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Fast ion transport during TAE Avalanches

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E D Fredrickson, D Darrow, N N Gorelenkov,
W. Heidbrink, D. Liu, S S Medley, S Kubota,
N Crocker, H Yuh
and the NSTX Team

PPPL, Princeton University, Princeton, NJ
UCLA, Los Angeles, CA
UCI, Irvine, CA

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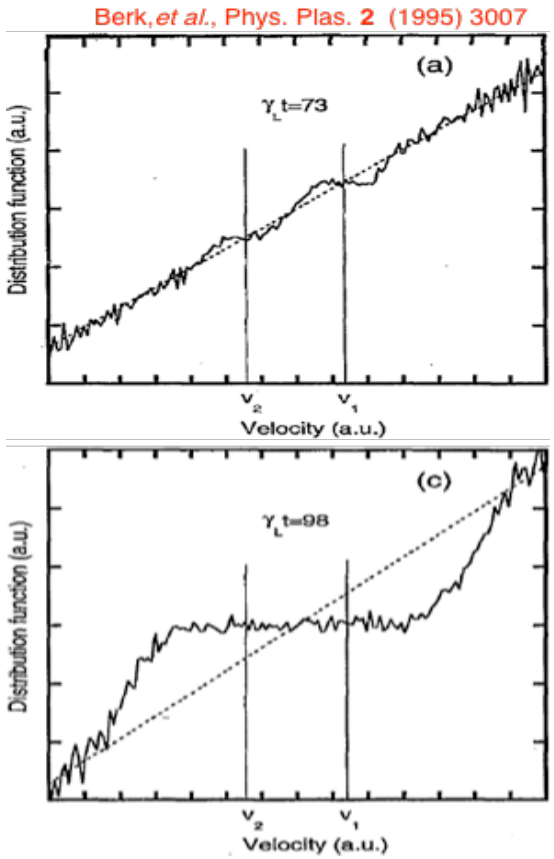
Introduction to talk

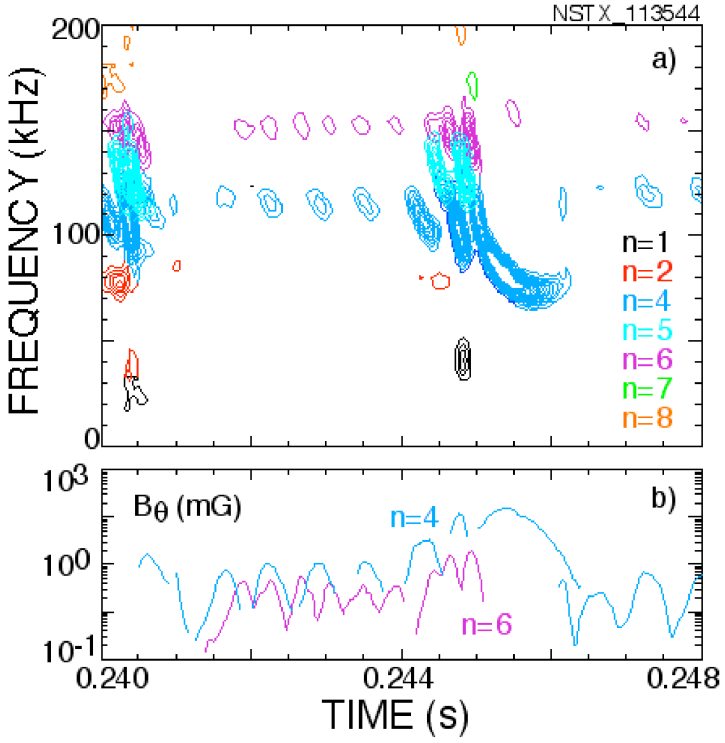
- An experiment to determine the threshold β_{fast} for excitation of TAE and TAE avalanches is described.
- Identified quiescent plasma conditions for benchmarking TRANSP beam current drive models.
- Provided detailed equilibrium data at TAE threshold to benchmark NOVA.
- Provided detailed equilibrium data at avalanche threshold to benchmark M3D-k or NOVA/ORBIT.
- And made detailed measurements of the internal structure of the modes, for comparison with NOVA predictions and ORBIT simulations.

