

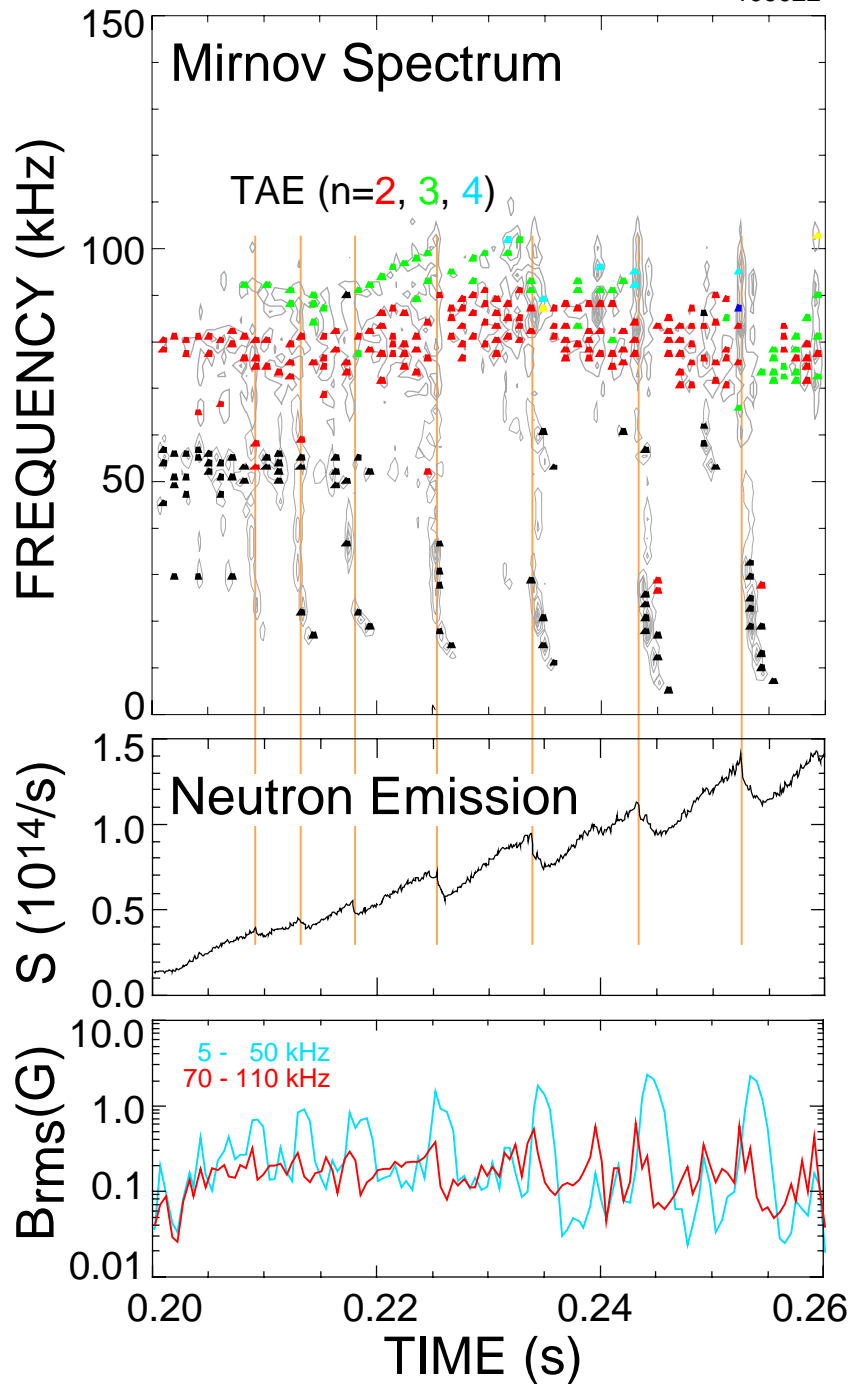
Wave driven fast ion loss in the National Spherical Torus Experiment

E D Fredrickson, R White, L Chen, C Z Cheng, G Fu,
N Gorelenkov, G Kramer, J Menard, S Medley,
D Darrow, L Roquemore

Will fast ion driven instabilities be important in the CTF?



