

Modeling of a Vortexing Circulating Fluidized Bed (VCFB) for process intensification

Justin Weber

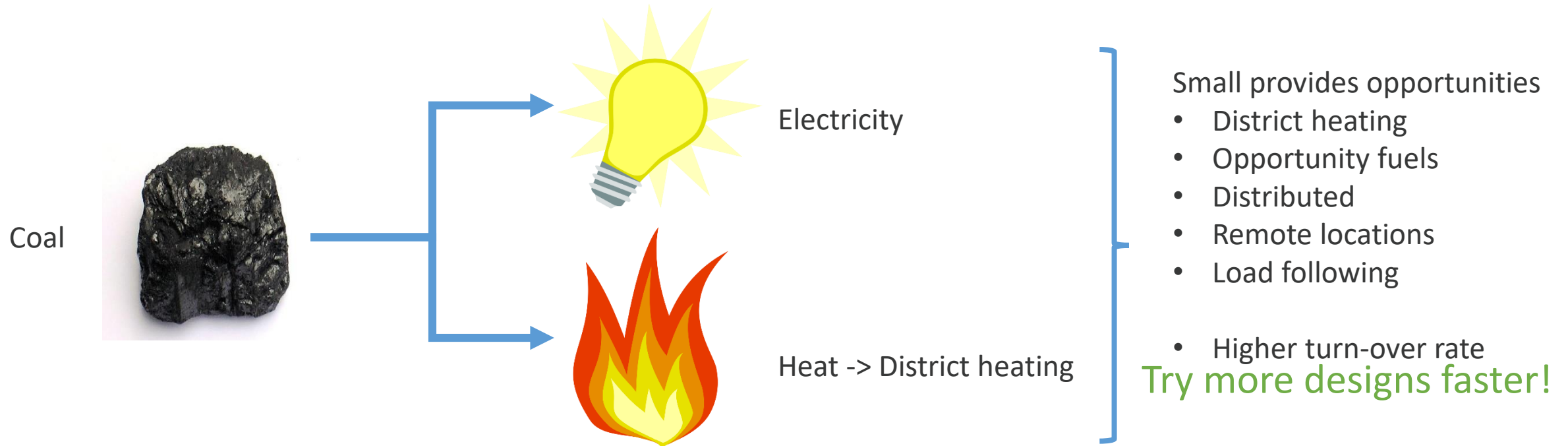
June 28, 2019



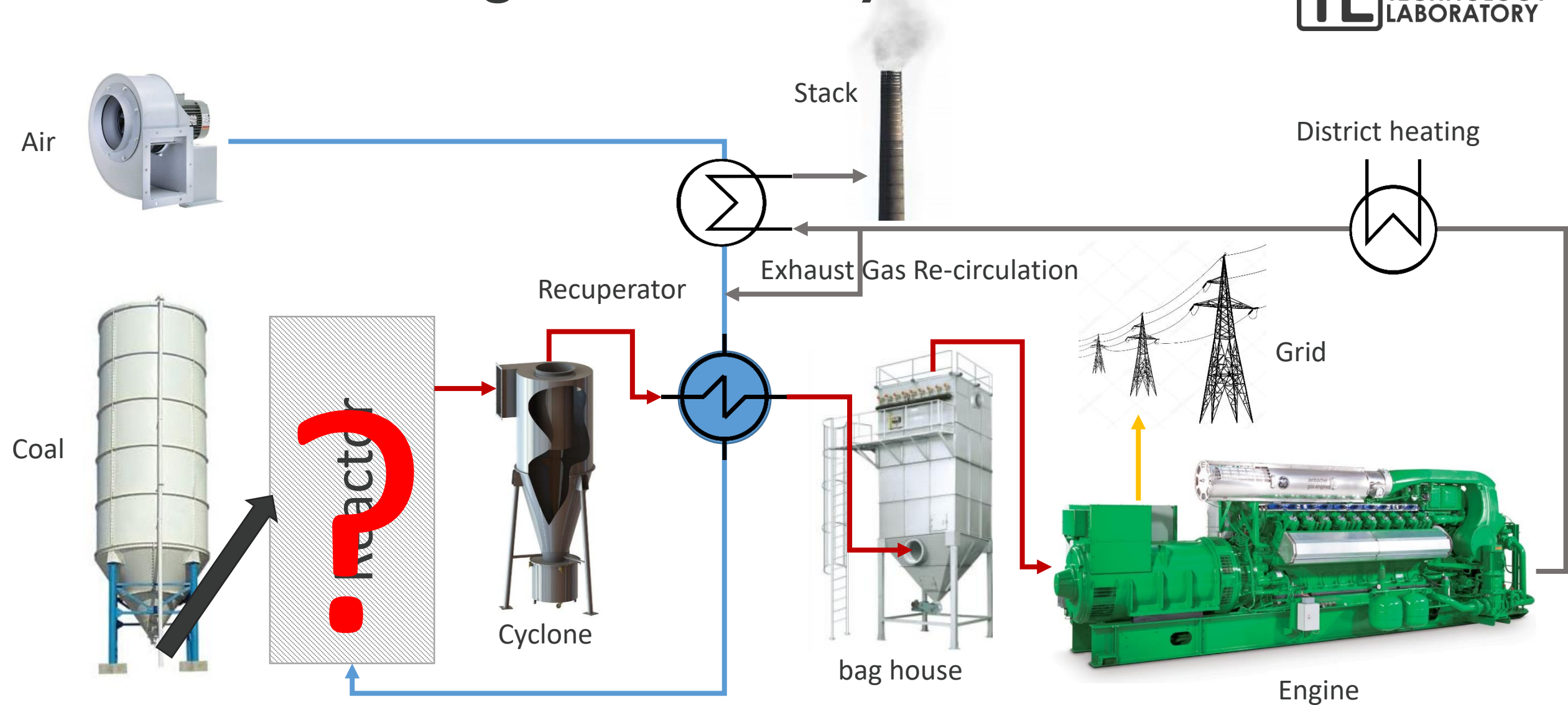
Solutions for Today | Options for Tomorrow

