EFDA
EUROPEAN FUSION DEVELOPMENT AGREEMENT
Task Force
INTEGRATED TOKAMAK MODELLING

INTEGRATED SCENARIO MODELLING
Summary of ISM group activities 2013

Irina Voitsekhovitch, Jeronimo Garcia and ITER Scenario Modelling group

TF Leader : G. Falchetto
Deputies: R. Coelho, D. Coster
EFDA CSU Contact Person: D. Kalupin

ISM 2013 participants

ISM group: ***J. Garcia, B. Baiocchi, Yu. Baranov, E. Barbato, V. Basiuk, J. Bizarro, T. Bolzonella, E. Fable, J. Ferreira, A. Figueiredo, L. Garzotti, G.M.D. Hogeweij, I. Ivanova-Stanik, F. Koechl, X. Litaudon, A. Merle, E. Militello-Asp, D. Moreau, F. Nabais, F. Nave, S. Nowak, O. Sauter, P. Strand, R. Stankiewicz, P. Siren, G. Telesca, J. Urban, I. Voitsekhovitch***

ISM contributors: ***J. Citrin, S. Moradi, F. Felici, J. van Dongen***

JET: ***E. Joffrin, J. Hobirk***

IOS ITPA: ***G. Sips***

IO: ***A. Polevoi, S.-H. Kim, S. Pinches, A. Loarte, J. Snipes***

Outline

1) ISM-2013: participants, meetings

2) ACT1: Support to the validation and physics application of the ETS and ITM tools

3) ACT2: Developing and validating plasma scenarios simulations for existing devices

4) ACT3: Support to predictive scenario modelling for future devices (e.g. JT-60SA, ITER, DEMO)

5) List of publications

ISM 2013: brief summary

- **28+ participants**
- **Two ISM working sessions (March and June 2013) and remaining session in December 2013**
- **8 remote meetings**
- **3 papers published in 2013, 4 papers prepared for publications**
- **Conferences and meetings: EPS conference (4), H-mode Workshop (2), 2 IOS ITPA group meetings (5), PET conference (1)**
- **Collaboration with IO, IOS & TC ITPA groups, JET experimentalist**

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ACT1: Support to the validation and physics application of the ETS and ITM tools

T1. Benchmarking of new modules integrated within ETS workflows, following the ETS development (in collaboration with EDRG, IMP3, IMP4-ACT4 and IMP5-ACT1)

Benchmarking was not requested in 2013. Depending on the ETS status after this Code camp benchmarking case for neutral model (EIRENE/JETTO) can be produced during the 3rd ISM WS (F. Nave, I. Ivanova-Stanik)

ACT1: Support to the validation and physics application of the ETS and ITM tools

T2. ETS validation and application of ITM workflows to physics studies:

a. Integrated modelling of ITER scenarios with ETS workflows, based on the existing scenario developed with CRONOS, JETTO and ASTRA – MHD stability, core turbulence with dedicated ITM workflows (in collaboration with IMP12, IMP3, IMP4 and IMP5). **Scenarios provided in 2012, Bruce has been using for turbulence simulations**

b. Effect of NTM on transport and confinement in Hybrid Scenarios. Application of the ETS workflows including the NTM module to either ASDEX-Upgrade or ITER discharges: estimation of island width (in collaboration with IMP12-ACT1, IMP3-ACT1)

c. Core impurity transport in ASDEX-Upgrade in L mode as well as baseline ELMy discharges for JET with the new Be/W ITER like wall and ASDEX-Upgrade with W wall (in collaboration with IMP3-ACT1). Comparison of simulated radiation profile with experiments.

d. Self-consistent (Te, Ti, ne, j) predictive modelling for JET plasmas with the ETS – increase of the database, particle transport

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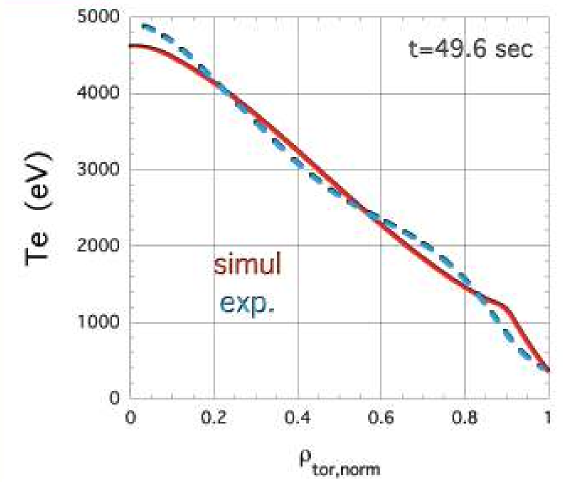
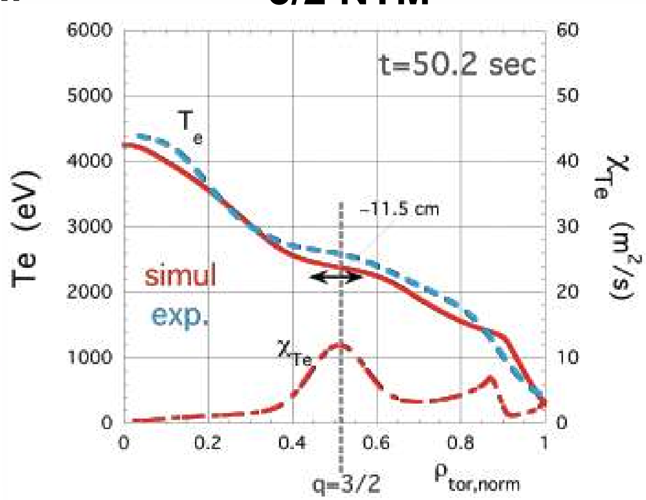
ACT1: Support to the validation and physics application of the ETS and ITM tools

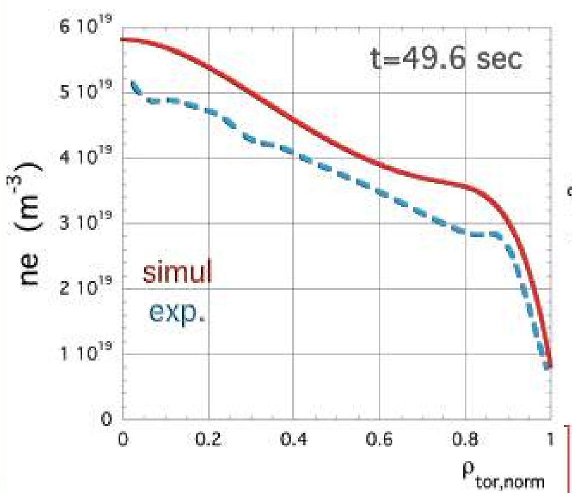
T2b. Effect of NTM on transport and confinement in Hybrid Scenarios (S. Nowak, O. Sauter, V. Basiuk, P. Huynh, A. Merle, 3rd ITM CC, July 2013)

