High-Field-Side MHD Activity During Local Helicity Injection

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PEGASUS Toroidal Experiment

Layout Slide (Include for Posters)

US Legal
8.5 x 14”

US Letter
8.5 x 11”

12:1 scale Panel size: 8’ x 4’

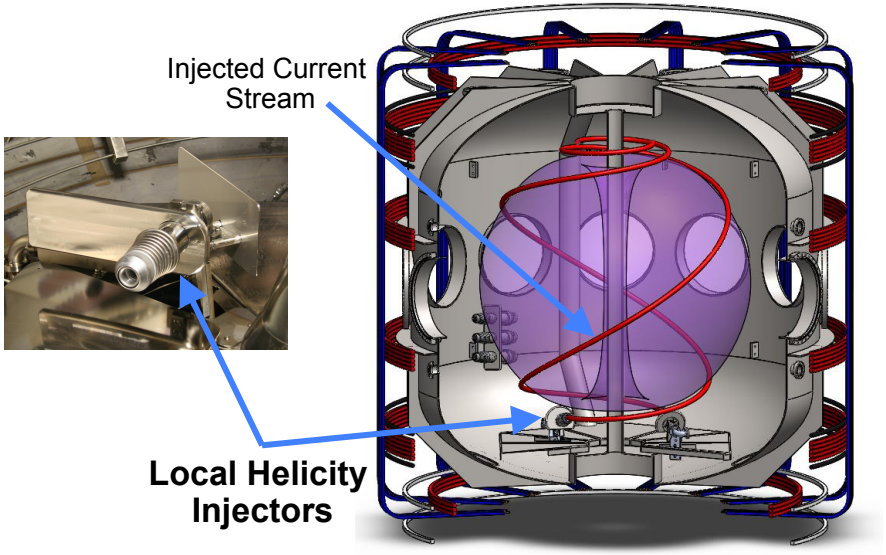
Title Slide	Elimination of EMI-driven switching noise	MHD transition	High amplitude MHD behavior on HFS	Low amplitude MHD behavior on HFS
Overview/LHI Introduction	Motivation for Noise Reduction	HFS LHI MHD Transition Behavior	Coherence vs. poloidal angle	Coherence vs. poloidal angle
PEGASUS Magnetic Diagnostic Locations	Troubleshooting Noise Source	Transition Behavior Differs Greatly between the LFS and HFS	Toroidal Mode Number: LFS vs. HFS	Toroidal Mode Number on HFS
NIMROD Simulated n=1 Activity Present in Experiment on Low-Field-Side (LFS)	Noise Suppression Solution	Large Changes in MHD Auto-Power at Transition: LFS vs. HFS	High Frequency Spectra of HFS	High Frequency Spectra of HFS
NIMROD Provides Simulation of Injected Current Streams	Results of implemented solution	Little Correlation between HFS and LFS	Summary of high MHD on HFS	Summary of low MHD on HFS

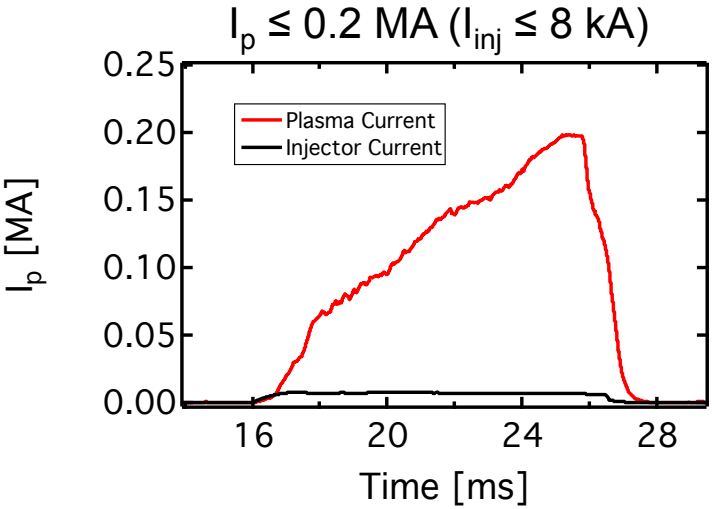
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Local Helicity Injection Current Drive

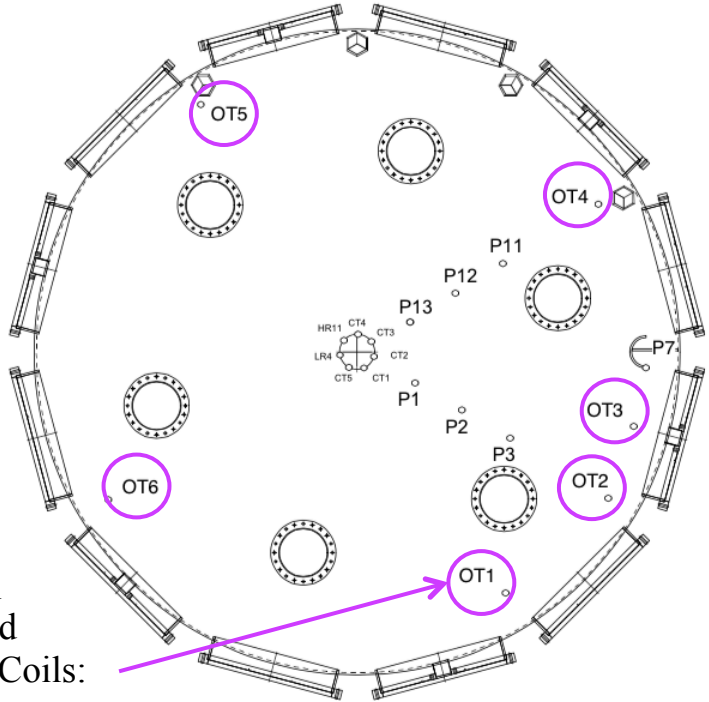
Local Helicity Injection (LHI)





- Non-solenoidal startup on PEGASUS
- High-Field-Side (HFS) current injection
- Reduced-MHD regime discovered

