Recent Experiments on the STOR-M Tokamak

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Plasma Laboratory
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33rd Annual Conference of CNS
Saskatoon, June 10-13, 2012

University of Saskatchewan

PPL

Acknowledgements

Dr. T. Onchi

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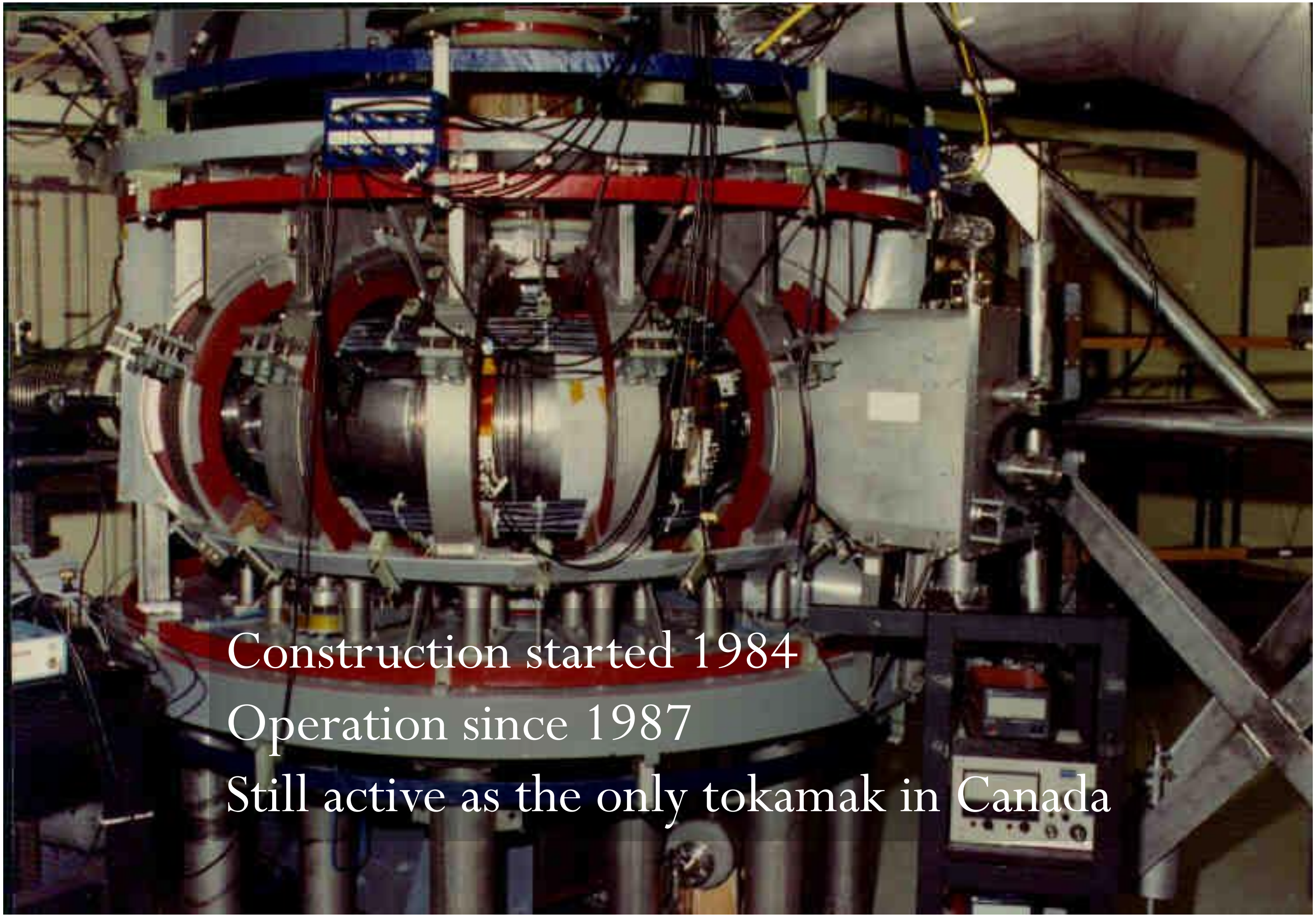
Prof. A. Hirose

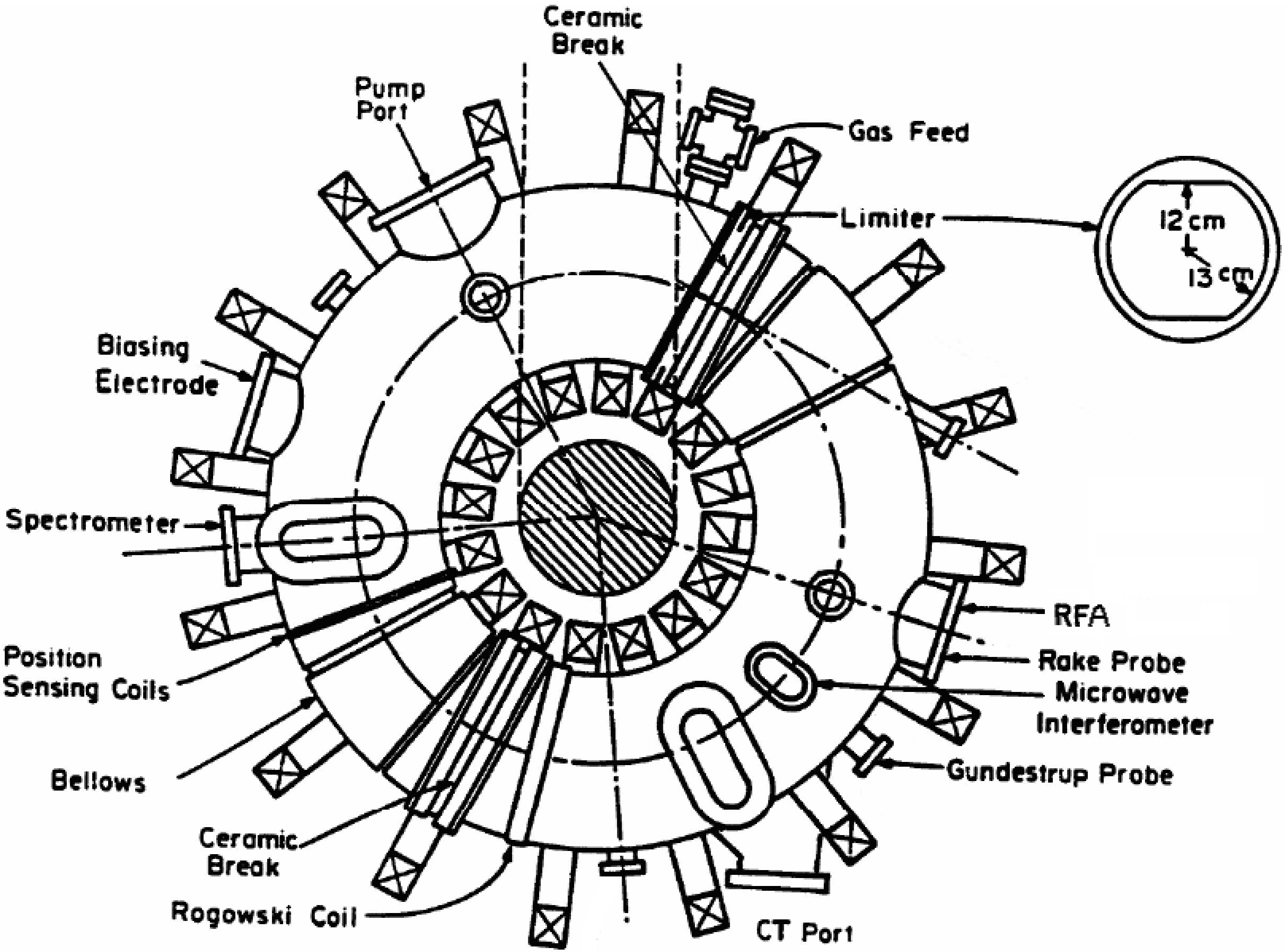
Supported by CRC and NSERC

Outline

- STOR-M Tokamak Program
- Motivation for Resonant Magnetic Perturbation (RMP) Experiments
- Experimental Setup
- Model Predictions
- Experimental Results
- Conclusions

