RF Modeling Upgrades and Results

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Outline

- **TORIC in TRANSP code development:**
  - **Ongoing verification activities and future work.**
- **Proof of principle calculation for a parallel TORIC implementation in TRANSP.**
- **Slow wave mode conversion studies in NSTX:**
  - **TORIC and AORSA simulations.**

TORIC in TRANSP code integrity maintained through multiple major physics upgrades using verification techniques

- ***Primary tools:*** **CVS/SVN version control, regression testing, and comparison with other simulation models (AORSA, GENRAY):**
  - **J. Wright (MIT), C. K. Phillips, D. McCune and K. Indireshkumar (PPPL), J. Conboy (JET), E.F. Jaeger (XCEL Engineering / ORNL), M. Brambilla and R. Bilato (IPP)**
- ***Recent finding:*** **corrected a $2\pi(c/\omega)^3$ error in the TORIC fast wave current drive (FWCD) calculation:**
  - **Impacts simulations of HHFW CD in NSTX start-up scenarios and FWCD in ITER using TRANSP / PTRANSP.**
- ***Verification activity in 2011:*** **focus on benchmarking ion absorption calculation in TORIC against AORSA and GENRAY:**
  - **Important for more accurate simulations of HHFW – NBI interaction in NSTX.**

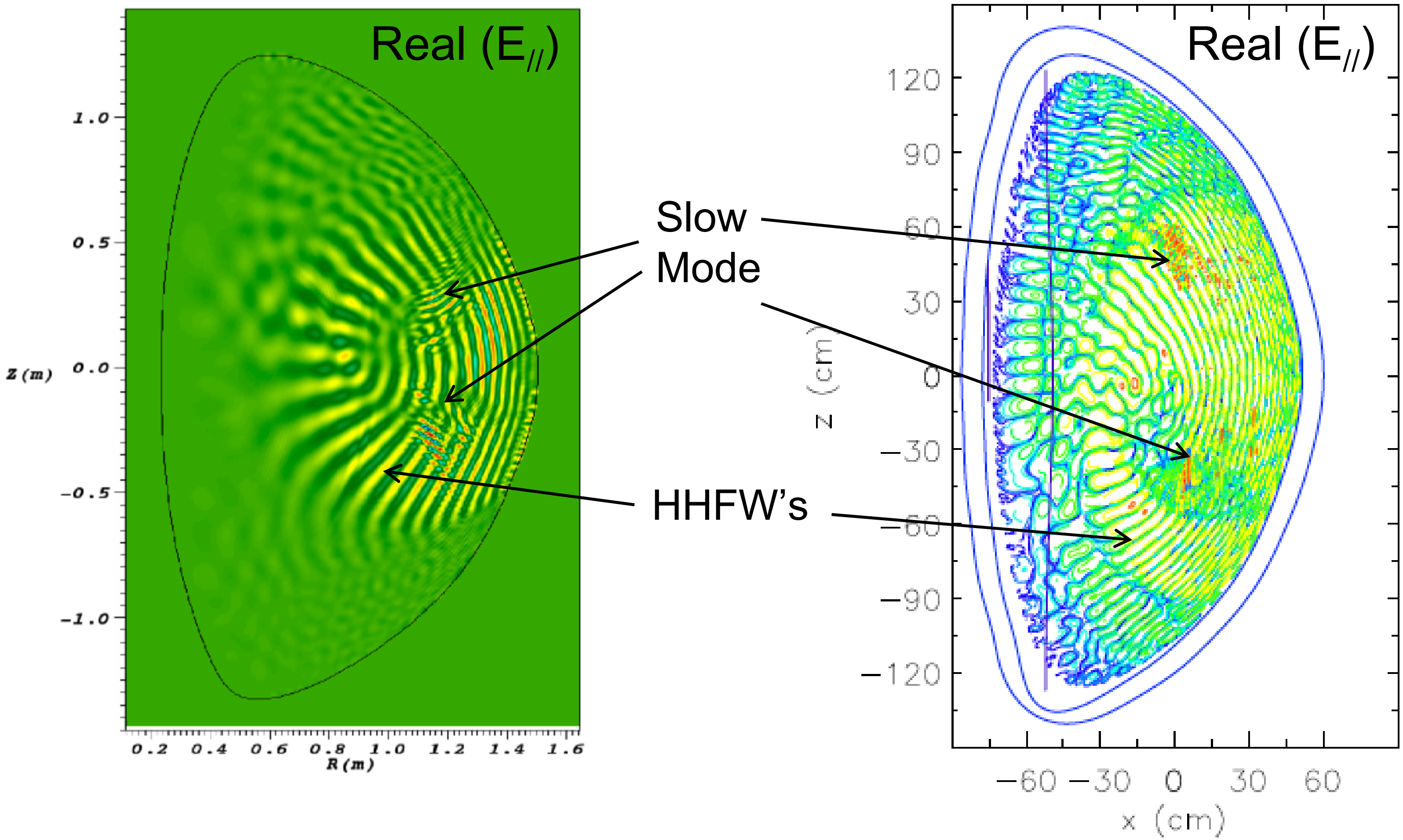
Parallel TORIC solver has been implemented in TRANSP and proof of principle calculation has been done