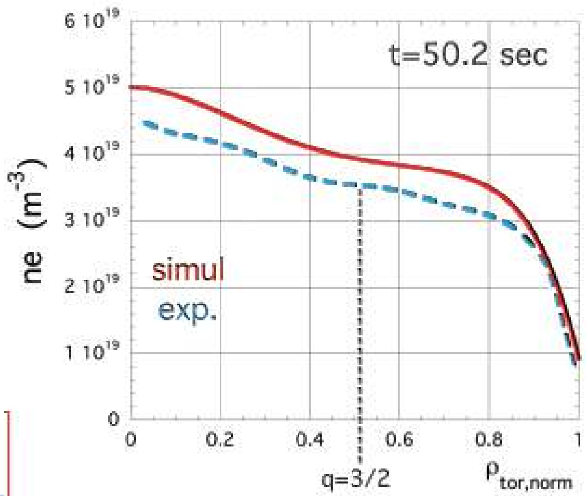
JET 76791, before NTM



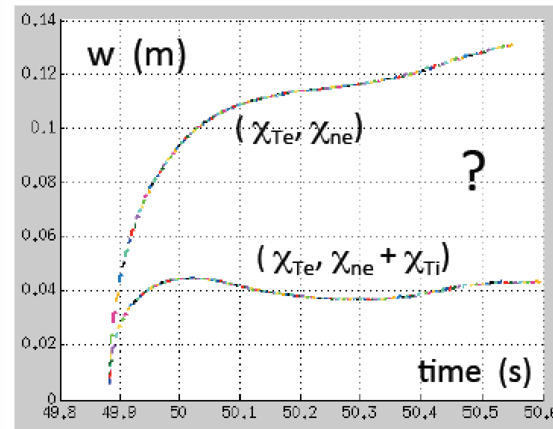
3/2 NTM







Next steps



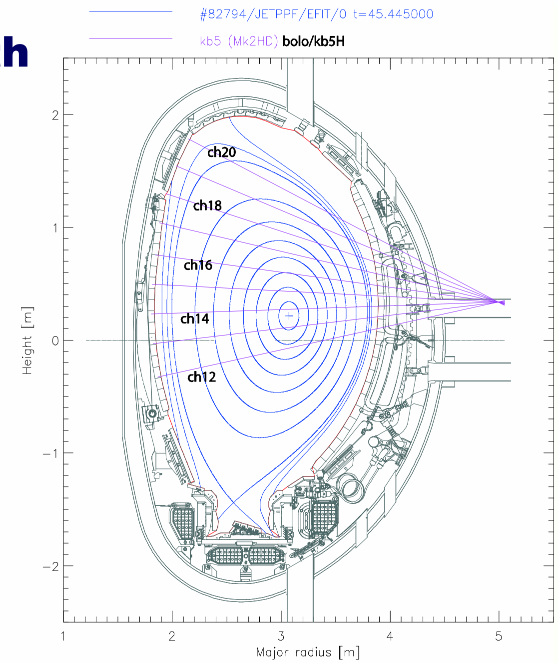
Remaining work:

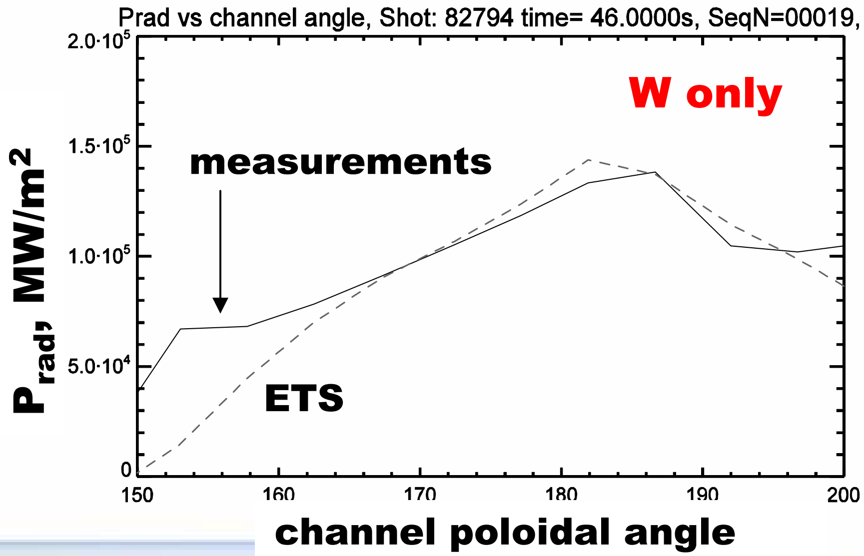
- NTM amplitude drops when Ti is simulated, understanding of the NTM effects on Ti
- estimation of NTM effect on thermal energy
- application to other JET as well as AUG discharges

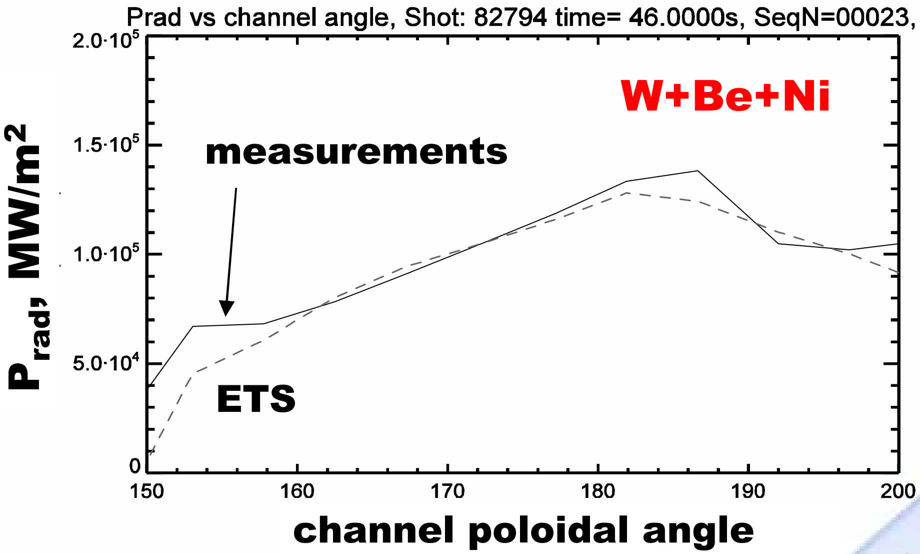
ACT1: Support to the validation and physics application of the ETS and ITM tools

T2c. Core impurity transport in JET hybrid discharge with ILW. Comparison of simulated radiation profile with measurements [I. Ivanova-Stanik, Yu. Baranov, J. Ferreira, D. Kalupin, 1st ISM WS 2013]

- *simulated impurity, fixed plasma parameters (ETS)*
- *adjusted diffusion ($2D_{BgB}$+2.5 m/s), pinch (V_W=5 m/s, V_{Be}=3.5 m/s, V_{Ni}=4 m/s) and boundary densities to match total Prad and central line averaged Zeff. Ni concentration is measured*
- *JET scripts are used to simulate the radiation along the bolometer lines of sight*







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ACT1: Support to the validation and physics application of the ETS and ITM tools

T2d. Self-consistent (Te, Ti, nD, j, nC) predictive modelling for JET plasmas with the ETS (A.C.A. Figueiredo et al, EPS 2013)

- JET 79635 (P_{NBI}=6MW, $n_e=3\times10^{19}$ m^{-3}) & 77922 (P_{NBI}=18 MW, ne=6×10^{19} m^{-3})

- BgB + NCLASS for thermal & particle transport (Garzotti et al EPS 2012, S=2), same carbon and deuterium transport

