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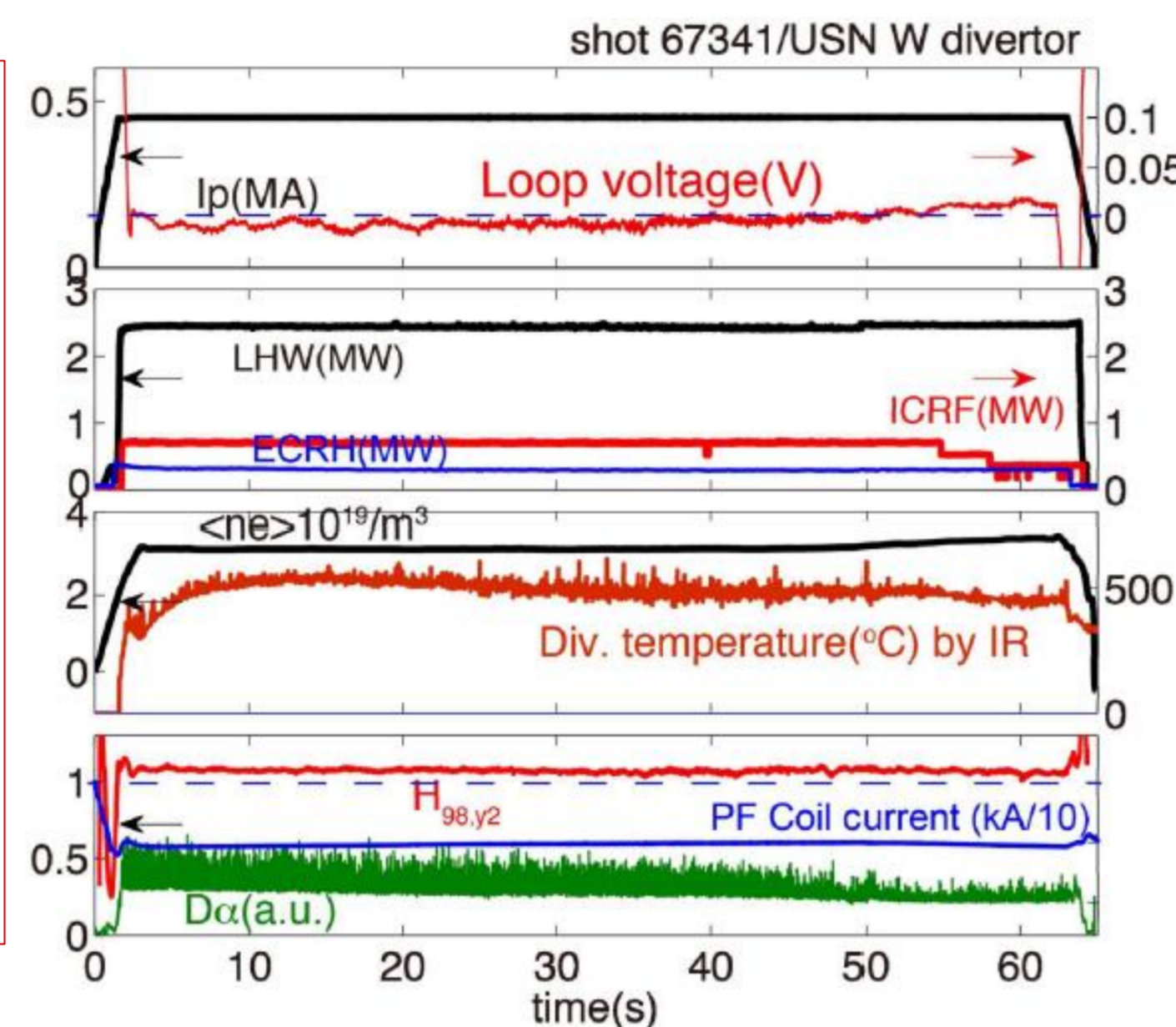


LHCD results in EAST for long pulse optimisation

Long pulse, steady state operation ($V_{Loop} = 0$) requires efficient non-inductive current drive system, e.g. Lower Hybrid Current Drive (LHCD).