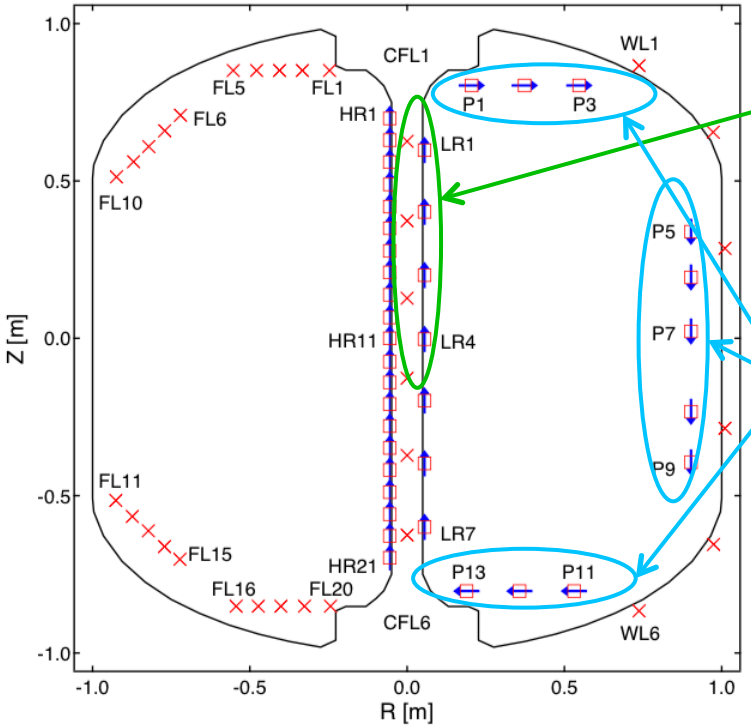
PEGASUS Magnetic Diagnostic Locations



(a) Toroidal Mirnovs

Toroidal Outboard Mirnov Coils:

"Otor 1-6"



(b) Poloidal Mirnovs and flux loops

Poloidal Inboard High Resolution Mirnov Coils:

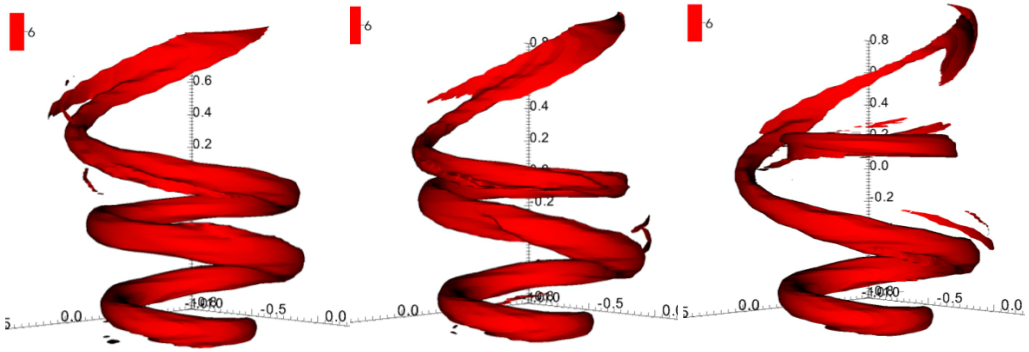
"HighRes1-12"

Poloidal Outboard Mirnov Coils:

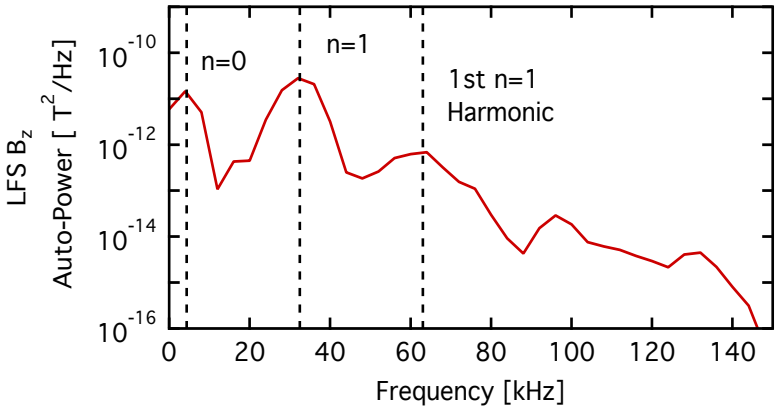
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NIMROD Simulated n=1 Activity Present in Experiment on Low-Field-Side (LFS)



1. Streams follow field lines
2. Adjacent passes attract
3. Reconnection pinches off current rings

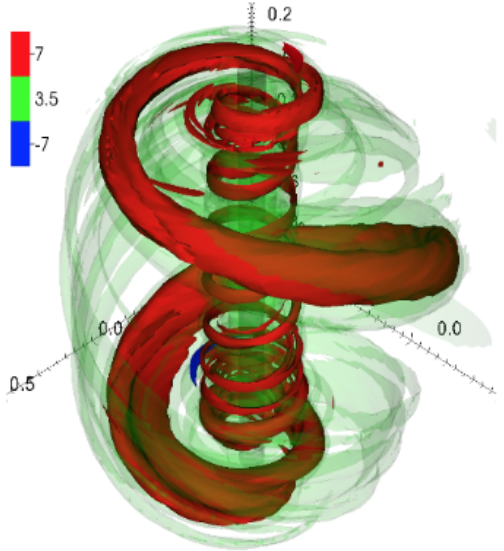


- NIMROD simulates mechanism for current growth during LHI
  - Build toroidal current and poloidal flux
  - Induce large magnetic bursting phenomena

- LHI exhibits large Alfvénic, n=1 MHD activity
  - Both continuous and bursting behavior
  - Structure consistent with island coalescence and/or kinking of injected current streams

NIMROD Provides Simulation of Injected Current Streams

- Simulations indicate coherent streams and reconnection activity on both LFS and HFS
- Experiment has shown evidence of coherent injected streams in plasma edge at LFS
  - Outboard magnetic signature
- Do the current streams exist, and how do they behave on the Inboard side during experiment?
  - Upgrade Inboard magnetic diagnostics to view magnetic activity down the center column



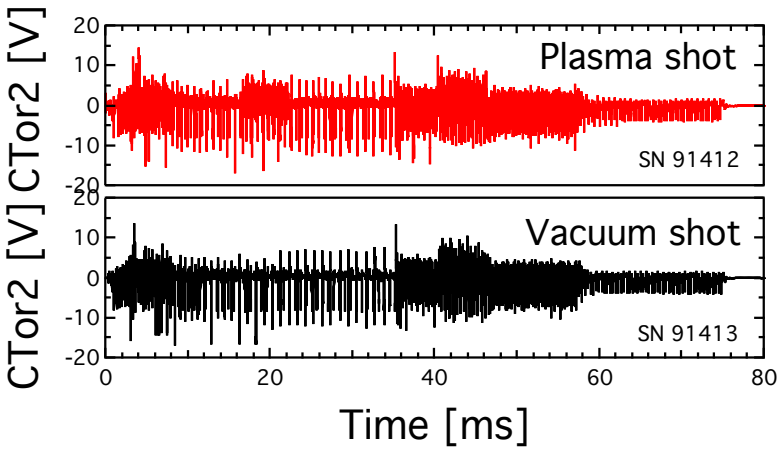
NIMROD Simulation
[O'Bryan PhD 2014]

