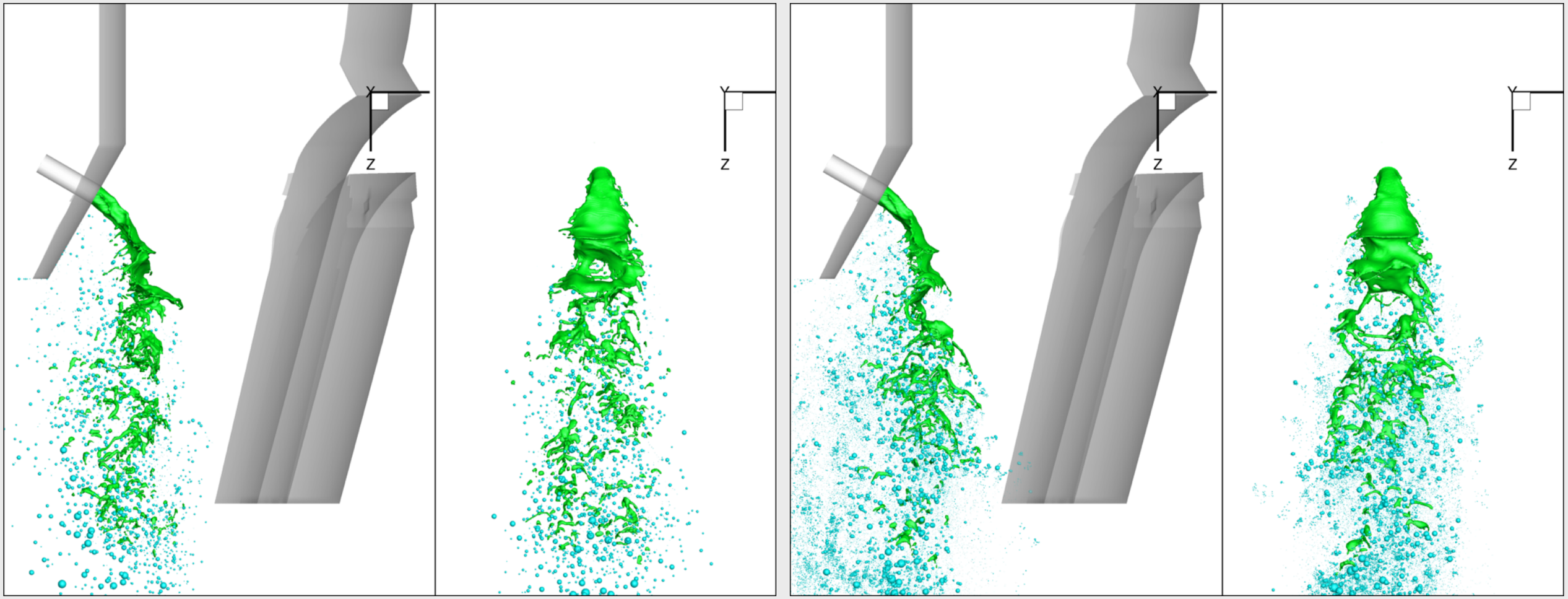
Impact of Secondary Breakup Model

no secondary breakup model

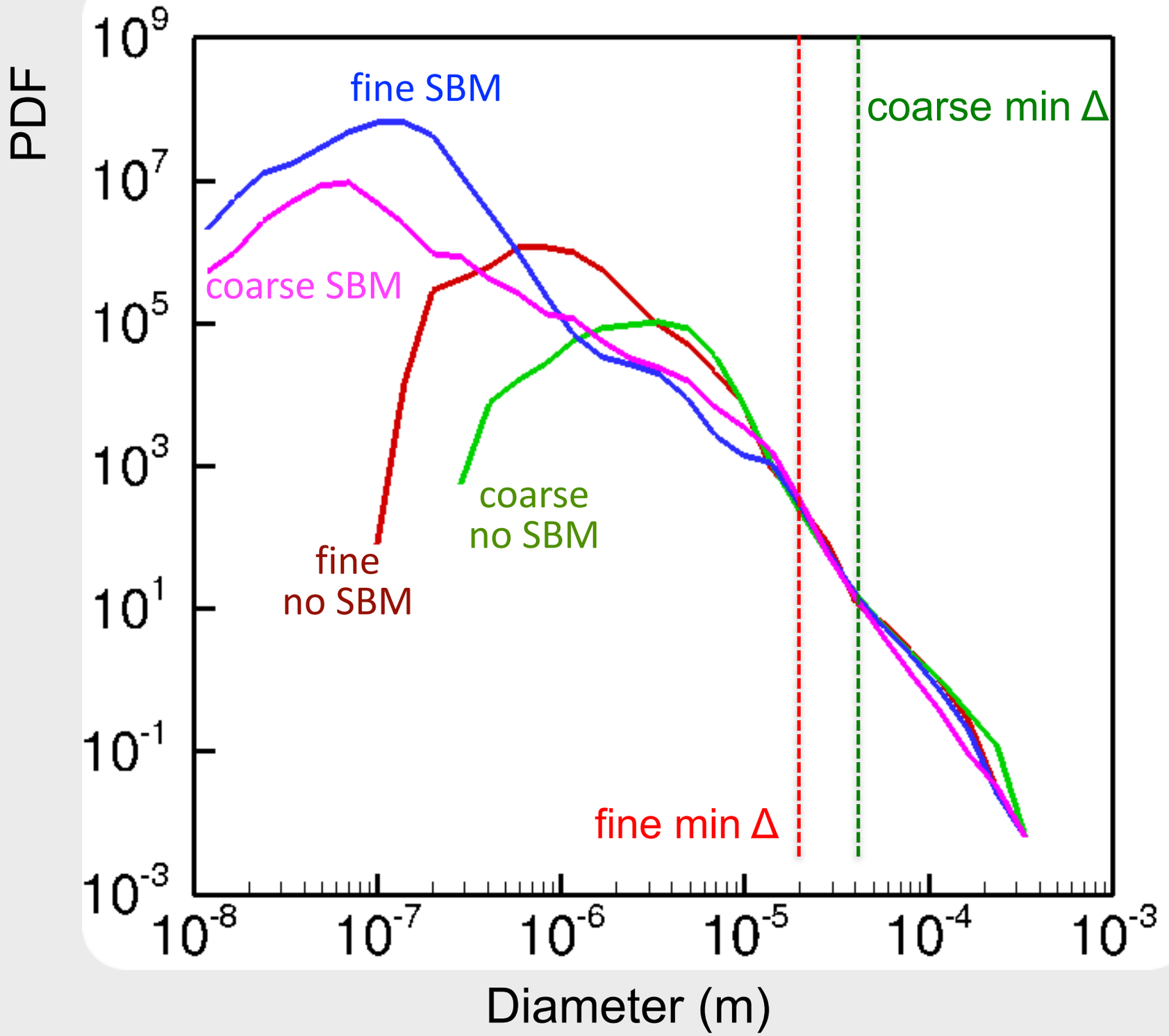
stochastic secondary breakup model



VoF = 0.5 iso-contours

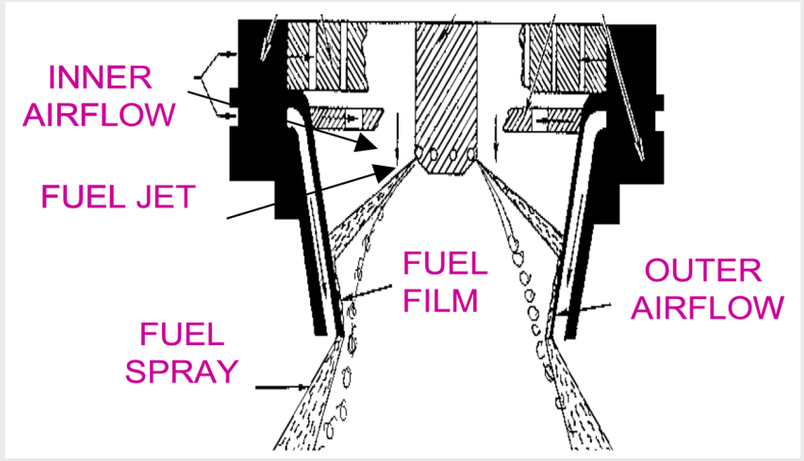
:Lagrangian drops

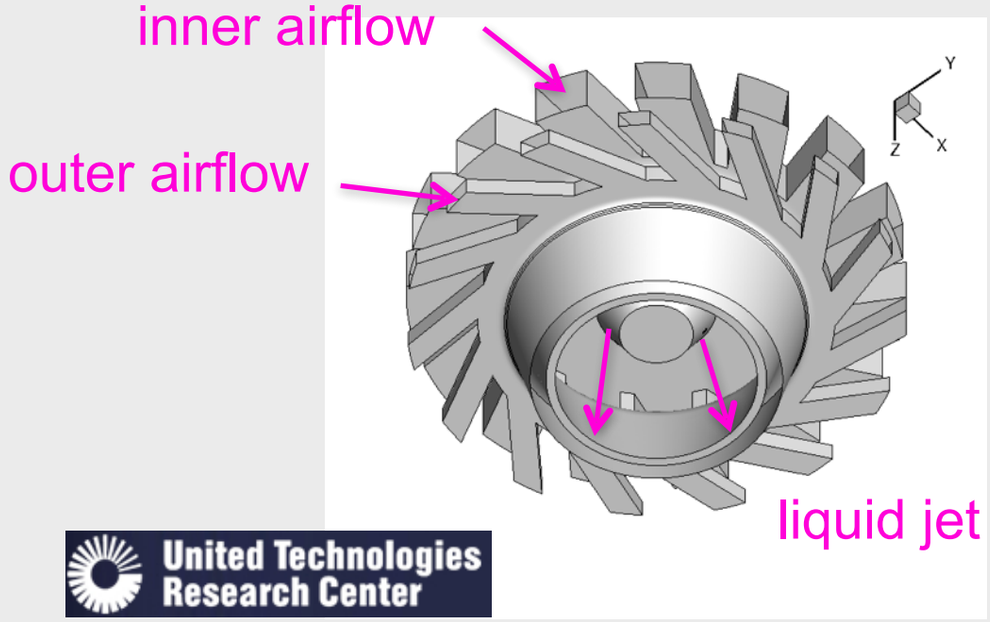
Drop-Sizes: Impact of Grid Resolution and Secondary Breakup Model (SBM)



High-Shear Nozzle Injector

- High shear injector with inner and outer swirl





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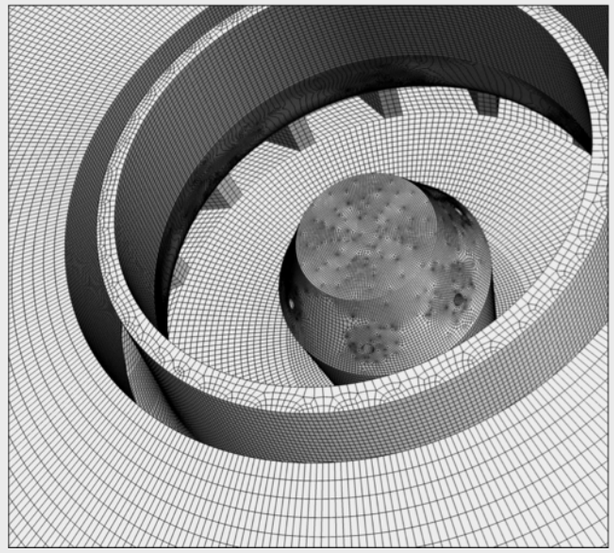
- Radial inflow swirler details



