Observation of passing fast ion transport induced by fishbone via passive BES on HL-2A

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I. Introduction

- An initial beam emission spectroscopy diagnostic system (BES) has been developed and deployed on the HL-2A tokamak.
- Fluorescence emitted by fast ions charge exchanging in the high neutral-density region at the edge region makes appreciable contributions to the BES signals.
- Instabilities in the core region may expel fast ions from the core to the edge. This fluorescence can complicate the analysis of density fluctuation measurement by BES system.
- On the other hand, the presence of passive FIDA light in BES signals may provide useful information about the fast-ion losses.

I. Introdution

- D_α emission are composed of six main processes

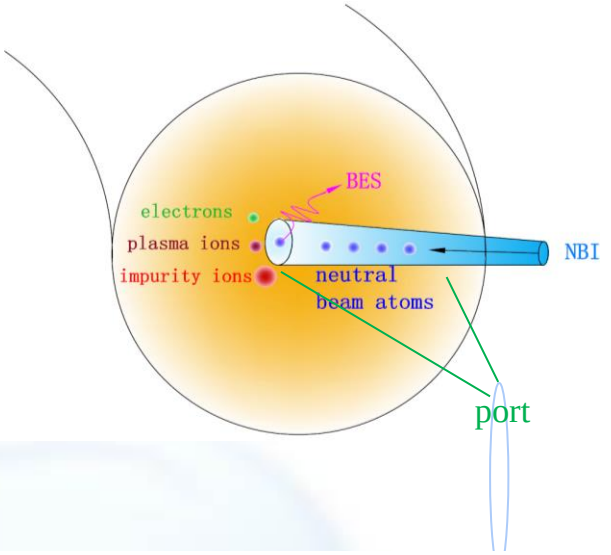
$$(\mathrm{BES})D_b^0 + D_{th}^+/e^- \rightarrow D_b^0(n') + D_{th}^+/e^-$$

$$(\mathrm{DCX})D_b^0 + D_{th}^+ \rightarrow D_b^+ + D_{th}^0(n')$$

$$(\mathrm{aFIDA})D_b^0 + D_{FA}^+ \rightarrow D_b^+ + D_{FA}^0(n')$$

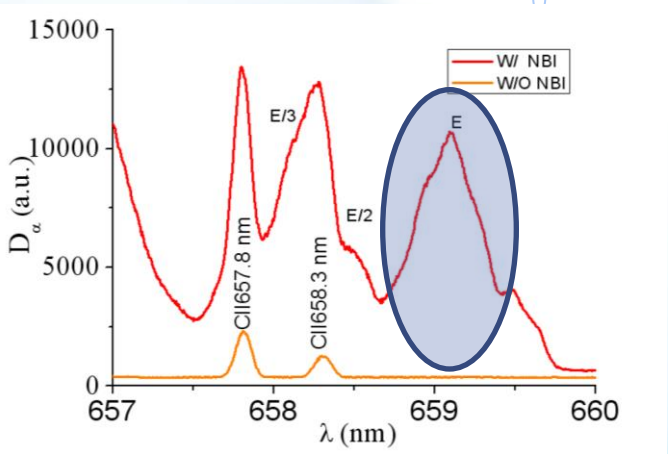
$$(\mathrm{pFIDA})D_{th}^0 + D_{FP}^+ \rightarrow D_{th}^+ + D_{FP}^0(n')$$

$$(\mathrm{Halo})D_{th}^0 + D_{th}^+ \rightarrow D_{th}^+ + D_{th}^0(n')$$



- For BES signals, the local plasma density

$$\frac{\tilde{n}}{n_0} = K(T_e, n_e, \ldots)\frac{\tilde{I}}{I_0}, K \sim \text{const.}$$

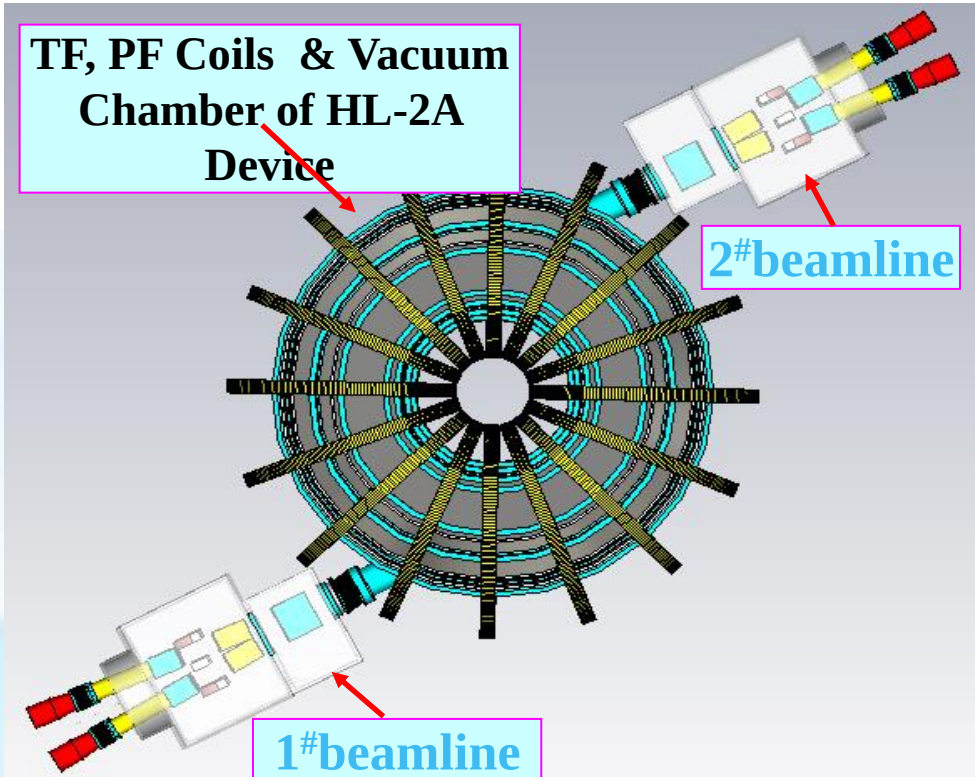


II. BES on HL-2A tokamak

- Two beamlines are available now on HL-2A tokamak.

Table Main parameters of HL-2A tokamak

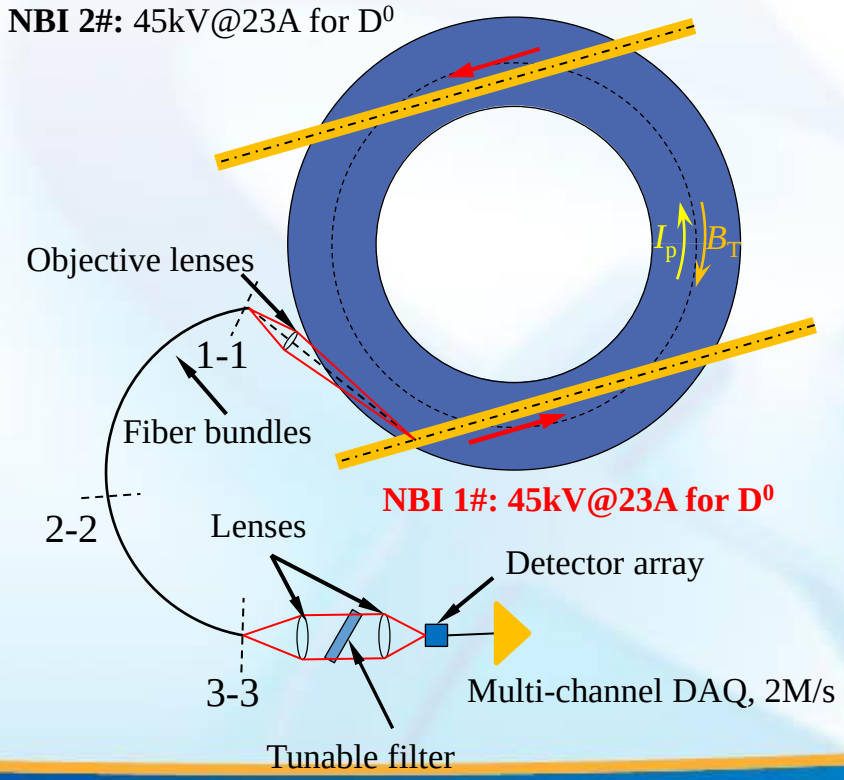
Parameters	Value
Major radius, R	1.65 m
Minor radius, a	0.4 m
Toroidal field, B_T	1.2~2.8 T
Plasma density, n	$1\sim6\times10^{19}$ m^{-3}
LHCD	2 MW@3.7 GHz
ECRH	3 MW@68 GHz, 1 MW@105 GHz, 1 MW@140GHz
NBI	**1.5~2 MW×2**

