MHD-Induced Beam Ion Loss from NSTX Plasmas

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Abstract

The Scintillator Fast Lost Ion Probe (sFLIP) on NSTX measures the loss of neutral beam ions lost to the wall near the outer midplane, resolved in gyroradius and pitch angle. The diagnostic has recently been upgraded to record the characteristics of the loss at up to 40,500 frames/s, allowing resolution of losses arising from neutral beam driven bursting MHD modes. The mode begins as an n=1 mode and sweeps in frequency, then spawns n=2 & n=3 modes. The beam ion loss is unvarying during the interval of frequency sweeping, but increases in intensity and extends to a broad range of pitch angles when modes of more than one n value are simulatneously present.

Motivations

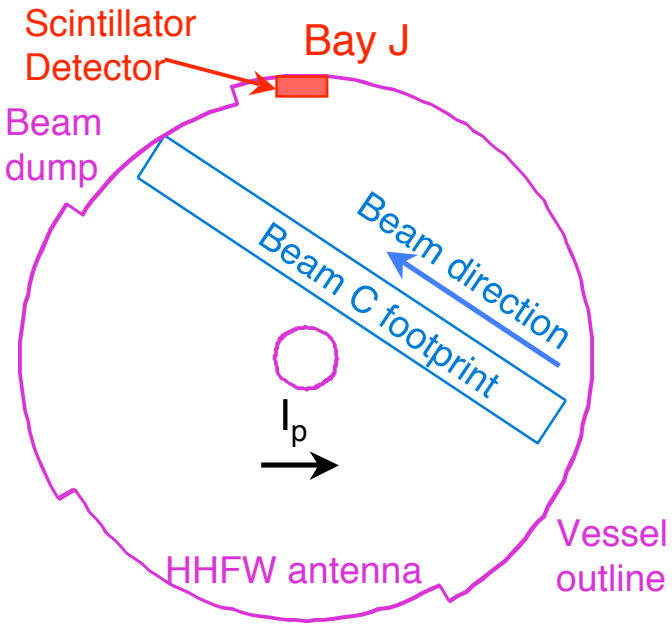
- Dimensionless parameters of beam ions similar to 3.5 MeV αs in DT spherical tokamak (good model system)
- Lost beam ion characteristics can reveal internal physics, especially effects of MHD instabilities
- MHD-induced loss often seen in NSTX plasmas

Fast ion loss mechanisms

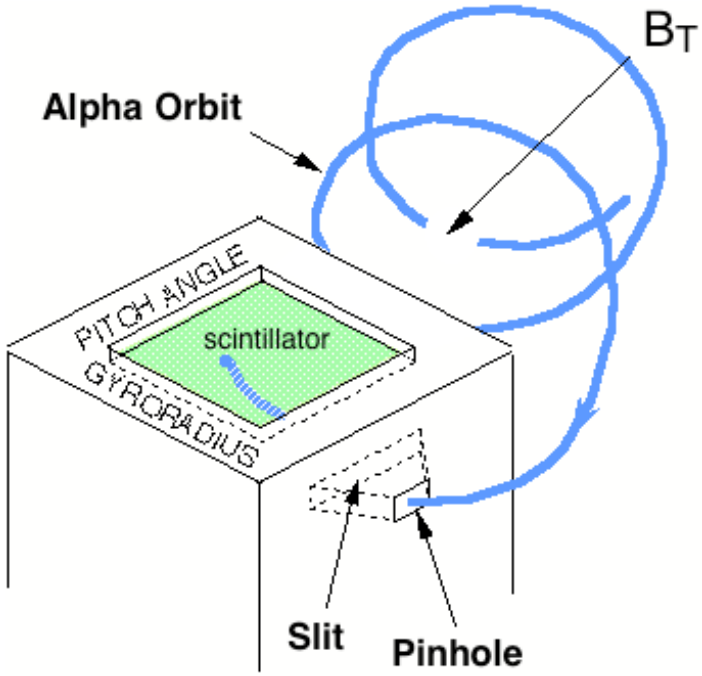
- Prompt orbit loss: fast ion born in loss cone
- Radial transport to wall (arises from changes in toroidal momentum, P_ϕ):
  - MHD
  - TF ripple
- Pitch angle scattering into loss cone (arises from changes in the magnetic moment, μ):
  - Classical collisions
  - ICRF heating

Scintillator fast lost ion (sFLIP) probe is magnetic spectrometer

- Combination of B and aperture geometry disperse different pitch angles and energies on scintillator plate

