

Committee on US Research at ITER
Washington 14-15 December 2007

**ITER and the European Fusion
Research programme**

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EFDA Leader

CONTENT

1- Organisation of fusion R&D in Europe

2- EU strategy towards DEMO

3- Research Programme

The start of ITER has led Europe to change significantly the organisation of its fusion programme

- *Need to set-up a Domestic Agency as foreseen in the ITER Agreement***
- *EU's specific responsibility as Host***
- *Clear separation, for the sake of efficiency, between responsibilities related to projects (construction of ITER and "Broader Approach" projects) and research***

The overall fusion programme remains coordinated by the Commission in the frame of Euratom

New Organisation in force end 2007

Joint Undertaking for ITER

“Fusion for Energy” (F4E)

- Domestic Agency to provide and manage EU contribution to ITER
- EU Contribution to Broader Approach
- located in Spain (Barcelona)

European Fusion Development Agreement (EFDA)

- Agreement between all EU fusion labs and Euratom
- Coordinated research (physics in support to ITER, longer term technology) and JET
- Garching (D) and Culham(UK)

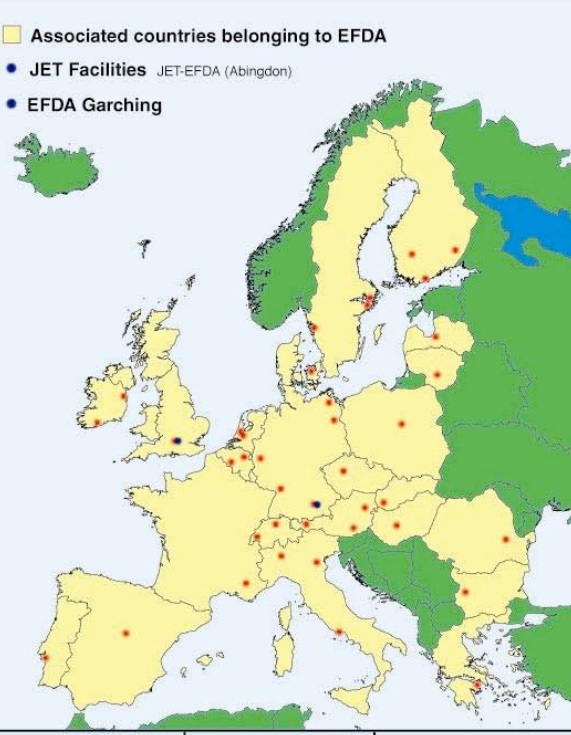
Associations:

European Fusion Laboratories associated to Euratom through “Contracts of Association”

EFDA

All EU Laboratories/Institutions working on Fusion are parties to EFDA

- **Collective use of JET**
- **Reinforced coordination of physics and technology in EU laboratories**
- **Training**

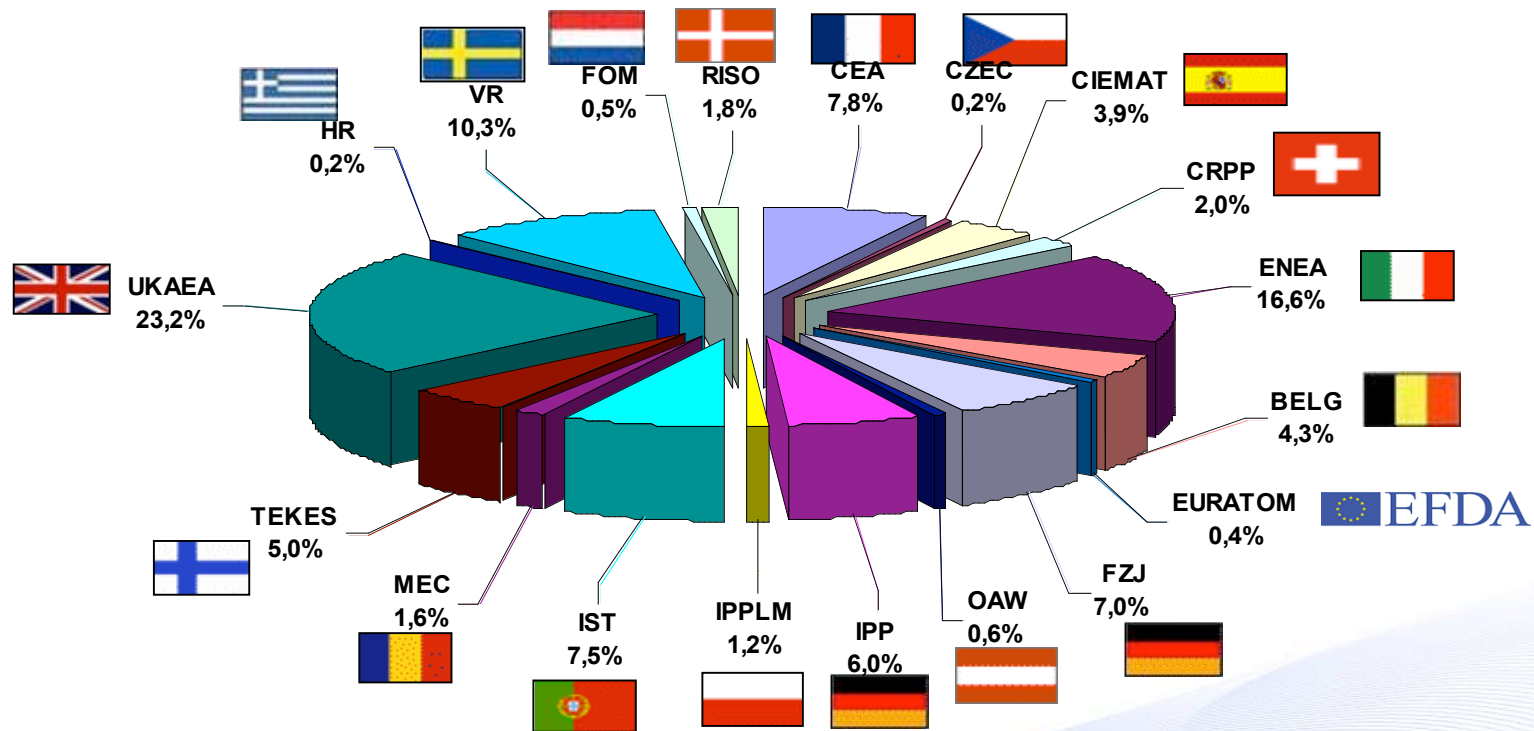
EURATOM : KEY ACTION FUSION Associated Laboratories, parties to EFDA			
Euratom - Belgian State (Brussels) - (Mol)	 <ul style="list-style-type: none"> ■ Associated countries belonging to EFDA ● JET Facilities JET-EFDA (Abingdon) ● EFDA Garching 	Euratom - HAS (Budapest)	Euratom - IPP Asdex Upgrade - Wendelstein 7-AS Wendelstein 7-X (Garching) - (Greifswald) - (Berlin)
Euratom - CEA TORE SUPRA (Cadarache)		Euratom - IPP.CR CASTOR (Prague)	
Euratom - CIEMAT TJ-II (Madrid)		Euratom - IST ISTTOK (Lisbon)	
Euratom - Conf. Suisse TCV - SULTAN (Lausanne) - (Villigen)		Euratom - Latvia (Riga)	
Euratom - DCU (Dublin) - (Cork)		Euratom - MEC (Bucharest)	
Euratom - ENEA FTU - RFX (Frascati) - (Milan) - (Padua)		Euratom - ÖAW (Vienna) - (Graz) - (Innsbruck)	
Euratom - FOM (Petten) - (Nieuwegein)		Euratom - RISØ (Roskilde)	
Euratom - FZJ TEXTOR (Julich)		Euratom - TEKES (Helsinki) - (Tampere) - (Lappeenranta)	
Euratom - FZK TOSKA (Karlsruhe)		Euratom - UKAEA MAST - JET (Culham)	
Euratom - Greece (Athens) - (Heraklion) - (Ioannina)		Euratom - INRNE (Sofia)	Euratom - LEI (Kaunas)
		Euratom - VR EXTRAP T2R (Stockholm) - (Lund) (Gothenburg) - (Studsvik) - (Uppsala)	