What is needed:

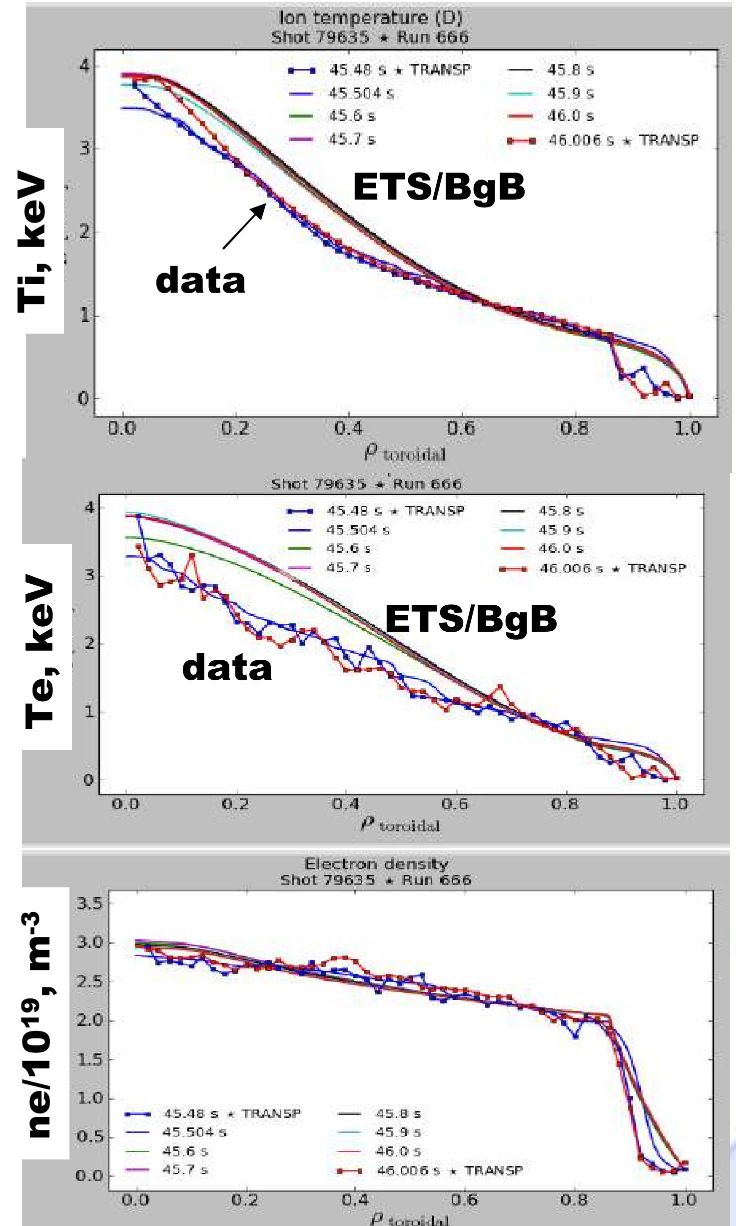
- Fast ion density (different species) to be included properly (pb. with NCLASS, convection in temperature eqs., e-i collisions, equilibrium)

- impurity neoclassical transport:

⇒ prescribed D(r) and V(r) (eg., computed with NCLASS/TRANSP)

⇒ NCLASS (work with Vincent in progress)

⇒ NEOART (spiky, smoothing of input profiles?)



ACT2: Interpretative and predictive integrated scenario modelling on existing devices

1. **Modelling of density evolution self-consistently with current diffusion and temperatures, validation of first principle transport models (GLF23, TGLF, QualiKiz). Stability analysis and transport modelling with QualiKiz code.**

2. **Comparison and modelling of JT-60U and JET plasmas in typical operational domains. Performance and characteristics of the JET and JT-60U plasmas.**

3. **Comparison of current diffusion, transport and confinement in JET C and ILW discharges**

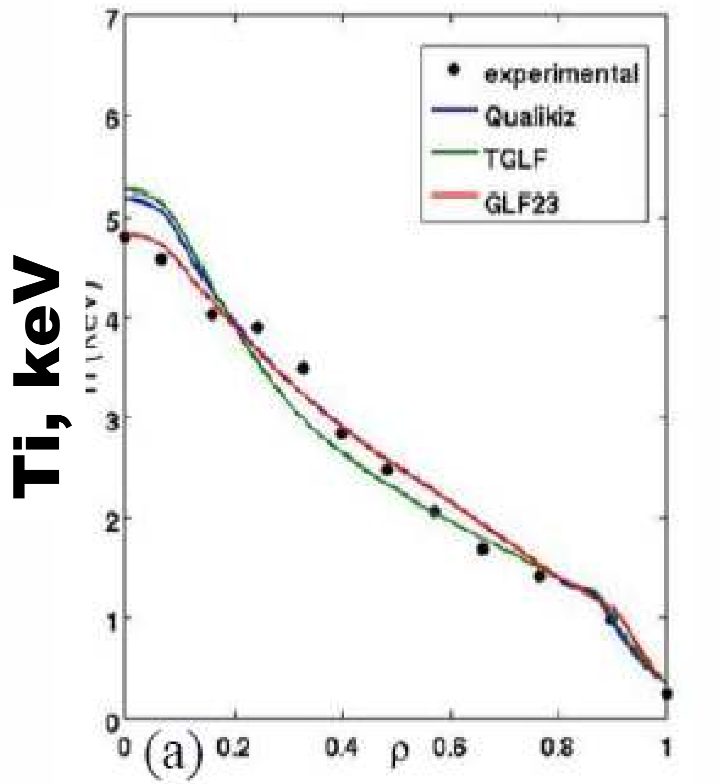
4. **Current ramp down modelling**

5. **Pedestal - SOL modeling for JET ILW discharges (continuation of 2012 task, presented at EPS 2013)**

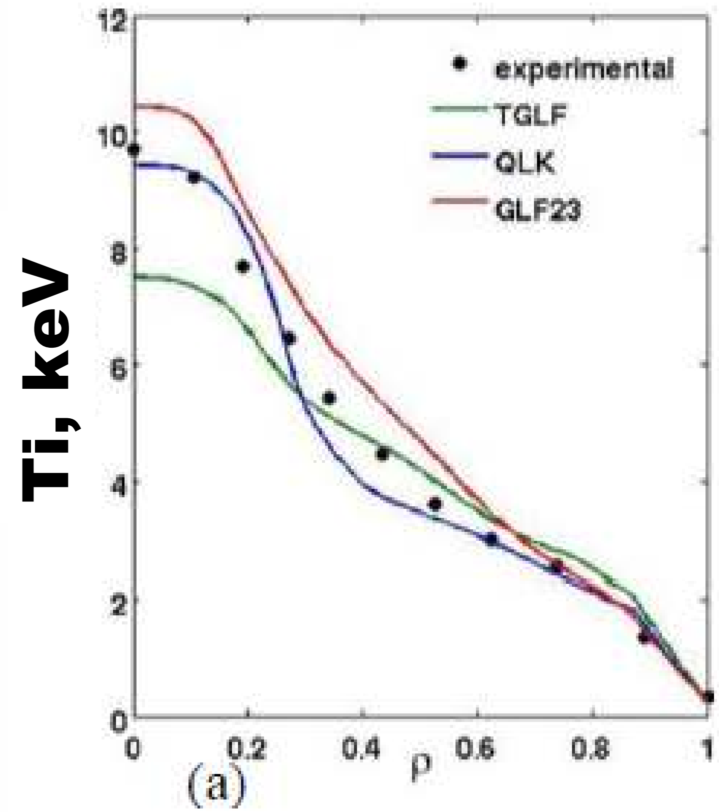
ACT2: validation of first principle transport models (GLF23, TGLF, QualiKiz)

