Project CESR:
The Design of a World-Class Cold-Neutron Source at NIST

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Topics of Discussion

Reactor Physics 101

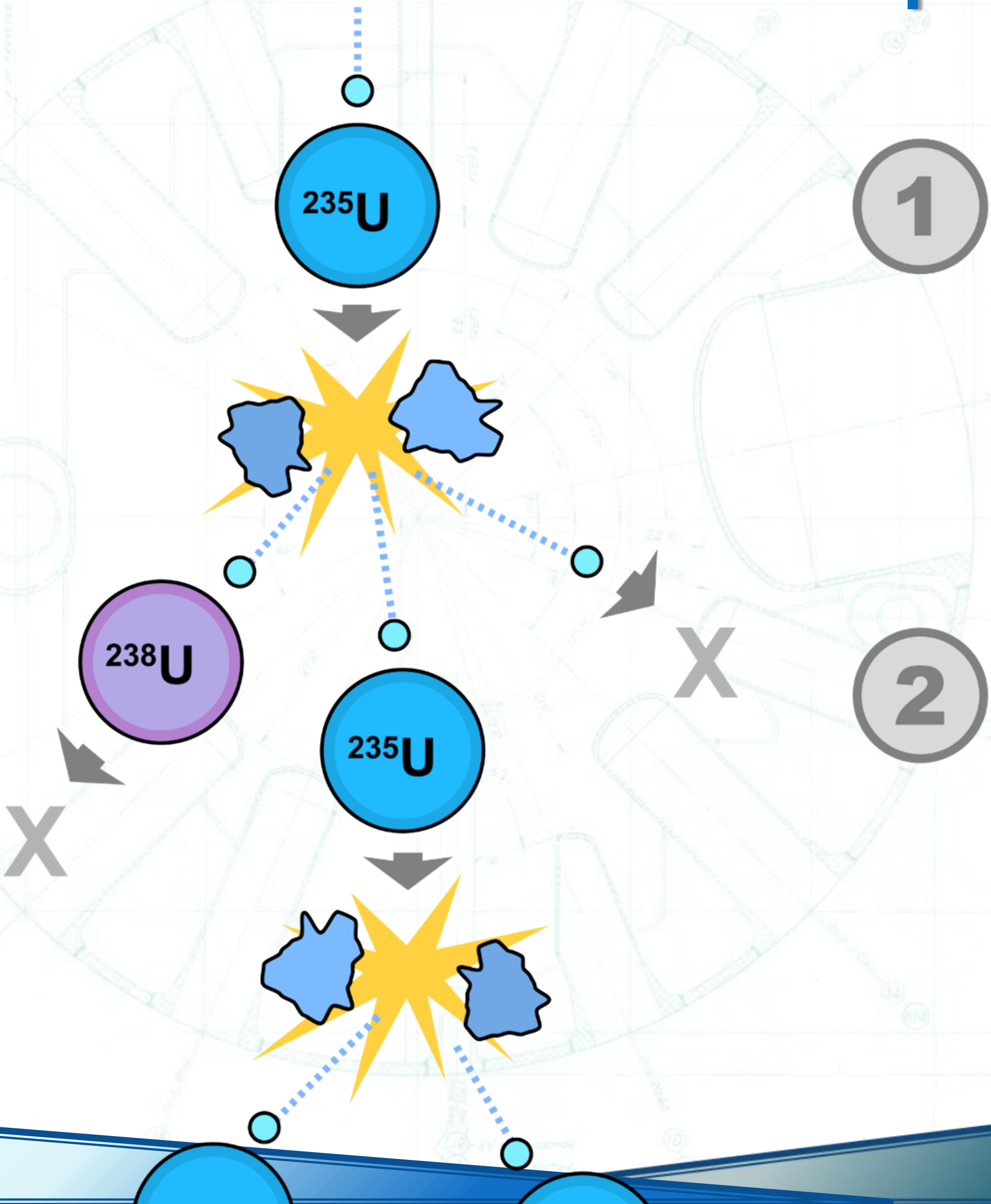
NIST's Cold Neutron (CN) Source

CESR: Cold-Energy-n Source Reactor

CESR design features and comparison

Summary of Successes

First, a crash course in reactor physics…



In Terms of Neutronics

The Neutron Multiplication Factor describes the efficiency of a reactor:

$$K_{eff} = \frac{\text{Number of neutrons in one generation}}{\text{Number of neutrons in the previous generation}}$$

- K_{eff} is 1.00000… for a critical reactor (steady power)

Reactivity describes changes in K_{eff}:

$$\Delta\rho = \frac{K_{eff_1} - K_{eff_2}}{K_{eff_1} \cdot K_{eff_2}}$$

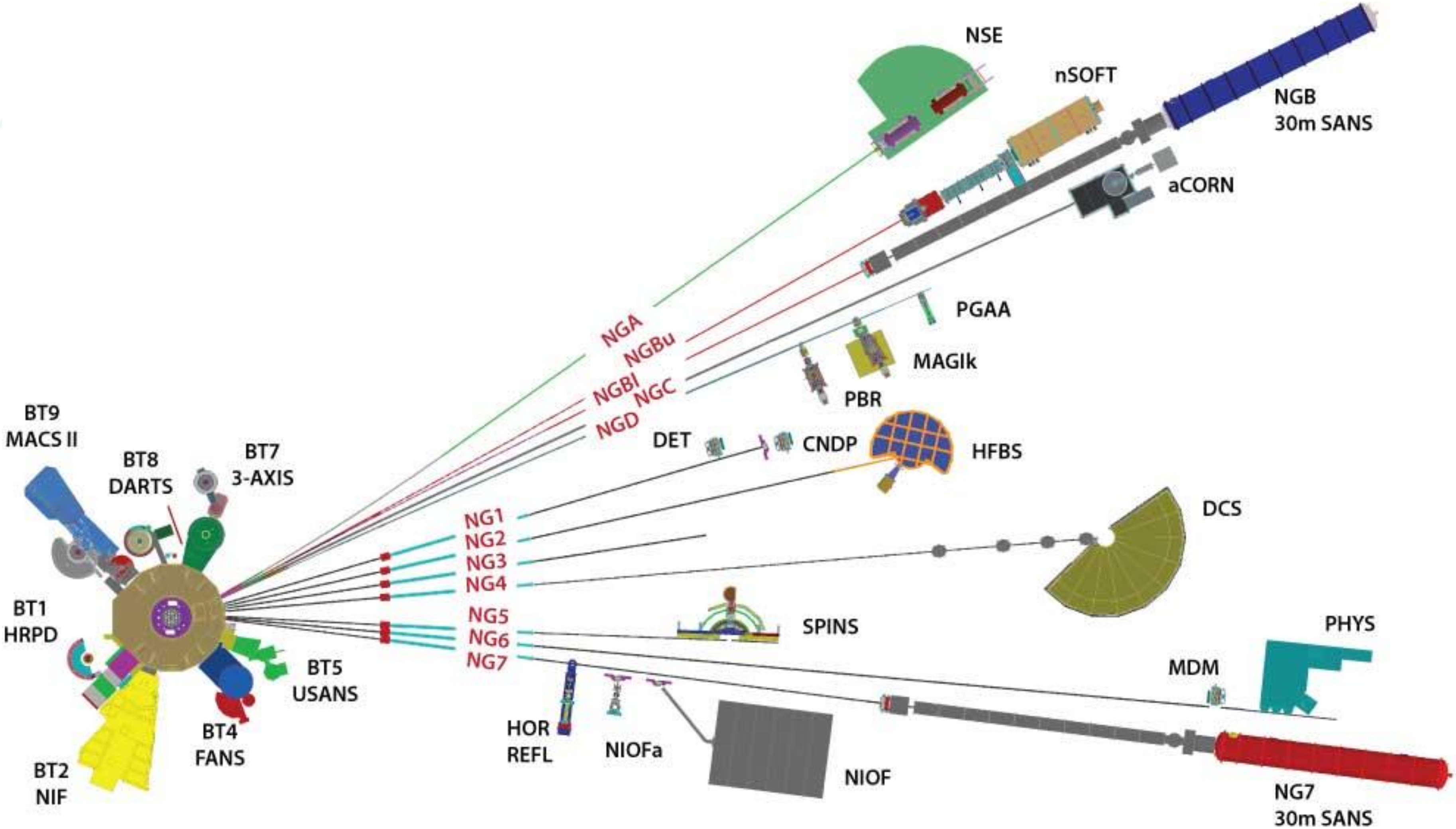
- Typical units of reactivity are Δk/k

Neutron Flux describes the amount of neutrons traveling through a space:

$$\varphi = \frac{\text{number of neutrons}}{\text{unit area} * \text{unit time}}$$

- Typical units of flux are n/cm^2s

CNs → 2/3 of all NCNR Research



Project Inception

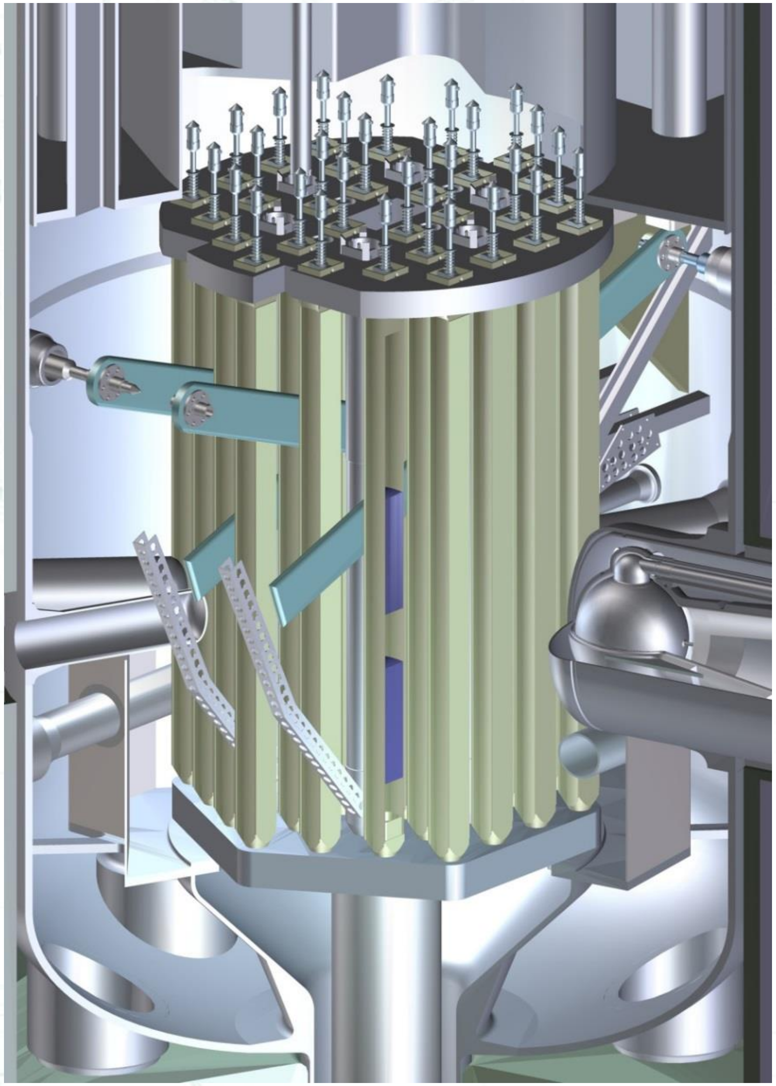
- 2000+ users annually, from industry to academia
- Finite reactor life – built in the 1960's!
- Politics – phasing out of highly-enriched fuels
- One of the greatest collections of instruments for CN experiments in the world

Task:

- ❑ Design a base conceptual model
- ❑ Optimize for CN production

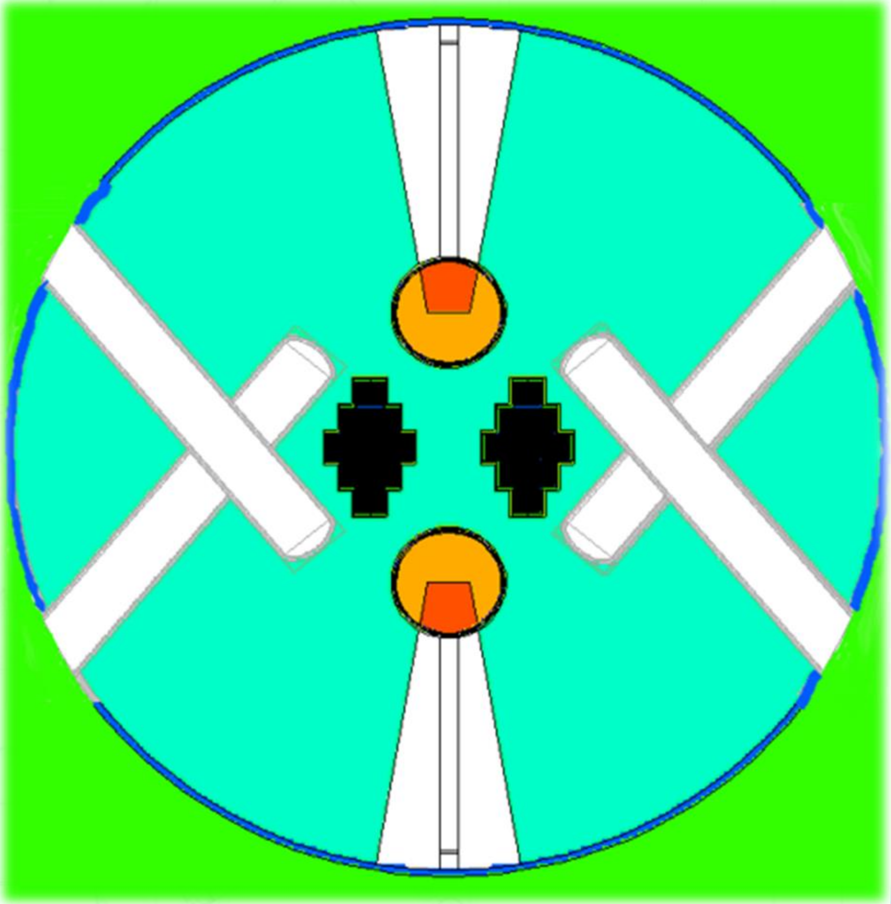
NBSR: Cut-away View

- Vertical flux trap
- Highly enriched uranium fuel
- ~1.2m in diameter
- Thermal flux peaks in center
- Fast flux is high near CNS