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Collective use of JET under EFDA

- Under the responsibility of the EFDA-JET Leader (F.Romanelli)
- Task Forces
 - Topical TFs: plasma scenarios (2 TFs), Edge and Exhaust, MHD, Transport, Heating, Diagnostics, DT operation, Fusion Technology
 - constituted by scientists from European Laboratories
 - TF Leaders selected on the basis of scientific background and leadership capabilities
- Programme:
 - elaborated yearly by the EFDA-JET Leader supported by the Task Forces
 - elements of the programme selected on the basis of scientific priorities (ITER focus) and scientific value
 - assessed by Science committee (STAC) and approved by the EFDA Steering Committee
- Participation of laboratories in the experimental programme based on a Call for Participation

Collective use of JET under EFDA



**Participation of European labs to the JET experimental programme
 (about 300 scientists; plus 400 staff involved in Operation under UKAEA)**

There are also significant collaborations with US and Russian Laboratories and participation of Japanese, Korean and Chinese scientists

International collaborations

EU is involved in several implementing agreements under the IEA.

EU has bilateral agreements with Japan, Kazakhstan, Korea Russia, Ukraine and USA, and prepares other agreements with Brazil, China and India.

Joint experimentation is now regularly conducted on top-priority subjects involving several tokamaks around the world from EU, US, Japan, Russia, etc..

A guiding role is played by the International Tokamak Physics Activity (ITPA) formerly under the IAEA and now under ITER.

Broader Approach projects constitute a major collaboration between EU and Japan.

A Facilities Review will be conducted in Europe over the year 2008

An Panel (with international participation) will review “all significant facilities in the programme existing or under construction, including proposed or considered upgrades and taking account of EU international commitments such as ITER and projects within the Broader Approach Agreement with Japan”

The preparation of this review has triggered a very active programmatic reflexion between the European laboratories; input is prepared under EFDA coordination

CONTENT

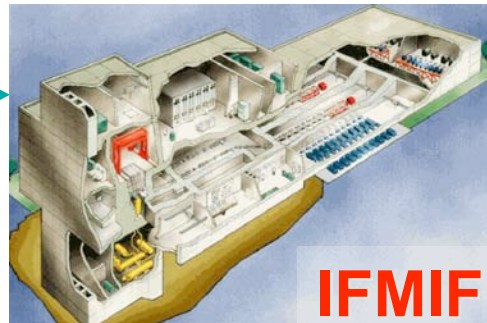
1- Organisation of fusion R&D in Europe

2- EU strategy towards DEMO

3- Research Programme

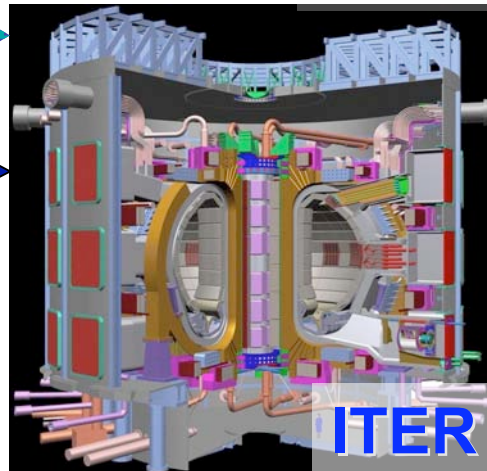
EU Strategy towards DEMO

**Structural Materials
And T breeding**



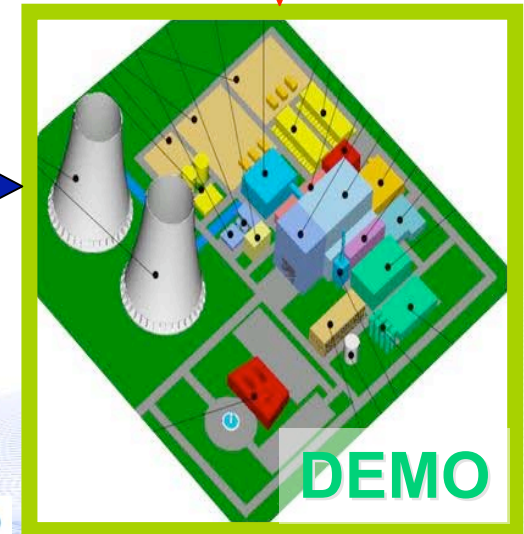
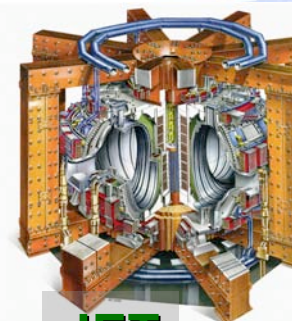
Components

- SC Magnets
- Tritium Handling System
- Plasma Facing Compts.
- Remote Mainten. System
- Heating System
- Safety
- Test Blanket Modules
- Diagnostics



Facilities for Plasma R&D

- Confinement
- Impurity Control
- Plasma Stability
- ITER/DEMO Physics Support



Key elements of the strategy towards DEMO are getting in place:

ITER

**Broader Approach agreement
between EU and Japan**

JT60 SA

IFMIF EVEDA

ITER's objectives make it the keystone of the strategy

• Physics:

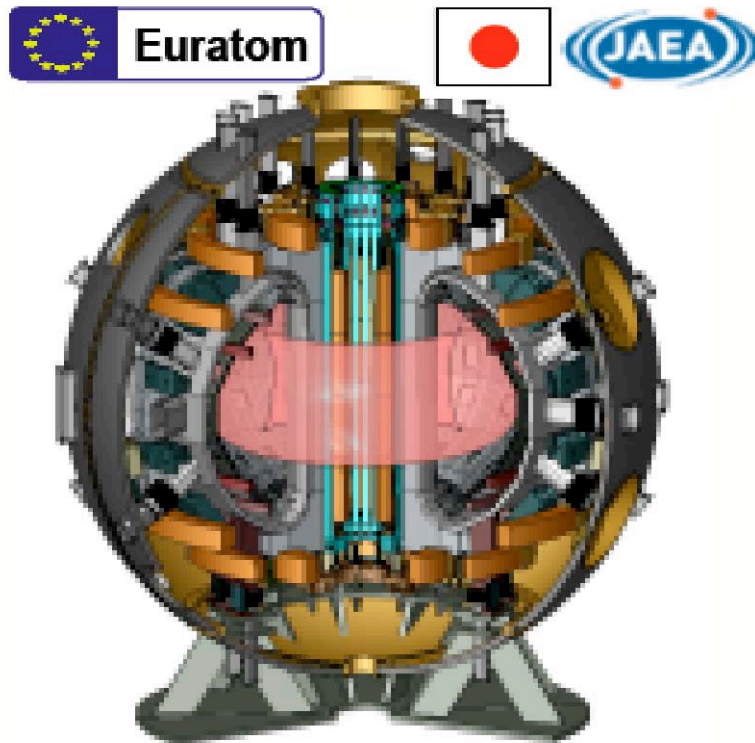
- burning plasma dominated by α -particle heating
- fusion power amplification factor ($Q \geq 10$)
- aim to achieve steady-state operation at $Q = 5$
- possibility of exploring 'controlled ignition'

