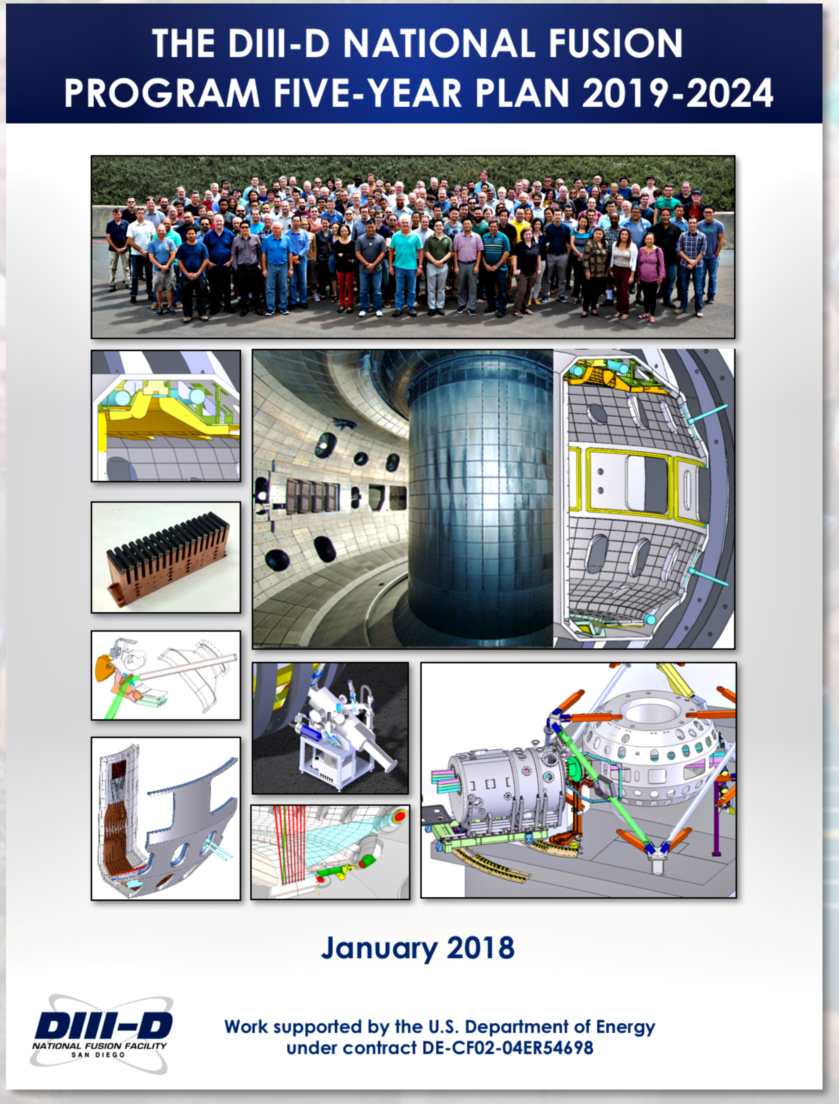
The DIII-D National Fusion Program: Five-Year Plan Overview

by
D.N. Hill

Presented to the
DIII-D Program Advisory Committee
San Diego, California

April 24–26, 2018



Renewal Proposal For FY19 – 24 DIII-D Cooperative Agreement Submitted on January 26th

- **Made possible by hard work from a dedicated, multi-institutional team**
- **Provides world-class facility for U.S. Fusion Program**
- **Positions the U.S. for a leading role in ITER research**
- **Informs U.S. Program planning for next-step experiments**

Ready to move forward now!

The Recommendations of the 2017 DIII-D PAC Provided Valuable Guidance as We Prepared the New Five-Year Plan

- We appreciate your support of our high level view of the DIII-D program and its role
  - The DIII-D team, in their introductory presentations, articulated a vision for their program, which the PAC endorses
    - Research with an Energy Goal
      Address challenges to achieving fusion energy
    - Scientific Excellence
      Fastest route to success and developing predictive capability
    - World-Class Facility for U.S. Office of Science
      Upgrades for access to new physics
      Highly capable scientific & operations team
      Train future generation of fusion experts
  - The DIII-D team also made it clear that ITER success continues to be their overarching top priority. We support this as well…
- "*In terms of the program extending out to 2024 we found, early in the meeting, that greater clarity on the strategic priorities was needed, specifically 1) key progress metrics through the 5-year planning period, and 2) key decision points.*"
  - **This was kept in mind throughout the generation of the plan**

The PAC also provided a number of detailed recommendations for each of our scientific areas… these were incorporated into our planning and we have included detailed responses from the DIII-D Experimental Science Division and Boundary Center as part of the materials provided

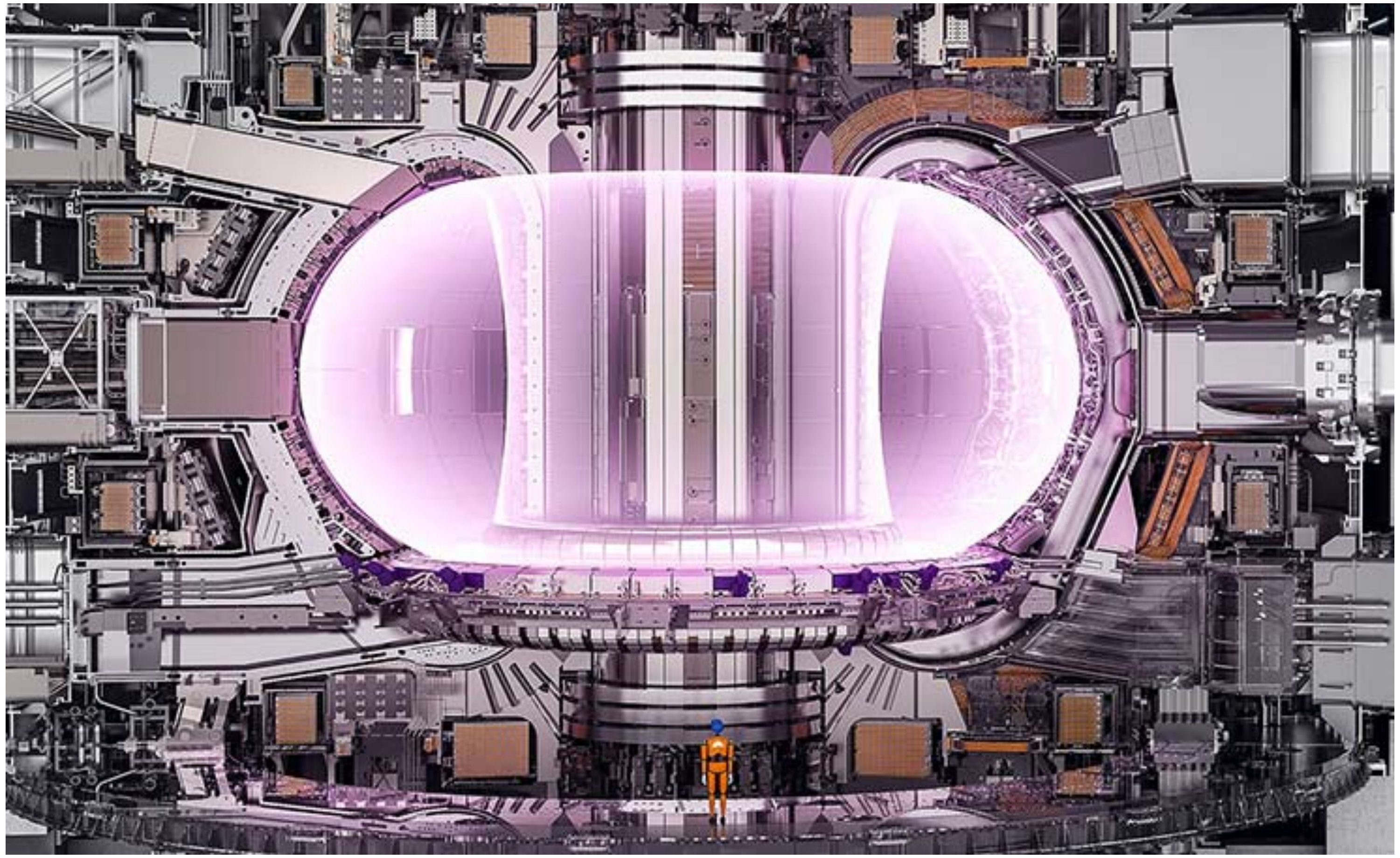
Topics Covered in this Talk

- **PAC Charge**
- **Background, context, and recent events**
- **Major elements of the Five-year Program Plan**
- **Recent DIII-D Program Performance**
- **DIII-D users and International Collaborations**

Charge to the 2018 DIII-D Program Advisory Committee

- **The DIII-D Program has developed a Five-Year Research Plan for the years 2019-2024. We expect a DOE peer review in May. We seek the DIII-D Program Advisory Committee's advice on major elements of the plan and how best to present it**
- **Please consider the following as you review the three sections of the research plan (Core, Boundary, and Core-Edge Integration)**
- **Is the overall plan logical and coherent?**
  - Are the individual elements clearly articulated?
  - Are there places where the technical basis could be strengthened? If so, how?
- **Will the proposed research address key scientific and technical needs for ITER and the steady-state tokamak path to fusion energy?**
  - Does the proposed research exploit the unique capabilities of the DIII-D facility? Are these capabilities clearly explained?
- **Is the DIII-D program positioned to support the proposed research?**
  - Do the proposed facility and diagnostic upgrades appropriately increase capabilities in support of the planned research?

DOE Ten-Year Perspective (2015– 2025) and NAS Interim Report Centers on ITER for Realization of Next-step for U.S. Burning Plasma Research



NAS Interim Report: *As a burning plasma experiment, ITER is a critical step along the path to advance the science and technology of a fusion power source.*

ITER is the world's flagship project for burning plasma science.

DIII-D
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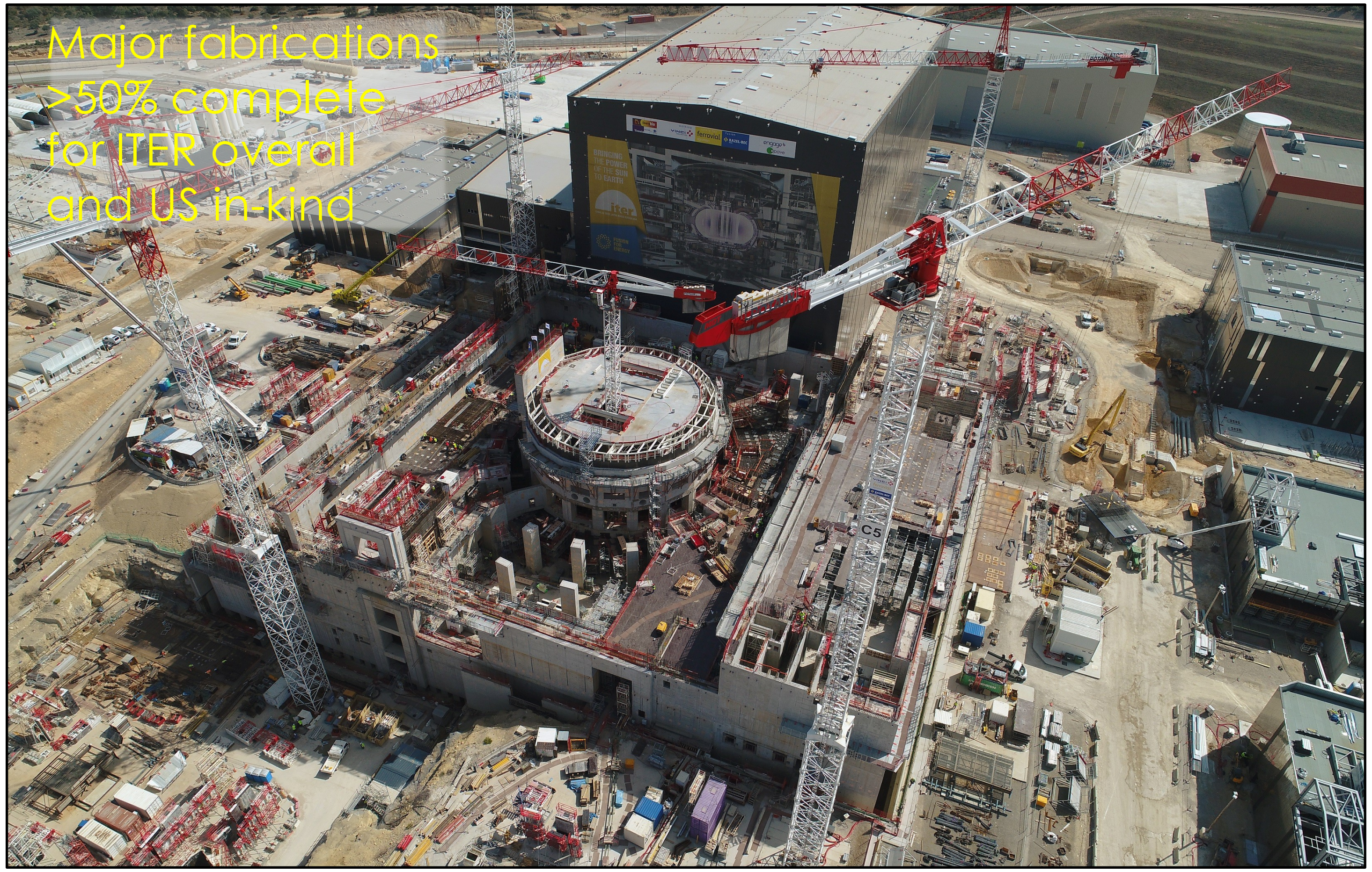
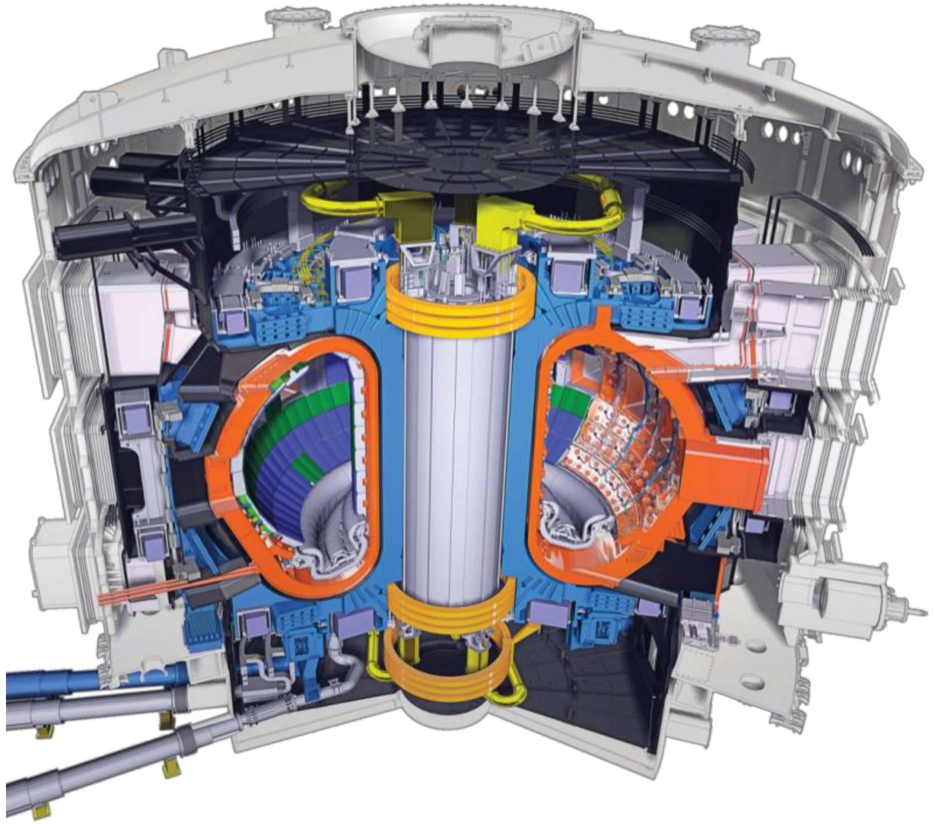
Steady Progress on ITER and New Private-Sector Investment May Be Changing the Funding Situation for Fusion Research in the U.S.



