DELTA-PRIME CALCULATIONS FOR NCSX

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Motivation: tearing modes in current-carrying stellarators sometimes lead to disruptions, which should be avoided in NCSX.

Assumptions in Δ′ calculation: Cylindrical, 1-D model
Zero β

Neoclassical effects (not included in this study) may suppress growth of tearing modes in QAS configuration of NCSX

Framework of method:

Free potential energy of ideal and tearing modes:

$$\delta W = -4\pi^2 R_o \int_0^b r\,dr \left[\left(\frac{d\psi}{dr}\right)^2 + \frac{m^2}{r^2}\psi^2 + \left(\frac{mr}{m\iota(r) - n}\right)\frac{\mu_o R_o}{B_o}\frac{dj}{dr}\psi^2 \right];$$

ψ = perturbed helical flux function

Euler equation of free energy integral is solved for ψ:

$$\frac{1}{r}\frac{d}{dr}\left(r\frac{d\psi}{dr}\right) - \frac{m^2}{r^2}\psi - \left(\frac{mr}{m\iota(r) - n}\right)\frac{\mu_o R_o}{B_o}\frac{dj}{dr}\psi = 0$$

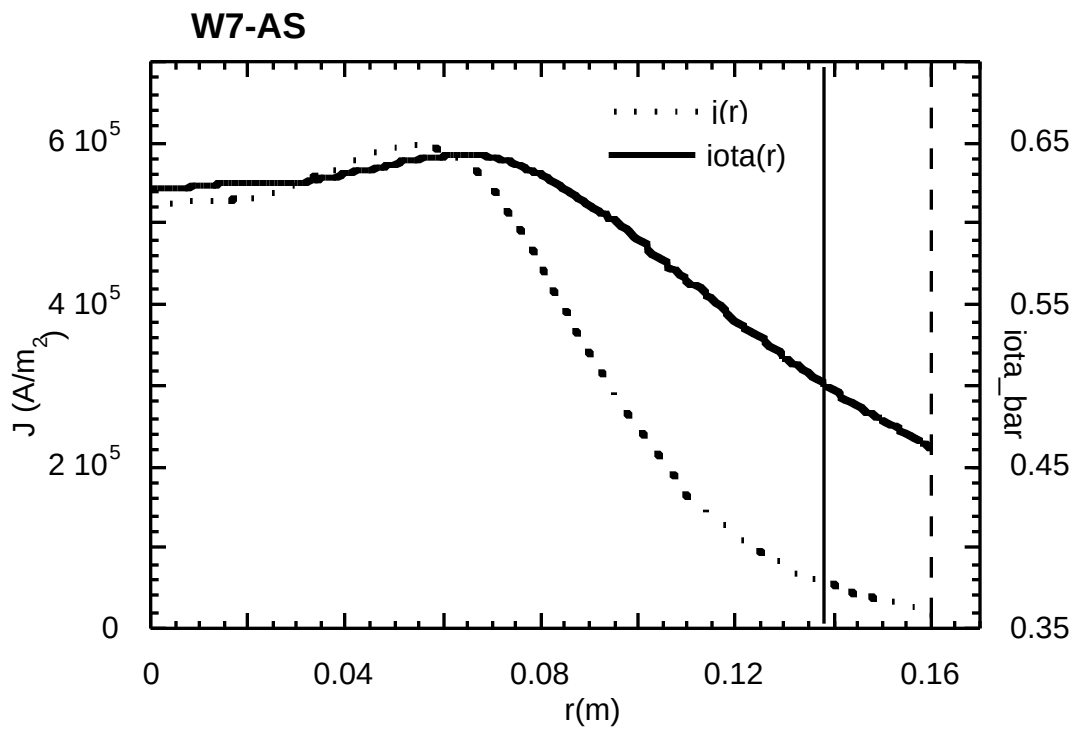
In stellarator, j(r) is partially decoupled from rotational transform.

