NSTX

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High-k scattering of low frequency MHD activities in NSTX

by

K.L. Wong, E. Mazzucato, D.R. Smith[1], K. Tritz[2], S. Kaye

PPPL, Princeton University

[1]The University of Wisconsin

[2]The Johns Hopkins University

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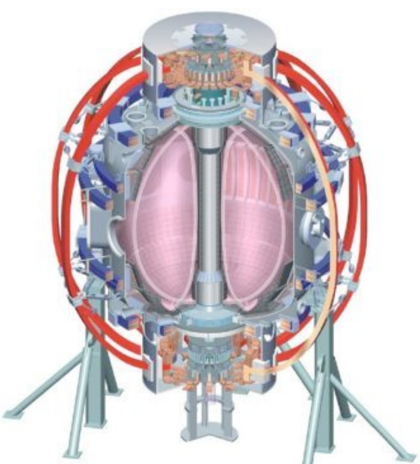


Introduction

- MHD activities are often detrimental to plasma performance

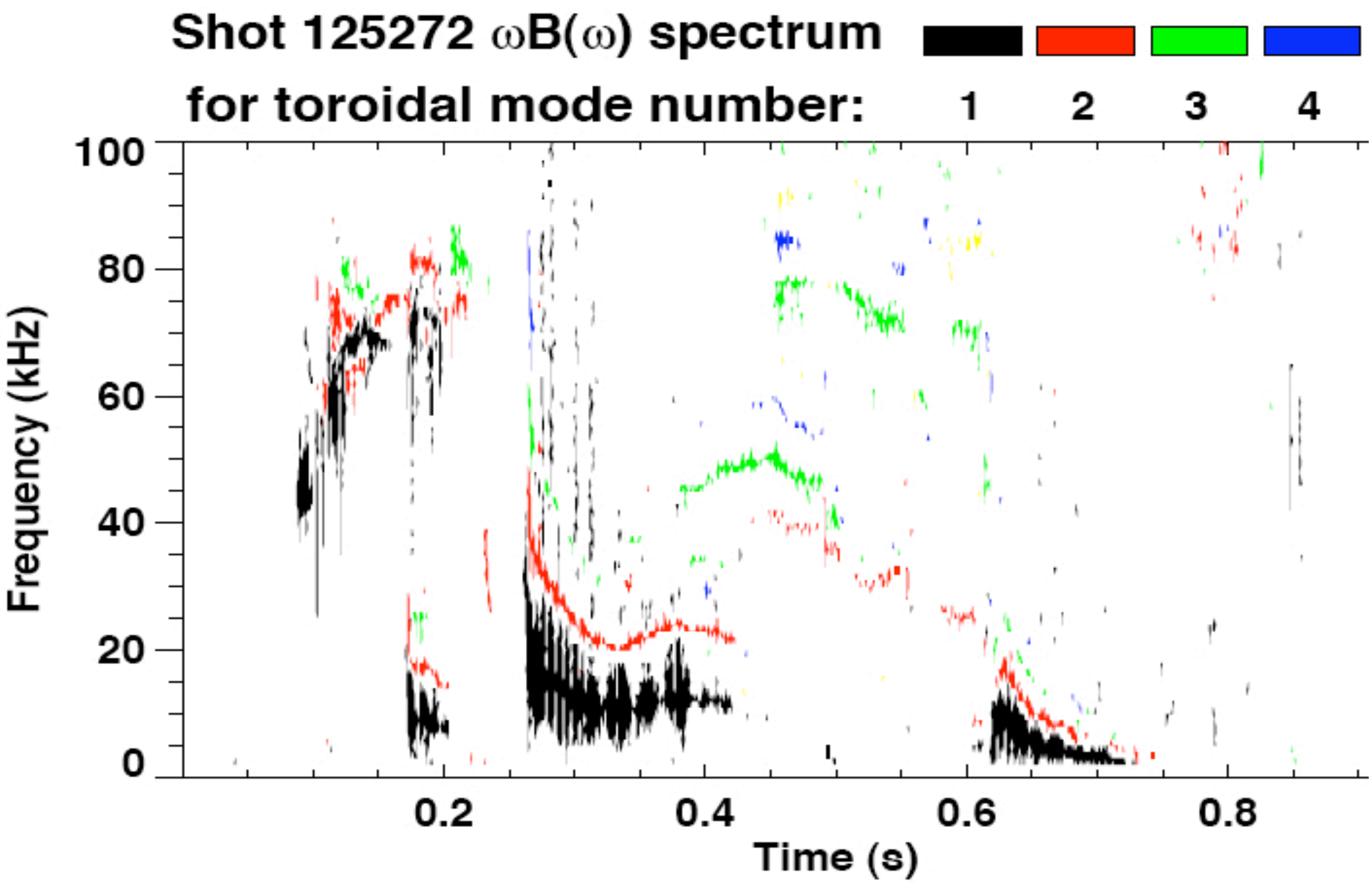
  Ref: Nave, Smeulders et al., NF **37**,809 (1997)

- Various MHD activities can be coupled and can affect the plasma pressure profile over the entire cross section

- Low frequency MHD usually have long wavelengths outside the detection range of high-k scattering

- Why do they (f <100 kHz) appear in the high-k scattering signal in NSTX ?

