P6-23

Comparison of Three Types of Impurity Diagnostics on Reheat Mode Discharges in the Compact Helical System

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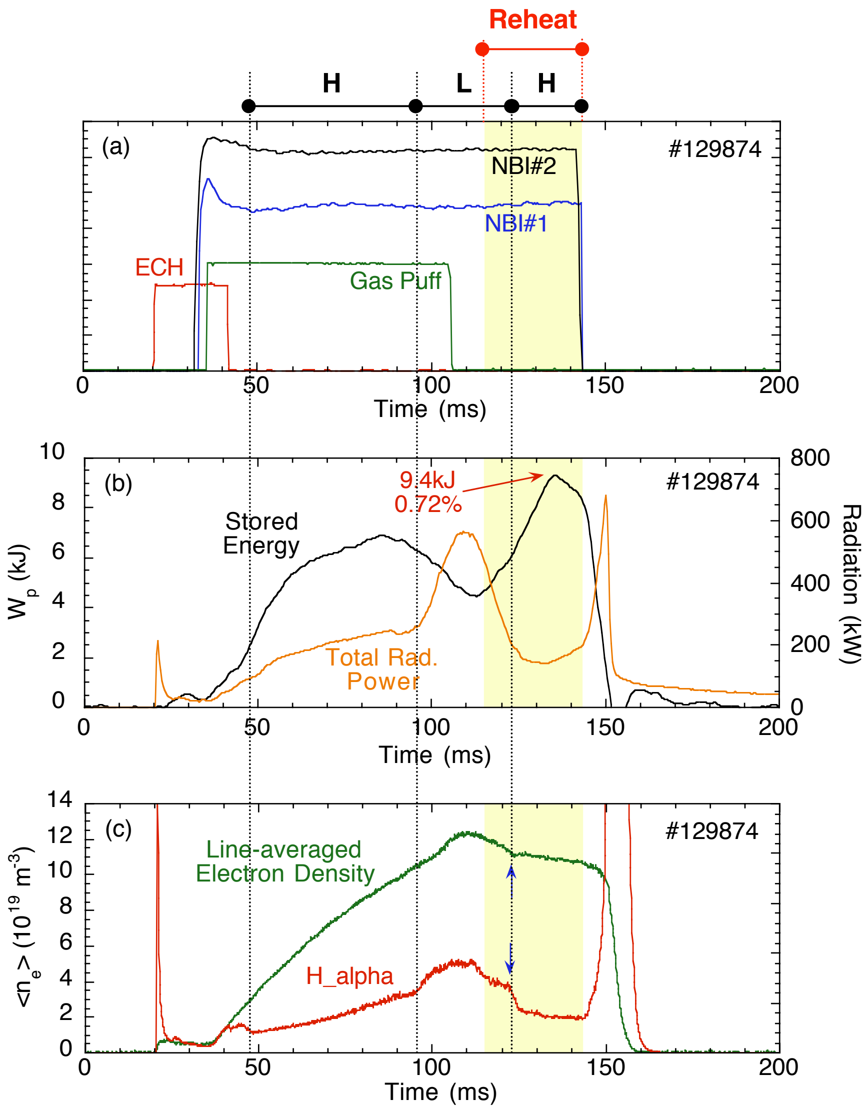
Background

- Spatial and temporal behaviors of radiation brightness and impurity ions in magnetically confined high temperature plasmas for fusion research are important from the viewpoint of power balance and achievable plasma performance.

- Three types of impurity diagnostics have been equipped in the Compact Helical System (CHS). A pyroelectric detector as a conventional thermal bolometer, an absolute extreme ultraviolet (AXUV) photodiode array, and a vacuum ultraviolet (VUV) spectrometer for identification of impurity ion species.

- These diagnostics have been applied to reheat mode discharges for exploring the maximum stored energy since the different features of the three types of diagnostics are well demonstrated in this discharge.

