Prospects of Nuclear Fusion Energy Research in Lebanon and the Middle-East

Ghassan Antar

Physics Department

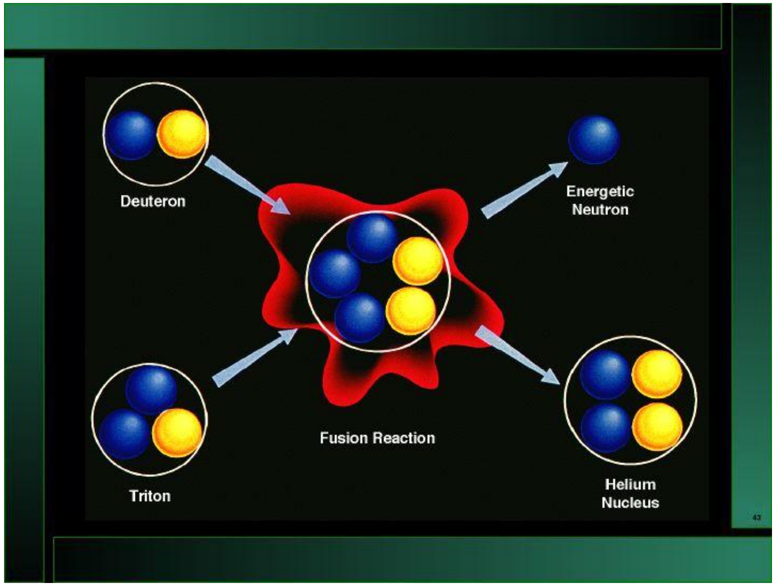
American University of Beirut

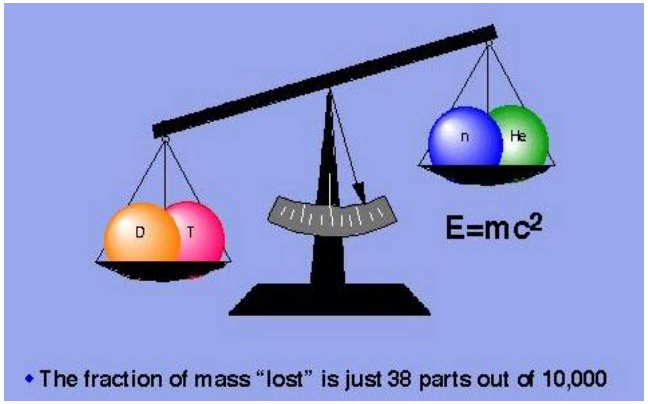
http://www.aub.edu.lb/physics/lpfd

Outline

1. Introduction and Motivation to Magnetic Fusion Research
2. Challenge I: Experimental Research on Turbulence
3. Challenge II: Theoretical Research on Turbulence
4. Challenge III: Research on Disruption mitigation
5. Challenge IV: Research on Plasma Facing Components
6. Conclusion

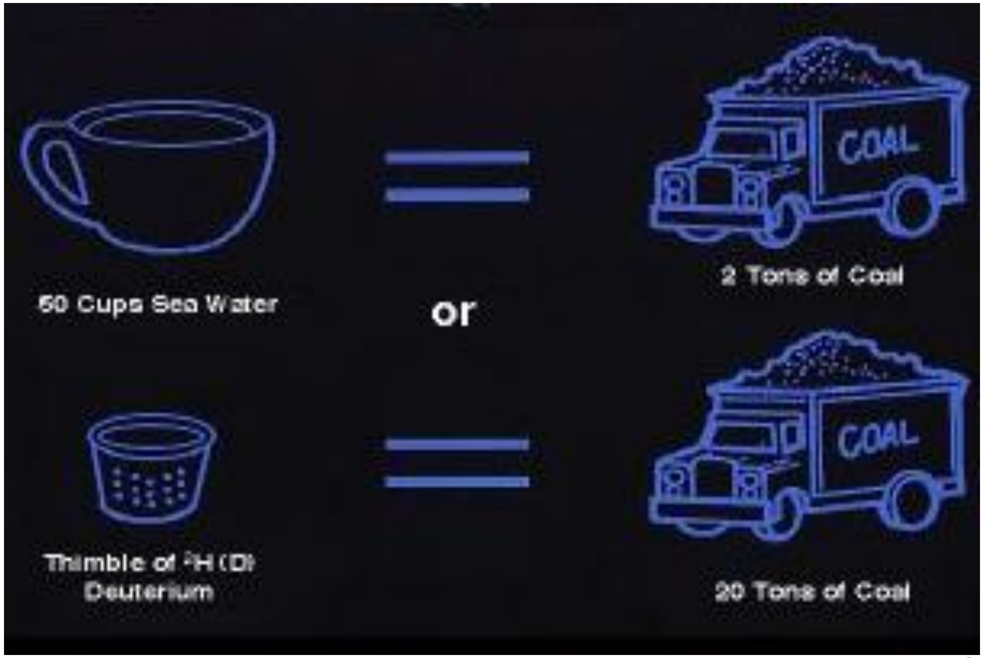
Fusion Occurs when Two Nuclei Unite to Form One