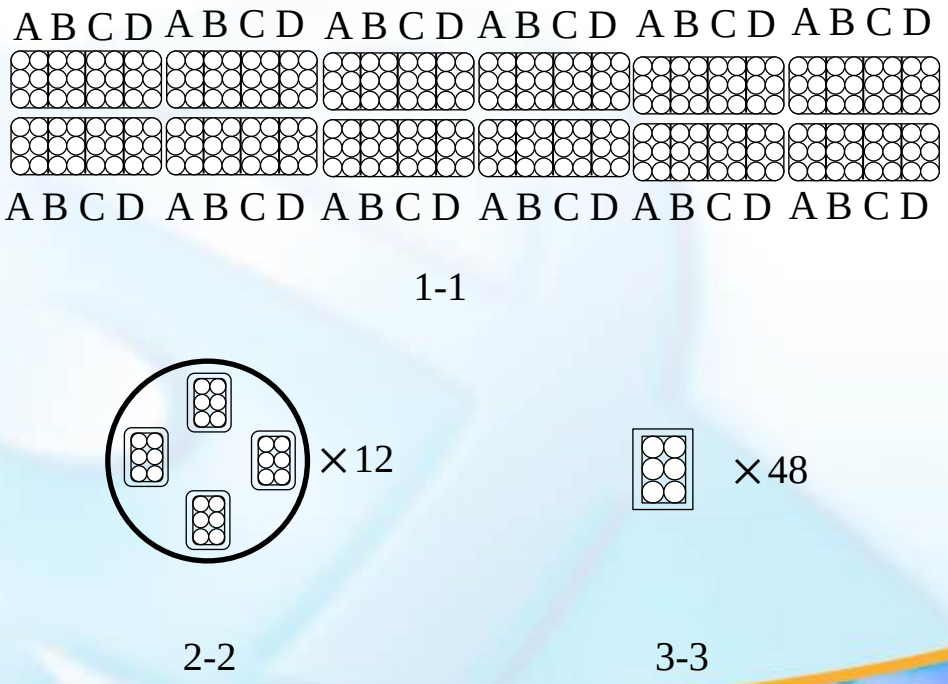


Arrangement of NBI Injectors on HL-2A

II. BES on HL-2A tokamak

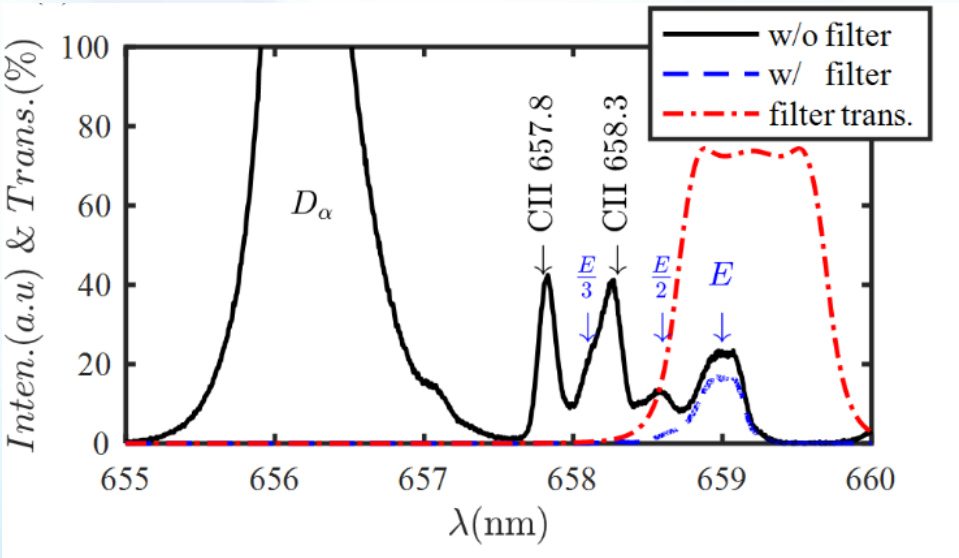
- **Focusing on 1# neutral beam;**
- Detecting region covers R = 1.77 ~ 2.09 m (r = 12 ~ 44 cm), Z = −5 ~5 cm;
- Spatial resolution: Δr = 0.7 (edge) ~ 1.2 (core) cm, ΔZ = 1.2 cm;
- Temporal resolution: Δt = 0.5 μs (2 M/s).

