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High-Precision Neutron-Induced Cross-Section Measurements on $^{191,193}Ir$

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Summer Undergraduate Students: Andres Gonzalez (RIT),
Ralph Elisson (Florida Memorial U.)

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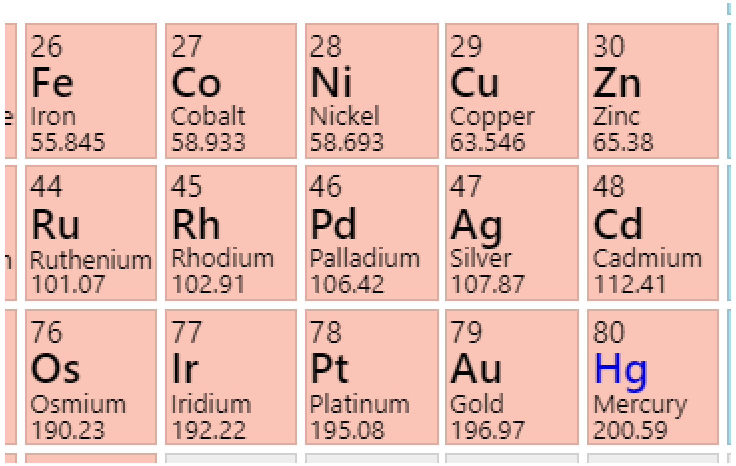
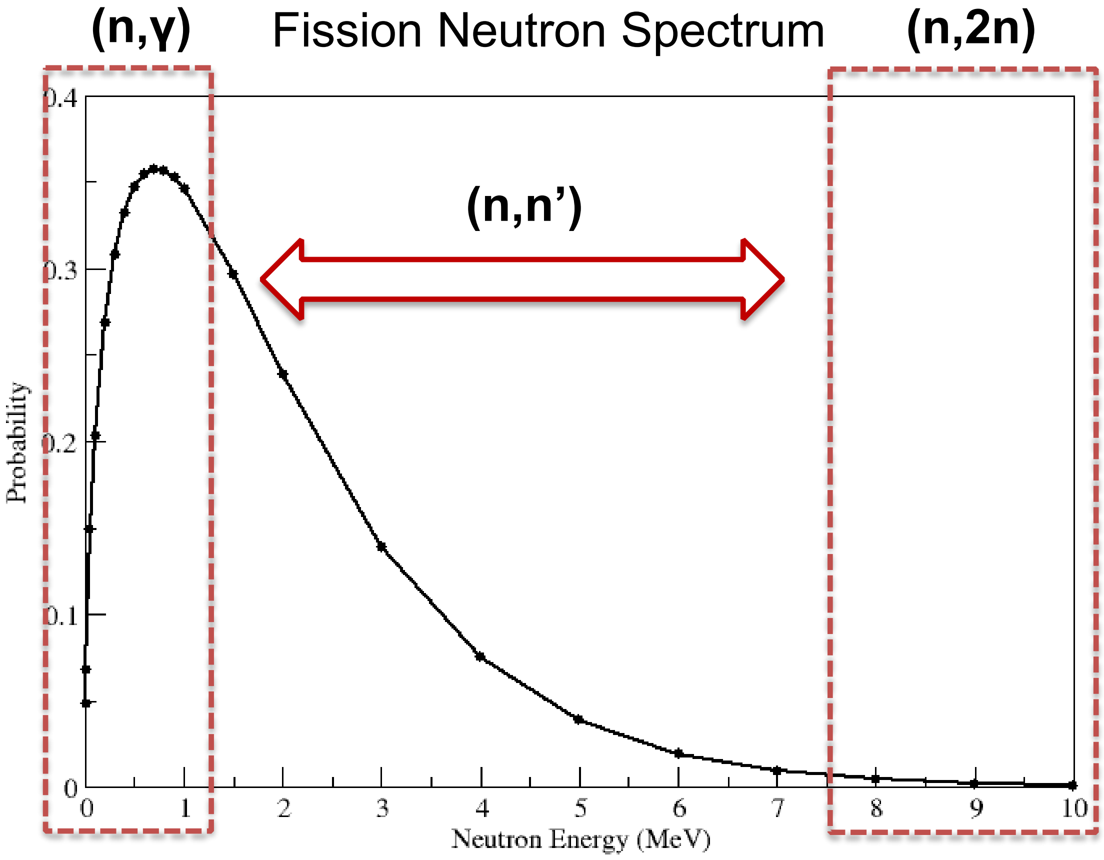
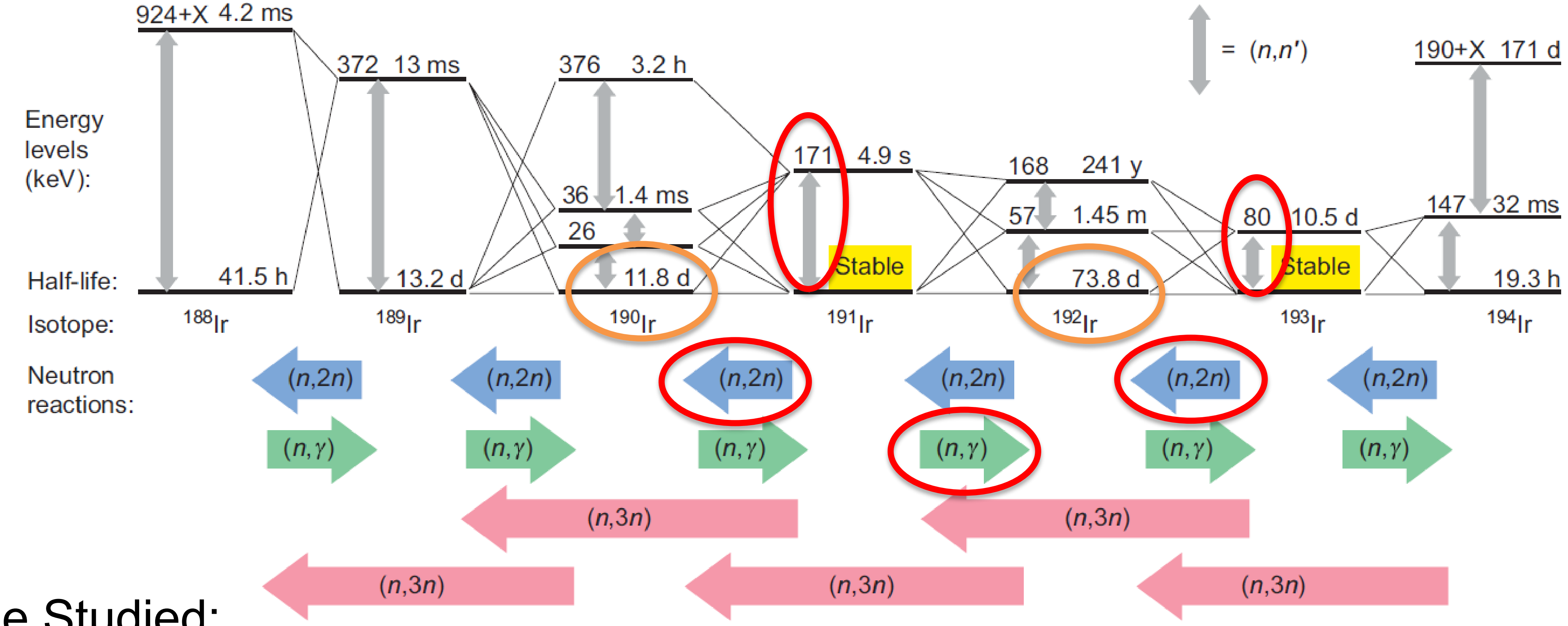
Iridium

