Δ’ calculations with neoclassical terms and error fields

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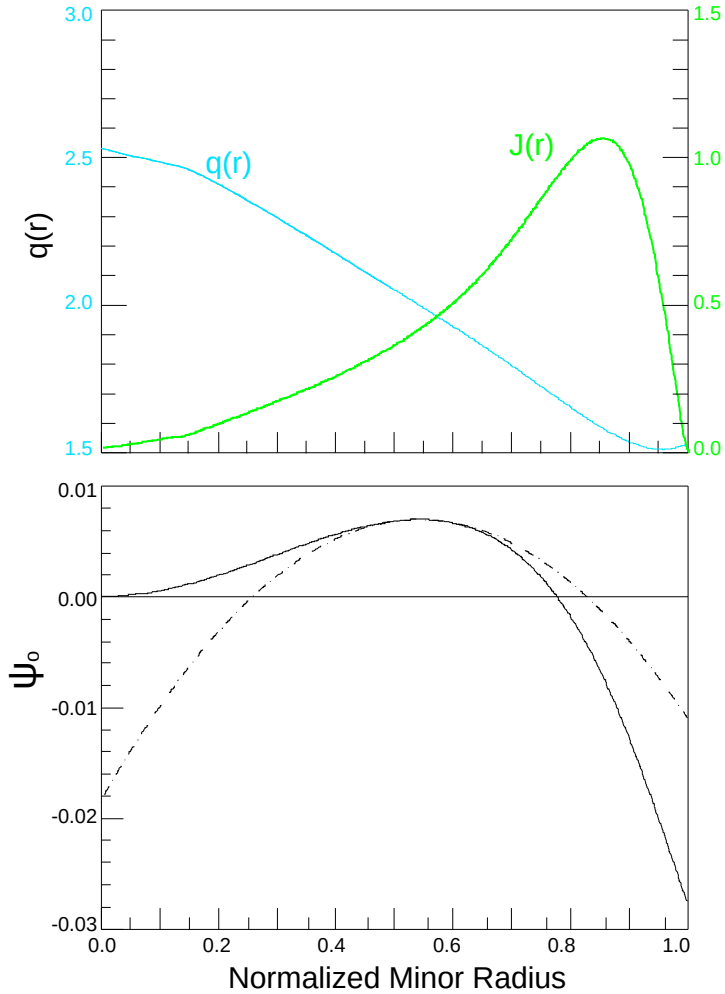
Outline

- Basic Δ’ calculations
- Scaling of Δ’ with r_s (scaling q in 383)
- Saturated Island widths with neoclassical term and error fields.
- Effect of neoclassical term on negative shear islands (double tearing in TFTR).

Normalized current density is fairly large for “383”

