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NSTX

Millimeter-wave measurements of edge electron density profiles and fluctuations during NSTX H-mode discharges

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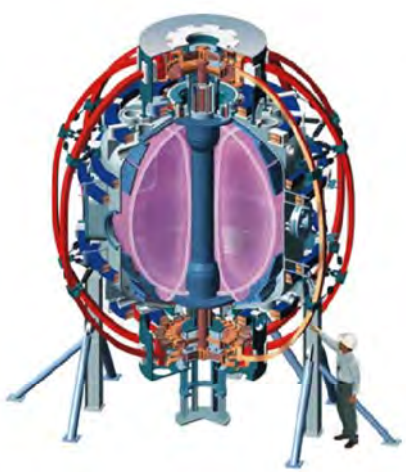

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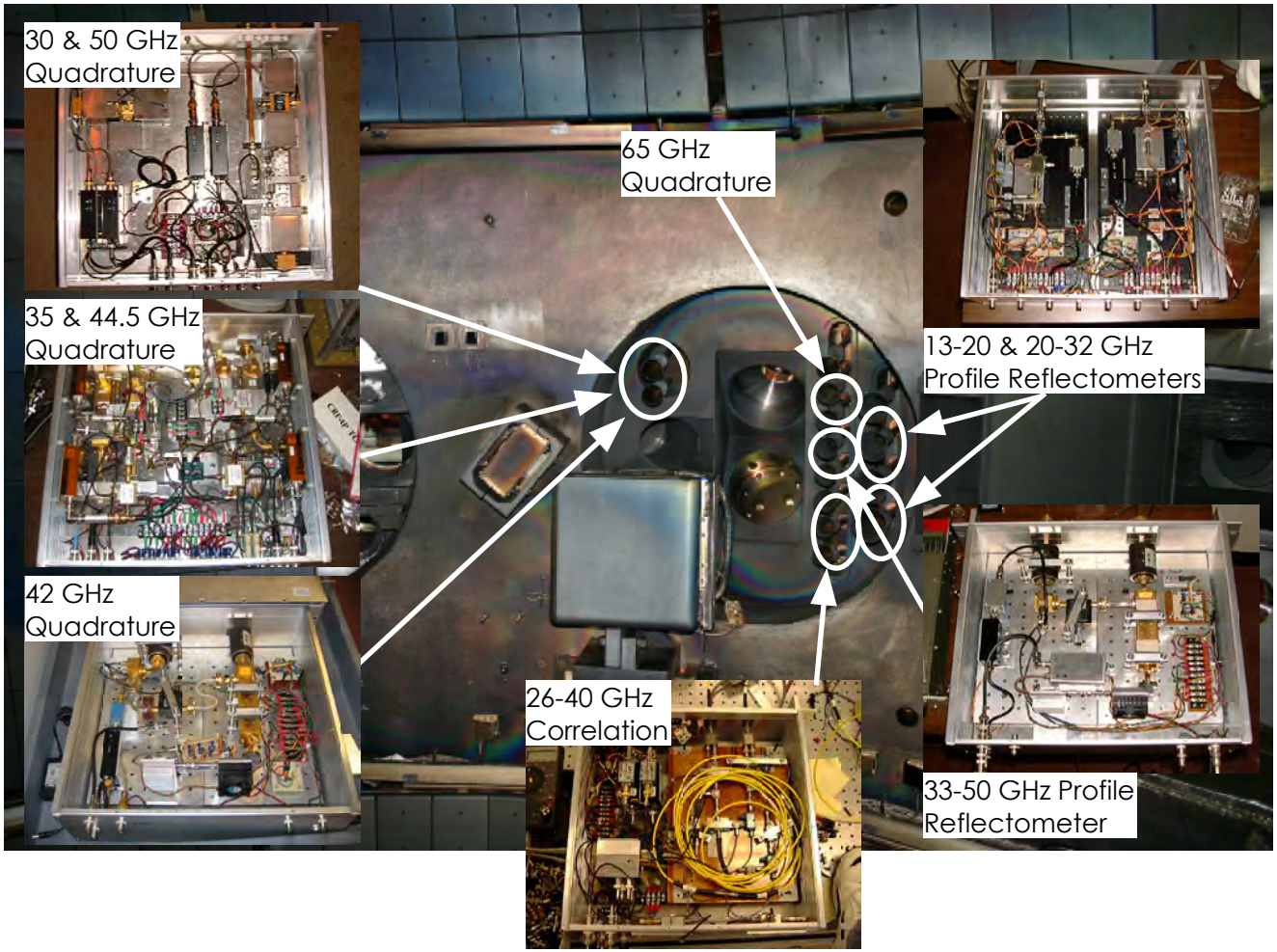
Abstract

Millimeter-wave measurements of edge electron density profiles and fluctuations during NSTX H-mode discharges[1]

The fast evolution of the density profile and the associated changes in turbulence are measured near the plasma edge in NSTX H-mode discharges using millimeter-wave reflectometry. FMCW reflectometry (13-50 GHz) provides fast profile measurements with 20 us resolution, while multiplexed fixed-frequency systems (30, 35, 42, 44.5, 50, 65 GHz) monitor fluctuations at various cutoff radii. A new correlation reflectometer (29-40 GHz) is used to measure the poloidal propagation of turbulence. The bulk poloidal velocity can be inferred from these measurements while the the propagation of individual turbulence structures is also visible. In addition to the L-H transition, profile and turbulence characteristics are monitored for the various ELM types (Type I, III, V) present in NSTX.

[1]Supported by U.S. DoE Grant DE-FG03-99ER54527.

Millimeter-Wave Diagnostics for 2007 Campaign

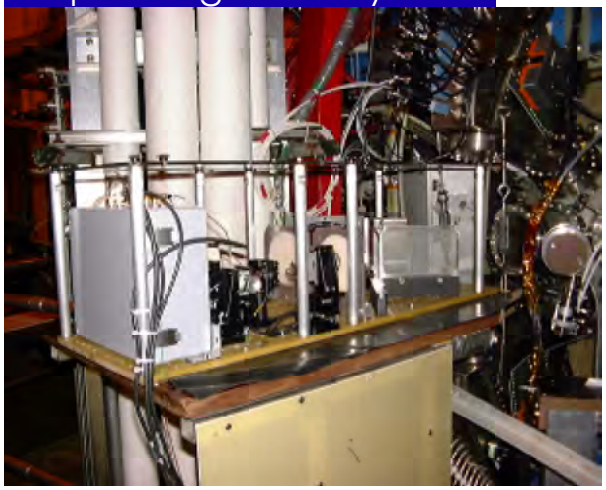


Bay J Reflectometers

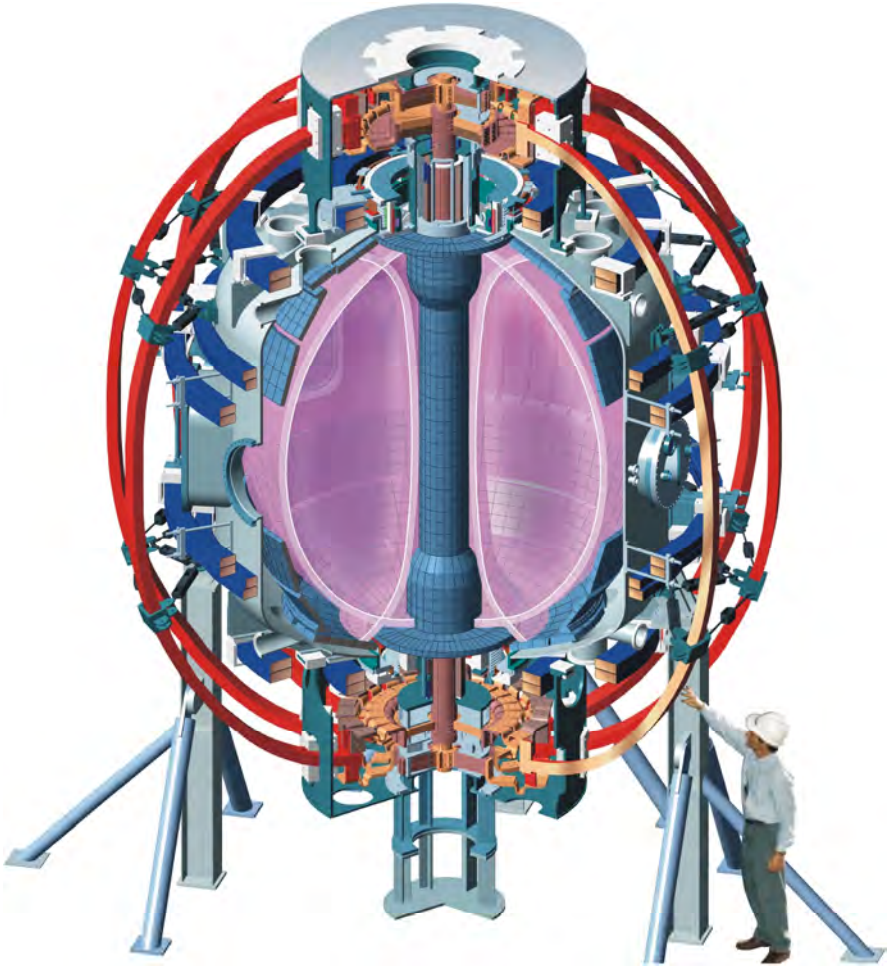
- Fluctuation levels
- Spectra
- Profiles

