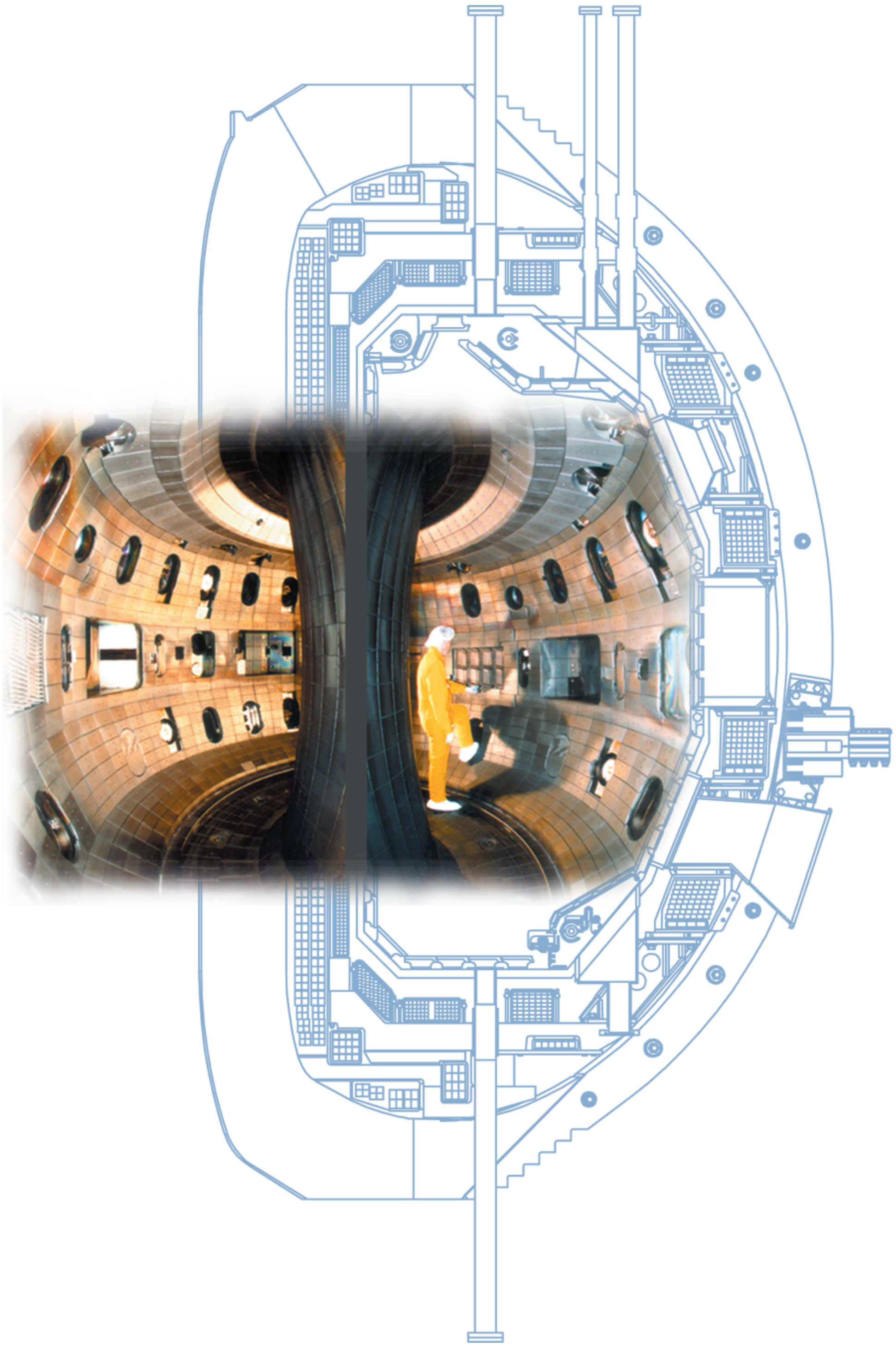


Overview of Physics Results from the 1999 DIII–D Campaign

by

S. L. Allen

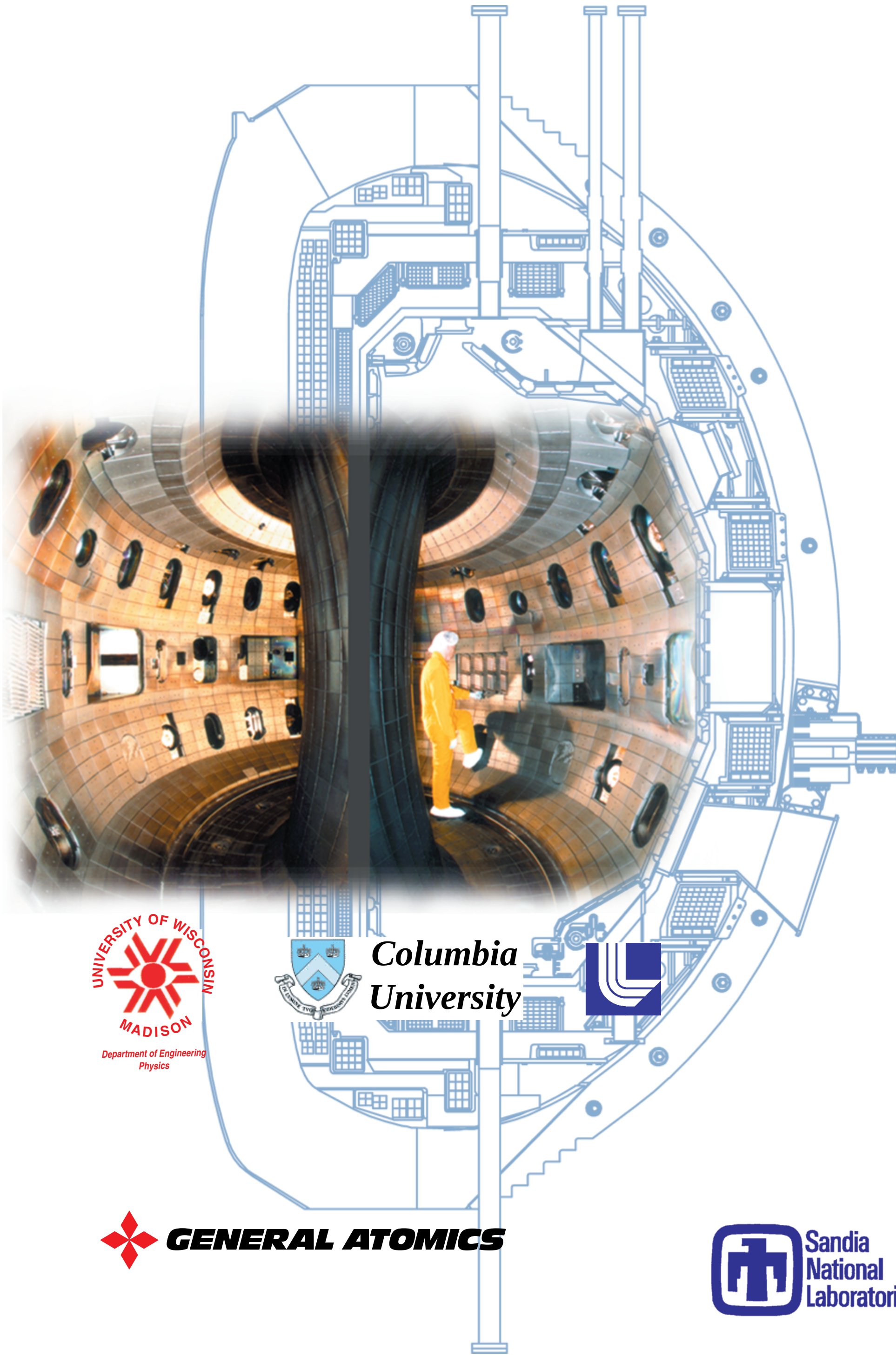
and the

DIII–D Team

Presented at
the American Physical Society
Division of Plasma Physics Meeting
Seattle, Washington

November 15–19, 1999

DIII–D
NATIONAL FUSION FACILITY



Overview of Physics Results from the 1999 DIII–D Campaign

by

S. L. Allen

and the

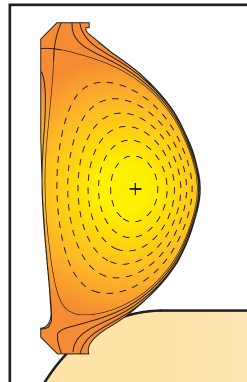
DIII–D Team

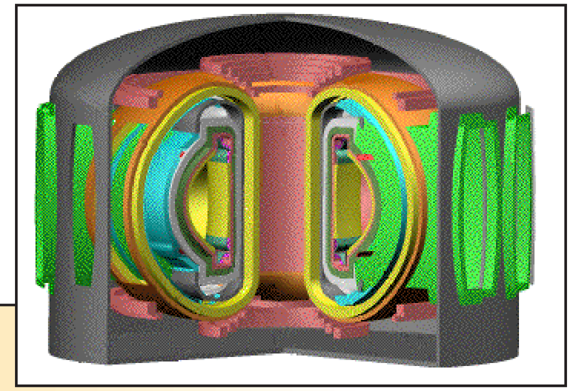
Presented at
the American Physical Society
Division of Plasma Physics Meeting
Seattle, Washington

November 15–19, 1999

University of Wisconsin Madison, Department of Engineering Physics
Columbia University
ornl
GENERAL ATOMICS
Sandia National Laboratories
PPPL Princeton Plasma Physics Laboratory
DIII–D National Fusion Facility

