

Modelling of the STEP ramp-down phase with JETTO

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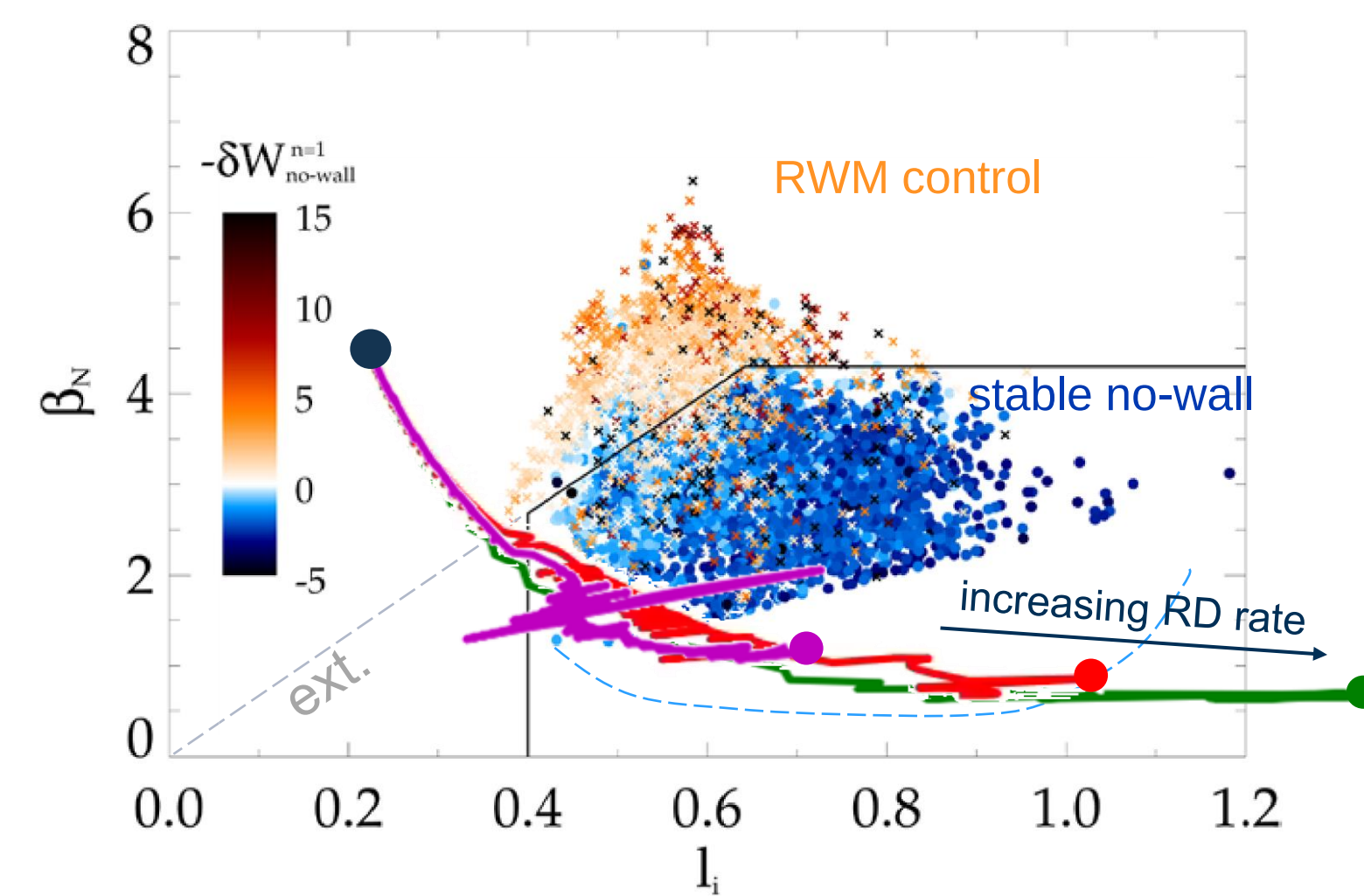
Motivation

