Regional Information Day
on the Euratom Framework Programme
for Nuclear Research and Training
Activities (2012-2013) - FP7+2

Croatian fusion-related research

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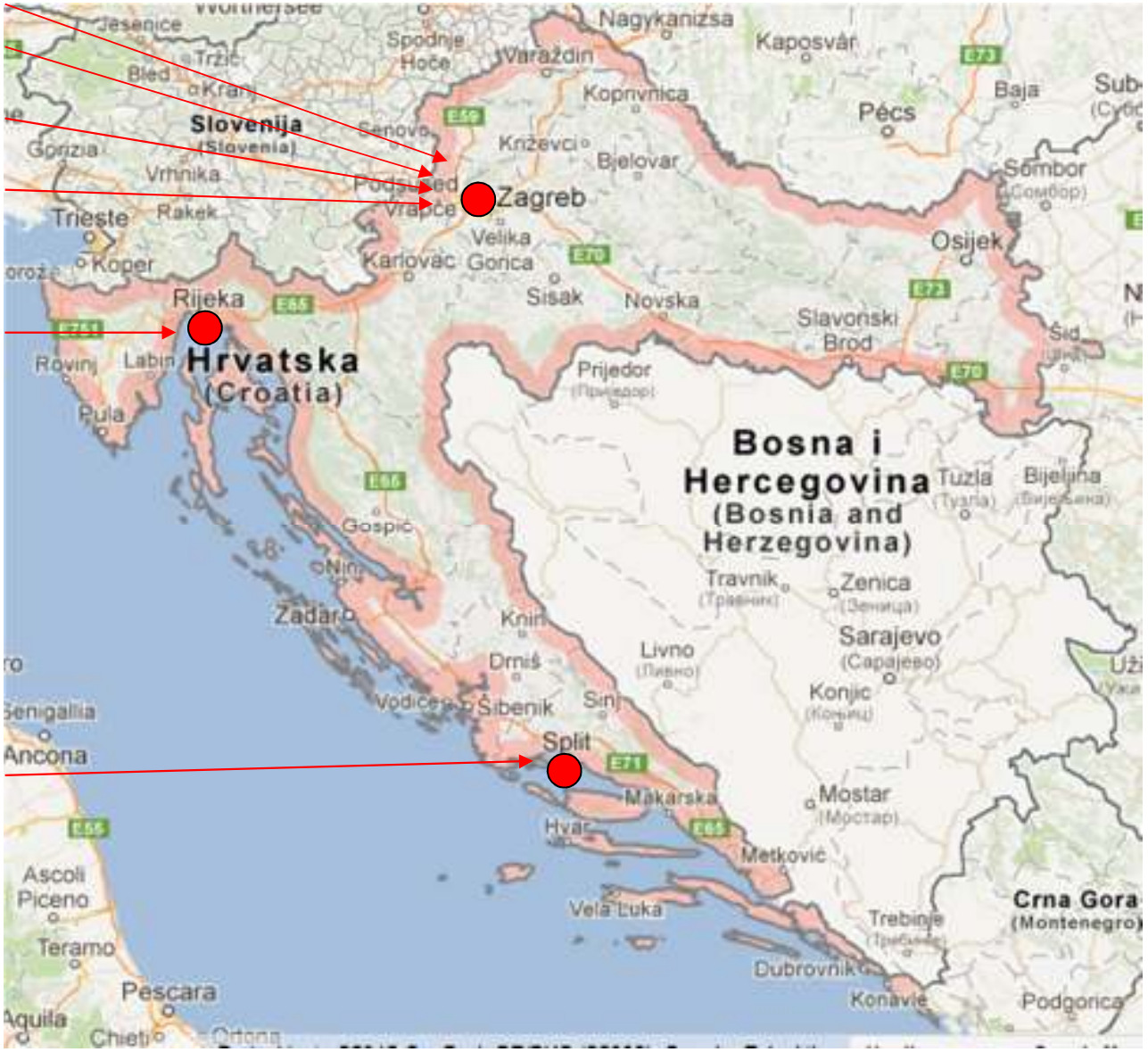
Ambiguous questioning of fusion research in Croatia

- Who does fusion research in Croatia now?
  - Answer: Nobody !
- Who in Croatia should like to participate in Euratom fusion related research?
  - Answer: 10 research groups at least !