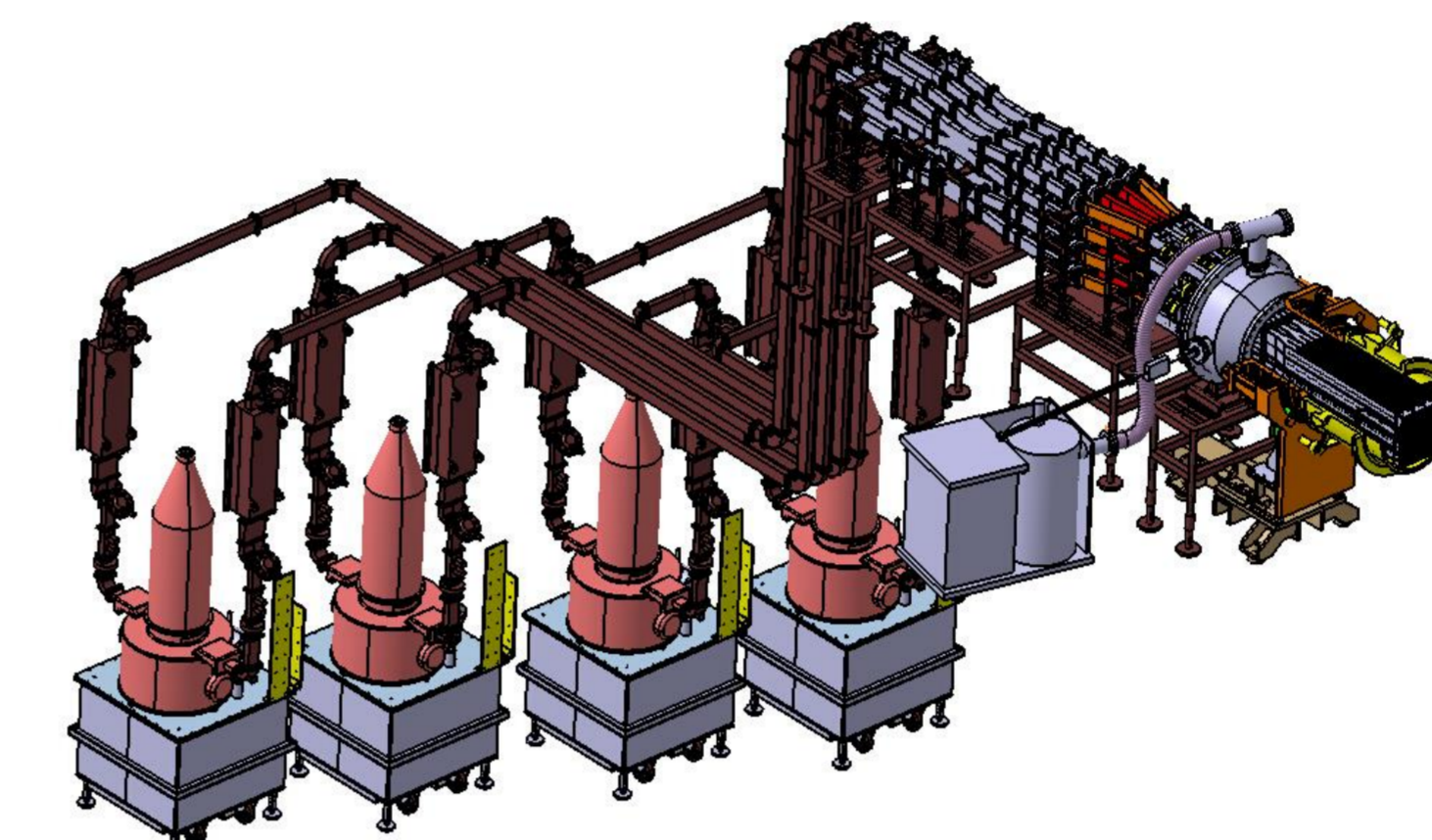
Efficient LH current drive: Optimisation of LH coupling conditions needed.

- The LHCD systems in EAST (4.6 GHz and 2.45 GHz) [1] are crucial for long pulse, steady state operation.
- 100 s long H-mode achieved ([2] X Z Gong et al., this conference, paper EX/3-1).
- Joint experiments on LH coupling and LH current drive carried out in view of optimisation for long pulse operation.
- Experiments supported with modelling with EU codes: ALOHA [3], C3PO/LUKE [4], LH^{star} [5].



LHCD results with the PAM in HL-2A

- Collaboration CEA/IRFM-SWIP on LHCD since 2013.
- Passive Active Multijunction (PAM) launcher [7] designed by SWIP, assisted by IRFM.
- Four klystrons (3.7 GHz) installed and commissioned as part of the collaboration.
- Fast Electron Bremsstrahlung camera, on loan from IRFM, installed on HL-2A.
- Joint experiments on LH current drive, LH coupling in H-mode, ELM-control [8].



