NSTX

Investigation of ELM Magnetic Precursors in NSTX Discharges with and without Lithium

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PPPL PRINCETON PLASMA PHYSICS LABORATORY

Abstract

The evolution of ELM magnetic precursors in a series of NSTX discharges without and with lithium and with increasing lithium deposition [1,2] are examined. Data from the high-n Mirnov array were used to estimate the toroidal mode number (n) of the precursors. ELMs were observed to have mid-f n=1/n=2 magnetic precursors with some delayed modes in the range from n=3 to n=6, which persist as the lithium coating is increased and ELMs become partially suppressed. The D-alpha signal of a few ELMs is preceded by a slow growing plateau period which appear to be dominated by low-f n=1/n=2 and n=3 to n=6 modes, however, mid-f n=1 and/or n=2 modes appear as precursors to the main ELM peak. Mid-f n=1/n=2 precursors likely peeling modes in NSTX and/or SOL currents, similar to those observed in DIII-D [3] and modeled theoretically [4].

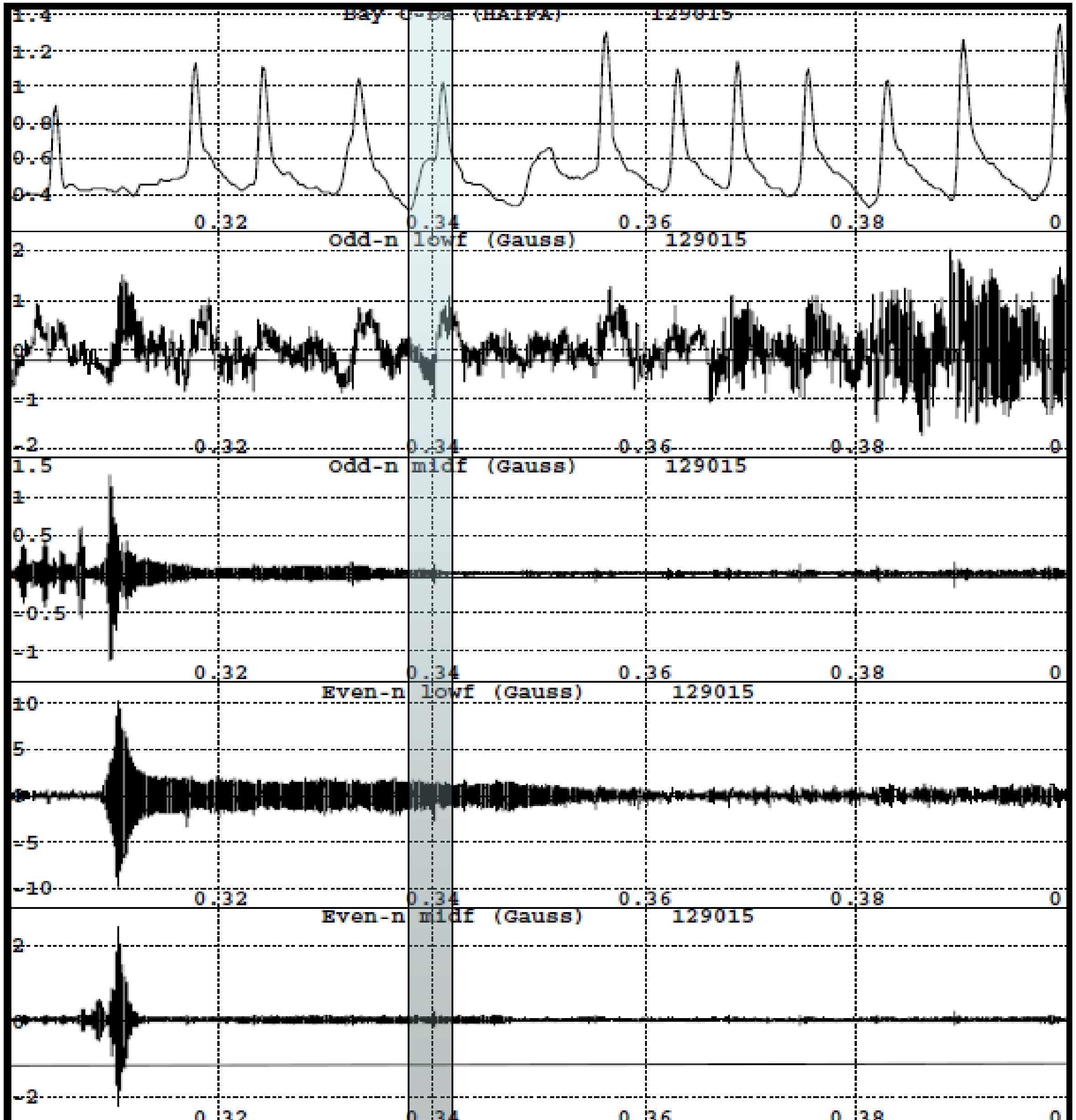
[1] R. Maingi, et al., 36th Eur. Phys. Conf. on Plasma Physics, P2.175

[2] R. Maingi, et al., Phys. Rev. Lett. (2009) at press.

[3] H. Takahashi, et al., Nucl. Fusion 44 (2004) 1075.

[4] T.E. Evans, et al., J. Nucl. Mater. 390-391 (2009) 789.

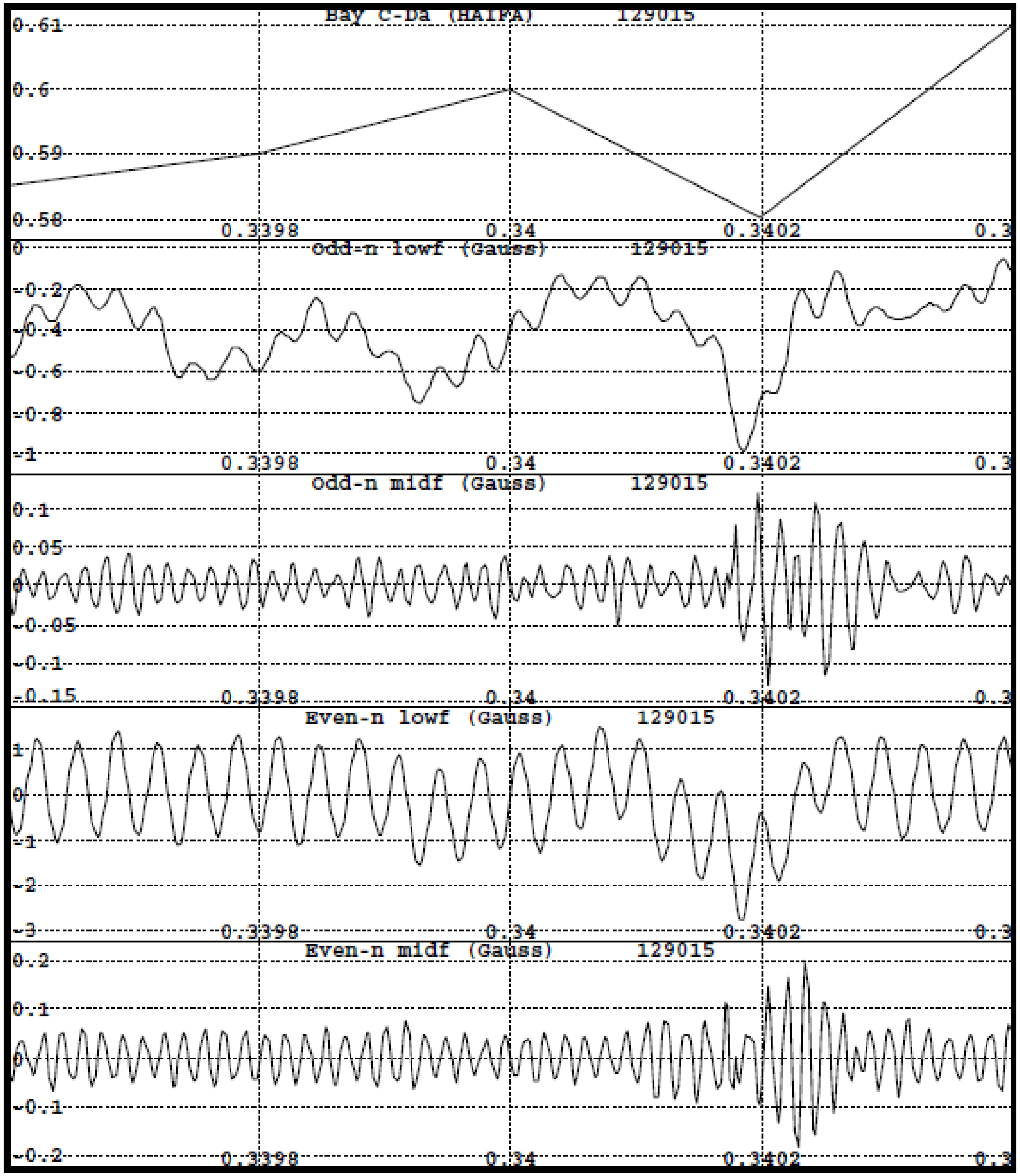
NSTX 129015 from 300 to 400 ms - without lithium



At left are div D_α, odd-n low-f, odd-n mid-f, even-n mid-f and even-n mid-f traces for 300 ms. to 400 ms period. The next slide shows a rotating kink? mode at 5 kHz, multiple modes modulating the odd-n mid-f and an n =2, 68 kHz mode on the even-n mid-f in light blue period.

