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Exploration of using neon-like xenon lines on X-ray crystal spectrometers on EAST

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Outline

- Background
- Upgrade of XCS on EAST
- Performance and data validation
- Future collaboration plan
- Summary

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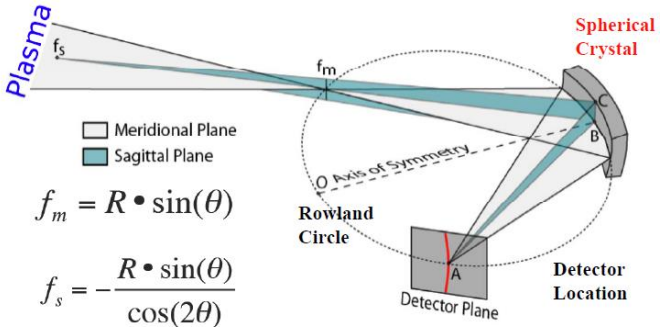
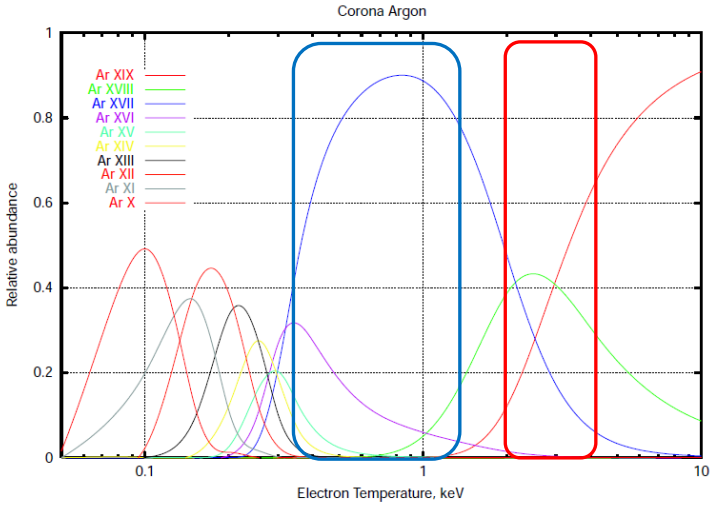
Background

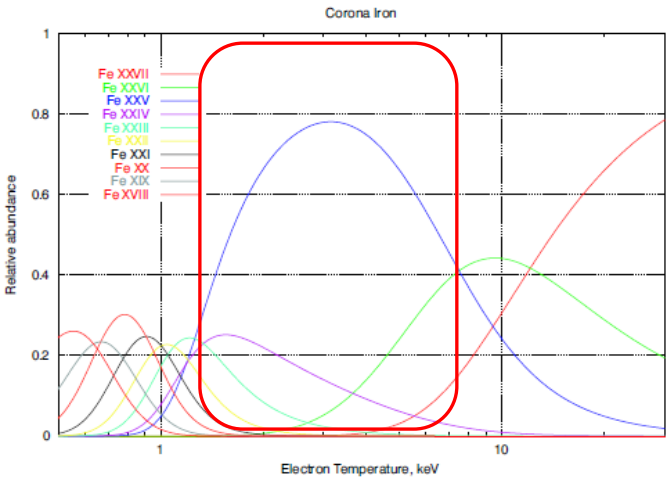
- Ar XVII becomes hollow and Ar XVIII is relatively low in the outer low electron temperature region.
- **Measuring two spectra simultaneously** is one of the way of obtaining the whole profile.





He-like Ar 0.3-3keV

H-like Ar 1.5-10keV



- **He-like Fe 1.5-7keV**

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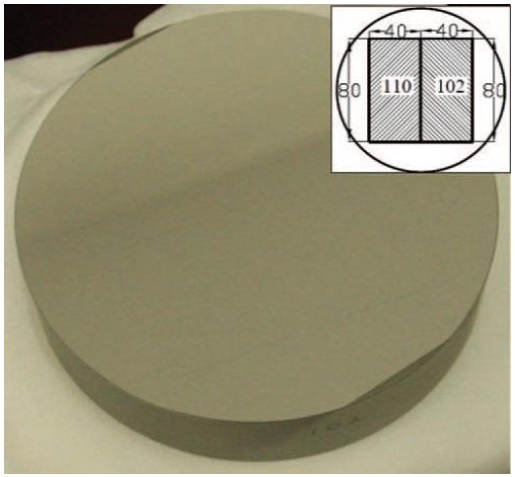
Parameters of the two-crystal assembly

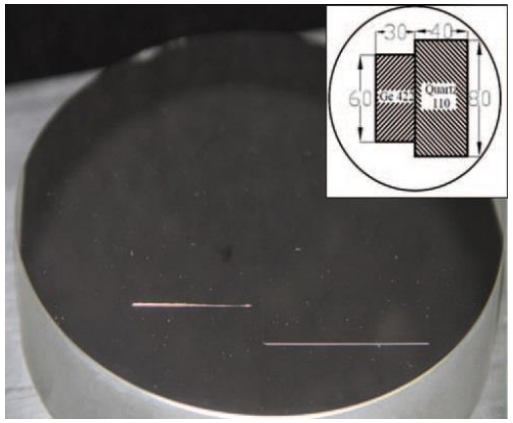
Double-crystal assembly for TXCS (He- and H-like Ar)

Impurity	Crystal	2d of crystal / Å	Wavelength Å	Bragg angle (°)
Ar XVII	Quartz 110	4.91304	λ_1=3.9494 (W) λ_2=3.9944 (Z)	θ_1=53.5010 θ_2=54.3927
Ar XVIII	Quartz 102	4.56225	λ_3=3.7300 ($Ly_{\alpha 1}$) λ_4=3.7353 ($Ly_{\alpha 2}$)	θ_3=54.8432 θ_4=54.9589



Double-crystal assembly for PXCS (He-like Ar and Fe)

