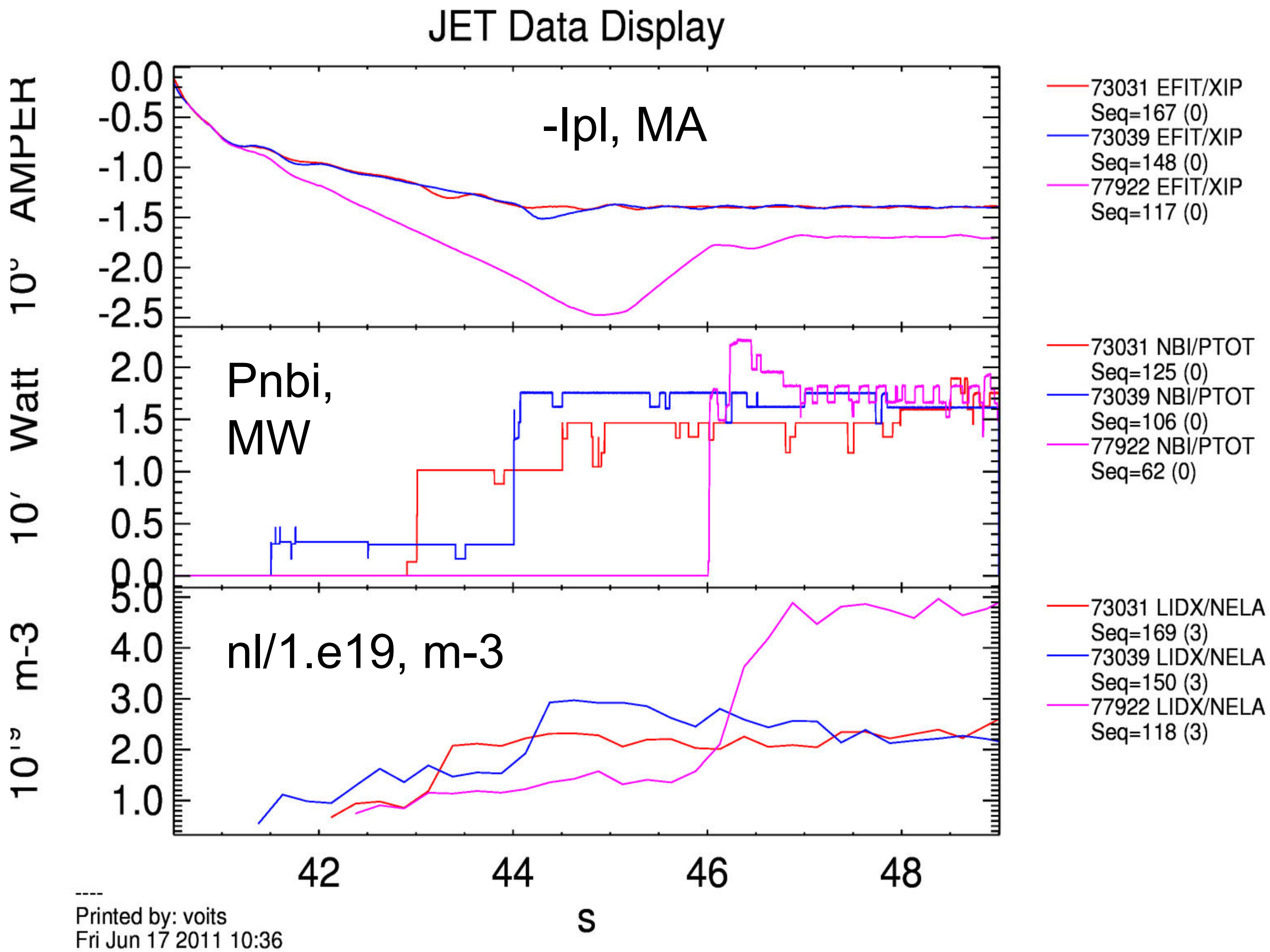
Current ramp up in JET hybrid scenarios

Outline:

1. Experimental scenarios
2. Current diffusion and transport modelling
3. Comparison of current ramp up with/without the overshoot technique
4. Summary