Next are two spectrograms done for 300 ms to 400 ms period and light blue period shows continuous n = 3, 4, 5, 6 modes of 35 kHz to 55 kHz and n = 1, 2 modes of ~5 kHz and ~10 kHz In slow growing small ELM from 337 ms to 340 ms and transient n = 1, 2 modes of ~50 kHz and ~75 kHz, respectively around 340.2 ms before fast growing large ELM.

NSTX 129015 from 339.6 to 340.4 ms - without lithium



Toroidal mode #
Frequency

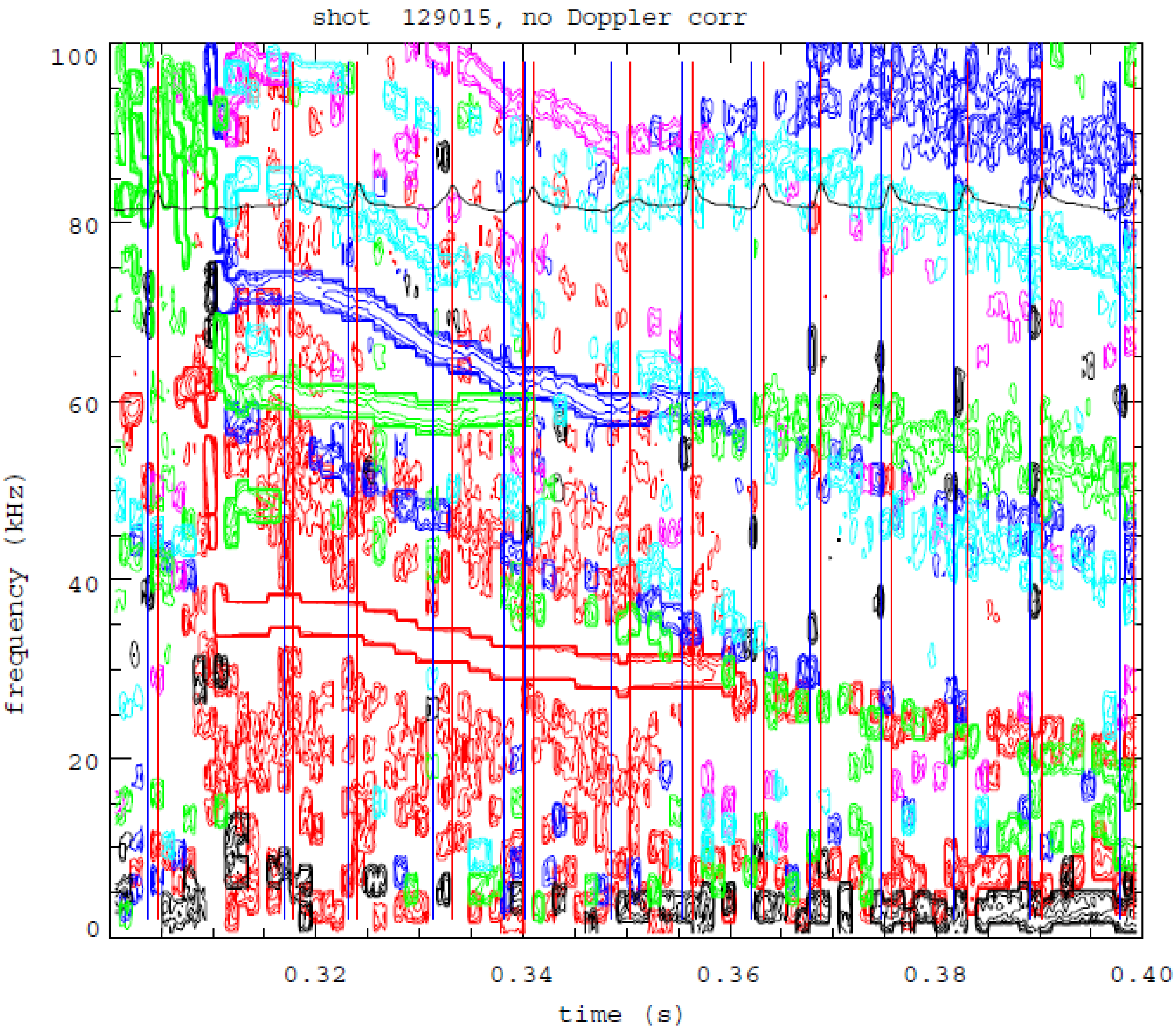
n = 1 kink mode?
~ 5 kHz

modulated by multiple modes

n = 2
