

Disruption processes and their characteristics on the SUNIST spherical tokamak

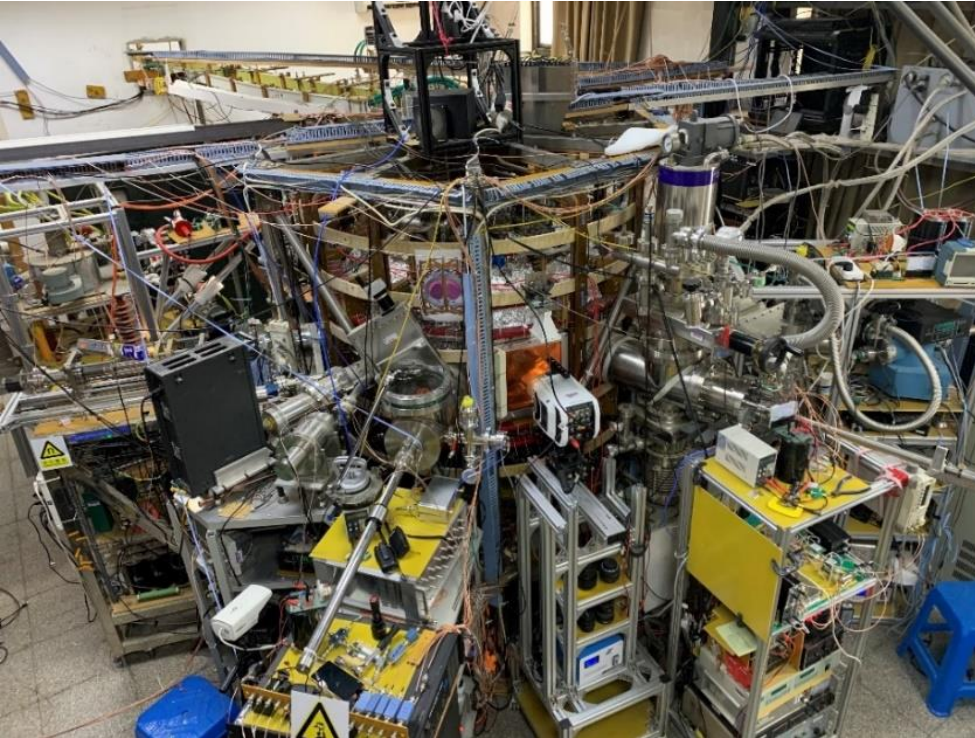
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Wenbin Liu, Yi Tan, Long Zeng, Zhe Gao

SUNIST, Tsinghua University

Experimental setup

Platform: SUNIST tokamak

Basic parameters



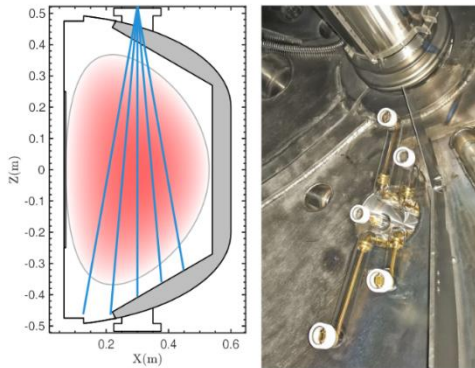
Parameter	Value
Major radius R	0.3 m
Minor radius a	0.23 m
Magnetic field B_t	<0.3 T
Plasma current I_p	<100 kA
Electron density n_e	$0.2 \sim 3 \times 10^{19} m^{-3}$

Experimental setup

Diagnostics:

Five-channel interferometer

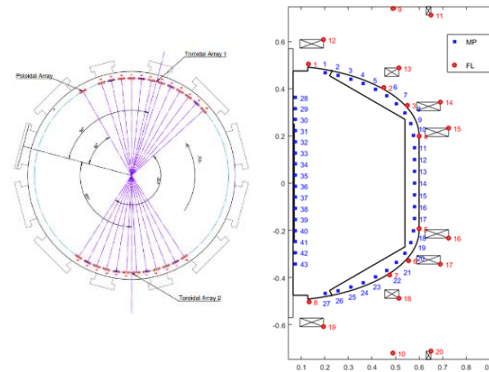
- high density resolution: $<6 \times 10^{15} m^{-2}$
- high frequency resolution: $<1\mu s$



