Neutron Scattering Cross Sections: (n,n') (n,γ) (n,n'γ)

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US Naval Academy, Annapolis, Maryland

Current Team Members

University of Kentucky
Yongchi Xiao, postdoc
Erin Peters, instructor
Steven Yates, prof

Univ Dallas
Elizabeth Chouinard, undergrad
Sarah Evans, undergrad
Sally Hicks, prof

Mississippi State
Kofi Assumin-Gyimah, gradstudent
Stephan Vajdic, gradstudent
Daniel Araya, grad student
Ben Crider, prof

US Naval Academy
Avi Perkoff, undergrad
Jeff Vanhoy, prof

- UnivKY Lab Overview
- Primary Projects
- Secondary Projects
- Highlights

Special thanks to Anthony Ramirez, currently @ LLNL.

Supported by U.S. DoE FY20/21 awards SC0021424, SC0021243, SC0021175, SC000056
Supported by U.S. DoE FY22 awards unknown, SC0021243, SC0021175, unknown

University of Kentucky Accelerator Laboratory (UKAL)

- 7-MV single-ended Van de Graaff accelerator
- p, d, ^{3}He and α beams
- pulsed and bunched beam:
  - f = 1.875 MHz and Δt ~1 ns
- primarily conducts neutron-induced reactions and scattering experiments

Basic Nuclear Science

- Nuclear structure via (n,n'γ)

