
cpfd

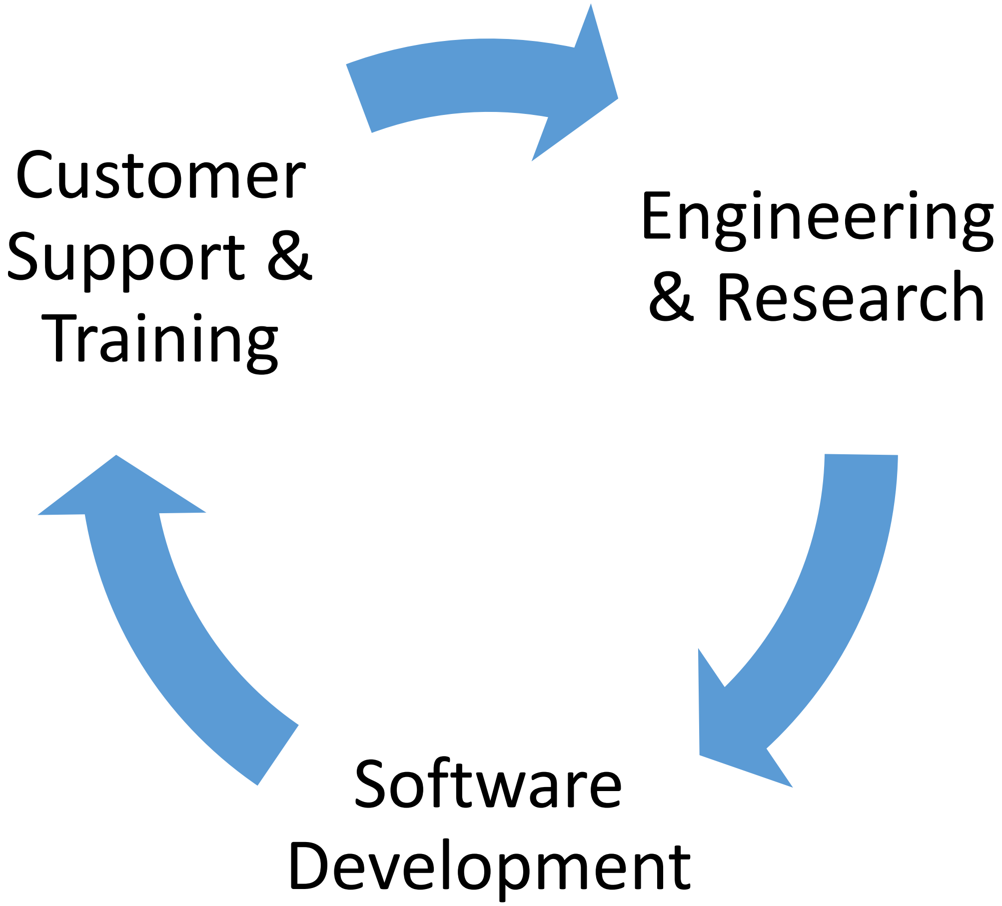
# CPFD Software Technology Overview

James Parker, PhD

CPFD Software

June 25, 2026

# The Barracuda Virtual Reactor Development Team





Paul Zhao


Sam Clark


James Parker


Andrew Larson


Rosemary Clark


Paul Earhart


Hoan Larson


Shashank Karra


Pramod Bangalore


Tanner Stelmach


Saurav Mitra


Keshav Ramchandran

# Engineering and Research

Time and effort

Engineering Problem → CFD-based Solution **Space**

## Application Fit

- *Product Features*
- *Application Models*

## Increasing calculation speed & domain sizes

- *GPU Development*
- *Numerical efficiency*

## Improving usability

- *GUI*
- *Model setup*
- *Analysis*

## Reduced Order Modeling

# Afternoon Technology Talks

- **Application Models**
  - Overview, Hydrogen Production, and Liquid Slurry Flows - *Shashank Karra*
  - Cement Calciner and Conditioning Tower - *Pramod Bangalore*
  - TRISO Particle Production - *Keshav Ramchandran*
  - Industrial CFB Combustion - *Tanner Stelmach*
- **Accelerating Barracuda Virtual Reactor Workflow with AI-Powered ROMs –** *Saurav Mitra*
- **Product Updates –** *Andrew Larson*
- **Support and Training Updates –** *Sam Clark*
- **Q&A**

# Development areas

**Recent development:**

- Particle-particle physics (Elastic Dense Phase Model)
- Liquid modeling
- Thermal modeling
- Erosion modeling

