

# Portuguese participation on the European Fusion Programme

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*Member of Directive Board*  
*Industrial Liaison Officer*



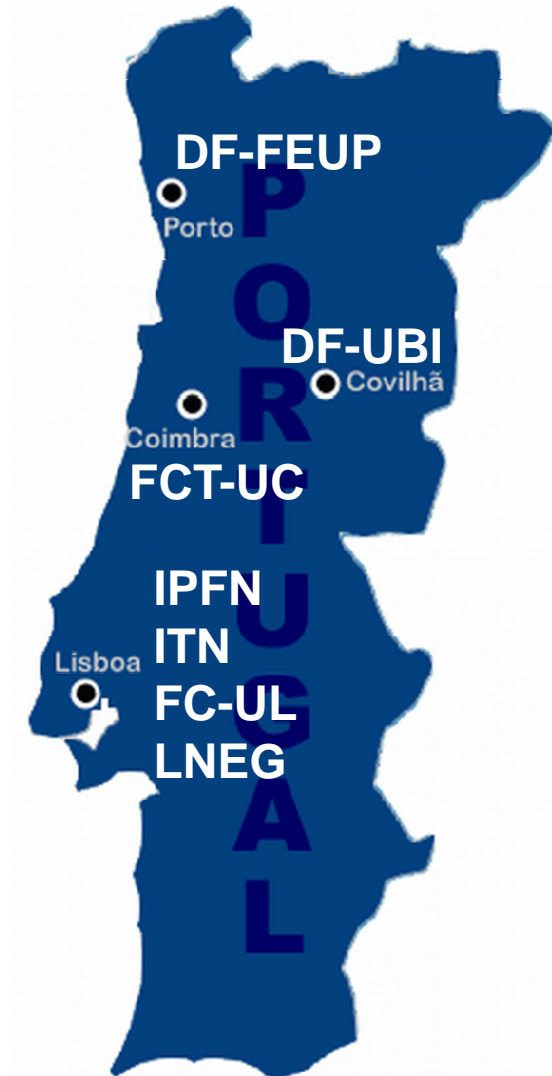
Instituto de Plasmas e Fusão Nuclear  
Instituto Superior Técnico  
Lisbon, Portugal  
<http://www.ipfn.ist.utl.pt>

# What is IPFN?

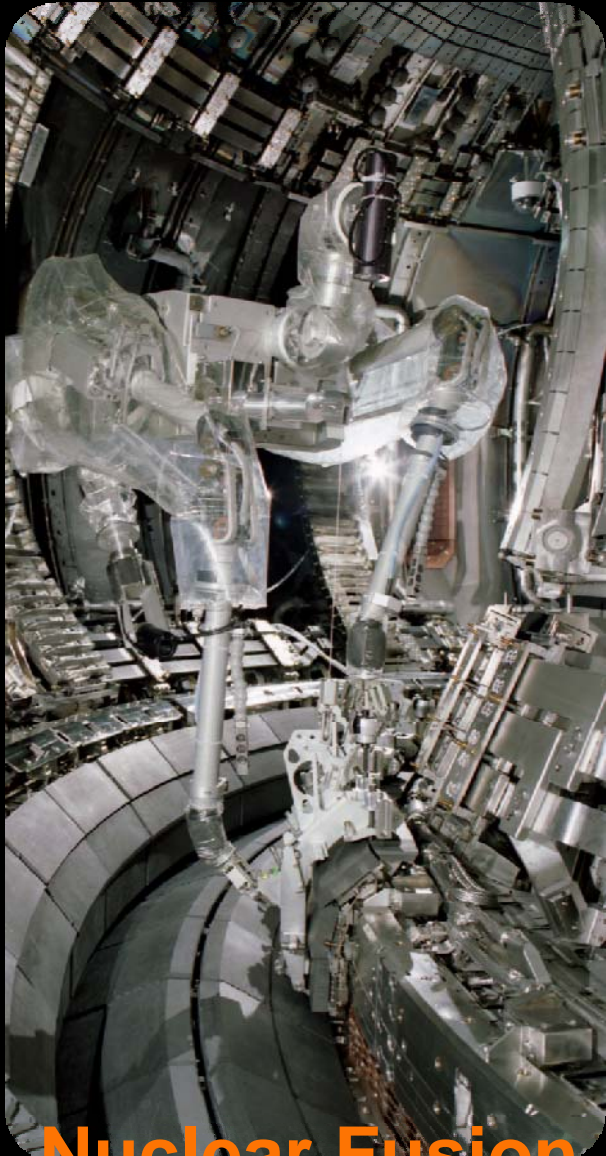


- IPFN is the Research Unit of the Contract of Association EURATOM/IST
- IPFN has the status of “Associated Laboratory” from “Fundação para a Ciência e a Tecnologia” (FCT).

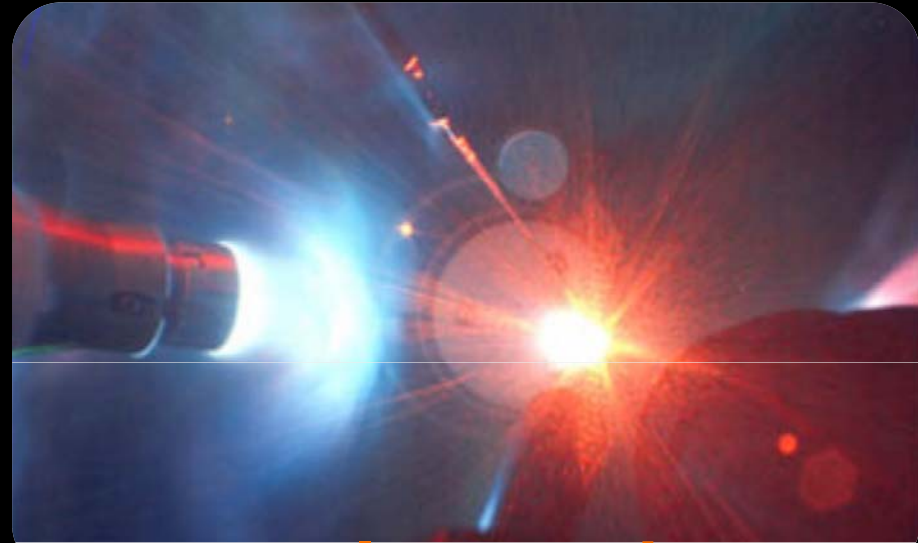
**IST, through IPFN, has the mandate to coordinate Portuguese Nuclear Fusion Activity**



# Key research fields



**Nuclear Fusion**



**Intense Lasers**

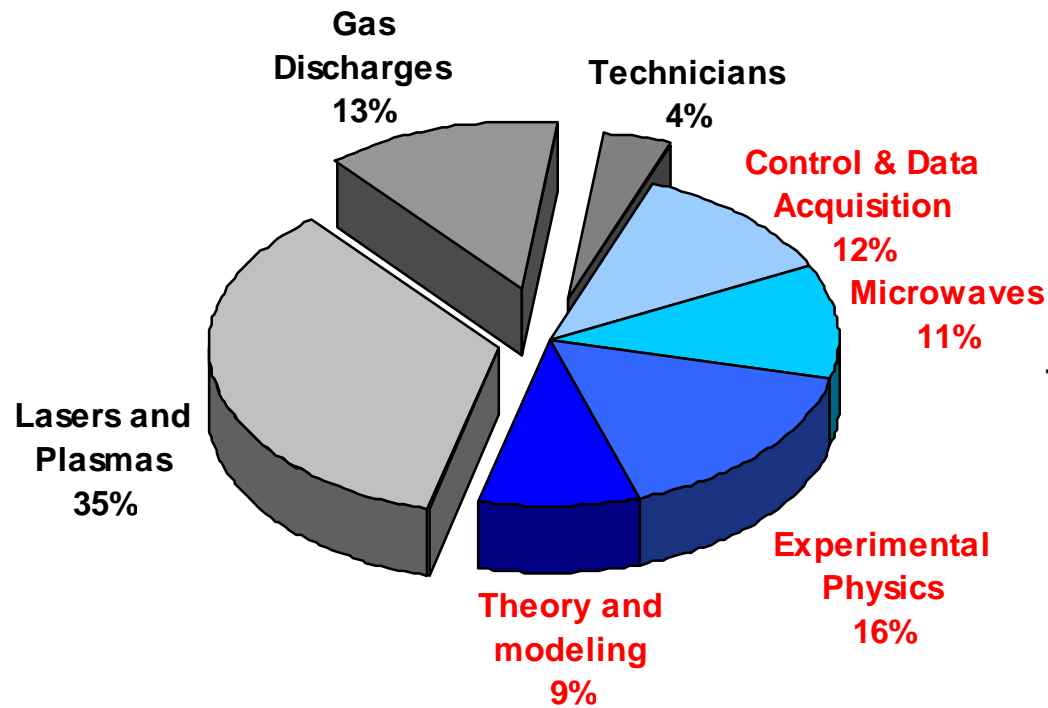


**Space**

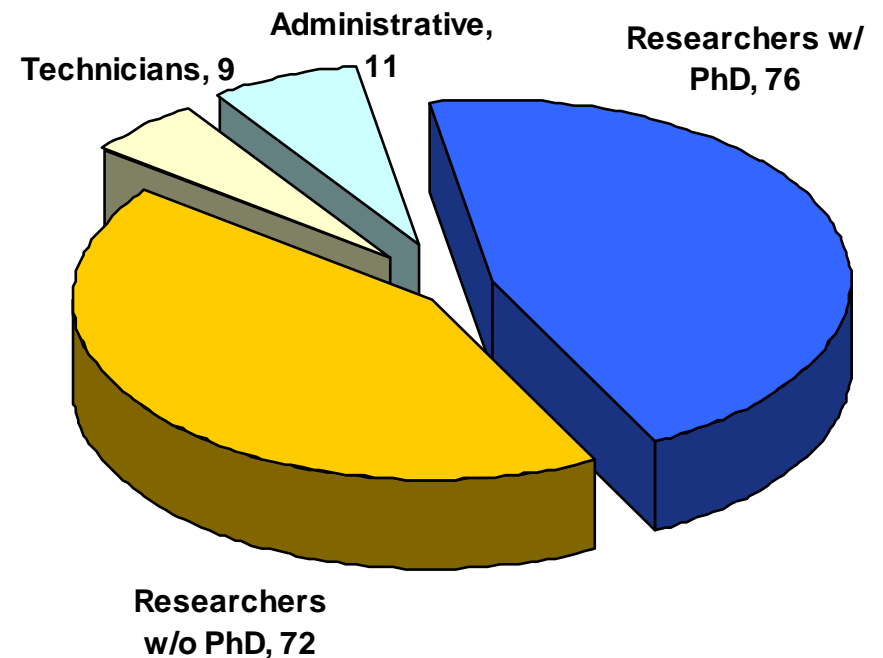
# IPFN's Staff



## Division by Scientific Groups



## Division by category





# Framework of the fusion activities

Controlled Nuclear Fusion activities are developed within the long-term *EURATOM Fusion Programme*