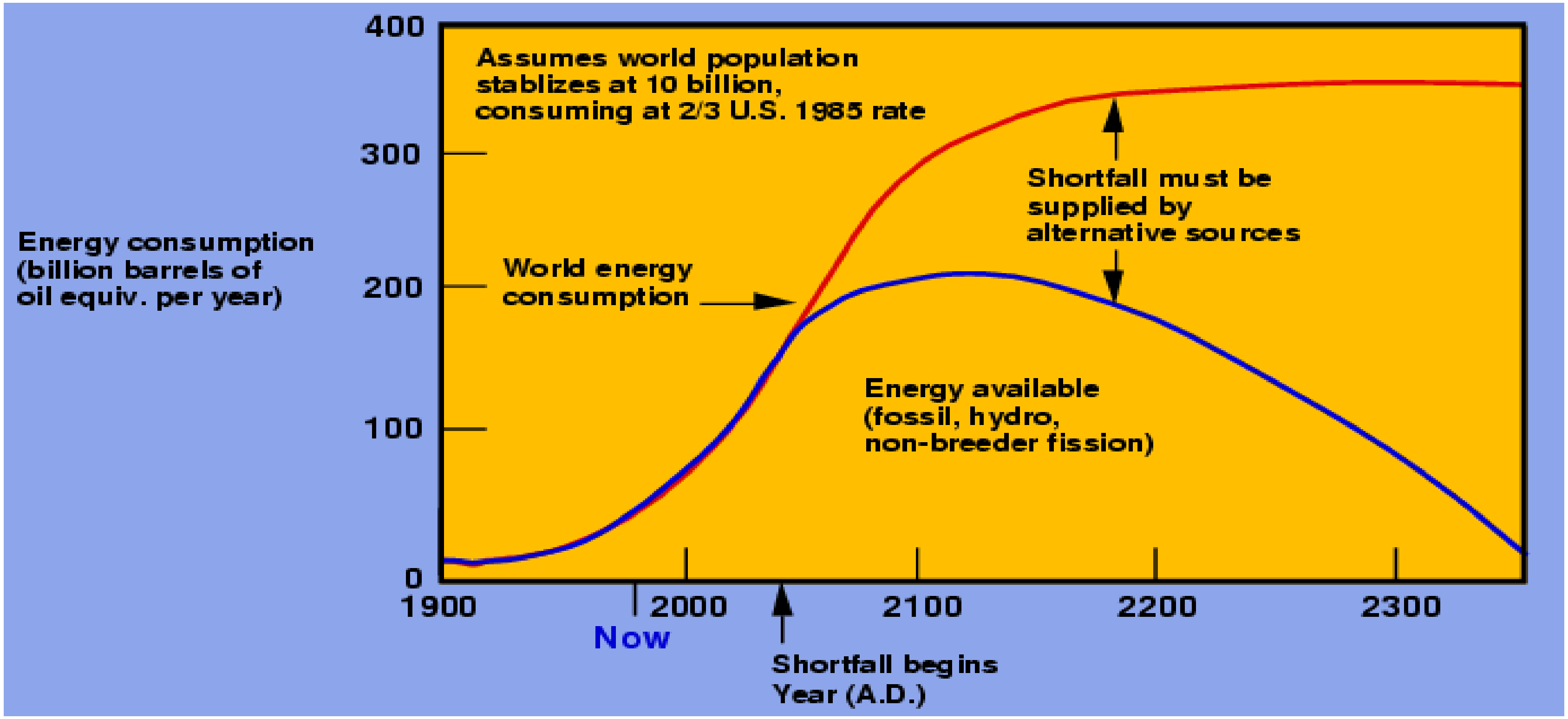
The Energy Results from the Difference in Mass between the Initial and the Final Nuclei

Abundant Energy from Sea Water, few numbers to keep in mind!



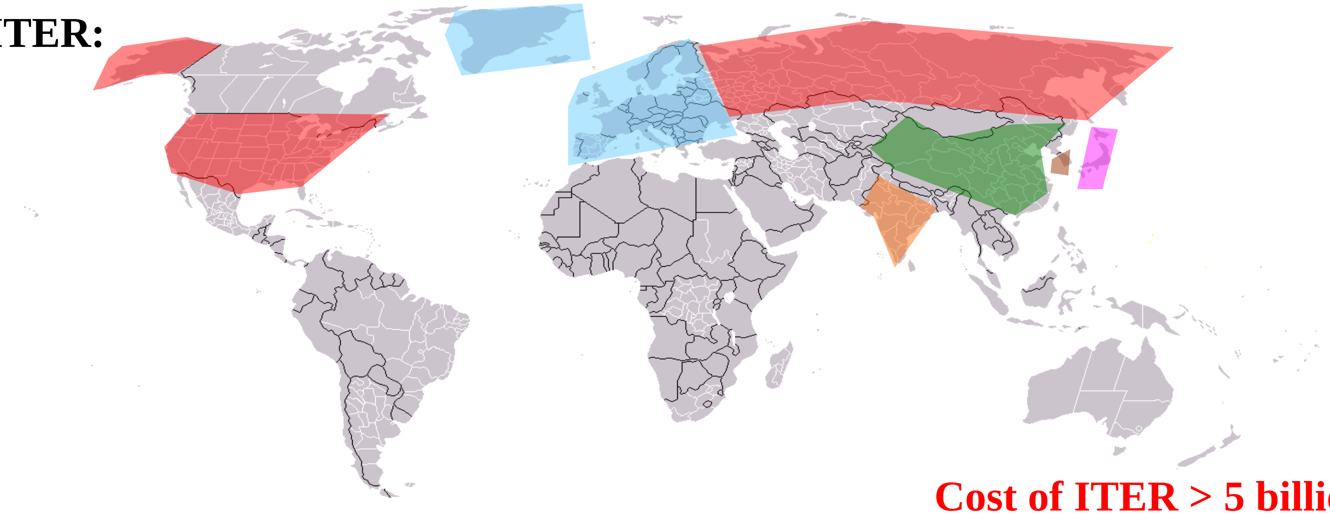
Advantages of Fusion on other ways to Produce Energy

- 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

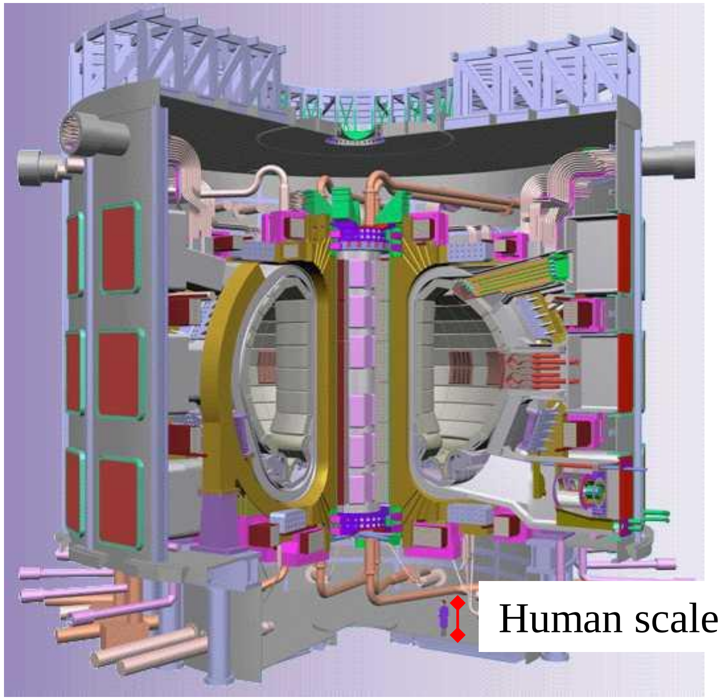


The Strategic Importance of Fusion: The ITER Project

Countries in ITER:

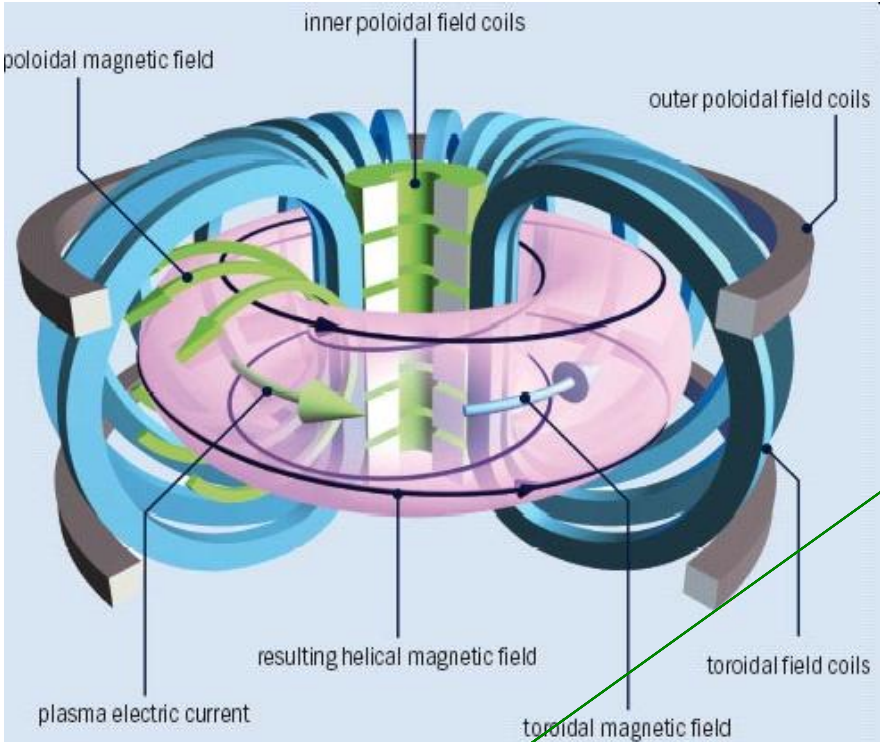


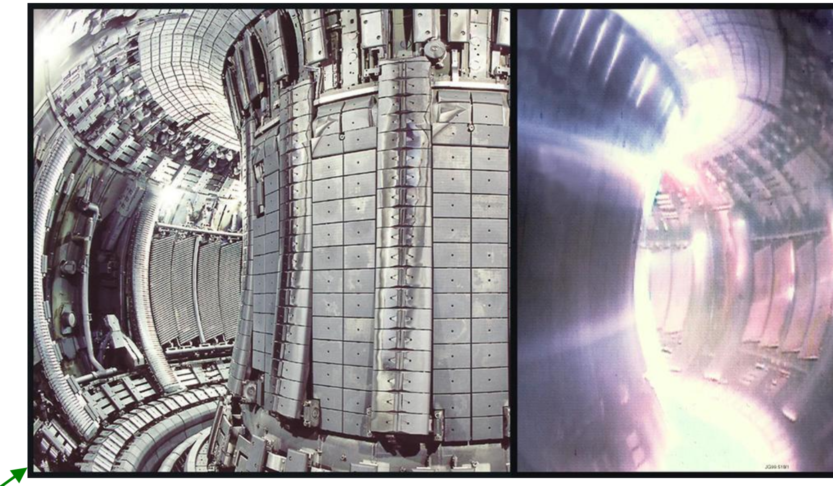
Cost of ITER > 5 billion dollars



Site of ITER: Cadarache (France)

Magnetic Fusion: Particle are Confined Inside a Tokamak so as to increase the Probability of Nuclear Reaction

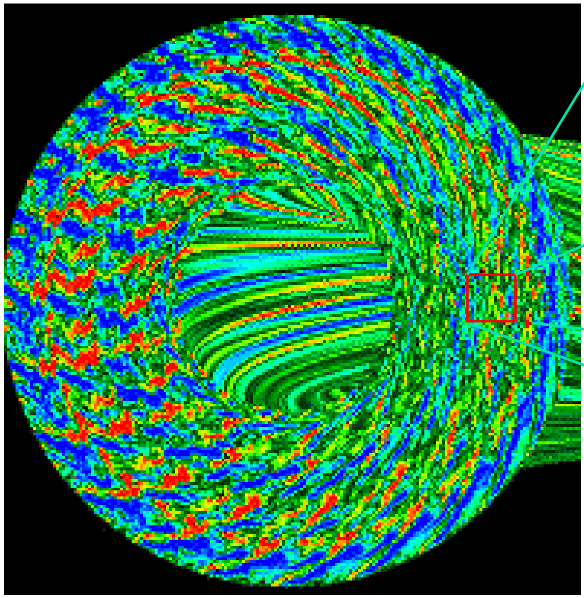


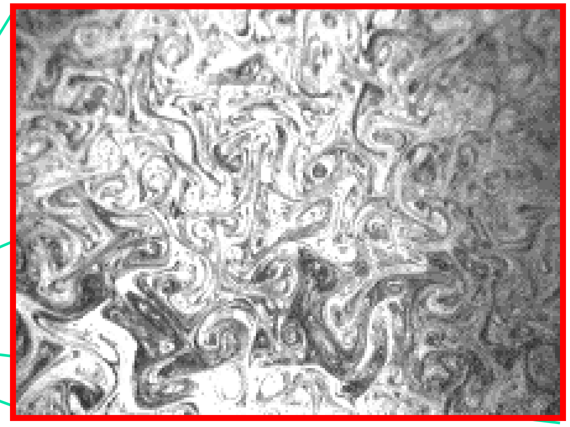


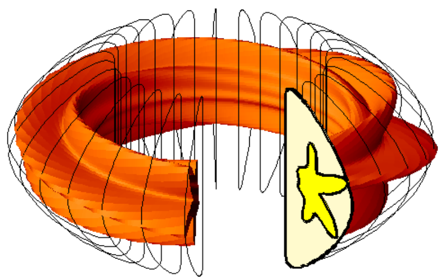
- The JET (Joint European Torus) tokamak from Inside without plasma and with plasma
- Movie from the MAST tokamak

