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

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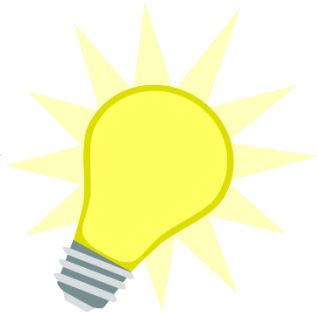
June 28, 2019

Challenge

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

Coal



Electricity

Heat -> District heating

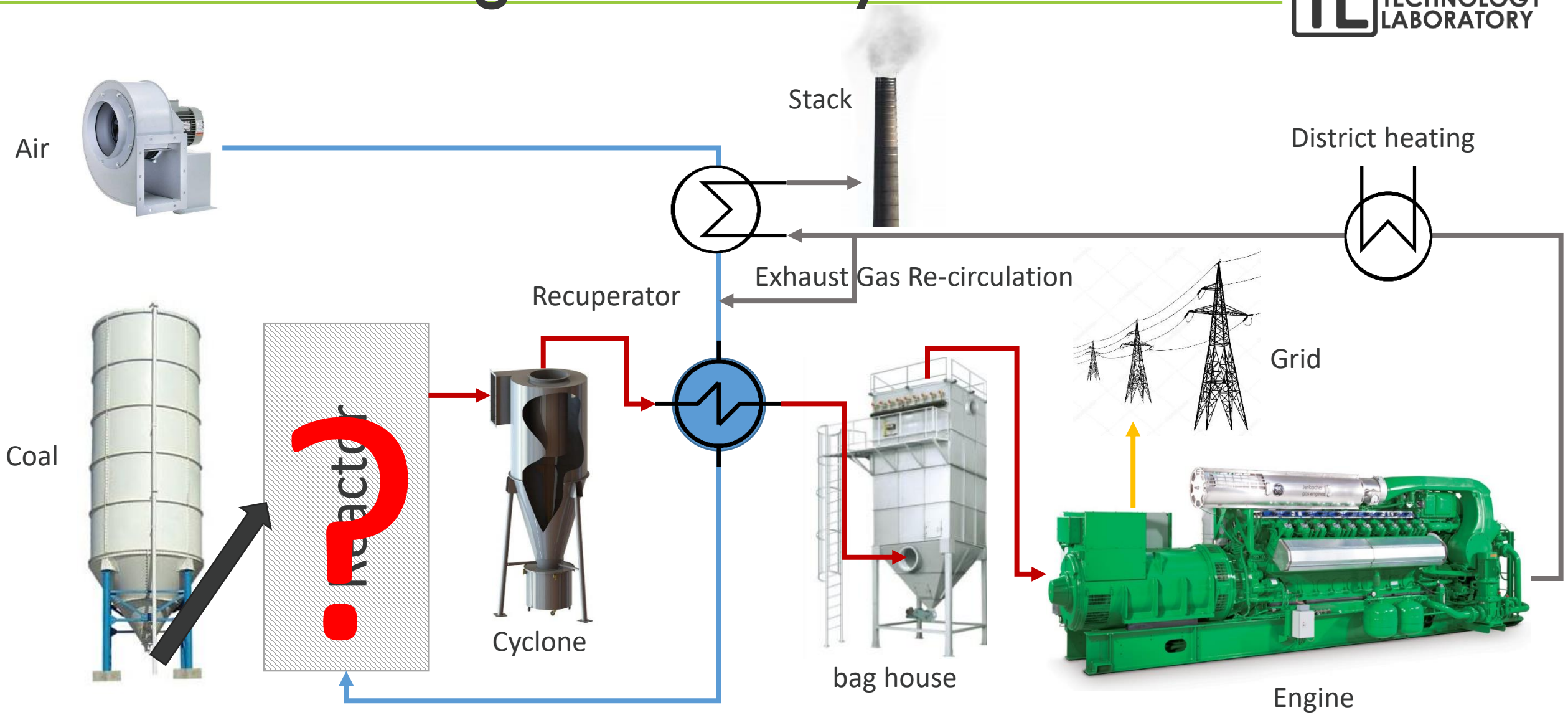
Small provides opportunities

- District heating
- Opportunity fuels
- Distributed
- Remote locations
- Load following

- Higher turn-over rate

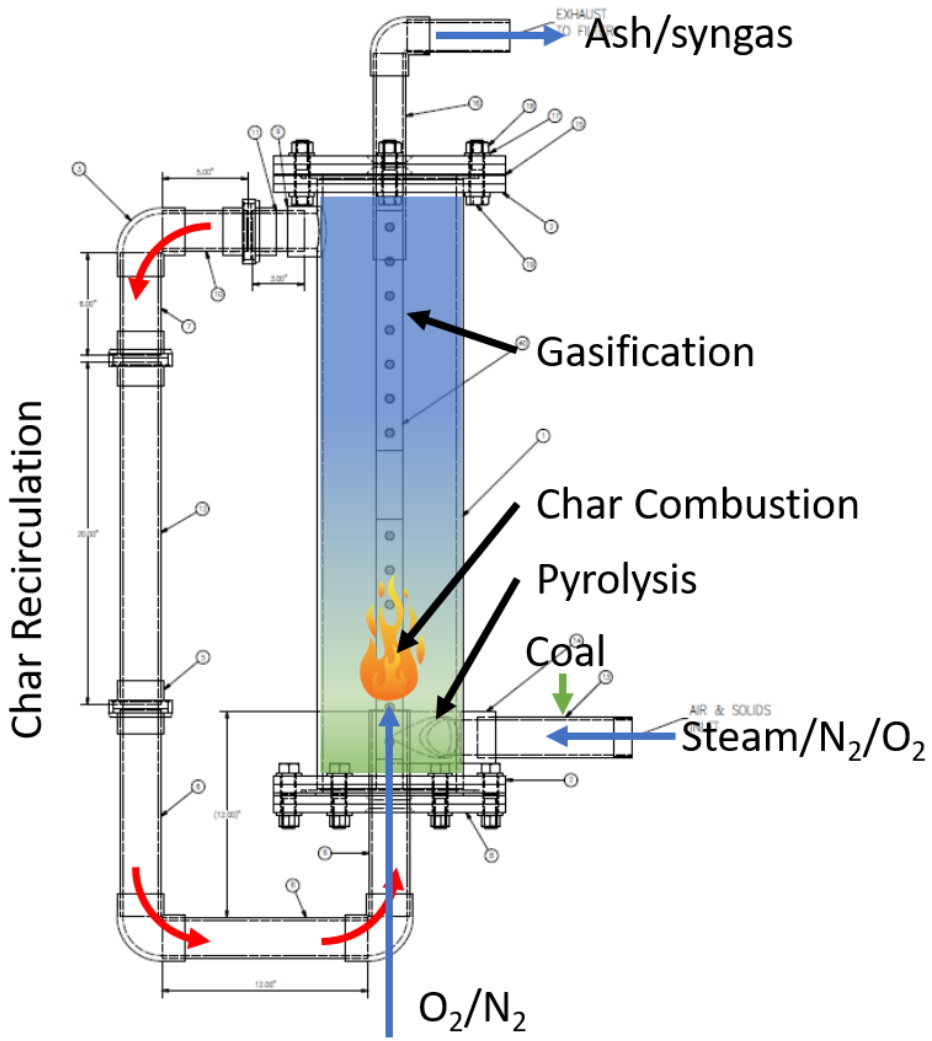
Try more designs faster!

Small modular gasification systems

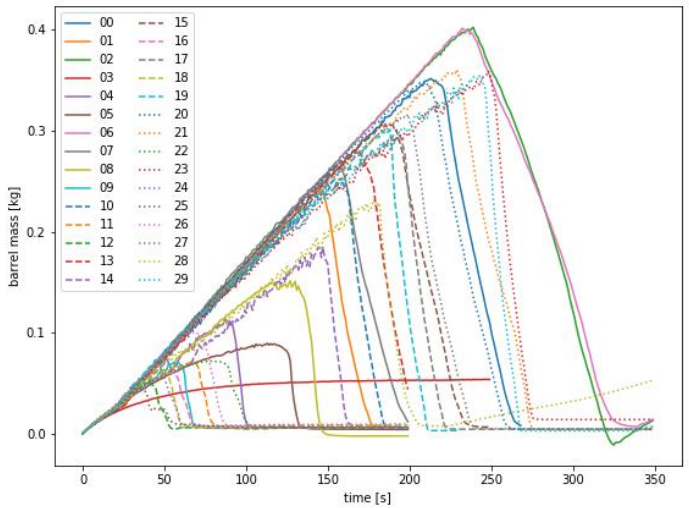


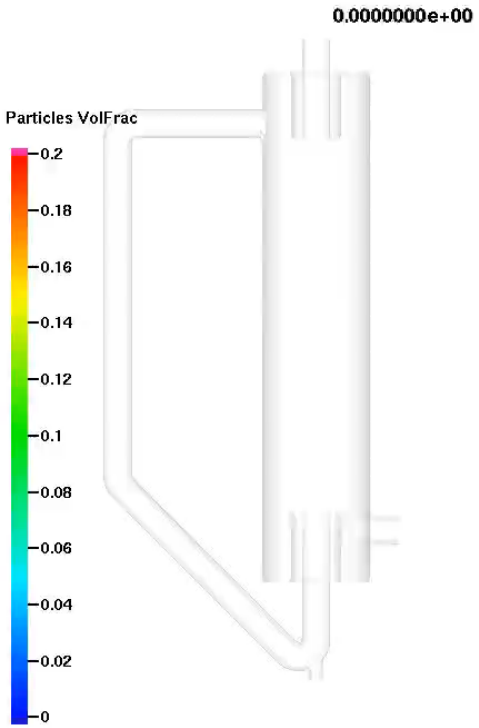
Can we shrink the TRIG?

