



# Simulating TRISO Coating in a Fluidized-Bed CVD Reactor using CPFDF

2026 Barracuda Virtual Reactor Users' Conference

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# Overview

- Background
  - Kairos Power
  - Tri-structural ISOtropic (TRISO) fuel
  - DOE Technology Commercialization Fund Collaboration
- Benchmarking validation for fluidized bed
- Preliminary results for TRISO simulation
  - Project purpose
  - Geometry and setup
  - Results for various stages
- Ongoing work





# Kairos Power

Our mission is to enable the world's clean energy transition to improve people's quality of life while protecting the environment.

To achieve this mission, we are focused on delivering a technology that is both **safe** and **affordable**.



# Kairos Power Overview

- Nuclear energy engineering, design, and manufacturing company singularly focused on the commercialization of the fluoride salt-cooled high-temperature reactor (FHR)
- Novel approach to nuclear development that includes iterative hardware demonstrations and in-house manufacturing to achieve disruptive cost reduction and provide true cost certainty
- Driving toward US demonstration by 2030 (or earlier) and rapid deployment ramp in 2030s
- Cost targets set to be competitive with natural gas in the US electricity market



Founded in 2016



550+ Full time employees



Alameda Headquarters



Albuquerque Manufacturing Development Campus



Oak Ridge Reactor Demonstration Campus



# Fluoride Salt-Cooled High Temperature Reactor



**TRISO**  
Coated Particle Fuel



**Flibe ( $2\text{LiF}-\text{BeF}_2$ )**  
Liquid Fluoride Salt Coolant



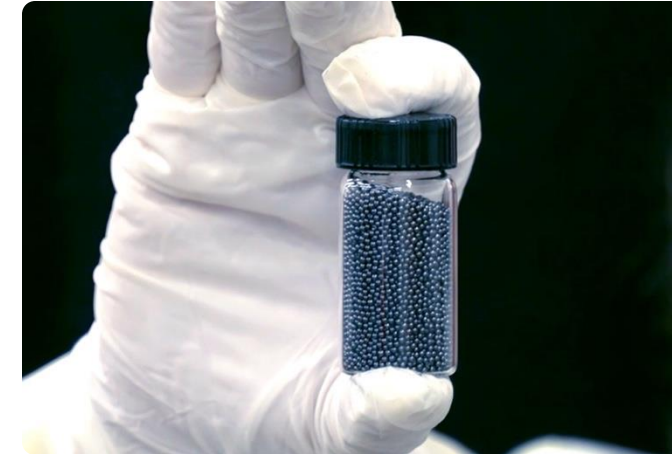
## Fuel Production

- Our Fuels team has implemented a fully automated process to mass-produce the annular TRISO pebble fuel form starting with 60,000 pebbles for ETU 2
- Fuel manufacturing processes optimized in Kairos Power's Pebble and TRISO Development Labs will be implemented at Los Alamos National Laboratory to produce fuel for Hermes using HALEU provided by the U.S. Department of Energy



## Commercial Fuel Production

- Kairos Power and BWXT are exploring opportunities to collaborate on commercial TRISO fuel production for Kairos Power reactors and other potential customers
- Combines BWXT's 20+ years of TRISO manufacturing experience with Kairos Power's state-of-the-art R&D facilities and established capabilities in annular graphite pebble production
- Creates a pathway to aggregate future demand, accelerate commercial scale-up, and lower TRISO fuel costs for the advanced reactor industry



**Kairos Power**

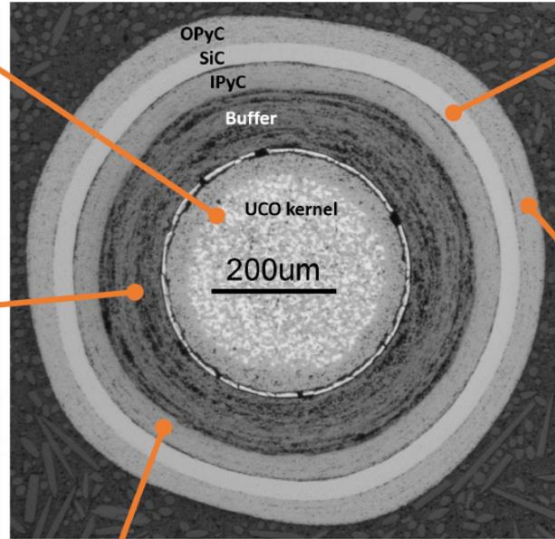
# General TRISO Fuel Design

- **Kernel (350-500  $\mu\text{m}$ )**

- $\text{UO}_2$  or UCO
- Retention of fission products

- **Buffer (~100  $\mu\text{m}$ )**

- ~50% dense pyrolytic carbon
- Provides space for fission gas and  $\text{CO}(\text{g})$  accumulation
- Accommodates fission recoils



- **SiC (~35  $\mu\text{m}$ )**

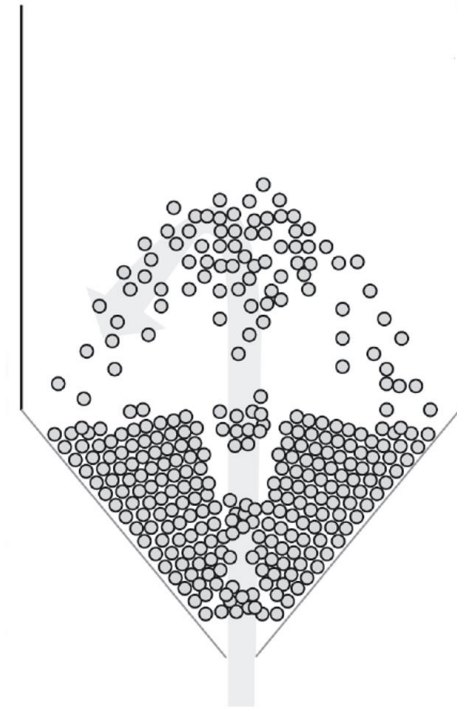
- Main structural layer
- Primary coating layer for retaining non-gaseous fission products

- **OPyC (~40  $\mu\text{m}$ )**

- Contributes to fission gas retention
- Surface for bonding to matrix
- Protects SiC layer during handling

- **IPyC (~40  $\mu\text{m}$ )**

- Protects kernel from chloride during SiC deposition
- Surface for SiC deposition
- Contributes to fission gas retention