United Technologies Research Center

Swirler Design

- # of slots = 15 each for inner/outer
- Area ratio (i:o) = 82:18
- exit diameter = 0.8 inch

Fuel Injector Design

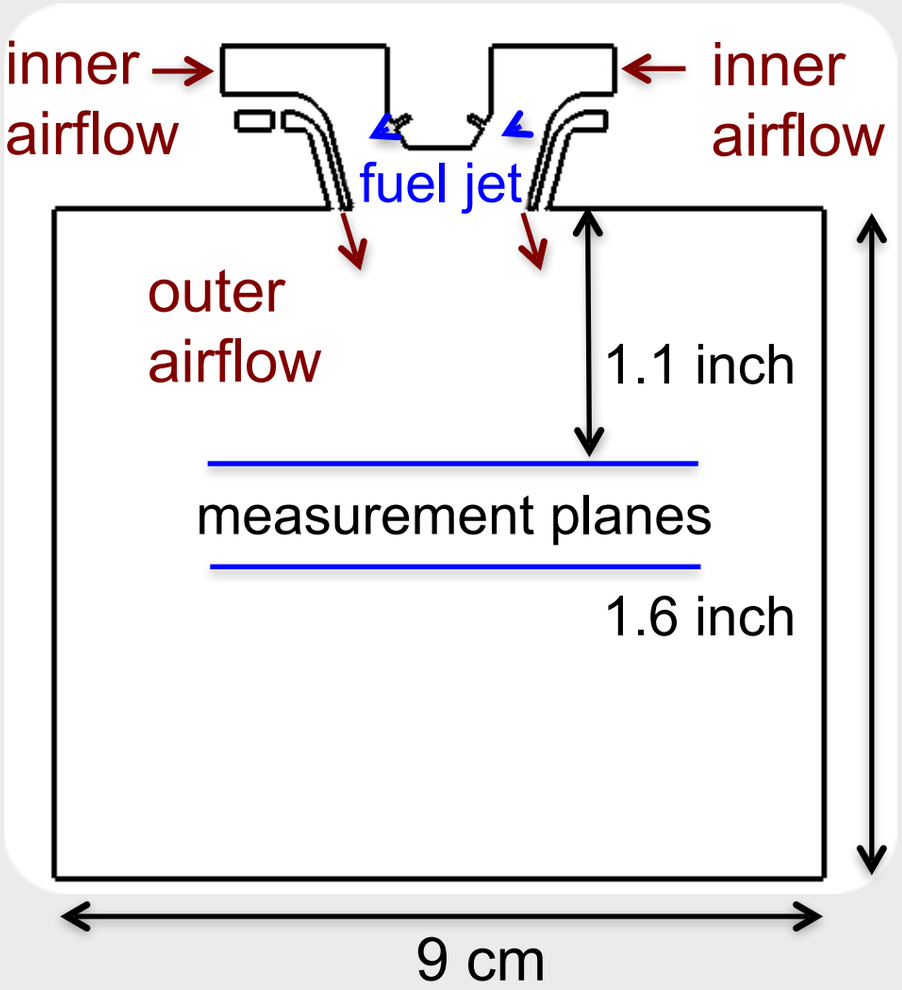
- six fuel orifices (0.025 inch)
- angled 60° from centerline

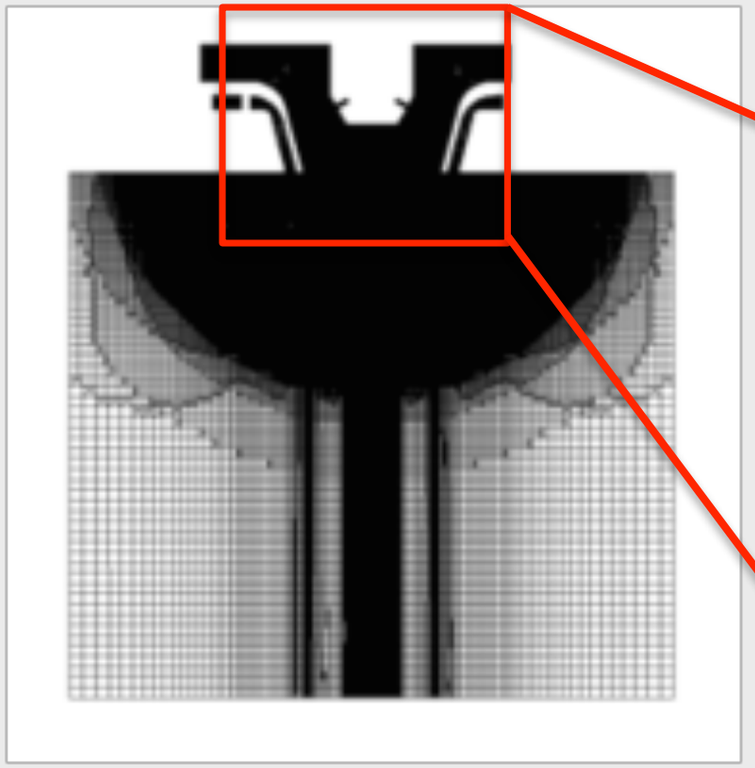
Full Swirling High-Shear Nozzle Injector

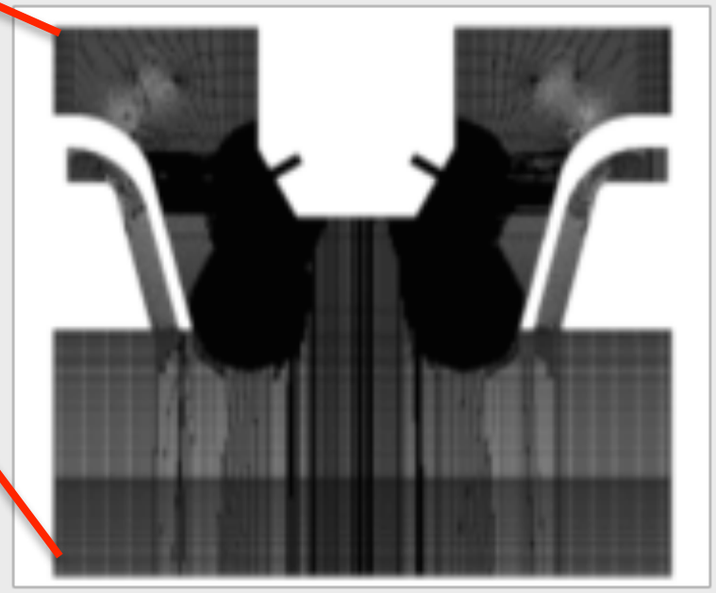
	UTRC
momentum ratio	*9.4*
Gas Weber number	*155*
Primary Atomization	*shear breakup*
Injector Diameter	*0.635 mm*
Estimated Hinze scale	*38 micro-meter*
Measured Dp_min	*10 micro-meter*

	Case 1 (coarse grid)	Case 2 (fine grid)
Number of grids	*18,000,000*	*240,000,000*
Min grid size	*D/8 (80 µm)*	*D/32 (20 µm)*
Secondary breakup model	*Stochastic*	*w/ & w/o Stochastic*