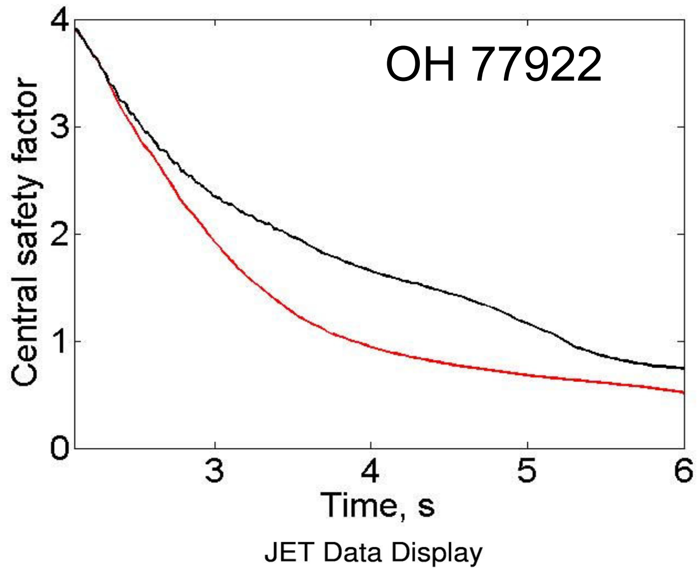
Experimental current ramp up scenarios

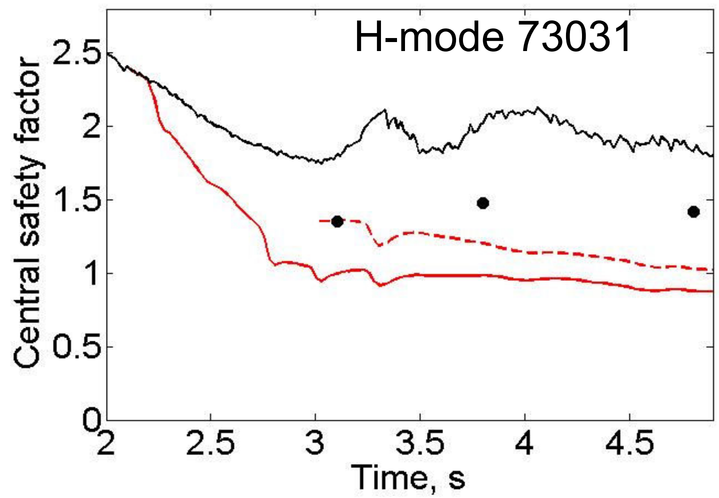


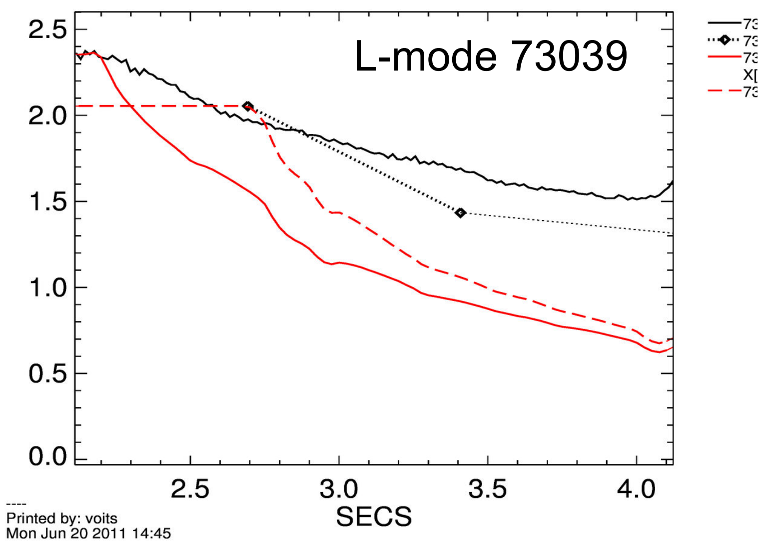
- *selected discharges: OH (77922), L-mode (73039), H-mode (73031)*
- *no sawteeth during current ramp up*
- *no MHD in L- and H-mode, short and weak n=1 (4.6-4.8 s) during ohmic ramp up*
- *measurements: MSE for L- and H-mode, CX for current ramp up in H-mode. HRTS, ECE for Te and ne in three shots. KS3/ZEFV when CX data are not available*

Current ramp up simulated with measured Te and flat Zeff profile normalised to KS3/ZEFV (NCLASS/TRANSP)

EFIT (black curves), EFTM (symbols), NCLASS/TRANSP (red curves)





