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First implementation of active divertor heat flux feedback control in EAST PCS

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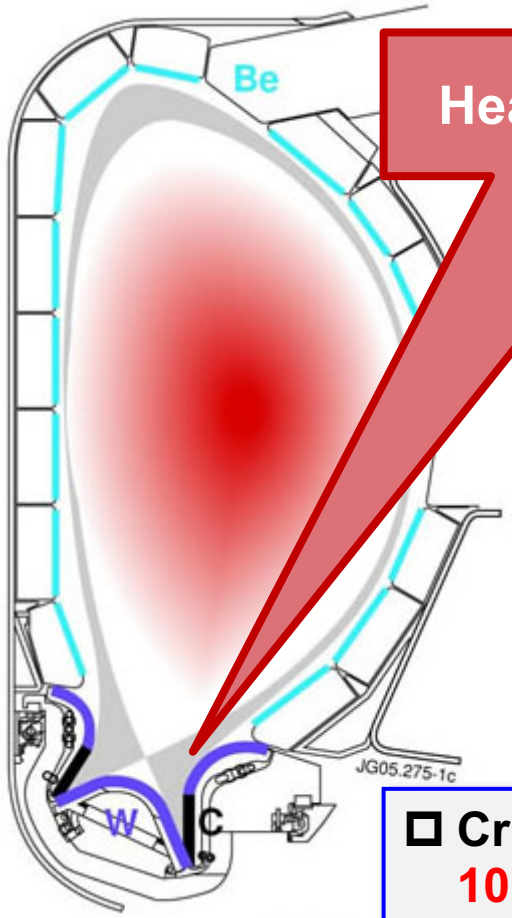
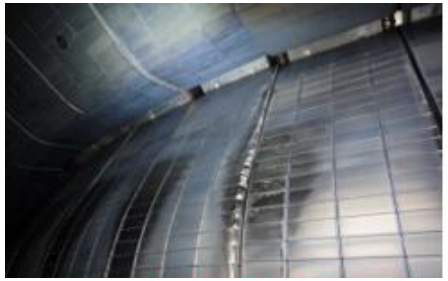
Outline

- Motivation
- Previous achievements
- Detachment control in EAST H-mode
- Summary

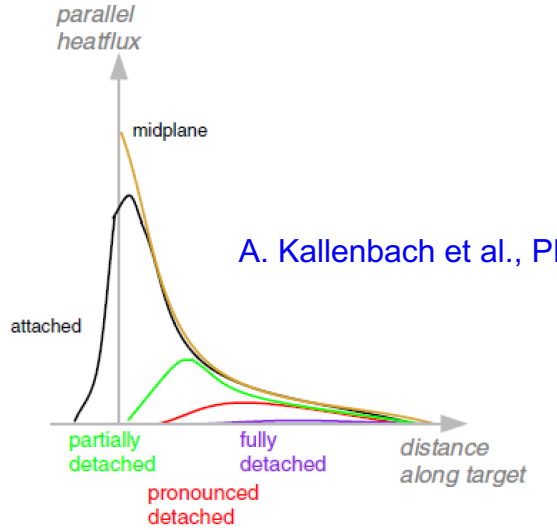
Motivation



Heat flux > 10 MW/m^2



- **Damage the divertor material**
- **Pollute plasma and cause disruption**



A. Kallenbach et al., PPCF (2012)

Figure 1. Qualitative sketch of target heat flux profiles for different detachment states.

- **Critical challenges for EAST long-pulse operation, especially with heating power > 10 MW in the next-step.**
- **Radiative divertor induced detachment is the most promising means for steady-state heat load control.**

