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Fast particle confinement and TAEs in JT-60U

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JAERI

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Introduction to Alfvén Eigenmode Study in JT-60U

Alfvén Eigenmode (AE) experiments have been performed by using
Negative-ion-based Neutral Beam (E_{NNB}>360keV, P_{NNB}>4MW)

- in Weak shear plasma

Abrupt Large-amplitude Events (ALEs), Fast Frequency Sweeping modes

(K. Shinohara, et al.,Nucl. Fusion 41(2001) p603)

(18th. IAEA Fusion Energy Conference)

- in Reversed shear plasma

Reversed-Shear induced Alfvén Eigenmode (RSAE), its transition to TAE

(19th. IAEA Fusion Energy Conference)

Reduction of Total Neutron Emission Rate due to AEs has been observed

beam-thermal reaction is dominant

energetic ion transport due to AEs

However, It is not understood how energetic ions transport

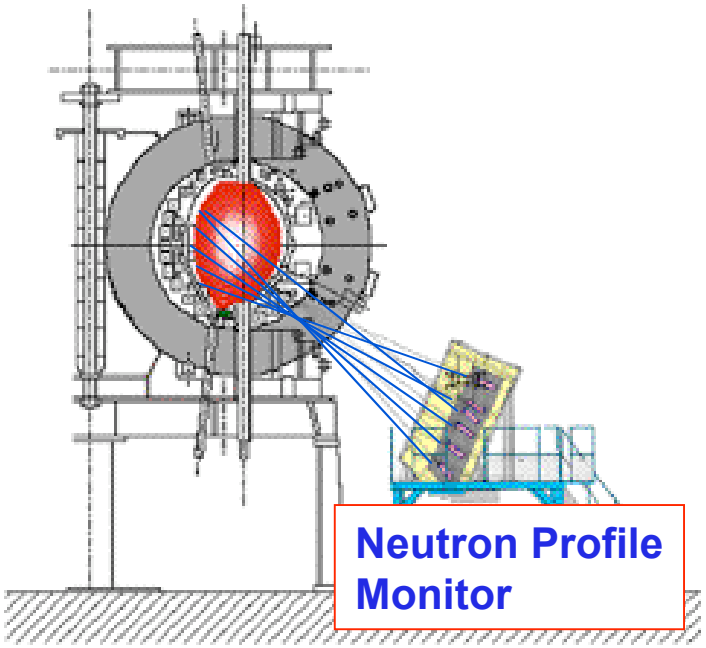
- neutron emission profile
- detailed energy distribution of neutral particle fluxes

have been newly measured in order to investigate energetic ion transport

Diagnostics for investigation of energetic ion transport

JT-60U

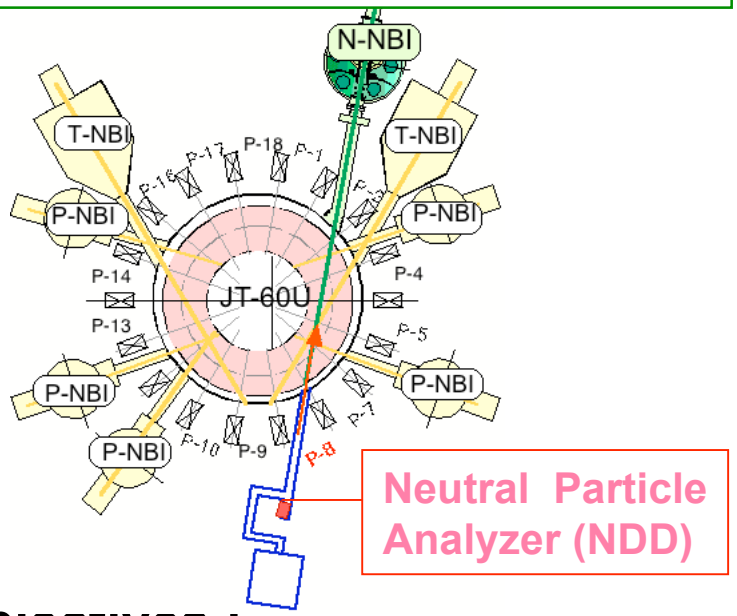
6 channel Neutron monitor



Objectives :

