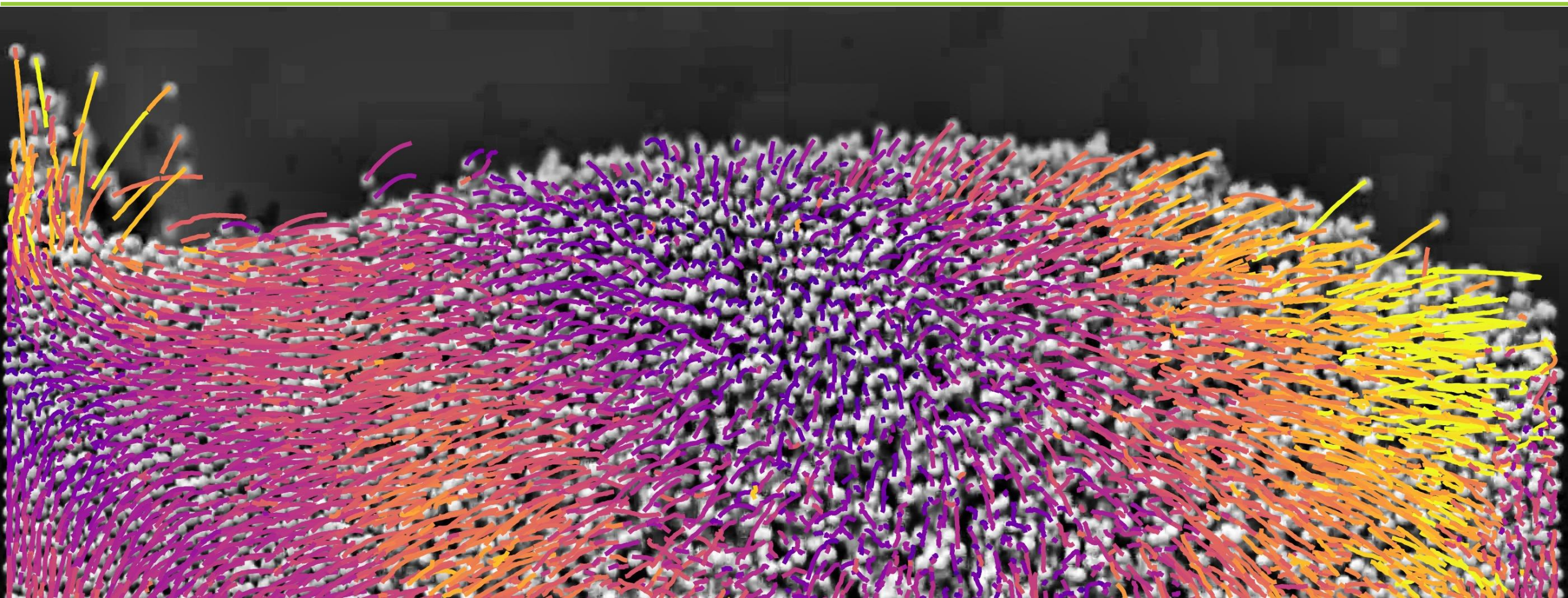
Tracker

Justin Weber, Michael Bobek, Steven Rowan, Jingsi Yang, Ronald Breault

Research and Innovation Center (RIC)



Cold flow units

4in Fluid bed

Spouted beds 1in x 4in & 3in x 12in

4in Moving Bed

4in Circulating fluid bed

12in Circulating fluid bed

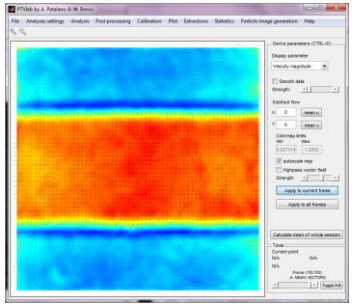
8in Vortexing Circulating fluid bed

Problem

- Lots of PTV tools
  - PTVLab
  - PTVResearch
  - OpenPTV
  - TracTrac
- Lots of methods
  - Shake-the-box
  - HsPIV
  - Voroni
  - Predictor methods

What I want

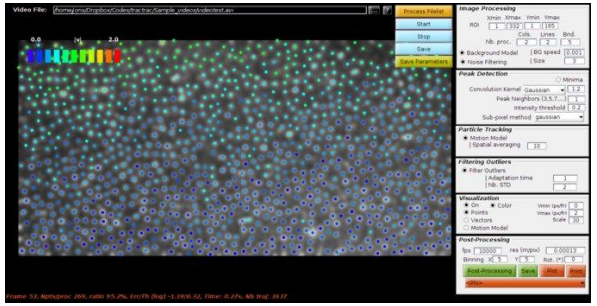
- Open source
- Doesn't rely on expensive software (MATLAB)
- Integrated tool-chain
- Cross-platform
- Continuously developed
- Parallel
- Graphical user interface
- Well documented
- Continuously tested
- Verified with synthetic and experimental data



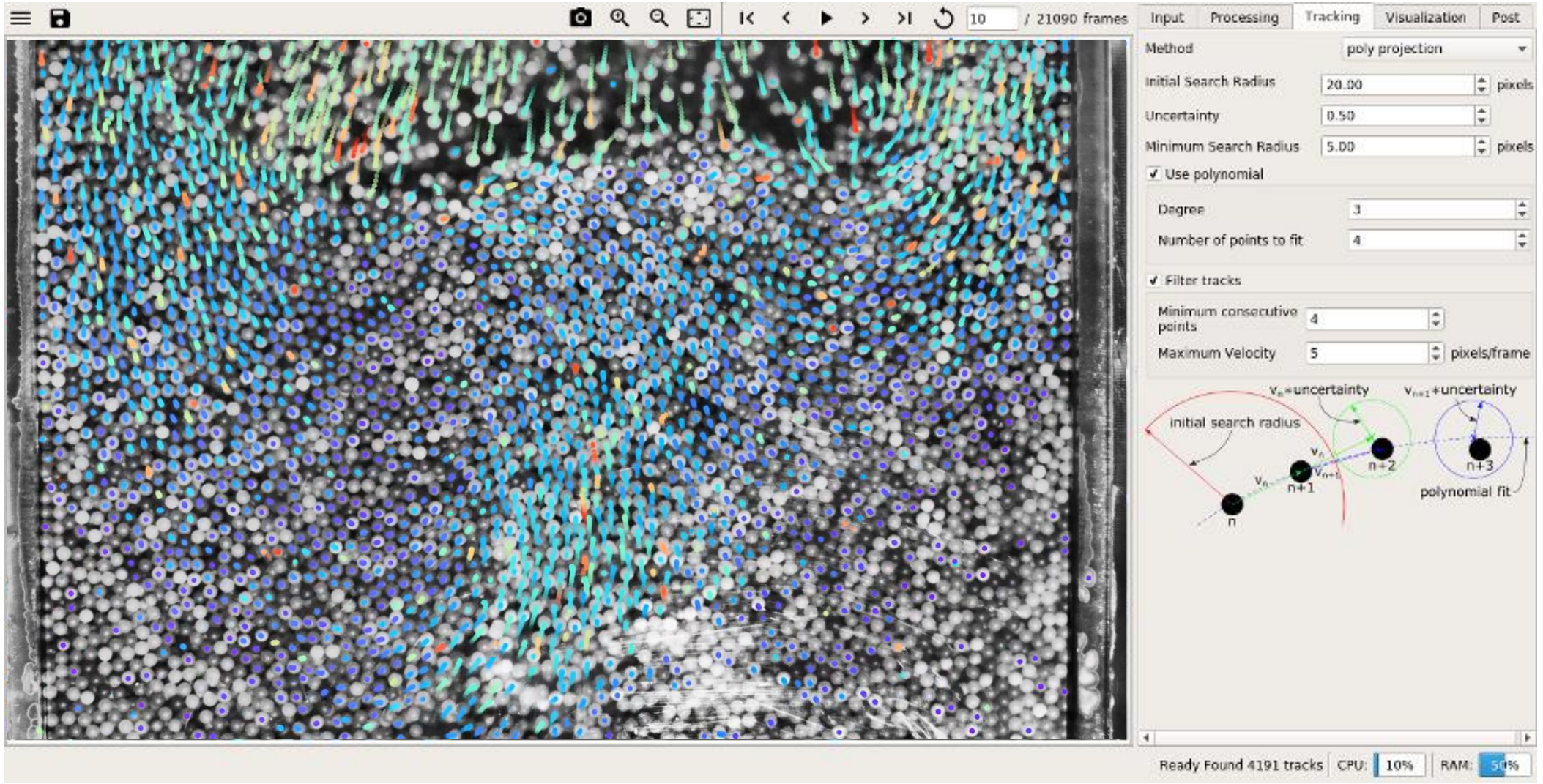
PTVresearch
Particle Tracking Velocimetry

