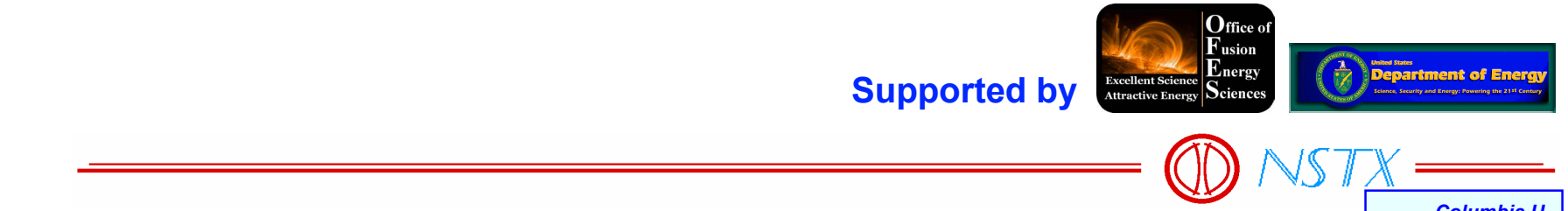
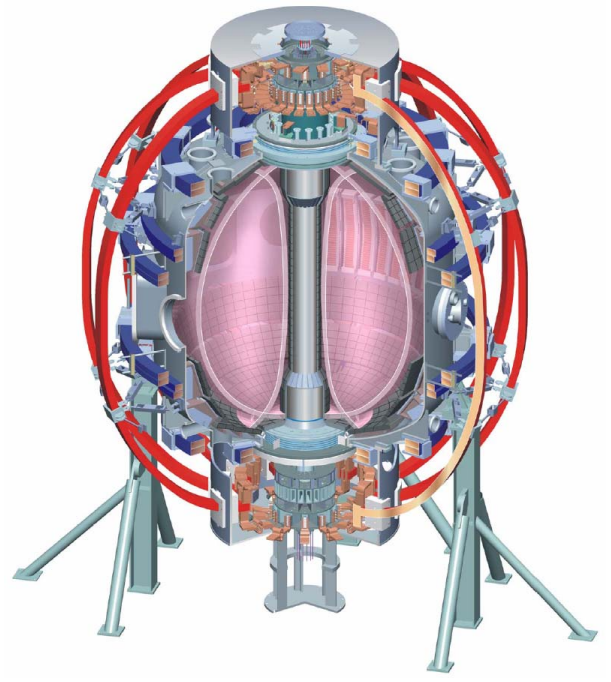
Supported by



NSTX

Measurement of the fluctuations and ELMs using fast camera in NSTX



Nobuhiro Nishino [1], L.Roquemore[2], T.Biewer[2], S.J.Zweben[2], R.Maqueda[3], R.Maingi[4], C.Bush[4], and NSTX team

1) Hiroshima University
2) PPPL
3) Nova Photonics
4) ORNL

Columbia U
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General Atomics
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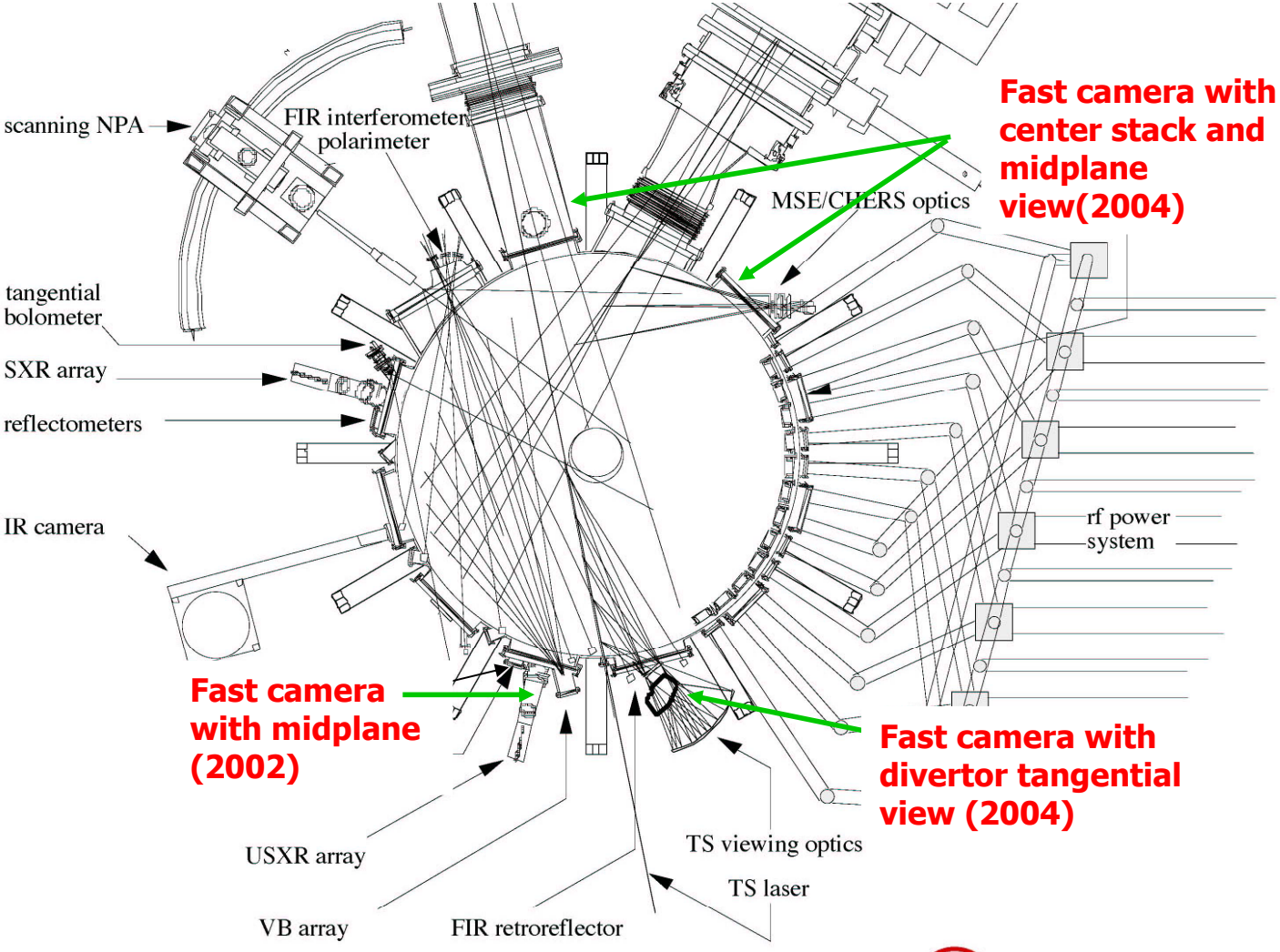
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
U Quebec

Introduction

- Fast camera measurement
  - Divertor camera using midplane port (STW2002)
  - Divertor tangential camera (STW2004)
    - A proposal under US-Japan collaborative activity since 1998
  - Center stack camera (STW2004)
  - GPI with side view (STW2002-)
- Results and discussion
  - Fluctuations and ELMs
  - Trial to categorize fluctuations and ELMs?
- Conclusion



Fast camera with center stack and midplane view(2004)

Fast camera with midplane (2002)

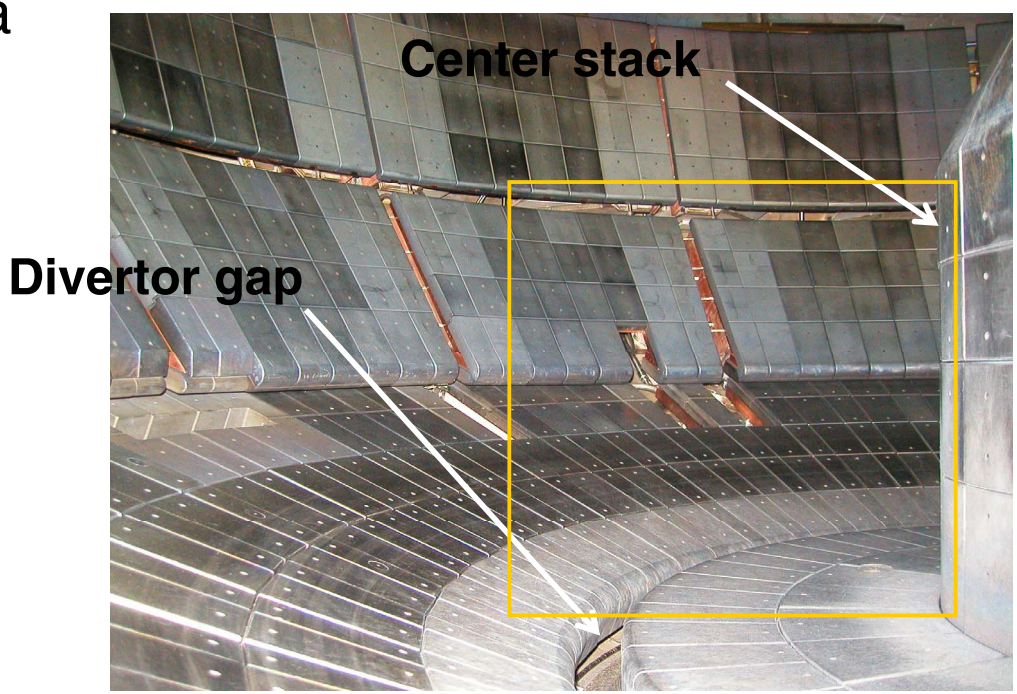
Fast camera with divertor tangential view (2004)

NSTX

PPPL PRINCETON PLASMA PHYSICS LABORATORY

Field of view of the divertor fast camera (2004)

- Approximate camera field of view (yellow box, but left side is limited by passive plate)



