Wave driven fast ion loss in the National Spherical Torus Experiment

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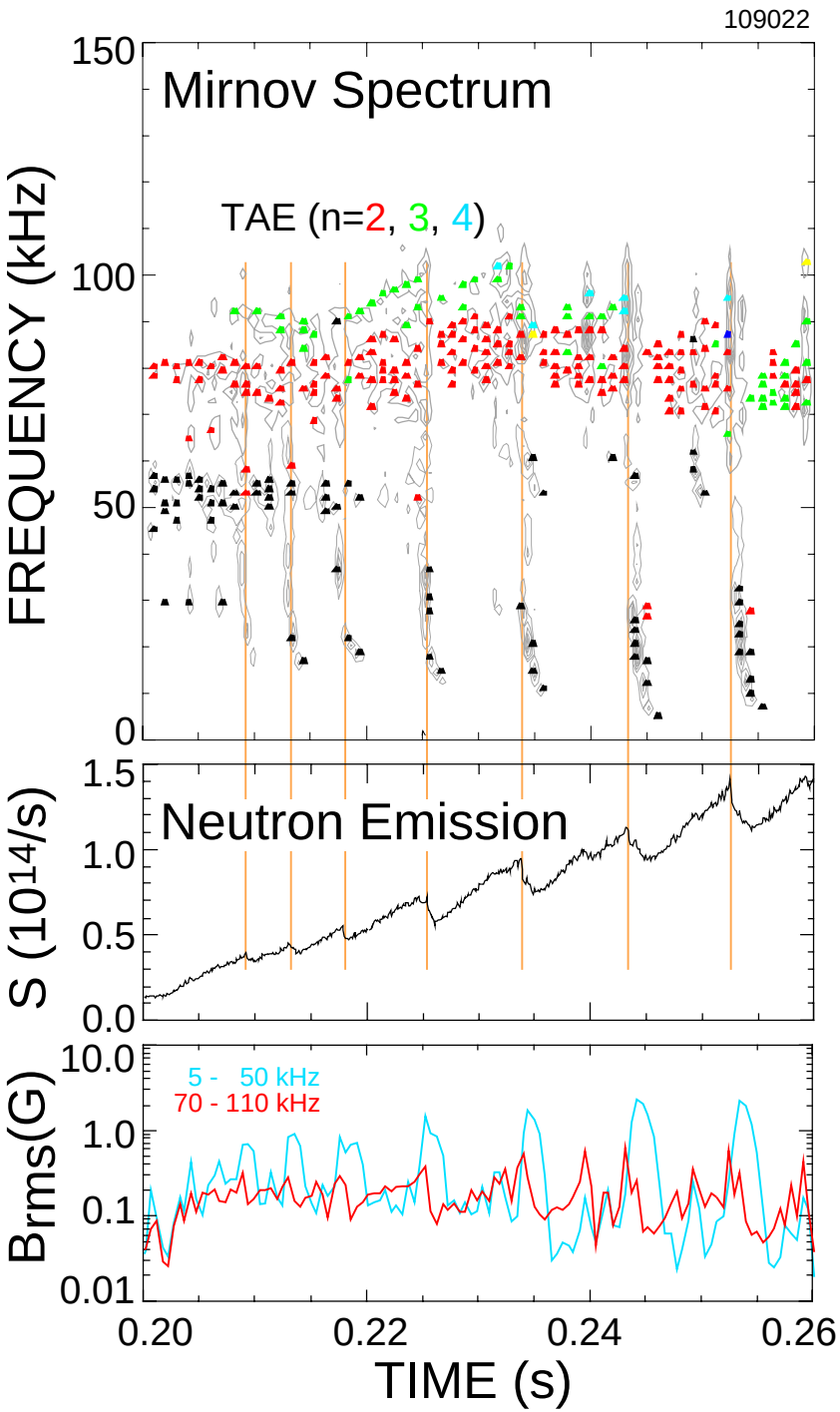
Will fast ion driven instabilities be important in the CTF?

