INL/CON-19-55967-Revision-0

Four Design Demonstration Elments (DDEs) to be irradiated in the Advanced Test Reactor (ATR) and the Belgian Reactor 2 (BR2)

October 2019

Gregory K Housley, Warren F Jones, Irina Glagolenko, Hikaru Hiruta, Tamara E Shokes, Matthew R Hammond

Changing the World's Energy Future

Idaho National Laboratory

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

INL/CON=19-55967

Four Design Demonstration Elements (DDEs) to be Irradiated in the Advanced Test Reactor (ATR) and Belgian Reactor 2 (BR2)

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Idaho National Laboratory

RERTR 2019 – 40th International Meeting on
Reduced Enrichment for Research and Test Reactors

October 6-9, 2019
Westin Zagreb Hotel
Zagreb, Croatia

– PERMANENT THREAT REDUCTION –

MATERIAL MANAGEMENT AND MINIMIZATION

CONVERT, REMOVE, DISPOSE

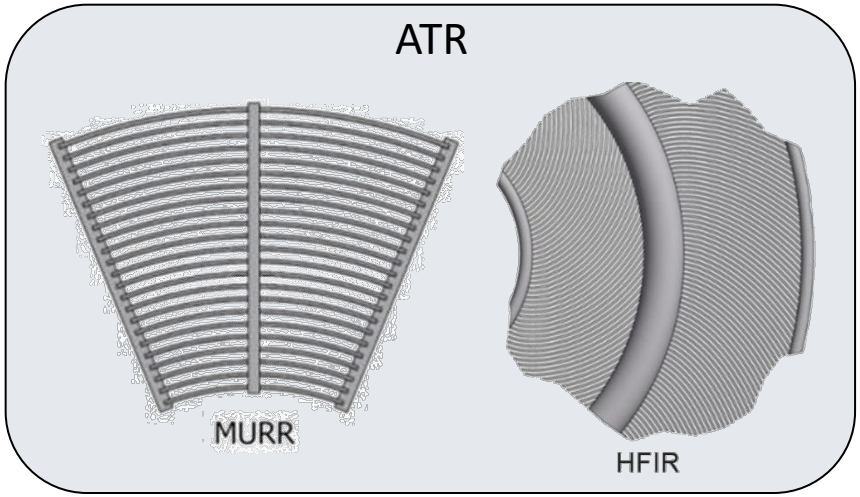
Outline

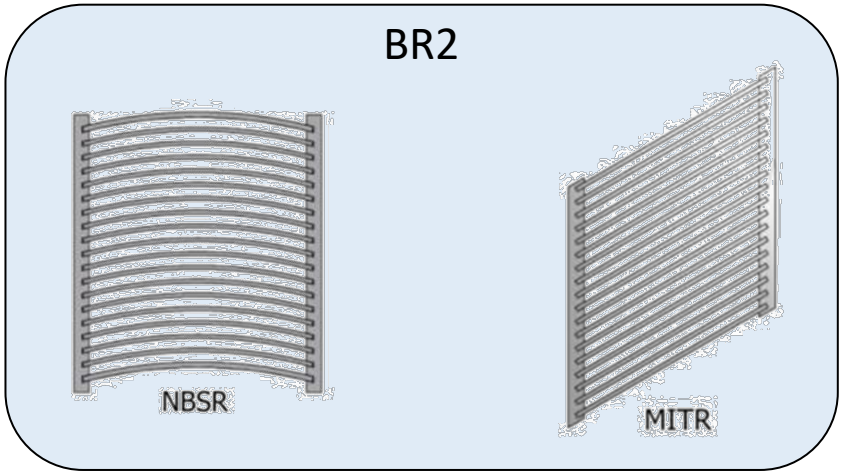
- Introduction to Design Demonstration Elements (DDEs)
- Requirements for all DDEs
- 2018 Scoping Study
- DDEs at ATR
  - DDE-MURR
  - DDE-HFIR
- DDEs at BR2
  - BR2 Capability Development
  - DDE-NBSR
  - DDE-MITR
- Conclusions