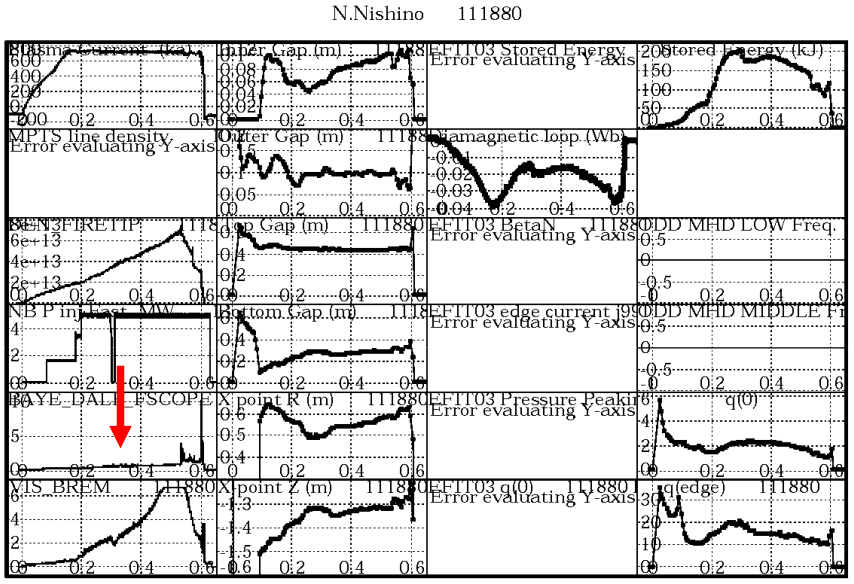
Nishino (U. Hiroshima), Roquemore, Maingi (ORNL)

Categories of fluctuations and ELMs

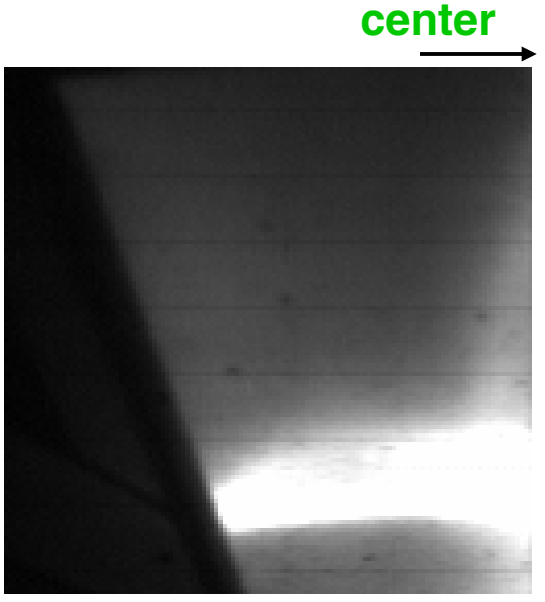
- Structure difference (Effect on the confinement?)
  - Filament
  - Wave pattern near the inner separatrix
  - L-H transition near the inner separatrix
  - L-H transition near the outer separatrix

- Effect on the energy confinement
  - Giant ELM (TYPE I)
  - Medium/Intermediate ELM (TYPE I and TYPE II?/III)
  - Small ELM (TYPE II?/III)
  - Small ELM (do not lead to a severe loss of stored energy)
    - Labeled TYPE V (authorized?)
  - Inner region ELM in DN configuration
    - Labeled TYPE VI (private)

Filament with tangential view

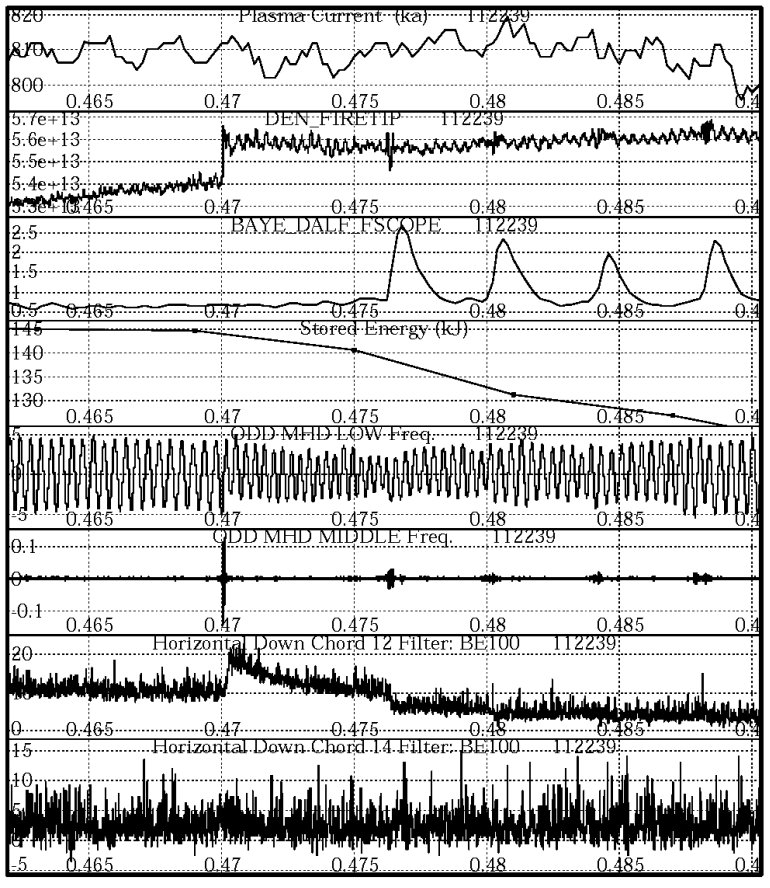


There are many filaments in outer region.



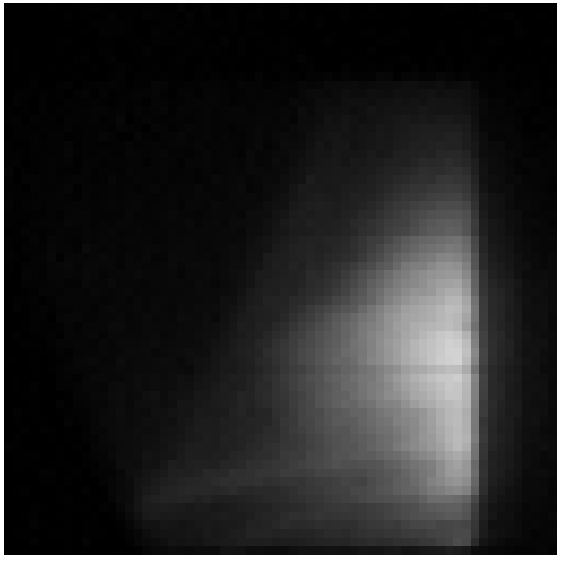
- **0.30-0.34sec**

Wave pattern (finger) near the inner separatrix and small ELMs



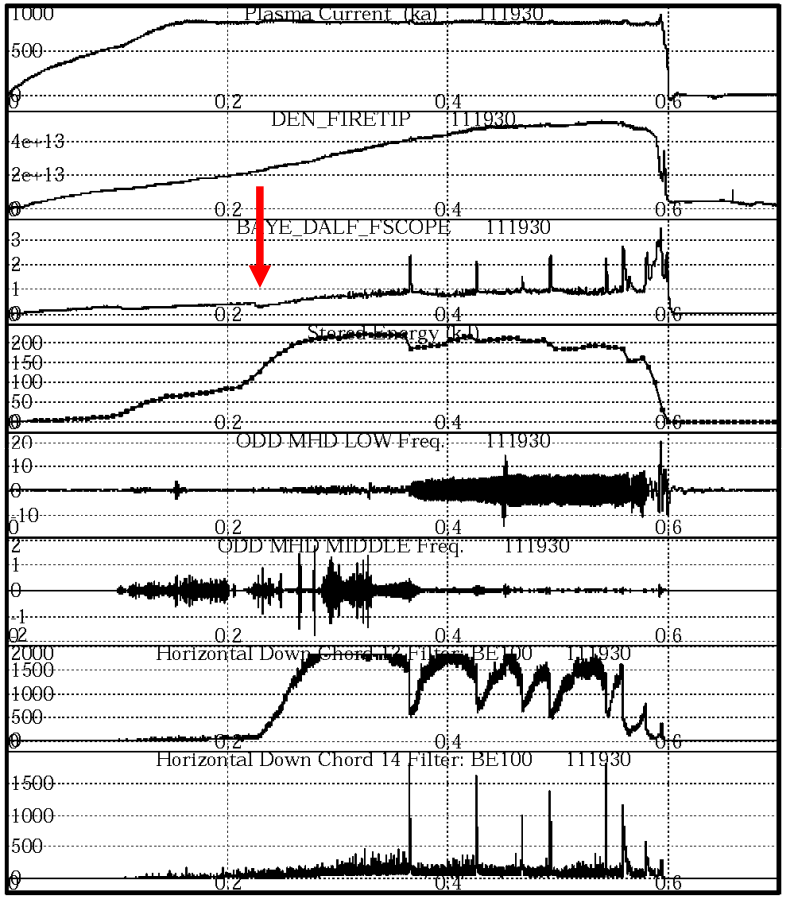
Filament fingers from inner region can be seen.