process intensification



Methodology



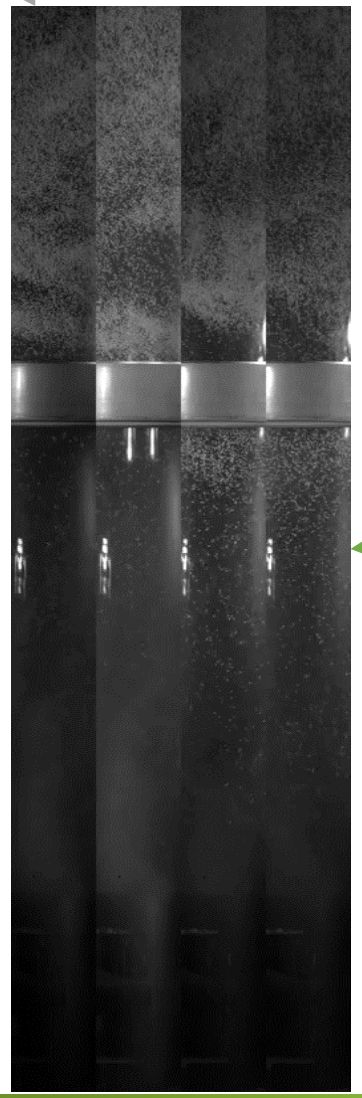


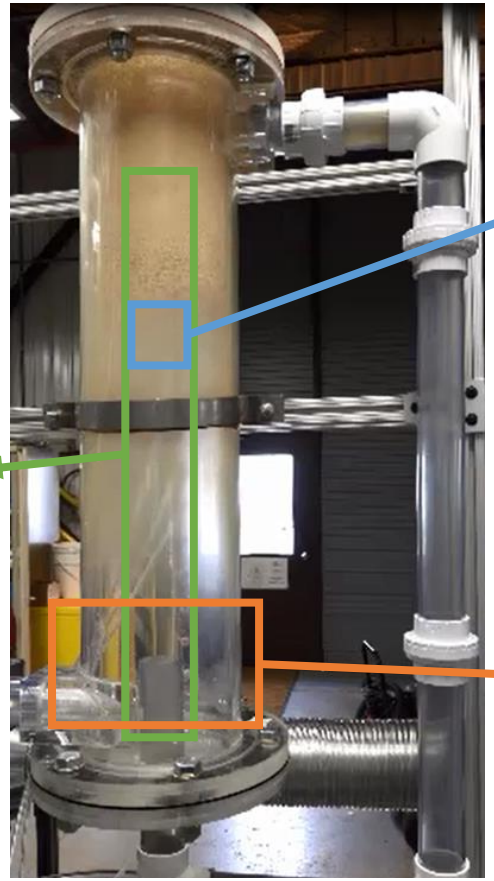
NETL Chemical Looping Reactor

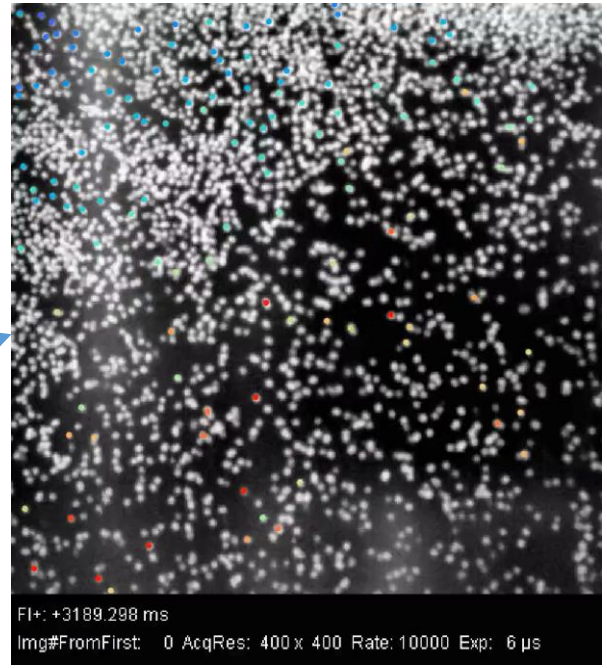
Cold Flow → Model Calibration → Reacting model performance prediction → Hot reacting unit

