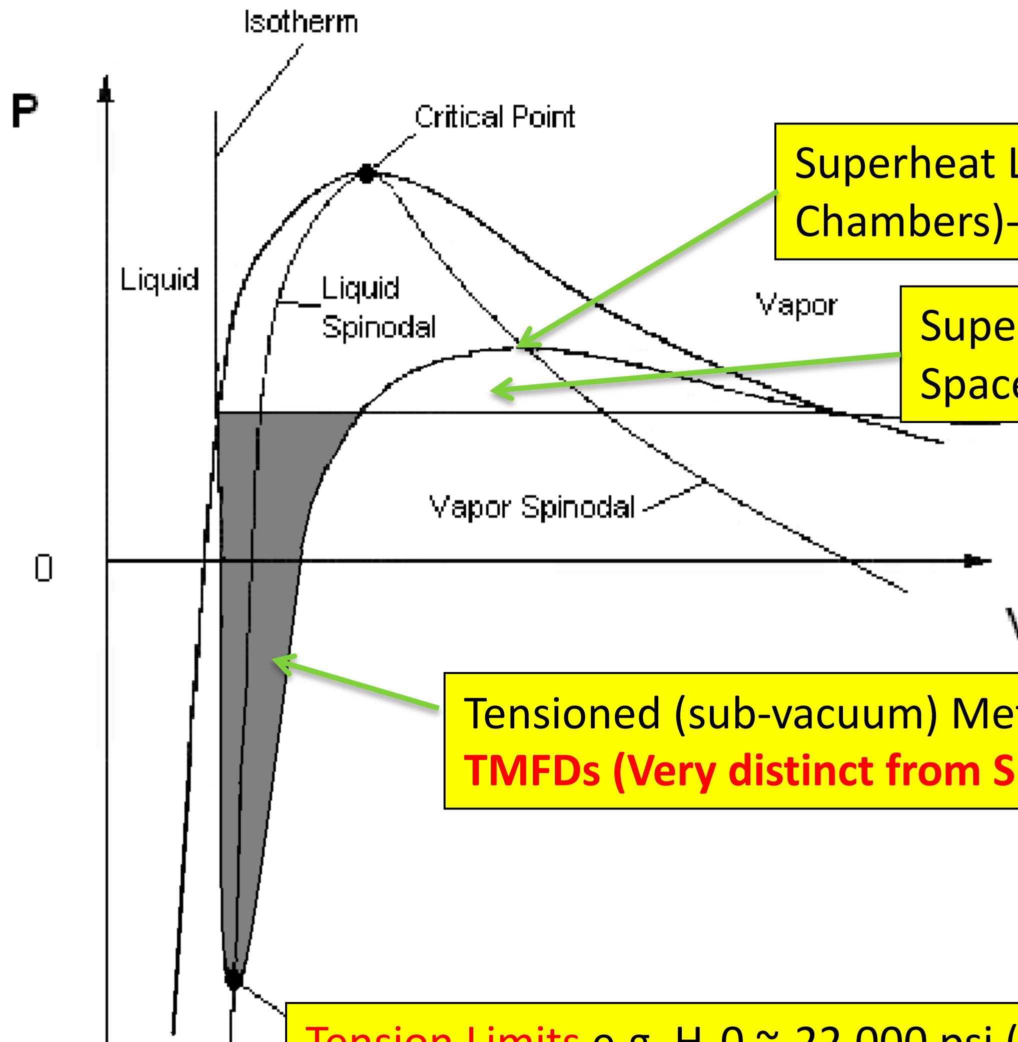
Parameter	^{3}He Detector	TMFD System
Intrinsic efficiency Absolute (RPM) efficiency	~ 15% (for 3.5L, 3 atm. Tubes with 1.27cm front and ~ 5cm+ CH_2 sides); < 1% (MeV neutrons) **0%** (incapable of alpha-fission det.) 2.8 – 3.5 cps/ng ^{252}Cf (PNNL-18471)	~85% (MeV and ~0.01 eV neutrons) (using ~80+ cc volumes; ~60% already achieved with 40cc; no need for moderator) **~95%+** (alphas, fission) at pCi/cc within mins. **> 10 cps/ng ^{252}Cf** (MCNP-POLIMI est. for TMFD based RPM system)
Use in high photon-n pulsed fields	possible saturation during pulsed active interrogation	Microsecond on-off, adaptable for pulsed systems
Gamma-Beta-Muon blindness and rejection (GARRn)?	No-saturation in high gamma fields; $\varepsilon_{int,\gamma n}$ ~10^{-6}; 0.9 < GARRn < 1.1 in 10 mR/h exposure.	Yes-no gamma saturation issues; $\varepsilon_{int,\gamma n}$ =0; GARRn = 1; tested under 50 R/h to 700 R/h exposure for 100% rejection.
Neutron multiplicity &/or directionality?	Not with single detector; Yes if arrays are used	Yes (to <10^o) & ~10^{-12} s multiplicity with a single system
Can system detect neutrons and alphas & be used for spectroscopy?	No; neutron spectroscopy requires Bonner spheres and spectrum unfolding	Yes; same system can be adapted to detect neutrons, and alphas + spectroscopy to ultra-trace sub-pCi levels
Cost/Mass (retail quote – ^{3}He; matls & labor - TMFDs)	High (~ $55K quote for single 3.5L - 3atm tube from LND, Inc.; $200K+ est. for 4 tube RPM system.);120kg	Low-to-moderate; < ~30 kg panel

Brief Introduction to TMFD Science & Technology

Metastability – Brief Primer

Liquids

Sub-Ze ... e – Trees)



Superheat Limit (Bubble Chambers)-Glasser, 1960 → SDDs

Superheat Metastability Space **→SDDs**

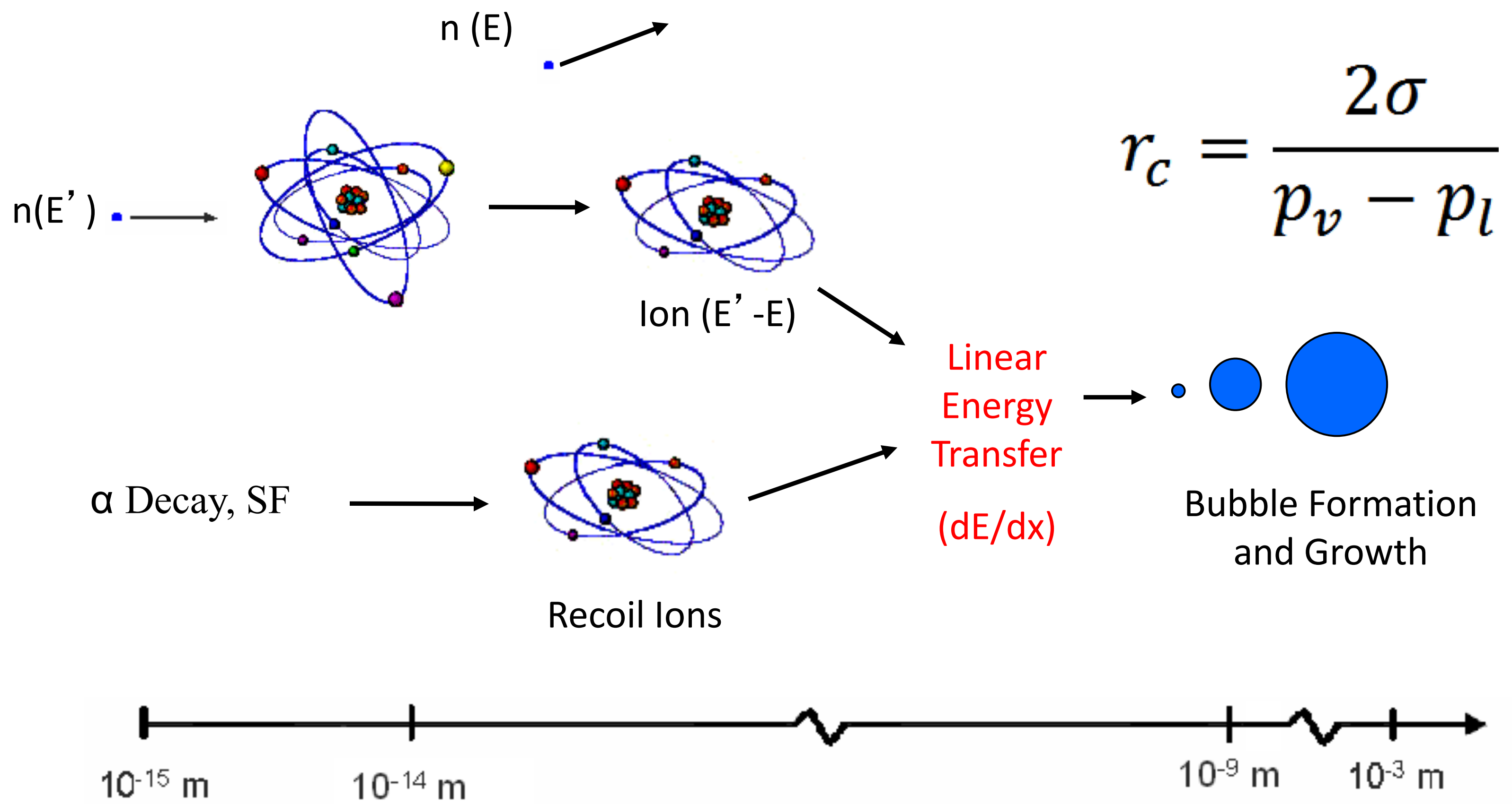
Tensioned (sub-vacuum) Metastability Space → **TMFDs (Very distinct from SDDs)**