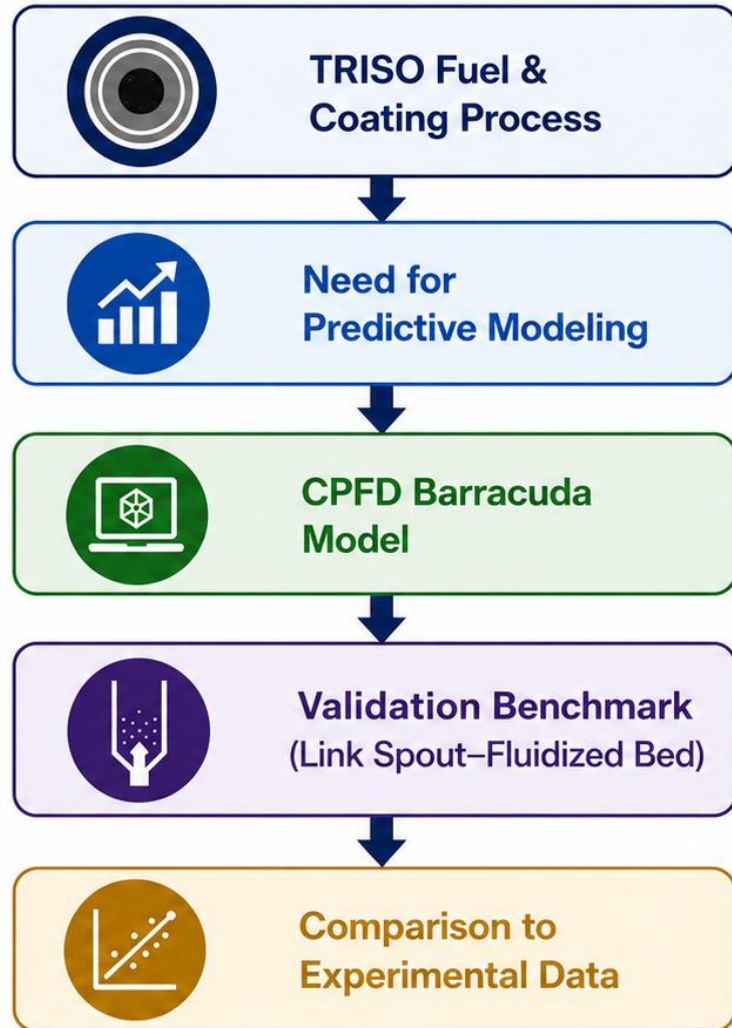
## BACKGROUND

# DOE Technology Commercialization Fund Collaboration

- Project initiated through a DOE Technology Commercialization Fund (TCF) voucher award
- Support provided by:
  - DOE Office of Technology Transitions (OTT)
  - DOE Office of Clean Energy Demonstrations (OCED)
- Voucher support included:
  - Access to Barracuda Virtual Reactor
  - Software training and onboarding
  - Initial simulation setup support



# Spout-Fluidized Bed Experimental Validation

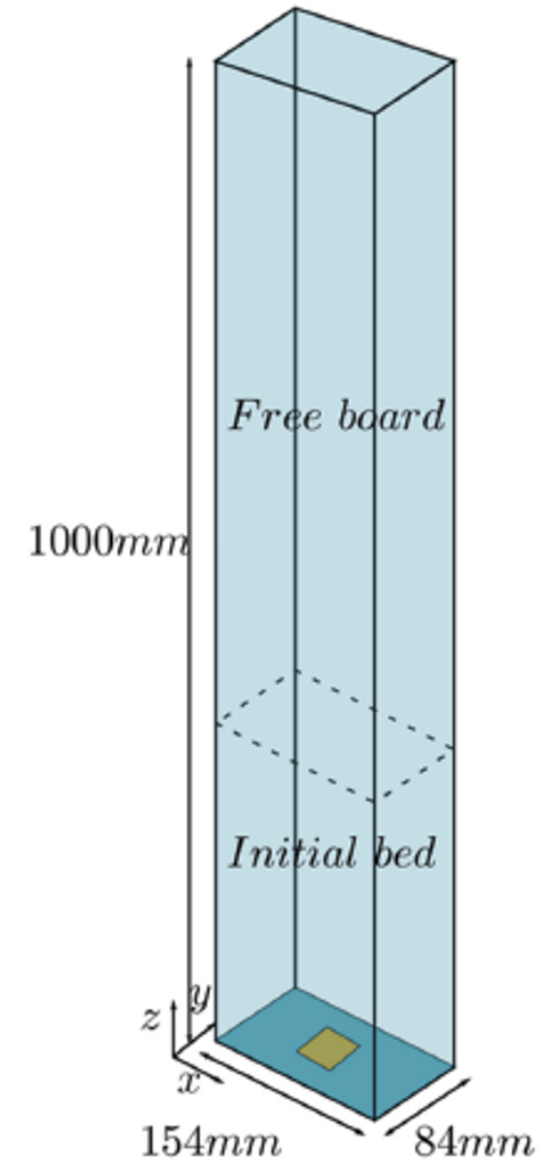
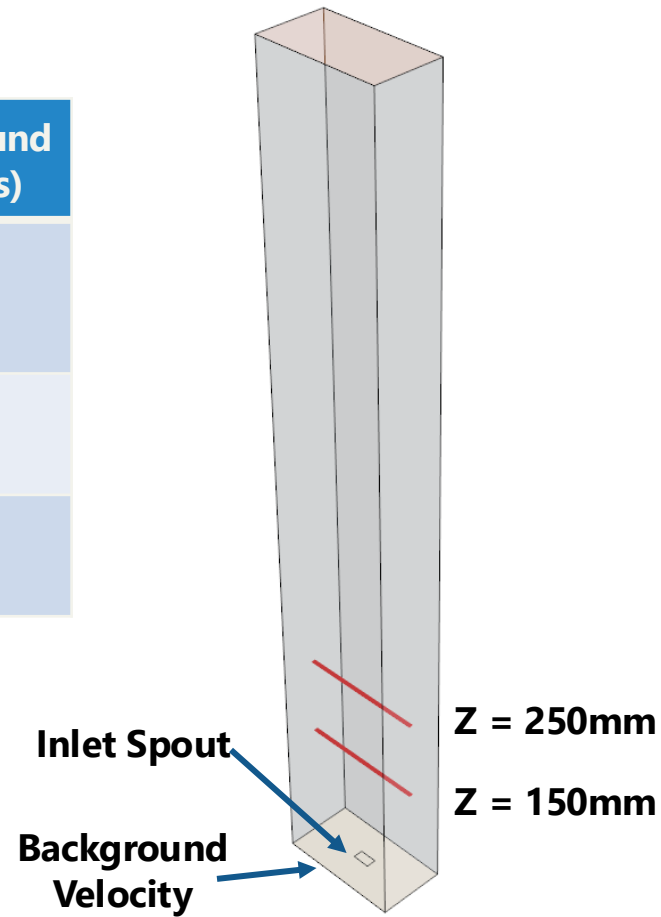


## Purpose of Validation

- ✓ Establish confidence in the simulation methodology
- ✓ Compare Barracuda predictions against published experimental measurements from the Link spout-fluidized bed and traditional DEM-CFD modeling results from STAR-CCM+
- ✓ Evaluate the model's ability to capture key fluidization behavior
- ✓ Provide a foundation for subsequent TRISO coating simulations

# Spout-Fluidized Bed Experimental Validation Setup

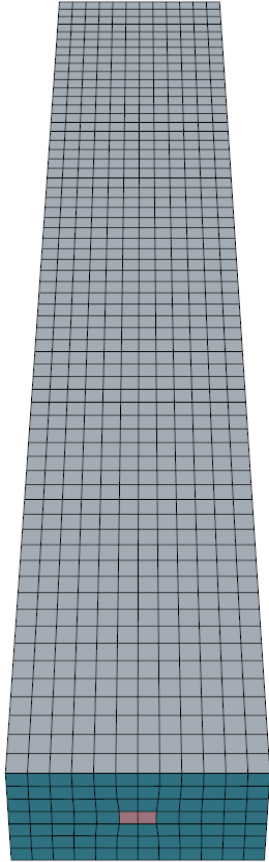
Case	Inlet Spout Velocity (m/s)	Inlet Background Velocity (m/s)
1 (Intermediate spout-fluidization)	60	2.5
2 (Spouting with aeration)	90	2.5
3 (Jet in fluidized-bed)	65	3.5



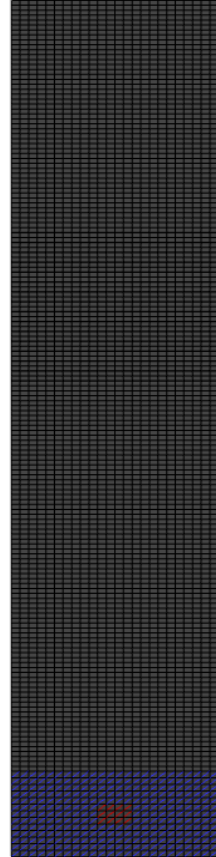
Experimental data reproduced from J. M. Link et al., "PEPT and discrete particle simulation study of spout-fluid bed regimes," *AIChE Journal*, vol. 54, no. 5, 2008, doi: 10.1002/aic.11456.

Figures reproduced from A. Rahmani, M. Tamtaji, and A. M. Dehkordi, "Numerical Simulation of A Cubic Spout-Fluid Bed: Influences of Inlet Gas Temperature and Jet to Bed Cross-Section Ratio," *Int. J. Chem. React. Eng.*, vol. 18, no. 3, 2020, doi: 10.1515/ijcre-2019-0144.