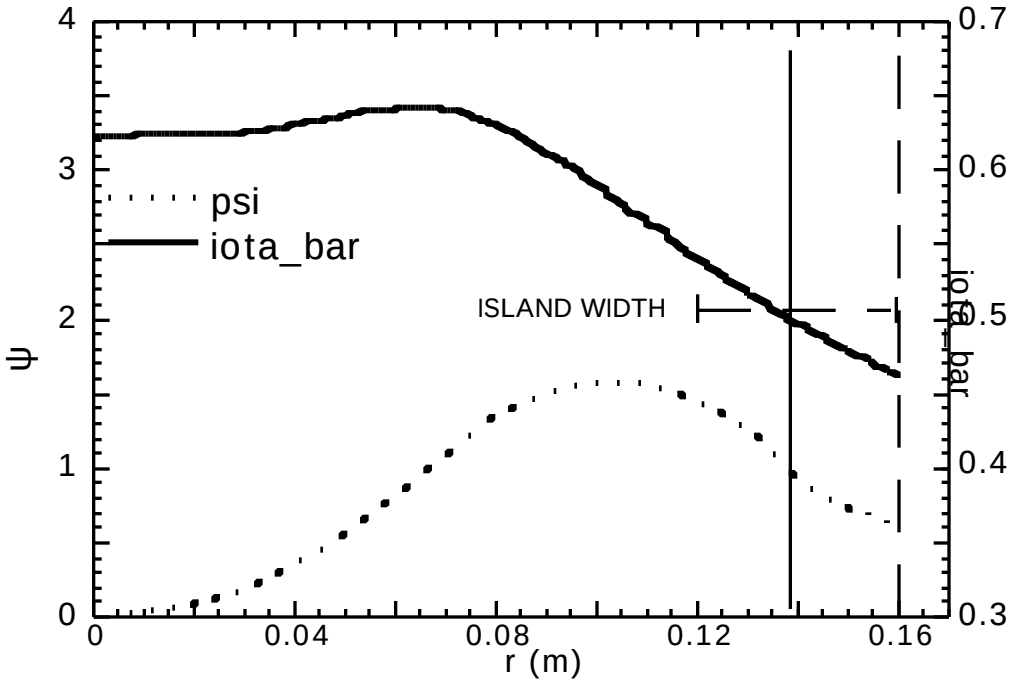
• Tearing modes

$$\Delta'(w) = \frac{1}{\psi(r_s)}\left[\frac{d\psi(r_s+\varepsilon)}{dr} - \frac{d\psi(r_s-\varepsilon)}{dr}\right]_{\varepsilon \to 0}$$

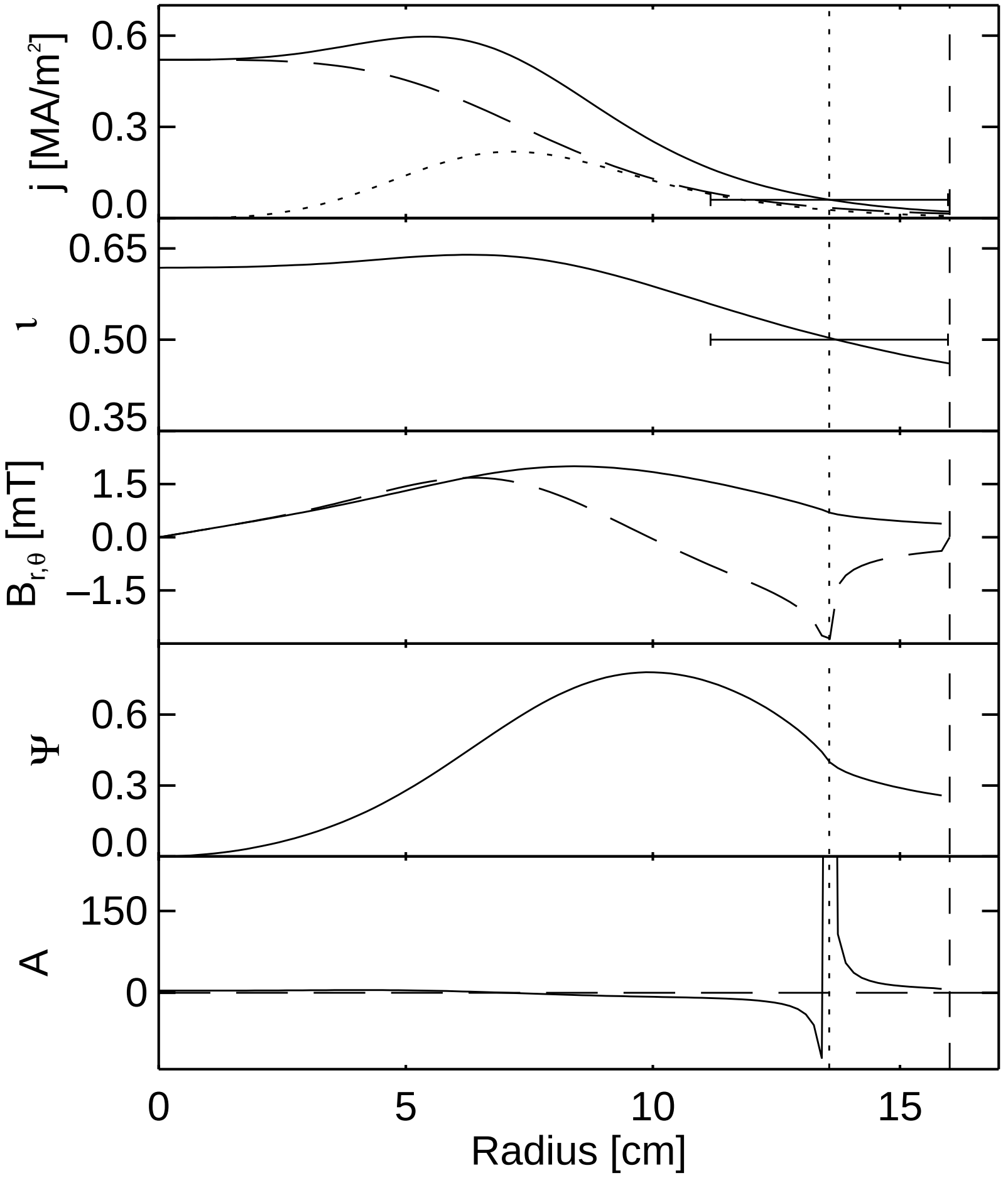
• Kink modes: ψ(r) has a root at 0 < r < b.

