ISTTOK diagnostics

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Outline

- Introduction

- Electric probes

- Magnetic probes

- Spectroscopy

- Tomography

- Interferometer

- Heavy ion beam

Introduction

- Brief overview of ISTTOK diagnostic

- More detailed description during remaining of the course

- ISTTOK is a flexible machine: diagnostics can easily be replaced and are experimental campaign specific

- Availability

- Measured parameters

Diagnostics layout

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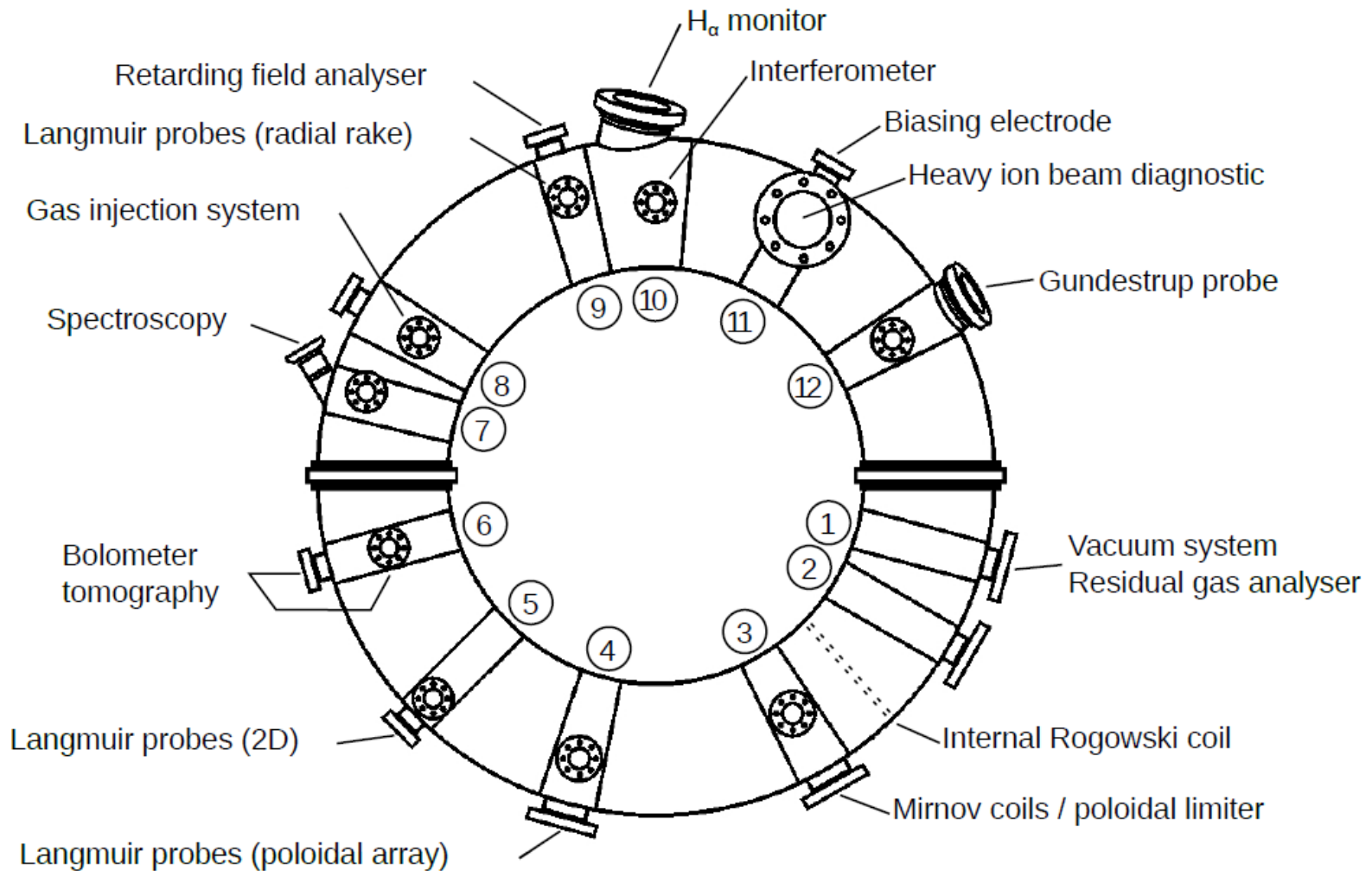
Electric probes

- Intensive scientific exploitation on ISTTOK: similar edge plasma properties as in large size devices

- Several different electric probe systems may be used:

  (i) radial array of probes (rake probe)

  (ii) multi-pin arrays (poloidal)

  (iii) Gundestrup probe

  (iv) emissive probes

- The probe system can be exchanged overnight (one port only)

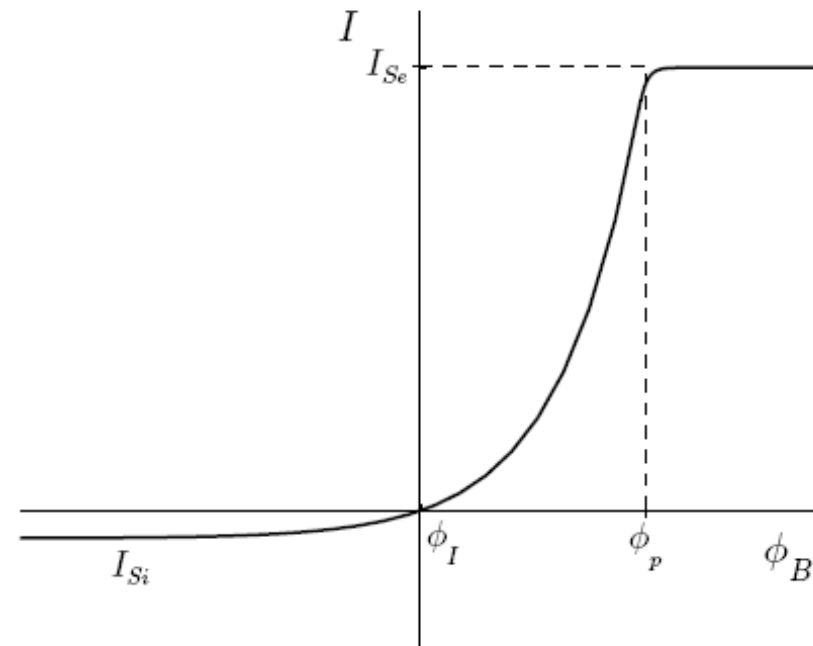- The available probes used to study: GAM, zonal flows, fluctuations, Mach number, Reynold stress (E_r/E_ϕ)….

- Langmuir probes measure n_e, T_e and floating potential. Operated in I_{sat} mode, floating potential or sweep.

$$I_{sat} \propto n_e \left(T_e\right)^{\frac{1}{2}}$$
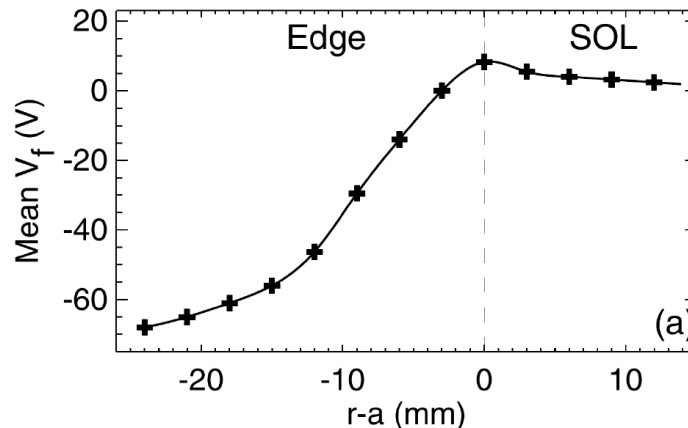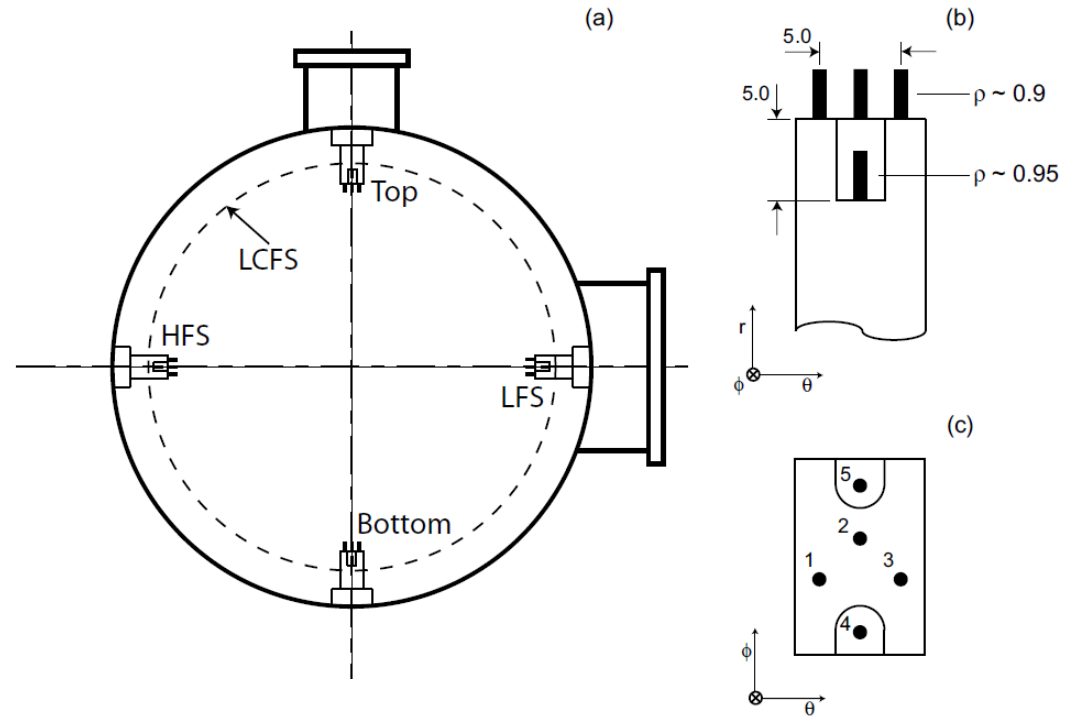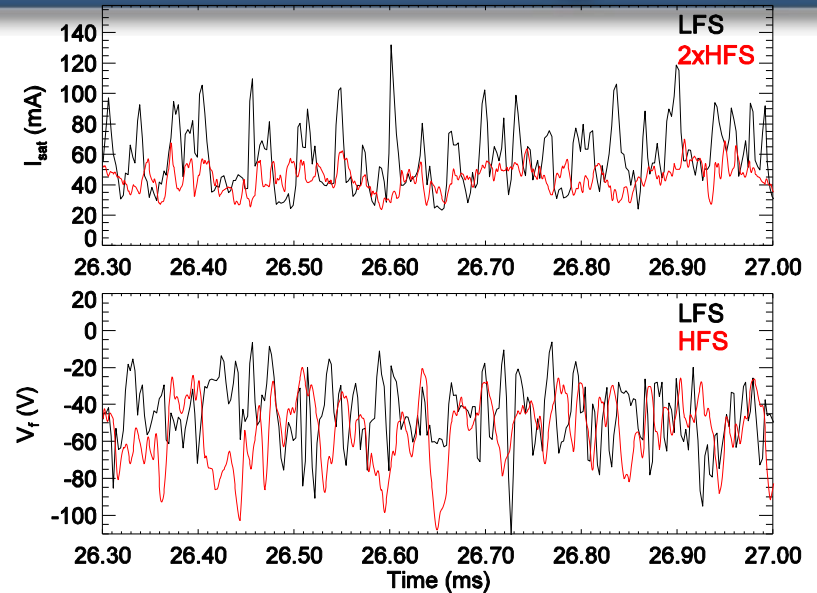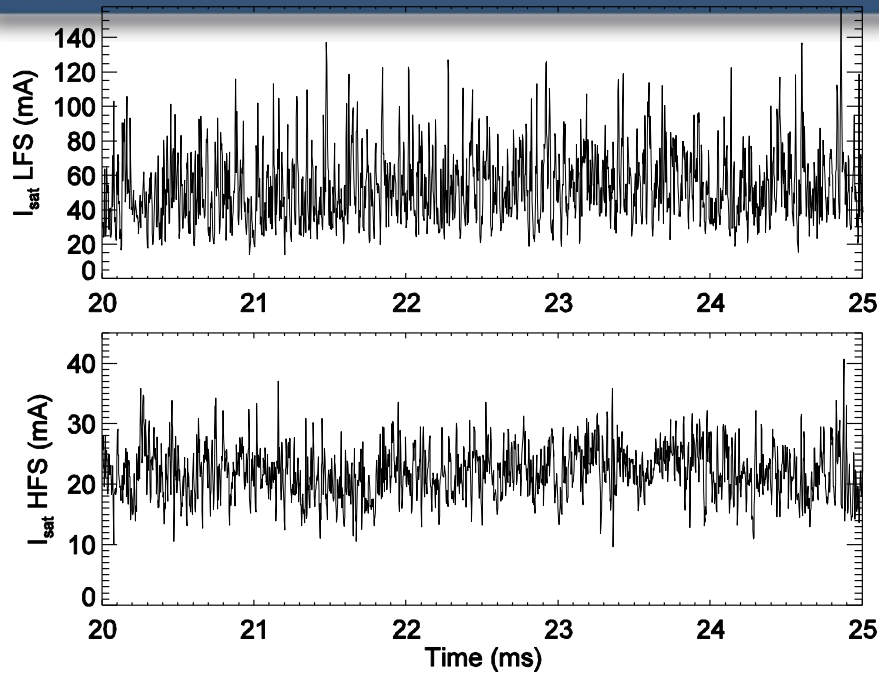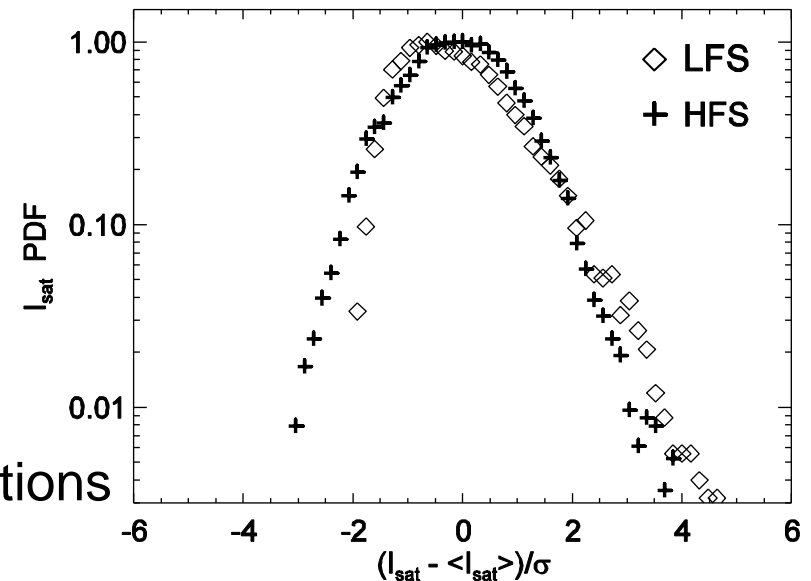
$$V_f = V_p - \alpha \frac{T_e}{e}$$

