Collaboration with NSTX-U in Calculations of Radiofrequency and Neutral Beam Heating and Current Drive Sources

R.W. Harvey and Yu.V. Petrov, CompX, Calif.

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Research Goals/Plans FY15-19 (full program):

1) Complete the coupling of the GENRAY ray tracing and CQL3D Fokker-Planck codes to TRANSP. [GENRAY work is presently underway by Jardin group, based on previous CompX/SWIM coupling to the PPPL Plasma State software, consulting with MIT/CompX].

2) Calculate time-dependent finite-orbit-width (FOW) NBI+HHFW distributions with CQL3D, and apply to synthetic diagnostics such as FIDA, neutrons, NPA, energy loss and wall loss spectra, heating and current drive. [Hybrid Model completed, Full neoclassical ~operational].

3) Work with and/support PPPL scientists in Fokker-Planck, ray tracing, and full wave calculations of (1) HHFW interaction with electrons and with fast ions, including from NBI, (2) ECH, and (3) EBW. [Presently with Gary Taylor and Deyong Liu, Bill Heidbrink, and Ben LeBlanc.]

4) Investigate ion cyclotron emissions (ICE) due to non-thermal distributions resulting from time-dependent NBI and HHFW. This investigation uses existing functionality in CQL3D-GENRAY to calculated IC growth/damping and propagation.

5) Perform TGLF-DEP/CQL3D validation studies by inclusion of the velocity-dependence of turbulent radial transport in CQL3D and compare with NSTX-U experiment.

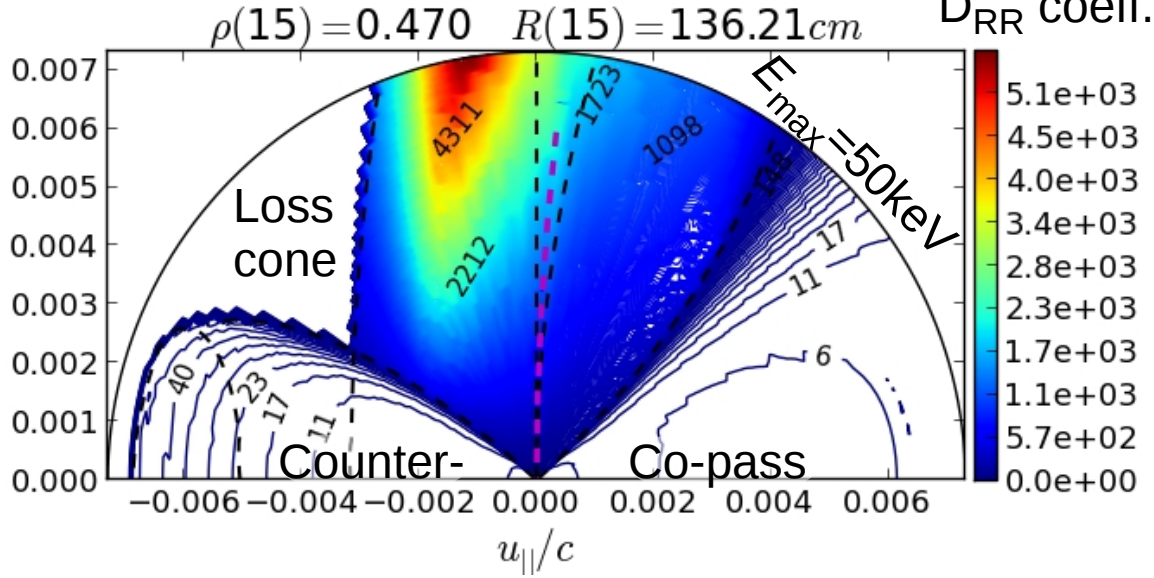
6) Time-dependent simulations of GAE modes related to the HEF described in the NF2013 paper by Medley et al. This uses CQL3D-FOW in combination with the DC Lorentz orbit diffusion coefficient calculator in given MHD fields.

