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Neutral Particle Analyzer Vertically Scanning Measurements of MHD-induced Energetic Ion Redistribution or Loss in NSTX

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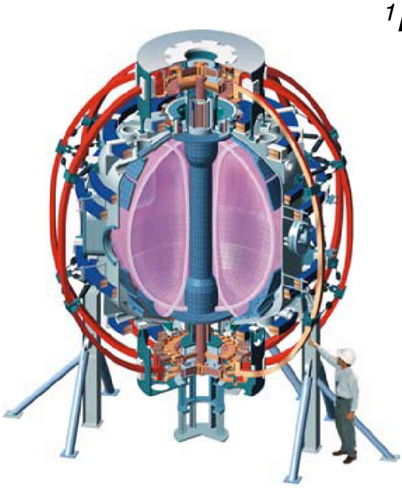

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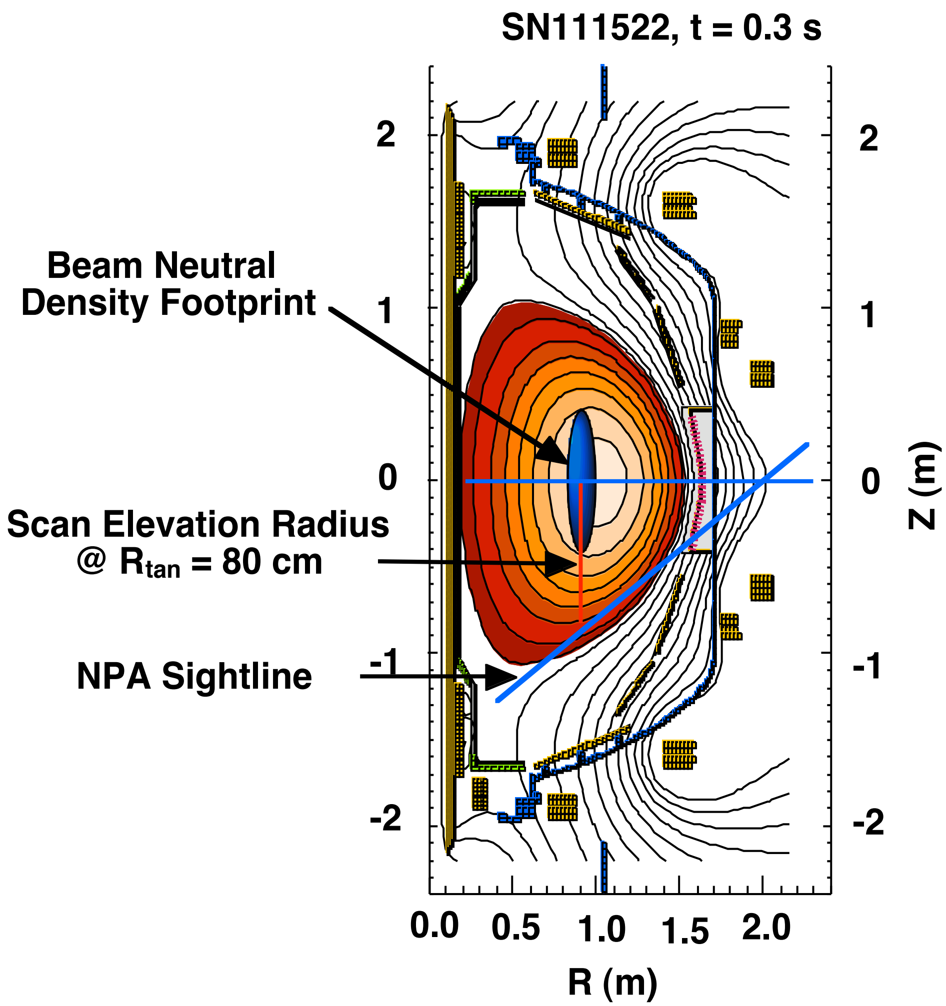
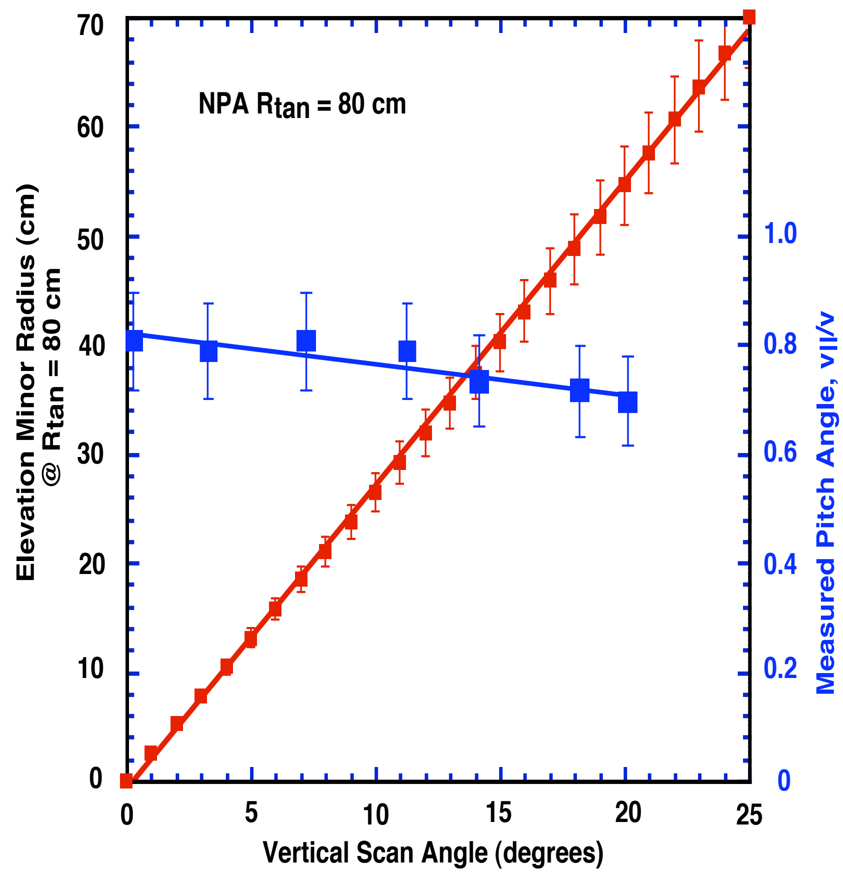
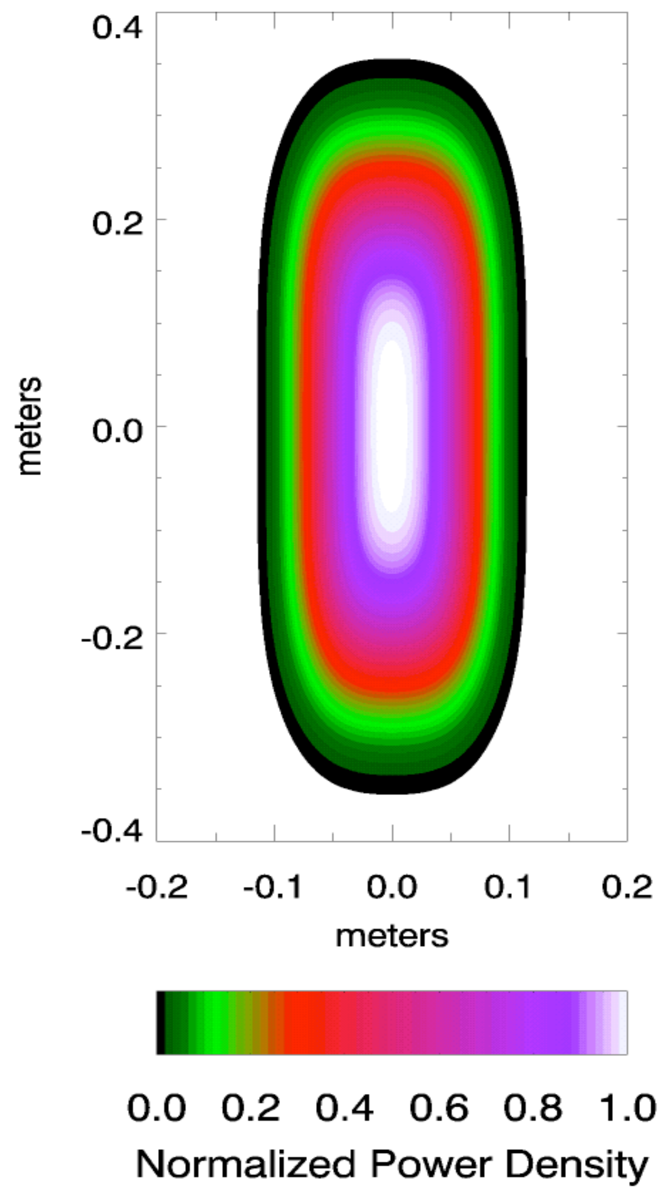
The Neutral Particle Analyzer (NPA) on NSTX Scans Vertically Over a Wide Range of Angles on a Shot-to-Shot Basis

