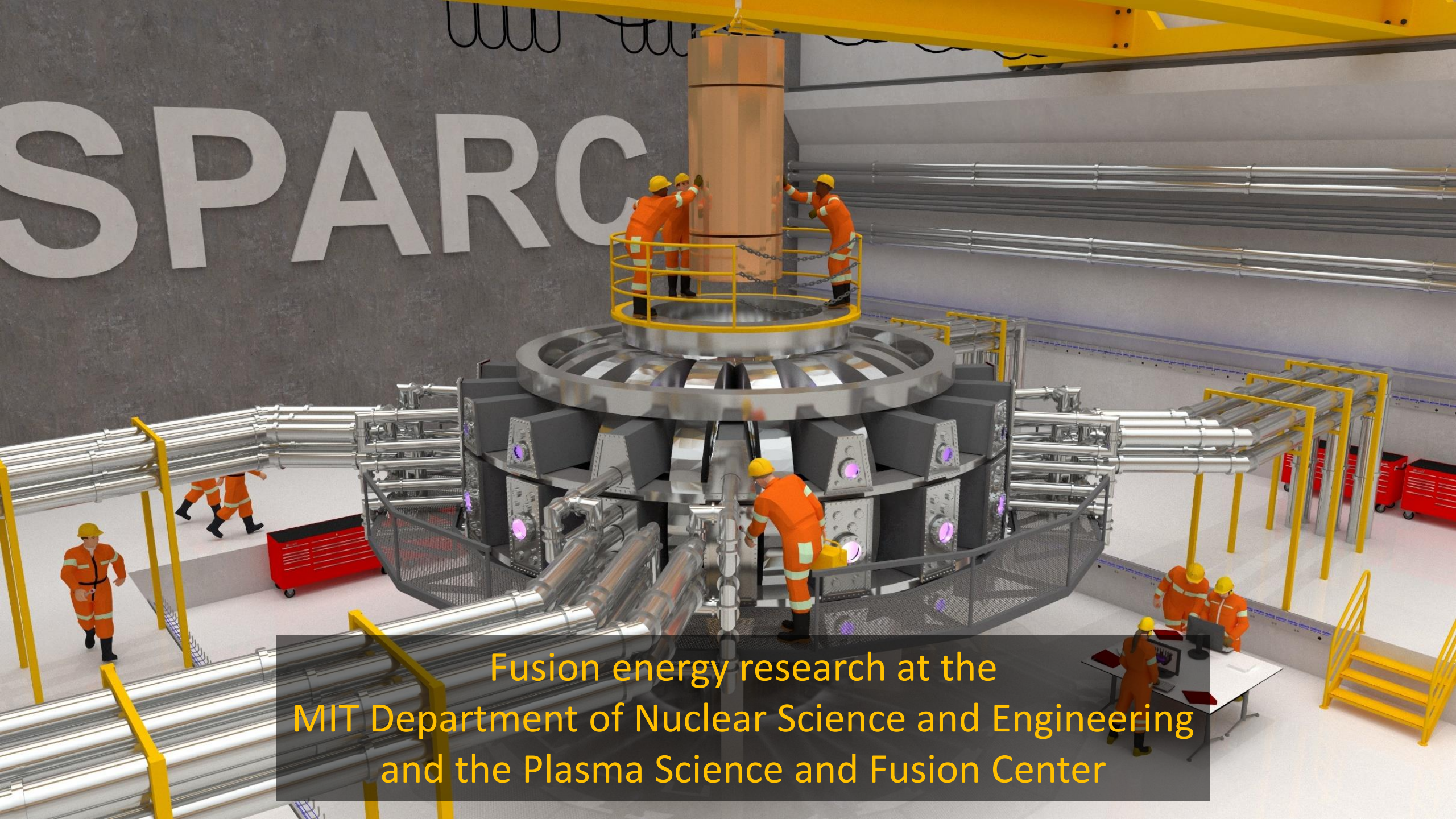


Fusion energy research at the MIT Department of Nuclear Science and Engineering and the Plasma Science and Fusion Center

NSE plays a major role in the MIT Plasma Science and Fusion Center

PSFC

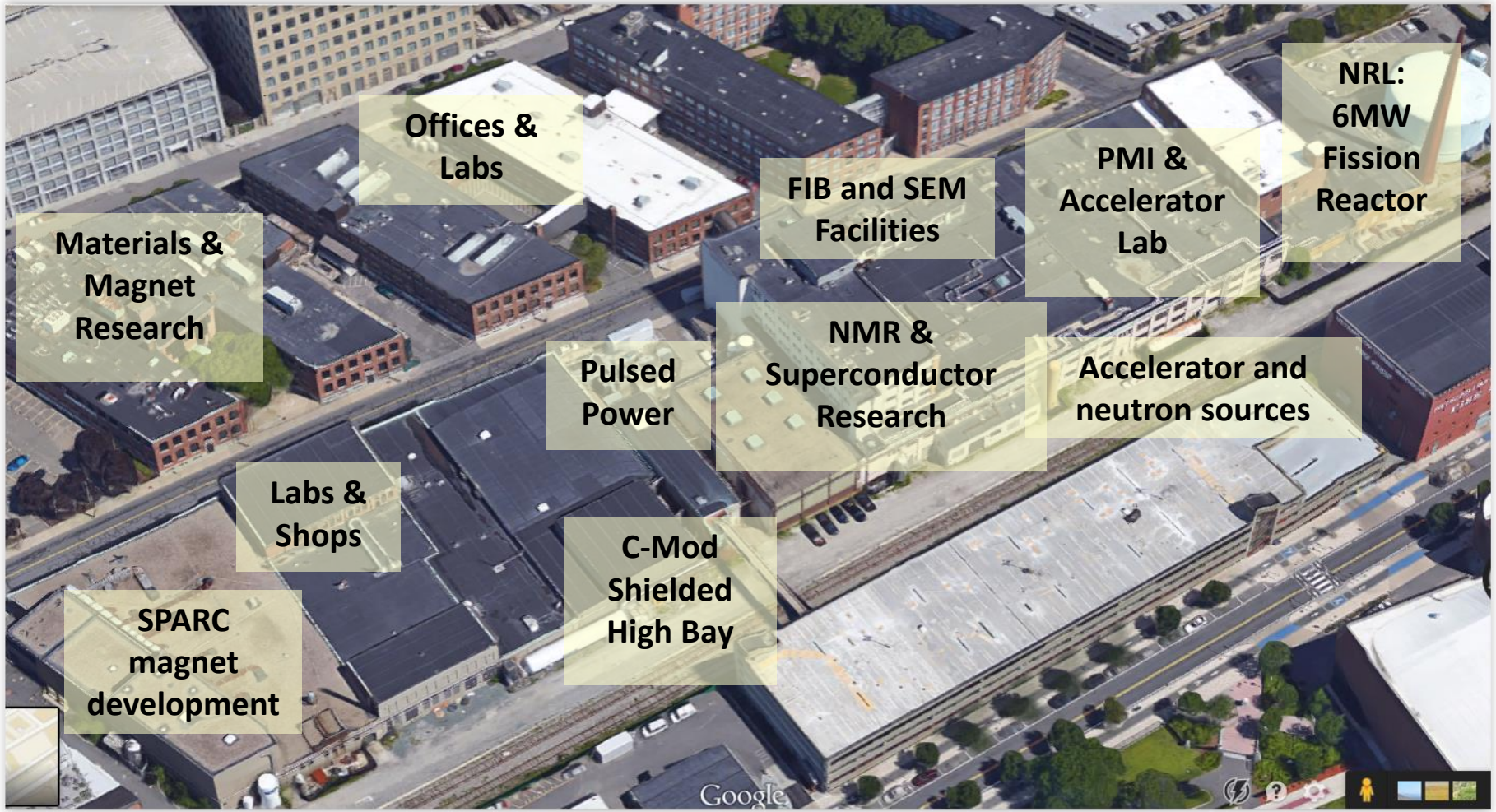
- The PSFC is the second largest laboratory at MIT, comprising ~5% of MIT research budget
- It is housed in a large collection of buildings in the heart of Cambridge on Albany St.
  - 250,000 sq ft of research and office space
  - Former cheese and Nabisco cookie factories
- NSE provides majority faculty, students in fusion:
  - Zach Hartwig (fusion sci. and eng.)
  - Ian Hutchinson (plasma computation)
  - Nuno Louriero (plasma theory)
  - Anne White (experimental plasma)
  - Dennis Whyte (fusion sci. and eng.)
  - 2 Active Emeritus (Freidberg, Parker)