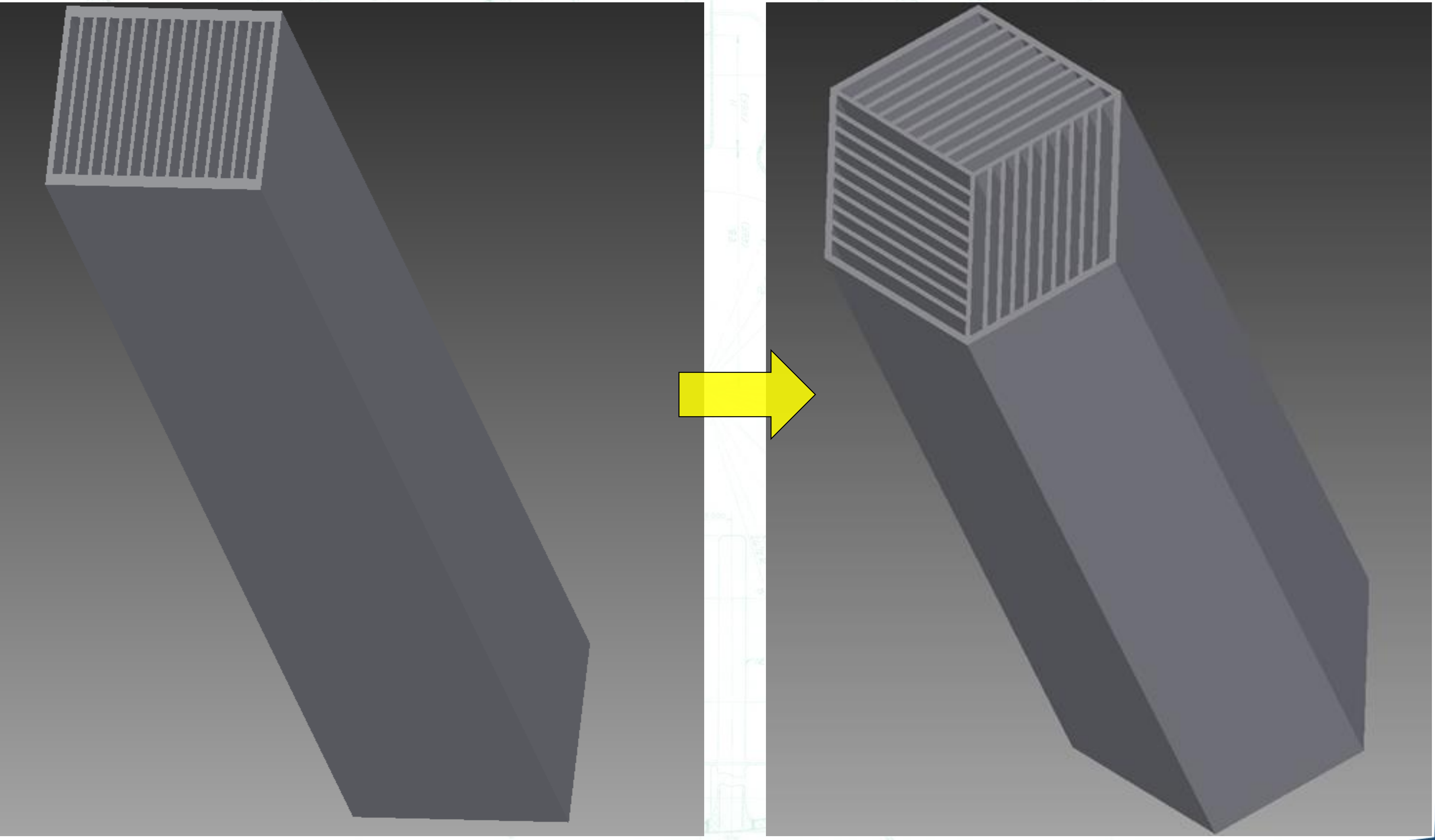


Split-core Design (NBSR-2)

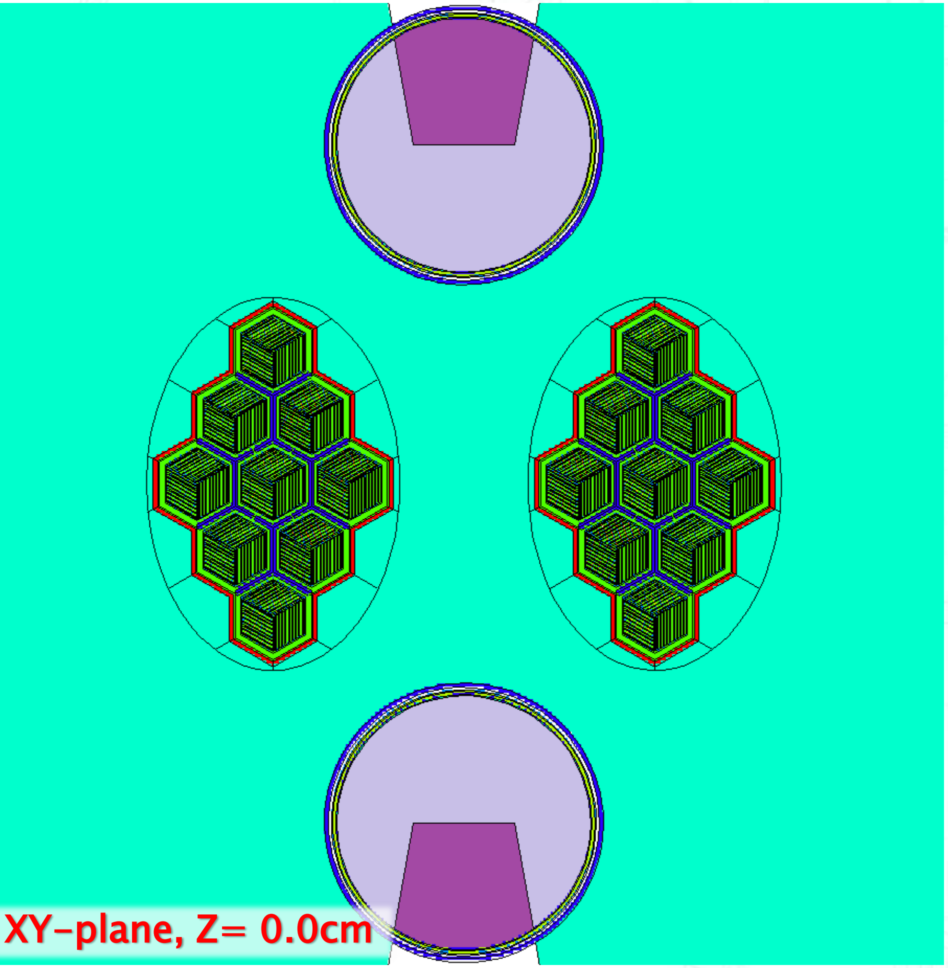
- Horizontal flux trap
- Low enriched uranium fuel
- <0.5m across both cores
- More efficient thermal flux trapping
- Reduction of fast flux at CNS tubes
- Approximately doubles capacity for CN facilities