STOR-M Tokamak





Ceramic Break
Pump Port
Gas Feed
Limiter
12 cm
13 cm
Biasing Electrode
Spectrometer
RFA
Rake Probe
Microwave Interferometer
Position Sensing Coils
Gundestrup Probe
Bellows
Ceramic Break
Rogowski Coil
CT Port

STOR-M Tokamak Parameters

Major radius	R	46 cm
Minor radius (limiter)	a	12 cm
Toroidal B field	B_ϕ	1 T
Plasma current	I_p	30-50 kA
Average electron density	n_e	$1 \sim 3\times\ 10^{13}$ cm^{-3}
Electron temperature	T_e	220 eV
Ion temperature	T_i	50~100 eV
Discharge duration	t_d	50 ms
Energy confinement time	τ_E	1~3 ms

STOR-M Programs

- Transport studies

  Ohmic H-modes induced by CT injection, plasma biasing, edge heating
- **Compact torus** (CT) injection

  fuelling, pressure profile (bootstrap current) control in burning plasmas
- AC (alternating current) operation

  quasi-steady state tokamak operation

  most efficient ohmic heating method
- Diagnostics development
  - **Plasma flow velocity measurements**
  - Ion temperature measurement
  - Microwave scattering, reflectometry

STOR-M Programs (cont.)

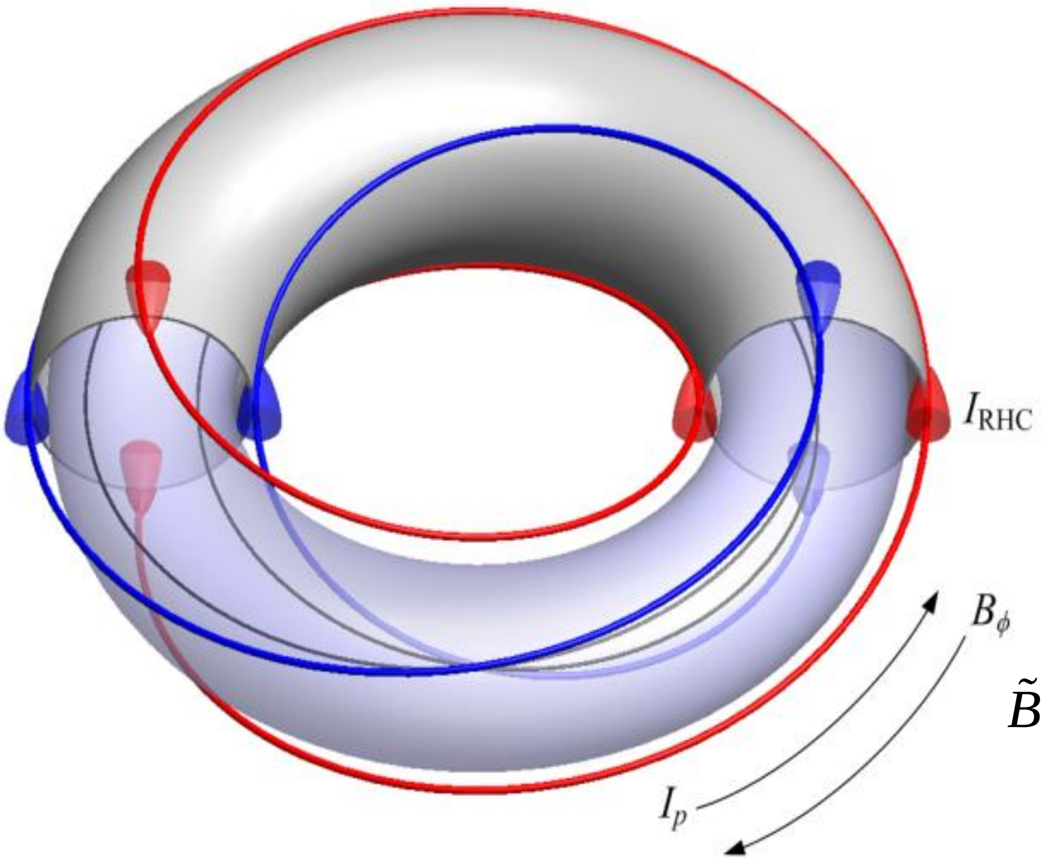
- Magnetohydrodynamic (MHD) studies by resonant magnetic perturbations (RMPs)
  - **Suppression of m=2 MHD fluctuations**
  - **Modification of plasma flow**

PPL is a member of IAEA CRP using small fusion devices

Motivations

- Magnetohydrodynamic (MHD) instabilities in tokamak have adverse/dangerous effects
  - Degrade confinement
  - Cause major disruptions → heat load, structural damages
- Benefits of resonant magnetic perturbations (RMP)
  - Reduce magnetic perturbations
  - Modify plasma flow velocities which may lead to
    - H-mode triggering
    - Shielding of error field
    - Prevent disruptions

