Introduction of FIRE

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for the FIRE Study Team

Overview
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http://fire.pppl.gov

Fusion Science Objectives for a Major Next Step Burning Plasma Experiment

Explore and understand the strong non-linear coupling that is fundamental to fusion-dominated plasma behavior (self-organization)

- Energy and particle transport (extend confinement predictability)
- Macroscopic stability (β-limit, wall stabilization, NTMs)
- Wave-particle interactions (fast alpha particle driven effects)
- Plasma boundary (density limit, power and particle flow)

- Test/Develop techniques to control and optimize fusion-dominated plasmas.
- Sustain fusion-dominated plasmas - high-power-density exhaust of plasma particles and energy, alpha ash exhaust, study effects of profile evolution due to alpha heating on macro stability, transport barriers and energetic particle modes.
- Explore and understand various advanced operating modes and configurations in fusion-dominated plasmas to provide generic knowledge for fusion and non-fusion plasma science, and to provide a foundation for attractive fusion applications.

Advanced Burning Plasma Exp't Requirements

Burning Plasma Physics

Q	≥ 5, ~ 10 as target,	ignition not precluded
$f_\alpha = P_\alpha/P_{heat}$	$\geq 50\%$, ~ 66% as target, up to 83% at Q = 25	
TAE/EPM	stable at nominal point, able to access unstable	

Advanced Toroidal Physics

$f_{bs} = I_{bs}/I_p$	$\geq 50\%$	up to 75%
β_N	~ 2.5, no wall	~ 3.6, n = 1 wall stabilized

Quasi-stationary Burn Duration

Pressure profile evolution and burn control	$> 10\ \tau_E$
Alpha ash accumulation/pumping	$>$ several τ_{He}
Plasma current profile evolution	1 to 3 τ_{skin}
Divertor pumping and heat removal	several $\tau_{divertor}$

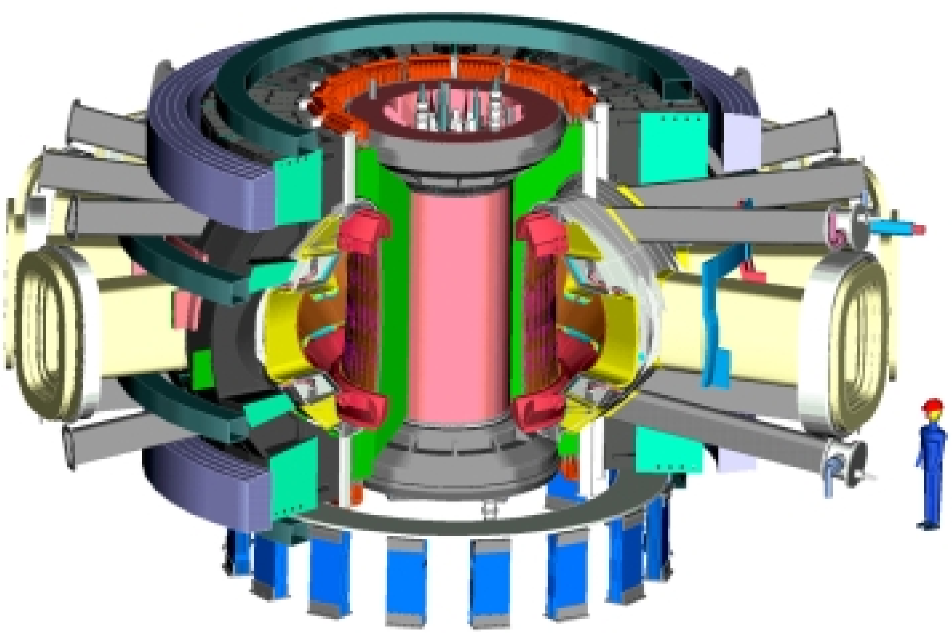
FIRE has Adopted the Advanced Tokamak Features Identified by ARIES Studies

- High toroidal field
- Double null
- Strong shaping
  - $\kappa = 2.0$, $\delta = 0.7$
- Internal vertical position control coils
- Cu wall stabilizers for vertical and kink instabilities
- Very low ripple (0.3%)
- ICRF/FW on-axis CD
- LH off-axis CD
- LHCD stabilization of NTMs
- Tungsten divertor targets
- Feedback coil stabilization for Resistive Wall Modes (RWM)
- Burn times exceeding current diffusion times
- Pumped divertor/pellet fueling/impurity control to optimize plasma edge

