

Onset conditions for disruptions during VDEs

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Overview



- Vertical Displacement Events, VDEs, often last for several milliseconds, before terminating in a disruption
- The plasma shifts vertically and pushes against a material surface and shrinks
- Plasma equilibrium is maintained during this period, and q-edge decreases
- When q-edge reaches a critical value, the plasma disrupts
- Usually at $q < 2$.

VDE disruption model



- The plasma shrinks and q-edge decreases as the VDE evolves
- At some point, near q-2, the n=1 kink is destabilized
- Halo currents are induced to stabilize the mode
- When the growth-rate becomes too large then the plasma disrupts

Current associated with magnetic perturbations



By examining the power required to drive a current potential it can be shown that the energy for a specific ideal MHD mode is,

$$\delta W = I\Phi/2$$

where

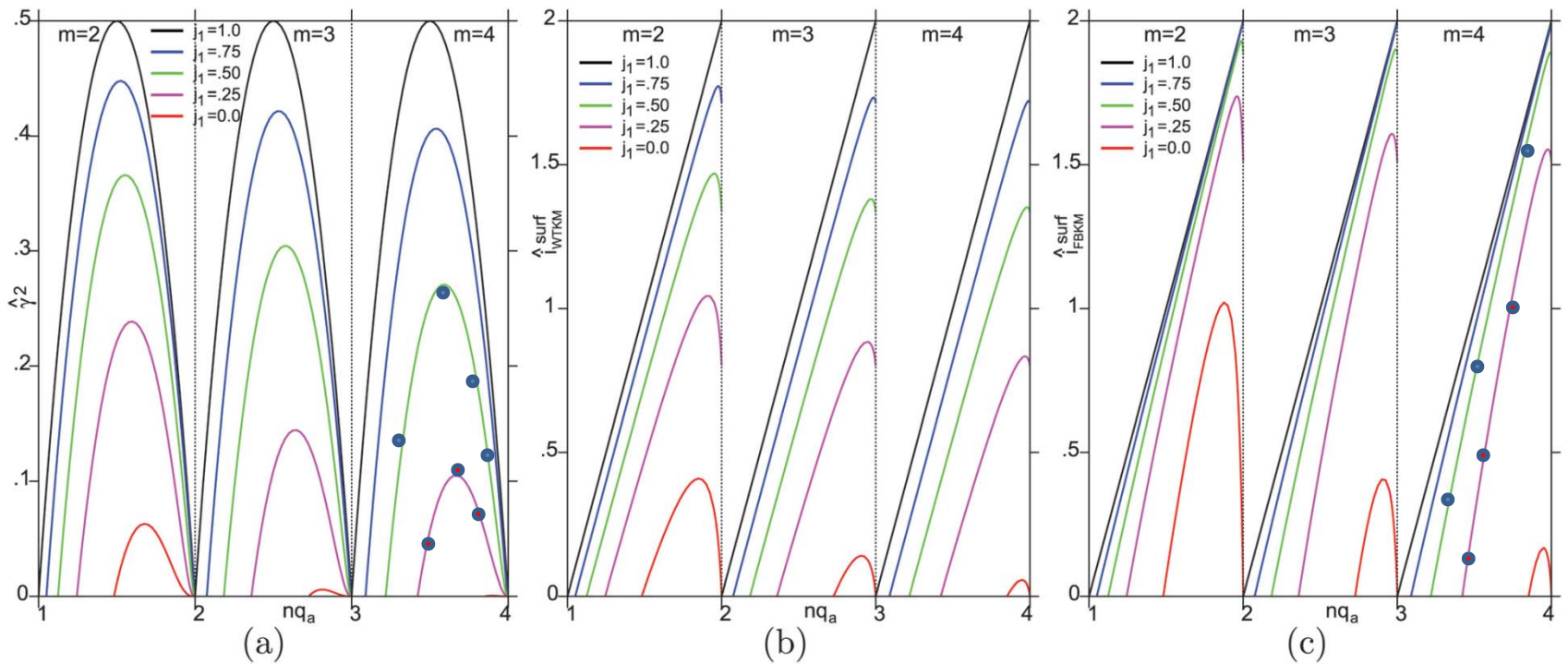
$$\Phi^2 = \oint (2\pi \vec{B} \cdot \vec{\nabla} \psi \mathcal{J})^2 d\theta d\varphi;$$

$$I = \frac{2\delta W}{\Phi}.$$

Benchmarking



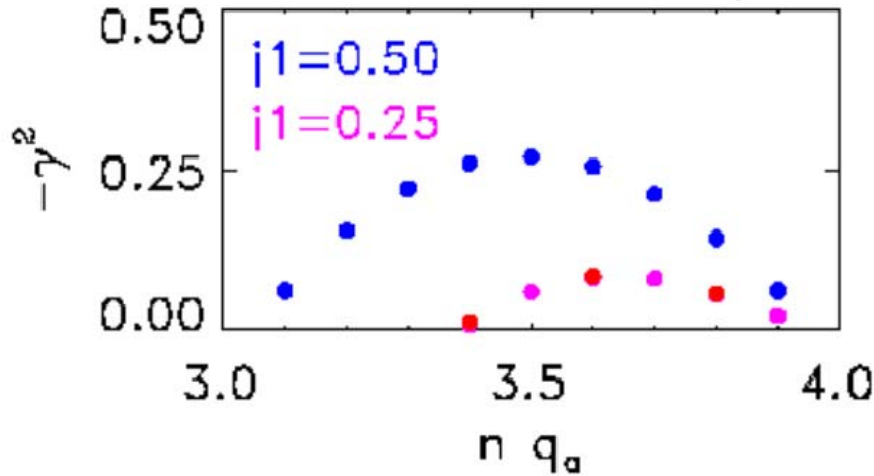
- Zakharov PHYSICS OF PLASMAS 18, 062503 (2011)



