21th IAEA FEC
'06.10.16th ~ 21th, Chengdu, China

EX/6-2

Confinement Degradation of Energetic Ions due to Alfvén Eigenmodes in JT-60U Negative-Ion-Based Neutral Beam Injection Plasmas

Presented by

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Background

Burning plasmas are self-sustained by **alpha-particle heating**

However, a high alpha particle pressure gradient could destabilize

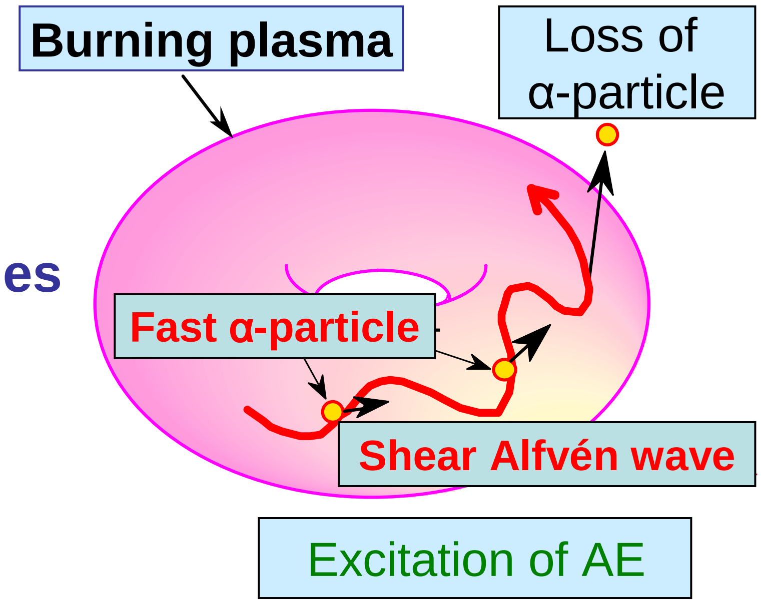
Alfvén eigenmodes (AEs)

↓

AEs induce

the enhanced transport of alpha-particles from the core region

- **A performance of a burning plasma could be degraded**
- **First walls could be damaged by lost alpha-particles**



⇨ Understanding of the alpha particle transport in the presence of AEs is the important research issues for ITER

Previous results and issues of AE studies in JT-60U

In JT-60U, AE experiments have been performed utilizing

Co-injected *Negative-ion-based Neutral Beam (NNB)*

(E_{NNB} : 340 ~ 400keV, P_{NNB} :3 ~ 5MW)

in several kinds of magnetic shear plasma under combination with PNBs

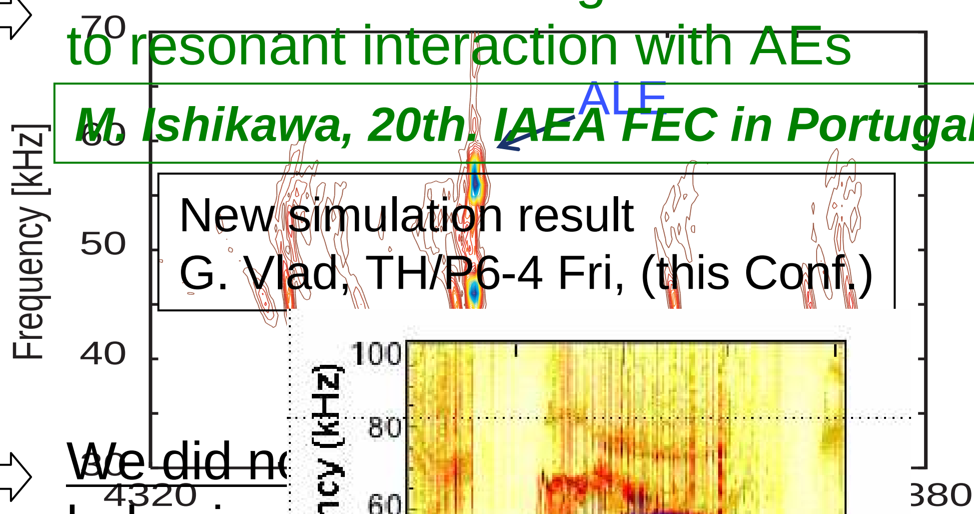
- **In weak shear plasma with large β_h** (β_h : energetic ion beta)
  - **Bursting AEs called Abrupt Large amplitude Events (ALEs)**

