Modeling of HHFW-Fast Ion Interactions

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- High harmonic fast waves interact strongly with NB injected fast ions in NSTX.

- The resulting fast ion distributions can be calculated with the GENRAY/CQL3D ray tracing and Fokker- Planck codes.
  (SciDAC work will includes coupling to AORSA and TORIC full wave codes).

- The 3D FP calculations include banana orbit losses (although the code uses a zero banana assumption in lowest order). and provide a model for the FW induced fast ion losses to the plasma periphery.

- For comparison with the experiment, this provides a 3D $(u_{\|}, u_{\perp}, \rho)$ model for f_i giving:

  (1) Absorption of FW self- consistent with the NBI and RF quasilinear distortion of the ion distribution.

  (2) Effect of banana losses on the fast ion power to the bulk plasma.

  (3) Fast ion fluxes to the the plasma periphery.

  (4) Neutron flux (Bosch and Hale, NF 1992).

  (5) NPA (with code by Robert Andre).

  (6) Radial transport.

  (7) [Also, modeling of electron distributions f_e ==>CD, etc.]

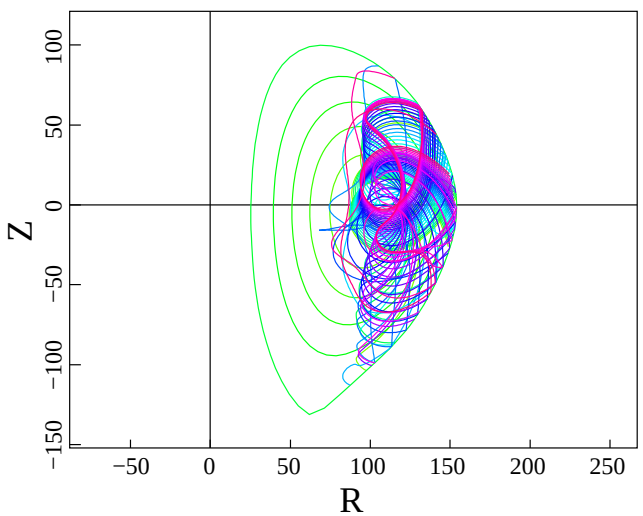
CQL3D/GENRAY Modeling of NSTX FW with/without NBI

(105830_0193 test case)

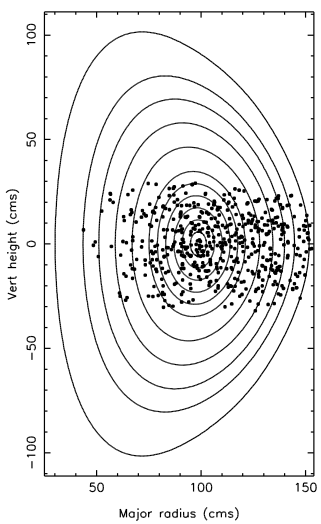
Features:

- *GENRAY rays are cold (or optionally hot).
- *CQL3D uses ray data to calculate 2−velocity/1−radius collisional/quasilinear electron and ion distributions.
- *Ray absorption is iterated to be self−consistent with the ql distortion of the distributions.
- *RF interaction with NB injected fast ions included.
- *Primary limitation of model: −CQL3D is zero−banana width model, but fast ion loss regions included.
  −Full−wave effects to be included within next year.

