Opportunities at Kentucky

Jeff Vanhoy
US Naval Academy, Annapolis, Maryland

Supported by U.S. DoE FY20/21/22/23 awards
SC0021424, SC0021243, SC0021175, SSC000056

Today's Members

University of Kentucky, Chemistry
Erin Peters, ½ lecturer , lab director, PI
Jackson Dowie, postdoc
Steven Yates, lab director

University of Dallas
Sally Hicks, emeritus

University Kentucky, Physics
4

Mississippi State University
Daniel Araya, grad student
Jayden Ratcliffe, grad student
Stephan Vajdic, grad student
Ben Crider, prof

ugrad & grad students

US Naval Academy
Jeff Vanhoy, prof

FiberTek, Inc & Army Res Lab - Adelphi
Jarrod Marsh

learning neutrons for govt research

NSF 1913028 / 2209178

Recent Players

University of Kentucky, Chemistry
Yongchi Xiao, postdoc

University of Dallas
Elizabeth Chouinard, undergrad
Sarah Evans, undergrad

Mississippi State University
'Tutu' Assumin-Gyimah, grad student

US Naval Academy
Avi Perkoff, undergrad
Madison Roskos, undergrad

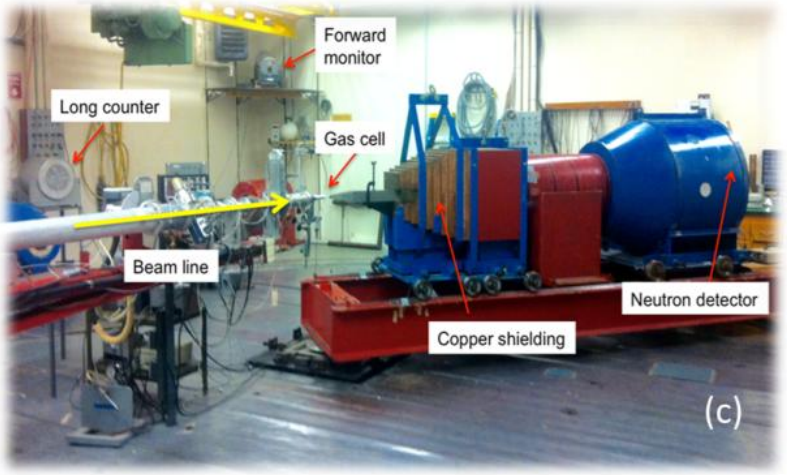
LLNL
Anthony Ramirez

Staffing
(n,n')
(n,n'γ)
(n,n'γ–γ) & (n,n'–γ)
Side Projects
DANCE capture

People about to be Invited

silo

digital DAQ



exptl bay 1

Accelerator

HVEC Model CN: 7 MV
rf source
p, d, ^{3}He, α, … ions
Authorized for ^{3}H gas targets
measure exit neutron energy
1 ns pulse widths every 533 ns

University of Kentucky 60 years 1964-2024 Accelerator Laboratory

- **Basic Nuclear Science**
  - Nuclear Structure via (n,n'γ)
    - Level Schemes & Transitions
    - Spectroscopic Information
    - DSAM Lifetimes
  - (^{3}He,nγ)

- **Applied Nuclear Science**
  - Differential (n,n') Cross Sections
    - ^{12,13}C, ^{7}Li, ^{19}F , ^{54,56}Fe , ^{23}Na , ^{28}Si
  - Detector Development
    - Univ Guelph / TRIUMF
  - measurements for 'friends'

historically ~50d BOT/y

Staffing

(n,n’)

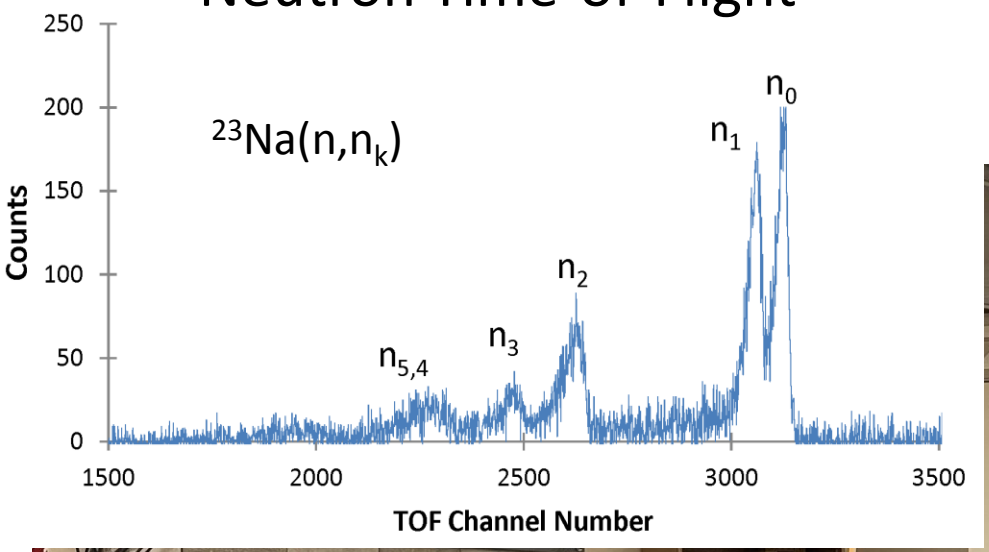
(n,n’γ)

(n,n’γ–γ) & (n,n’–γ)

Side Projects

DANCE capture

Neutron Time-of-Flight



Pulsed beam. PSD.
Exit channel neutrons sort by flight time.

MAIN
n detector

13C
7Li
27Al & 51V
others?
19F, 20xPb, 24Mg , 9Be

Anthony
Ramirez
LLNL

goniometer rotates 0 to ~155 deg

(n,n')