time scale : < 1 ms
amplitude : large

⇨ redistribution of energetic ions due to resonant interaction with AEs

M. Ishikawa, 20th. IAEA FEC in Portugal

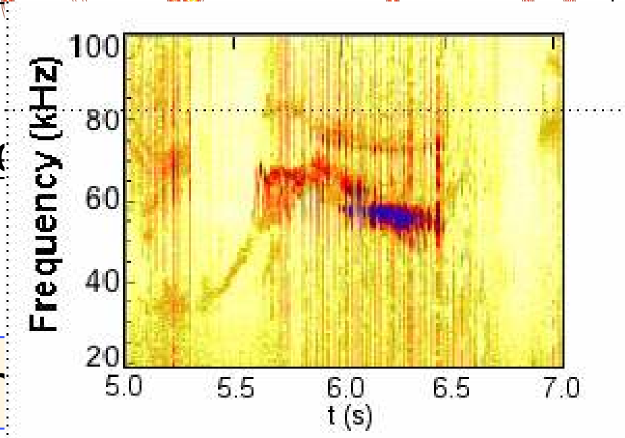
New simulation result
G. Vlad, TH/P6-4 Fri, (this Conf.)



- **In weak shear plasma with moc**

time scale : 100ms ~ 1 s
amplitude : moderate

⇨ We did n
behavior



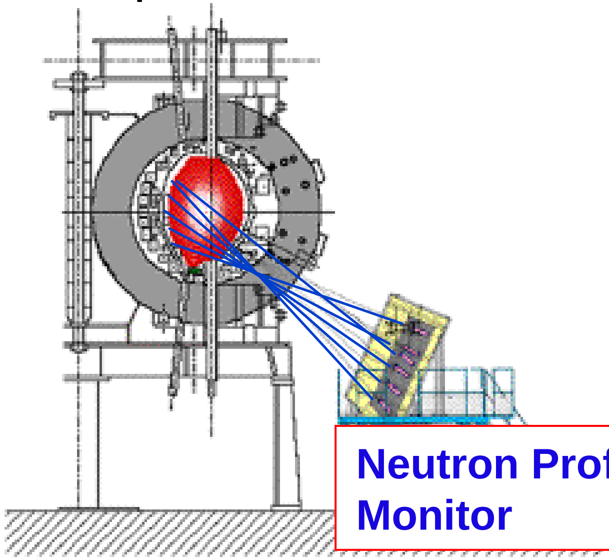
Investigation energetic ior

Diagnostics for investigation of energetic ion transport

To investigate energetic ion behavior in the presence of AEs

radial profile