B. Baiocchi et al, EPS 2013

JET H-mode discharge (73344)



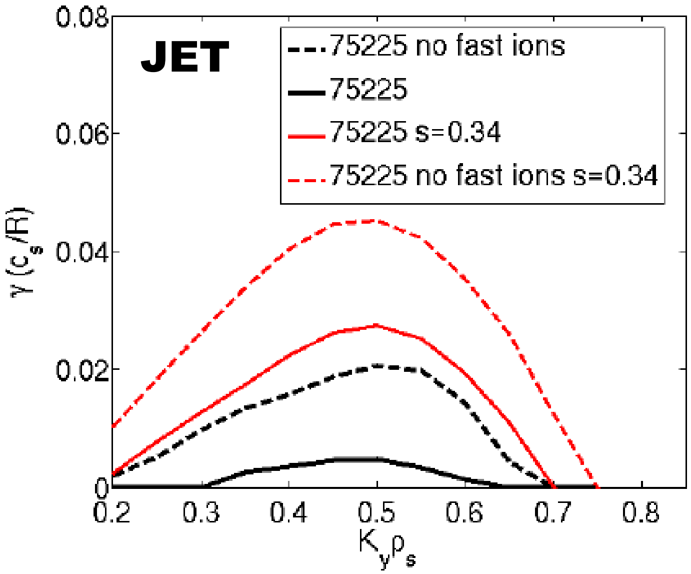
JET hybrid scenario (75225)

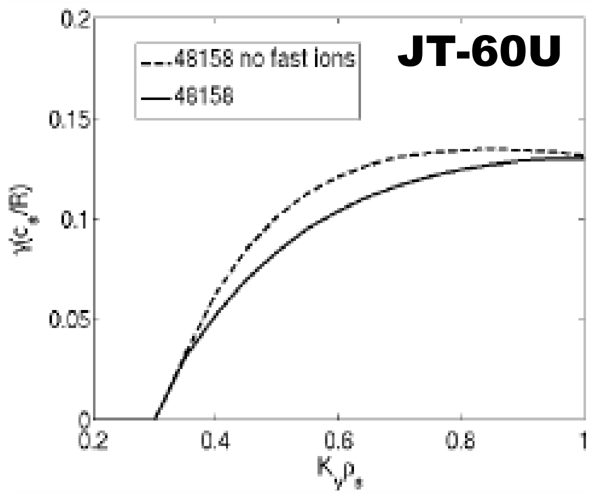


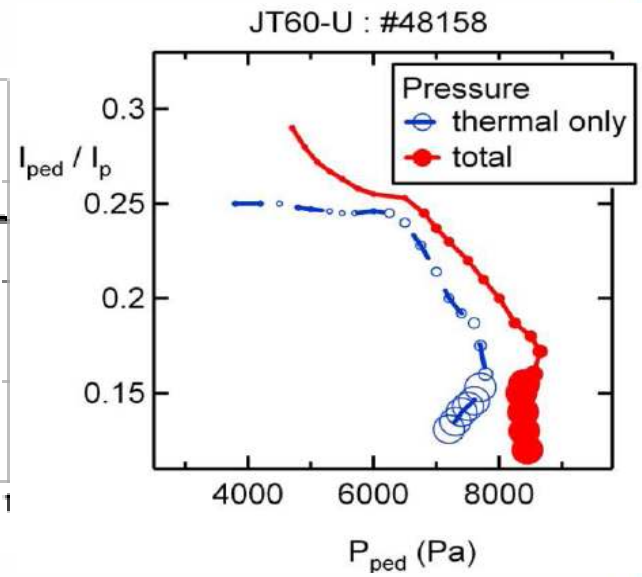
Different models give similar prediction for H-mode, but diverges in hybrid scenario

ACT2: Comparison and modelling of JT-60U and JET plasmas in typical operational domains

J. Garcia et al, IOS ITPA and 14th H-mode workshop, 2013







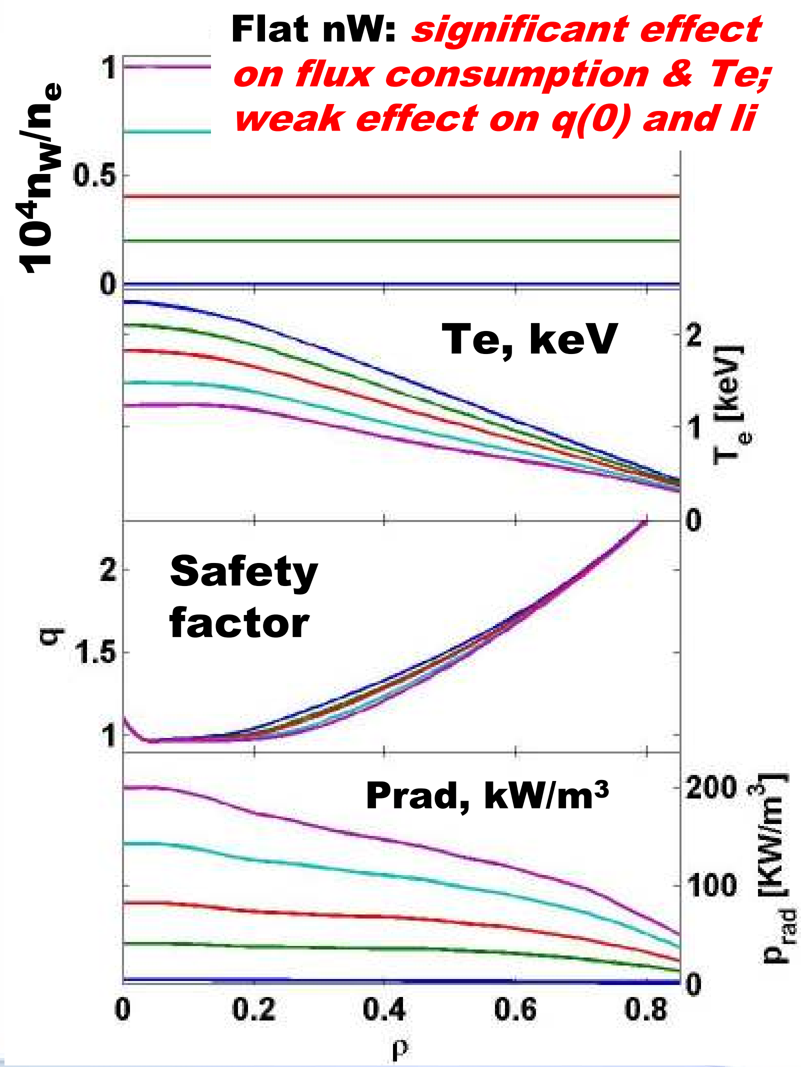
- *Gyrokinetic (GENE) and ideal MHD (MISHKA) analysis: fast ions are important for turbulence reduction and edge stability in AS*