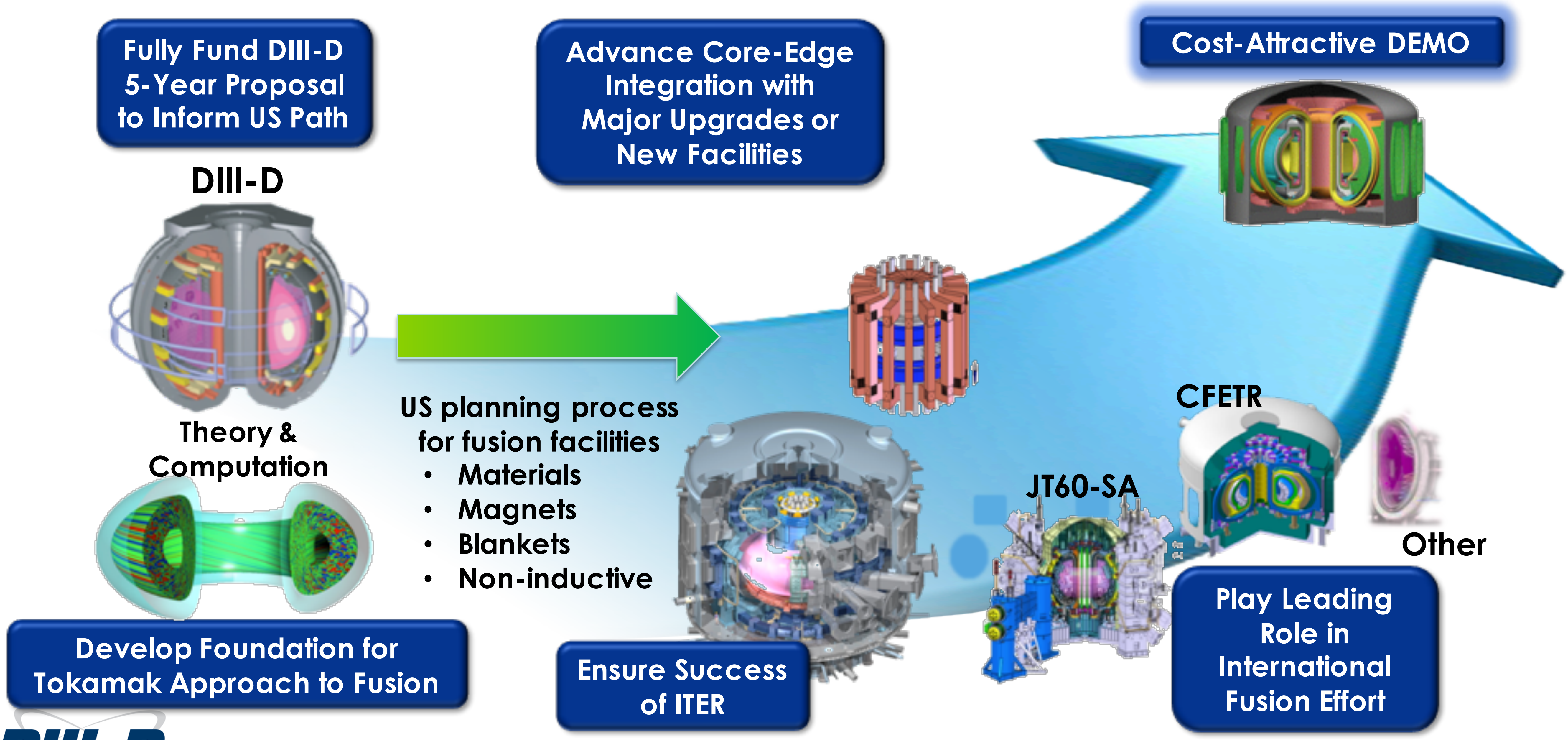
ITER Mission

"To demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes."



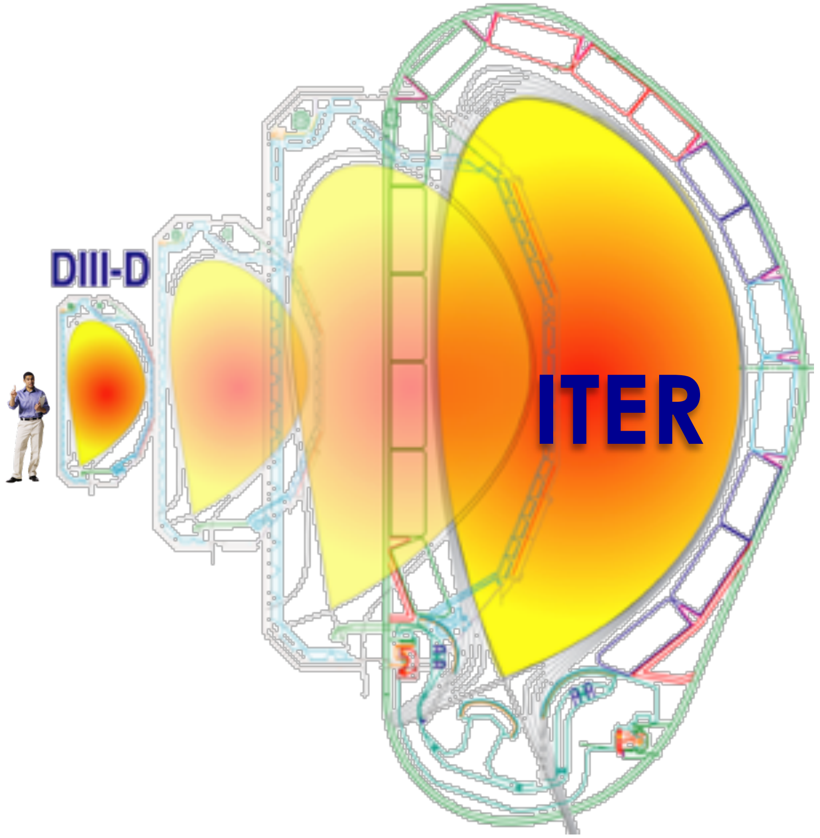
Evolving good news for fusion (Positive Congressional Hearings, Excellent Progress on ITER, Recent budget action, and increased private-sector investments)

Our Vision and Strategy Is Based on Scientific Excellence Leading to Fusion Energy Development

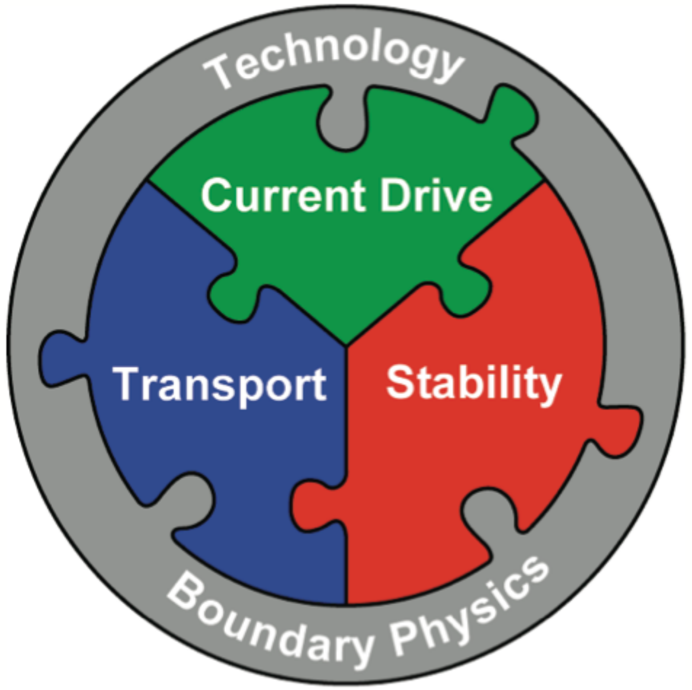


DIII-D Research Addresses Key Challenges for Fusion In Support of U.S. DOE-FES High Priority Research

DIII-D Is a ¼ Scale ITER



Integrated Steady-State Scenarios and Robust Boundary Solutions

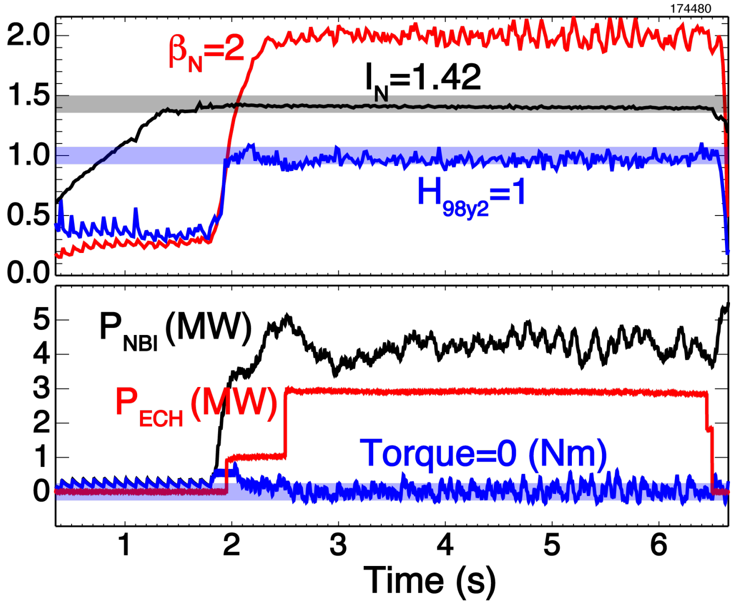


DIII-D and International are Preparing the Basis for Successful ITER Operation

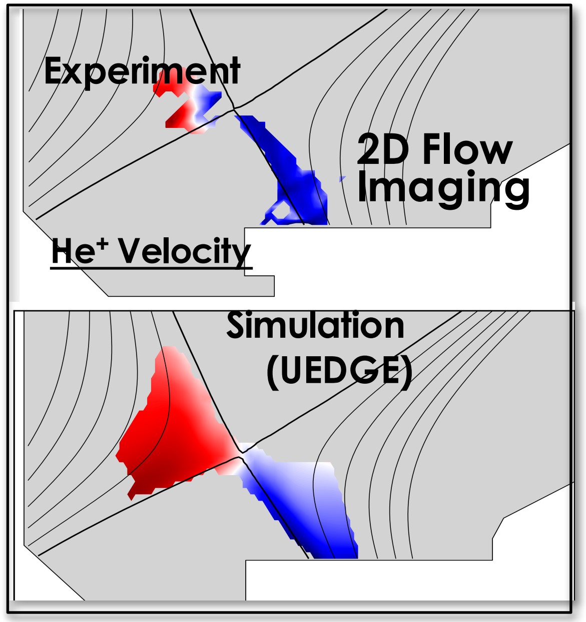
Research Aims to Address Key Physics in an Integrated Manner

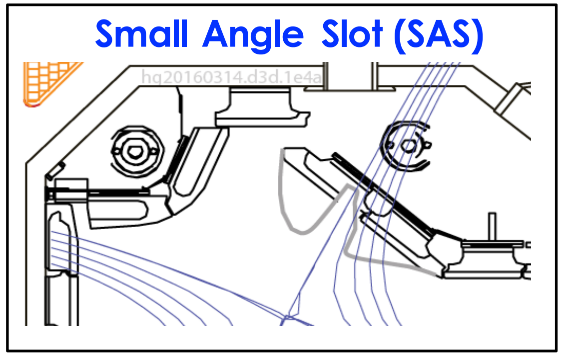
Present Five Year Plan Has Enabled Key Advances In Scenario Development, Control Tools, and Building Scientific Foundations

Low torque ITER baseline

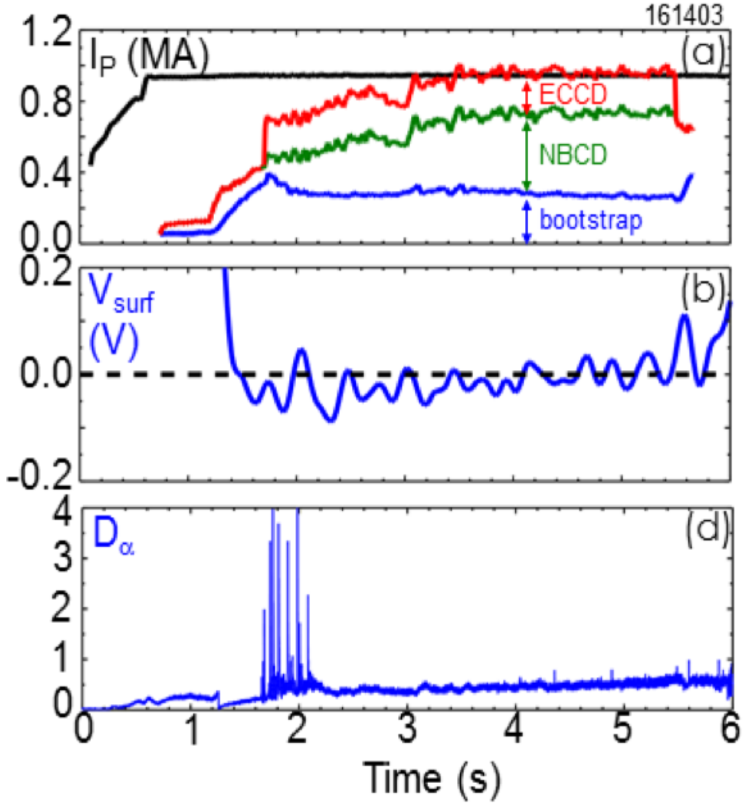


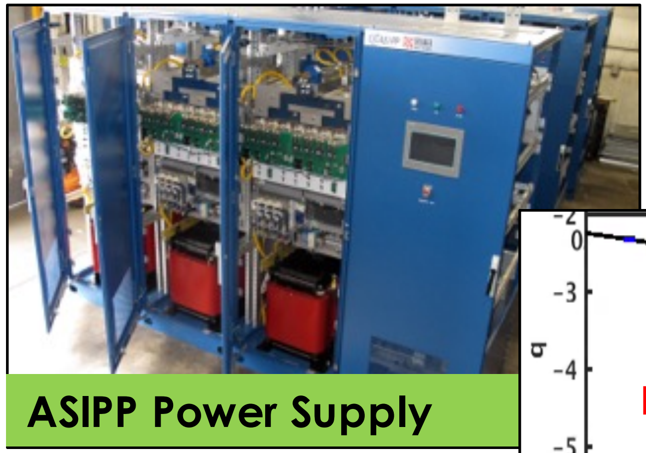
Detachment Physics, Divertor Closure, and High-Z materials studies