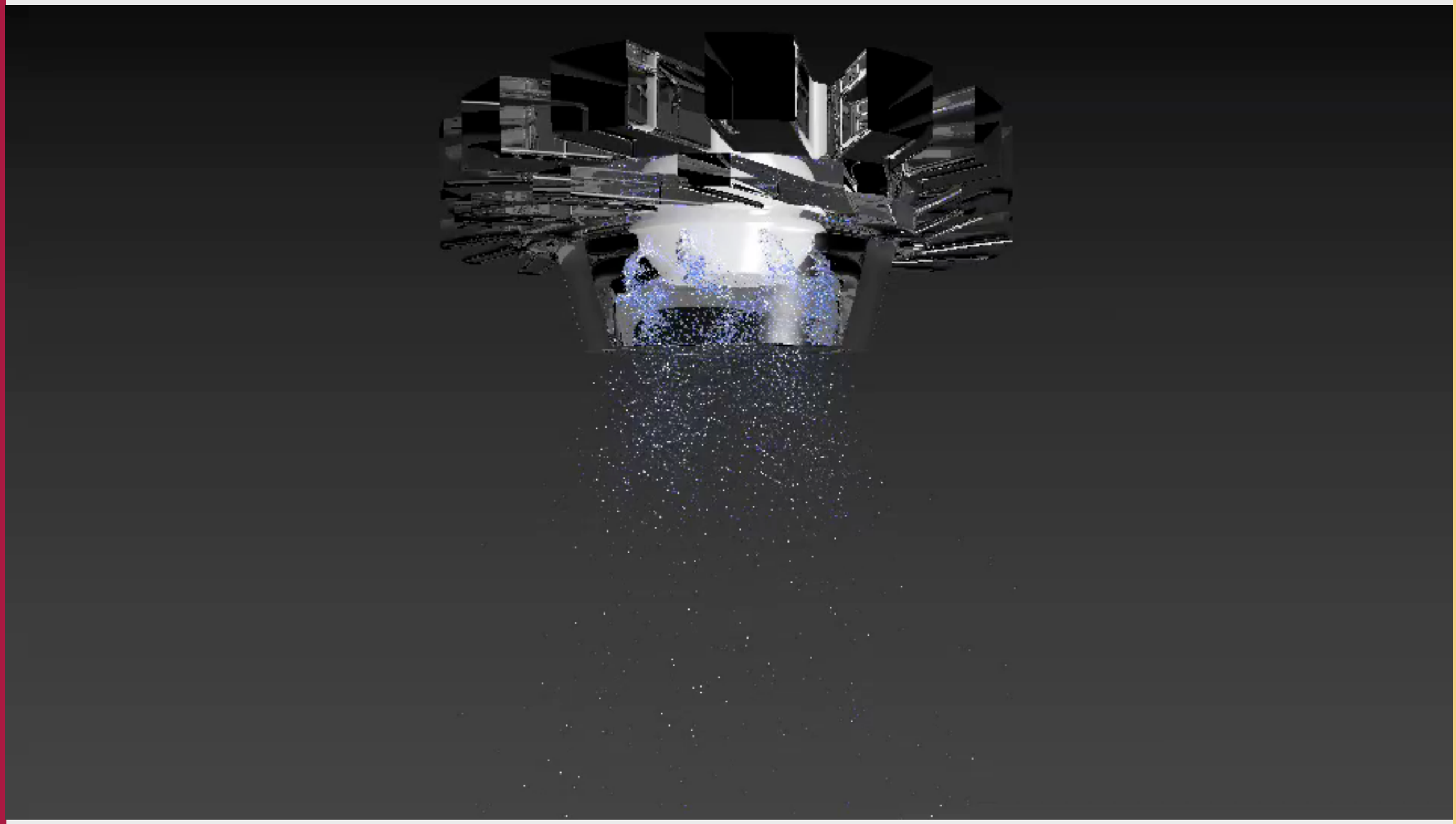
Computational Domain & Grid



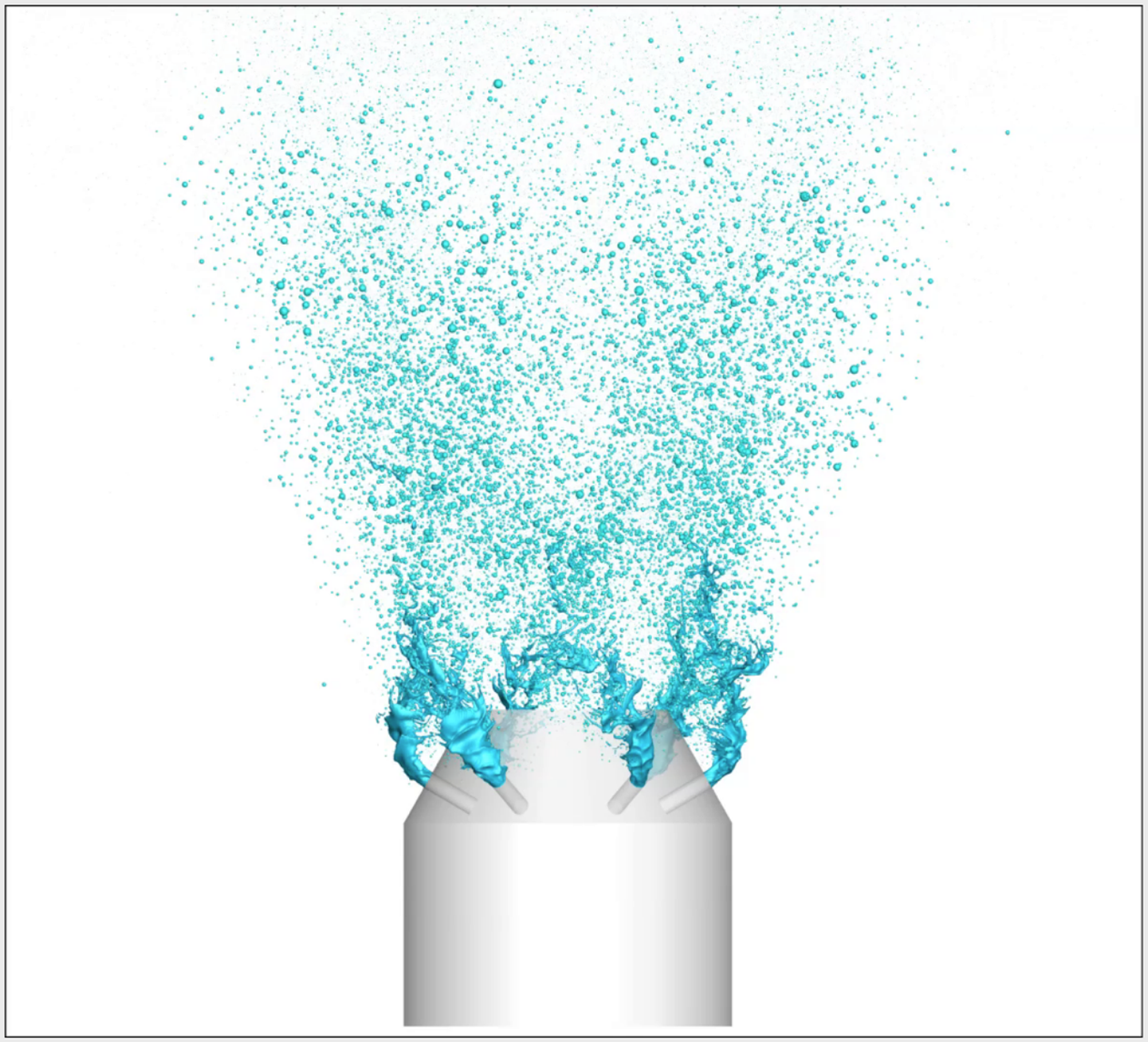


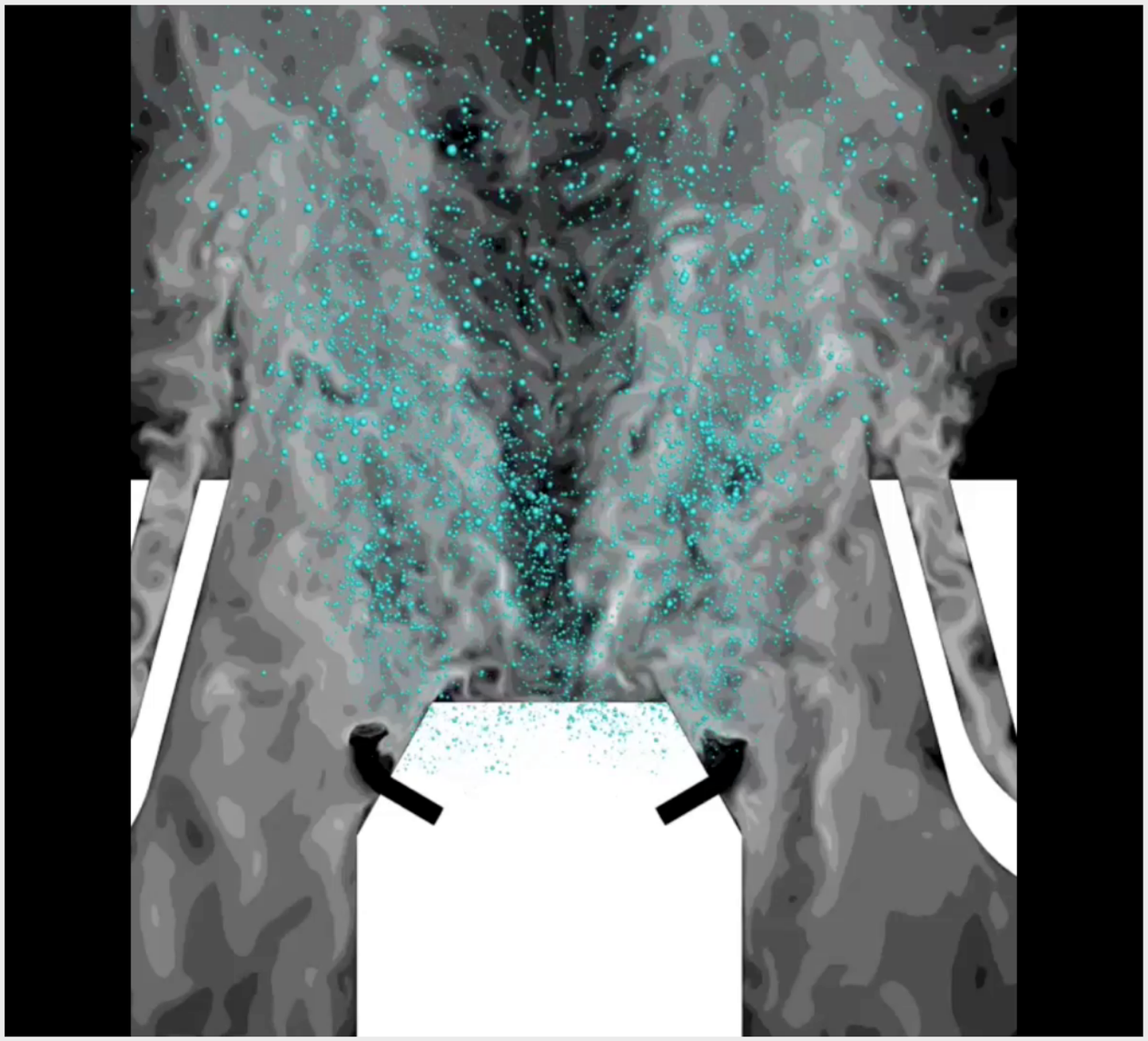


Flow Visualization



Near Injector Region

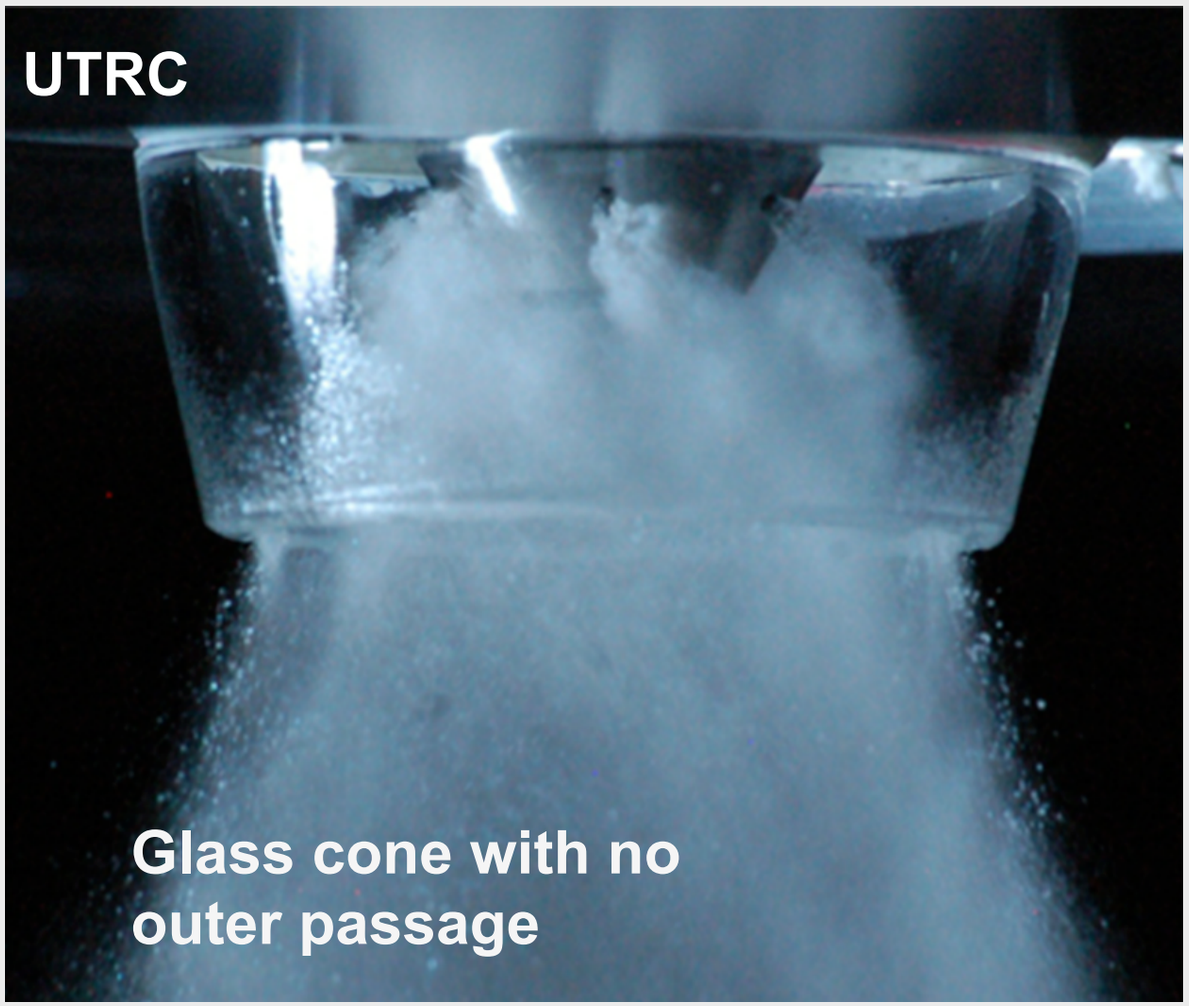


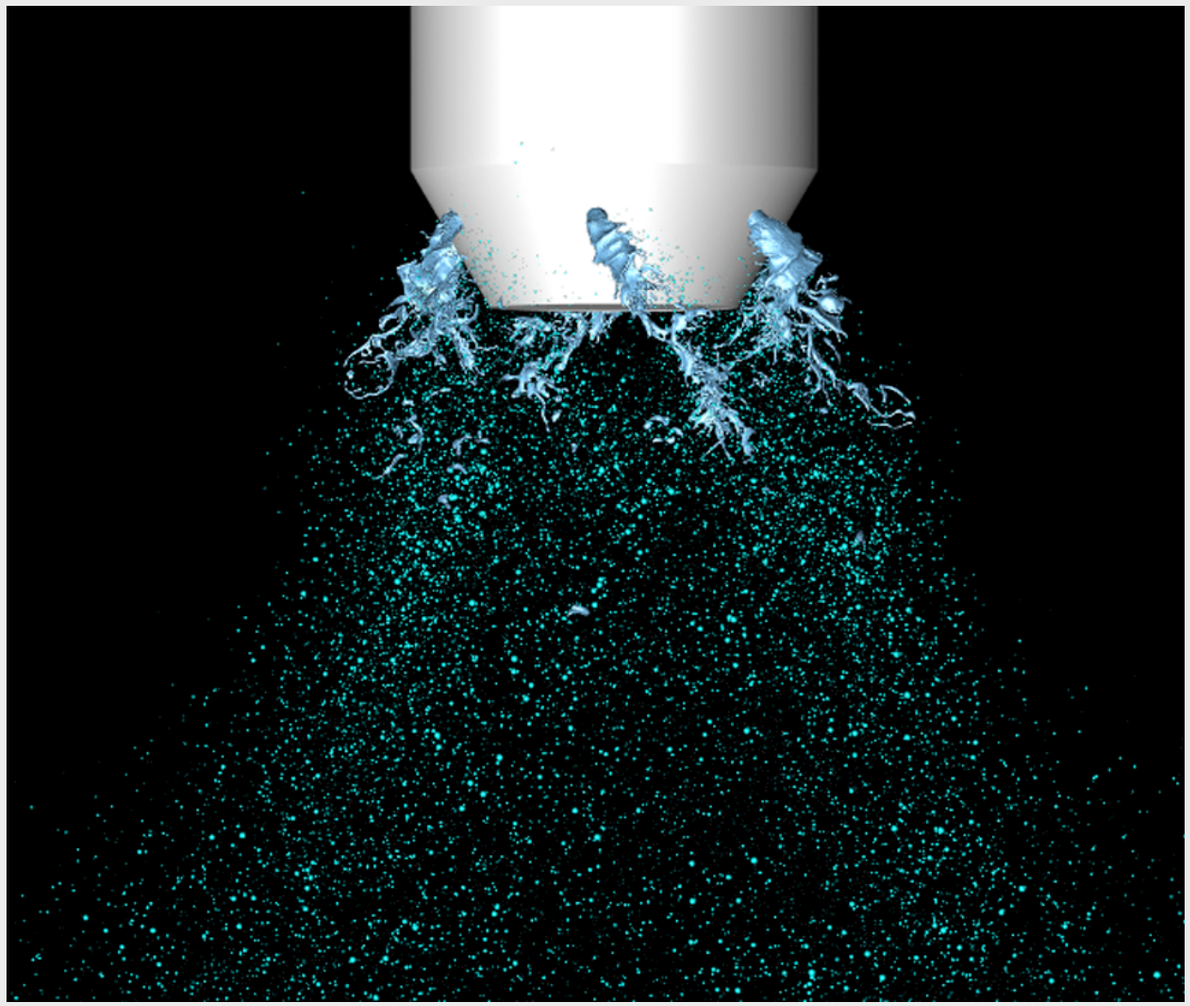