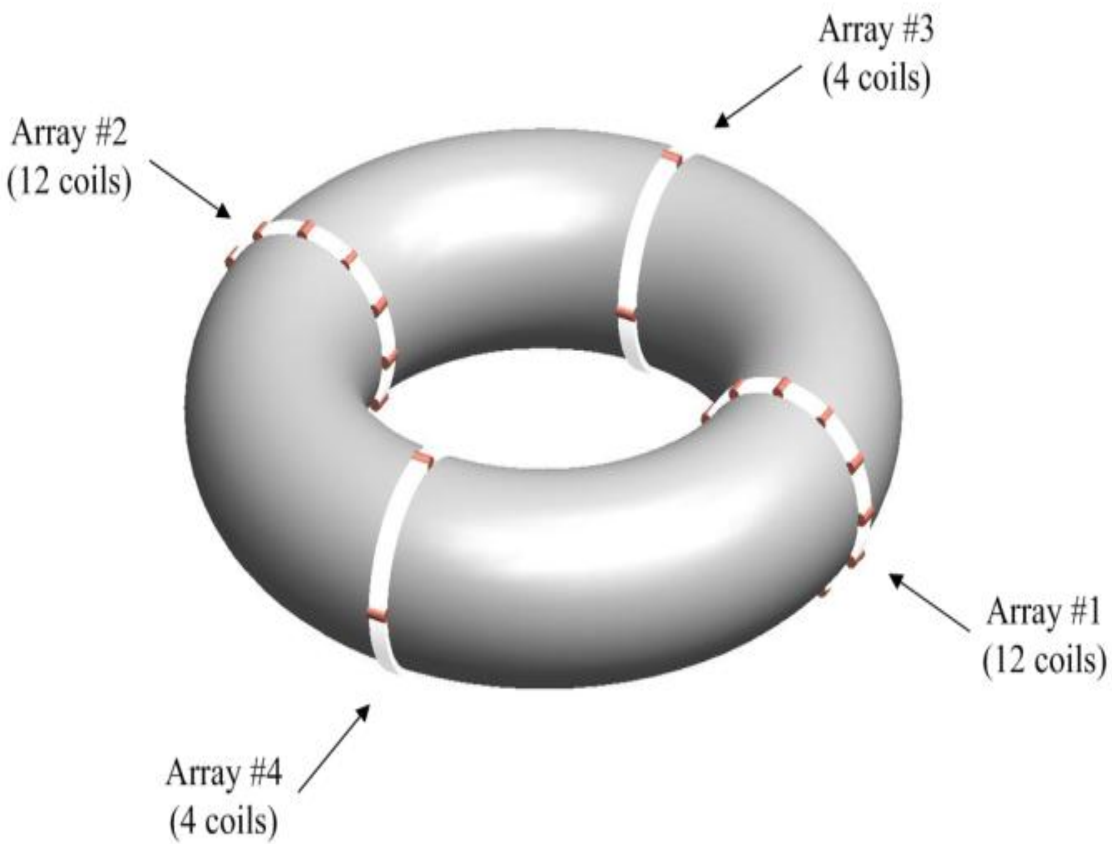
Experimental Setup



m/n=2/1 helical coils to suppress the dominant mode

$$\tilde{B} = B_0 \exp\left[i \left(m\theta - n\varphi - \omega t \right) \right]$$

Mirnov coils



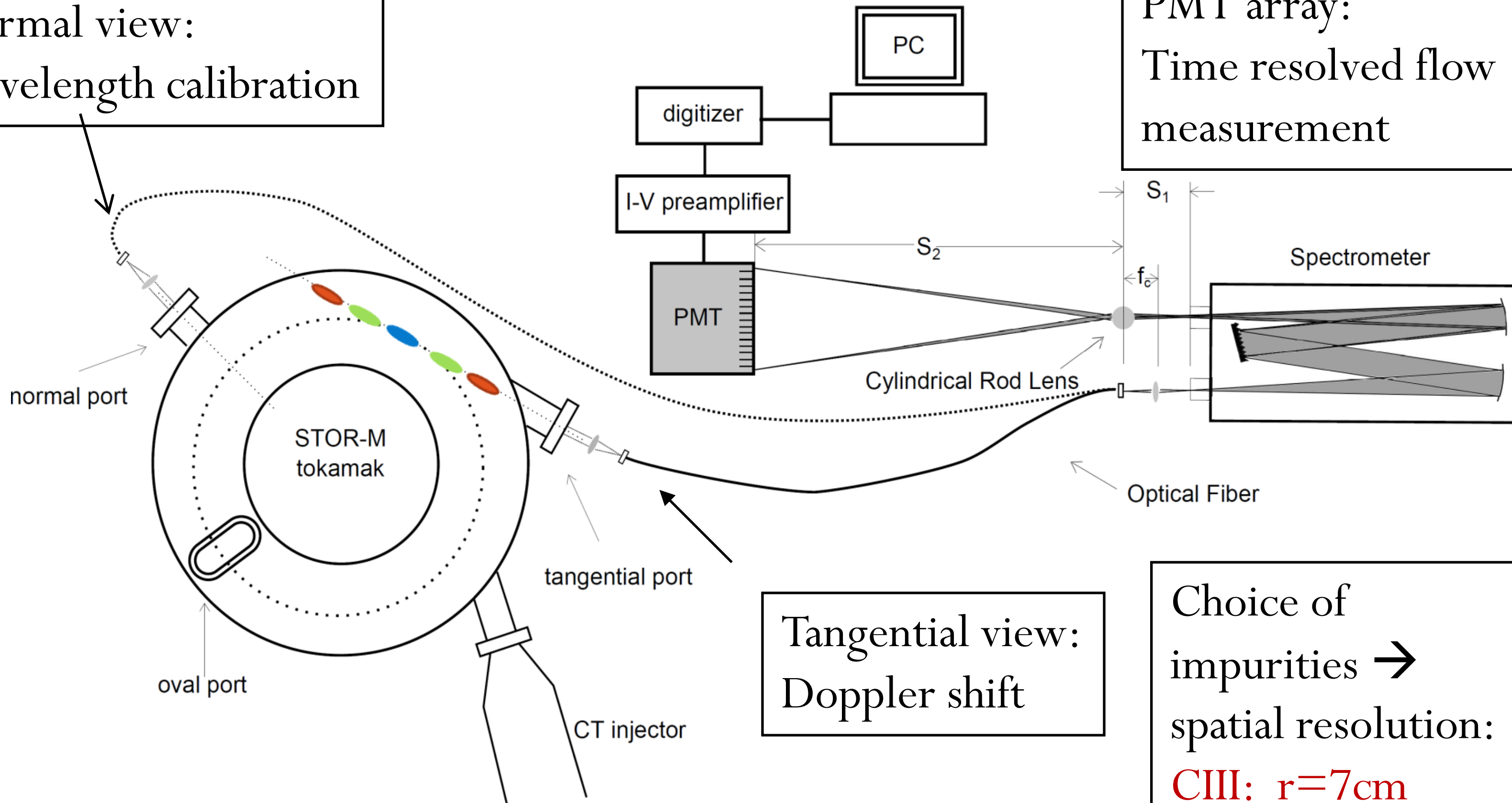
Mirnov coil arrays used to detect the mode structure and frequencies.