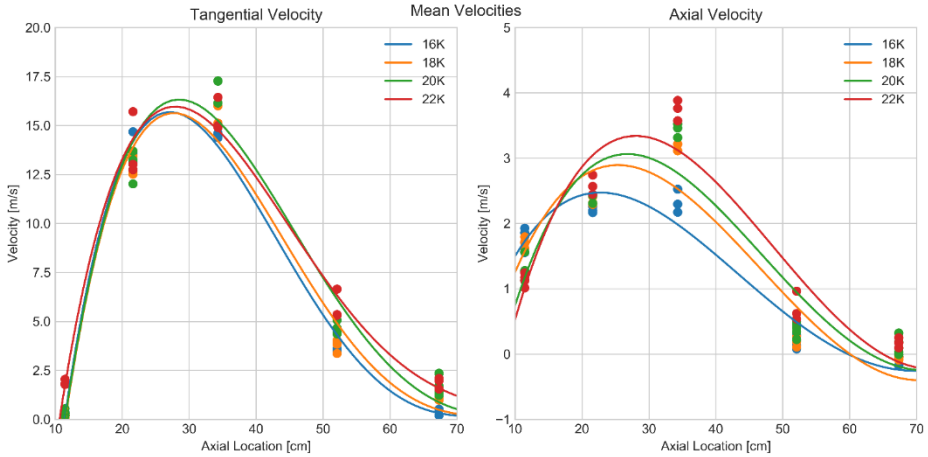
Experiment

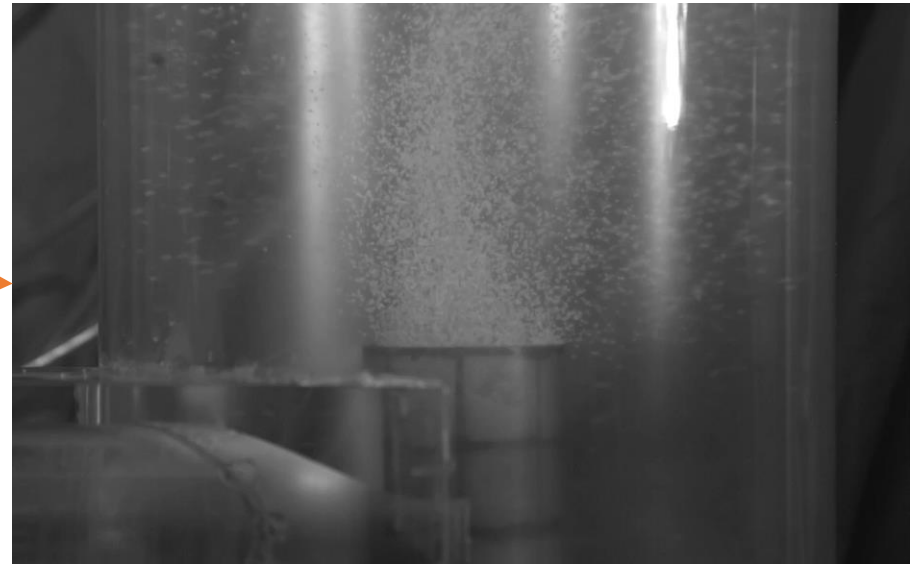
↑Gas Velocity



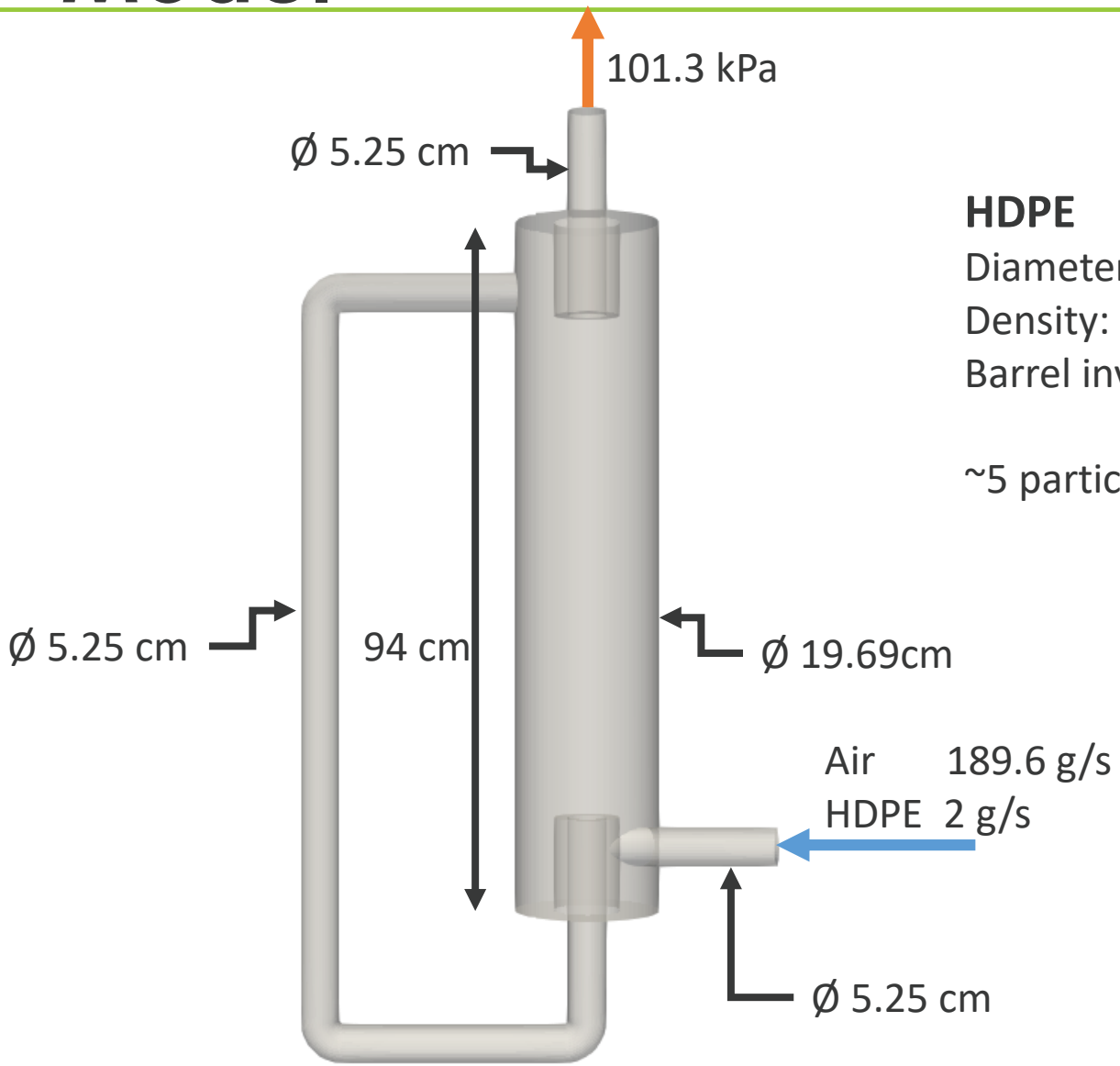








Model



HDPE

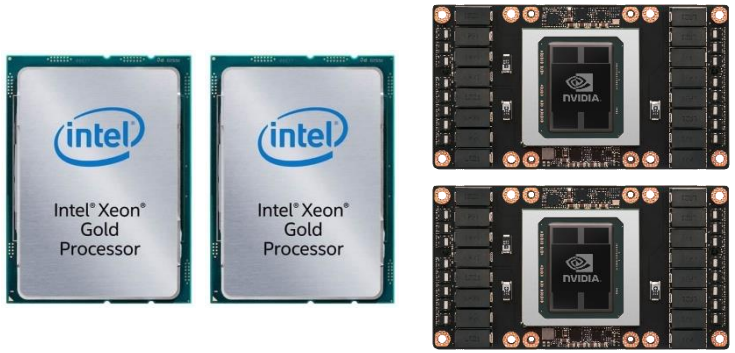
Diameter: 878 µm

Density: 860 kg/m^3