Impurity	Crystal	2d of crystal / Å	Wavelength Å	Bragg angle (°)
Ar XVII	Quartz 110	4.91304	λ_1=3.9494 (W) λ_2=3.9944 (Z)	θ_1=53.5010 θ_2=54.3927
Fe XXV	Ge 422	2.3098	λ_3=1.8480(W) λ_4=1.8730(Z)	θ_3=53.1367 θ_4=54.1832



B. Lyu et al. RSI 85 (2014) 11E406

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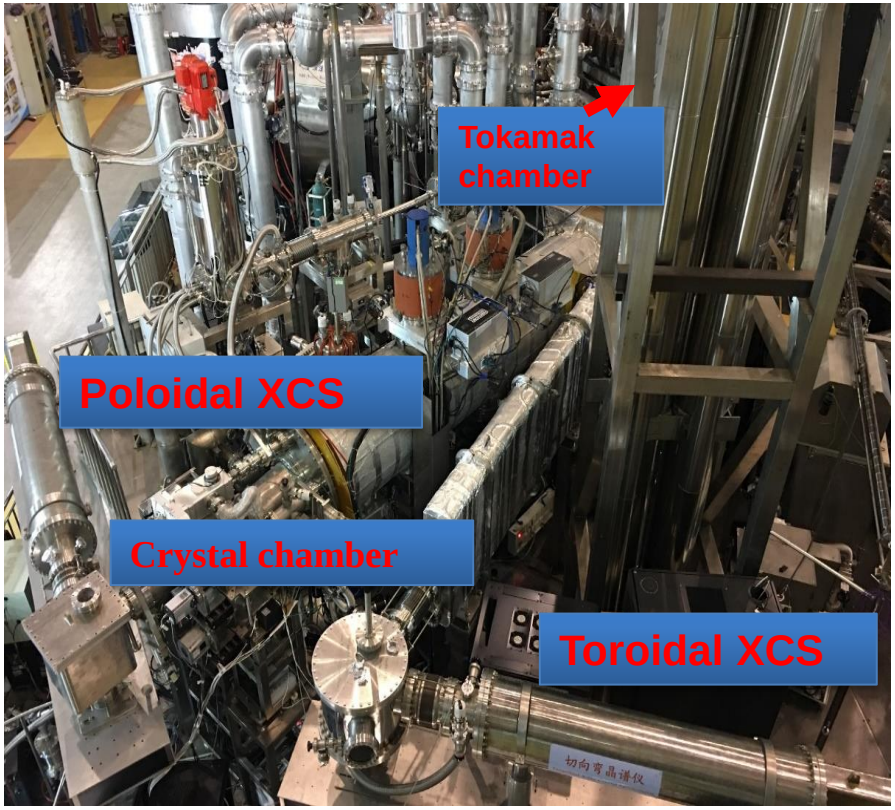
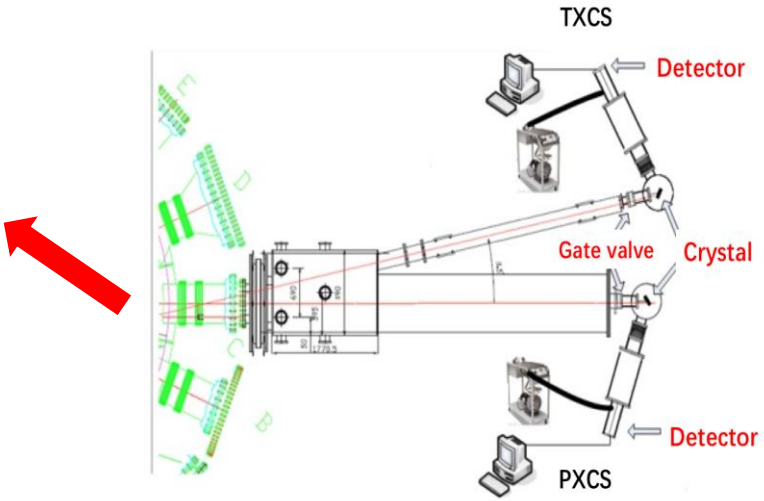
Current XCS system on EAST



PILATUS 900K

- Large area: 83.8*325.3cm^2 /300Hz
- Pixelated: single-photon counting > 1GHz
- Water-cooled for long-pulse operation



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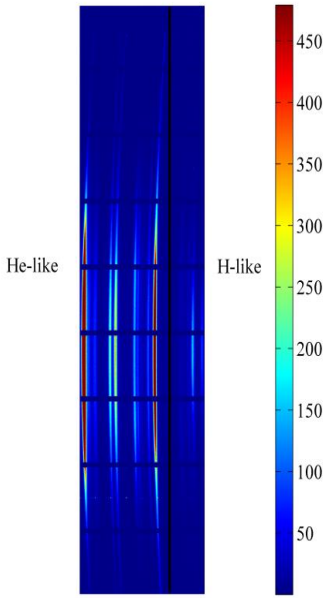
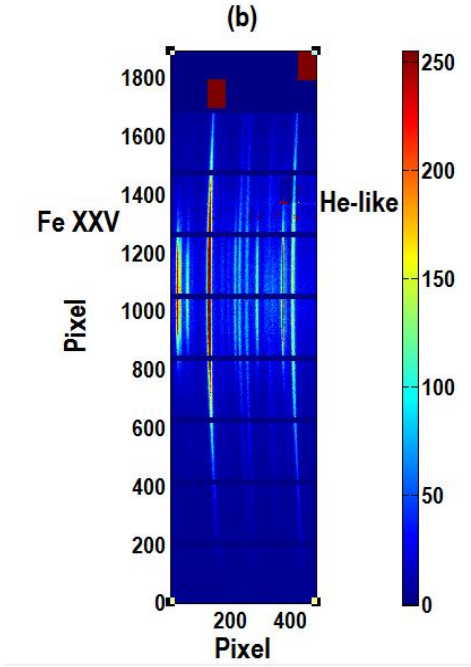
He-like and H-like spectra measured by XCS

