Analysis of the ramp-down phase using the Fenix flight simulator

R. Coosemans[1], E. Fable[2], C. Contré[1], P. David[2], F. Felici[1], S. Medvedev[3], A. Merle[1], T. Pütterich[2], O. Sauter[1], S. Van Mulders[1], C. Wu[4], the ASDEX Upgrade Team[1]

[1] *Ecole Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015 Lausanne, Switzerland*
[2] *Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany*
[3] *Tokamak Energy Ltd, Culham Science Centre, Abingdon, OX14 3DB, United Kingdom*
[4] *Karlsruher Institut für Technologie, 76344 Eggenstein-Leopoldshafen, Germany*

Abstract

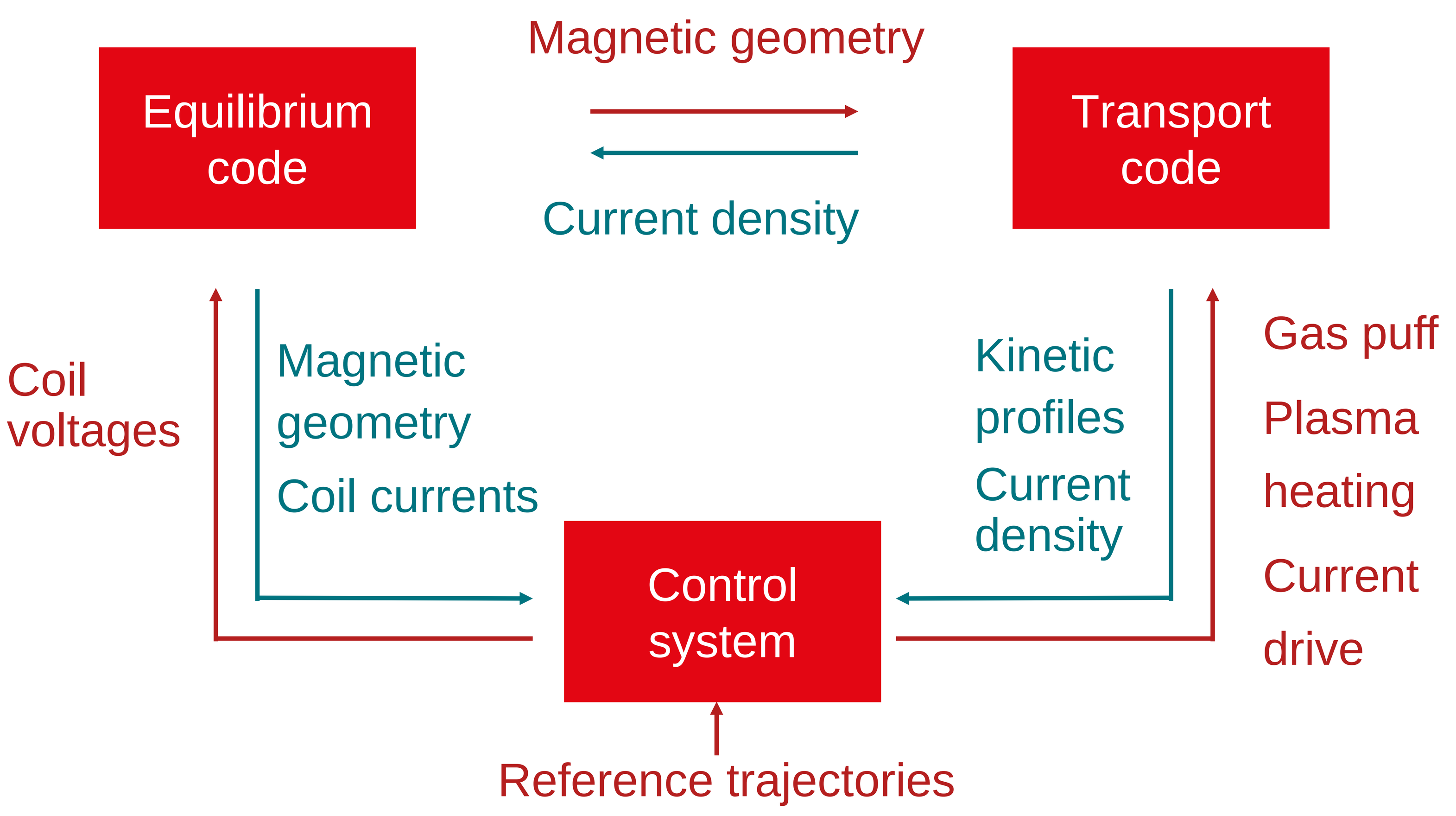
- Accurate design of plasma scenarios required for success of future reactors
- Tokamak flight simulators integrate physics and control for testing and discharge preparation