center



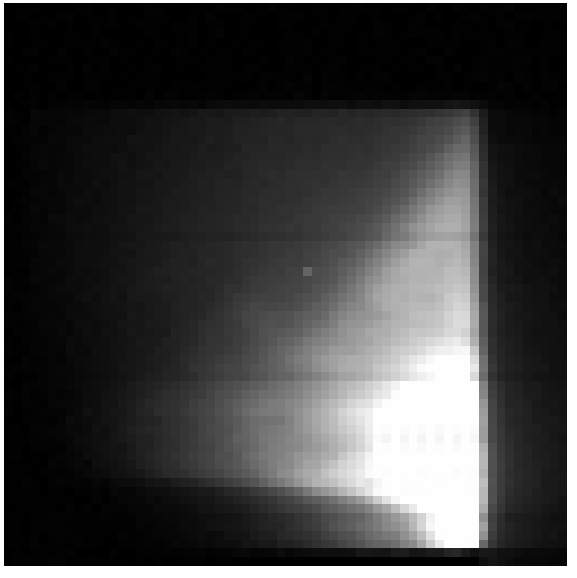
- **0.47-0.484sec**

L-H transition near the inner separatrix



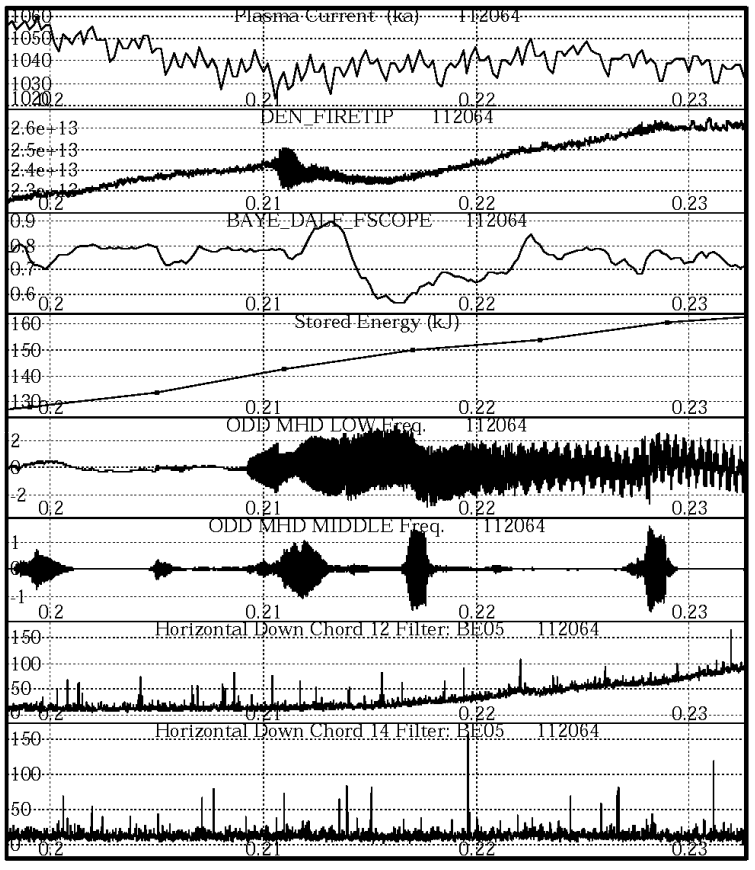
Fluctuations are suppressed during L-H transition.

center



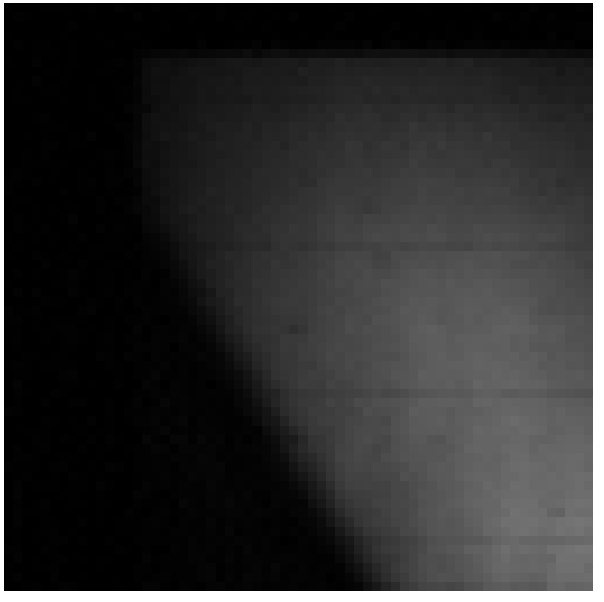
- **0.22-0.239sec**

L-H transition near the outer separatrix



- **Some spatial structure is seen in H-mode**

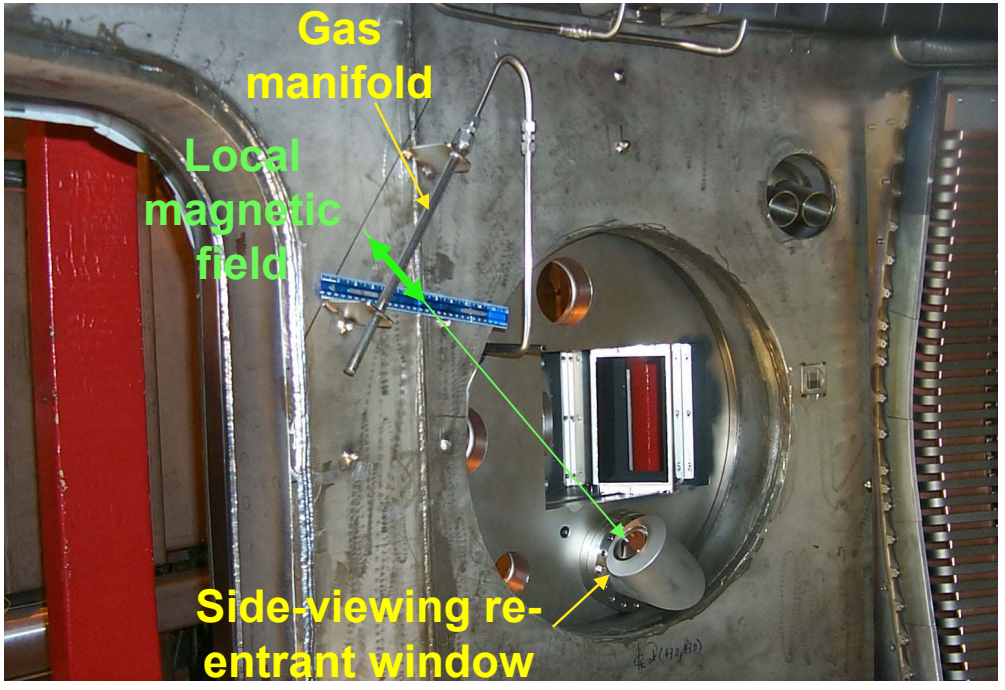
center

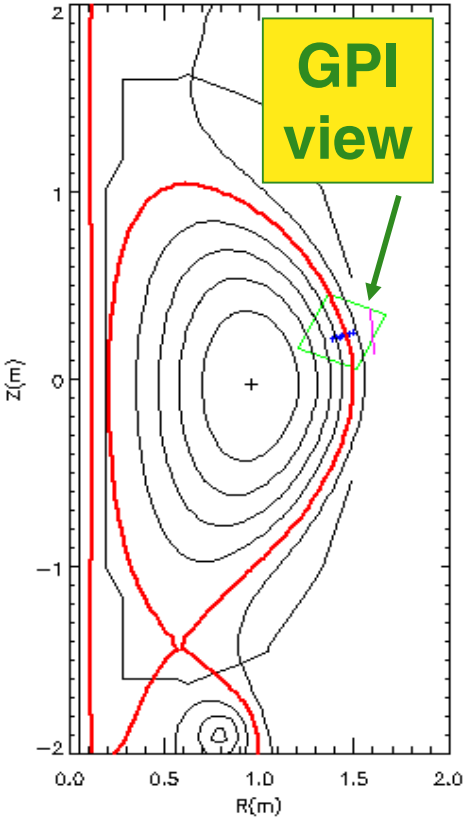


•0.21-0.22sec

GPI Diagnostic setup in NSTX

- Use re-entrant port and linear gas manifold.
- Use **He**, D_2, or Ar puffs.
- Use beam-splitter and PMTs (100 kHz bandwidth) for discrete fast chords.



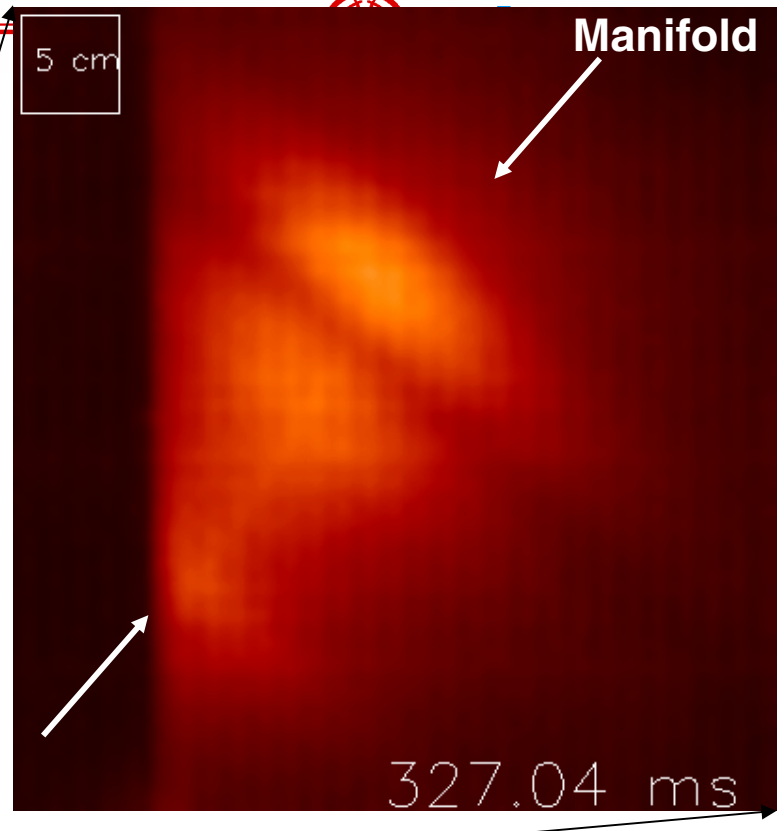


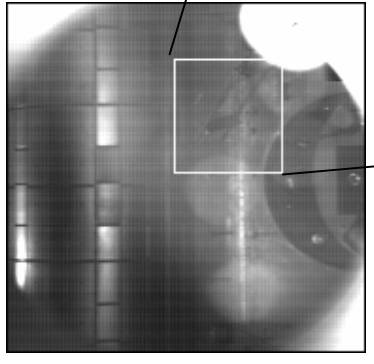
Gas puff from linear manifold viewed across torus