-Measure radial profile of neutron emission rate

CX-Neutral Particle Analyzer (Natural Diamond Detector)



Objectives :

-Measure fast neutral particle flux and energy distribution

investigate energetic ion transport from change in neutron emission profile and enhanced neutral particle fluxes

Bursting AE(Abrupt Large-amplitude Event, ALE) in Weak Shear Plasmas

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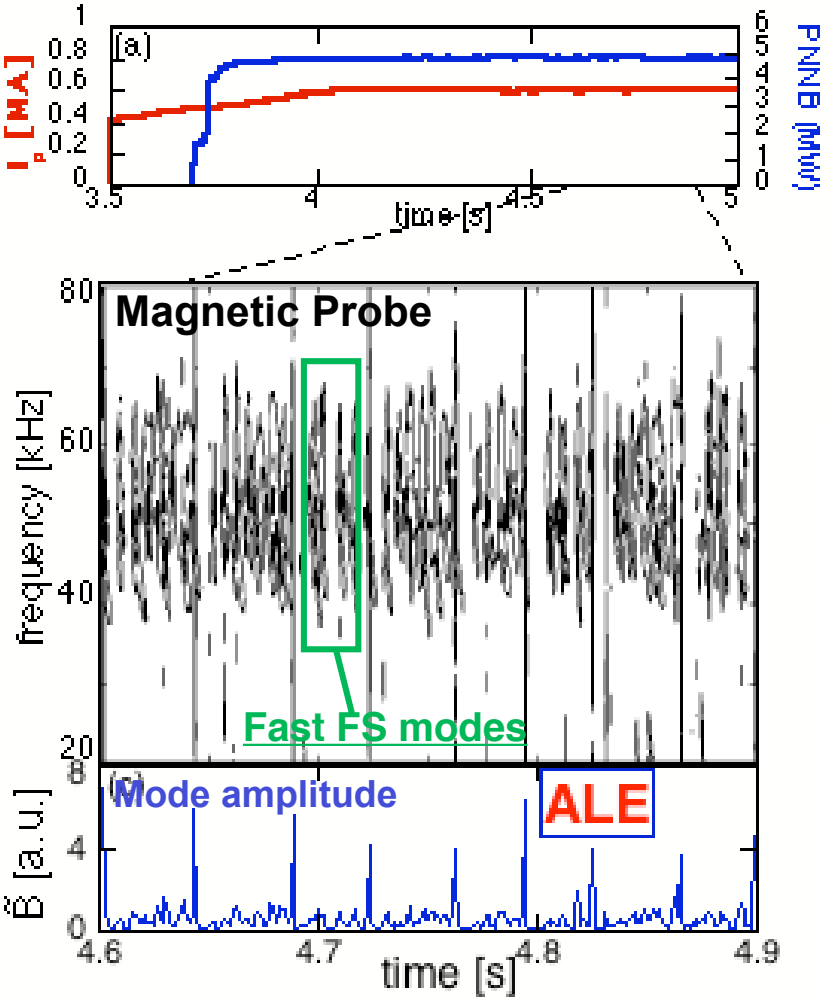
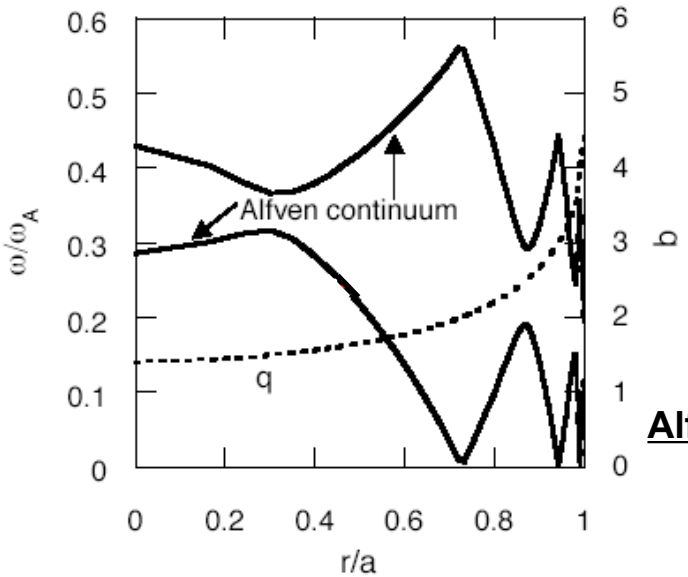
E43014, I_P=0.6MA, B_T=1.2T
P_{NNB}~ 4.8MW, E_{NNB}~387keV
$<\beta_h>$ ~ 0.6%, $v_{b//}/v_A$ ~1.03



