Status of CURRAY Integration into TRANSP and HHFW H&CD Modeling

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Two Tasks in Support of HHFW Campaign

- Integrate CURRAY into the TRANSP transport analysis code
  - Heating
  - Current drive with non-zero E_{dc}

- Compare and benchmark CURRAY results with other codes and experiments, and improve on physics model
  - Heating
  - Current Drive
  - Interaction with energetic beam ions

CURRAY has been integrated into TRANSP

- CURRAY has been incorporated as a subroutine in TRANSP. [Indireshkumar]
  - Wave parameters are part of input to TRANSP
  - CURRAY reads EQDSK and TRXPL.OUT files from TRANSP
  - Returns calculated HHFW power deposition and driven current profiles to TRANSP
  - Energetic beam ions from TRANSP are treated as Maxwellian species

- Debugging of CURRAY/TRANSP runs is facilitated by generating the needed input files (EQDSK, wave and plasma input) for stand-alone CURRAY execution.

- CURRAY/TRANSP has been used in analyzing HHFW heated H-mode discharges and NBI discharges. [LeBlanc]

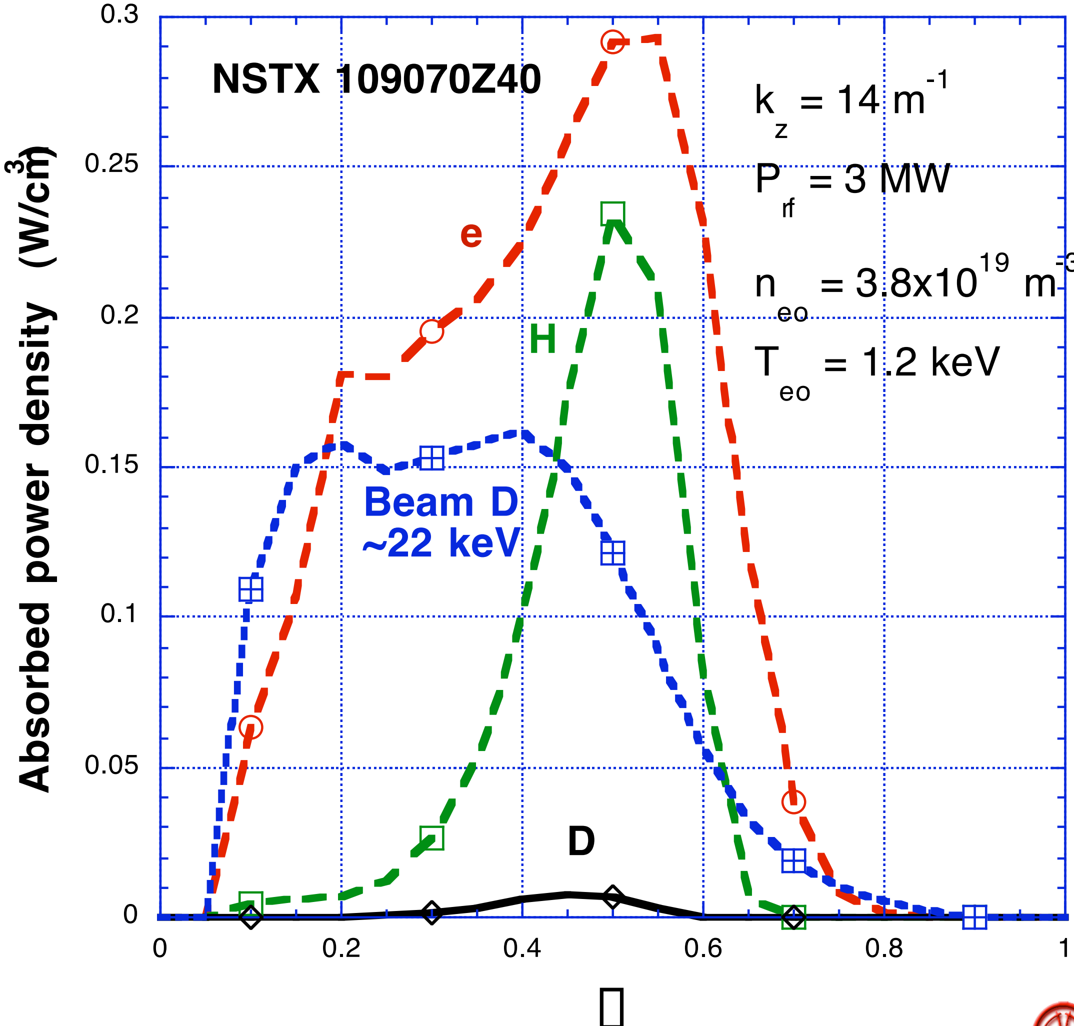
- During test phase with TRANSP, the ray marching routine in CURRAY has been further improved to obtain drastic reduction of incidences of ray “crashing” during time-dependent runs.