Challenge

Design a 1 - 5MW_{th} small modular system with turn down for



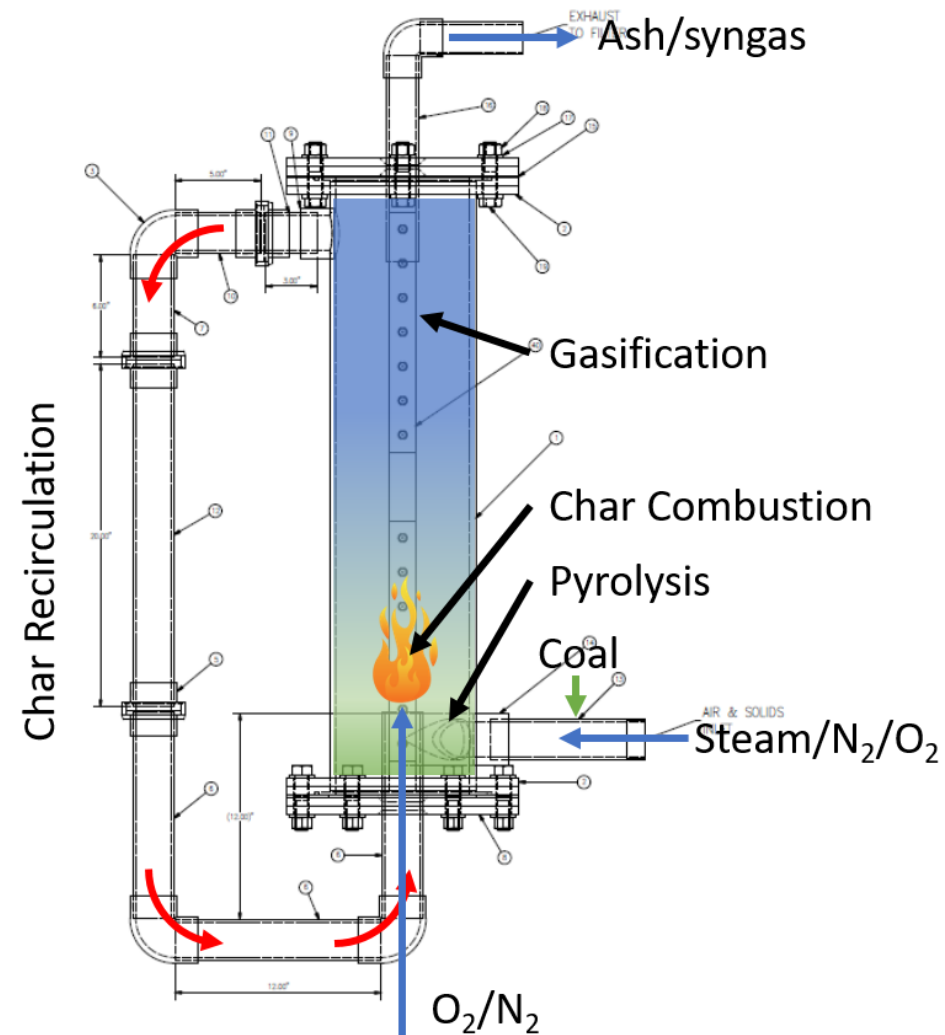
Small modular gasification systems



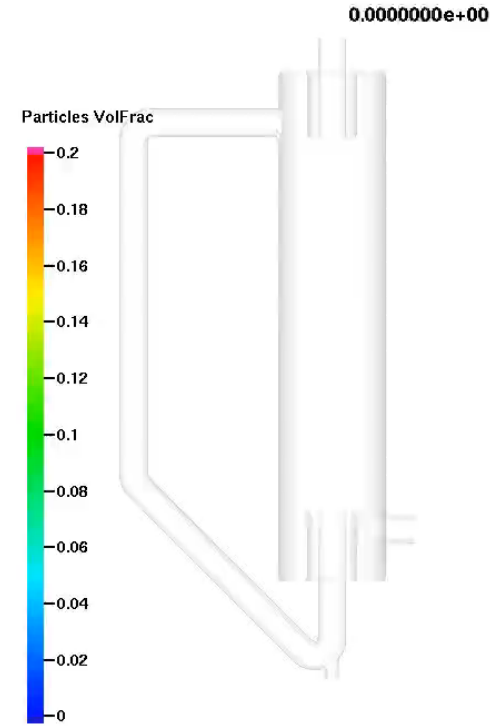
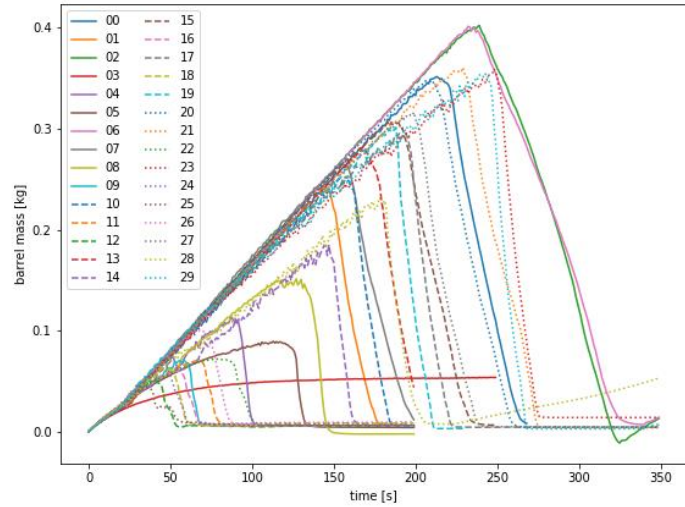
Can we shrink the TRIG?



process intensification



Methodology



NETL Chemical Looping Reactor

Cold Flow

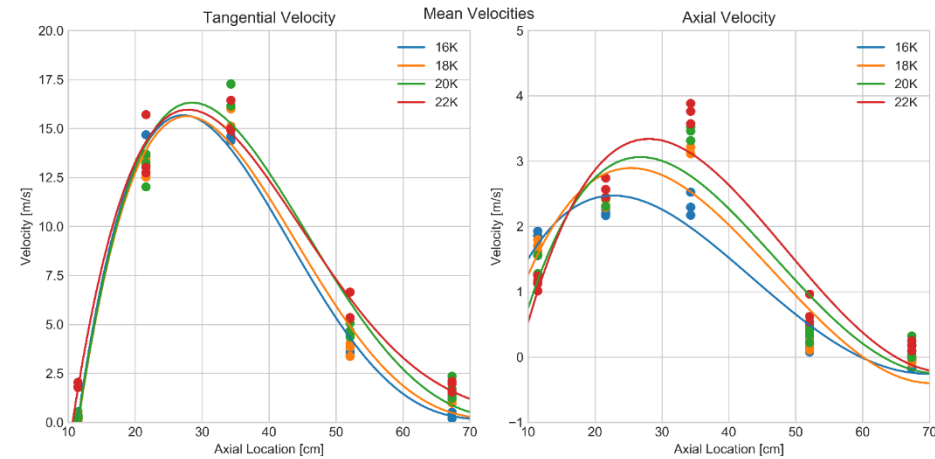
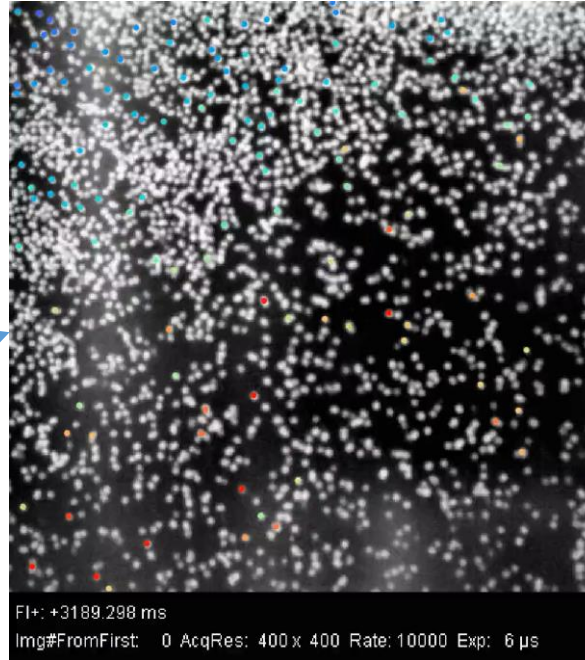
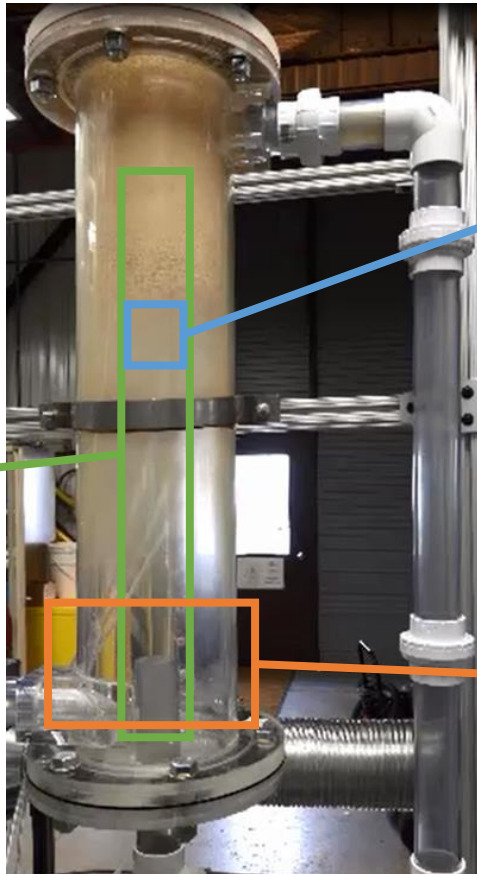
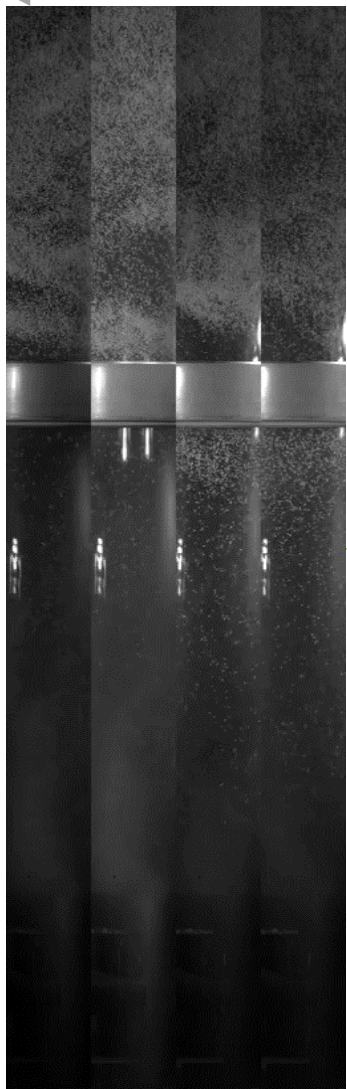
Model Calibration