- Set of 4 probes distributed along the poloidal cross section
- Measure poloidal asymmetries & plasma position
- Availability: permanent
- Scientific and operational diagnostic (plasma position)

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Comparison LFS/HFS fluctuations

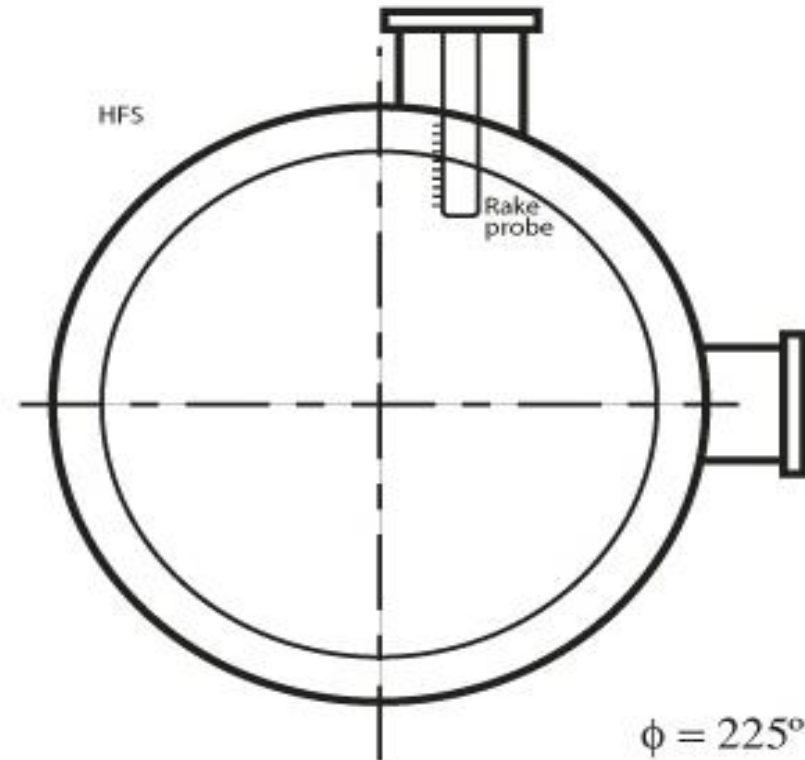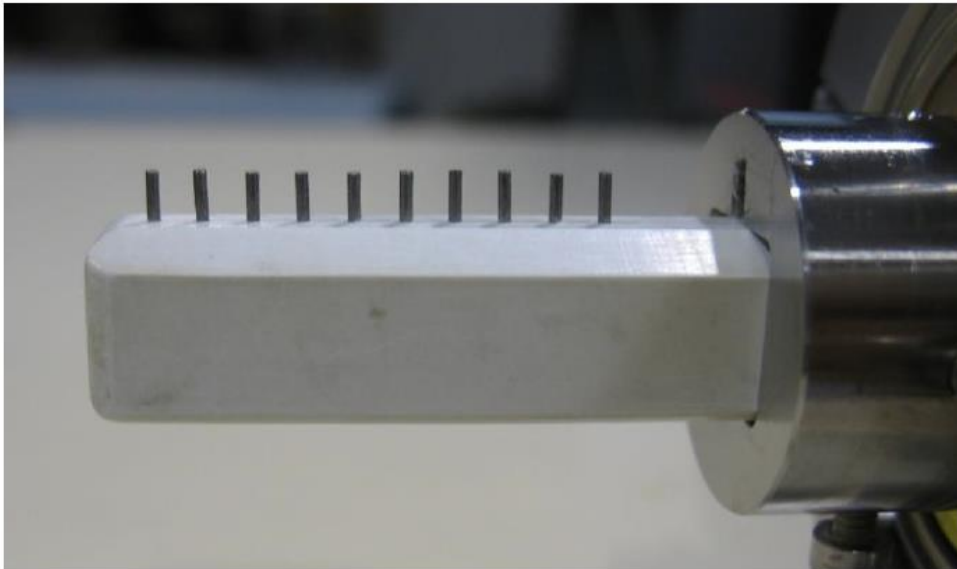|	I_{sat}	σ_{Isat}	S_{Isat}	K_{Isat}
LFS	55.6	22.3	0.95	0.9
HFS	22.1	4.5	0.25	0.4

❑ LFS: Large asymmetric fluctuations
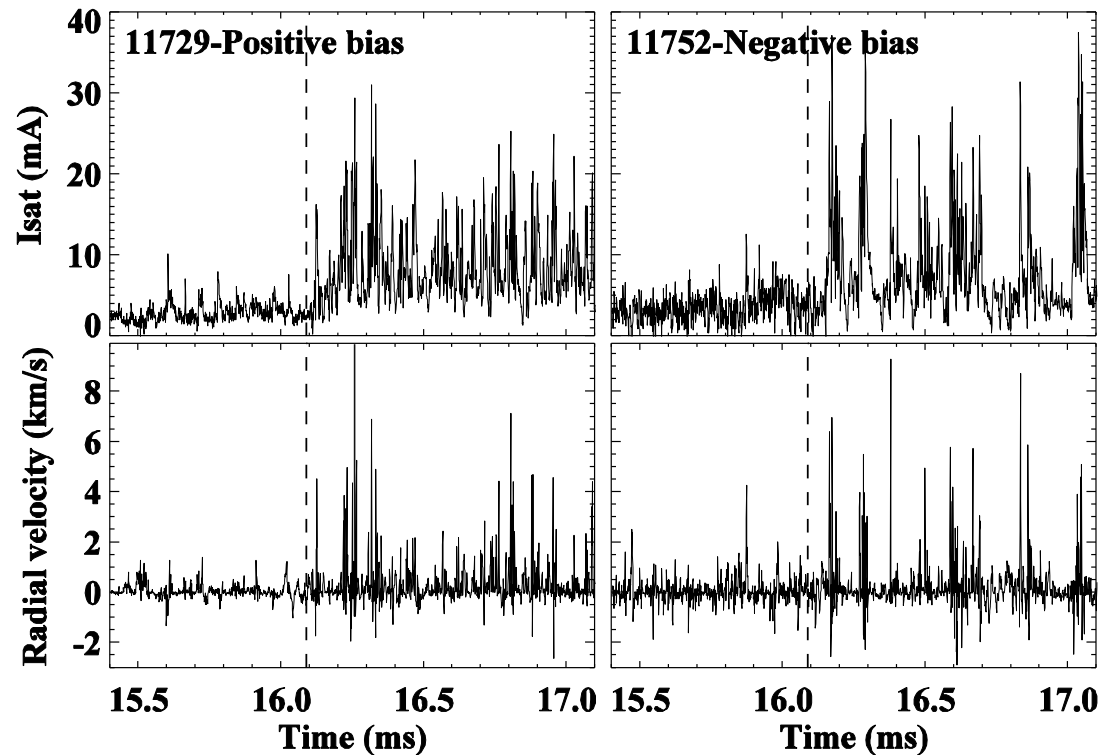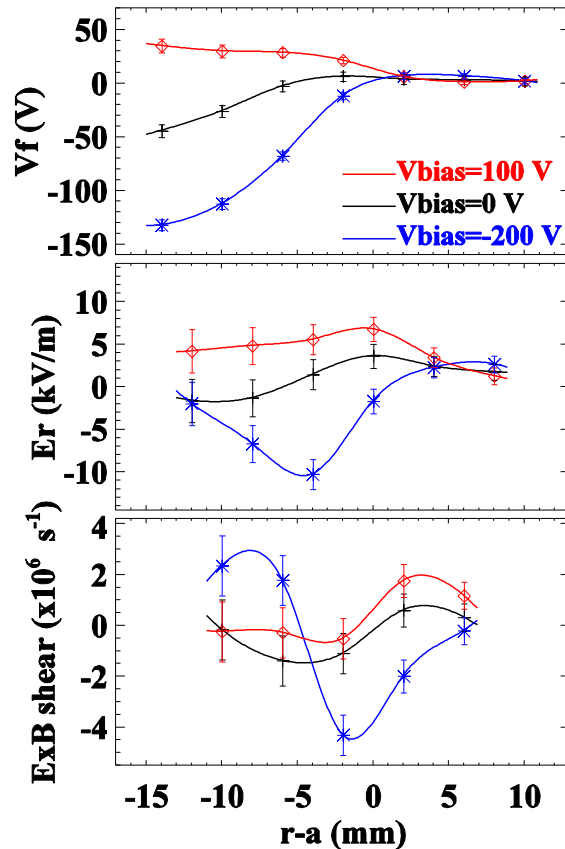
❑ HFS: Low amplitude Gaussian fluctuations