• Technology:

- integrated operation of technologies for a fusion power plant
- testing of components required for a fusion power plant
- testing concepts for tritium breeding modules

JT-60SA as a satellite to ITER (support to ITER during ITER operation)

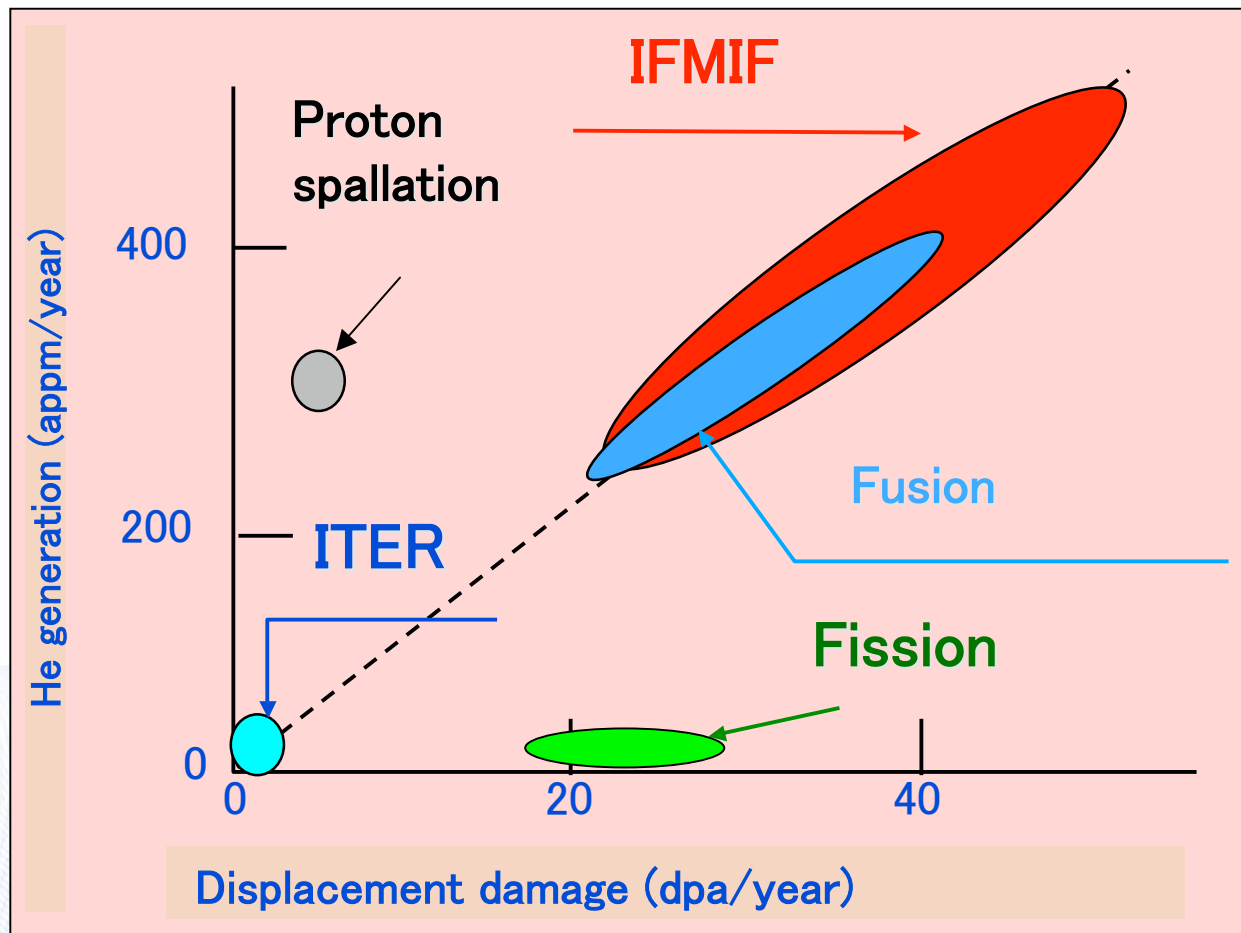
- Enhanced flexibility in aspect ratio ($A=2.6-3.1$) and plasma shape.
- High power heating/current-drive system, 41MW for 100 s, will be prepared.
- High beta steady-state operation ($\beta_N \sim 4$, $f_{BS} \sim 70\%$) for DEMO and high density ELMy H-mode operation ($n_e \sim 9 \times 10^{19} \text{m}^{-3}$) for ITER are planned.



parameters	
Plasma Current	5.5MA/3.5MA
Major Radius	3.01m / 3.16m
Minor radius	1.14m / 1.02m
Elongation κ_{95}	1.83 / 1.7
Triangularity δ_{95}	0.57 / 0.33
Toroidal field B_t	2.72 / 2.59
Safety factor q_{95}	3.77/ 3.0
Flat top	100s (8hours)
H&CD power	41MWx100s
Perp NB	16MW
Co P-NB	4MW
CTR P-NB	4MW
N-NB	10MW
ECRF	7MW
PFC heat flux	10MW/m ²
Annual neutron	4x10 ²¹