- New TORIC matrix solver has excellent inverse scaling of wall clock time in the 30-100 processor range:
  - Ideally suited for running TORIC as a parallel subroutine from TRANSP.
- Proof of principle simulation done by K. Indireshkumar:
  - Re-ran an analysis run of a JET discharge (from R. Budny) at moderate solver resolution (255 poloidal modes and 244 radial points)
  - Run time reduced from about 660 hours (a month) with the serial solver to about 30 wall clock hours with the parallel solver.
- Will make it possible in the future to carry out time dependent TRANSP runs with TORIC executed at sufficiently high poloidal mode resolution.

Short Wavelength Mode Seen in High Resolution Simulations of HHFW in NSTX

AORSA with 256x256 modes

TORIC with nmod=255 and nelm=300



NSTX shot 130608: f = 30 MHz, B_0 = 0.511 T, n_φ = 12, T_i = 4 x Chers

Slow Mode Excitation in Simulations is Caused by "Warm Electrons"

- It vanishes if the electrons are "cold" ($\omega > k_{//} v_{the}$).
- It remains if the ions are "cold".
- It appears primarily in the $E_{//}$ direction.
- It appears off-midplane, as expected if $k_{//}$ - upshift due to B_p is required:
  - It disappears if $k_{//}$ is held constant or very high values of $k_{//}$ are omitted.
- It appears in regions where $\omega > \Omega_{ci}$ (i. e., $K_{xxc} = S$) is negative [in NSTX in the HHFW regime and in C-Mod on the low field side of the ion cyclotron layers].
- It appears to damp quickly in the simulations.

The Nature of the Slow Mode is Under Discussion

Theoretical models indicate that the new mode may be an electrostatic 'slow mode' that requires hot electrons ($\omega < k_{//} v_{the}$) and $k_{//}$-upshift to propagate.

- More detailed comparisons against models for the dispersion relation for these modes are ongoing
- Analysis is ongoing to rule out numerical origins for the mode

A related mode has been identified in simulations of the fast wave fields in C-Mod in the ion cyclotron range of frequencies (ICRF).

Prospects for detecting the mode experimentally require modifications of existing diagnostics on NSTX, C-Mod and DIII-D for frequency response and/or diagnostic sightlines.

Enhancements of Existing Diagnostics are Needed to Detect This Slow Mode in Experiments

NSTX: The upper frequency range of the High-k scattering or the BES diagnostics would need to be extended to the 30 MHz range [D.R. Smith]

- both can resolve structures of a few cm in extent
- may be detectable by beat-wave excitation of modes in the 1-2 MHz range with the HHFW sources

C-Mod: The PCI diagnostic has the appropriate frequency range and spatial resolution but the sight lines would need to be adjusted. [P.T. Bonoli]

- the existing sightline is sensitive to wave electric fields in the major radial direction

DIII-D: The digitizers for the ECEI diagnostic would need to be increased to the 60 MHz range [B. Tobias; G. Taylor]

- As in NSTX, may be detectable by beat-wave excitation of modes in the 1-2 MHz range with the HHFW sources