## Present Tools:

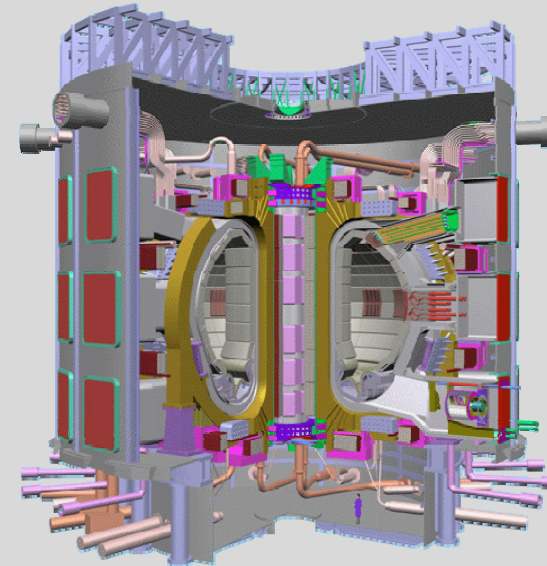
- Contract of **Association EURATOM/IST** [1990-2013]
- **EURATOM Mobility Agreement** [1990-2013]
- **European Fusion Development Agreement (EFDA)** [2000-2013]
- European Joint Undertaking for ITER and the Development of Fusion Energy “**Fusion for Energy (F4E)**” [2007-2042]

# Main goal



- Develop endogenous competencies
- Train qualified staff
- Transfer of knowledge
- Involve industry in nuclear fusion activities

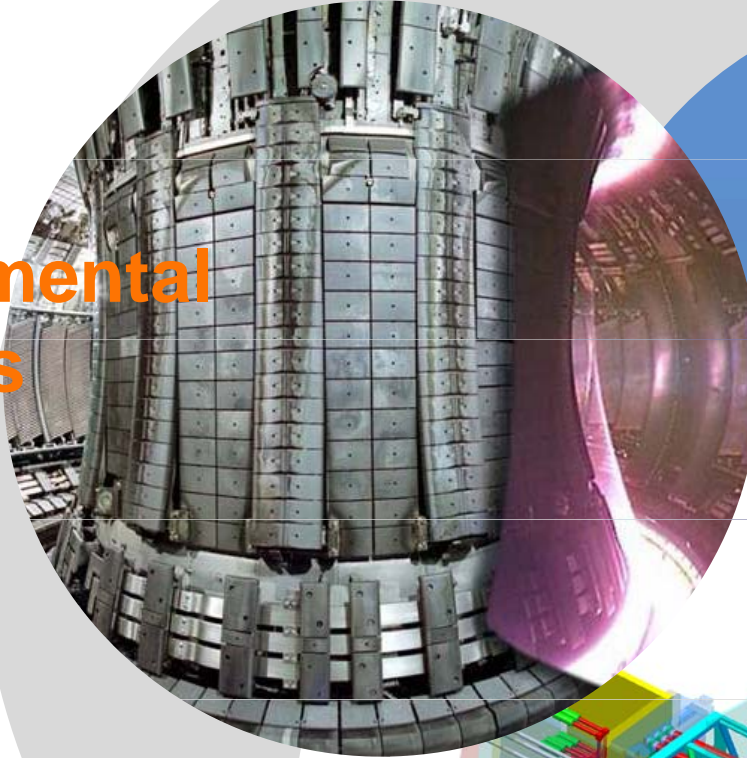
## Participation in ITER (“International Thermonuclear Experimental Reactor”)



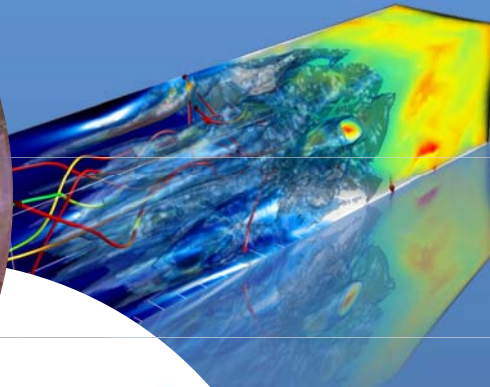
- Participation in the tokamak construction
- Preparation for the scientific exploitation

# Key areas

**Experimental  
Physics**



**Theory &  
Modeling**



**Engineering & Systems  
Integration**



**Society**

# Tokamak ISTTOK



## *Exploitation of a home-based device:*

- Development of new diagnostics (HIBP,...)
- New concepts (Ga liquid metal jet limiter)
- Control and data acquisition systems
- Physics studies
- Education and training



# Education and training

Collaboration with Portuguese universities in 2<sup>nd</sup> and 3<sup>rd</sup> cycles courses

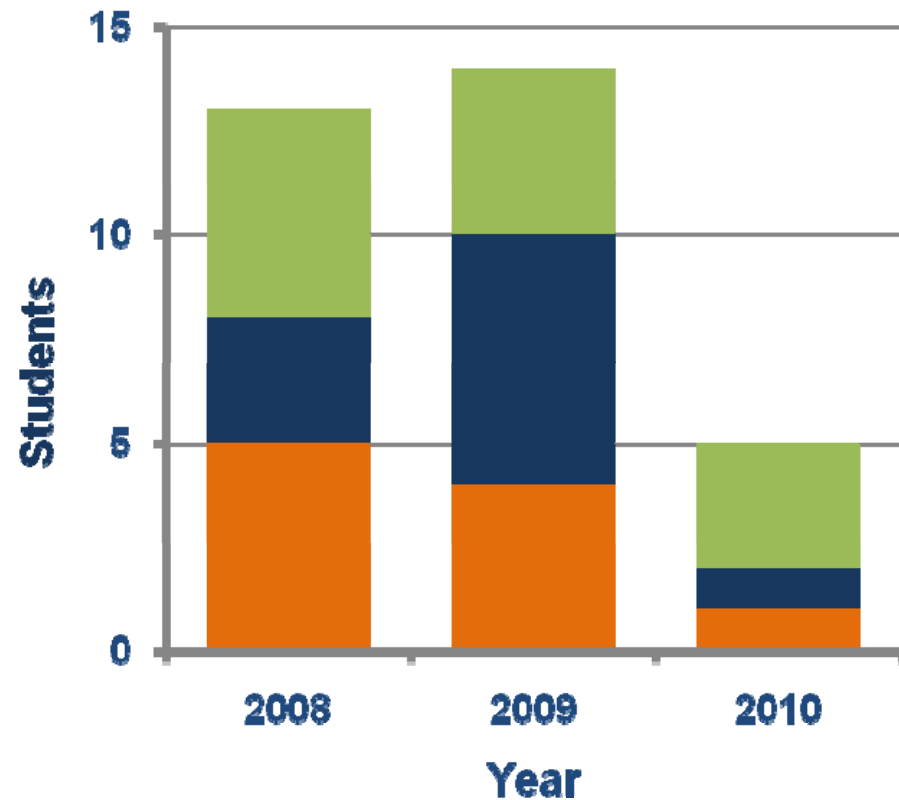
- Master and Ph.D programmes on Technological Physics Engineering of IST

European Ph.D. programme on Fusion Science and Engineering

- IST
- University of Padova
- Maximillian University of Munich

IPFN staff responsible for the lectures on:

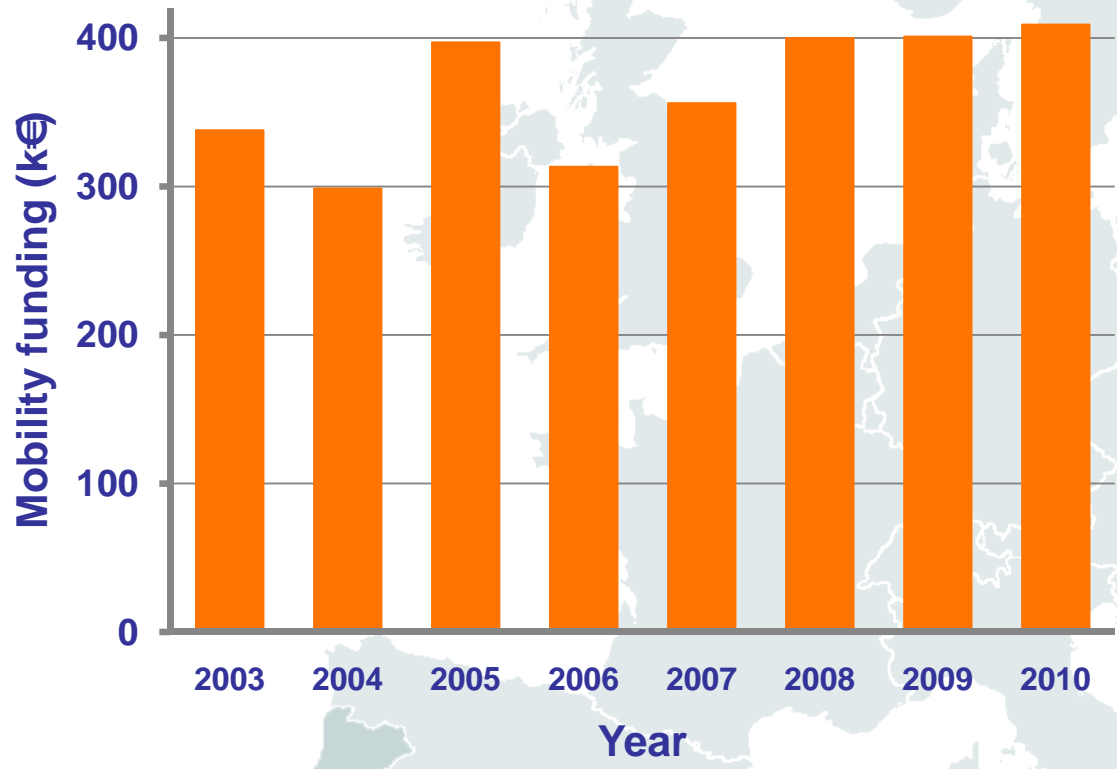
- Plasma Diagnostics
- Control and Data Acquisition



