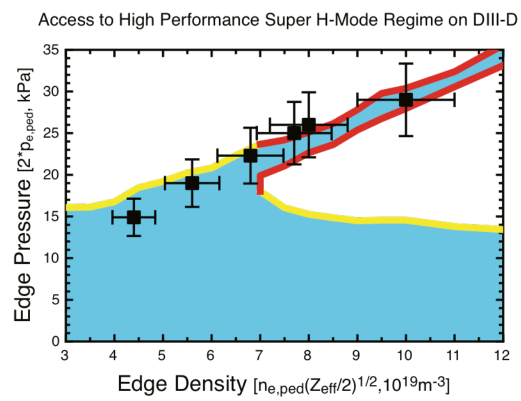
Precise navigation brings plasma experiment to high fusion performance

Milwaukee, WI -- The realization of fusion energy requires very high temperature and pressure, resulting in the state of matter known as plasma, a gas that is so hot that atoms separate into electrically charged particles. Because the particles have electrical charge, specially shaped magnetic fields can be used to contain and insulate the plasma. The efficiency of future fusion power plants will strongly depend on how much pressure can be sustained in the edge of the plasma for a given strength of magnetic field. However, there are physical limits to how much pressure can be confined without the magnetic field releasing the plasma particles onto the chamber walls.

In an exciting new development, scientists at General Atomics' DIII-D experimental facility in San Diego achieved magnetic confinement of plasma at exceptionally high edge pressure. Theoretical analysis of both small scale instabilities that drive turbulence, and larger scale modes, known as "peeling" and "ballooning," produces a map of stable operation. As shown by the colored lines in the figure, the map's shoreline includes a narrow (red) channel that extends to conditions of very high edge pressure. Operation in this narrow channel, known as “Super H-Mode,” is predicted to enable very high fusion performance in both today’s tokamaks and the planned ITER project.



Safe passage of the DIII-D experiment (black symbols) to high edge pressure (red-bounded Super-H Mode region) requires precise navigation through operating conditions. [Courtesy of General Atomics]

Experimentalists then used this information to navigate DIII-D plasma experiments to very high edge pressure and fusion performance. A sequence of DIII-D experiments systematically established operation further and further up the predicted Super H-Mode channel. The achieved plasma conditions are shown by the black squares that are plotted over the theoretical stability map. Temperatures more than ten times hotter than the core of the sun, and more than 20,000 trillion fusion reactions per second, were achieved.

The development of precise control of pressure and density was a key technical achievement that helped enable this success. Additional control of the density with 3D magnetic fields has extended the duration of high performance operation, which is also important for developing plasma confinement for energy production. Future experiments are planned to establish operation yet further up the channel and to enable continuous operation at even higher performance.

Tag line: Theoretical cartography and improved plasma control in the laboratory allow the DIII-D experiment to very high fusion performance.

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