CQL3D Fokker-Planck Solver and Coupling Issues
Swim Conference, Sept. 24-26, Bloomington, In.

•A 3D bounce-averaged FP equation is solved, time-dependent or interative to SS:

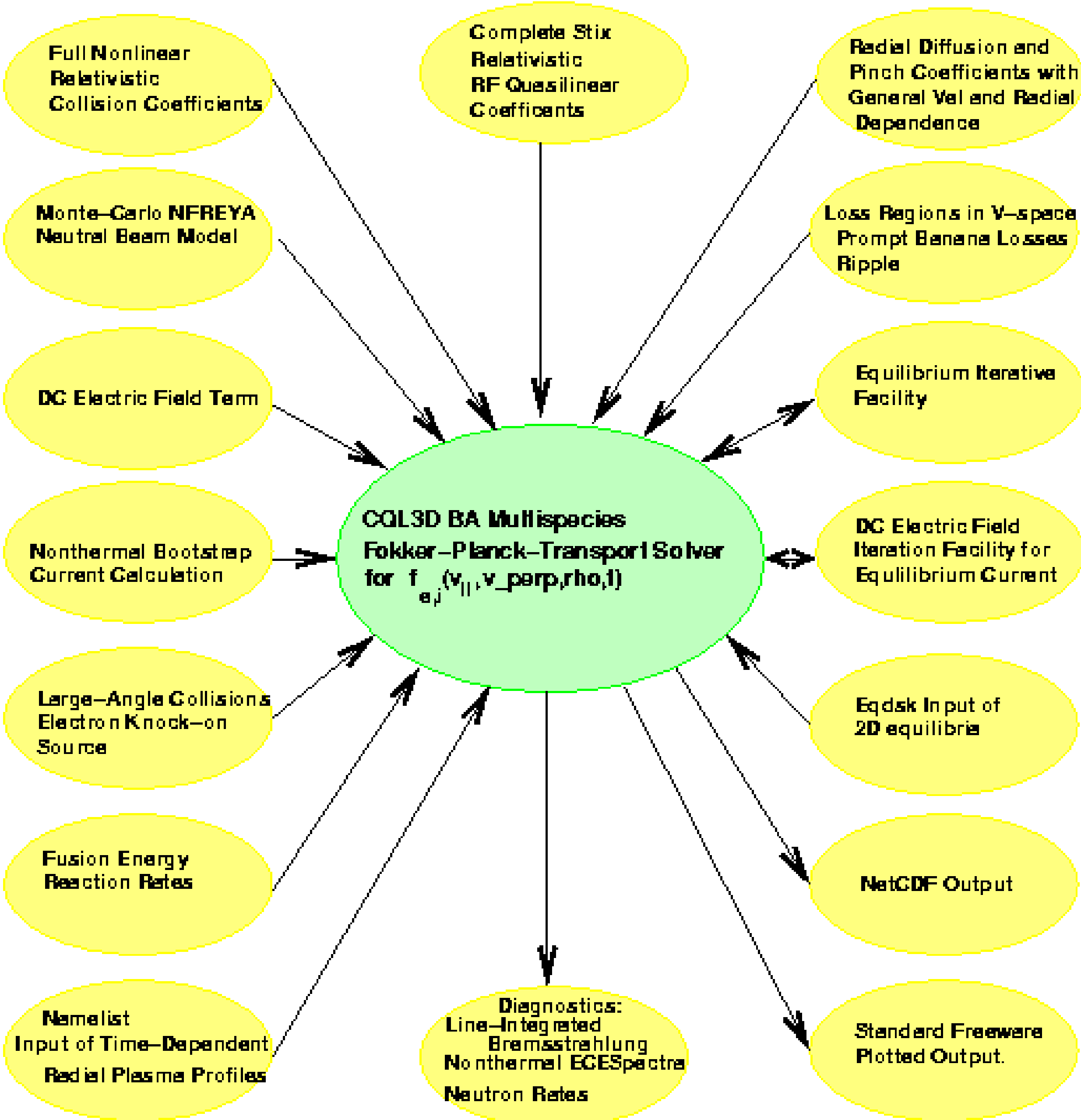
$$\frac{df(u_o, \theta_{0,} \rho, t)}{dt} = \langle\langle C(f) + Q(f) + E(f) + S(f) \rangle\rangle$$