~ 68 kHz

Spectrogram of NSTX 129015 (w/o lithium) from 300 to 400 ms

NSTX



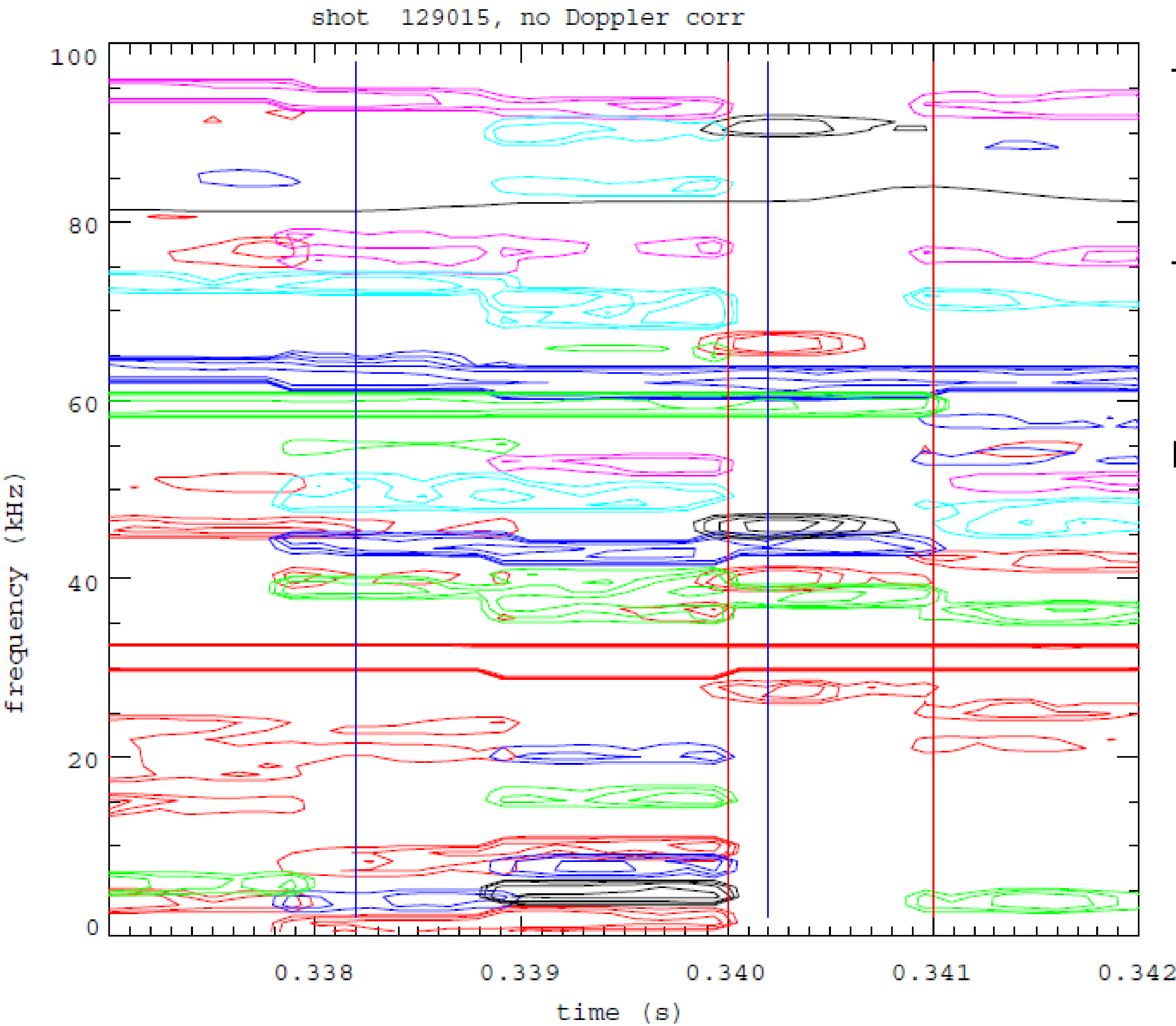
Toroidal mode # color code

- n = 1
- n = 2
- n = 3
- n = 4
- n = 5
- n = 6

ELM D_α onset |

ELM D_α peak |

NSTX 129015 w/o lithium - ELMs at 0.3400 and 0.3410 s



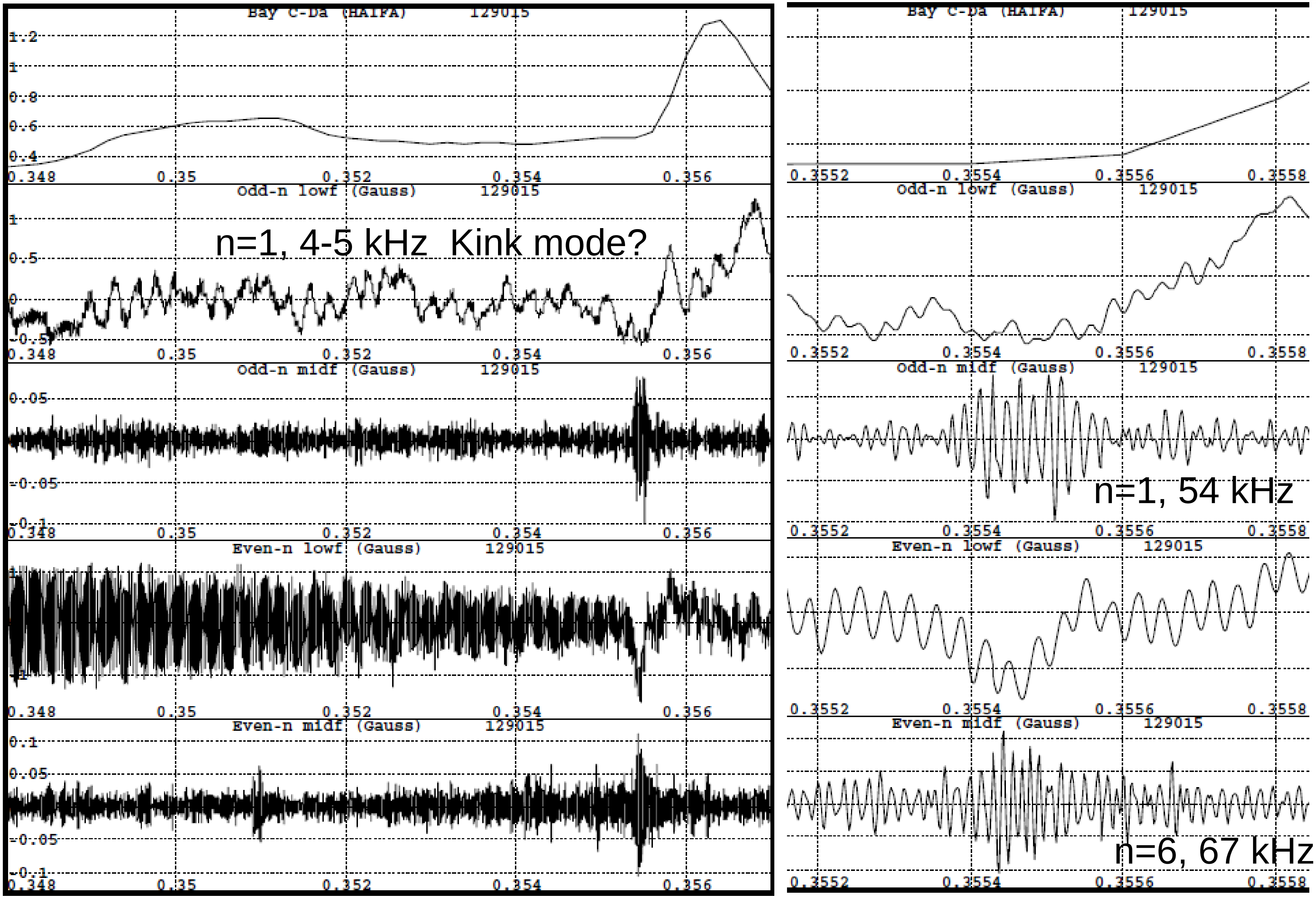
Transient
n=1, 90 kHz mode
n=1, 46 kHz mode

Transient
n=2, 67 kHz mode
n=2, 40 kHz mode

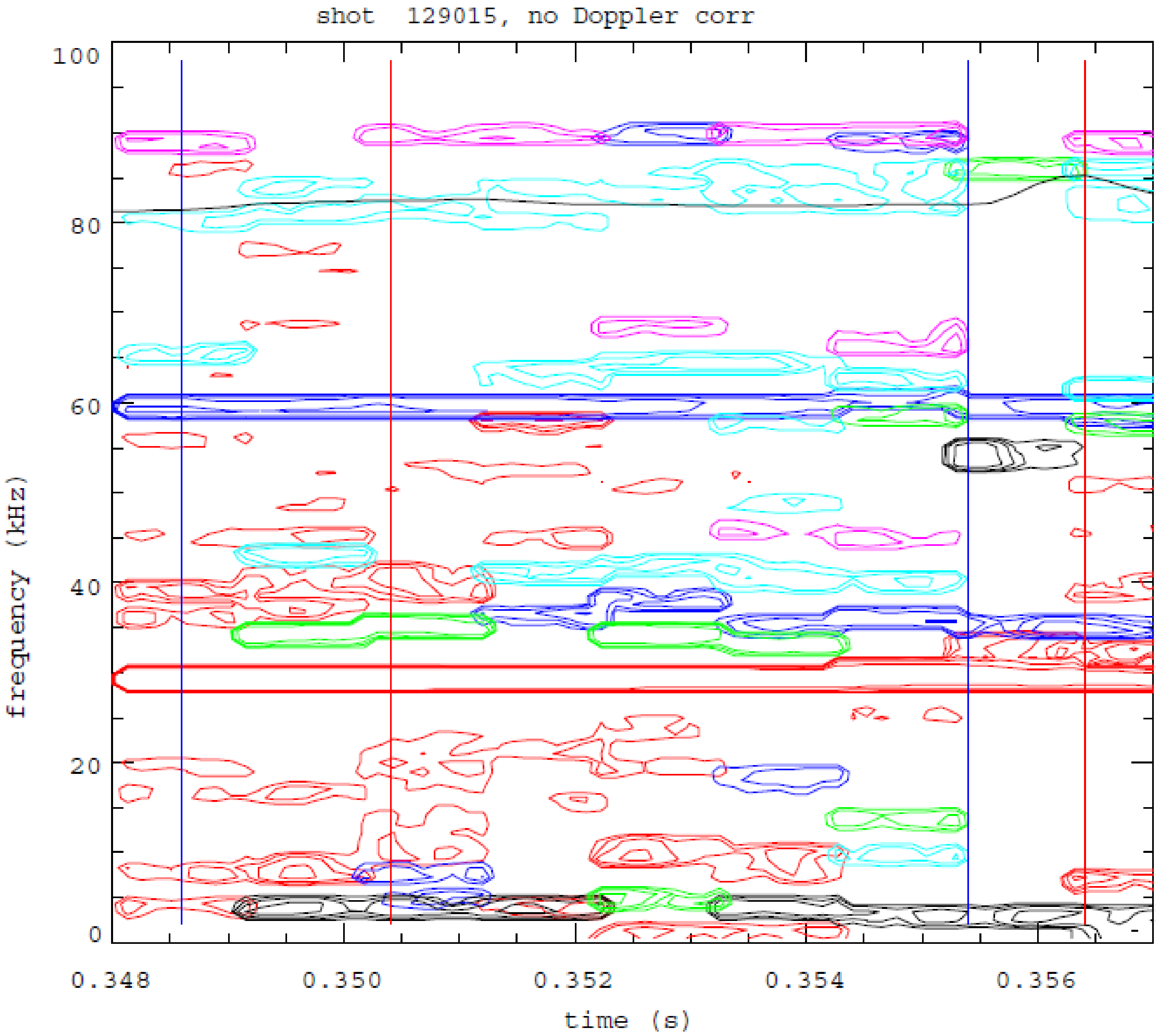
Peeling modes?
n=6, 54 kHz
n=5, 50 kHz
n=4, 44 kHz
n=3, 39 kHz

