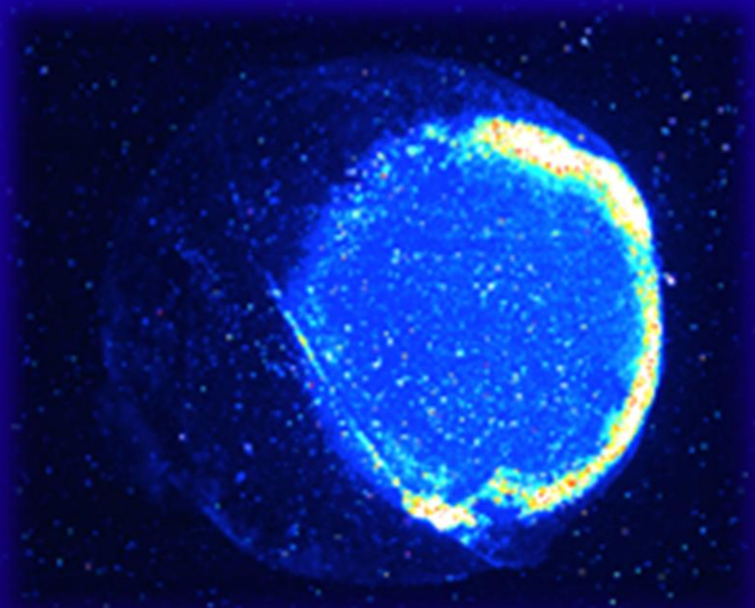
Rotation dynamics of ideal non-spherical particles and extension to field measurements



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ENGINEERING LABORATORY FOR FLUID MOTION IN THE ENVIRONMENT

Outline

Part 1
Measuring angular velocity of model particles in the lab

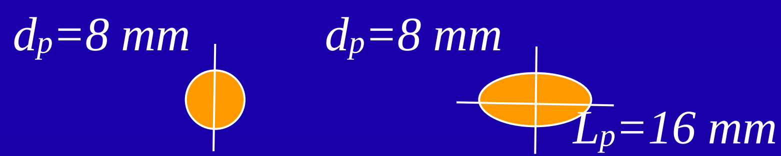
Part 2
Measuring trajectories of real particles in the field

Part1: rotation measurements
-Objective-

-Simultaneously measure fluid velocity and rotation of rates of particles of various shapes (spherical and non-spherical) to test in H.I. turbulence tank.

Particles must be refractively matched to water, yet neutrally buoyant

Refractive index matched particles



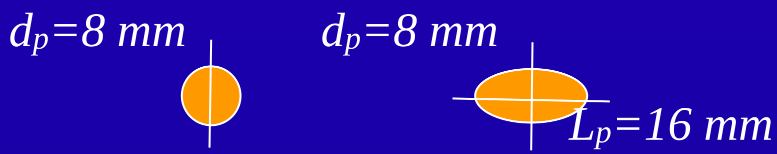
Material:

Agarose-water solution (99.5%)

Manufacturing:

Injection molding

Refractive index matched particles



Material:

Agarose-water solution (99.5%)

Manufacturing:

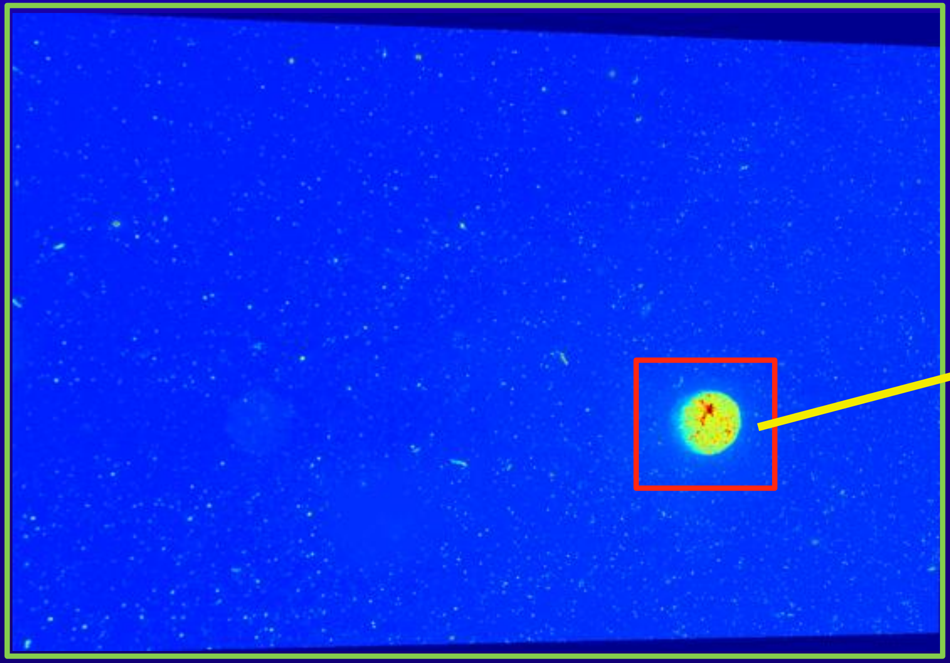
Injection molding

Properties:

$$\rho_p = 1.05 \text{ kg/m}^3$$

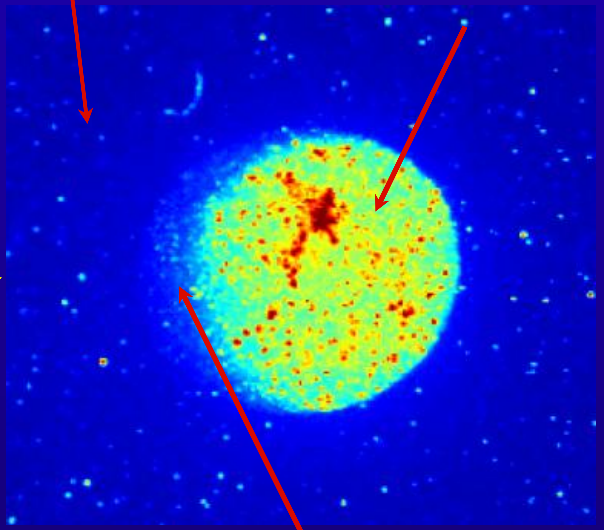
$$IoR = 1.337$$

Measurement technique



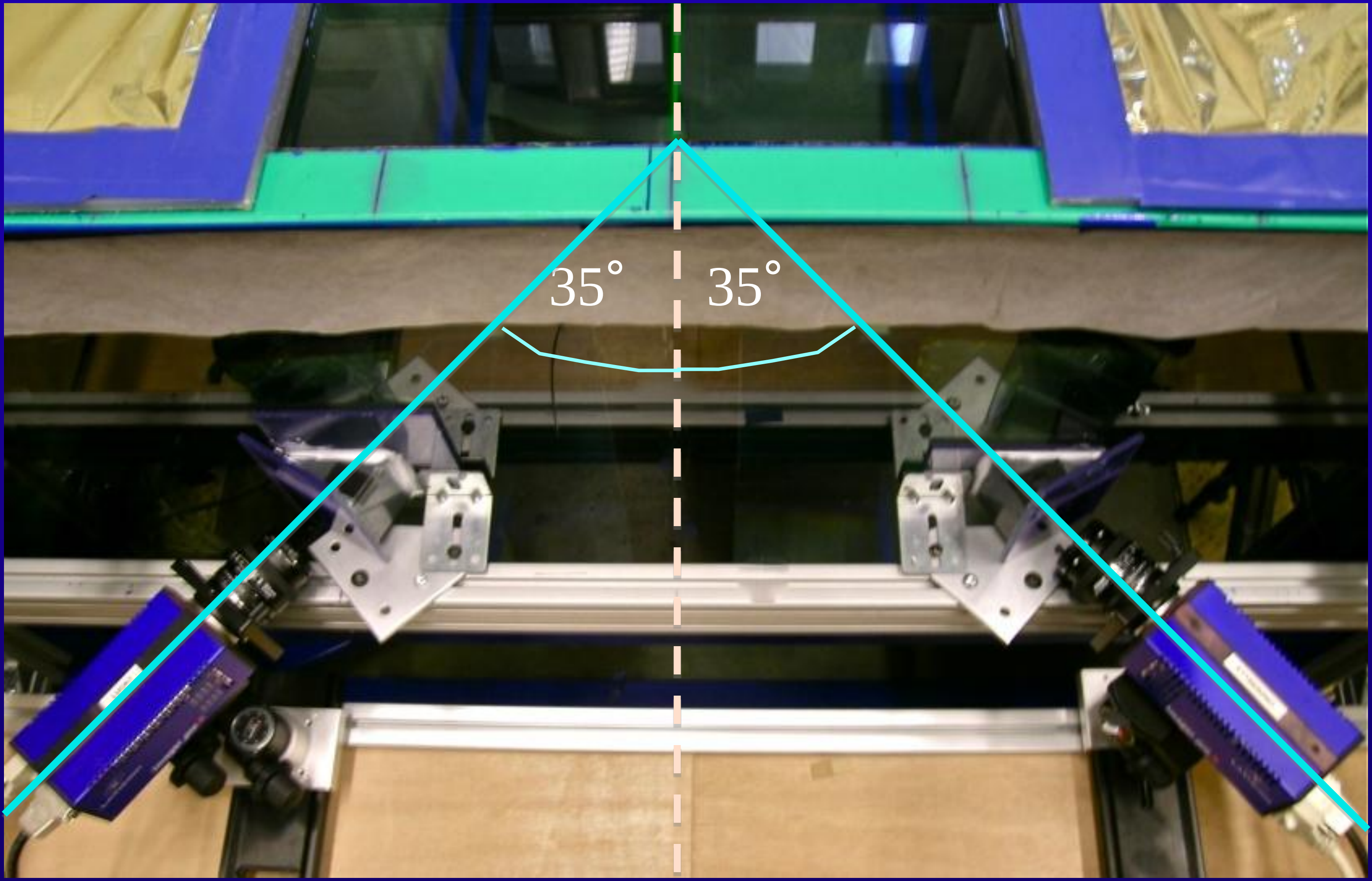
Fluid phase

In-plane particle slice

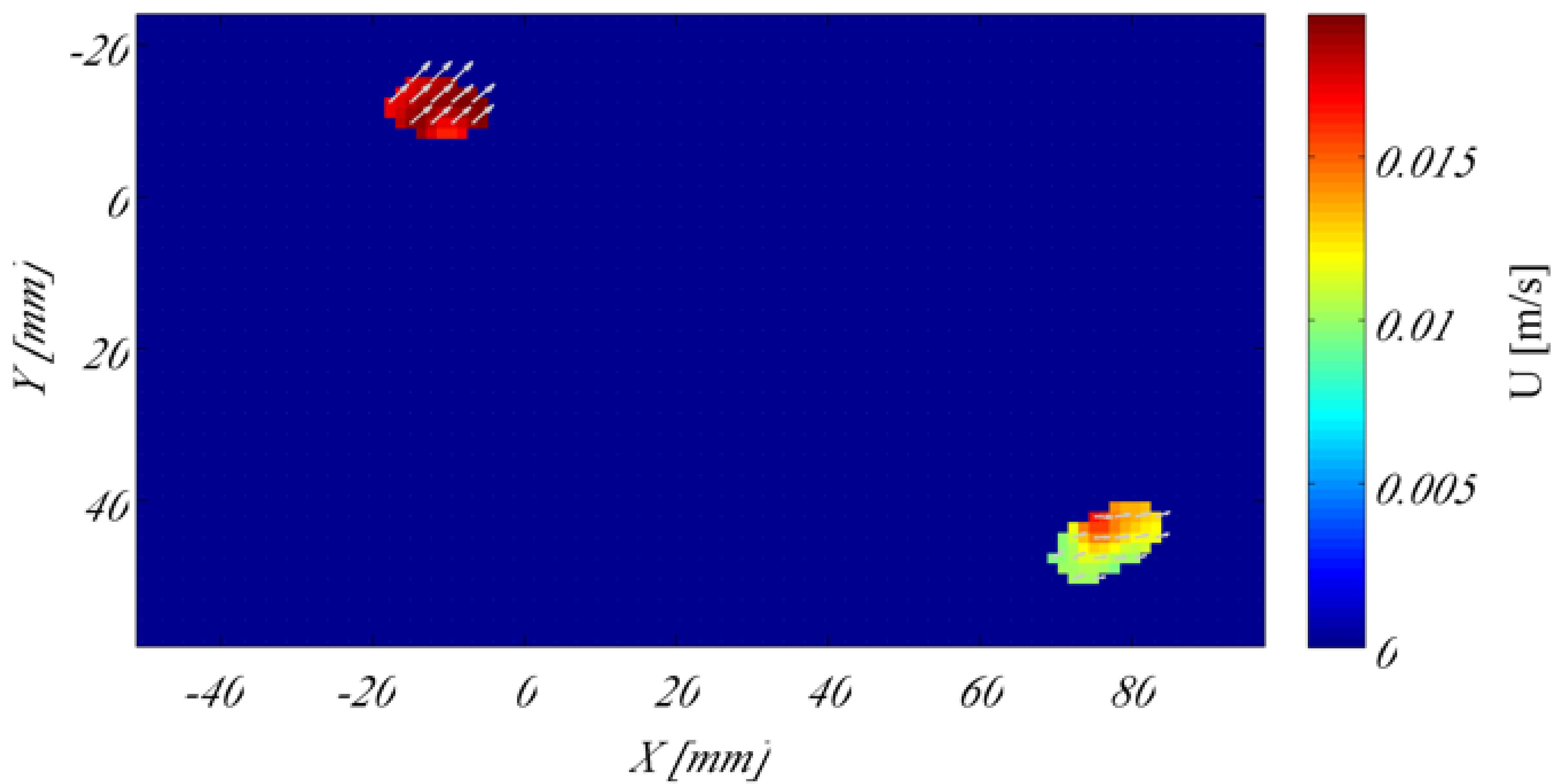


Out-of-plane particle slice

Stereo PIV

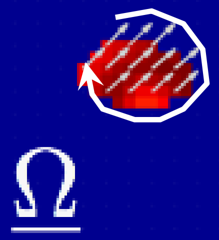


Example velocity field



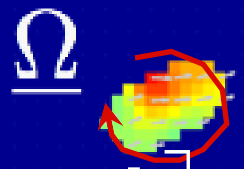
Rotation measurement

From S-PIV we get velocity measurements within the particles in one plane :



$$\underline{U}_m - \underline{U}_n = \underline{\Omega} \times (\underline{X}_m - \underline{X}_n)$$

PIV output ($\underline{U}_m$, $\underline{U}_n$) PIV input ($\underline{X}_m$, $\underline{X}_n$)



Equation underdetermined for Ω_x and Ω_y, so we need one more point

Rotation measurement

$$\underline{U}_m - \underline{U}_n =] \times (\underline{X}_m - \underline{X}_n)$$

$$\underline{U}_m - \underline{U}_p =] \times (\underline{X}_m - \underline{X}_p)$$

3 measured vectors within the particle give:

- 1 measurement of $]_x$
- 1 measurement of $]_y$
- 4 measurements of $]_z$

Preliminary results in Stationary H.I.T.