jonny.e.higham@gmail.com

OpenPTV
open source particle tracking velocimetry

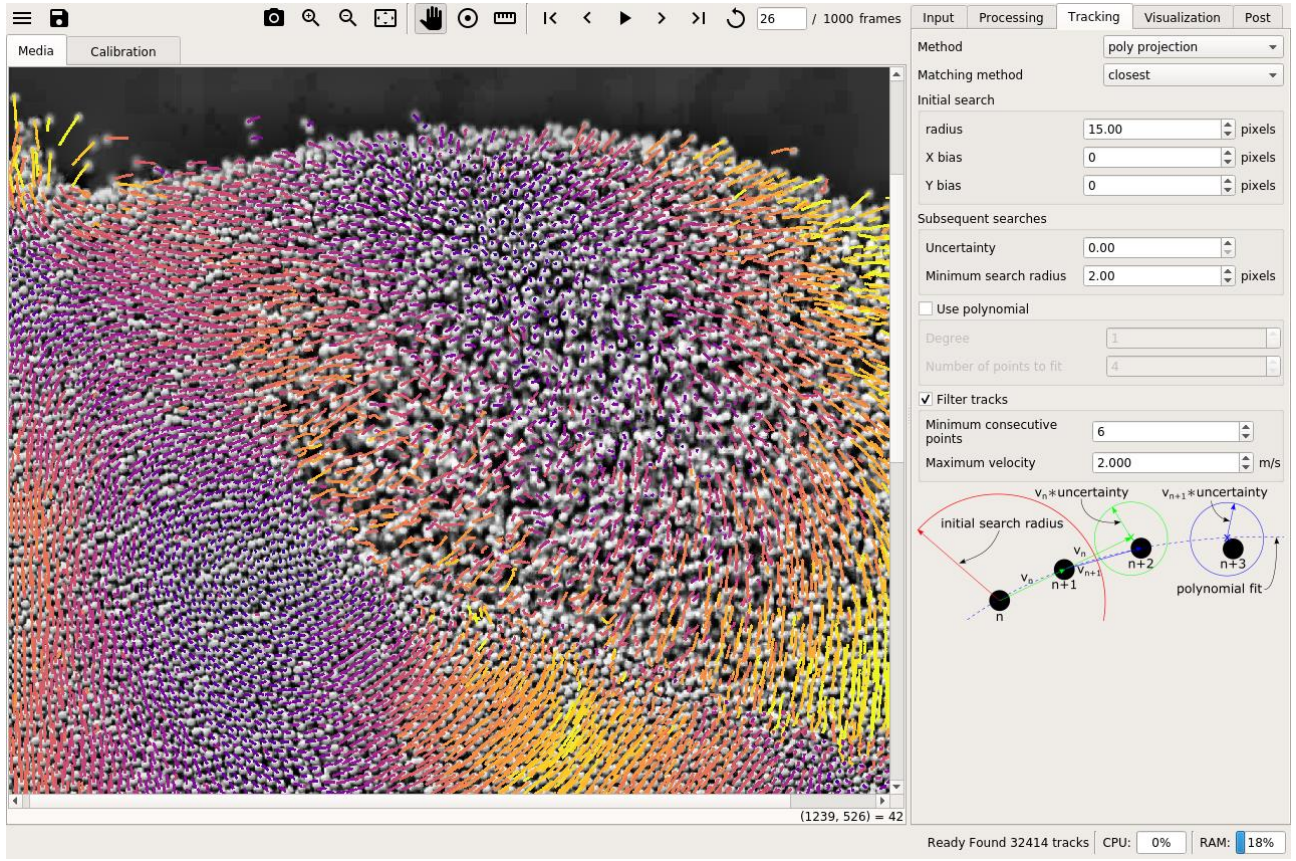


Introducing: Tracker

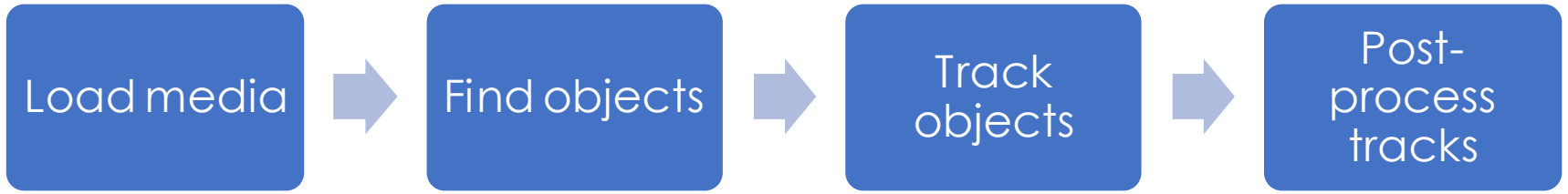


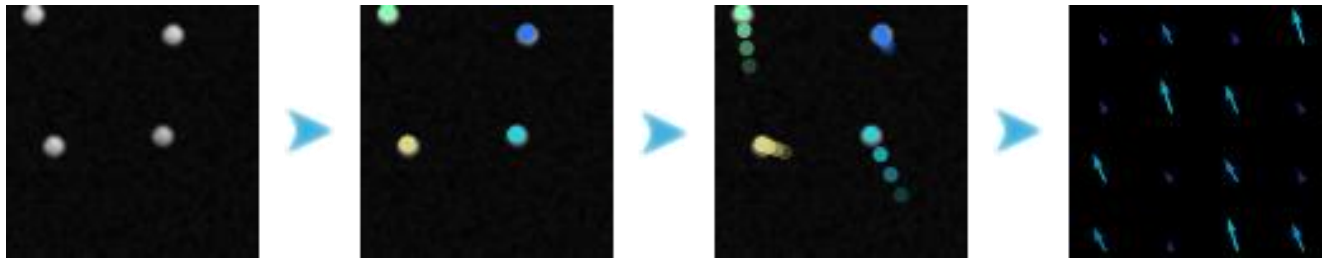
What is Tracker?

- Particle Tracking Velocimetry (PTV) application
  - Opensource
  - Continuously develop
  - Written in Python
    - Opencv, numpy, scipy, Qt, matplotlib
  - Uses git for version control
  - Test harness runs every commit



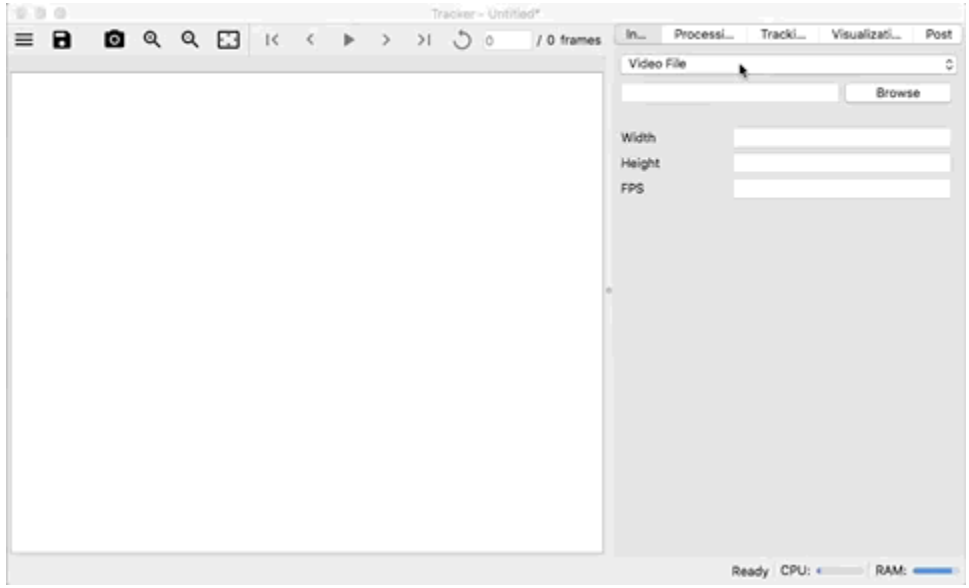
Workflow

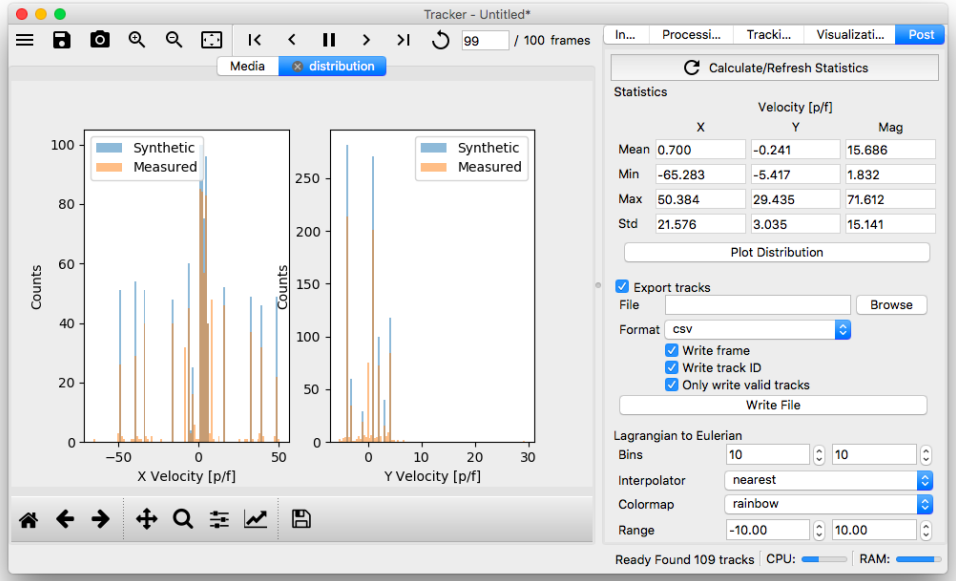




Load media

- Read videos (almost every format)
- Image stacks
- Synthetic data
  - Gaussian, circle, or template
  - Count, resolution, velocity, acceleration