Bay G Interferometer

- Radial line density
- Operating routinely



Machine Parameters



Aspect Ratio A	1.27
Elongation κ	2.5
Triangularity δ	0.8
Major Radius R_0	0.85 m
Plasma Current I_p	1.5 MA
Toroidal Field B_{T0}	0.6 T
Pulse Length	1.5 s
Auxiliary Heating	
NBI (100 kV)	7 MW
RF (30 MHz)	6 MW
Central Temperature	1-3 keV

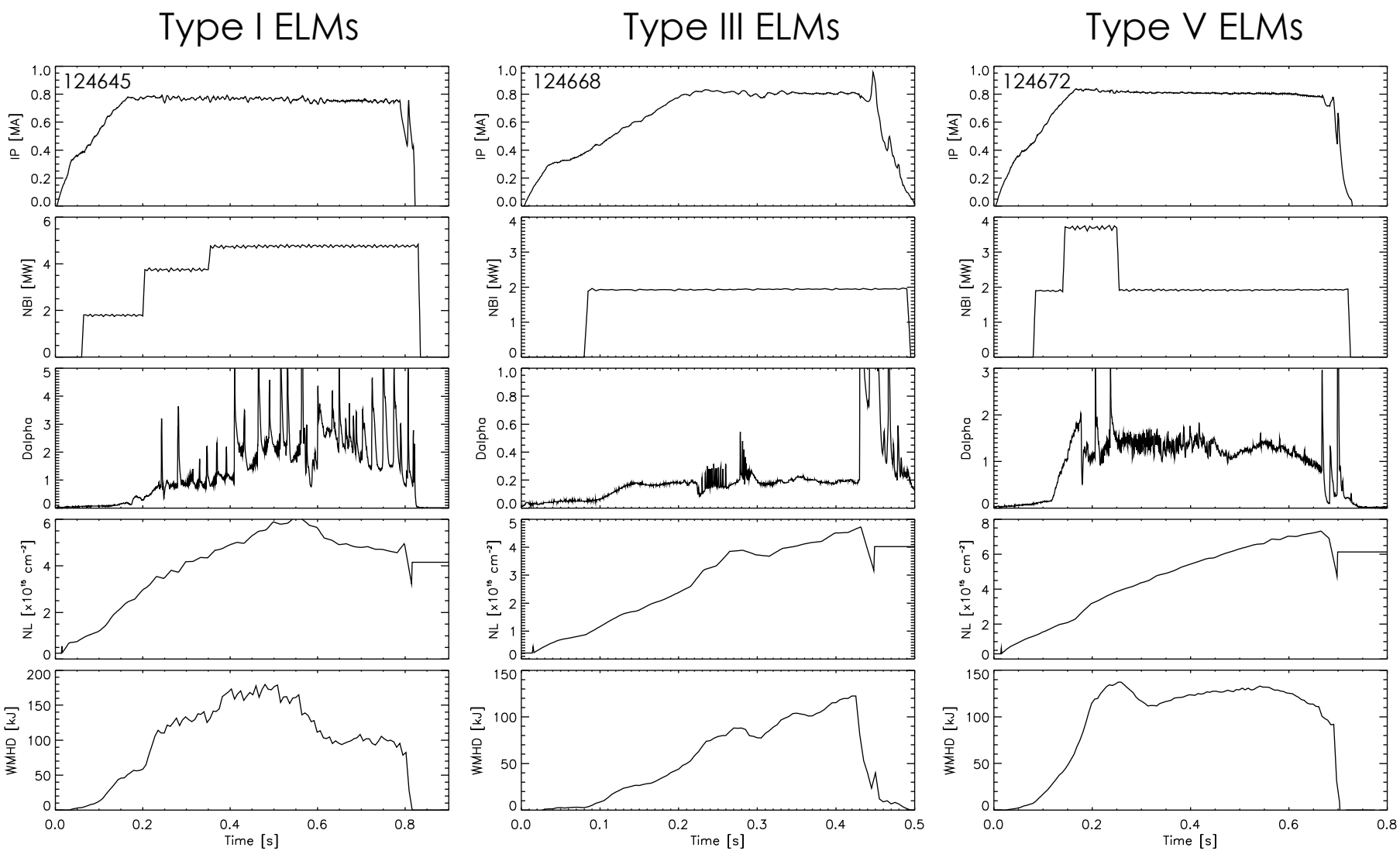
Background and Motivation

- **Understanding ELM physics is important for the ST and other fusion devices:**
  - Predictive capabilities and control are important for H-mode operation.
  - Impacts edge particle/energy transport (concern for ITER).
- **Type I, III and V ELMs are routinely seen in the H-mode edge of NSTX:**
  - Associated with filaments that propagate poloidally and toroidally, as well as radially.
  - Associated with increased turbulence and blob activity in SOL.
  - ELMs can impact edge transport severely (brief transition to L-mode like profiles over the entire plasma for large Type I).
- **Documentation of ELM phenomena uniquely suited for reflectometers:**
  - Fast-scanning and multiple-channel reflectometers measure radial profiles and fluctuations simultaneously. For profiles, spatial- and time-resolutions of **$\Delta r<0.5$ cm and $\Delta t>20$ μs**). Flucutation measurements with bandwidth up to 4 MHz.
  - NSTX H-modes have electron density profiles with large 'ears' in the pedestal. **Measurements are localized near the edge, both inside and outside the LCFS**. Core access during H-mode is rare.
  - **First comprehensive documentation of ELMs with reflectometry for NSTX.**