Croatian fusion-related groups

- RBI
- IFS
- FER
- FSB
- RiTeh
- FESB



Croatian fusion-related groups (1)

- ***"Ruđer Bošković" Institute, Zagreb (IRB)***
  Division of Experimental Physics
  Laboratory for ion beam interactions
  Contact Person: Dr. Milko Jakšić; milko.jaksic@irb.hr
- ***"Ruđer Bošković" Institute, Zagreb (IRB)***
  Division of Experimental physics
  Laboratory for nuclear physics
  Contact Person: Dr. Zoran Basrak; zoran.basrak@irb.hr
- ***"Ruđer Bošković" Institute, Zagreb (IRB)***
  Division of Experimental Physics
  Laboratory for low-level radioactivity (C14 & Tritium lab)
  Contact Person: Dr. Ines Krajcar-Bronić; ines.krajcar.bronic@irb.hr
- ***"Ruđer Bošković" Institute, Zagreb (IRB)***
  Division of Material Physics
  Laboratory for semiconductors
  Contact Person: Dr. Branko Pivac; Branko.Pivac@irb.hr
- ***"Ruđer Bošković" Institute, Zagreb (IRB)***
  Theoretical Physics Division
  Contact Person: Dr. Hrvoje Štefančić; shrvoje@irb.hr

Croatian fusion-related groups (2)

- ***Institute of Physics, Zagreb (IFS)***
  Laboratory for laser spectroscopy of cold plasma
  Contact person: Dr. Slobodan Milošević; slobodan@ifs.hr
- ***Institute of Physics, Zagreb (IFS)***
  Laboratory for surface sciences and supported nano-structures
  Contact Person: Dr. Petar Pervan; pervan@ifs.hr
- ***Faculty of Electrical Engineering and Computing (FER)***
  University of Zagreb
  Power Systems Department
  Contact Person: Prof. Dr. Nikola Cavlina; nikola.cavlina@fer.hr
- ***Faculty of Electrical Engineering and Computing (FER)***
  University of Zagreb
  Radio Communications Department
  Contact Person: Prof. Dr. Zvonimir Šipuš; zvonimir.sipus@fer.hr
- ***Faculty of Mechanical Enginering and Naval architecture (FSB)***
  University of Zagreb
  Department of Energy, Power Engineering and Environment
  Contact Person: Prof. Dr. Željko Bogdan; zeljko.bogdan@fsb.hr

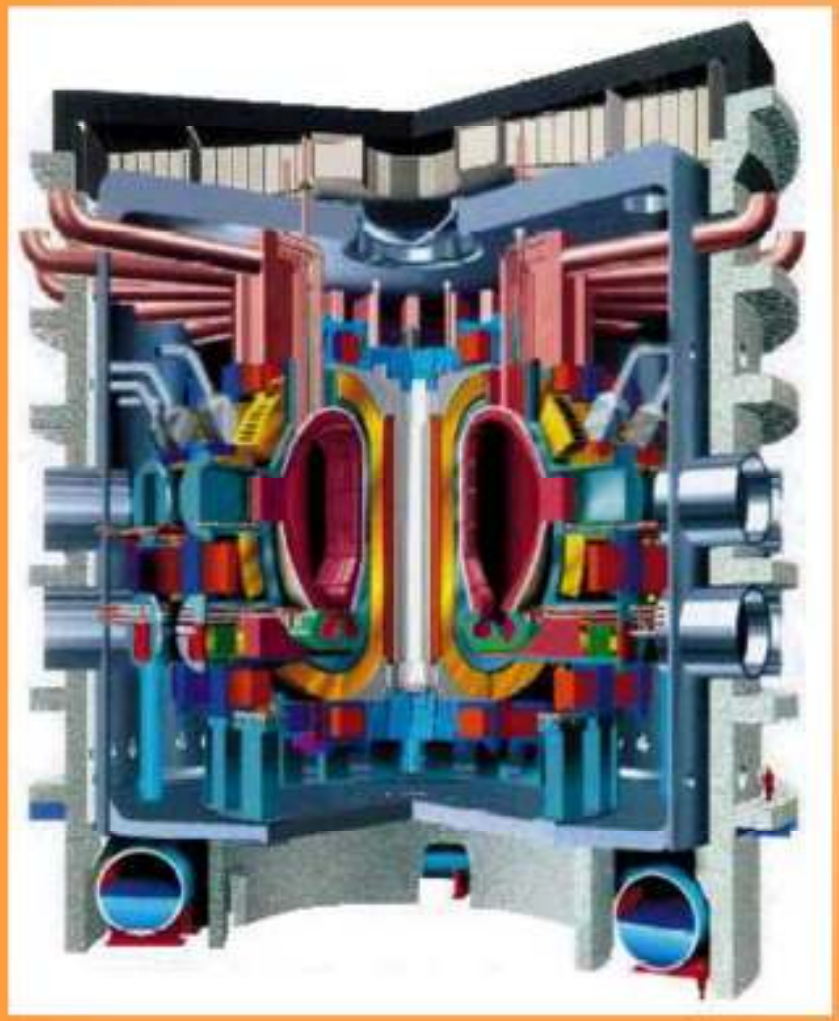
Croatian fusion-related groups (3)

