Use of virtual actuators (VA) in ASDEX Upgrade control

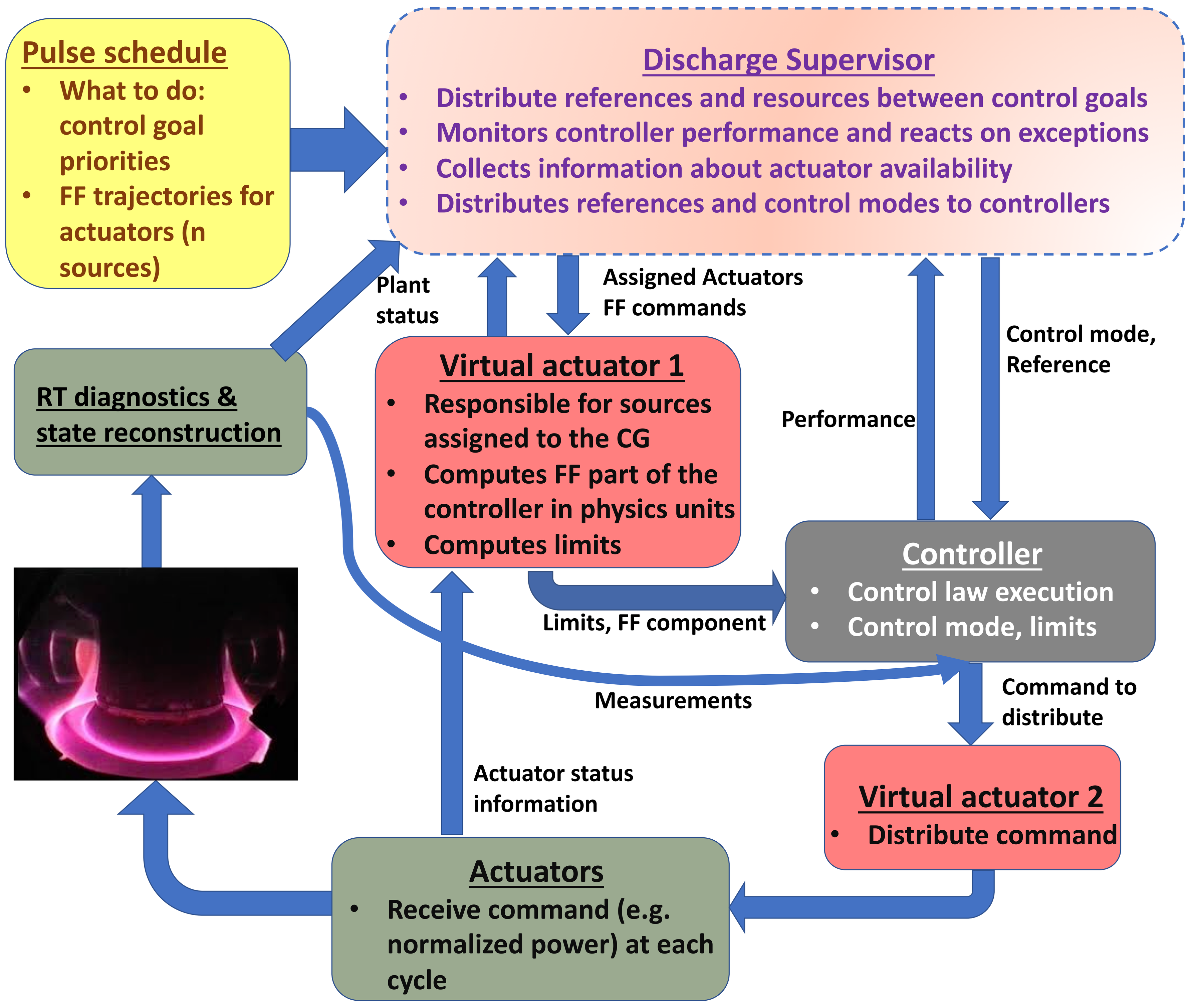
Max-Planck-Institut für Plasmaphysik

O. Kudlacek[1], W. Treutterer[1], F. Janky[1], B. Sieglin[1], F. Felici[2], I. Gomez-Ortiz[1], A. Gräter[1], T. Maceina[1], M. Maraschek[1], T. Zehetbauer[1], The ASDEX Upgrade Team[3], The MST1 Team[4]