Tension Limits e.g. H_20 ~-22,000 psi (-1,700 bar)

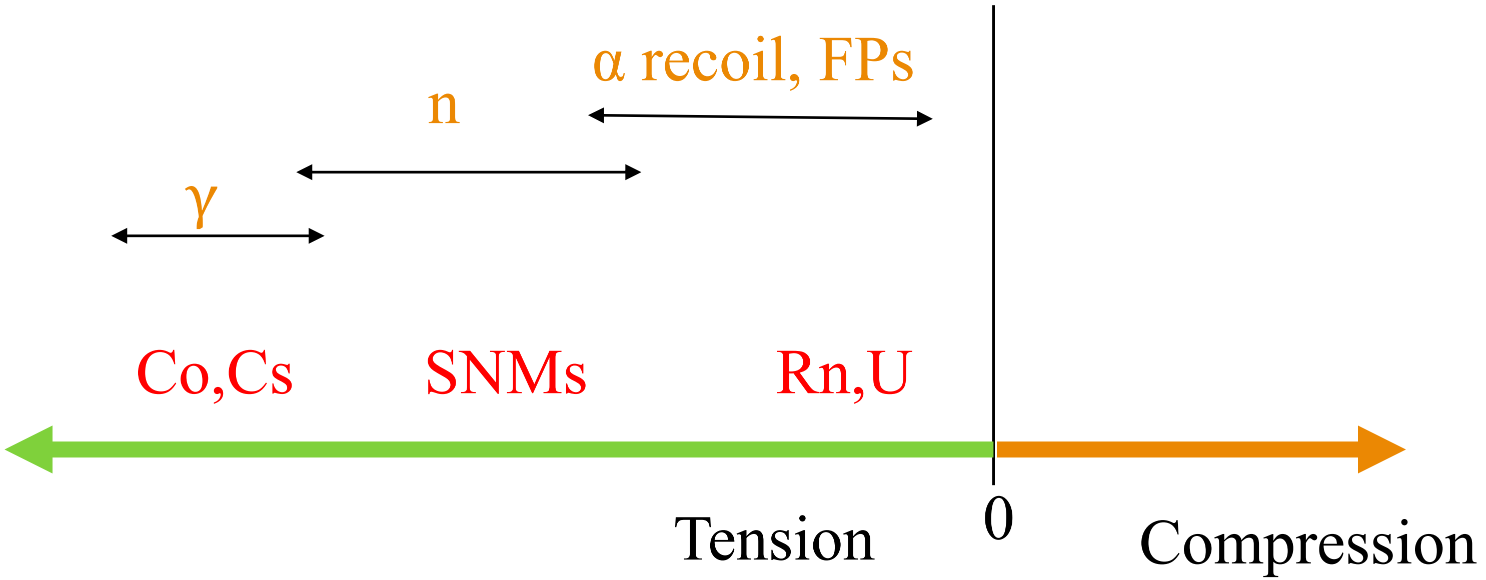
Detection Control via Triggering Stored Energy Release

dE/dx = ~1(for ϒ,β); ~ 10^3 to 10^4 (for n, α, FPs)