IFMIF and Materials

Activation by fusion neutrons: a specific problem



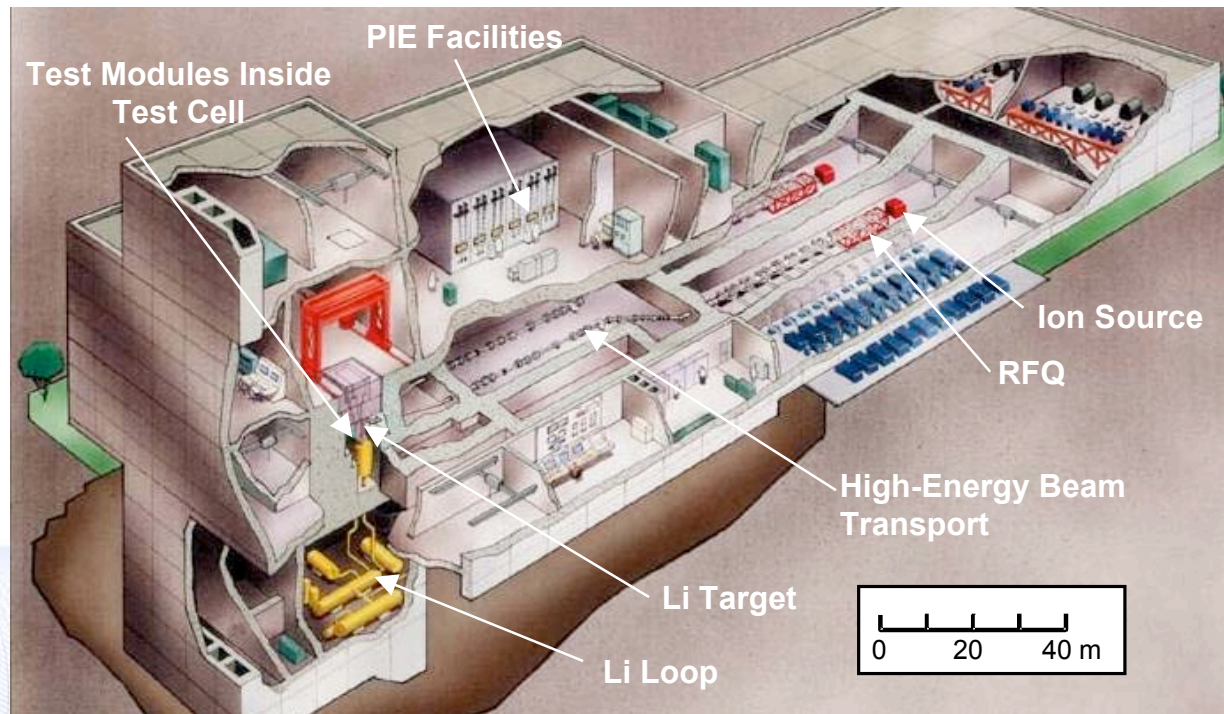
**14 MeV
neutrons from
DT reactions:
He generation
rate higher than
from slower
neutrons**

**Requires a
specific facility
(IFMIF)**

IFMIF and Materials

International Fusion Materials Irradiation Facility

Engineering, Validation and Design Activities starting in the frame of the EU-Japan Broader Approach



Overview of the IFMIF design with major subsystems

Strategic Energy Technology Plan (SET Plan)

- initiative launched by the European Commission in 2007

“Recognizing the need to strengthen energy research in particular to accelerate competitiveness of sustainable energies, notably renewables, and low carbon technologies and the further development of energy efficiency technologies”, the Commission conducted hearings with several groups of experts.

- A fusion group, under the leadership of Chairman of CCE-FU (Consultative Committee Euratom-Fusion), has submitted a report. Fusion group recommends reinforcing the programme and launching a DEMO conceptual study involving industry and conducting also a Component Test Facility feasibility study.
- EC recommendations aim at strengthening the development of fusion.

http://ec.europa.eu/energy/res/setplan/communication_2007_en.htm

CONTENT

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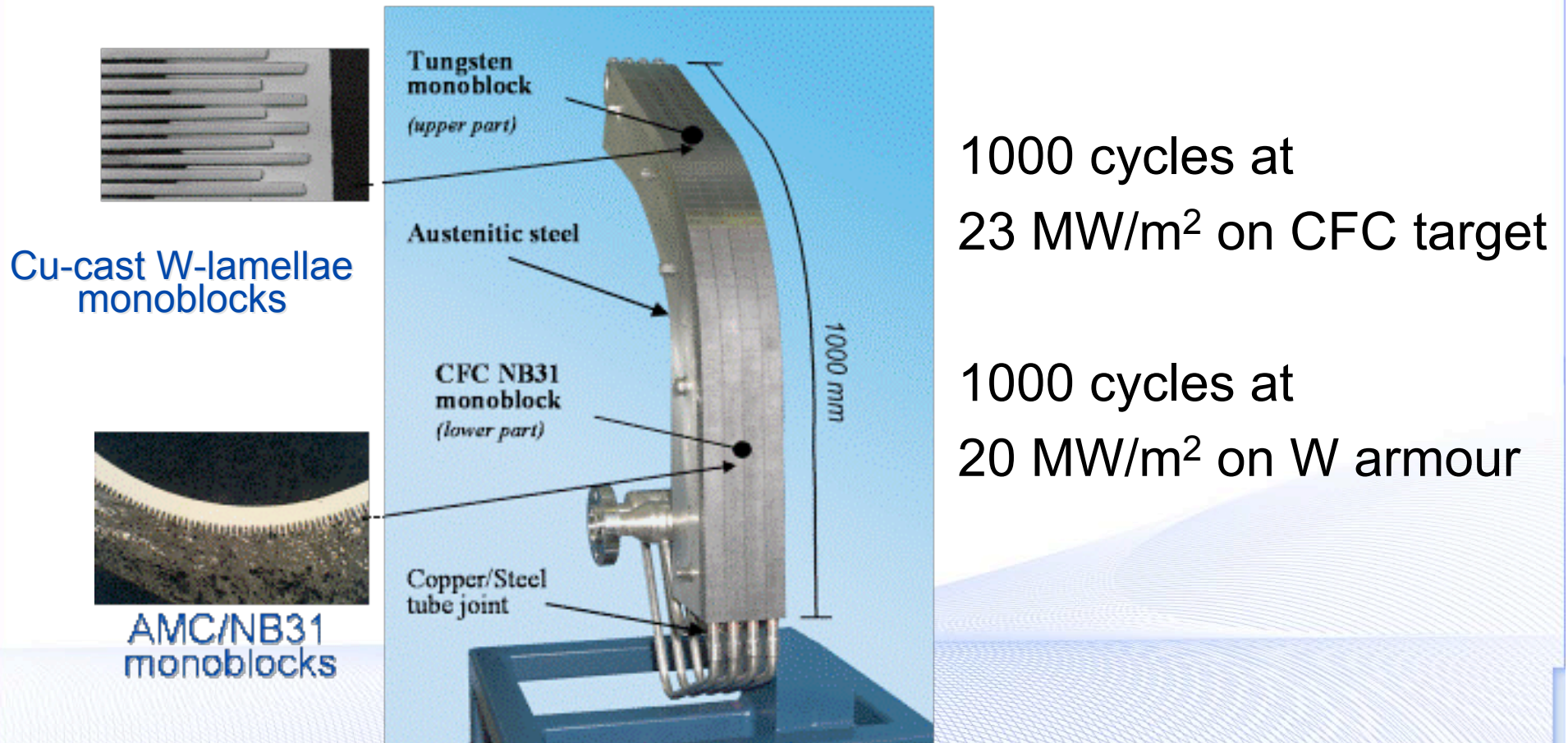
3- A Research Programme strongly shaped by ITER

EU design activities and Technology R&D in support of ITER

EU provided substantial contributions to ITER throughout, since the start of the project in 1988 and even after the end of the EDA phase (2001)

EU contributions to ITER construction will be based on successful achievements of a focused technology R&D programme

EU Technology R&D in support of ITER: Divertor Full-Scale Vertical Target Prototype