  - Level Schemes and Transitions
  - Spectroscopic Information
  - DSAM Lifetimes

Applied Nuclear Science

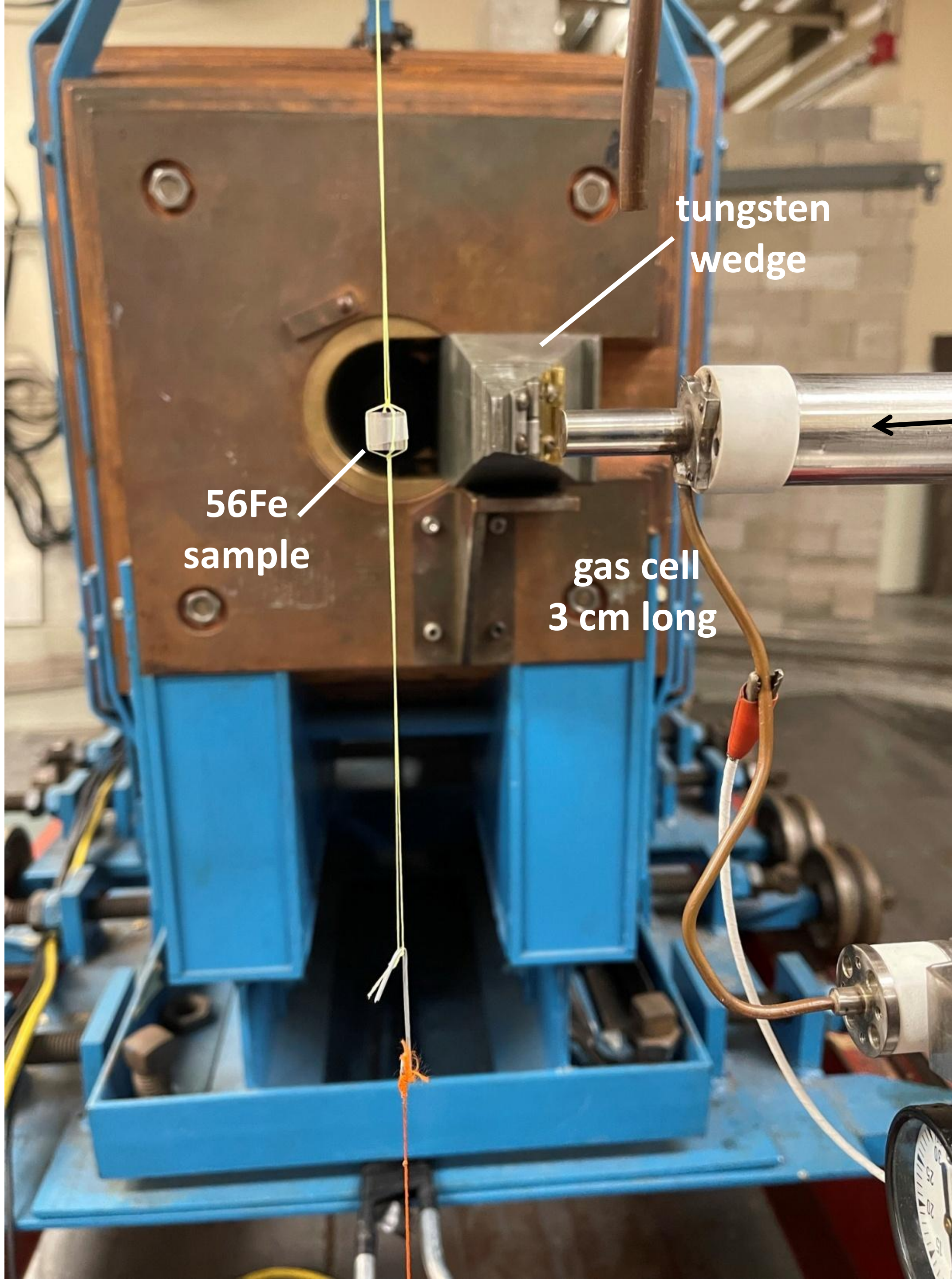
- Cross section measurements

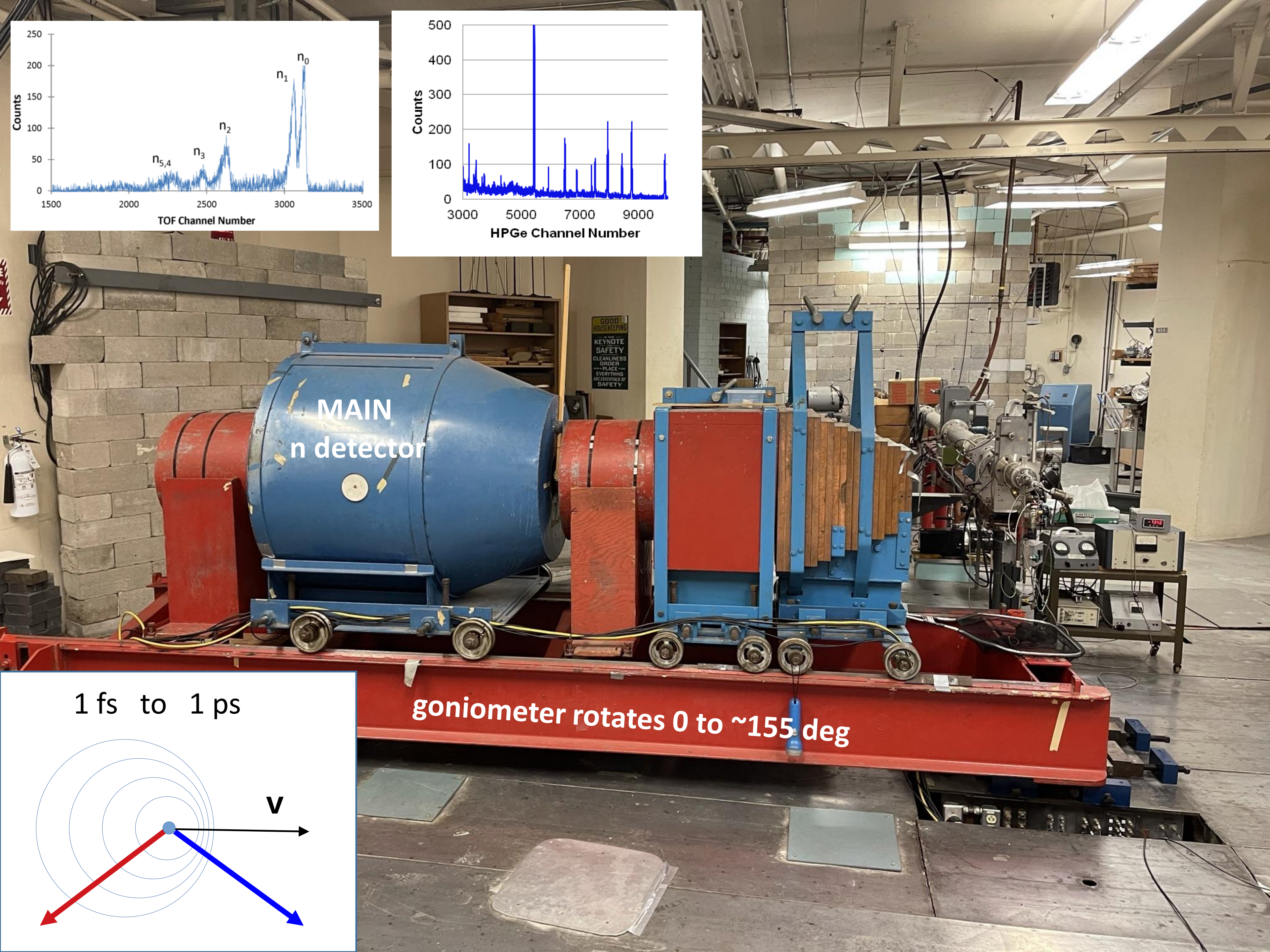
  - (n,n') - Elastic and inelastic cross sections

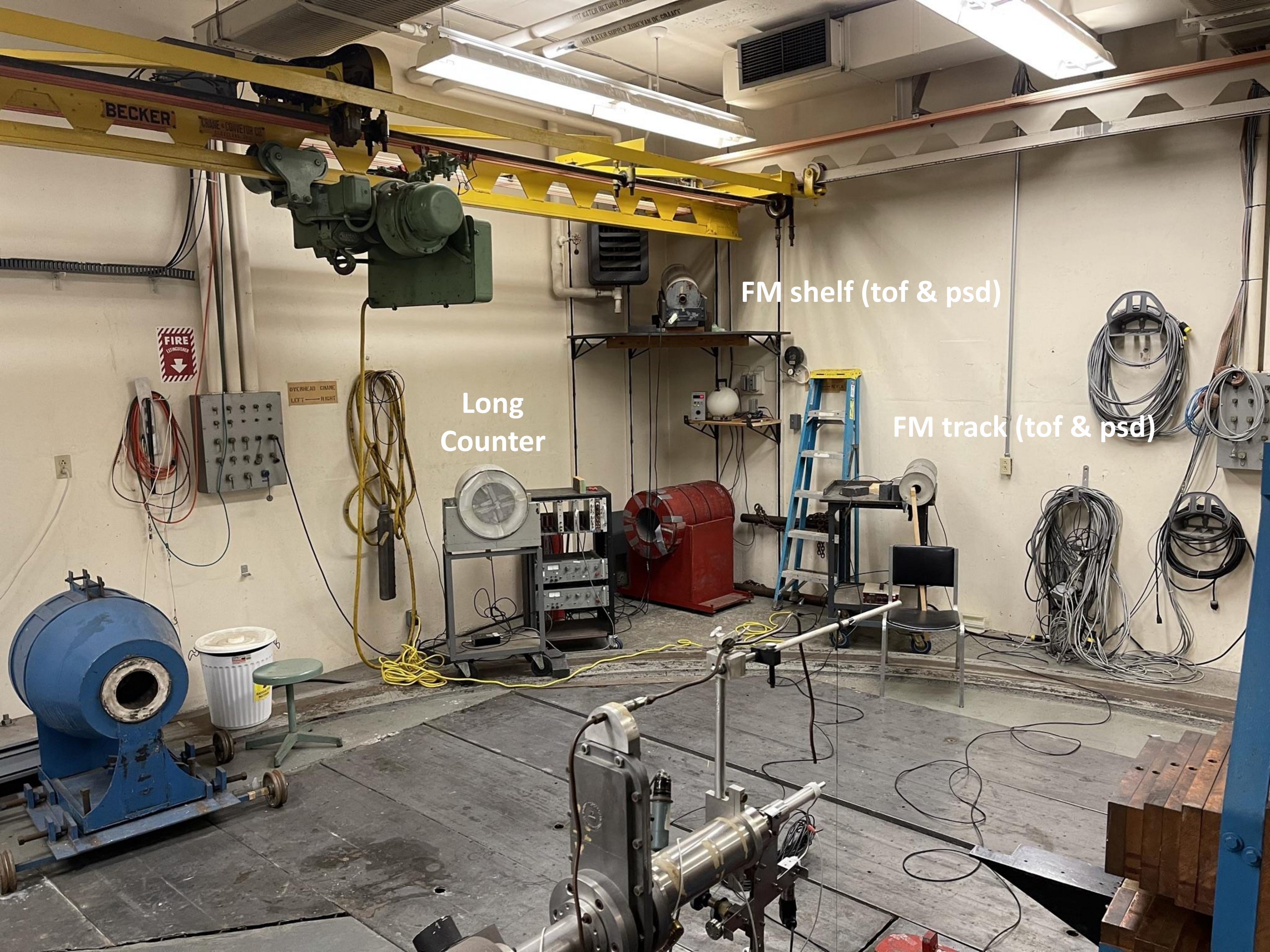
    ^{23}Na, ^{56}Fe, ^{54}Fe, ^{12}C, ^{nat}Si, ^{nat}Li