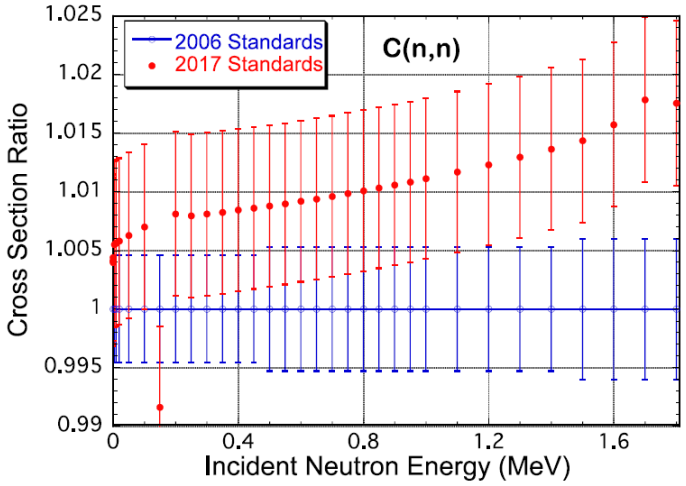
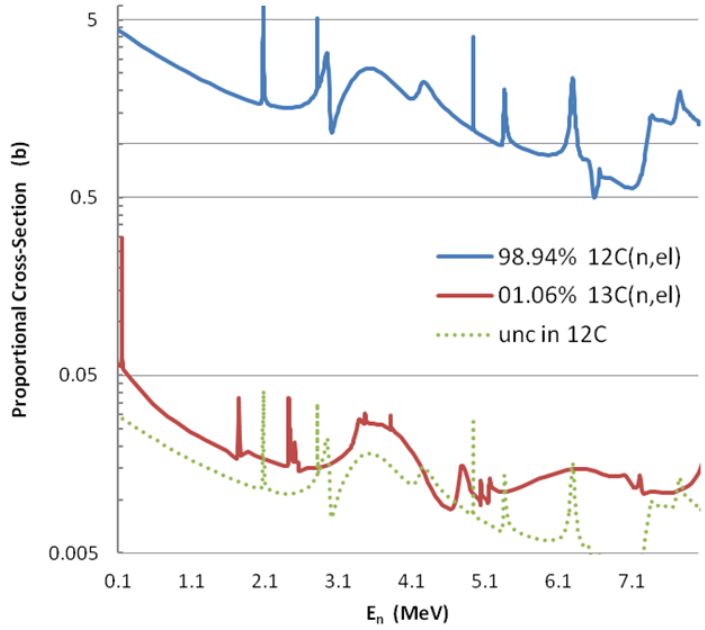
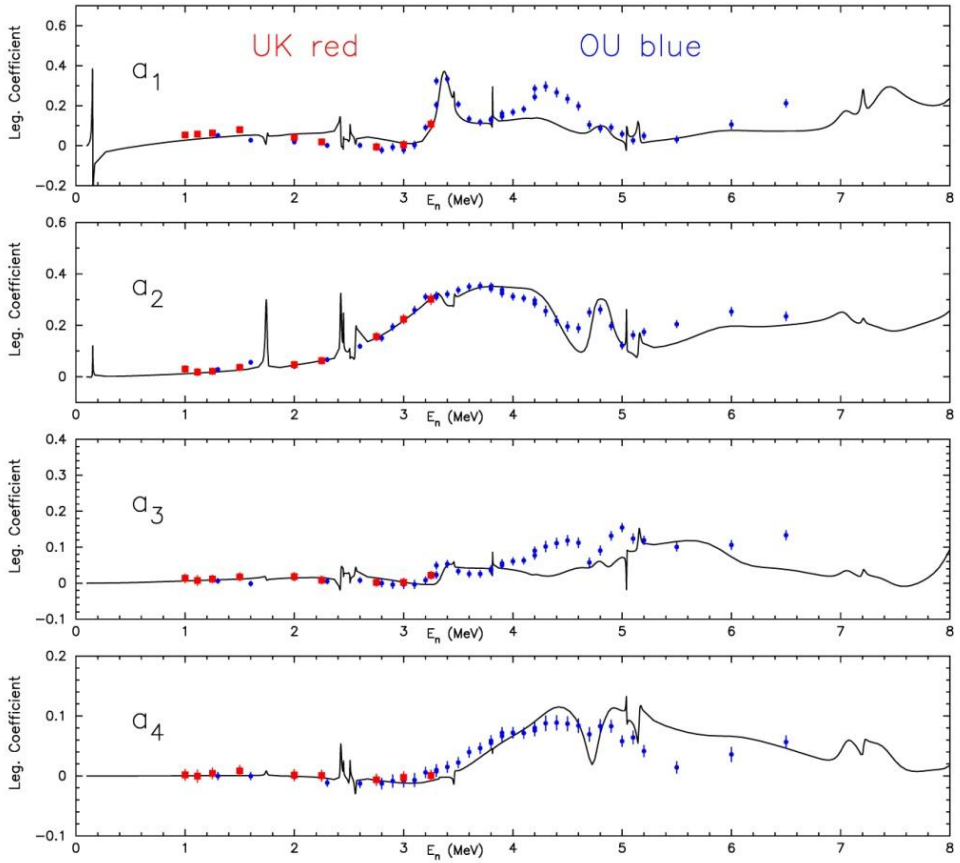


FIG. 18. (Color online) Comparison of the carbon total elastic cross section for the 2017 evaluation with the 2006 standards evaluation. The unrecognized systematic uncertainty of 0.65 %

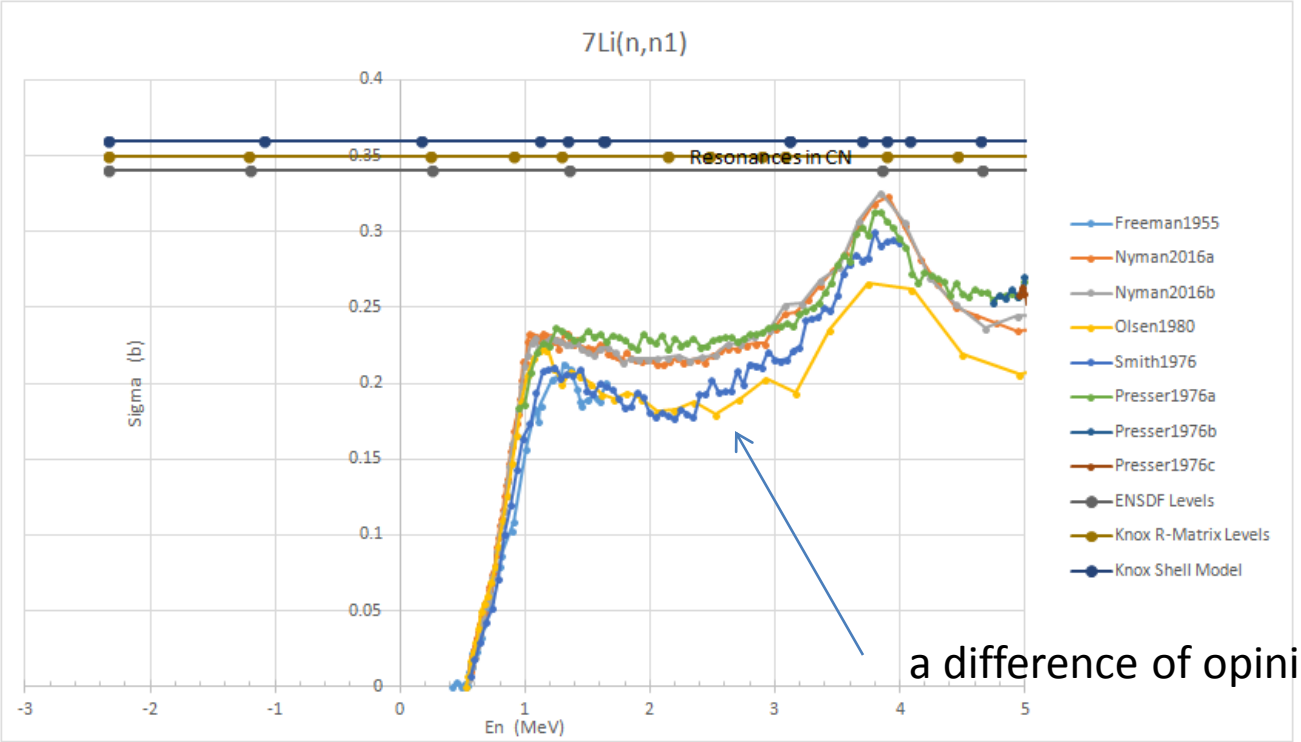


^{13}C

Thanks to OU & LANL
Originally the Lane 1981 samples
Allan Carlson
Thomas Massey
Matt Devlin



