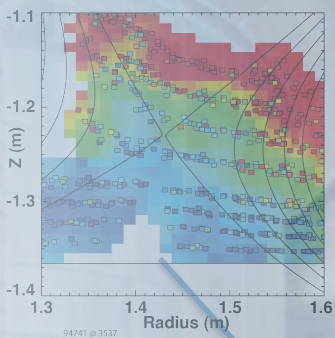
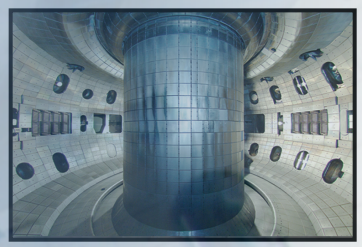
DIII-D Boundary/PMI Center

by
H.Y. Guo

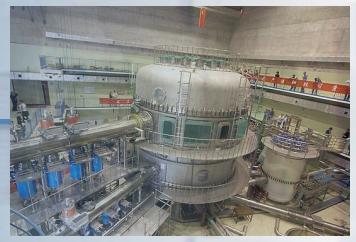
Plasma Seminar at
VLT

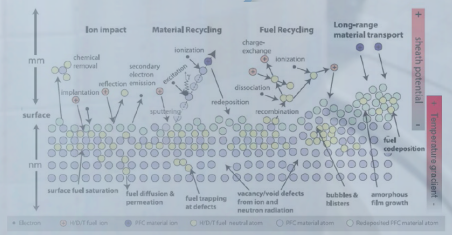
June 18, 2014





Center for Boundary & PMI Validation





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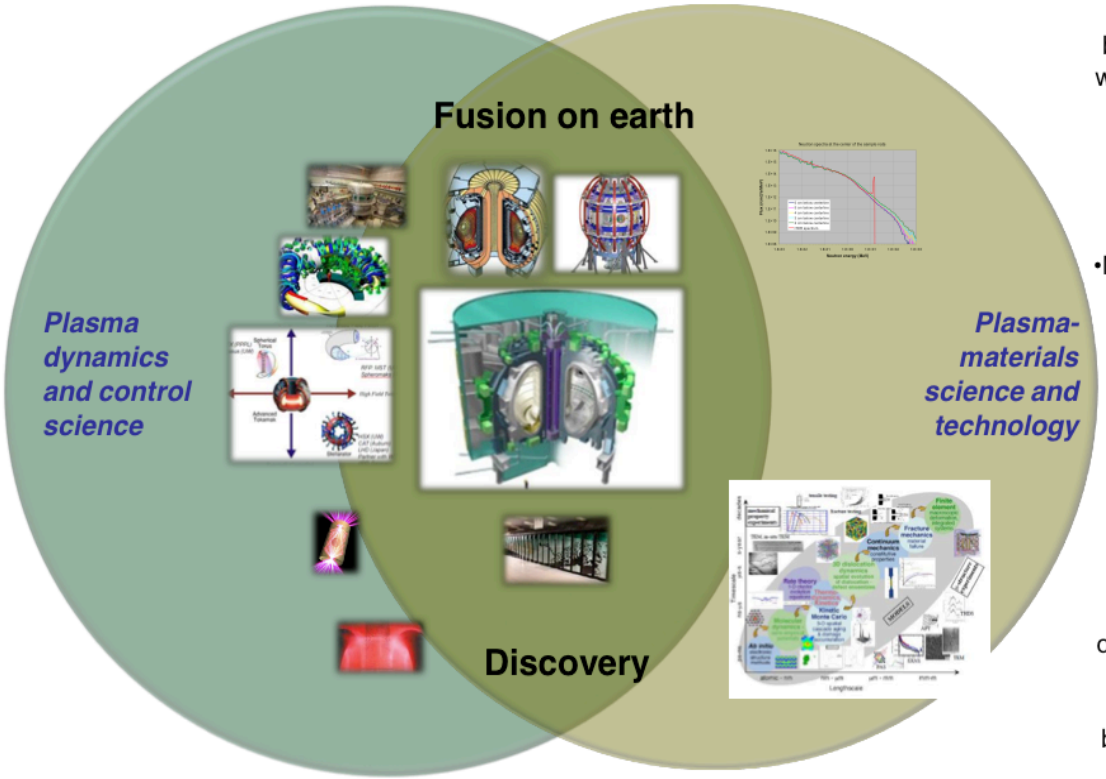
The Path to Long Pulse and FNSF Motivates an Increased Emphasis on the Boundary/Plasma-Material Interface