Status of CQL3D: Two Finite-Orbit-Width (FOW) extensions:

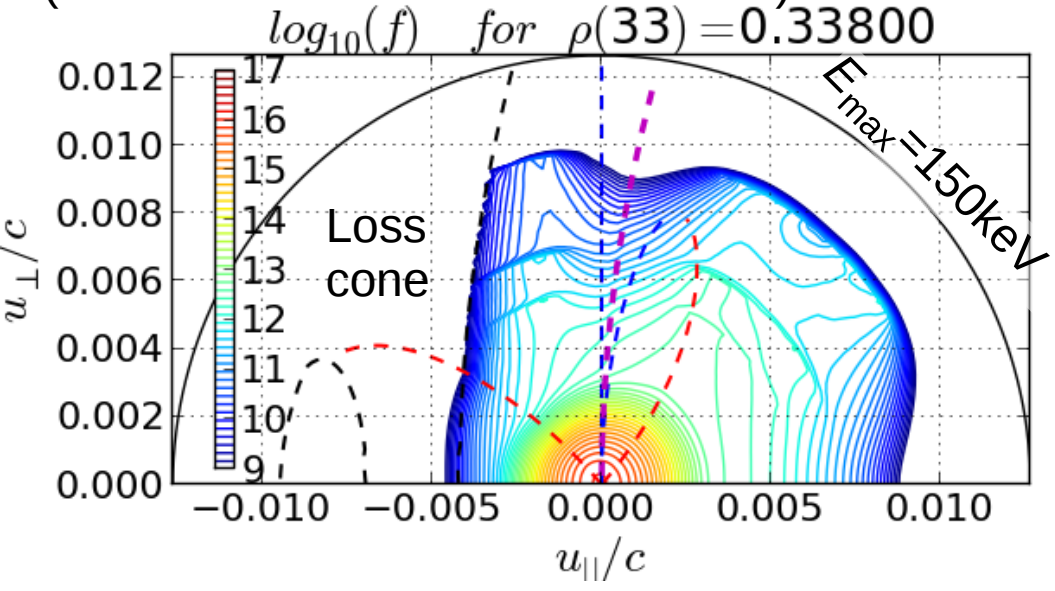
– Hybrid-FOW (fast, but only partial FOW capabilities; No neoclass.transp.)

– Full-FOW (strict reformulation of FPE):

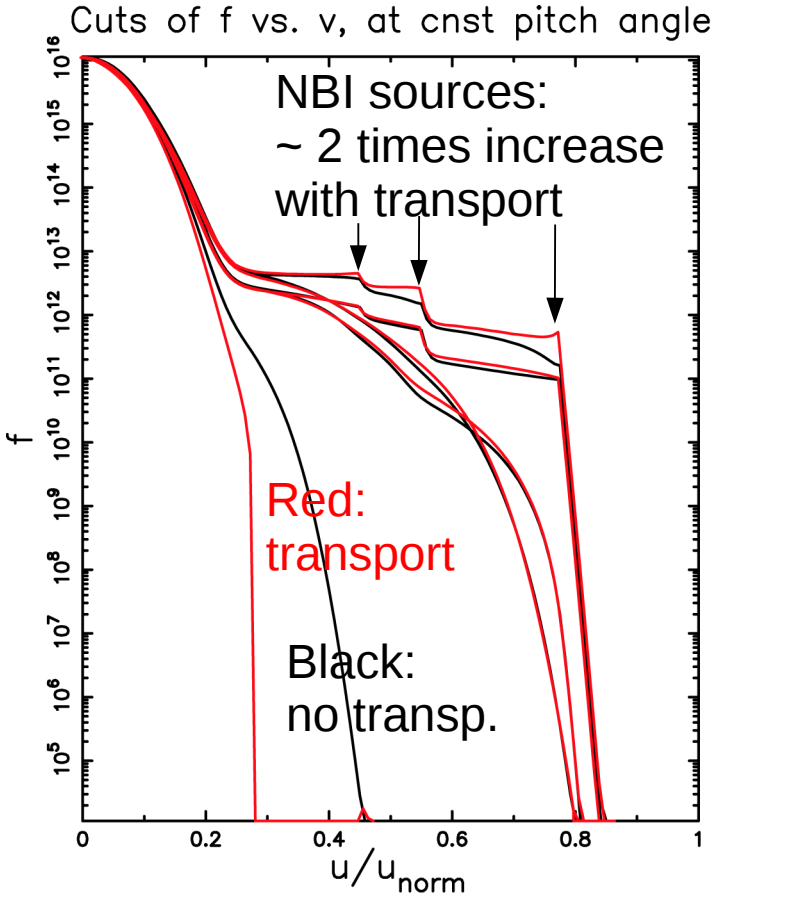
Example of NSTX coll. Radial diffusion coeffs. [cm^2/sec]



