Status of FIRE

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Fusion Power Associates
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http://fire.pppl.gov

FIRE Lighting the Way to Fusion

VLT

FESAC has Recommended a Dual Path Strategy for Burning Plasmas

Based on the Snowmass Assessment, FESAC found that:

“ITER and FIRE are each attractive options for the study of burning plasma science. Each could serve as the primary burning plasma facility, although they lead to different fusion energy development paths.

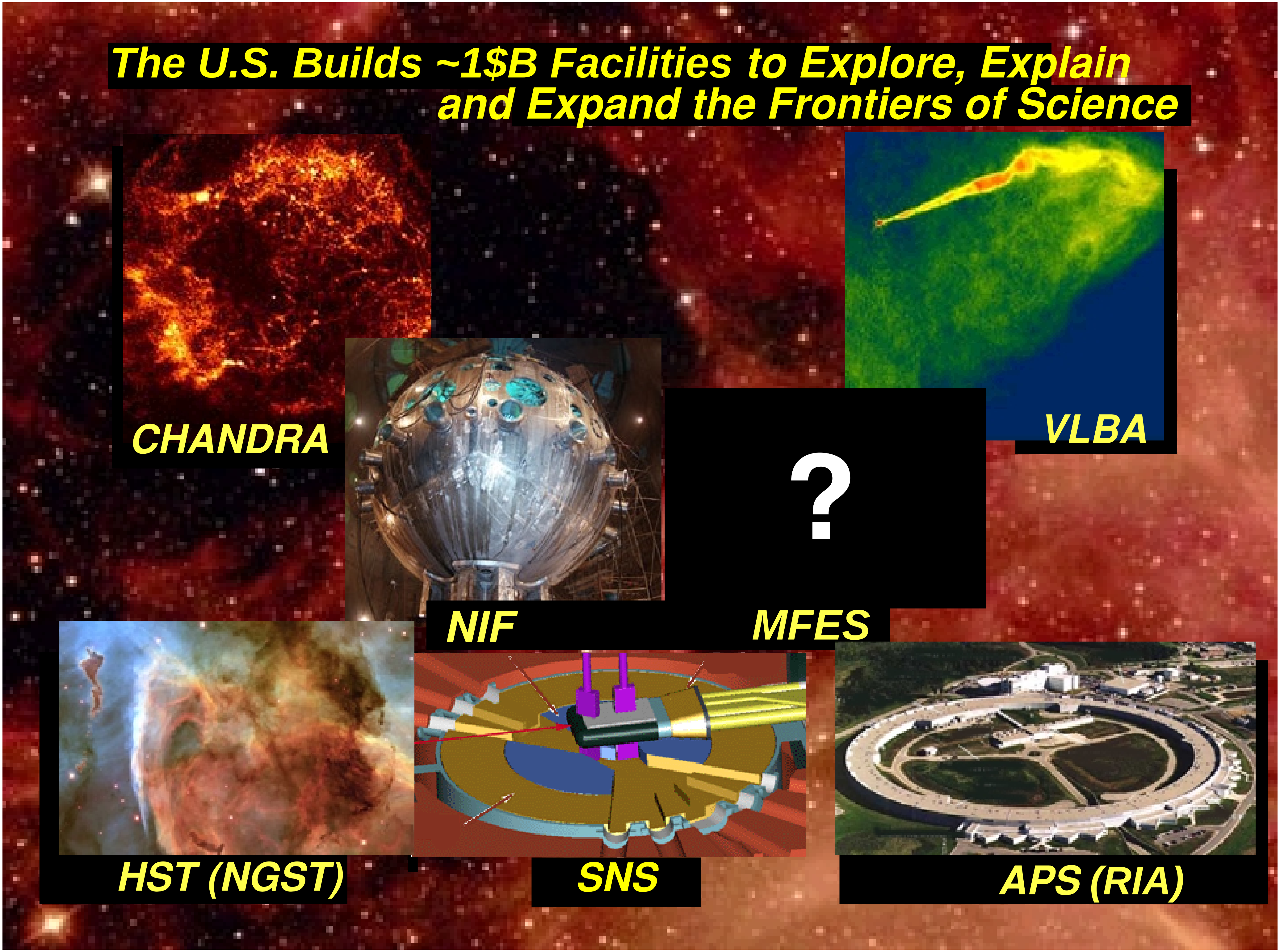
Because additional steps are needed for the approval of construction of ITER or FIRE, a strategy that allows for the possibility of either burning plasma option is appropriate.”

FESAC recommended a dual path strategy:

1. that the US should seek to join ITER negotiations as a full participant
   - US should do analysis of cost to join ITER and ITER project cost.
   - negotiations and construction decision are to be concluded by July 2004.