Su et al., 2021

Magnetic probe array

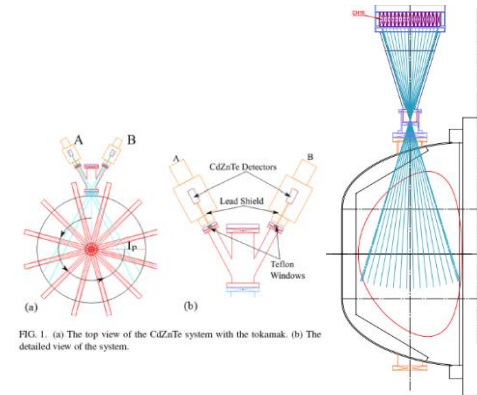
- 24 channels in toroidal
- 43 channels in poloidal



Cheng et al., 2021

HXR array

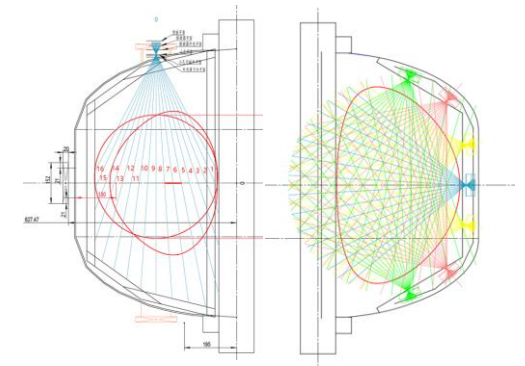
- 2 channels in midplane
- 16 channels in poloidal



Yang et al., 2021

AXUV array

- 112+16 channels in poloidal

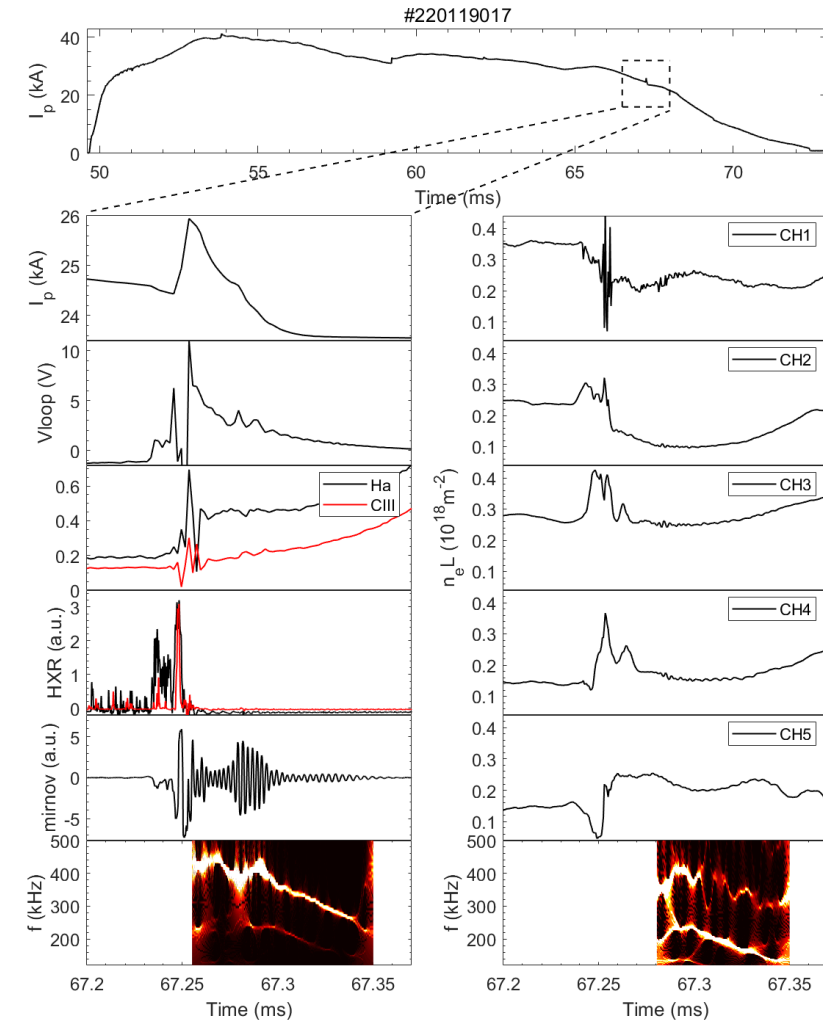


Wang et al., 2018

Disruption process

Typical characteristics:

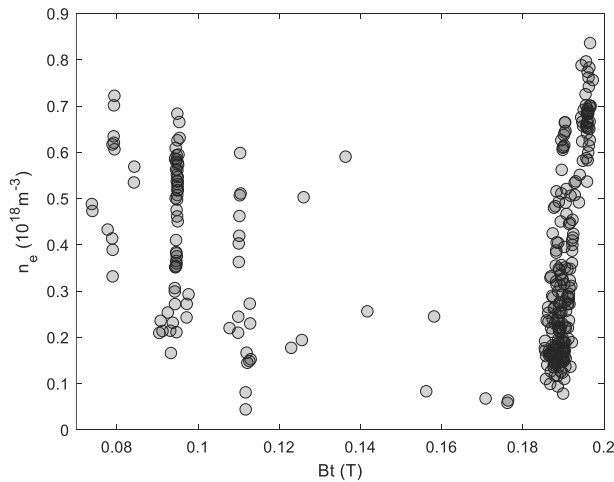
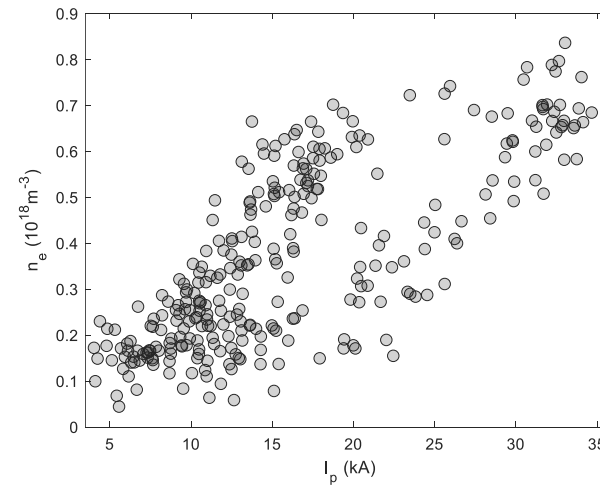
- Plasma current spikes
- Loop voltage increases significantly
- Magnetic perturbation
- HXR increases significantly, then disappears completely
- Electron density ejection
- Density perturbation



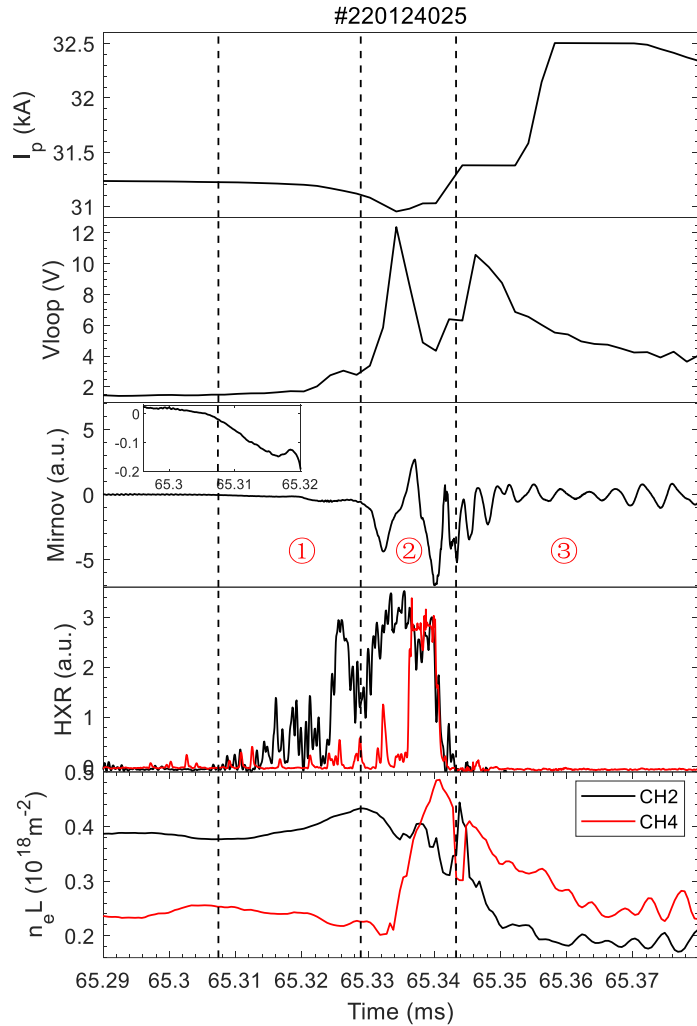
The discharge condition for disruptions

Low electron density, Low toroidal field——provide conditions for runaway electrons

