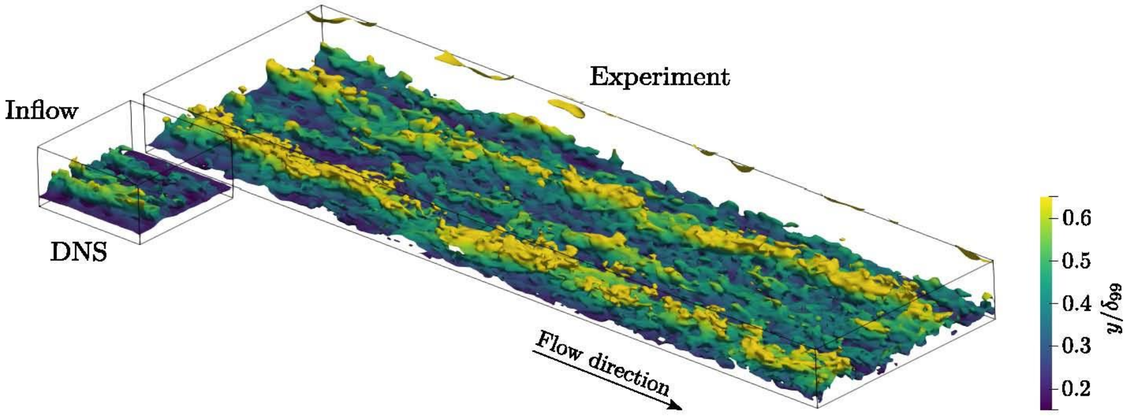
Numerical investigations of large-scale motions in turbulent flat-plate boundary layers with pressure gradient



Comparison of Iso-Surfaces of the Streamwise Velocity Component between Experiment and a Short Test DNS-Domain Using Experimental Input

A positive pressure gradient in flow direction leads to a faster increase of the boundary layer thickness compared to the standard case without pressure gradient, and thus to an earlier occurrence of turbulent large-scale motions, which are the main subject of the present project. Based on the recent observation that high- and low-speed streaks correspond to Lagrangian Coherent Structures (LCS) in our data, further evaluations of existing DNS data sets will be performed to quantify the large-scale motions and their development. Resolvent analysis is applied to the time-averaged flow of DNS to determine the strongest transient response of the linearized Navier-Stokes equations between two stations in flow direction. Since comparisons with similar approaches in the literature and preliminary own results of this method look very promising, we believe that we can detect the origin and dynamics of large-scale motions in turbulent flat-plate boundary layers.

For the first time, we will perform DNS with transient, three-dimensional input from high-resolution PIV (Particle Image Velocimetry) for direct comparisons with wind tunnel experiments. This will show to what extent the turbulent large-scale motions are already contained in the inflow plane and to what extent they are determined by small or subtle differences. Additional DNS with intentional excitation of favorable and unfavorable modes in the inflow and at the wall will help to better understand these influences. Collaboration and data exchange with partners performing wind-tunnel experiments will allow us to extend our analysis to larger Reynolds numbers than is currently possible with DNS only. The results from DNS at lower Reynolds numbers will then be compared with the results from experiments and simulations at higher Reynolds numbers.