NSTX

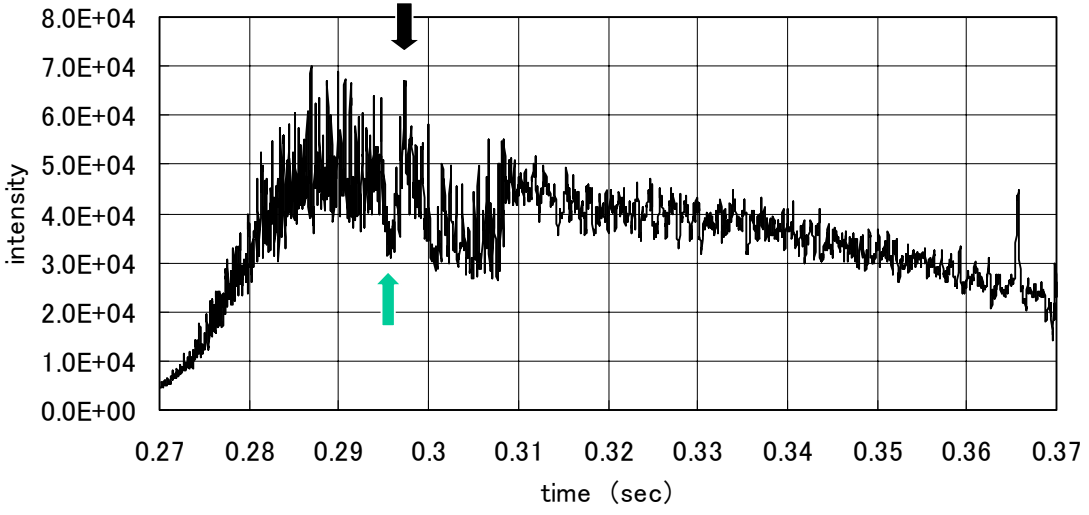
Shot 108975
0.9 MA - 0.35 T
HeI filter (587.6 nm)
74 μs exposure

Photron
Fastcam-Ultima SE





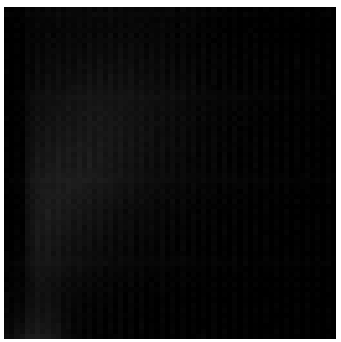
HeI intensity in GPI experiment



L & H-mode in GPI experiment (STW2002)

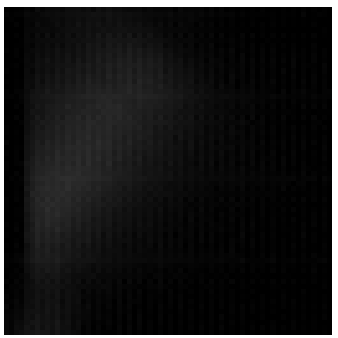
- View image of L and H-modes during He gas puff by mid plane port
- There are many filaments in L-mode, and a few filament in H-mode.
- No new structure has found in L and H-modes.

Filaments are seen sometimes



H-mode

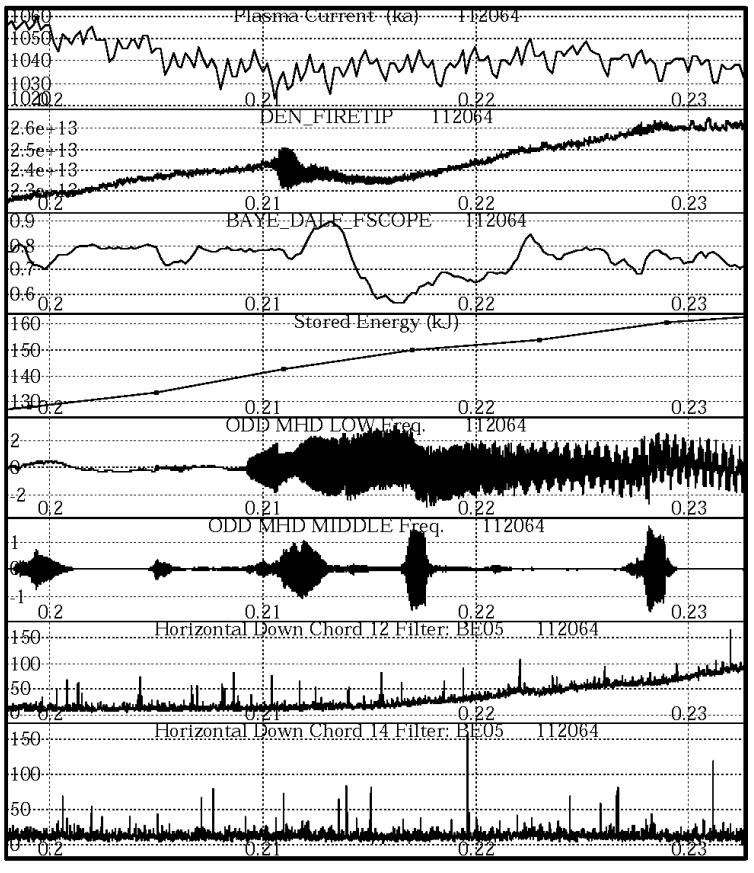
Many filaments are seen



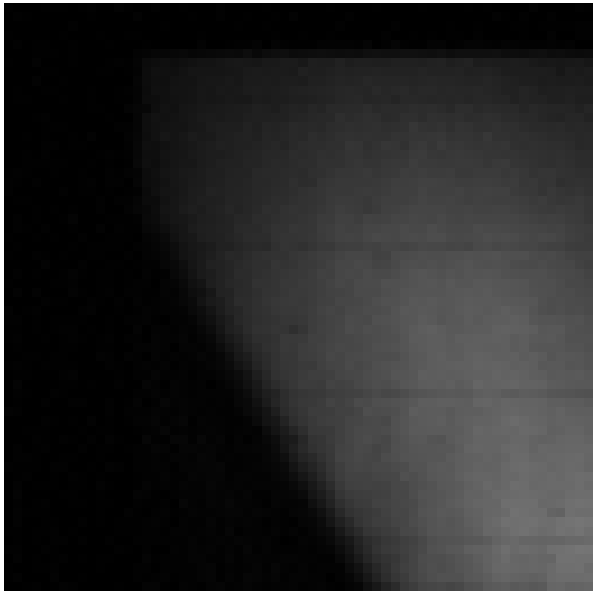
L-mode

#108979 40500fps with He I filter (587.6nm)

L-H transition near the outer separatrix



- **What is the key to understand H-mode?**
- **Need complete H-mode theory**



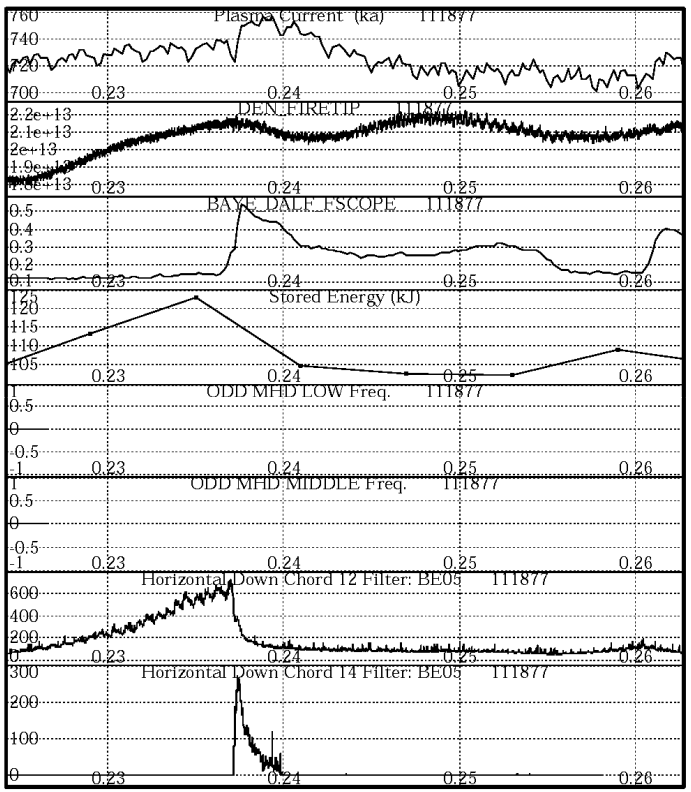
•0.21-0.22sec

Fluctuations

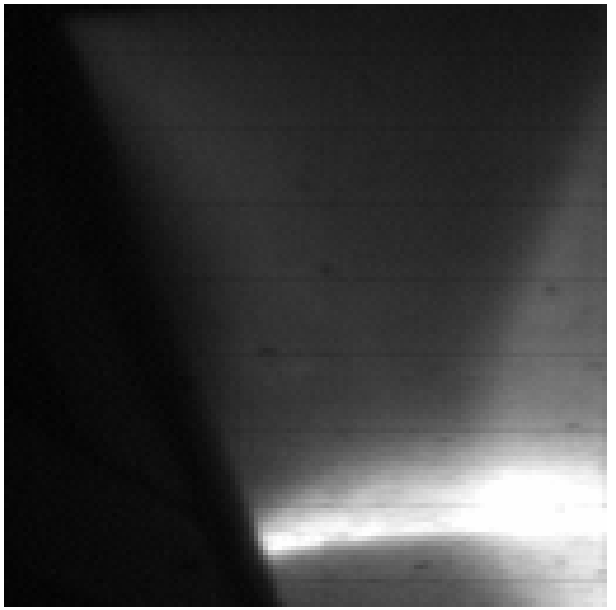
- Wave pattern (finger) observed frequently in the inner region
- Many filaments in L-mode
- Less filament in H-mode, but not zero
- Some spatial structure is found in H-mode, and this structure and filament can exist together

- What is the filaments?
  - Possibly High density region from GPI
- What is the key of H-mode physics?
  - Filament is not the key!?