Fusion Ignition Research Experiment

(FIRE)

http://fire.pppl.gov



1,400 tonne

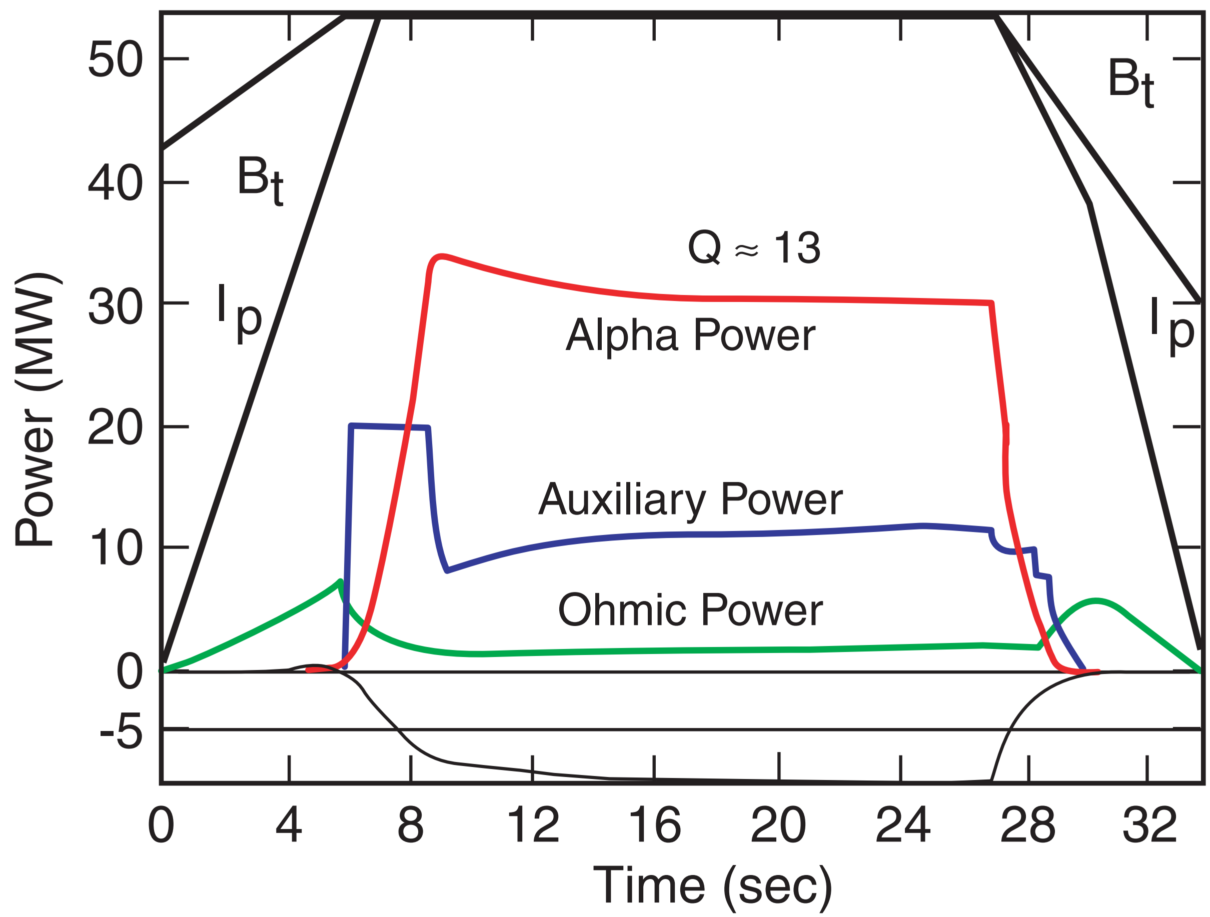
Design Features

- R = 2.14 m, a = 0.595 m
- B = 10 T
- W_{mag}= 5.2 GJ
- I_p = 7.7 MA
- $P_{aux} \leq$ 20 MW
- Q $\approx$ 10, P_{fusion} ~ 150 MW
- Burn Time $\approx$ 20 s (2 tau_cr)
- Tokamak Cost $\approx$ $351M (FY02)
- Total Project Cost $\approx$ $1.2B(FY02) at Green Field site.