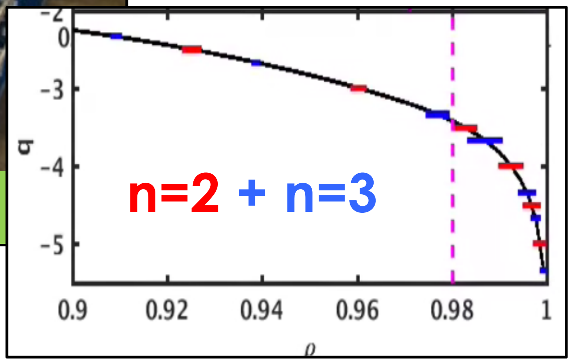


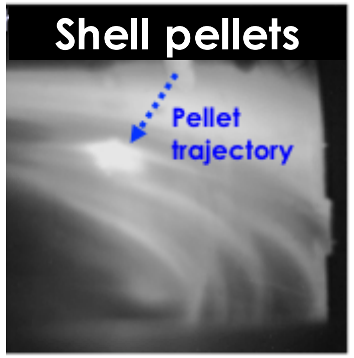
Fully non-inductive with RMP-ELM suppression

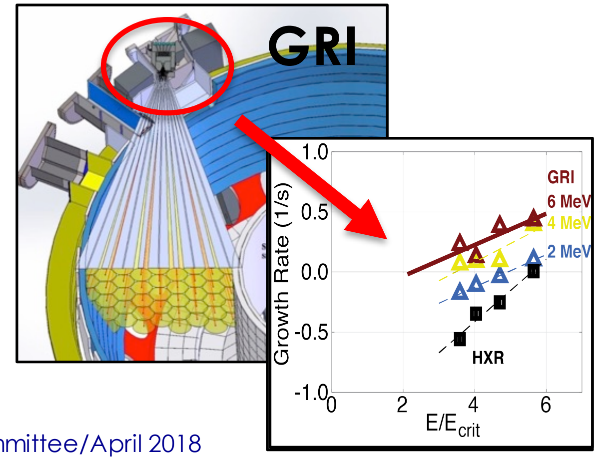




Reduced RMP threshold





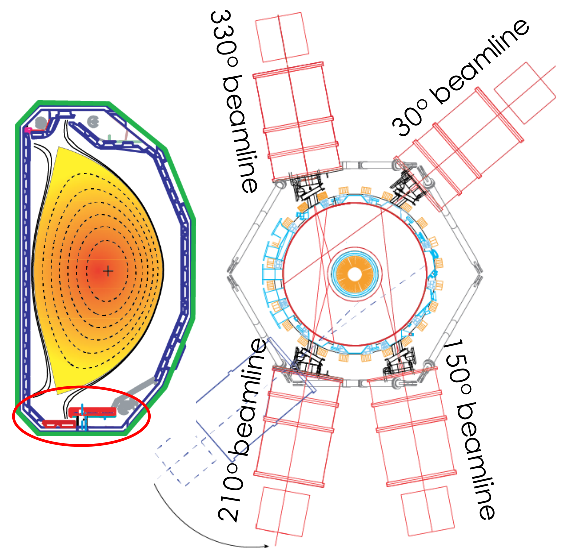


Disruption mitigation

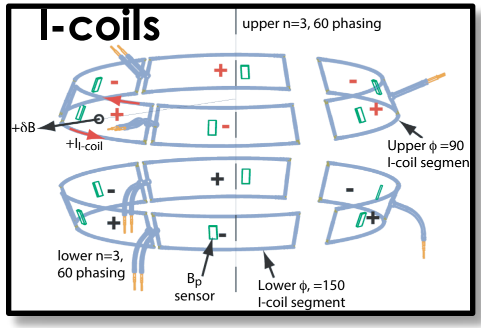
- RE diagnostics
- Shattered pellets
- Shell pellets

Next Five-Year Plan Builds Upon Previous Successful Upgrades to Provide A Highly Capable U.S. National Facility for the Future

LTO 1



LTO 2

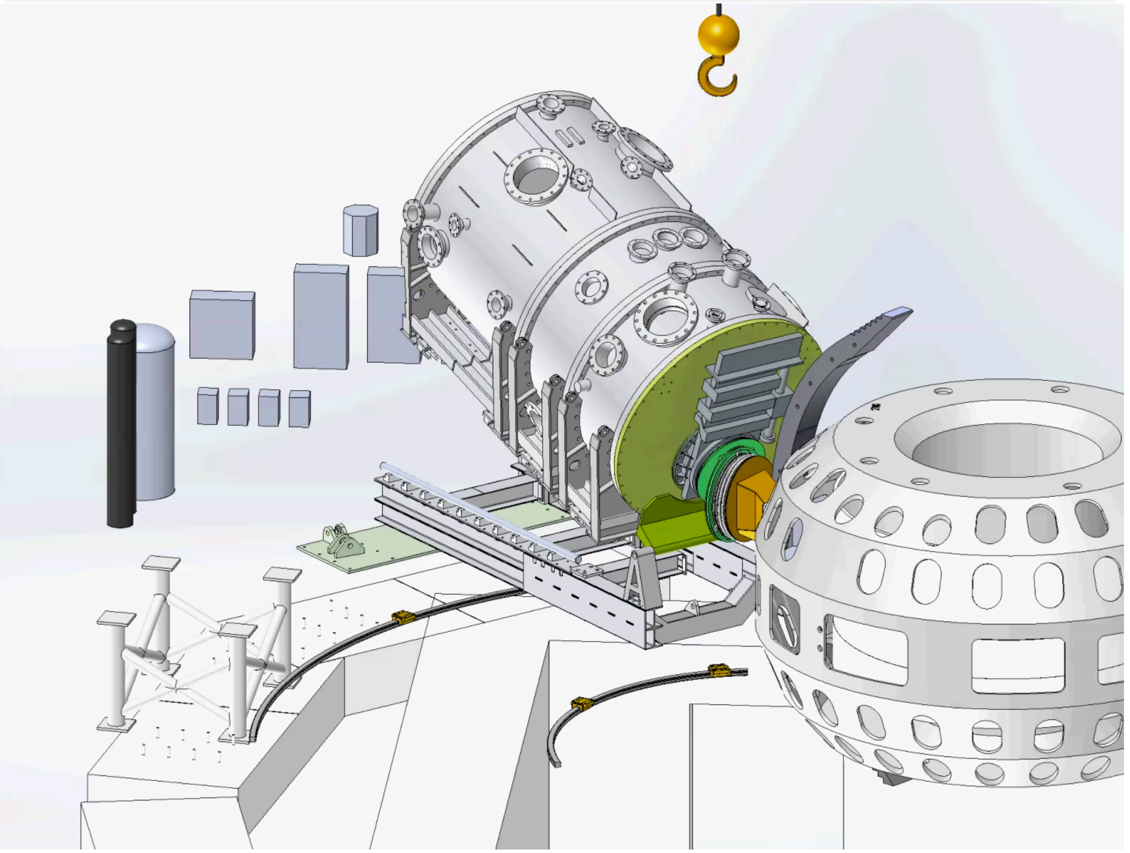


- **Long torus openings have been effective for making significant beam modifications while maintaining annual operating weeks**
  - LTO1: 210° counter-Ip beam, lower divertor extension (ASIPP)
  - LTO2: 150° Off-axis beam
  - LTO3: Co-Counter steerable off-axis beam (now!)
- **Regular upgrades and modifications**
  - Heating systems (e.g. ECH)
  - Coil systems (e.g. I-coils)
  - Divertor modifications (lower, SAS)
  - Power supplies (ASIPP "super supply")

Demonstrated capabilities to deliver proposed 5YP upgrades

LTO3 Provides Major Capability Improvements and Facility Refurbishments Under the Present Cooperative Agreement

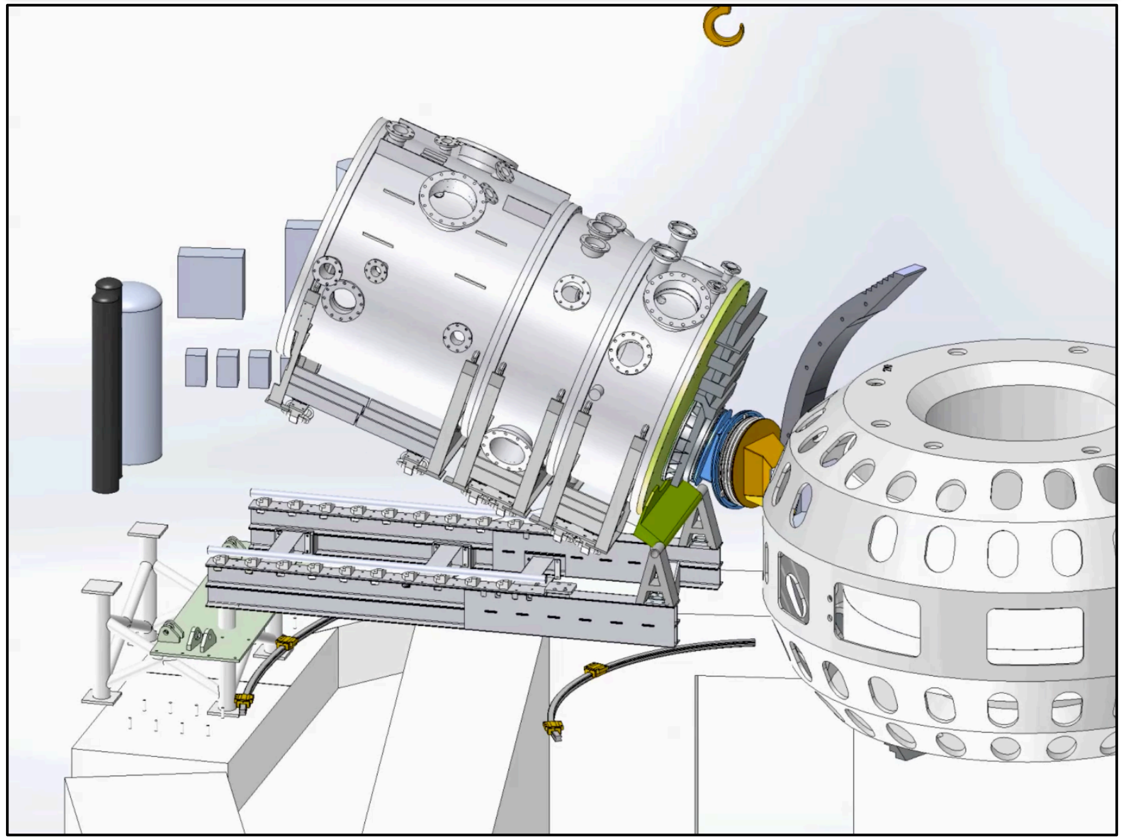
210 Co-counter OANB #2:



- **Install Toroidally Steerable Off-Axis Beam**
  ➡ ***World's First!***

LTO3 Provides Major Capability Improvements and Facility Refurbishments Under the Present Cooperative Agreement

210 Co-counter OANB #2:

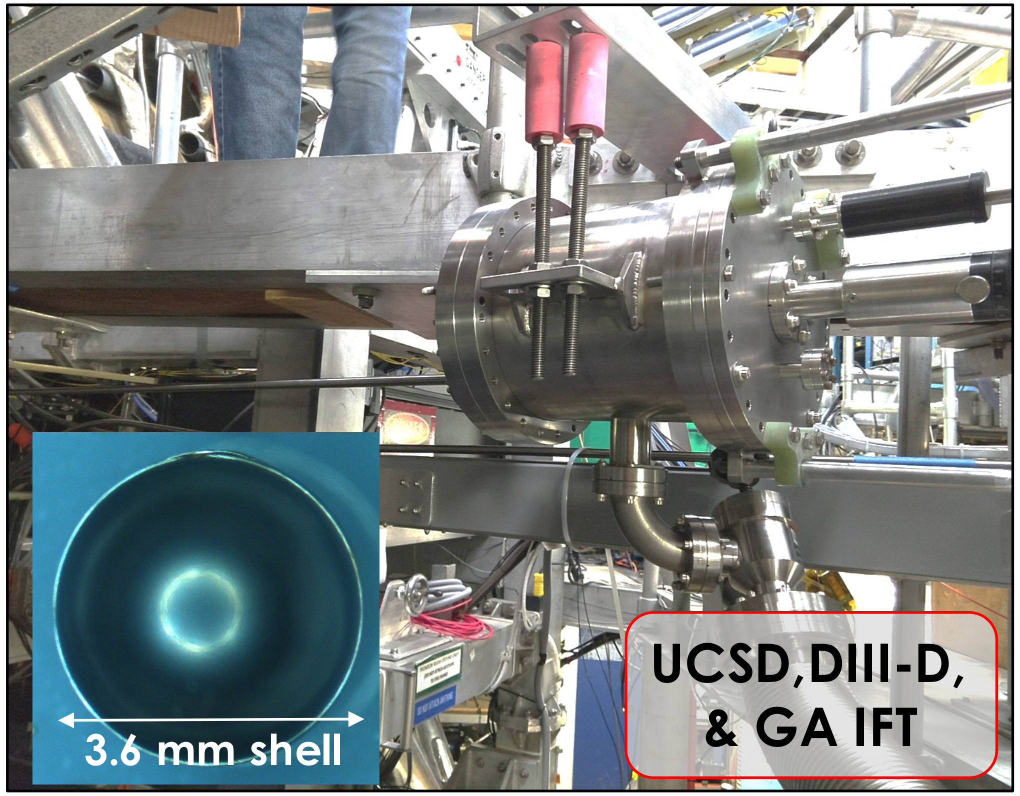


Ready to begin on May 7th

- **Install Toroidally Steerable Off-Axis Beam**
  ➡ ***World's First!***
- **Optimize alignment of upper SAS tiles with associated diagnostic upgrades**
- **Motor-Generator Refurbishments (cables and cooling water)**
- **Replacement of two more NB Local Control Stations (GA/PPPL)**
- **Replacement of 150 beamline high-heat load internal components and installation of new calorimeter (GA/PPPL)**
- **ECH: continued commissioning new 1.5W 117GHz, repairing two 1MW 110 GHz tubes**
- **Top-launch ECH**

Final Research Campaign in April To Test Shell Pellet Disruption Mitigation and Replica HFS-LHCD Launcher

Shell Pellet Injector Installed on DIII-D



- Si- and B-filled Si shells (from Inertial Fusion Technology under IR&D)
- Successfully injecting into DIII-D
- Up to three ½ day sessions scheduled

MIT Replica Launcher Is in Place

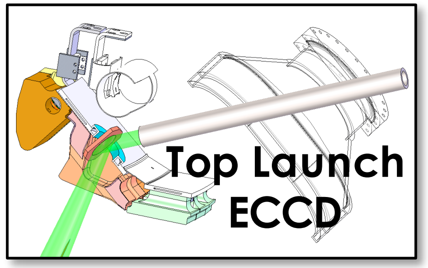
- 3D Moly printing for replica
- Installed
- In place for 2 operating weeks
- Wide range of operation, including disruption studies

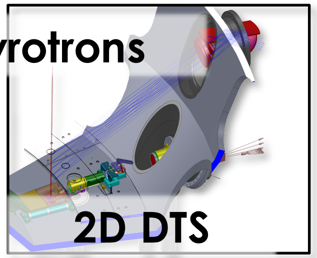
Unprecedented FY18 Mid-Year Funding Increase Enables Head Start on the Next DIII-D Five-Year Plan

