Status of modelling of DIII-D current ramp up discharges and comparison with JET

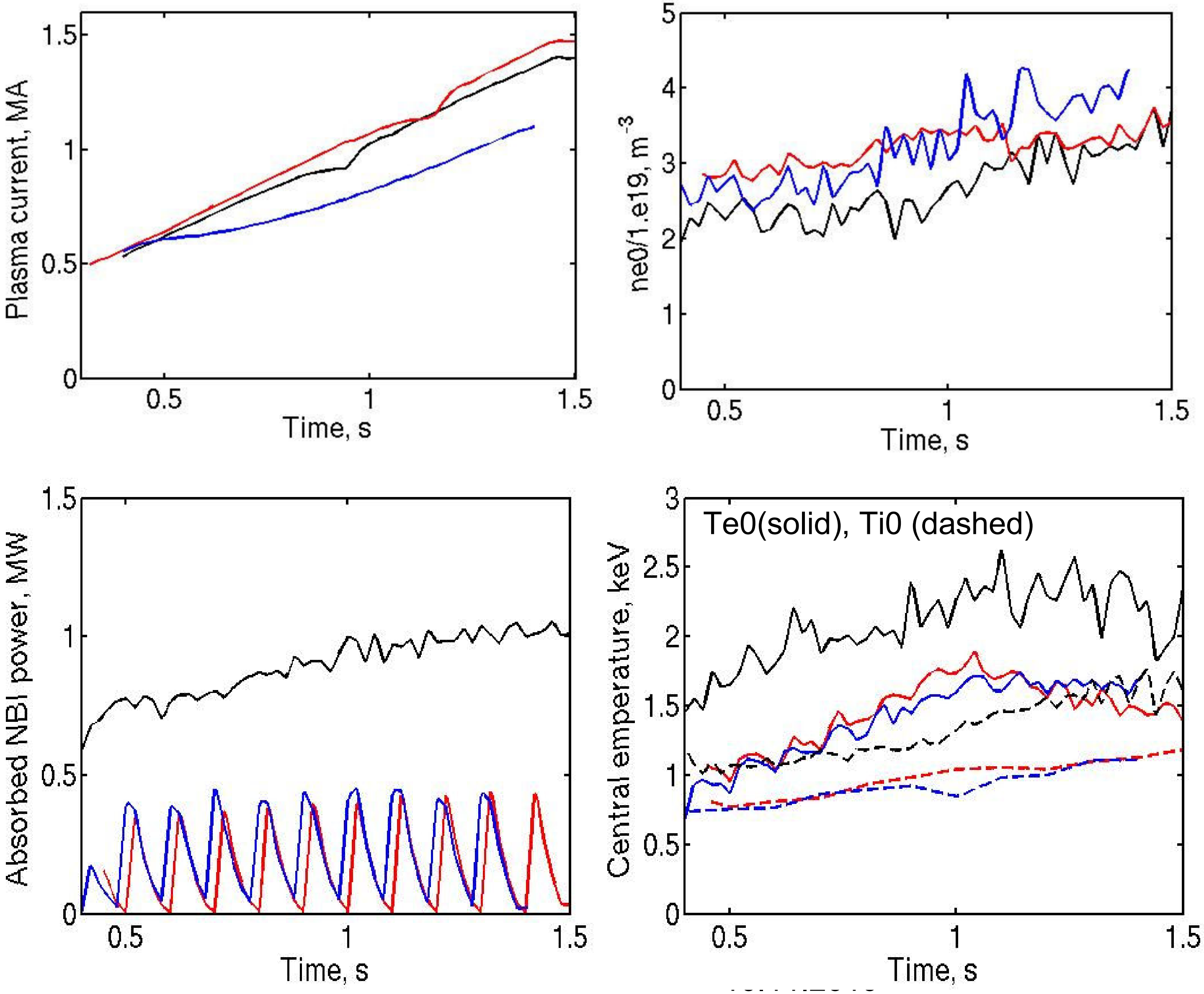
Acknowledgements: J M Park, R Prater, D Mikkelsen

Outline:

1. Experimental scenarios
2. Simulation of current diffusion
3. Validation of transport models (Bohm-gyroBohm, GLF23, Coppi-Tang)
4. Summary

Experimental scenarios

132411 (B_t=2.1 T, κ=1.86, δ=0.5), 136303 (B_t=1.86 T, κ=1.8, δ=0.5), 136779 (B_t=1.85 T, κ=1.75, δ=0.48)



- *two OH pulses with diagnostic beam blips, one NBI heated L-mode*

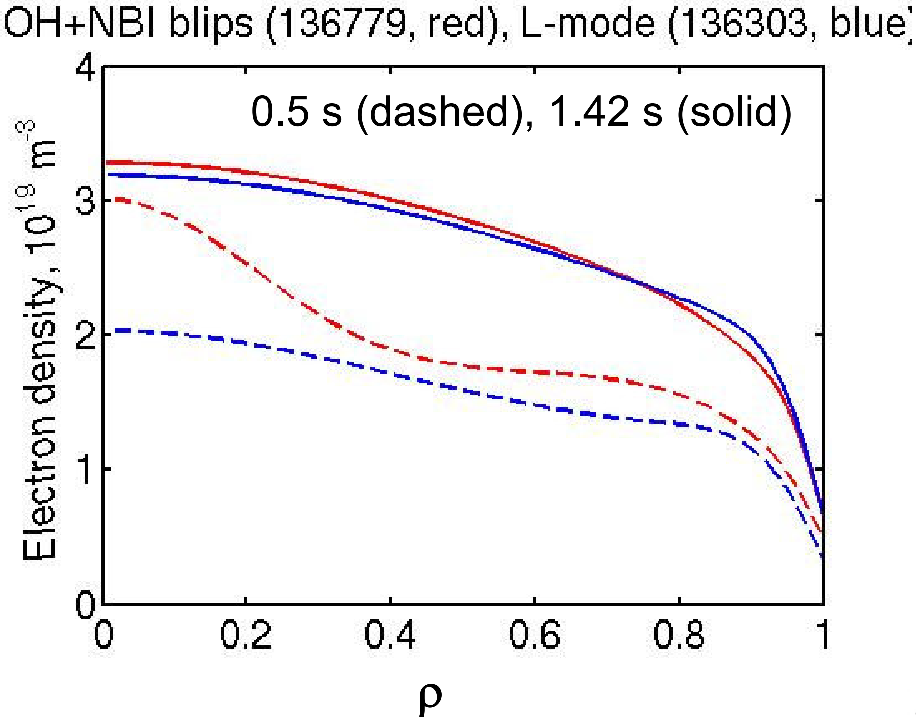
- *$dI_{pl}/dt \cong 0.54$ – 0.88 MA/s (JET: 0.19 - 0.36 MA/s)*

- *similar central density in three discharges, $n/n_{gw} \cong$ 0.2-0.25*

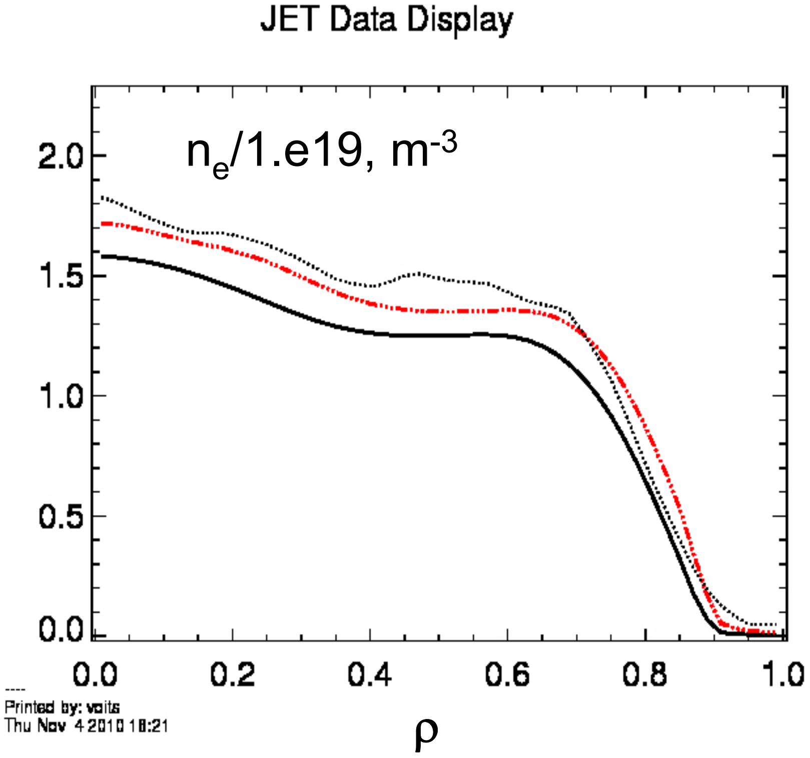
- *central temperatures saturate around 1 s – sawteeth?*