Where does fusion energy research get done on campus?

PSFC

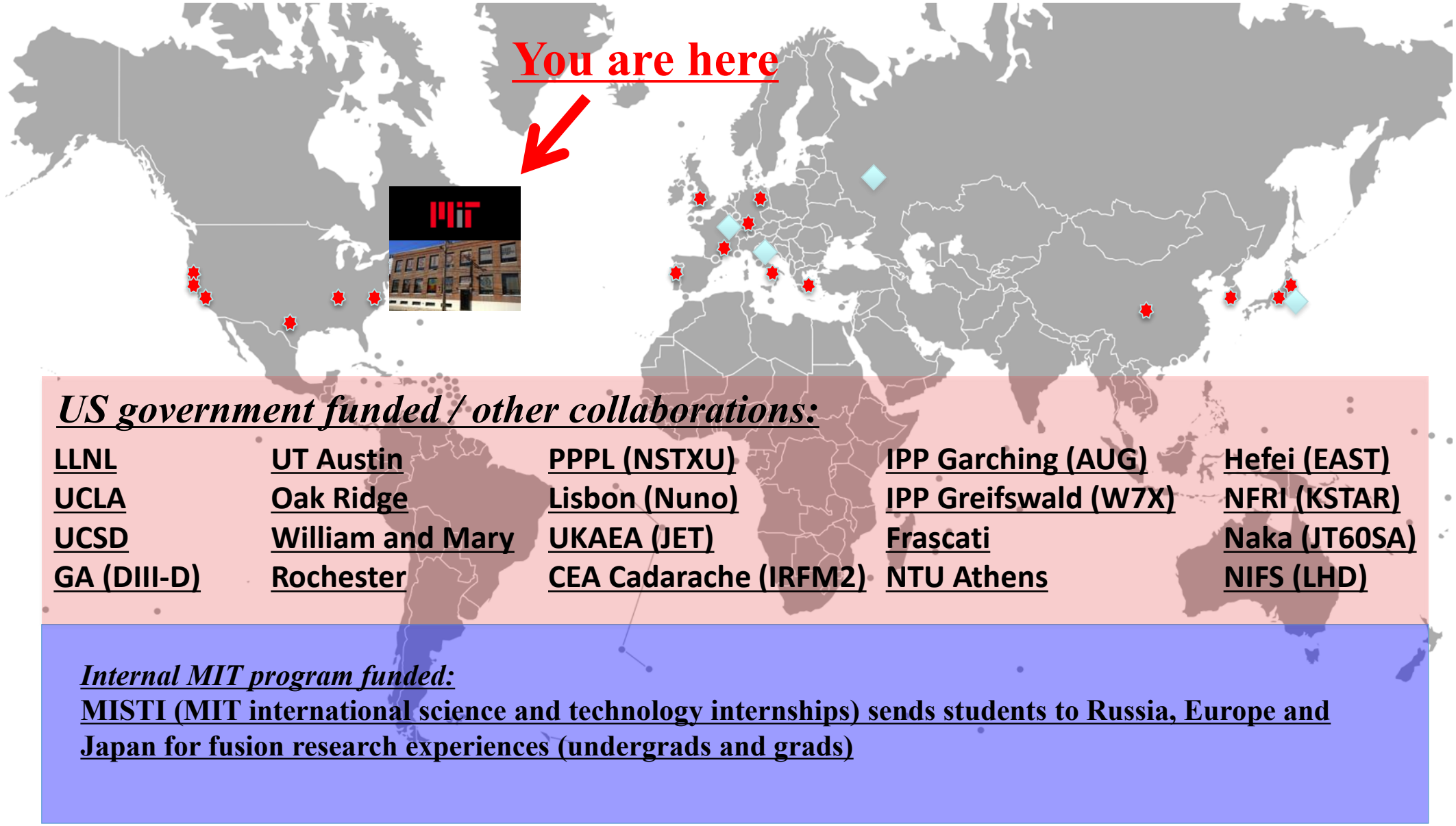
NSE and PSFC together host an impressive capability on Albany Street

PSFC



The PSFC is a gateway to a worldwide group of collaborators in fusion energy

PSFC



US government funded / other collaborations:

LLNL	UT Austin	PPPL (NSTXU)	IPP Garching (AUG)	Hefei (EAST)
UCLA	Oak Ridge	Lisbon (Nuno)	IPP Greifswald (W7X)	NFRI (KSTAR)
UCSD	William and Mary	UKAEA (JET)	Frascati	Naka (JT60SA)
GA (DIII-D)	Rochester	CEA Cadarache (IRFM2)	NTU Athens	NIFS (LHD)

Internal MIT program funded:

MISTI (MIT international science and technology internships) sends students to Russia, Europe and Japan for fusion research experiences (undergrads and grads)

- Magnetic Fusion Energy Division
  - Experimental collaborations
  - Laboratory for Innovation in Fusion Technology (LIFT)
  - The SPARC Project
- CSTAR: Accelerator-based nuclear science laboratory
- Plasma Theory Division
- High Energy Density Physics Division
- Waves and Beams Division

Magnetic Fusion Energy division is broadly divided into three areas:

- *Collaborations:* US DOE sponsored research primarily focused on the development of measurement instrumentation and experimental physics of magnetically confined plasma. Conducted at over 10 major MFE facilities around the US and the world.

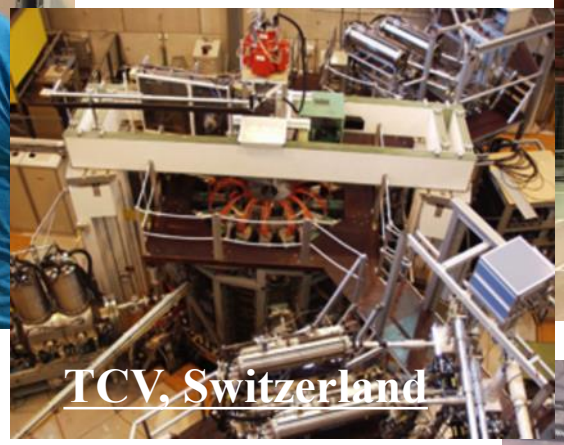
- *Laboratory for Innovation in Fusion Technology (LIFT):* US DOE and Privately sponsored, medium to long term fusion energy research in the applied science and technology required to achieve commercial fusion energy

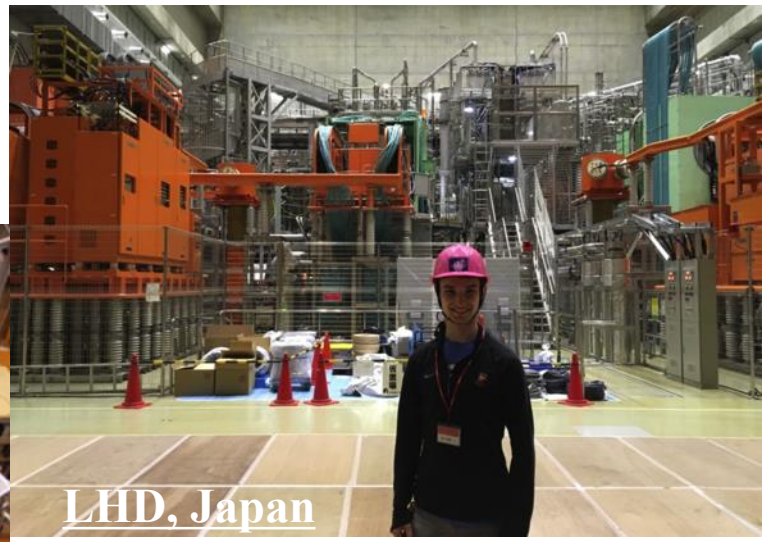
- *The SPARC Project:* An innovative collaboration between PSFC and a private company (Commonwealth Fusion Systems) to rapidly accelerate fusion energy by first developing the next generation of high-field superconducting magnets and then building a 100 MW, Q>2 class compact tokamak

Collaborations: NSE Faculty and students work on fusion around the world!

PSFC


ASDEX Upgrade, Germany


TCV, Switzerland

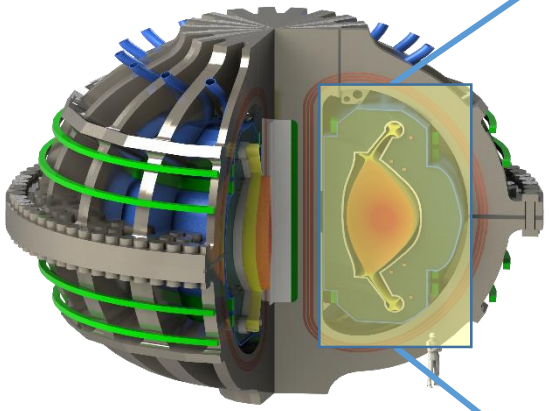

LHD, Japan


W7-X, Germany

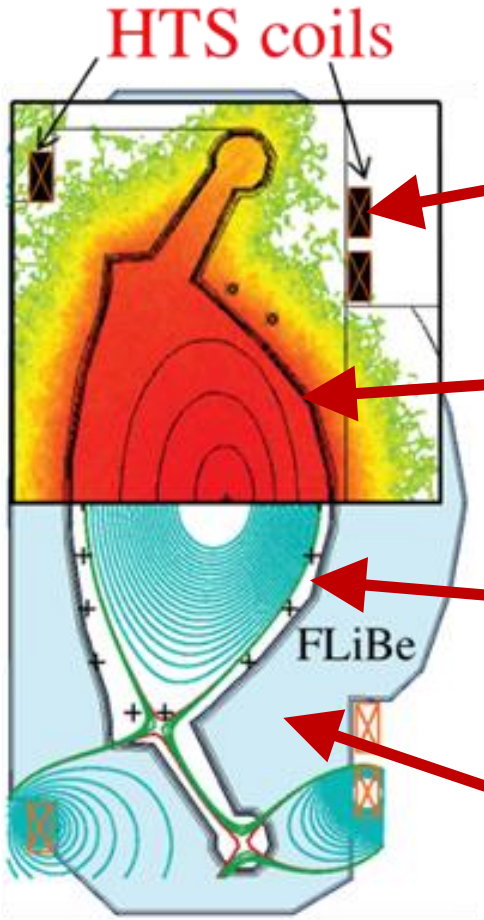

DIII-D, San Diego

LIFT: 4 Project focused on enabling fusion technology faster and cheaper.

