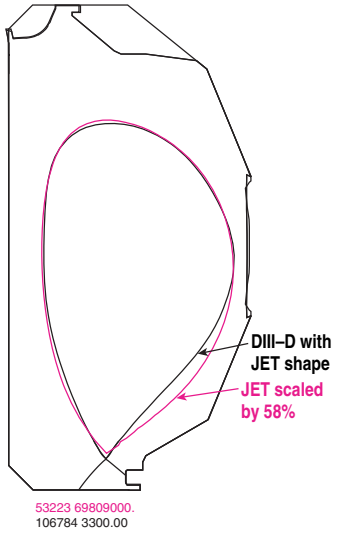
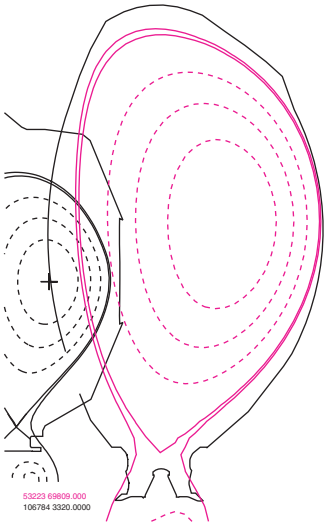
JET/DIII–D "Wind Tunnel" Comparison of Neoclassical Tearing Modes

In tokamaks, the growth of pressure-driven magnetic islands known as neoclassical tearing modes is often the practical limit to high plasma pressure operation. Future reactor-grade tokamaks will be larger in size than any present tokamak and we have no direct measurement of the pressure limit due to magnetic islands under such conditions. However, the pressure limit in future devices can be extrapolated from smaller existing tokamaks just as aircraft design is tested using scale models in wind tunnel experiments. For example, the JET device is 1.75 times larger than DIII–D in the linear dimension and 5.4 times larger in volume, allowing trends with the size of the plasma to be determined by comparison of the two machines.

If the underlying physics of the appearance of magnetic islands is common among tokamaks, the dependence on magnetic field strength and plasma size can be expressed by a few simple parameters such as the ratio of plasma pressure to magnetic field pressure, and the ratio of the plasma size to the size of the small orbits the ions make within the plasma. This principle can be tested by comparing plasmas



Overlay of JET and DIII–D with JET scaled down by 58%



Overlay of JET and DIII–D in real dimensions

which have different sizes but the same values of these simple parameters; the results should be similar in these terms, despite the difference in plasma size. Then these parameters can be used to predict the behavior of other plasmas.

Coordinated experiments were performed at JET and DIII–D to test this "scaling" principle, including participation by JET staff on DIII–D experiments and analysis. Plasmas that were similar in shape and other characteristics were made in both devices, differing only in the plasma size. The occurrence of magnetic islands was found to depend on the simple parameters described above in the same way in both machines, supporting the "scaling" principle. The two experiments spanned a wide range in the ratio of plasma size to ion orbit size, providing valuable information for extrapolation to even larger plasma sizes. Such wind tunnel-type experiments give confidence in our understanding of the physics of magnetic islands and in the use of the "scaling" principle for extrapolation to future reactor-size tokamaks.

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For more information, contact Rob La Haye e-mail lahaye@fusion.gat.com (858) 455-3134
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