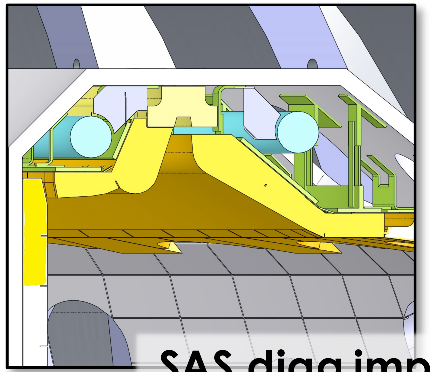
- **Essential refurbishments maintain safe and reliable operations with high availability**

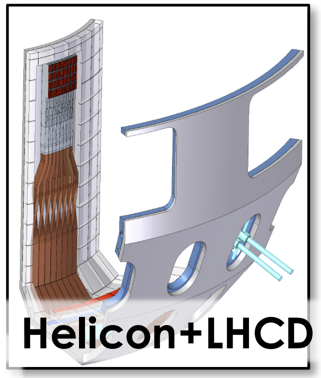
- **Major upgrades provide compelling scientific opportunities for the US scientific community as we prepare for ITER**

- **Significant boundary diagnostic enhancements to develop the boundary solution for fusion energy**









First time that DOE funding guidance matches the Five-Year Plan Funding

GA Renewal Proposal For FY19 – 24 DIII-D Cooperative Agreement Submitted on January 26th

• Existing Cooperative Agreement ends	June 30, 2019
• Proposal Submitted to DOE	January 26, 2018
• DOE Review Panel	May 22-26, 2018
• DOE review complete	~ July 2018
• DOE Internal processing (formal cost review)	~Jan 1 – June 30, 2019
• Cooperative Agreement funded	July 1, 2019

Broad and Highly Collaborative Participation In Developing the DIII-D Five-Year Program Proposal for FY19 – 24

- 2016 Strategic planning workshop (Dec. 1-2, 2016)
  - initial brainstorming open to all program participants at all levels
- DIII-D Executive Committee Meetings (2016 – 2018)
- 2017 Program Advisory Committee (you)
- Co-authored by topical experts from many institutions (key contributors listed in each section)
- Informed by FESAC panel reports and 2017 Community workshops
- "Red Team" consisting of GA and outside experts reading the draft program plan (November 2017)
- Final edits completed early January, 2018

DIII-D 5 Year Program Planning for 2019-24

1-2 December 2016
America/Los_Angeles timezone

- Overview
- Document sharing
- Workshop Agenda
- Upload presentation
- List of ideas
- Idea Submission

Workshop Agenda

Thursday, December 1

Time	Title	Presenter	Duration (min)
08:45	Introduction	Hill	15
09:00	#145: DIII-D To Meet Critical Research Needs in the Path to Fusion Energy	Buttery	
09:10 - 10:55	STEADY-STATE		
09:10	#160: Conceptual overview of steady-state research plan in the next five year phase	Ferron	10
09:20	#159: Tearing mode stable access to betaN required for fully noninductive operation through improved ideal-wall stability margin	Ferron	5
09:25	#149: Maintain and improve basics diagnostics for high-power and high-current scenarios	Turco	10
09:35	#151: Add a diagnostic beam to DIII-D	Turco	5
09:40	#167: Integration of Steady-State Core with High-Density Edge	Petty	10
09:50	#214: Steady-State Hybrids	Petty	5
09:55	#150: Super H-mode development path for steady state research on DIII-D	Nazikian	10
10:05	#163: High betaP Advance Tokamak	Staebler	10
10:15	#195: Decouple high performance and steady-state program goals	Hanson	10
10:25	Discussion	Holcomb	30
10:55 - 11:15	BREAK		
11:15 - 12:15	DIVERTOR (I)		
11:15	#187: A Flexible Divertor Testbed for Shaping/Closure	Covele	10
11:25	#190: PF Coil Upgrade for Super X-Divertors with No Internal Coils	Covele	5
11:30	#216: Diagnostics in small places	McLean	10
11:40	#219: EUV spectroscopy for high triangularity	McLean	5
11:45	#200: Discussion on the Role of DIII-D in Solving the Heat Flux Challenge	Jarvinen	10
11:55	#203: Discussion of a strategy toward validation of scrape-off layer physics models	Groth	10
12:05	Discussion	All	10
12:15 - 01:15	LUNCH		
01:15 - 02:20	DIVERTOR (II)		

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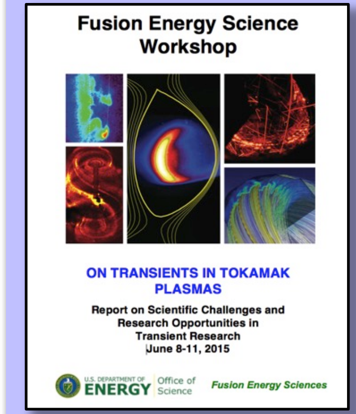
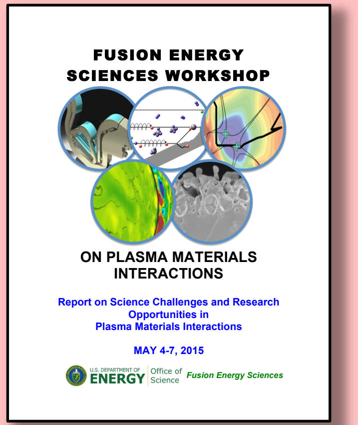
The DIII-D Research Program Emphasizes Key Issues for ITER and Future Fusion Facilities Highlighted in Recent FESAC Workshop Reports

Research Program Elements → **Predictive Understanding**

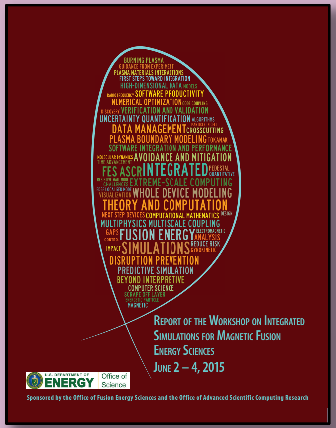


- **Scientific Basis for Burning Plasma Core**
  - Transient Control
  - Enabling ITER Q=10
  - Path to Long Pulse



- **Scientific Basis for Boundary Solutions**
  - Detachment control
  - Divertor optimization
  - Test new wall materials

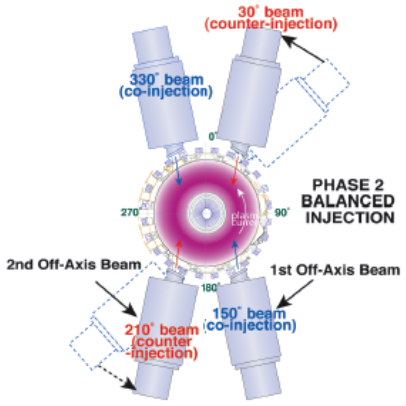
Core-Pedestal-Boundary Integration



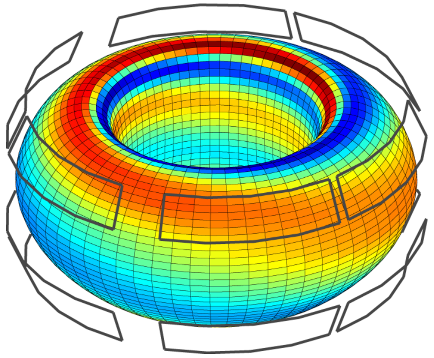
- **Integrated Approach to Physics Interpretation**
  - Innovative diagnostics
  - High-performance computing
  - Experiments targeting model validation

DIII-D Research Will Provide a Scientific Foundation for Mitigating the Risk of Uncontrolled Transients

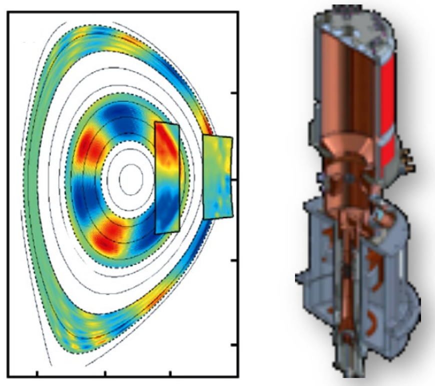
- **Unique capabilities support science of disruption avoidance and mitigation**



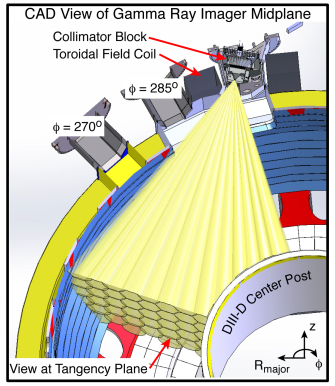
Rotation Control



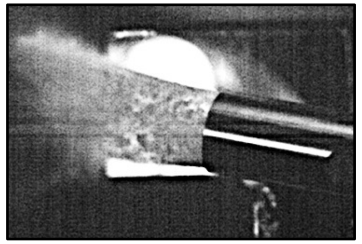
MHD simulation



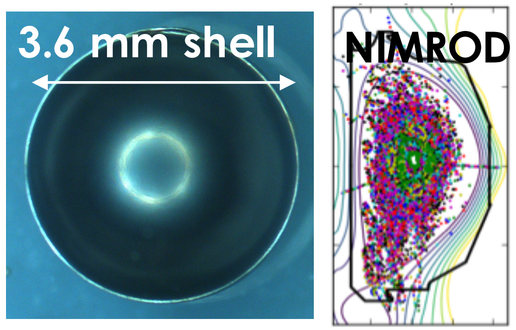
NTM control



Diagnostics

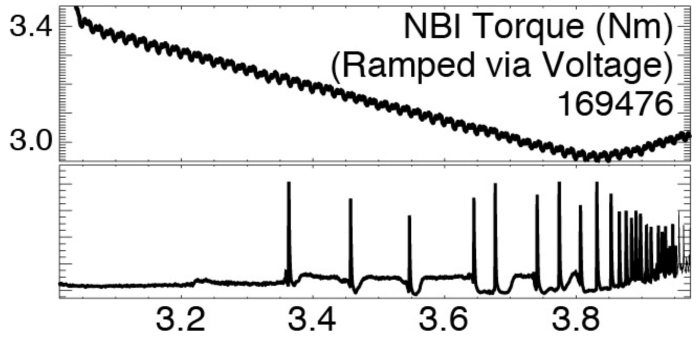


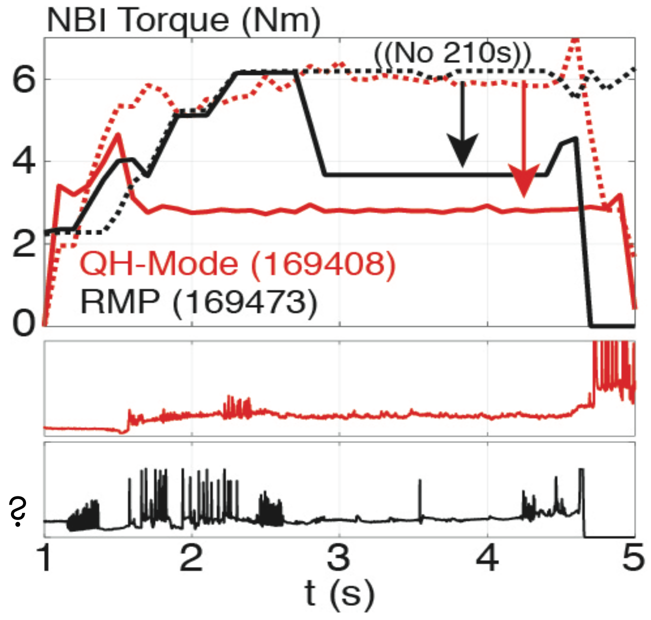
Mitigation: Shattered Pellets



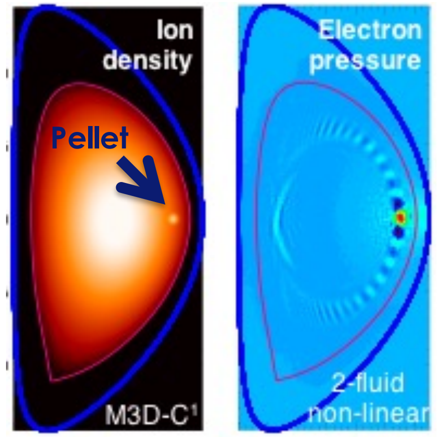
Mitigation: Shell Pellets

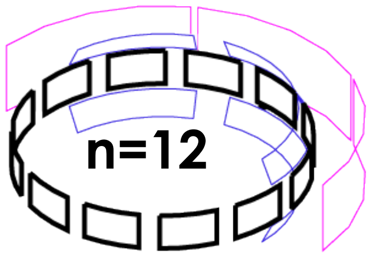
- **Explore and optimize ELM control solutions for ITER and steady state tokamaks**





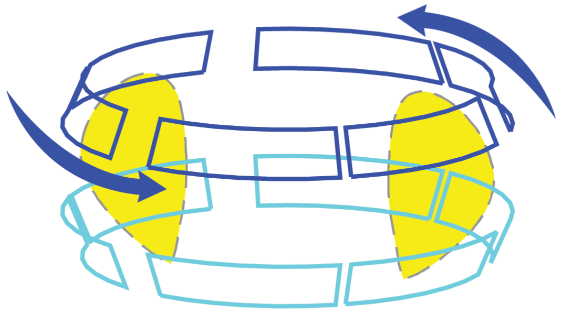
Non-linear M3D-C[1] sim. of D_2 pellet, S. Diem