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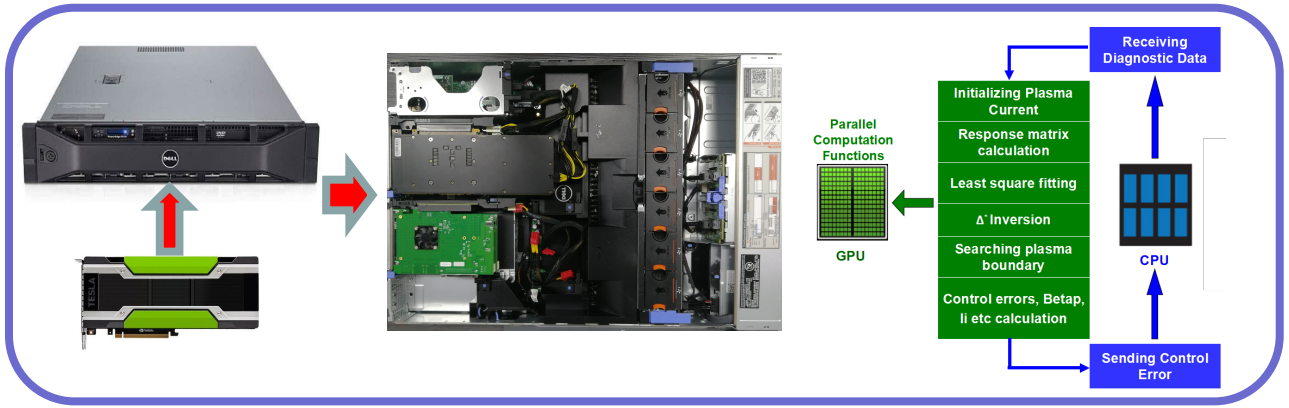
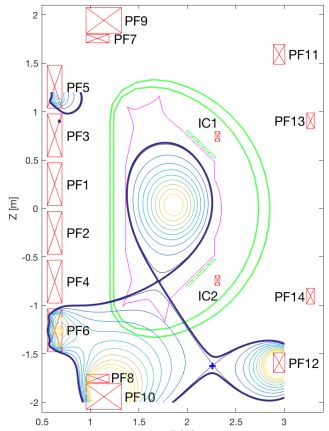
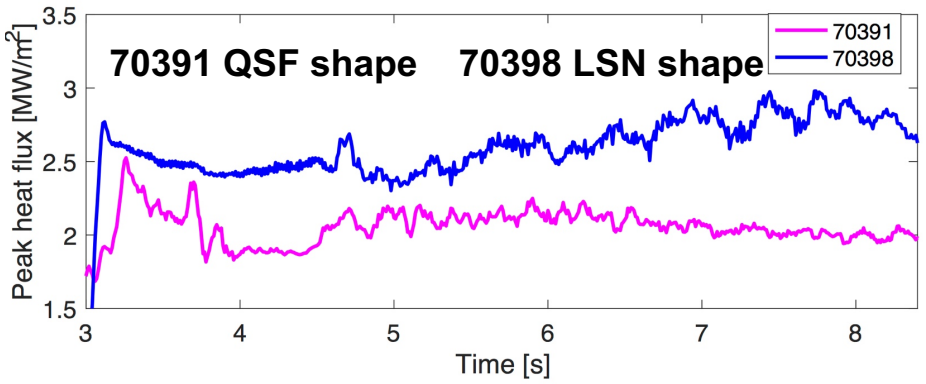
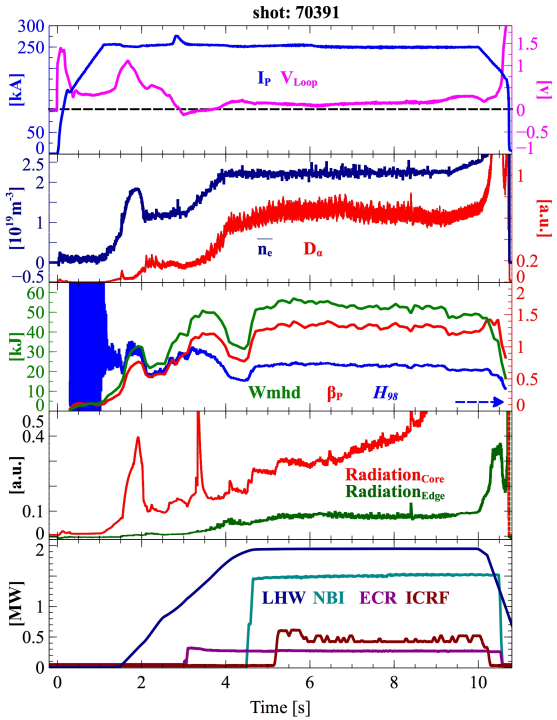
Advanced divertor configuration effectively reduces heat flux