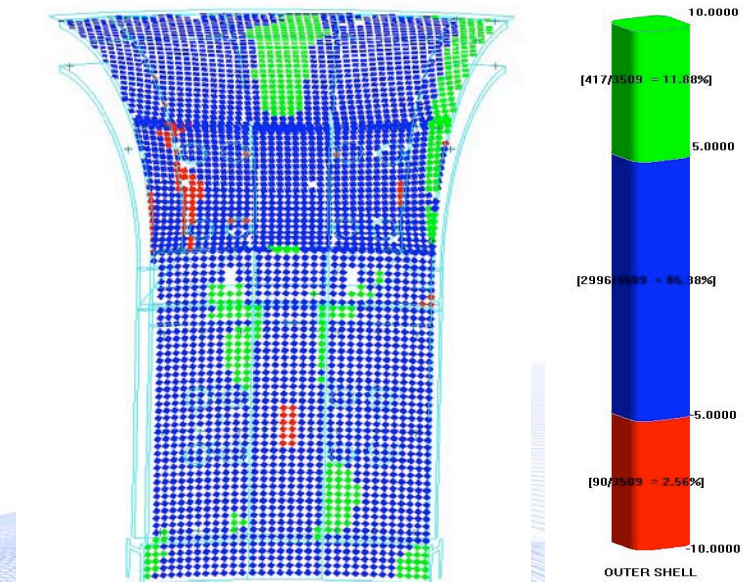
EU Technology R&D in support of ITER : Vessel

Vacuum Vessel Poloidal Segment Model
after jig removal and cleaning



Vacuum Vessel Poloidal
Segment Model

Measured weld distortions

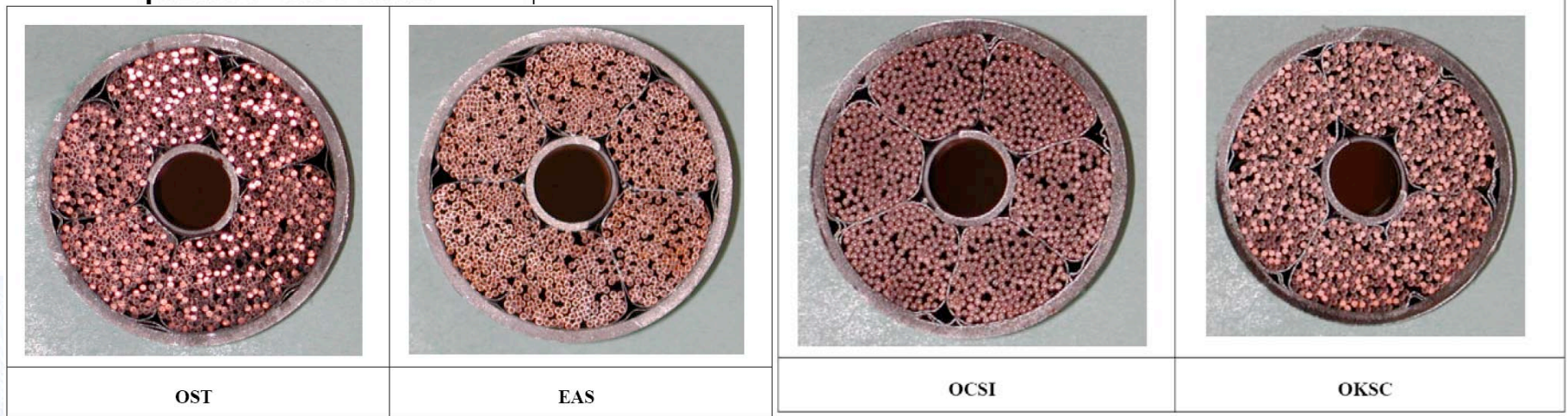


- In compliance with the acceptance criterion tolerances (± 10 mm).

EU Technology R&D in support of ITER : Magnets

Magnets – Full Size Conductor Tests

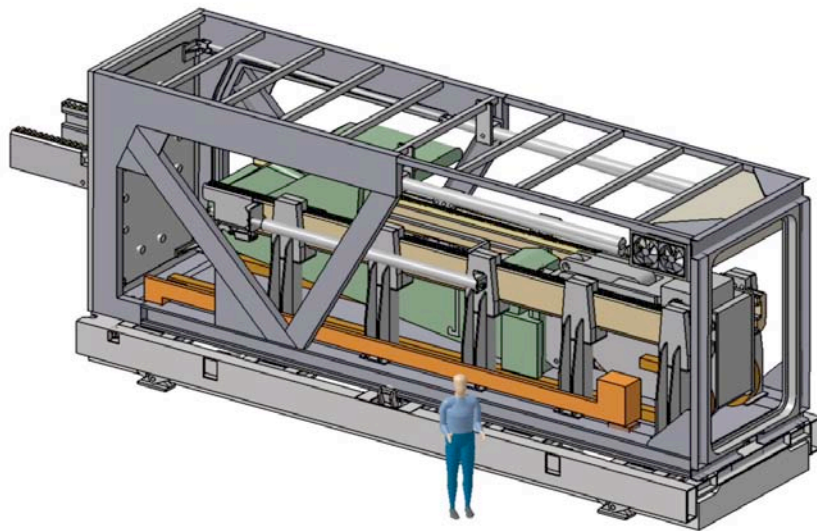
TFPRO1 L vf 33.8% EAS I	Tcs > 6K, ΔV with/without correction	☺
TFPRO1 R vf 29.3% EAS II	Tcs > 6K, ΔV with/without correction	☺
TFPRO2 L vf 28.3% OST2	Tcs > 7K, ΔV with/without correction, Cal	☺
TFPRO2 R vf 29.7% OST1	Tcs > 6K, ΔV with/without correction, Cal	☺



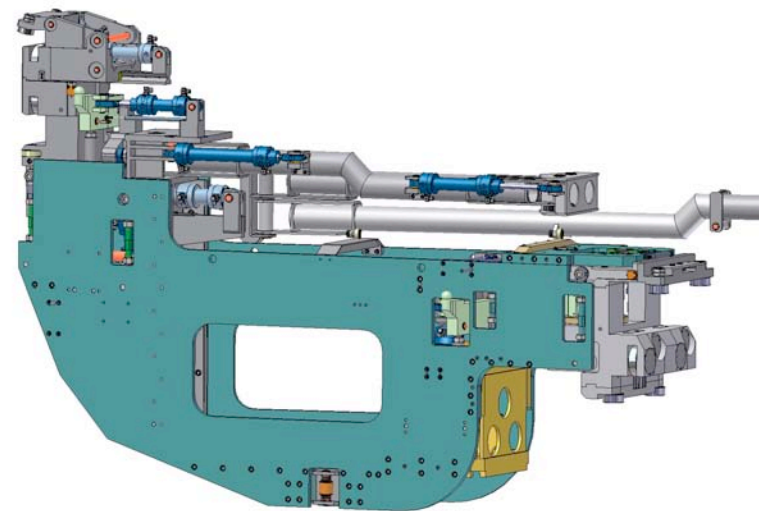
All four EU conductors fulfilled ITER specification with ample margin