$$\frac{\rho_p}{\rho_f} \approx 1.05$$

$$d_p/\eta \approx 80$$

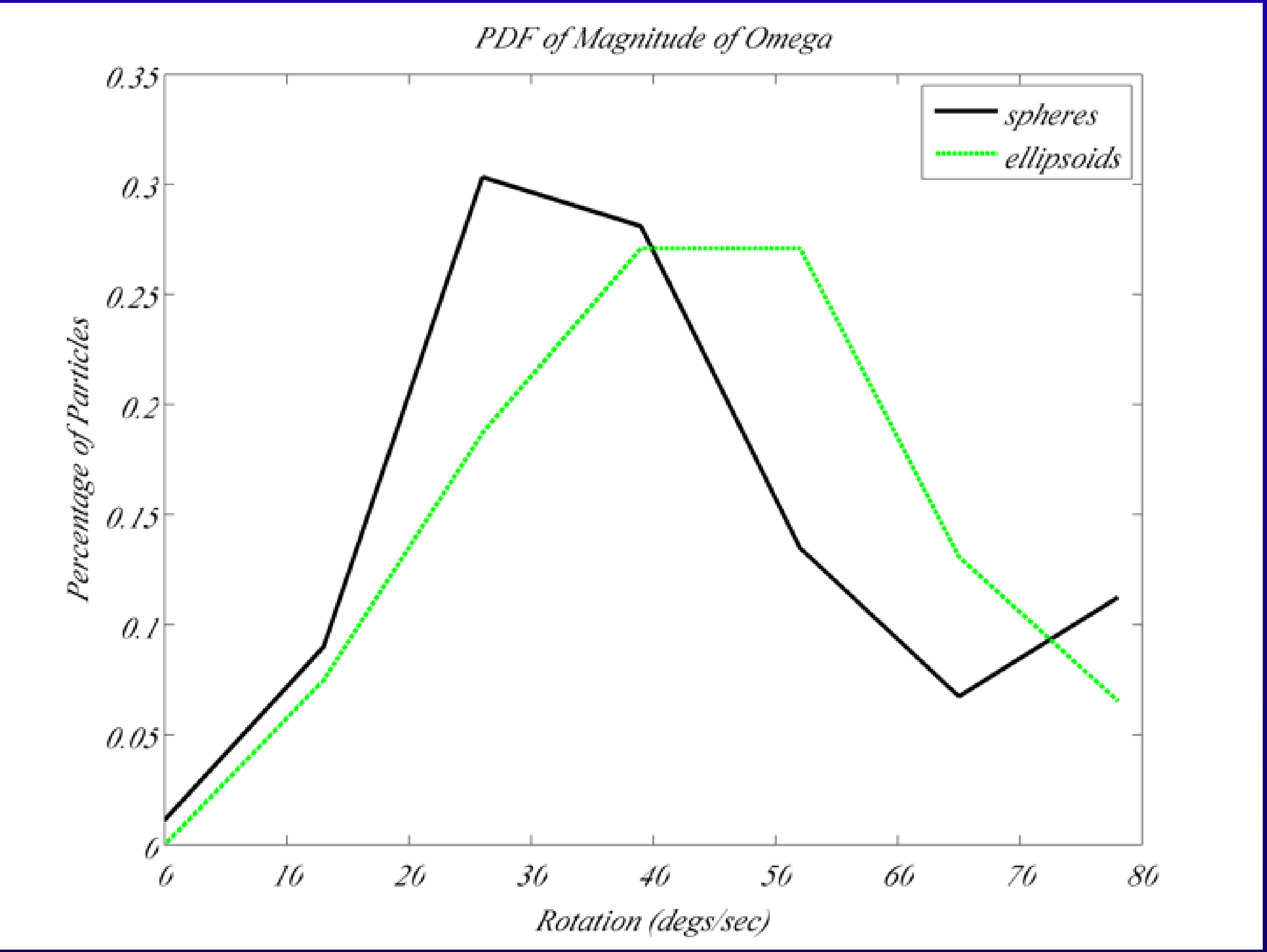
$$d_p/\Lambda \approx 0.2$$

$$St \gg 1$$

$$\Phi_v \approx 0.1$$

Preliminary results in H.I.T.