PSFC



ARC conceptual fusion power plants



Poloidal cross section of the ARC power core

Initial 4 LIFT projects

1. High-temperature Superconductor Radiation Damage under High Fluence *(PSFC Accelerator Labs; NW13)*
2. Using Intermediate Energy Ions to Characterize Material Damage *(PSFC Accelerator Labs; NW13)*
3. Ultra-thin Liquid First Wall Surfaces for the ARC Fusion Energy Pilot Plant *(PSFC Accelerator Labs; NW13)*
4. Characterizing Molten Salt Fluid Dynamics in High-Magnetic Fields for Fusion Energy *(West Cell, NW21)*

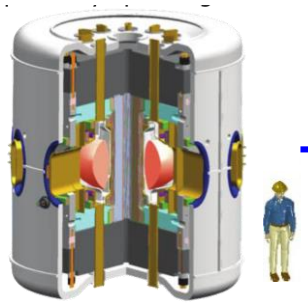
SPARC: Building better magnets to make fusion smaller, cheaper, faster

PSFC

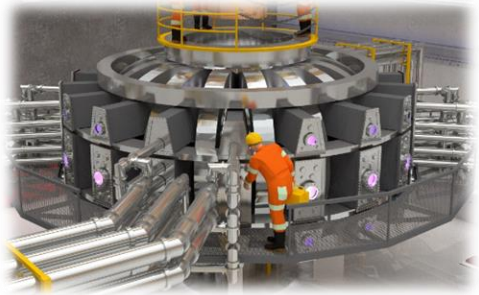
Higher magnetic field enables much higher performance plasma at smaller size

SPARC couples breakthroughs in magnet engineering to 50 years of proven physics

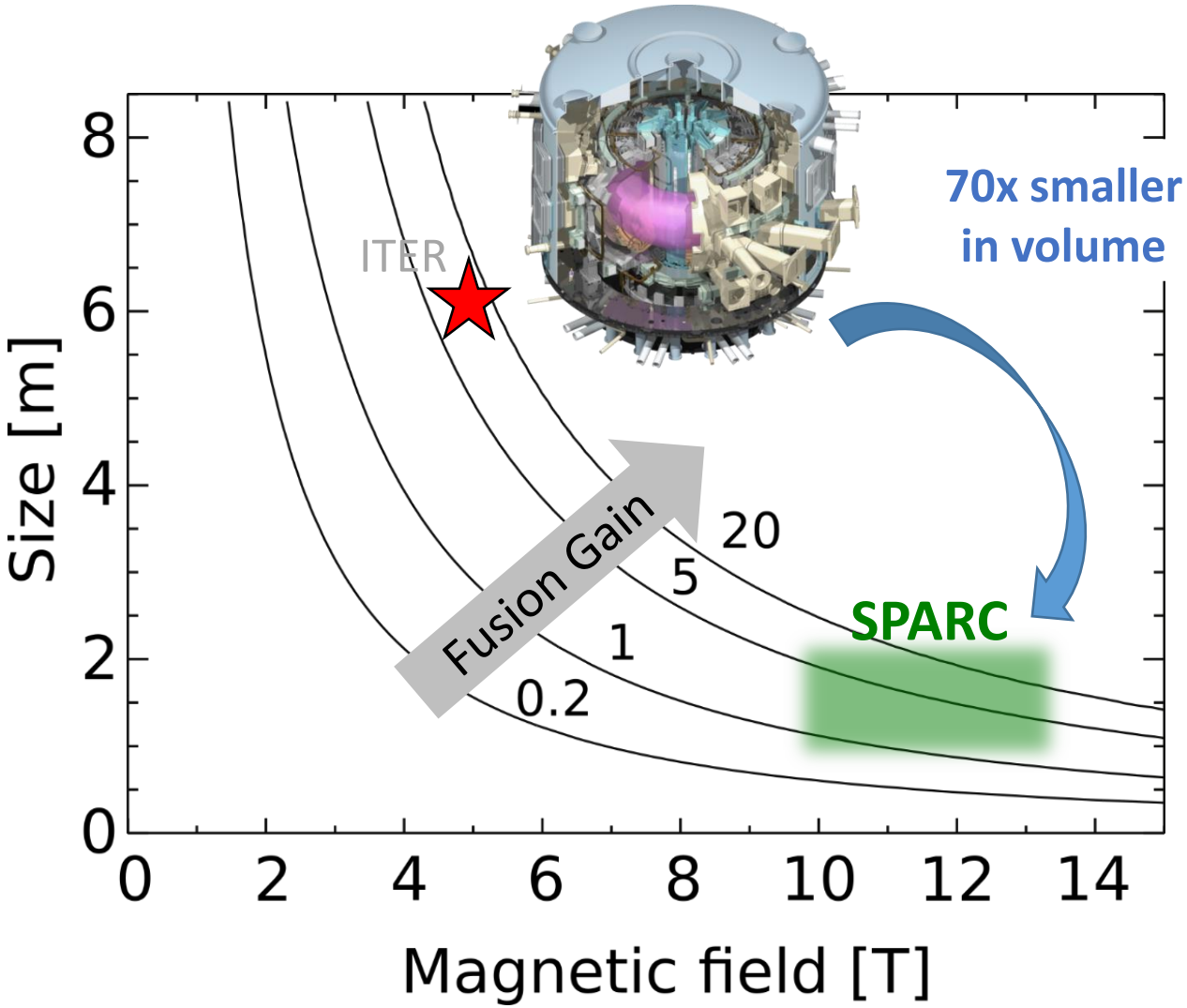
SPARC is only ~2x larger than Alcator C-Mod, the device we built and operated at MIT PSFC for 20 years … but outputs 100 MW of fusion power at Q>2!