Example of Full-FOW solution
(local distribution with NBI sources)



Compare no transp, w neocl transp

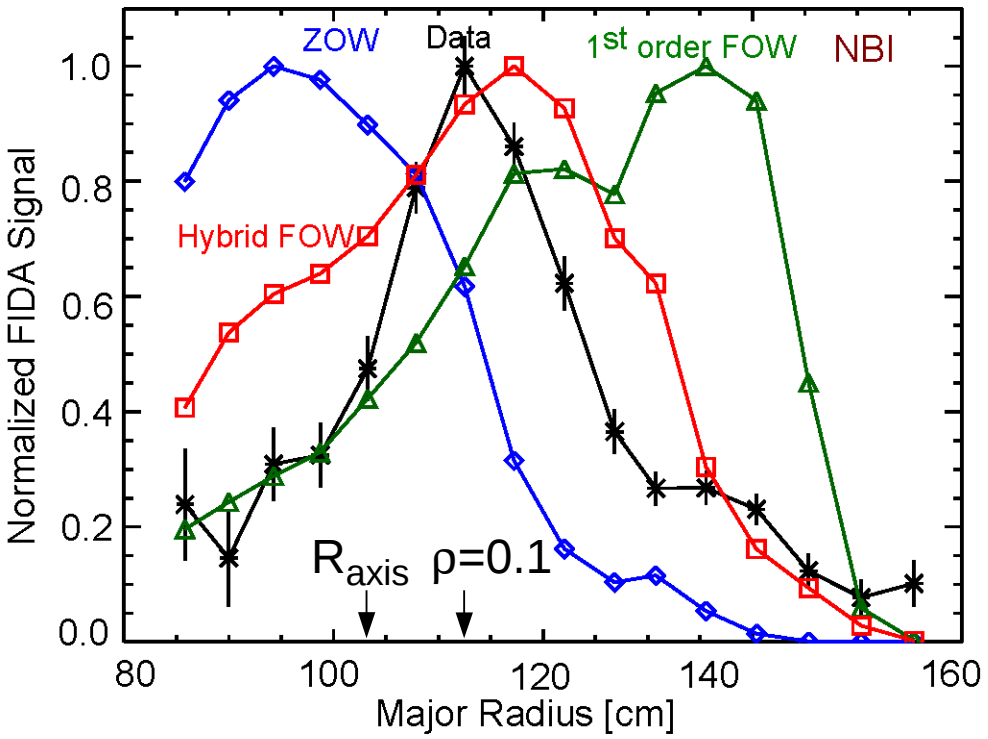


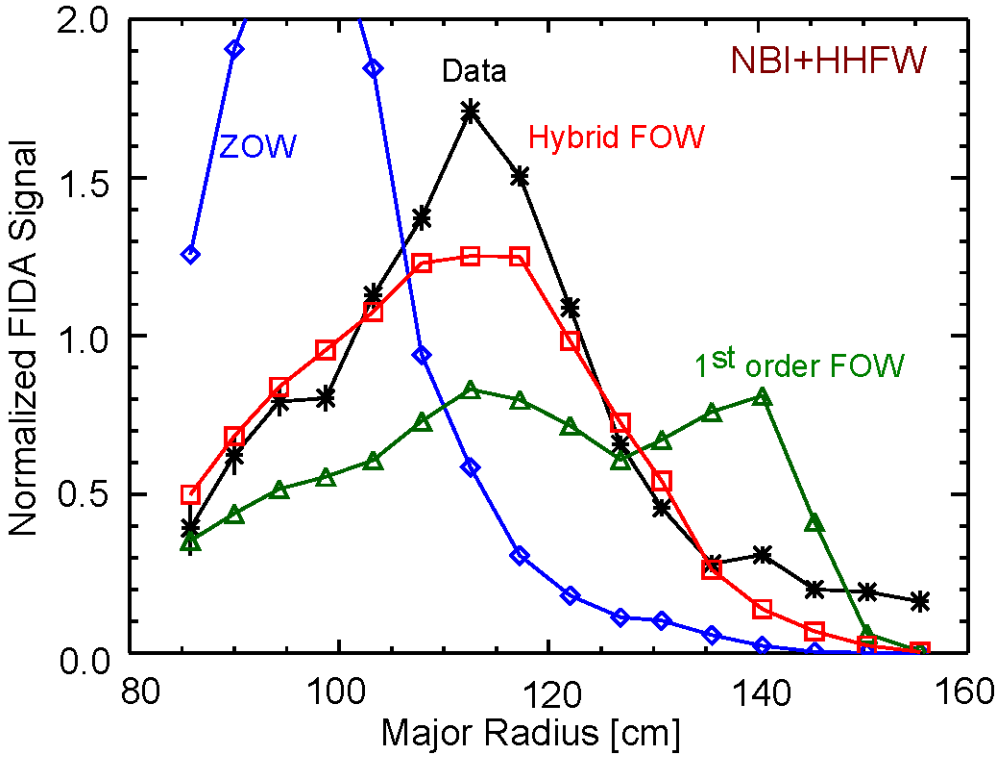
Distribution function vs. velocity for some angles
Species number=1, enorm= 1.50D+02
time step (n)= 9 time= 0.450000E+00 secs
r/a= 3.38E-01 radial position(r)= 3.51E+01 cm

Recent addition: Losses of FI on neutrals through CX

– The radial profiles of neutrals are generated by TRANSP/FRANTIC (1D).
– Can be time-dependent: $n_n(\rho,t)$.
– Profiles are read by CQL3D at given time steps and interpolated in time.

FIDA: – Almost no effect in NBI-only case (after renormalization).
~18% reduction (at peak) in NBI+HHFW case.