PDF of $|\underline{\Omega}|$



Part 2: measuring trajectories of real particles in the field

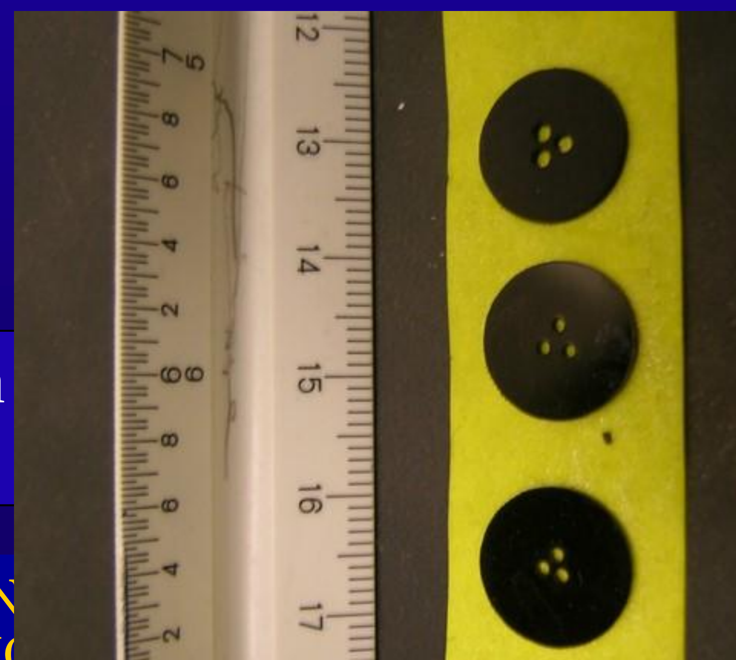
VoPI =

Volumetric
Particle
Imager

Multi-iris camera

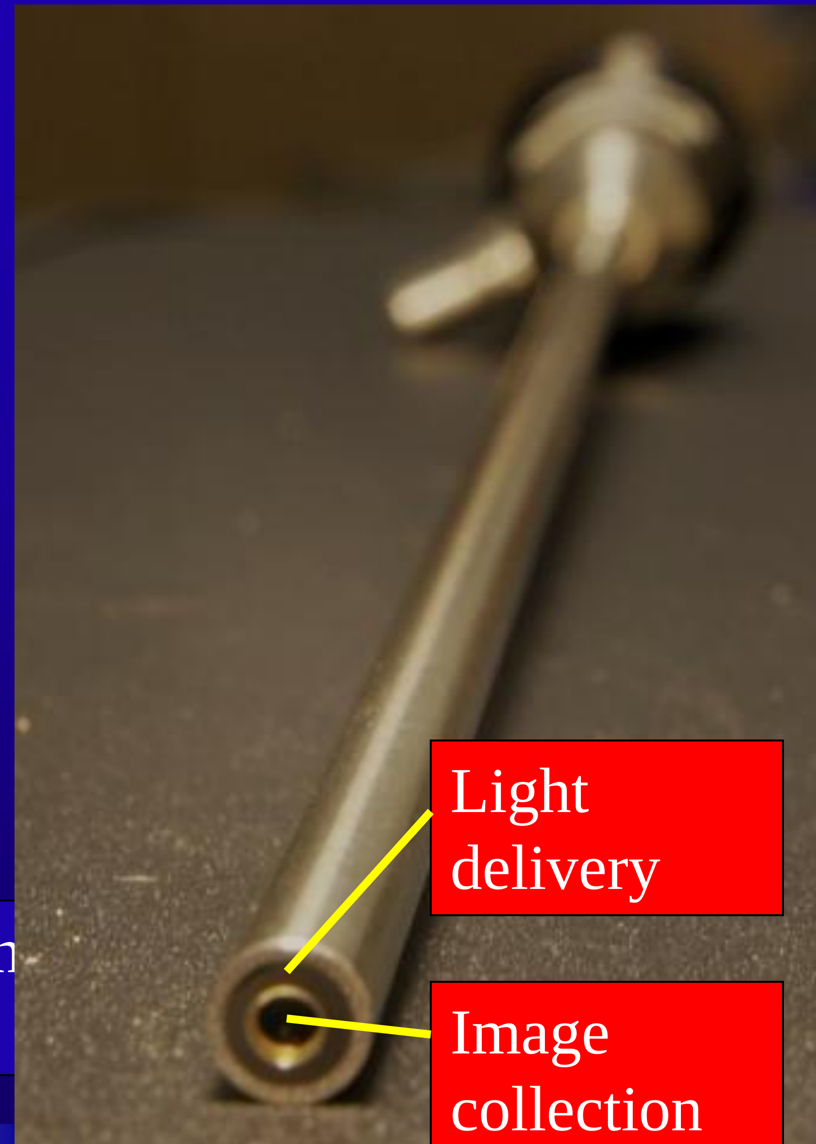
