Introduction to Magnetic Thermonuclear Fusion and Related Research Projects

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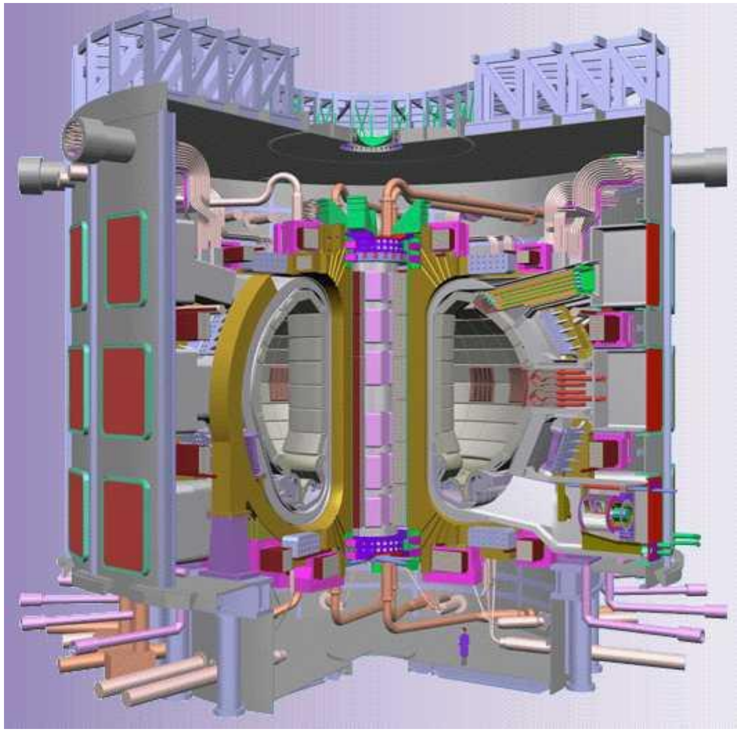
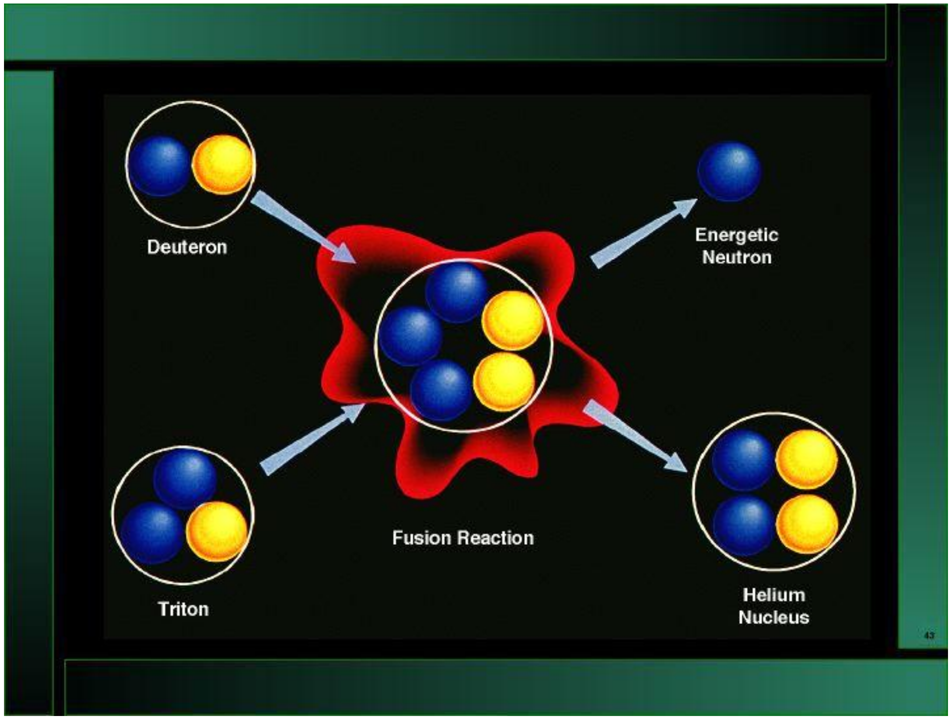
Outline

1. A Brief Introduction to Magnetic Fusion
2. Research on Turbulence (Theory and Experiment)
3. Research on Disruptions
4. Research on Plasma Facing Components