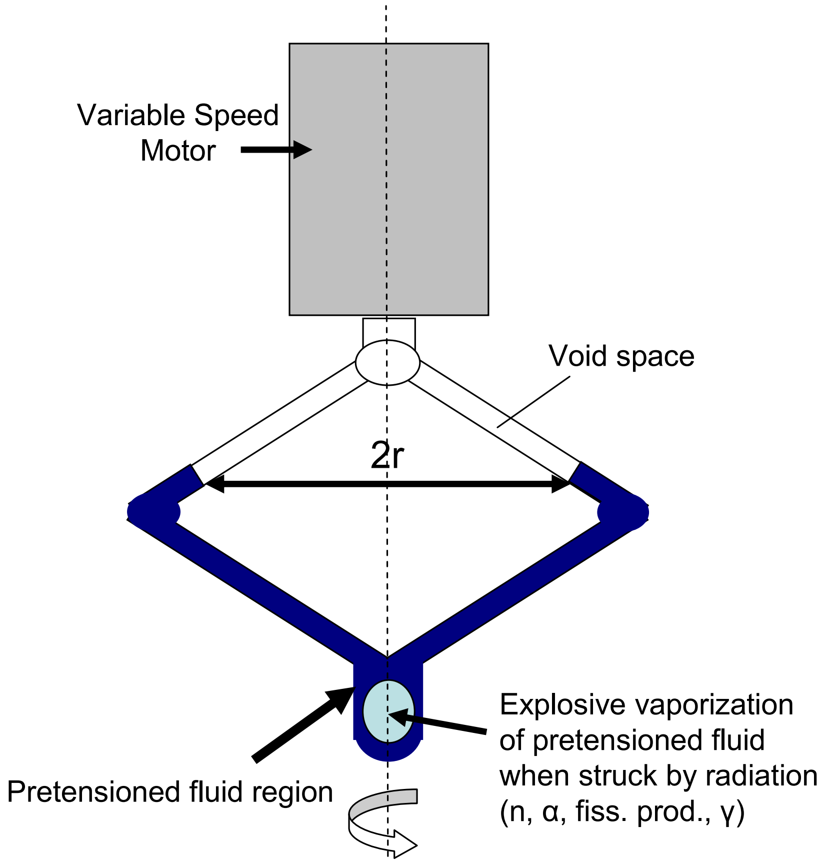
$$r_c = \frac{2\sigma}{p_v - p_l}$$

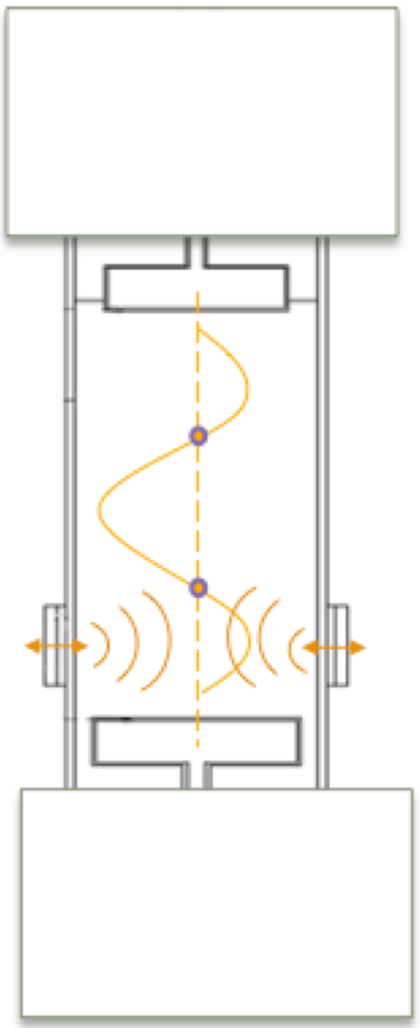


Metastable Fluid Detector
- Same System for Multiple Uses



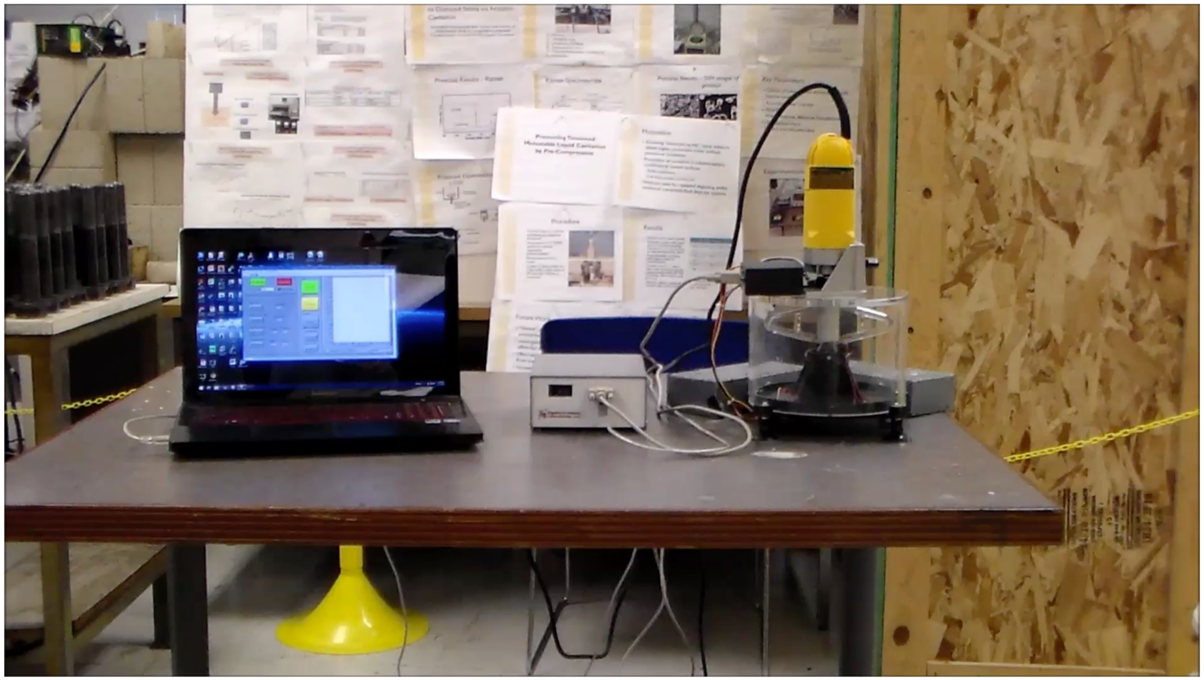
CTMF & ATMF Detectors





Hand Portable (~2-3 kg; 0.25m x 0.25m x 0.3m)

"See-Hear Radiation"
Always On CTMFD
(Centrifugally Tensioned Metastable Fluid Detector)



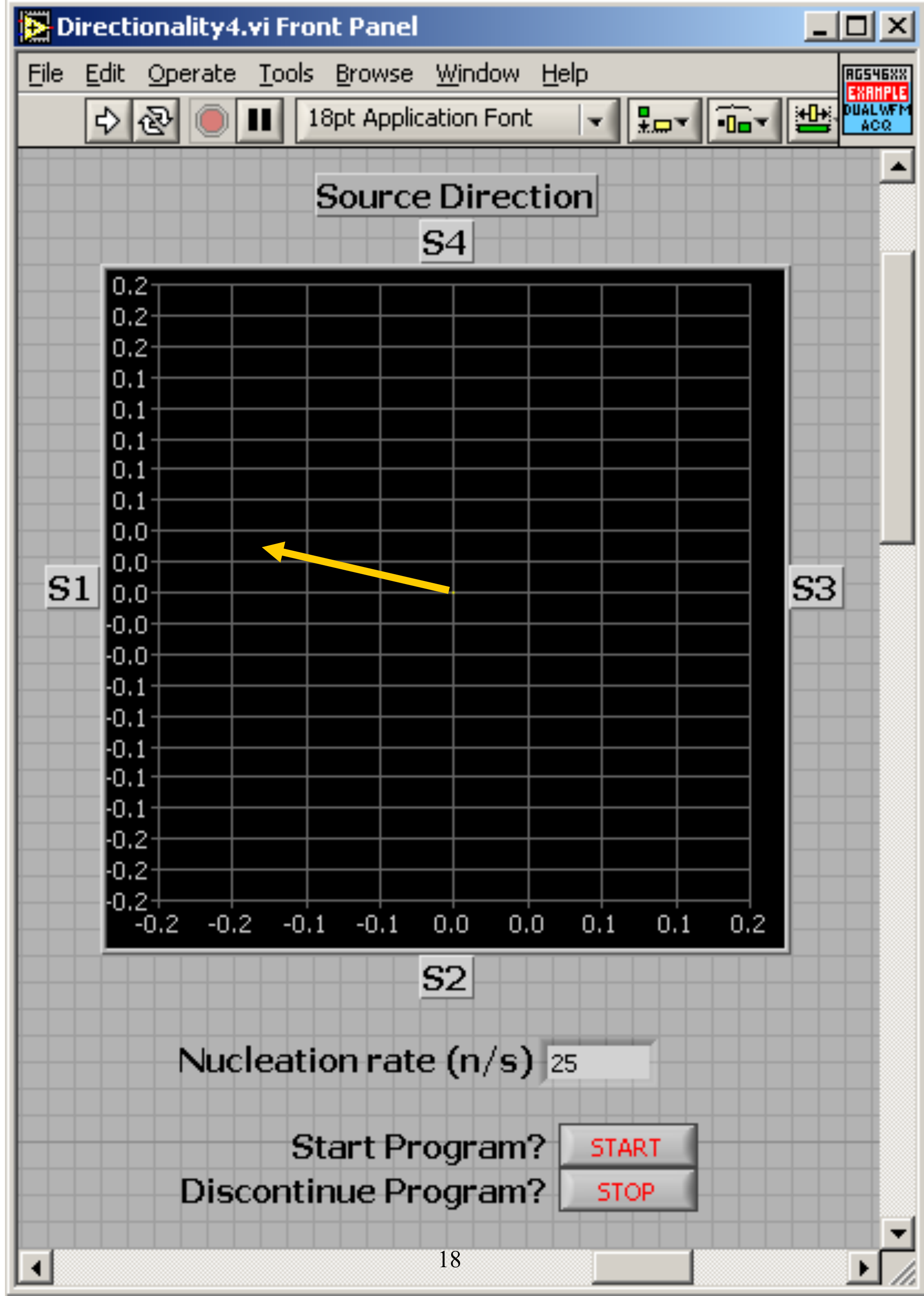
http://web.ics.purdue.edu/~ahagen/link_1.mp4

”See-Hear Radiation”
Acoustic TMFD (kHz to MHz – On/Off)