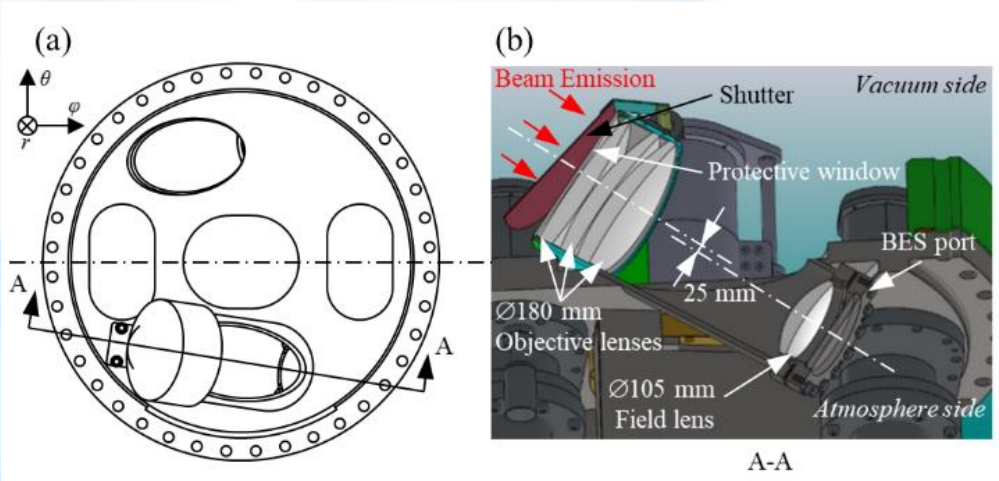




II. BES on HL-2A tokamak

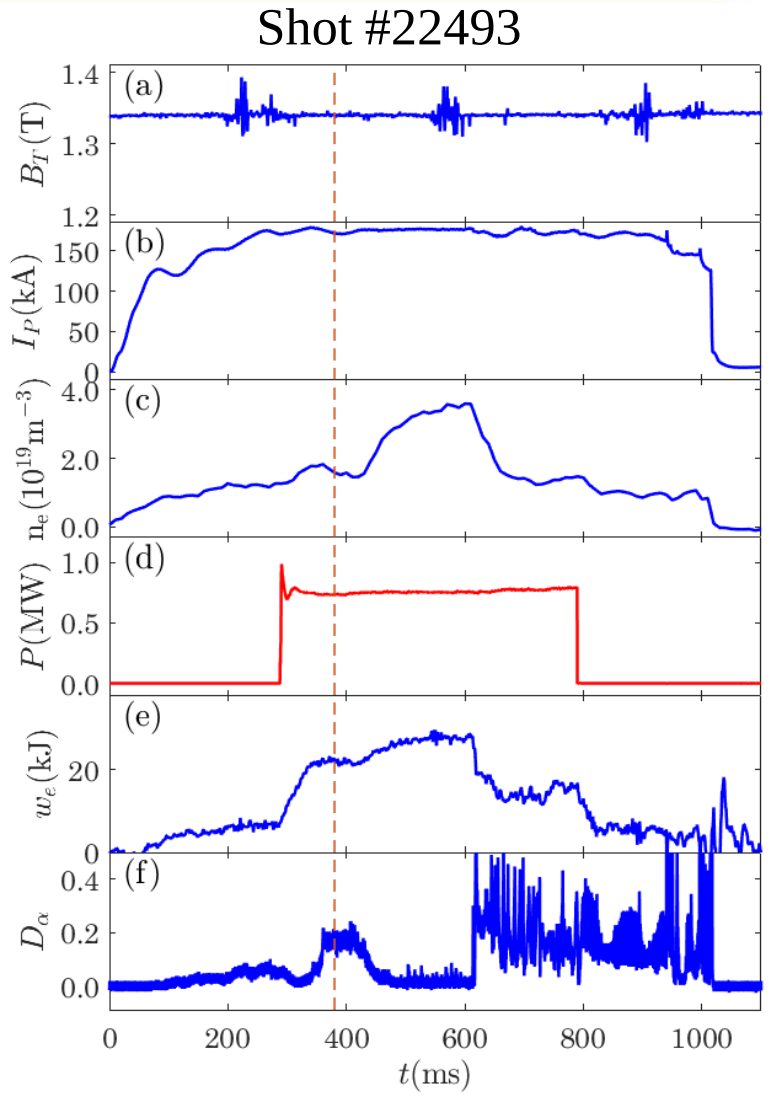
- Flexible configuration by rearrange fiber bundles on the fiber mount.
- Large objective lenses (18 cm), and off-axis design to fit the limit space.
- 48 channels (12 units of 4×1 array) are available.
- 10 Å broadband, sharp-edge filter, **658.6~659.6 nm**;
- Transmission > 75% for full energy peak, < 5% for CII6583.





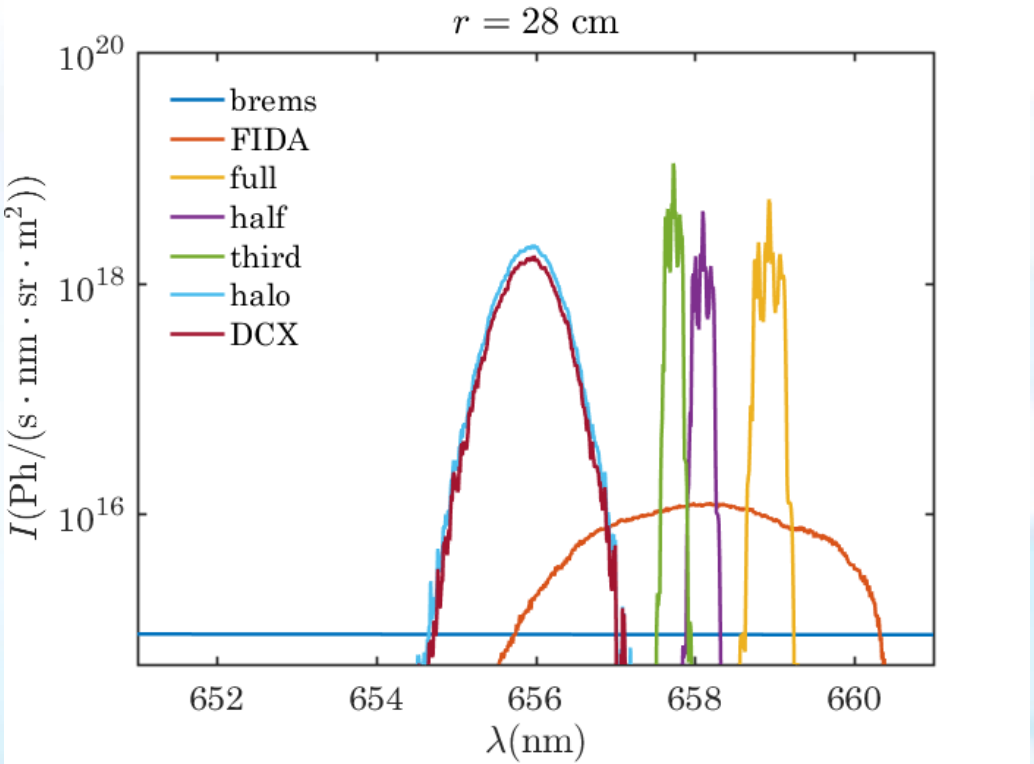
III. Fast-ion D_α Calculated by FIDAsim

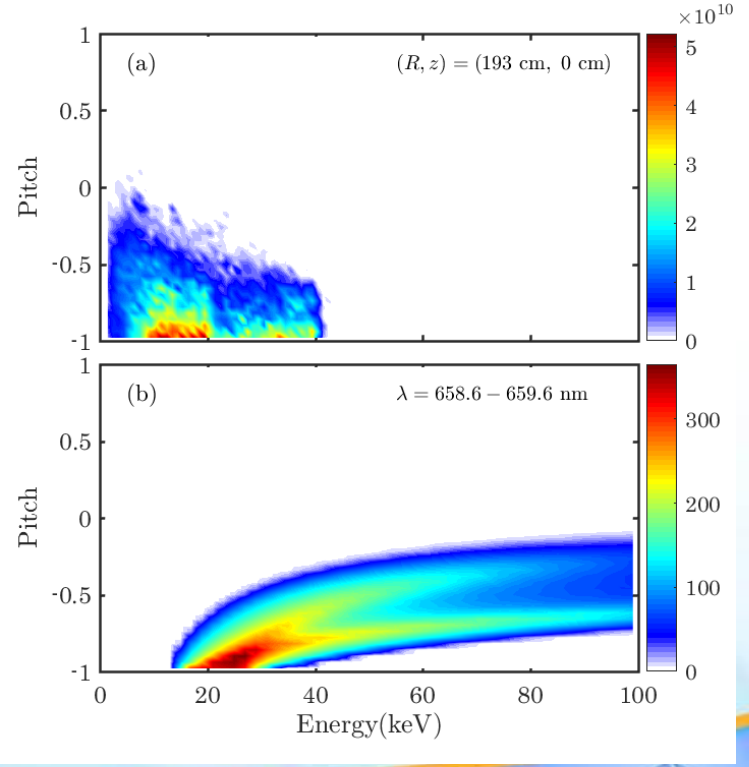
- Discharge conditions and plasma profiles of shot #22493 at 380 ms are used as input for TRANSP.
- TRANSP provides the plasma profiles, equilibrium fitting and fast-ion distribution function as the input of FIDAsim.
- The 1# NBI is on and 2# NBI is off.
- The axis of BES objective lenses is chose as the scope sightline.



III. Fast-ion D_α Calculated by FIDAsim

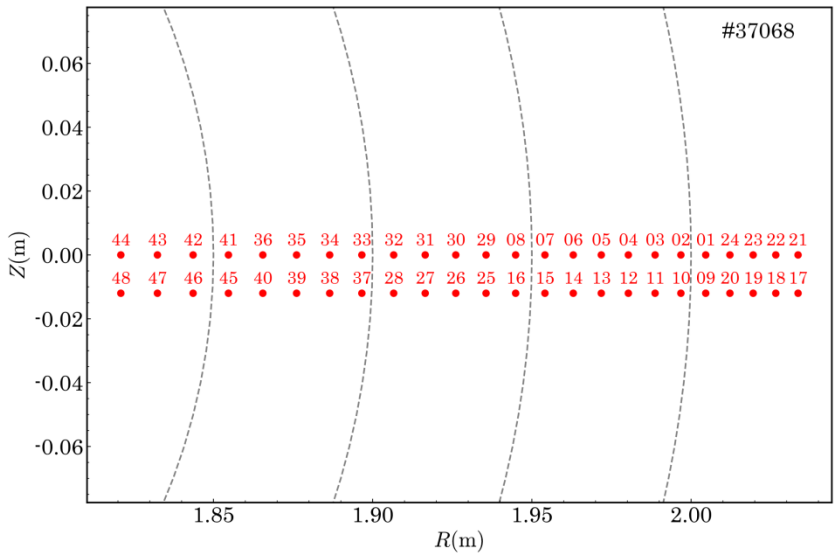
- The results of FIDAsim calculation indicate that the fluorescence emitted by fast-ion charge exchanging will beam neutrals is 1~2 orders weaker than the full energy beam emission spectroscopy.