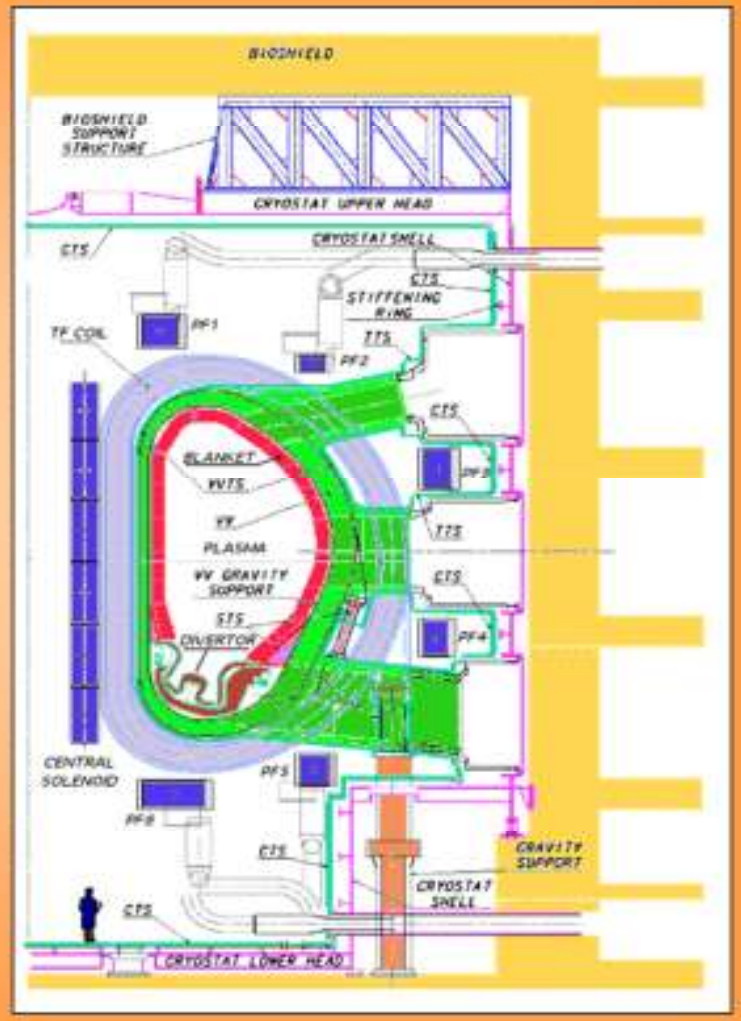
- ***Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture (FESB)***
  University of Split
  Department of Electronics
  Group for Electromagnetic Compatibility and Numerical Methods in Electrical Engineering
  Contact Person: Prof. Dr. Dragan Poljak; dpoljak@fesb.hr

- *Faculty of Electrical Engineering and Computing (FER)*
  University of Zagreb
  Department of Control and Computer Engineering
- *Faculty of Technology (RITEH)*
  University of Rijeka
  Department for Industrial Engineering and Management
- *Faculty of Mechanical Enginering and Naval architecture (FSB)*
  University of Zagreb
  Department of Robotics and Production System Automation

The International Thermonuclear Experimental Reactor

ITER





Research fields of interest for EFDA/ITER
(A) Plasma diagnostics and tokamak detector systems

In JET plasma diagnostics is provided by:

- Langmuir probes
- neutral atom beam injection
- laser irradiation with Thompson scattering
- neutron, α, γ, UV, IR i X spectroscopy
- bolometric cameras

Detectors, optical fibres, antennas - exposed to strong n & γ radiation; fuel (D&T), He & impurities deposit on plates, on detectors and on antennas within tokamak