Preliminary scoping of STEP plasma current ramp down pathways

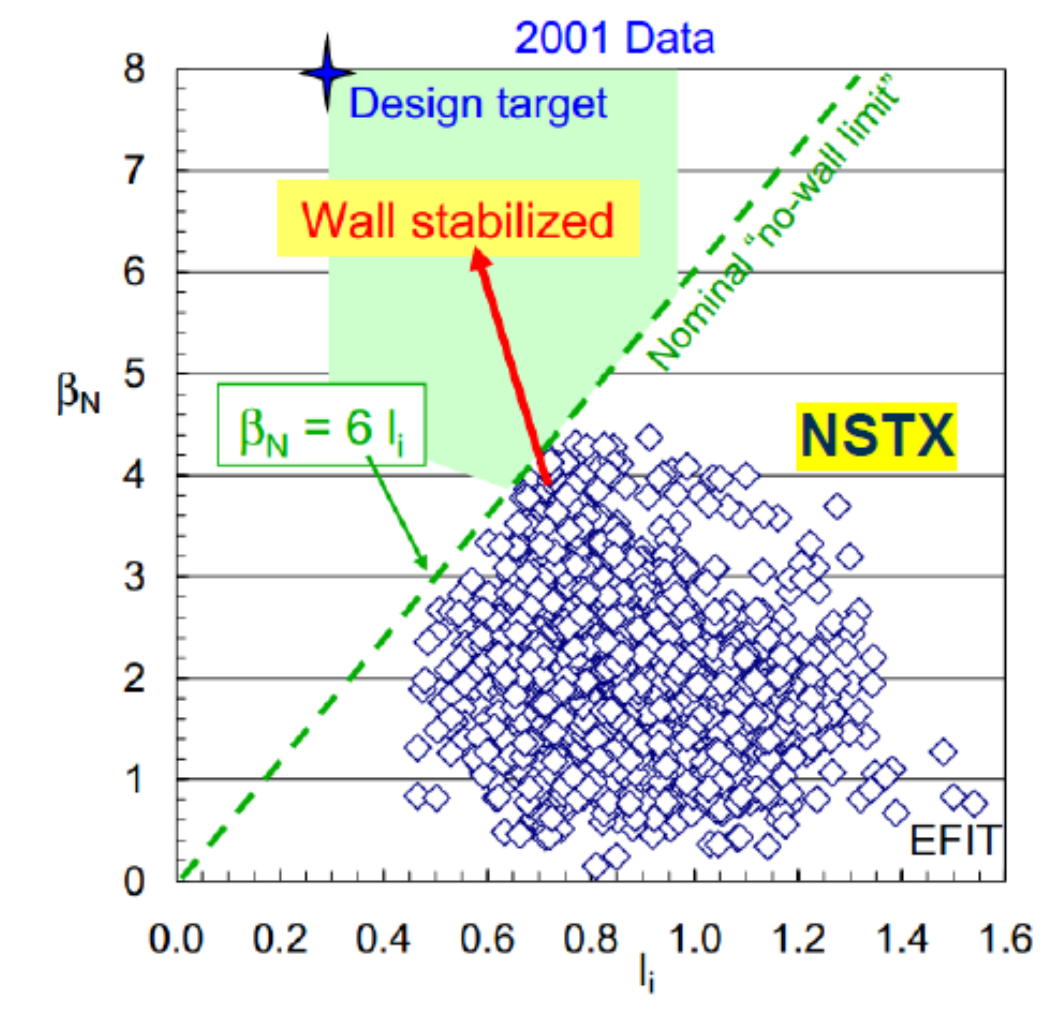
- List the constraints and modelling limitations for the ramp-down scenario
- Simulate current diffusion and fusion power decay during auxiliary current drive ramp-down. Identify a fuelling and heating pathway which remains MHD stable with vertical control
- Investigate additional ramp-down pathways needed in case early termination is triggered

Modelling assumption and limits

- Electron density measured relative to the plasma current below the Greenwald limit
- Internal inductance remains sufficiently low to allow for vertical control, elongation below $\sim 1.7 * (1.09 + 0.26/(li(3))) * (1.5/A)^{0.4}$
- Total plasma current at the end of ramp-down is sufficiently low to allow for a disruption
- Plasma shape is controlled and stays diverted for long enough to allow for a safe burn phase exit, managing the exhaust heat fluxes and wall load
- Impurity accumulation is controlled/avoided to prevent a radiation fraction collapse
- Core transport with JETTO BgB with prescribed anomalous diffusion coefficients, edge ETB reduced transport dependent on L-H threshold
- Feedback model on target β_N value ~ 4.4 , and pellet source to maintain prescribed n_{GW}