Our goal is a sustained Advanced Tokamak



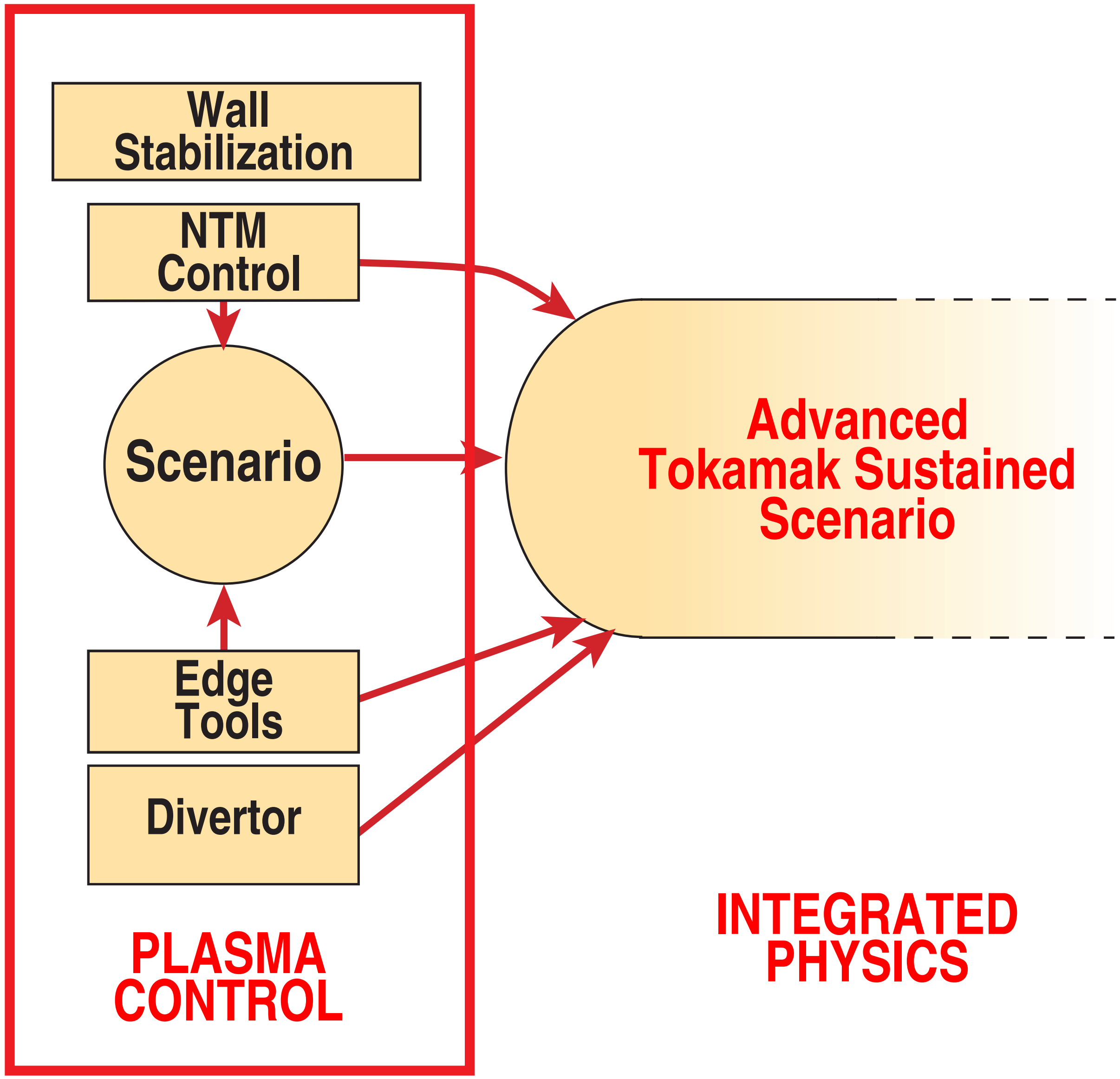


Advanced
Tokamak Sustained
Scenario

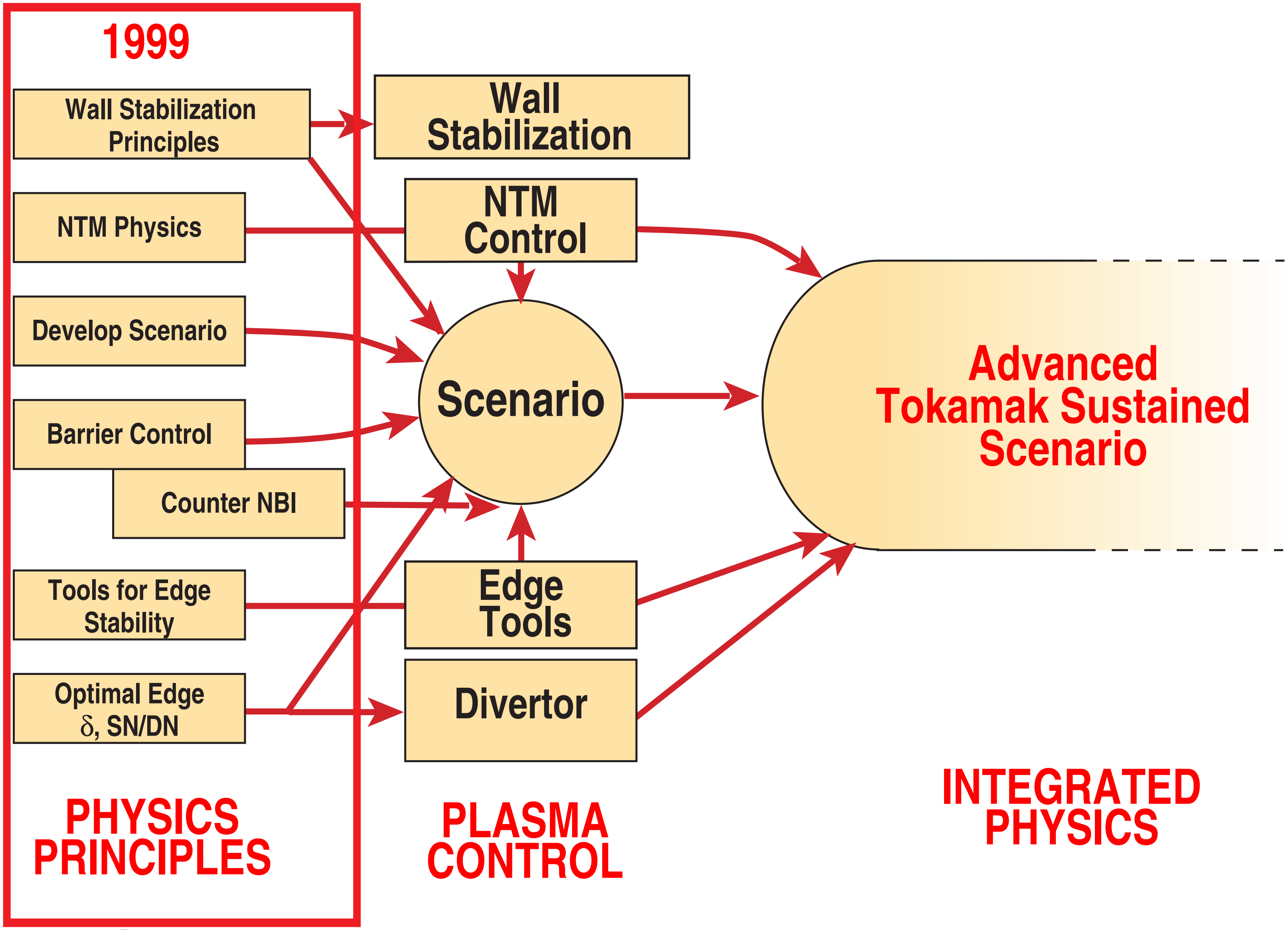
INTEGRATED
PHYSICS

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

Plasma control techniques are necessary



We focused on physics principles in the 1999 Campaign



DIII-D NATIONAL FUSION FACILITY SAN DIEGO

The “Thrust Areas” For the 1999 DIII-D Campaign

1999

Wall Stabilization Physics

PHYSICS
PRINCIPLES

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

The “Thrust Areas” For the 1999 DIII-D Campaign

1999

Wall Stabilization Physics

Neoclassical Tearing Mode (NTM) physics

PHYSICS
PRINCIPLES

DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

The “Thrust Areas” For the 1999 DIII-D Campaign

1999

Wall Stabilization Physics

Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

PHYSICS
PRINCIPLES

The "Thrust Areas" For the 1999 DIII-D Campaign

1999

Wall Stabilization Physics

Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

Internal Transport Barrier (ITB) Control

Counter Neutral Beam Injection

PHYSICS
PRINCIPLES

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

The “Thrust Areas” For the 1999 DIII-D Campaign

1999

Wall Stabilization Physics

Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

Internal Transport Barrier (ITB) Control

Counter Neutral Beam Injection

Tools for edge stability

PHYSICS
PRINCIPLES

DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

The "Thrust Areas" For the 1999 DIII-D Campaign

1999

Wall Stabilization Physics

Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

Internal Transport Barrier (ITB) Control

Counter Neutral Beam Injection

Tools for edge stability

Optimal plasma shape, divertor

PHYSICS
PRINCIPLES

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

AT modes were limited by Resistive Wall Modes

1999

Wall Stabilization Physics

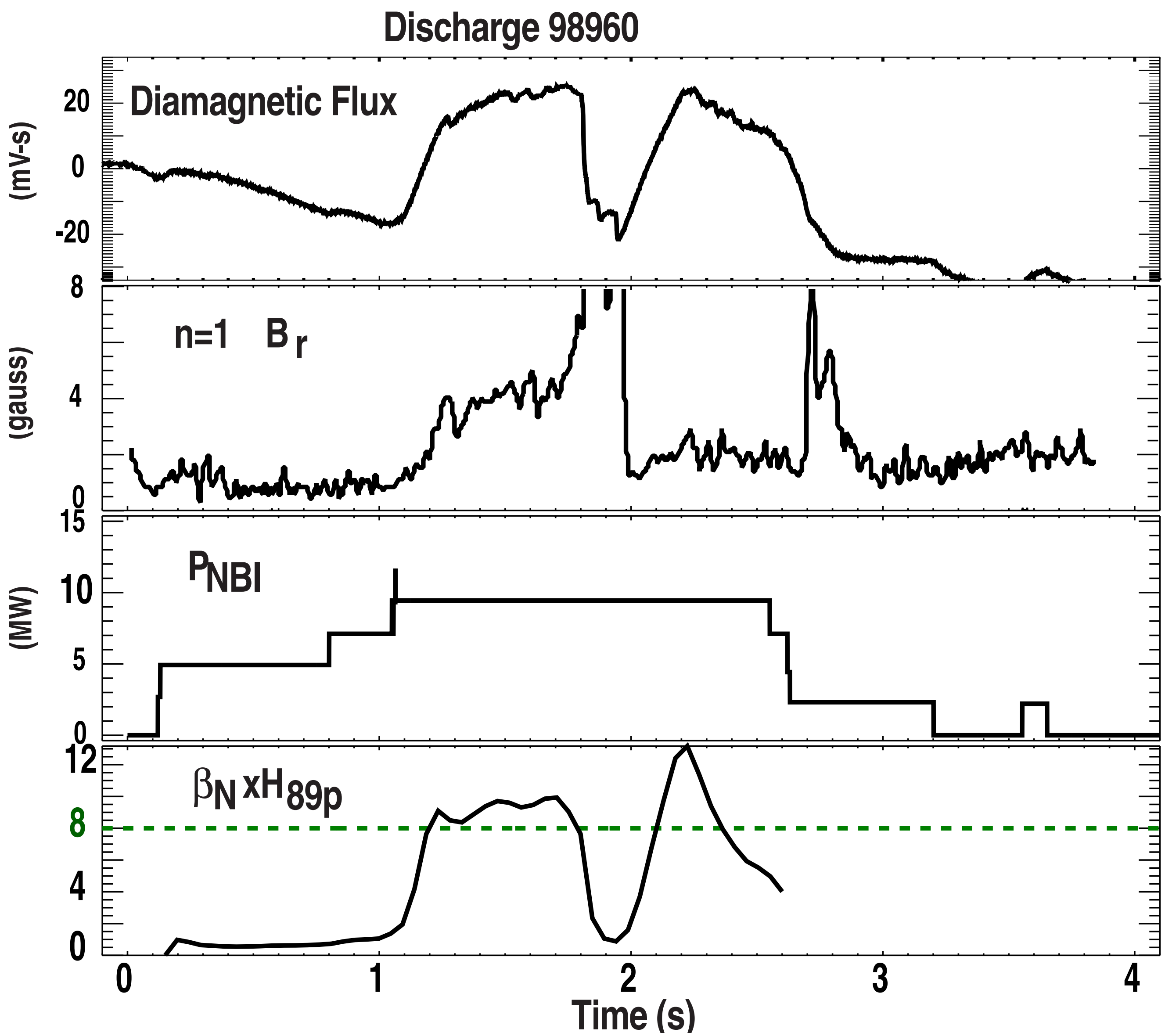
Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

PHYSICS
PRINCIPLES

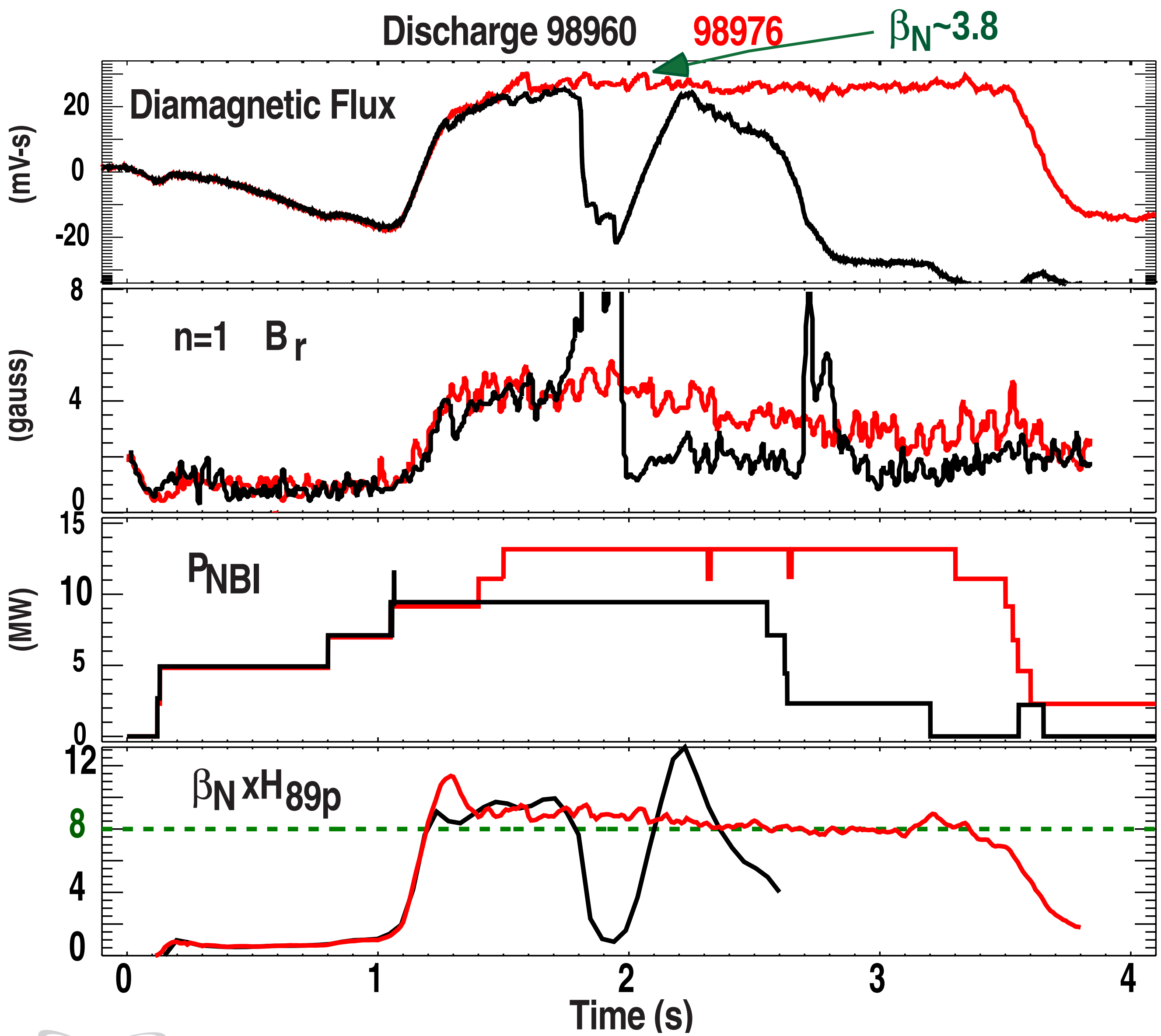
DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

AT Discharge Affected by Resistive Wall Mode



- I_p=1.2 MA, B_t=1.6 T
  q_{min} ~1.7, q_{95}~5.5
- β_N limited to about 4li (no wall limit) by bursty RWM