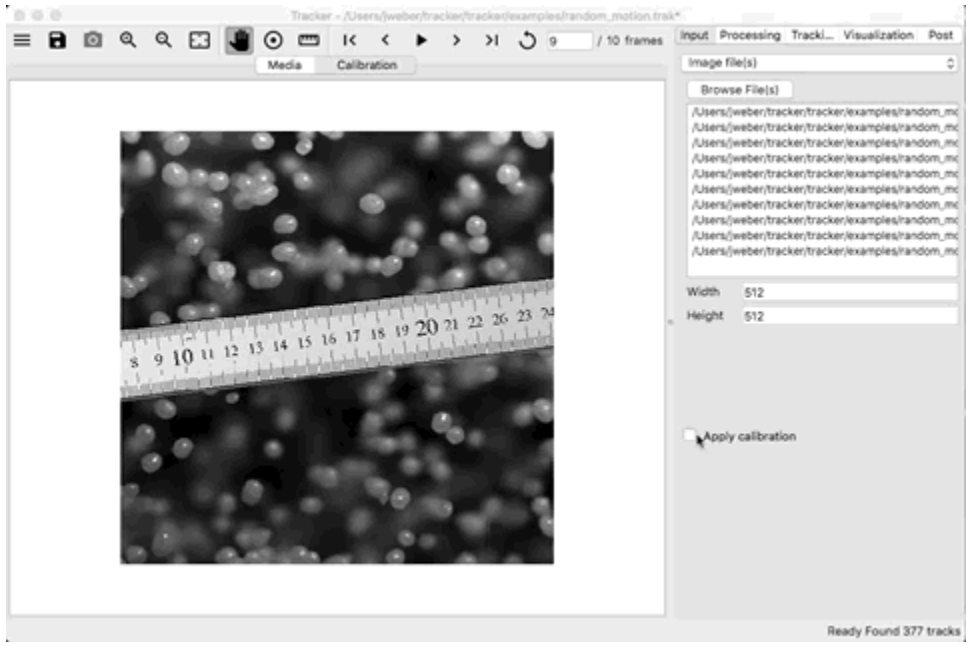




Calibration

Simple calibration tool

- Load image with length reference
- Draw line on image
- Set the real line length
- Set frames/second

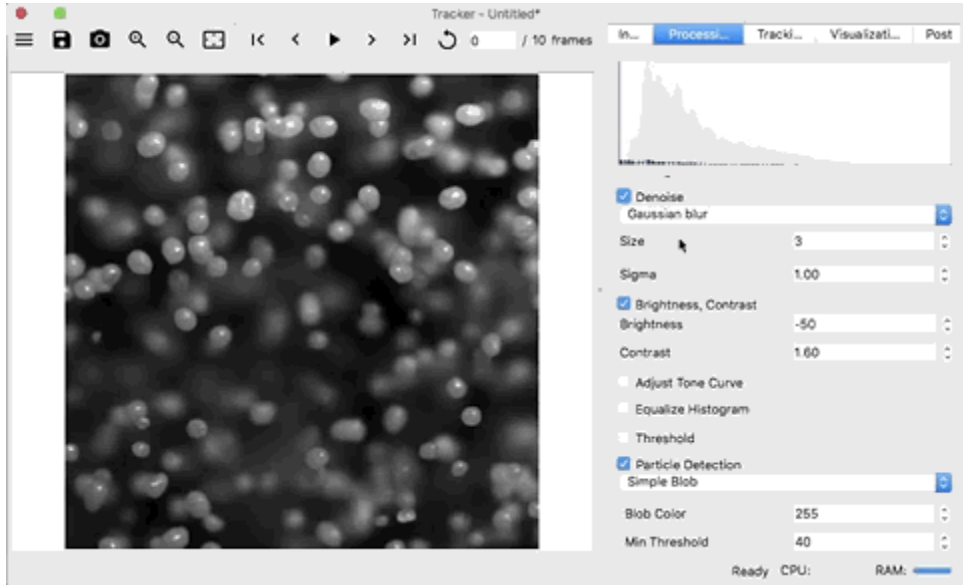


pixels/frame -> m/s

Image processing

Image processing tools include

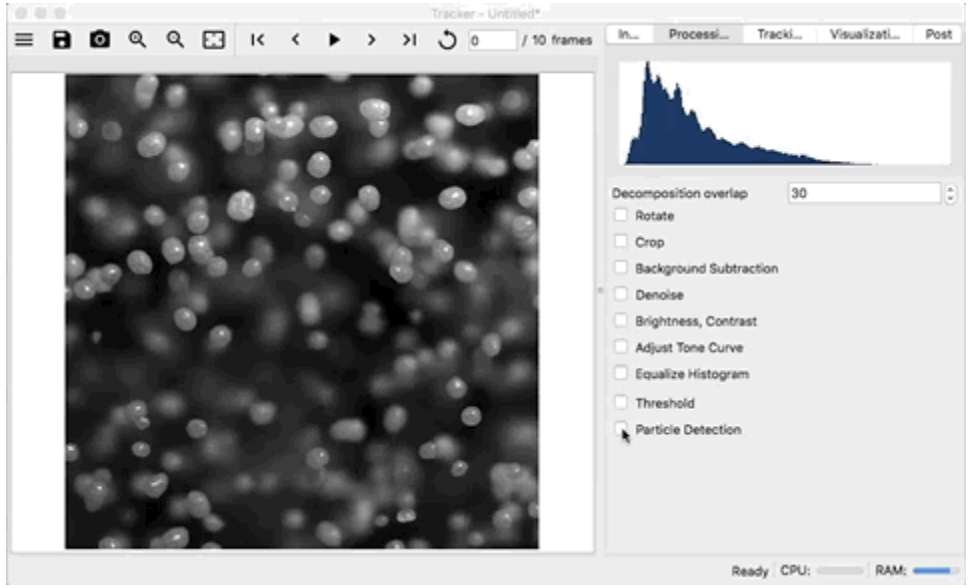
- Rotation (90° increments)
- Cropping
- Background Subtraction
  - Mean, MOG2, KNN
- Denoise
  - Gaussian, median, bilateral
- Brightness/contrast (linear)
- Tone curve
- Equalize histogram
- Threshold