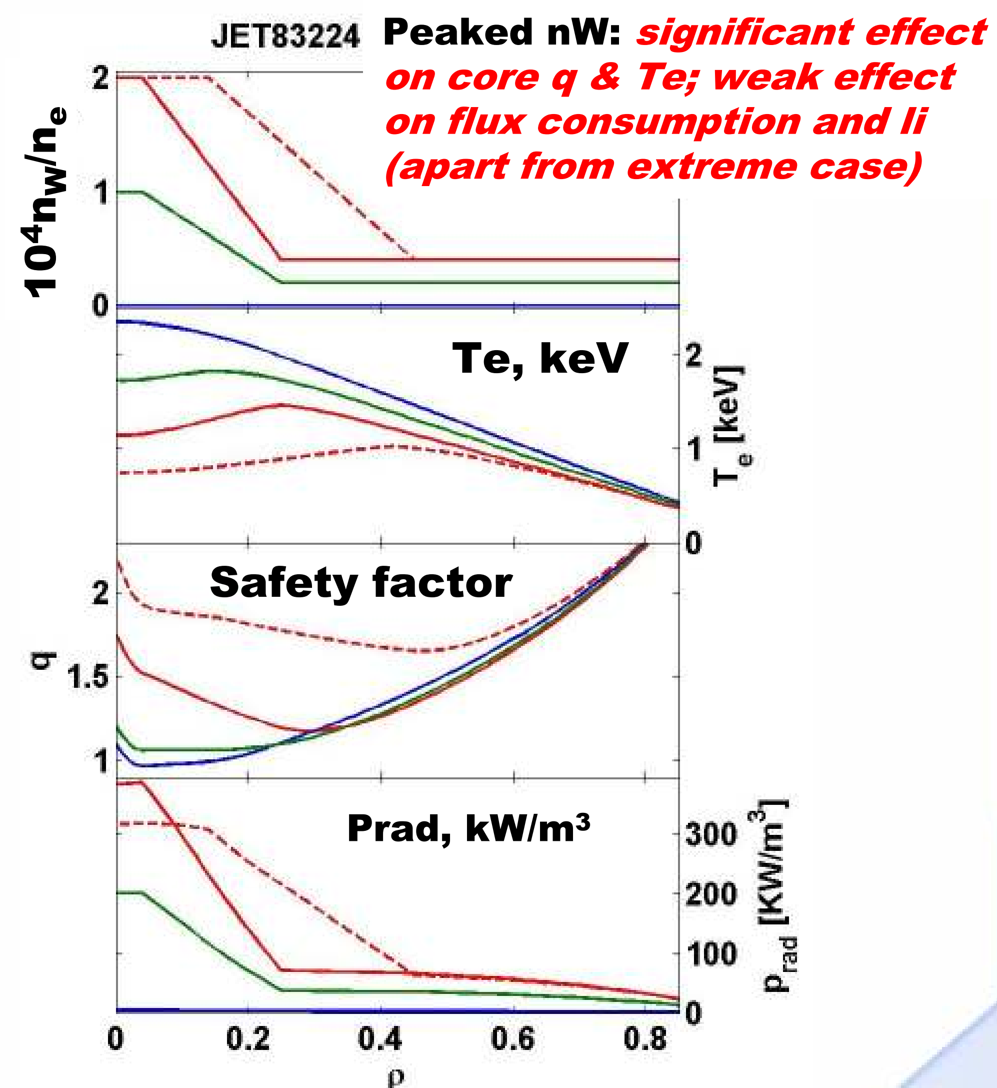
- *Different turbulence regimes: ITG (JET), ITG and TEM coexist due to large density peaking (JT-60U)*

- *Thermal transport: GLF23 good for H-mode (JET&JT-60U) as ITG dominates. Impact of rotation and TEM are overestimated by GLF23 in advanced regimes. CDBM is more appropriate. Core particle transport is well predicted with GLF23*

ACT2: Comparison of current diffusion in JET C and ILW discharges

Effect of n_W profile on the current ramp up scenario [G.M.D. Hogeweij et al, 14th H-mode workshop, 2013]





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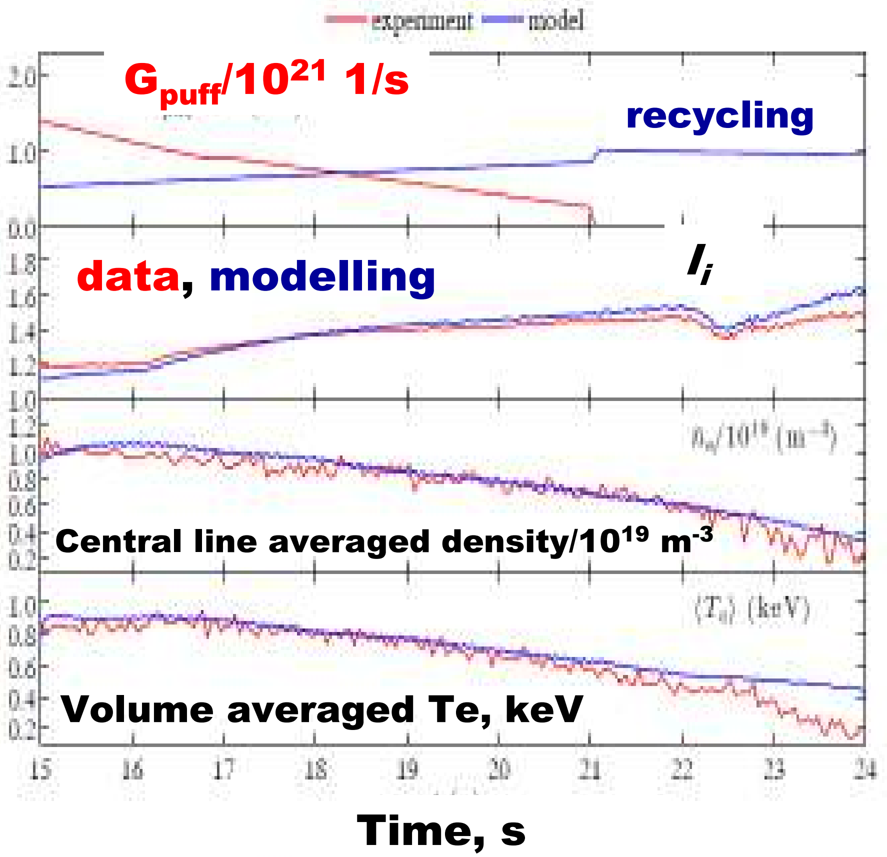
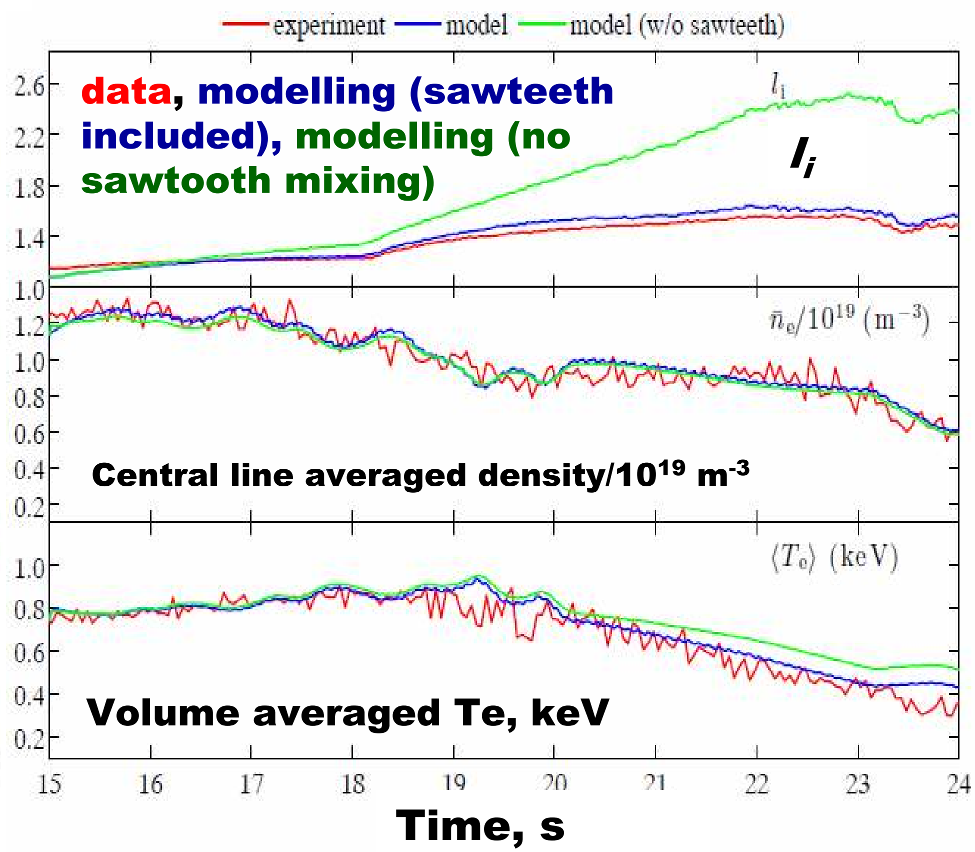
ACT2: OH current ramp down modelling for JET