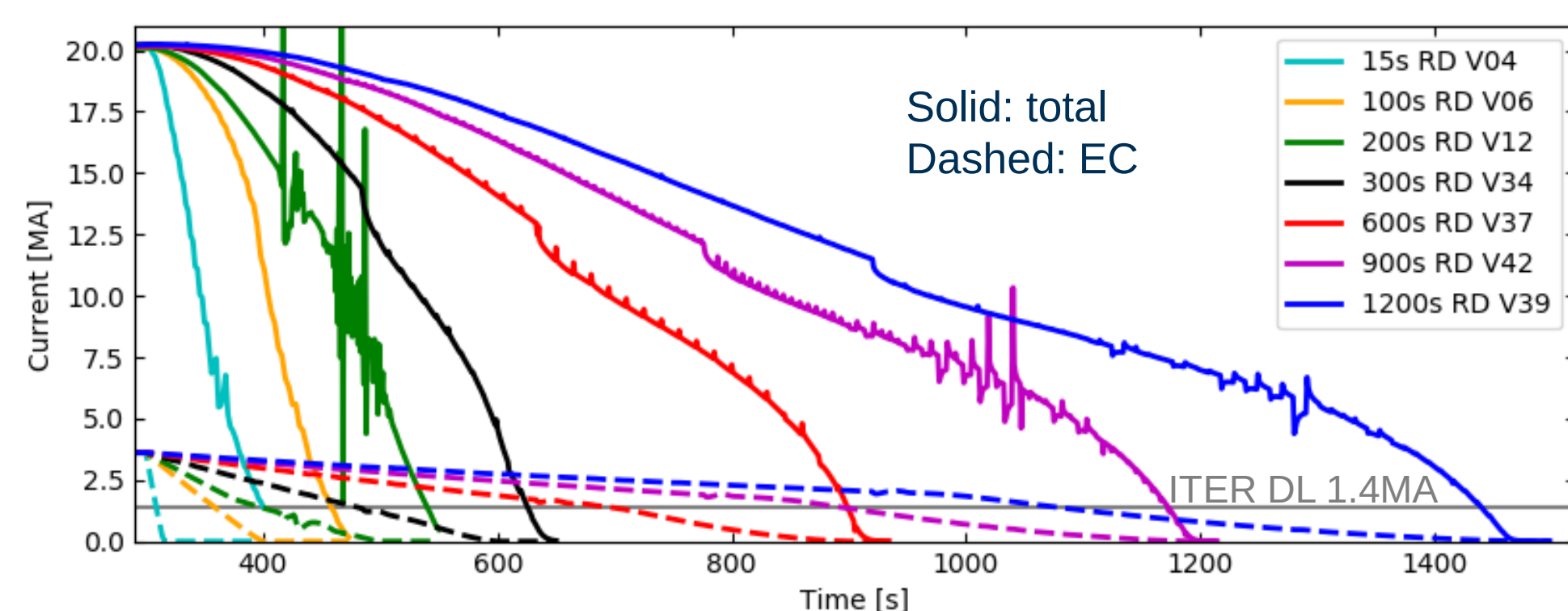
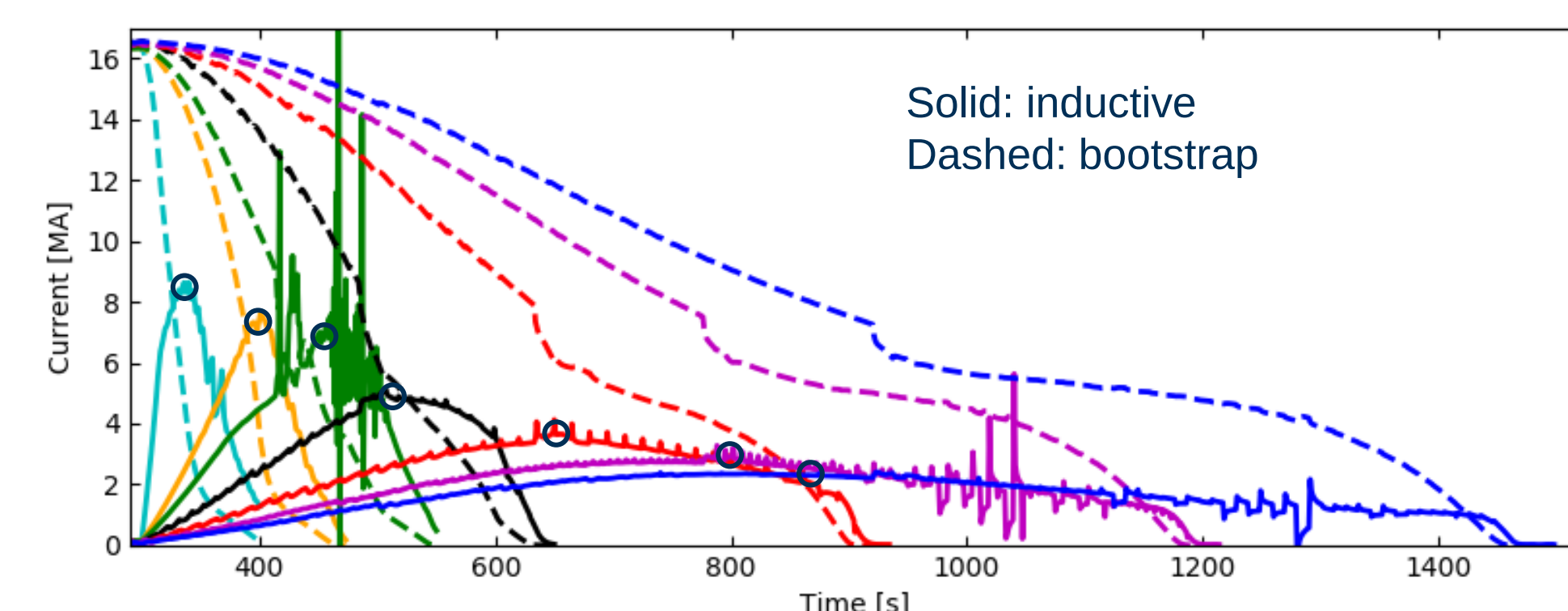