Giant ELM or TYPE I

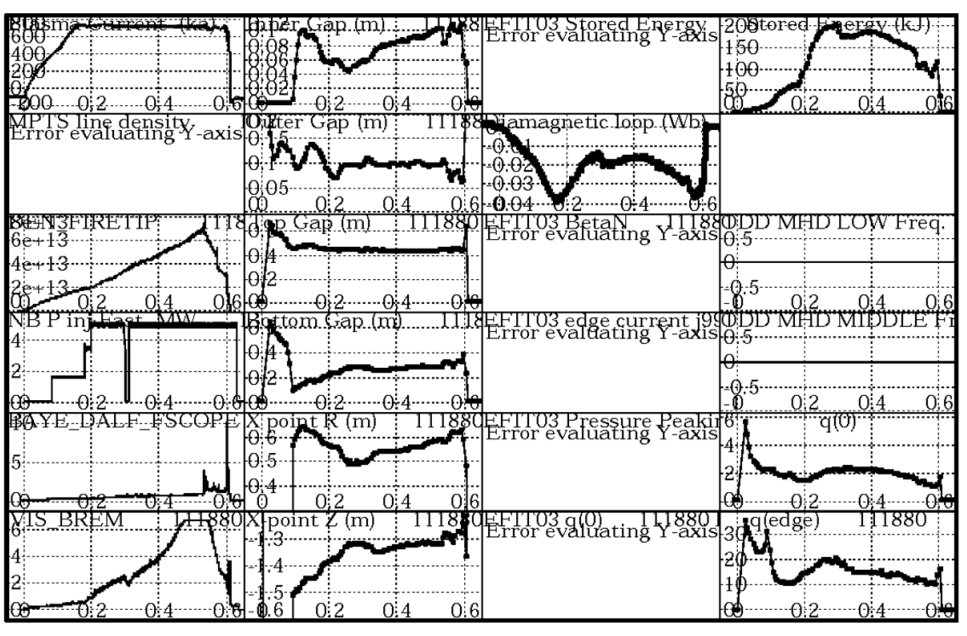


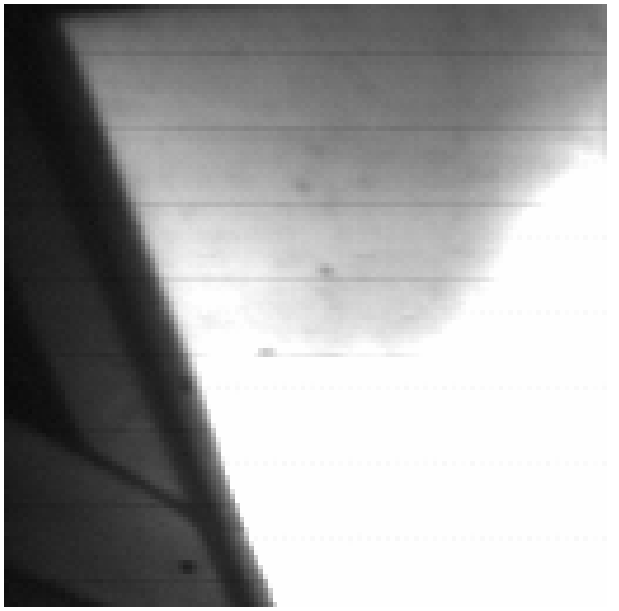
- Many filaments are seen outer region of separatrix.
- It looks like inner region fluctuation is independent of filaments



0.23-0.26sec

Giant ELM

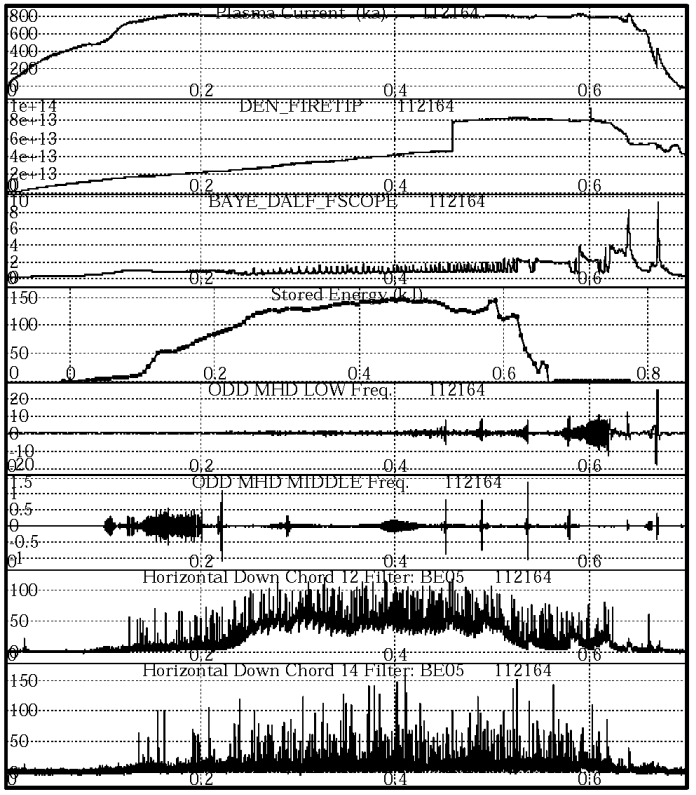


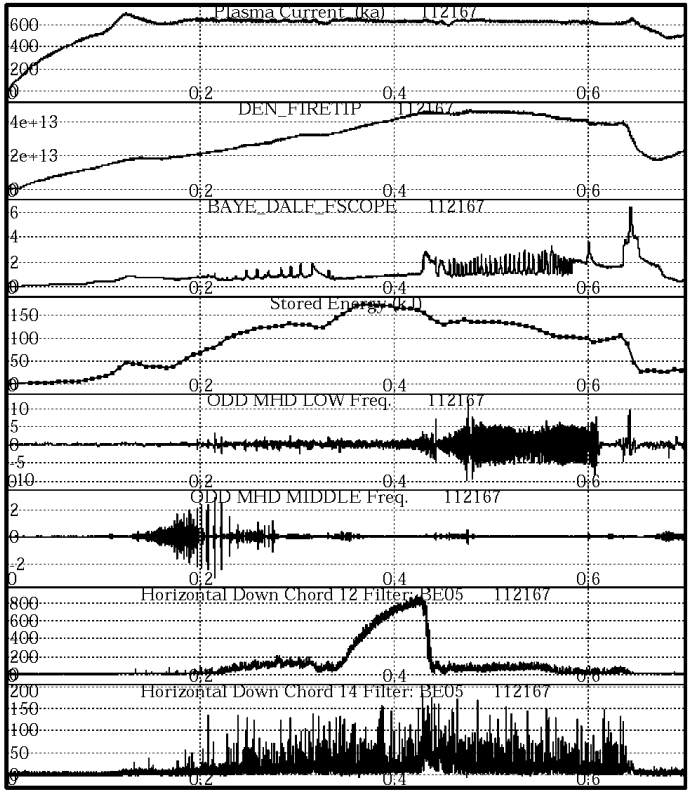


- **0.53-0.55sec**

Typical waveforms of Medium ELM

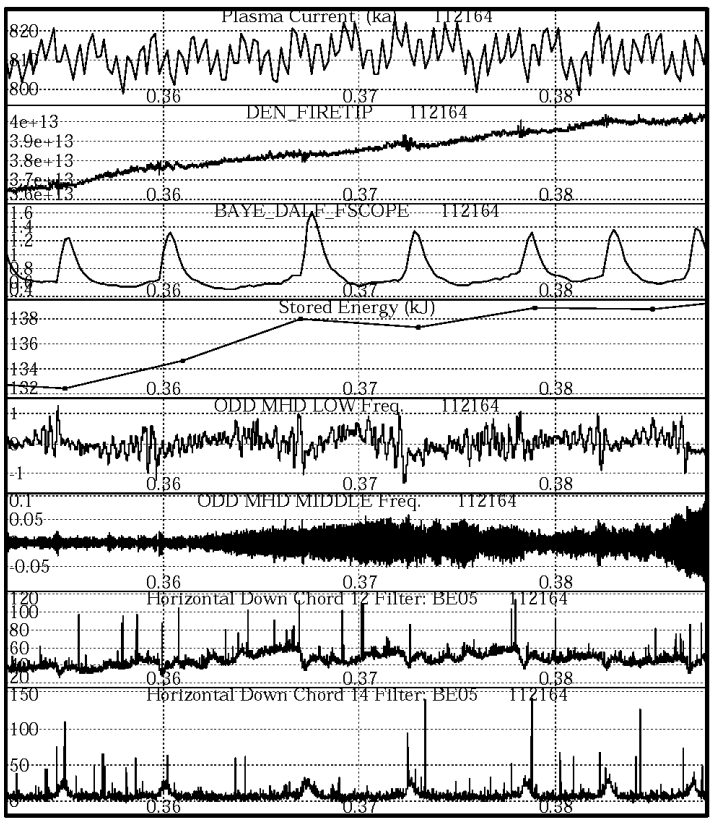
- ELM with precursor (left) and without precursor (right)