Neutron emission profile measurement

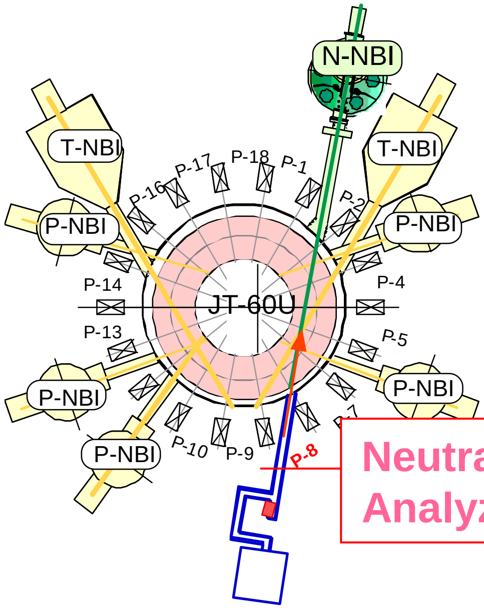


Neutron Profile Monitor

Beam -Thermal neutron is dominant component of the total neutron rate

energy distribution

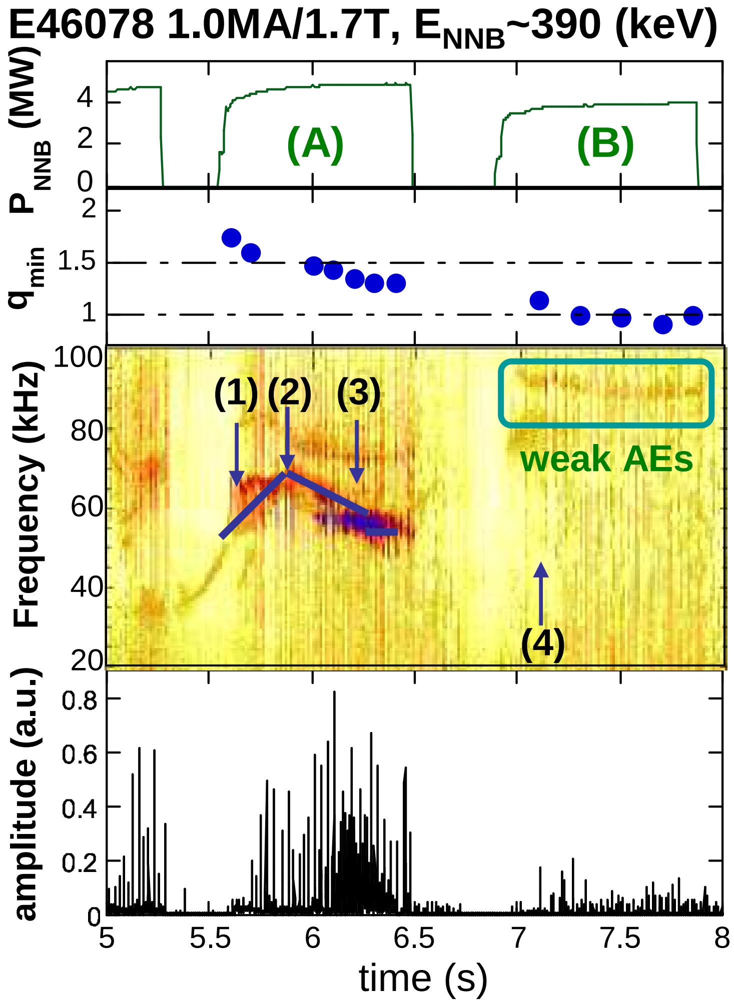
CX neutral particle measurement



Neutral Particle Analyzer (NDD)

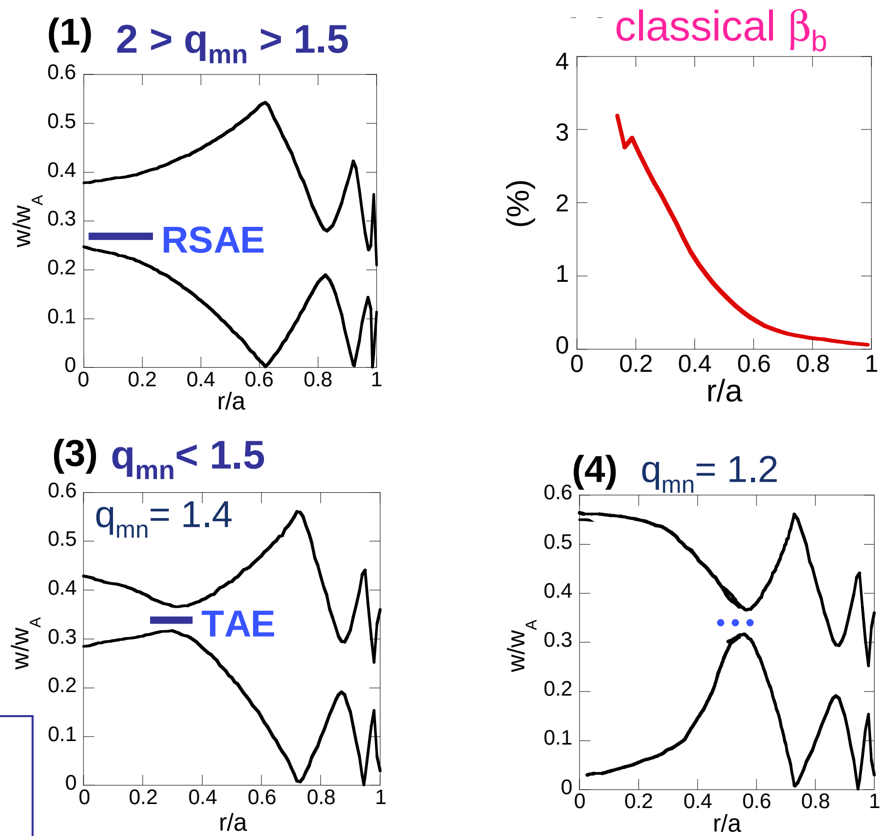
Energy distribution of neutral particles has information on energy distribution of energetic ions

AEs in Weak Shear Plasma (moderate β_h)



(A) → n =1 modes with up-frequency sweeping are observed and its frequency saturates.