**Current and future development:**

- Rotating systems
- Reduced order model development

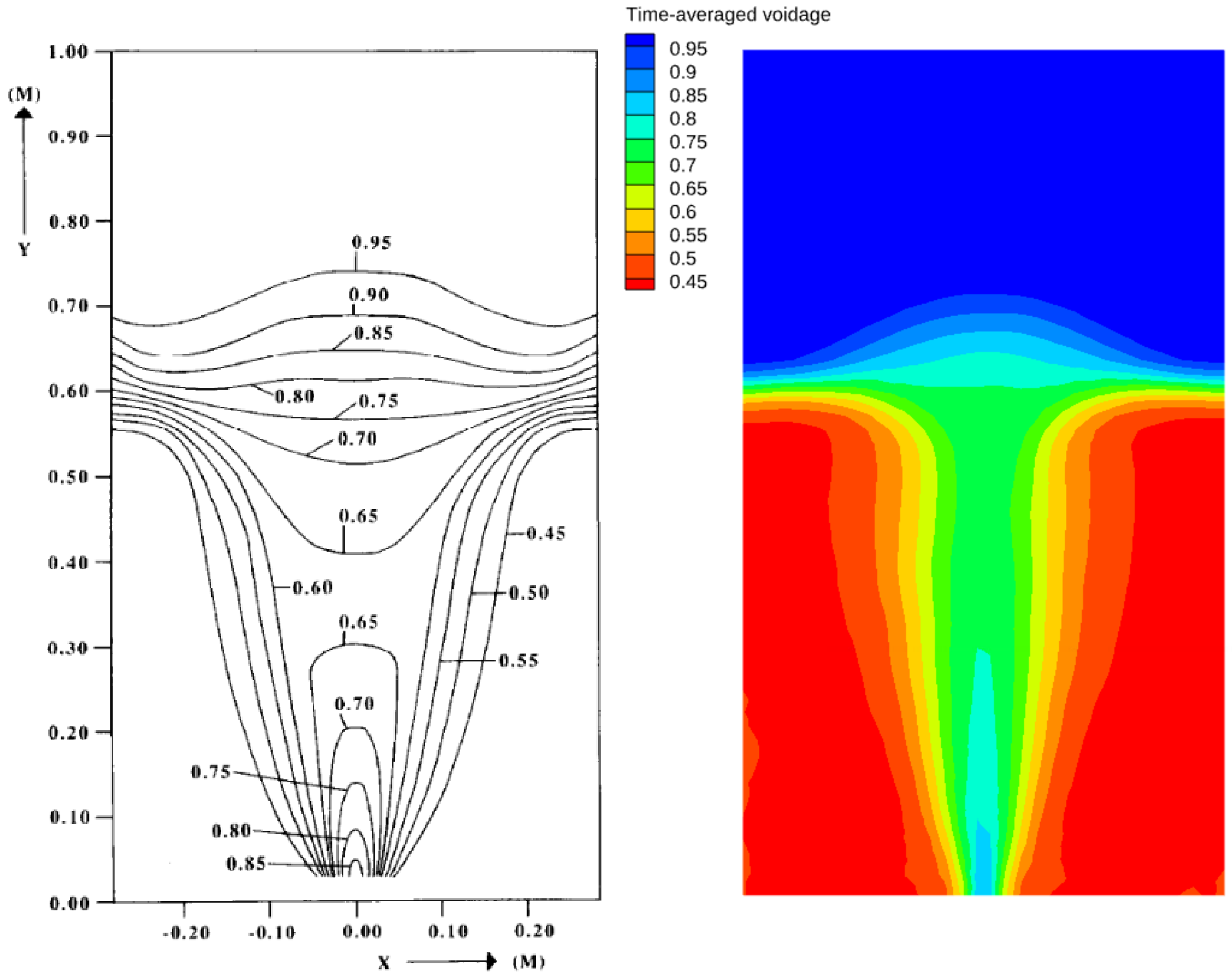
# Elastic Dense Phase Collision model

- Elastic Dense Phase Collision model released in version 26.0
    - Angle of Internal friction
    - Stick-slip / friction on wall boundaries
    - Greatly improved grid independence and dense phase modeling

- Implementation based-on the paper:

  *"A novel approach to MP-PIC: Continuum particle model for dense particle flows in fluidized beds" by Verma and Padding, 2020*

  with significant adjustments to grid and solver approach




**Kuiper's bed model with Elastic Dense Phase Collision**

# Elastic Dense Phase Collision model

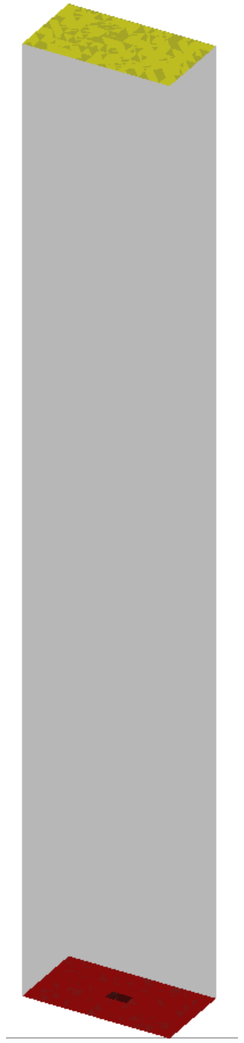
## Spouted bed model (Link et al, 2008)

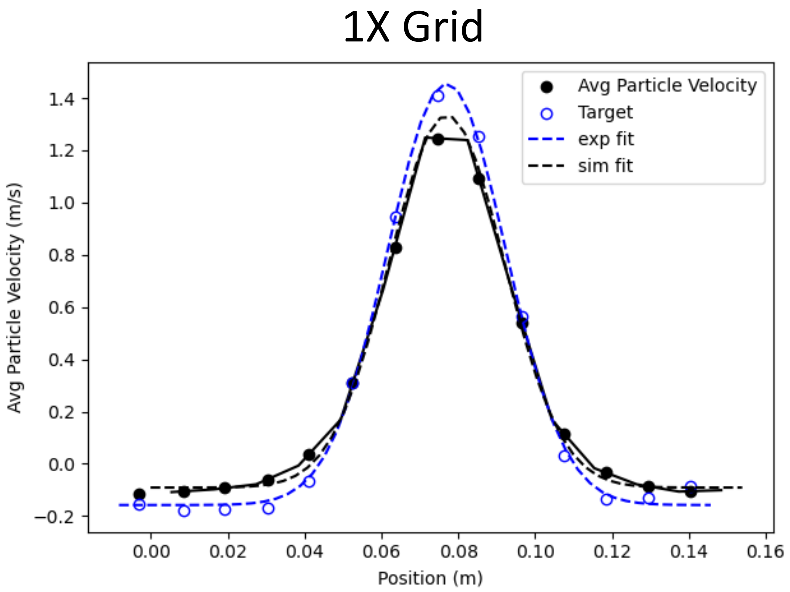
- Lab-scale fluidized bed with 60 m/s center jet
- 4mm glass beads
- 84mm x 154mm x 1 m
- Velocity profiles measured with PEPT

