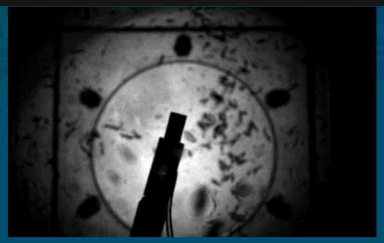
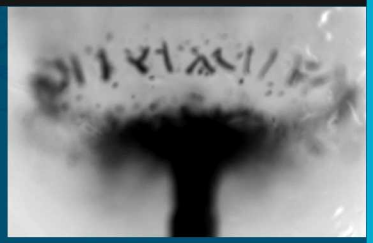
SAND2018-6382C

3D particle location from perspective-shifted plenoptic images





PRESENTED BY

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Motivation

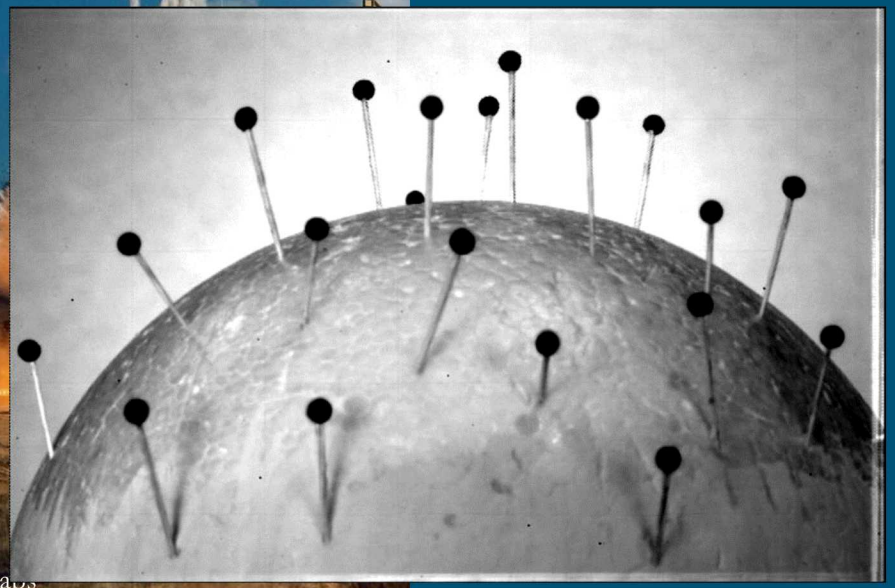


Photo courtesy of Sandia National Labs

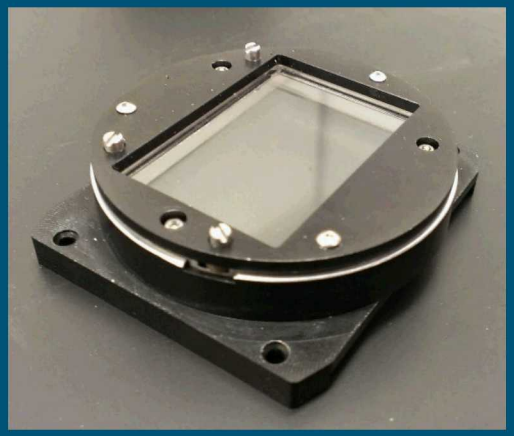
Particle tracking for a variety of highly 3D applications

- Fluid flow analysis
- Explosion mitigation
- Measurement of fragment size, shape, velocity

Measure and improve particle location capability

- Quantify/reduce uncertainty
- Reduce computational requirements

Plenoptic Imaging



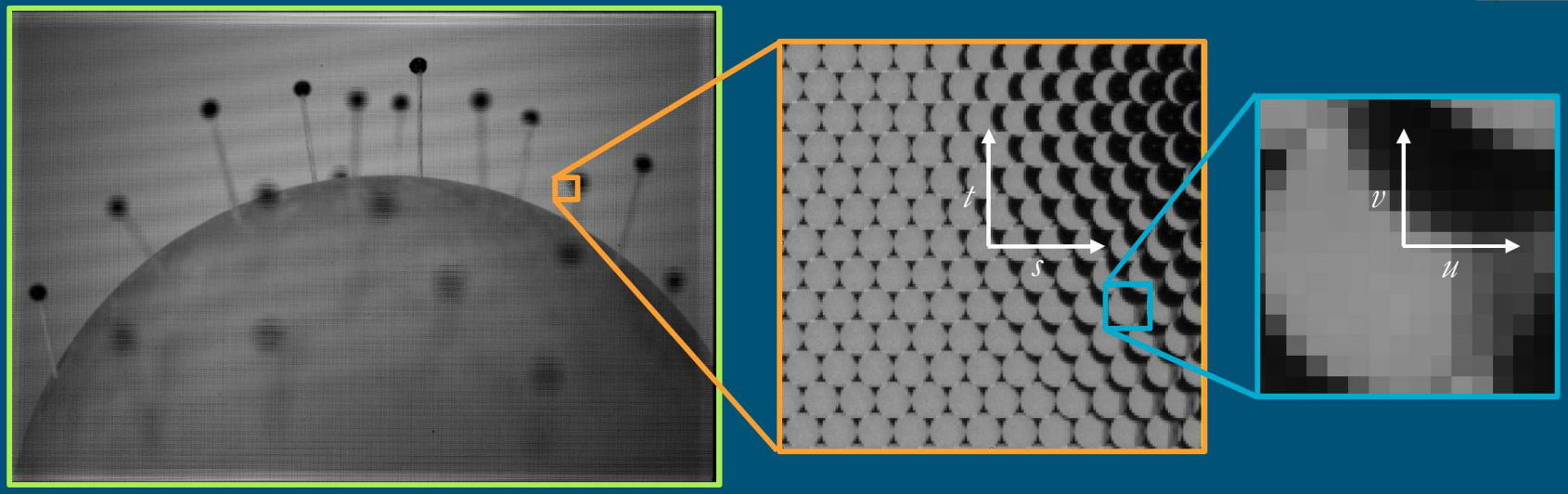
Camera modified by the insertion of a ***microlens array*** between the main lens and image sensor