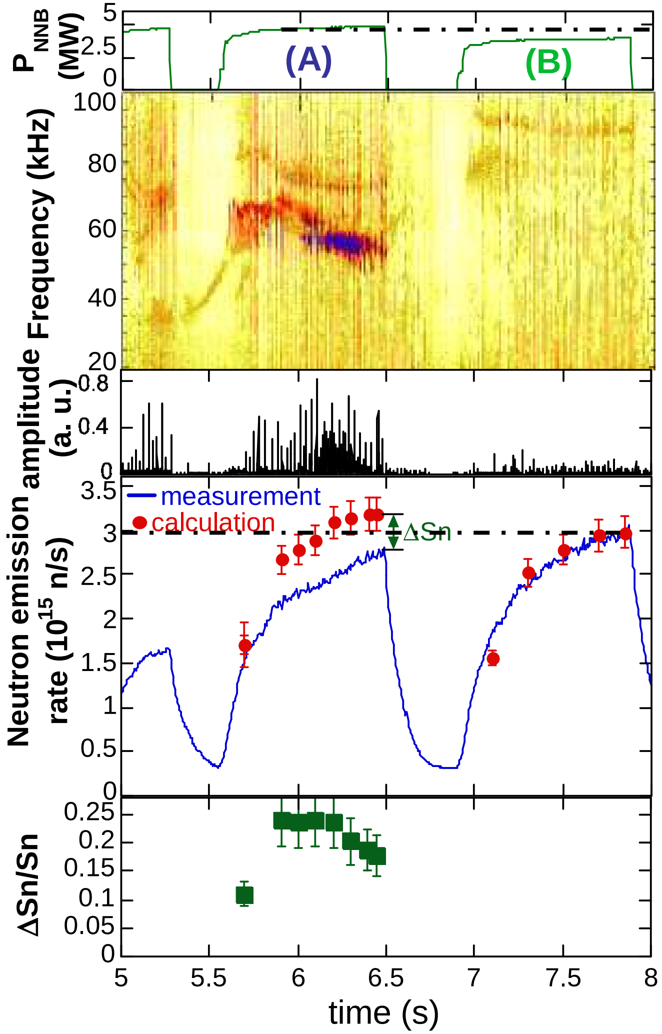
(B) → Only weak AEs are observed



Energetic ion confinement with AE can be investigated by compared with that in the later NNB injection phase

RSAE is global AEs localized near the zero magnetic shear region.

Confinement degradation of energetic ions due to n = 1 AEs



Energetic ion transport ?

To investigate energetic ion confinement, the total neutron rate (Sn) is calculated with the OFMC code