- Bursting modes called ALEs are observed in the frequency range of TAE during NNB injection.
- **mode amplitude of ALEs reaches $\tilde{B}_\theta/B_\theta$ ~10^{-4} at the first wall**
- Alfvén gap exist at r/a∼0.2-0.4

➡ It is considered that modes is localized in core region



Alfven continuum and safety factor

Neutron Emission and Fast Ion Flux during ALE

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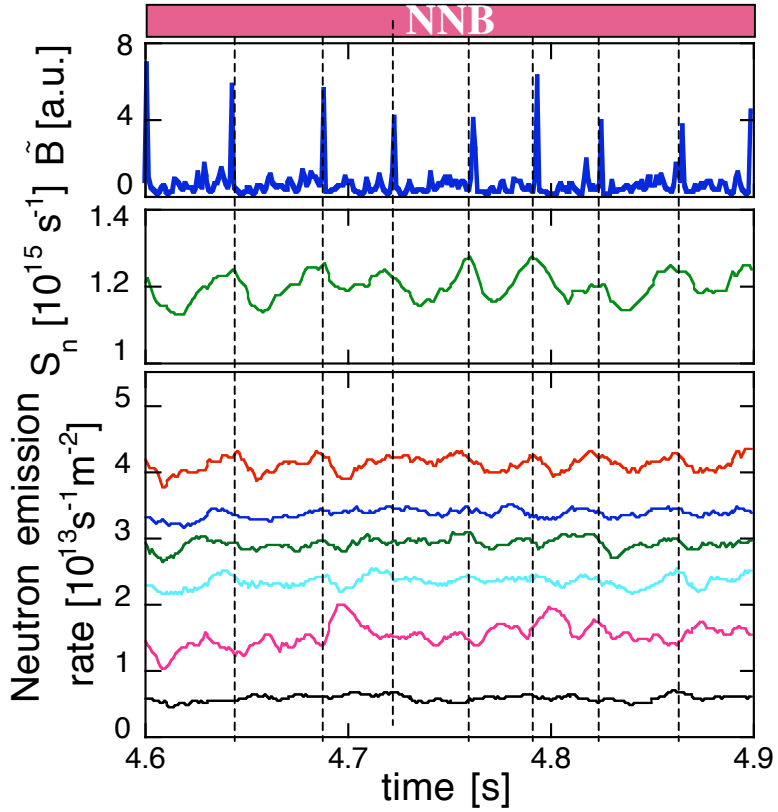
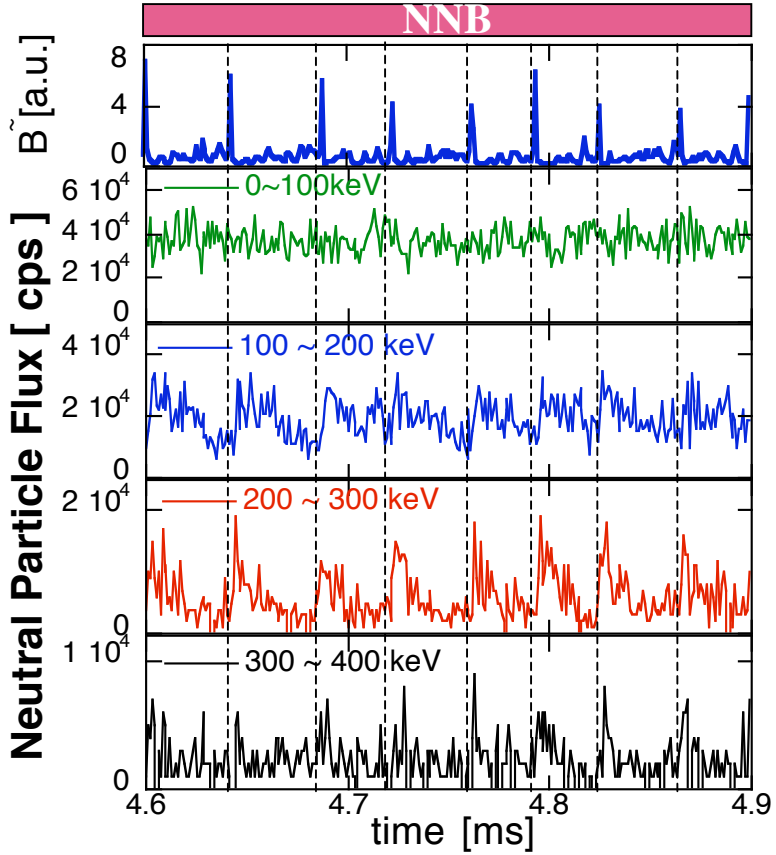
<Neutron Profile Measurement>



Drop of the signals of inner channels (ch.1-3) was observed, while increase of the signal of the outer channels (ch.5,6) was often observed

<Neutral Particle Flux>



Enhance of neutral particle flux with energy of 100-400keV was observed on the occurrence of ALE

→ Suggest redistribution of the energetic ions with limited energy region due to ALE

Change in energy distribution of neutral particle fluxes

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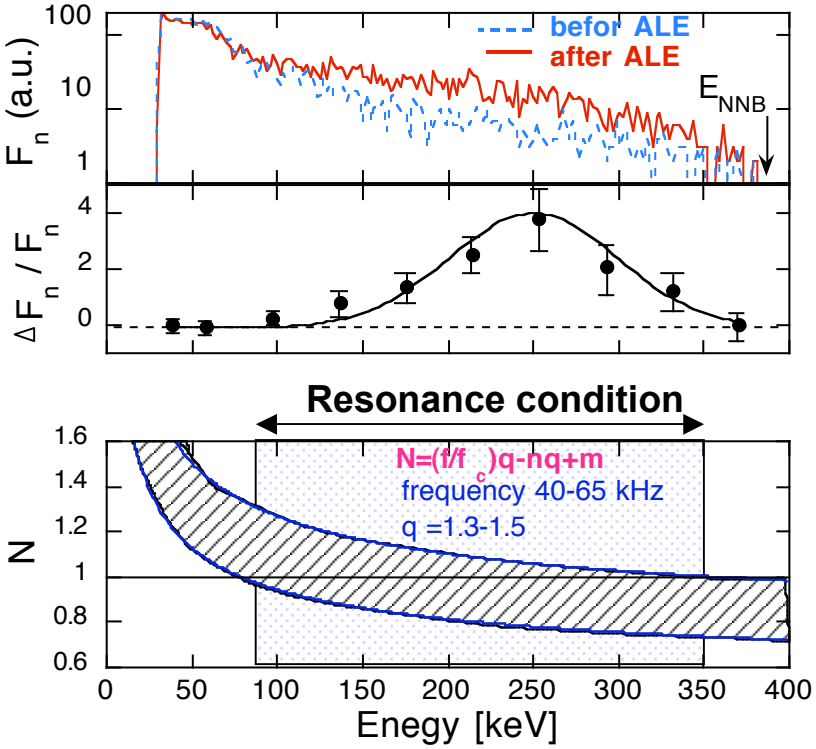
- Detail of energy distribution of neutral particle fluxes has been measured.
- The energetic ions are neutralized through a charge exchange reaction with D^0 or C^{5+} in outer region



Enhance of neutral particle fluxes in limited energy range (100 ~ 370 keV) has been observed for the first time.

Peak fraction of enhanced neutral particle flux is ~250 keV.