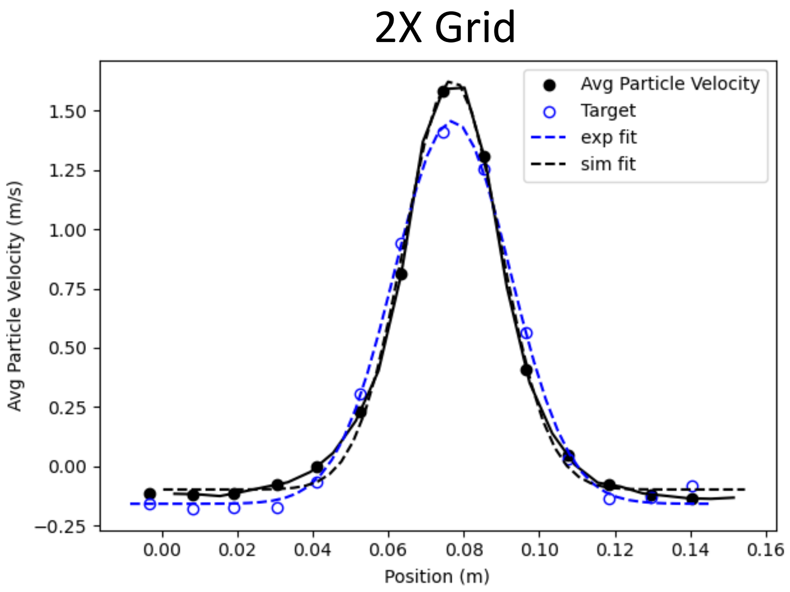
**Applications Models**

- **TRISO Particles**
- **DRI Shaft Furnace**

**General improvement in particle modeling for dense phase applications, flow on angled surfaces, etc**





# Liquid modeling features

**Liquid sprays –**liquid coating, vapor/liquid equilibrium

**Liquid continuous phase**

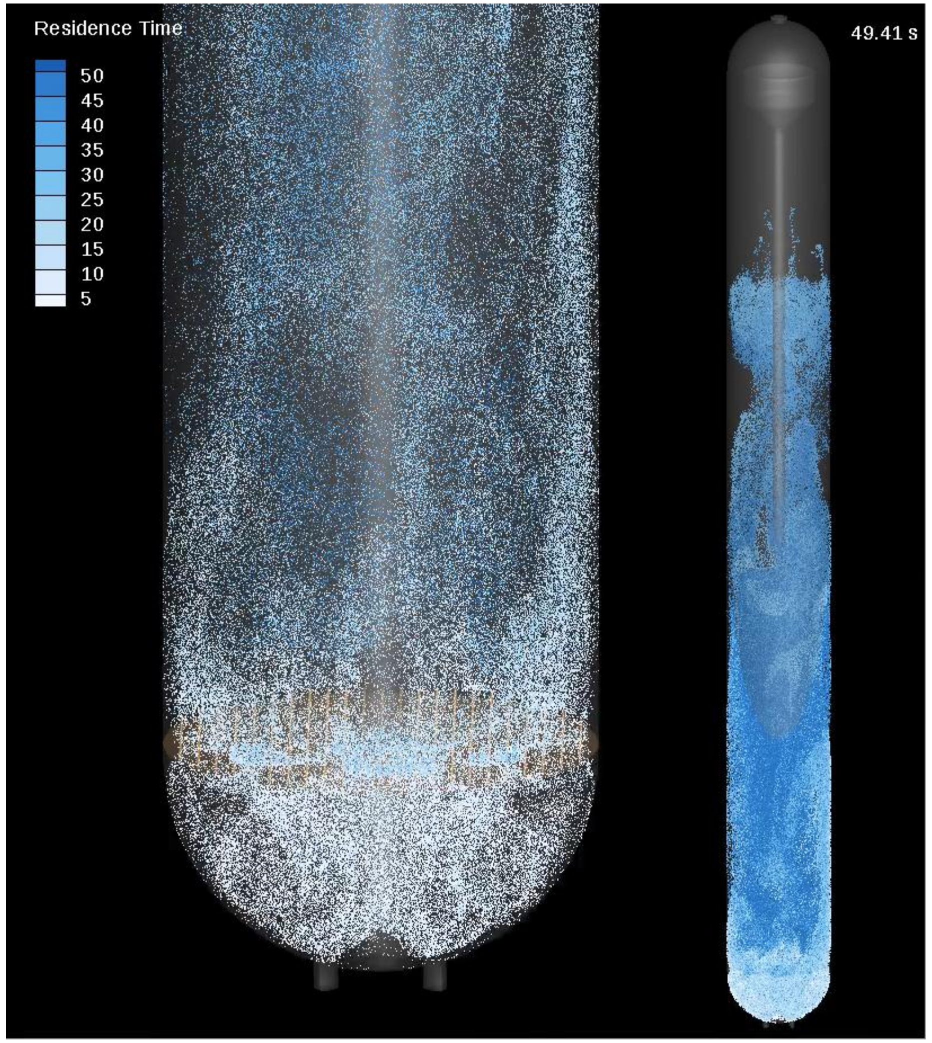
- Solid particles
- Bubbles
- Bubble coalescence/breakup
- Gas absorption
- Vapor liquid equilibrium
- Reactions

**Applications Models**

- **Proppant Transport**
- **Conditioning Tower**
- **Molten Metal Bubble Column**

**General Applications**

- **FCC Risers**
- **Ebullated bed hydrocrackers**
- **Drying/evaporation**




# Heat transfer

## Heat transfer

- Particle-particle conduction
- Wall resistance
- Thermal wall heat flux

**Applications Models**

- Industrial CFB
- DRI Shaft Furnace

**General Applications**

- Ambient heat losses
- Heat transfer surfaces
- Electrical heating elements
- Fixed or moving bed applications

cpfd® Profile

Industrial Scale Circulating Fluidized Bed Combustor

Home / Application Models / Industrial Scale Circulating Fluidized Bed...