Velocity magnitude contours

Qualitative Comparison

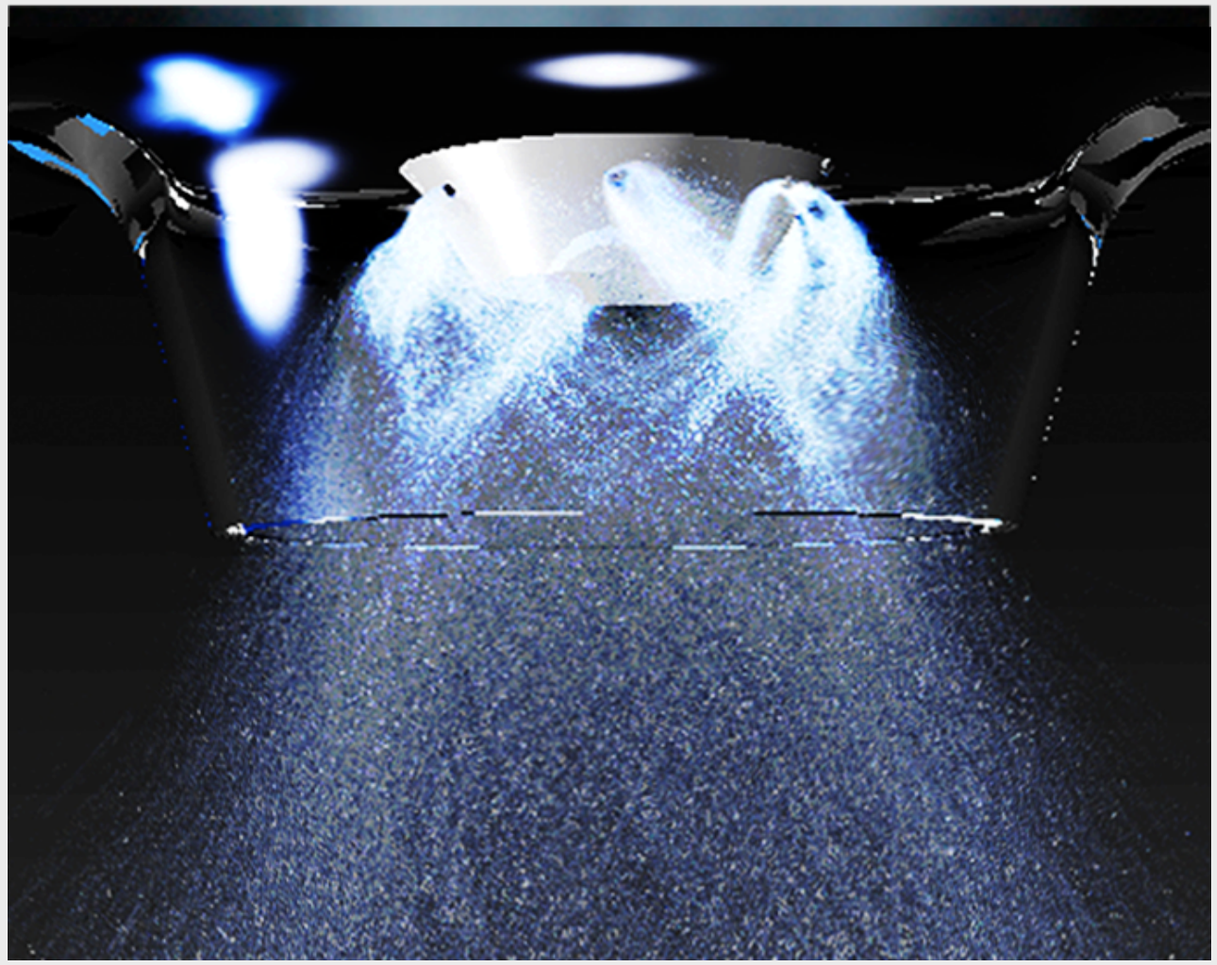
- Near-field photo





Qualitative Comparison

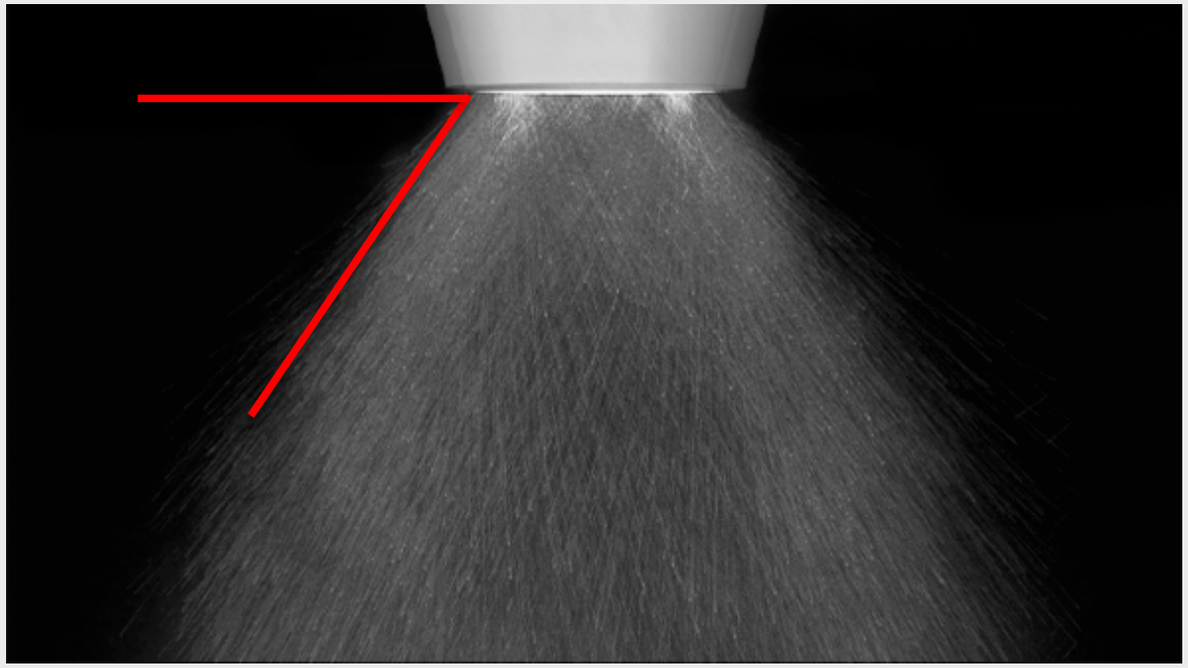
- Near-field photo – attempt to include exposure effects



Quantitative Comparison: Spray Angle

Experiment (UTRC)