Numerical approximation



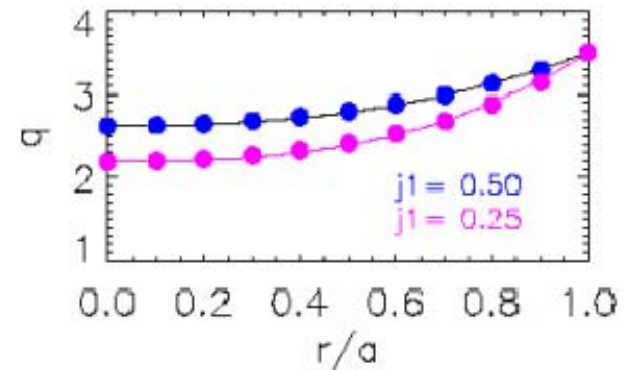
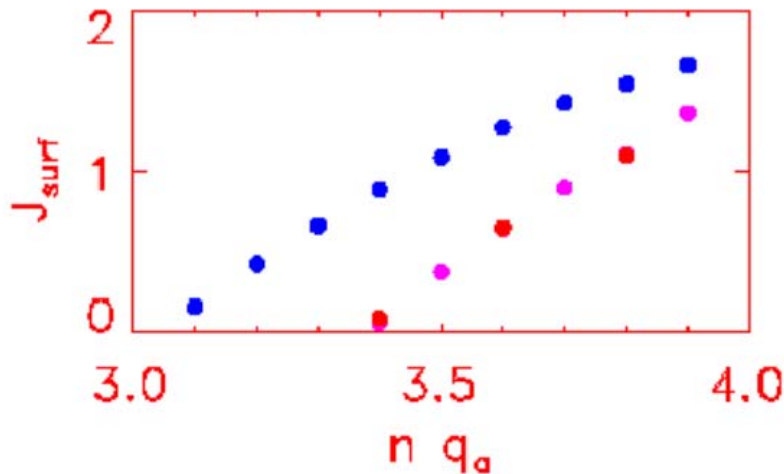
CYLINDRICAL LIMIT $R/a=20$



$R/a = 20$

Circular cross-section

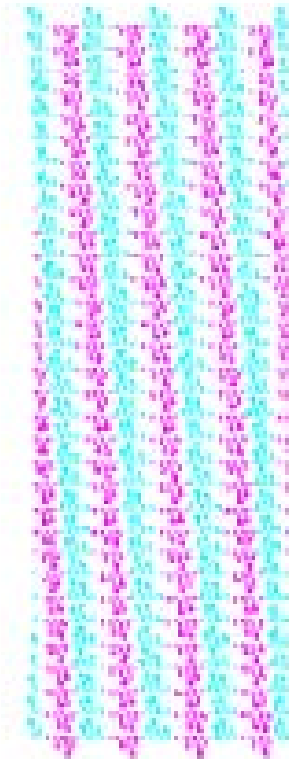
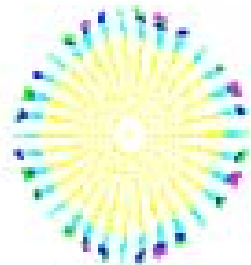
$\rho = \text{constant}$



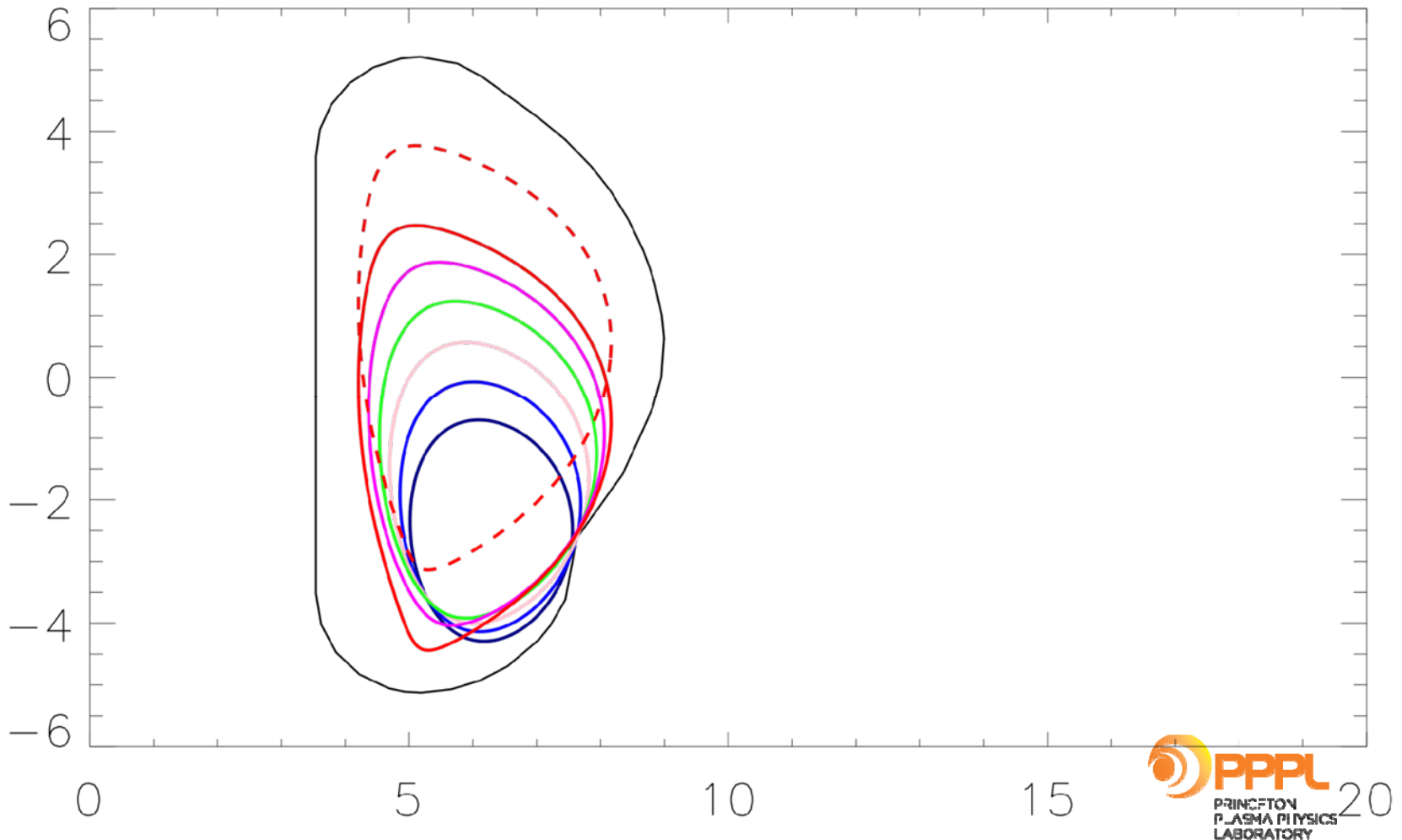
Displacement vector and surface currents



