

# Impact of Stark broadening on ion temperature measurement in the ITER divertor plasma

M. Goto<sup>1,2</sup>, K. Nojiri<sup>3</sup>, A. Calisti<sup>4</sup>, S. Ferri<sup>4</sup>, M. Koubiti<sup>4</sup>, J. Rosato<sup>4</sup>, J. J. Simons<sup>2</sup>, T. Kawate<sup>3</sup>, T. Oishi<sup>5</sup>, E. Yatsuka<sup>3</sup>, Y. Yanagihara<sup>1</sup>, M. Isobe<sup>1,2</sup>, Y. Nunoya<sup>3</sup>

<sup>1</sup>National Institute for Fusion Science, <sup>2</sup>Graduate University for Advanced Studies, SOKENDAI, <sup>3</sup>Naka Institute for Fusion Science and Technology, National Institutes for Quantum Science and Technology, <sup>4</sup>Aix Marseille University, CNRS, PIIM laboratory, <sup>5</sup>Department of Quantum Science and Energy Engineering, Tohoku University  
e-mail: goto.motoshi@nifs.ac.jp

## 1. Introduction

- DIM measures impurity ion spectra in the ITER divertor plasma.
- Precise ion temperature ( $T_i$ ) measurement is essential to evaluate divertor sputtering.
- Impurity flow direction and magnitude are also key for detachment control.
- Low-Z materials (Be, B) provide useful emission lines for diagnostics.
- Line broadening by Zeeman effect and Stark broadening must be clarified.

## 2. Method

- The Stark broadening is modeled by ion (static) and electron (impact) contributions.
- Electron broadening follows Griem's model with a Lorentzian line shape.
- The width is proportional to electron density:
- Ion microfields are described by the Holtsmark distribution assuming  $n_i = n_e$ .
- The plasma is isotropic, but the magnetic field introduces anisotropy.
- The total Hamiltonian under arbitrary external fields is

$$H = H_0 - \mu_B B (g_L L_z + g_S S_z) - E d_\xi$$

- The quantization axis is taken along the magnetic field direction.
- The electric-field axis is defined by Euler rotation  $R(\theta_1, \theta_2)$ :

$$|LJM\rangle_\xi = \sum_m |LJm\rangle D_{Mm}^{(J)*}(R).$$

$$\langle LJM | -E d_\xi | L'J'M' \rangle = -E \sum D^{(J)} D^{(J)*} \langle LJm | d | L'J'm' \rangle$$

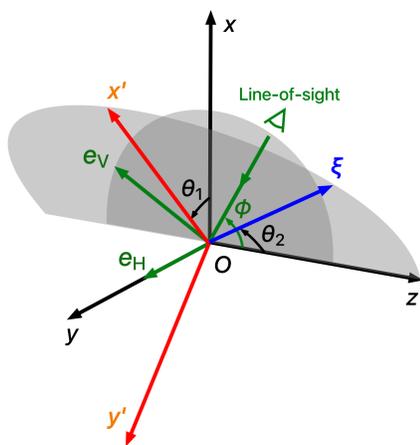


Fig. 1: Euler rotation for turning the quantization axis ( $z$ -axis) into the  $\xi$ -axis direction by first rotating  $\theta_1$  around the  $z$ -axis and then  $\theta_2$  around the  $y'$ -axis which is the new  $y$ -axis after the first rotation. The definition of observation vectors  $e_V$  and  $e_H$  are also shown: The former is in the  $x$ - $z$  plane and is perpendicular to the line-of-sight, and the latter is on the  $y$ -axis.