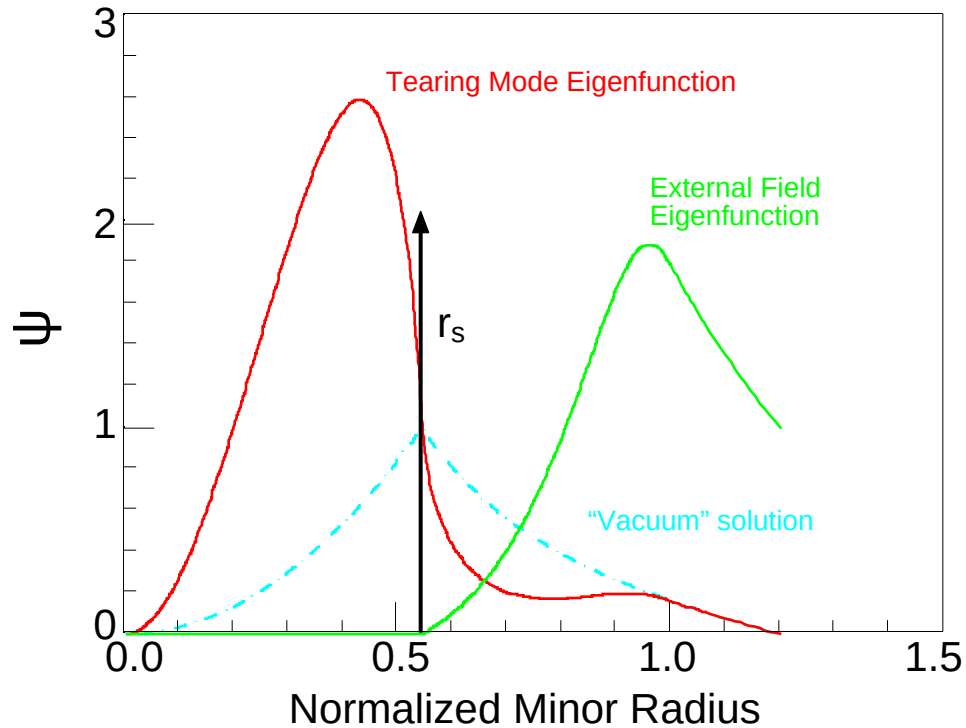


- J(r) normalized so that J(r)=1 on axis => q=1.
- Broken line shows parabolic approximation to helical flux function near r_s.
- For larger islands, inward shift has to be considered in Δ’(w) calculation.

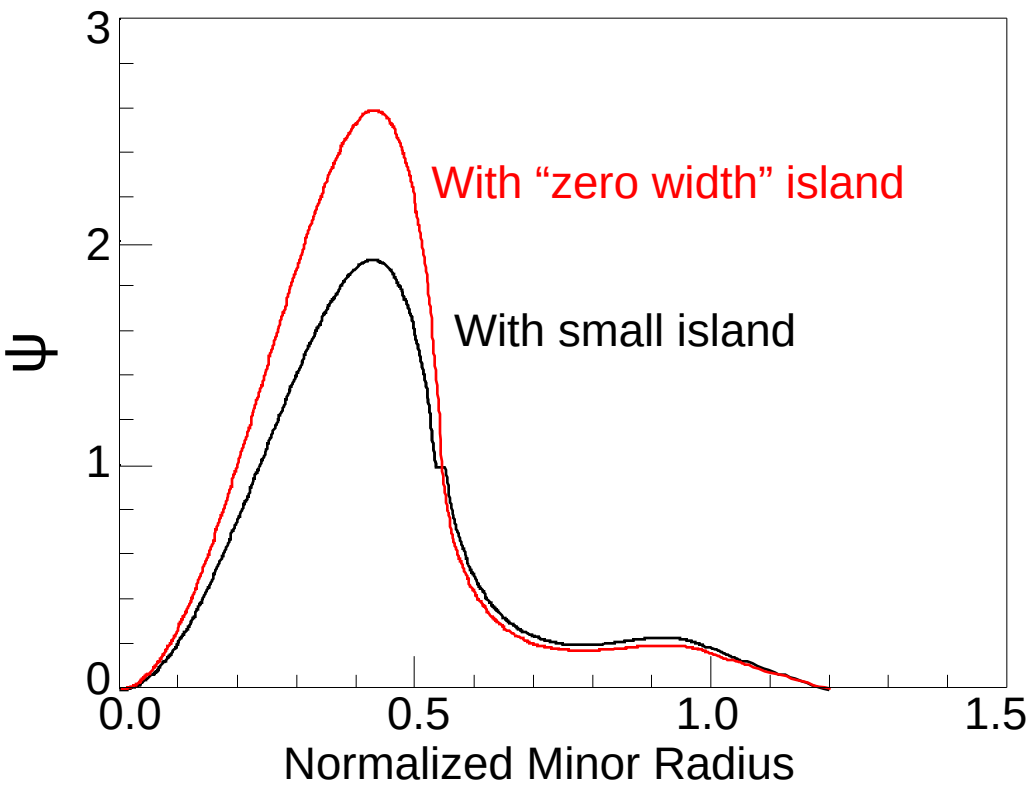
Eigenfunction shape much different than “vacuum”