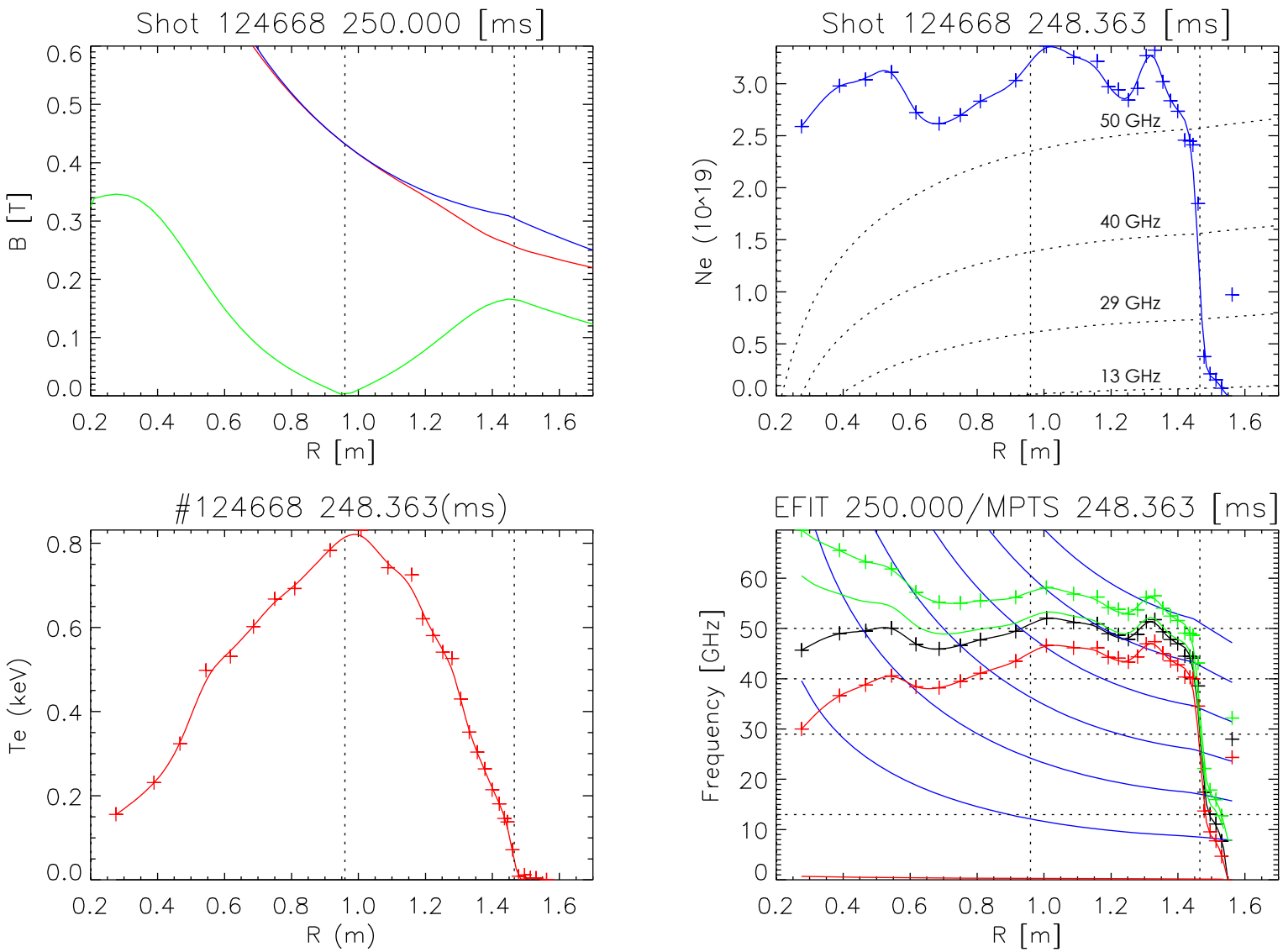
Some ELM Properties on NSTX

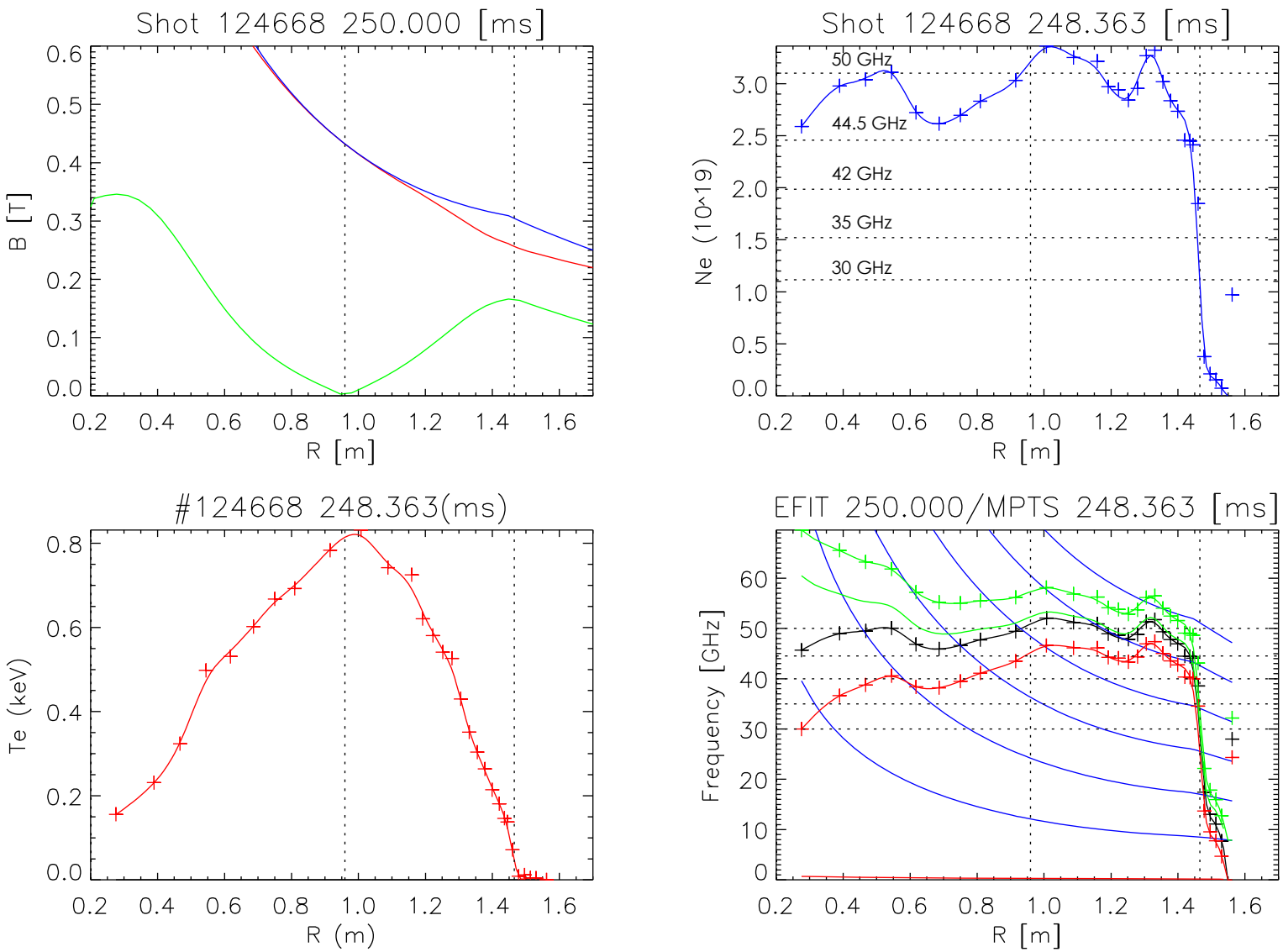
- **Type I ELMs**
  - Size decreases with increasing density.
  - Size decreases as equilibrium is shifted from DND to LSN.
  - Plasma stored energy loss up to 10%. Giant ELMs up to 30%.
  - Frequency increases with density.
- **Type III ELMs**
  - Plasma stored energy loss 1-3%.
  - Inverse heating power/frequency relation.
  - Occur close to the L-H power threshold.
  - Electromagnetic precursor oscillation.
- **Type V ELMs**
  - Appears for LSN high fueling rates.
  - Intermittent n=1 MHD mode or filament rotating counter to the plasma current and persists for ~2 toroidal transit times. Poloidal propagation is observed on poloidal Mirnov array and in the USXR system.
  - Indiscernible impact on stored energy for individual ELM.

Discharge Parameters for ELM Experiment

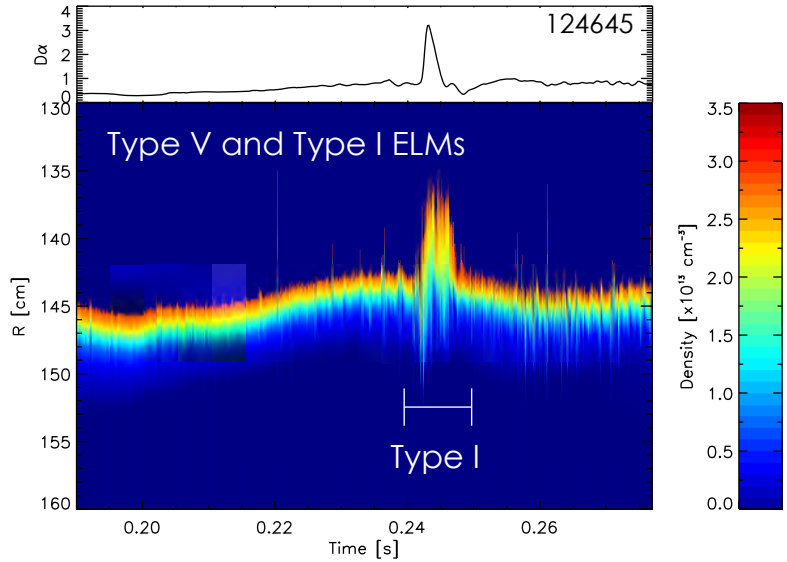


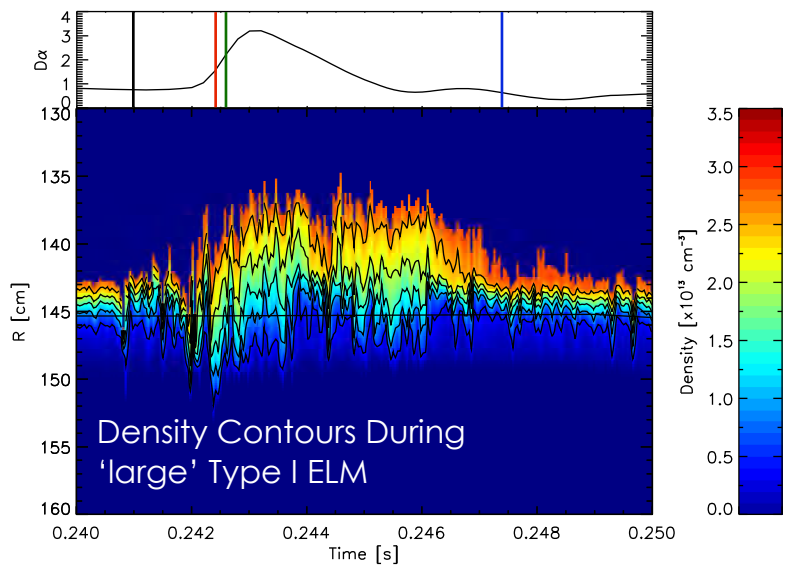
Characteristic Frequencies During ELMy H-Mode

