Defocusing PTV for the viscous wall region of a turbulent channel flow

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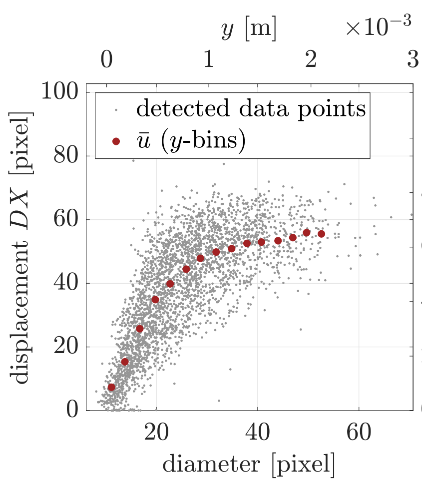
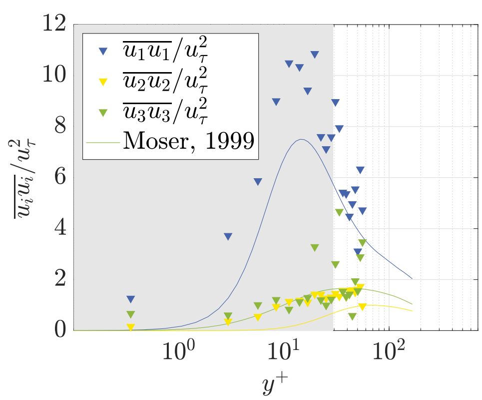
A detailed knowledge of velocity profiles for turbulent channel flows is of great interest for a large variety of research topics. Besides the academic interest of the exact ongoing effects, many engineering applications use skin-friction manipulating techniques to reduce the occurring drag, such as e.g. Hehner *et al.*(2019)[1] and von Deyn *et al.*(2022)[2], where an inhomogeneity in spanwise direction is introduced. For higher Reynolds numbers and small physical dimensions, the extraction of a precise wall-normal information is shifted into the sub-millimeter region close to the wall. However, accurate near-wall velocity measurements are challenging. A variety of direct and indirect methods are available for a wall-shear stress estimation. An overview can be found in the treatise of Örlü & Vinuesa (2020)[3].
The present contribution aims to extract the near-wall velocity profile by the measurement technique Defocusing Particle Tracking Velocimetry (Defocusing PTV, DPTV). These efforts continue the approach presented by Leister *et al.*(2023)[4], where a macroscopic camera set-up is used to extract approximately two millimeters of wall-normal direction in a liquid laminar flow. The focus of the present study is a detailed extraction of flow information of the inner layer in a turbulent channel flow in air. The metrologial uncertainties are evaluated and quantified accordingly, especially with the use of higher-order statistical properties of the well-documented canonical case of the channel flow. Figure 1 gives a first impression of the results obtained with this technique. Figure 1a shows the streamwise velocity u as wall-normal profile in pixel coordinates and physical units. Additionally, the spatially-averaged mean velocity is shown in red color. The defocusing technique is able to extract around two millimeters of the wall-normal direction. Figure 1b shows all three $\overline{u_i u_i}$-fluctuations in a normalized diagram together with DNS reference data of Moser *et al.*[5] for a similar Reynolds number $Re_\tau = 359$.
Concluding, this method allows for a 3D3C-measurement of the near-wall flow through a single optical access for imaging and illumination, and thus serves as an excellent complement to the already existing techniques.



(a) streamwise displacement/velocity diagram



(b) Velocity fluctuations for all three spatial directions

Figure 1: Defocusing PTV results for a friction Reynolds number of $Re_\tau = u_\tau h/\nu = 350$ with half channel height $h = 12.6$ mm.

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[1] Hehner et al., *Physics of Fluids* **31** (2019).
[2] von Deyn et al., *Journal of Fluid Mechanics* **951** (2022).
[3] Örlü & Vinuesa, *Measurement Science and Technology* **31** (2020).
[4] Leister et al., *Experiments in Fluids* **64** (2023).
[5] Moser et al., *Physics of Fluids* **11** (1999).