Discharge tuning results in long duration AT Mode

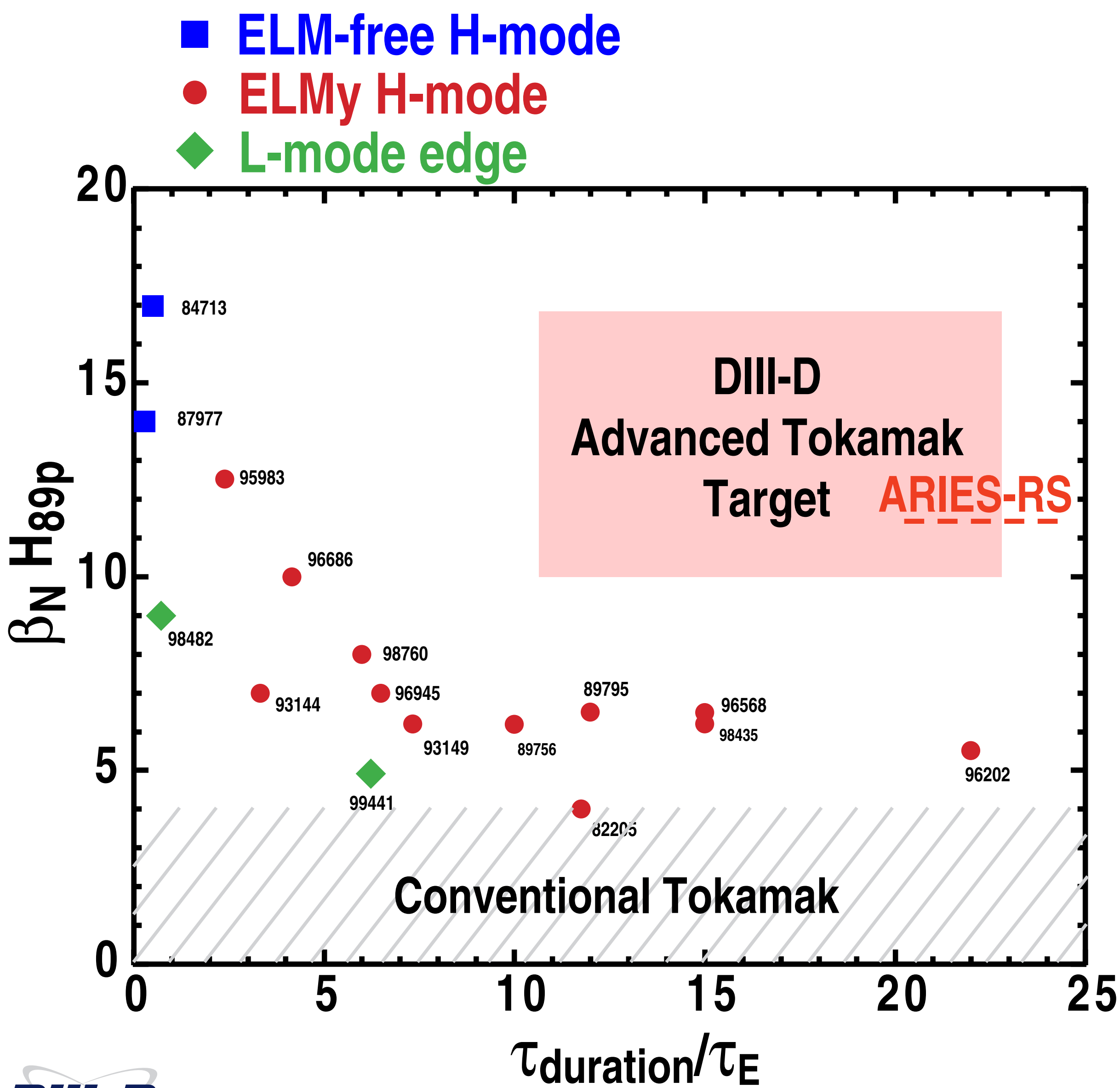


- I_p=1.2 MA, B_t=1.6 T
  q_{min} ~1.7, q_{95}~5.5
- β_N limited to about 4li (no wall limit) by bursty RWM
- Higher NBI power improves stability and duration
- 75 % current non-inductive
  >50% bootstrap

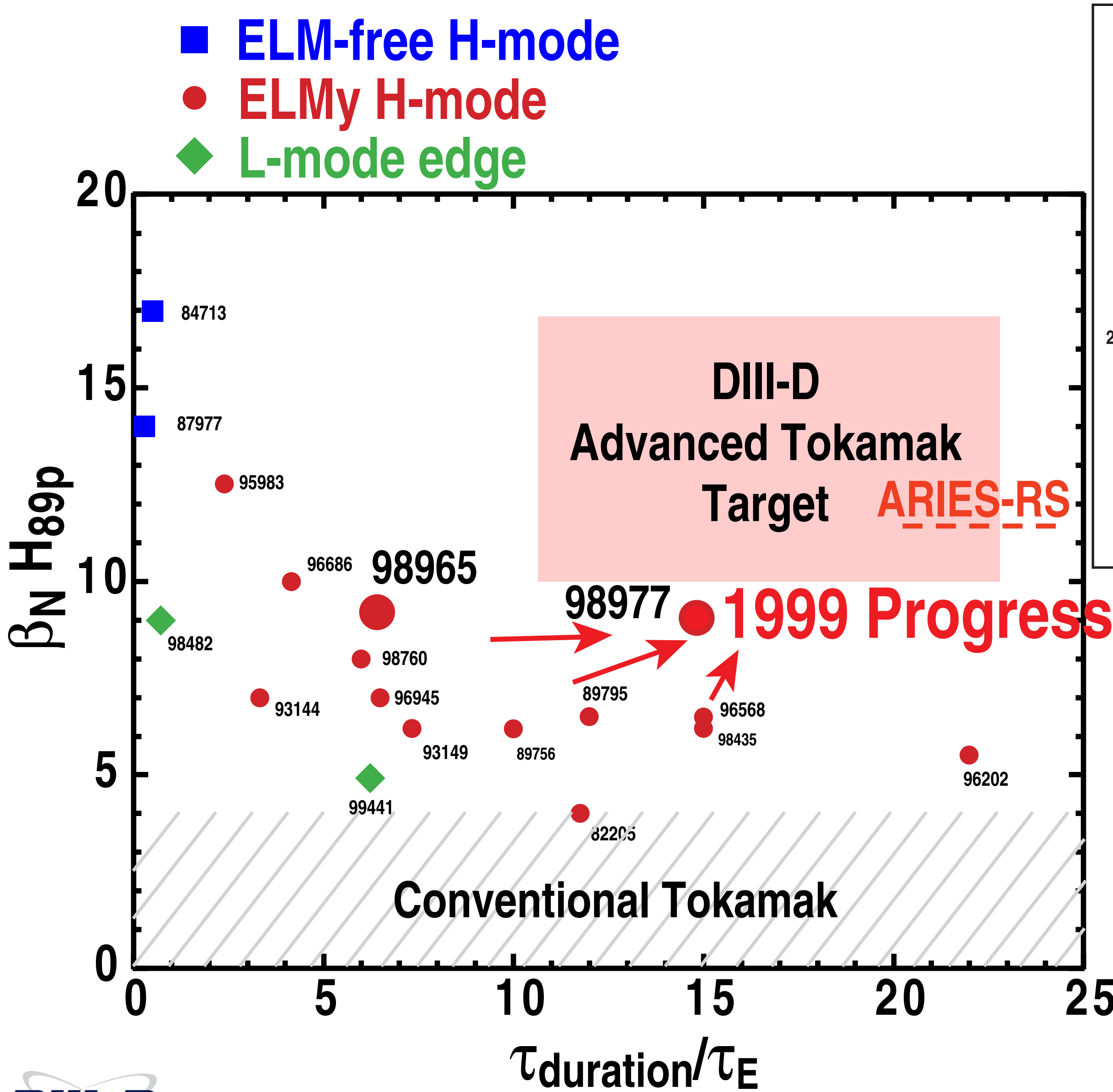
DIII-D NATIONAL FUSION FACILITY SAN DIEGO

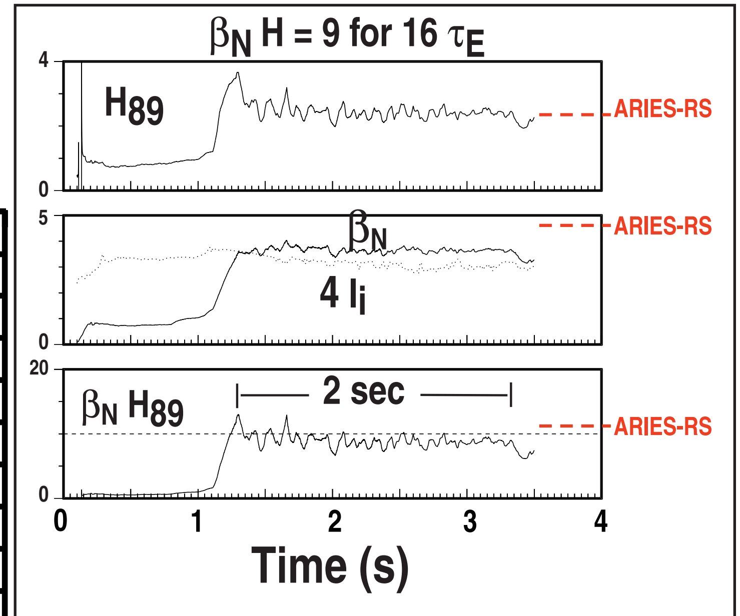
2000 DAC Allen

AT Performance vs. Duration

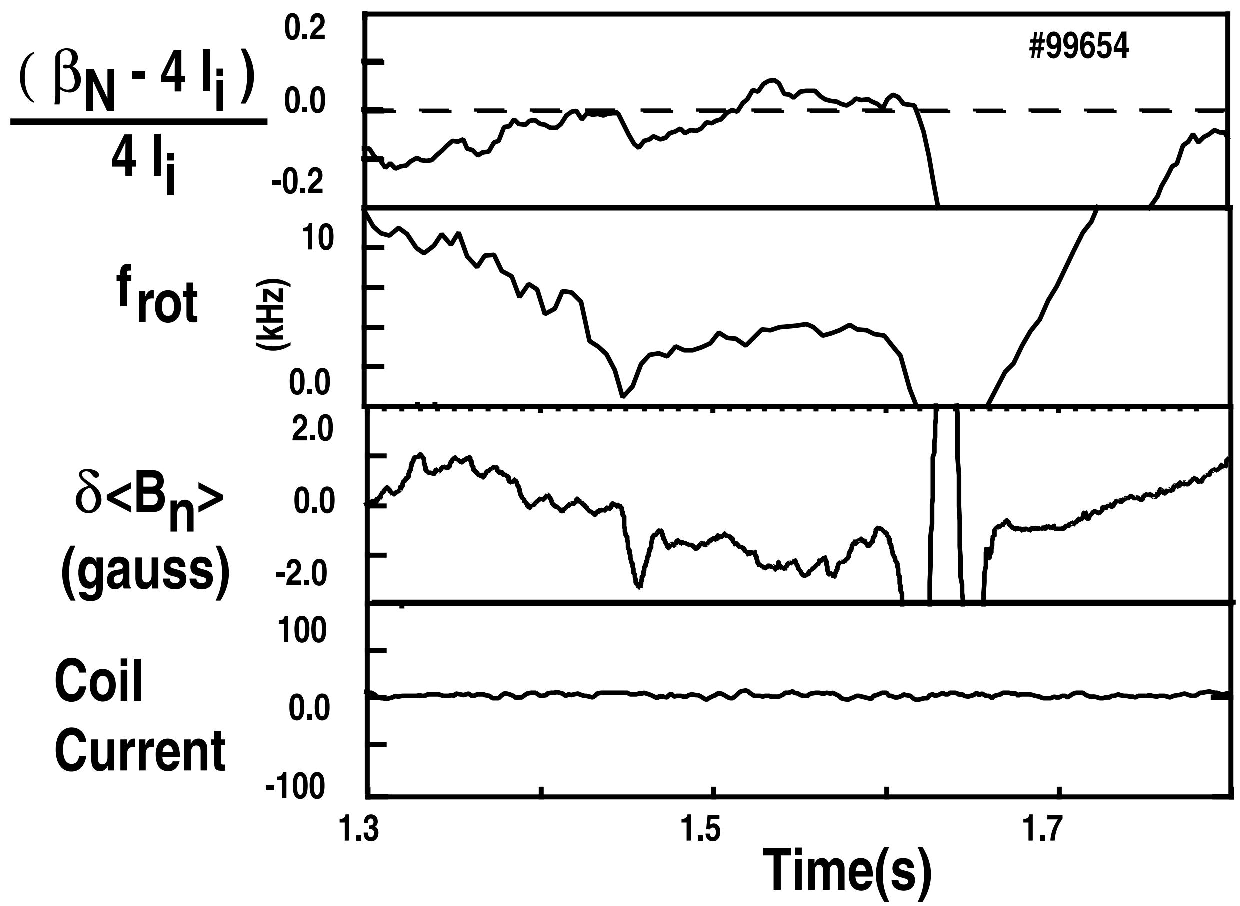


AT Performance vs. Duration *Increased in 1999*



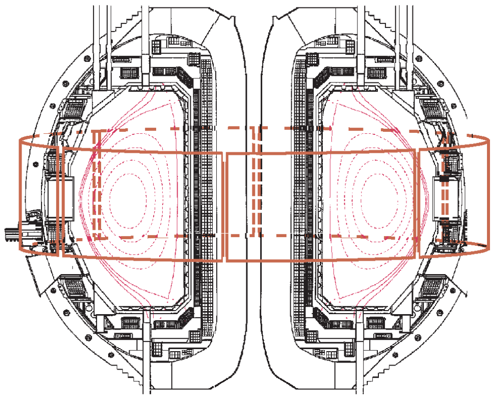


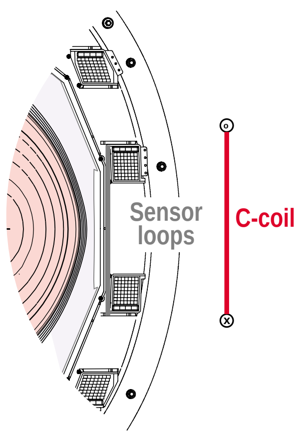
Preliminary RWM Feedback Experiments Show