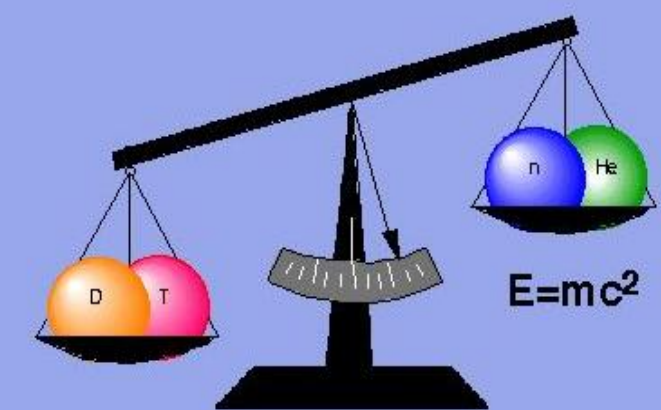


Fusion Occurs when Two Nuclei Unite to Form One



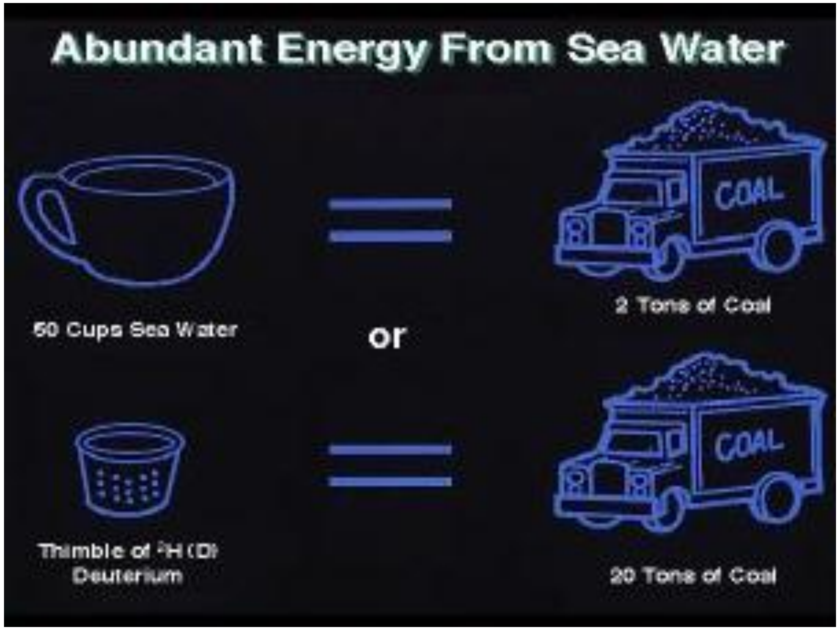
Reaction		Ignition Temperature		Output Energy
Fuel	Product	(millions of °C)	(keV)	(keV)
D + T	^{4}He + n	45	4	17,600

The Energy Results from the Difference in Mass between the Initial and the Final Nuclei

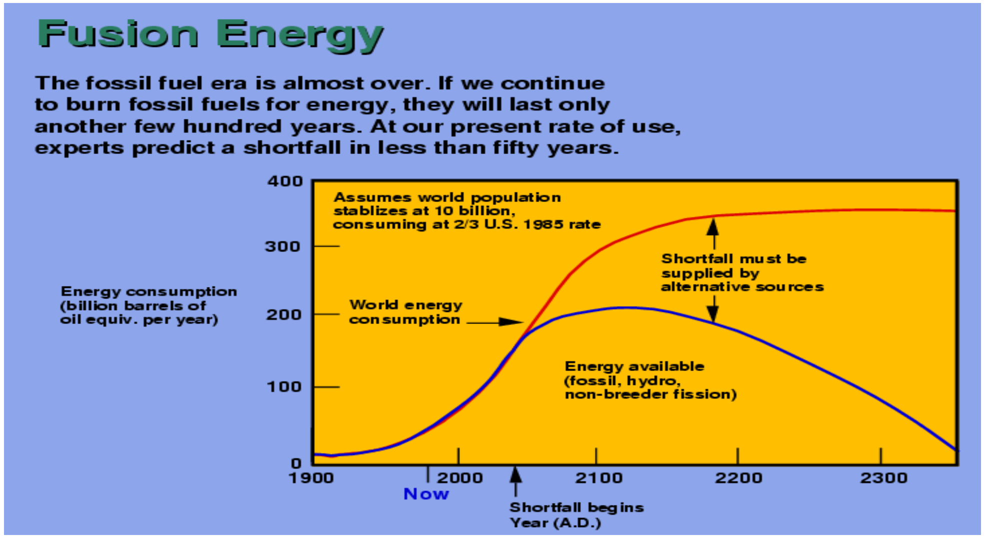


- The fraction of mass "lost" is just 38 parts out of 10,000

Advantages of Fusion on other ways to Produce Energy

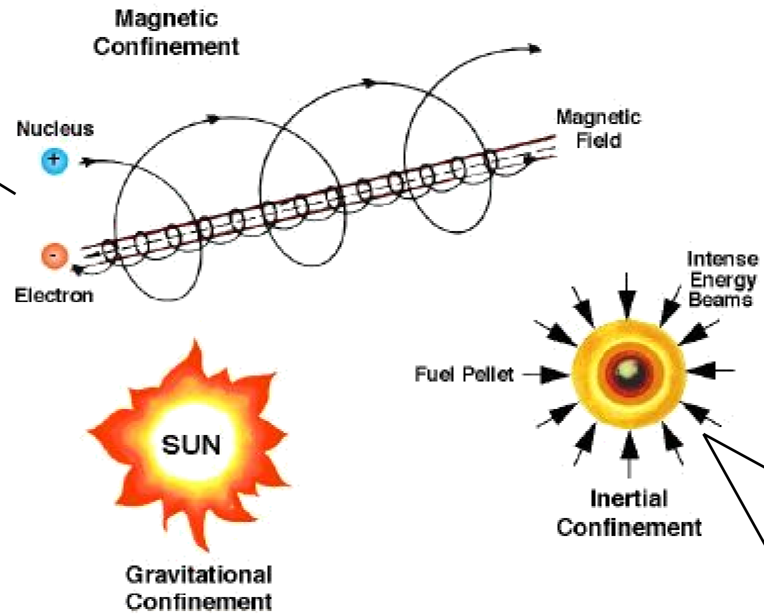


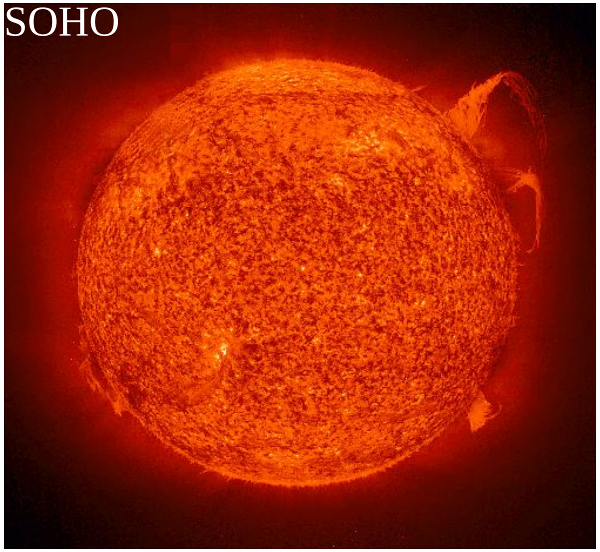
- Abundant Fuel Supply on Earth and Beyond
- No Risk of a Nuclear Accident
- No Air Pollution
- No High-level Nuclear Waste
- No Generation of Weapons Material