- Toroidal field: <0.2 T
- Electron density: $<0.8 \times 10^{18} m^{-3}$
- Plasma current: 5~35kA

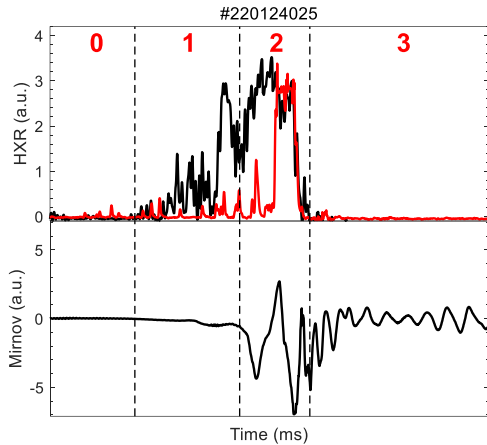
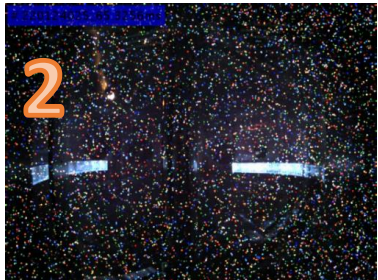


Magnetic and HXR evolution



	Magnetic	HXR
① precursor stage	Low amplitude; grow slowly	Increase
② explosion stage	Grow rapidly; huge amplitude; 1~2 period	Increase significantly
③ Quiet stage	Mode damping	Disappear completely

Fast camera image

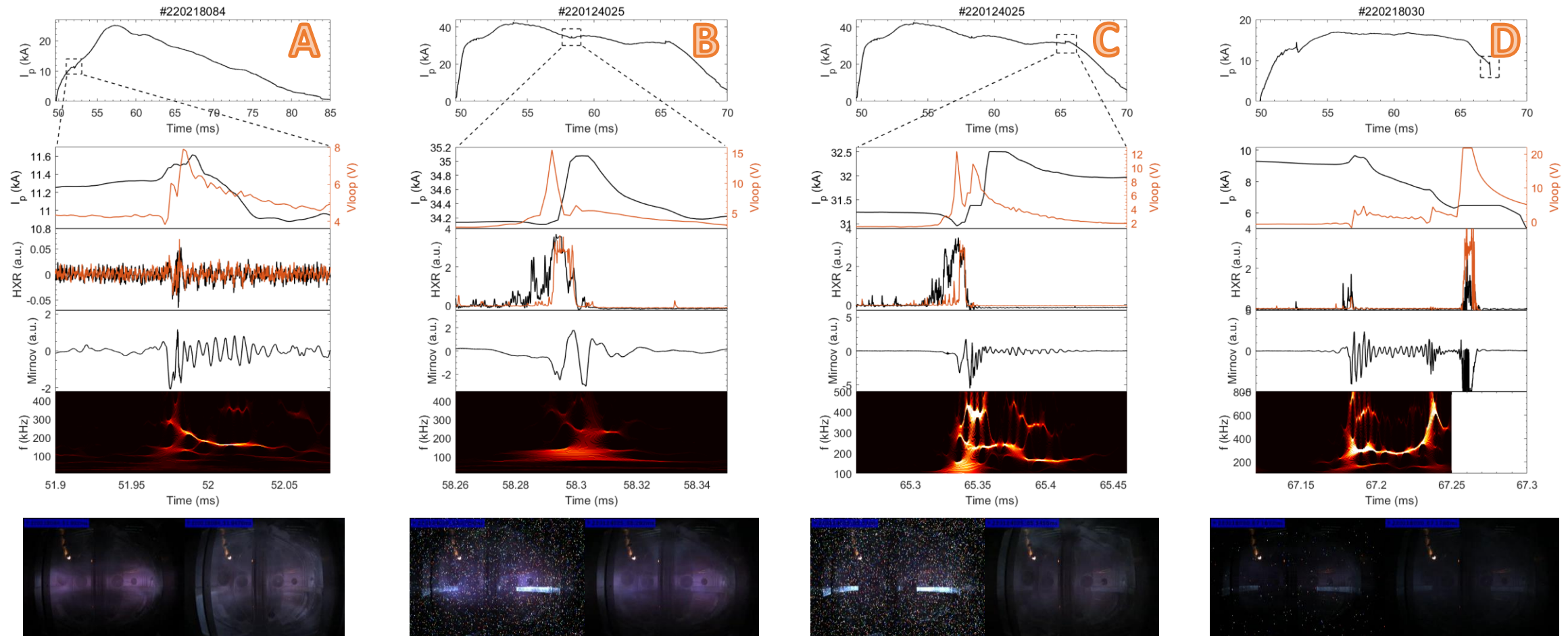


	HXR	Fast camera
0 before disruption	Not so high (~0.2)	A few 'snowflake'
1 precursor stage	Increase	More 'snowflake'
2 explosion stage	Increase significantly; REs/plasma hit the wall	A large number of 'snowflake'
3 Quiet stage	Disappear completely; REs lost	Without any 'snowflake'; Impurities entry