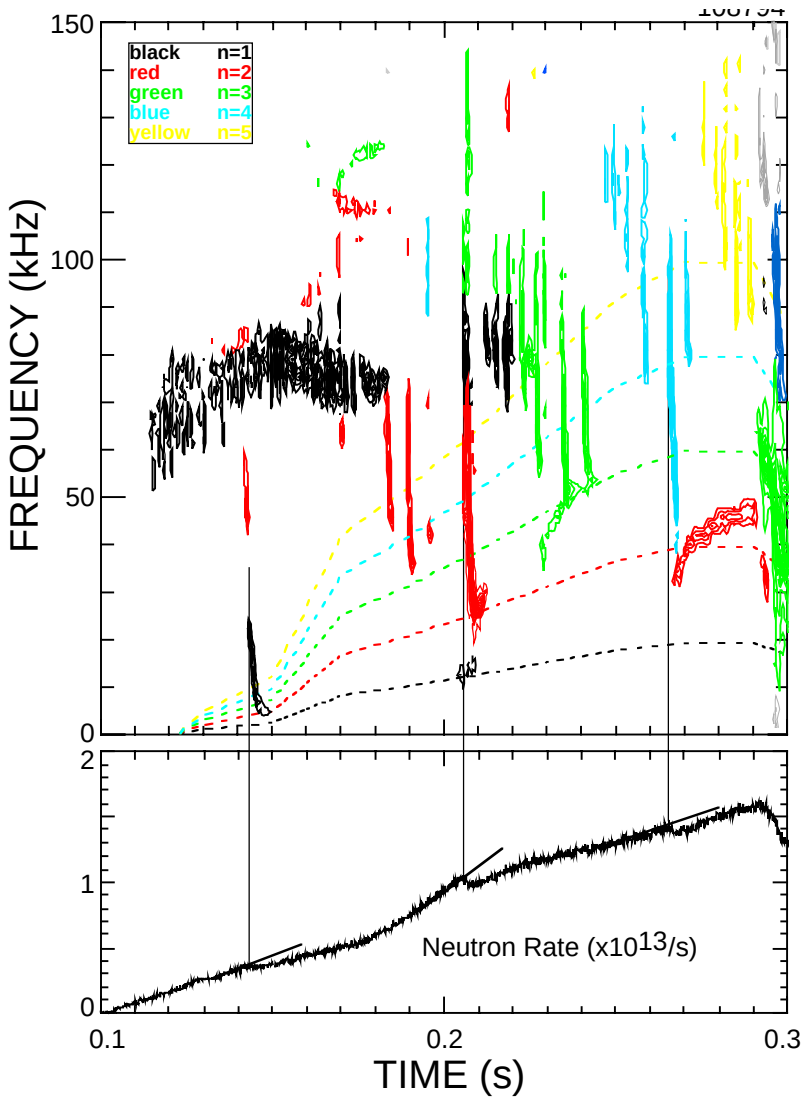
- Fast ion instabilities have potential to impact ignition threshold in fusion reactors;
  - Fast ion losses, first wall damage
  - "alpha-channeling"
- ST's, with intrinsic low field, are particularly susceptible to fast ion driven instabilities.
- Need to understand instability drive, loss mechanisms.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

