keV Capture Measurements and Preliminary Results for Cr

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Presented by:

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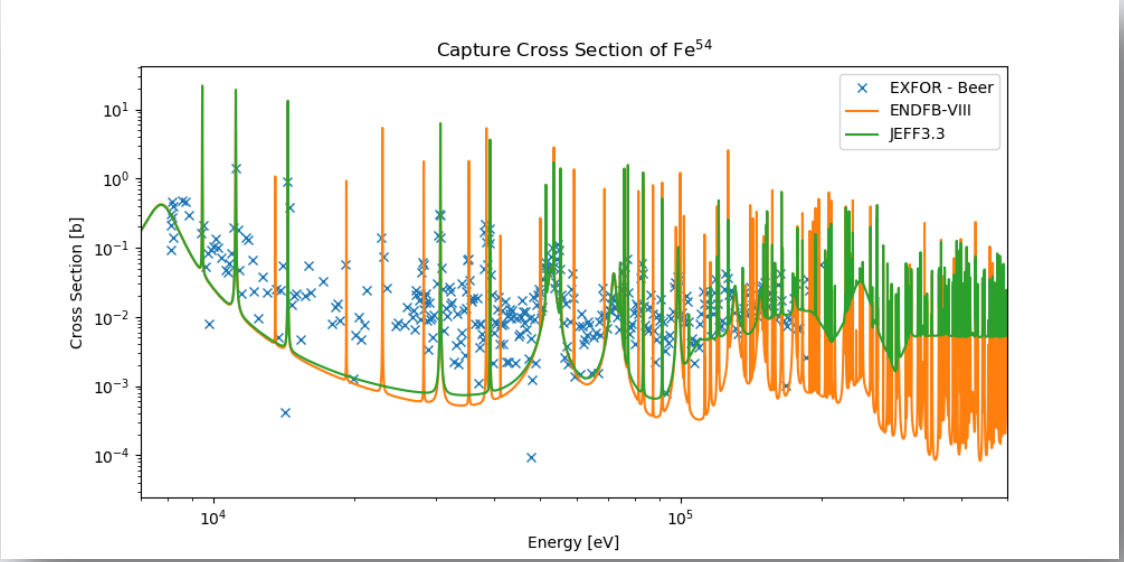
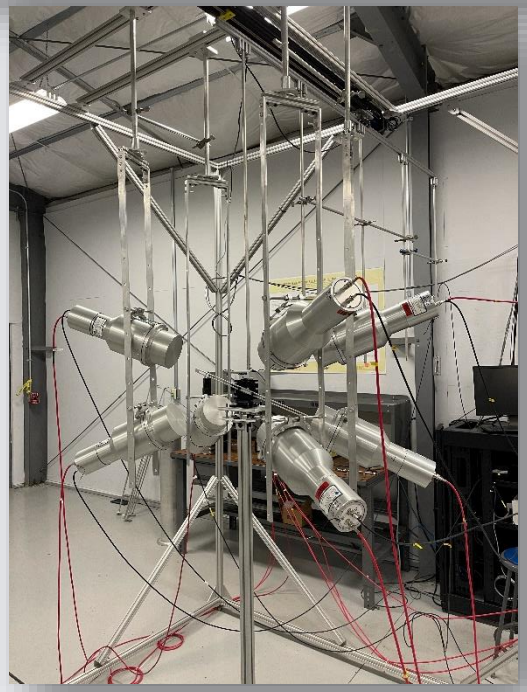
Introduction and Motivation

- **Motivation:**
  - There is a lack of experimental data in EXFOR for ^{54}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}Cr and ^{54}Fe
- **Project Goals:**
  - Resolve differences between two conflicting ^{53}Cr radiative capture evaluations
  - Perform radiative capture measurements for ^{54}Fe using an enriched Fe sample