Reacting model performance prediction

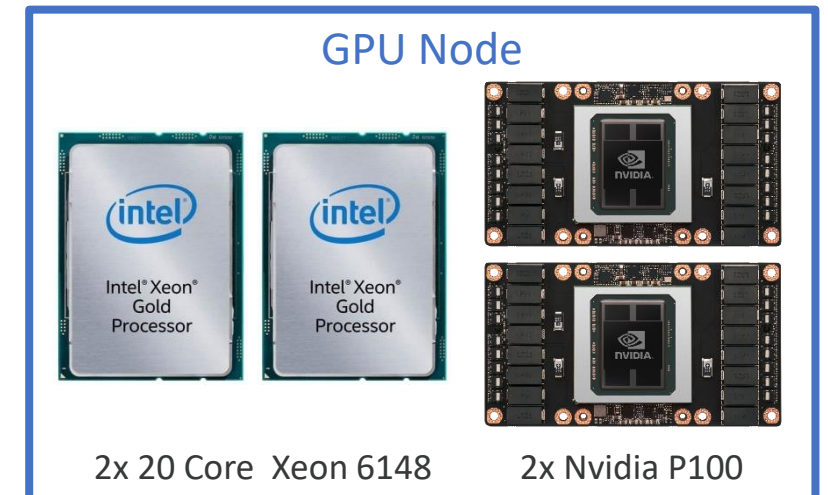
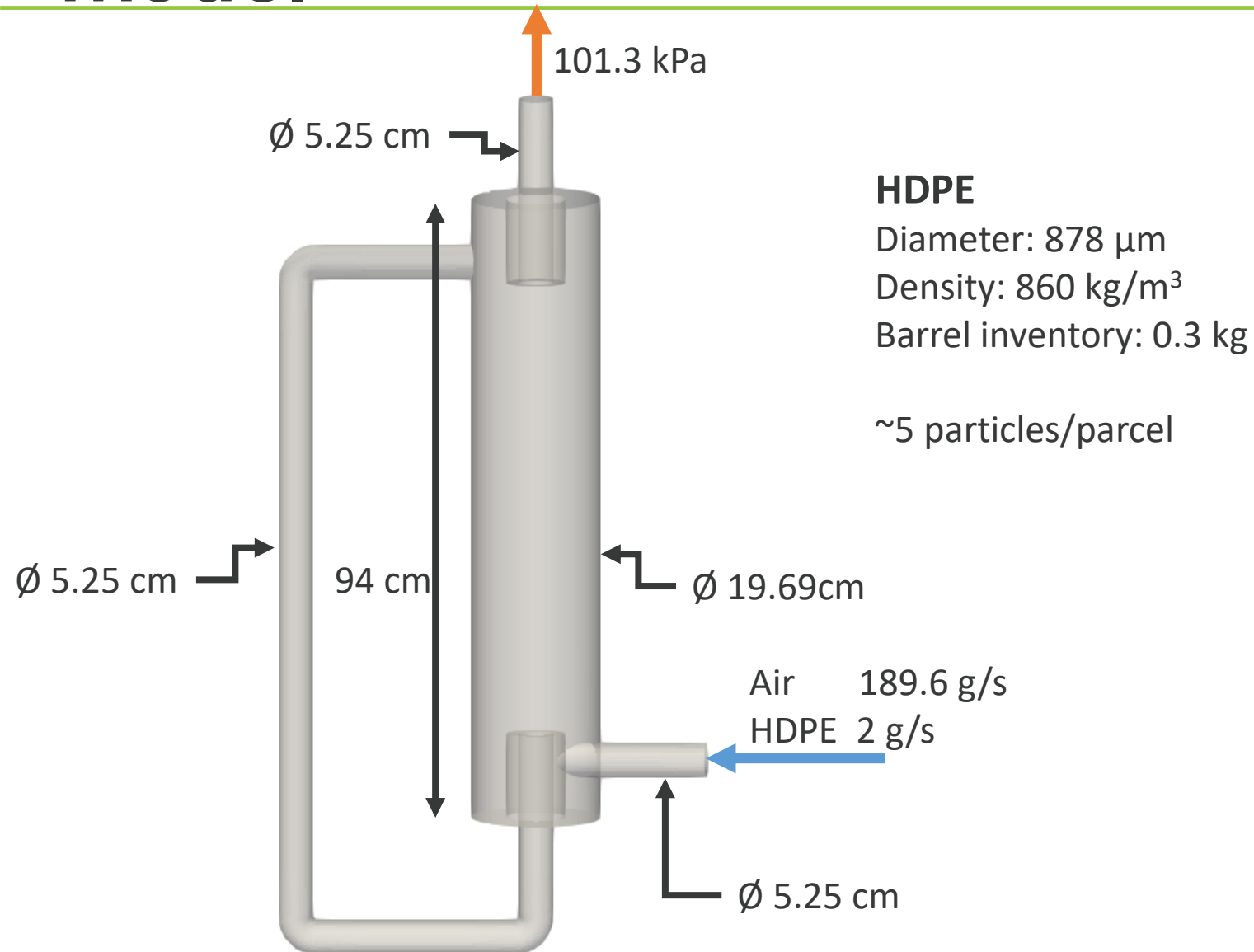
Hot reacting unit