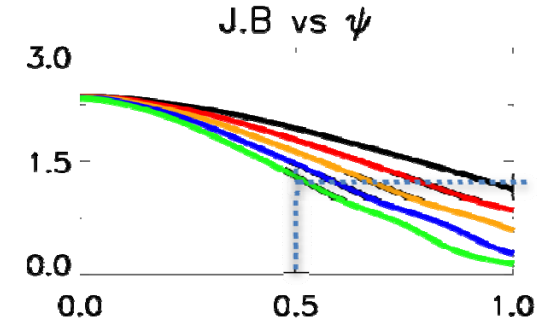
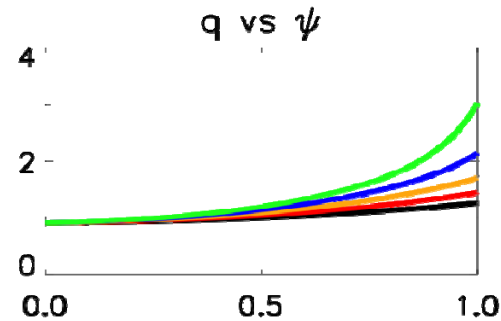
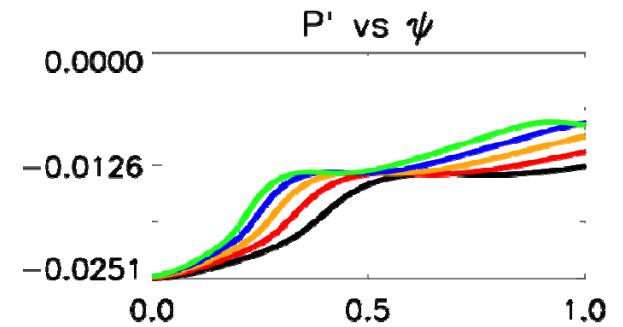
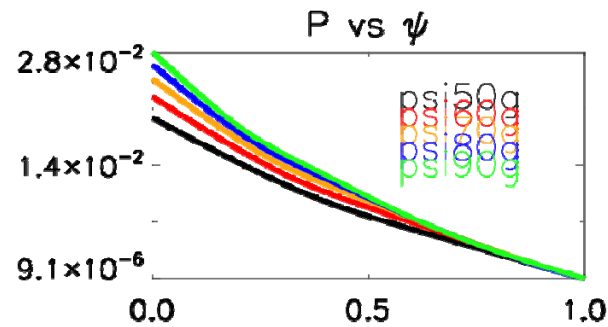
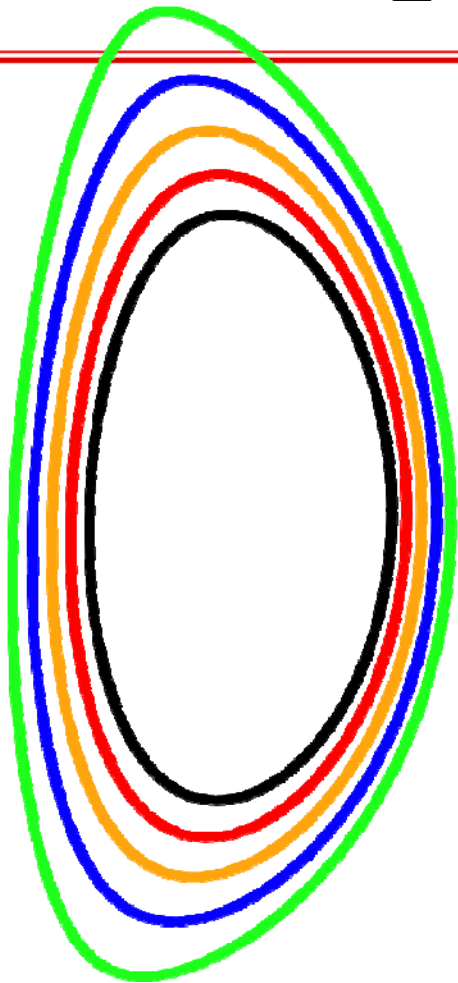
ξ – displacement Surface current