- **Confinement of energetic ions is classical**

(B) with only weak AEs

Time evolution of measured Sn agrees with calculated Sn

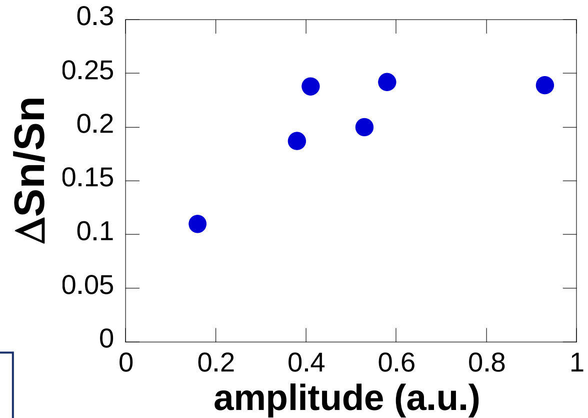
⇨ **~ Classical confinement**

(A) with clear AEs

Measured Sn is smaller than calculated one

⇨ **Confinement degradation**

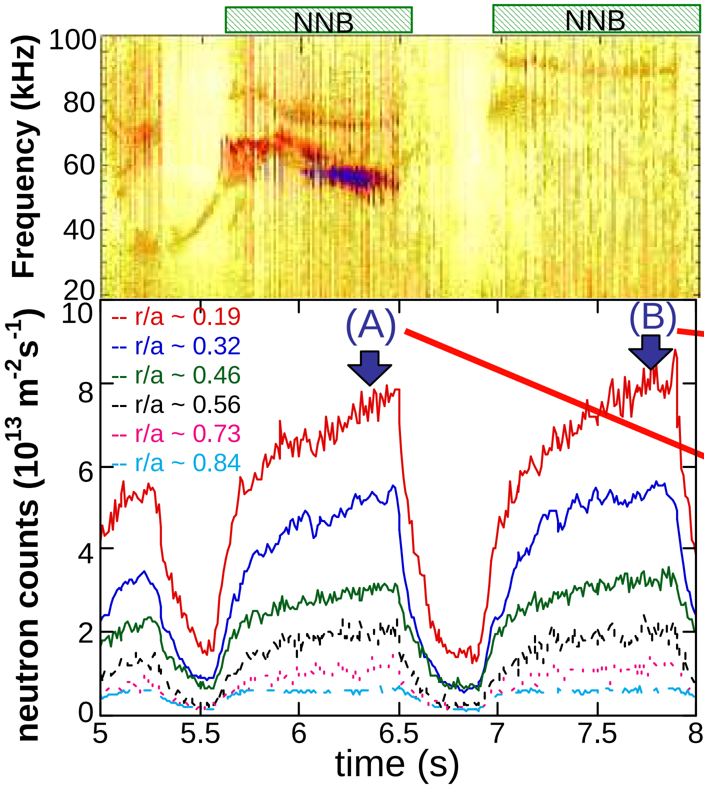
ΔSn/Sn ~ 25 %

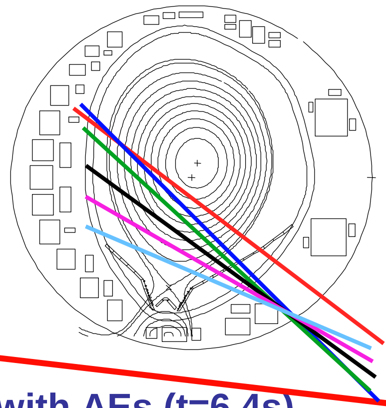


Reduction rate in Sn increases when mode amplitude increases

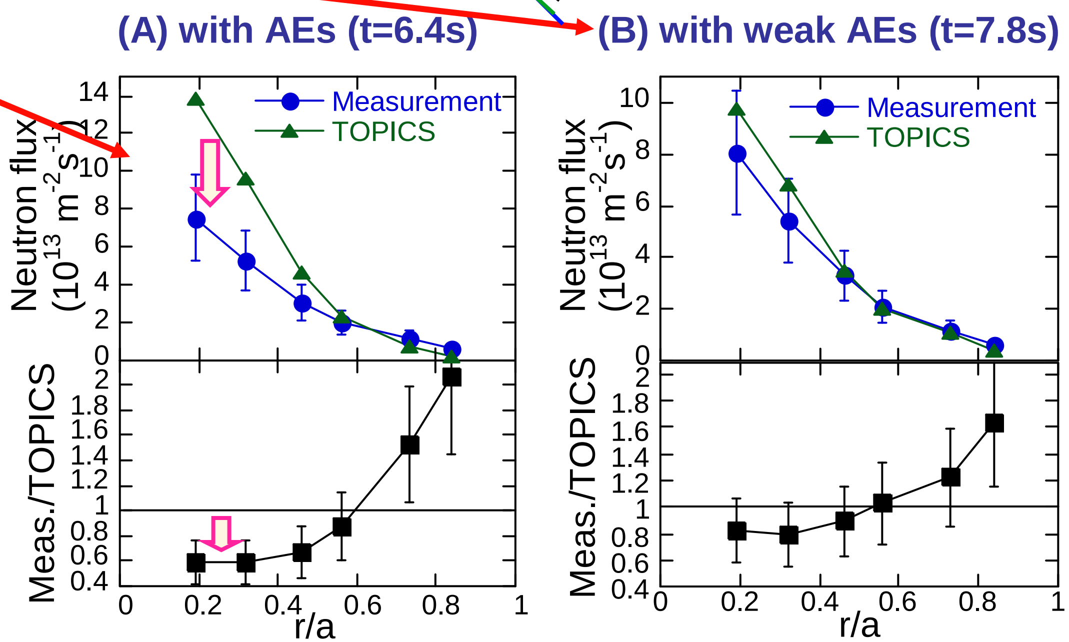
Energetic ion transport from the core region due to AEs

