PPPL PRINCETON PLASMA PHYSICS LABORATORY
A Collaborative National Center for Fusion & Plasma Research
U.S. DEPARTMENT OF ENERGY
WEEKLY
May 1, 2017

THIS WEEK

TUESDAY, MAY 2

STOP class
1:30–3:30 p.m. ◆ Mod 6 conference room
Please contact Dorothy Strauss, x3072, dstrauss@pppl.gov, to enroll.

PCTS Annual Lectureship Series, Seminar #1
2:30 p.m. ◆ PCTS, Jadwin Hall Room 407
Symmetry Protected Topological Insulators and Semimetals
Charles Kane, University of Pennsylvania
See page 5 for details.

THURSDAY, MAY 4

PCTS Annual Lectureship Series, Donald R. Hamilton Lecture
8 p.m. ◆ McDonnell Hall Room A-02
Topological Phases of Matter
Charles Kane, University of Pennsylvania
See page 5 for details.

FRIDAY, MAY 5

Last day for Green Team's plant photo contest
See page 4 for details.

PCTS Annual Lectureship Series, Seminar #2
11 a.m. ◆ PCTS, Jadwin Hall Room 407
Clustering in Luttinger liquids and the quantum Hall effect
Charles Kane, University of Pennsylvania
See page 5 for details.

SATURDAY, MAY 6

Obscura Day Tours
10:30 a.m. and 1 p.m.

UPCOMING

TUESDAY, MAY 9

Facts & Snacks
11:30 a.m.–12:30 p.m. ◆ LSB, B318
See page 2 for details.

INSIDE

Computer simulations of DIII-D experiments shed light on mysterious plasma flows

By John Greenwald

Researchers at PPPL and General Atomics have simulated a mysterious self-organized flow of the superhot plasma that fuels fusion reactions. The findings show that pumping more heat into the core of the plasma can drive instabilities that create plasma rotation inside the doughnut-shaped tokamak that houses the hot charged gas. This rotation may be used to improve the stability and performance of fusion devices.

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NSTX-U Recovery Team holds last of 12 DVVRs to identify gaps in system

By Jeanne Jackson DeVoe

Team members, from left: David Gates, Tom Todd, Dennis Mueller, Ed Lawson, Dan Boyer. *(Photo by Elle Starkman)*

The NSTX-U Recovery Team reached a major milestone on April 20 when it finished the last of 12 design verification and validation reviews (DVVRs) designed to identify gaps in the design and construction of major systems of the National Spherical Torus Experiment-Upgrade.

The DVVRs were a major effort by the team of responsible engineers and numerous others who prepared detailed system design descriptions and presented the information to review teams at each session starting in January.

"I want to express my gratitude to the engineers who worked so hard over the last four months to get to this stage," said Rich Hawryluk, the head of the Recovery Project. "Four months ago we were just getting started on this whole DVVR process and now we've completed it."

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Team of consultants and PPPL'ers begins root cause analysis of coil failure that caused shutdown of NSTX-U

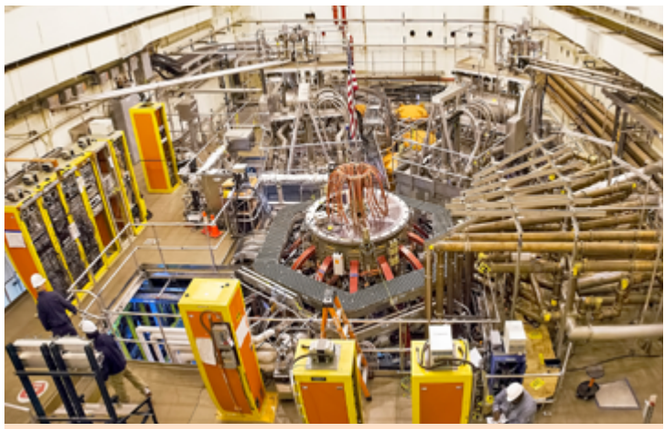
By Jeanne Jackson DeVoe

A team of consultants and PPPL staff members is conducting a root cause analysis of the failure of a magnet that caused the shut-down of the National Spherical Torus Experiment-Upgrade (NSTX-U) last summer. The investigation is a major step in determining what needs to be done by PPPL's NSTX-U Recovery Team to correct the deficiencies that resulted in the coil's failure. This is an important step in the recovery of NSTX-U, said Les Hill, who is spearheading the analysis. Corrective actions revealed by the analysis will be included in PPPL's plan owed to the U.S. Department of Energy in September on how it will address NSTX-U performance and reliability issues.