Maximum Stored Energy with Reheat Mode

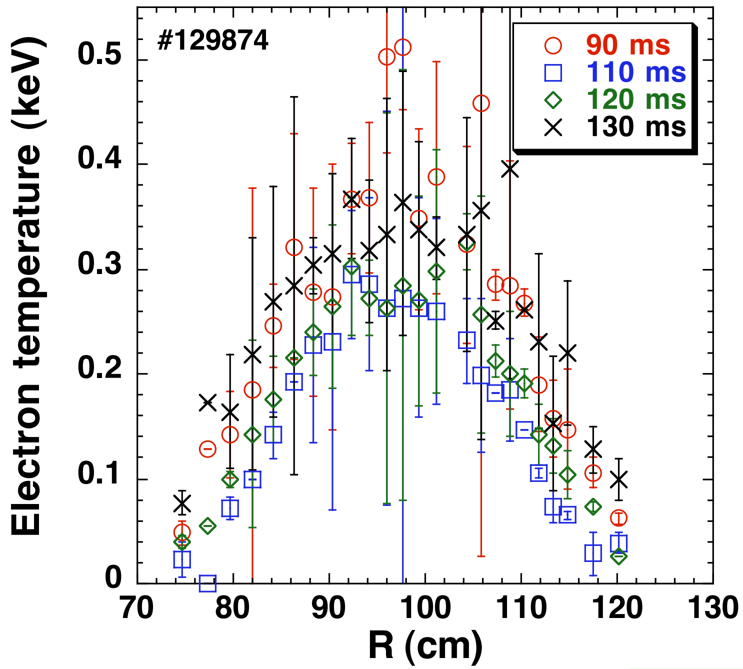


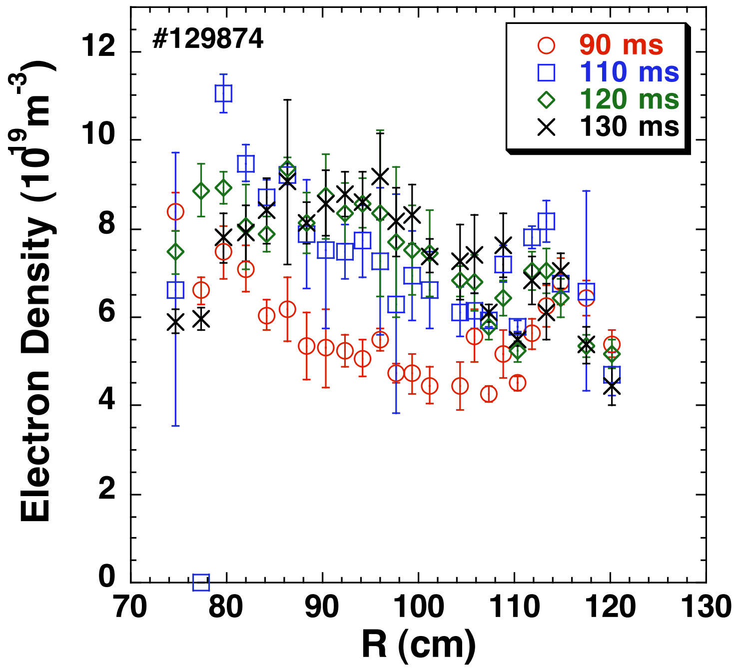
R_{ax} = 94.9 cm, B_q = -50 %

- **The stored energy began to recover rapidly at t = 115 ms (10 ms after the termination of the gas puff) due to the reheat mode.**
- **The maximum stored energy (9.4 kJ) was achieved under B_t = 1.8 T and P_{NBI} = 1.6 MW.**
- **Suppression of the decrease in n_e and an abrupt drop of Balmer alpha intensity at 123 ms are observed, which implies Edge Transport Barrier (ETB) during the reheat phase.**

T. Minami *et al.*, Plasma Fusion Res. **1**, 047 (2006)

T_e and n_e Profiles in Reheat Mode





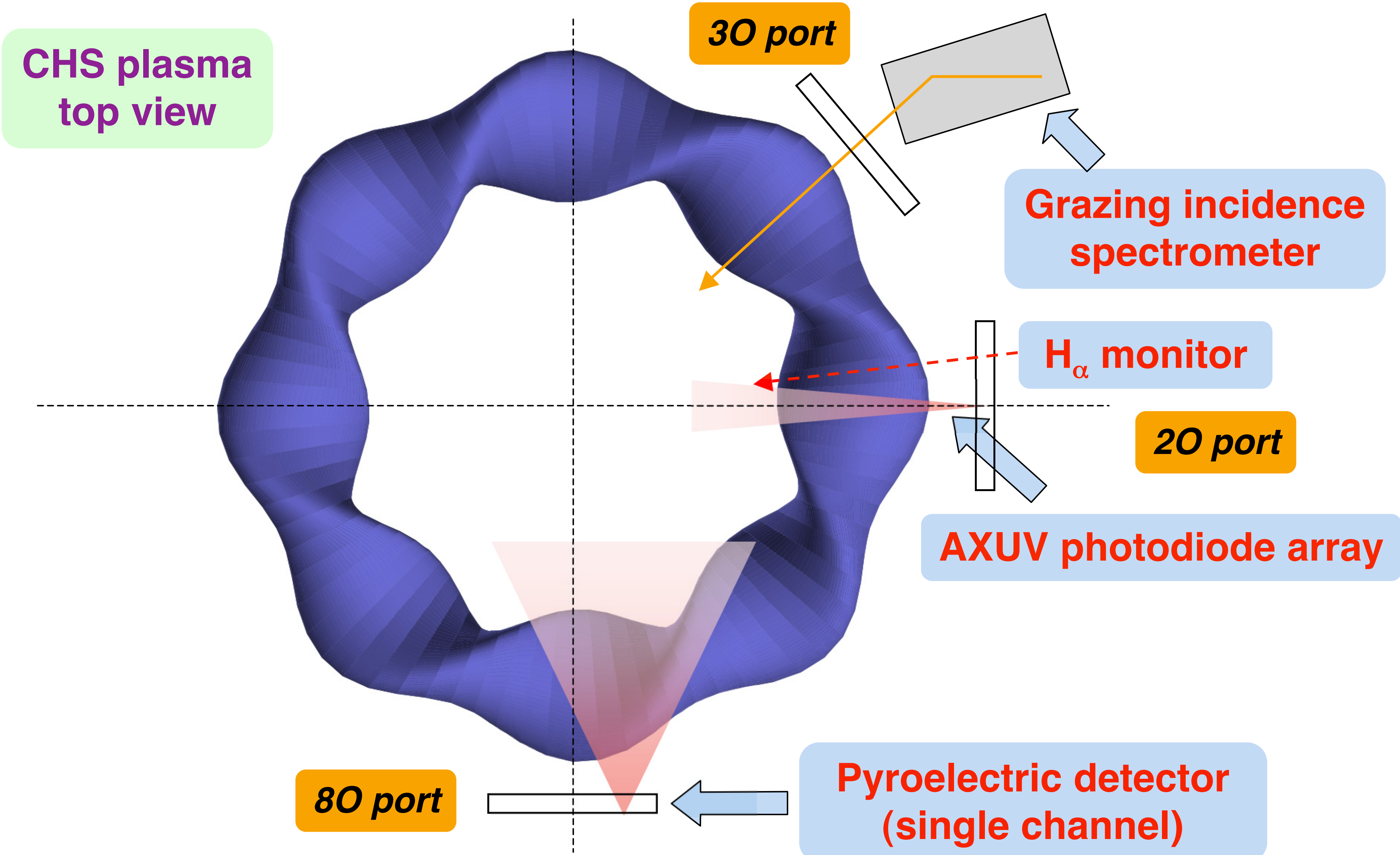
T_e

90 ms: H phase
110 ms: L phase
120 ms: reheat (L phase)
130 ms: reheat (H phase)

