Zonal Flow & Streamers in JIPPT-IIU Tokamak Plasmas

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1) Change of zonal flow spectrum of low-density Ohmic plasmas and additionally heated plasmas.

2) Coherence of low-frequency zonal flow with ECE radiation.

3) Streamers outside the half radius of low-density Ohmic plasmas.

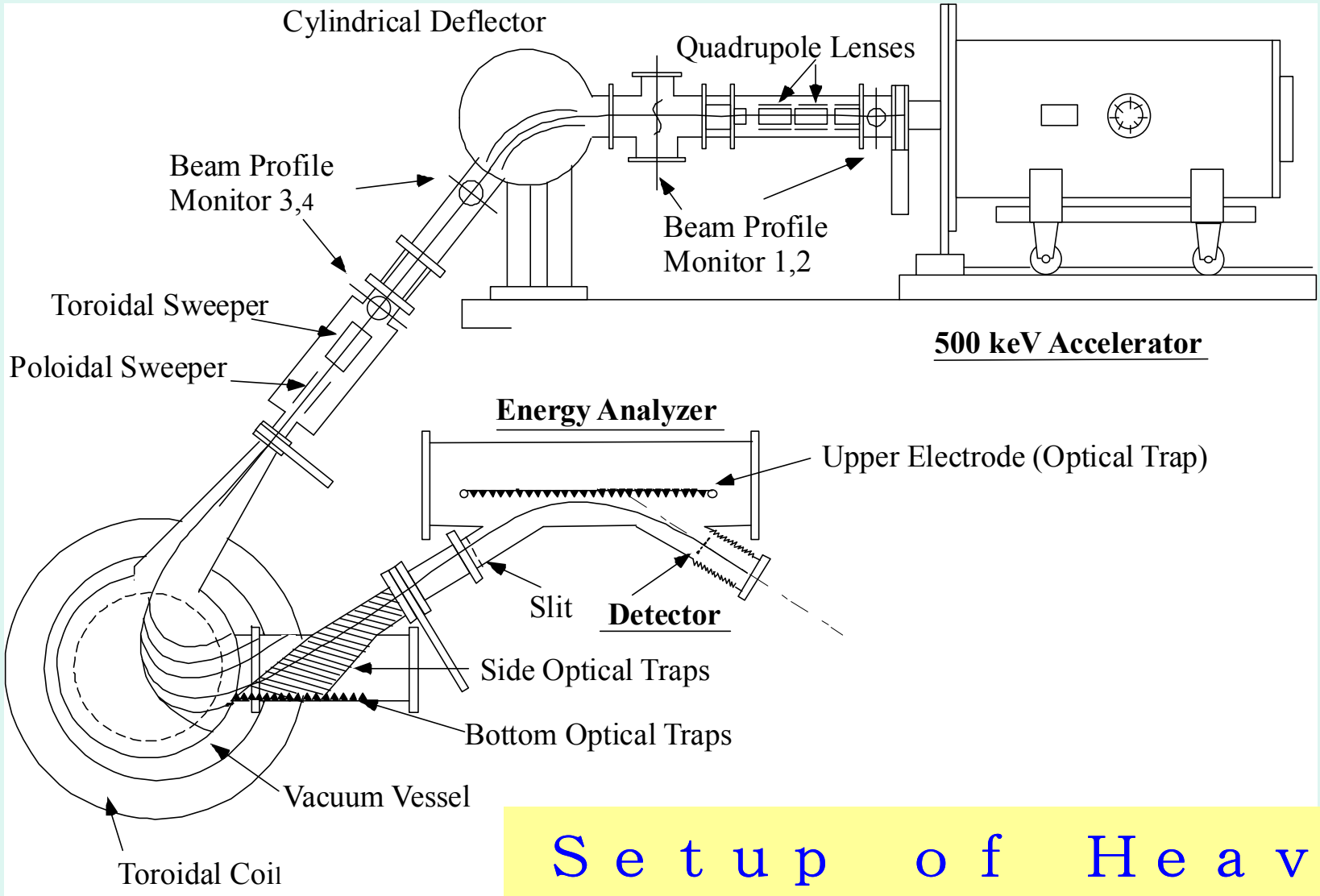
4) Wavelet scalogram of density and potential fluctuations.

Background of Our Work

In 1995, we reported at Toki International Conference on Plasma Physics and Controlled Fusion, the existence of m=0 potential oscillations of about 300 Vp-p and 30-40 kHz in the core of tokamak plasmas. Y. Hamada et. al., Fusion Eng. Design 34-35, (1997) 663.

Also the potential measured HIBP has sharp potential change to induce the fast MHD motion at the sawtooth crash. Y. Hamada et. al., Nuclear Fusion, 36 (1996) 515.

Both HIBP and ECE measurements are the local and fast measurements in the core of the hot tokamak plasma and we took both data (HIBP and ECE) by 1 μs sampling time. We found both have weak coherence each other at zonal flow as well as strong coherence by MHD activity.