- IFS – Laboratory for laser spectroscopy and cold plasma
- IFS – Laboratory for surface sciences & supported nano-structures
- IRB – Laboratory for nuclear physics
- IRB – Laboratorij for ion beam interactions
- IRB – Laboratorij for semiconductors

Research fields of interest for EFDA/ITER
(B) Neutron physics and fusion 14.1 MeV neutrons

ITER - expected neutron fluxes up to $1.5 \cdot 10^{20}$ n/s

- The most of experience is based on 2.4 MeV neutrons from fission reactors
- In all parts of ITER neutron flux would not be so high but still enough high to cause damage in tokamak material, in superconductor magnets or in tissue

- **Cross sections for nuclear reactions with 14.1 MeV n**
- **Neutron damage at strong neutron fluxes**
- **Neutron shielding**
- **Effects of 14-MeV neutron radiation can be simulated or modelled by dual-beam chambers (like one at IRB)**
- **IRB – Laboratory for nuclear physics**
- **IRB – Laboratorij for ion beam interactions**
- **FSB – University of Zagreb, Department of Energy, Power Engineering and Environment**

Research fields of interest for EFDA/ITER
(C) Fusion power plant design and operation

- **Fusion power plant design and operation cause similar problems as fission nuclear power plant**
  - **Location selection**
  - **Heat transfer and steam generation**
  - **Control systems**
- **Main differences:**
  - **ITER, DEMO and fusion power plants would be strong emiters of 14.1 MeV neutrons**
  - **Lithium cooled tokamak**
- **EFDA dept: Power plant physics and technology (PPPT)**

- **FER – University of Zagreb, Power Systems Department**
- **FSB – University of Zagreb, Department of Energy, Power Engineering and Environment**

Research fields of interest for EFDA/ITER
(D) Plasma heating: EM waves & neutral atom injection

Plasma heating in tokamak:

- **by neutral atom beams of 80-140 keV**
  - **at JET plasma heating of 23 MW**
- **by electromagnetic waves of frequency 23-57 MHz using "ion cyclotron resonant heating"**
  - **at JET by 32 MW antenna**
- **by electromagnetic waves of frequency 3.7 GHz using "lower hybrid current drive"**
  - **at JET by 12 MW antenna**

- **FER – University of Zagreb, Radio Communication Department**
- **IRB – Laboratory for ion beam interactions**

Research fields of interest for EFDA/ITER
(E) Advanced robotics for tokamak internal maintenance

- **Due to high radiation level, as well as due to Be and T contamination all maintenance within ITER should be done by advanced robotic systems:**
  - **W plates replacement**
  - **divertor maintenance**
  - **repairs at radio antennas**
  - **installation and repairs of detectors & diagnostic systems**
  - **at JET: by two robotic arms**

- FER – University of Zagreb, Department of Control and Computer Engineering
- FSB – University of Zagreb, Department of Robotics and Production System Automation
- RITEH – University of Rijeka, Department for industrial engineering and management

Research fields of interest for EFDA/ITER
(F) Numerical simulation of magnetic fields and development of superconducting magnets

- **Strong magnetic fields, produced by poloidal and toroidal magnets need permanent adjustments to match plasma instablities**
- **Particles in plasma particles have complex trajectories**
- **Complex adjustment of field or complex coils**

