FY 24 ORNL Integral Experiment work

FY 24 Annual NCSP Technical Program Review

December 3–5, 2024, Drury Plaza Hotel, Santa Fe

Hosted by Los Alamos National Laboratory

Mathieu Dupont

Collaborators: Eirini Klemes (NCSU), B. J. Marshall, Jordan McDonnell

ORNL Integral Experiment work during FY 24

Critical/Subcritical Experiment Design Team (CeDT) and Integral Experiment Request (IER) support:

IER #	IER description	Action	Staff in charge
IER-537	"Copper Critical Cerberus"	CED-3b sign off	Jordan McDonnell
IER-329	"TEX-U-233"	CED-2 sign off	B.J. Marshall
IER-499	"TEX-HEU with Cl"	CED-3a and 3b sign off	
IER-523	"UO2-BeO Critical"	CED-1 sign off	
IER-532	"TEX-Hf"	CED-4a and 4b sign off	

Integral Experiment Design leads from ORNL

- IER-498: Godiva IV Criticality Accident Alarm System (CAAS) Shielding Benchmark (Los Alamos National Laboratory - National Criticality Experiments Research Center [LANL-NCERC])
  - Priority shifted to FY25
  - CED-3a due in in FY25
- IER-304: Temperature-dependent experiments (Sandia National Laboratories – Sandia Pulsed Reactor Facility – Critical Experiments [SNL-SPRF/CX])
  - Priority shifted to FY25
  - CED-3a due in in FY25
- IER-441: Tantalum rods effects on critical system (SNL-SPRF/CX)
  - Experiments were completed in FY24 by SNL
  - ICSBEP evaluation due at 2026 ICSBEP TRG
- IER-554: Neutron Absorber Plates in SPRF/CX (SNL-SPRF/CX)
  - CED-3a started
  - Experiments should be completed in FY25

IER-441: tantalum rod effects on critical system

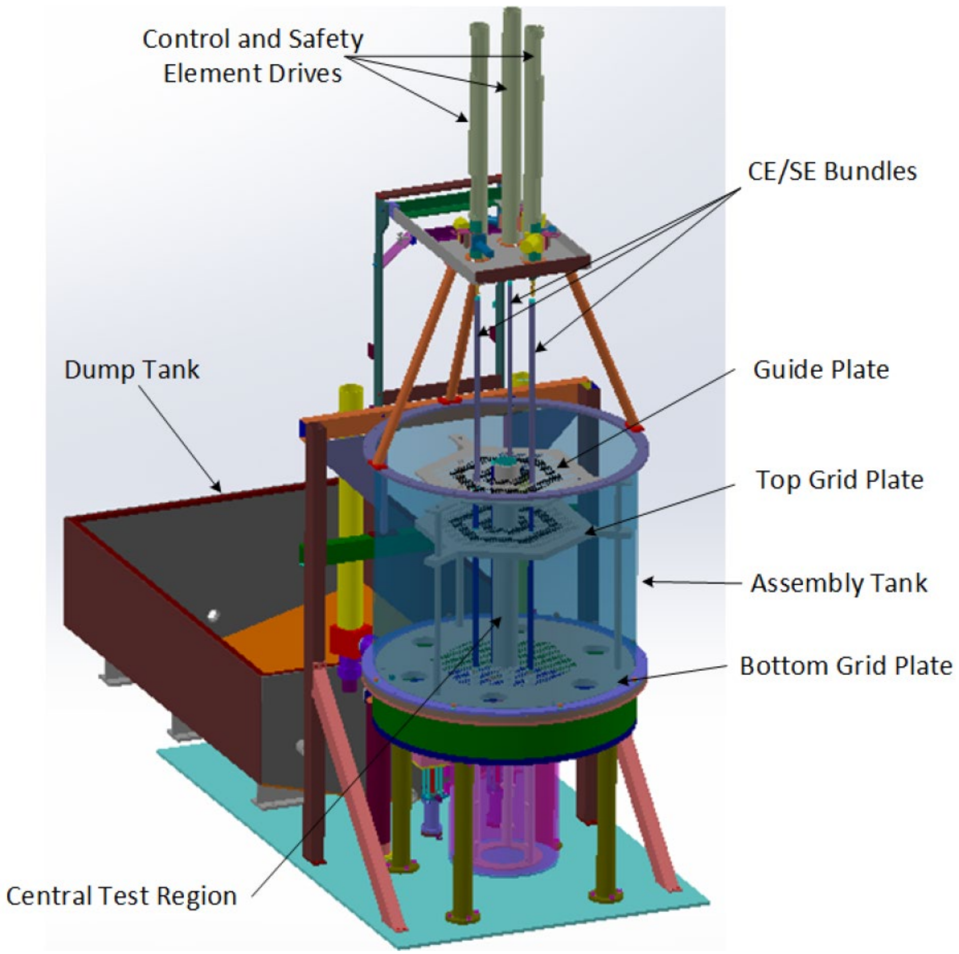
Base case: no Ta rods in central region

IER-441: tantalum rod effects on critical system

Full case: 86 Ta rods in central region

IER-554: neutron absorber plates in SPRF/CX

- Experiments analyze the effects of commercially available neutron absorber plate insertion in light-water assembly (SPRF/CX) on k_{eff}
- Boralcan plates comprise B_4C powder particles in aluminum matrix
- IER-441 grid plates are used
- Neutron absorber plates can be inserted into the same central test region
- CED-2 was officially completed in Q2 FY24 [1]



IER 441: Experiments to measure the effect of tantalum on critical systems (SNL/ORNL), David Ames, NCSP Technical Program Review 2023 [2]

IER-554: neutron absorber plates in SPRF/CX

Absorber plate to be inserted in the IER 441 grid plate

Aluminum plate holder (design to be updated by SNL)

Neutron absorber plate (12 × 3.25 in, variable thickness)