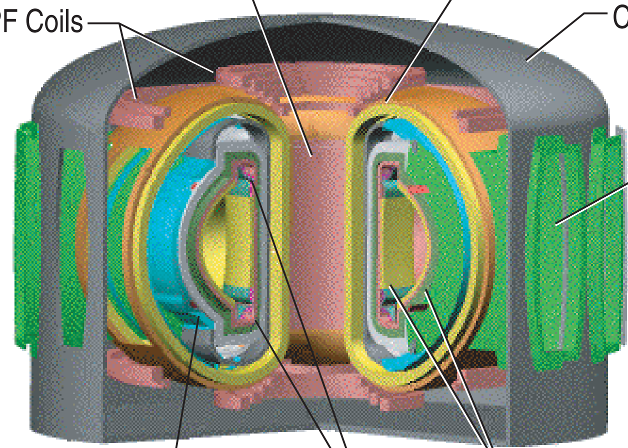
2. that the FIRE activities continue toward a Physics Validation as planned and be prepared to start Conceptual Design at the time of the ITER Decision.

3. If ITER does not move forward, then FIRE should be advanced as a U.S.-based burning plasma experiment.


The U.S. Builds ~1$B Facilities to Explore, Explain
and Expand the Frontiers of Science
CHANDRA
VLBA
?
NIF
MFES
HST (NGST)
SNS
APS (RIA)

A Decade of Power Plant Studies in the U.S. has led to an Attractive Vision for MFE