^{7}Li



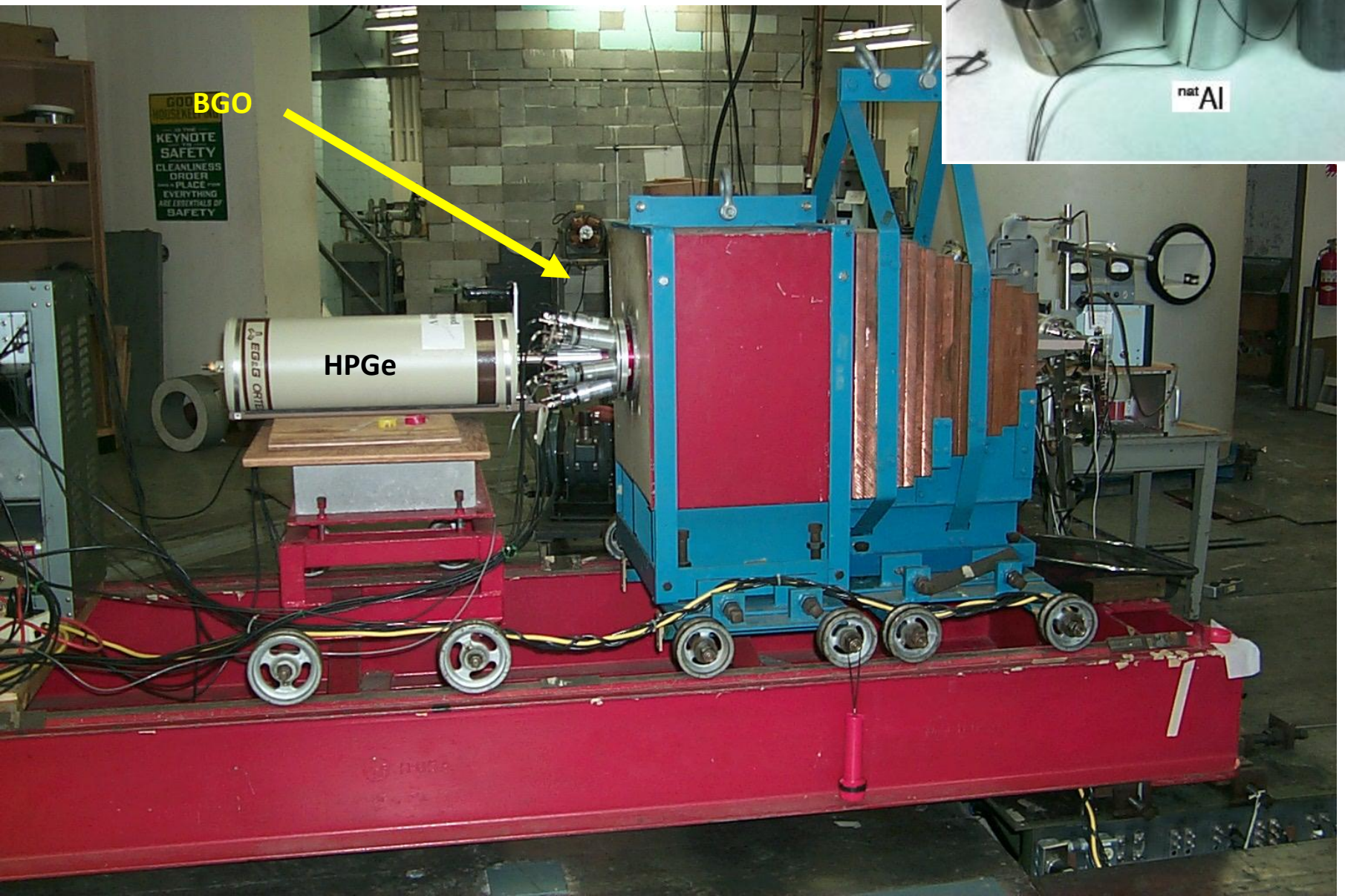
a difference of opinions

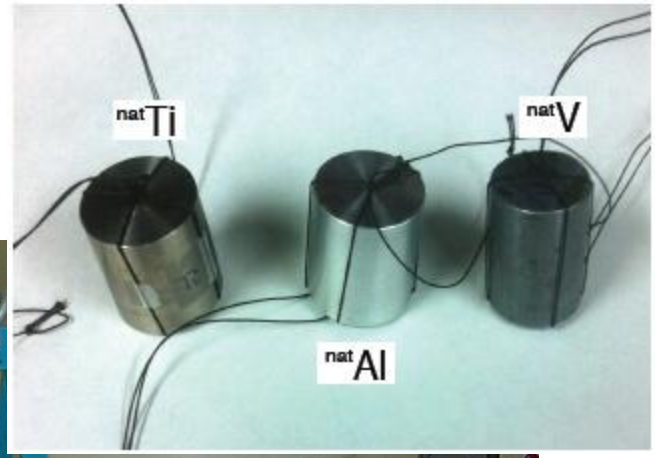
Daniel Araya
MS State

IRMM/GELINA measurements favor high road
UKAL natLi(n,n') measurements 2018, 2019
nELBE 2017 (2023) measurements favor low road
Price of enriched Li goes up 3x
OhioU loaned us enriched targets 2022
- - - targets didn't have matching empty container.
Re-canned in March 2023
Re-measured in July 2023 with dDAQ, analysis w ROOT.
-- one of the largest samples we've ever done: atten & MS
-- challenges with (sample-container) subtr at forward angles.