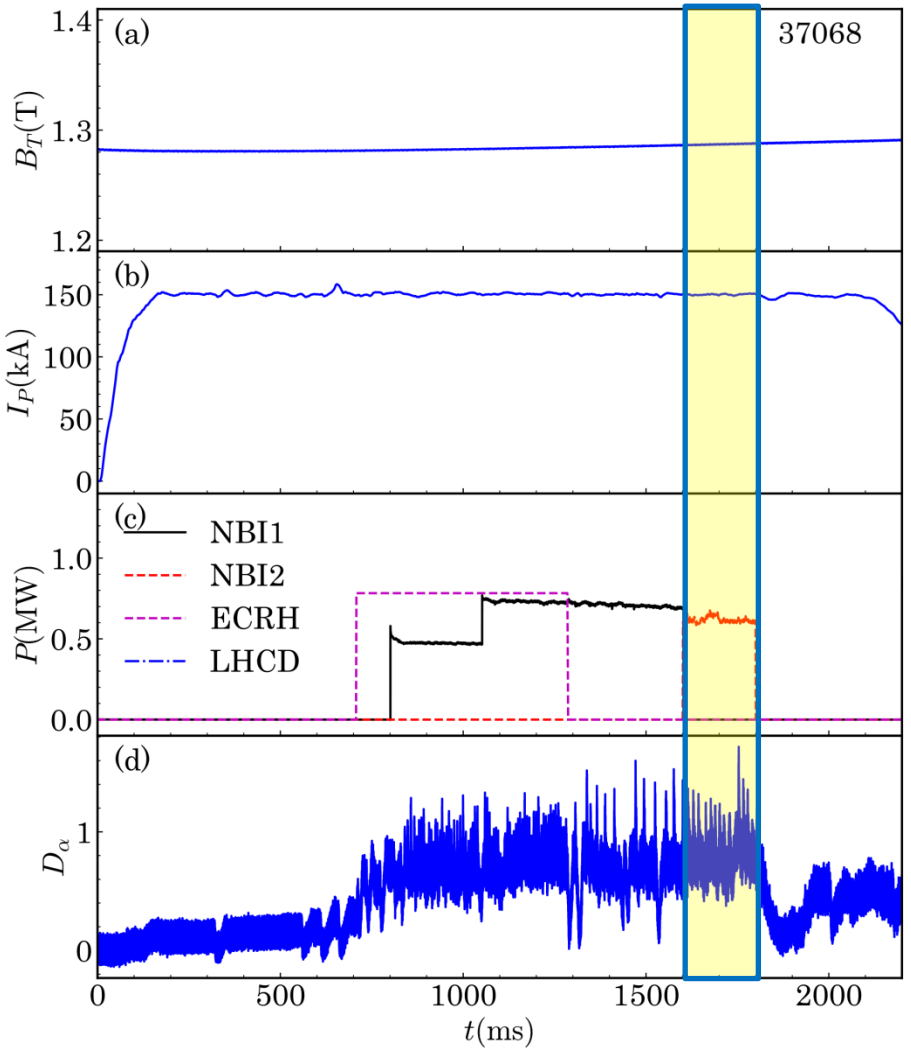




IV. Experiments setup

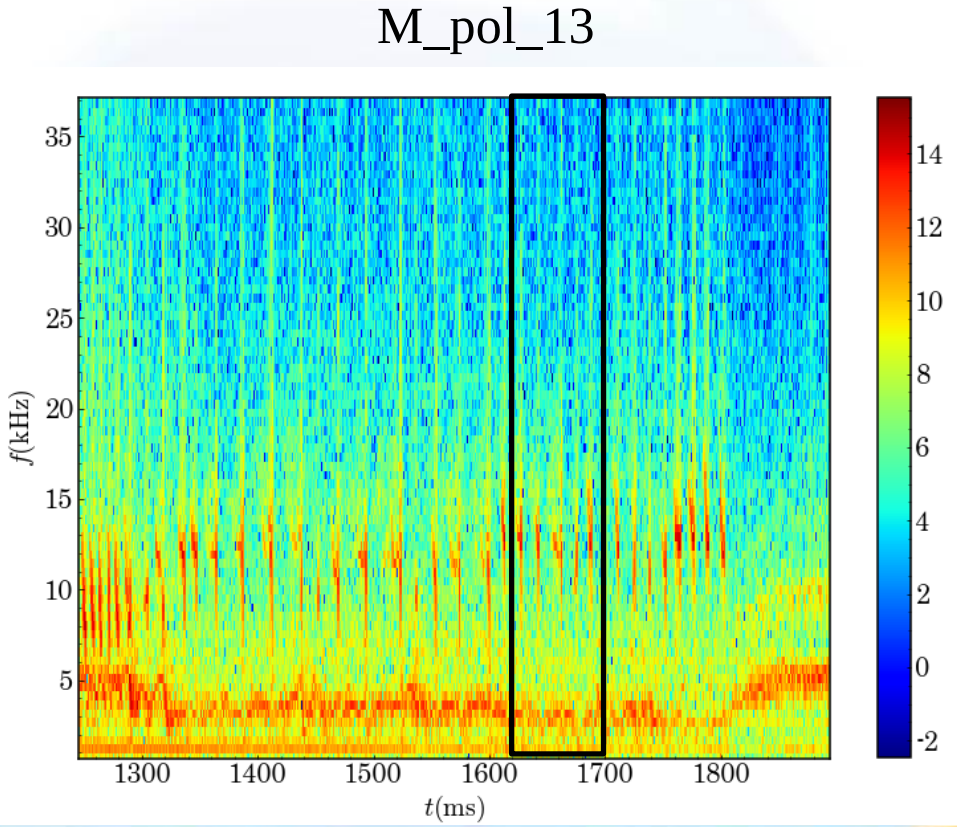
- 48-channel BES system (arranged as 2×24 array) covers r/a = 0.43 ~ 1.
- NBI 1 # was turned off at 1600 ms, and NBI 2# was on during 1600~1800 ms.
- L-mode discharge.

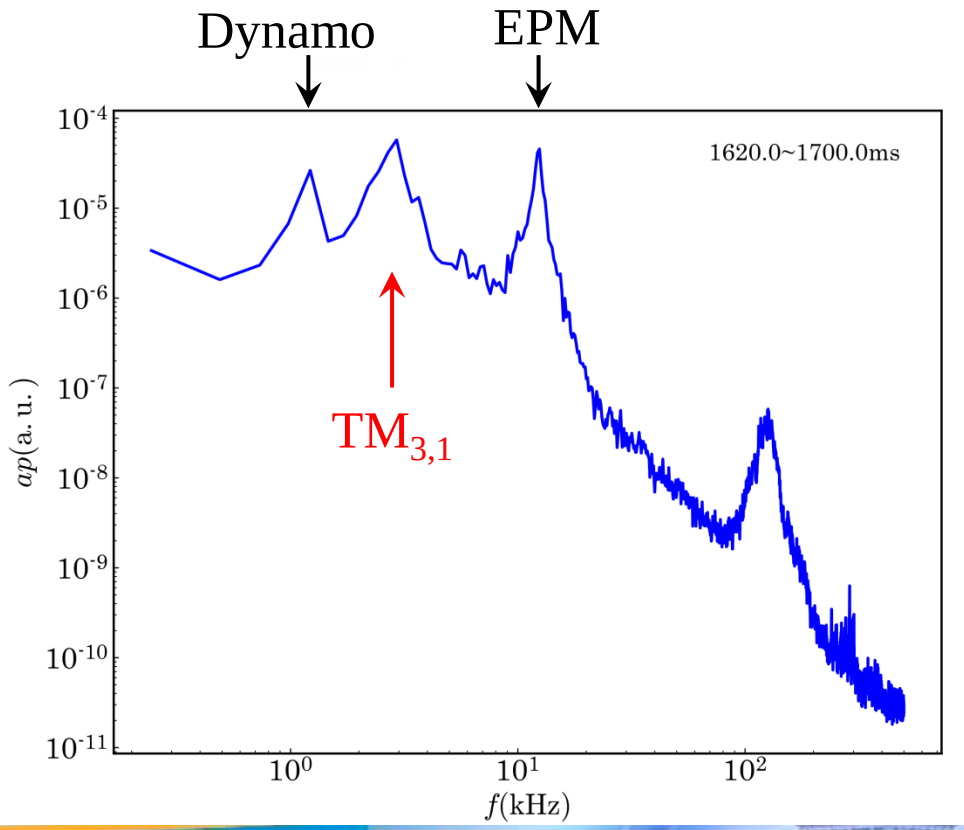




Magnetic perturbations

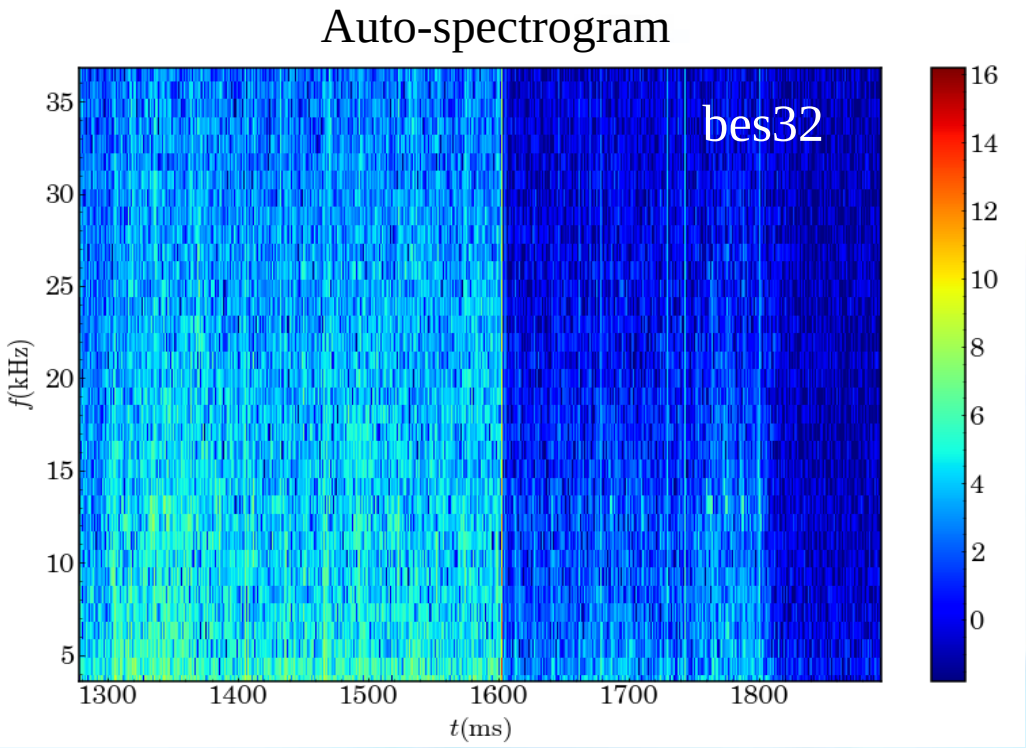
- Averaged over 80 ms when NBI#1 is off and NBI#2 is on.
- 1.2 kHz: power frequency induced by dynamo.
- ~3 kHz: Tearing mode, m/n = 3/1.
- 10~15 kHz: fast downwards chirping, typical energetic particle modes on HL-2A.

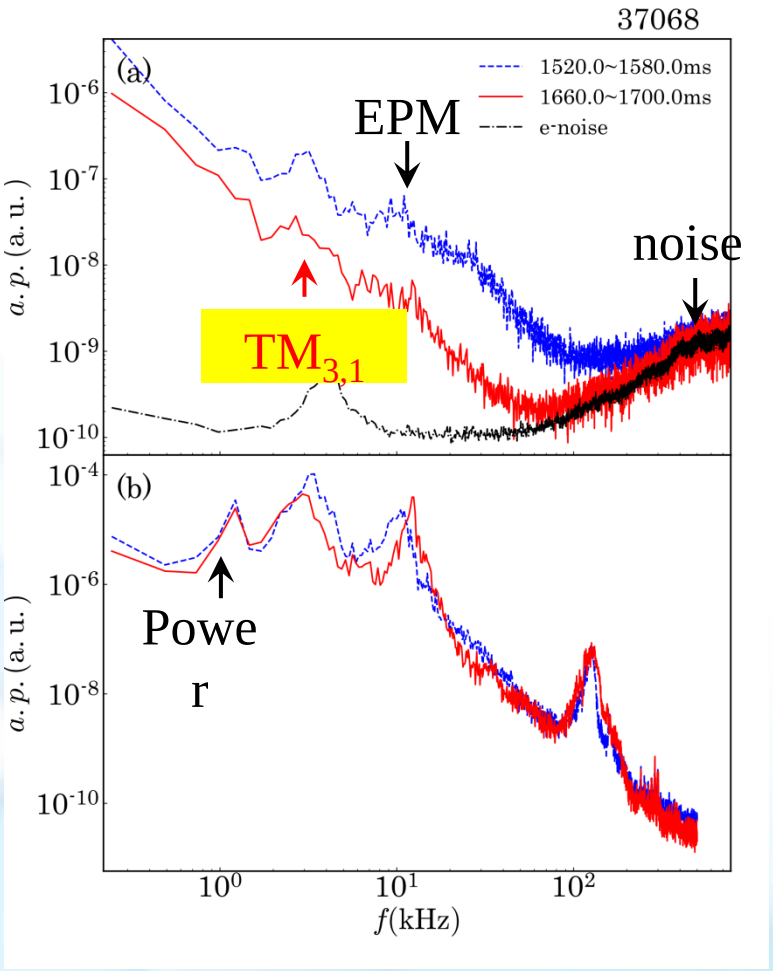




Passive BES responses

- Both EPMs and TMs are observed either w/ NBI#1 or w/ NBI #2.

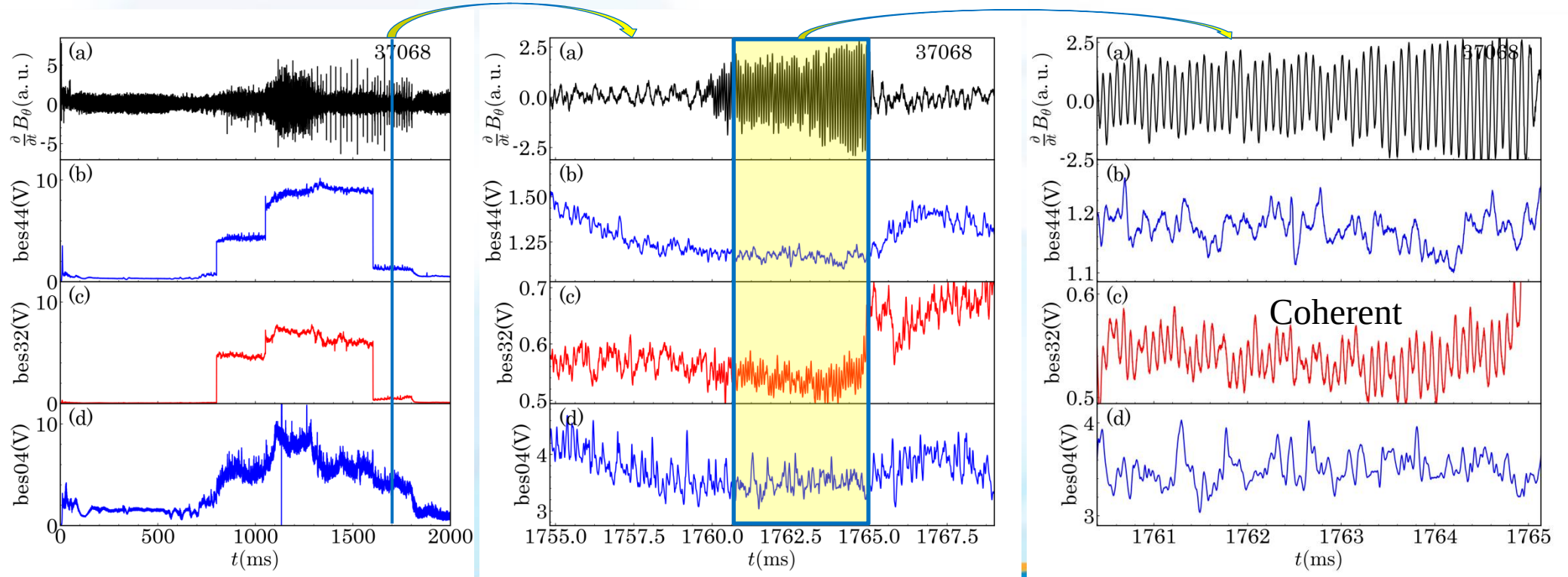




NBI #1 turned off and NBI#2 turned on.

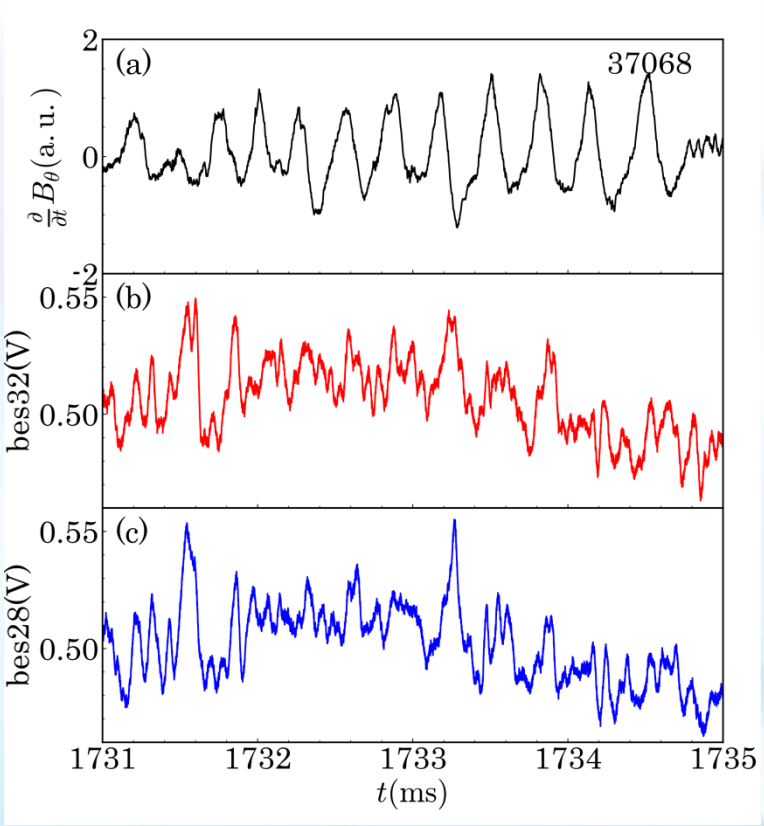
Passive BES response to EPMs

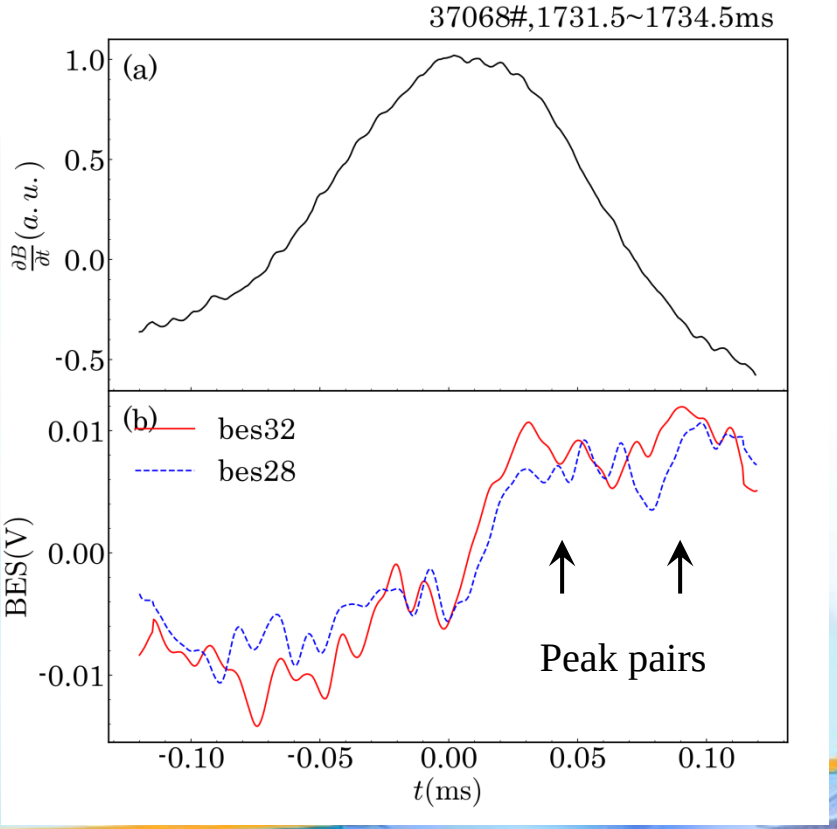
- Coherent response are only observed on certain channels, which may suggest the angle between sightline and magnetic field lines counts for passive BES.
  - R = 1.82~1.90 m (bes44~bes41): Only incoherent bumps
  - R = 1.91~1.97 m (bes32~bes05) : Coherent & Incoherent bumps
  - R = 1.98~2.03 m (bes05~bes21): Only weak or no incoherent bumps



Passive BES response to TMs

- Conditional average over 10 periods of 2.8 kHz tearing mode.
- Coherent response of passive BES to TMs is observed.
- Two peaks in every TM period, since the sightline crosses the boundary twice. Slight phase shift between different channels are also observed.



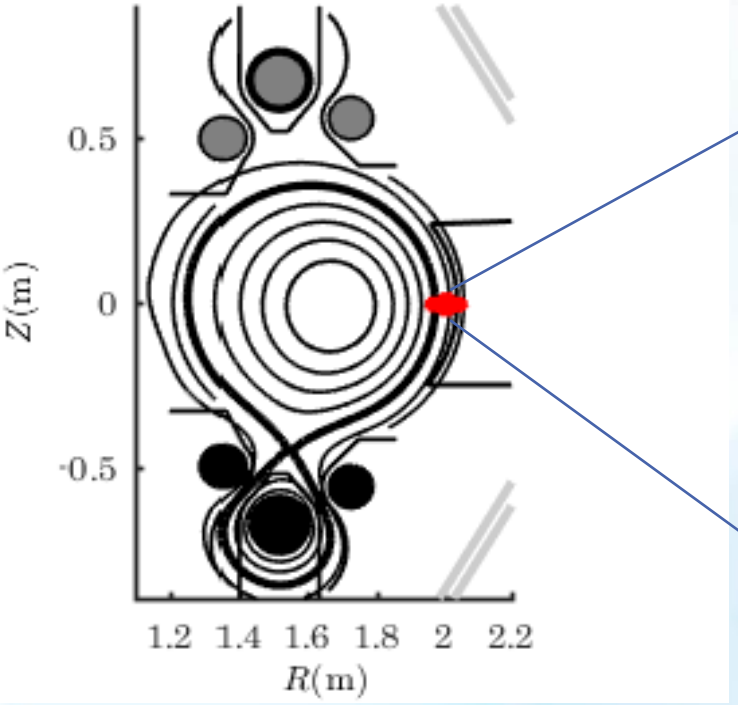


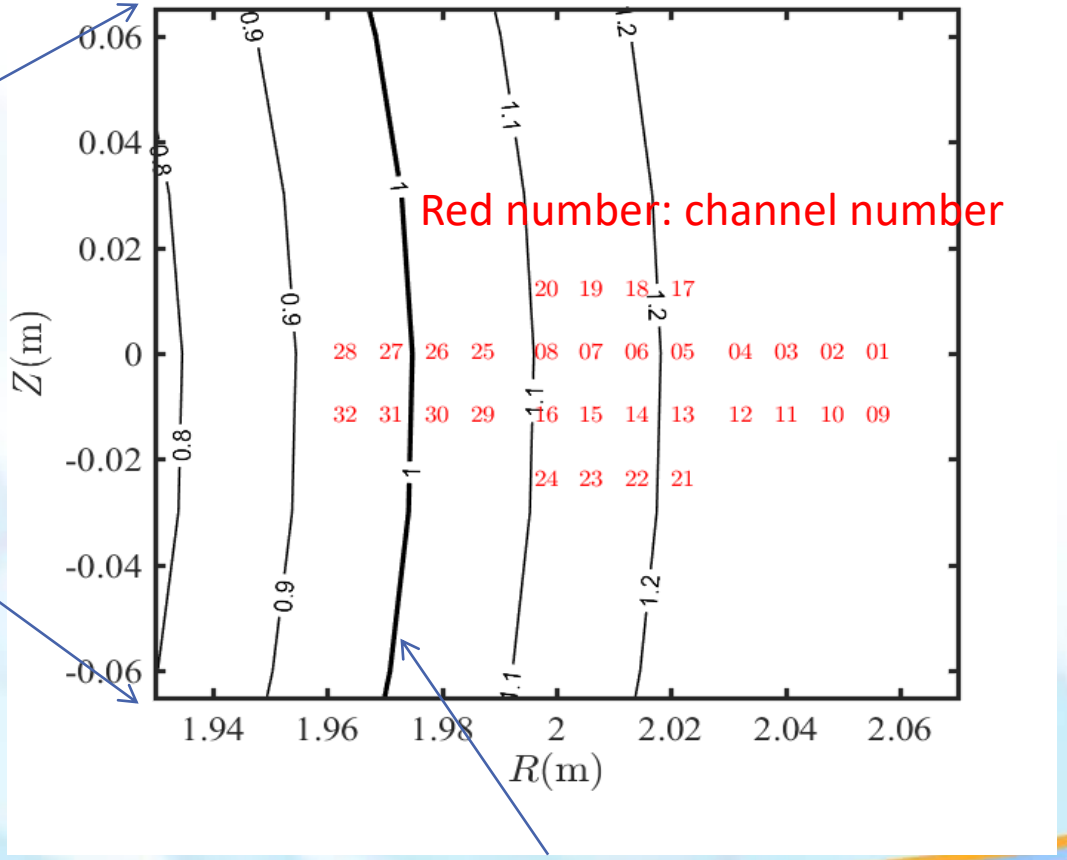
V. Discussion and Summary

- 48-channel initial BES system has been developed and deployed on the HL-2A tokamak with high spatial and temporal resolution.
- Energetic particle transport induced by instabilities could be observed by passive BES signals.
- Adding the edge neutral density distribution function into the FIDAsim needs to be done.
- Detailed energetic particle transport behaviors are under analysis. The coherence analysis and comparison between BES signal and other diagnostics will be done in the future.