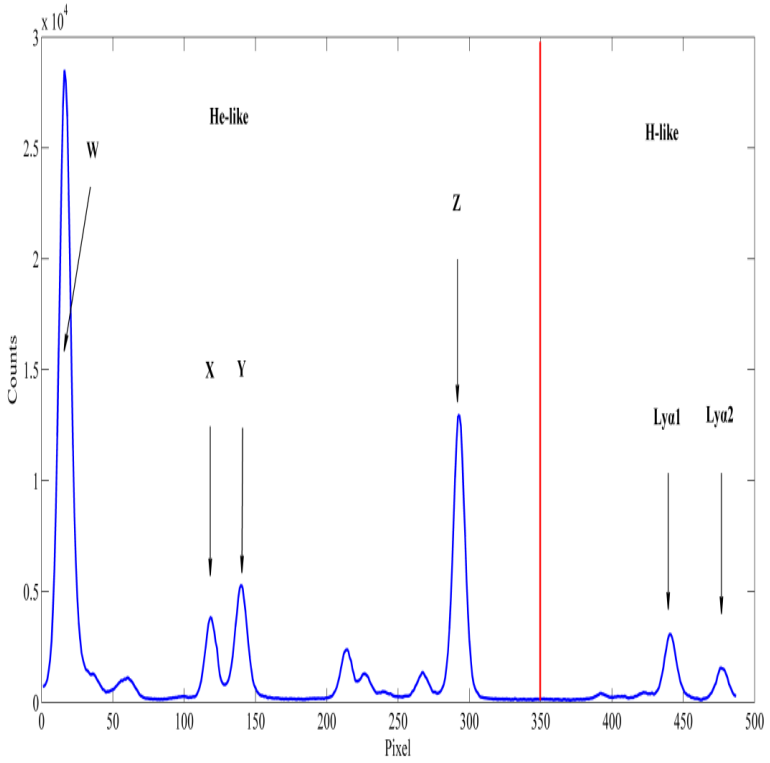
TXCS: He- and H-like Ar



PXCS: He-like Fe and Ar



Raw spectra data from TXCS



Helium-like and Hydrogen-like Argon spectra

B. Lyu et al. RSI 87 (2016) 11E326

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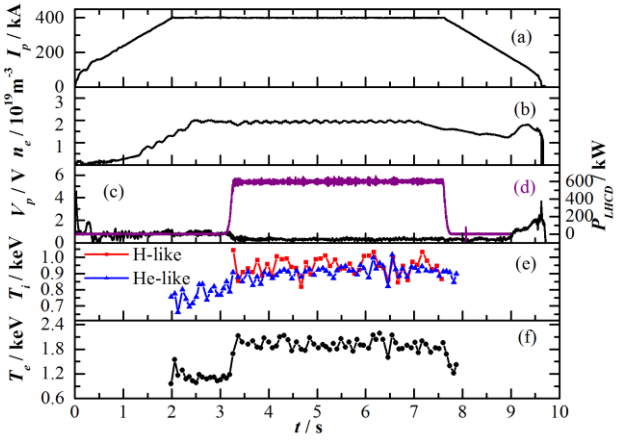
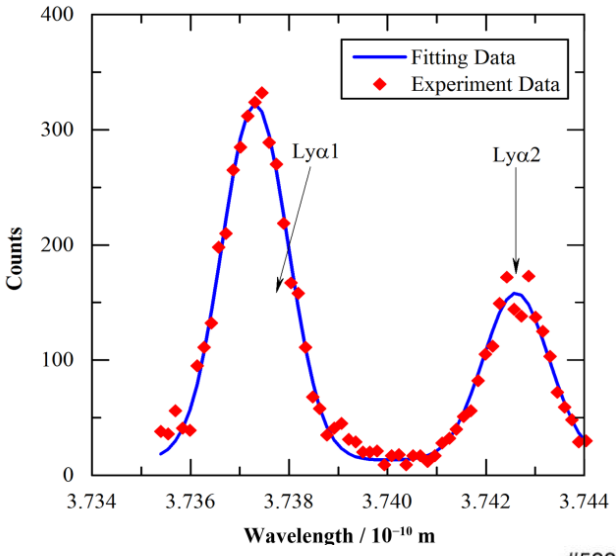
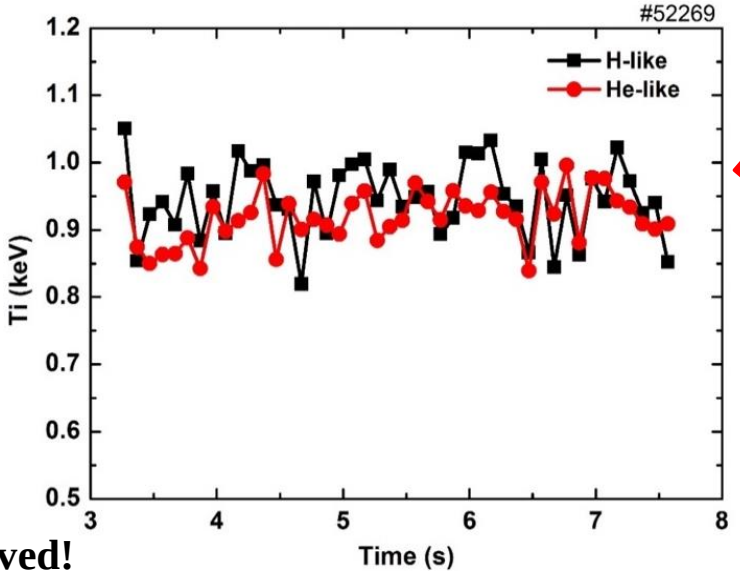
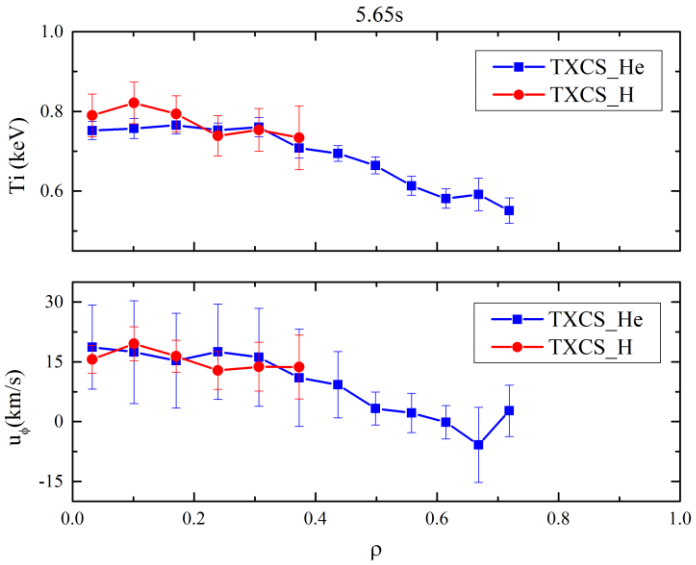
Data validation of H-like Ar spectra