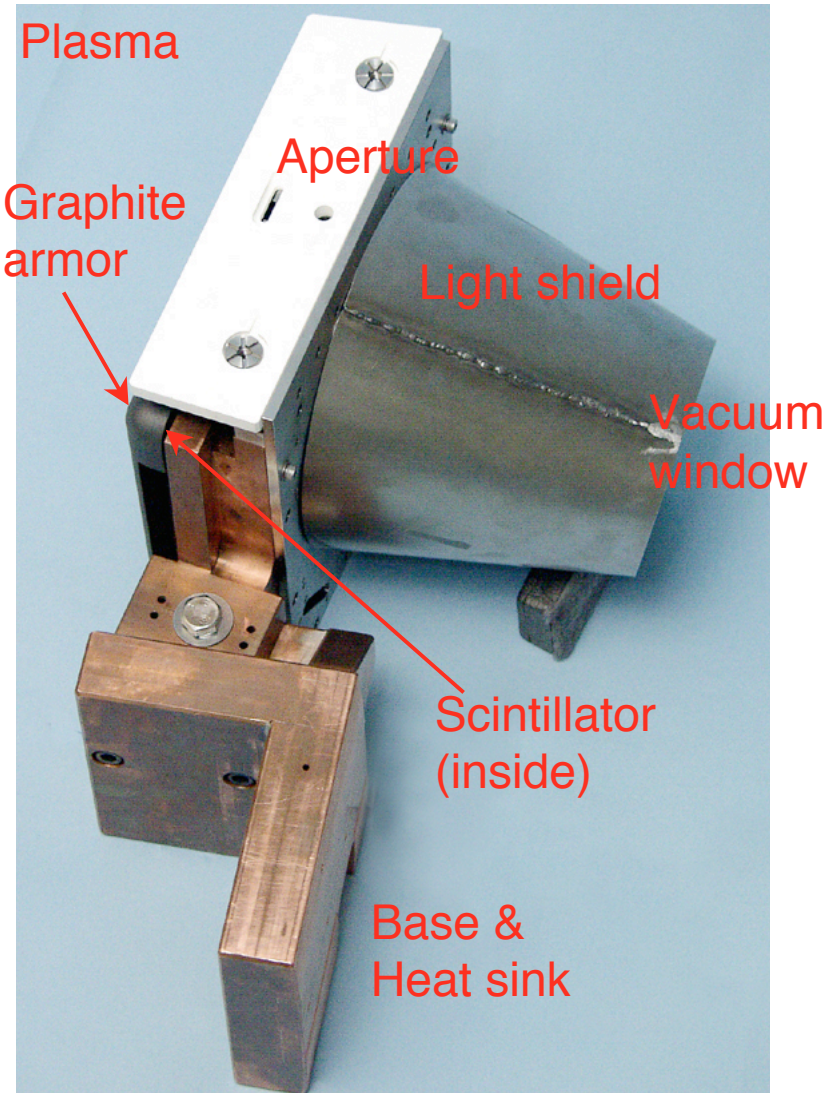


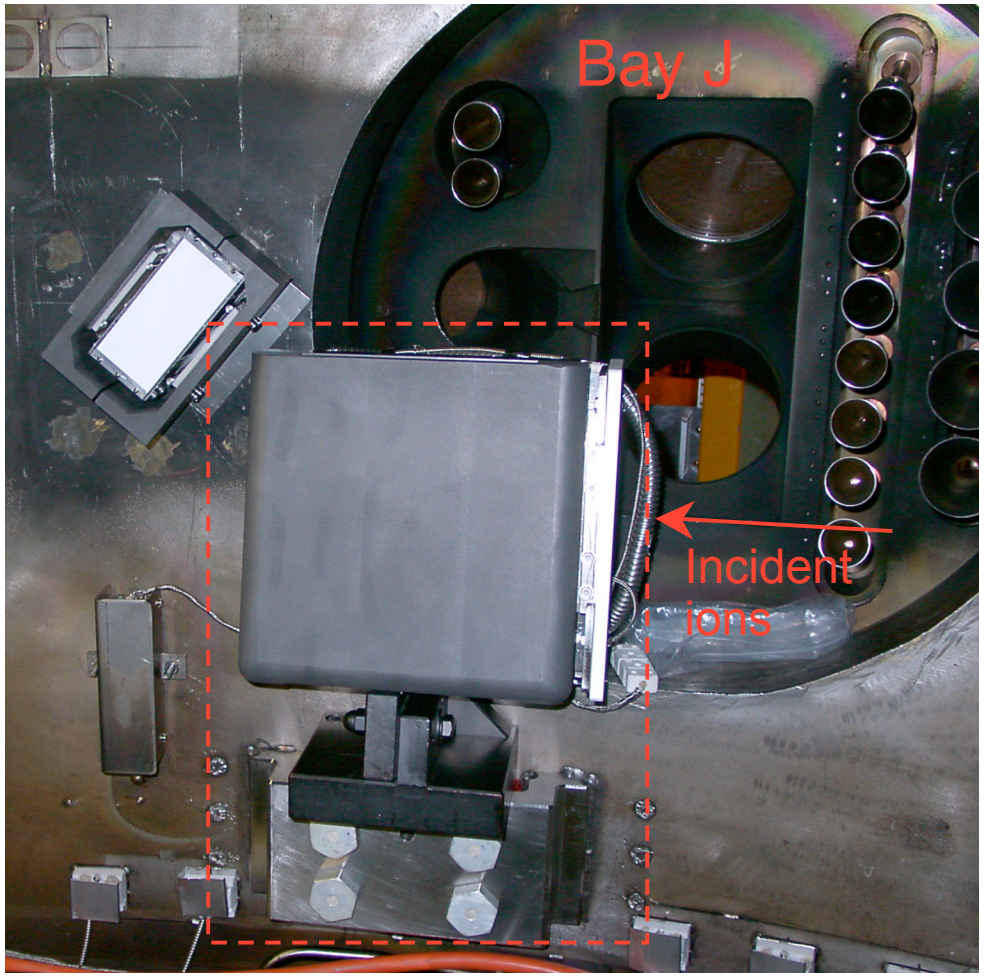
NSTX Midplane



Scintillator detector: principle of operation

Scintillator probe assembly