U.S. DEPARTMENT OF ENERGY | Office of Science

Ultimately, the U.S. fusion's path forward will be expressed in terms of scientific elements and will include changes of emphasis



- Burning plasma science and stewarding broader plasma science will be key elements, but program scope may have to be reduced for lower funding level scenarios

- Major domestic facilities will still engage in plasma dynamics and control, but will shift focus towards challenging metrics relevant to fusion materials science

- Leverage between domestic and international research opportunities in MFE will become even more important in tough budget times, if the U.S. is to obtain access to the leading scientific questions in the next decade

Synakowski, FESAC, Feb, 2012

Divertor/PFC Challenge: Reliably Dissipate Heat and Particle Flux in a GW-scale Fusion Reactor

Prior studies show gaps

- Predictable boundary plasma control to bridge the transition from the hot fusion core to material surfaces.
- Qualified plasma-facing components designed for the expected reactor environment
- Fully integrated solutions for core, boundary, and components producing high fusion gain.

Starting FNSF Design in 2025 increases urgency to resolve the PMI challenge

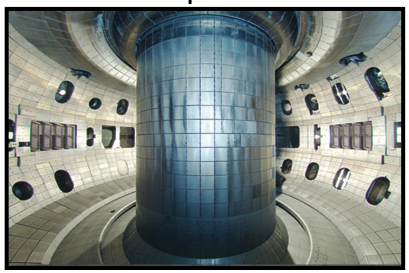
Hill,
FESAC, June, 2014

Critical Plasma-Material Interface Issues for Fusion in the ITER era

Challenges	Needs	DIII-D Approaches
Heat and particle exhaust	• Acceptable heat flux on PFCs including divertor & chamber wall • Control fuelling and density and facilitate ash removal	• Validate divertor/boundary codes and upgrade divertor to facilitate plasma detachment • Optimize divertor geometry to improve divertor pumping
Erosion/ redepostion and material migration	• Adequate PFC lifetime • Minimal core contamination • Minimal Tritium retention	• Test models and provide data under realistic tokamak conditions to community on PMI • Look into advanced approaches and alternative wall materials to carbon and tungsten
Integration of core and boundary	• Viable divertor/boundary solutions with adequate core performance	• Test new divertor using high performance plasma scenarios

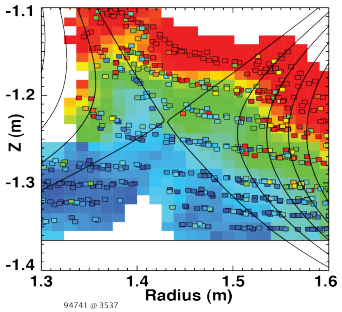
Boundary Center has been Built on Strong Collaborative Efforts within DIII-D and DiMES Programs

DIII-D Experiments



DiMES

Model Validation



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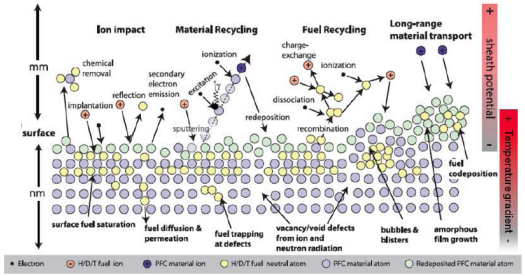
Surface Analysis (SNL)

Materials (SciDAC, MIT-PSIC)



Edge Theory

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Boundary Center has been Built on Strong Collaborative Efforts within DIII-D and DiMES Programs

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Mission of Boundary/PMI Center

- **Develop Optimized Boundary/ PMI Solutions for Application to Burning Plasma Devices**

