Error Field Update

Josh Breslau

CEMM Meeting

Denver, Colorado

May 2, 2009

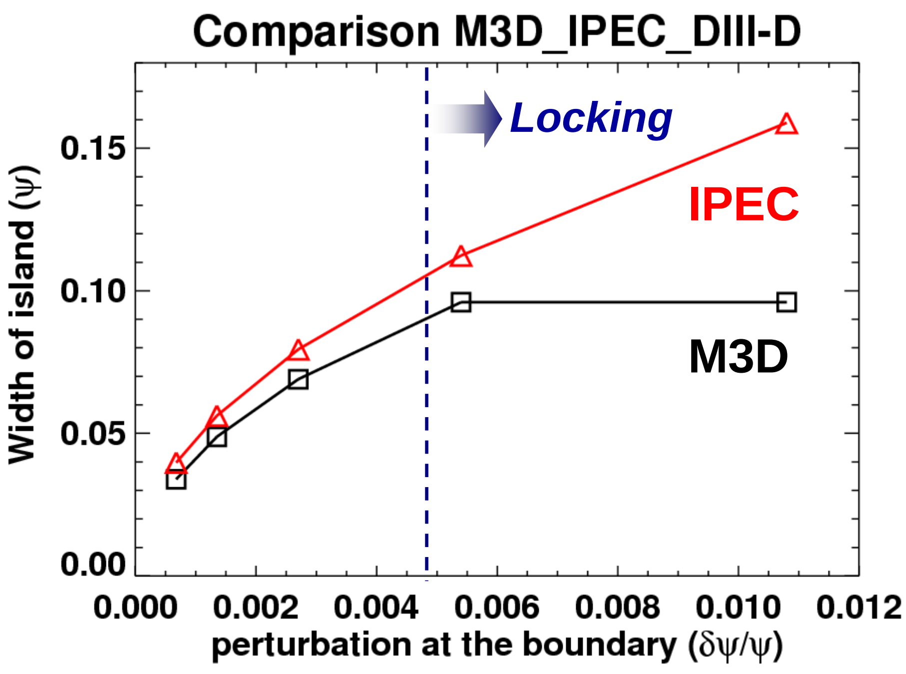
Motivation

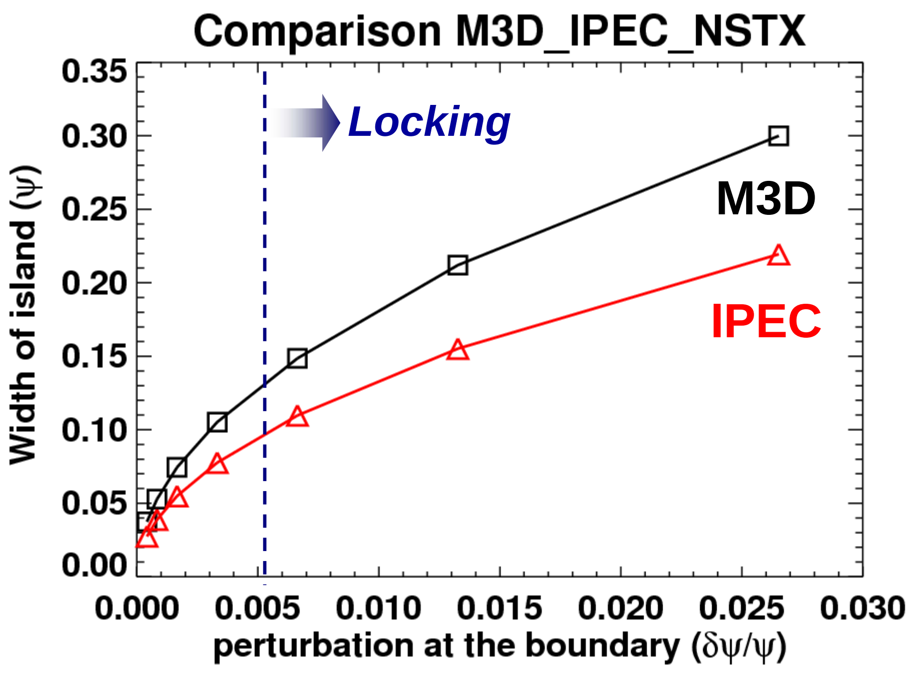
- Left uncorrected, the NSTX error field produces magnetic islands that can mode lock, braking plasma rotation and destabilizing RWMs.
- Analysis with IPEC has helped to predict these effects and design effective mitigation strategies.
- Analysis with M3D can extend these results to the nonlinear, resistive, rotating plasma regime inaccessible to the ideal linear code.
- M3D analysis should be extendable to other RMP effects, such as potential ELM mitigation or destabilization.

2,1 Island Widths agree with Inferred IPEC Widths in Linear Regime

IPEC prediction is inferred from formula based on singular current sheet at rational surface in ideal model, shielding interior. Current sheet was not observable in M3D.