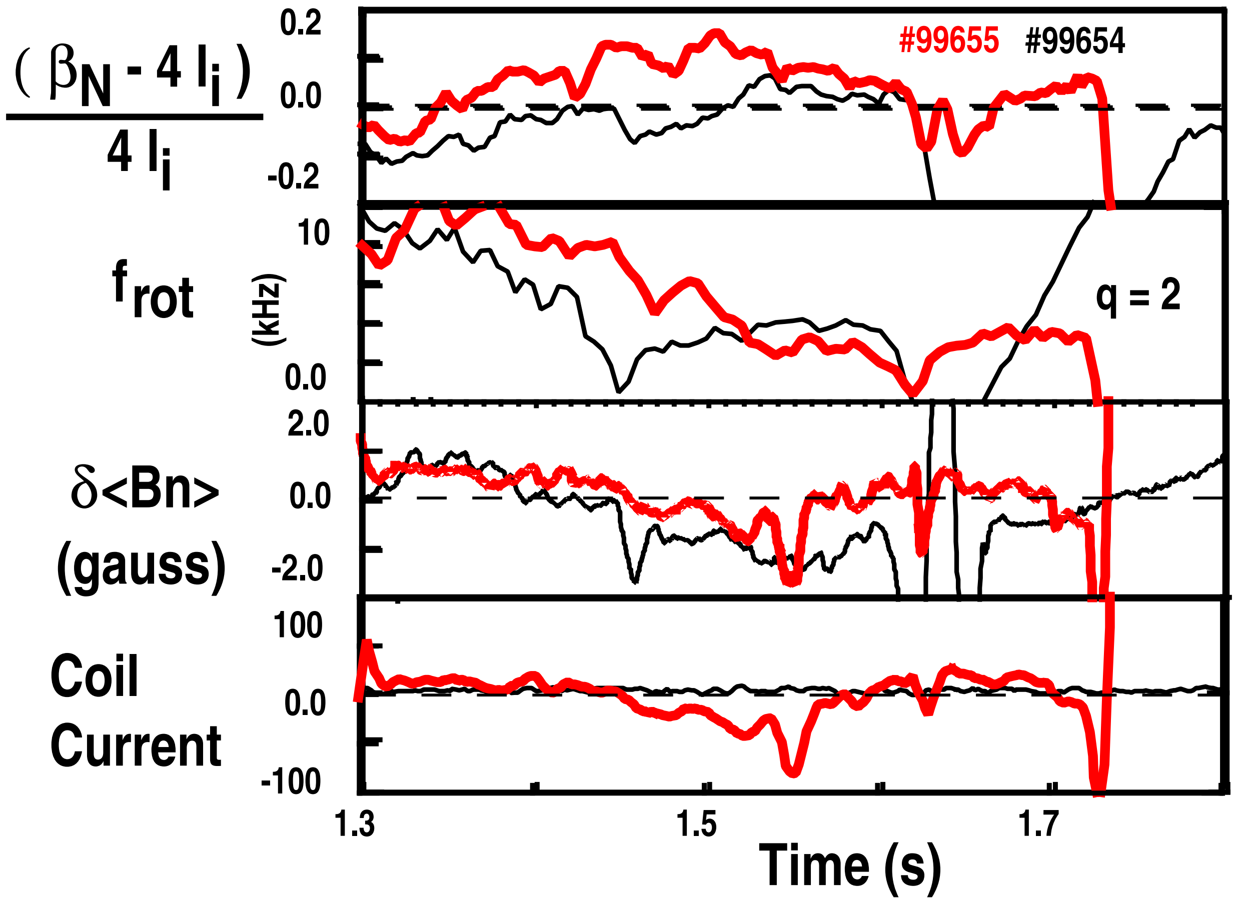


DIII–D NATIONAL FUSION FACILITY SAN DIEGO

Preliminary RWM Feedback Experiments Show
Extended Duration







Research in Neoclassical Tearing Modes

1999

Wall Stabilization Physics

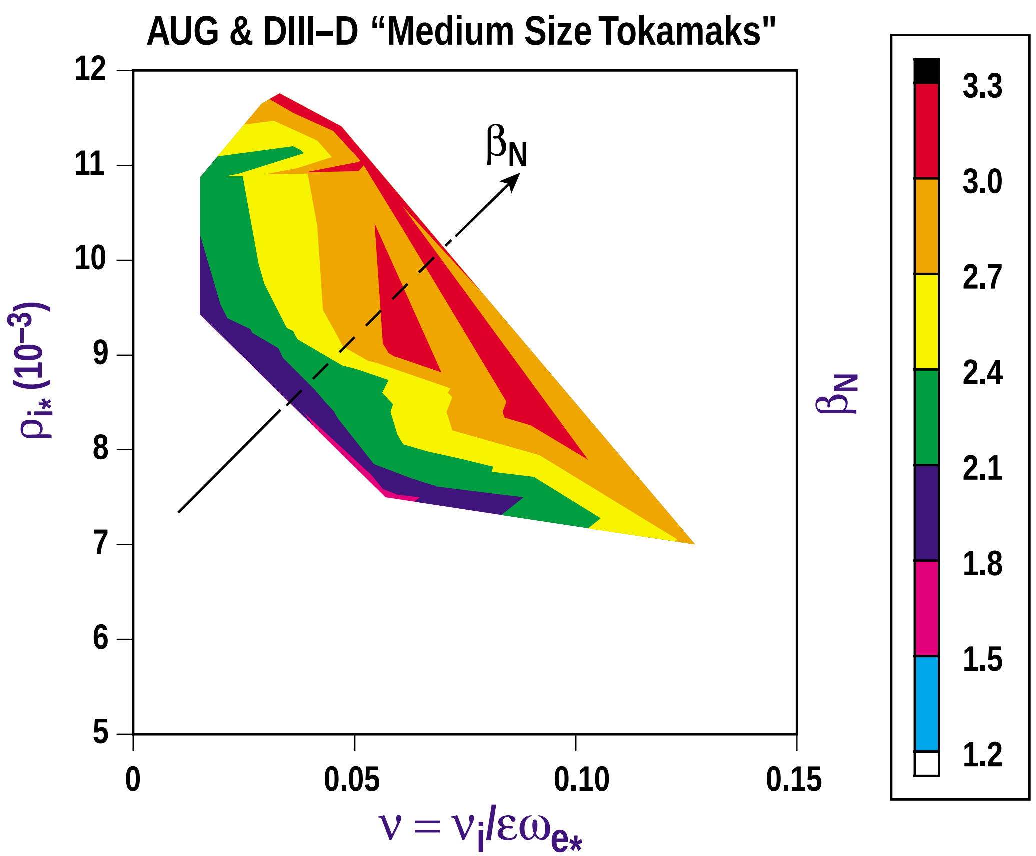
Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

PHYSICS
PRINCIPLES

NTM Critical β_N power law scaling

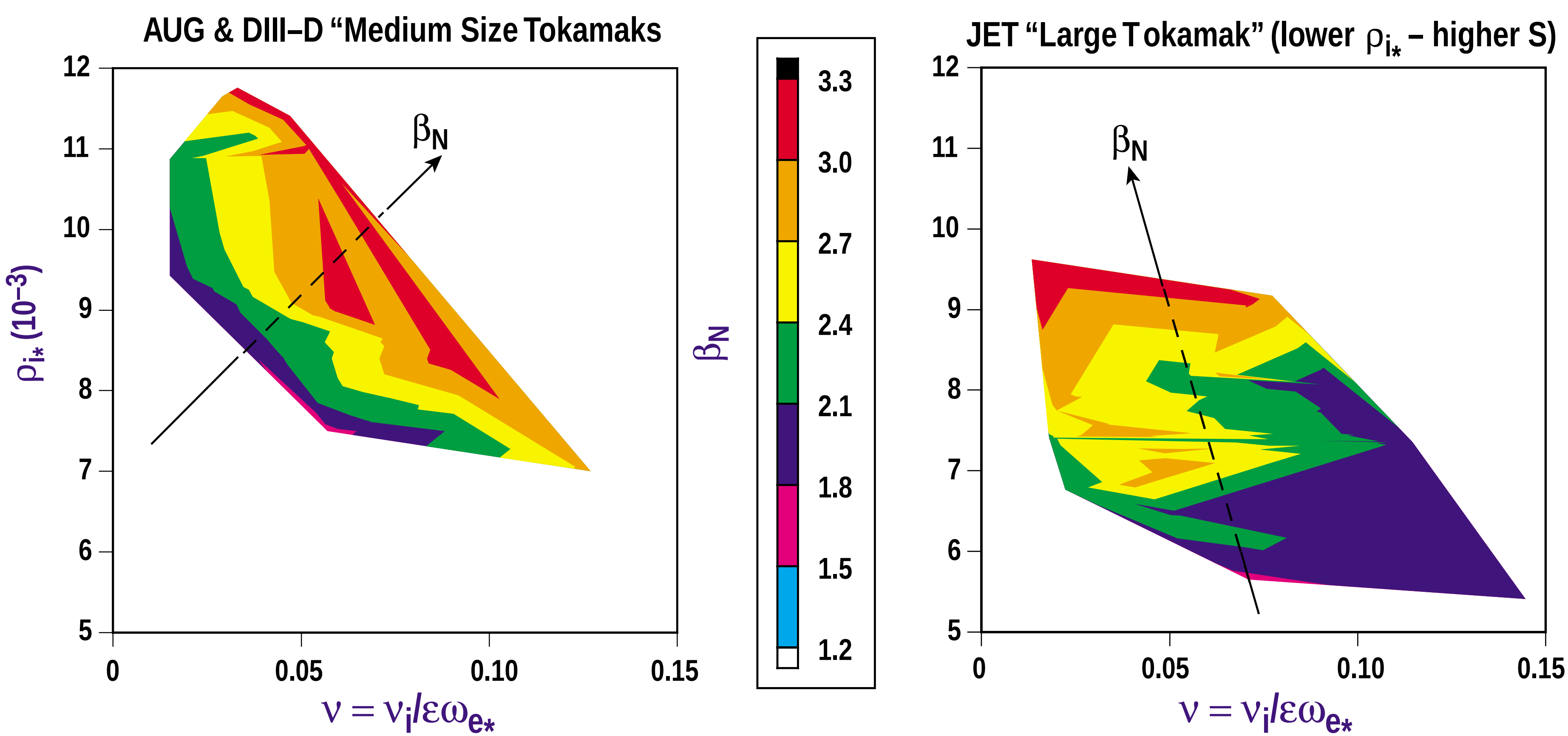
$$\beta_{NC} \propto \rho_{i*}^{x} (\nu_i/\varepsilon\omega_{e*})^{y}$$



DIII–D NATIONAL FUSION FACILITY SAN DIEGO

NTM Critical β_N power law scaling is complicated!

$$\beta_{NC} \propto \rho_{i*}^{x} (\nu_i/\varepsilon\omega_{e*})^{y}$$



New tools for ITB control, including counter NBI

1999

Wall Stabilization Physics

Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

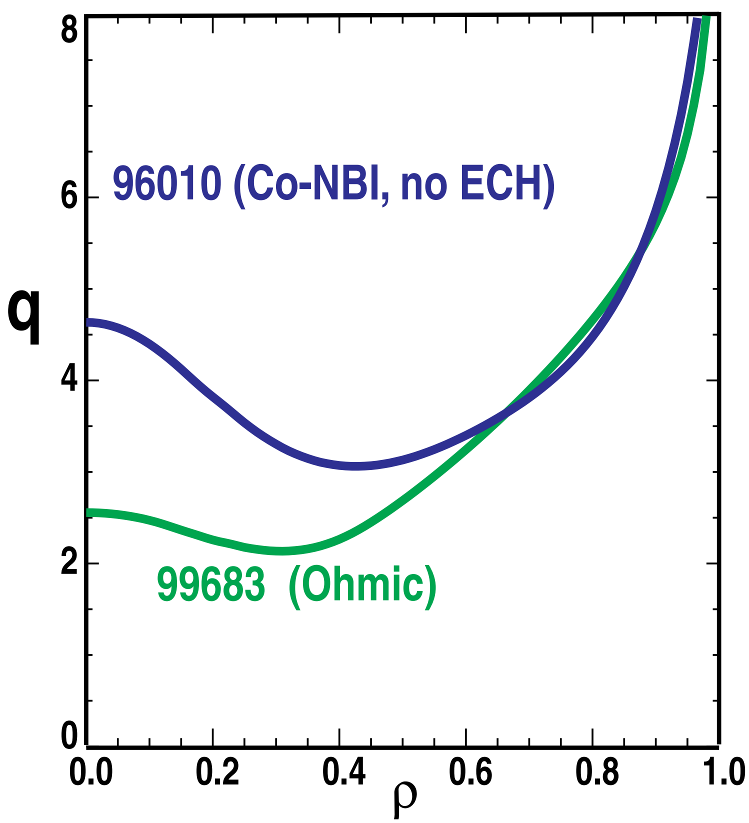
Internal Transport Barrier (ITB) Control