⇒ Fast, relatively accurate simulations of the complete discharge

- Ramp-down phase is important for future reactors because of high energy content needing to be removed safely
- Highly transient phase, challenging test for flight simulators

⇒ Apply Fenix flight simulator [2] to AUG IBL ramp-downs [3]

Fenix Flight simulator

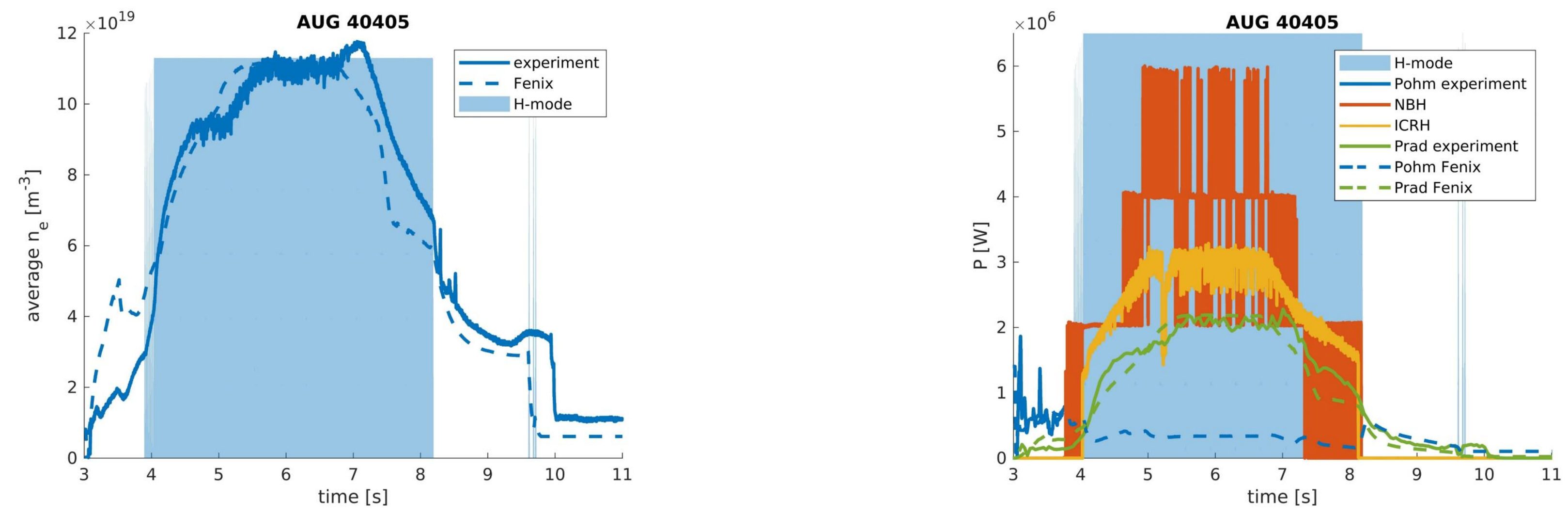


Fenix model

			Generic?
transport		ASTRA code [4]	
	NBI	Rabbit code [5]	✓
	ECRH	Torbeam code [6]	✓
	ICRH	Gaussian distribution	✓
	radiation	Bremsstrahlung + synchrotron + impurities	✓
	Current transport	Neoclassical conductivity + bootstrap + sawthooth	✓
	Heat transport	Gyrobohm with empirical constant in core	✗
		Pedestal scaling [7] with empirical constant in H-mode edge	✗
		Fixed edge diffusivity in L-mode	✗
	Particle transport	Continuity equations for D,He,B,W,N,Ne,H,Kr,Ar	✓
		Semi-empirical diffusion and convection coefficients	✗
	SOL-divertor-wall	Multi-zone model for particle content	✗
		Two-point model for temperature at separatrix [10]	✓
equilibrium		SPIDER free boundary [8]	✓
controller		PCSSP-Simulink [9] emulating AUG controller	✗