Ash
Coal

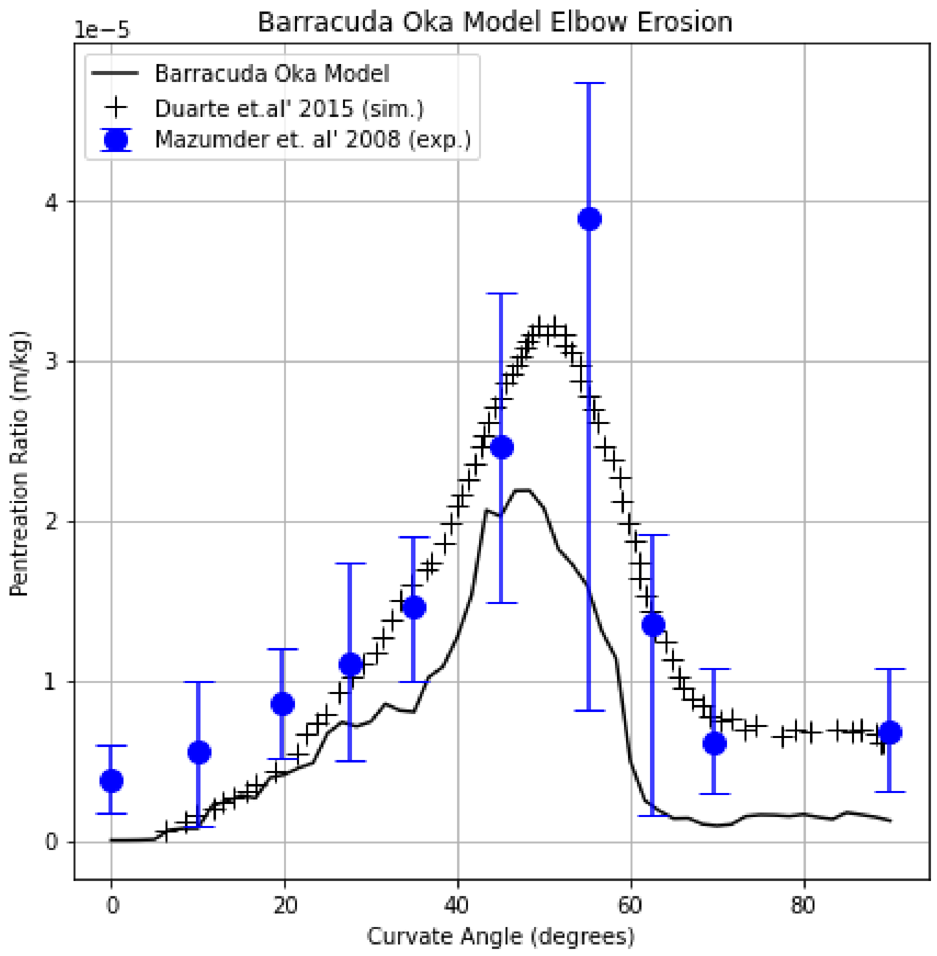
Application Model Overview

Circulating fluidized bed (CFB) combustors provide a robust and flexible pathway for coal- and waste-derived power generation while operating at lower temperatures (≈800–900 °C) than pulverized-coal boilers. This lower-temperature, solids-rich environment promotes strong gas–solid mixing, long residence times, and effective burnout of challenging fuels—including high-ash coals, petcoke, biomass, and waste-derived fuels—while also helping reduce pollutant formation. In a typical CFB, solids (primarily ash and sorbent) circulate continuously through the riser and cyclones, enabling uniform temperatures, efficient heat transfer, and opportunities for in-furnace emissions control.

This application model uses Barracuda Virtual Reactor to simulate an industrial-scale CFB combustor based on a 110 MW unit described in the open literature. The model includes realistic

# Erosion model improvements

- Multiple models, selection zones
- Oka, accretion model




**Applications Models**

- **Elbow Erosion**

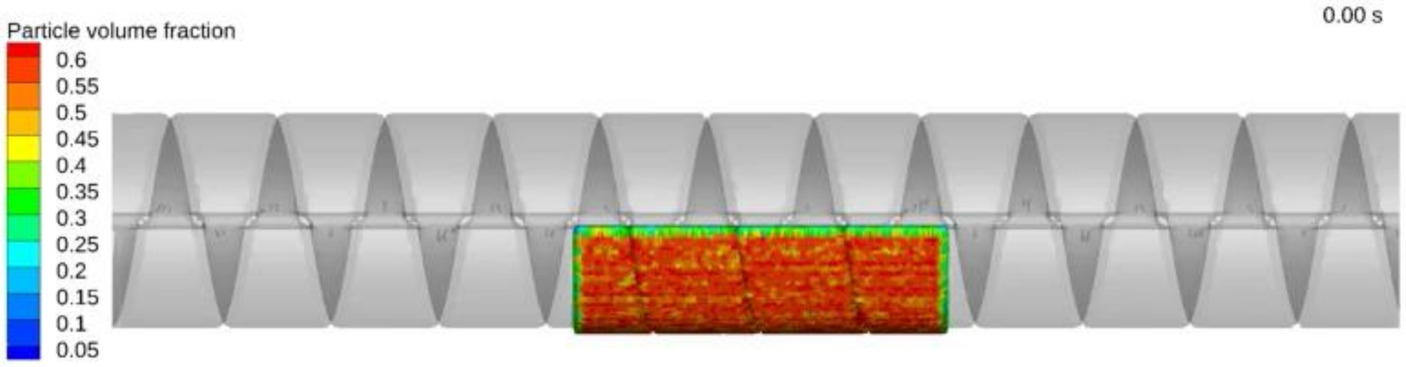
**General Applications**

- **FCC erosion (slide valve, distributors, cyclones)**
- **Upstream applications**

# Current and Future Development Areas

**Rotating systems – "beta" feature**

- Rotating frame of reference
- Body forces on particles and fluid
- Velocity boundaries