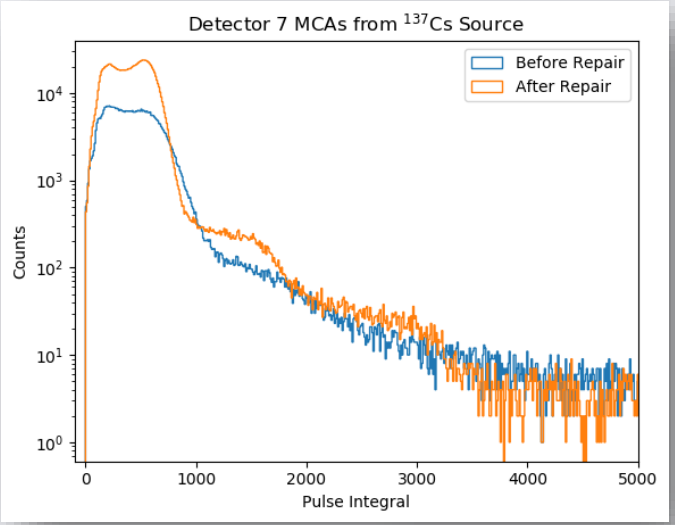
Upgrades to C_6D_6 capture system

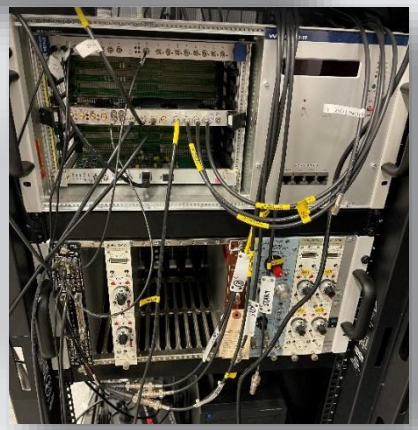
- Number of detectors increased from four to seven
- Update detector mounts - Improved rigidity reduces degree of swaying during a measurement
- Alignment jig developed to precisely determine location and orientation of detectors
  - Accurate positioning reduces systematic uncertainty introduced from 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

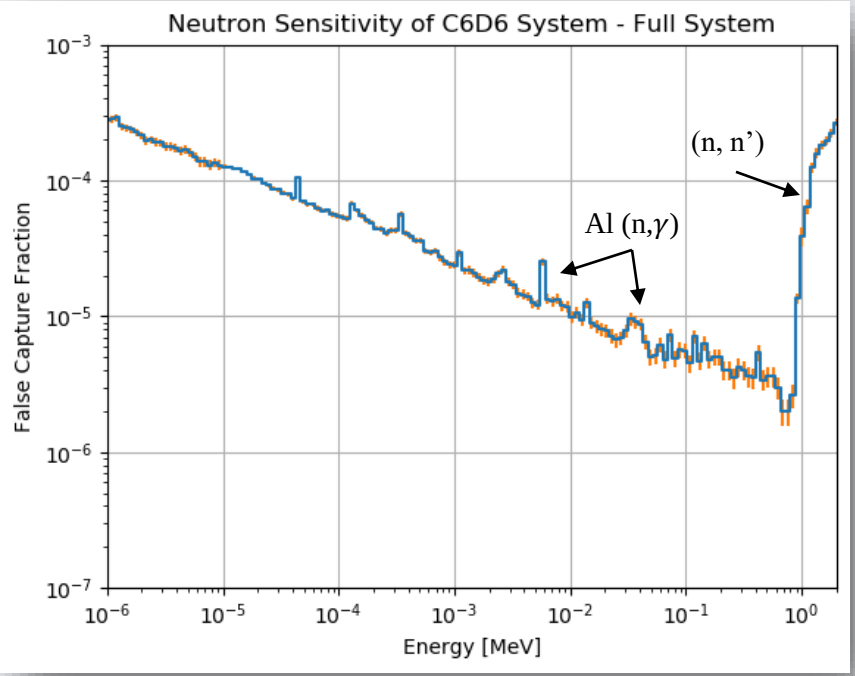
- An SIS-3305 10-bit digitizer was installed into the system
  - Each channel confirmed to produce same output pulse given a fixed input
- Three new ELJEN C_6D_6 detectors were installed and were initially found to have poor resolution
  - These were sent back to ELJEN for repairs following preliminary 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