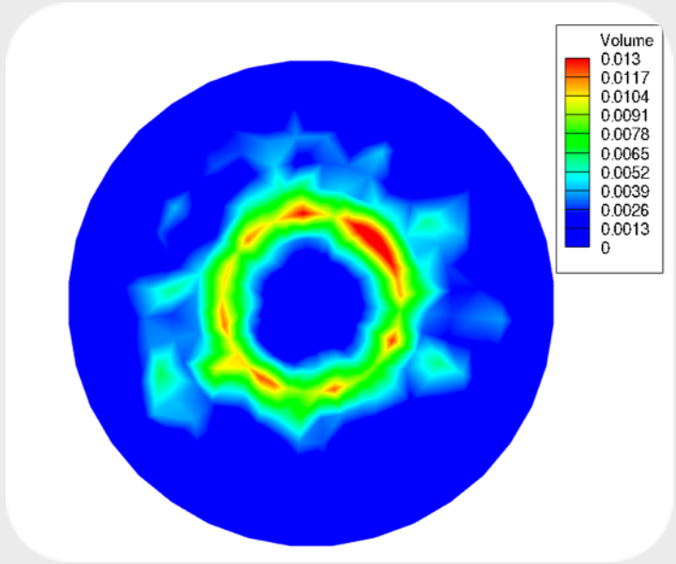
High-speed photograpy



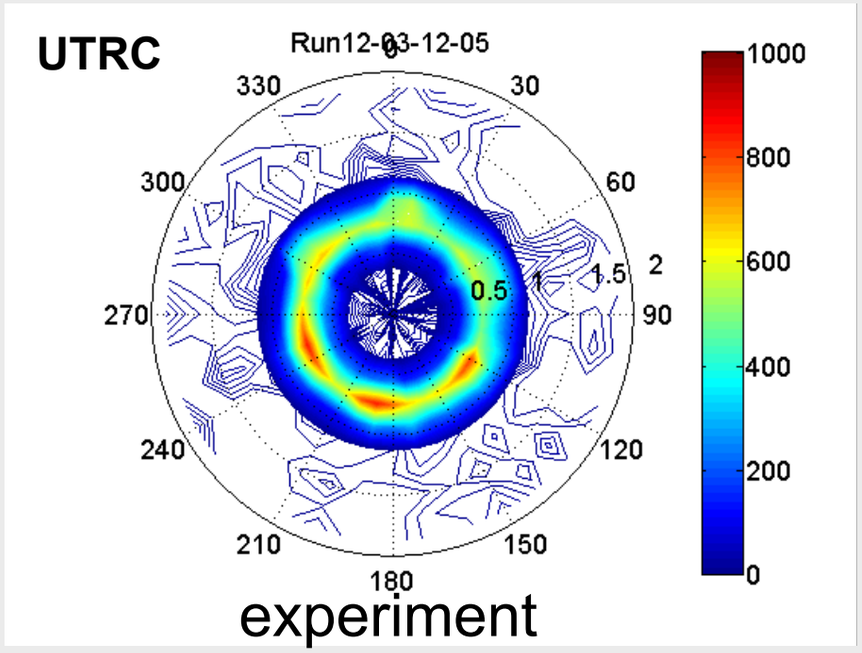
Simulation

External Flow Quantification: Fuel Flow

- 1.1” measurement plane

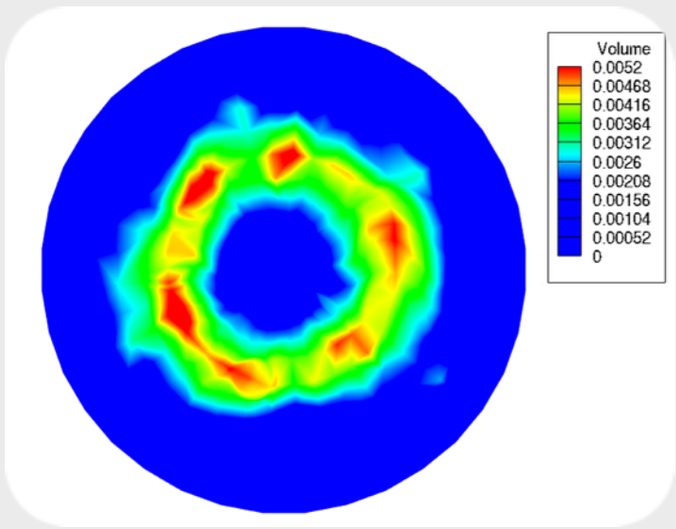


simulation

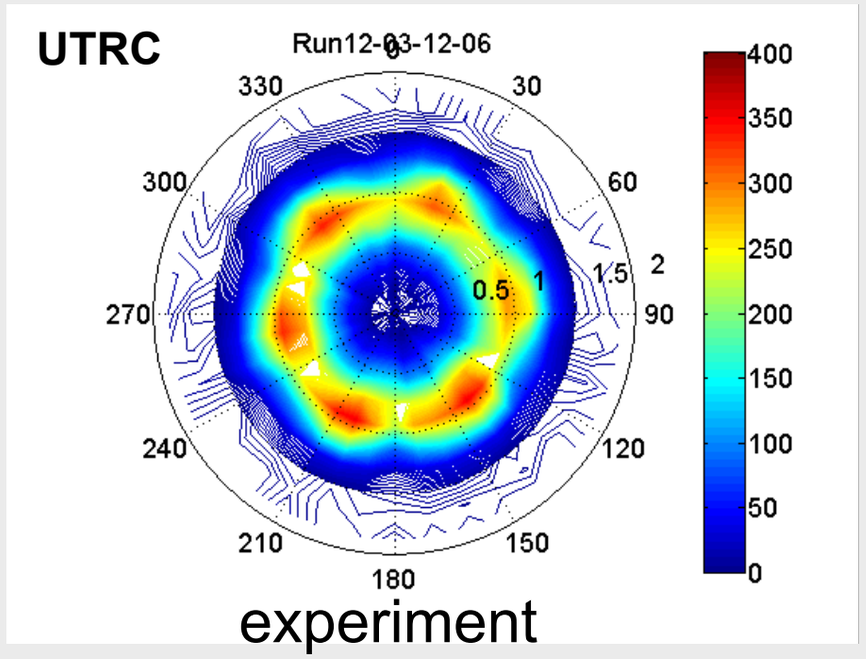


experiment

- 1.6” measurement plane