- Very dense, rare metal
- Two natural stable isotopes:
  - ^{191}Ir (37.3%)
  - ^{193}Ir (62.7%)
- Interest as a radiochem diagnostic material
- Used in Underground Test Program to measure neutron fluence





Images from https://periodictable.com/Elements/077/index.html and https://ptable.com/

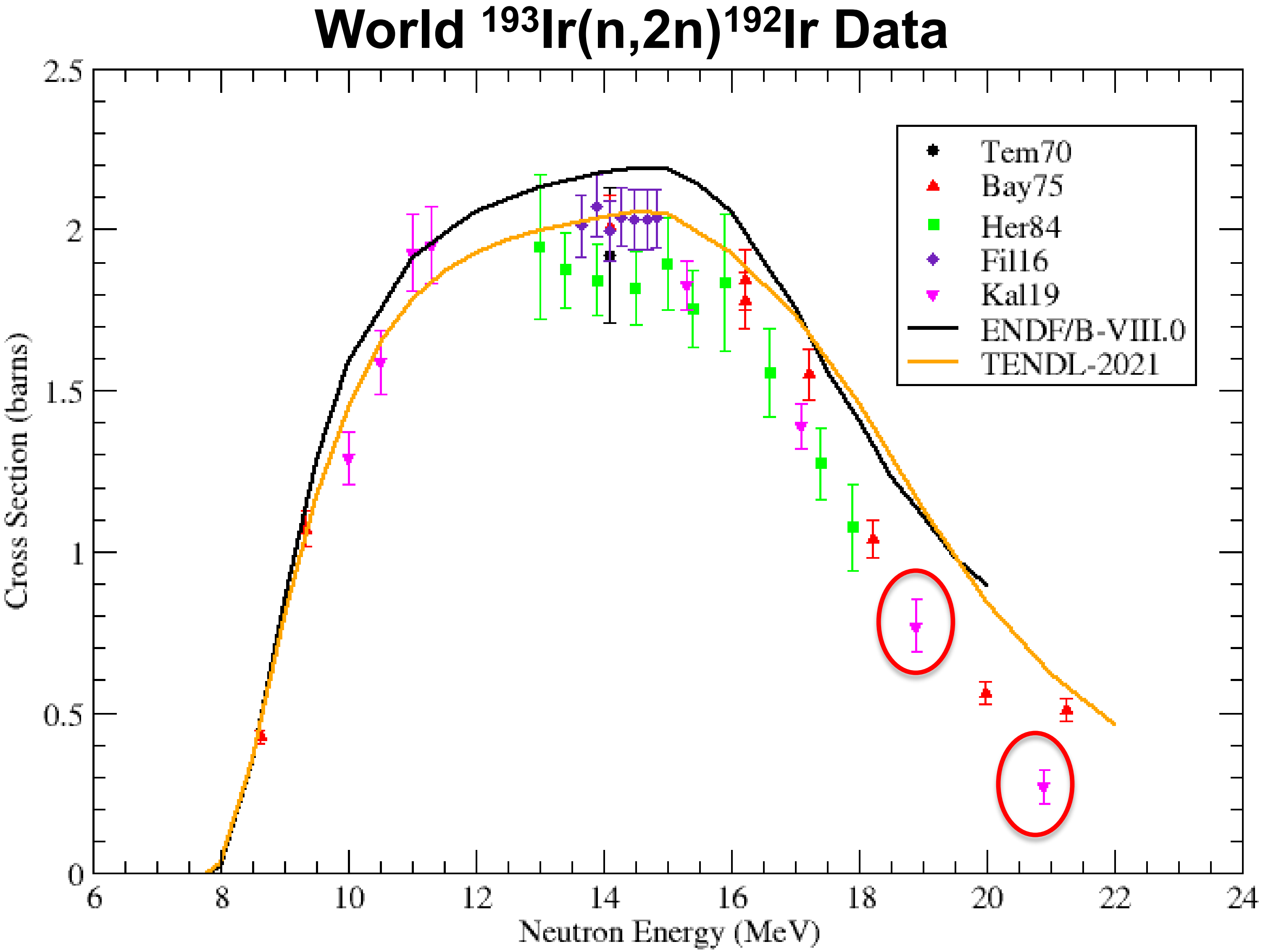


Reactions to be Studied:

1. $^{191,193}Ir(n,2n)^{190,192}Ir$
2. $^{191}Ir(n,\gamma)^{192}Ir$ ← **FOCUS OF THIS TALK**
3. $^{191}Ir(n,n'\gamma)^{191m}Ir$
4. $^{193}Ir(n,n'\gamma)^{193m}Ir$

Figure from R.C. Haight *et al.,* Los Alamos Science **30**, 68 (2006)