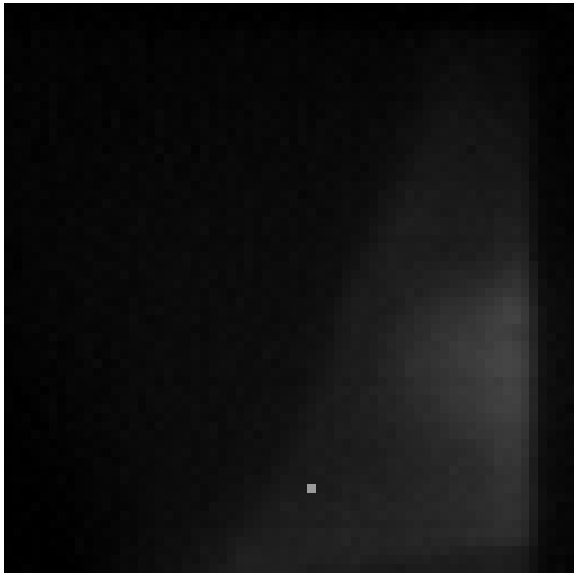


Medium ELM (TYPE III with 2kHz MHD precursor)

Precursor with MHD odd-n signals



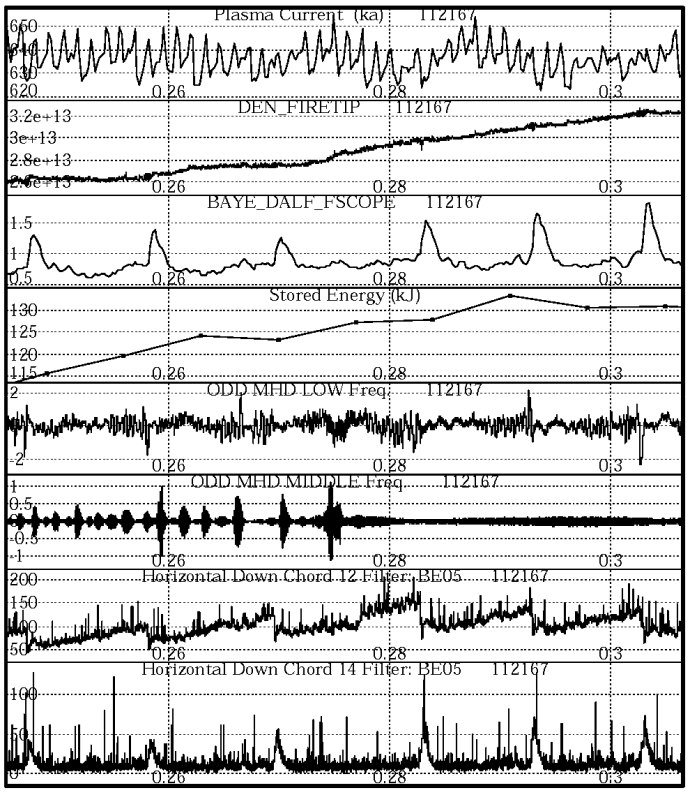
center



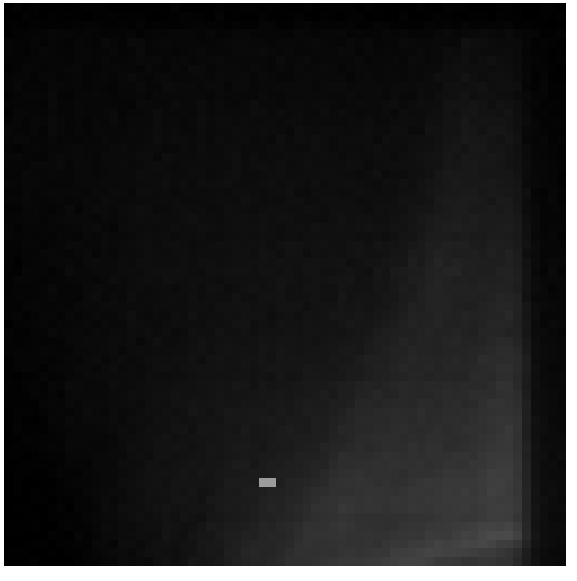
- **0.364-0.381sec**

TYPE III with precursor?

Week precursor with MHD odd-n signals

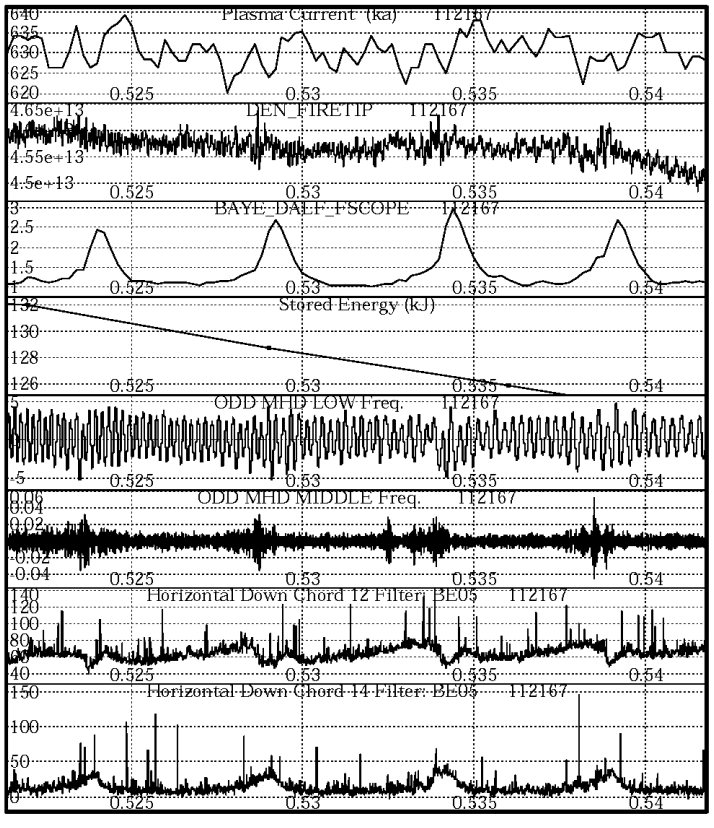


center

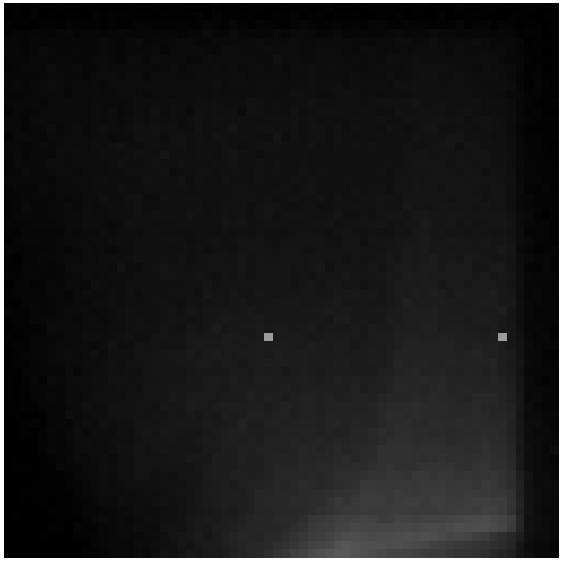


- **0.297-0.31sec**

TYPE III without precursor ?