- *still missing: beam driven current, fast ion density, atomic losses*

Evolution of density profile in DIIID discharges and comparison with JET

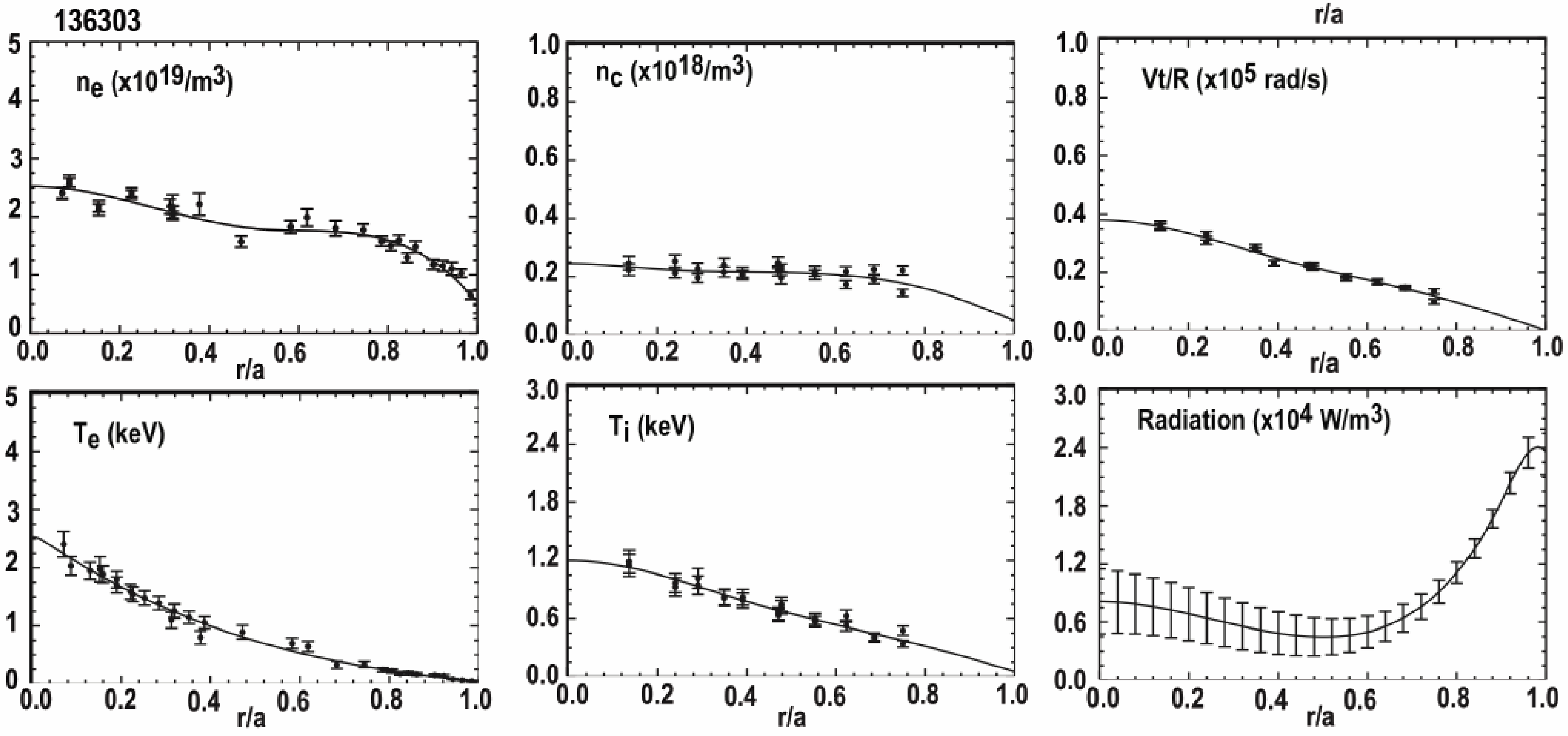


- *peaked core density (fit of exp. data) at the early phase of the current ramp up (flat/slightly reversed q);*
- *flat profiles by the end of the current ramp up*



Density profiles during ITER-like current ramp up at JET (72516, 72467)

Typical Discharge Submitted to the ITPA Profile Database

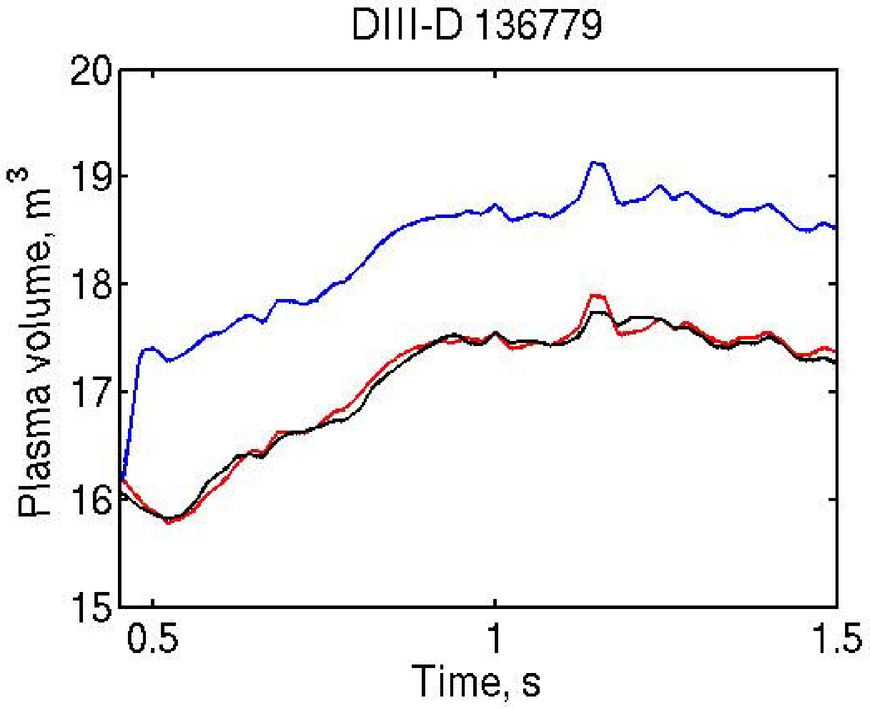


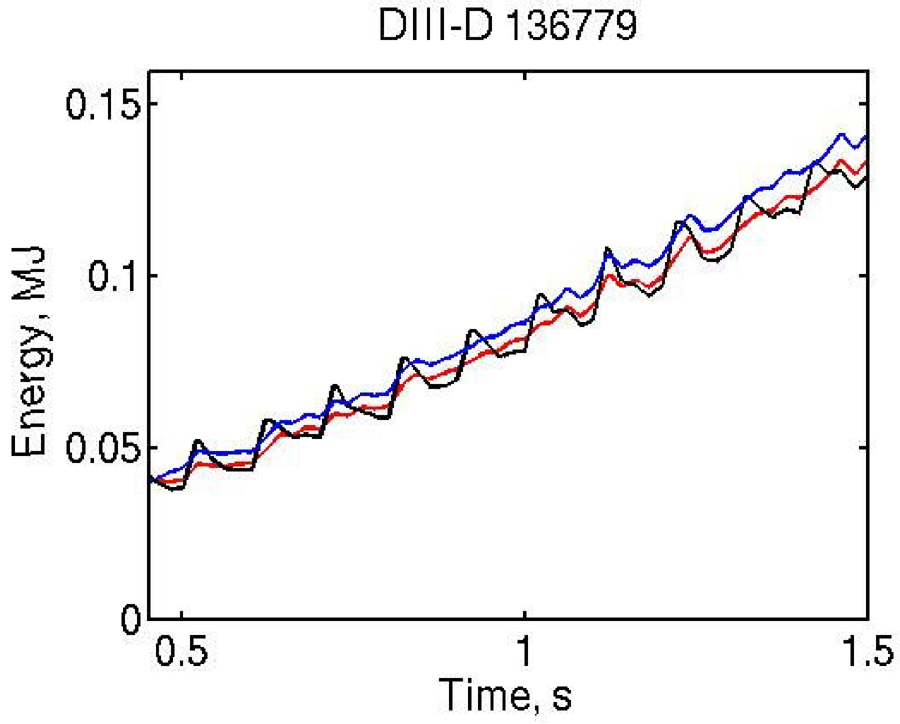
- n_e, T_e : Thomson, mapped to EFIT time grid (every 20 msec)
- T_i, V_t [V_p, E_r], Z_{eff}: CER, every 100 msec at beam blip

Courtesy of J M Park

Data consistency (136779)

Equilibrium and current diffusion simulations (ASTRA) with provided plasma shape (blue) and adjusted R_{geo} to match plasma volume (red). Data are shown by black curves.