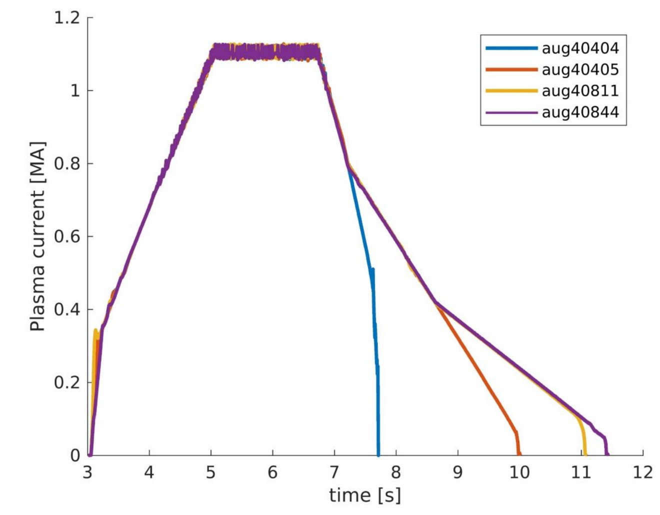
ASDEX ramp-down cases

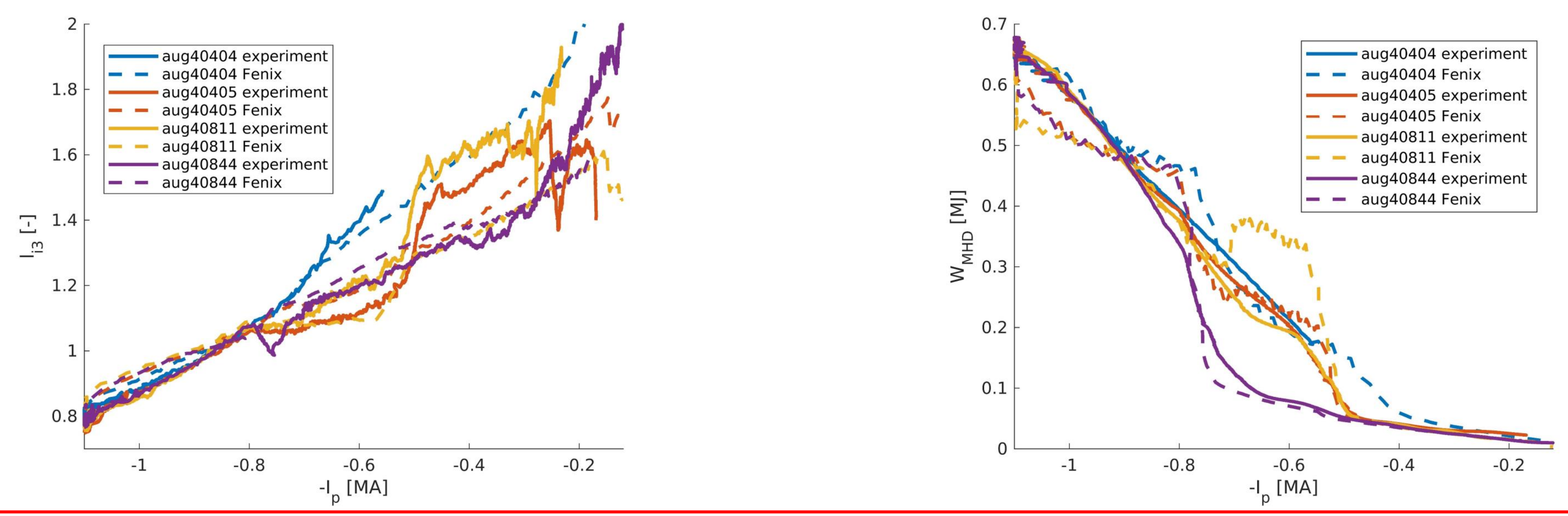
Simulate ASDEX-Upgrade ITER baseline scenarios with variable current ramp down rates [3]



Fast current ramp-rate → edge current decreases faster than current transport can redistribute → current profile becomes steeper → internal inductance l_{i3} increases