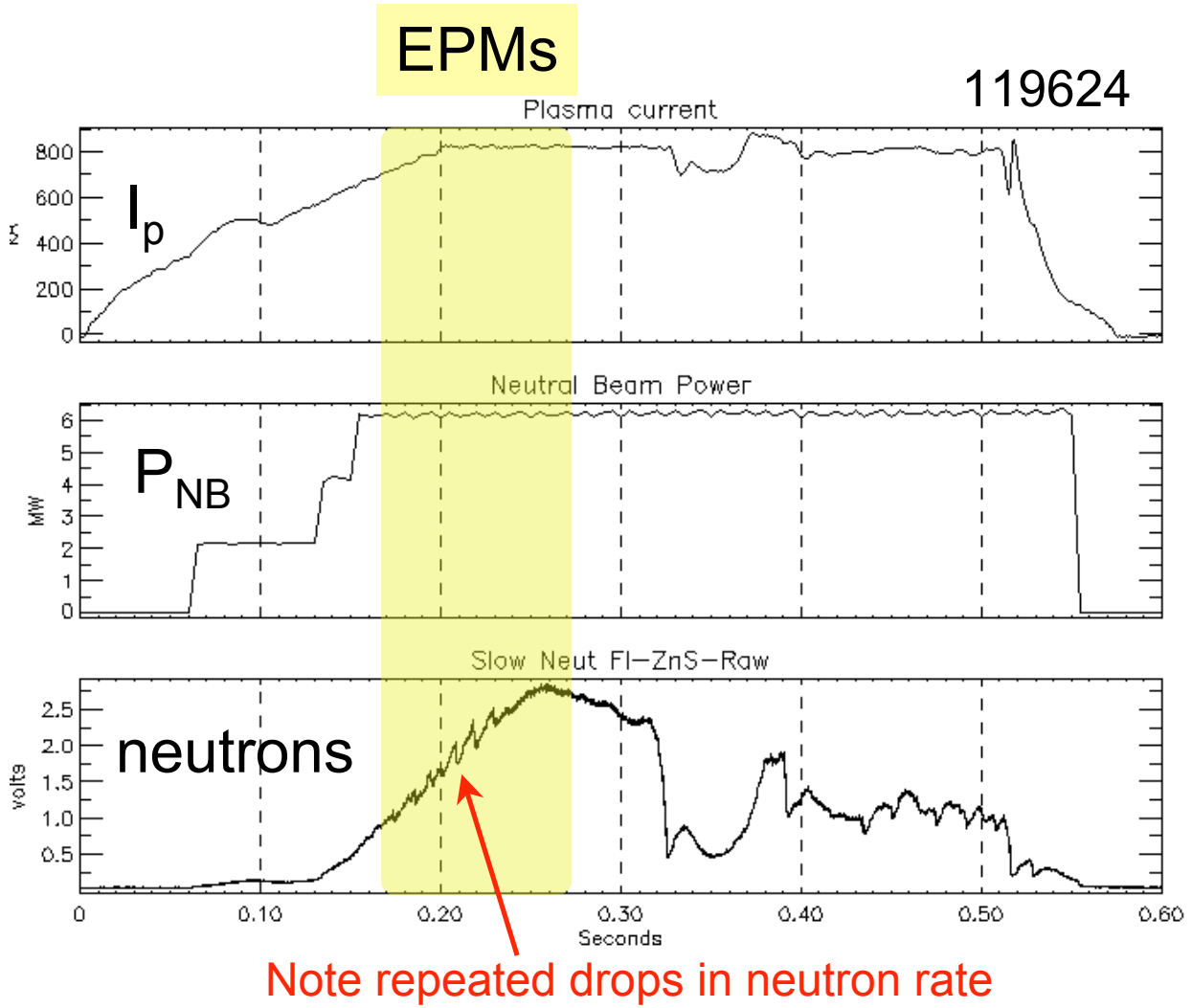


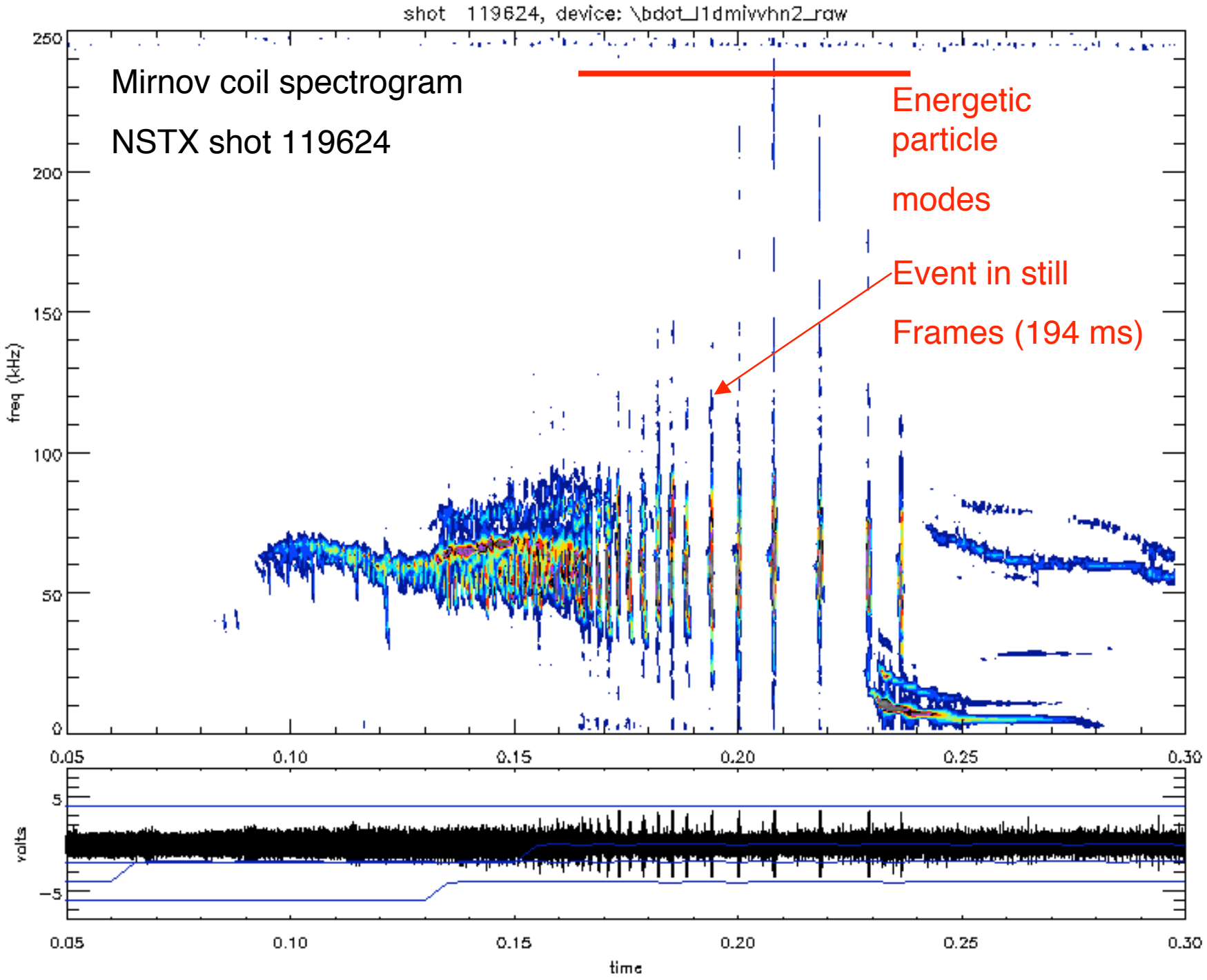
ρ: 5–60 cm, χ: 10°–70° (typ.)

Scintillator images recorded by fast videocamera