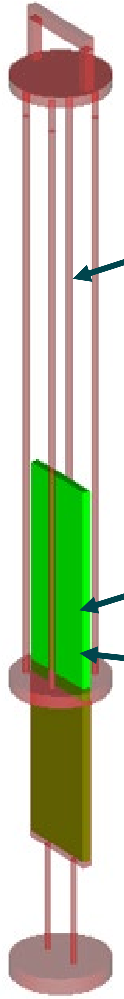
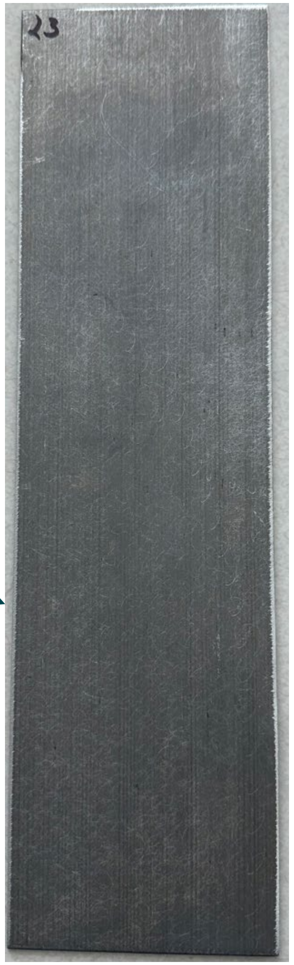


Plate holder [1]



Procured plate

IER-554: CED-3a progress

- Plates were received in Q1 FY25
- Plates are of different B_4C concentrations and thicknesses
- More than one sample was obtained from each plate to check for the potential influence of nonuniformities on k_{eff}

Characteristics of the procured Boralcan plates

B_4C concentration (%)	Width (in.)	Length (in.)	Thickness (in.)	Quantity
17	12	3.25	0.085 ± 0.005	3
19	12	3.25	0.073 ± 0.005	3
21	12	3.25	0.080 ± 0.005	3
23	12	3.25	0.080 ± 0.005	3

Procured Boralcan plates

IER-554: responsibilities

ORNL

ORNL procurement and initial geometrical characterization of the plates

↓

X-ray CT scan

3D image at ORNL

↓

Chemical assay and neutron transmission by Curtiss-Wright

↓

Transfer of plates from Curtiss-Wright to SNL

SNL

Plate holder, aluminum plate sleeves, and plate blank design

↓

SNL procurement, reception of plates, and weight/geometrical characterization

↓

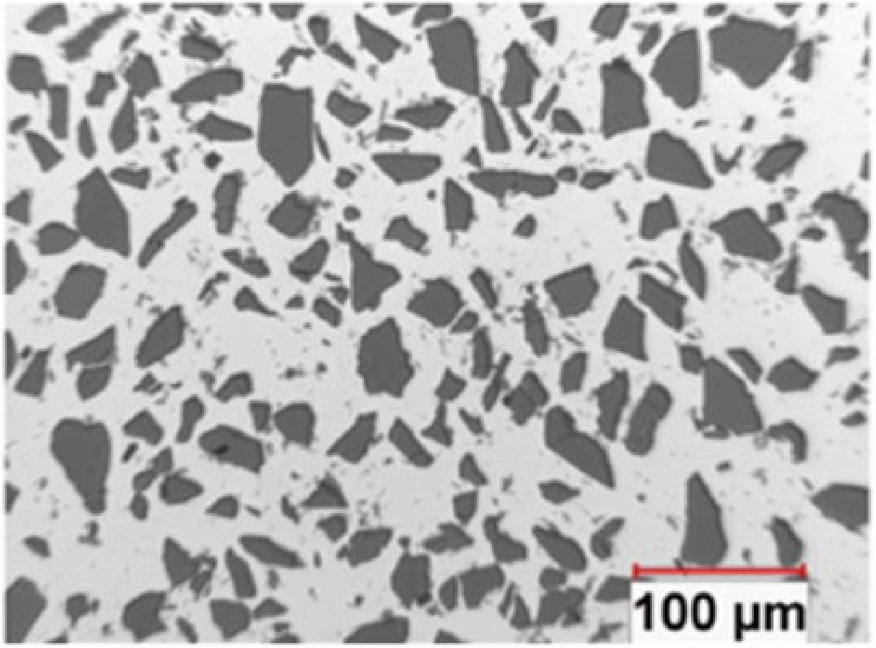
Component manufacturing

↓

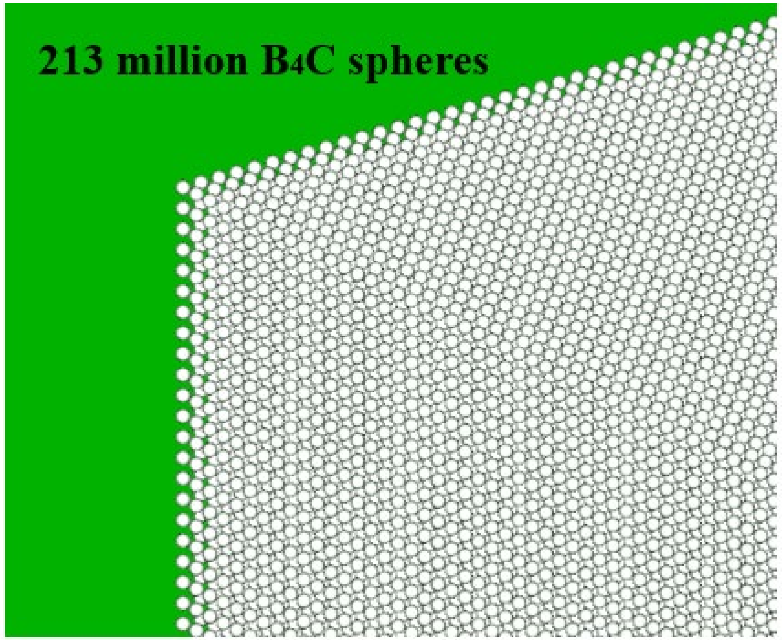
Experiment plans, readiness level determination, and core analysis report

IER-554: neutron absorber plates in SPRF/CX

- For benchmark specifications:
  - Can plates be modeled with a homogeneous B_4C / aluminum mixture?
  - How uniformly distributed is the B_4C in those plates?
  - What is the influence on k_{eff}?
- CED-1 study: explicit B_4C particles modeled on k_{eff} while keeping B_4C mass constant