⇒ good qualitative match of l_{i3} for varying ramp rates



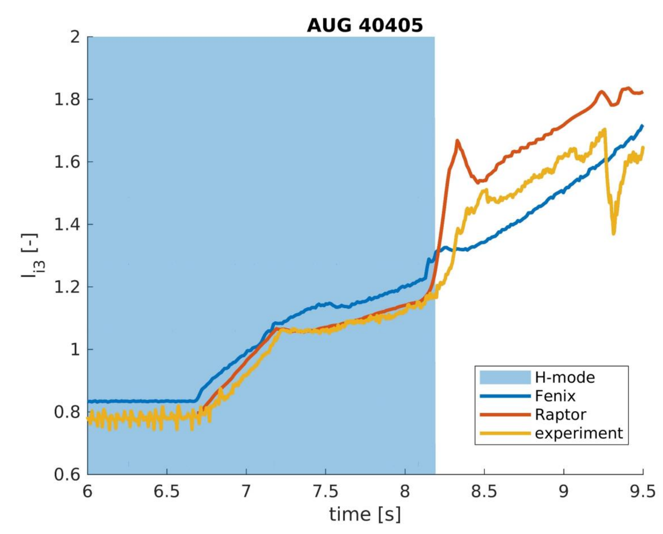


Zoom on H-L transition

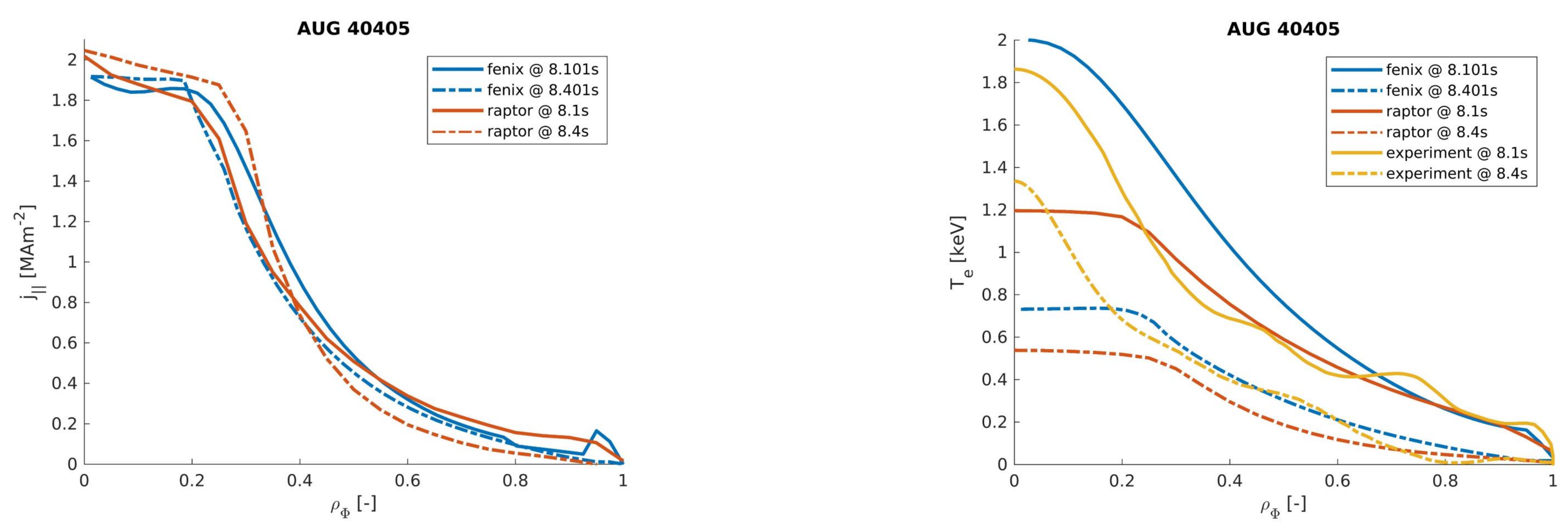
H-L transition → sudden decrease of J_{BS} and T_e in edge → more j_{OH} required and fast current decay in edge → jump in l_{i3}

⇒ H-L transition not abrupt enough to capture this in Fenix

⇒ RAPTOR simulations were able to reproduce this [11]



Remark: auxiliary heating in L-mode avoids l_{i3} jump in AUG 40844



Conclusions

- Fenix manages to capture the salient features of AUG IBL ramp-down discharges ⇒ testifies of Fenix robustness
  - Some parameter tuning was needed though
  - Some details remain elusive, e.g. improved L-mode transport model required for T_e flattening in the edge (see also [11])
- Application to TCV should allow to further validate Fenix and pinpoint deficiencies and models that need to be generalised

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This work was supported in part by the Swiss National Science Foundation.

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This work has been carried out within the framework of the EUROfusion Consortium, partially funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). The Swiss contribution to this work has been funded by the Swiss State Secretariat for Education, Research and Innovation (SERI). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, the European Commission or SERI. Neither the European Union nor SERI can be held responsible for them.