m=2, *n*=1 perturbation applied at boundary





J.K. Park

Isolating Physics Responsible for Current Sheet Formation

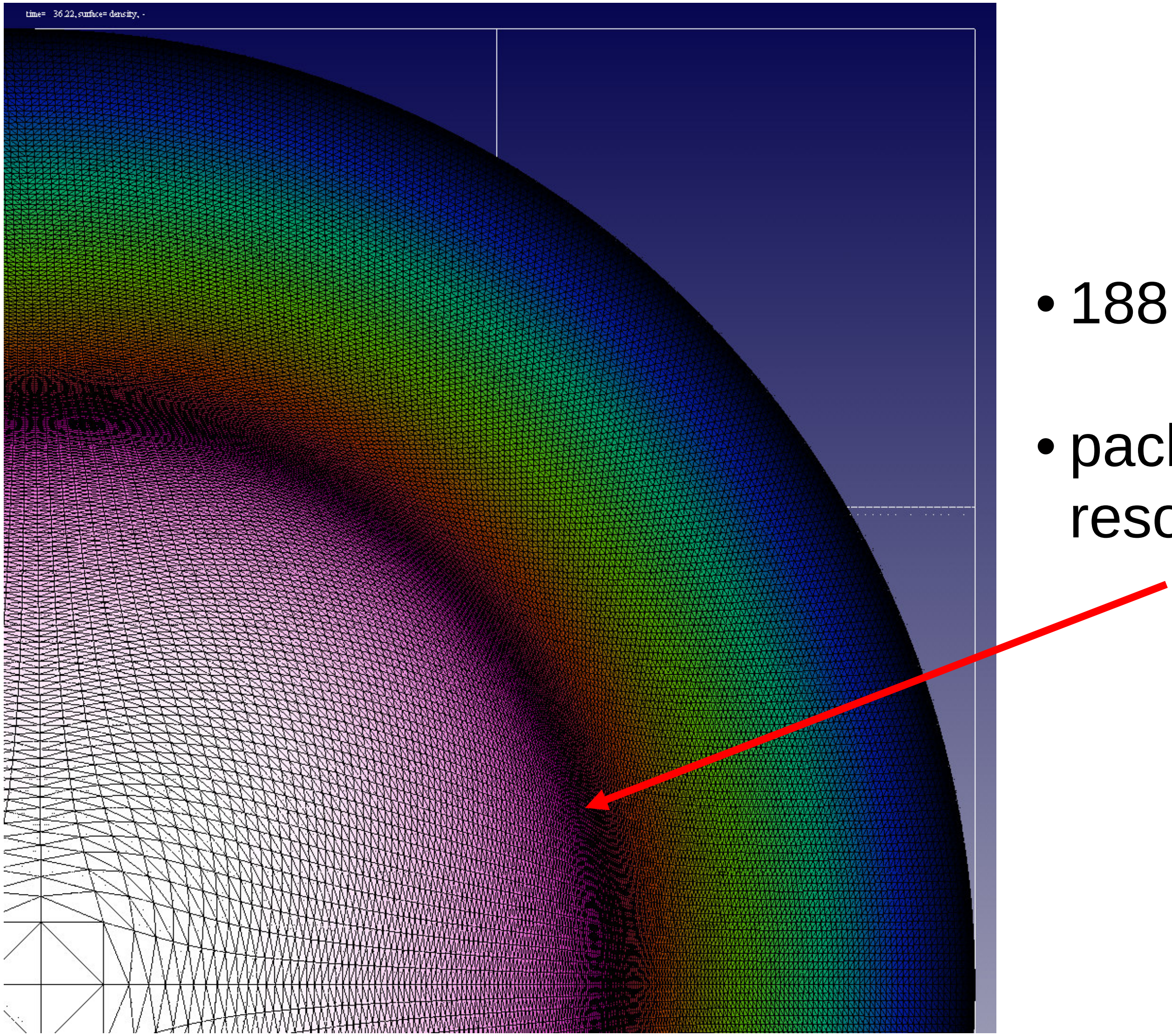
- Connect to analytic theory by approaching straight circular cylinder limit as aspect ratio $A \rightarrow \infty$.

- Equilibria: minor radius=1, periodicity length=6π, B_{ax} = 10 T, q_{min}=3.75 / A

- Perturbations: m=2, n=# of field periods=A/3, `pmag`=7A/3000, $t_{ramp} = 4.0\ \tau_A$.
  (Gives zero-plasma-response island width ~20% of minor radius).

- Parameters: $\eta_{interior} = 10^{-5}$; $\mu_{interior} = 10^{-3;}$ $\eta_{edge} = 10^{-2}$; $\mu_{edge} = 1$

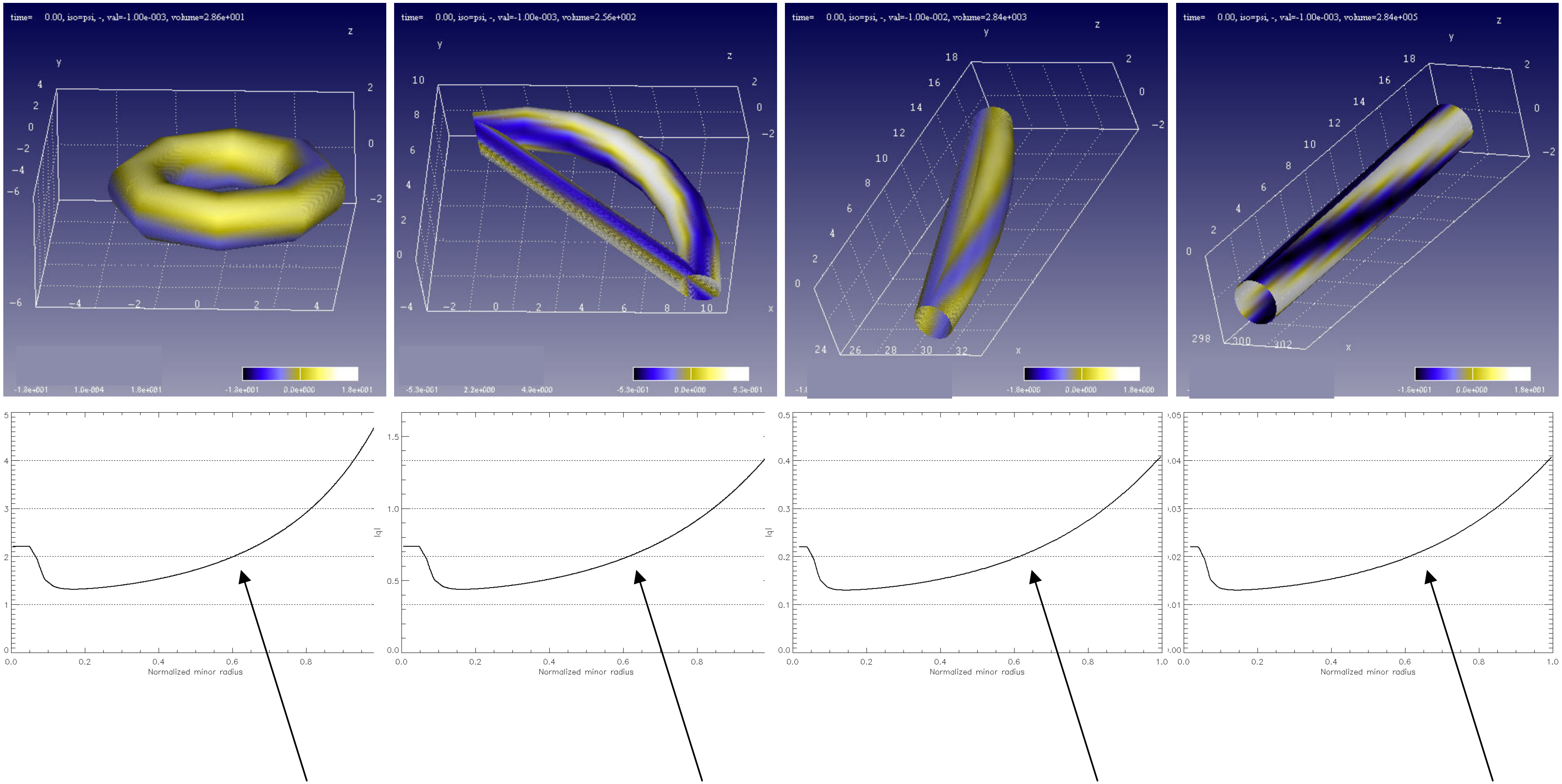
Use High Resolution, Mesh Packing to Resolve Current Sheets