EU Technology R&D in support of ITER : RH

Divertor Remote Handling demonstrated/tested on two EU RH test platforms



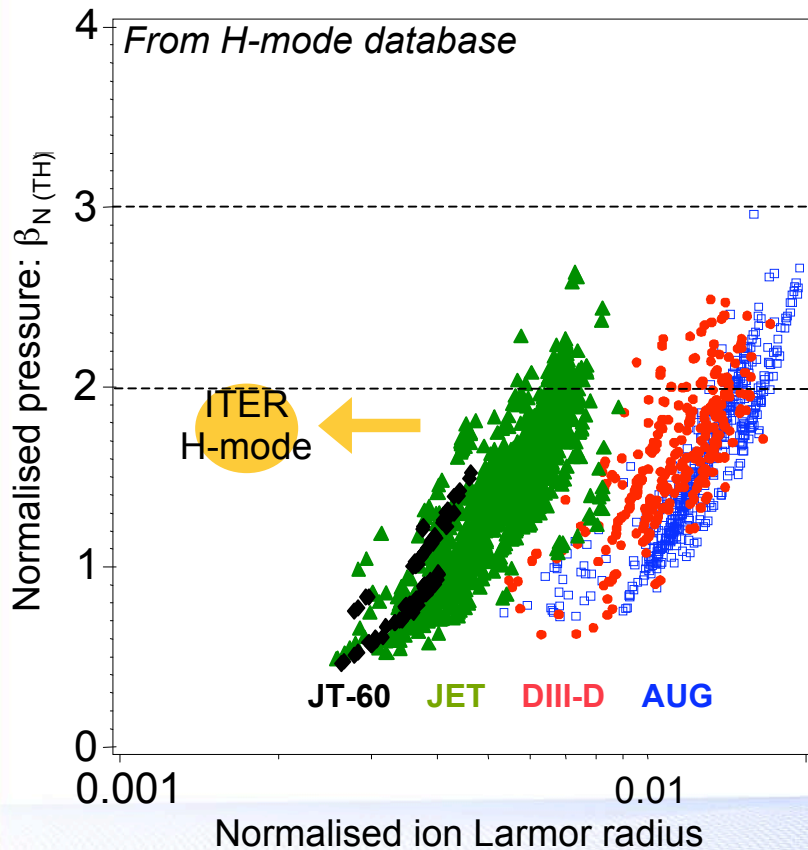
RH Transfer Cask



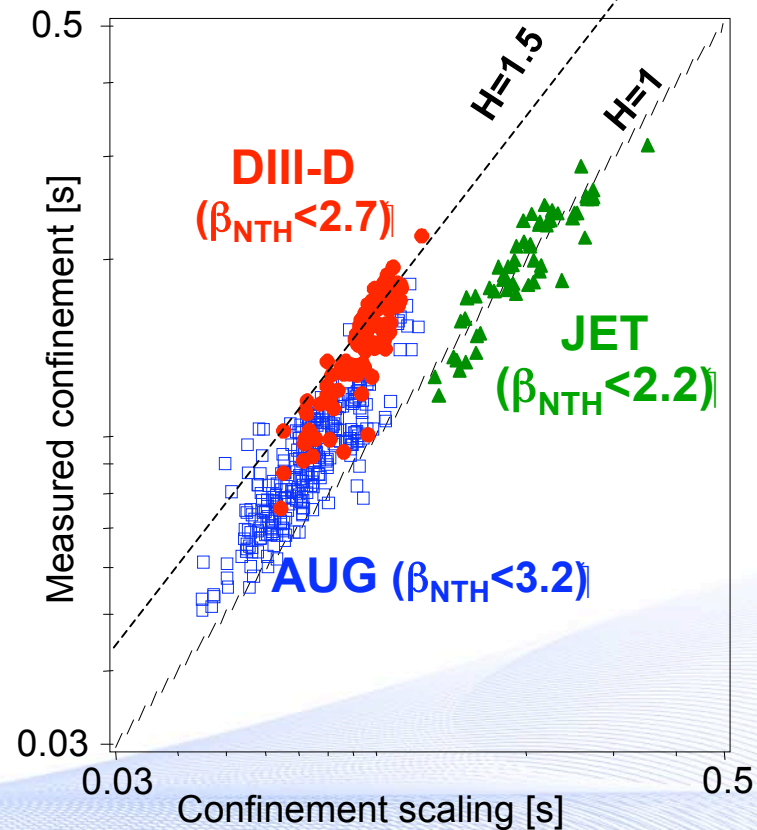
Cassette Toroidal Mover

EU physics activities in support of ITER

With JET and AUG, Europe has 2 of the most ITER relevant tokamaks today



H-mode data base
(reference for ITER Q=10)

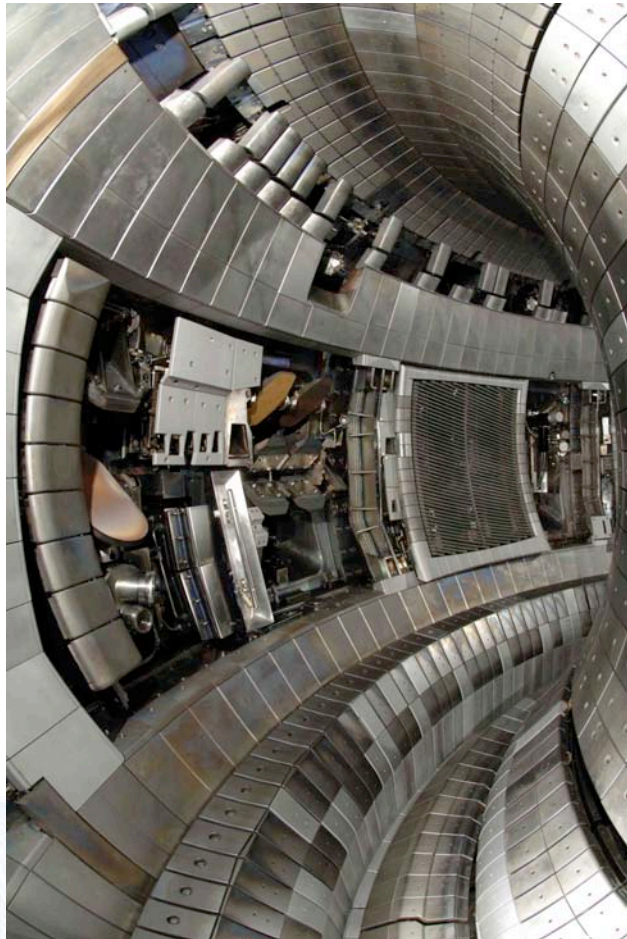


hybrid scenario data base
(candidate for ITER long pulse operation)