Introduction to DDE

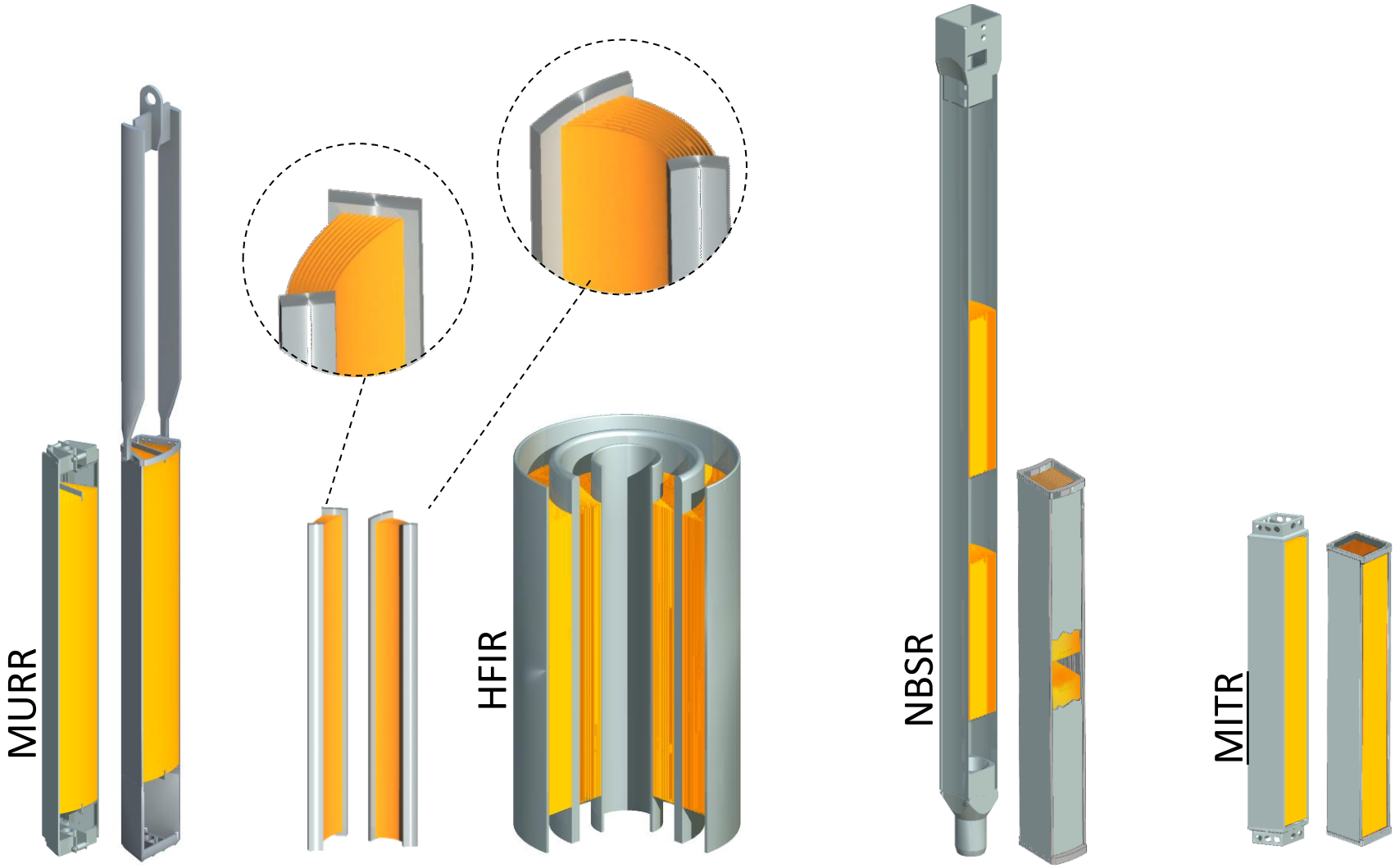
What is the purpose of a DDE?

- Demonstrate successful irradiation of a representative fuel element assembly (same fuel plates, fabrication processes, and assembly) prior to licensing that reactor.
- Not a base fuel qualification test
- Used to confirm the performance of the LEU fuel and the element assembly in an operational environment approximating its respective reactor.
- Supports each specific reactor licensing submittal.





Actual Element vs. Proposed DDE



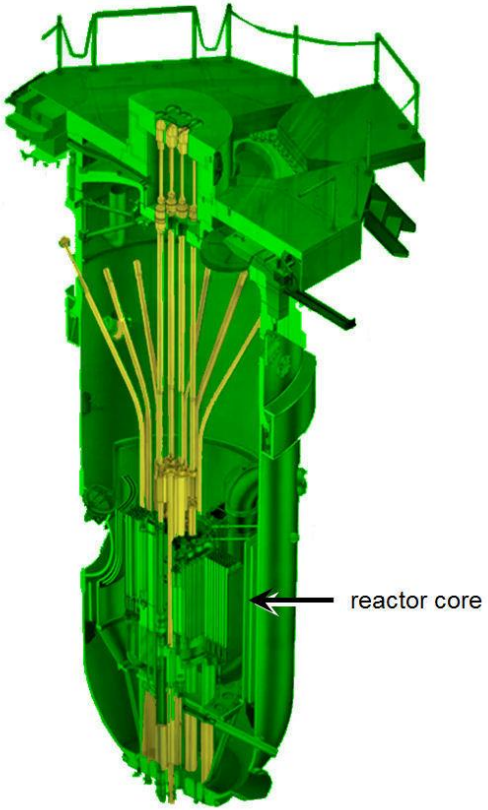
Key Requirements for testing DDEs

- Physically similar as possible to the represented element
- Acceptable differences involve changes to fit within the flux trap or channel to which it is being irradiated and for channel gap probe (CGP) measurements
- Reach peak power and fission density targets for that element.
- Closely match flow conditions
- Match surface temperatures
- Match power distribution across each plate as closely as possible
- Check against all failure modes, as PIE allows, i.e. corrosion, blister threshold, flow induced vibrations, etc.
- Evaluate for off-normal operation via blister threshold testing

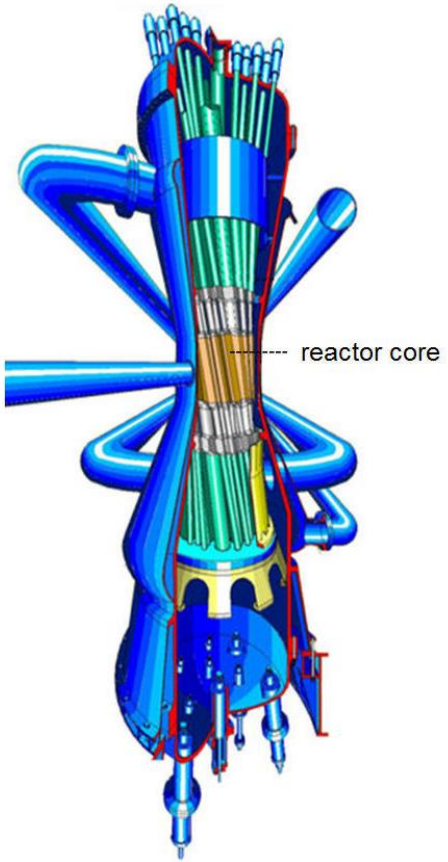
Scoping Study

Recap on Scoping Study performed in 2018

- Neutronics analysis was performed by both INL and SCK•CEN
- Both groups showed that the DDEs could be irradiated in either ATR or BR2