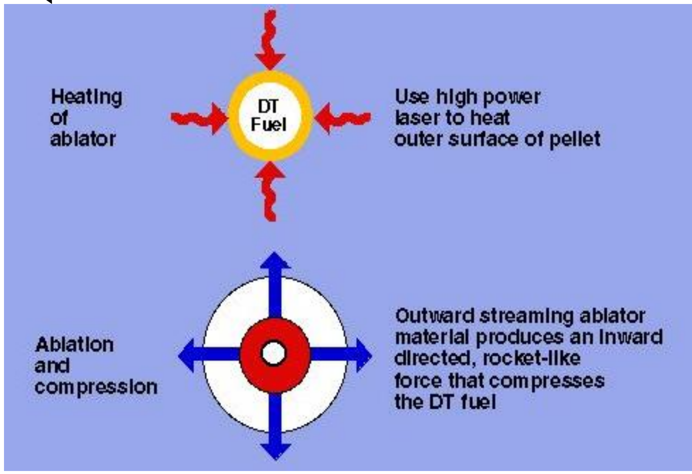


Three Ways to Achieve Fusion

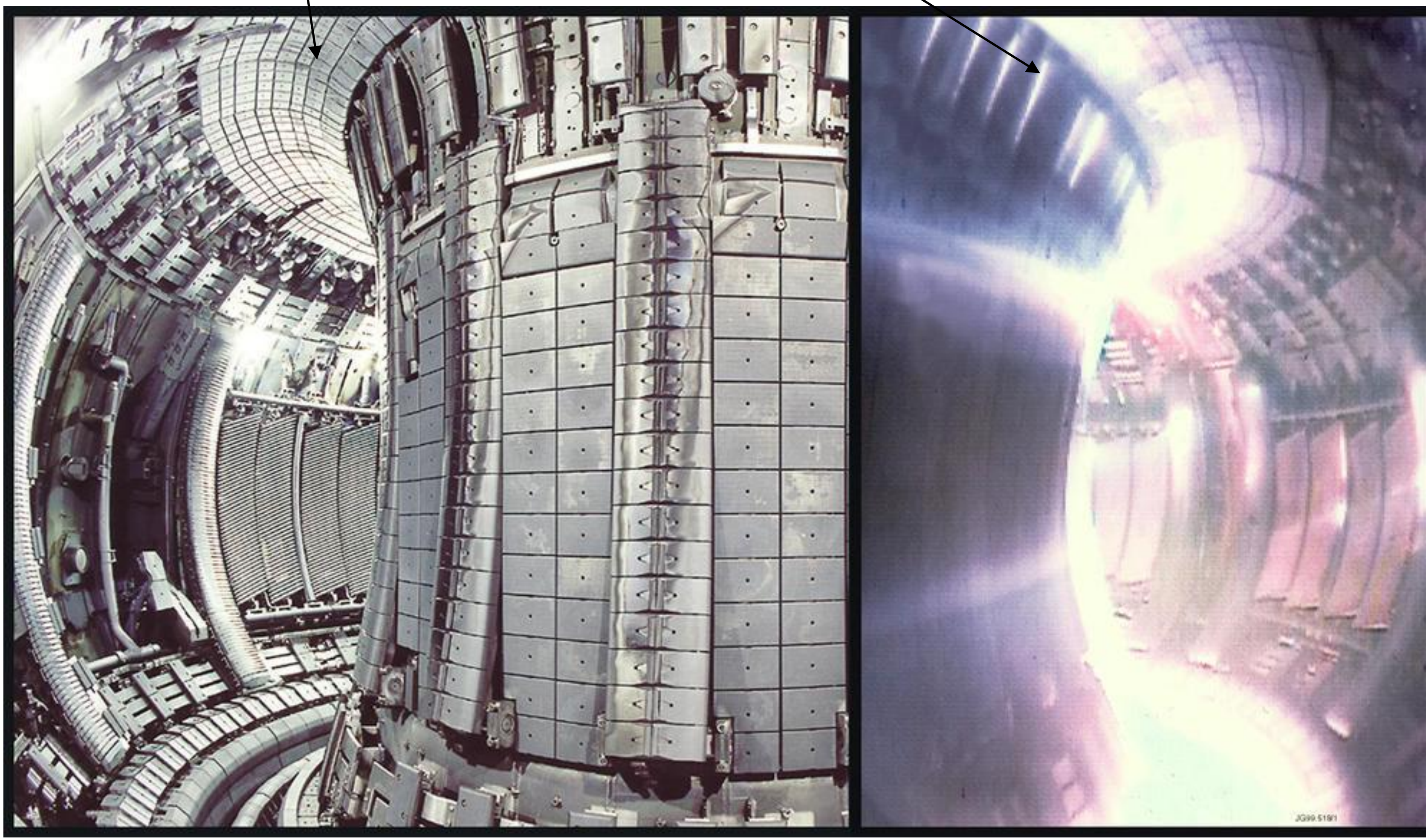
This presentation



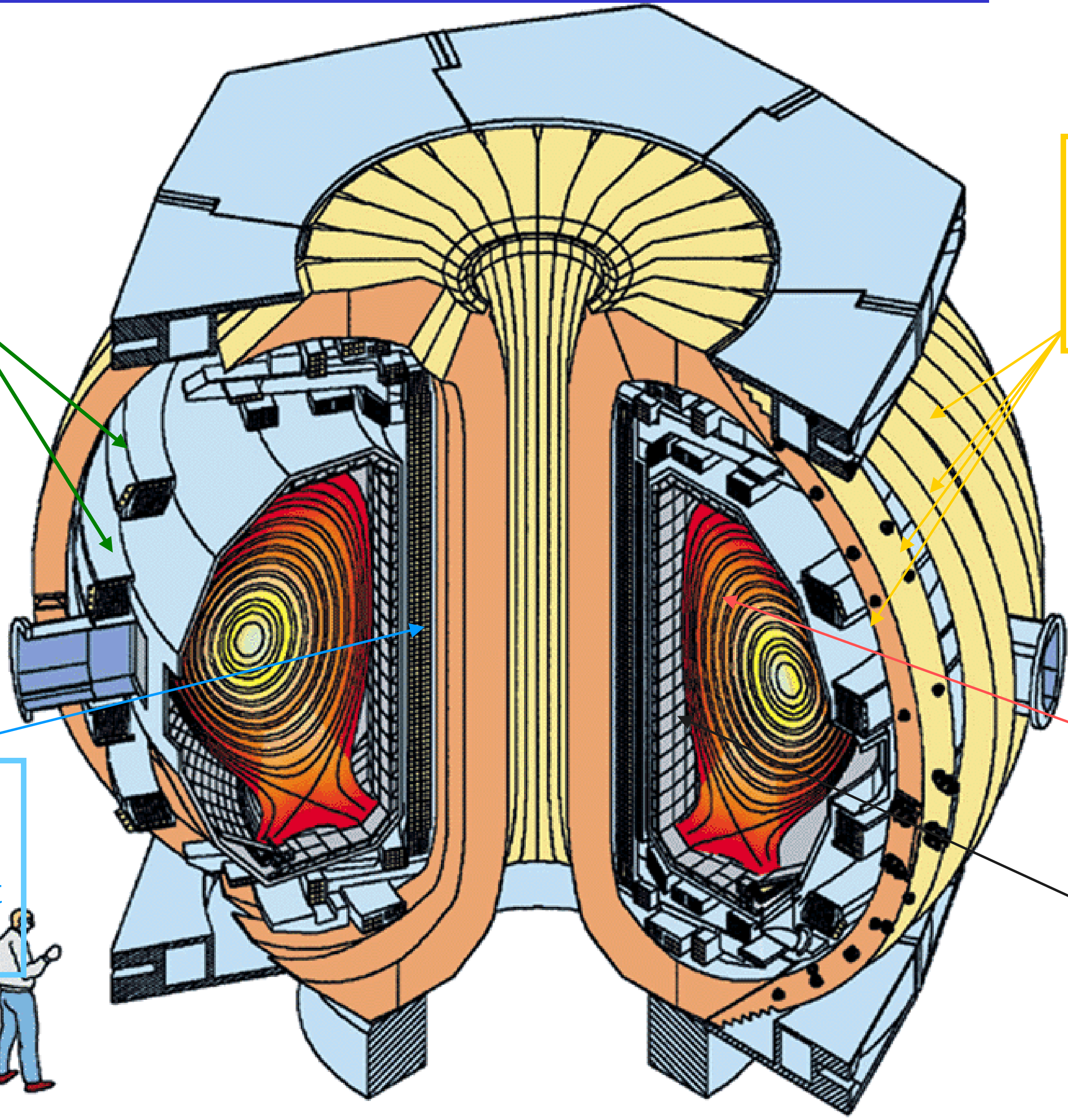




The JET (Joint European Torus) tokamak from Inside without plasma and with plasma