Goals of Boundary/PMI Center

- **Advance scientific understanding and develop predictive capability of the non-linear and transient interaction of boundary plasma and PMI for extrapolation to future fusion devices**
  - Enhance integrated boundary/PMI modeling capabilities: validate codes with experiment
  - Develop advanced diagnostic capabilities for boundary plasma/materials Interface
- **Develop a new divertor concept in DIII-D to address heat/ particle exhaust and PMI issues including chamber wall**
  - Provide validated solution to FNSF

New DIII-D Boundary/PMI Center Will Coordinate And Stimulate Increased Effort in These Critical Areas:

Divertor Optimization

Advanced Materials Validation

Integrated Modeling

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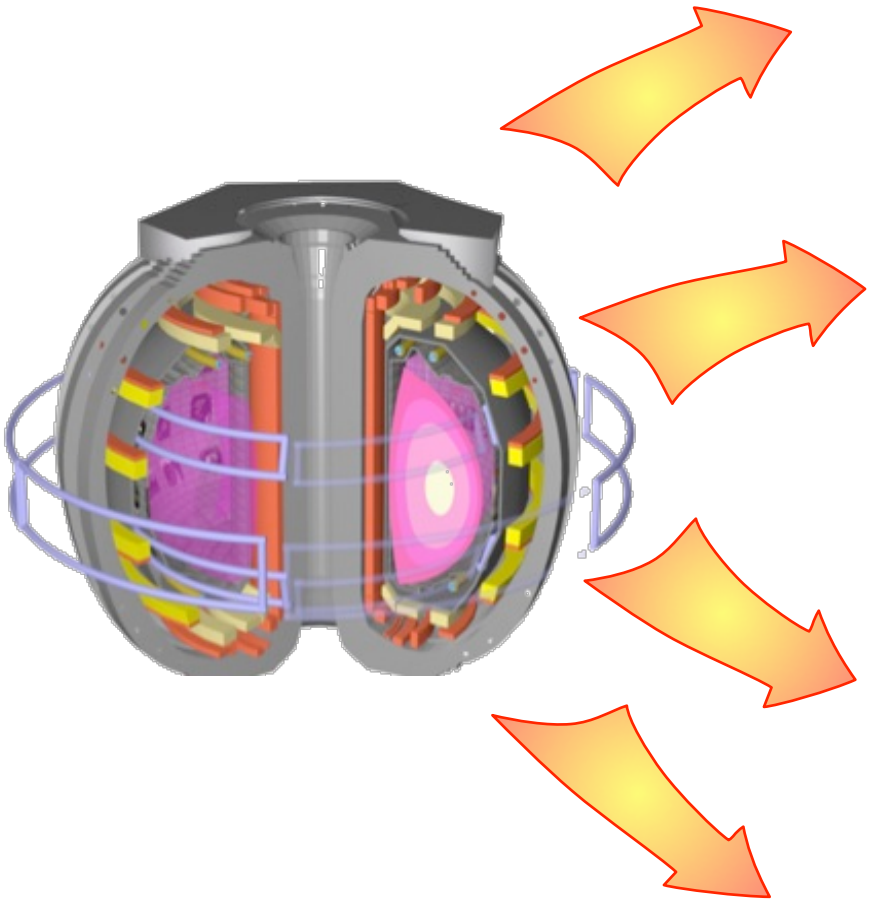
New DIII-D Boundary/PMI Center Will Coordinate And Stimulate Increased Effort in These Critical Areas:

- **Divertor Optimization**
  - Validate divertor/boundary codes for divertor optimization
  - Identify viable divertor/boundary solution with adequate core performance for next-step devices
- **Advanced Materials Validation**
  - Demonstrate advanced alternative wall materials to carbon and tungsten for FNSF and DEMO.
  - Strengthen collaboration with linear devices, such as MPEX and PISCES, Magnum-PSI, and high power, long pulse devices, such as EAST, KSTAR, JT-60SA and WEST.
- **Integrated Modeling**
  - Provide validated tool for developing a new divertor concept in DIII-D, optimizing ITER scenarios and the designing next-step fusion devices.
  - Provide relevant data for realistic fusion environments to the PMI community.