- 10 probes radial direction (separated 3 mm)

- Radial profiles of n_e, T_e; V_f, I_{sat}

- Scientific diagnostic

- Availability: permanent

HFS

Rake probe

$\phi = 225°$

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Edge plasma studies with probes

- ❑ Determination of plasma parameters in different regimes
- ❑ Heat and particle loads
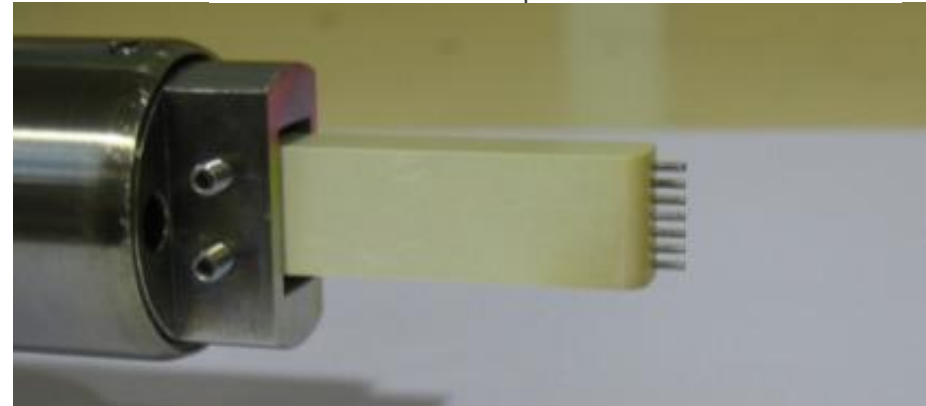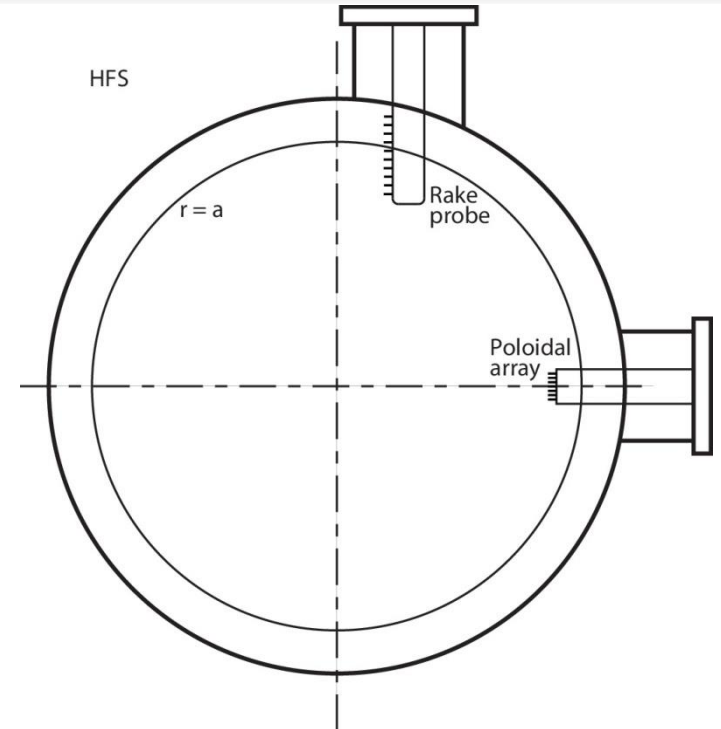- ❑ *Characterization and control of turbulence*
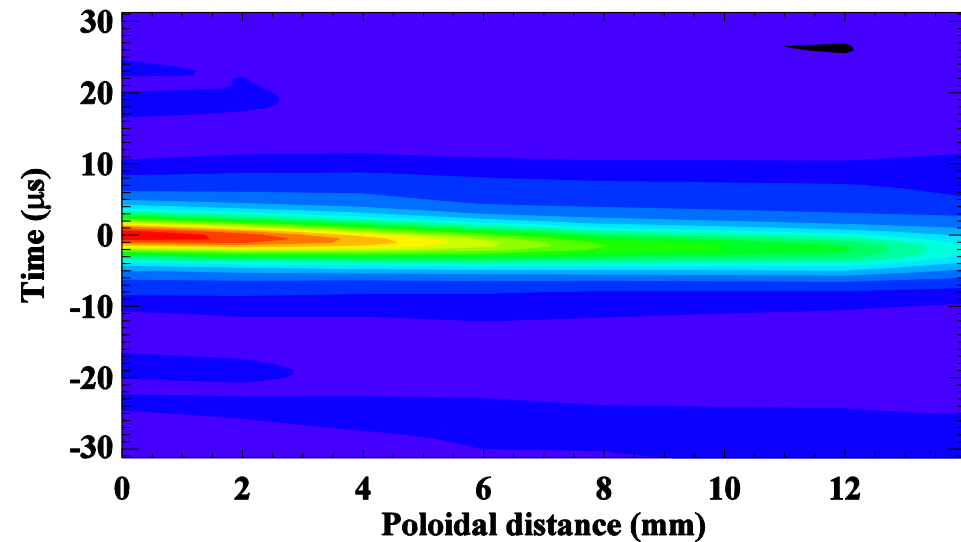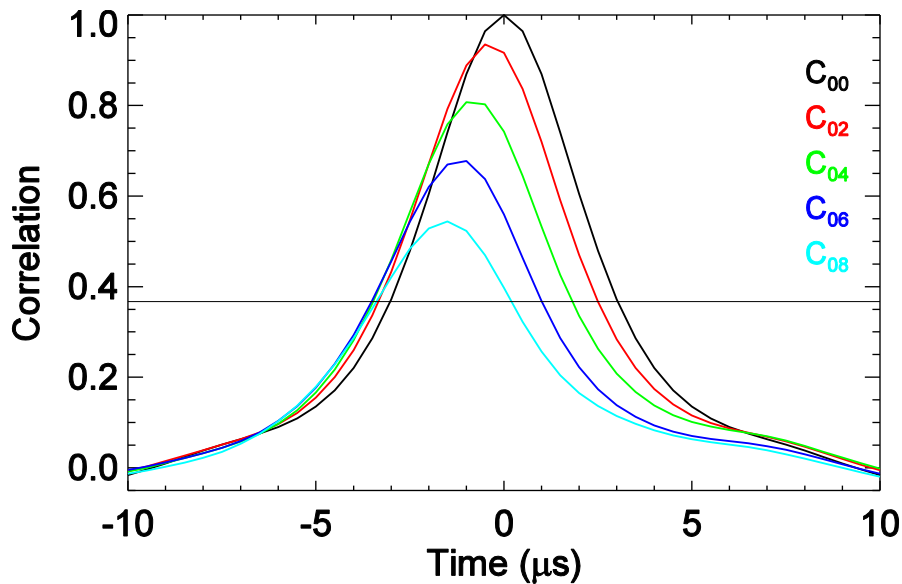
Electric probes: poloidal 7 pin array

- Poloidal array of 7 probes (Δx=2 mm).

- Parameters: V_f and I_{sat}

- Cross-correlation to study turbulence

- Turbulent particle flux:

$$\Gamma_{E\times B} = \left\langle \tilde{n} \tilde{E}_\theta \right\rangle / B$$
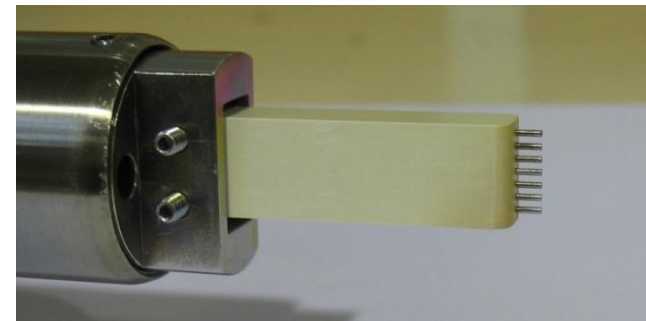
- Availability: on request