To investigate energetic ion transport, neutron emission profile was measured





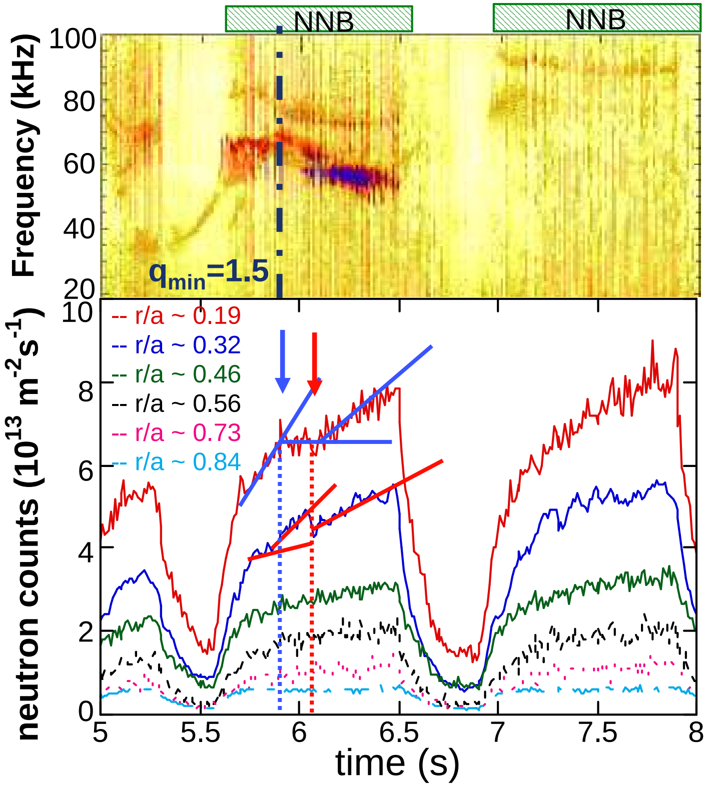
Plasma configuration and sight lines



Calculated line integrated neutron profile with a transport code (TOPICS) is compared with the measurement.

⇨ Energetic ion transport from the core region of the plasma

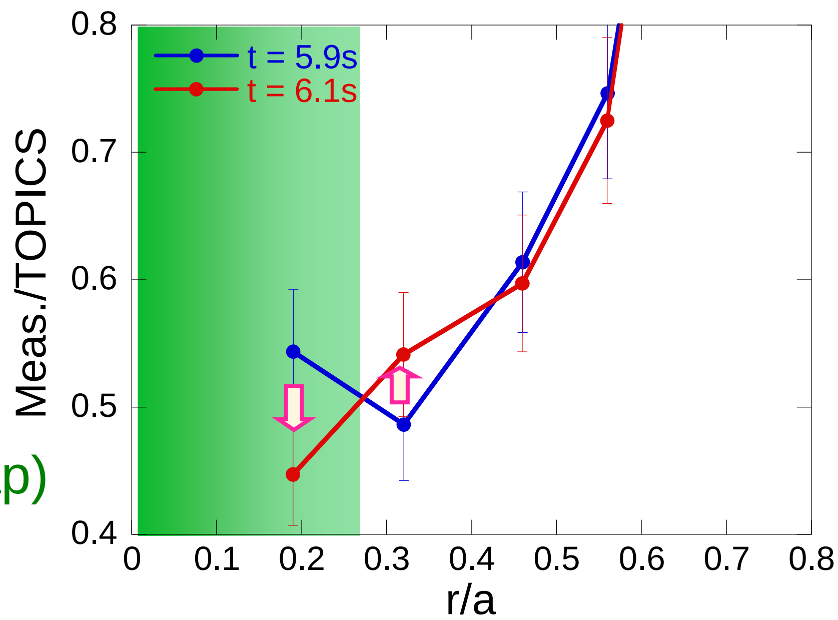
Local transport of energetic ions in the transition phase



