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**Title:** Critical Experiment Design with Iron and Chromium Using Monte Carlo Methods for the Comet Assembly

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# Critical Experiment Design with Iron and Chromium Using Monte Carlo Methods for the Comet assembly

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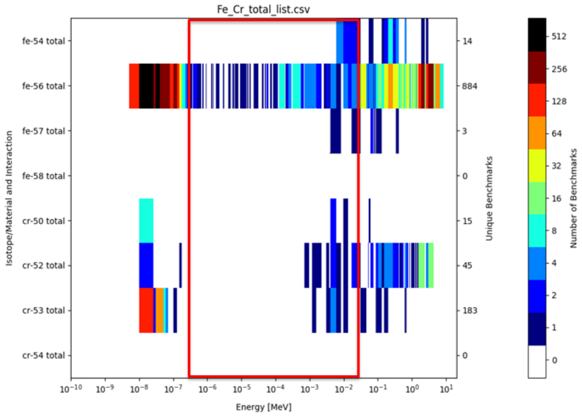
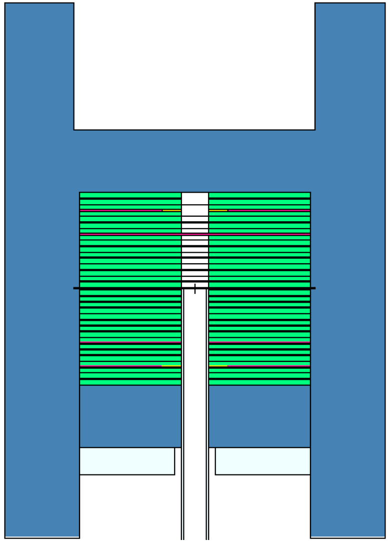
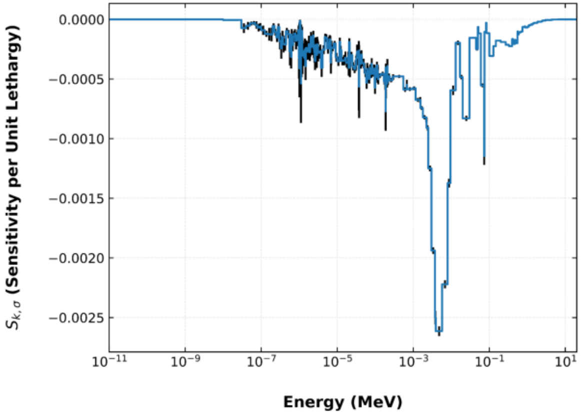
Los Alamos NATIONAL LABORATORY

# Critical experiments are designed for iron & chromium using MCNP simulations for nuclear data validation.

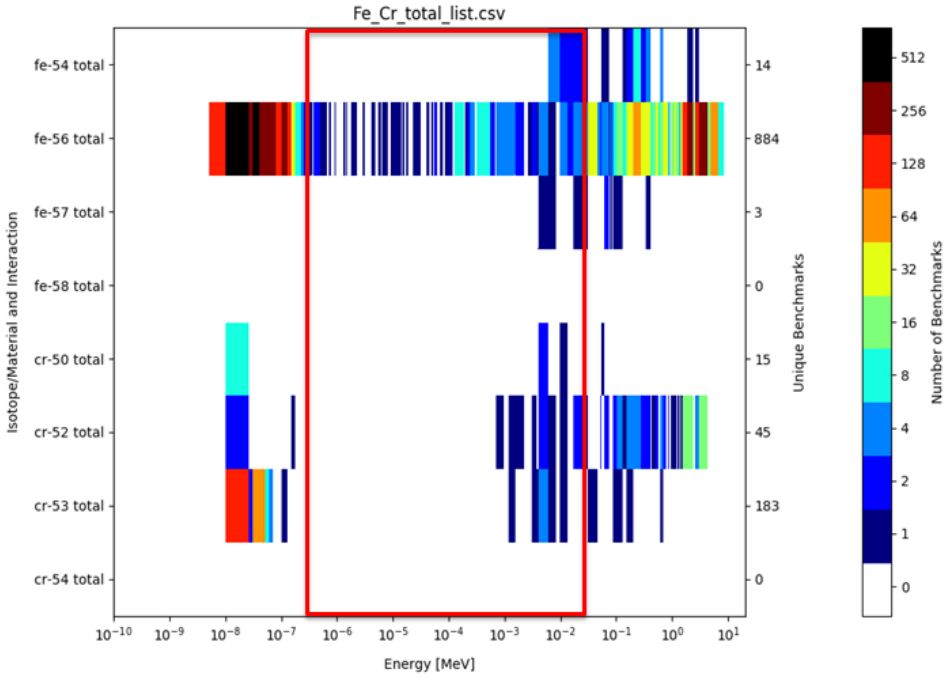




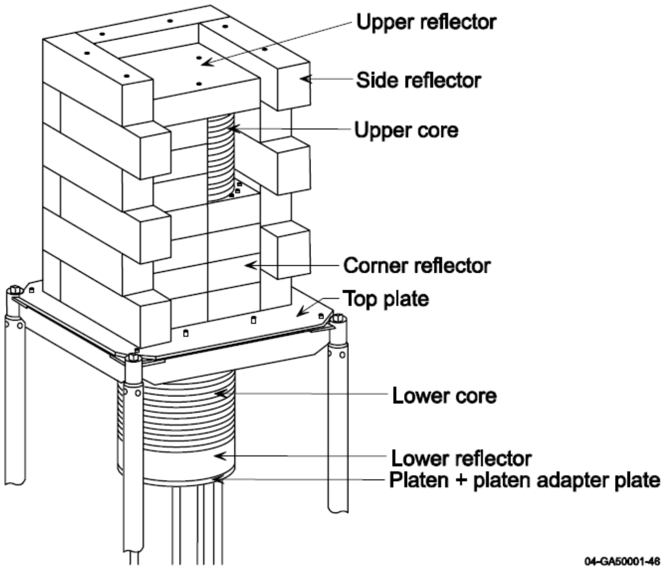

1. **Nuclear Data Validation**
2. **MCNP Modeling**
3. **Simulation Analysis**

# As nuclear data is collected, benchmarking experiments are necessary to validate the data for accurate models and simulations, promoting safety.