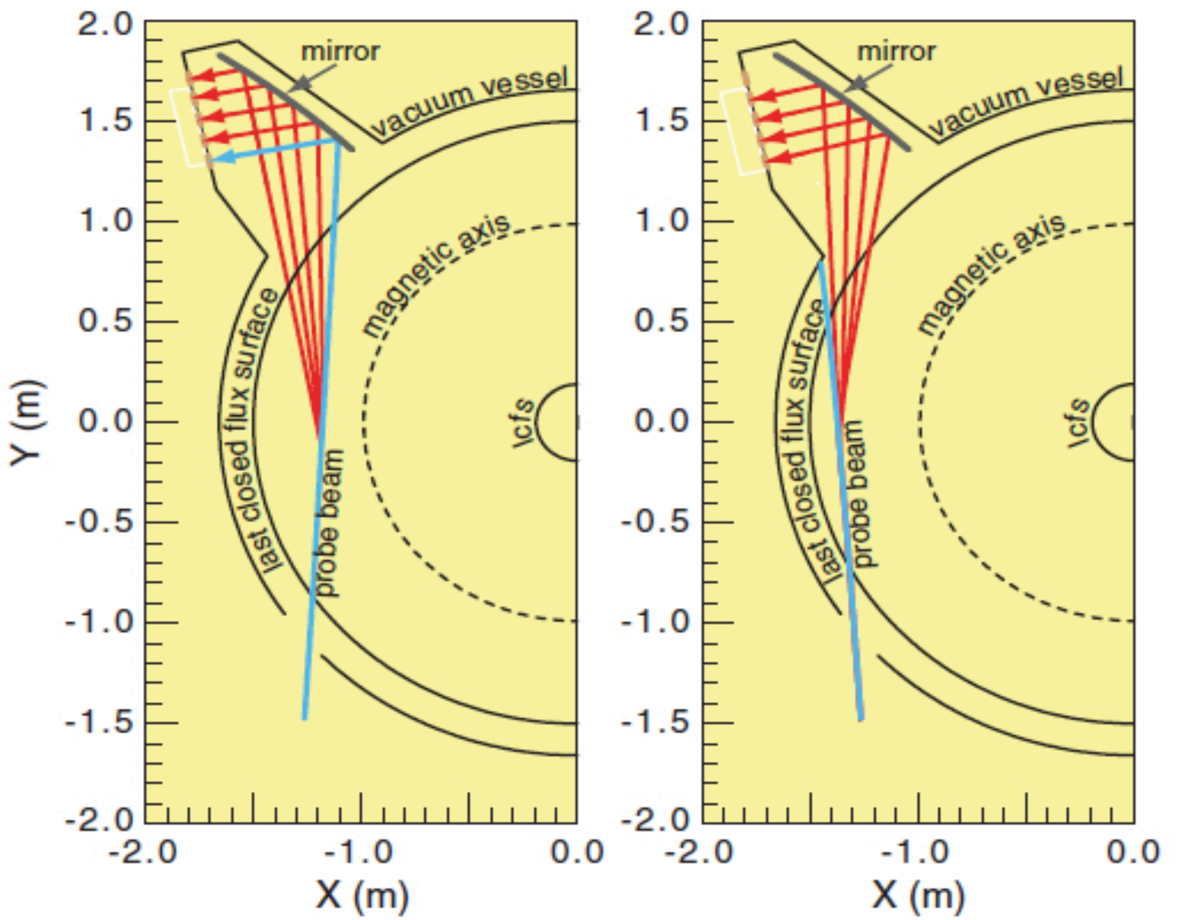
Mirnov coil spectrograph for #125272 (MHD rich)



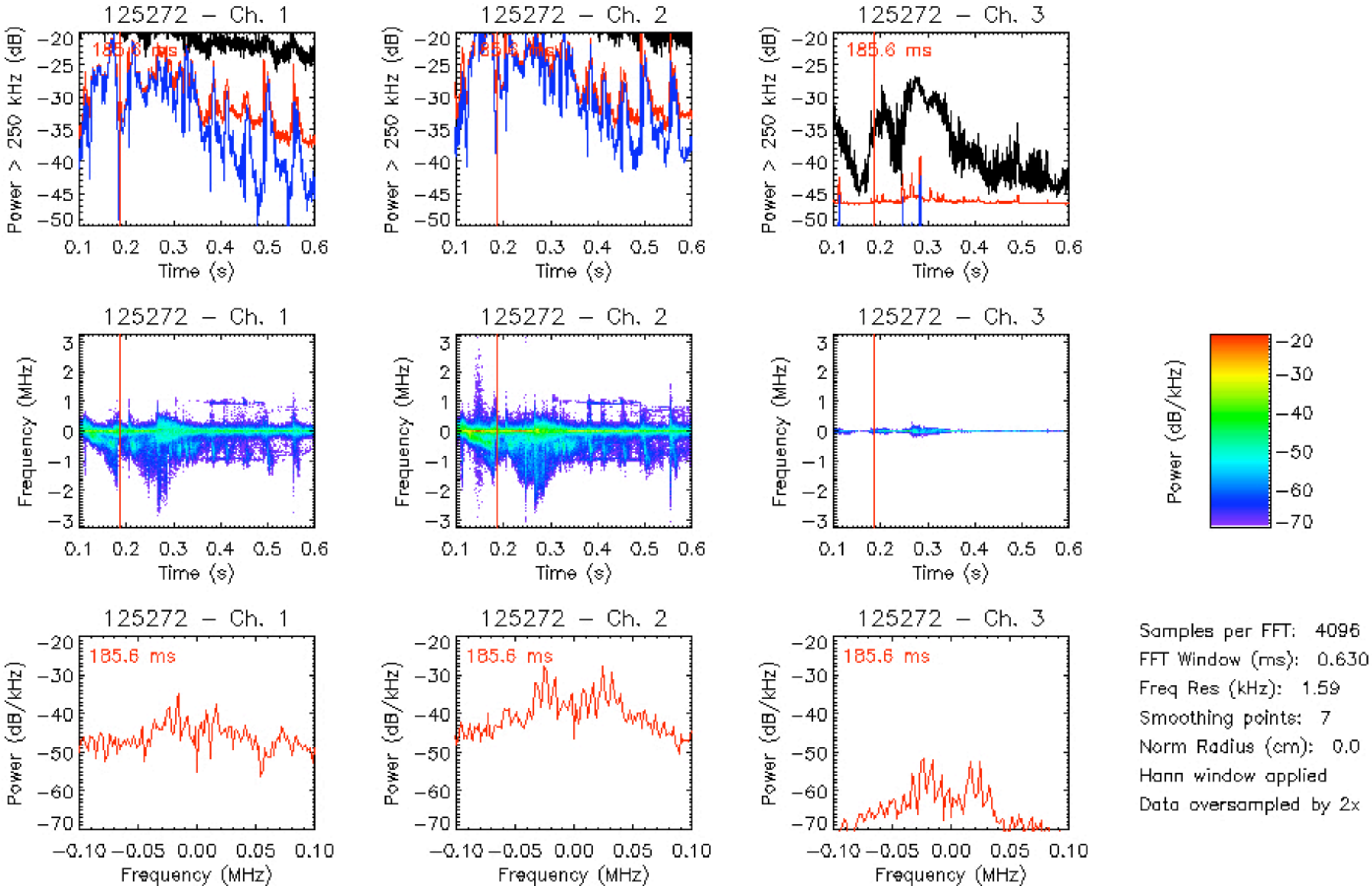
1 mm scattering system on NSTX

It is configured to measure **k**$_r$ – the radial component of **k**

Ref: Mazzucato: PRL **101**, 075001 (2008)

