The role of the n=1, m=1 mode in determining the stability properties of a tokamak.

J. Manickam
Princeton Plasma Physics Laboratory
Box 451, Princeton NJ 08543
USA

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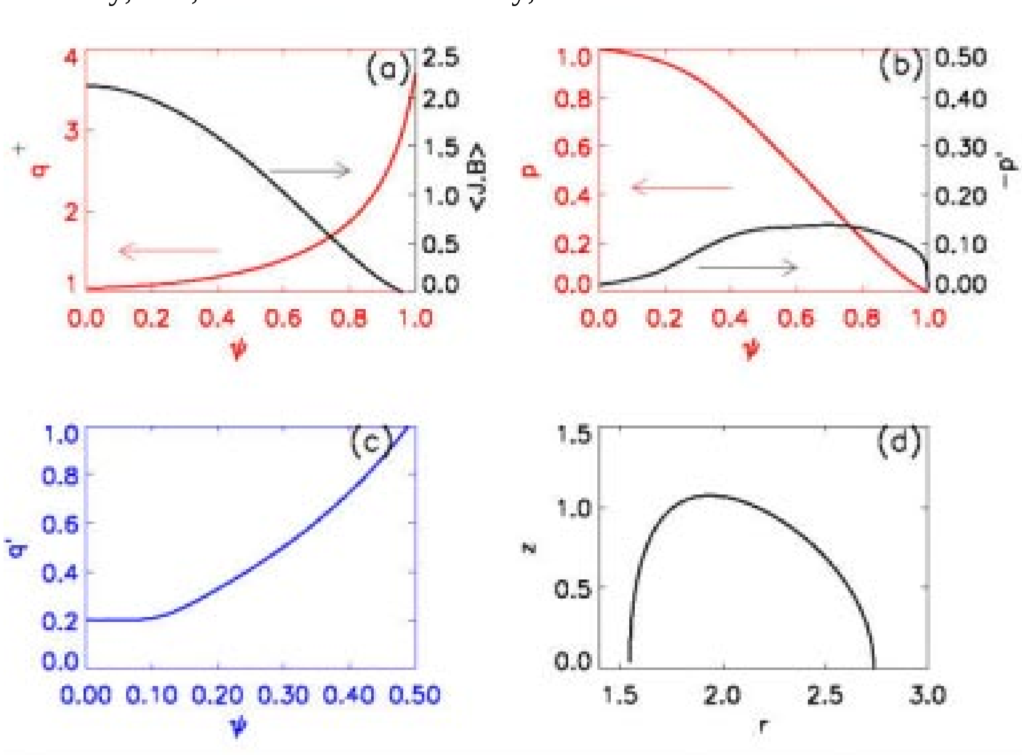
Theoretical study of beta-limits due to ideal MHD stability in tokamaks is often based on equilibria with q_axis at or above unity. This assumption is used even in the face of experimental evidence, such as the appearance of sawteeth oscillations, which are identified with the n=1,m=1 mode, where n and m refer to the toroidal and poloidal mode numbers respectively, and are generally observed when the safety-factor at the magnetic axis, q_axis, has a value below unity. The widespread use of the Motional Stark Effect, MSE, diagnostic has confirmed the observation that q_axis is often in the range 0.7 < q_axis <1. The common procedure for addressing this instability is to invoke the role of energetic particles, which can serve as a stabilizing influence, or to argue that the primary role of the instability is to induce sawteeth which are often acceptable MHD phenomena in the sense that they result only in local fluctuations of the temperature profile inside the q=1 surface without causing disruptions. The ‘giant-sawteeth’ are an exception to this statement. In this report we examine the effect of details of the plasma profile in the vicinity of the magnetic axis.

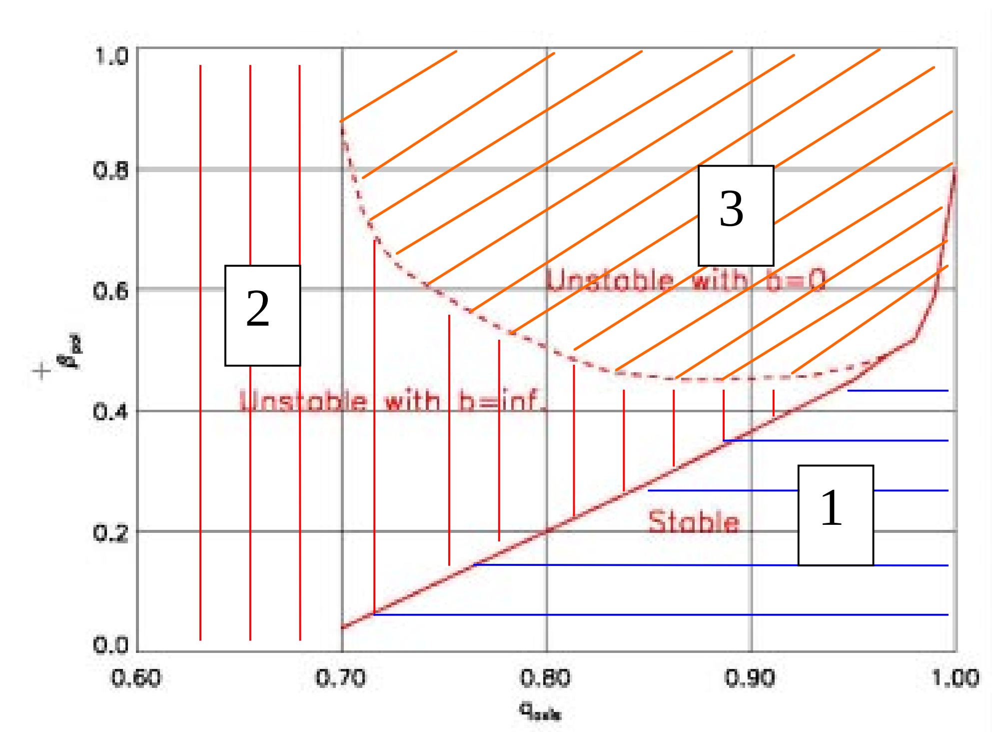
The general procedure is to generate a sequence of equilibria with increasing beta keeping the shape of the current profile, prescribed by <J.B>/B^2, as well as the pressure profile. This studies uses tabulated profiles. For each combination of profiles the beta is increased by scaling the pressure. The value of q_axis is approximately unity. To study the effect of varying q_axis we scale the toroidal field at constant beta-poloidal, this permits us to determine the beta-poloidal threshold for the instability as a function of q-axis. We obtain the stability criterion with boundary conditions corresponding to a wall at the plasma boundary and also with the wall at infinity, b=0 and b=infinity.

Figure 1 shows the profiles used in one of the sets of equilibria and figure 2 shows the corresponding stability results. The space, beta-poloidal vs q_axis separates into three regions, labeled, 1, 2 and 3. In the region marked 1, the plasma is stable to the n=1 instability, in region 2, it is unstable to the n=1 if there is no nearby conducting shell, the region three indicates instability even with the conducting wall on the plasma boundary. This is the internal kink unstable regime.