The U.S. ARIES — AT system study



Economically Competitive - COE ~ 5¢/kWhr

Enviromentally Benign - Low Level Waste

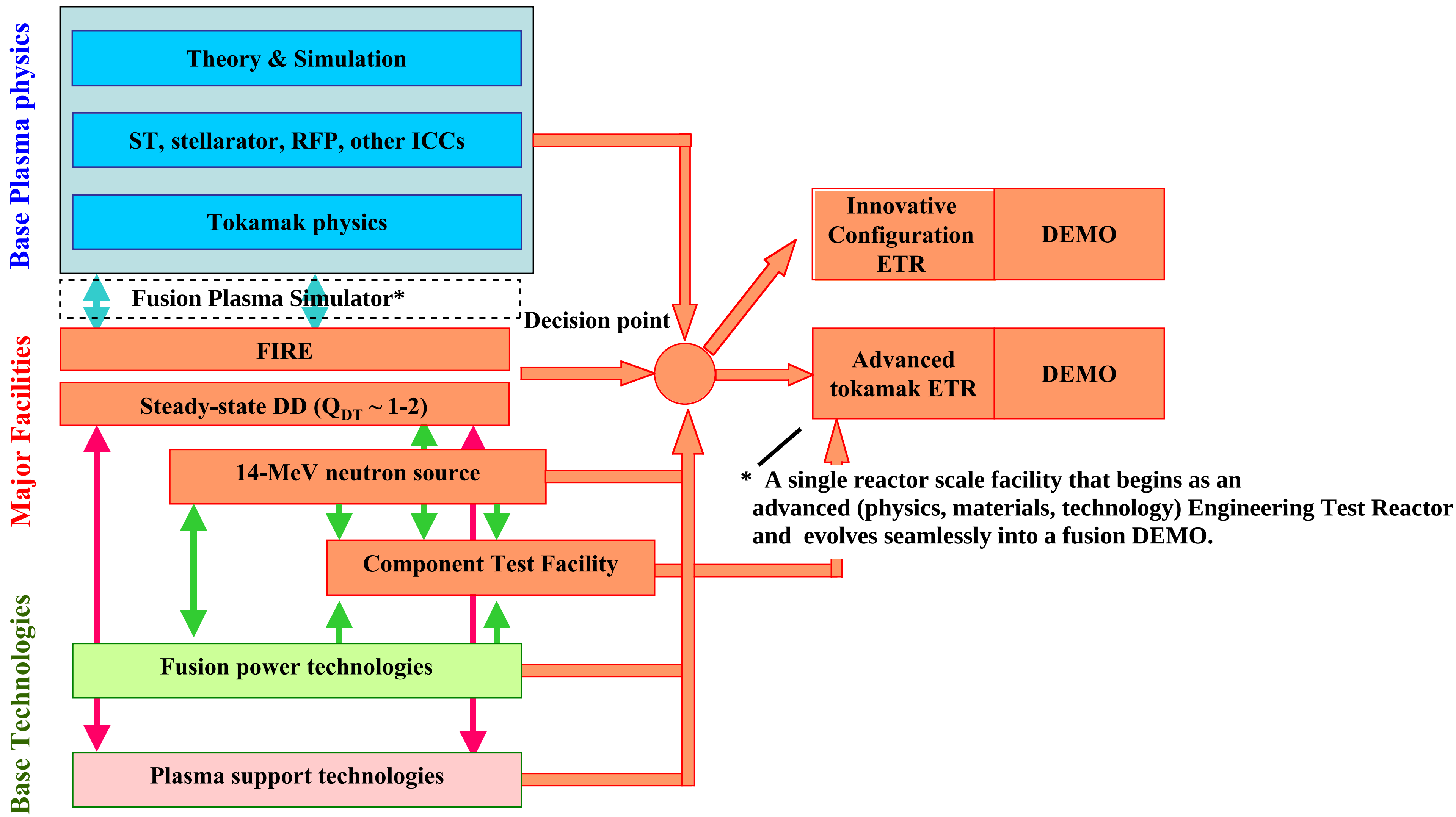
Safety - No evacuation

- **Advanced Tokamak Physics Features**
  - High Power density $\beta_N \sim 5$
  - Steady-State $f_{BS} \sim 90\%$
  - Exhaust Power P/NR ~ 40 MW/m

- **Advanced Technology Features**
  - Hi Tc Superconductors
  - Neutron Resistant >150 dpa
  - Low Activation materials

Major Advances in Physics and Technolgy are needed to achieve this goal.

FIRE-Based Development Path



* The Fusion Plasma Simulator would serve as the intellectual integrator of physics phenomena in advanced tokamak configurations, advanced stellarators and tokamak burning plasma experiments.

FIRE will Emphasize Advanced Tokamak Goals

Burning Plasma Physics

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

Advanced Toroidal Physics

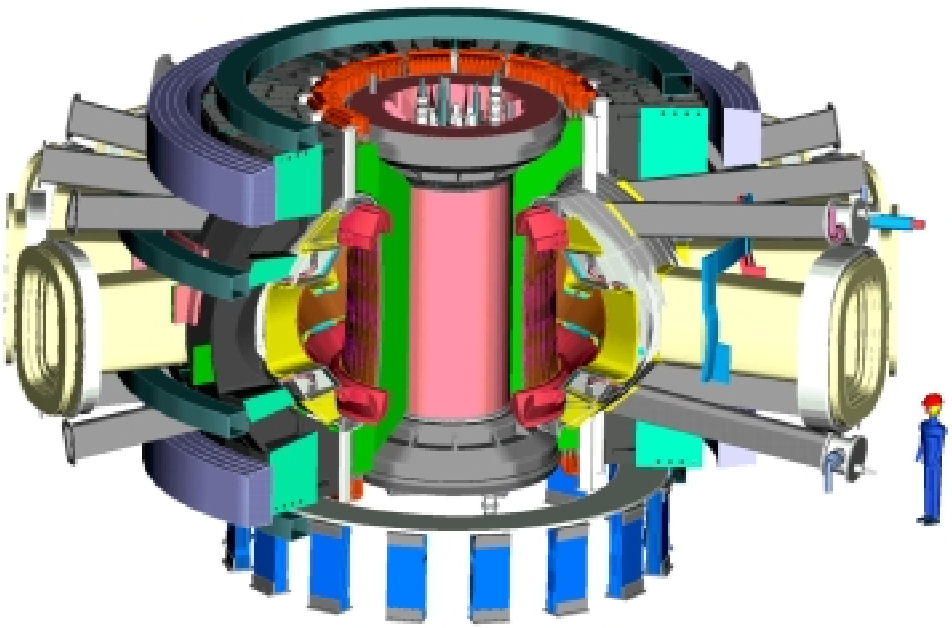
$f_{bs} = I_{bs}/I_p$	~ 80% (goal)
β_N	~ 4.0, n = 1 wall stabilized

Quasi-stationary Burn Duration

Pressure profile evolution and burn control	> 10 τ_E
Alpha ash accumulation/pumping	> several τ_{He}
Plasma current profile evolution	2 to 5 τ_{skin}
Divertor pumping and heat removal	several $\tau_{divertor}$

Fusion Ignition Research Experiment (FIRE)