http://web.ics.purdue.edu/~ahagen/link_2.mp4

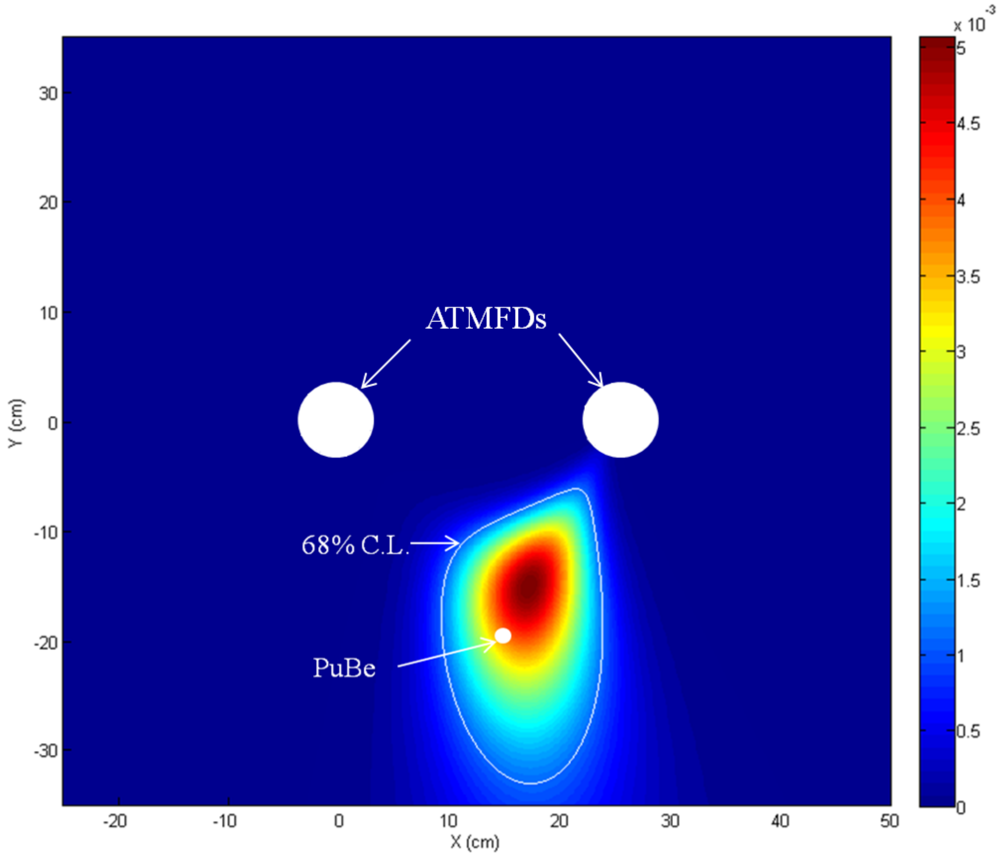
Directionality - Automated Readout

- LabVIEW™ virtual instrument & control
  - All in one data acquisition and signal processing
  - Easy to use graphical user interface
  - Results in near real time (*ms*)



RADIATION Source Positioning POSSIBLE

EXPERIMENTAL RESULTS



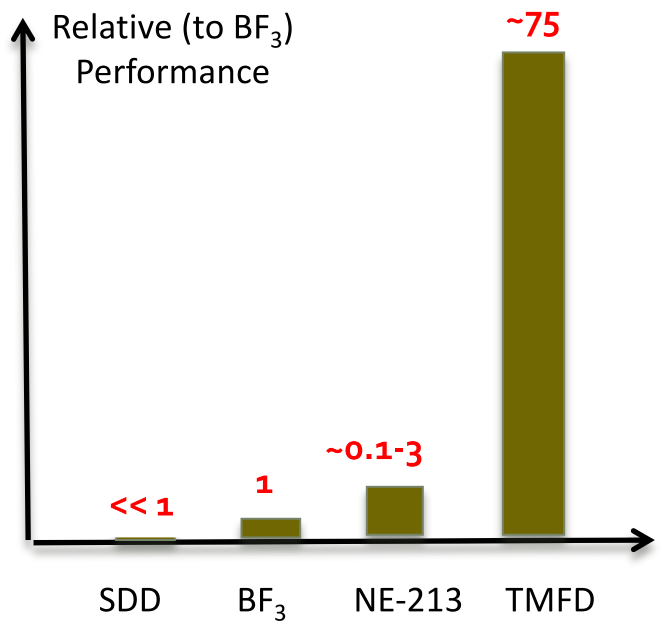
High Efficiency, Near Real-Time TMFD Based Alpha-Fission-Neutron "Spectroscopy"*

(*) – Spectroscopy Permits Nuclide (Nuke/Non-Nuke) ID

SNM Fission Neutron Detection Efficiency Comparisons – TMFD vs. State-of-Art

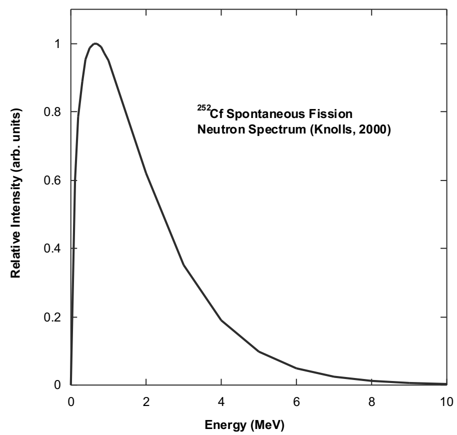
x50 to 1,000 Higher Efficiency

(Using Certified Cf-252 SF Neutron Source)

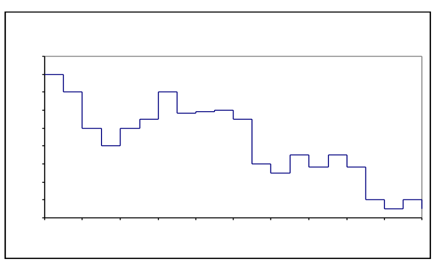


Note: Intrinsic eff. ~ 15% for moderated He-3 based RPM (3.55L; 3bar;1.8m) – PNNL-18471

SNM Neutron Detection & Spectrometry - Identify "Nuke" vs "Industrial-Use"



Fission - Nuke

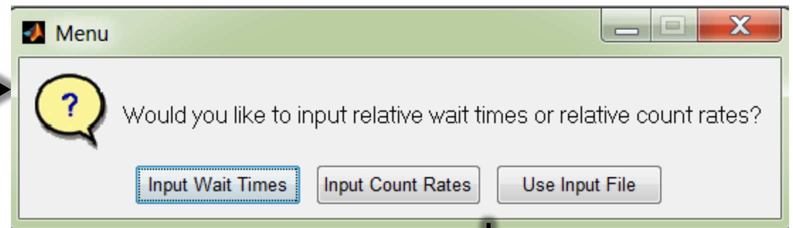


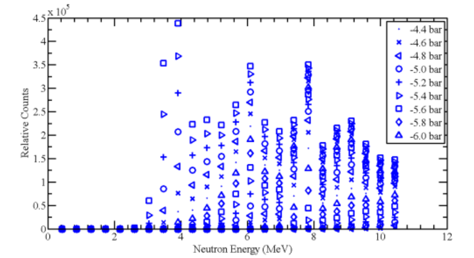
Random – Oil Well, Smoke Det. (alpha,n)

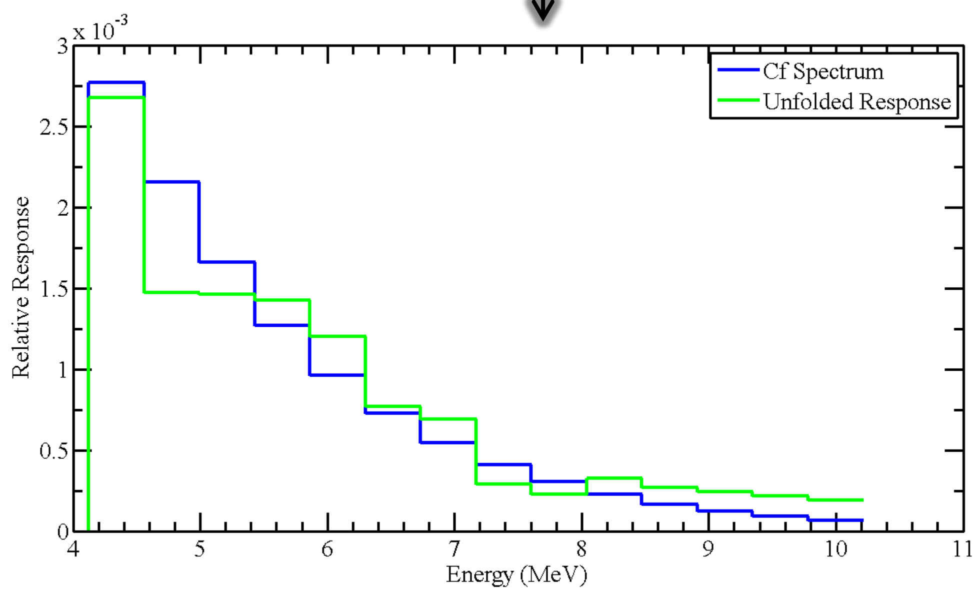
Neutron Spectroscopy via TMFDs–

via Simply Scanning Pneg States

Negative Pressure (bar)	Average Wait Time (s)
5.5	115.40
5.6	83.39
5.7	53.47
5.8	62.51
5.9	39.77
6	32.74
6.1	27.53
6.2	30.73
6.3	21.27
6.4	16.84
6.5	11.55
6.6	16.20
6.7	11.34
6.8	9.17