Barrel inventory: 0.3 kg

~5 particles/parcel

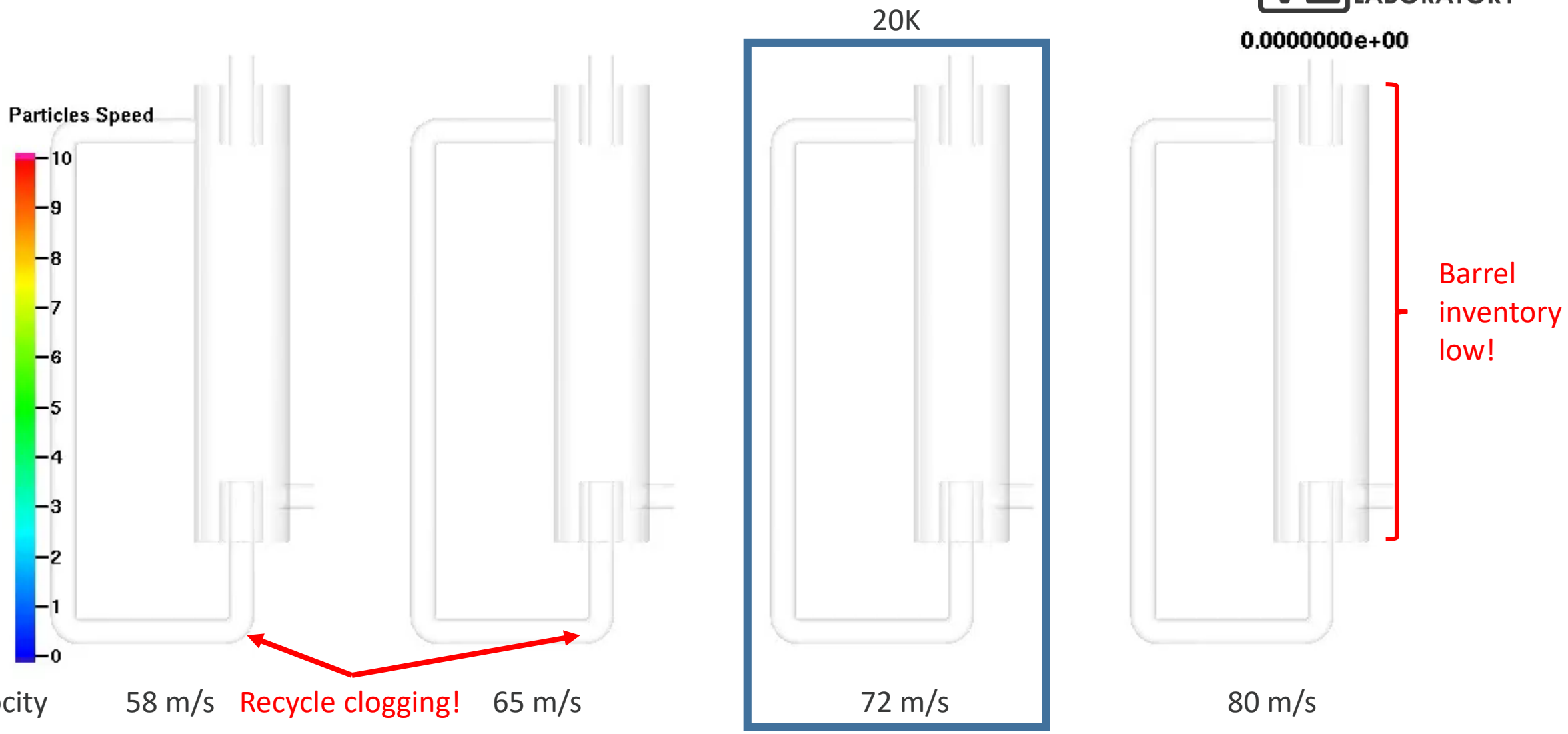
GPU Node



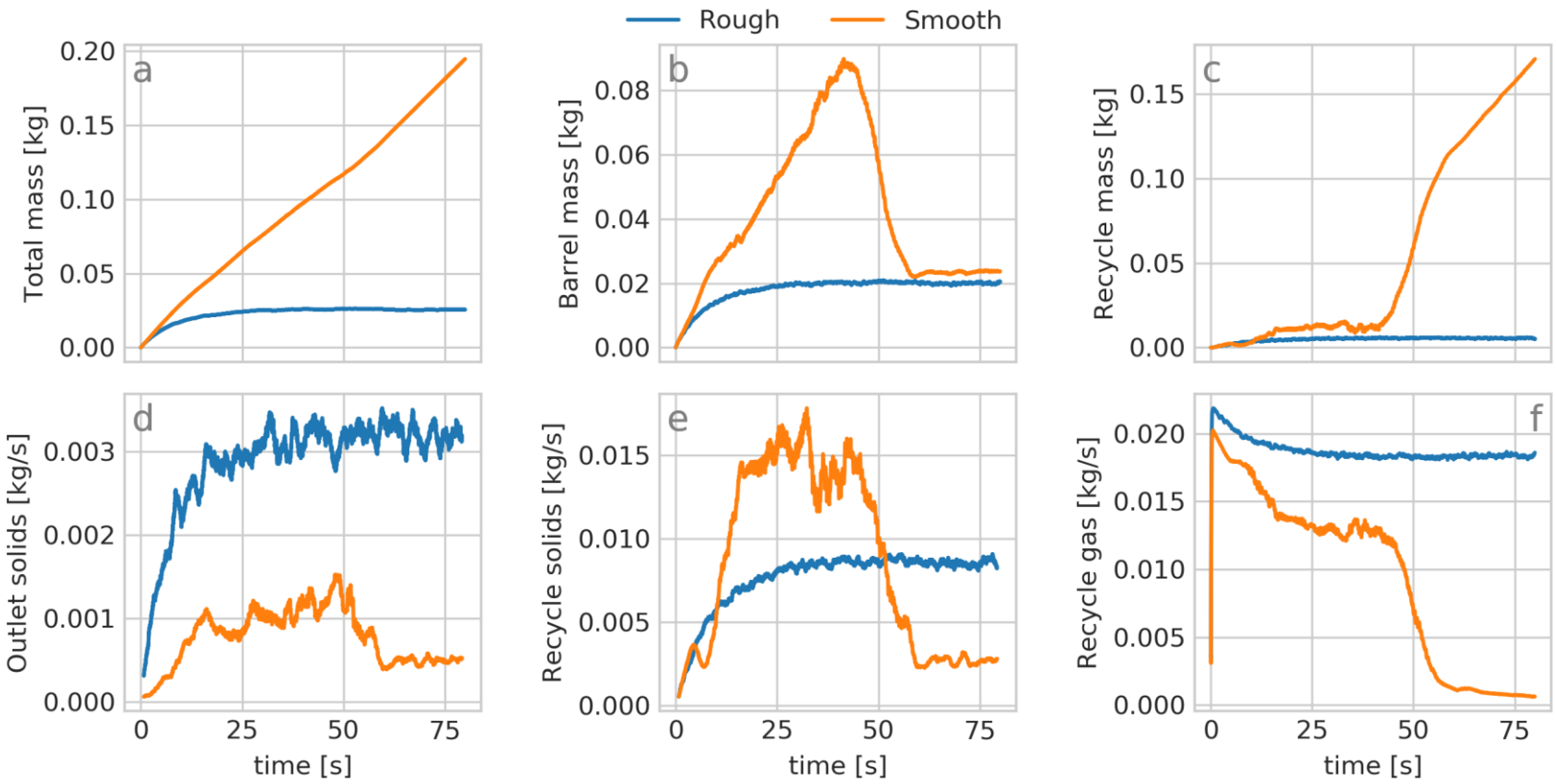
2x 20 Core Xeon 6148 2x Nvidia P100

100 GPU Nodes

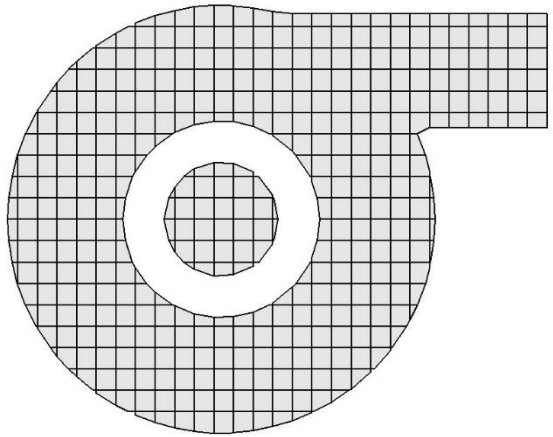
Let's try it!