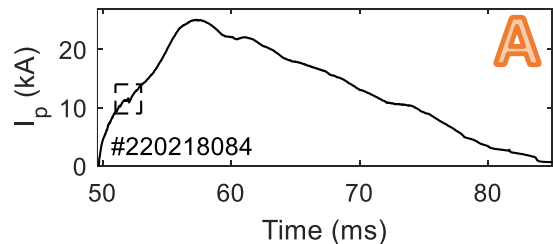
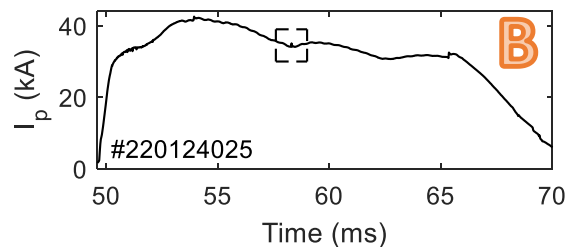
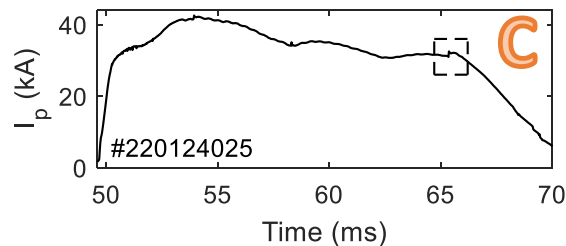
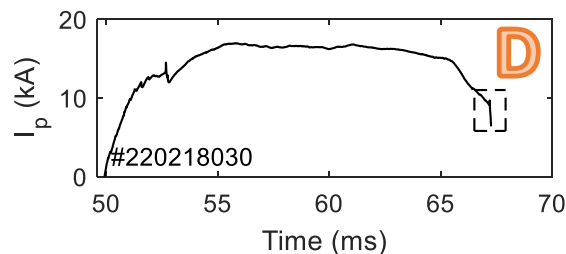
- The loop voltage creates more Runaway Electrons (REs).
- the magnetic perturbation causes Runaway Electrons lost.

Classification of disruption process

- The disruption can occur at different stage of the discharge pulse, and show different magnetic perturbation, HXR, runaway electron evolution.