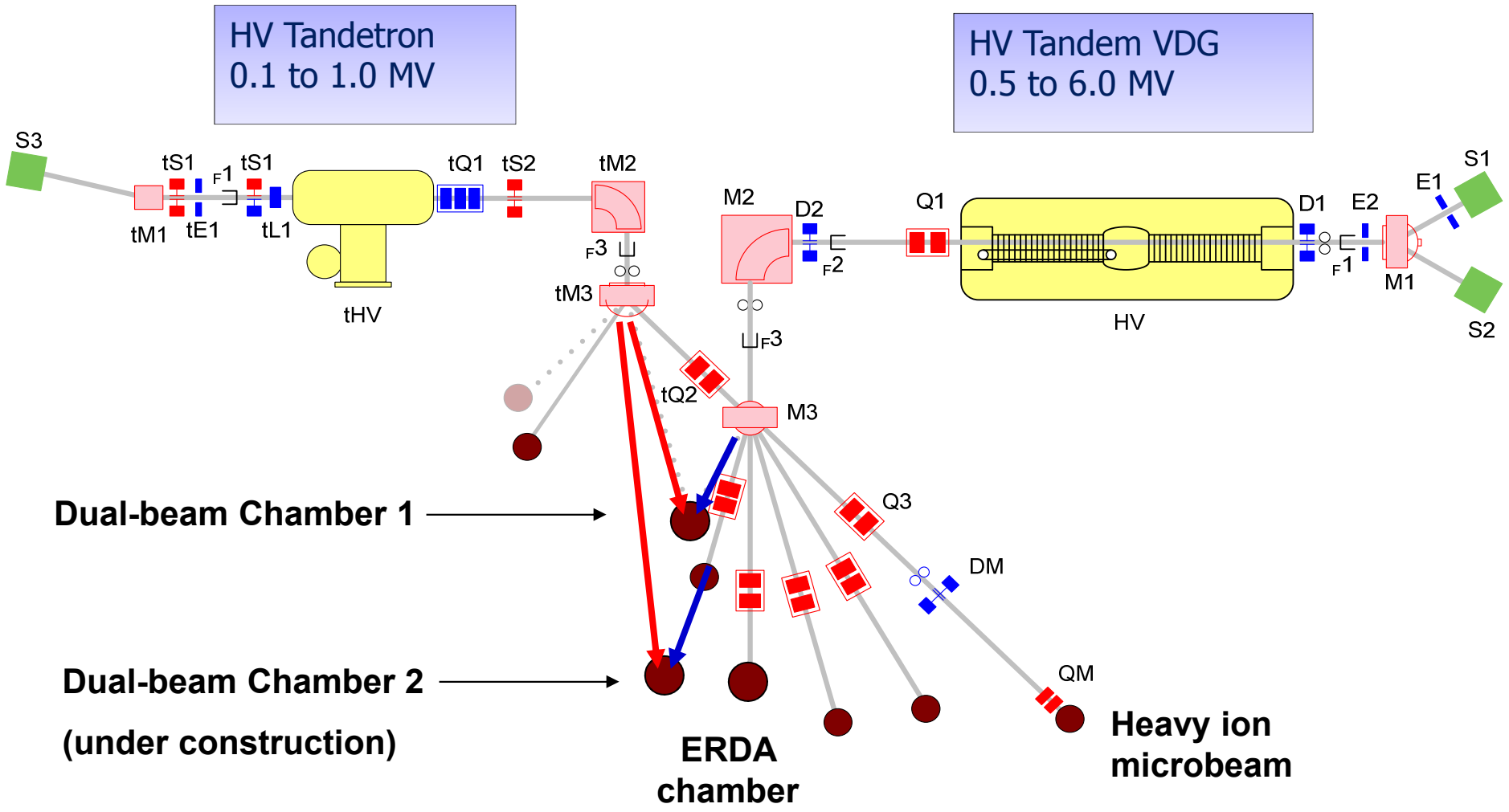
- **IRB - Theoretical Physics Division**
- **FESB - University of Split**
  Department of Electronics; Group for Electromagnetic Compatibility and Numerical Methods in Electrical Engineering
- **FSB - University of Zagreb**
  Department of Energy, Power Engineering and Environment