Kink modes?
n=4, 8 kHz
n=2, 2 & 10 kHz
n=1, 5 kHz

NSTX 129015 w/o lithium - ELMs at 0.3512 and 0.3564 s



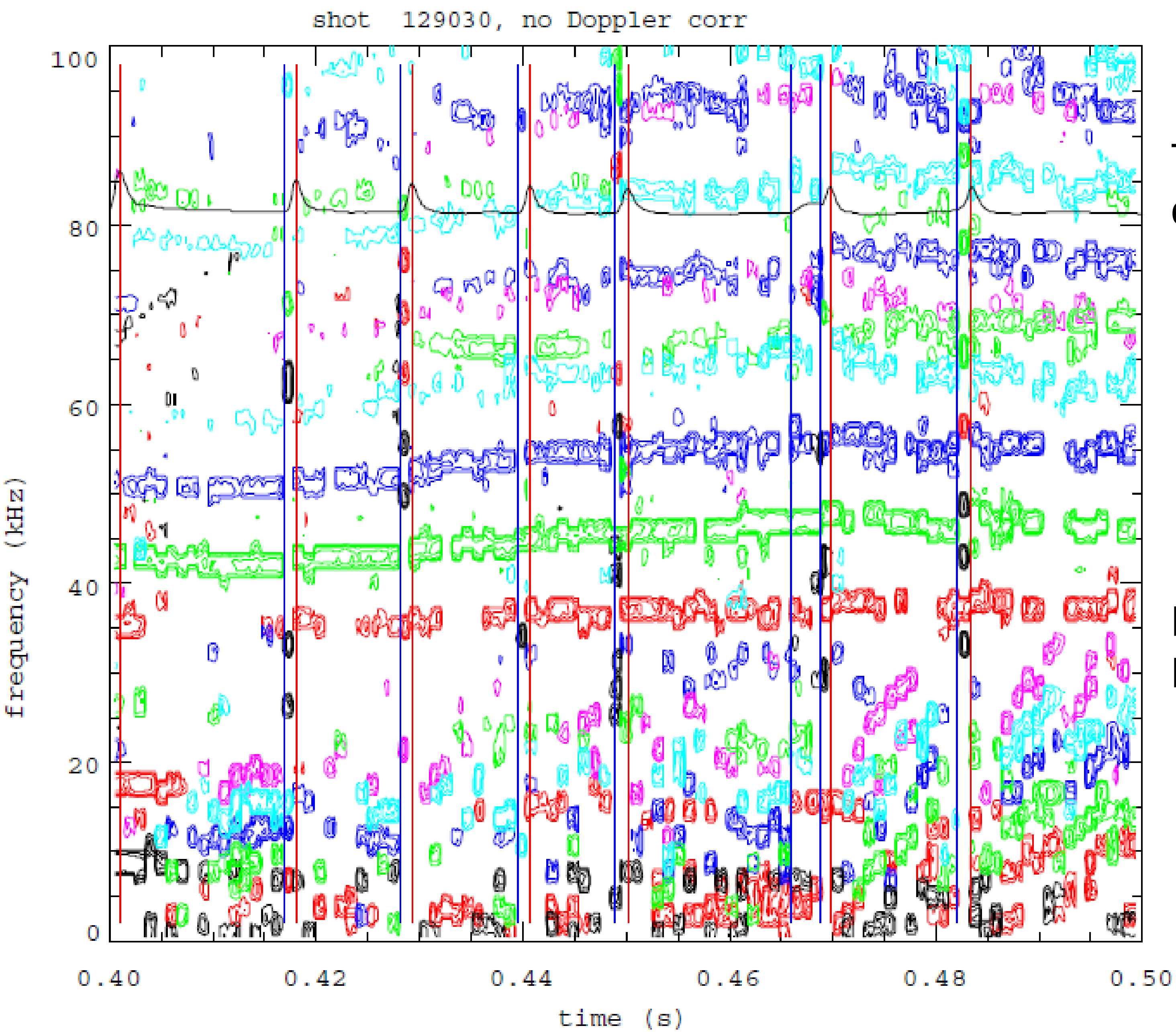
NSTX 129015 w/o lithium - ELMs at 0.3512 and 0.3564 s



Transient
n=6, 67 kHz mode
n=1, 54 kHz mode

Kink mode?
n=1, 4-5 kHz

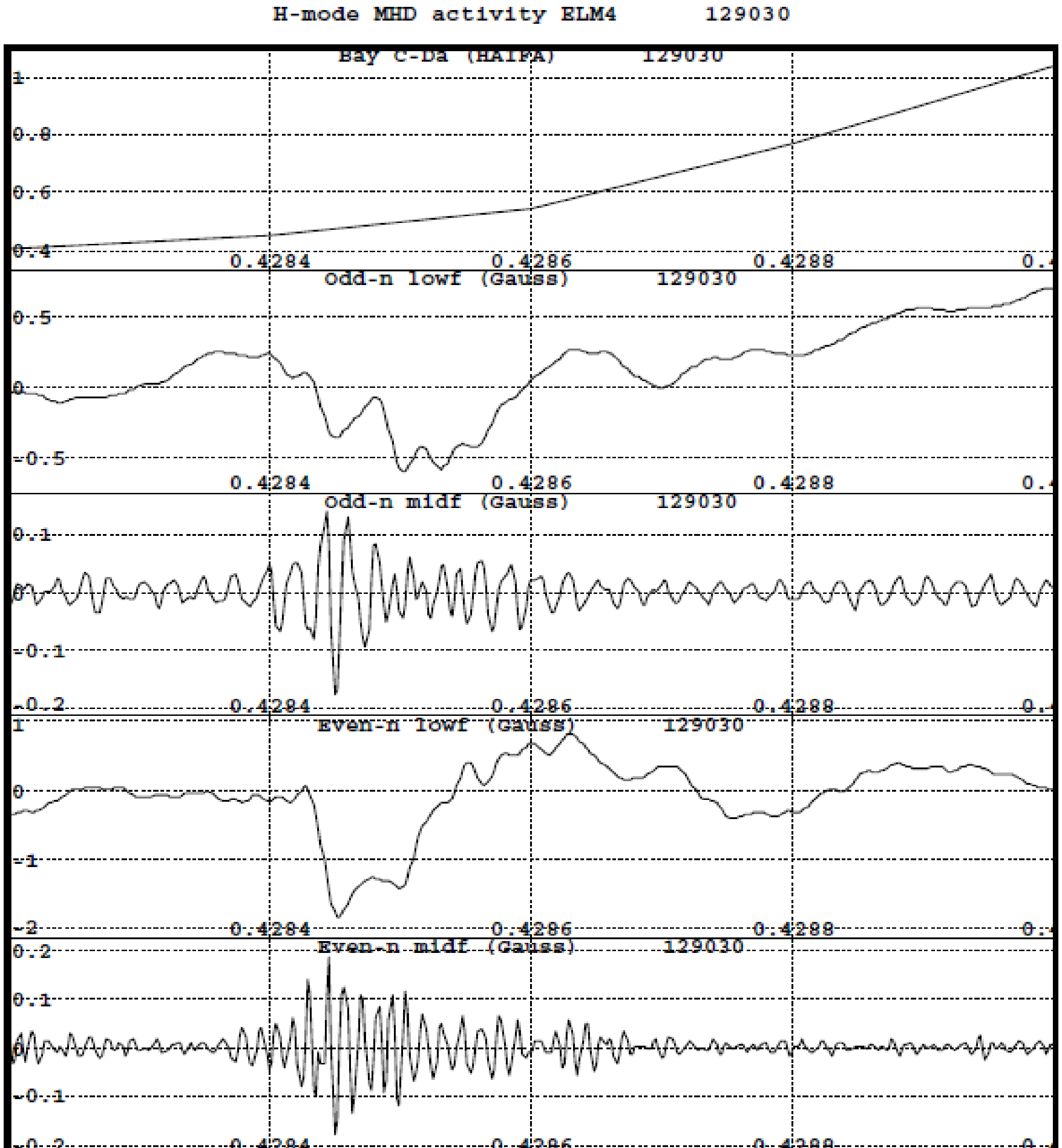
Spectrogram of NSTX 129030 with lithium from 400 to 500 ms



