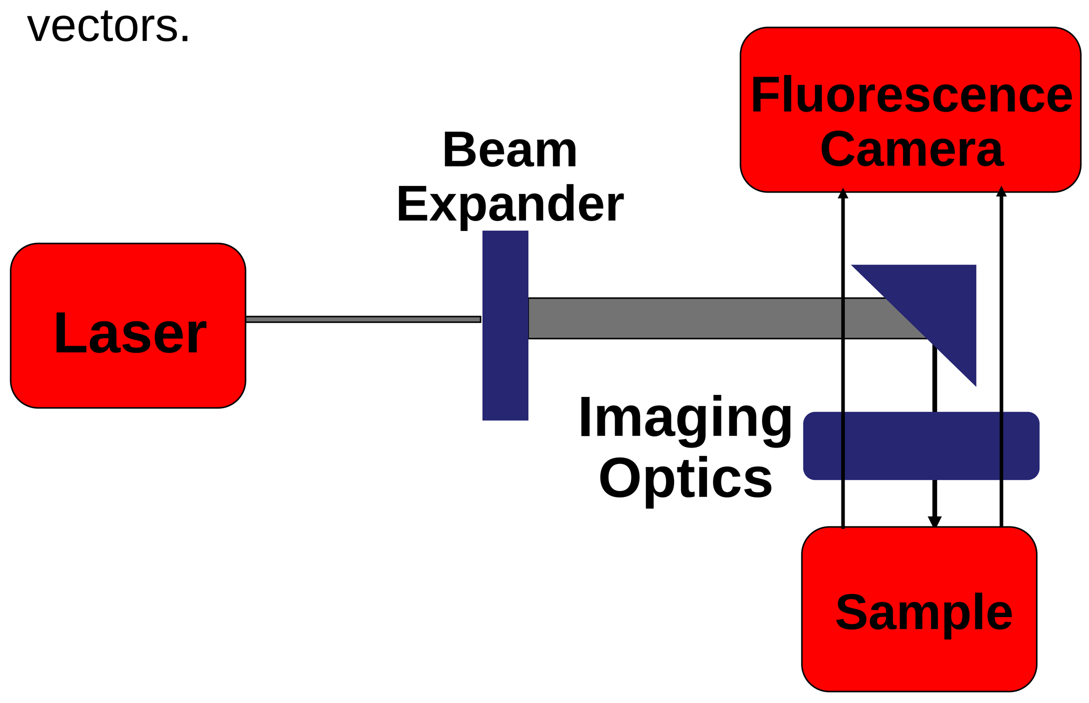
Accuracy of Flow-Vectors Obtained via microPIV