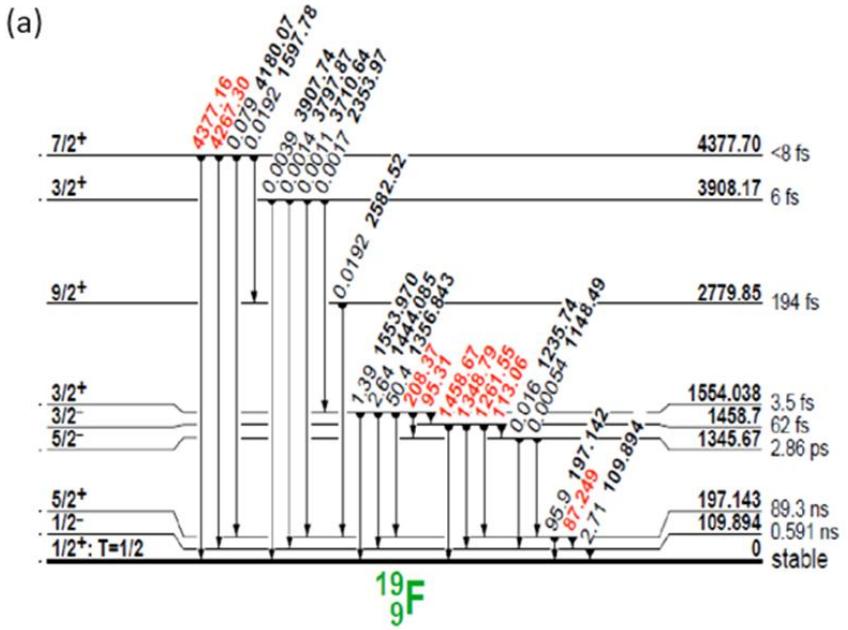
Arnd Junghans WINS2023

(n,n'γ)