J. Bizarro et al, submitted to Nucl. Fusion





ne and Te are well predicted with Bohm-gyroBohm model and adjusted recycling

Sawteeth are important during the current ramp down strongly reducing li

ACT3: Support to predictive scenario modelling for future devices (e.g. JT-60SA, ITER, DEMO)

1. **Current diffusion and transport modelling for ITER hybrid current ramp up (effect of W)**
2. **Predictive density modelling with first principle models for ITER, addressing the density peaking and impurity effects**
3. **ITER scenario modelling with METIS (operational domain ...) including simulation of the real time control of the fusion burn.**
4. **Expansion of the operational domain of ITER hybrid scenario with q on-axis below one by controlling the sawtooth period**
5. **1D JT-60SA scenario modelling: implementation of the JT-60SA H&CD configuration (NBI, ECRH) in EU transport codes. Predictive scenario modelling with transport models validated in ISM-ACT2.**
6. **DEMO modelling using ITM Kepler workflows, in coordination with EFDA**

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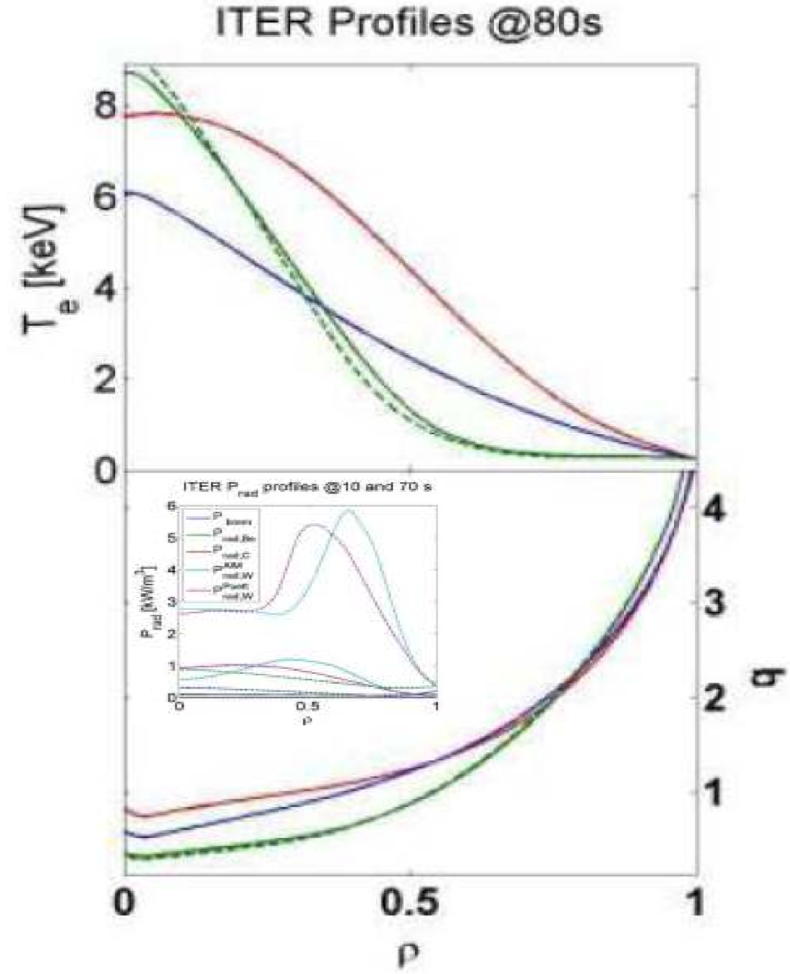
ACT3: Current diffusion and transport modelling for ITER hybrid current ramp up – effect of W

G.M.D. Hogeweij

- OH current ramp up to 12 MA in 80 s
- Bohm-gyroBohm thermal transport, prescribed ne=0.25n_{GW}
- Flat Zeff, scan of W concentration

Results:

- shrink of plasma column when nW/ne $\geq 10^{-4}$ due to off-axis radiation
- peaked Te leads to faster drop of q0
- too high l_i (up to 1.6)
- extra flux consumption (up to 40 Vs)
- off-axis ECRH (ρ = 0.4-0.6) applied between 30 and 50 s compensate W radiation and restores safe ramp up parameters



