Integrated Modeling of Burning Plasmas with TSC

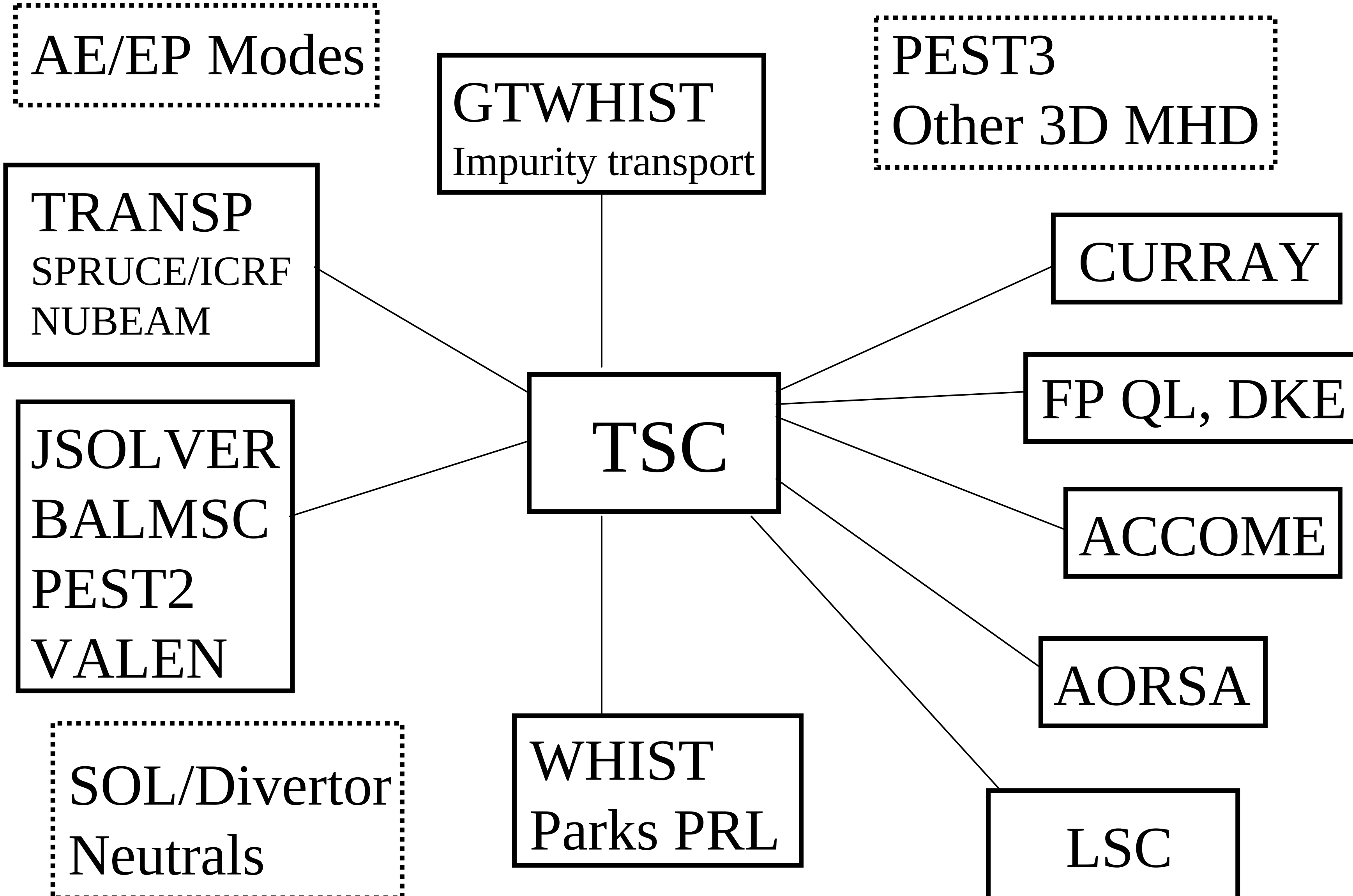
C. Kessel

Princeton Plasma Physics Laboratory

U.S.-Japan Workshop on Integrated Modeling,

9/21-24/2004, PPPL

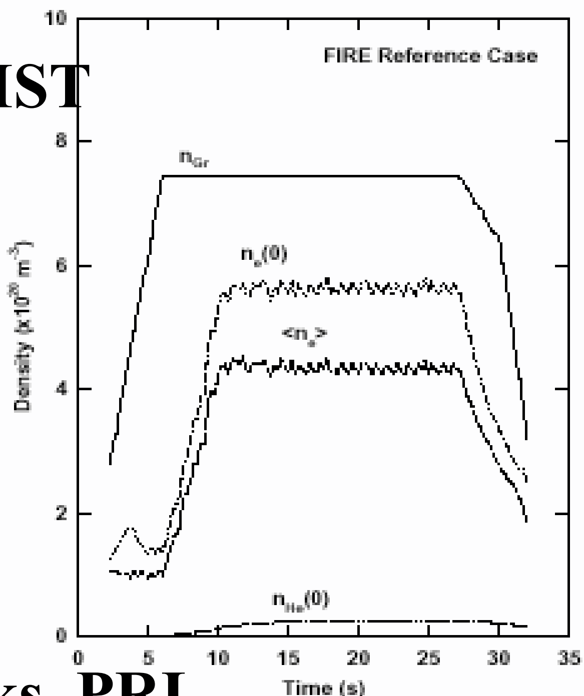
Integrated Modeling for FIRE Burning Plasmas



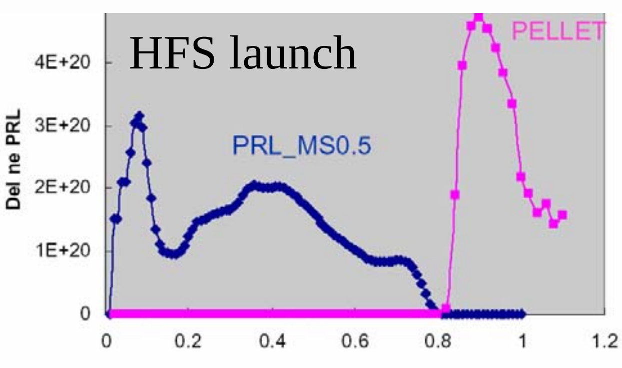
Integrating Results of Separate Analyses

