keV Capture Measurements and Preliminary Results for Cr
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Introduction and Motivation

- **Motivation:**
  - There is a lack of experimental data in EXFOR for $^{54}\text{Fe}$, only low resolution cross section data is from Beer, although multiple measurements exist
    - Inconsistencies between ENDF and JEFF libraries may stem from lack of experimental data
  - There is a continued need to collect new nuclear data using pre-existing infrastructure at RPI.
  - Significant interest exists in radiative capture measurements of $^{53}\text{Cr}$ and $^{54}\text{Fe}$

- **Project Goals:**
  - Resolve differences between two conflicting $^{53}\text{Cr}$ radiative capture evaluations
  - Perform radiative capture measurements for $^{54}\text{Fe}$ using an enriched Fe sample
Upgrades to $C_6D_6$ capture system

- Number of detectors increased from four to seven
- Update detector mounts - Improved rigidity reduces degree of swaying during a measurement
- Alignment jig developed to precisely determine location and orientation of detectors
  - Accurate positioning reduces systematic uncertainty introduced from weighting functions
- Mass of overall system has been increased, but MCNP simulations show a minimal impact on the false capture sensitivity
  - For high scattering samples it is important to be insensitive to false capture for samples being measured.
Upgrades to $C_6D_6$ capture system

- An SIS-3305 10-bit digitizer was installed into the system
  - Each channel confirmed to produce same output pulse given a fixed input
- Three new ELJEN $C_6D_6$ detectors were installed and were initially found to have poor resolution
  - These were sent back to ELJEN for repairs following preliminary Cr experiment
  - They were found to have a reduced volume of scintillator liquid
  - Have since been repaired and sent back to RPI and verified to work properly
- Small improvements have been made to the DAQ code, and post-processing codes have been developed in C++, Python & Julia
- Subsequent experiments will have the full benefit of good data from all detector modules
False Capture Sensitivity

- Measurements involving Cr and Fe require low false capture sensitivity
  - Samples have high scattering to capture ratios
- MCNP Calculations were performed to calculate the expected false capture fraction as a function of neutron energy
- The expected false capture yield was then calculated for each sample
  - \( Y_{FC} = Y_s \times FCF \)
$^{53}$Cr neutron capture

- Stieglitz (RPI, 1971) and Guber (ORNL, 2011) experimental data differ by a factor of ~1.6, with Stieglitz falling higher.

- ENDF/B-VIII.0 more closely follows the Guber dataset.

- There are issues with ICSBEP benchmarks, ZPR-6/10, which are sensitive to $^{53}$Cr (n,γ) cross section.
  - Updating resonance parameters to match Stieglitz dataset improves benchmark performance.

- **Challenge**: Elastic scattering yield is ~800 times greater in magnitude than capture yield.

- **Goal**: Perform a natural Cr measurement to resolve differences between Guber and Stieglitz data.
Natural Cr Preliminary Experiment

- From 09/22/20 – 09/25/20, preliminary data were collected of a 6mm natural Cr sample
  - Two 3mm plates were combined
  - Total DAQ time was ~30 hours
- Multiple samples measured
  - Pb – indicator of in-beam background
  - Carbon – indicator of false capture
  - \(B_4C\) – indicator of flux shape
- Carbon sample is almost a pure scatterer, but also scatters in-beam time dependent gamma background
- Low capture to scattering ratio from Cr sample makes it very difficult to see capture signal, especially if there is any neutron sensitivity elsewhere
Yield in the Cr sample was calculated using equation on right

\[ Y_{Cr} = f_n \frac{C_{Cr} - C_{O} M_{Cr}}{M_{O}} - k_p \left( C_{Pb} \frac{M_{Cr}}{M_{Pb}} - C_{O} \frac{M_{Cr}}{M_{O}} \right) \]

\[ C_{Cr} - C_{O} \frac{M_{Cr}}{M_{O}} = \frac{C_{B4C}^{UW} - C_{O}^{UW} \frac{M_{B4C}}{M_{O}}}{Y_{B4C}} \]

All sample counts are beam monitor normalized

Weighting functions are calculated and applied to more heavily weight high energy photons that normally have low efficiency

Weighting functions require accurate MCNP simulations of individual detector responses
Preliminary Experiment Results

- Capture yields from natural Cr sample calculated using ENDF/B-VIII.0 and Stieglitz data
- Cr experimental capture yield was normalized to MCNP calculations
- Poor statistics in short Cr run make it very difficult to make solid conclusions
  - Data must be taken for several weeks
  - $^{54}$Fe data has higher priority while our (old) LINAC is working
54Fe neutron capture measurement

- There are inconsistencies between ENDF and JEFF, perhaps from lack of data

- Elastic scattering cross section dominates total cross section
  - Once again, it is important to be insensitive to scattered neutrons, due to low capture to scattering ratio expected from sample

- Status
  - Preliminary experiment planned in Feb 2021
  - Enriched 54Fe sample received from ORNL
Accomplishments and Future Work

• FY20 Accomplishments:
  – Various upgrades have been made to the full capture detector array
    • Future experiments will benefit from implemented improvements
  – A preliminary capture experiment on a natural Cr sample has been completed
    • A full production experiment will be based on LINAC availability and priority of experiments

• FY21 Goals:
  – Conduct all experiments that are planned for $^{54}\text{Fe}$ radiative capture
    • First preliminary experiment already planned for Feb 2021
    • All experiments will be completed prior to LINAC shutdown