Typical Deposition Profiles of a HHFW/NBI Discharges from CURRAY/TRANSP

- The D plasma contains minority H and slowing-down D beam ions.

- Power absorption fractions:

  $P_e = 0.5$
  $P_H = 0.21$
  $P_D = 0.01$
  $P_B = 0.28$



HHFW CD Modeling with CURRAY/TRANSP Needs Further Work

- Work is ongoing to complete incorporation of the current drive package into TRANSP.
  - Need to evaluate $j_{rf}(E_{dc})$ and $\partial j_{rf}/ \partial E_{dc}$ for modeling transients during rf turn-on, to avoid numerical problems (Ignat).
  - Original plan is to calculate a table of j/p (□,□,w,E_{dc}), by incorporating features of an existing adjoint code (Karney & Fisch) with nonzero E_{dc} without toroidal trapping effects into the present CURRAY model (zero E_{dc} with trapping).

    This is found to be more time-consuming than present resources allow.
  - Since $w=v_{res}/v_{te}$ ~1.6 for fast waves, Ignat's analytic expression of $j_{rf}(E_{dc})$ for LH waves is questionable as it assumes $v_{res}/v_{te} >> 1$.
- We now propose to use the CQL3D kinetic code combined with either CURRAY or GENRAY to carry out the calculations.
  - CQL3D has an existing capability to solve the rf quasilinear diffusion equation with a non-zero E_{dc}.
  - Will decide if generating a suitably limited look-up table for j/p (□,□,w,E_{dc}), or direct evaluation, is the best approach.

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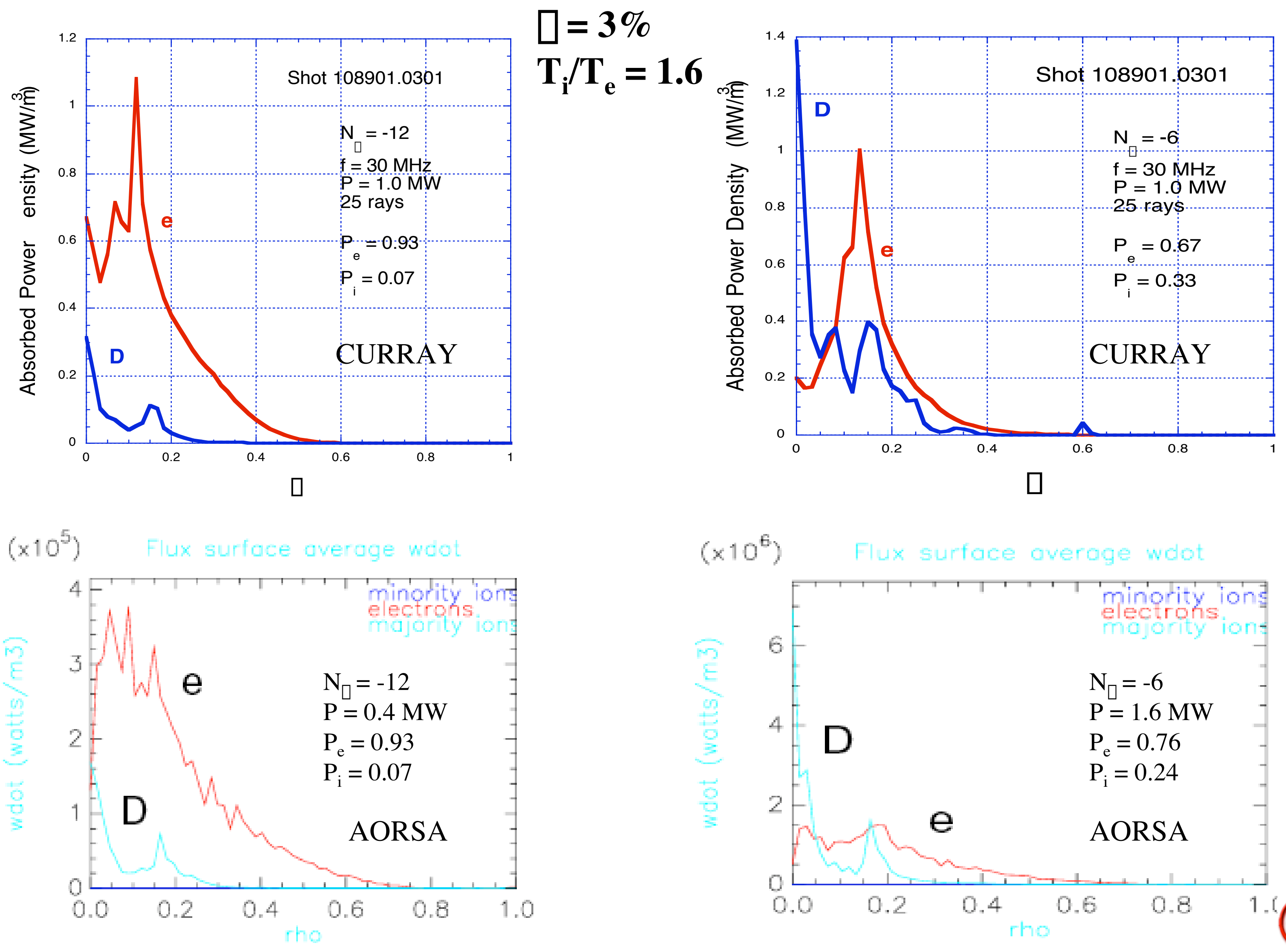
Reasonable Agreement between CURRAY and AORSA for Case with Thermal Ions Only, Shot 108901