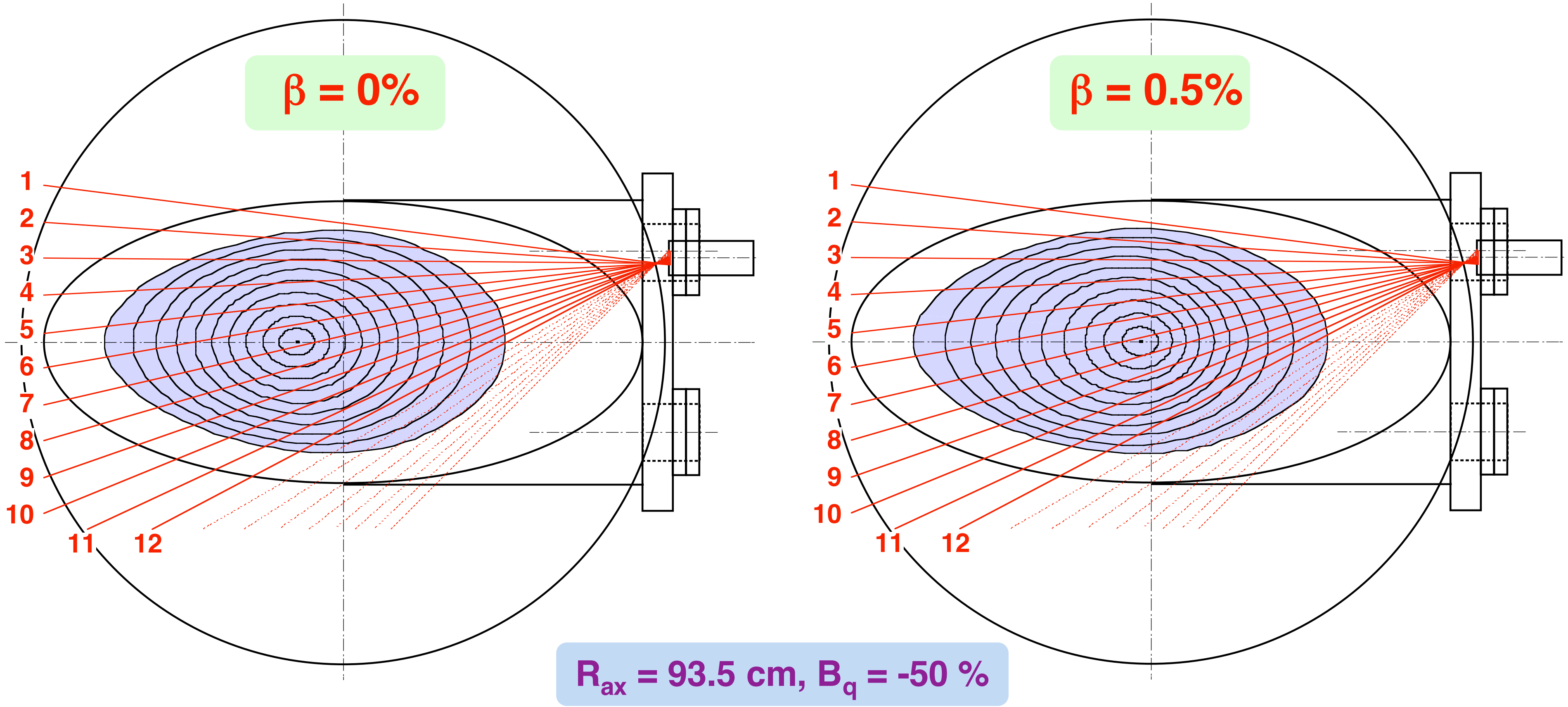
n_e

- **Electron temperature recovers by ~100 eV through the whole area of the plasma, which largely contributes to the increased stored energy.**
- **Electron density profile slightly becomes peaked after the reheat.**

