Supported by

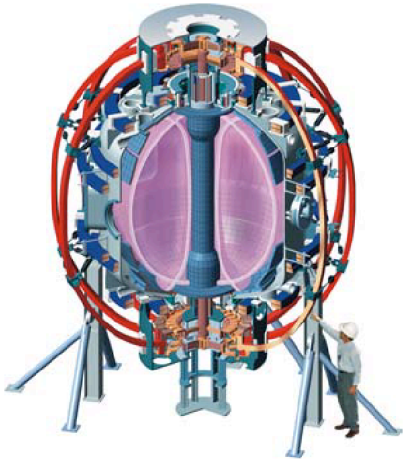
Office of Science

NSTX

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

S. S. Medley, R. Andre, R. E. Bell, D. S. Darrow, E. D. Fredrickson, N. N. Gorelenkov, B. P. LeBlanc, A. L. Roquemore and E. Ruskov*

Princeton Plasma Physics Laboratory, Princeton, NJ 08543
**University of California at Irvine, Irvine, CA 92687*



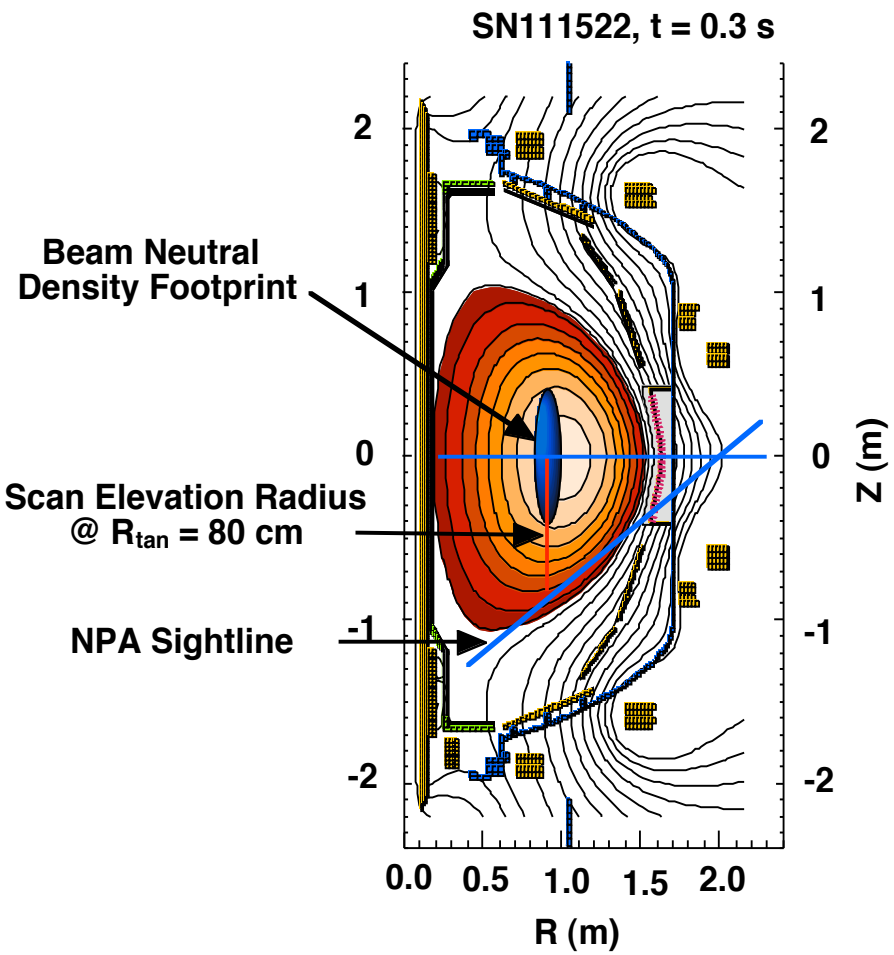
NSTX Research Forum
November 27 - 29, 2007
Princeton Plasma Physics Laboratory

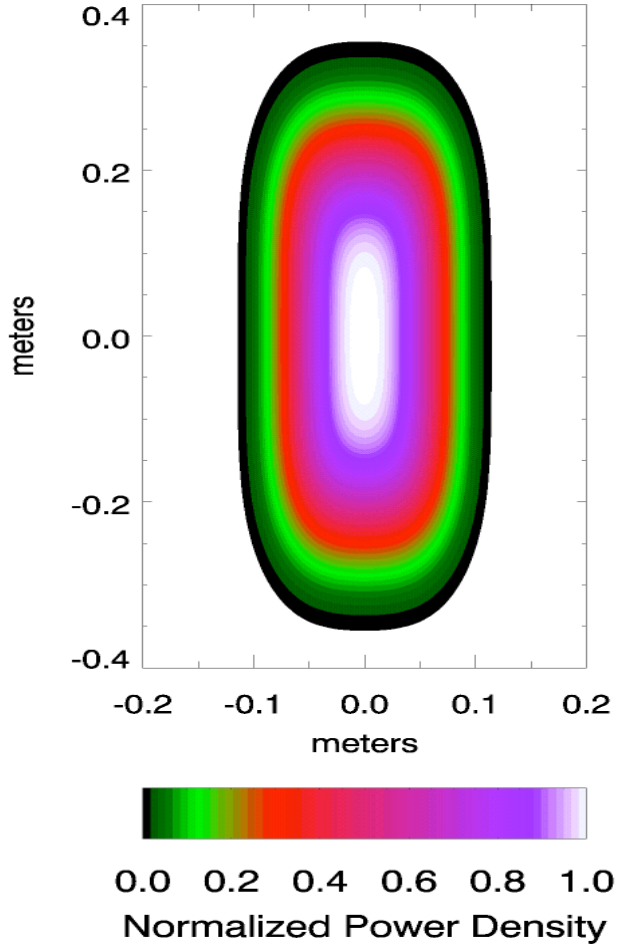
PPPL PRINCETON PLASMA PHYSICS LABORATORY

UCIrvine University of California, Irvine

Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
NYU
ORNL
PPPL
PSI
SNL
UC Davis
UC Irvine
UCLA
UCSD
U Maryland
U New Mexico
U Rochester
U Washington
U Wisconsin
Culham Sci Ctr
Hiroshima U
HIST
Kyushu Tokai U
Niigata U
Tsukuba U
U Tokyo
JAEA
Ioffe Inst
TRINITI
KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
U Quebec