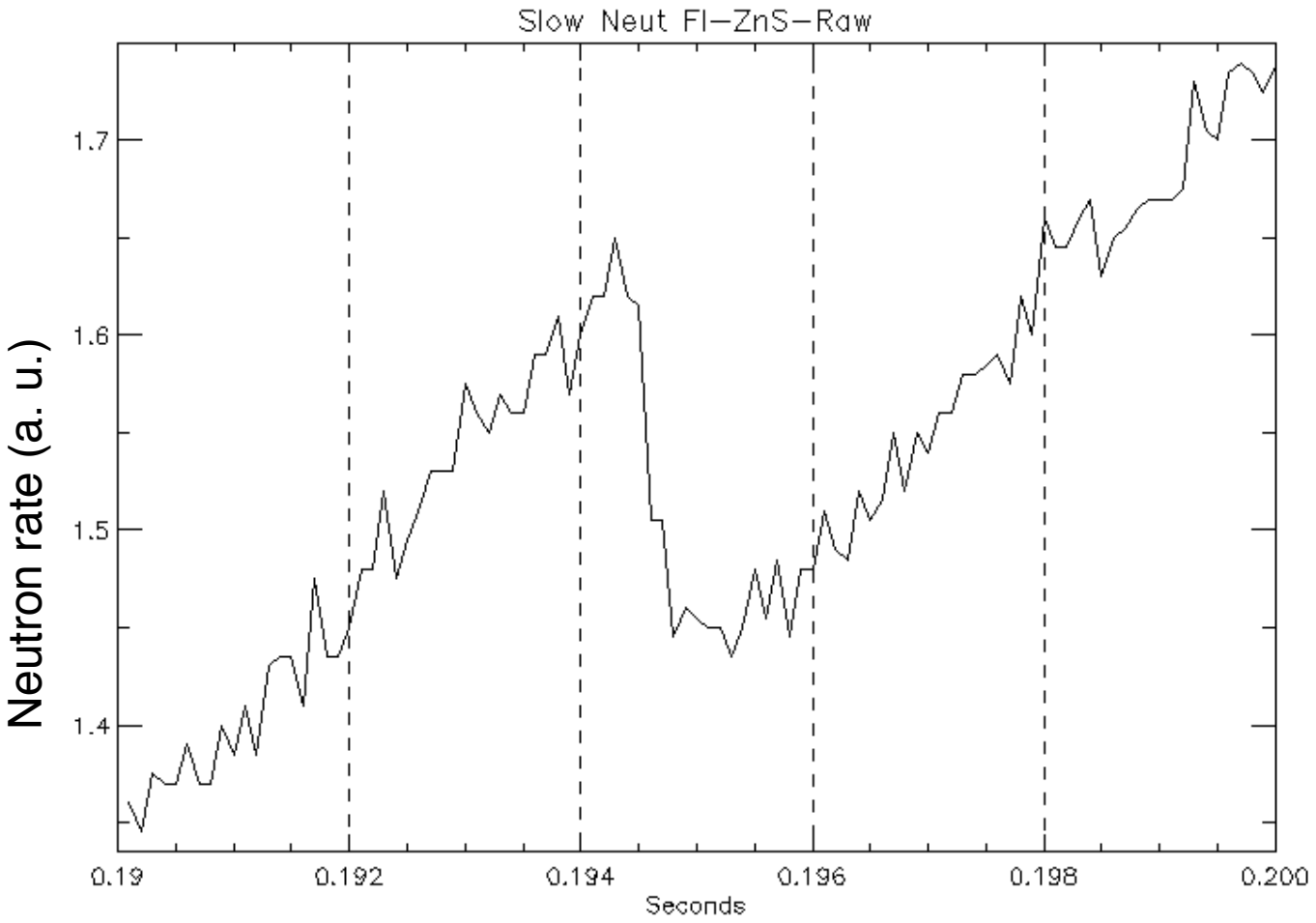
- Photron Fastcam on loan from JAEA for 2005 & 2006 campaigns
- Gives ≤40,500 frames/s
- Good for resolution of MHD & other rapidly-varying loss

