Update on Self-Consistent Plasma Modeling of ARIES Baseline Design Points

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Progress Made in Implementing Planned Self Consistent Simulation for ARIES-AT Baseline

- **Overview of proposed approach and optimization procedure**
- **Recent progress in implementing first steps:**
  - Pedestal model incorporated in profiles consistent with EPED1 model for peeling-ballooning stability
  - GENRAY code modified to allow multiple frequency waves launched from different launchers:
    - Required for 2006 ARIES AT scenario
  - Self consistent transport simulation using previous GLF23 model
  - Self consistent transport simulation using TGLF model with real geometry
- **Main Results:**
  - Self consistent transport simulation using new TGLF model is significantly more pessimistic:
    - Unable to find steady state solution
    - Profiles collapse
- **Future plans**

Proposal is Intended to Repeat Previous 2000 Effort For ARIES-AT With Improved Tools and Understanding

- **Analysis will involve:**
  - Coupled equilibrium, transport, current drive, fuelling, and stability calculations to obtain a steady state solution
  - In a self consistent simulation using:
    - Latest core transport models
    - Coupled to edge pedestal models

Key Features

- **Self consistent H-mode pedestal:**
  - Realistic pedestal height and width predictions with EPED1
- **Transport model TGLF in place of GLF23:**
  - Real shaped geometry instead of GLF23 shifted circle model
- **Lower hybrid and ICCD modeling**
- **Improved resistive wall stability understanding:**
  - Stabilization at low rotation
  - Role of error fields in braking at low rotation
  - New angular momentum transport models

Previous Progress Through April 2011 Set up Initial Case and Largely Reproduced Published Results

- **Initial case set up:**
  - Equilibrium with H-mode pedestal reproduced
- **Simulated electron and ion densities and temperatures (ONETWO):**
  - Edge density pedestal produced consistent with equilibrium pressure pedestal
  - No temperature pedestal
- **Current drive from Lower Hybrid and ICCD systems reproduced using GENRAY:**
  - Driven current shortfall compared with 2006 CURRAY results
  - Presumably due to H-mode pedestal

Next Steps Intend to Complete Self Consistent Optimization of ARIES-AT Design Point

- **Include consistent pedestal :**
  - Both temperature and density modified to reproduce H-mode pedestals:
    - Consistent with equilibrium H-mode pressure pedestal
  - Equilibrium pedestal modified for consistency with peeling-ballooning (ELM) stability:
    - EPED1 model to provide pedestal height and width for given pedestal β_{pol}
- **Self consistent steady state scenario iteration:**
  - Heating and current drive optimization using TGLF transport model
  - Pedestal optimization for β_{pol} consistent with transport simulation and EPED1 model
- **Iteration on β, q profile, and ultimately cross section:**
  - Varied around design point as needed
  - Resistive wall mode stability considered

Capability of Launching Multiple Waves with Different Frequency Added to GENRAY

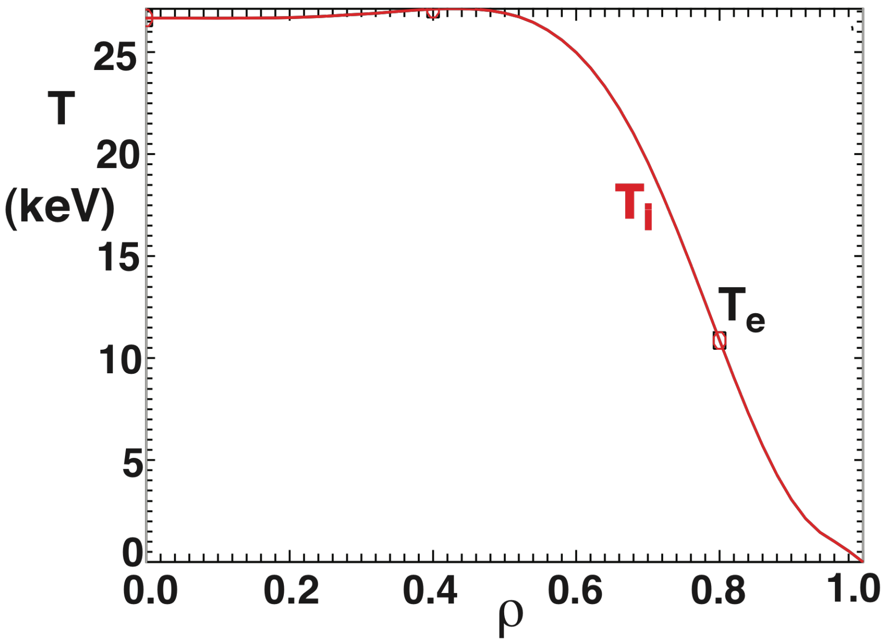
- **ARIES-AT scenario requires multiple frequency Lower Hybrid waves from different launchers:**
  - Scenario 1 5th grill launches different frequency from others
  - In general, each grill in practice can launch a different frequency wave