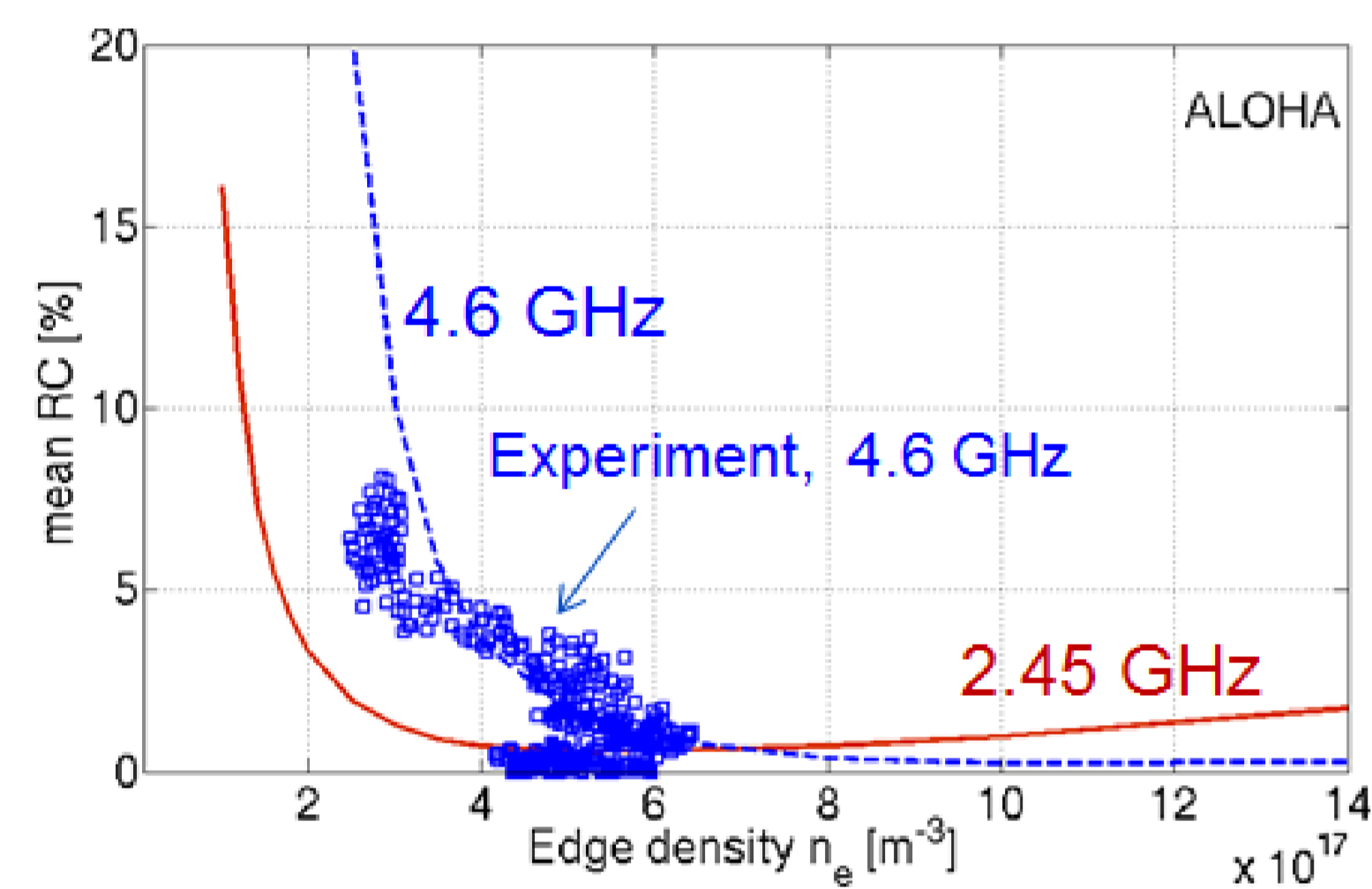
Passive-Active Multijunction (PAM)