University of Glasgow

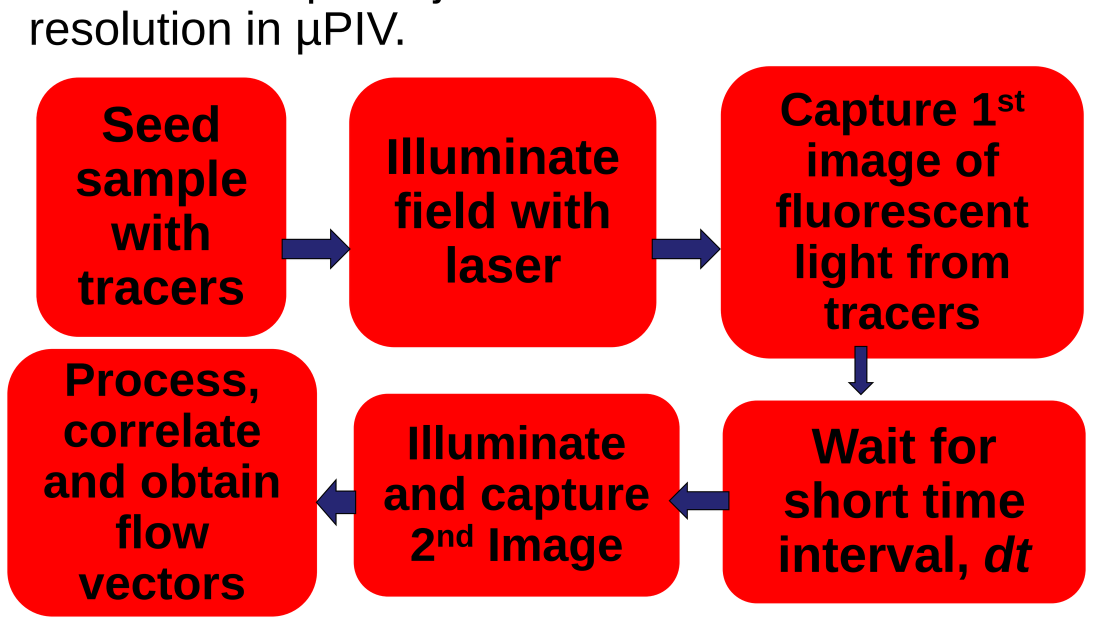
2141801O@student.gla.ac.uk

μPIV - Background

Micro Particle Velocimetry (μPIV) is an experimental technique for mapping microfluidic flows. It involves seeding the fluid with tracer particles and then capturing pairs of images via epifluorescent microscopy at short time intervals *dt*. Images are then cross correlated to obtain flow vectors.

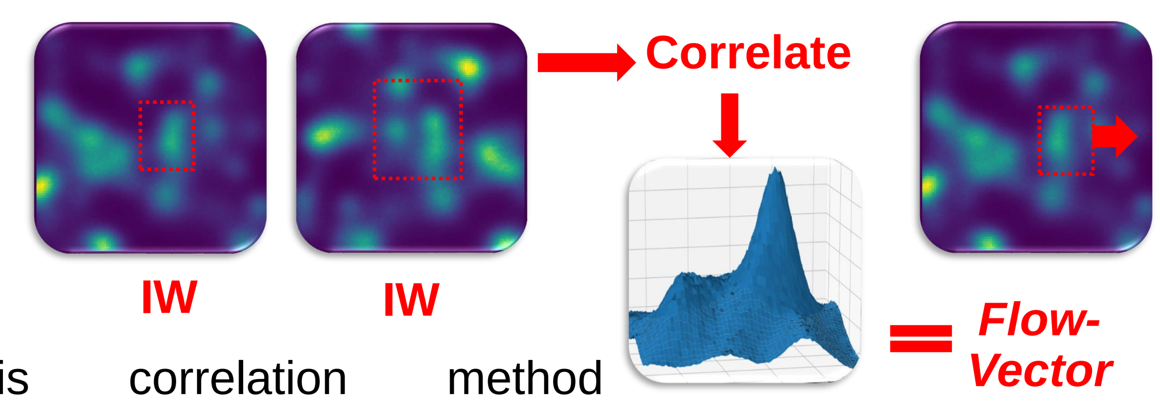


μPIV derives from macro scale PIV, where individual planes of the sample are illuminated via light sheet microscopy and then imaged. The light sheet thickness therefore defines the z-resolution. On the micro scale, illuminating individual planes is experimentally difficult and therefore the full volume is illuminated. The depth of correlation, related to (but not the same as) the focal depth of the microscope objective therefore defines the z resolution in μPIV.



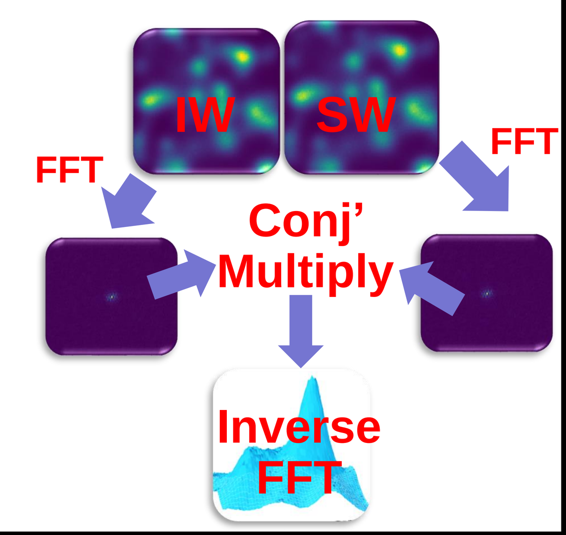
Flow Vector Calculation

Vectors are obtained via the technique of cross correlation. A small interrogation window (IW) from the first frame is 'slid' over a larger search window (SW) from the second frame. In each location, the pixel values are multiplied and summed. The peak of the cross correlation signifies the most probable shift of the first image onto the second.