  - (n,n'γ) - γ-ray production cross sections

    Level cross sections
- Detector development


tungsten
wedge
56Fe
sample
gas cell
3 cm long
pulsed
p, d, 3He

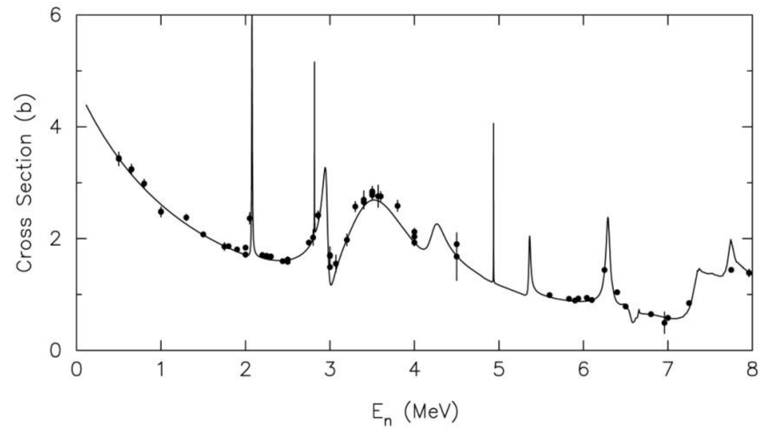

Counts
250
200
150
100
50
0
1500
2000
2500
3000
3500
TOF Channel Number
n_0
n_1
n_2
n_3
$n_{5,4}$
500
400
300
200
100
0
Counts
3000
5000
7000
9000
HPGe Channel Number
MAIN
n detector
goniometer rotates 0 to ~155 deg
1 fs to 1 ps
v
GOOD HOUSEKEEPING
KEYNOTE
SAFETY
CLEANLINESS
ORDER
EVERYTHING
SAFETY


FM shelf (tof & psd)
Long
Counter
FM track (tof & psd)
BECKER
FIRE

Primary Projects

Carbon-12 is a component in …..

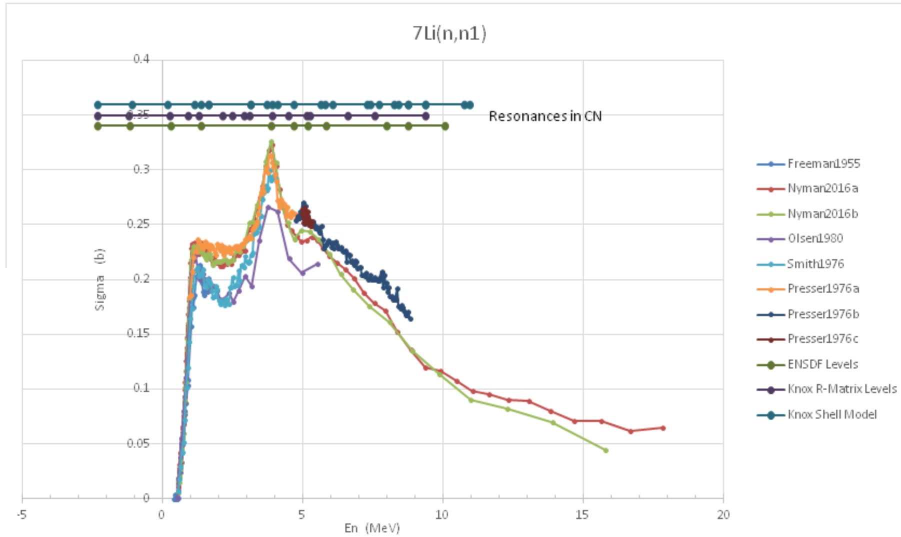
4-6 additional angular distribution measurements are needed in the range 5-8 MeV to assist with (n,n_1) resonance parameter analysis.

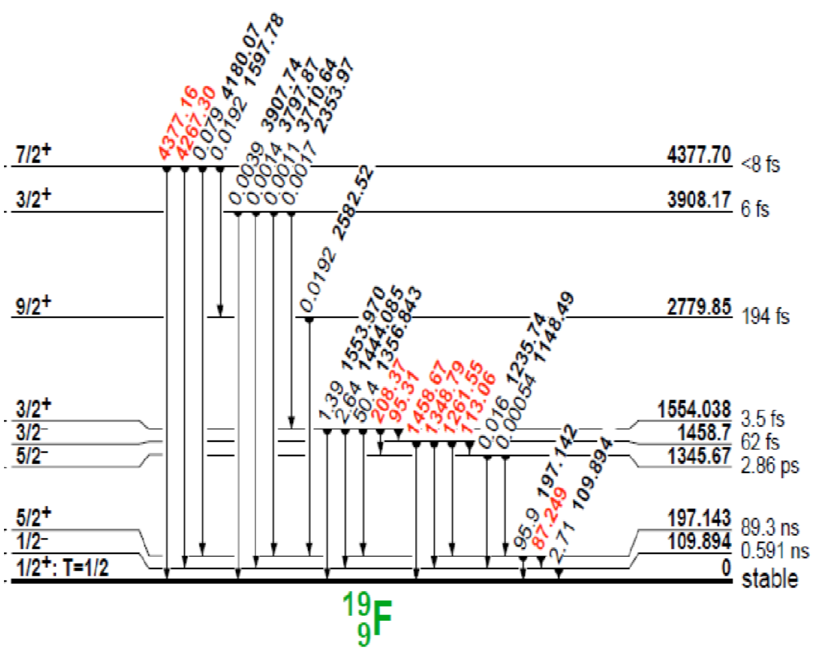


Lithium-7 is a component in …..

Resolve ambiguity above threshold for n_1

More ang distrib for resonance information





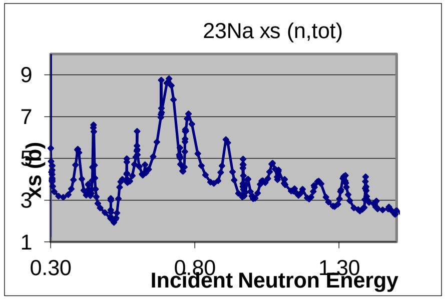
Flourine-19, Effectively no data since 1950s-1960s. Industrial manufacturers of compact molten salt reactors employ FLiBe as a base material and have called for an increased understanding of its properties..

Secondary Projects (if we have time)

Sodium-23 is a component in …..

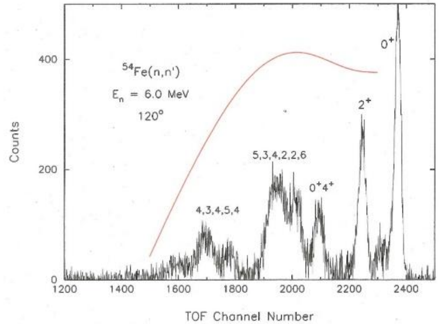
Measurements below 1.3 MeV.

More ang distrib for resonance information



Magnesium-24 is a component in …..

More ang distrib for resonance information



Iron-56, one of the most ubiquitous materials, ….

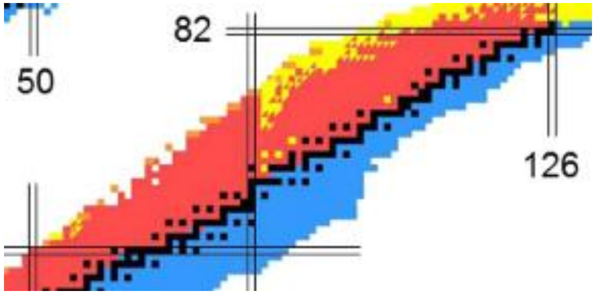
Possible addn'l measurements upon request.

Conversion of existing HE data to neutron emission spectra.

Conversion of Previously Measured Angular Distribution Data to Differential Cross Sections.