Energetic Particle Modes produce strong beam ion loss

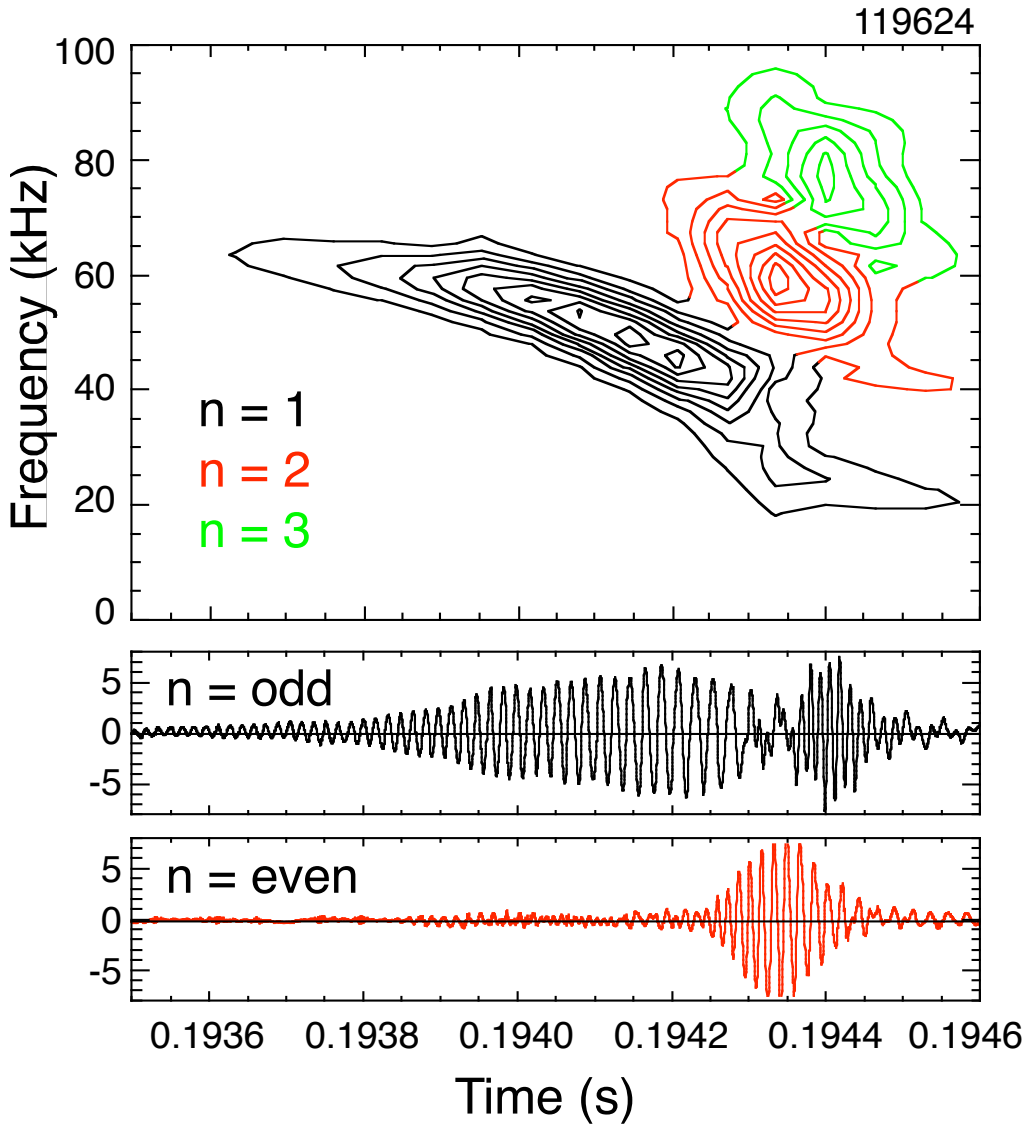



shot 119624, device: \bdot_l1dmivvhn2_raw
Mirnov coil spectrogram
NSTX shot 119624
Energetic particle modes
Event in still Frames (194 ms)
freq (kHz)
250
200
150
100
50
0
0.05
0.10
0.15
0.20
0.25
0.30
volts
5
−5
time