Arrangement of the Diagnostics

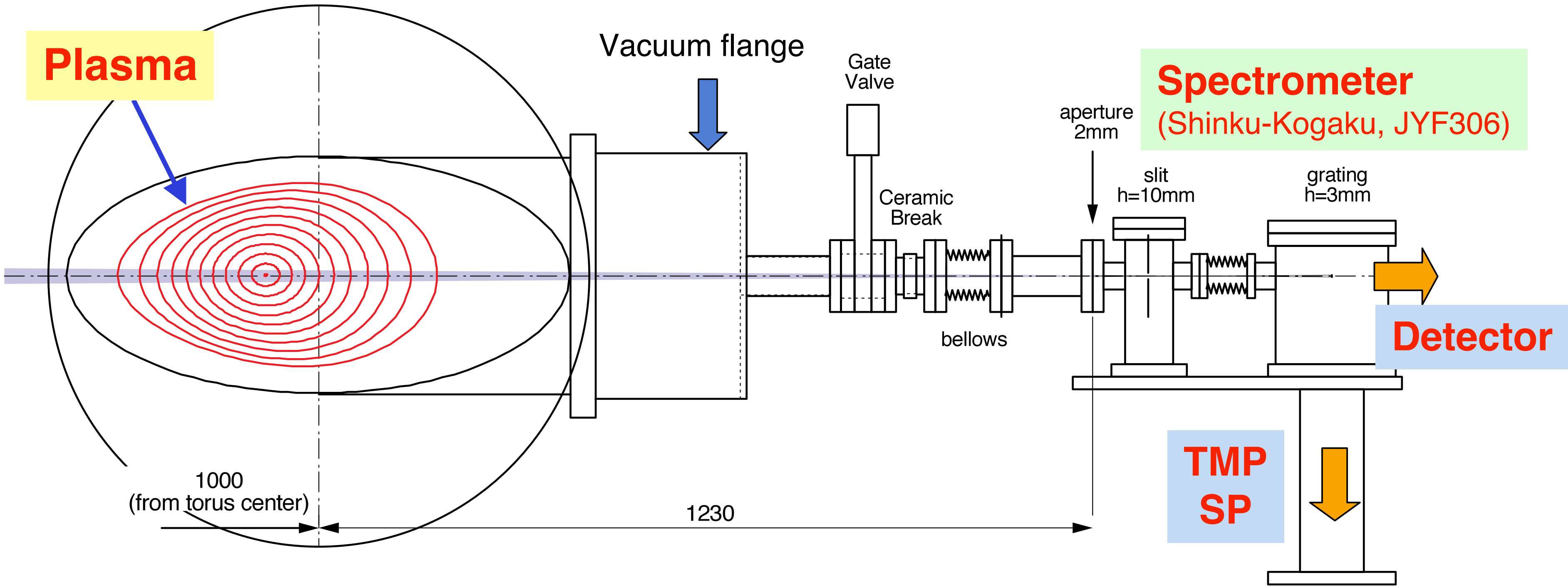


Viewing Chords of AXUV Photodiode Array



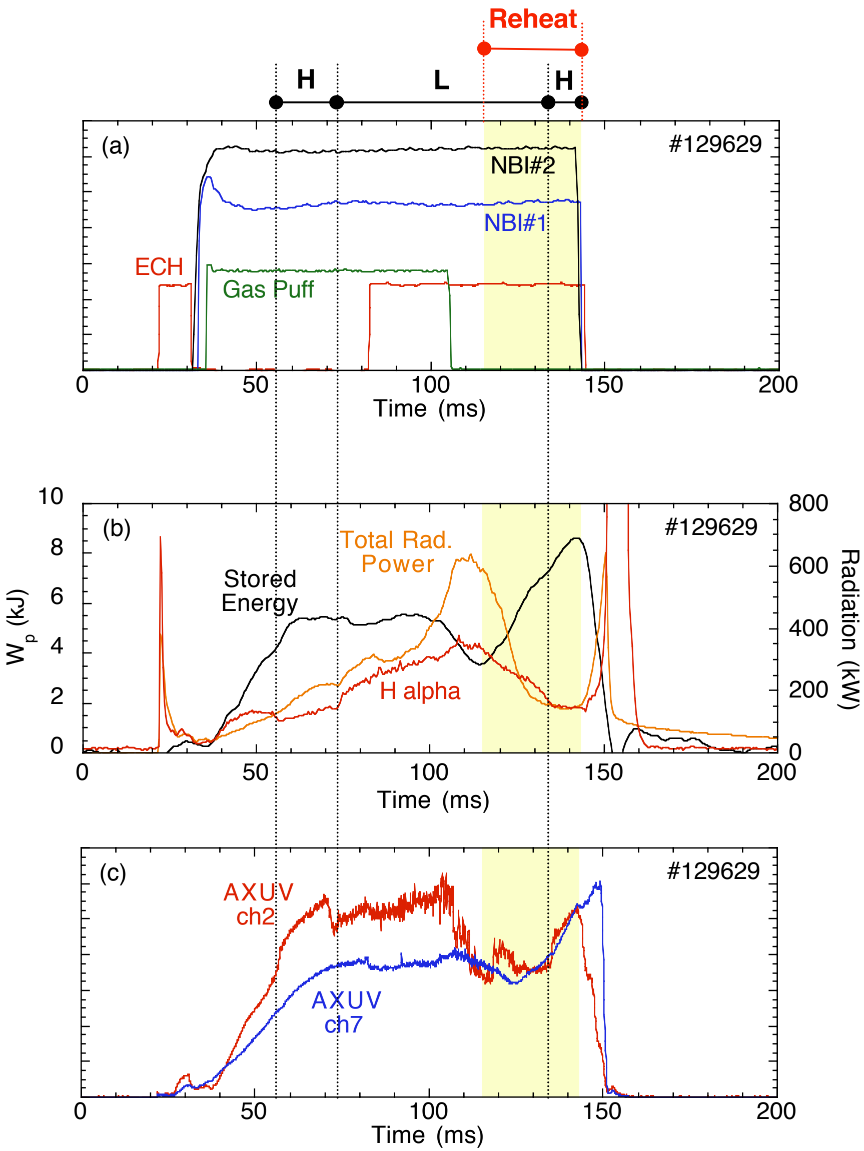
- The viewing chords are arranged within a horizontally elongated cross section.
- Simultaneous data acquisition of 12 channels of the AXUV photodiode array is possible by digitizers.

