

Fast MHD Physics
Accomplishments and Targets:
Current Ramp-Up and ICRF
Heating in Alcator C-Mod

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Outline

- Discuss progress in simulating current ramp-up and ICRF heating phases in Alcator C-Mod:
 - Description of physics target
 - TSC simulation and coupling to the IPS / Plasma State
 - AORSA and TORIC interfaces to TSC simulation through the Plasma State.
 - Future work needed to perform self-consistent simulation of current ramp-up with ICRF heating.
- New physics target proposal:
 - Simulation of current ramp-up in Alcator C-Mod with combined ICRF heating and lower hybrid current drive (LHCD).

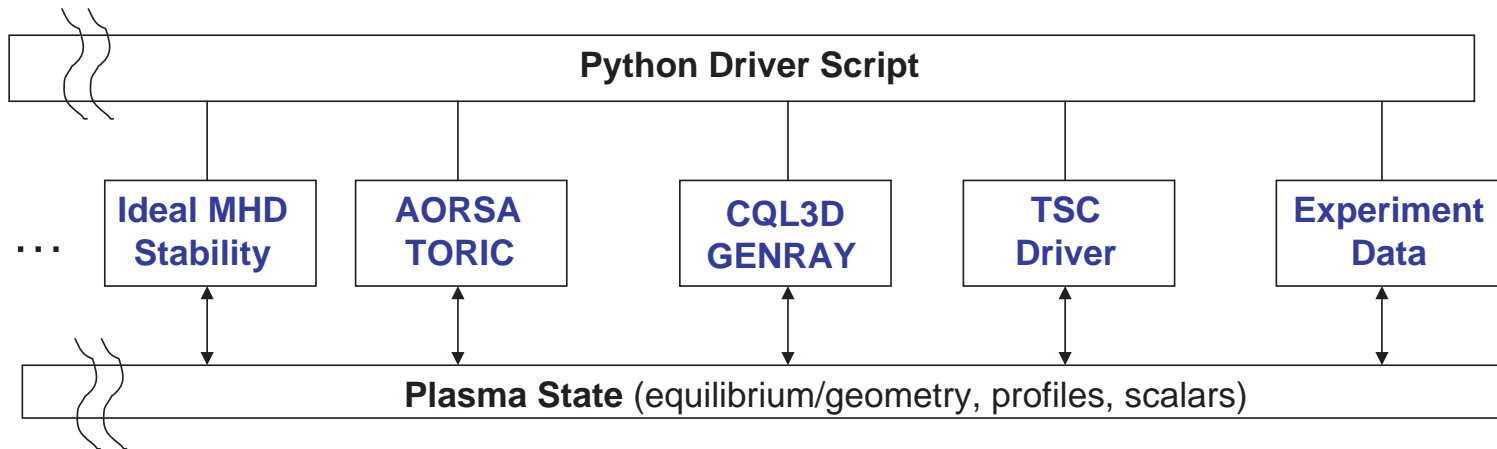
Simulation of Current Ramp-Up and ICRF Heating Phases in Alcator C-Mod

- Physics target:
 - Canonical C-Mod discharge with an initial fast current ramp-up followed by an EDA H-mode transition produced with ICRF minority heating:
 - $B_T = 5.4$ T, $I_p = 0.66$ MA, D-majority, H-minority
 - $f_0 = 80$ MHz, $P_{\text{ICRF}} = 3.5$ MW
 - Discharge is a good physics target because we have validated the AORSA-CQL3D simulation model against minority heating experiments on C-Mod.