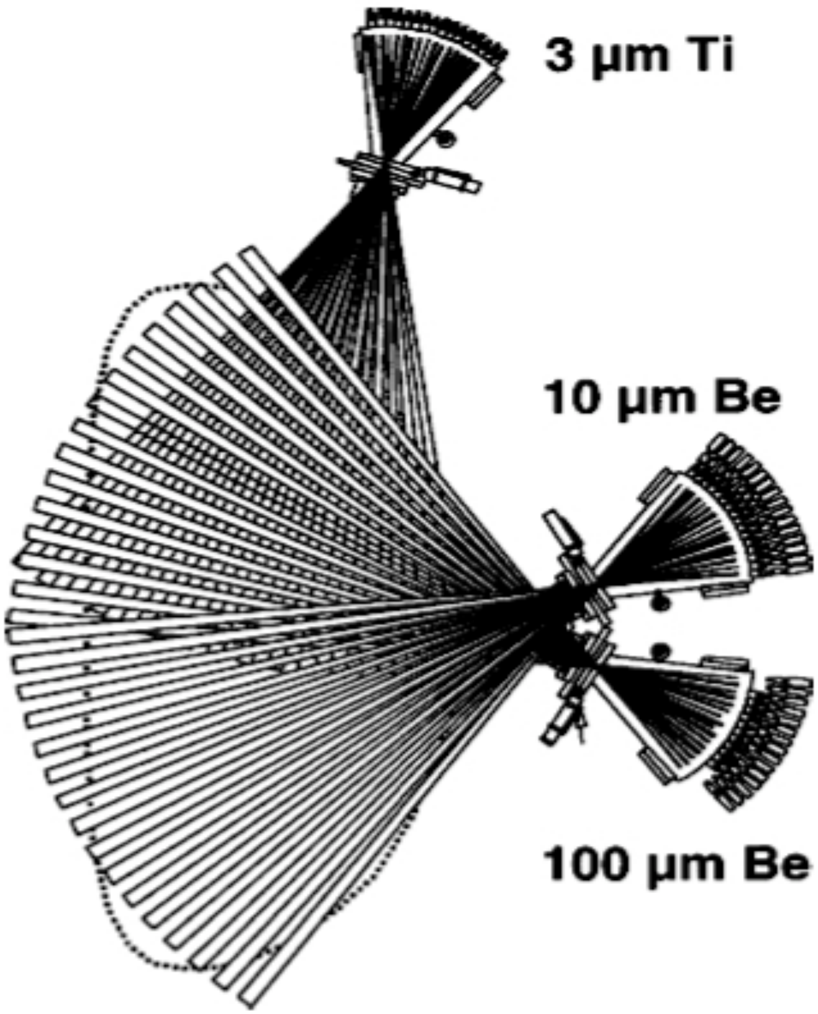


How can MHD noise enter high-k scattering signal?



X-ray camera (46 viewing chords)

Ref: Stutman et al., RSI 74,1982 (2003)



Identification of MHD: m/n=2/1 mode

- Mirnov coil : toroidal array shows n=1 (easy)
- SVD analysis of USXR data shows m=2, localized at q=2