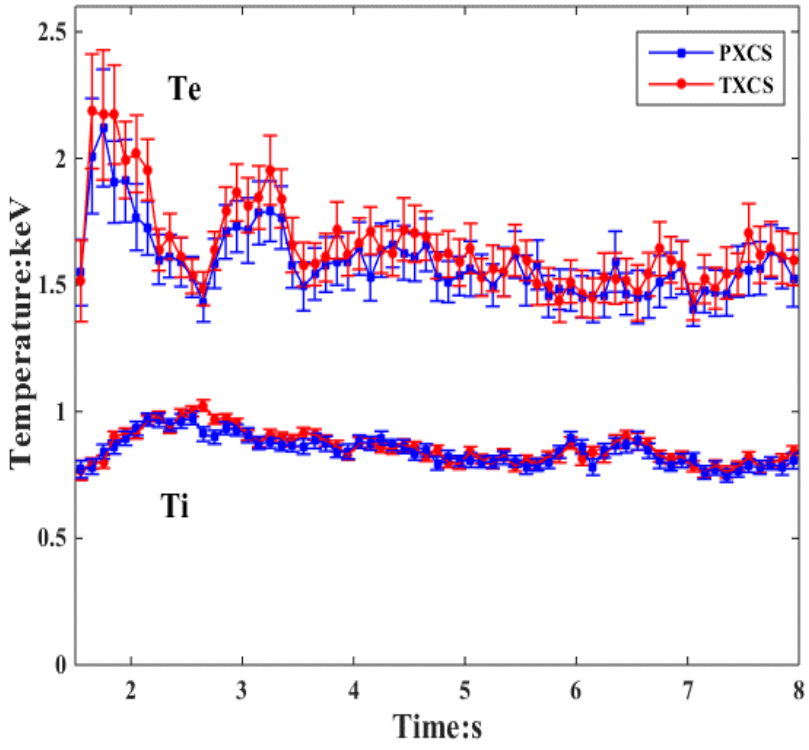


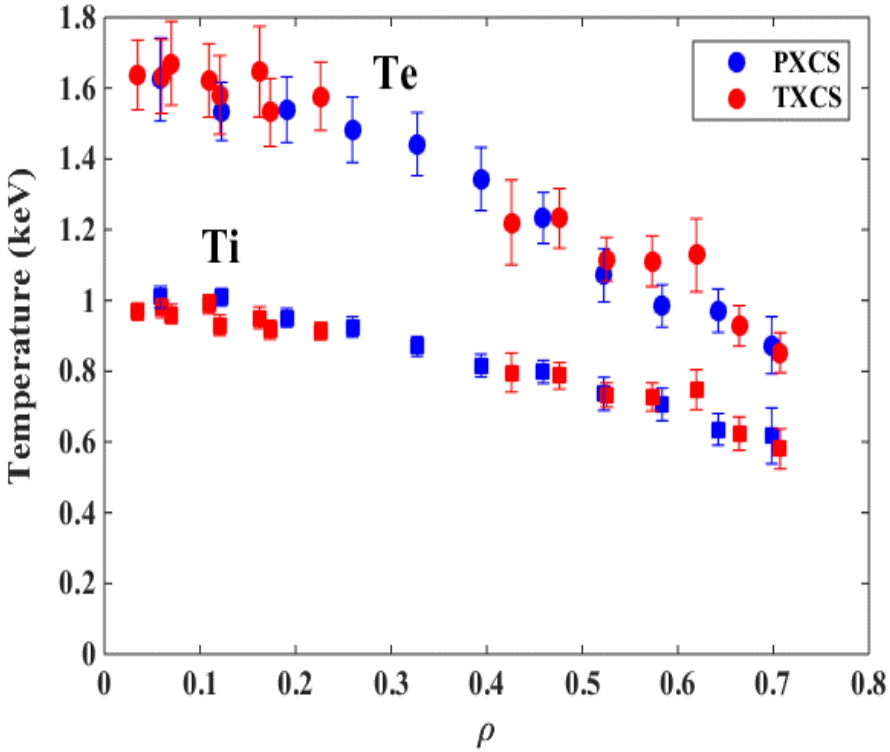
➢ **Good agreement between two spectra was observed!**

J. Chen et al. Nucl. Tech 38 (2015) 110403

Comparison between PXCS and TXCS

- **Both evolution and radial profiles of Te and Ti for two spectrometers agrees within the uncertainty**