- 188 radial zones
- packing factor 4.0 at resonant surface

Perturbed Equilibria

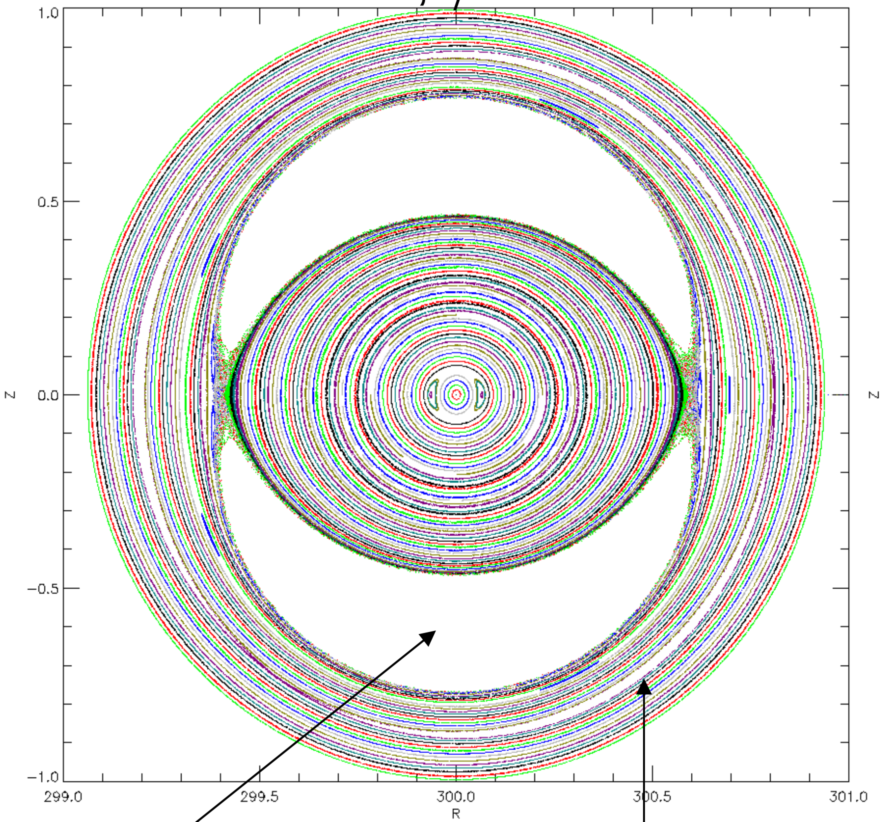
A=3 A=9 A=30 A=300



q = 2 *q* = 2/3 *q* = 0.2 *q* = 0.02

Zero plasma response, large A: Poincaré plots

A=300, $\phi = \pi/100$

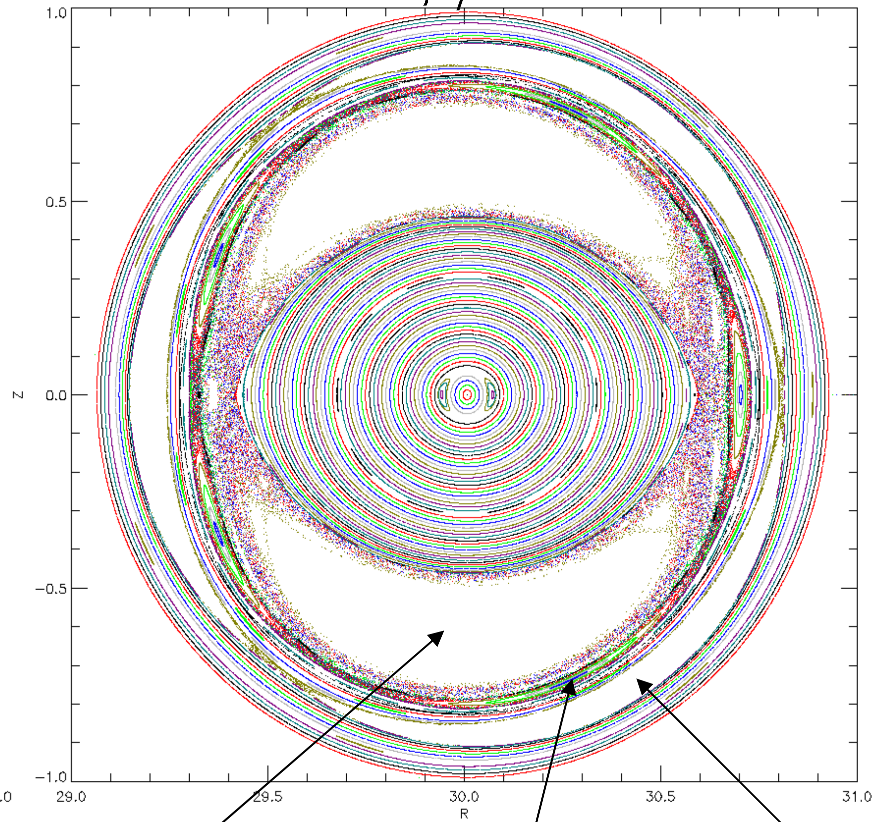


2,100 island
fw = 0.281

3,100 island

"Pure" (2,100)