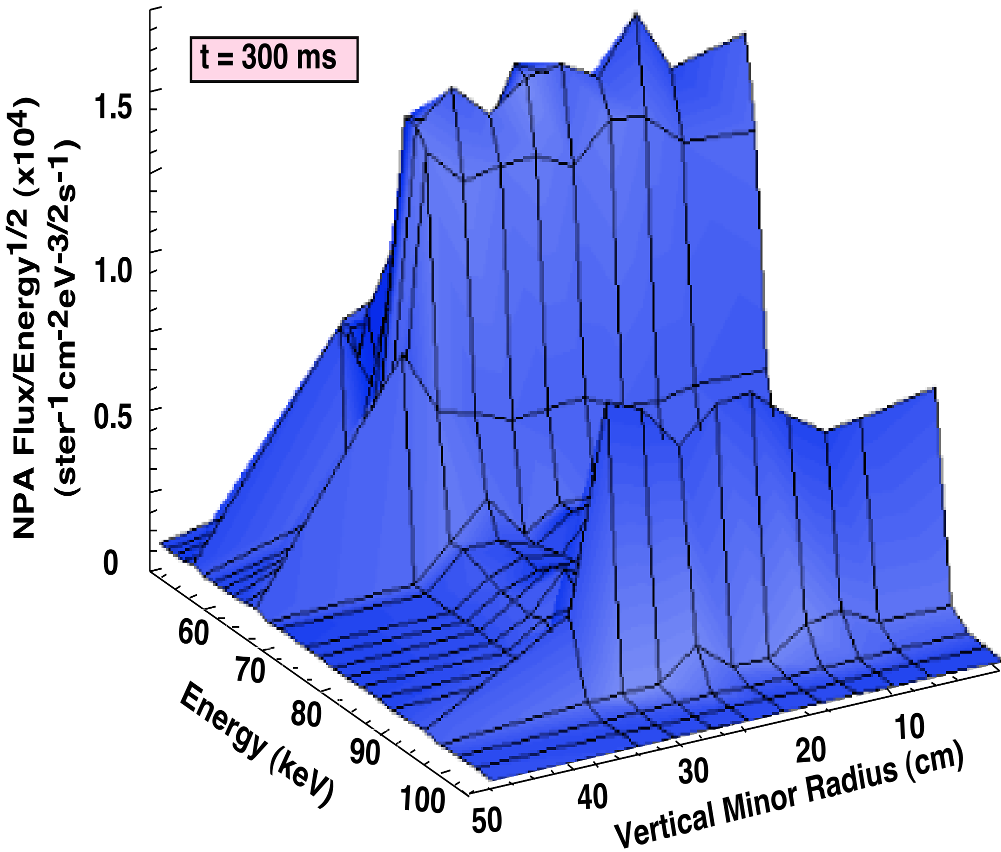




- Dominance of charge exchange emissivity by beam neutrals results in both field pitch and spatial localization of NPA measurements.

NPA Vertical Scanning Measurement of the Neutral Beam Footprint Agrees with NB Calibration