http://fire.pppl.gov



1,400 tonne

Design Features

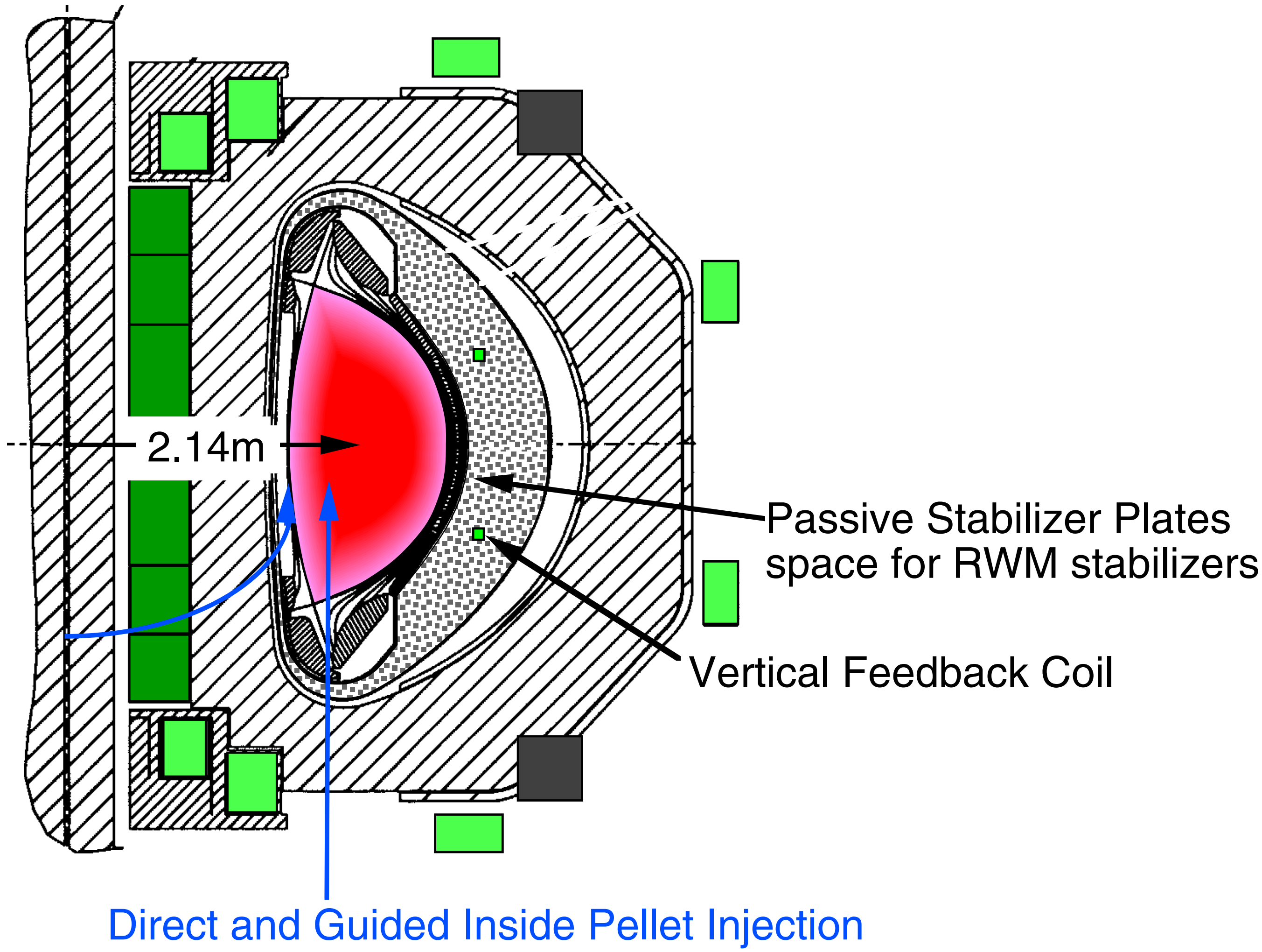
- $R =$ 2.14 m, $a = 0.595$ m
- $B =$ 10 T (~6.5 T AT)
- $W_{mag} = 5.2$ GJ
- $I_p =$ 7.7 MA (~5 MA AT)
- $P_{aux} \leq 20$ MW
- $Q \approx 10$, $P_{fusion} \sim 150$ MW
- Burn Time ≈ 20 s (~ 40 s AT)
- Tokamak Cost ≈ $350M (FY02)
- Total Project Cost ≈ $1.2B (FY02) at Green Field site.

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

FIRE has Adopted the ARIES-RS Plasma Cross-section

AT Features

- strong shaping
  κ_x, κ_a = 2.0, 1.85
  δ_x, δ_{95} = 0.7, 0.55
- segmented central solenoid
- double null double divertor pumped
- low ripple (<0.3%)
- internal control coils
- space for RWM stabilizers
- inside pellet injection