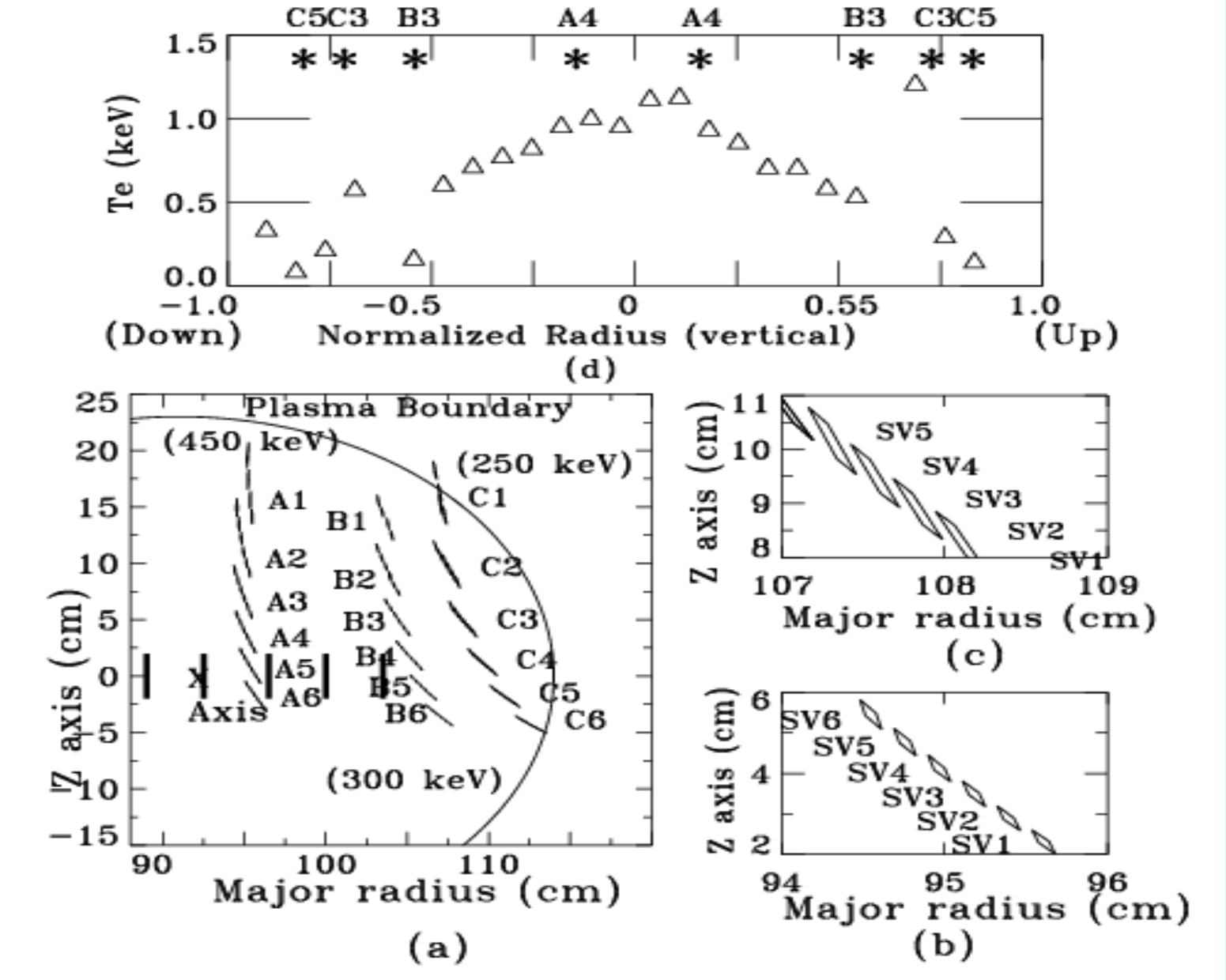
Bt=3 T

Rp=92 cm

ap=23 cm

Setup of Heavy Ion Beam Probe (HIBP) i

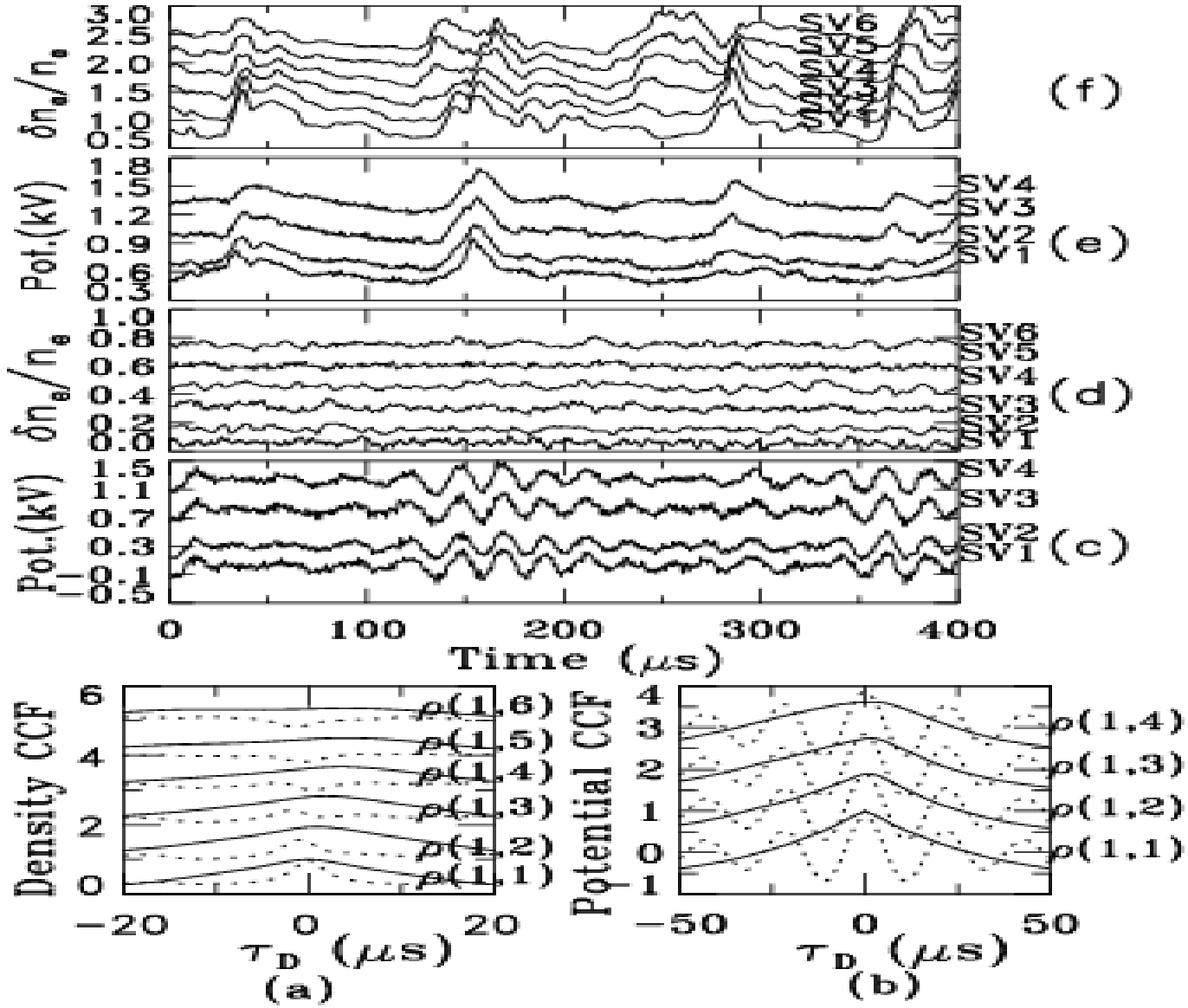
Position and Shape of Sample Volume



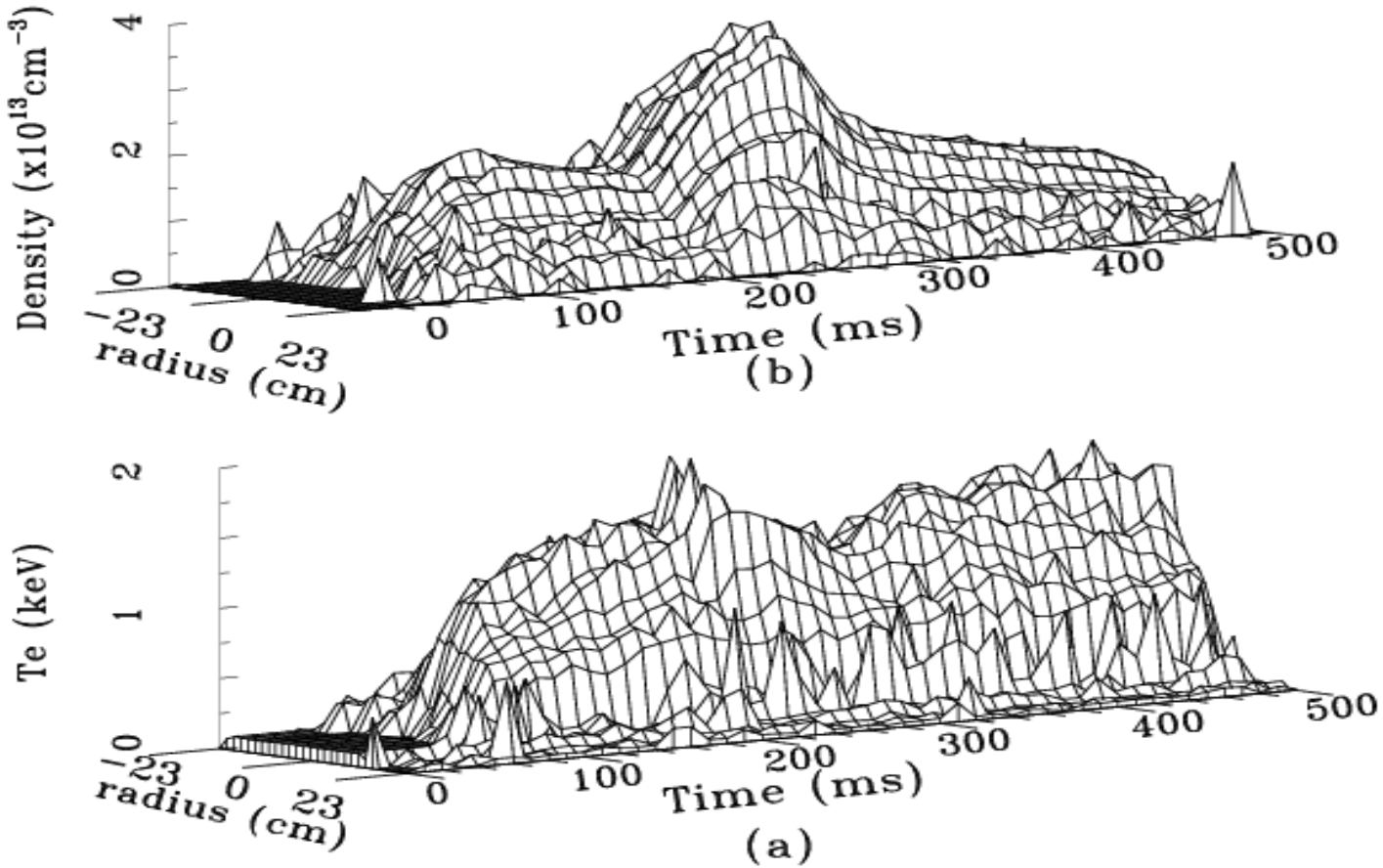
Position, Length, Distance and Coherent Length of SVs

Step	R(cm)	Z(cm)	r (cm)	*rl*(cm)	δr(cm)	η (coherence ratio)	*lc* (coherence length)
A1	95.46	14.10	14.32	1.32	3.25	0.20	2.00
A2	95.32	9.14	9.43	0.89	1.74	0.25	1.24
A3	95.40	5.44	5.95	0.71	1.23	0.72	3.78
A4	95.61	2.30	3.48	0.61	0.64	0.89	5.48
A5	95.91	-0.43	2.94	0.53	-0.41	0.80	1.78
A6	96.28	-2.93	4.40	0.49	-0.90	0.57	1.61