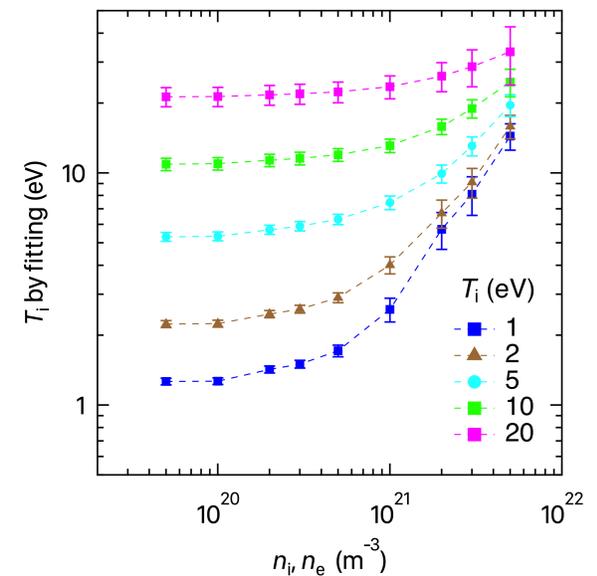
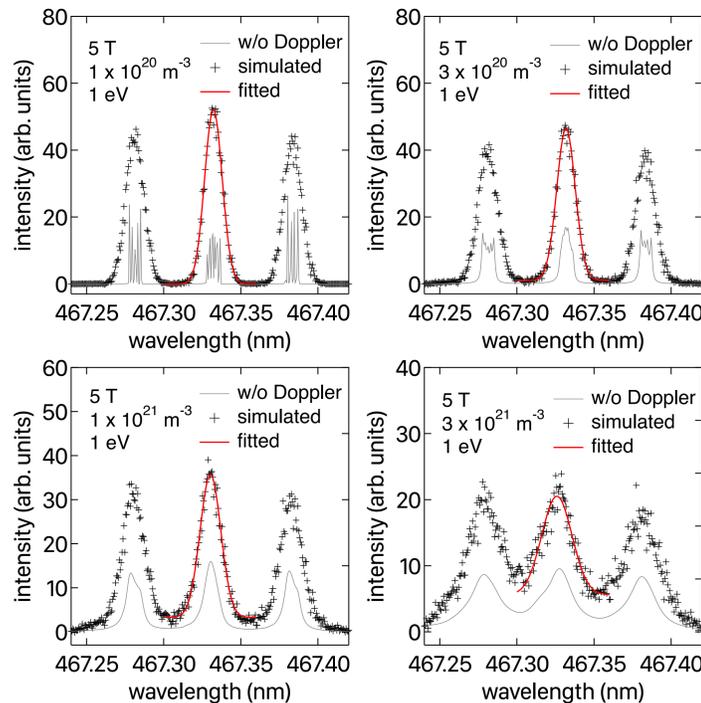
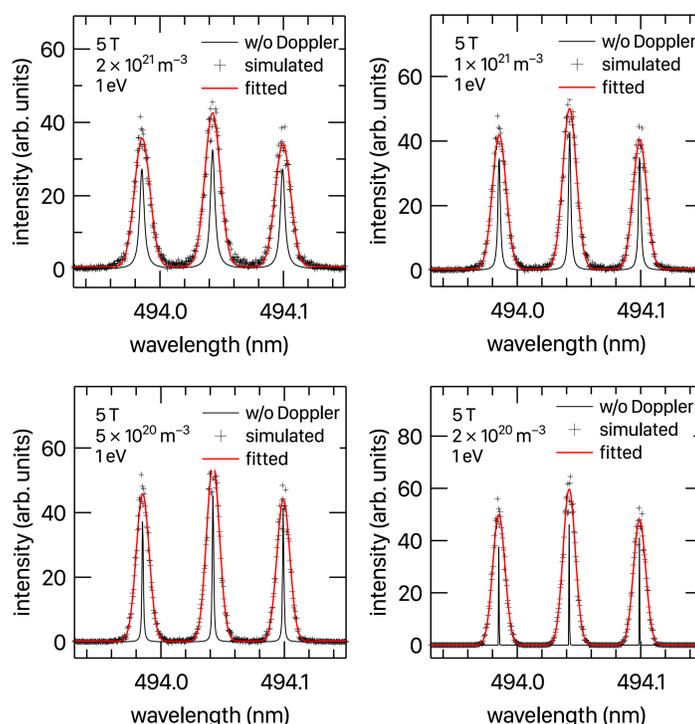


Fig. 2: Examples of calculated spectra and fitting results with a Gaussian profile for Be II 467.3 nm line.

- Matrix elements include Zeeman and Stark interactions between sublevels.
- Perturbed energies are obtained by diagonalizing the total Hamiltonian.
- Transition intensities are evaluated from  $I = |\langle l | e \cdot d | u \rangle|^2$ .
- Observed polarization is decomposed into horizontal ( $e_H$ ) and vertical ( $e_V$ ) components.
- The final line shape is obtained by integrating over all microfields and convolving with the impact profile.

## 3. Results: Be II (467 nm)

- Line splits into  $\pi$  and  $\sigma$  components under 5 T magnetic field.
- At  $n_e > 10^{21} \text{ m}^{-3}$ , Stark broadening becomes significant.
- Gaussian fitting to central peak overestimates  $T_i$ .



- Even at low density, Zeeman splitting inflates apparent  $T_i$ .

## 4. Results: B II lines

- 412 nm line: complex triplet structure, difficult for  $T_i$  diagnostics.
- 494 nm line: Stark broadening visible above  $5 \times 10^{20} \text{ m}^{-3}$ .
- 345 nm line: negligible Stark effect, dominated by Doppler width.
- Combining 494 nm and 345 nm lines enables  $T_i + n_e$  diagnostics.

## 5. Summary

- Stark broadening affects Be II (467 nm) at high density.
- B II (494 nm, 345 nm) offer complementary diagnostic capability.
- Simultaneous  $T_i$  and  $n_e$  measurements possible for ITER divertor plasma.

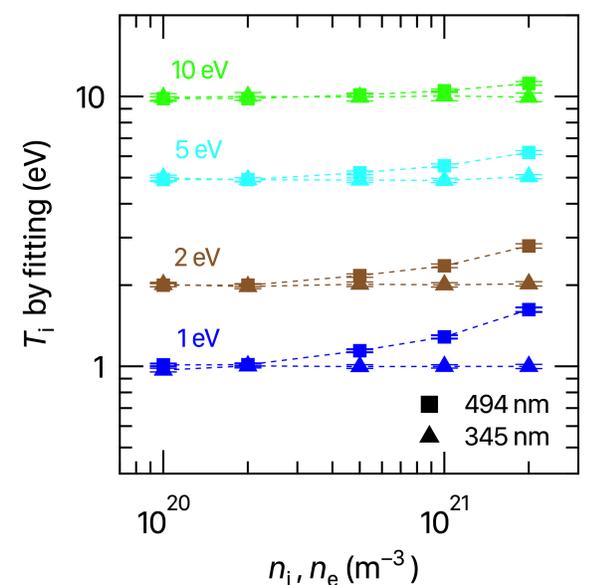


Fig. 3: Examples of calculated spectra and fitting results with Gaussian profiles for B II 494.0 nm.