# STAR-CCM+ and Barracuda Virtual Reactor Setup



**STAR-CCM+**  
**Number of cells: 5,376**  
**Average cell length: 1.2 cm**

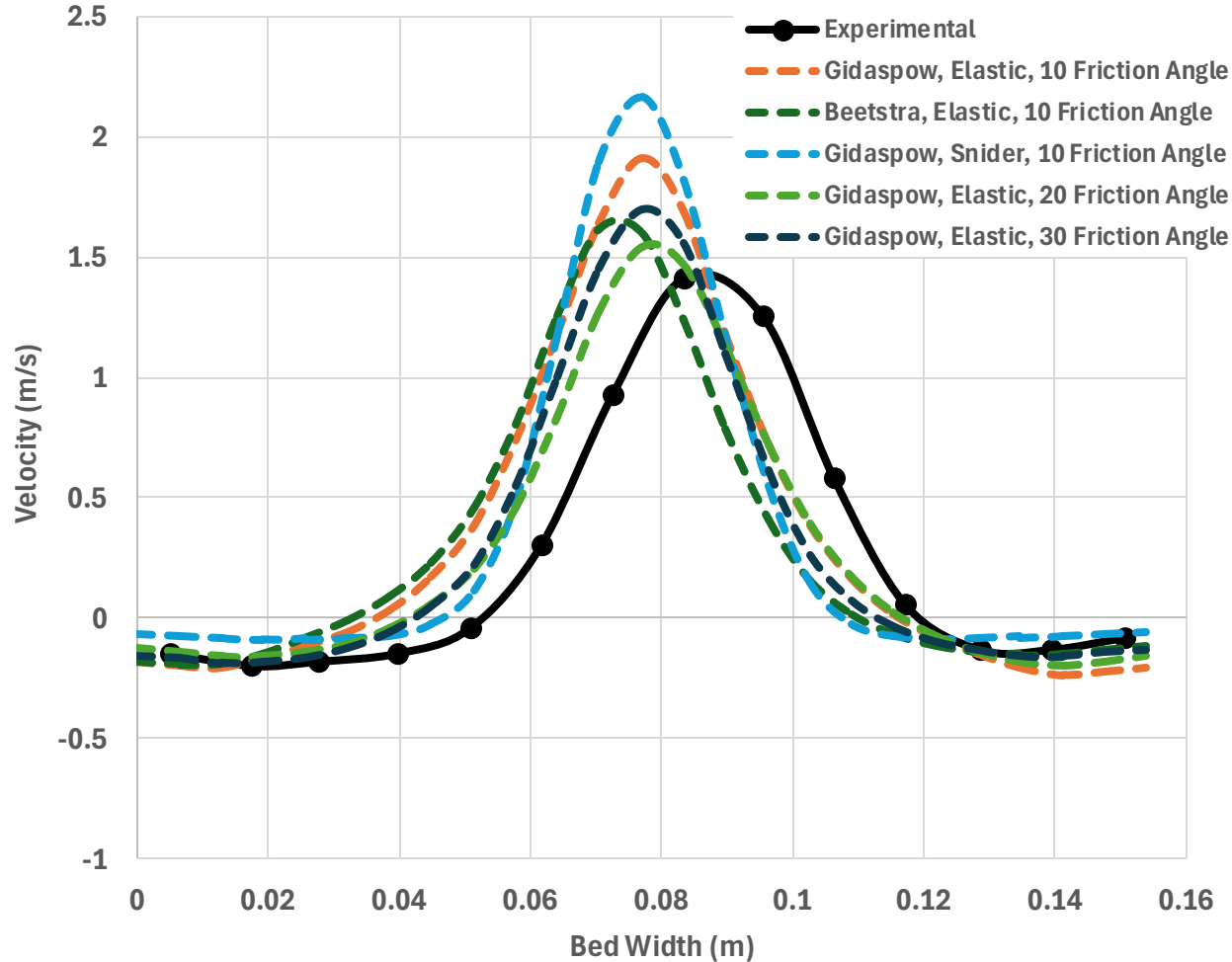


**Barracuda**  
**Number of cells: 48,672**  
**Average cell length: 0.6 cm**

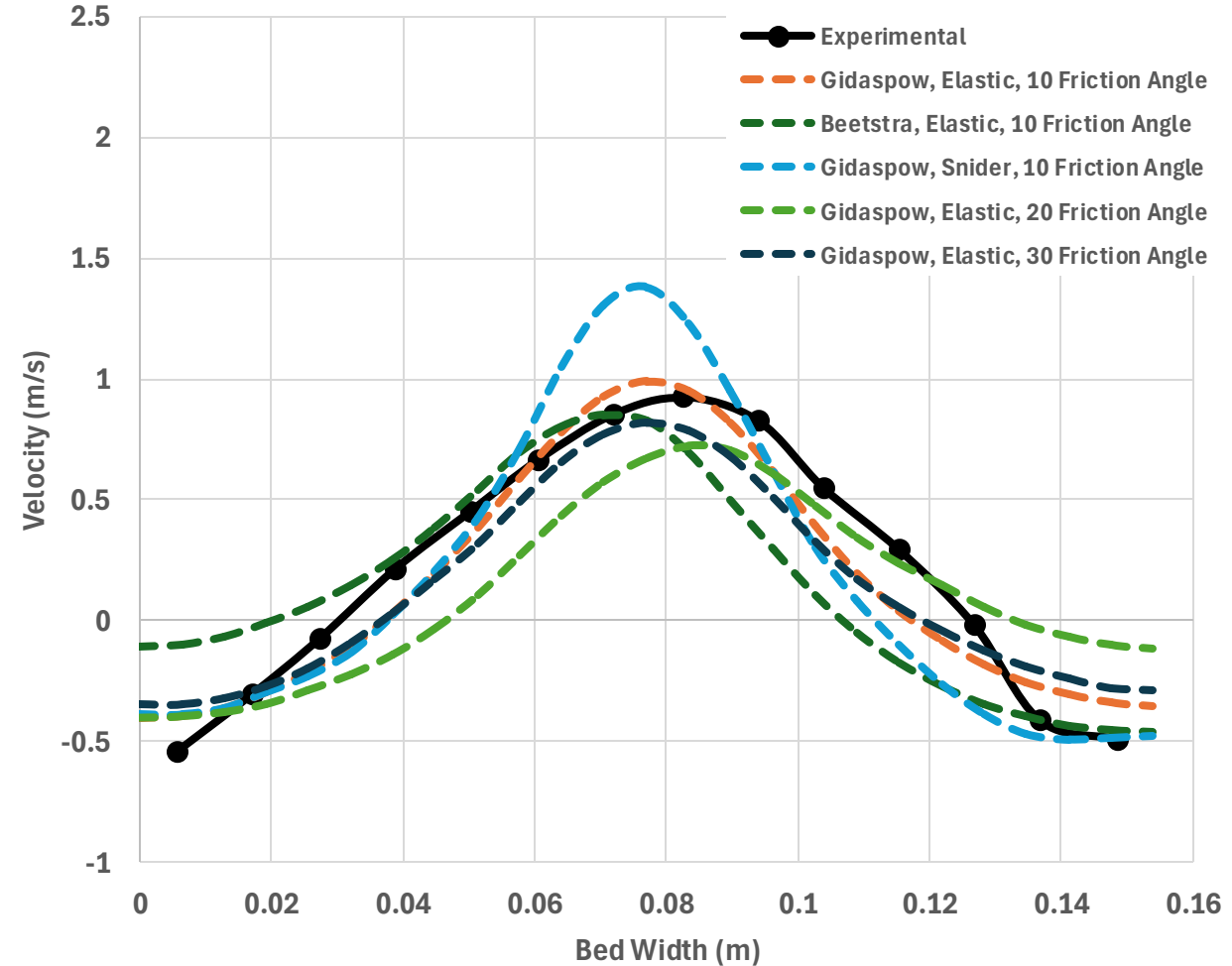
Parameter	STAR-CCM+ 2506.0001	Barracuda 25.1.1
Gas density (kg/m <sup>3</sup> )	1.225	1.225
Gas viscosity (Pa-s)	2E-5	2E-5
Particle density (kg/m <sup>3</sup> )	2526	2526
Particle diameter (mm)	4.04	4.04
Number of particles	44,800	44,800
Collision model	-	Elastic
Restitution coefficient	0.97	0.97
Angle of internal friction (°)	-	10
Normal/tangent restitution coefficient	-	0.97
Particle friction	0.1	-
Wall friction	0.3	0.3