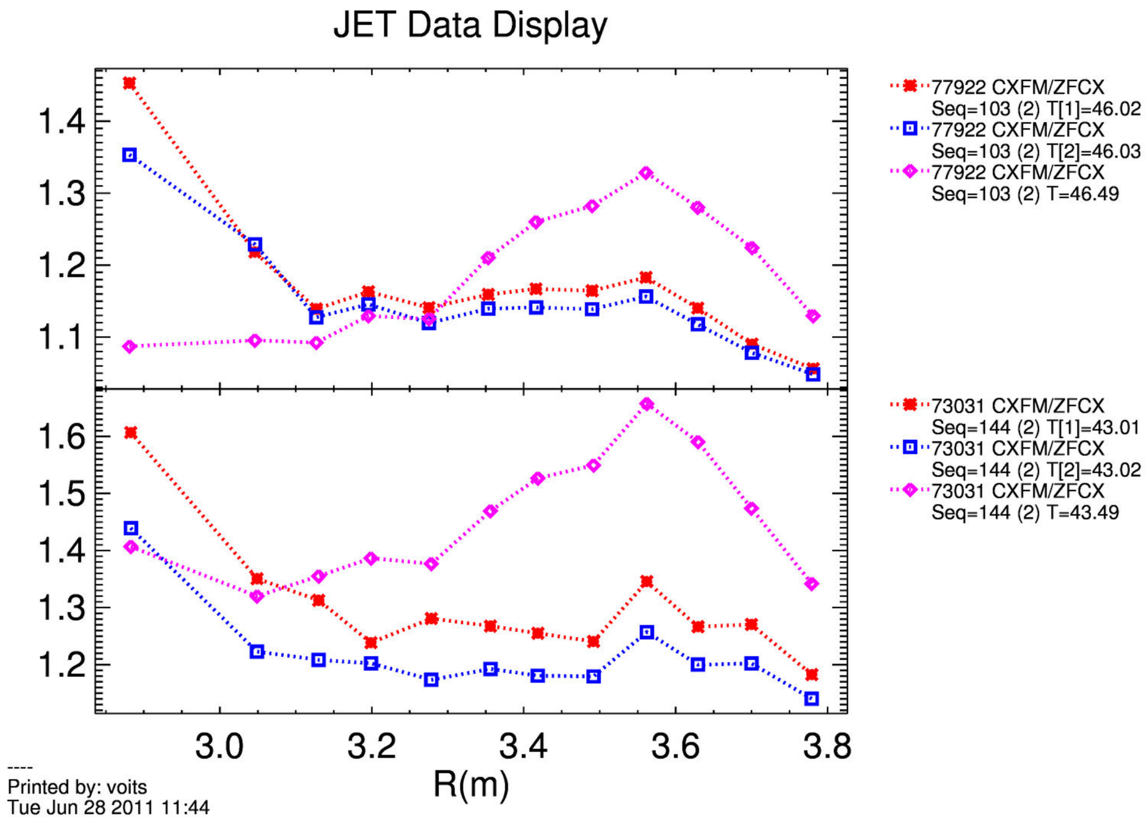


- *initial conditions have been varied: EFIT/Q at 2.3 s or the first EFTM/Q profile later on (73031 & 73039 only)*

- *rapid reduction of simulated q0 is inconsistent with the absence of sawteeth (77922, 73039) and reconstructed (EFTM) q-profile (73031, 73039)*