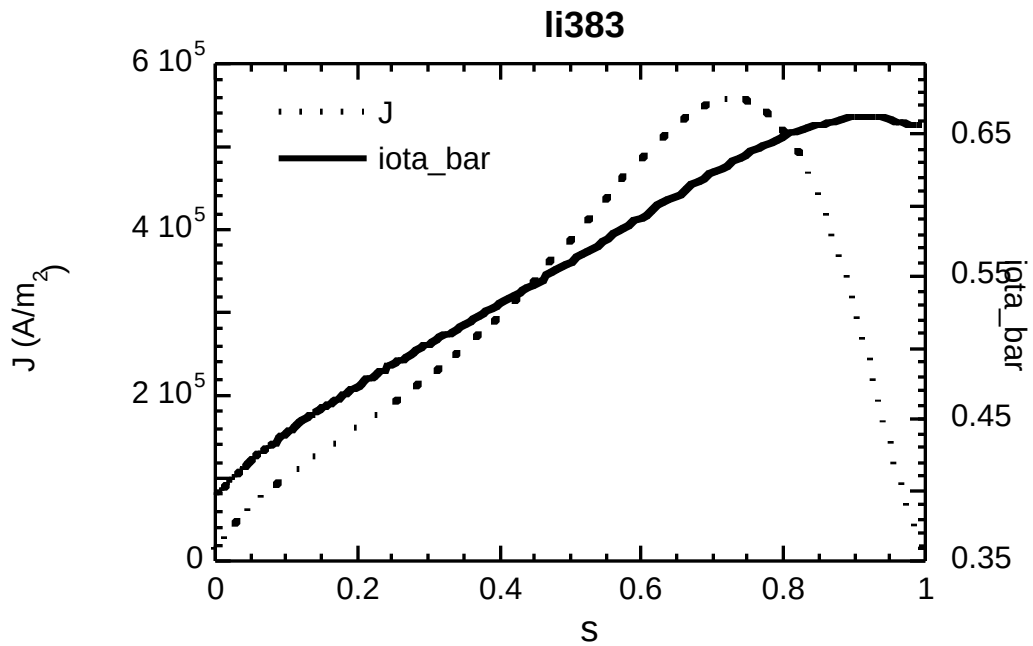
- Benchmarked against W7-AS calculation and experiment.
- Examined li_383, hi_3351, & ii395 NCSX cases.