# Barracuda Virtual Reactor Input Parameter Study: Case 1

Average Particle Velocity at Z = 150 mm

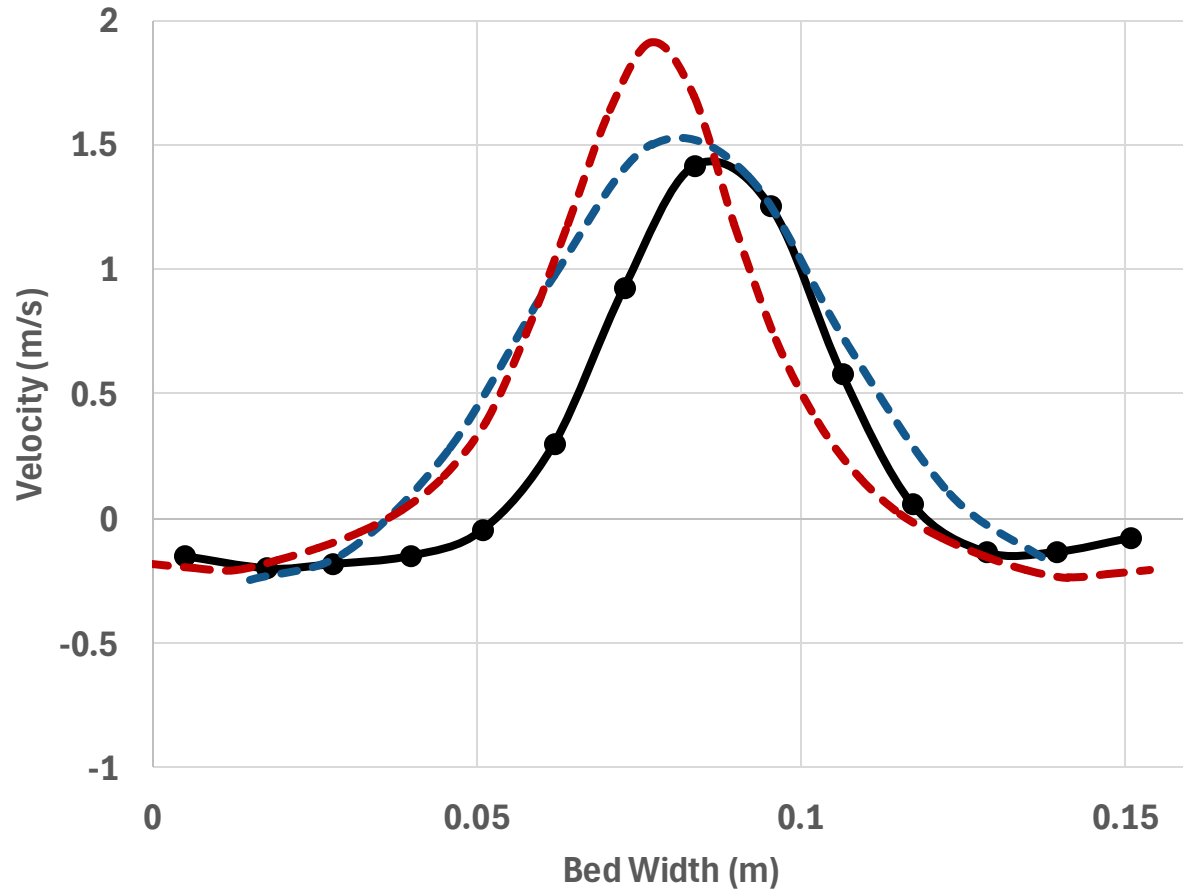


Average Particle Velocity at Z = 250 mm



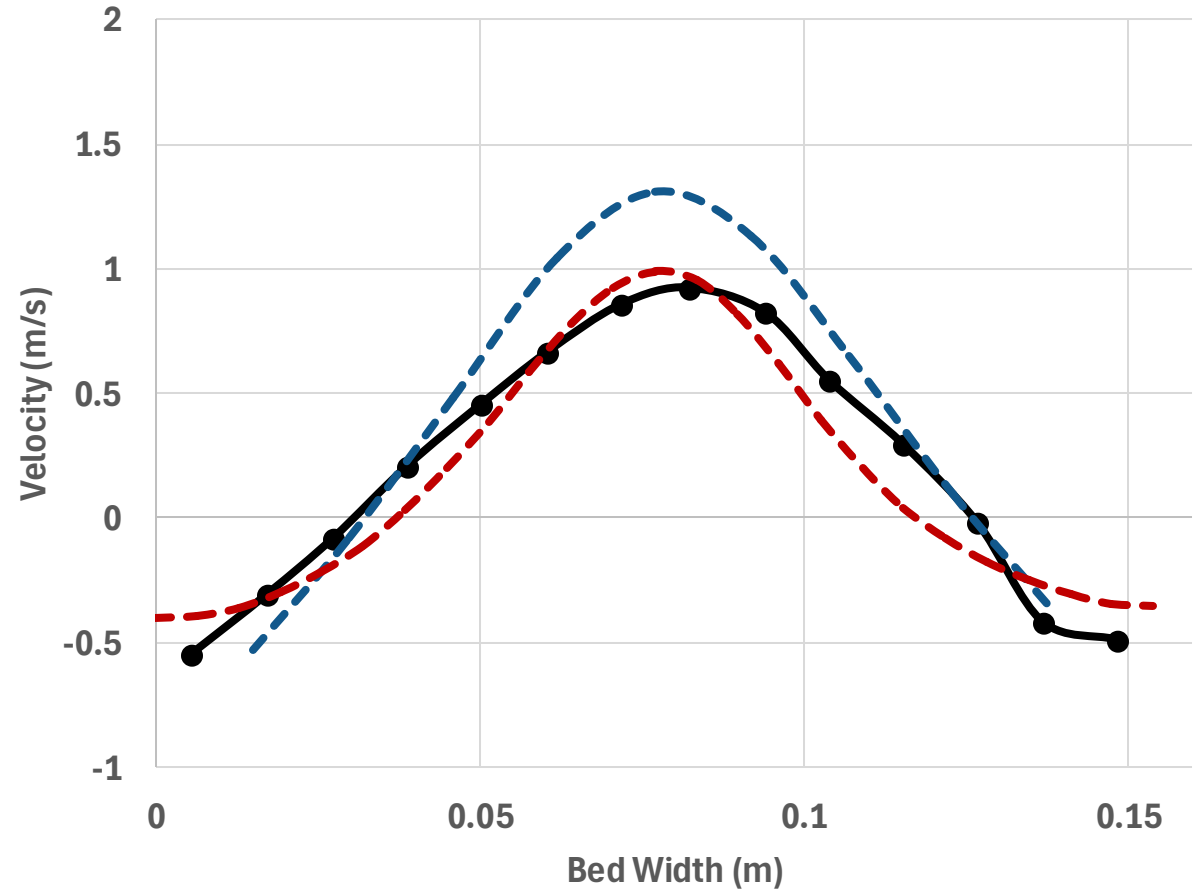
# STAR-CCM+ and Barracuda Virtual Reactor Comparison: Case 1