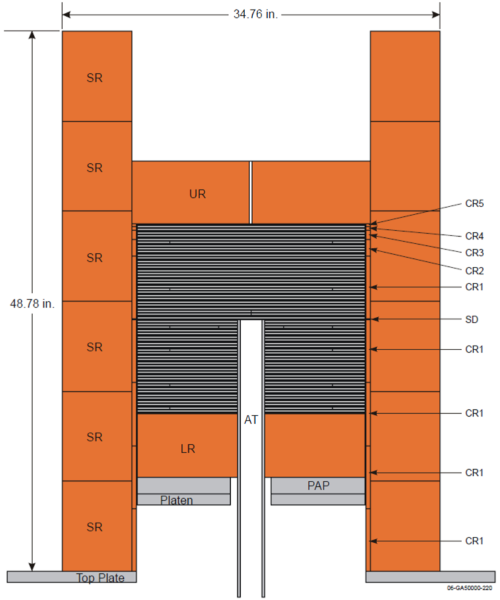



Total Cross Section Heatmap, Fe-Cr [1]

# Comet is a vertical-lift critical assembly at NCERC, which is used to perform benchmarking experiments to validate nuclear data.




Original Zeus Experiment Schematic [2]




Cross Section of Zeus Experiment [2]

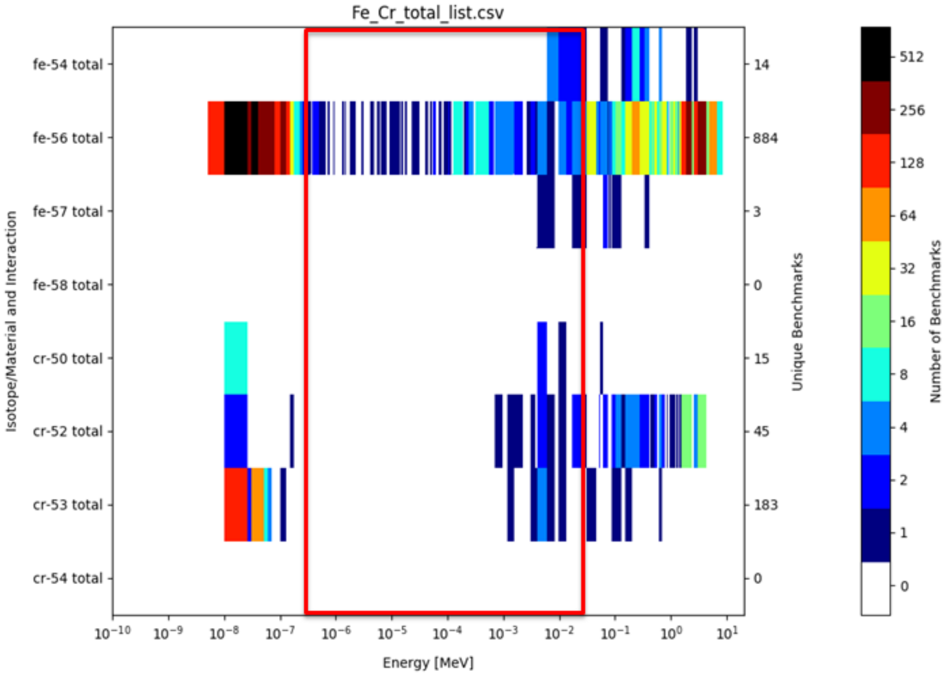
# The experimental design must be feasible and yield desirable results while meeting physical and experimental design criteria.

## Energy Ranges

**Fast: 1 MeV - 20 MeV**

**High Inter.: 10 keV - 100 keV**

**Low Inter.: 0.5 eV - 10 keV**



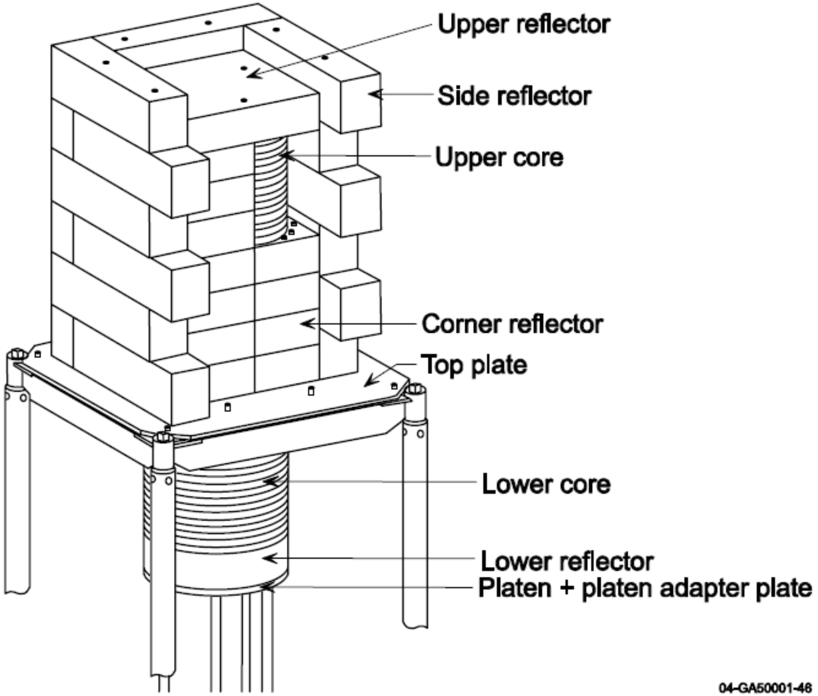

Total Cross Section Heatmap, Fe-Cr [1]

# The experimental design must be feasible and yield desirable results while meeting physical and experimental design criteria.