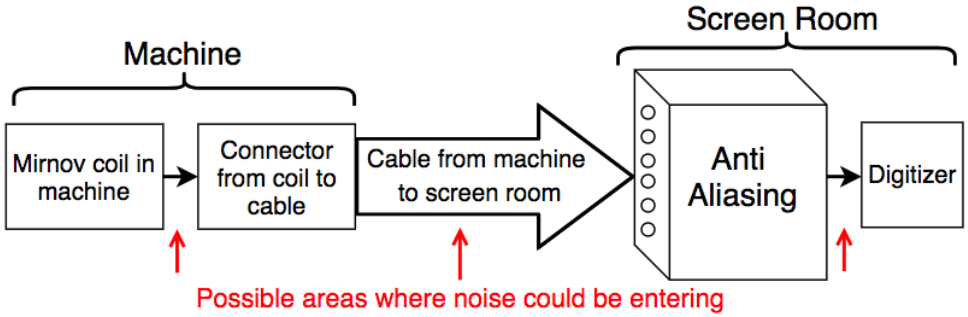
Elimination of EMI-driven Switching Noise

Motivation for Noise Reduction on Core Magnetics

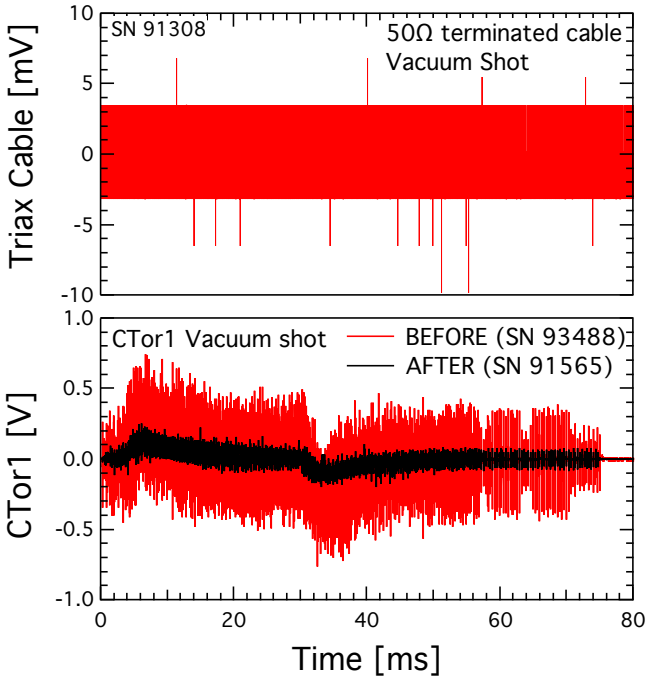
- Switching power supply systems introduce EMI-driven switching noise
  - Many Mirnov coils along the center column were unusable
- Core magnetics needed to study HFS magnetic activity
- Mitigate noise on the HFS Mirnov coils
  - Characterize where noise is originating
  - Determine if coil, connections, or signal processing are problem areas

Example of noisy Mirnov coil:

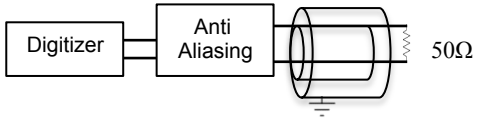




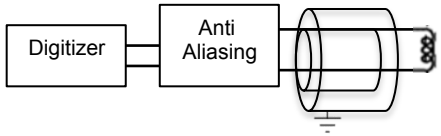
Troubleshooting Noise Source



- Tested stand alone triax cable through clean, properly shielded signal processing
  - Terminated cable with 50Ω resistor
  - Typical noise level ≈ 400 mV



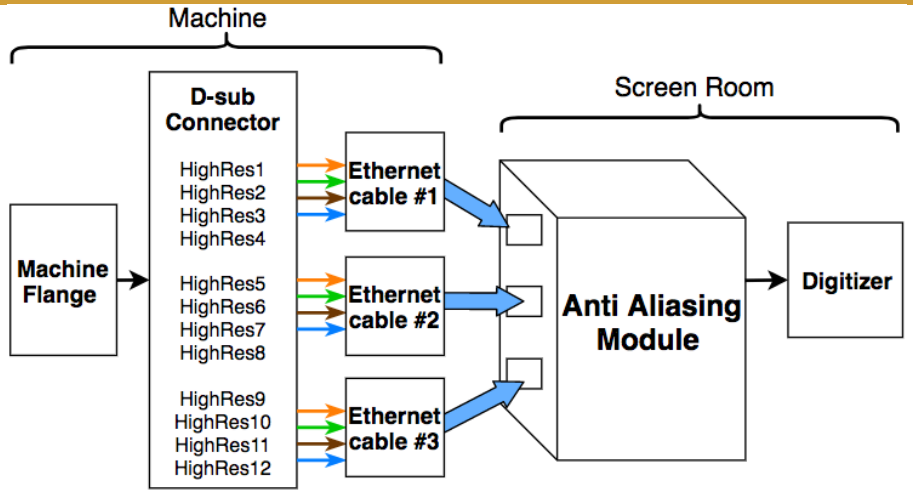
- Looked at noise level on Mirnov coils
  - Noise-free triax cable run used with properly executed signal processing

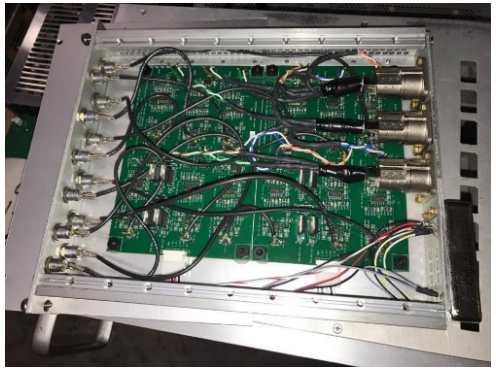


- Results:
  - Decreased noise level from 800mV to 150mV on CTor's
  - Coils with bad signals are recoverable, not damaged

Noise Suppression Solution

- New shielded cable runs from the machine to the screen room
  - Cat7A Ethernet cable is Shielded Shielded Twisted Pair (SSTP)
  - Low cost, industry standard to 1GHz
- Modify anti aliasing module
  - Input SSTP
  - Output shielded LEMO cables
  - Output differentially driven