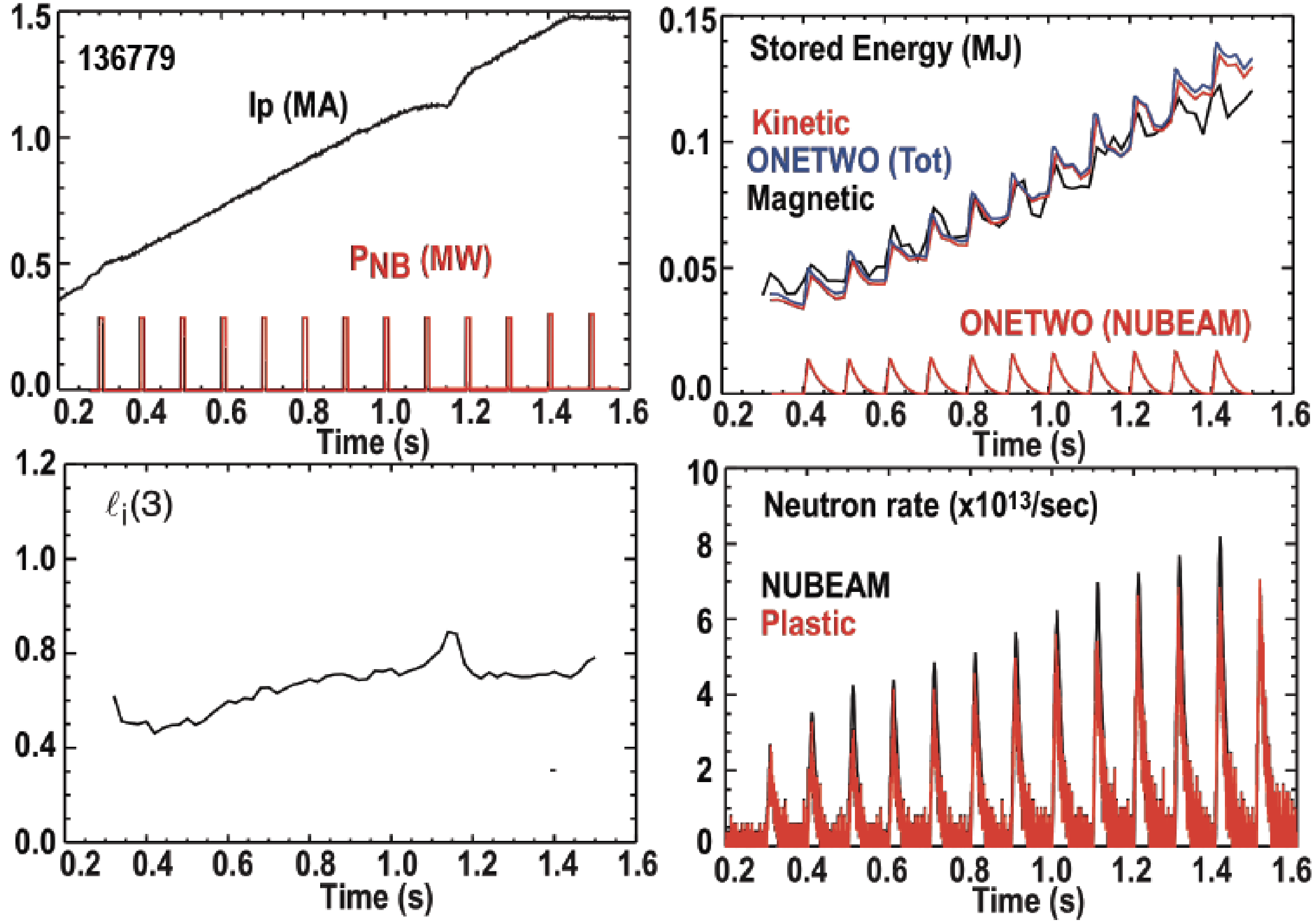


- *6-9% difference in plasma volume calculated in ASTRA and given in ufile*

- *R_{geo} is reduced to match plasma volume and total energy*

Red and blue curves show the calculated bulk energy. Energy of fast ions is not yet provided. Black curve shows the total energy taken from ufiles.