Toroidal mode # color code
n = 1
n = 2
n = 3
n = 4
n = 5
n = 6

ELM D_α onset |
ELM D_α peak |

NSTX 129030 with lithium from 428.2 to 429.0 ms



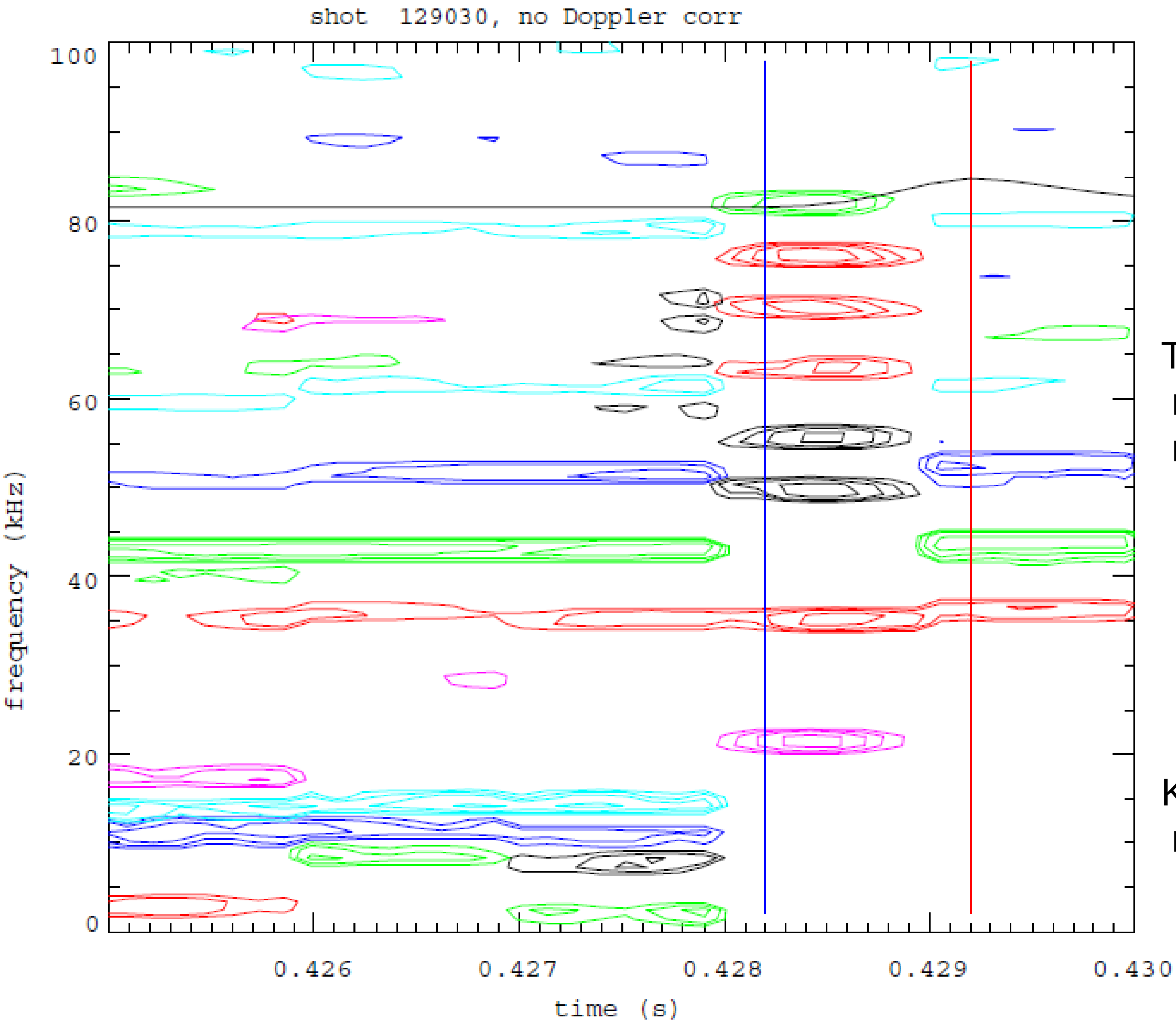
Lithium walls result in much clearer magnetic precursors due lower overall MHD activity.

Toroidal mode # Frequency

n = 1
~ 50 kHz

n = 2
~ 75 kHz

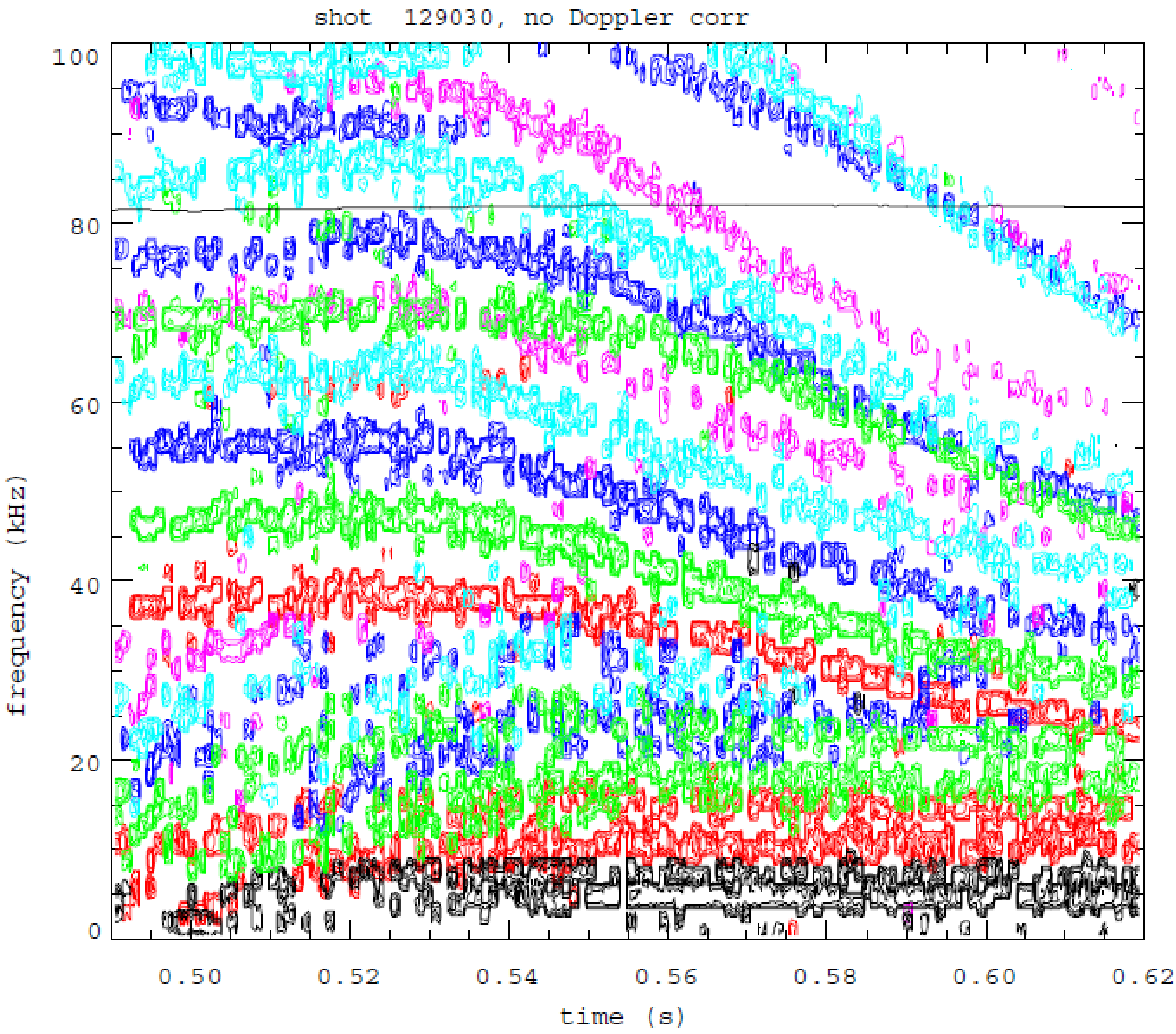
NSTX 129030 w / lithium - ELM at 0.4292 s