- Fast ion instabilities have potential to impact ignition threshold in fusion reactors;
 - Fast ion losses, first wall damage
 - "alpha-channeling"
- ST's, with intrinsic low field, are particularly susceptible to fast ion driven instabilities.
- Need to understand instability drive, loss mechanisms.
- Results may be important for CAT reactors.

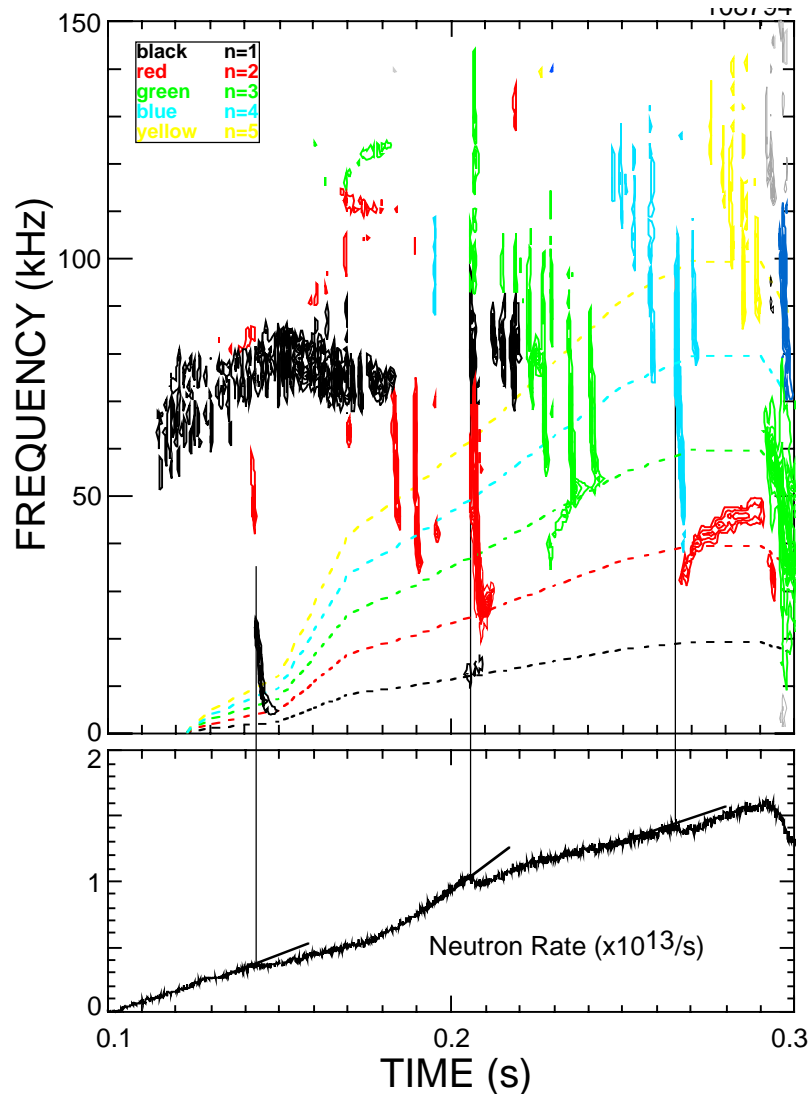


Fast ion losses are seen in NSTX



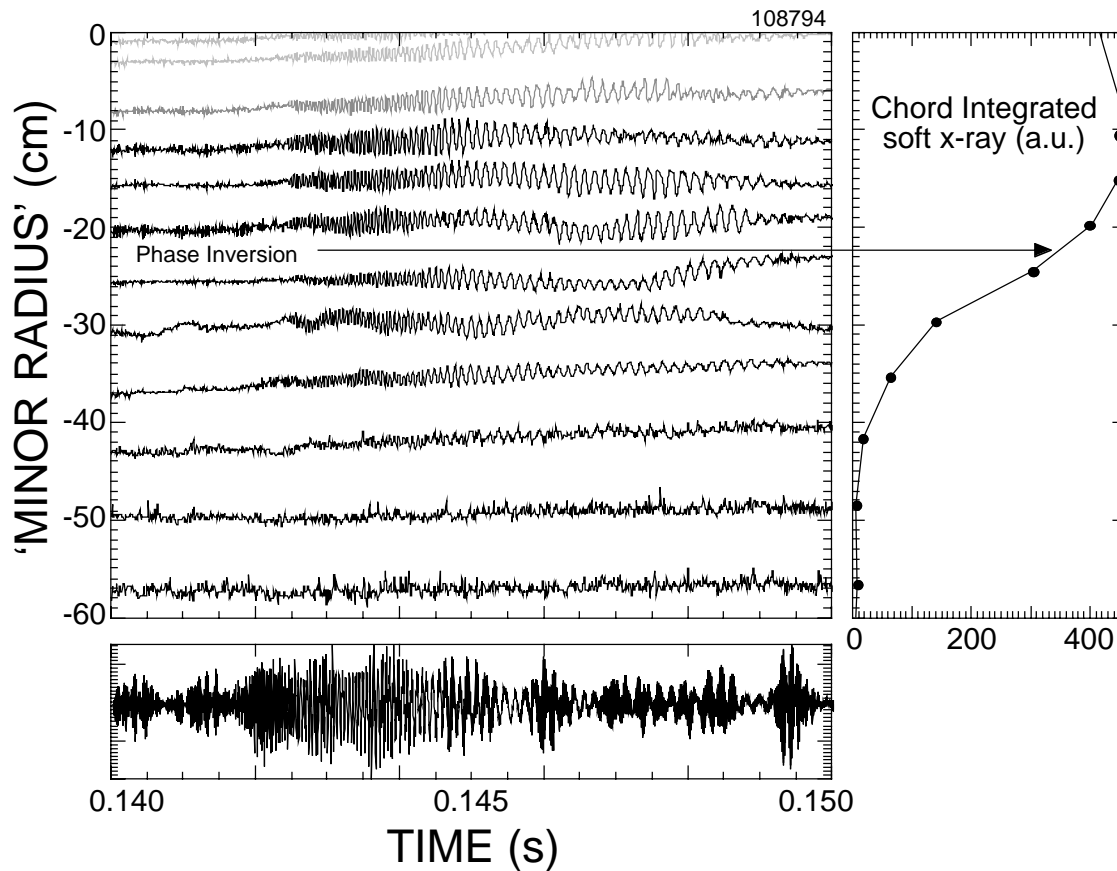
- Neutrons are beam-target; -
- $\delta S \propto \delta n_{fi}$
- Instabilities are TAE and "fishbones".
- TAE bursts cause initial, fast drop, fishbones later, slower drop.
- Correlation of f.b. and TAE bursts suggests coupling.

"Not your father's fishbones..."



- Retain strong frequency chirping and periodic bursting character.
- Toroidal mode numbers up to $n=5$ have been seen.
- Often with $q(0) > 1$
- Onset frequency well above precession drift frequency.

Mode amplitude typically largest near core, limited data.