Experiment

↑ Gas Velocity

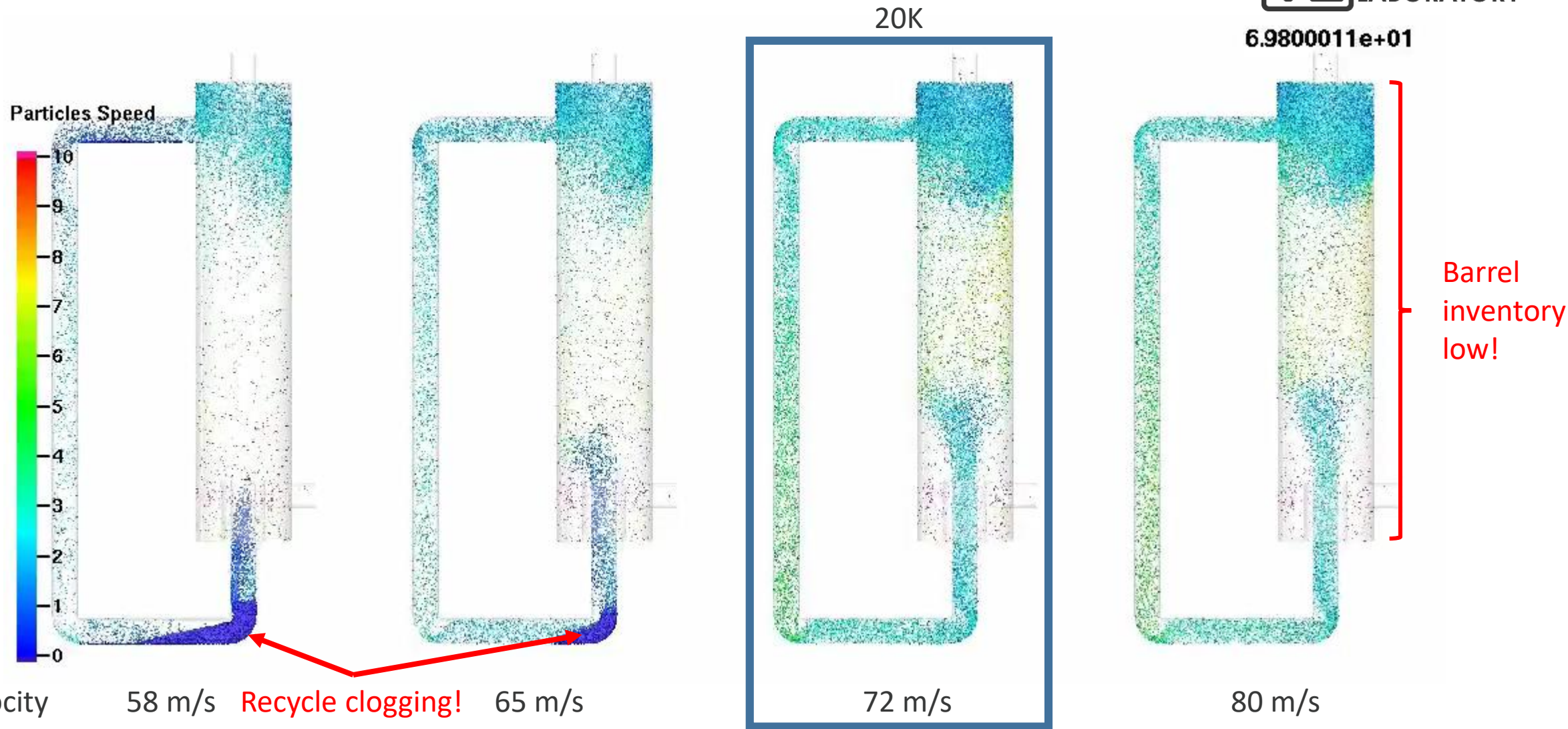


Model

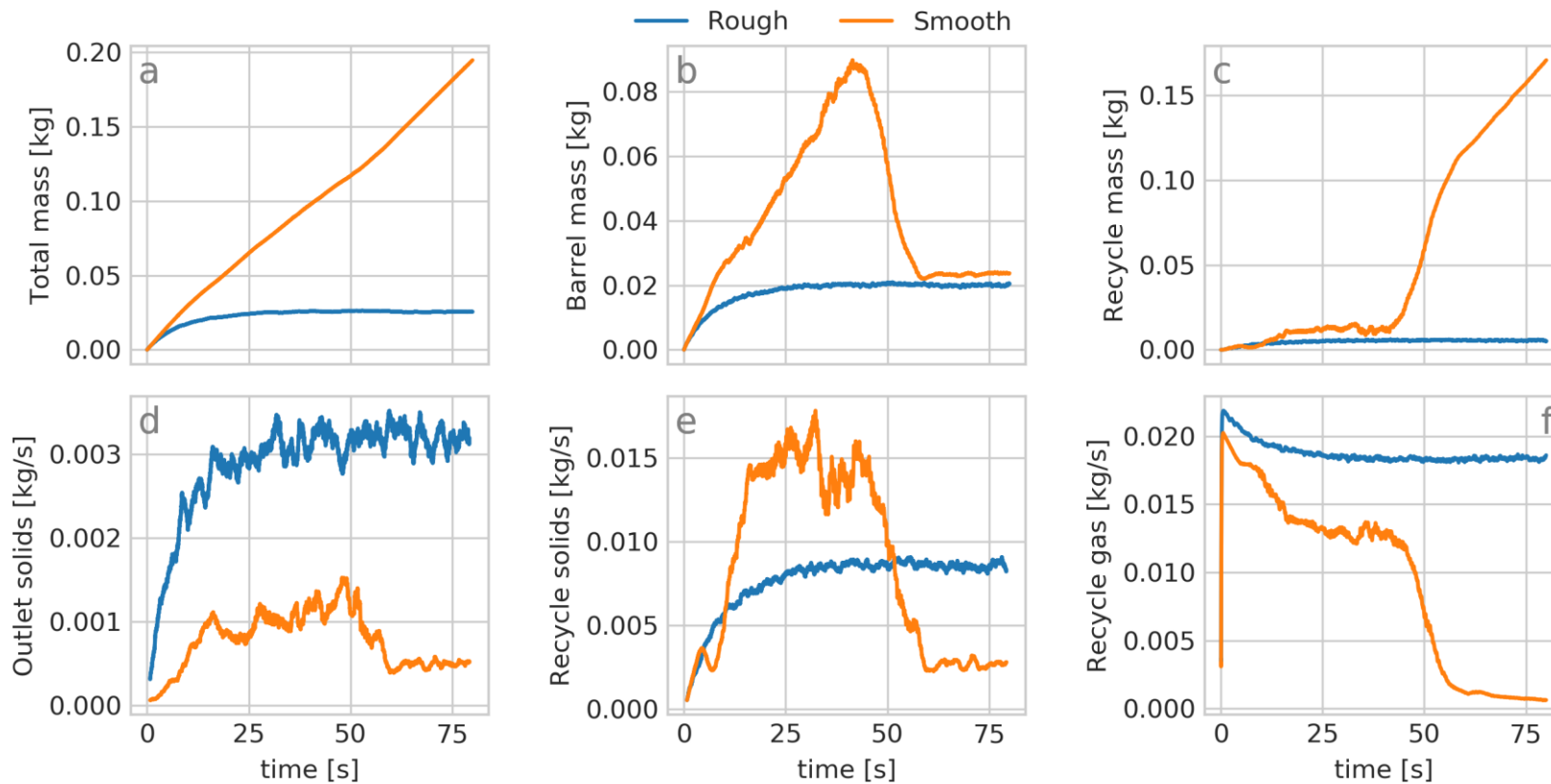


100 GPU Nodes

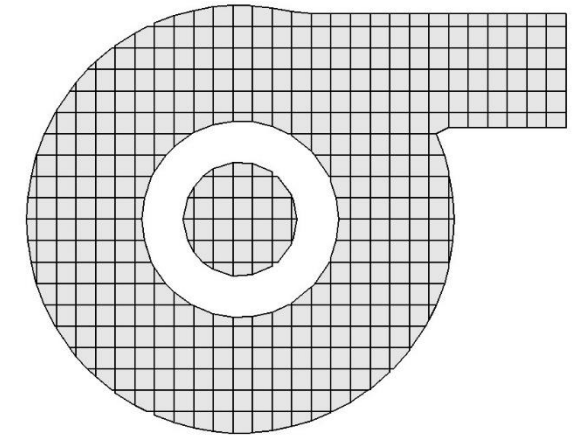
Let's try it!