[1] *Max Planck Institute of Plasma Physics, Garching, Germany*
[2] *Swiss Plasma Centre, EPFL, Lausanne, Switzerland*
[3] *see A. Kallenbach et al, Nuclear Fusion 57 2017 102015[2]*
[4] *see H. Meyer et al, Nuclear Fusion 57 2017 102015*

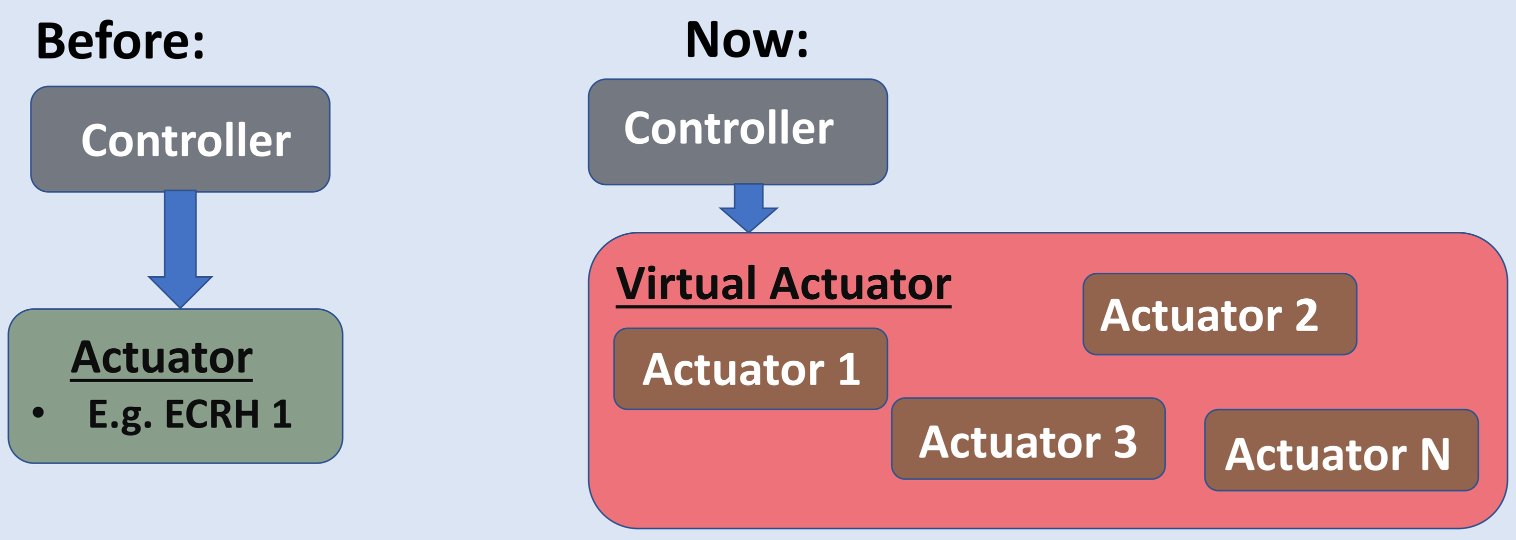
Email: ondrej.kudlacek@ipp.mpg.de

Envisioned Plasma Control Structure