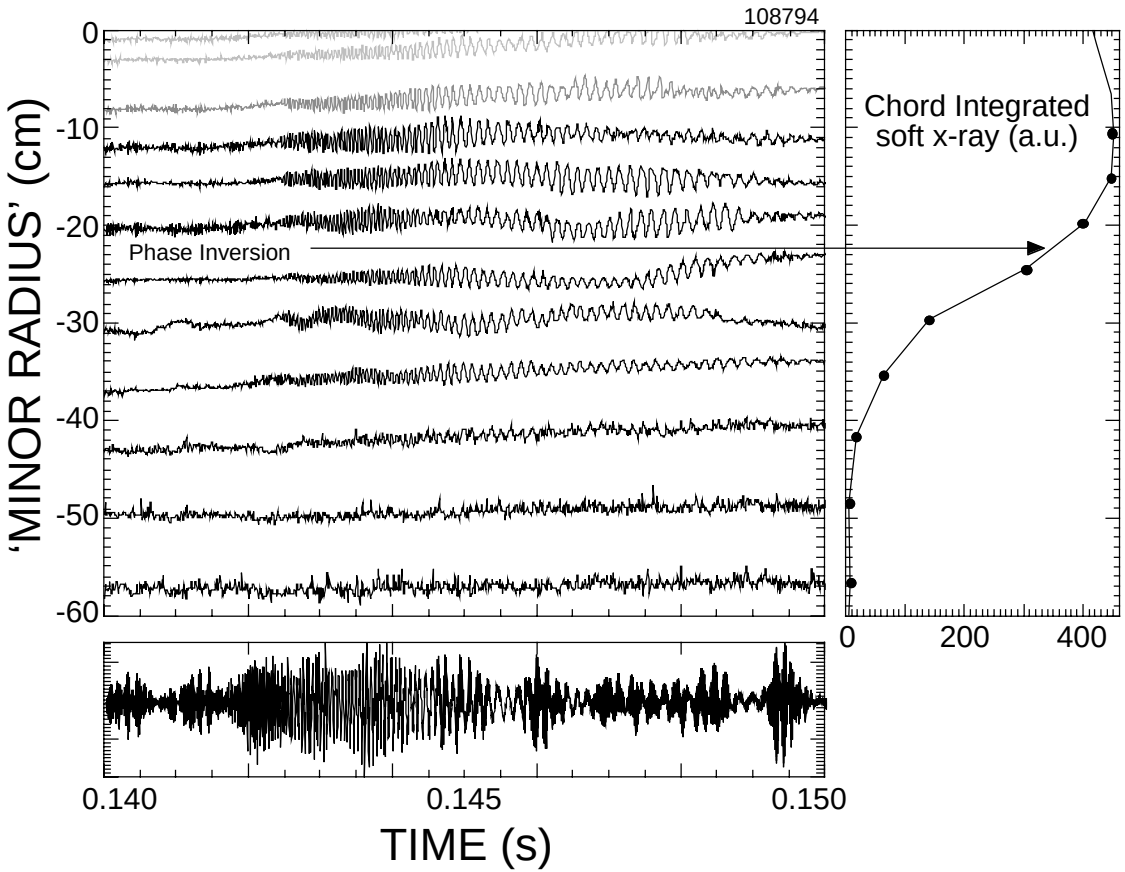
"Not your father's fishbones…"



- 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.

L Chen, E D Fredrickson, R White, submitted to Phys. of Plasmas

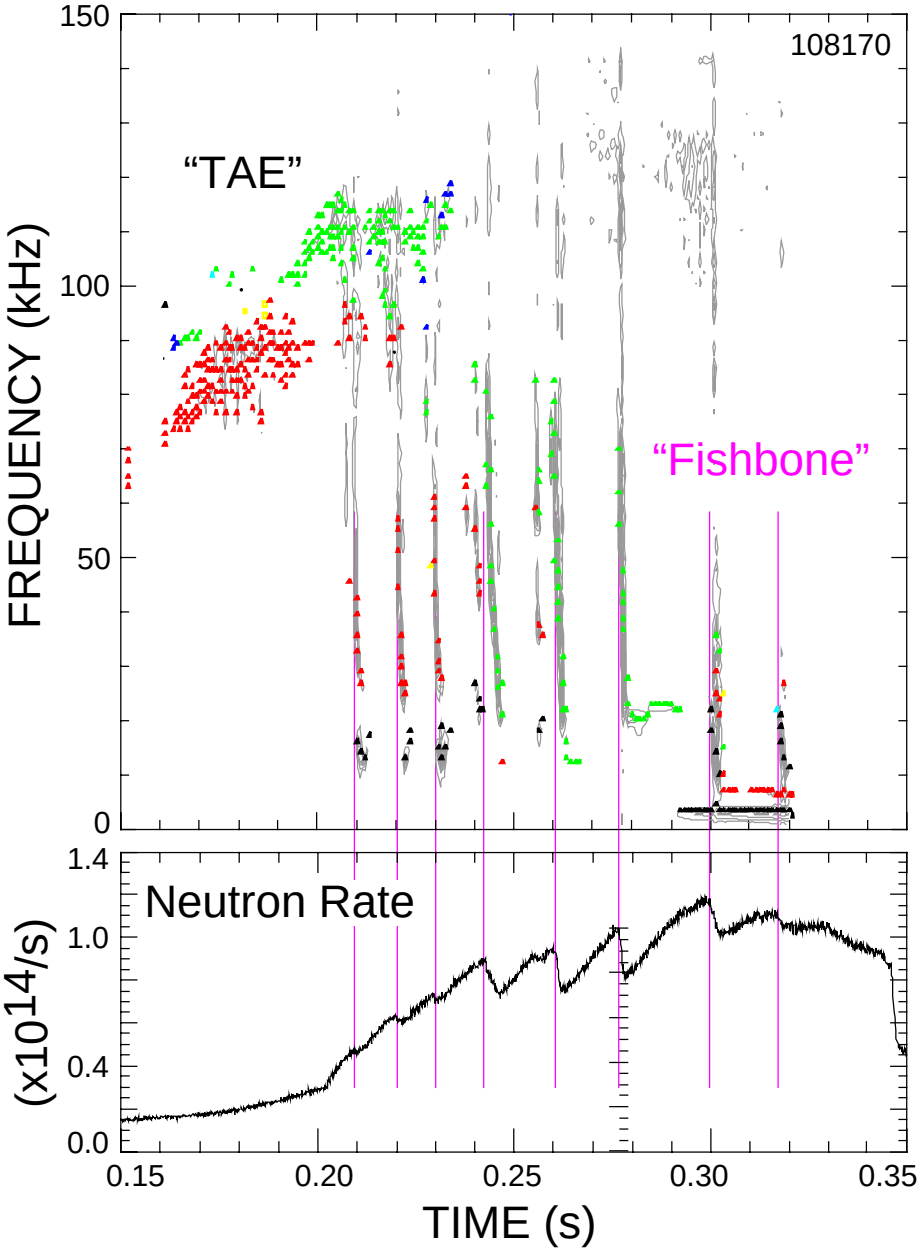
Mode amplitude typically largest near core, limited data.