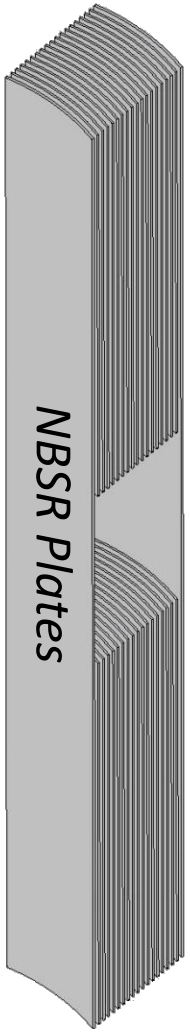
DDE-MURR and DDE-HFIR at ATR



DDE-NBSR and DDE-MITR at BR2

Scoping Study Conclusions

- Both ATR and BR2 are capable of performing the irradiations for all the monolithic DDEs.
- The decision to irradiate DDE-MITR and DDE-NBSR in BR2 had much to do with their ability to irradiate both DDEs simultaneously
- Design-Path Forward
  - More accurate match to power distribution targets of each of the elements being represented



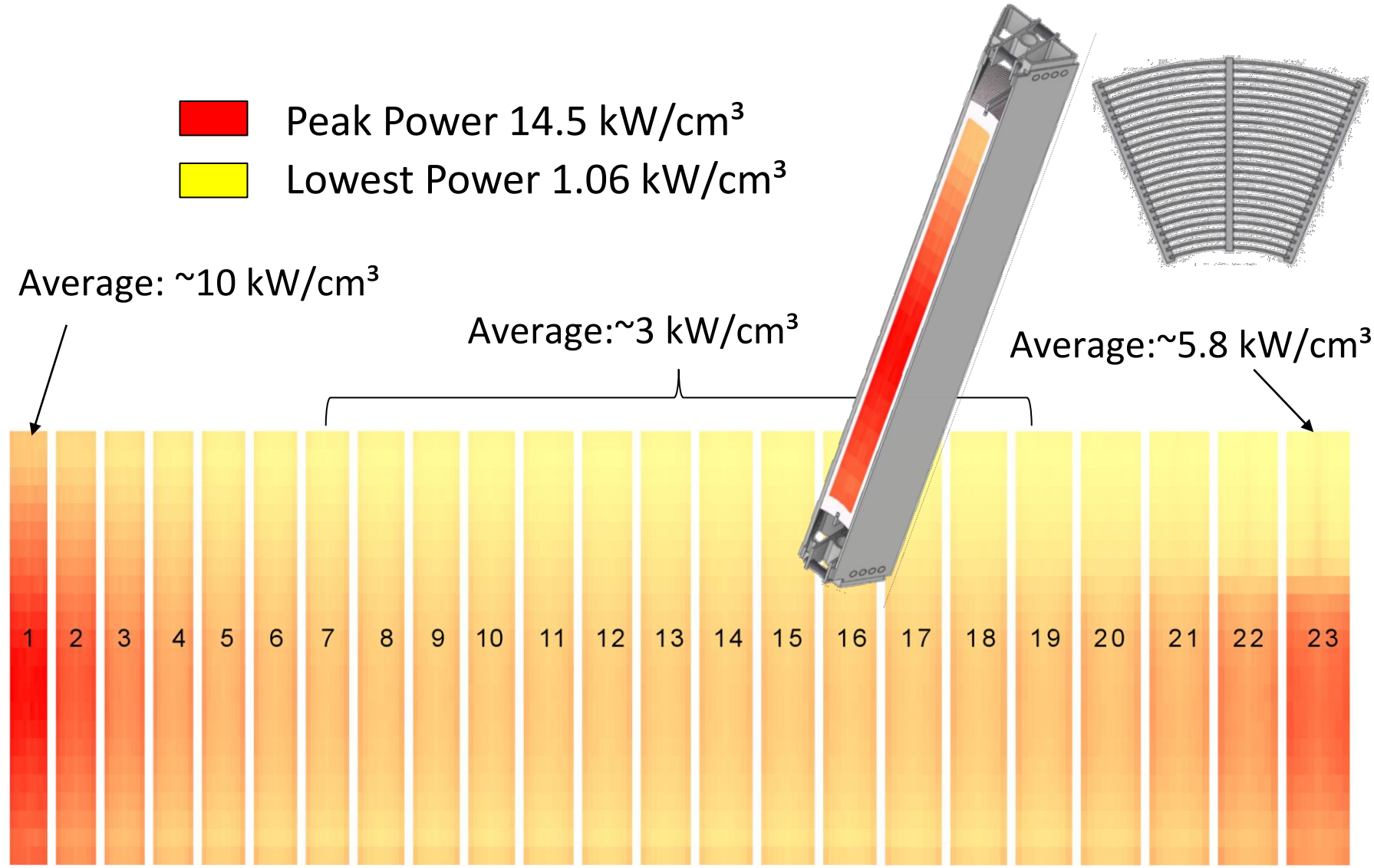
Target

Surface Heat Flux

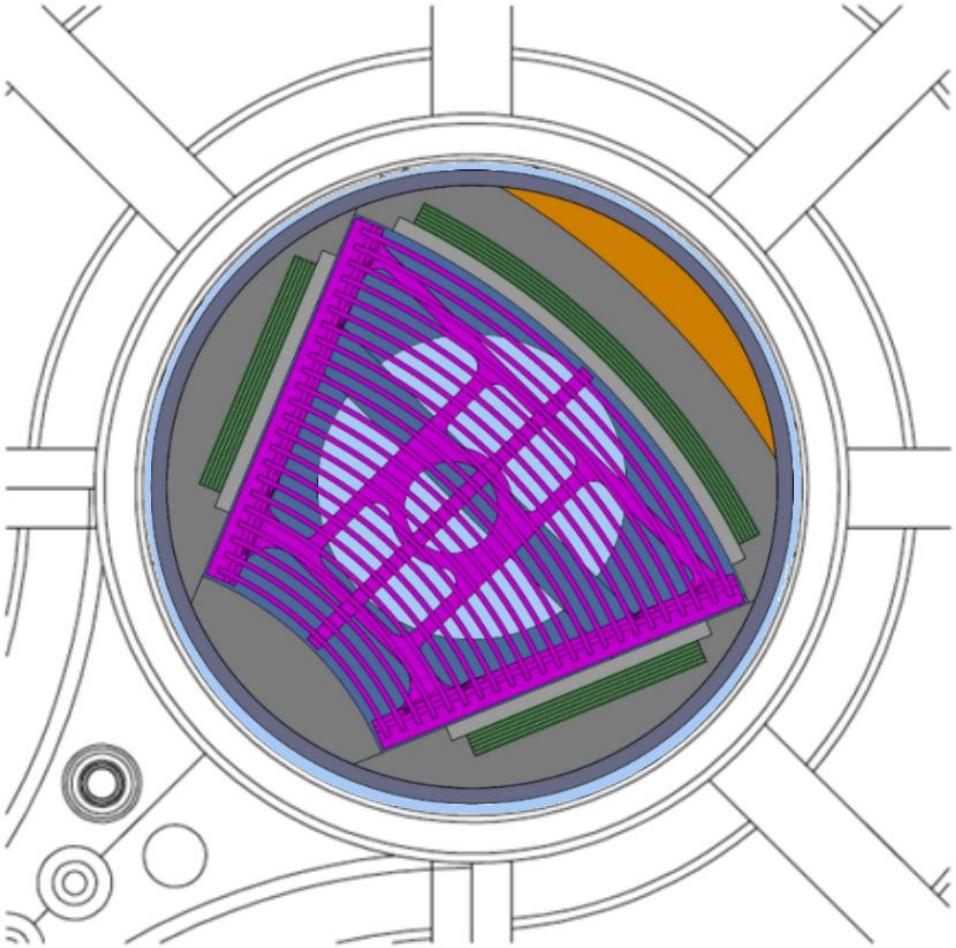
Target NBSR Surface Heat Flux (W/cm2)			
	Tranverse Nodes		
Upper Plate Row	91.85	82.96	91.85
	86.91	72.10	80.99
	86.91	72.10	80.00