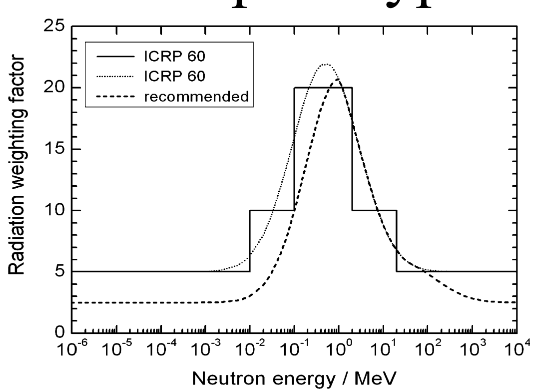
H*10 Portable Neutron Dosimeter Project (NSRD)

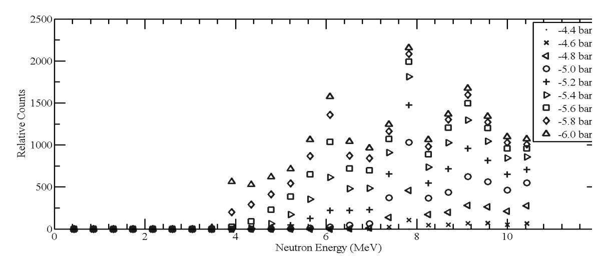
Goal: Novel, Low-Cost ($10-20K vs $400K(SRL), High Efficiency, Gamma-Beta Blind H*10 capable neutron dosimeter

Period: 1y R&D; Partnership: Purdue, ORNL, SALabs,LLC

Why?

- Neutron dose is very non-linear with neutron energy (x20 vs x1)
- Spectrum weighted current detectors (e.g., Rospec) cost ~$400K
- Rospec (Bonner Sphere) approaches → Days/Weeks
- Can lead to increased exposure (w/o spectroscopy included)
- H*-TMFD prototype vetted for enablement at ORNL → Fielding

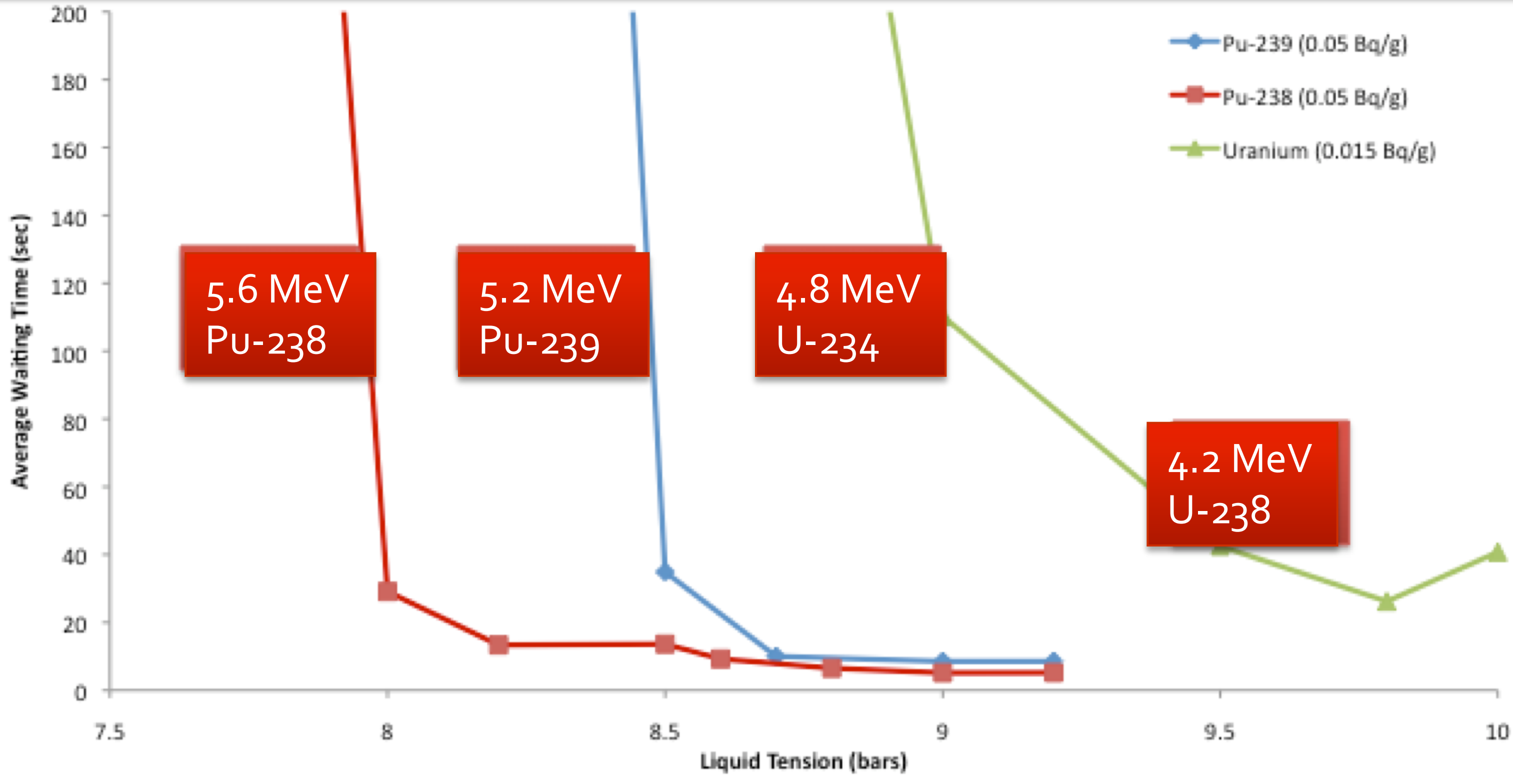




Builds upon NSF-sponsored SAS Model (Grimes et al., 2015)
Develop Response Matrix for Arbitrary Neutron Spectrum
Encode into TMFD control-analysis software → H*-TMFD

Rapidly Detecting Air/Liquid/Soil Borne High Lethality Radiation (alpha-fission)

REAL-TIME ULTRA-TRACE ALPHA-FISSION SPECTROMETRY (Sensitivity → x100 of Beckman LS6500 Spectrometer) - NIST Certified/Supplied Pu/Am (0.05 Bq/g)Sources



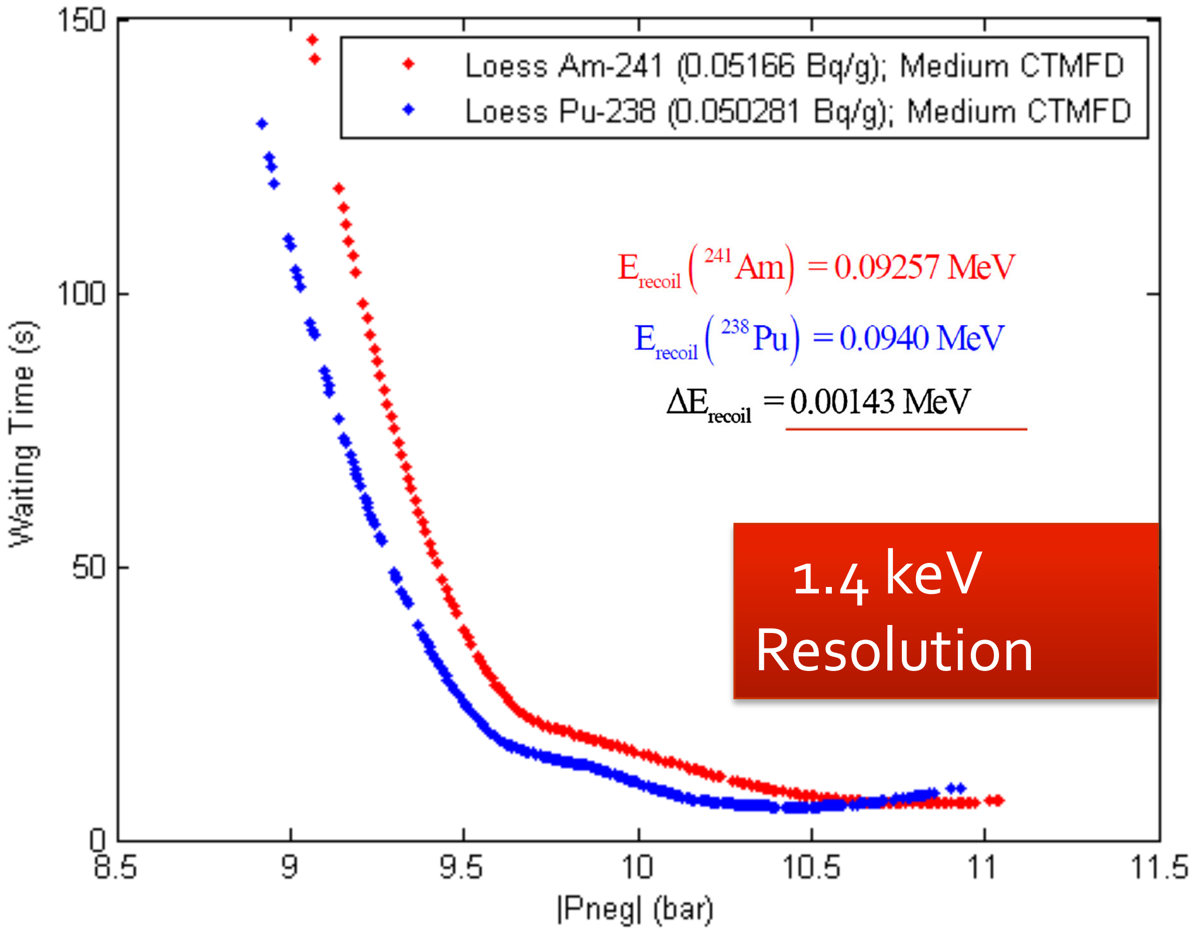
• Proven ability to discriminate the different alpha sources based on energy:

•Uranium: 4.2MeV - 4.8MeV, Pu-239: 5.2 MeV , and Pu-238: 5.6 MeV

•Capable of determining activity of isotopes based on minimum waiting time

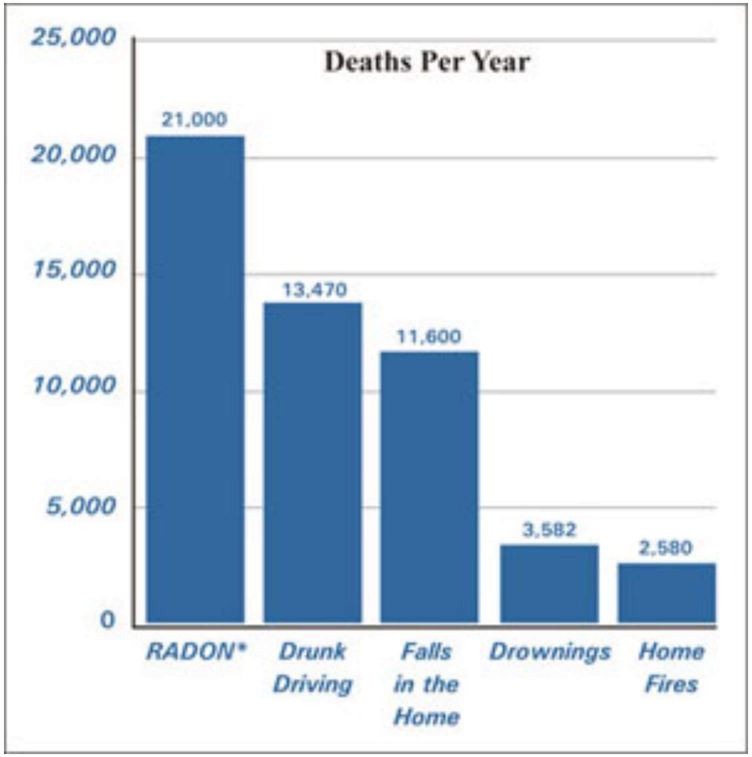
RusiTaleyarkhan - CONFIDENTIAL

~1keV Resolution for Alpha Spectrometry (^{241}Am vs ^{238}Pu; femtogram levels)



EPA Limits for Alphas – Very Low

- E.g., for Radon < 4 pCi/L (1:10^{17}); 21,000 lung cancer deaths/y - USA
- For Pu/U/Am (SNM Detonation) Even Lower x1,000



http://www.who.int/ionizing_radiation/env/radon/en/

http://www.epa.gov/radon/

Radon Progeny Identification in R-CTMFD

UNIQUE NEGATIVE PRESSURE THRESHOLDS FOR RADON AND PROGENY

Rn-222

$T_{1/2}$ = 3.82 days, E_{α} = 5.5 MeV

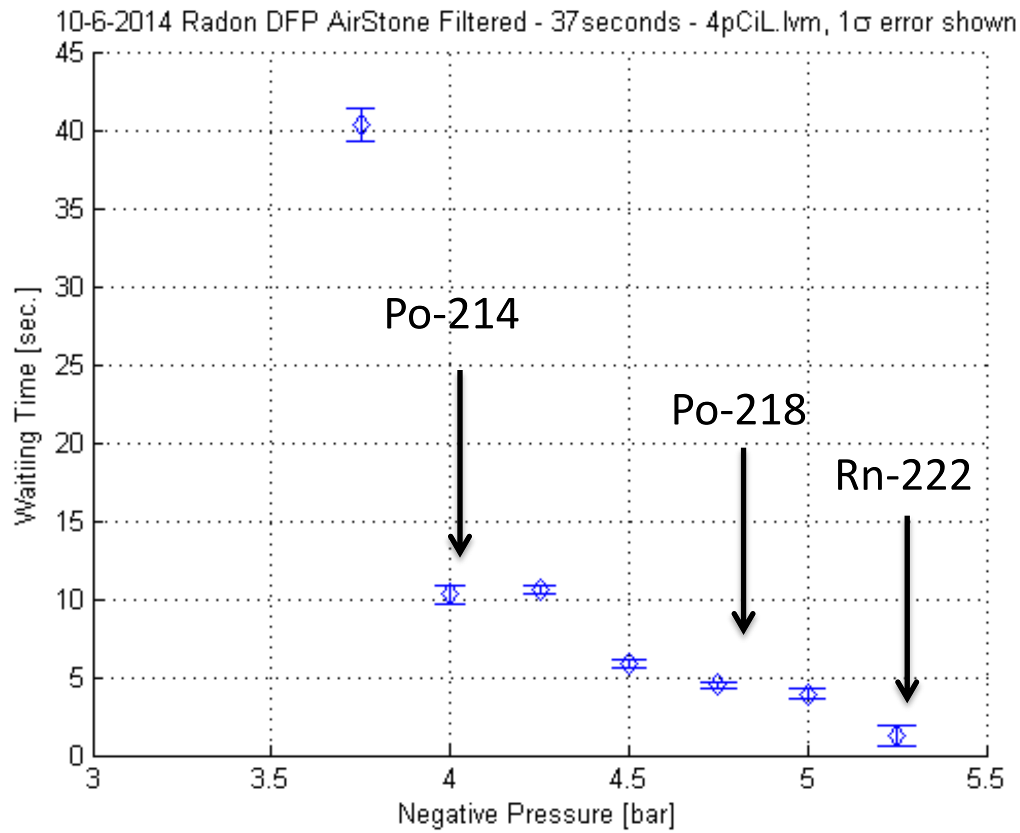
Po-218

$T_{1/2}$ = 3.1 min, E_{α} = 6.0 MeV

Po-214

$T_{1/2}$ = 164 us, E_{α} = 7.7 MeV

Decided to use 7 bar to ensure measurement of Radon and progeny



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CTMFD Alpha(Rn) Detection Efficiency → Readily matches/exceeds state-of-art

