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The Graduate University for Advanced Studies
Sokendai

Edge MHD Mode Structure and Effect from the Externally Applied Magnetic Field in LHD

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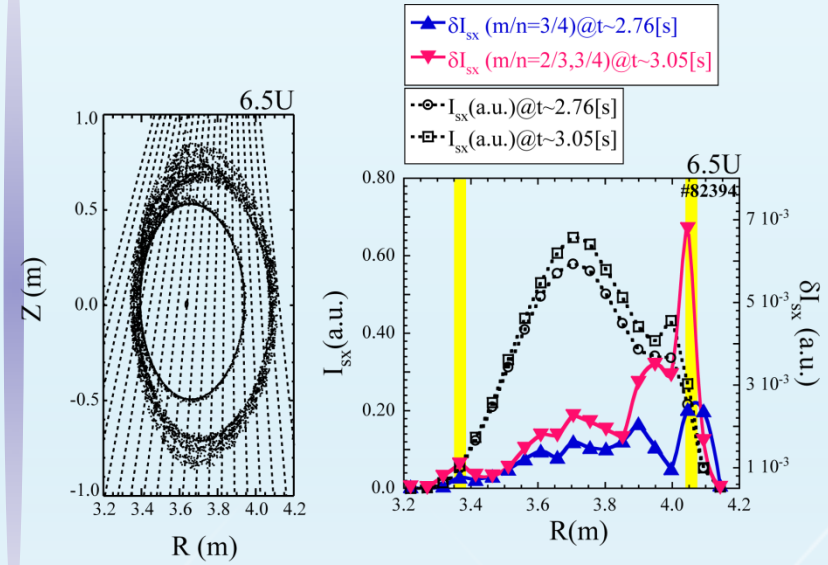
Outline

1. Motivations
2. High speed VUV camera system on LHD
3. Principle for 2D image simulation
4. Experiment results
5. Summary

Motivations

- ELMs are dangerous to in-vessel components of magnetic fusion devices.
- RMPs were found to suppress ELMs in some tokamaks, (*T.E. Evans, et al, 2004,VOLUME 92, NUMBER 23*)



- MHD mode structure is modified due to the existence of RMP on LHD. (F.Watanabe, *et al,* Nucl. Fusion 48 (2008) 024010)
- Understandings of the interaction between the plasma and the RMP field effect on the existed MHD are important. 2D imaging measurement is tried to investigate the mode structure.

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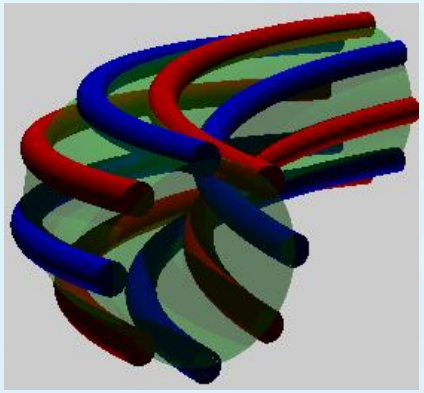
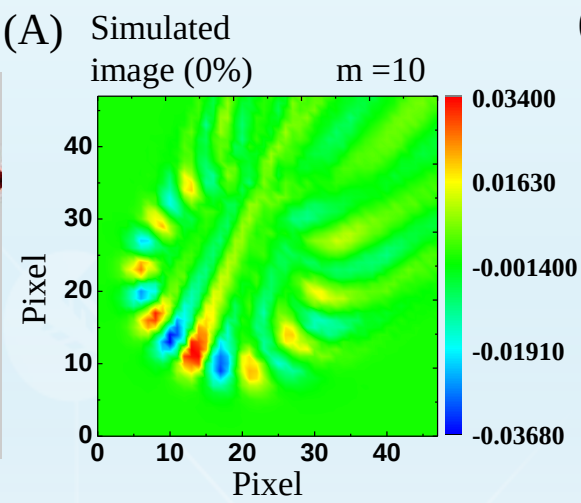
Merits of the tangentially viewing camera