SVD algorithm is used to analyze the MHD modes

Ion Doppler Spectroscopy

Normal view:
Wavelength calibration

PMT array:
Time resolved flow measurement

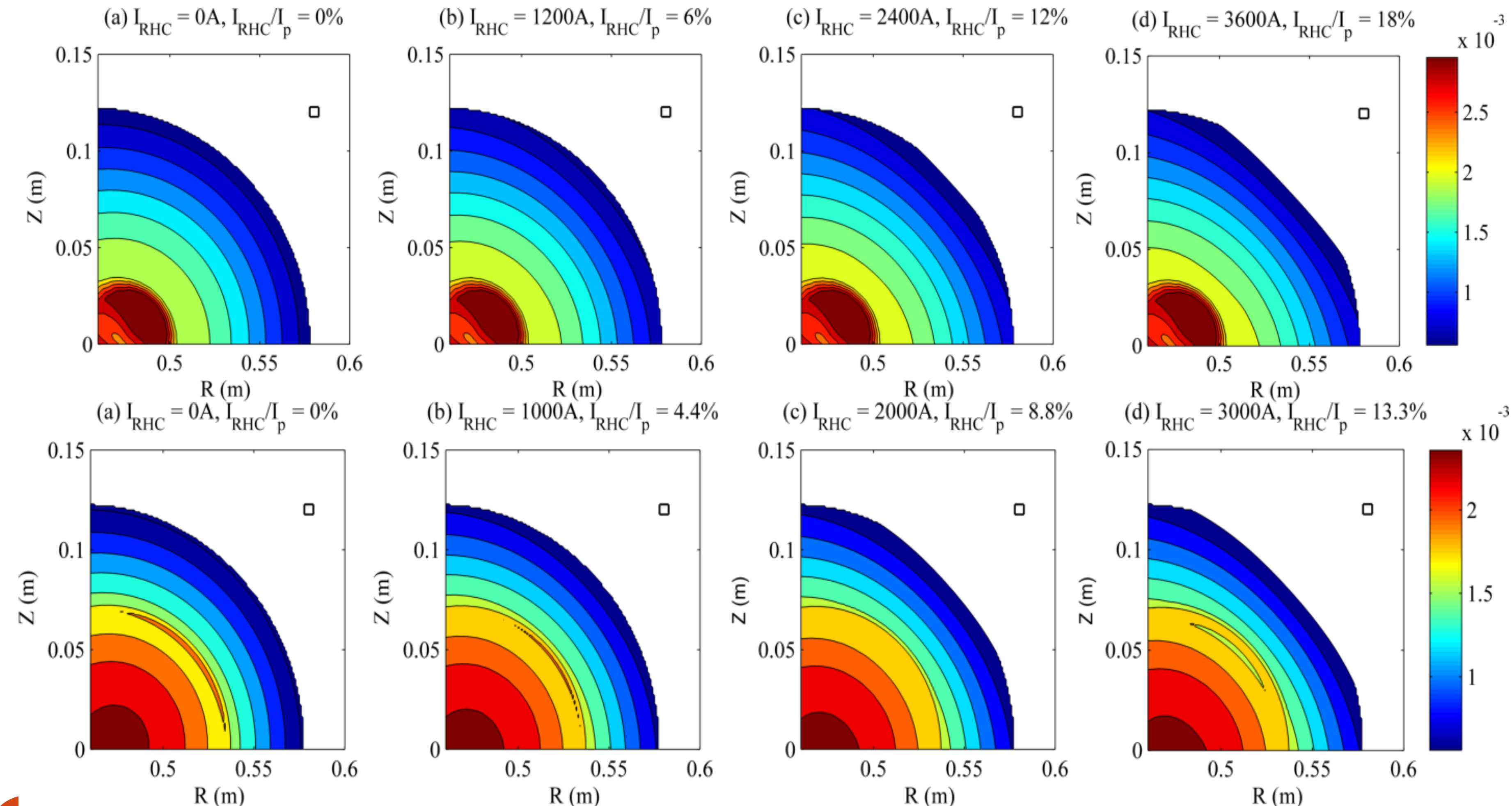


Tangential view:
Doppler shift

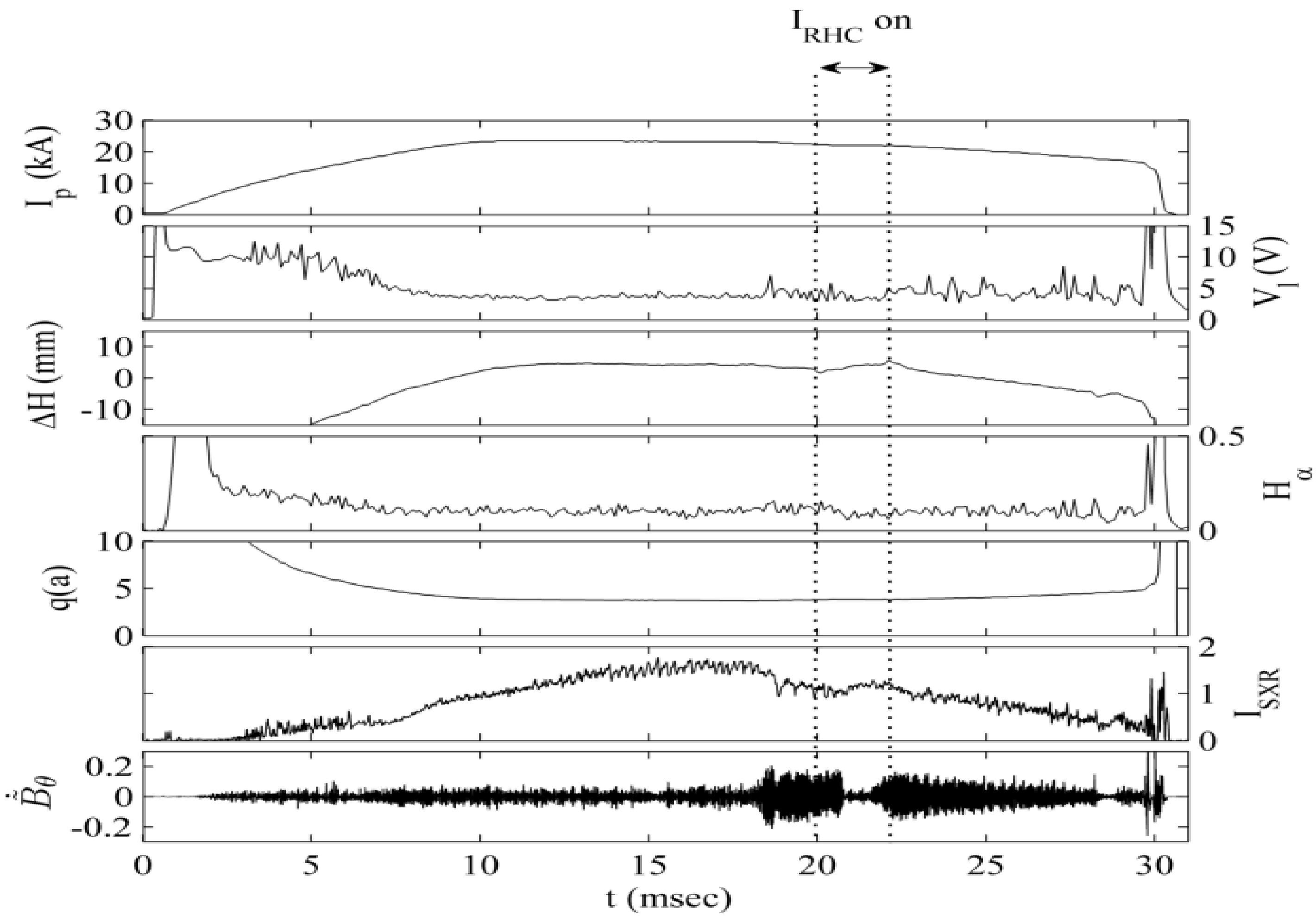
Choice of impurities → spatial resolution:

- CIII: r=7cm
- OV: r= 4cm
- CVI: r=0cm

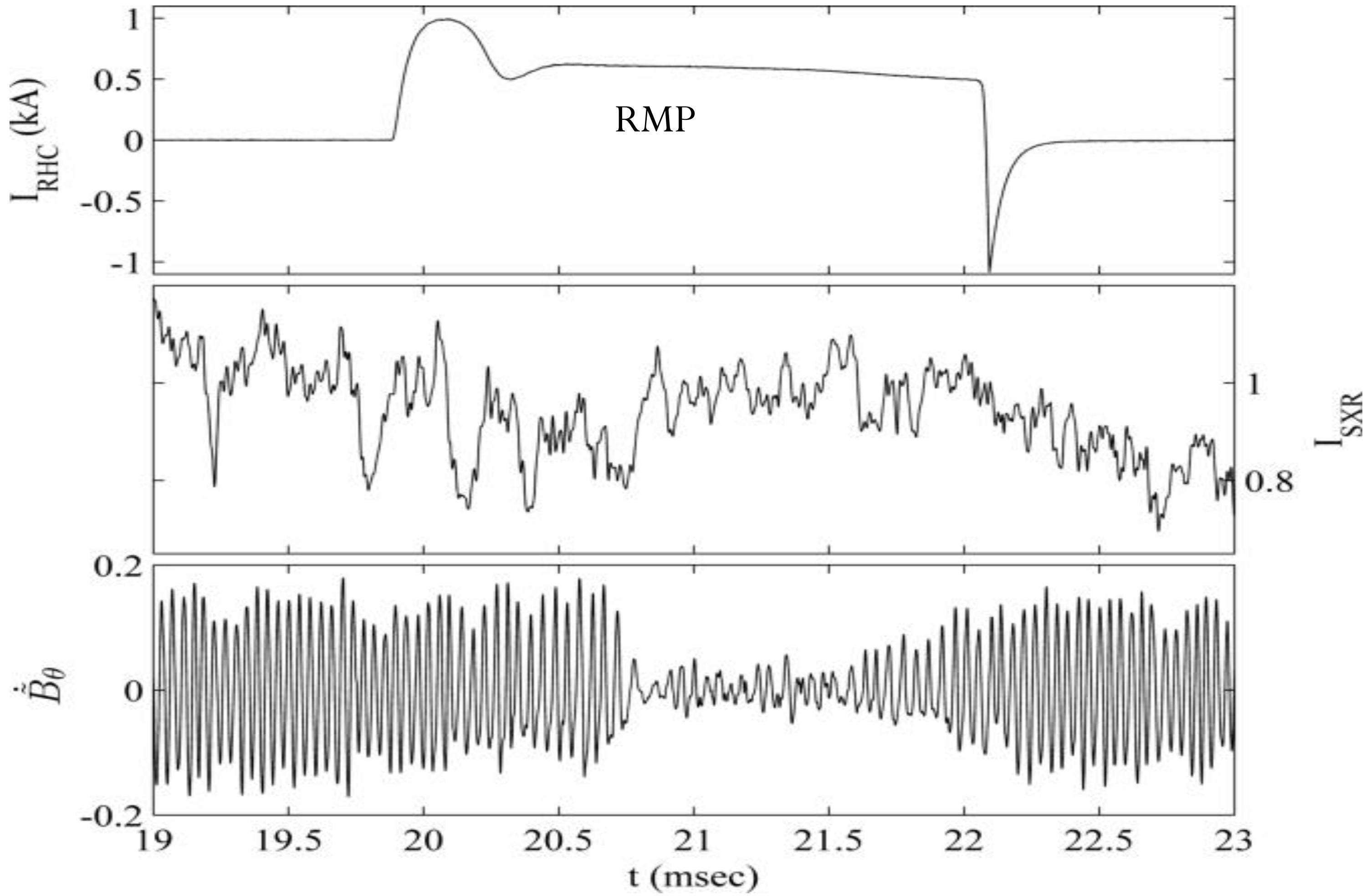
Model Predictions



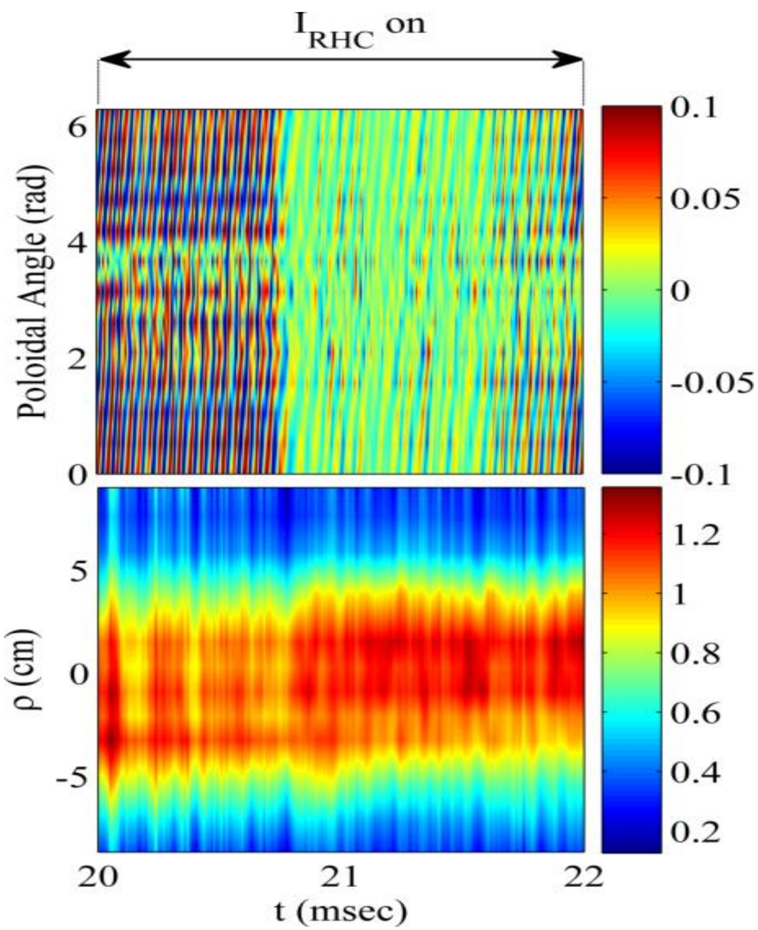
Results -Suppression

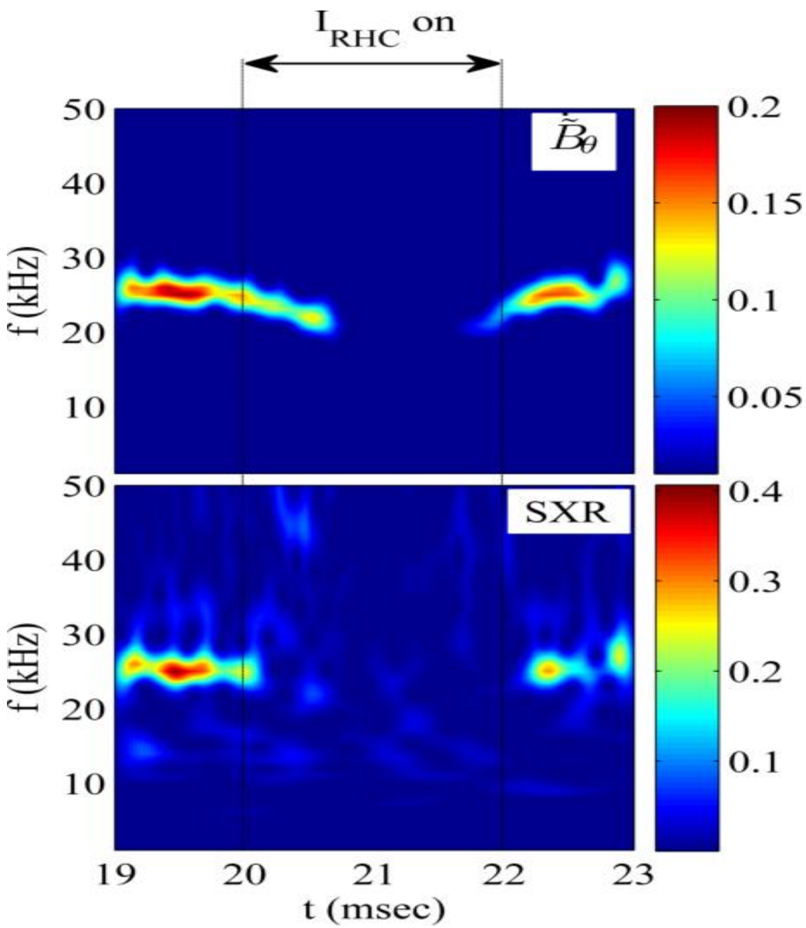


Expanded traces

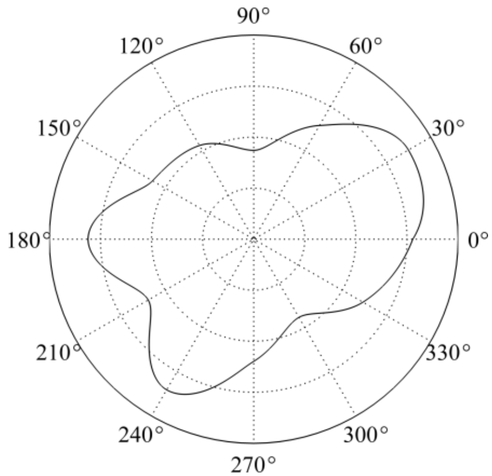