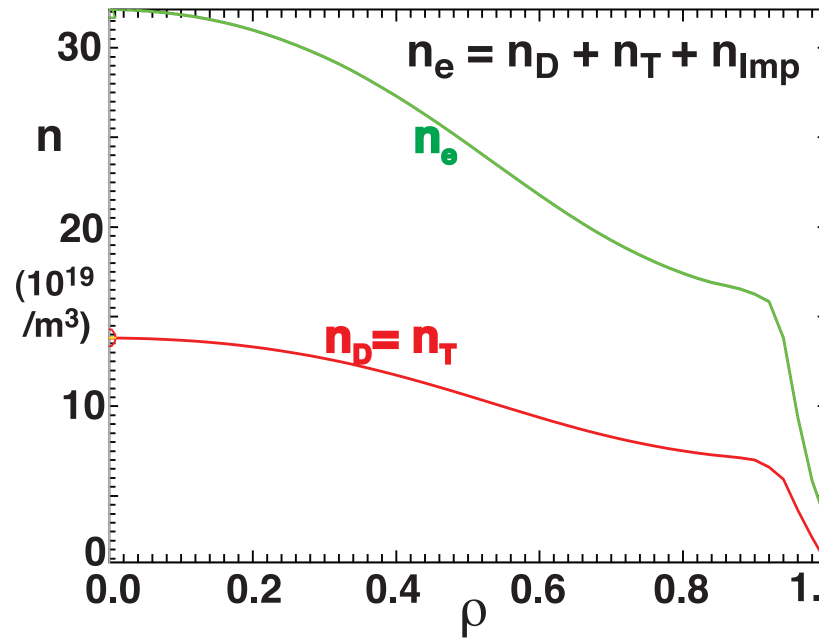
Freq (GHz)	$N_{//}$	θ	Power (37 MW)	I/P (A/W)
3.6	1.65	-90	3.06	0.053
3.6	2.0	-90	4.40	0.049
3.6	2.5	-90	8.22	0.039
3.6	3.5	-90	8.87	0.024
2.5	5.0	-90	12.39	0.013

- **In the previous version of the general ray tracing code GENRAY every grill was assumed to launch the same frequency wave:**
  - Heating and driven current from separate simulations from each grill summed to compute the total
- **New capability added to GENRAY by including multiple grills in the poloidal plane:**
  - Heating and current drive identical to previous summed result

Incorporated Temperature and Density Pedestal Consistent with EPED1 Model H-mode Pressure Pedestal

- **EPED1 model predicted H-mode pedestal height and width:**
  - In place of the *ad-hoc* pedestal imposed on the published ARIES-AT base configuration
  - Pedestal β_N of 1.0 near $\rho = 0.93$
- **Pedestal added to published profiles:**
  - Equilibrium recomputed and used as initial profile in simulation