- Back-up slides

BES monitors the edge perturbations



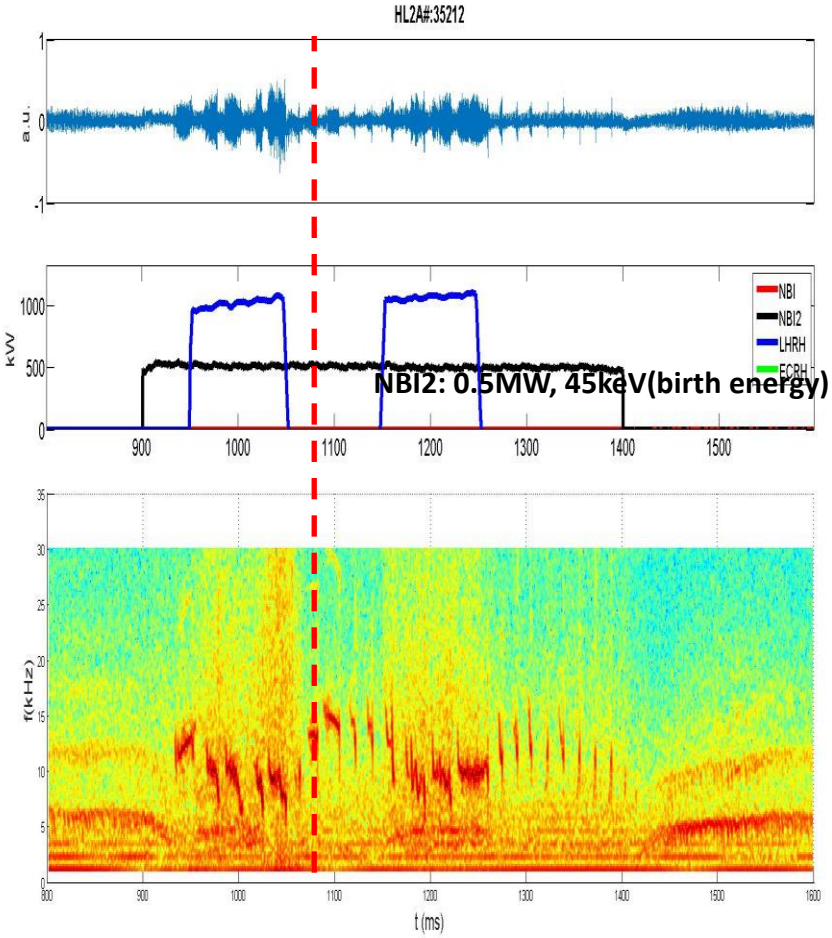


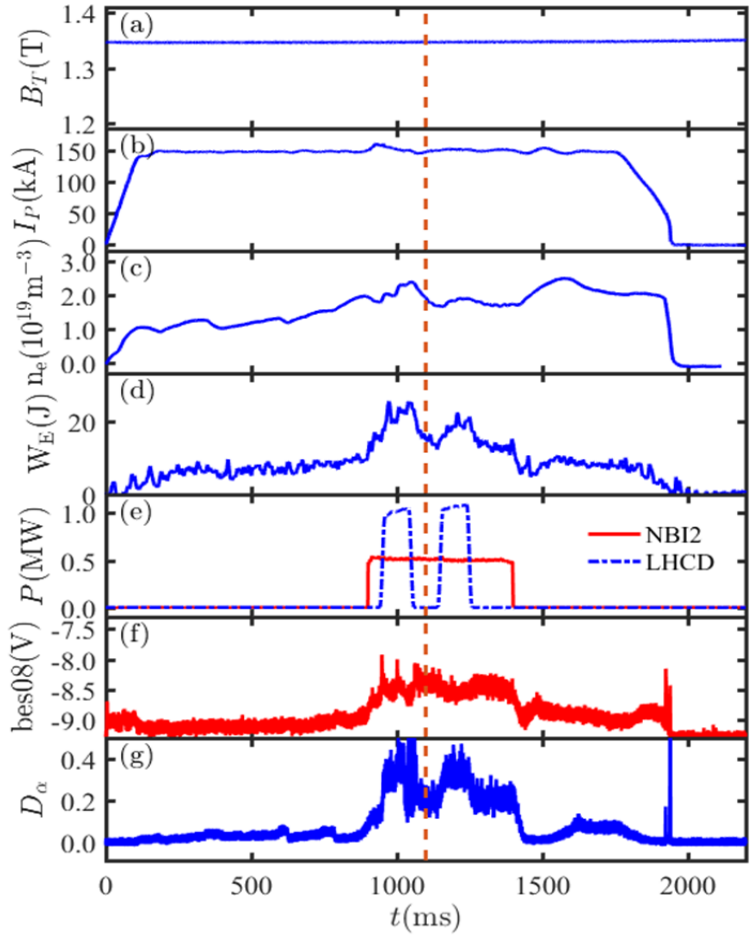
Last flux surface

We know : delta S_32 /S_32

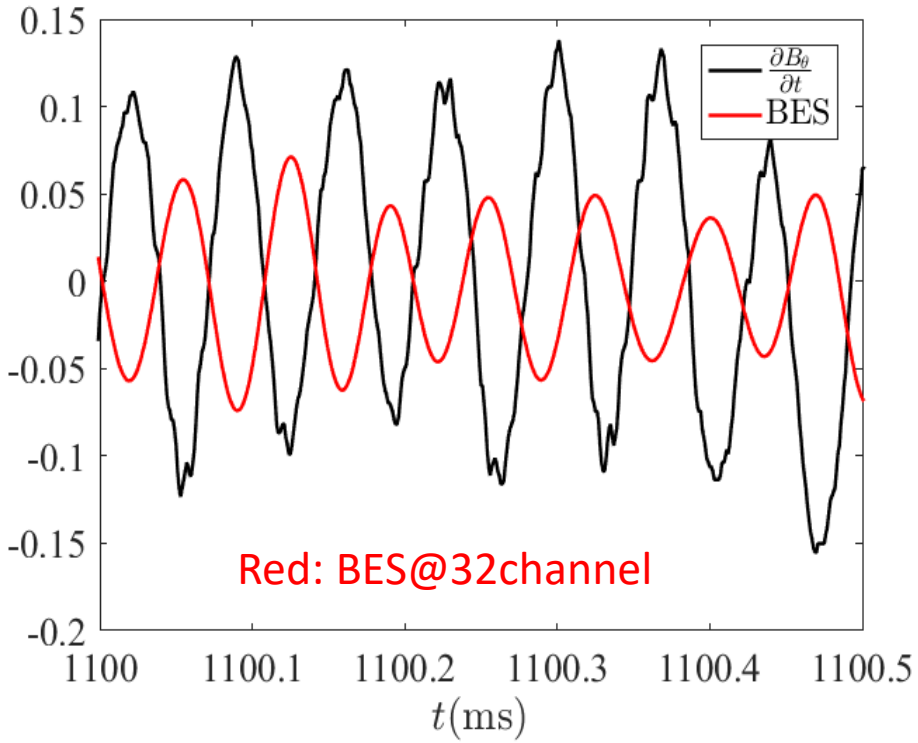
But we did not make the channel to channel calibration for BES

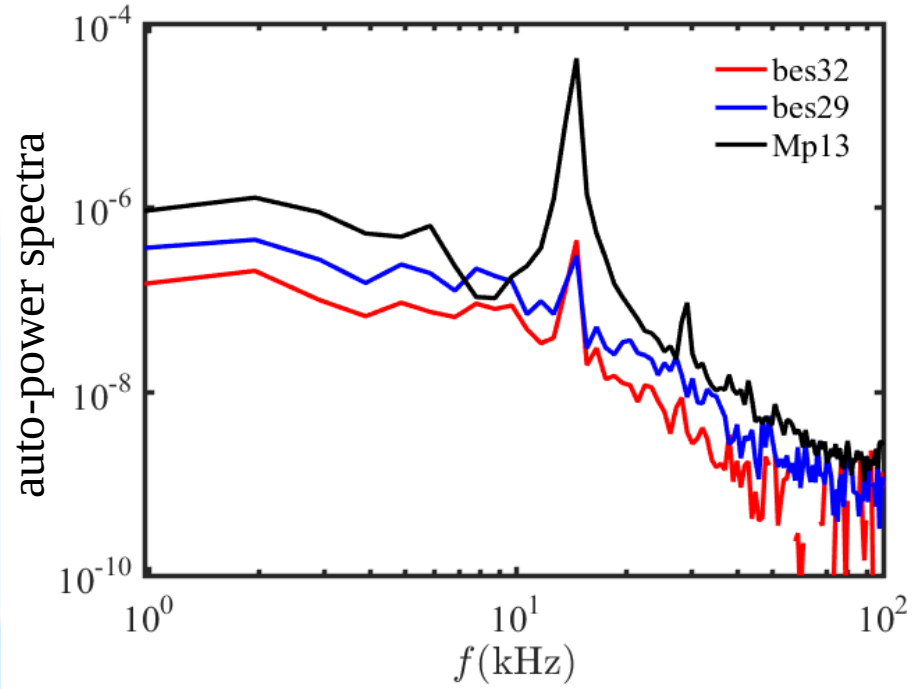
We choose a time window to study the response of passive FIDA signal to the EPM





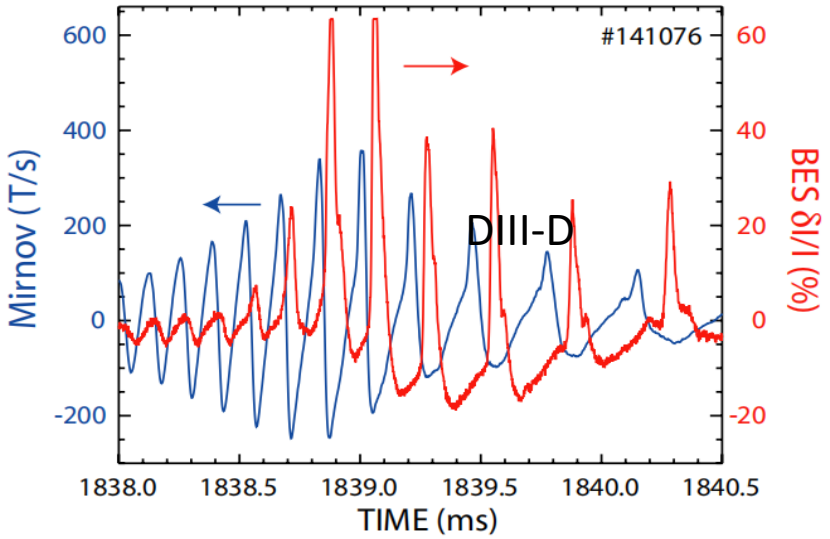
BES synchronization with Mirnov signal



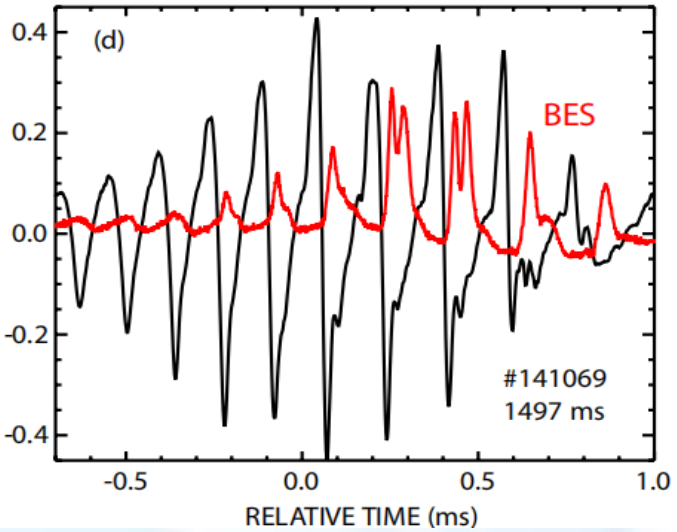


We are considering: Does it imply that the EPM on HL-2A induce the transport of passing fast ions with Full energy?

Passive FIDA signal measured by BES on the DIII-D were reported



Heidbrink et al., PPCF 53 (2011) 085007



Heidbrink et al., PPCF,53 (2011) 085028

At present, on the HL-2A, it seems that we also obtain the passive FIDA signal by BES diagnostic. BES signal seems to very similar to that found on the DIII-D.

Questions and Comments