EQUILIBRIUM SEQUENCE DISPLAYING VERTICAL SHIFT AND PLASMA SCRAPE-OFF



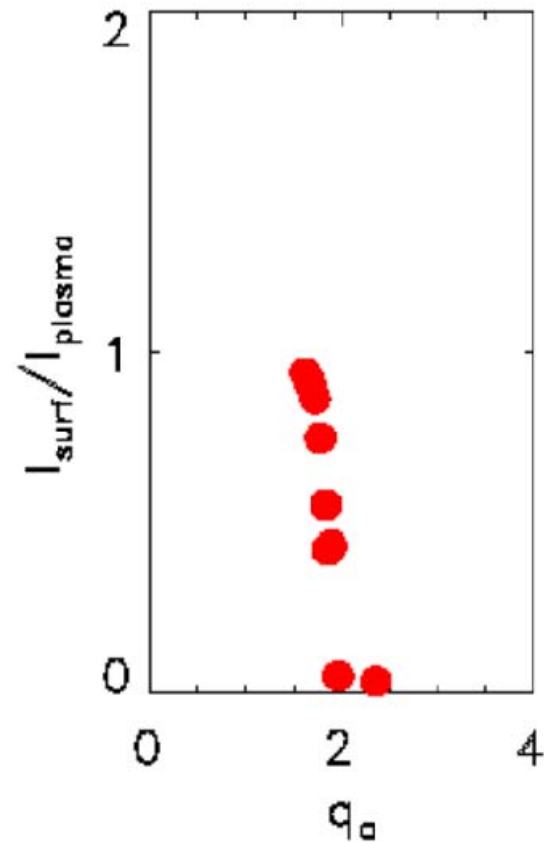
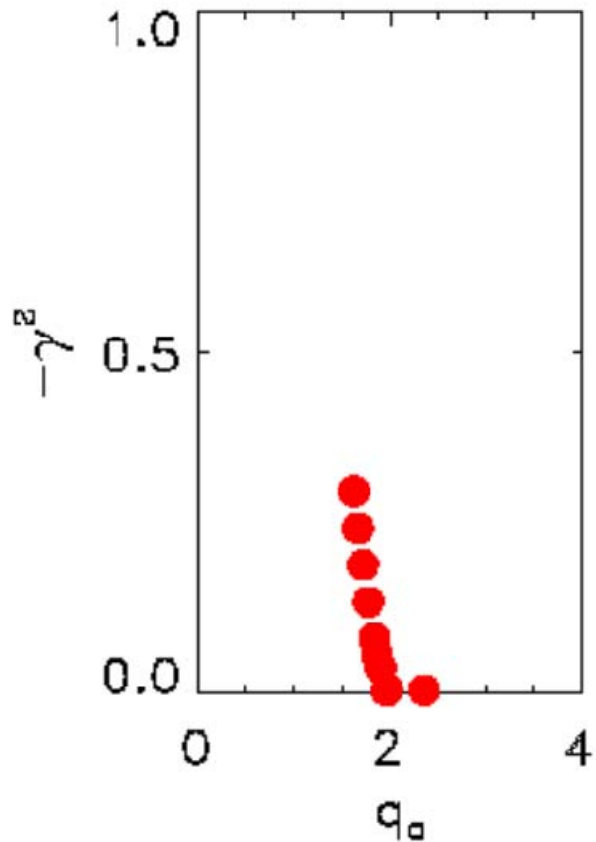
EQUILIBRIUM MODEL



Current is approximately constant as is q-axis. However q-edge varies.

Select flux surface
Truncate $\langle J.B \rangle$, p'
Compute new equilibrium

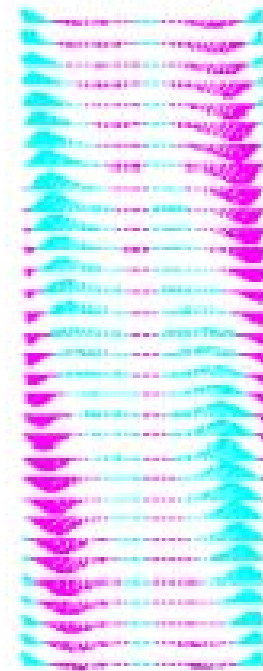
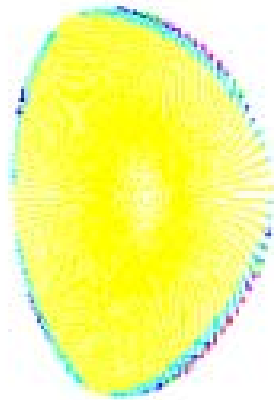
ITER model – based on TRANSP



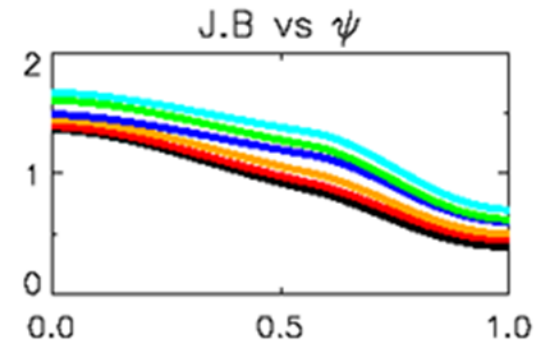
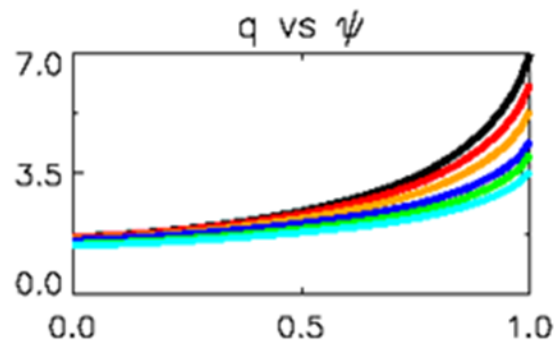
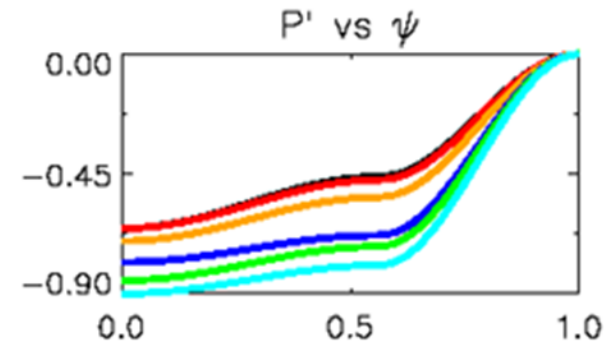
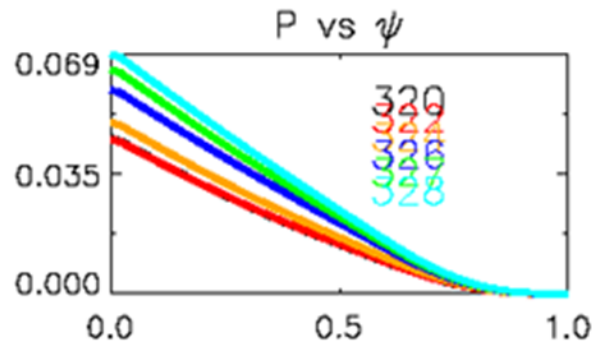
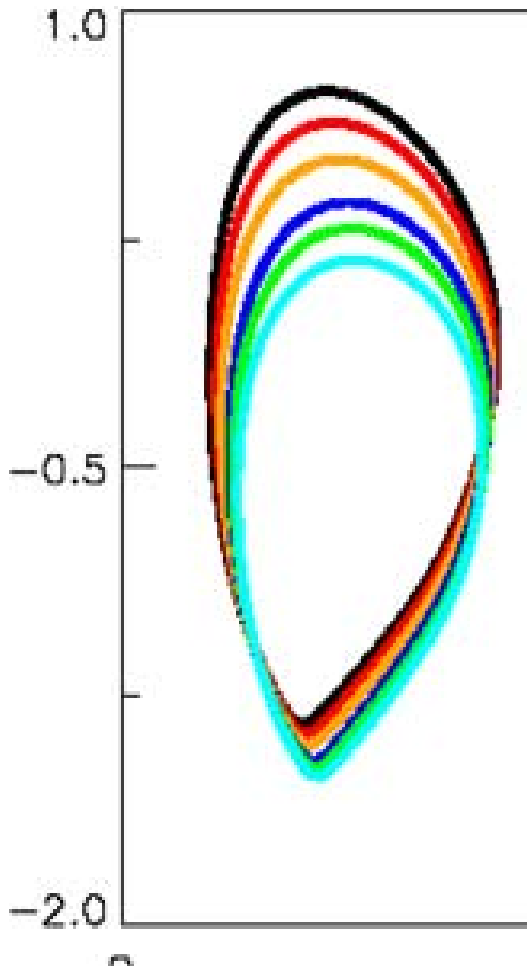
ITER