B1	104.05	12.47	16.66	0.90	0.77	0.64	1.72
B2	104.45	7.43	13.65	0.62	0.42	0.91	4.32
B3	105.07	3.79	12.65	0.52	-0.14	0.93	1.91
B4	105.82	0.71	12.84	0.45	-0.48	0.77	1.85
B5	106.69	-1.97	13.83	0.40	-0.65	0.63	1.39
B6	107.67	-4.28	15.28	0.37	-0.72	0.15	0.37
C1	107.30	14.23	20.18	1.64	1.04	0.80	4.66
C2	108.10	8.31	17.23	1.11	0.16	0.91	1.70
C3	109.11	3.83	16.56	0.86	-0.30	0.93	3.98
C4	110.32	0.33	17.33	0.73	-0.53	0.76	1.91
C5	111.73	-2.55	18.90	0.65	-0.64	0.44	0.77
C6	113.34	-4.90	20.93	0.61	-0.68	0.05	0.23

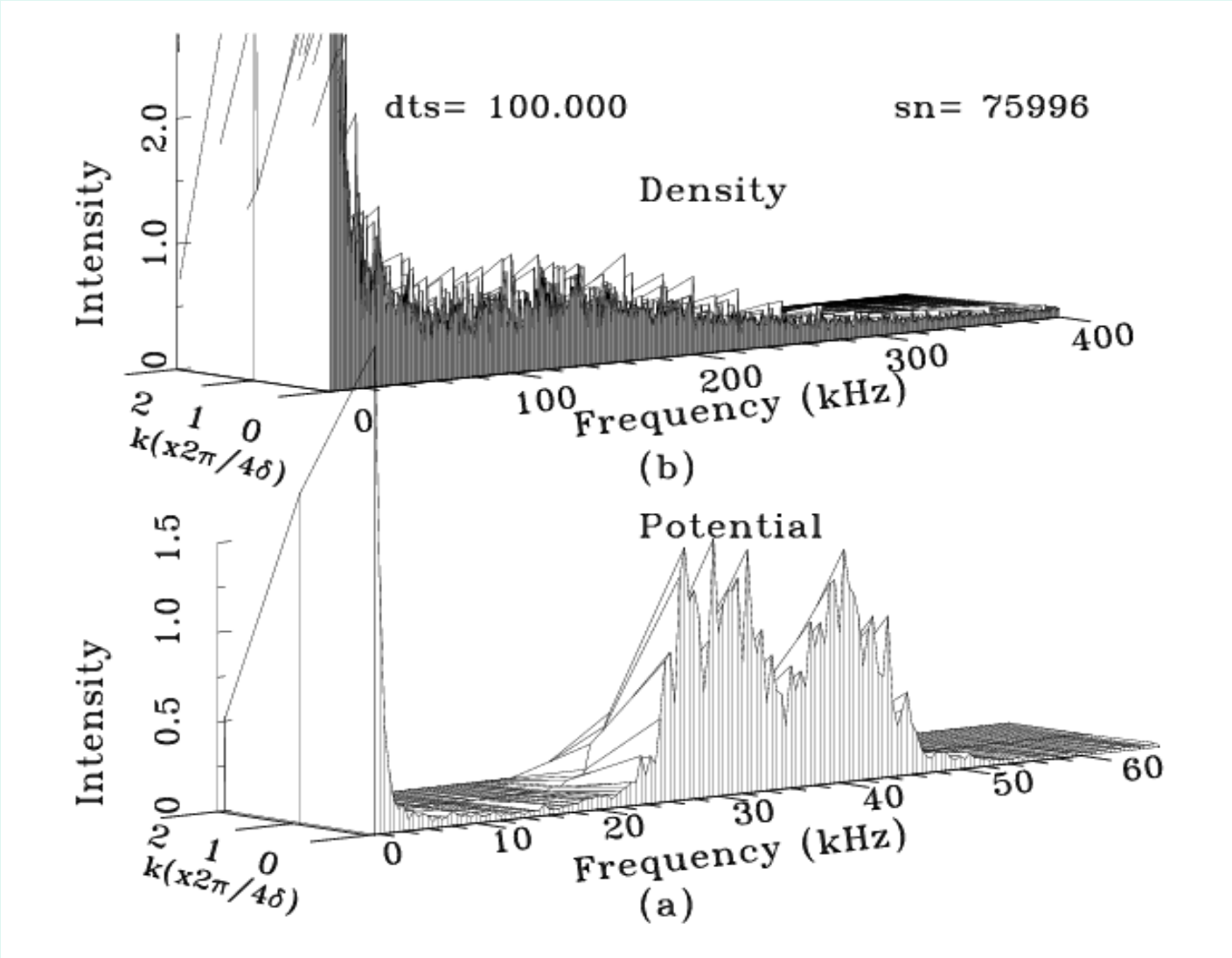
Typical Waveform of Potential and Density in the Core (A4) and Outer Area (C2).