Soft x-ray data from JHU cameras.

- 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.

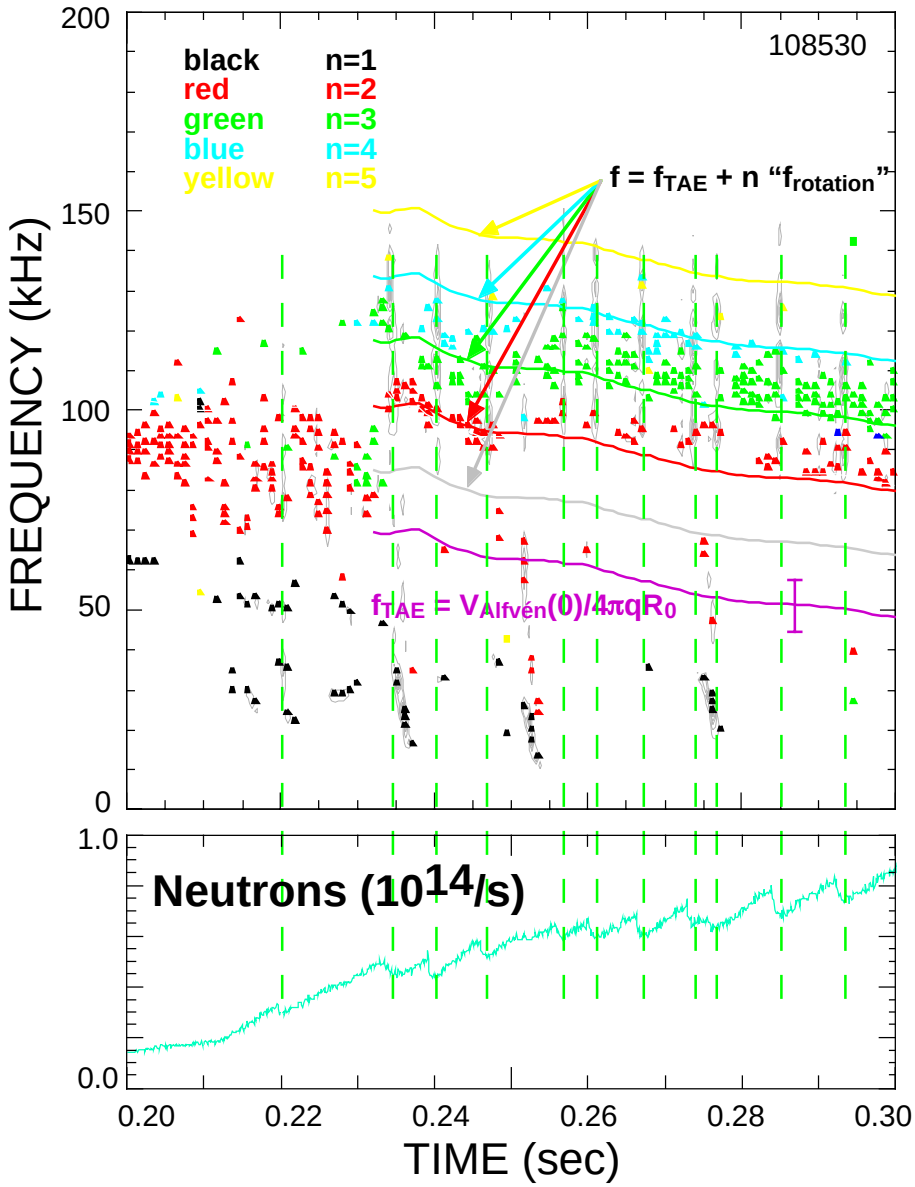
Ip = 0.8 MA, Pbeam = 3.4 MW



Large fast ion losses also with "pure" fishbones