Motivation for (n,γ) Measurements



^{192}Ir is also produced by

^{191}Ir(n,γ)^{192}Ir reaction

NCSR Group (Greece) calculated contributions to (n,2n) cross section:

< 12% at low energies
50% - 60% at highest energies

Kalamara *et al.*, EPJA, **55**, 187 (2019)

World $^{191}Ir(n,\gamma)^{192}Ir$ Data

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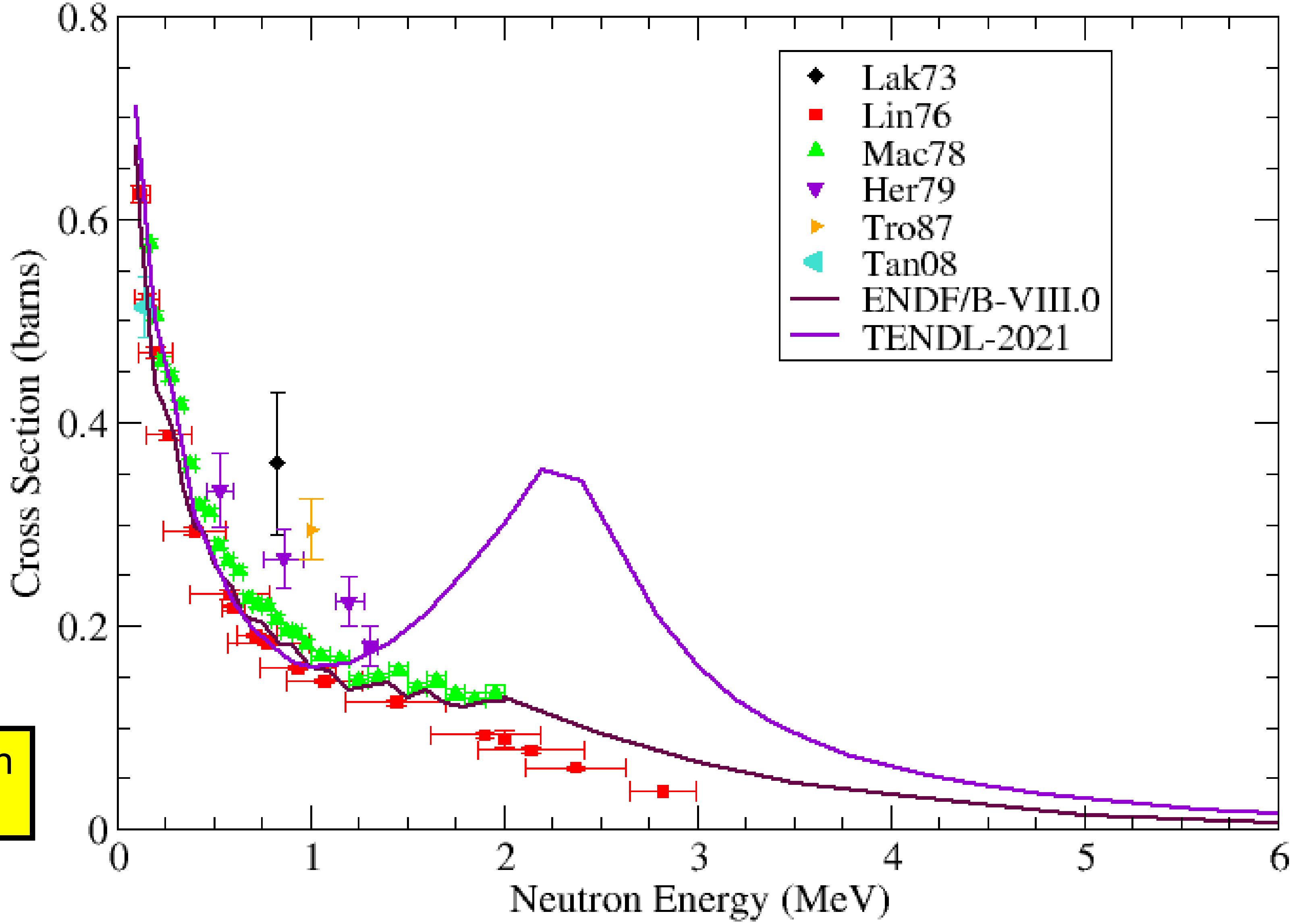
- Sparse data above 1 MeV
- Some disagreement between theoretical treatment and evaluation
- Would like to add high quality data to better tune TALYS calculations