Average Particle Velocity at Z = 150 mm



● Experimental    - - - STAR-CCM+    - - - Barracuda

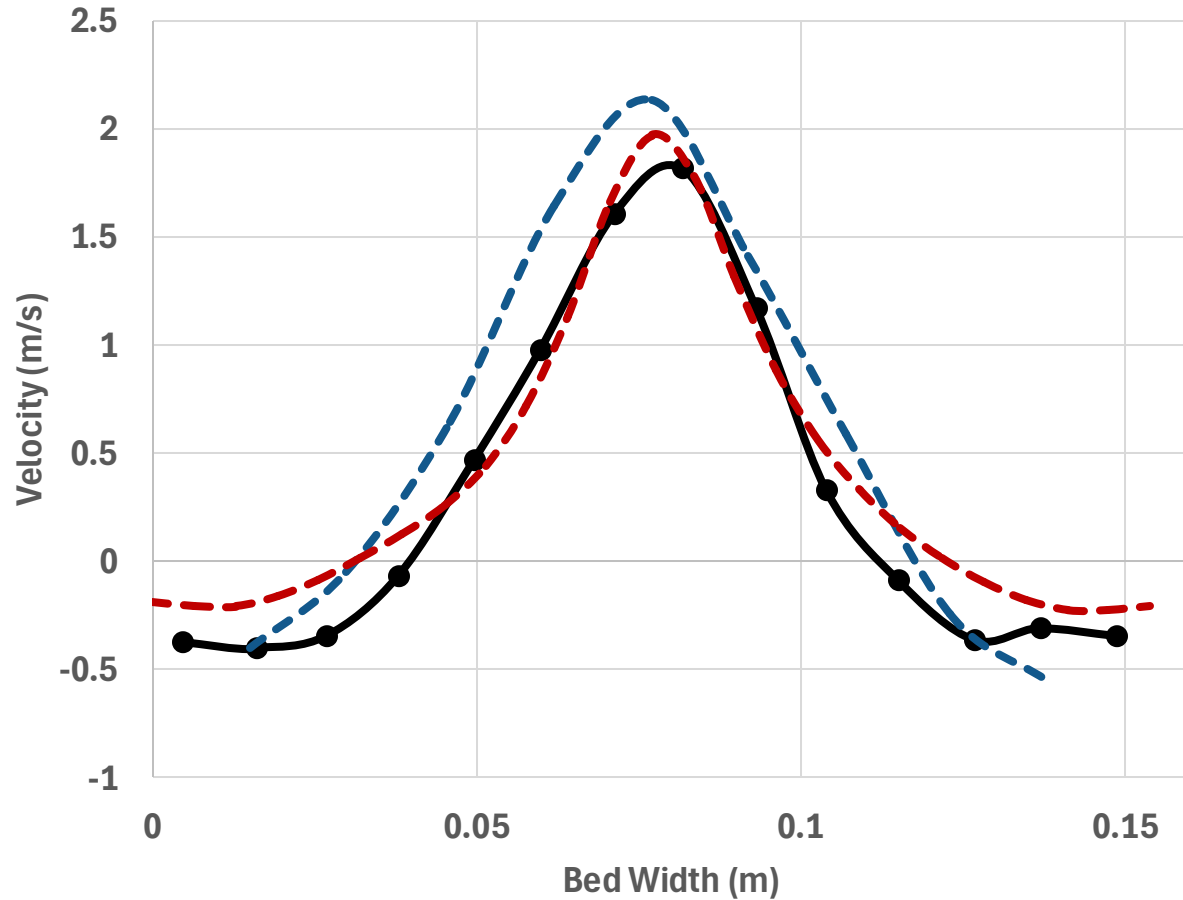
Average Particle Velocity at Z = 250 mm



● Experimental    - - - STAR-CCM+    - - - Barracuda

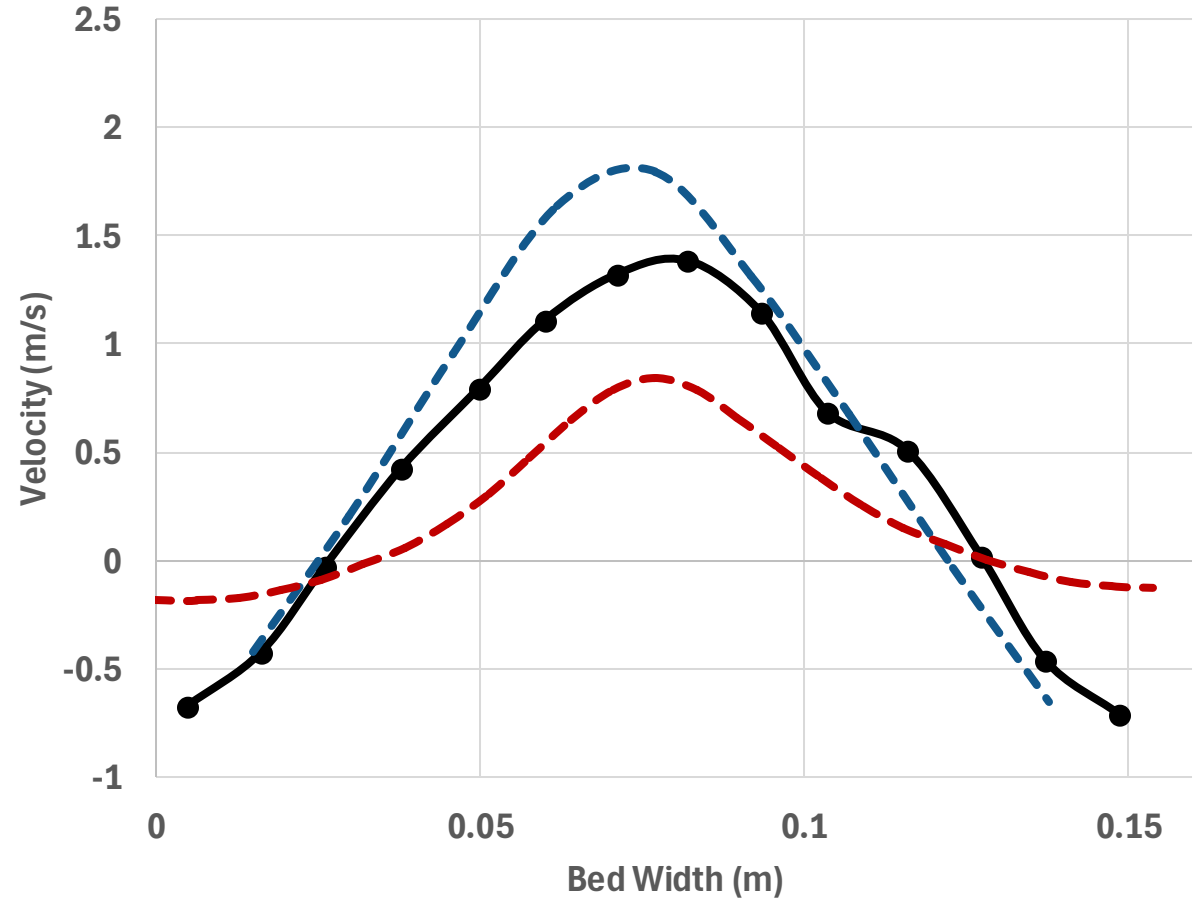
# STAR-CCM+ and Barracuda Virtual Reactor Comparison: Case 3