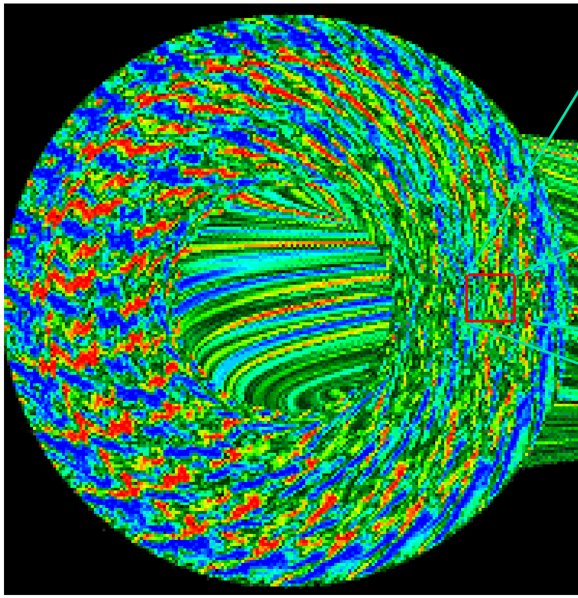
The Main Control "Knobs" in a tokamak are the Magnetic Fields

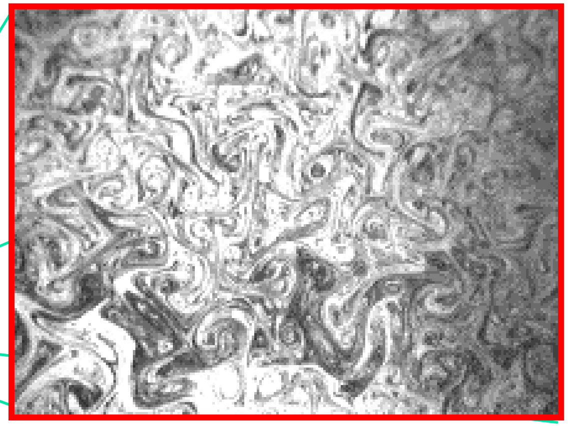


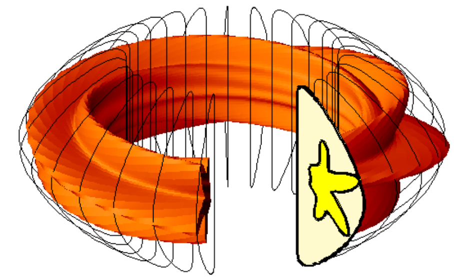
A Black and White Movie (MAST)