20K
0.0000000e+00
Particles Speed
10
9
8
7
6
5
4
3
2
1
0
Barrel inventory low!
Inlet velocity
58 m/s
Recycle clogging!
65 m/s
72 m/s
80 m/s

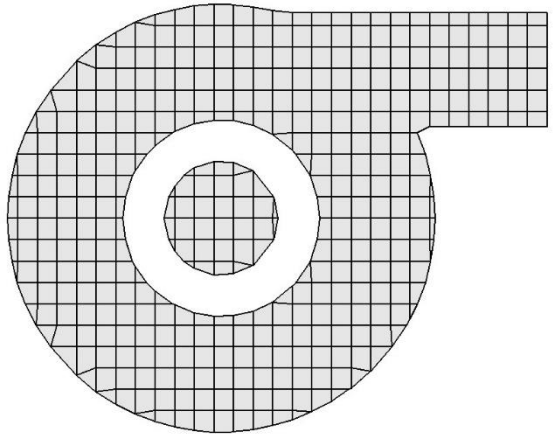
Rough vs Smooth



rough

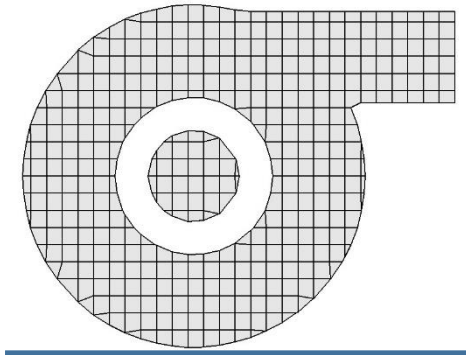


smooth

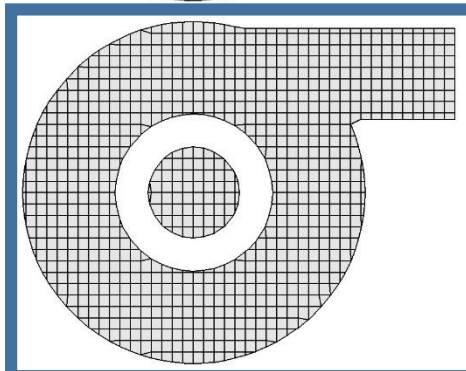


Merge small cells instead of removing them

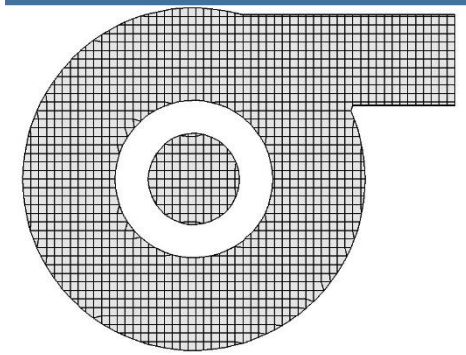
Grid resolution



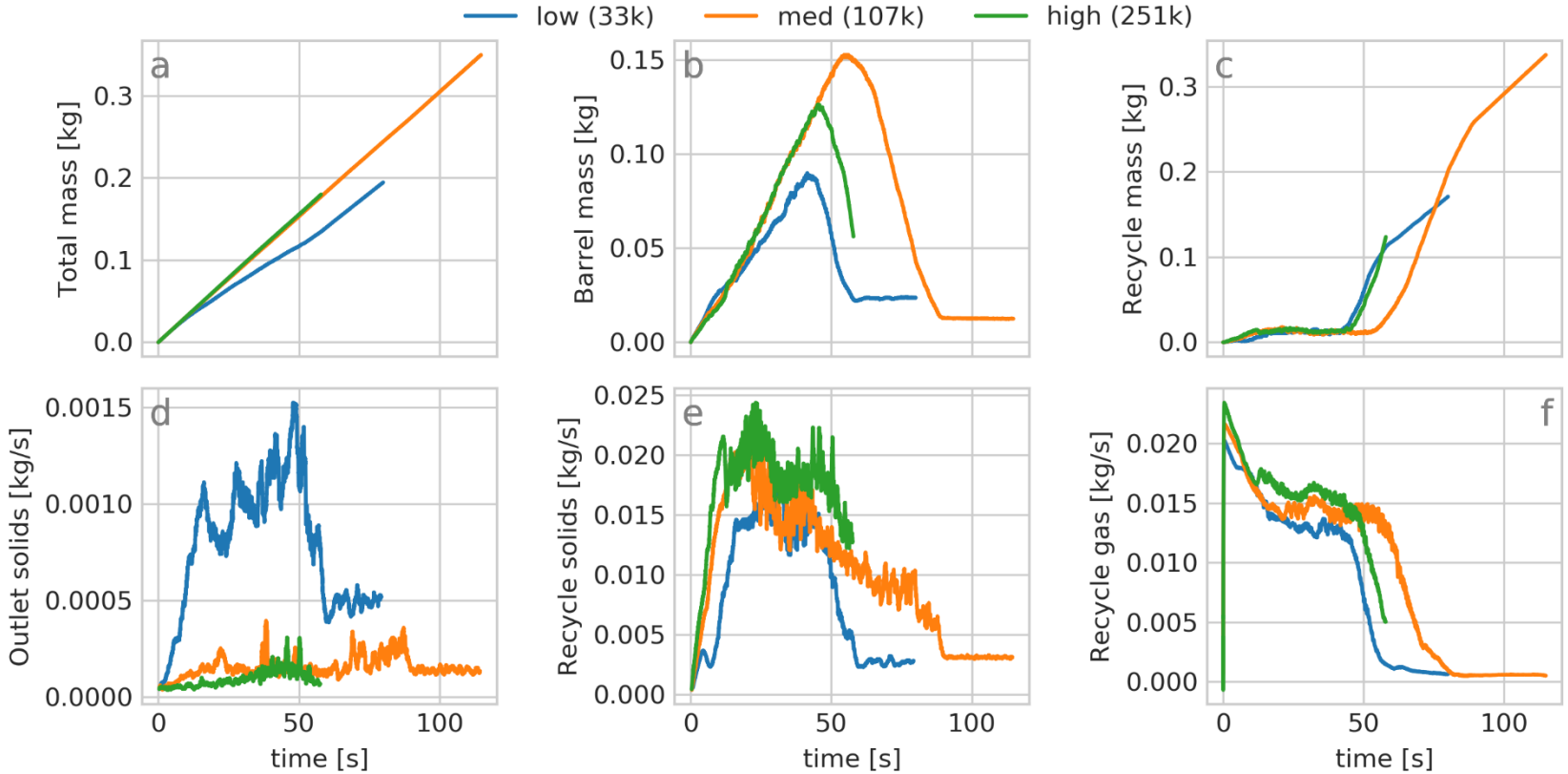
low
33k real cells
dx 10e-3
200 s/day



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

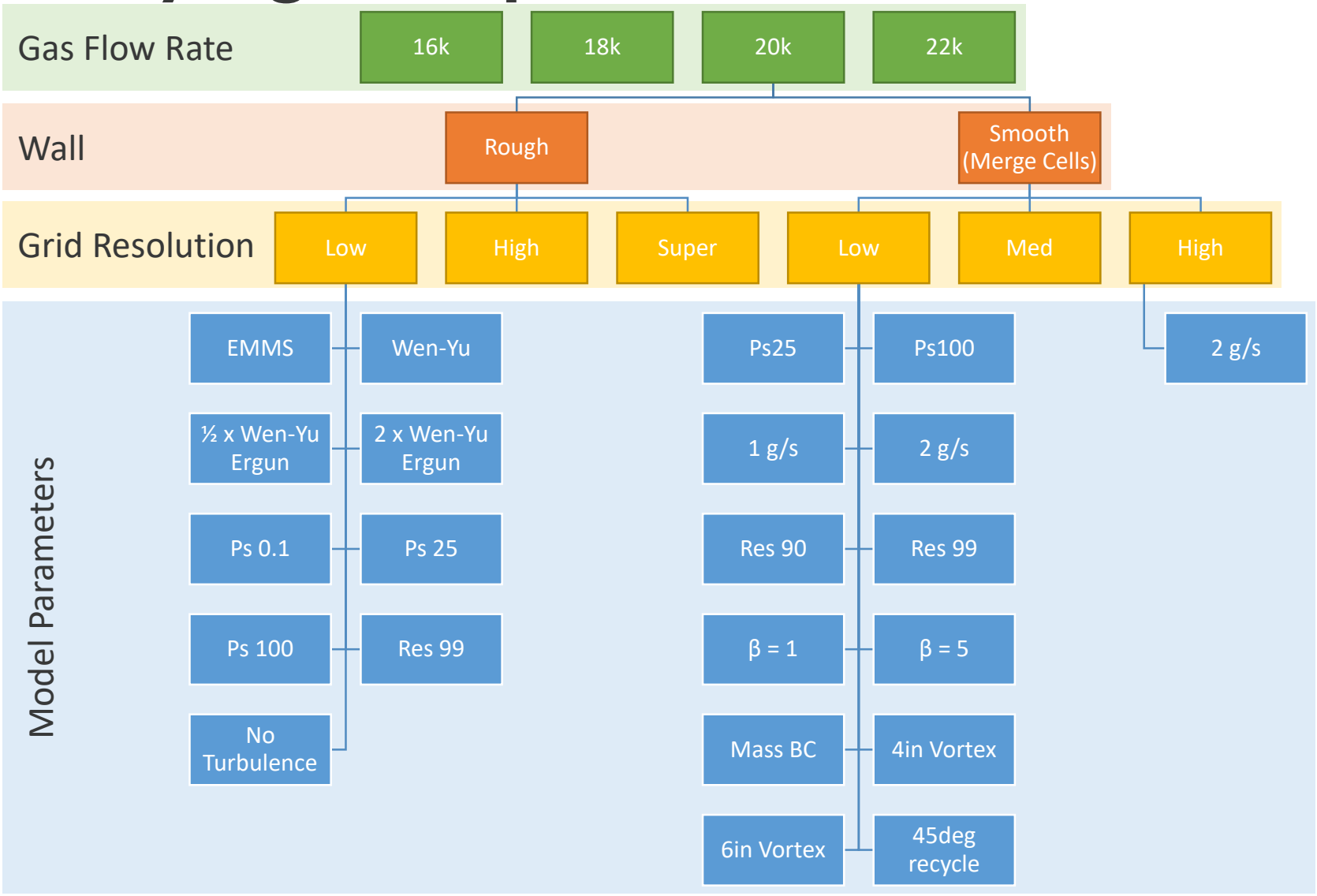


high
252k real cells
dx 5e-3
30 s/day



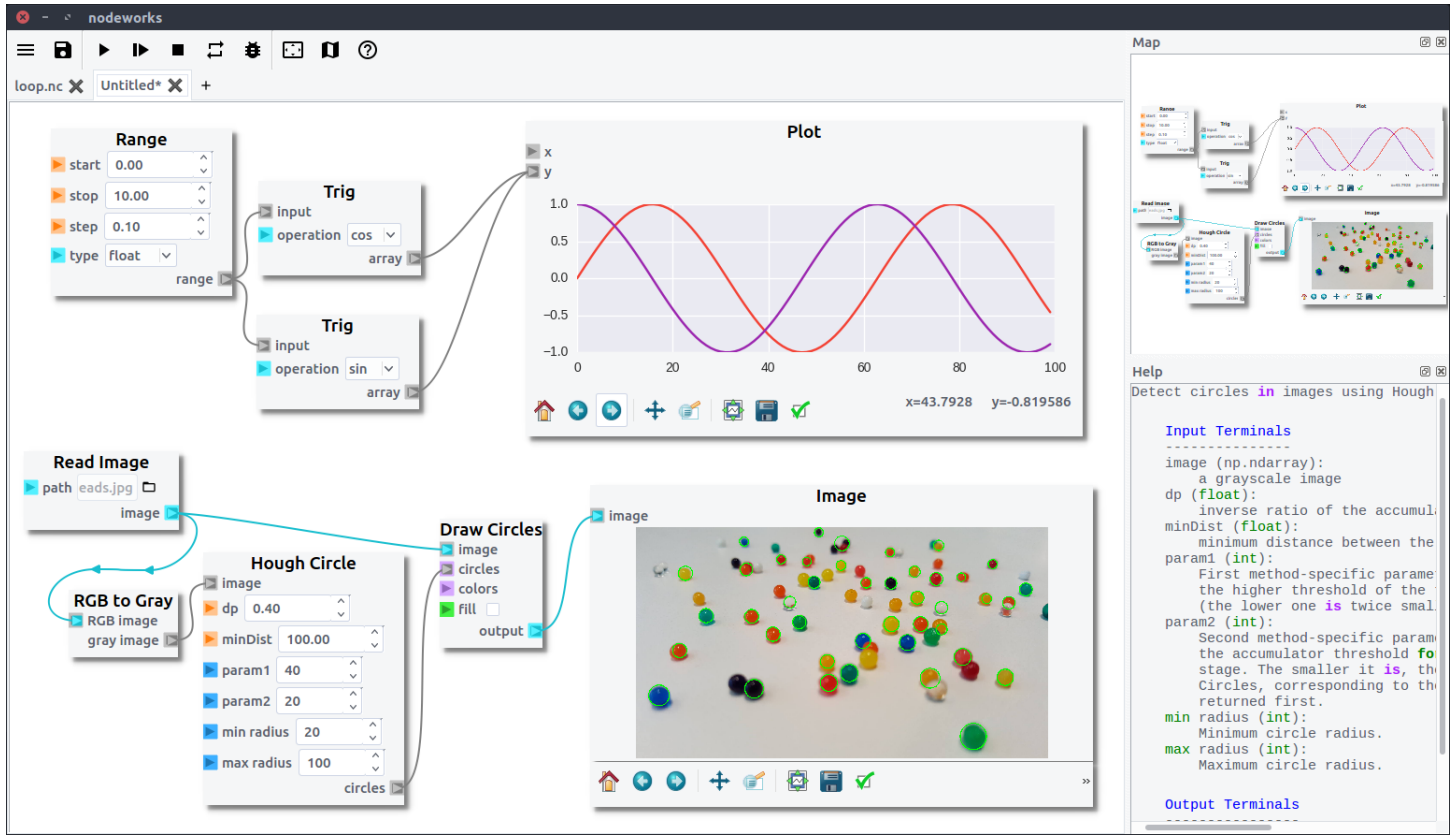
Note: timing varied, typical times using a Nvidia P100 GPU