The list includes most major stable isotopes of the elements

Na, Fe, Ge, Se, Zr, Mo, Ru, Pd, Cd, Sn, Te, I, Xe, Ba, Ce, Nd, Sm, Gd, Dy,



Neutron capture.

DANCE @ LANL: pulsed n beam w BaF detectors – total emission energy

130,132,134,136Xe proposed

FIPPS @ ILL: continuous n beam w HPGe – detailed γ-ray emissions btw levels

CdTe(n,γ)

100Ru(n,γ)

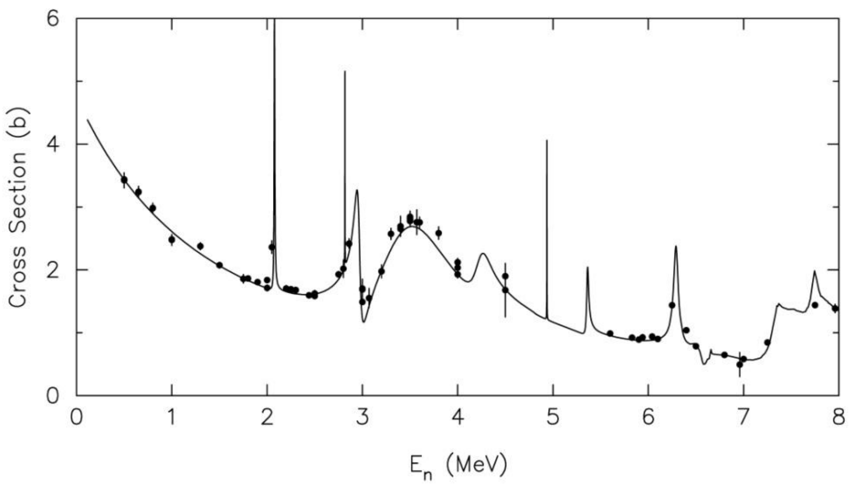
Sarah Evans   Elizabeth Chouinard

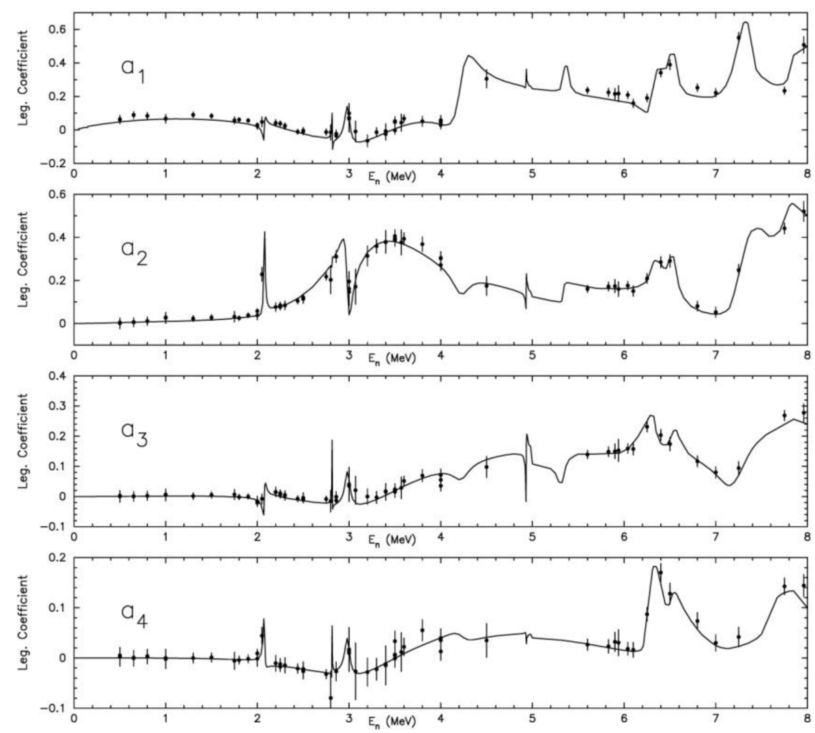
On-site at Univ KY ~1 June to ~1 Aug

Participated in all Nucl Data & Nucl Structure expts

invited to join the Univ KY Nucl Phys REU sessions

(n,elas)





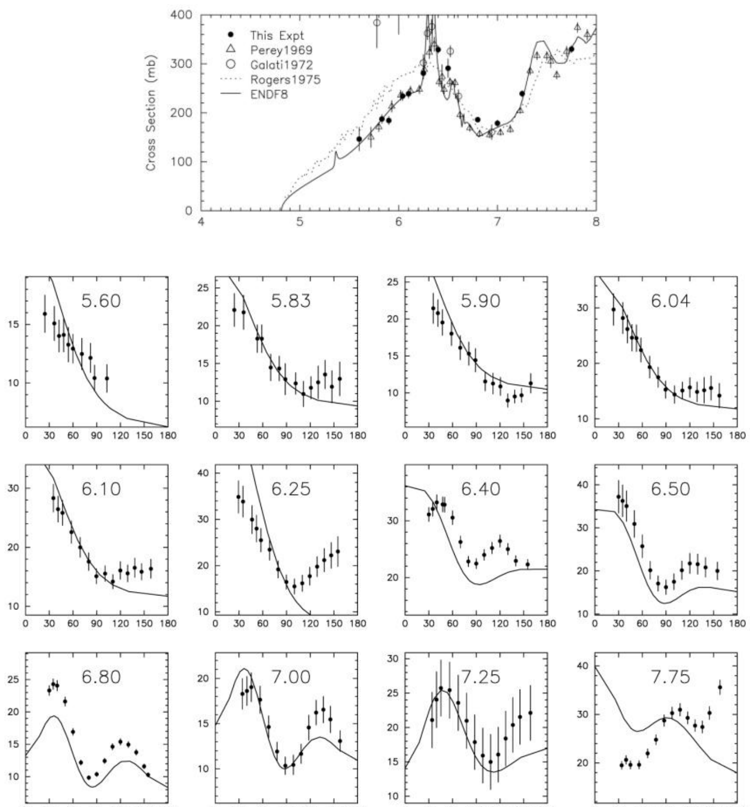
45 energies
64 elas diff xs
12 inelas diff xs