"We're starting upstream with the initial engineering and design of the coil," Hill said. "We're going all the way back to the beginning. We're looking at how the coil was designed, how it was built and how it was tested, installed and operated. We're piecing together the cradle-to-grave story of the failed coil. We don't want to take anything for granted about what may or may not have happened."

The team consists of consultants from McCallum-Turner Inc., a management consulting company from Annapolis, Maryland, that has headed many such investigations at DOE laboratories and elsewhere. Robert McCallum is heading the team. PPPL team members are Frank Malinowski, of PPPL's Quality Assurance office, and engineer Irving Zatz, who headed the forensic investigation of the failed coil last fall. Other team members are Rui Viera, of MIT's Plasma Science and Fusion Center, who has been an external committee member on DVVRs, and Roy Lebel, who manages the Quality Management Office at Brookhaven National Laboratory.

The forensic analysis was focused on the physical conditions that led to or were associated with the coil failure. The scope of this analysis did not include the determination of the coil's failure – the root cause analysis is picking up where the forensic analysis ended. Hill said the forensic report will be helpful to the team in reaching their conclusions as to the causes. "I think the forensics report was extremely well done. There was a great deal of thought and effort put into it," he said. "They did a great job defining the conditions, but you don't want to put blinders on and assume that's all the information you can or need to acquire."



An overhead shot of the NSTX-U test cell. *(Photo by Elle Starkman)*

A broader look

The root cause analysis will look at the coil failure more broadly to include not only the physical conditions found during the forensic analysis, but also the policies and procedures, human performance or behavioral aspects that may be associated with the failure, Hill said.

The consultants were on site at PPPL the second week in April, Hill said. While here, the team gathered documents and information, including that resulting from interviews of current and previous employees, and employees at Everson Tesla, which manufactured the coil.

Their conclusions will be detailed in a report that Hill will present to the Laboratory, and that will include recommendations for needed actions to prevent the same or similar equipment failures. Formulating and implementing the needed corrective actions is an important initial step in NSTX-U recovery, he said. The objective, Hill said, is to build coils that will perform as defined and last the full lifetime of NSTX-U. Hill said he expects the work to be done in May. "It's an incremental process," he said. "It's like unpeeling an onion. You keep peeling the onion until there's no onion left." The results of the root cause analysis will be fully considered in the Extent of Cause Review which is a broader improvement initiative intended to support not only NSTX-U recovery, but also the full portfolio of PPPL projects.

Facts & Snacks!

A fun guide to PPPL Publications

May 9, 11:30 a.m.–12:30 p.m.

LSB, B318

Refreshments will be provided!

Not on-site, but would like to attend remotely? Email Aileen Pritch at apritch@pppl.gov for more information.

DIII-D simulations

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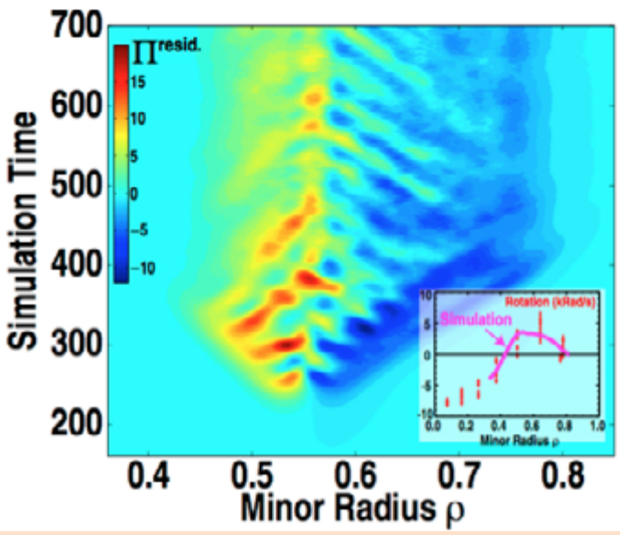

Simulation of plasma turbulence generating positive (red) and negative (blue) residual stress that drives rotation shear. Comparison between measured and simulated rotation profile (inset). *(Image courtesy of W.X. Wang)*

The results, reported in January in the journal *Physical Review Letters*, use first principles-based plasma turbulence simulations of experiments performed on the DIII-D National Fusion Facility that General Atomics operates for the DOE in San Diego. The findings could lead to improved control of fusion reactions in ITER, the international experiment under construction in France to demonstrate the feasibility of fusion power. Support for this research comes from the DOE Office of Science with simulations performed at the National Energy Research Scientific Computing Center (NERSC), a DOE Office of Science User Facility at Lawrence Berkeley National Laboratory.

To enhance stability and confinement of the plasma, a gas composed of electrons and ions that is often called the fourth state of matter, physicists have traditionally injected high energy beams of neutral atoms. These energetic beams cause the core and outer region of the plasma to spin at different rates, creating a sheared flow, or rotation, that improves stability and confinement. One persistent mystery is how the plasma sometimes generates its own sheared flow, spontaneously.