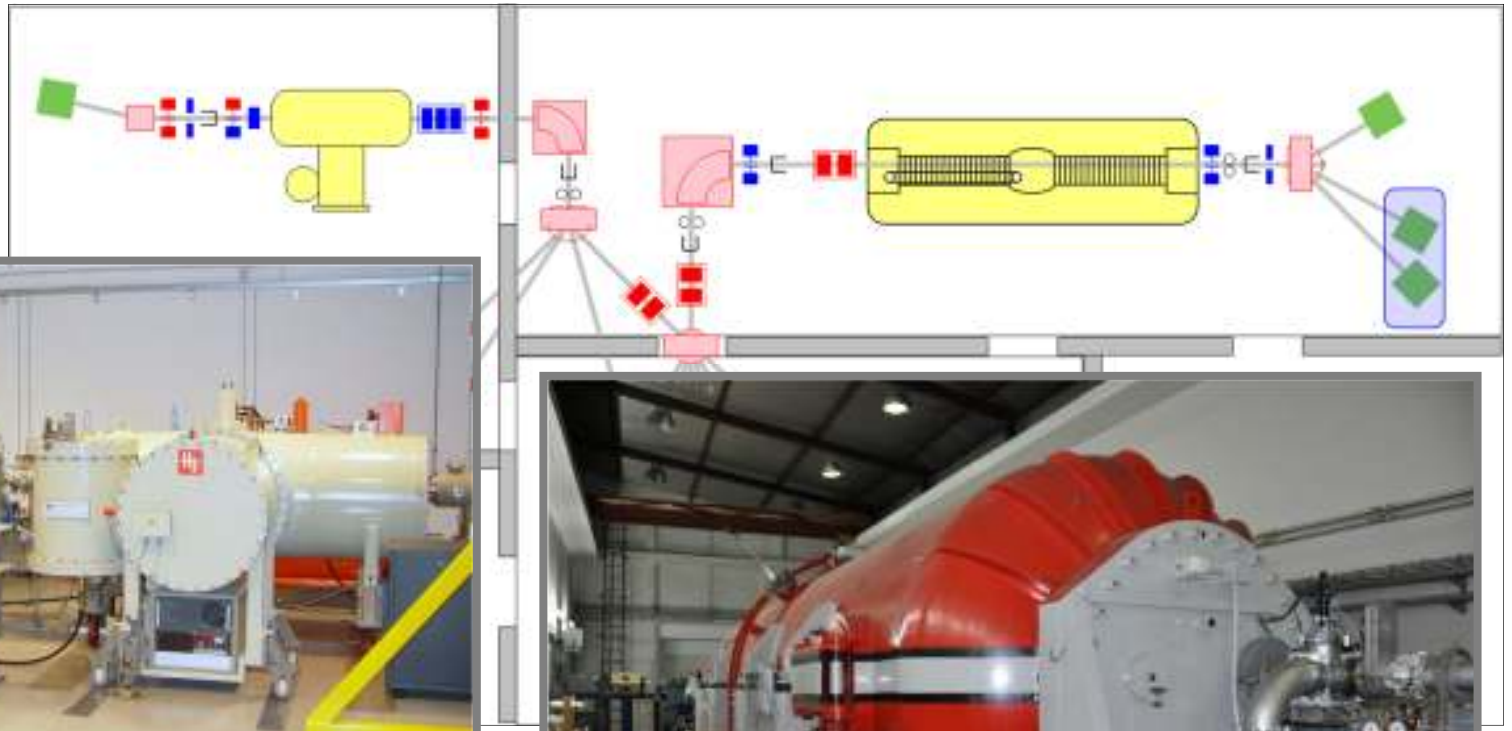
Research fields of interest for EFDA/ITER
(G) T monitoring & T and Be contaminated materials

- **Handling and storage of T and Be contaminated materials requires special protocols**
  - **JET - methods for removal of tritium from contaminated surfaces within tokamak**
- **Tritium monitoring at ITER and fusion power plants would be necessary**

- **IRB – Laboratory for low level radioactivity**
  - **(C14 and Tritium Lab)**

Dual beam chamber, ERDA chamber and Heavy ion microbeam @ RBI's Accelerator center