Rays



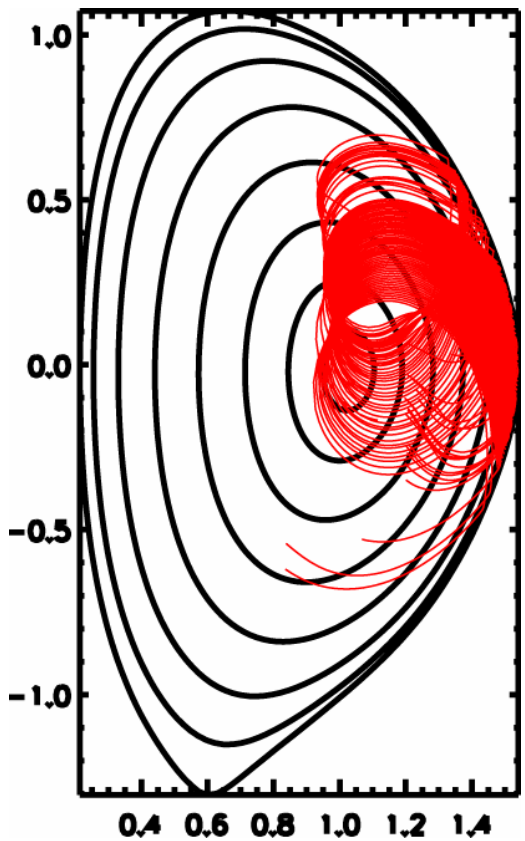
NBI

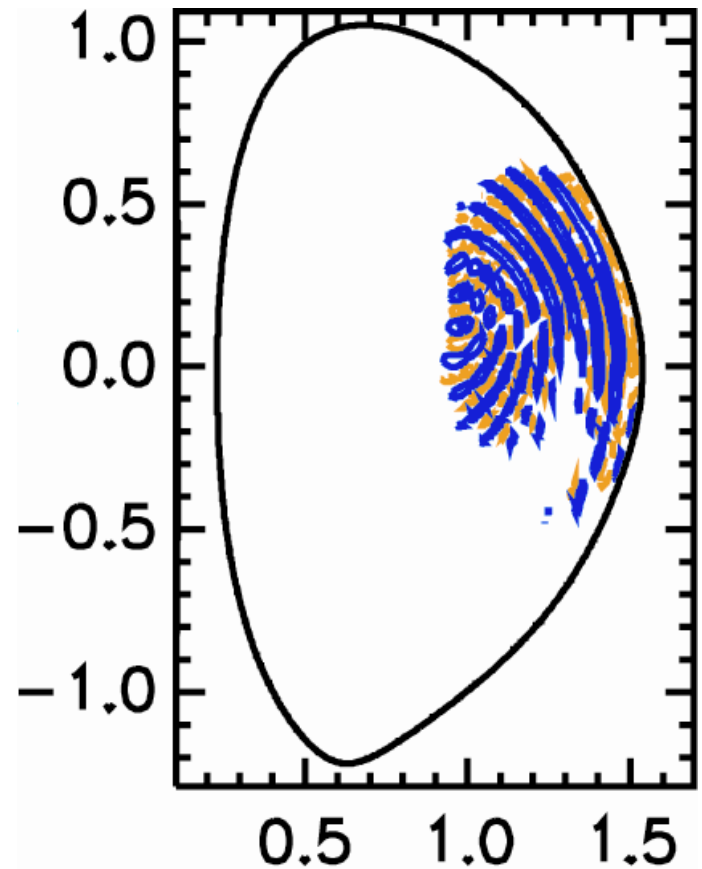


CompX

Ray-tracing and full wave codes see similar significant 2D effect in propagation

HPRT
50 rays
(99% absorbed)