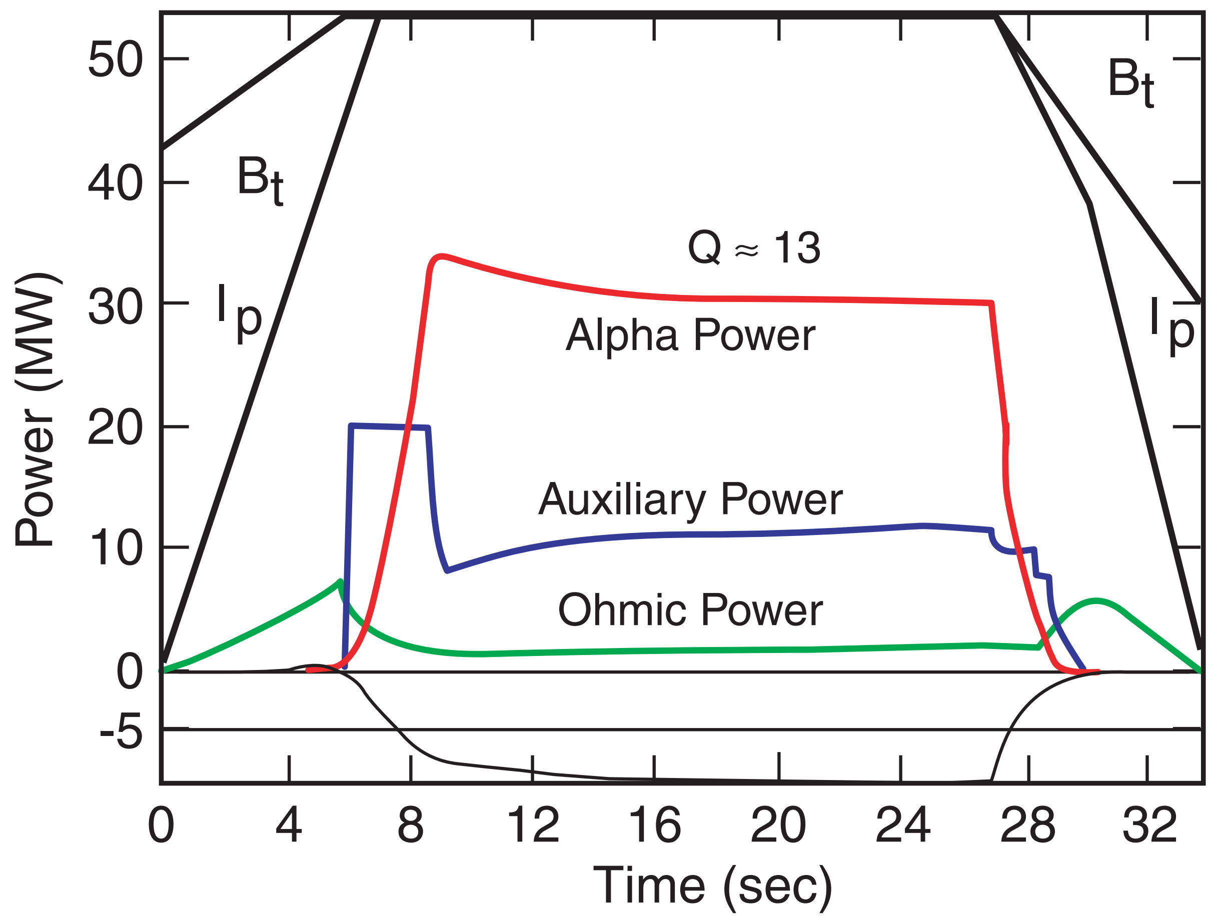
Snowmass Conclusions on Confinement Projections for FIRE

- Based on 0D and 1.5D modeling, all three devices (ITER, FIRE and IGNITOR) have baseline scenarios which appear capable of reaching Q = 5 – 15 with the advocates' assumptions. ITER and FIRE scenarios are based on standard ELMing H–mode and are reasonable extrapolations from the existing database.

- More accurate prediction of fusion performance of the three devices is not currently possible due to known uncertainties in the transport models. An ongoing effort within the base fusion science program is underway to improve the projections through increased understanding of transport.

Note: part of the purpose of a next step burning plasma experiment is to extend our understanding of confinement into the burning plasma regime