# Internationalization



# Internationalization: Collaboration with other Associations

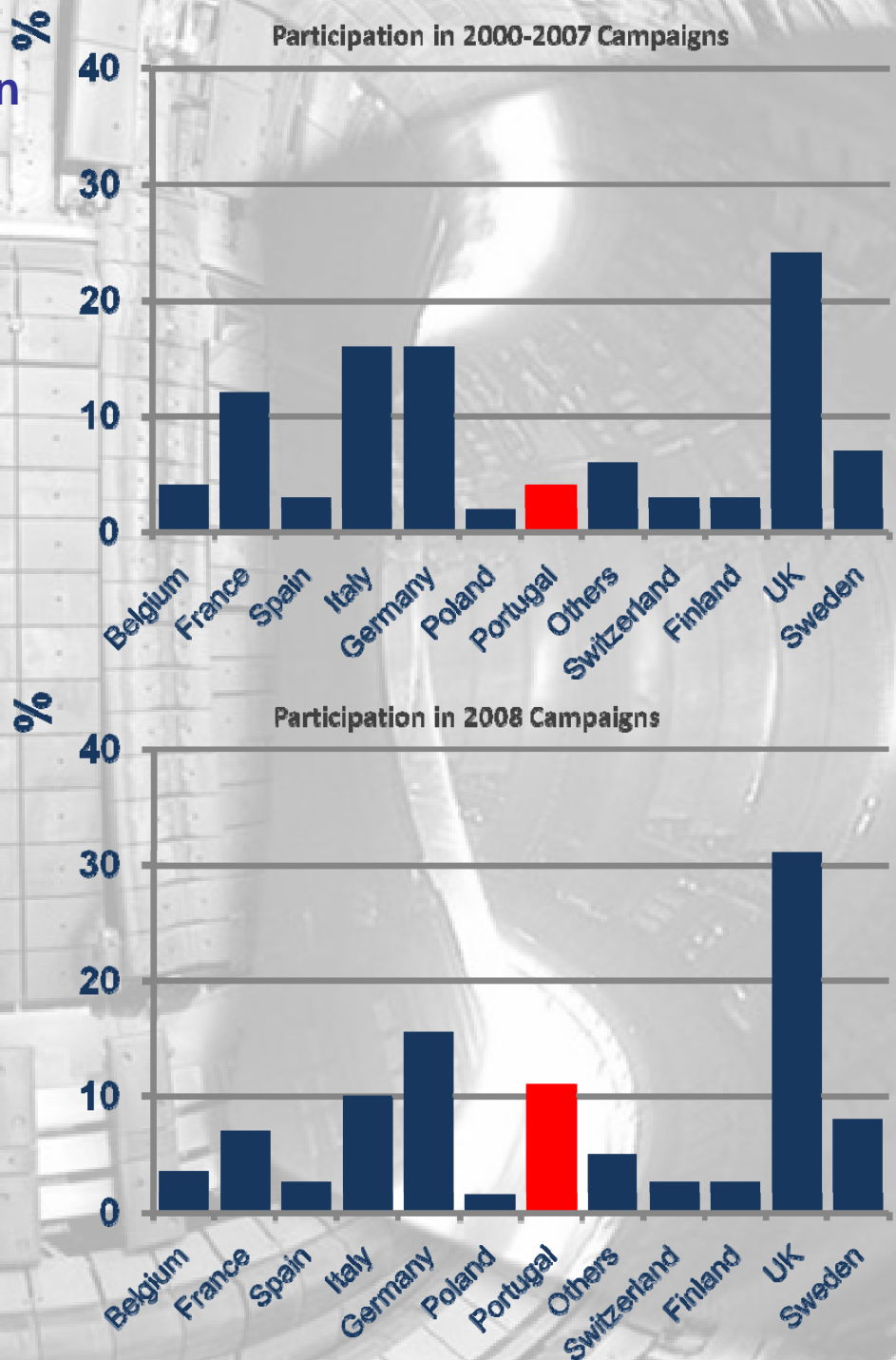


**Missions** carried out in the frame of the **Mobility Agreement** have been increasing

IPFN has a **strong participation** on the **European Fusion Programme**, particularly, on **JET**

- Experimental campaigns
  - ~20 researchers
- Operation
  - 2 “Session Leaders”
- Scientific exploitation

Association EURATOM/IST staff reached the **third highest participation** during JET experimental Campaigns in 2008

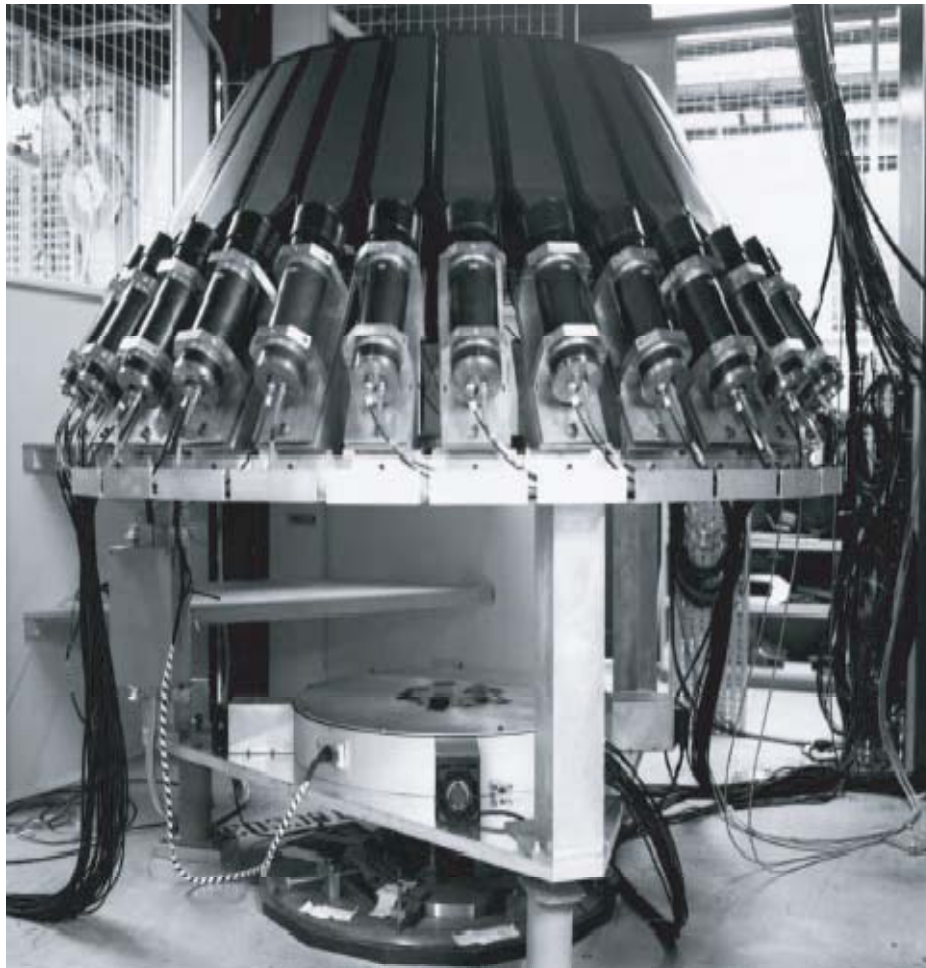




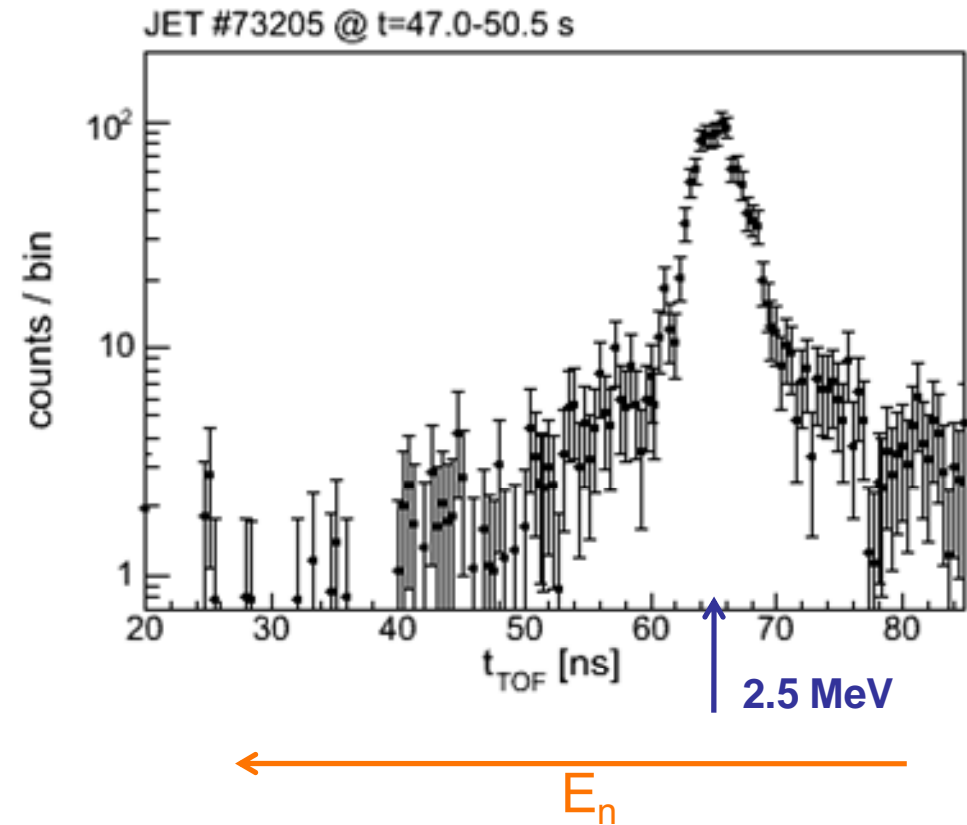
# JET Enhancement Projects

- Microwave Access for Reflectometry and ECE
- Multichannel X-mode reflectometer for density profiles (KG10)
- Data acquisition for
  - TOFOR neutron diagnostics
  - Neutron Camera diagnostic
  - Gamma Ray Spectroscopy
- ATCA hardware platform for the Plasma Vertical Stabilization Control
- Real-time measurement & control Diagnostics and Infrastructure
- Real-Time Test Bench
- Fast Wave reflectometer
- Fast visible camera