Average Particle Velocity at Z = 150 mm



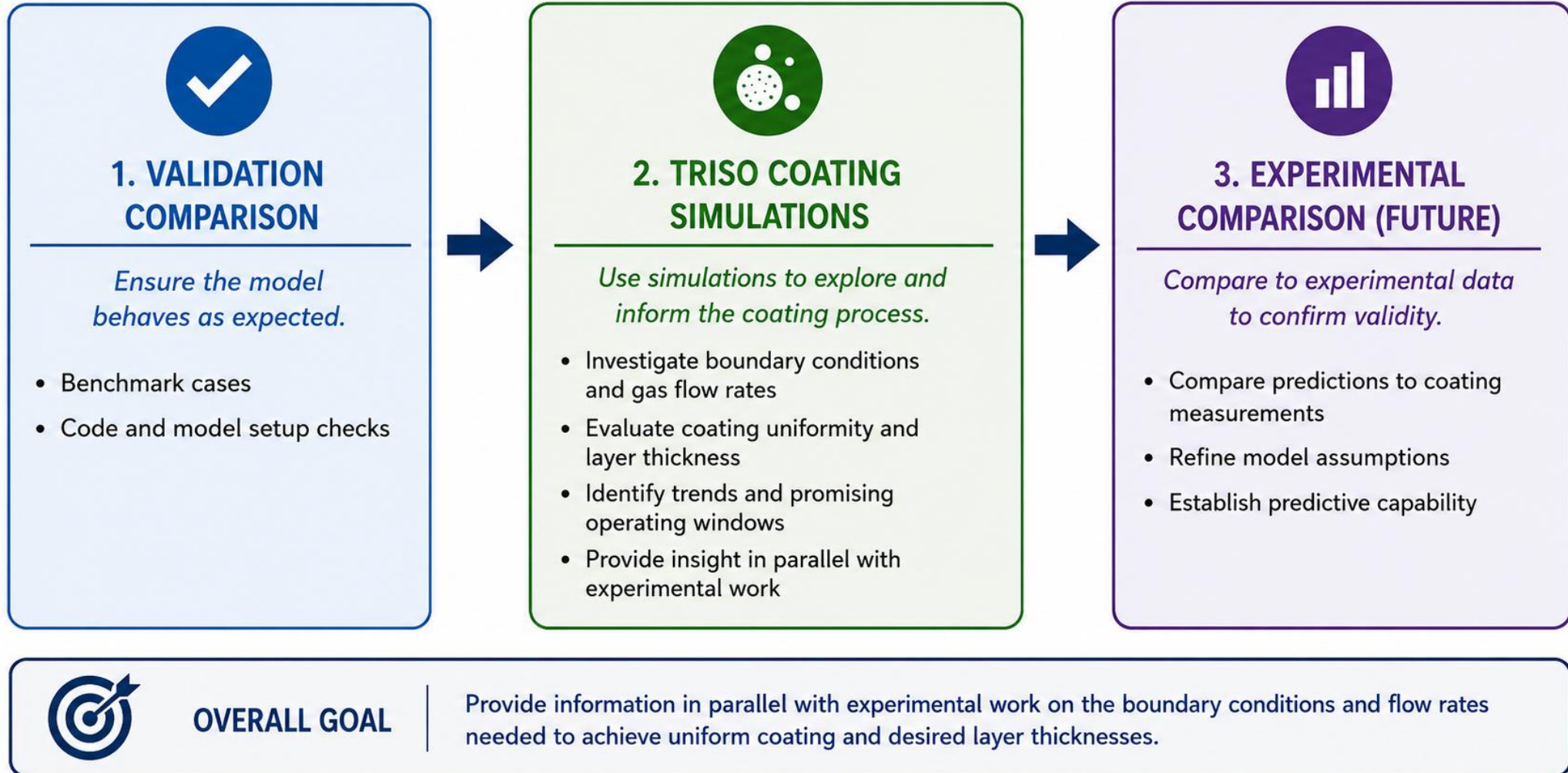
—●— Experimental    - - - STAR-CCM+    - - - Barracuda

Average Particle Velocity at Z = 250 mm



—●— Experimental    - - - STAR-CCM+    - - - Barracuda

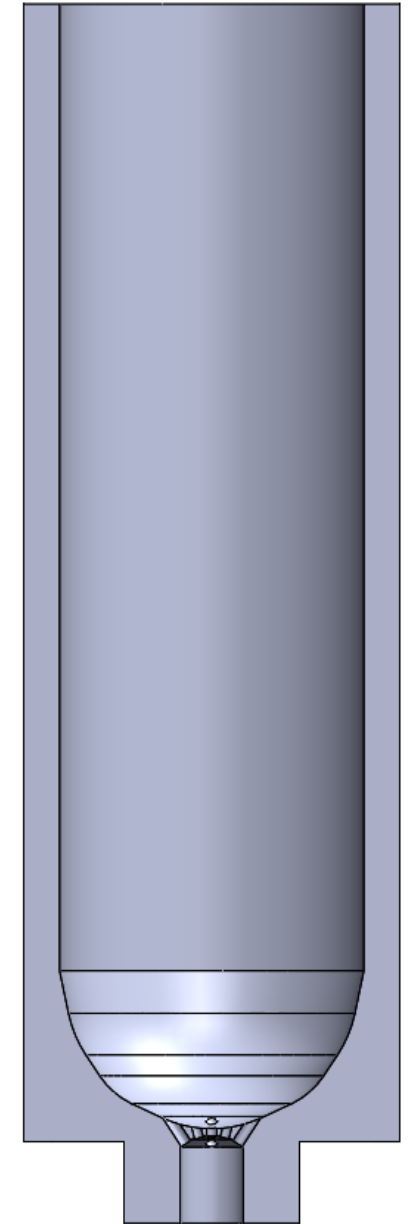
# From Validation to TRISO Coating Application



# TRISO Coater Geometry and Stages

Material	Layer Thickness (μm)	Layer Density (g/cm <sup>3</sup> )	Particle Diameter (μm)	Particle Density (g/cm <sup>3</sup> )	Coating Time (min)
<b>Kernel</b>	-	-	<b>425</b>	<b>11.1</b>	-
<b>Buffer</b>	<b>100</b>	<b>1.00</b>	<b>625</b>	<b>4.18</b>	<b>5</b>
<b>IPyC</b>	<b>40</b>	<b>1.90</b>	<b>705</b>	<b>3.49</b>	<b>12</b>
<b>Silicon Carbide</b>	<b>35</b>	<b>3.20</b>	<b>775</b>	<b>3.42</b>	<b>100</b>
<b>OPyC</b>	<b>40</b>	<b>1.90</b>	<b>855</b>	<b>3.03</b>	<b>13</b>

Nominal TRISO particle data adapted from Marshall (2017), Spouted Bed Design Considerations for Coated Nuclear Fuel Particles, <https://www.osti.gov/servlets/purl/1367510>



# TRISO Coater Barracuda Setup and Boundary Conditions

Parameter	Stage 1	Stage 2	Stage 3	Stage 4
Gas mass flow rate (kg/min)	0.4	0.9	0.2	0.9
Temperature (°C)	1400	1290	1425	1290
Reaction 1	$C_2H_2 \rightarrow 2C + H_2$	$C_3H_6 \rightarrow 3C + 3H_2$	$CH_3SiCl_3 \rightarrow SiC + 3HCl$	$C_3H_6 \rightarrow 3C + 3H_2$
Reaction 2		$C_2H_2 \rightarrow 2C + H_2$		$C_2H_2 \rightarrow 2C + H_2$

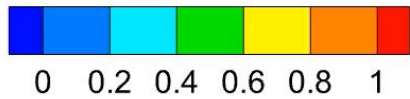
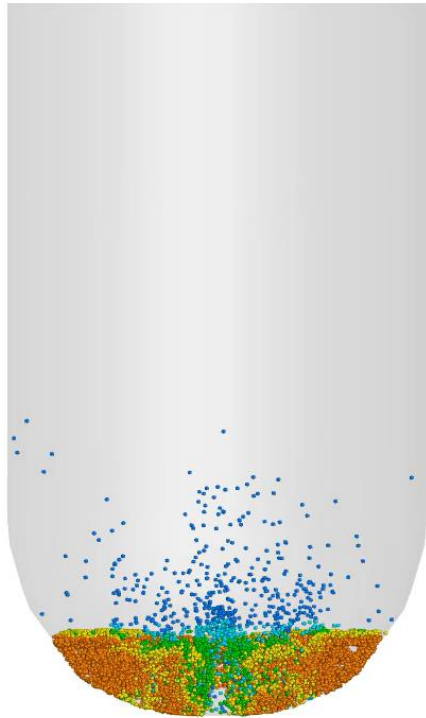
Constant Temperature Wall