DIII-D Boundary Center Leverages Unique DIII-D Capabilities to Address Boundary/PMI Issues



Versatile DIII-D facility

- Flexible magnetic geometry, easily modified divertor hardware
- Robust plasma/divertor plasma control: density, impurity

World-leading divertor diagnostics

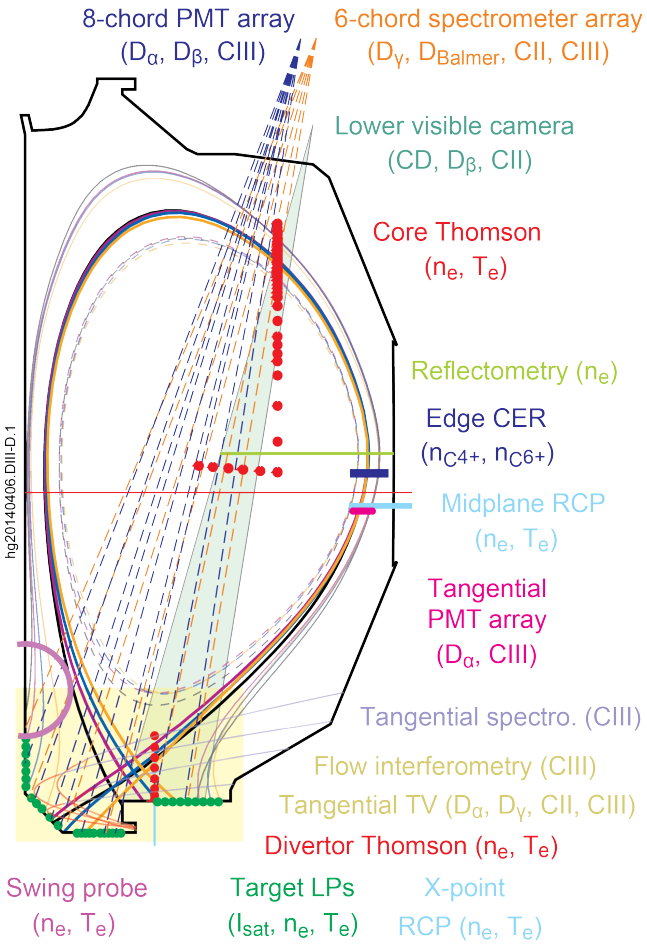
- 2D Thomson scattering
- 2D Flow measurements
- Edge main ion CER
- Swing probes

Excellent existing platform for PMI studies

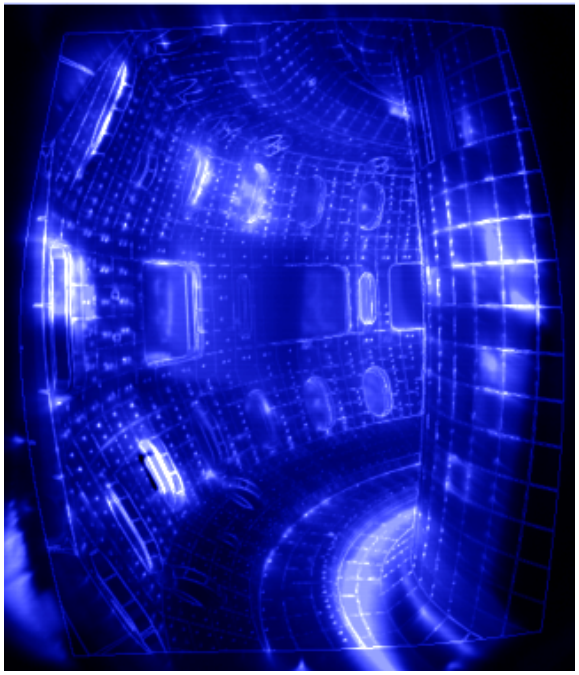
- DiMES/SciDAC, Materials/Modeling

Validate models, provide relevant data in realistic environments to the PMI community