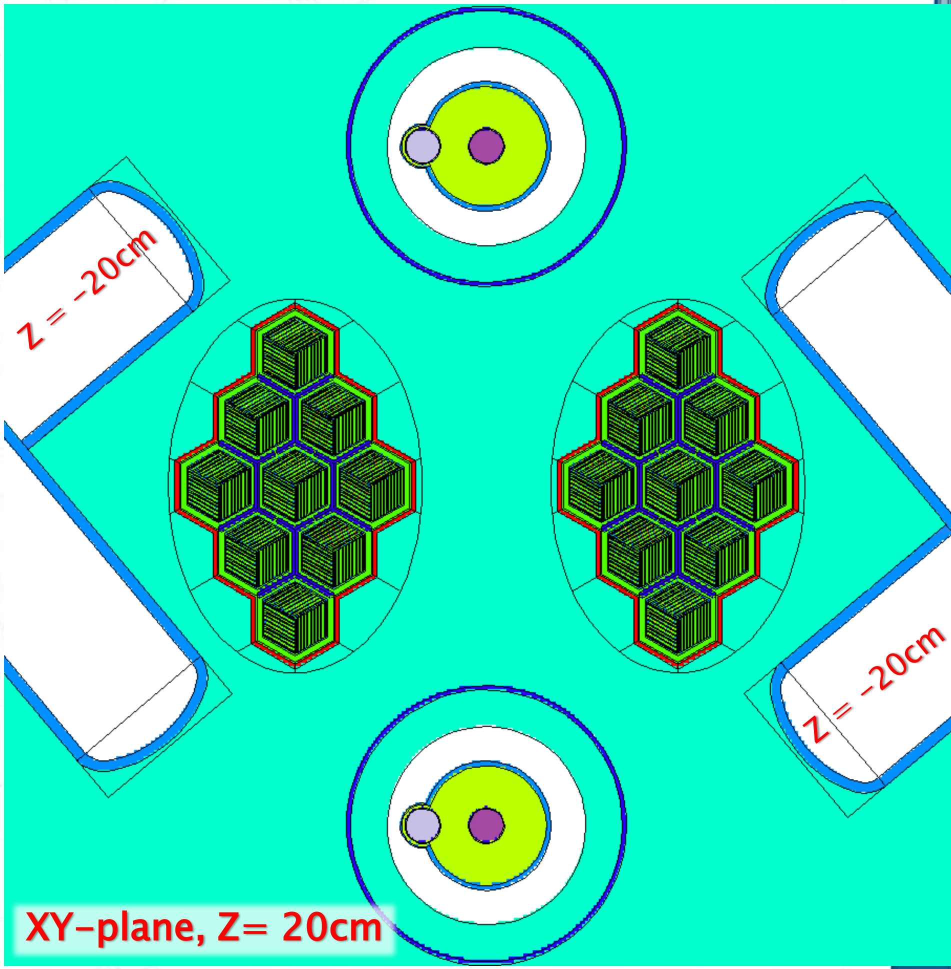


Proposition: Hexagonal Fuel Elements

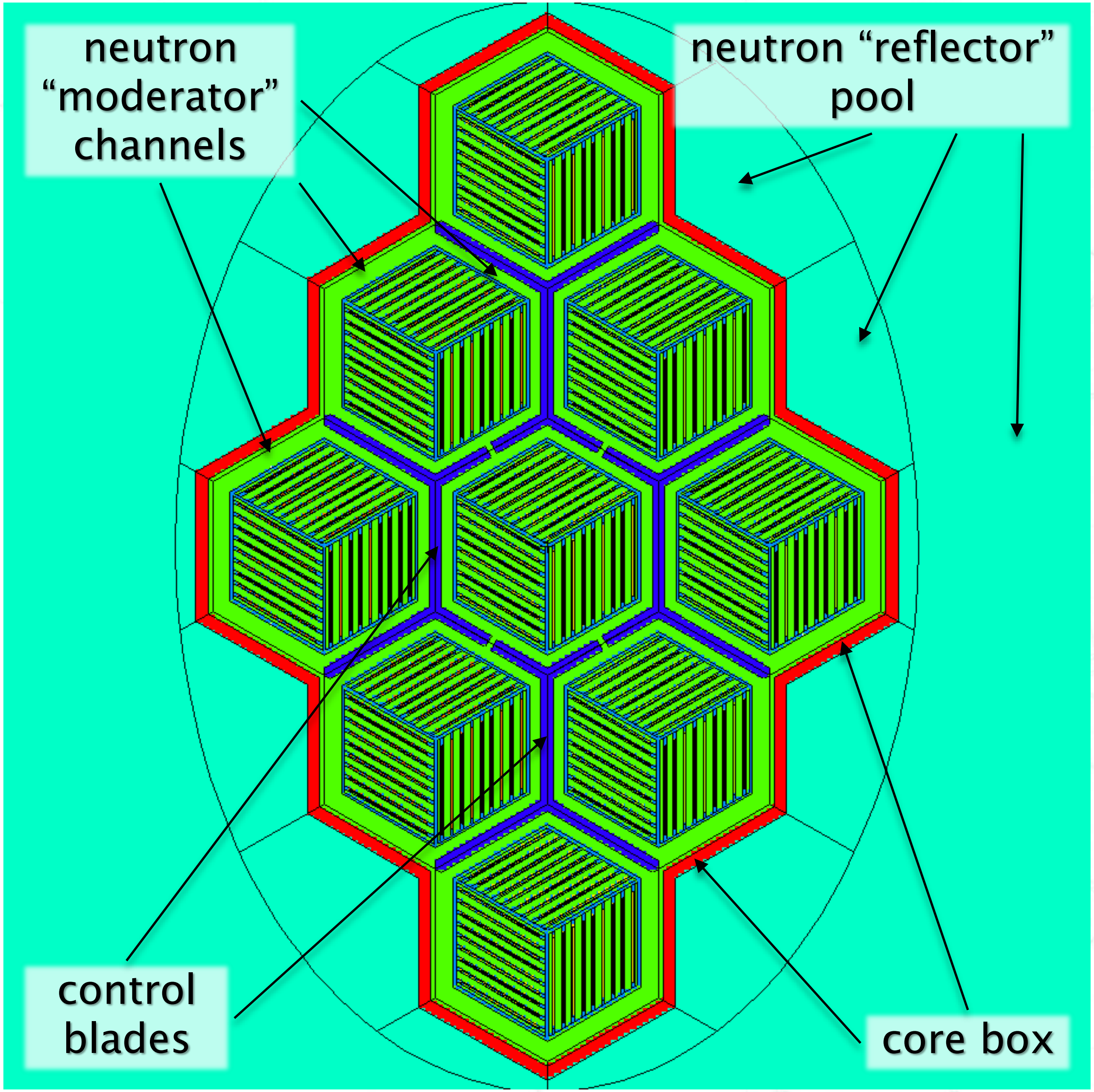


CESR Design – Inside the Reflector Barrel



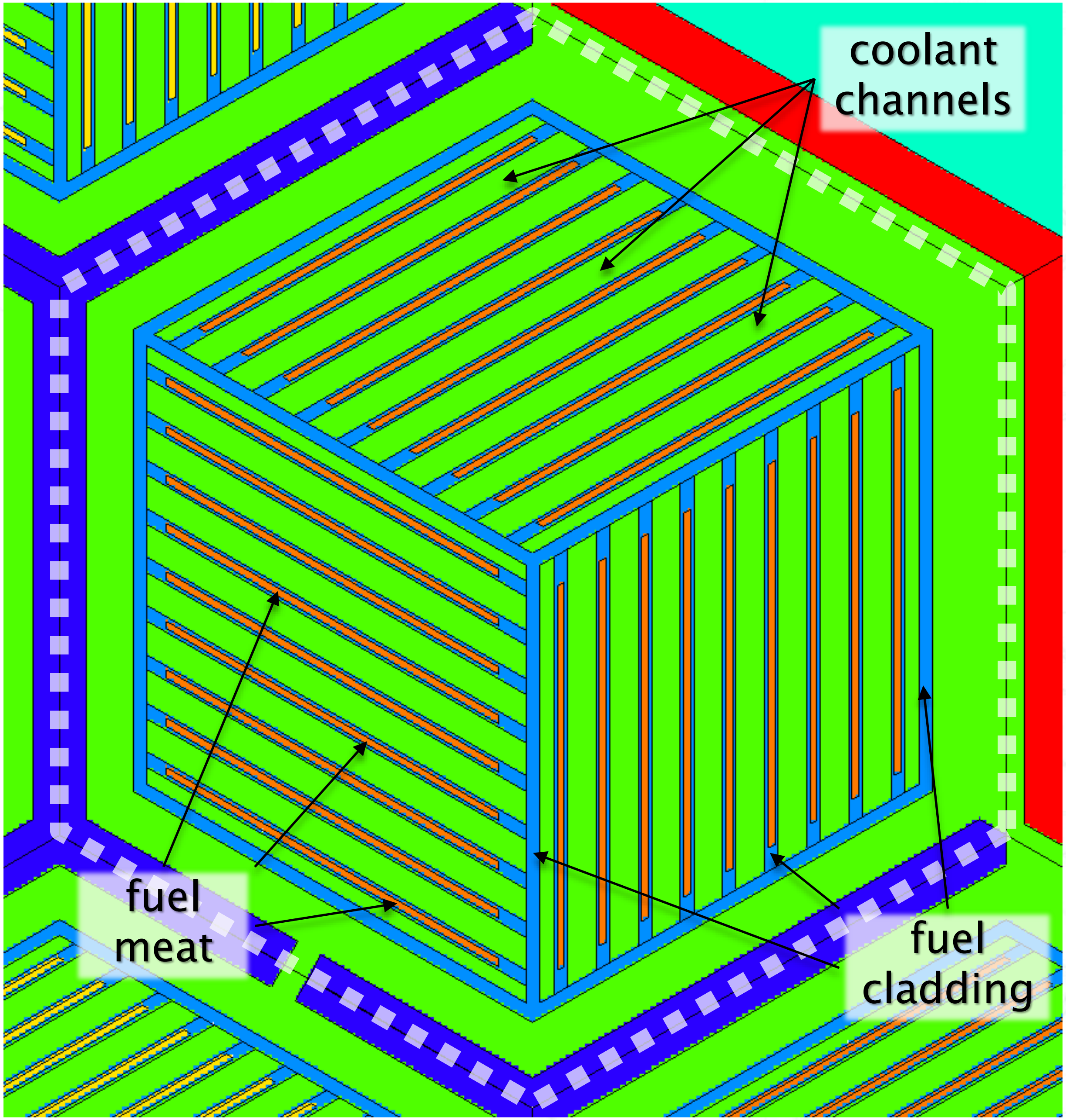


Rhombic Core-Half



- D_2O (heavy water)