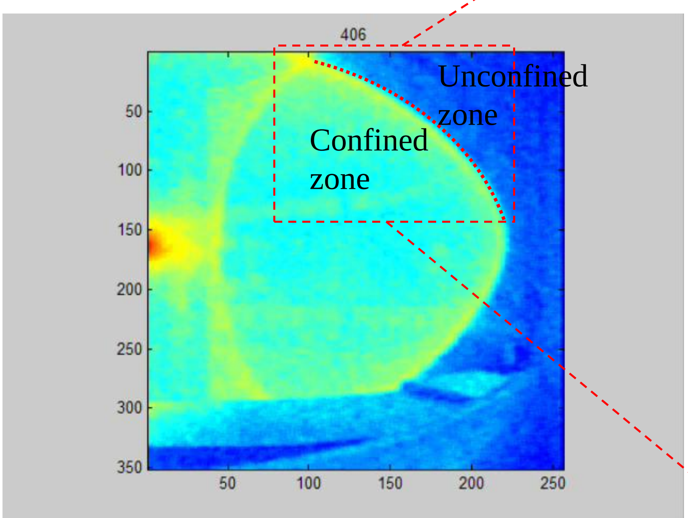
Challenge I: Develop Local Experimental Tools to Study Turbulent transport

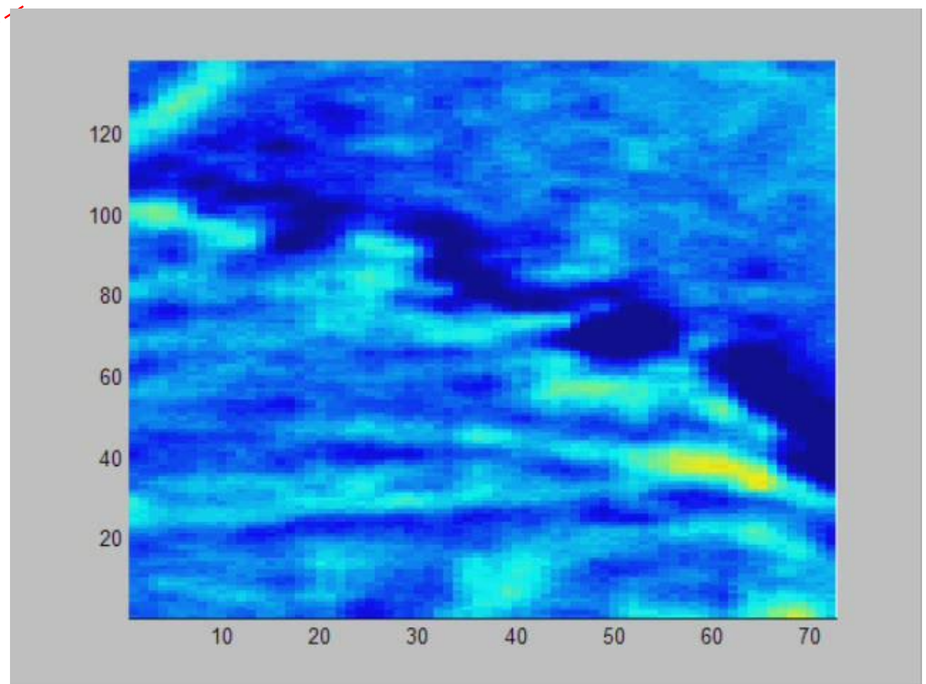
Turbulence decreases the confinement time of magnetic confinement devices