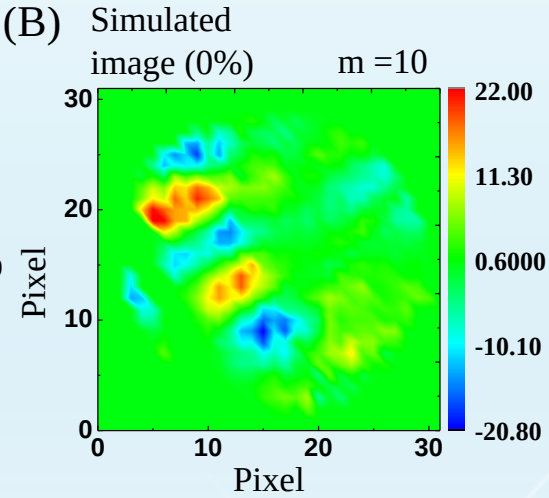
m/n=3/2



Tangentially viewing on simple torus



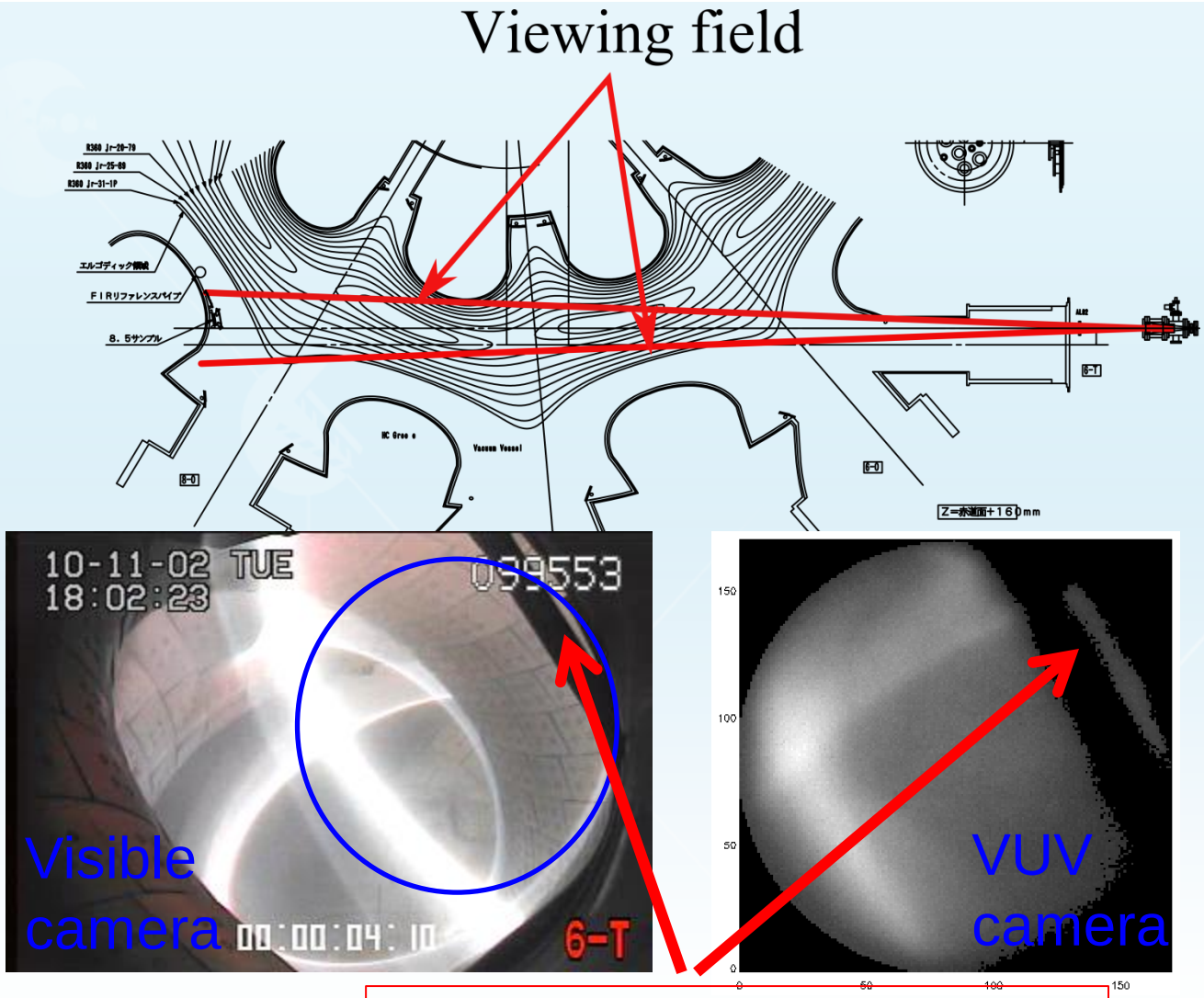
Tokamak configuration



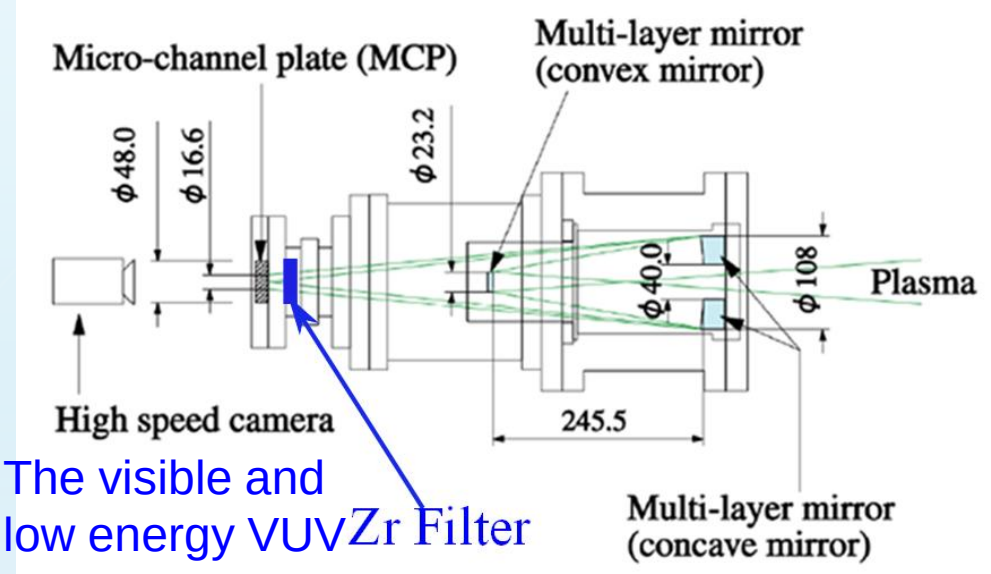
LHD configuration

- Poloidal mode number can be identified from the raw data easily without complicated reconstruction.
- However, tomographic reconstruction is required to obtain the radial structure of the mode.

Viewing field

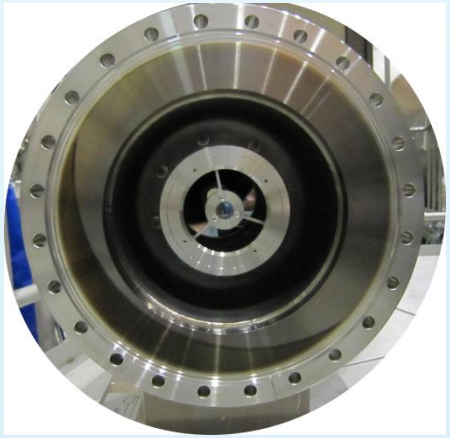


High speed VUV camera in LHD

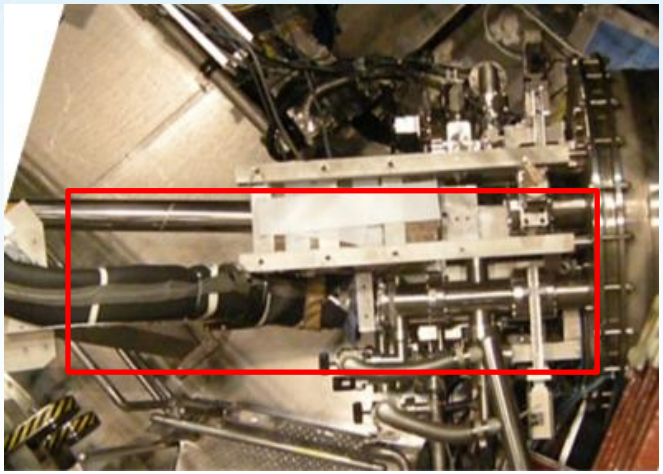


The visible and low energy VUV photons are cut off by the Zr filter

Mo/Si Mirror



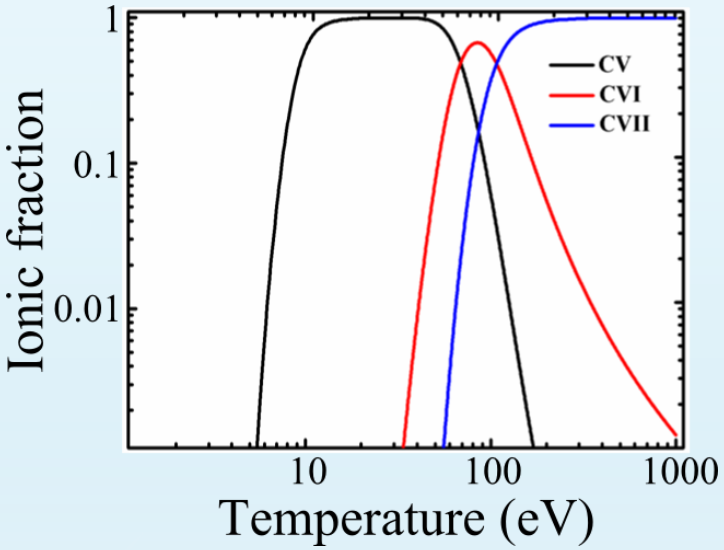
LHD 6T port



- Specifications:
  - Framing rate: 10k frames/s in 128×128 pixels
  - Focal length :7m
  - Spatial resolution: 2.5 cm

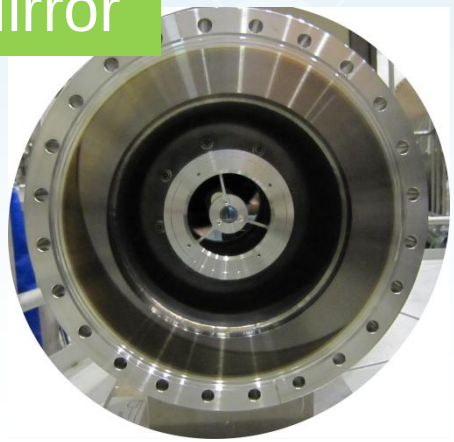
Reflectance of the multi-layer mirror

- In the edge region in LHD, line emission from CVI (13.5 nm) can be expected. The best reflectance can be obtained by Mo/Si mirror (13.5 nm), which is available commercially.
- The CVI emission is a function of the electron density, the electron temperature and the impurity density. The density fluctuations can be studied mainly.