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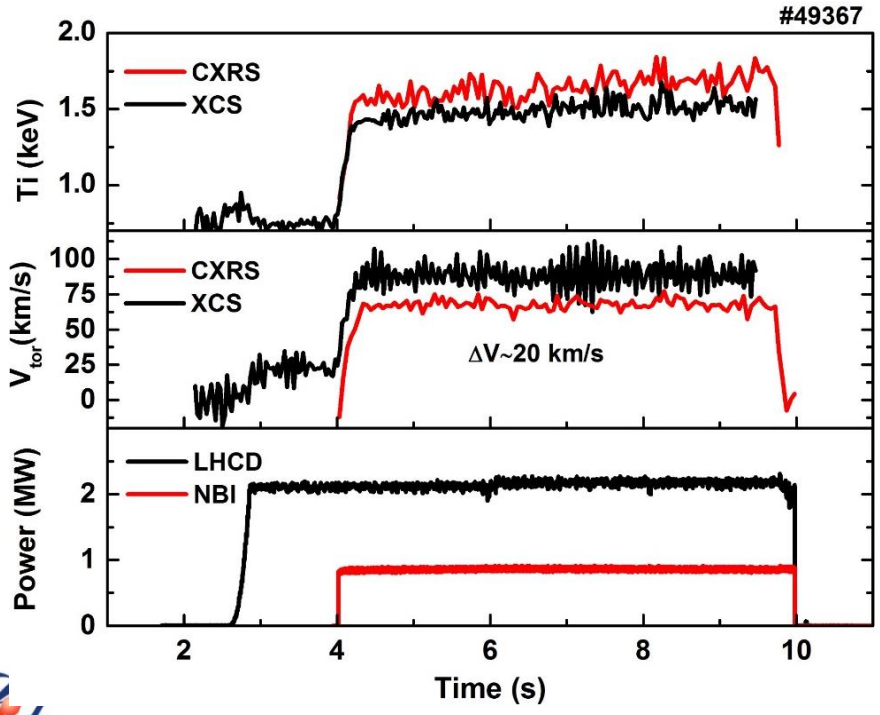
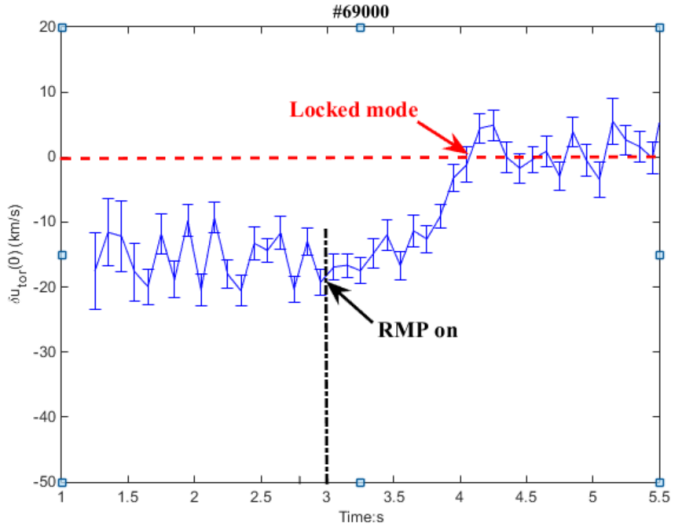
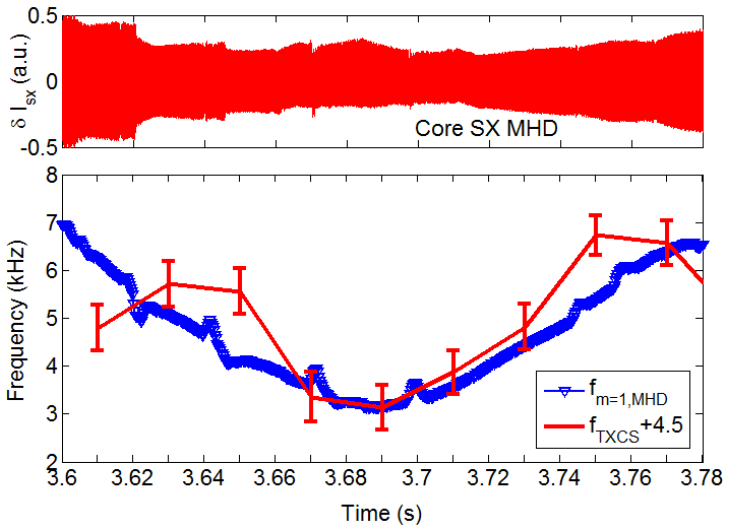
Method of wavelength calibration

- Locked mode
- Comparison with MHD frequency
- Cross comparison with CXRS







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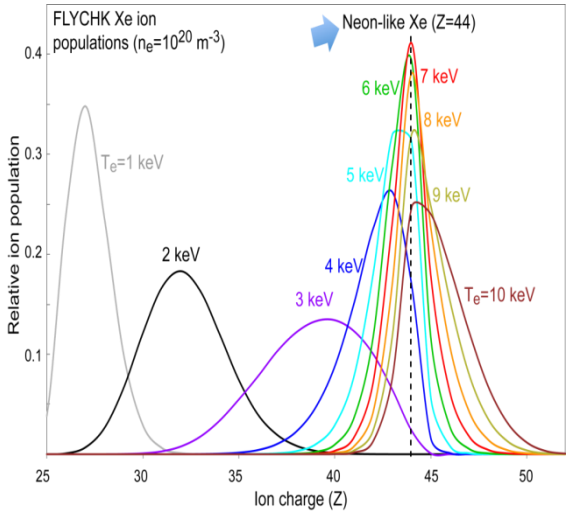
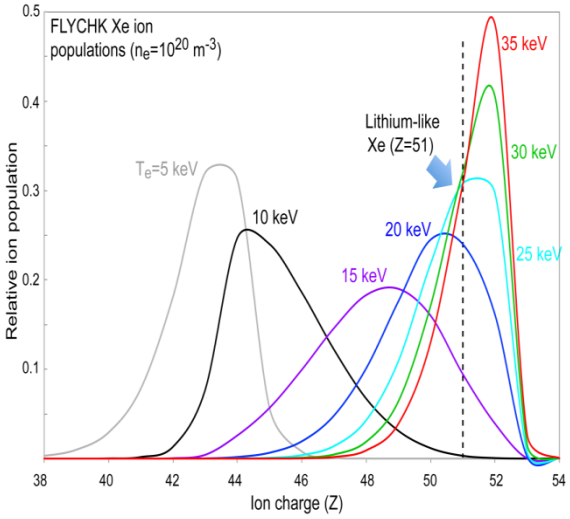
Consideration for ITER and CFETR