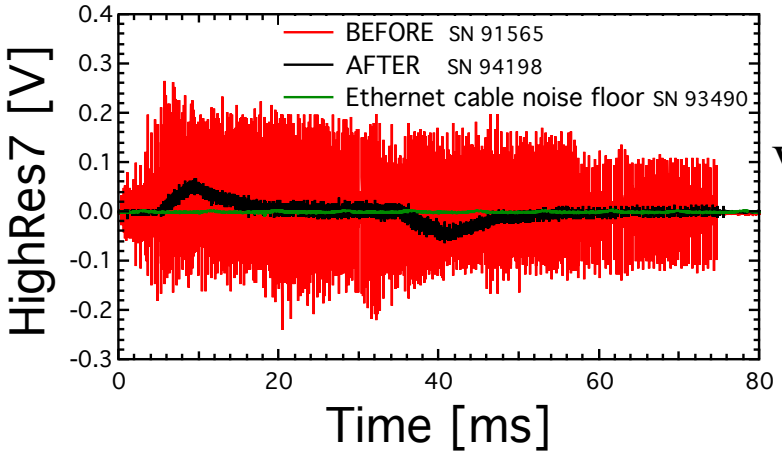


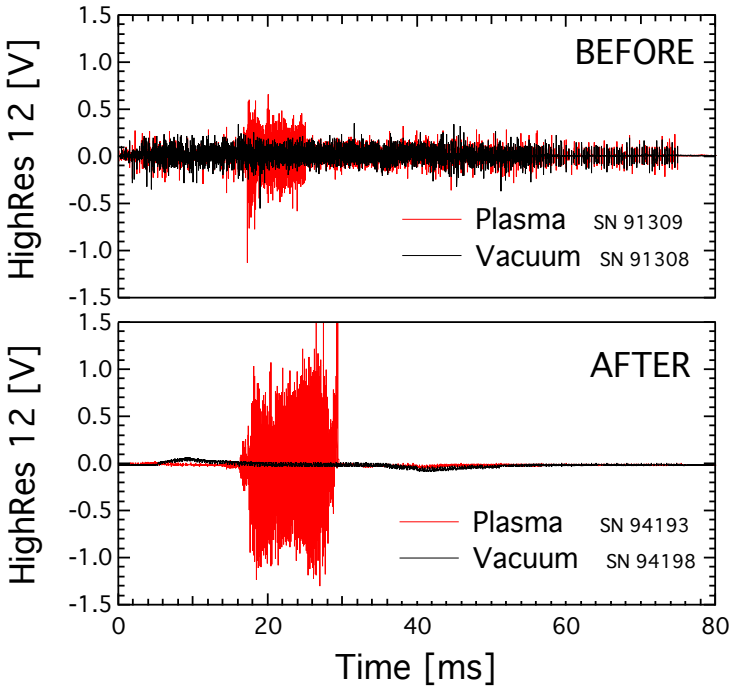




Results of Implemented Solution

- EMI-driven switching noise reduced by an order of magnitude
  - From 400mV to 40mV
- Plasma signal no longer polluted with noise
  - Accurate enough to use for detailed spectral analysis

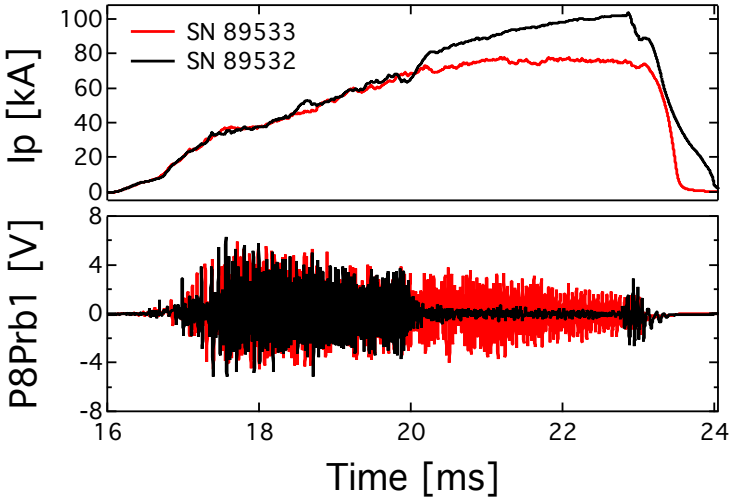


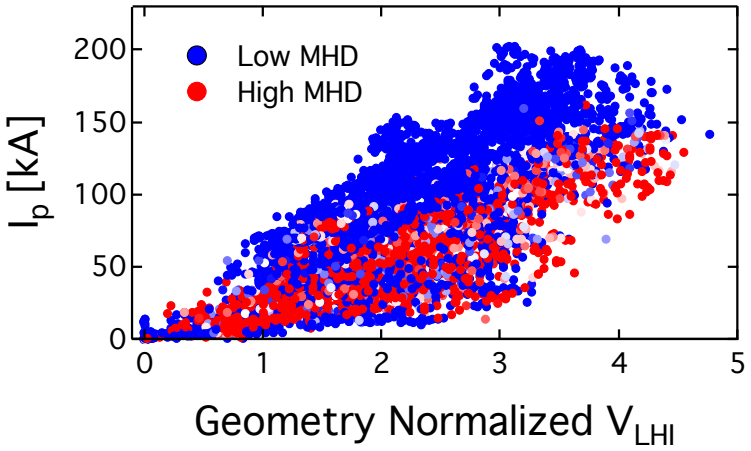


MHD Transition

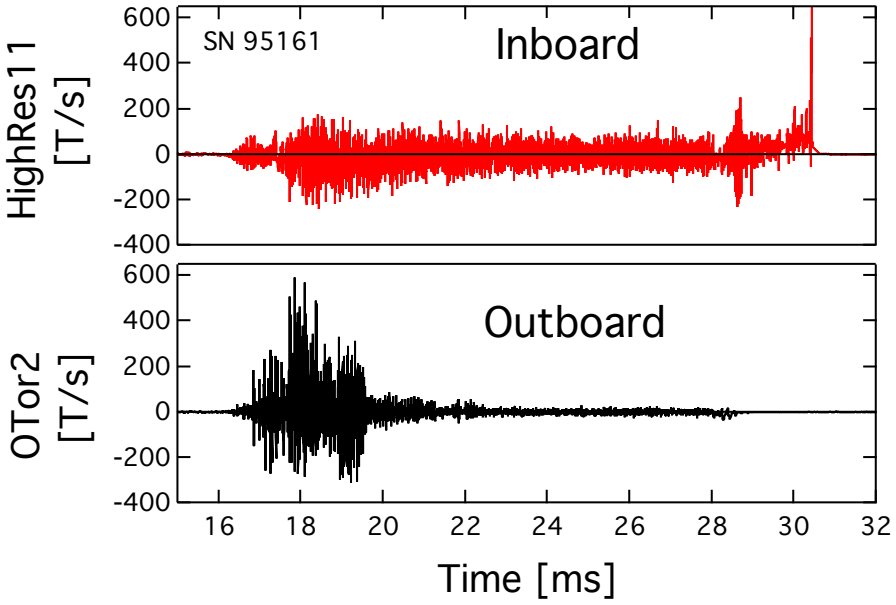
HFS LHI MHD Transition Behavior

- Abrupt MHD transition can occur:
  - Low-*f* n=1 activity reduced by over 10x
  - Current growth continues after transition
- Understanding and controlling this MHD activity may be central to increasing I_p