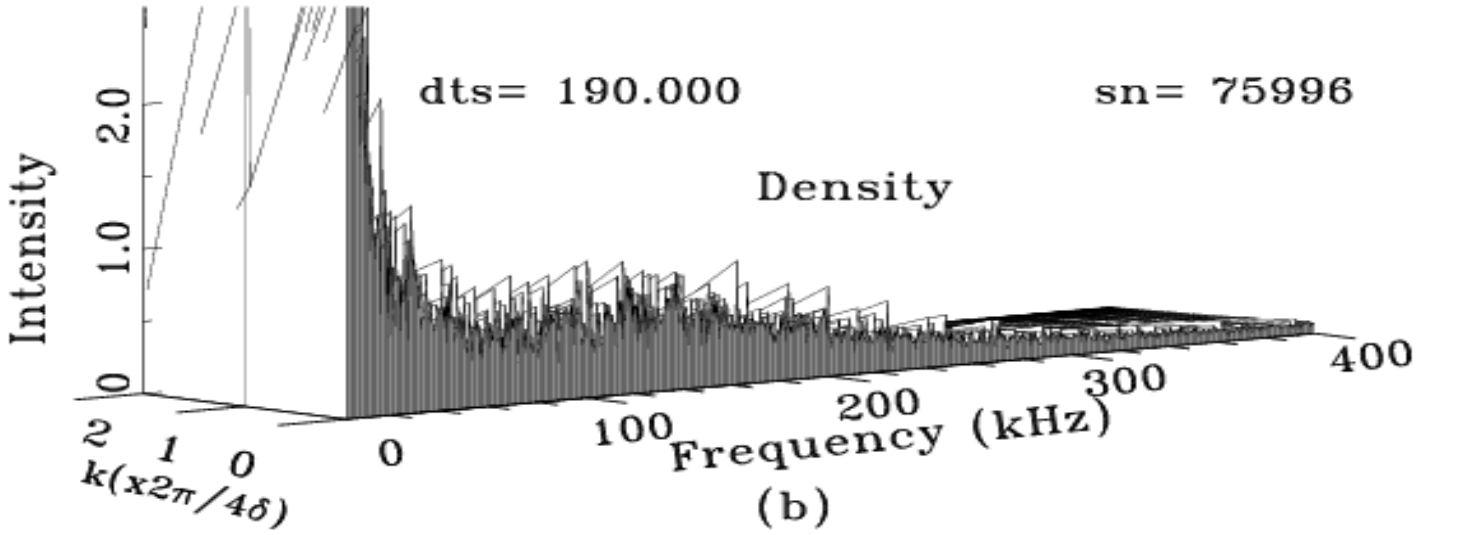
Density & Temperature Radial Profile at OH and Heating Phase