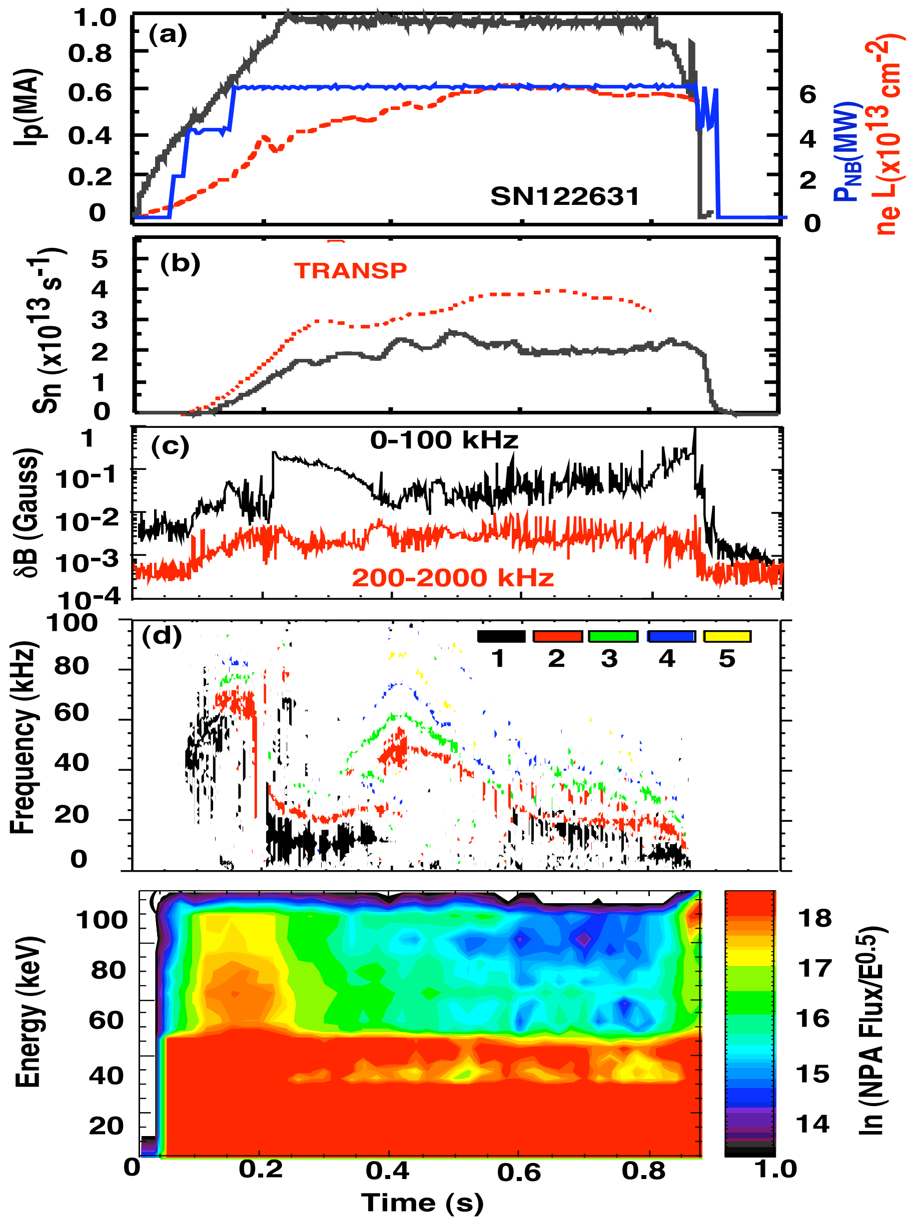


• **Neutral Beam Particle Fractions**

NPA Data: $E_b/3: E_b/2:E_b= 0.42:0.42:0.16$

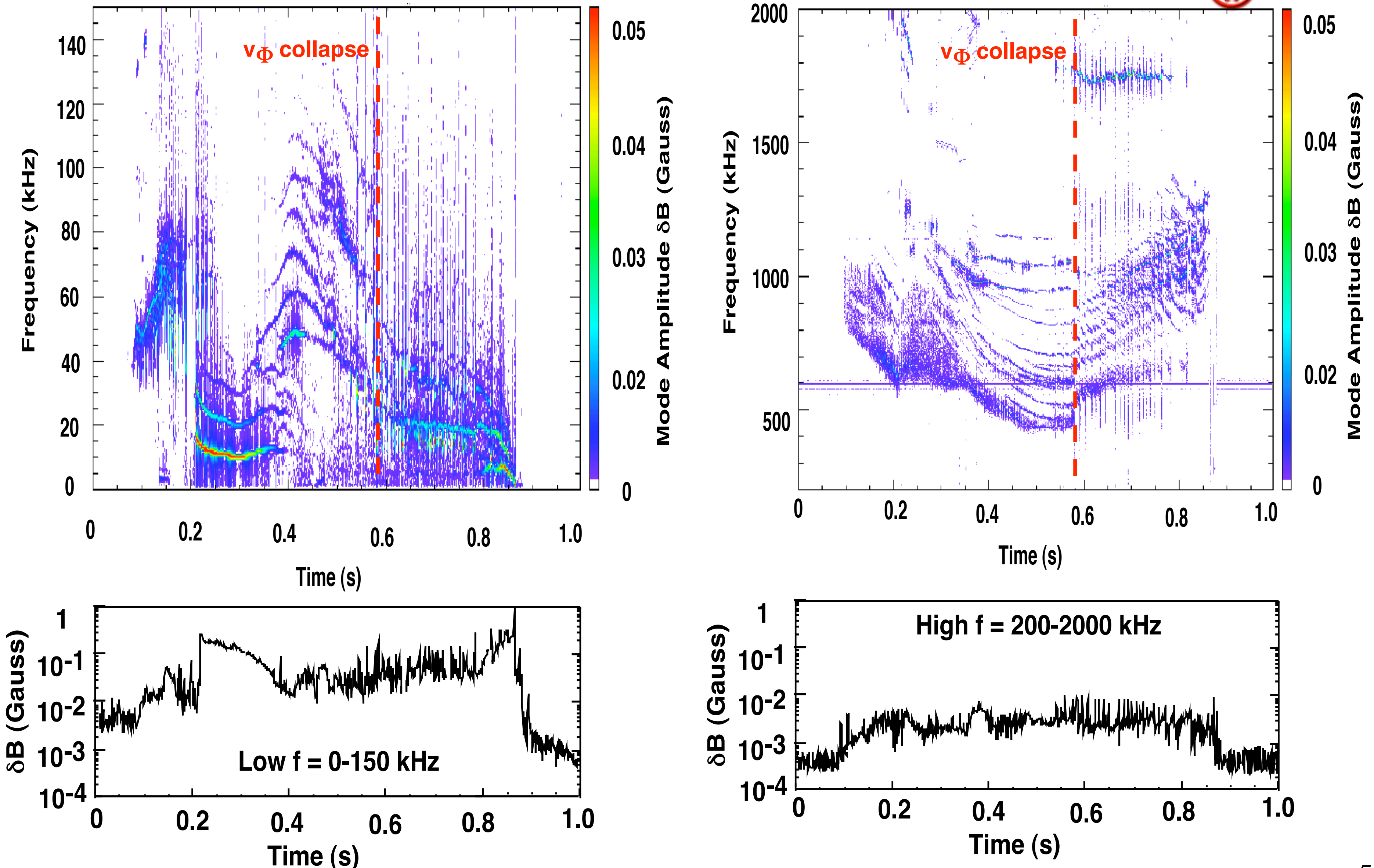
NB Calibration: $E_b/3: E_b/2:E_b= 0.44:0.39:0.17$

Vertical Scan Discharge Characteristics: 122631

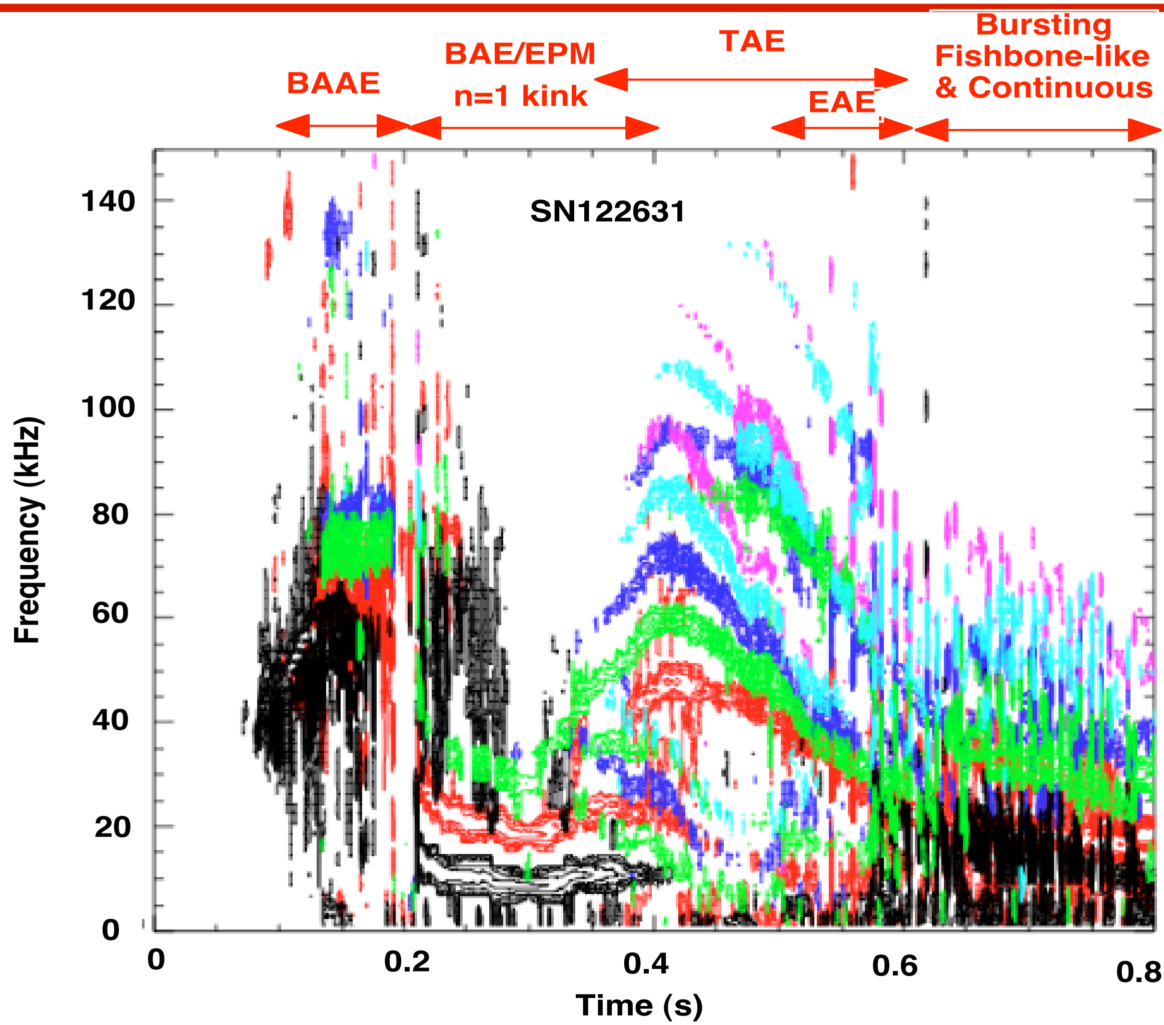


- H-mode with Ip = 1 MA, B_T = 4.5 kG A, B, C @ 90 keV and P_{NB} = 6 MW. Shot range: 122626 - 122645.
- Calculated neutrons are up to 2x measurement.
- Stable outer gap ~ 10 cm early in discharge and n_e(r) 'flattop' after t ~ 0.5 s (i.e. no 'faux' depletion effects).
- Wide range of robust and reproducible *AE and MHD activity.
- Strong depletion of the NPA energetic ion spectrum primarily above E/2.

MHD Activity during the NPA Vertical Scan is Robust and Reproducible

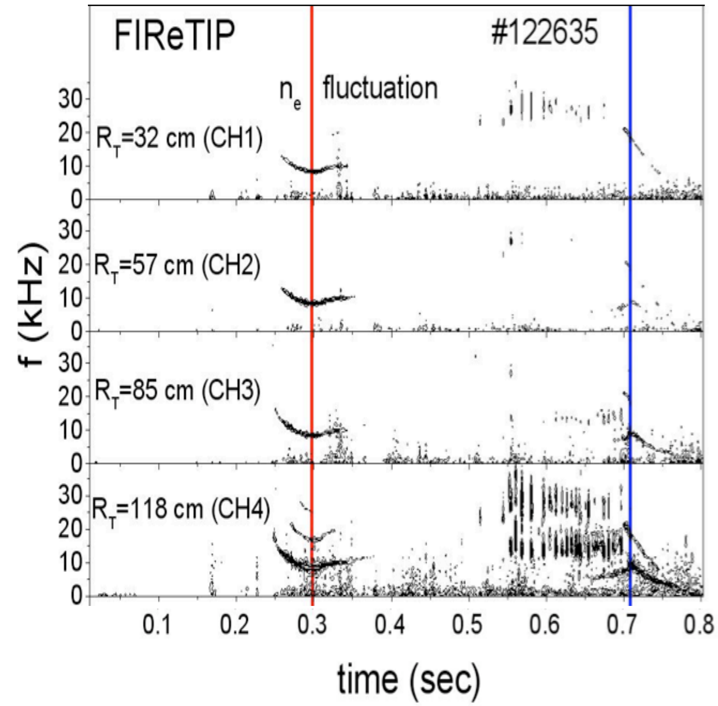


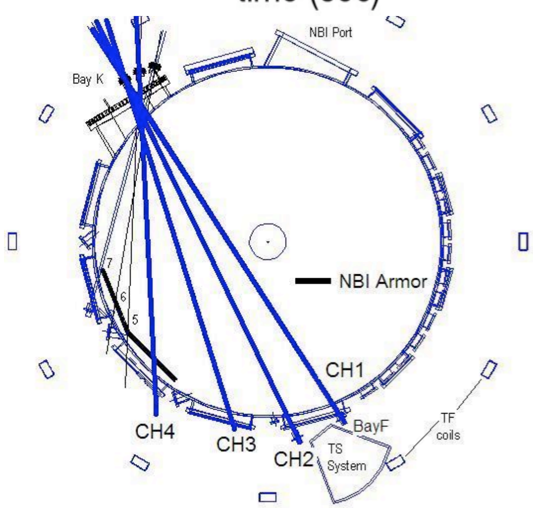
Identification of Low Frequency MHD Modes

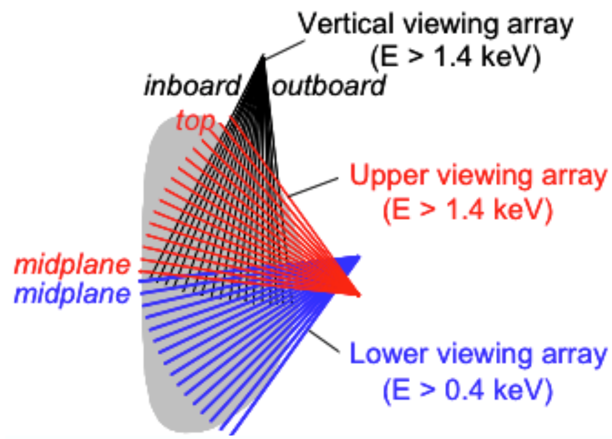


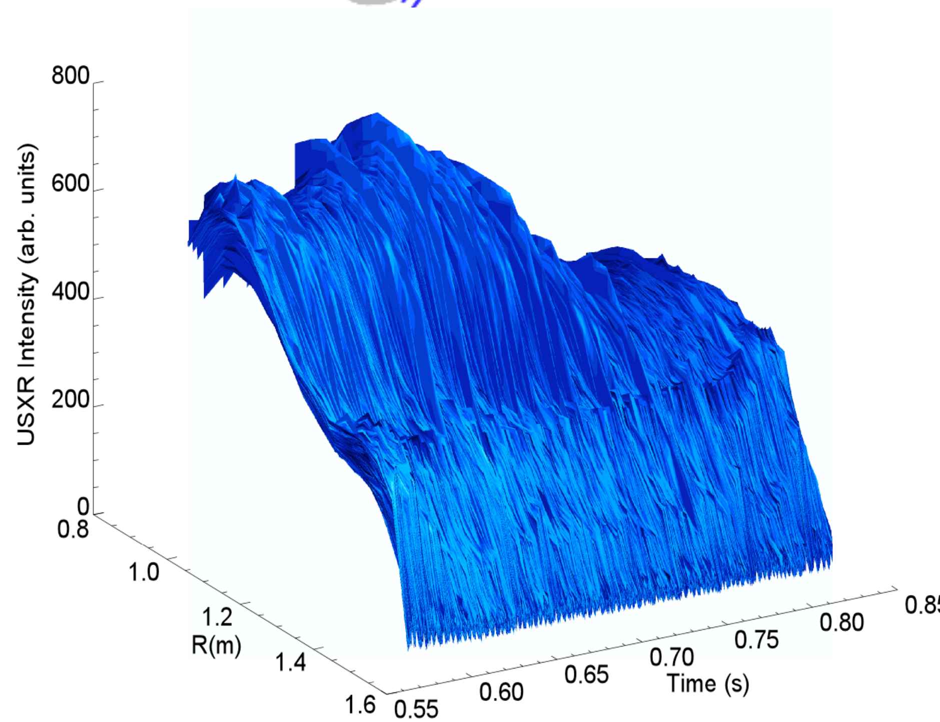
- Continuous low-f kink-type and bursting fishbone-like MHD activity is intermingled with a “sea of Alfvénic modes”.

FIReTIP $\delta n_e/n_e$ Fluctuations and USXR Profiles Show MHD Activity is Localized Near the Shafranov-shifted Core





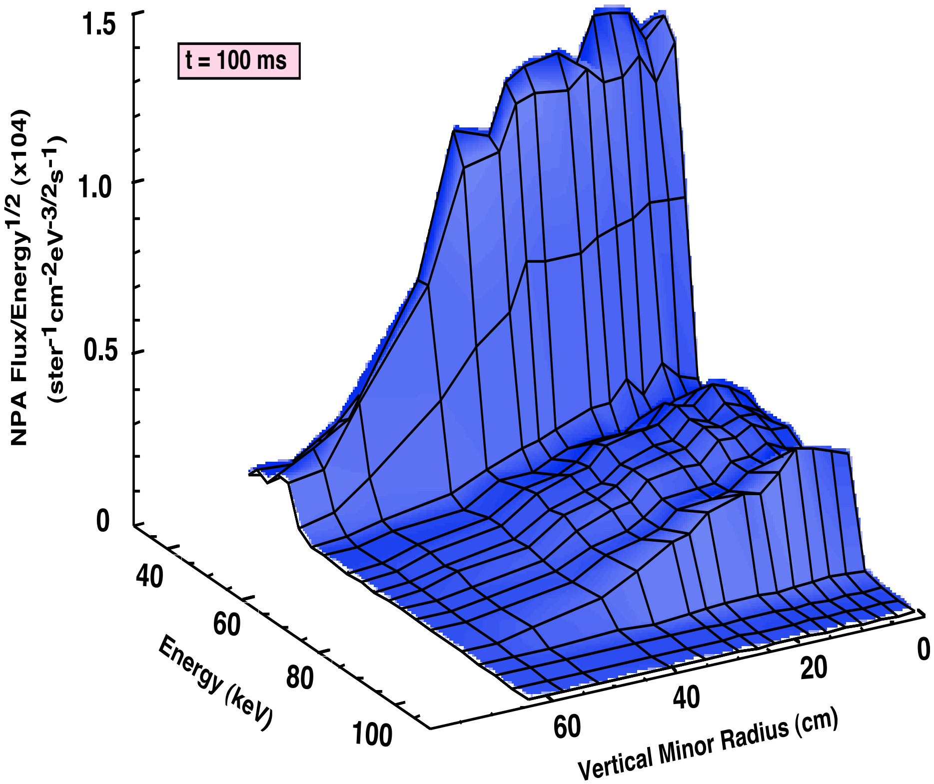




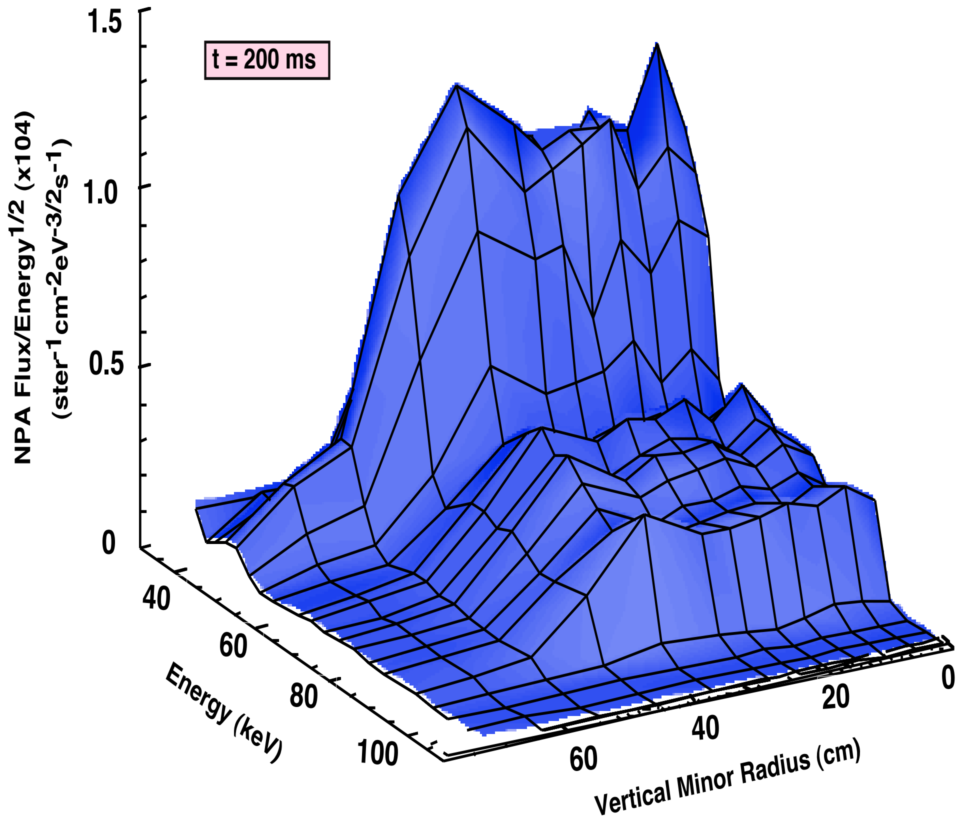
Initially Monotonic NPA Vertical Scan Profile is Flattened by MHD-Induced Fast Ion Redistribution

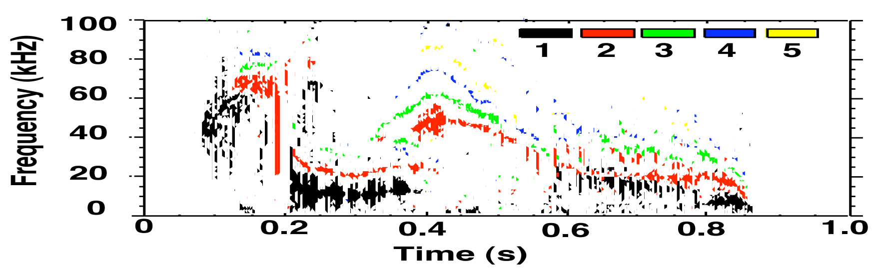
NSTX

L-mode "Quiescent"

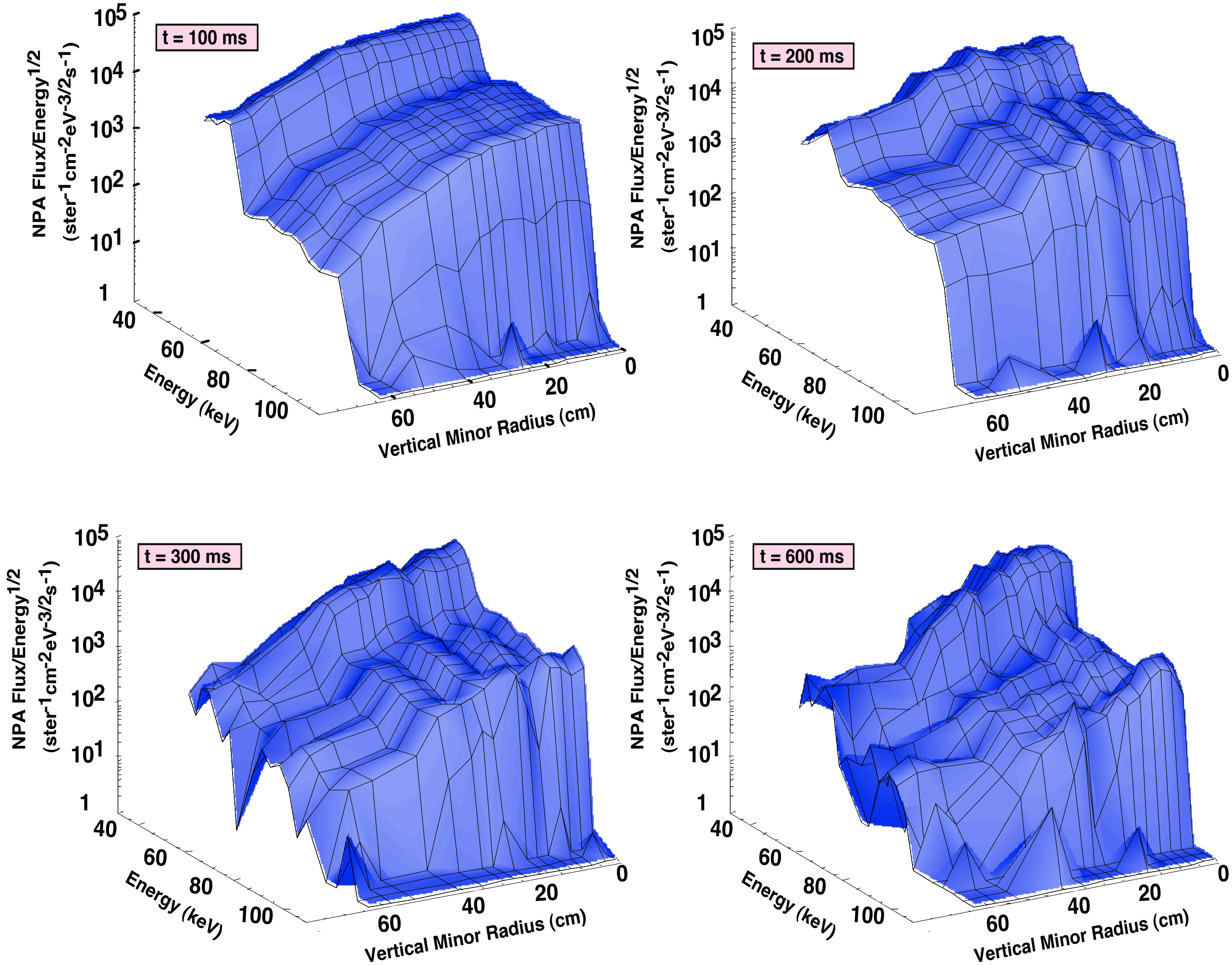


H-mode "MHD Active"



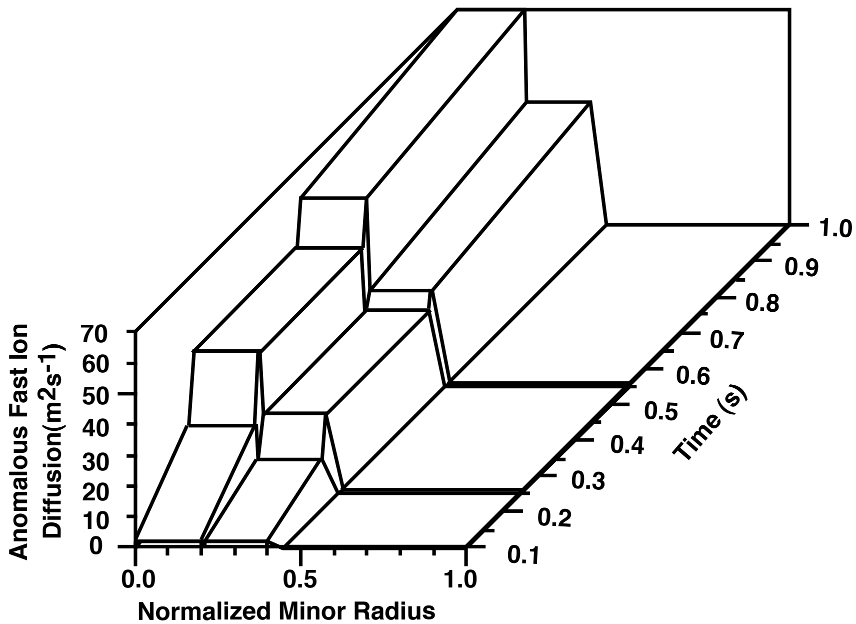


Later in the Discharge the NPA Vertical Scan Profile is Further Depleted by MHD-induced Fast Ion Redistribution

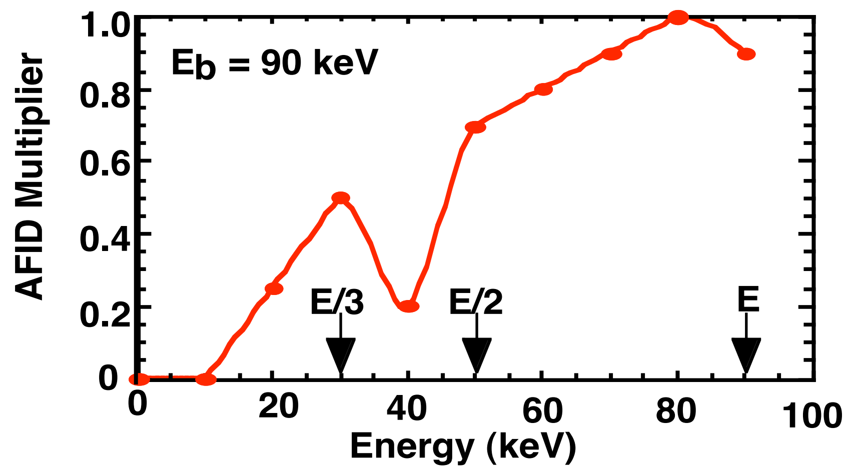


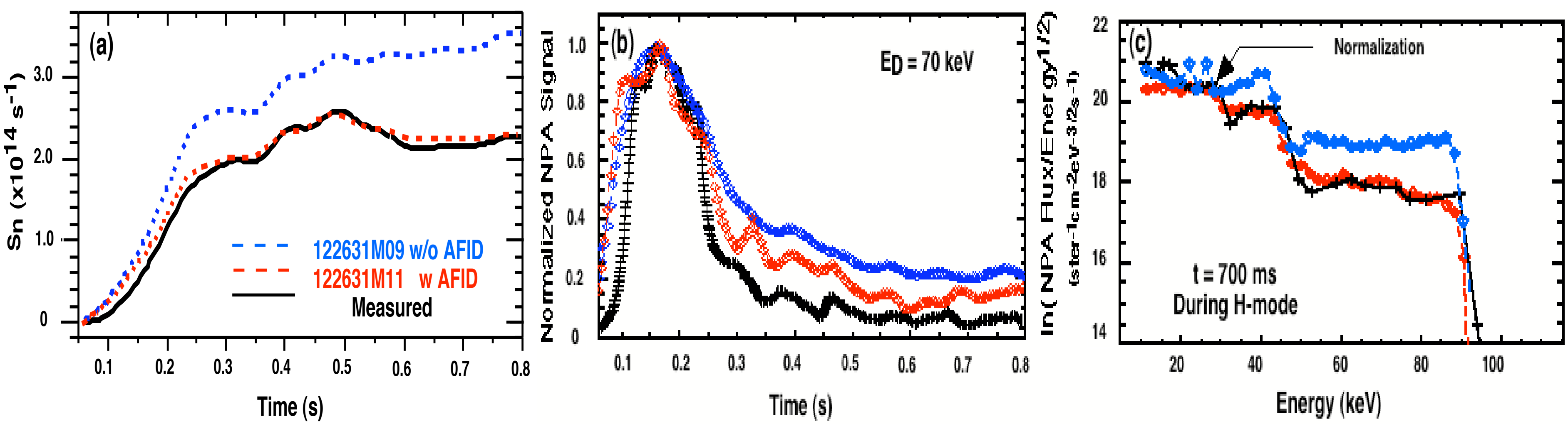
TRANSP Anomalous Fast Ion Diffusion (AFID) Can Simultaneously Match $S_n(t)$, $S_{npa}(t)$ and $f_{npa}(E)$

NSTX

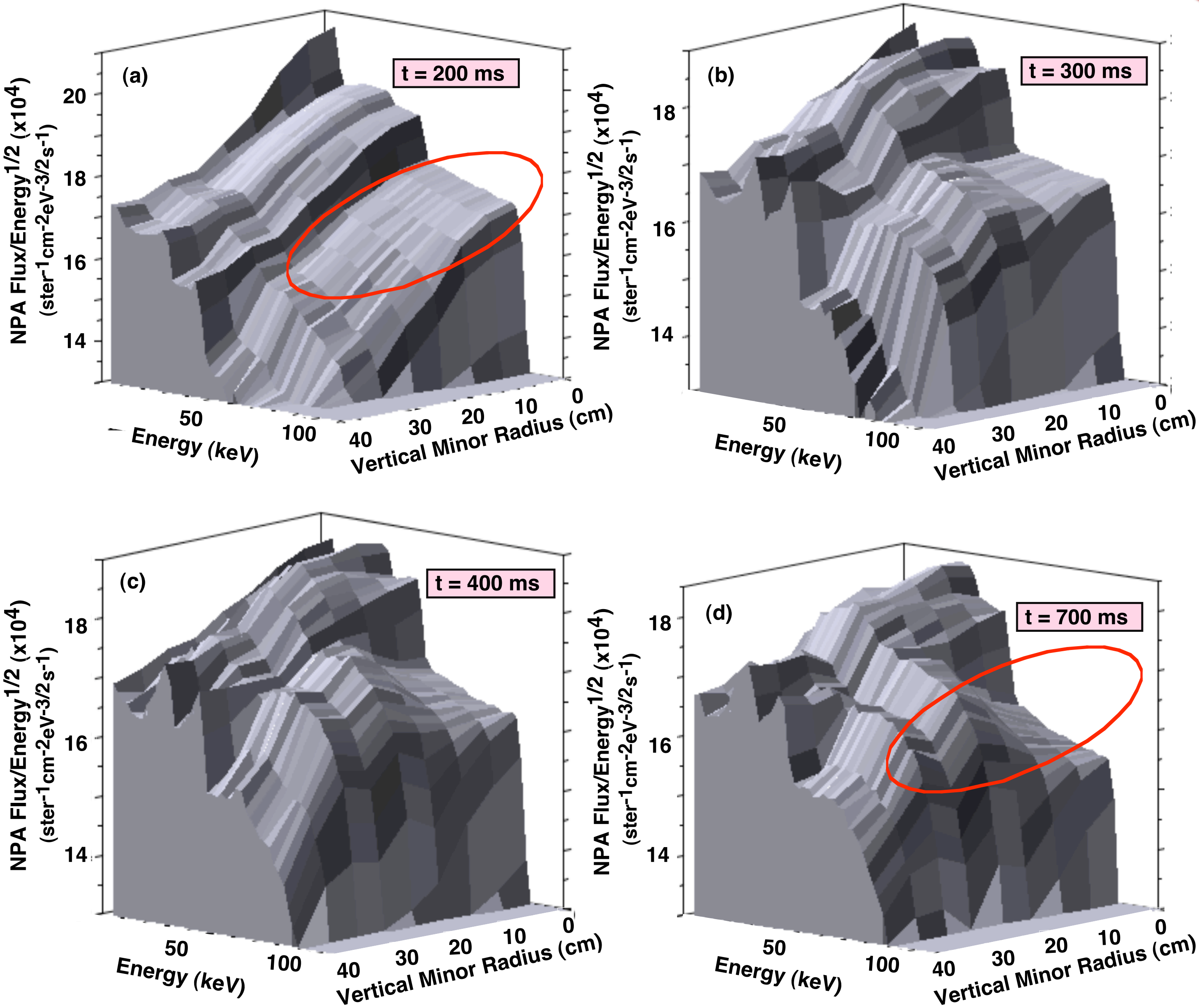


- In TRANSP, AFID can be specified in space, time and fast-ion energy.



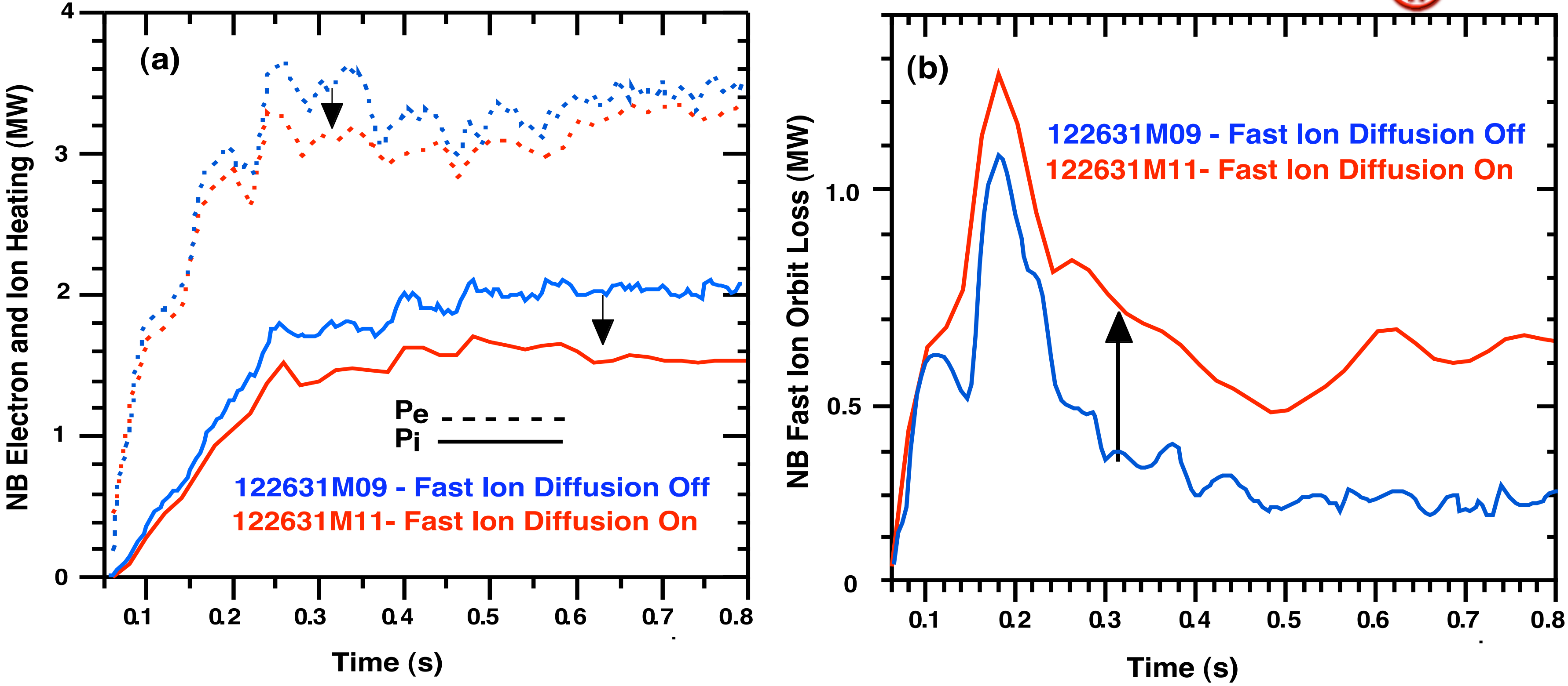


TRANSPP Simulation of a NPA Vertical Scan with AFID Shows Outward Redistribution of Core Fast Ions



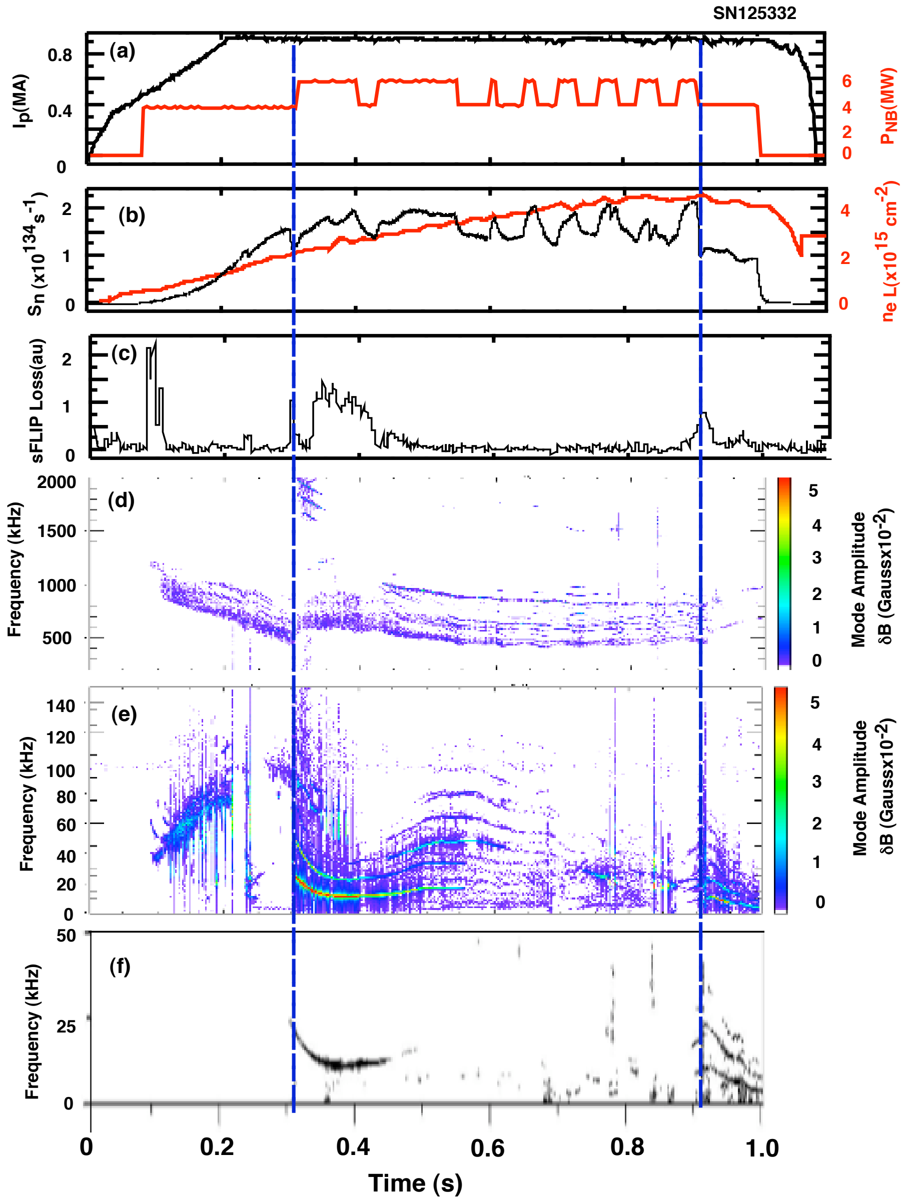
AFID Reduces Electron and Ion Heating and Increases Fast Ion Orbit Loss