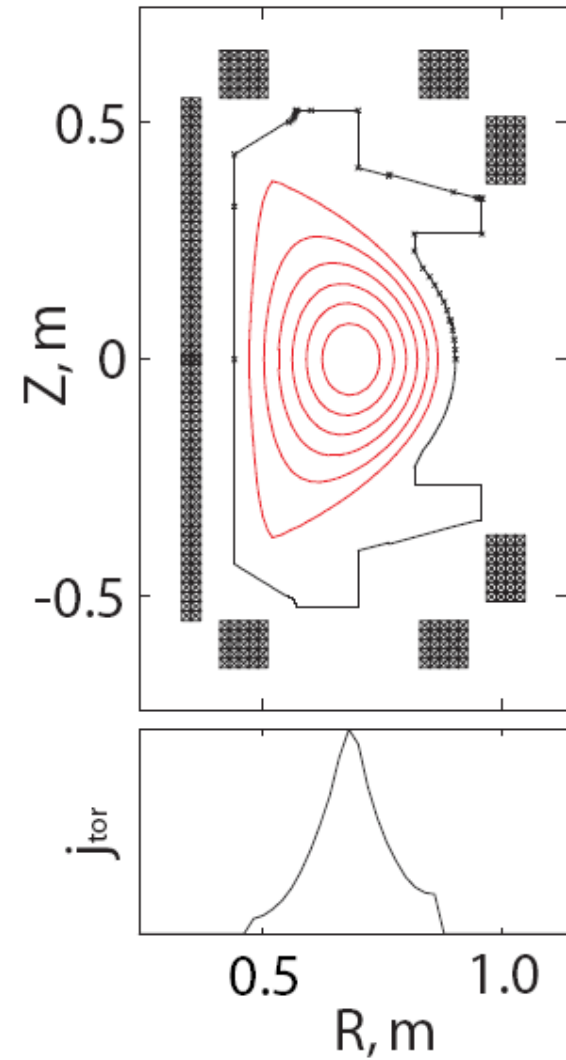
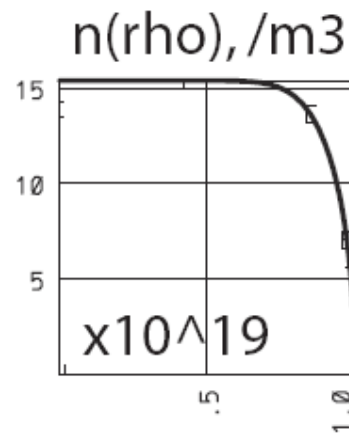
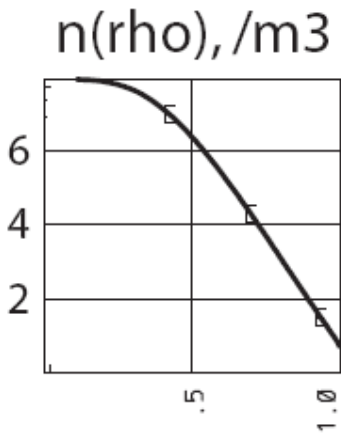
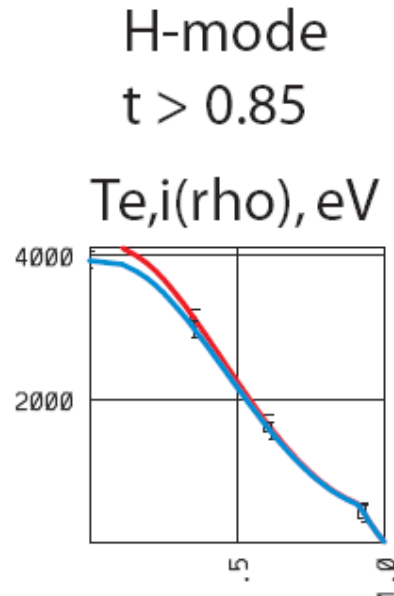
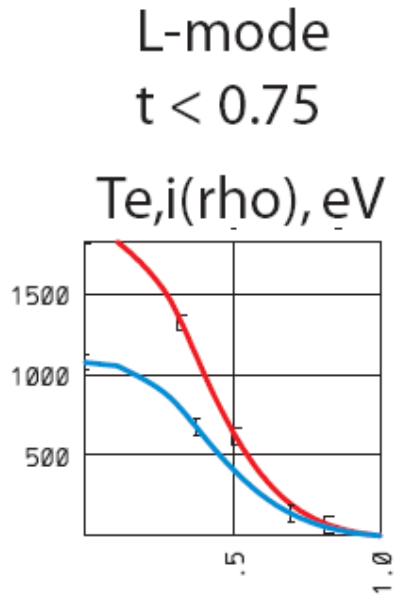
Status of C-Mod Simulation Work

- Initial C-Mod simulation was done by C. Kessel (PPPL):
 - Used C-Mod coil set and *model* ICRF heating sources.
- TSC simulation was redone by L.- P. Ku:
 - Equilibrium and profile information were written to the Plasma State in the Integrated Plasma Simulator (IPS).
- AORSA (L. Berry, E. Jaeger) and TORIC (J. Wright) have been interfaced to the TSC simulation through the Plasma State:
 - **Each code has successfully read from and written its results to the Plasma State for a few time slices.**