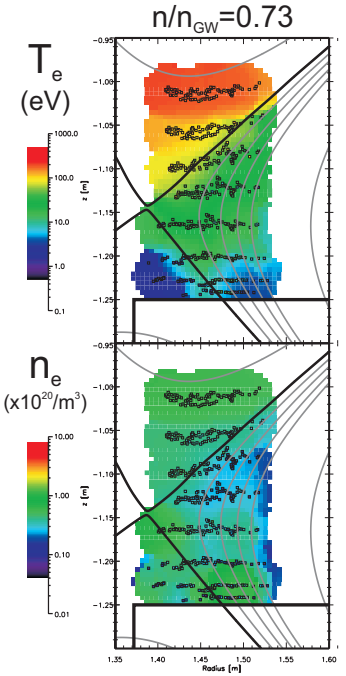
Extensive Divertor Diagnostic Set Provides a Compelling Basis for Model Validation



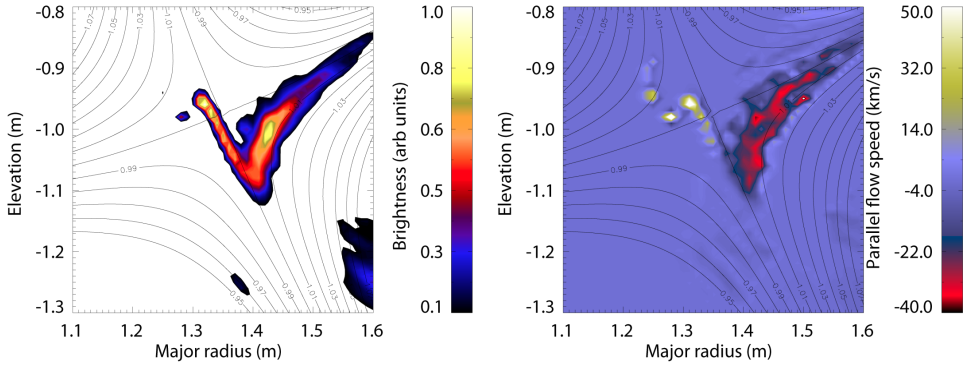
IR/Visible 3D Imaging



Divertor Thomson



Coherence Imaging (v and T_i)



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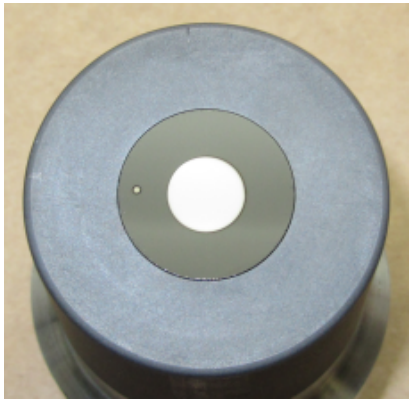
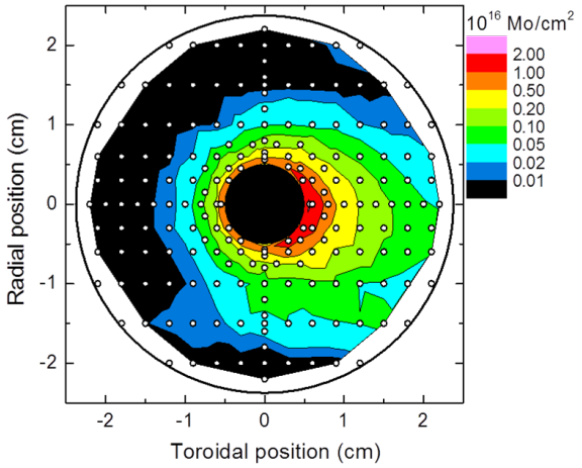
Center Will Advance Understanding of Plasma Surface Interactions in Realistic Plasma Conditions

DiMES





- Local erosion/ redeposition and materials migration
- Surface morphology change and material damage
- Uptake and permeation of hydrogen isotopes
- Examine advanced materials in collaboration with linear devices