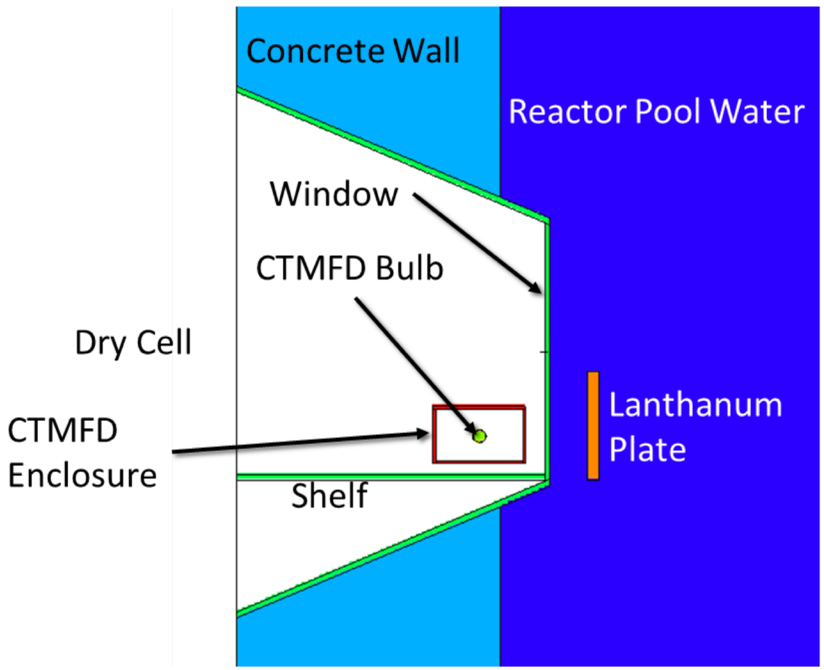
15cc CTMFD radon detection at 4 pCi/L:

Radon sensitivity 0.25 CPM/(pCi/L)
Note: With only 2 min Sampling Time
(Potential for x 10+ increased sensitivity to 2.5 CPM/(pCi/L)

Already On par / superior to other radon detection systems (24h; to $10-30K each):

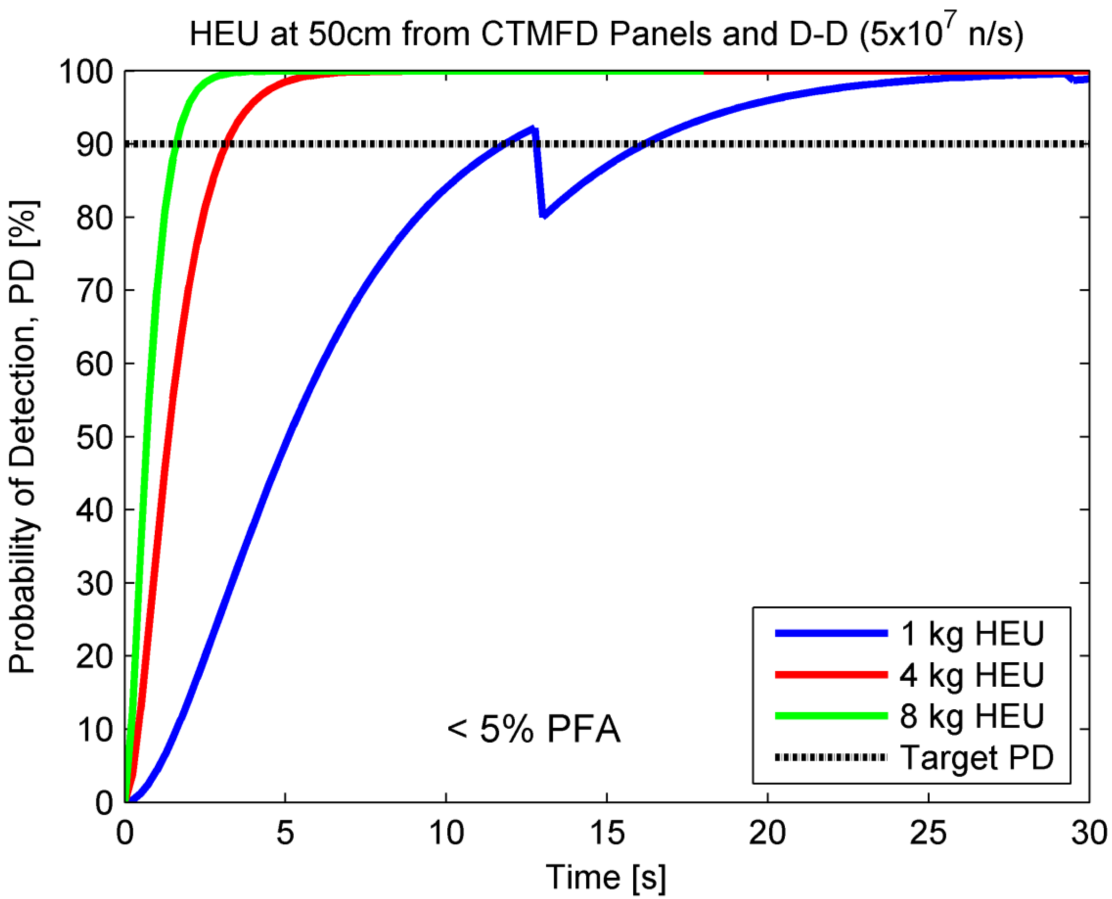
Femtotech CRM-510LP ~0.3 CPM/(pCi/L)
Sun Nuclear 1027 ~0.045 CPM/(pCi/L)
Durridge RAD7 ~0.25-0.5 CPM/(pCi/L)

Photon Blindness Confirmed –TAMU (700 R/h); PNNL (50 R/h)



Lanthanum γ source in reactor pool

Detecting 1-4 kg qty. SNM (HEU) within Seconds - Active Interrogation (1m standoff); 2017 IEEE NSS Cor



Note: IAEA Threat Level HEU = 25 kg

CUSTOMIZED TMFDs MARKETED WORLDWIDE

SINGLE/ARRAY UNITS

AVAILABLE via
Sagamore Adams Labs., LLC

ATMFD Product Brochure

TECHNOLOGY*PROFILE*

ATMFD *–Acoustically Tensioned Metastable Fluid Detector*

Novel, Low Cost (Gamma Beta-Blind) Directional-Position Sensing Fast & Thermal Neutron Detector-Spectrometer System

Directional neutron detectors have a number of potential applications, including locating and monitoring sources of neutrons, monitoring special nuclear material (SNM) at nuclear facilities under safeguards regimes, and detecting sources of fast neutrons, including SNMs, in containers and packages being scanned. The ATMFD system represents a significant advancement to the current state-of-the-art directional neutron detectors. A single D-ATMFD system is capable of the directional detection of neutrons in a single portable detector with an unlimited field of view (4π), at high intrinsic efficiency and at a significant reduction in size while remaining completely blind to non-neutron background. This is accomplished with the potential for a significant cost reduction over comparable directional systems [e.g. ~$10-20K for (Fig.1) ATMFD vs. $150K - >$300K for conventional multi-unit directionality sensing systems).

Figure 1. E-ATMFD system (Model E-ATMFD.1, on sale custom orders).

One of the unique applications of directional-capable neutron detectors is the exciting capability to image the actual location of a neutron source which allows the possibility to determine the source shape, size and (in combination with known detection efficiency) the neutron source strength. Imaging detectors thus can play an important role in non-proliferation type applications.

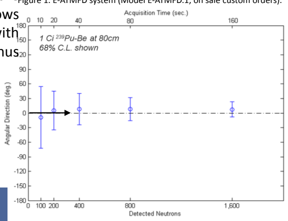


Figure 2. Example of directional capabilities of the D-ATMFD system.

Directional, position-sensing & imaging ability (see Fig. 2 and Fig. 3) of the ATMFD are experimentally validated and benchmarked with MCNP-POLIMI simulations.

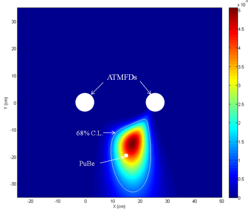
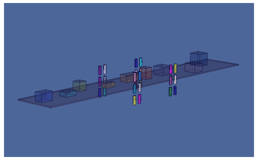


Figure 3. Example of position-sensing capabilities of the D-ATMFD system.



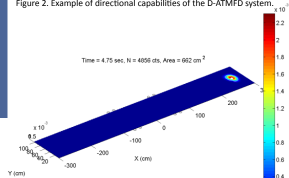


Figure 4. Simulations of passage of a 4 kg mass of WGP thru the prototype D-AMTFD based ANSI Cat. E. RPM. Example of position-sensing capabilities of the D-ATMFD system.

Application Examples: (i) External non-intrusive RPM monitoring of a storage facility (Fig.4) where the location and movement of specific SNMs may be of interest; (ii) counting spent-fuel assemblies in a safeguarded regime; (iii) Determining an SNM mass for material accounting, or counting warheads as part of a verification protocol.