Typical Discharge Submitted to the ITPA Profile Database

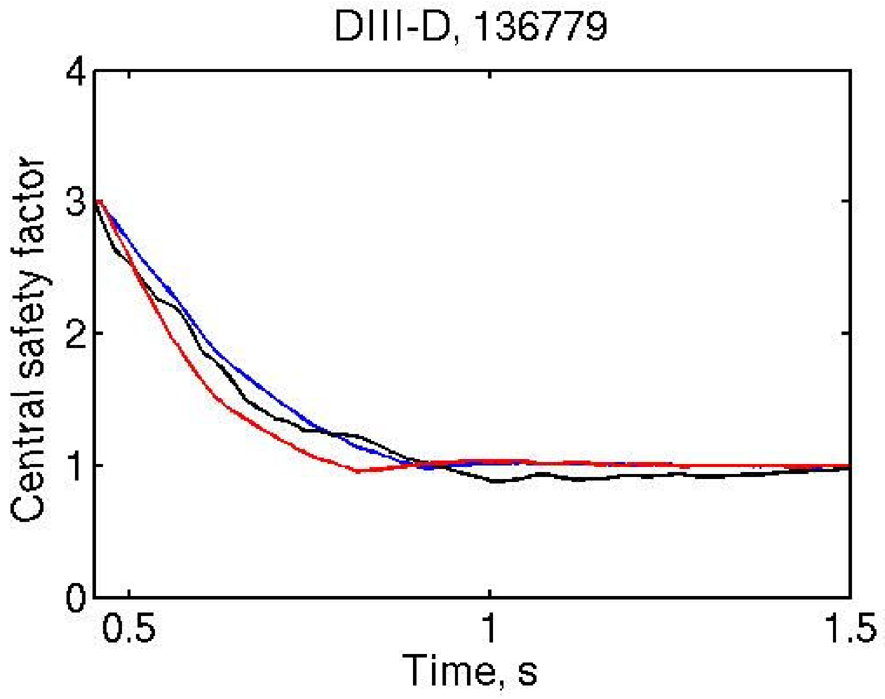


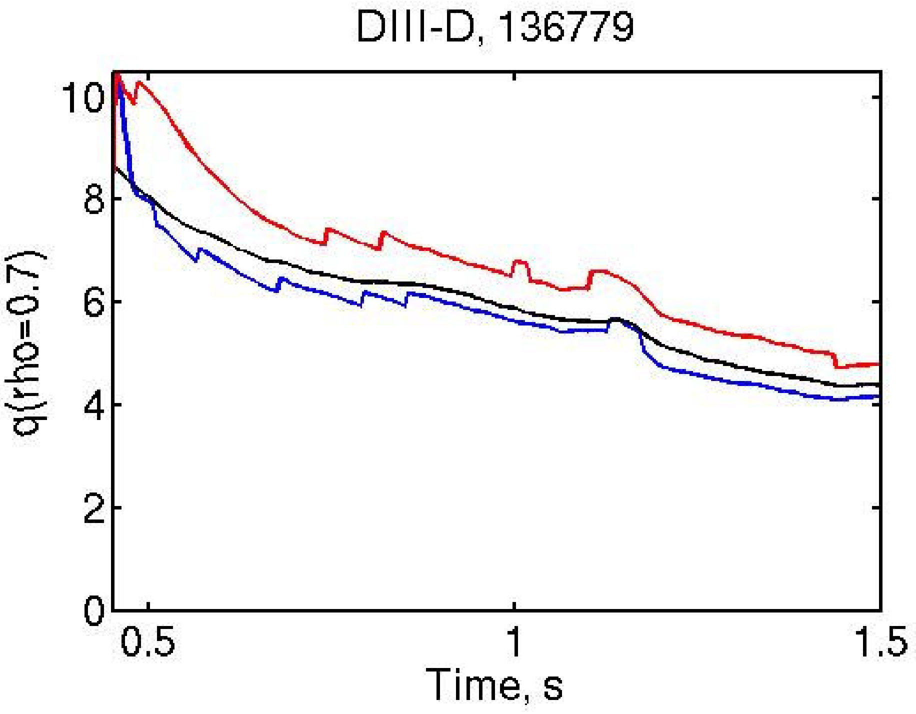
- **Beam blip:**
  - every 100 msec
- **Time widow:**
  - First beam blip time ~ start time of plattop
- **Equilibrium reconstruction:**
  - Kinetic efit with MSE constraint
  - Every 20 msec

Courtesy of J M Park

Current diffusion in OH discharge (NCLASS, sawtooth constraint on q, measured Te, no beam driven current):

Rgeo is taken from ufile (blue), horizontal shift is adjusted to match plasma volume (red), data (black)

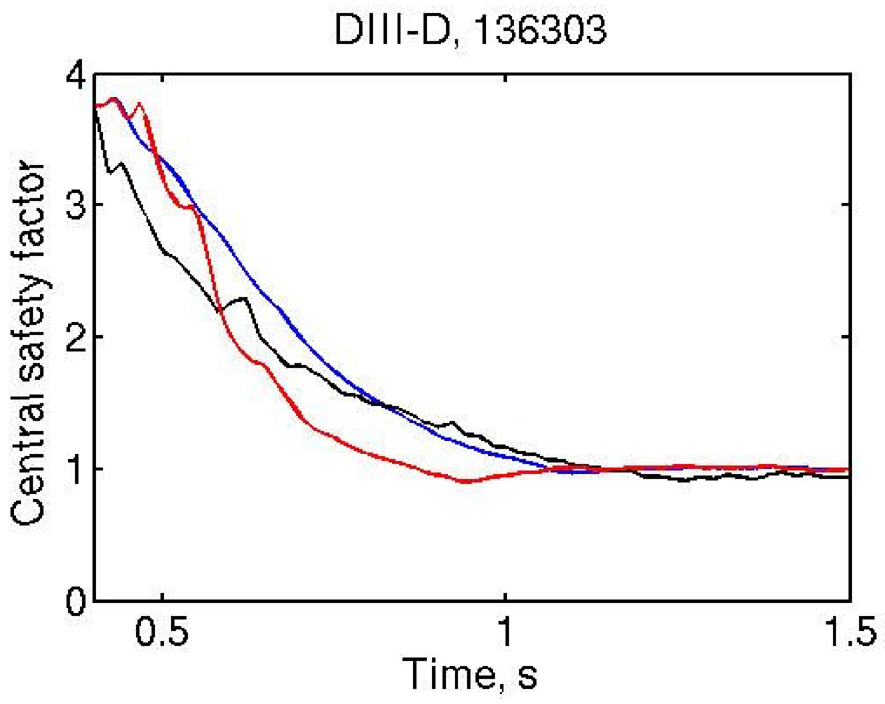


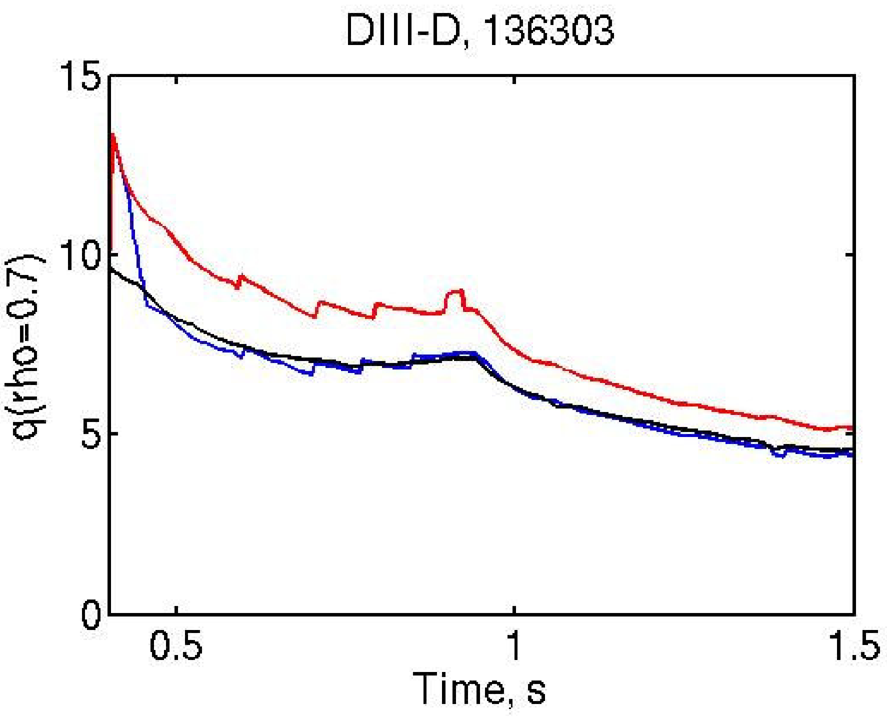


q-profile evolution is consistent with neoclassical conductivity when provided plasma shape is used [similar conclusion in Jackson et al, Phys. Plasmas 2010]

Current diffusion in L-mode discharge (NCLASS, sawtooth constraint on q, measured Te, no beam driven current):

Rgeo is taken from ufile (blue), horizontal shift is adjusted to match plasma volume (red), data (black)