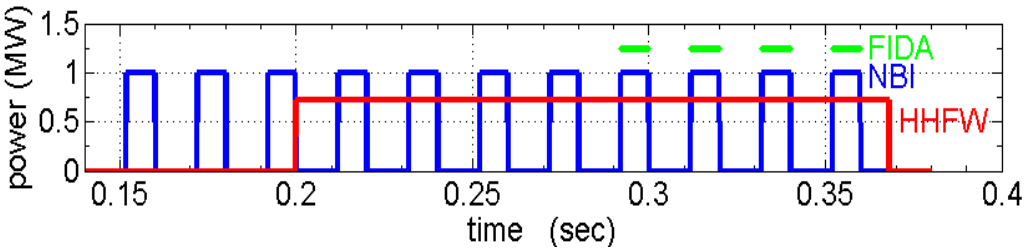


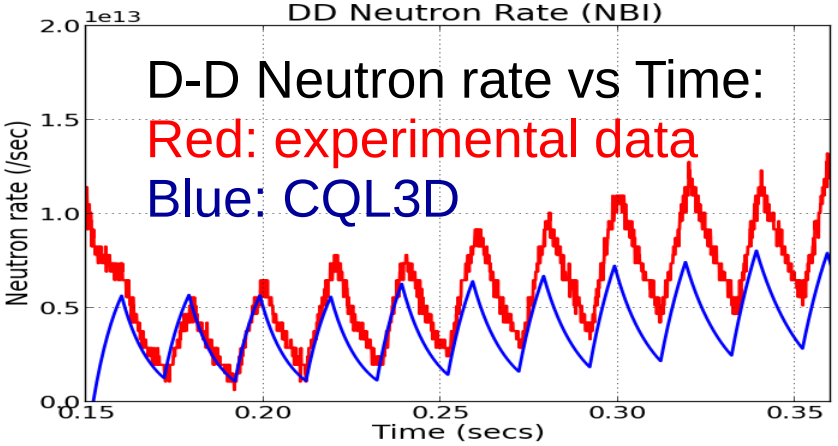


(Provided by Deyong Liu, using TRANSP plasma/FIDASIM with CQL3D distributions)

Latest: Finer radial griding of NBI related profiles has significantly narrowed FI profiles<
With further improvement of the FIDA validation expected.

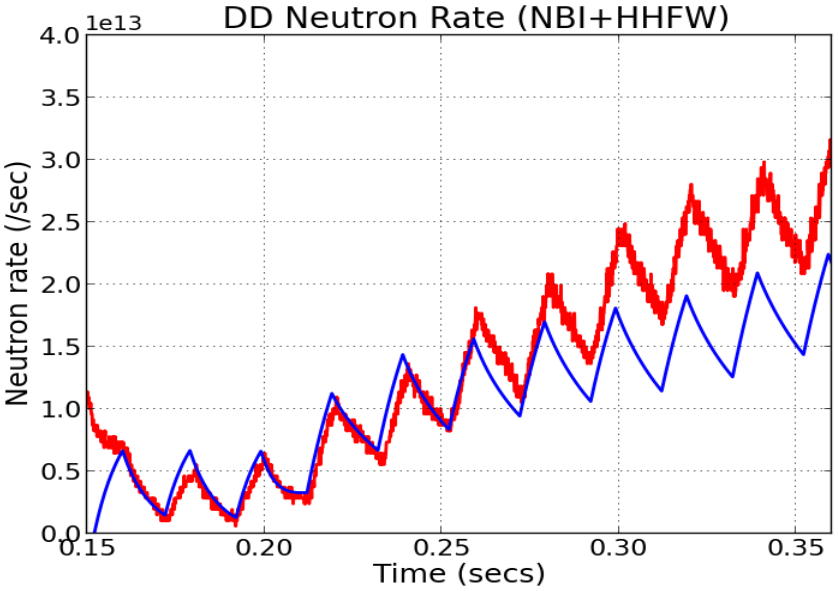
…cont-ed: **Effect of FI-CX losses: Neutron Rate**





NBI only

Experimental uncertainty: up to 20%



NBI+HHFW

<u>Before the FI-CX losses</u> were included, the simulated neutron rate was higher than experimental.

<u>With FI-CX losses:</u>
Good agreement at early times => Evidence of correct modeling of heating rates/QL diffusion (growth of tail), and coll. slowing down of the tail.