# JET TOFOR Neutron spectrometers: data acquisition

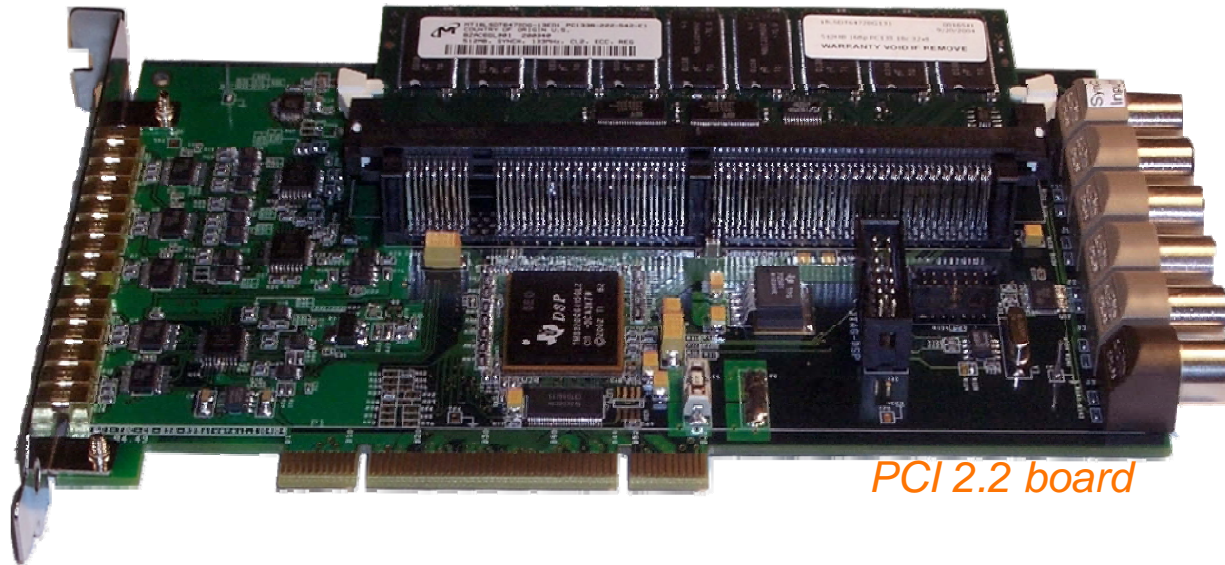


Optimized Time-of-Flight(TOFOR) system  
for 1.5 – 2.5 – 7 MeV



*In collaboration with  
Uppsala University, EURATOM-VR Association*

# JET TOFOR Neutron spectrometers: Time-to-digital converter



*PCI 2.2 board*

- 8 independent Time-to-Digital Converter (TDC) channels
- Programmable resolution and dead-time between pulses of 0.4 -2 ns
- Peak event rate of 1.25 Gevents/sec/channel
- Sustained event rate: 5 Mevents/sec/channel
- Local memory up to 64 Mevents (8 Mevents/channel)
- DSP+FPGA/SoC for real-time control/monitoring and data processing
- Up to 5 boards (32 channels) can be synchronized
- 6 inputs for tagging events from up to 32 sources (16 ns min.)



# Gamma ray spectroscopy: data acquisition

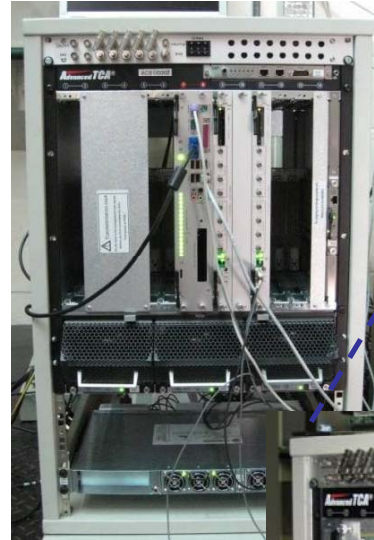


**Intelligent modules** (with FPGAs) are used for real time pulse processing:

- Pulse height analyzer; Pile-up rejection; and Pulse shape discriminator

Digitizer modules centered around an FPGA, which:

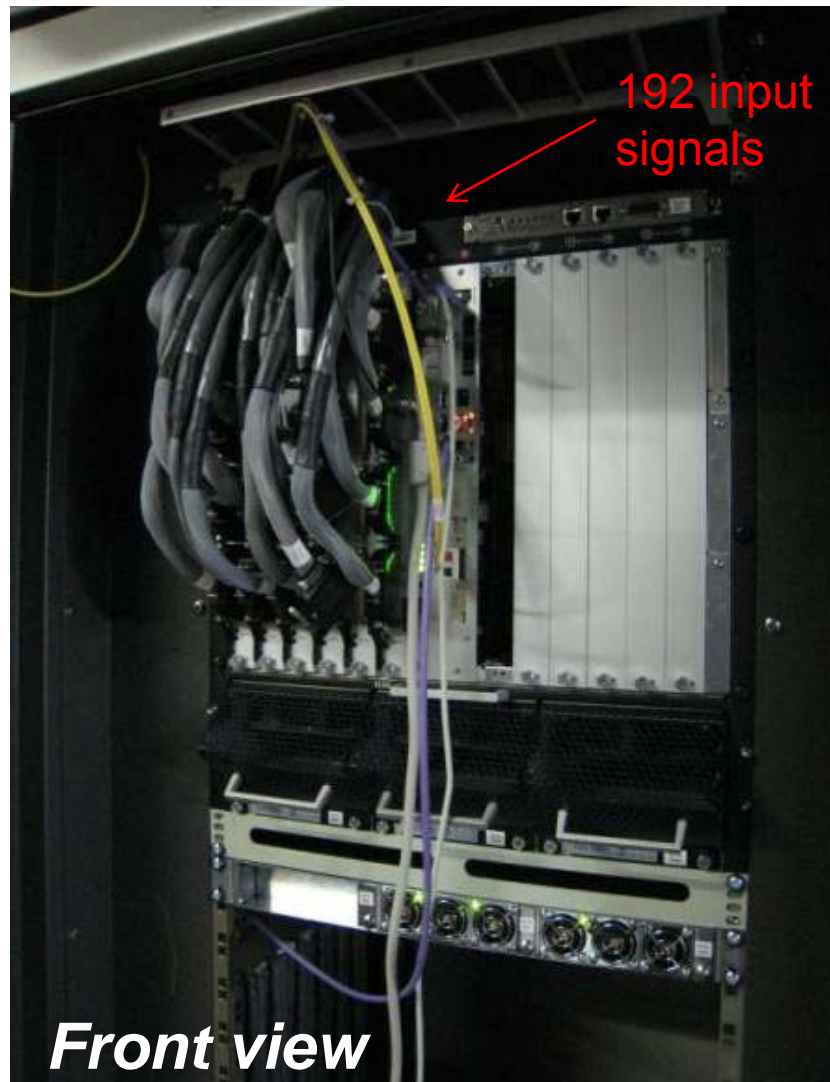
- controls ADCs and local memory,
  - provides the gigabit interconnections
  - runs DSP algorithms
  - Concurrent algorithms can be implemented on the FPGA and each one can be parallelized (e.g. 4 pipes at 250 MSPS  $\equiv$  1 GSPS with reduced ENOB  $\sim$ 10-bit)
- 
- Data transfer rate of up to 800 Mbyte/s over x4 PCI Express to the host processor.
  - Choice of resolution
    - 250 MSPS @ 13-bit,
    - 400 MSPS @ 14-bit,
    - 500 MSPS @ 12-bit
  - Maximum pulse rate of 5 Mpulse/s;



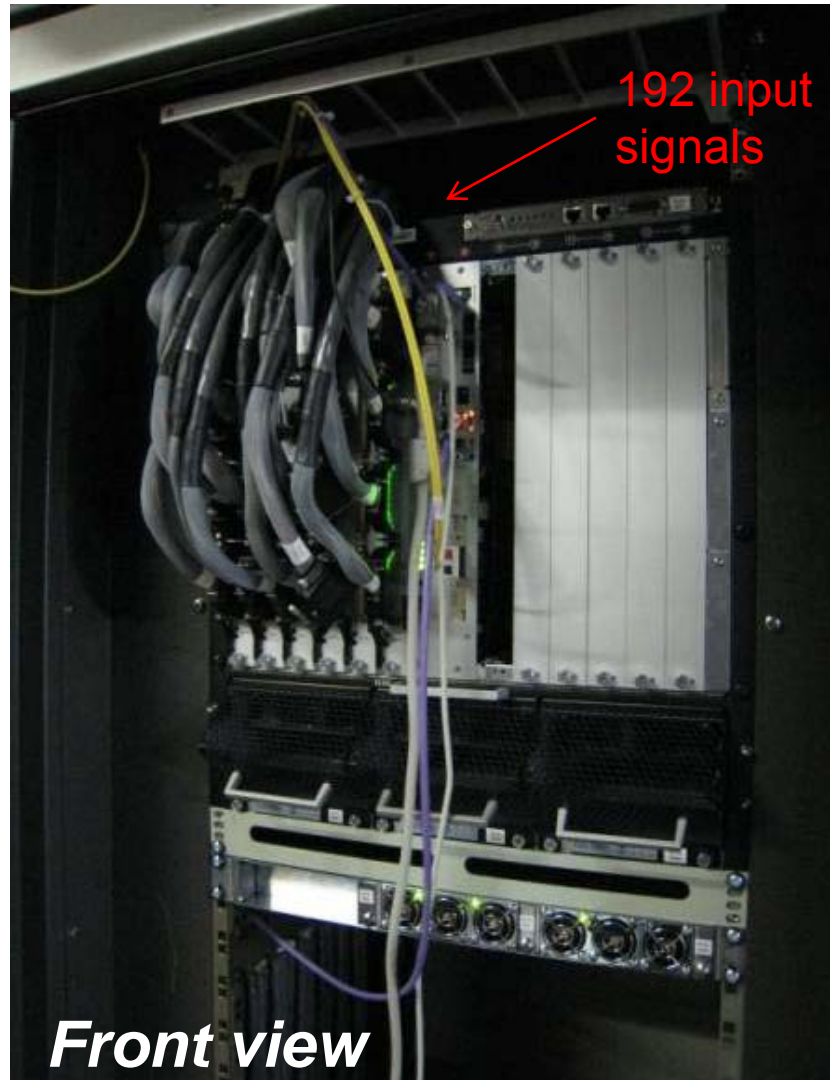
**Data reduction rate of at least 80% attainable with pulse height analysis**