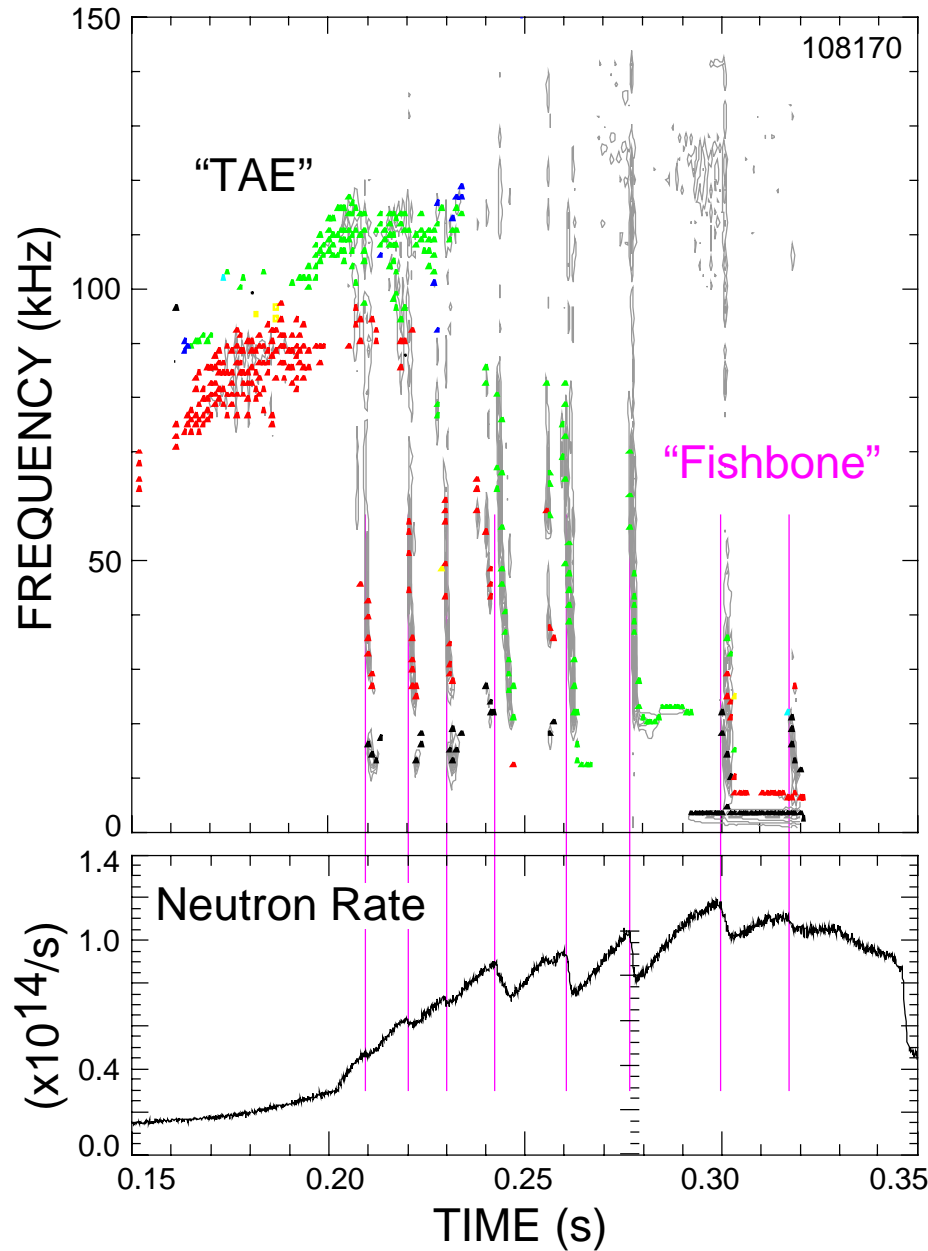


- Data acquisition rate ≈ 200 kHz.
- Horizontally viewing camera.
- Phase inversion at "minor radius" of ≈ 23 cm.
- High frequency f.b.s also seen; much weaker.

Soft x-ray data from JHU cameras.