Counter Neutral Beam Injection

Tools for edge stability

PHYSICS
PRINCIPLES

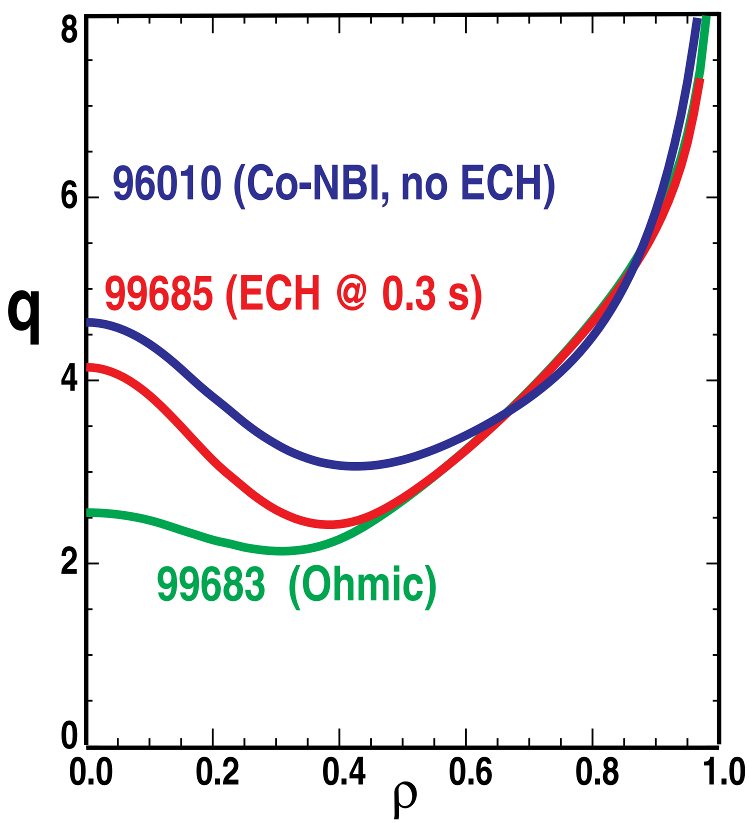
Tools for ITB control: Counter NBI and ECH Preheat



- Routine counter NBI injection achieved (previously not routine on DIII–D)

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

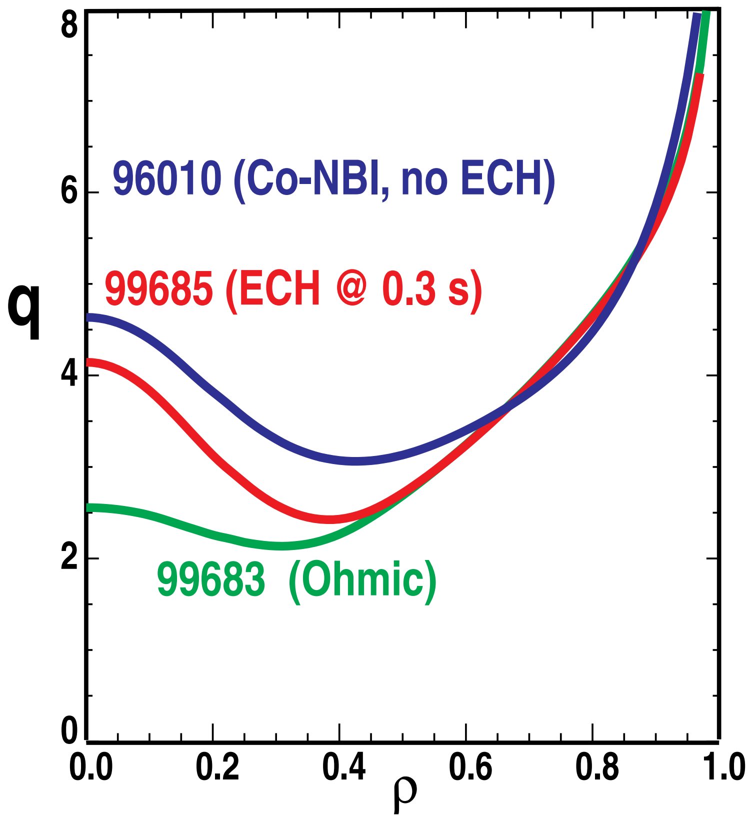
Tools for ITB control: Counter NBI and ECH Preheat



- Routine counter NBI injection achieved (previously not routine on DIII–D)

- ECH Preheat controls q-profile
  --Counter NBI less NCS
  --ECH + Counter NBI better profile

Tools for ITB control: Counter NBI and ECH Preheat



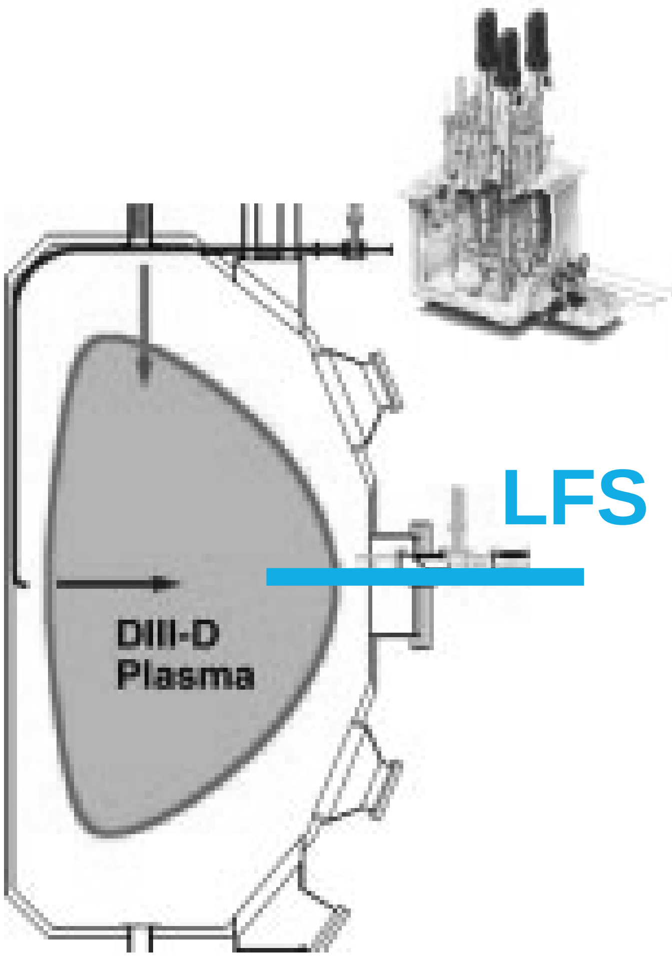
- Routine counter NBI injection achieved (previously not routine on DIII–D)

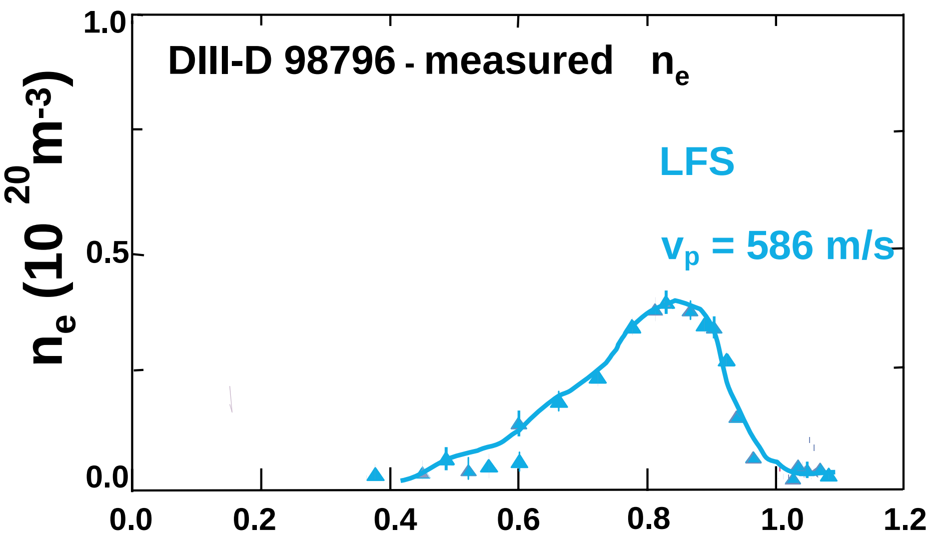
- ECH Preheat controls q-profile
  --Counter NBI less NCS
  --ECH + Counter NBI better profile

Differences Compared to CO-ITB:
-- ITB formed, but required more NBI power
--Broader barriers, with less steep gradients
--Sustainment work in 2000

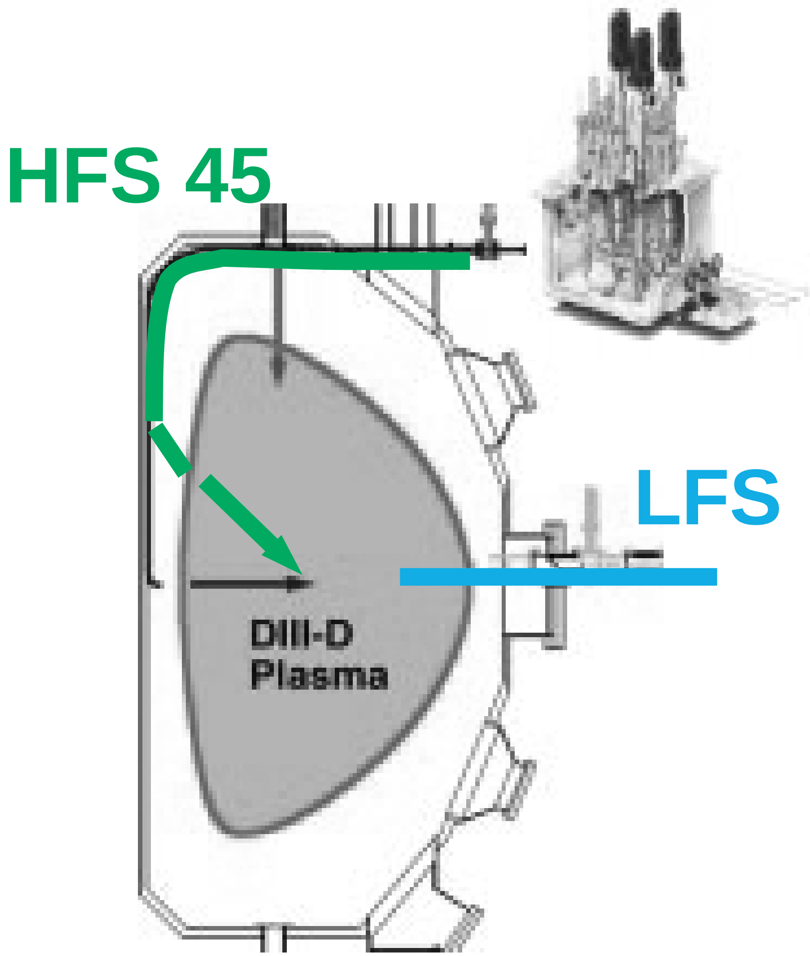
DIII–D NATIONAL FUSION FACILITY SAN DIEGO

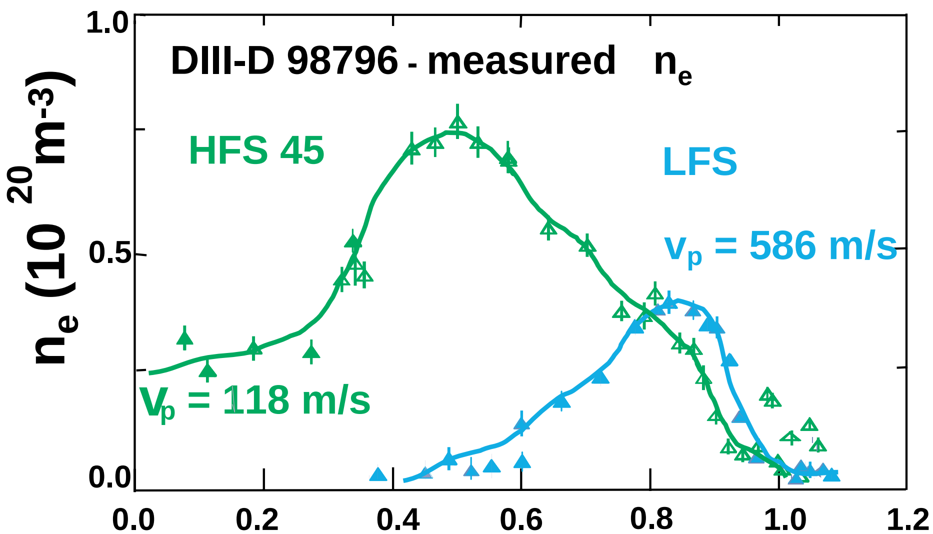
Tools for ITB control: Flexible Pellet





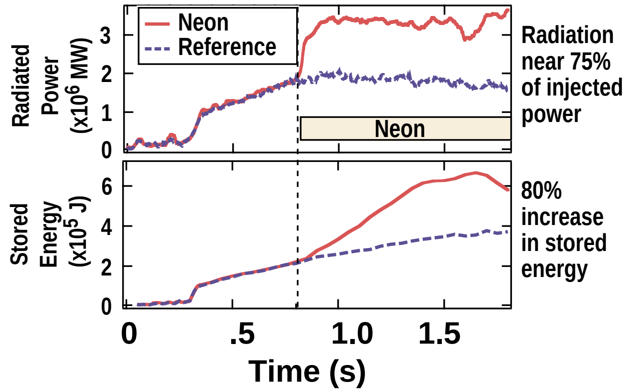
Tools for ITB control: Flexible Pellet Injection