	86.91	74.07	80.00
	84.94	76.05	81.97
	89.88	75.06	80.00
	93.83	79.01	82.96
	92.84	80.99	85.93
	101.73	85.93	94.81
	104.69	84.94	95.80
	111.60	89.88	98.77
	119.51	98.77	103.70
	126.42	107.65	112.59
	154.07	134.32	134.32
Lower Plate Row	160.00	140.25	139.26
	138.27	116.54	122.47
	130.37	103.70	106.67
	120.49	101.73	104.69
	118.52	94.81	101.73
	115.56	91.85	97.78
	111.60	89.88	94.81
	107.65	87.90	89.88
	105.68	83.95	86.91
	99.75	82.96	86.91
	101.73	82.96	86.91
	100.74	79.01	86.91
	99.75	84.94	86.91
	112.59	94.81	94.81

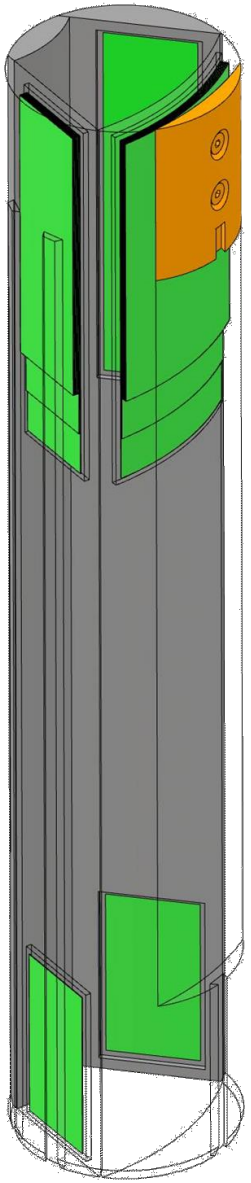
DDEs at ATR

Target Power Density Distribution for MURR Element (cycle zero) provided by ANL



DDE-MURR Neutronics Model (Preliminary)