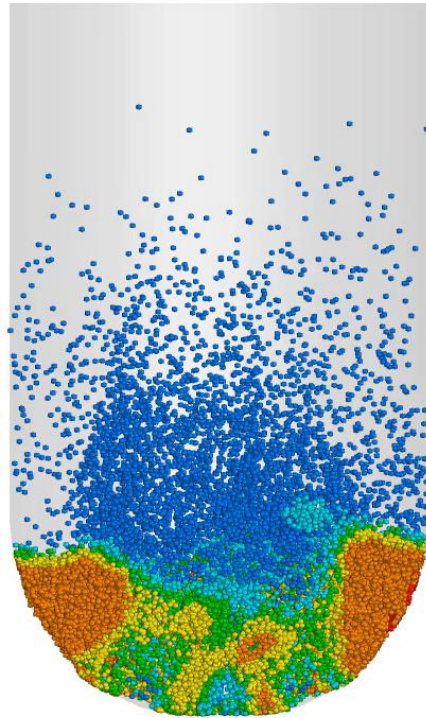
Inlet Injections

Inlet parameters adapted from Idaho National Laboratory, "Sort\_68190," INL Digital Library, Apr. 2026. [Online]. Available: [https://inldigitallibrary.inl.gov/content/uploads/50/2026/04/Sort\\_68190.pdf](https://inldigitallibrary.inl.gov/content/uploads/50/2026/04/Sort_68190.pdf)

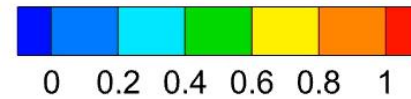
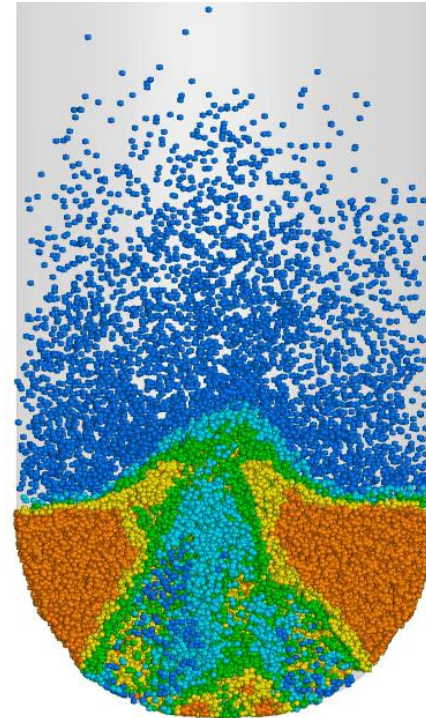
# Non-Dimensional Volume Fraction



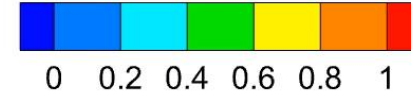
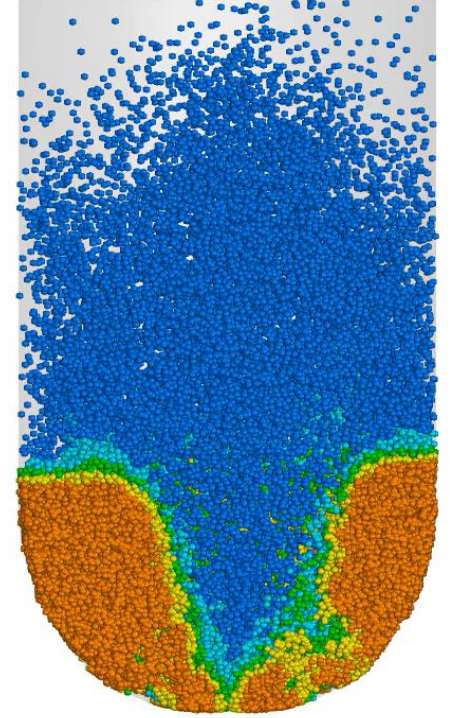
10.00 s  
Stage 1



10.00 s  
Stage 2

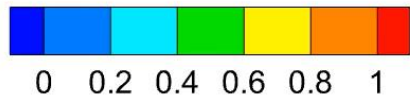
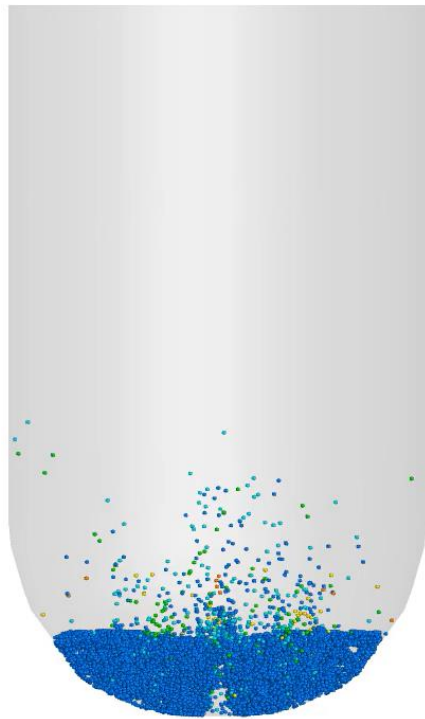


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Stage 3

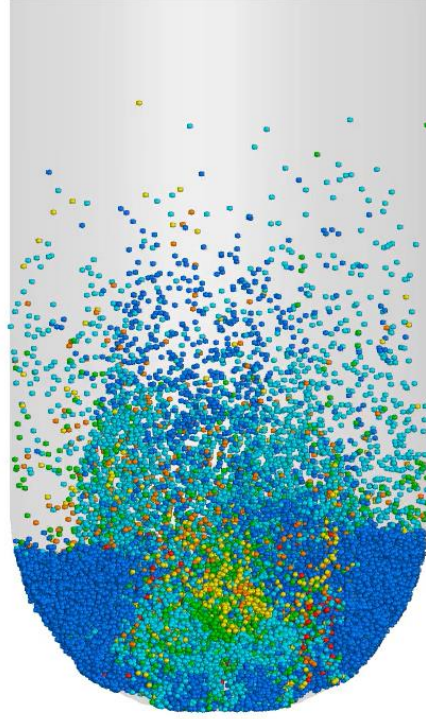


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Stage 4

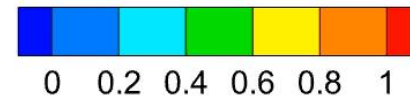
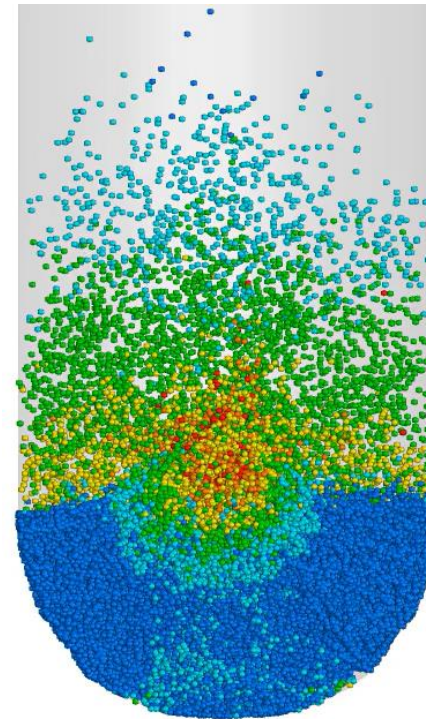
# Non-Dimensional Particle Velocity