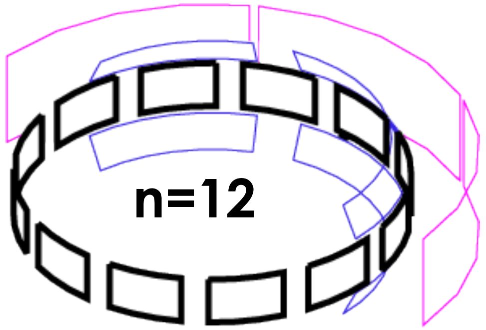




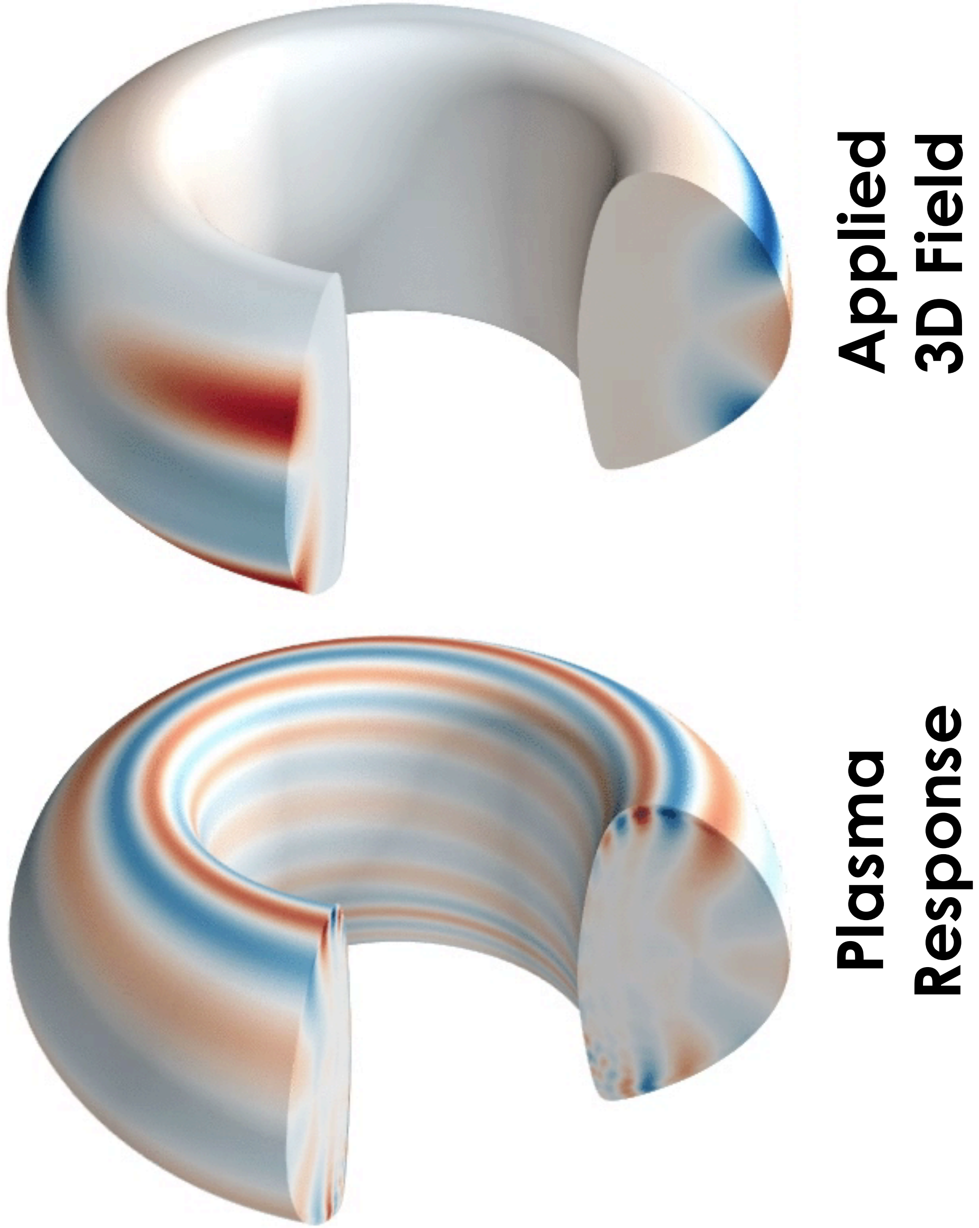
ELM Suppression Studies Show Significant Benefit Expected From New n=12 Midplane Coils and Additional 3D Power Supply

- Rotating perturbations elucidate plasma response, point to reduced 3D perturbations with higher order perturbations





✓2nd Supply Available in FY20



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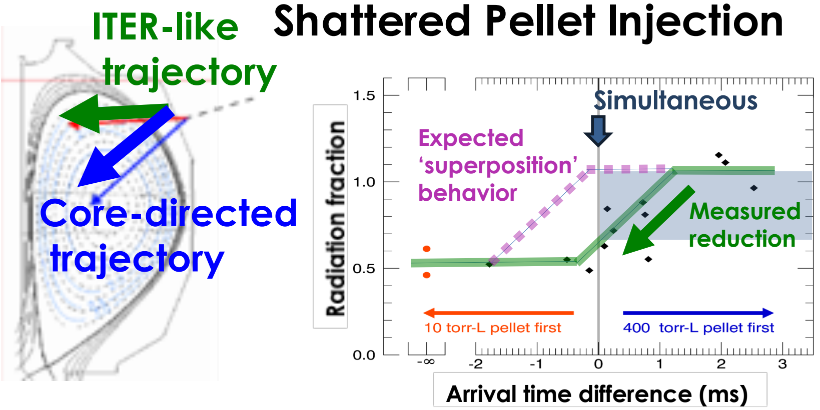
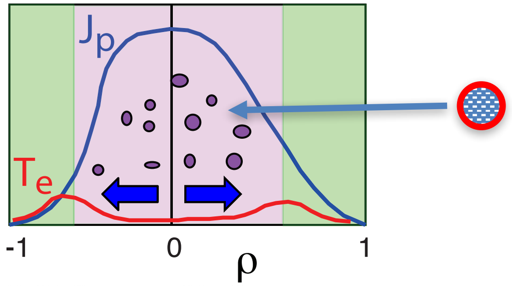
ITER's Success Continues to be DIII-D's Highest Priority

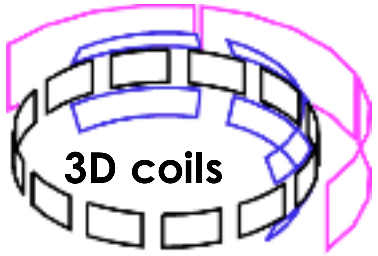
- **Transient control is a major emphasis**
  - Disruption prediction and avoidance
  - Unique tests of disruption mitigation techniques
  - DIII-D can access all of ITER's candidate ELM control techniques
    - RMP, QH-mode, Pellets, I-mode
- **ITER's design is mostly complete, but DIII-D can react quickly when issues are identified**
  - Error field control, He operation,…
- **Emphasis is transitioning to research exploitation**
  - Operating scenarios
  - Plasma control
  - Energetic particle behavior
  - Testing ITER prototype diagnostics

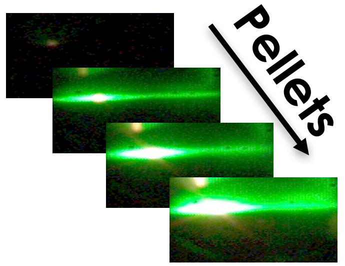
Shattered Pellet Injection

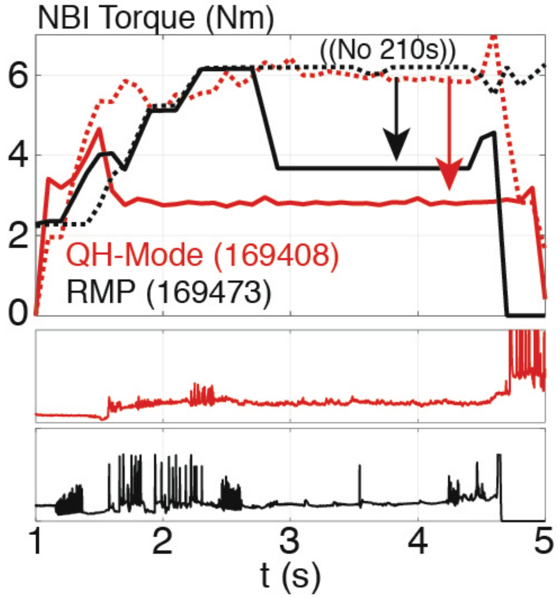


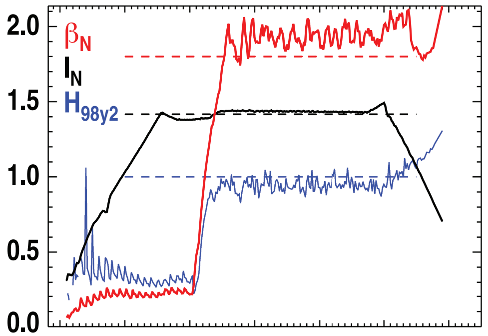
Shell Pellet Injection











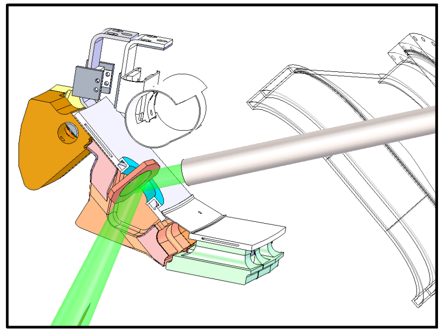
ITER baseline

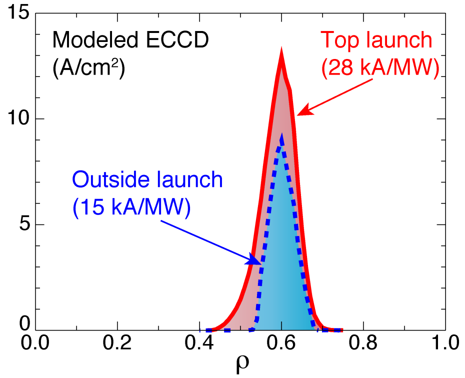
Balanced NBI+ECH allows high power zero-torque operation

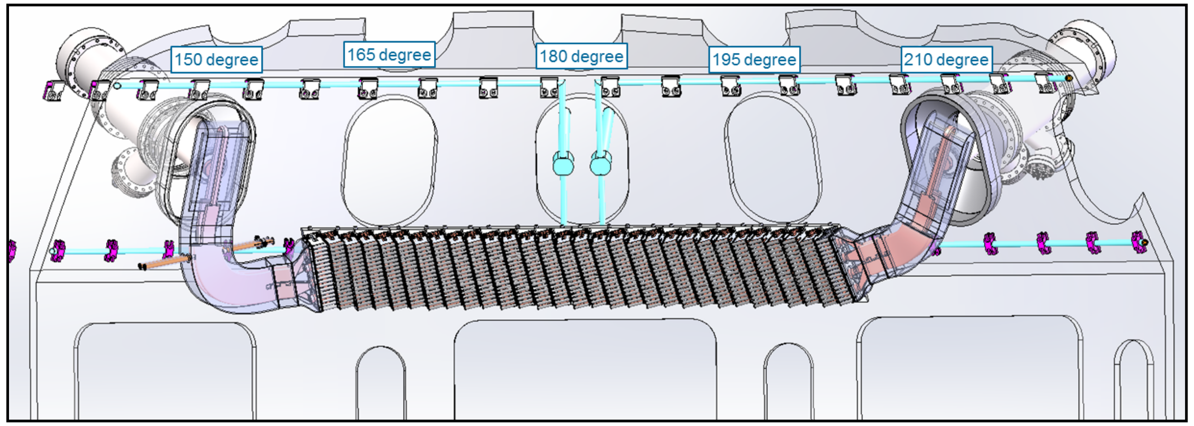
Improved pace of ITER construction inspires us to resolve outstanding issues to enable successful burning plasma experiments

DIII-D Will Test Three Current Drive Technologies Offering High Efficiency and Improved Access for Higher-Density Scenarios

- **Top launch ECCD doubles efficiency**
  - PAC rated priority #1,
  - Designed with GA corporate funding

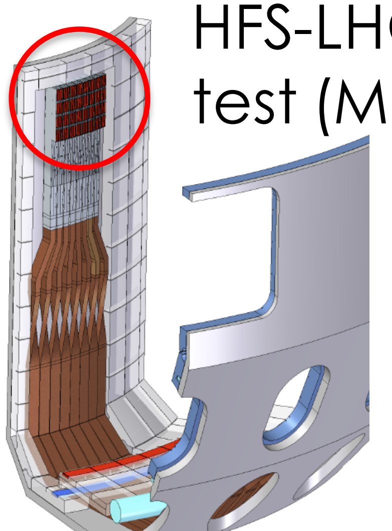




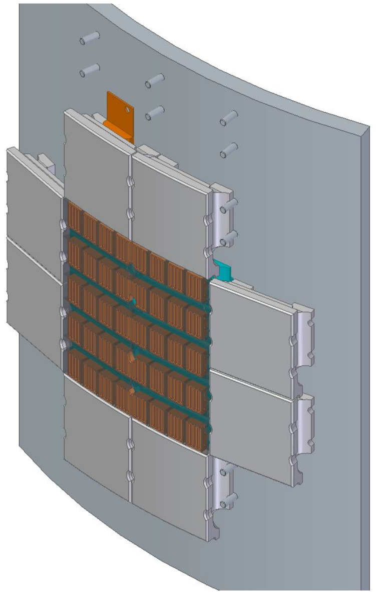


- **Helicon ready to test physics of coupling at high power**
  - Install 1MW launcher in during LT03 (with ASIPP)
  - Klystron from SLAC (with NFRI/KSTAR)

- **HFS LHCD in development**
  - AT plasmas found compatible with low inner gaps →
  - HFS test tile in FY18, completion after LTO3



HFS-LHCD test (MIT)



Replica Launcher test April 2018

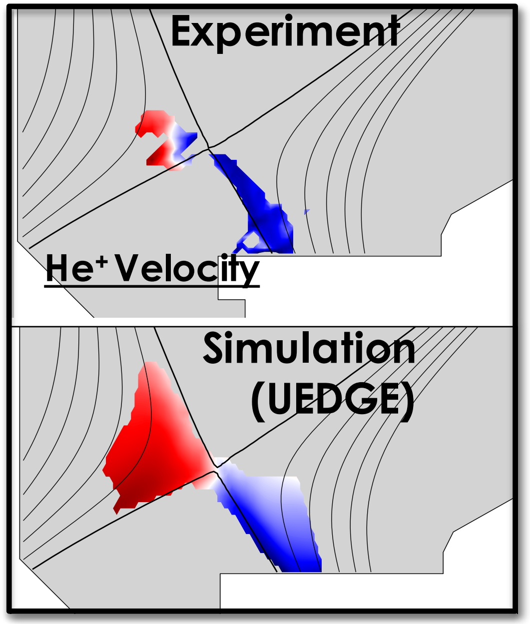
19-20 investments

DIII-D Is Developing a Scientific Basis for Boundary Solutions Needed for Future High-Power Steady-State Reactors

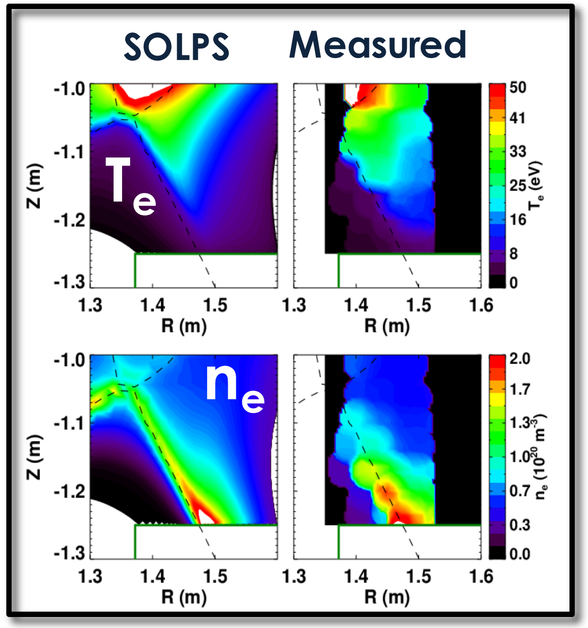
- **Reliable power and particle control compatible with high-performance core plasmas is required**

- **DIII-D will advance scientific understanding and predictive capability through *key measurements* and *systematic model validation***