Blue: Be impurity only
Green: Be & nW/ne=10^{-4}
Red: Be & nW/ne=10^{-4}, ECRH

ACT3: Self-consistent core-SOL-divertor-impurity simulations for ITER

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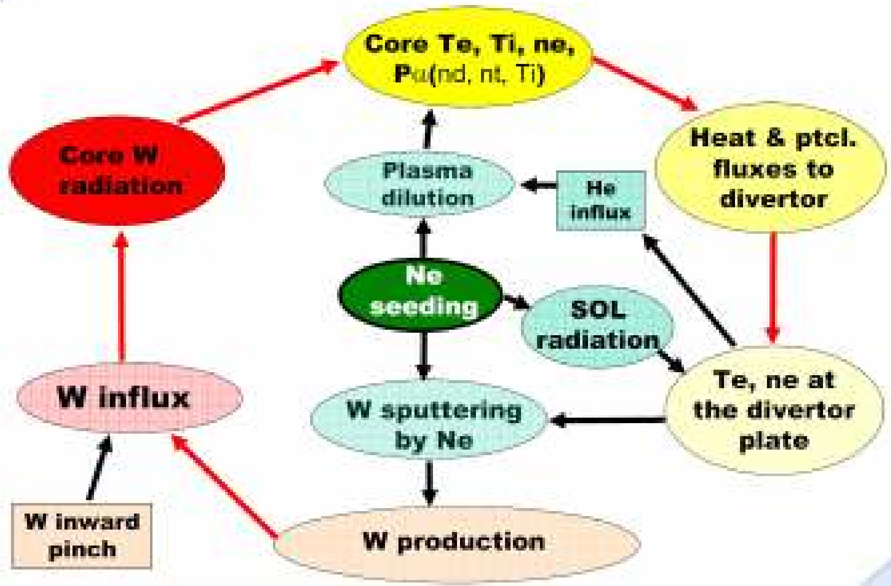
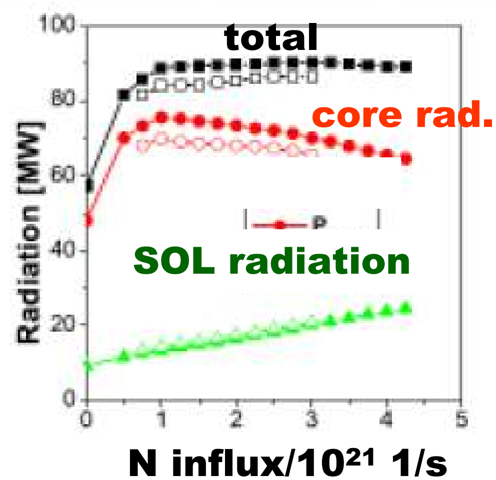
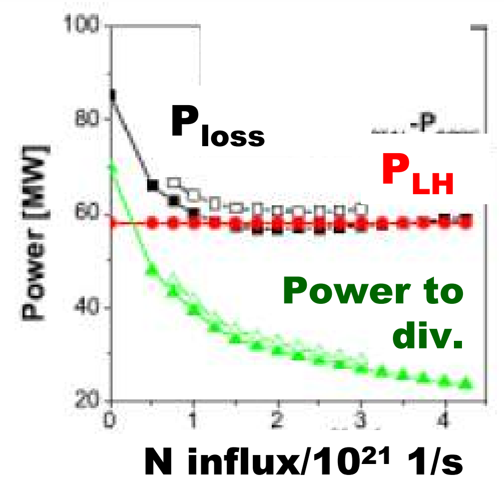
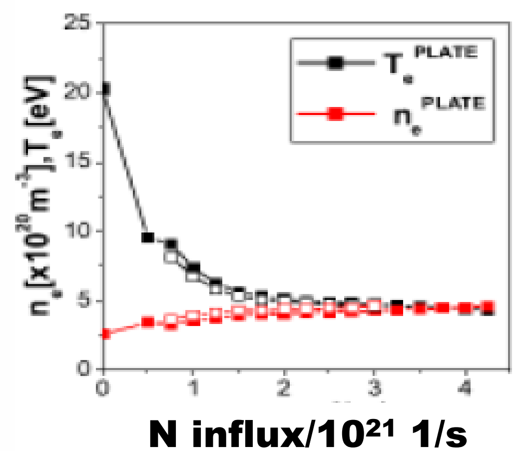
I. Ivanova-Stanik, F. Koechl, et al, PET 2013







- Iterative JETTO (ASTRA) GLF23 – COREDIV simulations
- medium density H-mode with too high divertor loads ⇒ impurities radiating in SOL
- N seeding: narrow/no operational window: acceptable divertor heat loads, Ploss at/below the H-mode power threshold
- high density H-mode is sensitive to core transport model (no H-mode operation with GLF23, while H-mode is achieved with H_{98}-based model)



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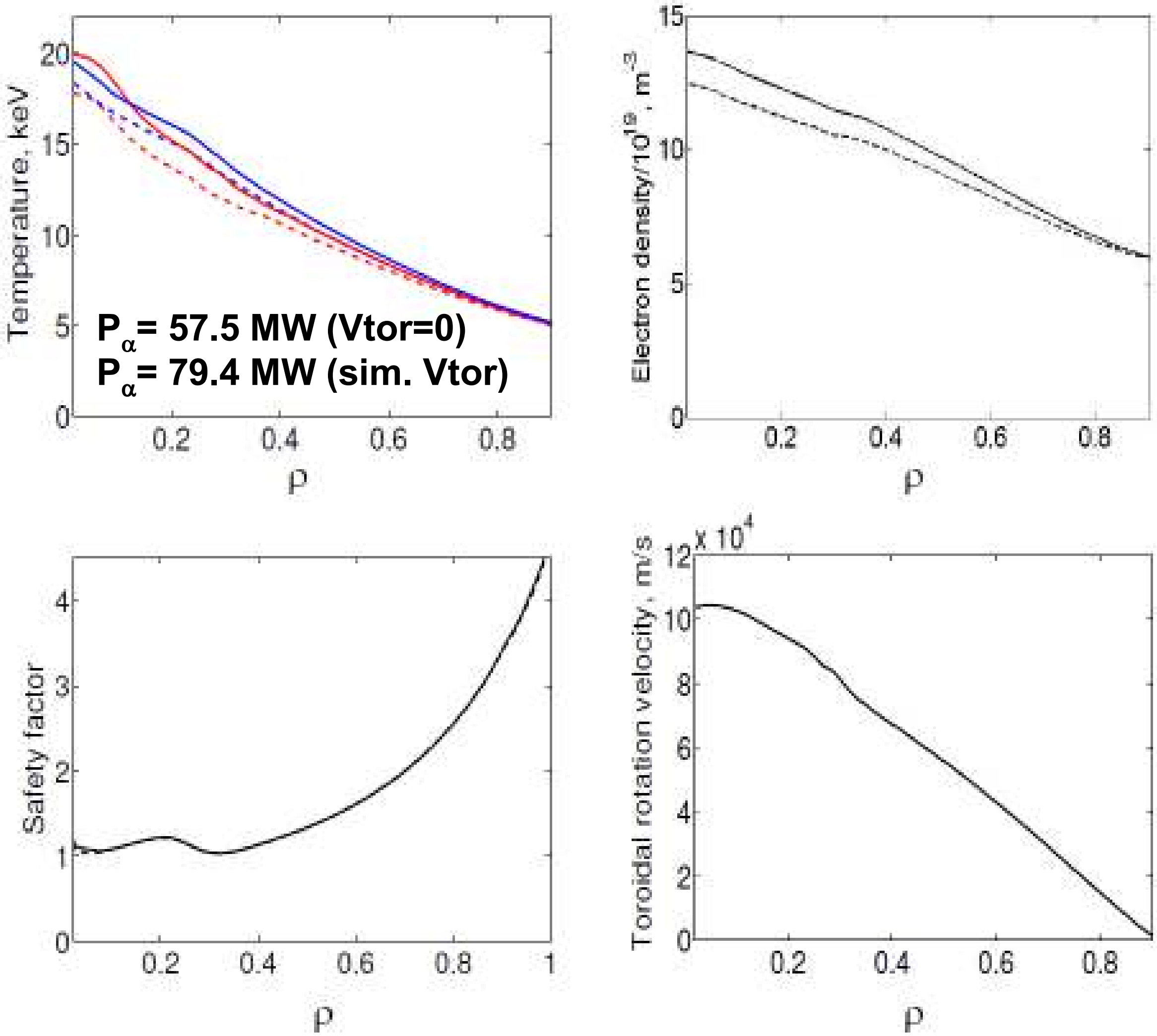
ACT3: four-field modelling of ITER hybrid scenario