TAE bursts suggest "Avalanche" physics



- No correlation of repetitive small bursts; increased amplitude leads to strong multiple mode burst

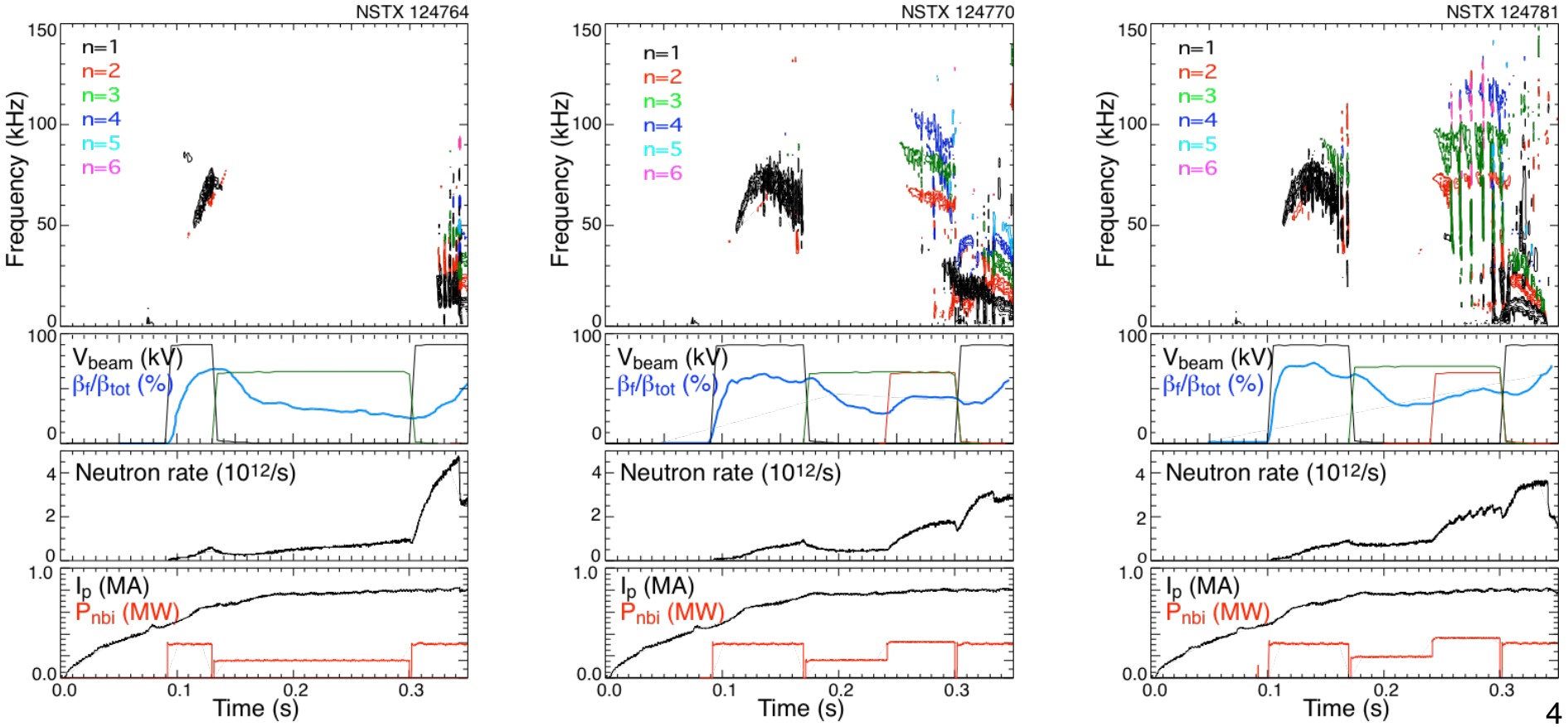
Berk, et al., PoP **2** 2007



- Large amplitude modes overlap in fast-ion phase-space.
- Interaction results in stronger modes, destabilizes new modes; more fast ion transport
- TAE have multiple resonances, more complex physics