# Maximum Weight

## Upper: 20,000 lb

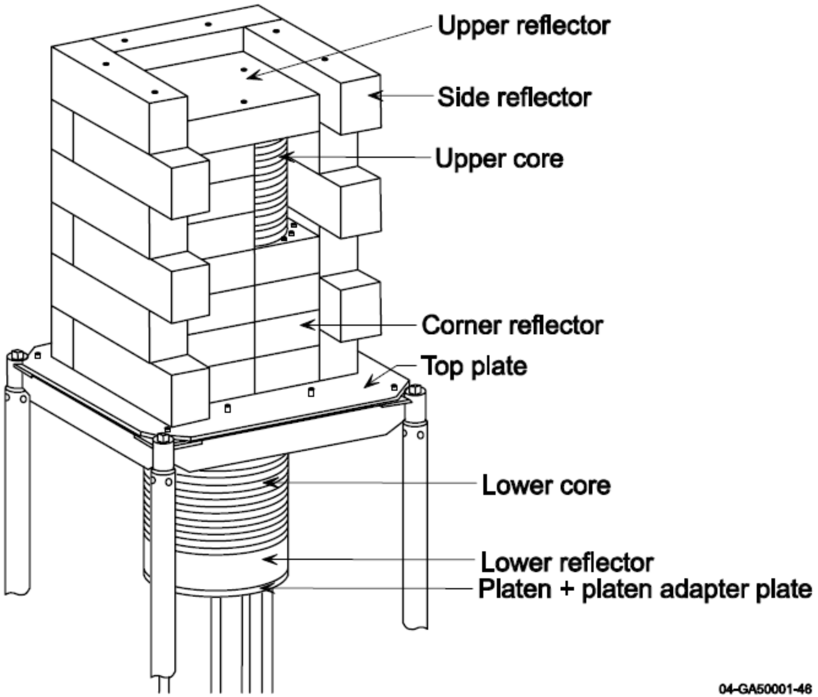
## Lower: 2,000 lb



# The experimental design must be feasible and yield desirable results while meeting physical and experimental design criteria.

**Maximum Height**

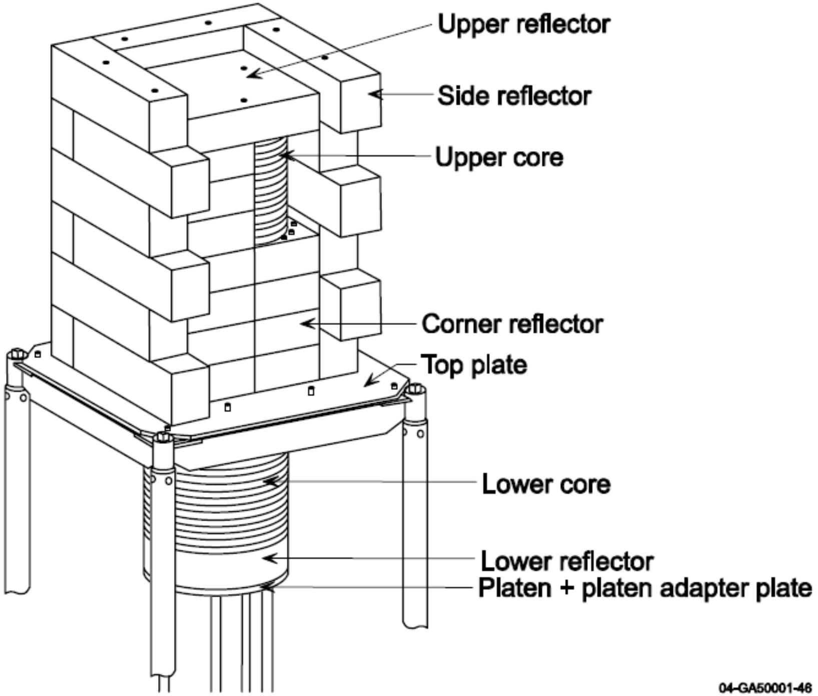
**Including Reflector: 4.065 ft**



# The experimental design must be feasible and yield desirable results while meeting physical and experimental design criteria.

## Estimated Cost

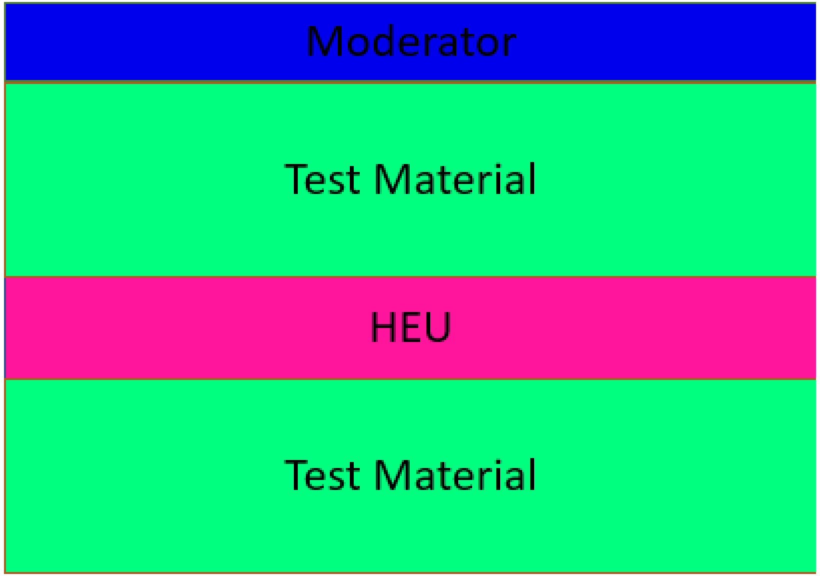
## ~$500,000 for project



# The experimental design must be feasible and yield desirable results while meeting physical and experimental design criteria.

## Repeated Units

## Fuel, Test, & Moderator Plates



The experimental design must be feasible and yield desirable results while meeting physical and experimental design criteria.