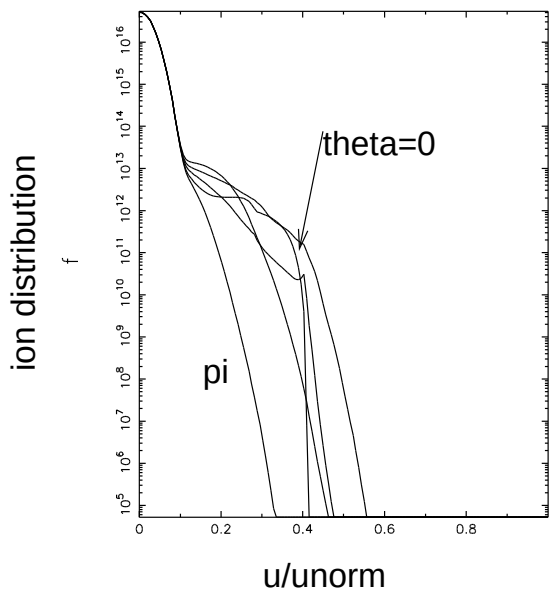


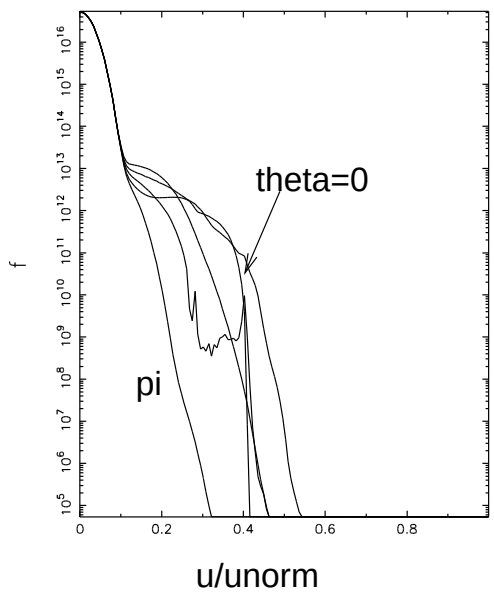
AORSA

- $N_\phi = 24$, $\beta_t = 5\%$, fast ion shot

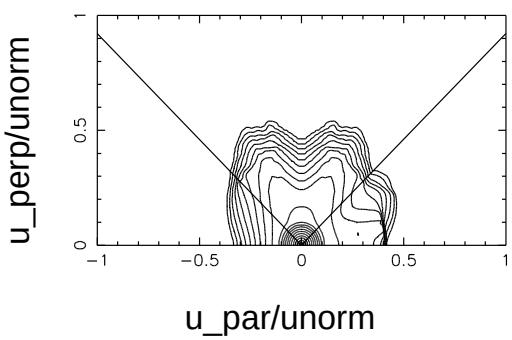
Comparison of NBI+FW Ion Distribution Functions with/without Banana Losses

(Cuts through f(v,theta) at cnst theta, and 2D distn, at rho =0.5a, shot 108251)
(unorm corresponds to 500 keV.)