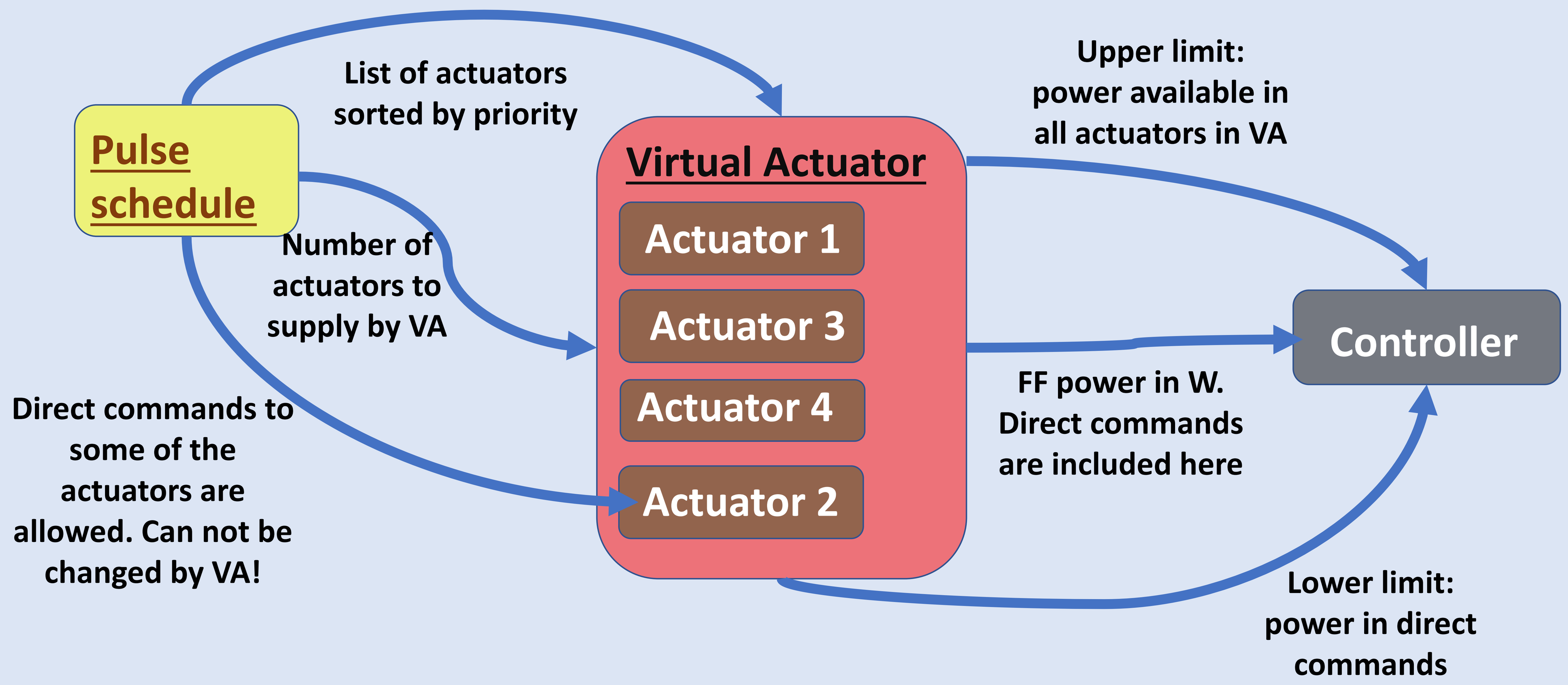


Virtual actuator

- An object containing real actuators, not necessarily of the same type
- Arbitrary number of actuators for one control goal: done for ECRH
- Actuators selected in Pulse Schedule and sorted by priority



- Virtual actuator computes FF component for the controller
- Supplies also upper and lower limit to the controller