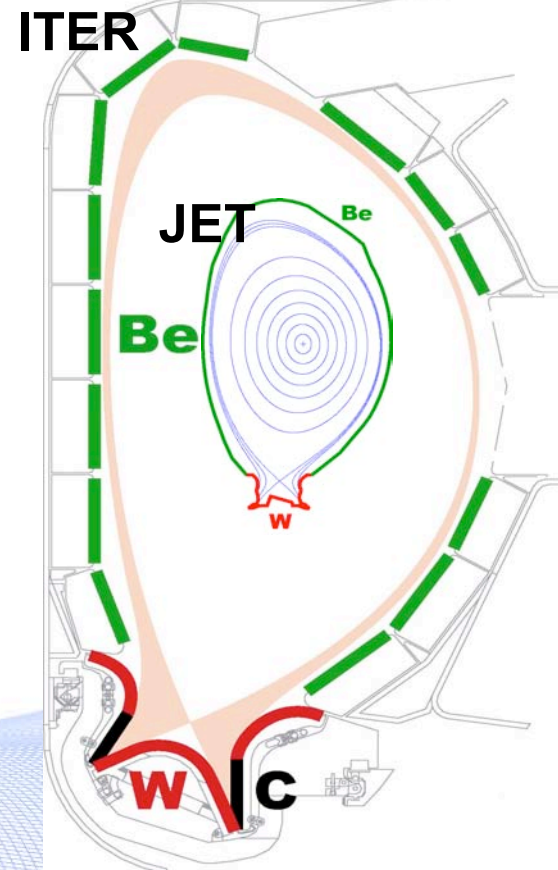


Plasma facing materials choices are driven by ITER and DEMO needs

AUG full W machine since 2007



JET ITER-like wall experiment (unique Be capability) to be operational end 2010



*ITER foresees to use **W** and **Be** for the DT experiments (no Carbon)*

- ⇒ Coordinated Research: European Task Force on Plasma Wall Interaction
- ⇒ A growing recognition that plasma operation shall comply with constraints fixed by materials

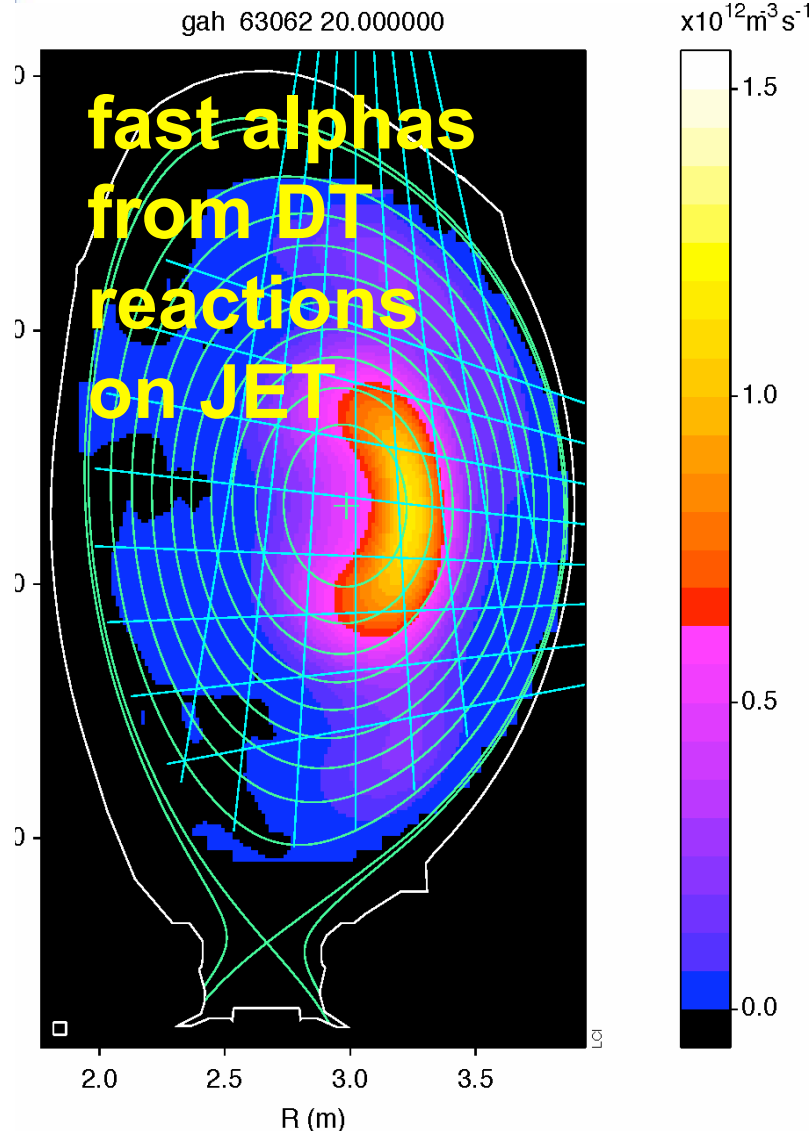
JET retains its DT capability

Further key DT contributions would be possible in support to ITER preparation:

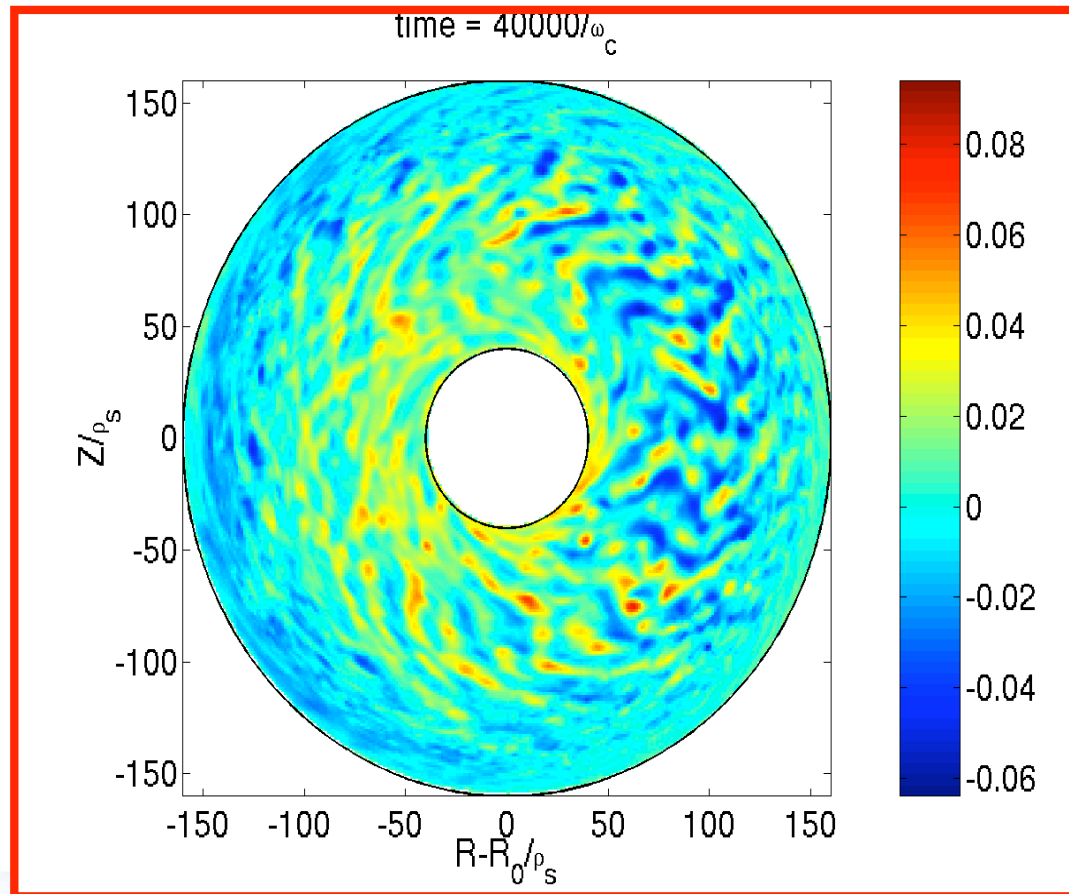
- *burning plasma physics*
- *study of tritium retention with all metallic walls*
- *isotopic effects in ITER-relevant plasma scenarios and physics*

no DT experiment planned as of today, but growing interest in preparation of ITER operation