Transient
n=2, 75 kHz mode
n=1, 50 kHz mode

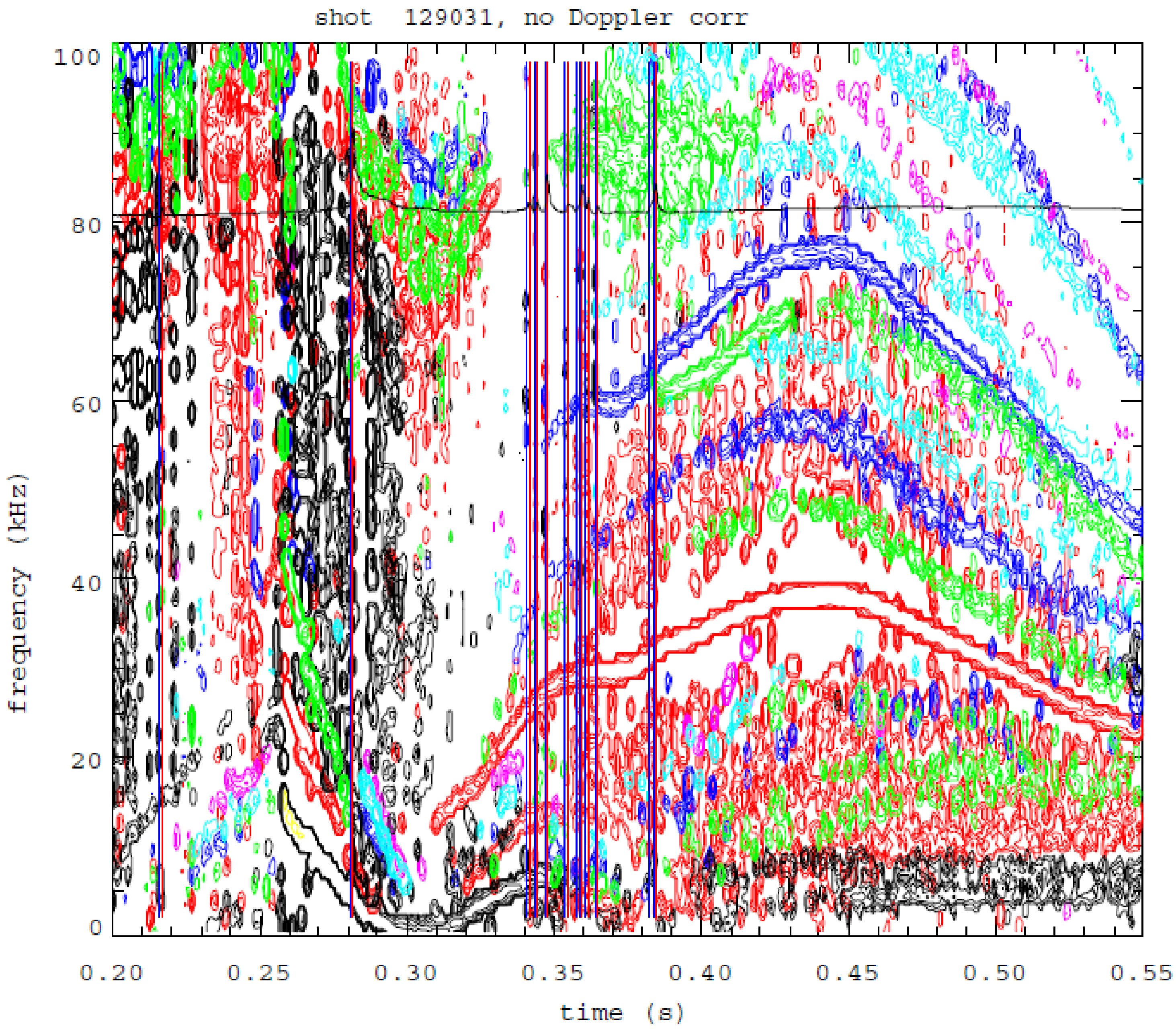
Kink mode?
n=1, 8 kHz

NSTX 129030 with lithium from 490 to 620 ms: ELM free phase



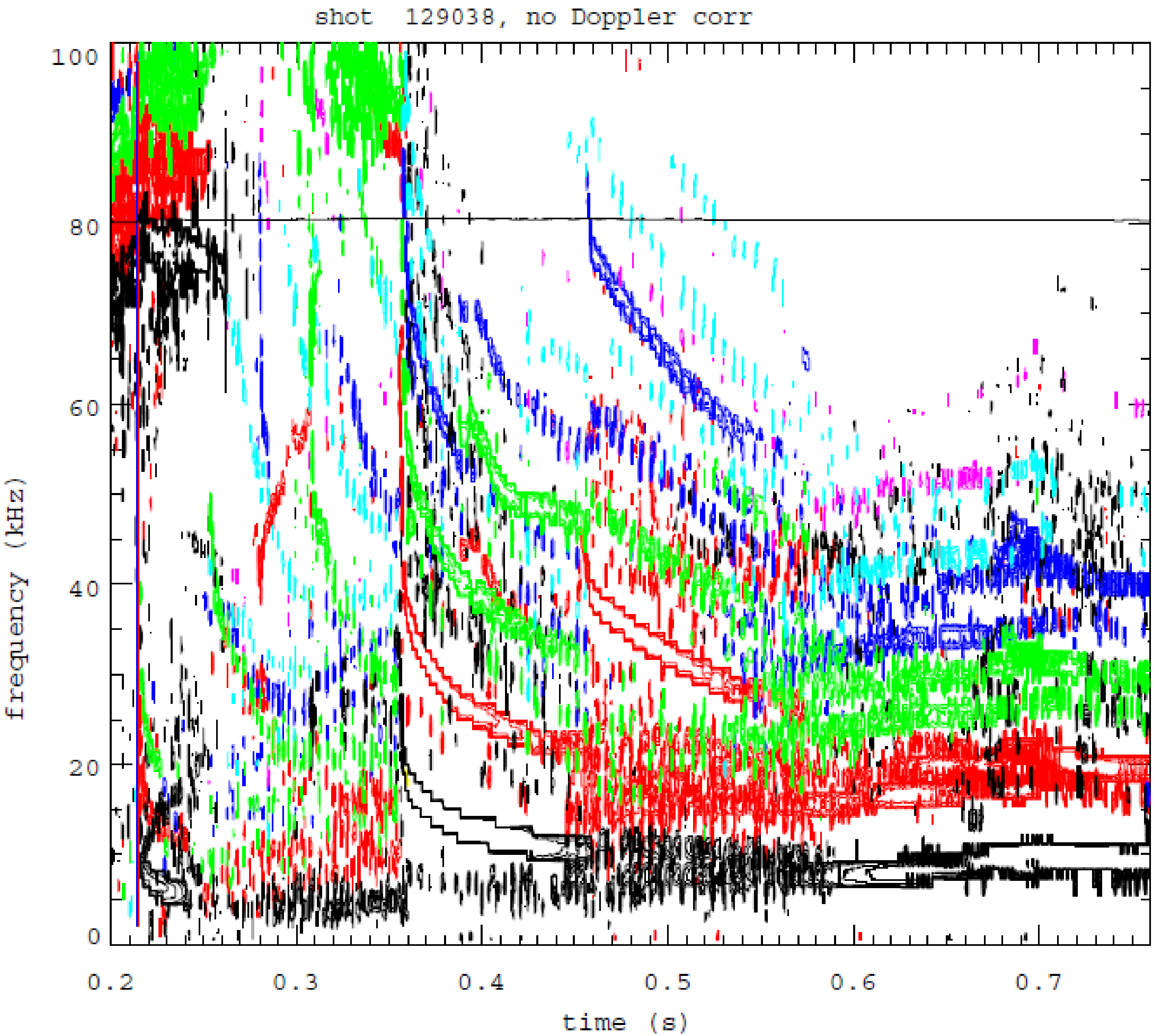
Occasional weak mid-f n =1 modes, but no ELMs!

NSTX 129031 with lithium



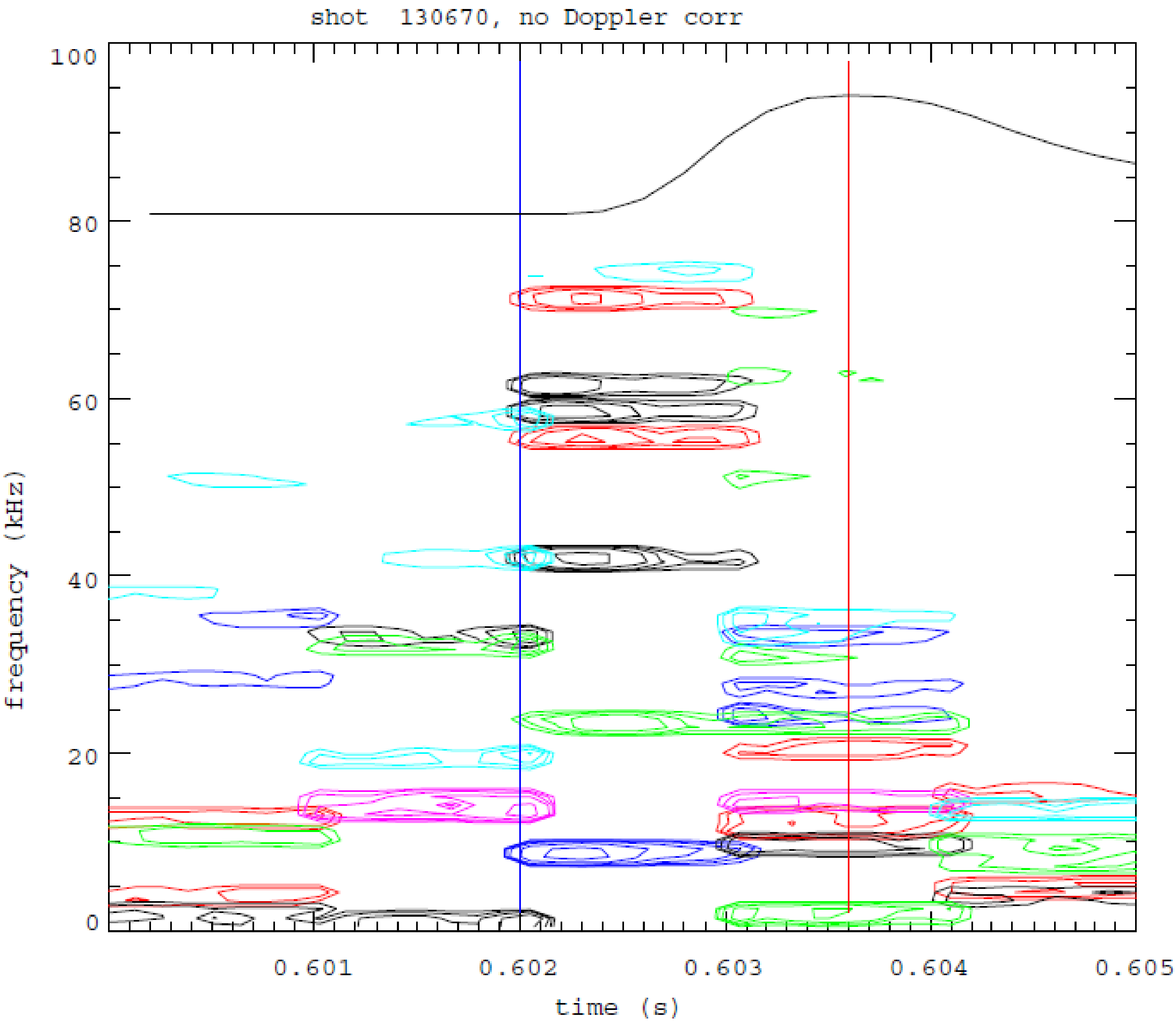
Strong n = 1 mode, before ELMs return!