# Slightly Supercritical

# 80¢ Reactivity Increase Limit on Comet

$$\$ = \frac{\rho}{\beta}$$

$$\rho = \frac{k-1}{k}$$

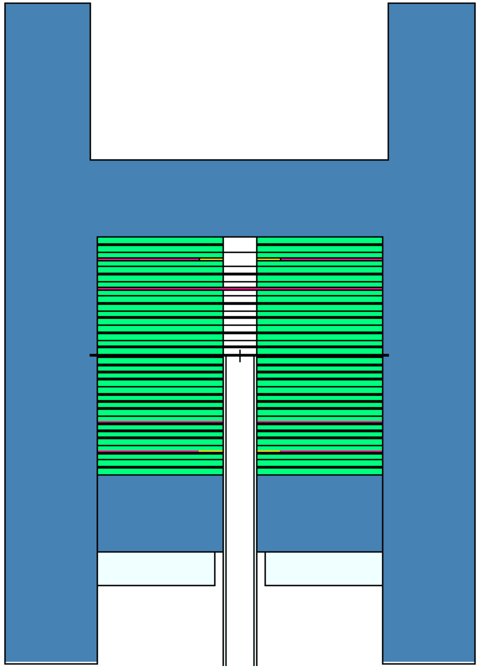
# Maximizing Sensitivity

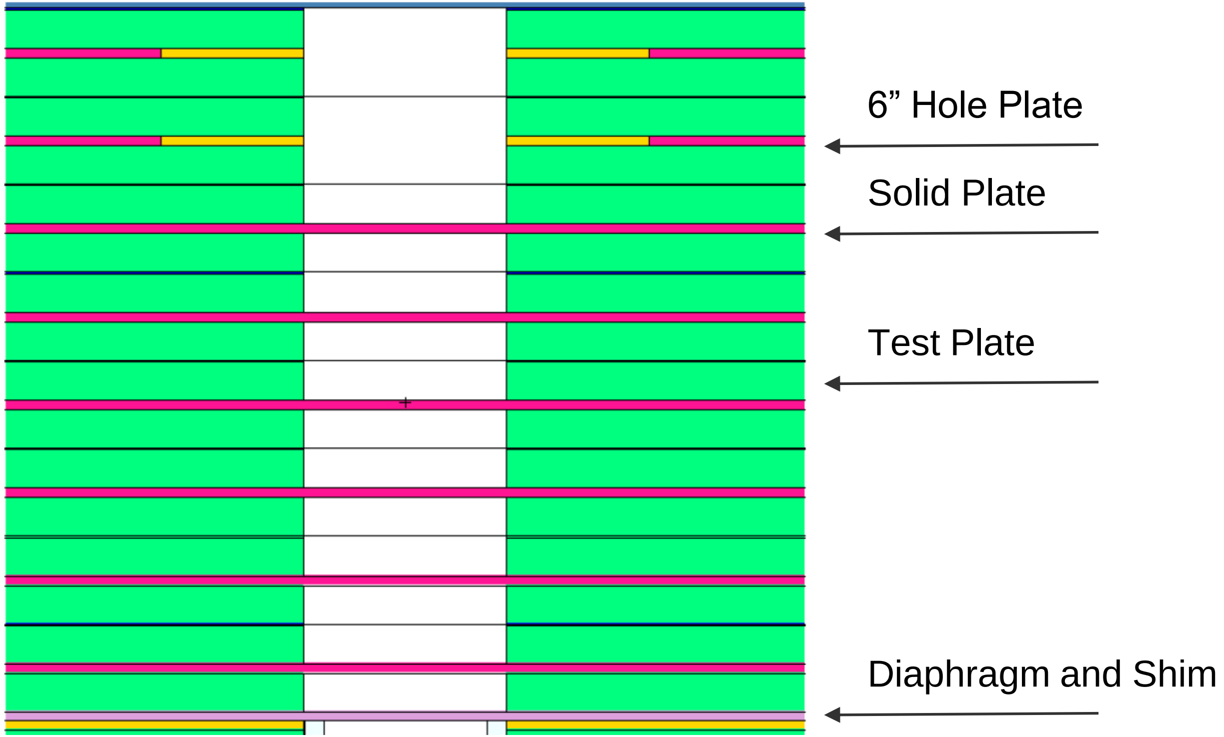
**Change in $k_{eff}$ for change in σ**

$$S_{k,\sigma} = \left(\frac{\sigma}{k}\right)\left(\frac{\partial k}{\partial \sigma}\right)$$

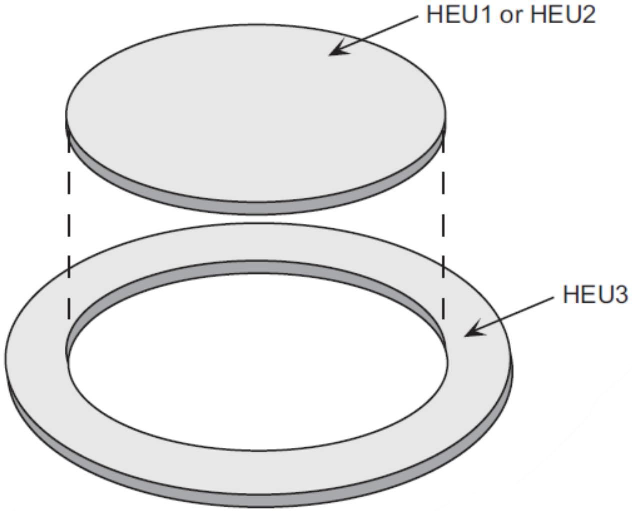
**High relative sensitivity decreases σ uncertainty**

# The MCNP model was based on the previous ZEUS experiment performed at NCERC for copper/uranium but includes some simplifications.