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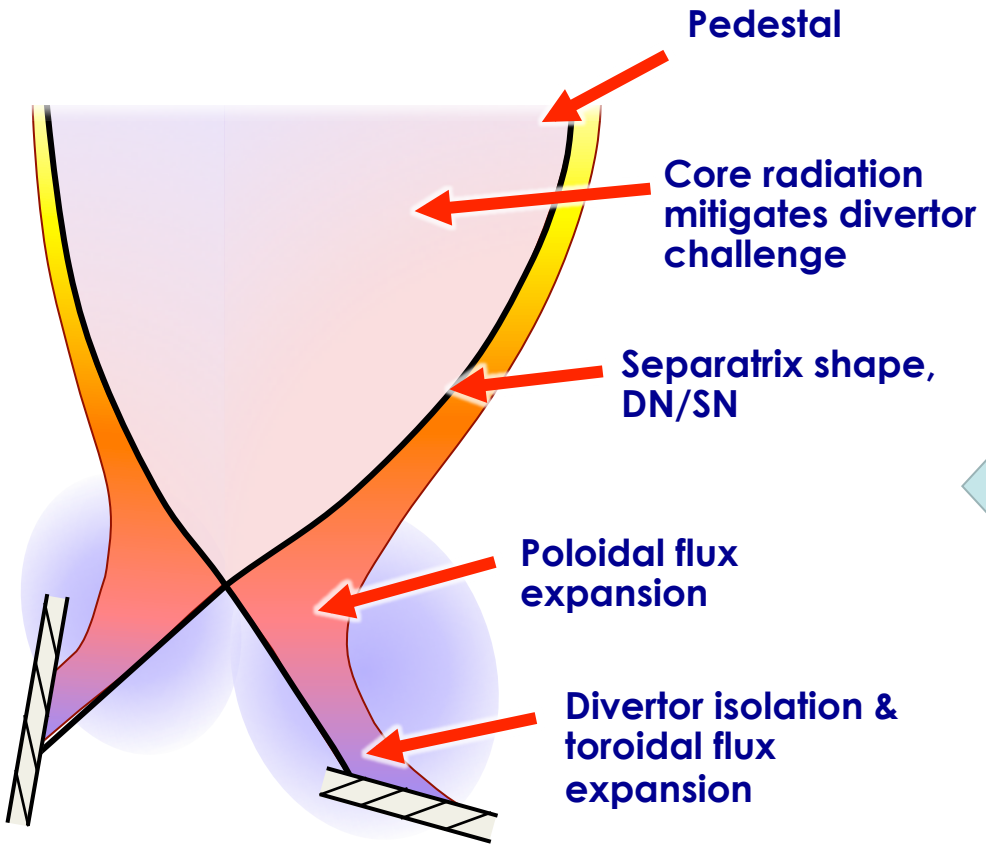
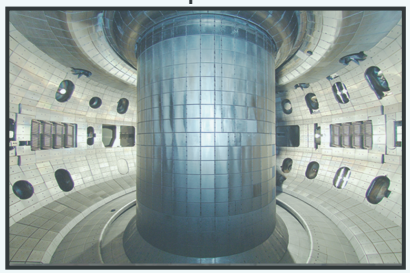
Center Will Develop Integrated Core/Boundary Scenarios in Collaboration with Core Physics/Control Groups



Provide viable divertor/boundary solutions compatible with high core performance

New Center Will Leverage DIII-D Capabilities to Develop Synergistic Programs with Materials and Long-Pulse Facilities

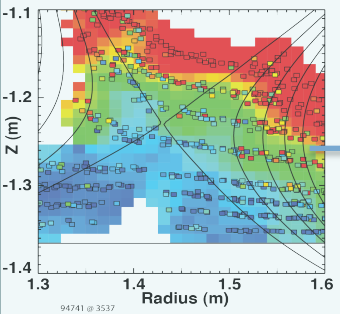
DIII-D Experiments



DiMES

International (EAST, KSTAR, JT-60SA, WEST)

Model Validation

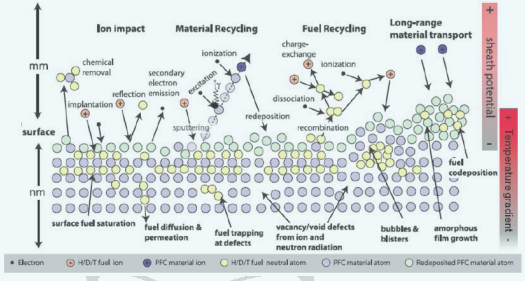


DIII-D Boundary/PMI Center

Surface Analysis (SNL)