BGO
HPGe
KEYNOTE
SAFETY
CLEANLINESS
ORDER
PLACE
EVERYTHING
SAFETY


natTi
natV
natAl

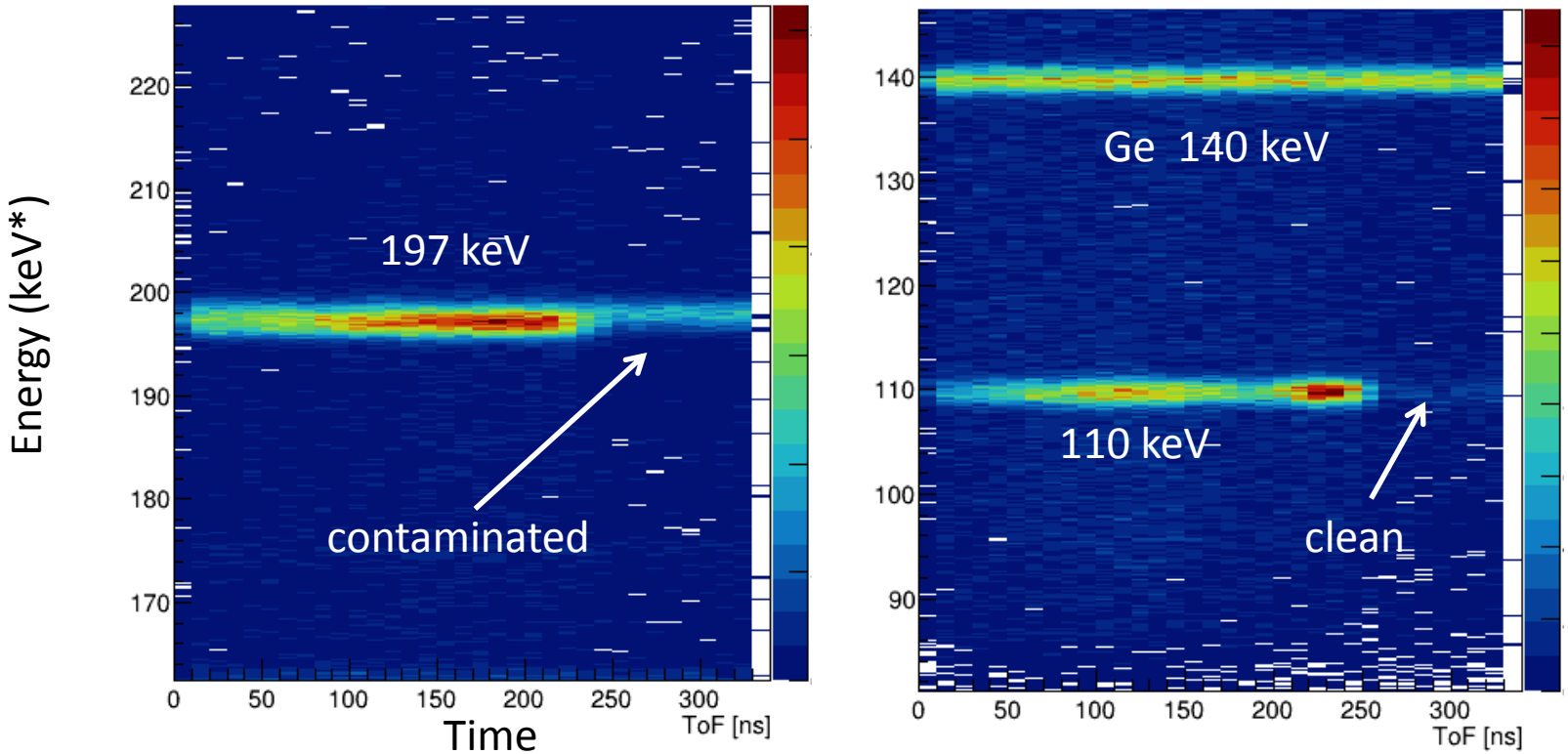
^{19}F



WINS2018 mtg
-- problems w both UKAL & GELINA measurements

GELINA status

UKAL
22-29 Oct 2023

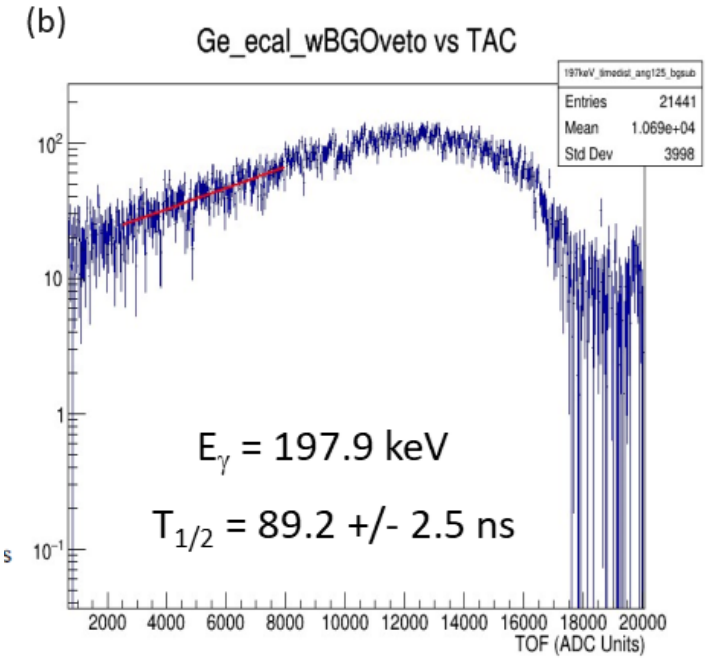


^{19}F

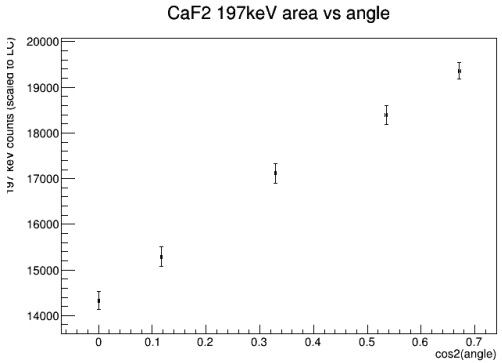
UKAL

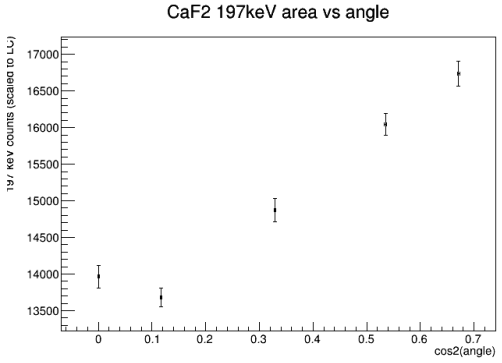
2 weeks ago

22-29 Oct 2023
ExcFn 1.2-2.3 MeV
CaF_2, ^{56}Fe, ^{nat}Ti, ^{nat}C, blank
5 pt AngDist to detect a4s
sample change every 20 min
Determined γ-ray a_4s ^{19}F, ^{nat}Ti & ^{56}Fe



ENSDF 89.3(10) ns





displayed values
un-corrected for
n γ atten
& MS

If plot
yield vs $\cos^2$
then a_4
jumps out at you

From attempts to use 51V(n,n'γ) as an xs normalization, something ain't right.

^{51}V

E_i(level)	J_i^π	E_γ †	I_γ ‡	E_f	J_f^π
320.18	5/2⁻	320.12 *7*	100	0	7/2⁻
928.74	3/2⁻	608.6 *1*	16.0# *5*	320.18	5/2⁻
		928.6 *1*	84.0# *5*	0	7/2⁻
1608.91	11/2⁻	1608.9 *1*	100	0	7/2⁻
1813.12	9/2⁻	1492.9 *1*	22# *1*	320.18	5/2⁻
		1813.2 *1*	78# *1*	0	7/2⁻
2410.73	3/2⁻	1482.6 *3*	13	928.74	3/2⁻
		2090.4 *1*	64	320.18	5/2⁻
		2411.1 *2*	23	0	7/2⁻
2547.8		1619 *1*	100	928.74	3/2⁻
2677.58	(3/2)⁺	1748.8 *1*	100	928.74	3/2⁻
2699.62	(15/2⁻)	1090.7 *1*	100	1608.91	11/2⁻
3083.55	(5/2⁻)	2155.0 *2*	47@ *9*	928.74	3/2⁻
		2763.3 *2*	36@ *12*	320.18	5/2⁻
		3083.2 *2*	17@ *5*	0	7/2⁻
3213	(3/2⁻)	805	50	2410.73	3/2⁻
		2287.0 *5*	100	928.74	3/2⁻
		2895	50	320.18	5/2⁻
3264.25	(5/2)⁻	2334.9 *2*	46	928.74	3/2⁻
		2945.2 *3*	54	320.18	5/2⁻
3280.09	(5/2)	2352.2 *4*	25	928.74	3/2⁻
		2959.3 *3*	75	320.18	5/2⁻
3377.42	(5/2⁻)	3377.3 *2*	100	0	7/2⁻
3386.05	13/2⁻	1777.1 *2*	100	1608.91	11/2⁻
3395.57	(13/2⁻)	1582.3 *2*	62	1813.12	9/2⁻
		1786.9 *3*	23	1608.91	11/2⁻
		3396.1 *4*	15	0	7/2⁻
3444.01		2515.2 *2*	100	928.74	3/2⁻
3454.17	9/2⁻	3133.8 *2*	62	320.18	5/2⁻
		3454.6 *5*	38	0	7/2⁻
3517.0	9/2⁻	3197.0 *5*	20	320.18	5/2⁻
		3516.7 *3*	80	0	7/2⁻
3555.5		3555.4 *10*	100	0	7/2⁻

Something's wrong here.

E_i(level)	J_i^π	E_γ †	I_γ ‡	E_f	J_f^π
3562.6		3562.5 *10*	100	0	7/2⁻
3576.75	(3/2⁻,5/2,7/2⁻)	3256.2 *3*	60	320.18	5/2⁻
		3577.2 *3*	40	0	7/2⁻
3614.55	(9/2,11/2)⁻	1801	38	1813.12	9/2⁻
		2005.6 *1*	62	1608.91	11/2⁻
3624.1		3303.8 *5*	79@ *6*	320.18	5/2⁻
		3624	21@ *6*	0	7/2⁻
3632.11	–	3311.8 *2*	62	320.18	5/2⁻
		3632.1 *5*	38	0	7/2⁻
3663.1	1/2⁻,3/2⁻	3663 *2*	100@	0	7/2⁻
3678.5	(3/2)⁻	3678.4 *5*	100	0	7/2⁻
3723.1		3723 *2*	100@	0	7/2⁻
3779.5	(5/2,7/2)⁺	3460.0 *5*	60	320.18	5/2⁻
		3778.9 *4*	40	0	7/2⁻
3796.6	(3/2,5/2,7/2)⁻	2867.4 *3*	40	928.74	3/2⁻
		3797.5 *5*	60	0	7/2⁻
3803.8		2194.8 *3*	100	1608.91	11/2⁻
3874.04	15/2⁻	488	25	3386.05	13/2⁻
		1174.4 *2*	75	2699.62	(15/2⁻)
3903.0	(9/2,11/2)⁺	2294.0 *5*	100	1608.91	11/2⁻
3919.71	9/2⁻	2108.6 *5*	20	1813.12	9/2⁻
		2310.3 *4*	20	1608.91	11/2⁻
		3598.9 *3*	60	320.18	5/2⁻
3944.22		2131.2 *2*	75	1813.12	9/2⁻
		3014.4 *5*	25	928.74	3/2⁻
4001.2	(7/2⁻,9/2⁻)	4001 *1*	100	0	7/2⁻
4025.18		2212.0 *2*	100	1813.12	9/2⁻
4052.6	(⁻)	3732.3 *5*	100	320.18	5/2⁻
4124.18	(7/2,9/2,11/2)⁻	2515.2 *2*	100	1608.91	11/2⁻