# The experiments will utilize highly-enriched uranium (HEU) fuel plates currently available in the NCERC inventory.

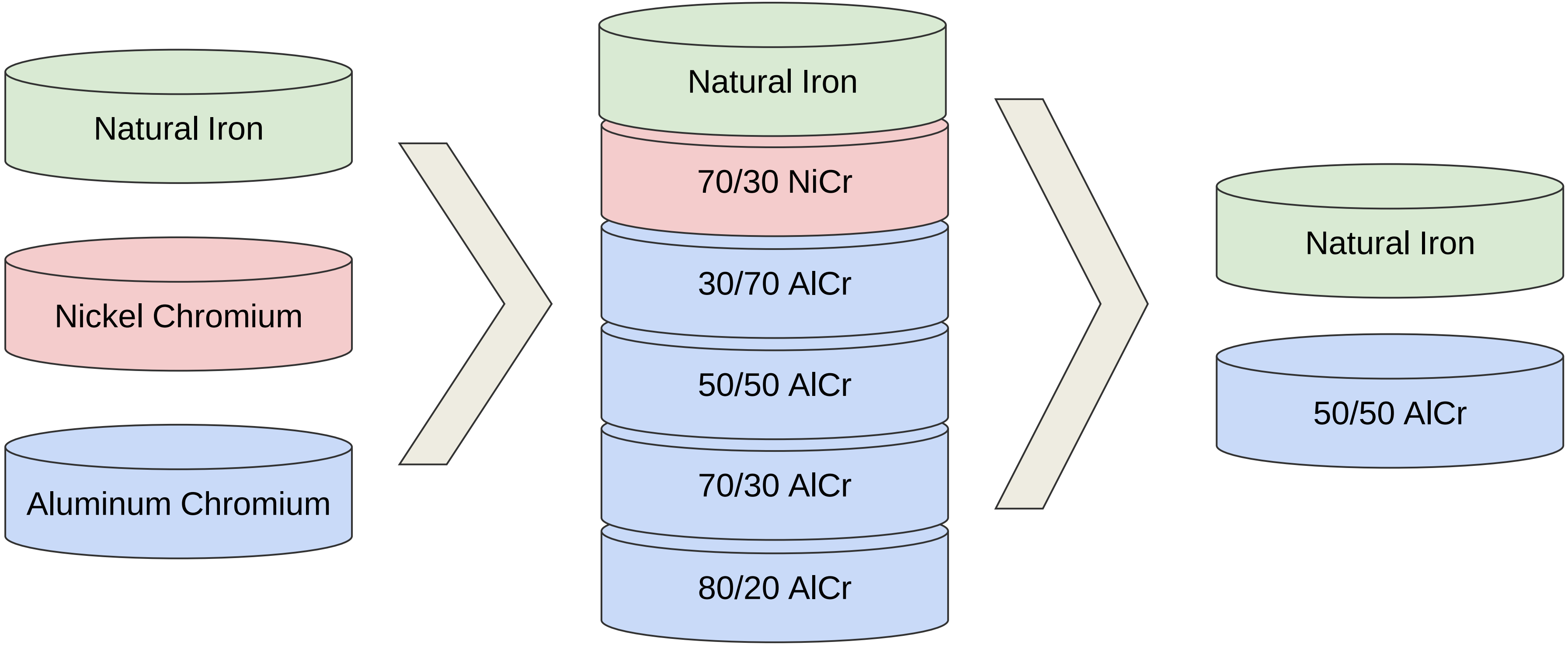



Nesting Fuel Plates [2]

Fuel Plate Dimensions

| Plate Name | OD (in) | ID (in) |
|---|---|---|
| Ring | 21 | 15 |
| Solid Disk | 15 | - |
| 2.5 in Hole | 15 | 2.5 |
| 6 in Hole | 15 | 2.5 |
| 6 in Piece | 6 | - |

# MCNP simulations are used for determining test plate materials, moderator plate material, plate thicknesses, and numbers of repeated units.



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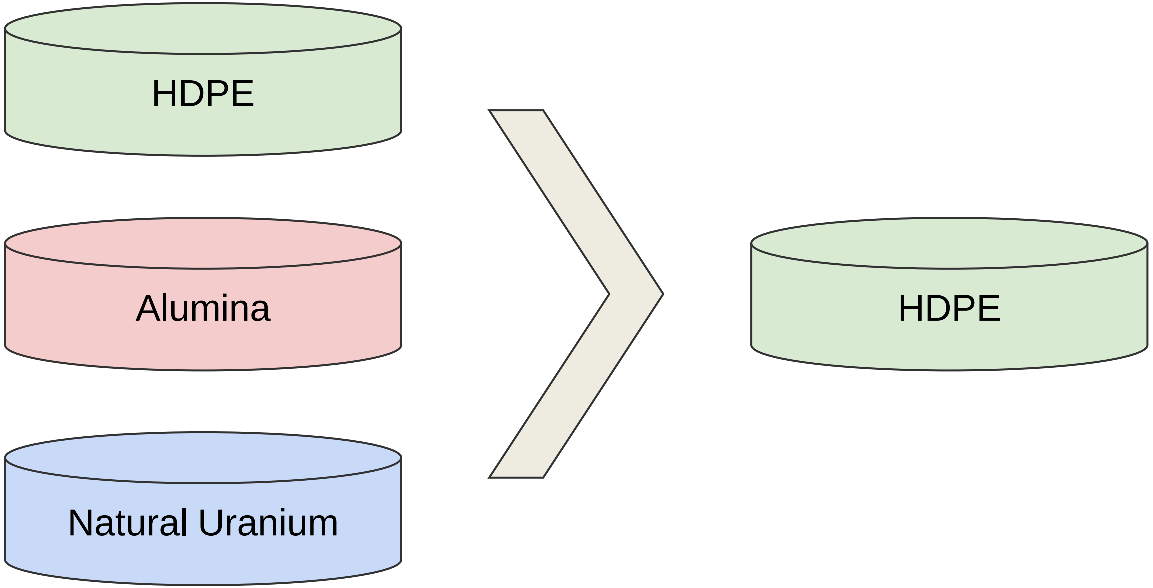
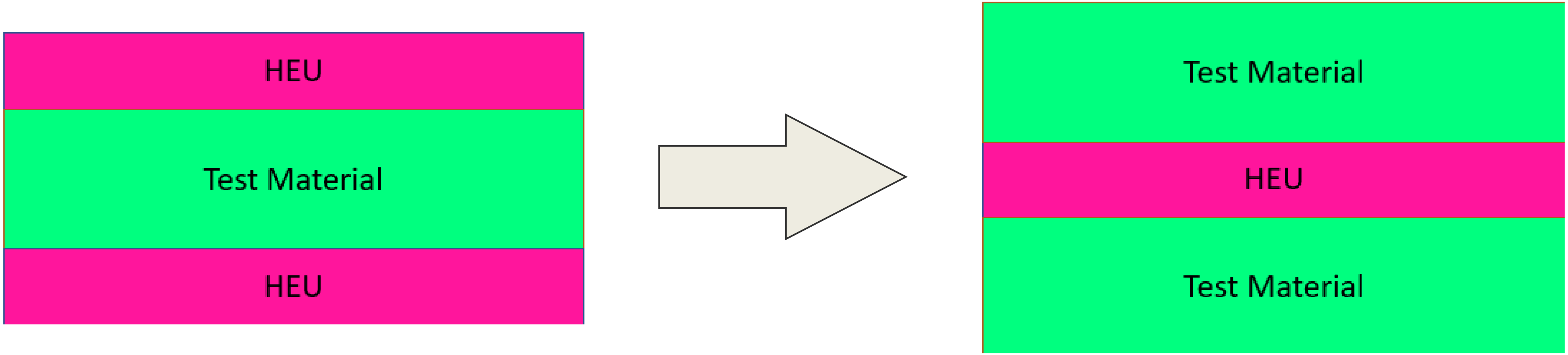