Alcator C-Mod
(MIT PSFC today)



SPARC
(MIT + CFS tomorrow)



Current and on-going projects related to fusion:

- Lithium film deposition and analysis with plasma exposure: solid or liquid film chemistry/stability, hydrogenic and helium retention (Prof. Dennis Whyte)
- Development of implanted depth markers for erosion/deposition measurements using in situ and ex situ analysis (Prof. Zach Hartwig)
- Development of in situ transient grating spectroscopy for surface monitoring in fusion energy devices (Prof. Mike Short)
- Study of the viability of molten salt as plasma-facing material in a fusion pilot plant (Prof. Dennis Whyte)
- Study of high energy proton damage to test shielding materials necessary for fusion pilot plant (Prof. Zach Hartwig)
- Development of universal mirror Langmuir probe for high temporal resolution plasma measurements (Dr. Brian LaBombard, PSFC)
- Study of irradiation damage effects on superconducting materials performance (Prof. Zach Hartwig)

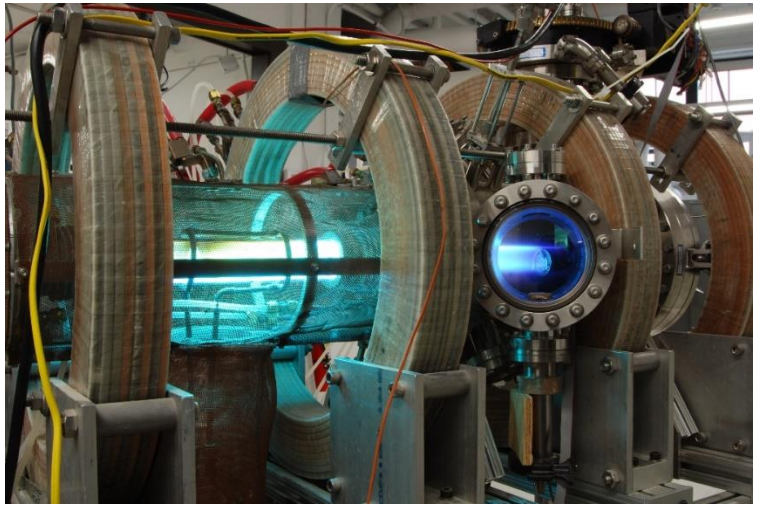
CSTAR: Center for Science and Technology with Accelerators and Radiation