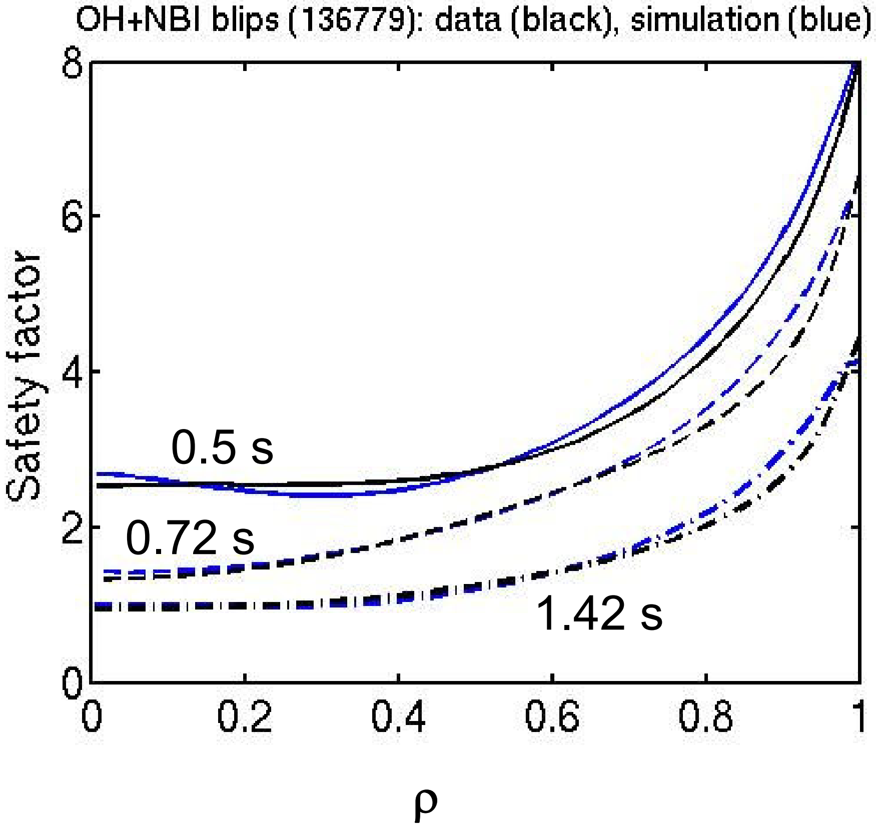


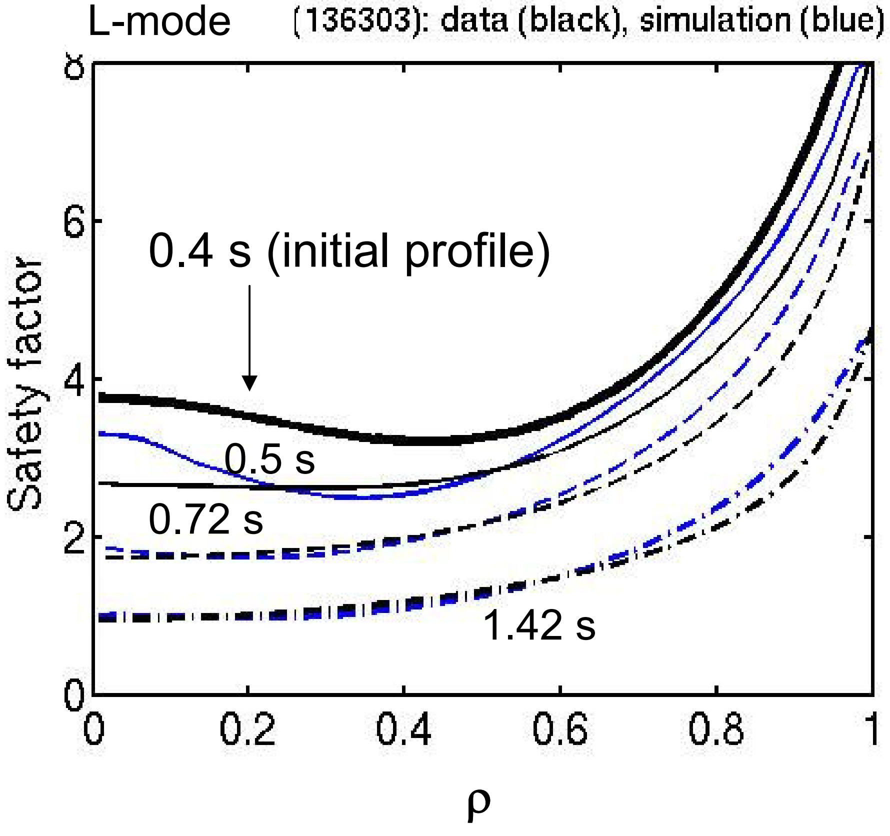


- *q-profile evolution is consistent with neoclassical conductivity after ~0.6 s for reference (provided plasma shape) case. This is different with JET current ramp up discharges*

- *effect of plasma heating: q0 =1 is achieved 220 ms later in L-mode as compared to OH discharge*

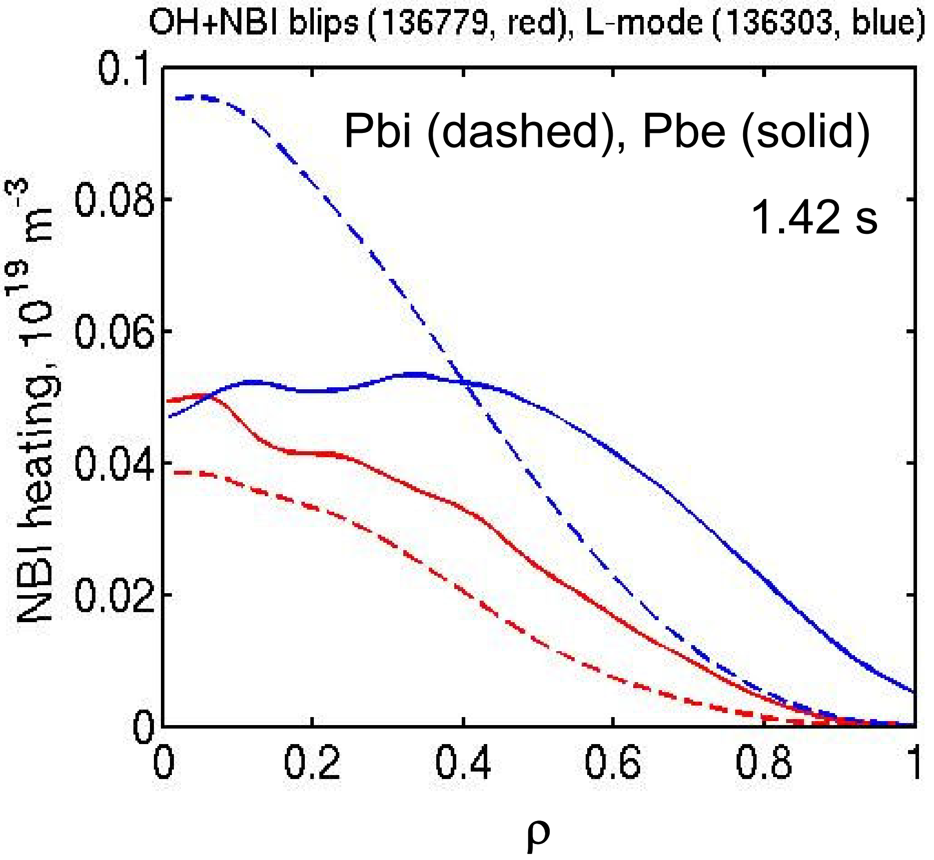
q-profile evolution for reference case (provided plasma shape)