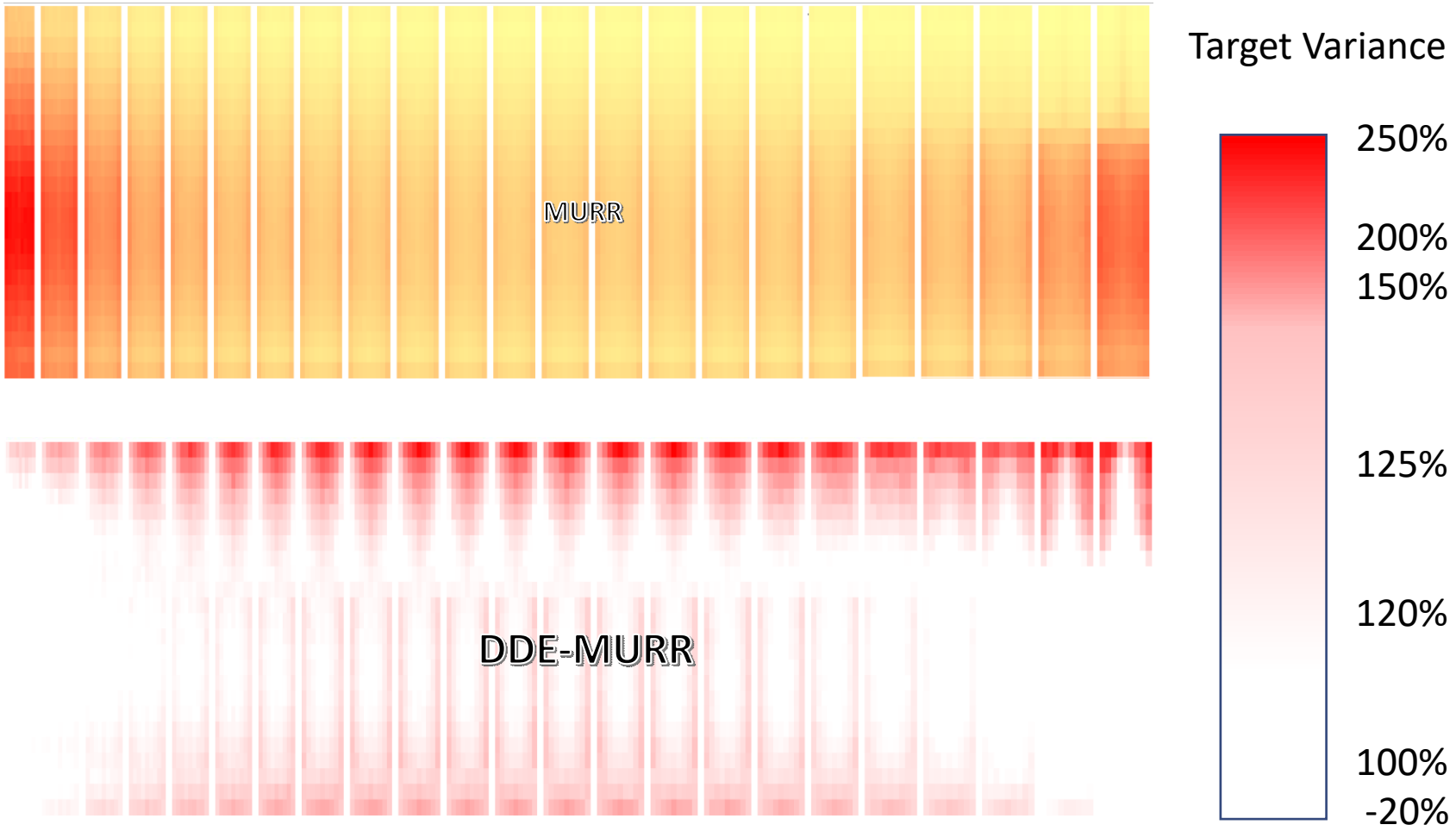




Total Core ATR Power = 96.25 MW

N.E. Lobe Power = 16.33 MW

Comparing MURR to DDE-MURR power density



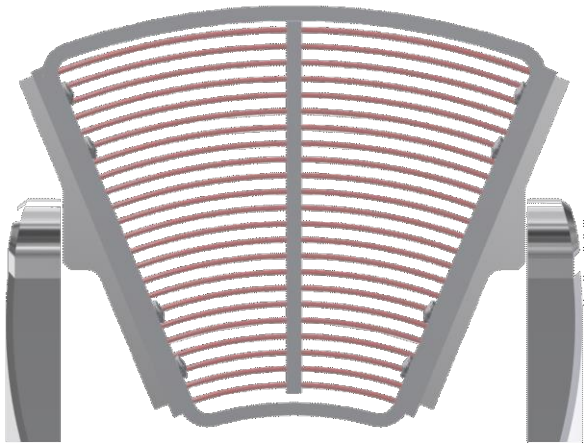
Continuing Design…

- Once we are satisfied with neutronics results, we present them to Reactor Conversion Pillar (RC) and the Experiment Working Group (EWG) and the test reactor representatives.
- If the results are shown to be satisfactory to RC and EWG, we continue.
- The goals are to match:
  - Power density distribution for each represented element
  - Fission density targets
  - Volumetric coolant flow conditions

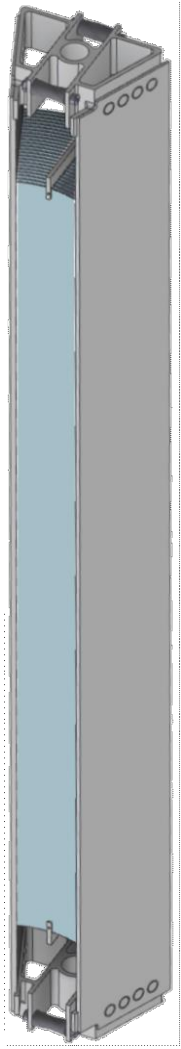
Comparison of MURR element to DDE-MURR

- MURR element is 32.5” tall & DDE-MURR is 32.5” tall
- Both have 23 fuel plates
- Plates are 25.5” long
- DDE-MURR has a lift handle