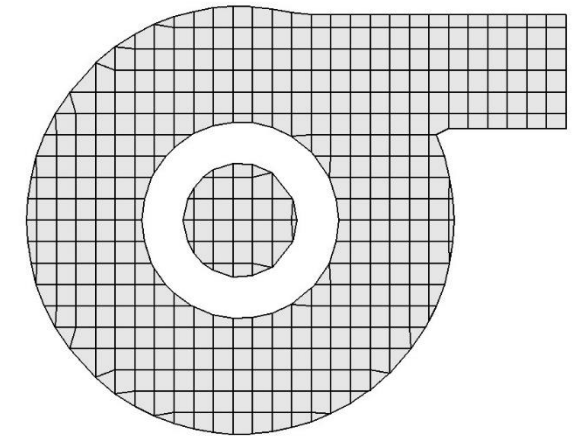
Rough vs Smooth



rough

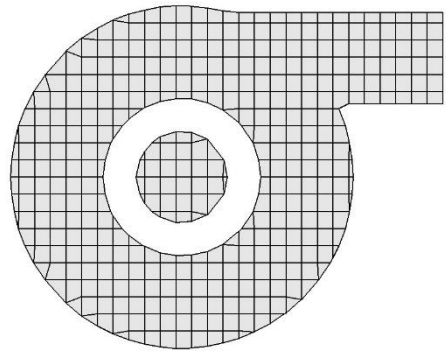


smooth

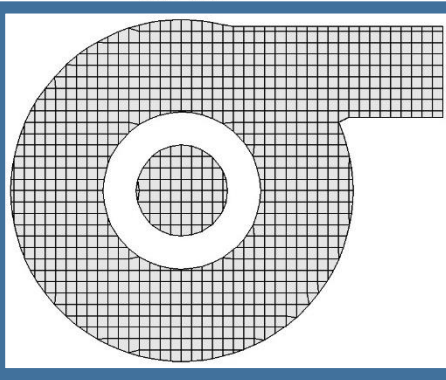


Merge small cells instead of removing them

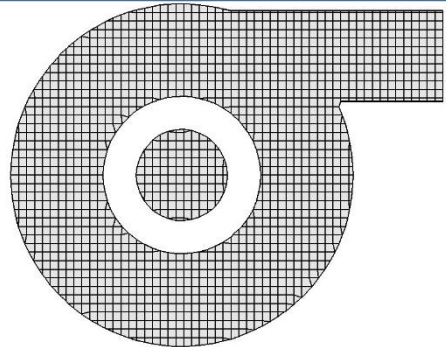
Grid resolution



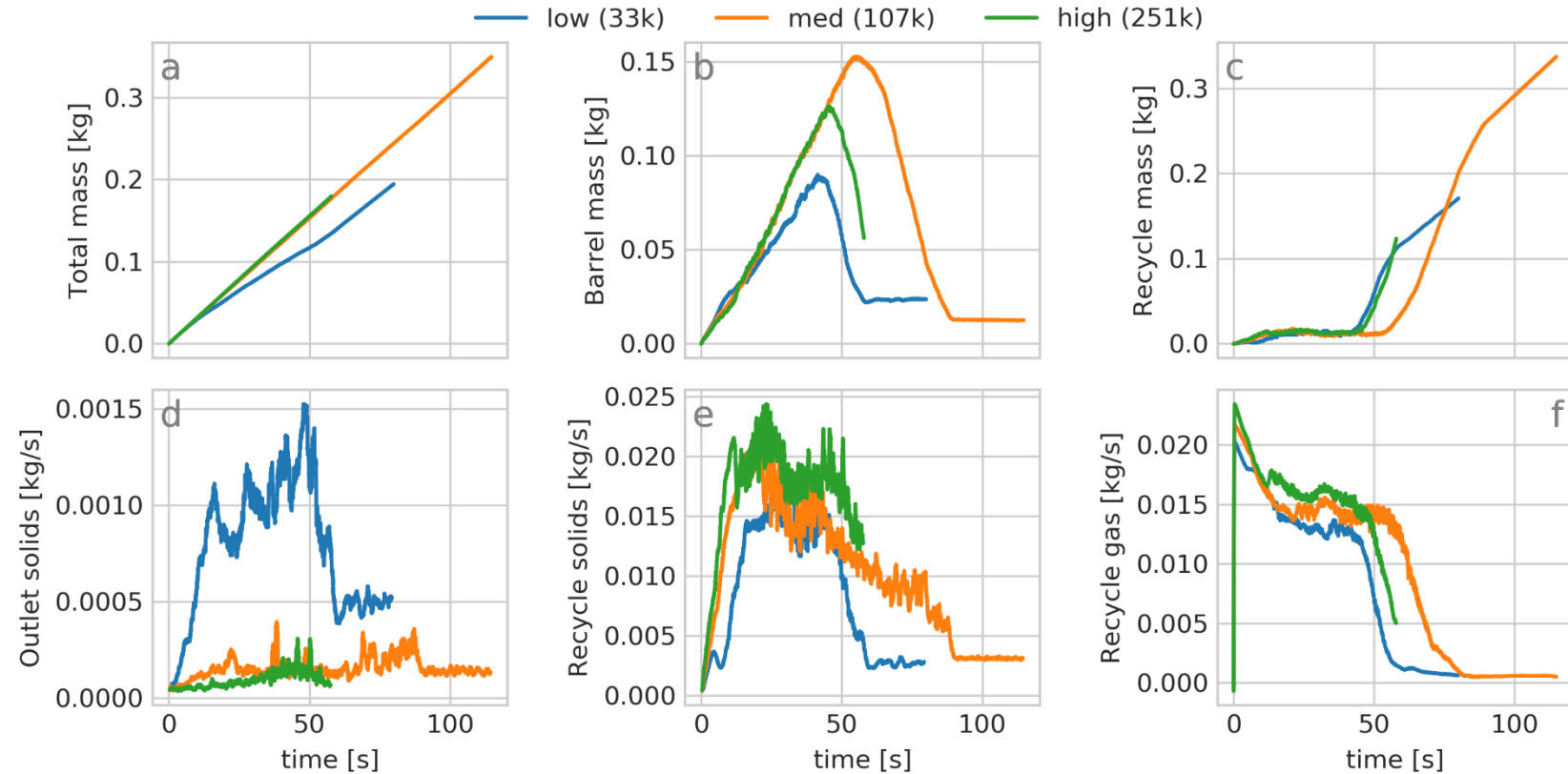
low
33k real cells
dx 10e-3
200 s/day



med
106k real cells
dx 6.56e-3
50-60 s/day

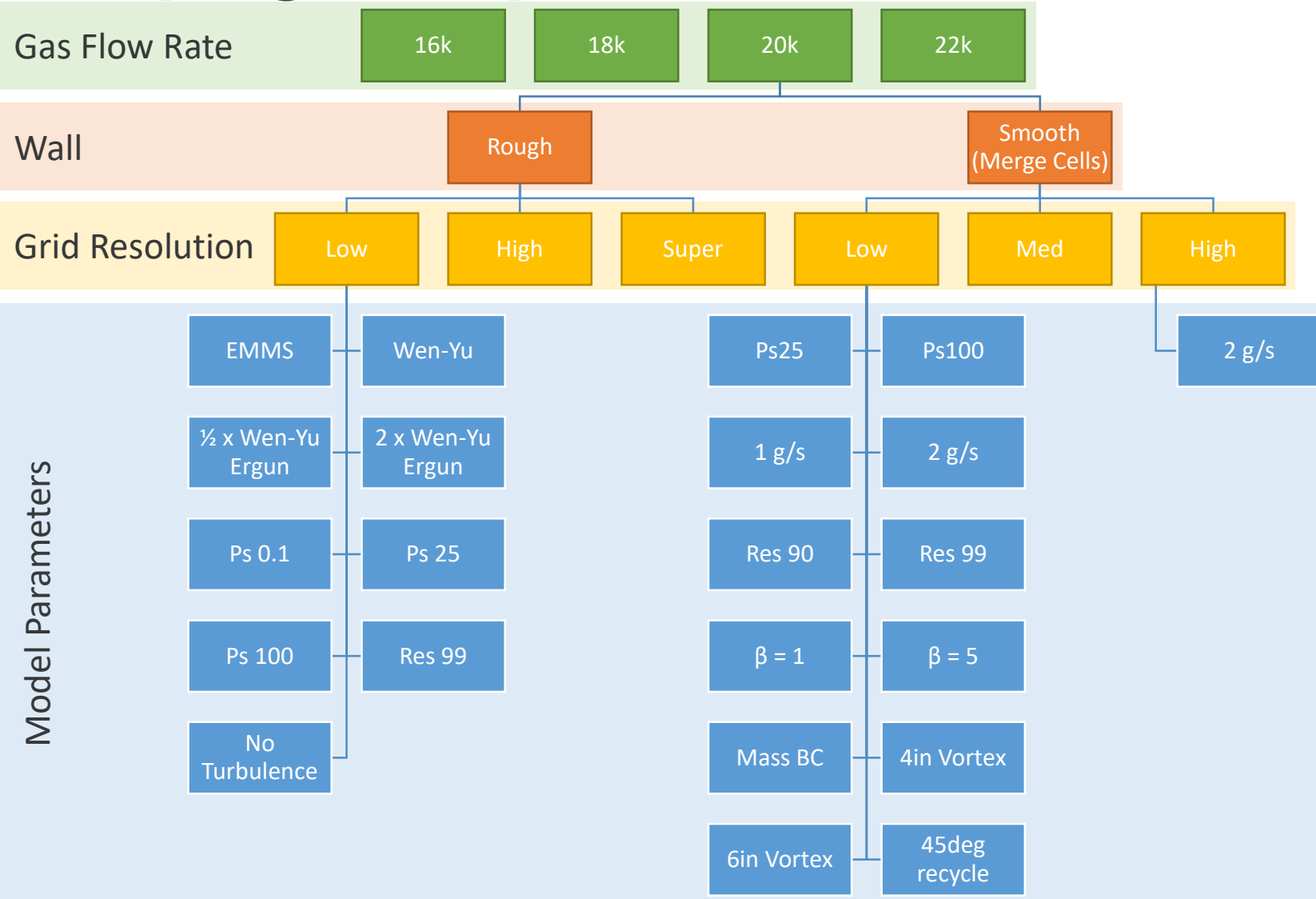


high
252k real cells
dx 5e-3
30 s/day



Note: timing varied, typical times using a Nvidia P100 GPU

Playing with parameters



Wait, I have a tool!



The screenshot shows the Nodeworks software interface with a workflow for image processing and plotting. The workflow includes the following components:

- Range**: A node with parameters: start: 0.00, stop: 10.00, step: 0.10, type: float.
- Trig**: Two nodes, one with operation: cos and one with operation: sin.
- Plot**: A graph showing two sine waves (one red, one purple) plotted against x and y axes. The x-axis ranges from 0 to 100, and the y-axis ranges from -1.0 to 1.0. The current cursor position is x=43.7928, y=-0.819586.
- Read Image**: A node with path: eads.jpg.
- RGB to Gray**: A node with parameters: dp: 0.40, minDist: 100.00, param1: 40, param2: 20, min radius: 20, max radius: 100.
- Hough Circle**: A node with parameters: dp: 0.40, minDist: 100.00, param1: 40, param2: 20, min radius: 20, max radius: 100.
- Draw Circles**: A node with parameters: image, circles, colors, fill, output.
- Image**: A node displaying the output image with colored circles overlaid on it.

The interface also includes a **Map** window showing a smaller version of the workflow and a **Help** window with the following text:

```
Detect circles in images using Hough
```

Input Terminals

- image (np.ndarray): a grayscale image
- dp (float): inverse ratio of the accumul.
- minDist (float): minimum distance between the
- param1 (int): First method-specific param
- param2 (int): Second method-specific param
- min radius (int): Minimum circle radius.
- max radius (int): Maximum circle radius.

Output Terminals

Design of Experiments



Model evaluation

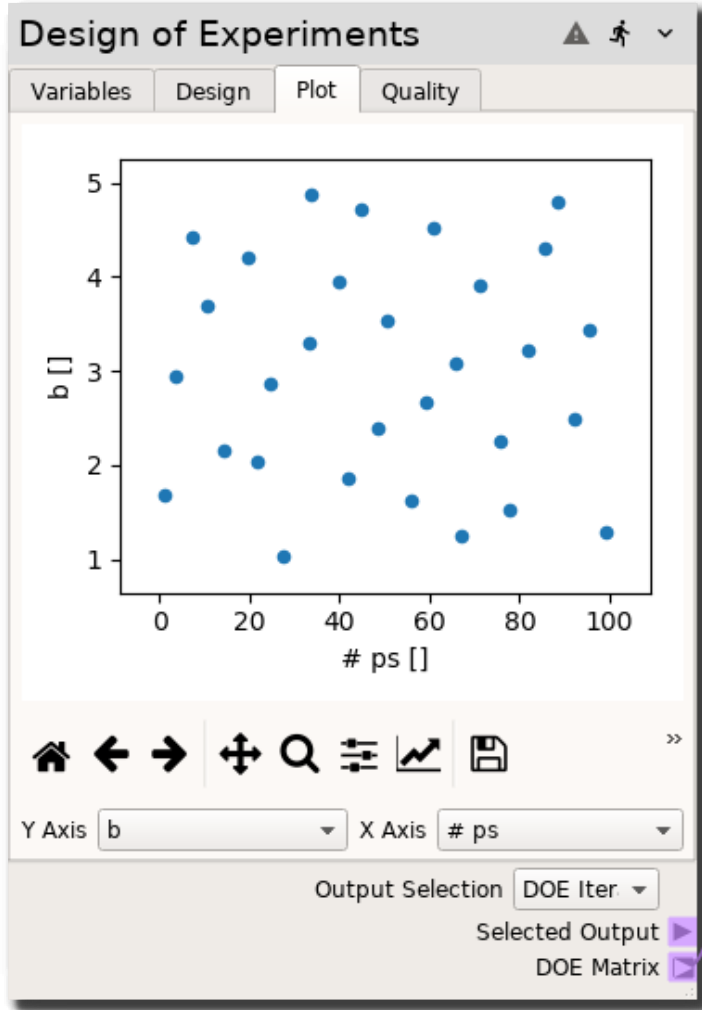
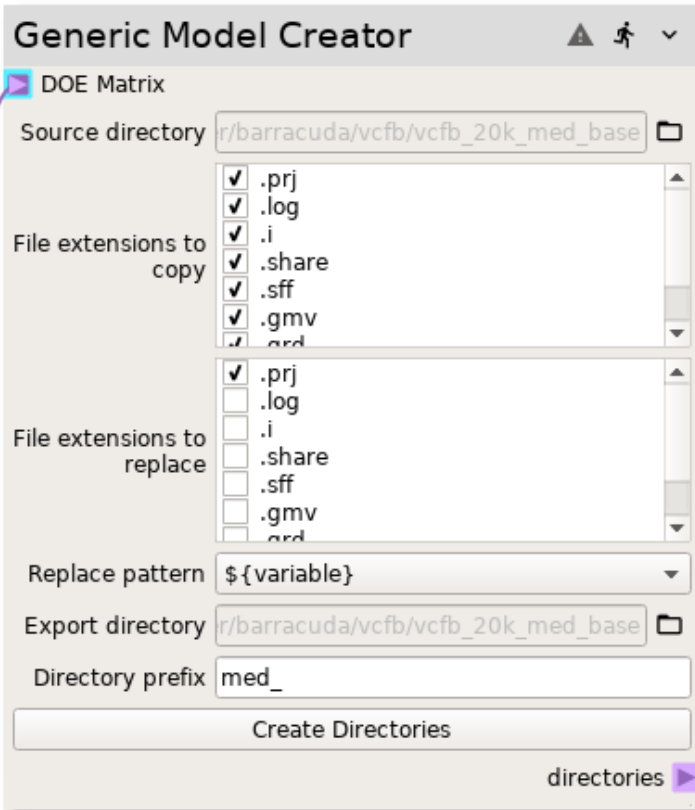


Response Surface Construction



Optimization

Let's use statistics!