Mission: Attain, explore, understand and optimize magnetically-confined fusion-dominated plasmas.

CIT + TPX = FIRE leading to ARIES

Simulation of Burning Plasma in FIRE



B = 10 T

I_p = 7.7 MA

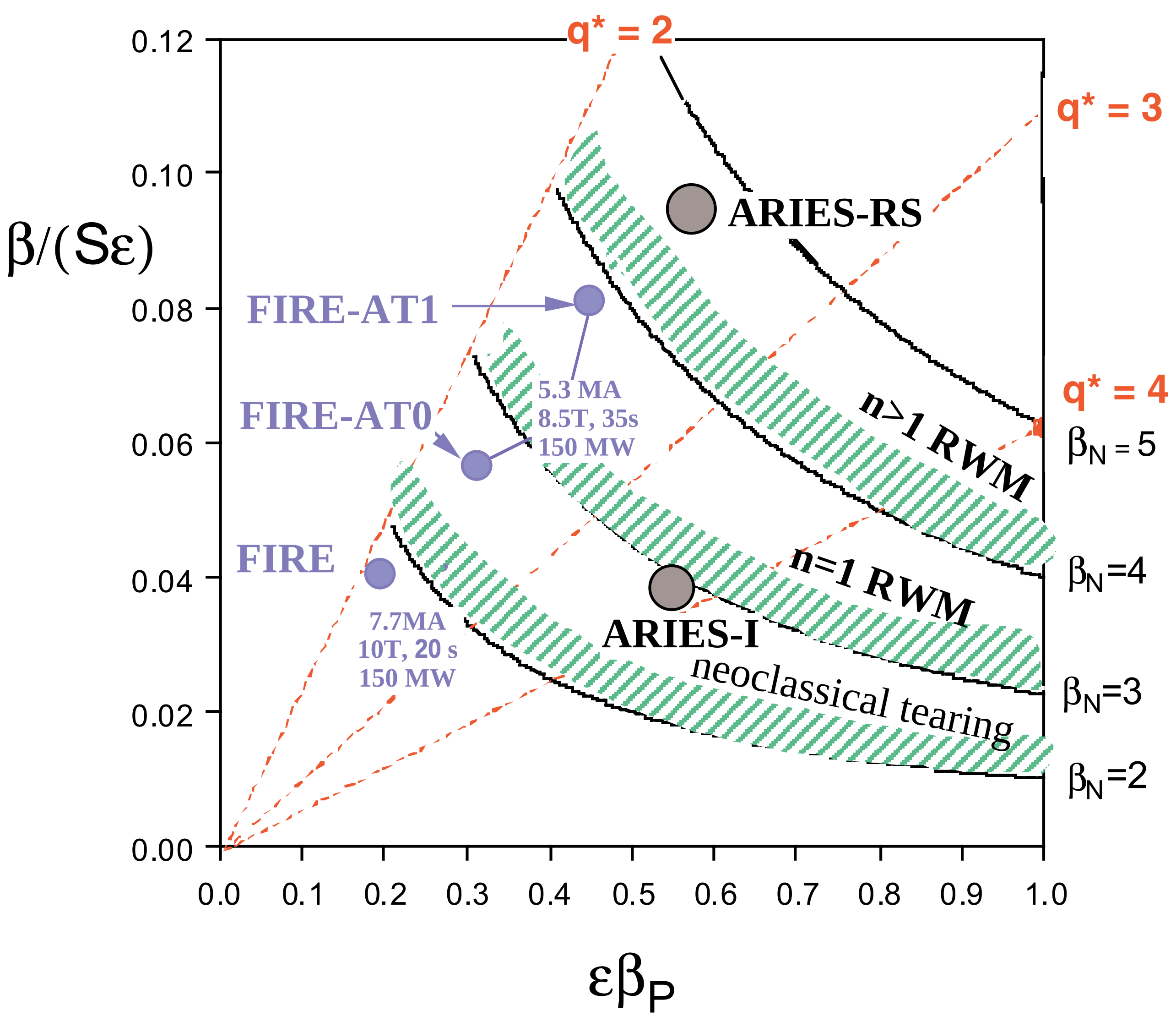
R = 2.14 m

A = 3.6

- ITER98(y, 2) with H(y, 2) = 1.1, $n(0)/\langle n \rangle = 1.2$, and $n/n_{GW} = 0.67$
- Burn Time ≈ 20 s ≈ $21\tau_E \approx 4\tau_{He} \approx 2\tau_{CR}$