Borescope

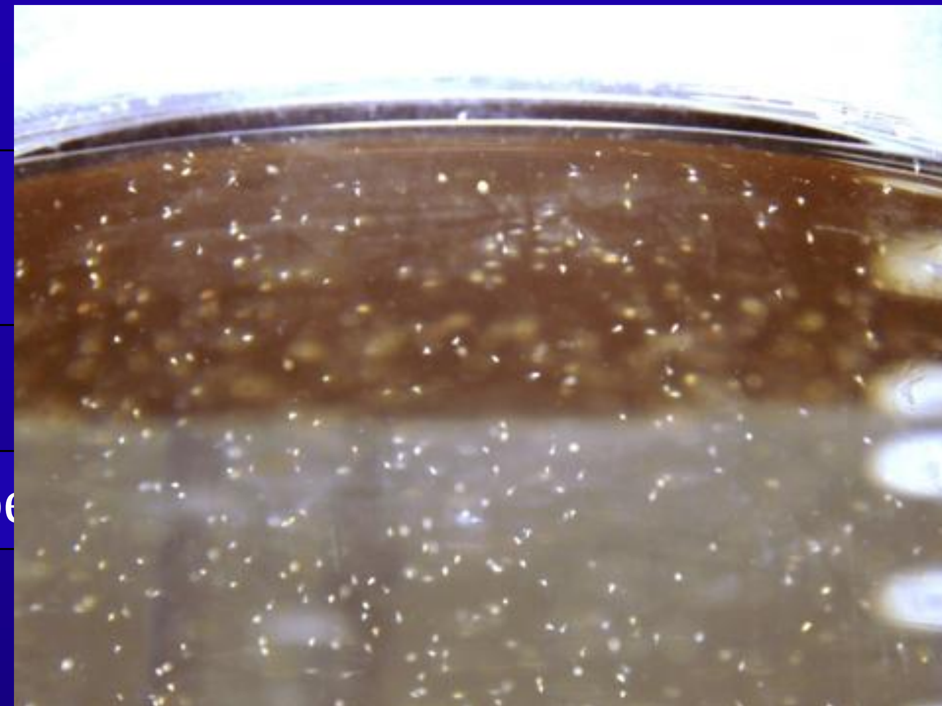
Plankton sample




Multi-iris camera
Borescope
Plankton sample

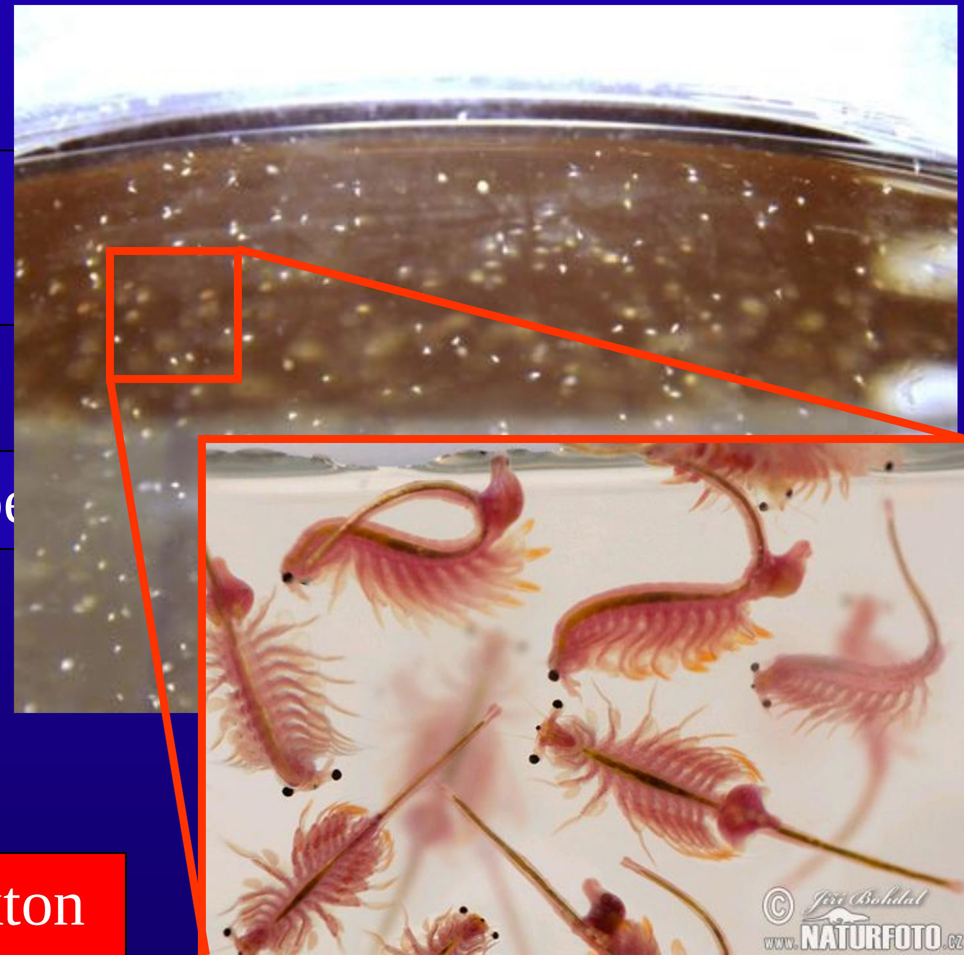

Multi-iris camera
Borescope
Plankton sample


Light delivery