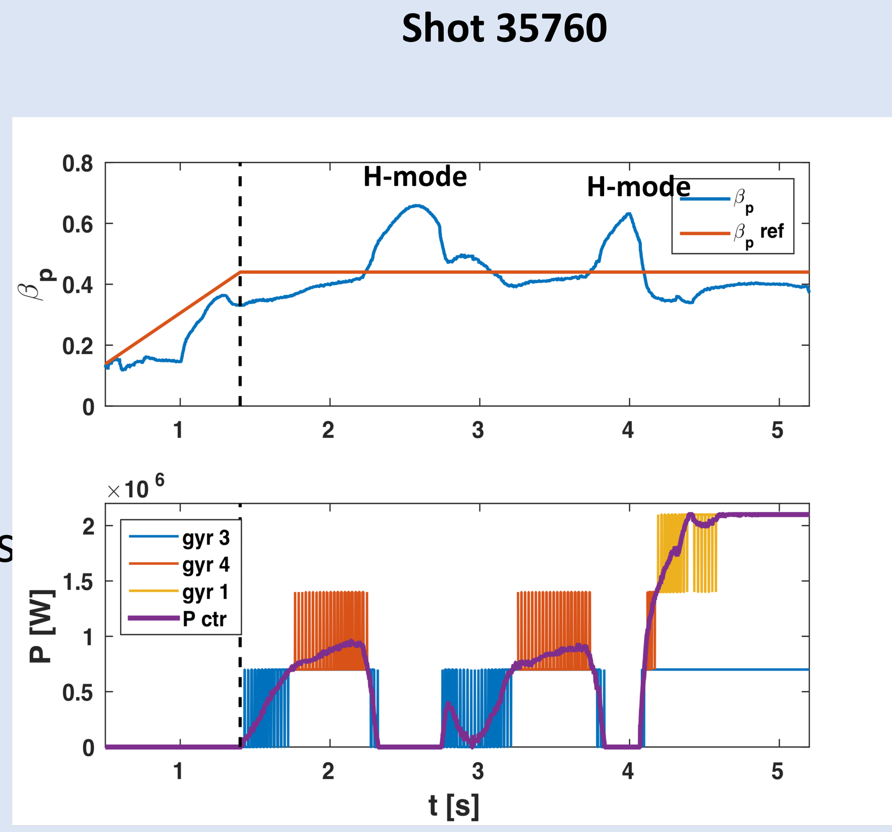


- Virtual actuator distributes power to actuators with highest priority

Experimental use cases

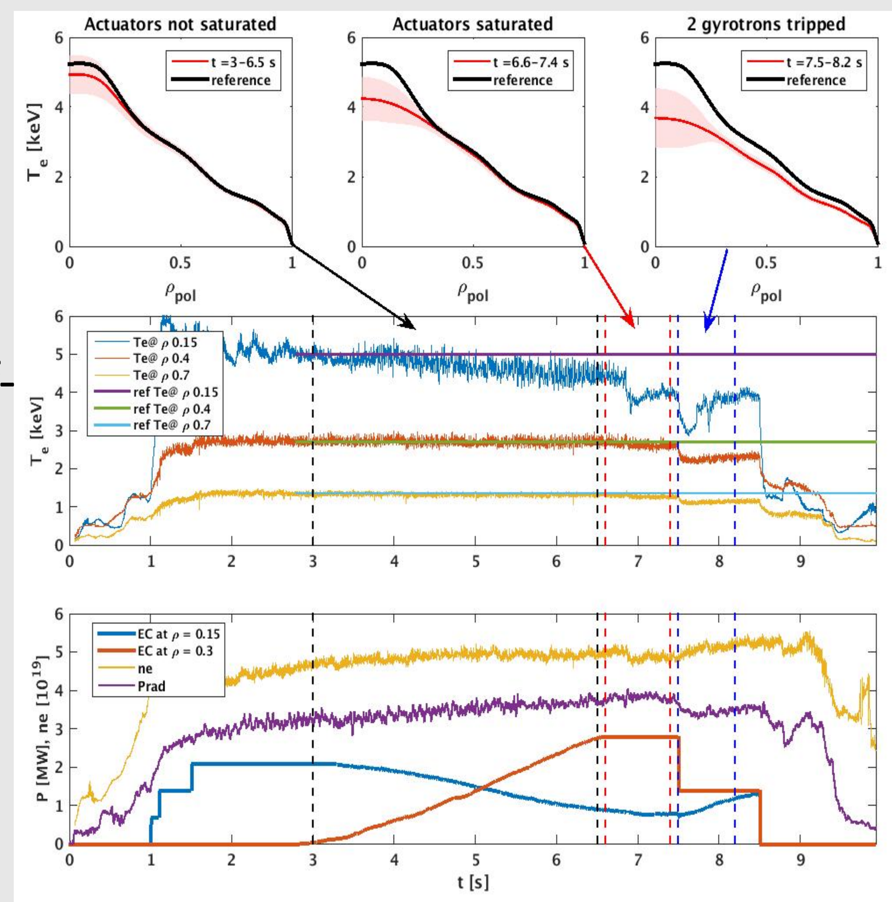
1. β_p control in I-mode discharges

- I mode requirement: β_p in narrow range => FB control
- 3 gyrotrons used for control: gyr 3,4, and 1
- 2 gyrotrons on, but not under VA
- Power distributed to the gyrotrons with the highest priority
- Controller keeps β_p mostly around desired value and helps to keep I-mode