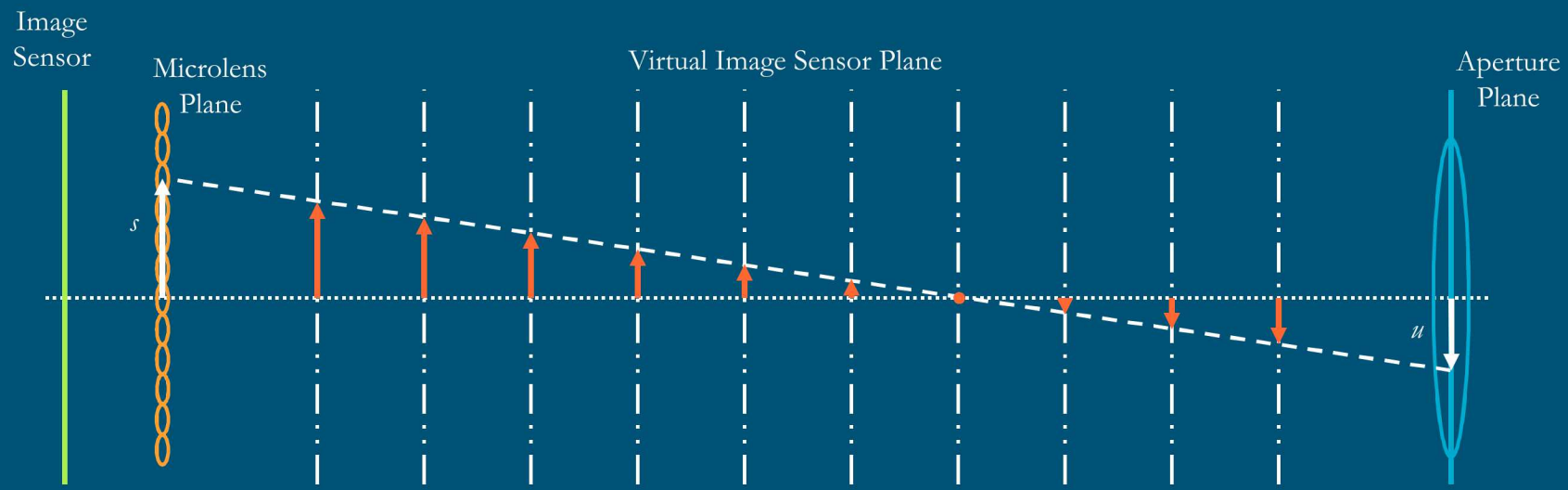
Captures ***spatial and angular*** information which can be processed to extract 3D information

Refocus and change perspective from a ***single snapshot in post processing***

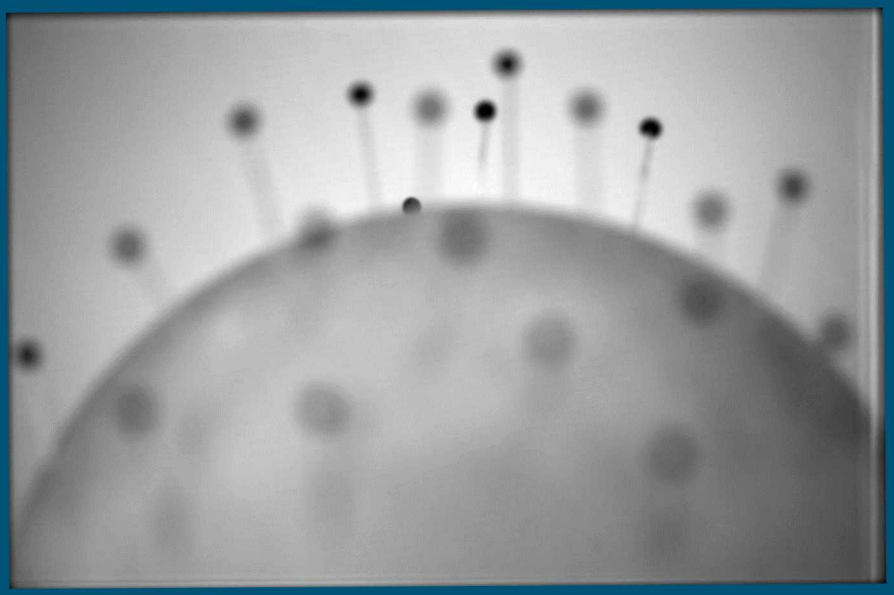
Single compact camera allows for experimental simplification and flexibility