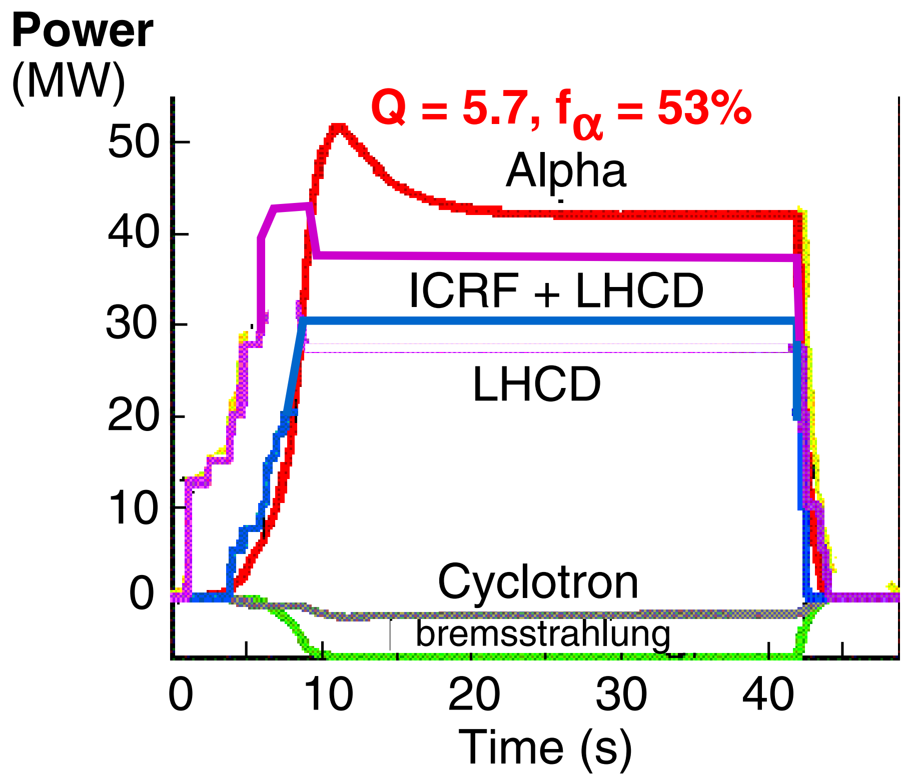
Q = Pfusion/(Paux + Poh)

