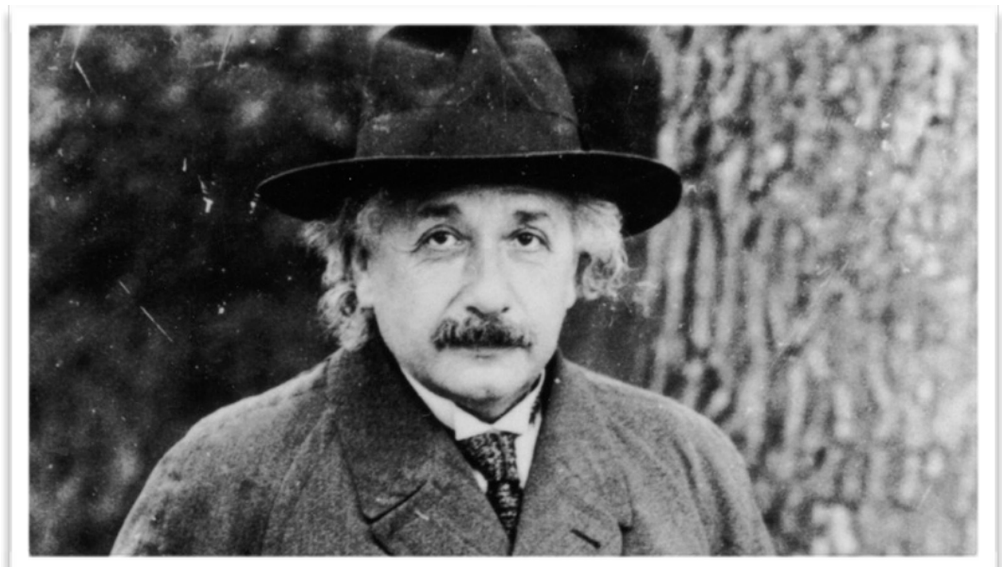
**Concerning matter, we have been all wrong. What we have called matter is energy, whose vibration has been so lowered as to be perceptible to the senses. There is no matter.**

**Albert Einstein**



Arizona State University
SES 194

# Energy in Everyday Life

## Tokamak Fusion

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# Two two key problems for controlled fusion on Earth are heating and containment.

Spider Man 2

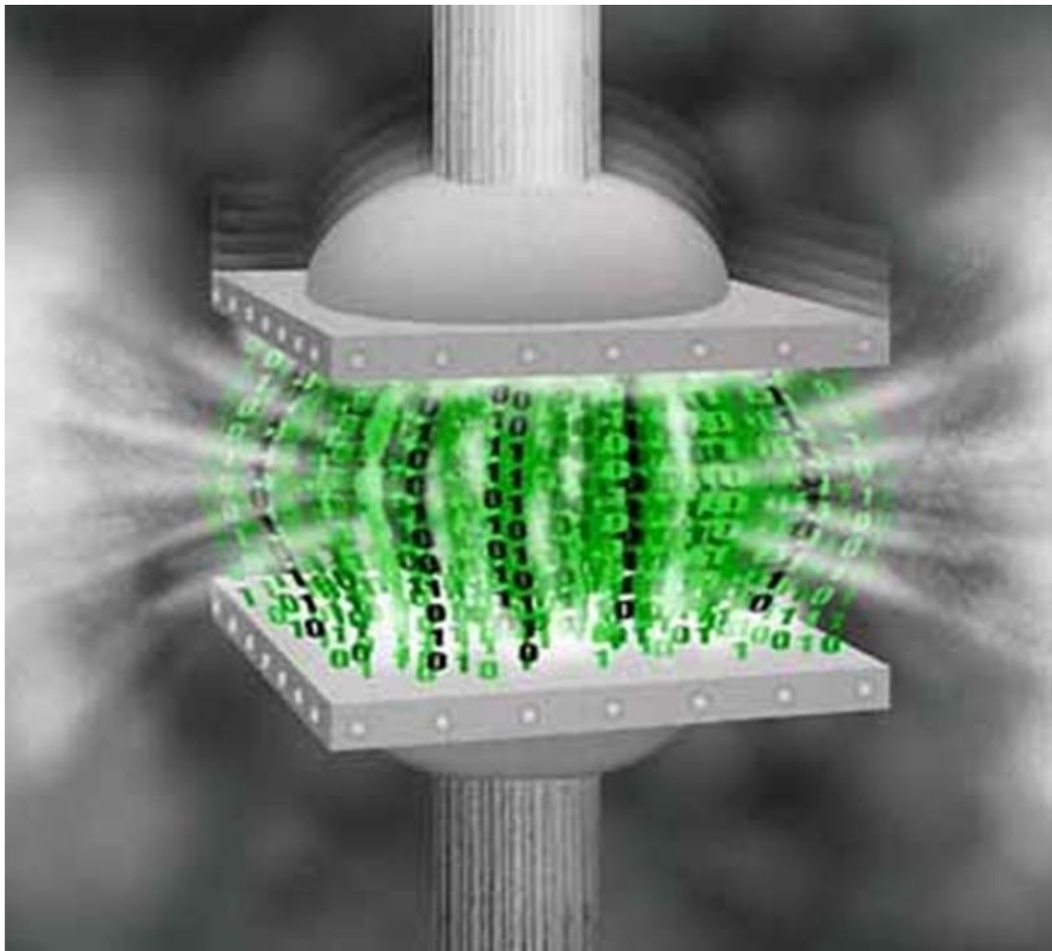
**The reactants must be at sufficiently high temperature, more than $10^8$ K, so that they collide with enough energy to fuse.**