- Current density is relatively large near edge; depresses eigenfunction.
- Shear is low in center; overcomes low current to peak eigenfunction.
- Together, cause instability.
- J(r) => 0.5 J(r) gives r_s Δ’ = -2.

r_s Δ’ = 12.2



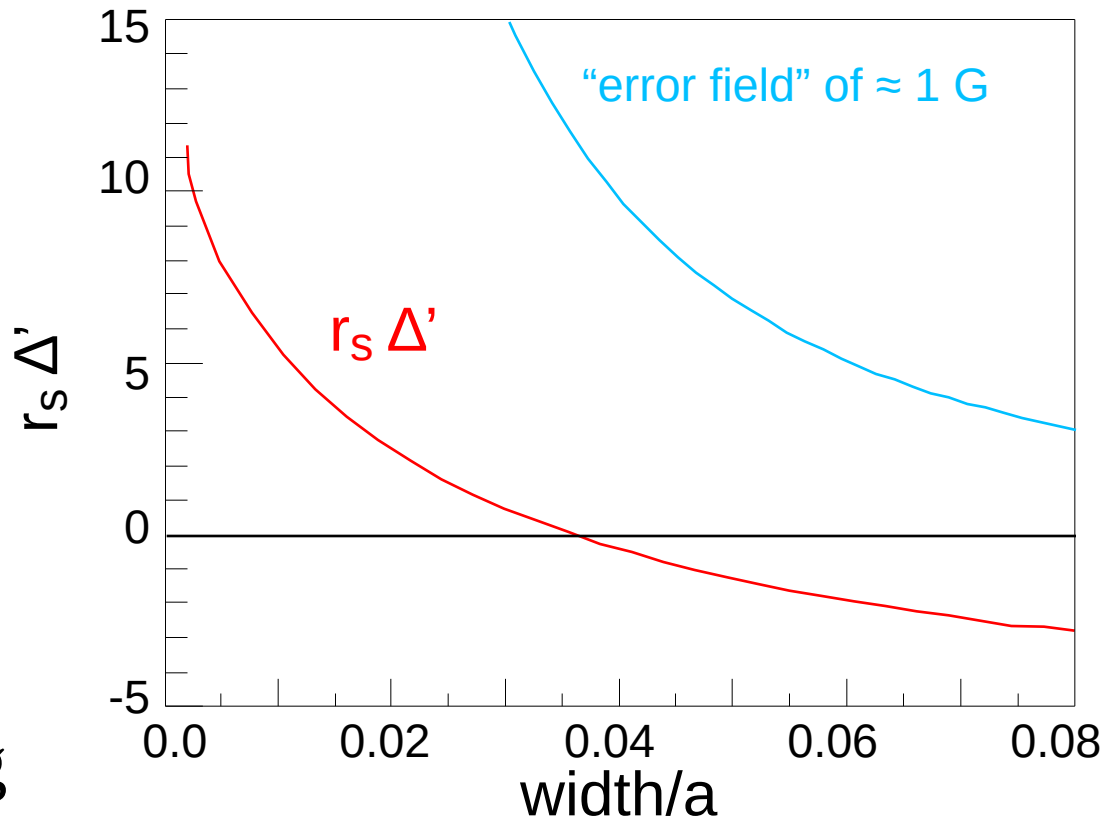
“Constant-ψ” approximation means renormalization of eigenfunction



- Renormalization reduces ψ’ inside rs
- Renormalization increases ψ’ outside rs
- “Constant- ψ” means island saturates at smaller size