Local gas injection valves at three poloidal locations

Langmuir probes for T_e and n_e at two radial locations

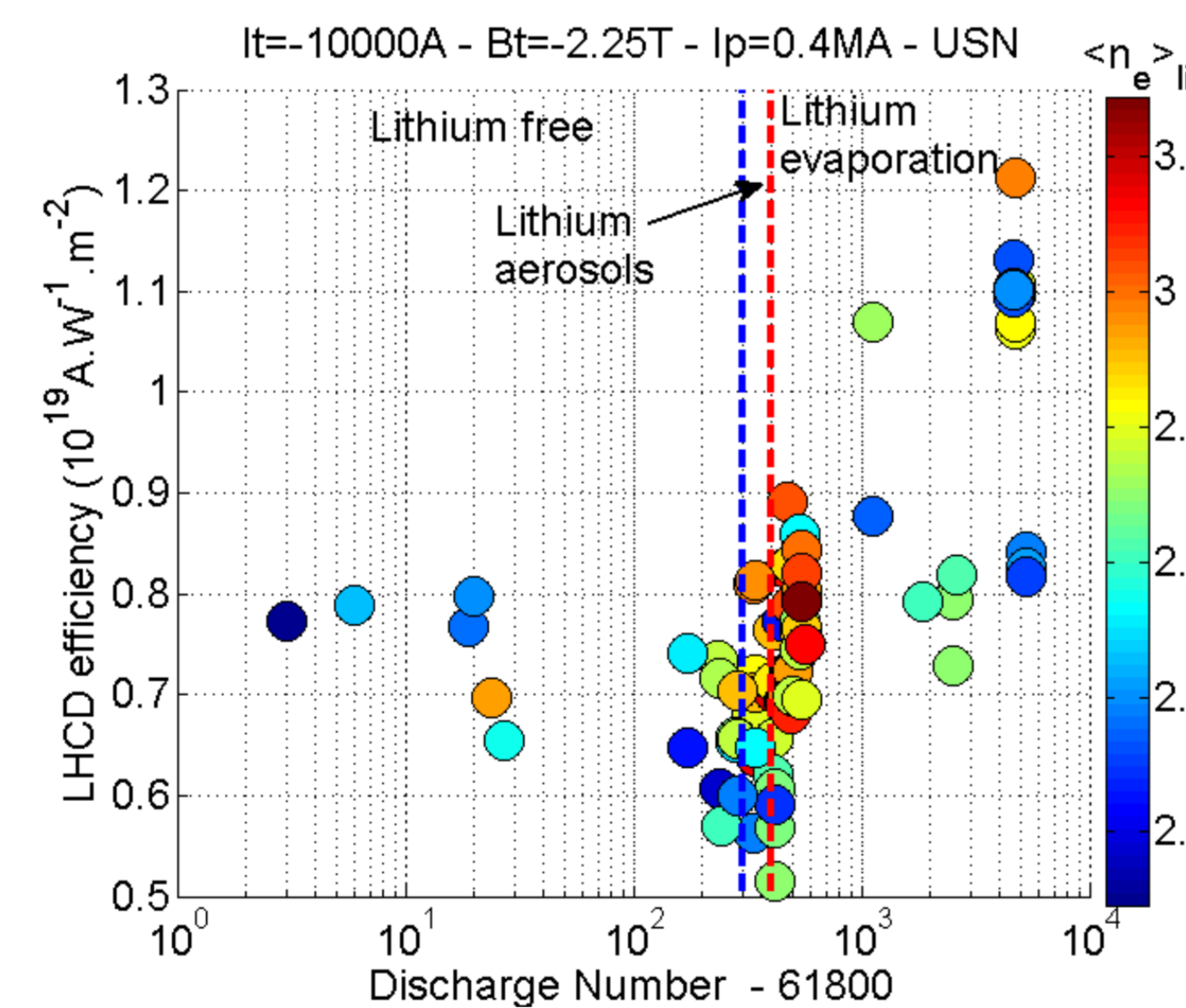
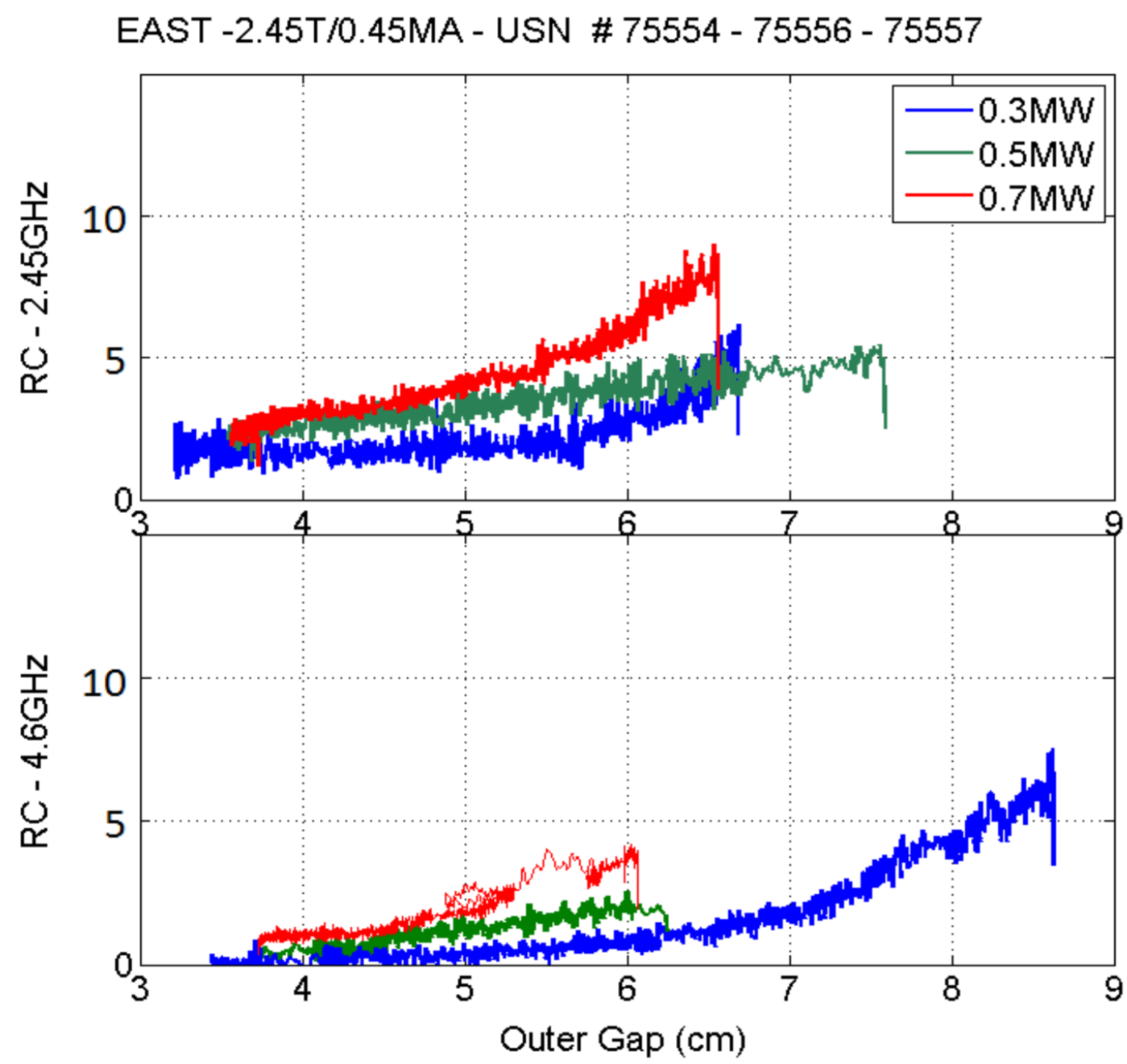
LH coupling and CD efficiency experiments