- Scientific diagnostic

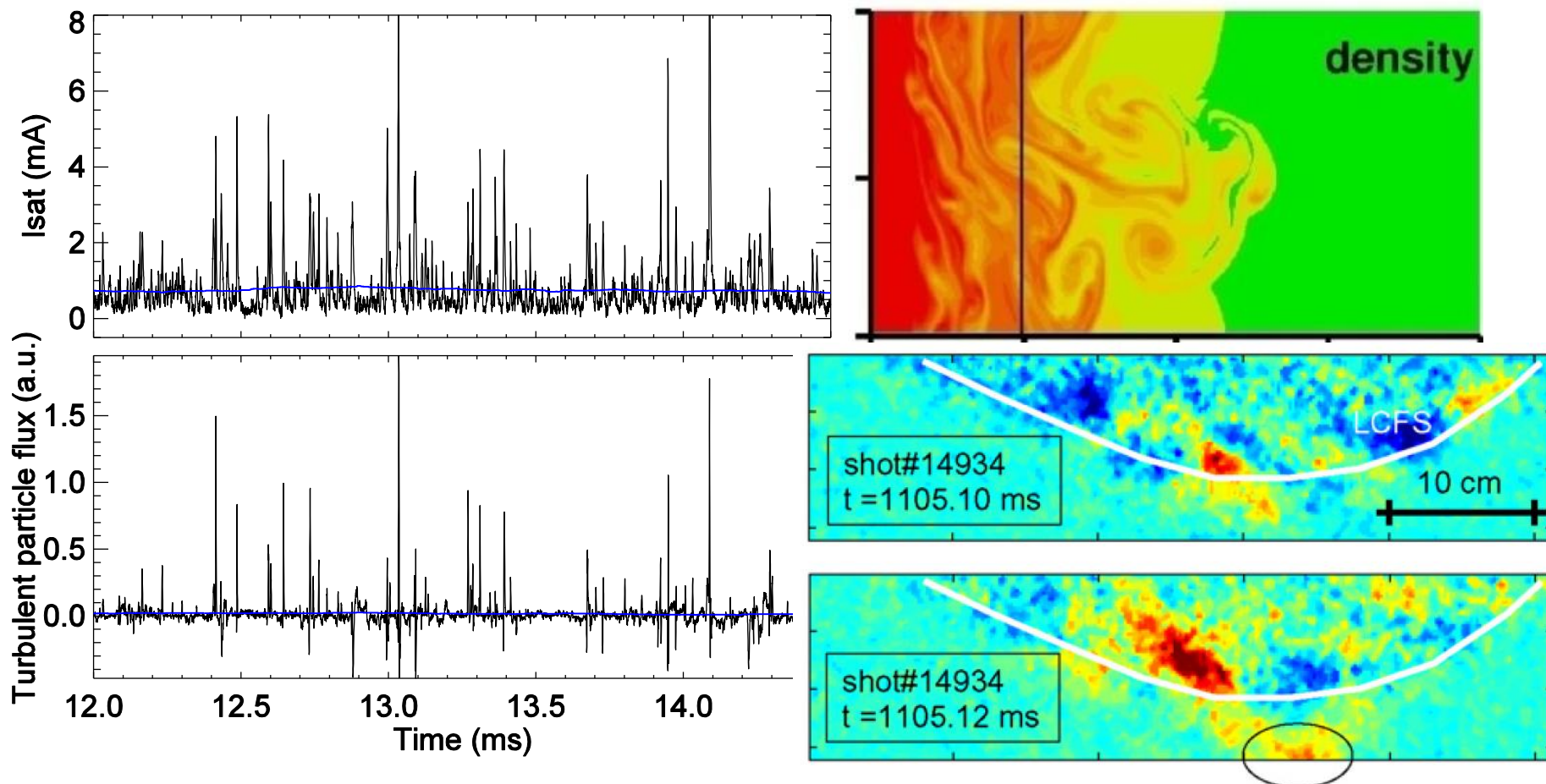Parameters estimated from cross-correlation

❑ Propagation velocity (time delay)

❑ Correlation length

❑ Characteristic time of the fluctuations

□ Transport caused mainly by filaments: intermittent convective bursts associated with large radial transport

- SOL: consistent with the typical broad band turbulent fluctuations
- Edge: dominated by low frequency fluctuations with low poloidal wavenumber
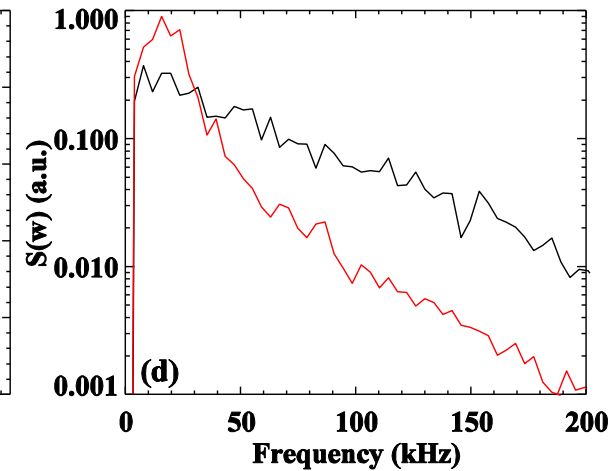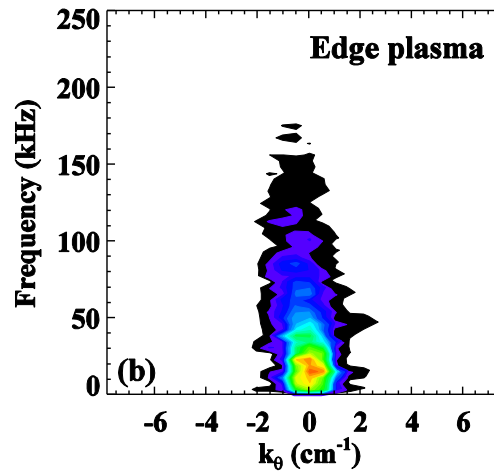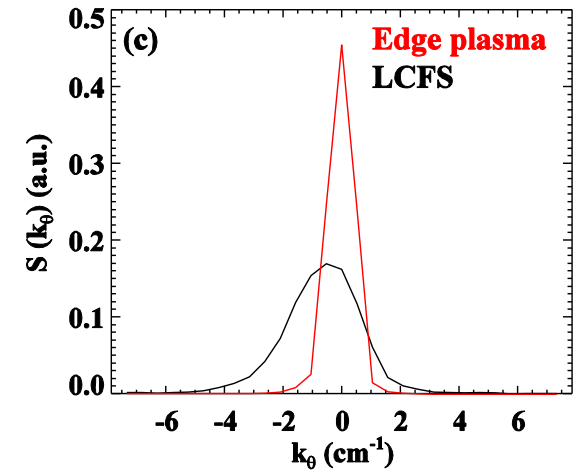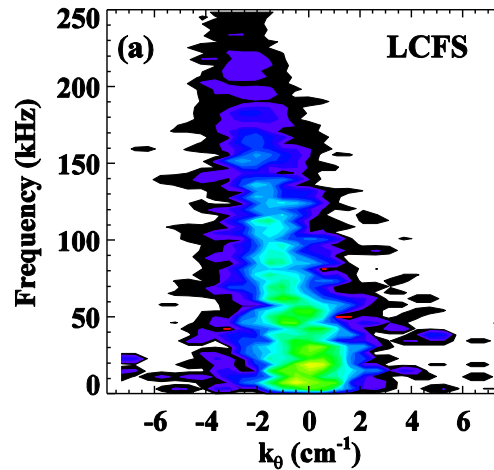
Electric probes: Vorticity

- Determination of the poloidal plasma rotation and floating potential profiles, Reynolds stress ($E_r E_\theta / B^2$)

- Availability: mounted on probe manipulator
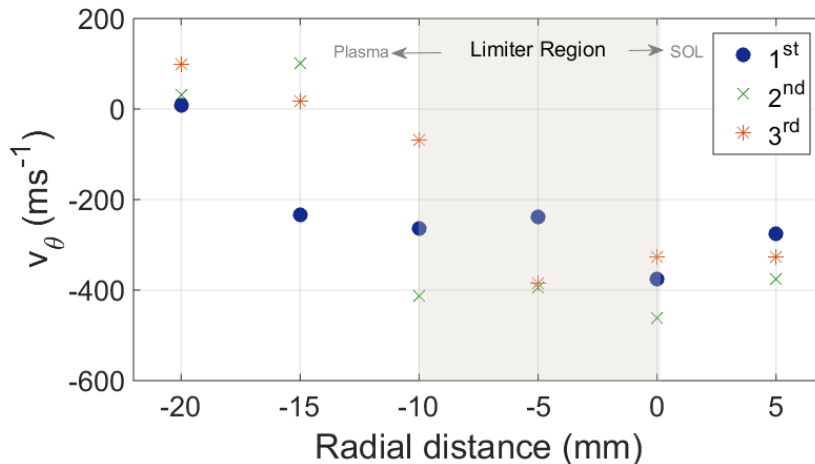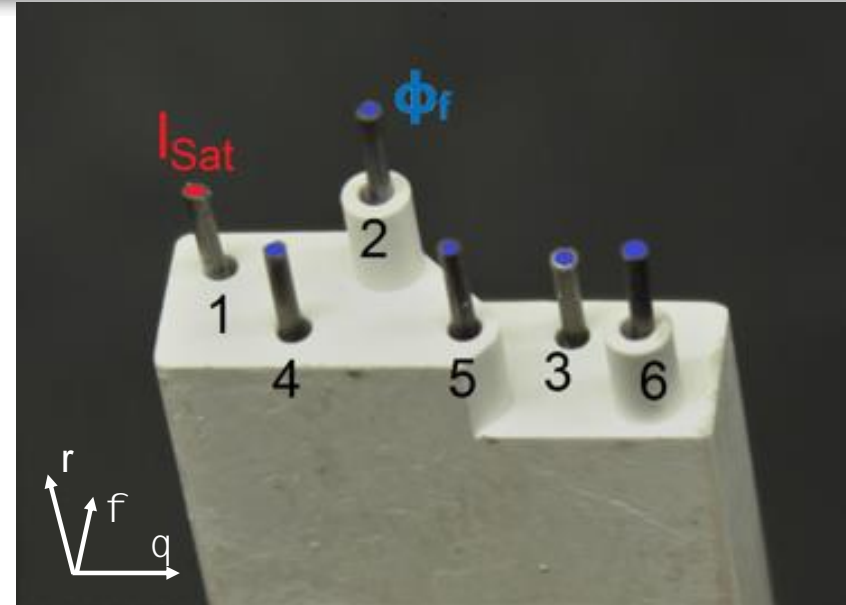
Retarding Field Analyzer

- **Langmuir probes cannot provide information on T_i:** requires measuring ion current at positive voltages at which the current to the Langmuir probe is dominated by highly mobile electrons.

- RFA measures ions energy distribution

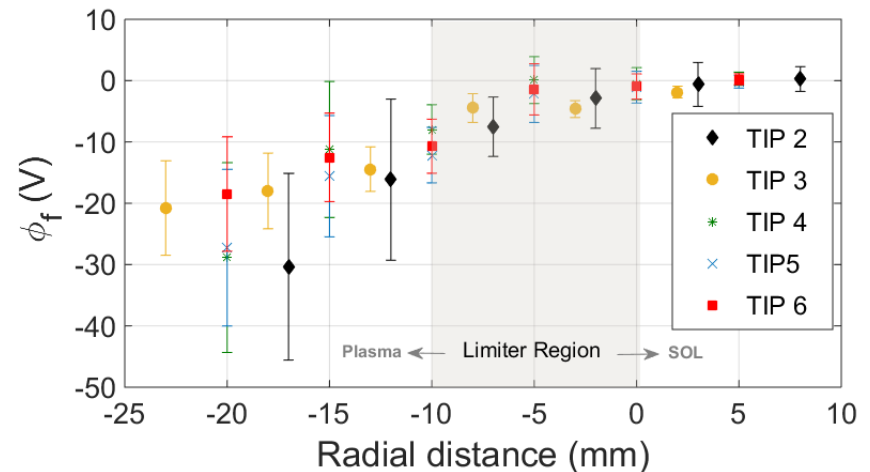- RFA operation: The slit plate is biased negatively to repel electrons. The transmitted ions are retarded in the electric field created by a swept positive voltage applied to grid 1. The collector measures the ion current