Ionic state of carbon based on the coronal equilibrium

Mo/Si Mirror



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Principle for 2D image simulation

- For a 2D emission profile E(x,y), the *i'th* nonlocal measurement I_i can be described by

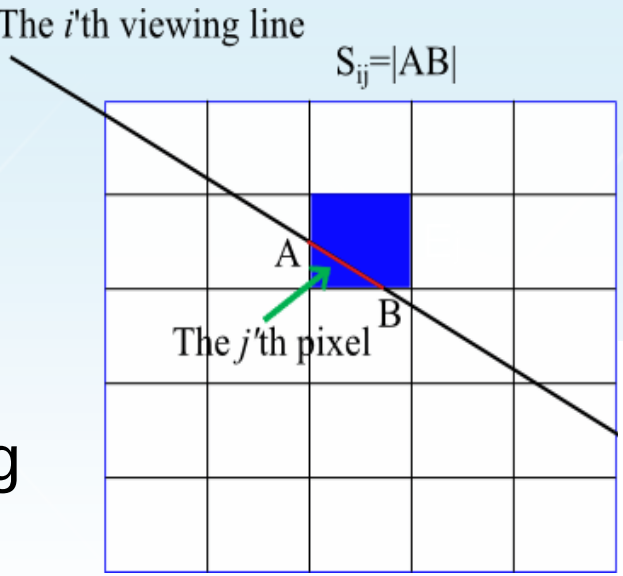
$$I_i = \iint S_i(x,y)E(x,y)dxdy \quad (1)$$

Measurement (unknown)	Weight function (known)	Local emissivity (assumed)

- The discrete algebra form of (1) :

$$\mathbf{I} = \mathbf{SE} \quad (2)$$

with $I = \begin{bmatrix} I_1 \\ \dots \\ I_M \end{bmatrix}$ $E = \begin{bmatrix} E_1 \\ \dots \\ E_K \end{bmatrix}$

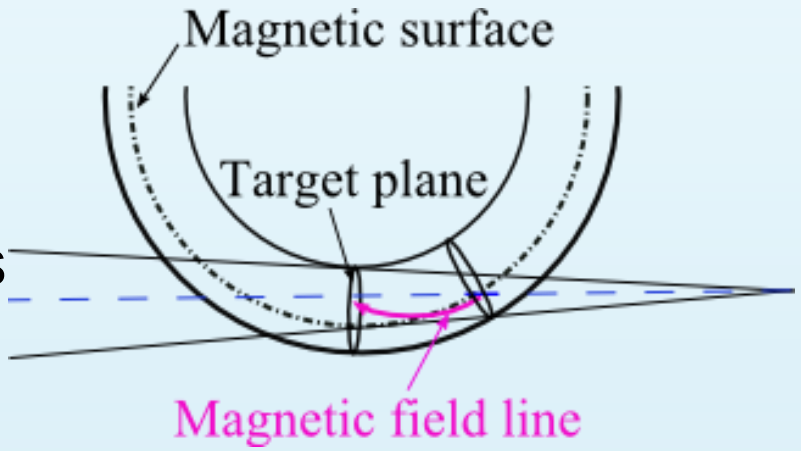


Here, M is the number of viewing lines, K is the number of pixels.

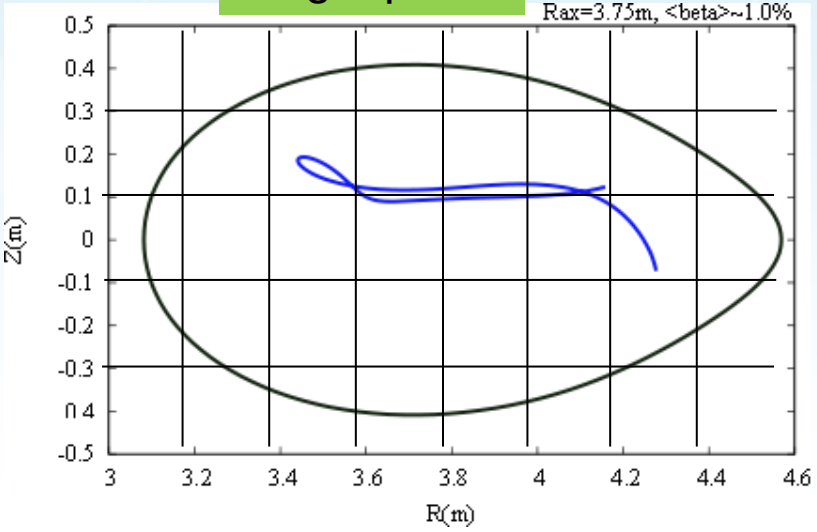
S_{ij} describes the contribution to the i*th* measurement from the j*th* pixel.

S_{ij} for tangential viewing camera system

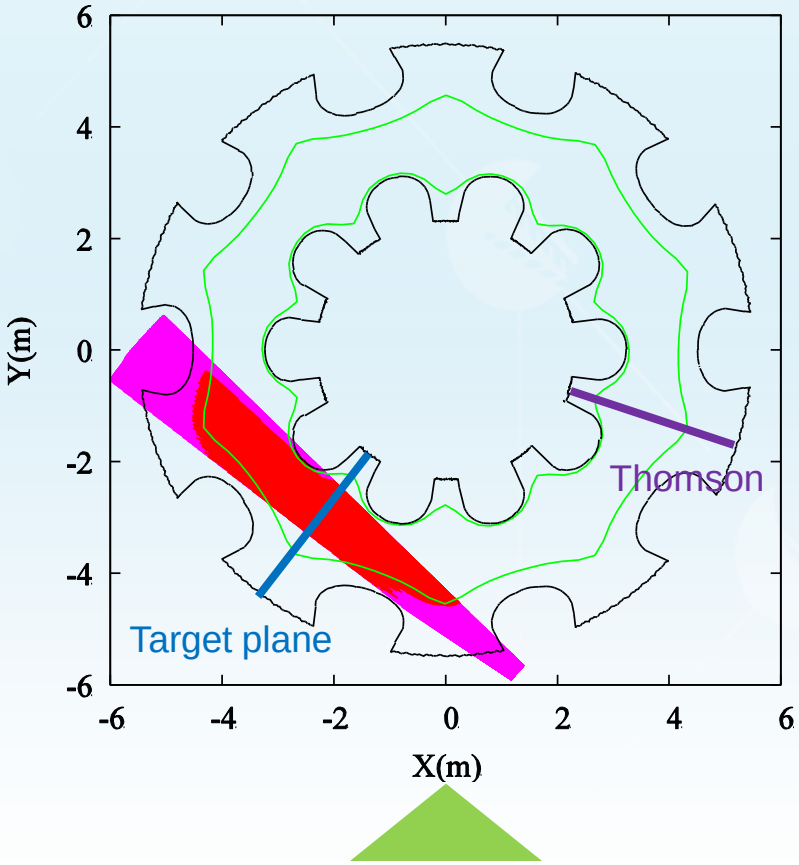
- The constant emissivity along the magnetic field line is assumed.
- Magnetic filed line traces are obtained using HINT-2 equilibrium code, which can trace the magnetic field line in the stochastic region.
- S_{ij} is obtained by counting the total number of the projected points inside the *j*'th pixel from the *i*'th viewing line.