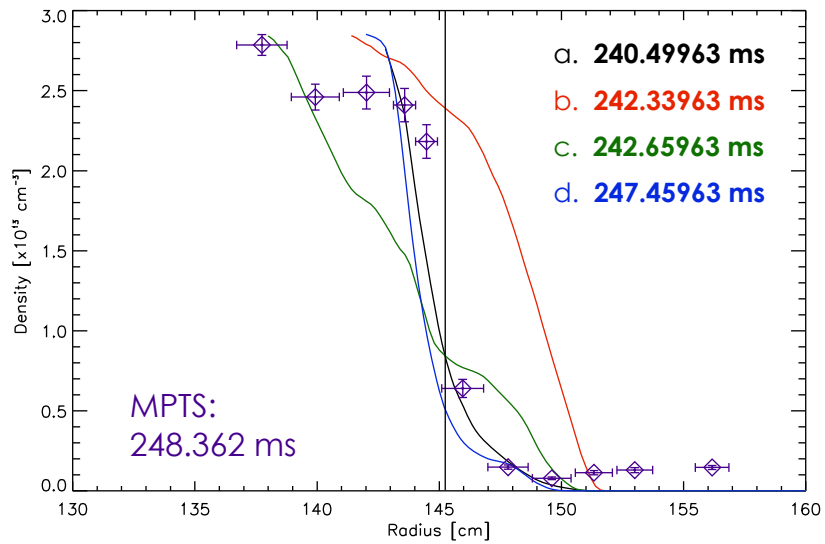



Shot 124668 250.000 [ms]
B [T]
R [m]
Shot 124668 248.363 [ms]
50 GHz
44.5 GHz
42 GHz
35 GHz
30 GHz
Ne (10^19)
R [m]
#124668 248.363(ms)
Te (keV)
R (m)
EFIT 250.000/MPTS 248.363 [ms]
Frequency [GHz]
R [m]