Excerpt of Boralcan metallographic report created by Rio Tinto

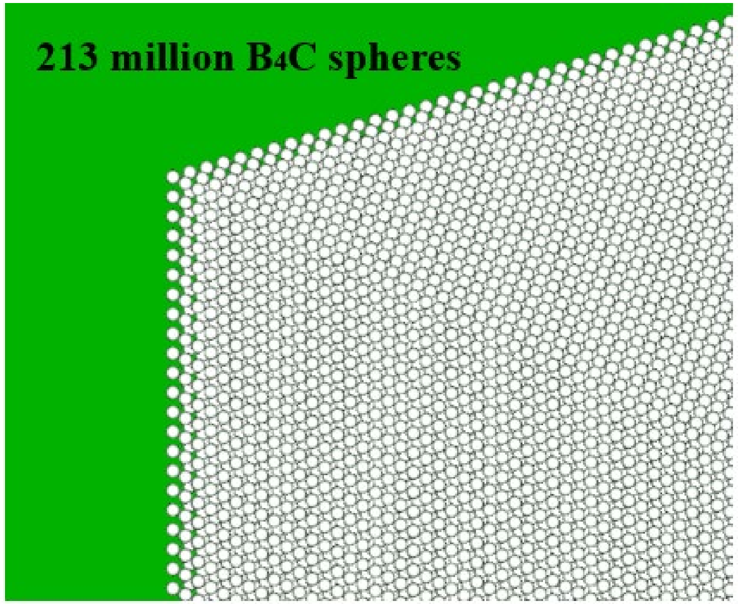


B_4C particles individually modeled, enlarged 4,000 times [3]

IER-554: neutron absorber plates in SPRF/CX

Influence of Boralcan modeling methodology on k_{eff}

Modeling method	Plate dimensions (width × length × thickness in cm)	B_4C sphere diameter (µm)	k_{eff} (sig=10 pcm)
Homogeneous	5 × 5 × 0.75	N/A	1.00006
Individually modeled B_4C particles	5 × 5 × 0.75	100	0.99993
Individually modeled B_4C particles	5 × 5 × 0.75	30	0.99988



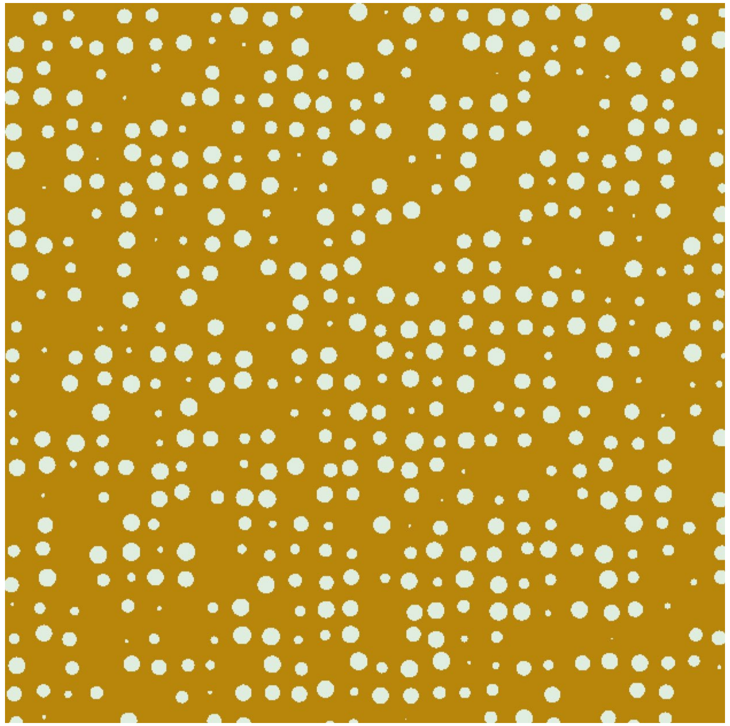
B_4C particles individually modeled, enlarged 4,000 times [3]