- *delay of inward current diffusion in H-mode*

Zeff profile measured with CX diagnostics

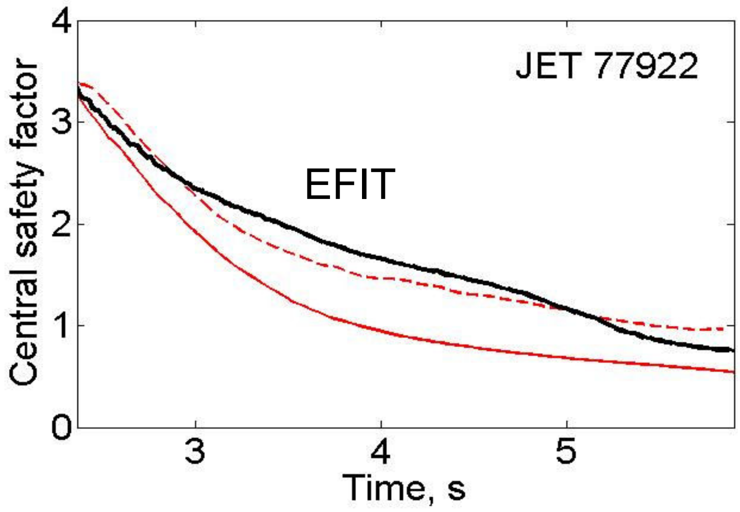


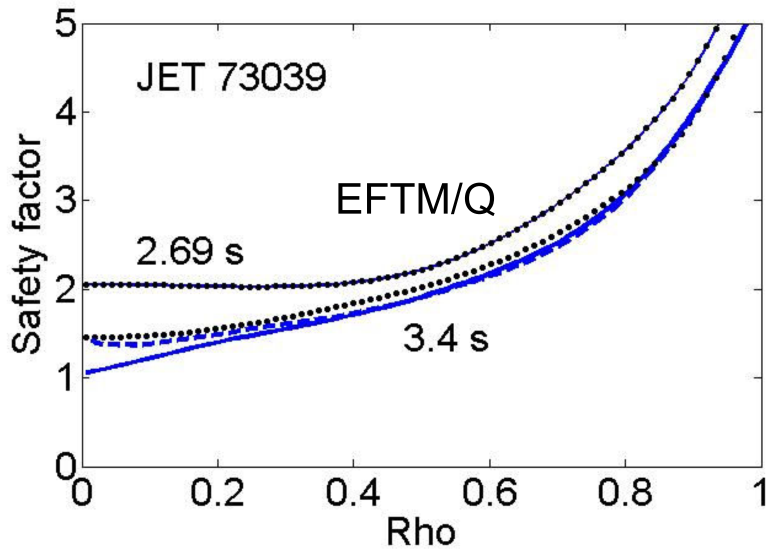
- *measurements taken at 10 ms (red) and 20 (blue) ms after the NBI start: on-axis peak of Zeff (within 15-20 cm), nearly flat Zeff outside 3.1-3.2 m*

- *typical off-axis Zeff after 0.5 s (pink)*

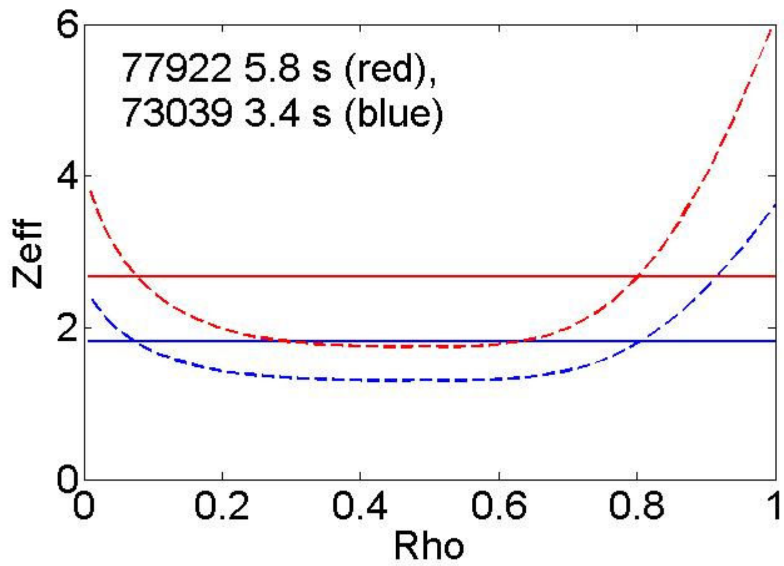
- *the outer part of plasma (R > 3.78m) is not covered by the CX measurements*