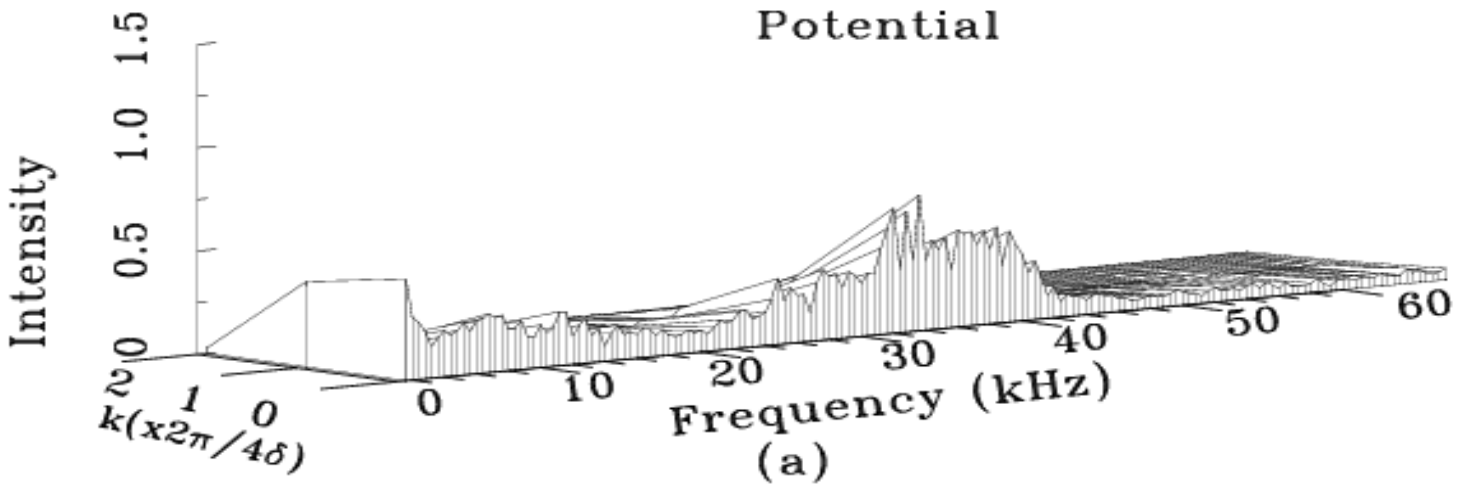


2-D Fourier Spectra of n_e, Φ

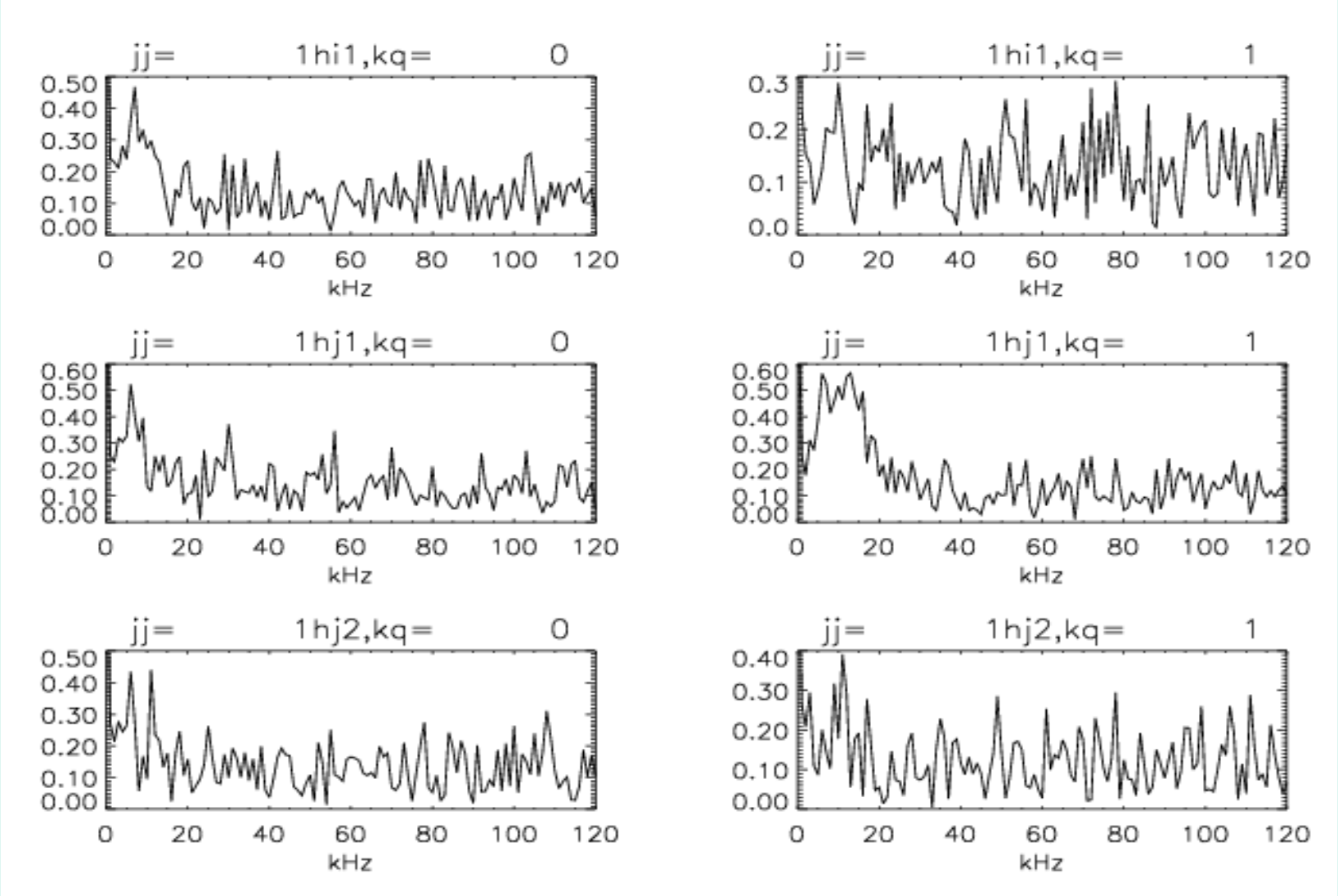


2-D Fourier Spectra at Heating Phase

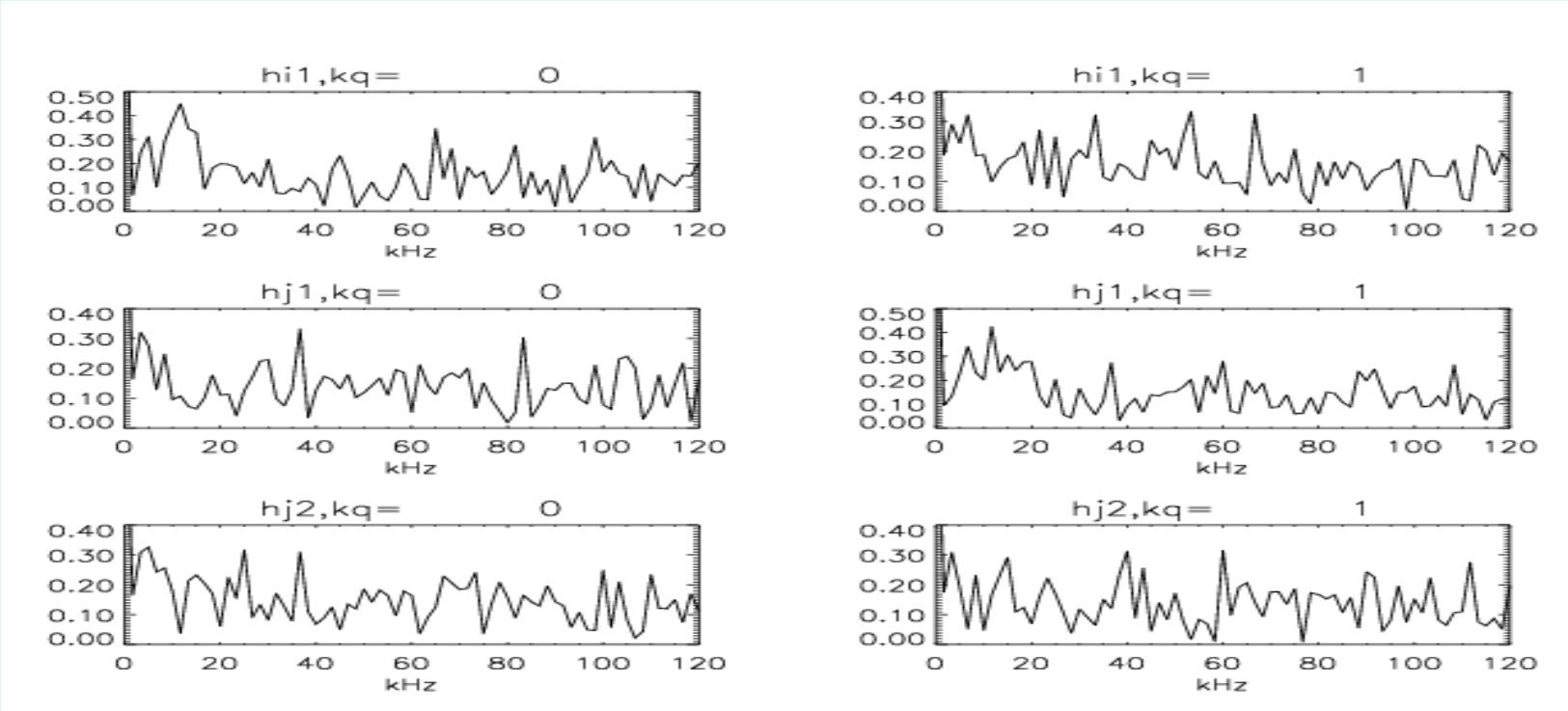


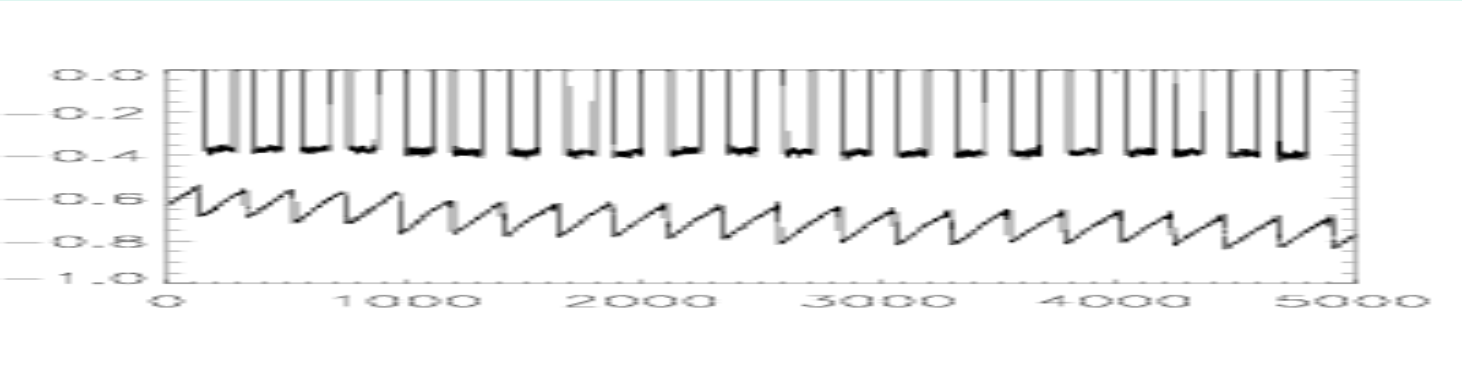


Coherence of Zonal Flow and ECE Signals(1)