- ✓ P100 GPU installed in PCS server
- ✓ P-EFIT: 129*129 380us/iteration

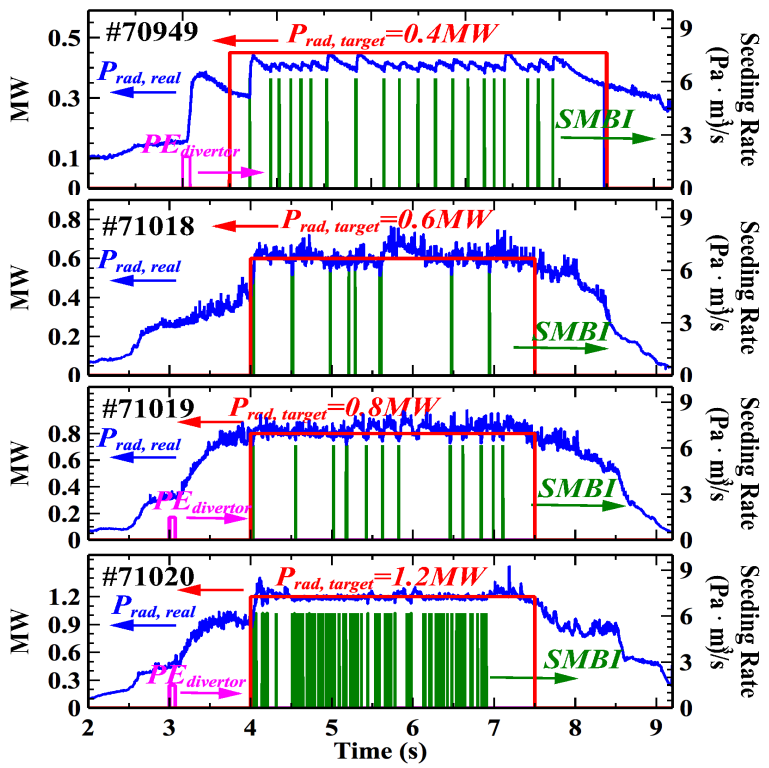


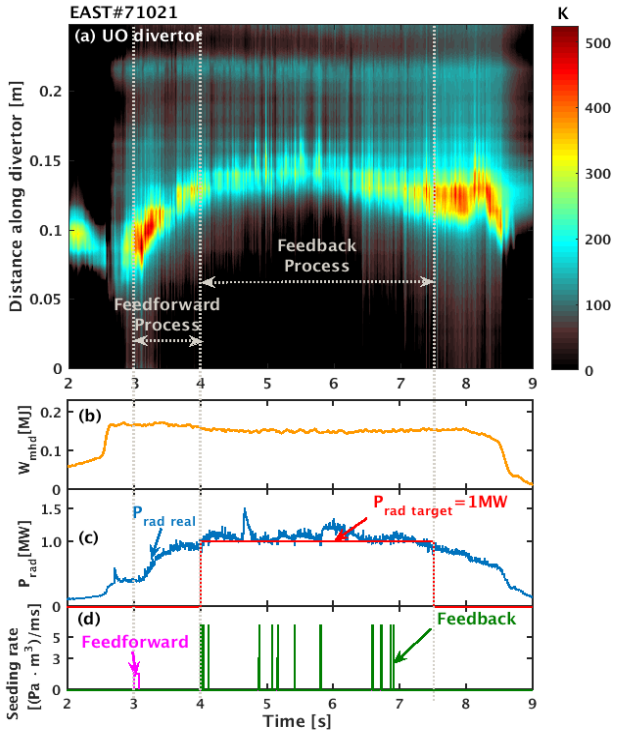




- ➢ Stable QSF divertor configuration have been achieved by PEFIT/ISOFLUX control
- ➢ IR measurements show a peak heat flux reduction of a factor ~1.5

Radiative feedback control for power exhaust





Divertor target temperature:

decrease 250~300K

K. Wu, Q.P. Yuan* et al., Nucl. Fusion (2018)

- **Total radiation power was actively controlled by LFS SMBI neon seeding.**
  - Slight loss of plasma stored energy: 7 - 11%
  - Total radiation fraction can be controlled within 18-36%, in H-mode regime. f_{rad} extended to 41% in 2018.

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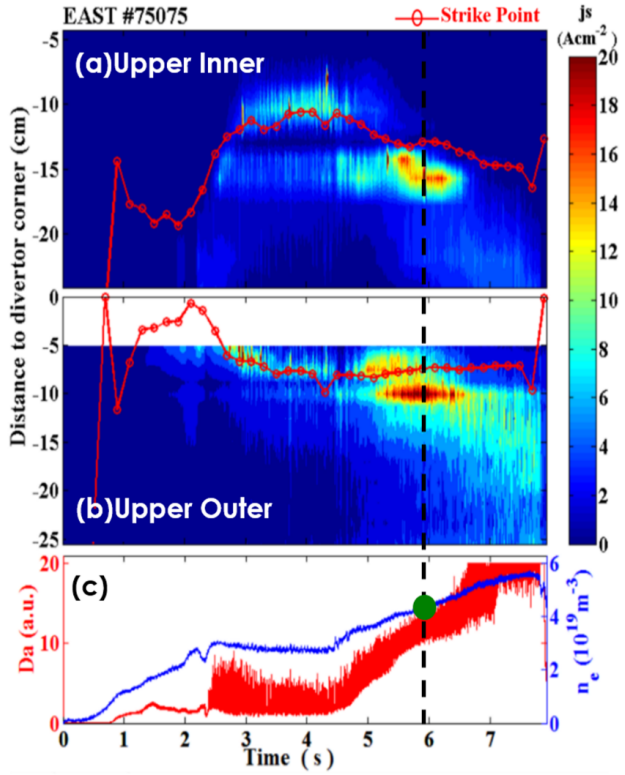
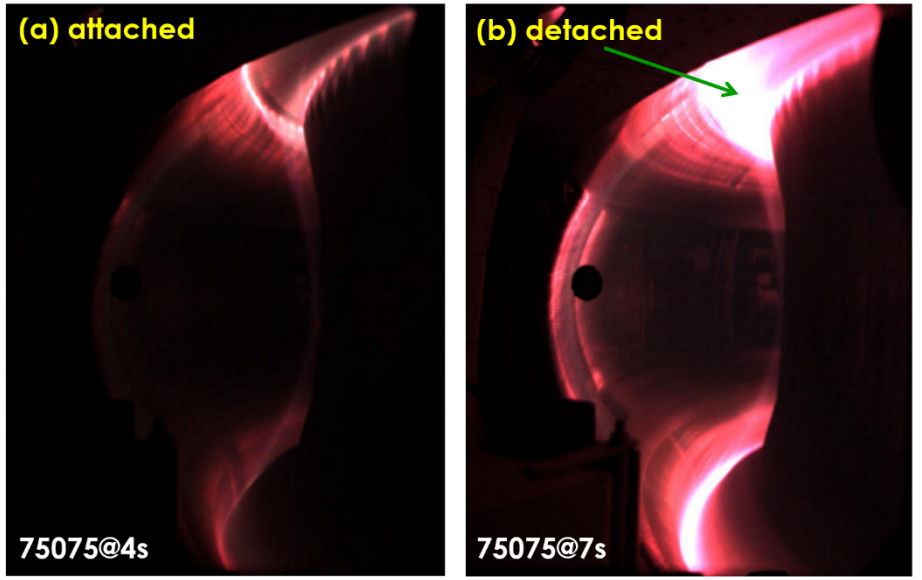
First H-mode detachment with W divertor in EAST