Event at 194 ms reduces neutron rate by 13 %

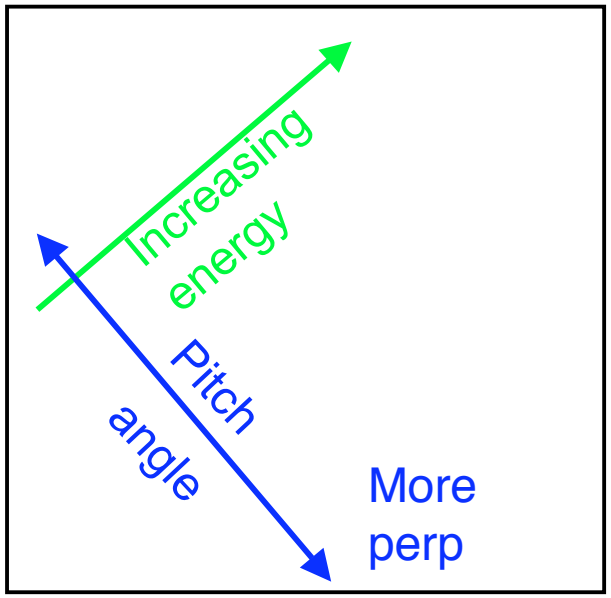


Event has significant frequency chirping, multiple n values

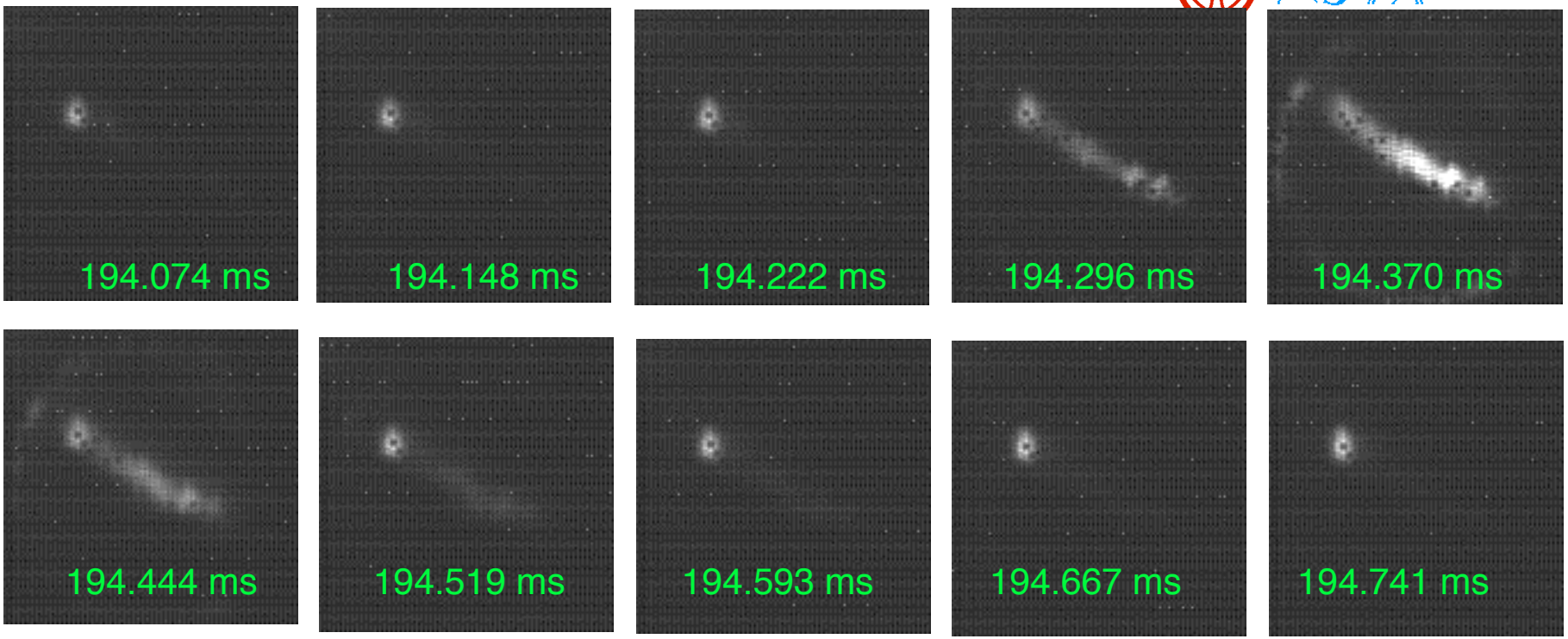


- n=1 chirps 65 to 40 kHz in 500 μs
- n=1, 2, & 3 all present

Scintillator image interpretation



Loss varies rapidly in time

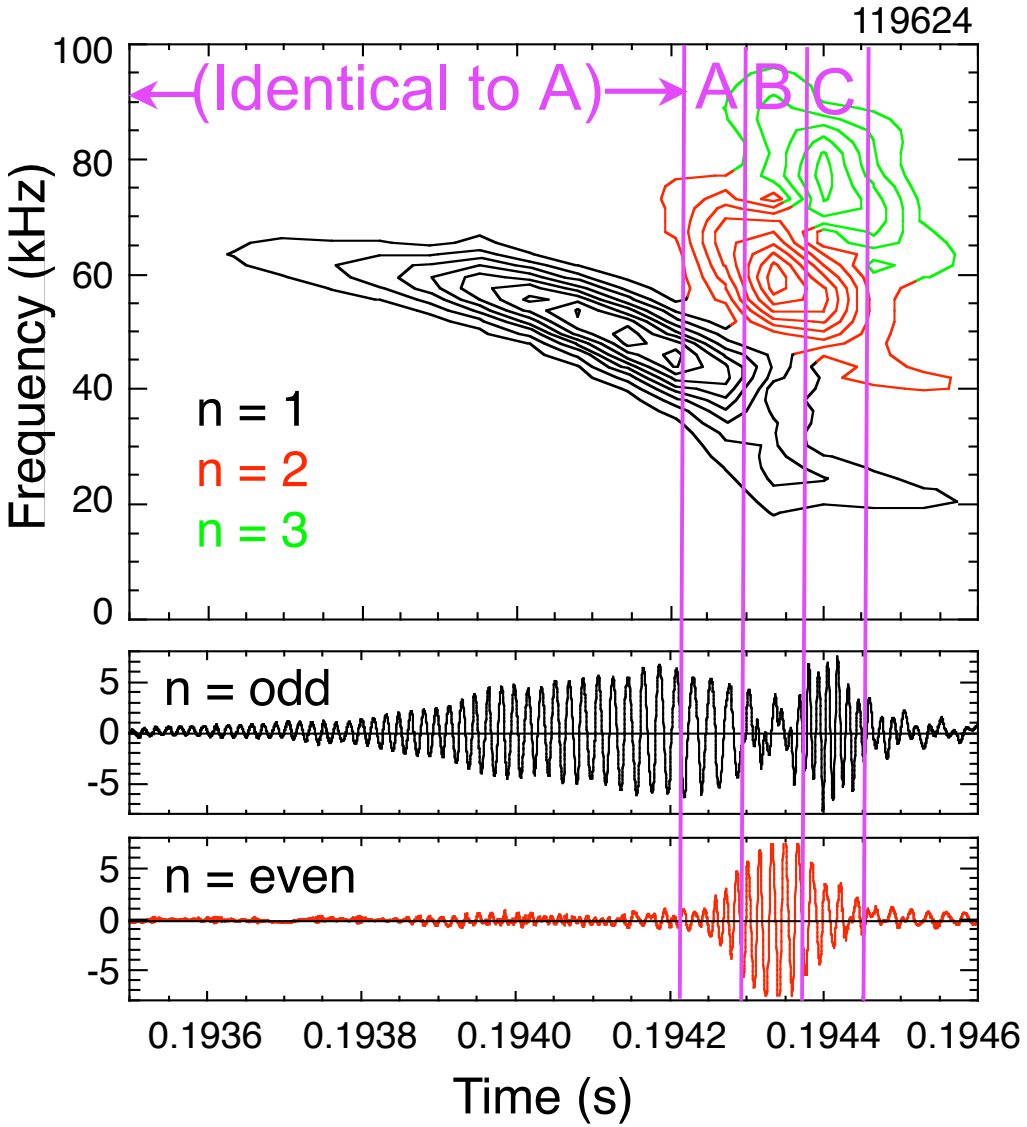


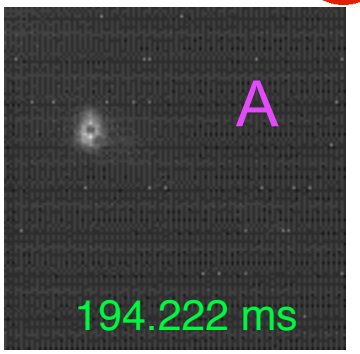
- 13,500 frames/s
- Full beam energy loss only (80 keV D)
- Upper left loss spot exists before, during, & after, i.e. not MHD loss

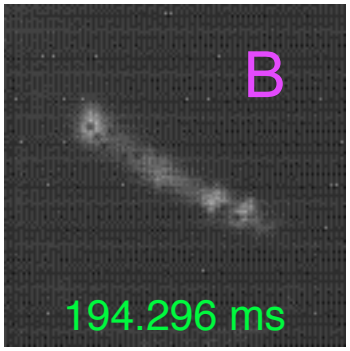
Broad range of pitch angles lost

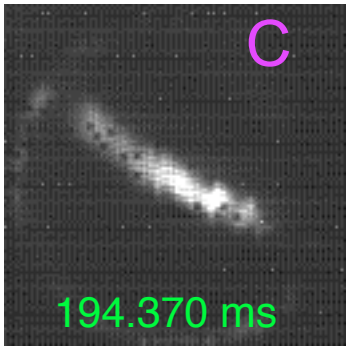
- Wide range of pitch angles lost in single frame (<100 μs)
- No evidence of sweeping in pitch angle at this time scale, i.e. loss spot does not move through a succession of pitch angles from one frame to another, but only appears as a single discrete pitch angle or a broad range within each individual frame.