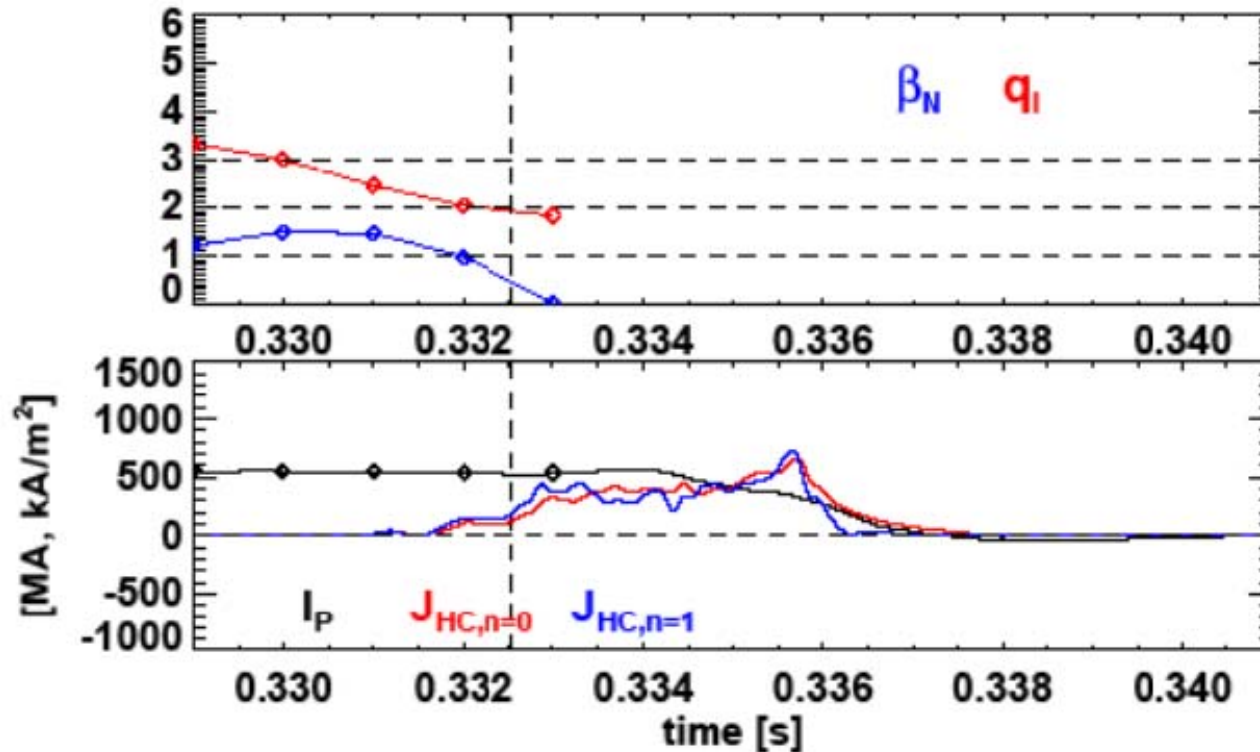
ξ – displacement Surface current



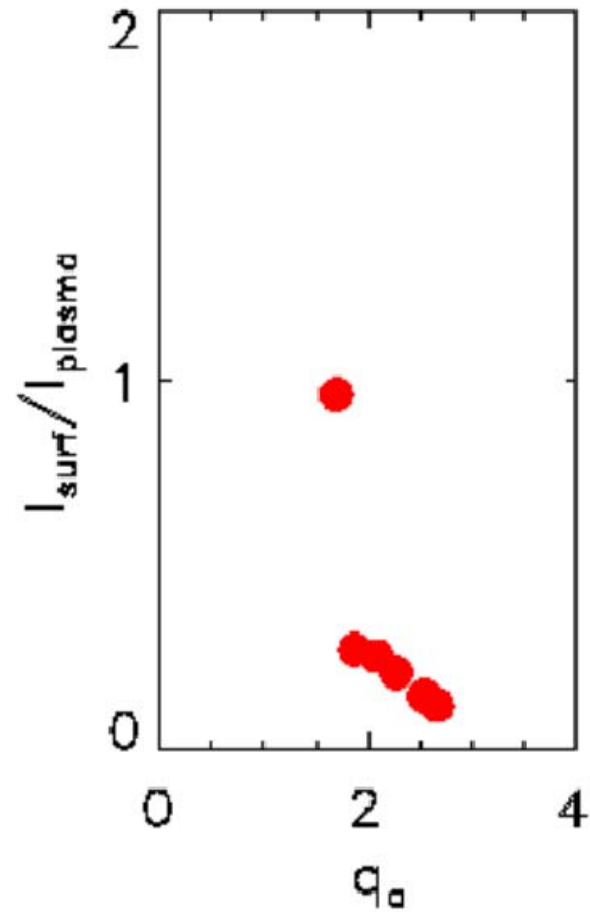
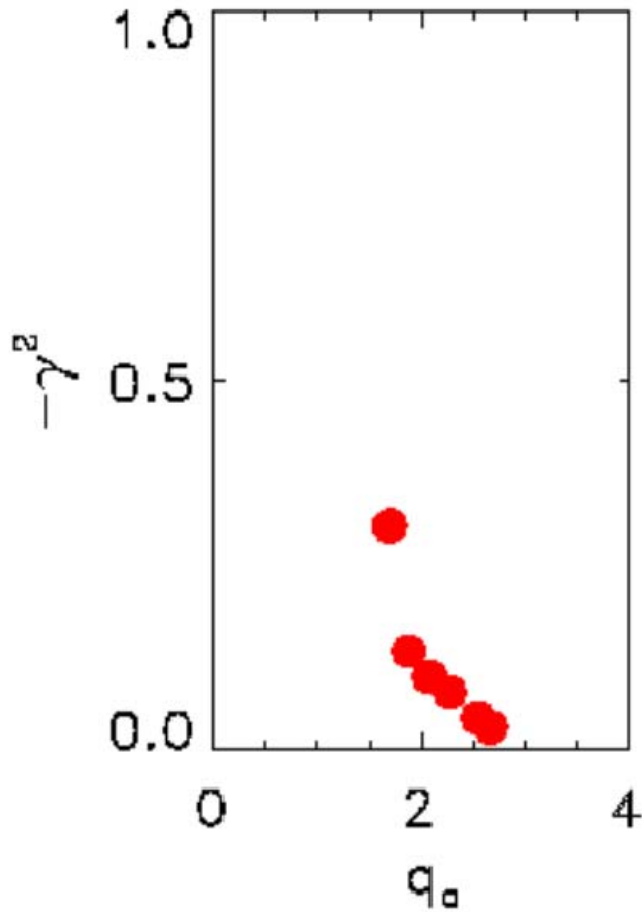
Profiles/Shape vs time (139540)



Halo currents in 139540



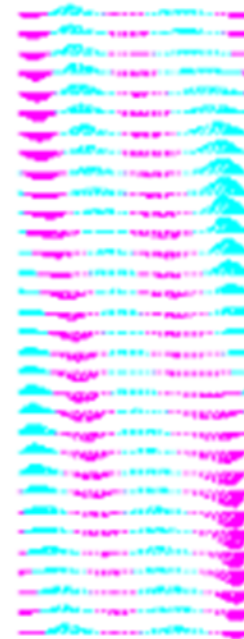
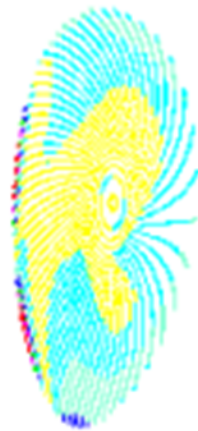
NSTX 139540