HFS pellet ablation and density peaking

WHIST

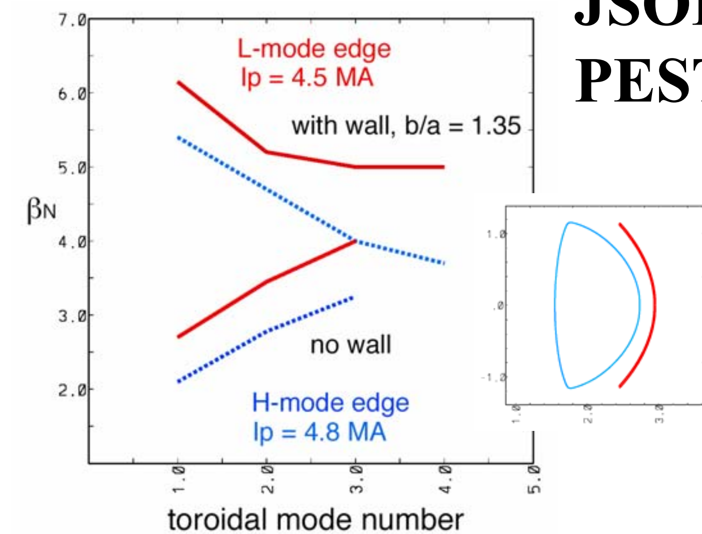


Parks, PRL



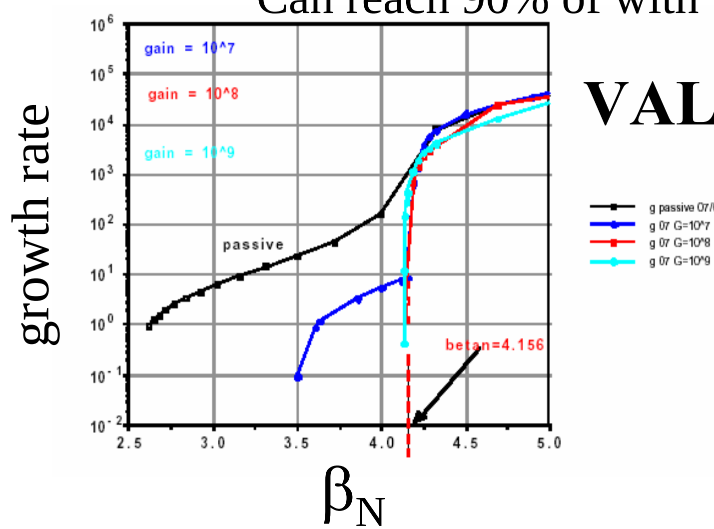
Ideal β_N limits and accessible limit with feedback