- Availability: not installed
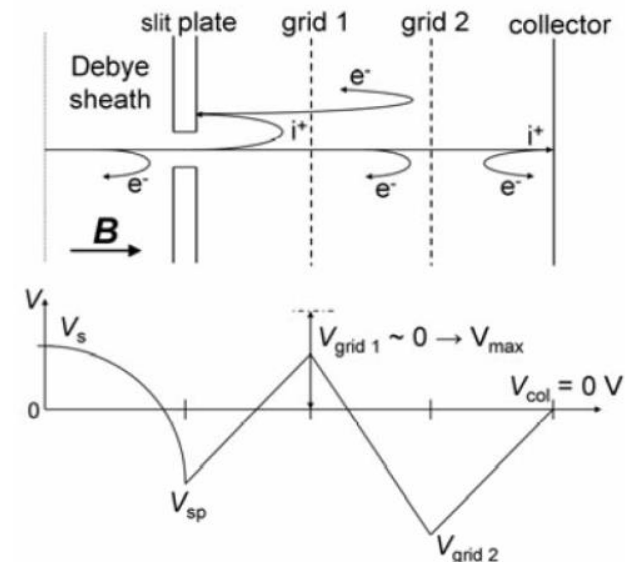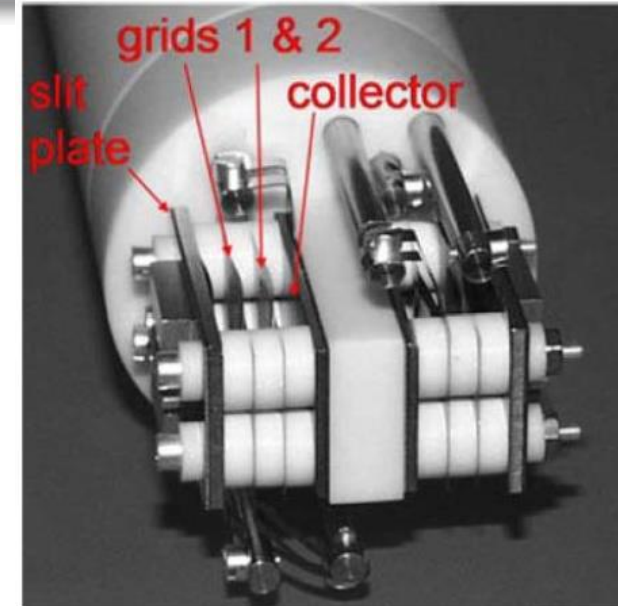
Magnetic probes

- **Rogowski coils:** There are two coils of this type, with 500 turns each and 3.25mm in diameter, measuring both the internal (plasma) and the external (total) toroidal currents:

$$V = -\frac{A.\,N.\,\mu_0}{2\pi R}\frac{dI}{dt}$$

- Availability: permanent.

- **Toroidal loop**: This diagnostic is constituted by a single loop around iron core.

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

- **sine/cosine coils**: loop density varying as sine/cosine to measure plasma displacement.

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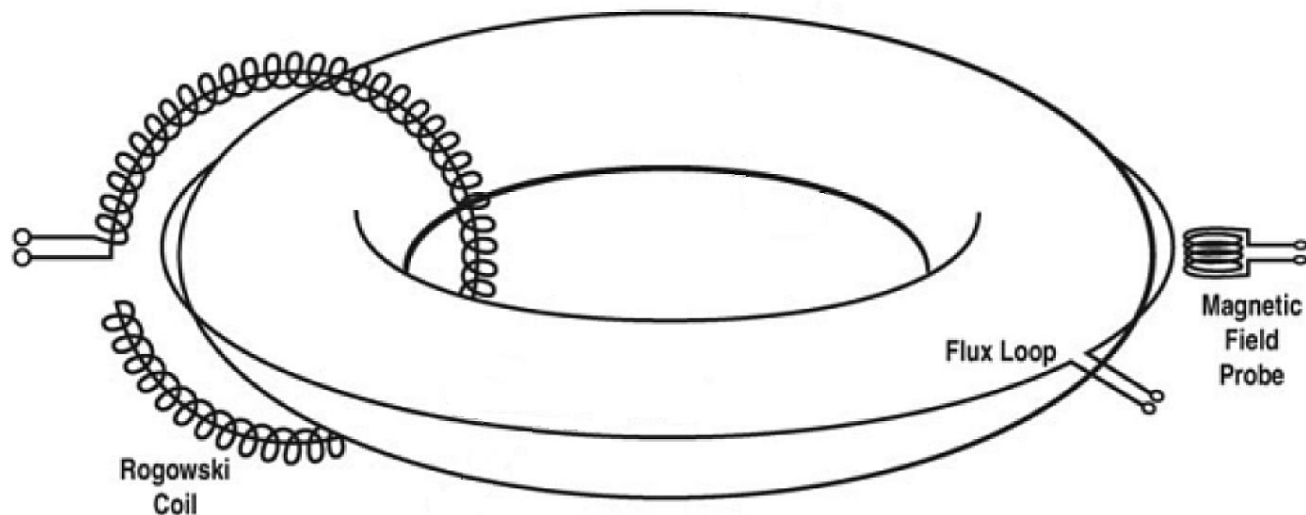
- **Mirnov coils:** poloidal array of 12 Mirnov coils (50 turn 25 mm^2) used to study the plasma MHD activity and to evaluate the plasma position:

$$R_p = \frac{\sum_{i=1}^{N} R_{probe}^i \times H_p^i}{\sum_{i=1}^{N} H_p^i}$$

$$V_p = \frac{\sum_{i=1}^{N} V_{probe}^i \times H_p^i}{\sum_{i=1}^{N} H_p^i}$$

- Availability: permanent
- Input to real time system for feedback to plasma position control
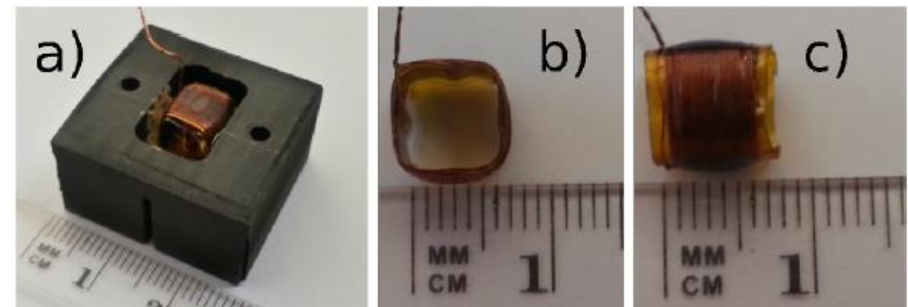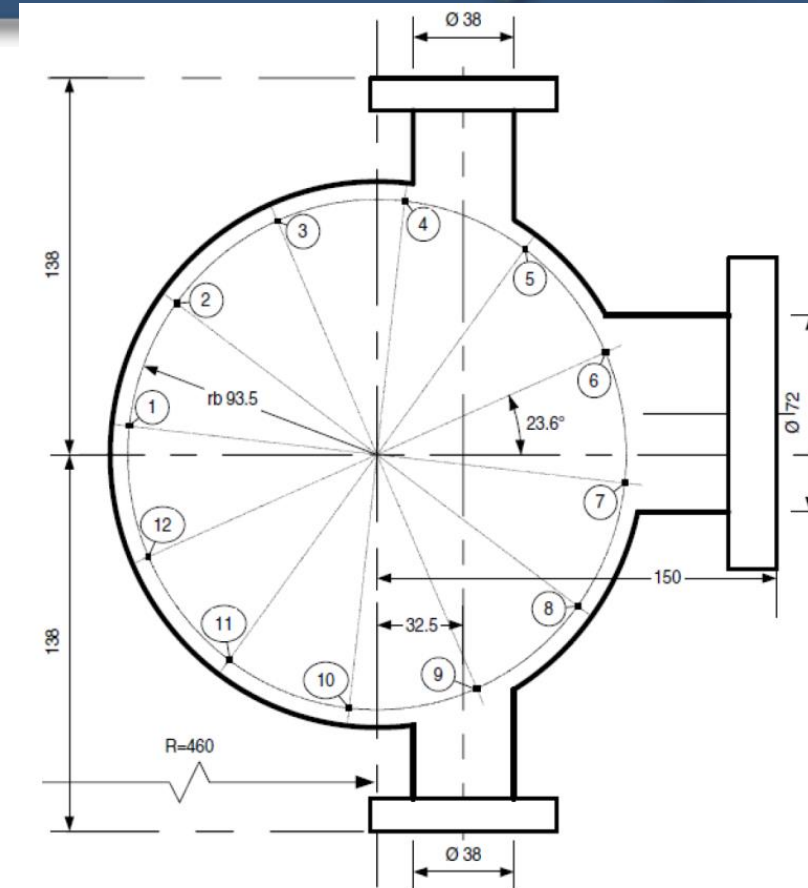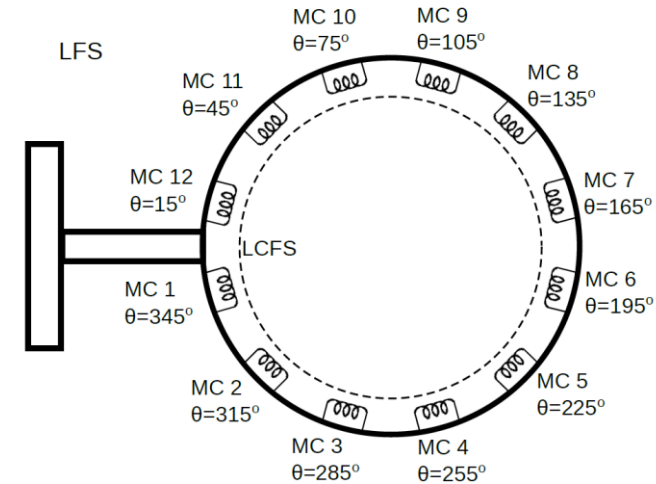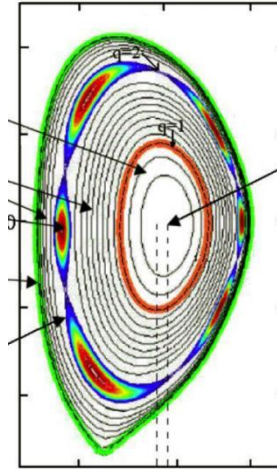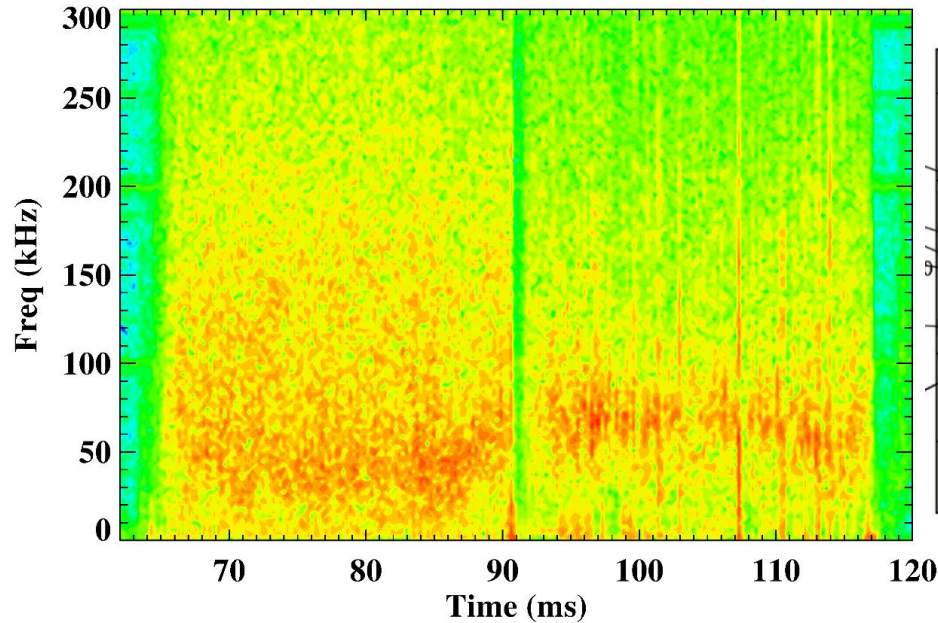
- MHD mode visible in the spectrogram
- Modes rotate
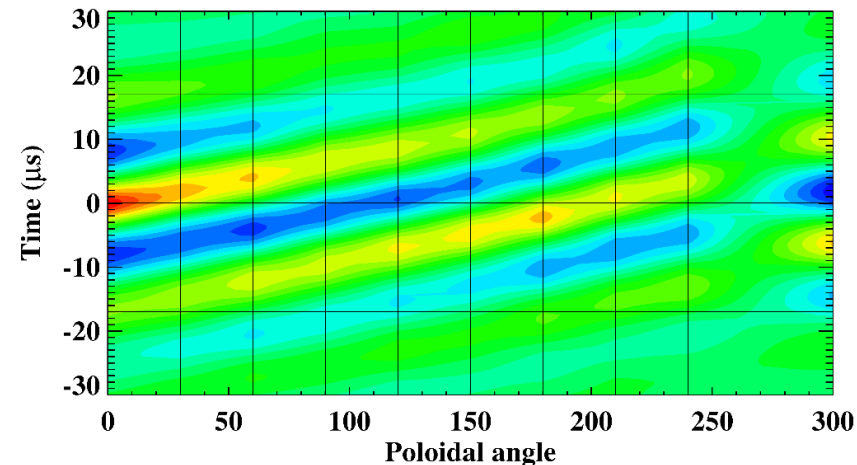
Spectroscopy diagnostics