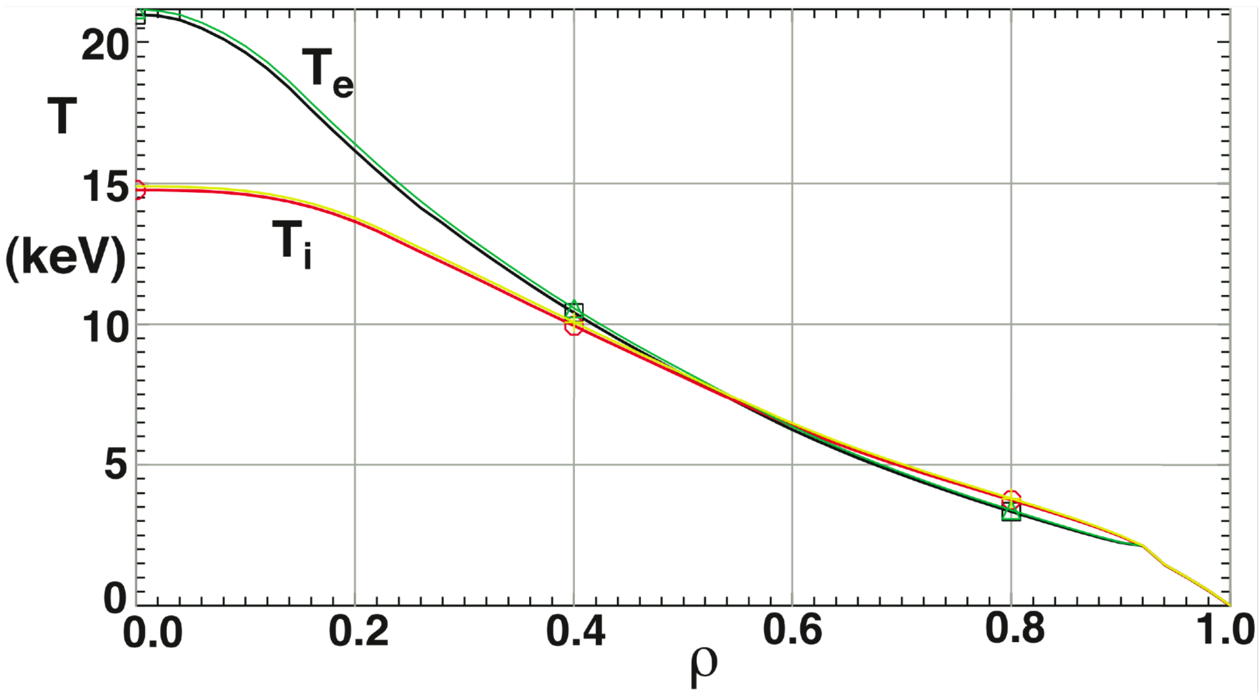




Initial Results Obtained using GLF23 and TGLF Transport Models with Lower Hybrid Current Drive From GENRAY

- **Steady state result achieved using GLF23 after one full second of evolution**
  - Fixed density and RF heating profiles
  - Shifted circle geometry assumed by the GLF23 model

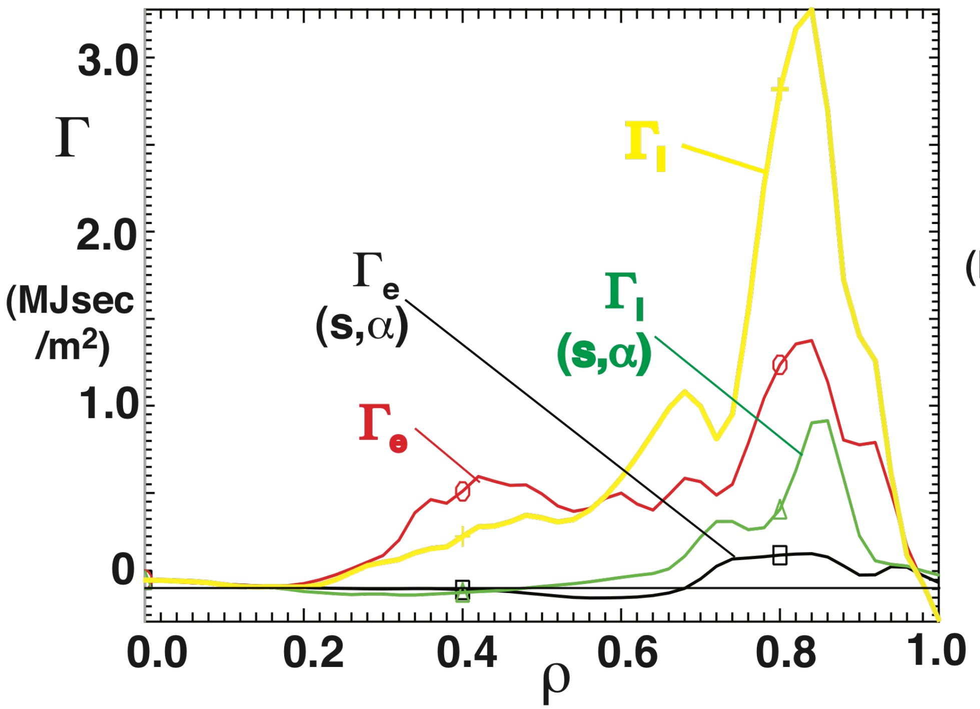
- **Steady state profiles using GLF23:**
  - Slightly different curves obtained from different computational models