- H_2O (light water)
- Zircaloy-4
- Natural Hafnium
- Aluminum-6061
- U_3Si_2 "meat" batches

Hexagonal Fuel Element



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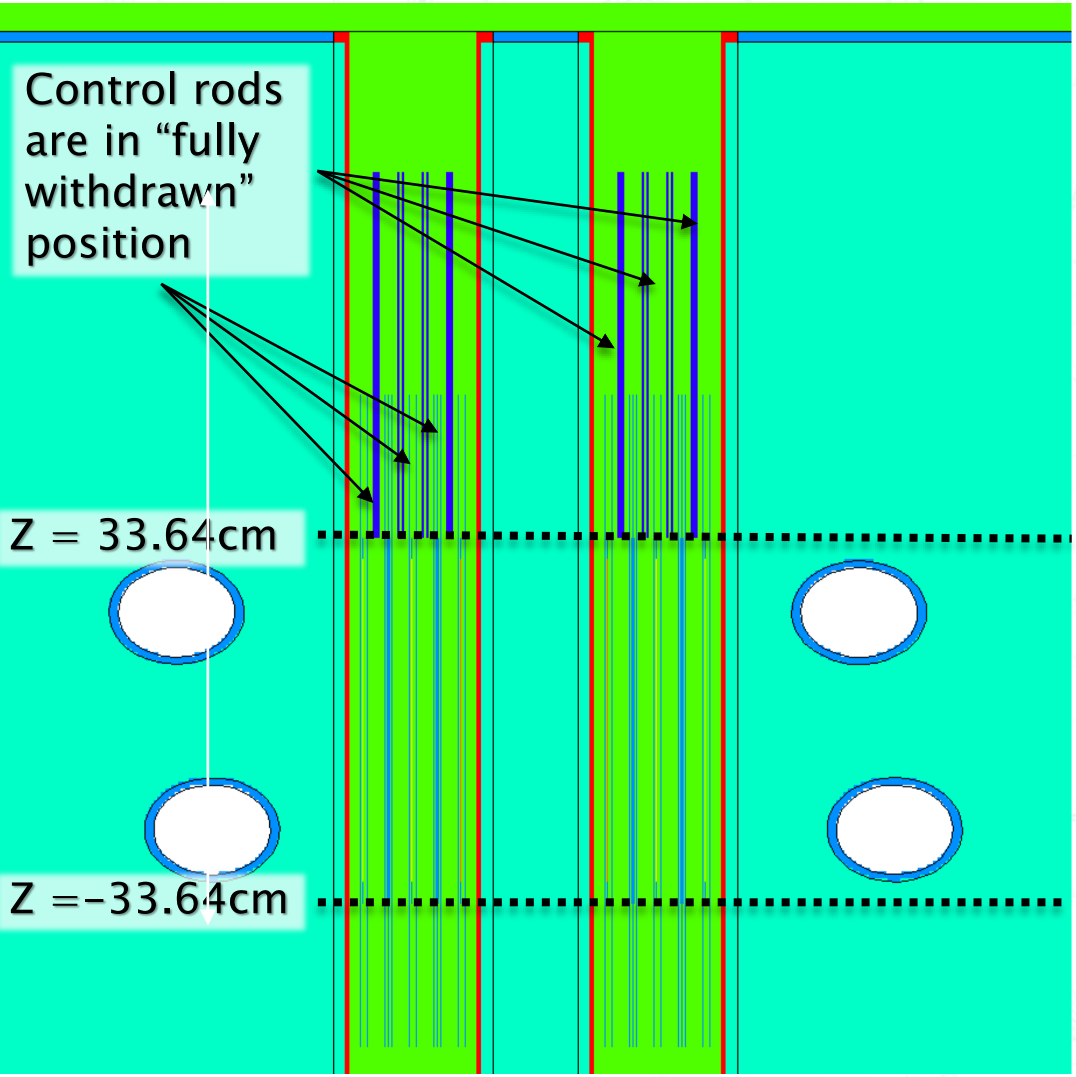
Control Rod Thickness Selection