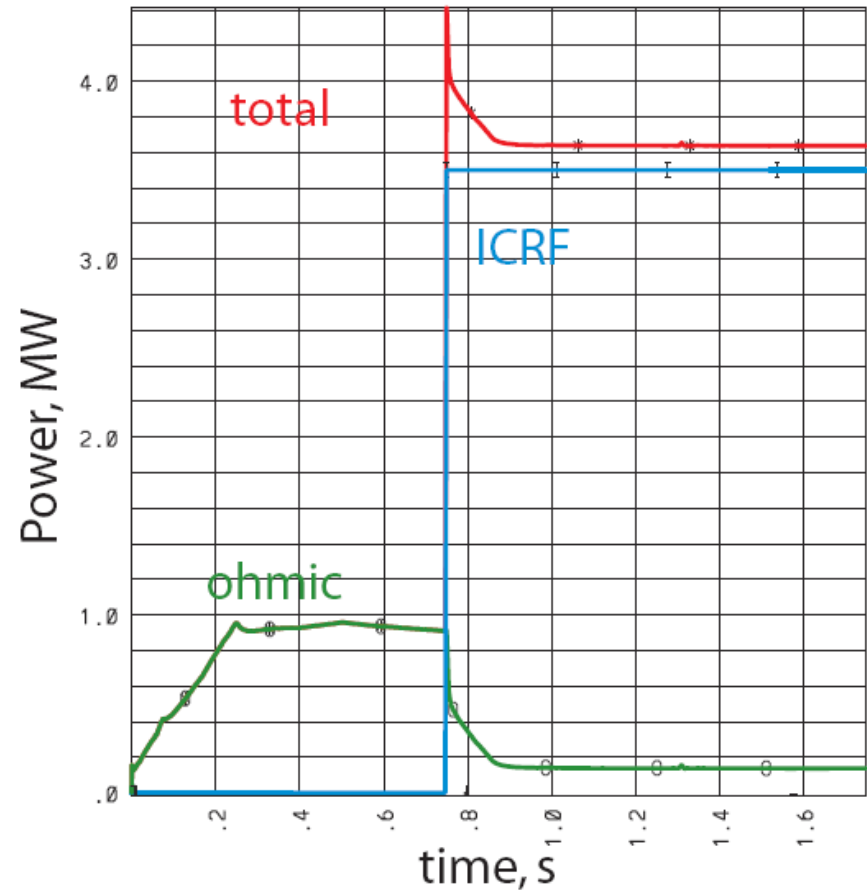
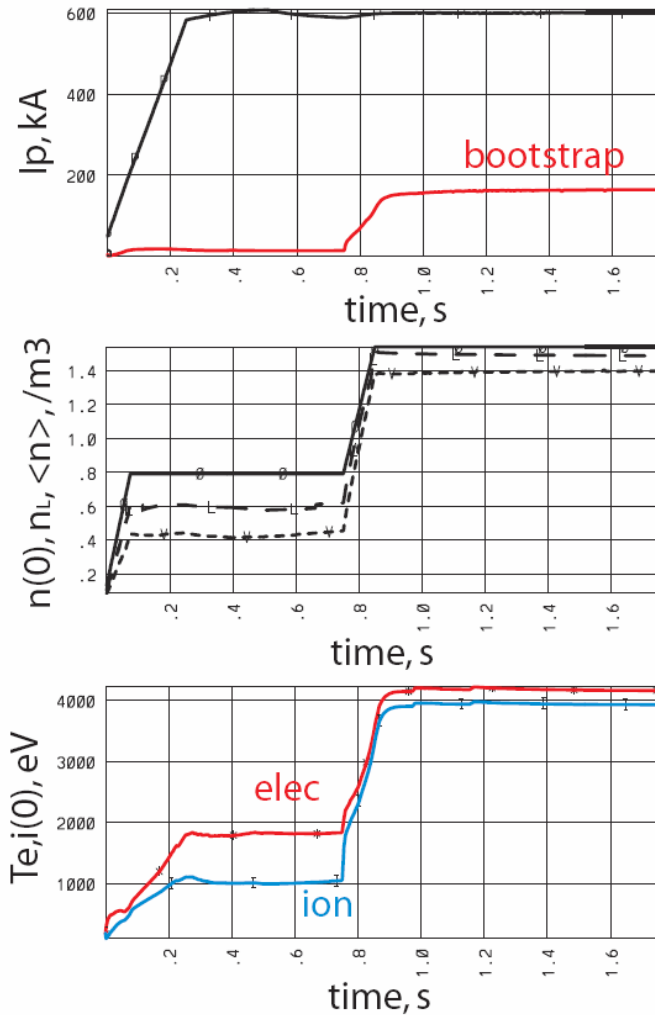
SWIM Framework for Integrated Fusion Plasma Modeling: “Integrated Plasma Simulator -IPS”