- Two different LHCD systems: LH coupling needs to be optimised for both simultaneously, i.e. low reflection coefficients (RC) needed.

- Non-linear effects can be observed (ponderomotive force). Can decrease LH current drive efficiency at high LHCD power [6]. Control of edge conditions important.

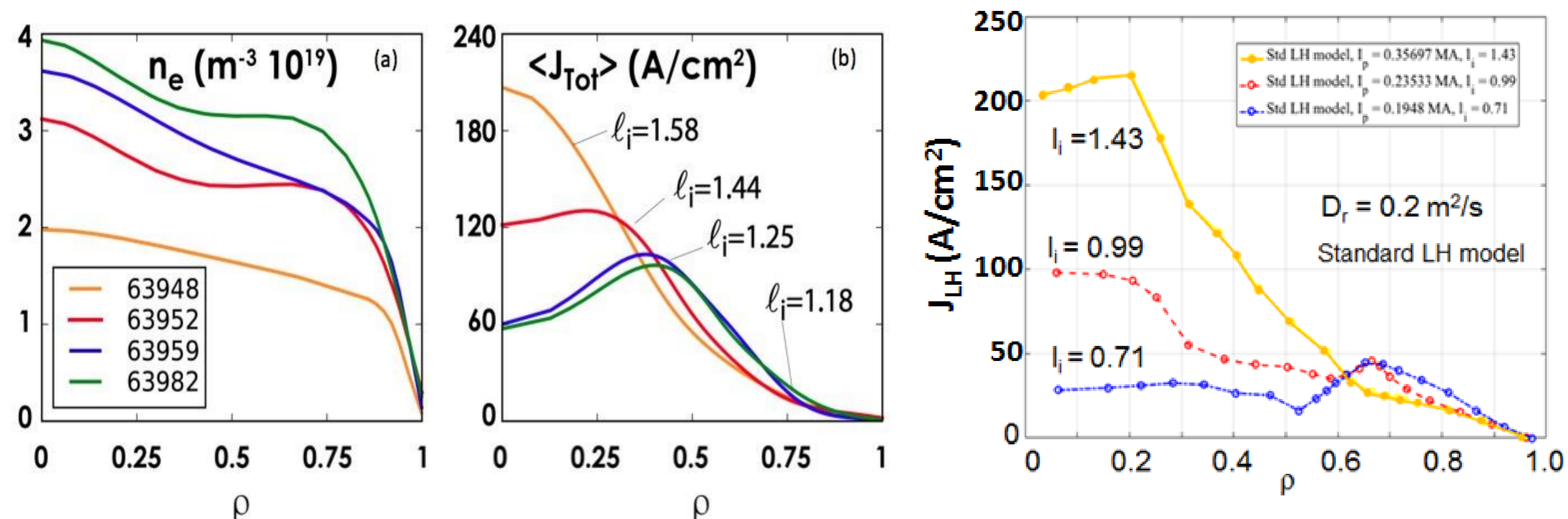
- Study of the CD efficiency shows effect of Lithium coating. Highest CD efficiency obtained after several Lithium evaporations [6]. Higher CD efficiency probably due to higher T_e lower and/or lower Z_{eff} .



