Lagrangian and Eulerian analysis of superstructures in wall-bounded turbulence based on large-scale, time-resolved and volumetric measurements using Shake-The-Box and FlowFit

The understanding of the formation and the dynamics of very-large scale motions (VLSMs) or turbulent superstructures (TSS) within TBLs and turbulent pipe flows at high Reynolds numbers has become an important research topic in experimental fluid mechanics. Main investigation areas are the separation of scales from small-scale motions (SSMs), as well as their mutual interference on e.g. the wall shear stress. As shown by experimental data these superstructures directly interact with small-scale structures near the wall (leaving a modulating 'footprint'). This impact on the conditions near the wall is of particular interest for the induced drag production, as the large-scale structures underlie outer scaling (their spatial extent is dependent on δ and therefore also on the Reynolds number), while it was assumed that near-wall structures do not.

An enhanced understanding of the dynamics and statistics of fluid and momentum exchange mechanisms is of eminent interest. Such insights can be gained by a direct comparison of high Reynolds number turbulent pipe and ZPG-TBL flows in terms of velocity and Reynolds stress profiles, scaling properties of coherent structures and the interaction of scales in the near wall, logarithmic and bulk/wake region. A further examination of the formation and evolution of superstructures in their fully temporal and spatial extension is therefore of major interest for a better understanding of turbulent (wall bounded) flows in general. The successful application of large- and small scale investigations using the innovative 3D Shake-The-Box and FlowFit techniques will be extended in several collaborative projects in well controlled high Reynolds number turbulent pipe and ZPG-TBL flows in the 2nd phase of our SPP providing unique dense Lagrangian and Eulerian experimental data.
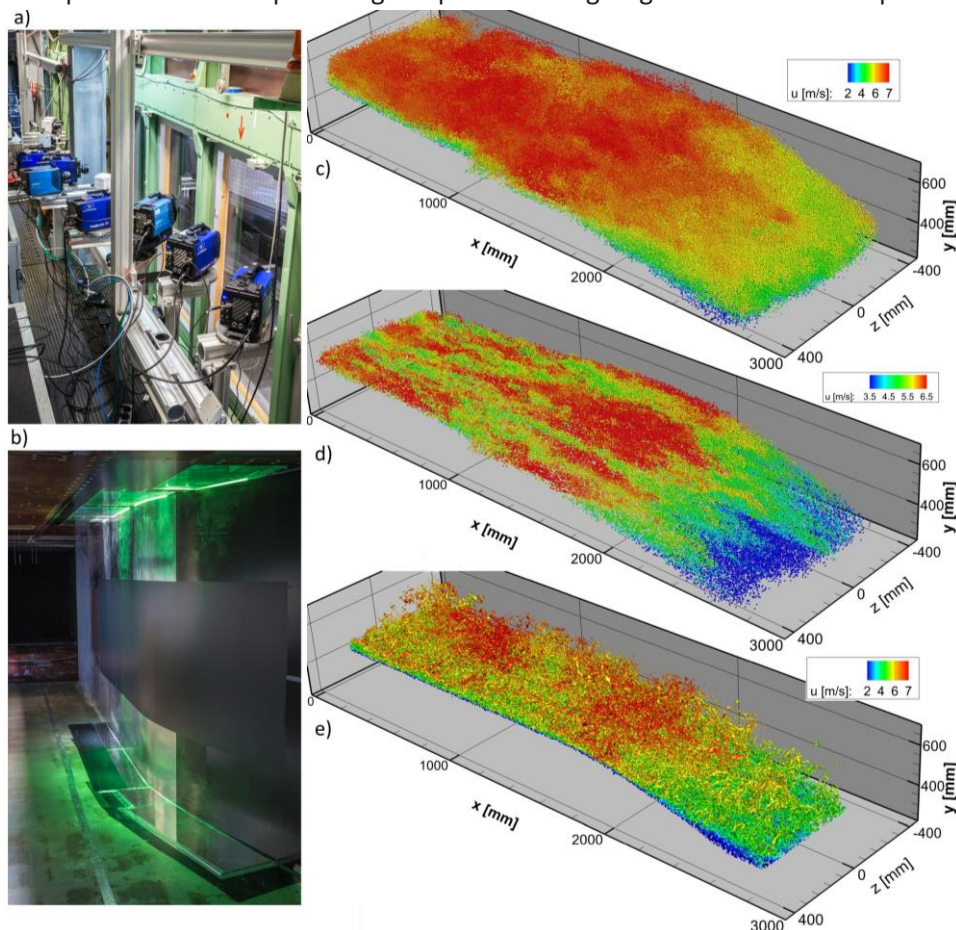

Figure 1: Snapshot of TBL from ZPG to APG flow at U = 7 m/s, measured with 12-cameras (a) in AWM (b): (c) 620.000 tracked particles, color-coded with streamwise velocity; (d) wall-parallel cut through particle field, showcasing TSSs; (e) FlowFit interpolation with Isosurfaces of Q-criterion (Q = 1000/s);