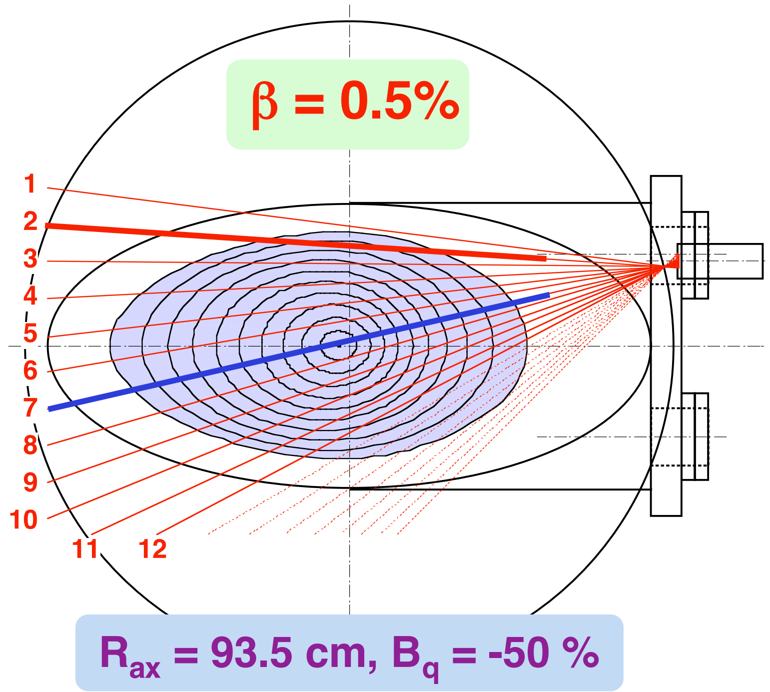
Arrangement of the VUV Spectrometer



Spectrometer type	grazing incidence, flat field
Grooves	450 grooves/mm, unequally spacing
Grating shape	Pt coated toroidal concave (R = 919.3 mm, r = 102.57 mm)
Wavelength (Energy)	10 ~ 110 nm (124 ~ 11 eV)
Detector	MCP + phosphor + CCD image sensor
Spectral resolution	~ 0.3 nm

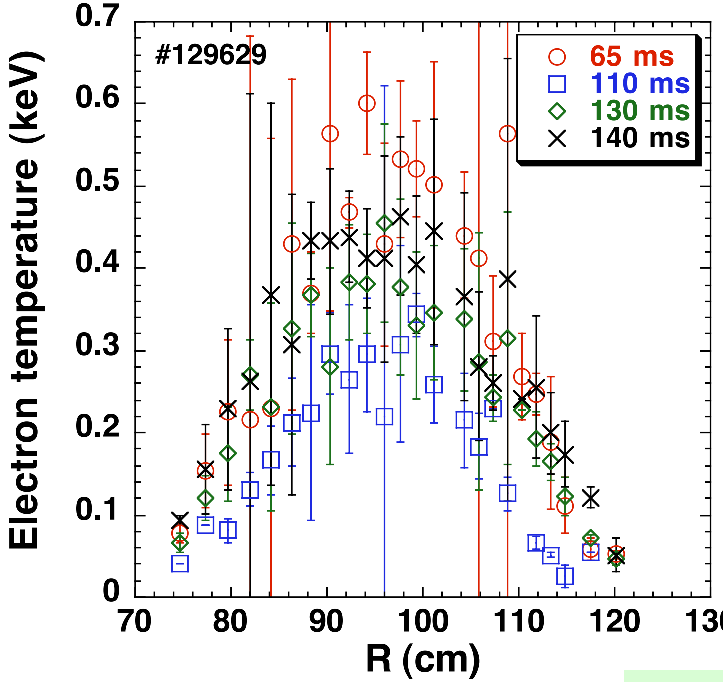
AXUV Photodiode Array Signals

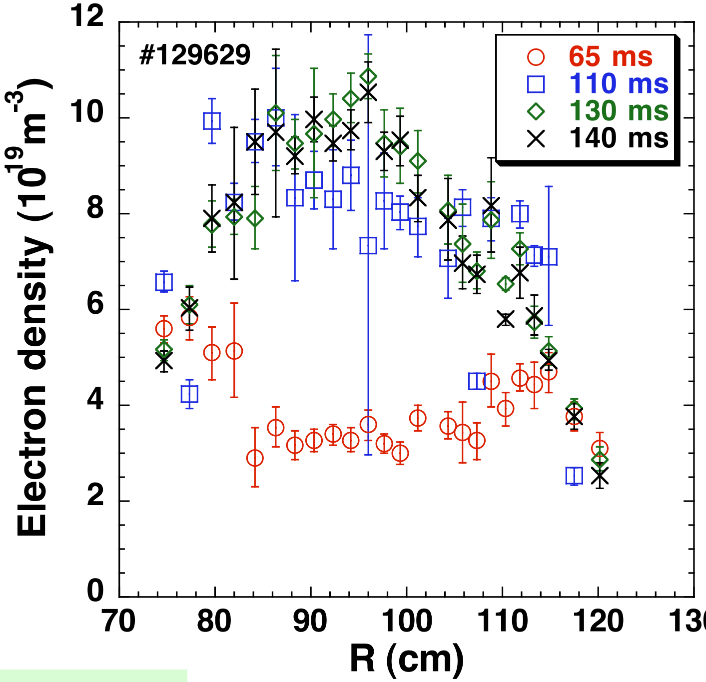




- **The center chord (ch7; ρ_{min}=0.04) signal increases in the reheat phase in spite of the decrease in the total radiation power.**
- **The edge chord (ch2; ρ_{min}=0.87) signal began to increase in the reheat + ETB phase.**