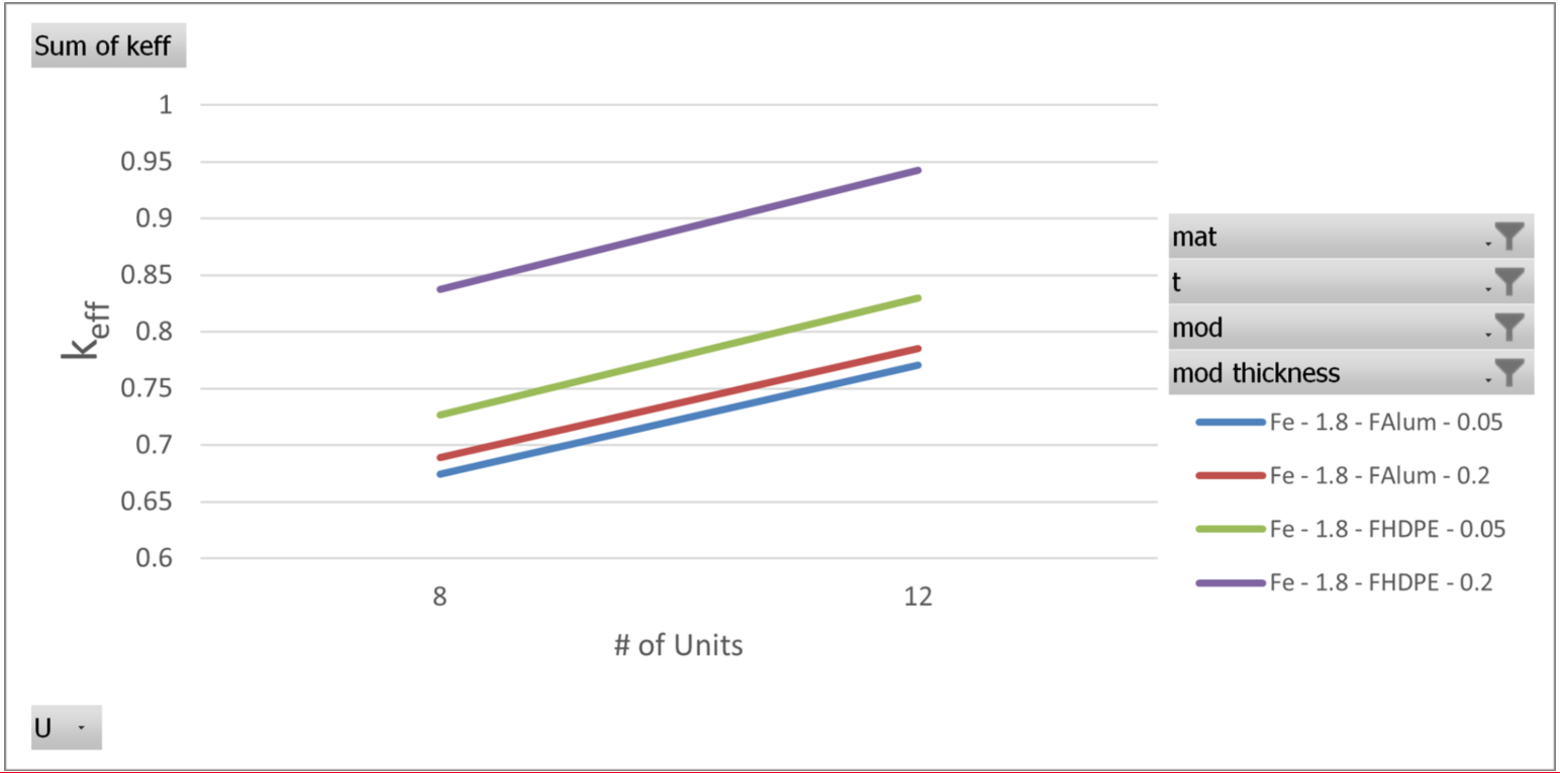
# Two plate configurations were evaluated from MCNP simulation results to inform our fuel and test plate layering order.



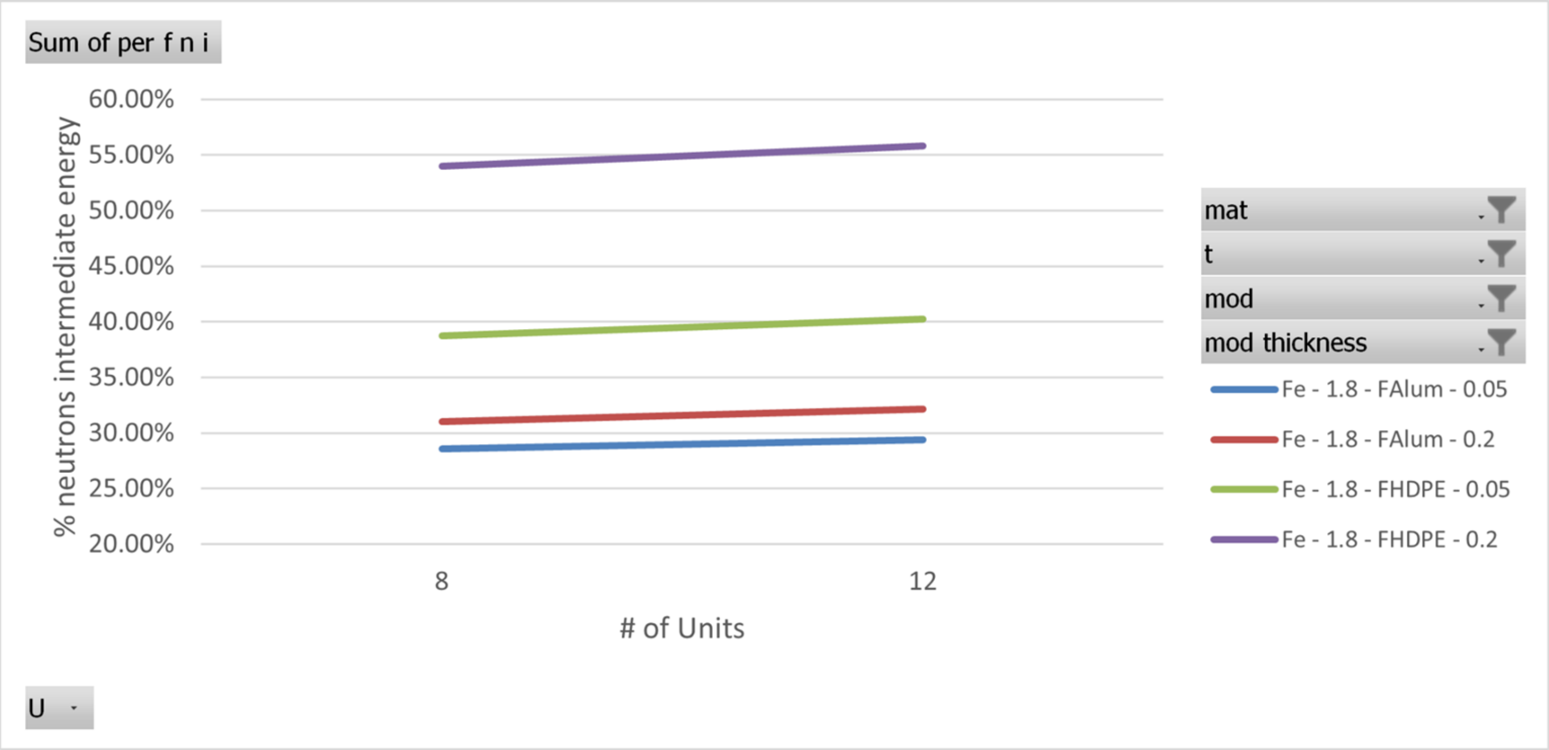

Test Plate Sandwich (TPS)