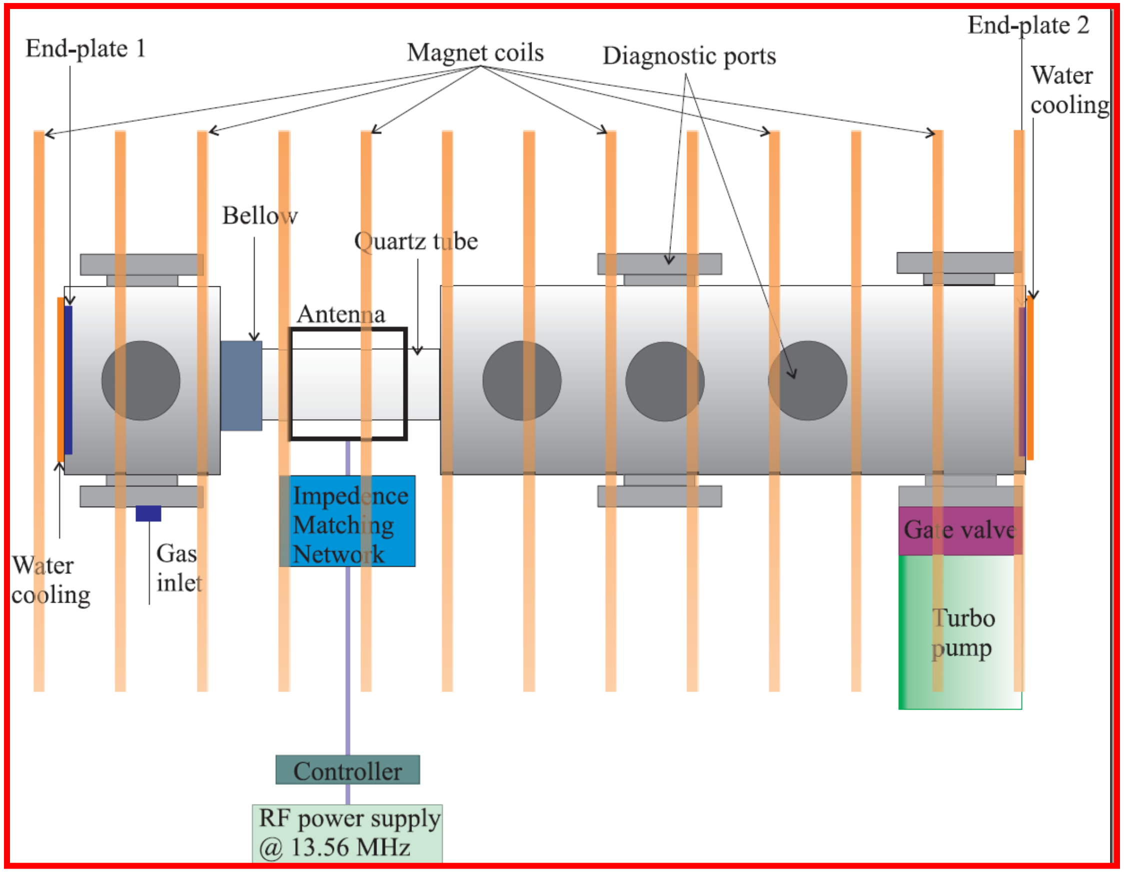


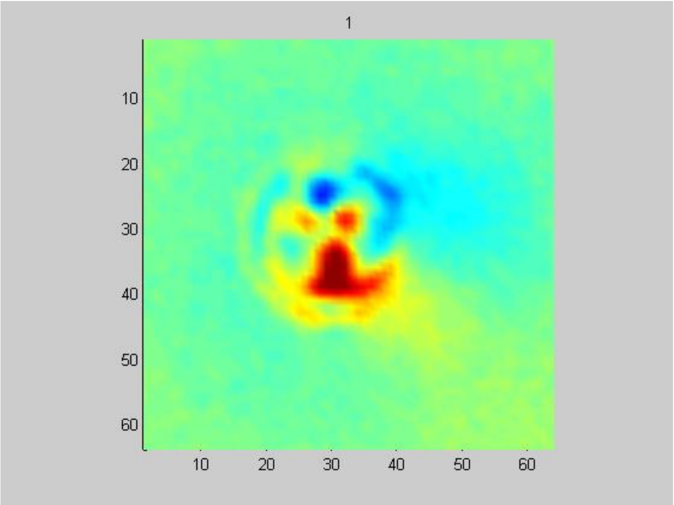




Challenge I: Build the Lebanese Linear Plasma Device [LLPD)

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



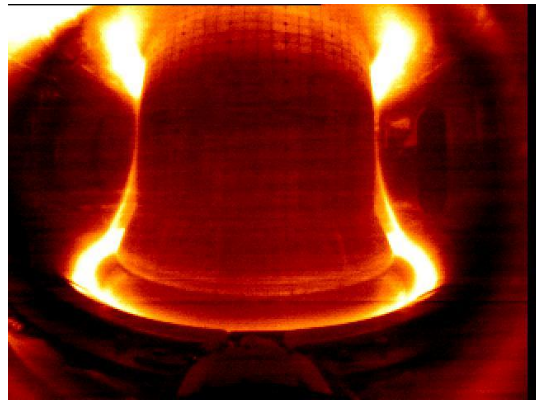


Challenge I: Maintain a high-level of International Collaboration with France, Germany, UK and the USA

Tore Supra tokamak

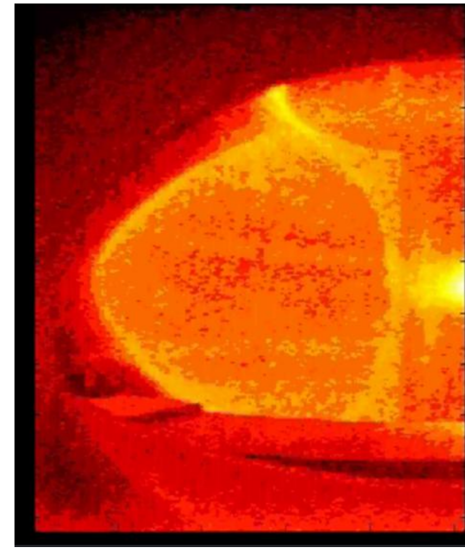
- $a = 76$ cm, $R = 2.32$ m
- $B_T = 3.5$ T, Ip =1 MA
- limiter machine

Alcator C-MOD tokamak



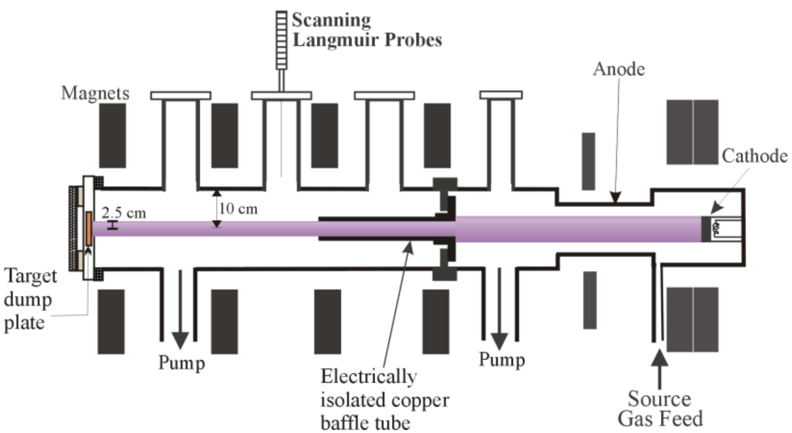
- $a = 21$ cm, $R = 70$ cm
- $B_T = 5.3$ T $I_p \sim 0.8$ MA
- divertor machine

MAST Spherical tokamak



- $a = 52$ cm, $R = 73$ cm
- $B_T = 0.6$ T, I_p =700 kA
- First wall far from the LCFS