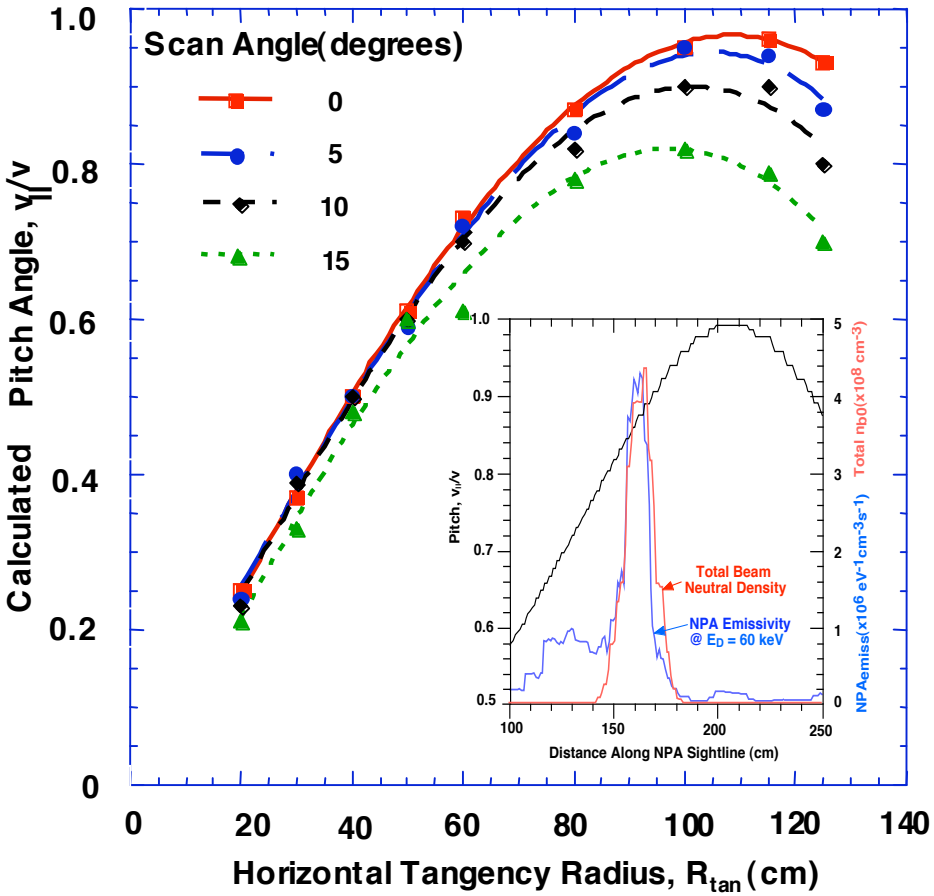
The Neutral Particle Analyzer (NPA) on NSTX Scans Vertically Over a Wide Range of Angles on a Shot-to-Shot Basis

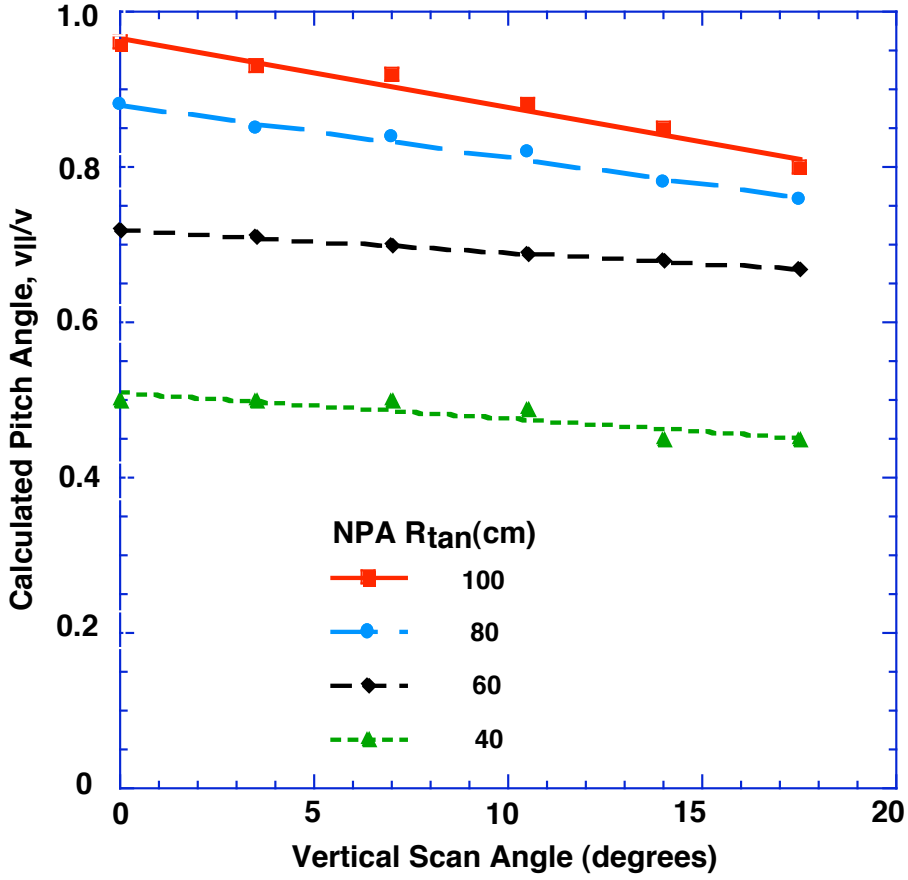




• The line-integrated NPA measurements (left panel) are 'localized' in pitch and space by intersection with the beam NB footprint (right panel). Radial resolution is ~ 20 cm due to footprint width.