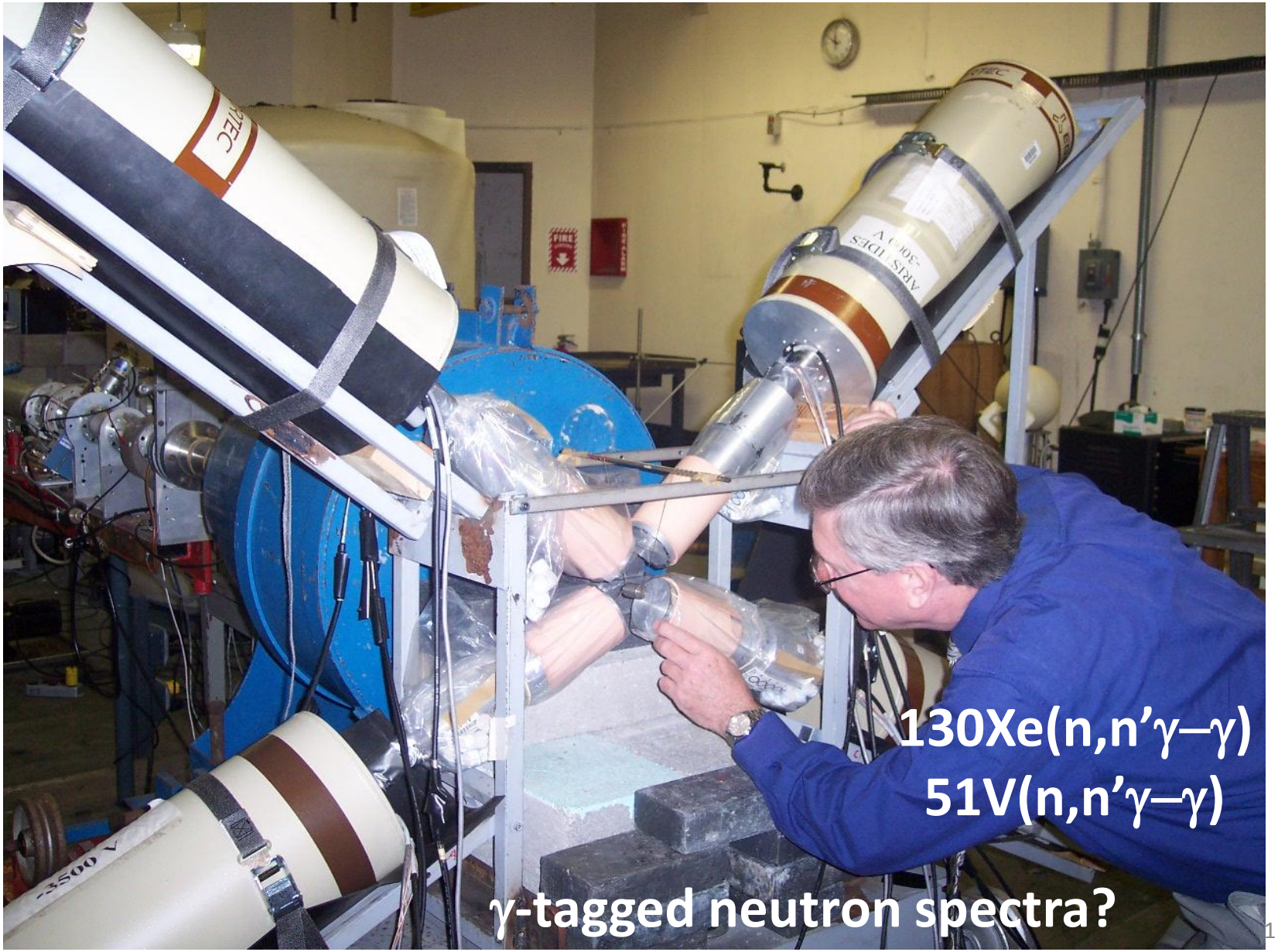
ENSDF Eval, Jimin & Xiaolong, Mar 2016

Anthony Ramirez LLNL

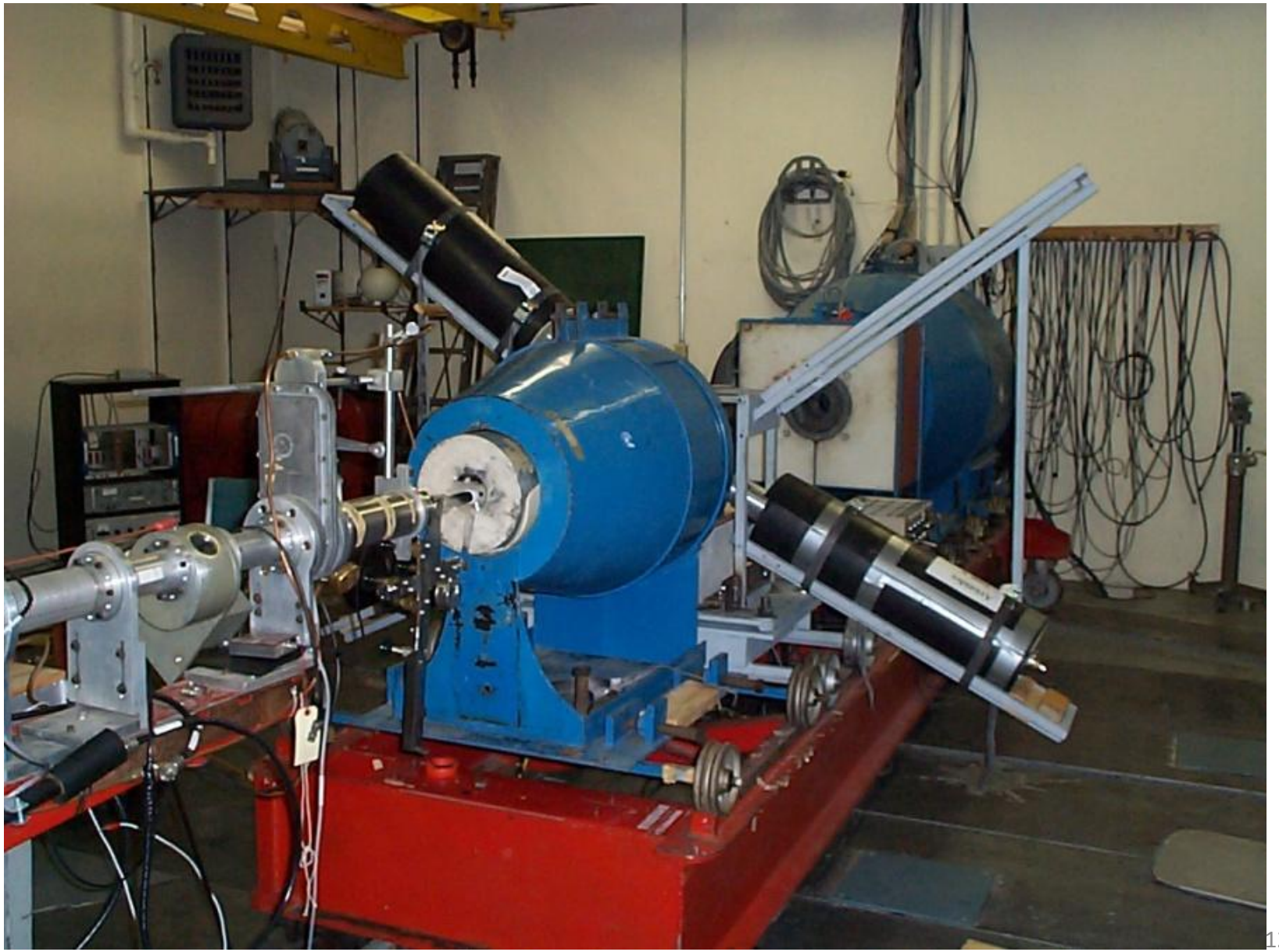
Return of (n,n'γγ) coincidence

1999-2004

natCd,natXe Chris McGrath nat,126Te



Return of (n,n'γγ) coincidence 1999-2004



SIDE PROJECTS

Can the technique of **Dynamic Biasing** help in the modern world? → **LLD & ULD = fn (E deposited in scintillator)**

1960 Boring γ-ray atten in samples

1971-x dynamic biasing becomes popular

1970-1 Englebrecht methods for neutron atten and MS corrections.

1975 Velkey describes Monte Carlo methods for correcting ang dist

1980-y McEllistrem writes MULCAT

1980 MULCAT-BRC Lilley & MTM

1984 GAMBIT has been written by now.