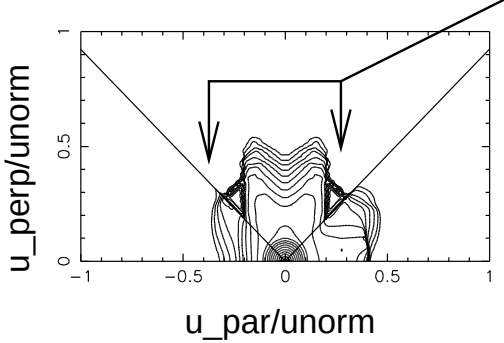




No banana loss



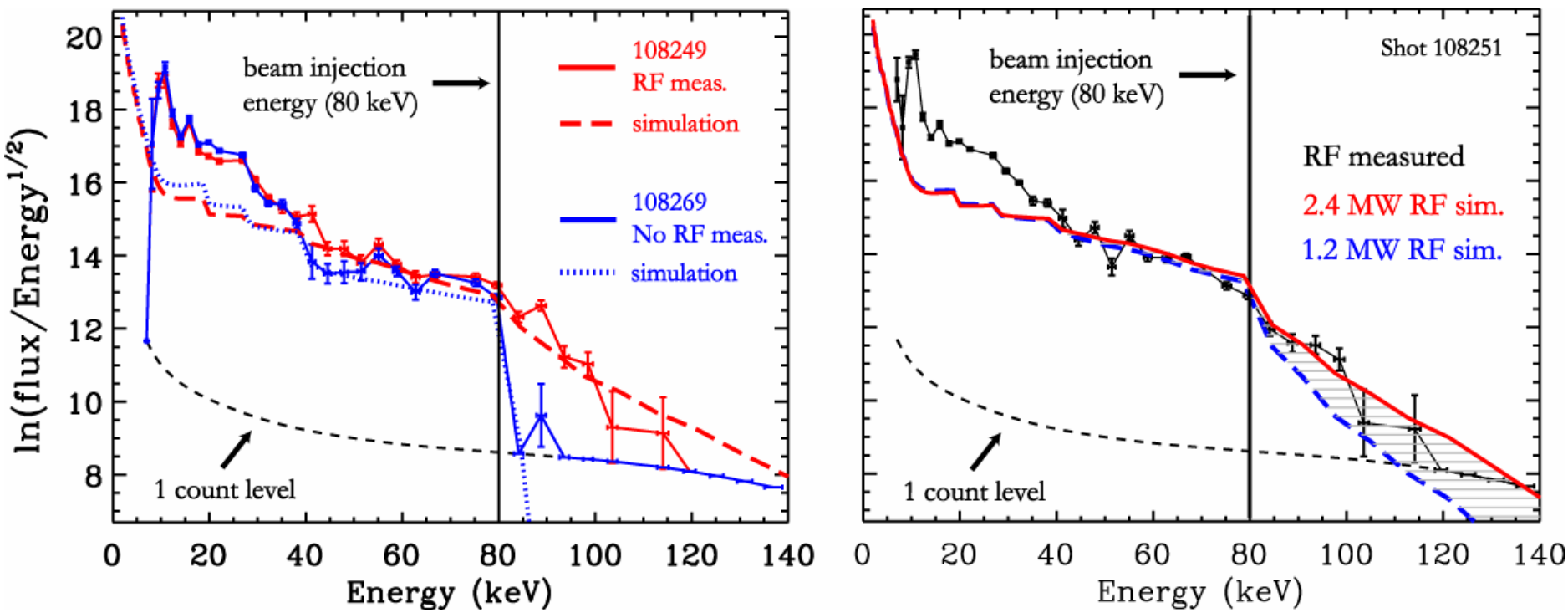
With banana loss



Fast ion banana loss for rho_banana > (a−r).