Top View of DDE-MURR

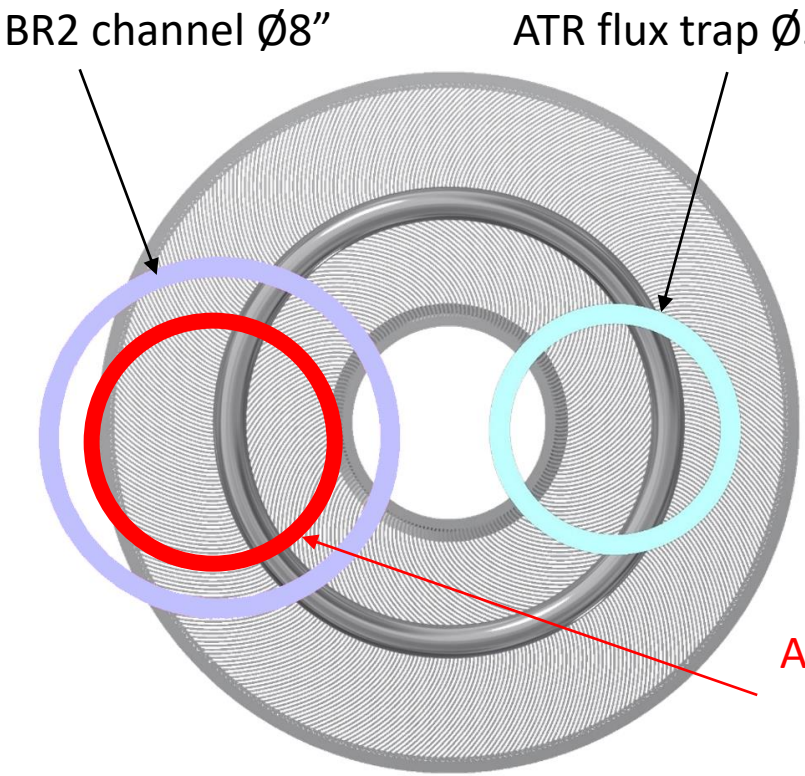


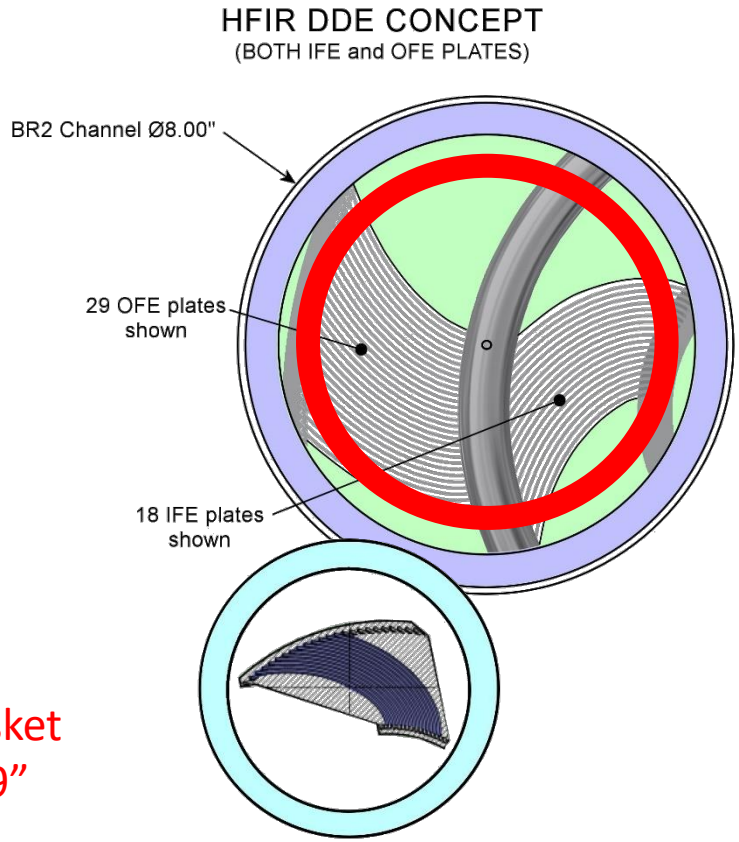
Top View of MURR element



DDE-HFIR is Unique

- An actual full-size DDE is not possible due to size constraints of test positions available.
- Challenge - design a DDE of an element segment to collect data representative of a full element.