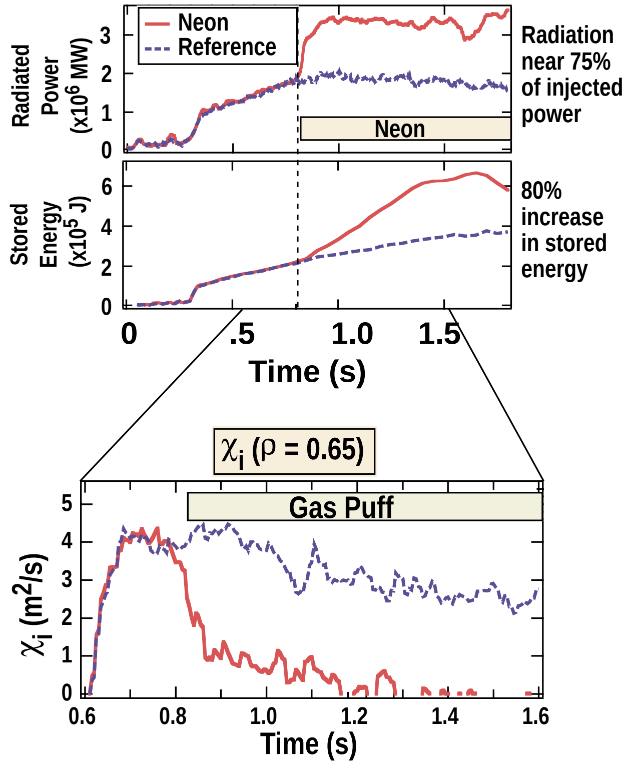
Tools for ITB control: Impurity Injection

Neon
Increases
Stored
Energy



Tools for ITB control: Impurity Injection

Neon Increases Stored Energy



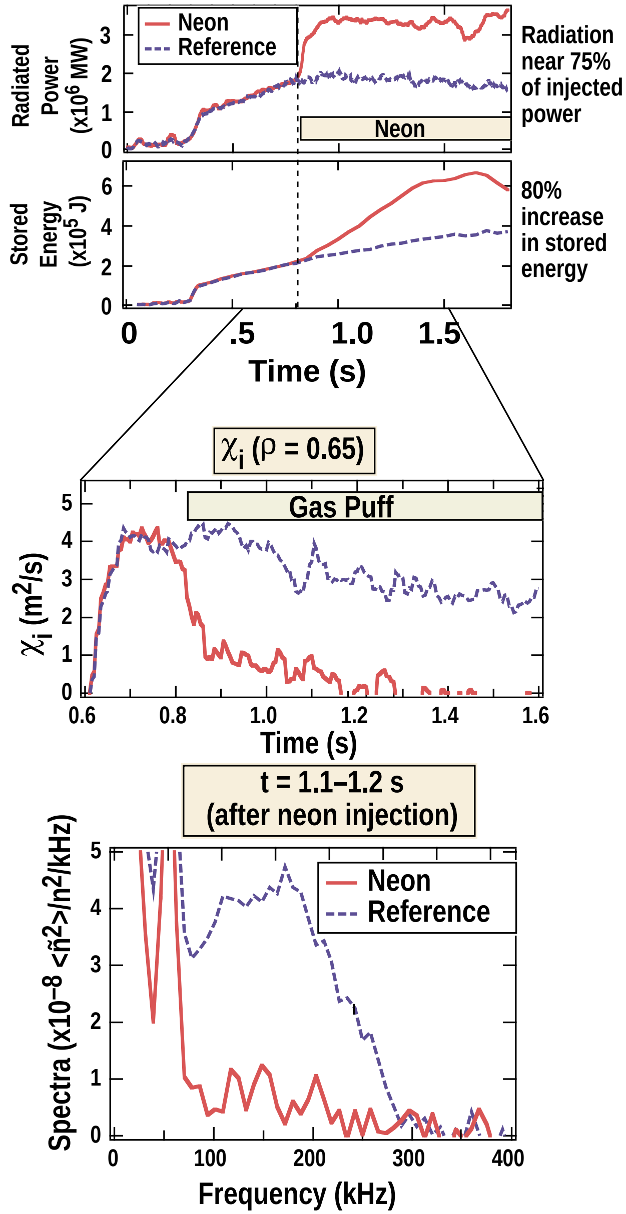
Ion Transport Reduced

Tools for ITB control: Impurity Injection

Neon Increases Stored Energy

Ion Transport Reduced

BES Fluctuations Drop



We explored the affects of shape on Confinement

1999

Wall Stabilization Physics

Neoclassical Tearing Mode (NTM) physics

Advanced Tokamak Scenario Development

Internal Transport Barrier (ITB) Control

Counter Neutral Beam Injection

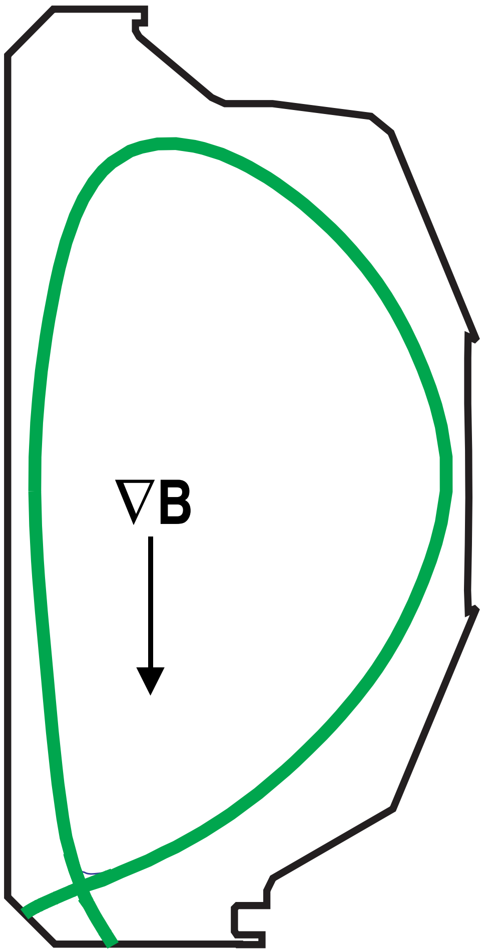
Tools for edge stability

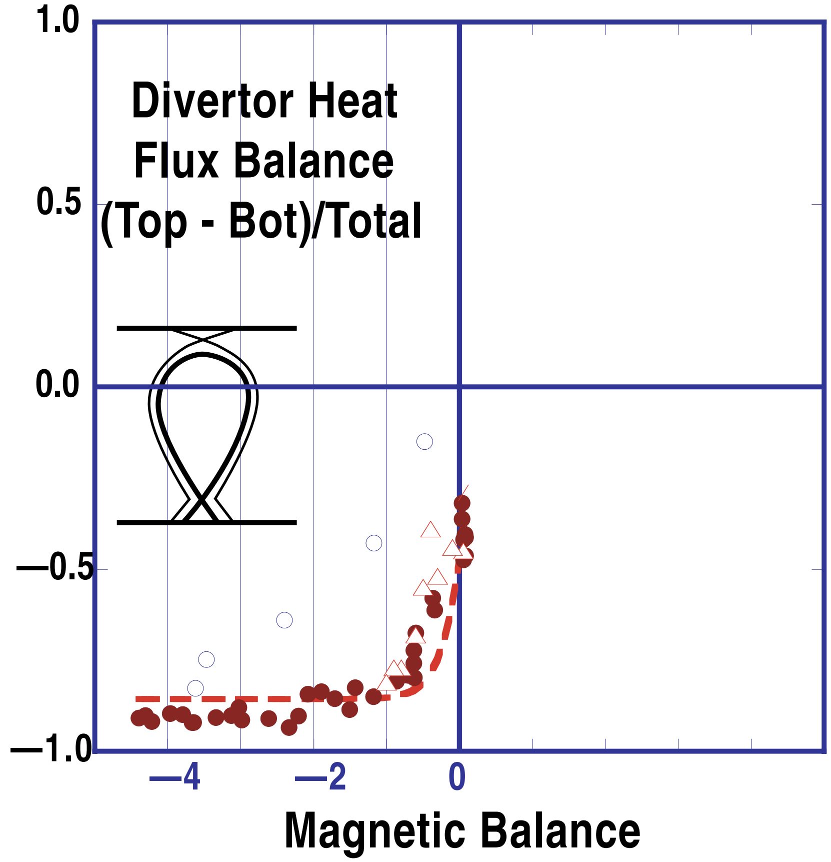
Optimal plasma shape, divertor

PHYSICS
PRINCIPLES

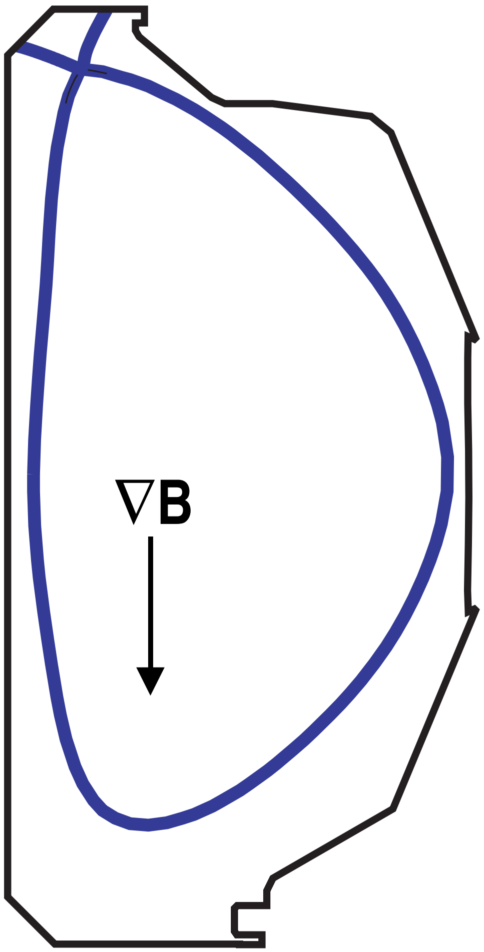
DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

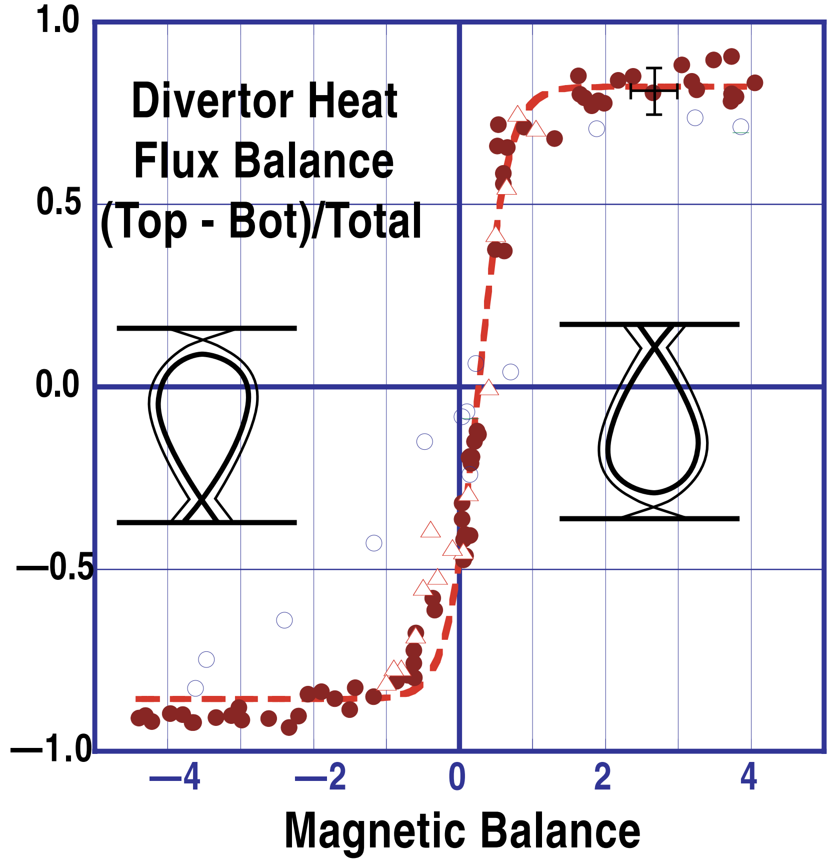
Plasma shape studies included variation from LSN to USN