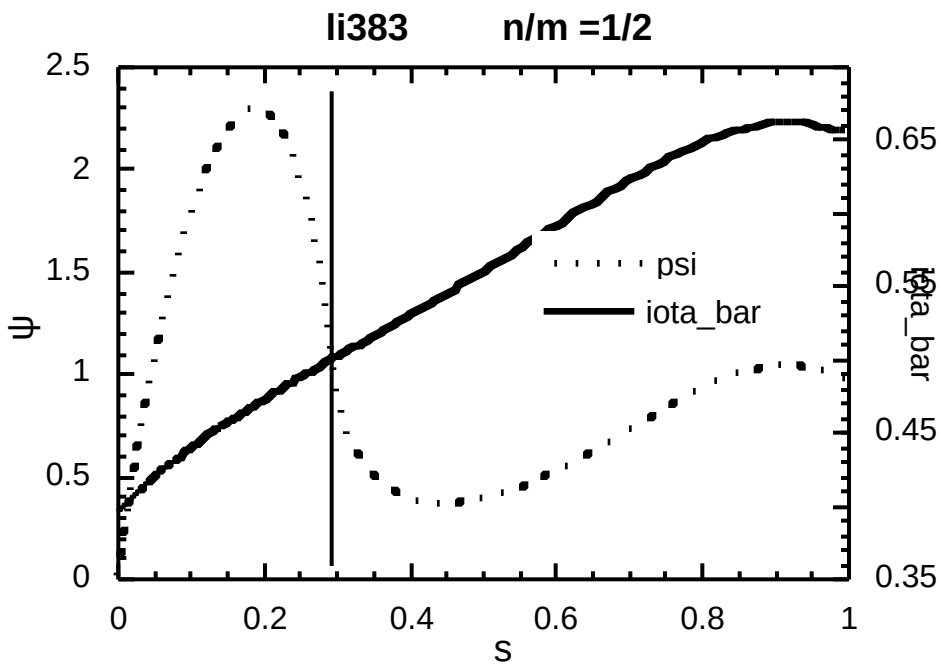




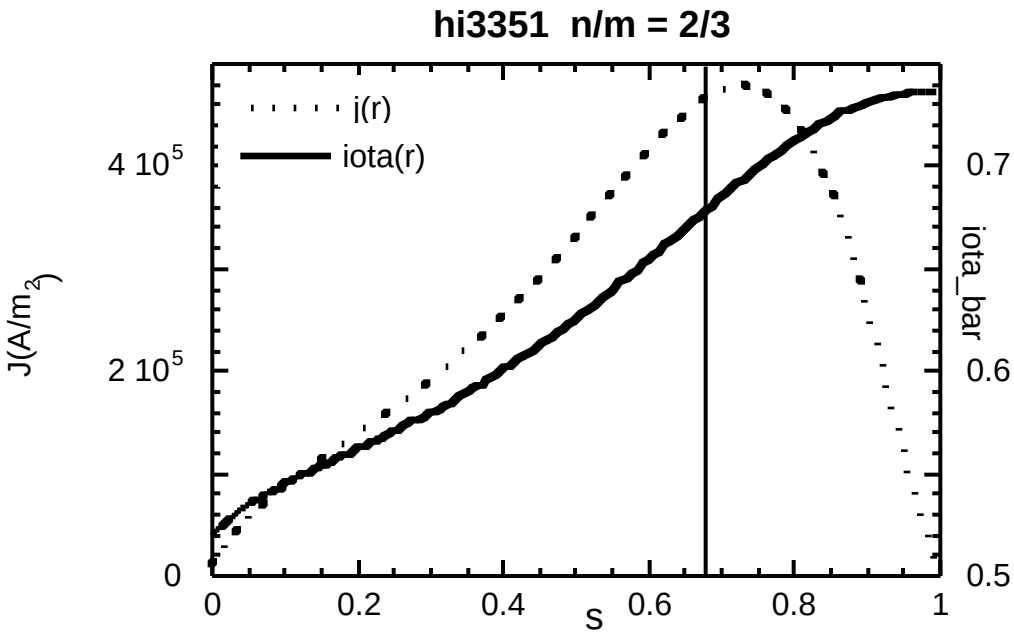
Modeling of W7-AS shot #47623 shown in E. Sallander et al, paper presented at 12 Int, Workshop on Stellarators, Madison, 1999; & Nucl. Fusion **40**, 1499 (2000)
Shown on next page is corresponding figure from W7-AS paper.