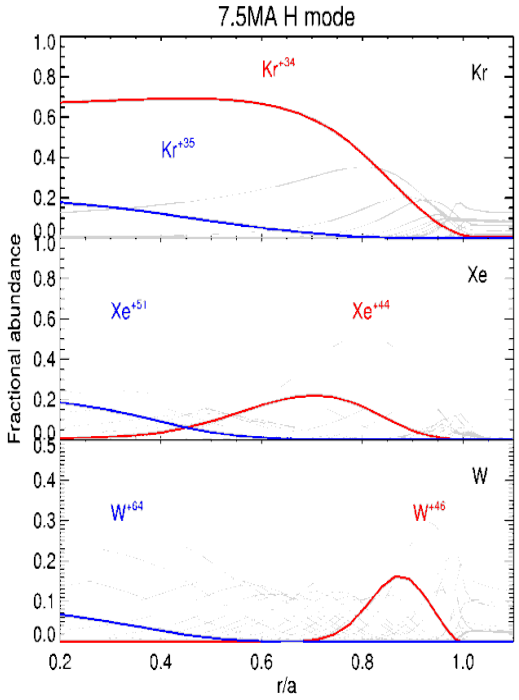
- ITER XCS is proposed to use W or Kr as the diagnosing ion
- Xenon is another good candidate as for both core and edge diagnostics
  - Higer line intensity than Kr for same radiated power loss

T_{e0}~4-10keV



T_{e0} up to 30keV





Impurity profile prediction on ITER

L.F. Delgado-Aparicio *et al.*, 32nd Meeting of ITPA Topical Group on Diagnostics, May 9-12, 2017, Chengdu, China.

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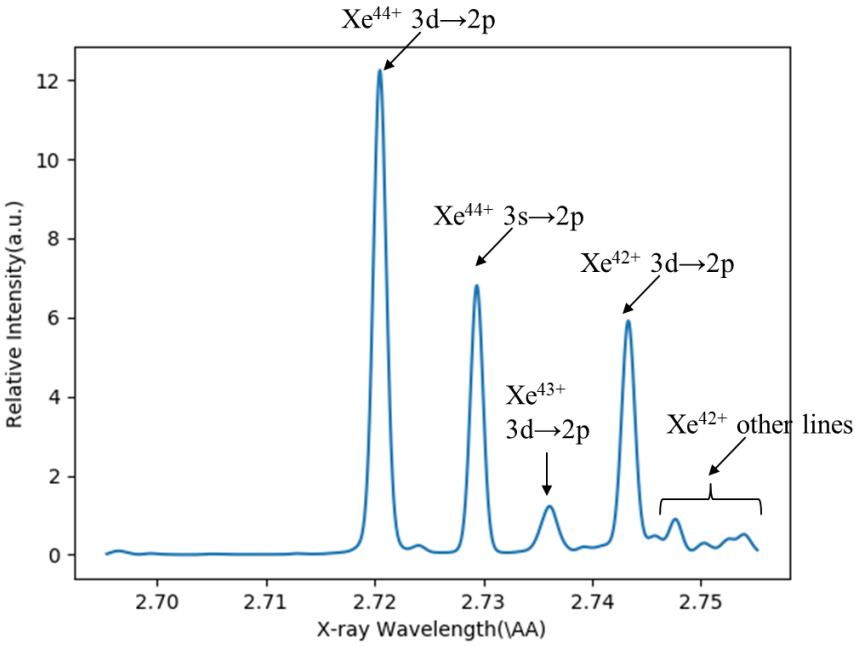
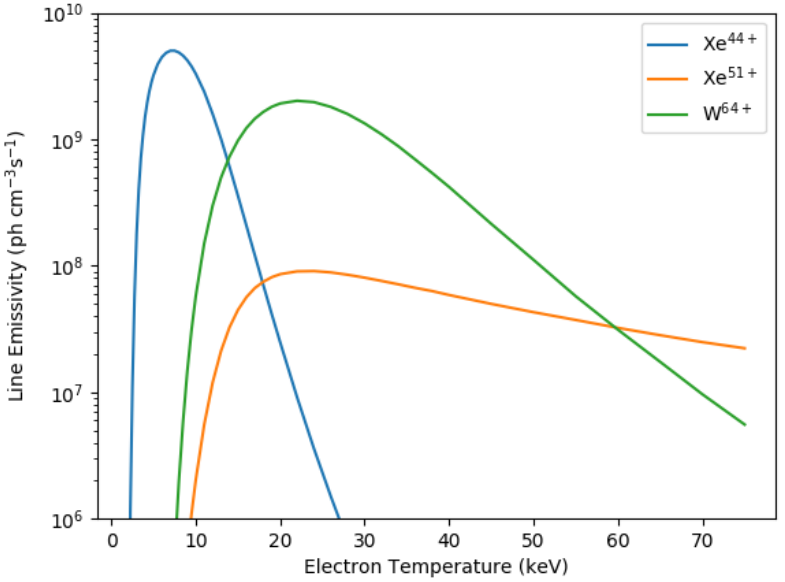
Xe Spectrum Simulation

- Te > 5 keV， Coronal equilibrium, collisional radiative model.





- A simulation of emissivity for Xe and W lines. Coronal equilibrium, collisional radiative model. $n_e = 10^{20} m^{-3}$.