Collisions RF E-field Part. source

Effectively 4D, i.e., incl. pol. angle, since usually $\tau_{bounce} \ll \tau_{coll}$

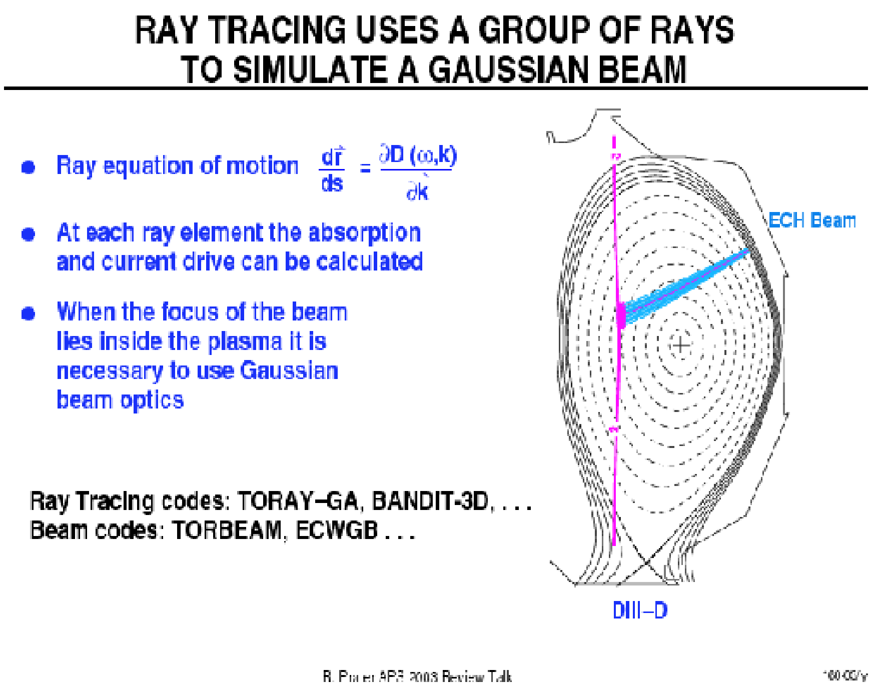
•Will discuss:

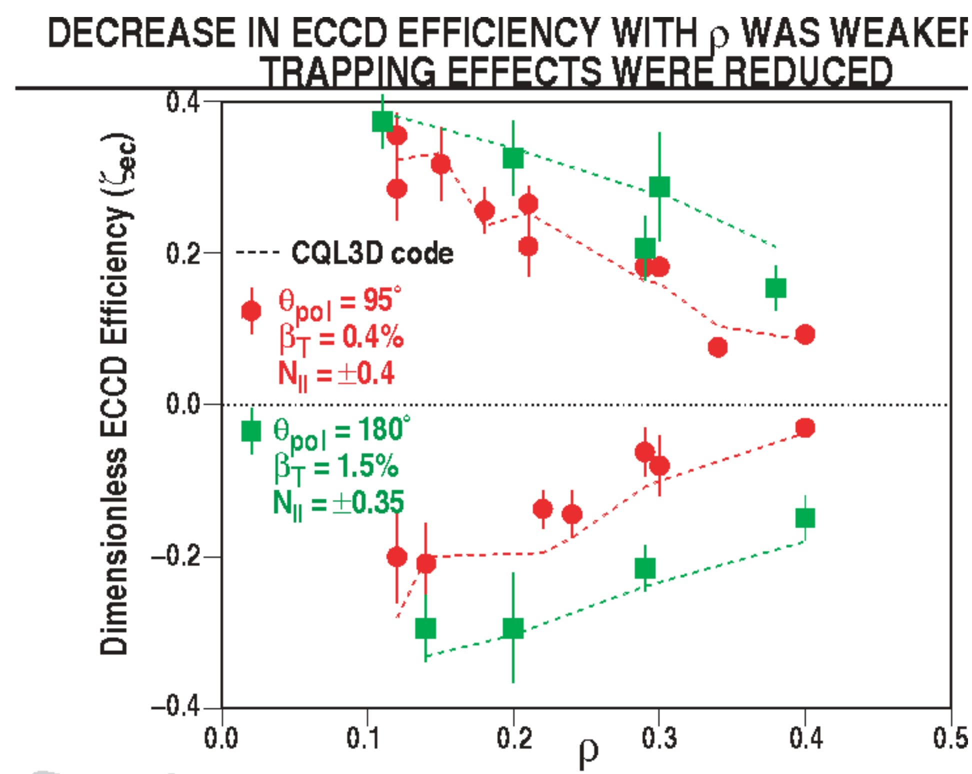
- Code schematic
- What is code used for (few examples)
- Inputs/Outputs
- Coupling Issues (Some)