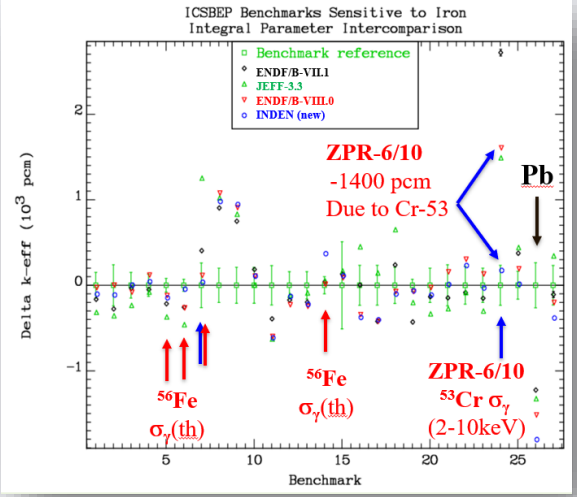
False Capture Sensitivity

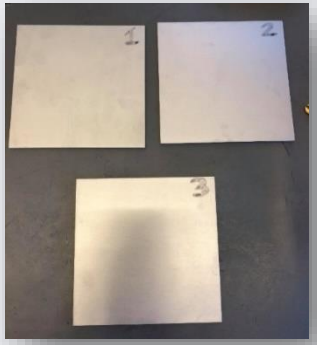
- Measurements involving Cr and Fe require low false capture sensitivity
  - Samples have high scattering to capture ratios
- MCNP Calculations were performed to calculate the expected false capture fraction as a function of neutron energy
- The expected false capture yield was then calculated for each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