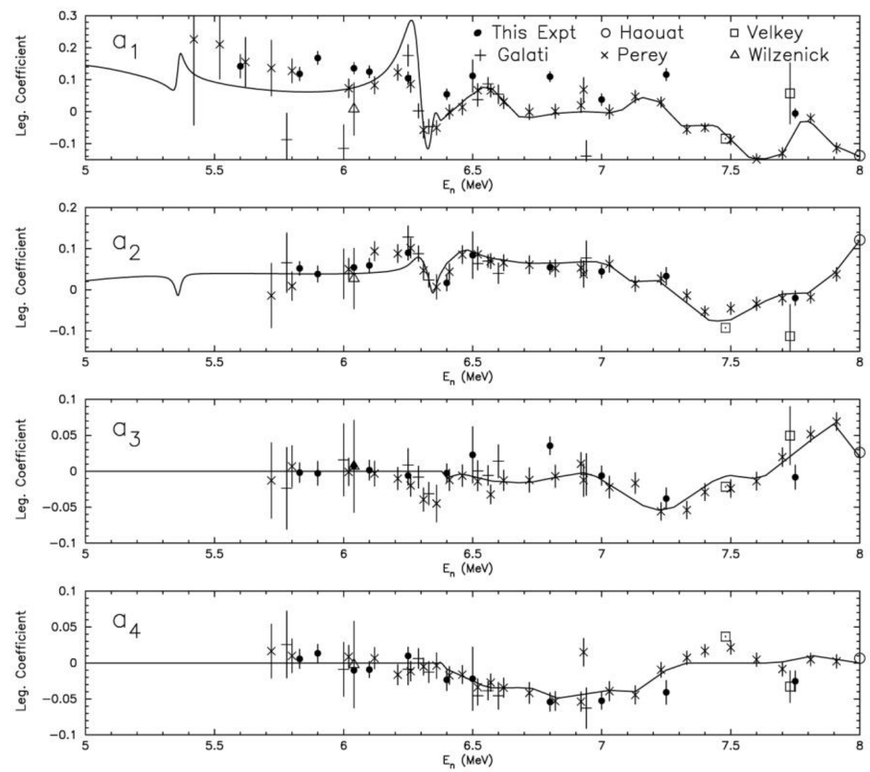
Sarah Evans Elizabeth Chouinard

low-energy (n,elas) 7 days
0.3, 0.2, 0.5 MeV

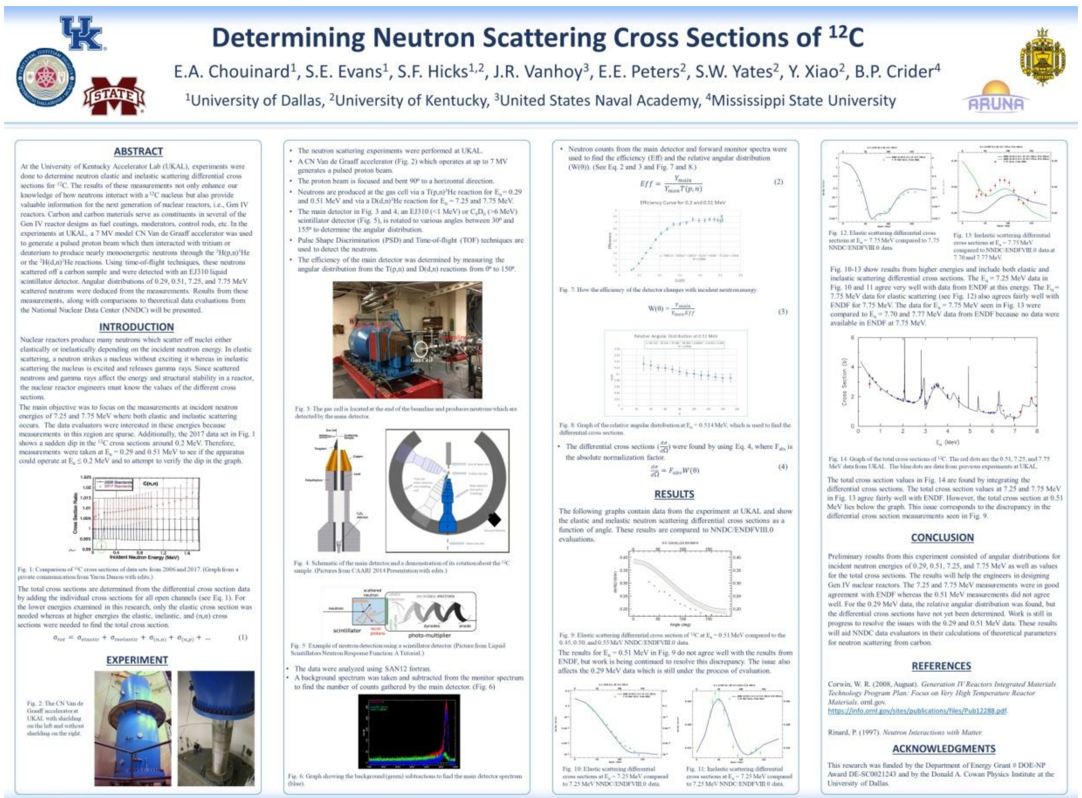
high energy (n,n_1) 11days
6.4, 6.5, 6.8, 7.25, 7.75 MeV

(n,n_1)





Sarah Evans   Elizabeth Chouinard



<u>2 presentations</u>

Exploring Innovation in Appalachia: an Undergrad Research Symposium @ UWV Aug 2011