Object segmentation

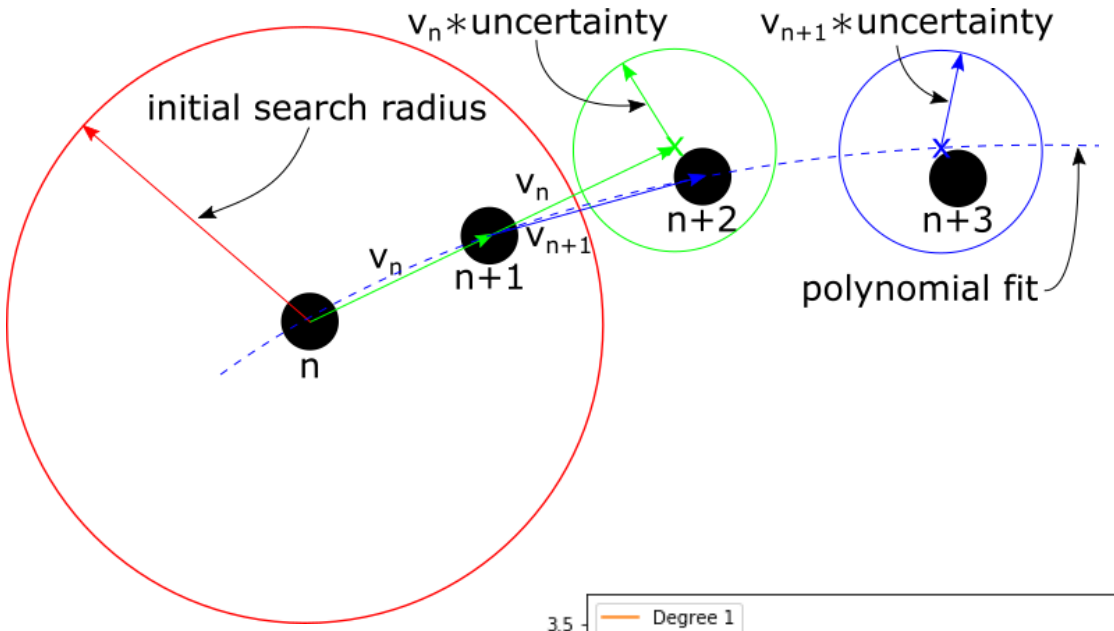
Object segmentation

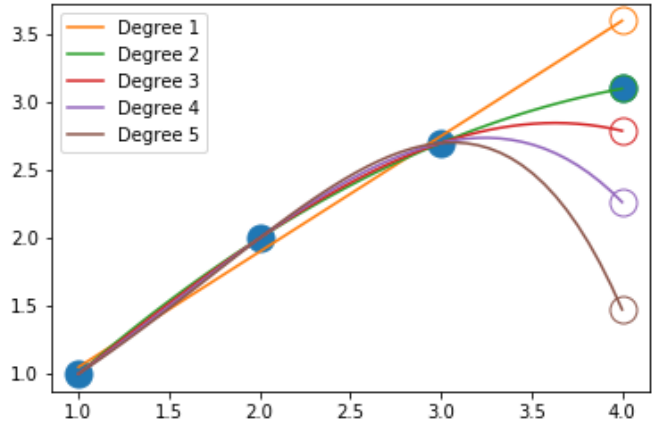
- Label
- Hough circles
- Simple Blob



Tracking | Poly Projection

Frame	Description
n	An object is identified
n+1	Within $r_{default}$, find the closest object to the previous location, p(n).
n+2	Using p(n) and p(n+1), calculate the velocity v(n). Using this velocity, predict the next location. Within the r_{search}(n+2), find the closest object.
n+3	Using p(n), p(n+1), and p(n+2), fit a polynomial, f(). Evaluate the polynomial, f(n+3), to predict the next location. Within the r_{search}(n+3), find the closest object.
n+i	Repeat the n+3 step until an object cannot be found within r_{search}(n+i).

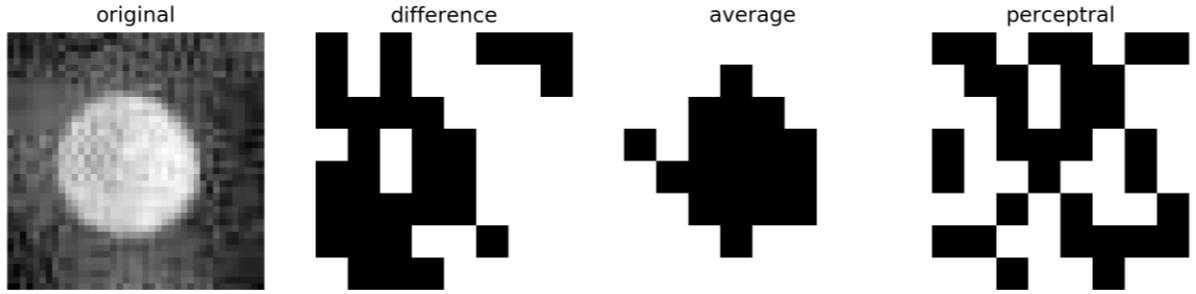




Tracking | Template Matching

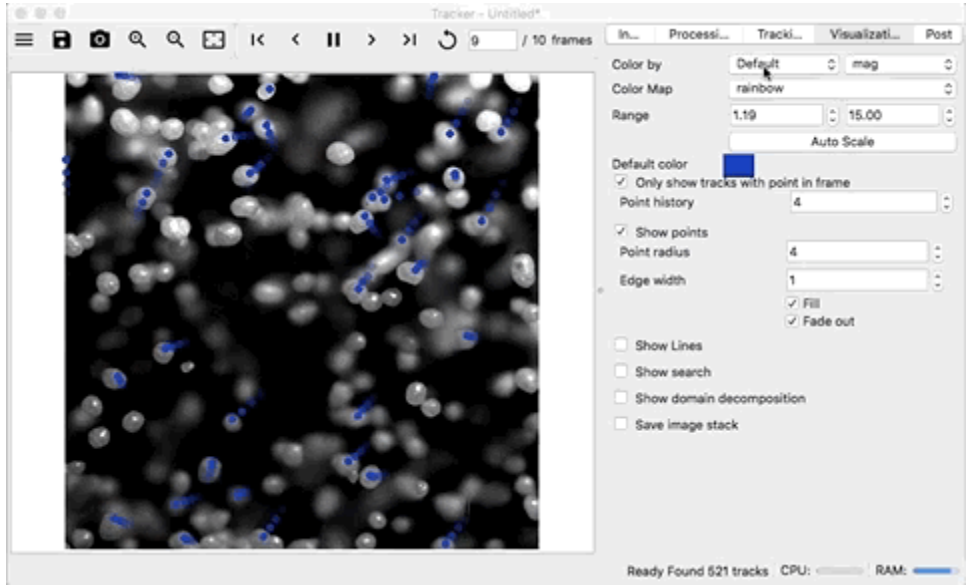
Frame	Description
n	An object is identified
n+1	Within $r_{default}$, find the object with the closest Hamming distance for the image hashes or the smallest error metric.
n+i	Repeat the n+1 step until an object cannot be found within r_{search}(n+i).

- aHash – average image hashing
- pHash – perceptual image hashing
- dHash – difference image hashing
- SSE – sum of squared errors
- MSE – mean squared error
- L1 norm
- Linf norm



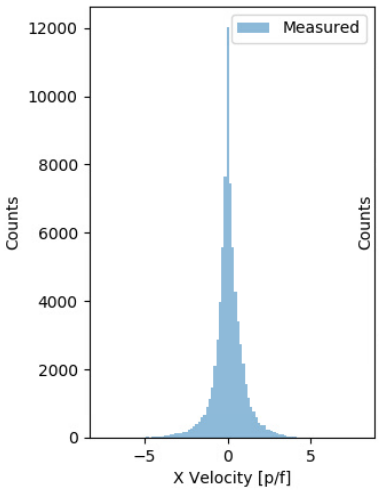
Visualization

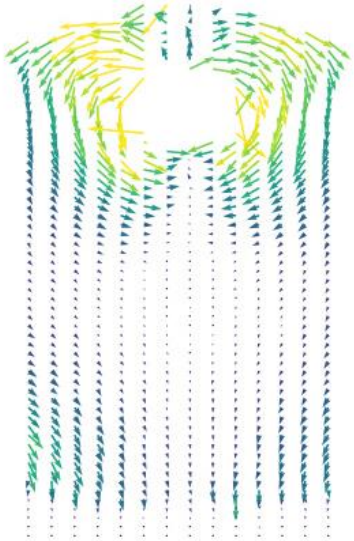
- Points and/or lines
- Change history length
- Color by
  - Track, velocity, or constant
- Save image stacks for pretty videos!