The new research, led by PPPL physicists Brian Grierson and Weixing Wang, shows that sufficient heating of the core of the plasma generates a special type of turbulence that produces an intrinsic torque, or twisting force, that causes the plasma to generate its own sheared flow. The findings have relevance to large, future reactors, since neutral beam injection will create only limited rotation in the huge plasmas inside such facilities.

The collaborative research by PPPL and General Atomics scientists found that plasmas can organize themselves to produce sheared rotation when heat is added in the right way. The process works like this:

- Heating the core of the plasma produces turbulence that fluctuates in strength along the radius of the gas.
- The fluctuations generate a "residual stress" that acts like a torque that causes the inner and outer parts of the plasma to rotate opposite to each other at different speeds.
- The different rotation speeds represent a balance between the turbulence-produced torque and the viscosity of the plasma, which keeps the gas from spinning arbitrarily fast.

Researchers used the GTS code to simulate the physics of turbulent plasma transport by modeling the behavior of plasma particles as they cycled around magnetic fields. The simulation predicted the rotation profile by modeling the intrinsic torque of the turbulence and the diffusion of its momentum. The predicted rotation agreed quite well, in shape and magnitude, with the rotation observed in DIII-D experiments.

A key next challenge will be to extrapolate the processes for ITER. Such modeling will require massive simulations that will push the limits of the high-performance supercomputers currently available. "With careful experiments and detailed simulations of fundamental physics, we are beginning to understand how the plasma creates its own sheared rotation," said Grierson. "This is a key step along the road to optimizing the plasma flow to make fusion plasmas more stable, and operate with high efficiency."

Physicist Brian Grierson

Safety Training Observation Program (STOP) class

Last session will be held:
Tues., May 2 — 1:30-3:30 p.m., Mod 6 conference room

Please contact Dorothy Strauss, x3072, dstrauss@pppl.gov, to enroll.

Final DVVR

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The DVVR committees identified any potential issues with the major systems and then reviewed those issues to identify anything that might prevent the NSTX-U from restarting and operating reliably. Those issues are then reviewed by an external Extent of Condition (EOC) Committee, which will recommend what actions are needed to remedy those problems. The EOC committee will meet for the second time from May 15 to 18; it met in March to review the first four major systems of the NSTX-U. Its report will form the basis of a corrective action plan that PPPL must submit to the U.S. Department of Energy by September.

Final DVVR on control systems

The final DVVR, April 19 and 20, focused on real-time control and protection systems—the complex computer systems that are used to operate NSTX-U during plasma shots or experiments and are designed to stop operation if something suddenly goes wrong.

Members of the review committee questioned whether the system needs more sophisticated algorithms that would detect problems as they develop since the system did not detect the coil failure. "It's clear with the benefit of hindsight that there were indications of problems that were so small that the systems didn't pick them up," Hawryluk said.

The control system will also have to be changed to reflect any changes in the NSTX-U coils. If PPPL makes changes in the design of new coils to replace the PF1 upper and lower coils, those changes will also have to be reflected in the control system.

From left: Bob Marsala, Tom Todd, Axel Winter, Stefan Gerhardt *(Photo by Elle Starkman)*

From left: Dennis Mueller, Stefan Gerhardt, Axel Winter, Tom Todd, Ed Lawson *(Photo by Elle Starkman)*

The review team also discussed having redundant systems for ground faults so that there is a backup immediately available if a system fails.

Frank Hoffman was the responsible engineer for the DVVR and Stefan Gerhardt, the deputy head of engineering for the Recovery Project, chaired the meeting. External reviewers Tom Todd, the head of the EOC Committee, and Axel Winter, from ITER, attended the meeting at PPPL. Other members are Michel Huguet, former head of ITER magnets, and a member of the EOC Committee, along with Dave Terry and Jim Irby, of MIT's Plasma Science and Fusion Center, and David Humphrey from General Atomics, who also is a member of the EOC Committee.

From left: Frank Hoffman, Keith Erickson, Ed Lawson, Bob Marsala, Al von Halle *(Photo by Elle Starkman)*

Dress Up Your Plant!

PPPL's Green Team gave away 100 succulents in honor of Earth Day.

PPPLers can now show off their plants in the Green Team's photo contest. The contest will run from April 24 to May 5. PPPLers may submit one entry each. Five winners will be randomly selected. Please send your submissions to https://goo.gl/forms/XLuVmSZIbIONPxWr1.