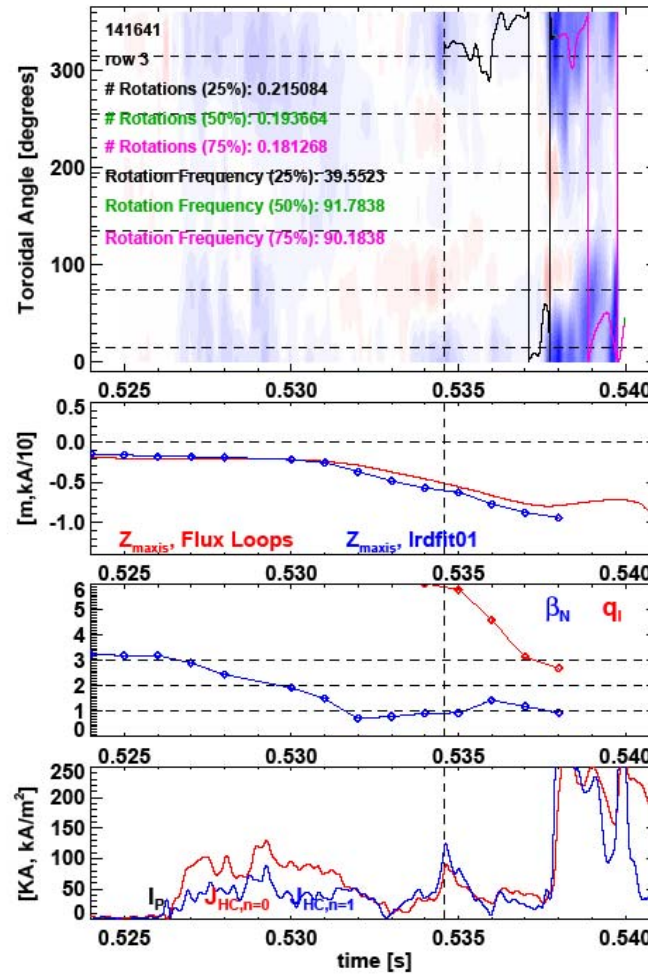
NSTX 139540



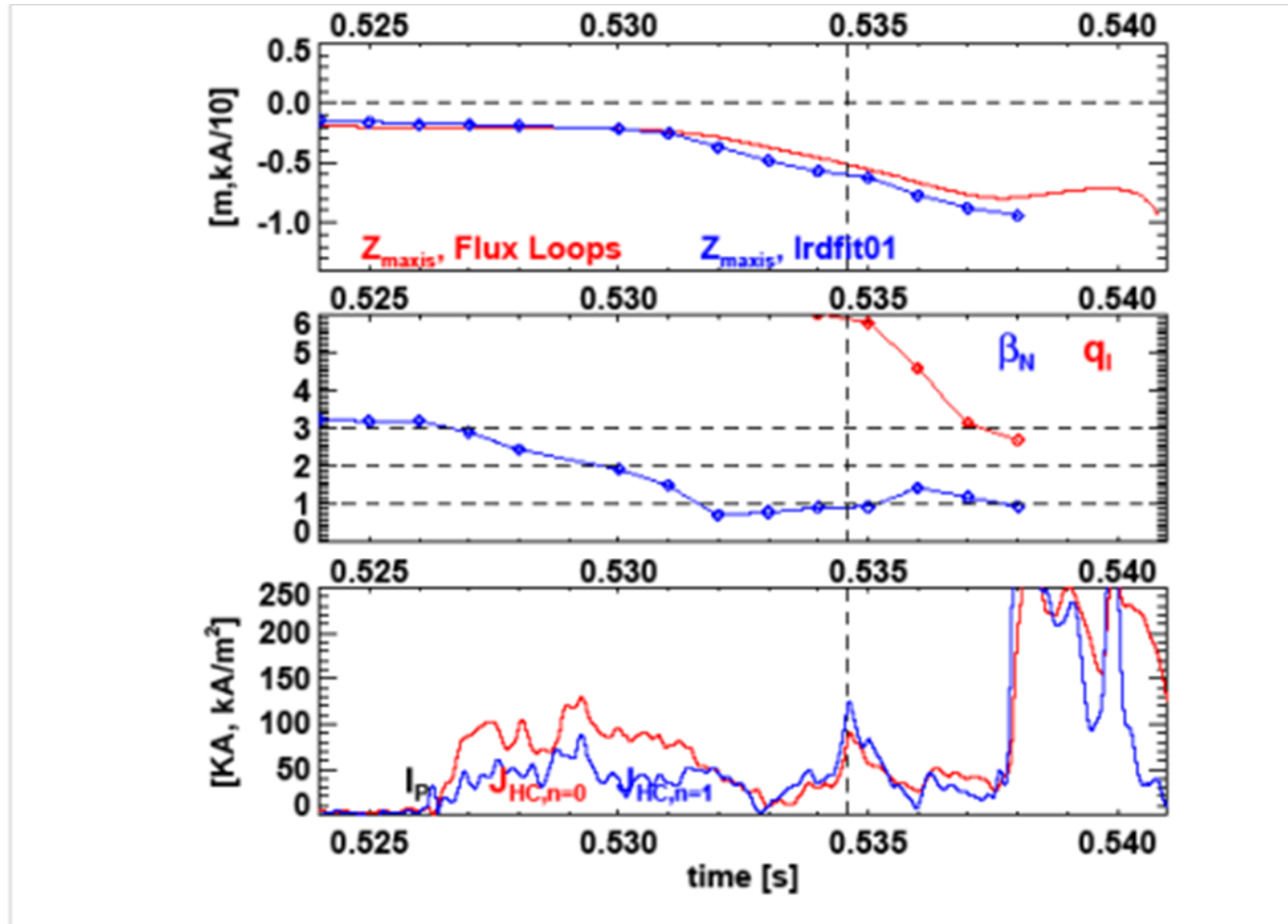
ξ – displacement