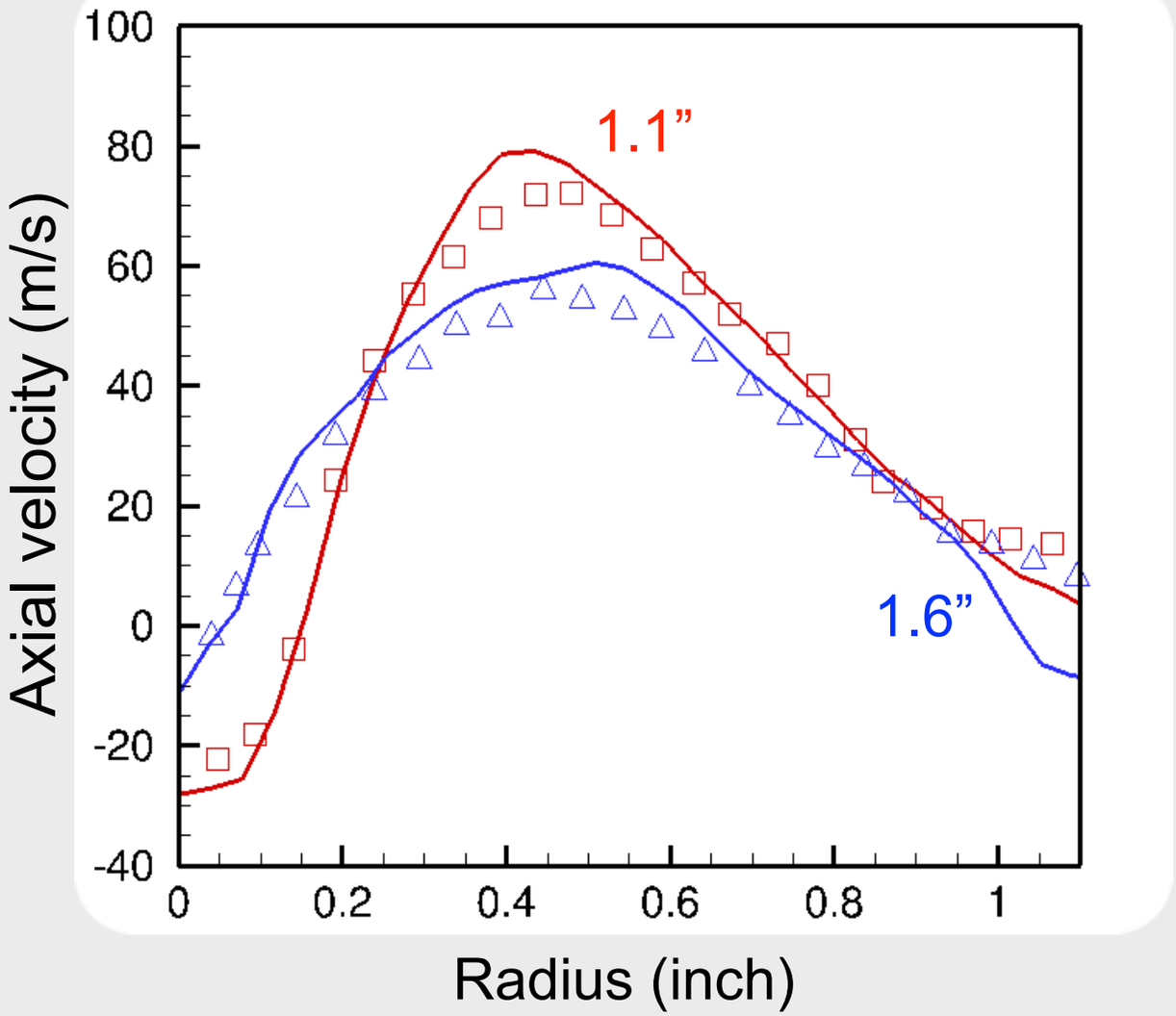
simulation



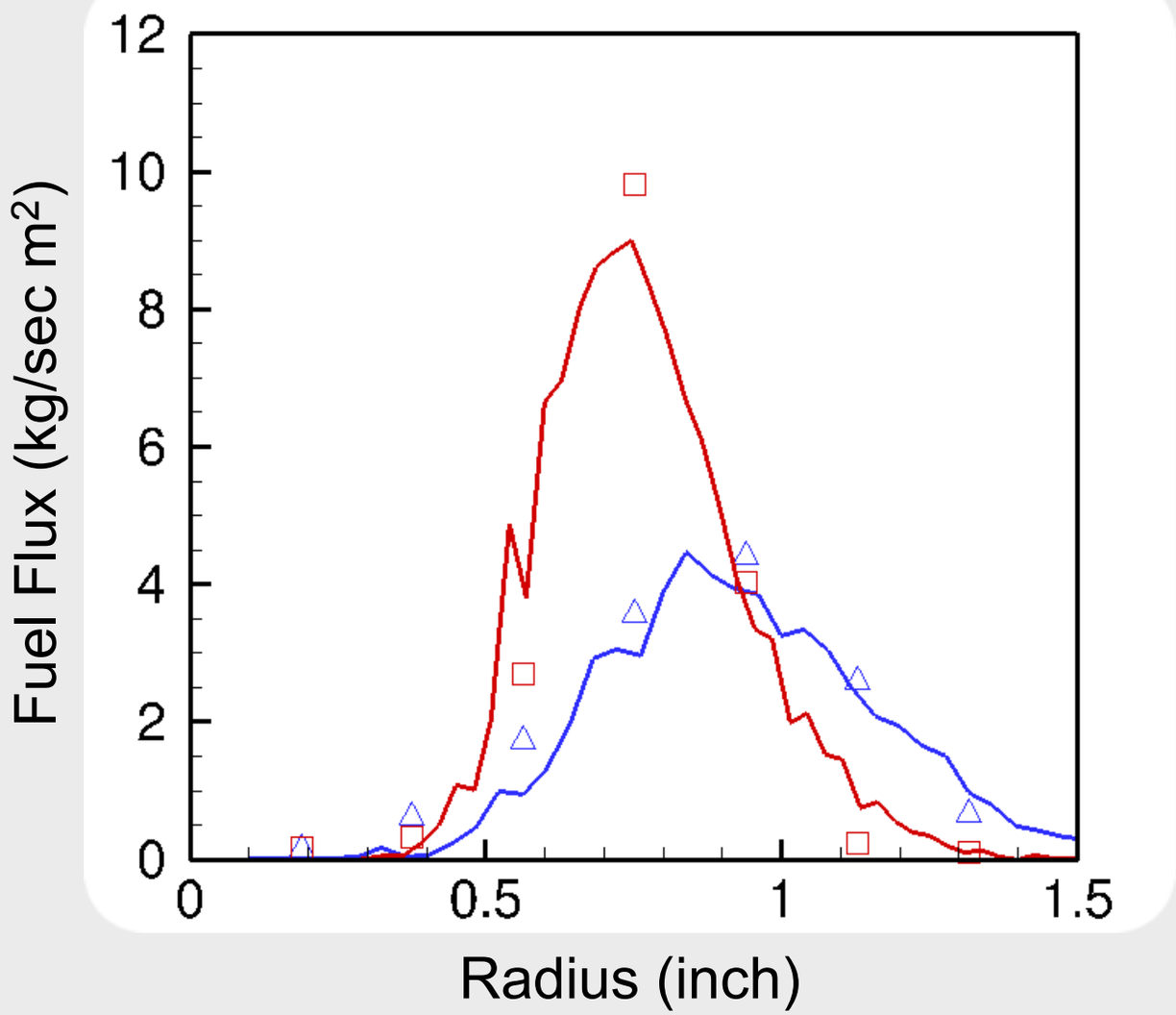
experiment

Quantitative Comparison

axial velocity

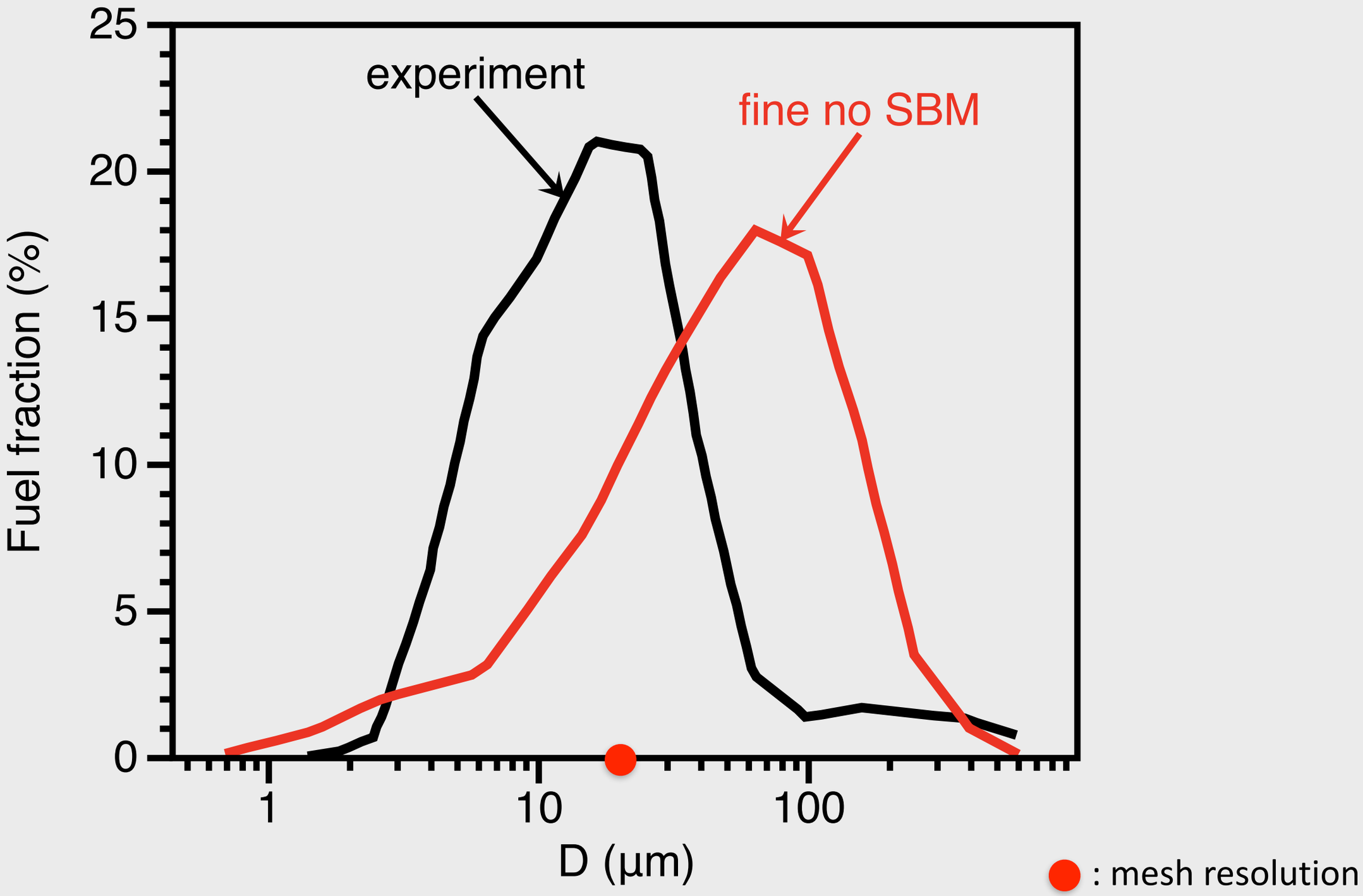


fuel mass flux

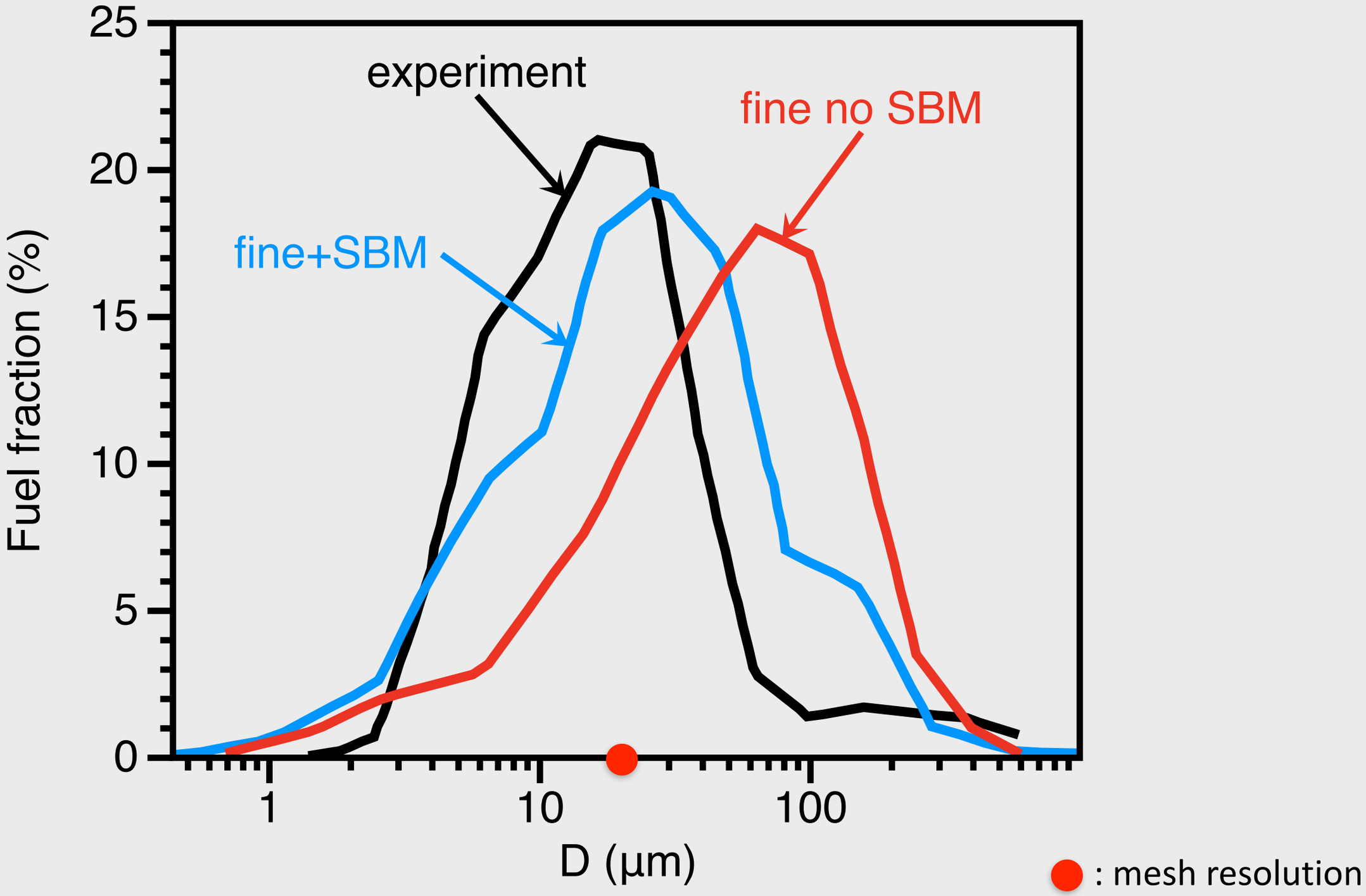


experiment: symbols
simulation: lines

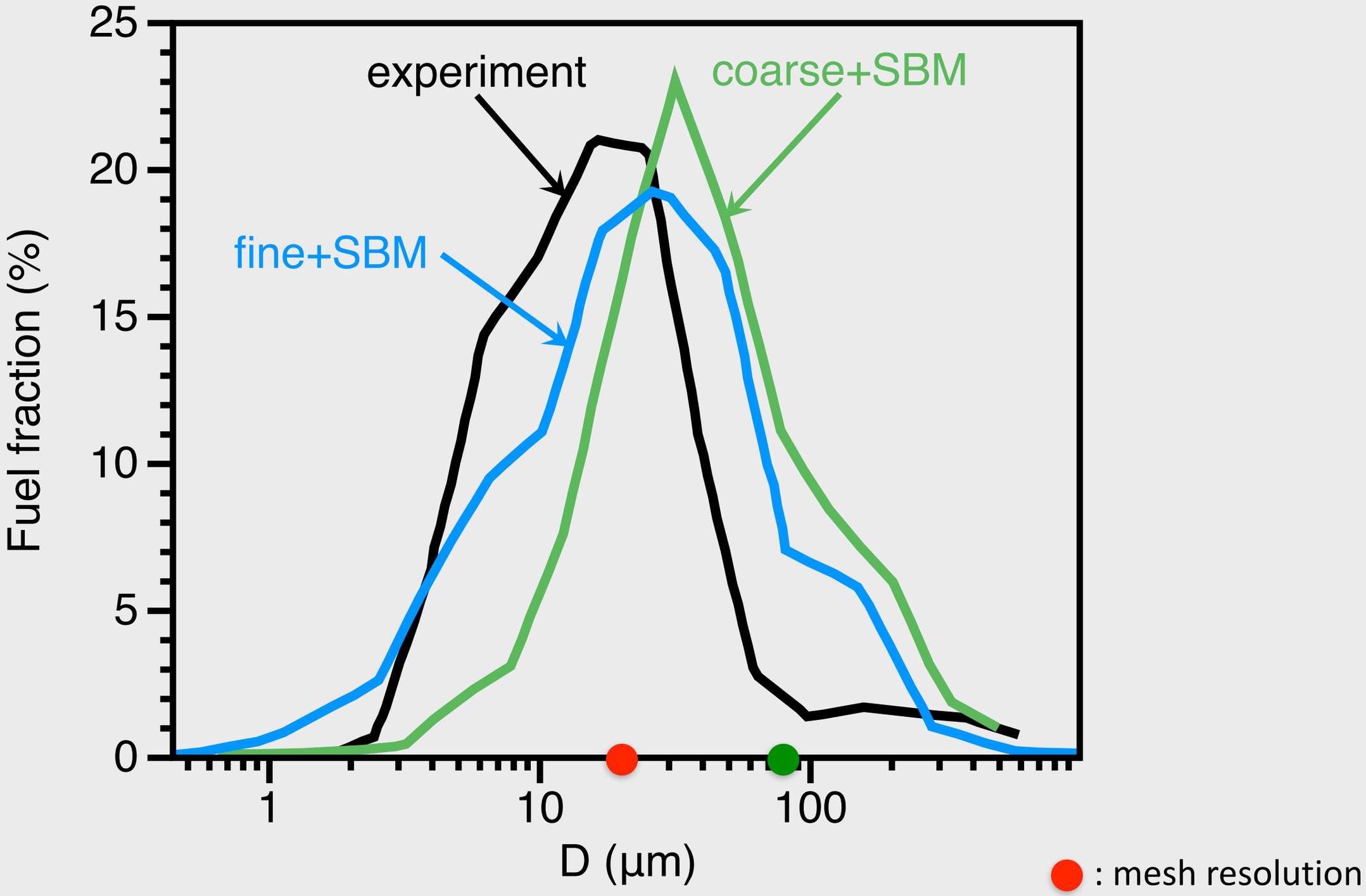