PISCES



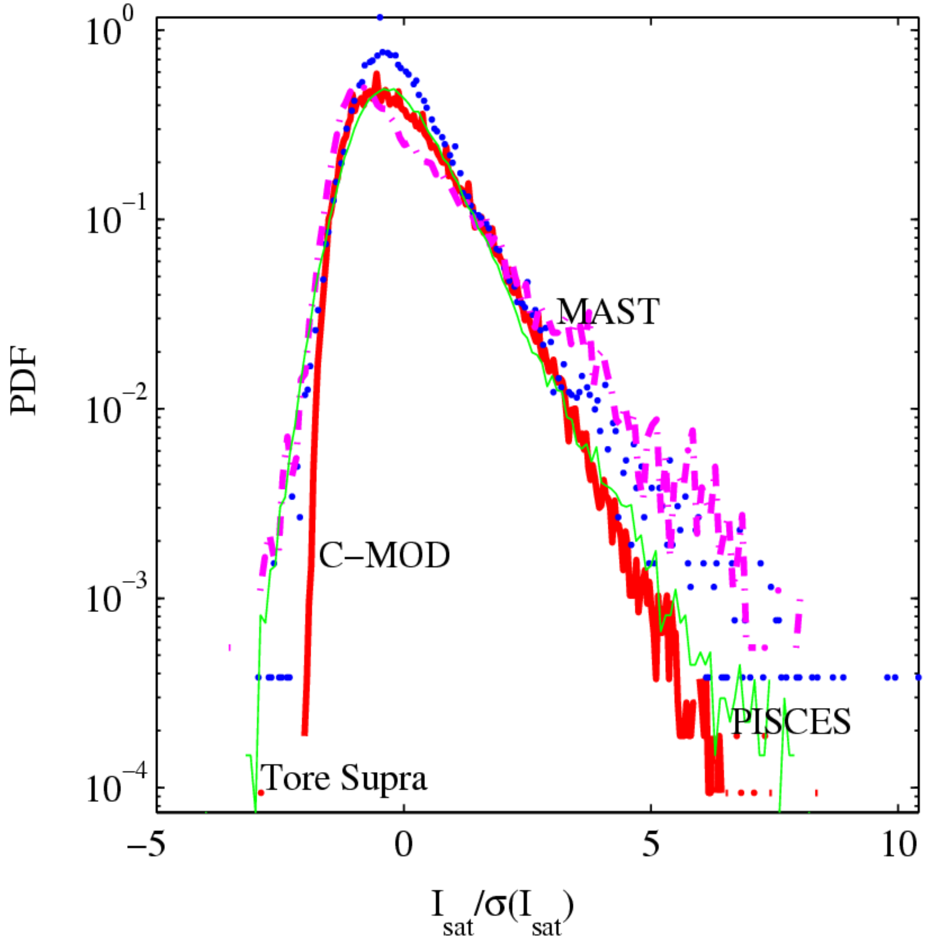
$n_e \sim 10^{17}$ m^{-3}, $T_e \sim 10$ eV,
B = 0.12-0.24 T

- Plasma radius = 2.5 cm
- Vessel radius = 10 cm

Research done on linear devices is relevant to toroidal fusion tokamak physics

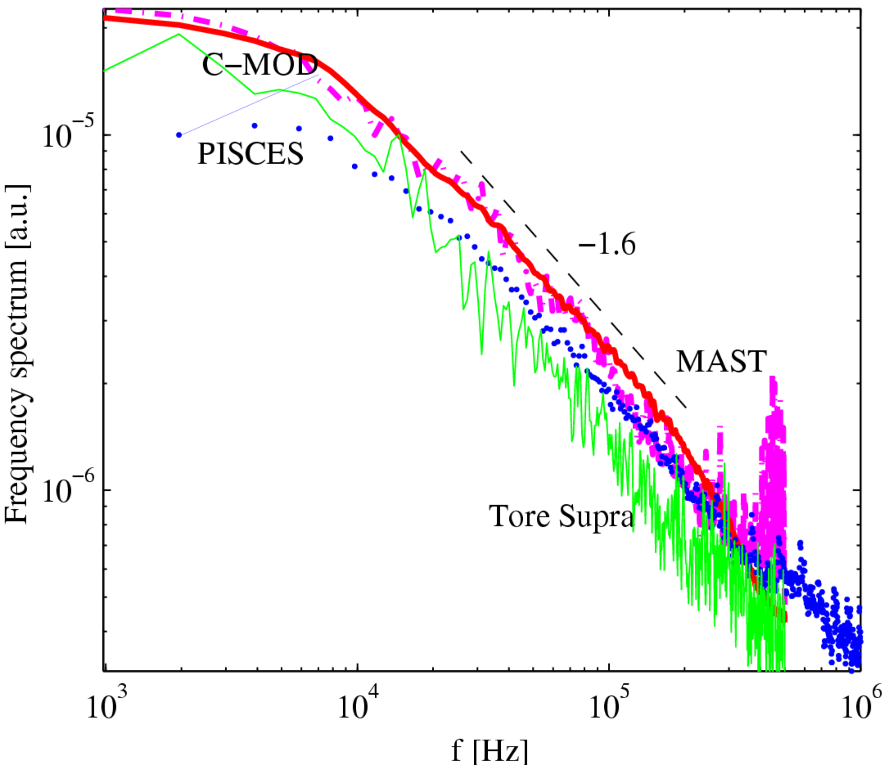
Similarity of the PDF of I_{sat} fluctuations

- Gaussian for negative fluctuations
- Strongly Skewed for positive fluctuations



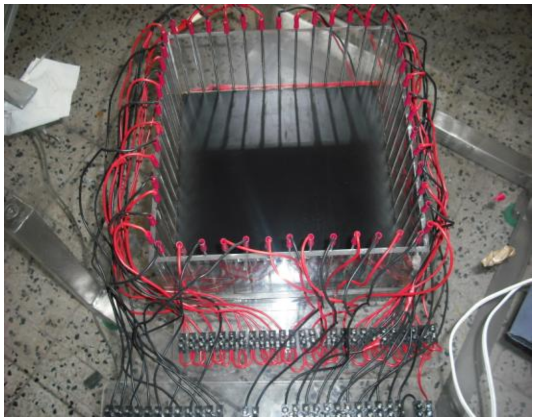
Similarity of the power spectra of I_{sat}

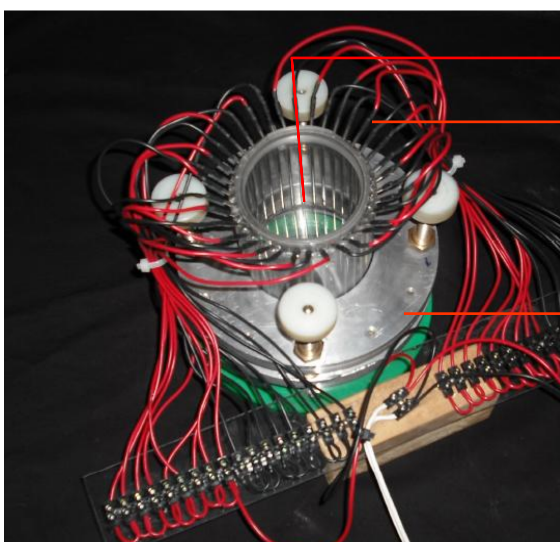
- One scaling region
- approximately the same scaling exponent -1.6