# ATCA @ JET Vertical Stabilization



# ATCA @ JET Vertical Stabilization



- 192 signals acquired by ADCs and transferred at each cycle
- 50  $\mu\text{s}$  control loop cycle time with jitter  $< 1 \mu\text{s}$
- Always in real-time (24 hours per day)
  - $1.728 \times 10^9$  50  $\mu\text{s}$  cycles/day
  - Crucial for ITER very long pulses



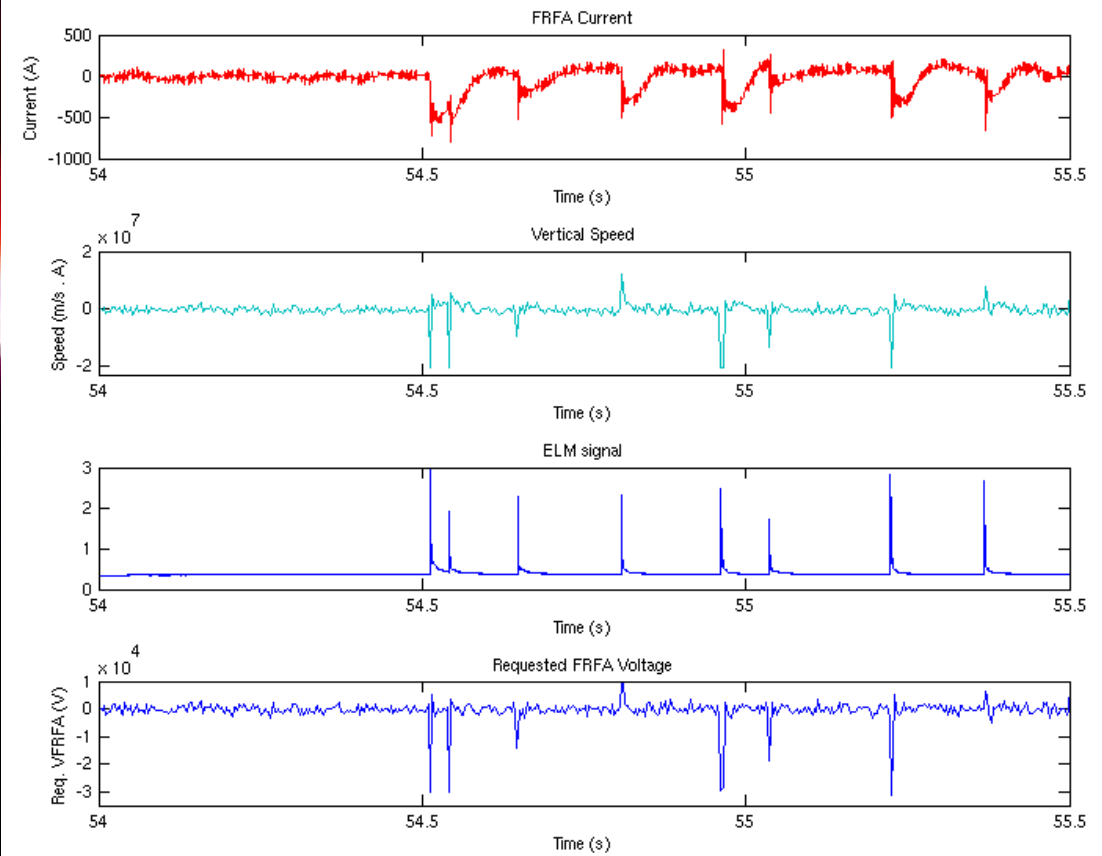
# ATCA @ JET Vertical Stabilization: “the star of the show”



# Does it work?



## VS controller in action - Vertical kicks experiment





# Control and Data Acquisition: towards ITER relevant solutions



- ISTTOK
- TCV •TJ-II
- TCA/Br
- MAST



- JET



- JET



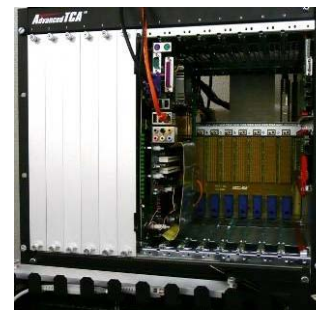
- ETE



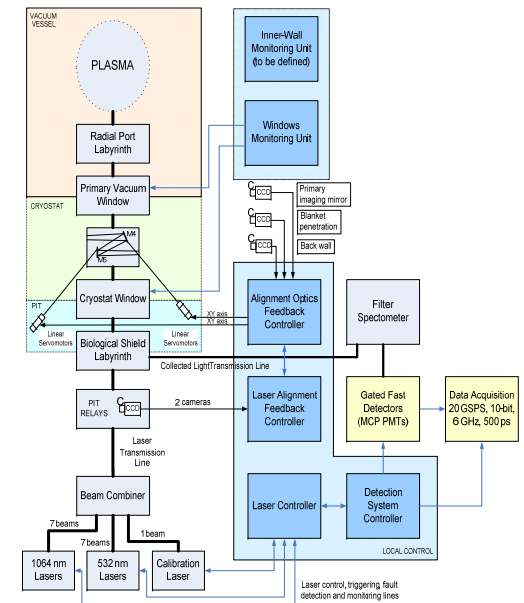
- JET



- ISTTOK
- Compass



- ITER



*ITER LIDAR  
conceptual design*

**Control and Data acquisition activities build upon Fusion specific needs**

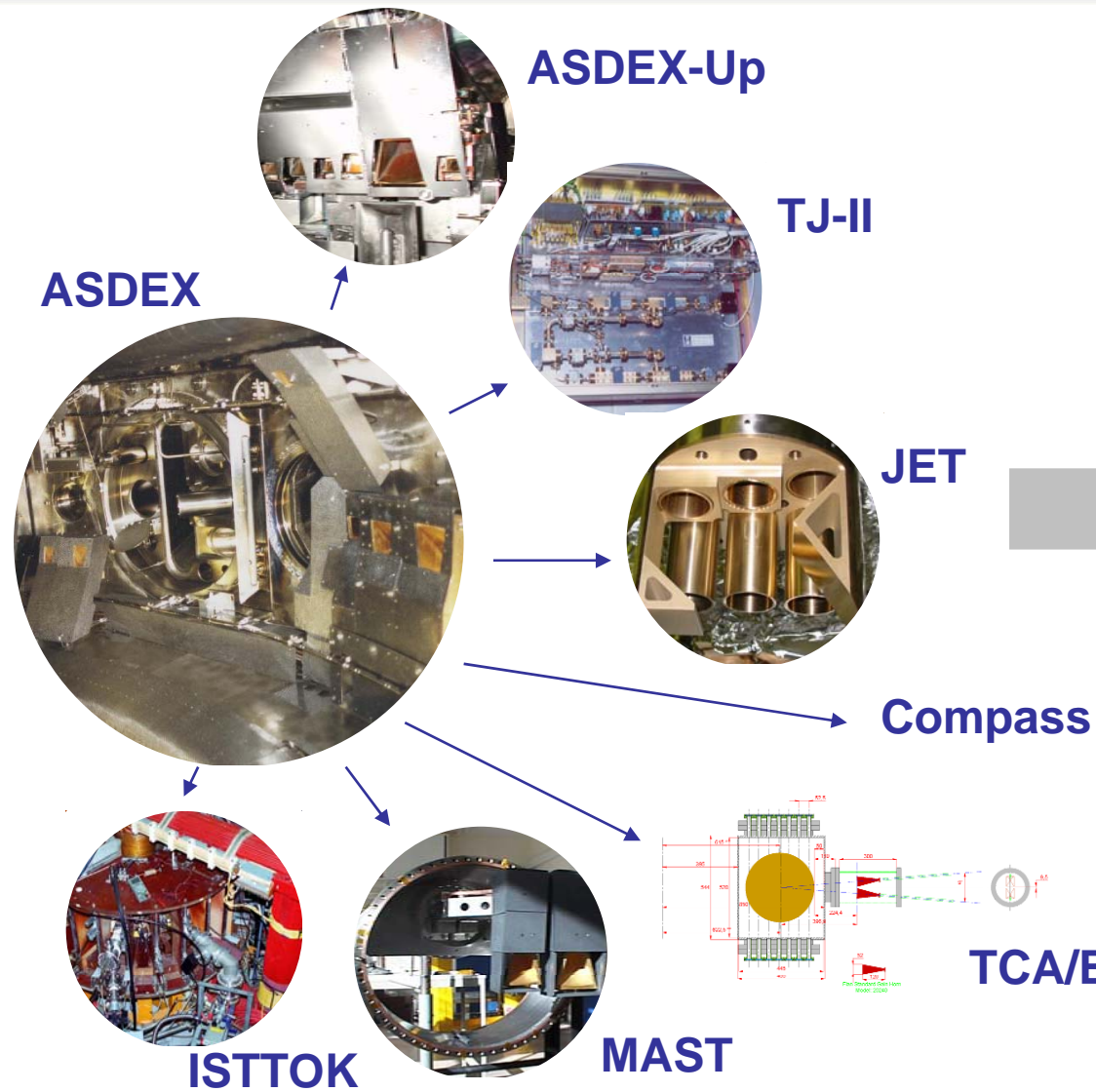
# EIROforum Instrumentation Working Group