2D Flow Imaging



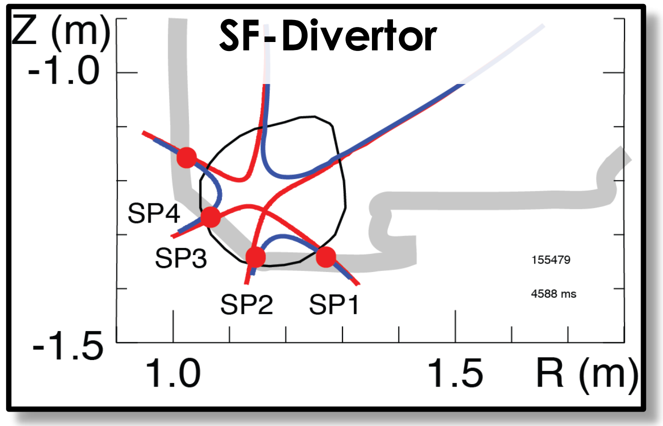
2D Edge Modeling

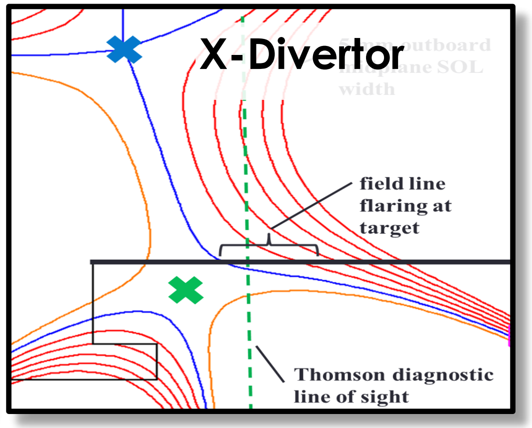


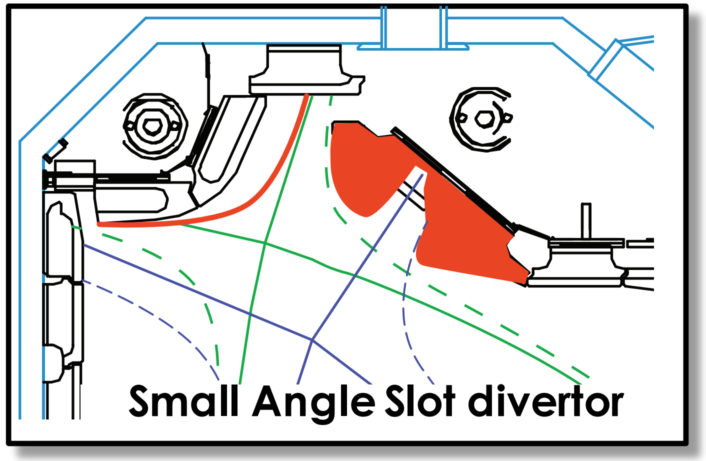
Active collaboration with 2D simulation efforts is key for data analysis, interpretation, design, and prediction

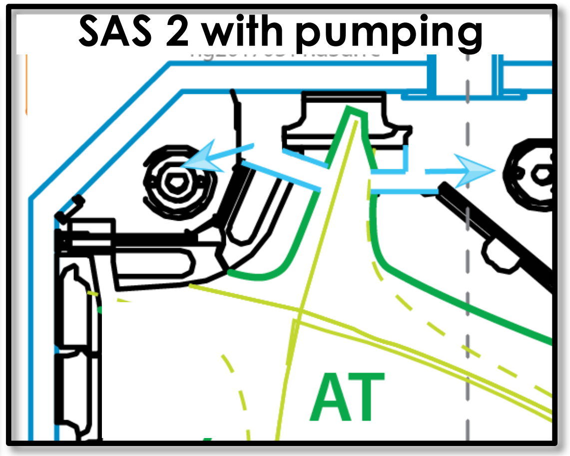
DIII-D Is Developing a Scientific Basis for Boundary Solutions Needed for Future High-Power Steady-State Reactors

- **Evaluate alternate divertor concepts compatible with high performance**
  - Increase divertor density and impurity concentration with minimal impact on core performance
  - Expand radiating volume and reduce surface heat flux
- **Staged divertor concept tests using sufficient diagnostics to compare with simulation**



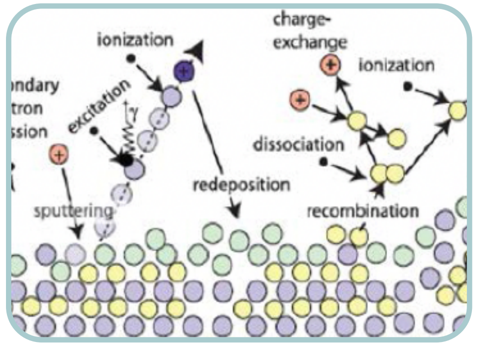


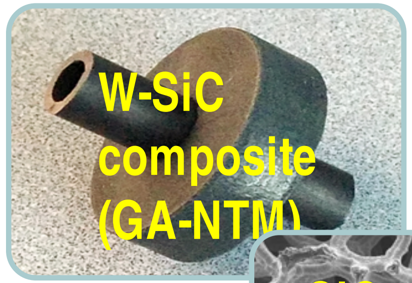


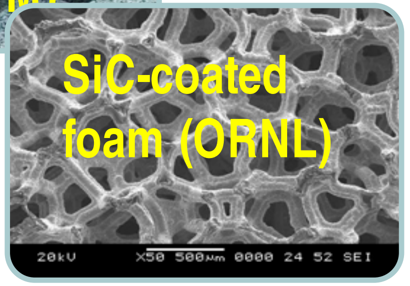


<u>Advanced Divertors</u> maximize volume for fusion energy production and minimize volume and complexity required to provide reliable power and particle exhaust

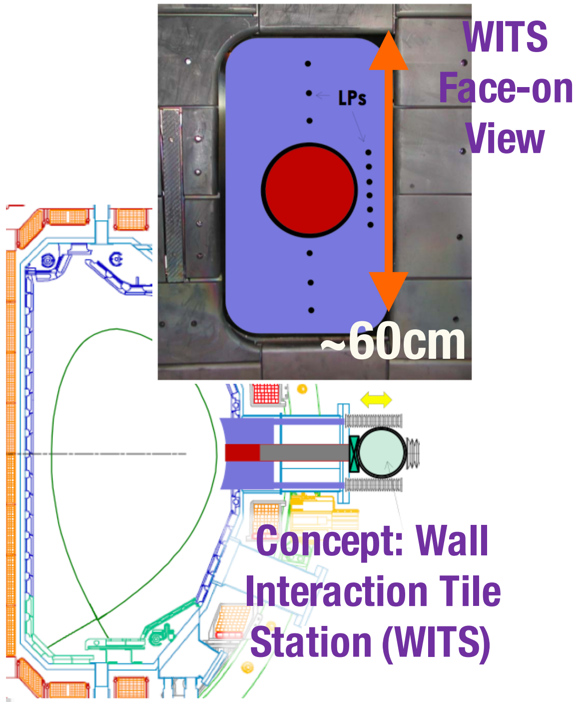
DIII-D Boundary Center Is Systematically Evaluating Fusion-relevant Candidate Materials

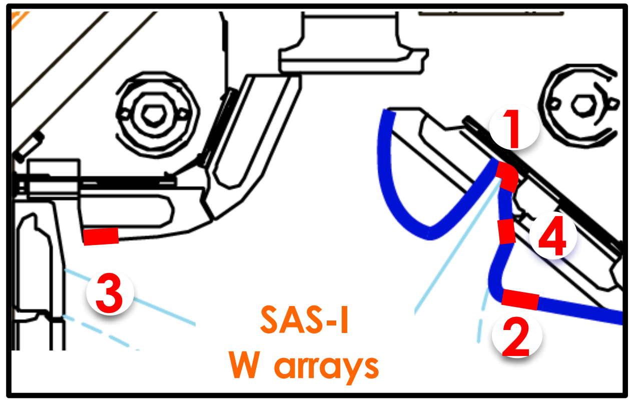






- **Understand surface evolution with plasma interactions**
  - Erosion/redeposition and surface evolution (DIMES, MIMES) + WiTS
  - Hydrogenic retention & permeation
- **Understand material migration/mitigation in high performance plasmas**
  - Interaction with large-scale PFCs
  - Impact on core
- **Evaluate reactor-relevant plasma-facing materials (Linear facilities, DIMES, MIMES)**
  - Novel materials for divertor targets
  - Engineered main chamber components





DIII-D NATIONAL FUSION FACILITY SAN DIEGO

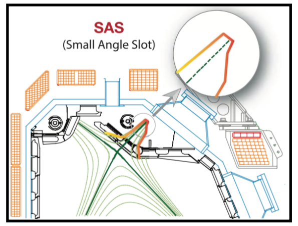
DIII-D Will Explore the Physics Basis For Integrating Improved Core-Pedestal-Edge Solutions

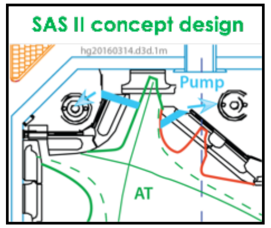
Core
Pressure determines fusion power

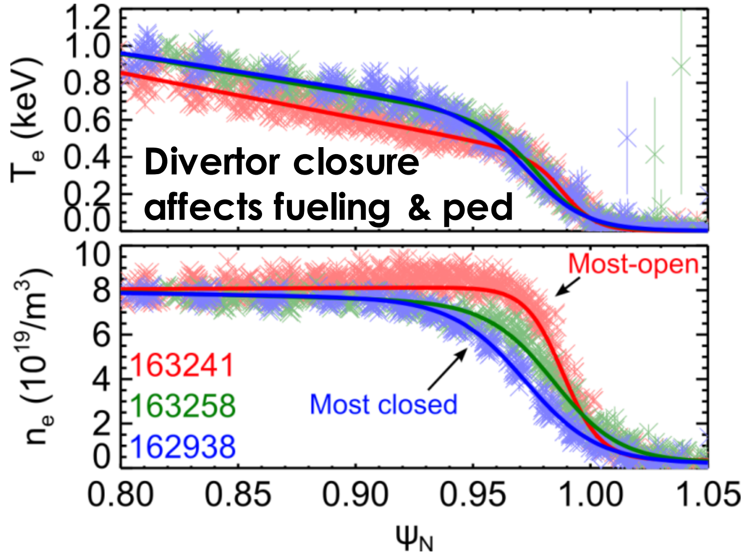
Pedestal
Processes set core boundary condition

Boundary
Reliable heat and particle removal

- **Pedestal mediates the interaction between core and the boundary plasmas**
- **Research focused on quantifying pedestal processes that determine pedestal structure**
  – Ionization sources (fuel, impurity)
  – Turbulent transport, rotation, impurities
  – MHD stability (profiles: current, n_e, T_e, Z)
- **Develop the scientific basis for optimizing scenarios**
  – Pedestal manipulation to raise performance
  – Reactor relevant materials and geometries







Planned Facility Enhancements Will Strengthen Steady State AT and Boundary/PMI Research

	Facility Upgrades	Research Goals
Steady State AT	Co-Counter NB	Increased co- power for high β scenarios, Low rotation high β SS scenarios
	Helicon/ HFS Lower Hybrid Top Launch EC, CCOANBI	High efficiency off-axis current drive at higher density
	Expanded EC	Increase Te/Ti; Zero-torque H&CD; Off-axis j(r); NTM stabilization; Perturbative transport
	NB Pulse/Power Extension	$T \longrightarrow 2\ \tau_R$; Higher β scenarios
Boundary/PMI	New 2D/3D Power Supplies, New 3D coils	Improved divertor shaping RMP and 3D physics
	Divertor Geometry Modification	Heat flux and density control; detachment physics
	Divertor diagnostics, LBO, pedestal Lyα arrays	Dissipative physics, SOL flows and momentum, turbulence and transport, fueling, impurity xport
	W inserts & PFCs tests	Understand sources and develop mitigation techniques

DIII-D Research Program is Well Aligned With DOE-FES Strategic Plan

U.S. DEPARTMENT OF ENERGY

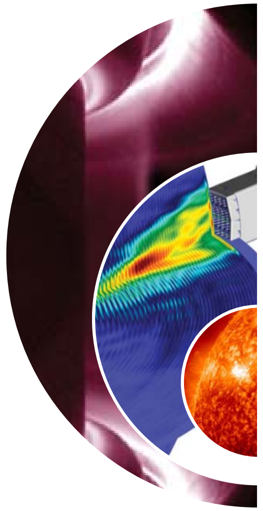
The Office of Science's Fusion Energy Sciences Program: A Ten-Year Perspective

Report to Congress
December 2015

United States Department of Energ
Washington, DC 2058

U.S. DEPARTMENT OF ENERGY
Office of Science

U.S. Fusion Energy Sciences program is organized along scientific topical lines



Burning Plasma Science

Foundations Focusing on domestic capabilities; major and university facilities in partnership, targeting key scientific issues. Theory and computation focus on questions central to understanding the burning plasma state ✓

Challenge: Understand the fundamentals of transport, macro-stability, wave-particle physics, plasma-wall interactions

Long Pulse Building on domestic capabilities and furthered by international partnership ✓

Challenge: Establish the basis for indefinitely maintaining the burning plasma state including: maintaining magnetic field structure to enable burning plasma confinement and developing the materials to endure and function in this environment

High Power ITER is the keystone as it strives to integrate foundational burning plasma science with the science and technology girding long pulse, sustained operations. ✓

Challenge: Establishing the scientific basis for att
self-heated, burning plasma state

Discovery Plasma Science

Plasma Science Frontiers & Measurement

General plasma science, exploratory magnetized

3

U.S. DEPARTMENT OF ENERGY
Office of Science

Burning Plasma Science

Foundations

Advanced Tokamak (DIII-D and Smaller Scale) ✓ & Spherical Tokamak (NSTX-U and Smaller Scale)

- *Highly collaborative; strong university partnerships*
- *High scientific complementarity between these facilities*
- *High potential for growing student engagement on our nation's major fusion science experimental facilities*

Theory and Simulation ✓

- *US strength in engaging with experiment to develop predictive understanding*
- *Essential if high-risk gaps in fusion are to be closed*
- *Leverages DOE investments in leadership-class computing resources*