ASTRA simulations with flat (solid curves) and shaped (dashed curves) Zeff



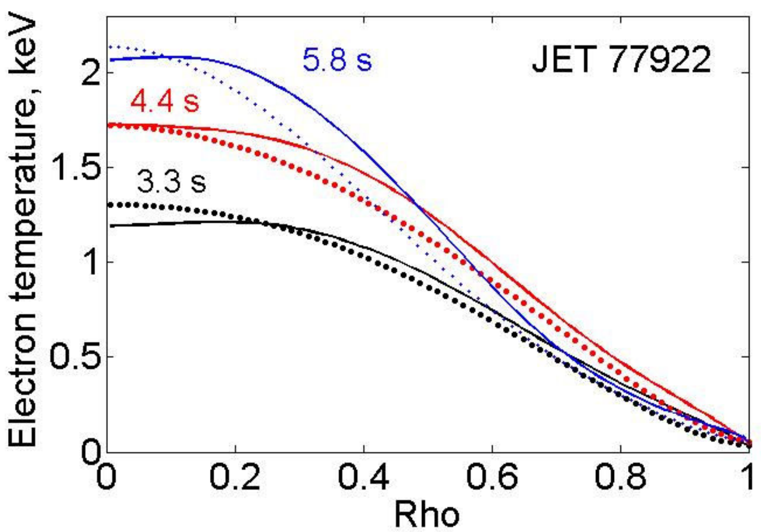


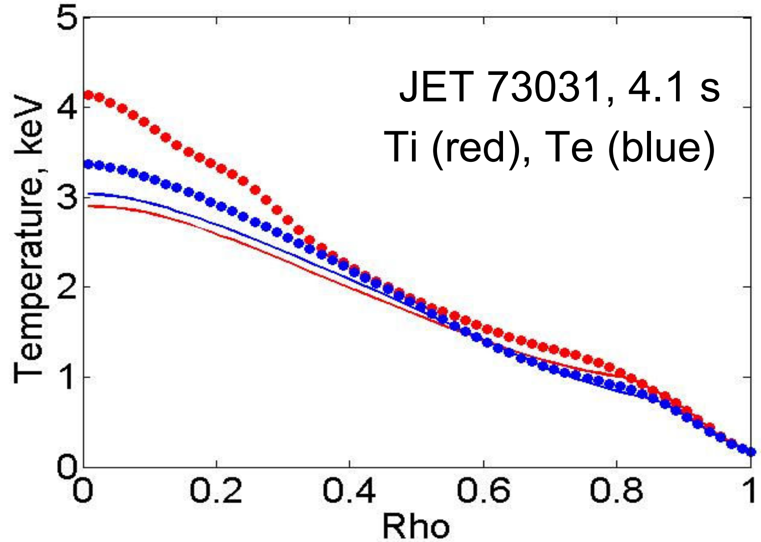
- *adjusted Zeff profile to provide q0>0.9 in OH discharge and q-profile matching EFTM/Q in L-mode;*
- *adjustment constrains: measured Zeff shape and KS3/ZEFV*
- *L-mode: the discrepancy between EFIT and TRANSP/flat Zeff is inside $\rho \approx 0.2$ although the considered time interval (0.7 s) is very short*

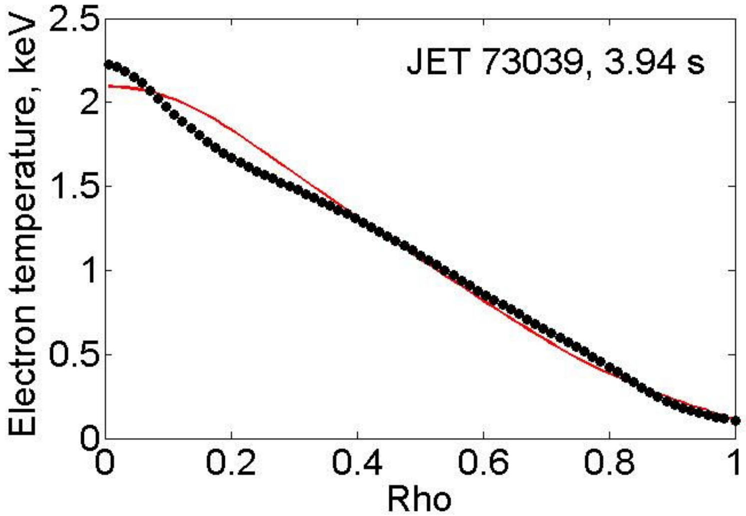


Modelling of temperature evolution with Bohm-gyroBohm transport model

ASTRA simulations (solid curves), measurements (symbols)







- *simulated j, Te and Ti for OH and L-mode discharges, EFTM/Q for H-mode;*

- *simulations region includes $0 \le \rho < 1$ for OH and L-mode plasmas, $0 \le \rho < 0.85$ for H-mode*

- *slightly broader simulated profiles in OH plasma, good agreement in L-mode region, steep core Ti profile in H-mode is not reproduced*