the idea:

Each channel in a nTOF spectrum is intended to represent a specific energy of scattered neutrons.

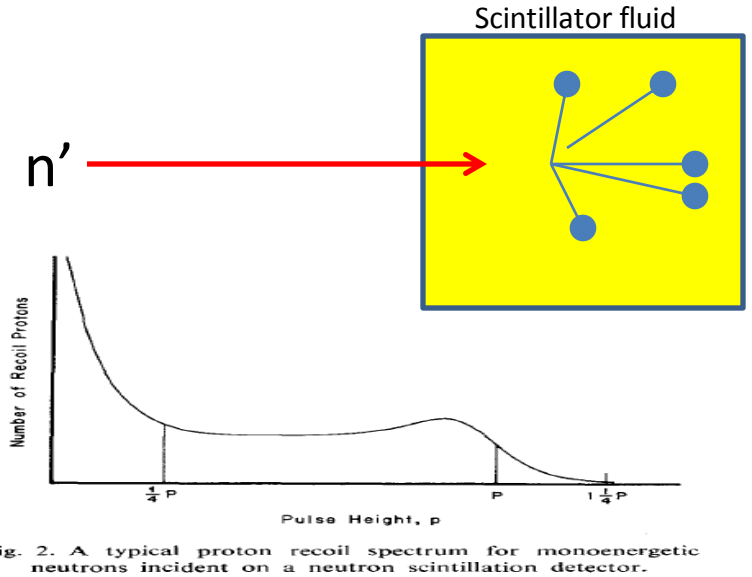


Fig. 2. A typical proton recoil spectrum for monoenergetic neutrons incident on a neutron scintillation detector.

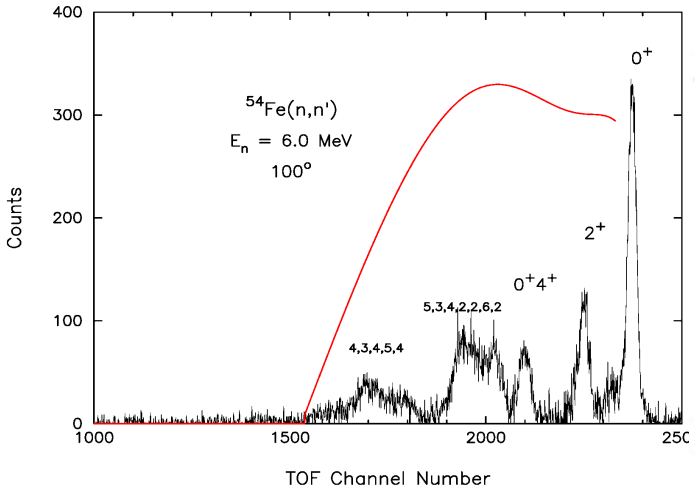
Using signals from forward recoiling protons reduces bckgnd & **sharpens TOF peaks**, especially for low energy n.

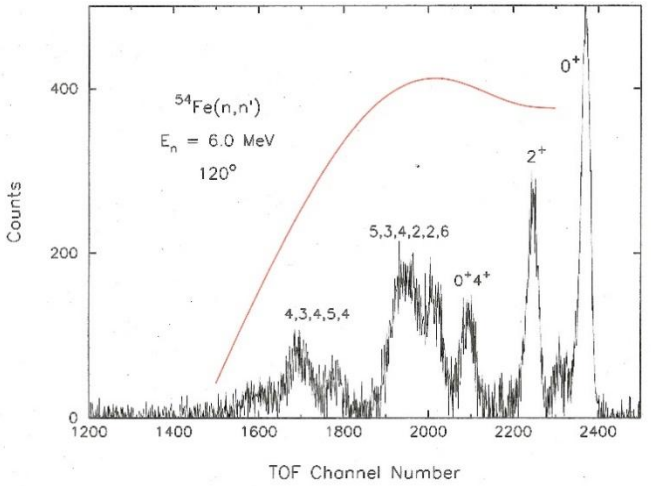
Brandenberger & Grandy, NIM 93, 495 (1971)

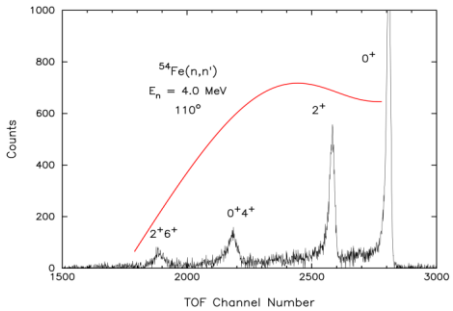
Transforming tof histograms → energy domain i.e. Emission Spectra

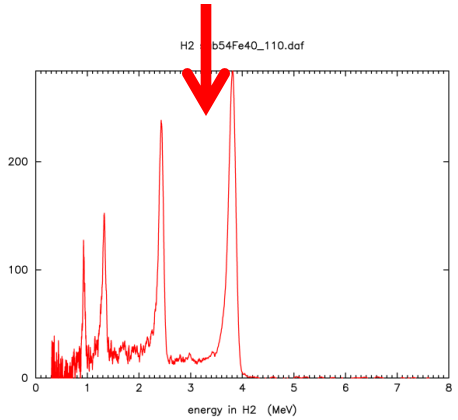
(efficiency corrected and normalized)