**The temperature must not be allowed to cool before more energy emerges than what we put in (activation energy).**

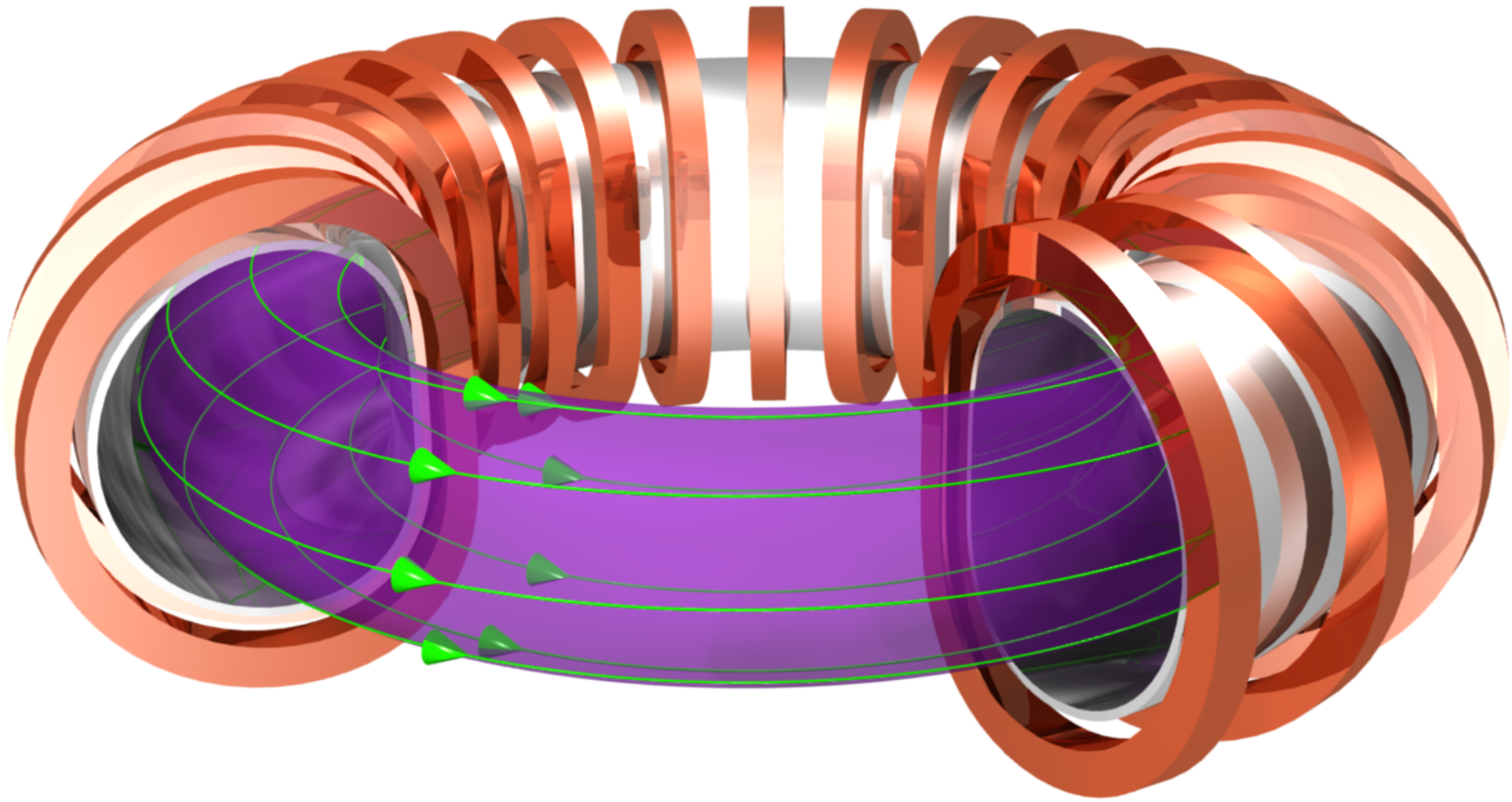
**If hot particles touch any material object, they quickly cool and all possibility of a reaction is lost.**