Radial eigenfctn

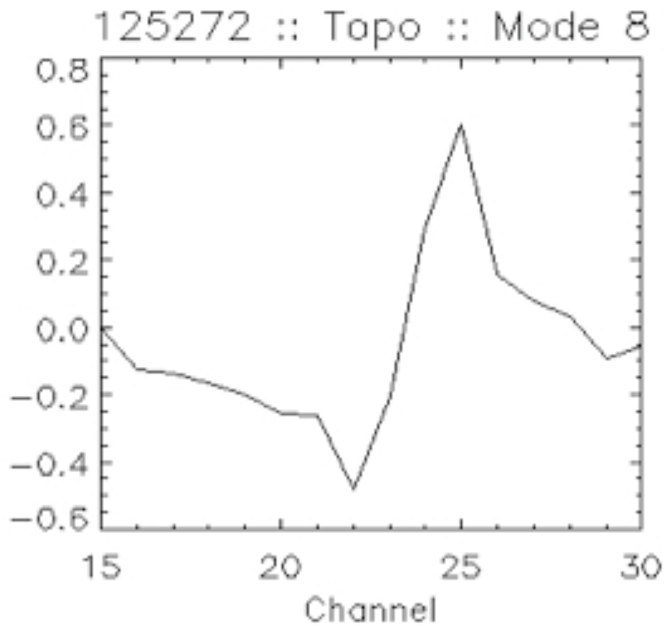
for m=2 mode ⇒

Peaked signal at Ch.25

R_{tan} ~ 124 cm

Node at Ch.24 where

R_{tan} ~ 121 cm , q~2.0

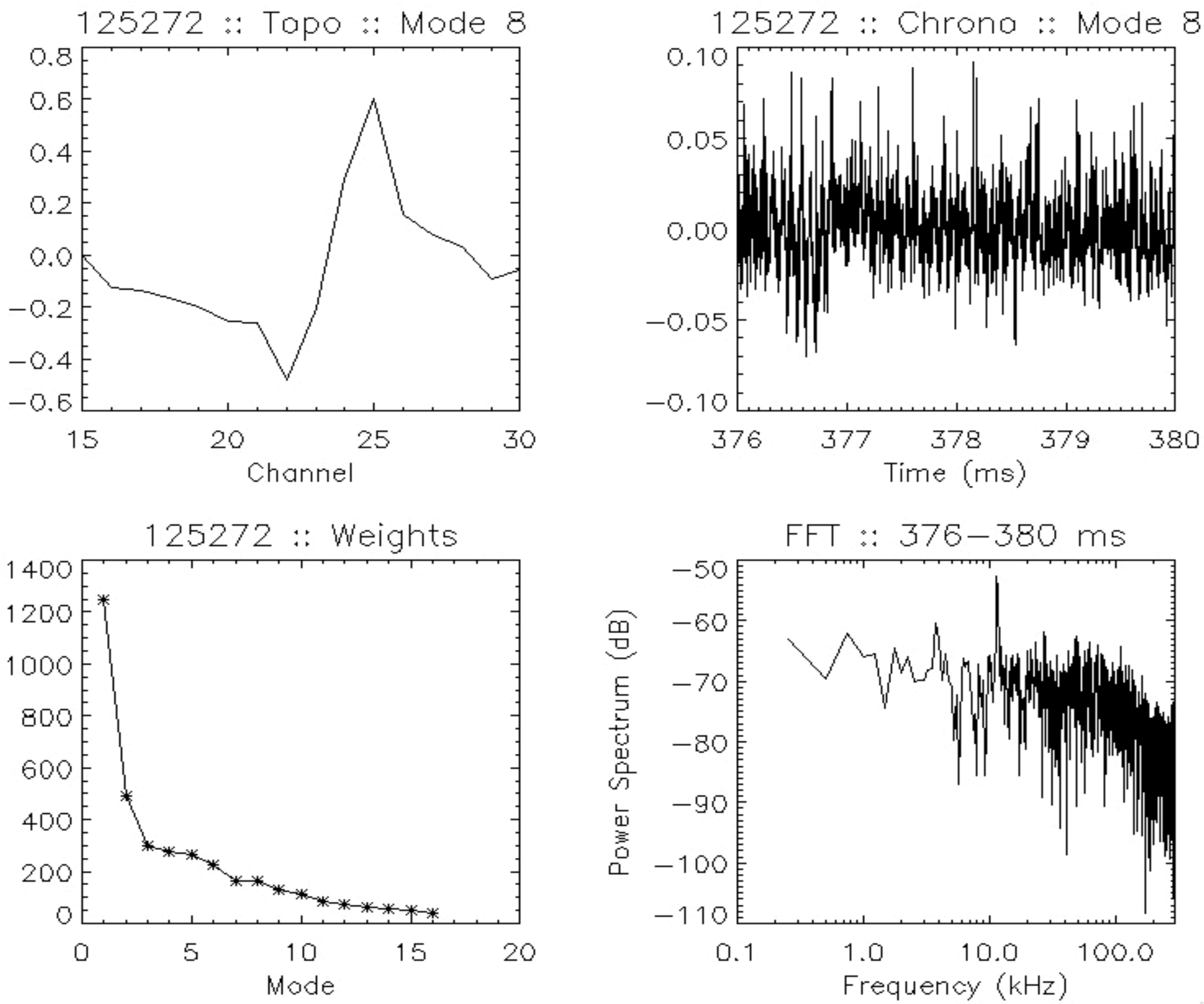


- Mode freq = plasma rotation freq at q=2 surface

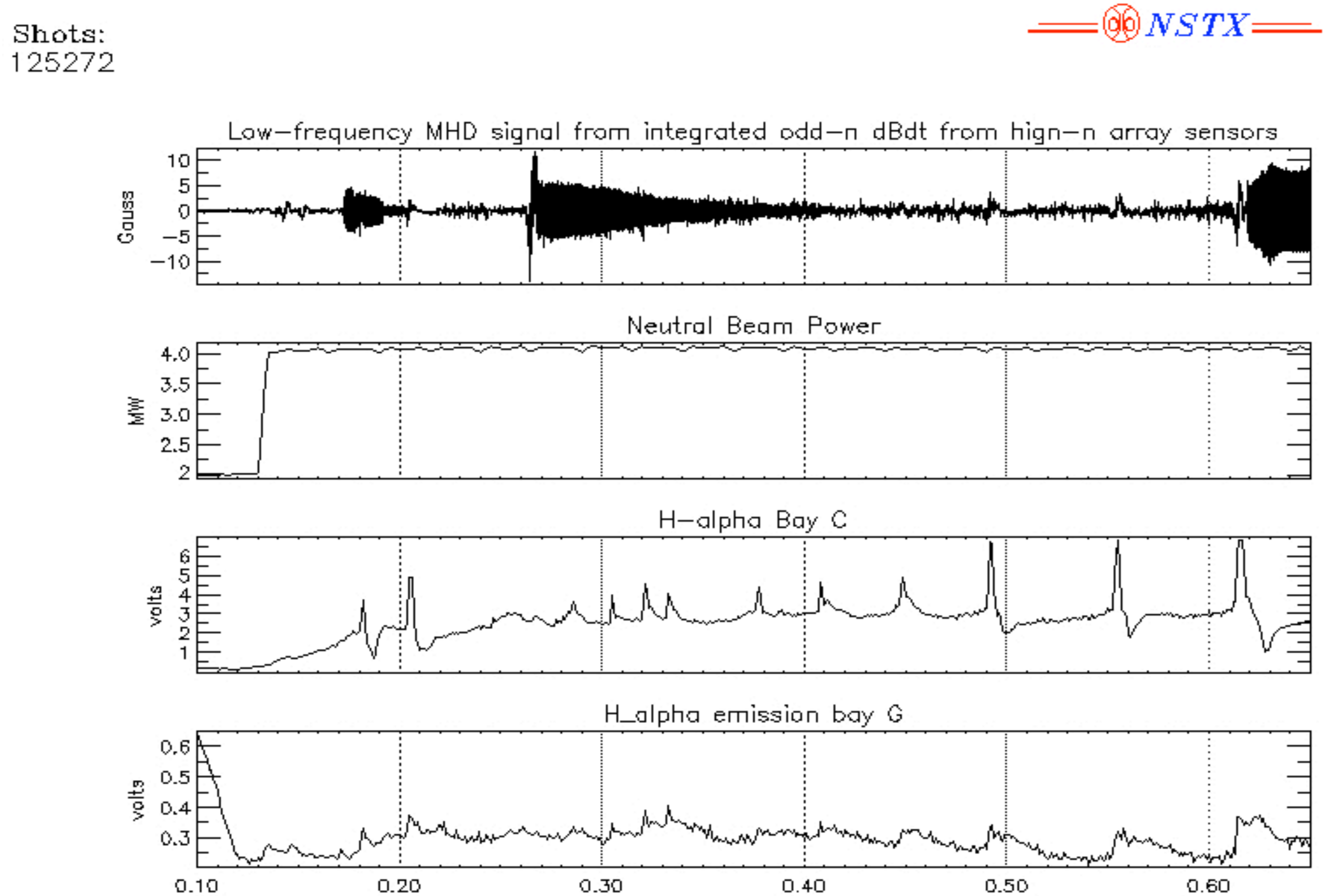
(Ω_{tor} ~ 12 kHz)

SVD result of USXR data (H-down array)