JSOLVER PEST2



Can reach 90% of with wall limit

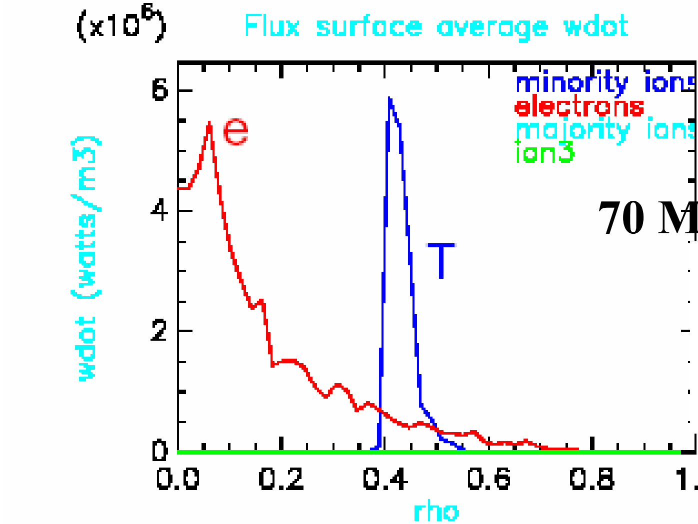
VALEN



Integrated Results of Separate Analyses

ICRF/FW deposition and CD efficiency

AORSA

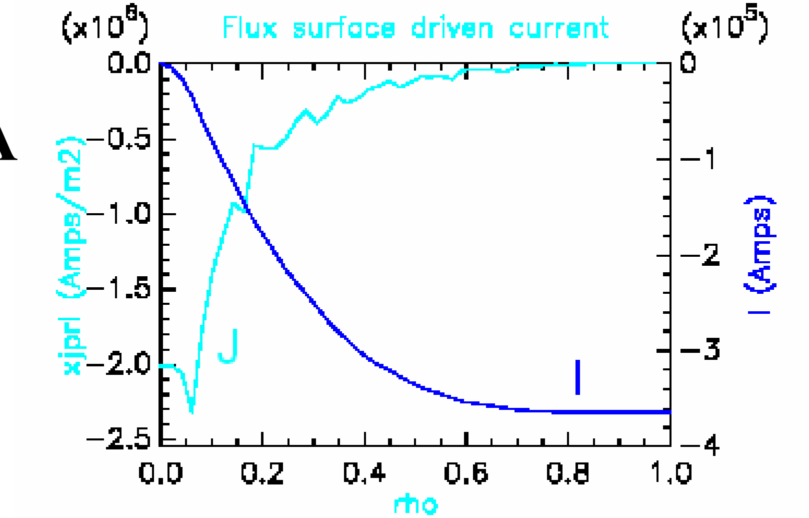


70 MHz

$P_e=0.65$

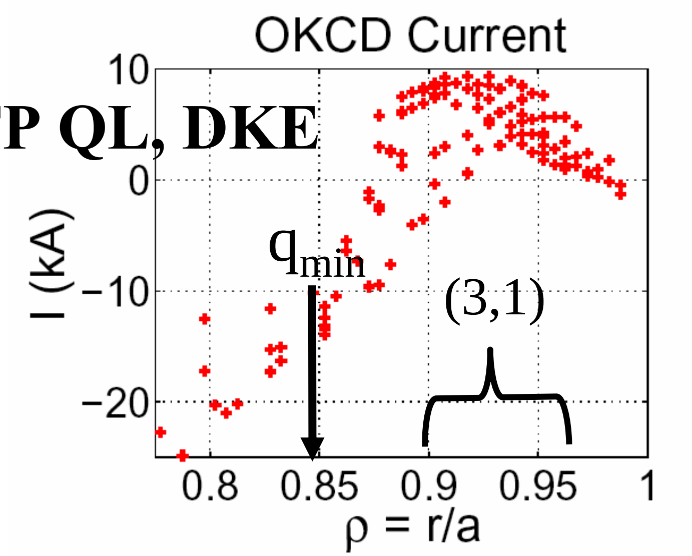
$P_T=0.32$

$P_{Be}=0.0$



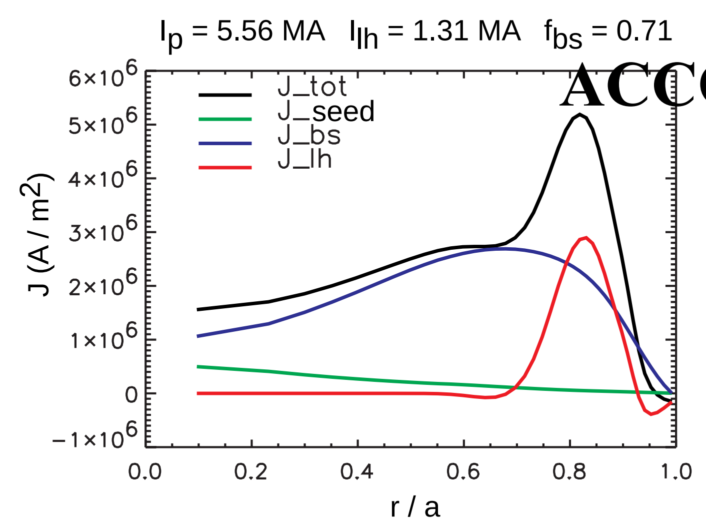
EC deposition and CD efficiency

FP QL, DKE



Benchmark LH deposition and CD efficiency against LSC

ACCOME

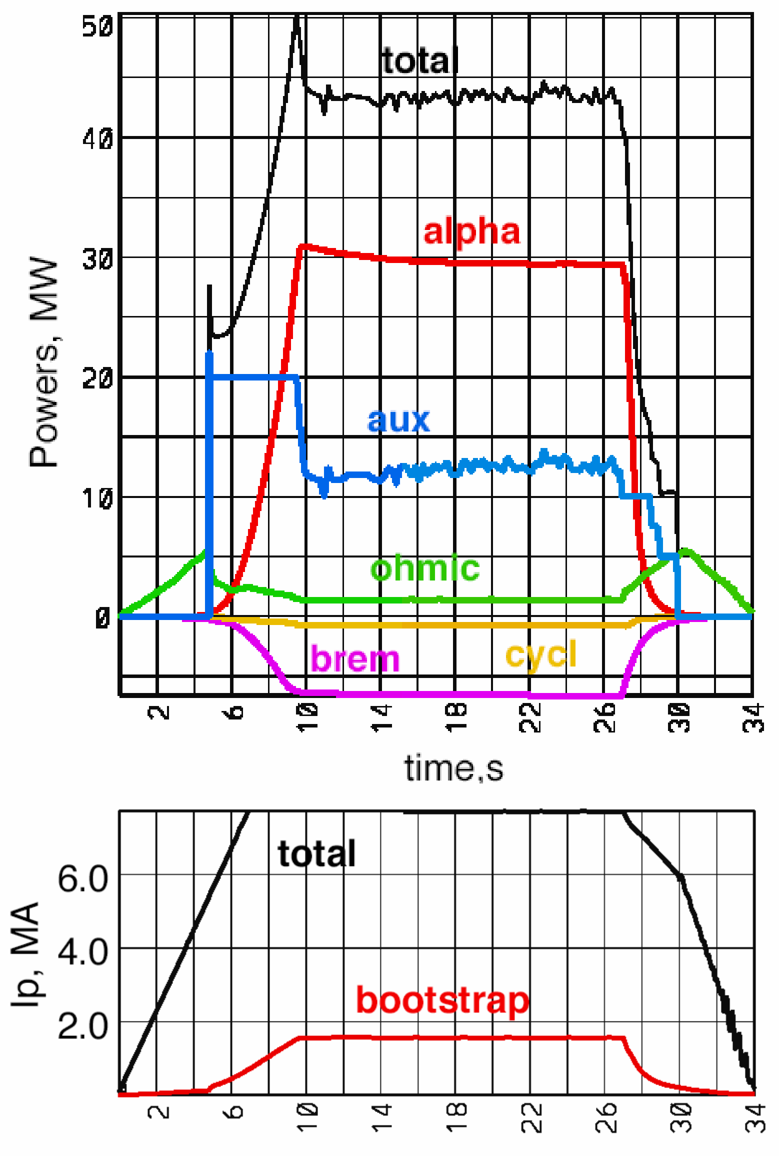


Modeling of FIRE Burning H-mode

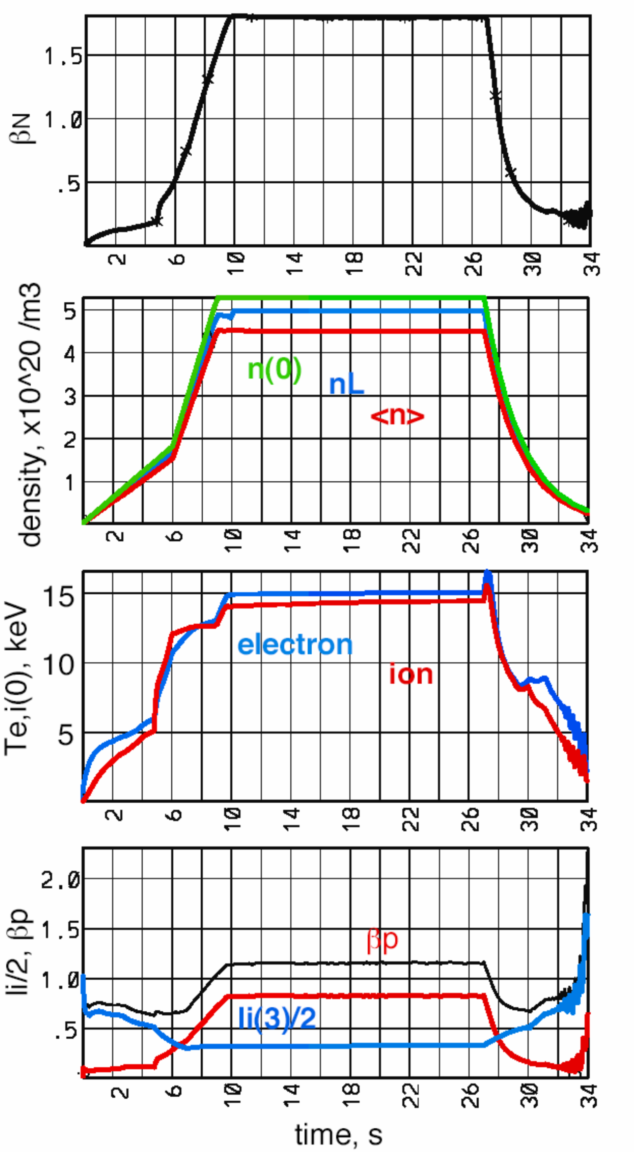
FIRE H-mode Discharge Simulation

Free-boundary
Energy and current transport
GLF23 core energy transport
Density profiles assumed
Assumed pedestal height/location
ICRF heating, data from SPRUCE
Bootstrap current, Sauter single ion
Porcelli sawtooth model
Coronal equilibrium radiation
Impurities with electron density profile
PF coils and conducting structures
Feedback systems on position, shape, current
Use stored energy control