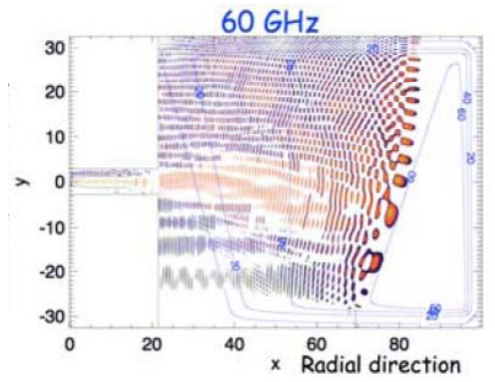
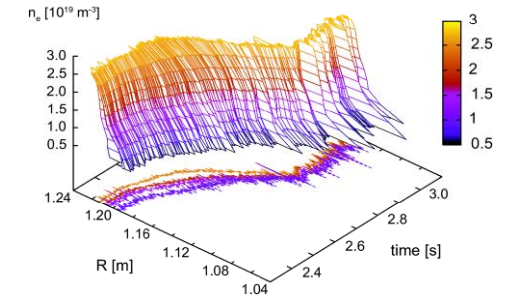
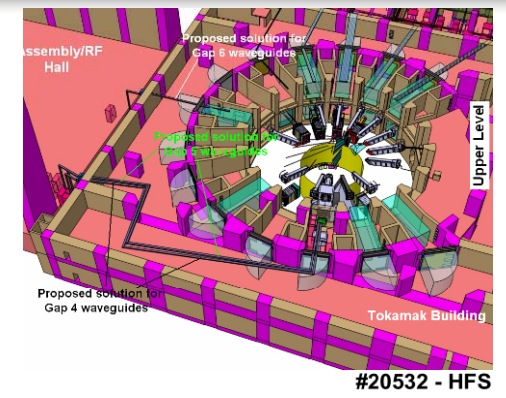
The screenshot shows a web browser window with the URL <http://iter.cfn.ist.utl.pt/RadHard2010>. The page features the EIROforum logo and the text: **EIRO WORKSHOP RADIATION HARDNESS MEASUREMENT, TESTING AND MATERIALS 16-18 MARCH 2010, LISBON, PORTUGAL**. A navigation menu includes Home, Team, and Contact. A sidebar on the left lists various sections like News, Overview, and Registration. The main content area displays a welcome message and logos for CERN, EFDA, JET, EMBL, ESA, ESF, and ESRF. A news section on the right shows a registration announcement from 2010-01-21.

IPFN researcher is the EFDA-JET representative at the EIROforum Instrumentation Working Group

# Microwave Diagnostics: Building expertise to ITER



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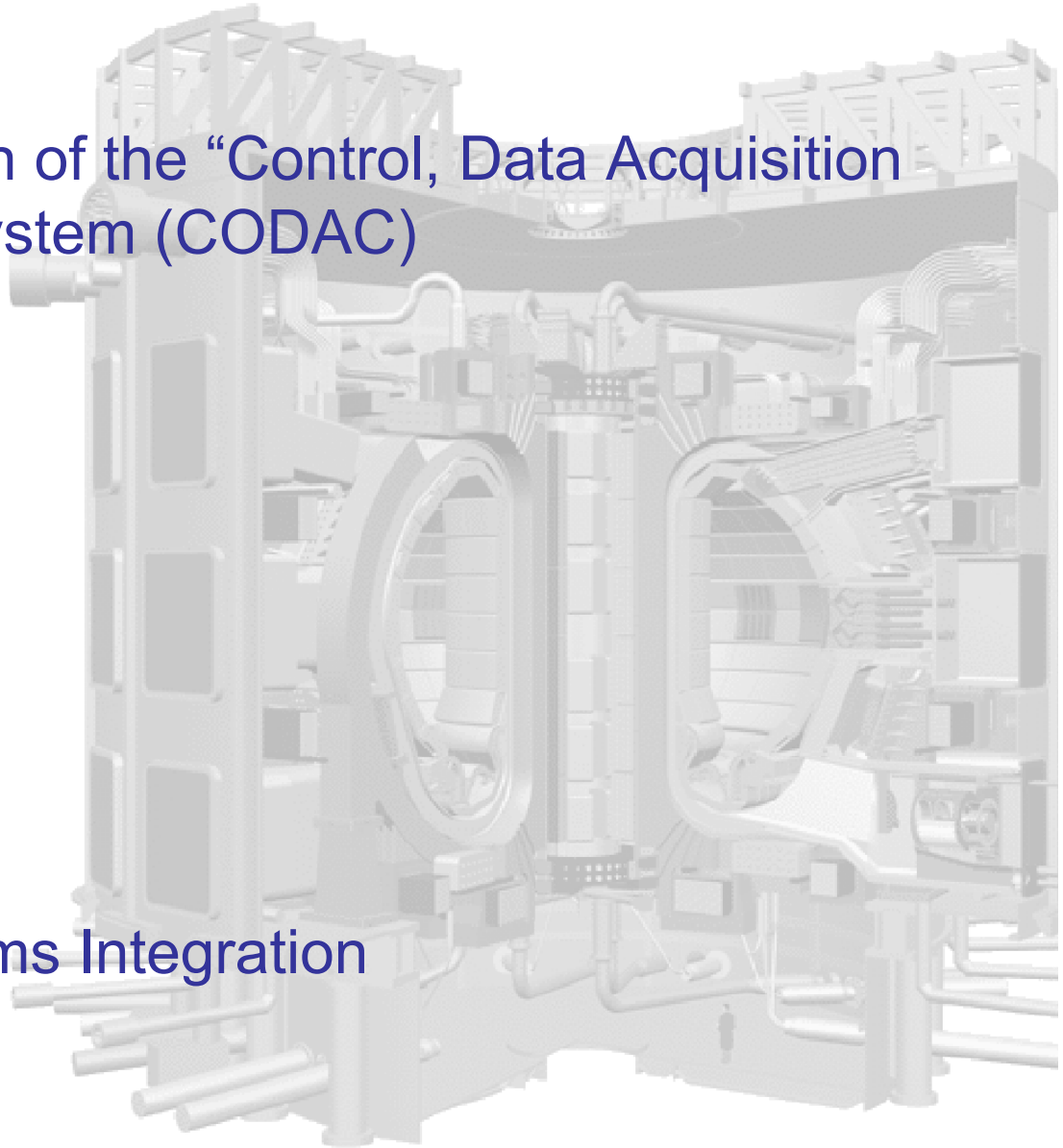




# ITER:

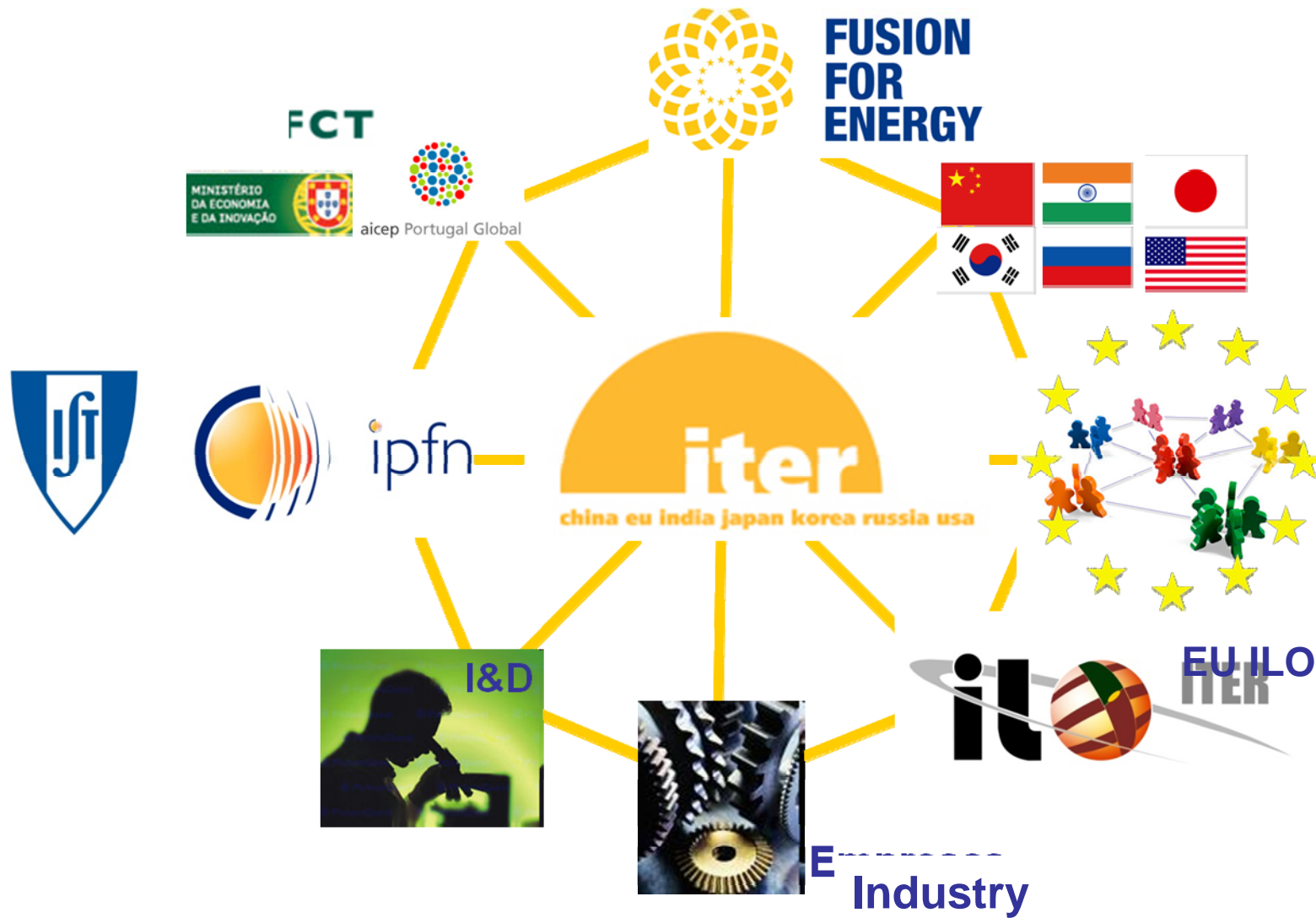
## Areas of interest

- Design and construction of the “Control, Data Acquisition and Communication” system (CODAC)
- Plasma Diagnostics
- Remote Handling
- Materials
- Quality Assurance
- Theory and Modelling
- Engineering and Systems Integration