NSTX



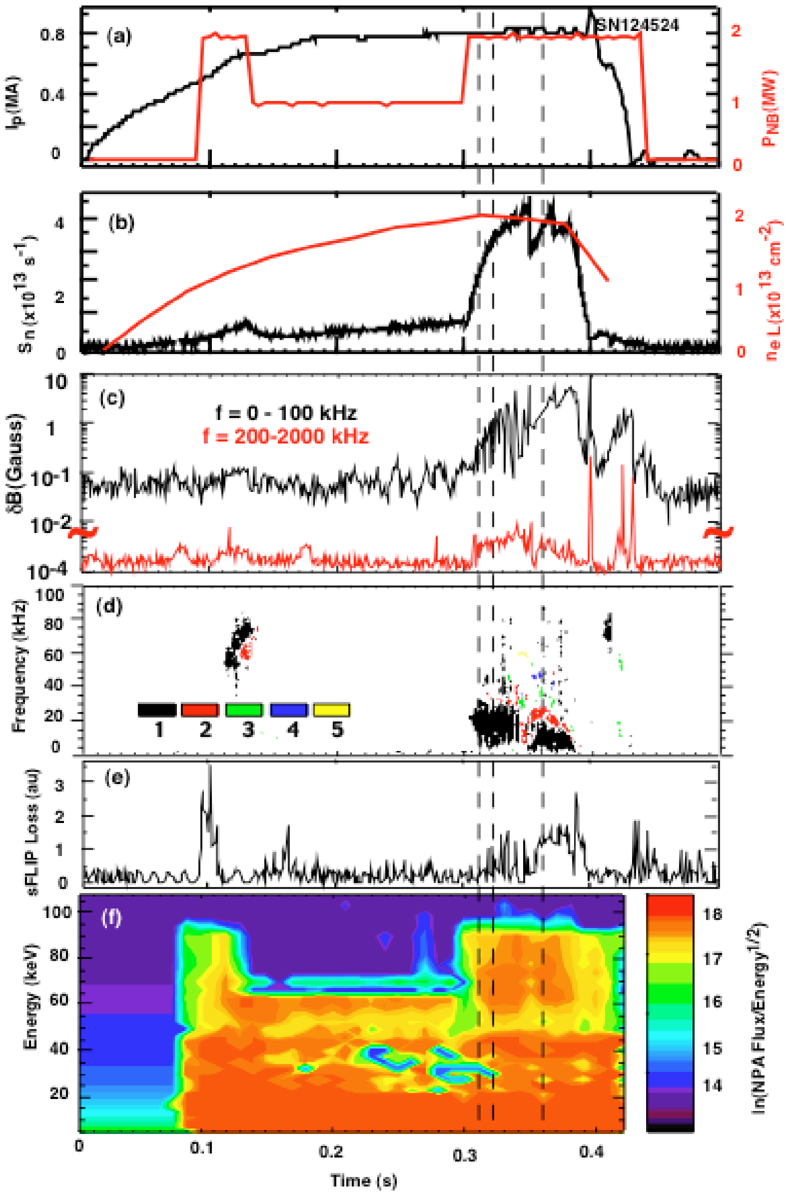
- Electron heating is reduced by ~ 10% and ion heating is reduced by ~ 25%.
- Fast ion orbit loss approximately doubles, increasing by ~ 0.25 MW and reaching ~ 10% of the injected beam power.
- TRANSP compensates for loss of heating by reducing all diffusivities.
- Comparison of the calculated and MSE-reconstructed current profiles is TBD.

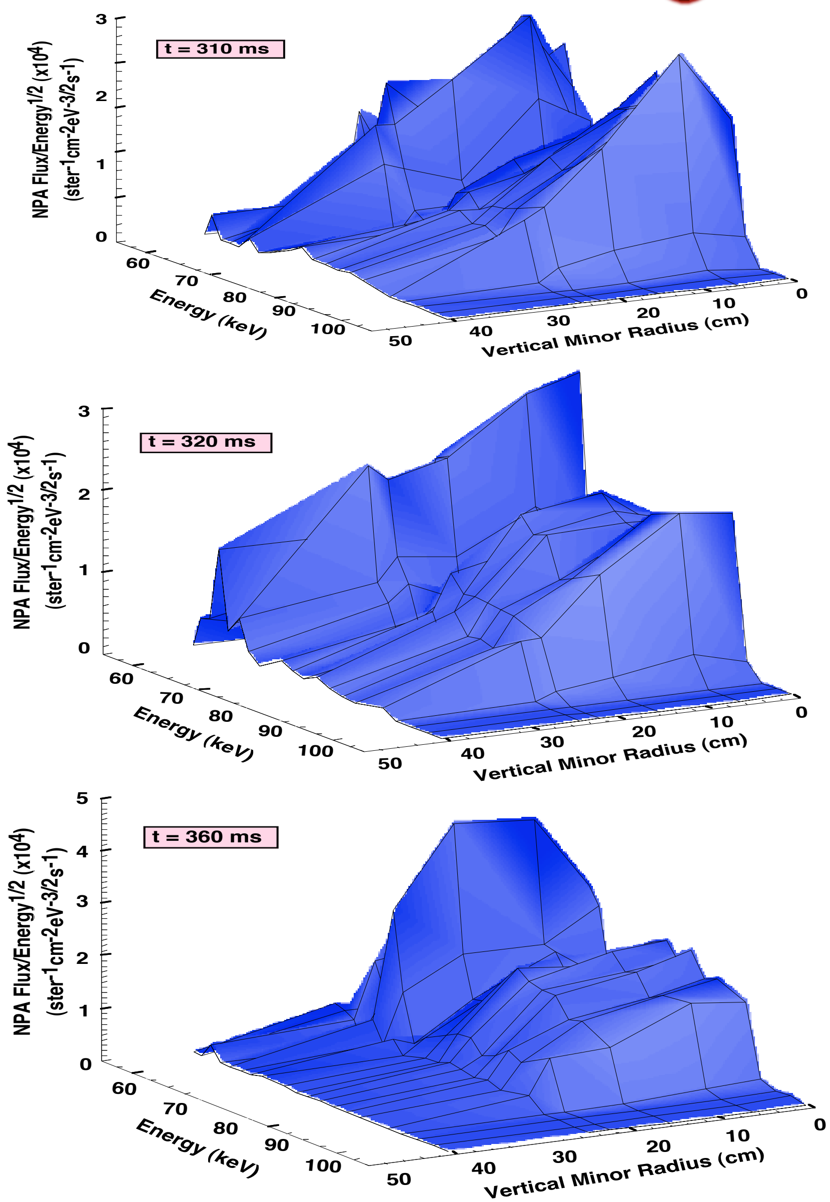
FIReTIP $\delta n_e/n_e$ Fluctuations and sFLIP Ion Loss Correlate with Low-f Kink-type MHD Activity



- Discharge parameters are similar to 122631 in the NPA vertical scan except source C is modulated.
- Onset of sFLIP energetic ion loss (panel c) and FIReTIP $\delta n_e/n_e$ fluctuations (panel f) at t ~ 0.3 s and t ~ 0.9 s (vertical lines) correlate with onset of low-f < 20 kHz MHD activity (panel e).
- sFLIP/FIReTIP signatures are absent during TAE/CAE/GAE only activity from t ~ 0.43 - 0.9 s.
- Conclude that TAE/CAE/GAE can drive energetic ion redistribution (from TRANSP analysis of neutron deficit and NPA depletion) but not loss.

First Observation of MHD-induced Energetic Ion Redistribution in He L-mode Plasmas (Fredrickson, XP-705)





Summary

NSTX

- NPA vertical scanning provides a direct measurement (minimal $v_{||}/v$ variation) of MHD-induced energetic ion redistribution.

- The NPA vertical scan presented herein views passing energetic ions having a narrow range in field pitch: $v_{||}/v \sim 0.78 \pm 0.06$.

- MHD-induced energetic ion redistribution modeling using anomalous fast ion diffusion reduces the TRANSP-calculated neutron yield, NPA fast ion efflux and core-driven NBICD.

- sFLIP was not available during the vertical scan. A surrogate discharge with sFLIP loss and FIReTIP $\delta n_e/n_e$ fluctuation data indicates low-f modes drive energetic ion loss but TAE/CAE/GAE causes only redistribution and energetic ions remain confined.

- First observation of MHD-induced energetic ion redistribution in He L-mode plasmas was made during a vertical scan in XP-705.