Generic Model Creator

DOE Matrix

Source directory r/barracuda/vcfb/vcfb_20k_med_base

File extensions to copy

- .prj
- .log
- .i
- .share
- .sff
- .gmv
- .ord

File extensions to replace

- .prj
- .log
- .i
- .share
- .sff
- .gmv
- .ord

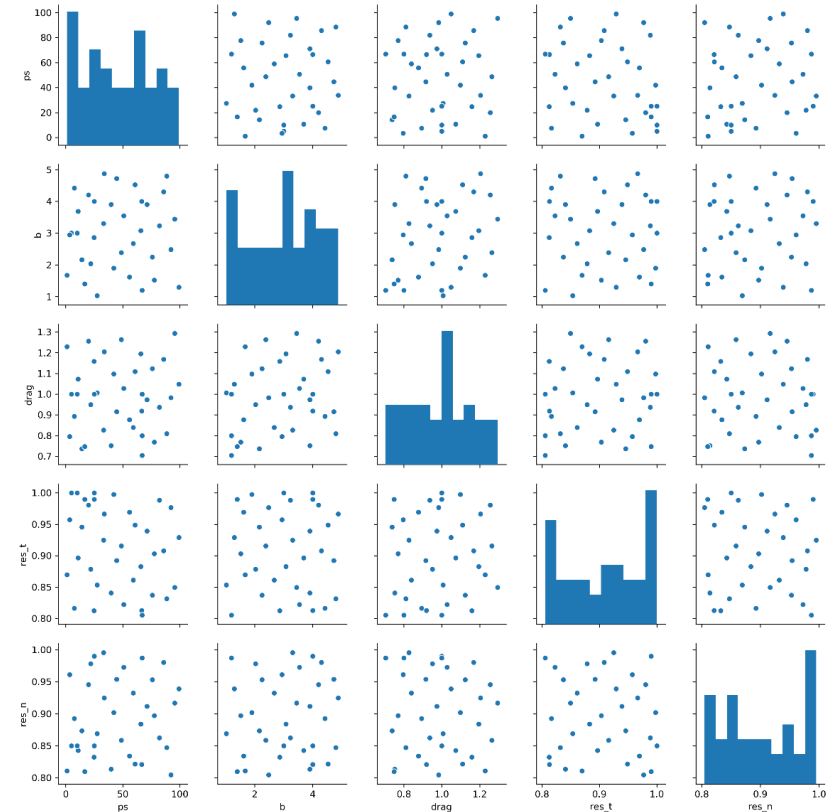
Replace pattern \${variable}

Export directory r/barracuda/vcfb/vcfb_20k_med_base

Directory prefix med_

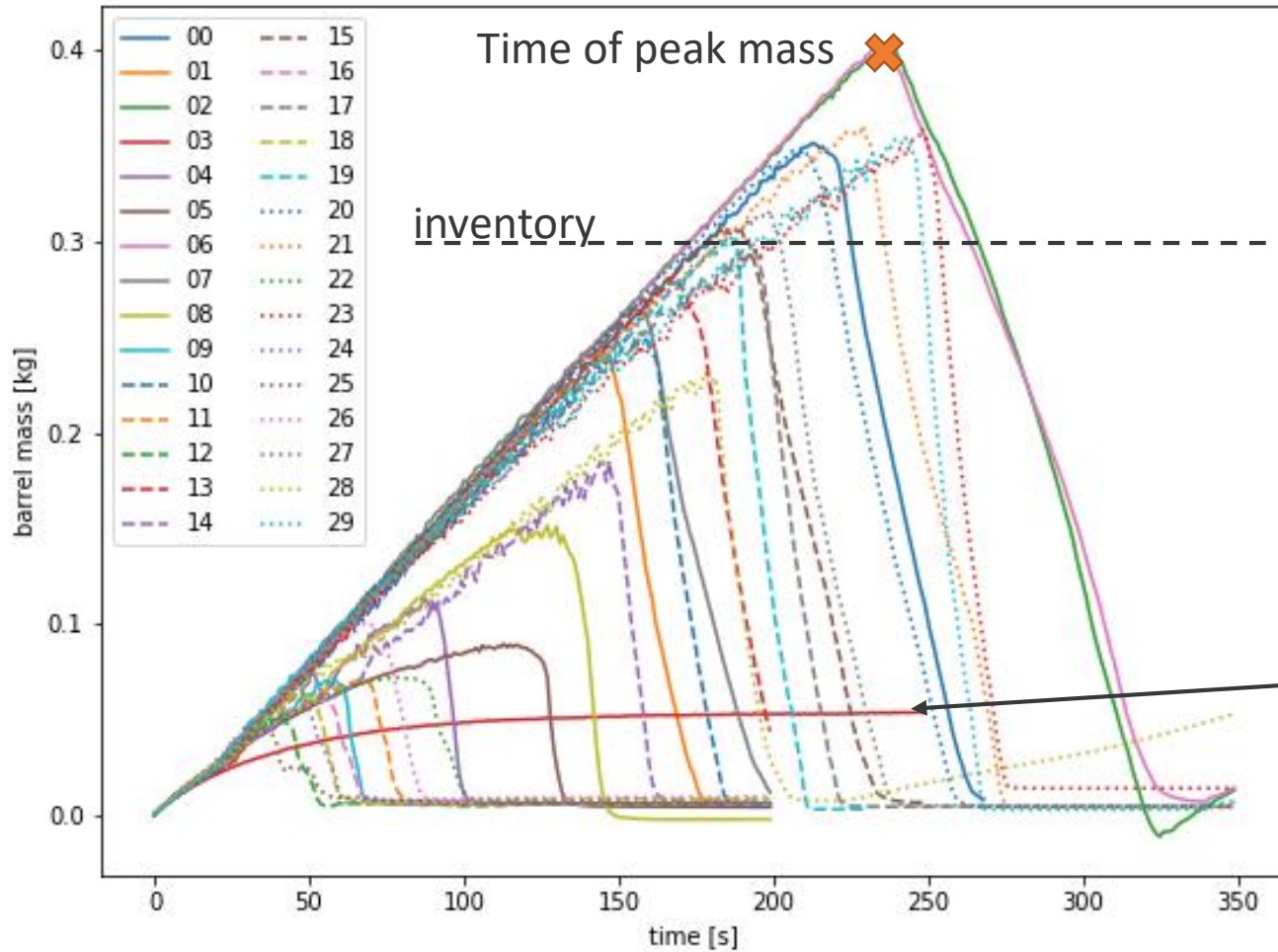
Create Directories

directories



$$\tau(\theta_p) = \frac{10 P_s \theta_p^\beta}{\max[\theta_{cp} - \theta_p, \varepsilon(1 - \theta_p)]}$$

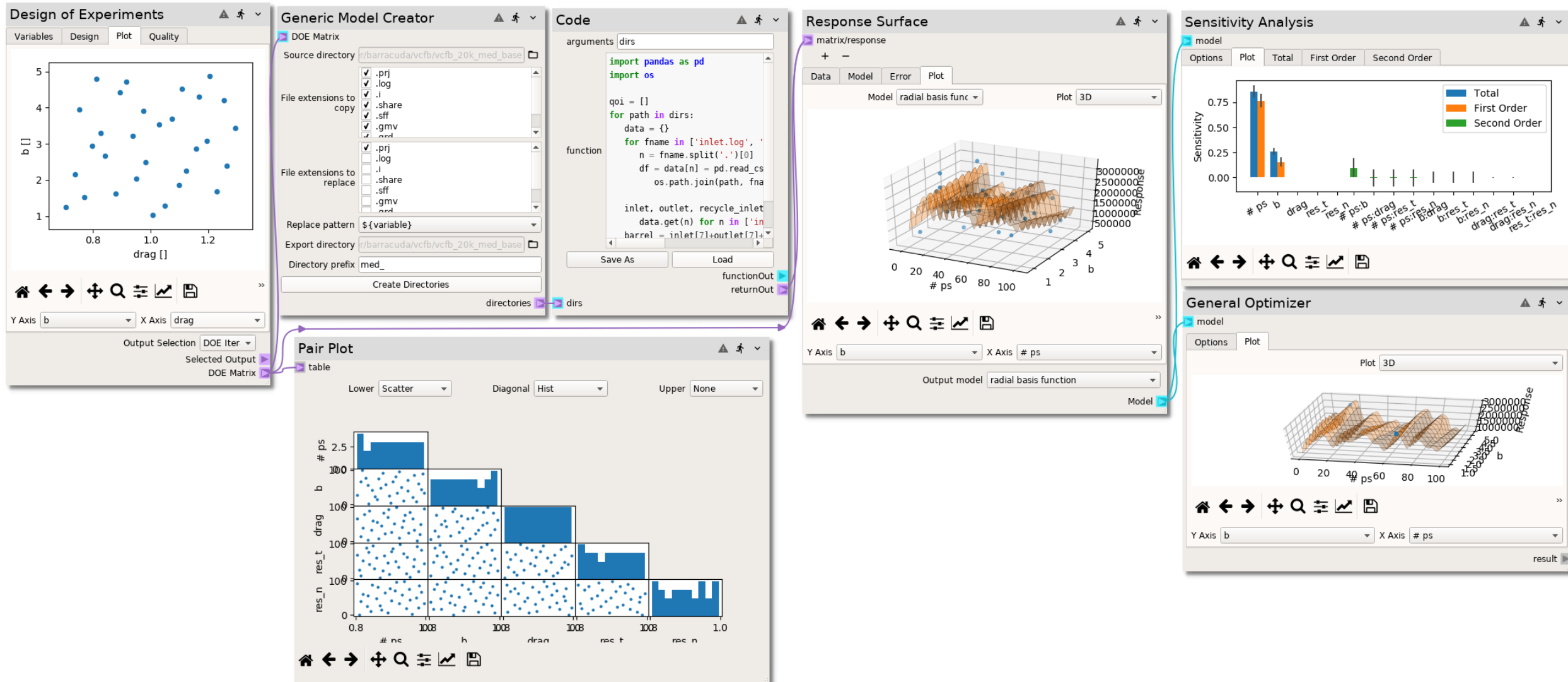
They all clog!