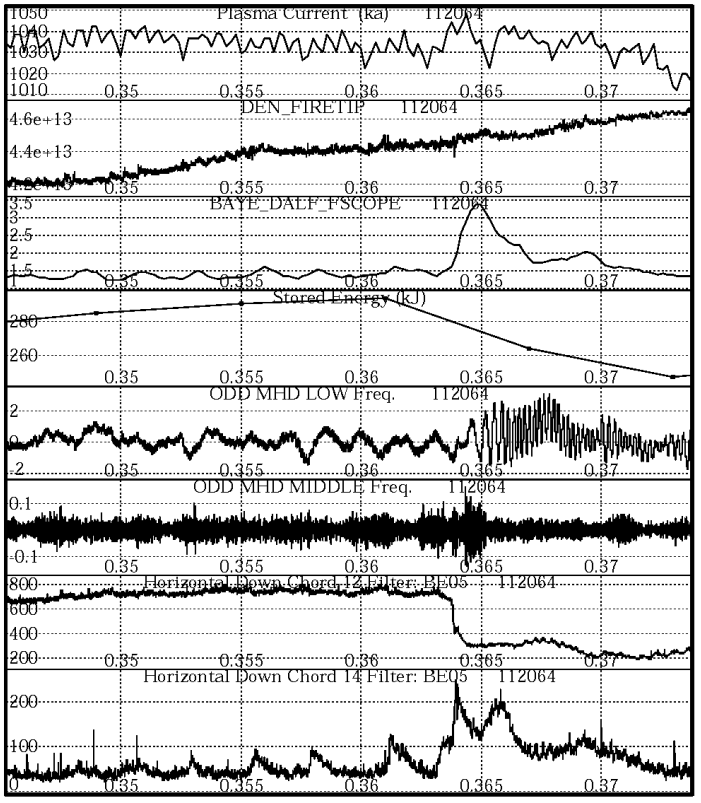


center



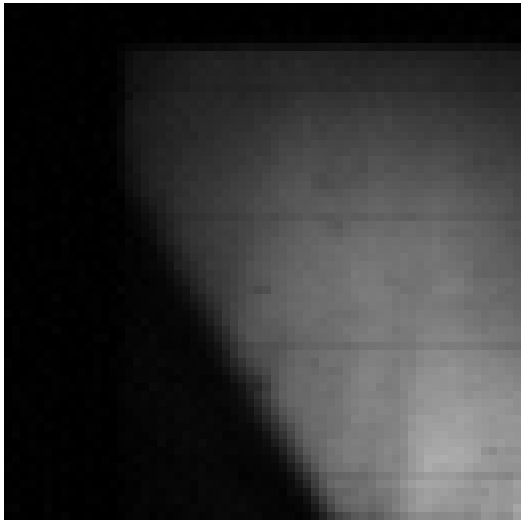
- **0.525-0.537sec**

TYPE V and Giant ELM



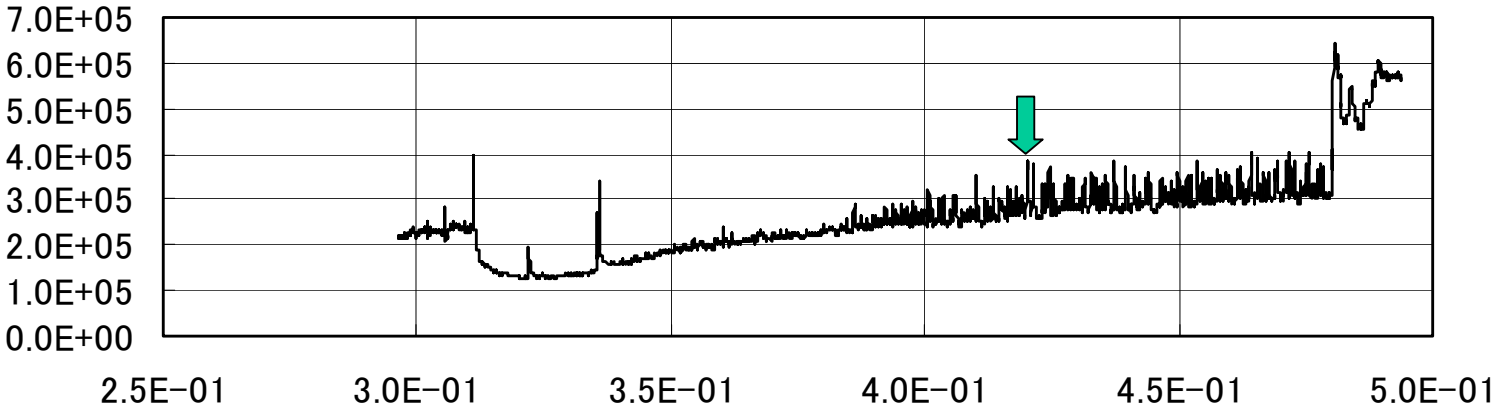
- **H-mode structure and filament can exist together**

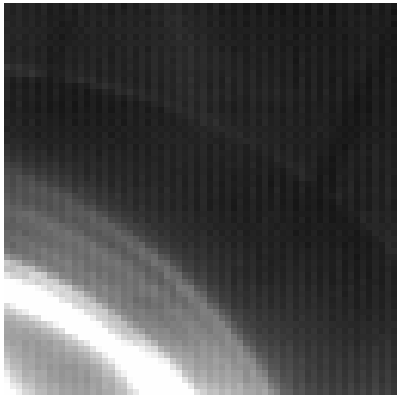
center



0.34-0.383sec

TYPE V with midplane view (STW2002)



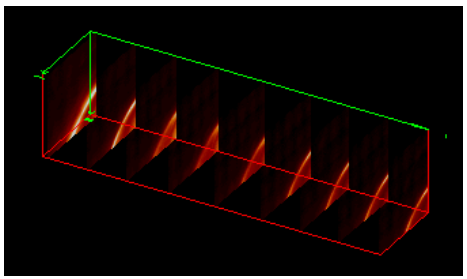


TYPE V ELMs occur periodically.

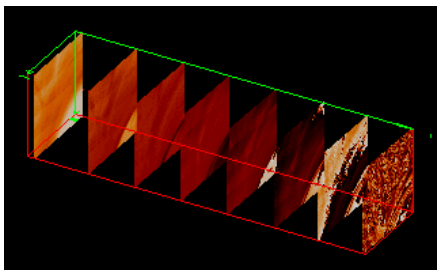
But 1-2kHz movement can be seen using FFT <=> TYPE III precursor

Auto-correlation function of each pixels (STW2002)

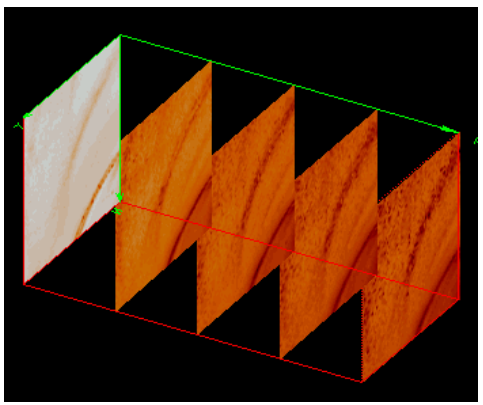
- **2D auto-correlation function plotted shown by arrows.**



Original image



Auto-correlation function

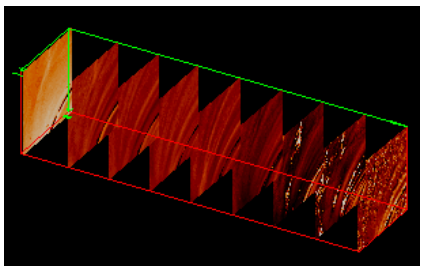


Power spectrum

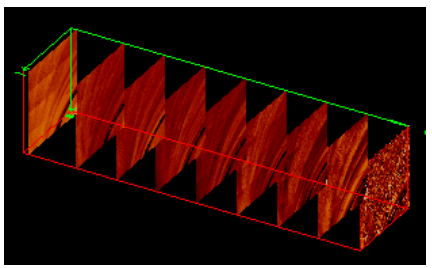
Continued. during small ELMs (STW2002)

– 4-8

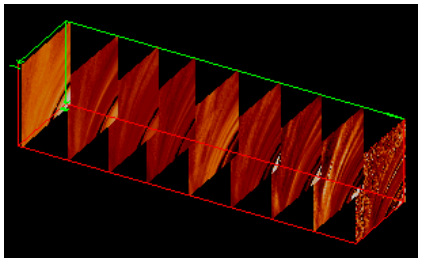
4



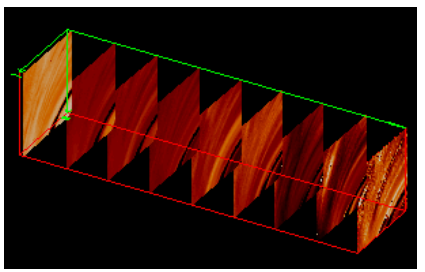
5



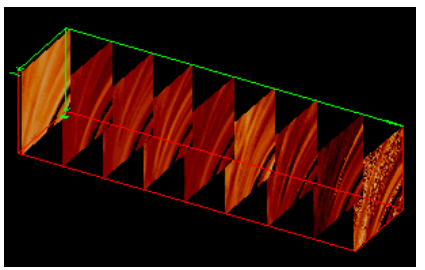
6



7

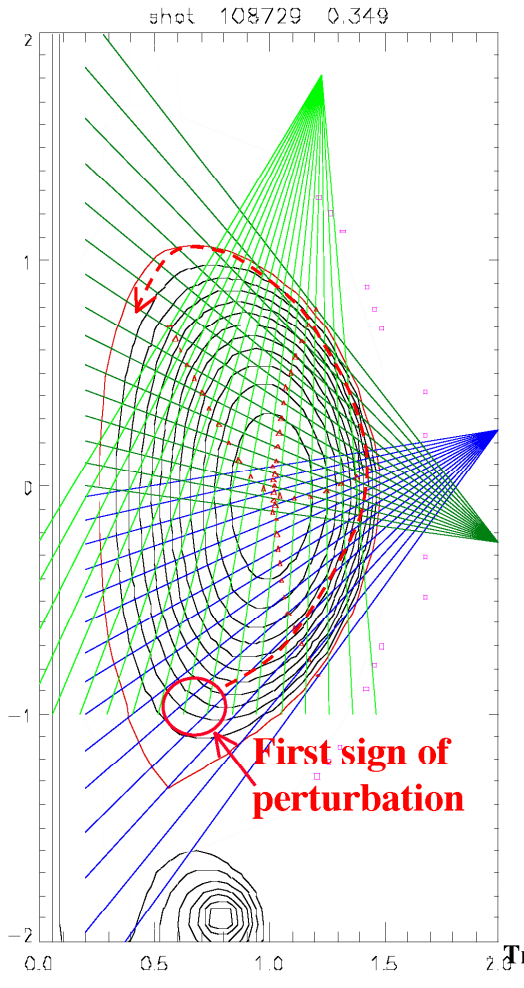


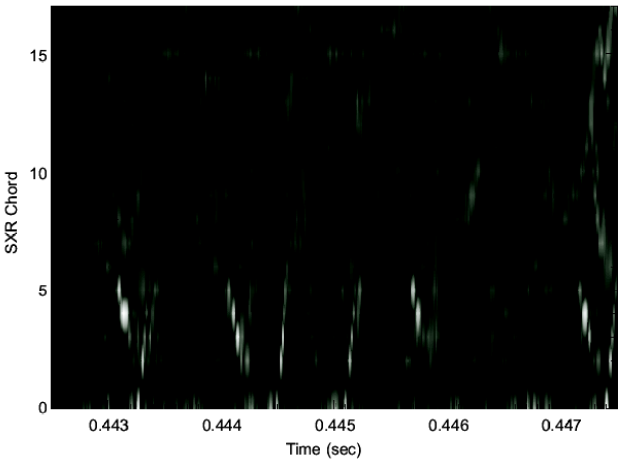
8

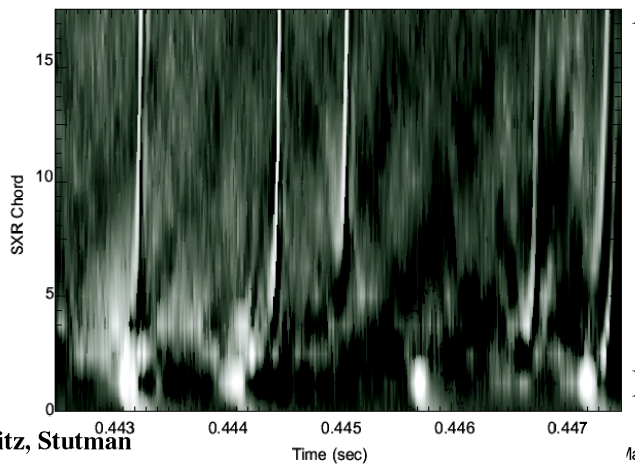


1-2kHz peak spectra along the helical line are founded (not shown in figure)

