Status of IOS-JA6

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- Status of IOS-JA6 ("Benchmarking ICRH full-wave solvers for ITER")
  - Paper still in review at Nucl. Fus.
  - One review received by Editors, 2nd still out
- Plans for continuation

Reminder of cases

- 4 ITER cases: Baseline DT and 3 pre-activation at half-field, half-current

Case	Case 1 (DT)	Case 2 (H)	Case 3 (H)	Case 4 (He^4)
bulk ion species	DT	H	H	He^4
Impurity species	ash, Ar, Be	C	C	C
Fast ion species	D-beam, alphas	H-beam	H-beam	none
B_T [T]	5.314	2.678	2.665	2.665
I_p [MA]	15.0	7.5	7.5	7.5
$n_e(0)$ [$10^{20} m^{-3}$]	1.05	0.46	0.46	0.46
$T_i(0)$ [keV]	27.5	10	12	13.5
$T_e(0)$ [keV]	25	14	15	12.5
T_{ped} [keV]	5.3	1.5	2.5	1.8
β_n	2.0	1.5	1.8	1.2
P_{NNBI} [MW]	17.0	17.0	33.0	0.0
P_{EC} [MW]	20.0	20.0	20.0	20.0
P_{IC} [MW]	10.0	20.0	20.0	20.0
ICRF frequency [MHz]	52.5	52.5	52.5	42.0
minority species	He^3	He^3	He^3	H
n_{minor} / n_e	0.02	0.03	0.20	0.20
$E_{\|\|}$(minor) [MJ]	1.6	0.4	3.7	3.7
$E_{\perp}$(minor) [MJ]	3.4	1.5	10.0	9.5

Table 1: *Summary of the benchmarking cases predicted by PTRANSP.*

Reminder of codes

Code	general geom?	MC?	FLR	Numerical methods
AORSA	Yes	Yes	all orders	Fourier collocation in $k_{\boldsymbol{x}}$, $k_{\boldsymbol{y}}$, $k_{\boldsymbol{\phi}}$
EVE	Yes	Yes	2^{nd} order	Variation method; tor and pol modes; radial finite elements
CYRANO	No	No	2^{nd} order	Variation method; tor and pol modes; radial finite elements
PSTELION	Approx	Yes	2^{nd} order	Finite differences in radial coordinate
TORIC	Yes	Yes	2^{nd} order	Variation method; tor and pol modes; radial finite elements
TASK/WM	No	No	2^{nd} order	Tor and pol modes; radial finite element

Table 2: *Summary of full-wave solvers and their ability to treat general geometry, mode conversion (MC), order of Finite Larmor Radii (FLR) approximations, and numerical methods.*

Reminder of results for baseline DT H-mode

- Results from 6 groups for heating partitions
- Isotropic and anisotropic assumptions for effective minority temperatures

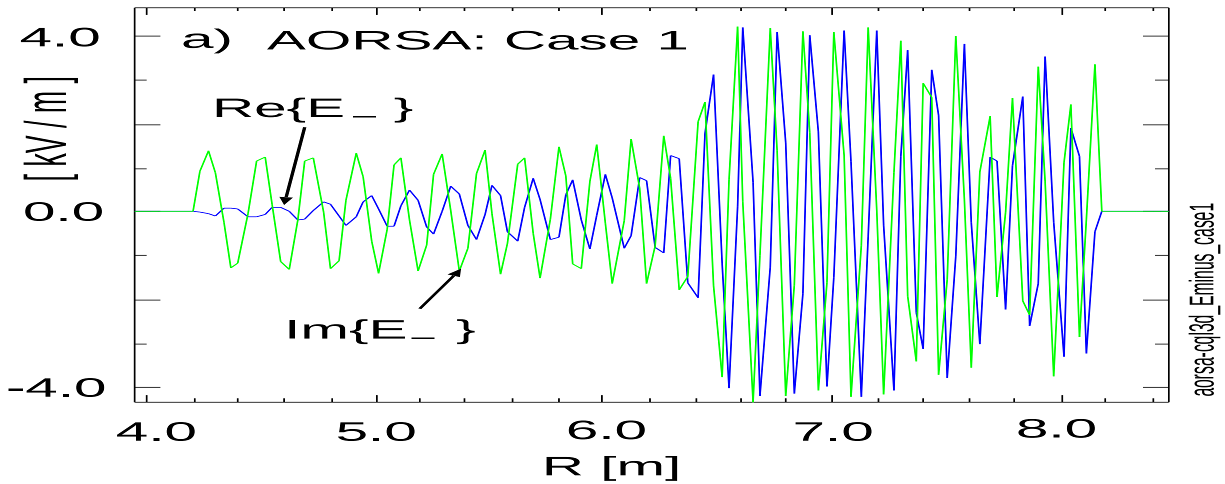
Solver	T	thermal D	minority	He^4 ash	electrons	Ar	Be	D-beams	fast alphas
PTRANSP-aniso	12.4	0.8	49.7	0.11	36.5 / 0.3	0.1	0.1	0.02	0.12
AORSA-iso	14.1	0.6	55.6	0.3	29.6	0.2	0.3	0.0	0.0
CYRANO	18.0	1.0	41.0	NA	39.0	-	-	-	1.0
EVE-aniso	12.5	0.4	48.8	0.1	36.8	1.1	0.2	0.0	0.1
EVE-iso	12.4	0.4	48.6	0.1	37.0	1.2	0.2	0.0	0.1
PSTELION	18.4	0.1	67.0	0.02	13.6 / 0.6	-	-	-	-
TASK/WM	15.2	1.1	48.4	0.03	25.7	-	-	-	-
TORIC-iso	16.0	0.5	51.2	0.03	31.7 / 0.7	-	-	-	-
AORSA-CQL3D	13.4	0.6	56.7	0.3	29.3	0.2	0.3	0.0	0.0