Challenge I: Developing table-top experiments to Investigate Quasi-2D turbulence

This setup uses a solution of KOH

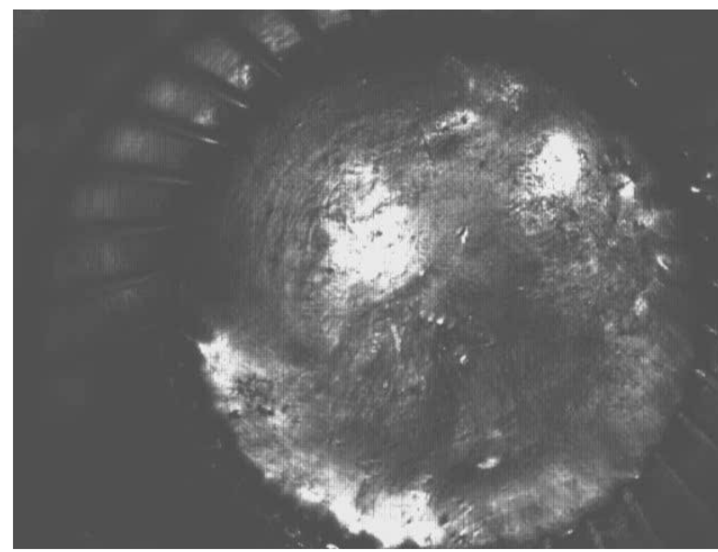




Liquid gallium

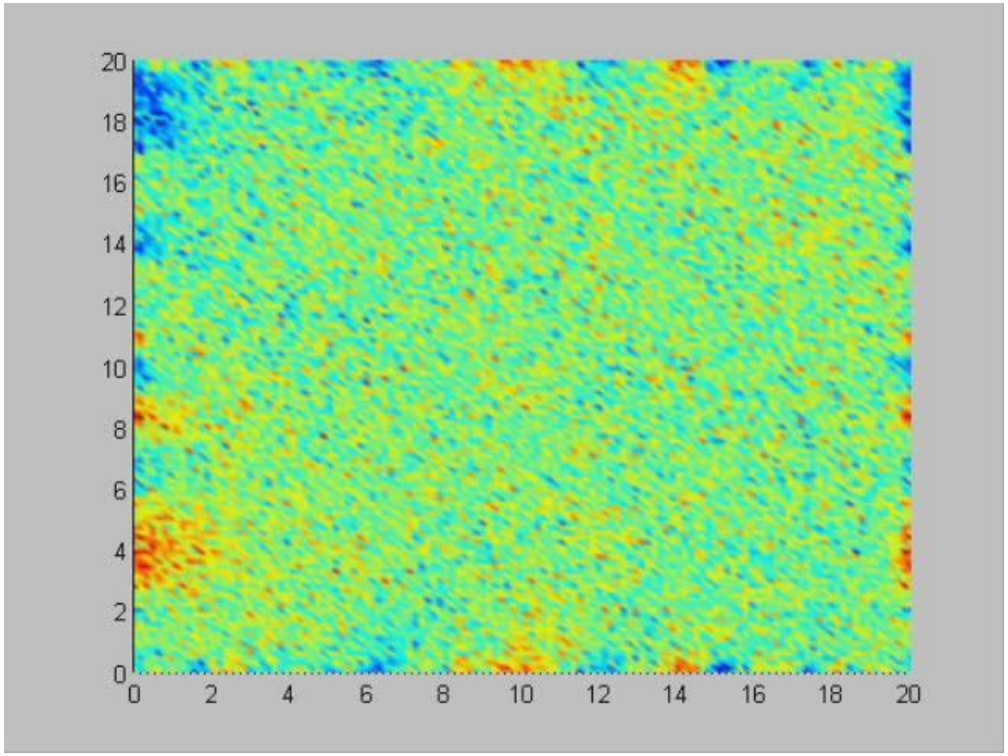
Electrodes

Magnetic coils



Challenge II: Develop Activity to Complement the Experiment based on Numerical Simulation of Turbulence

- The goal is to develop knowledge and expertise in simulating plasma turbulence.
- Our starting point is to use simple models (e.g. Hasegawa-Mima and Hasegawa-Wakatani) for turbulence and then gradually increase the complexity of the problem.
- Apply the newest numerical schemes that do not generate artificial vorticity and energy as they both have to be conserved.
- Develop strong collaborations with the fluid community taking advantage of their expertise.

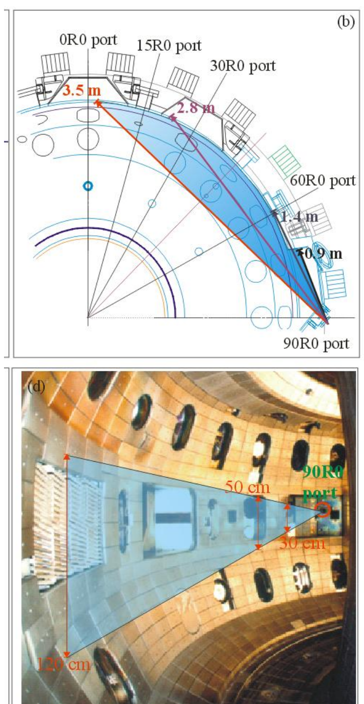


Challenge III: Simulating disruption mitigation in tokamaks using experiment and simulation

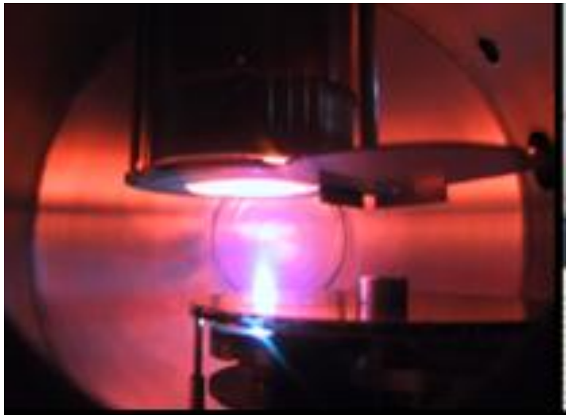
It is proposed to **mitigate disruptions** by using a massive gas jet which as it penetrates the plasma, density is increased by ionization which also leads to the decrease of temperature.

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?