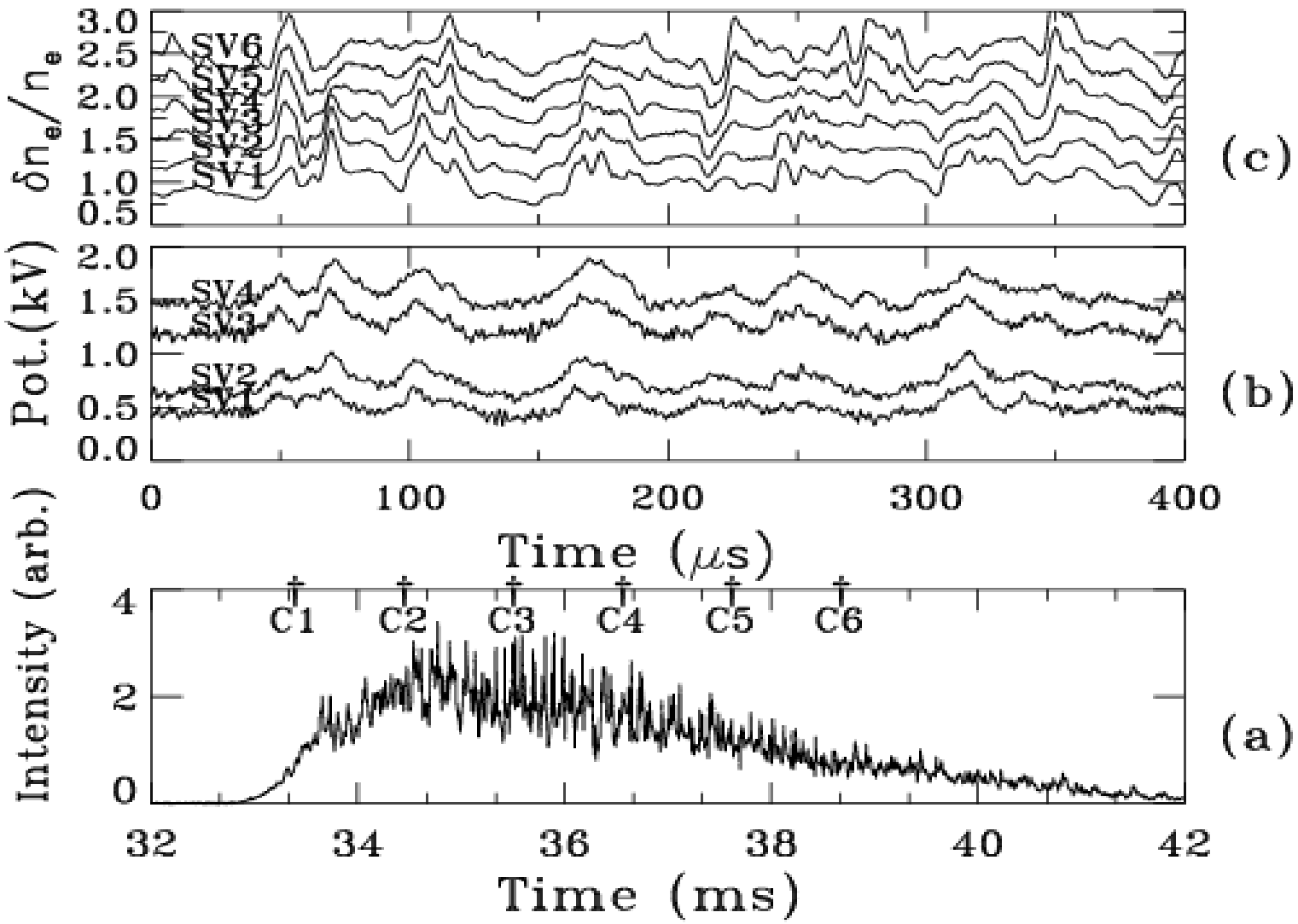


Coherence of Zonal Flow and ECE Signals(2)