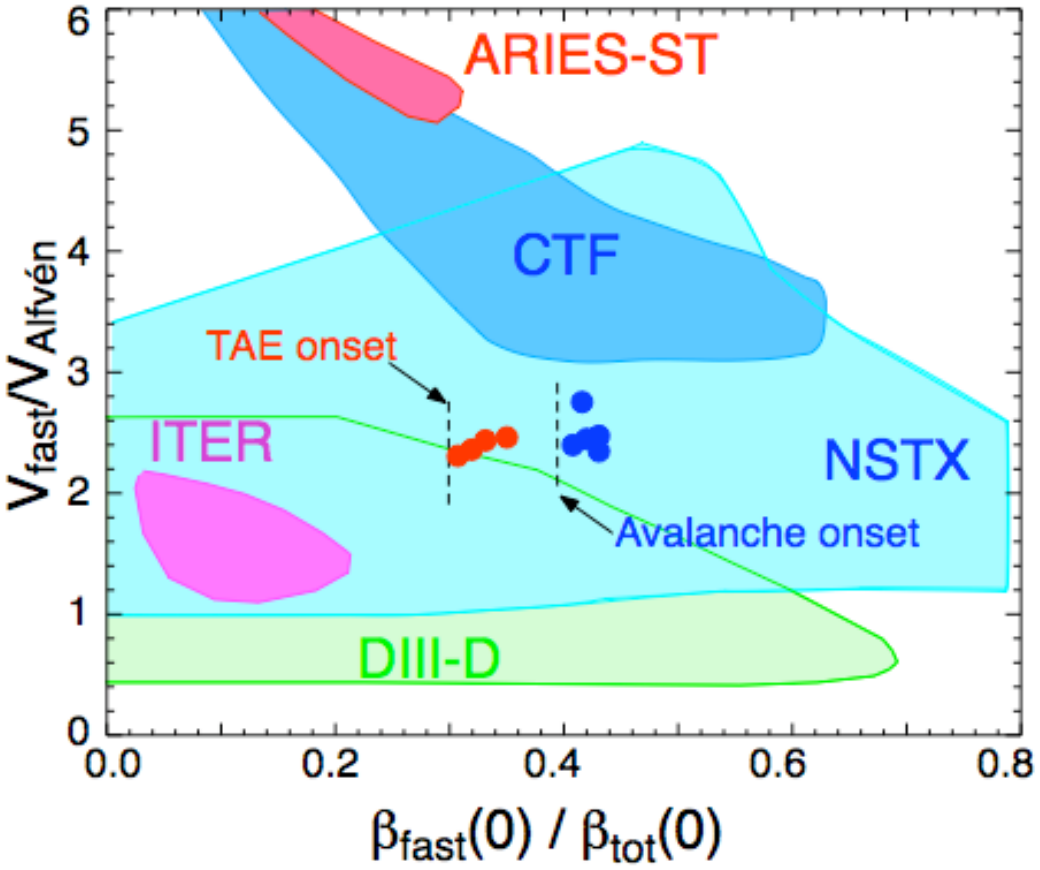
β_{fast} scan determines threshold for TAE, TAE-avalanche

- Beam power avalanche threshold 10% above TAE threshold
- q-profile evolution measured before/after TAE window