LHCD modelling for EAST full current drive discharges

- Several EAST discharges close to $V_{loop} = 0$ V have been modelled with C3PO/LUKE [4]. The ALOHA code [3] is used to provide the LH power spectra launched by the antennas.

The current profile and tendency in I_i -variation can be well reproduced

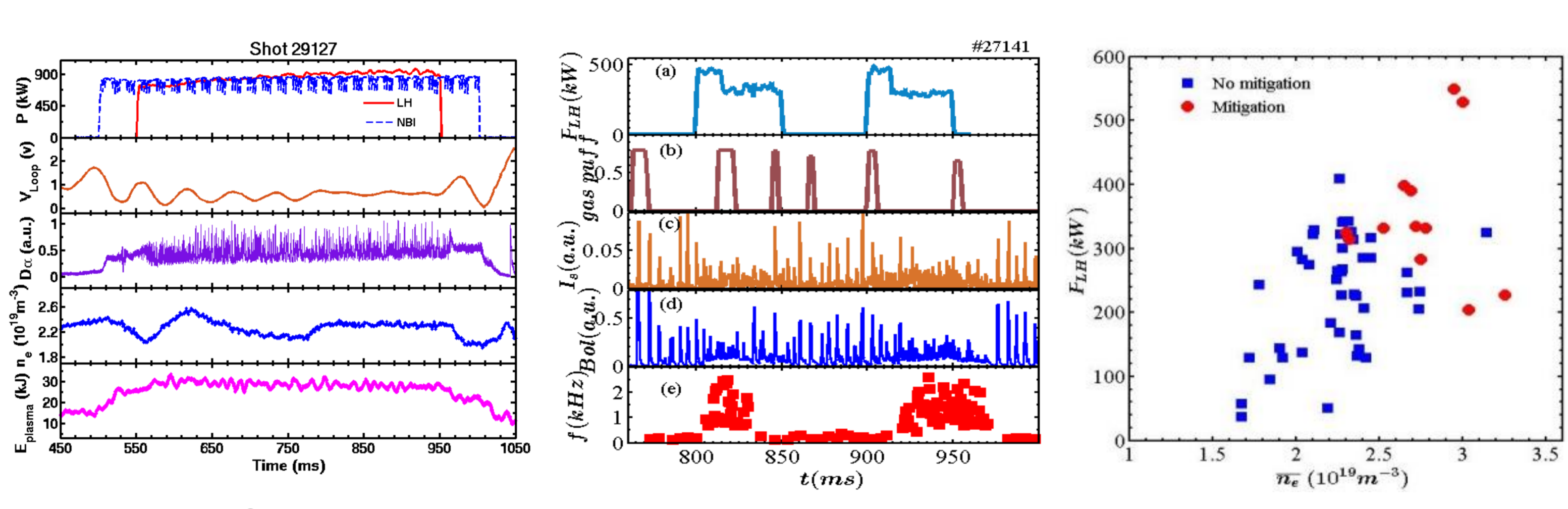


References

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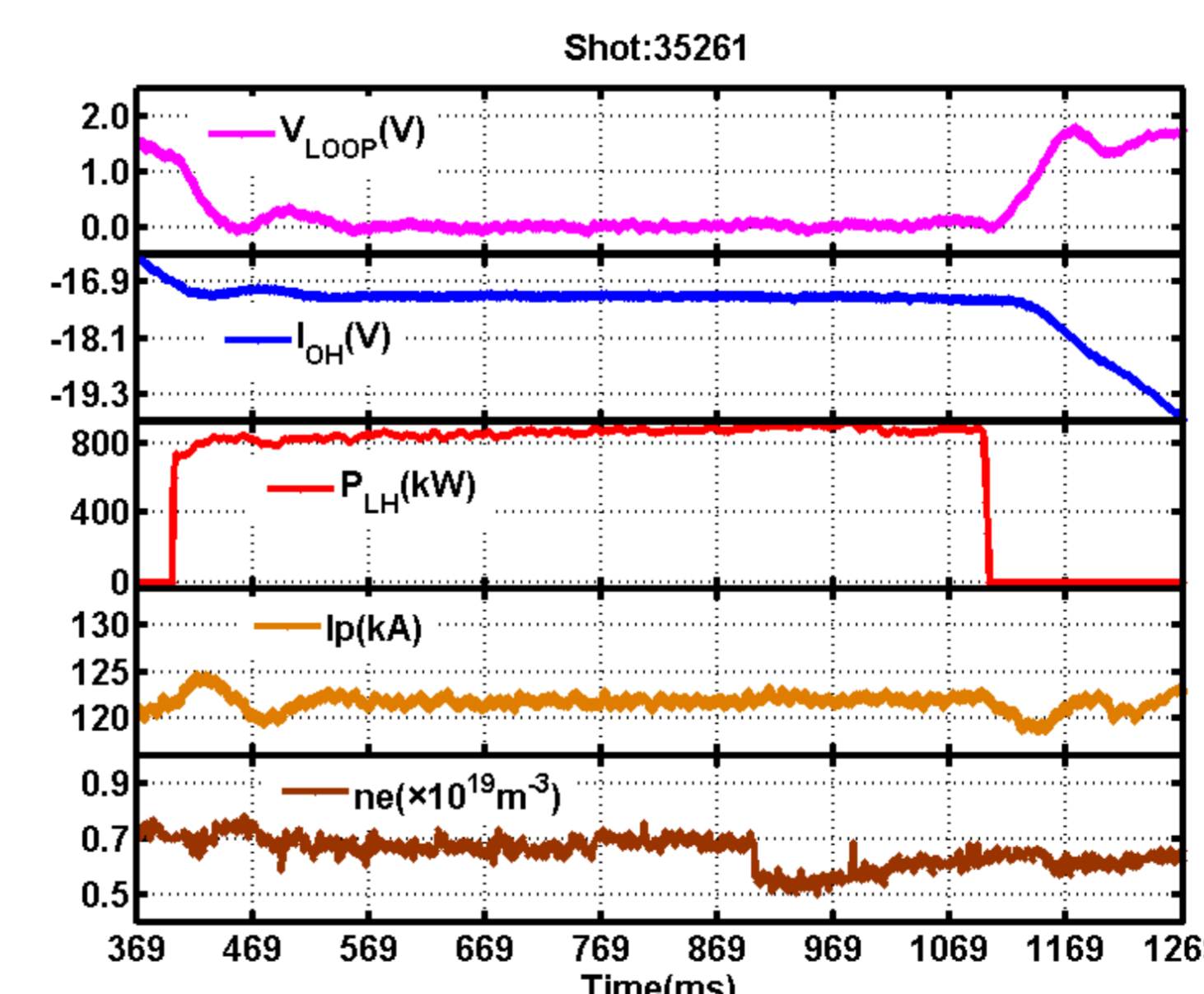
[5] R Cesario et al., Phys. Rev. Lett. **92** (2004) 175002
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LH coupling on ELMs and ELM control on HL-2A