NSTX 129038 with lithium: long ELM free phase



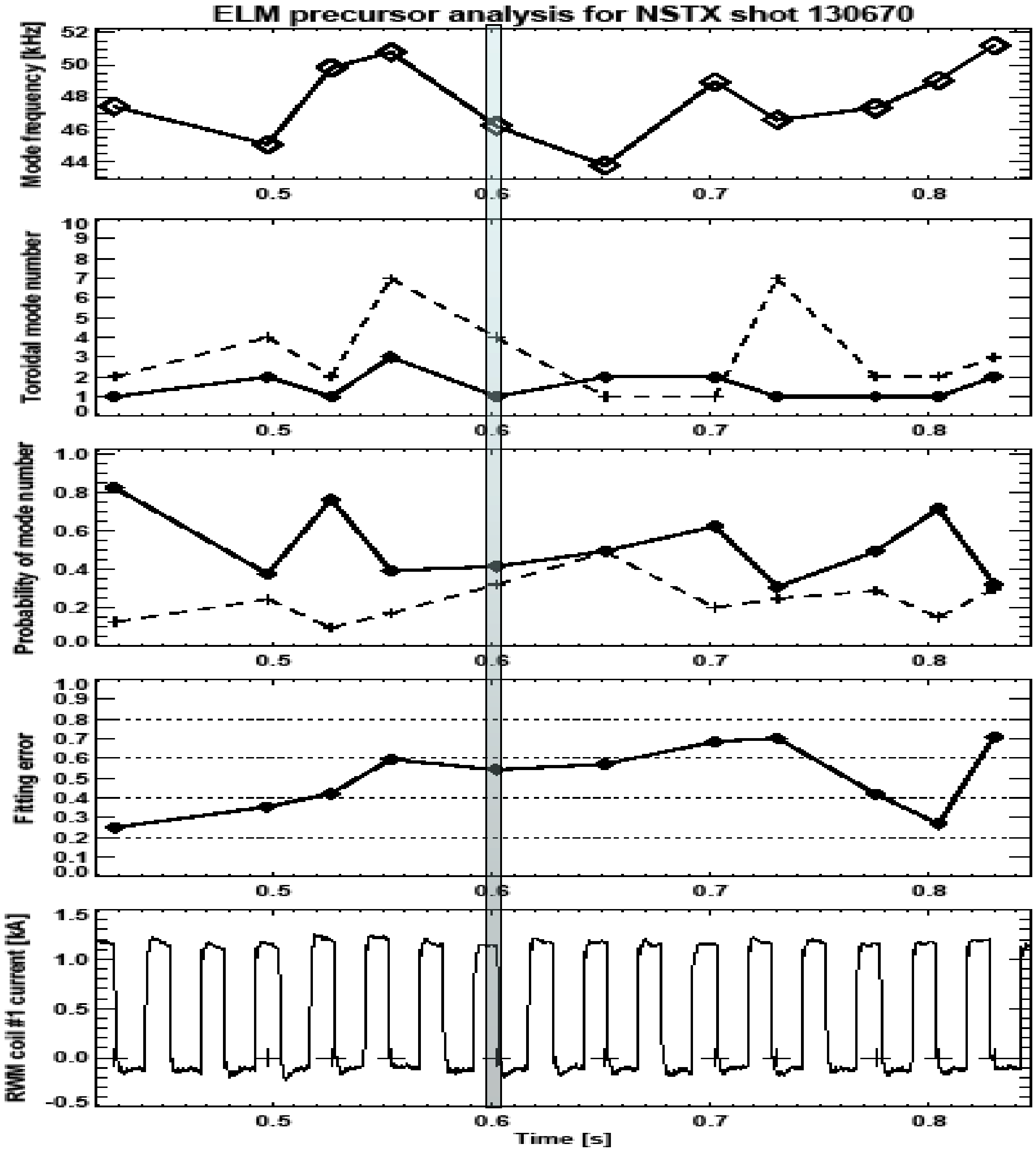
Many n = 1 modes, but no ELMs!?

NSTX 130670 w/ nRMP w/o lithium – ELM at 0.6036 s



Transient modes
n=4, 8 kHz
n=2, 56 & 72 kHz
n=1, 42 & 60 kHz

Cross-check with J. Menard's ELM-FIT code



f = 46 kHz for most probable mode

n =1 most probable
n =4 next most prob.

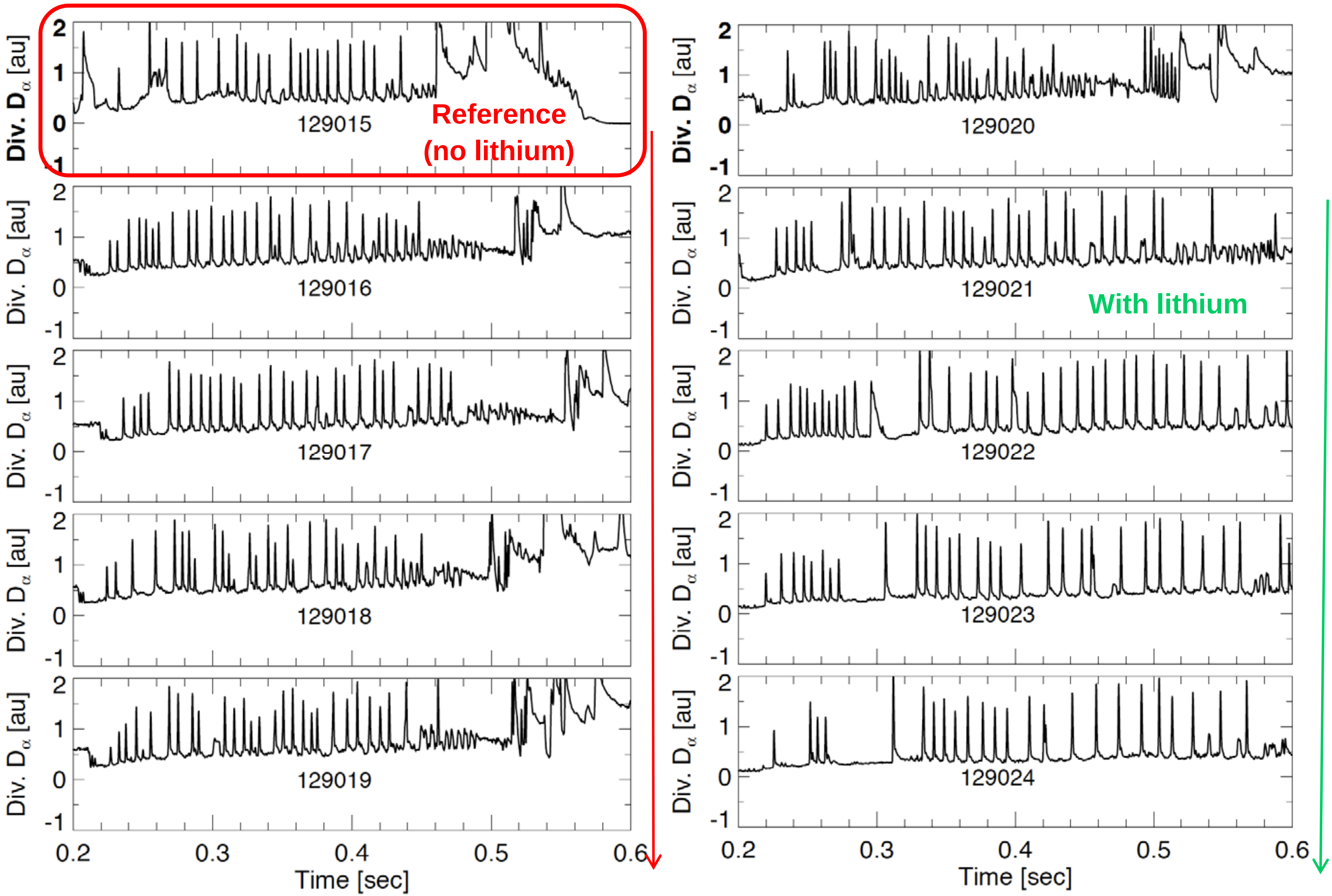
Large fitting error of most prob. mode

RWM coil #1 current [kA]