# ITER network



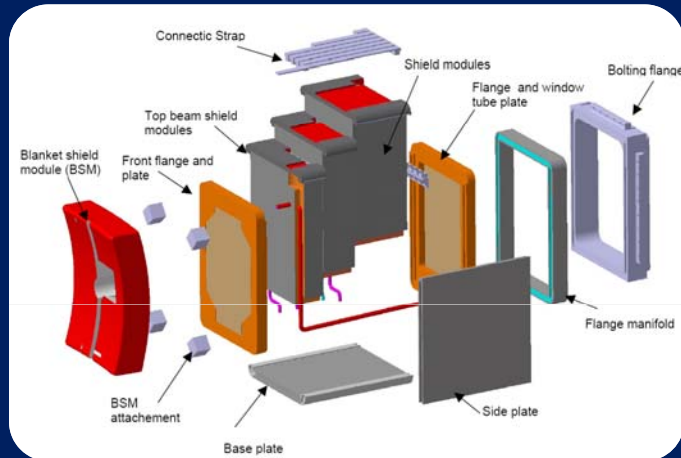
No concept of Geographic return

All Contracts and Grants are fully competitive!!

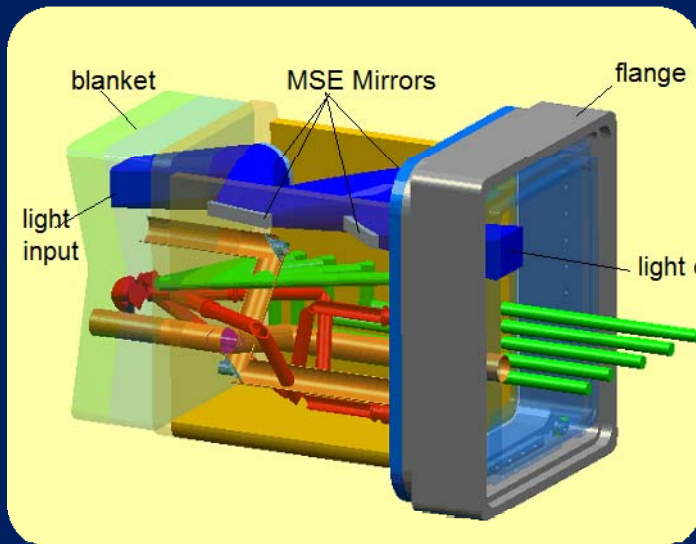


**Leap longer!**

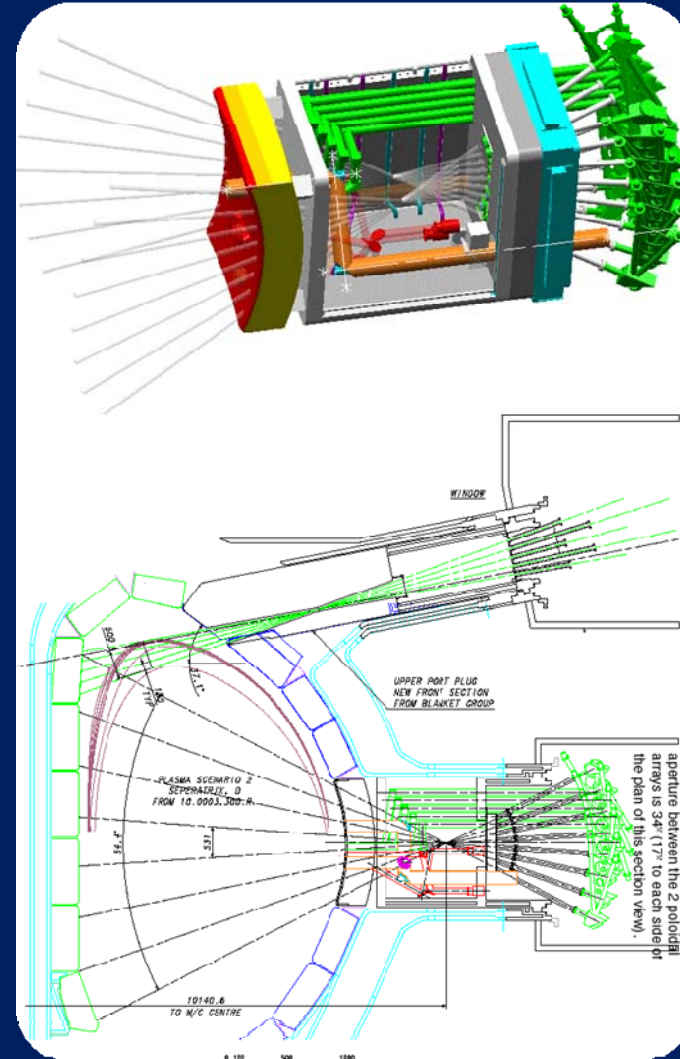
# Participation in ITER: Diagnostic Design and Integration



**Port Plug**



**Motional Stark Effect Diagnostic**



**Multichannel X-ray System**

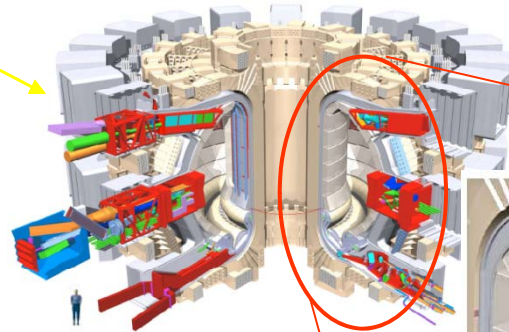
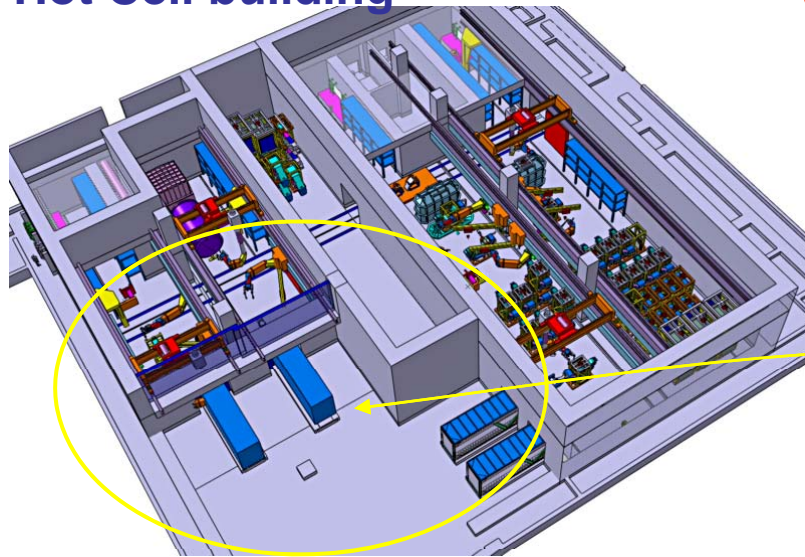


# Participation in ITER: Transfer Cask System to Hot-Cell building



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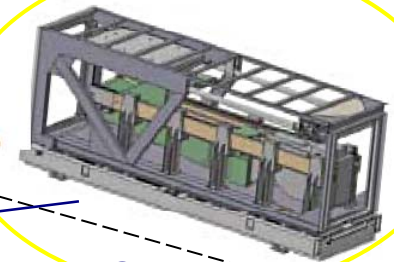
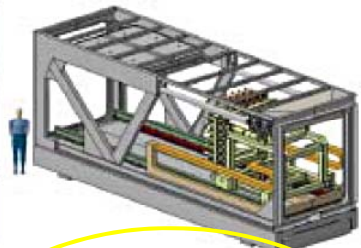
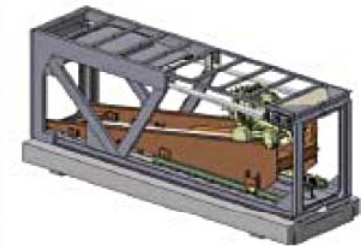
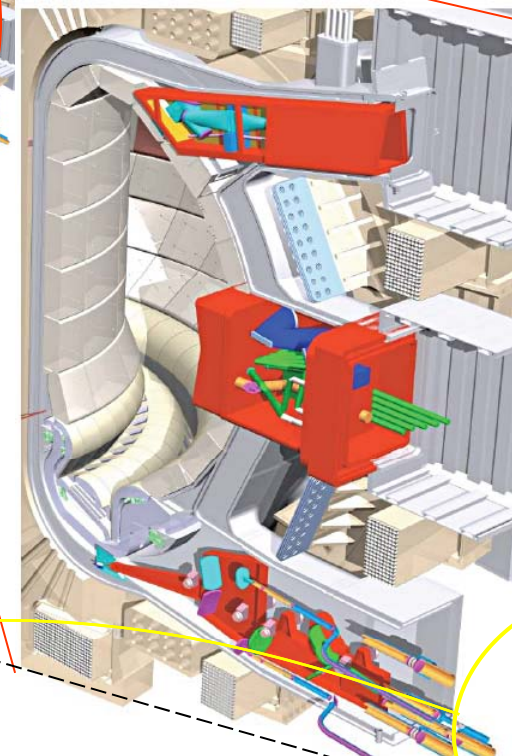
Hot Cell building