Notably, the ATMFD remains gamma-beta blind and possesses the ability to turn on/off neutron sensitivity within microseconds making it ideal for photo-fission and/or pulsed-neutron based active interrogation applications.

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Sagamore Adams Laboratories, LLC

CTMFD Product Brochure

TECHNOLOGY*PROFILE*

CTMFD – Centrifugally Tensioned Metastable Fluid Detector

Novel, Low Cost (Gamma/Beta-Blind) Neutron-Alpha Spectrometer

Ultra-Low High Efficiency Real-Time Alpha Spectroscopy: The M-CTMFD (Fig.1) is ideal for use in the detection of key actinide isotopes constituting special nuclear material (SNM) via their alpha decay signatures and neutron emission. CTMFDs conduct (~100% efficient) alpha spectroscopy over ~4-6 MeV (with ~1 keV resolution) spanning Cm-Am-Pu-U actinides of interest in spent nuclear fuel (SNF) – Fig. 2. The CTMFD system has the ability to differentiate key actinides even at ultra-trace concentrations of ~0.05 ppt and ~15 ppt respectively (which is unprecedented – i.e., *x10 to x100* more sensitive than with a conventional liquid scintillation spectrometer).

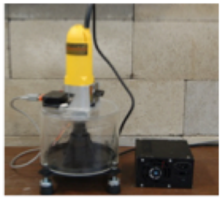

Figure 1. M-CTMFD (Model M-CTMFD .1, on sale-custom orders)

Figure 2. Real-Time, ~100% detection efficiency, alpha spectroscopy with CTMFD system.

Real-Time Low-Cost, high intrinsic efficiency (60%+) (thermal & fast) Neutron Spectroscopy: An inherent capability of TMFD systems concerns on demand tailoring of fluid tension (negative Pressure – Pneg) levels allowing for on-demand neutron-alpha energy discrimination and spectroscopy while remaining 100% gamma-beta blind. This offers an unprecedented opportunity for real-time dosimetry and spectroscopy as well – thereby, permitting separation of fission from random (α,n) neutrons, e.g., from Pu-Be or cosmic type sources. Fig. 3 presents data taken with a 40cc CTMFD with a Cf-252 fission source. By scanning Pneg states, ~0.1 to 12 MeV energy neutrons can be detected with overall ~60% intrinsic (~100% theoretical maximum) efficiency.

Real-Time, Low-Cost Neutron Dosimetry: Fig. 4 shows results of comparison of neutron dose from the (~3cc) light weight (~5-lb) M-CTMFD system vs moderated (~90cc BF_3, 25-lb) dose-meters. The M-CTMFD offered comparable performance with x30 less detection volume .

Real-Time, Low-Cost Radon Monitoring: The CTMFD system is capable of detecting 1-4 pCi/L Radon in Air, as well as 400-4,000 pCi/L Radon in Water at/below EPA limits - within minutes to < 1h.

Customized Product Overview: Lower (x10 to x100) Cost, Lighter (x5) Weight, High (90%+) Efficiency Neutron-Alpha Spectrometry & Dosimetry solutions from *S/A Labs., LLC*

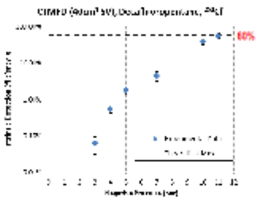

Figure 3. High-Efficiency Neutron Detection ~0 to 12 MeV Fission Spectrum

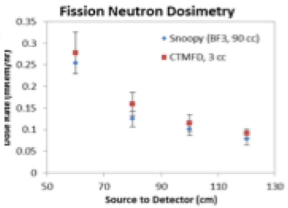

Figure 4. Fission Neutron Dosimetry with M-CTMFD.1

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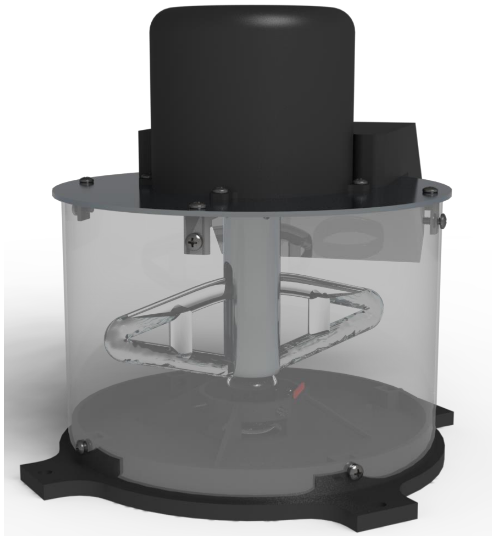

Figure 1. CTMFD (Model LW-MCTMFD, on sale-custom orders)

R-CTMFD Product Brochure

TECHNOLOGY*PROFILE*

R-CTMFD *– Centrifugally Tensioned Metastable Fluid Detector*

Transformational (γ/β -Blind) Radon Monitoring Solutions

SALabs.,LLC's Radon specific model-Centrifugally Tensioned Metastable Fluid Detector **(R-CTMFD) system (Fig. 1)** offers significant advantages over the current state of the art in radon detection. Advantages include rapid, **high intrinsic efficiency (>95%) alpha spectroscopy**, **100% γ/β blind** – Cs-137 gammas (> 3R/h) and P-32 betas (>10^7 pCi/L) sources, spectroscopic capabilities including **ready discrimination between Radon and alpha-emitting progeny** (see Fig. 2), and the ability to operate in dirty/humid environments without bulky filters and desiccant systems. **Dual benefit** includes the R-CTMFD, as-is, for **eV-MeV neutron detection & dosimetry.**

Figure 1. Radon CTMFD (Model R-CTMFD .1, on sale-custom orders)

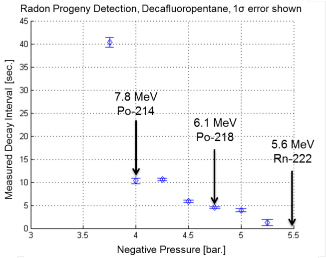

Figure 2. Real-Time, ~95% detection efficiency, alpha spectroscopy with CTMFD system.

The R-CTMFD has the ability to **detect Radon-222 collected from water and air** at environments equivalent to the EPA standard of 300 pCi/L in water and 4 pCi/L in air. This was accomplished utilizing NIST calibrated Radon producing sources to **create environments ranging from 1.4 pCi/L to 200 pCi/L** indicating a capability to measure Radon concentrations below the EPA standard of 4 pCi/L. Radon collection procedures for **grab sampling (1 min), short-term and long-term (48 hours) testing have been developed and are possible with a light weight portable air sampler** (Fig 3.)

The R-CTMFD as developed is capable of measuring the radon activity at the EPA standard level, while remaining **completely immune to buildup of beta emitters such as Pb-210**. It meets **or exceeds the sensitivity of state of the art radon detectors (>0.5 cpm/(pCi/L)** with a collection time of ≤ 1 minute – single shot or spread out over time. **Successful blind testing has been vetted by Bowser-Morner, Inc. (EPA's Radon reference laboratory**) to demonstrate that the R-CTMFD as developed is capable of detecting radon in-air concentrations to within the required specifications of ±20% relative percent error (see Fig. 4).

Customized Product Overview: Lowered Cost (tailored), Lighter (x5) Weight, High (90%+) Efficiency, Portable-Fixed Neutron-Alpha Spectrometry & Dosimetry solution from *S/A Labs., LLC*

Figure 3. Light- weight portable Radon CTMFD air sampling box allows user desired short-long term programmable Radon sampling.

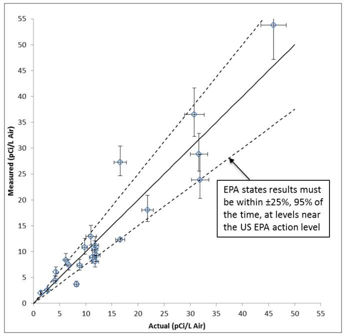

Figure 4. Performance of Radon CTMFD with 1 min sampling times. Results shown with 95% confidence levels.

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THANK YOU FOR THE OPPORTUNITY
Credit to Students & Colleagues (Past/Present)

Comments-Suggestions?