ELM evolution with shot number

R. Maingi PI2.03

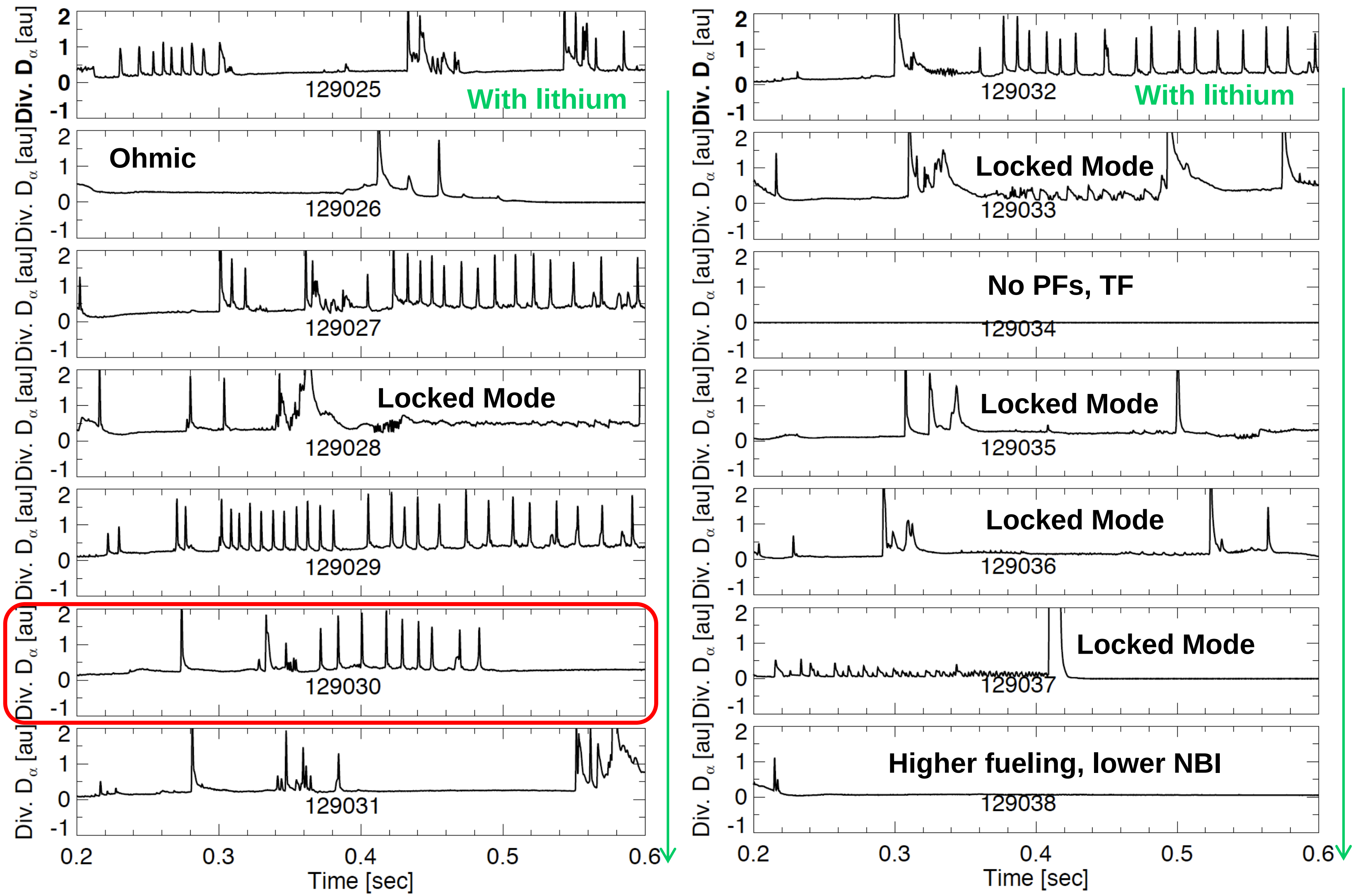
NSTX



ELM evolution with shot number

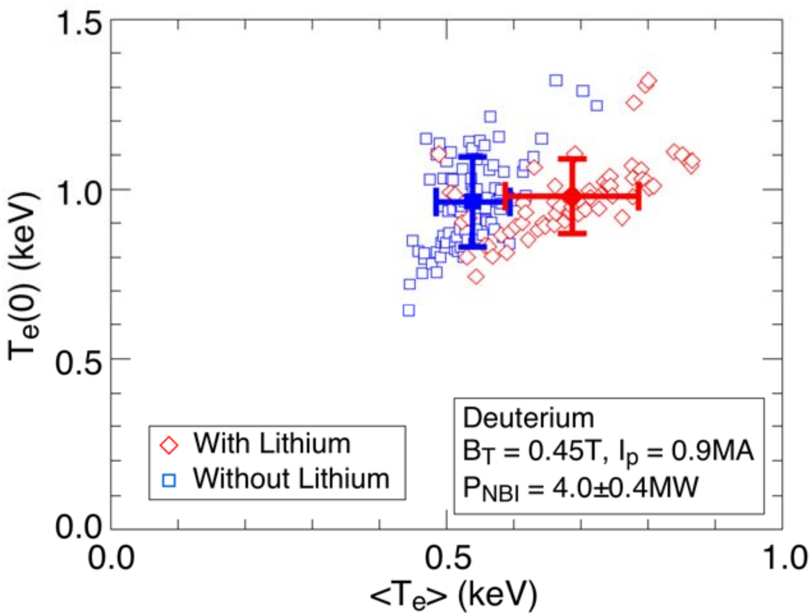
R. Maingi PI2.03

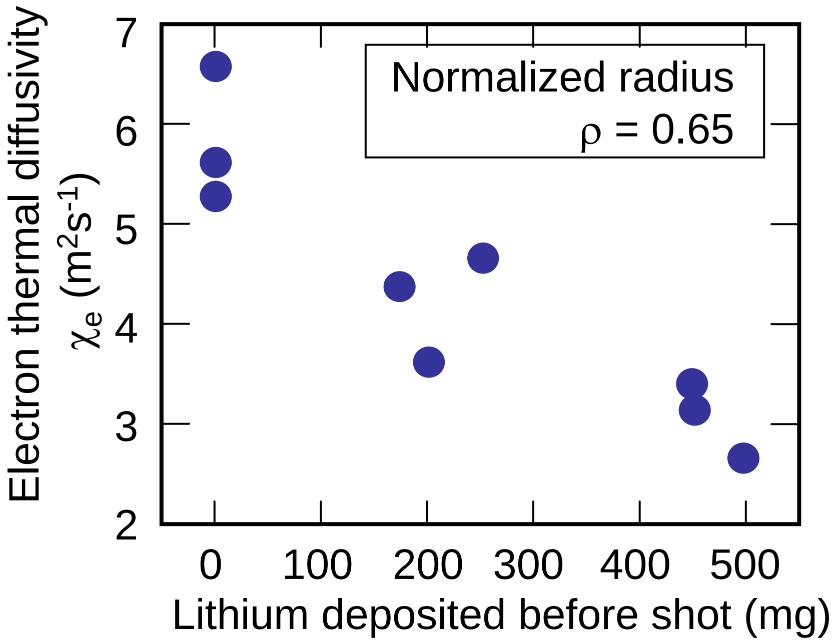
NSTX



Improvement in Electron Confinement Arises from Broadening of Temperature Profile

M. Bell JO4.02





- TRANSP analysis confirms electron thermal transport in outer region progressively reduced by lithium
- Fast-ion contribution to total energy increased
- Thermal ion confinement remains close to neoclassical level both with and without lithium

*M. Bell, B. LeBlanc, S. Kaye, **S. Ding (PP8.47)***

Discussion of Results

n = 3,4,5,6 modes -> slowly growing ELMs that are smaller, but perhaps excited by 5 kHz, n =1 rotating kink? mode.

n= 1/n=2 modes necessary for fast growing, large amplitude ELMs, but perhaps excited by 5 kHz, n =1 rotating kink? mode.

Kink/peeling modes driven by edge currents are likely candidates for n= 1/n= 2 modes. Also Pegasus: Bongard et al., JO4.07 this meeting.

Thermoelectric SOL Current driven similar to DIII-D, e.g. Takahashi et al., NF 44 (2004) 1075

Increasing lithium wall coating dramatically illustrates that the neutral flux thorough the edge is destabilizing.

Lithium coated walls result in much less MHD activity, confinement improves and electron thermal transport reduced, e.g. M. Bell, JO.02 this meeting.

Discussion of Results

ELM sequence outlined by T. Evans et al. JNM 390-391 (2009) 789.

1) Transient event initiated by peeling-ballooning mode as pedestal pressure gradient limit > marginal stability limit. Initial pulse of heat and particles propagates into preexisting homoclinic separatrix tangle.

2) Onset of thermoelectric current driven between outer and inner target plates due to T_e difference between plates from initial heat pulse.

3) Original helical filament grows explosively as thermoelectric currents amplify the lobes of the homoclinic tangle and induce strong pedestal stochasticity. Results in self-amplification of lobes due to positive feedback loop between lobe size, stochastic layer width and increase heat flux to target plates driving the current.

4) ELM crash- temperature in pedestal drops enough for plasma to become more collisional and resistive. A) Shuts down energy source for thermoelectric currents collapsing lobes to pre-ELM configuration. B) Decrease electron collisional mfp compared to connection length of filamentary lobes which reduces parallel thermal conductivity and shuts down heat flux to target plates.