Mirnov and SXR signal amplitudes and their wavelet spectra

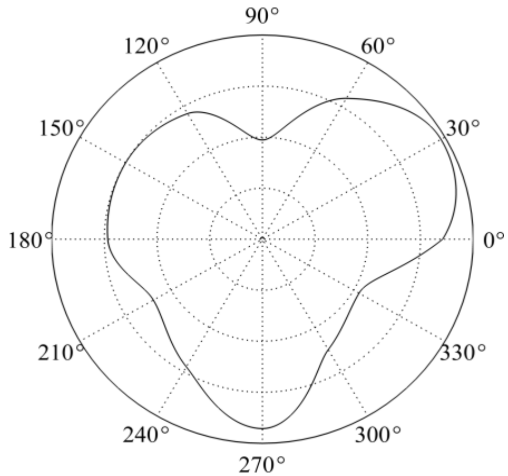




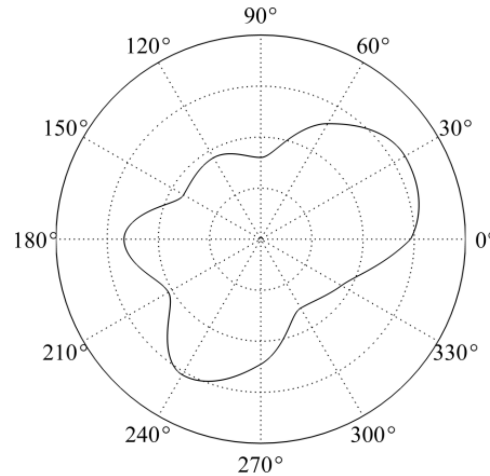
Spatial structure of modes



Before RMP
(m=2)

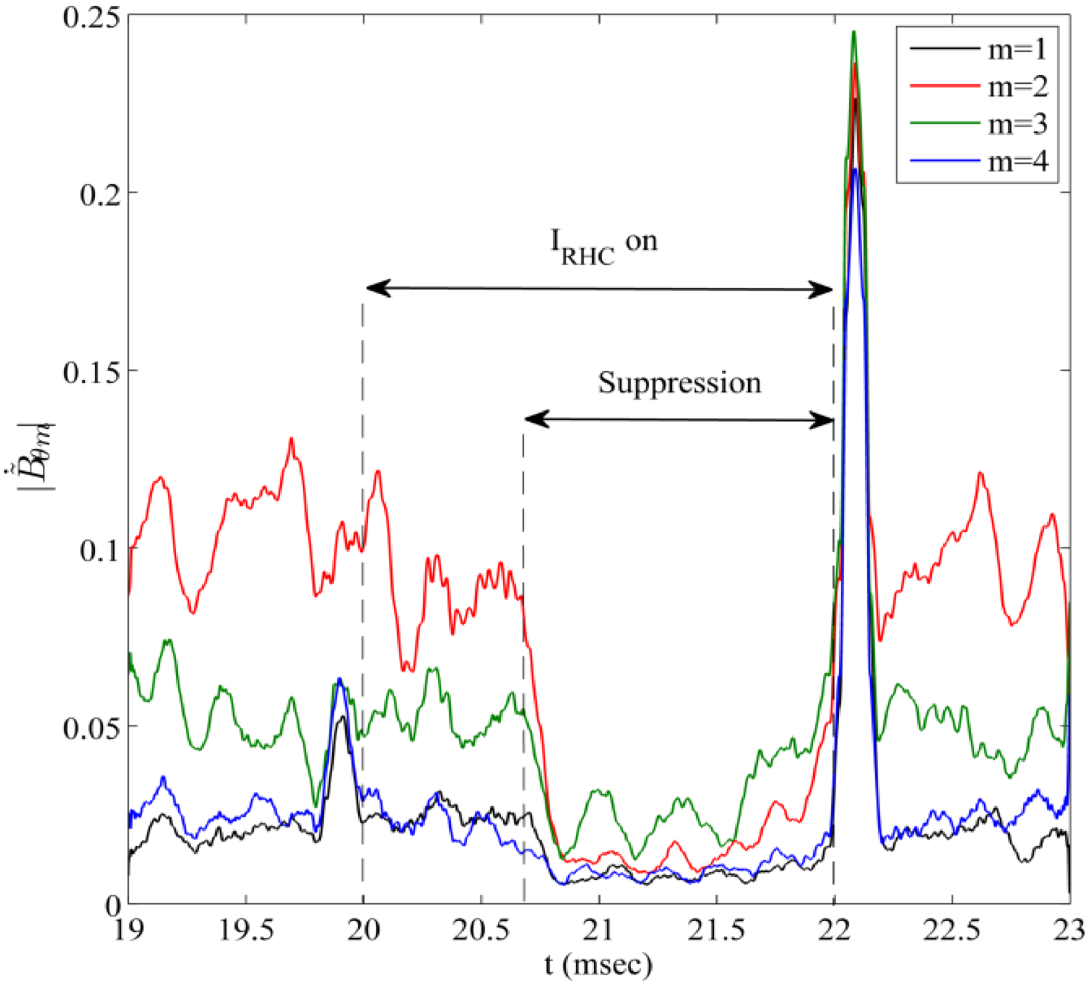


During RMP
(m=3)

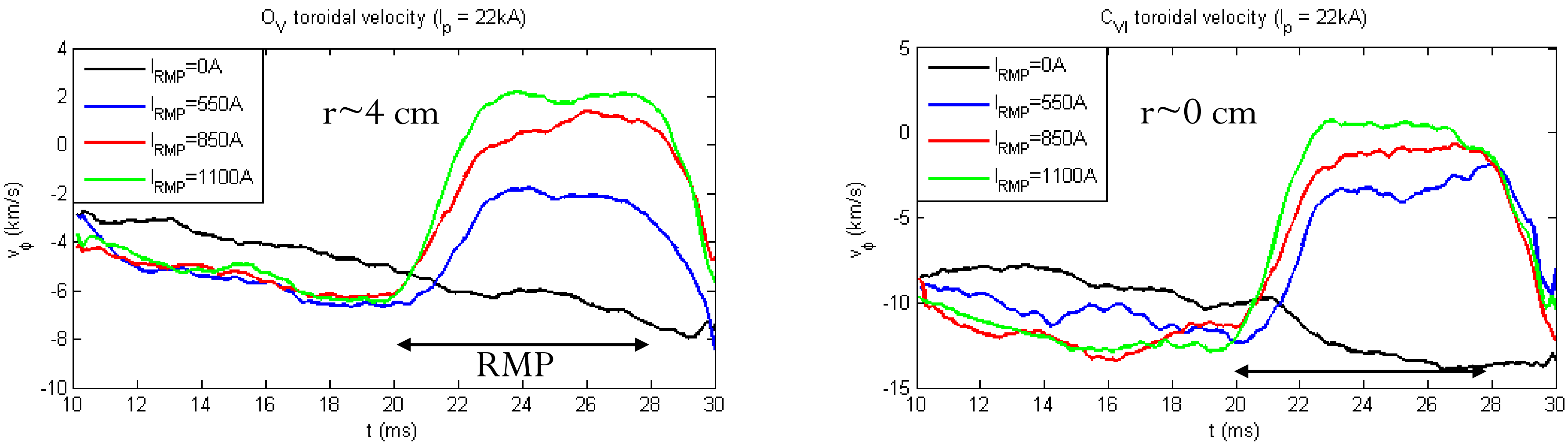


After RMP
(m=2)