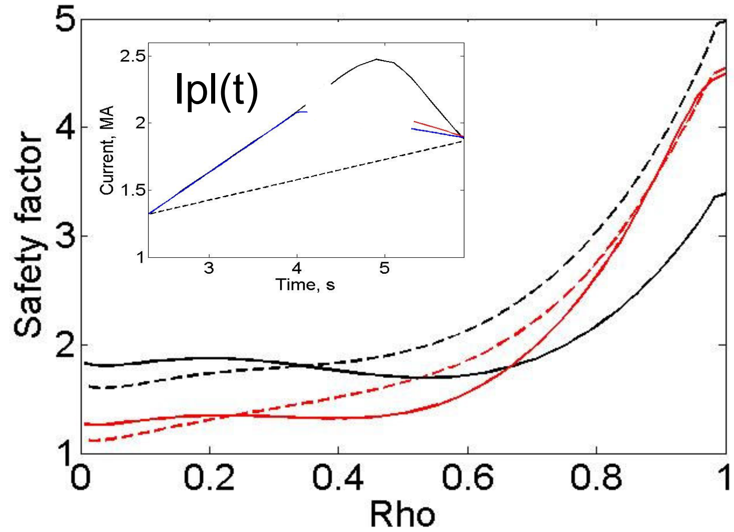
Comparison of current ramp up with/without overshoot:

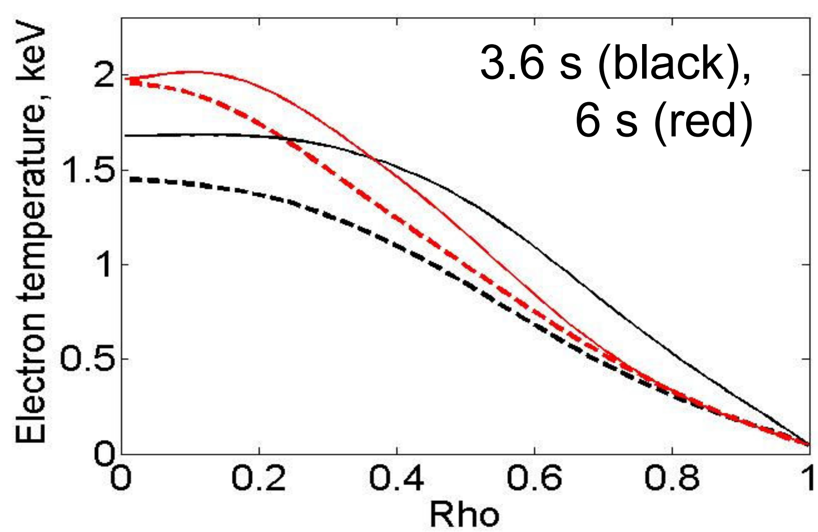
- Based on validated models: NCLASS, adjusted Zeff, Bohm-gyroBohm transport model

- Questions to be addressed:
  - *optimisation of the current overshoot parameters*
  - *role of transport and OH heating in formation of target q with current overshoot*
  - *effect of plasma size*

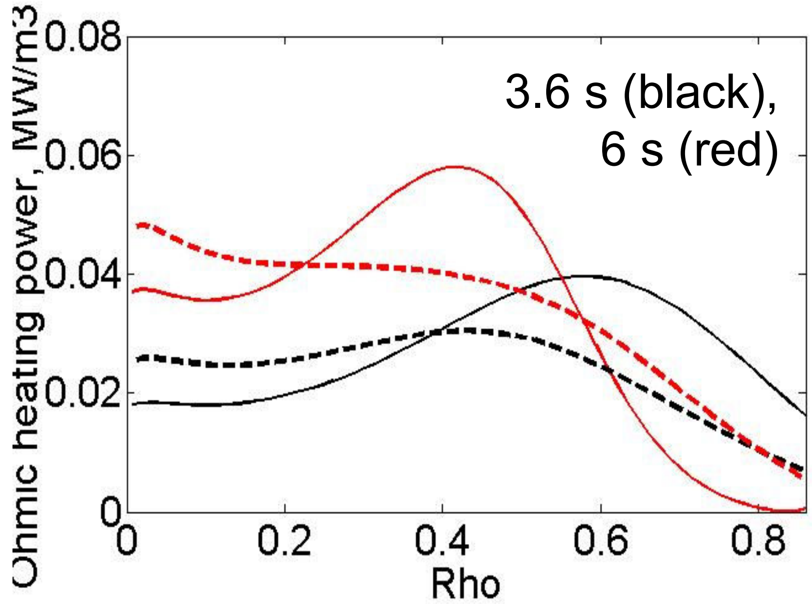
- Simulations are based on #77922 (same Zeff and ne) – scan in plasma current waveform