A=30, $\phi = \pi/10$



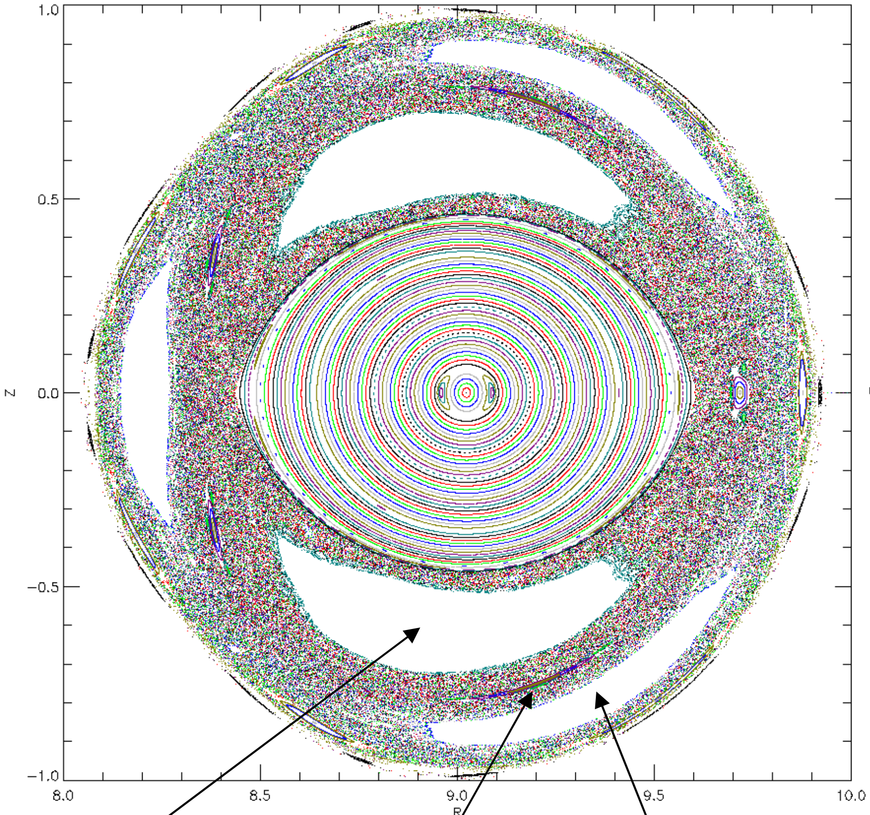
2,10 island
fw = 0.239

5,20 island

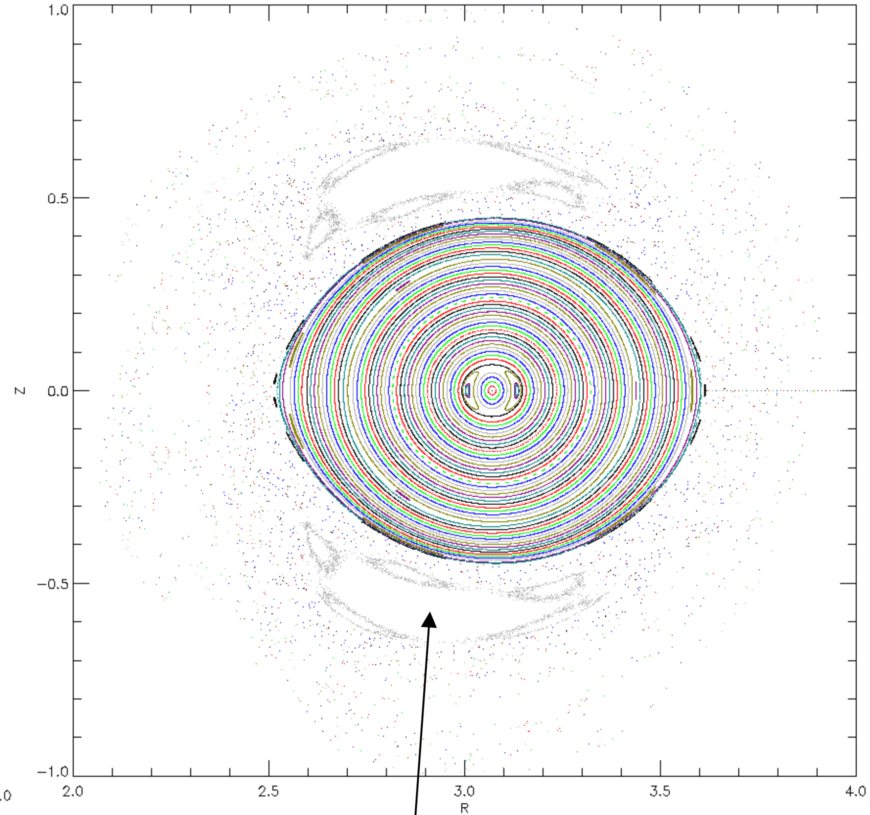
3,10 island

Zero plasma response, small A: Poincaré plots

A=9, $\phi=\pi/3$



A=3, $\phi=\pi$



2,3 island
fw = 0.194

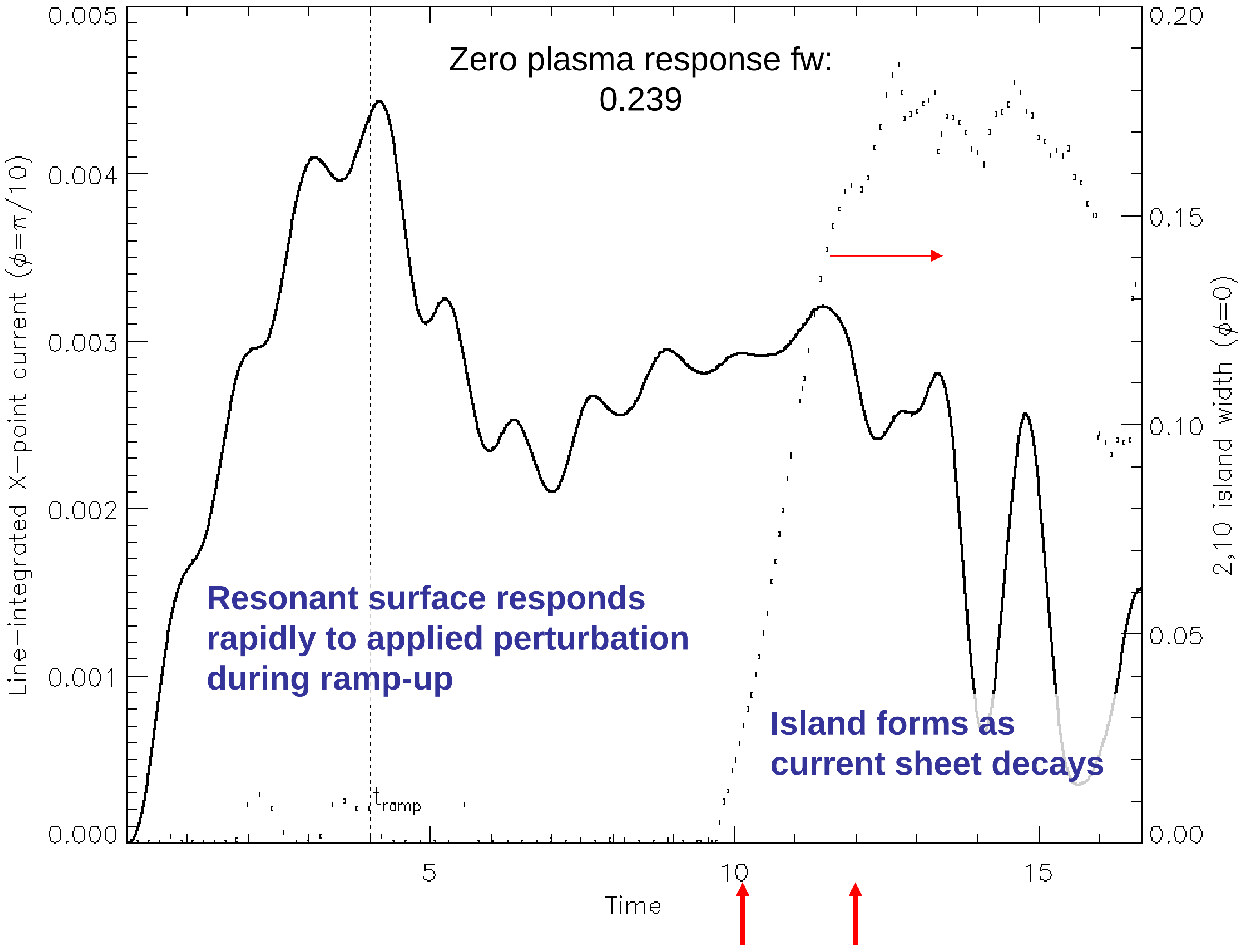
