Neutron Scattering Cross Sections: \((n,n')\) \((n,\gamma)\) \((n,n'\gamma)\)

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Current Team Members

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

**Univ Dallas**
Sally Hicks, prof

**Mississippi State**
Kofi Assumin-Gyimah, gradstudent
Stephan Vajdic, gradstudent
Ben Crider, prof

**US Naval Academy**
Bijan Nichols, undergrad
Jeff Vanhoy, prof

- Lab Overview
- Where we are today
- Primary Projects
- Secondary Projects

Special thanks to Anthony Ramirez, currently @ LLNL.

Supported by U.S. DoE FY20/21 awards SC000056, SC0021175, SC0021243, SC0021424
University of Kentucky Accelerator Laboratory (UKAL)

- 7-MV single-ended Van de Graaff accelerator
- p, d, $^3$He and $\alpha$ beams
- pulsed and bunched beam:
  - $f = 1.875$ MHz and $\Delta t \sim 1$ ns
- primarily conducts neutron-induced reactions and scattering experiments

**Basic Nuclear Science**

- Nuclear structure via $(n,n'\gamma)$
  - 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
  - $(n,n'\gamma)$ - $\gamma$-ray production cross sections
    - Level cross sections
- Detector development
UKAL Experimental Hall

- Neutron and γ-ray detection
  - time-of-flight (TOF) method to extract neutron energy spectrum
  - TOF gating also employed to reduce background neutrons and γ-rays
- Angular distribution and excitation function measurements

\[ ^3\text{H}(p,n)^3\text{He} \approx -0.76 \text{ MeV} \] (for En < 5 MeV)
\[ ^2\text{H}(d,n)^3\text{He} \approx 3.3 \text{ MeV} \] (for En = 5 – 8 MeV)

\[ ^{56}\text{Fe} \]
Today’s Status

- **DE-FOA-0002114 NDIAWG (2019)**
  - Collaboration is holding weekly mtgs
  - New DAQ quotes -- ready to order
  - COVID restrictions prevent major runs

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- **Hired postdoc Yongchi Xiao**
  - Hired from other funds (started 1 Oct)
  - Learning/developing $\gamma$-ray data analysis procedures in ROOT for UnivKY DSAM style data
  - Responsible for on-site project mgmt & daq system

- **Recruited Students**
  - Undergrad: Bijan Nichols
  - Gradstudents: Kofi Assumin-Gyimah, Stephan Vajdic

- $^{110,111,112,114}\text{Cd}(n,\gamma)$ measurements at DANCE completed !

- **Lee Bernstein, LBL**
  - Perhaps sending students to help during summer.
Primary Projects

$^{12}\text{C}(n,n')$

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

Angular distribution Legendre Analysis

Fig. 1. The ENDF8 [11] angle-integrated $^{12}\text{C}(n,n)$ cross sections; data are from previous UKAL measurements.

Fig. 2. The ENDF8 angle-integrated $^{12}\text{C}(n,n_1)$ cross section annotated with previous experimental measurements found in EXFOR. UKAL data are given by blackened circles.

→ Elastic agreement is very satisfying.

→ Describing $(n,n_1)$ is difficult.
Primary Projects

\[ ^{7}\text{Li}(n,n_{k}) \text{ and } (n,n'\gamma) \]

We need isotopic samples to generate useful information.

Fig. 3. Measured / inferred \(^{7}\text{Li}(n,n_{k})\) cross sections from EXFOR compared to two R-matrix calculations. The position of the resonances are indicated along with the adopted levels of the \(^{8}\text{Li}\) compound nucleus from ENSDF.
Surprisingly few detailed neutron scattering data exist for $^{19}\text{F}$. Industrial manufacturers of compact molten salt reactors employ FLiBe as a base material and have called for an increased understanding of its properties.

The $^{19}\text{F}(n,n'\gamma)$ reaction is of particular interest. The 89 ns isomer causes a lot of trouble for cross section measurements.
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 $\gamma$-ray emissions btw levels  
$\text{CdTe}(n,\gamma)$ -- scheduled for Feb 2021  
100Ru$(n,\gamma)$ -- awaiting rescheduling
SUMMARY:
Much to do.
Have identified the students.
Waiting for UnivKY funds to arrive in order to pay postdoc & purchase DAQ.
Must travel to take data and efficiently collaborate.
Have completed proposed Cd measurements at LANL-DANCE.

END

Supported by U.S. DoE FY20/21 awards SC000056, SC0021175, SC0021243, SC0021424
New Postdoc, New Data Acquisition System

Until the DAQ system arrives, YX trying to use ROOT to fit "Kentucky data"
110,111Cd(n,γ) @ DANCE 14 days in Sept 2020

Step 0: Develop all corrections specific to the measurement.

Step 1: Convert to XS

Step 2: Extract γ-ray strength function

Kofi

Stephan