- The particle flux roll over was clearly observed



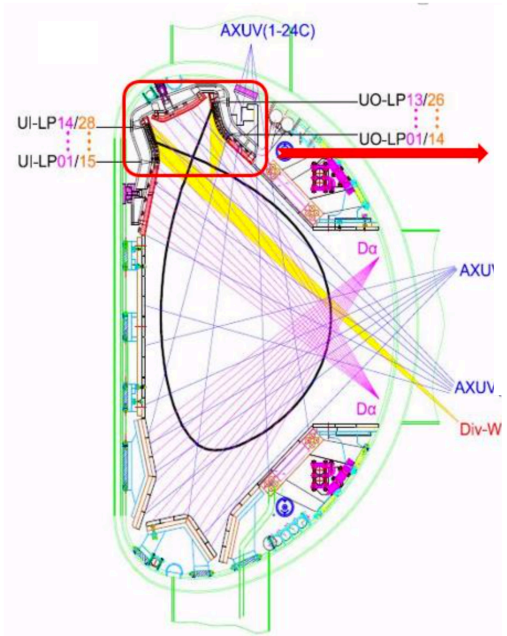


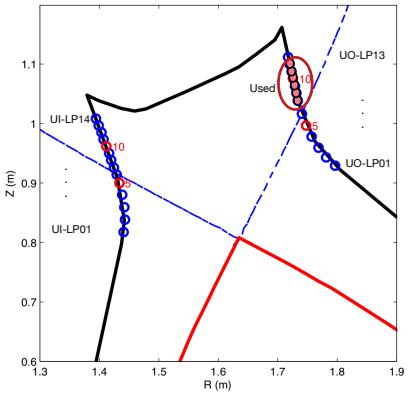
J. B. Liu, 23rd PSI Conf., 2018 US

- The H-mode detachment has n_e threshold ($4.5 \times 10^{19} m^{-3}$, $n_e/n_G \sim 0.65$, Ip=0.45MA)

First implementation of detachment control

➢ Diagnostic： Langmuir probes





➢ Data processing

$$Js(filtered) = filter\left(Js(raw)\right)$$

$$Js_{max} = max(Js1, Js2, Js3, Js4 \ldots)$$

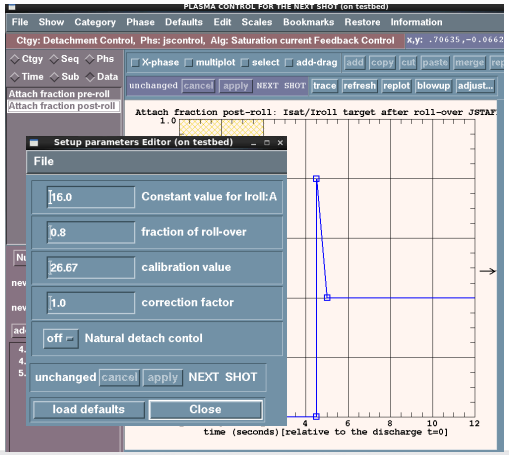
$$A_{frac}(t) = \frac{Js_{max}(t)}{Js_{roll}}$$

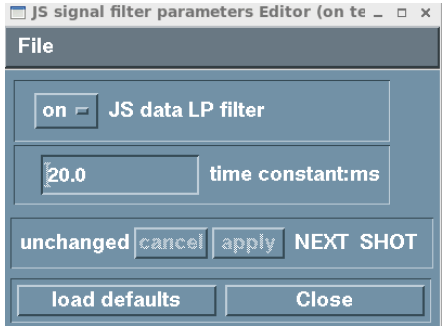
➢ Gas puffing system

- Piezoelectric (PE) valves in divertor region
- Supersonic Molecular Beam Injection (SMBI) in LFS mid-plane