Type I ELMs Influence Edge Profile Significantly

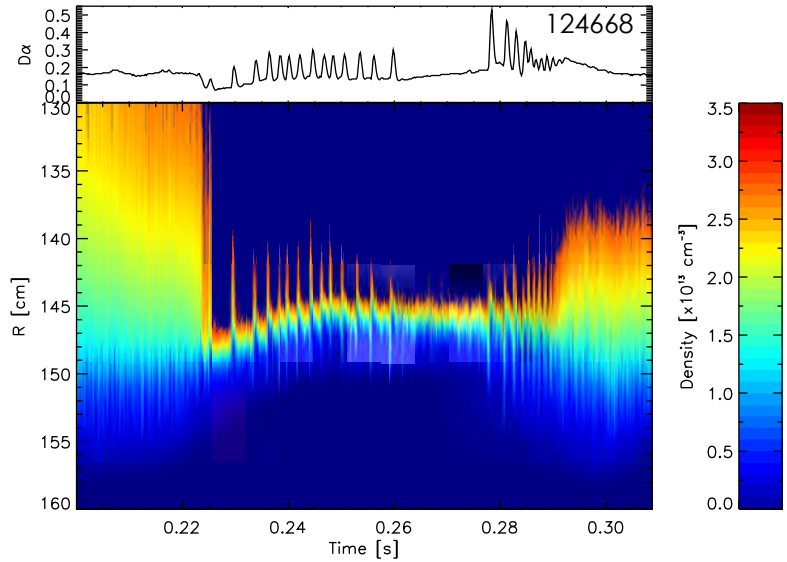


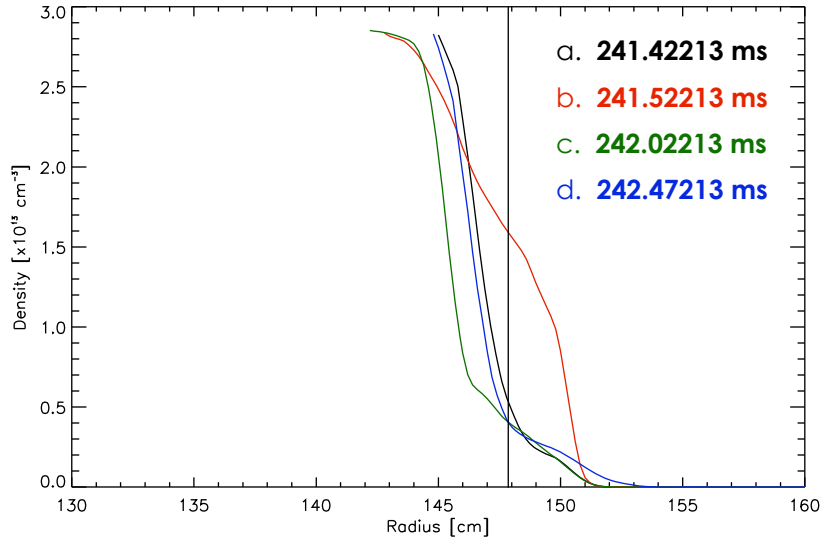


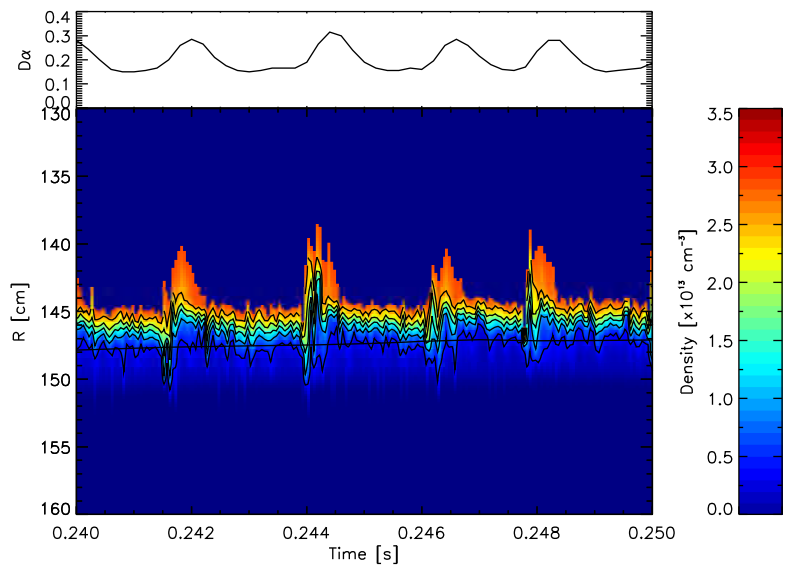


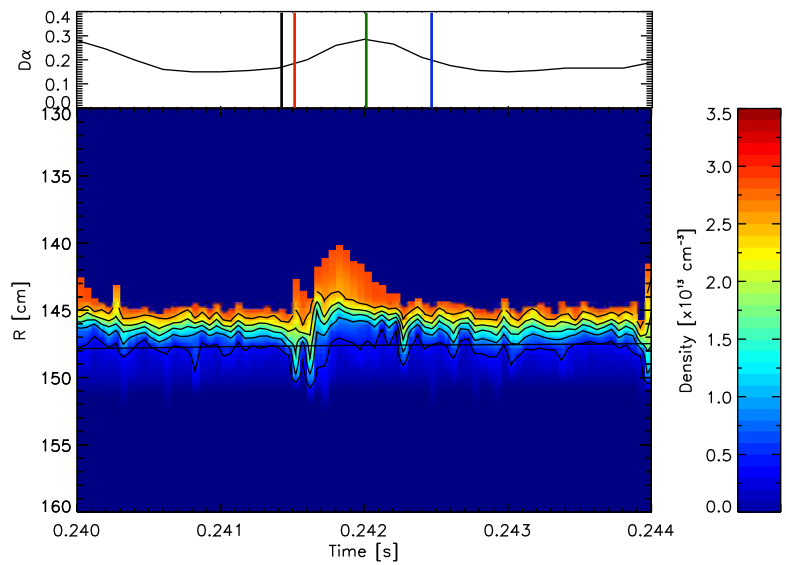
$\Delta W_{MHD} \sim 4\%$

Significant Perturbation During Type III ELMs

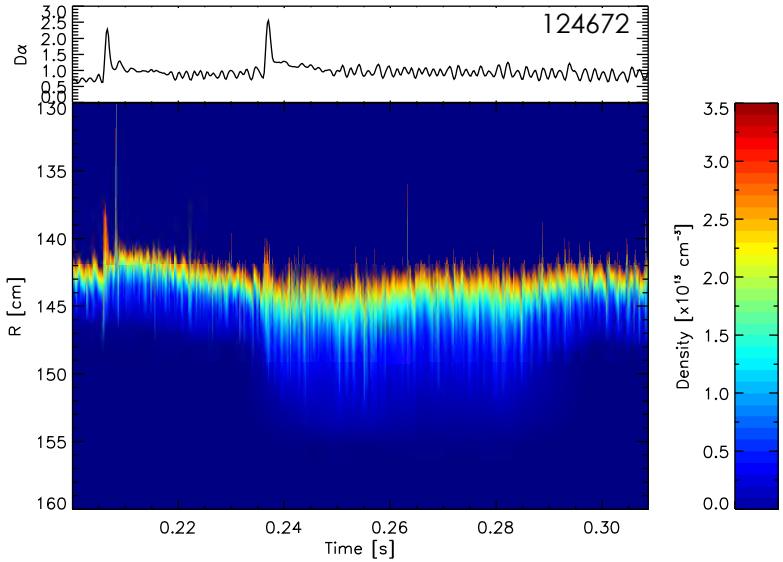


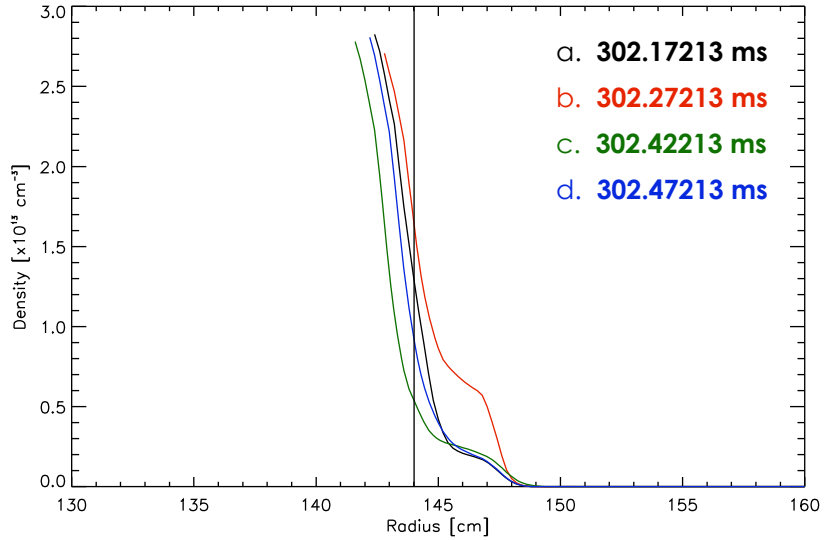


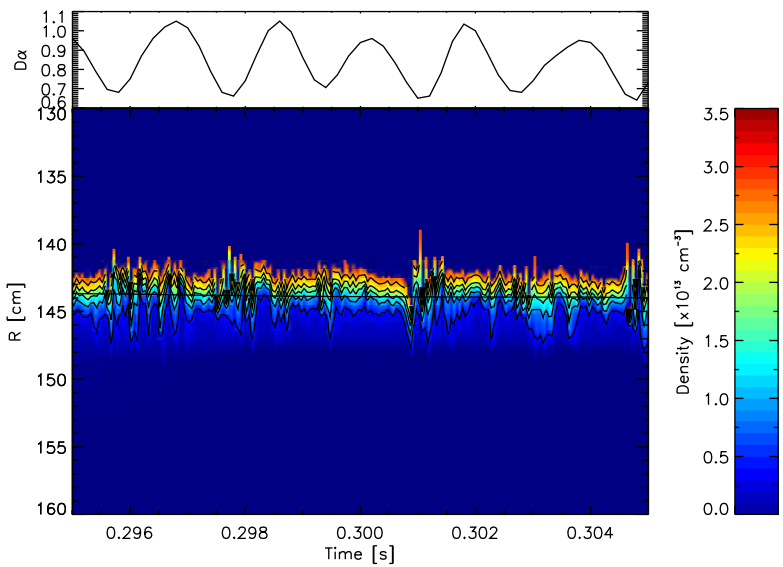


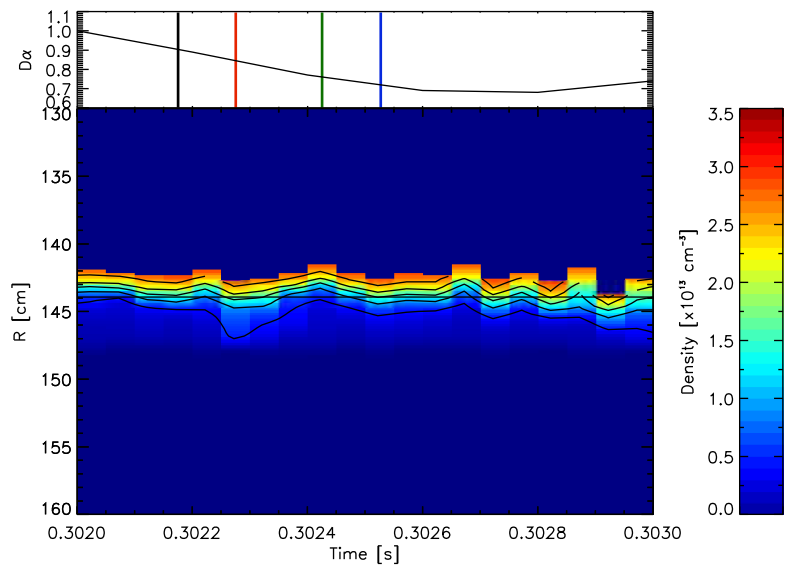


Profile Perturbations Smaller for Type V ELMs