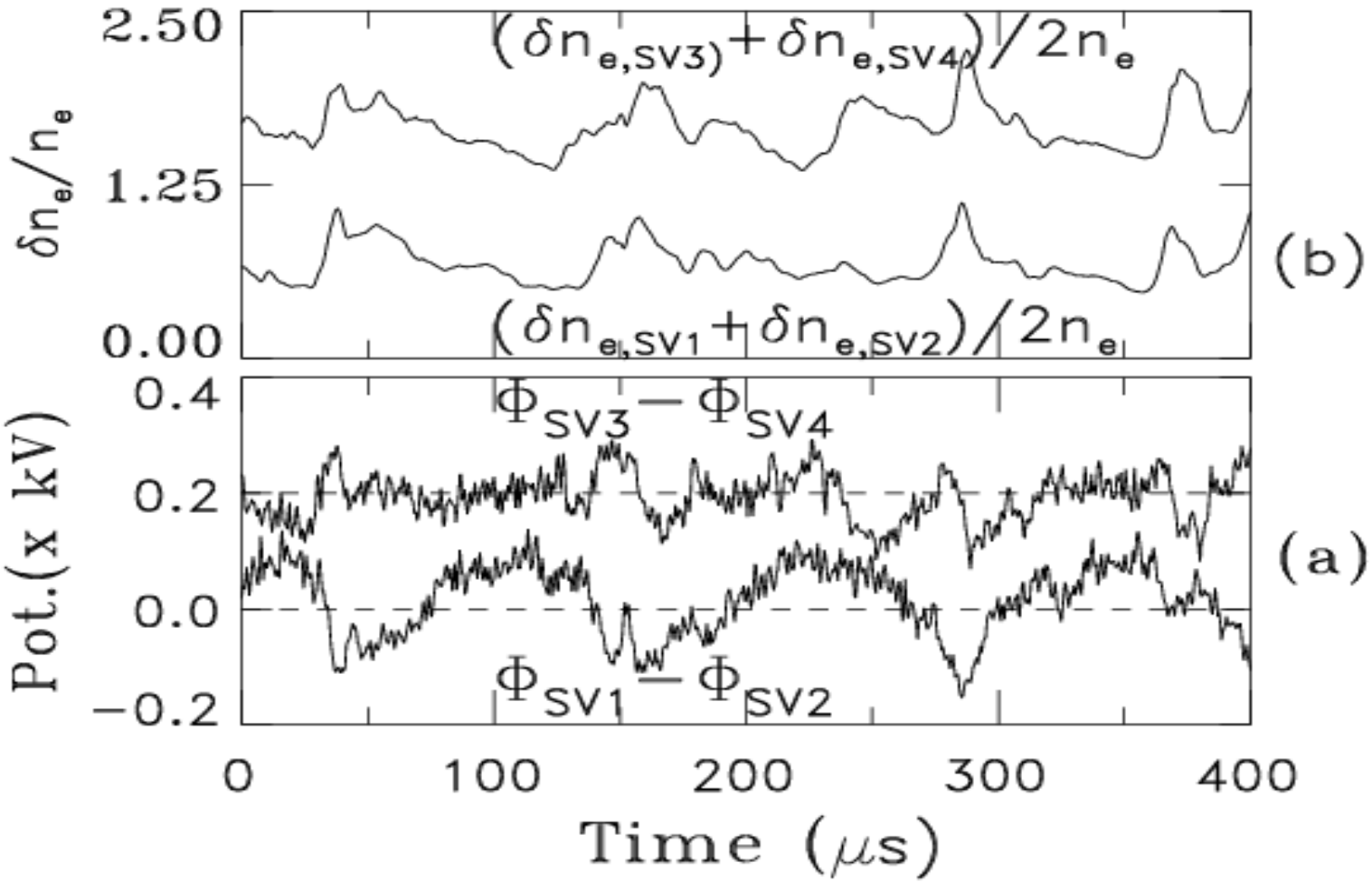




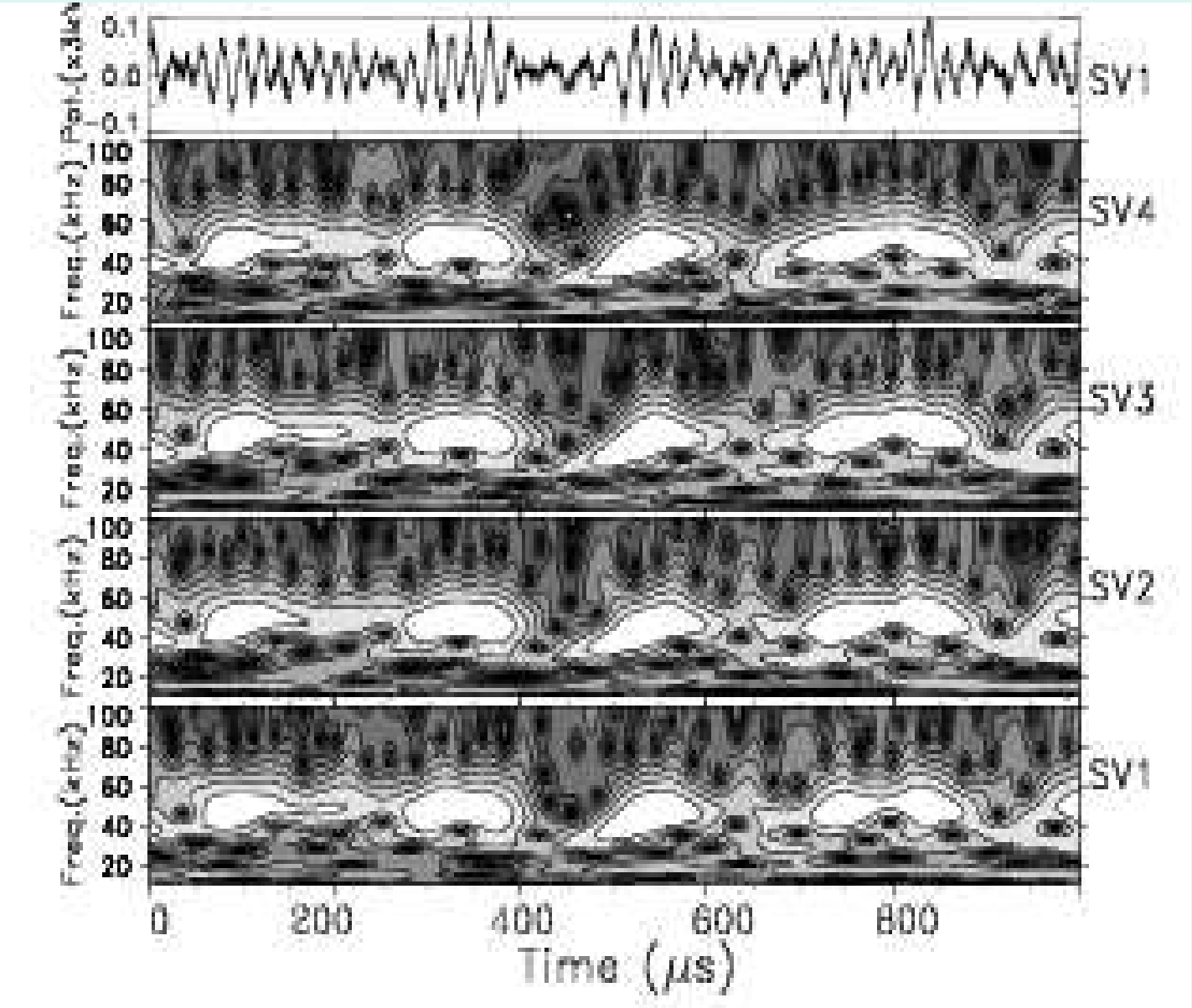
Streamers in Fixed and Scanning Mode



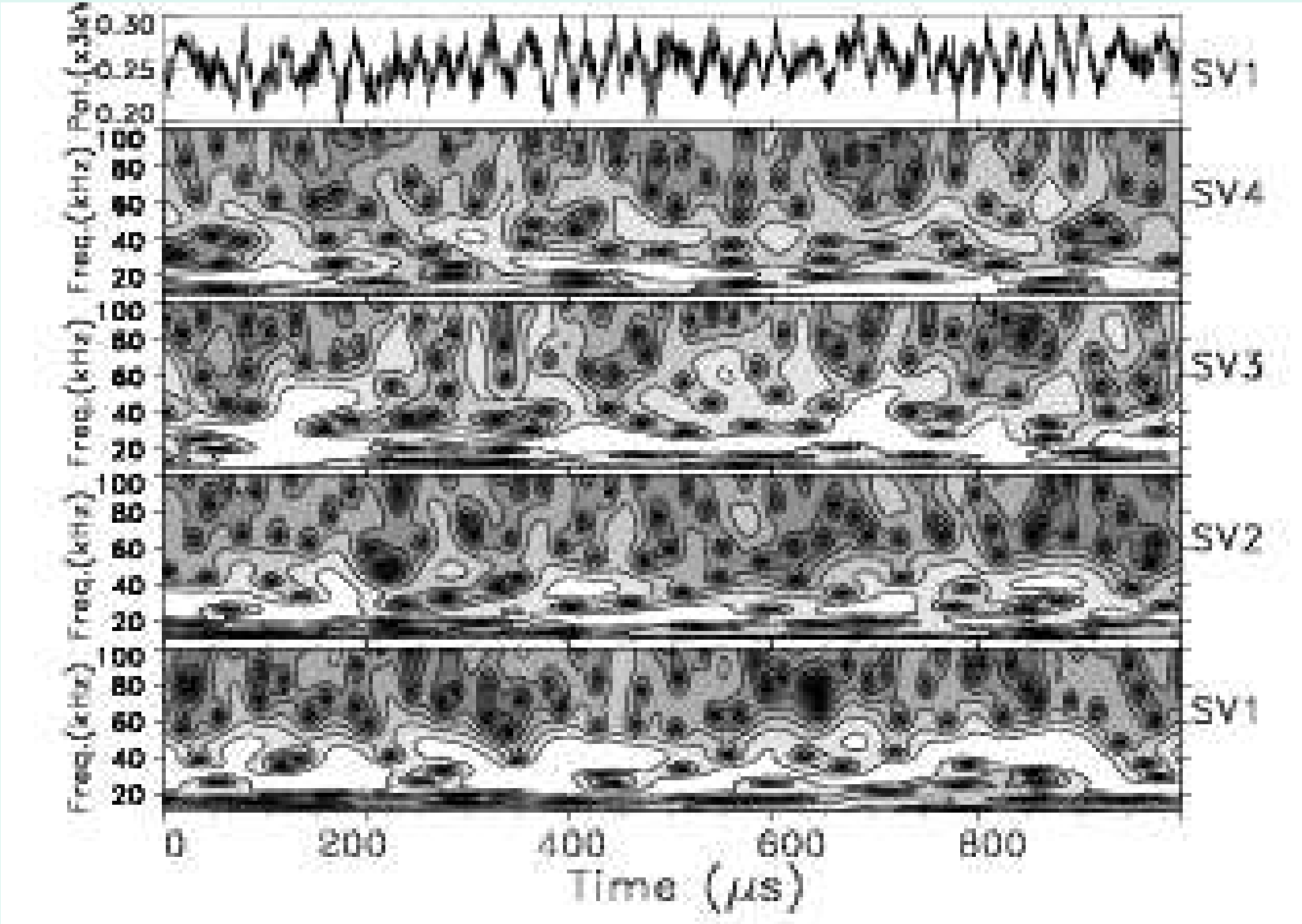
Indication of Poloidal Size of Streamers