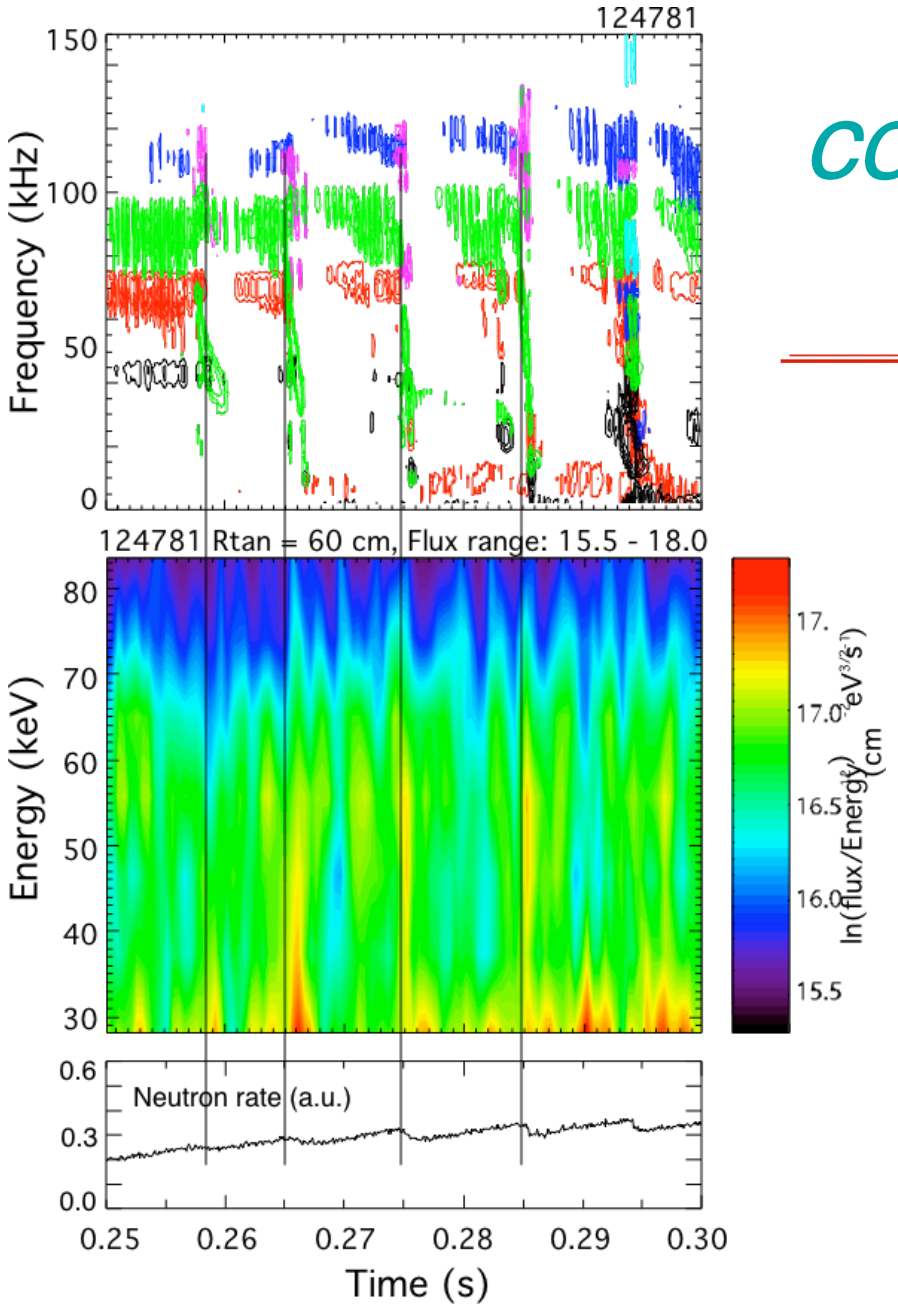
TAE threshold above ITER β_α

- The ITER β_{fast} includes only the alpha component; NBI is needed to destabilize TAE.
- The TAE threshold very likely is also dependent on the density and current profiles.
- The avalanche threshold is is less than 30% above the onset threshold for TAE



- In future experiments we can push towards CTF regime by increasing density and lowering toroidal field.