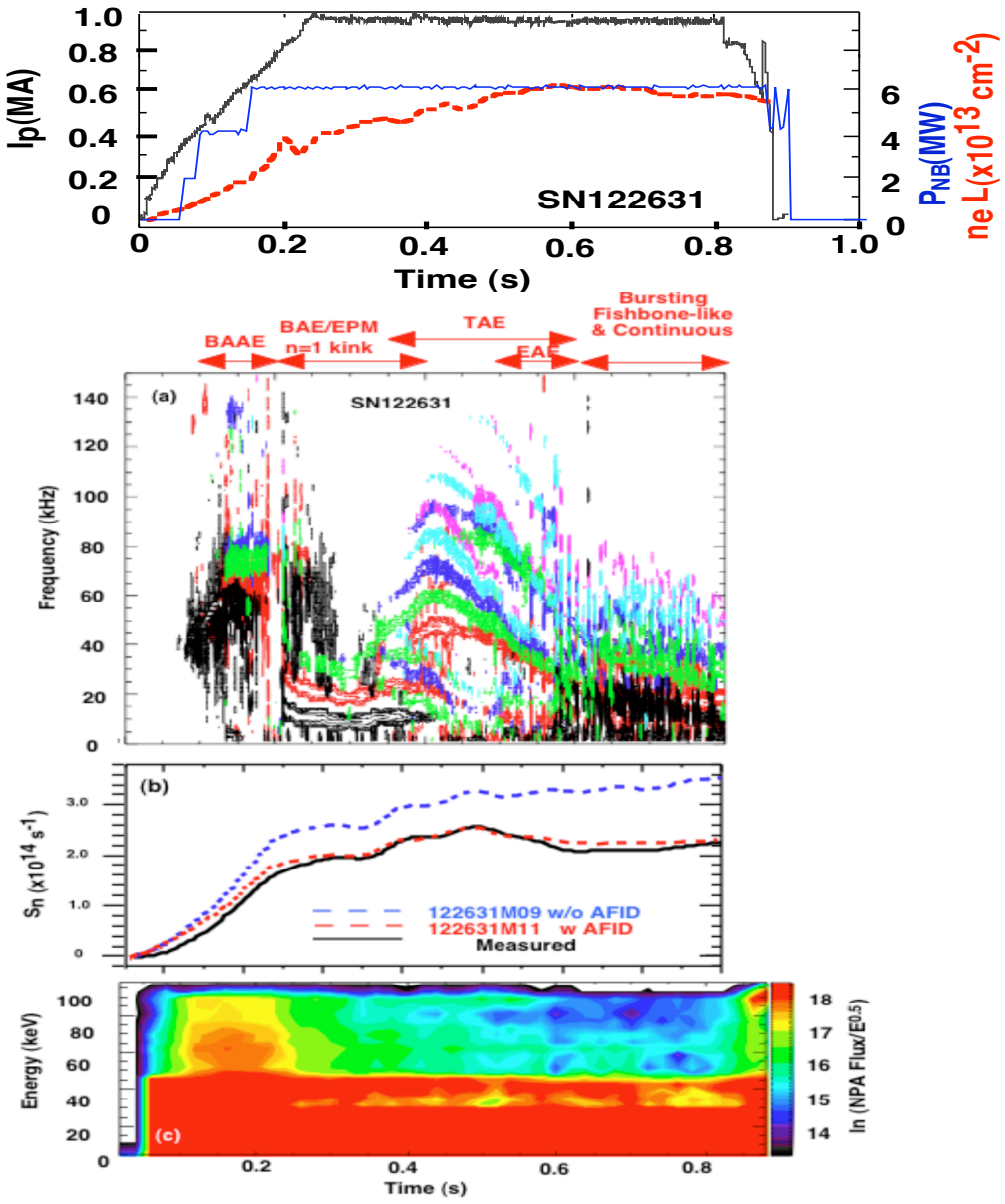
Pitch Angle Variation during NPA Horizontal and Vertical Scanning
(Data is from TRANSP simulation of NPA scanning.)





- During vertical scanning, the field pitch varies modestly around a mean value determined by the chosen horizontal tangency radius.

XP-707 Vertical Scan Discharge Characteristics: 122631

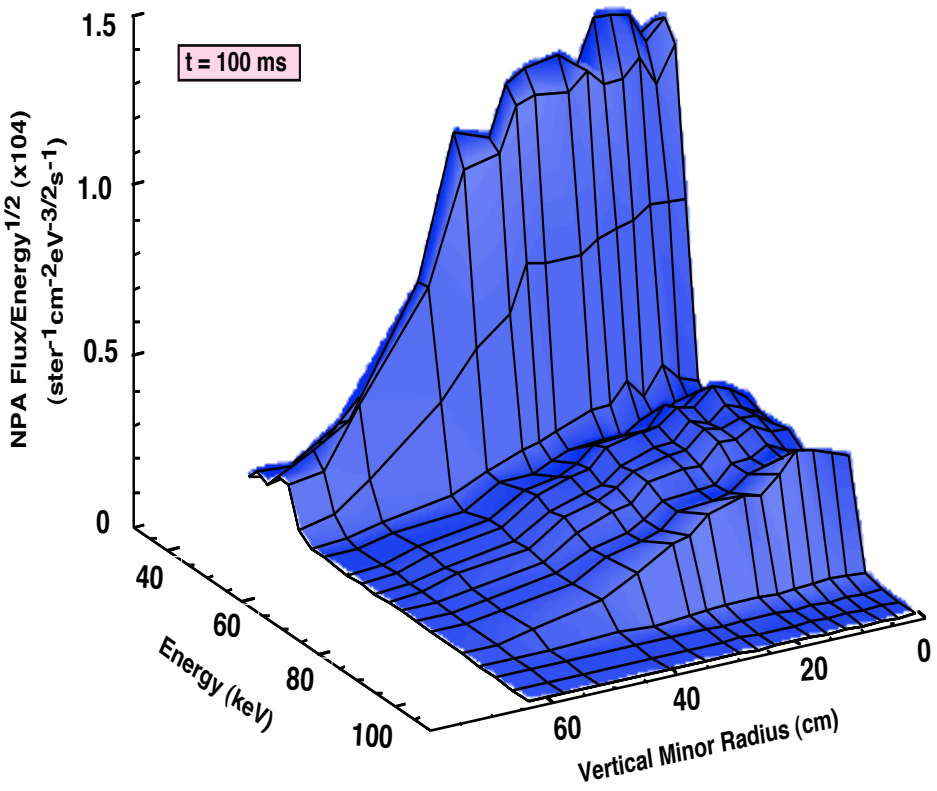


- H-mode with Ip = 1 MA, B_T = 4.5 kG A, B, C @ 90 keV and P_{NB} = 6 MW.
- TRANSP-calculated neutrons ~ 1.5x measured.
- Stable outer gap ~ 10 cm early in discharge and $n_e(r)$ 'flattop' at t > 0.5 s (i.e. no 'faux' depletion effects).
- Strong energetic ion depletion above E/2 after H-mode onset at t ~ 0.2 s.
- High f ~ 400-1000 kHz modes existed during the discharge but with $\delta B_{Low}/\delta B_{High}$ ~ 40.