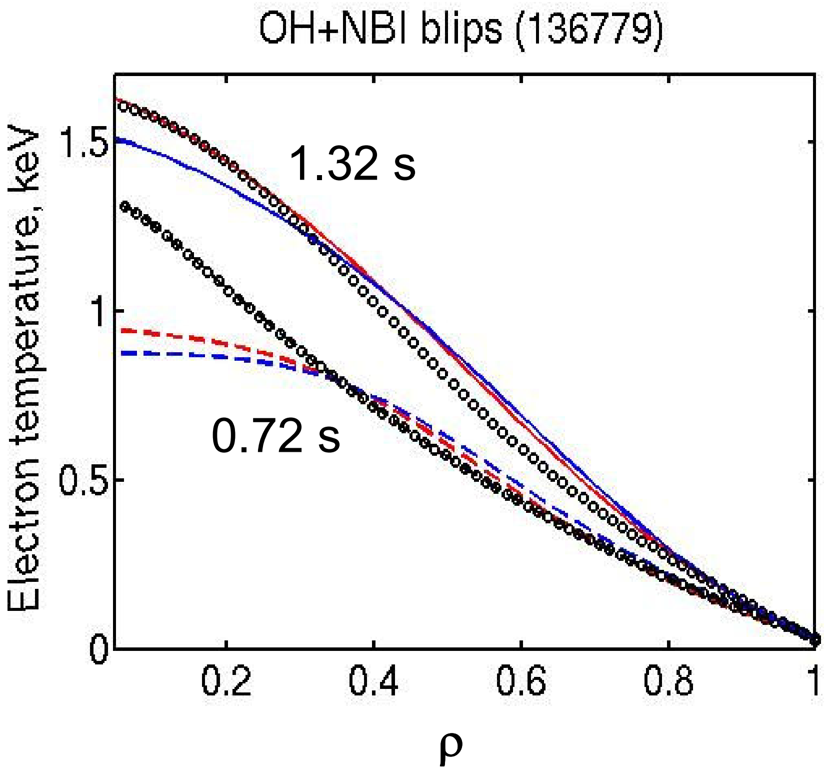
Validation of transport models

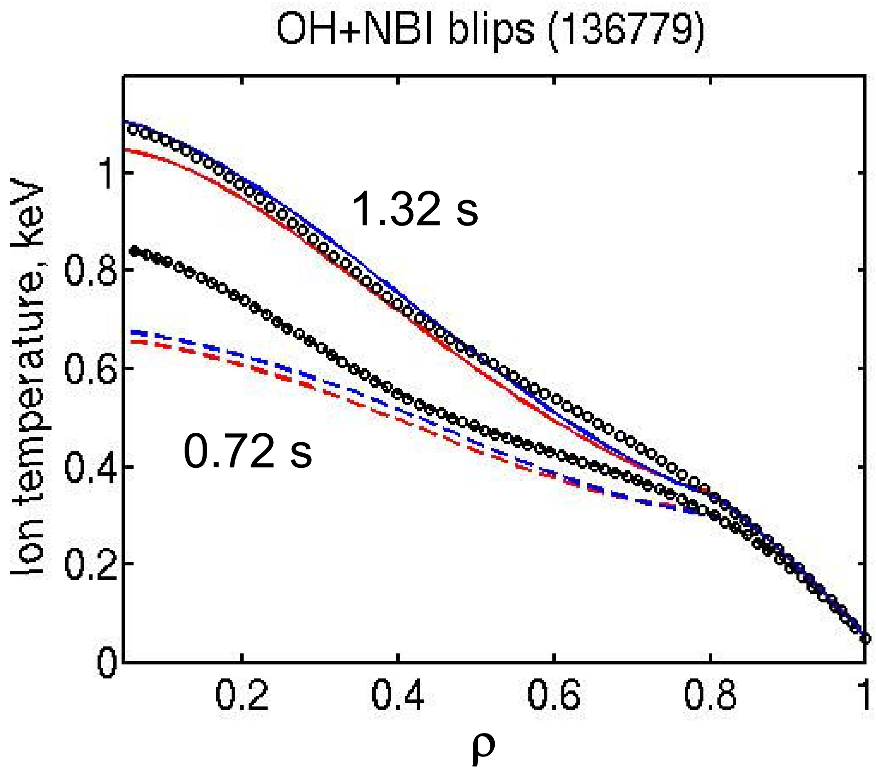
- *Equilibrium, current diffusion (NCLASS), Te and Ti are simulated*
- *Prescribed electron density, carbon is the only impurity, no beam ion density*
- *Measured toroidal rotation*
- *Central NBI heating, broad heating profiles*
- *Bohm-gyroBohm, GLF23 and Coppi-Tang models are tested*



OH discharge: Bohm-gyroBohm model

Data (black), simulations: reference case (blue), adjusted volume (red)





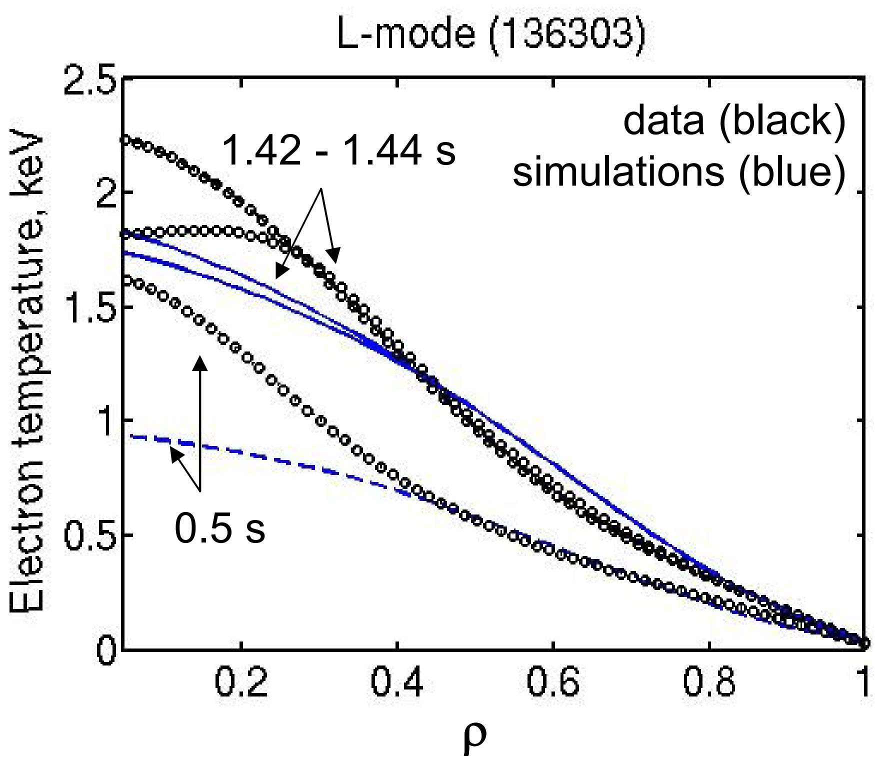
- *Te: under-estimated core temperature during first half of the ramp up, good agreement with the measured profiles later on;*

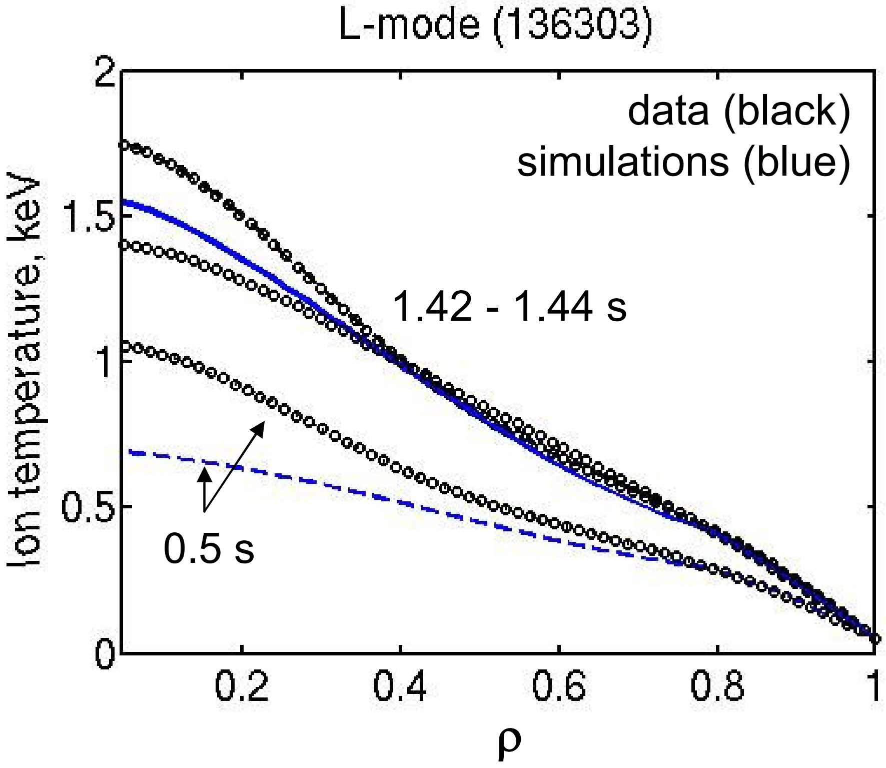
- *Ti : strongly underestimated at the beginning of current ramp up, accurately predicted after 1 s;*

- *weak dependence of predicted temperatures on plasma shape*

L-mode discharge: Bohm-gyroBohm model

Data (black), simulations: reference case (blue)