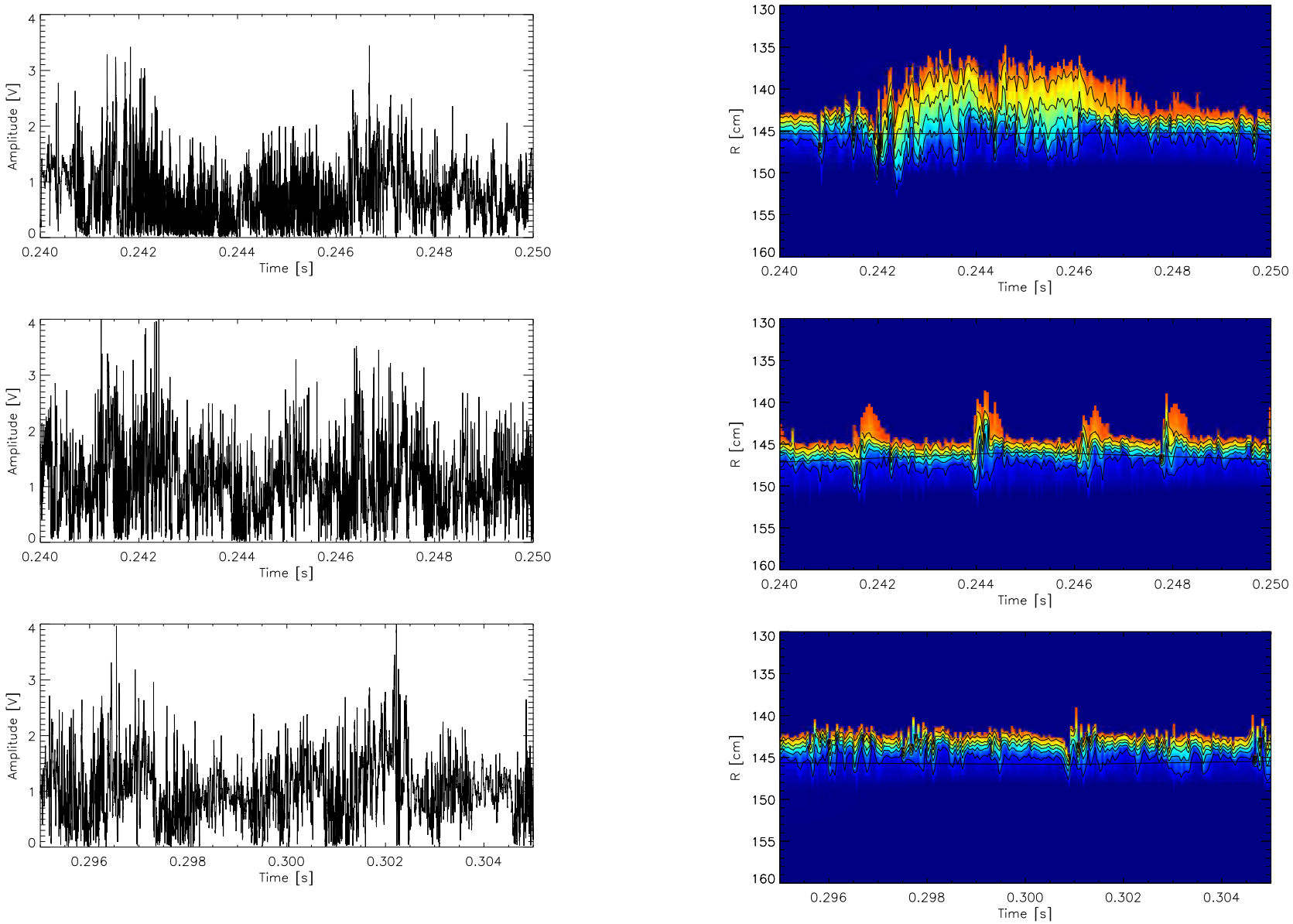




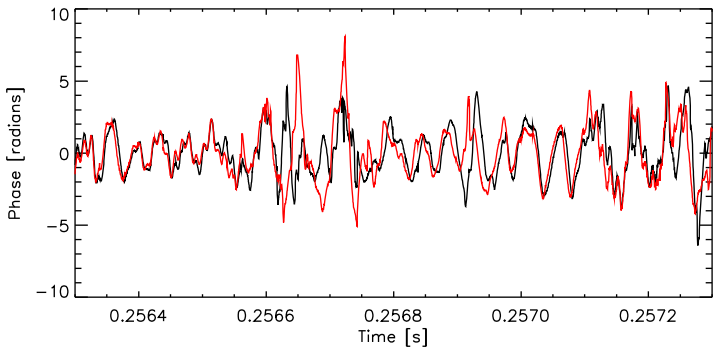


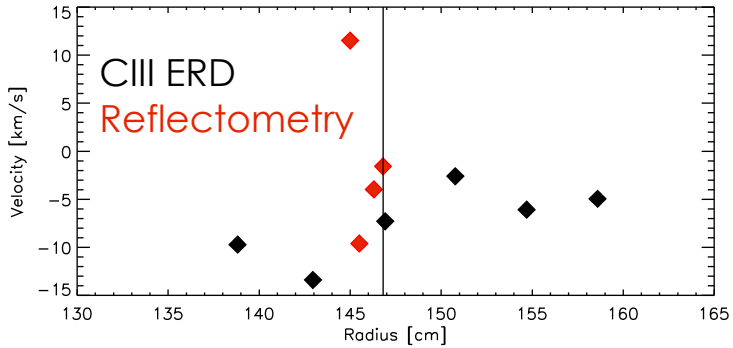


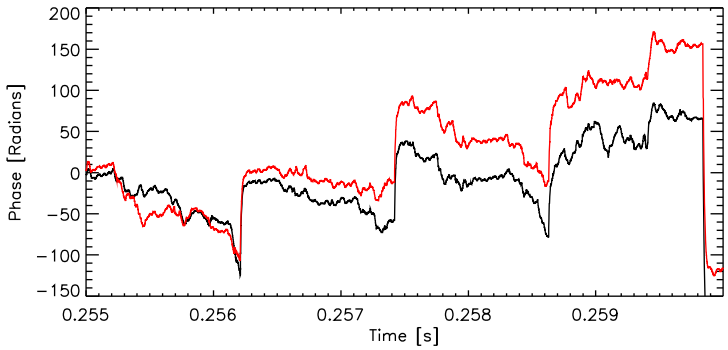
Strong Amplitude Modulation of Signal Correlated With ELMs



Estimate of V_{pol} Edge Profile Shows Agreement With ERD

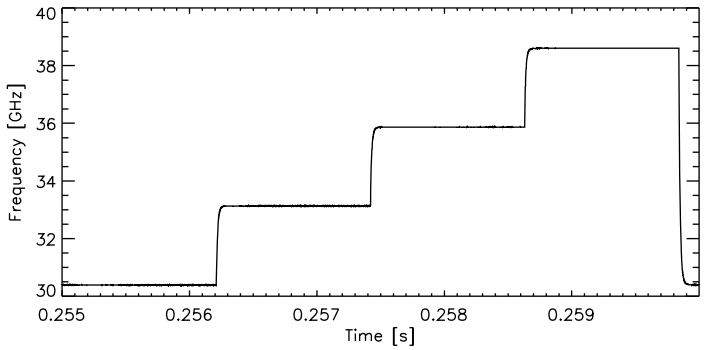






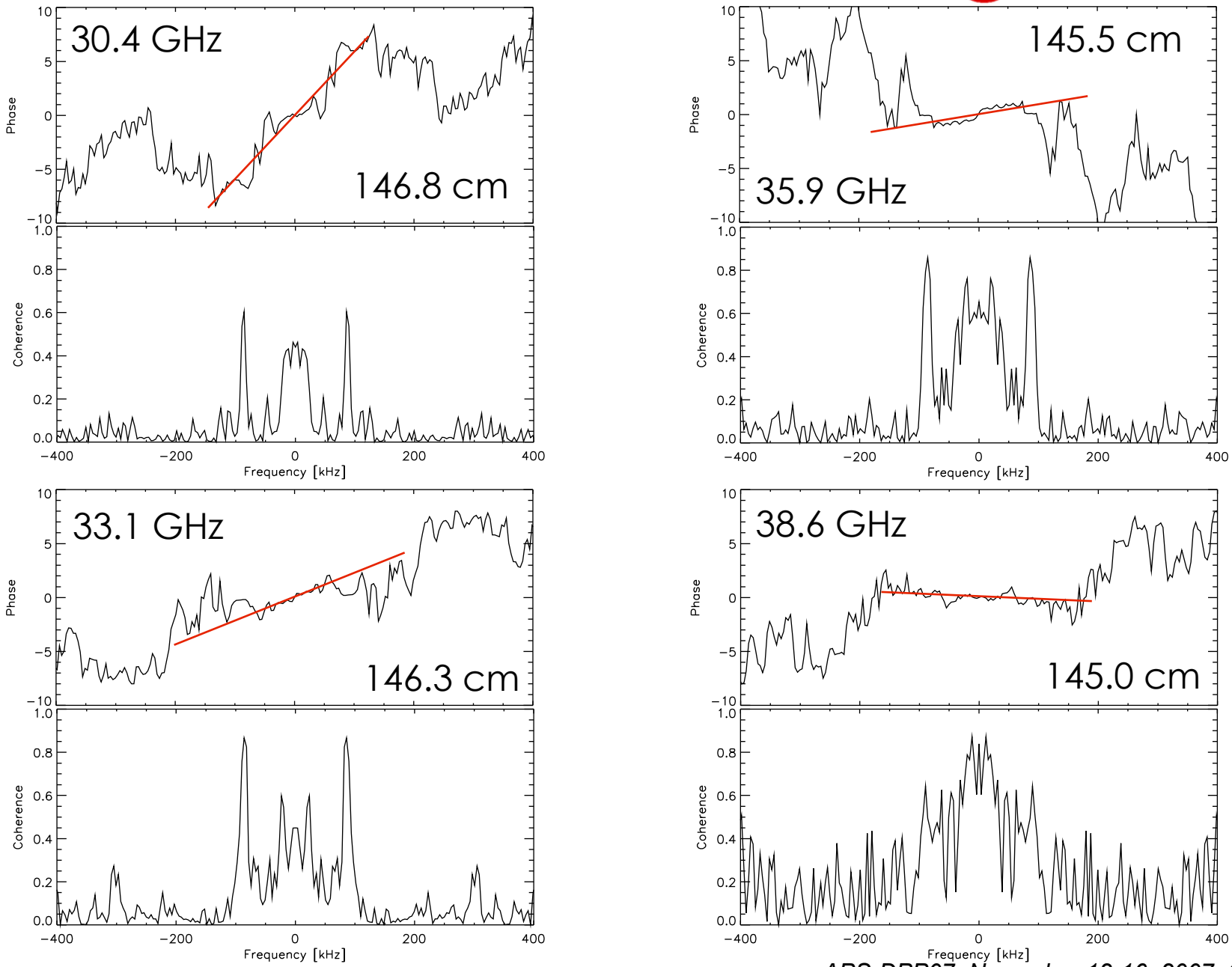
$$\tau = \frac{d\phi}{d\omega}$$

$$v = \frac{L}{\tau}$$



Here we crudely assumed L~1.4 cm.