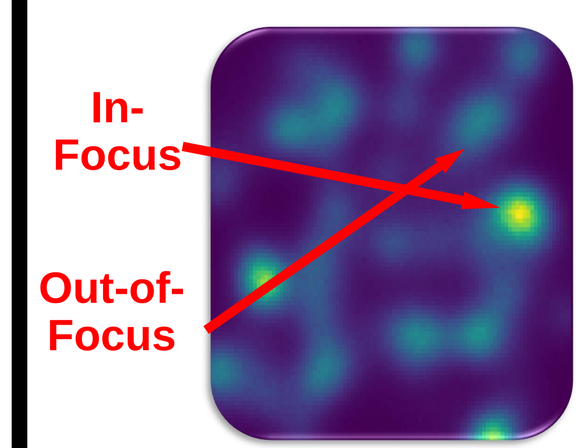
This correlation method involves vast numbers of calculations. It is more efficient to correlate in the spatial frequency domain.

Correlation theory: the Fourier transform of a cross-correlation of 2 functions is the same as the complex conjugate multiplication of their respective Fourier transforms.



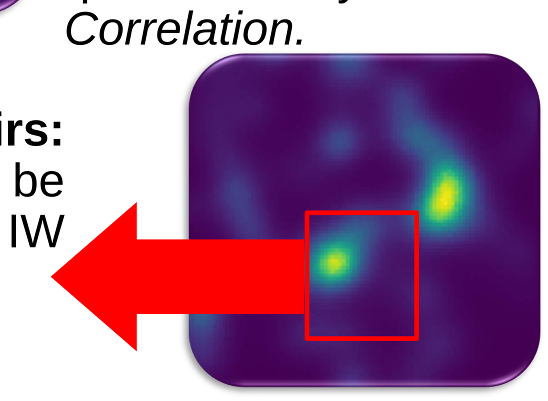
Inaccuracy in Flow Vectors

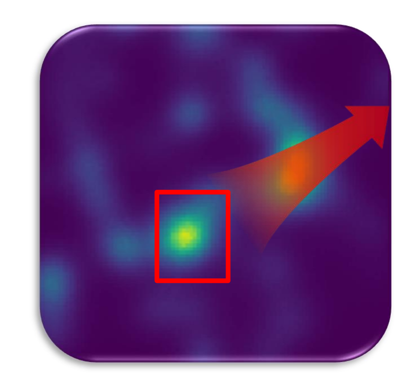
Several phenomena contribute to inaccuracies in flow vectors including (but not limited to) depth of correlation (DOC), in-plane loss of pairs and out of plane motion.



DOC: Because the full volume is illuminated, there will be a contribution to μPIV images from tracers outside the focal depth. Calculated vectors will be influenced by these particles; this effect is quantified by the *Depth of Correlation.*