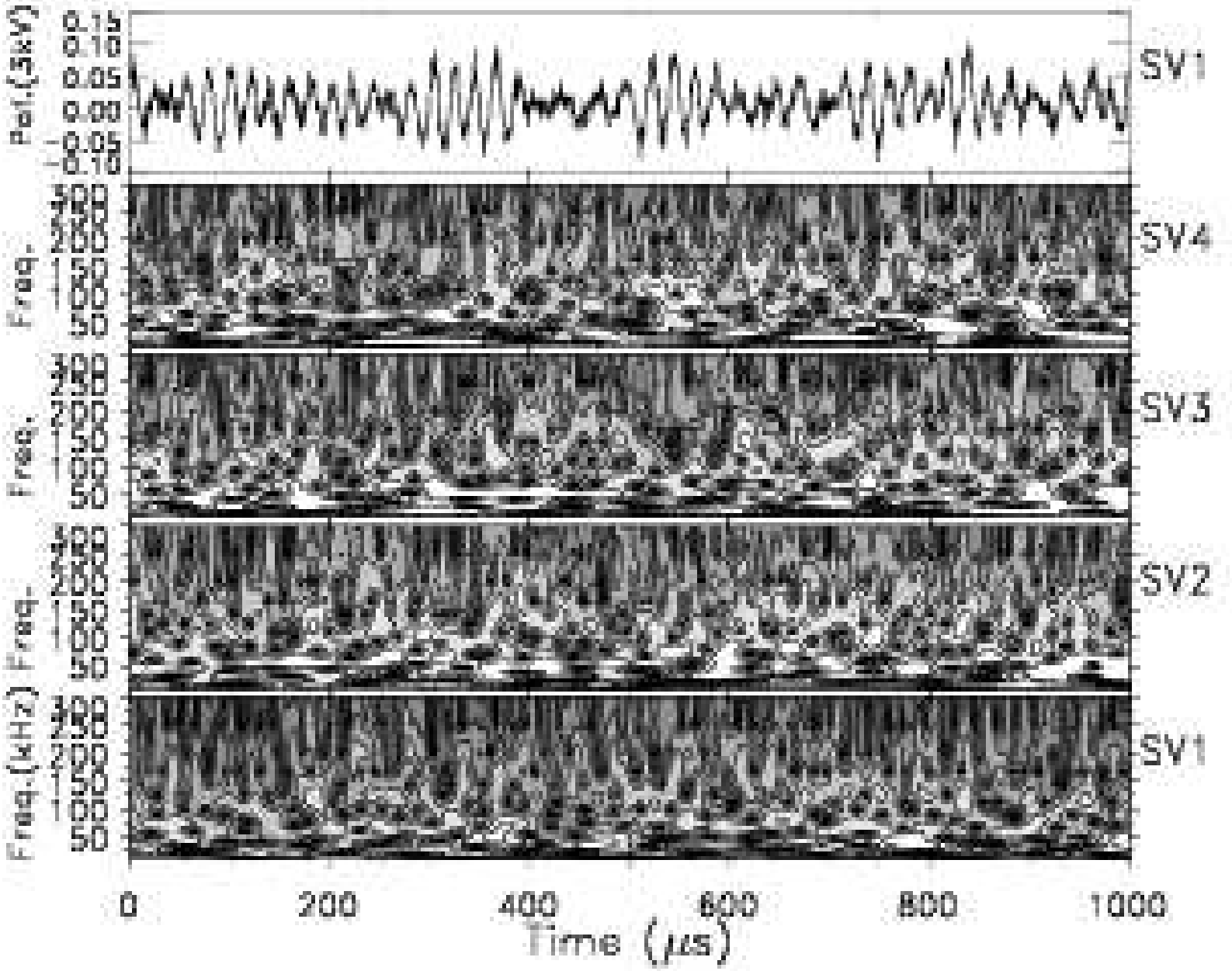
Scalograms of Potential Oscillation at A4



Scalograms of Potential Oscillation at A2



Density Scalogram at the Core (A4)



Conclusion 1

Large potential oscillations in the GAM frequency with m=0 mode are observed in wide area of the plasma cross-section with the amplitude reaching 400 Vp-p with correlation length of 1-2 cm and the life time of about 100 μ s.

Conclusion 2

In the outer region of the plasma ($r/a \geq 0.7$ and $T_e < 500$ eV, the region of turbulence propagating into ion diamagnetic drift direction, the streamers with normalized amplitude of order of 0.5-1.0 were observed with order of 10 μs pulse width and positive polarity.

Conclusion 3

Zonal flow of low-density Ohmic plasma (TEM plasma) has much larger intensity at high-frequency zonal flow compared with low-frequency zonal flow.

Conclusion 4

During the additional heating by NBI or higher-harmonics ICRF heating/CD, the intensity of high-frequency zonal flow becomes smaller and low-frequency zonal flow grows to comparable intensity.

Conclusion 5

The ECE emission also has high coherency with low- frequency zonal flow and if we analyze with the time spans without sawtooth crash the coherency is about 0.4.

Conclusion 6

Observed streamer-like phenomena has large phase change across about 2 cm, showing narrow poloidal width.

Conclusion 7

Wavelet analysis of density fluctuations, shows that the density turbulence is much more chaotic and lifetime is shorter than that of GAM. There is no clear indications of regulation of turbulence by zonal flow.

Thank You
For Your Attention