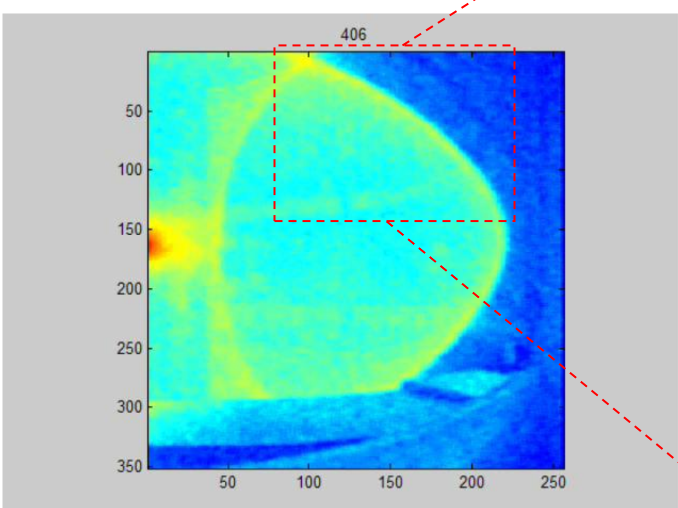
Challenge I: Turbulent transport of particles and energy from the confined region to the walls

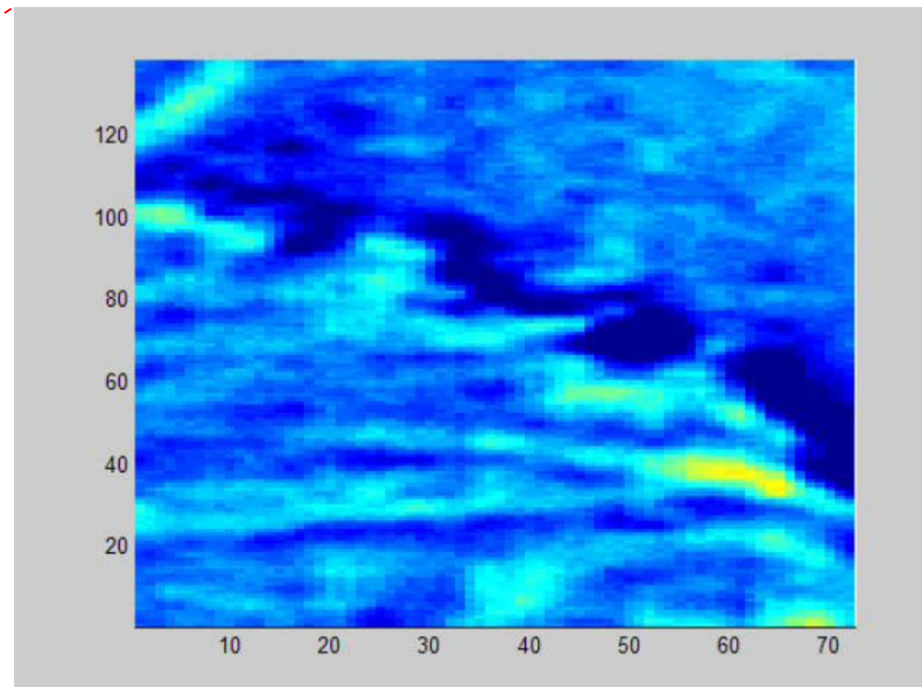
Turbulence decreases the confinement time of magnetic confinement devices