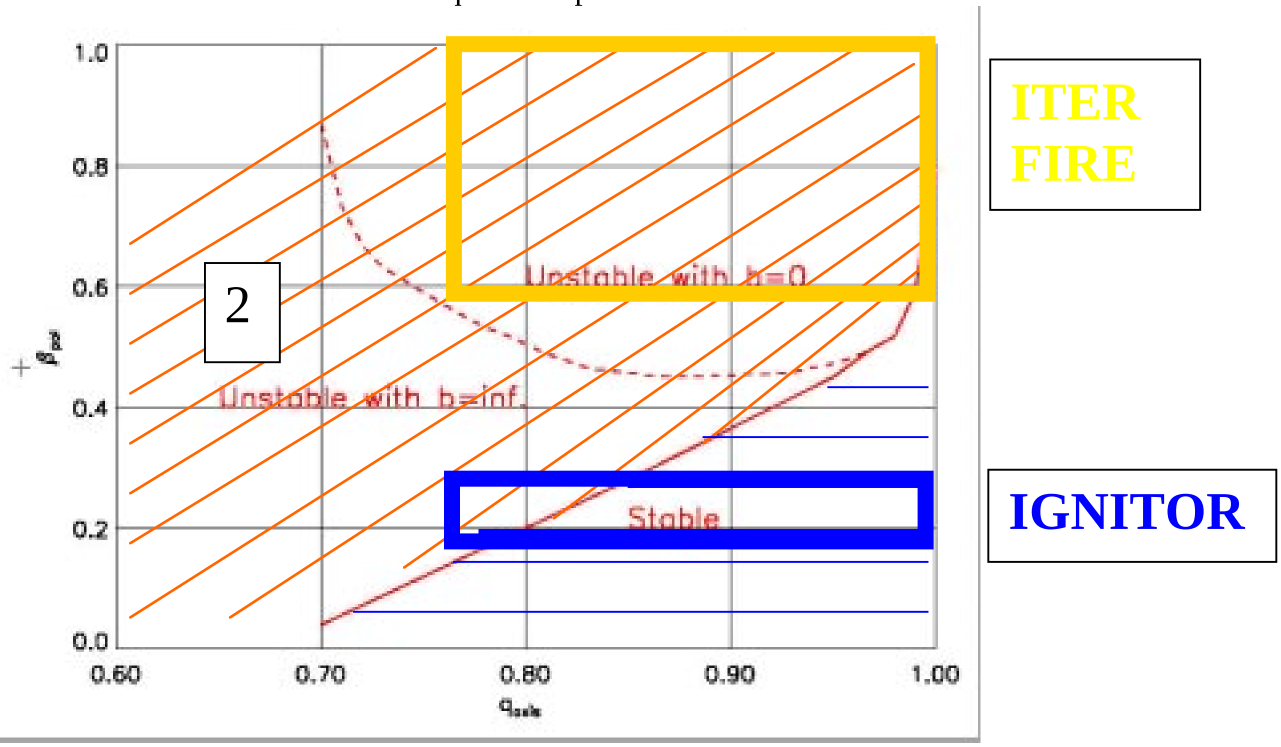
The practical stability criteria for the n=1 mode should be determined by the wall at a distance, as such we effectively combine regions 2 and 3 as the unstable region and consider 1 to be the stable region in our subsequent discussions.

In figure 1 we show plots of the profiles used. a) q and <J.B> vs Psi, b) p and dp/dpsi vs Psi, c) is a detail of q' vs Psi and d) shows an outline of the plasma boundary in the upper-half plane. Figure 2 shows the stability of the n=1 mode with a wall on the plasma boundary, b=0; and with a free boundary, b=inf.