In transition phase,

The innermost channel signal does not increase

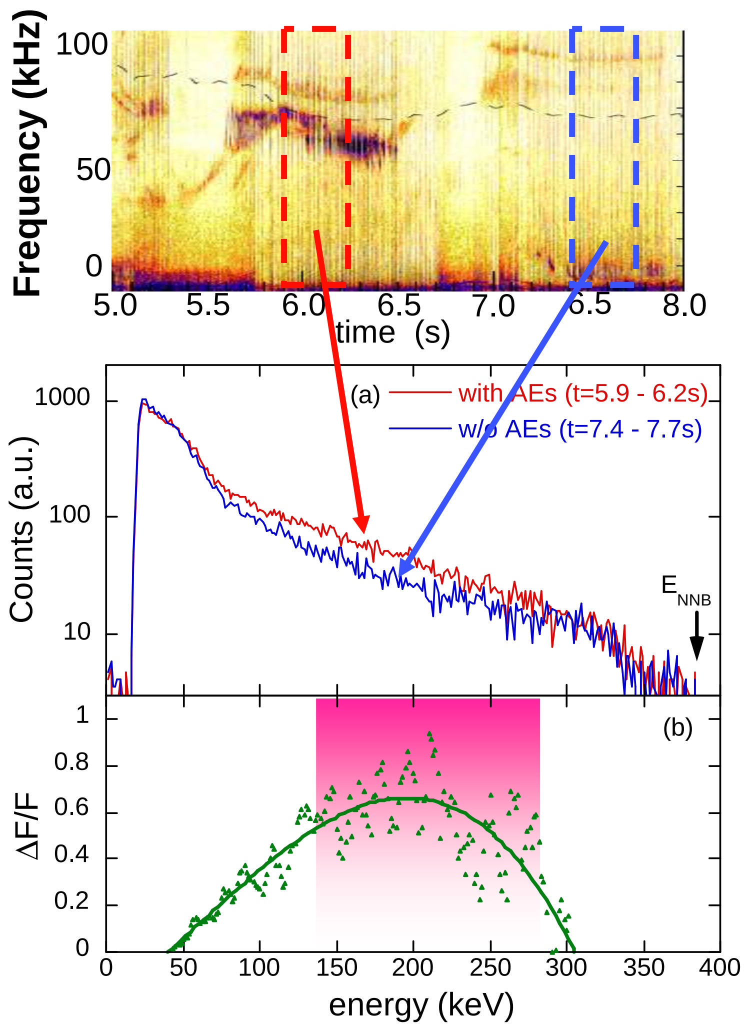
The second channel signal increases rapidly



⇦ q_{min} and q = 1.5 surface (TAE gap) both lie around r/a < 0.3

⇨ **Local transport of energetic ions in the center region**

Resonant interaction with AEs and eneregetic ions



Neutral particle fluxes in limited energy range (50 ~ 300 keV) are enhanced.

Peak fraction of enhanced neutral particle flux is ~ 200 keV.

[Resonance condition with the mode]

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

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

- **f = mode frequency (60 - 70 kHz)**
- **q = safety factor (1.4 - 1.6)**
- **n, m = toroidal, poloidal mode number**
- **F_c = troidal transition frequency of energetic ions**

Resonant energy range => 140 ~ 280 keV

Changes in the energy distribution suggest **the resonant interaction between energetic ions and modes**