Playing with parameters



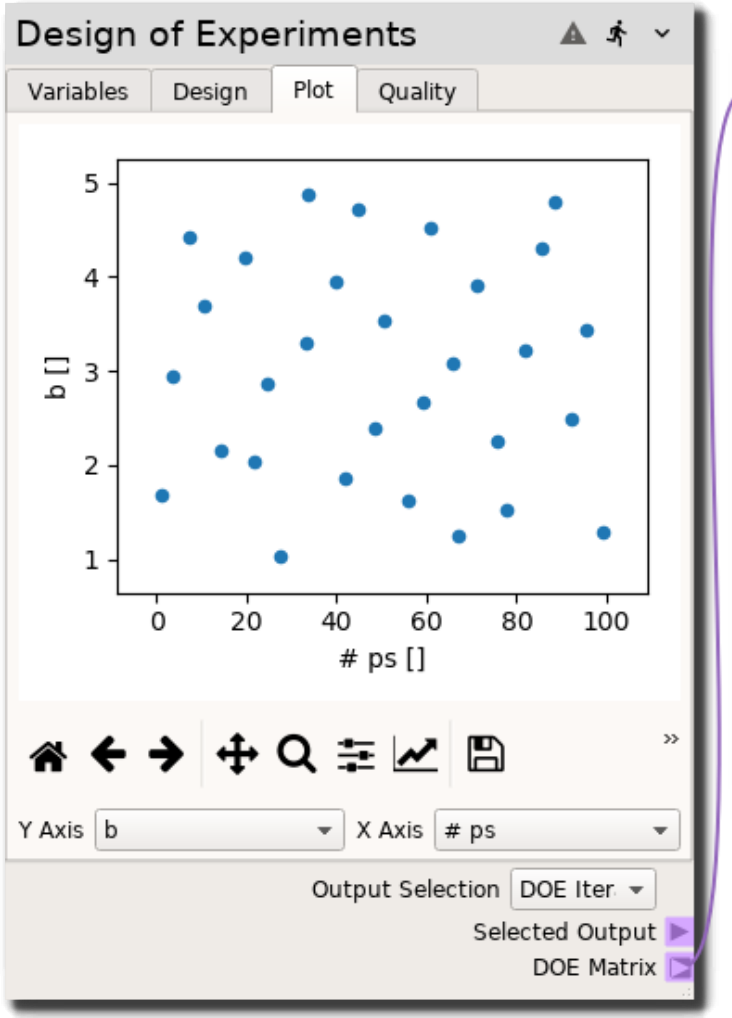
Experiment

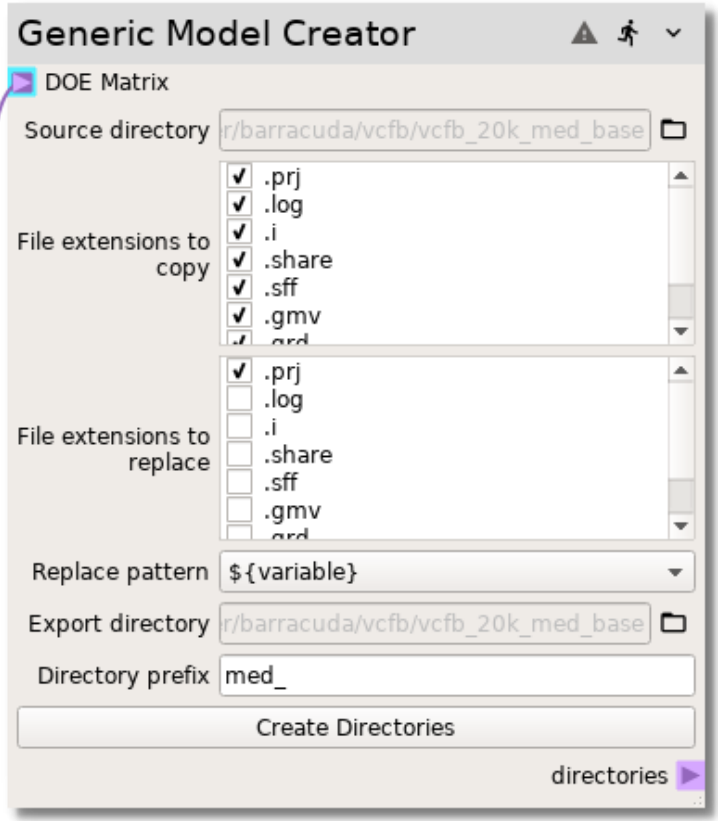
Wait, I have a tool! Nodeworks

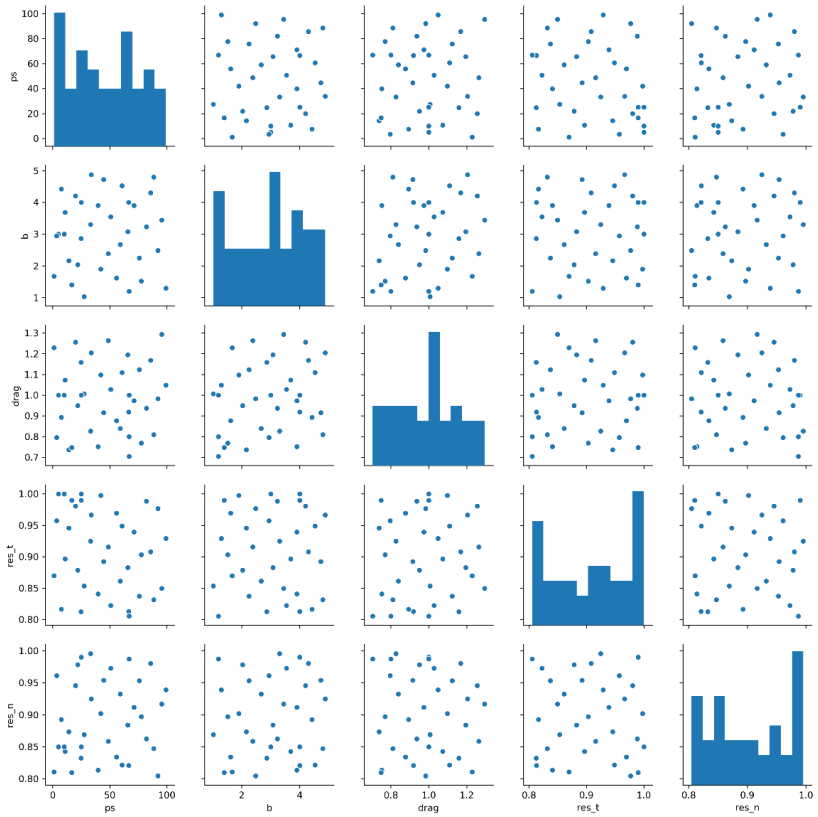


Design of Experiments → Model evaluation → Response Surface Construction → Optimization

Let's use statistics!

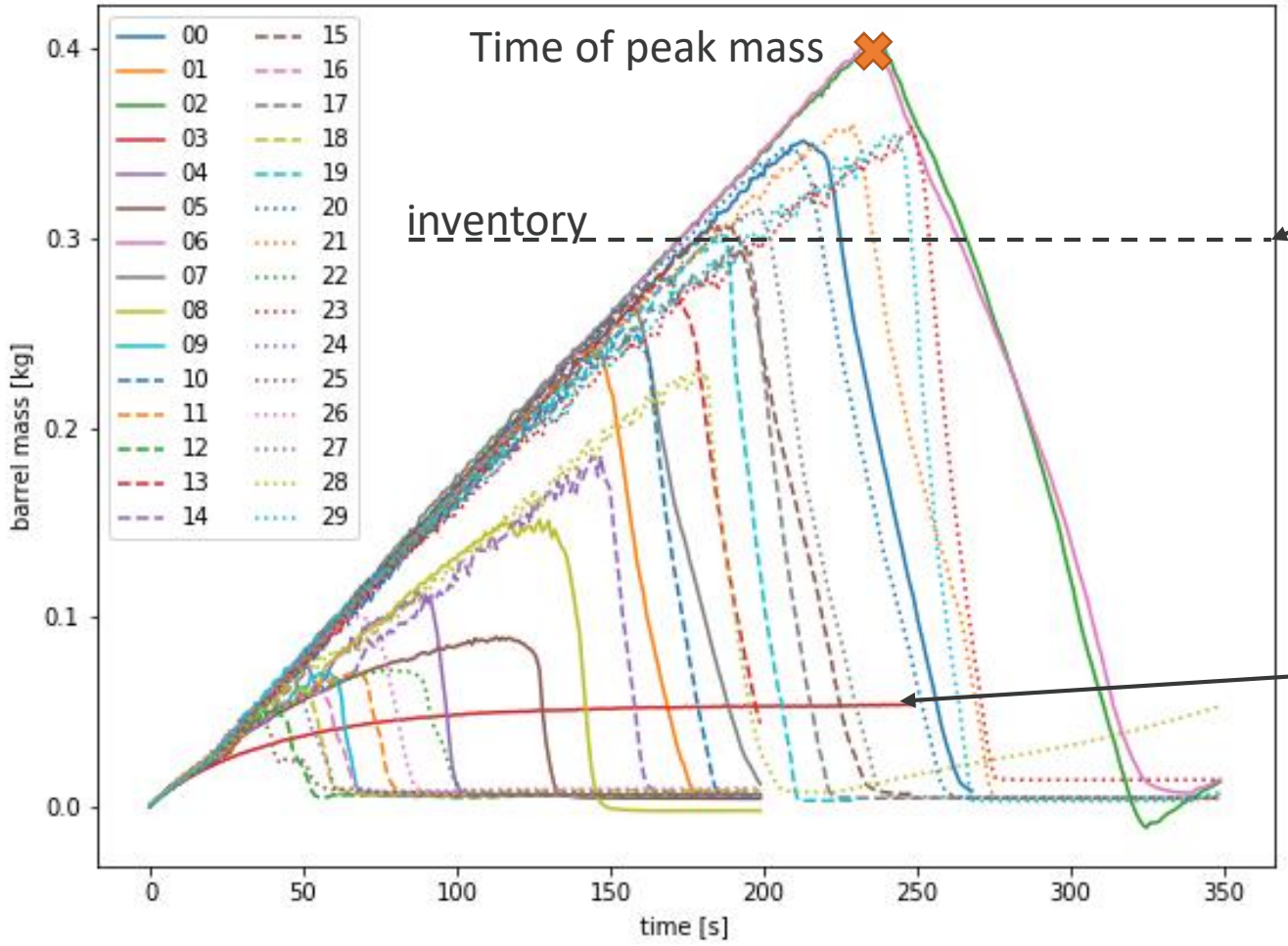






$$\tau\left(\theta_p\right) = \frac{10 P_s \theta_p^{\beta}}{\max\left[\theta_{cp} - \theta_p, \varepsilon\left(1 - \theta_p\right)\right]}$$

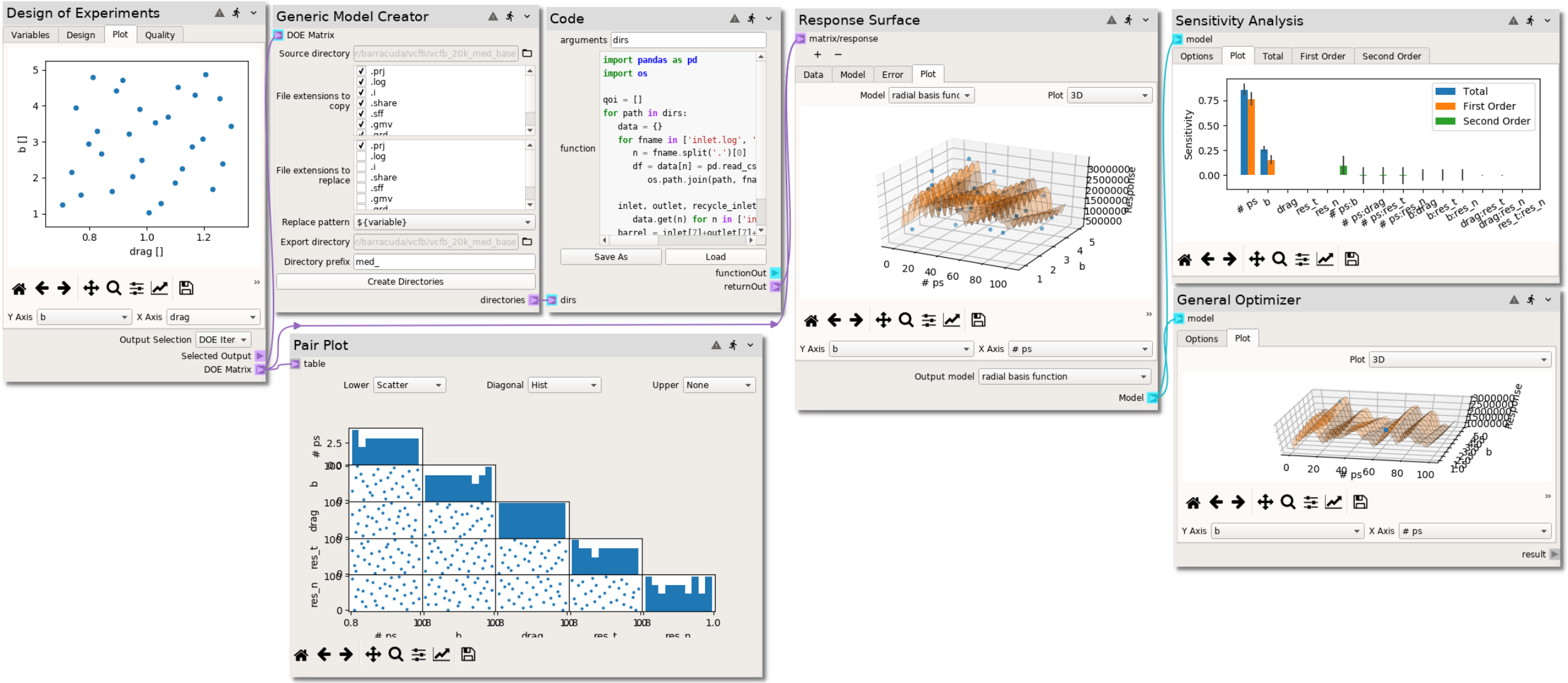
They all clog!