1mm-thick rods:

32.1% Δk/k total worth at SU
35.0% Δk/k total worth at EOC

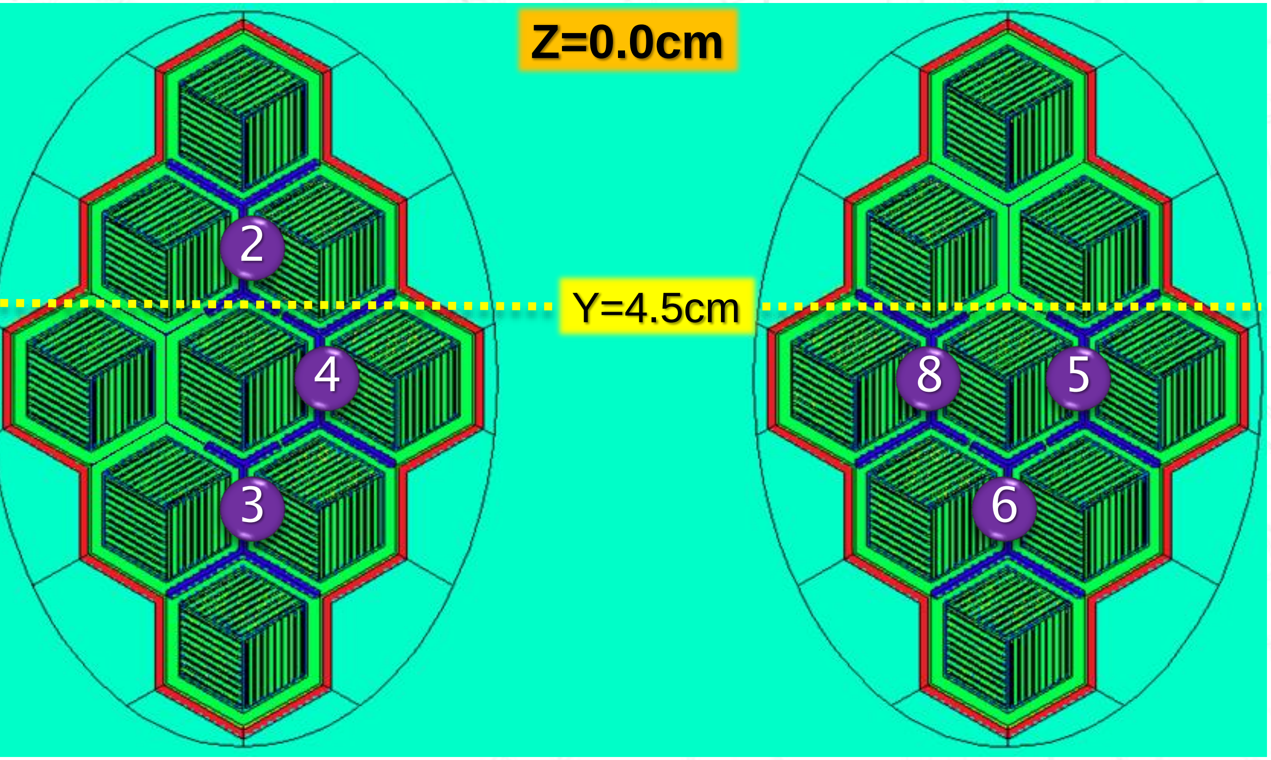
Above NRC standards for NBSR

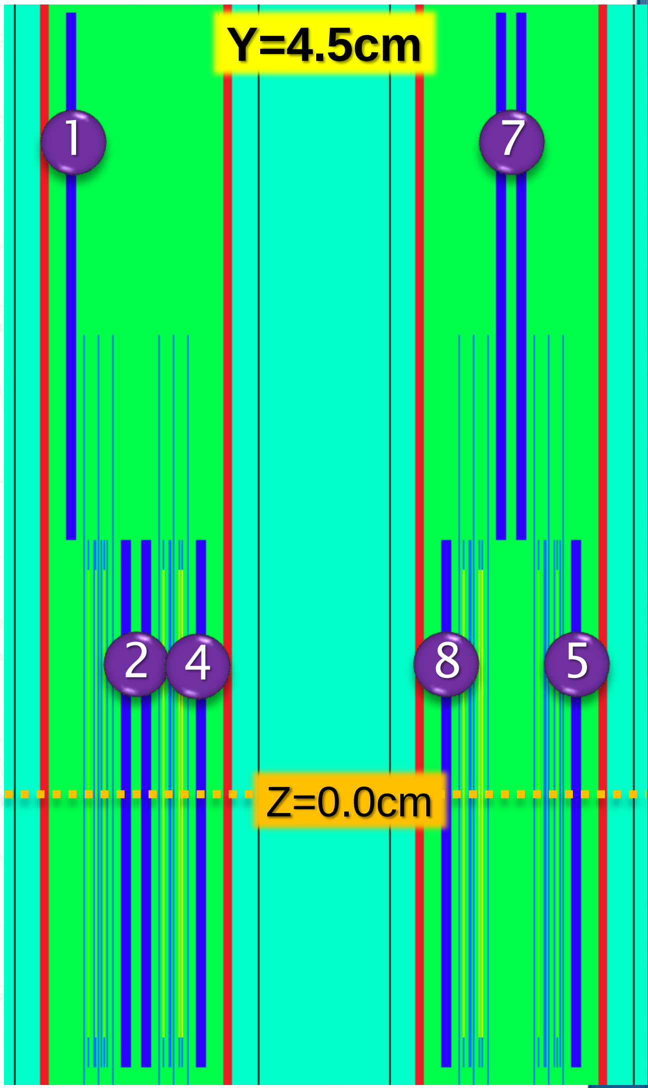
SU ρ_{ex} = 8.27% Δk/k
EOC ρ_{ex} = 1.58% Δk/k

