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Video simulation puts a new twist on fusion plasma research

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Samuel Lazerson, an associate research physicist in advanced projects at the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL), has created a video simulation showing the intricate nature of a plasma pulse within an experimental fusion machine known as a heliotron. The simulation shows the superconducting field coils, saddle loops, and plasma of the Large Helical Device (LHD) at the National Institute for Fusion Science in Japan.

Unlike a tokamak-type device, which uses current drive to twist the magnetic field, the LHD uses three-dimensional coils to provide the twisting of the magnetic field needed for particle confinement.

"This video is a depiction of three major components of the Large Helical Device," Lazerson said. "The large circular rings and the helical (twisting pair) component are the magnetic field coils. These are superconducting coils that produce a nearly 3 [T] (Tesla, the Earth's magnetic field at the equator is about 0.00003 Tesla) field in the plasma (depicted in red). The red plasma shape is a twisted ellipse when viewed in cross section. The complex 3D configuration of the coils shapes the plasma. The saddle loops—which appear as thin lines in this video—are a type of magnetic diagnostic used to measure local currents in the plasma. We use these measurements to calculate how the plasma reacts to the field produced by the superconducting coils."

The coils and saddle loops are real machinery. The plasma (red) in the movie is the result of a simulation calculating an equilibrium between the plasma pressure, magnetic field, and plasma currents. The simulation helps him greatly with his research, Lazerson said. Measurements such as these are used in 3D reconstruction codes to fit computer simulations of the plasma to experimental data. This gives researchers a more complete picture of the experiment, allowing them to assess the properties of the plasma for future reactor designs.

"It is extremely difficult to measure quantities inside the plasma," Lazerson noted. "Making detailed 3D measurements is also very difficult. Reconstructions allow us to combine 1D measurements across the plasma and measurements made outside the plasma with models of the physics of the plasma itself. This provides researchers with a detailed 3D picture of the plasma. This allows us to not only have a more detailed interpretation of our measurements but also allows us to perform calculations of quantities that we simply cannot measure."

The relationship between measurements and simulations is a two-way street, he added. "Often, we take measurements that on their own do not tell us much," Lazerson said. "But when we combine these with the geometric information provided by a reconstruction, this allows us to process that data into a more detailed picture of what was happening in the plasma. The data measured in an experiment both constrains our simulation and helps us to calculate more detailed quantities from the measurements."

More information: The work is part of research being presented by Lazerson and colleagues at the 53rd Annual Meeting of the American Physical Society Division of Plasma Physics, being held Nov. 14 - 18, in Salt Lake City, Utah.

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