T_e and n_e Profiles in Reheat Mode





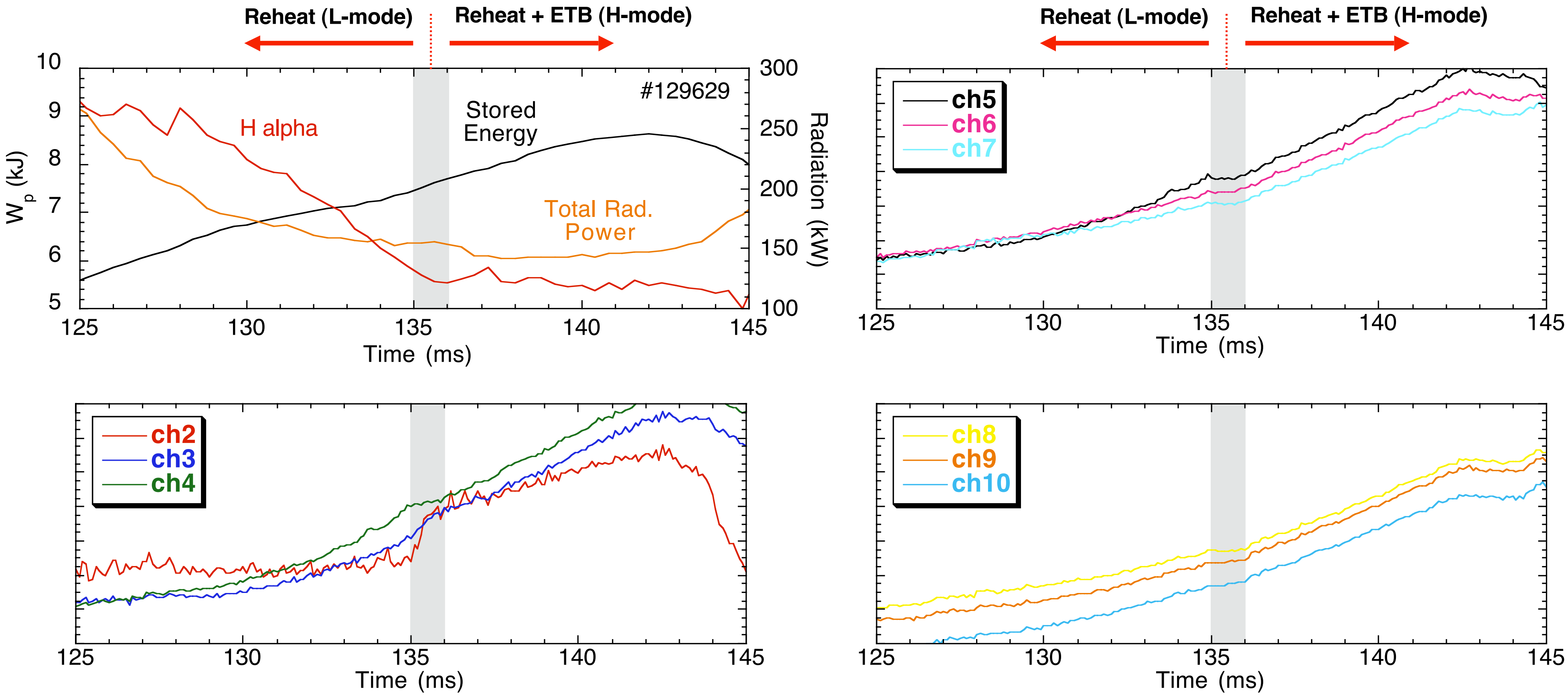
T_e

65 ms: H phase
110 ms: L phase
130 ms: reheat (L phase)
140 ms: reheat (H phase)

n_e

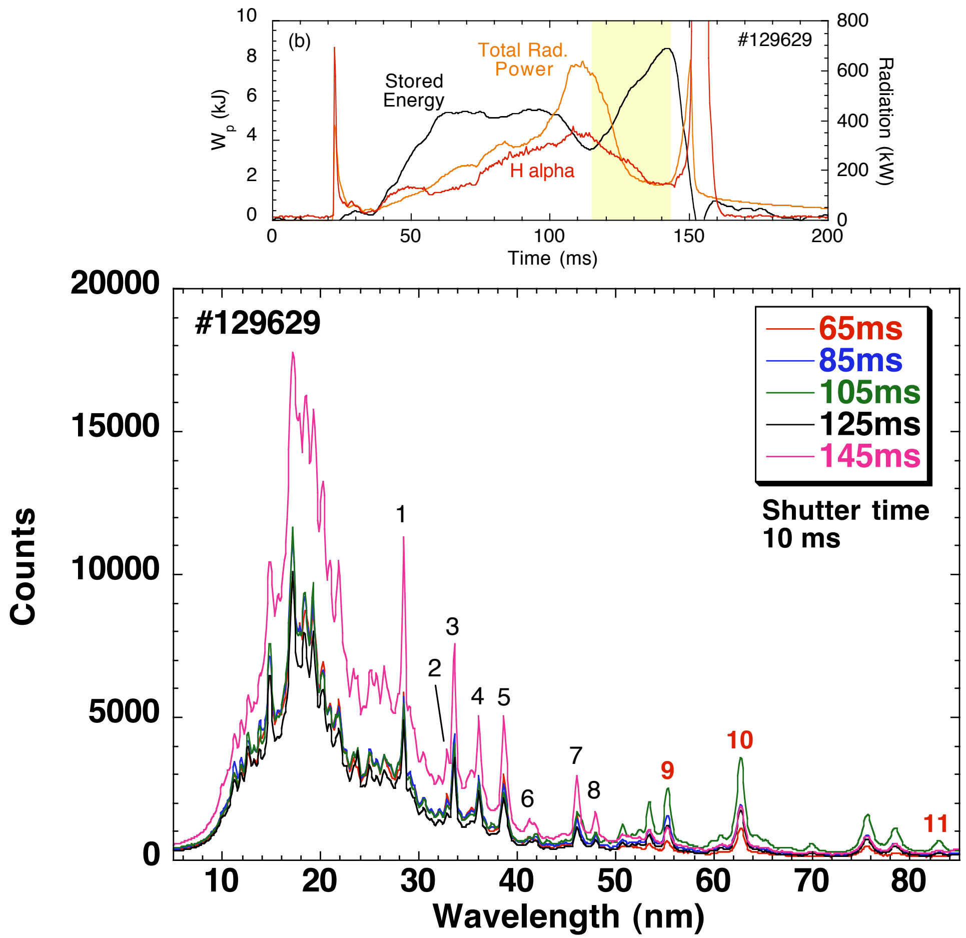
- **Electron temperature recovers by ~100 eV through the whole area of the plasma, which largely contributes to the increased stored energy.**
- **Electron density profile becomes peaked after the reheat.**