Slow current ramp up (dashed curves) vs fast current ramp up/down (solid curves) in OH plasma

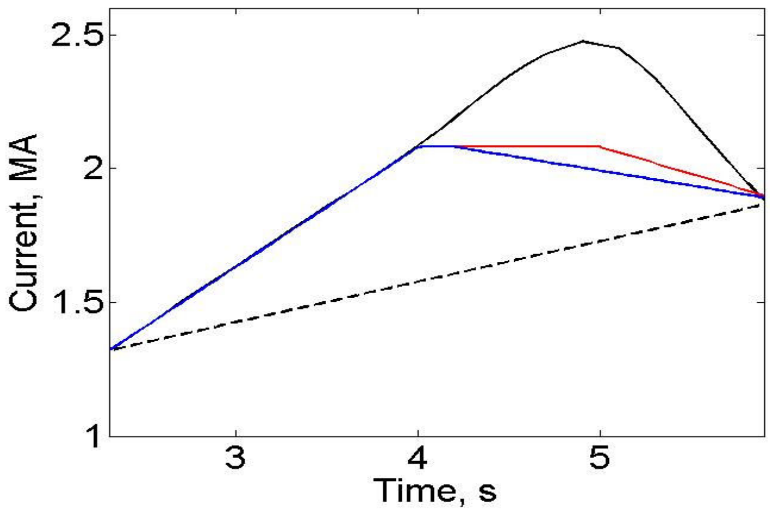


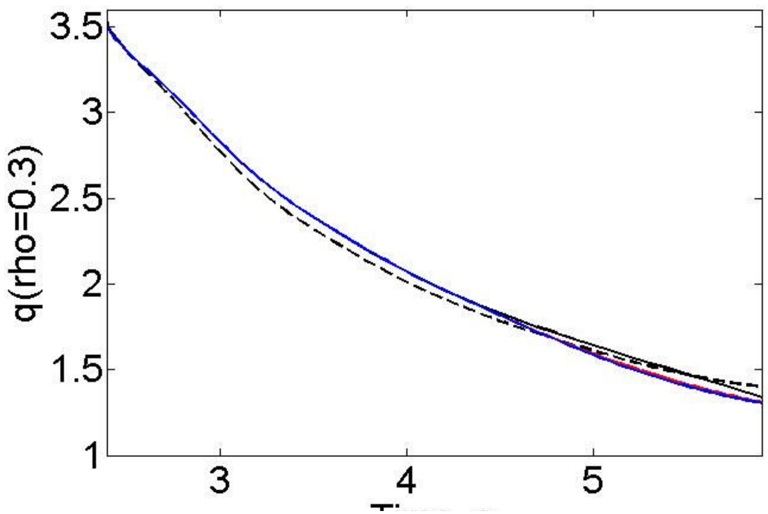


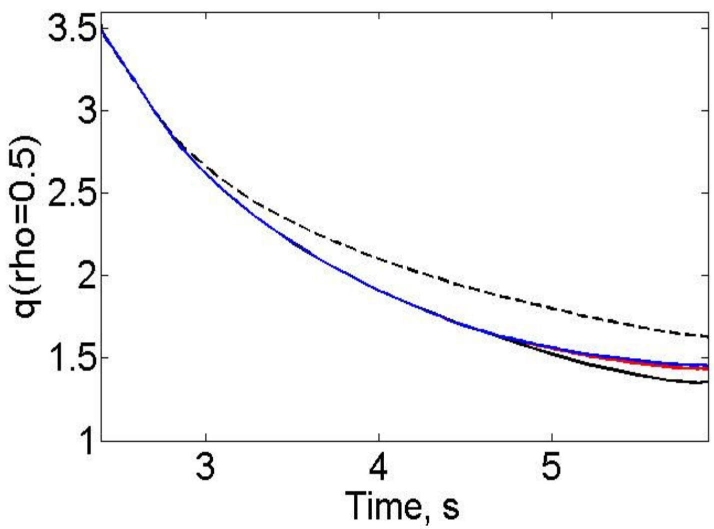
- *low magnetic shear at low q in a broad region is achieved with current overshoot: favourable q-profile for confinement*
- *broader Te(r) with current overshoot delays the inwd current diffusion*
- *Bohm-gyroBohm transport coefficients are nearly the same in two scenarios*
- *broadening of Te is caused by the off-axis OH heating in scenario with current overshoot*