**General Applications**

- Kilns
- Auger systems
- Mixers
- Liquid Impeller

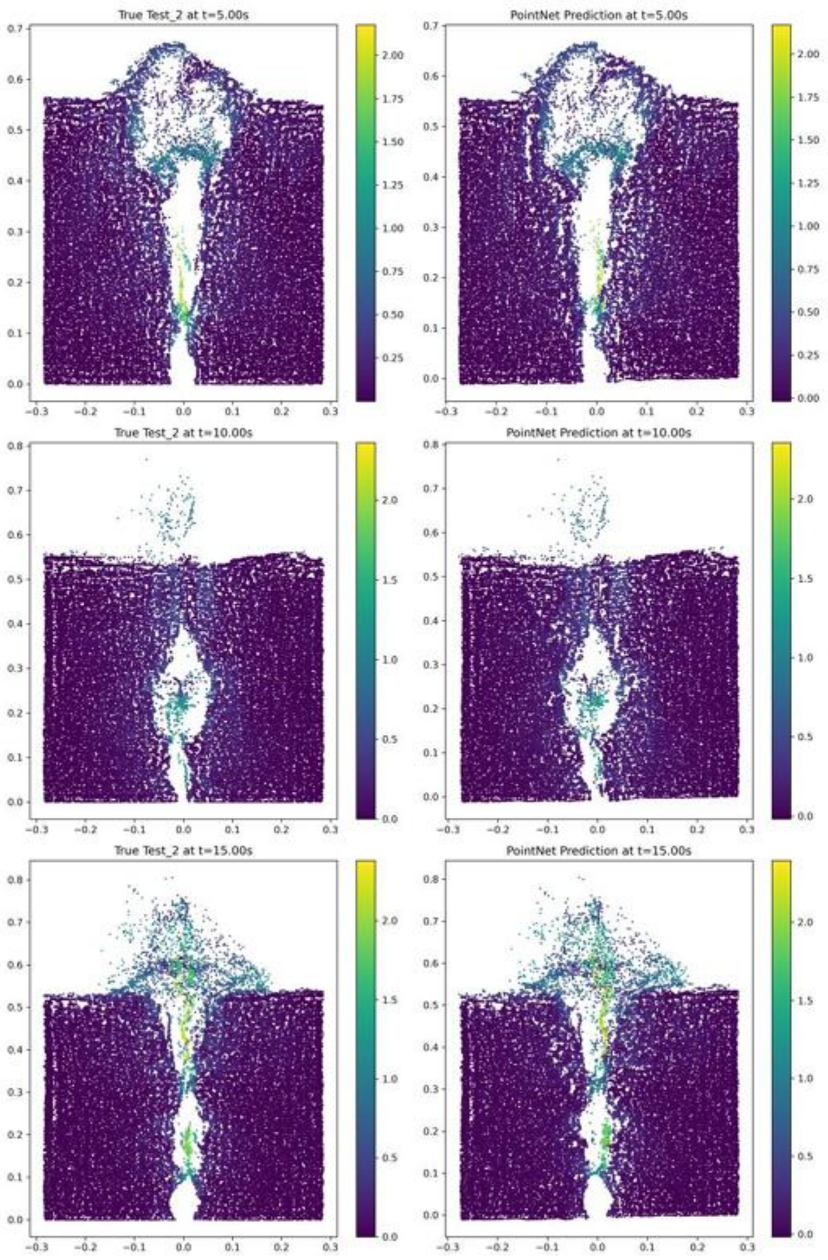
# Current and Future Development Areas

## Reduced Order Modeling

- Training a reduced order model using CFD data
- Accuracy is a function of training
- Model tuning / calibration
- Design optimization
- **CFD solution → CFD solution space**

## CPFD ROM Tool

- In development for the past year+
- Release target in Q4 2026




**Deep learning model of Kuipers Bed**

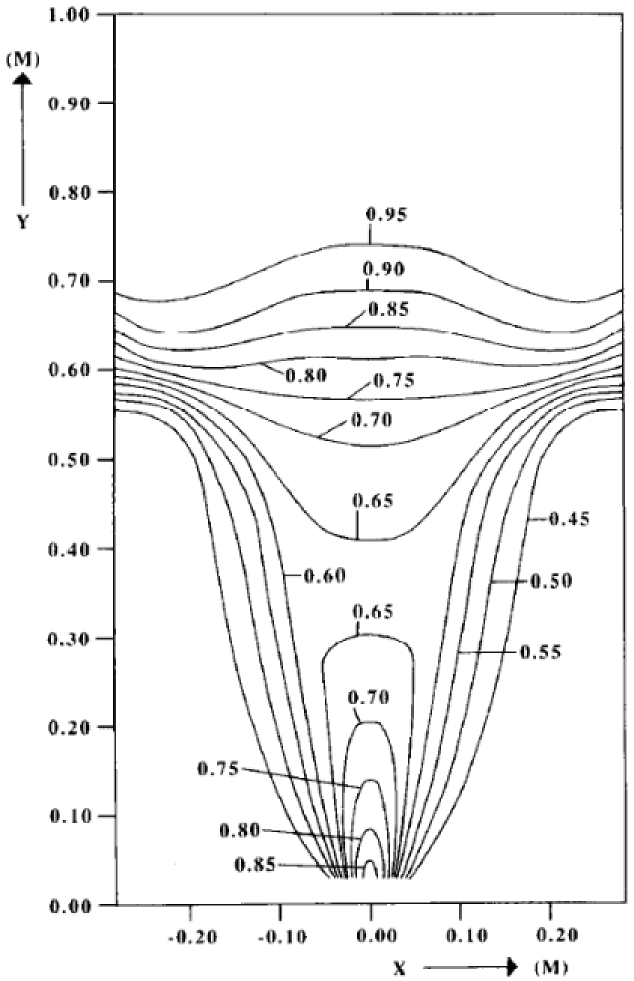
# ROM Demonstration – Tuning Kuipers Training problem

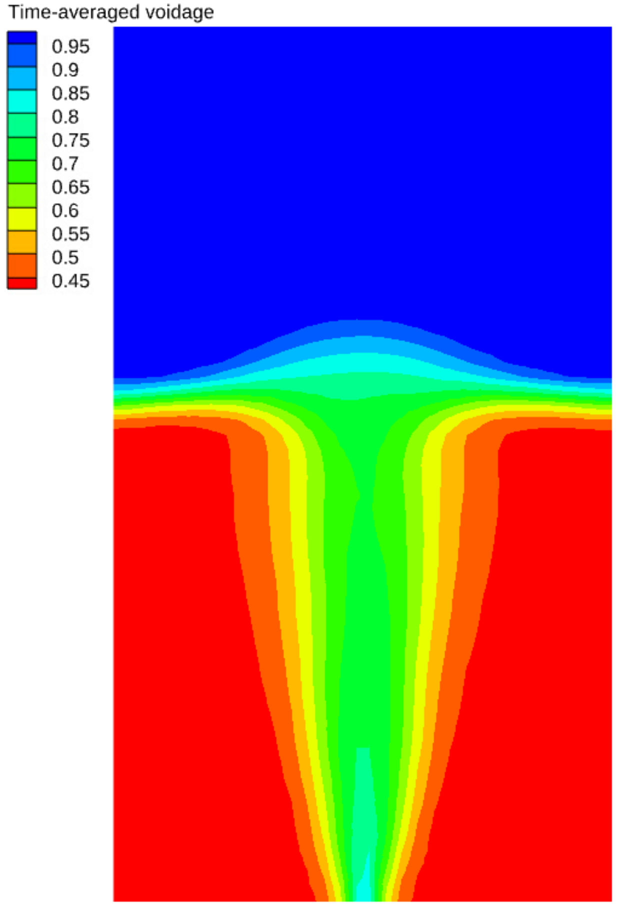
- **Kuiper's bed**
  - 500 micron glass beads
  - "2D" bed in 1.5 cm gap between two plexiglass sheets
  - Fluidizing air on sides, center jet in middle
  - Complicated by asymmetry in experiments
  - Modeled with Beetstra drag model