Plenoptic imaging

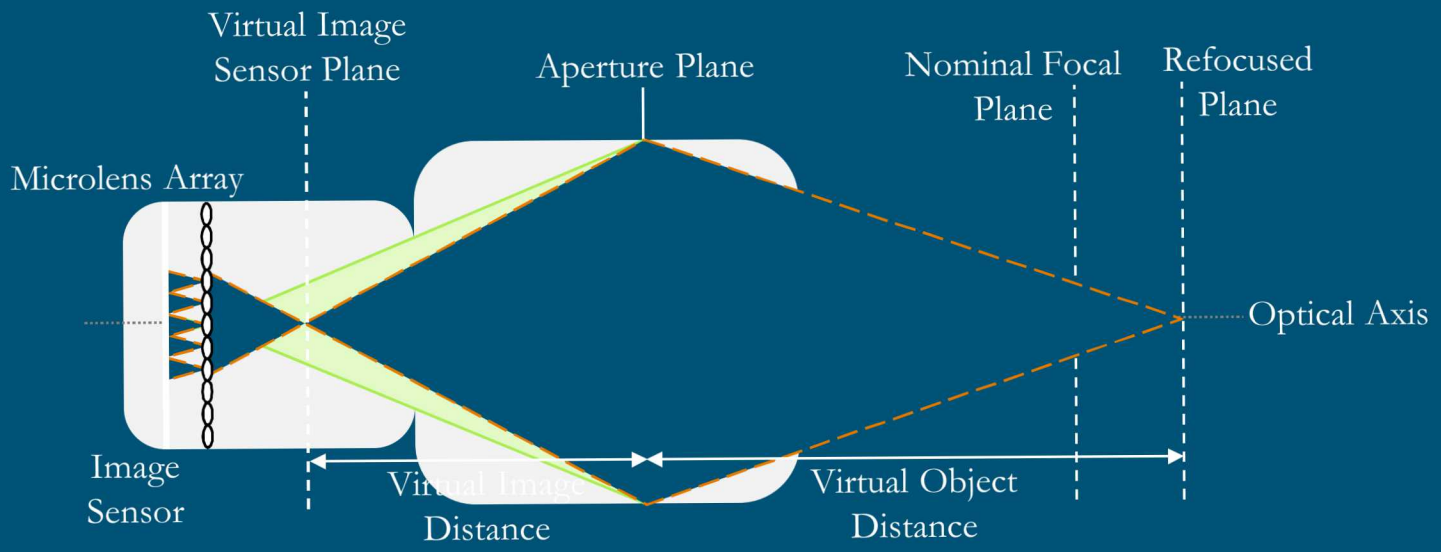




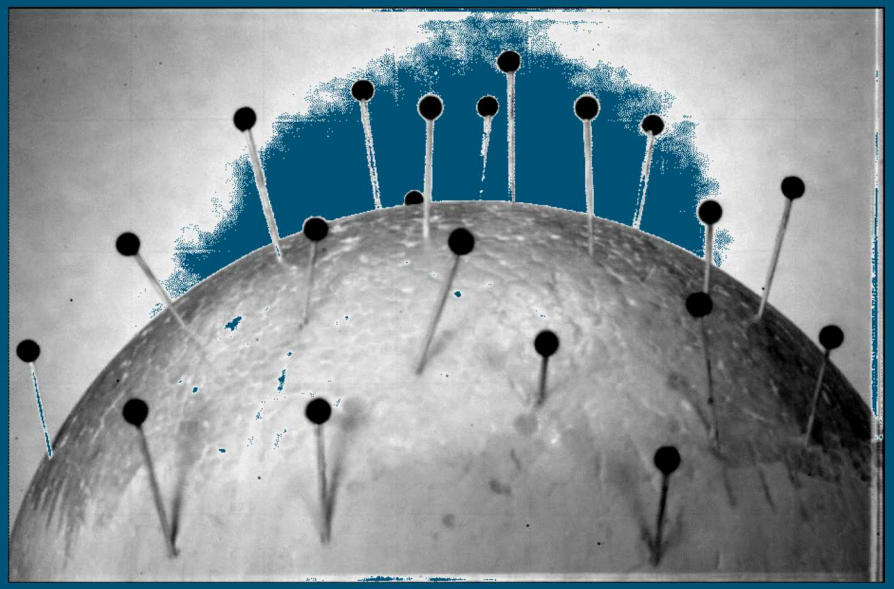
Refocusing



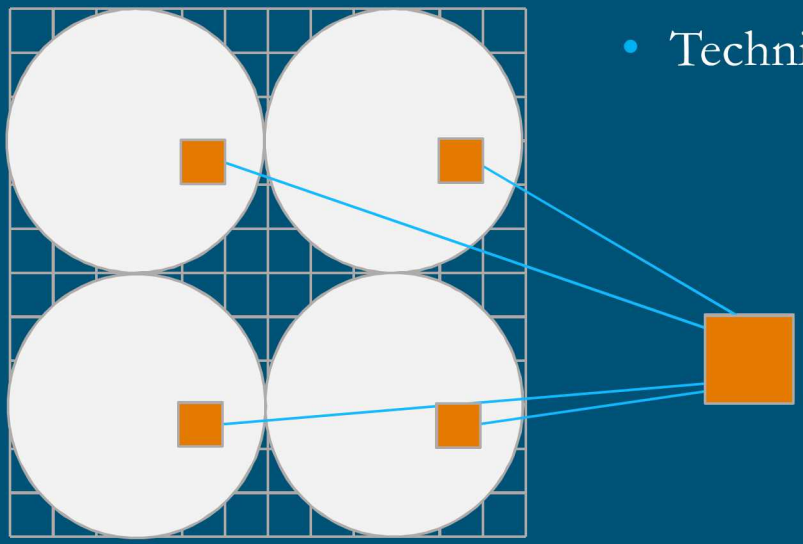
- Allows a change in the depth of the focal plane
- Resulting images are focused over a range of depths
- Object depth determined based on focus
- Integration = computationally expensive



Perspective



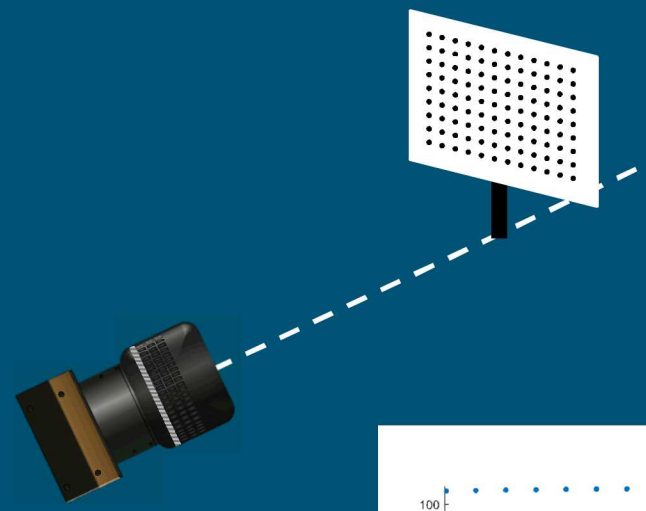
- Allows a change in perspective within the range of the aperture
- Resulting image as if from a small portion of the aperture
- Object depth can be determined based on apparent motion
- Selection of single pixels = computationally *inexpensive*
- Technique of choice in this work

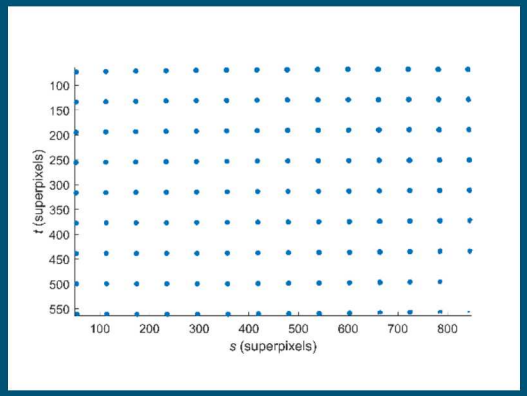


Perspective-shift algorithm

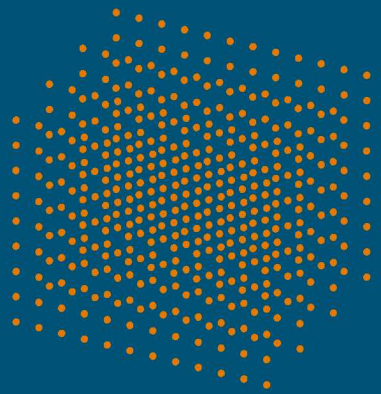
- Volumetric calibration
- Perspective view particle location
- 3D particle location