[J.W. Berkery et al 2015 Nucl. Fusion 55 123007]



[J.E. Menard et al 1997 Nucl. Fusion 37 595]

Current evolution (including H-L transition)

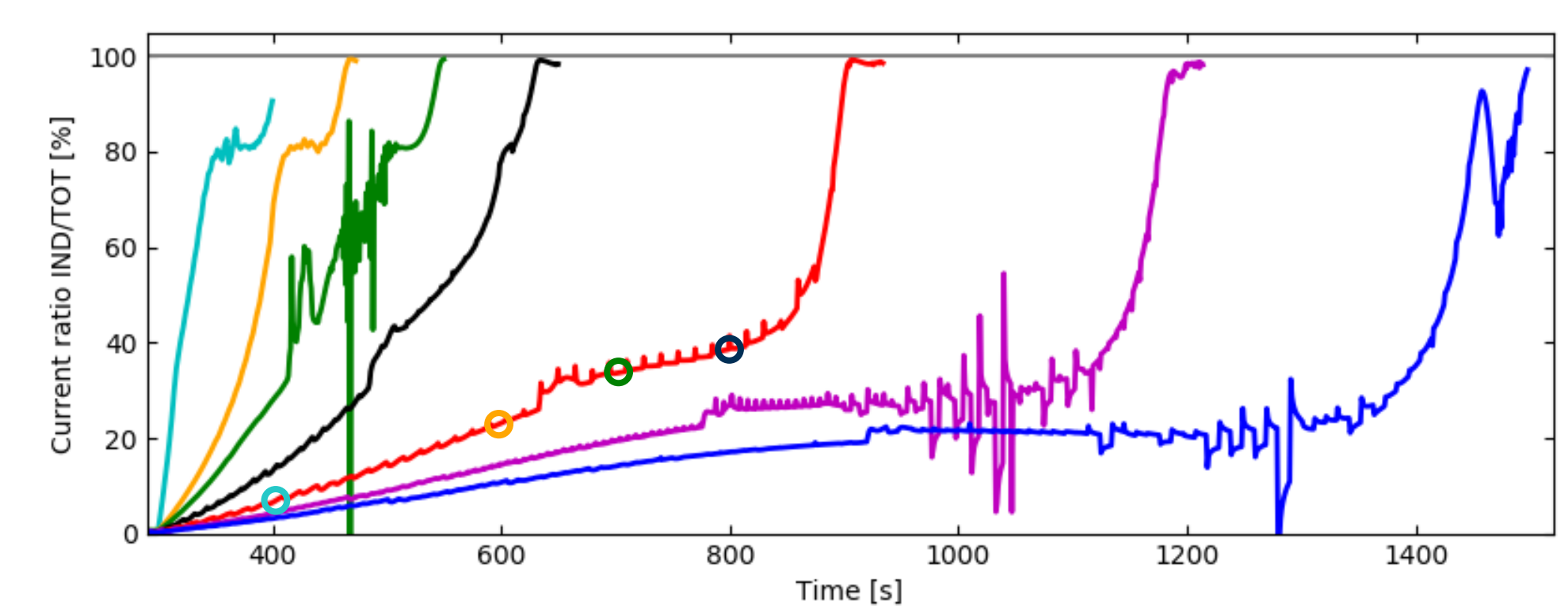
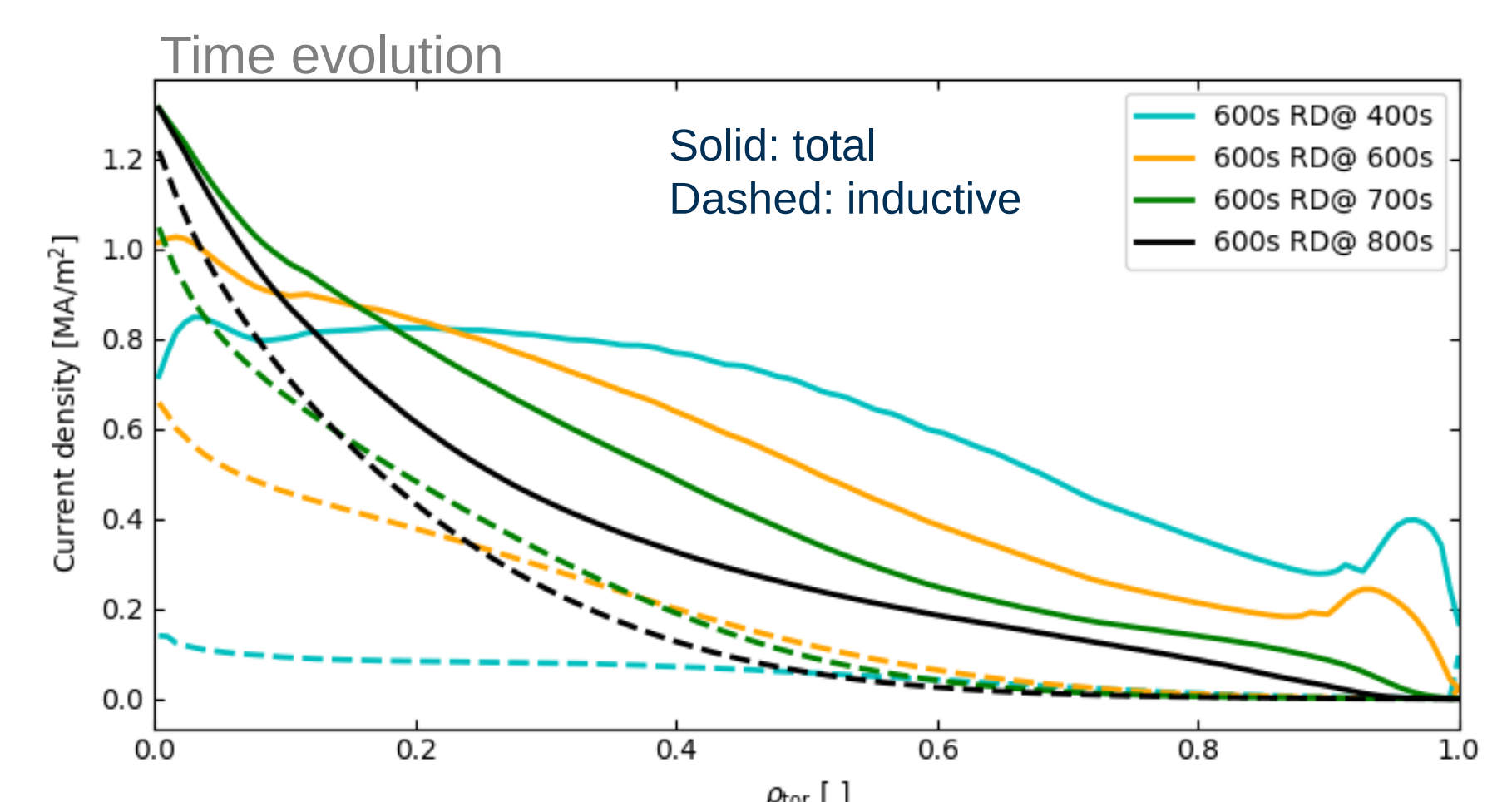