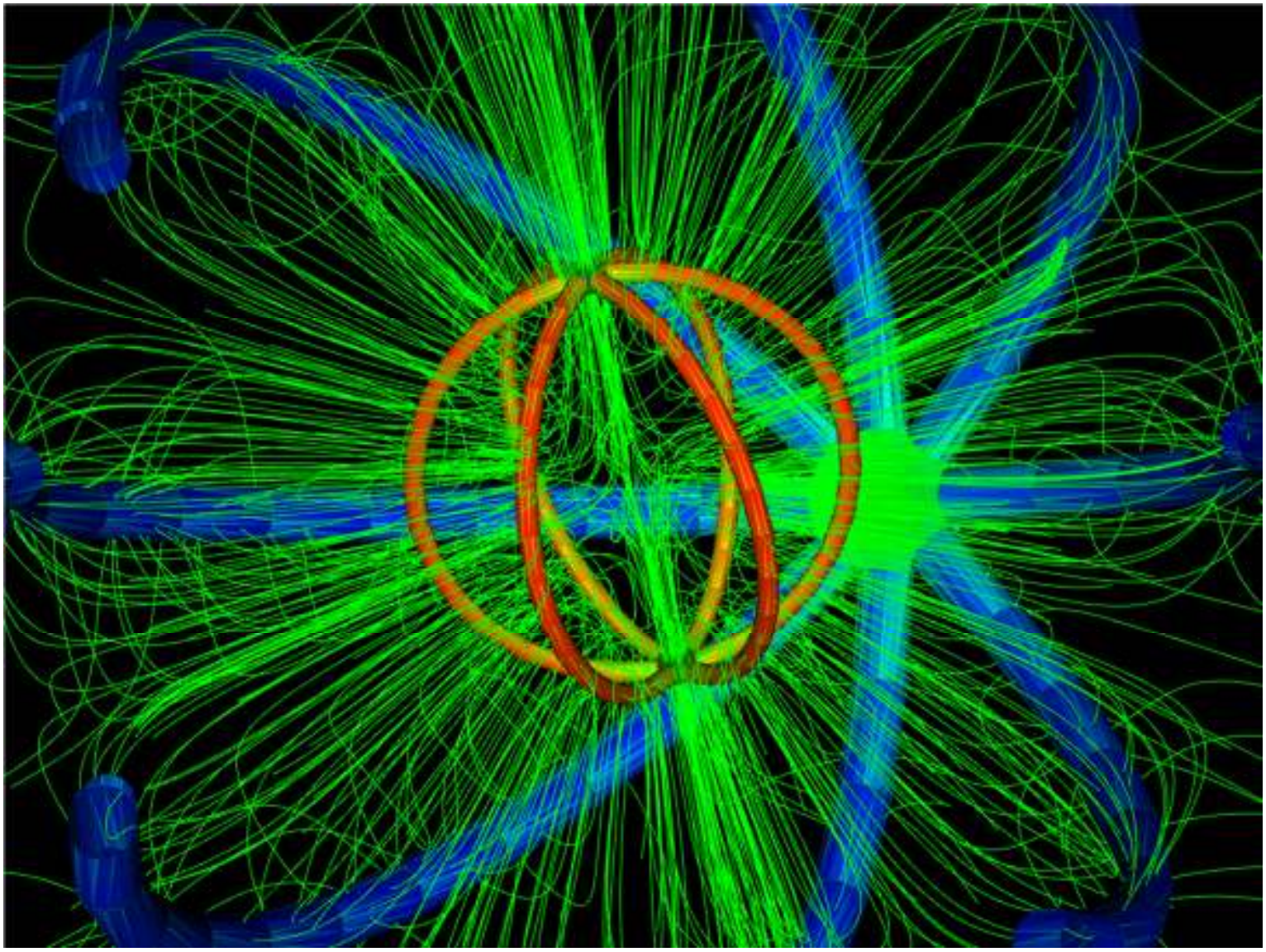
Who else does have dual-beam facility ?

Table 2
Multi-irradiation facilities available in the world

Laboratory	Facilities	Application field
a) dual or triple MeV ion beams		
MSD, IGCAR Kalpakkam, India	1.7 MV Tandetron Ion implanter (30–150 keV)	Irradiation behaviour of nuclear alloys
HIT Tokyo, Japan	3.75 MV Van de Graaff 1 MV Tandetron	Irradiation behaviour of nuclear alloys and ceramics
DNE Nagoya University, Japan	2 MV Van de Graaff 200 kV ion implanter	Irradiation behaviour of nuclear alloys and ceramics
FZ Rossendorf, Germany	3 MV Tandetron 500 kV ion implanter	Synthesis of nanostructured ceramics assisted by irradiation Ion beam modification of materials
FSU Iena, Germany	3 MV Tandetron JULIA 400 kV ion implanter ROMEO	Synthesis of nanostructured ceramics assisted by irradiation Irradiation behaviour of nuclear alloys
IAE Kyoto, Japan	1.7 MV Tandetron 1 MV Van de Graaff 1 MV Singletron	Evolution of microstructure under multi-irradiation
JAERI Takasaki, Japan	3 MV Tandem 3 MV Van de Graaff 400 kV ion implanter	Synthesis of nanostructured ceramics assisted by irradiation Behaviour of alloys and ceramics under irradiation
DMN Saclay, France (ready to operate at the beginning of 2008)	3 MV Pelletron ÉPIMÉTHÉE 2.5 MV Van de Graaff YVETTE 2.25 MV Tandetron	Irradiation behaviour of nuclear materials Ion beam modification of materials

Yves Serruys et al., "JANNUS: experimental validation at the scale of atomic modelling", C. R. Physique 9 (2008) 437–444

Simulation of IEC fuzor for inertial electrostatic confinement fusion - by Robin Hood method



http://www.youtube.com/watch?v=zZL-ob6uBpo