Volumetric calibration





- Collect images of dot cards over depth range of interest
- Measure dot positions in perspective views for each image
- Define known dot card positions in object space (*X*,*Y*,*Z*)
- Create polynomial mapping between image sensor coordinates (*u*,*v*,*s*,*t*) and object space



$$E(s,t) = L(u_0, v_0, P_s(X,Y,Z,u,v), P_t(X,Y,Z,u,v))$$

Perspective view particle location

generate perspective views

identify particle locations in all views

execute clustering for each k value

select minimized solution

select minimum for current k

repeat for 50 sets of seed points

determine if there are any double identified particle images

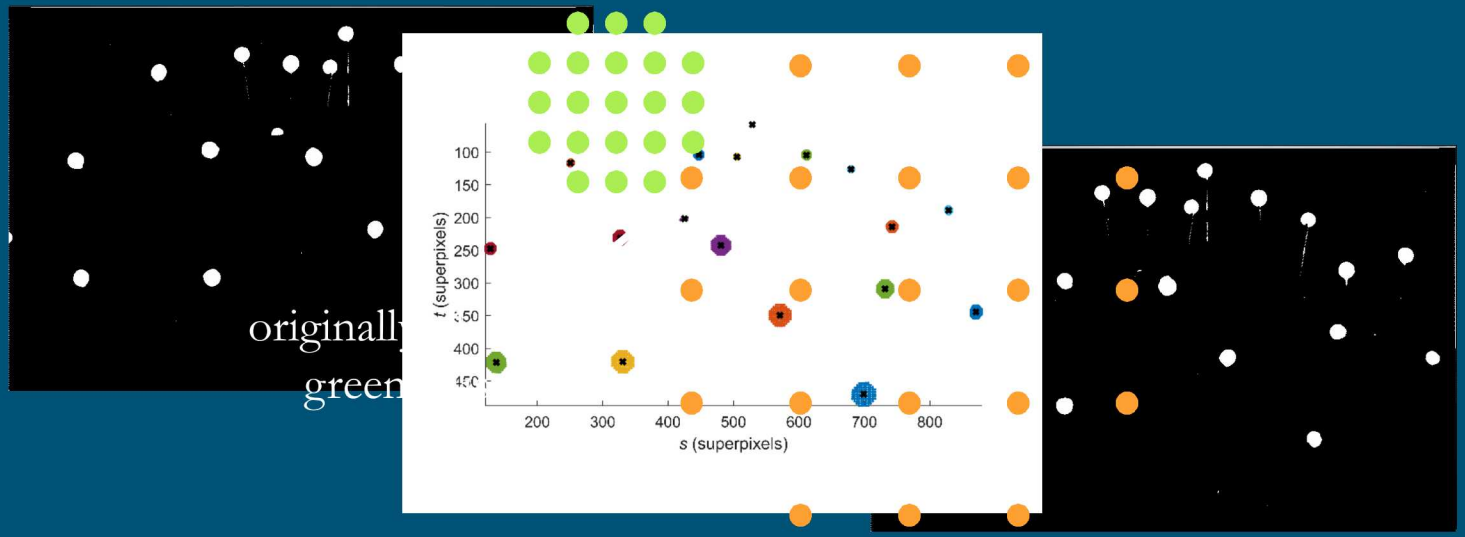
yes

select correct particle image

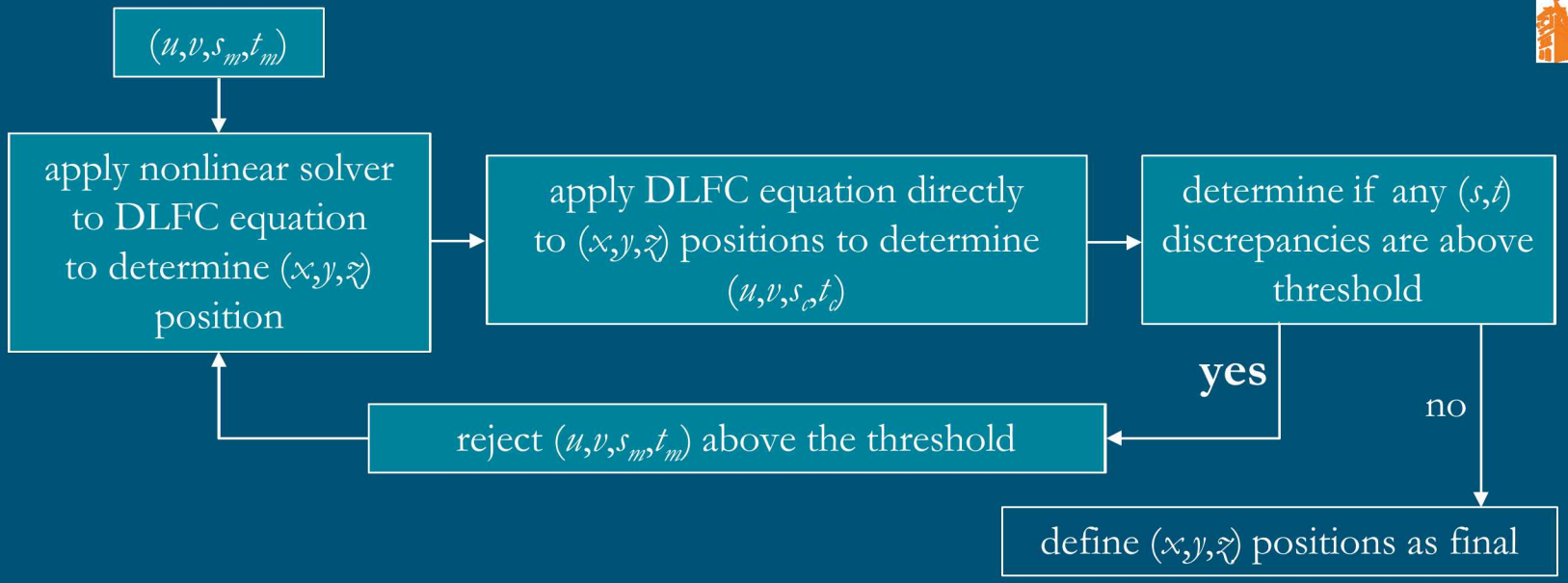
reassign incorrect particle image(s)