**Demonstration:**

Improving fit to experimental data by adjusting

- Drag multiplier
- Angle of internal friction



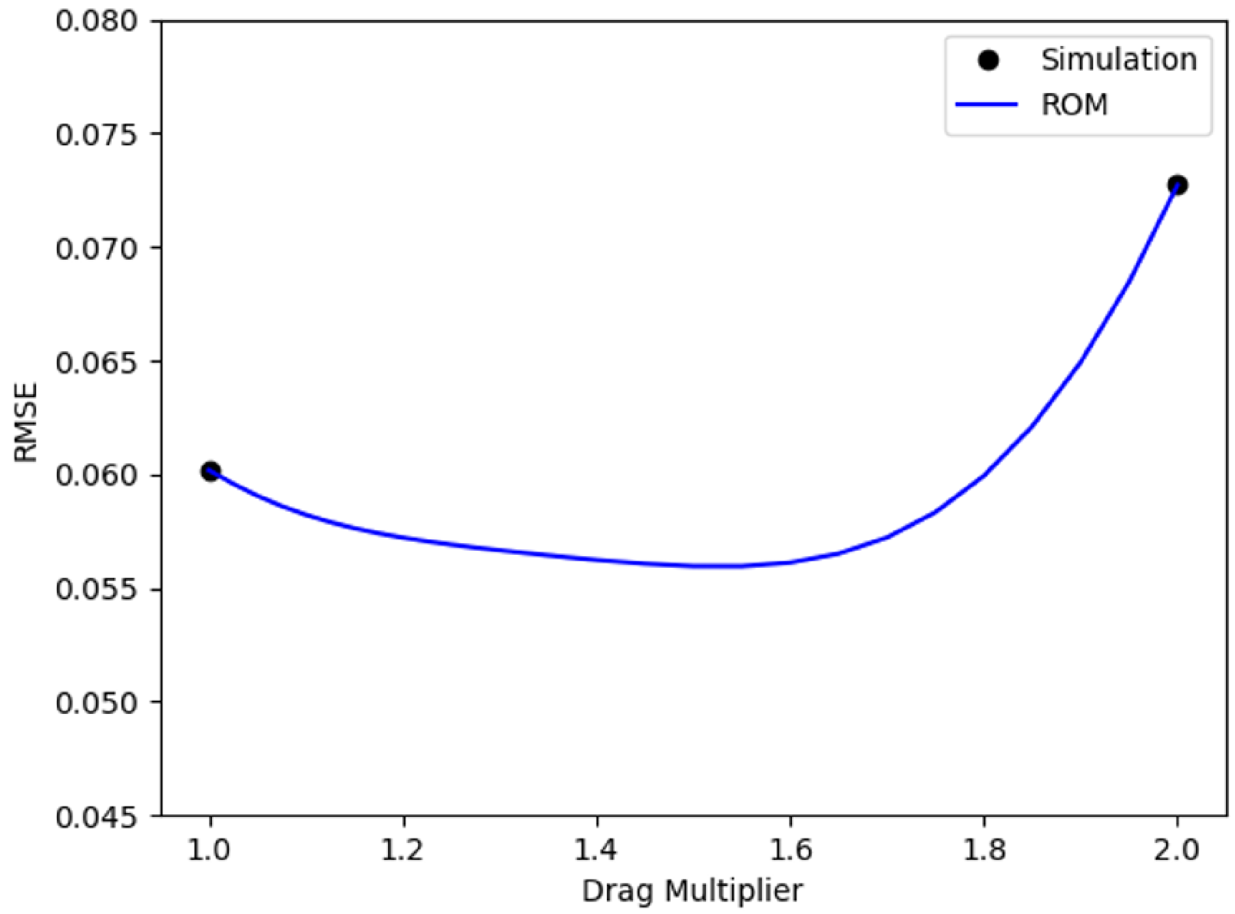




**Kuiper's bed model with Elastic Dense Phase Collision**

# Tuning a drag multiplier

1. **Initial tuning**
    a. Initial chose multipliers of 1.0 and 2.0
    b. Ran simulations
    c. Calculated RSME comparison with reported time-averaged voidage

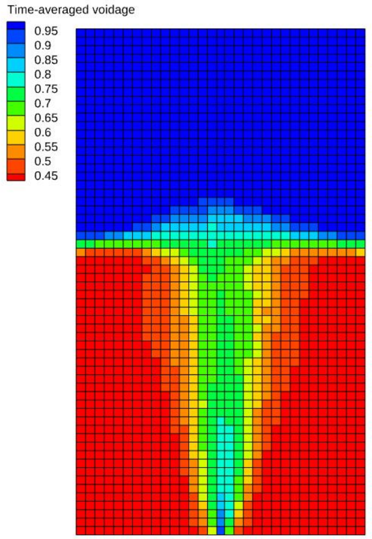
2. **ROM training and inference**
    a. Train ROM using CPFD's internal ROM tool from two data points
    b. Infer new results at intermediate multipliers
    c. Calculated RSME comparison with reported time-averaged voidage