3,3 island

5,6 island

2,1 "island"
fw = 0.116

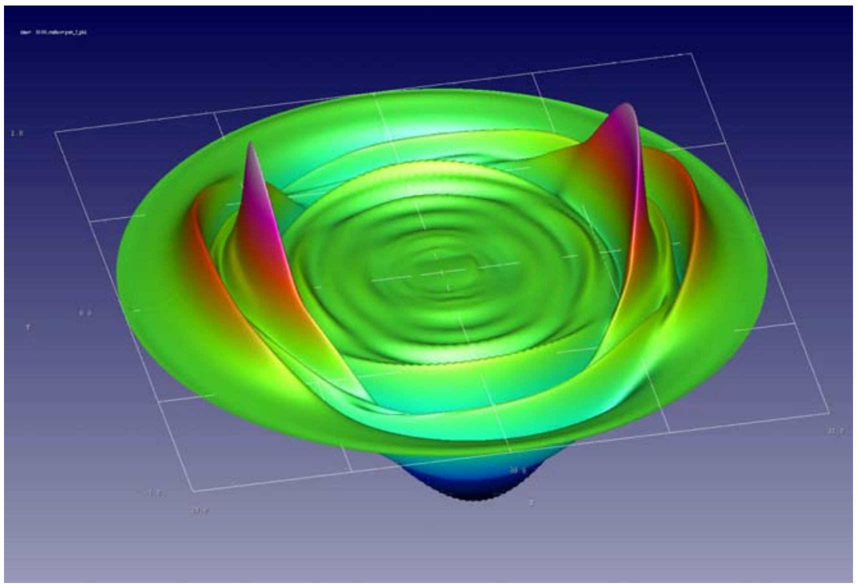
Many modes

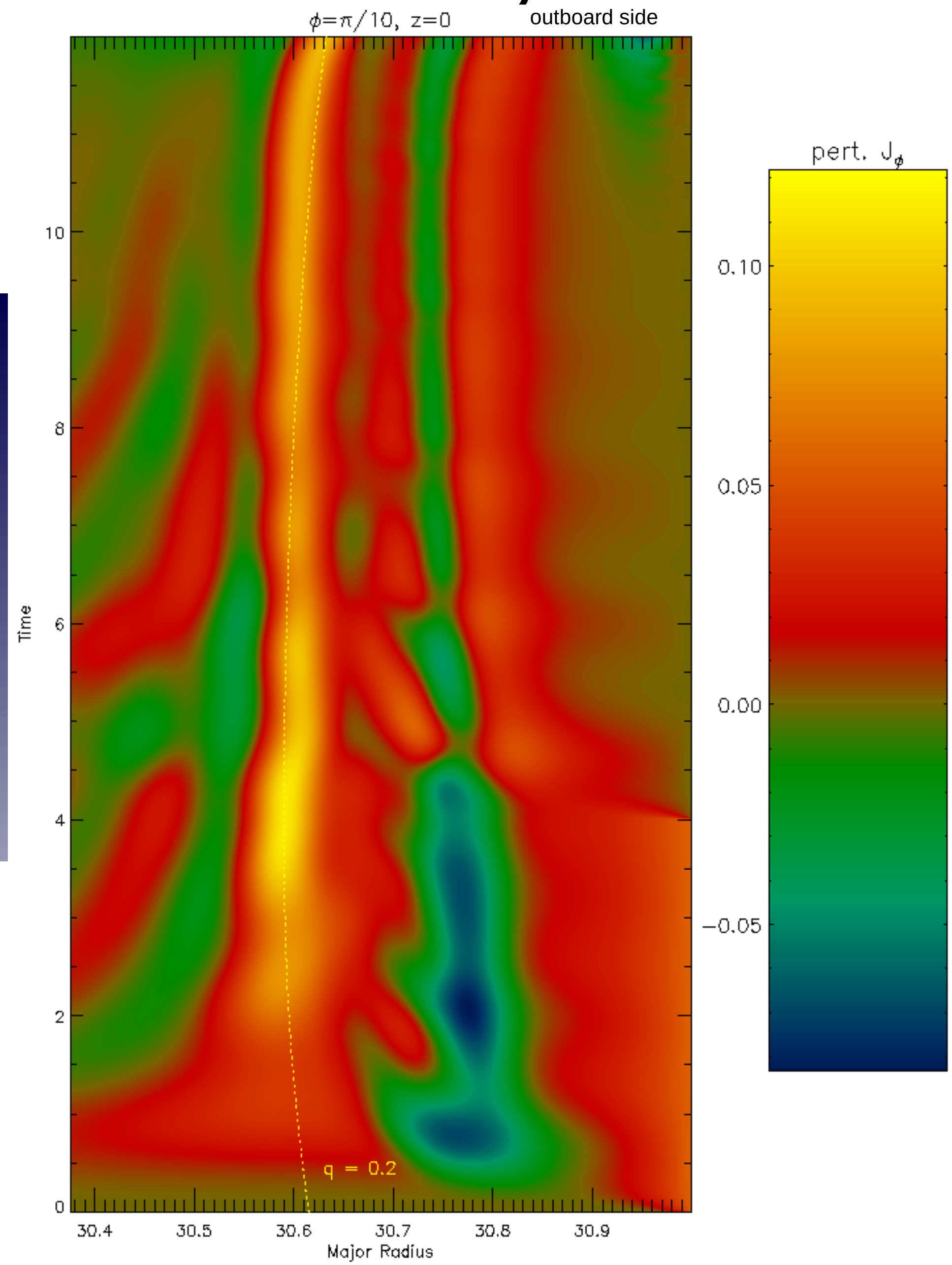
Plasma Response: A=30



Current sheet formation, A=30

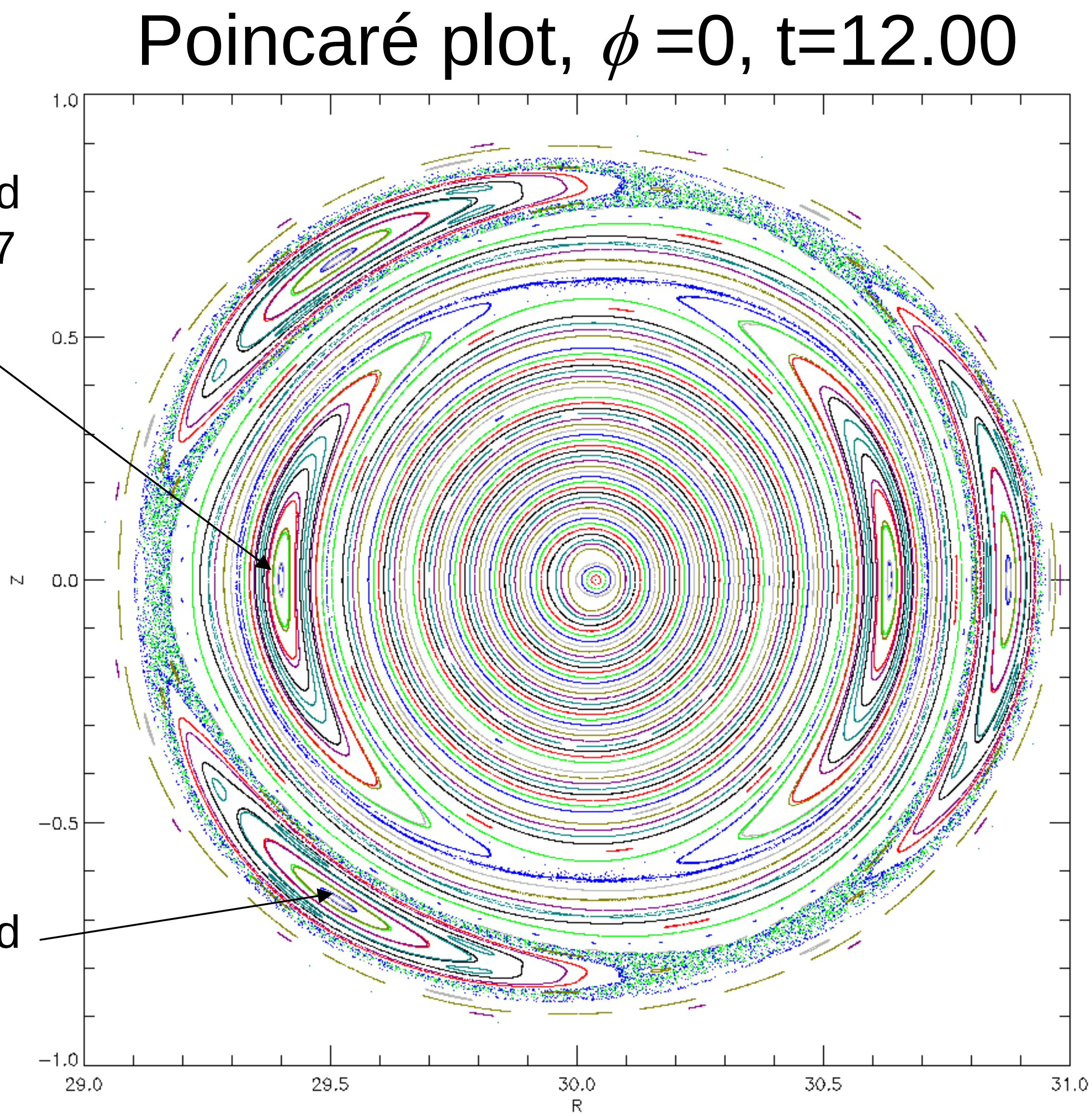
Perturbed component of J_{ϕ},
$\phi=\pi/10$, t =10.00