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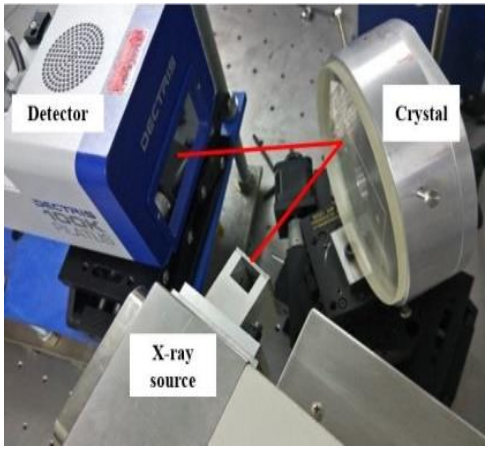
Xe-Ar crystal assembly

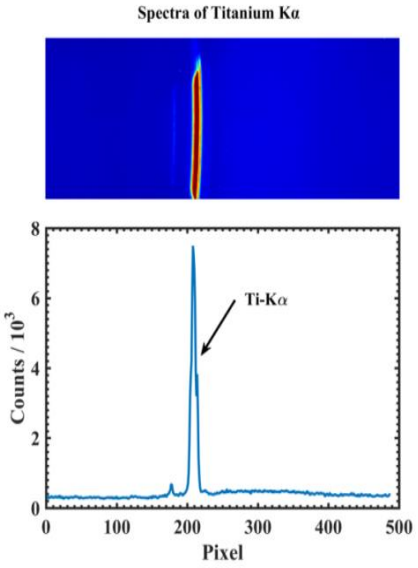
- New Ne-like Xe crystals with similar Bragg angle to He-like Ar
- Installed on the poloidal XCS to measure two-spectra simultaneously
- X-ray testing with titanium anode shows the crystal reflectivity and potential application for wavelength calibration

Line	Wavelength (Å)	Crystal 2d (Å)	Bragg angle (deg)
Ar XVII W	3.9494	4.913	53.5010
Xe XLIV	2.7368	6.686	54.9515

Crystal assembly and specification



Setup and test results



Hu et al, RSI 89(2018)10F110

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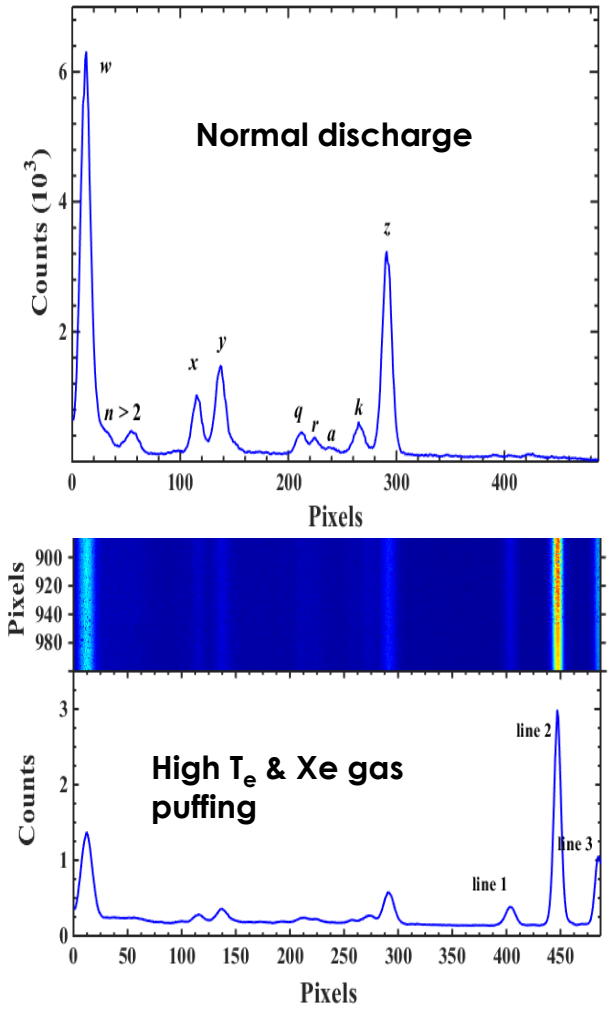
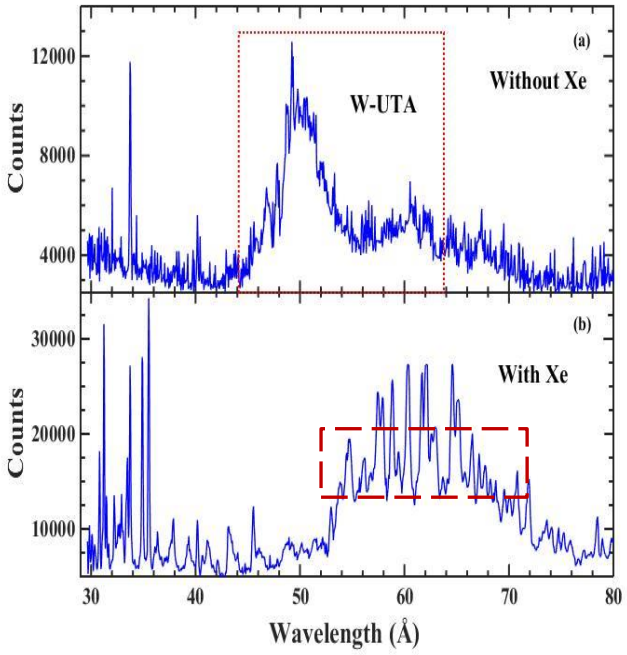
Measurement of Xe spectra



Comparison of measured spectra with/without Xe

- New lines were observed with Xe injection in both XCS and EUV spectrometers
- One line was determined to be Xe line through 2nd order diffraction from the crystal