Target plane

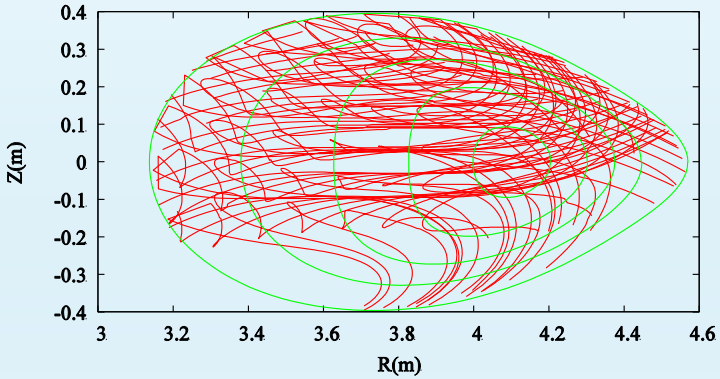


Consideration of the wall limitation



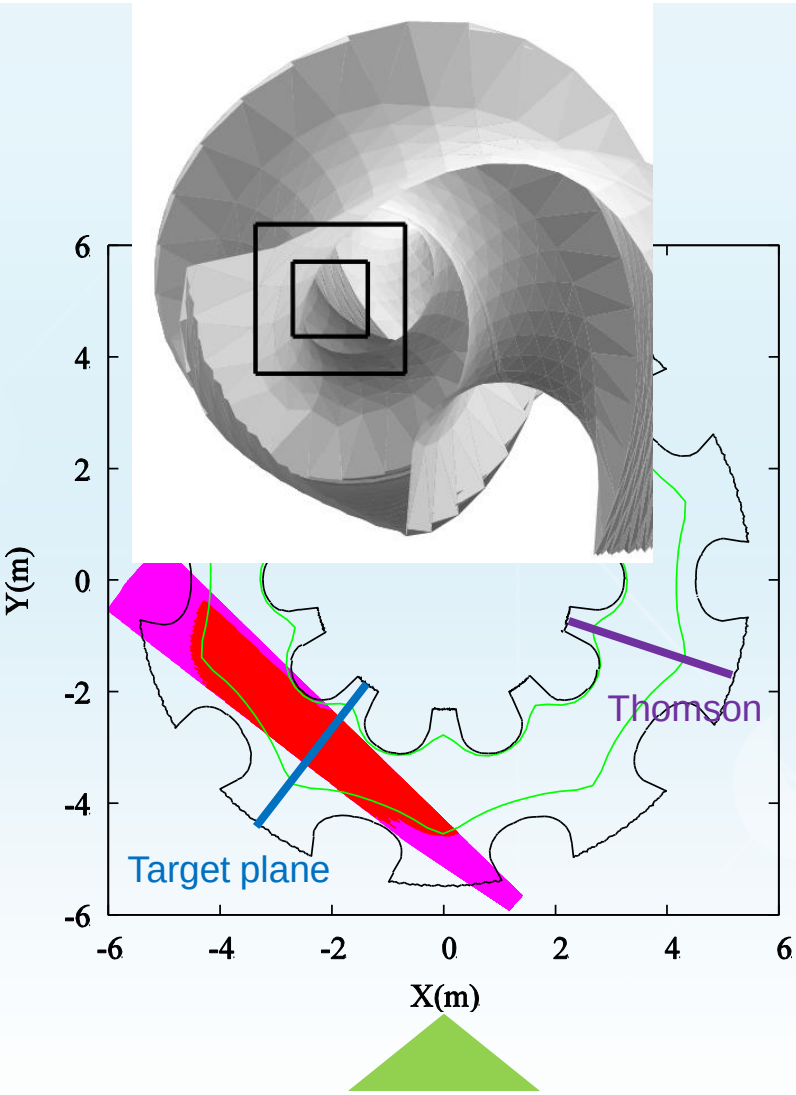
Top view of the viewing field.

Projection of the viewing lines



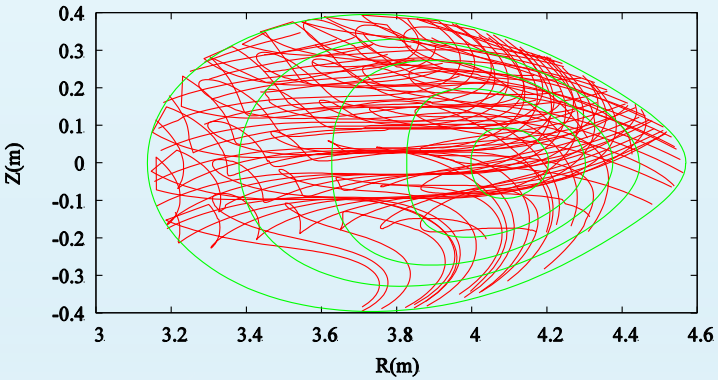
- Intersection of each viewing line and the inner wall of LHD should be considered.

Consideration of the wall limitation



Top view of the viewing field.

Projection of the viewing lines



- Intersection of each viewing line and the inner wall of LHD should be considered.
- The wall surface is simulated by lots of small triangles.

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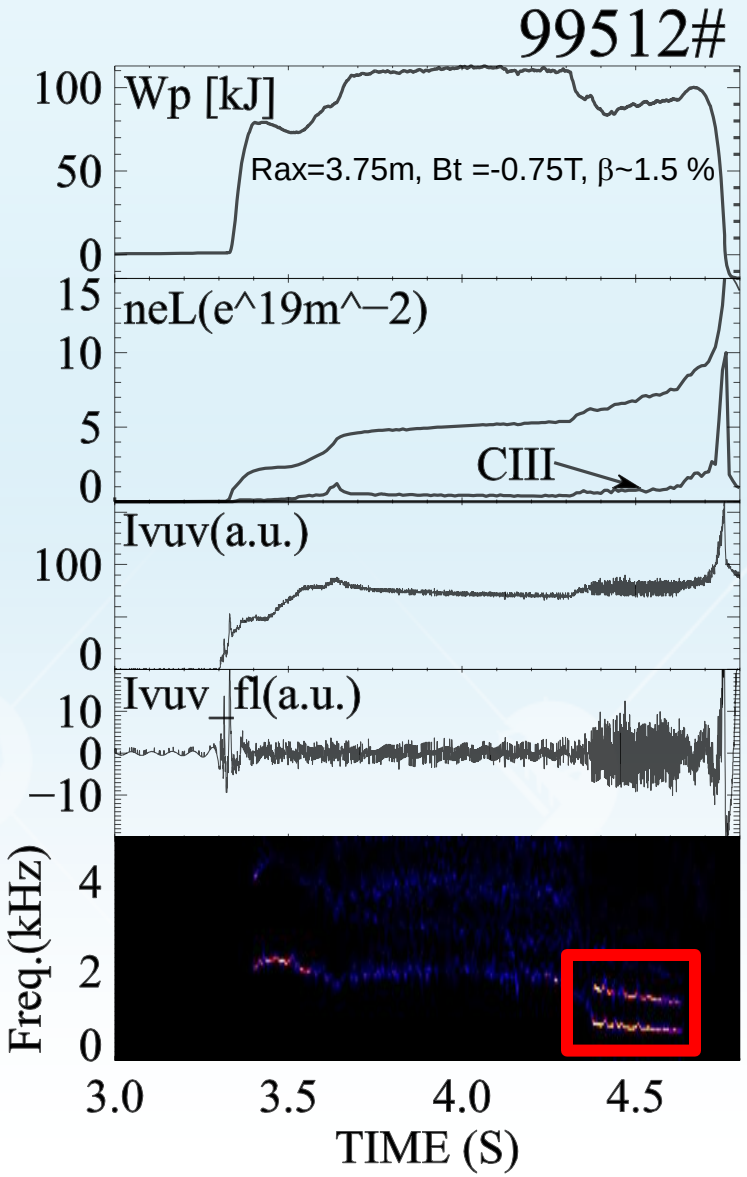
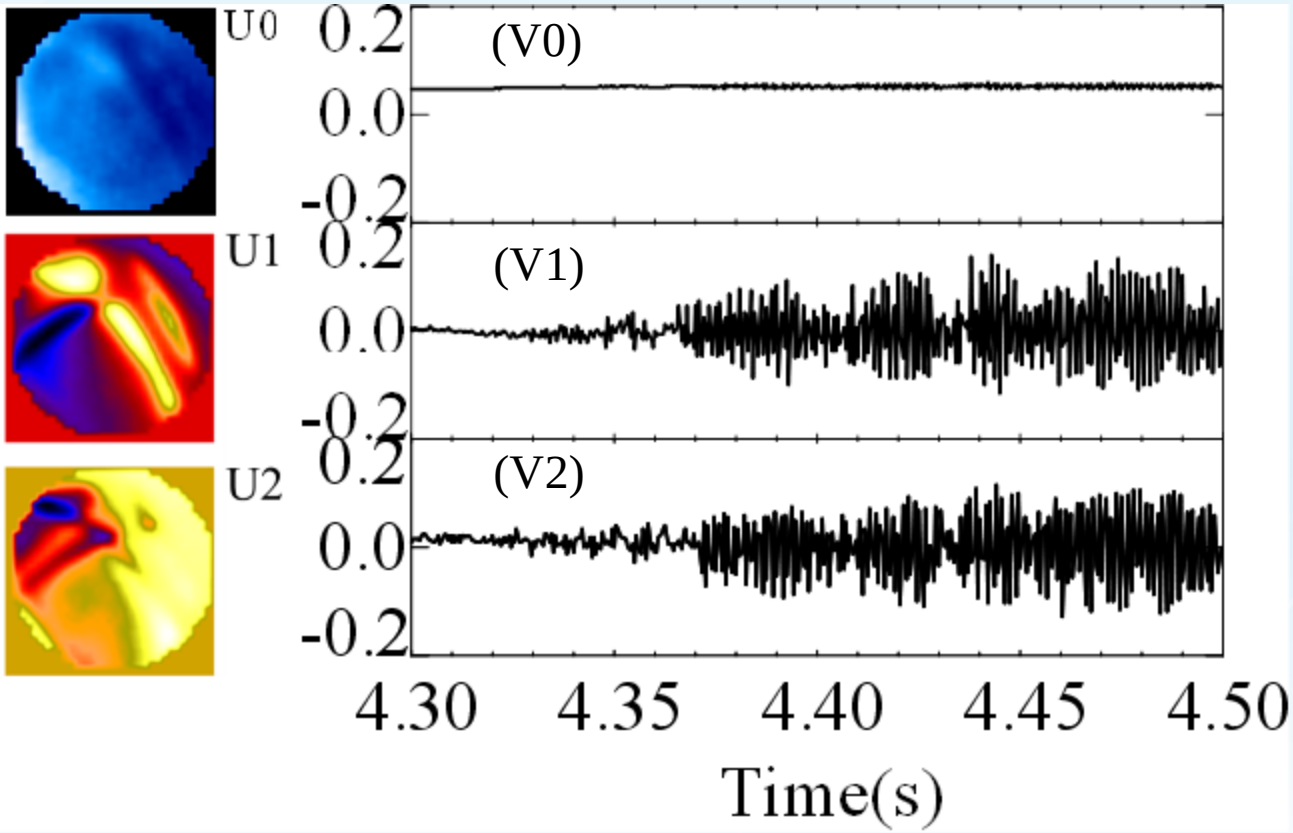
Low frequency fluctuation is measured