Fuel Plate Sandwich (FPS)

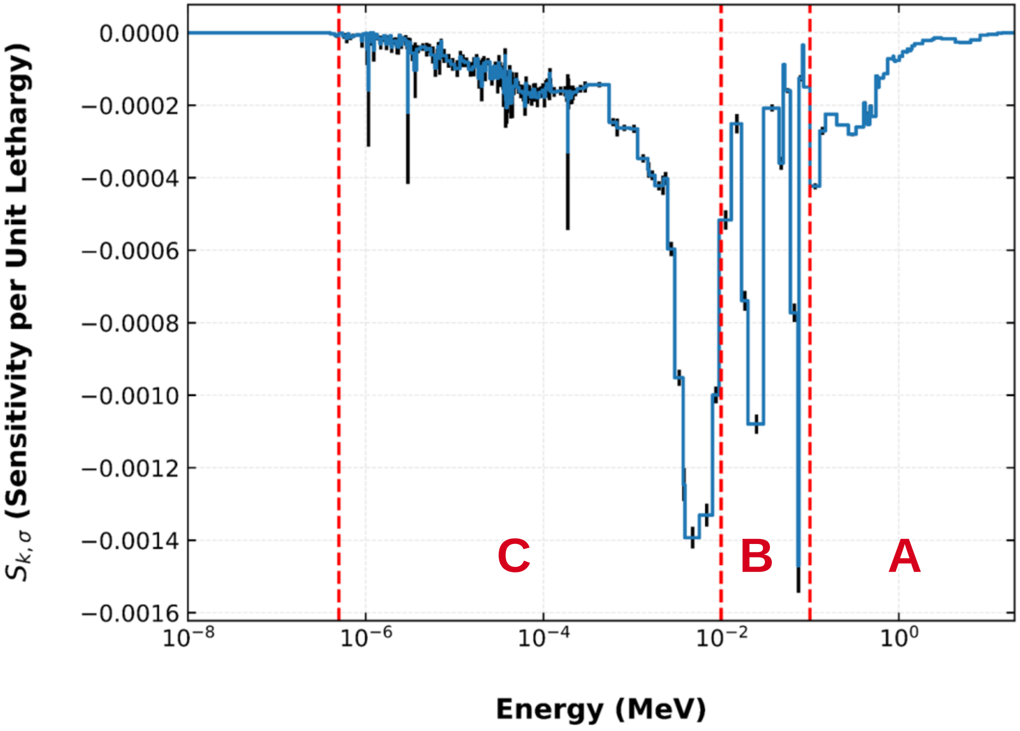
# From the many simulated tests, important parameter trends such as $k_{eff}$ and the neutron energy distribution are compared to inform future simulations.



# From the many simulated tests, important parameter trends such as $k_{eff}$ and the neutron energy distribution are compared to inform future simulations.



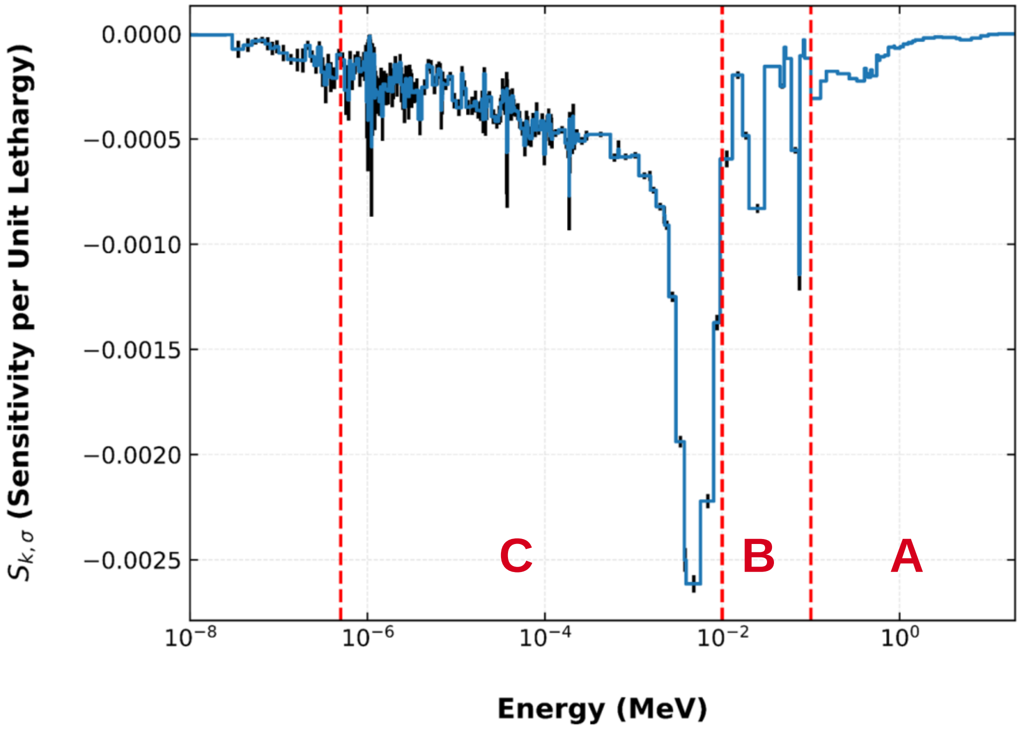
# Sensitivity profiles are used to optimize designs for specific energy regions, and they are compared as various designs are considered.




## Un-moderated Cr-53 Capture

- **A)** Fast: 1 MeV - 20 MeV
- **B)** High Inter.: 10 keV - 100 keV
- **C)** Low Inter.: 0.5 eV - 10 keV

# Sensitivity profiles are used to optimize designs for specific energy regions, and they are compared as various designs are considered.