PSFC

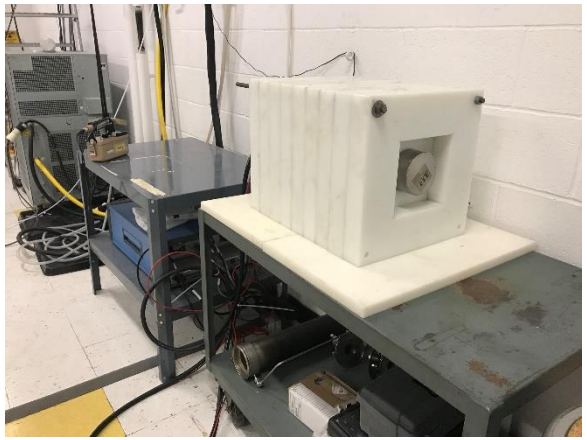
CLASS: 1.7 MV tandem accelerator

DANTE: 2 MV tandem accelerator

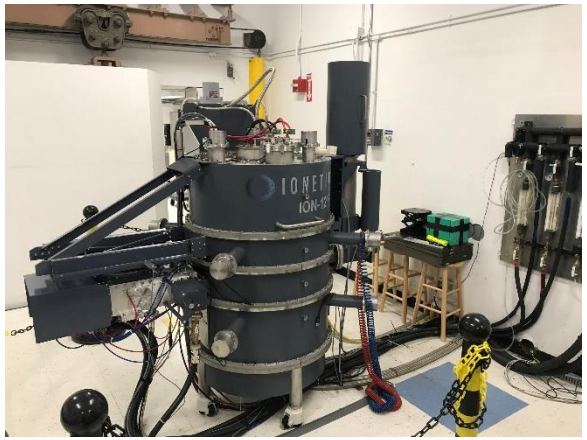
DIONISOS: Helicon plasma



DT neutron generator



CHARON: 12.5 MeV proton cyclotron



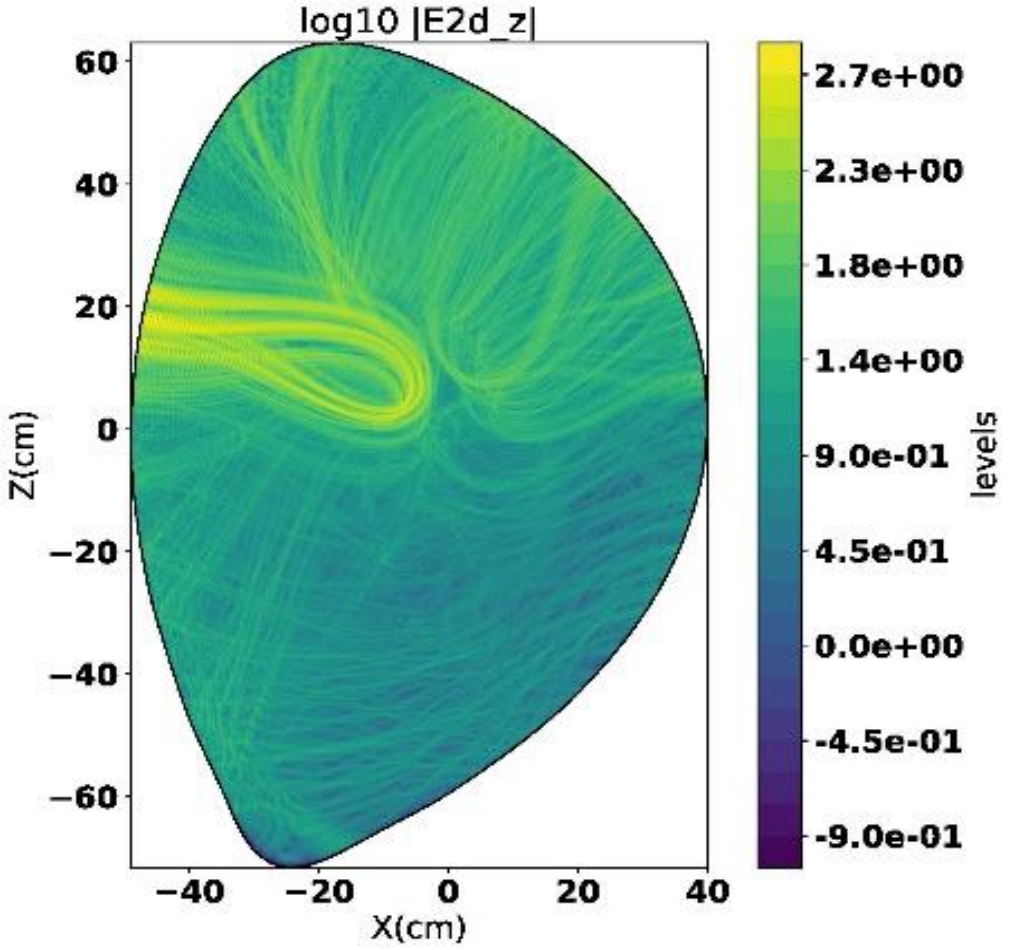
The Plasma Theory Division

PSFC

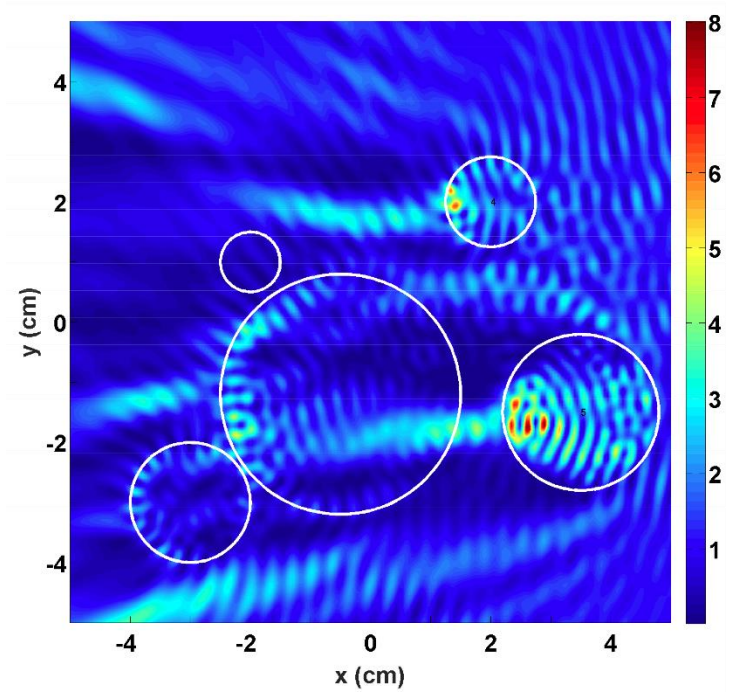
The Theory and Modelling Division focuses on:

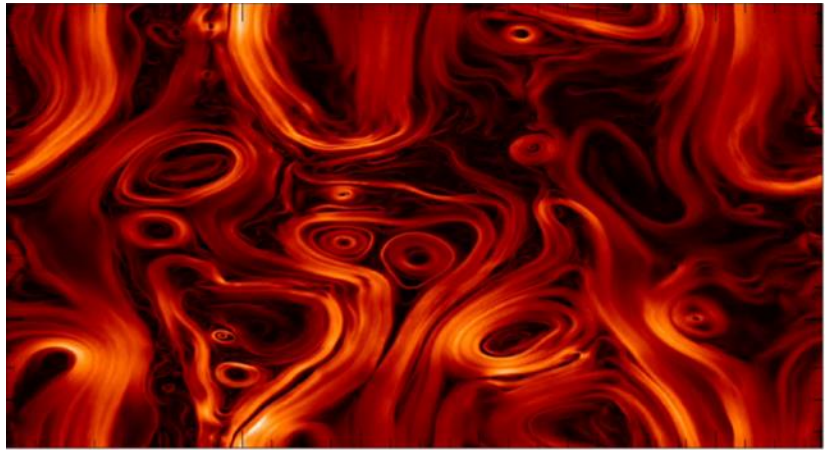
- First principles theoretical understanding of plasma confinement
- Numerical simulation and modelling of plasma dynamics in magnetic confinement fusion devices
- Discovery plasma science: understanding of fundamental plasma physics problems of relevance to fusion, space and astro plasma physics.

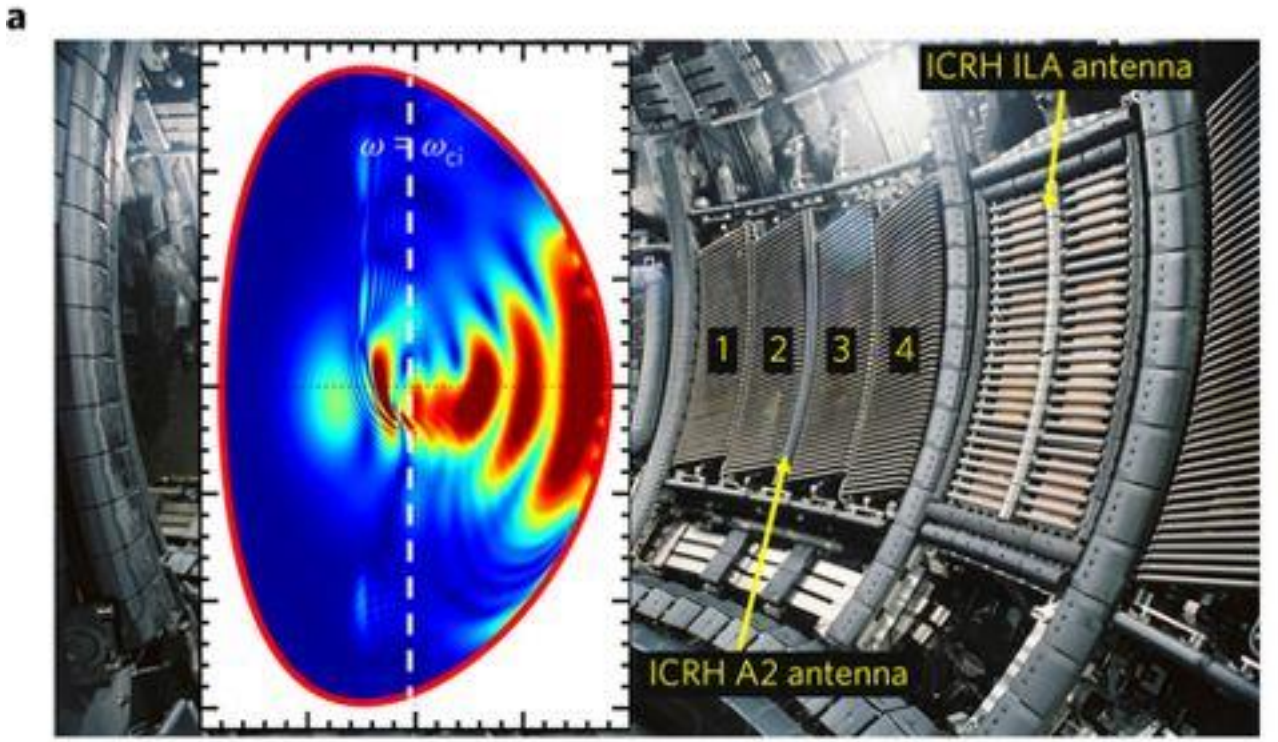
T&M Division is led by Dr. Paul Bonoli. Other senior members are Dr. Peter Catto, Dr. Darin Ernst, Prof. Jeff Freidberg (Emeritus), Prof. Nuno Loureiro (assistant Head), Dr. Abhay Ram, Dr. John Wright. Currently has 4 post-doctoral researchers and 4 PhD students.