Island formation, A=30

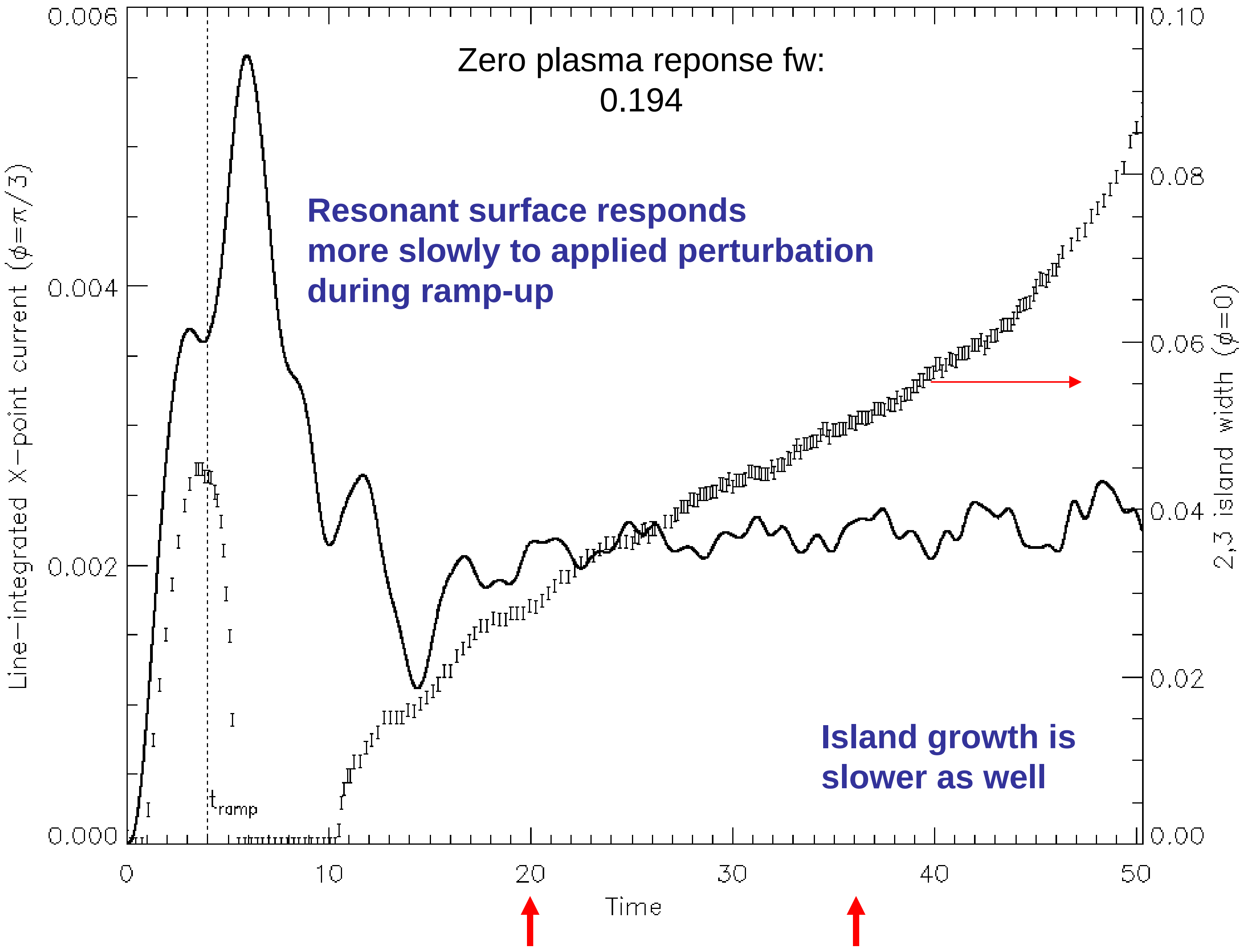
2,10 island
fw = 0.157



3,10 island

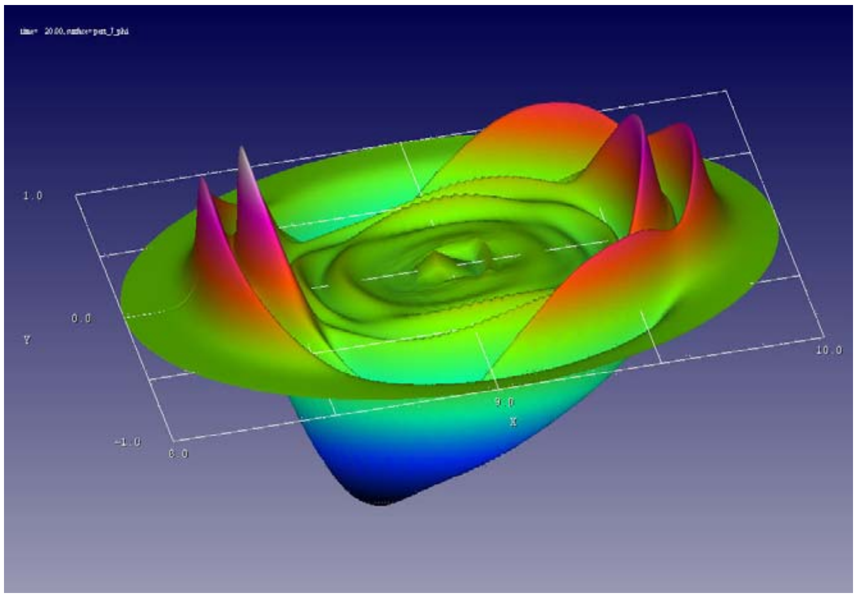
- Plasma response reduces island width compared to vacuum value.(.239)
- Width at later times is limited by overlap, stochasticity.