In Plane loss of pairs: Particles may not be present in both the IW and SW

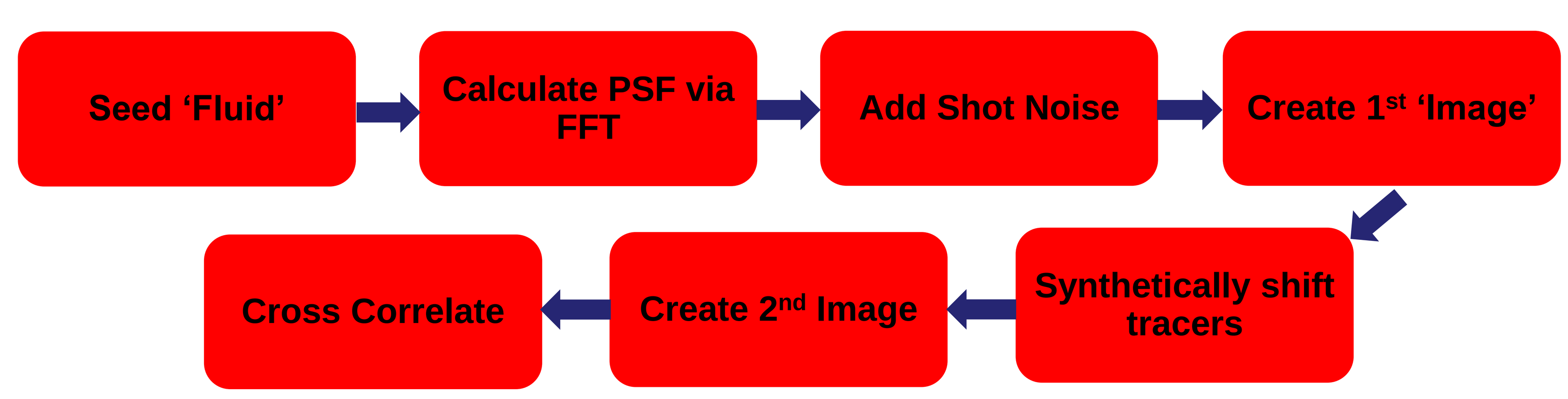




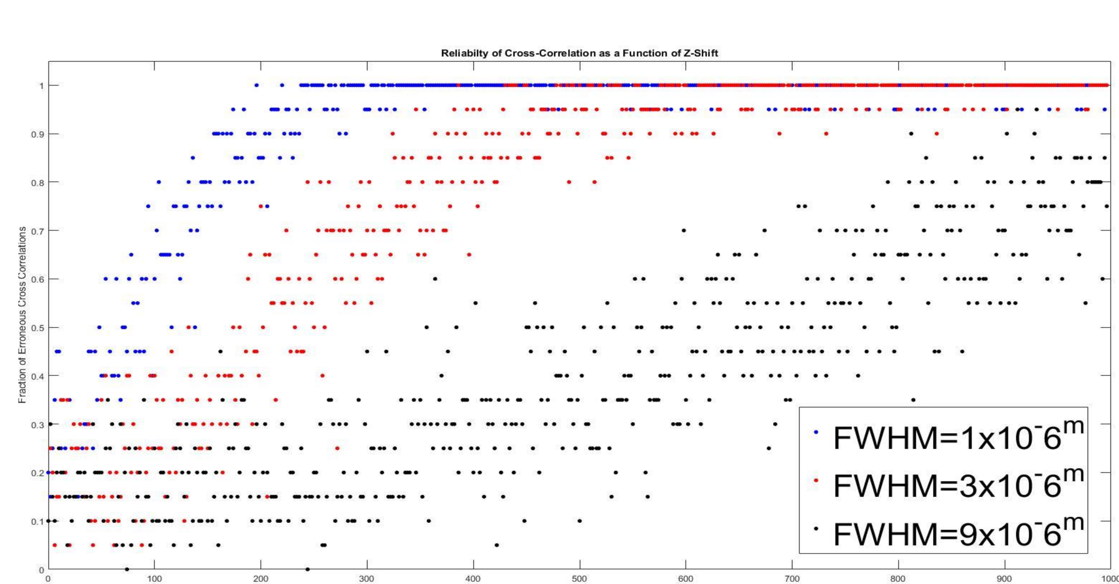
Out-of-plane motion (OOPM) : particles may have a velocity component that is normal to the light sheet

Computational Model

Because of the experimental difficulty in controlling flow parameters in microfluids, synthetic PIV images were used. These were generated via a computational model which considered how images were formed through the imaging optics. Fourier optics were considered to calculate point spread functions (PSF's). Linear system theory was applied to obtain the final tracer images.