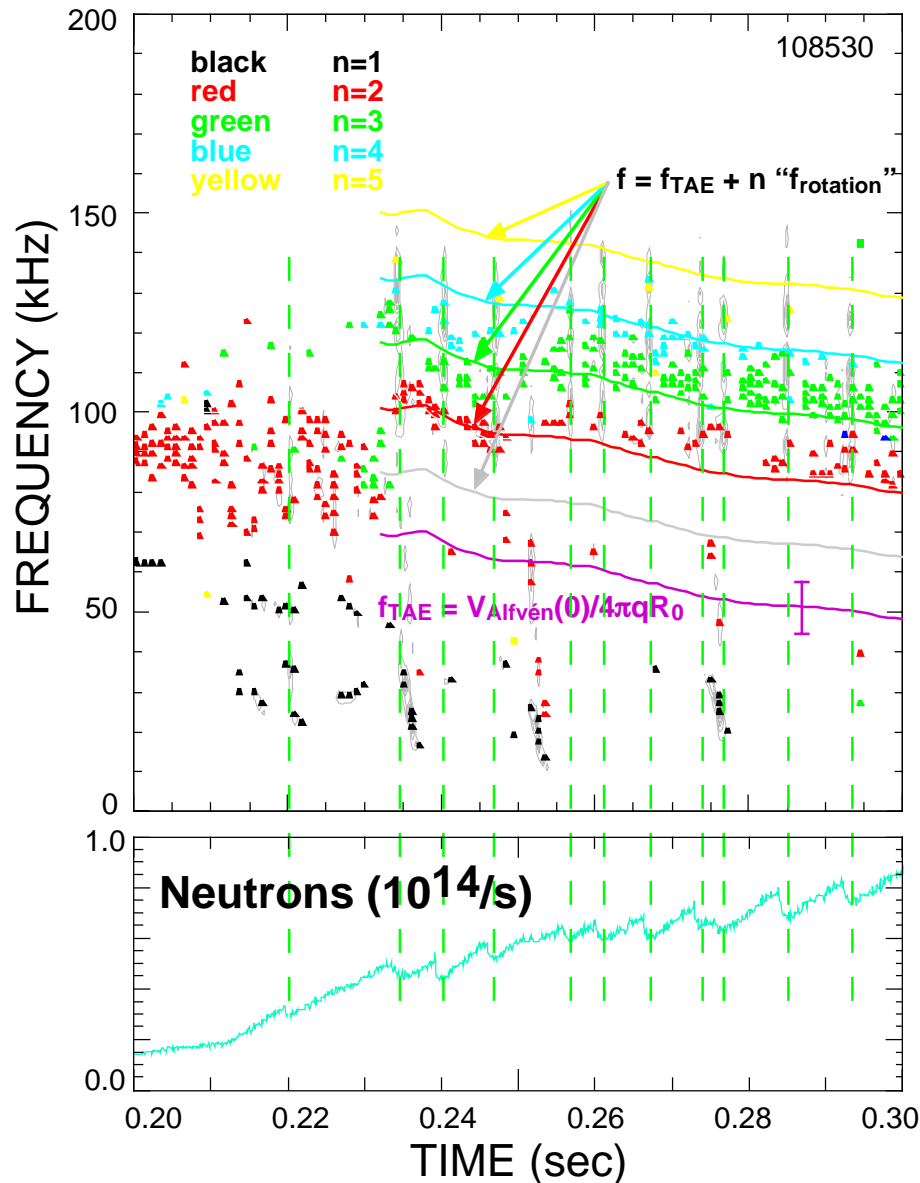
$I_p = 0.8 \text{ MA}$, $P_{\text{beam}} = 3.4 \text{ MW}$

Large fast ion losses also with "pure" fishbones



- Up to 20% drops in the neutron rate, with f.b. periods of $\approx 10 \text{ ms}$; steady-state reduction in fast ion population of $\approx 50\%$.
- Possibly multiple modes present.
- TAE present, but weak.