⇒ **m=2:** Ch_24 has Rtan@q=2(R=121cm),Ωt=12kHz

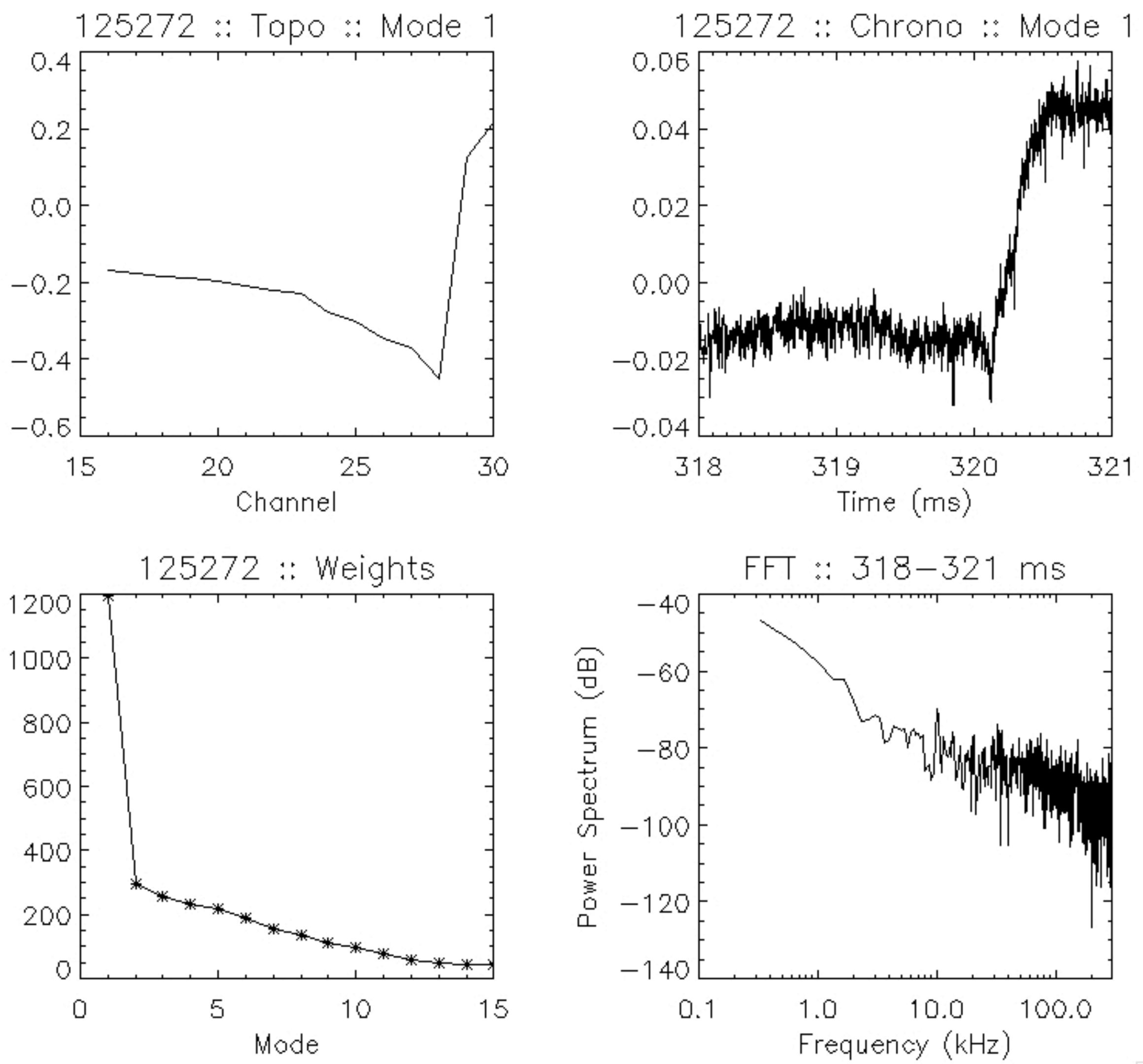


Large ELMs in shot 125272

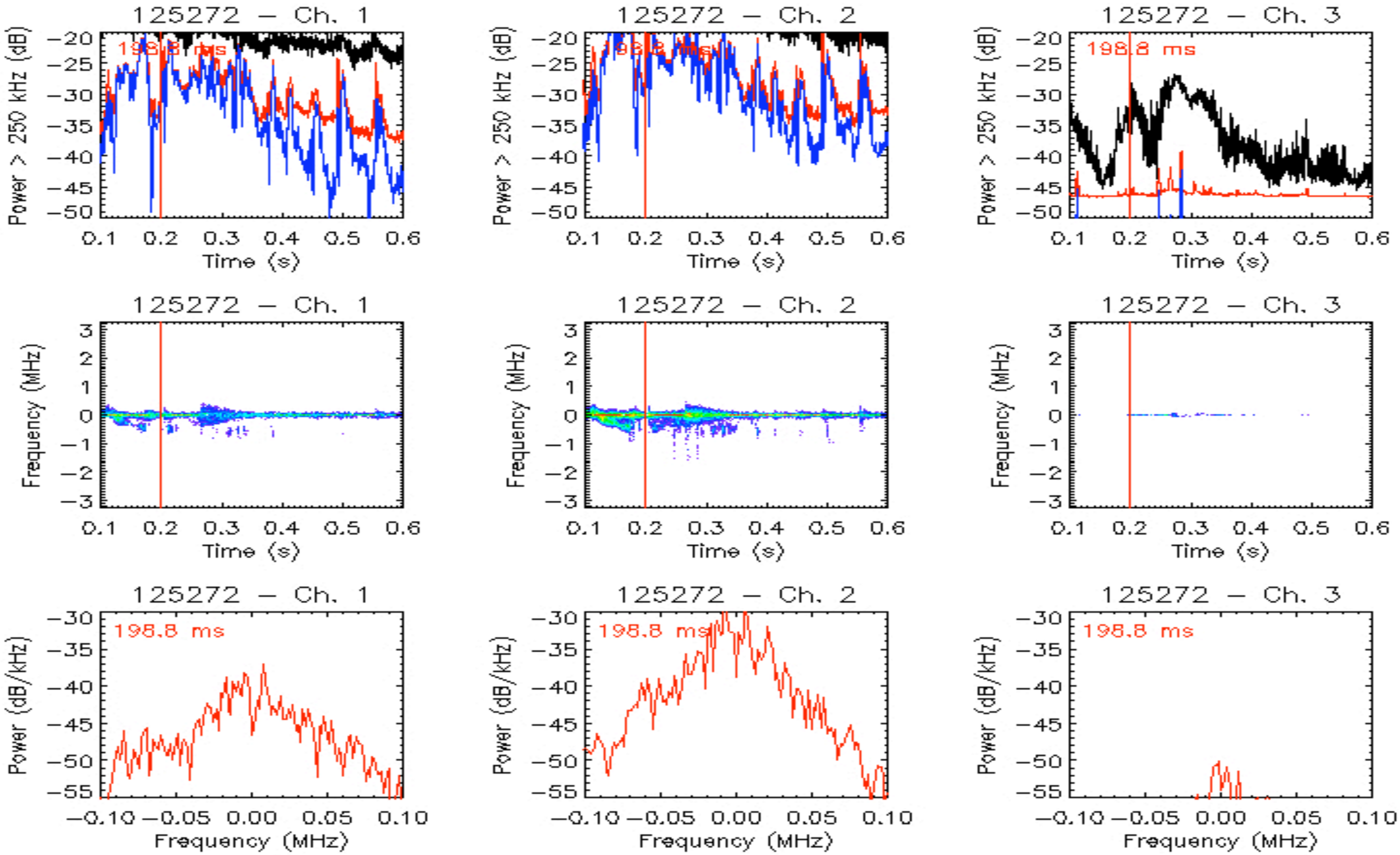


- Cold front propagates into plasma and cools plasma fast
- This can alter the high-k spectrum substantially, but the MHD noise persists

Cold front observed by SVD – the dominant mode (Mode 1) (Ch.16:r~0,Ch.29:r~a) Ref: Tritz et al., PoP (2007)

