

# Validation of stellarator optimization via extended neoclassical simulations and dedicated experiments

*CIEMAT participation in WP14-S1,  
in collaboration with NIFS and IPP*

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...

## Inter-machine validation study of neoclassical transport modelling in medium- to high-density Stellarator-Heliotron plasmas

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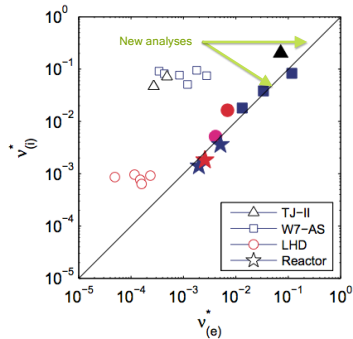
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<sup>3</sup> The National Fusion Laboratory, CIEMAT, EURATOM Association, Madrid, Spain

<sup>4</sup> Princeton Plasma Physics Laboratory, Princeton, NJ, USA

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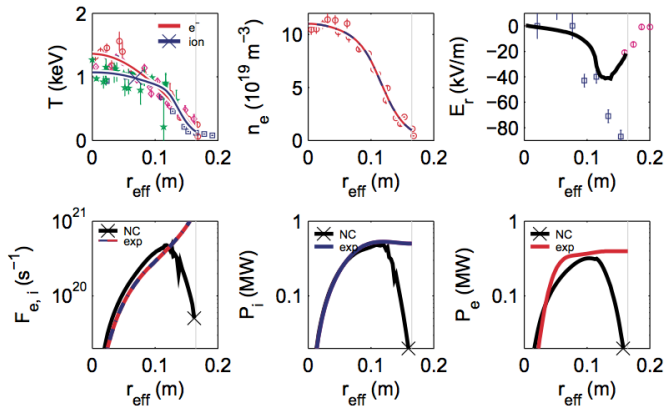
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- Expand database [Arevalo NF 2013, Arevalo NF 2014].
  - $T_i(\rho)$  measured, low  $\nu_i^*$  + not too low  $\nu_e^*$   $\Rightarrow$  ion root.
  - Also interesting: plasmas with high  $n$  (2 NBIs).
- Complement local (DKES) with non-local NC (FORTEC-3D) simulations [Satake ISHW 2013].

Long term goal: support to W7-X and stellarator reactors.

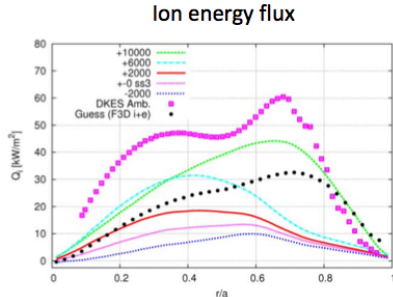
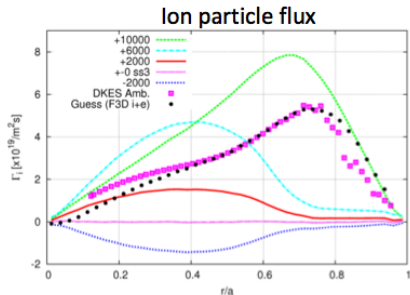
Wendelstein 7-AS (#34609,  $t = 0.3$  s)



**Figure 3.** Transport analysis W7-AS (for #34313 and #34609 see [18]). Open red circles are Thomson scattering data ( $n_e$ ,  $T_e$ ). Magenta diamonds are ECE measurements ( $T_e$ ), blue squares are from CXRS ( $T_i$ ,  $E_r$ ), green stars from NPA ( $T_i$ ) and magenta circles from passive BIV spectroscopy ( $E_r$ ). The grey vertical lines

In previous slide, local NC simulations:

- Good agreement up to  $r/a = 0.5$  but note log. scale  $\Rightarrow$  room for improvement.
- Bad agreement in outer positions. Not necessarily turbulence.



Preliminary results of simulations with FORTEC-3D predict that non-local effects have more impact in  $Q_i$  than in  $\Gamma$ .