Initial TSC Simulation of Alcator C-Mod current Ramp-Up and ICRF Heating Phase (C. Kessel)



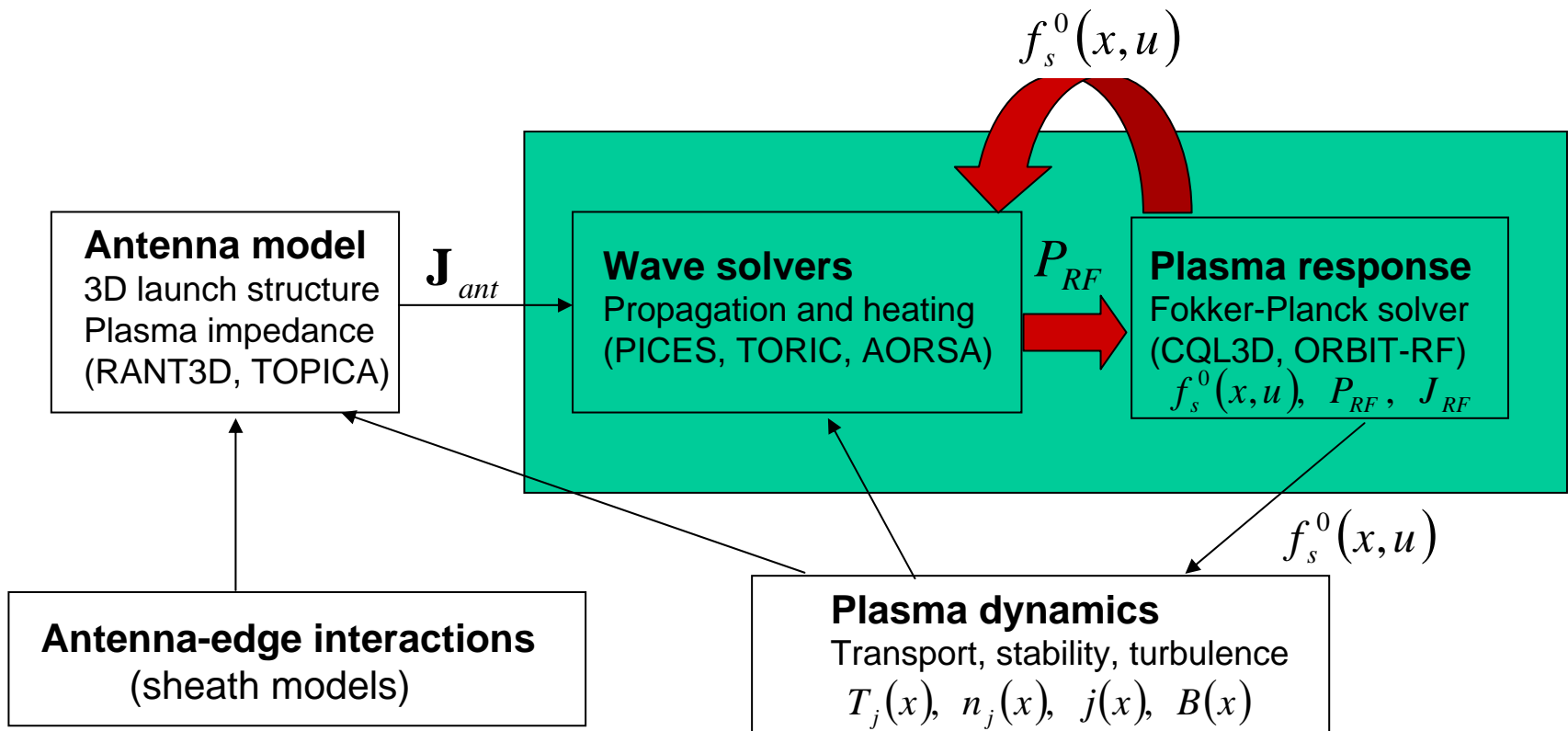
Initial TSC Simulation of Alcator C-Mod current Ramp-Up and ICRF Heating Phase (C. Kessel)