Ip = 7.7 MA, B_T = 10 T

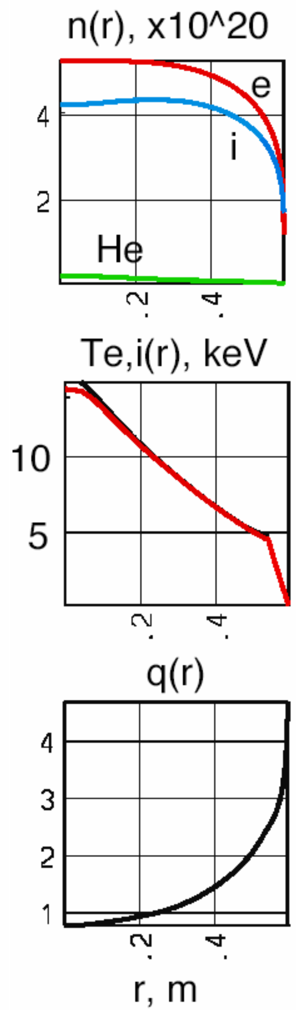


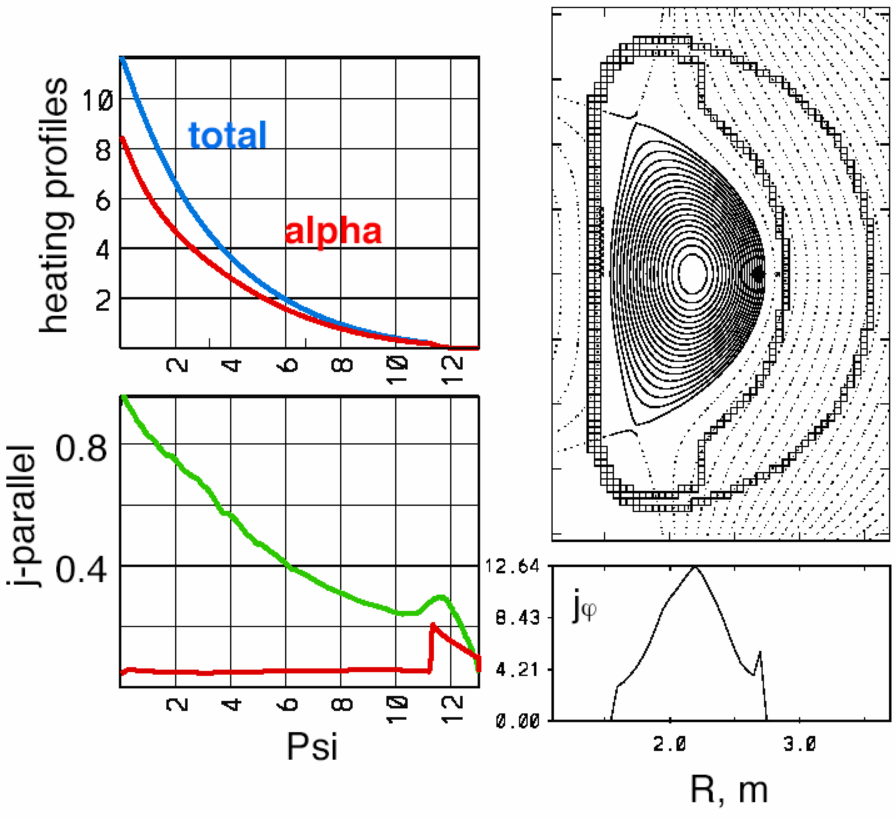
Modeling of FIRE Burning H-mode



FIRE H-mode GLF23

Ip = 7.7 MA, B_T = 10 T





Applied the GLF23 Transport Model in TSC

Parametrics for FIRE H-mode fusion performance

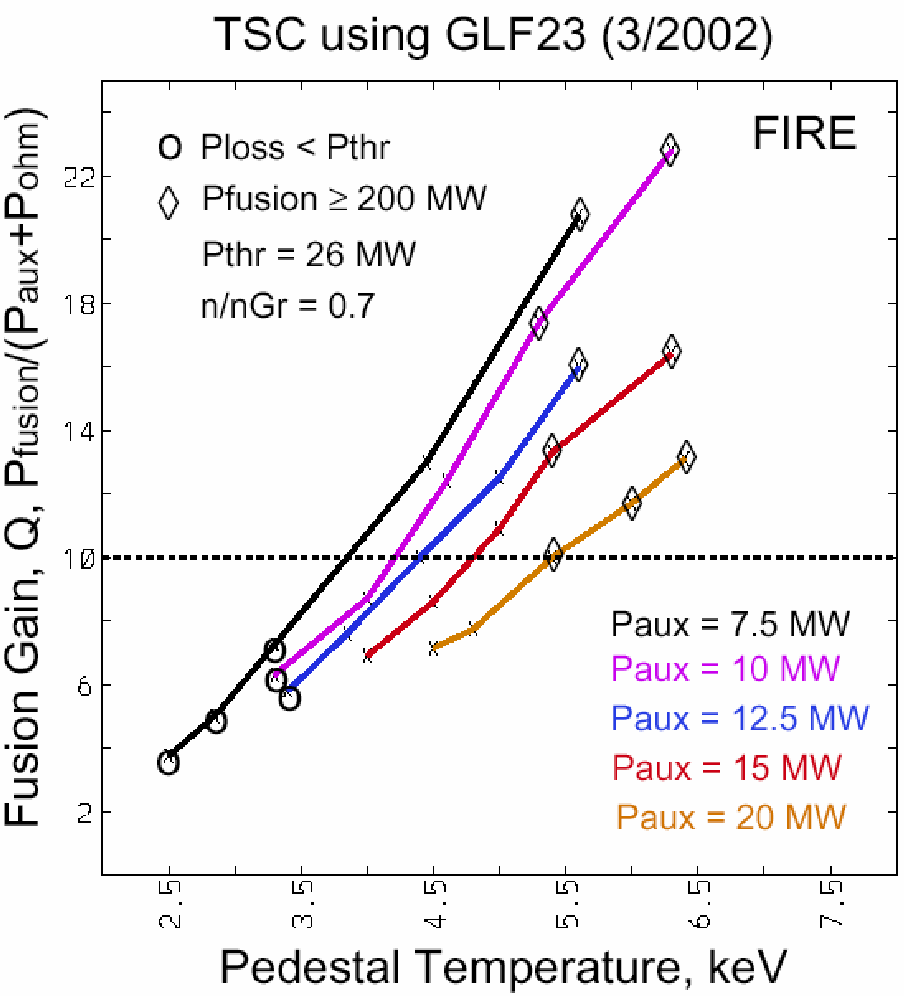
T_{ped}* ≈ 3.5-5.5 keV

Q ≈ 10

P_{aux} ≈ 7.5-20 MW

***ITER Pedestal Database (2003) projects about 5.4 keV for FIRE**

FIRE	Q	Paux(MW)	Tped(keV)
TSC GLF	10.3	13.5	4.5
	10.0	7.5	3.8
	10.0	10.0	4.1
	10.0	12.5	4.4
	10.0	15.0	4.7
	10.0	20.0	5.4