- Modeling is not realistic: we need to go further

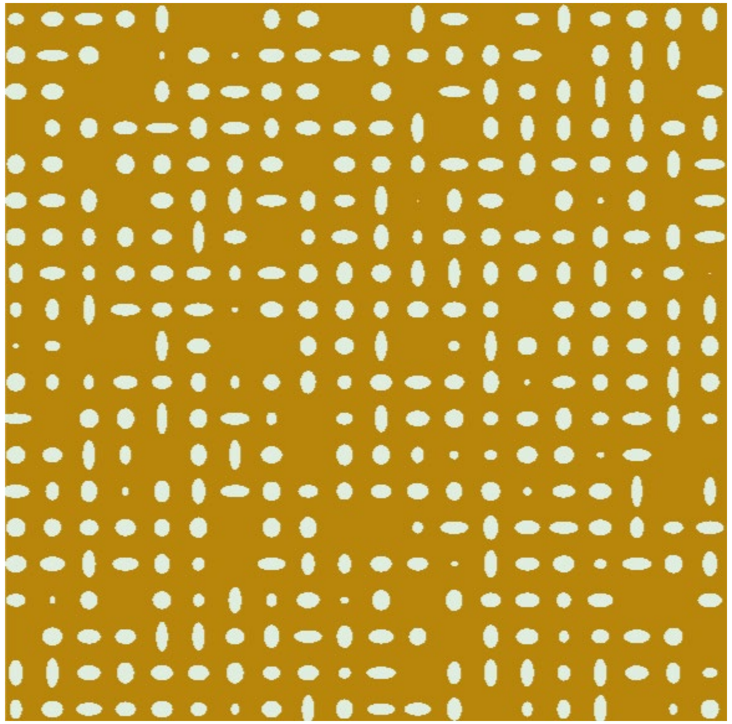
OAK RIDGE National Laboratory

IER-554: neutron absorber plates in SPRF/CX

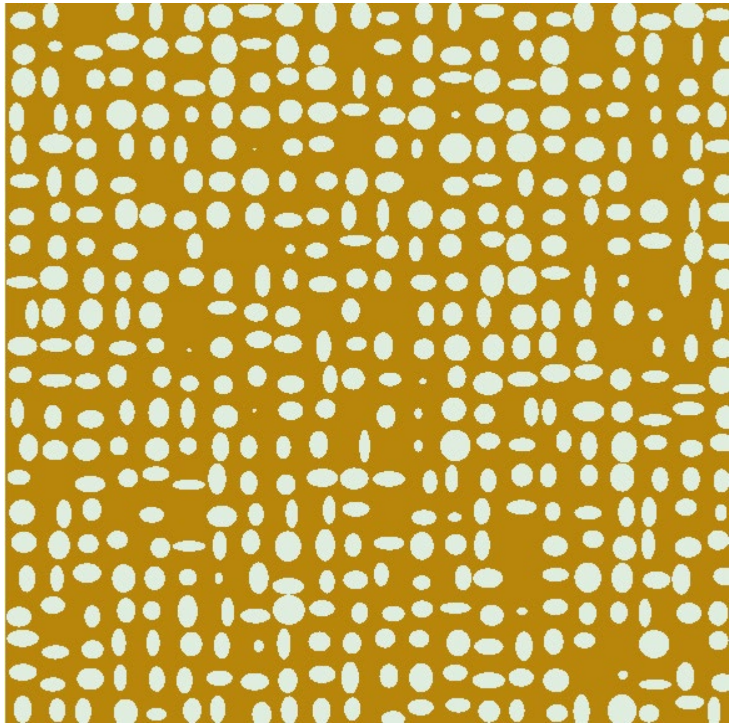
- CED-3a study on the use of randomly sampled origin and randomly sampled shapes dimensions for explicit B_4C particles modeling (Eirini Klemes, NCSU, summer intern at ORNL) [4]



Random origin spheres



Random size ellipsoids



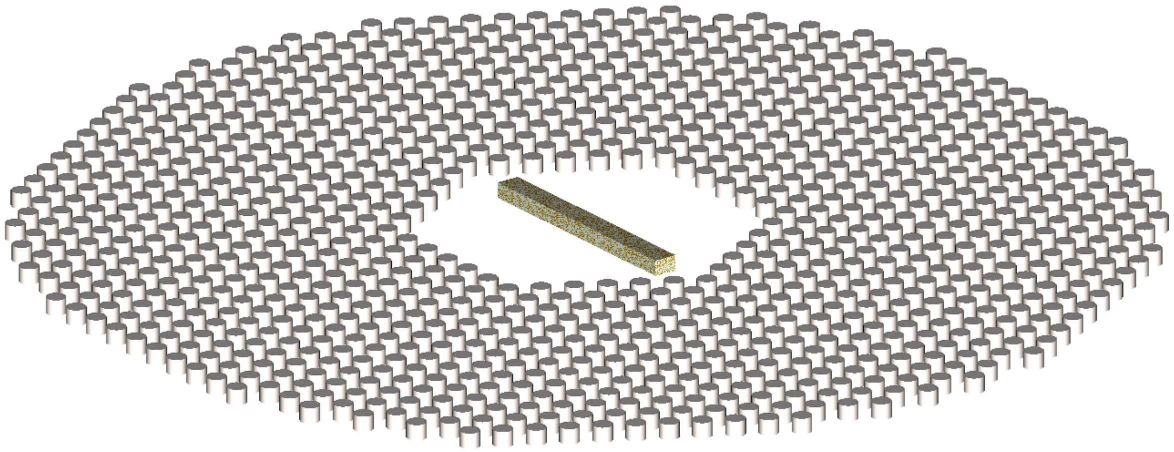
Random size and origin ellipsoids

IER-554: neutron absorber plates in SPRF/CX

- Klemes CED-3a study:
  - Fragmentation of the problem was implemented by modeling a 0.5 cm thick slice with reflective boundary conditions
  - Influence on k_{inf} should be the same

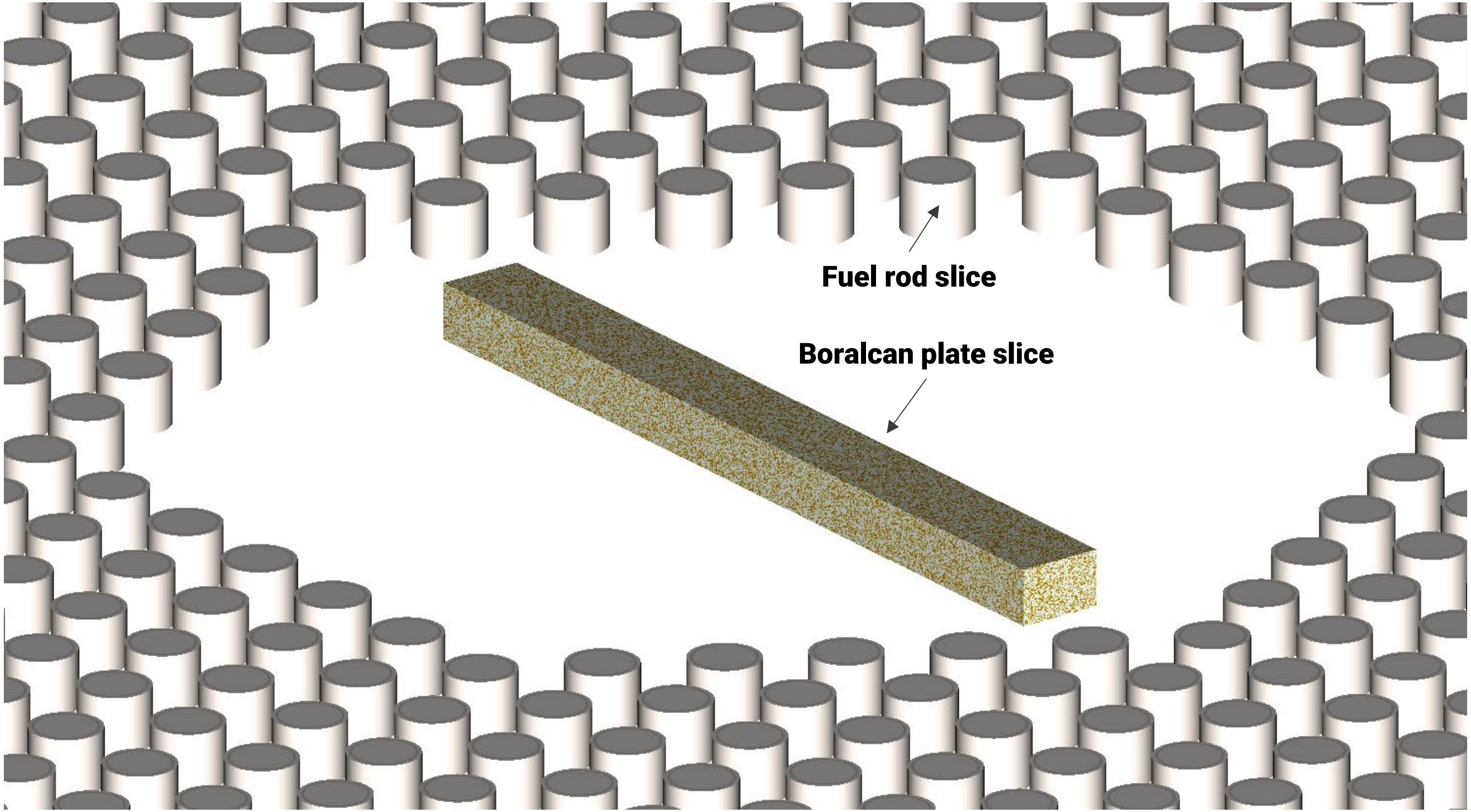
```
=shell
    ln -s /Users/eiriniklemes/.../sampler/size_gen_samp.part sampler.part
end
=sampler
read parameters
n_samples=10
 perturb_geometry=yes
 run_cases=no
library="ce_v8.0"
end parameters

read case[c1]
import="home/ek2/P1/sampler/keno_ellipsoids.inp"
'import="/Users/eiriniklemes/.../sampler/keno_ellipsoids.inp"
<sampler.part
end case
end
```