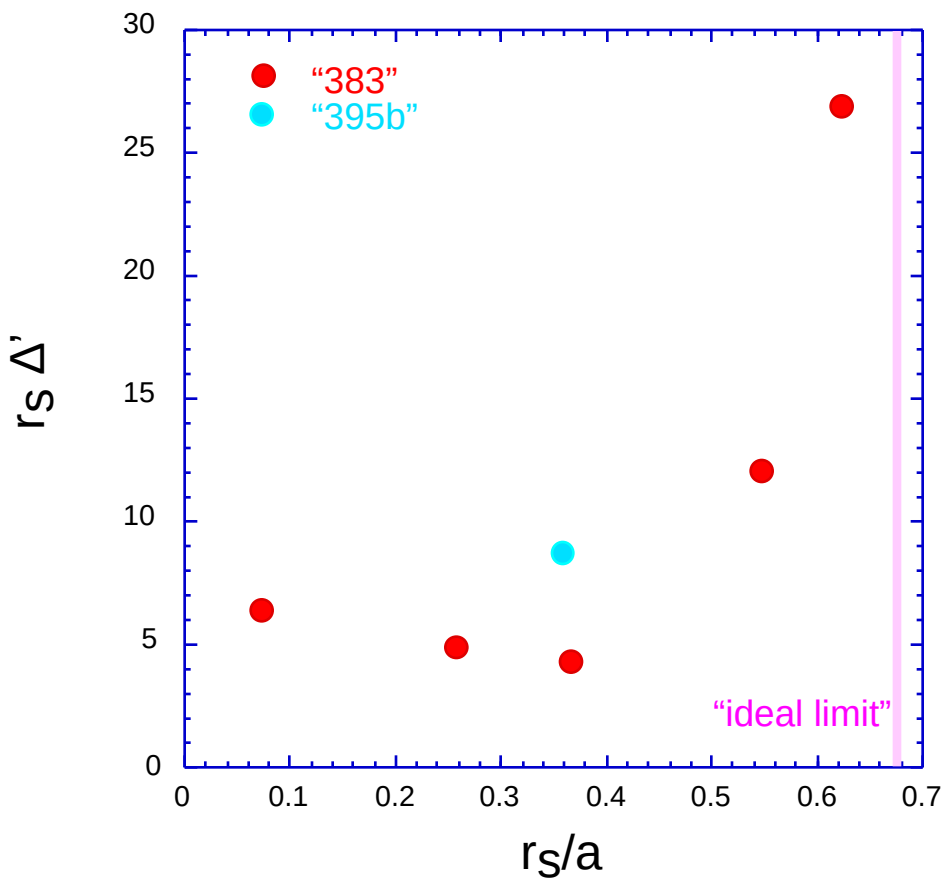
Δ' falls off rapidly with island width

- The drive from the error field falls off approximately as w^{-2}.
- Island width scales weakly with B_{error} without neoclassical term.
- The neoclassical term is negative, increasing linearly with width.