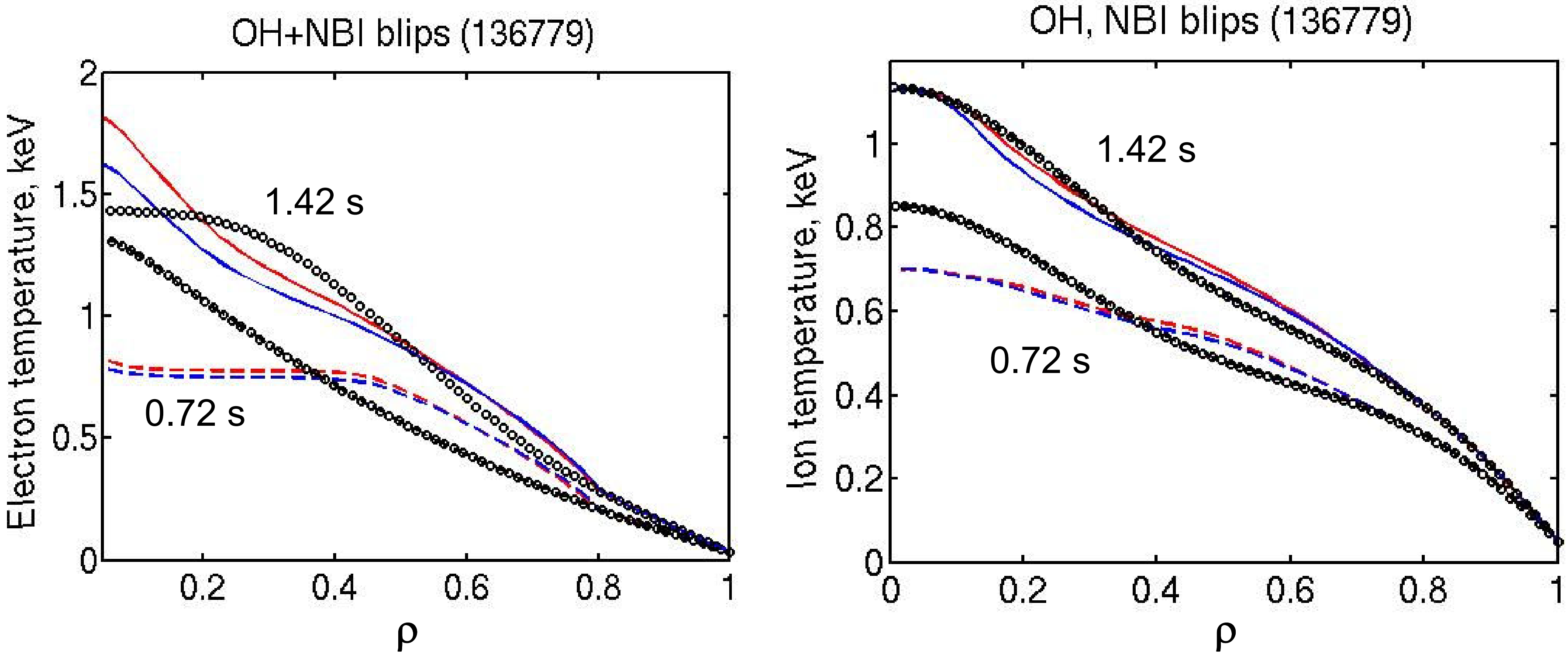


- *Te: under-estimated core temperature, slightly over-estimated Te around ρ = 0.6-0.7 during second half of the ramp up*

- *Ti : strongly underestimated core Ti during first half of the ramp, accurately predicted at the end of the ramp up*

OH discharge: GLF23 model

Data (black), simulations: reference case (blue), adjusted volume (red)



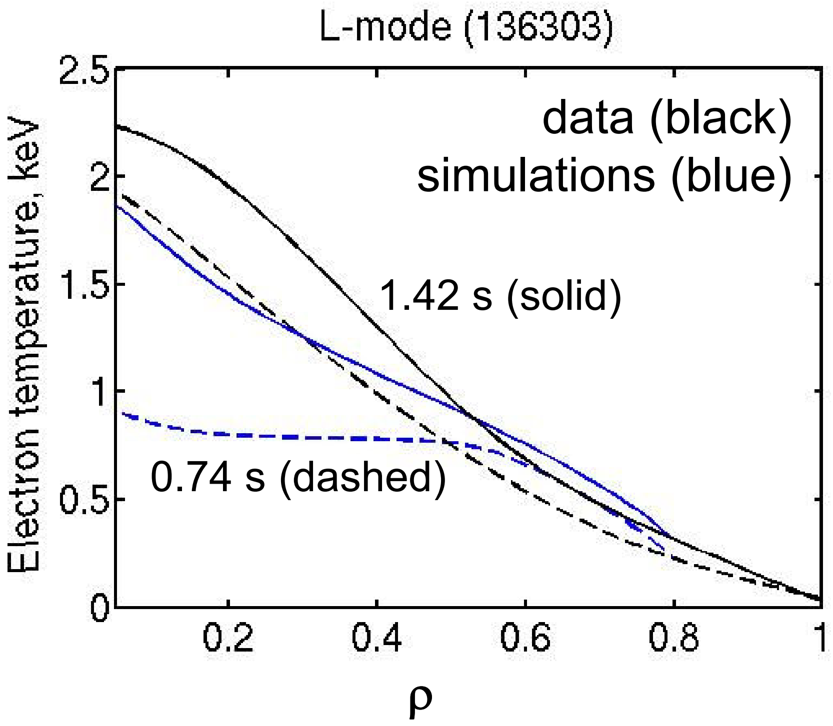
- *under-predicted core Te, large χe in the region of peaked density. Over-predicted Te outside mid-radius;*

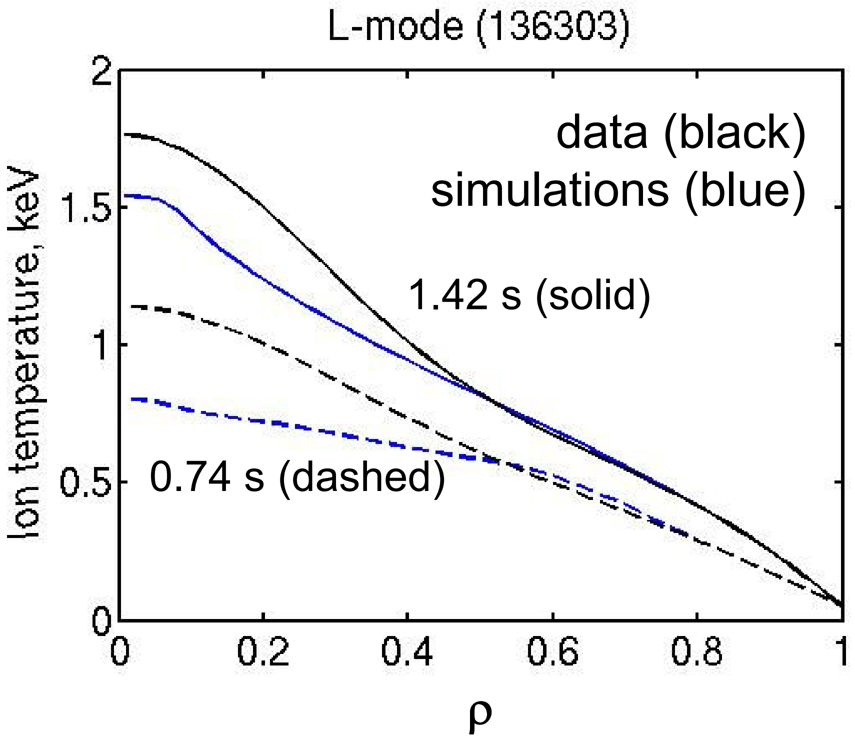
- *more accurate Te prediction during the phase with flat ne;*

- *Ti prediction is relatively accurate outside mid-radius, core temperature is under-predicted during the first half of the current ramp up*

L-mode discharge: GLF23 model

Data (black), simulations: reference case (blue)





- *selected time slices: 0.74 s (peaked n_e) and 1.42 s (flat n_e);*
- *destabilising effect of peaked density – large χe and χi in the region of peaked n_e ($0.2 \le \rho \le 0.4$) – flat temperatures*
- *more accurate prediction during the 2nd half of the ramp up phase (flat n_e), but still under-estimated core temperature*