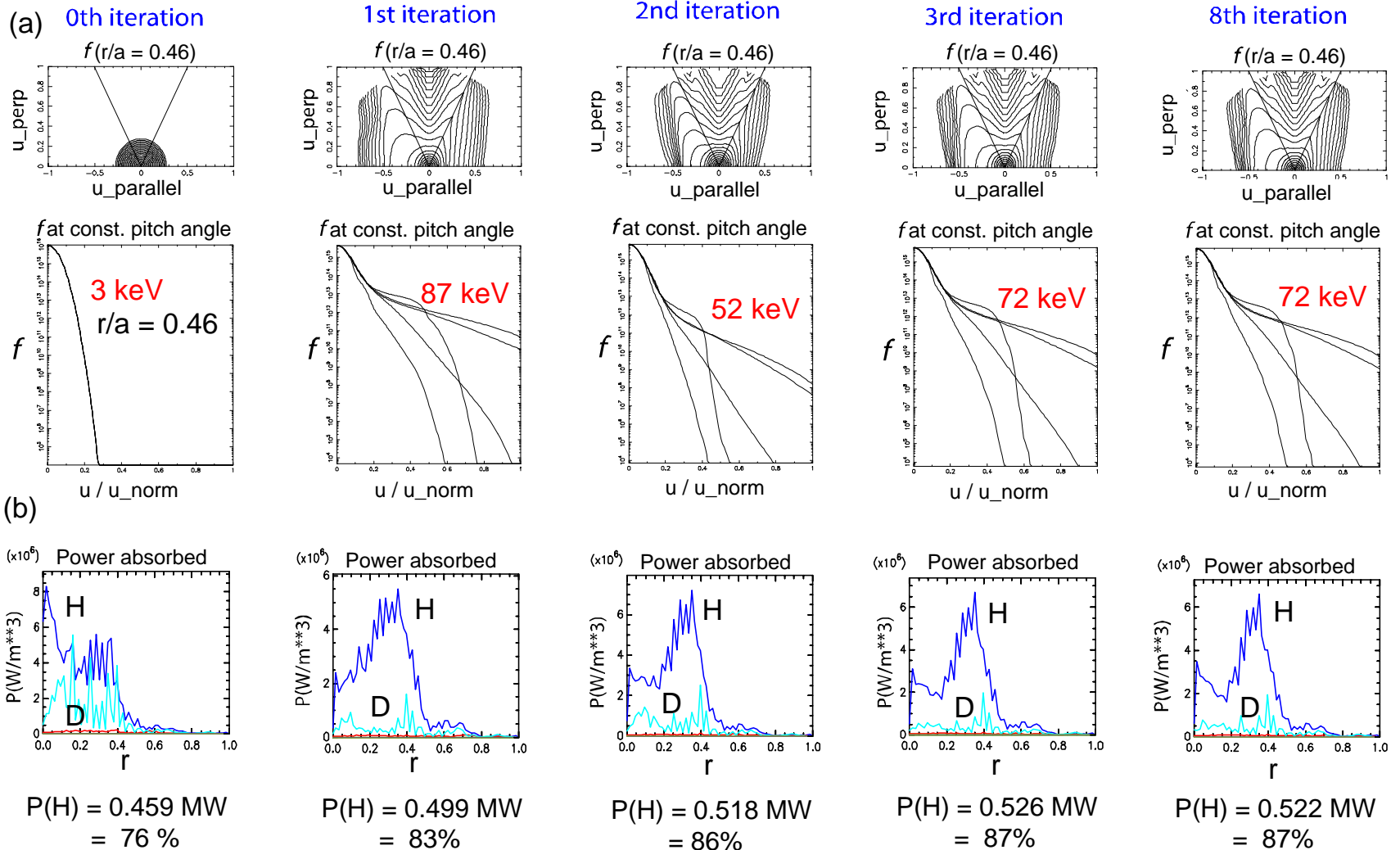
Future Work Needed for the C-Mod Ramp Up and ICRF Heating Simulation

- Complete verification of the AORSA and TORIC calculations:
 - Call codes for more time slices in the Plasma State and check the results using CSTATE.
- Self-consistent evolution of the nonthermal minority (H) distribution during the C-Mod discharge evolution:
 - Advance equilibrium and profiles using TSC.
 - Write results to the Plasma State.
 - Call AORSA/CQL3D from the IPS to evolve the nonthermal (H), compute the bulk plasma heating sources from the tail, and write results to the Plasma State (> 1000 cpu-hours).
 - Advance the discharge using TSC.
 - Repeat
 - *Note: Calculation time of nonthermal tail will be greatly reduced when TORIC/CQL3D coupling is completed through CSWPI.*