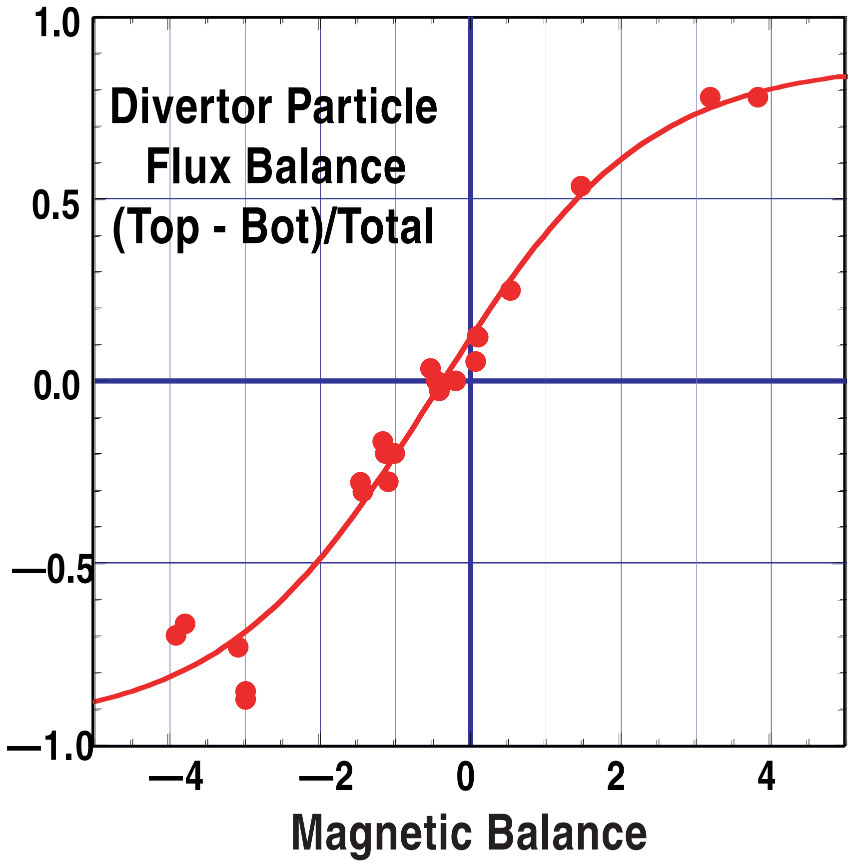


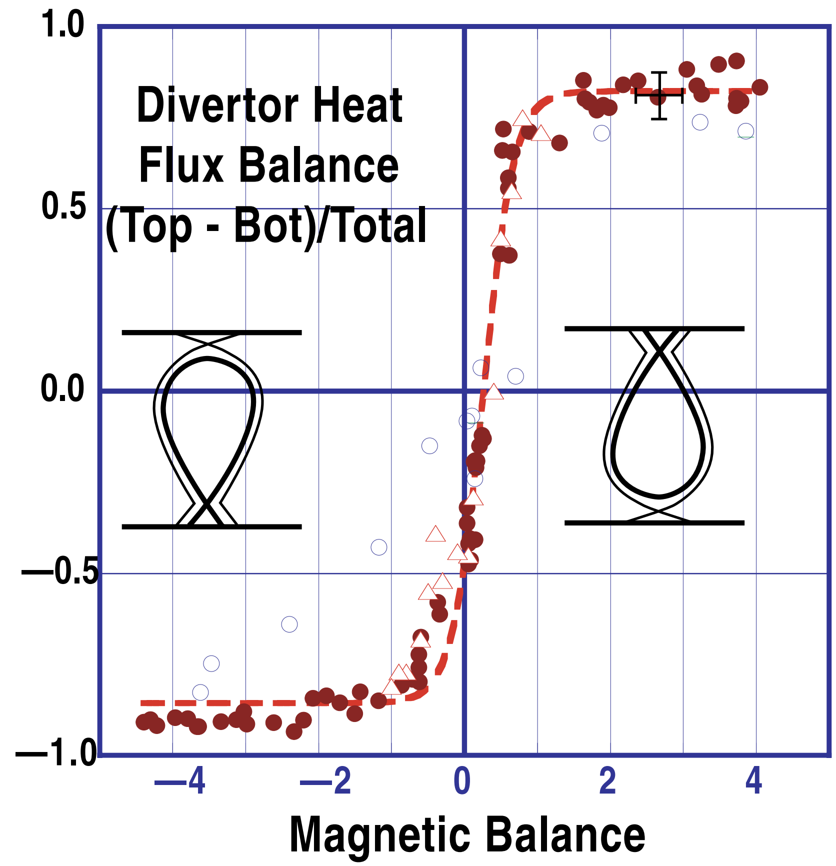
Plasma shape studies included variation from LSN to USN





Plasma shape studies included variation from LSN to USN

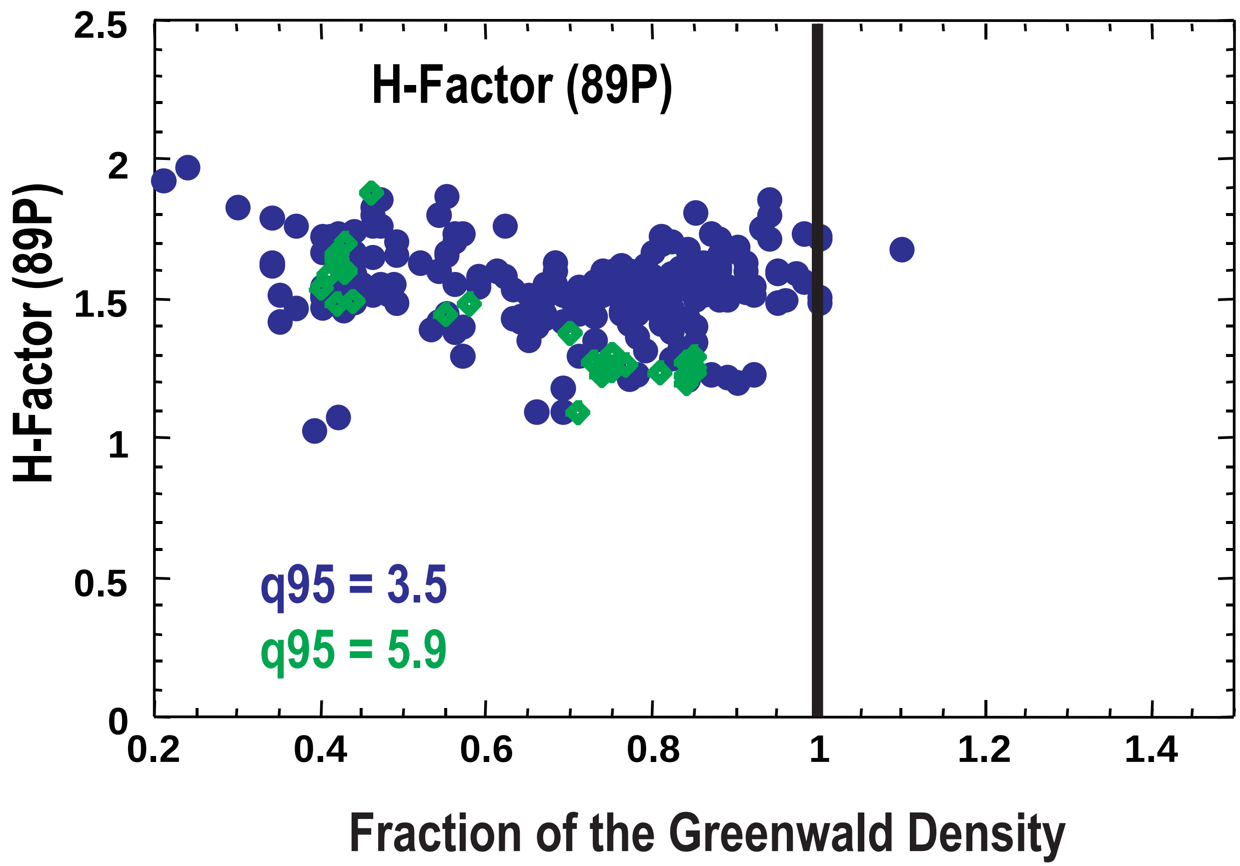




DIII-D NATIONAL FUSION FACILITY SAN DIEGO

Experiments in the “Topical Science Areas” -- Pedestal Physics

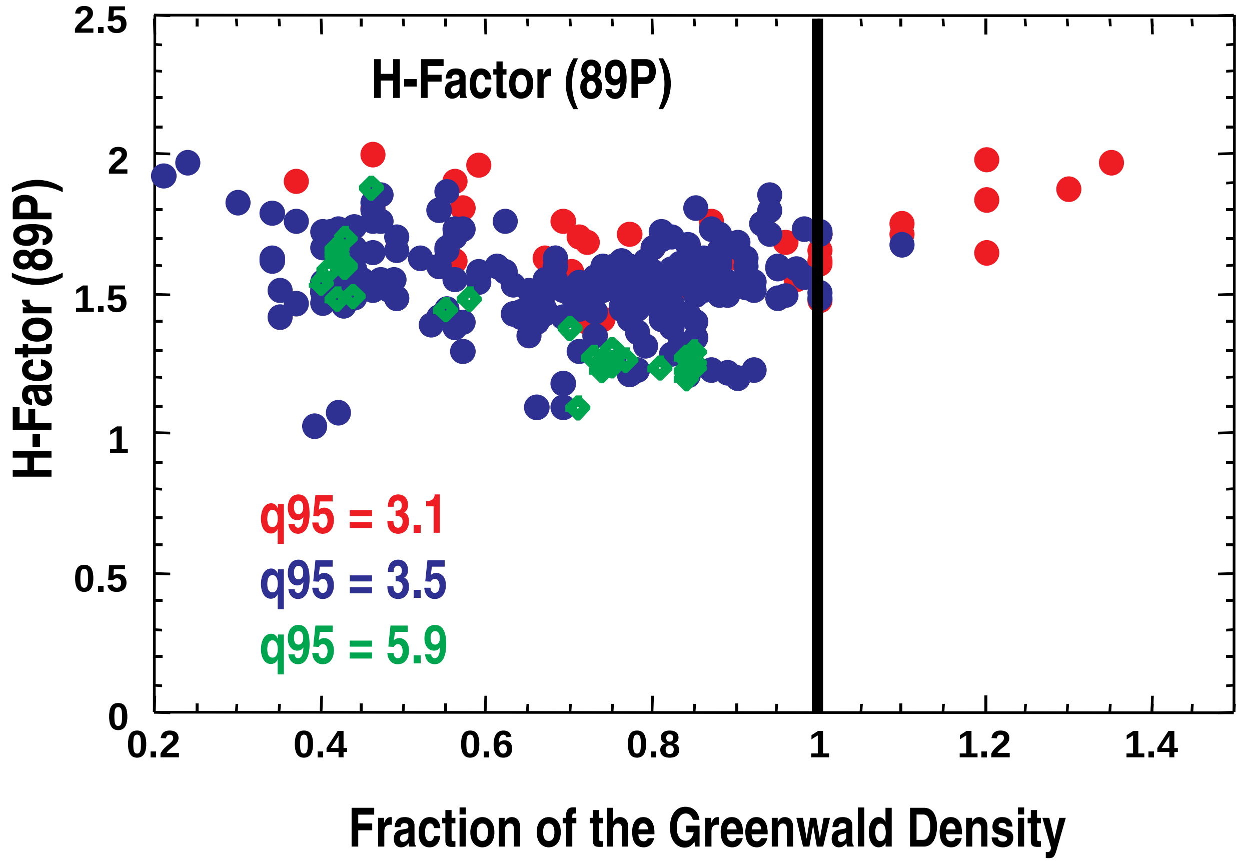
- Confinement and Transport, Heating & Current Drive, Stability, Divertor