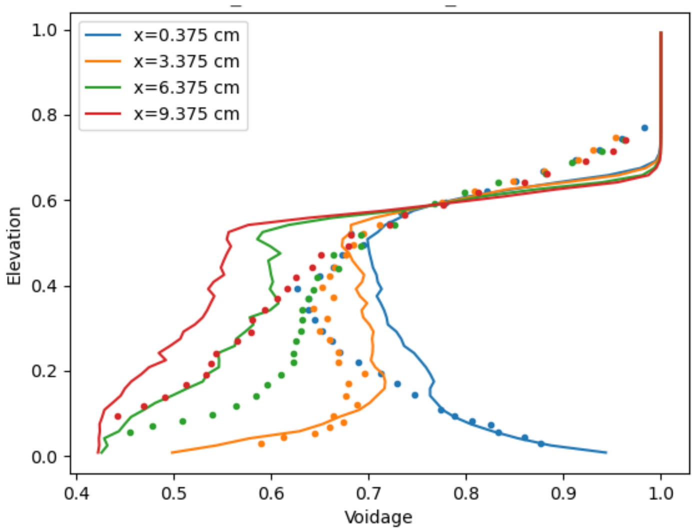


# Tuning a drag multiplier

**Barracuda Virtual Reactor**

**Drag multiplier = 1.0**

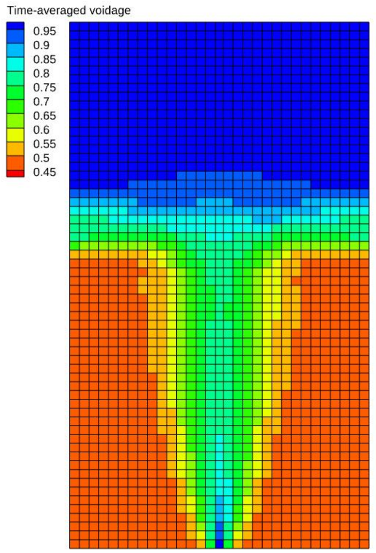


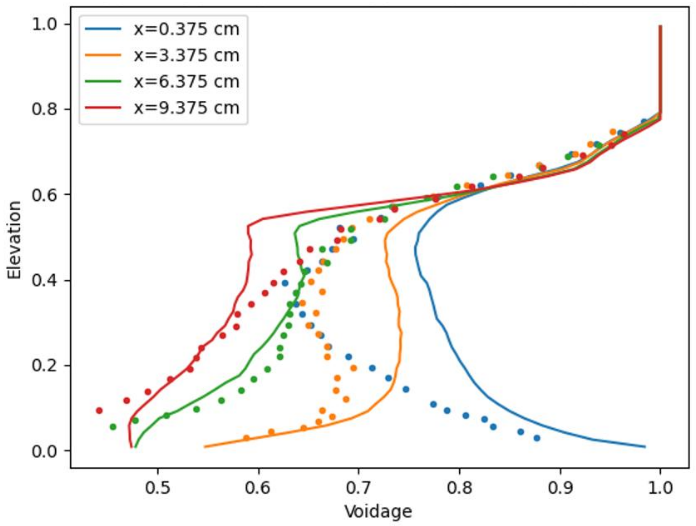




**Simulation**
**RMSE = 0.0602**

**Reduced Order Model**

**Drag multiplier = 1.55**



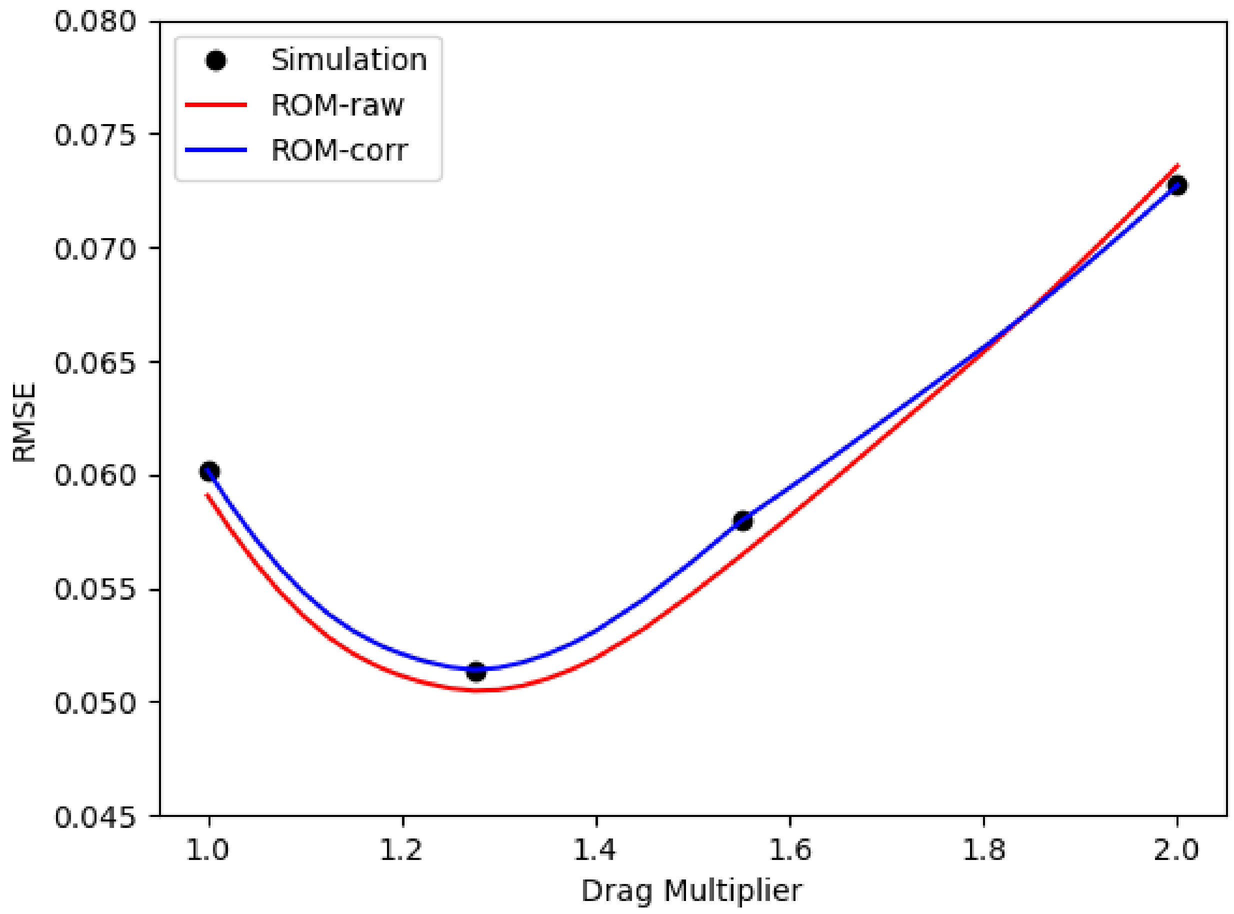




**ROM**
**RMSE = 0.0556**

# Tuning drag multiplier

1. **Apply Active Learning**
   a. Run simulation at suggested minimum
   b. Retrain ROM
   c. Apply residual correction
   d. Reassess minimum and repeat