Schematic of CQL3D Functionalities

ECCD in DIII-D calculated with No-free-parameters, for Wide Range of Conditions





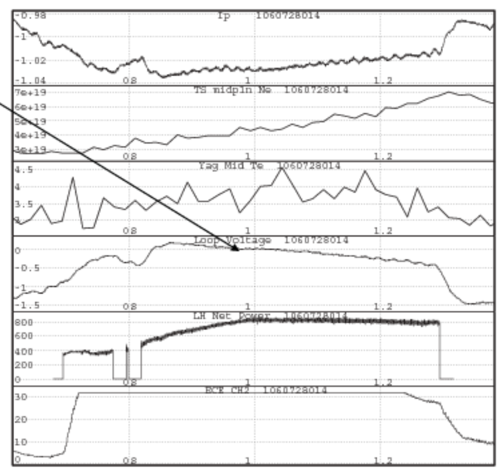
C-Mod LH Power Absorption and CD Modeled with No-free-parameters.

Antenna spectrum of LH waves from Brambilla code.
Ray tracing with GENRAY.

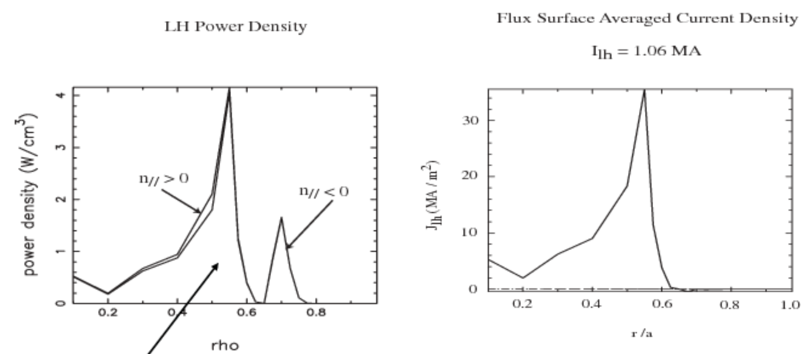
Experimental Observation on Shot 1060728014 was that Loop Voltage was Driven to Zero for ≅ 100 ms with LHCD

- Loop voltage driven to zero with 800 kW LH power
- LH launcher run with $\Delta\phi$=60 Deg. ($n_{//}$ = 1.6 → E_{res} = 144 keV)

1 MA Shot with LHCD



Driven LH Current is peaked off-axis



- Agreement between RF power computed in Fokker Planck Equ'n. and RF power damped along rays indicates calculation is converged.