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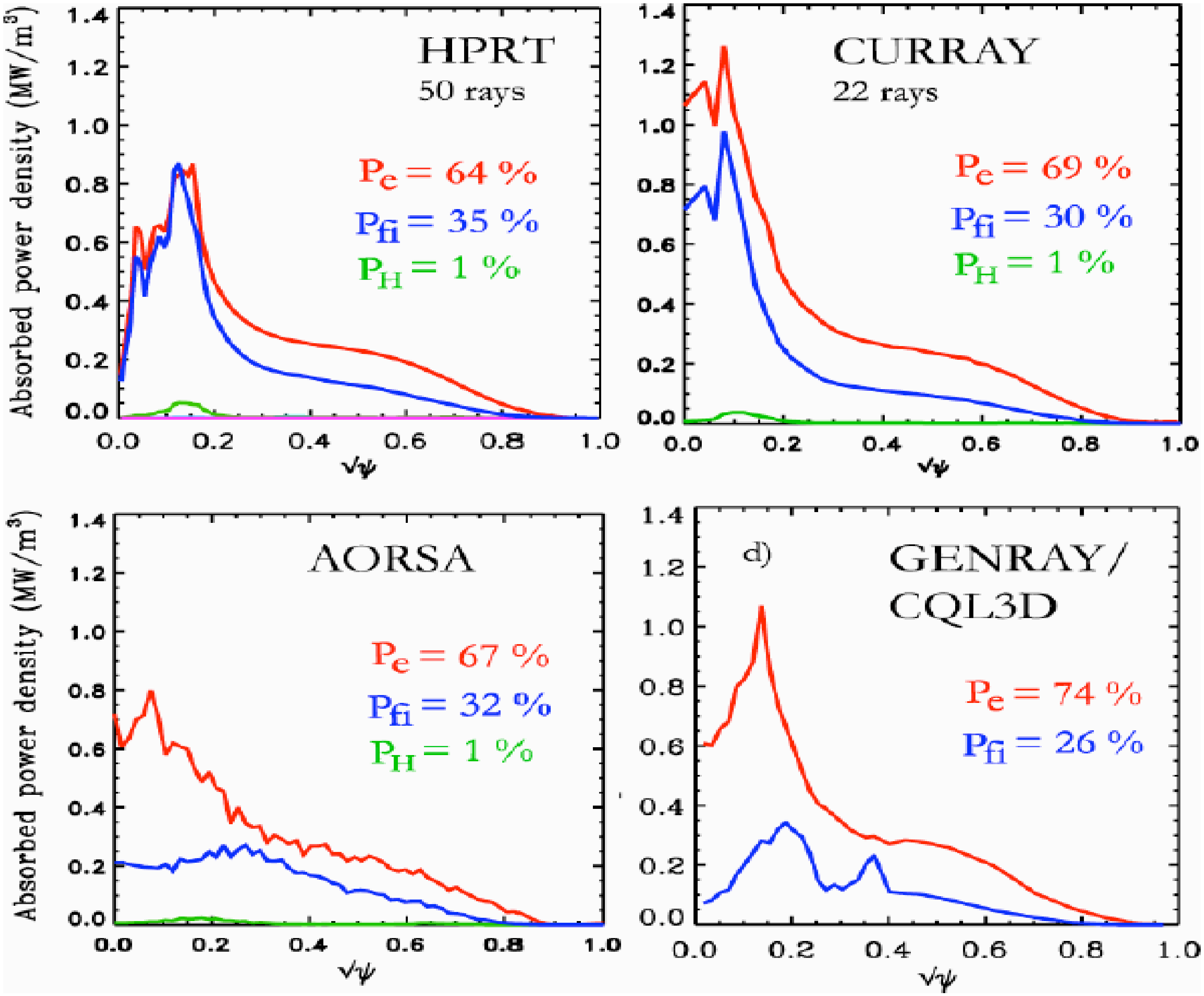
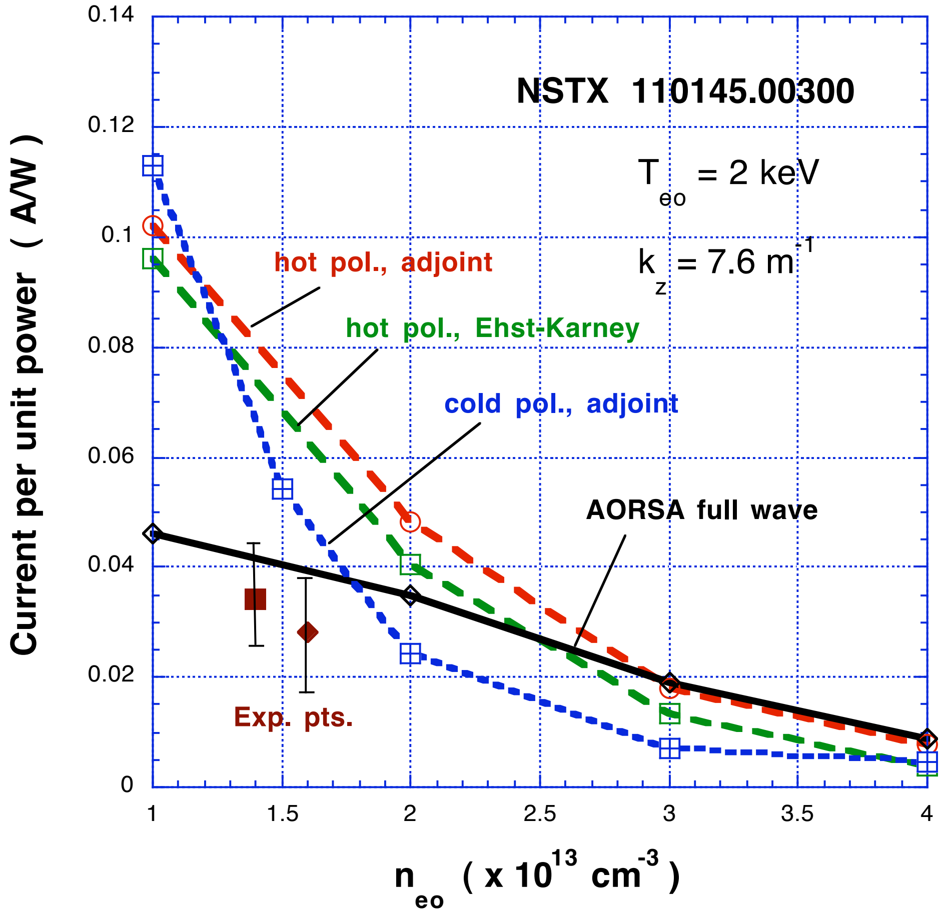
Reasonable Agreement between HPRT, CURRAY, AORSA, and GENRAY/CQL3D for $N_{□}$ = 24, for NBI plasma (Shot 108251)