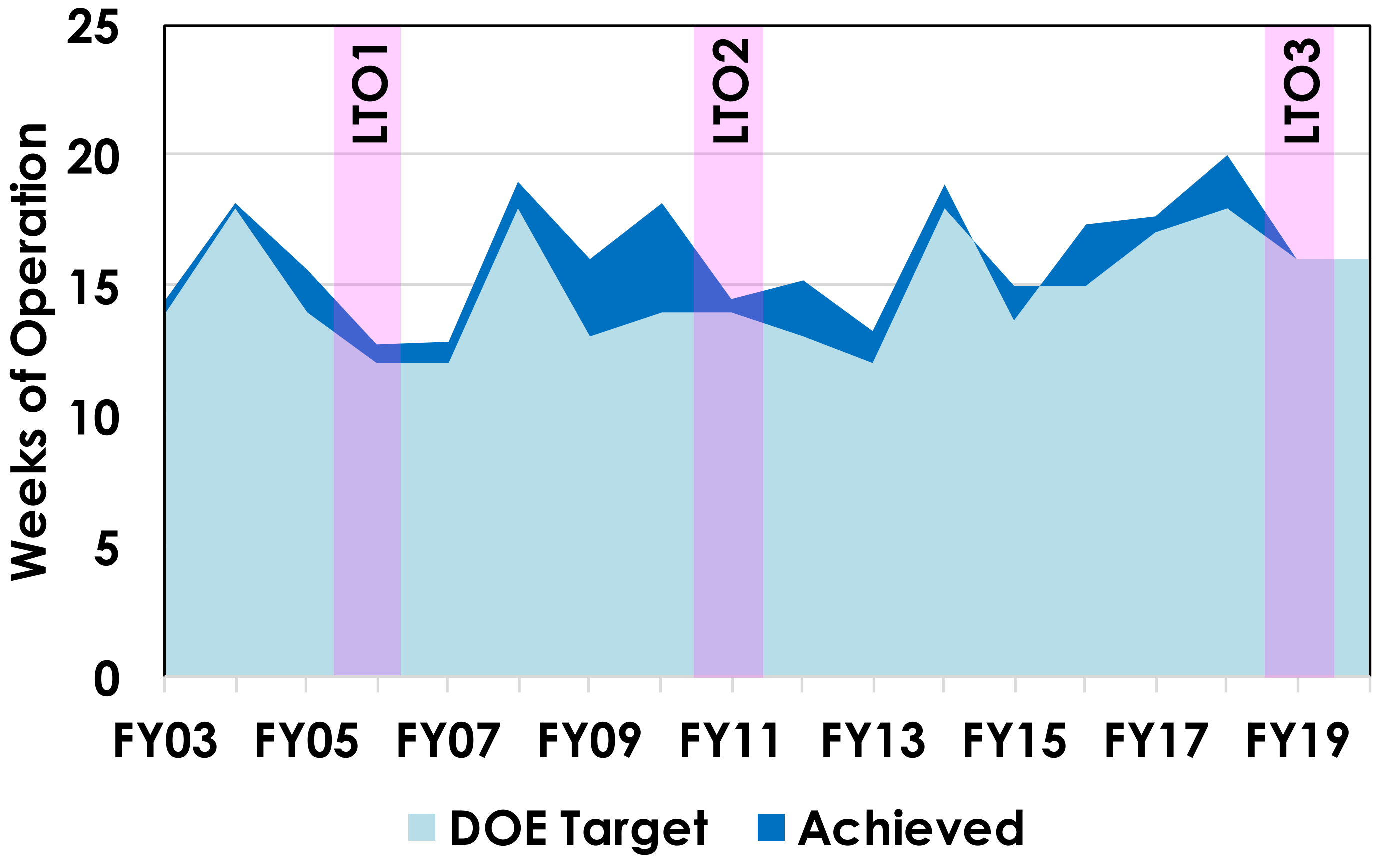
DIII-D Program Has an Excellent Track Record Meeting Research Milestones Proposed And Approved by DOE

#	Topic	Date	Leader(s)
185	Quantify plasma response to externally imposed 3D fields (supports JRT)	September 2014 ✓	E. Strait, N. Ferraro
186	Explore heat flux reduction and plasma detachment through variation in divertor conditions and geometry	September 2014 ✓	A. Leonard, T. Petrie, S. Allen
187	Investigate nonlinear Interaction of Energetic Particles with Internal MHD Modes and Applied Fields	September 2014 ✓	D. Pace, G. Kramer, M. Van Zeeland
188	Establish requirements for control of TBM-induced effects for ITER	September 2014 ✓	M. Lanctot, R. LaHaye, W. Heidbrink
189	Assess the physics of the localized bulk ion edge flow velocity as a source of non-beam driven rotation for ITER	September 2014 ✓	J. deGrassie, J. Boedo, B. Grierson
190	Establish the physics basis for proposed ITER Disruption Mitigation Systems	September 2015 ✓	E. Hollmann, N. Commaux, N. Eidietis
191	Test transport models and evaluate potential for improved performance in ITER-like conditions	September 2015 ✓	B. Grierson, W. Solomon, G. Staebler
192	Assess trade-offs of peaked vs. broad current and pressure profiles in possible steady-state scenarios	September 2015 ✓	C. Holcomb, F. Turco, J. Ferron
193	Effect of Divertor Closure on Heat Flux Reduction and Detachment	September 2016 ✓	A. Moser, S. Allen, T. Petrie
194	Develop integrated stability control strategies for robust high performance operation	September 2016 ✓	E. Strait, R. La Haye, D. Humphreys
195	Size scaling of momentum transport and toroidal rotation	September 2016 ✓	J. deGrassie, B. Grierson, G. Staebler
196	Evaluate high-Z divertor material erosion, surface migration, and impact on high performance plasma operation	September 2016 ✓	E. Unterberg, P. Stangeby, D. Thomas
197	Test predictive models of fast ion transport by multiple Alfven Eigenmodes	January 2017 ✓	Heidbrink, Gorelenkov, Pace, Waltz
198	Exploit New Power Supplies for Enhanced 3D Spectral Control, Plasma Response, and Operational Space	September 2017 ✓	Paz-Soldan, Nazikian, Youwen Sun
199	Quantify the roles of parallel and perpendicular transport, radiative and atomic physics in divertor detachment	September 2017 ✓	Covele, McLean, Wang

- **15/15 programmatic milestones completed on time (2014-2017)**
- **Strong contributor to 10 FES Joint Research Targets (2008-2017)**
  – DIII-D was lead facility for 4 of these and will lead the 2019 JRT

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

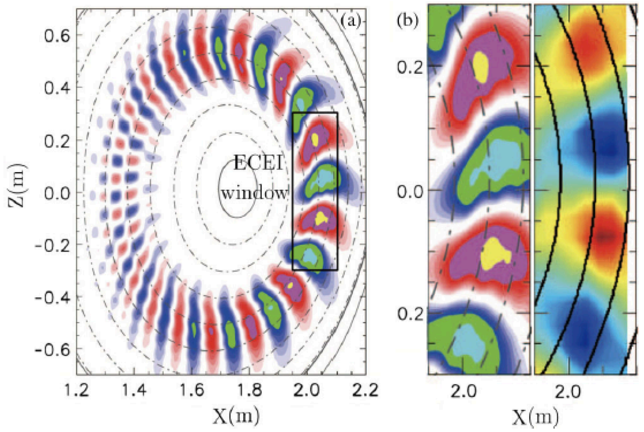
DIII-D National Fusion Facility Maintains An Excellent Record Consistently Delivering Research Operation for DOE



- From FY03-FY18, DIII-D ran for 257.4 weeks, 8.6% above DOE target
- Total Proposed for last 5 years: 70 wks; Total Achieved: 76.3 wks
- Average availability 77%
- OSHA-recordable incidents flat since 2014 and remain 2x lower than industry standard.

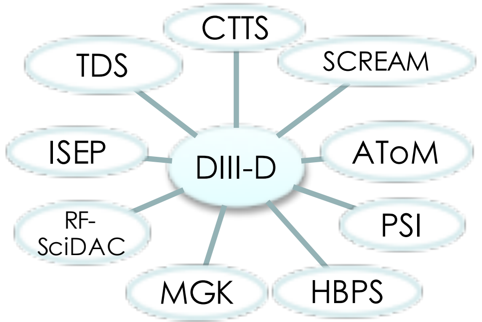
Close Coupling Between Theory and Experiments Enables Rapid Progress in Understanding

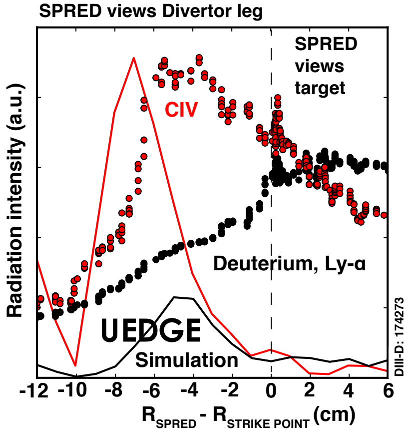
- **Connect advances in plasma theory and experiments through innovative high performance computer codes and diagnostics and novel framework**
- **Energetic-particle physics**
  - **Verified and validated EP instabilities**
- **Performance prediction**
  - **Extensively tested pedestal predictive capability and predicted high-performance regimes**
- **Prediction and control of transient events**
- **Testing models for radiative dissipation, divertor detachment and impurity migration**

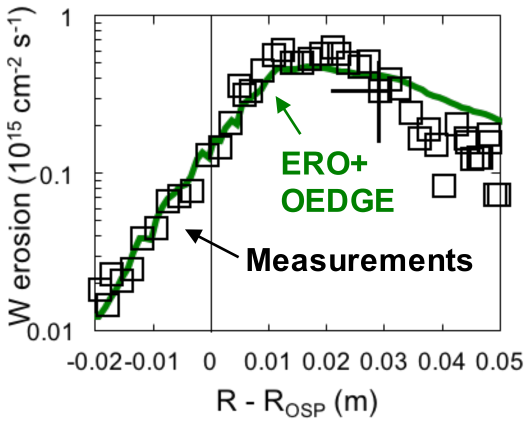


GTC Validation of TAE Localization with DIII-D ECE Measurement

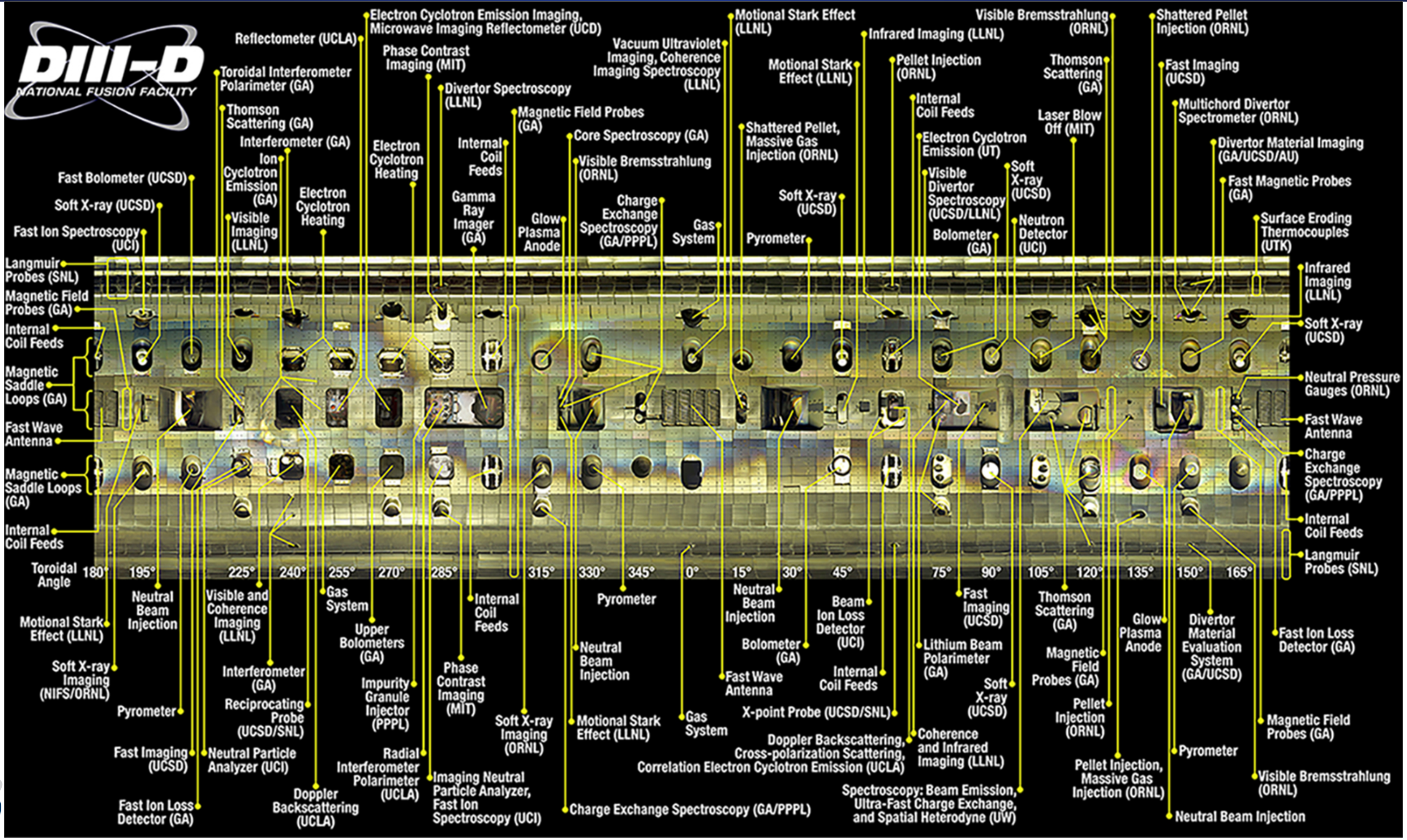
SciDAC Centers







Key Strength of the DIII-D Program: 82 Diagnostic Systems Managed by Universities, National Labs, and Industry



DIII-D Is a Key Facility for U.S. Scientific Leadership in Fusion Research

Chris Holcomb
LLNL

Recognition for DIII-D Scientists in 2017

Chris Holcomb (LLNL): FPA Excellence in Fusion Engineering
Brian Grierson (PPPL): Princeton University Kaul Award
David Humphreys (GA): IEEE Fusion Technology Award
Rick Moyer (UCSD): Fellow of the American Physical Society

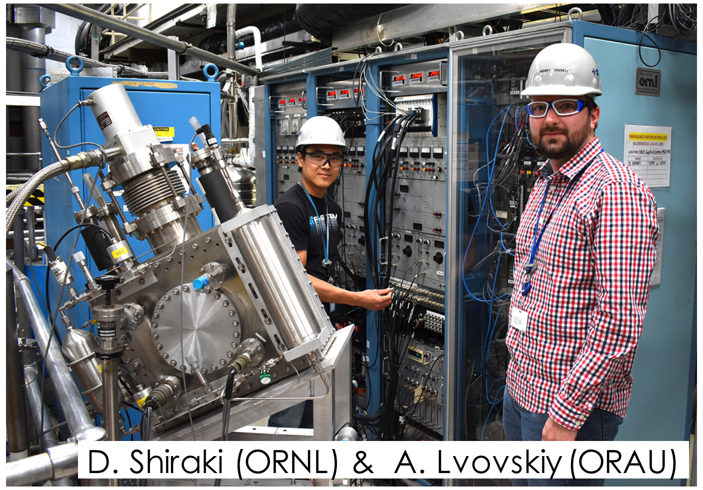
Brian Grierson
PPPL

Many Prizes and Awards in the past five years

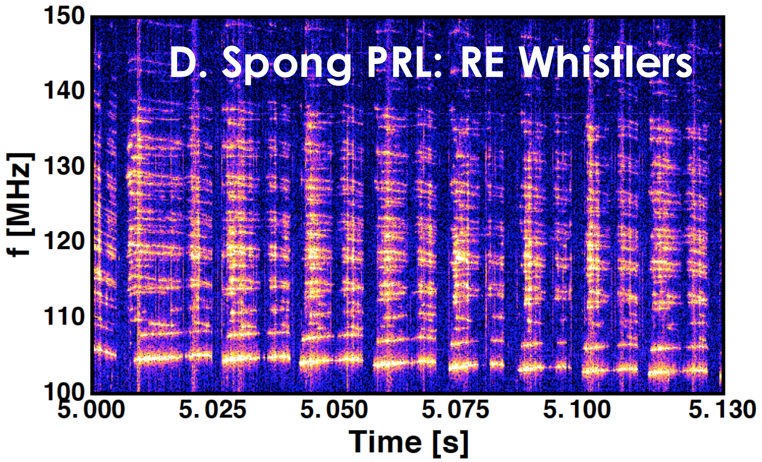
- John Dawson Award for Excellence in Plasma Physics Research (2)
- EPS Landau Spitzer Award for Outstanding Contributions in Plasma Physics (2)
- Fellows of the American Physical Society (6)
- Katherine Weimer Award for Women in Plasma Science (1)
- IEEE Fusion Technology Award (1)
- Fusion Power Associates Excellence in Fusion Engineering (4)
- DOE Early Career Awards (2)