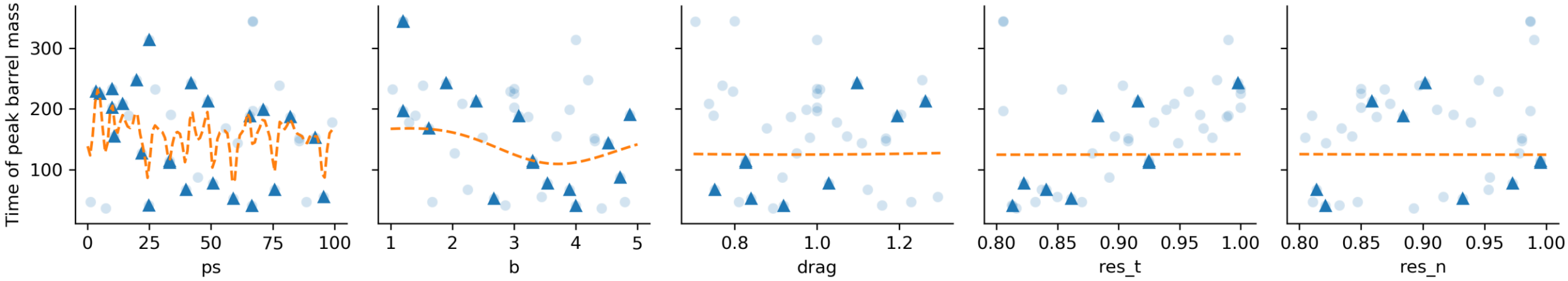
Some reach the target inventory

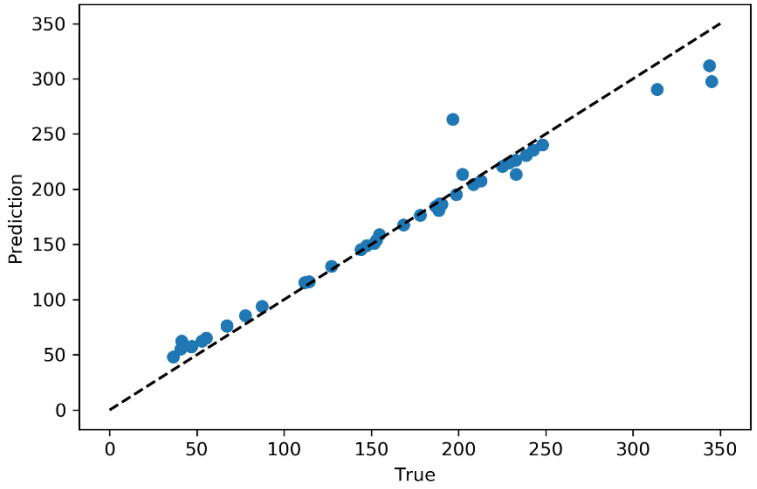
All clog except for one at a low inventory

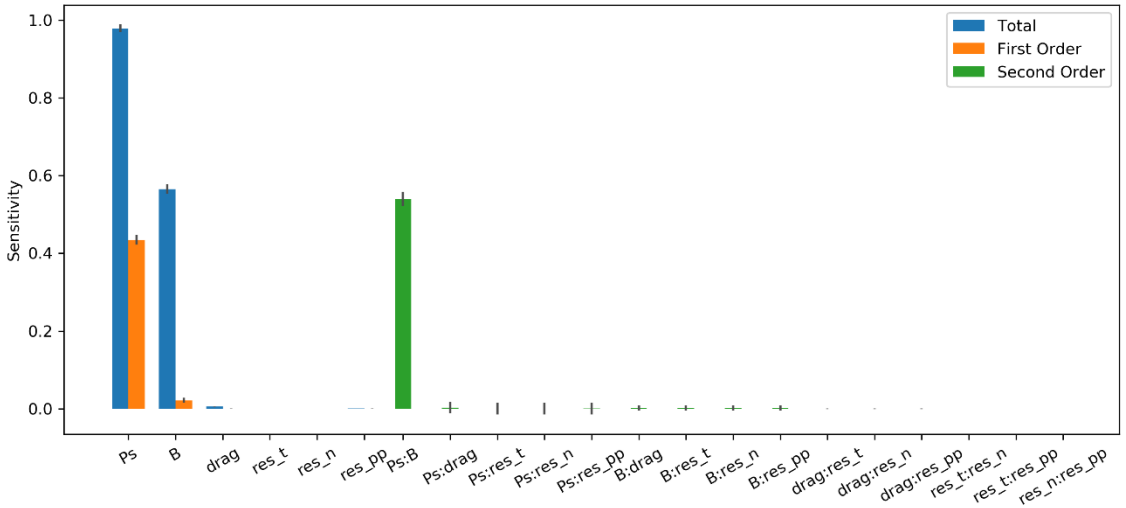
The rest of the workflow



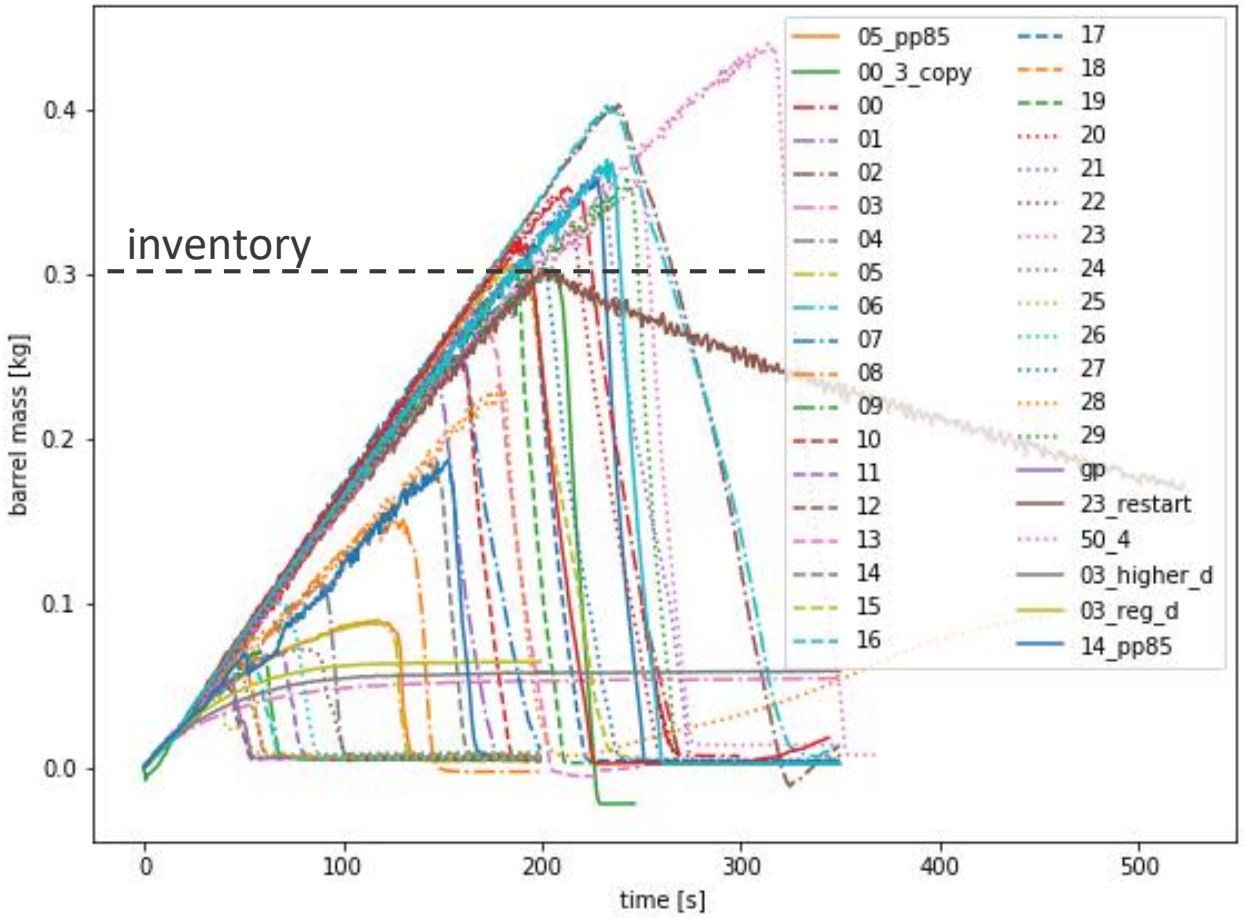
Results


Time of peak barrel mass
300
200
100
0
25
50
75
100
ps
1
2
3
4
5
b
0.8
1.0
1.2
drag
0.80
0.85
0.90
0.95
1.00
res_t
0.80
0.85
0.90
0.95
1.00
res_n

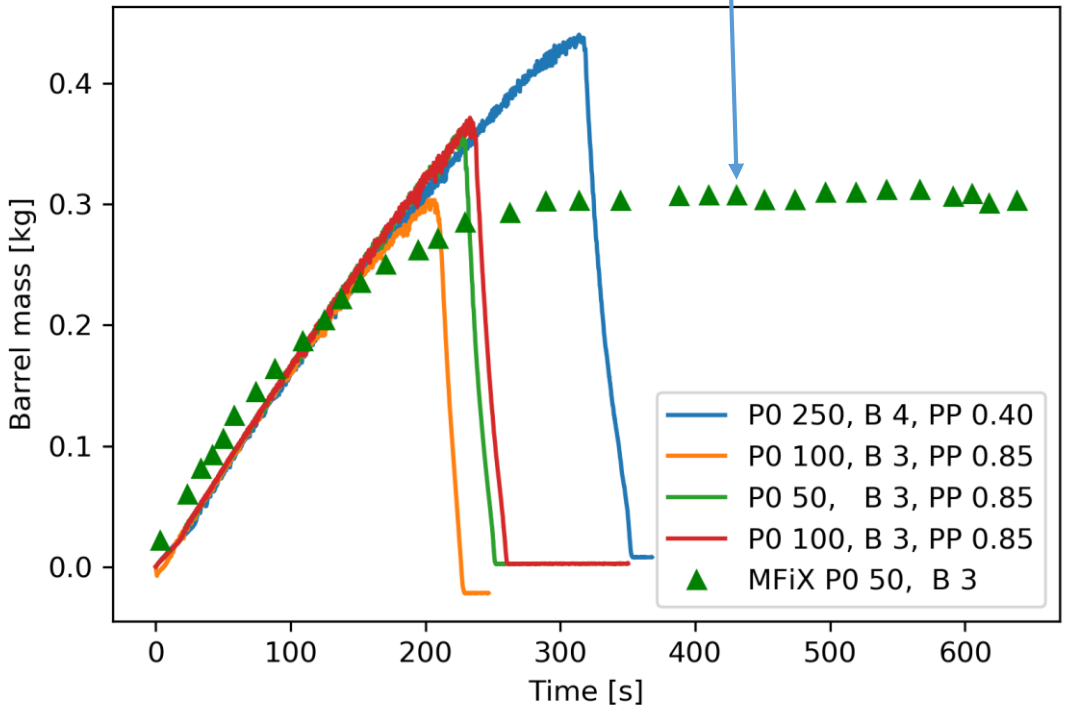

Prediction
True
0
50
100
150
200
250
300
350


Total
First Order
Second Order
Sensitivity
1.0
0.8
0.6
0.4
0.2
0.0
Ps
B
drag
res_t
res_n
res_pp
Ps:B
Ps:drag
Ps:res_t
Ps:res_n
Ps:res_pp
B:drag
B:res_t
B:res_n
B:res_pp
drag:res_t
drag:res_n
drag:res_pp
res_t:res_n
res_t:res_pp
res_n:res_pp

