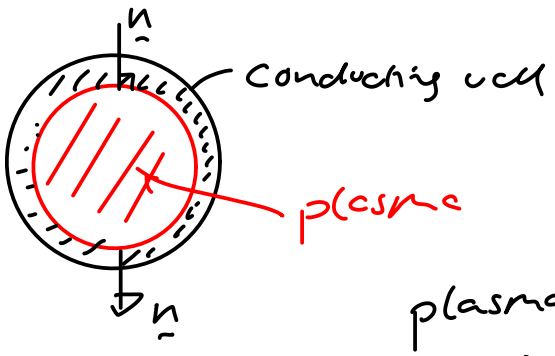
Types of instabilities

Contents

- Internal and External modes
- Interchange and Ballooning modes
- Kink modes

Internal



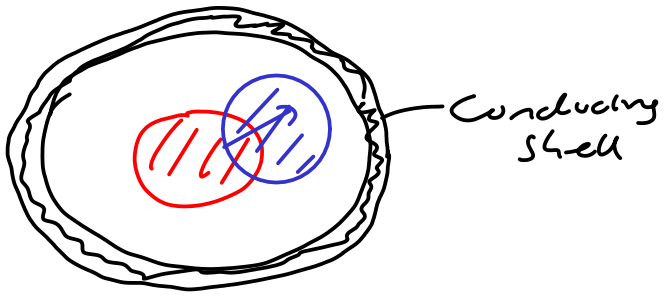
displacement

$\underline{\xi} \cdot \underline{n} = 0$

plasma unstable even if the edge is fixed

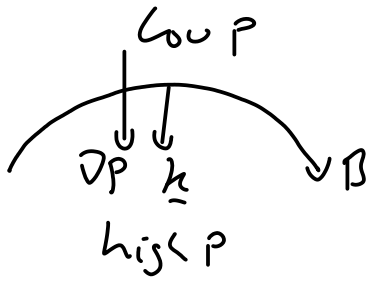
Extend

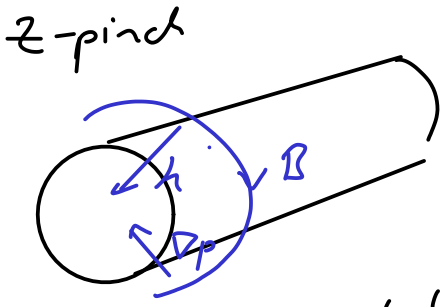
Modes which are only unstable if the plasma edge can move



Plasma Instability drives

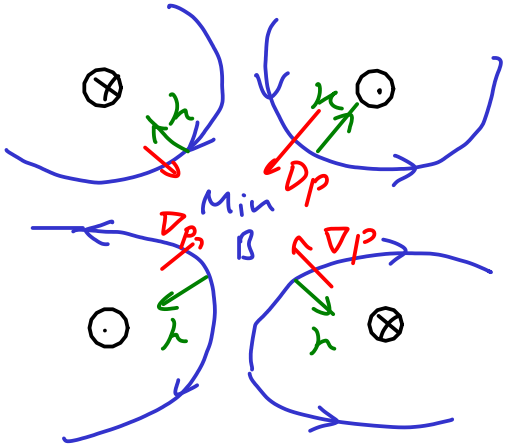
- $\nabla p \cdot \underline{n} > 0$ Interchange, ballooning
- $J_{\parallel}$ kink instabilities





⇒ unstable

Magnetic cusp



$\nabla p \cdot \underset{\sim}{k} < 0$

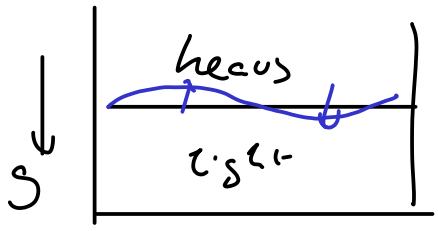
stable

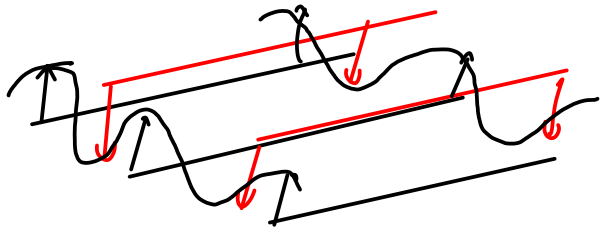
Interchange modes

$k_{\parallel} = \underset{\sim}{b} \cdot \underset{\sim}{k} \simeq 0$

$(\underset{\sim}{b} \cdot \nabla)\xi \simeq 0$

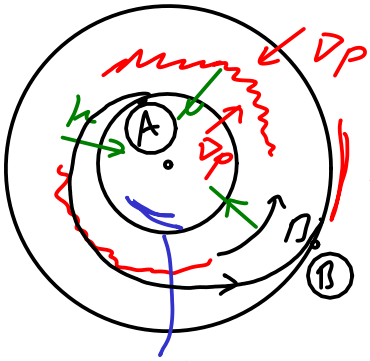
Similar to Rayleigh-Taylor in fluids





Ballooning modes

$k_{\parallel} \neq 0$

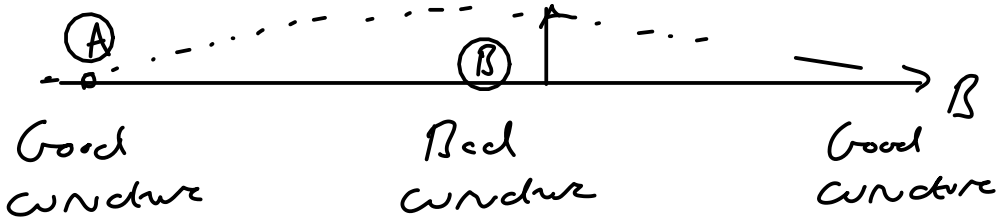


Bad curvature

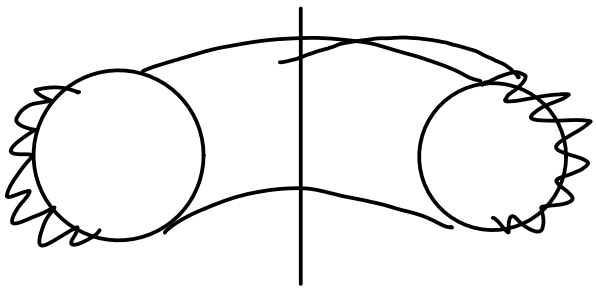
$\nabla p \cdot \underline{\kappa} > 0$

Good curvature

$\nabla p \cdot \underline{\kappa} < 0$



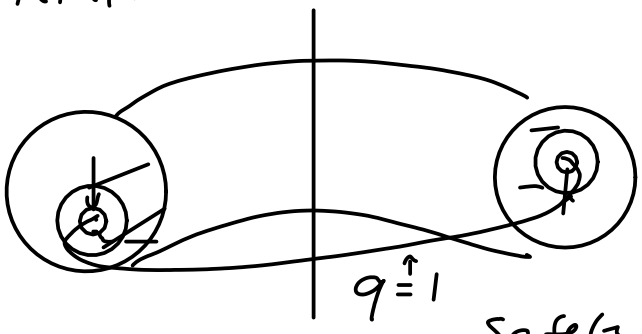
Bending of field lines $\delta W \quad \frac{|\delta B_\perp|^2}{2\mu_0}$



e.g. Edge Localised Modes (ELMs)

Kink Instabilities

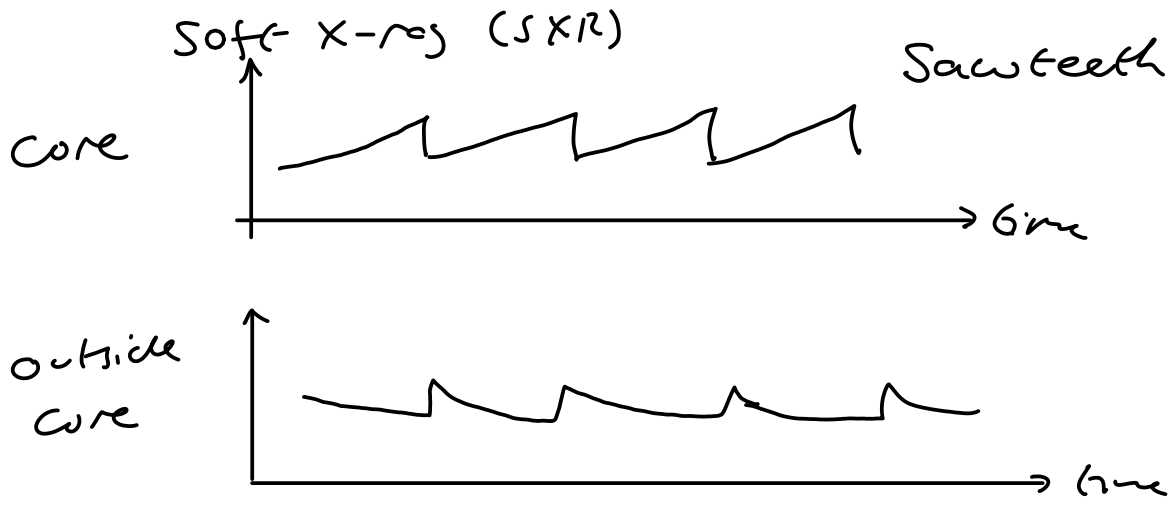
Internal kink



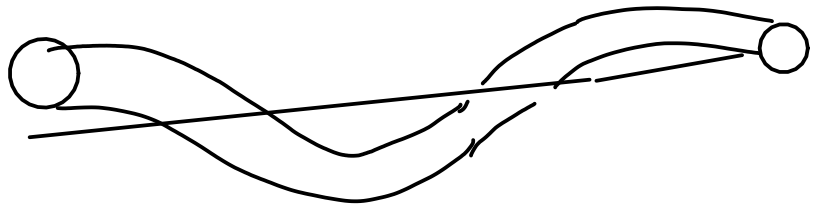
Too much current in plasma core

⟶ instability

Safety factor $q < 1$

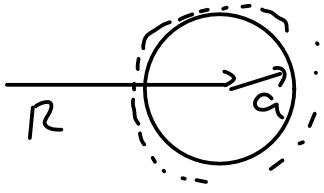


External kink



$q_a < 1$ Kruskhal - Shafranov Limit

Safety factor $q_a \simeq \dfrac{B_\phi\, a}{B_\theta\, R} > 1$ stable



$\oint \underline{B}_\theta \cdot d\underline{l} = \mu_0 I_p$

$\underbrace{\quad}_{2\pi a B_\theta}$

$$\frac{B_\phi\, a}{\left(\frac{\mu_0 I}{2\pi a}\right) R} > 1 \quad \Rightarrow \quad \underline{I_p < \frac{B_\phi\, a^2\, 2\pi}{\mu_0 R}}$$

e.g. ITER $R \sim 6.2\text{m}$ $a \sim 2\text{m}$ $B_\phi \sim 5.3\text{T}$

$\Rightarrow$ $\underline{I_p \lesssim 17\text{ MA}}$ stable

Note: Elongation increases this limit