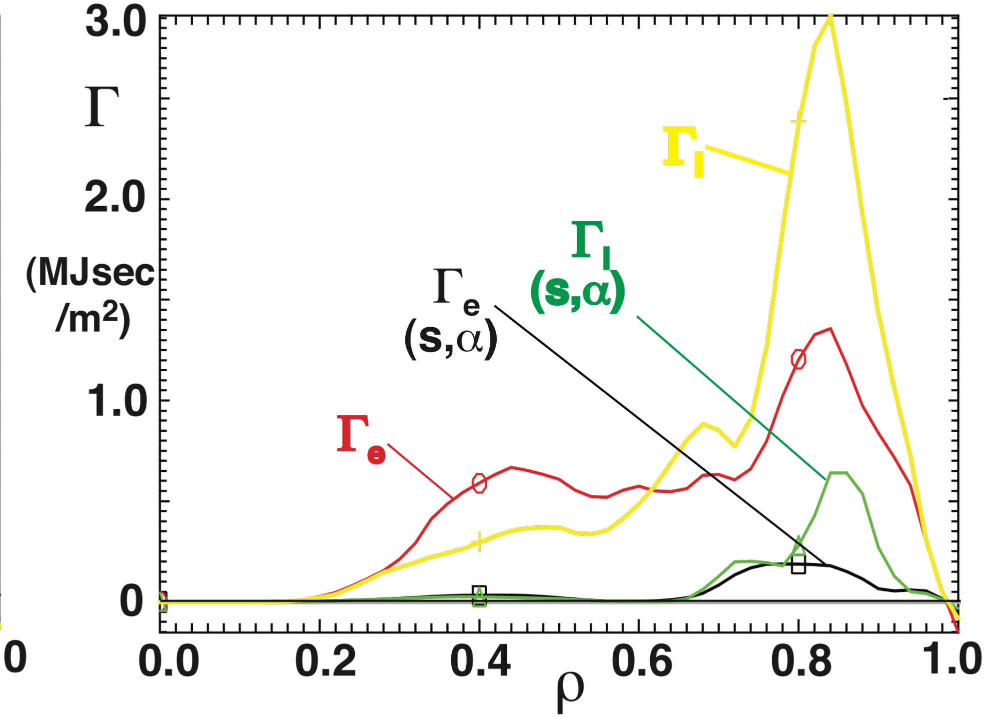
More Sophisticated TGLF Model Incorporates Cross Section Shaping But is Significantly More Pessimistic

- **Same case run with the TGLF model did not reach steady state:**
  - Increasing fusion heating power did not yield improvement

Total Electron and Ion energy flux Including neoclassical



Electron and Ion energy flux Without neoclassical



Pessimistic TGLF Result May be Due to Full Geometry or to Other Features of the Model

- **Run one iteration to obtain individual fluxes and sources:**
  - Calculate individual fluxes and compare with:
    - TGLF with shifted circle geometry
    - GLF23 (shifted circle geometry)
- **Run to steady state:**
  - If TGLF reaches steady state with shifted circle geometry then the shaping is the culprit:
    - Determine sensitivity to small tweaks in shape and profiles
  - Otherwise it may be simply higher accuracy of the TGLF model
  - May need rotational shear stabilization from neutral beams
- **TGLF and GLF23 are known to fail to predict experiments for $\rho > 0.85$ even in L-mode:**
  - Present boundary condition taken to be at pedestal ($\rho = 0.93$)
  - Option to move this boundary condition in and apply at $\rho = 0.85$:
    - Steady state was reached with boundary arbitrarily moved to $\rho = 0.82$
  - Need to properly match profiles between $\rho = 0.85$ and $\rho = 0.93$

Future Plans Intend to Complete Optimization for Self Consistent Steady State Scenario

- **β optimization:**
  - Initialize with β_N = 5.7
  - Check ideal stability
  - Optimize to converge to maximum stable β_N
- **q profile optimization:**
  - Adjustment of q profile to improve stability and current drive potential
- **Shape and size optimization:**
  - Elongation, triangularity and aspect ratio
  - Size adjustments as needed
- **Aim to use IMFIT for automation of core loop of transport self consistently optimized with heating and current drive**

- **In the initial steps of the subsequent optimization, the GLF23 transport model will be used:**
  - Considerably faster than the more accurate TGLF model
  - Utilize TGLF once simulations are partially converged

Backup slides

“FRQNCYG” in Namelist GRILL Is Added to Launch Different Frequency From Each Grill

- **Input file “genray.dat” for ARIES Scenario 1**

```
&WAVE
  FRQNCY =   3.6
&END

&GRILL
   NGRILL =   1
   N// = 1.65
   POWERS = 3.1
&END
```

+

```
&WAVE
  FRQNCY =   3.6
&END

&GRILL
   NGRILL =   1
   N// = 2.0
   POWERS = 4.4
&END
```

+

```
&WAVE
  FRQNCY =   3.6
&END

&GRILL
   NGRILL =   1
   N// = 2.5
   POWERS = 8.2
&END
```

+

```
&WAVE
  FRQNCY =   3.6
&END

&GRILL
   NGRILL =   1
   N// = 3.5
   POWERS = 8.9
&END
```

+

```
&WAVE
  FRQNCY =   2.5
&END

&GRILL
   NGRILL =   1
   N// = 5.0
   POWERS = 12
&END
```

```
 &GRILL
   NGRILL     =  5
   N//        =  1.65  2.0  2.5  3.5  5.0
   FRQNCYG =  3.6    3.6  3.6  3.6  2.5
   POWERS     =  3.1    4.4  8.2  8.9  12
&END
```