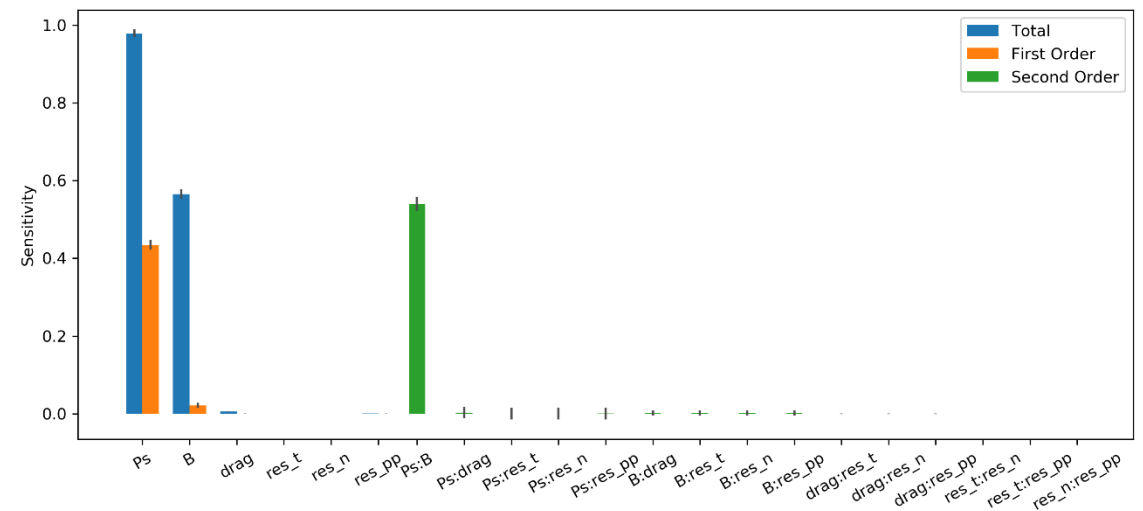
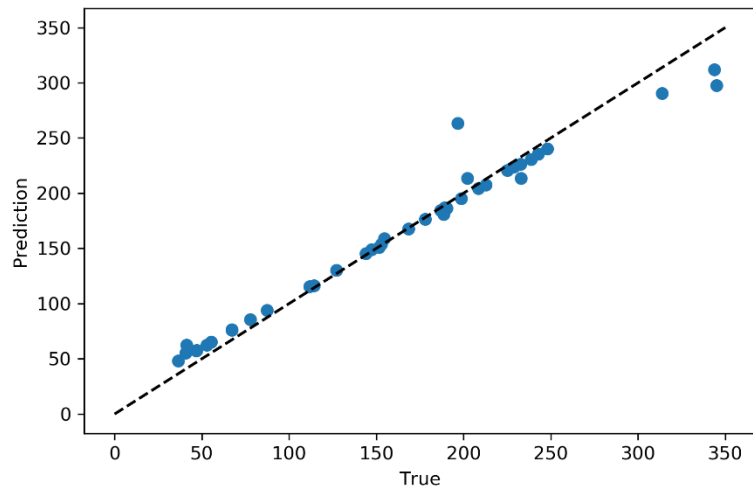
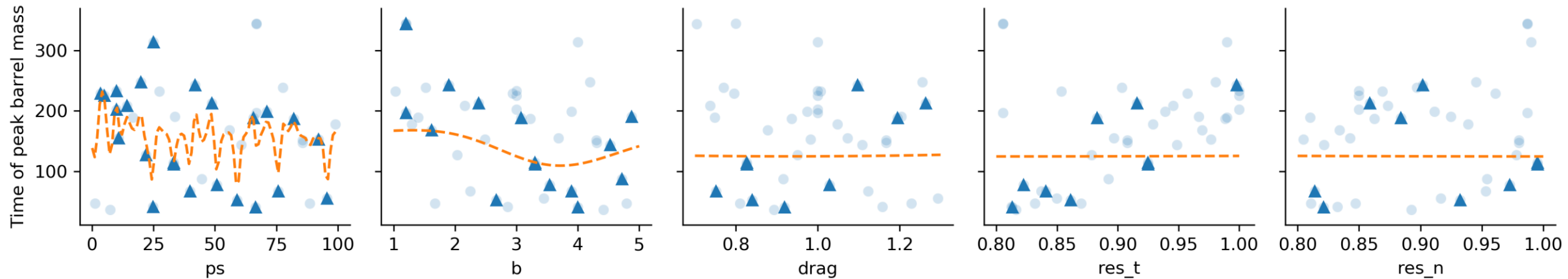
Some reach the target inventory

All clog except for one at a low inventory

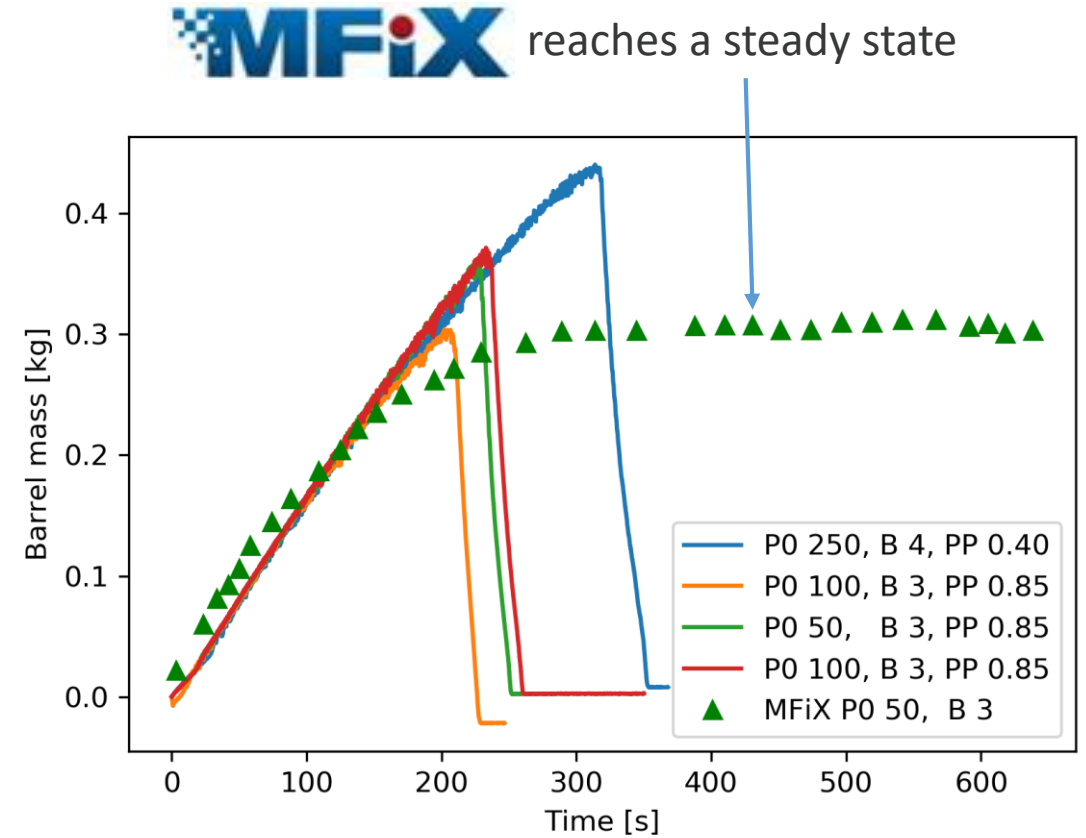
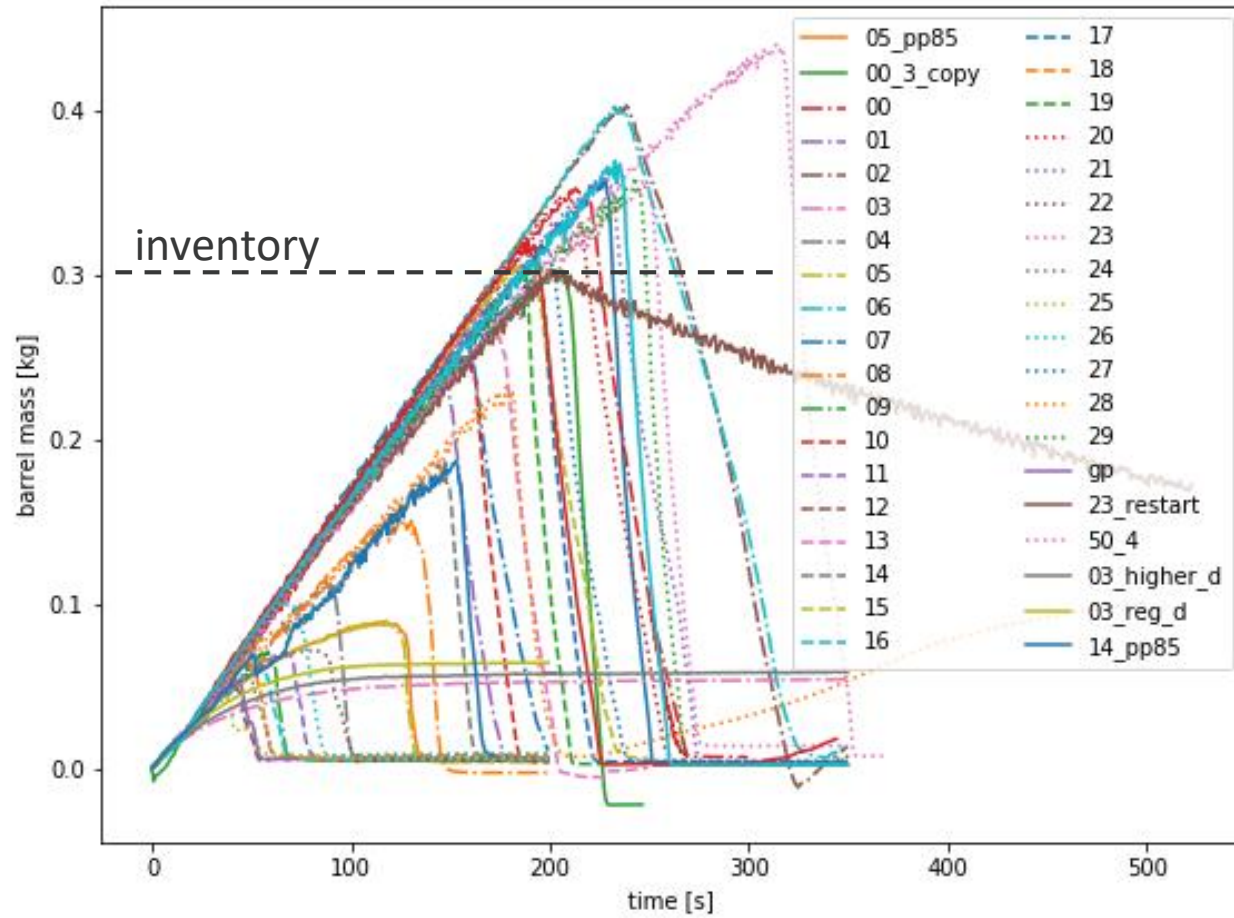
The rest of the workflow