Image collection



~20 mm

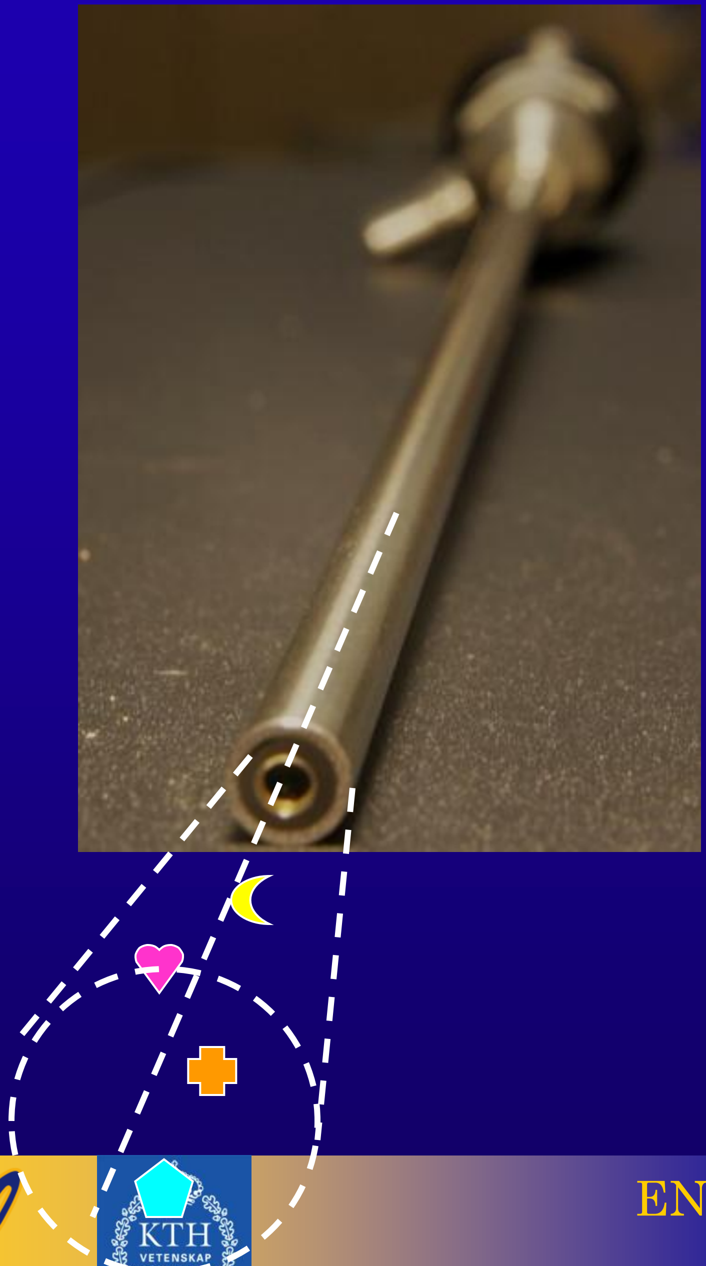
Artemia salina



~0.5 mm

Artemia salina

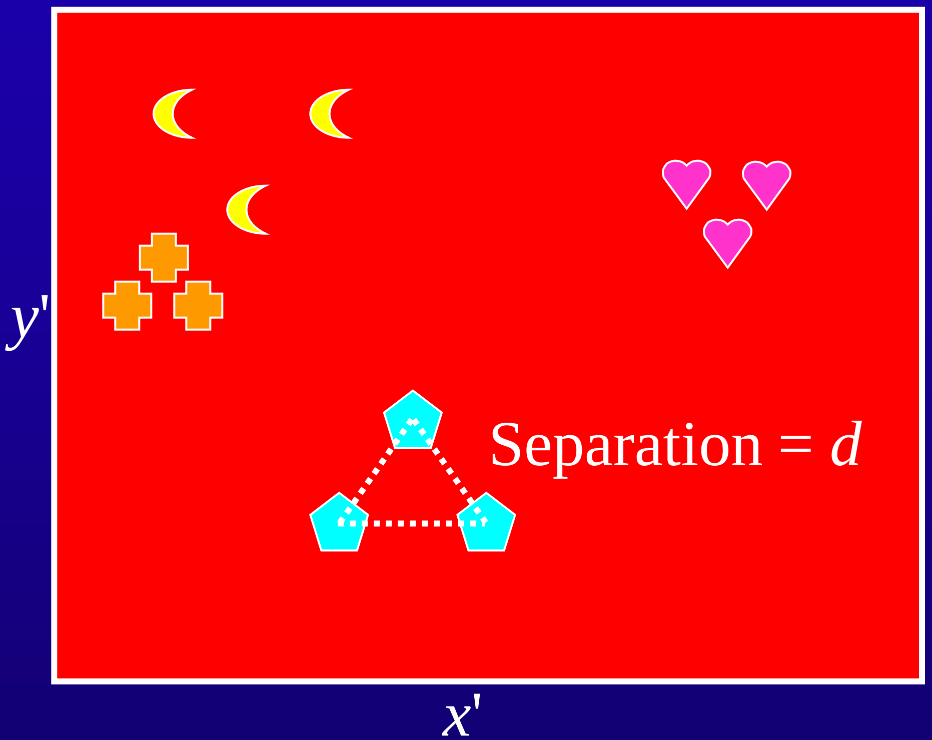
Photo by Jiri Bohdal

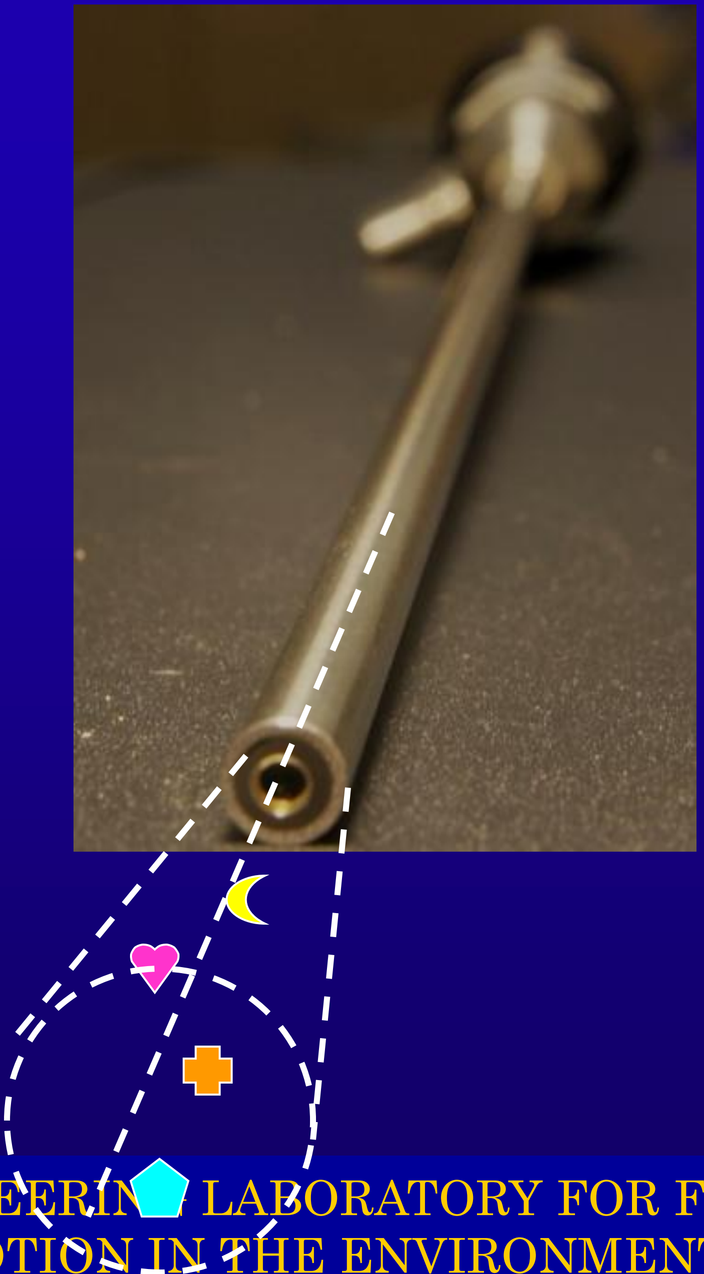