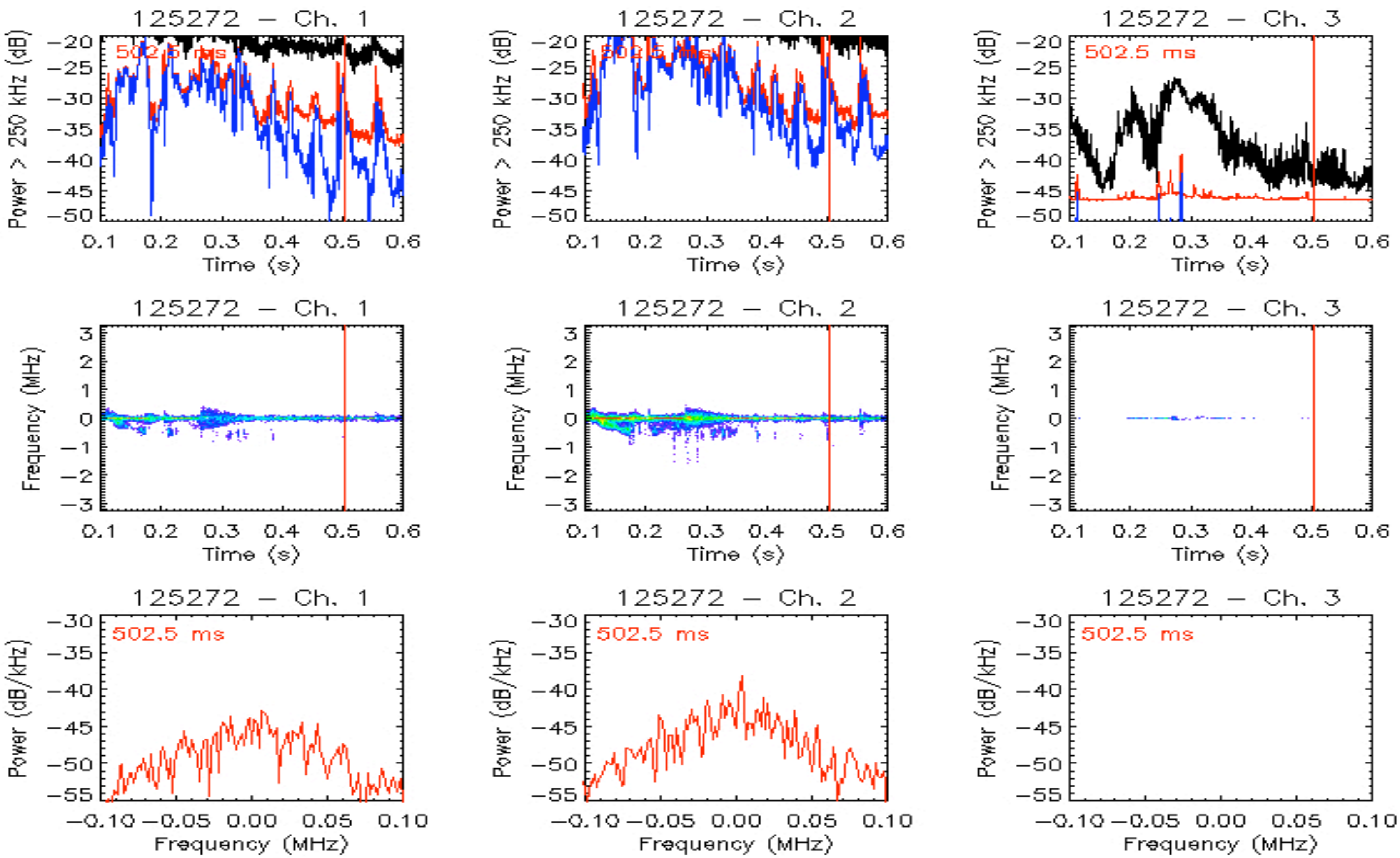


Scattering signal 20ms after type-1 ELM (2/1 very small)
⇒ harmonic signals are associated with 2/1 island