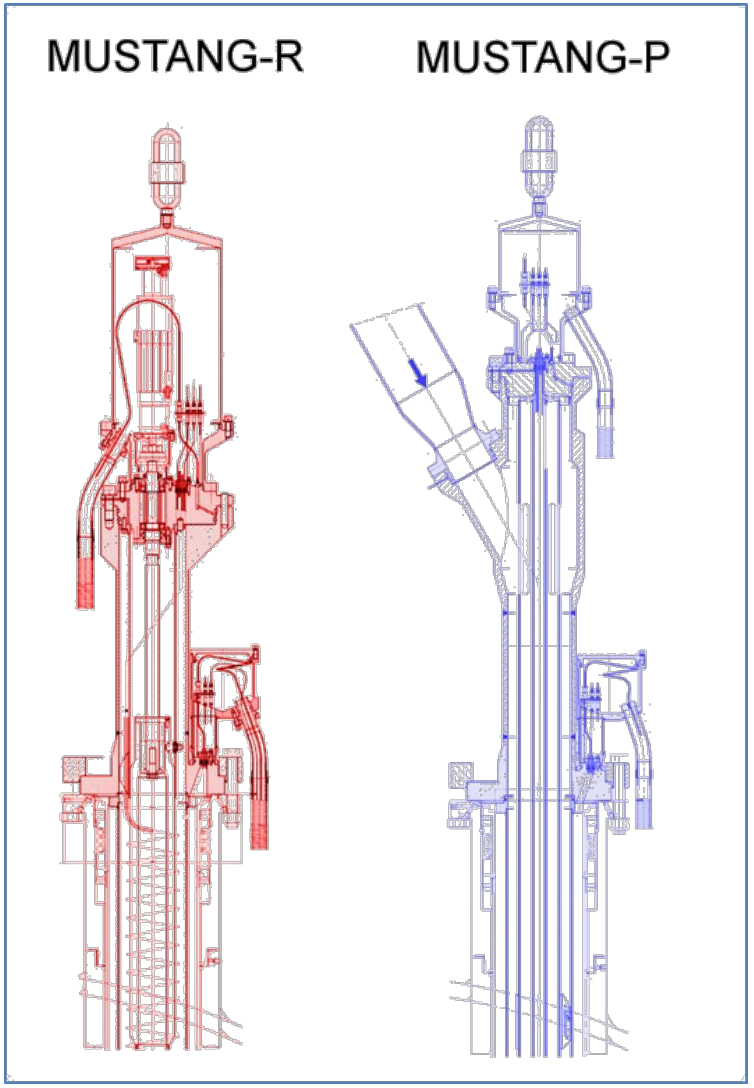




DDEs at BR2

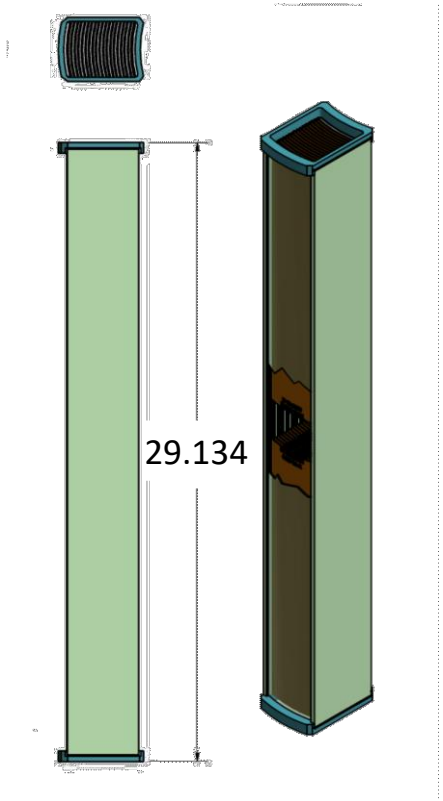
Capability Development Requirements

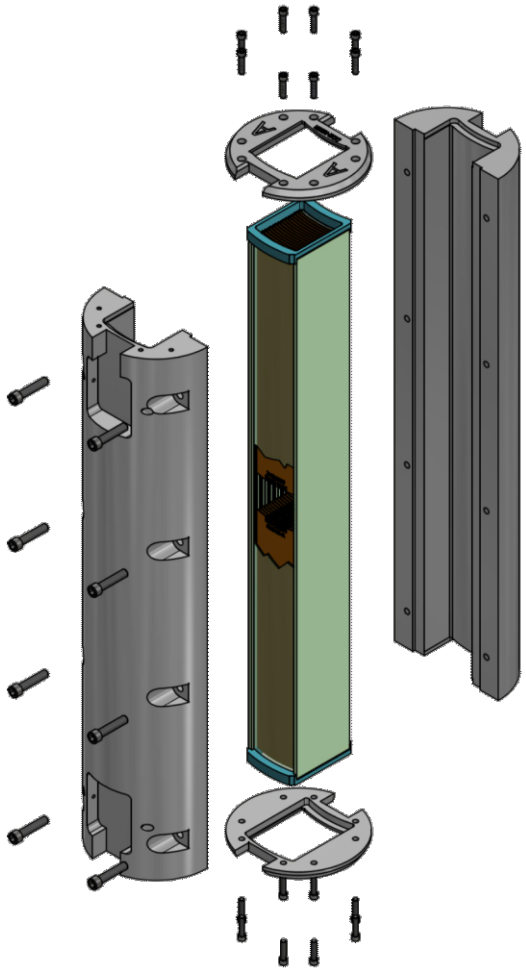
- Mustang-R (restrict) –
  - Device to hold irradiation vehicles in the channel. Has adjustable flow.
- Mustang-P (pump) –
  - Device to hold irradiation vehicle and allow for external pump to increase cooling flow.
- DDE Requirements –
  - DDE-MITR: MUSTANG-R
  - DDE-MURR: MUSTANG-R
  - DDE-NBSR: MUSTANG-R
  - DDE-HFIR: MUSTANG-P



Capability Development – Working together

- FQ pillar provides conceptual design of DDE-NBSR
- Input from both Fuel Fabricators and the Reactor Conversion pillar

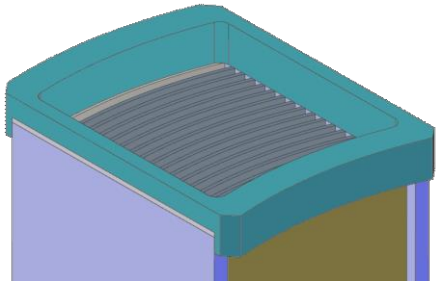


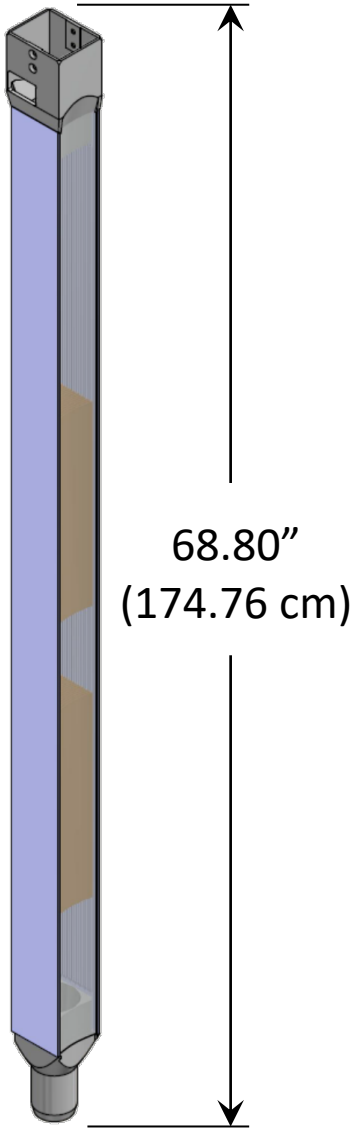


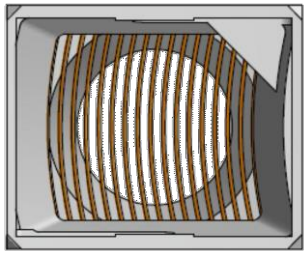
SCK-CEN designs basket to fit with the DDE design

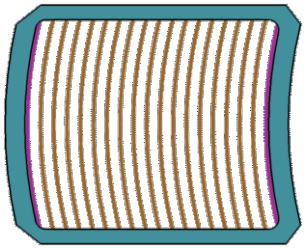
NBSR vs. DDE-NBSR

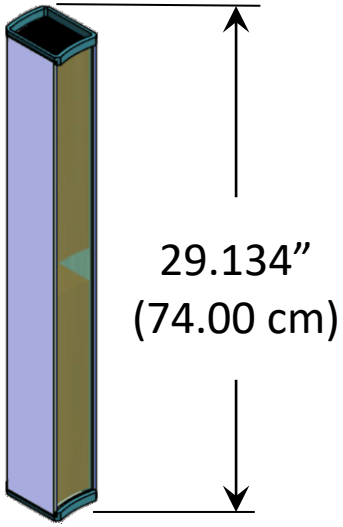
- DDE-NBSR is ~42% NBSR height
- DDE-NBSR has better access for CGP measurements
- DDE-NBSR fits within the BR2 core
- DDE-NBSR = 2” (50.8 mm) plate gap
  NBSR element = 5.5” (139.7 mm) gap
- Both
  - Two sets of 17 fuel plates (34 fuel plates total)
  - Fuel Plates = 13” (330.2 mm) long