- Spectrometers:

  - High resolution McPherson model 2051

  - CVI DK480 CCD

  - Broadband spectrometer

- Line radiation monitors:

  - Filtered photodiodes

  - Filtered photo-multiplier tubes

input slit

grating

exit slit

M_1

M_2
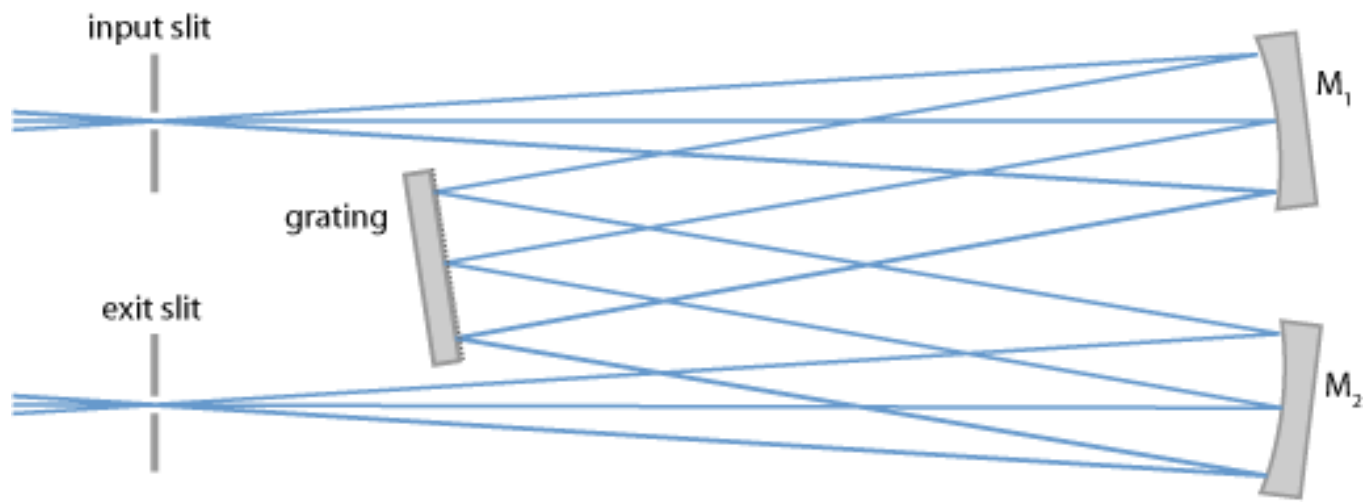
Spectrometers: McPherson 2051

- f/8.7, 1 m focal length.

- Resolution:0.1 Å with 1200 g/mm grating, blazed @ 500 nm, 110x110 mm^2.

- Inverse dispersion: 8.33 Å/mm.

- Sensor: Alton LS2000 PCCD (14x200 μm) / Intensified.

- Availability: on request

- Measurement: ion temperatures in visible.

ISTTOK spectra obtained with McPherson 2051
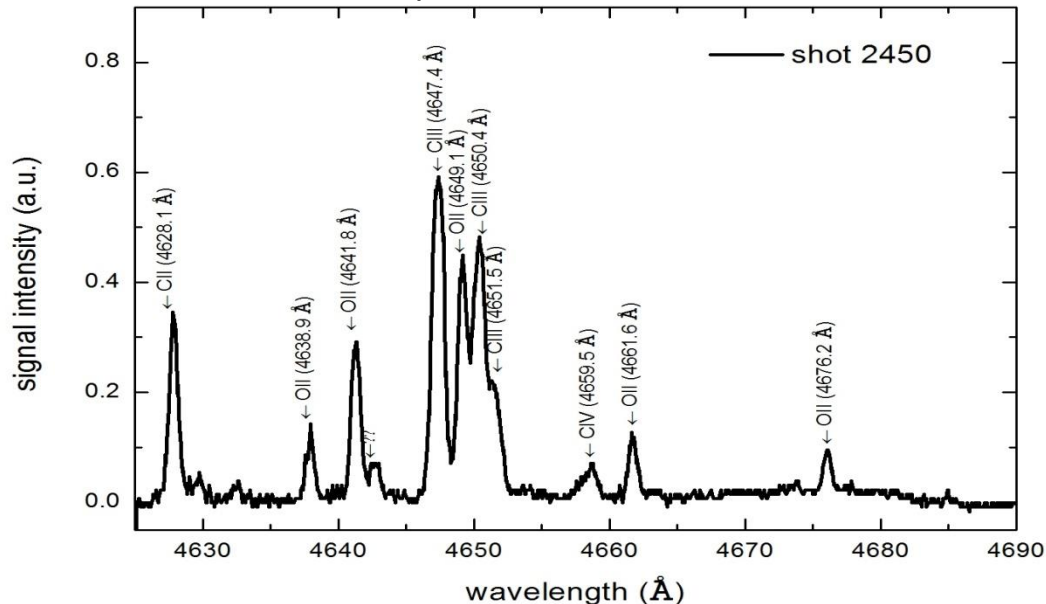
Spectrometers: CVI DK 480i

- Imaging spectrograph, f/7.8, 1/2 m focal length.

- 3 x grating turret, 1200 gr/mm, blazed at 300, 500 and 750 nm, 68x68 mm^2.

- 0.6 Å resolution.

- 16 Å/mm inverse dispersion.

- High sensitivity, fast EMCCD camera (Andor iXon 888), 1024 x 1024 pixels,13x13 μm^2

- Measures: impurity line intensity

- Availability: on request
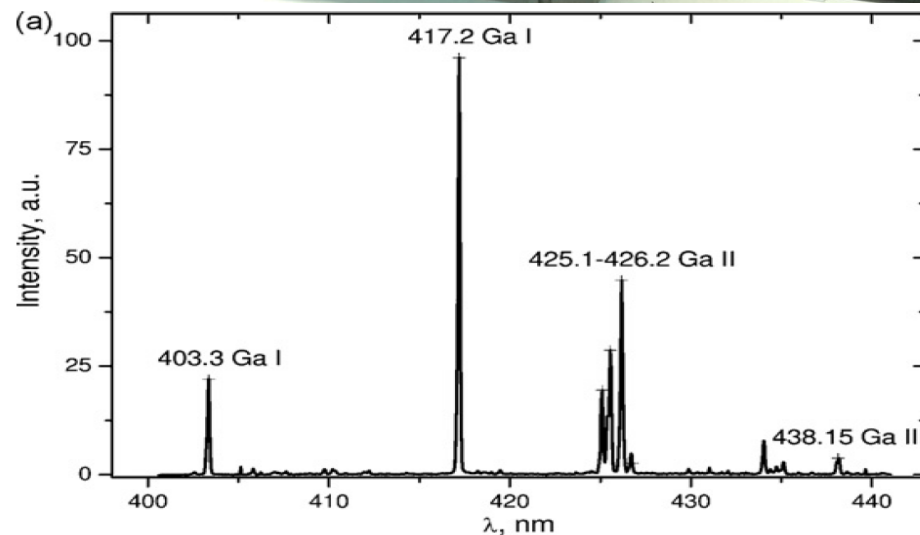
Characteristic ISTTOK spectra obtained during plasma-gallium jet interaction studies

Spectrometers: SARSPEC Spec Res+

- Compact (12x 9 x 6 cm³), fully integrated low resolution (6 Å), broadband spectrograph.

- 600 g/mm blazed @300 nm.

- Spectra from 200 to 900 nm.

- 3648 pixels linear array CCD sensor (8 x 200 µm).

- Availability: permanent.

- Measures plasma impurity content in UV/VIS/NIR.
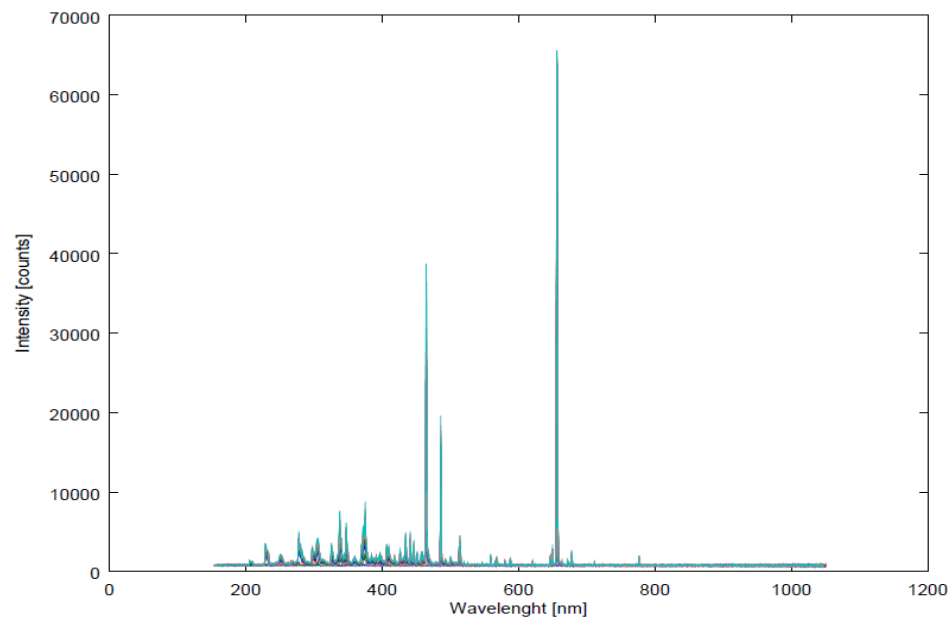
Line radiation monitor

- Filtered Si-photodiode for Hα temporal evolution + 3 nm narrow band filter.

- Operation diagnostic (input for gas puffing control).

- Availability: permanent.