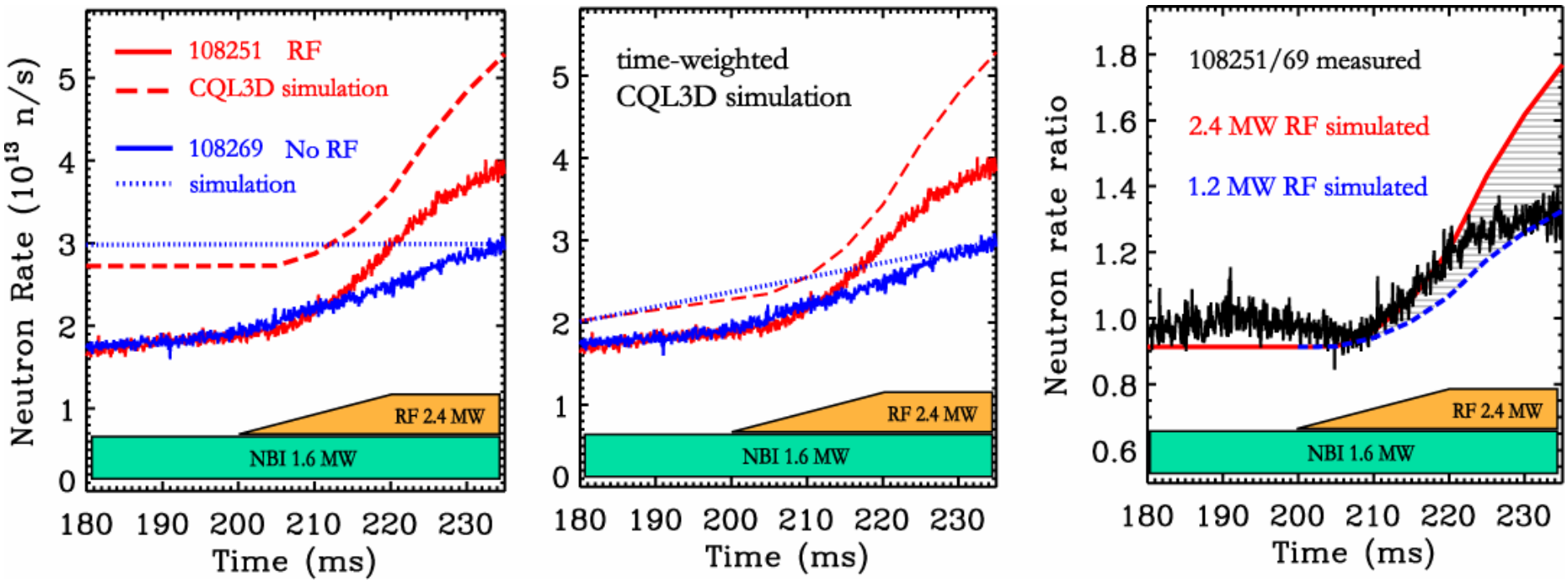
CompX

NPA simulator in good agreement with measurement



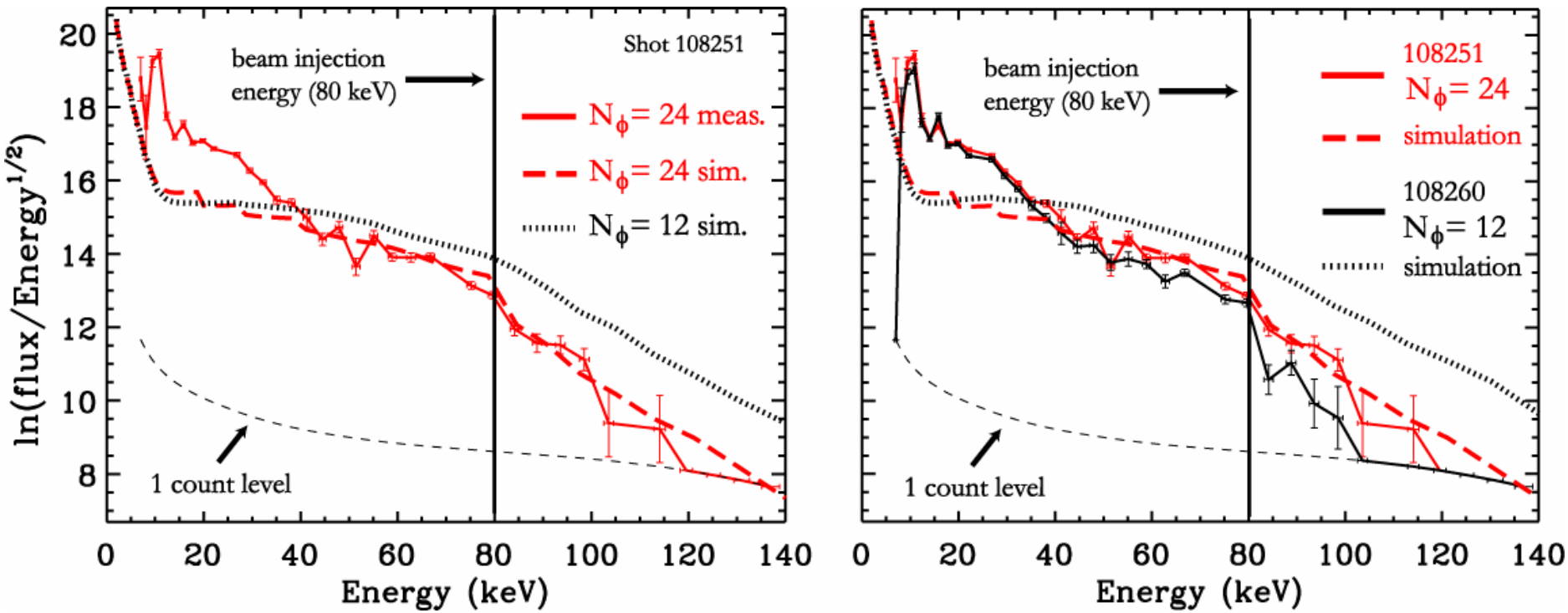
- Agreement above 80 keV within error bars
- Discrepancy below ~30 keV likely due to large uncertainty in 1D wall neutral model
- Half-to-full RF power spans error bars, edge absorption observed

Significant RF-induced neutron rate enhancement predicted and observed



- Equilibria at t = 235 ms used
  - Time-weighted solution also using t = 180 ms equilibria
- Error in absolute neutron rate at least +/- 10 %
- Time dependence, total RF in bulk plasma significant effects

Much larger fast ion tail at higher $k_{||}$ predicted, smaller tail observed



- No $k_{||}$ evolution measurement available
- Edge-coupling effects, theory breakdown at low $k_{||}$?
  - To be reinvestigated in better antenna, plasma conditions

Proposed Research Activities

- Code Work:
  -Implement greater than 3 cyclotron harmonic modeling.
  -Implement time-dependent splined plasma profiles.
  -Improve FI orbit loss model.
  -NPA work.

- Calculations:
  -FWCD due to FI's, electrons, toroidal electric field.
  -Flux spectrum of prompt losses to plasma edge.
  -Neoclassical radial classical transport effects on FI.

- Comparison of theory and experiment:
  -Investigate the $k_{||}$-dependence disagreement for FI tail found by Rosenberg.
  -CD comparisons.

- [EBW calculations/support.]