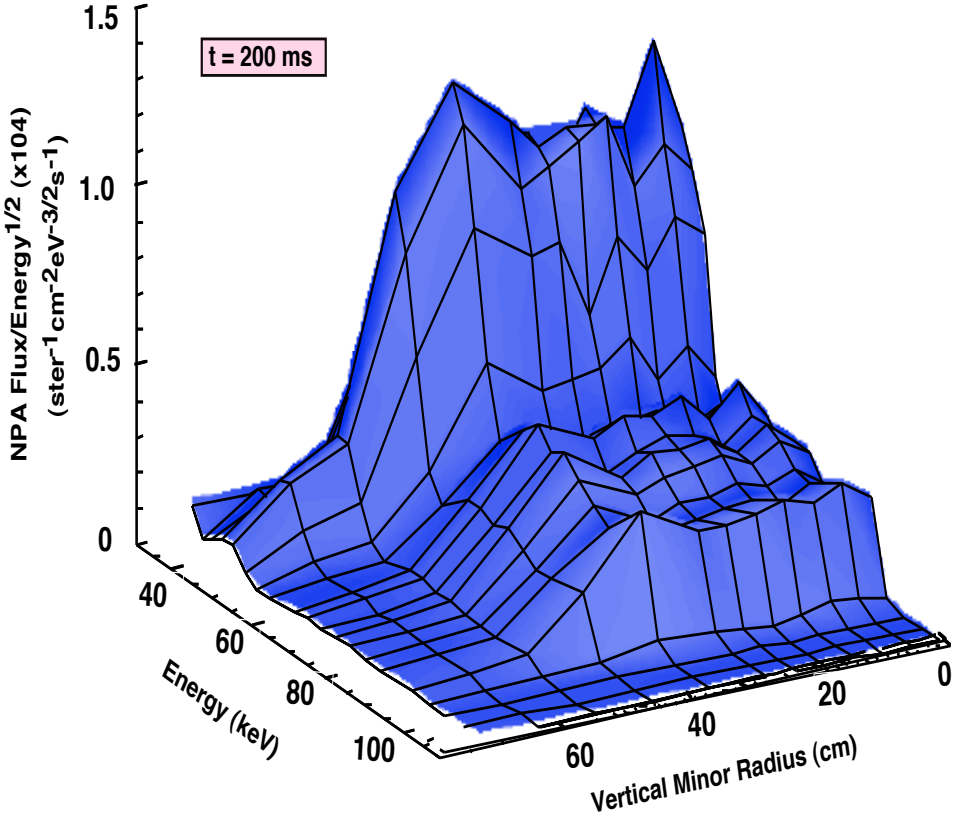
Initially Monotonic NPA Vertical Scan Profile is Flattened by MHD-Induced Fast Ion Redistribution

NSTX

L-mode "Quiescent"



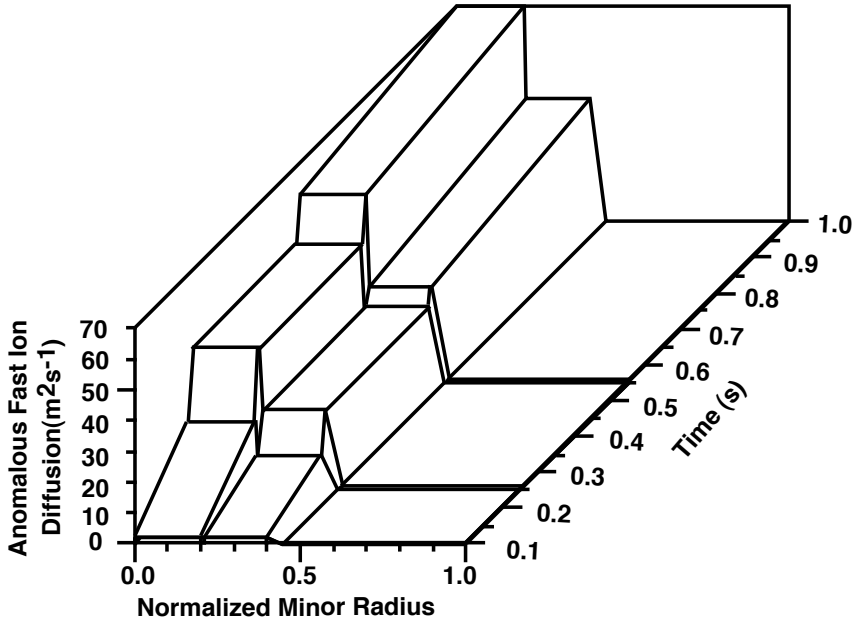
H-mode "MHD Active"



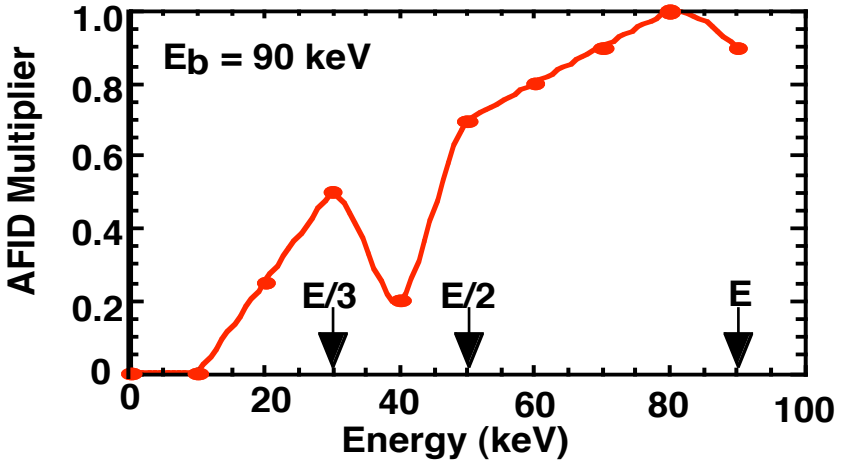
- The core-ion redistribution observed at t = 200 ms continues to progress for the duration of the H-mode discharge.

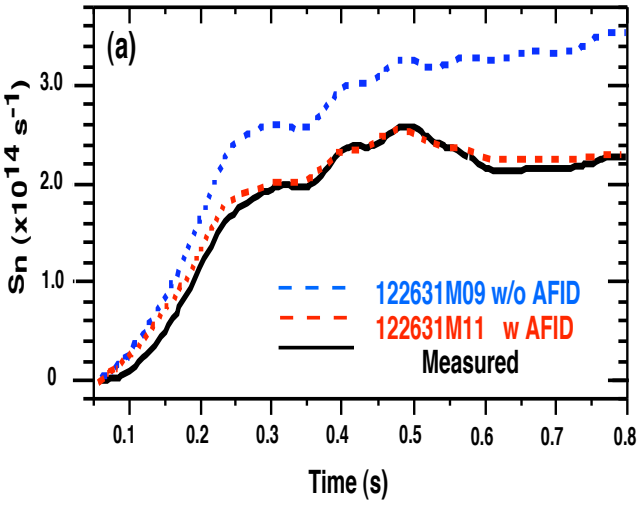
TRANSP Anomalous Fast Ion Diffusion (AFID) Can Simultaneously Match $S_n(t)$, $S_{npa}(t)$ and $f_{npa}(E)$

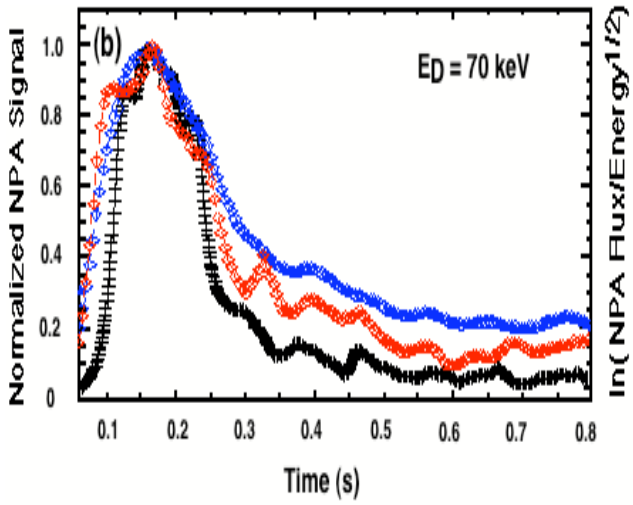
NSTX

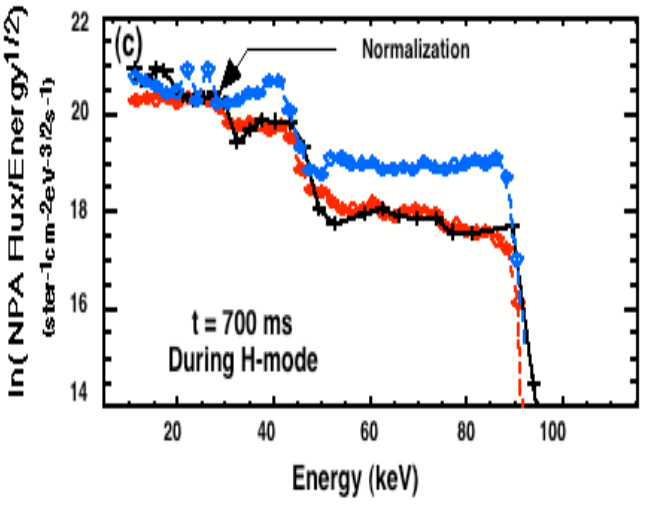


- In TRANSP, AFID can be specified in space, time and fast-ion energy.

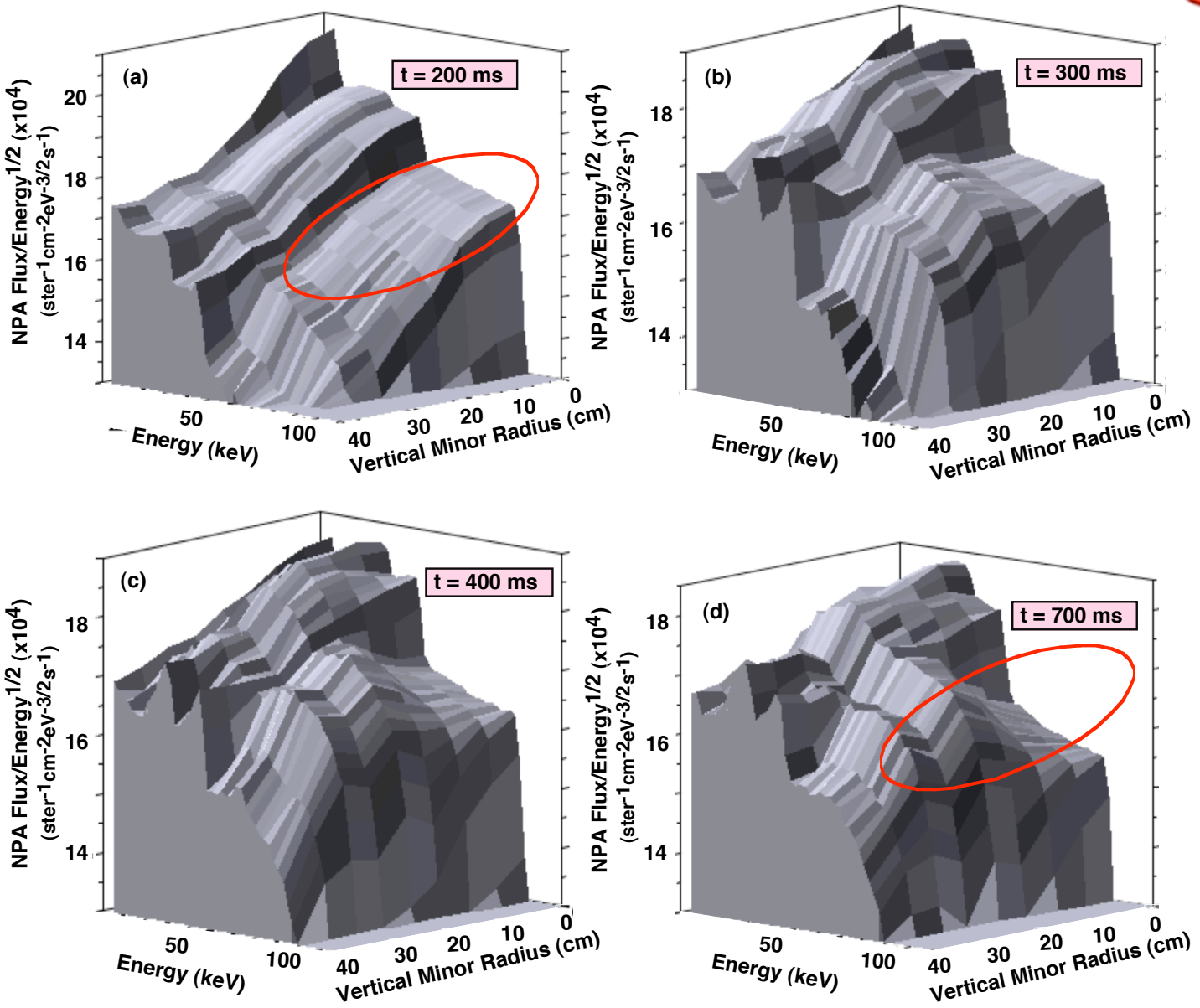




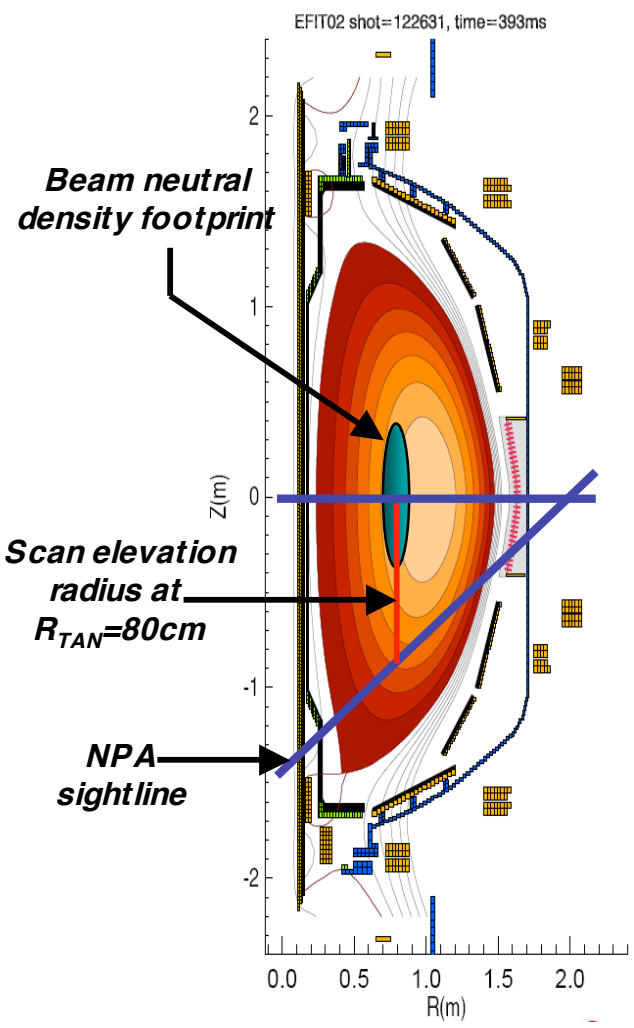


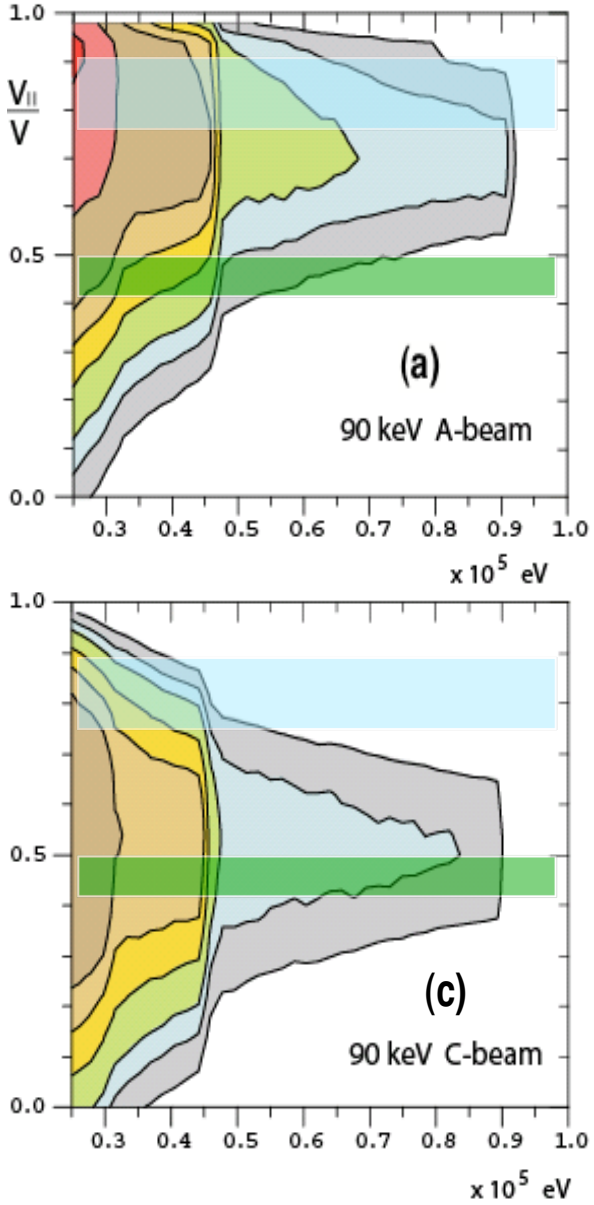


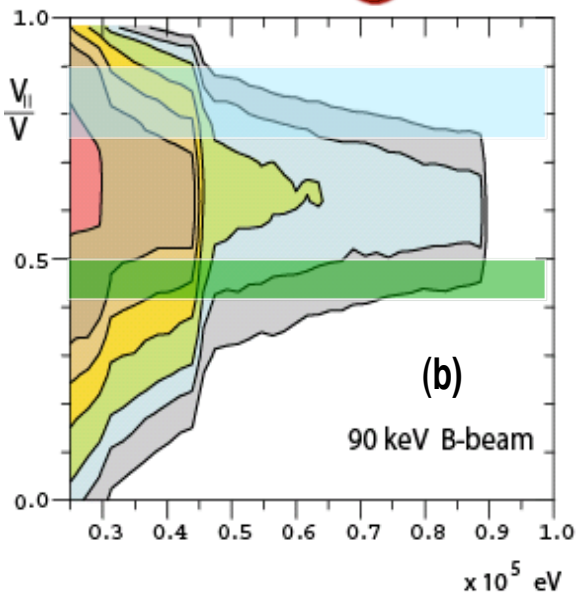
TRANSP Simulation with AFID Yields Outward Redistribution of Core Fast Ions Consistent with NPA Vertical Scan Data

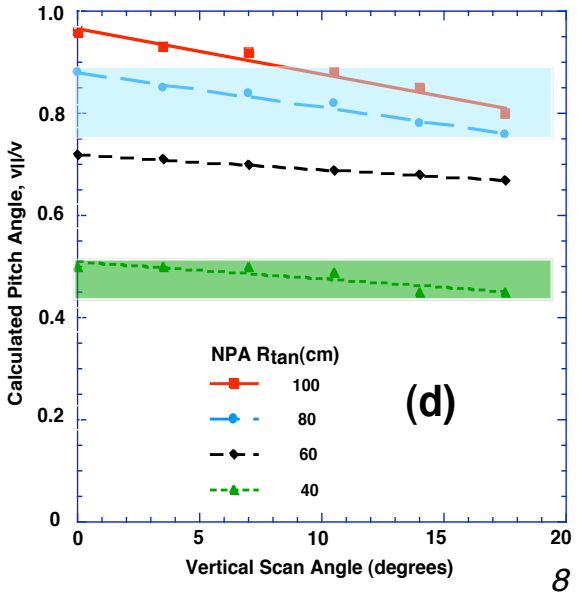


Proposed XP-8** Part I: Addresses NPA Vertically Scanning Measurement of MHD-induced Energetic Ion Redistribution at Reduced Field Pitch: $v_{||}/v \sim 0.47 \pm 0.03$.