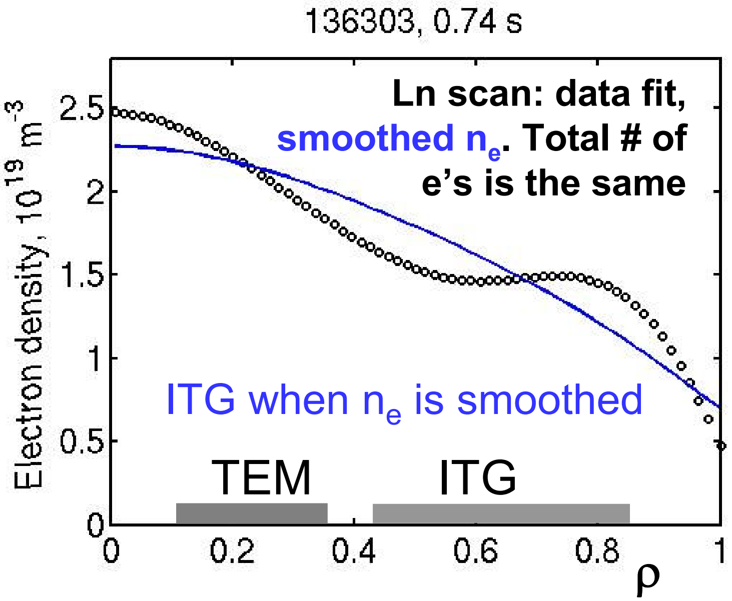
GLF23 prediction: sensitivity study

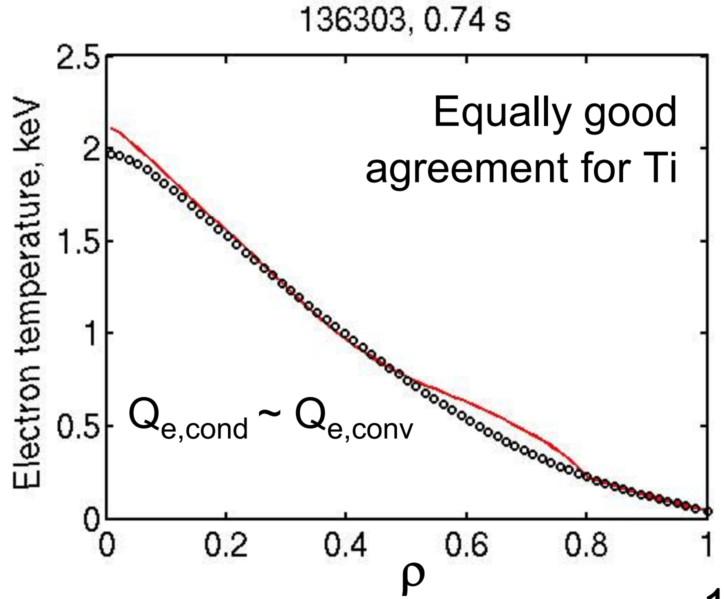
- Turbulence simulations show that α_{ExB} is not a constant. *T_i can be accurately predicted with larger α_{ExB} ~ 4 (T_e is weakly affected)*

- Destabilising effect of peaked density $\Rightarrow$ *R/L_n has been varied from ~2.6 to 1.1 (max. value within $\rho \leq 0.4$), T_e change by ~20% and still under-predicted*

- Stability analysis with GLF23:
(a) measured data: TEM is dominant in the core region (ρ < 0.3-0.4) till ~ 1 s, then - ITG dominant regime, outer part of plasma is always in ITG dominant regime.
(b) TEM dominant plasma core is obtained in modelling with $T_{e0} \sim T_{i0}$ (both are underestimated)

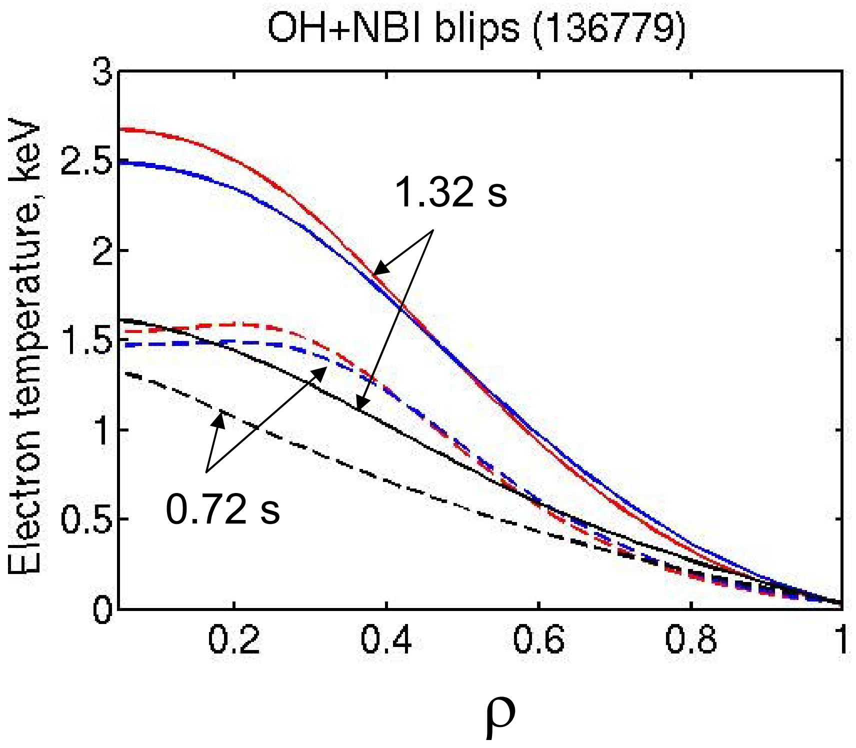
- if pinch is applied – what should be its magnitude:
$Q_{cond,e,I} \sim \chi_{e,i} n_{e,i} \nabla T_{e,i}$, $Q_{conv,e,i} \sim D_{e,i} T_{e,i} \nabla n_{e,i}$, $D_e = 2\chi_{e,GLF}$, $D_i = \chi_{i,GLF}$ – *unrealistically strong assumption*

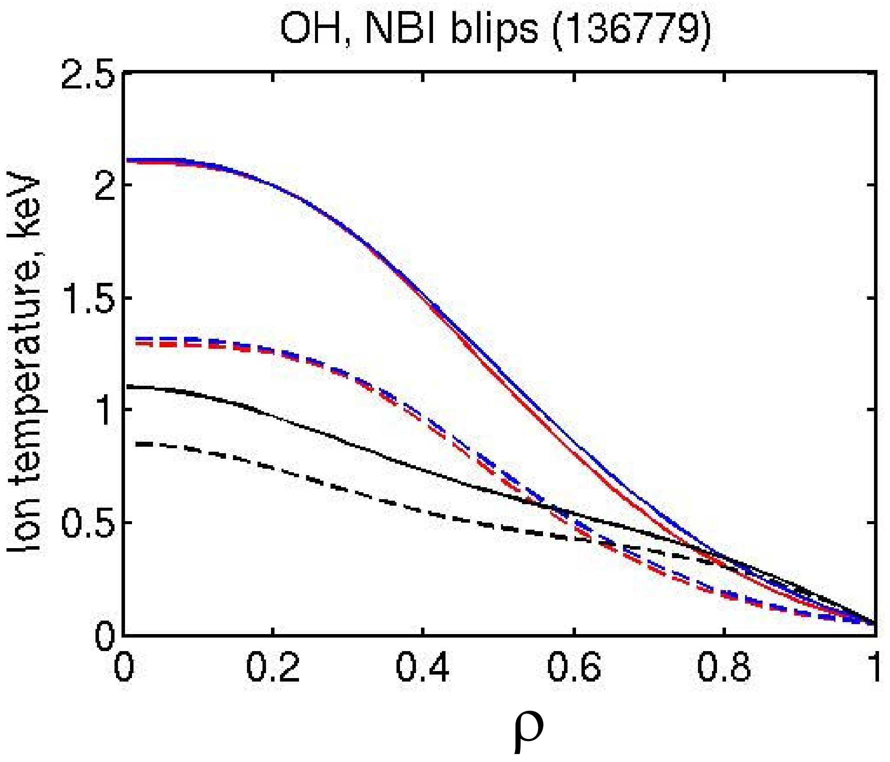




OH discharge with NBI blips: Coppi-Tang model

Data (black), simulations: reference case (blue), adjusted volume (red)





similar discrepancy between measured and simulated temperatures is obtained for L-mode discharge 136303 [similar conclusions to Jackson et al, Phys. Plasmas 2010]

Summary and future work

- Requests to ITPA/DIII-D:
  - *need in complete the dataset (jnbi,nbeam)*
  - *information about the MHD would be useful*

- Preliminary conclusions for low Btor discharges:

  (1) current diffusion is consistent with prediction based on neoclassical resistivity (different with ASTRA&TRANSP simulations for JET current ramp up discharges)

  (2) BgB: under-predicted core Te and Ti during the 1st half of the current ramp up, otherwise its prediction is relatively accurate

  (3) GLF23: - destabilising effect of peaked density;
  - more accurate stability analysis, better model for TEM driven transport (to be discussed with theoreticians?)
  (JET: ITG-driven transport, accurate GLF23 prediction for NBI heated discharge)

  (4) under-predicted core temperatures with BgB and GLF23 models ⇒ stabilising effect of flat q-profile?

  (5) Coppi-Tang model over-predicts the temperatures (similar for JET plasmas)

- Cmod current ramp up data are coming…

- Benchmarking: CT model with CORSICA? GLF23 for momentum transport?