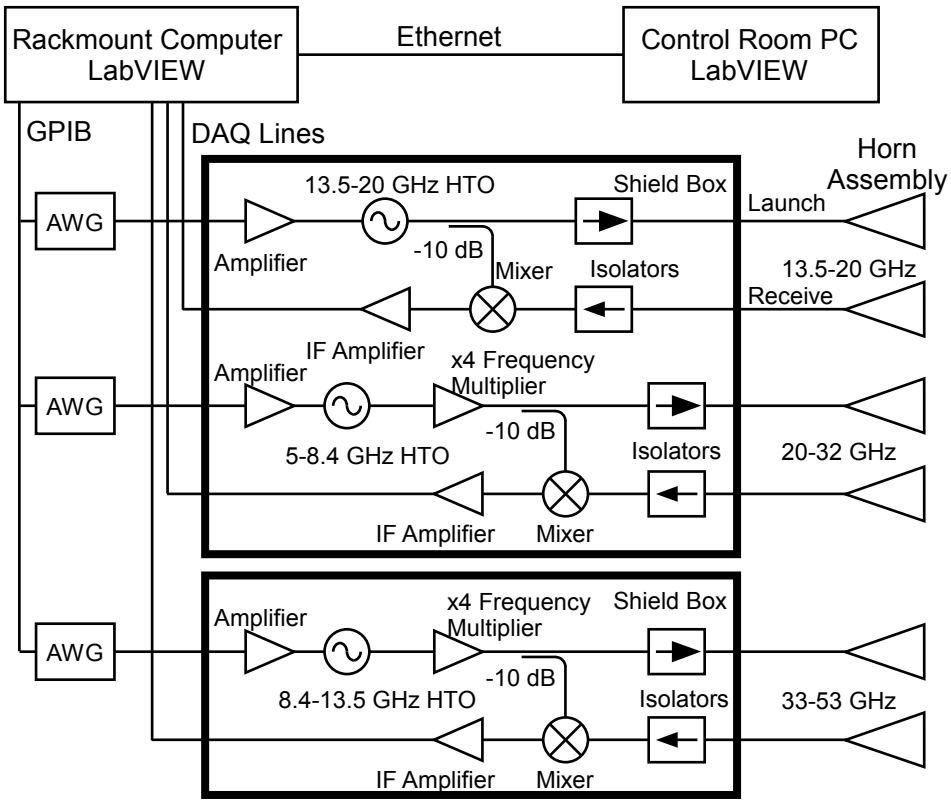
Coherence at Different Radii

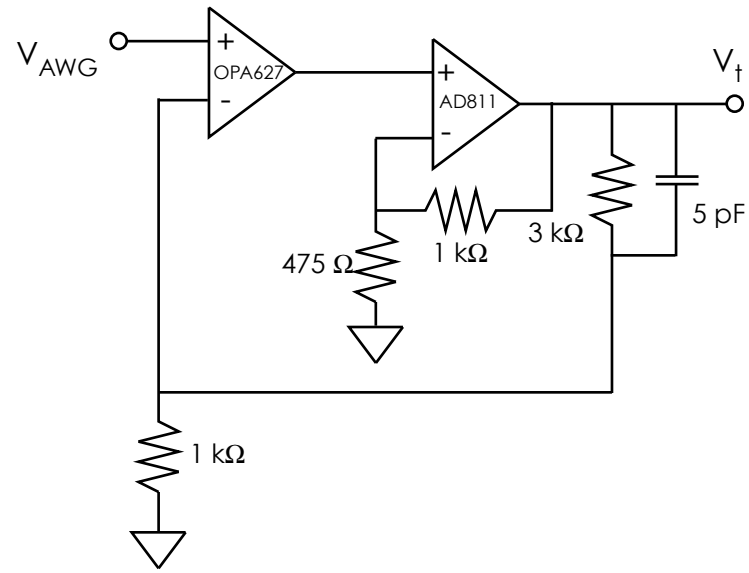


Poster Summary and Future Work

- **Summary**
  - Profile evolution during ELMy H-modes (Type I, III and V) were characterized. Associated density oscillations were seen through-out the growth, crash and recovery phases.
  - For all ELM types observed, the reflectometers showed strong amplitude modulations (L-mode-like) during ELM events.
  - Smaller ELM-like events/oscillations are omnipresent and mostly localized around or outside the separatrix. Not all of these events seem to be fully resolved (temporally and spatially) by the current diagnostics.
  - Preliminary estimates of edge poloidal rotation using poloidal cor relation reflectometry were made and agreed well with ERD. This demonstrates the possibility of monitoring Er during fast events (ELMs or the L-H transition).
- **Future Work**
  - A more detailed analysis of the poloidal correlation as well as radial correlation data will be presented elsewhere. Possibility of δv measurements: GAMs?
  - Clear benefits to having even faster sweep rates for the profile measurement (<10 μs?).

FM-CW Reflecometer Circuitry





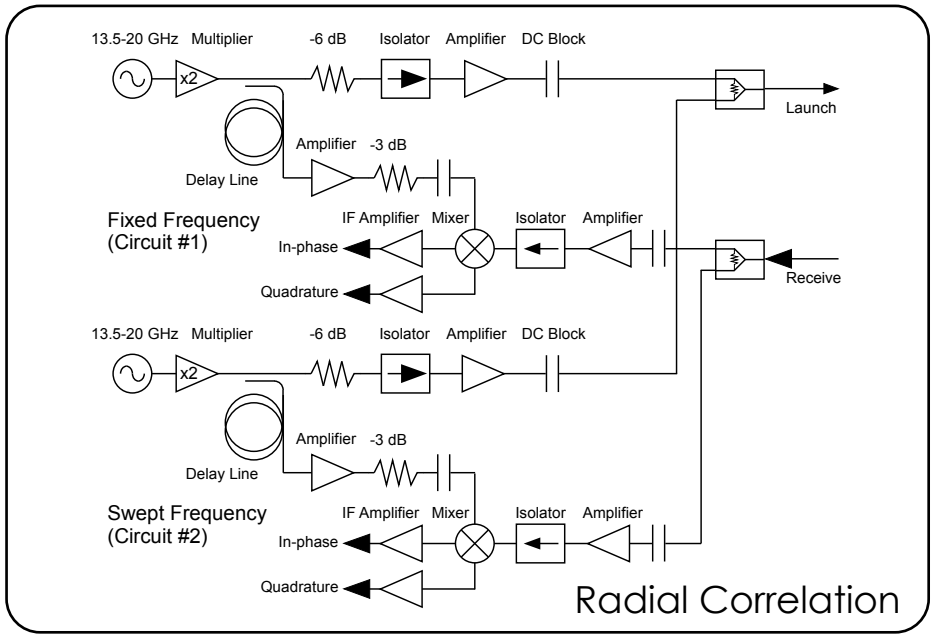
FMCW System

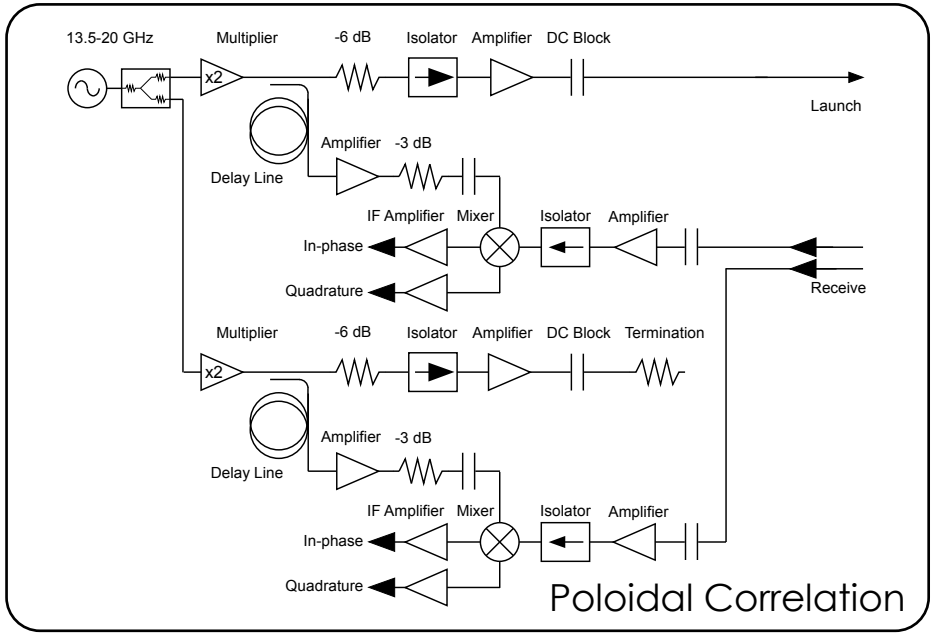
- 13-53 GHz coverage (2.1×10^{12} to 3.5×10^{13} cm^{-3}).
- Maximum repetition rate of 20 μs/sweep (3840 total profiles per shot).
- Using spline fit to Thomson edge profile below $n_e=9\times10^{11}$ cm^{-3}.