Inductive current has a rollover shape with a more pronounced peak in faster RD. The bootstrap current remains large in slower RD and is clearly affected by LH transition.

Current evolution on the scale of L/R time, roughly $\propto a^2 T^{3/2} Z_{eff}^{-1}$

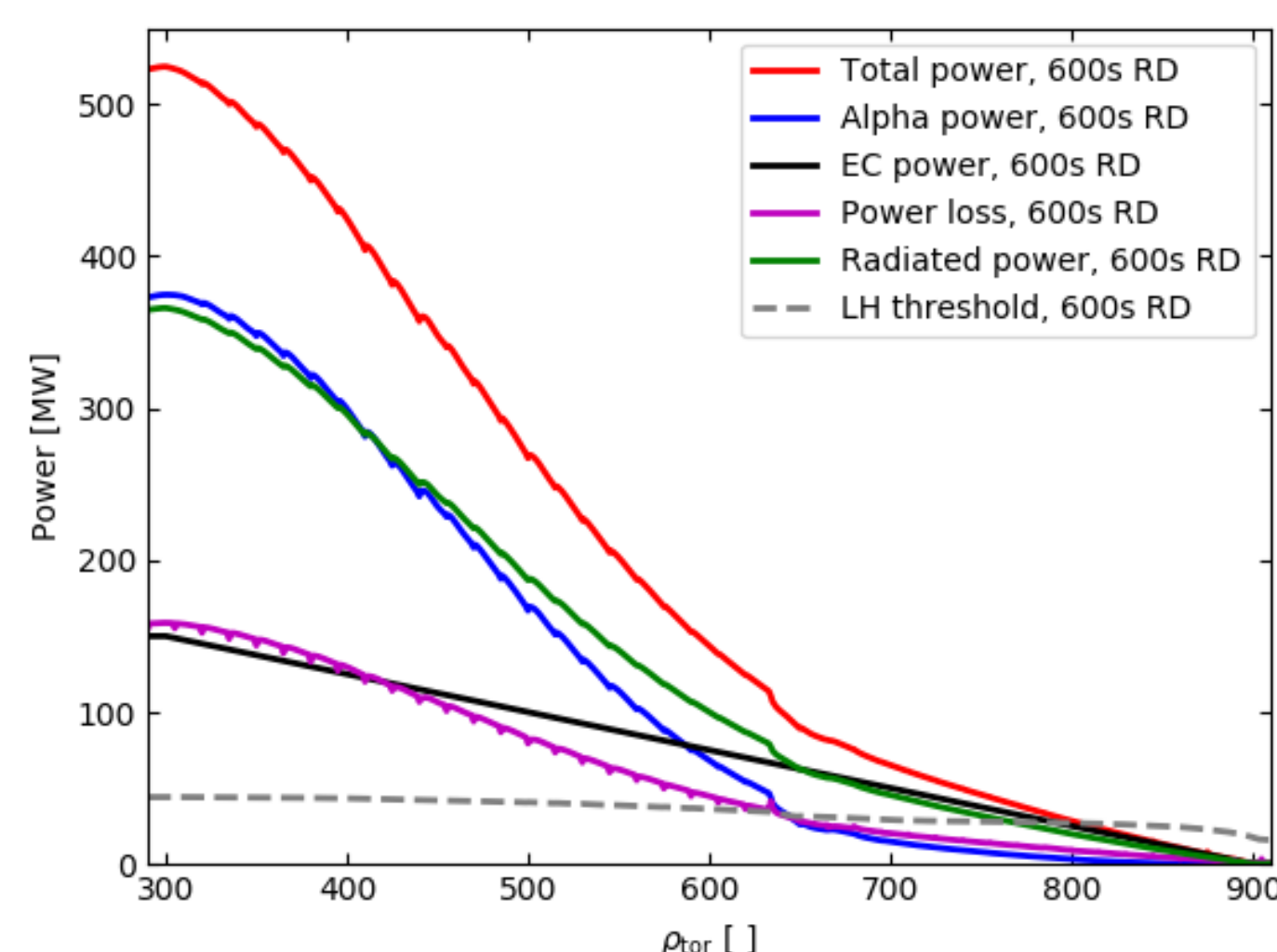
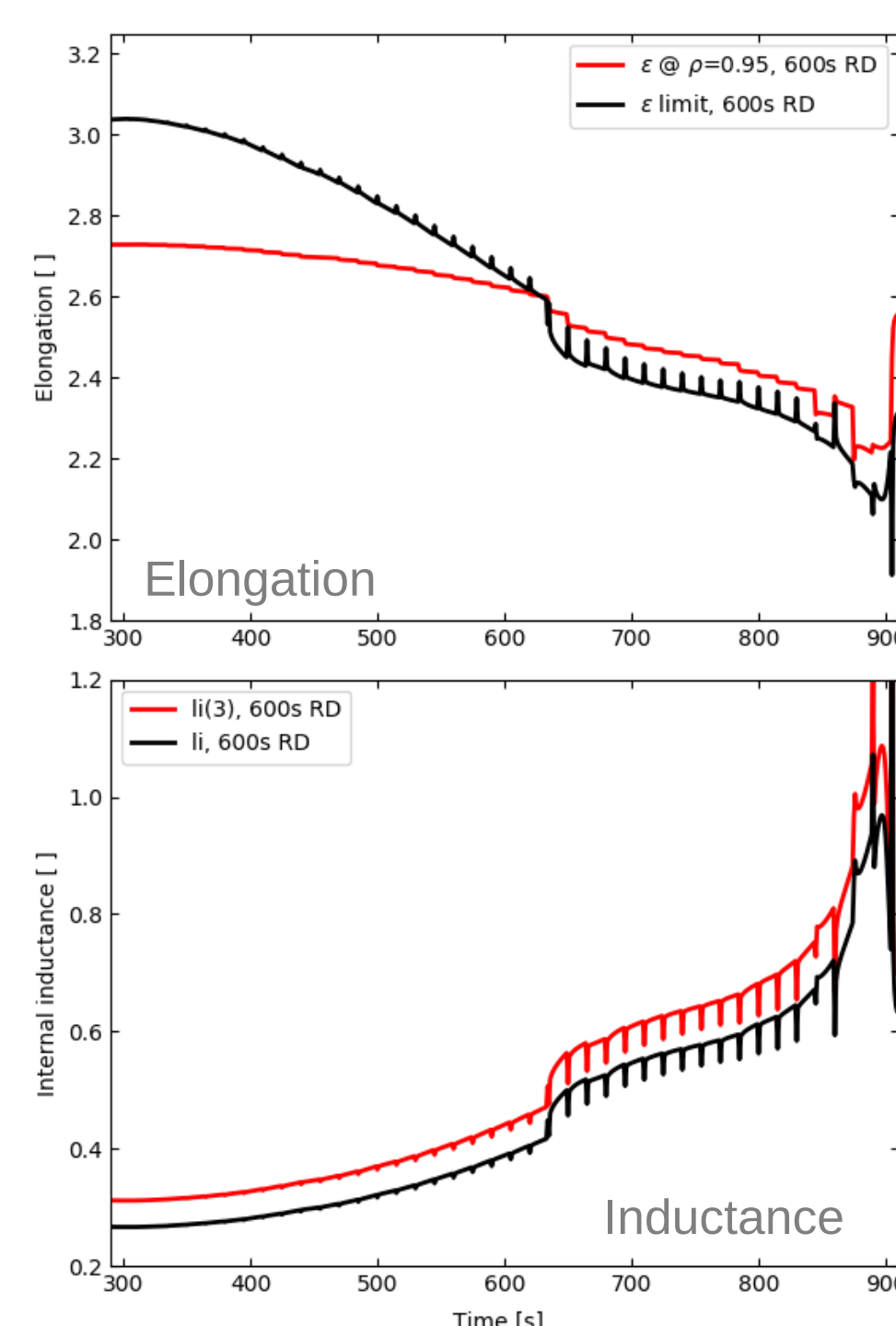
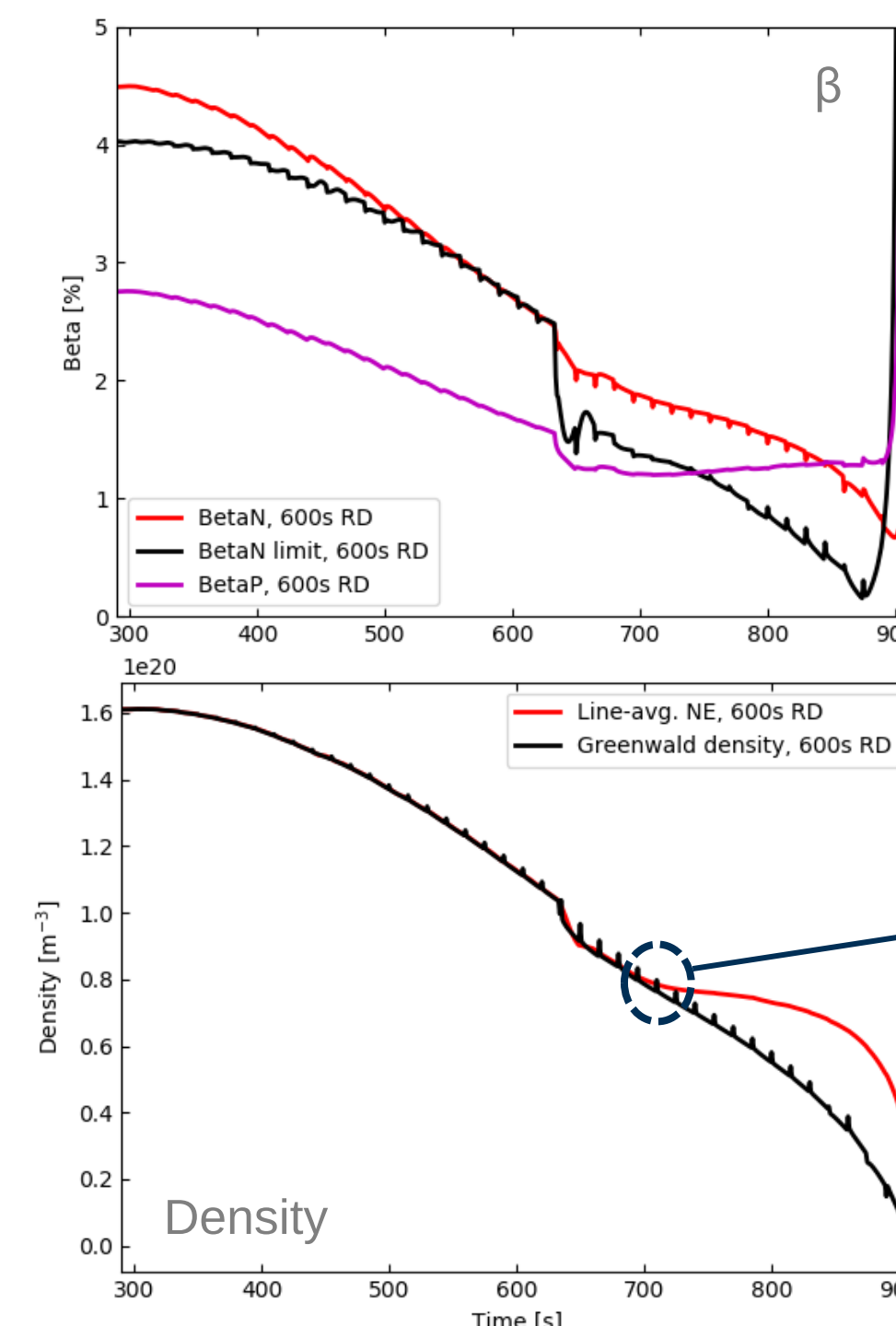
Ratio of inductive/total current with a saturation interval observed with slower RD