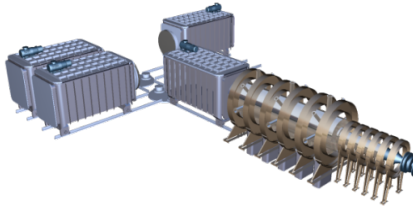
PISCES (UCSD)

Materials (SciDAC, MIT-PSIC)



Edge Theory

MPEX (ORNL)



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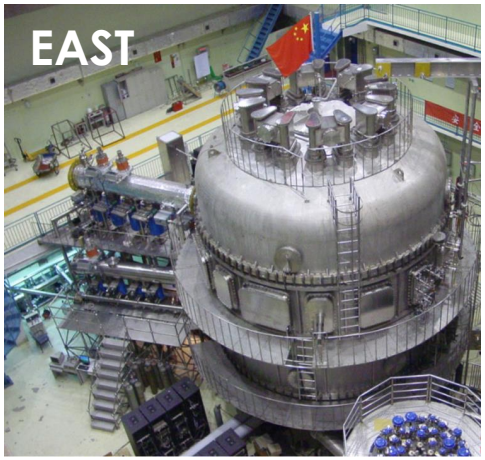
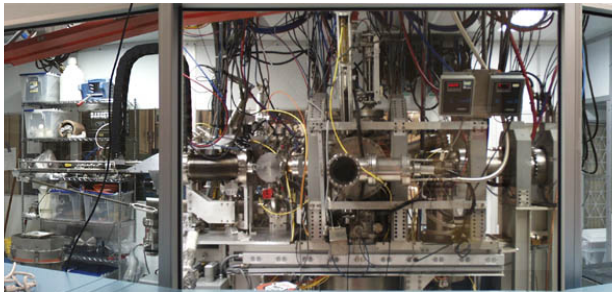
The Center Will Integrate Present Program Elements and Expand Collaborations

- **Partner with long-pulse facilities (EAST, KSTAR, JT-60SA, WEST) and EU programs on PMI**
  - Develop fusion-relevant boundary/PMI solutions and test in EAST long-pulse W divertor and other long-pulse environments

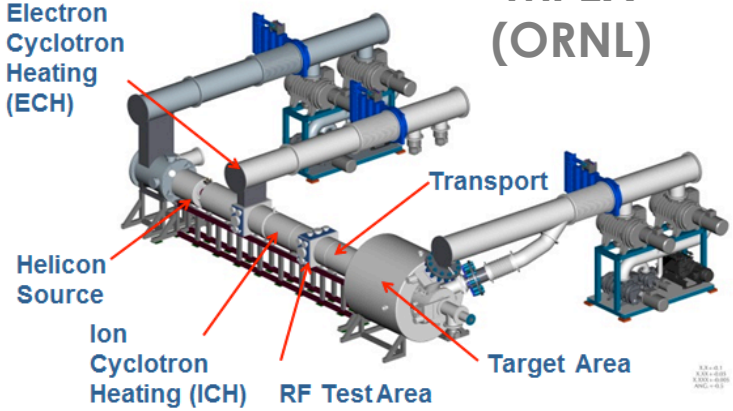


- **Strengthen collaborative efforts between DIII-D and linear devices (MPEX, PISCES)**
  - DIII-D will investigate PMI issues under realistic plasma conditions and complement controlled experiments in linear test devices

PISCES-B (UCSD)



MPEX (ORNL)



DIII-D Boundary/PMI Center Will Promote a Vibrant Research Program Aimed at Defining Divertor Solutions for FNSF and Beyond

- **Takes Advantage of Existing Capabilities**
  - DIII-D divertor program, DiMES/ALPS, SciDAC-PSI.
- **Promotes synergistic programs with linear machines carrying out basic material research**
- **Provides compelling bridge for US research on long-pulse facilities**

Let's work together to make the Center a world leader in this critical area!