Classification of disruption process



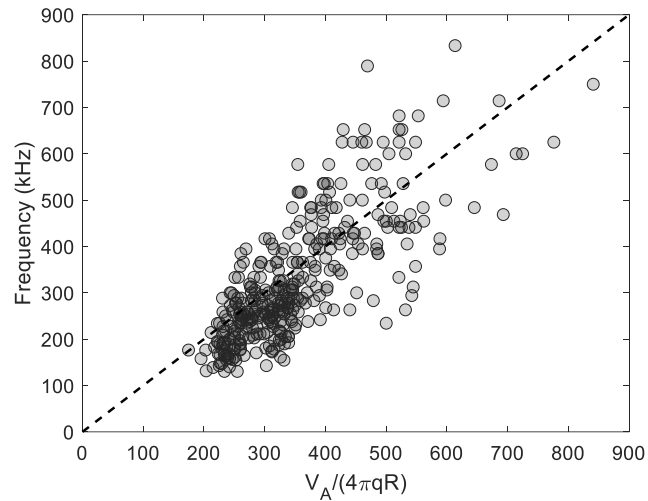
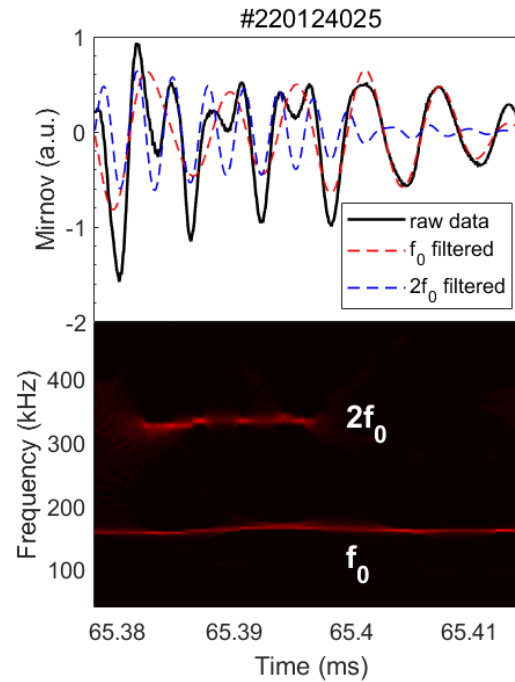
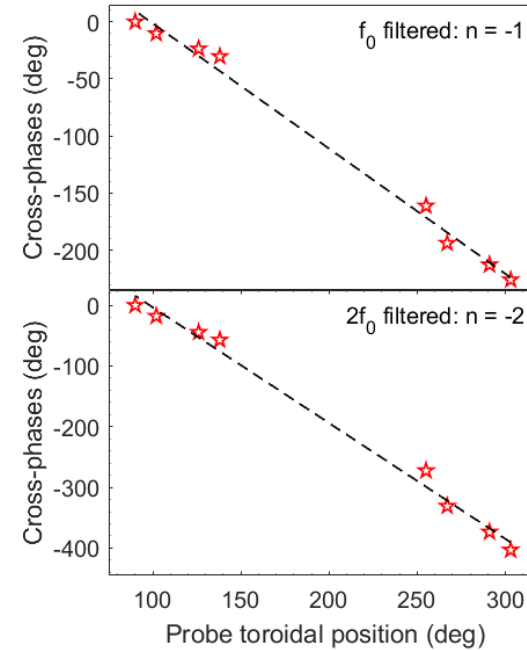
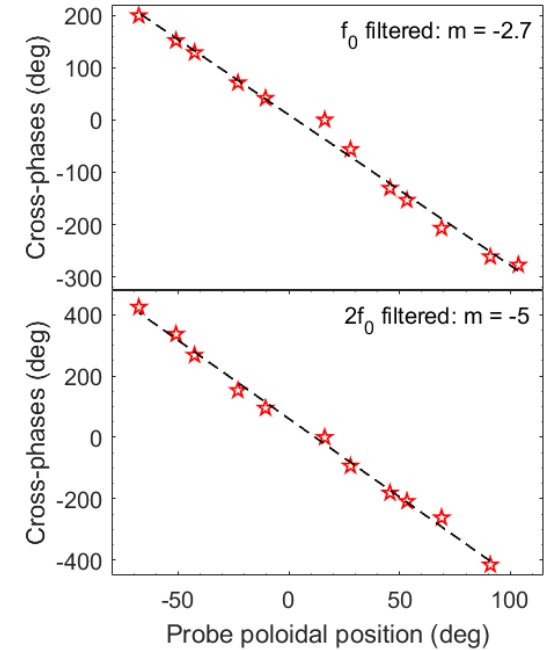
	Magnetic perturbation	HXR/'snowflake'/REs
A preliminary stage		Not increase and disappear; The gas ionization is not sufficient yet.
B platform stage	Only 1~3 period; The mode damping rapidly	increases significantly; then disappears completely
C later stage		
D ending stage	Higher frequency (~1MHz); Plasma moving inward or lower density	