summary

in weak shear plasma with moderate β_h

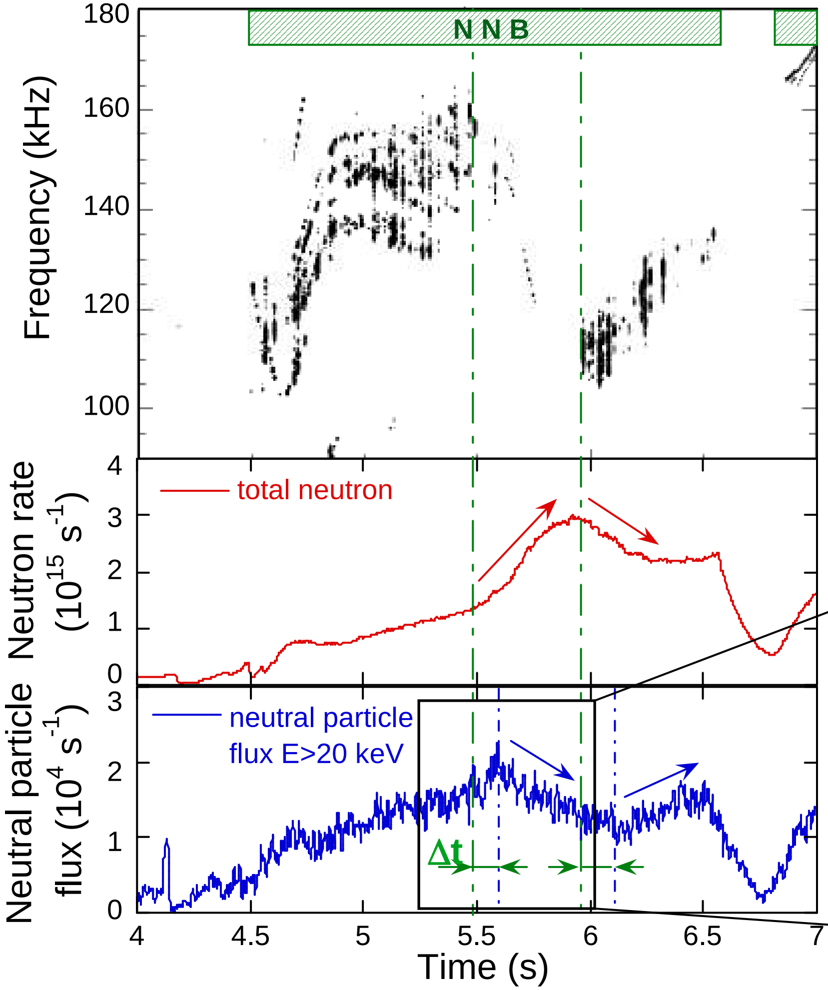
- **AEs with frequency sweeping**
  (time scale : 100ms ~ 1s, amplitude : moderate)

⇨ **Energetic ion behavior is investigated with**

- total neutron emission rate
- neutron emission profile
- charge exchange neutral particle flux

- **Confinement degradation of energetic ions are quantitatively observed.**
- Neutron emission profile measurements indicate **energetic ion transport from core region to outer region** and **local transport in the core region in the transition phase.**
- Changes in neutral particle flux suggest **the resonant interaction between energetic ions and modes.**

Change in neutral particle flux suggests energetic ion transport from core to outer region

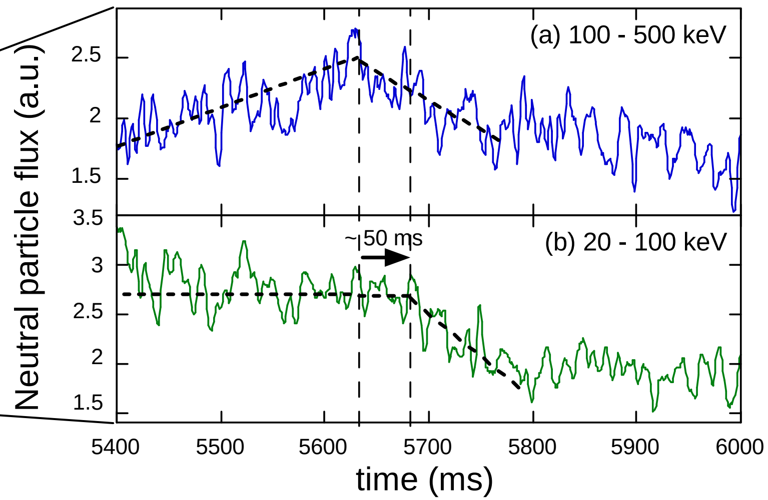


Neutral particle flux change after neutron emission rate changed

Time lag (Δt) ~ 100 ms

time scale of transport and /or slowing down

Energetic ions are neutralized through charge exchange reactions with D^0 or C^{5+} in outer region of the plasma



energetic ion transport from core region to outer region