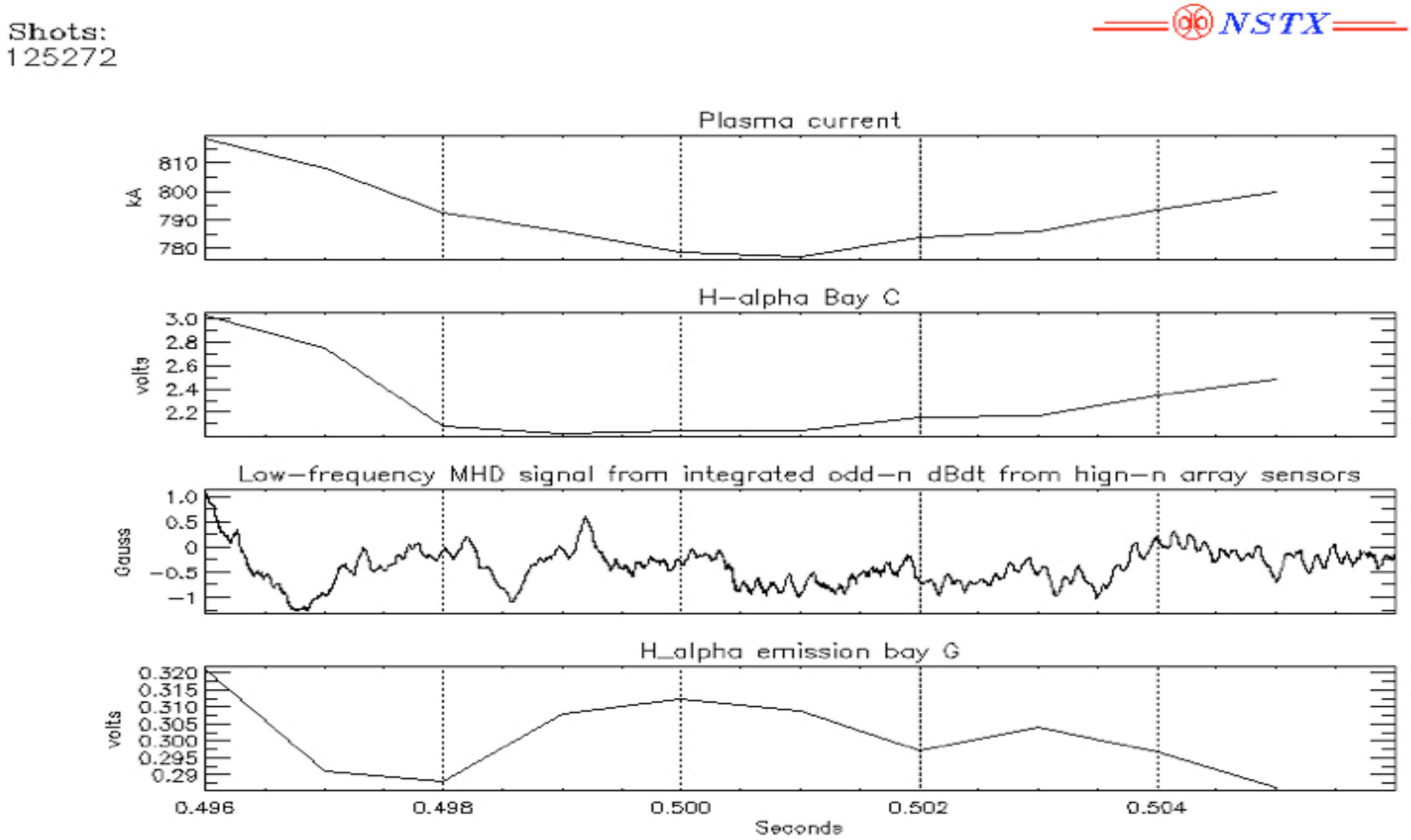


High-k scattering signal after a giant ELM - no 2/1 mode

r/a=.60, q~2.7, ch1: $k\rho_i$=22, ch2: $k\rho_i$ =16, ch3: blocked

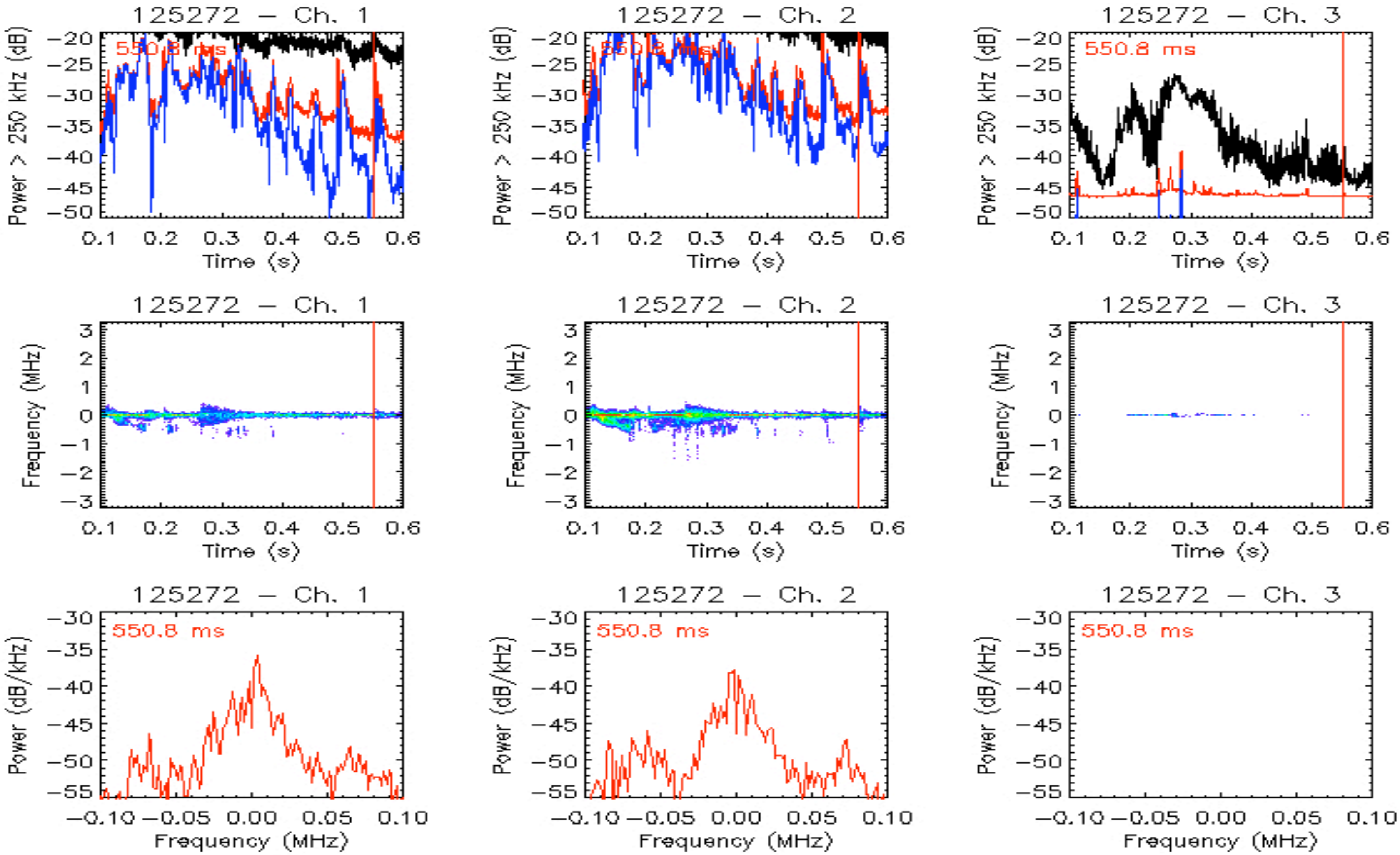


No coherent MHD signal in Mirnov coil after giant ELM



High-k scattering signal after another giant ELM

r/a=.55, q~2.4, ch1: $k\rho_i$=23, ch2: $k\rho_i$ =17



What are the possibilities

- Low frequency: $\omega \ll \omega_{ci} \ll \omega_{pi} \ll \omega_{ce} \ll \omega_{pe}$
- The low frequency modes are basically shear Alfvén waves

  - dispersion relation derived from ideal MHD theory
- Include kinetic effects: 1. Finite Larmor radius effect - $\rho_i > 0$

  2. Electron inertia effect - $m_e>0$

SAW can convert to KAW near Alfvén resonance

Ref: Stix - Waves in Plasmas (AIP-1992) pp. 354 - 358

Conversion of shear Alfvén wave to kinetic Alfvén wave

- Low frequency MHD are basically shear Alfvén waves(from ideal MHD)
- When FLR effect and $m_e>0$ are includes, SAW can convert to KAW near Alfvén resonance (include kinetic effects)

  Ref: Stix - Waves in Plasmas (AIP-1992) pp. 354 - 358

- Approx.* dispersion relation for KAW (*slab model, 4th order theory):

$$(\omega/k_{||}V_A)^2 = (k\rho_i)^2 / \{1 - I_o(k^2\rho_i^2)\exp(-k^2\rho_i^2)\} + (T_e/T_i)(k^2\rho_i^2)$$

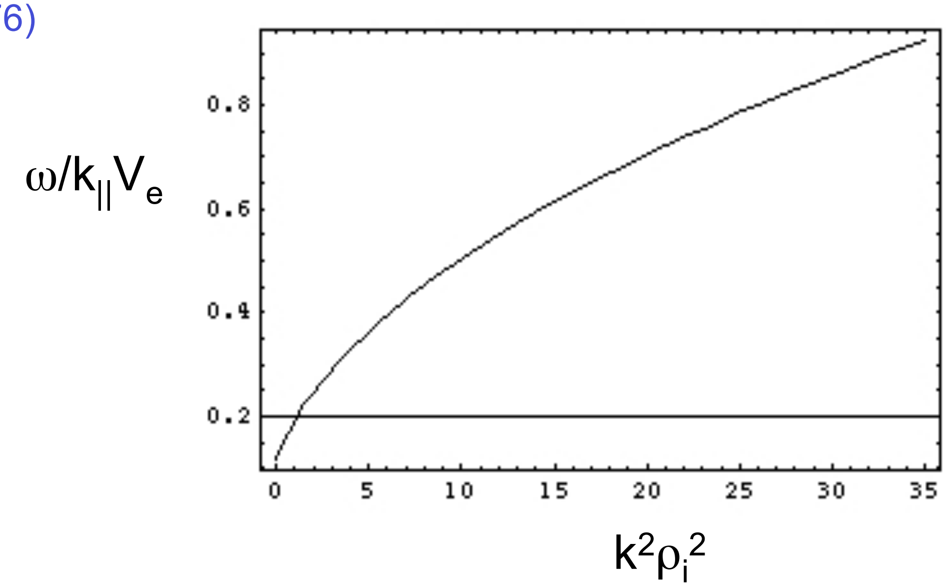
Ref: Hasagawa & Chen ,PoF(1976)

Weak ELD for $k\rho_i \sim 1$

- normal modes

Strong ELD for $k\rho_i >> 1$

- quasi modes



Where are they generated ?