➢ Working impurity gas: neon

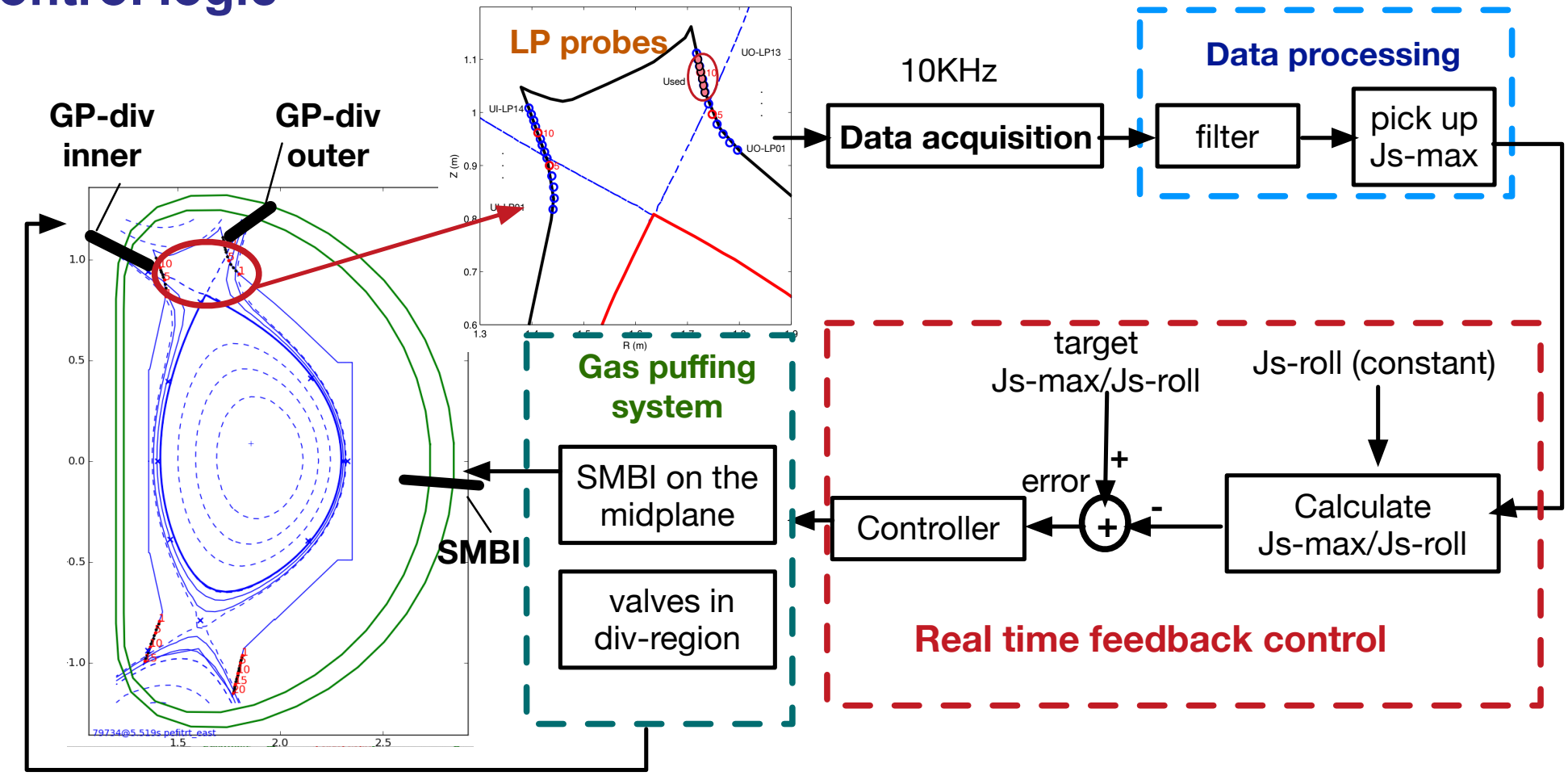
➢ GUI set in PCS



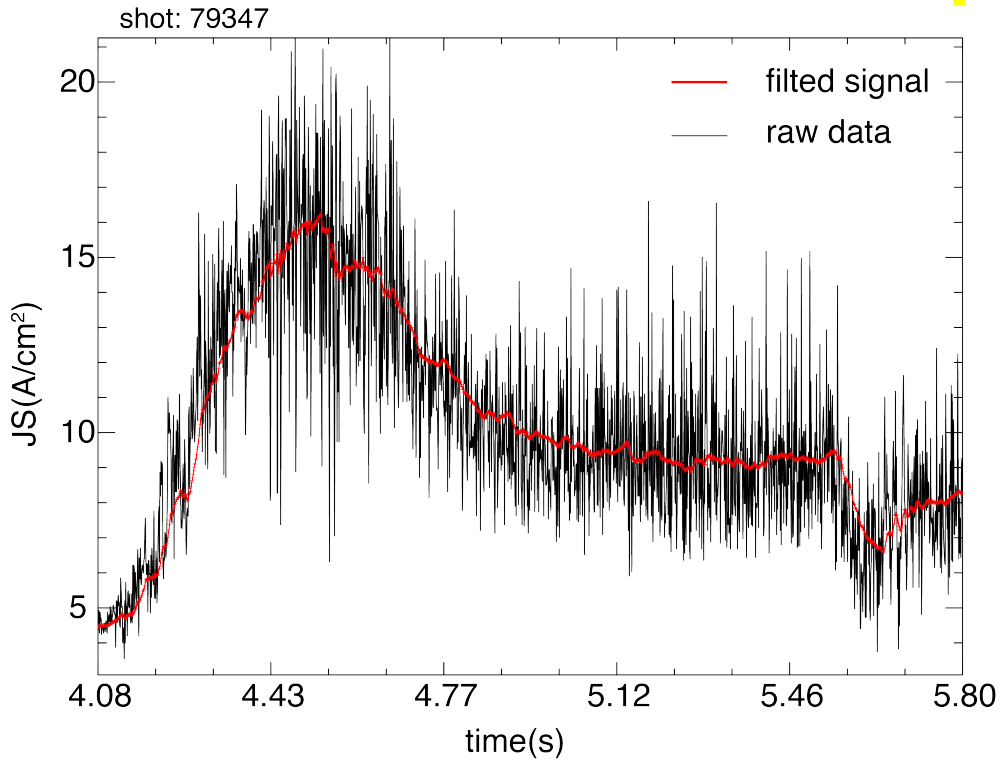


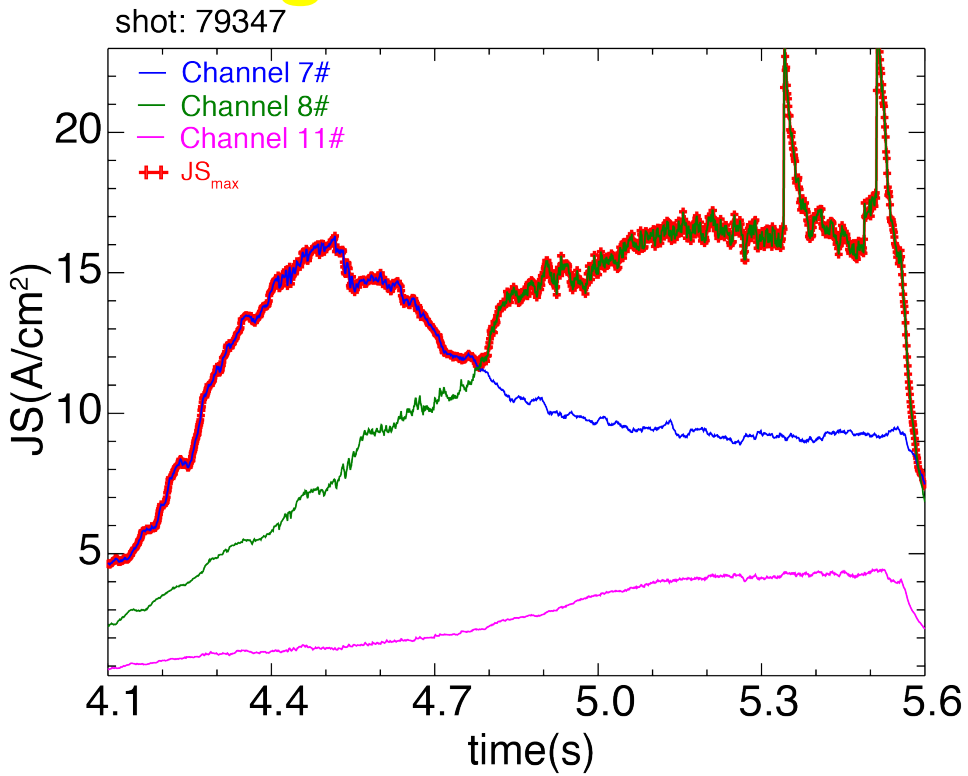