Results

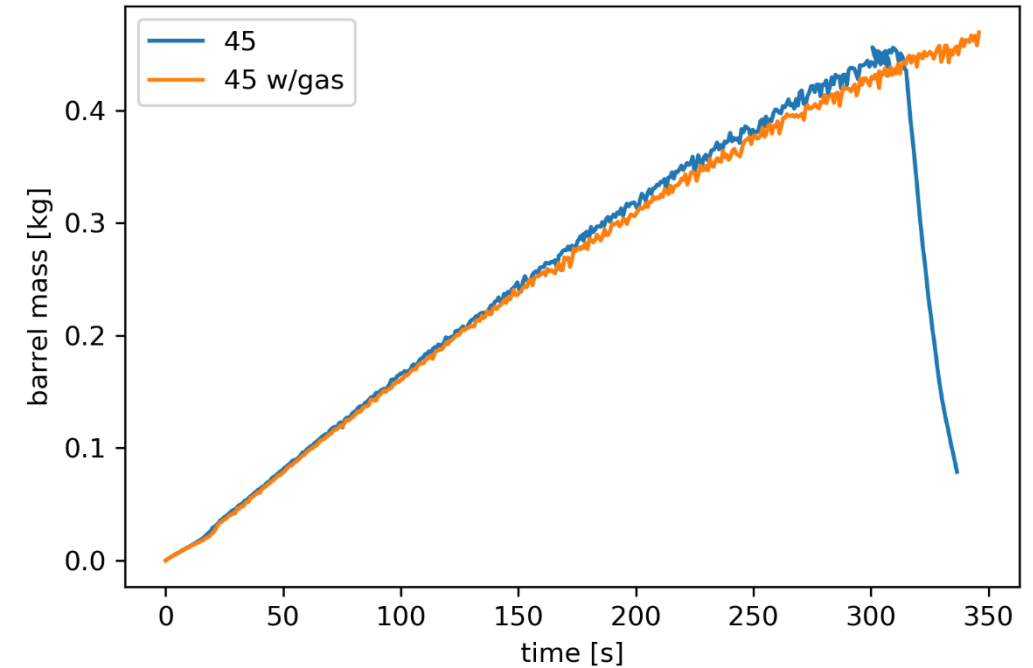
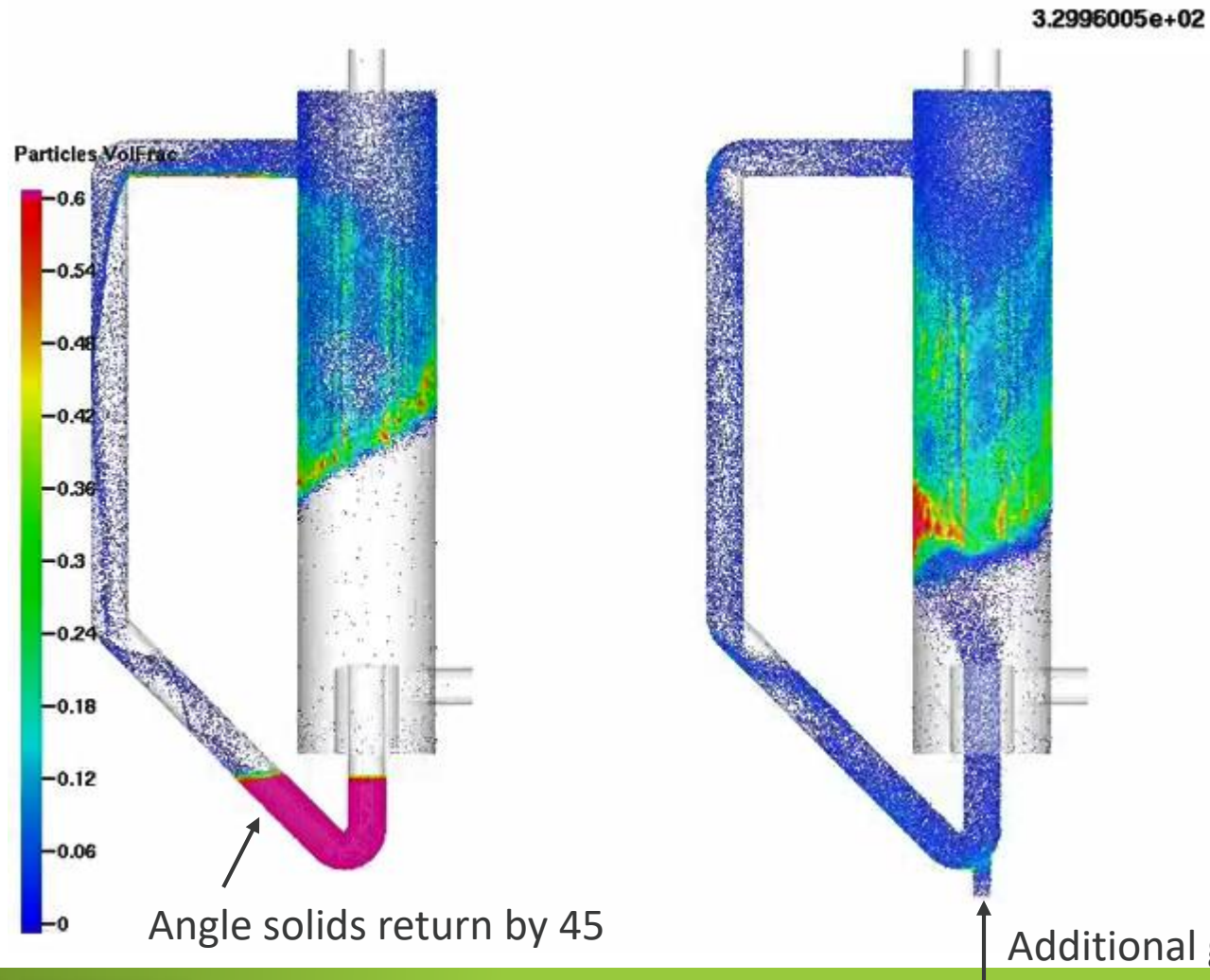


More runs



Wait, we can still use the model!

Let's try a different recycle design.



Summary

- The Vortexing Circulating Fluid Bed looks like a promising gas/solid reactor
- Struggling to match the Barracuda model to the experiment
 - For some reason MFiX reaches a steady state
- New proposed recycle design could prevent recycle solids clogging.

Future Work

- Get Barracuda to match the experiments
- Add coal kinetics to predict gasifier performance
- Use the model to investigate turn down potential