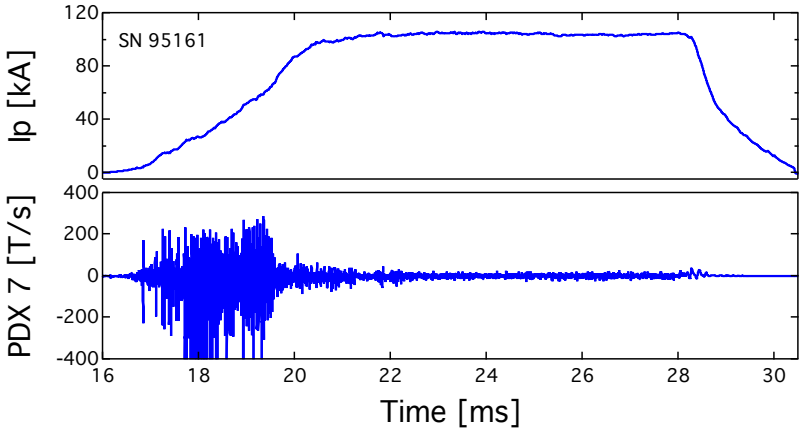


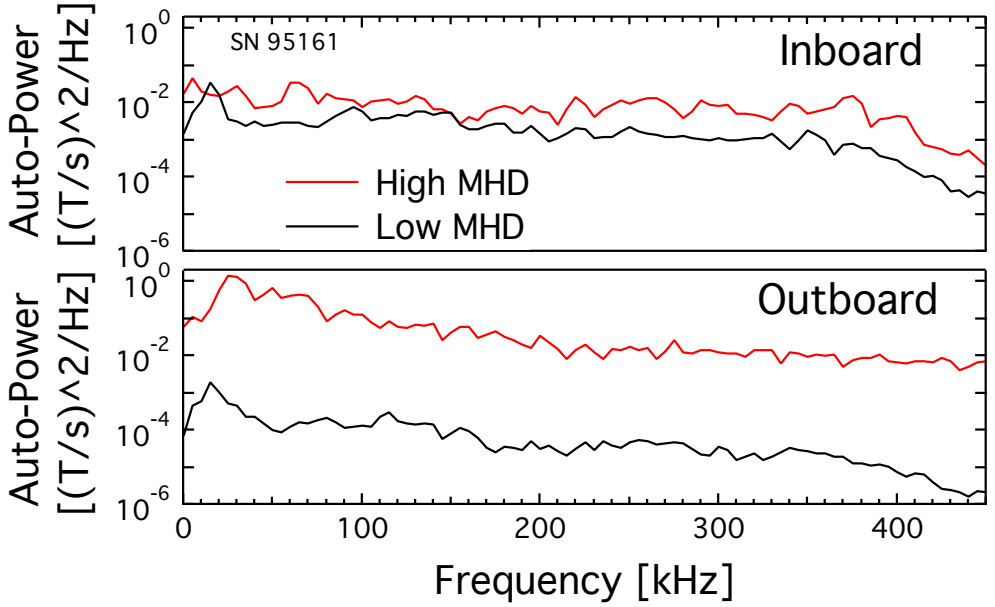
Transition Behavior Differs Greatly between the LFS and HFS



- Inboard magnetics show minimal reduction
- Outboard magnetics consistently experience abrupt MHD transition

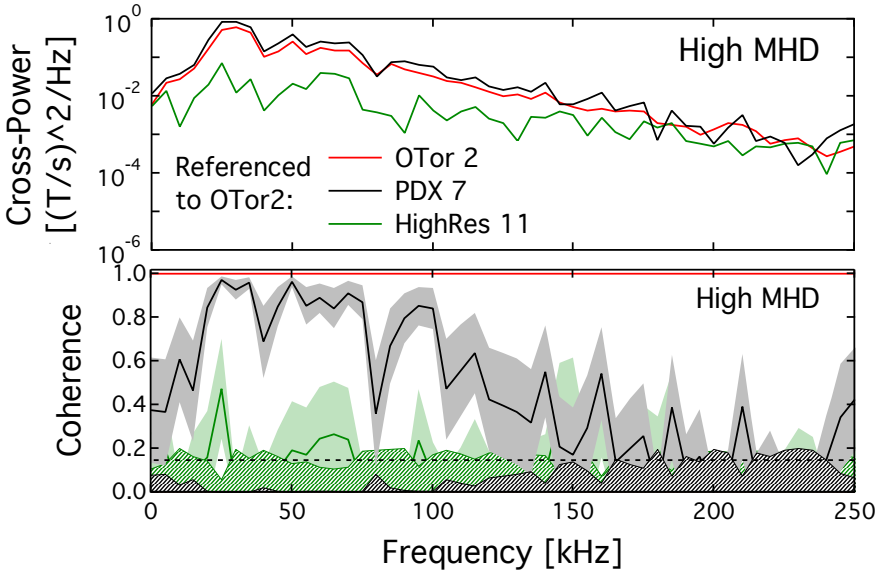
Large Changes in MHD Auto-Power at Transition: LFS vs. HFS

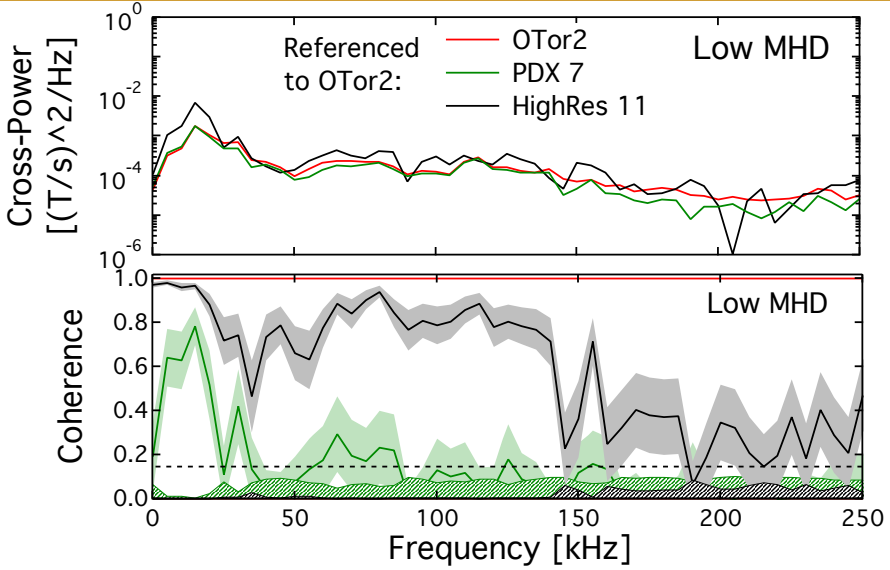




- Inboard Auto-Power:
  - Little changes in power after transition
  - Displays comparable magnetic activity at higher frequencies
- Outboard Auto-Power:
  - Dramatic drop after transition