Details during Reheat Phase



- The edge chord (ch2) firstly increase due to the transition to the reheat + ETB phase, during which the center chords remain flat.

VUV Spectrum in Reheat Mode Discharge

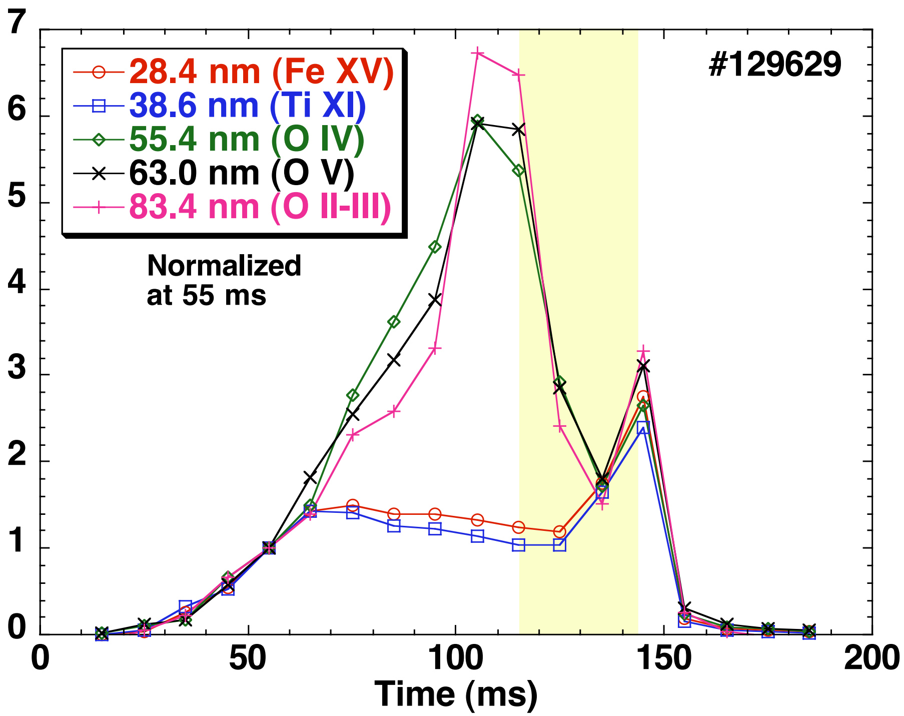


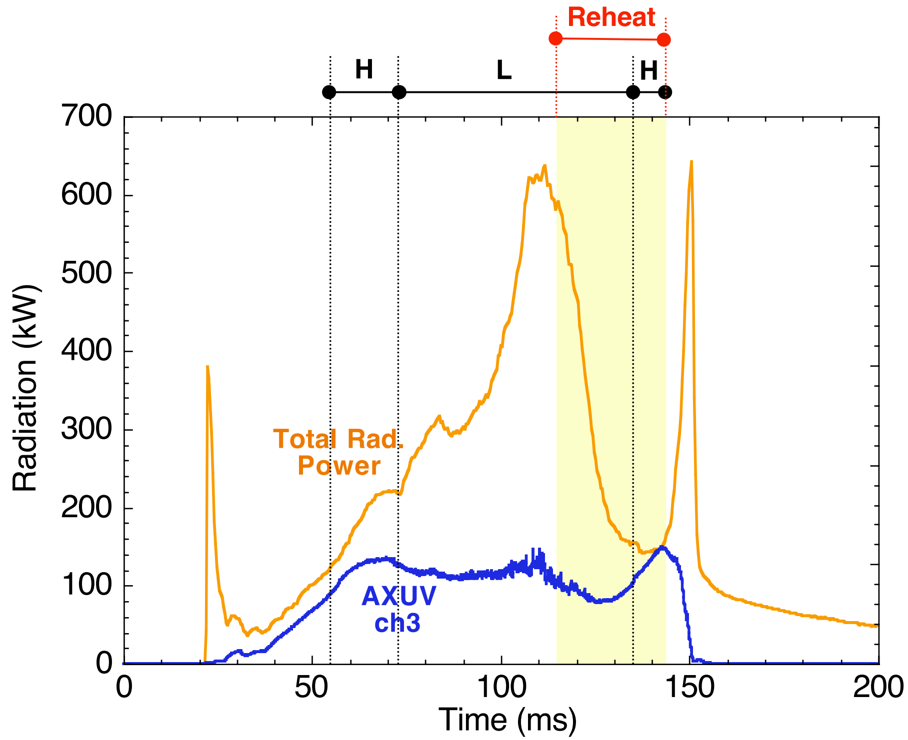
	Ion	Wavelength
1	Fe XV	28.42 nm
2	Cr XIII	32.83 nm
3	Fe XVI	33.54 nm
4	Fe XVI	36.08 nm
5	Ti XI	38.61 nm
6	Cr XIV	41.20 nm
7	Ti XII	46.08 nm
8	Ti XII	47.99 nm
9*	O IV	55.4 nm
10	O V	62.97 nm
11*	O II-III	83.4 nm