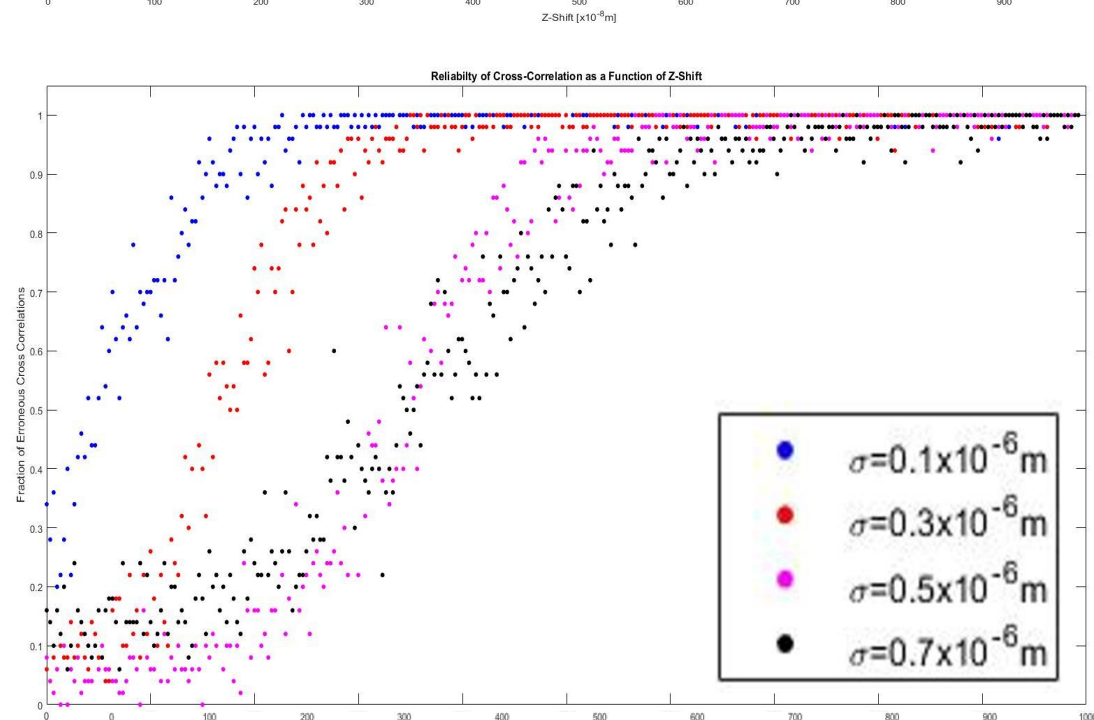


Full-Volume Shift



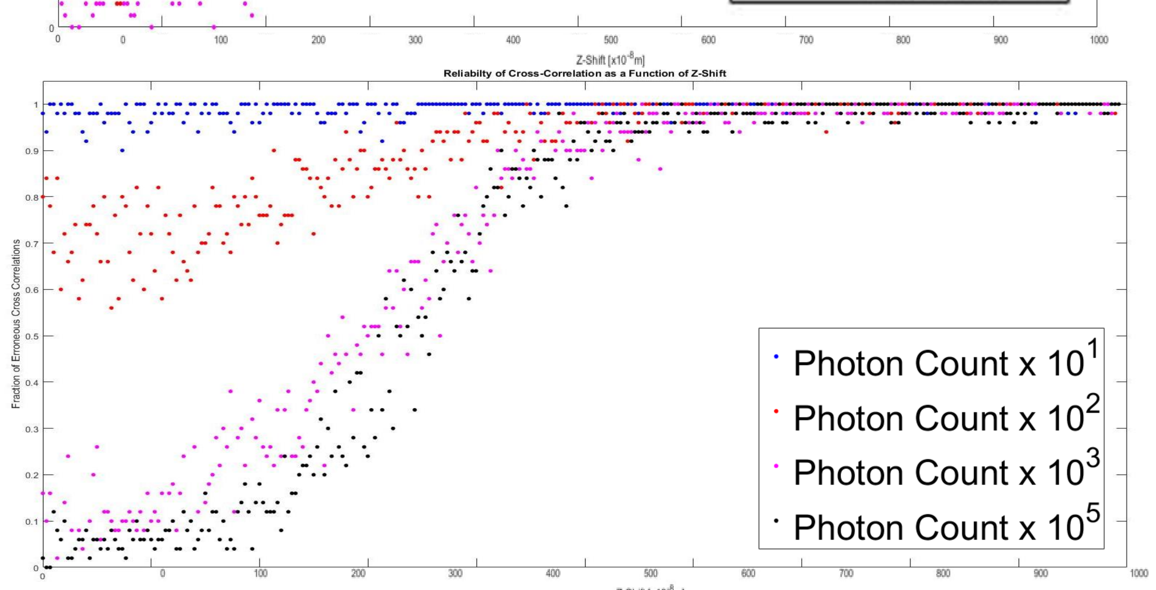
Light Sheet Profile

The larger the FWHM of the light sheet, the more OOPM can be tolerated before the cross correlation becomes erroneous**.**



Particle Size

The larger the radius, the more OOP can be tolerated. Too large, however, the motion will be unrepresentative of the fluid.