Surface current



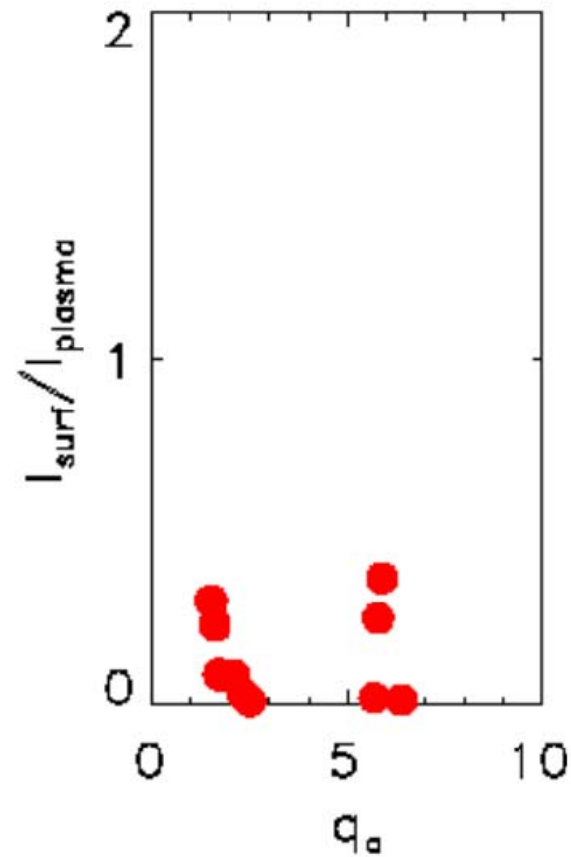
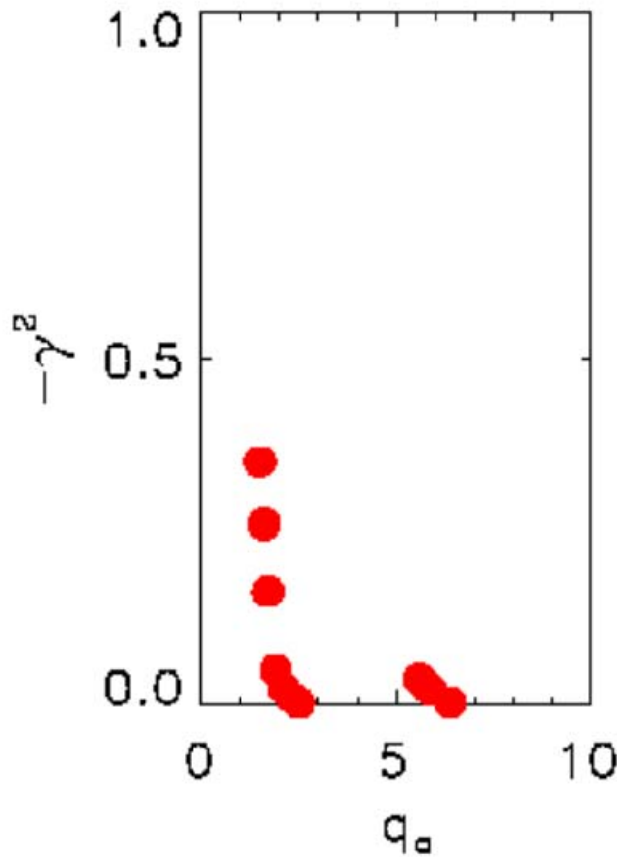
NSTX 141641