Eliz placed 4th (i.e. honorable mention) out of 65 presentations

<u>future plans</u>

Sarah: senior
1 year gap
professional Frisbee player

Elizabeth: junior
another REU
1 year gap
graduate school physics

Capture @ LANSCE: DANCE

https://lansce.lanl.gov/facilities/lujan/instruments/fp-14/about.php

completed

^{112,114}Cd(n,g) – onsite 2019,2020

^{110,111} Cd(n,g) – online 2020

attempted

$^{130,132}XeF_2$

Much effort in design and construction of the XeF_2 target @ UnivKY

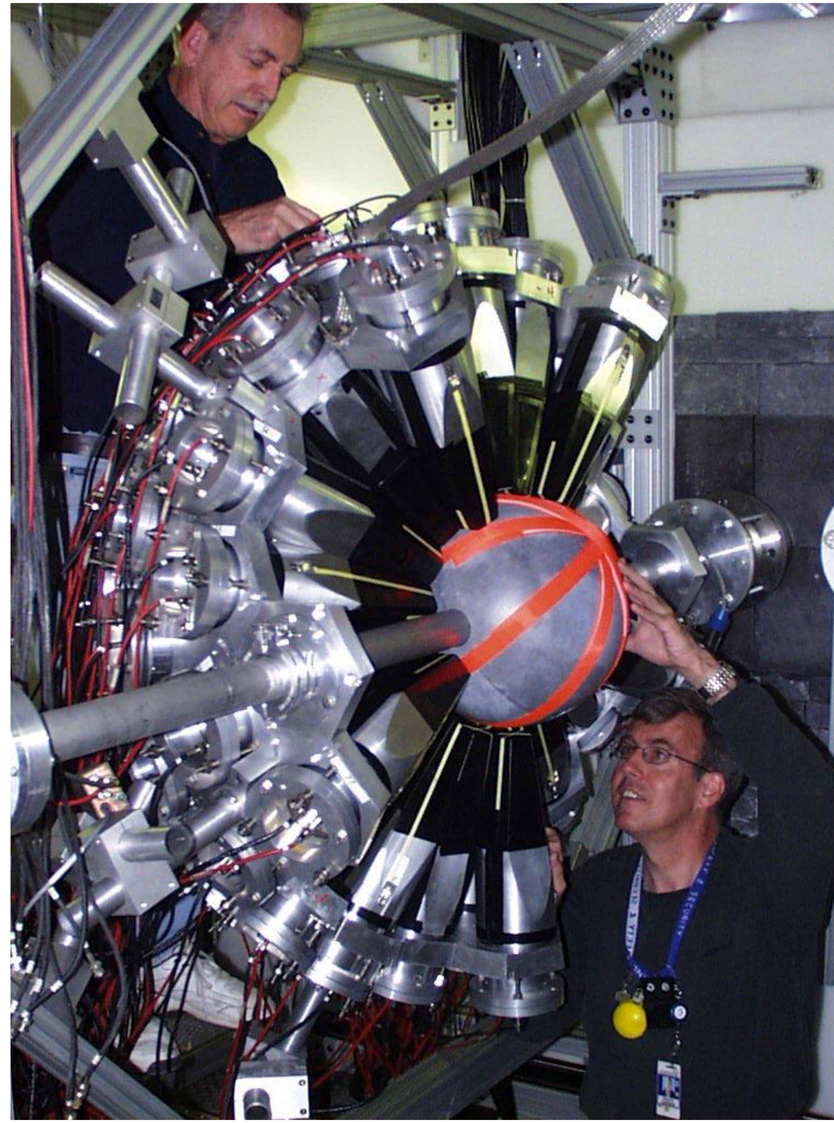
Scheduled 14 day Xe expt in Sept 2021

- LAMPF transformer fire
- target stuck in beampipe
- LiH absorber structural failure

→ shifted to distant future

Mississippi State: Dipangkar Dutta, Jeff Winger

National Lab partners: Aaron Couture, Catherine Fry, Matt Mumpower, Chris Prokop



4π BaF_2 array

Inside of the DANCE ball. The large gray sphere in the center is a ^{6}LiH neutron absorber.

Kofi "TuTu" Assumin-Gyimah

Participated in all expts
DANCE onsite Aug-Dec 2021

114Cd

Ph.D. expected <Dec 2022

Finalized DANCE array calibration.
Corrections of & caused by target
Isolated 114Cd(n,g) yields
GEANT sim of thresholds & multiplicities
(w Milan Krticka & Standa Valenta)

Stephan Vajdic

112,113Cd

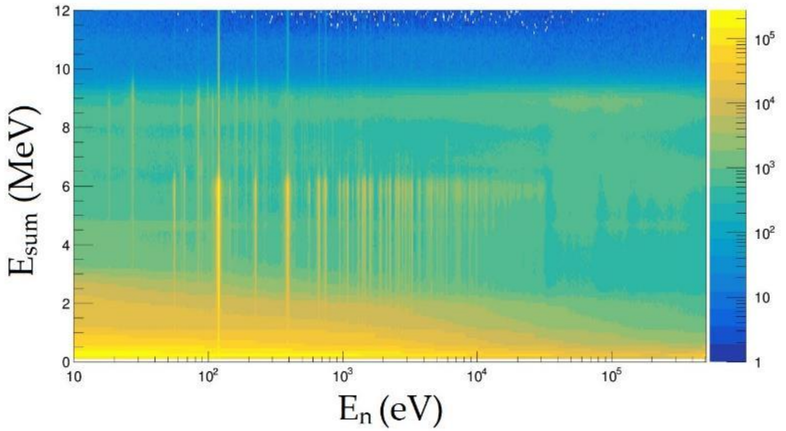
Started – several months in.

Daniel Araya

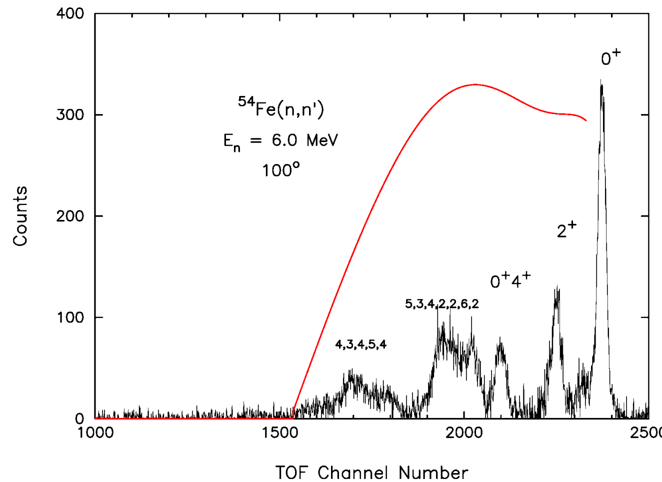
110,111Cd

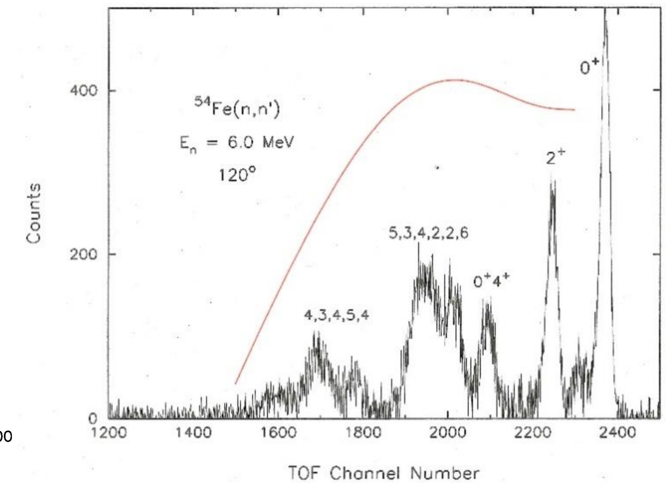
Getting Started.

Example Raw Data: γ-energy deposited vs En



Avi Perkoff

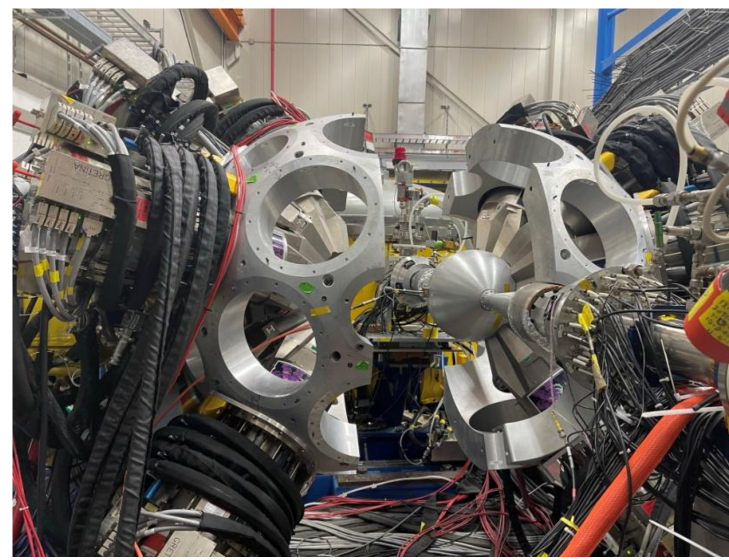




knew C++, Learning python

Converting previous UnivKY ^{56}Fe, ^{54}Fe, ^{23}Na
nTOF spectra(θ) into energy spectra(θ)
(efficiency corrected and normalized)