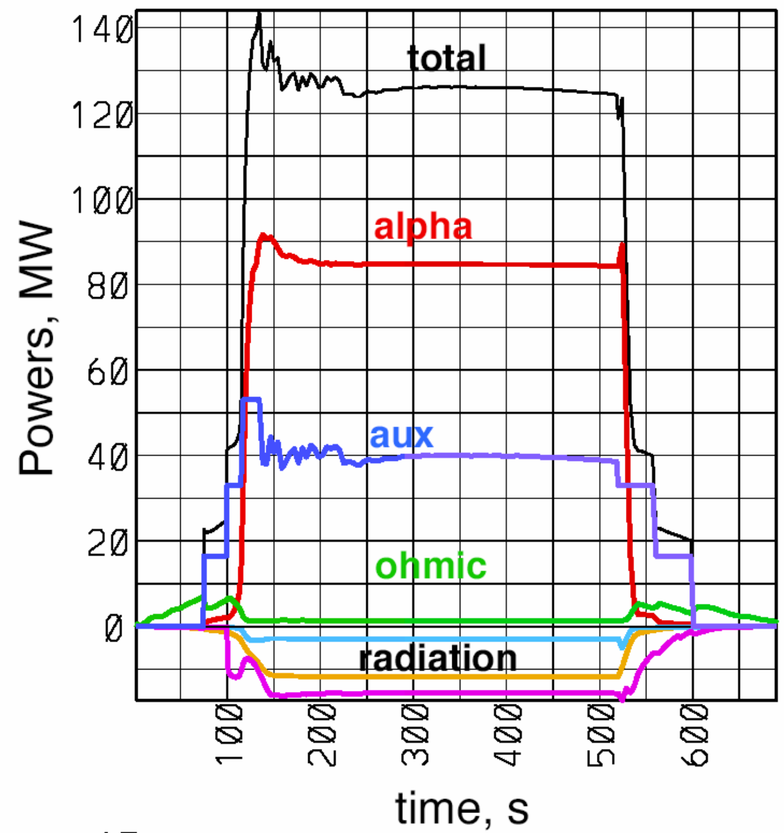


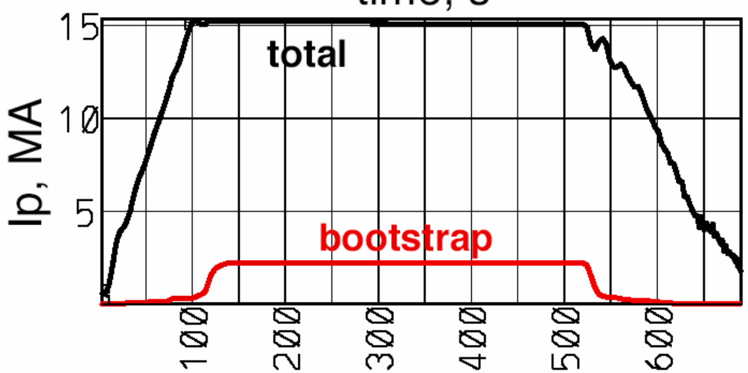
Modeling of ITER Burning H-mode

ITER H-mode Discharge Simulation

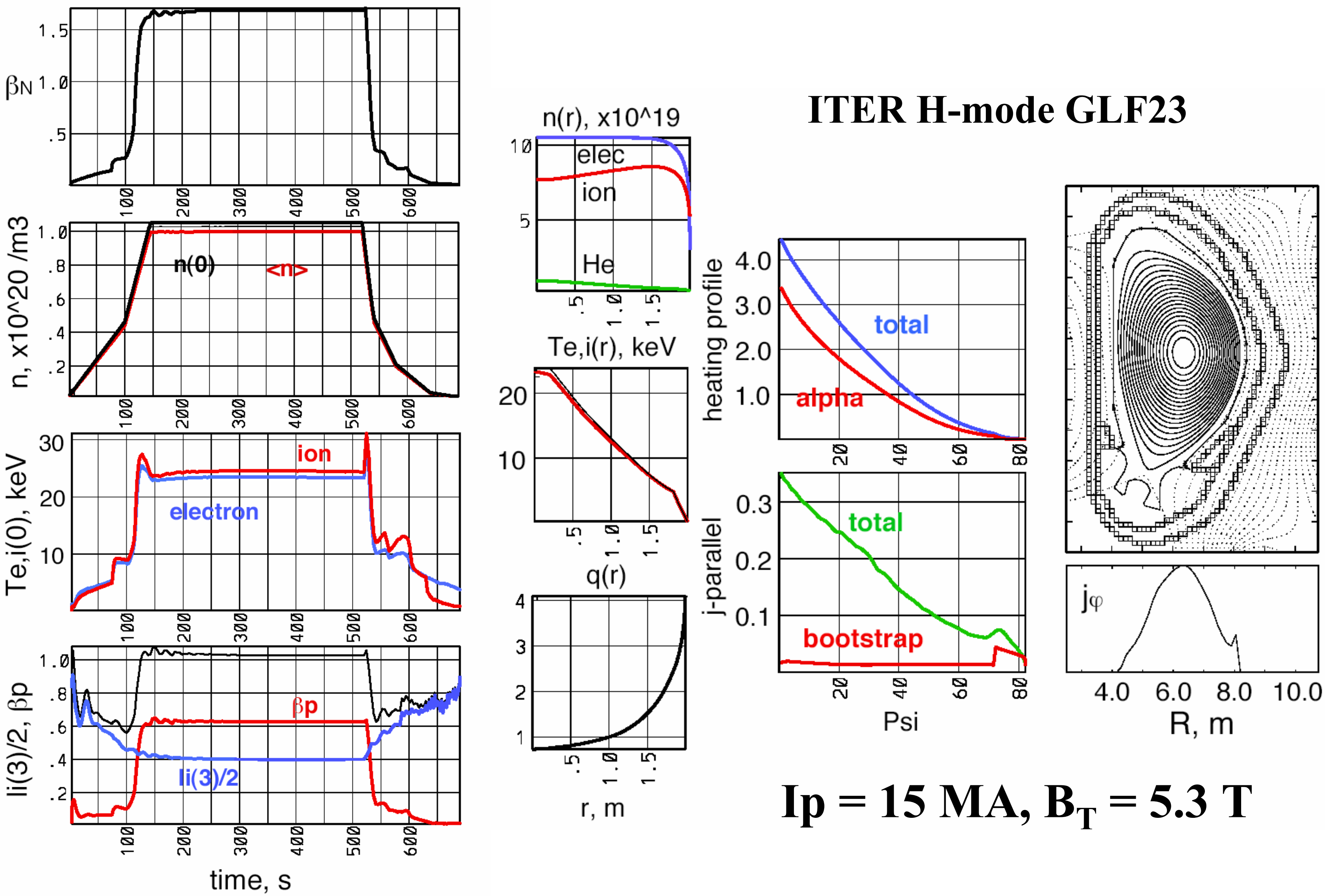
- Free-boundary
- Energy and current transport
- Density profiles assumed
- GLF23 core energy transport
- Assumed pedestal height/location
- ICRF heating, data from SPRUCE
- NBI heating data from Phys. Basis Doc.
- Bootstrap current, Sauter single ion
- Porcelli sawtooth model
- Coronal equilibrium radiation
- Impurities with electron density profile
- PF coils and conducting structures
- Feedback systems on position, shape, current
- Use stored energy control