## HPDE-moderated Cr-53 Capture

**A)** Fast: 1 MeV - 20 MeV

**B)** High Inter.: 10 keV - 100 keV

**C)** Low Inter.: 0.5 eV - 10 keV

Moving forward, the design will be optimized by introducing a figure of merit to quantitatively determine which designs are more desirable.

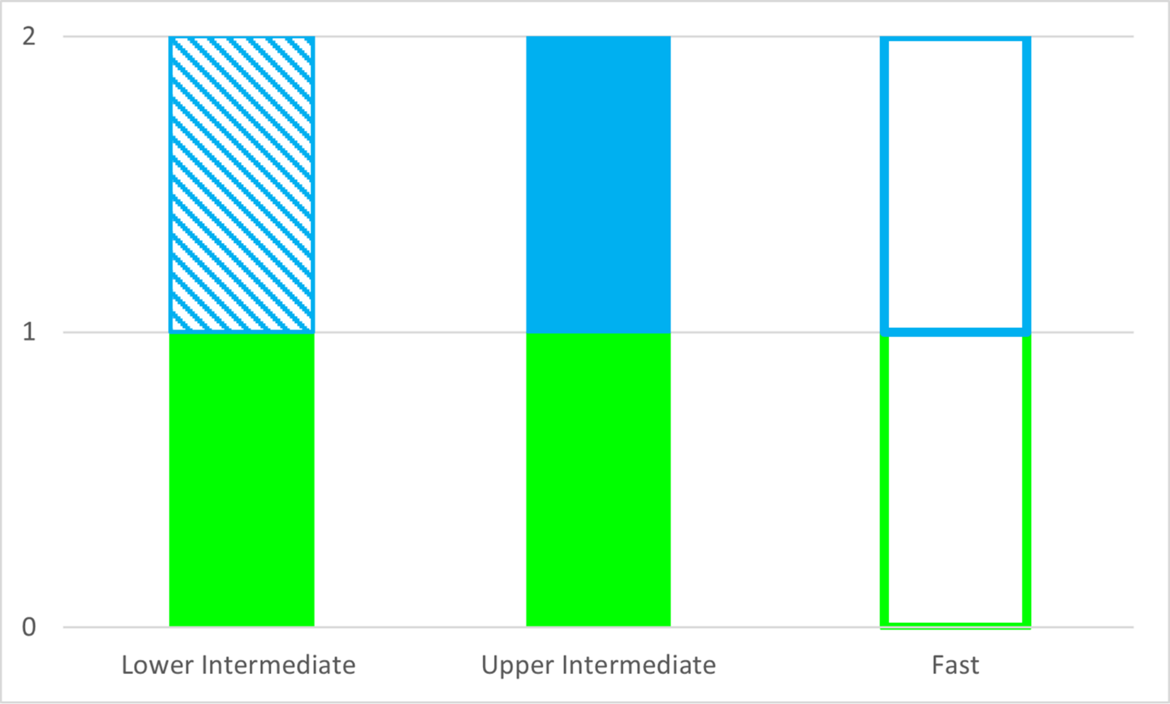
$$f = \begin{cases} \frac{1}{W}\int_{E_0}^{E_1} S_{k,\sigma} dE, & |1.0028 - k_{\text{eff}}| < 0.0028 \\ -\frac{1}{W}\int_{E_0}^{E_1} S_{k,\sigma} dE, & |1.0028 - k_{\text{eff}}| > 0.0028 \end{cases}$$

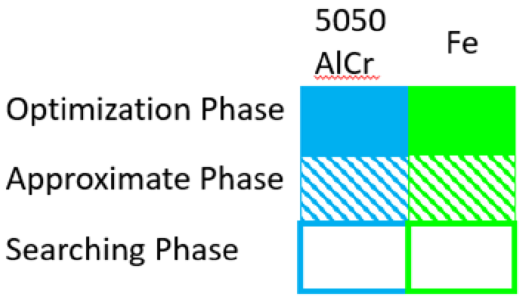
**Maximize:** Sensitivity ($S_{k,\sigma}$) within desired energy range ($E_0$ - $E_1$)

**Minimize:** Weight (W)

$k_{eff}$ between 1.0000 - 1.0056

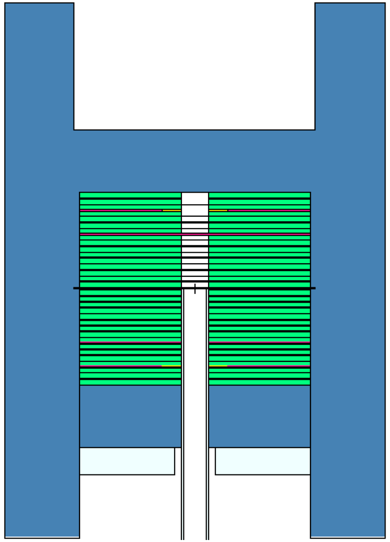
# 3 of the 6 critical experiment designs are ready for optimization, 1 design almost fits the design criteria, and 2 designs need to be edited significantly.



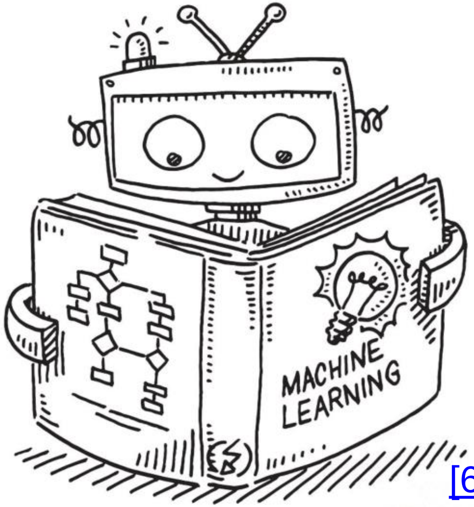



# This project is done to give nuclear data evaluators more tools for evaluating Fe & Cr data to, in theory, improve the data within libraries.

**RPI Nuclear Engineering Senior Design**



**Final Designs for Intermediate & Fast Energy**




[6]

**Machine Learning Optimization using FOM**

We would like to acknowledge our advisors at LANL & RPI as well as our course instructor & peers for our senior design project at RPI.

Dr. Nicholas Thompson
Jesson Hutchinson
Noah Kleedtke

Dr. Yaron Danon
Dr. Bimal Malaviya
Nuclear Engineering Senior Design

# References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