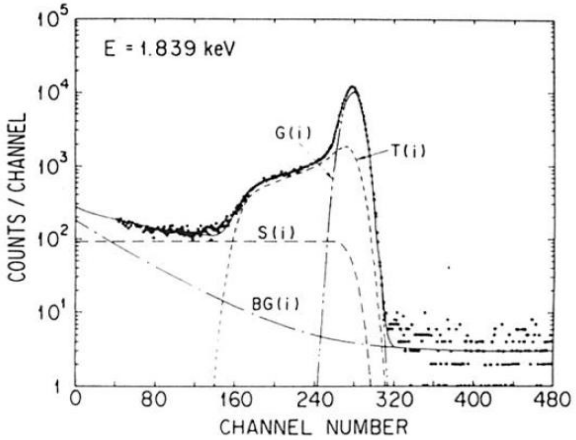
Templates: Arjan Koning (?): Only 5 entries into EXFOR DDX in last 5 years









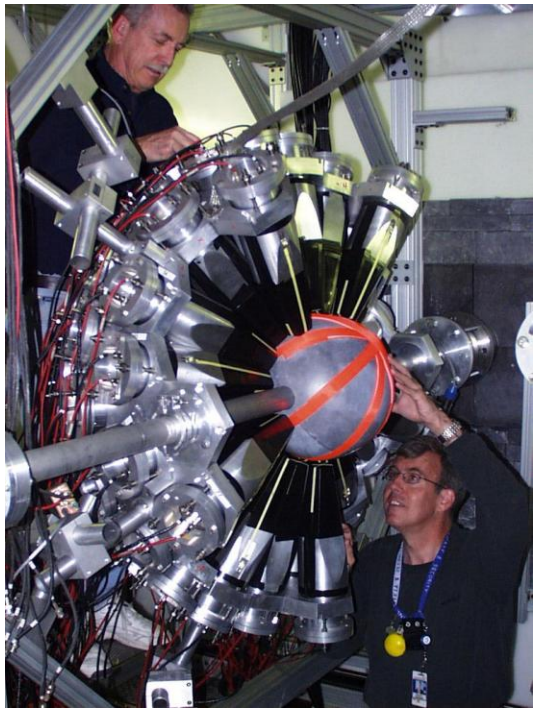


Johansson and Campbell, "PIXE: A Novel Technique for Elemental Analysis", JWiley&Sons

What generates the peak-Shirley effect in neutron detectors, and why is it masked in nTOF spectra?

Kentucky at DANCE

Staffing
(n,n')
(n,n'γ)
(n,n'γ–γ) & (n,n'–γ)
Side Projects
DANCE capture



4π BaF_2 array

$^{110,11,112,114}Cd(n,\gamma)$ — measurements completed, students analyzing

several in $^{130,\ 132,134,136}Xe(n,\gamma)$ — limboed by accel & LiH problems

$^{50,53}Cr(n,\gamma)$ — Not yet proposed

nat C

from Sally Hicks

Undergraduate students on the nat Carbon paper

data taken 2011-2016 & 2016-2020

64 (n,n') ang distrib at 45 incident energies btw 0.5 - 8 MeV
+ 12 (n,n'γ) btw 5.6-7.8 MeV

a monster project

ELSEVIER Nuclear Physics A 1023 (2022) 122446 www.elsevier.com/locate/nuclphysa

Neutron elastic and inelastic scattering differential cross sections on carbon

A.P.D. Ramirez [a,b], E.E. Peters [a], J.R. Vanhoy [c,*], S.F. Hicks [d,b], L.A. Alasagas [c], D.K. Alcorn-Dominguez [c], S.T. Block [d], S.T. Byrd [d], E.A. Chouinard [d], B.M. Combs [d], B.P. Crider [b], E.C. Derdyn [d], L. Downes [d], J.A. Erlanson [c], S.E. Evans [d], A.J. French [d], E.A. Garza [c], J. Girgis [d], T.D. Harrison [c], S.L. Henderson [d], T.J. Howard [d], D.T. Jackson [d], L.J. Kersting [d], A. Kumar [a], S.H. Liu [a], C.J. Lueck [d], E.M. Lyons [d], P.J. McDonough [d], M.T. McEllistrem [b,1], T.J. Morin [d], S. Mukhopadhyay [b], T.A. Nguyen [d], M. Nickel [d], S. Nigam [a], R.L. Pecha [d], J. Potter [a], F.M. Prados-Estévez [a,b], B.G. Rice [c], T.J. Ross [a,b], Z.C. Santonil [d], J. Schneiderjan [d], L.C. Sidwell [d], A.J. Sigillito [d], J.L. Steves [c], B.K. Thompson [c], D.W. Watts [c], Y. Xiao [a,b], S.W. Yates [a,b]

Industry, Compass Minerals
Ministry
MD U. Of KY (radiation oncology)
High school physics teacher
Unknown
Laboratory Tech, Eastfield College
Ph.D. U. of Wisc (Nuc Eng) **Sandia National Lab**
Industry, Raytheon
Ph.D. Texas Tech (CE), Jacobs
Ph.D. Candidate U. of FL (Nuc Eng) **LANL**

M.S. UTA (EE), SPARX Engineering
GNC Engineer, Lockheed Martin
UD Student
Ph.D. candidate, TAMU (Nuc Eng)
M.S. U. of KY (Rad Oncology)
Ph.D Notre Dame (Nuc Phy)
MD, Psychiatry, U. of Southern CA
Ph.D. Candidate, UC Santa Barbara, Photonics
MD U. Of KY, Internal Medicine
Ph.D. Princeton (EE); Faculty U. of PA

M.S. Notre Dame (EE), RF Eng at Lockheed Martin
Data analyst
Nurse
Ph.D. Candidate, U. of Kansas (particle)

Ramirez, Phys Rev C 1023, 122446 (2022)

Dirty Hands

Laboratory Skills

Operation, Maintenance, Repair, Design

brought to you by

University of Kentucky 60 years 1964-2024 Accelerator Laboratory

Conclusion

Damn the torpedoes, full speed ahead!

"This powerful phrase isn't about underwater weapons or blasphemy but rather a defiant call to take risks and push forward, no matter the odds."

Candace Osmond
"Damn the Torpedoes – Idiom, Origin & Meaning"
https://grammarist.com/idiom/damn-the-torpedoes/#:~:text=Origin%20and%20Etymology%20Behind%20Damn%20the%20Torpedoes&text=The%20phrase%20is%20attributed%20to,to%20a%20very%20surprising%20victory.

RADM David Farragut (1801-1870)

US Public Domain

Retrieved from:
https://en.wikipedia.org/wiki/David_Farragut#/media/File:Admiral_Farragut2.jpg

Story at: US Naval Institute:
https://www.usni.org/magazines/naval-history-magazine/2014/july/damn-torpedoes