Drop-Size Distribution



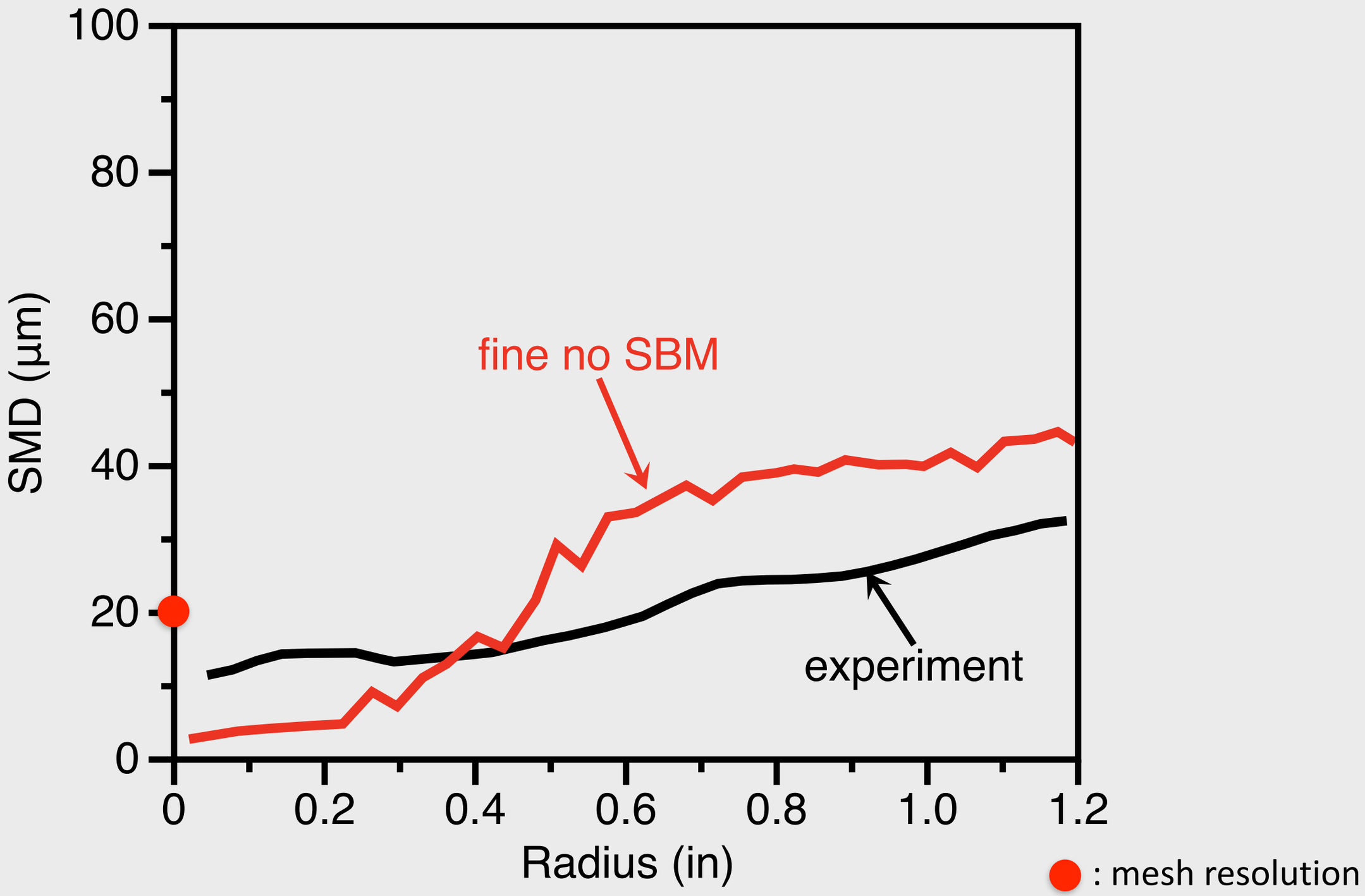
Drop-Size Distribution



Drop-Size Distribution



Drop-Size SMD



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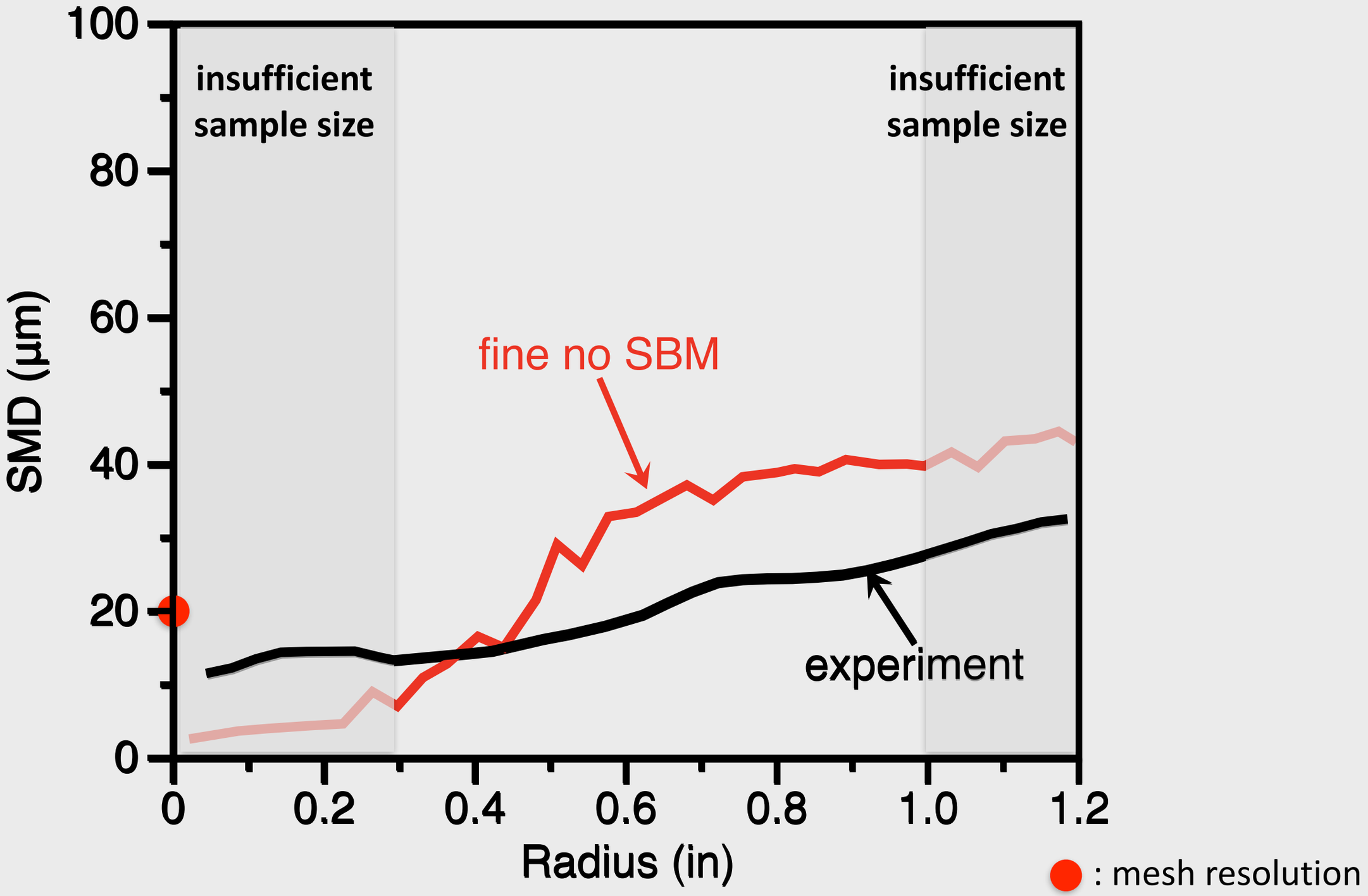
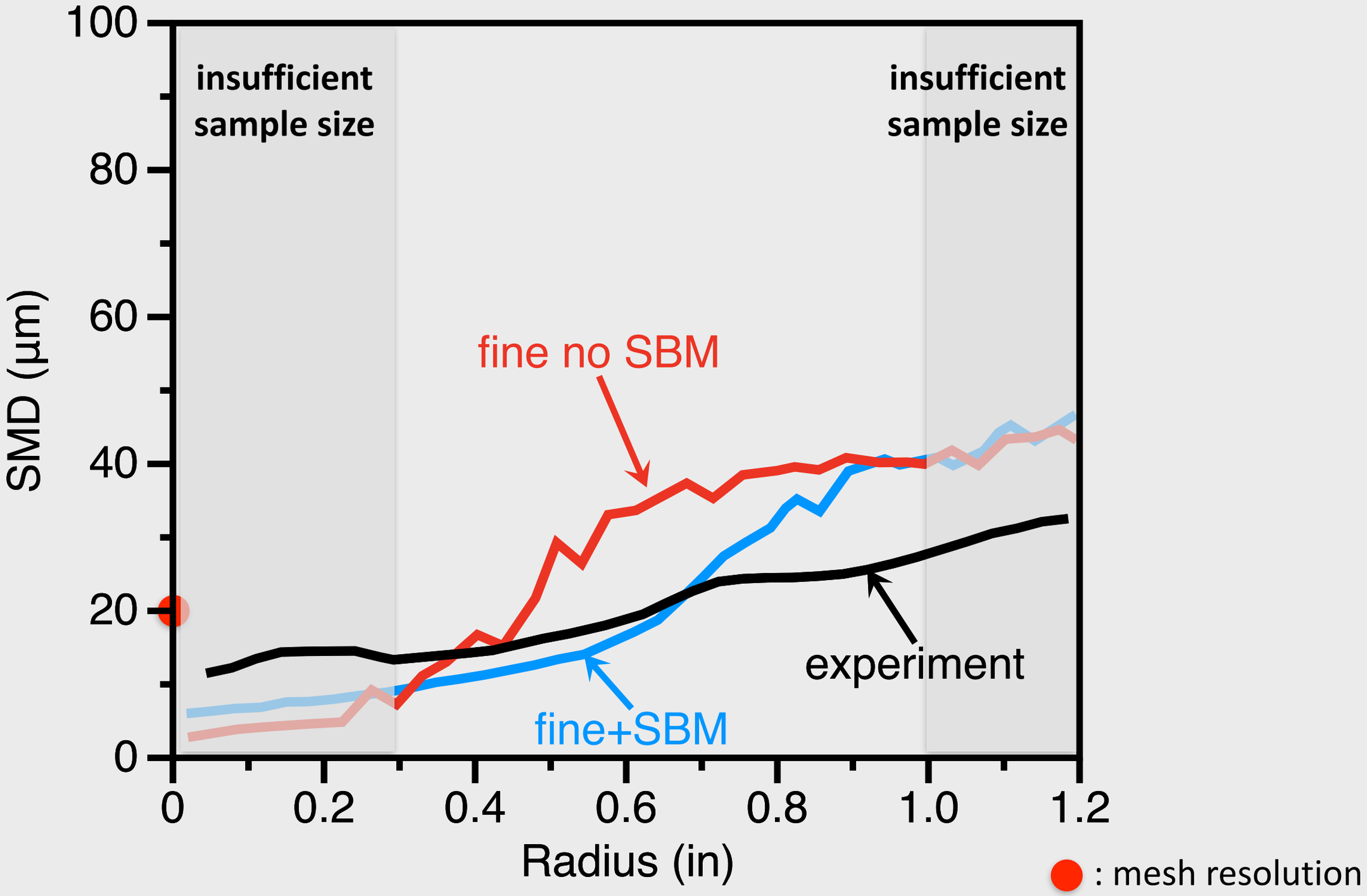
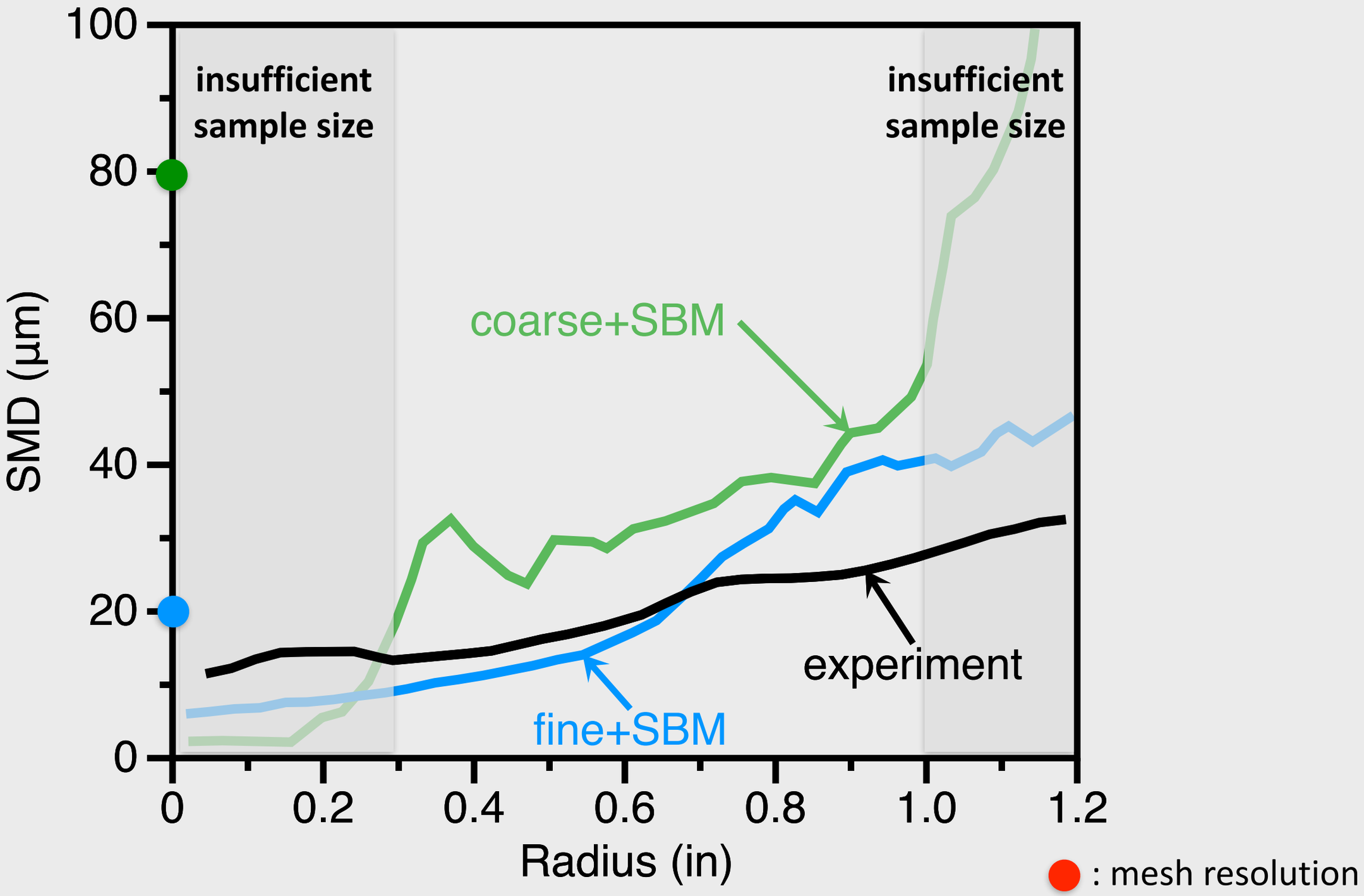