First implementation of detachment control

➢ Control logic



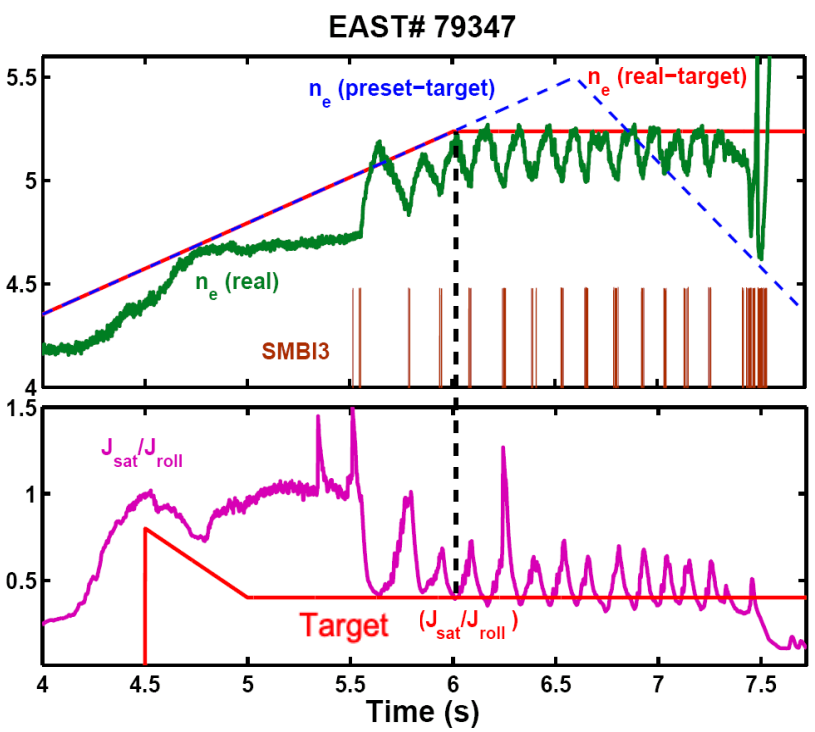
Achievement of H-mode detachment feedback control – data processing