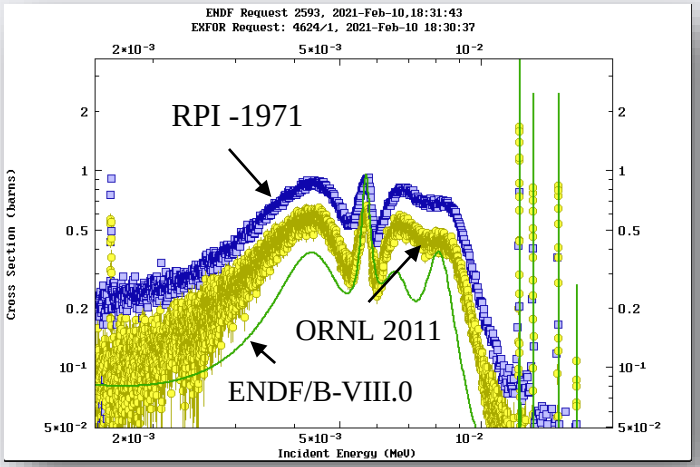


^{53}Cr neutron capture

- 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

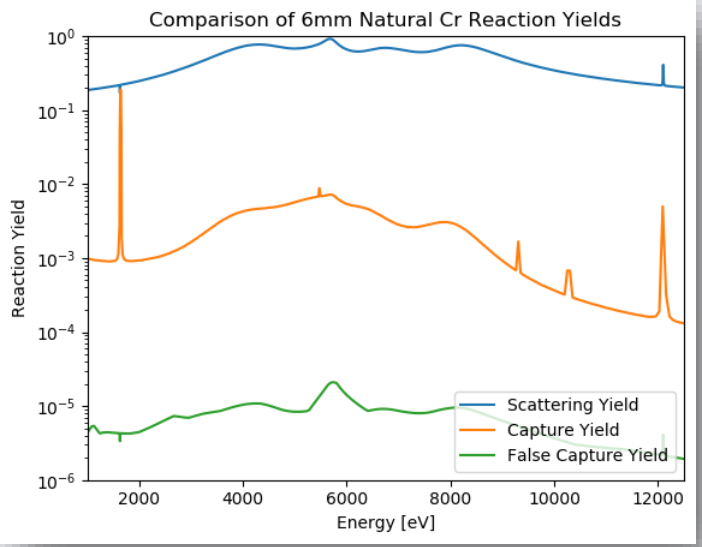


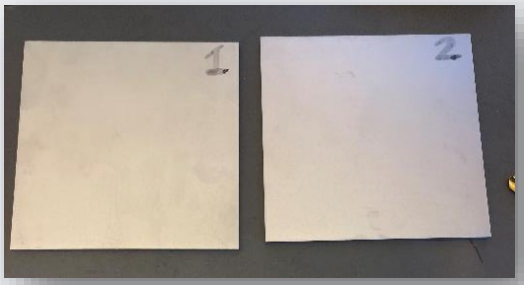




Natural Cr Preliminary Experiment

- 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

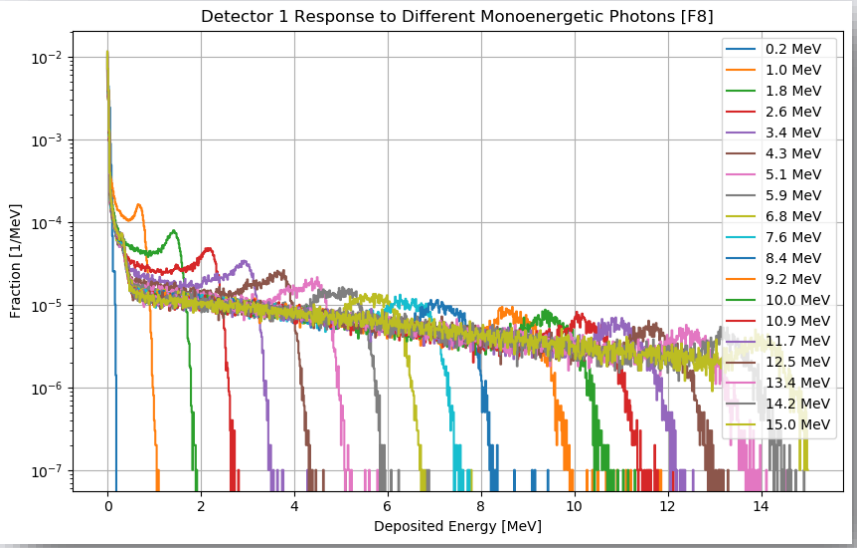




Experiment Capture Yield Calculation

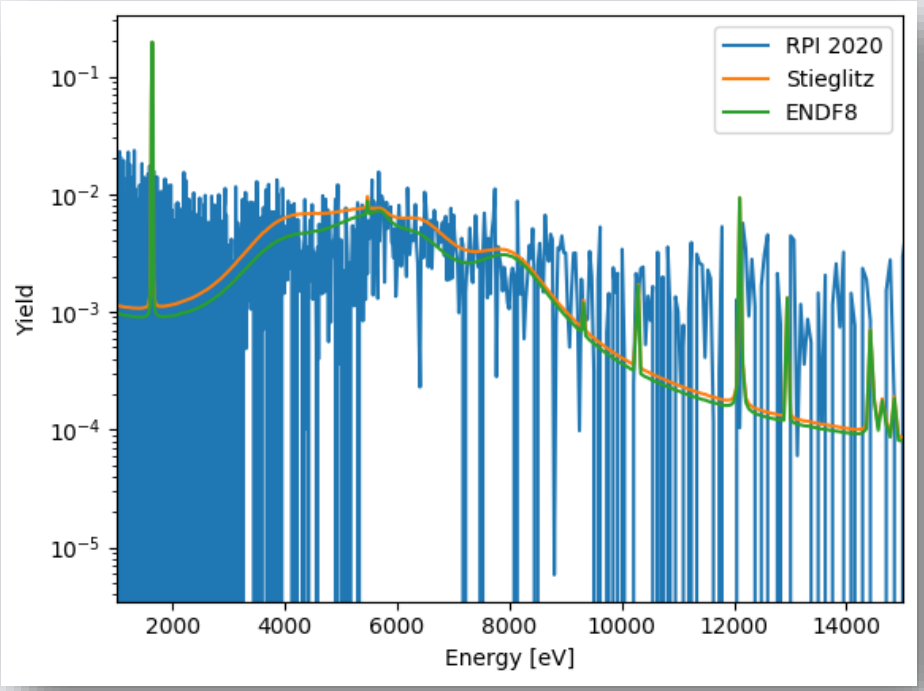
- Yield in the Cr sample was calculated using equation on right
- All sample counts are beam monitor normalized
- Weighting functions are calculated and applied to more heavily weight high energy photons that normally have low efficiency
- Weighting functions require accurate MCNP simulations of individual detector responses