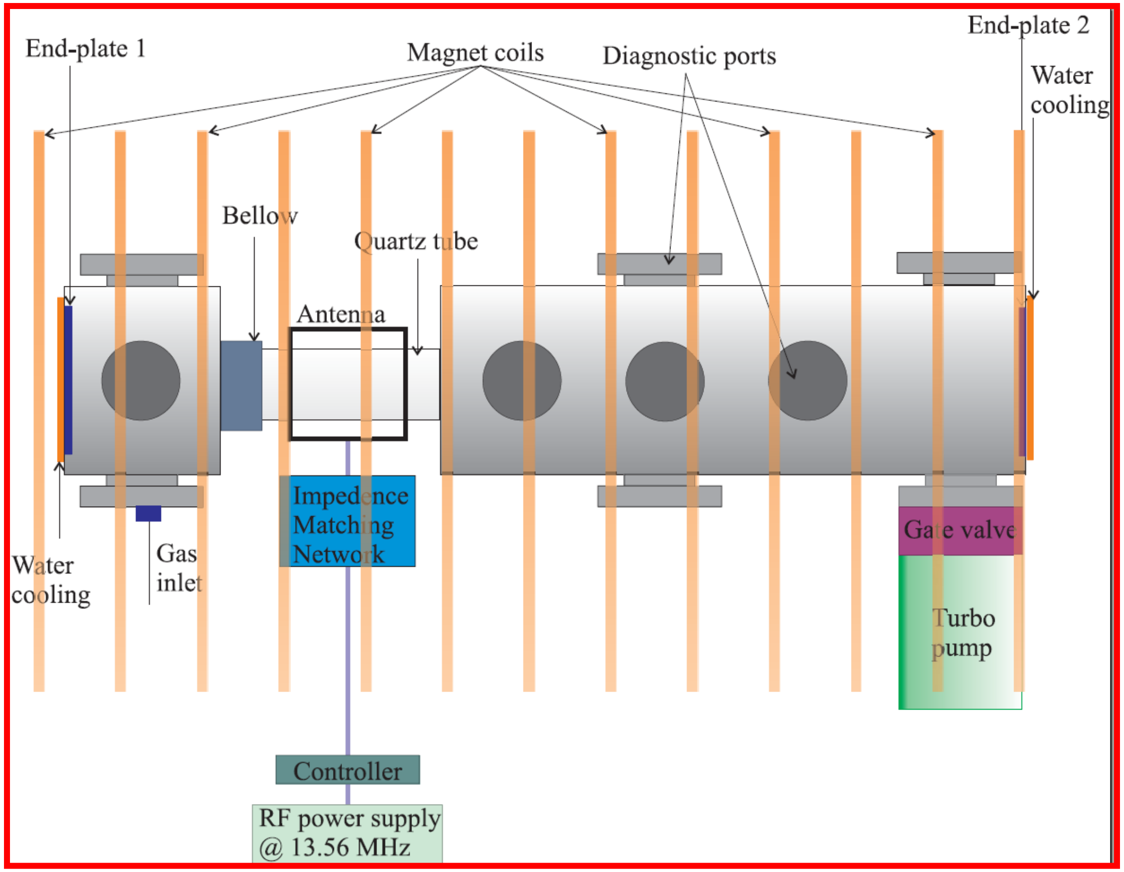




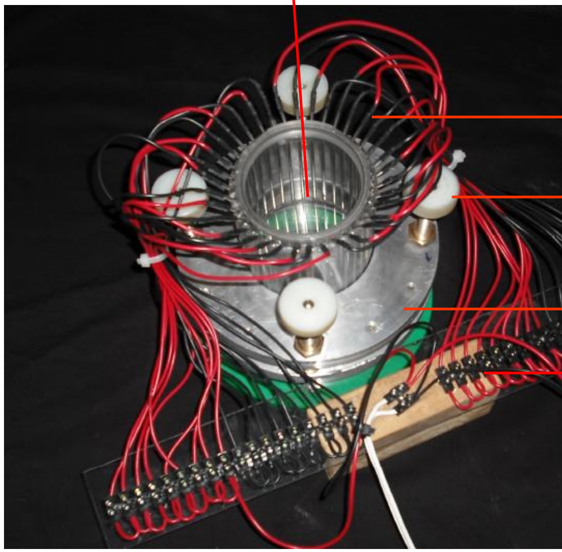


Lebanese Linear Plasma Device [LLPD)

- We are in the process of building a plasma simulator at the Physics Department of AUB. It consists of:
  - a vacuum chamber
  - an RF power source (2 MW)
  - an axial magnetic field about 1000 G.
  - Diagnostics



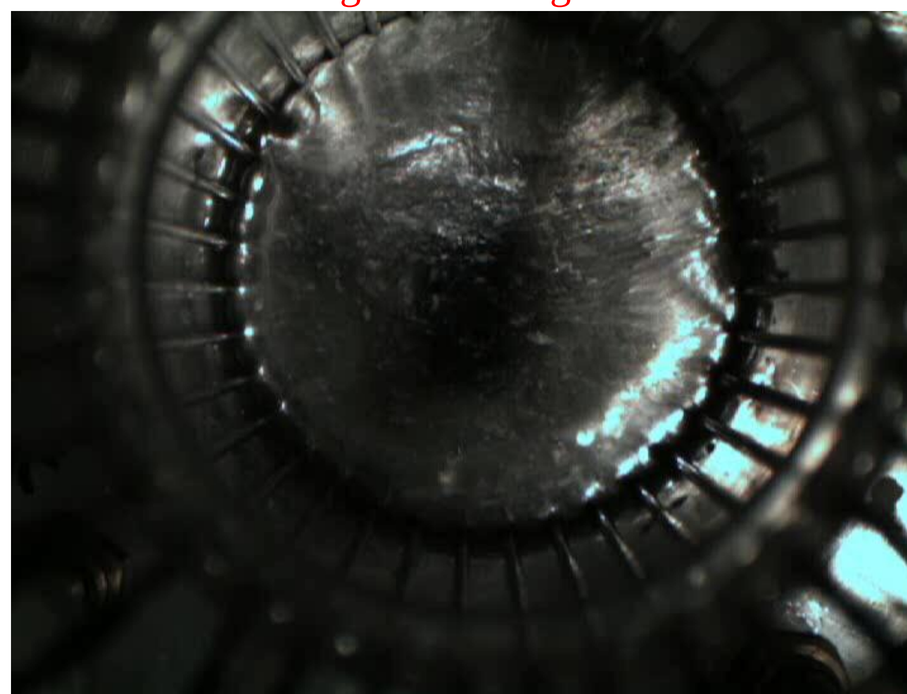
Quasi 2D turbulence, the Gallium Experiment (Poster L. Zaidouny *et al.*)



The experimental setup:

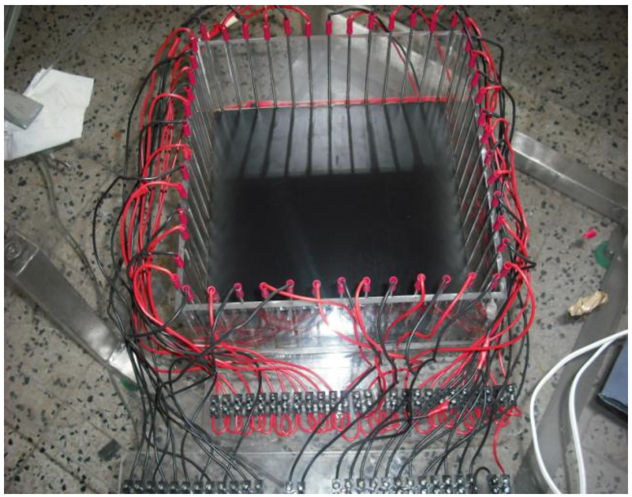
- A set of biased electrodes with variable number
- A strong axial magnetic field
- Liquid gallium with different height is poured in