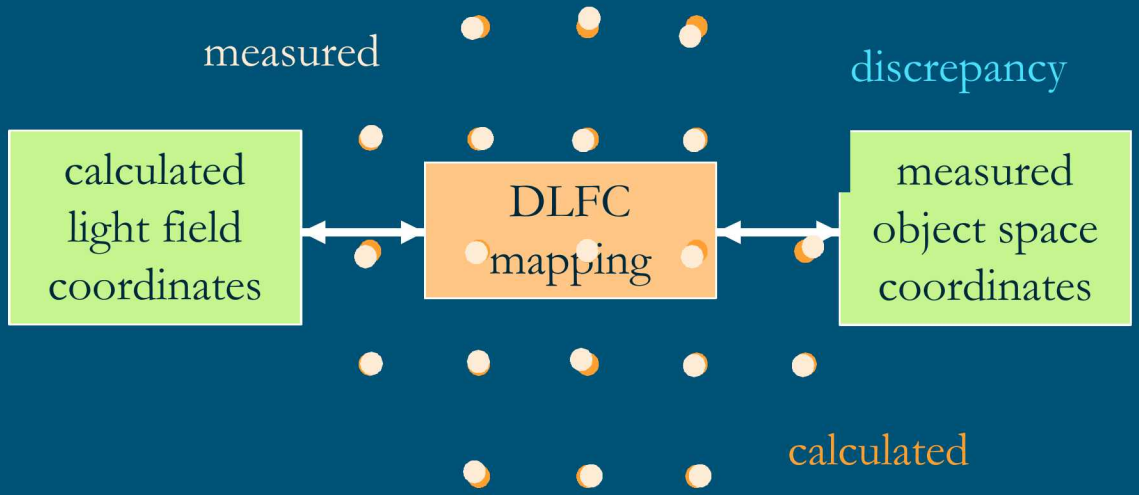
no

define (u,v,s_m,t_m) positions as final

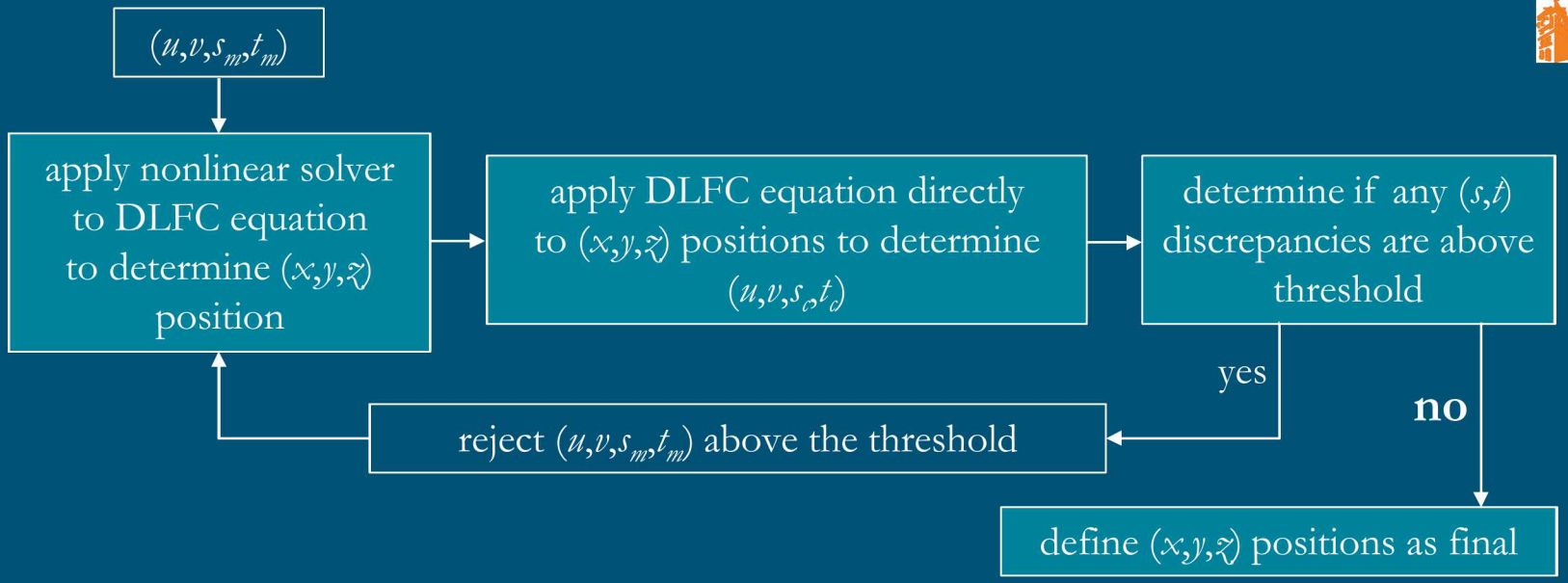


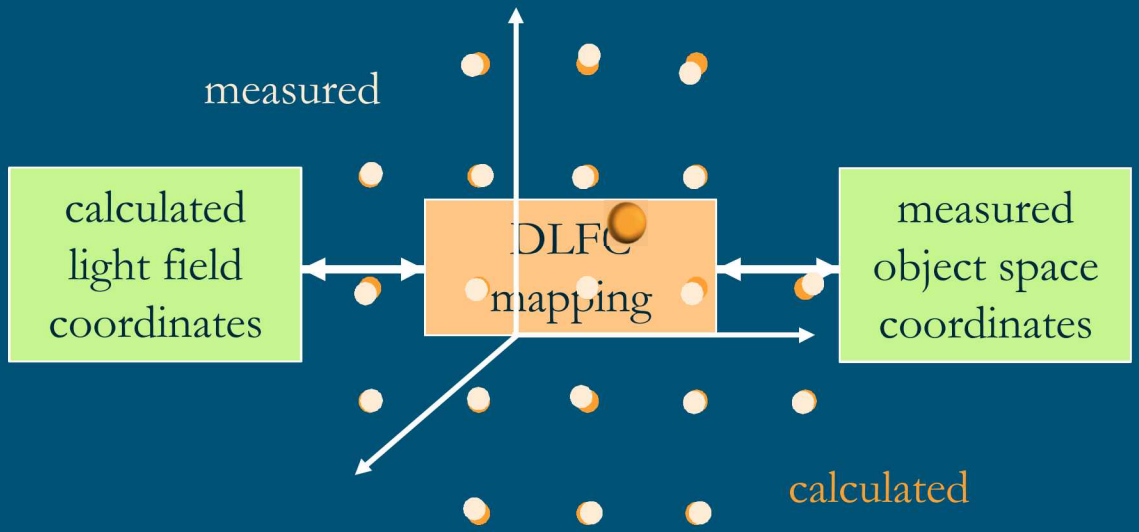
3D particle location





3D particle location

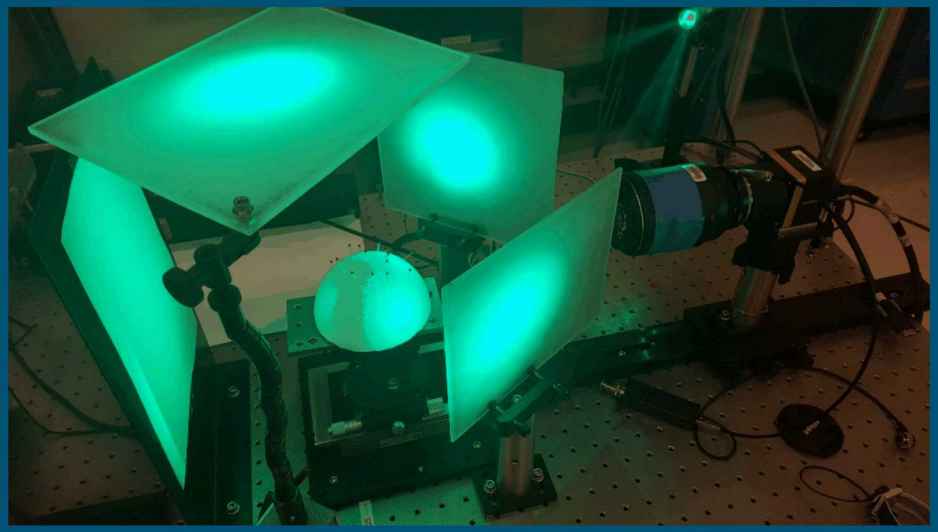


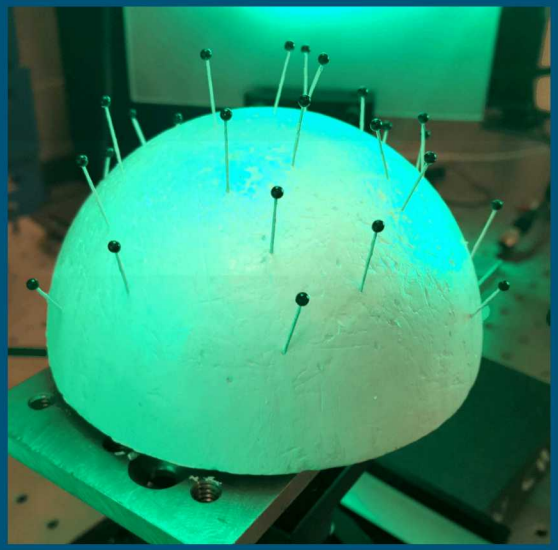


Experimental assessment

- Experimental configuration
- Error definition
- Accuracy and precision