Halo currents in 141641



NSTX 141641 *

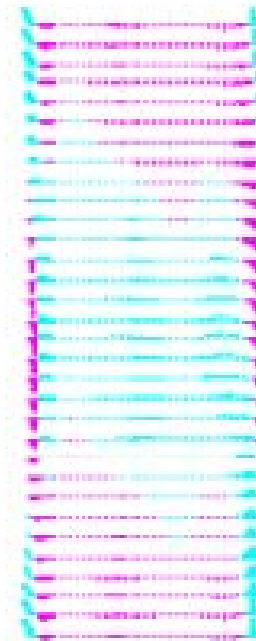


- q was changed by scaling the B-field
- $q = 5$ to 7 used $t = 0.525$ $\beta_N \sim 3$
- $q = 1$ to 3 used $t = 0.533$ $\beta_N \sim 1$

NSTX 141641 $q=5.8$



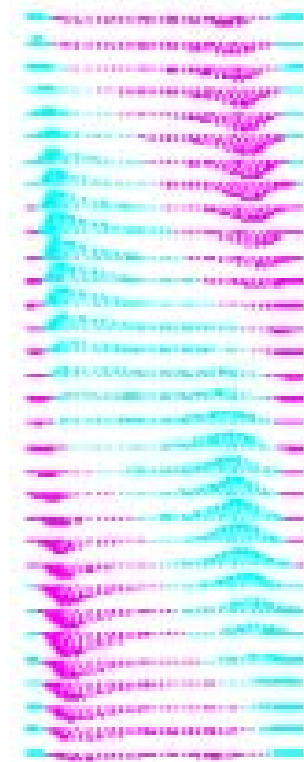
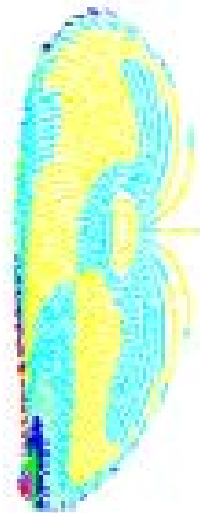
ξ – displacement Surface current



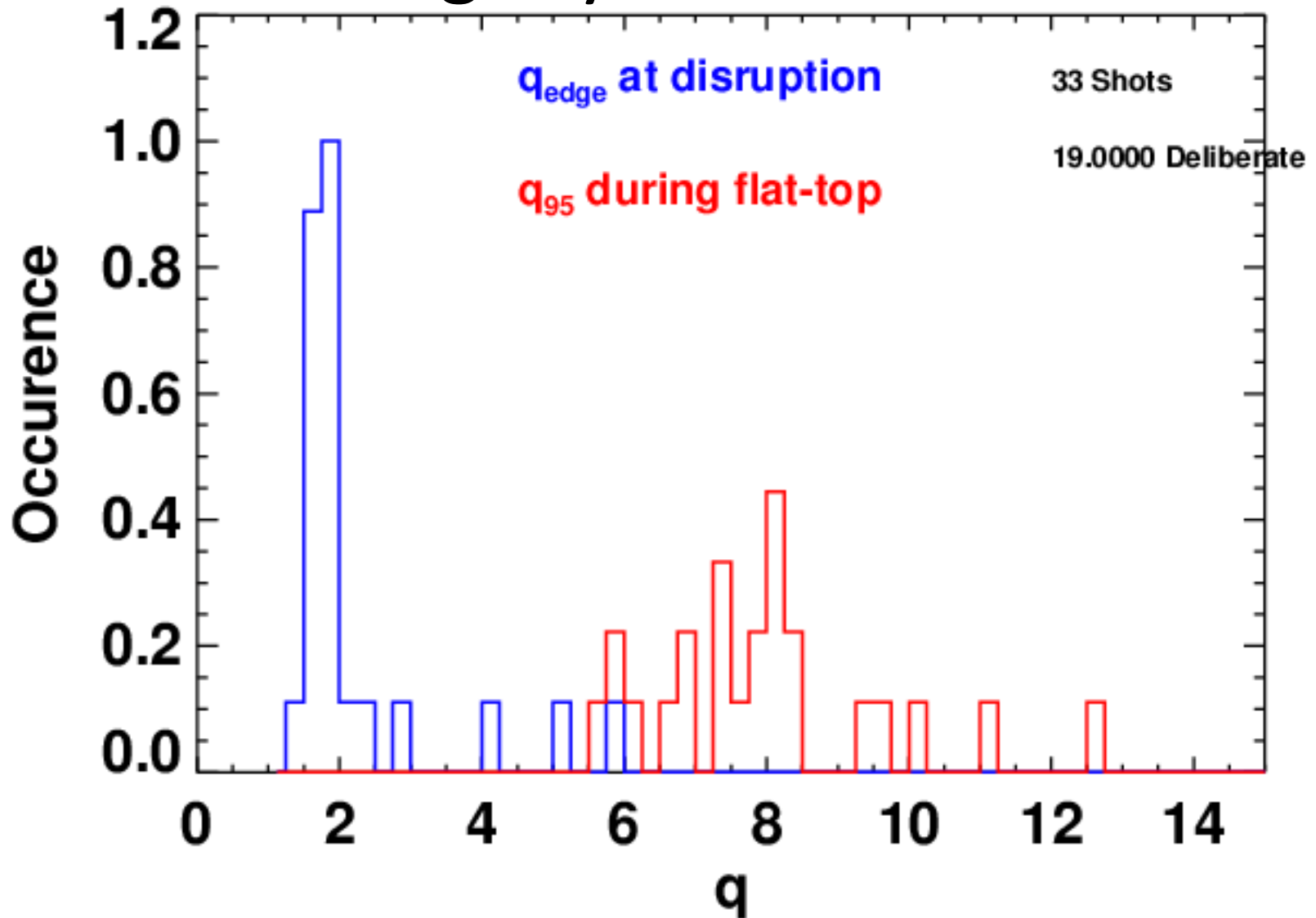
NSTX 141641 $q=2.8$



ξ – displacement Surface current



Most disruptions occur when q is slightly below 2



Summary



- Disruptions during VDEs are most likely due to 2/1 kinks
- The instability grows when q_{edge} drops below 2
- The surface currents due to the magnetic perturbations can be determined
- They are comparable to observed halo currents

Gamma vs q for Shot 139540 (no wall)