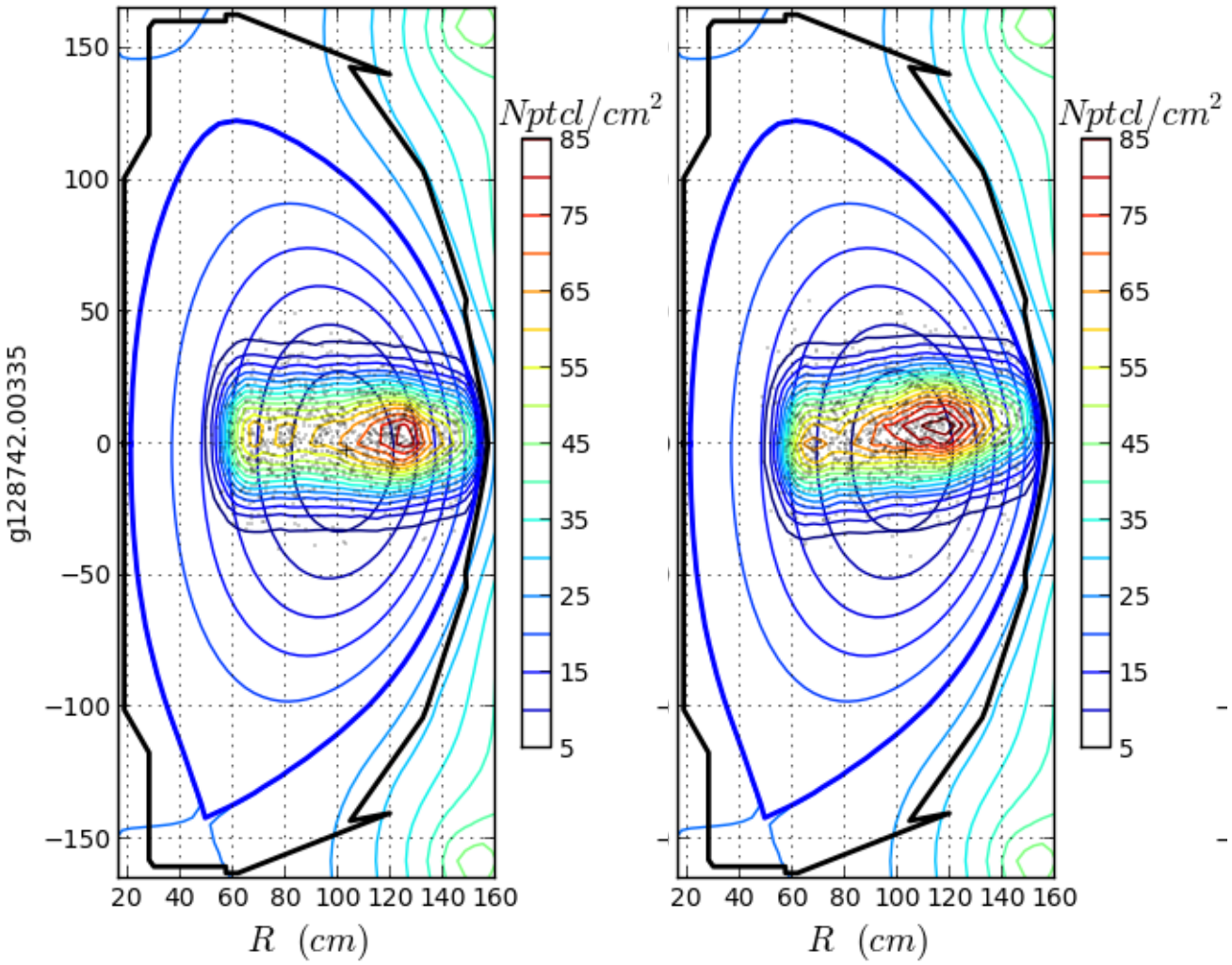
But, goes lower than experimental data at t>0.25s => Need more accurate 2D model for neutrals' profile?