I. Voitsekhovitch, et al, paper submitted to JET Pinboard

Stationary profiles obtained for ITER HS with optimised heat mix: 33 MW of NBI and 37 MW of ECCD



- self-consistent simulations of Te, Ti, nD, Vtor, current density, NBI

- GLF23 settings (Pr, $\alpha_E=\gamma_{max}/\gamma_{ExB}$ validated in JET hybrid discharges with different parameters

- **Q=4.2 with Vtor=0**

- **Q=5.8 with Pr=0.3 αE=0.9** (based on JET 75225, low ne)

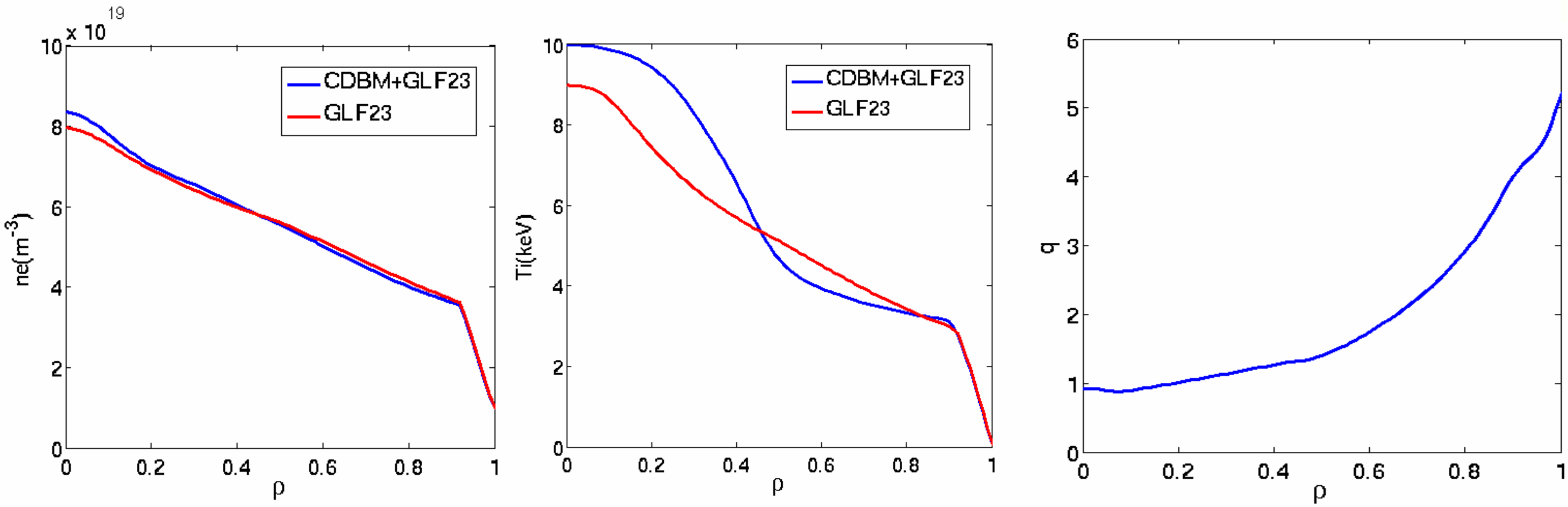
- **Q=4.8 with Pr=0.6, α_E=0.6** (based on JET 77922, medium ne)

- **Q increases by 12% due to βe stabilisation**

- **effect of pedestal: T_{ped} >4.25 keV to get Q > 5 with Pr=0.3 and α_E=0.9**

JT-60SA scenarios with validated transport models validated

J. Garcia, et al, 14th H-mode Workshop, Japan



- JT-60SA scenarios(inductive H-mode and Hybrid) are simulated
- Better performance for lower average density in JT-60SA
- Peeling-Ballooning analysis required for verifying pedestal predictions for JT-60SA

Journal publications 2013

- **X. Litaudon et al, "Modelling of Hybrid Scenario: from present-day experiments toward ITER", Nucl. Fusion 53 (2013) 073024**
- **G. M. D. Hogeweij et al, "Optimizing the current ramp-up phase for the hybrid ITER scenario", Nucl. Fusion 53 (2013) 013008**
- **J. Garcia et al, "Determination of the off-axis current for the sustainment of the q-profile on JET hybrid scenarios" Plasma Phys. Control. Fusion 55 (2013) 085006**
- **João P. S. Bizarro et al, "Modelling the Ohmic L-mode ramp-down phase of JET hybrid pulses using Bohm{gyro-Bohm transport in JETTO", submitted to Nucl. Fusion**
- **E. Barbato et al, "Temporal simulation of Lower Hybrid Current Drive in JET discharges", Nucl. Fusion, submitted to JET Pinboard**
- **I. Ivanova-Stanik et al, "Integrated core- SOL simulations of ITER H-mode scenarios with different pedestal density", Contributions to Plasma Physics, 2013**
- **I. Voitsekhovitch et al, "Modelling of JET hybrid scenarios with GLF23 transport model: *ExB* shear stabilization of anomalous transport", paper at the JET Pinboard, to be submitted to Nucl. Fusion**

Conferences 2013

- **A.C.A. Figueiredo et al, "Modelling of JET hybrid scenarios with the European Transport Solver", EPS 2013**
- **B. Baiocchi et al, "Turbulent transport analysis of JET H-mode and hybrid plasmas using QuaLiKiz, TGLF and GLF23", EPS 2013**
- **F. Köchl et al, "Integrated core + edge + MHD modelling of ELM mitigation at JET", EPS 2013**
- **P. Siren et al, "Current profile modelling in JET and JT-60U identity plasma experiments", EPS 2013**
- **I. Ivanova-Stanik et al, "Integrated core- SOL simulations of ITER H-mode scenarios with different pedestal density", PET, 2013**

Conferences 2013 (cont.):

- **14th International Workshop on H-mode Physics and Transport Barriers, Fukuoka, Japan , 2-4 October 2013**

- **G.M.D. Hogeweij et al Modelling of ITER-like current ramps in JET with ILW: lessons for ITER regarding H-mode and li control**

- **J. Garcia et al Physics comparison and modeling of JET and JT-60U core and edge: towards JT-60SA predictions**

- **IOS ITPA topical group meeting, 7-10 October 2013, Japan**

- **I. Voitsekhovitch, C. Kessel Proposals on modelling of density profiles in ITER baseline (presented by C. Kessel)**

- **I. Ivanova-Stanik et al Integrated core-SOL-divertor-impurity simulations for ITER H-mode (presented by J. Garcia)**

Continuation of ISM modelling activities

- **ACT1 (ETS validation & physics applications) → JET1 and MST1 WP (AUG14-1.1-1 - AUG14-1.1-5, AUG14-1.6-2) – particle, heat, momentum transport**

- **ACT2 (modelling for existing experiments) → JET1 and MST1 WP**

- **ACT3 → WPSA, 2 Enabling Research projects with ITER modelling included, IOS ITPA task on density modelling for ITER**