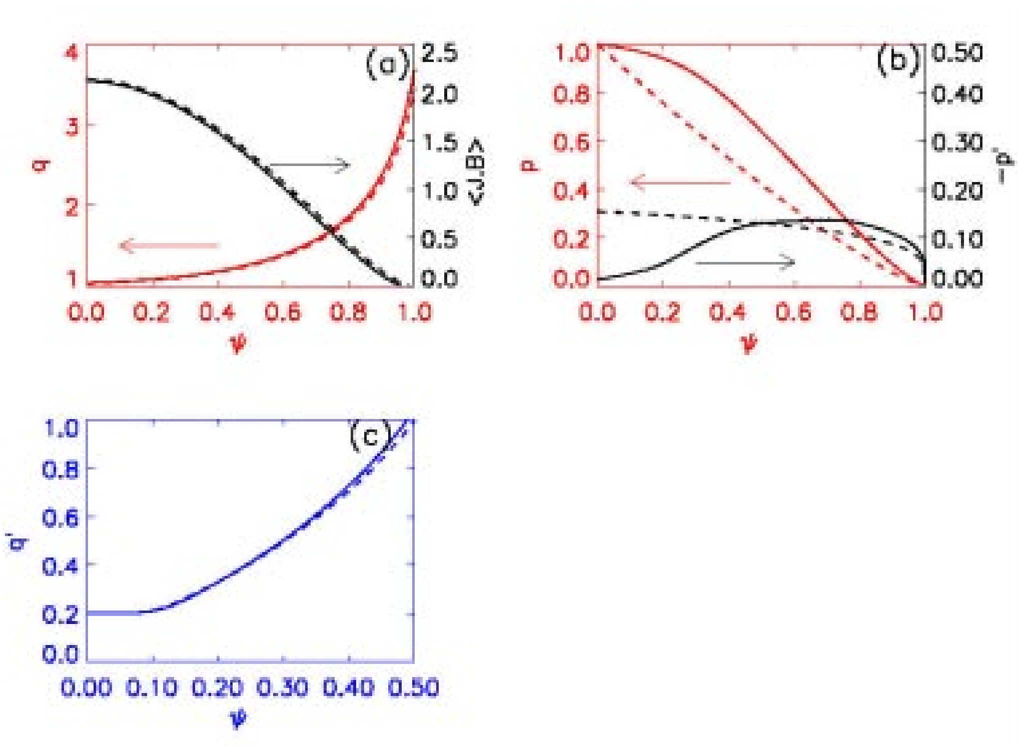


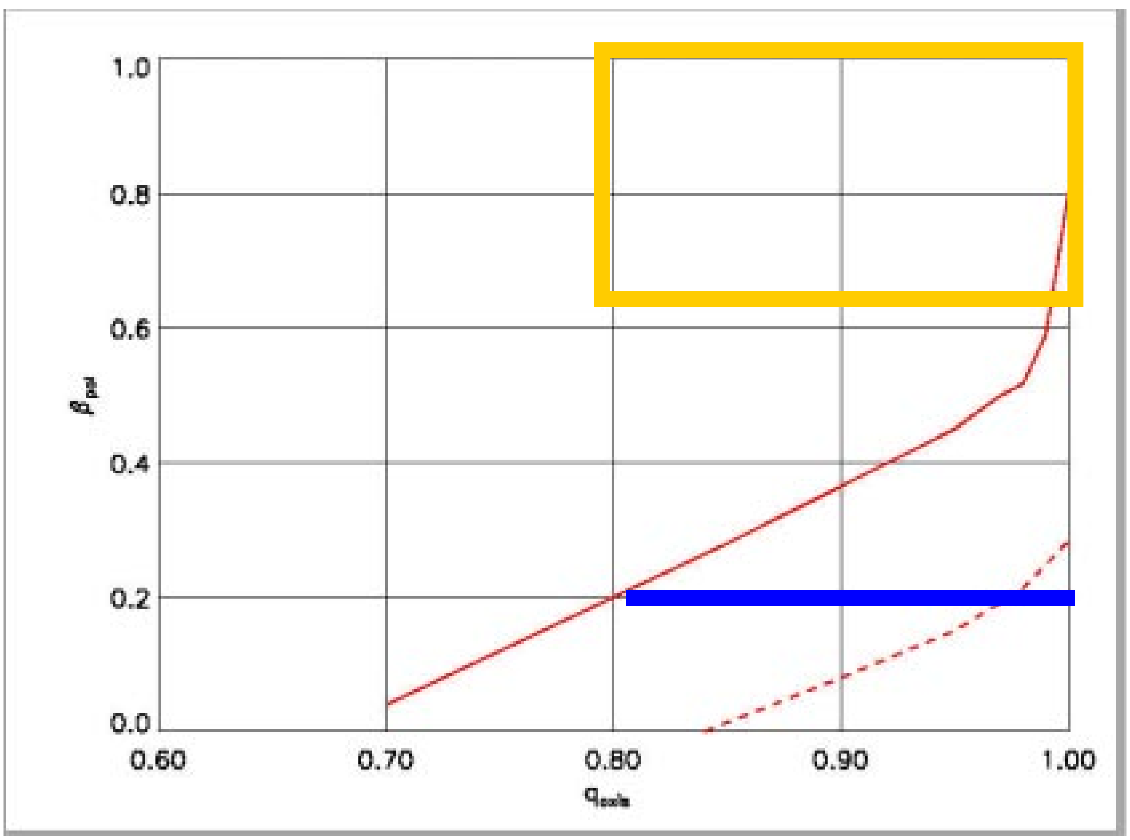


In figure 2 we show the expected operating rgimes for FIRE, IGNITOR and ITER.
Note that IGNITOR is stable unless q-axis drops below 0.8.