[Resonance condition with the mode]

(R. B. White *et.al.* Phys. Fluids 26 (1983) 2958)

$$N = (f / f_c)\, q - nq + m = \text{integer}$$

- f = mode frequency (40 - 65 kHz)
- q = safety factor (1.3 - 1.5)
- n, m = troidal, poloidal mode number (1, 2)
- F_c = troidal transition frequency of energetic ions

Resonant energy range => 80 ~ 350 keV

Energy region of enhanced neutral particle fluxes has agreed with that predicted form the resonant interaction between energetic ions and modes

Energetic ion transport by ALE

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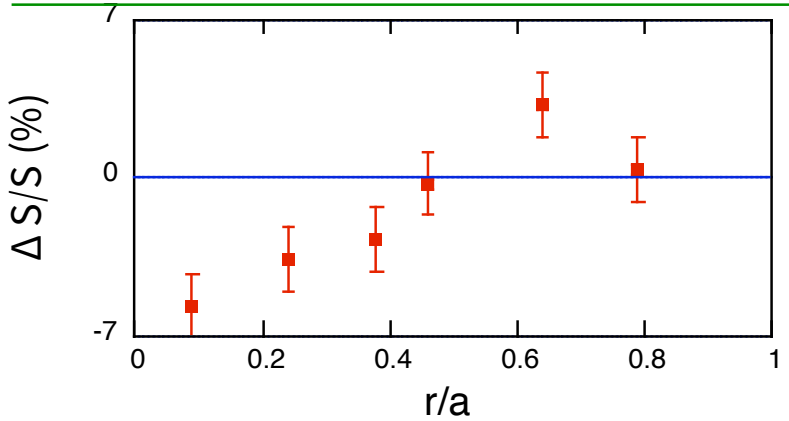


Drop of the neutron emission rate at the inner region was observed, while increase of the neutron emission rate at the outer region was observed

The energy of enhanced particle is over 100keV

Neutron emission rate
-beam-thermal: ~ 90%
-beam-beam : ~10%

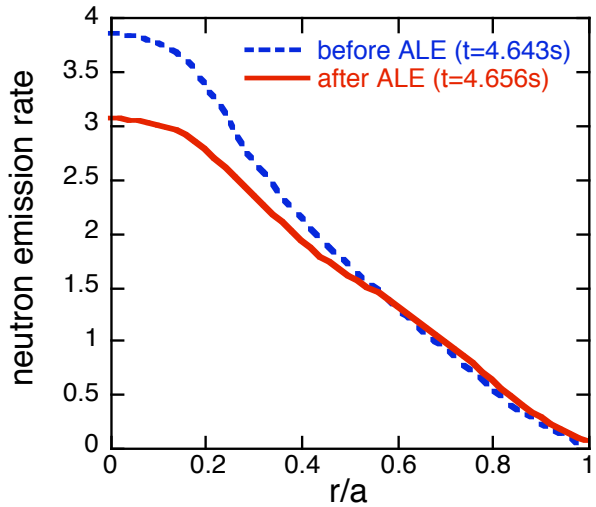
The change in the neutron emission profile is attributed to the transport of energetic ions produced by N-NB injection

※However、the values obtained in AE experiments are line-integrated value

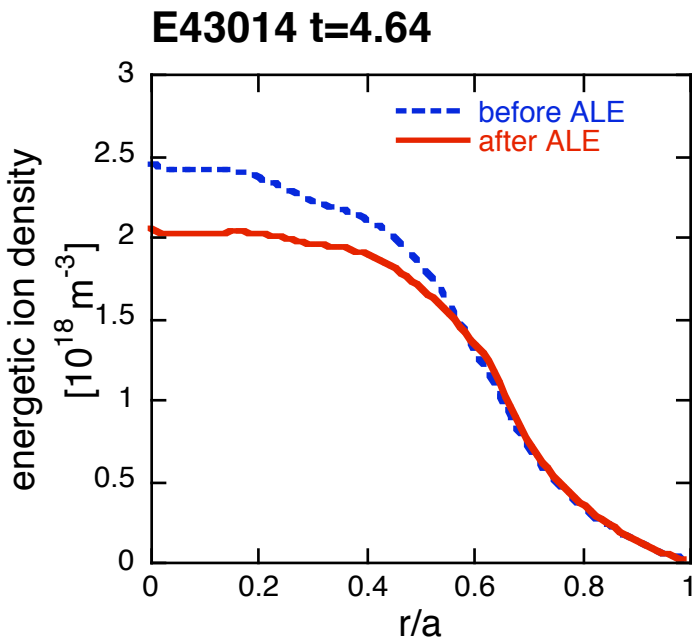
Abel inversion

Change of neutron radial profile

Neutron radial profile before and after ALE



Energetic ion transport due to ALE



Comparing energetic ion profile before and after the occurrence of ALEs

In central region (r/a < 0.6) energetic ion reduced. However, in peripheral region energetic ion slightly increased.