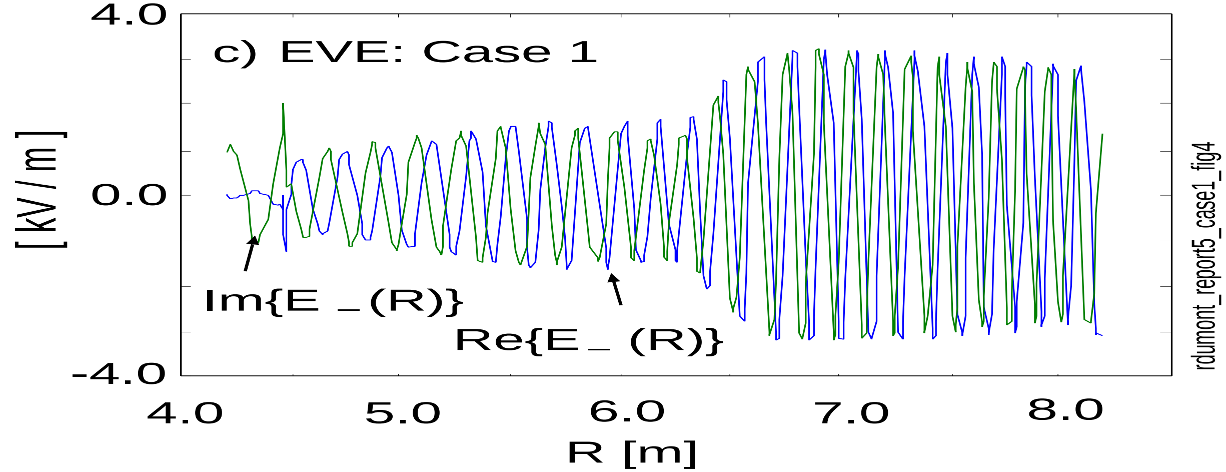
Table 3: *Comparisons of heating partitions (%)*

- PSTELION: low electron and high minority ion heating
- CYRANO: high electron and low minority ion heating

Reminder of results for 1D profiles

- Compare EM fields along midplane





Comparison of results for pre-activation cases

- OK agreement for half-field, half current He^{4} plasma with H-minority
- Poor agreement for half-field, half current H plasmas with He^{3}-minority
  - Low single-pass absorption
  - Resolution / convergence?
  - electron damping?
  - Kinetic effects (only $T_{||}$ and T_{prp} used in benchmarking)

Topics for continuation

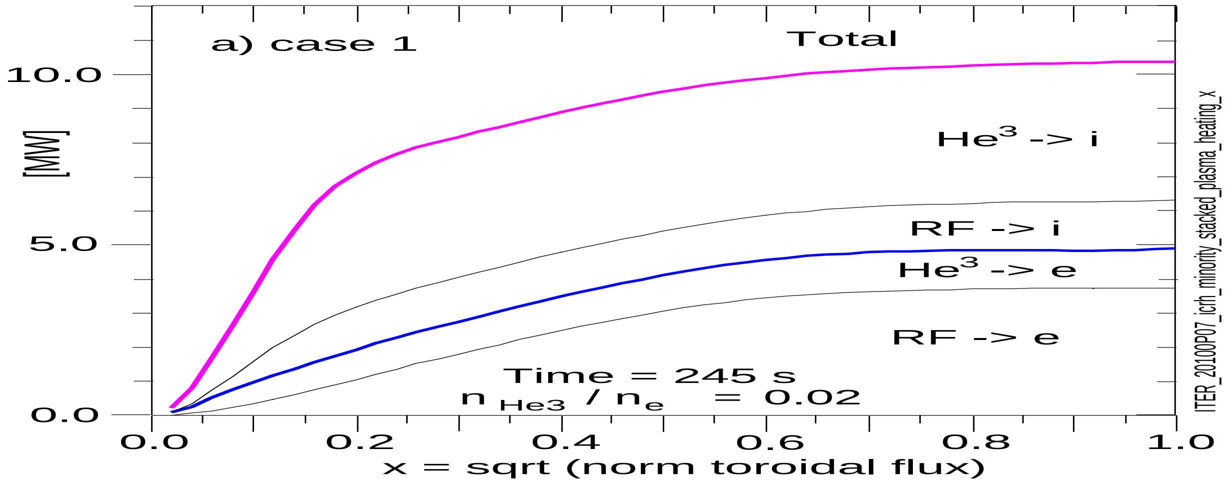
- 1) Deeper understanding of causes of different results from different codes
- 2) Extend benchmarking to Fokker-Planck
- 3) Closer examination of heating of impurities and fast ions
- 4) Extend benchmarking to include spectrum of toroidal modes n_ϕ
- 5) Extend benchmarking to include edge and antenna effects

Continuation: Deeper understanding of code differences

- Different treatment of electrons?
  - Landau-damping + TTMP + cross term
- Mode conversion issues?
  - Some solvers don't do mode conversion
- Extend studies of resolution / convergence

Continuation: Need to compute minority distributions and heating

- ICRH deposition depends on minority energy
- Core transport codes need total plasma heating profiles
- Full-wave solvers compute heat deposition on ions, electrons and minority ions
- Need to compute minority ion heating of the plasma
- Usually Fokker-Planck methods are used



Extra: Compare temperatures for Cases 1 and 4