EUV spectra with and without Xe

Lyu et al, RSI in preparation

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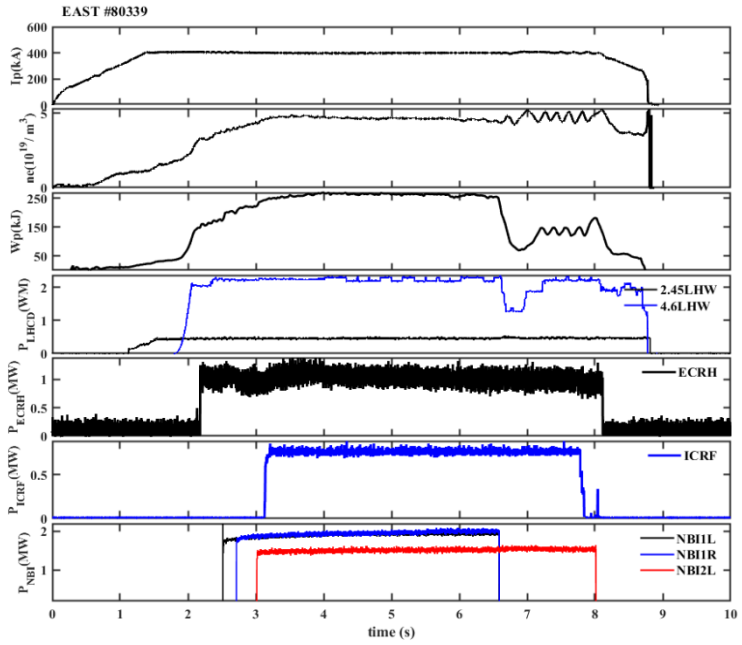
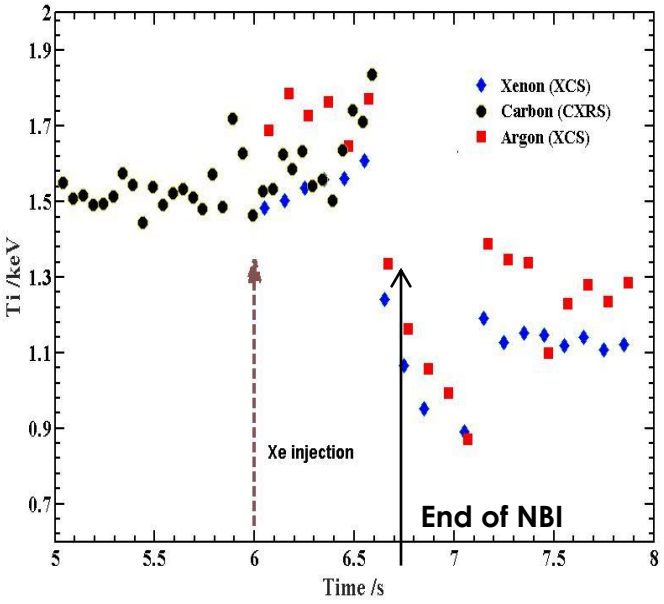
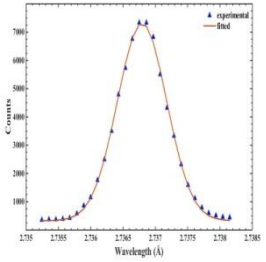
Ion temperature measurement

- Simultaneous measurement of two spectra provides additional data validation through T_i comparison
- Consistency in the T_i evolution is observed although there is some difference in the absolute value: possibly due to the strong line averged effect in Ar spectra
- Proof of concept for future high temperature diagnostics





T_i comparison for Ar and Xe ions



Gaussian fitting for Xe spectra

Lyu et al, RSI in preparation

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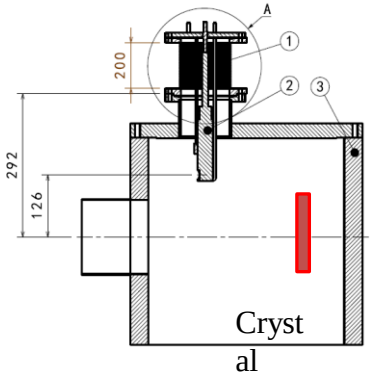
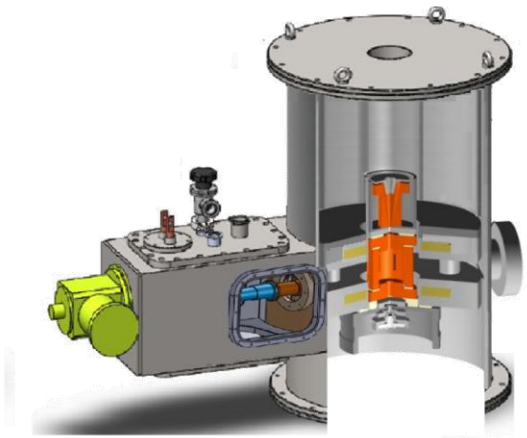
Collaboration plan

- **Further experimental analysis on Xenon spectra:**
  - **Effect on the discharge performance**
  - **Wavelength, intensity (effect of impurity transport)**
  - **Comparison with EBIT for verification**
- **Wavelength calibration with external source and Ti/Cd anodes**
  - **Preliminary lab test proved the feasibility**





Parameter	Value
Eeam energy	5-30keV
Beam current	~20mA
Magnetic field	~1.0T
Magnet type	NbTi
Cooling method	Conduction cooled (dry)
Spectra range	Visible to X-ray
Element	W (Fe, Xe, Ar)

A compact EBIT for impurity spectra

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Summary

- Upgrade of detector technology and two-crystal assembly has significantly elevated the performance in terms of time resolution and high temperature on EAST
- XCS can provide the ion temperature and rotation velocity profiles in high temperature after the application of double-crystal, with results from He-like and H-like spectra consistent with each other in low electron temperature
- New crystal testing was ready for probing the Ne-like Xe spectra: a testbed for fusion reactor

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Thank you!