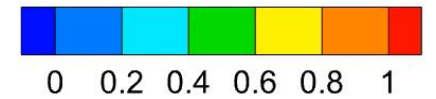
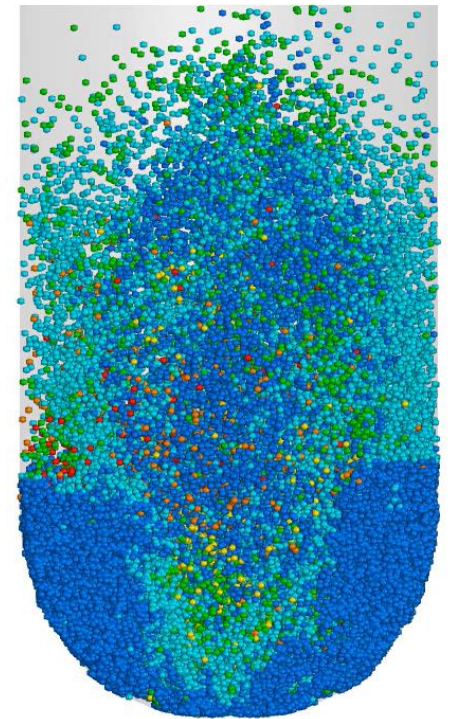
10.00 s  
Stage 1



10.00 s  
Stage 2

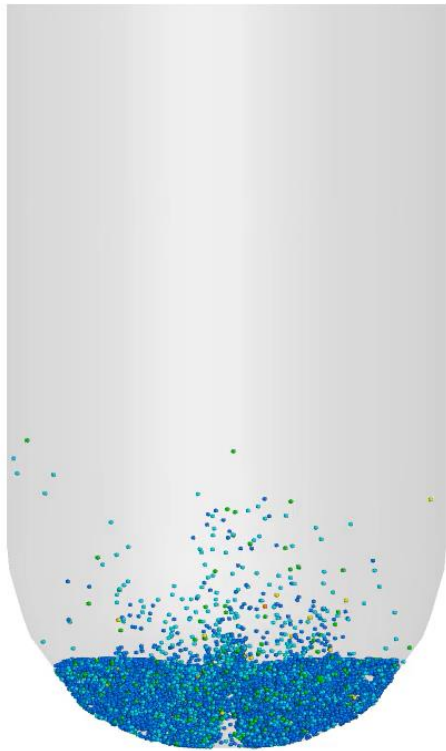


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Stage 3

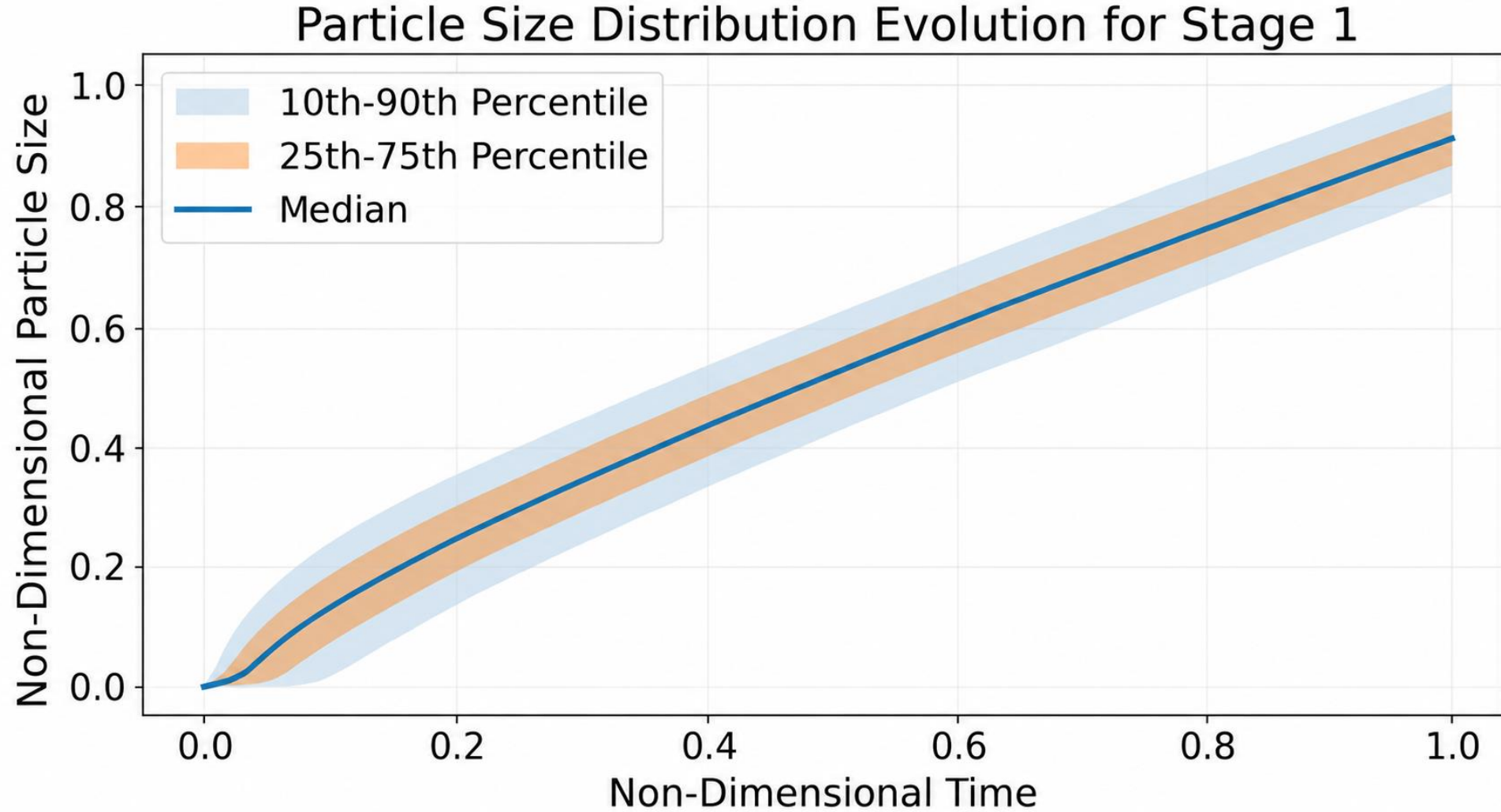


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Stage 4

# Stage 1 Non-Dimensional Particle Size Evolution

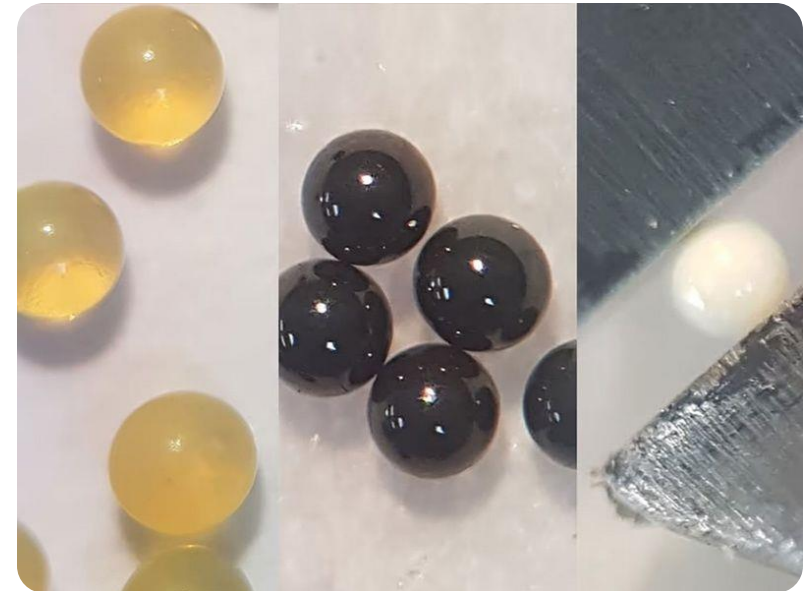


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## Ongoing Work and Next Steps

- Collect experimental particle size distribution (PSD) data for validation against simulation results at each process stage
- Refine and tune simulation parameters to improve predictive capability and support system design/operation, including:
  - Spout geometry optimization
  - Gas species composition and mixture
  - Inlet gas velocity
  - Stage time duration
- Evaluate sensitivity of process performance to operating conditions





# Kairos Power

THE CHALLENGE IS GREAT, BUT  
SO TOO IS THE OPPORTUNITY