Simulation of Conventional H-Mode in FIRE



B = 10 T

I_p = 7.7 MA

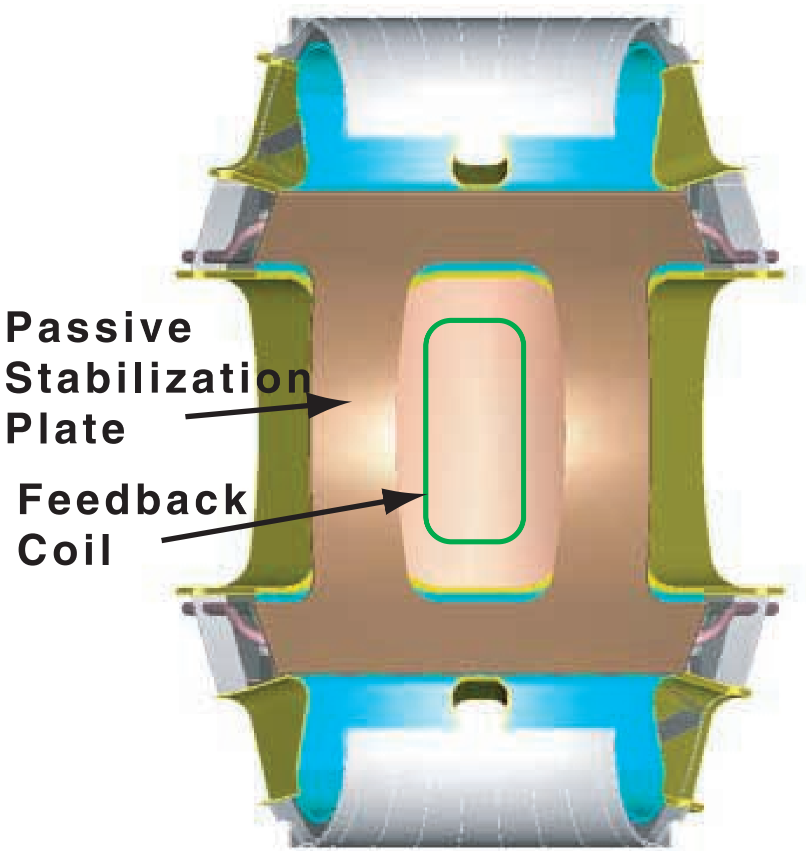
R = 2.14 m

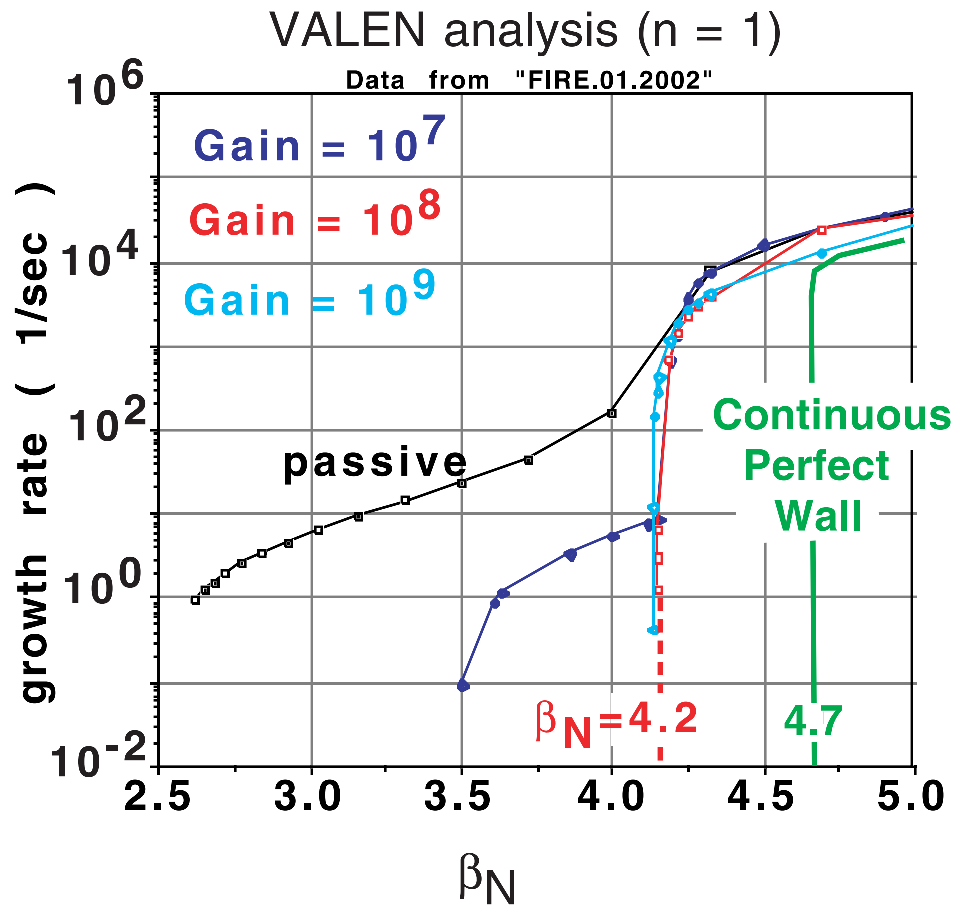
A = 3.6

- ITER98(y, 2) with H(y, 2) = 1.1, n(0)/⟨n⟩ = 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)