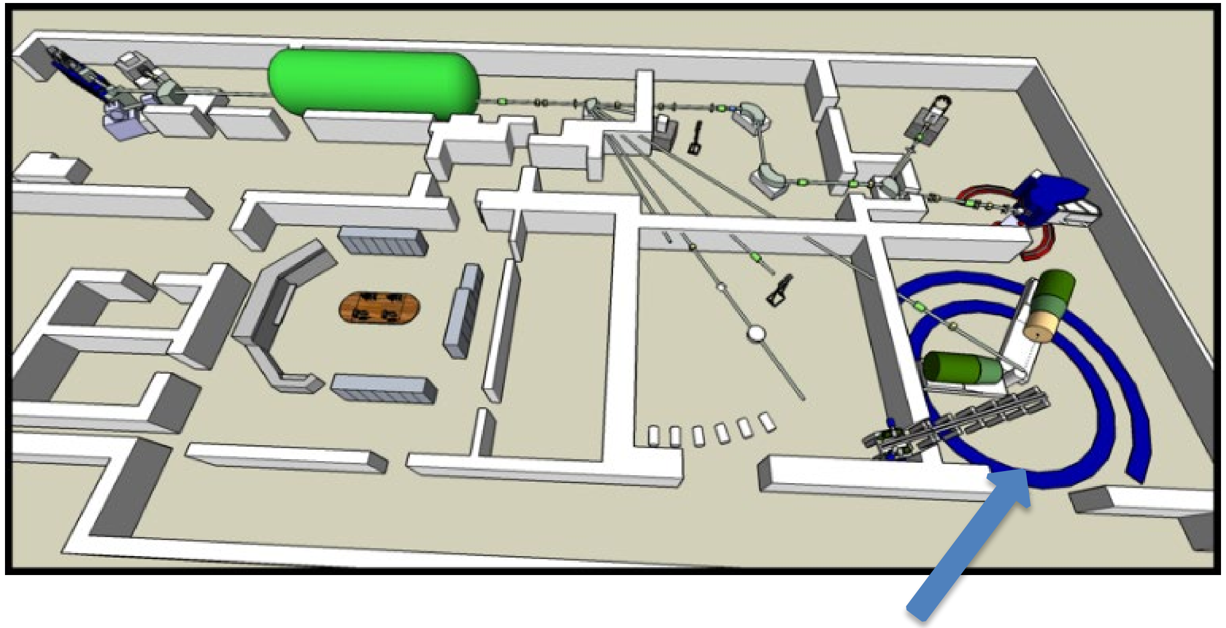
Objective: measure (n,γ) cross section

- 0.5 – 5.5 MeV in 0.5 MeV steps

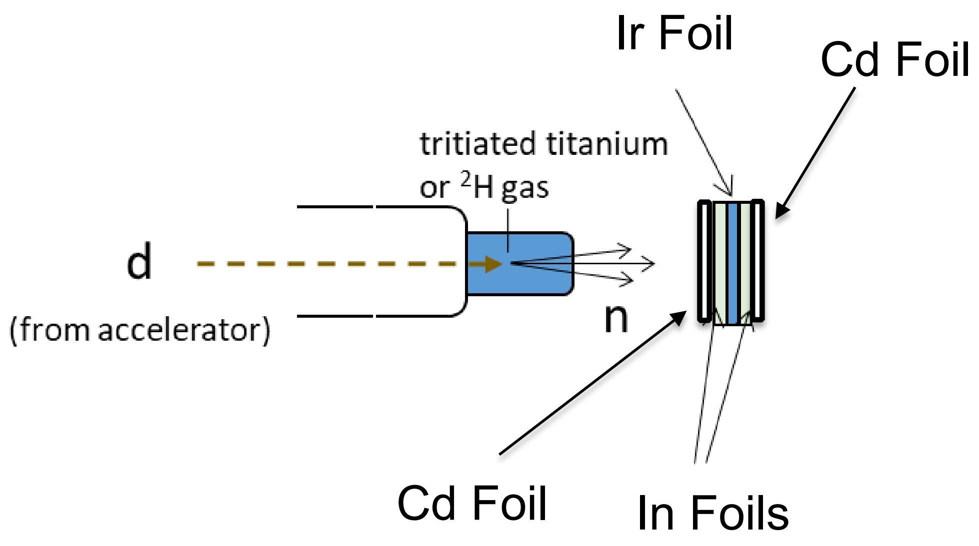
Neutron Activation Setup

Quasi-monoenergetic neutrons from TUNL tandem Van de Graaff accelerator

- ^{7}Li(p,n) $E_n < 1$ MeV
- ^{3}H(p,n) $E_n = 1 – 5$ MeV
- ^{2}H(d,n) $E_n = 5 – 14$ MeV