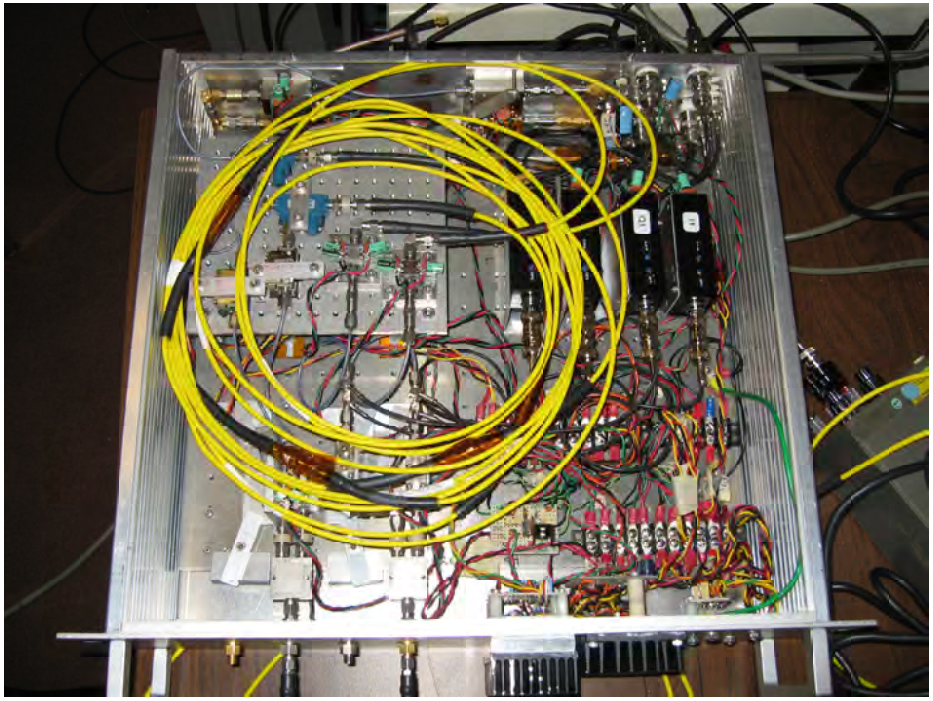
Modifications for 10 μs Repetition Interval

- IF amplifier bandwidth (0.05-130 MHz).
- Data acquisition at 100 MSa/s.
- Agilent 33220A: 14-bit, 50 MSa/s, 64 kSa.
- Tuning voltage x4 amplifier bandwidth increased to 10 MHz.

New Quadrature Correlation Reflectometer



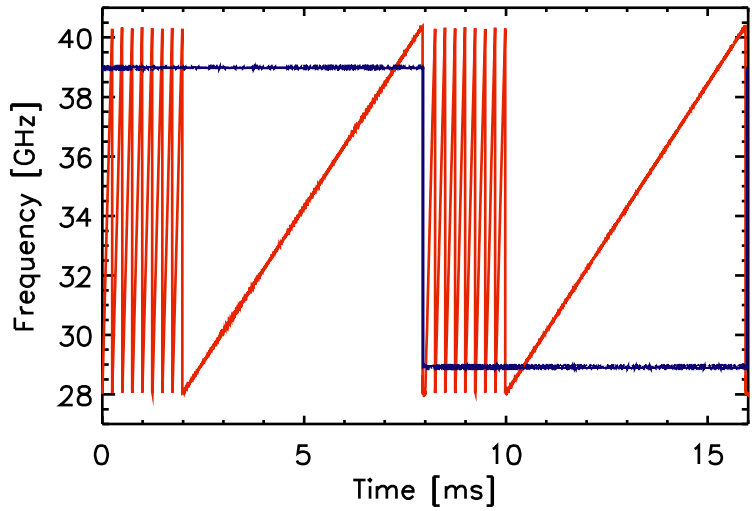


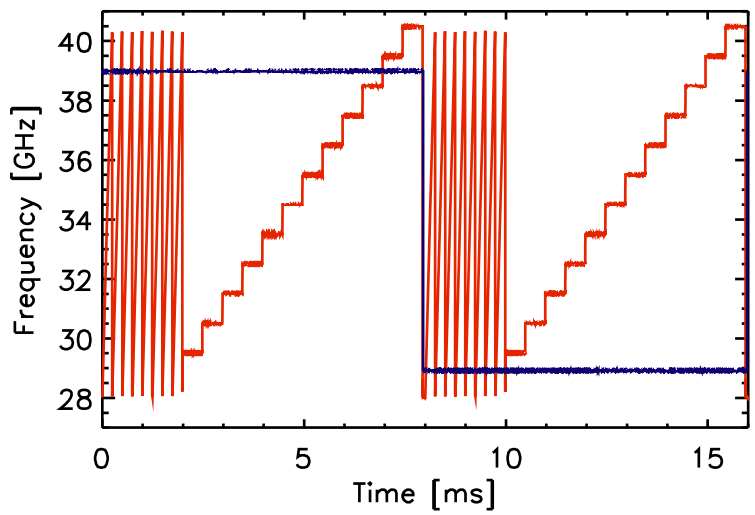


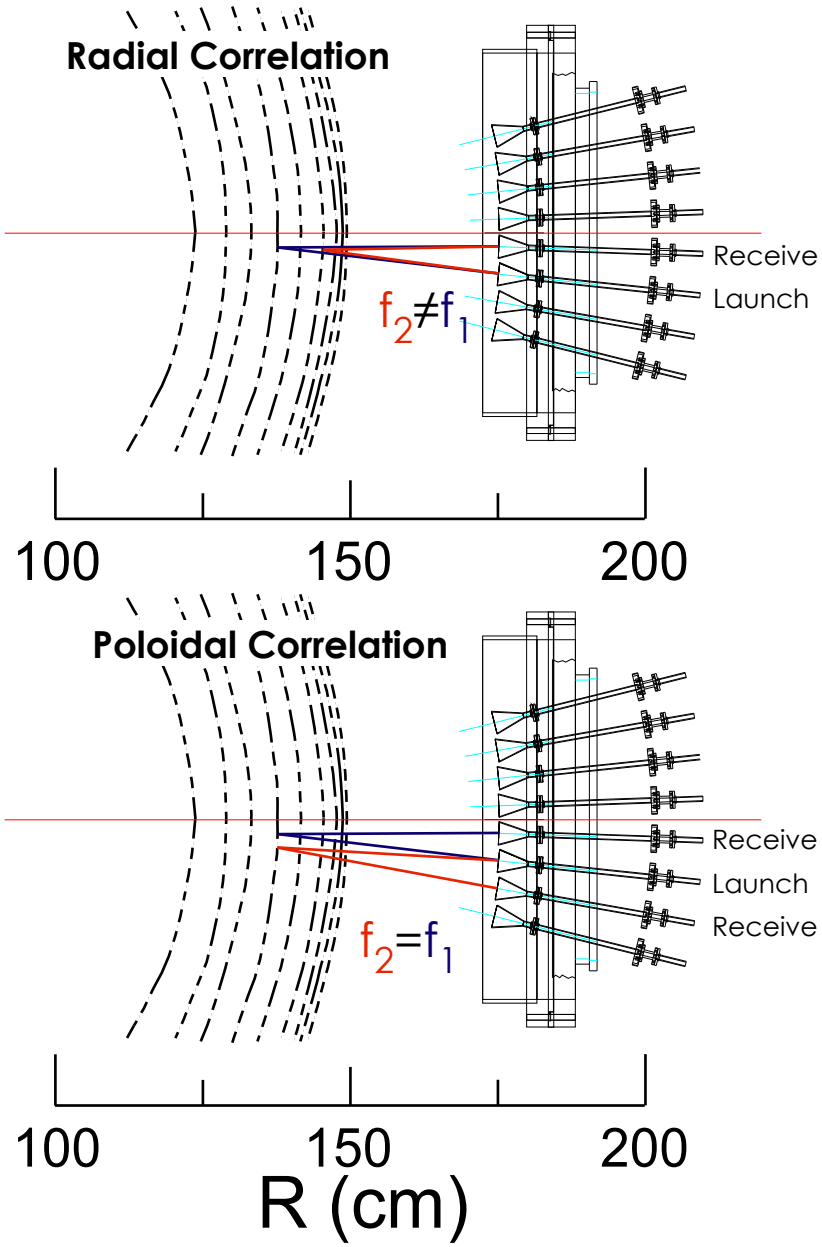
- Reflectometer uses direct-conversion quadrature detection.
- Complex signal (amplitude and phase information).
- Configured for either radial or poloidal correlation measurements.

Poloidal and Radial Correlation Measurements

Sample of Frequency Sweep Waveforms







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