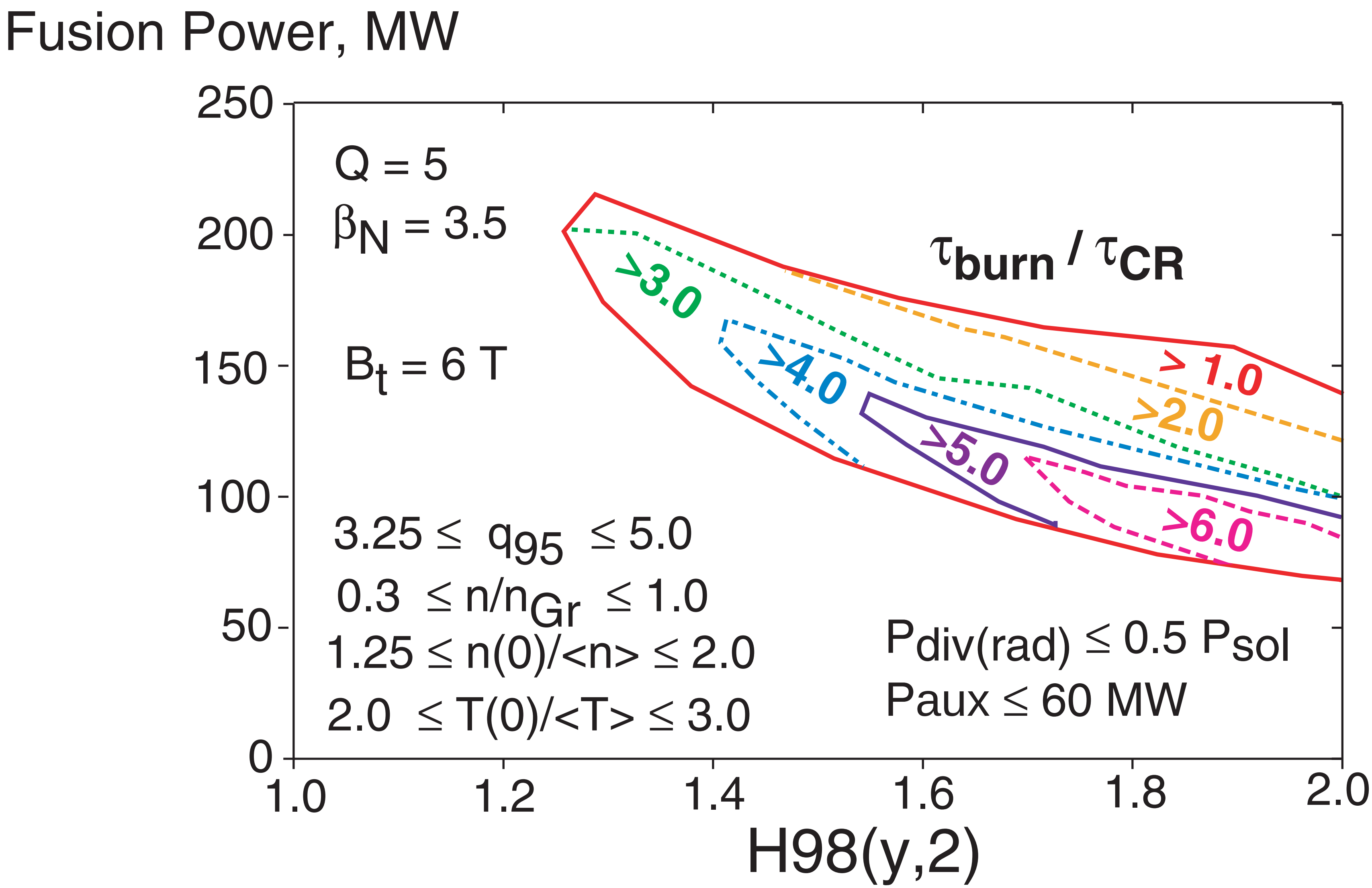
FIRE Accesses β_N ~ 4 with RWM Control



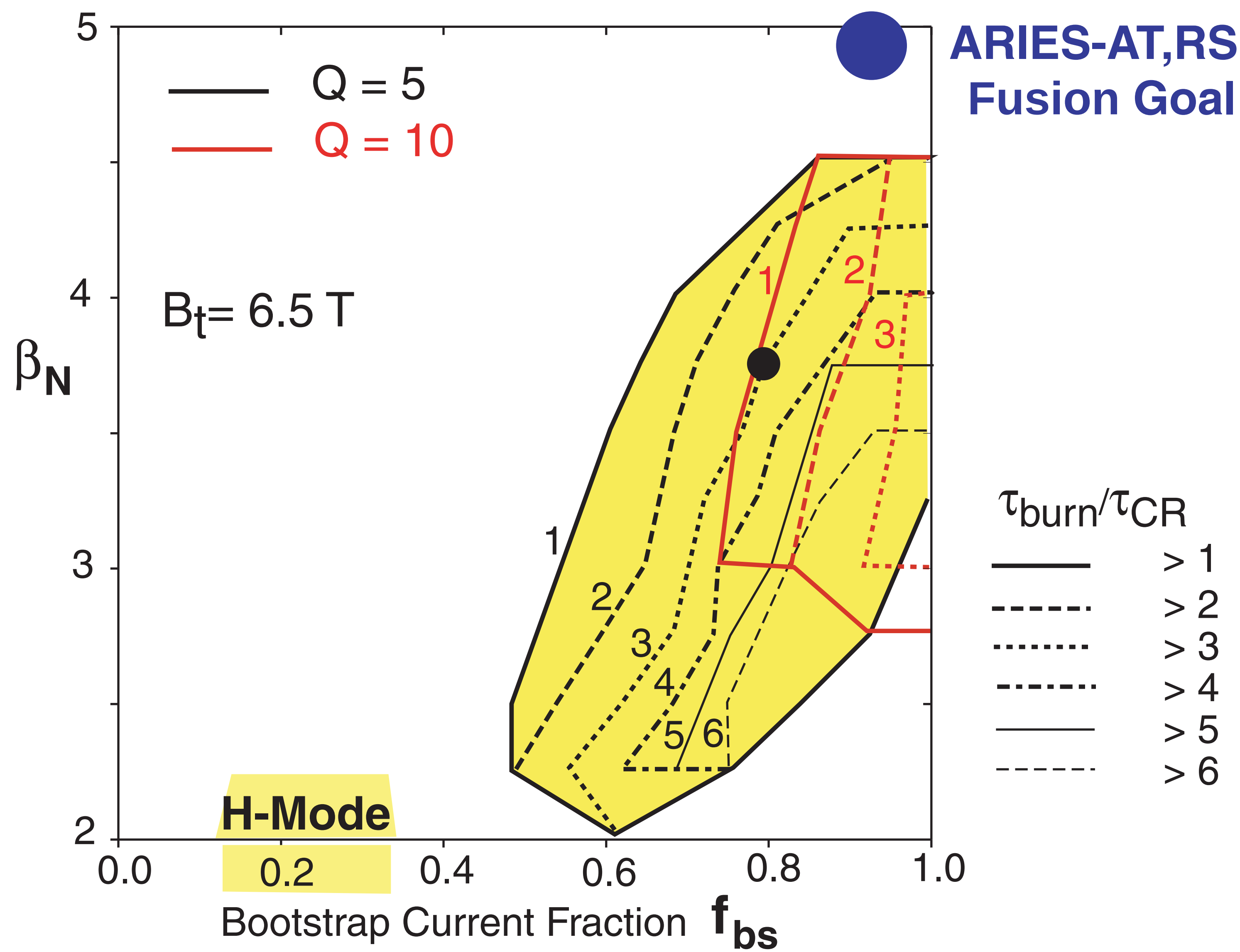


- Control Coils Located in 8 of 16 ports (4 n=1 coil pairs).
- Stable β_N for n = 1 reaches 4.2, 90% of continuous wall limit.
- Effects of n = 2 are being examined.

FIRE can Access High-β AT Modes under Quasi-Steady-State Conditions



AT Modes with $\beta_N \approx 4$, $f_{bs} \approx 90\%$ Sustained for 2 - 4 τ_{CR} are Energetically Accessible in FIRE



Next Steps for FIRE

- Listen and respond to critiques and suggestions at Snowmass.
- Update design goals and physics basis, review with Community, NSO PAC and DOE.
- Produce a Physics Description Document, and carry out a Physics Validation Review.
- Initiate Project Activities (in 2003-4) consistent with FESAC Strategy

    Form National Project Structure

    Begin Conceptual Design

    Initiate R&D Activities

    Begin Site Evaluations

Summary

- A Window of Opportunity may be opening for U.S. Energy R&D. We should be ready. The Diversified International Portfolio has advantages for addressing the science and technolgy issues of fusion.

- FIRE with a construction cost ~ $1.2B, has the potential to :

    - address the important burning plasma issues, performance ~ ITER
    - investigate the strong non-linear coupling between BP and AT,
    - stimulate the development of reactor relevant PFC technology, and
    - provide generic BP science and possibly BP infrastructure for non-tokamak BP experiments in the U. S.

- Some areas that need additional work to realize this potential include:

    - Apply recent enhanced confinement and advanced modes to FIRE
    - Understand conditions for enhanced confinement regimes-triangularity
    - Compare DN relative to SN - confinement, stability, divertor, etc
    - Complete disruption analysis, develop better disruption control/mitigation.

- If a postive decision is made in this year, FIRE is ready to begin Conceptual Design in FY2004 with target of first plasmas ~ 2011.

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