- ^{3}H(d,n) $E_n > 14$ MeV



NTOF Target Room



Natural iridium foil targets

- Mass ≈ 275 mg
- Thickness ≈ 0.125 mm

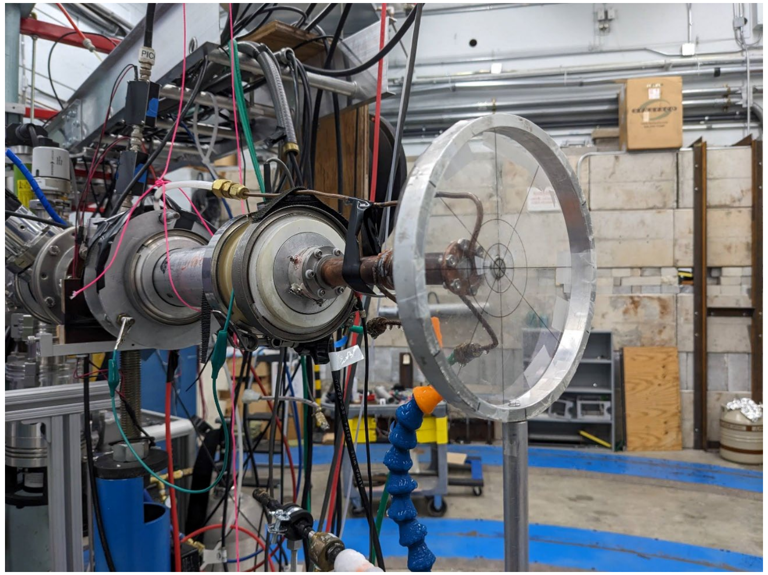
Indium monitor foils (front & back)

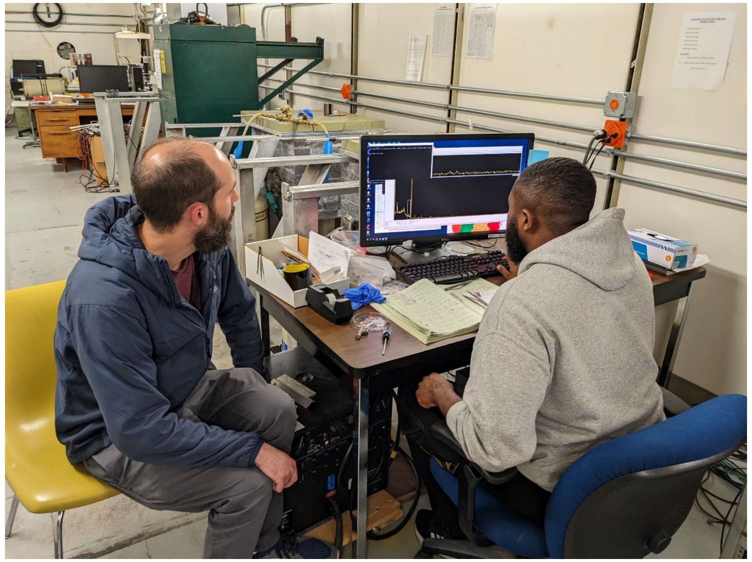
- Mass ≈ 90 - 130 mg
- Thickness ≈ 0.250 mm

Cadmium foils (front & back)