Similarly, TAE alone can also cause large fast ion loss



large fast ion loss

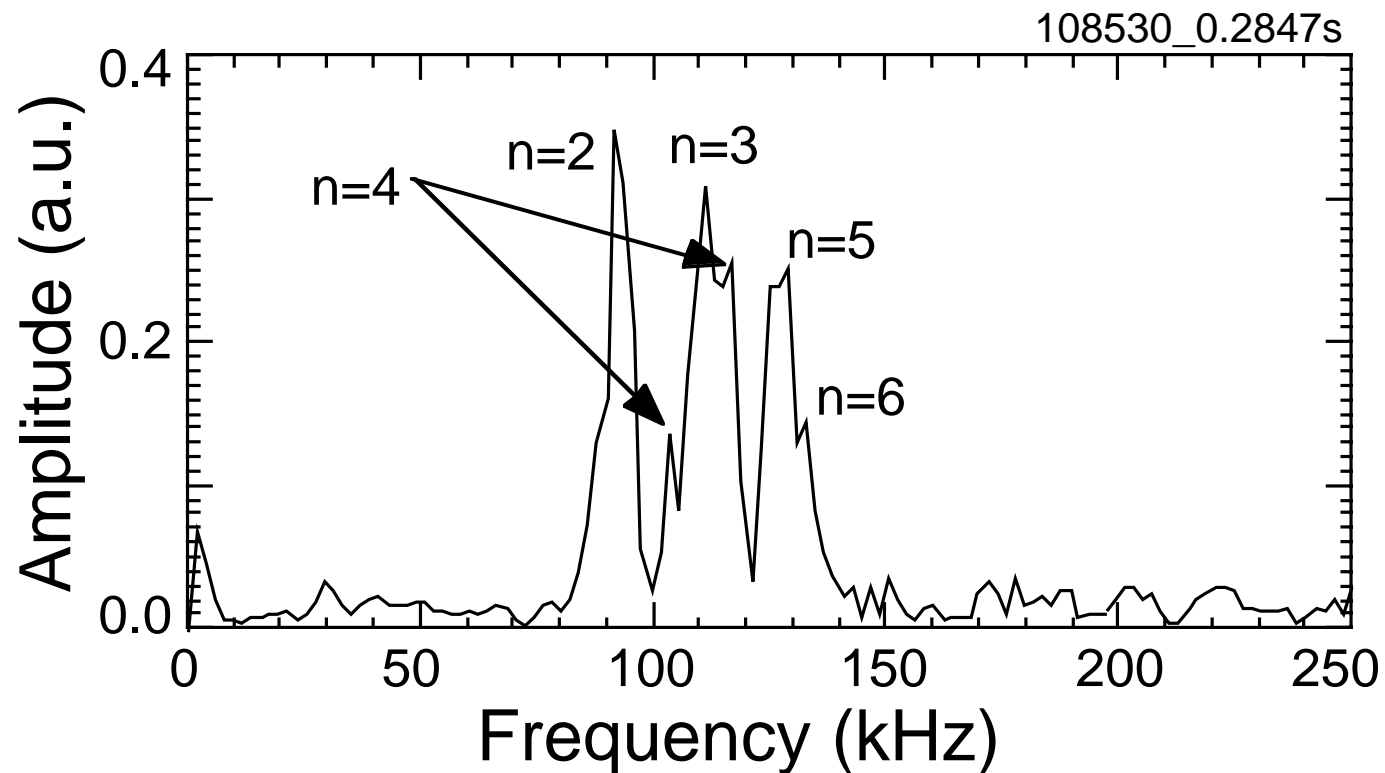


- Neutron drops $\approx 10\text{-}15\%$.
- Period is again $\approx 10\text{ ms}$.
- In steady-state, predicted reduction in fast ion beta of 40% .
- TAE have strong bursting character with multiple modes present.

ST's have large gaps due to low aspect ratio



- Multiple modes present, even with same toroidal mode number.



Summary



- "Collective" fast ion losses seen on NSTX
 - "fishbone" induced losses of up to 20% and new fishbone physics
 - TAE induced losses of 10-15% per burst
 - Coupled TAE/fishbone induced losses
- Losses are significant, either due to:
 - Raising ignition threshold
 - First wall power handling
- Need basis to extrapolate to NSST or ITER