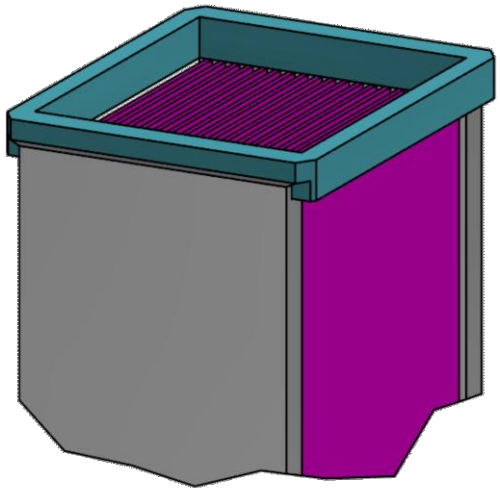


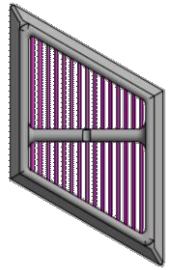


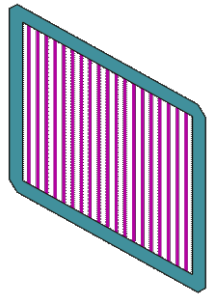


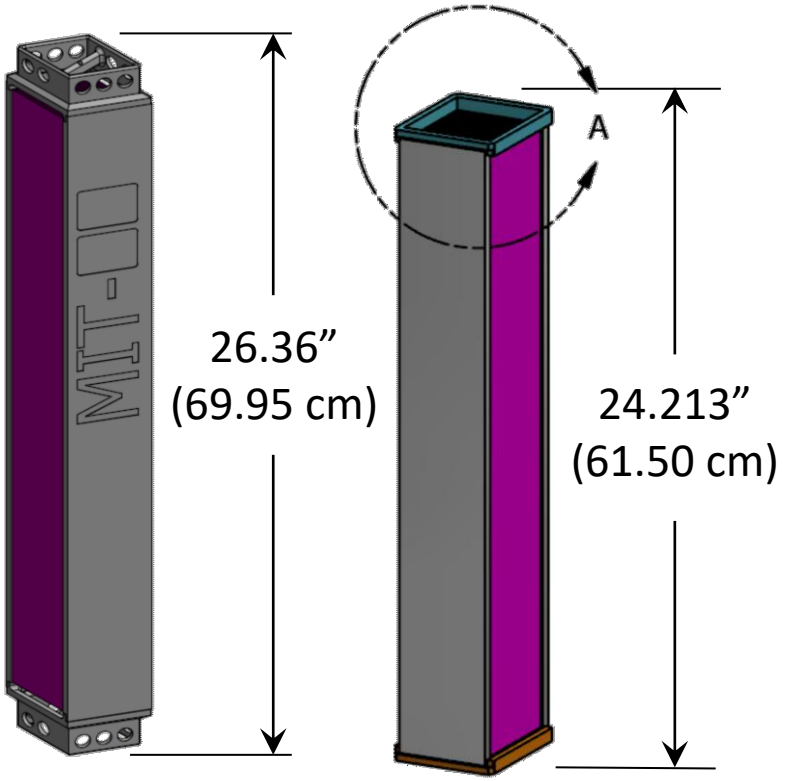
MITR vs. DDE-MITR

- DDE-MITR is roughly 92% MITR height
- DDE-MITR has better access for CGP measurements
- DDE-MITR fits within the BR2 core
- Both
  - 19 fuel plates
  - Fuel Plates = 23” (584.2 mm) long



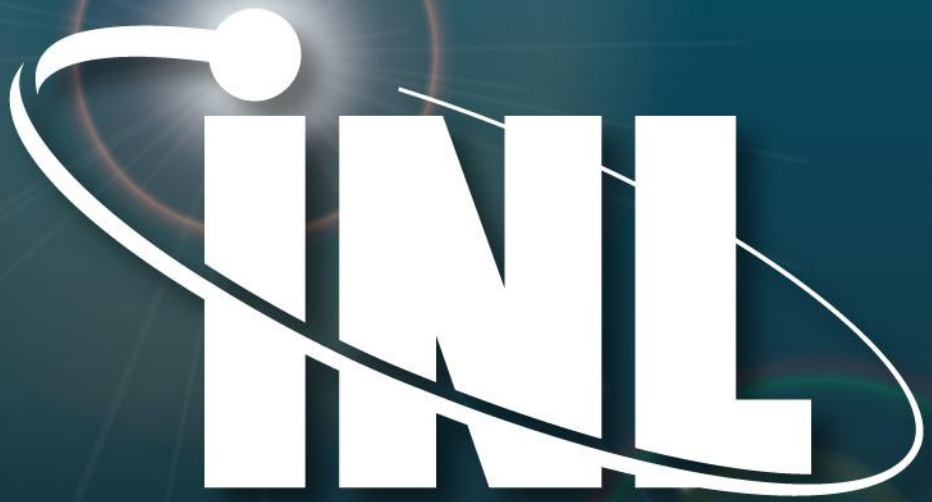






Conclusion

- DDE-MURR – Neutronics and design are well underway in Conceptual Design phase
- DDE-HFIR – Silicide Scoping study is laying the groundwork for upcoming FSP-HFIR and DDE-HFIR
- DDE-NBSR and DDE-MITR
  - The scoping study analysis at BR2 was very thorough. Both DDE elements' physical design are complete.
  - Baskets are being designed to allow flipping of the element. They are also being designed to account for any thermal expansion.
- Mustang-P is being designed.
- Mustang-R is being designed and materials are being purchased for fabrication.



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