The total energetic ion population integrated over the volume is reduced by 4% by the ALE, with a 14% reduction in the central region of r/a < 0.6

⇩

ALEs expel a significant energetic ion population from core to the outer region (redistribution and loss)

Transition of RSAE to TAE in Reversed Shear Plasma

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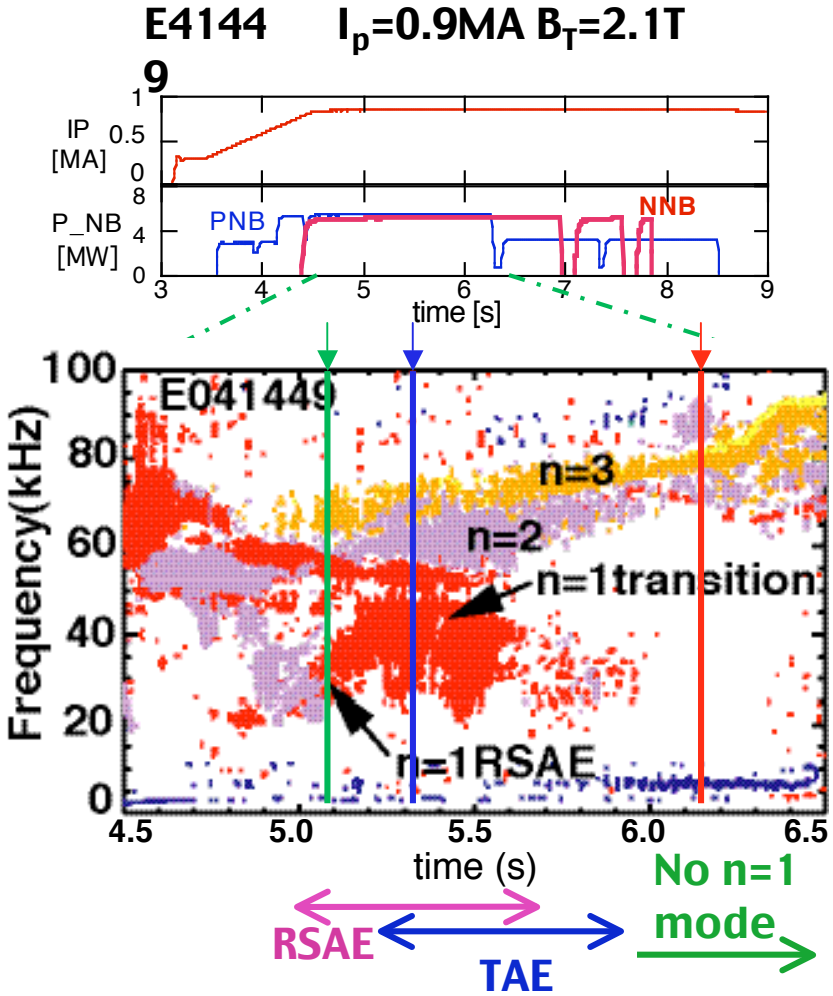
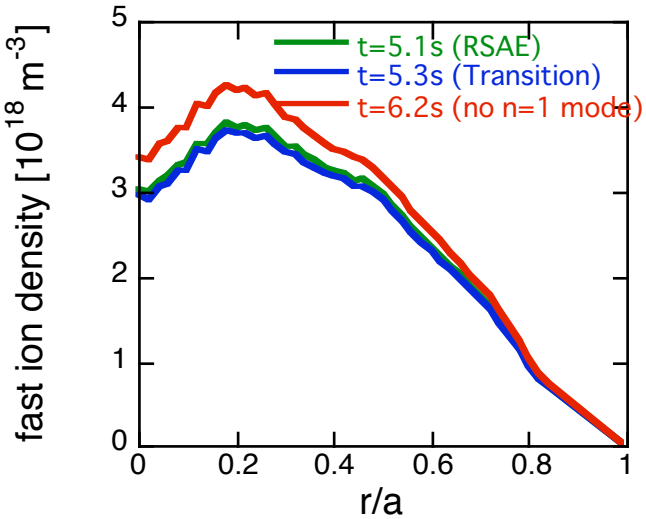


As q_{min} changes from 3 to 2.4, AEs change from RSAEs to TAEs.