Ip = 15 MA, B_T = 5.3 T





Modeling of ITER Burning H-mode



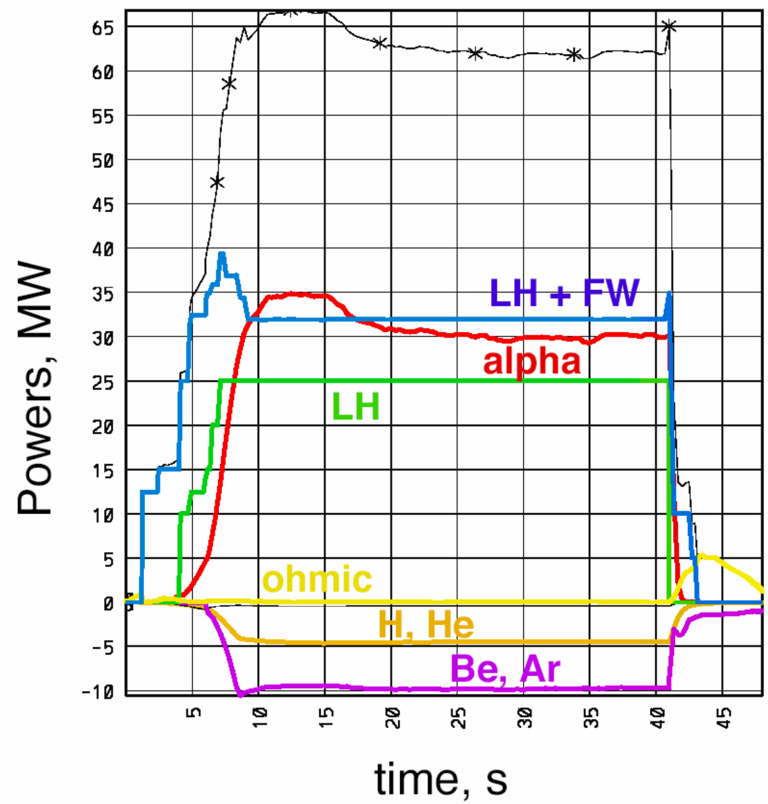
ITER H-mode GLF23

Ip = 15 MA, B_T = 5.3 T

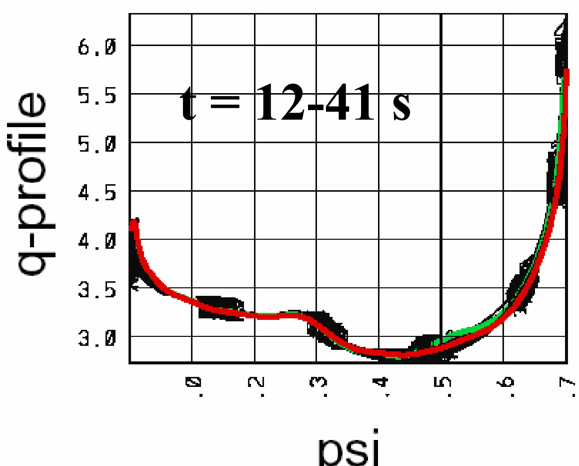
Modeling FIRE Burning Advanced Tokamak

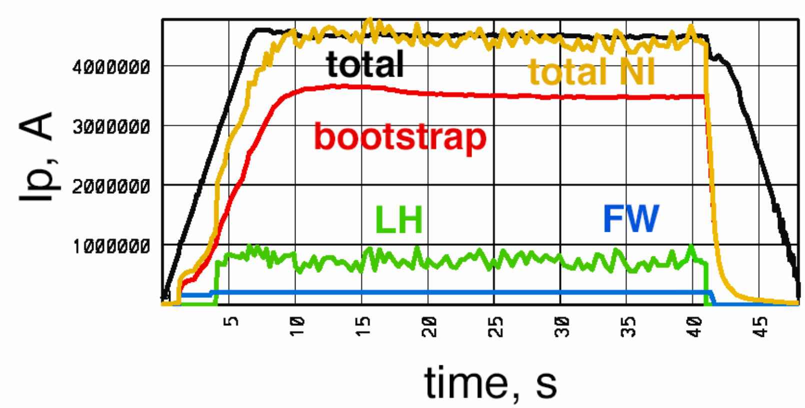
FIRE Advanced Tokamak

Free boundary
Energy and current transport
Density profile assumed
Empirical thermal diffusivities
ICRF/FW from AORSA
LHCD from LSC/ACCOME
Bootstrap current, Sauter single ion
Coronal equilibrium impurities
Ar introduced to radiate more power
PF coils and structures
Control of plasma current, position and shape