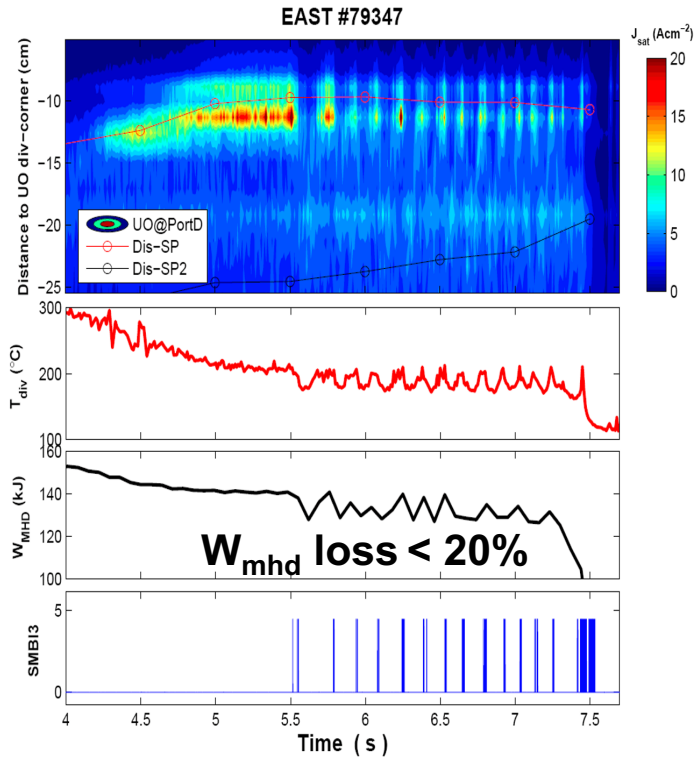




- 6 channels are connected to PCS, UO-LP07 ~ UO-LP12
- Raw data are filtered by a low-pass filter with time constant 20ms
- Js_{max} is the max value of the six filtered LP data