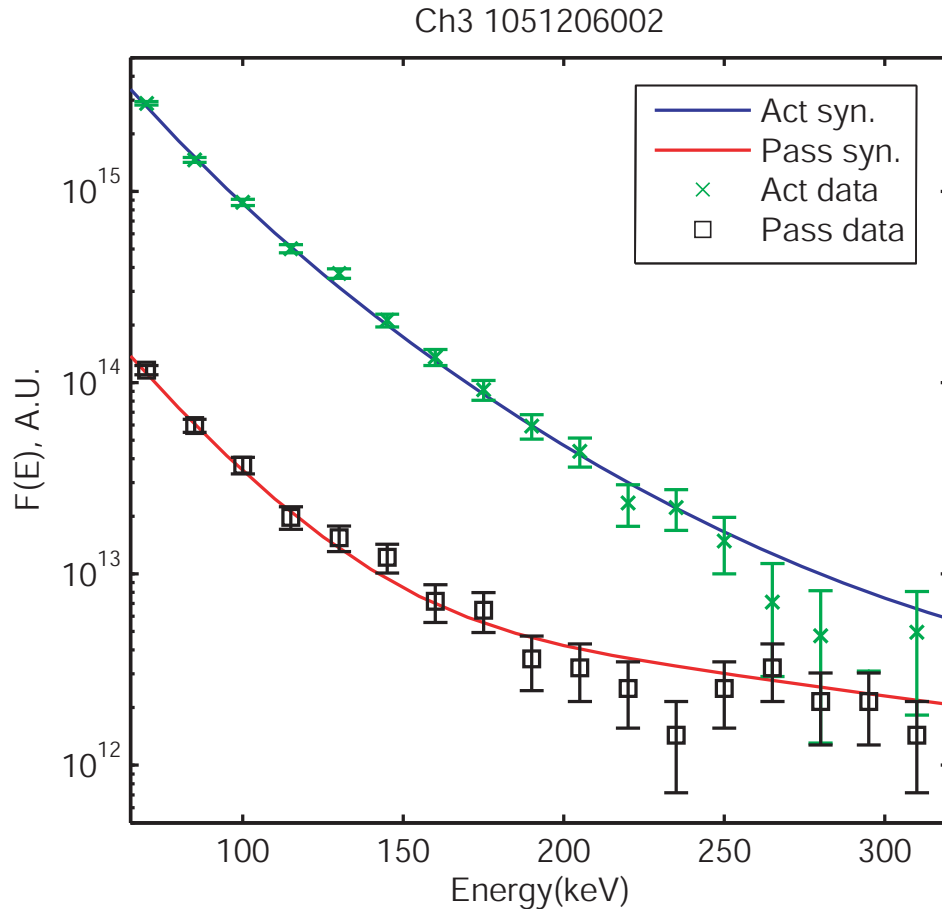
Iteration Scheme within the IPS for Self-Consistent Computation of the Nonthermal Minority (H) Tail



Calculation for C-Mod minority H, $N_R = 128, N_Z = 128,$ [256 processors for 3 hrs on Cray XT3 – ORNL]



3D ($r, V_{\perp}, V_{\parallel}$) distribution function from CQL3D – AORSA reproduces CNPA measurements using a synthetic code diagnostic



**V. Tang, PhD Thesis,
MIT (2006); also PPCF,
49, 873 (2007).**

New Physics Target Proposal:

- Simulation of advanced tokamak operating mode in Alcator C-Mod with combined ICRF heating and lower hybrid current drive (LHCD):
 - C-Mod now has a 3 MW LHRF system for performing off-axis current profile control to access improved confinement regimes near the ideal no-wall Beta-limit [see P. T. Bonoli *et al*, PPCF (1997).
 - Discharge can be evolved initially using TSC.
 - AORSA-CQL3D and / or TORIC-CQL3D can be used to compute the self-consistent ICRF heating sources from within the IPS.
 - CQL3D-GENRAY can be used to compute the self-consistent LH current drive from within the IPS.
 - Discharges can be then be analyzed for ideal stability to the $n=1$ external kink mode from within the IPS, using JSOLVER-PEST.
- Similar experiments could be analyzed for the JET device where LHCD is being used to produce discharges with “optimized shear”.