Drop-Size SMD

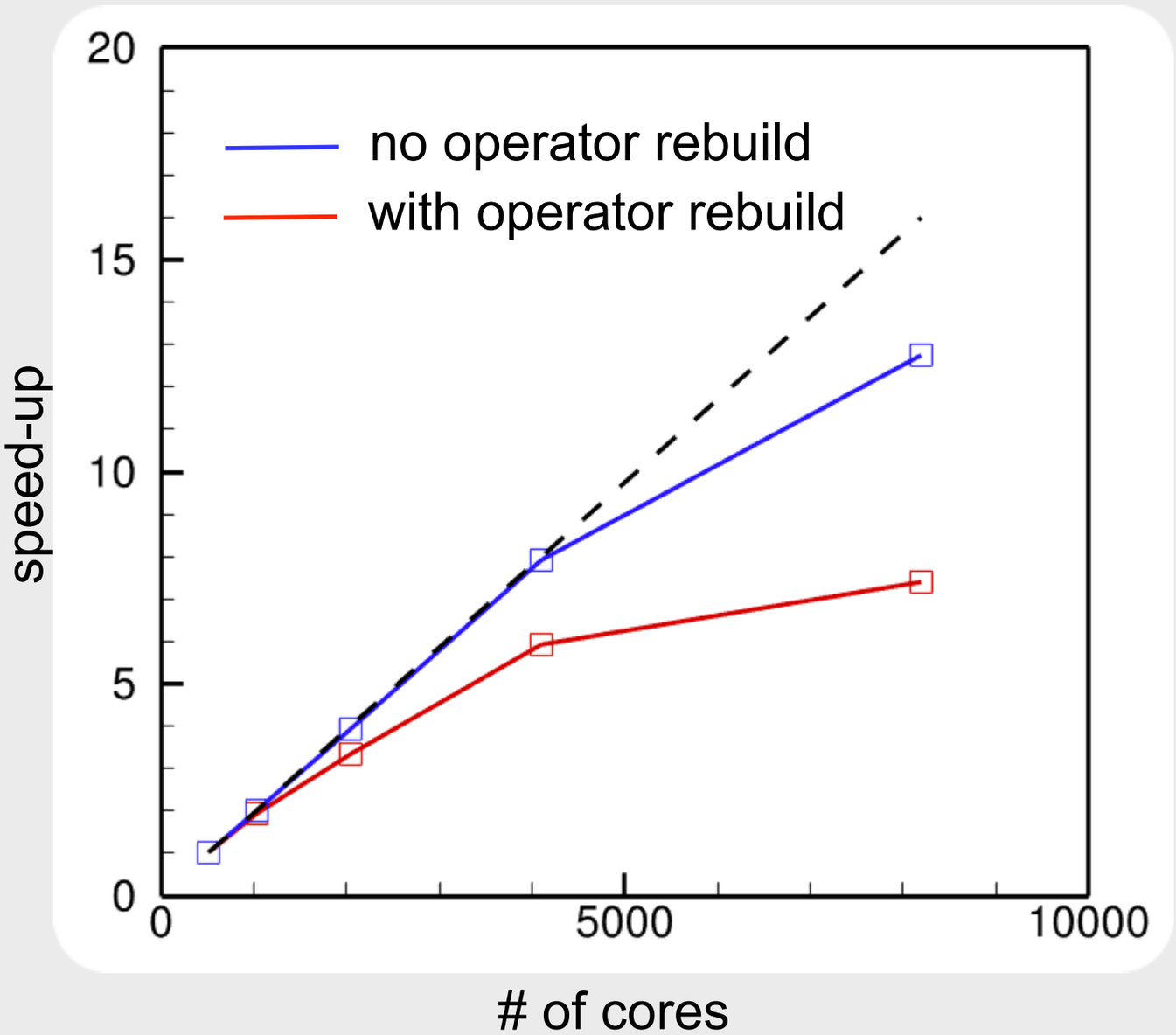


Drop-Size SMD



Scalability and Cost

- 75% parallel efficiency up to 4096 cores on DoD Spirit
  (due to CPU/network speed ratio)



DOD	Spirit Cluster
cpu	*Intel Sandy bridge*
cpu speed	*2.6GHz*
total nodes	*4590 (73,440 cpus)*
core/node	*16*
memory/node	*32Gbytes*

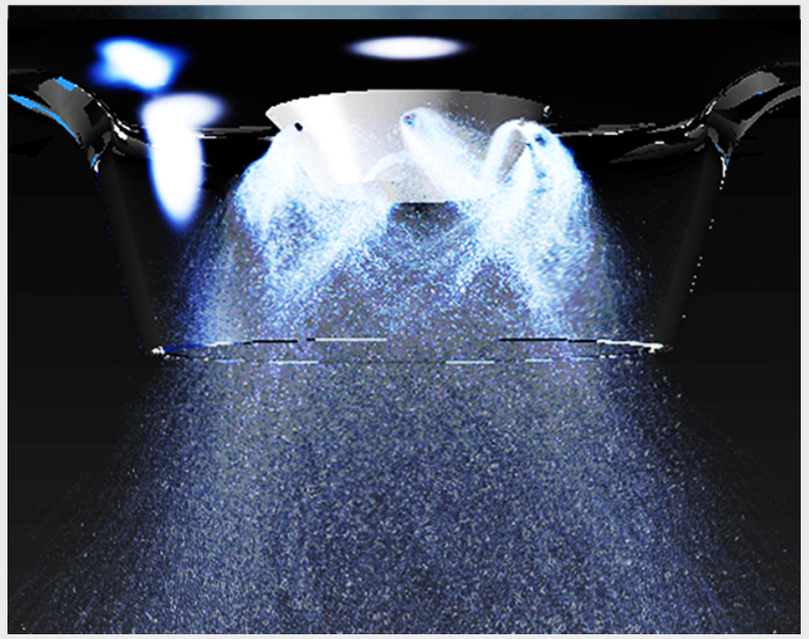
Computational time (210M cells, 2048 cpus)

$$D/u_{jet} \approx \text{6.6 hours}$$

$$L_z/u_{gas} \approx \text{4.3 days}$$

1.1in plane ≈ 1.2 days

Summary

- Predictive simulations of complex, realistic fuel injectors are conceivable:
  - unstructured meshes & flexible heterogeneous, anisotropic mesh refinement to concentrate resources into primary atomization region
  - hybrid approach combining interface capturing (level set or VoF) & Lagrangian spray models
  - can be done with existing parallel resources

- Potential straightforward coupling to combustor simulations due to Lagrangian spray description
- Future challenges
  - multicomponent fuels
  - compressibility & supercritical injection