3D positioning is achieved using 2D image and multiple-iris camera

Inspired by C.E.Willert and M. Gharib, Exp. Fluids,1992

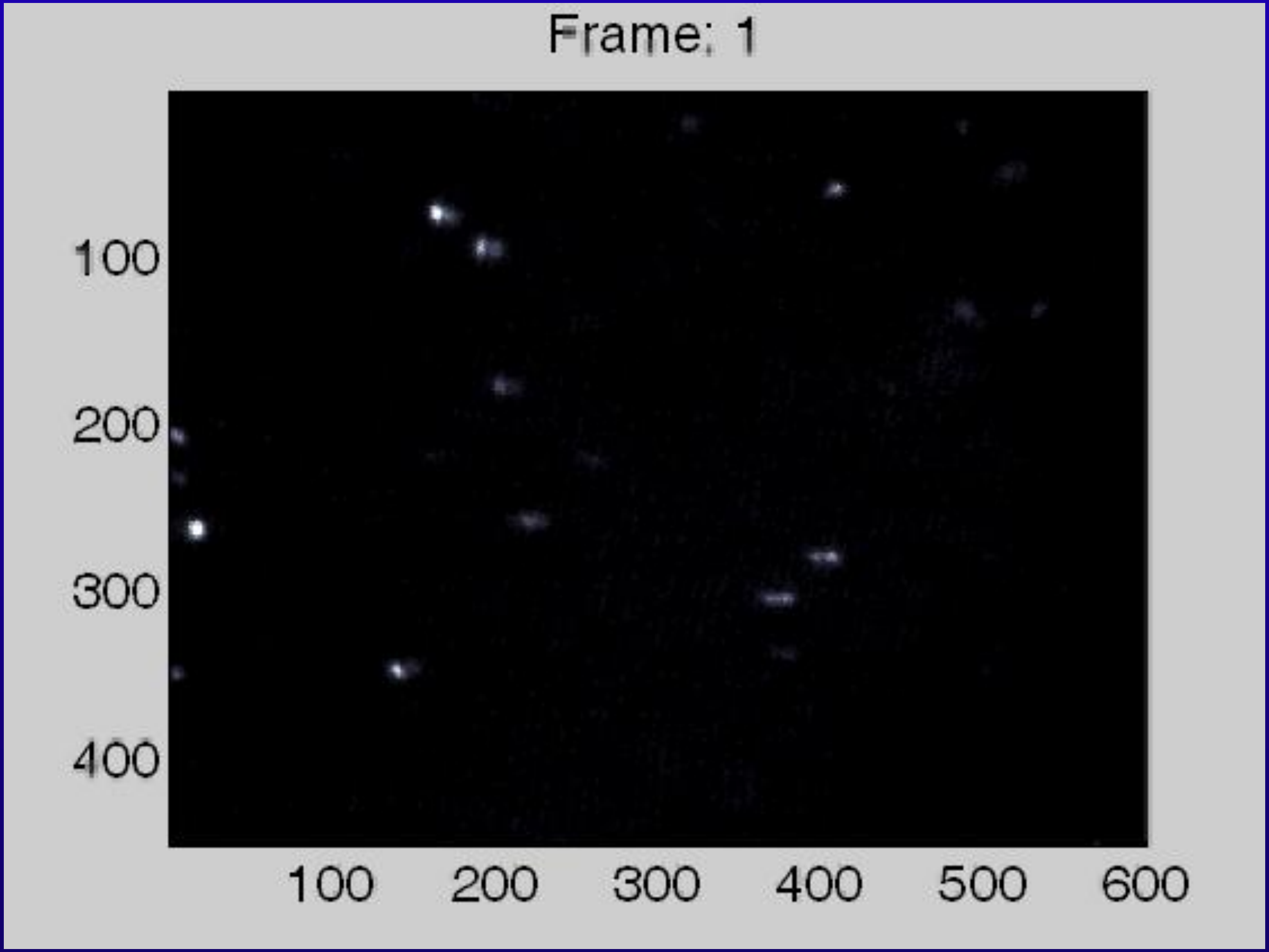
Particle locations are determined in 3D: $(x,y,z) = \mathrm{f}(x', y', d)$