- Stored energy decreases and transport increases after the edge fluctuations is excited.
- Fluctuation with low frequency ~1kHz is caught by the VUV telescope system.
- The fluctuation is thought to be an interchange mode due to the magnetic hill in the edge region of LHD.



SVD analysis

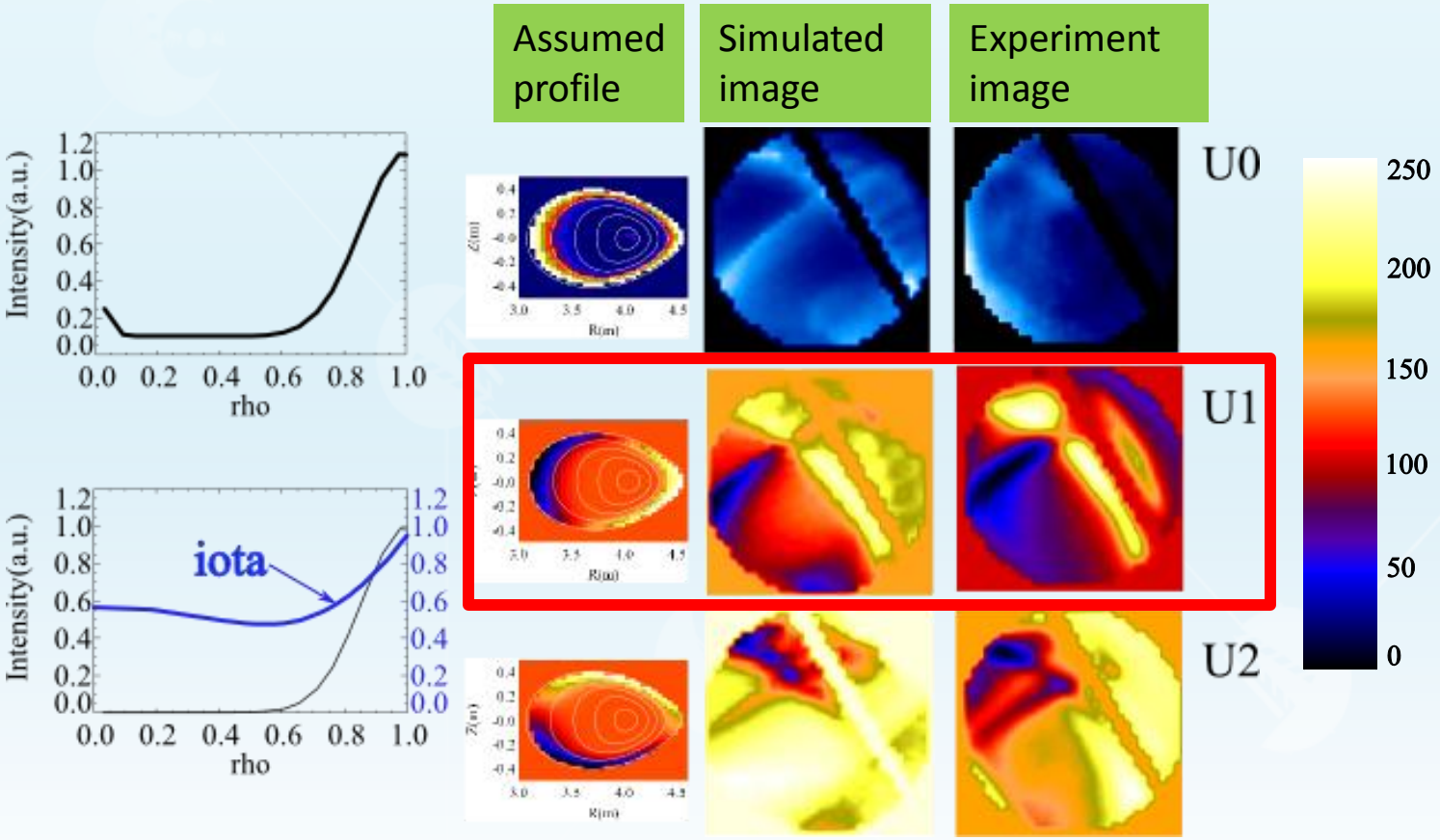
Space structure(Topos) Time evolution (Chronos)



- The images associated with the three leading modes of the fluctuation are shown as U0~U2.