Avalanche onset correlated with fast ion losses

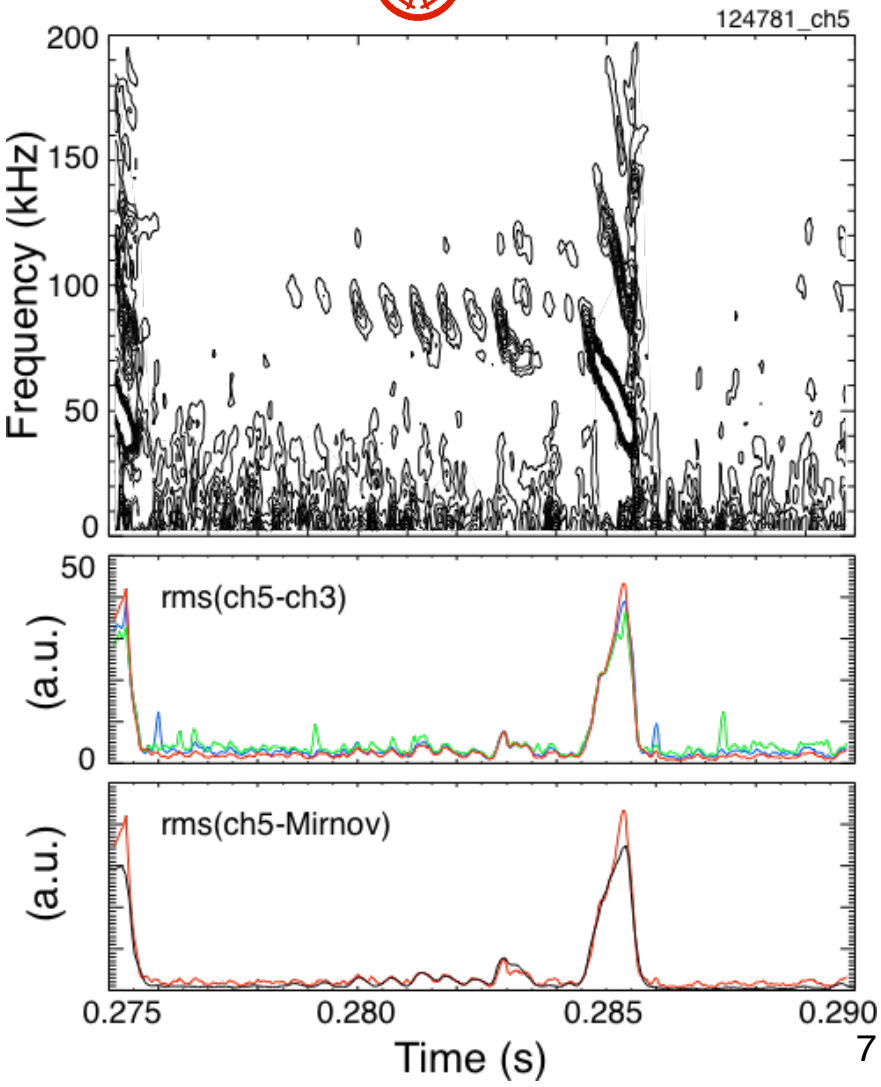


NSTX

- Chirping may play important role in fast ion loss.
- Neutron drops correlated with D-alpha spikes - fast ions are lost.
- Neutral particle analyzers (NPA) measure spectrum of charge-exchanged neutral ions from plasma.
- Transport appears largest at lower energies.
- Pitch angle of these particles is ≈ 0.9, i.e., passing fast ions.

Reflectometers provide internal measurement of amplitude, shape*

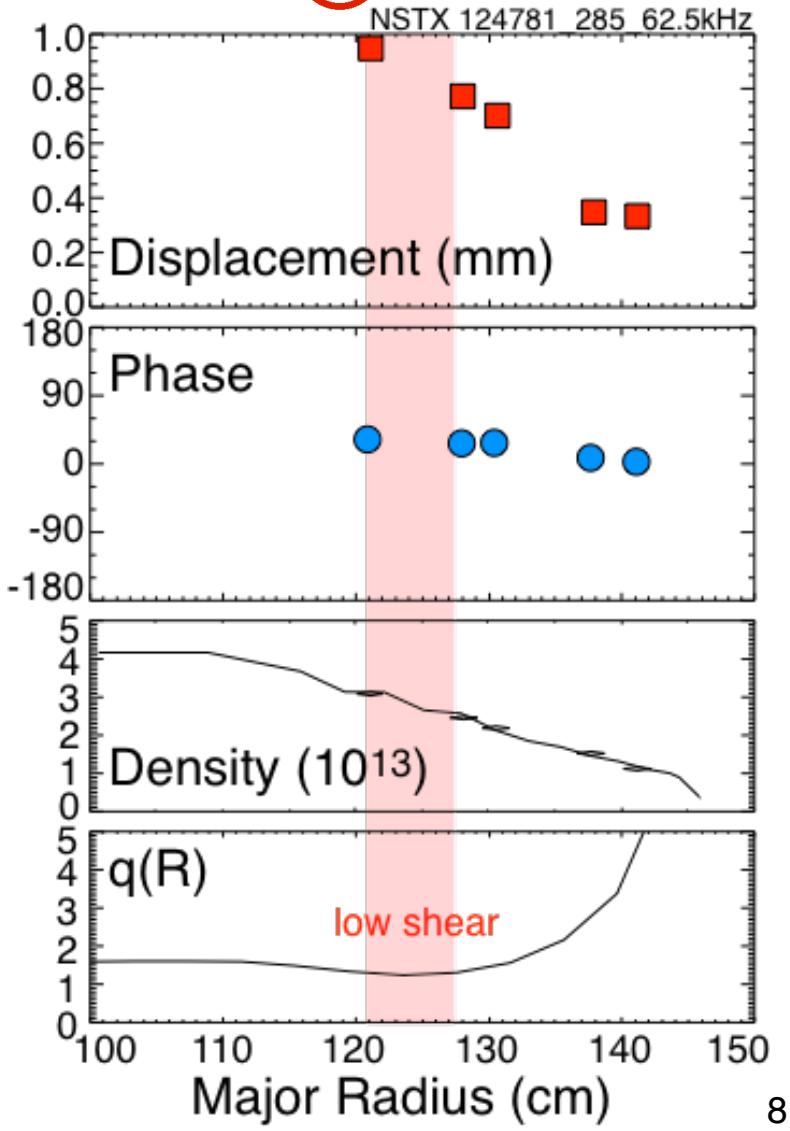
- Amplitude at time of avalanche much greater than earlier bursts.
- Relative amplitude tracks well through multiple modes, suggesting fixed mode structure...
- …except toward end of last burst, suggesting mode becoming more core-localized.