Significant JET enhancement ongoing with the above mentioned ITER-like wall, increase in power and control capabilities (>60Meuros)



Europe aims at developing a Numerical Tokamak



Turbulent transport simulated with the Gysela code

Coordinated effort :

- ***Integrated Modelling European Task Force***
- ***JET Transport and MHD code integration***
- ***Theory***
- ***Validation on experimental devices***

An essential tool for preparing and analysing ITER experiments and extrapolating to DEMO

The preparation of ITER exploitation will greatly shape the EU R&D programme: e.g. R&D Milestones are being identified that feed into ITER exploitation (*provisional list*)

~ 10 Years R&D Milestones feeding into first ITER experimental campaign

- diagnostic techniques for erosion, deposition, dust formation etc.
- dust and tritium removal techniques
- Fully developed plasma operation strategies
- plasma scenarios compatible with high-Z and mixed materials, and suitable for long-pulse and Steady-State Scenarios
- burning plasma physics predictive capability
- LHCD R&D completed
- solution to the coupling of ICCD and LHCD
- predictive capability for the H-mode pedestal
- availability of a 'numerical tokamak' for planning and analysing experiments
- Qualification of reference EUROFER for the Test Blanket Modules
- alternative divertor armour materials available (W tbc)

~15 years R&D Milestones, before start of ITER DT operation

- hydrogen/deuterium inventory data to establish the basis for DT operation and divertor materials optimisation

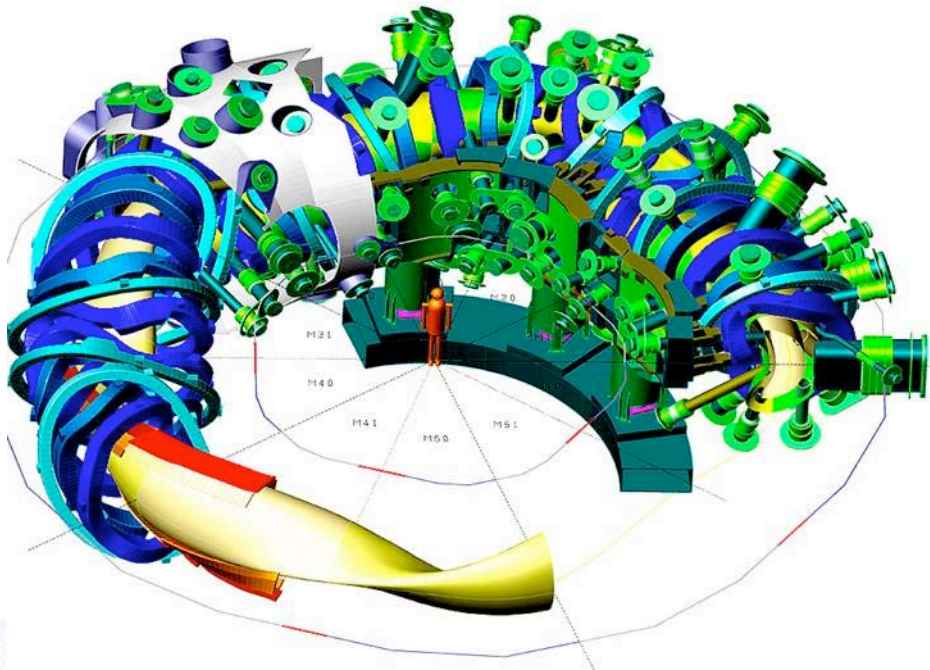
Similarly, ITER results will provide key information to DEMO

Several Milestones feeding into DEMO will result from ITER exploitation

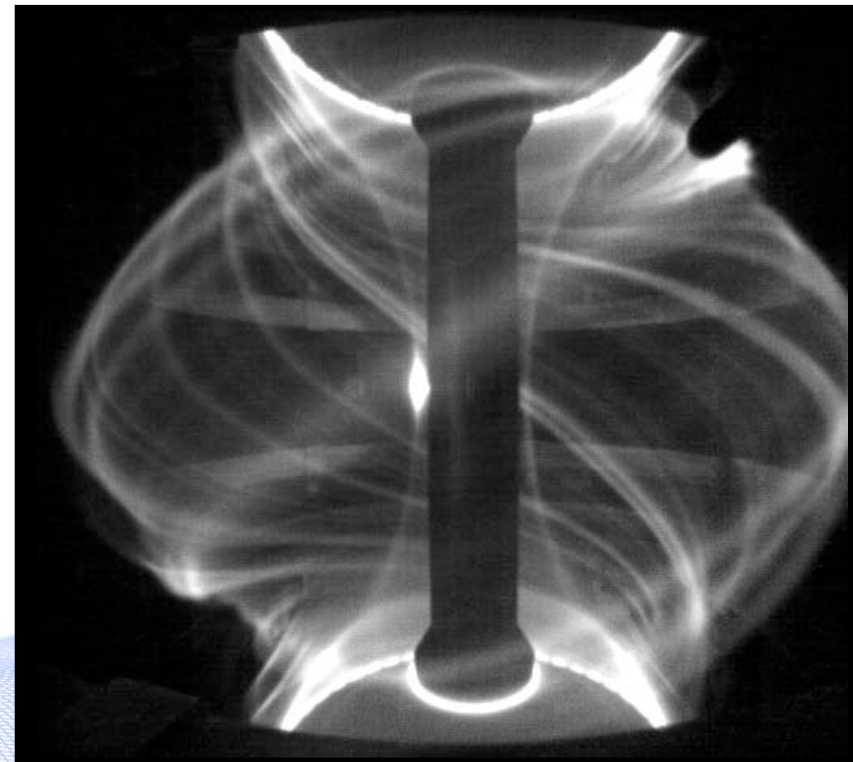
- confirmation of DEMO physics basis (plasma facing materials, long pulse plasma scenarios, etc.) (*main contributions are expected from ITER*)
- selection of appropriate diagnostics and control tools (*main contributions are expected from ITER*)
- Fully developed operation strategies and burn control capability (*demonstration on ITER*)
- Availability of a 'numerical tokamak' (*validation on ITER*)
- final selection of Blanket concepts (*key contribution from ITER: TBM*)
- selection of no more than 2 H&CD systems (*main contributions are expected from ITER*)

Besides this ITER driven programme, the EU programme includes studies of concept improvement of magnetic confinement

And a longer term technology R&D, in view of DEMO



W7X Optimised stellarator under construction at IPP-Greifswald (D)



MAST spherical tokamak operated at UKAEA-Culham (UK)

SUMMARY

The organisation of fusion R&D in Europe has been adapted to provide an efficient contribution to ITER construction and prepare for ITER scientific exploitation

***The EU strategy is reactor oriented
ITER is a key element of this strategy from which major benefits are expected:***

- ***scientific demonstration of fusion (controlled burning plasmas)***
- ***DEMO physics & plasma scenarios***
- ***demonstration of key technical components***
- ***breeding blanket modules testing***

The European research programme is strongly focused on the preparation of ITER operation and scientific exploitation