Inductive current profile is peaked – if dominant it has a detrimental effect on the evolution of q-profile and $li(3)$



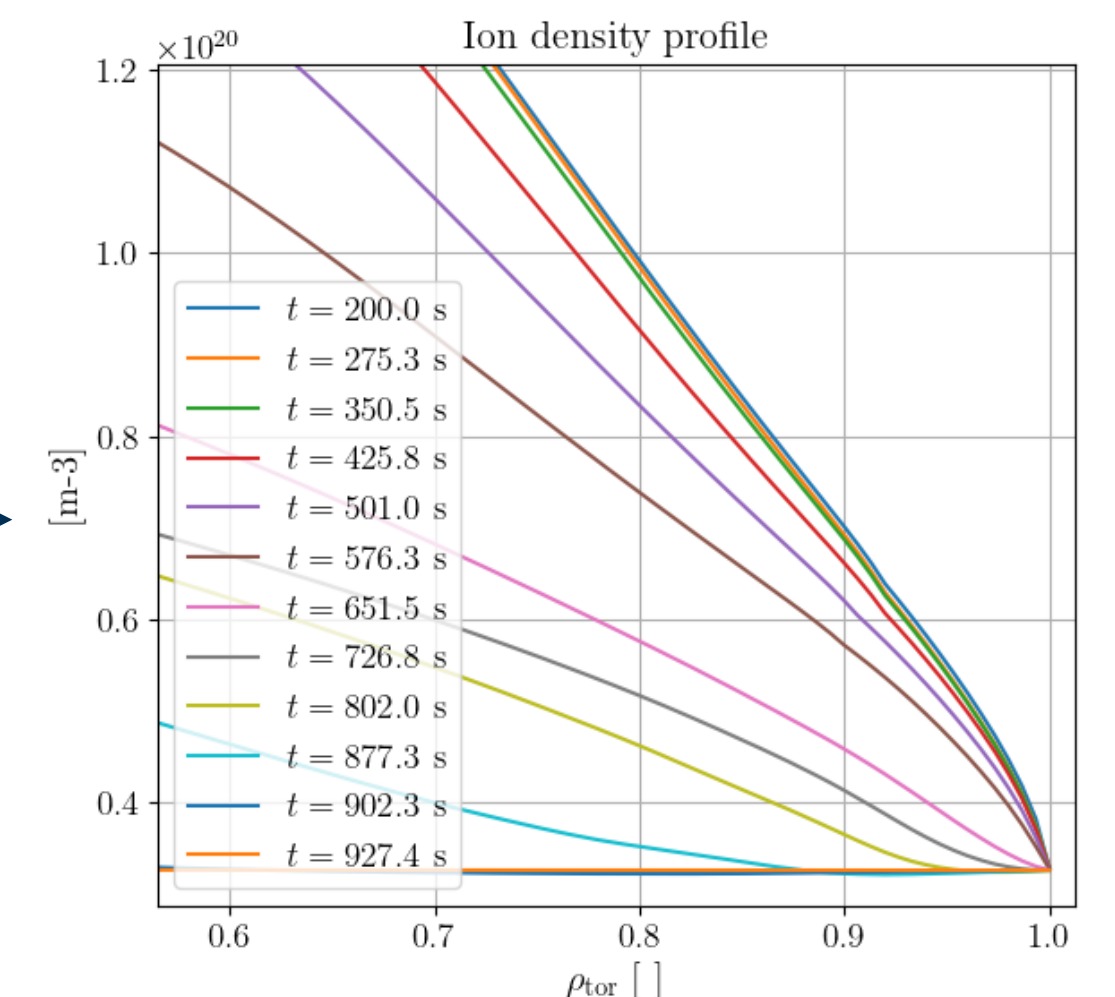
Plasma parameter evolution

Time evolution of selected plasma parameters in the 600 s linear ramp-down simulation



Internal inductance rises as a consequence of the increased peakedness of the total current density profile, which is dominated by the highly peaked inductive current component

When density decreases significantly and the pellet source falls to zero the electron boundary constraint is not anymore



Discussion

Initial modelling indicates long ramp-down of ~20+ min needed to navigate MHD stability limits, current peakedness, and manage heat exhaust

- How can we shape the EC current profiles and adjust EC drive efficiency to counter high profile density peaking?
- What are some of the quantitative limits for heat fluxes when transiting from a diverted to limiter plasma?
- Can we apply an exhaust or core-pedestal density scaling to better prescribe boundary density evolution in the ramp-down phase?
- How can RAPTOR help with optimizing the ramp-down phase? [A. A. Teplukhina et al 2017 Plasma Phys. Control. Fusion 59 124004]

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