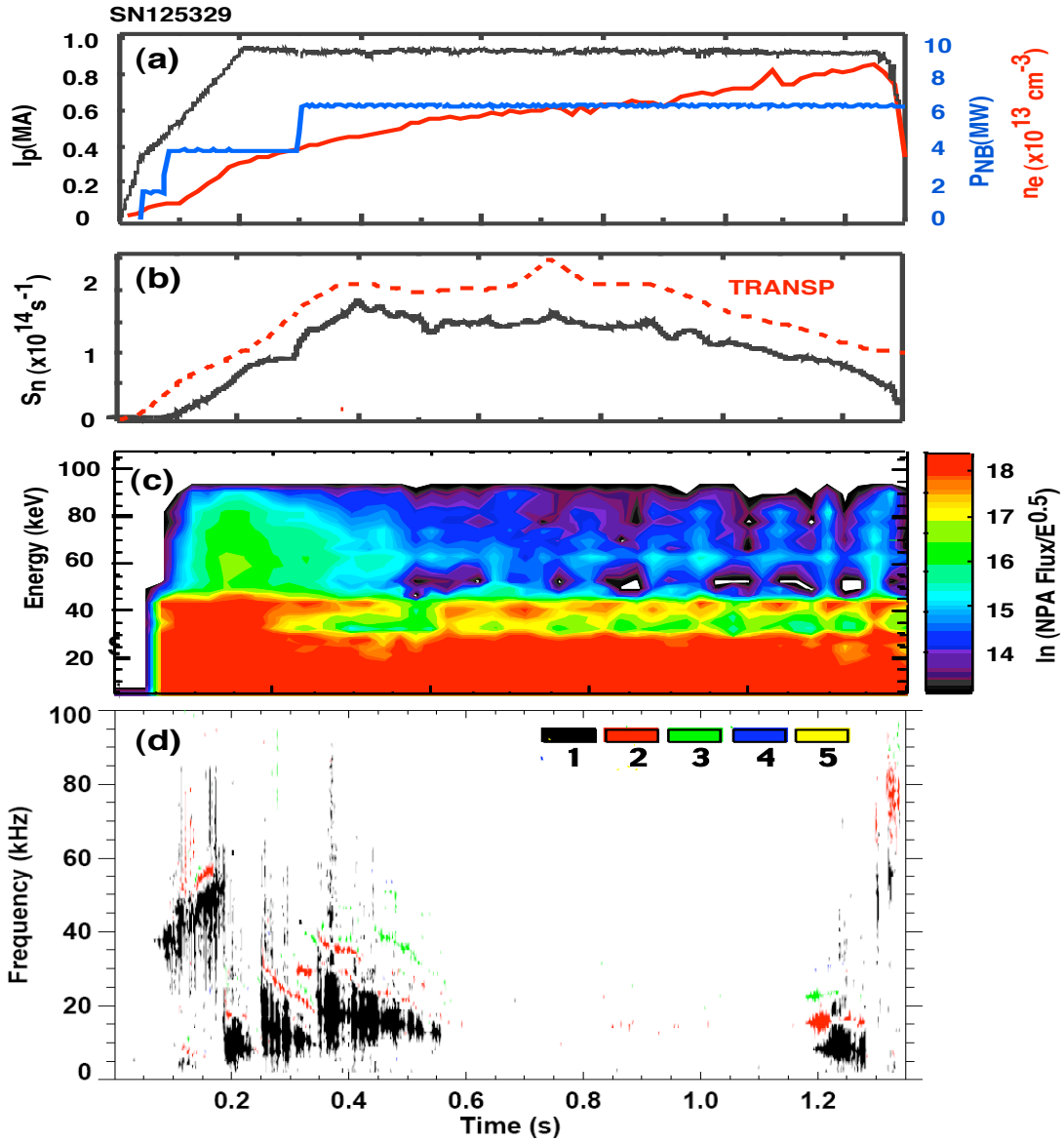






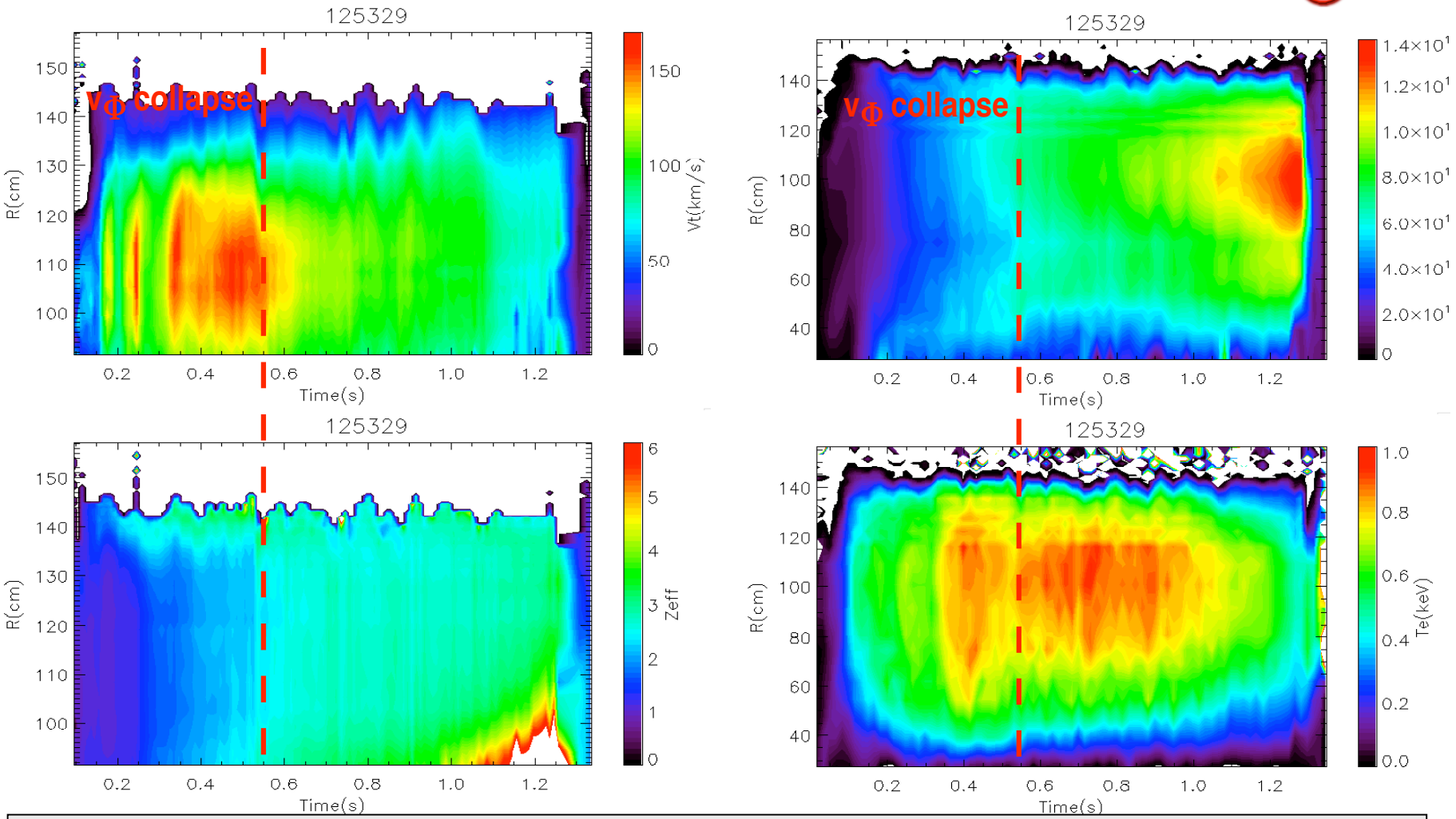


Proposed XP-8** Part II: Addresses NPA Vertically Scanning Measurement of Energetic Ion Redistribution during MHD "Quiescent" Phase - e.g. SN125329.



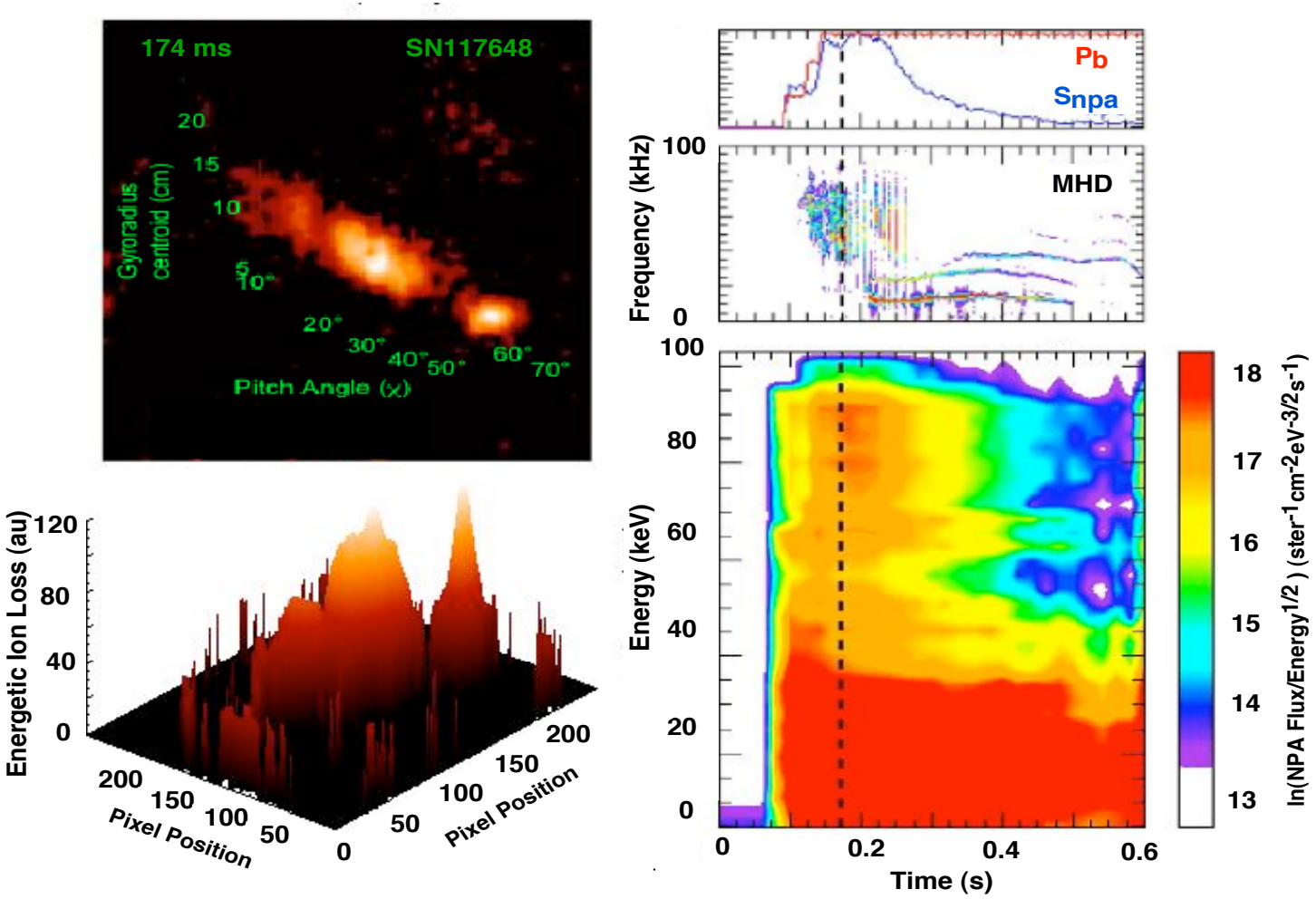
- H-mode with Ip = 0.9 MA, B_T = 4.5 kG A, B, C @ 90 keV and P_{NB} = 6 MW.
- TRANSP neutrons ~ 1.25x measured.
- Stable outer gap ~ 10 cm early in discharge and density ramp-up to $n_e(r) = 8x10^{13}$ cm^{-3}.
- Energetic ion depletion above E/2 after H-mode onset at t ~ 0.1 s.
- Even during the 'Low - f Quiescent' phase, however, $\delta B_{Low}/\delta B_{High} \sim 4$.

MPTS and CHERS Data for SN125329 - a Rare 'Low-f Quiescent' H-mode Discharge



- Collapse of v_Φ at t ~ 0.55 s coincides with ramp-up of carbon-dominated Z_{eff} and N_e.
- Electron temperature profile is broad, $T_e(0) \sim T_i(0) \sim 1$ keV & $S_n \sim 1/Z_{eff}$ @ t > 0.55 s.

Correlation of NPA Flux and Mirnov Data with sFLIP Images Identifies Redistribution vs Loss



- The scintillator Fast Loss Ion Probe (sFLIP) is a magnetic spectrometer.
- B_T and aperture geometry disperse pitch angles and energies onto a scintillator.

Summary

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

- The NPA vertical scan for XP-707 viewed passing energetic ions having a narrow range in field pitch: $v_{||}/v \sim 0.78 \pm 0.06$. NPA vertical scan results for XP-707 are documented in PPPL-4207.

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

- Proposed XP-8** will document NPA vertically scanning measurement of MHD-induced energetic ion redistribution at - Part I: reduced field pitch ($v_{||}/v \sim 0.47 \pm 0.03$), and Part II: during an MHD-quiescent H-mode phase.