SCALE Sampler input file



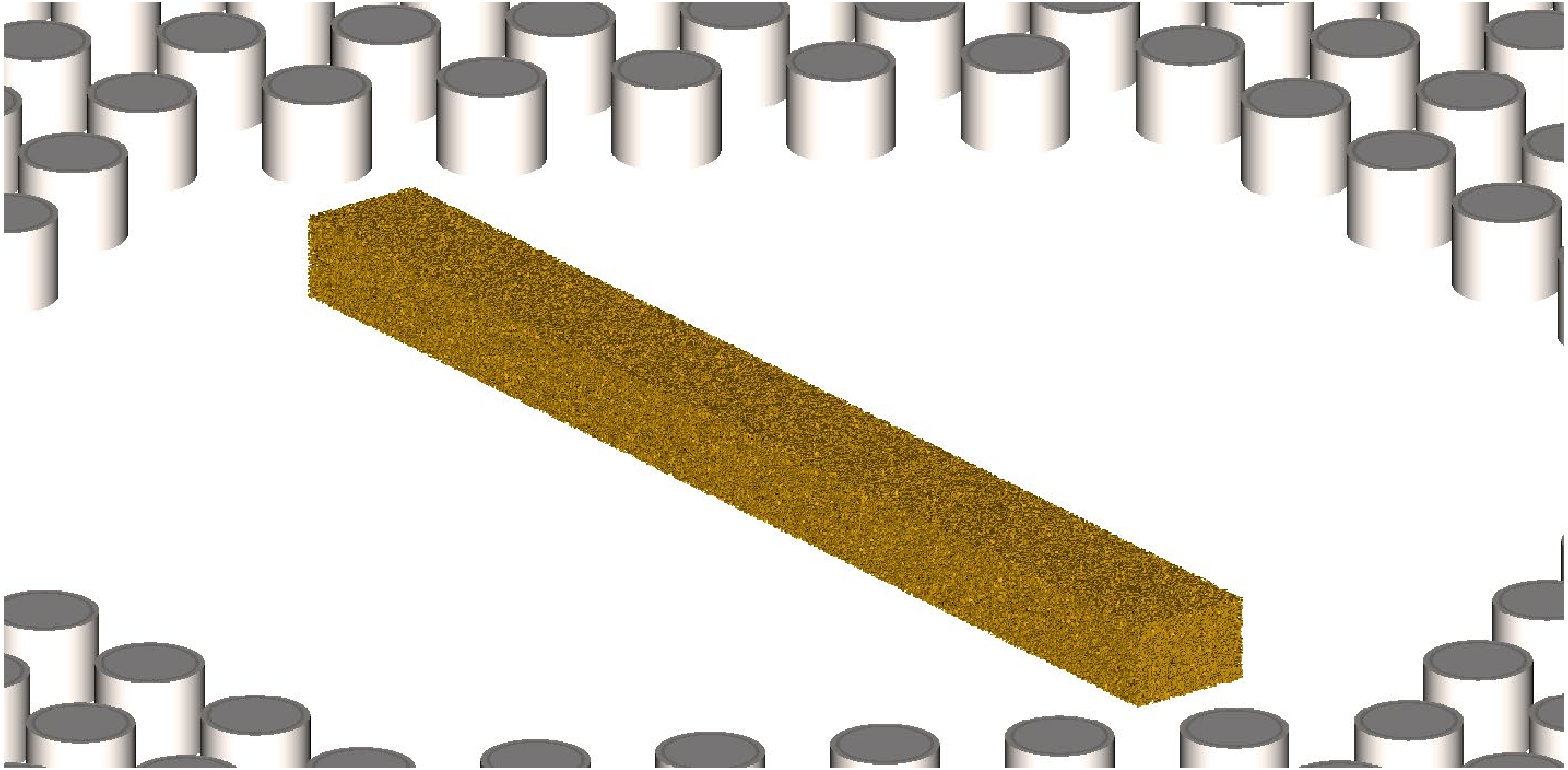
3-D view of 0.5 cm thick slice

IER-554: neutron absorber plates in SPRF/CX



3-D view of 0.5 cm thick slice zoomed on Boralcan plate

IER-554: neutron absorber plates in SPRF/CX

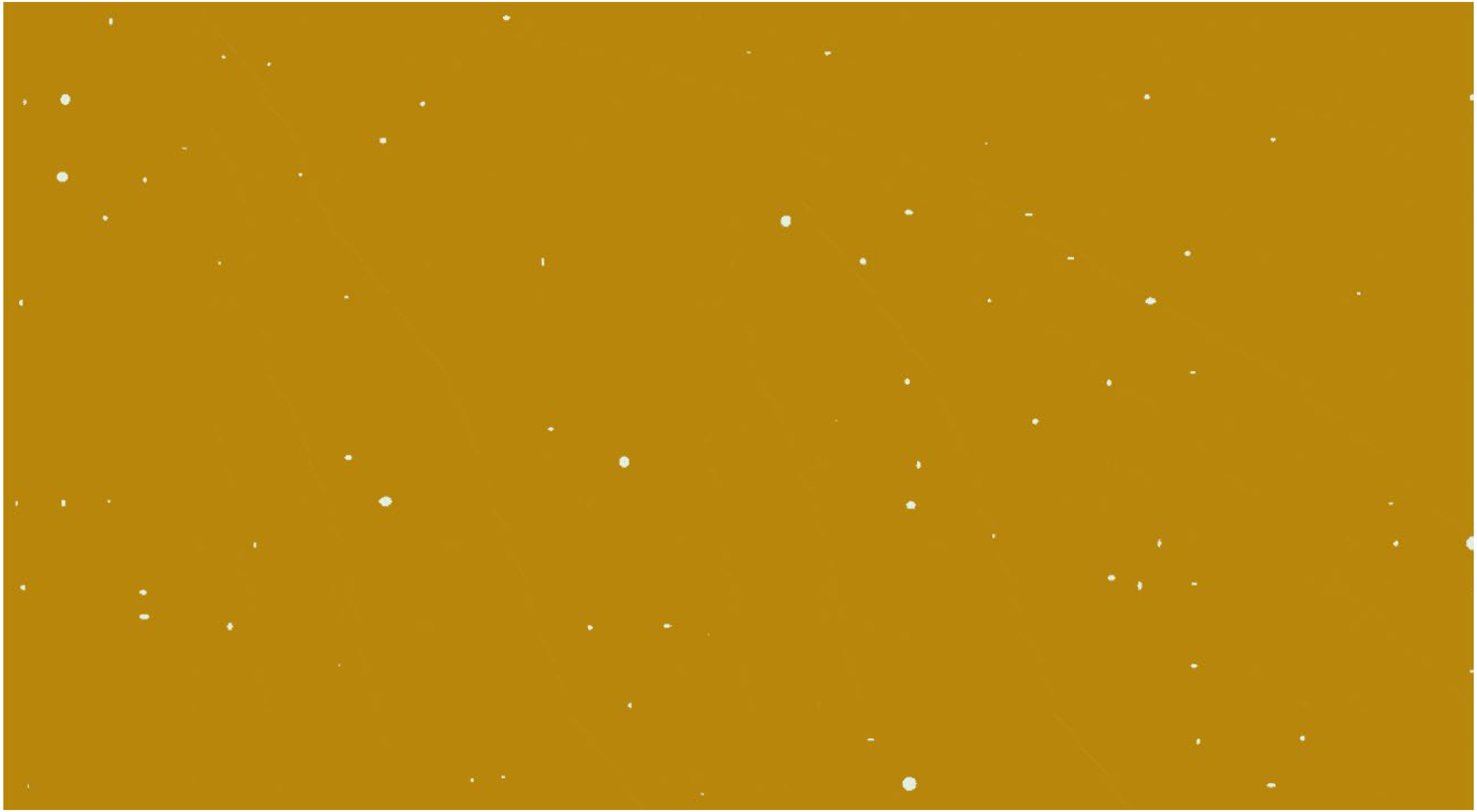


3-D view of 0.5 cm thick slice zoomed on Boralcan plate with aluminum mixture removed