Little Correlation between HFS and LFS





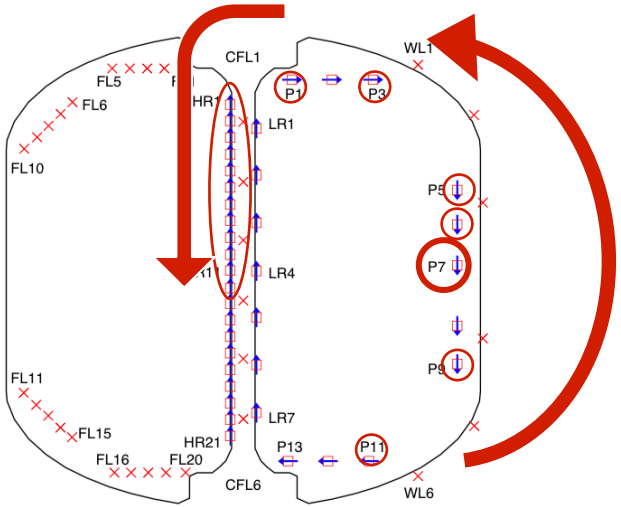
- Large n=1 mode on LFS strongly reduced after transition
- In general, decrease in activity at all frequencies
- For *f* > 15 kHz, no correlation between LFS and HFS activity
- High correlation toroidally on LFS

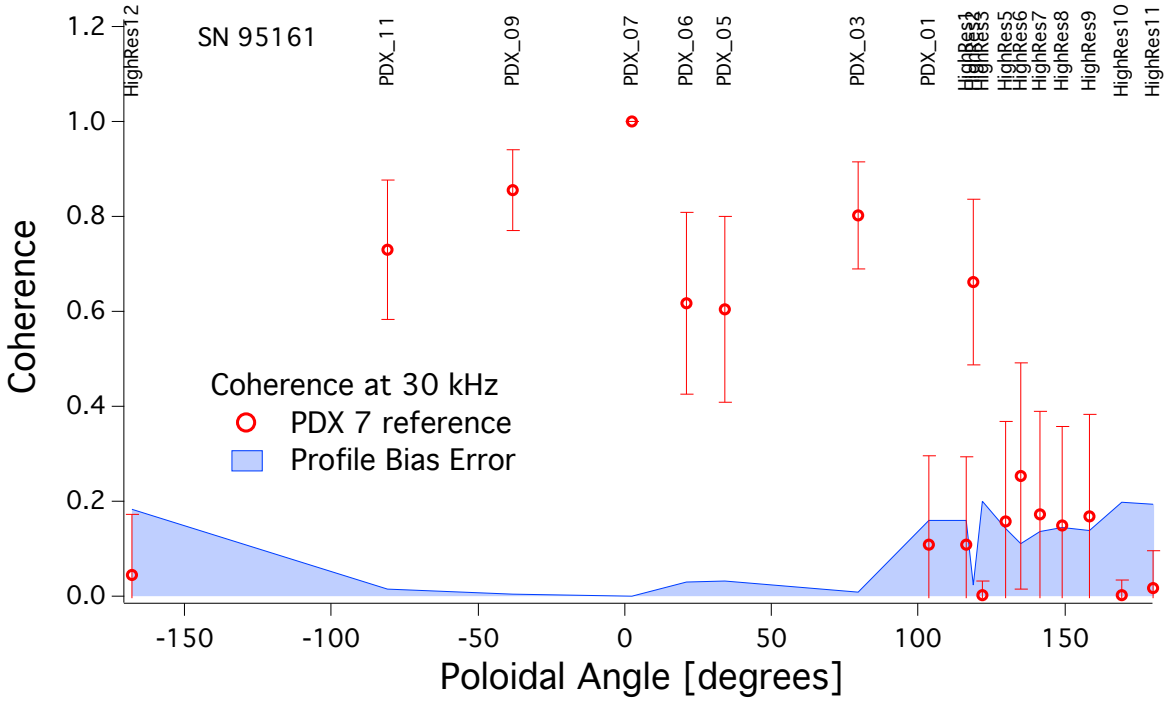
J.L. Pachicano, APS-DPP 2017

High Amplitude MHD Behavior on HFS

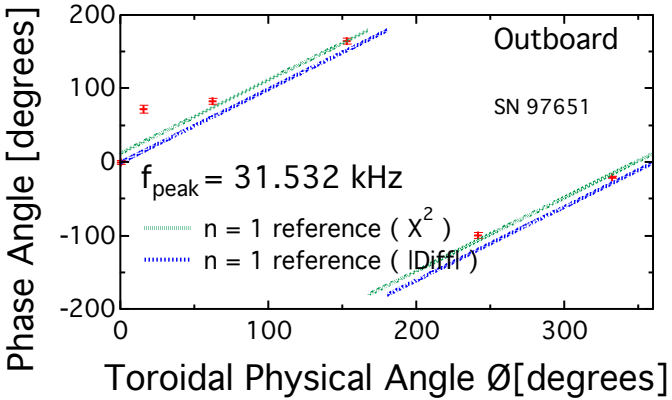
Coherence of n=1 MHD activity traced from the outboard side, around the machine, and down the center column

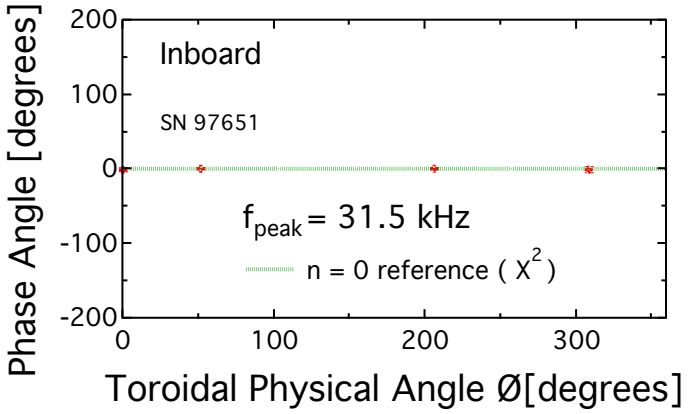
- n=1 activity at 30 kHz
  - Coherent on LFS
  - Dramatic drop in coherence on HFS



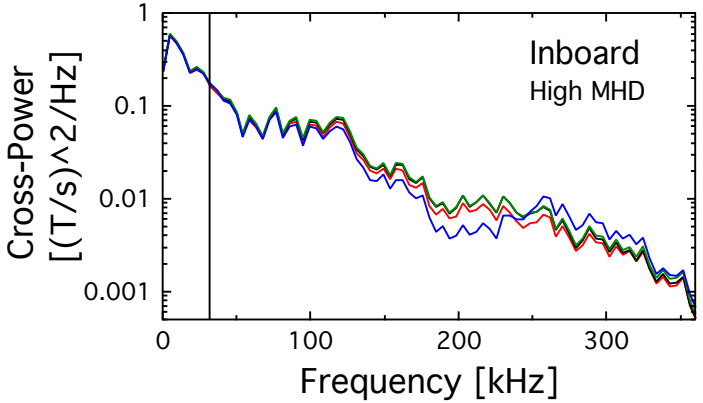


Toroidal Mode Number: LFS vs. HFS



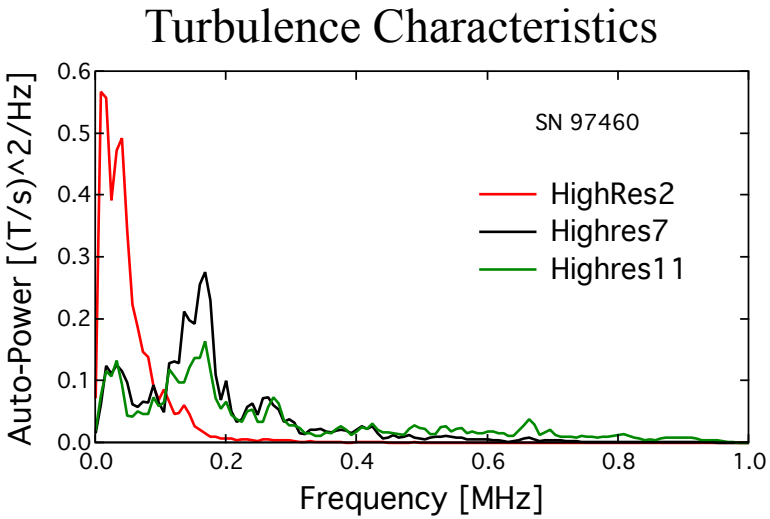


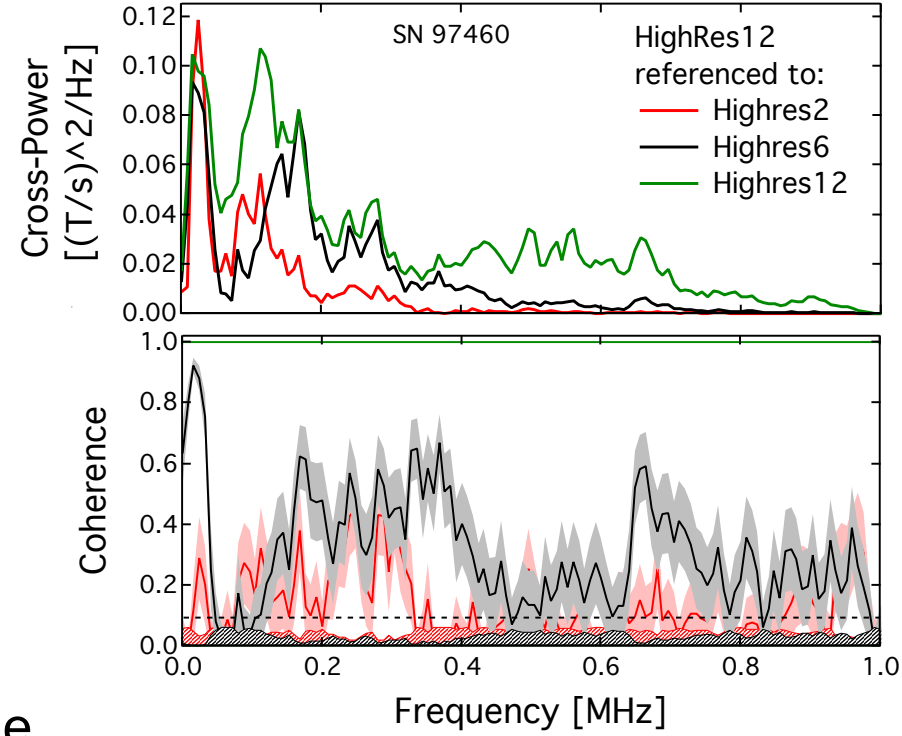
- LFS toroidal mode number is consistently n=1 before the transition
- HFS instead sees n=0 mode before and after the transition



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High Frequency Spectra of HFS Before Transition





- Top of the HFS exhibits magnetic activity at low-*f*
- Activity increases in frequency down the center column

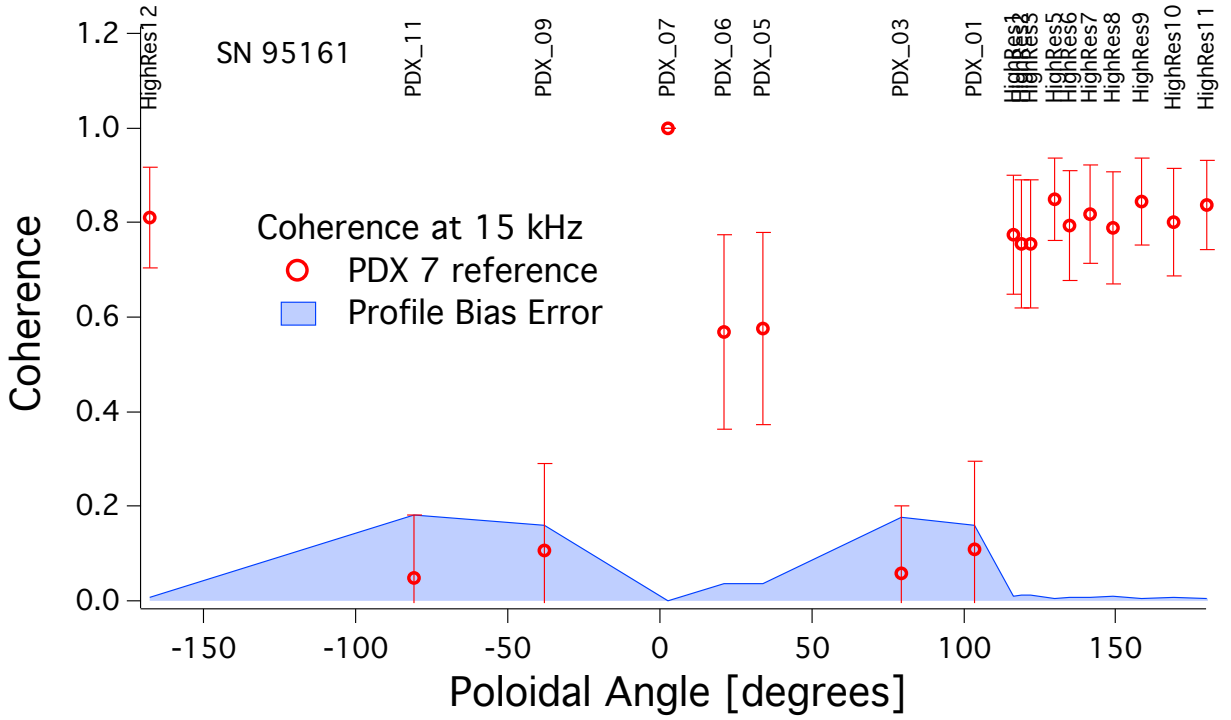
High Amplitude MHD Summary

- Strong n=1 mode on the LFS does not appear on the HFS
  - Little to no coherence
  - Toroidal mode number is n=0 on the HFS
- No obvious n=1 activity at higher frequency on HFS
- Indicates large-scale fluctuations of current streams may not be present on center column