FIRE would Test a Sequence of AT Modes



Advanced Burning Plasma Physics could be Explored in FIRE

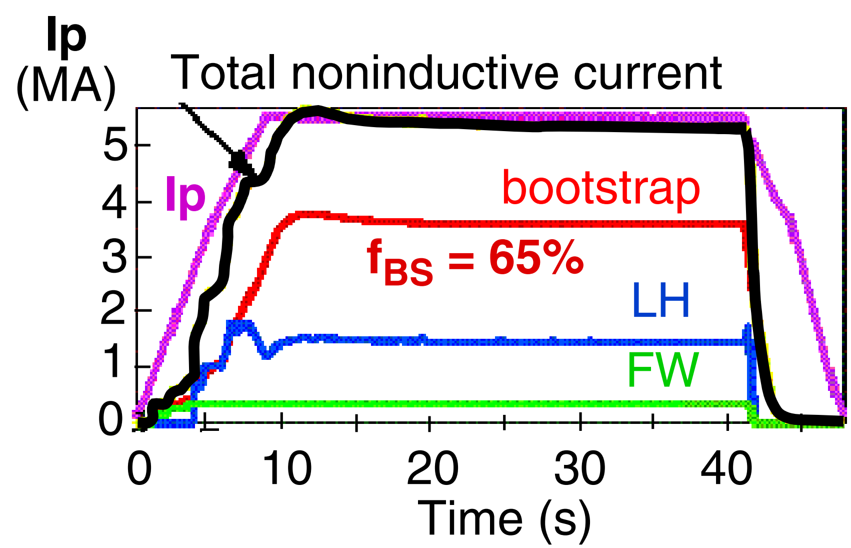
Self-Heating Dominant



Self-Current Drive Dominant

Fully Non-Inductive for > 1 τ_{CR}

8.5 T, 5.4 MA, t(flattop) = 32 s



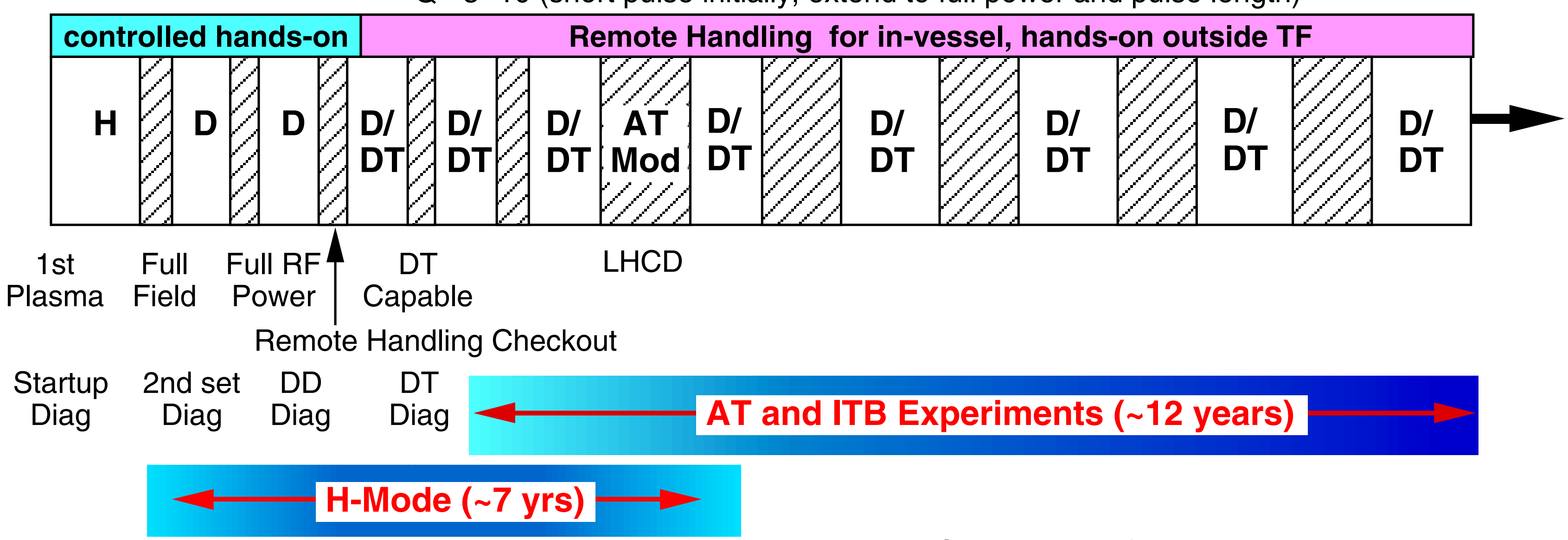
Tokamak simulation code results for H(y, 2) = 1.4, β_N = 3.5 , would require RW mode stabilization. q(0) = 2.9, q_{min} = 2.2 @ r/a = 0.8, 8.5 T, 5.5 MA

FIRE Experimental Plan

Years from 1st plasma

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	**Original* Limits**
Shots/ 2yr	4000	4000	4000	4000	3500	3500	3500	3500	**30,000**
Full B Shots/ 2yr	250	500	600	500	300	300	300	300	**3,000**
DT Energy(GJ)/ 2yr			1000	1000	1000	1000	1500	1000	**6,500**
Tritium Burnup(g)/2yr			2	2	2	2	3	2	

Q~ 5 -10 (short pulse initially, extend to full power and pulse length)



- Control
- Cleanup
- Fueling
- Diagnostics
- Operations
- RF tests

- InitialRF Heating
- Plasma Power Handling
- Initial Physics studies

- Alpha heating
- Energy transport
- Fast particle
- Particle and ash removal

- Global Burn control
- Transient Profile control
- Transient Adv Tok

- Optimization of AT modes
- Non Inductive Profile control
- Improve Divertor and FW power handling
- Extend pulse length