IER-554: neutron absorber plates in SPRF/CX

Top view of Boralcan slice model with random size and location of ellipsoids, sliding axially

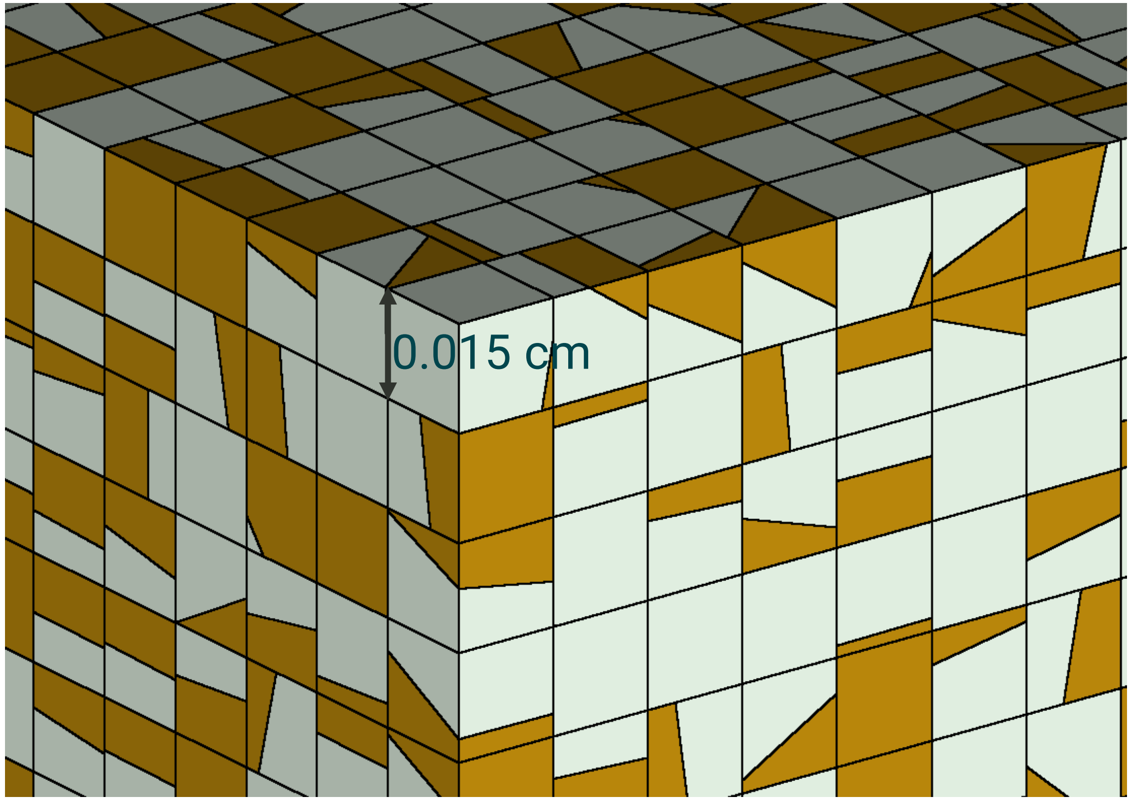
Oak Ridge National Laboratory



Top view of Boralcan slice model with random size and location of ellipsoids, sliding axially and zoomed