DIII-D NATIONAL FUSION FACILITY SAN DIEGO

Operation above the Greenwald Density

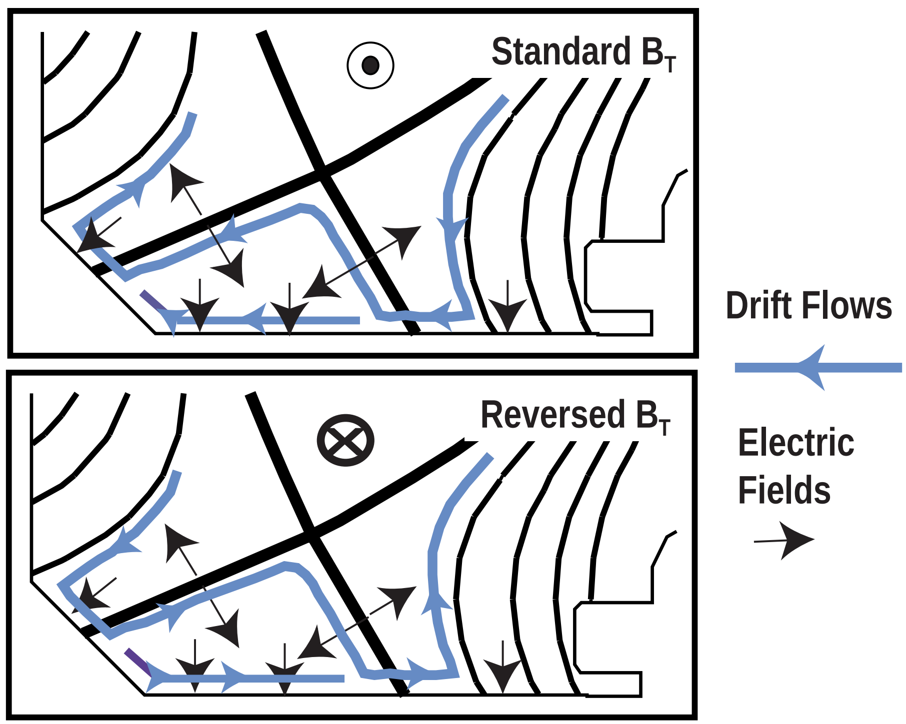
Pedestal Physics



Drifts near the x-point are important for confinement

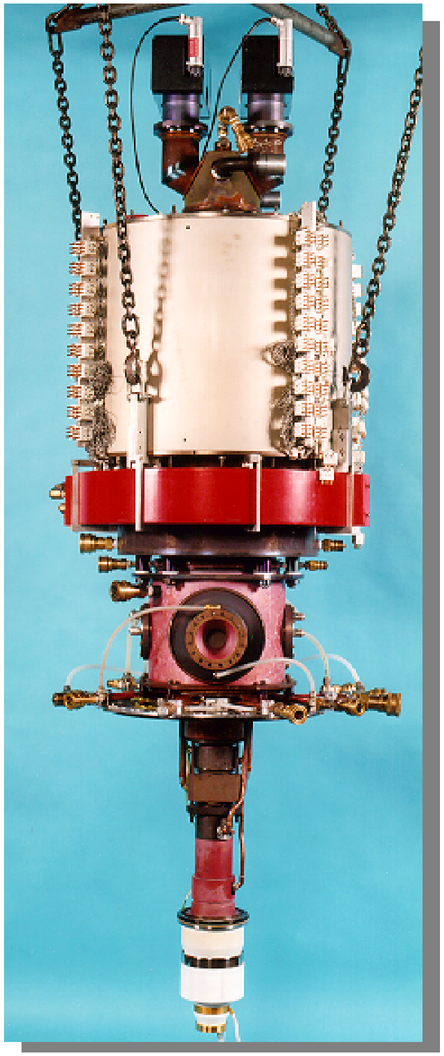
Drifts near X-point Important

- --Flows
- --Confinement
- --UEDGE Model w/ Flows



DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

New capabilities in 2000 -- ECH Power



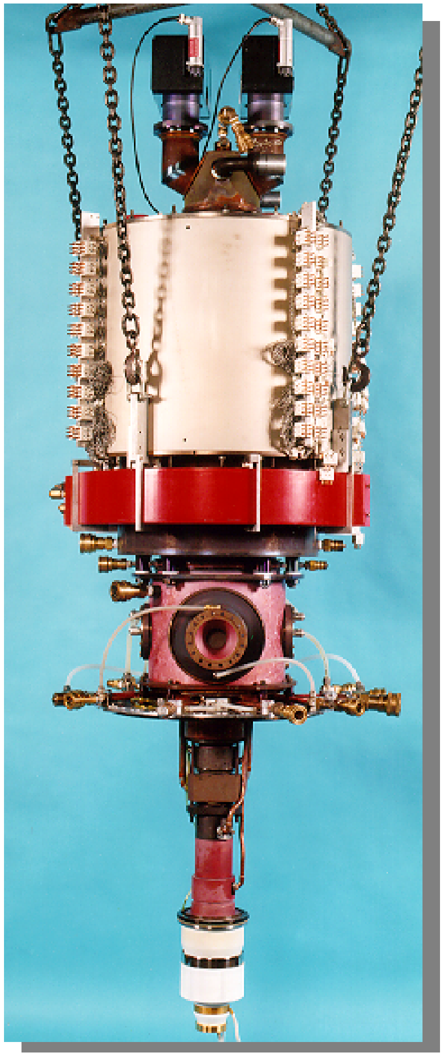
• 3 GYCOM Gyrotrons

--2 s pulse length

--includes 2 from TdeV

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

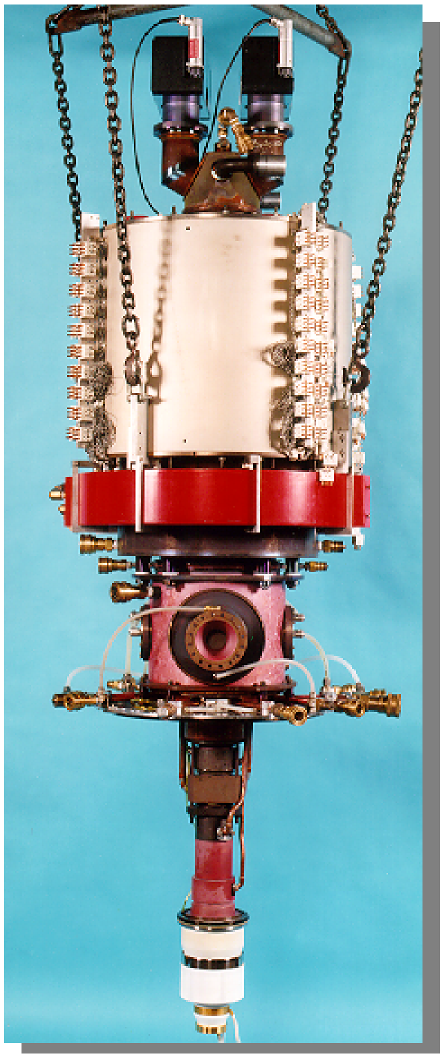
New capabilities in 2000 -- ECH Power



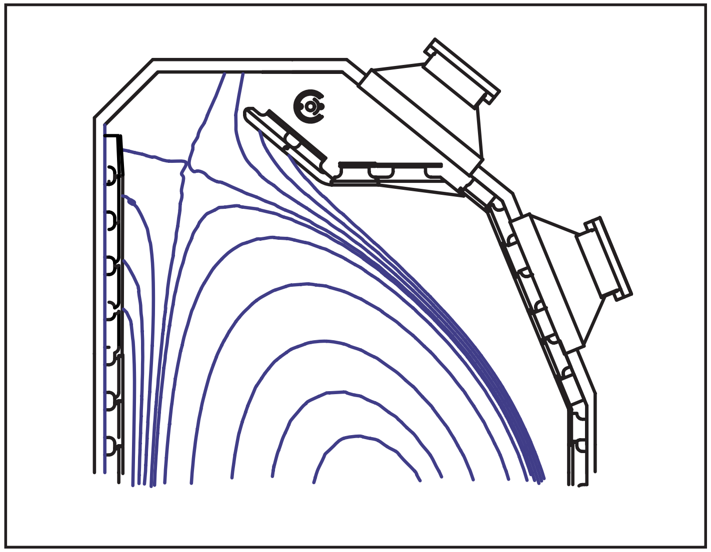
- 3 GYCOM Gyrotrons
  - --2 s pulse length
  - --includes 2 from TdeV
- 3 CPI Gyrotrons
  - --2 Long Pulse with Diamond Window
- New Steerable Launcher

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

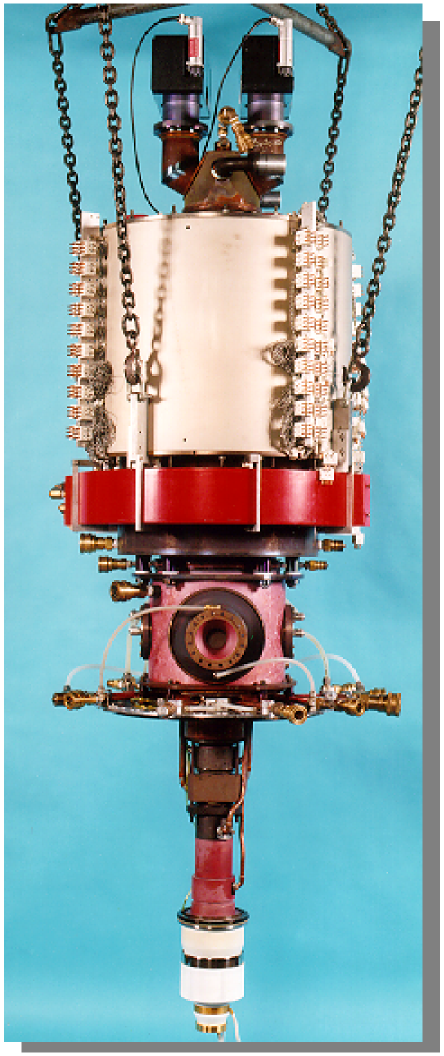
New capabilities in 2000 -- ECH Power and Divertor Pumping



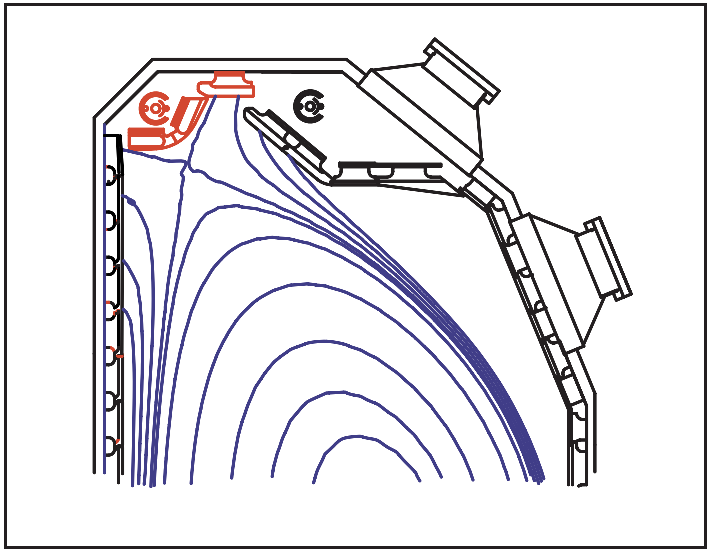
- 3 GYCOM Gyrotrons
  - --2 s pulse length
  - --includes 2 from TdeV
- 3 CPI Gyrotrons
  - --2 Long Pulse with Diamond Window
- New Steerable Launcher



New capabilities in 2000 -- ECH Power and Divertor Pumping

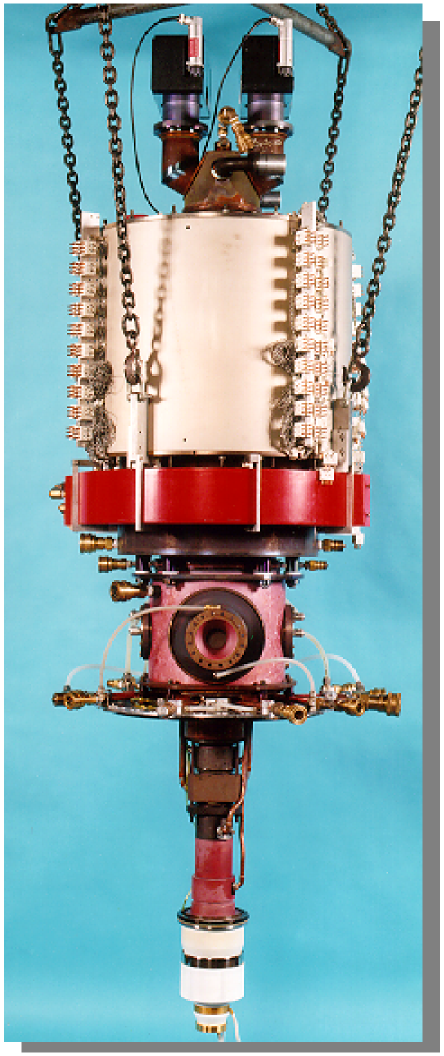


- 3 GYCOM Gyrotrons
  - --2 s pulse length
  - --includes 2 from TdeV
- 3 CPI Gyrotrons
  - --2 Long Pulse with Diamond Window
- New Steerable Launcher

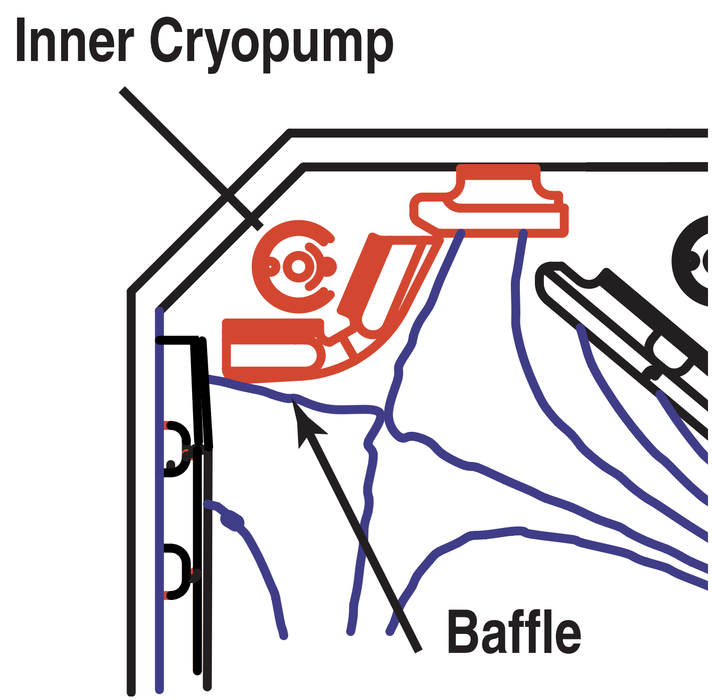


- New upper divertor:

New capabilities in 2000 -- ECH Power and Divertor Pumping



- 3 GYCOM Gyrotrons
  - --2 s pulse length
  - --includes 2 from TdeV
- 3 CPI Gyrotrons
  - --2 Long Pulse with Diamond Window
- New Steerable Launcher



- New upper divertor:
  - --Cryopump
  - --Baffle in Private Flux Region

Overview of DIII-D Presentations TODAY

- Monday (it's over)
  -- C. Greenfield - Invited Talk on Transport
  -- G. Mc Kee - Invited Talk on Transport
  -- Poster session on Transport

- Tuesday
  --This oral session (You're here, so stay)

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

Overview of DIII-D Presentations WEDNESDAY

- Monday (it's over)
  -- C. Greenfield - Invited Talk on Transport
  -- G. Mc Kee - Invited Talk on Transport
  -- Poster session on Transport

- Tuesday
  --This oral session (You're here, so stay)

- Wednesday
  --Poster Session on DIII-D Divertor, Wave Particle, and
  Diagnostics

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

Overview of DIII-D Presentations FRIDAY

- Monday (it's over)
  -- C. Greenfield - Invited Talk on Transport
  -- G. Mc Kee - Invited Talk on Transport
  -- Poster session on Transport

- Tuesday
  --This oral session (You're here, so stay)

- Wednesday
  --Poster Session on DIII-D Divertor, Wave Particle, and Diagnostics

- Friday
  --J. Ferron - Invited Talk on H-mode pedestal instabilities
  --L. Baylor - Invited Talk on Pellet Injection