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

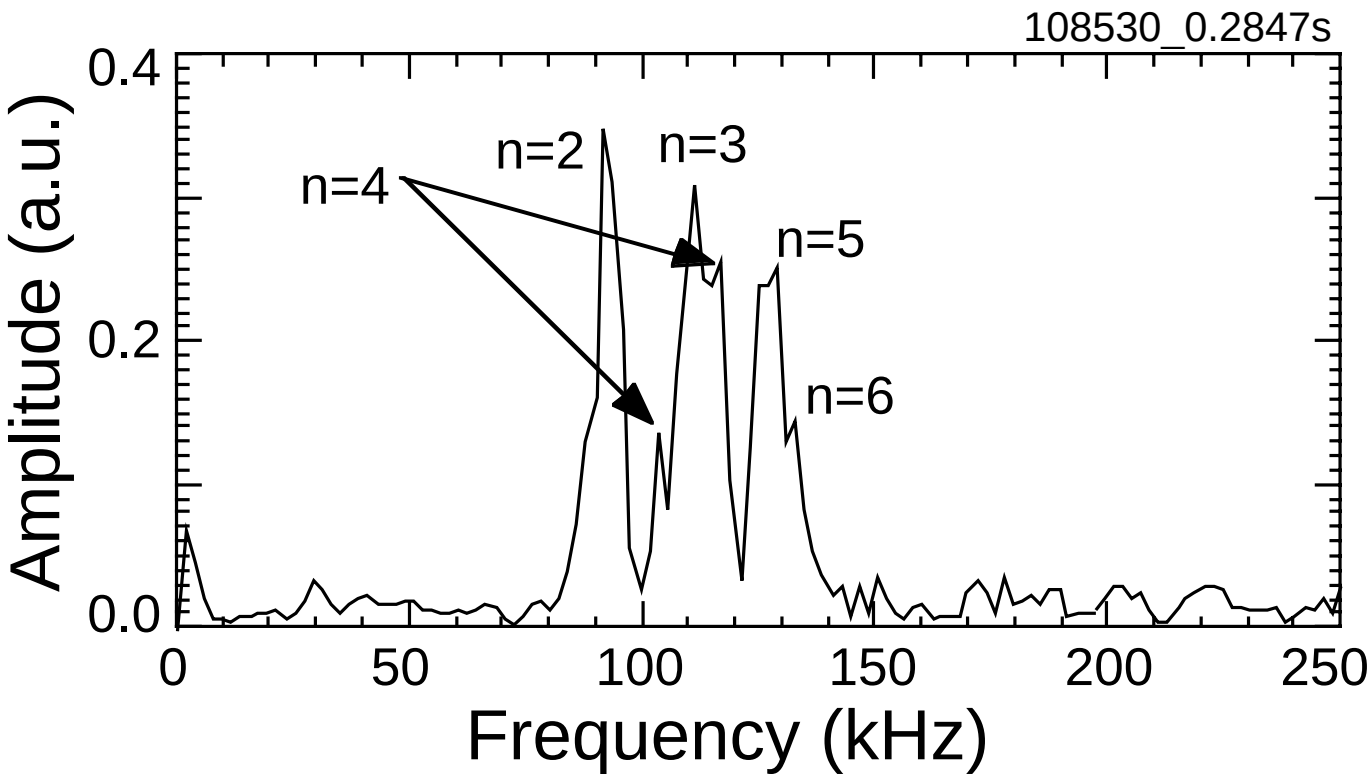
Similarly, TAE alone can also cause large fast ion loss



- Neutron drops ≈ 10-15 %.
- Period is again ≈ 10 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