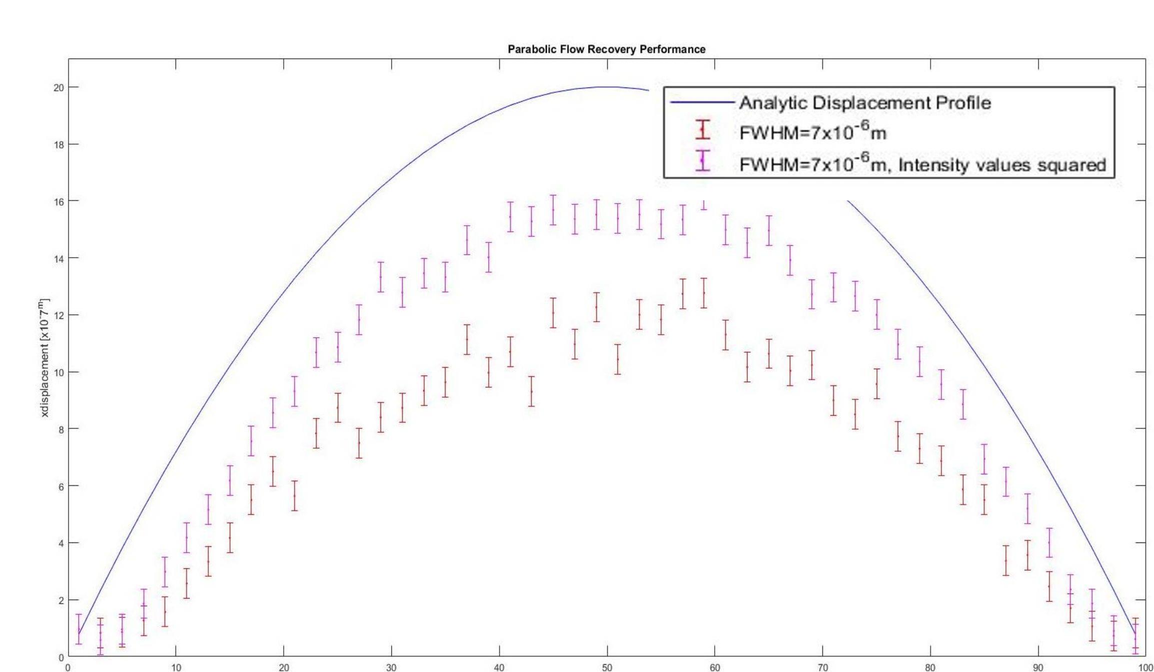
Noise

The more light received, the greater the signal-to-noise ratio and the more OOPM can be tolerated.

Poiseuille Flow

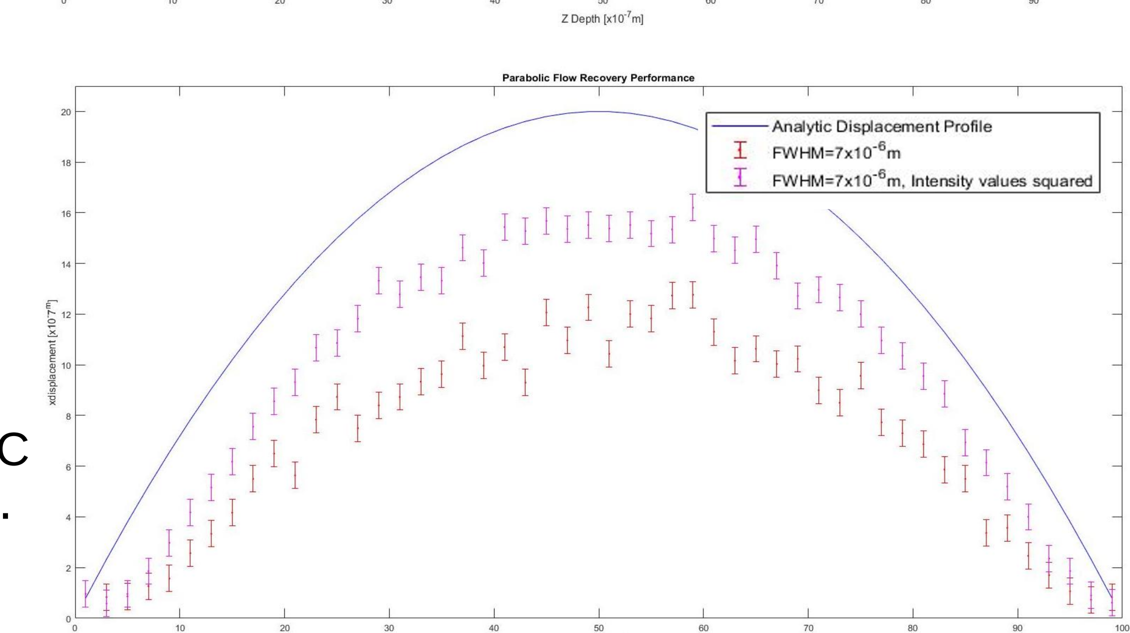
Light Sheet Profile

The thicker the light sheet, the greater the velocity underestimation.



Post-Processing (Power filter technique)

Squaring intensity values effectively reduces the DOC by approximately one half.



- **Unless otherwise stated, the light sheet FWHM was set to 3μm and the particle diameter to be 1μm. For the case of full volume shift, an in-plane shift of 20 pixels was applied to tracers, plus the z-shift indicated.**
- **A larger light sheet and tracer radius allow a greater OOPM tolerance, however z-resolution is lost and velocity underestimation is greater. Motion of large tracers may not represent that of host fluids.**