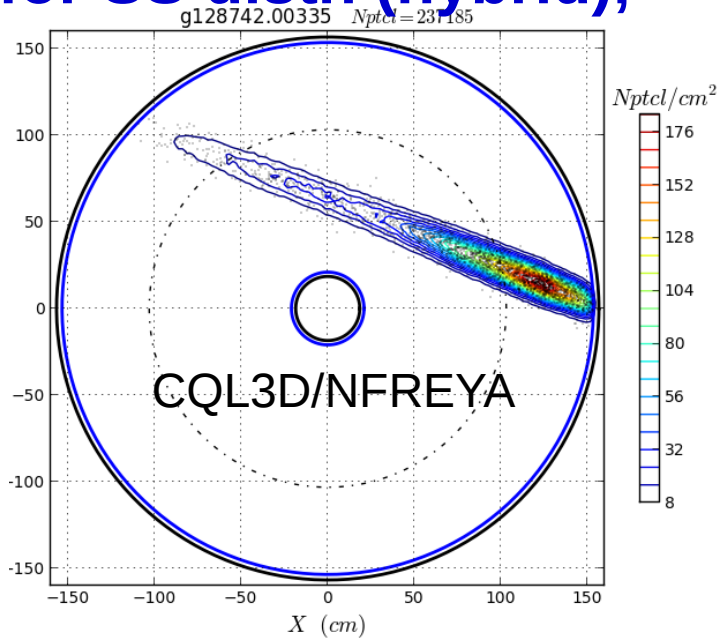
Updated beam stopping cross-sections in CQL3D/NFREYA giving good comparison with NUBEAM deposition.

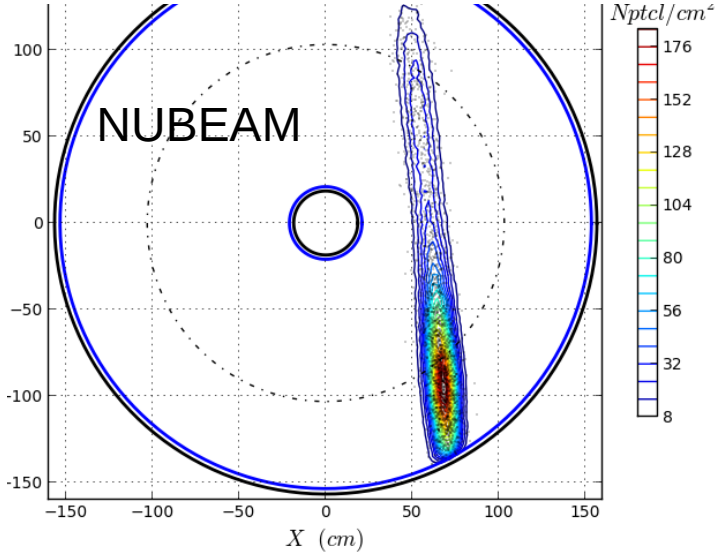
(For distn calculation: 5 min CPU time (/128 w parallelization) for orbit table (recalc for each eqdsk), ~1 min for SS distn (hybrid), 1 hour w 128 core.

CQL3D/NFREYA

NUBEAM







Additional Comments on Plans

- A collaboration with Dendy/McClements on ICE (Ion Cyclotron Emission) is being instituted with NSTX-U data targeted, using simple extensions of existing codes.
- The HEF events theory by Medley is an exciting challenge and a validation exercise for the range our codes. In particular, it gets us further into the internal MHD mode induced radial fluxes with DC, coupled into CQL3D.
- The comparison of TGLF-DEP microturbulence induced diffusion with the neoclassical (FOW) theory, will be directed at further investigation of physical significance (or not) of microturbulence on FI transport.

Other work in progress

- QL operator for Full-FOW.
- Extend radial grid to the left of magnetic axis (inboard FOW potatoes).
- A self-consistent, time-dependent toroidal electric field calculation.
- Publication (refereed) on CQL3D FOW-Hybrid Validation with NSTX.
- Coupling with 4D COGENT FP to include accurate edge and SOL region (a separate proposal).

Student Involvement

- Use of simulation codes for validation/comparison with experiments is an effective means for investigating the underlying physics, and develops familiarity with large scale computing.
- CompX codes have been used, for example, by MIT, UW, and PPPL students.
- We welcome involvement of students, and working with them to use and/or add to the codes for their particular needs.