Achievement of H-mode detachment feedback control with SMBI3-D2



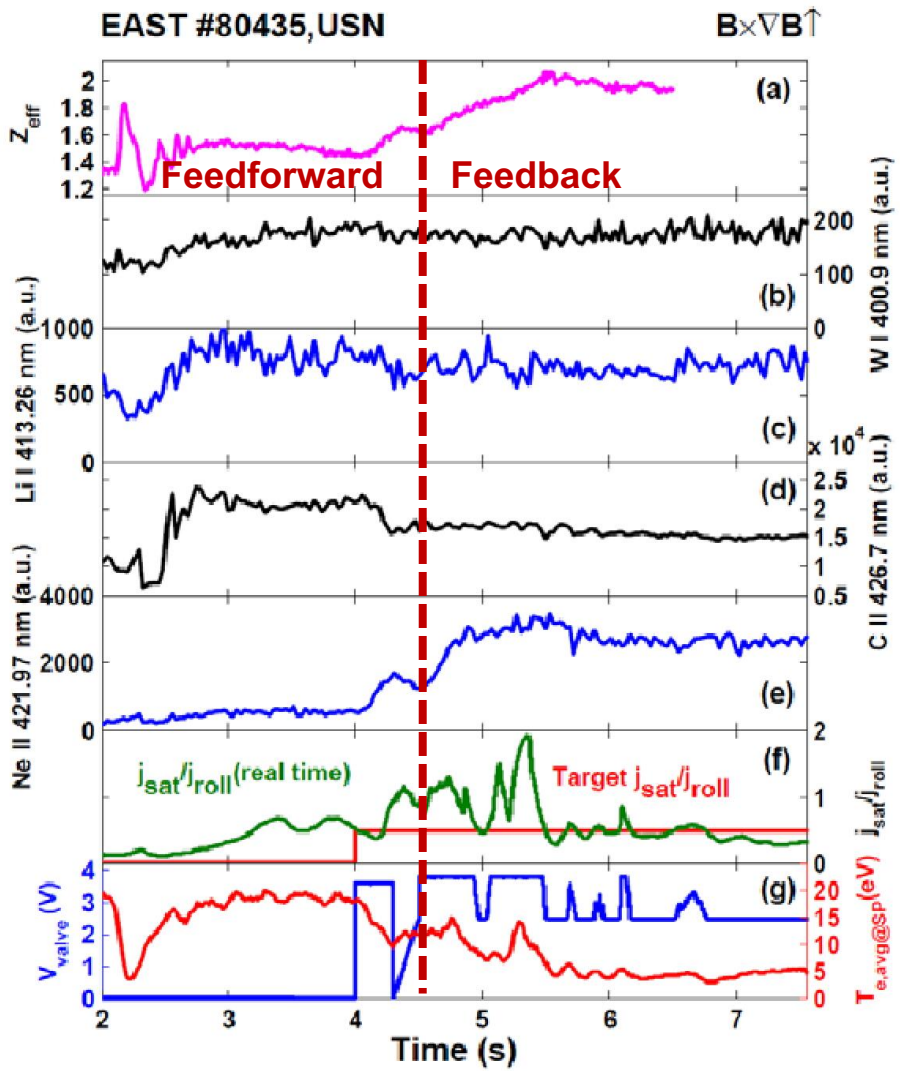


I. Raise the density to threshold for detachment

II. When Js/Jroll is lower than the target, set the density target as a constant with the threshold value

III. Feedback control the new density target using SMBI D_2 fueling

Achievement of H-mode detach. feedback control with divertor neon seeding



- **Before feedback, command is from the feedforward waveform set in the GUI**

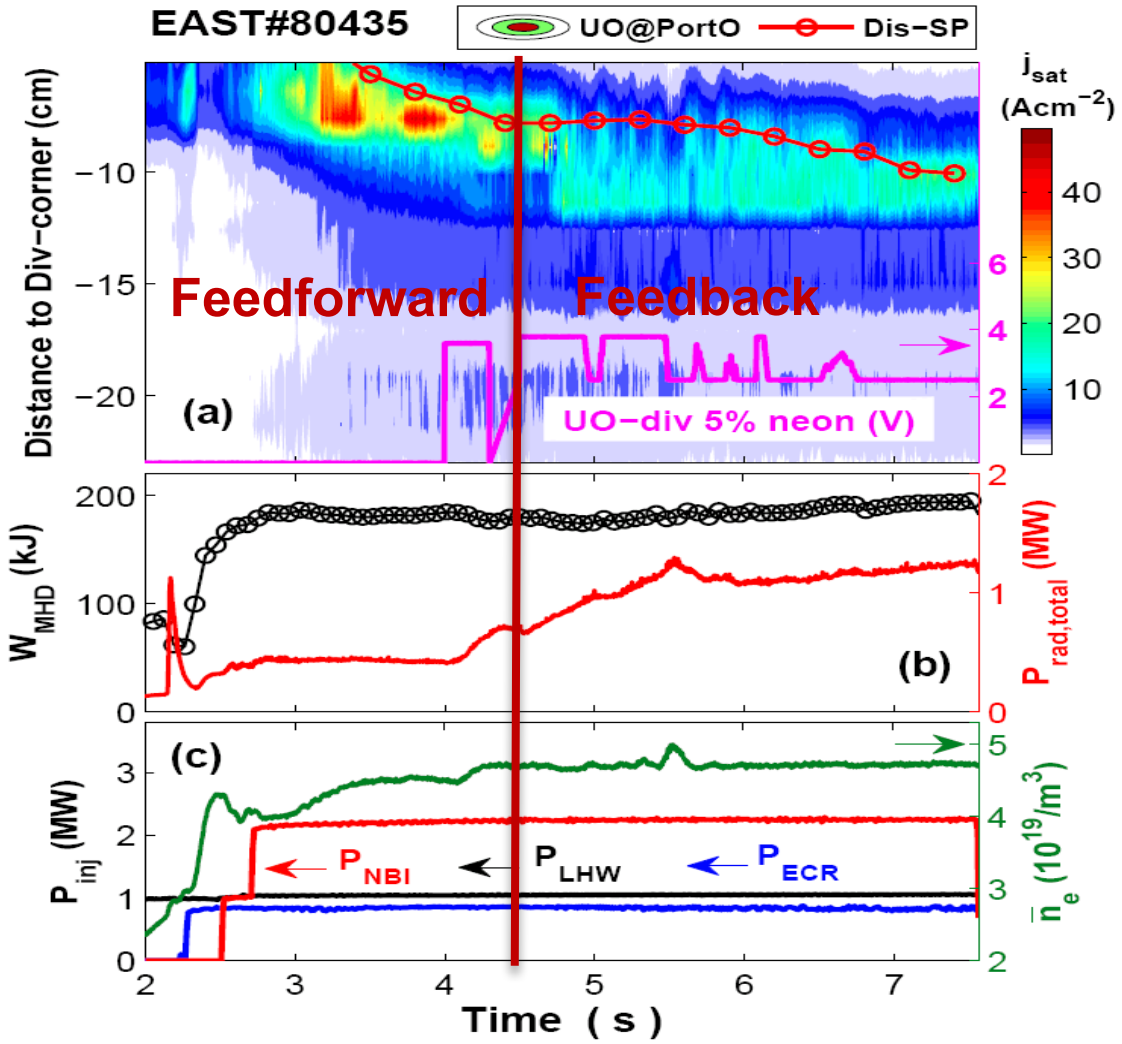
  Voupev2=V_{ff}

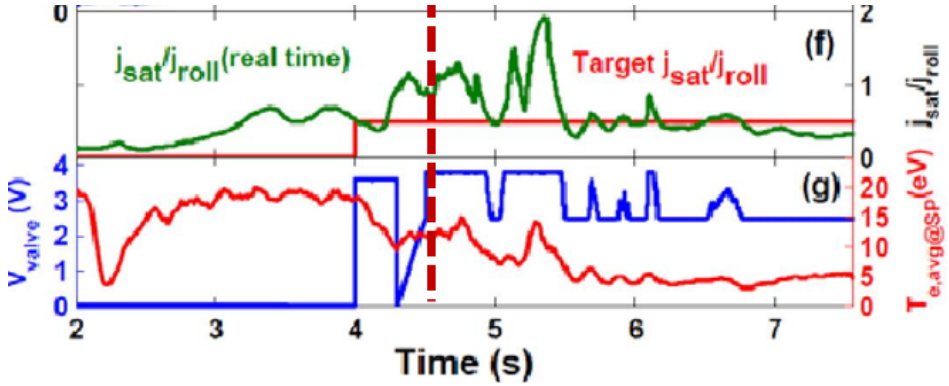
- **After feedback in on,**

  Voupev2=V_{ff} + V_{fb}

  - V_{ff} is set to the critical voltage of valve opening
  - V_{fb} is the output of PID controller

Achievement of H-mode detach. feedback control with divertor neon seeding





- The particle flux reduced
- The plasma stored energy slightly increases rather than decreases
- The plasma line-averaged density was maintained quite stably

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Summary

- EAST achieves heat load reduction by advanced divertor configuration (QSF), radiation power control, and radiative divertor induced detachment control.
- Active feedback control of H-mode detachment with D_2 fueling or divertor impurity seeding has been achieved successfully, with excellent compatibility with the core plasma performance.
- With the upgradation of divertor gas puffing and bottom divertor structure, the active detachment control will be optimized and applied in long pulse H-mode operation.

Thank you for your attention