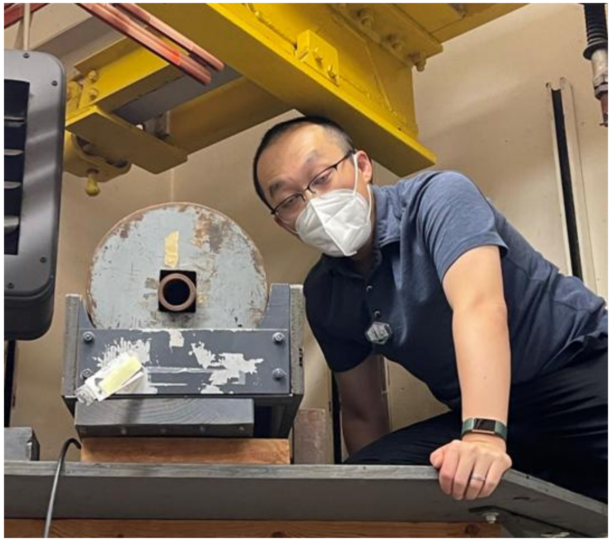
4 shifts (remotely) at a recent
^{130}Te CoulEx measurement at ANL/ATLAS
w CHICO / GRETINA arrays



Graduates May 2022 → USMC Pilot

USMC assigned him to continue with the project until Aug 2022.

Yongchi Xiao



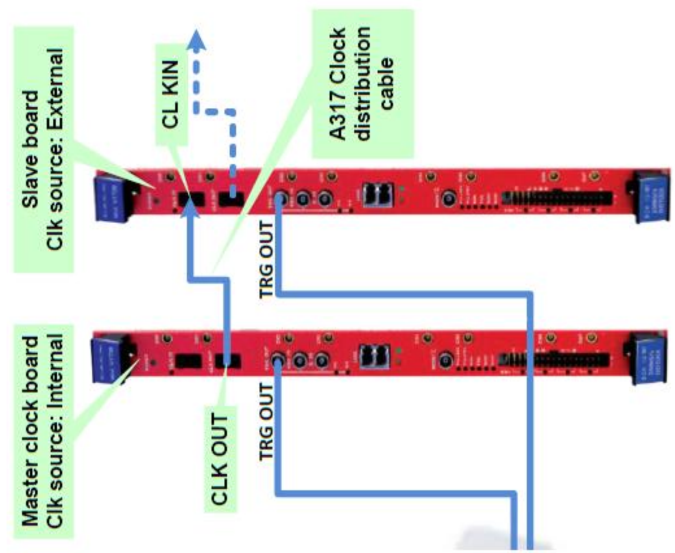
V1730   500 MS/s
scintillators nTOF
MAIN & FM
beam pulse

V1782 100 MS/s
HPGe
Long Counter

+ can record time-dependent γ-ray spectra
+ trapezoidal filter can be fine-tuned for each detector
+ can replay data & change your mind abt settings

- can't do detailed live-monitoring of data coming in
- time consuming development, testing, refining
- modules may not perform as expected,

CAEN may not have thought about some things



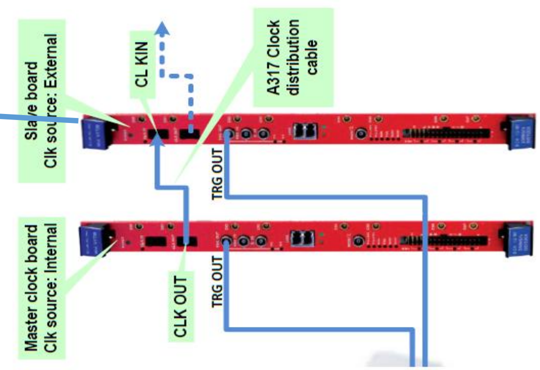
Presentation at 2021 DNP 11-14 Nov online
"Implementation and validation of a fully digital data acquisition system at the University of Kentucky Accelerator Laboratory"

- **General Ideas**

  - Must do γs in slow module and neutron in fast module
    - Fast module can't sufficiently amplify HPGe pulses
    - Fast module doesn't have adjustable trapezoidal filter required for γs

  - Time stamps btw modules loose precision synchronization when using fiber optic cables

  - Can operate both modules with an external trigger, but require a secondary on/off light switch to take data after click CoMPASS ▶



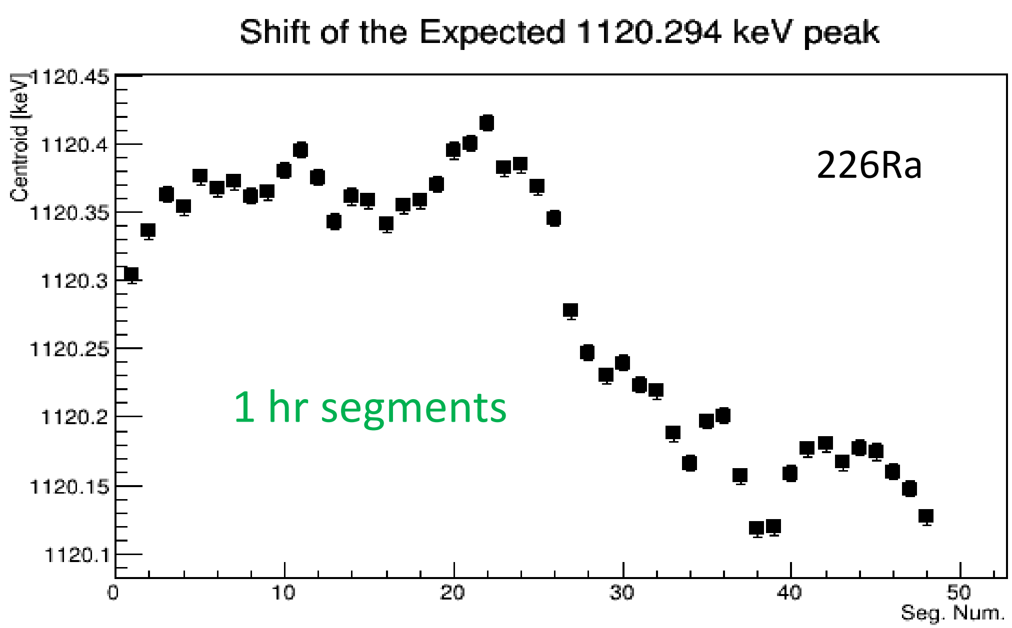
  - Onboard-CFD vs RC-CR2 timing technique
    - The manual describes the techniques, but not how to customize them for specific needs.