SU SDM = 19.63% Δk/k
EOC SDM = 25.04% Δk/k

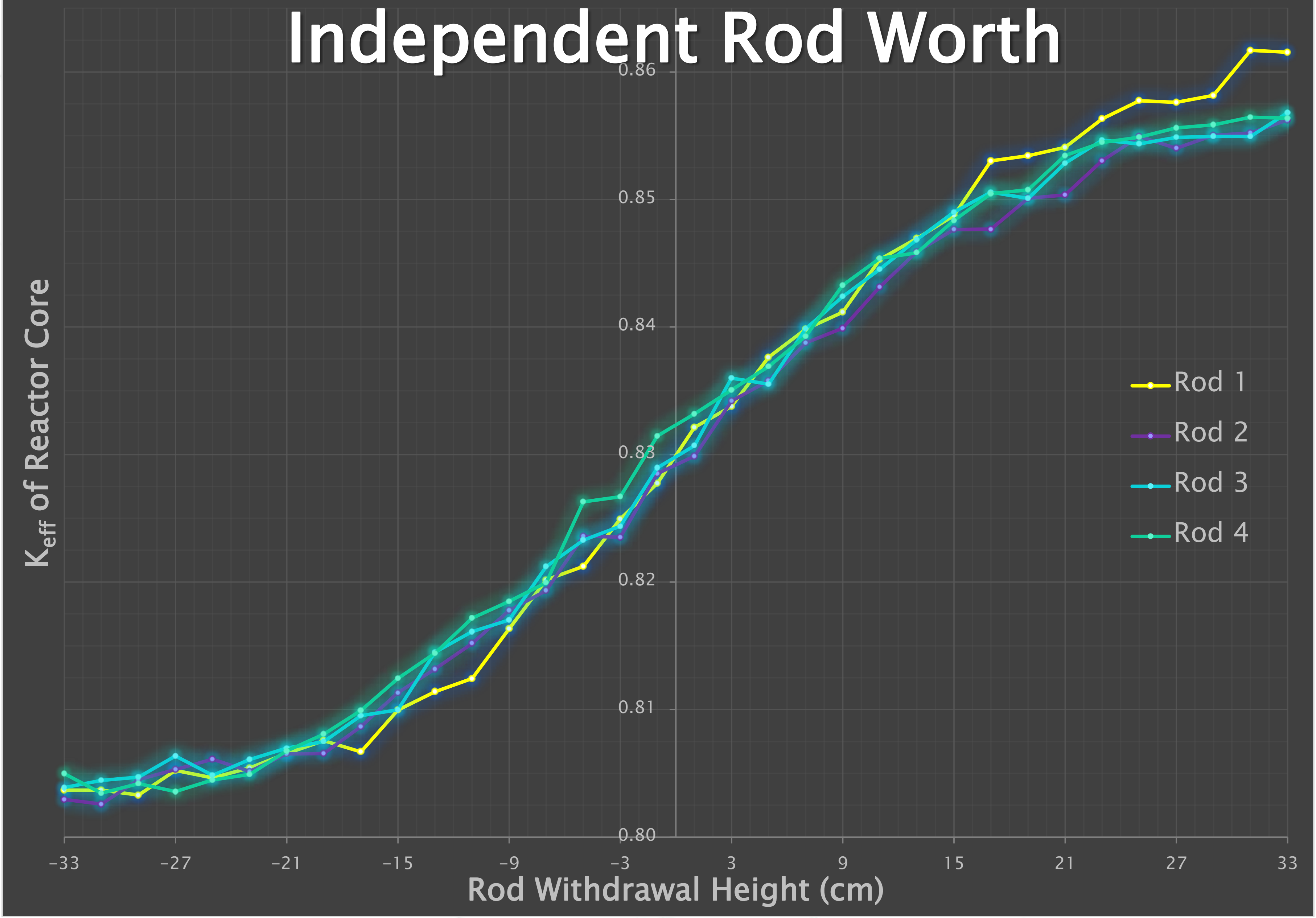
Critical Rod Height

Eight Independent Control Rods

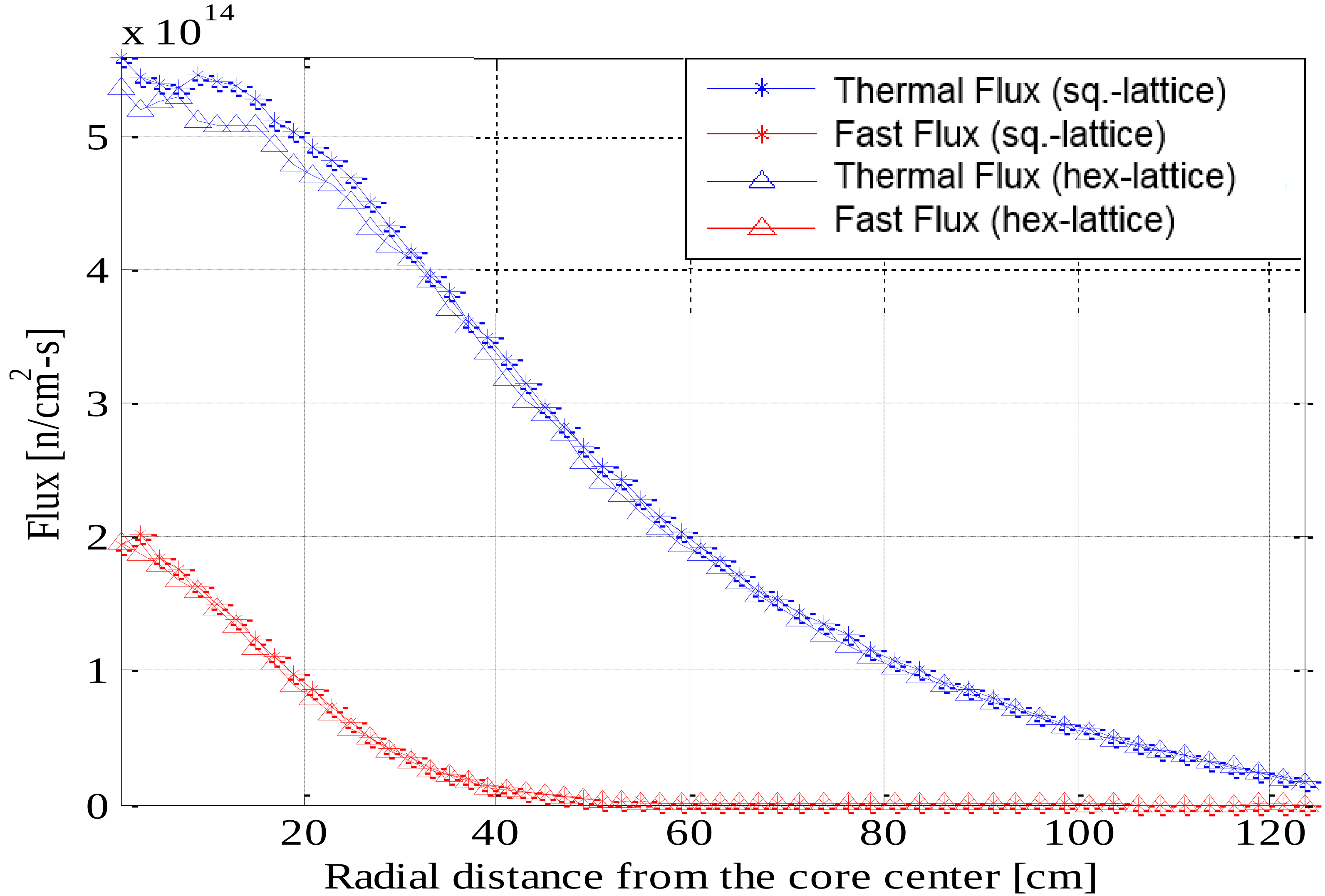




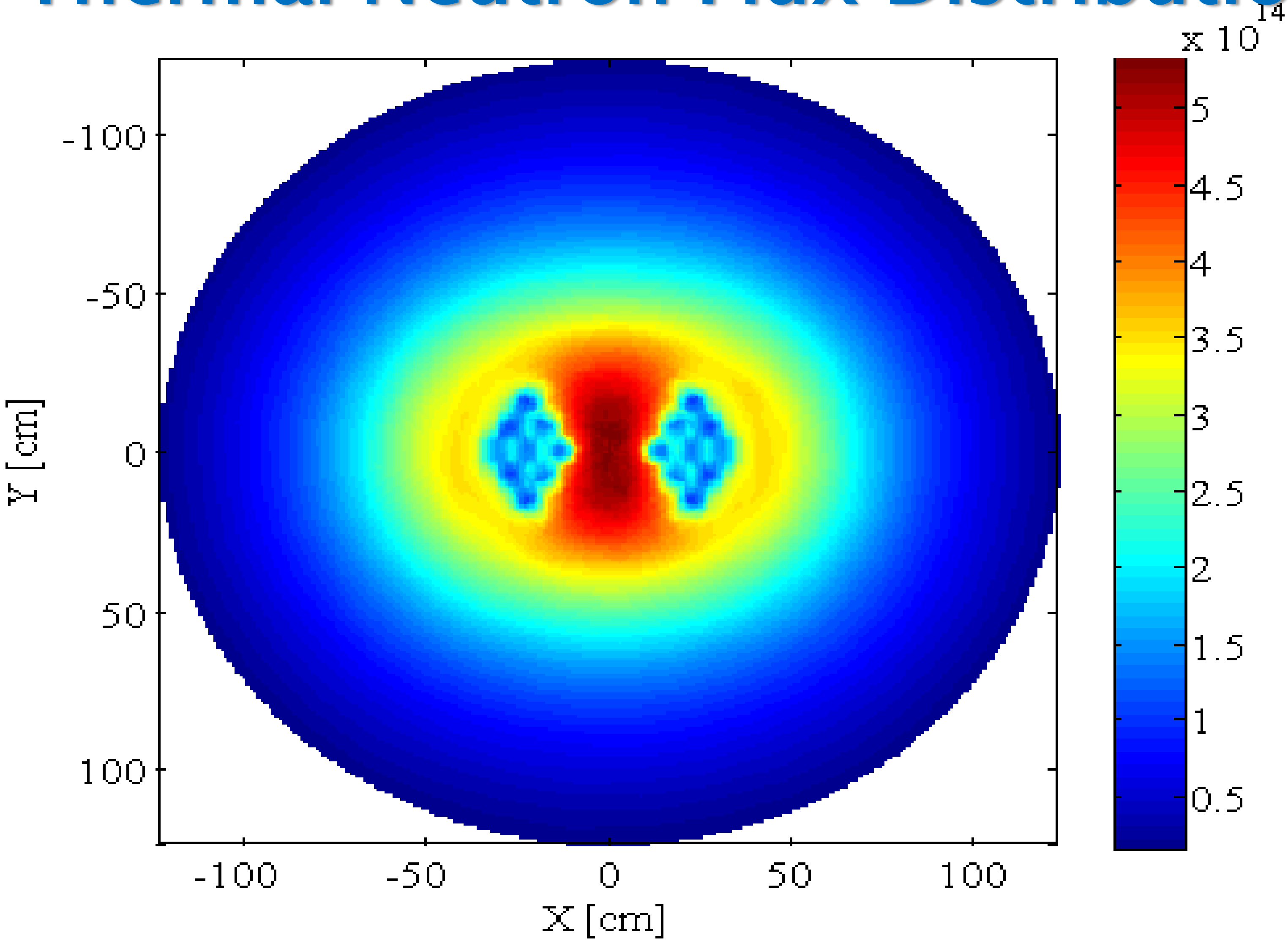
Independent Rod Worth



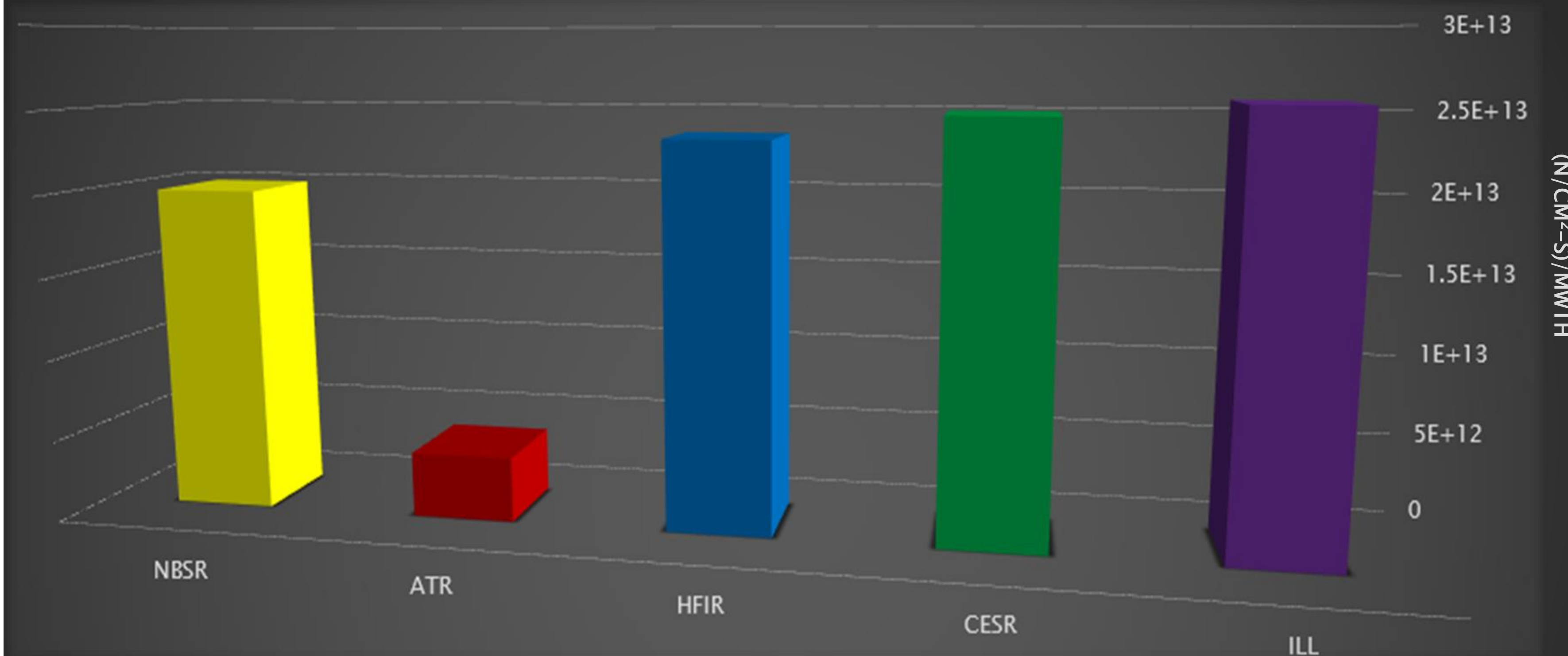
Flux Trap Comparison



Thermal Neutron Flux Distribution



Flux Heavyweight Champs



	Max thermal flux to operating power ratio
NBSR	2.00E+13
ATR	4.00E+12
HFIR	2.35E+13
CESR	2.50E+13
ILL	2.57E+13

All Hail CESR

- −5.5% fuel, and low-enriched $ ⬇⬇⬇
- −13.1% FE size; compact but complex $ ⬆
- −13.5% aluminum cladding mass $ ⬇
- +0.23% neutron multiplication (K_{eff}) $ ⬇
- **Room for control rods!**

Future Work

- CNS thermal/fast current ratio optimization
- Multi-physics modeling analysis
  - Thermal hydraulic feedback
  - Material degradation and life-extension studies
- Safety Analysis and Accident Scenarios

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NIST Center for Neutron Research

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Questions?

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CHRNS CENTER FOR HIGH RESOLUTION NEUTRON SCATTERING