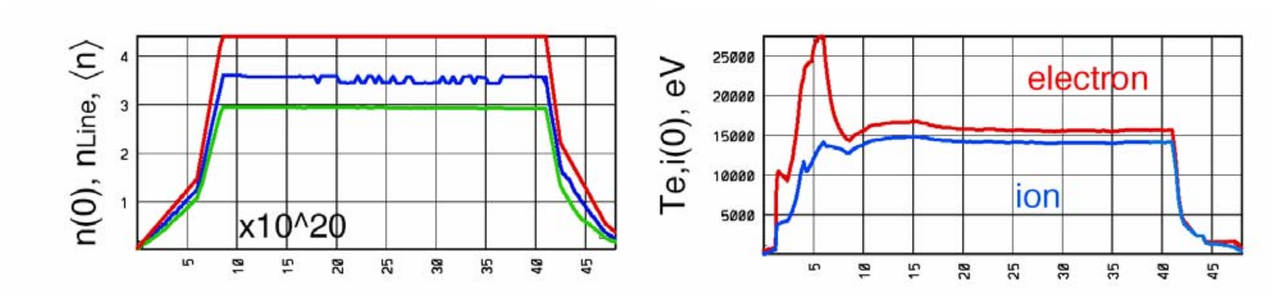


Ip = 4.5 MA
B_T **= 6.5 T**

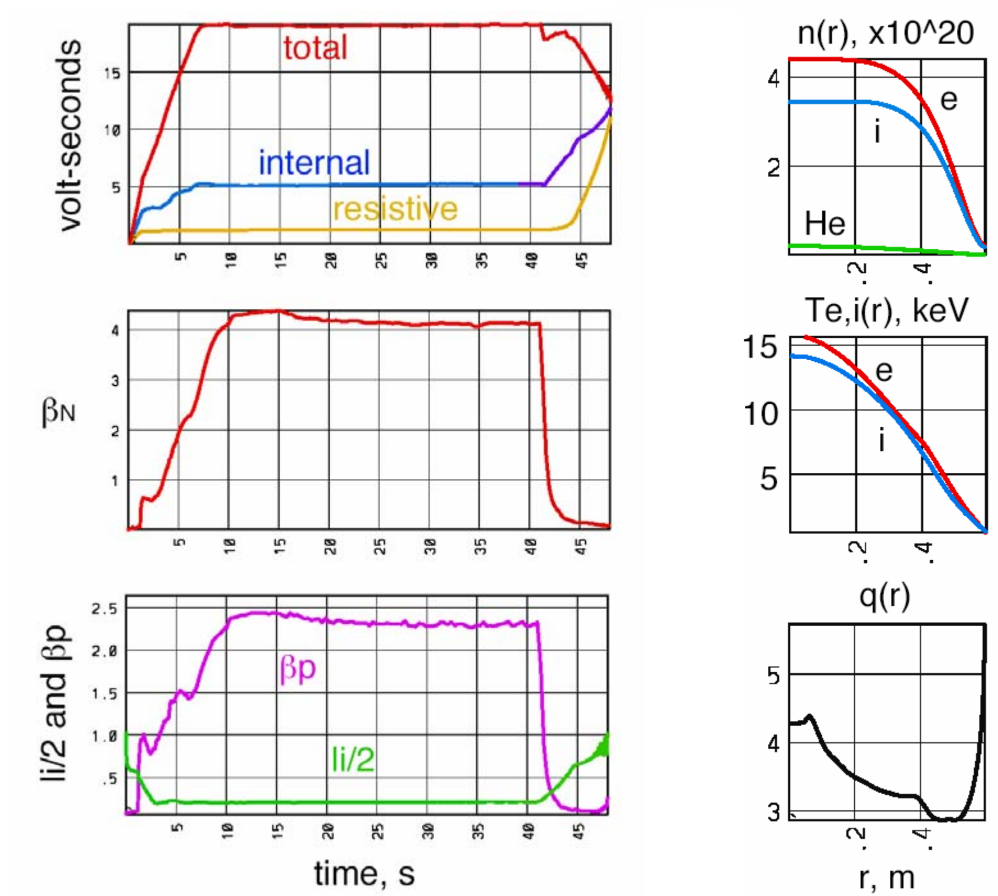




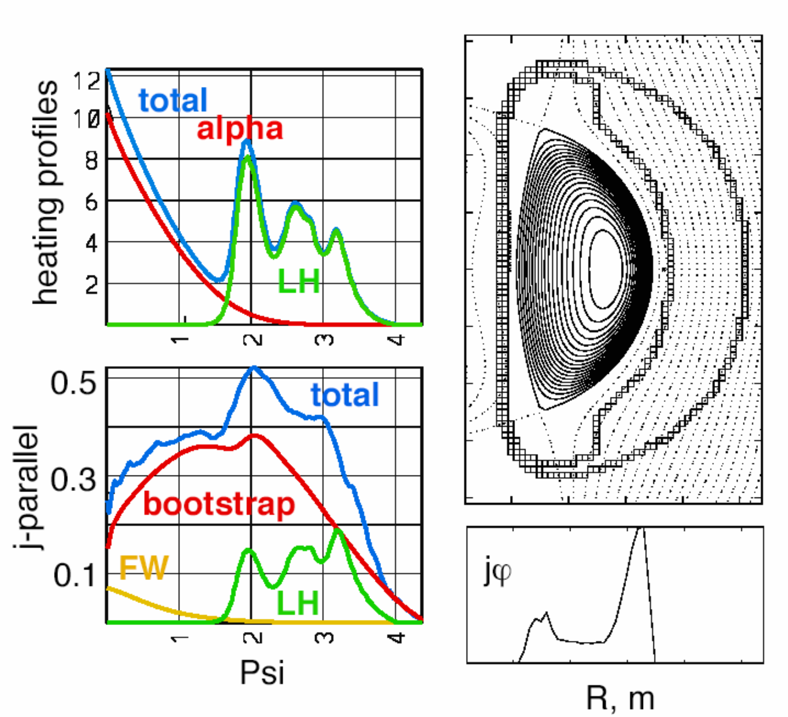
Modeling FIRE Burning Advanced Tokamak



Ip = 4.5 MA
B_T = 6.5 T



H-mode edge also simulated

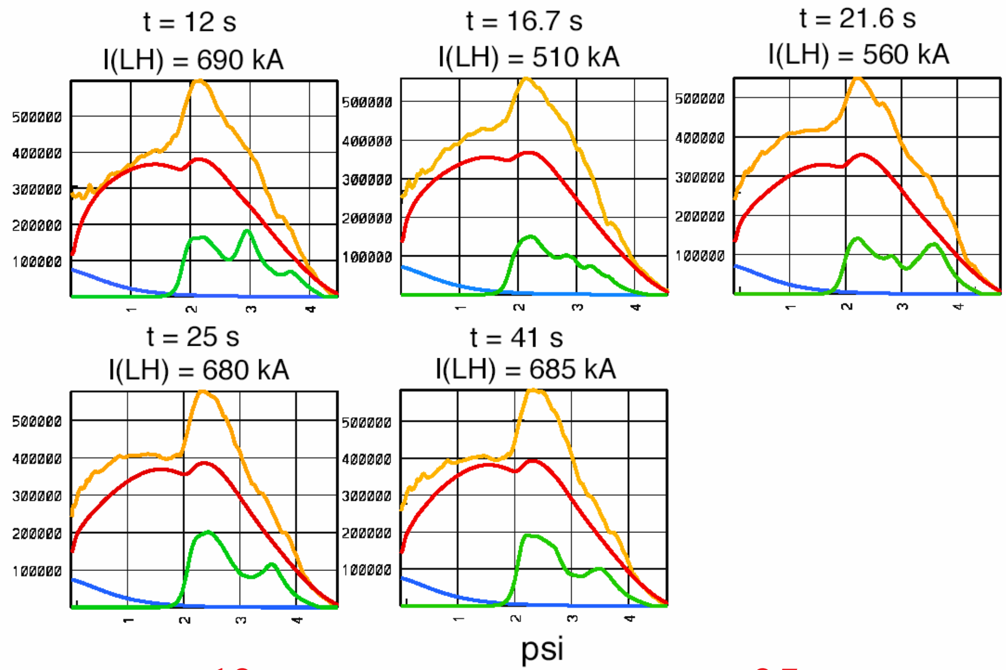


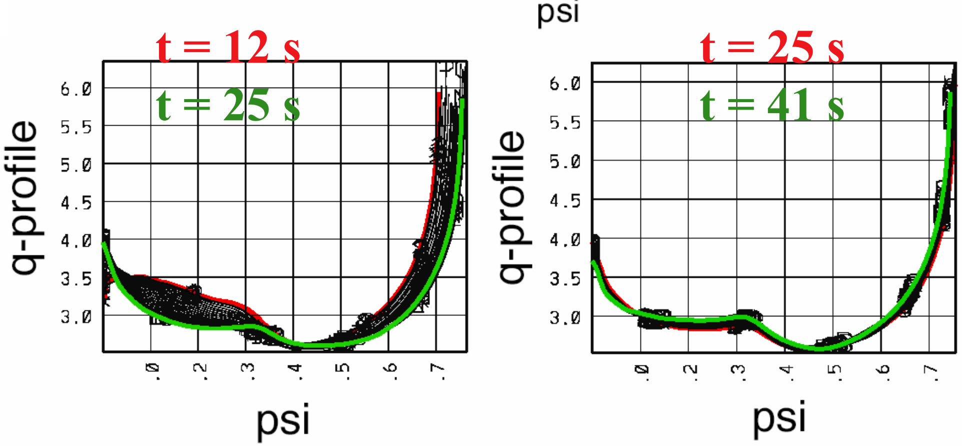
Examining Perturbations of FIRE Burning AT