- H7422 Hamamatsu Photo sensor module with narrow-band filter (3-10 nm) for low sensitivity lines (CIII , OII, …) .

- Availability: on request
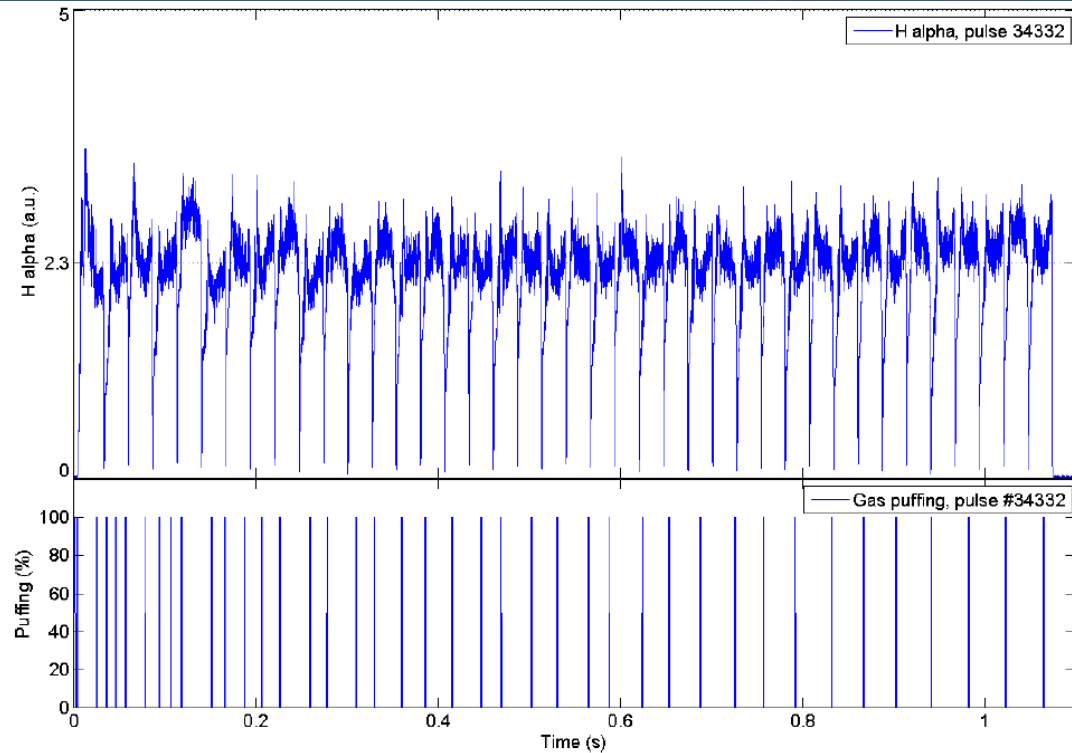
Tomography (1)

- Plasma emissivity (~power) reconstruction from line integrated signals.

- 3x 10 pixel camera system. Sensitive from soft Xray to visible

- Multiple, complex algorithm:

    – Filtered backprojection
    – Cormack basis functions
    – Constrained regularizations
    – Neural Networks

- Was used in the past for plasma position control
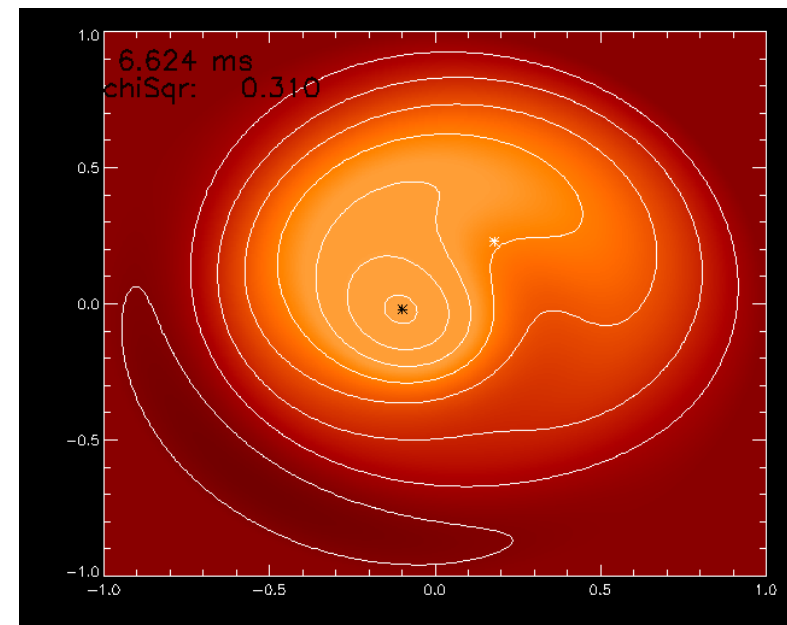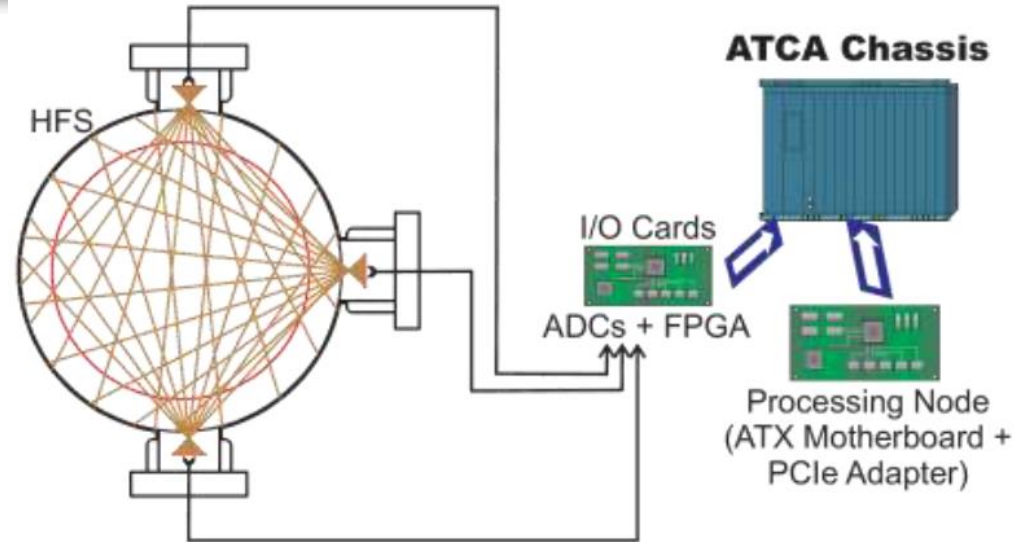
- Old system is being upgraded.

- 3 x16 pixels higher sensitivity sensor arrays (*AXUV20ELG*) + improved electronics.

- Under commissioning

- Availability: under development.
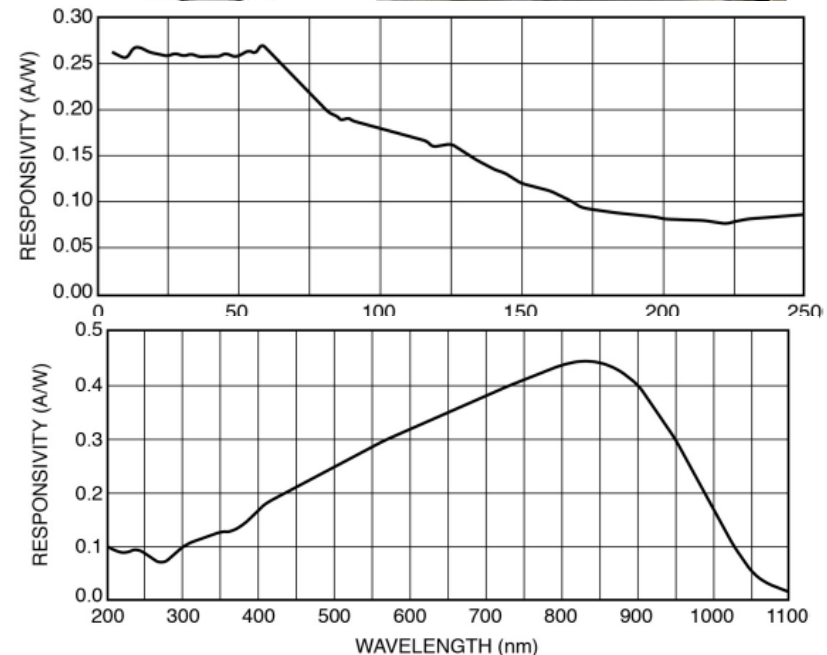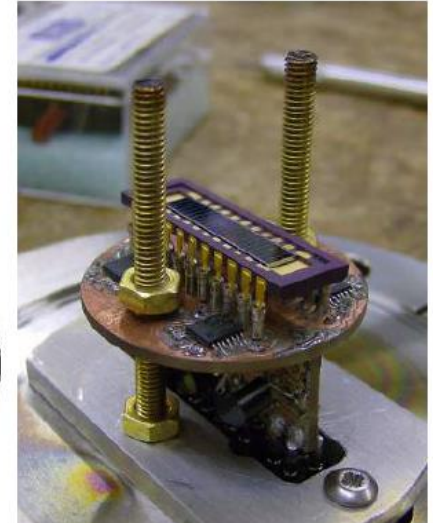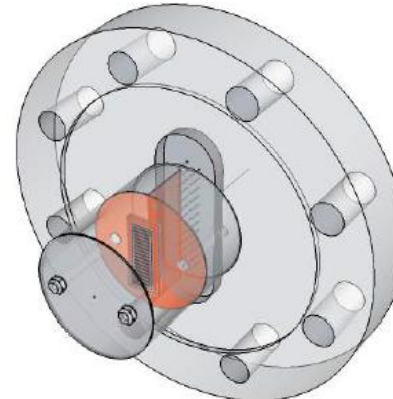
Interferometer

- Wave injected into the plasma suffers a phase shift

- 1 channel, 100 Ghz probing frequency

- Measures line average density (r=0)

- Suitable microwave electronics compares phase shift of transmitted wave with reference