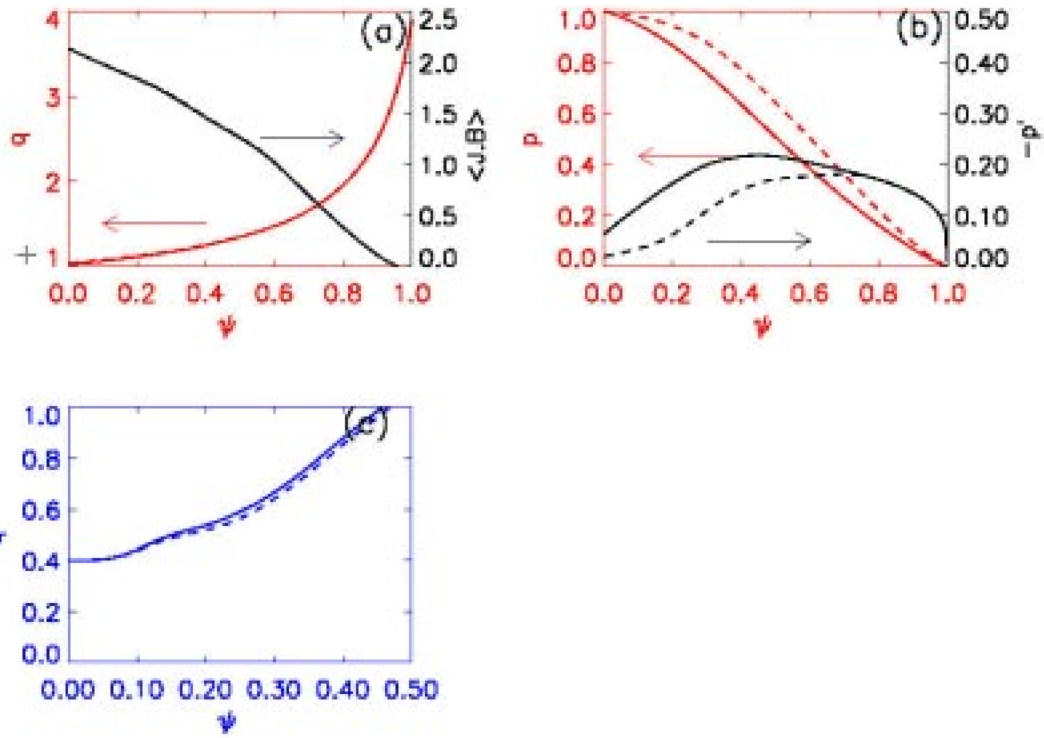


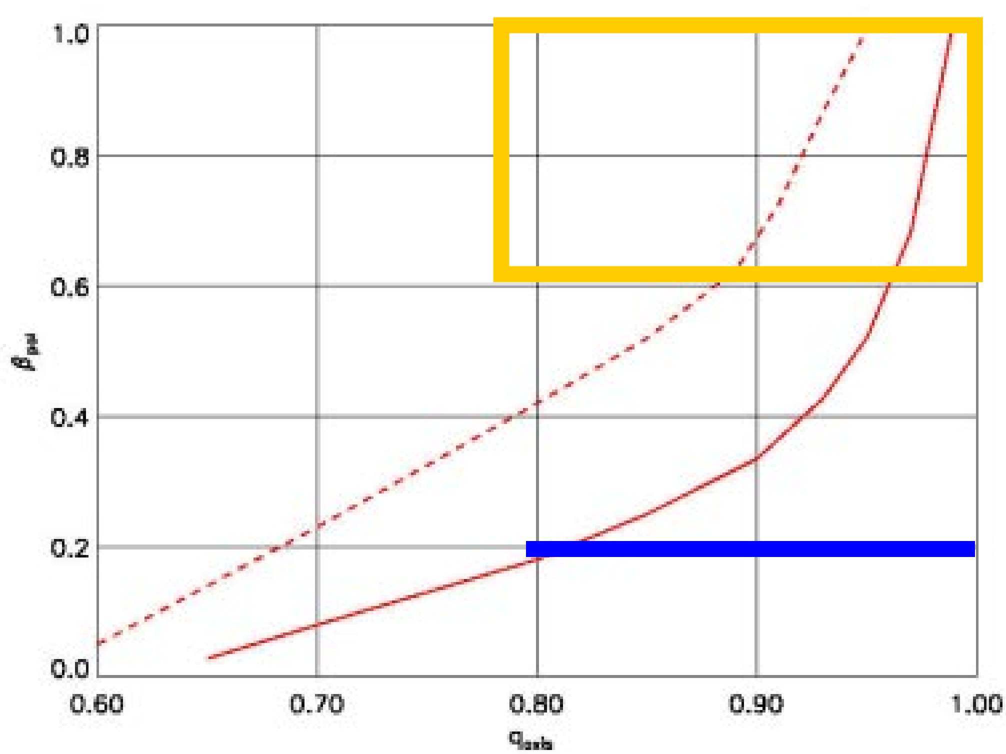
Figures 3 and 4 show the effect of varying the pressure profile.





Figures 5 and 6 show the effect of varying the pressure profile.





Figures 7 and 8 show the effect of modifying the current profile near the axis