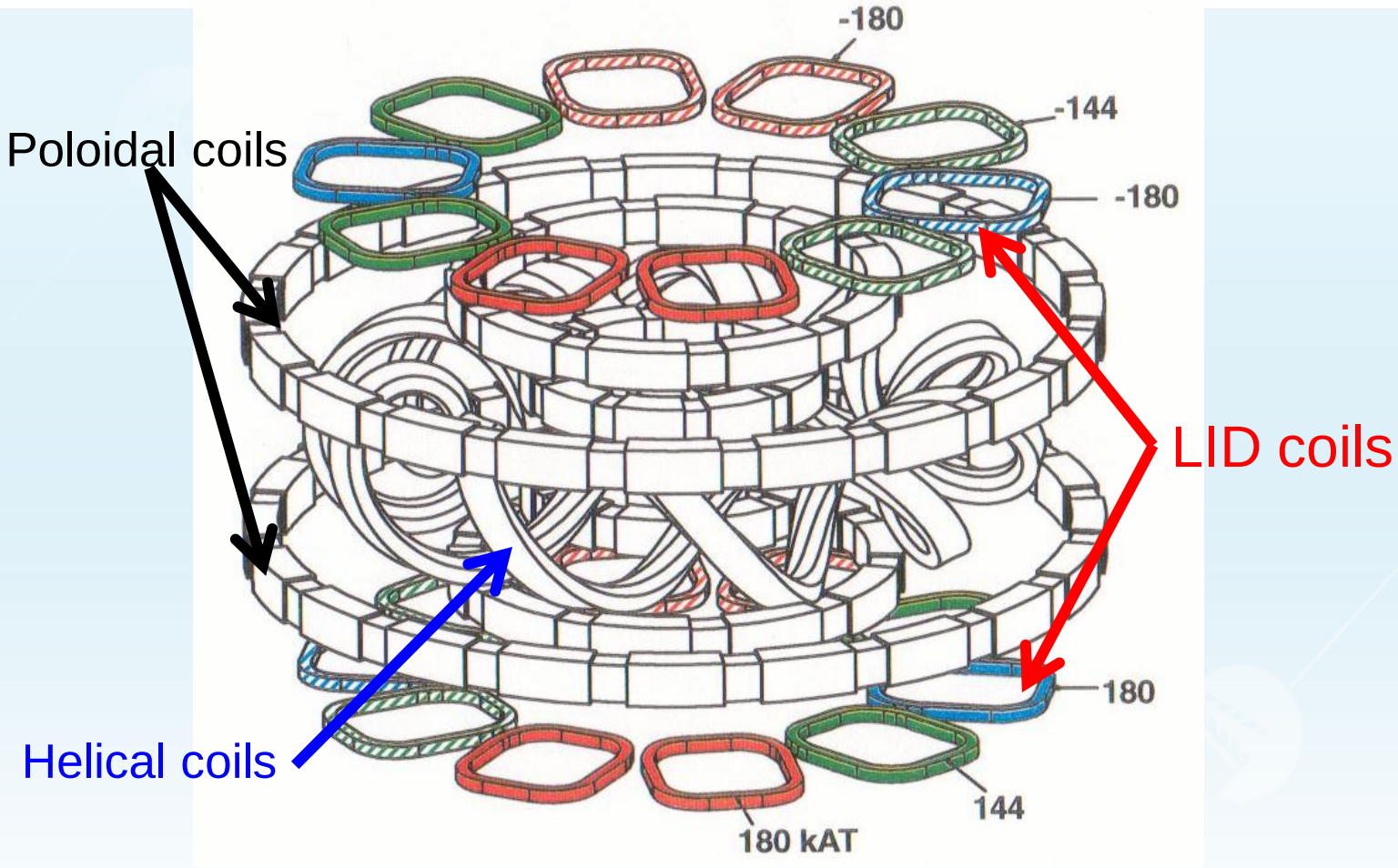
m/n=1/1 mode structure

Assumed profile: $\exp(- ((\rho - 1.0)/0.2)^2) \times \cos(m \times \theta - \Phi)$



- The 2D structure of the m/n=1/1 mode is identified from the comparison of simulated image and experiment data.

Resonant magnetic field coil system



- 10 pairs of normal conduct coil are installed to produce the m/n=1/1 island, with different phases at different toroidal positions.