IER-554: neutron absorber plates in SPRF/CX

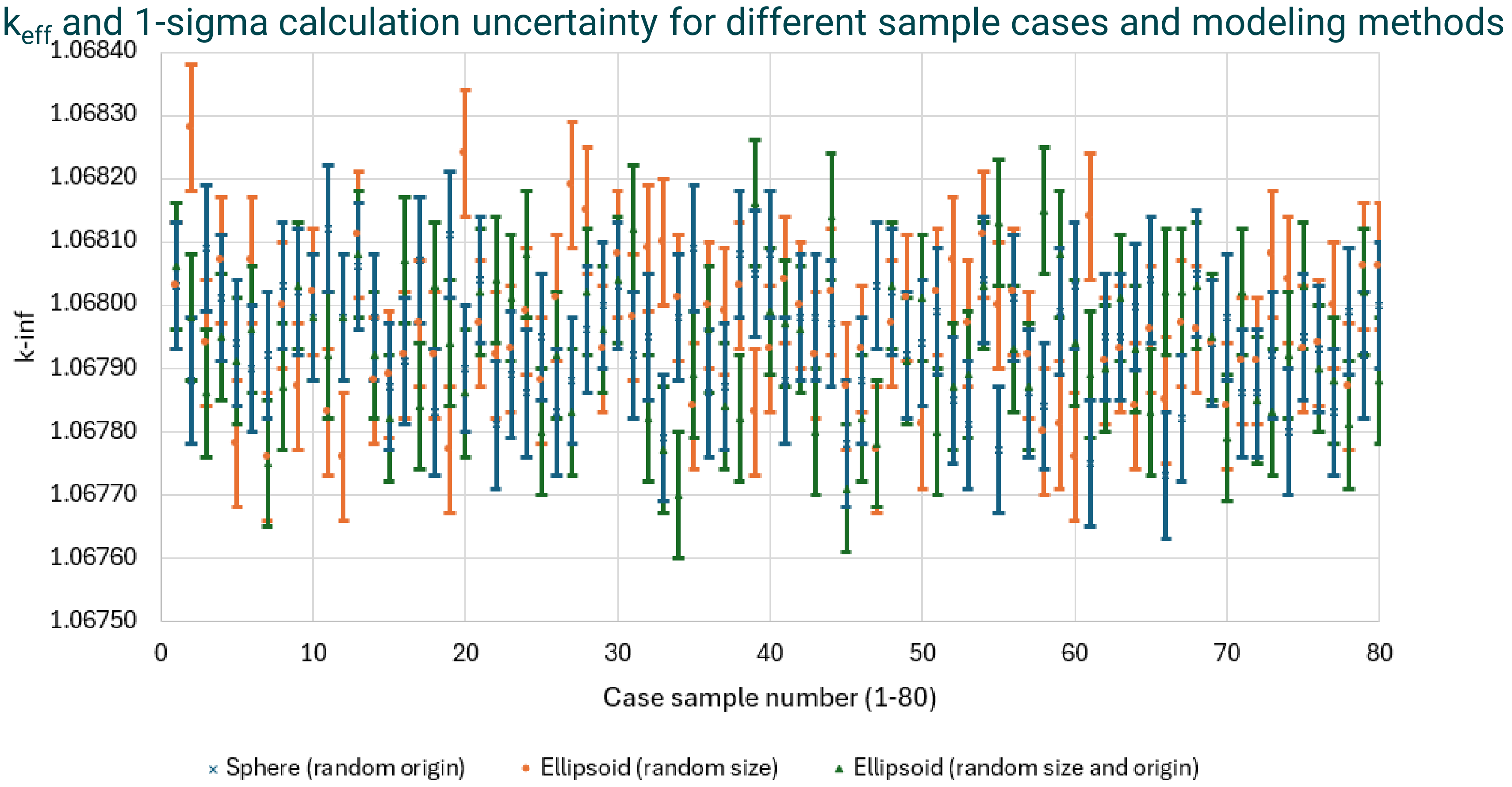
- Facts
  - 934,826 randomly sampled ellipsoid dimensions and origin
  - 3.7 million–line input file, 175 MB
  - 40 million–line output file, 1.69 GB
  - ~20 min. to load the file in Fulcrum
  - ~2 min. to load the 3D geometry
- SCALE limits were pushed, and several issues were discovered
- Generation of very small ellipsoids (~<0.01 cm semi-axis) was not working properly in SHIFT, but was acceptable in KENO-VI



Fulcrum 3-D visualization:
SCALE 6.3 ORANGE geometry builder transforms very small ellipsoids into planes

