External Kinks are important for Vertical Displacement Event (VDE) evolution.

- External kinks occur during VDEs when plasma interacts with the surface, scraping off the edge region.
- The unstable modes are resonant \((q = m/n)\) outside the plasma.
- Numerically resolving the instability in computations without a VDE help us understand what will be necessary for computations with a VDE.
We construct kink unstable equilibria in cylindrical geometry.

To create a kink unstable equilibrium, we have the $q$ profile near the plasma-vacuum boundary achieve a value consistent with a resonant surface. Initially, the $q$ profile is shown to the right. The results for $T$, $n$, and $p$ for a linear calculation are shown below.
Trying different $q$ values leads to different dominant modes.

- With a $q = 2.35$ throughout the plasma, we get the log energy plots to the right.

- With a $q = 1.8$ throughout the plasma, we get the log energy plots to the right.
External kink unstable equilibria create noticeable plasma distortions.

- Nonlinear cylindrical simulation results shows the shape of the distortion late in time ($t = 870\tau_A$) for a large aspect ratio cylinder ($R/a = 10$). This is for the $q = 1.8$ case.
It is important to distinguish the plasma surface in the numerical representation.

- Too few Fourier components in the simulation cause Gibbs-like phenomena and cause the simulation to crash.
- Below is a low-resolution non-linear run with 6 Fourier components in the azimuthal direction. (Alfvén time units are used.)
The plasma is distinguished with sufficient numerical resolution.

We can see the instability, which looks like a vacuum bubble\(^1\).

\(^1\)Rosenbluth, Monticello, Strauss and White, Phys. Fluids 19 (1976)
We have also tested external kink dynamics in toroidal geometry.

- Linear computation below shows the equilibrium being unstable to a $(1, 1)$ kink mode.
- The profile is also unstable to higher harmonics with $m/n = 1$.

Contours of constant temperature from the linear $n = 1$ eigenmode.

The $q$ profile versus poloidal flux.

The pressure profile versus poloidal flux.
A nonlinear computation with the same equilibrium demonstrates external kink distortion in toroidal geometry.

- Resistivity is determined by the evolving 3D temperature distribution.
- (2,2) and (3,3) components are large in this case.

Surface of constant pressure at $p(0)/8$ shows the plasma shape.
In toroidal geometry, other instabilities may arise, such as ballooning instability.

- The previous toroidal case had equilibria specially tailored to be external kink unstable.
- In realistic geometries other instabilities often arise. The double null case shown earlier exhibits a ballooning like instability.
Conclusions

- External kinks have been simulated in both cylindrical and toroidal geometry.
- External kink evolution requires sufficient numerical resolution of the plasma-vacuum boundary.
- External kink stability can be fairly well predicted based on the simple $q$-profile model.