Simulation of RF
wave fields in the EAST Tokamak



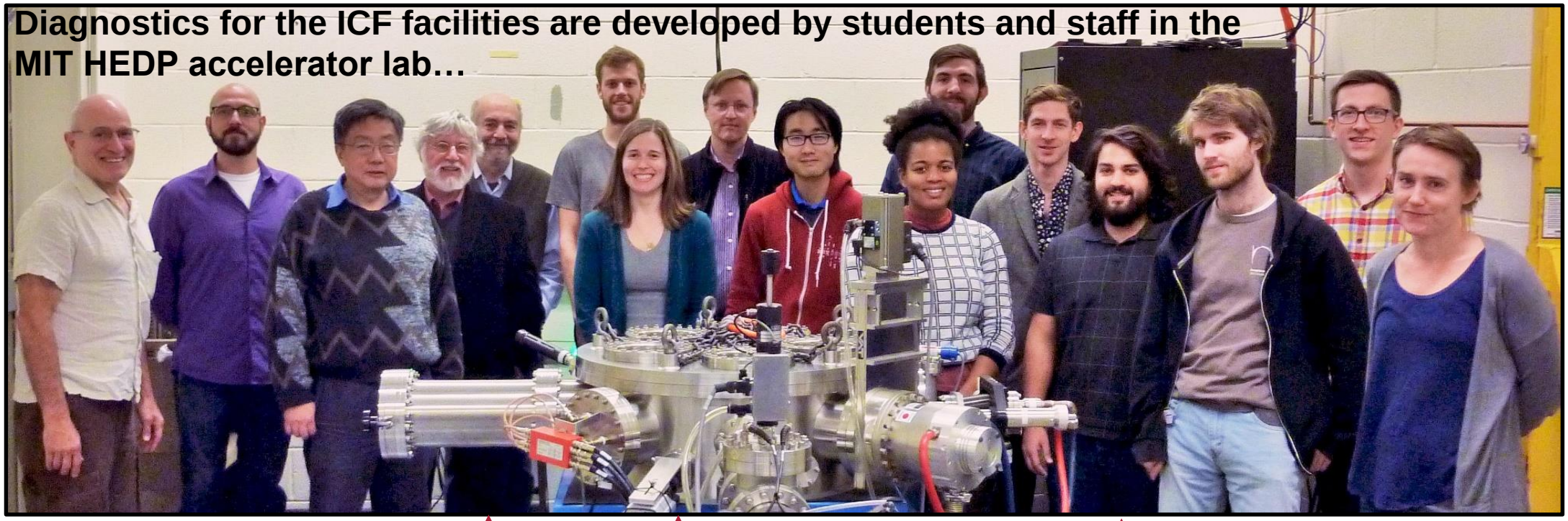




Three (pretty) examples of research conducted by the T&M Division: Top left: scattering of waves by perturbations in the plasma; Top right: Simulation of RF electric field on a JET plasma; Bottom left: kinetic turbulence in an astrophysical accretion disk.

The High Energy Density Physics Division explores high energy density science and inertial confinement fusion at OMEGA, NIF and Z using MIT-developed nuclear diagnostics