- Thickness ≈ 0.5 mm

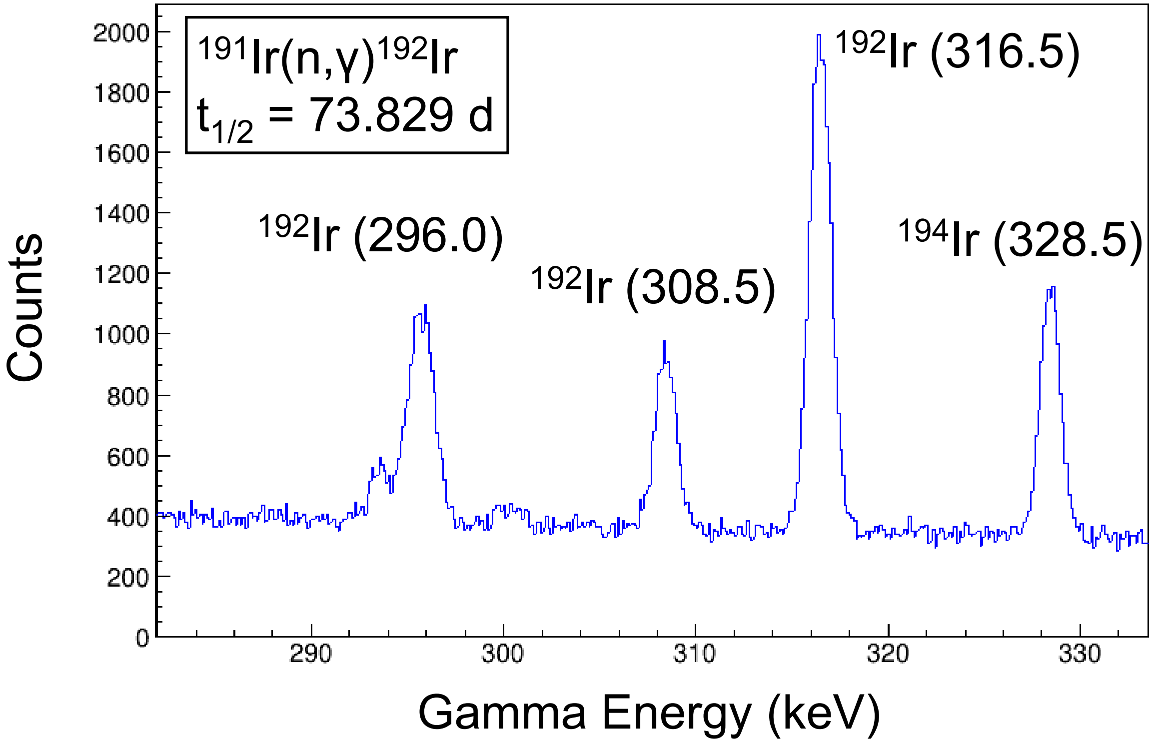
Opportunity for Undergraduate Education and Training