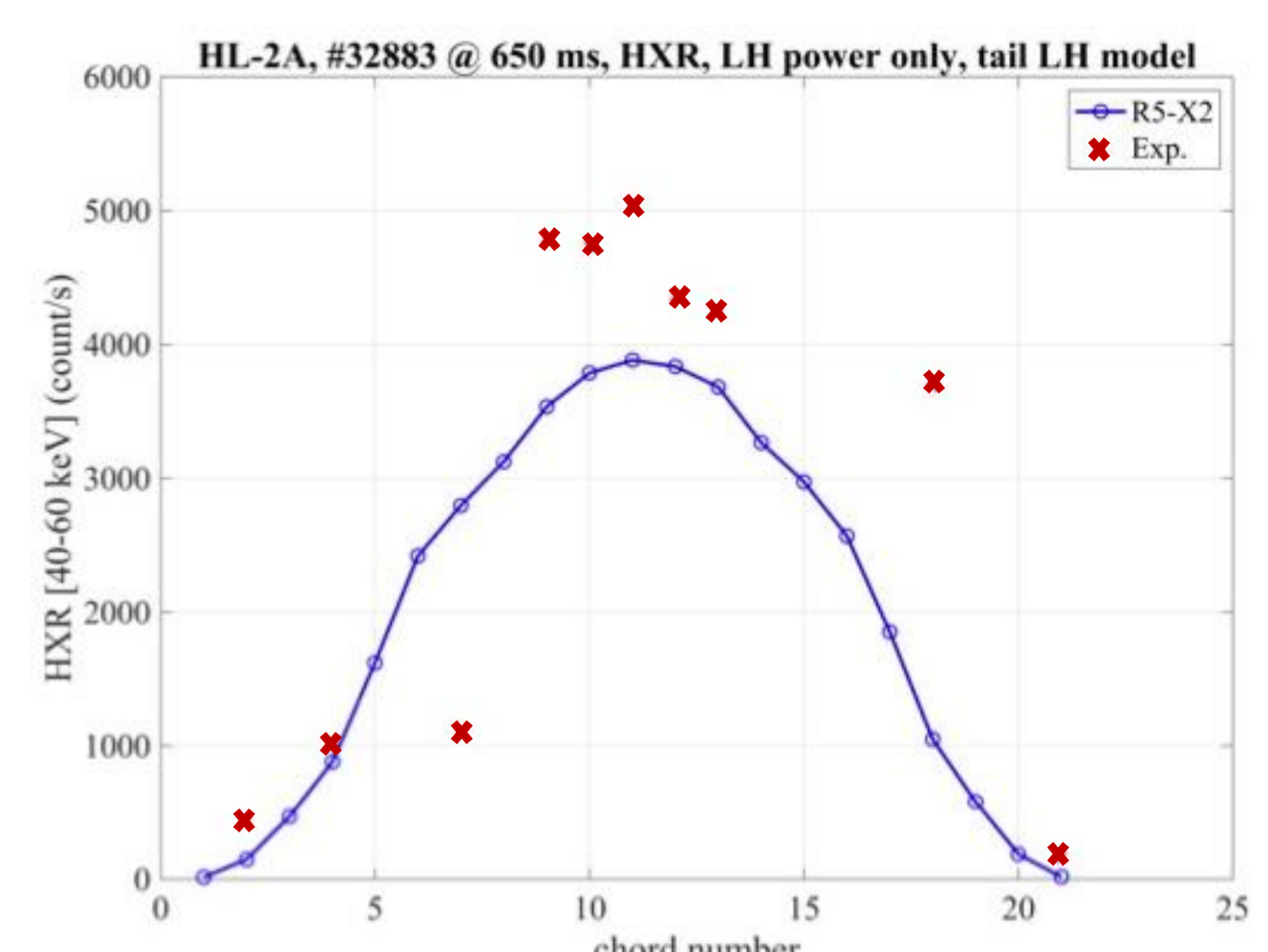


- 0.9 MW LHCD coupled in H-mode [7]. LHCD power helps trigger and sustain H-mode.
- ELM-frequency increases and ELM-amplitude decreases during LHCD.
- ELM-effect depends on LHCD power and plasma density.
- ELM-control effect is synchronized with an increase of the pedestal turbulence, measured by Doppler reflectometry.
- ELM control seems to be strongly correlated to pedestal turbulence enhancement. ([8] G L Xiao et al., this conference, paper EX/7-4).

Recent results: $V_{Loop} \sim 0$ achieved



Full current drive achieved with 1 MW LHCD ($I_p = 120$ kA, $B_T = 1.3$ T).



- Fast Electron Bremsstrahlung camera, on loan from CEA/IRFM, has been installed.
- Fairly peaked LH power deposition profile.

Summary and outlook

- Fruitful collaboration between EU and China over the last couple of years.
- 3.7 GHz LHCD system installed and used successfully in HL-2A: Coupling in H-mode & control of ELMs demonstrated.
- Joint experiments on LH coupling carried out in EAST and HL-2A: 100 s long H-mode achieved in EAST, sustained primarily by LHCD.
- Modelling of EAST and HL-2A results with EU codes: Experimental trends can be well reproduced.
- Future joint programme can integrate the preparation of HL-2M operation, in order to support ITER and CFETR.