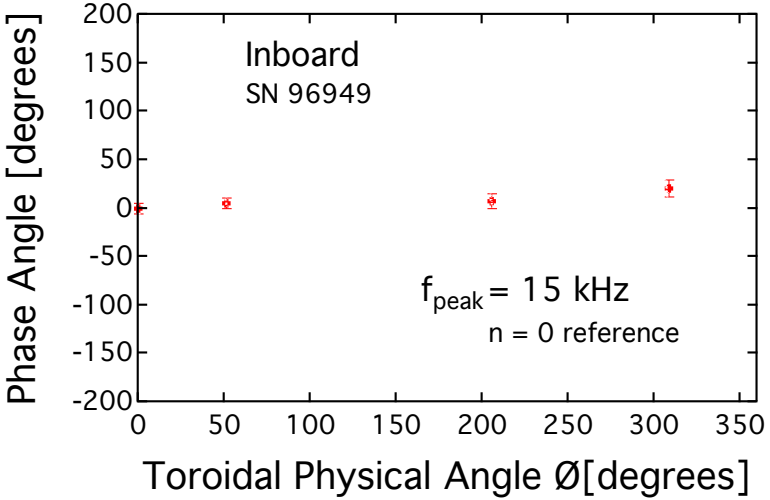
Low Amplitude MHD Behavior on HFS

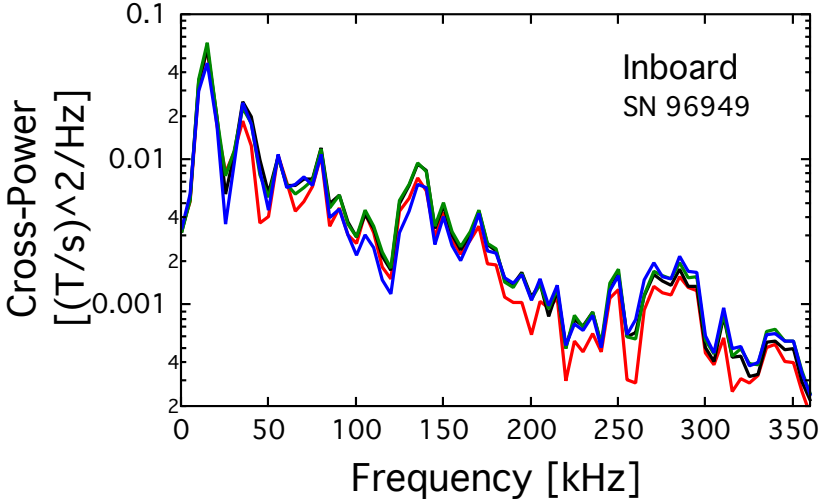
Coherence of magnetic activity traced from the outboard side, around the machine, and down the center column

- Low power magnetic activity at 15 kHz
- Good coherence between LFS midplane and HFS
  - Reduced coherence at the top and bottom



Toroidal Mode Number on HFS After Transition

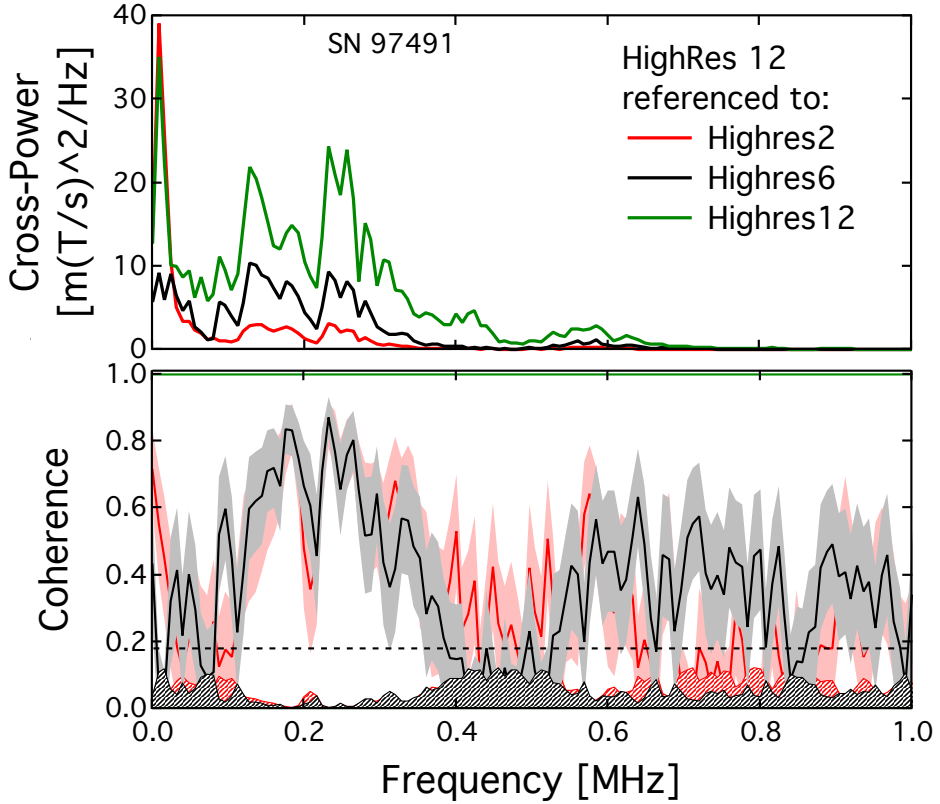




- HFS toroidal mode number is also n=0 after the transition

High Frequency Spectra on HFS After Transition

- Apparent vertical correlation length is about a quarter of the center column length
- Dominant magnetic activity occurs at higher frequencies
  - 150-350 kHz
- Related to slinking motion of streams around the core?



Low Amplitude MHD Summary

- Low power magnetic activity coherent on the LFS and HFS
  - I_p continues to increase after transition with lack on strong n=1 feature on LFS
- Toroidal mode number on HFS is consistently n=0 during the transition
- Higher Frequency magnetic activity seen after the transition
  - Coherent along the center column