- Kinetic Alfvén waves are electrostatic modes: $\mathbf{k} \times \mathbf{E} \sim 0$
  - forward wave perpendicular to **B** ($\mathbf{k} \cdot \mathbf{V}_g > 0$)
  - exist when $\beta > m_e/m_i$

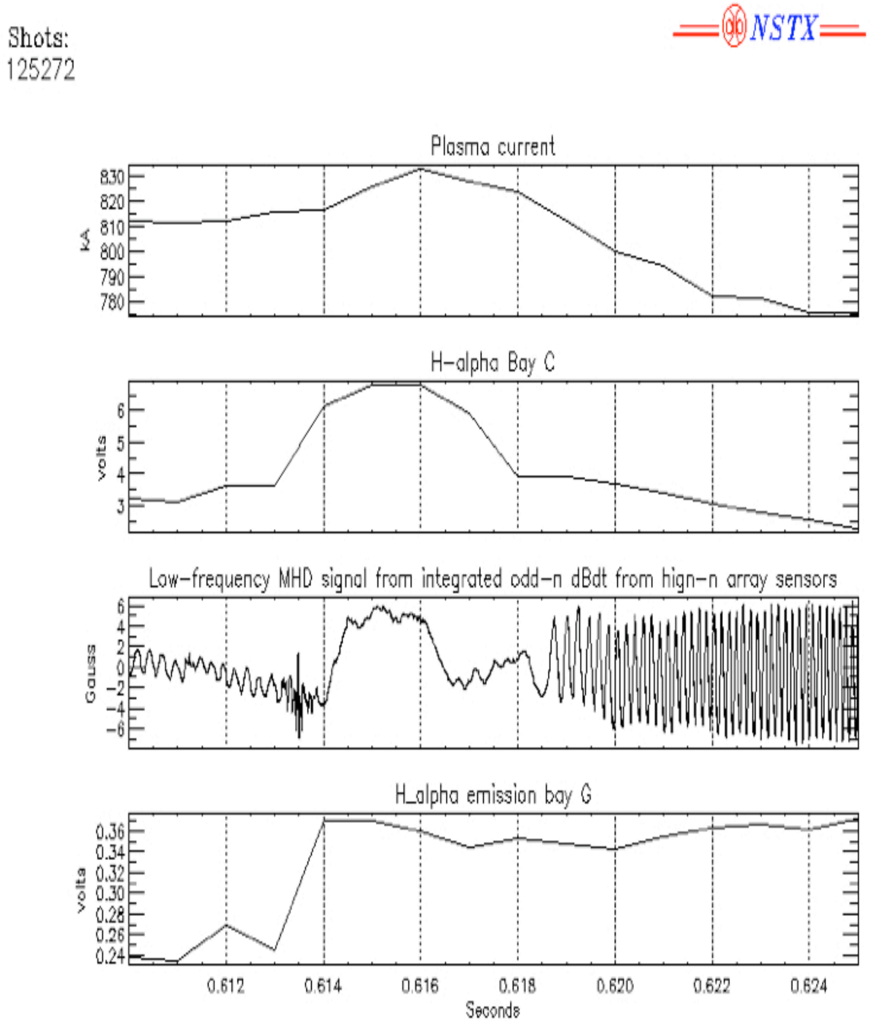
  Ref: Bellan, PoP (1998)

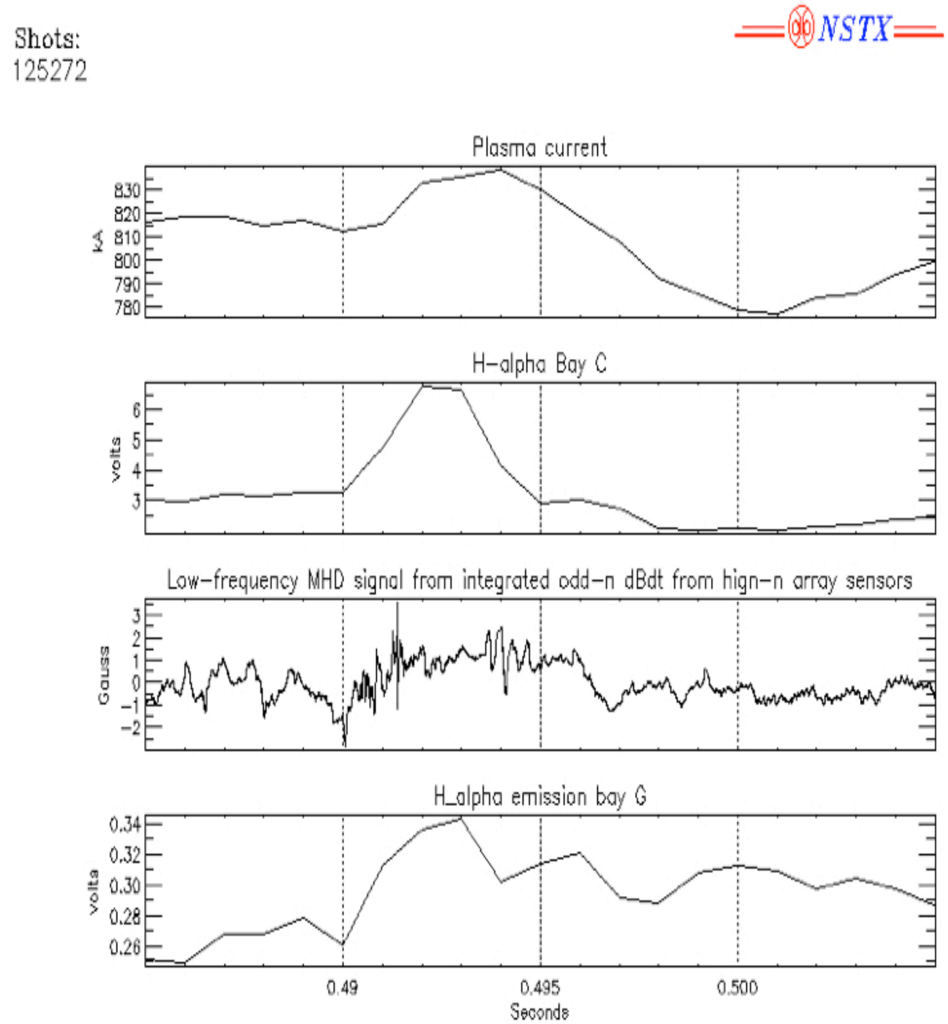
- Strong electron Landau damping when $k\rho_i >> 1$ ➔ $\omega/k_{||}V_e \sim 1$

  For KAW normal modes, $k\rho_i \sim O(1)$ ➔ $\omega/k_{||}V_e < 1/3$

Our scattering system looks at $k\rho_i \sim 10$ which means the KAW are generated not far from the scattering volume.

Giant ELM can trigger/enhance 2/1 mode
(No scattering data after 0.6 s)





Summary

- High-k scattering system can see MHD noise
- MHD activities are modified by ELMs, so are the scattering signal
- Kinetic Alfvén waves are likely possibilities; they are generated not far from the scattering volume
- More work in progress