—The Green Team

Spring 2017 Princeton Center for Theoretical Science Events

Details about the events and ***required registration*** can be found at http://pcts.princeton.edu/pcts/current_future_programs.html

EVENTS

PCTS Annual Lectureship Series

Charles Kane, University of Pennsylvania
May 1–5, 2017 (No registration is required.)
Details about seminars can be found here.

Tuesday, May 2 — 2:30 p.m.: Seminar #1, PCTS, Room 407 Jadwin Hall
"Symmetry Protected Topological Insulators and Semimetals"

Thursday, May 4 — 8:00 p.m.: Hamilton Lecture, Room A-02 McDonnell Hall
"Topological Phases of Matter"

Friday, May 5 — 11:00 a.m.: Seminar #2, PCTS, Room 407 Jadwin Hall
"Clustering in Luttinger Liquids and the Quantum Hall effect"

Registration is now open for:

"Bangs, Bounces, Black Holes, and Bubbles: Where General Relativity Meets Cosmology"
May 11-13, 2017

http://wwwphy.princeton.edu/pcts/BangsBounces2017/BangsBounces2017.html

PCTS programs do not have a registration fee, unless otherwise noted, however, online registration for participation is required.

All events are held at PCTS, Room 407 Jadwin Hall, unless otherwise noted.

May is National Bike Month

Join PPPL's Bike Month Challenge. Teams are forming now. Go to https://goo.gl/WfyTcU to register, or contact Robert Sheneman, x3392, rshenema@pppl.gov, for more information.

American Red Cross Blood Drive

Thursday, May 25
8 a.m.–1 p.m.

The blood mobile will be parked next to the warehouse near Mod 6 in the Lower Parking Lot. The check-in point will be the Mod 6 Conference Room.

Appointments are still available! Please call the OMO at ext. 3200 or go to redcrossblood.org and enter sponsor code PPPLPrinceton. You can make a difference! Your blood donation matters!

Thank you!
—American Red Cross, Occupational Medicine Office and Human Resources

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BROCK

NICK PETTI
Chef Manager

Café at PPPL

BREAKFAST ..... 7 a.m. • 10 a.m.
CONTINENTAL BREAKFAST ..... 10 a.m. • 11:30 a.m.
LUNCH ..... 11:30 a.m. • 1:30 p.m.
SNACK SERVICE ..... until 2:30 p.m.

	Monday May 1	Tuesday May 2	Wednesday May 3	Thursday May 4	Friday May 5
COMMAND PERFORMANCE **Chef's Feature**	**Chicken Cacciatore**	**Spaghetti with Meatballs** and Garlic Bread	**Carved Ham** over Barley Pilaf with Green Beans	**Beef Barbacoa**	**Pork Tinga Tostada** with Rice and Beans
Early Riser	**Belgian Waffle Sticks**	**Huevos Rancheros**	**Frittata Lorraine**	**Omelette Florentine** with Spinach, Tomato & Mozzarella	**Breakfast Tacos**
Country Kettle	**Chipotle Chicken**	**Pasta Fagioli**	**Turkey Wild Rice**	**Tomato Lentil**	**Chicken Tortilla**
Deli Special	**Smoked Turkey Baguette**	**Greek Tuna Salad** with Pita Chips over Lettuce	**Southwest Turkey, Peppers & Cheddar** with Jalapeño Ranch Spread	**Tomato & Fresh Mozz** on Ciabatta with Basil, Red Onion & Arugula	**Southwest Roasted Vegetable Wrap** with Guacamole
Grill Special	**Italian Grilled Cheese**	**Buffalo Chicken Steak Sandwich** with Fries	**Pizza Burger**	**Chicken Zen Sandwich**	**Chicken Fajita** served with Rice and Beans
Panini	**Buffalo Shrimp Wrap**	**Italian Beef** with Spinach and Provolone	**Portobello Mushroom Pizza**	**Crab Cake** on a Kaiser with Lettuce & Tomato	**Baja Chicken Panini** with Pepperjack, Pico de gallo, and Jalapeno Ranch

MENU SUBJECT TO CHANGE WITHOUT NOTICE

HEART HEALTHY | VEGETARIAN OPTION

WEEKLY

Editor: **Jeanne Jackson DeVoe** ◆ Layout and graphic design: **Kyle Palmer** ◆ Photography: **Elle Starkman** ◆ Science Editor: **John Greenwald** ◆ Science Writer: **Raphael Rosen** ◆ Webmaster: **Chris Cane** ◆ Communications Director: **Larry Bernard**

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DEADLINE for calendar item submissions is noon on WEDNESDAY. Other stories should be submitted no later than noon on TUESDAY.
Comments: commteam@pppl.gov ◆ **PPPL WEEKLY** is archived on the web at: http://w3.pppl.gov/communications/weekly/.