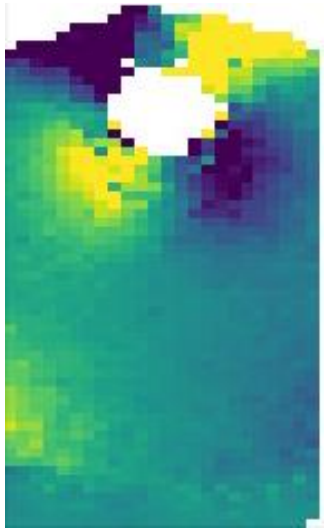


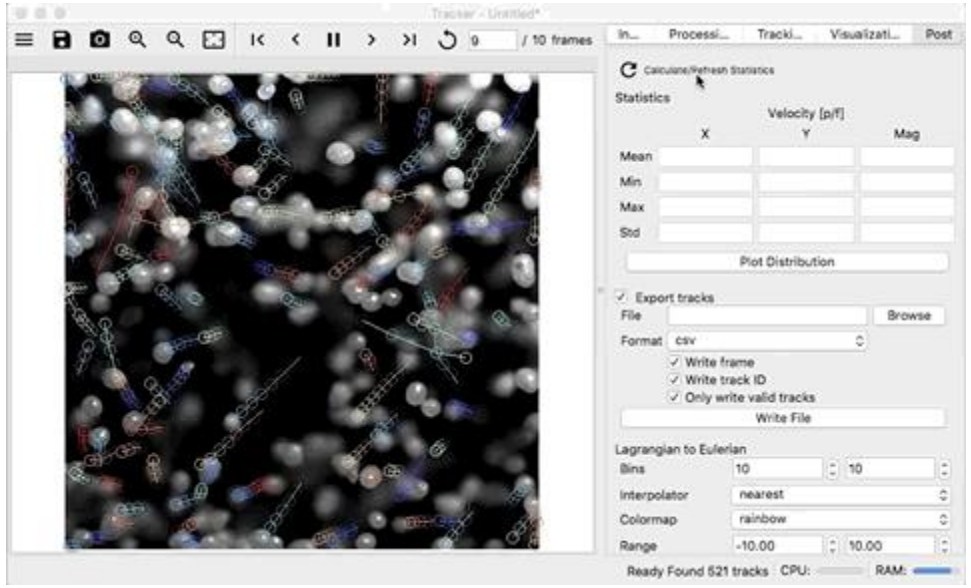
Post processing

- Distributions
- Quiver
- Spatially binned average

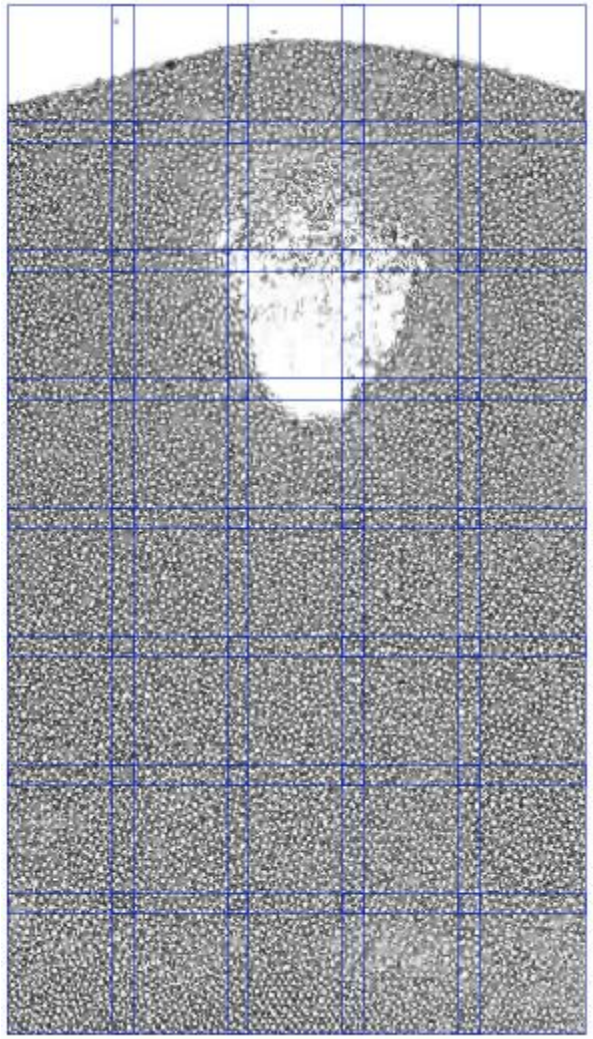


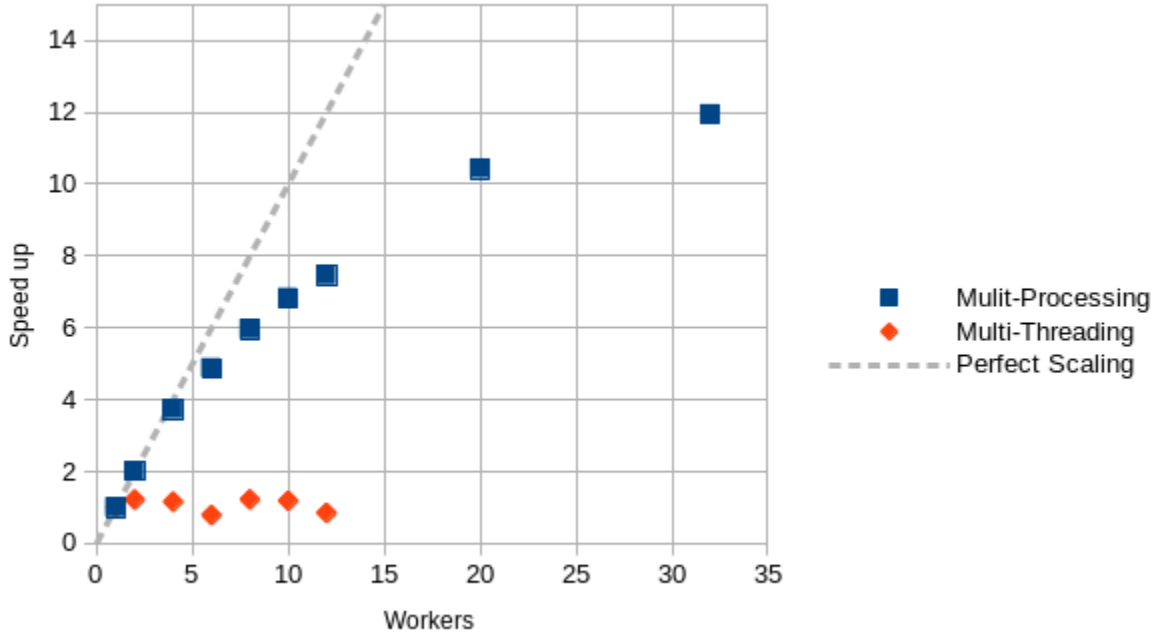






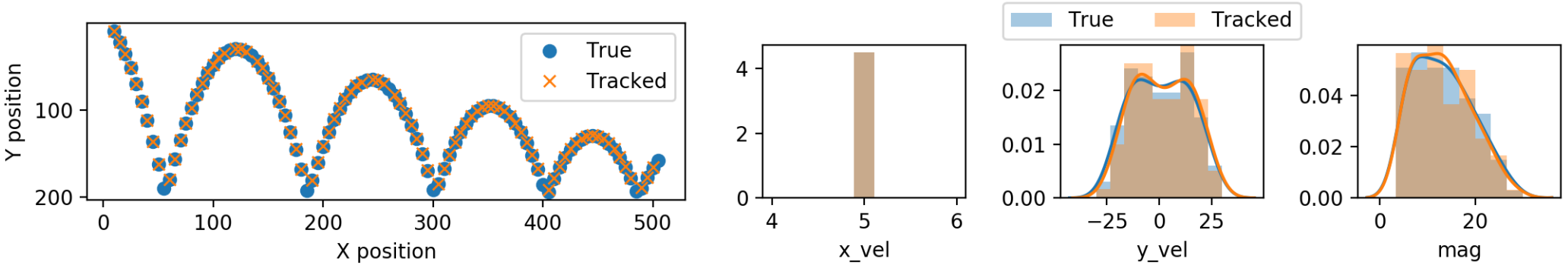
Parallelization



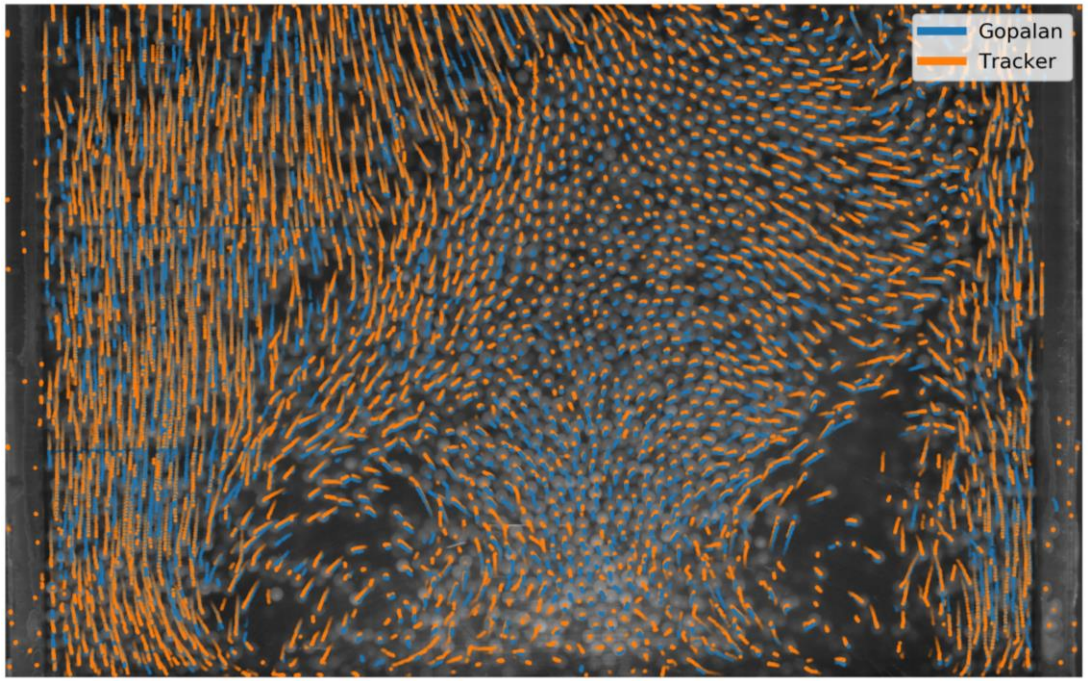


Verification | Single Particle Bounce

- Synthetic image stack

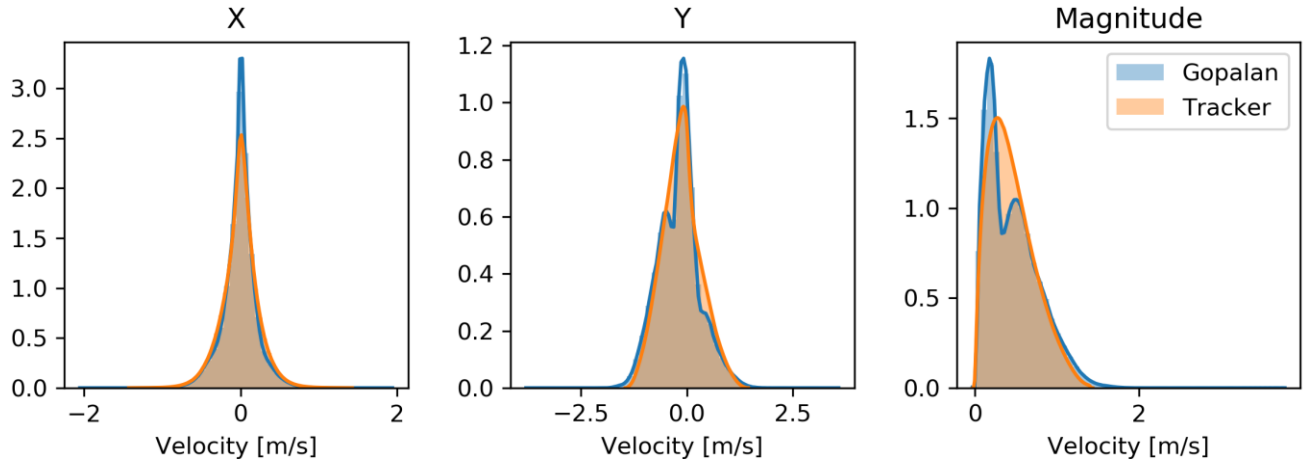


Verification | SSCP



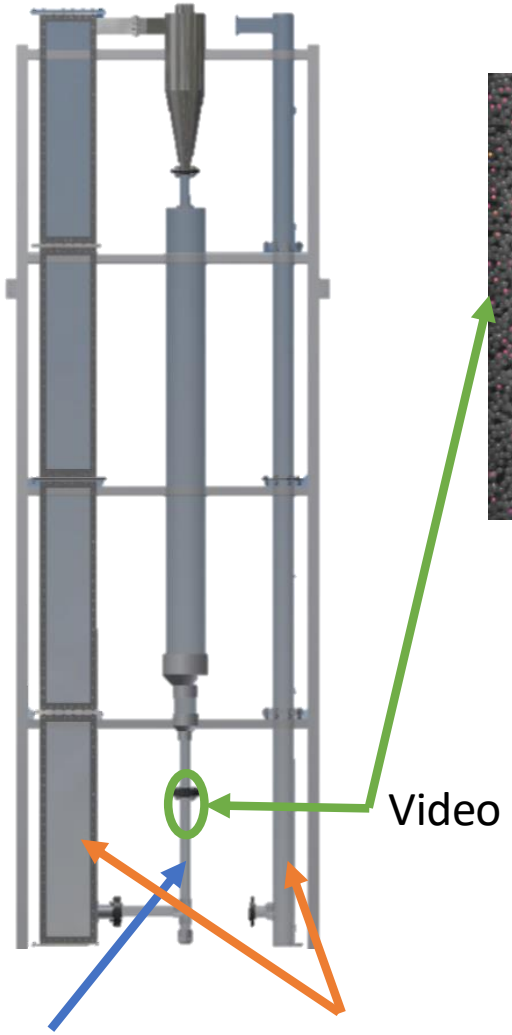
- NETL Small Scale Challenge Problem
- Compare to HsPIV*

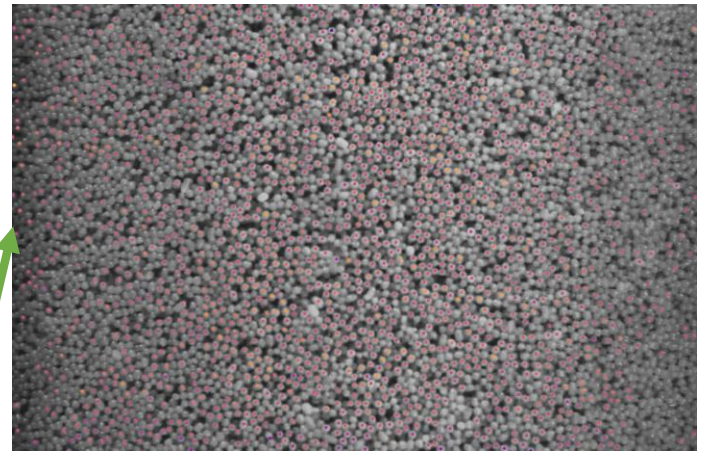
	TRACKER	GOPALAN
Velocity measurements	41,356,169	34,479,966
Mean X Velocity	-0.0042	-0.0060
Mean Y Velocity	-0.1299	-0.1457
Mean Magnitude	0.4589	0.4704



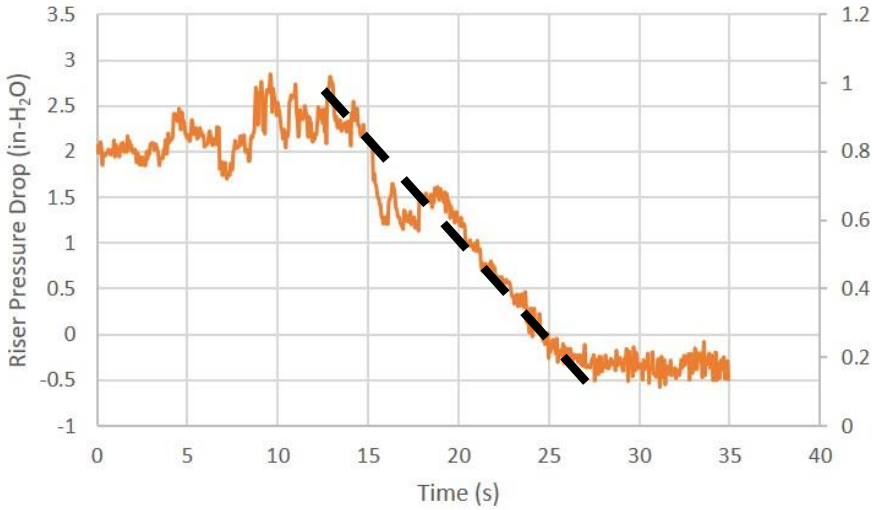
*Balaji Gopalan, Mehrdad Shahnam, Rupen Panday, Jonathan Tucker, Frank Shaffer, Lawrence Shadle, Joseph Mei, William Rogers, Chris Guenther, and Madhava Syamlal. Measurements of pressure drop and particle velocity in a pseudo 2-d rectangular bed with geldart group d particles. *Powder Technology*, 291:299 – 310, 2016.

Verification | Solid circulation rates



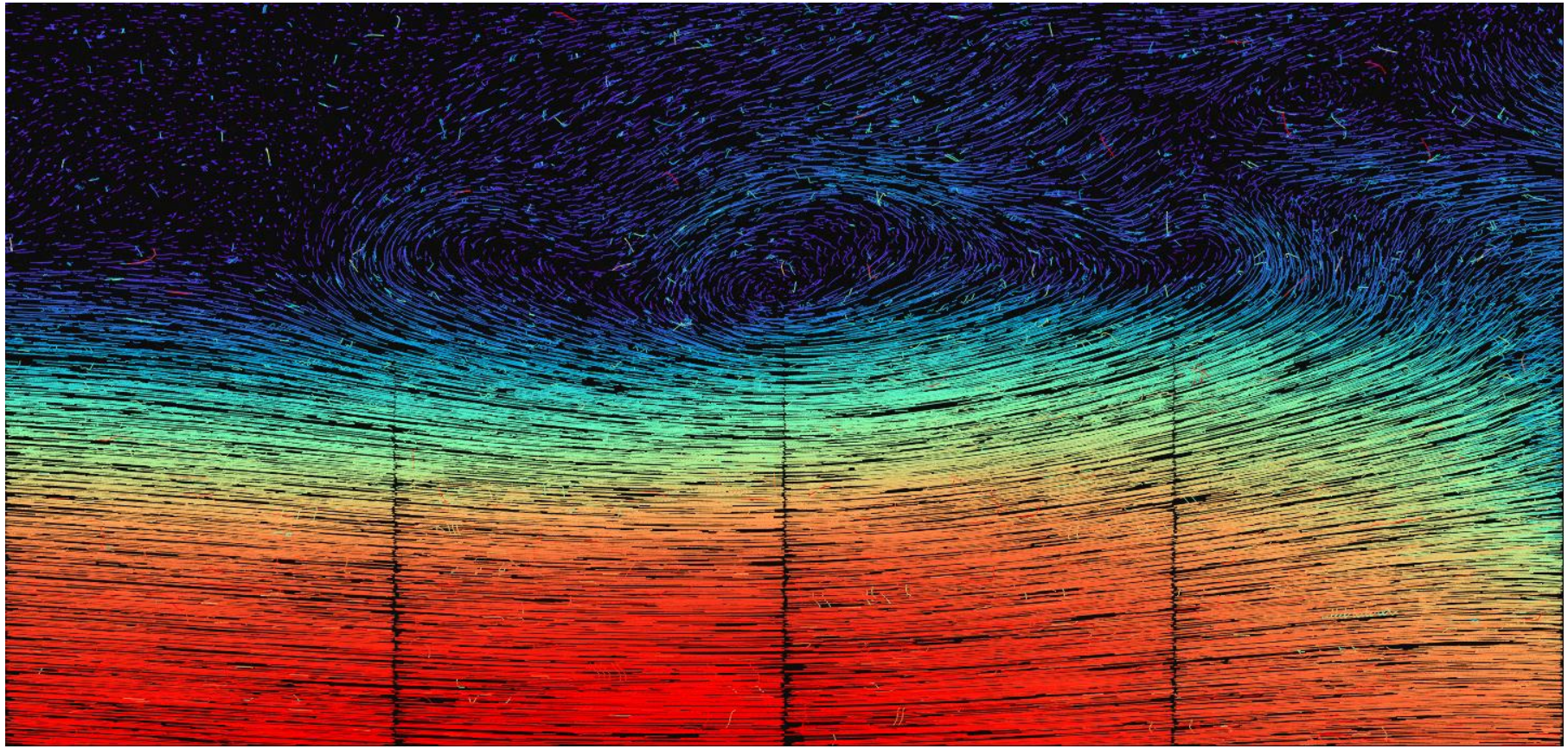


$$G_s = \frac{V_p \rho_p}{A_{riser} / A_{standpipe}}$$



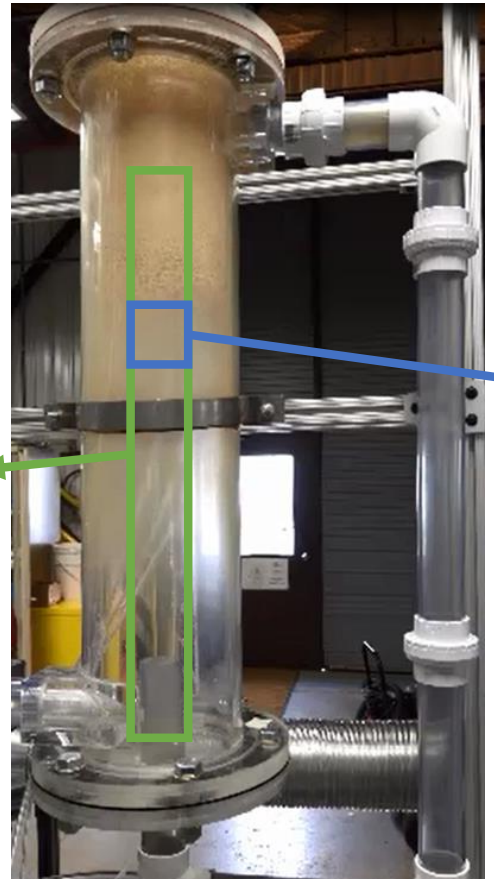
	TRACKER	CUT OFF	%ERROR
TEST 1	24.875 kg/m²s	24.25 kg/m²s	2.58
TEST 2	24.827 kg/m²s	24.23 kg/m²s	2.46

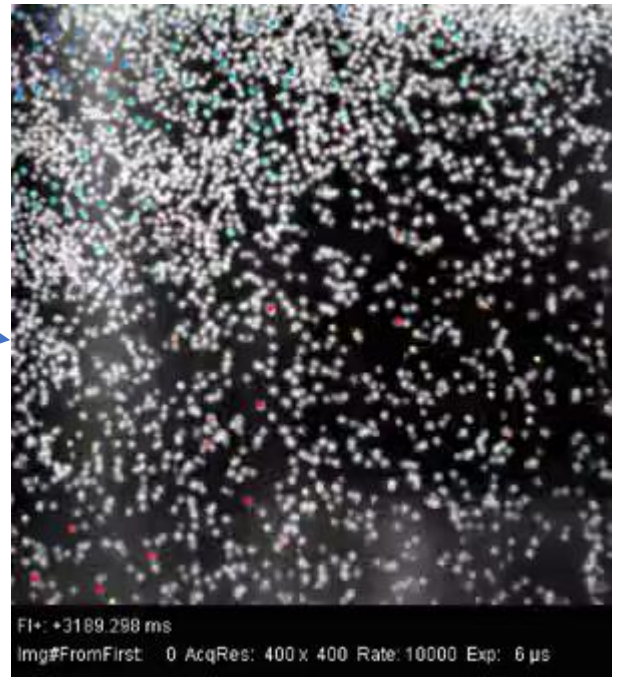
Verification | PIV Challenge

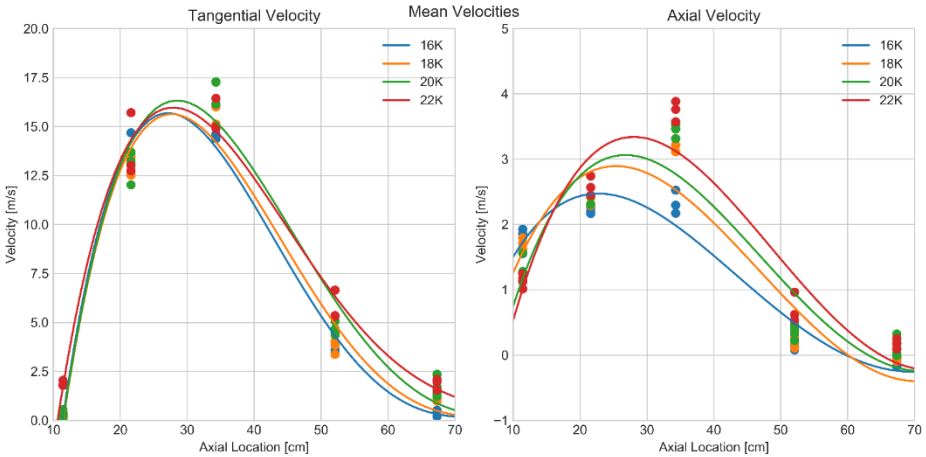


3rd PIV Challenge Case B: http://www.pivchallenge.org/

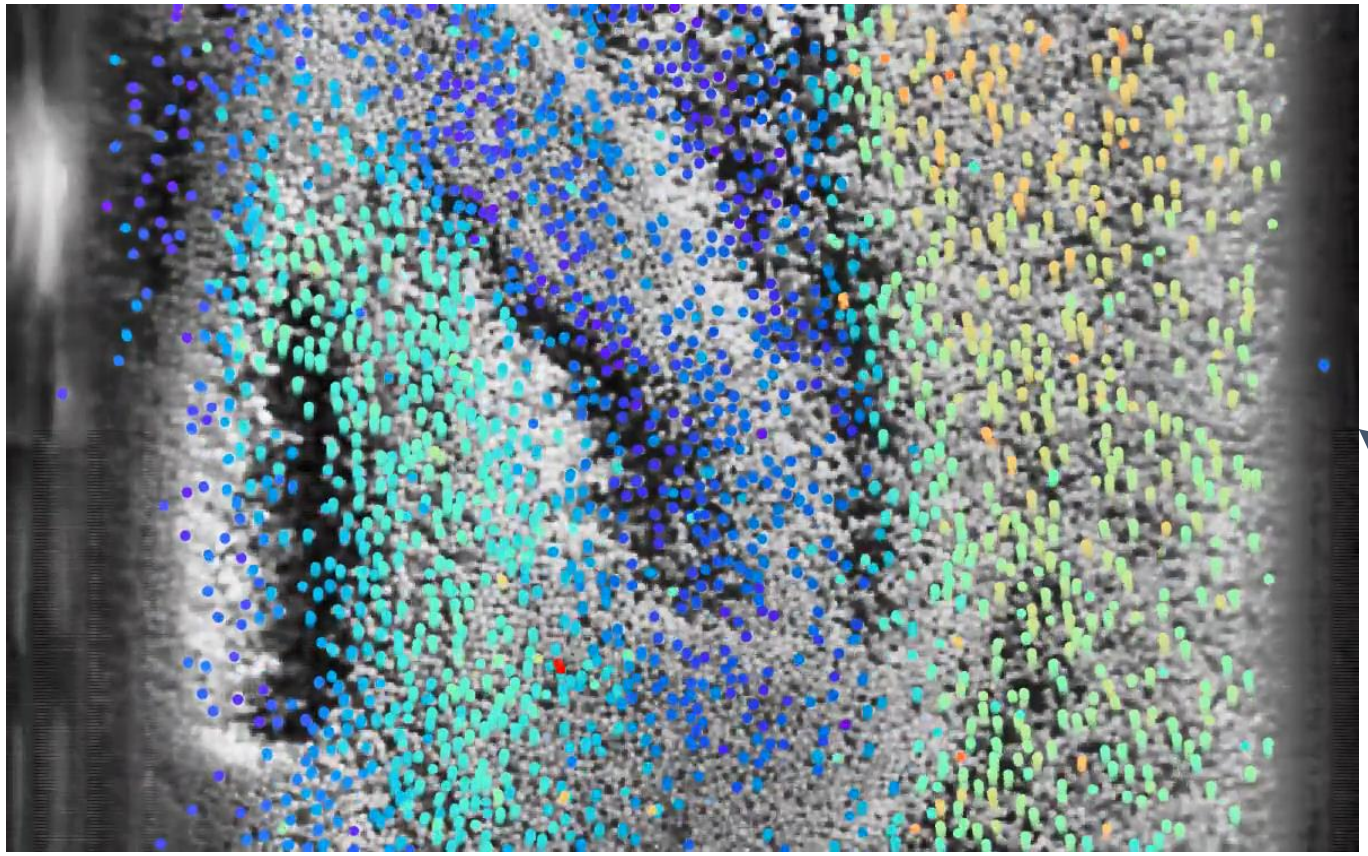
Usage | Vortexing Circulating Fluidized Bed

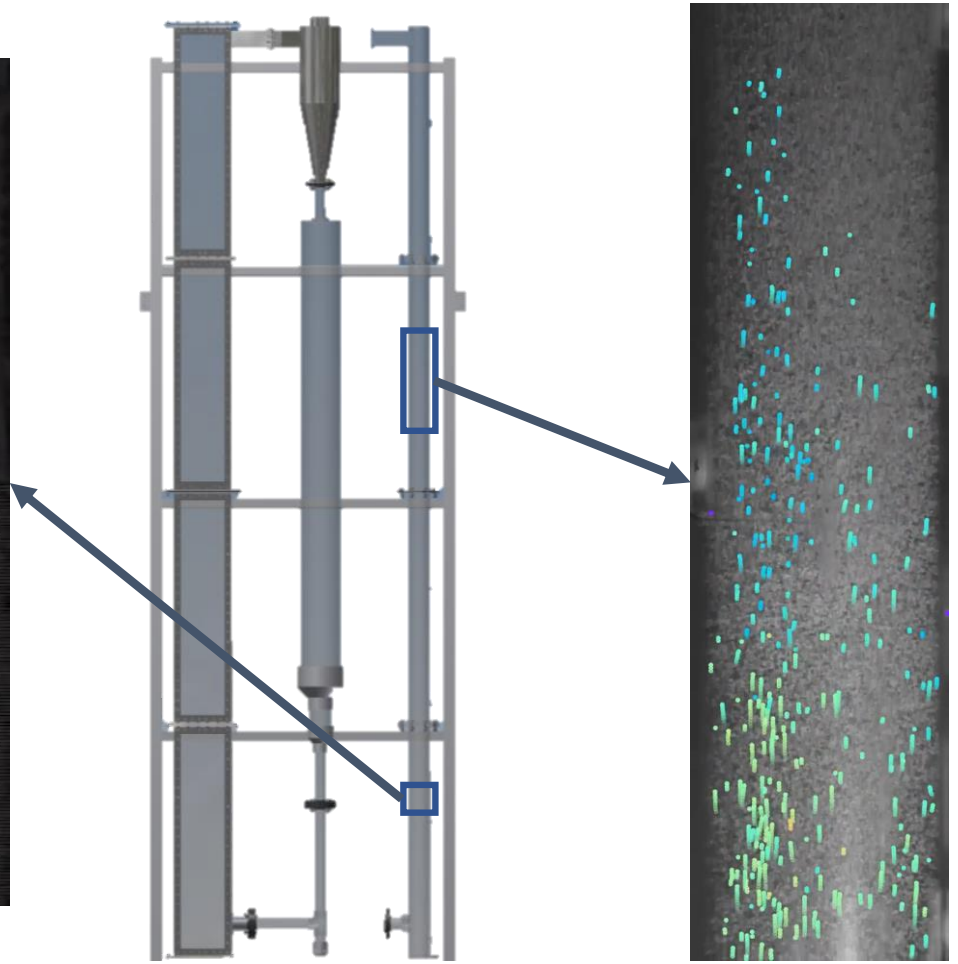






Usage | Risers





Summary

A new tool for particle tracking has been developed

- Open source
- cross-platform
- Parallel

Future work

- Add optical flow
- Validation

Questions?

mfix.netl.doe.gov

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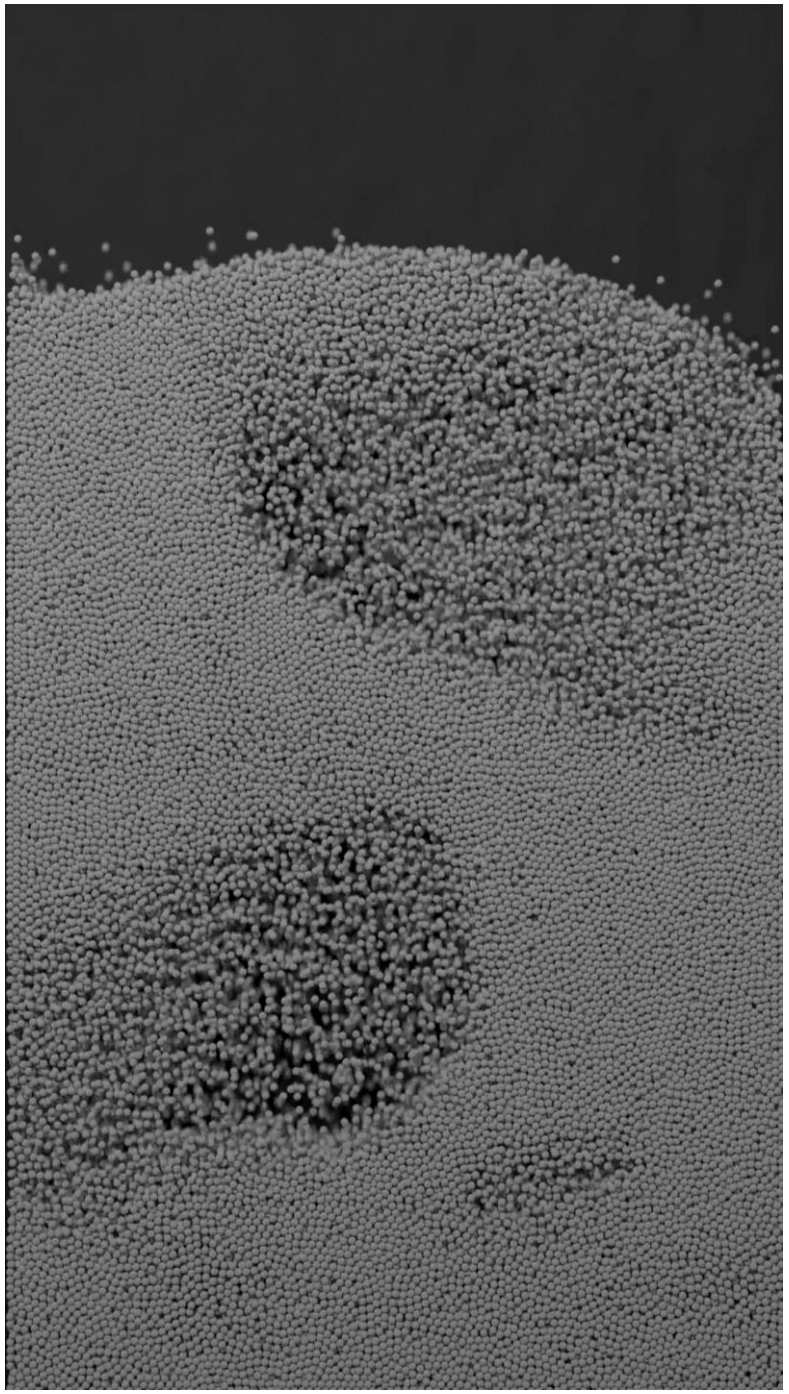
CONTACT:
Justin Weber
justin.weber@netl.doe.gov



PTV Challenge Problem?

MFiX-DEM Simulation

Rendered with Blender