Comparison of different current overshoot scenarios

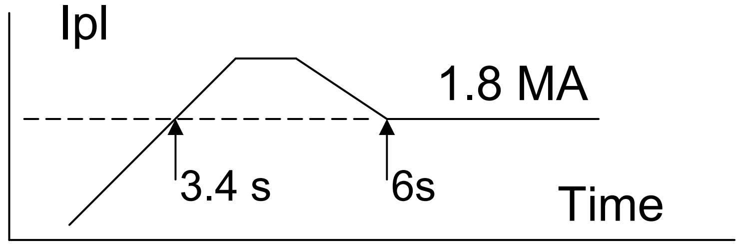


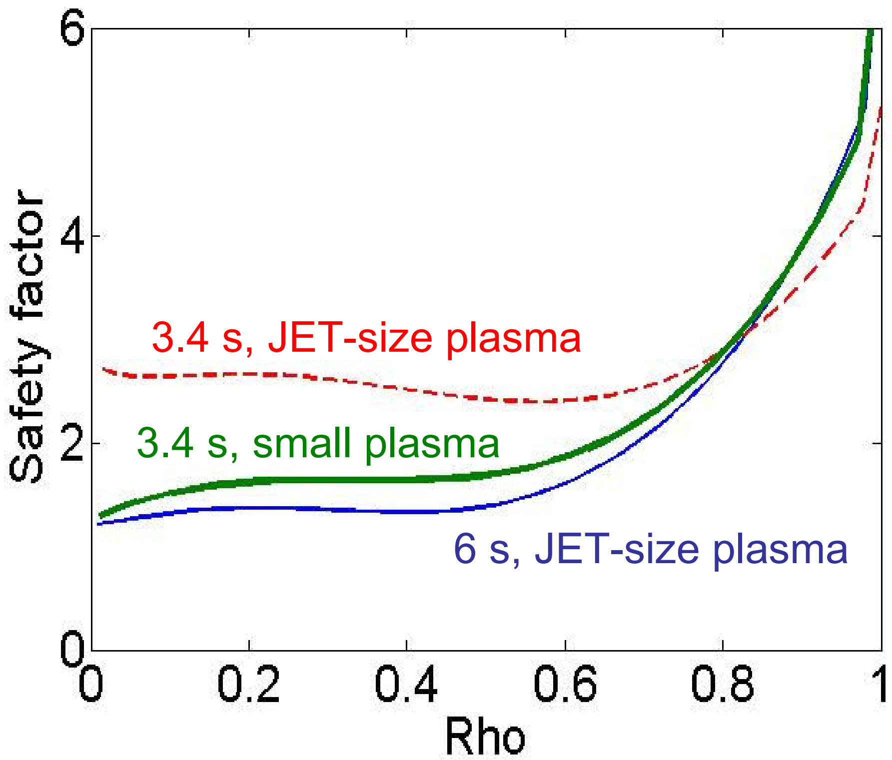




Longer current ramp up, short plateau and faster ramp down is more efficient, although the difference in target q-profile obtained with different overshoot scenarios is not big

Effect of plasma size: is the overshoot technique needed in smaller plasmas?





- reduced plasma size: minor radius is reduced by 36%, major radius and elongation are adjusted to get the same *q95*

- similar profiles are achieved at 6 s/1.8 MA in large plasma and at 3.4 s/1.8 MA (before the current overshoot) in small plasma

Summary

- Current diffusion is consistent with neoclassical prediction within the uncertainty on Zeff measurements in OH discharge. Time interval between the 1st and 2nd MSE measurement in L- and H–mode plasmas is too short for conclusion

- Thermal electron transport is in a relatively good agreement with Bohm-gyroBohm model

- The target q-profile obtained with current overshoot: *low and flat q-profile in a broad core region*

- The off-axis OH heating during the current overshoot is more important for broadening Te(r) than the q-dependent transport

- Overshoot technique is favourable for confinement, but not for duration of sawtooth-free phase → careful current profile alignment at the beginning of the main heating phase

- Application to ITER to reduce the requirements to NBI, LHCD and ECCD?

Possible ITER scenario with current overshoot