- Computational expense

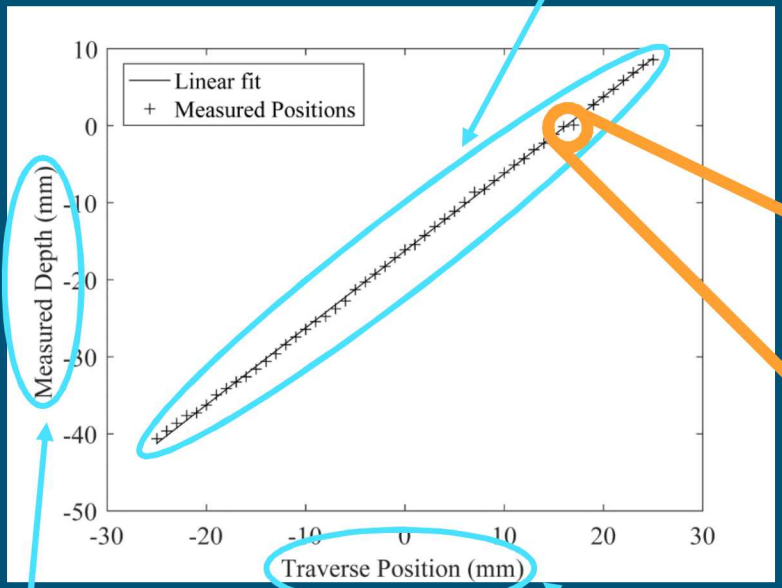
Experimental configuration

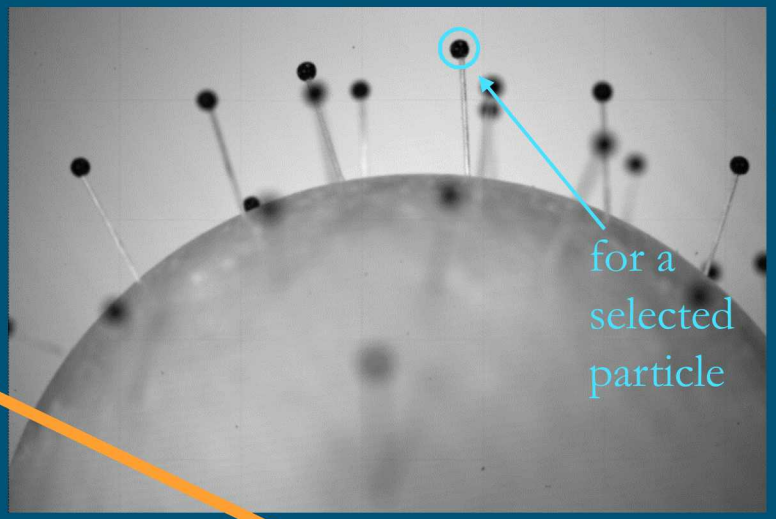




- Simulated static particle field
- Translated to provide known displacement
- Varied nominal magnification
- Large data set allows statistically significant quantitative measurements
- Same data set used in previous depth from focus study

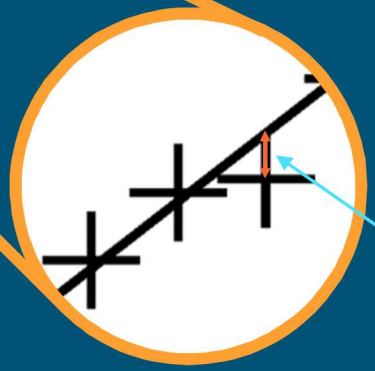
Uncertainty analysis





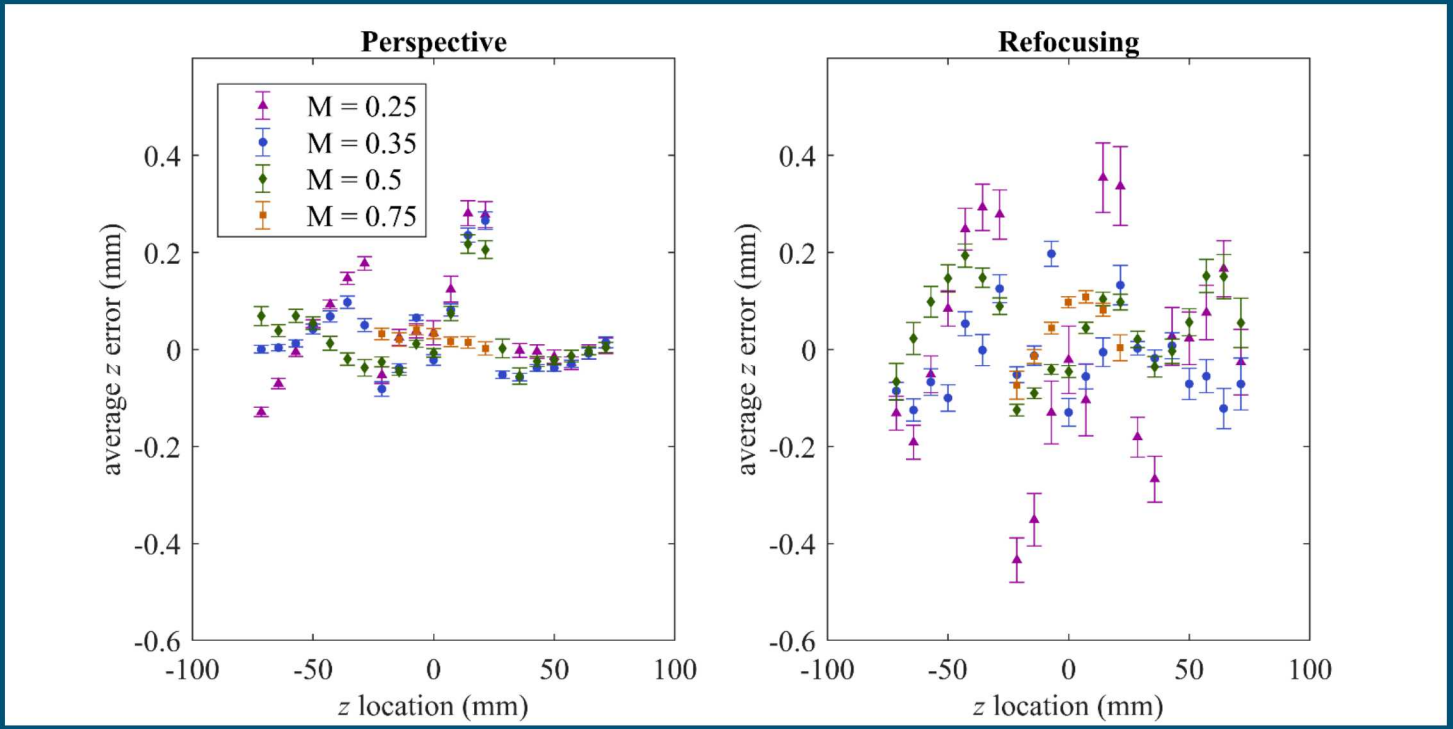
plot all the measured locations of the selected particle

as a function of the corresponding traverse position



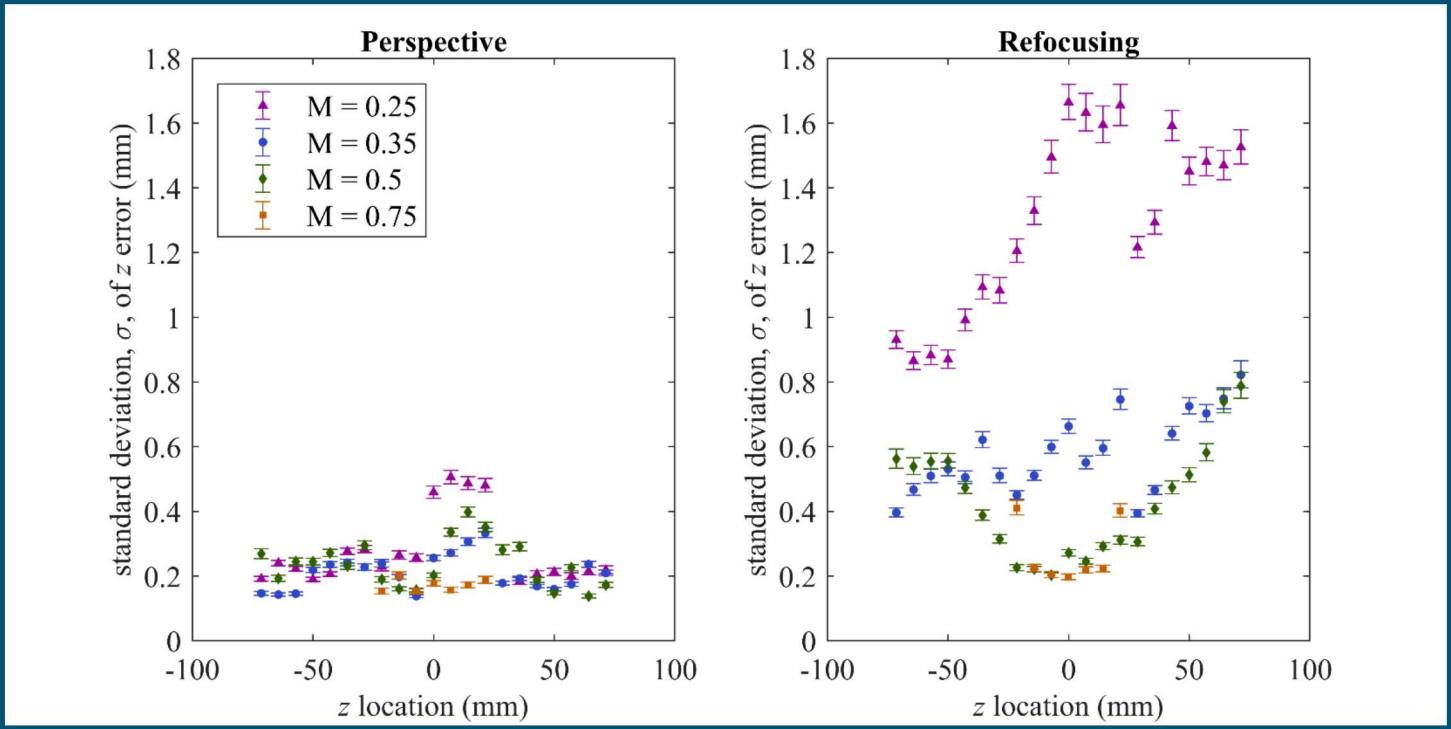
- Average depth displacement error = accuracy
- Standard deviation of depth displacement error = precision