**How long the reactants must be confined depends on the density.**

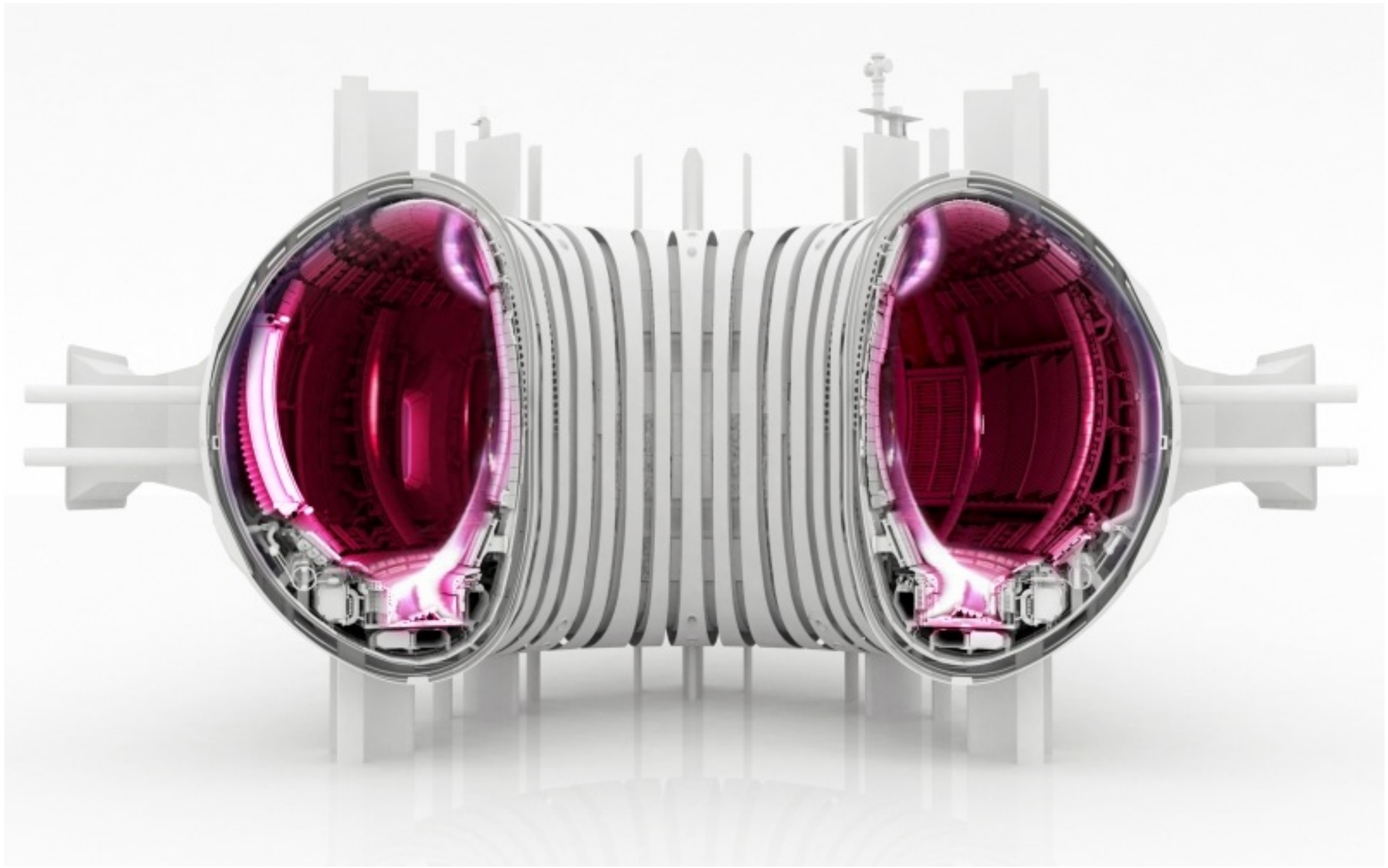
**The greater the density, the more collisions, and the more fusion reaction energy is released in a given time.**



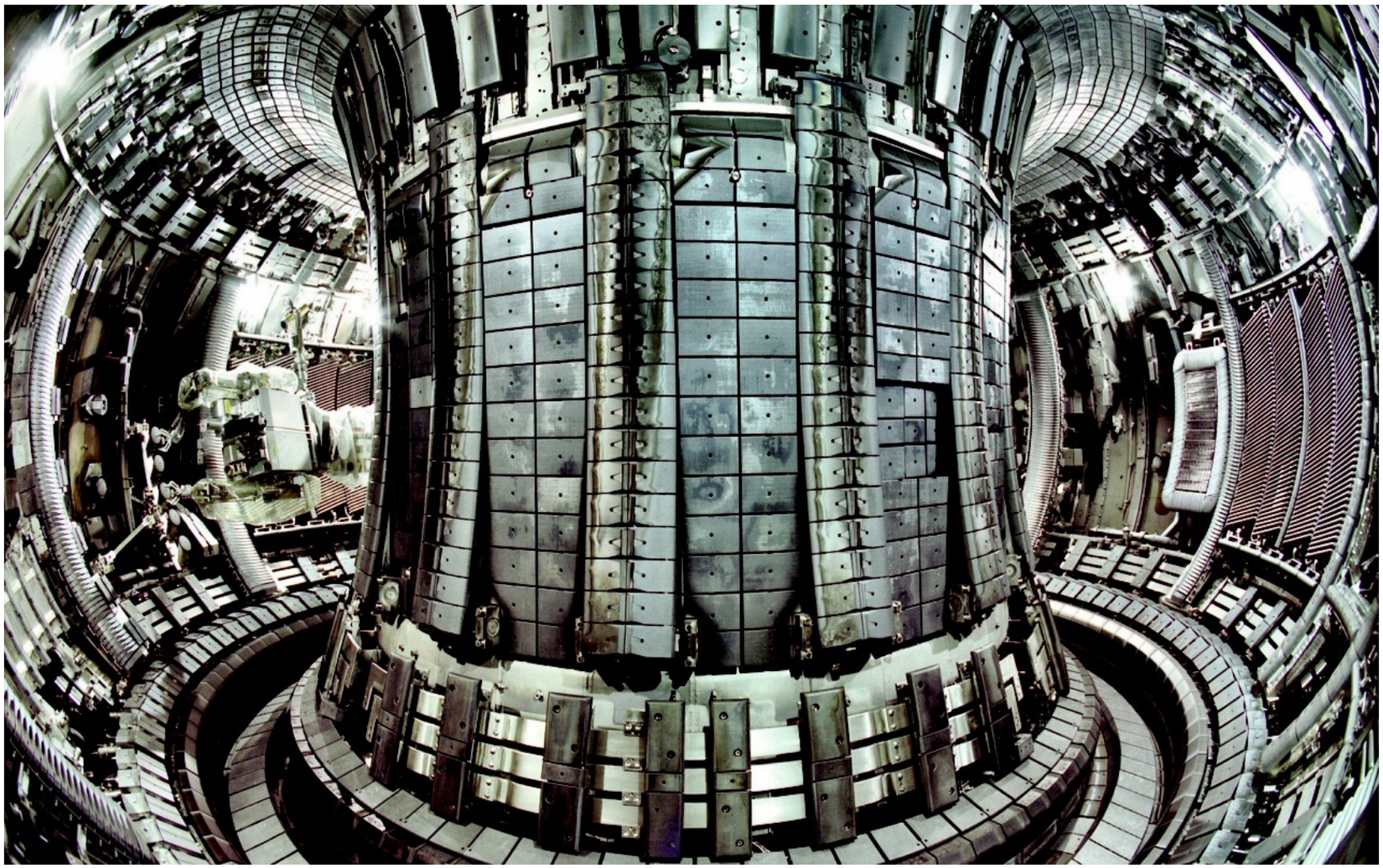
**Fusion on Earth is pursued by two main strategies: magnetic confinement (bottle without walls) and laser implosion (burn before escape).**



**The magnetic confinement idea arose because only a magnetic field, if it is strong enough, can keep hot, charged particles confined long enough by forming a magnetic bottle.**



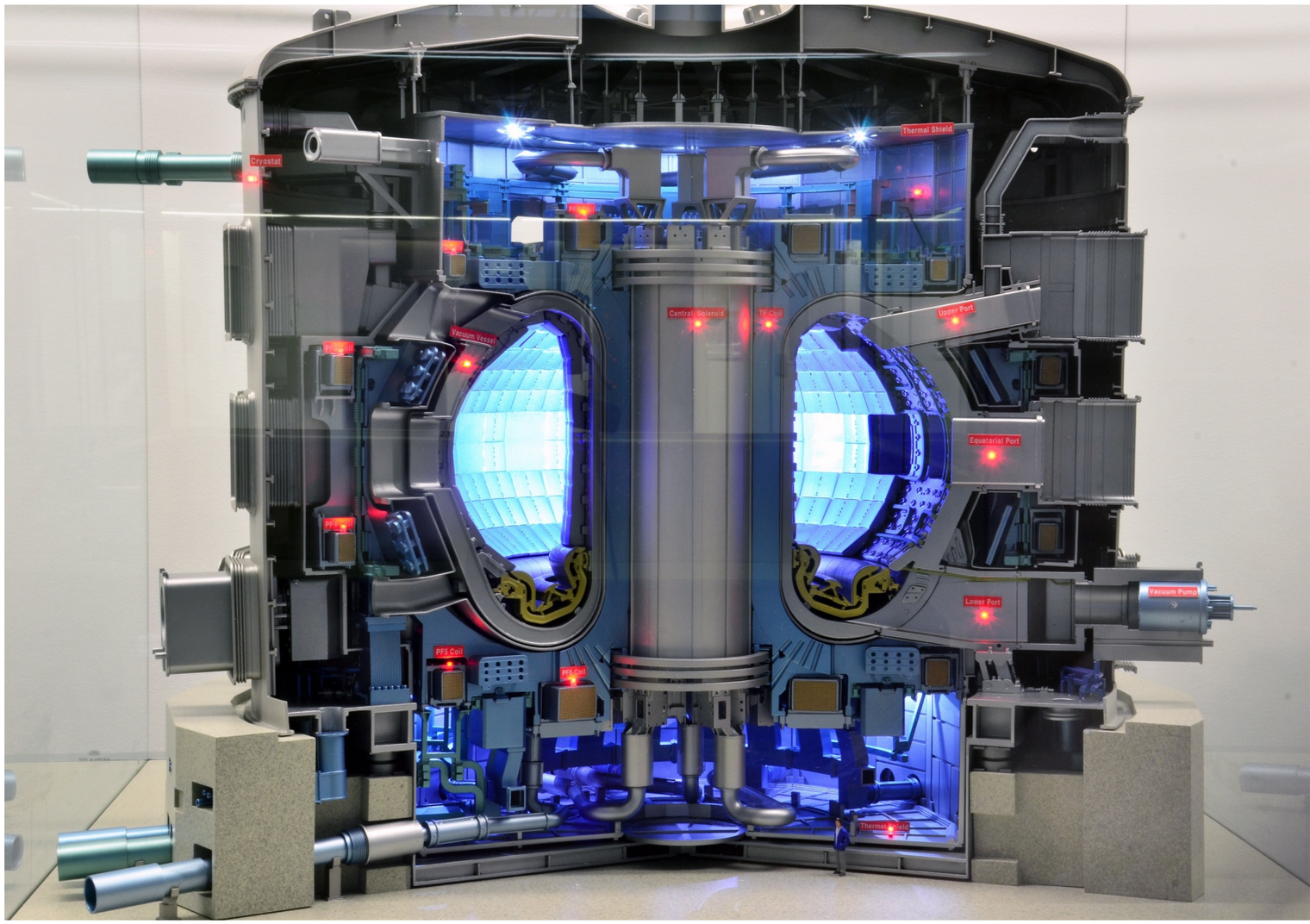
**A tokamak - a device using a magnetic field to confine the hot particles in the shape of a torus - has been one of the more popular approaches.**



**The pressure in the chamber is usually atmospheric with confinement times up to a few seconds.**

**ITER (International Thermonuclear Experimental Reactor and Latin for “the way” or “the road”) is a collaboration building a new tokamak in France.**

china eu india japan korea russia usa




**ITER aims to make the long-awaited transition from studies to full-scale electricity-producing fusion power plants.**

**The basic challenge with tokamaks is stability - keeping the hot reactants confined long enough before they squirt out of the magnetic bottle and cool.**

**Its like squeezing a balloon - the air will always attempt to "pop out" somewhere else.**

**At full power, the bottle can presently hold the hot particles for on the order of millisecond.**