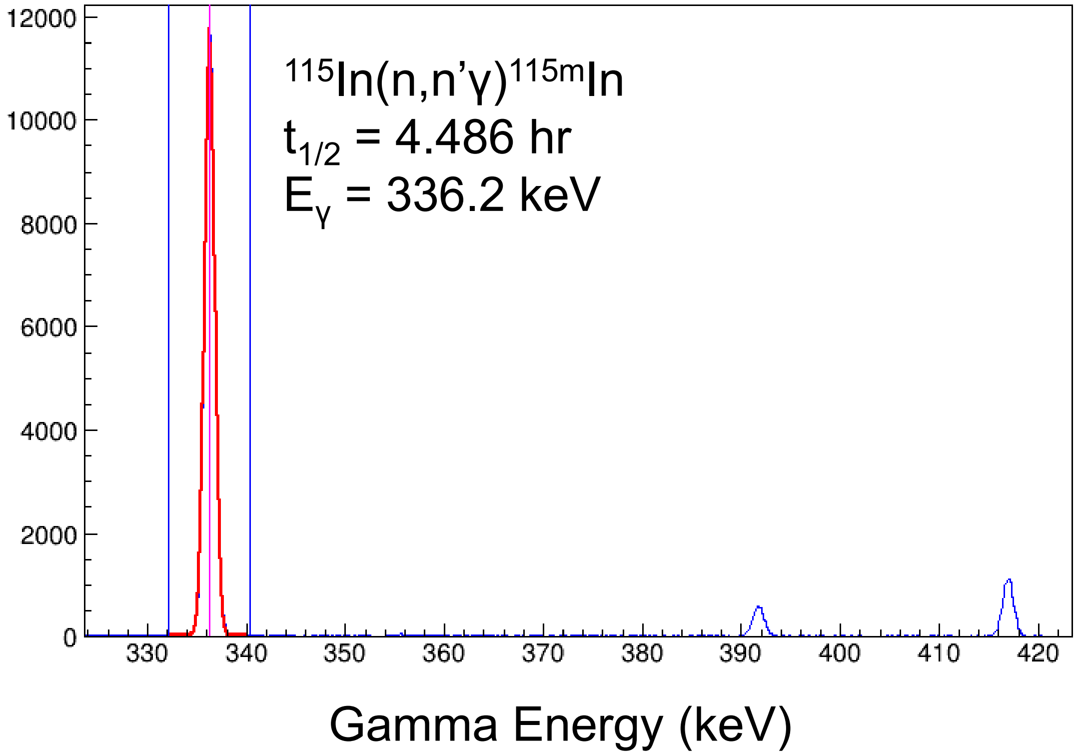


Gamma-Ray Data Analysis

$^{nat}Ir(n,\gamma)$, 14 days counting, E_n = 2.4 MeV



In Monitor Foils, 1 hr counting, E_n = 2.4 MeV

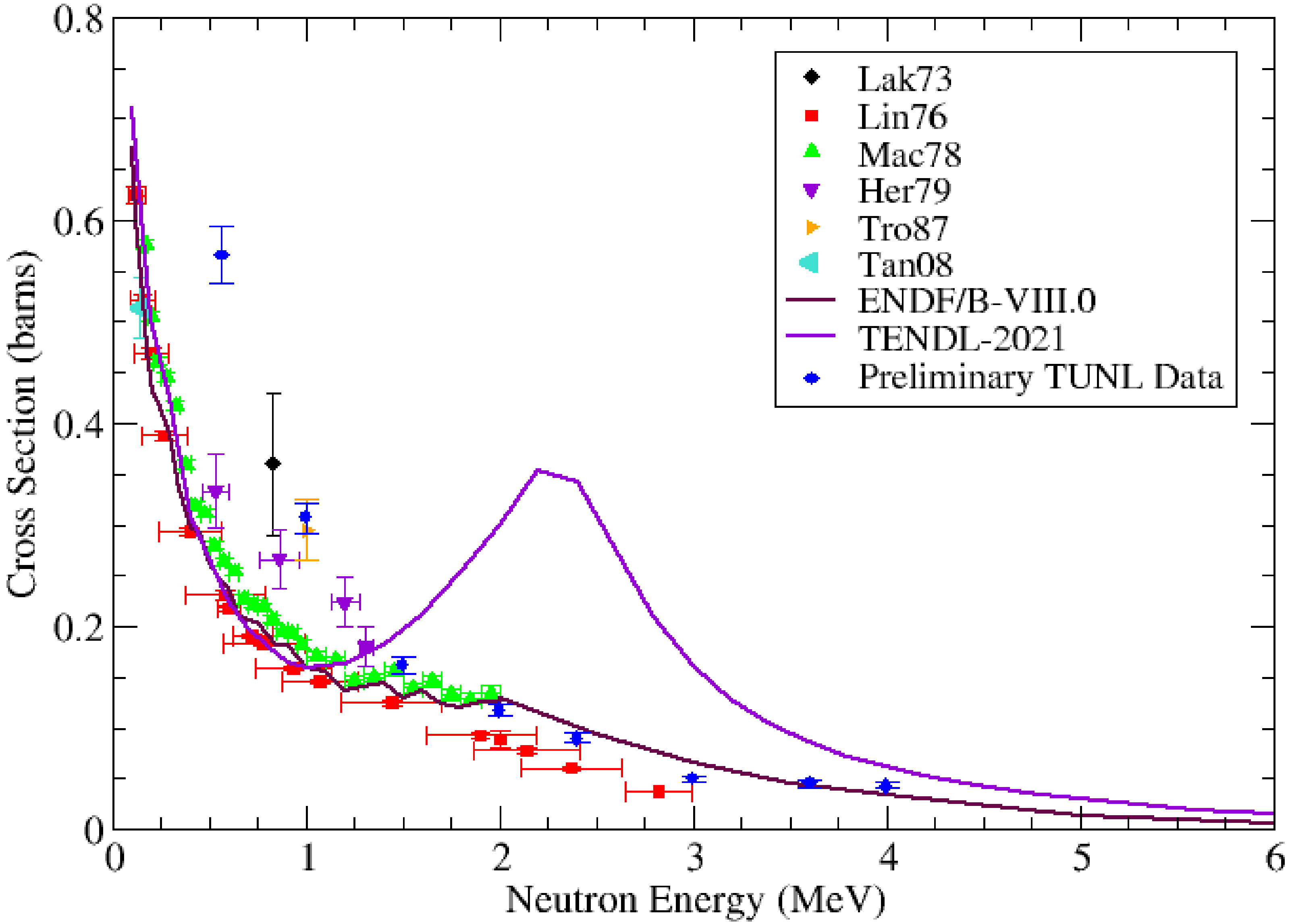


$$A = \sigma\varphi n\left(1 - e^{-\lambda t_i}\right)e^{-\lambda t_d}\left(1 - e^{-\lambda t_m}\right)$$

A = activity
σ = cross section
φ = neutron flux
n = # target nuclei

t_i = irradiation time
t_d = decay time
t_m = measurement time

Preliminary $^{191}Ir(n,\gamma)^{192}Ir$ Data



Future Plans:

- Data at E_n = 4.5, 5.0, and 5.5 MeV
- Revisit analysis of lowest energy points

^{193}Ir(n,n'γ)^{193m}Ir Studies

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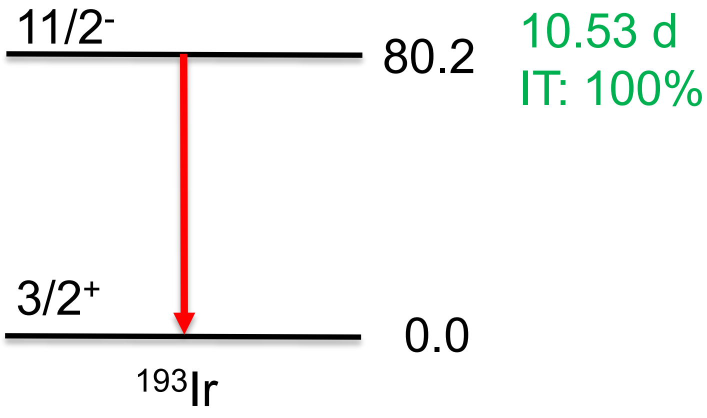
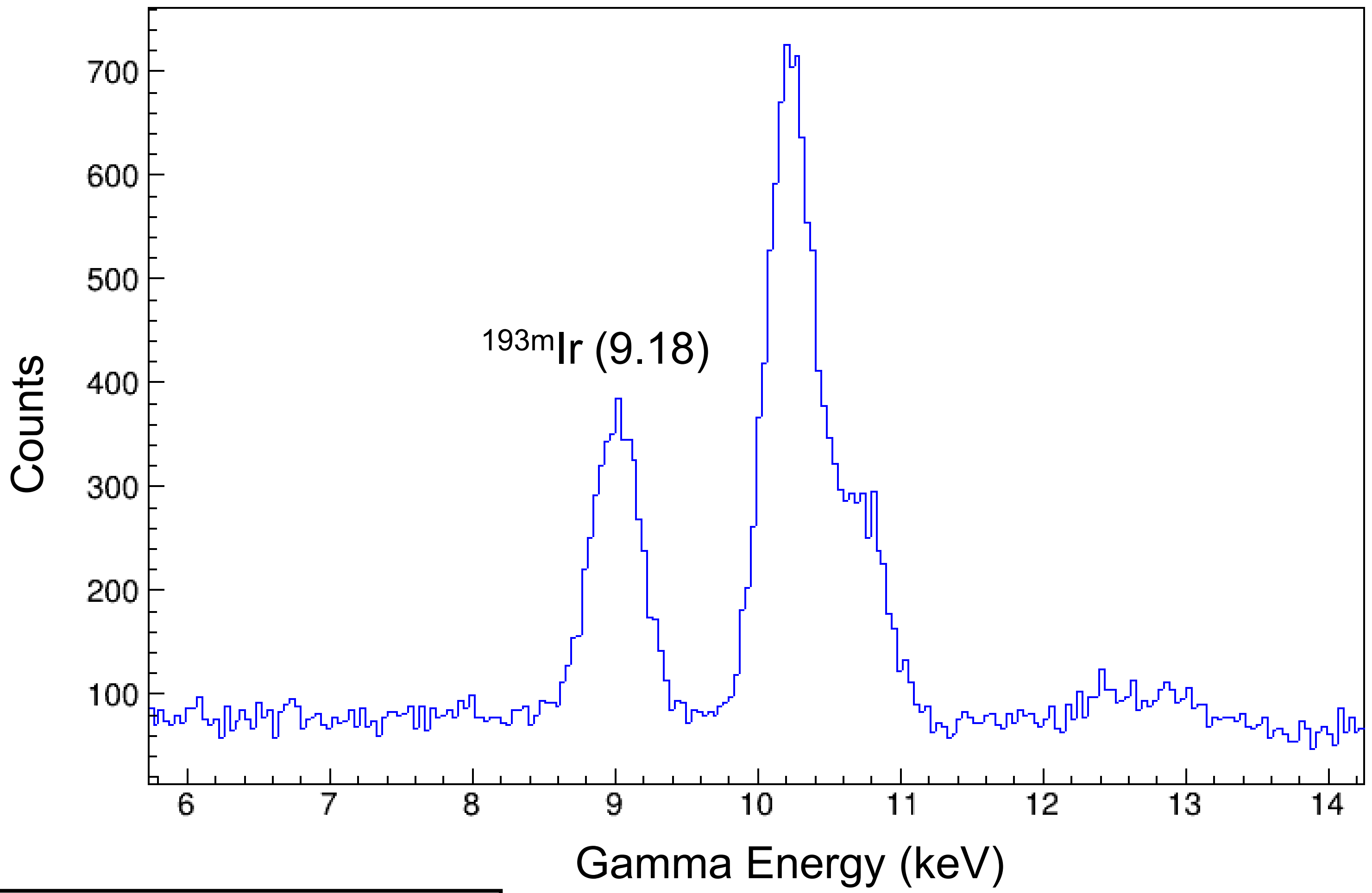


- Measure L x-ray @ 9.18 keV
- Use very thin Ir foil (0.01 mm) to minimize self-attenuation
- Count sample w/BEGe detectors
  - excellent energy resolution
  - good efficiency at low energies
- Compare to LANL SDDs

BEGe Detector Spectrum from ^{193}Ir(n,n'γ)^{193m}Ir, E_n = 6 MeV



Previous Work: Marenco *et al.* Appl. Rad. Iso., **195**, 110742 (2023)

Summary

- Preliminary cross section measurements of ^{191}Ir(n,γ)^{192}Ir have been made at neutron energies between 0.56 and 4.0 MeV

- Will continue to work with LANL on ^{193}Ir(n,n'γ)^{193m}Ir measurements

Students supported over the last 12 months:

Undergraduates:
1. Andres Gonzalez – REU student from Rochester Institute of Technology
2. Ralph Elisson – DOE Traineeship student from Florida Memorial University

Invited Presentations given:

1. Nuclear Data session, Low-Energy Community Meeting
   August 10, 2023 by Alexander Crowell

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