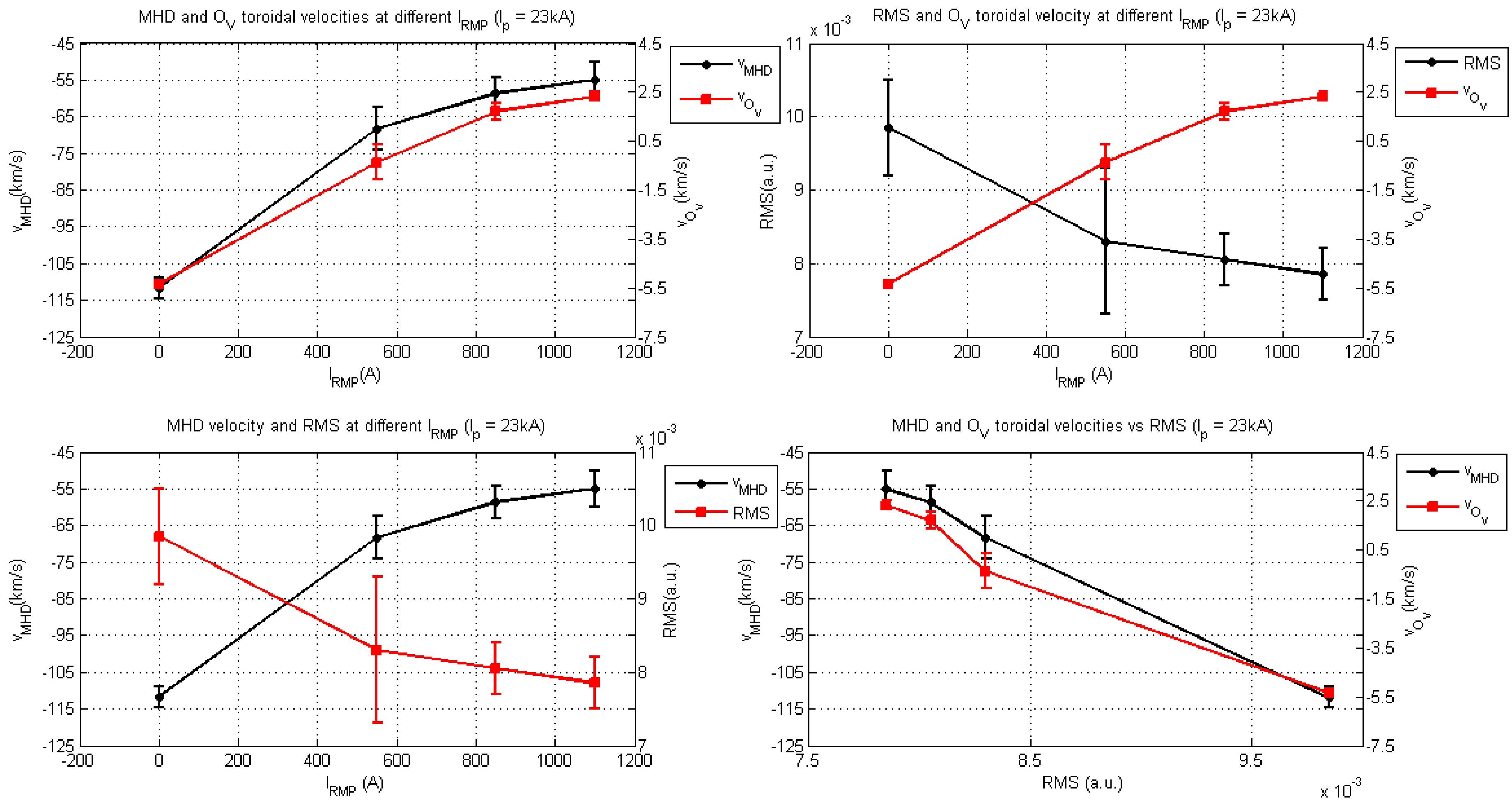
Spatitial Fourier analysis and the rms amplitudes of m=1 to m=4



Flow velocity measurements



O_V and C_{VI} flow measurements at different RMP current. RMP was fired at 20ms for 8ms