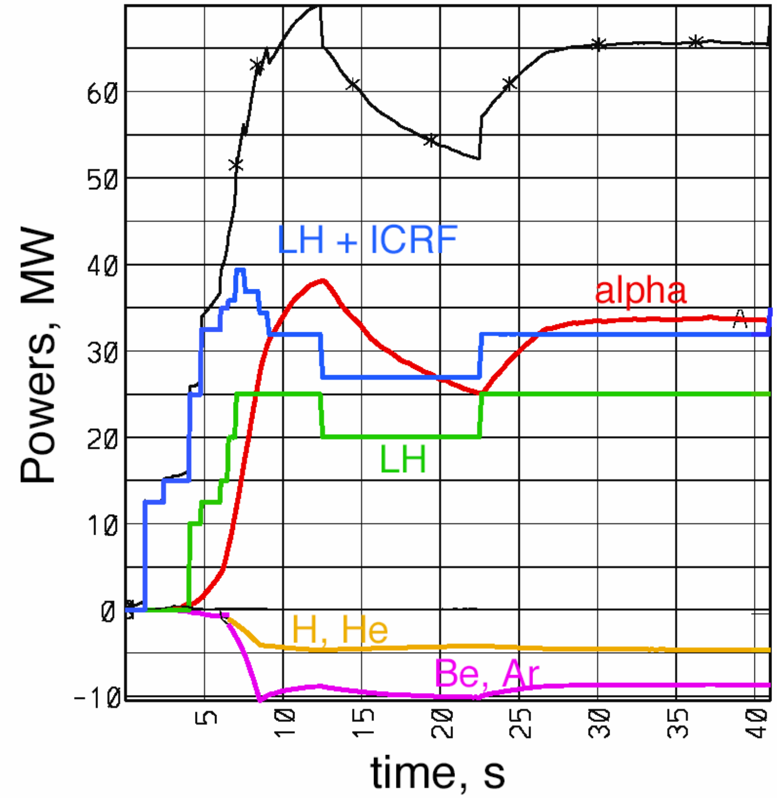
5 MW perturbation to P_{LH}

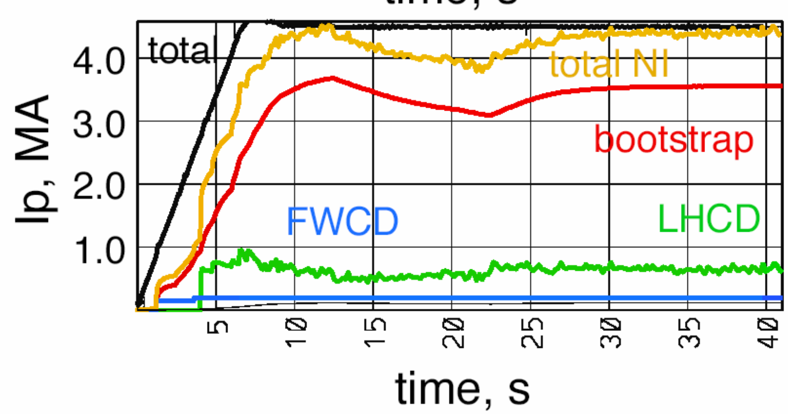
Flattop time is sufficient to examine CD control

Also examined density perturbations



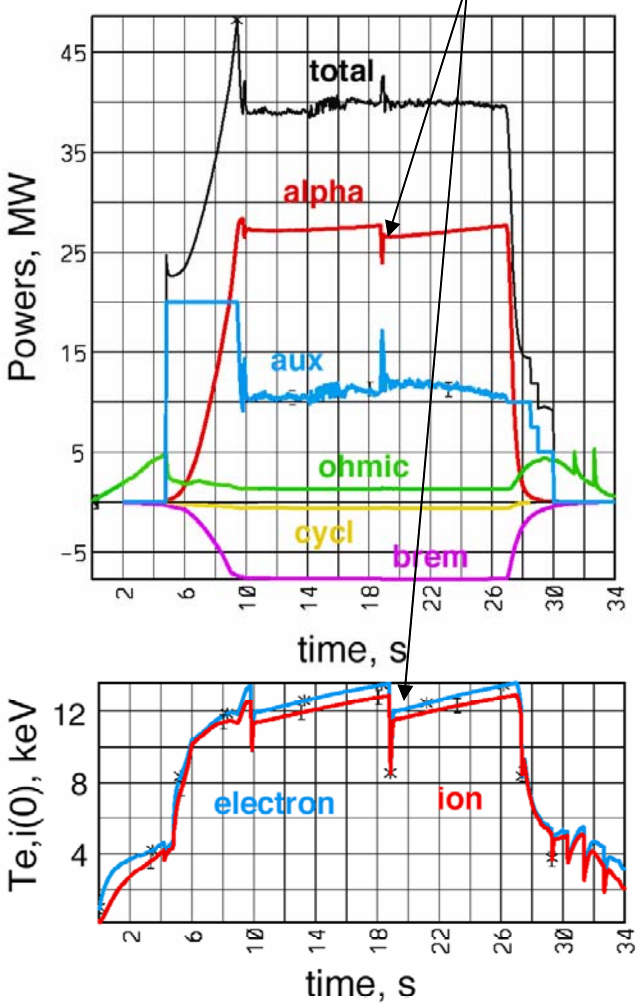




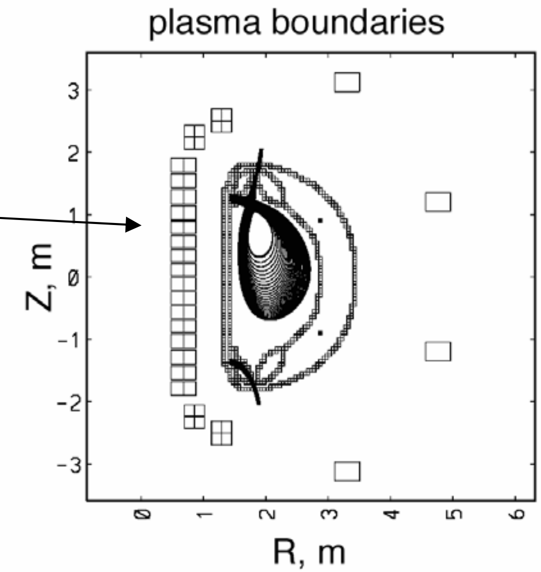


TSC Focused Studies for Burning Plasmas

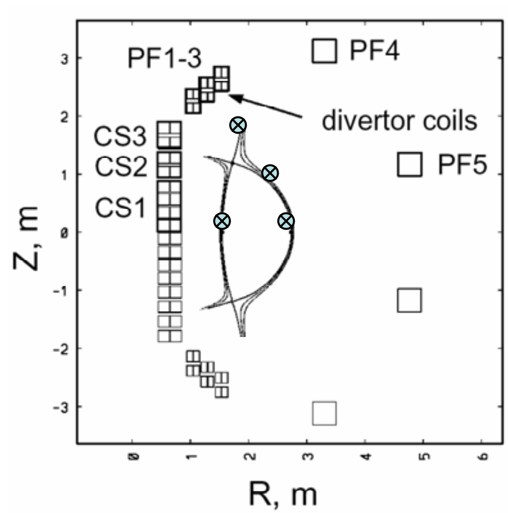
Impact of sawteeth on fusion performance



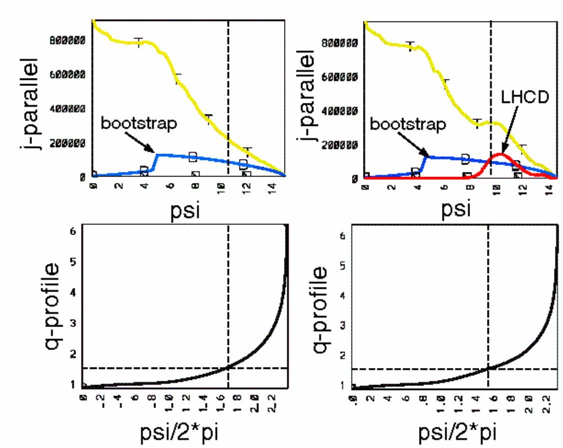
Plasma disruption simulations provide plasma evolution, structure toroidal and poloidal currents, and halo currents



Plasma shape control with MIMO controller in spite of li, β_p variations



TSC-LSC current profile modification at 3/2 surface



Integrated Modeling of Burning Plasmas with TSC

- TSC's most prominent feature is free-boundary evolution which is critical in advanced plasma modeling and transients
  - Strong li and plasma boundary coupling
  - Impact of plasma boundary shape on MHD stability, H-mode and pedestal/ELM behavior,….
  - Plasma control
- TSC needs more source modeling and can do more focused modeling
  - Presently I do a lot of off-line source modeling and iterating with TSC
  - Although there are numerous areas where off-line modeling will probably be the only method for some time
  - Interfaces between TSC and other codes are being expanded
  - In the mean time, must consider available models, running time, and pseudo-models of some phenomena
- Work has begun on using TSC to model experimental discharge behavior on DIII-D and NSTX in an interpretive mode