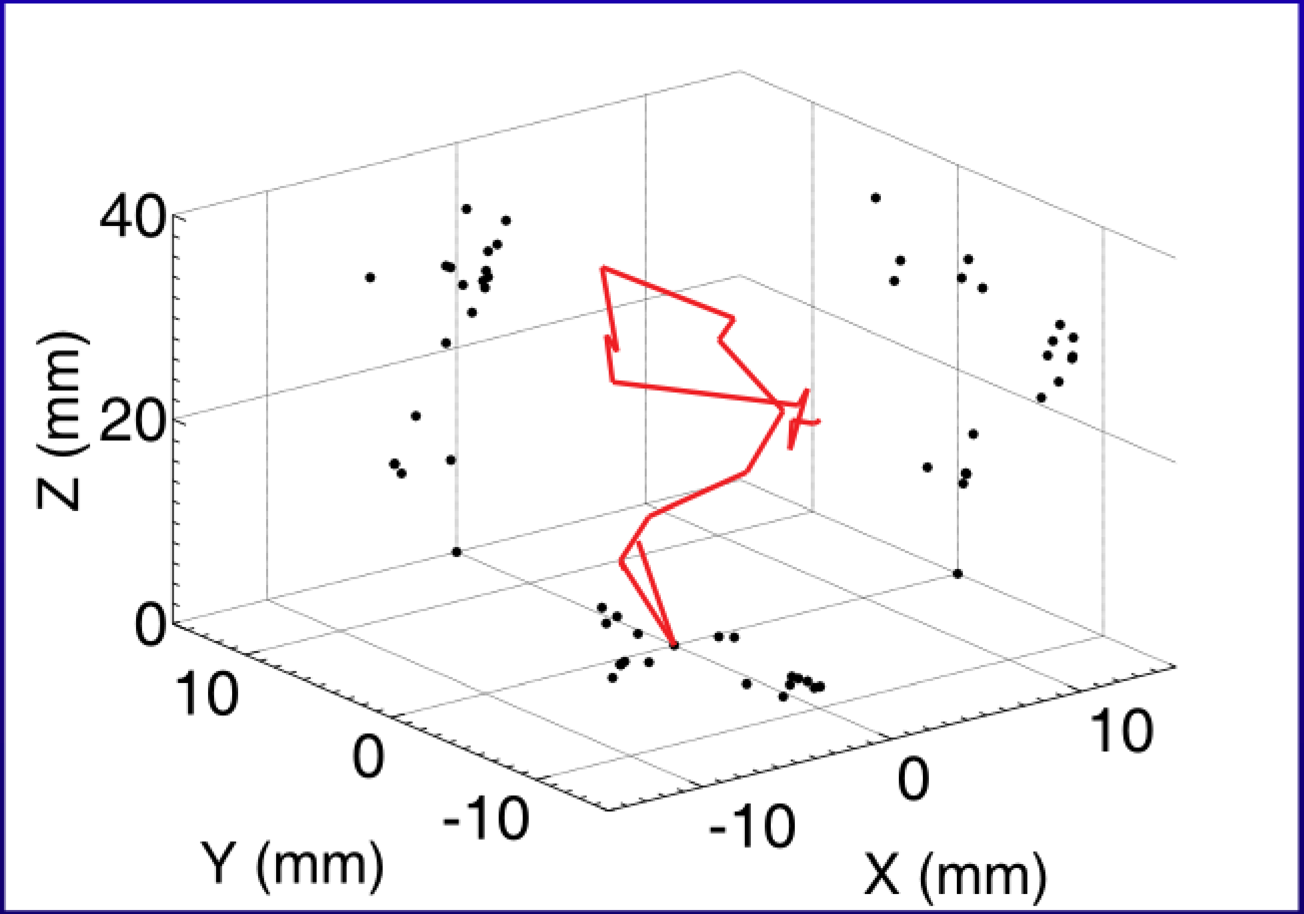


Calibration is a *fixed property* of the device!

Artemia eggs



Lagrangian tracking



Conclusions

A technique to measure large particle rotation and fluid velocity simultaneously has been developed

It can be applied to arbitrarily shaped particles

Preliminary results for particles in Stationary H.I.T. showed significant departure between spheres and ellipsoids

A borescope combined with a multi-iris camera is being developed for field experiments of multi-shape particles particles.

It allows lagrangian tracking that can be applied for nutrient and pollutant dispersion studies