Overview of Activities in Steady State Integration

by
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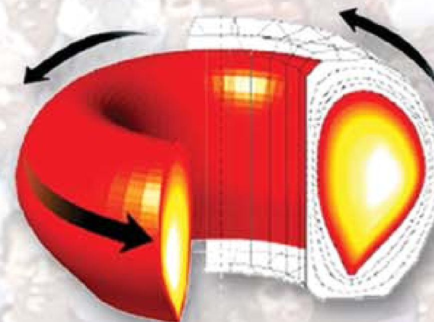
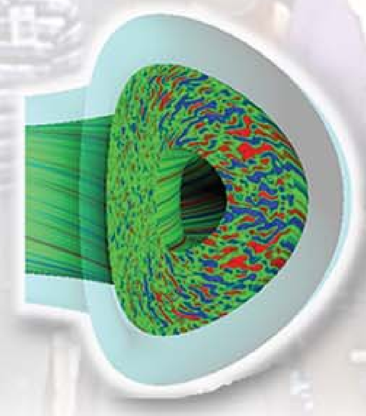


Presented to the
DIII–D Program
Advisory Committee



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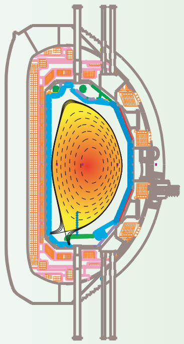
Long-Range Vision for Steady-State Scenario Development in DIII–D Points to DEMO with Advanced Scenario

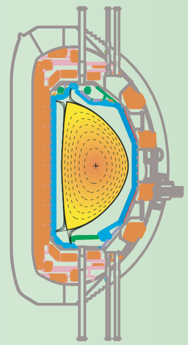
Steady-State Scenario for ITER

f_{BS} ~55%
β_N ~ 3.5
f_{NI} = 100%,
t_{DUR} ~5s



Steady-State Scenario for FDF

f_{BS} ~ 70%
β_N ~ 4
t_{DUR} ~ 10 s

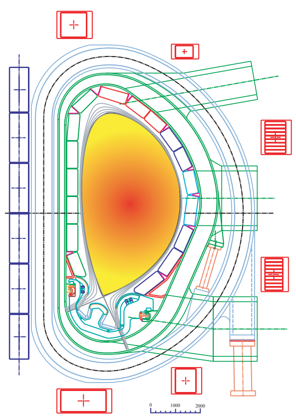


Establish Physics Basis for Steady-State Powerplant Optimization

$f_{BS} \rightarrow 90\%$
$\beta_N \rightarrow 5$
$t_{DUR} \rightarrow 10$ s

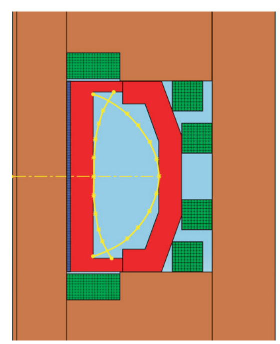
ITER

Q≥5
t_{DUR} ~1000s



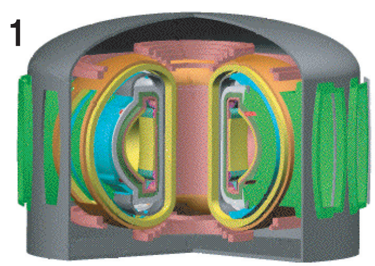
FDF

Net tritium
(1 kg/yr)
Blanket testing
($\rightarrow$ 1 MW yr/m^2)



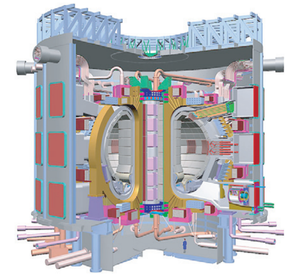
DEMO-AT

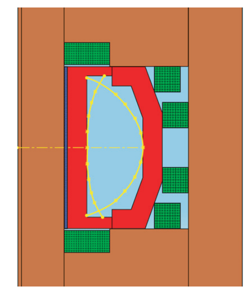
Plant Q > 1

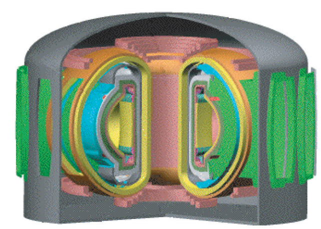


DIII–D Advanced Scenario Development Timeline (5 Year Perspective)

	1–2 years	3–5 years
ITER/ FDF Scenario	Demonstration of f_{NI} = 1 operation for > τ_R	Physics basis for projection operation > 2 τ_R β limit optimization Bootstrap optimization Integration of boundary solutions
DEMO-AT	Transient exploration of routes to β_N > 4	Demonstration of $\beta_N \Rightarrow$ 5 for > 5 τ_E







Access to β_N=5 and Operating There is A Challenging Goal

- Ideal MHD stability modeling indicates two scenarios in opposite directions:

Extreme Wall Stabilization

- Highest β solution known for conventional tokamaks
- Rotational or active stabilization of n=1 (maybe also n=2, 3)
- Very broad current profile ($\ell_i \rightarrow 0.5$) requires significant off-axis current
- Relaxed pressure and current profiles must be compatible ($f_{BS} \rightarrow 90\%$)

Extreme Shear Stabilization

- Highest β no-wall solution known for conventional tokamaks
- Significant vertical stability issues at high ℓ_i ($\ell_i \rightarrow 1.2–1.6$)
- Maximum potential requires stabilization of sawteeth
- Desire for reduced pedestal consistent with solutions to heat flux and ELM issues
- Demonstrated correlation of confinement with high ℓ_i

- Both scenarios have demonstrated $\beta_N > 4$ transiently

Where Do We Want to Be in 5 Years?

ITER and FDF scenarios:

- Clear existence proof of an attractive scenario, including integration of boundary solutions
- Substantial physics basis for projection of ITER and FDF
- Reproduction of ITER scenario (or at least key elements) on JET or JT–60U
- Definition of requirements to reproduce FDF scenario on KSTAR and JT-60SA
- Determintion of control demands on heating and current drive systems

β_N = 5 Scenario:

- Achieve β_N = 5 for >5τ_E
- Define upgrade path to >2τ_R in DIII–D (if possible)
- Define requirements to reproduce scenario in steady state on JT-60SA

What Will it Take to Reach These Goals?

- **Significant increase in EC or FW power**
  - Removing the uncertainties in the projection due to $T_i > T_e$ and rotation requires substantial central electron heating (hybrid and steady-state)
  - **Maintaining $\beta_N = 5$ for 5 τ_E requires ~20 MW with little central current driven**
  - Demonstration of control requires ~25% more power than the equilibrium condition
  - Based on 2:1 ratio of electron to ion energy transport in present experiments, 10–15 MW of electron heating in the plasma is needed for 10 s (present systems 7.5 MW)