- Questions we want to answer (already partially answered):
  - How accurately does NC theory describe radial heat and particle transport in the core?
  - Do non-local NC simulations improve the description (and where)?
  - Is the situation different for particle and heat transport?
- Extend database of discharges (actions 1 and 2):
  - [Arevalo NF 2013, Arevalo NF 2014].
  - low  $\nu_i^*$ , 100\_44\_64 (action 1).
  - high  $n$ , 100\_44\_64, depending on conditioning (action 1).
  - small conf. 101\_30\_60, if 100\_44\_64 is completed (action 2).
  - Other devices, existing discharges if possible (action 2).
- Analyze some of the discharges:
  - Calculate NC local and non-local fluxes (action 3).
  - Calculate experimental fluxes (action 4).

# Action 1, new experiments at TJ-II

Three days in the spring experimental campaign.

Calendario EXPERIMENTOS Febrero-Junio 2014			
Fecha / días	Parámetros de plasma/configuración	Objetivo general	Experimento de referencia y Coordinador Científico (CC) + experimentos satélites + Pilotos
			<b>III. S1/S2</b> VALIDATION OF STELLARATOR OPTIMIZATION VIA EXTENDED NEOCLASSICAL SIMULATIONS AND DEDICATED EXPERIMENTS: <b>S1_VAL</b> (3 sessions)

<b>April</b>			
23	ECRH / NBI	S1_VAL_1 / high density	
24	ECRH / NBI	S1_VAL_2 / collisionality	
<b>May</b>			
6	ECRH / NBI	S1_VAL_3 / S1_IMP_MT (configuration_scan)	

Up to three days in the autumn (october-december) experimental campaign.

# Action 2, dependence on magnetic configuration

- One of the three experimental days of TJ-II.
- Is it possible to expand the database also with other devices (LHD/H-J/HSX)?

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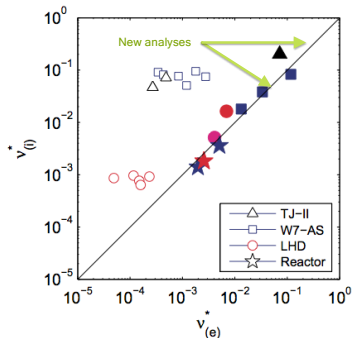
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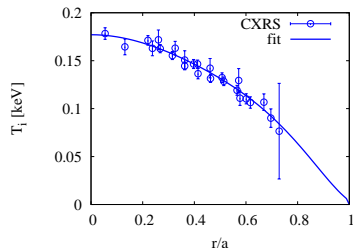
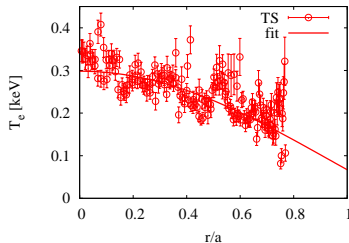
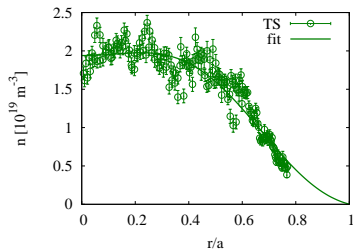
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- Experimental campaigns are tight. Existing discharges?
- WP14-S1 only this year, but there will be WP15-S1 and so on...

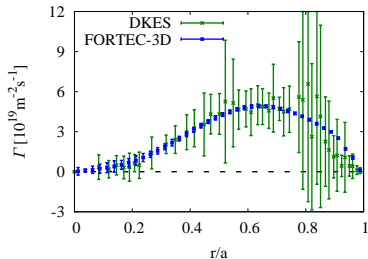
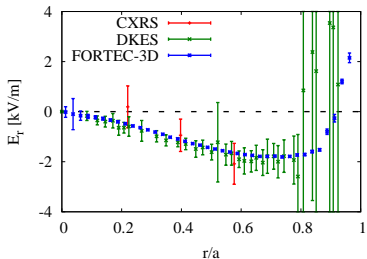
# Actions 3 and 4, very preliminary results



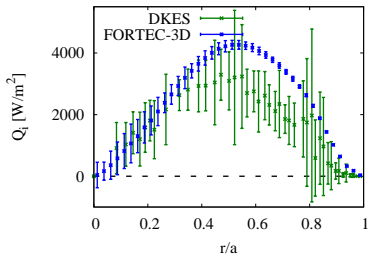
- #25801 from [Arevalo NF 2014]
- Low  $n$  NBI plasma:
  - Not too low  $T_i \Rightarrow \text{low } \nu_i^*$
  - Not too high  $T_e \Rightarrow \text{low } \nu_e^*$  but ion root.
- Extrapolated for  $\rho > 0.8$ .