$$Y_{Cr} = f_n \frac{C_{Cr}^{Cr} - C_O^{Cr}\frac{M_{Cr}}{M_O} - k_p\left(C_{Pb}^{Pb}\frac{M_{Cr}}{M_{Pb}} - C_O^{Pb}\frac{M_{Cr}}{M_O}\right)}{\frac{C_{B4C}^{UW} - C_O^{UW}\frac{M_{B4C}}{M_O}}{Y_{B4C}}}$$



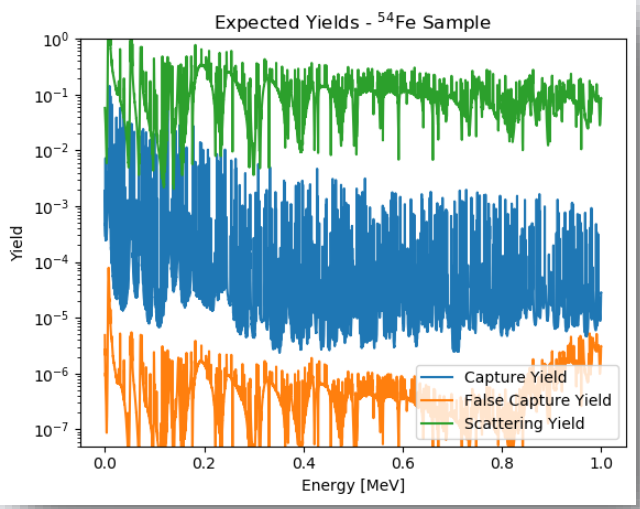
Preliminary Experiment Results

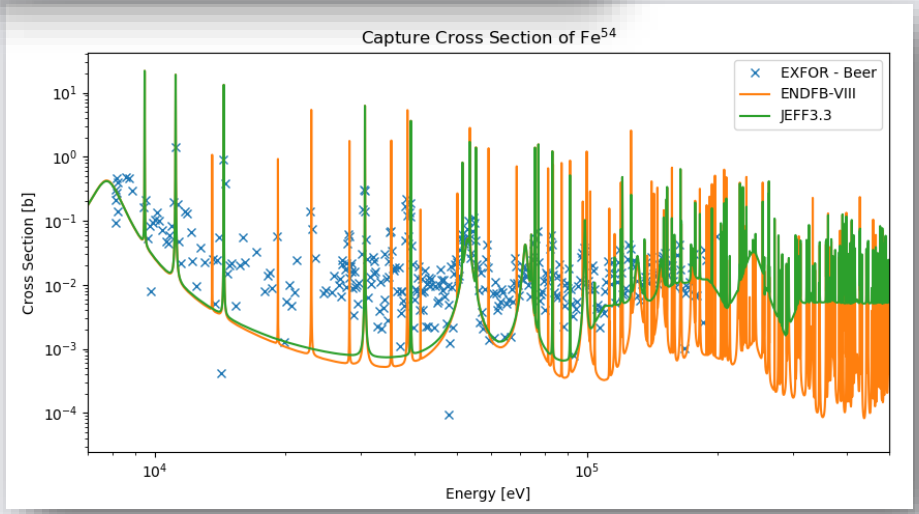
- Capture yields from natural Cr sample calculated using ENDF/B-VIII.0 and Stieglitz data
- Cr experimental capture yield was normalized to MCNP calculations
- Poor statistics in short Cr run make it very difficult to make solid conclusions
  - Data must be taken for several weeks
  - ^{54}Fe data has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



^{54}Fe 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 ^{54}Fe 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}Fe radiative capture
    - First preliminary experiment already planned for Feb 2021
    - All experiments will be completed prior to LINAC shutdown