Broad pitch range lost when multiple n values present

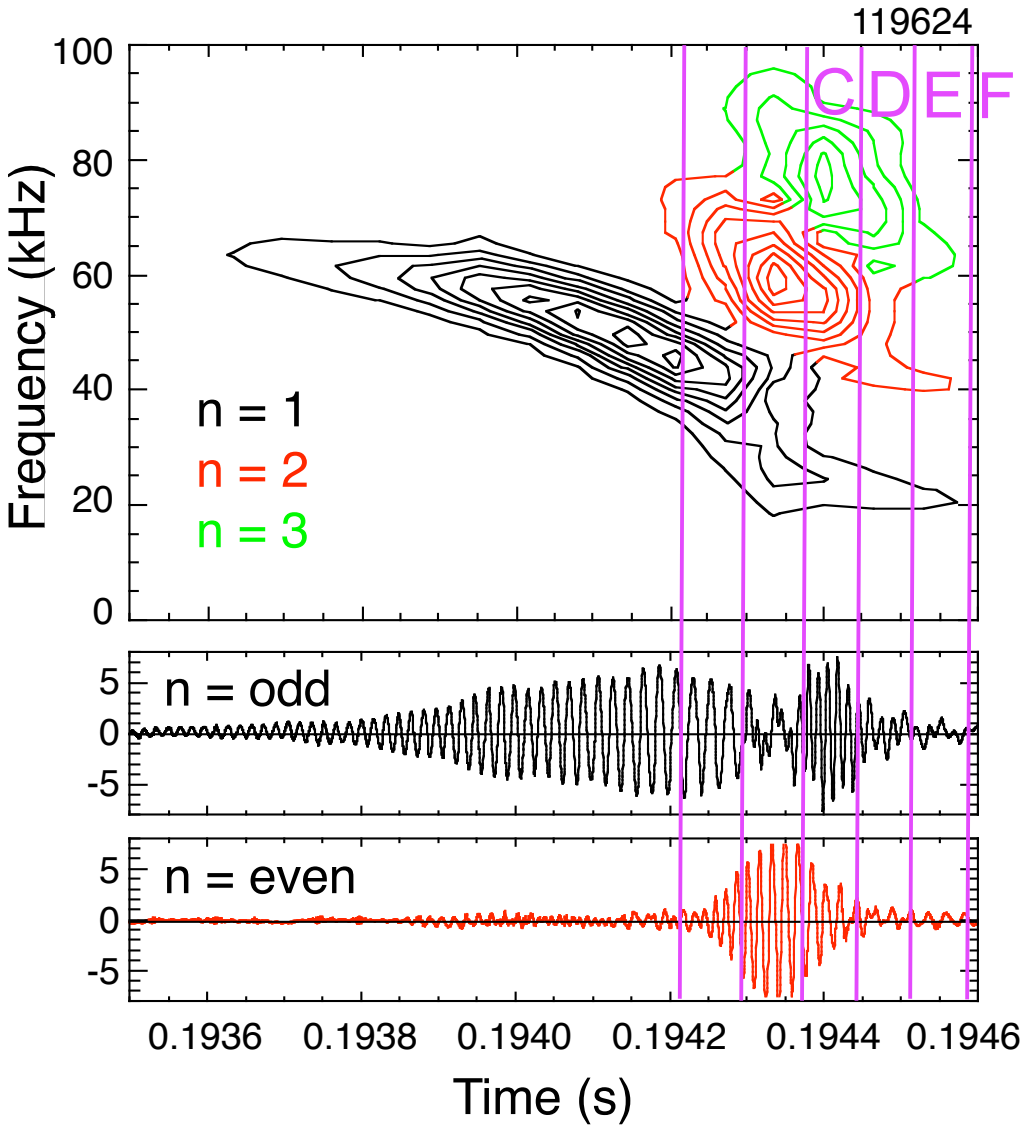


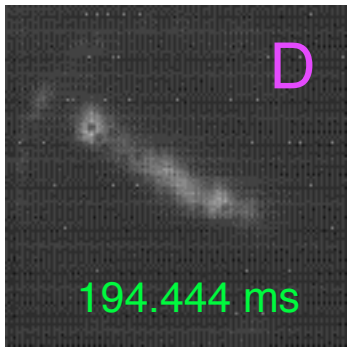


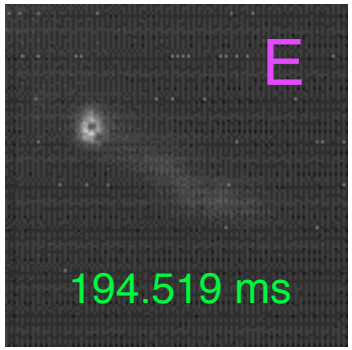


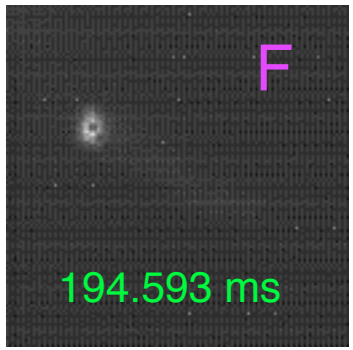


Broad pitch loss vanishes after mode overlap ends









Loss over broad pitch angle range from multi-n overlap?

- Wide pitch angle distributions seen during times when Mirnov signal shows multiple n values present, but not at other times
- Suggests some MHD-induced fast ion loss arises from phase space stochastization

Frequency chirping does not enhance loss rate

- No increased loss intensity or additional pitch angle features arise during interval when n=1 mode is chirping in frequency
- Implies that chirping does not move beam ions into loss cone, at least for these parameters

Future plans

- Apply (ρ, χ) grids to images
- Plot lost orbits
- Compute mode structures from experimental data & calculate losses expected