**Minimum value located at 1.275 with RMSE of 0.0514**

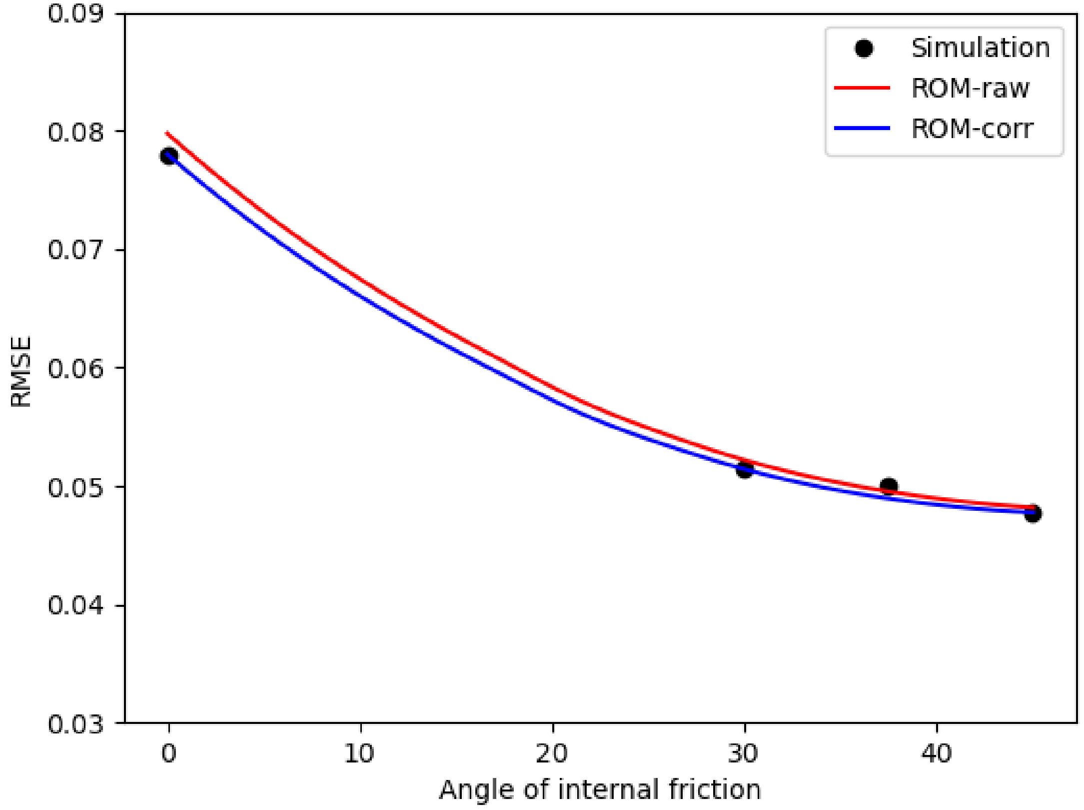


# Tuning internal angle of friction

1. Initial angles of 0°, 30°, and 45°
2. Apply Active Learning

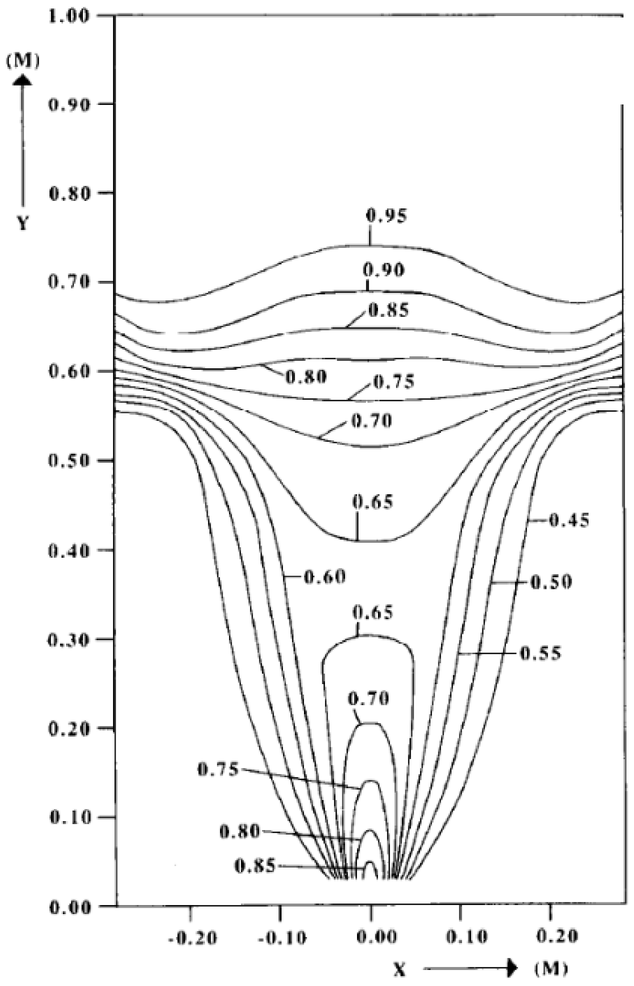
Not much progress beyond 30°

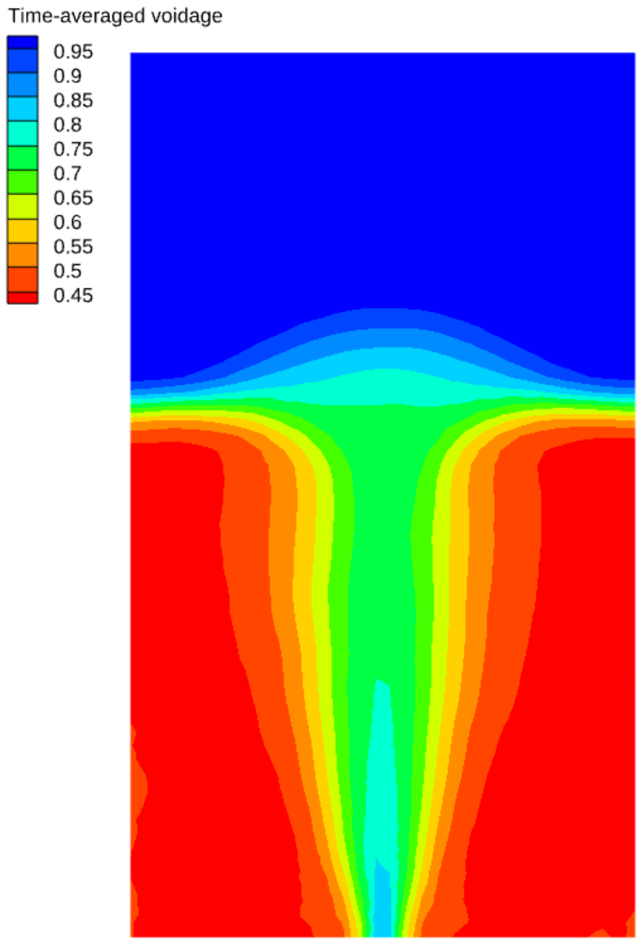
Staying with default, physically appropriate for glass beads



# ROM Demonstration – Tuning Kuipers Training problem

**Development of underlying ROM allows us to quickly examine and refine the solution space**




## CPFD ROM Tool

- Fast, easy to use
- Release target in Q4 2026

# Conclusions

**Broad technology development in support of particle applications at CPFD:**

- **Application models**
- **New product features**
- **Reduced order modeling tool**