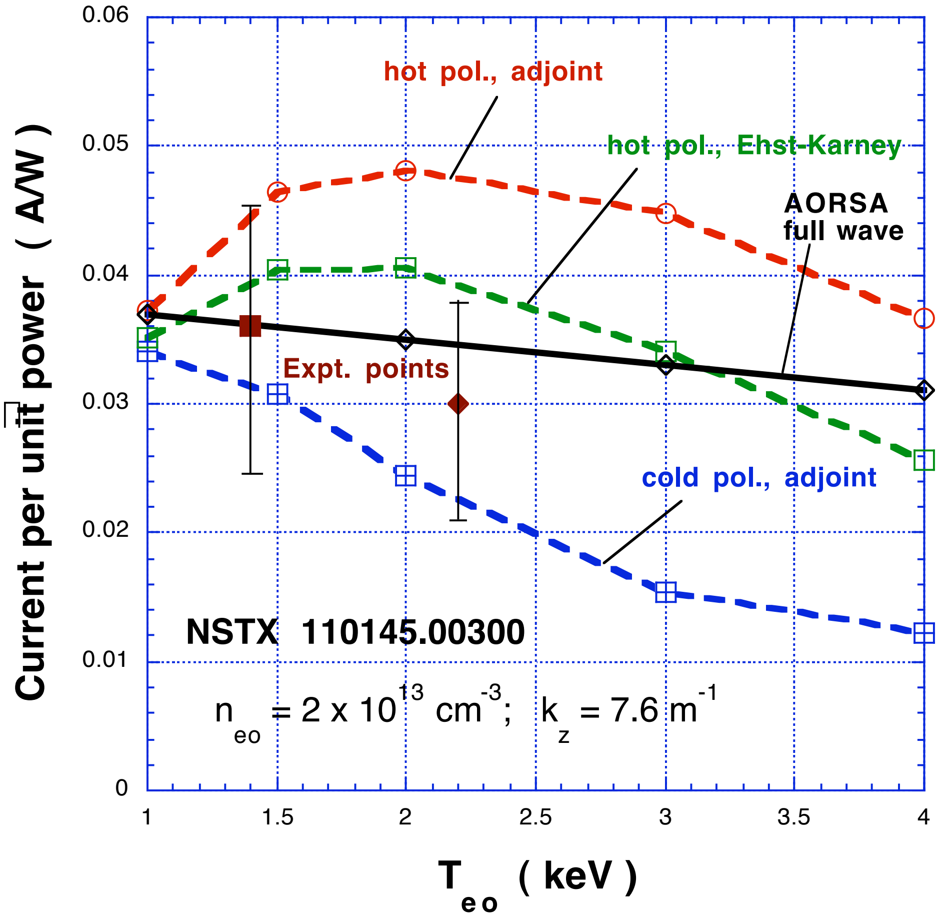


□ = 5 %
$T_i/T_e = 2$

From Rosenberg, APS/DPP03 Conference.

Comparison of CURRAY CD Results with AORSA and Experiments Warrants Further Investigation





- cold polarization : Use $k_{\perp}$ from ray tracing in evaluating K_{ij}'s.
- hot polarization : Use complex $k_{\perp}$ from order reduction to evaluate K_{ij}'s.

Summary and Future Work

- CURRAY has been run successfully with TRANSP for HHFW heating scenarios. Work is ongoing to incorporate a CD model including a DC electric field for modeling ramp-up. The use of CQL3D with CURRAY or GENRAY is being considered.

- Relatively good agreement in HHFW heating results between CURRAY and other codes has been obtained, particularly at higher $N_{\parallel}$. Investigation of physics model at lower $N_{\parallel}$ is warranted.

- The CURRAY CD model is being re-examined to try to explain its difference with AORSA and the experimental results.
  - An extended experimental data base at higher density (> 2×10^{13} cm^{-3}) and temperature (> 2 keV) will be highly desirable.
  - A more detailed comparison with AORSA is also warranted.
  - Detailed benchmarking with CQL3D/GENRAY is being carried out.