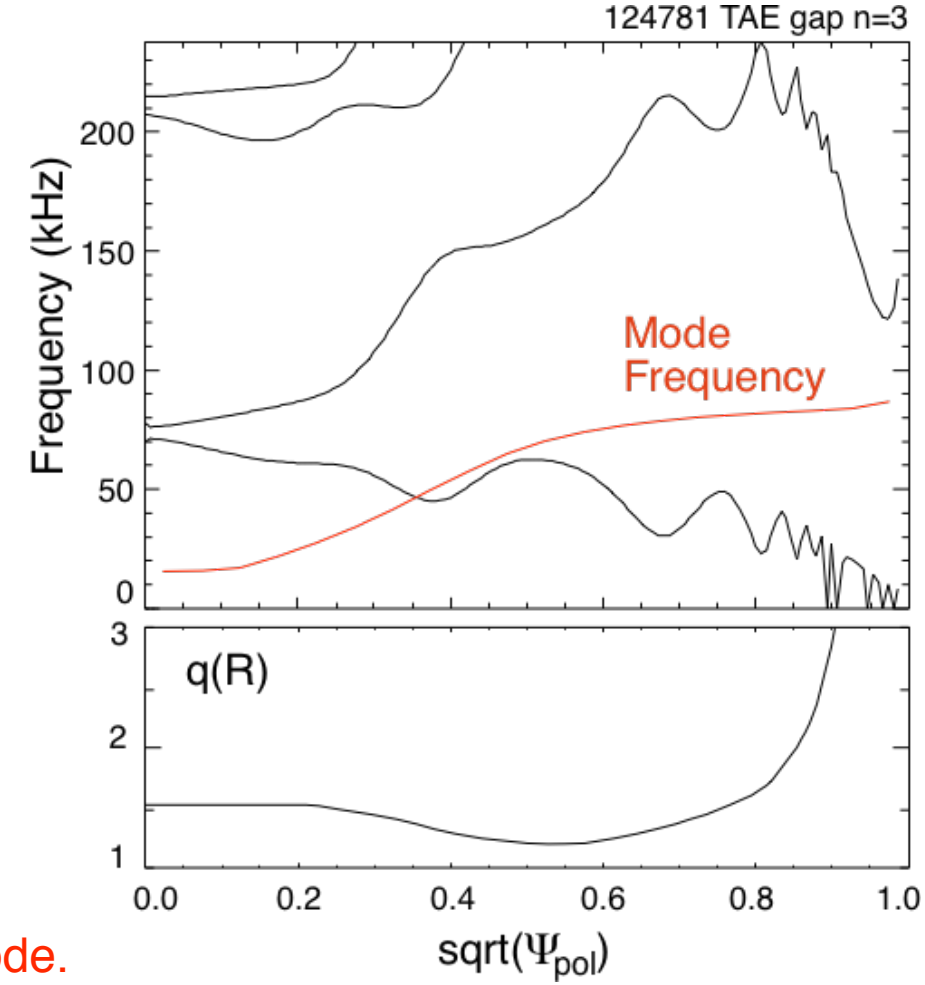
*Kubota, et al., Rev. Sci. Instrum. 72 (2001) 348.

Mode appears to peak near q_{min}

- Modes are fairly well localized (n = 3 mode is shown).
- No phase-inversion seen over range of reflectometer data; deepest reflectometer channel is near q_{min}.
- Amplitude deduced using simple "mirror" model; probably under-estimates actual amplitude (N. Crocker).
- q-profile calculated with LRDFIT, constrained by MSE data.



NOVA simulations confirm mode frequency in TAE gap



- Solid curves show "Chu-filtered" TAE gap.
- Solid red line shows n = 3 mode frequency, with radial Doppler correction profile.
- TAE mode structure shows strong coupling to plasma edge - no phase shifts.

N. Gorelenkov, G Kramer, NOVA code.

Summary

- Quiescent, beam heated plasmas have been made on NSTX, necessary for benchmarking TRANSP beam driven current model.
- The threshold in β_{fast} for exciting TAEs has been found.
- The threshold in β_{fast} for exciting TAE avalanches is found to be only slightly higher.
- The internal structure and amplitude of the modes has been measured with a multi-channel reflectometer array.
- Mode frequencies are consistent with NOVA predictions.