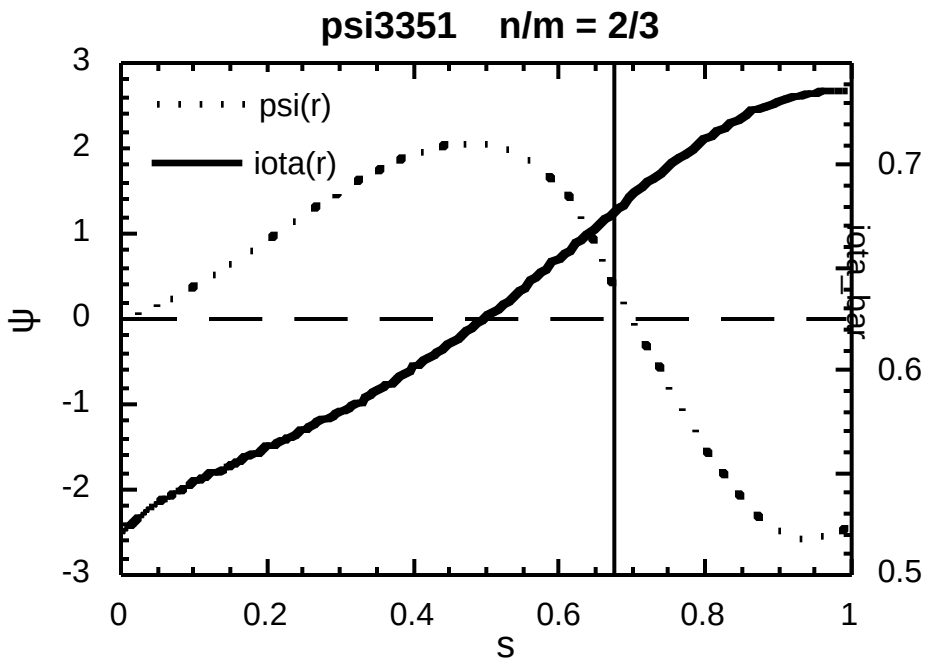

j [MA/m²]
0.6
0.3
0.0
ι
0.65
0.50
0.35
B_{r,θ} [mT]
1.5
0.0
–1.5
Ψ
0.6
0.3
0.0
A
150
0
0
5
10
15
Radius [cm]