Type V ELMs usually originate in lower divertor region in Ultra-soft X-ray Diagnostic and propagate upward

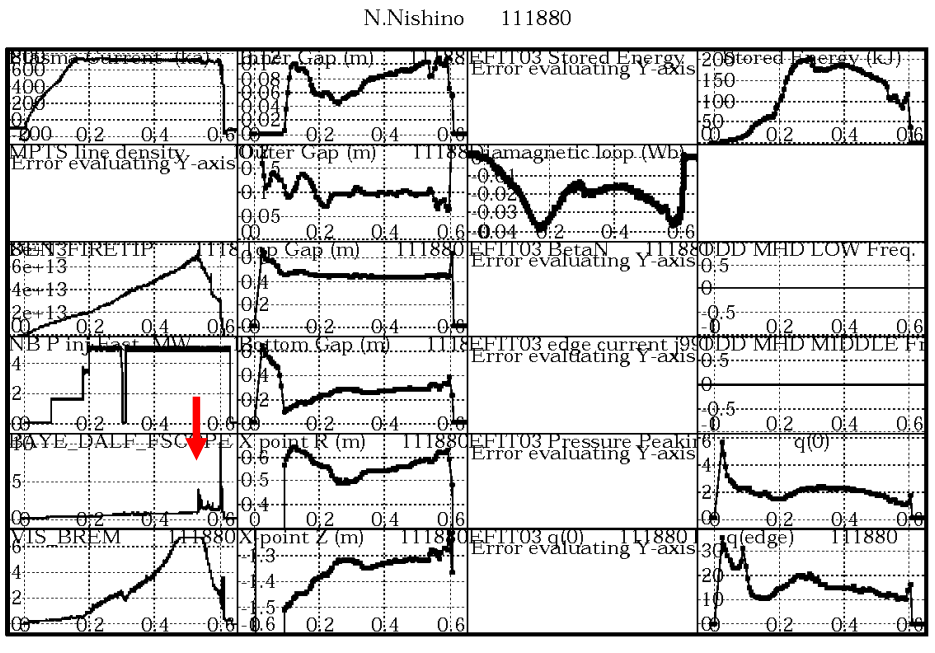


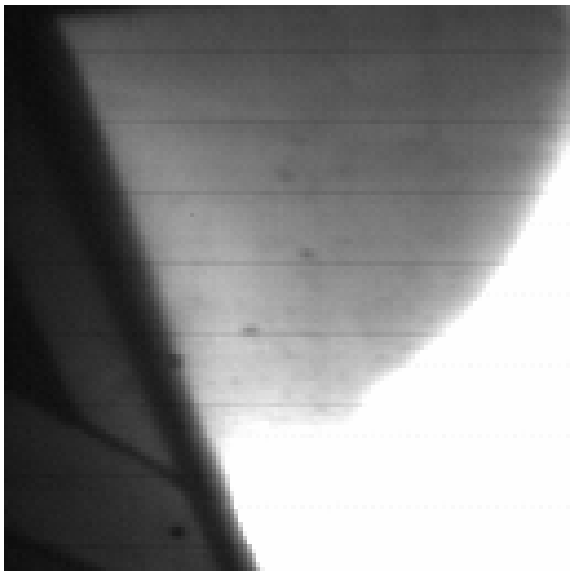




Tritz, Stutman

Origin of small ELM (TYPE V)

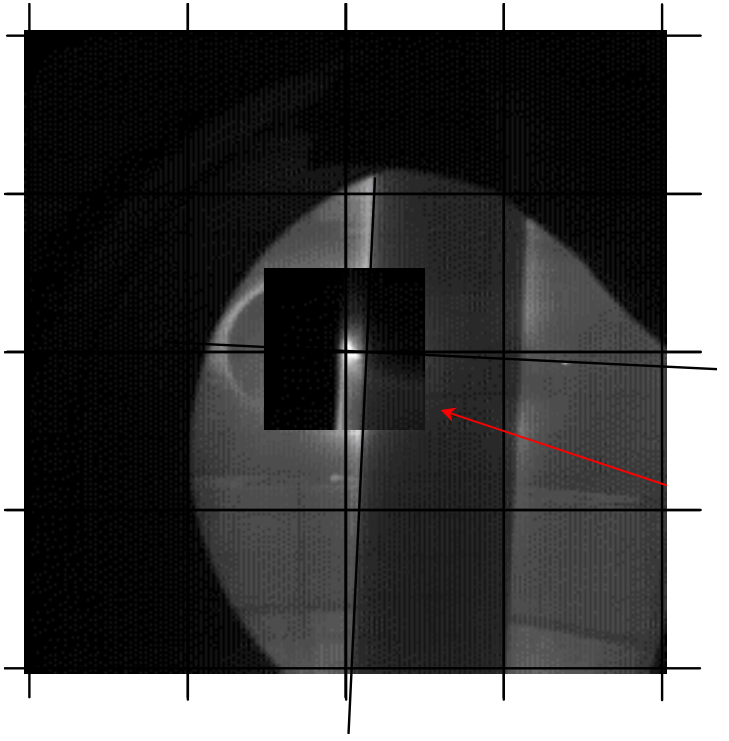




- **0.329-0.358sec**

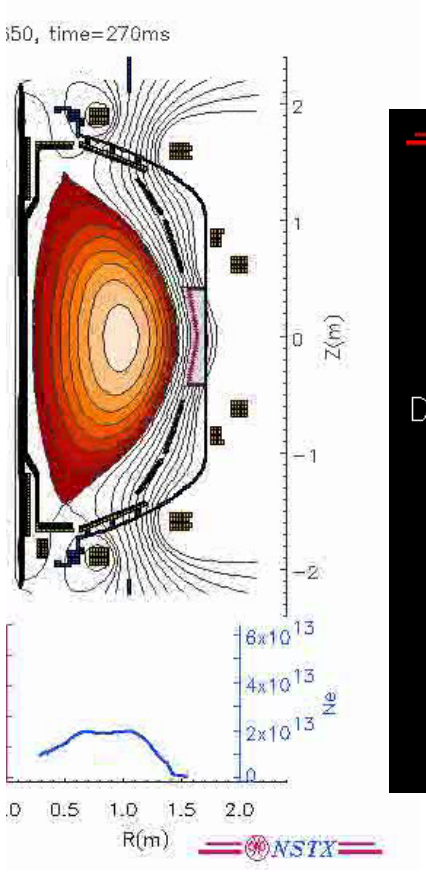
ELMs in the inner region in DN plasma

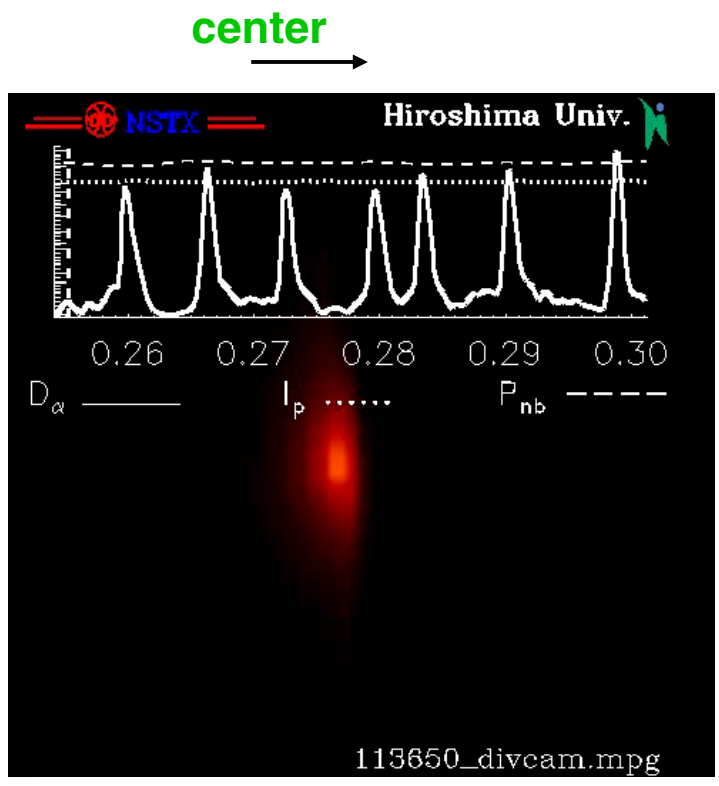
- It moves along the field line.
  - Its speed can be deduced by camera data & Mirnov.
- Field of view
  - Center 40500FPS
    - 64x64 pixels
  - Background 4500FPS
    - 256x256 pixels
  - (these shots are different.)



Inner region ELMs in DND configuration

- Inner region ELMs bounced near the center stack
- Only DND configuration
- What is the physics?
  - MHD or E-Static
- Locations of two X-points?





TYPE of ELMs in NSTX

- TYPE I (ideal ballooning mode)
- TYPE II? (access to second stability)
- TYPE III (resistive ballooning mode)
- TYPE V (New, Physics?)
  - Outer region in LN configuration (almost)
- TYPE VI？（Newer, Physics?)
  - Inner region in DN configuration (always)

- An attempt has been made to categorize the types of ELMs more precisely. Although useful, the definitions are somewhat imprecise. (from “Tokamaks” by J.Wesson)

- Too many data are to be analyzed, and the analysis will continue.

Conclusion

- The fact is that
  - Many ELMs and fluctuations are observed in NSTX.
  - In particular, new ELMs (labeled TYPE V and TYPE VI) are found very recently.

- But (to me)
  - the physics for new ELMs are needed.
  - Also, a filament model and the complete H-mode theory are necessary.

- Measurement system
  - Fast divertor camera is very useful for measurement of fluctuations and ELMs.
  - Additional information
    - Two fast cameras will be provided with NSTX to measure the inner region plasma and the divertor plasma simultaneously next year.