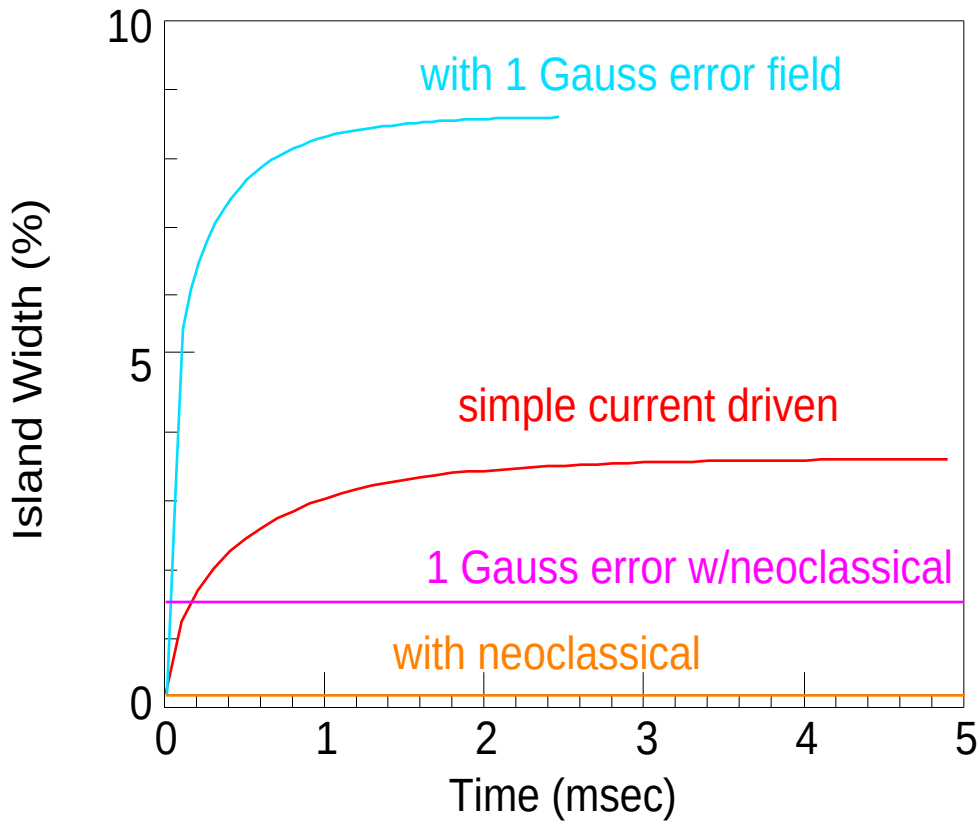


Shallow minimum in r_s Δ' for r_s near 0.4 a_p (in "383")

- For this data, kept J(r) the same, but scaled q(r) to move r_s.
- Also shown is baseline "395b" point - more unstable that scaled "383".
- q(r) = 1.1 q(r) was unphysical; "ideal limit".



Saturated island widths small, even without neoclassical terms



- A 1 Gauss error can lead to a substantial island.

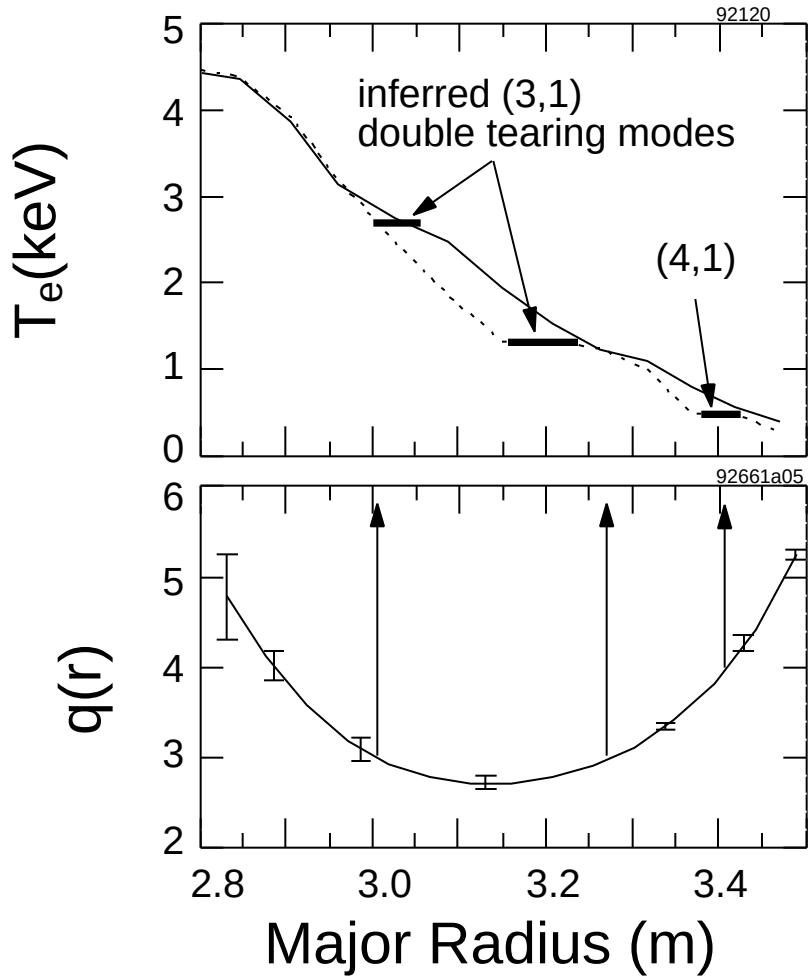
- Island size scales roughly $w^3 \alpha$ error-B_{rad} for small islands with neoclassical term.