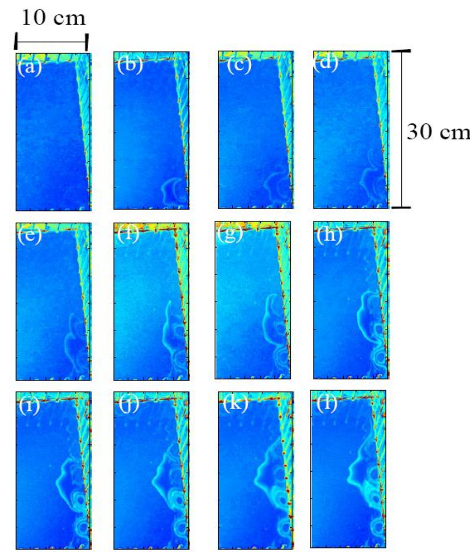
Movie showing motion of gallium in the bulk



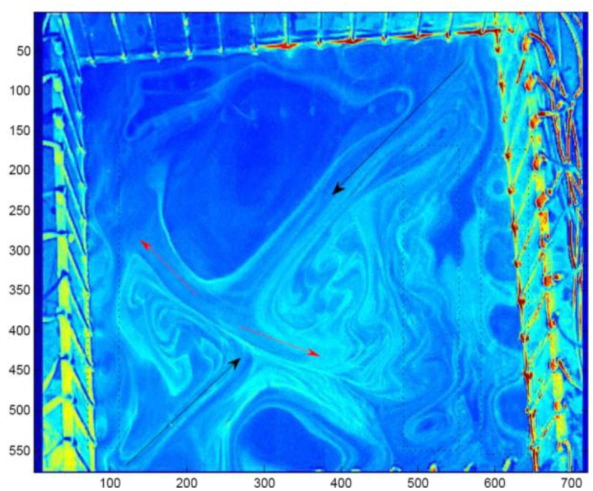
Quasi-2D turbulence, using Electrolytes (Poster L. Moubarak *et al.*)

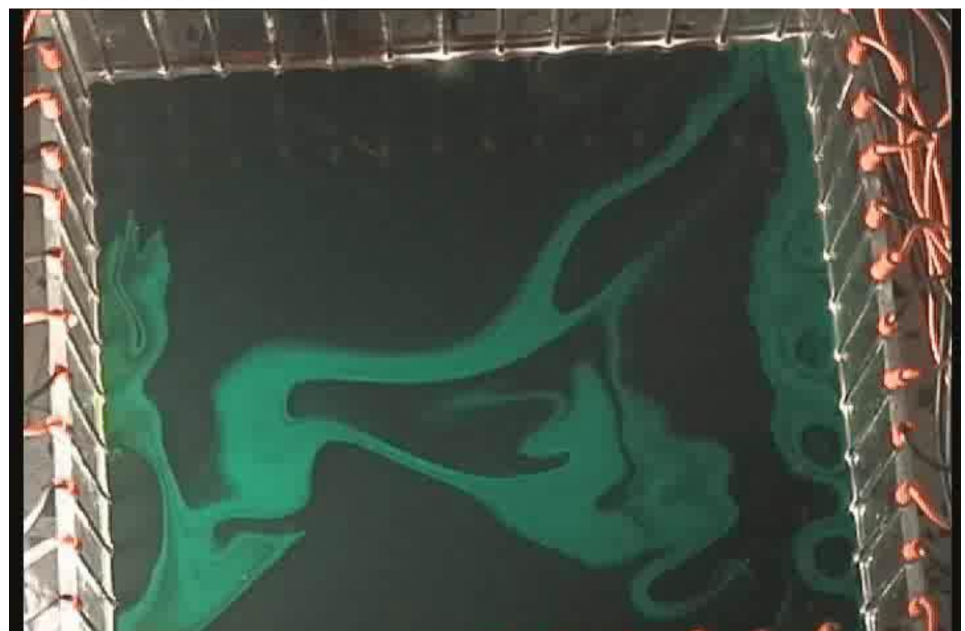
This setup uses the same basic idea as the liquid gallium one but uses a solution of KOH





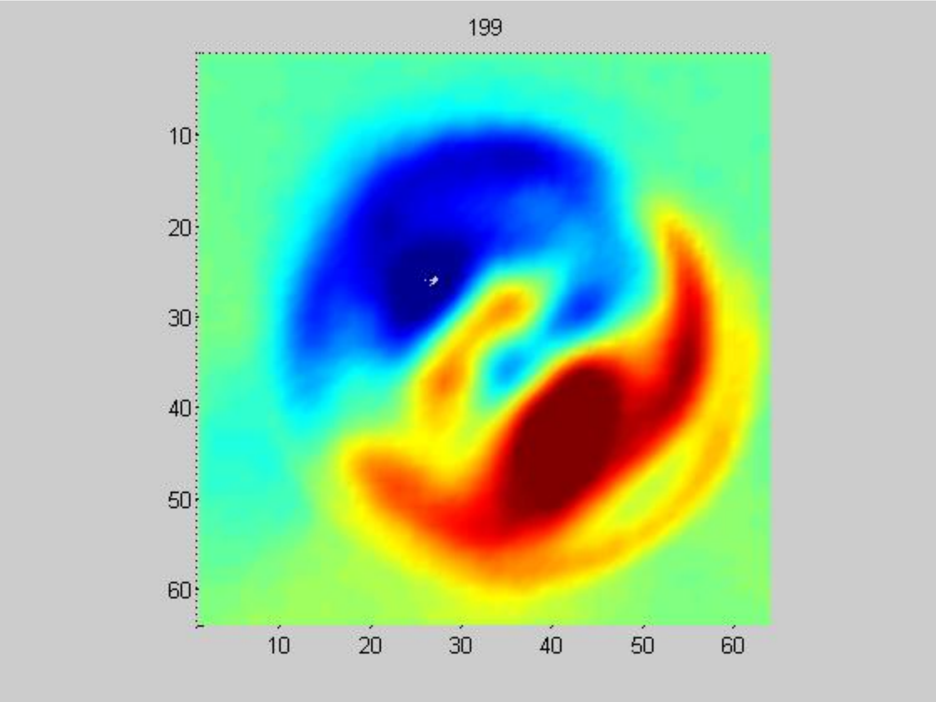
Vortices are reported in the solution as a consequence of electromagnetic forcing
This leads to rather complex dynamics at low Reynolds numbers