Broad Participation in DIII-D Research Reflects Growing Enthusiasm From the Domestic and International Communities

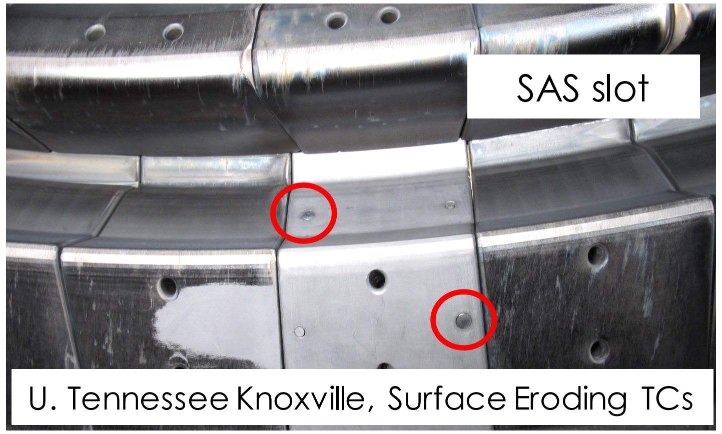
EAST/DIII-D Joint Experiments



95 grad students 68 post-docs

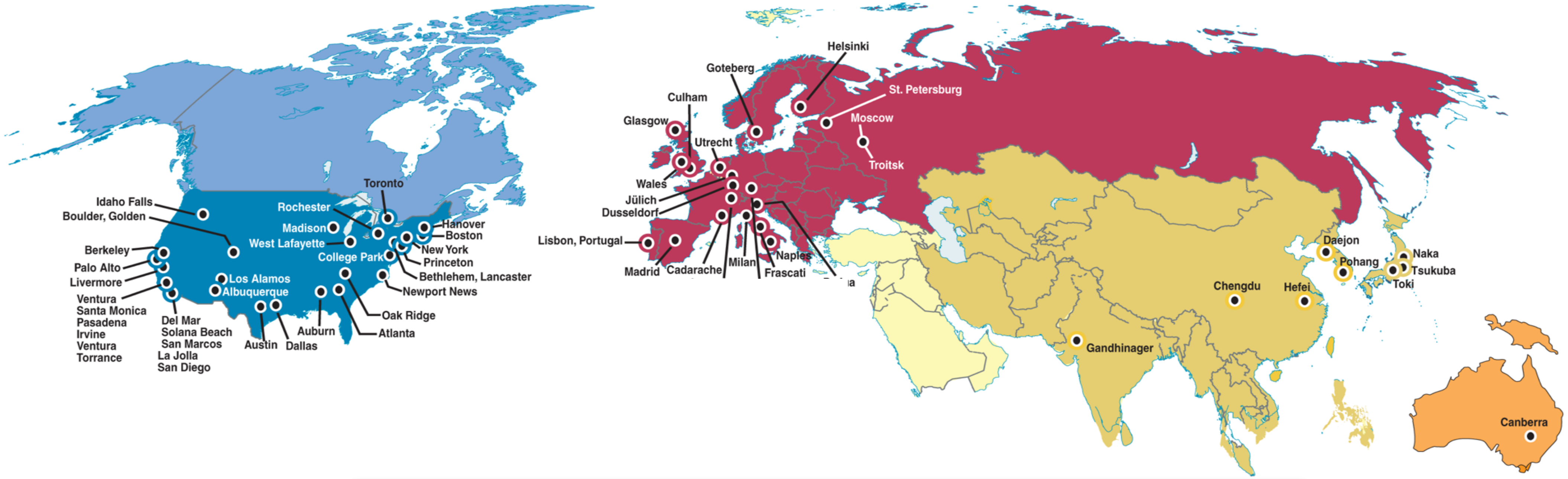


University Frontier Science Participation



24 responses to 2017 DOE FOA

DIII-D Is an Outstanding Research Laboratory for Fusion Scientists From Around the World



DIII-D Facility Users (2017 report)

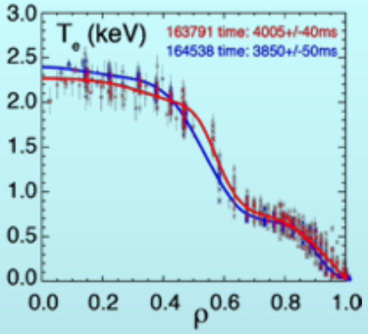
- 683 Research Users
- 323 On-site and 360 Remote
- 24 Countries
- 108 Institutions
- 95 Graduate Students
- 68 Post Doctoral Fellows

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

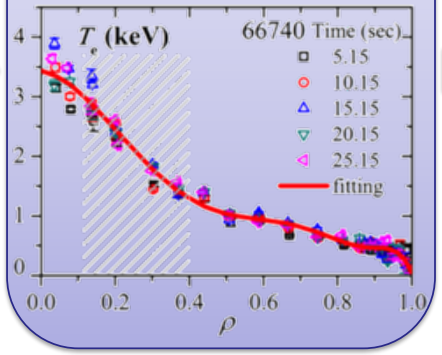
DIII-D International Collaborations Successfully Leverage Complementary Capabilities to Advance Fusion

- **DIII-D and EAST Teams worked together – with both tokamaks at their disposal – to develop a long-pulse high β_P operating scenario with application to future devices**

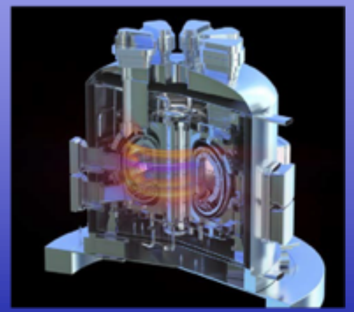
DIII-D
Unraveling physics mechanisms on turbulence suppression in High β_P scenario



EAST
Extend the High β_P scenario to long pulse with metal wall

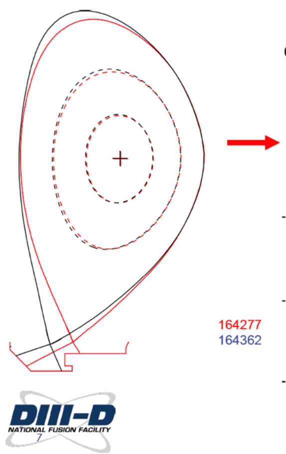


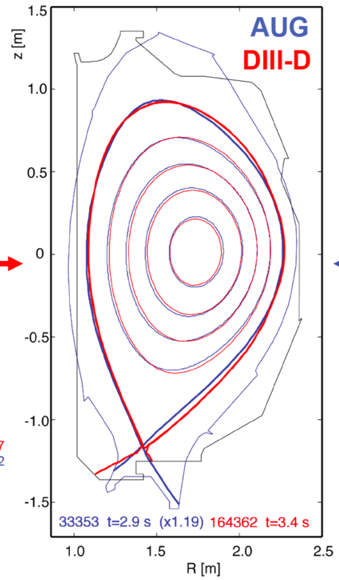
FNSF, CFETR,…
Use validated transport models to project to future devices



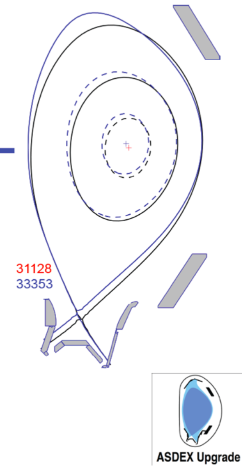
- **AUG/DIII-D similarity experiments obtained ELM suppression in AUG**
  - New regime for AUG research
  - Extension to metal-wall environment

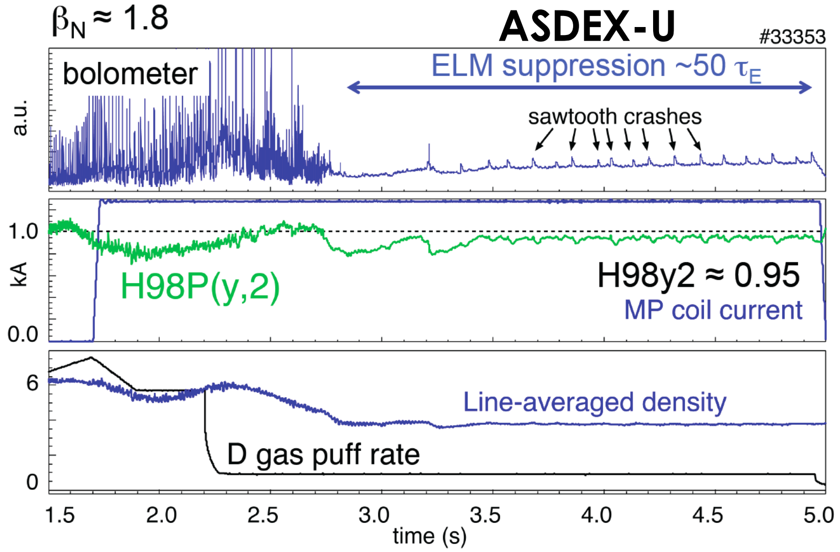
DIII-D, n=3
δ=0.5 → δ=0.3





AUG, n=2
δ=0.2 → δ=0.3



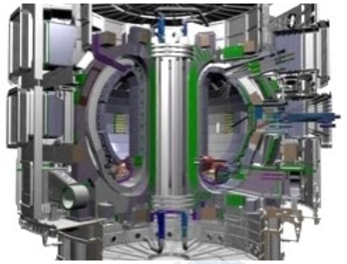


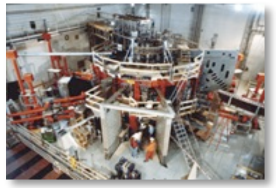
Working together toward our common interest – fusion energy

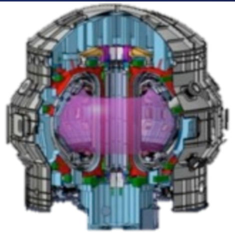
Working Together, We Can Leverage Complementary Capabilities to Develop a Basis for Fusion


JET


MAST-U


ITER

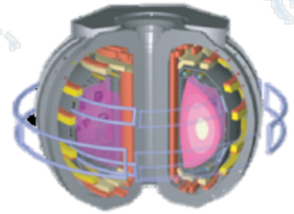

ASDEX-U

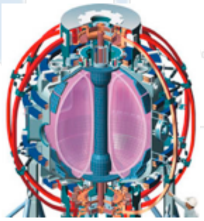

JT-60SA

Develop physics basis for controlled high performance scenarios

Develop and evaluate new materials and boundary solutions

Extend to long-pulse operation on superconducting devices


DIII-D


NSTX-U


TCV


WEST


SST-1


EAST

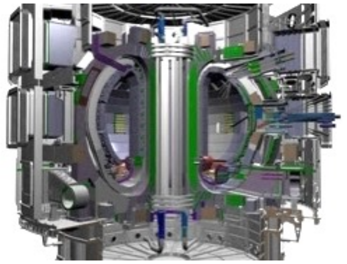

KSTAR

International collaboration accelerates fusion energy development

Working Together, We Can Leverage Complementary Capabilities to Develop a Basis for Fusion


JET


MAST-U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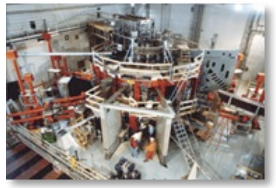
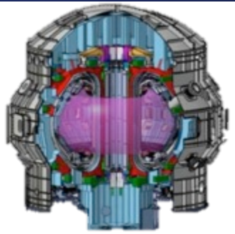

ASDEX-U


JT-60SA

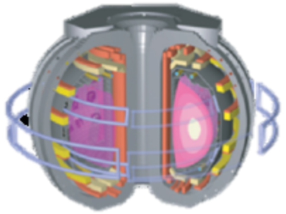
Divertor Configuration
DIII-D Strengths: Diagnostics, configuration variation

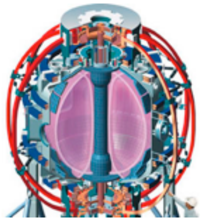
Plasma-facing materials
DIII-D Strengths: Diagnostics, local materials tests, possible first wall change

Transient Control
DIII-D Strengths: Disruption and ELM avoidance and mitigation tools

Size scaling
DIII-D Strengths: Flexible shaping, heating,…

Steady-state scenarios
DIII-D Strengths: Flexible heating, current drive, rotation drive, shaping


DIII-D


NSTX-U


TCV


WEST


SST-1

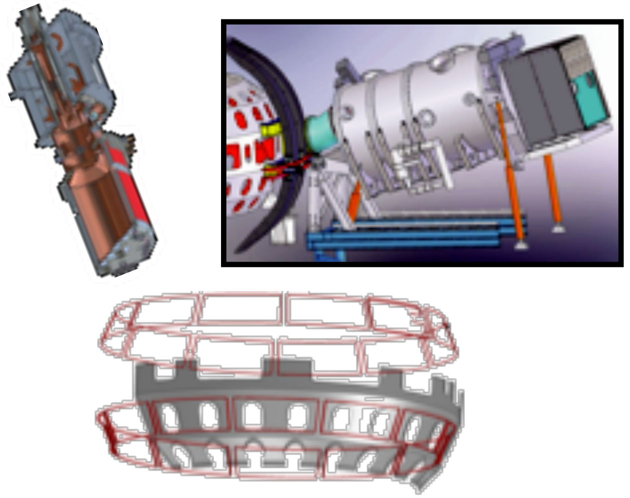

EAST


KSTAR

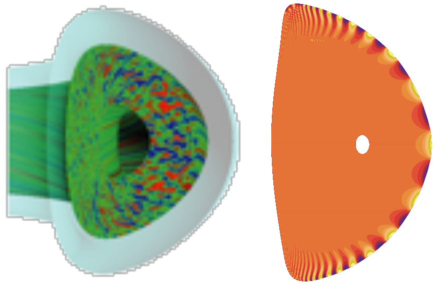
International collaboration accelerates fusion energy development

DIII-D Research Plan Offers Compelling Opportunity to Advance Fusion Research Towards the World's Energy Goal

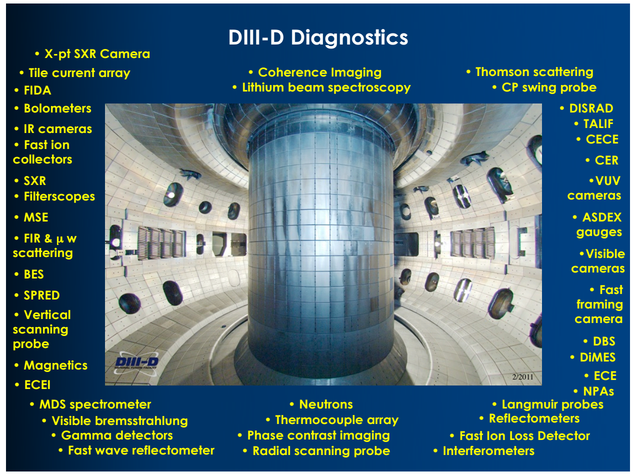
Extensive Plasma Control Tools



State-of-the-Art Predictive Models



Comprehensive Diagnostics



Highly Capable International Research Team

- **Address critical ITER preparation, transients and development of validated simulation capability**
- **Develop basis for tokamak path beyond ITER with high performance core & compatible boundary solution**