Future fusion reactors of the tokamak type will most likely operate in high-confinement mode (H-mode), a regime that enhances confinement through the formation of a steep pressure gradient at the plasma edge. This edge region, known as the pedestal, plays a crucial role in determining overall plasma performance. Higher pedestal pressure leads to increased core pressure, which in turn boosts fusion reaction rates and improves energy gain. On the other hand, the free energy stored in this steep gradient region can drive edge localised modes (ELMs), which cause energy and particle loss. These can be mitigated under specific pedestal conditions. Therefore, understanding which physical mechanisms govern the pedestal structure is crucial for optimising plasma performance. In this thesis, experiments were conducted on ASDEX Upgrade to systematically investigate how plasma shape and the normalised poloidal pressure βpol influence pedestal behaviour. The parameters are selected because they both affect kinetic ballooning modes (KBMs), which are a well-established hypothesis for determining the pedestal width.

A series of dedicated discharges were analysed, each designed to isolate the effects of the two quantities. Three discharges at varying βpol were conducted, each with two shaping phases where βpol is kept constant, yielding six distinct datasets. A wide range of experimental diagnostics and computational techniques were employed to reconstruct kinetic profiles, determine the magnetohydrodynamic (MHD) equilibrium and stability, and assess transport processes within the pedestal. Particular attention was given to the role of local ideal ballooning modes (IBMs), used here as a proxy for KBMs, and to the conditions enabling access to the second stability regime.

The results demonstrate that pedestal formation is not governed by a single transport mechanism but rather by the interplay of multiple instabilities across different pedestal regions, affection density and temperature of ions and electrons differently. Importantly, the study highlights the stabilising role of local magnetic shear, which can suppress KBMs and thereby impact the density pedestal structure. The top of the pedestal is largely regulated by KBMs. They are shown to influence both density, setting the width of its pedestal, and turbulent ion heat transport in the pedestal top region. A key finding is that access to the second stability regime plays a decisive role in setting the pedestal width. This is particularly evident at the pedestal top, where the most ballooning-unstable region shifts radially depending on second stability access.

Further insight into microturbulent transport mechanisms was obtained through local linear gyrokinetic simulations with GENE, which confirmed that KBMs dominate at the pedestal top, whereas ITG turbulence prevails in the outer core. The simulations also verified that shaping effects primarily stabilise KBMs, with the strongest impact occurring where the pressure gradient is steepest - further emphasising the role of second stability. Electron temperature gradient modes, which are thought to impose a well-defined temperature gradient length, determining the electron heat diffusivity, are also shown to be present in the pedestal.

The results underscore the necessity of treating the pedestal as a system of coupled but distinct components, rather than a single pressure pedestal. Ion and electron temperature pedestals, as well as the density pedestal, evolve according to different governing mechanisms and respond differently to shaping and βpol variations. This implies that global scaling laws may be insufficient for predicting pedestal behaviour in future devices without a more detailed, region-dependent description.

In this thesis, a range of complementary analytical methods are employed to provide a solid foundation for future work, which should validate the observed trends across a broader dataset and exploring their implications for predictive modelling. A deeper understanding of how KBMs behave in different plasma conditions will be crucial for optimising pedestal performance in future fusion devices.