“395b” is not much better than “383”

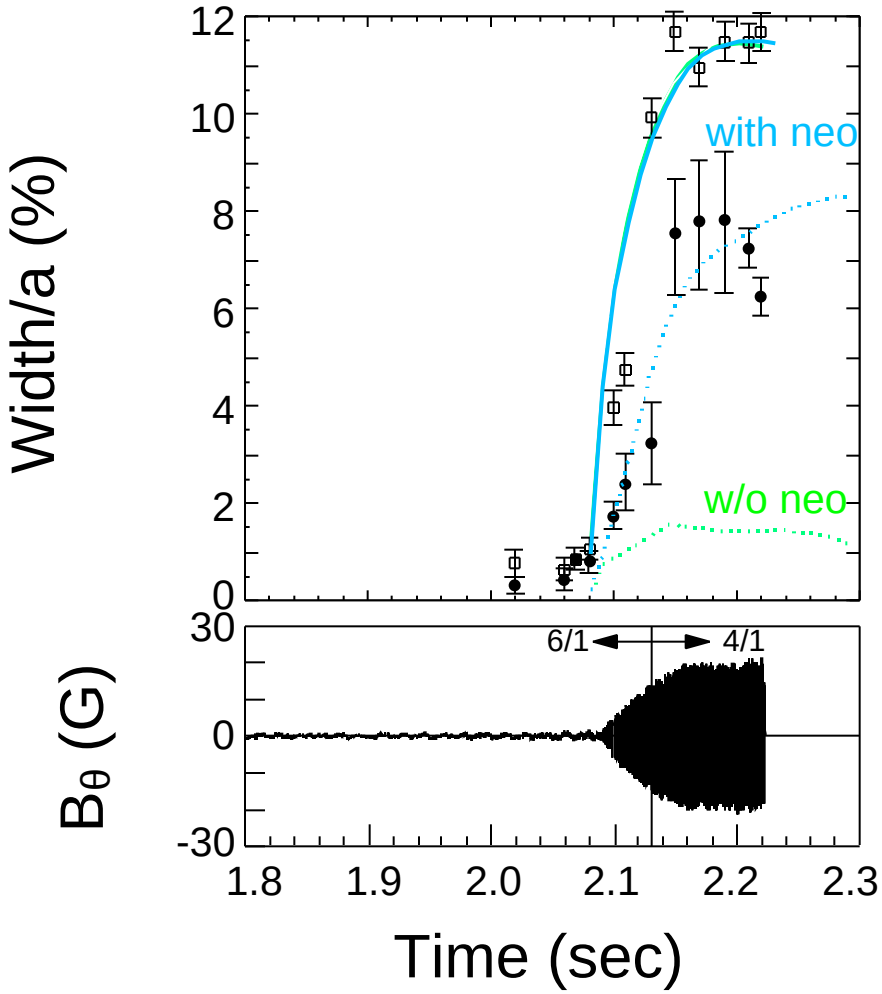
- For 2/1 island, $r_s \Delta' = 8.85$ but saturated island size 2.7%; with neoclassical 0.15%.
- The 3/2 mode, with $r_s = 0.82$, calculation is equivocal; the eigenfunction has a zero crossing.
- Decreasing q by about 0.95 leads to normal, strongly unstable mode.

Double tearing modes were studied on TFTR

- The island is present in negative shear region.
- Physics of double tearing mode stability (with other islands) could be more complicated than assumed here.



Island growth was simulated with Δ' code, including neoclassical term



- Code needed bootstrap current to match outer island size.
- Even small bootstrap current was strongly stabilizing for inner island.
- With neo-terms off, matched inner island.

Summary

- The 383 and 395b configurations are both unstable to the 2/1 tearing mode.
- The island saturates at a relatively small size, 2-4%.
- Neclassical effects limit island size to <0.5%
- Small error fields can generate larger islands.