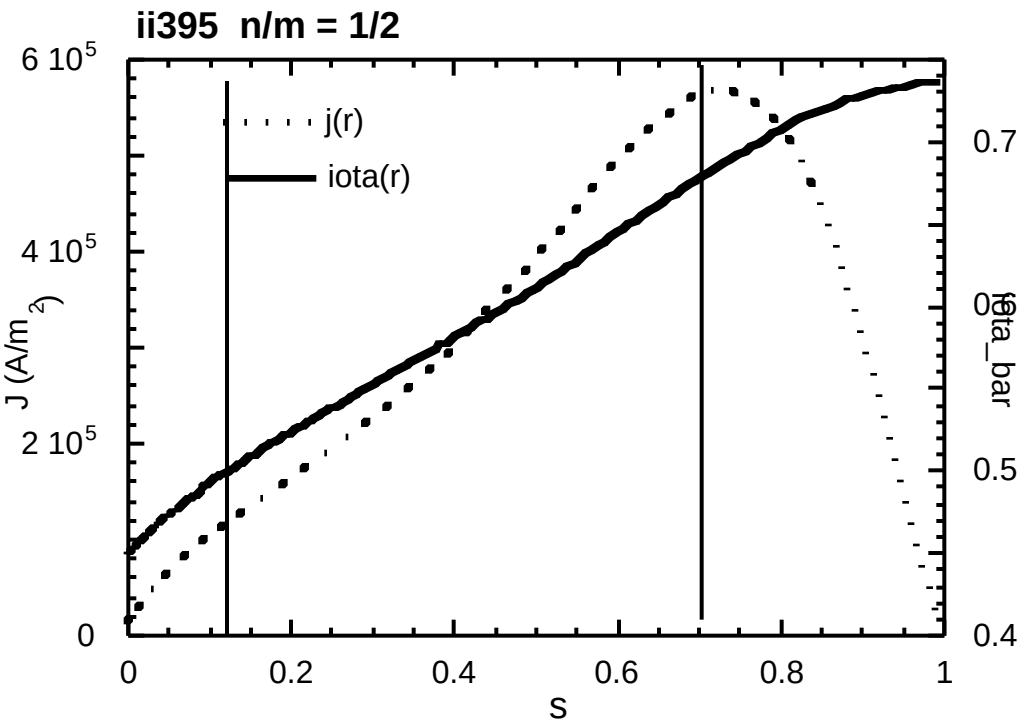


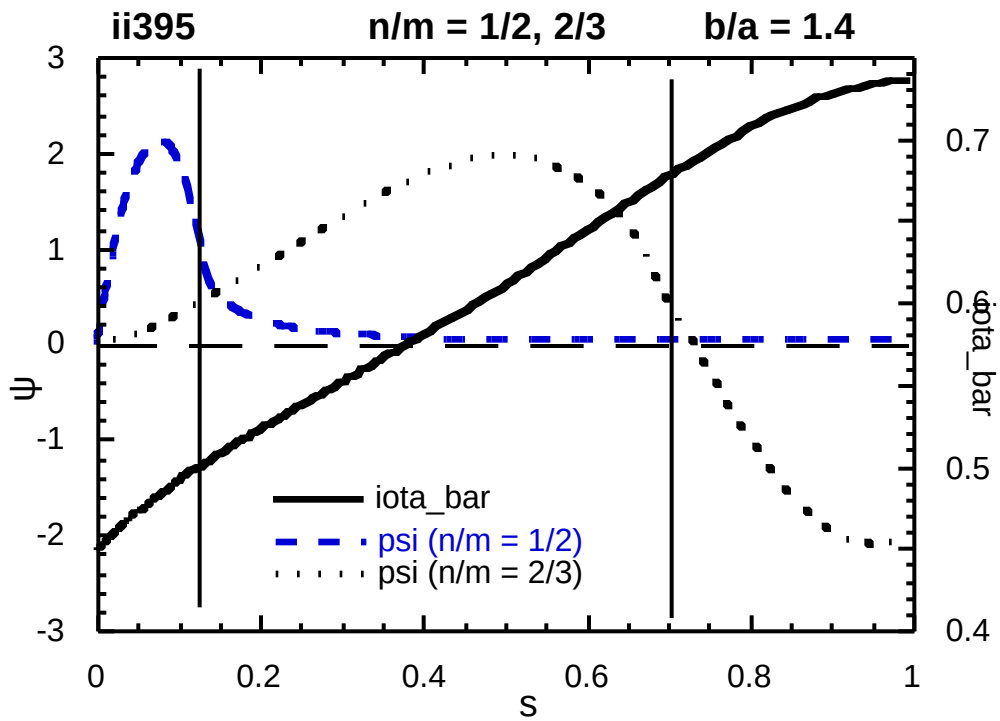
Li_383: Unstable to n/m = 1/2 tearing mode; $\Delta' = 40\ m^{-1}$.





Hi_3351: stable to n/m =2/3 tearing mode, but Ψ changes sign, indicating internal kink instability.





ii395: unstable to n/m = 1/2 tearing mode, stable to n/m = 2/3 tearing mode, but the 2/3 is ideally unstable.

Summary of delta-prime calculations

	li383	**ii395**		**hi3351**
n/m	1/2	1/2	2/3	2/3
r_s (m)	0.215	0.139	0.321	0.302
Δ' (m^{-1})	40	48.6	-65.6	-17.0
$\Delta' r_s$	8.6	6.8	-21.1	-5.2
width (m)	0.07	0.04	stable	stable

b/a varied between 1.2 & 1.4; little change in Δ'.

Conclusions

- The n/m = 1/2 tearing mode was found to be unstable in both cases in which the resonance was present in the plasma. The resonance was well in the interior, and the growth rate may be low due to the high temperature. Also, it is possible that the mode may be stabilized by neoclassical effects. It is interesting to note that in W7-AS, n/m = 1/2 modes are not destabilized with bootstrap & Ohkawa currents alone (no OH) even though the Δ' analysis predicts instability.

- The n/m = 2/3 tearing mode was stable in both ii395 and hi3351, although an ideal internal kink instability was predicted for both. The possibility of internal, and external, kinks should be looked at further, but can be more accurately evaluated with TERPSICHORE .