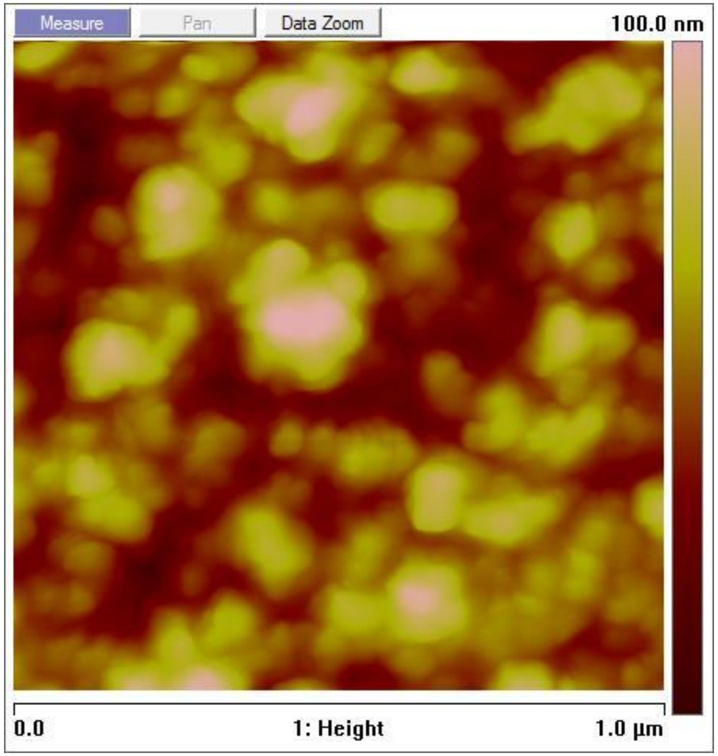


Challenge IV: Plasma Facing Components for Fusion Application



Surface properties as a function of the Laser Energy

250 mJ   320 mJ   420 mJ   512 mJ   612 mJ



• Fusion first wall is a major issue as it not only determines its life-time but also dictates the quality of the plasma by the type and the amount of impurities that it releases back into the plasma.

• Our goal is to understand and quantify the growth of tungsten films on graphite using, and for the first time, the pulsed laser deposition (PLD) technique and the surface diagnostics at AUB.

Conclusion

- Various experimental and theoretical research projects on nuclear fusion are being developed at AUB with the goal to have a Program in this field.
- These projects are in parallel to continuous collaborations with international institutions world-wide.
- The main application is to study **fundamental** issues encountered in magnetic fusion plasmas.
- What we need is: **"Education, education and education"** in science and engineering to build up our own expertise in this strategic field.
- Further funding and hiring in this field are also of prime importance to build the necessary equipments and to have at least a critical mass to start competing with other institutions.

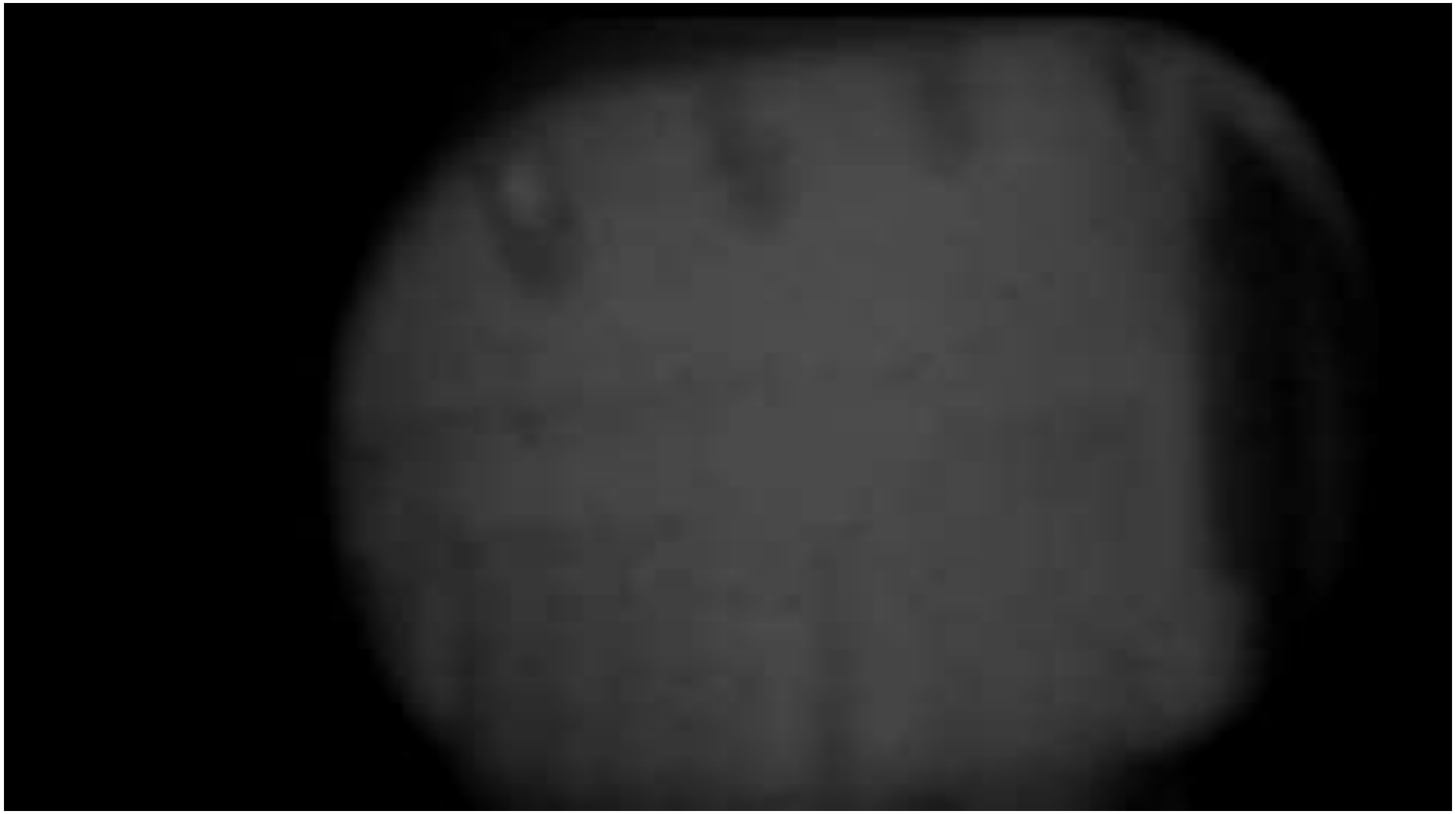
Simulating disruption mitigation in tokamaks I

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



Three Ways to Achieve Fusion

This presentation