Depth displacement accuracy



- Smaller average errors with perspective shift
- Narrower confidence intervals

Depth displacement precision



- Smaller standard deviations and narrow confidence intervals with perspective shift
- Perspective shift results more consistent with depth

Computational efficiency

For a single image, from raw image to 3D particle positions:

by refocusing…

pre-processing (1 minute)

creation of focal stack and particle identification (1 hour)

by perspective-shifting…

pre-processing (1 minute)

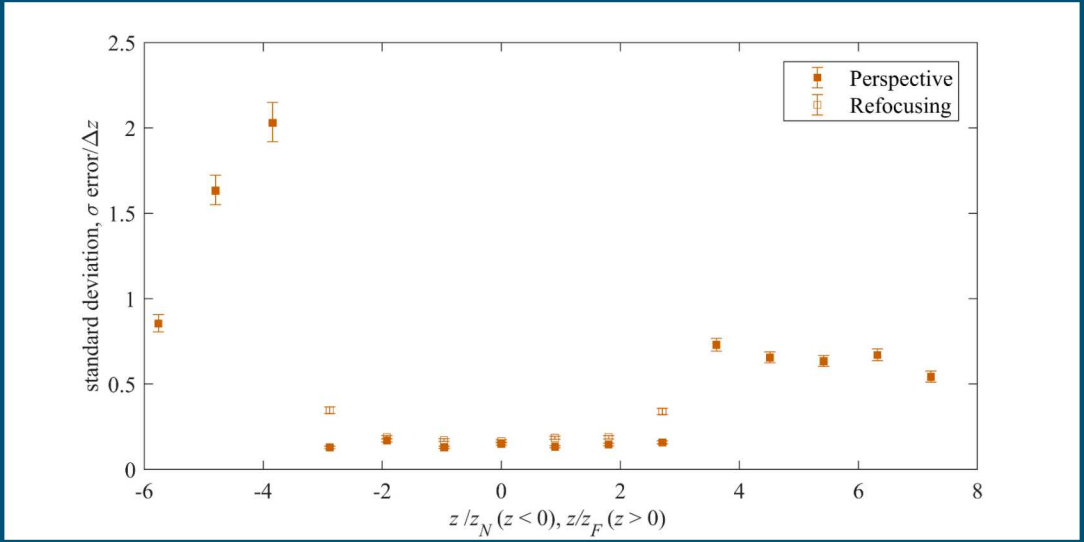
creation of perspective views and particle identification (10 seconds)

Conclusions

- Perspective-shifted images show ***improved accuracy and precision*** as well as dramatically ***reduced computational time*** over refocusing based methods
- Preliminary results indicate increasing particle density will increase the probability of mismatching particle images between views
- Future work includes:
  - Exploration of alternative matching schemes
  - Use of hybrid refocusing and perspective shift method for depth determination
  - Adaptations to allow/exploit particles with varied size and shape

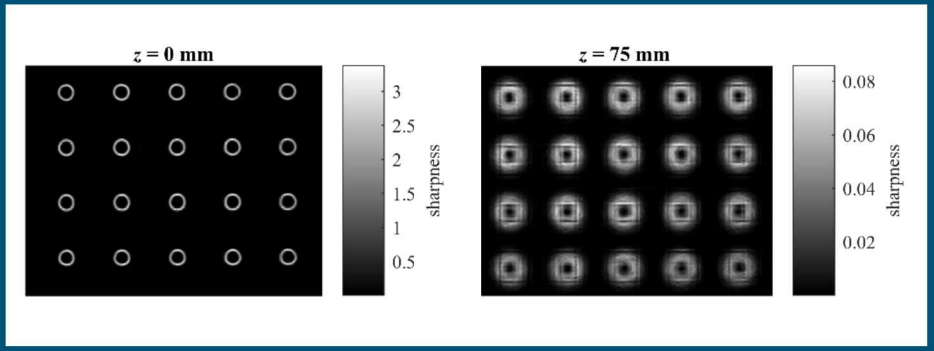

QUESTIONS?

Depth range

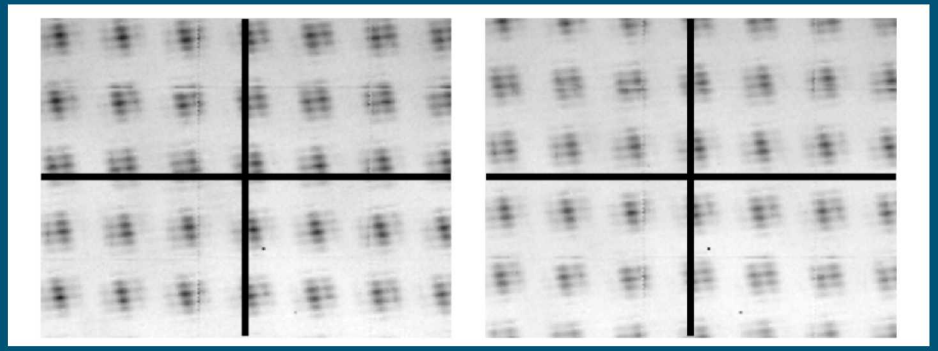


- Perspective shift allows particle location at greater depths
- Result of location metrics: sharpness vs. location

Sharpness maps from refocusing at center and extreme depths



Perspective views at extreme depth



Depth displacement precision: normalized by theoretical depth resolution