- May required phase jump correction

- Availability: permanent

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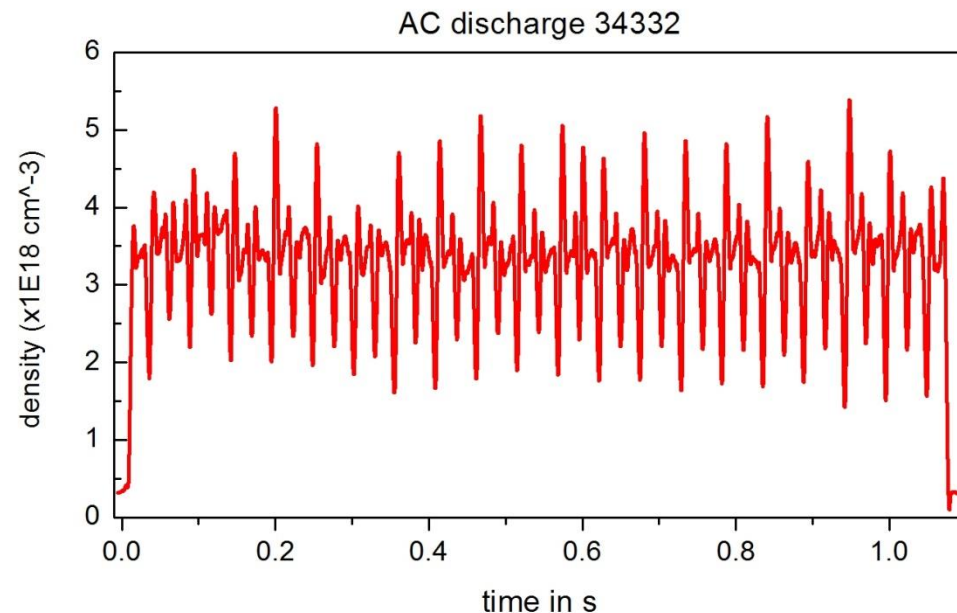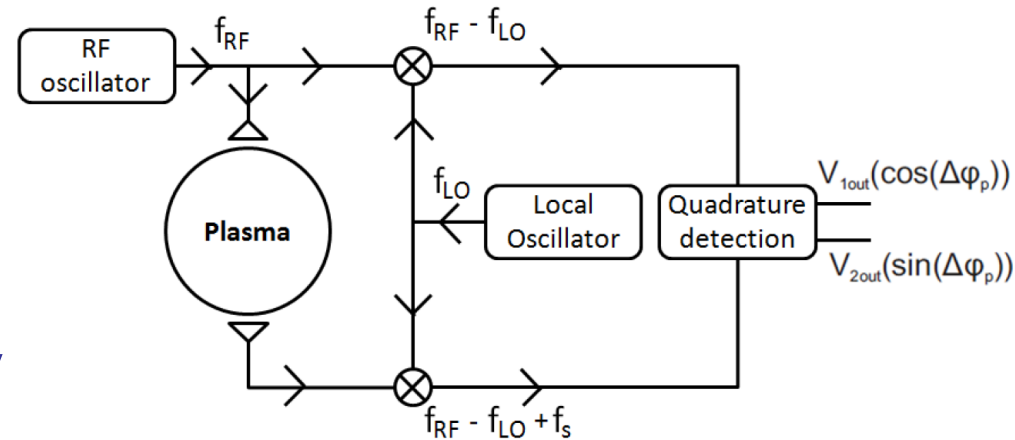
Heavy Ion beam

- 22 KeV Xe$^+$ (10 μA) is used to probe the plasma.

- Plasma characteristics achieved Xe^{2+} current on detector (14x4 Cu cell).

- Measured parameters:
  - N_e x $\sigma(T_e)$
  - V_p
  - Poloidal field

- Availability: permanent.

- Scientific diagnostic.

Ion source (Xe$^+$)

Accelerator and beam focussing system

Supplementary defelction system

Vaccum pump (turbo-molecular)

Pulser plates

Slit

Beam deflection system

Gate valve

Primary ion beam (Xe$^+$)

Vacuum chamber

Secondary ion beam (Xe^{2+})

Improved MCAD (secondary ion detector)

Primary ion detector

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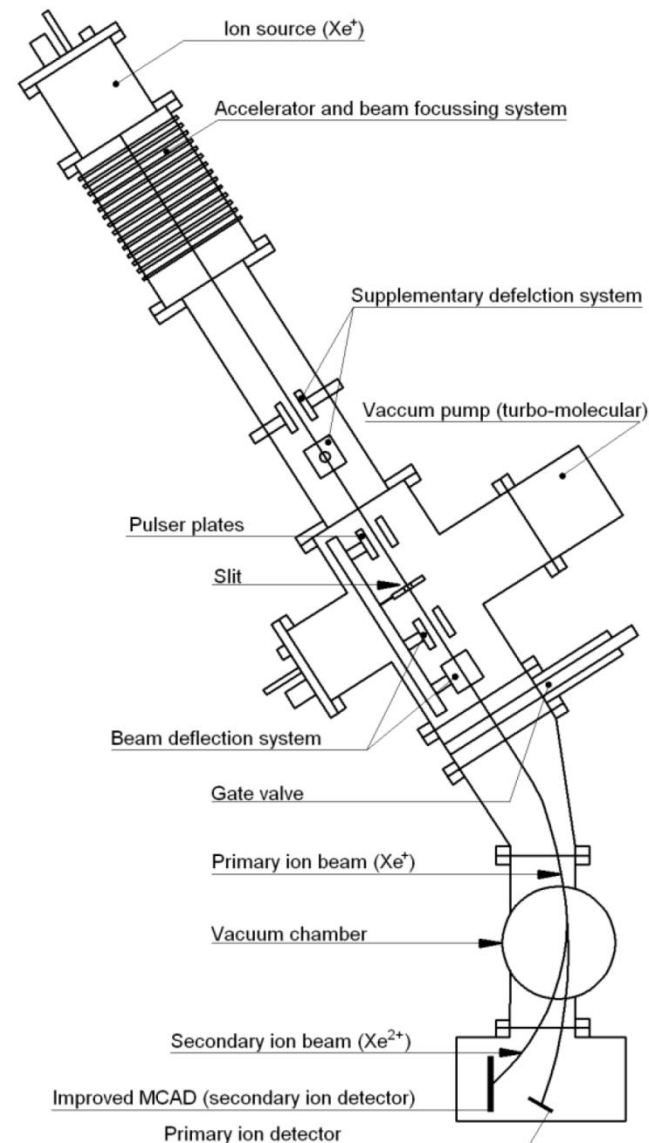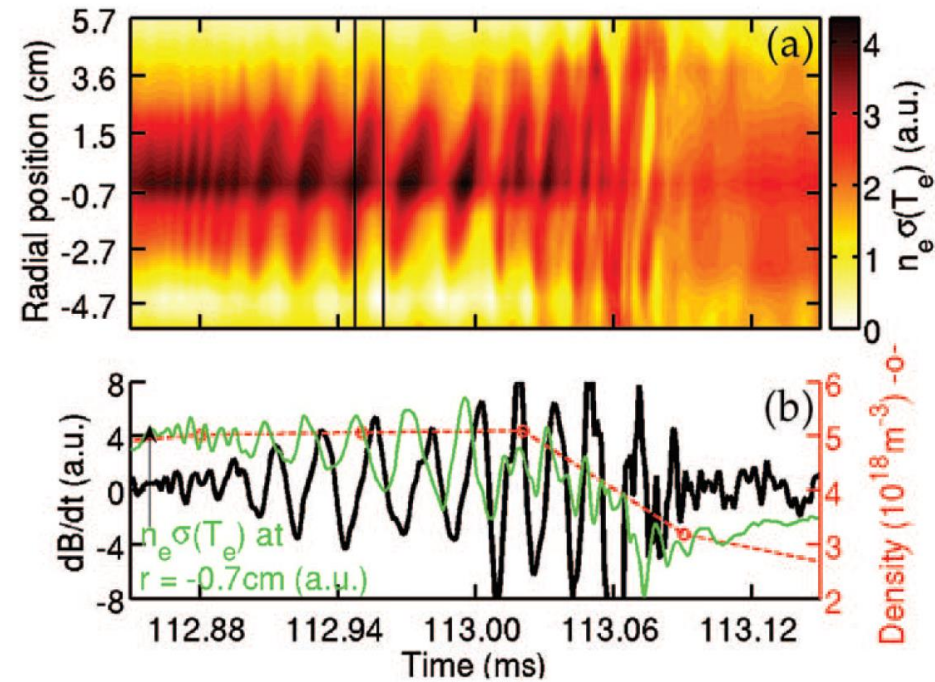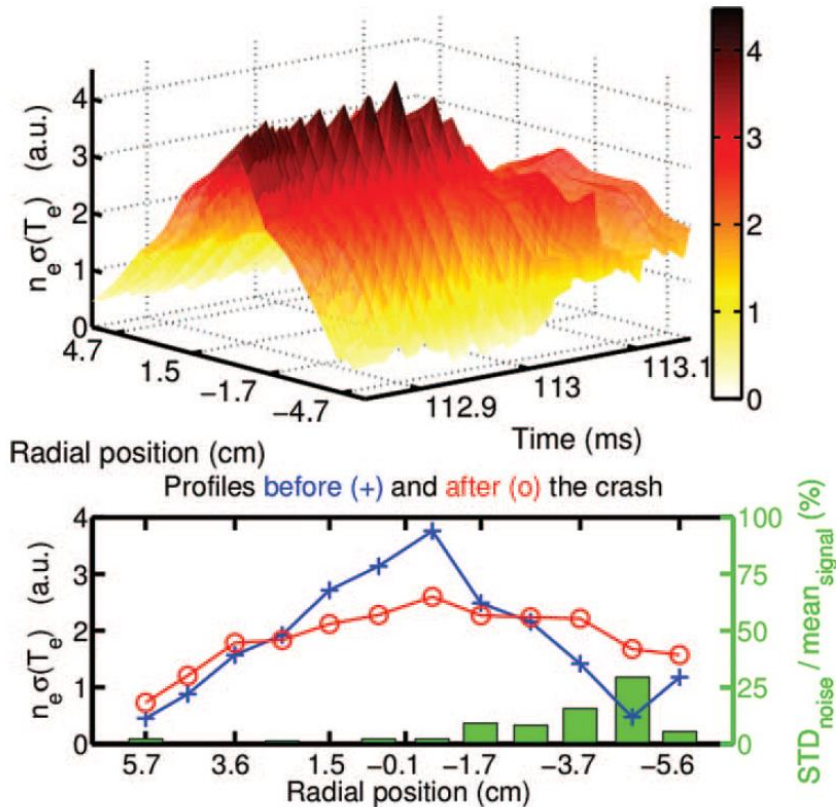
Further lectures on diagnostics

Time	Monday 22/7	Tuesday 23/7	Wednesday 24/7	Thursday 25/7	Friday 26/7
9h00 10h30	ISTTOK research activities H.Fernandes	Tokamak engineering I H.Fernandes	Tokamak engineering II H. Fernandes	Data acquisition in fusion devices J. Sousa	Tomography D.Ferreira
10h45 12h15	ISTTOK diagnostics C. Silva	Heavy Ion beam diagnostic A.Malaquias	Electric probes H.Figueiredo		Magnetic probes B.Carvalho
12h15	Lunch	Lunch	Lunch	Lunch	Lunch
14:00h 17:00h	Database access and hierarchy A.Duarte	Students' presentation Data analysis B.Carvalho	Crash course on Python L.Guimarães	MHD Activity by HIBD A. Melnikov Visit to ISTTOK H. Figueiredo	Electric probes exp. H.Figueiredo
17h	**Adjourn**	**Adjourn**	**Adjourn**	**Adjourn**	**Adjourn**

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Further lectures on diagnostics

Time	Monday 29/7	Tuesday 30/7	Wednesday 31/7
9h00 10h30	Plasma control D. Corona	Interferometry / HIBD J. Santos/I.Nedzelskiy	Interferometry / HIBD J.Santos/ I.Nedzelskiy
10h45 12h15	Tokamak operation H.Figueiredo		
12h15	Lunch	Lunch	Lunch
14h 17h	Magnetic probes/Tomography diagnostic B.Carvalho & D.Corona / R. Cardoso & H.Fernandes	Magnetic probes/Tomography diagnostic B.Carvalho & D.Corona / R. Cardoso & H.Fernandes	Course conclusions/Draft papers H.Fernandes
17h	**Adjourn**	**Adjourn**	**Closing session**