* several lines blended

- **Resonance lines for metallic impurities are dominant.**
- **Oxygen lines in longer wavelength lines become bright before the reheat phase.**

Temporal Evolutions of Impurity Line Intensities

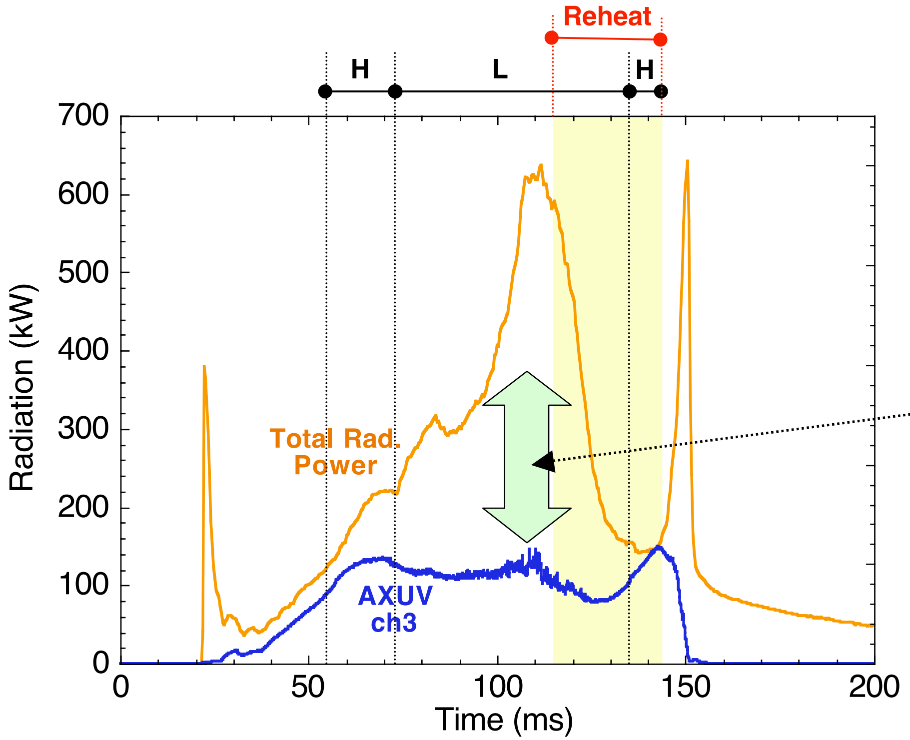


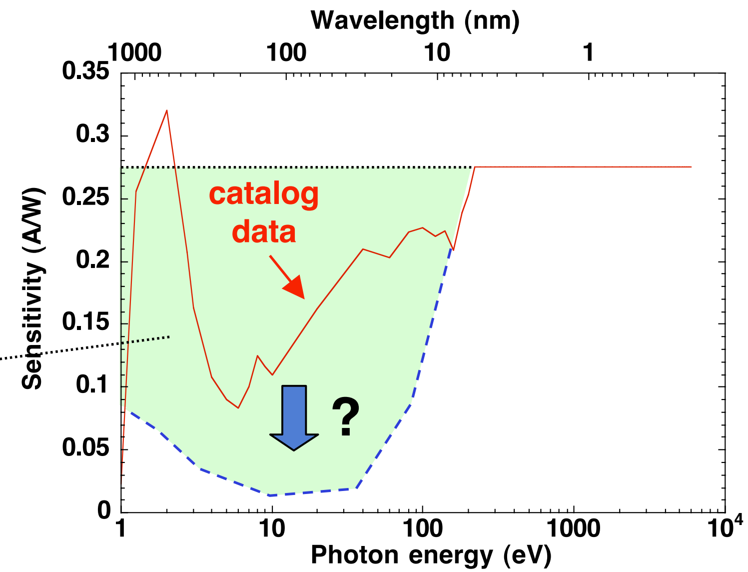


- **Metallic impurities (from core plasma)**
  - similar to the AXUV photodiode signal
  - represent impurity accumulation
- **Oxygen impurities (from edge plasma)**
  - similar to the total radiation power

Ionization	Required energy
Fe XIV -> XV	392 eV
Ti X -> XI	216 eV
O III -> IV	56 eV
O IV -> V	77 eV
O II -> III	35 eV

Difference between Two Bolometric Detectors





Sensitivity vs. photon energy

- **The sensitivity of the AXUV photodiode for low energy photons is reduced, and may be further degraded during the long-term exposure to emissions.**
- **The total radiation power measured by the pyroelectric detector may be dominated by lower energy photons from the edge plasma in high density L mode plasma.**
- **The AXUV signals reflect radiations only from relatively high energy photons.**

Conclusion

- **Radiation brightness and impurity emission lines for the reheat mode discharges in CHS have been measured by the AXUV photodiode array, the pyroelectric detector and the VUV spectrometer.**
- **The AXUV photodiode signals during the reheat mode rapidly increase especially for the center viewing chord, which would represent the impurity accumulation.**
- **According to the temporal evolutions of the VUV spectra, metallic and oxygen impurity line intensities behave like the AXUV and pyroelectric detectors, respectively.**
- **Opposite behaviors between the total radiation power and the AXUV photodiode signals have been observed in the reheat mode, which can be explained by the spectral dependence of the detector sensitivity.**
- **The combination of the three different types of diagnostics are helpful for a comprehensive understanding of impurity behaviors.**