Numerical Simulation of turbulence (F. Hariri Oral P5.6)

- The goal is to develop a code simulating plasma turbulence in two dimensions.
- Our first application is to simulate the non-stationary behavior of turbulence that is observed in linear plasma devices.
- We shall use the Hasegawa-Mima and the Hasegawa-Wakatani models for turbulence
- Apply numerical schemes that do not generate artificially vorticity and energy as they both have to be conserved.



⇛ Ion continuity equation

$$\frac{\partial n}{\partial t} + \nabla \cdot (n\mathbf{u}) = 0$$

⇛ Ion momentum balance equation

$$m_i n \left[\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u}\right] = -\nabla p_i + en(\mathbf{E} + \mathbf{u} \times \mathbf{B}) + \mathbf{F} - \nabla \Pi$$

$$\frac{\partial}{\partial t}(\nabla^2\phi - \phi) - [(\nabla\phi \times \hat{z}) \cdot \nabla]\left[\nabla^2\phi - ln\left(\frac{n_0}{\omega_{ci}}\right)\right] = 0$$

Hasegawa-Mima equation

$$\left(\frac{\partial}{\partial t} - \nabla\phi \times \hat{z} \cdot \nabla\right)\nabla^2\phi = c_1(\phi - n) + c_2\nabla^4\phi$$

$$\left(\frac{\partial}{\partial t} - \nabla\phi \times \hat{z} \cdot \nabla\right)(n + ln n_0) = c_1(\phi - n)$$

Hasegawa-Wakatani equations

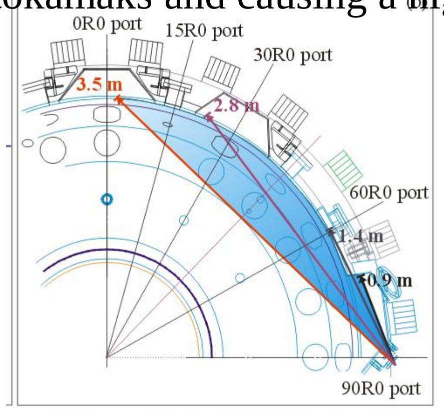
Simulating disruption mitigation in tokamaks (Poster R. Hajjar)

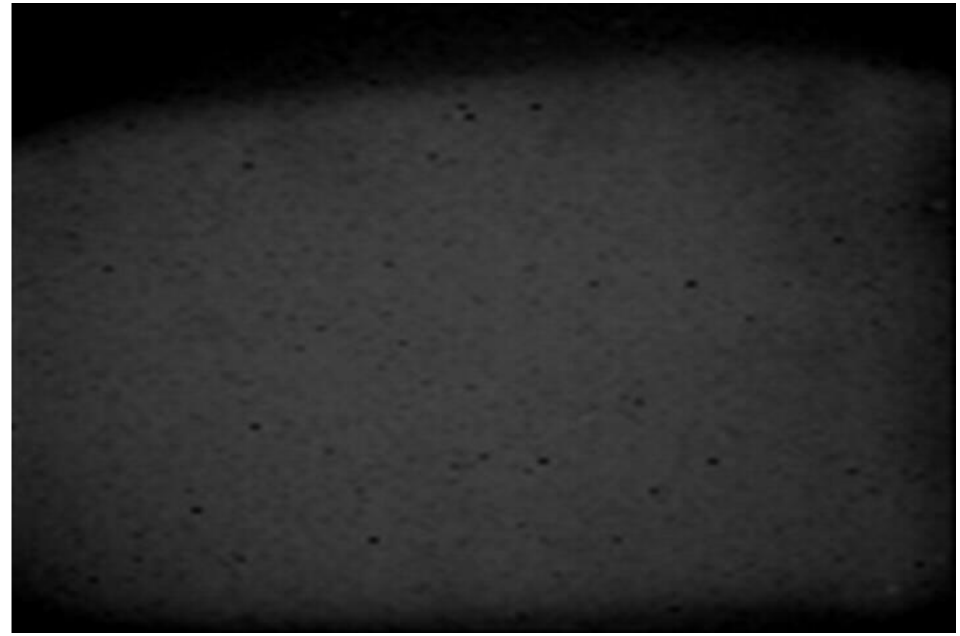
Disruptions are an abrupt and violent halt of the plasma.

Most of the plasma energy is dumped on the walls

Most of the magnetic energy is also dumped into the vessel structure

It is one the main parameters limiting the life-time of tokamaks and causing a high risk of a large damage





It is proposed to **mitigate disruptions** by using a massive gas jet which as it penetrates the plasma, density is increased by ionization which also leads to the decrease of temperature.

The questions we want to answer by numerical simulations:

- How deep will the jet penetrates
- How fast will the jet penetrates
- The type of gas to use
- The design of the setup will it help?

Conclusion

- Various experimental and theoretical research projects are being developed at AUB
- Interested people for collaborations are welcomed
- The main application is to study **fundamental** issues encountered in magnetic fusion plasmas
- These issues are also common to other scientific areas such as: ocean dynamics, atmospheric science, astrophysics, surface science, fluid dynamics etc.