FUSION  
FOR  
ENERGY



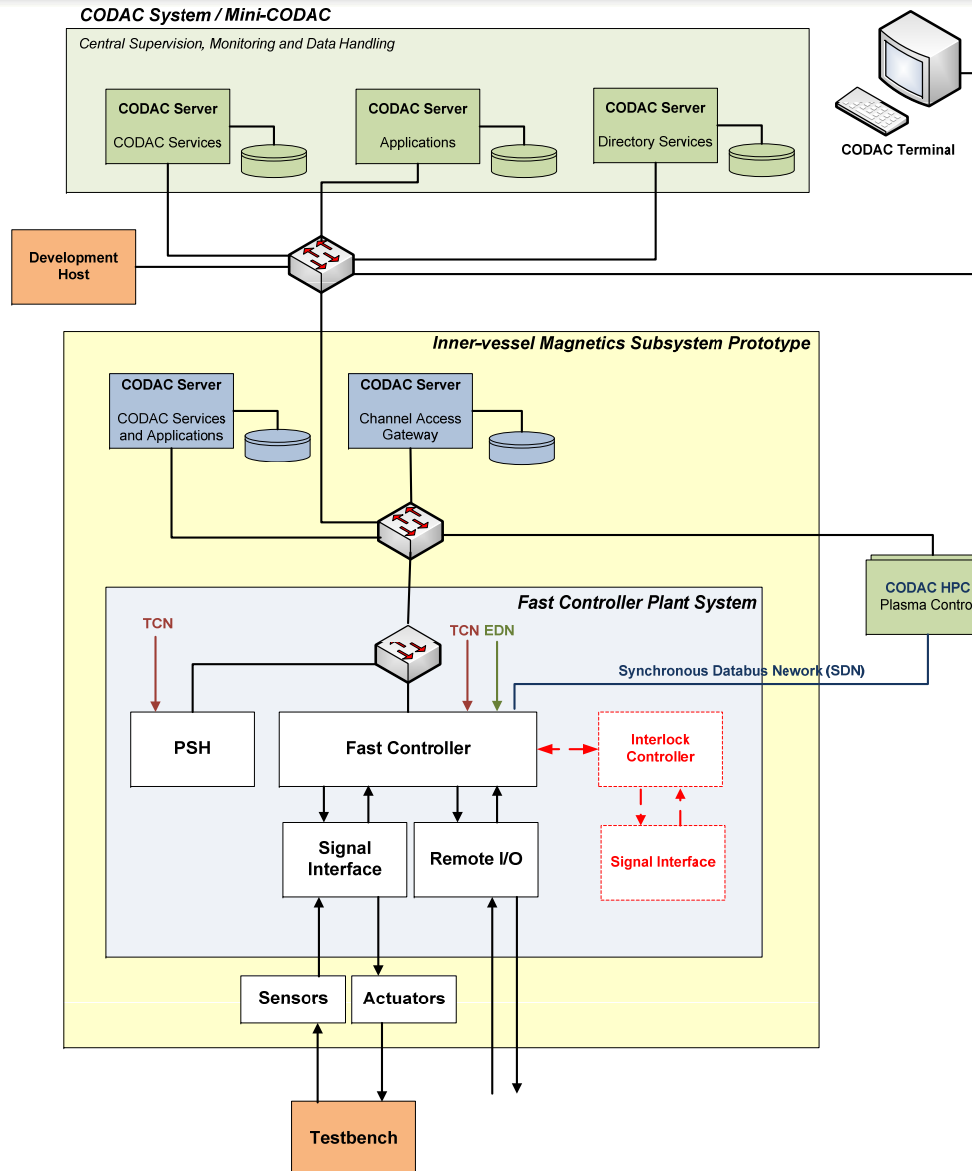
PÓLO DO I.S.T



Transfer Cask System (TCS) = Air-cushion Transfer System (ATS) + Pallet + Cask Envelope



# Participation in ITER: Prototype Fast Plant System Controller

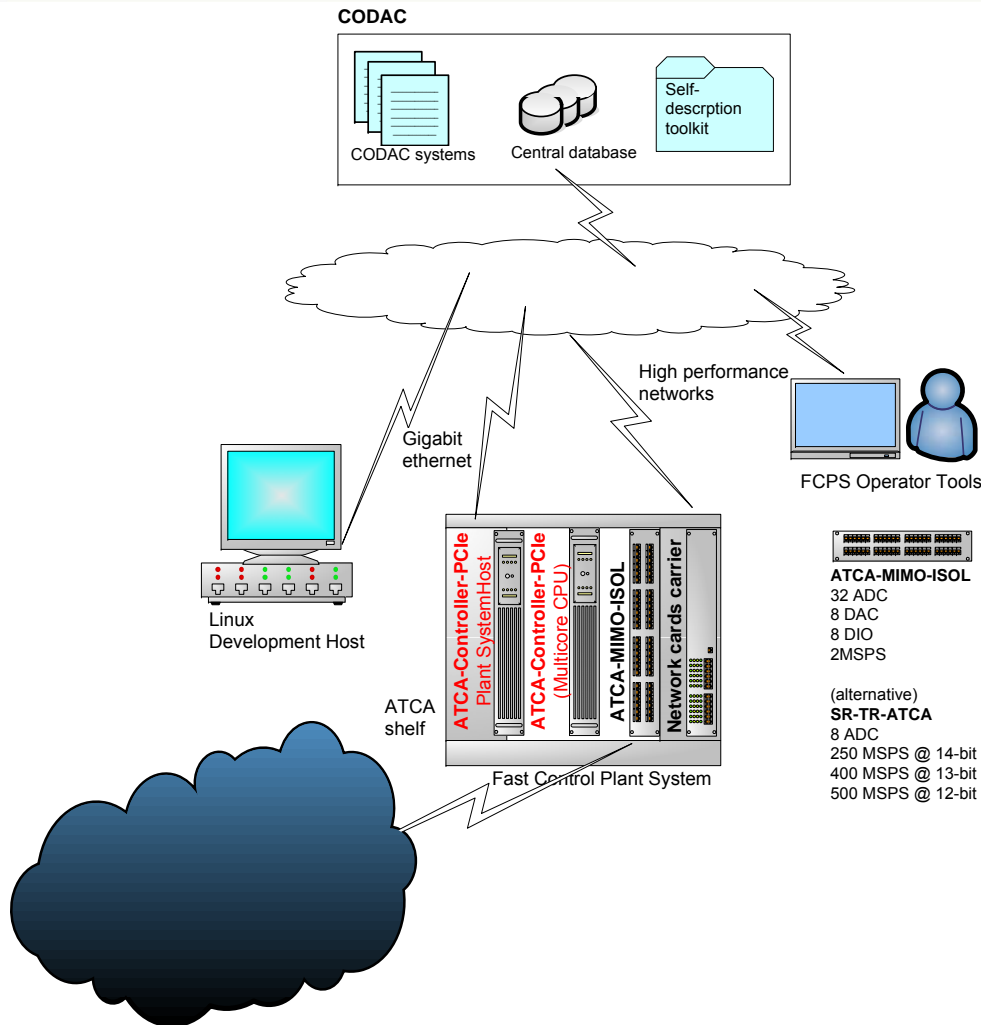


**Ciemat**  
Centro de Investigaciones  
Energéticas, Medioambientales  
y Tecnológicas

**inovov**  
inesc • inovação

**iter**  
china eu india japan korea russia usa

# Participation in ITER: Prototype Fast Plant System Controller



- Multicore processor controller
- ATCA ADC/DAC/DIO boards with MIMO capability at different data rates
- Redundancy management for added reliability
- Local control and autonomous operation
- Local data storage
- Timing, (synchronous) messages and high performance network interfaces

**ATCA** will add the required **robustness** to the platform

# Portuguese participation



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Laboratório Nacional de Energia e Geologia, I. P.



ipfn



PÓLO DO I.S.T

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software



space solutions



INNOVATING SOLUTIONS

FiberSensing  
bringing light to measurement



Instrumentation :: sensing :: wireless



technologies  
making space a global endeavour



inesc . inovação

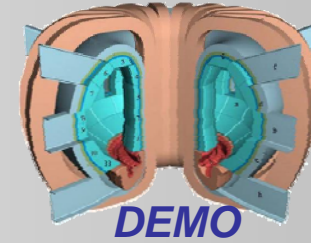
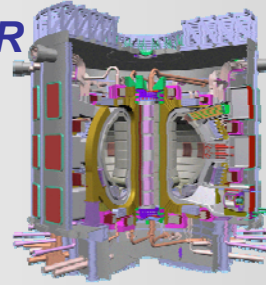
# Fostering competencies for large-scale projects

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JET

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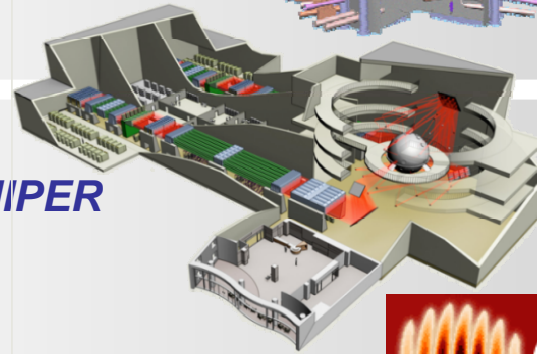


DEMO

Magnetic Confinement Fusion

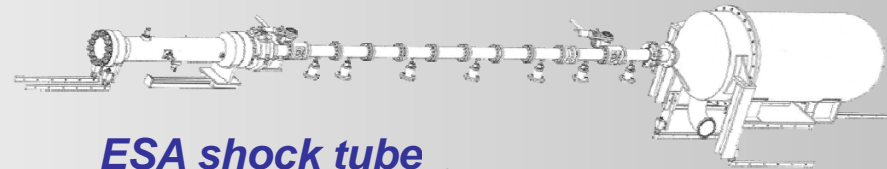
L  
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HIPER



Inercial Confinement Fusion

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P  
A  
C  
E



ESA shock tube

Present

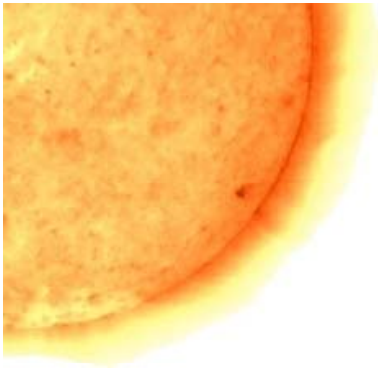
Future



# Finding the bridge with ESS



- Control, Data Acquisition and Communications
- Diagnostics engineering
- Systems integration



# Fostering competencies for tomorrow's projects



ipfn