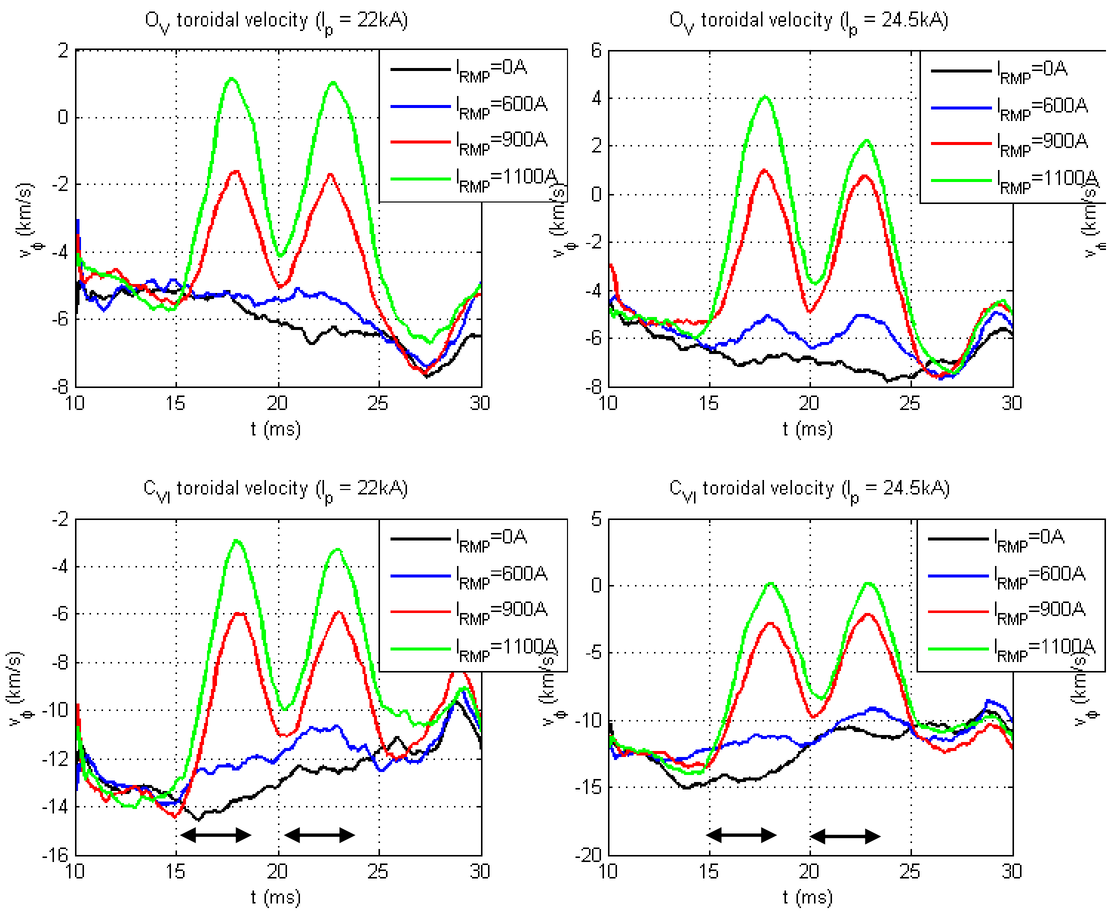


(Top left) MHD and O_V velocities vs IRMP

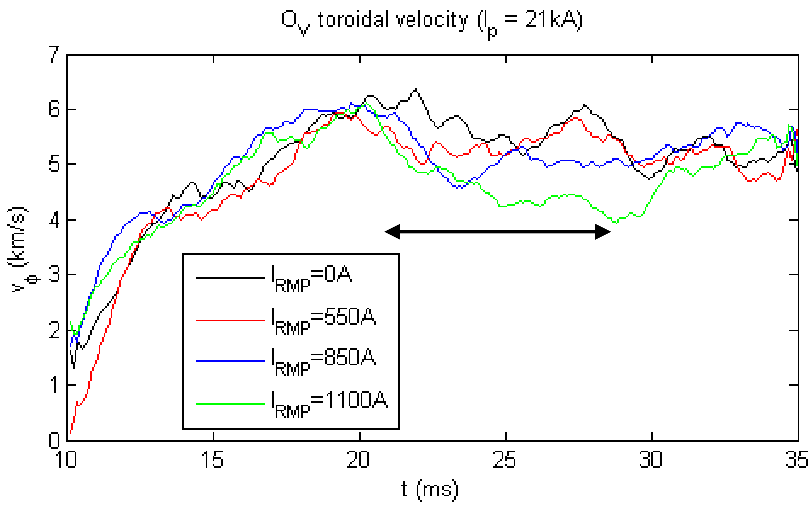
(Top right) RMS of MHD fluctuations and O_V flow vs IRMP

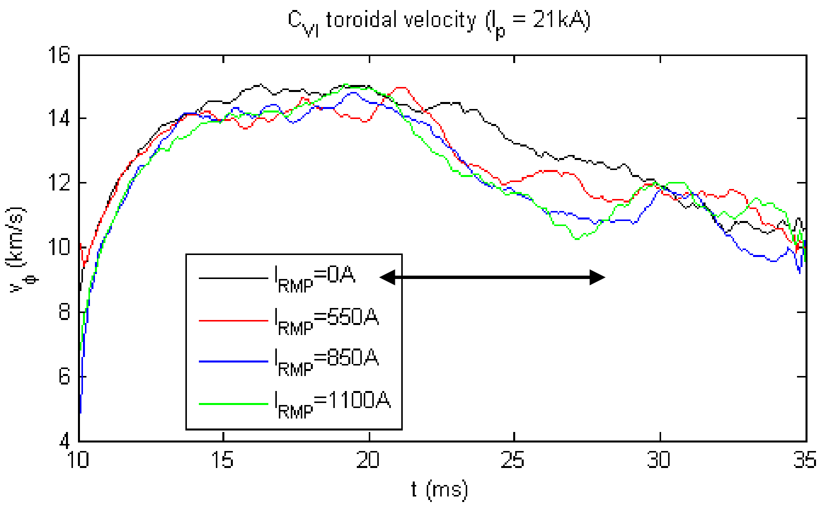
(Bottom left) MHD velocity and RMS vs IRMP

(Botton right) MHD and O_V velocities vs IRMP



O_V and C_{VI} flow measurements at different double RMP pulses and I_p. The first RMP was fired at 15ms for 3ms and the second was fired at 20ms for 3ms.





- O_V and C_{VI} flow measurements at different non resonant magnetic perturbations (NRMP). NRMP was fired at 20ms for 8ms

Conclusions

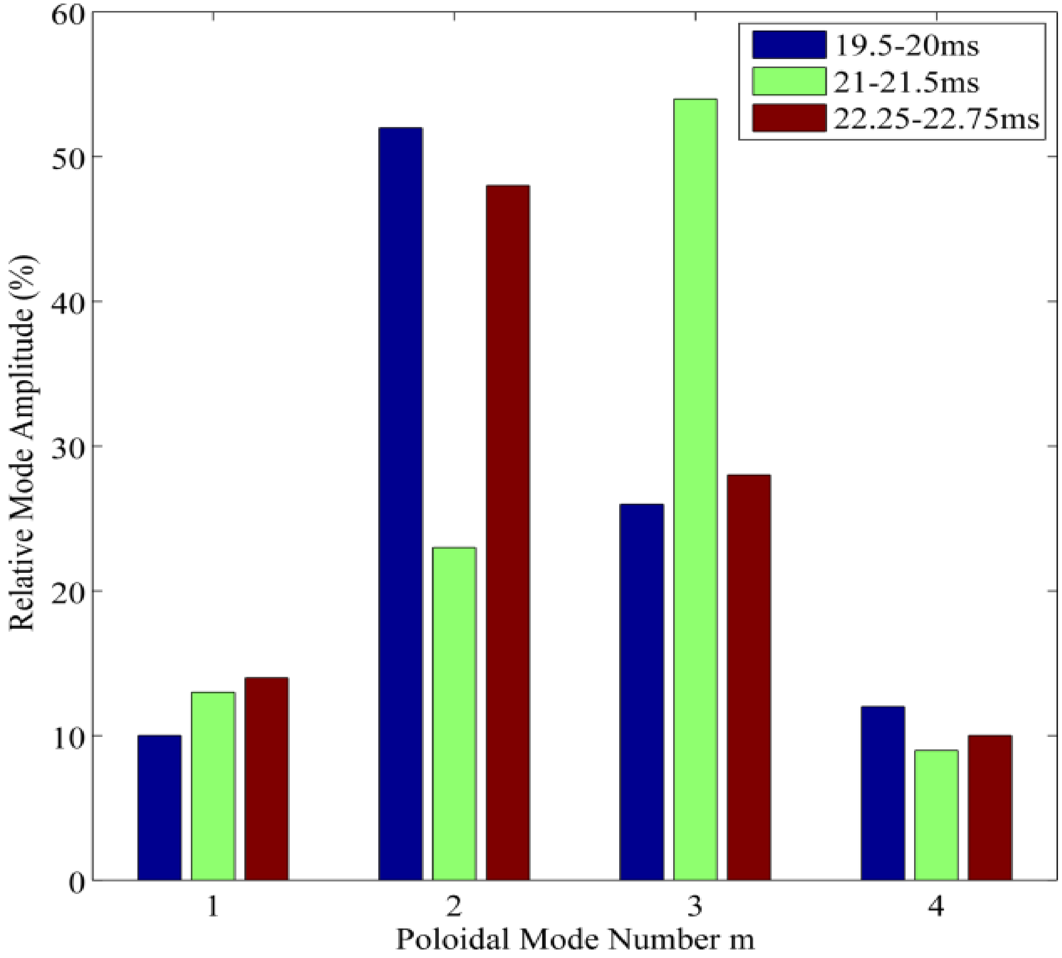
- RMP significantly suppresses the m=2/n=1 magnetic fluctuations
- Plasma flow in the counter-current direction slows down (even reverses direction) during RMP
- Flow velocity is approximately proportional to the magnetic fluctuation amplitude.
- Effects of RMP on magnetic island becomes more significant with increasing current through the RMP coils.

Thanks you!

Research in Plasma Physics Laboratory

- Fusion plasma theory (A. Hirose, A. Smolyakov)
- Partially ionized plasma theory (A. Smolyakov)
- Tokamak experiments (A. Hirose, C. Xiao)
- CT injection (C. Xiao, A. Hirose)
- Plasma Processing (A. Hirose, Q.Q. Yang, C. Xiao)
- Ion implantation, photonics (M. Bradley)

Relative mode amplitudes



Before Suppression

During suppression

After suppression