More runs

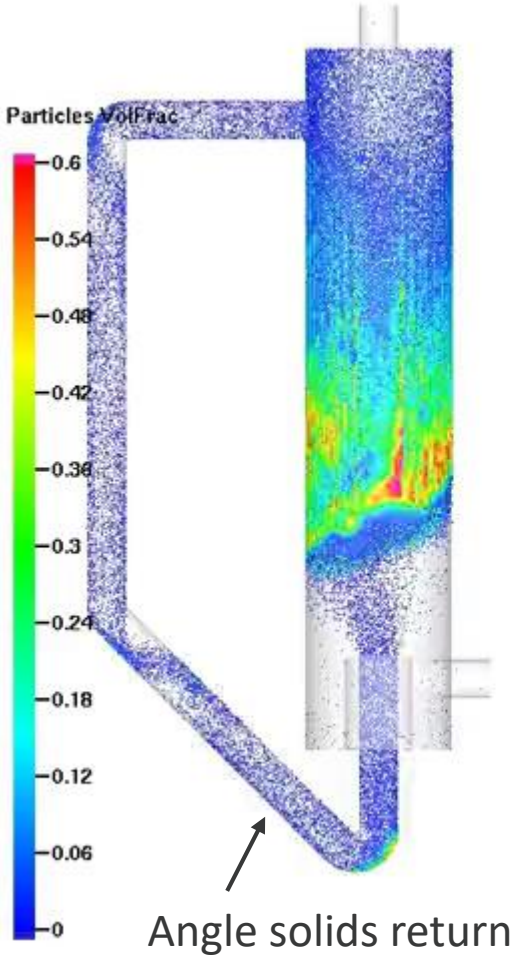


MFiX reaches a steady state

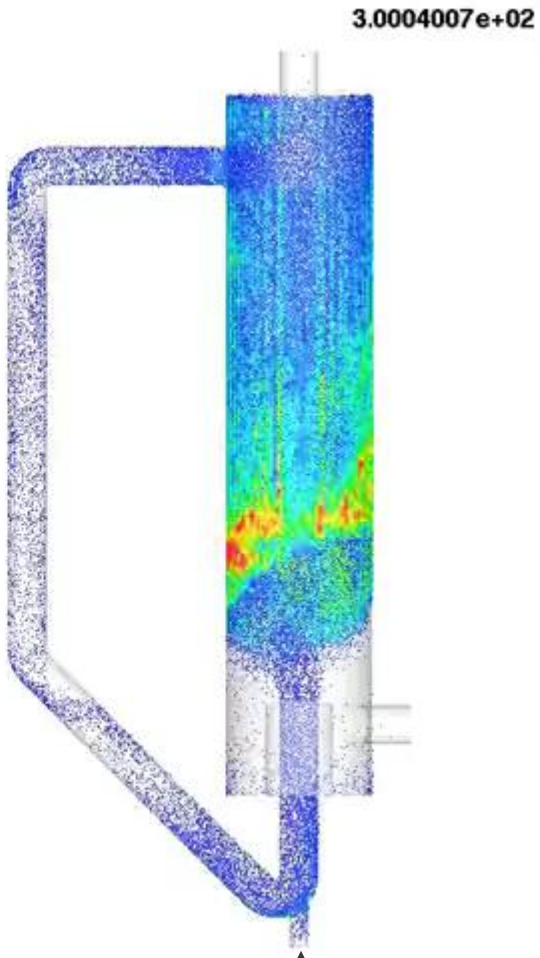


Wait, we can still use the model!

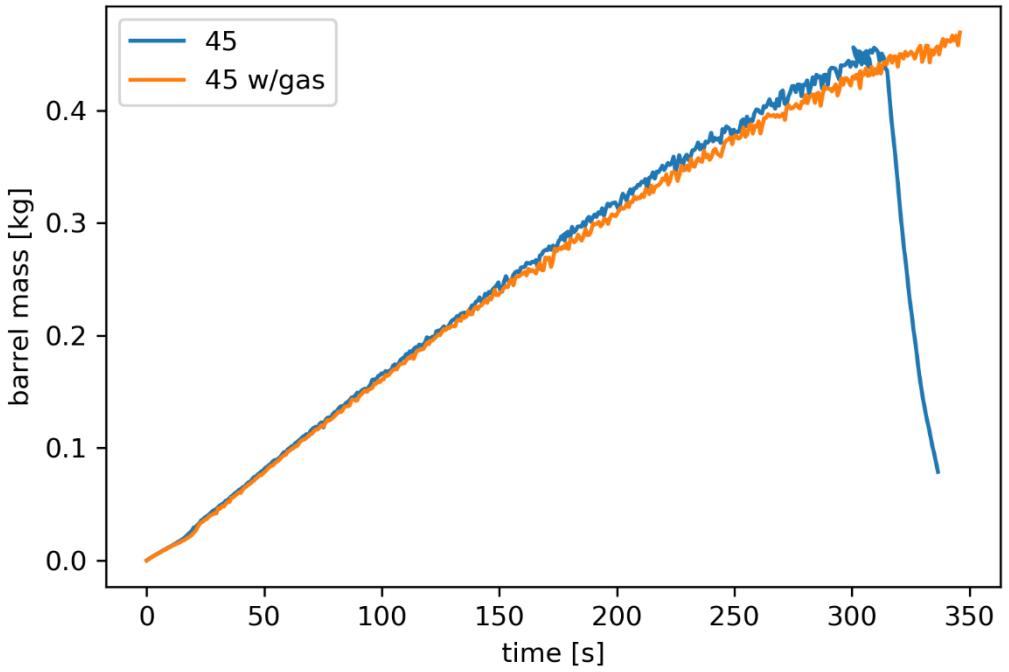
Let's try a different recycle design.



Angle solids return by 45

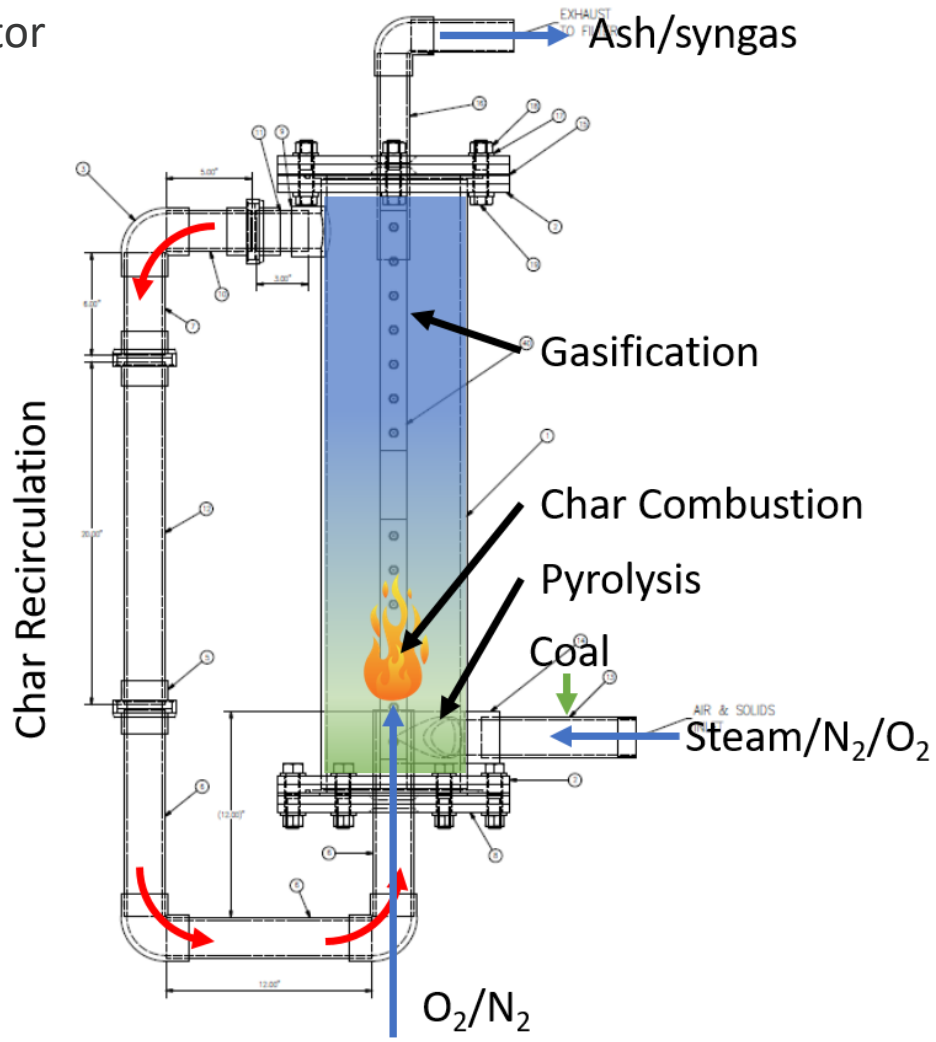


Additional gas



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