IER-554: neutron absorber plates in SPRF/CX

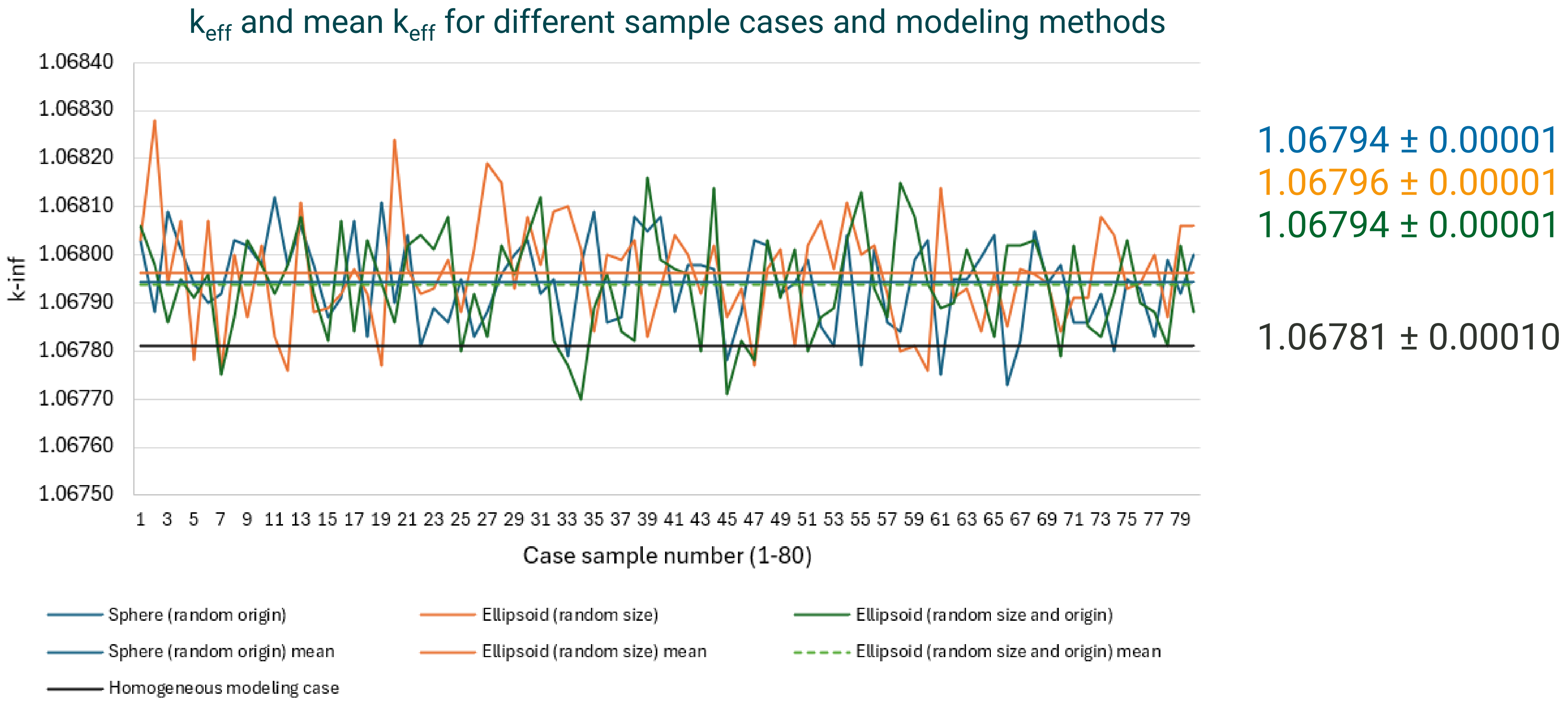
- Results



  - Standard deviation of approximately 10 pcm between the three cases
  - No significant changes between the three methods

IER-554: Neutron Absorber Plates in SPRF/CX

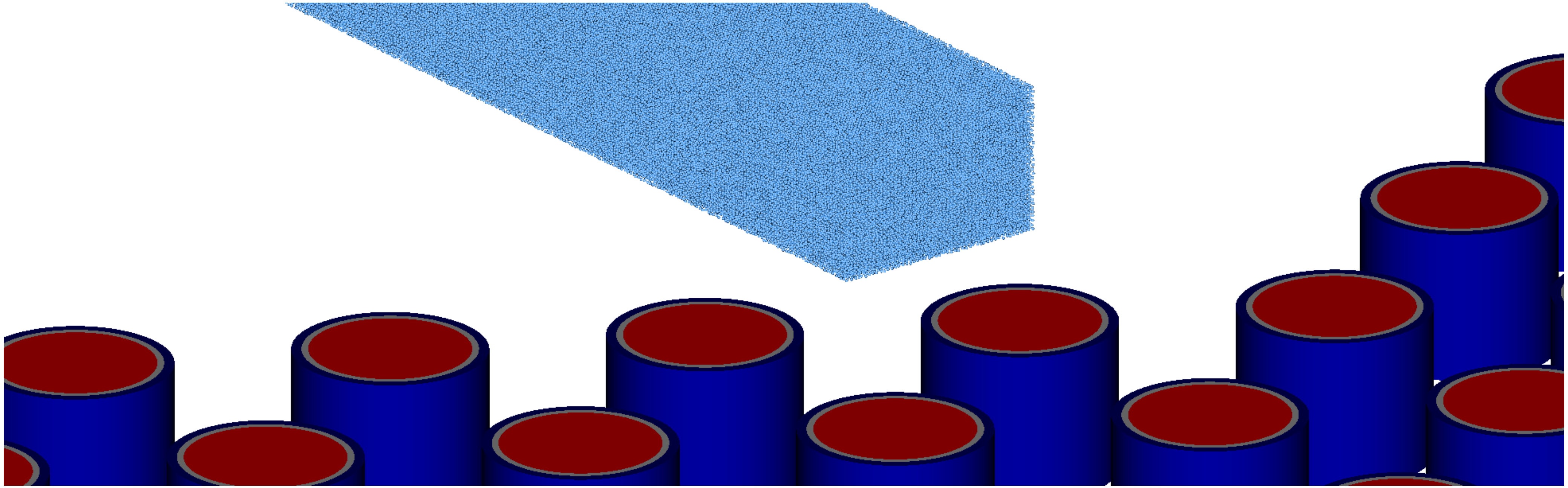
- Results



  - Mean results of 1.06794, 1.06796, and 1.06794 ± 0.00001 compared to 1.06781 ± 0.00010 for the homogeneous modeling method: little or no influence on k_{inf} results

IER-554: Neutron Absorber Plates in SPRF/CX

- Conclusions
  - CED-3a and b are on track for FY25
  - ORNL and SNL are working in parallel and collaborating
  - Explicit modeling of B_4C seems to have no influence on k_{eff}, but limitations exist, and more work can be done
  - Plate characterization will be very important for providing information on the future ICSBEP evaluation



Fulcrum 3-D visualization of 0.5 cm thick slice

References

[1] M. N. Dupont, D. Ames, G. Harms, W. J. Marshall, and M. Pigni *Integral Experiment Request 554: CED-2 Summary Report*, ORNL/TM-2023/3124, Oak Ridge National Laboratory (2023).

[2] D. E. Ames, M. N. Dupont, G. A. Harms, A. Chapa, and E. Lutz, IER-441: “Experiments to Measure the Effect of Tantalum on Critical Systems (SNL/ORNL),” Nuclear Criticality Safety Program Review Meeting, February 21–23, Albuquerque, NM (2023).

[3] M. N. Dupont, D. E. Ames, G. A. Harms, W. J. Marshall, and M. T. Pigni, *Integral Experiment Request 554 CED-1 Summary Report*, ORNL/TM-2022/2682, Oak Ridge National Laboratory, Oak Ridge, TN (2022).

[4] E. Klemes, M. N. Dupont, and W. J. Marshall, “Explicit Modeling of B_4C in Neutron Absorber Plates with SCALE,” SULI Intern Report, Oak Ridge National Laboratory, Oak Ridge, TN (2024).

This presentation was supported by the Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.

Oak Ridge National Laboratory

Questions?