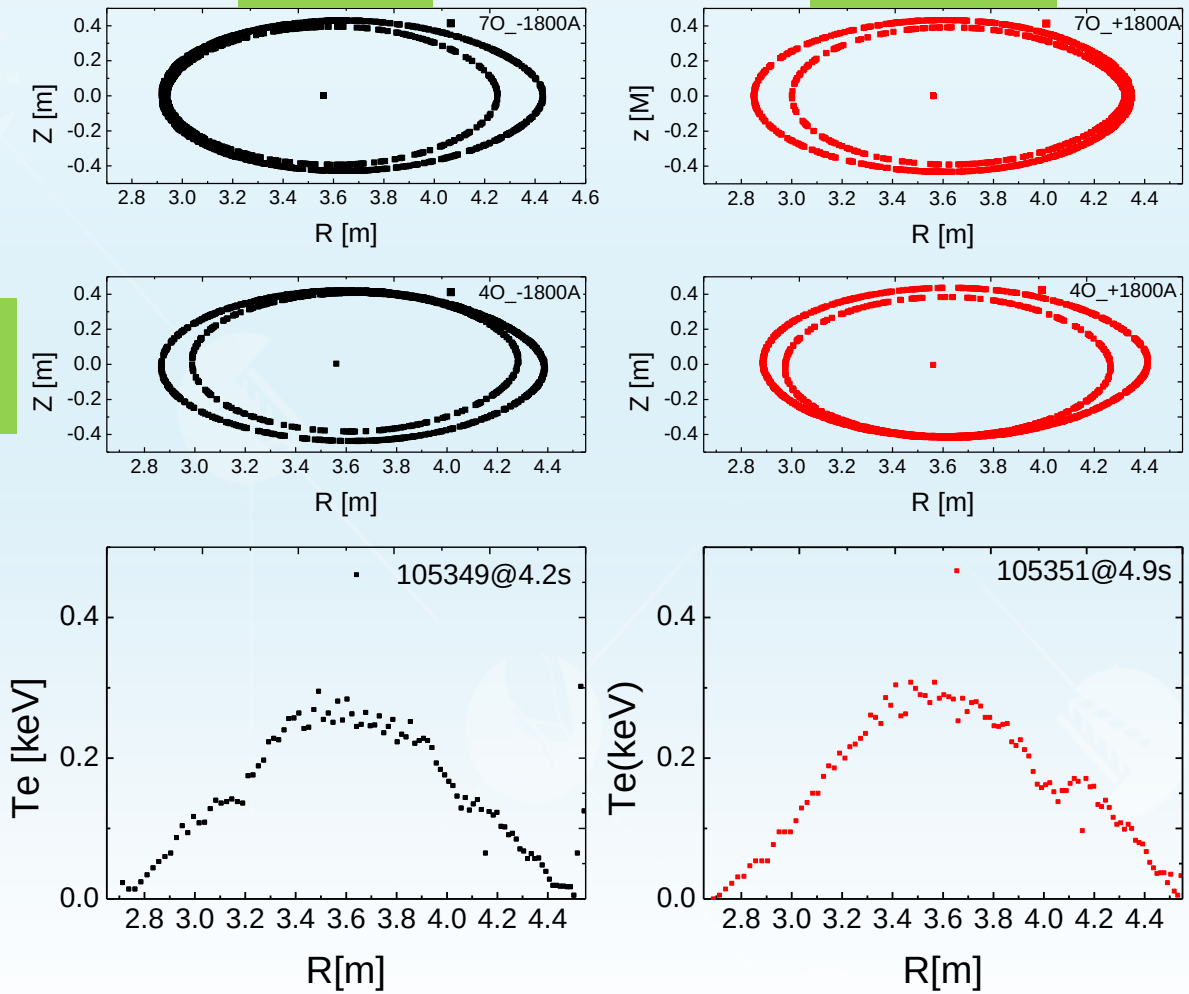
Magnetic island structure

Normal

Reversed

Target plane

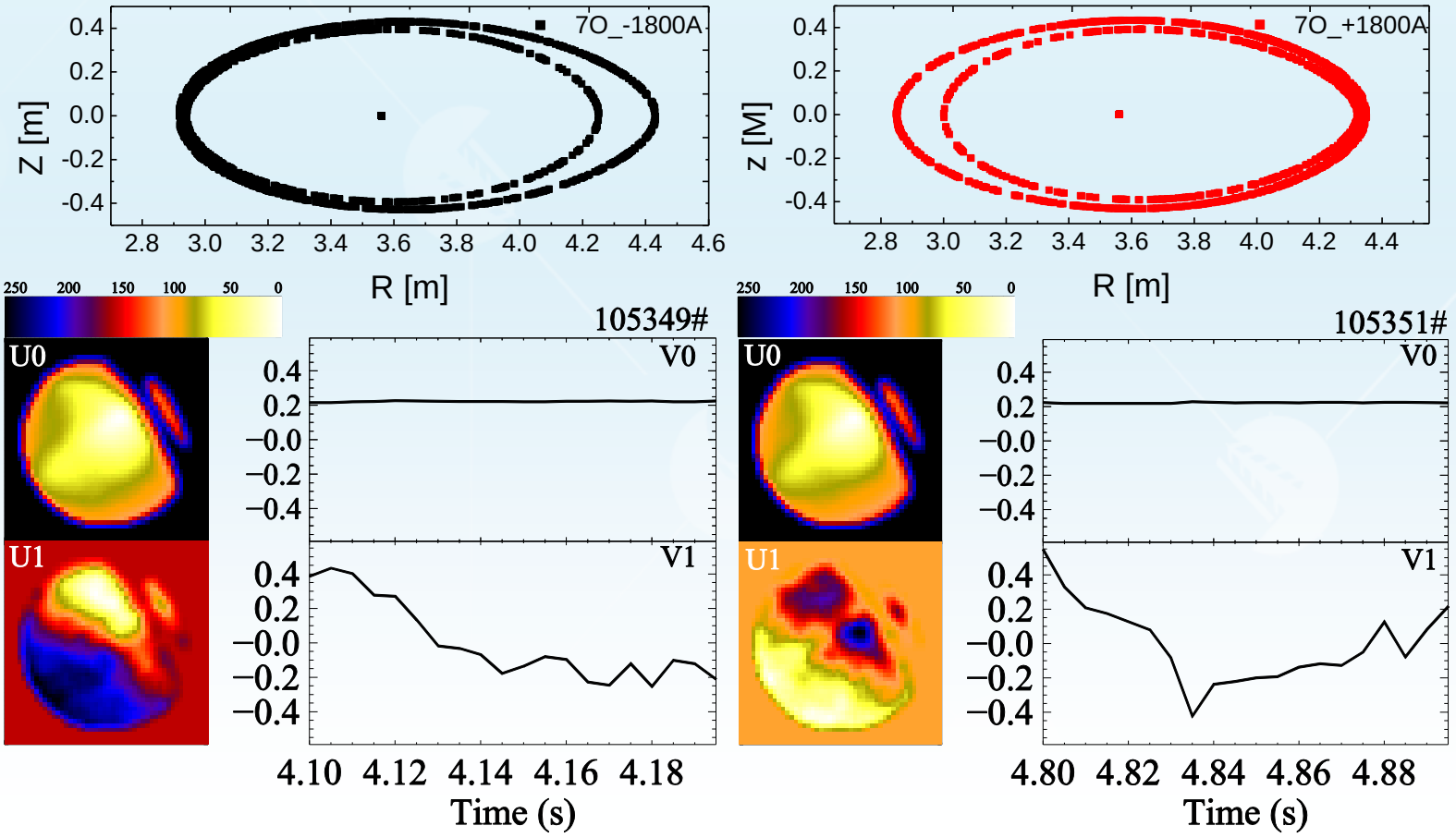
Thomson system



- For normal case, the O (X) point of the island locates at the outboard (inboard) side of 7O port.

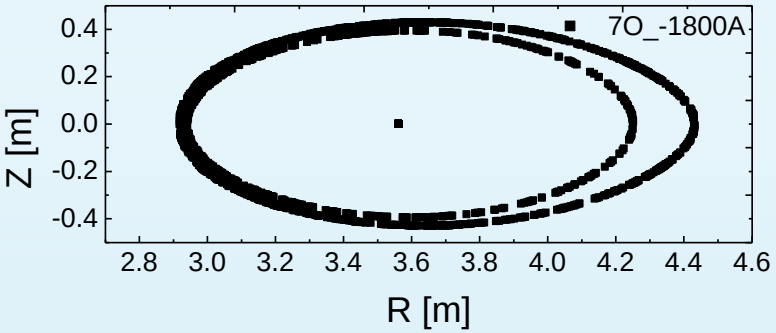
Emission profiles are modified by the RMP

- Impurity emission is modified due to the existence of RMP field: stronger in plasma center for the normal case, but stronger in plasma edge for reversed case.