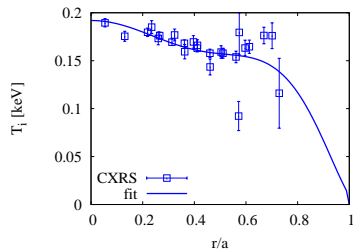
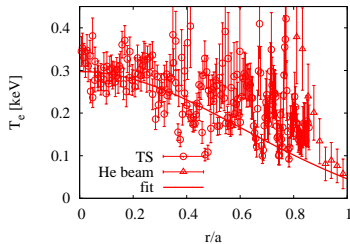
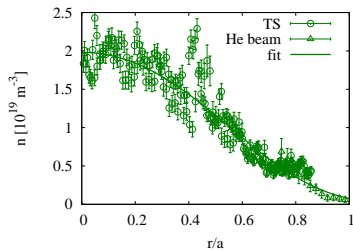
# Actions 3 and 4, very preliminary results



- Good agreement for  $E_r$  and  $\Gamma$ .
- Non-local effects only in  $Q_i(r/a > 0.5)$
- Results are not meaningful for  $r/a > 0.8$ .
- Not suitable for transport balance.

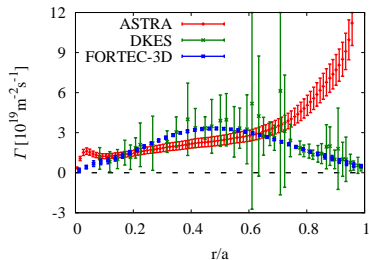
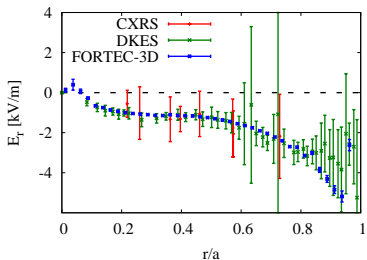


# Actions 3 and 4, very preliminary results

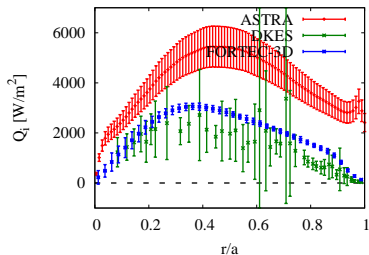


- #28263 from [Arevalo NF 2014]
- Low  $n$  NBI plasma:
  - Not too low  $T_i \Rightarrow$  low  $\nu_i^*$
  - Not too high  $T_e \Rightarrow$  low  $\nu_e^*$  but ion root.
- Only  $T_i$  extrapolated for  $\rho > 0.8$ .

# Actions 3 and 4, very preliminary results



- Good agreement for  $E_r$  and  $\Gamma$  up to  $\rho=0.8$ .
- Slight underestimation of  $Q_i$ ? Simplified errors in exp. fluxes.
- Non-local effects only in  $Q_i(r/a > 0.5)$
- $E_r > 0$  at the core?
- Peak of  $\Gamma_{exp}$  at the core?



Time constraints:

- February: 13th CWGM in Kyoto. Visit to NIFS the week after.
- June: S Satake will probably visit CIEMAT.
- End of June: 42th EPS in Berlin (and short 14th CWGM?).

With these constraints:

- Experiments at TJ-II before the EPS conference, spring campaign (actions 1 and 2). Already planned.
- Search for other configurations at CWGM (action 2, ongoing).
- Perform simulations as soon as the inputs (well-diagnosed discharges) are ready (actions 3 and 4).
- Discuss/present preliminary (but not too far from definitive) results during Satake's visit and EPS.
- Other experiments and simulations (those of other configurations?, those of TJ-II not completed in spring) after the EPS (as early as possible in the autumn campaign).

W7-X will be closer to reactor-relevant collisionalities  $\Rightarrow$   
 $\Rightarrow$  must perform validation of NC transport for W7-X discharges.

Would it be interesting to start already with:

- non-local neoclassical simulations for plasmas of W7-X based on predictive simulations?
- neoclassical simulations for reactor-size stellarators/heliotrons?
- in particular, comparison of local and non-local NC transport of reactor-size Helias and Heliotron devices?