The Alfvén eigenmode

➤ $f_{mode} \sim \frac{B_t}{\sqrt{n_e}}$

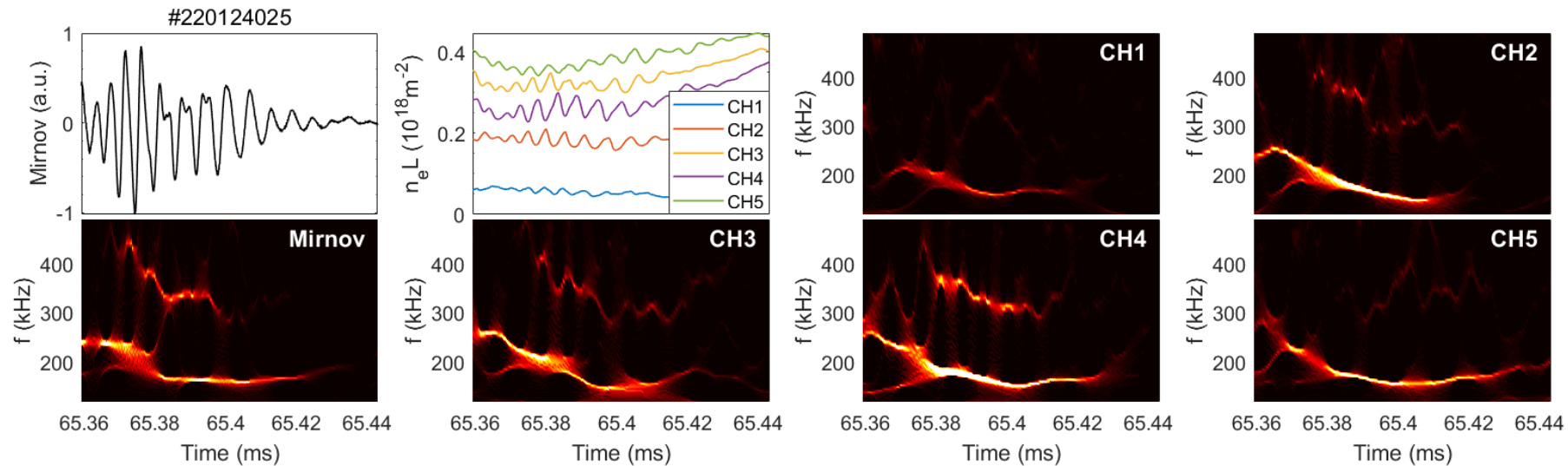
➤ Alfvén eigenmode

- Two modes coexist, the toroidal number n is $n = 1/n = 2$.
- propagates in the **electron diamagnetic drift** direction



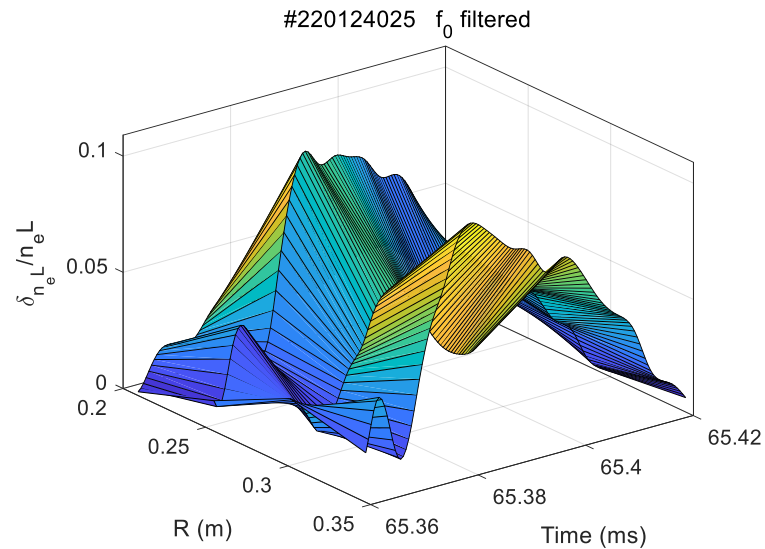
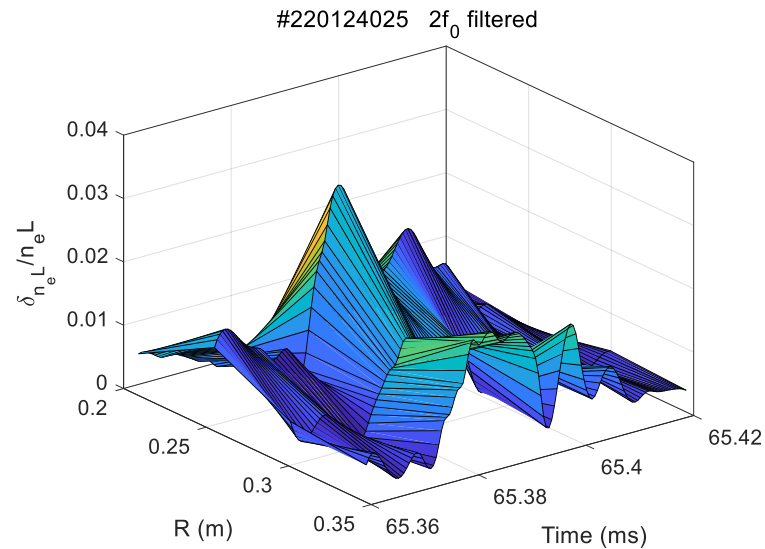
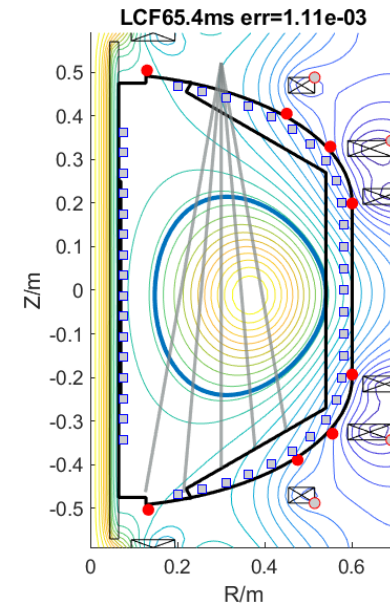
The electron density fluctuation