RSAE is an AE near the zero shear the region of the RS plasmas



The total energetic ion population integrated over the volume is reduced by ~ 11% during transition phase comparing with no n =1 modes

It is predicts by TASK/WM code that the mode amplitude is enhanced in the mode transition phase.

Energetic ion transport during transition phase (RSAE→TAE) is large

Summary

In AE experiment using NNB in JT-60U,

Energetic ion transport due to ALEs was investigate from change in neutron emission profile and enhanced neutral particle flux

ALEs expel a significant energetic ion population from core to the outer region (redistribution and loss)

- **Energetic ion reduced in central region (r/a < 0.6), while slightly increased in peripheral region due to ALE.**
- **The total energetic ion population integrated over the volume is reduced by ~ 4%**

Energy region of enhanced neutral particle flux has agreed with that predicted form the resonant interaction between energetic ions and AE modes

- **Enhance of neutral particle flux in limited energy range (100 ~ 370 keV) has been observed.**

Summary (2)

-RSAE and TAE expels energetic ions from plasma

Energetic ion transport during transition phase (RSAE -> TAE) is large.

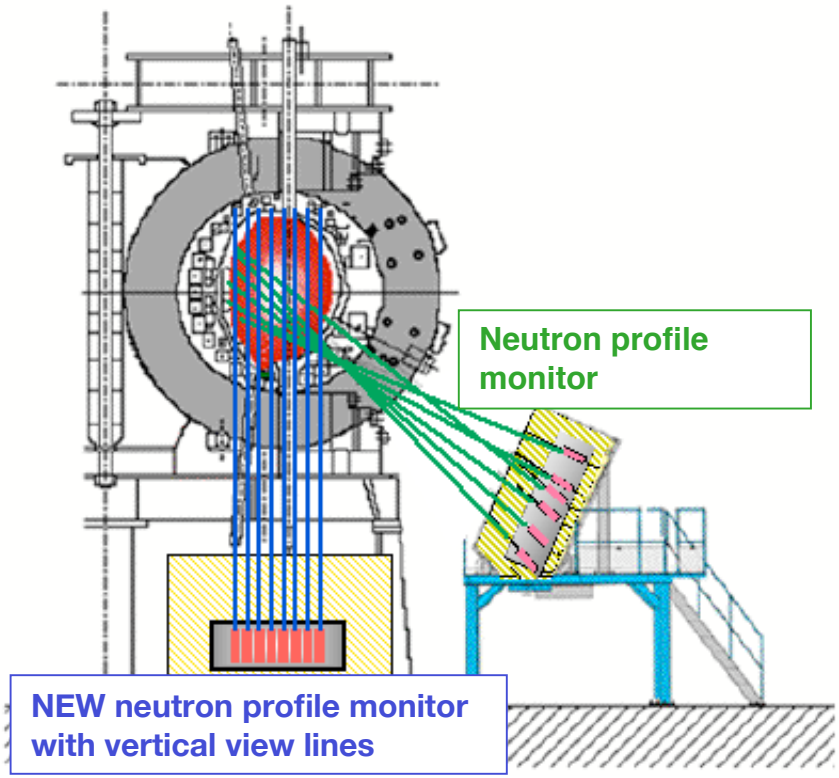
- **The total energetic ion population integrated over the volume is reduced by 11.4% during transition phase (RSAE ->TAE) comparing with no n =1 modes**

- However, since n = 2, 3 modes exist in this plasma even after the n = 1 mode disappears, the effect of these modes on energetic ion transport needs to be investigated.

Development of Diagnostics

New neutron monitor with vertical view line for tomography measurement.

Additional NDD to measure the radial profile of high energy neutral particles.



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New NDD data acquisition system with digital signal processor to increase counting rate for good time resolution.