Mode structures with RMP

2D structure of the static m/n=1/1 mode is identified



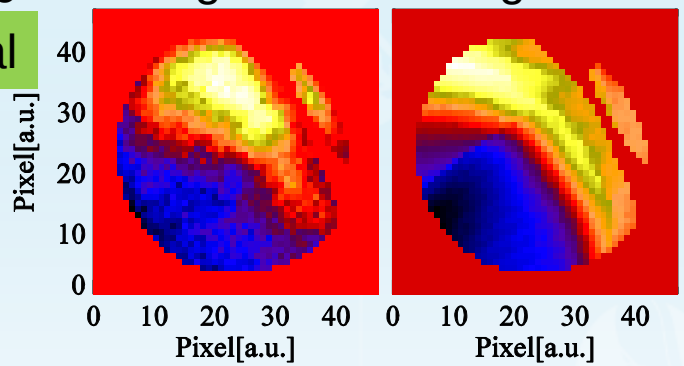
Experiment Image

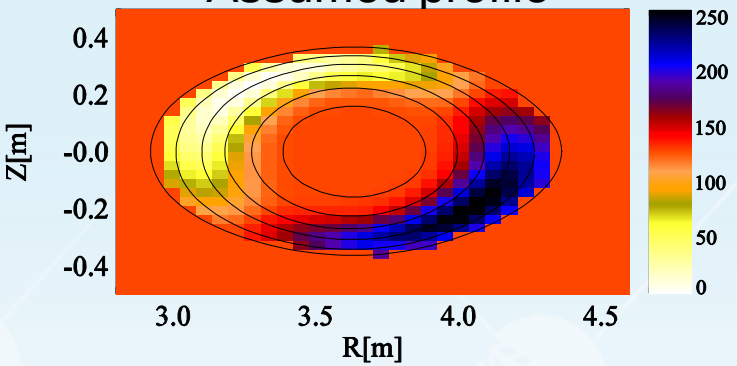
Simulated Image

Assumed profile

105349

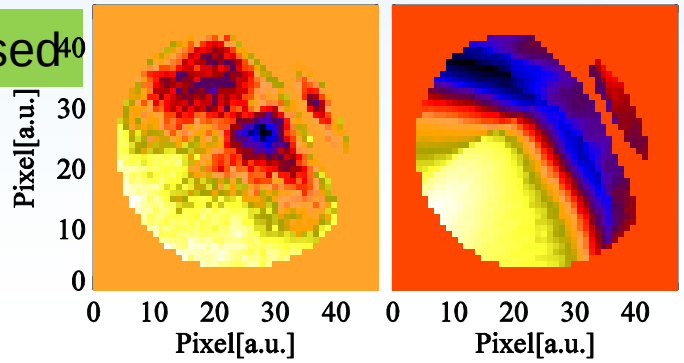
Normal

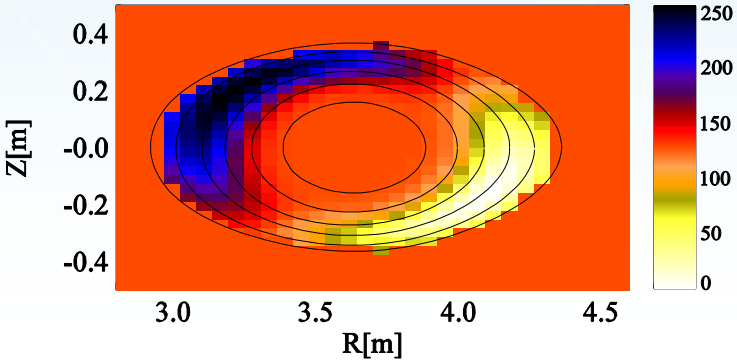




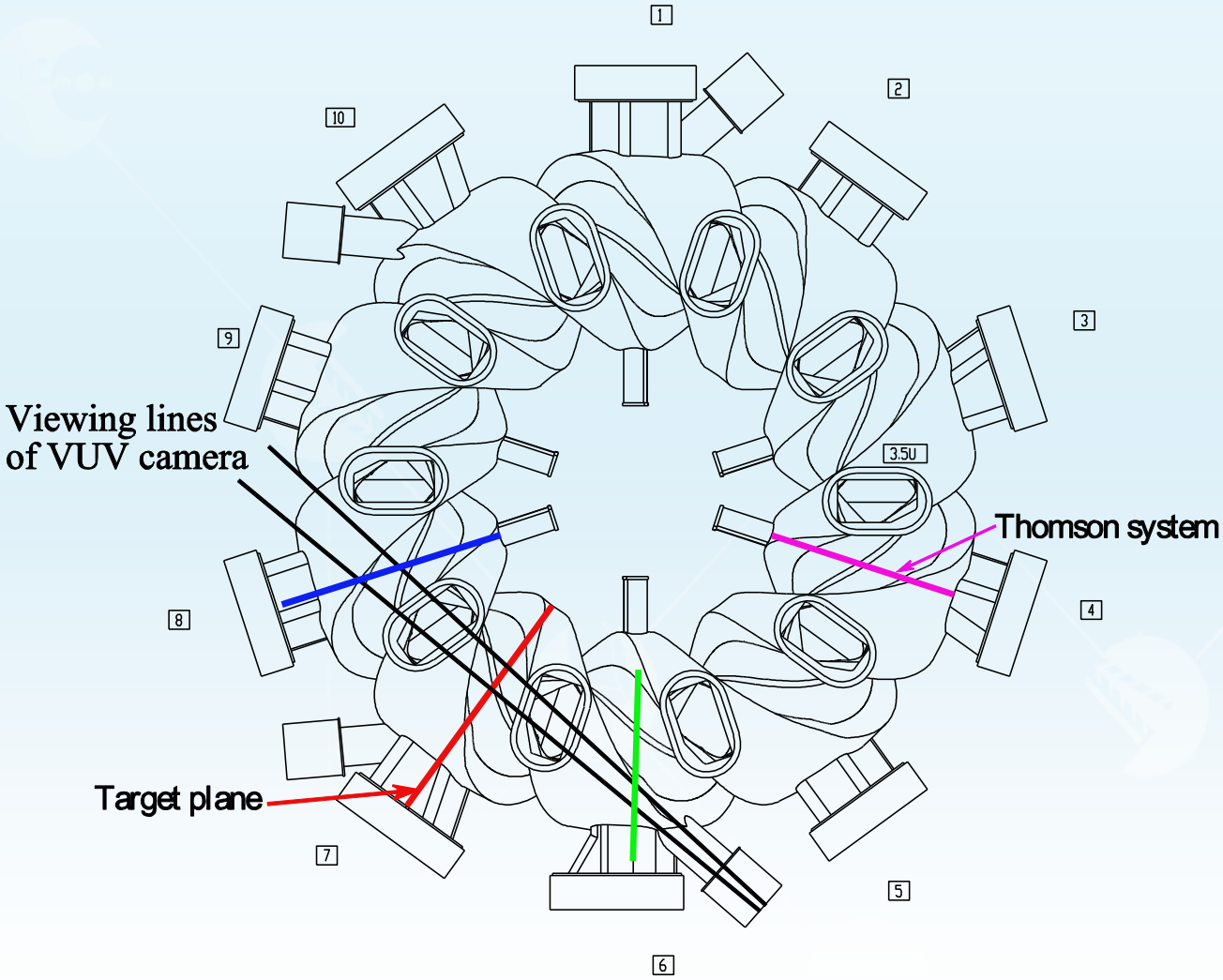
105351

Reversed





Phase shift due to the helical effect?



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- A high speed tangentially viewing VUV camera system is developed in LHD.
- m/n=1/1 mode structure with low frequency fluctuation(< 1kHz) has been identified .
- The 2D structure of the externally induced static m/n = 1/1 island is also detected from the change in the impurity emission profile.
- Analysis of the mode structure will be carried out, using HINT2 with considerations of the magnetic island effects.
- Interaction of the static island and MHD mode will be studied. (Upgrade of the imaging system is planned to investigate MHD activities with higher frequency(1~20kHz) on LHD using larger mirror optics for this purpose).

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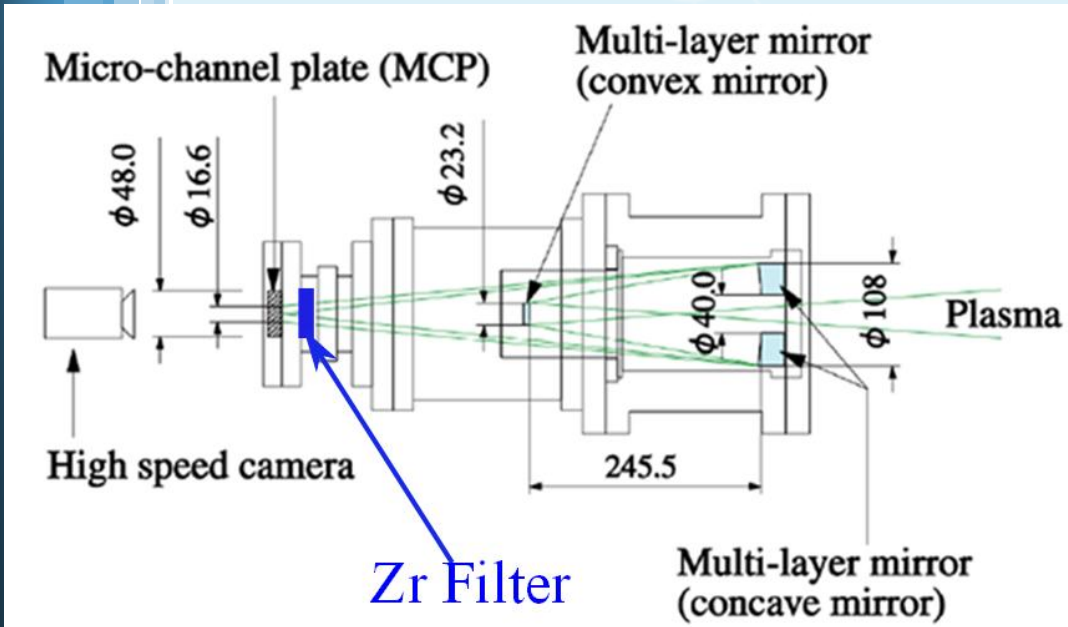
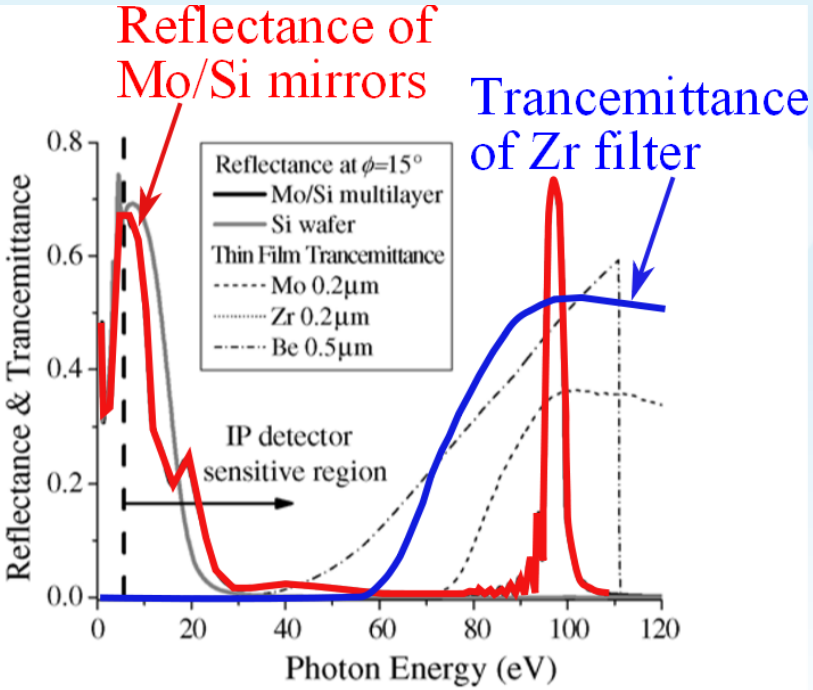
Thank You !

Any comment is appreciated.

Remove of the low energy stray light

- A low-energy-cut filter (zirconium (Zr) film 200nm in thickness) has been installed in front of the MCP. Low energy photons can be cut off.





(T, Harada *et.al*, Journal of Electron Spectroscopy and Related Phenomena 144・47 (2005) 1075・