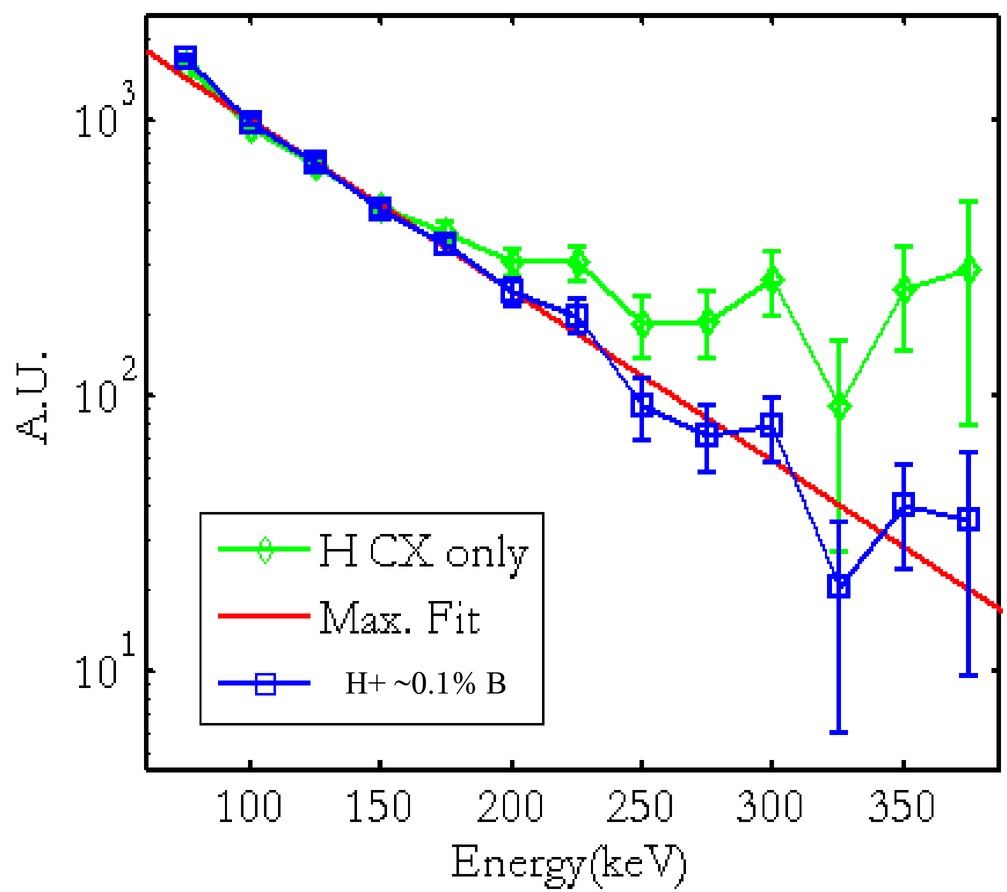
Decided to compare AORSA/CQL3D and ORBIT-RF on a minority ion heating case from Alcator C-Mod

Relatively low energetic tail energies might render finite ion orbit effects less important in which case AORSA/CQL3D and ORBIT-RF should agree

Fundamental minority ion absorption is well-understood.

Good experimental measurements of the energetic ion tail have been made using a compact neutral particle analyzer (CNPA)

•Using a Maxwellian fit to data gives $T_{ion} \sim 70$ keV.



Courtesy of Vincent Tang, MIT (APS, 2005)

What is Obtained from Comparison of FP Modeling and Expt?

- Validation that model has sufficient physics to predict power deposition and current drive profiles, and the distribution function (more req'd). (This is a nonlinear model, deposition affected by nonthermal particles, current drive calculated from distributions functions.)
- (Some) confidence in its usefulness for predicting future experiments.
- So far, this is almost entirely for steady state, given plasma profiles.
- So far, what we have is passive: did the expt, understood the result.

  So, we have some useful tools.

- What we want now:
  Our IPS as a model for active control of the plasma core:
  - Gives time-dependent modeling, including start-up phase.
  - Provides guidance on avoidance of electron runaway avalanche,
    control of radial profiles to avoid MHD instability,
    control of MHD by fast ions distributions (active and passive),
    control of radial transport through radial profiles, including momentum input.
  - (Need NT ion distributions coupled into MHD.)
  - Besides all-purpose deposition model, FP gives NT electron runaway, avalanche, RFCD, Fi's due to NBI, Alphas and RF.

Key Inputs/Outputs for CQL3D

INPUTS

- Toroidal equilibrium file (EQDSK)
- Plasma radial profiles: $n_s(\rho), T_s(\rho), s=$ electrons/ions, (Z_{eff})
- charges/masses (although mostly used one FP species at a time)
- NBI Parameters (inj specs, charge, power) and/or RF data (GENRAY and/or AORSA/TORIC)
- Toroidal Electric field (Alternatively, iterate to obtain given CD $j(\rho)$)
- Time step can be short, to resolve τ_{coll} , or long for effective iteration to SS

OUTPUTS

- Power deposition and current deposition profiles
- Various experimental diagnostic signals
- Electron and/or ion distributions, for further analysis

NEAR TERM (< 1 Yr) IMPROVEMENTS:

- Restart
- Alpha particle source
- Robust radial transport

COUPLING ISSUES

- Interpolate between time-steps: short time-steps or quasi-equilibria?
- Time-dependent equlibria (re-distribute radial particle distributions?; Induced E-flds?)