- **γ-ray detection in slower V1782 100MHz. We can:**

  - take UnivKY-style data w HPGe, BGO, LongCounter w ext Ortec TAC for beam pulse timing info
  - take ang distrib data for Doppler-shift lifetimes (comparable to analog system)
  - fine tune BGO-Compton rejection during replay (better than previous analog system)
  - measure time dependence of γ-ray background btw beam pulses
  - do as-we-go corrections for HPGE gain drift (never possible before)

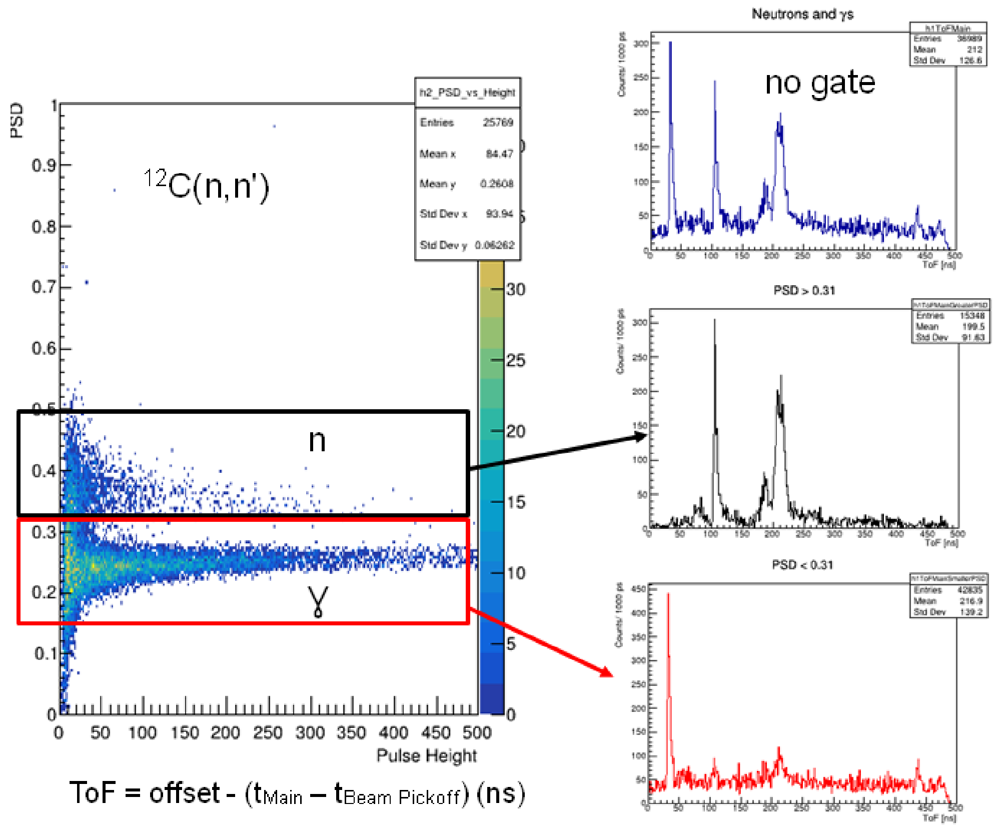
DSAM method requires centroids to ~ 100^{ths} of keV.

Took 1 wk of real Li(n,$n_1\gamma$) in Nov2021 to prep for 19F isomer measurements.



- **neutron detection in faster V1782 500MHz. We can:**

  - digitize the beam pulse (after valid event)
  - take UnivKY-style neutron TOF data w
    MAIN scintillator, Forward Monitors, & beampulse



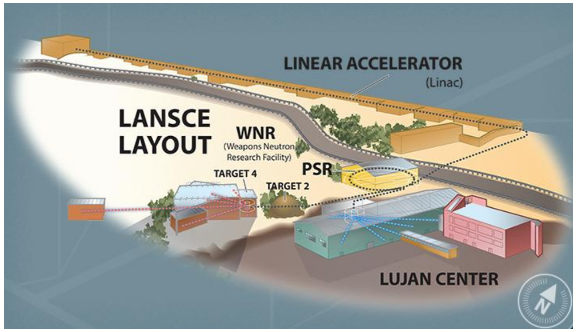
  - fast module doesn’t have adjustable trapezoidal filter

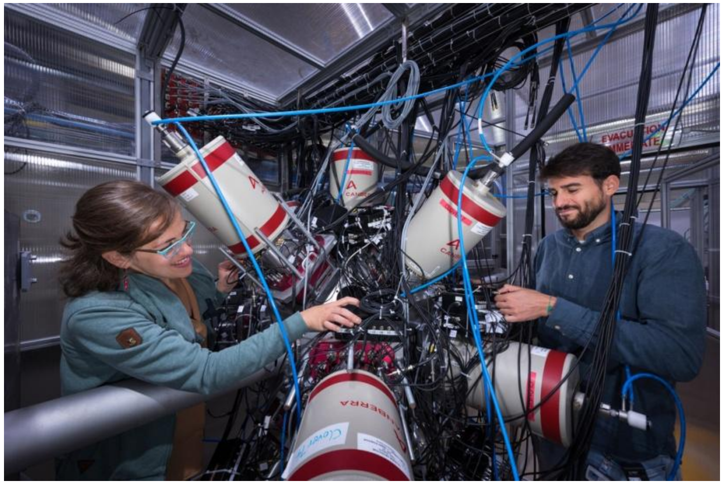
We’ve been working on γ-ray capabilities since ~June 2021

Other Projects

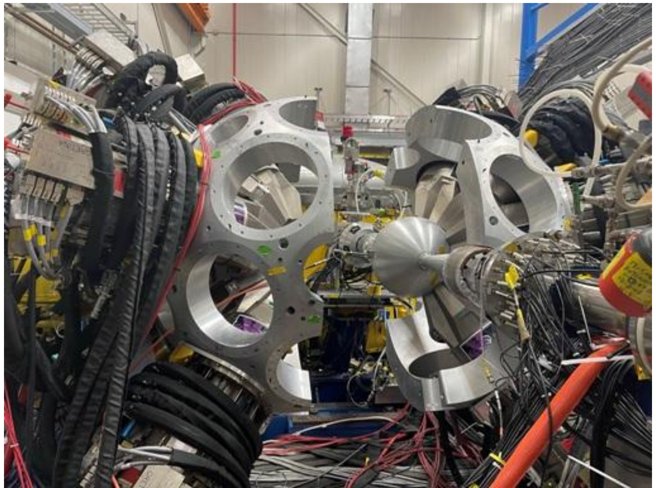
- Los Alamos LANSCE
  - DANCE – BaF2 array
  - Cd(n,γ) capture online ☹
  - Xe(n,γ) to be rescheduled
- ILL Grenoble
  - FIPPS – clover array
  - Cd&Te capture online ☹
  - 2-9July21, 9-21Sept21, 24-30Sept21
- ANL / ATLAS
  - CHICO & GRETINA
  - ^{130}Te CoulEx online & on-site ☺
  - 9-14Feb2021

https://lansce.lanl.gov/facilities/wnr/flight-paths/index.php





https://www.ill.eu/news-press-events/news/scientific-news/detail/improving-fipps-datasets-quality



SUMMARY:

- Weekly collaboration meetings.
- Many UnivKY runs during summer 2021 to catch up from covid shutdown.
- Pushing to get time-dependent (n,n'γ) data functional – isomer in ^{19}F.
- Need ^{7}Li metal ingot for good (n,n') -- 3*$ + other issues
- The team is working with many projects.

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