- Benefiting from the **high density resolution** and **high frequency resolution** of the five-channel interferometer, density fluctuations caused by the Alfvén mode can be captured clearly.
- The higher frequency mode is located within the position of CH2/3/4.



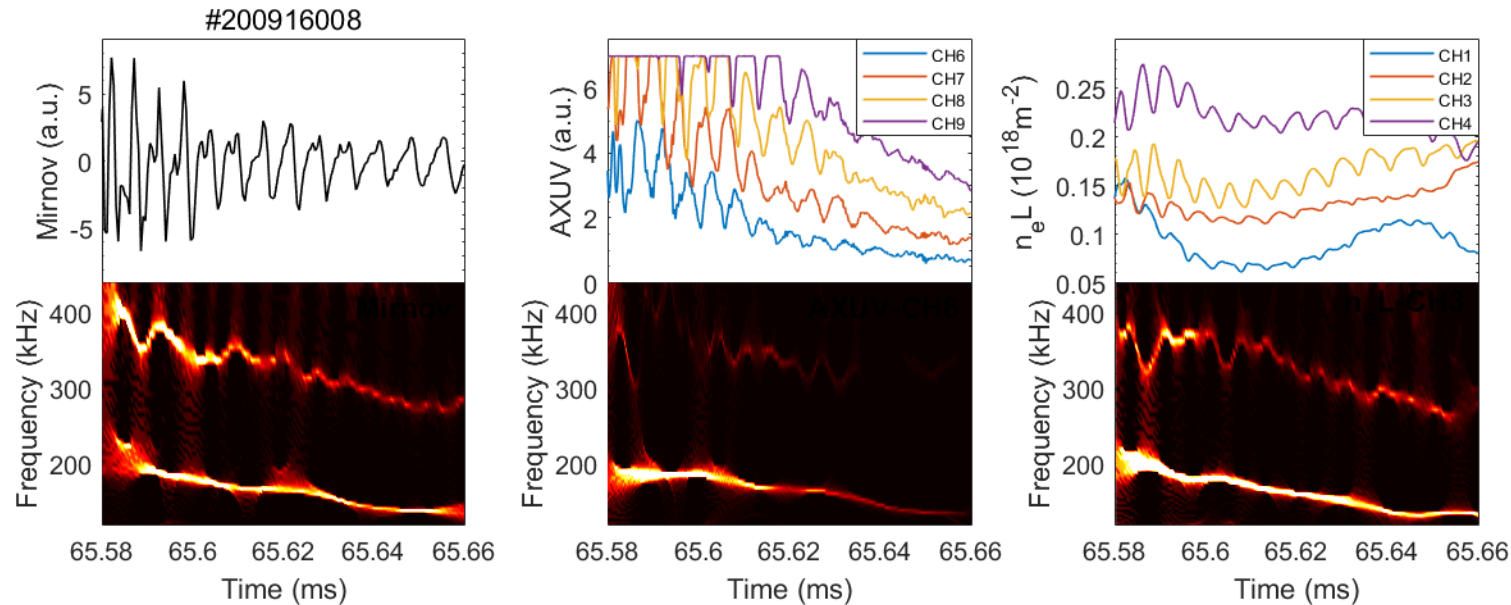
The electron density fluctuation

- The spatial distribution of density fluctuations will be used to study the spatial structure of the Alfvén mode.



The radiation fluctuation

- The radiation fluctuations caused by the Alfvén mode also can be measured by the AXUV array, and the mode structure is under analysis.



Summary

- Analyze and classify the minor disruption process on SUNIST tokamak.
- Study the characteristics of the disruption process on magnetic perturbation, HXR, runaway electrons, electron density fluctuation and radiation fluctuation.

Future works

- More direct measurement of runaway electrons.
- Investigate how the runaway electron excite this Alfvén mode.
- How to understand and apply this Alfvén mode on dissipating the runaway electrons.

Thanks for your attention!