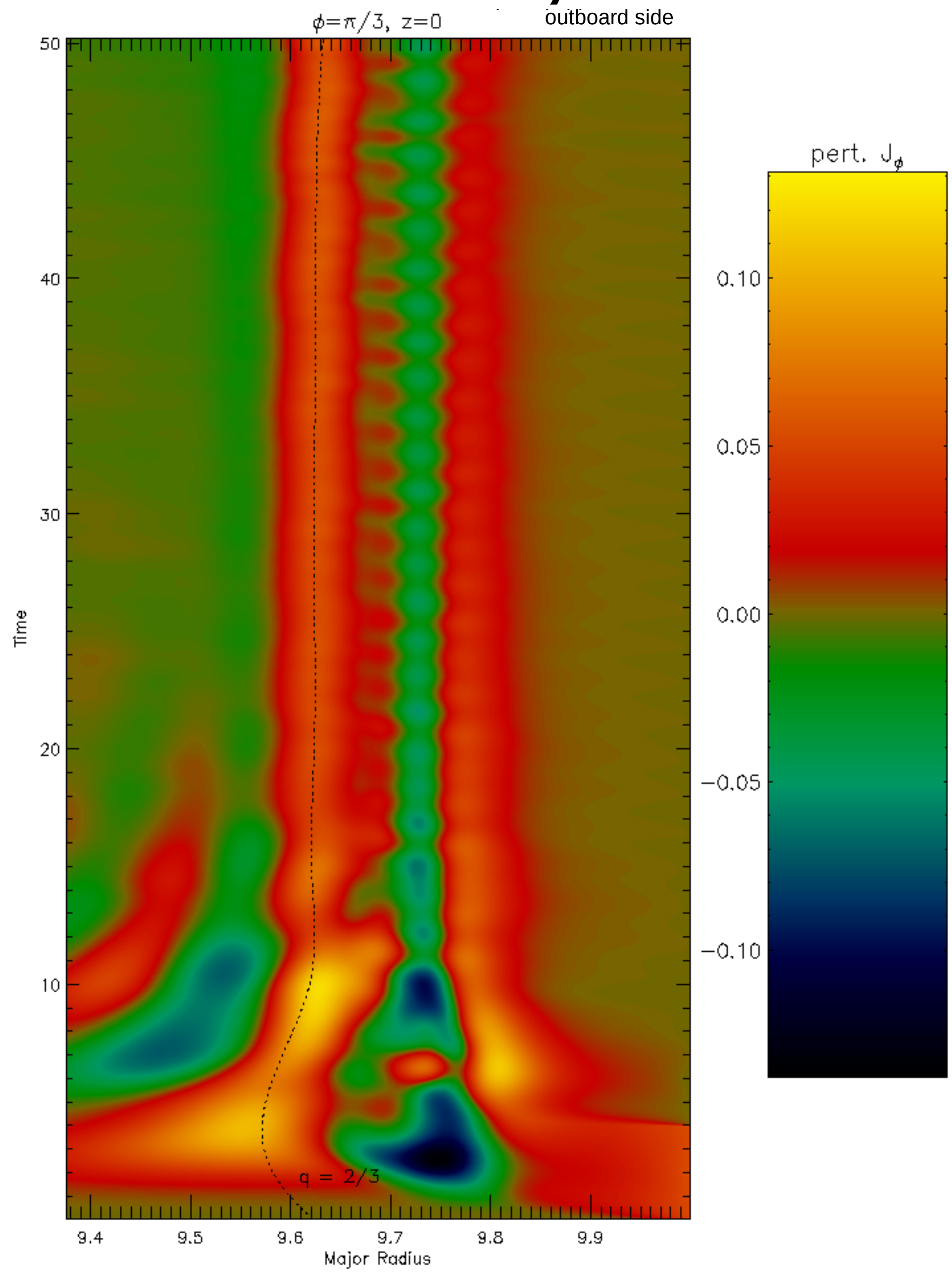
Plasma Response: A=9



Current sheet formation, A=9

Perturbed component of J_ϕ,
$\phi=\pi/3$, t =20.00

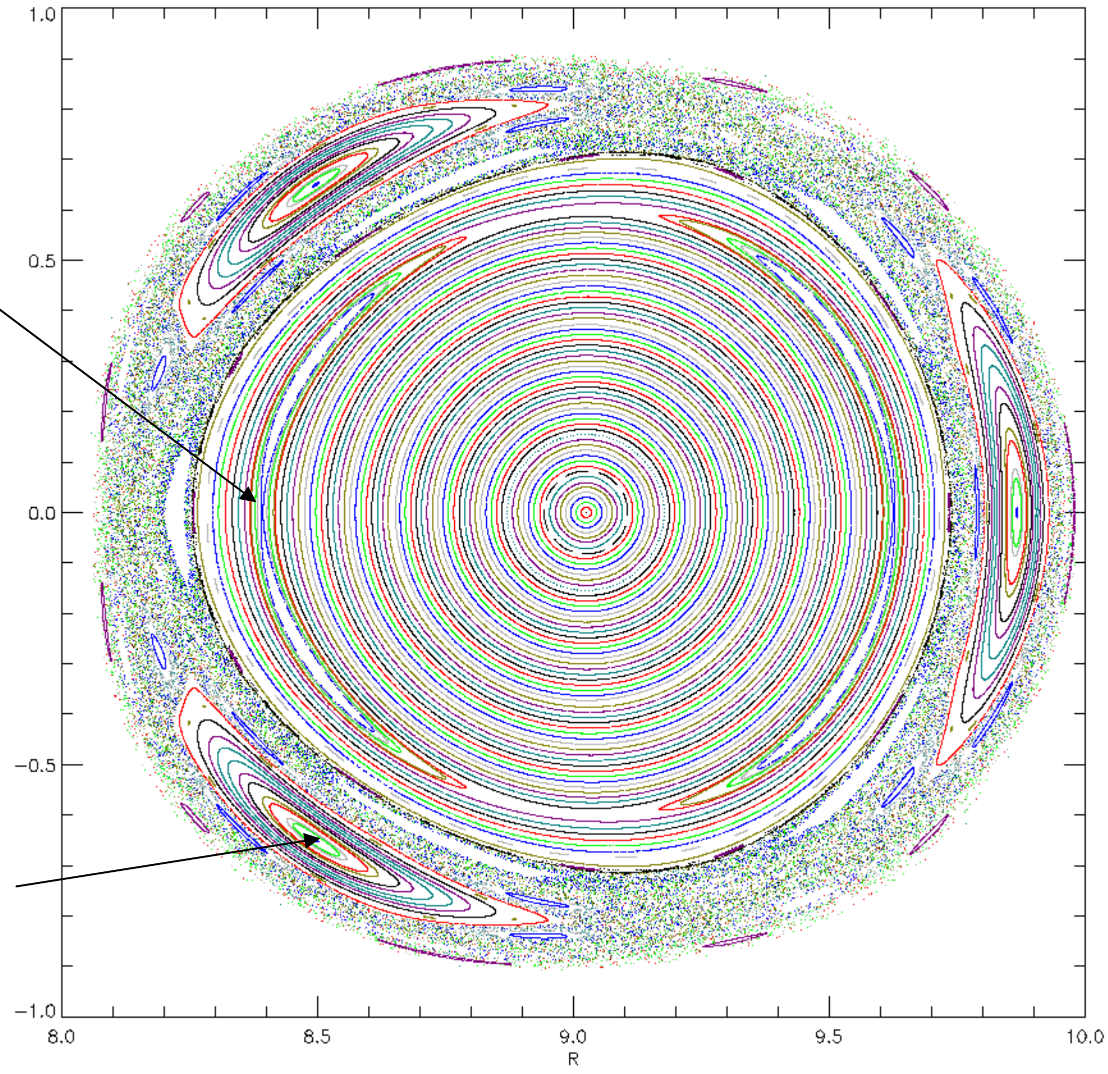




Island formation, A=9

Poincaré plot, ϕ =0, t=36.22

2,3 island
fw = 0.051

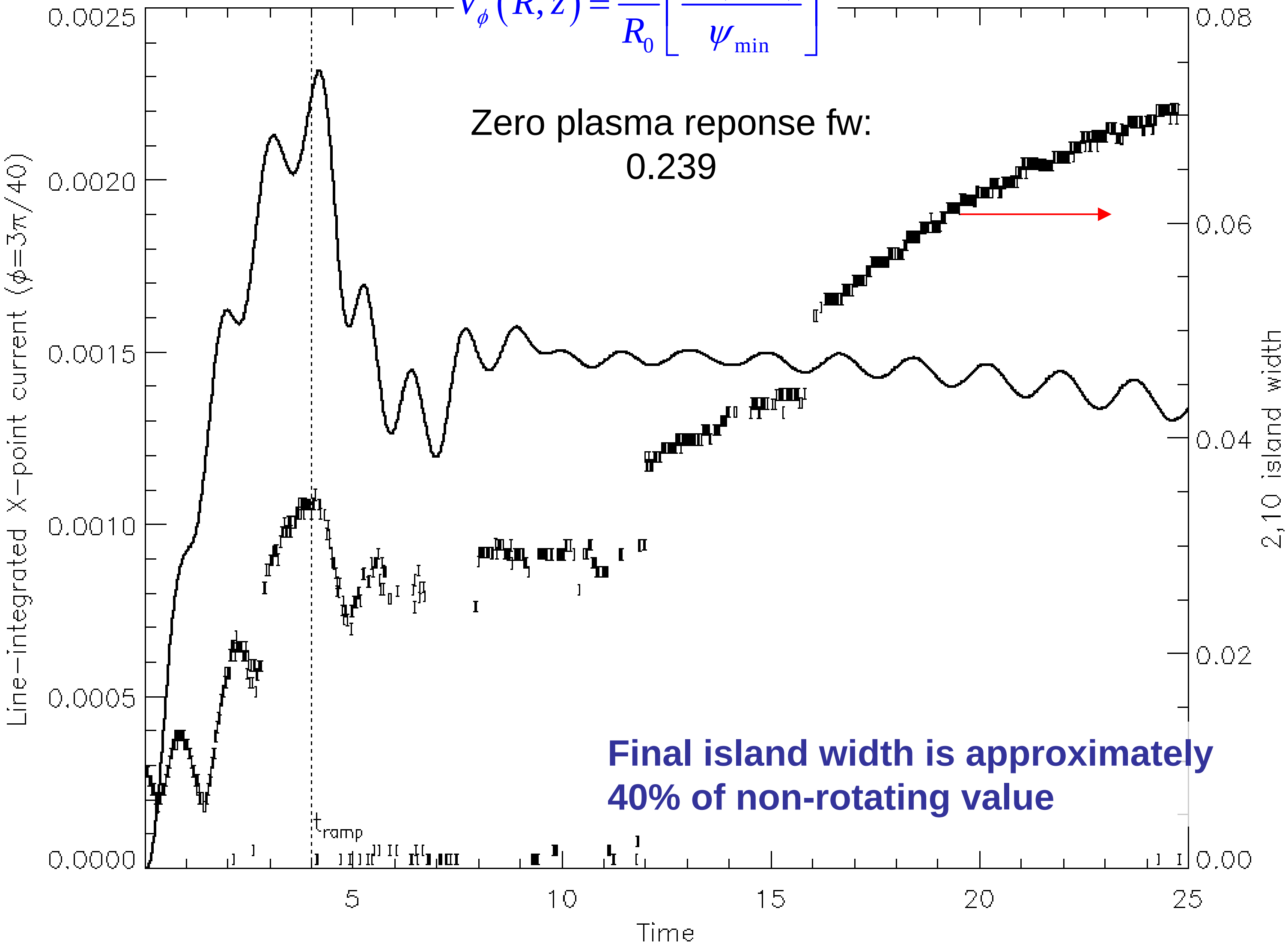


3,3 island

- At lower aspect ratio, toroidal coupling causes non-resonant 3,3 island to respond more strongly than 2,3 island to 2,3 perturbation.

Suppressing Island Growth with sheared toroidal rotation (A=30)

$$V_\phi(R,z) = \frac{R}{R_0}\left[\frac{\psi(R,z)}{\psi_{min}}\right]^2$$



Summary

- M3D island width predictions agree reasonably well with IPEC for tokamak test cases with 2,1 perturbation.
- Observing current sheet responses requires high resolution, suppression of edge response.
- Toroidal effects couple modes at low aspect ratio even with a circular cross-section, leading to preferential induction of islands closer to the plasma edge.
- Rotation suppresses island growth as expected; more systematic study is needed.