PSFC



…used at the

National Ignition Facility,

Omega Laser Facility,

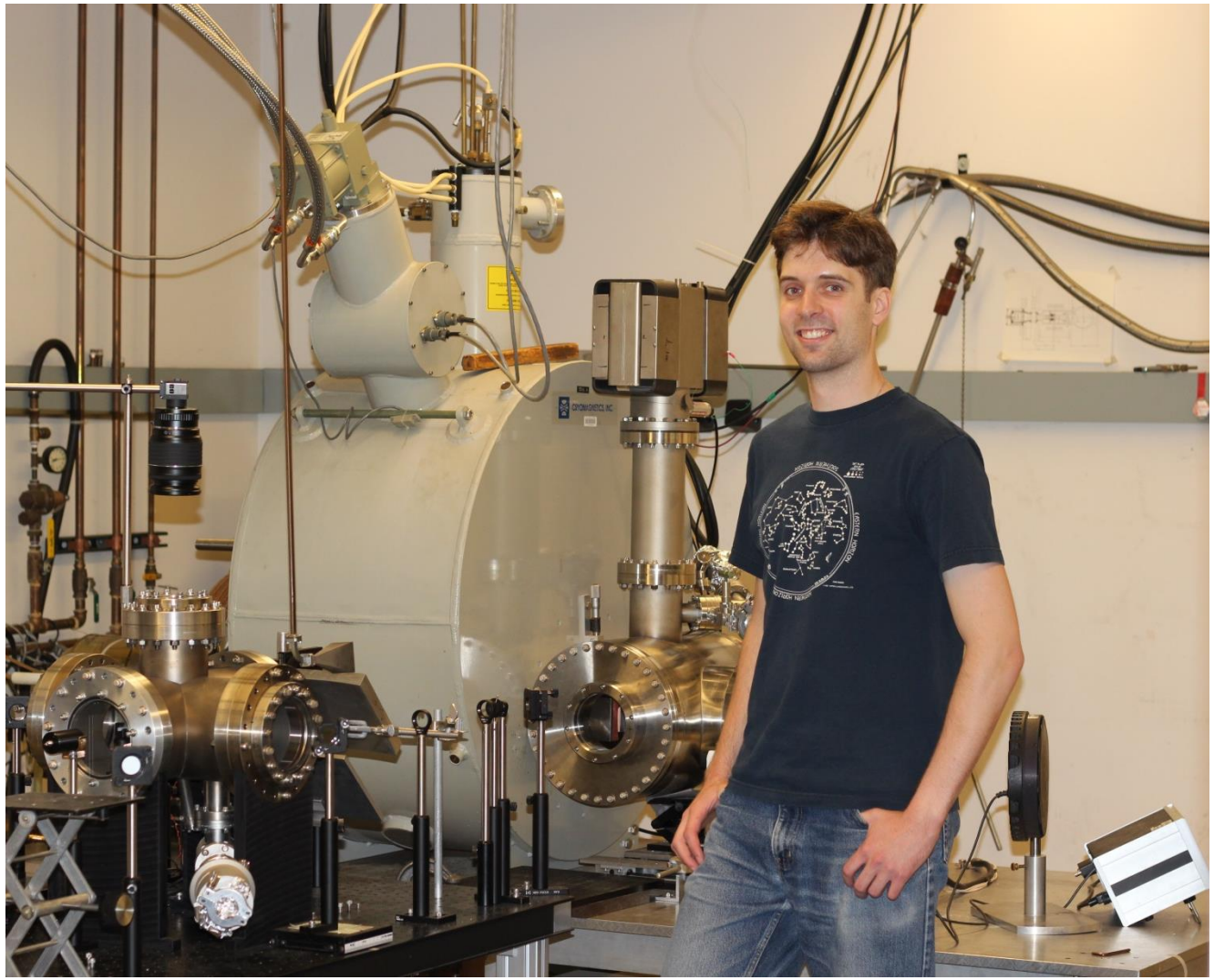
and Z Machine

HEDP is the study of matter under extreme states of pressure (> 1 M bar)
Examples: Earth core ~ 3 M bar; Solar core ~ 250 G bar

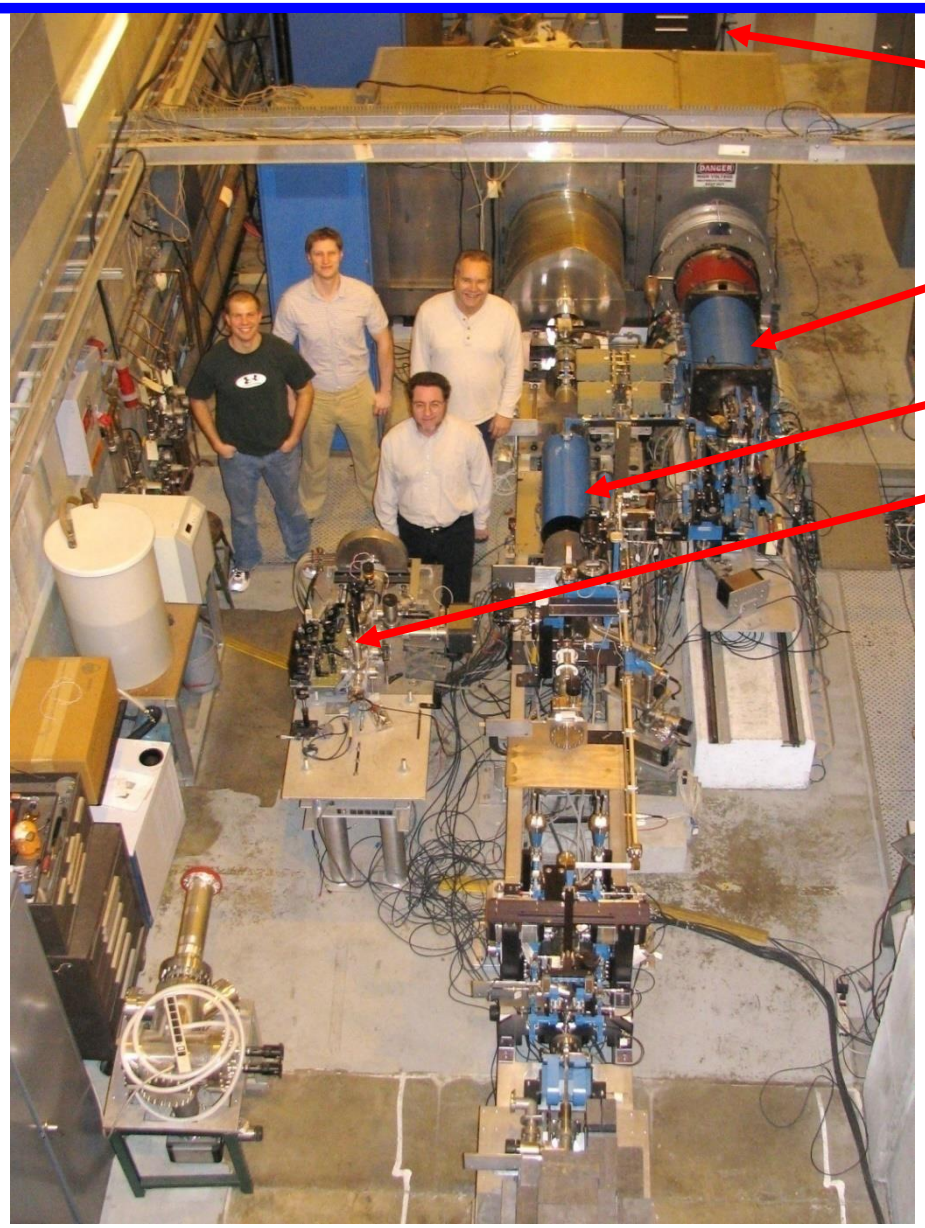
PSFC

- **Research topics include ICF, astrophysical jets, magnetic reconnection, stopping power, energy/particle transport, kinetic effects, and nuclear astrophysics**
- **The HEDP Division consists of 5 scientists, 2 postdocs, 9 graduate students and 3 technical staff and has extensive collaborations with LLE, LLNL, LANL, SNL and university groups throughout the US and in England and Italy**
- **Students generally work on both ICF-relevant and basic science-oriented projects, and get hands-on experience in the MIT-PSFC accelerator lab**
- **Students leave the Division with high profile publications and a broad network of collaborators. Two recent students received the Marshall N. Rosenbluth outstanding doctoral thesis award. Most former students now work at LLNL, LLE or LANL**

See http://www-internal.psfc.mit.edu/hedp/publications.html for extensive publications in high-profile journals.



- 1.5 MW, 110 GHz gyrotron
  - Prototype of DIII-D ECH system gyrotrons
- High frequency source for plasma heating
  - Research to improve the output power and efficiency
- Research on the waveguides that transmit gyrotron power to the ITER plasma
- Collaborations with General Atomics, Oak Ridge



Metamaterial HPM Source

25 MW Klystron

25 MeV Linac

Structure Test Stand

- High power microwave (HPM) source research
- High gradient accelerator research
- Collaborations with SLAC and Argonne National Labs