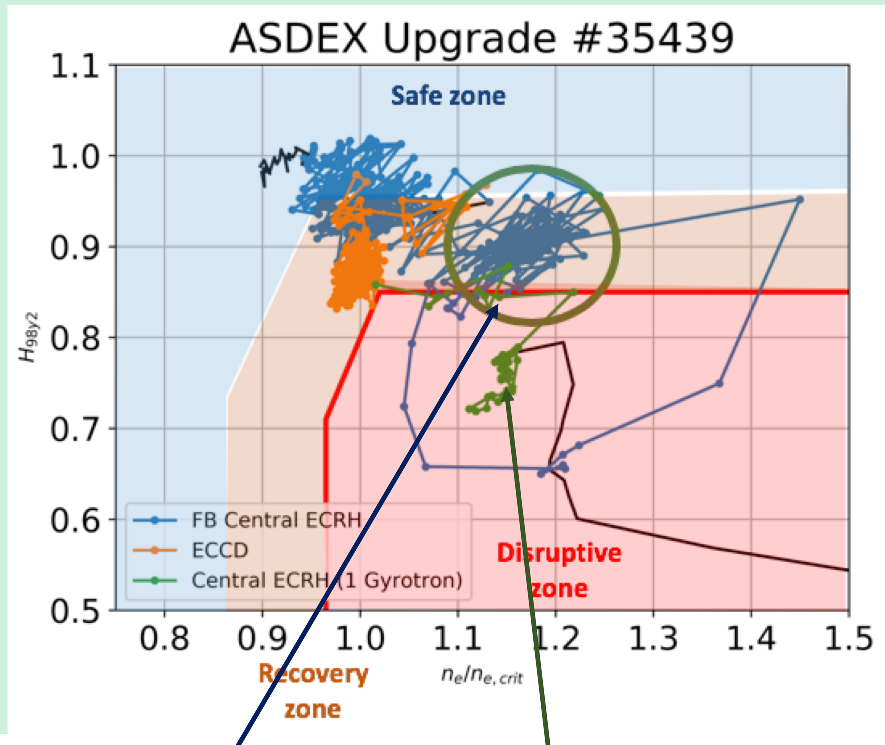
2. T_e profile control

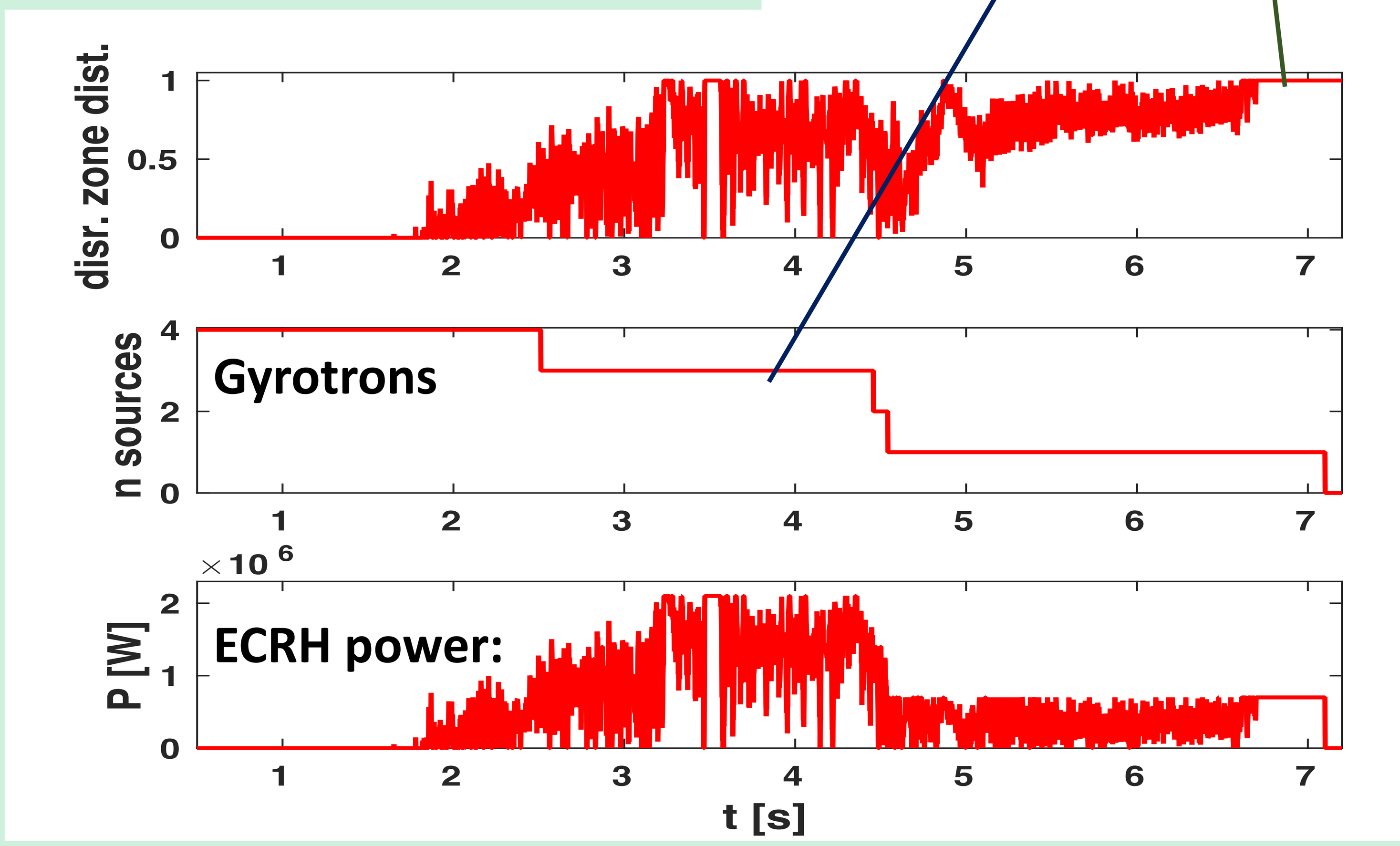
- Goal: keep T_e profile constant while swapping NBI/changing density
- Measurement: RAPTOR T_e profile
- 2 virtual actuators: on-axis and off-axis
- Each of the VA has 4 gyrotrons pointing to the same location
- 1 gyrotron in the center always on to avoid impurity accumulation
- T_e profile (almost) matching reference when density increases



3. Density limit disruption avoidance [see B. Sieglin, this conference]

- Goal: keep discharge away from disruptive zone in the parameter space of critical density fraction and H98 by ECRH central power
- Replacement of tripped gyrotrons





Conclusion & Outlook

- **Virtual actuator proved to be a useful concept for several applications**
- **The following steps will be taken for further development:**
    - **Dynamical allocation of gyrotrons to VA will be implemented**
    - **More virtual actuators will be introduced to allow additional replacement strategies**
- **Extension of the VA concept to additional heating and CD sources: NBI and ICRH**

Acknowledgement

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission