ITER: Status of the Project

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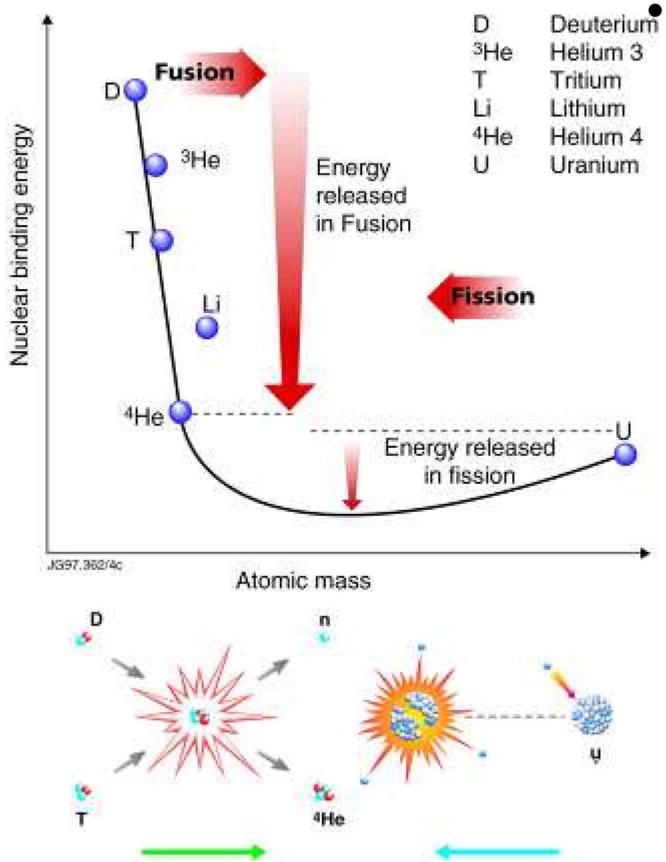
Information Day on H&CD Power Supplies for ITER

Barcelona, 27 th of May 2009

What is fusion ?

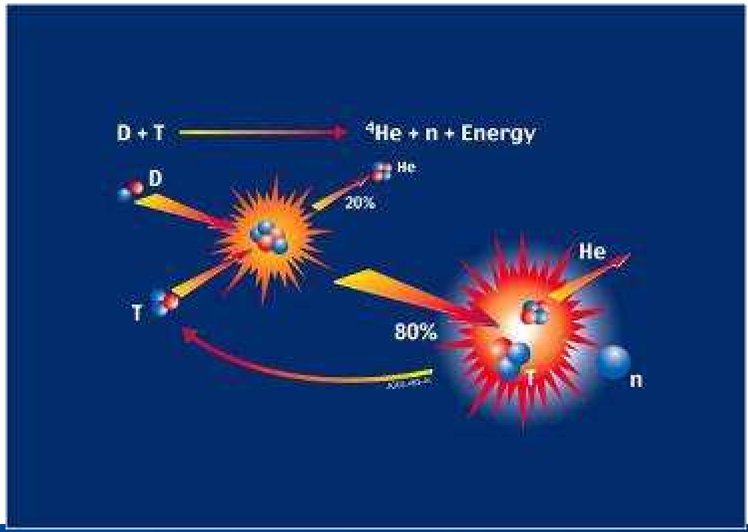
- **When nuclei of light atoms collide at very high energy they fuse and release an amount of energy much higher than the spent one**

- **Deuterium (D) + Tritium (T) is the “easiest” fusion reaction**



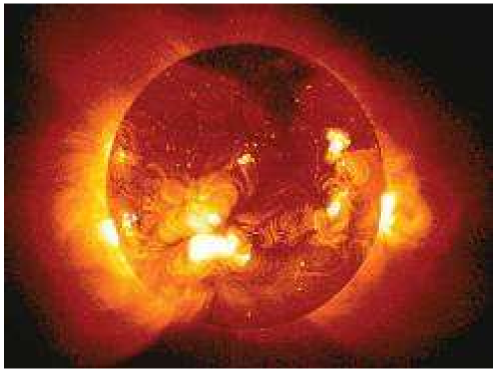
- **Fuels are largely available:**
Deuterium is extracted from water

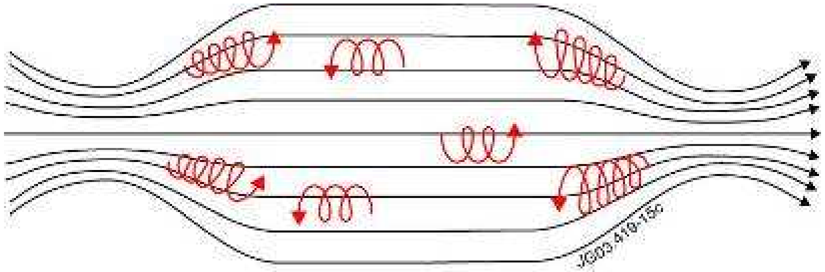
Tritium is produced inside the reactor from Lithium (abundant on earth’s crust and in the sea)

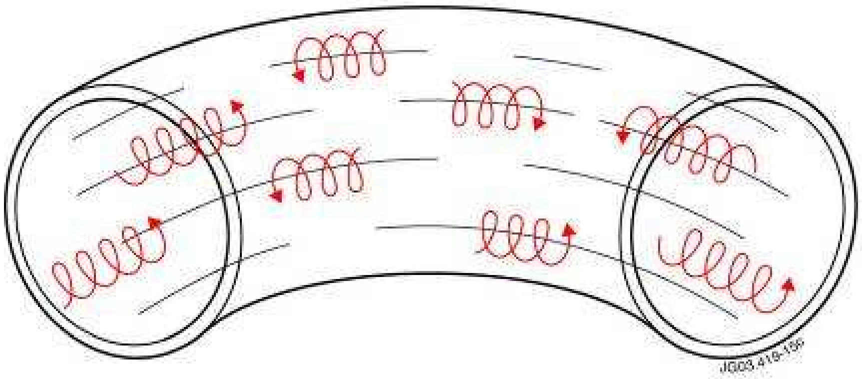


How does fusion work?

- In the core of the sun the temperature is about 10 million degrees.
- In fusion machines the temperature is above 100 million degrees to maximize the reaction rate.
- A way to confine the plasma is to use strong magnetic fields that create a “cage” preventing the particles to touch the walls of the “container”.
- To avoid the losses at the end of the “container” a closed, toroidal configuration is used

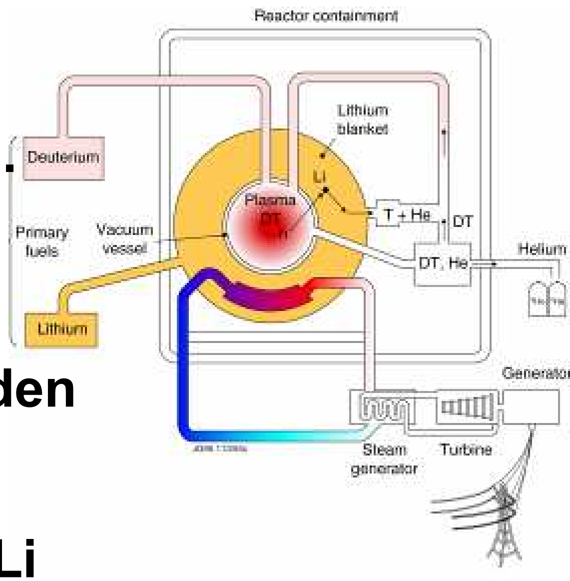




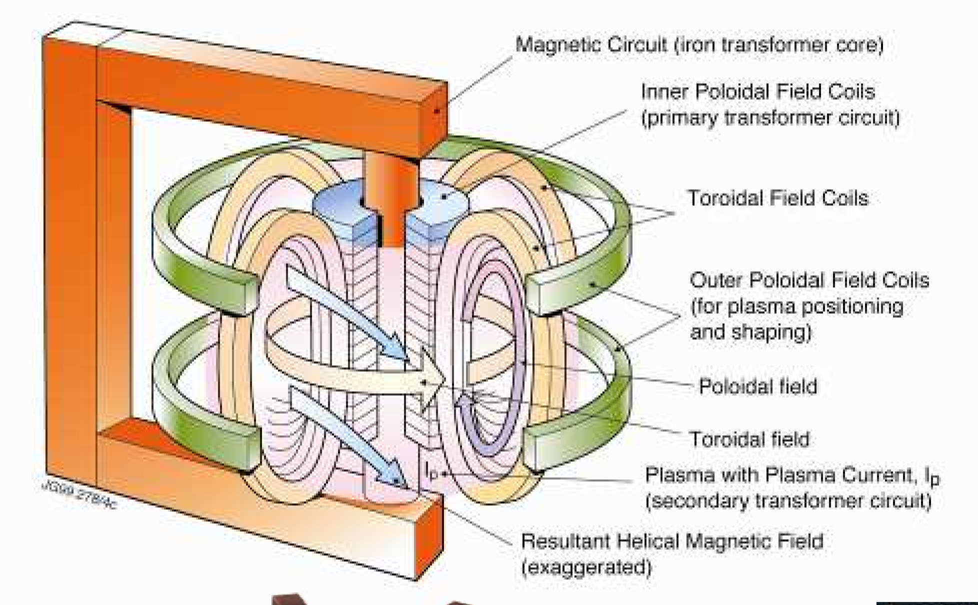


What are the merits of fusion?

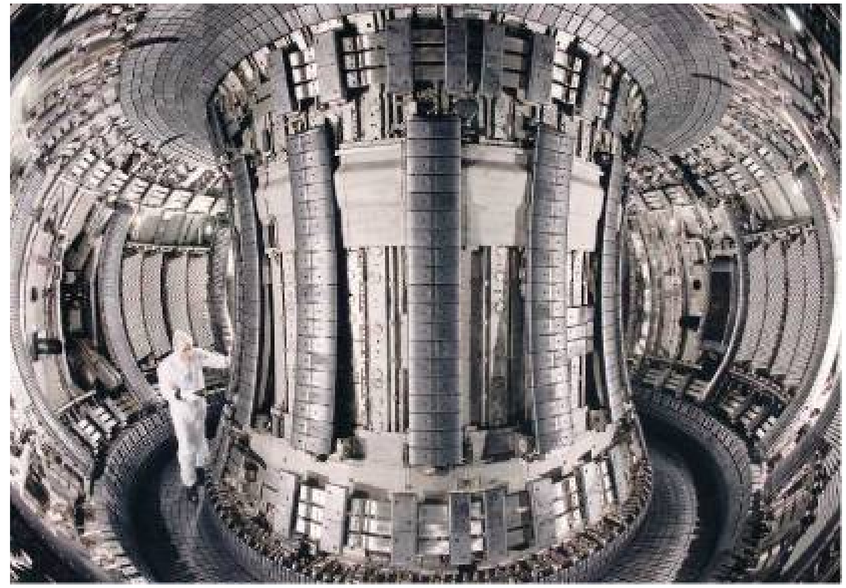
- **Fusion will be a large source of energy with basic fuels largely available in the sea**
- **No greenhouse gas emissions. Very low impact on the environment**
- **A fusion power station would not require the transport of radioactive materials**
- **Power Stations would be inherently safe. No possibility of “meltdown” or “runaway reactions”. Fusion reactors work like a gas burner: once the fuel supply is closed, the reaction stops**
- **No long-lasting radioactive waste to create a burden on future generations**
- **With about 3000 m^3 of water (->D) and 10 tons of Li ore (->T), a future 1 GW$_{el}$ fusion power plant will be able to operate one year**

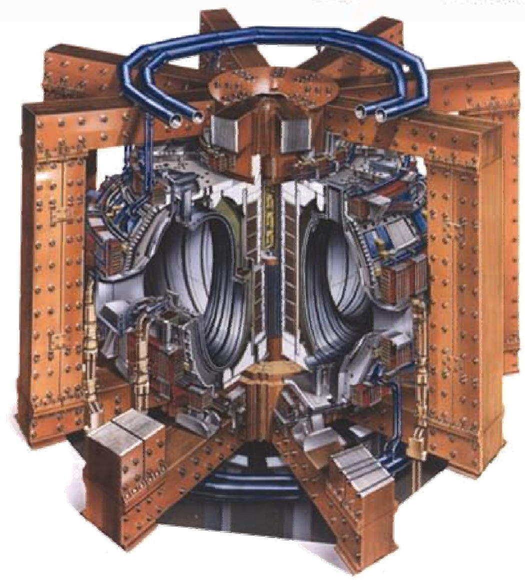


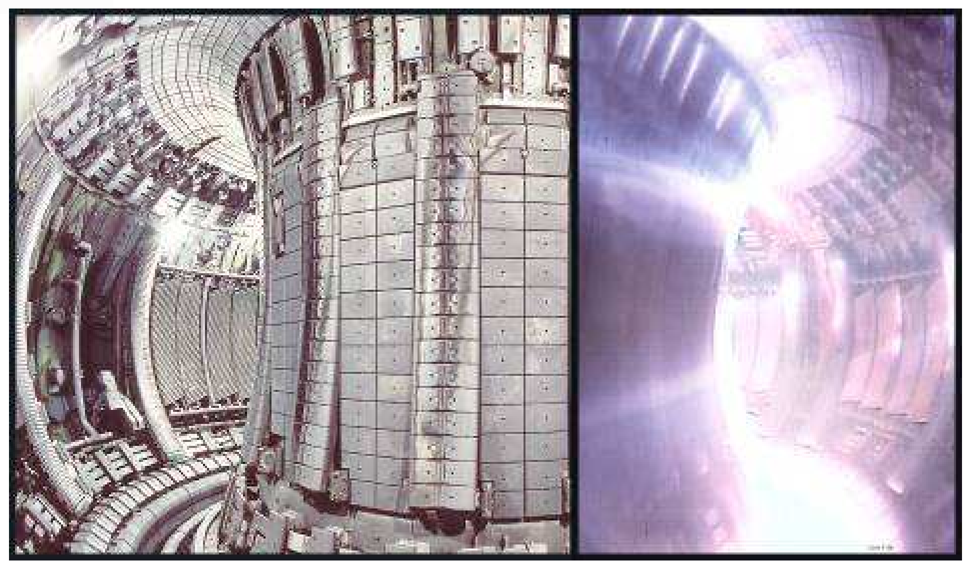
From JET …



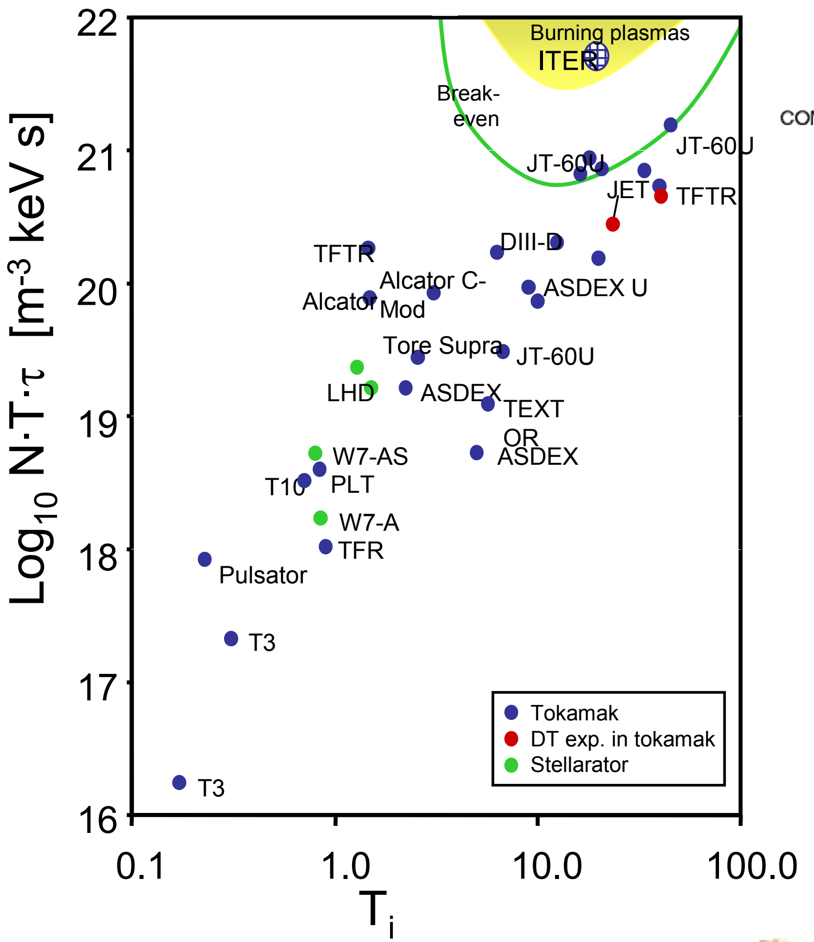
Magnetic Circuit (iron transformer core)
Inner Poloidal Field Coils
(primary transformer circuit)
Toroidal Field Coils
Outer Poloidal Field Coils
(for plasma positioning
and shaping)
Poloidal field
Toroidal field
Plasma with Plasma Current, I_p
(secondary transformer circuit)
Resultant Helical Magnetic Field
(exaggerated)
I_p
JG99.278/4c

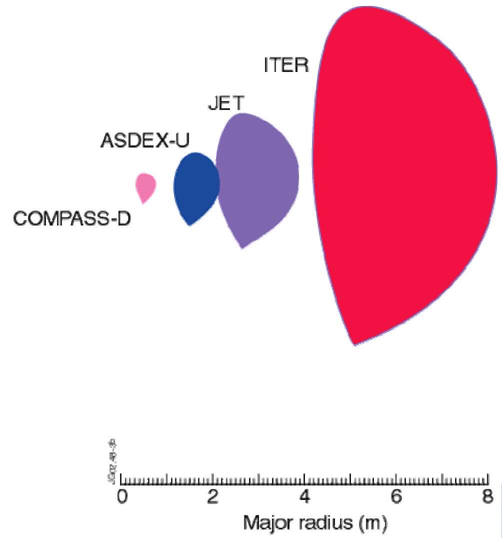


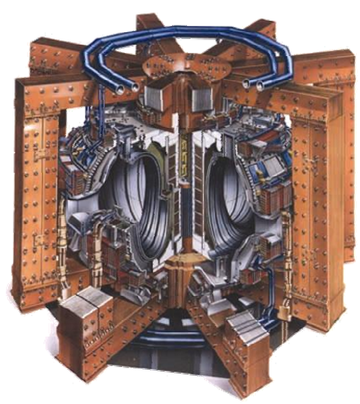


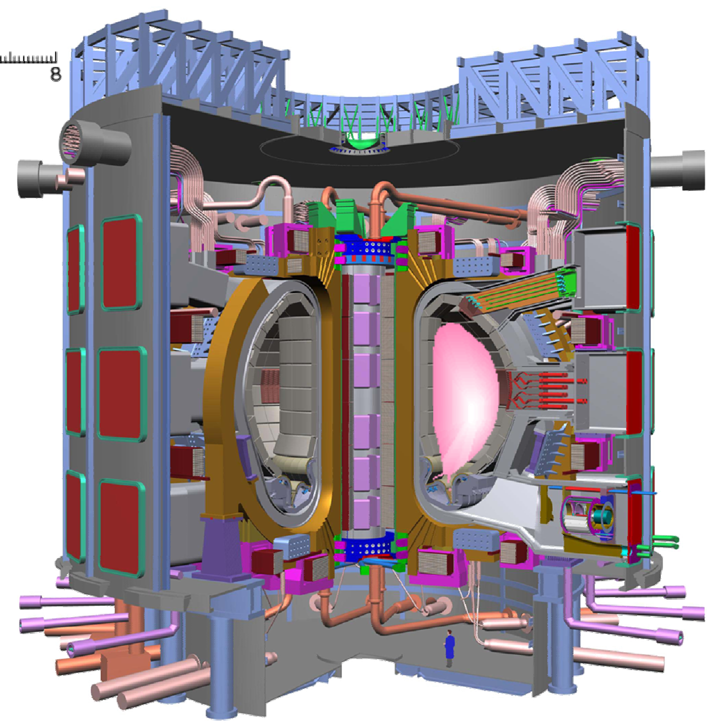


... to ITER


Burning plasmas
ITER
Break-even
JT-60U
JT-60U
JET
TFTR
DIII-D
TFTR
Alcator C-Mod
Alcator
ASDEX U
Tore Supra
JT-60U
LHD
ASDEX
TEXT
OR ASDEX
W7-AS
T10
PLT
W7-A
TFR
Pulsator
T3
T3
Tokamak
DT exp. in tokamak
Stellarator
22
21
20
19
18
17
16
Log10 N·T·τ [m-3 keV s]
0.1
1.0
10.0
100.0
Ti [keV]

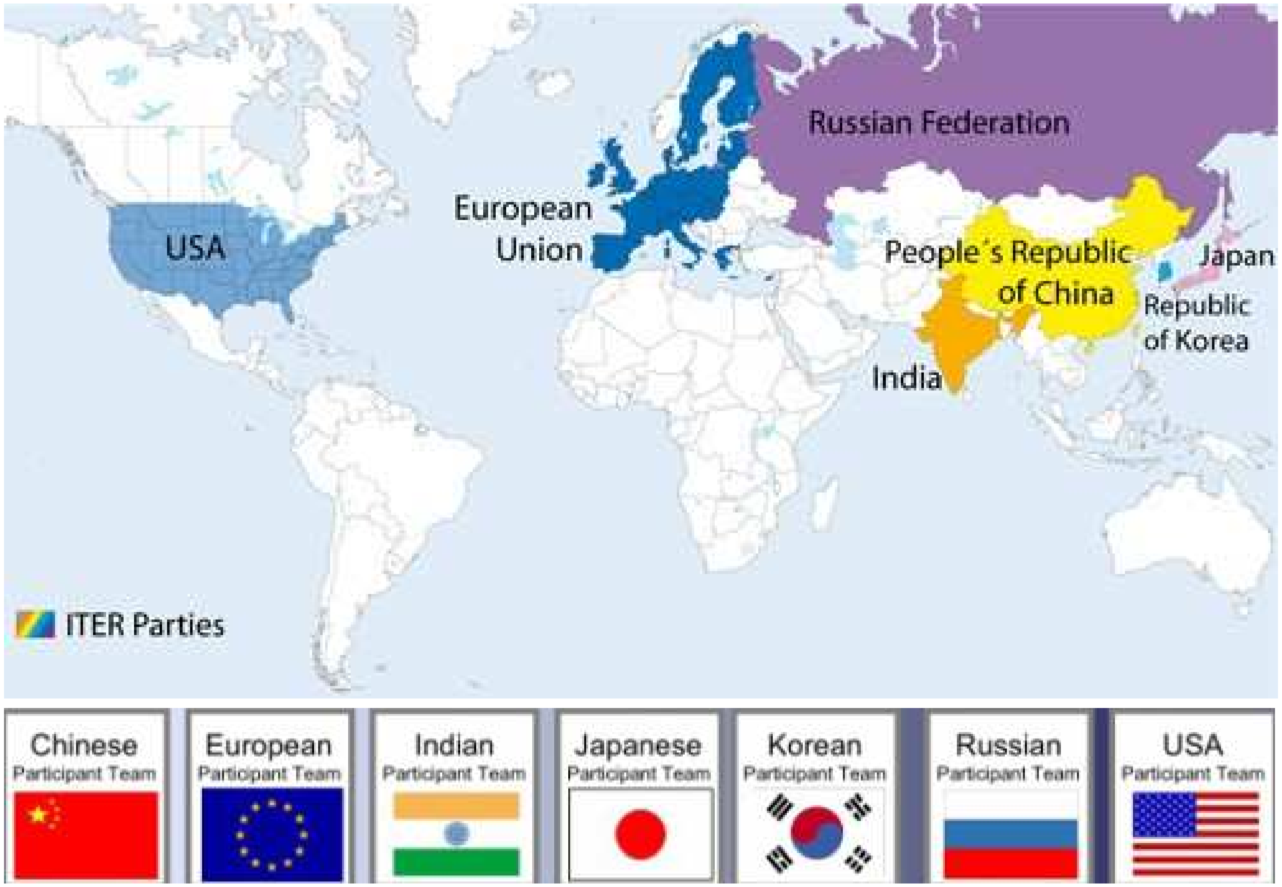

ITER
JET
ASDEX-U
COMPASS-D
0
2
4
6
8
Major radius (m)





Who participates in ITER?

Involvement of parties representing over half of world's population. The world's largest Research project



Aims of ITER

- **Demonstrate steady state fusion power production**
- **Produce about 500 MW of fusion power**
- **Power Amplification (Ratio Total Fusion Power/Input Power to the Plasma) ≥10**
- **Demonstrate the technologies required for fusion power stations (except structural materials inside the vacuum vessel containing the plasma and the breeding blanket)**

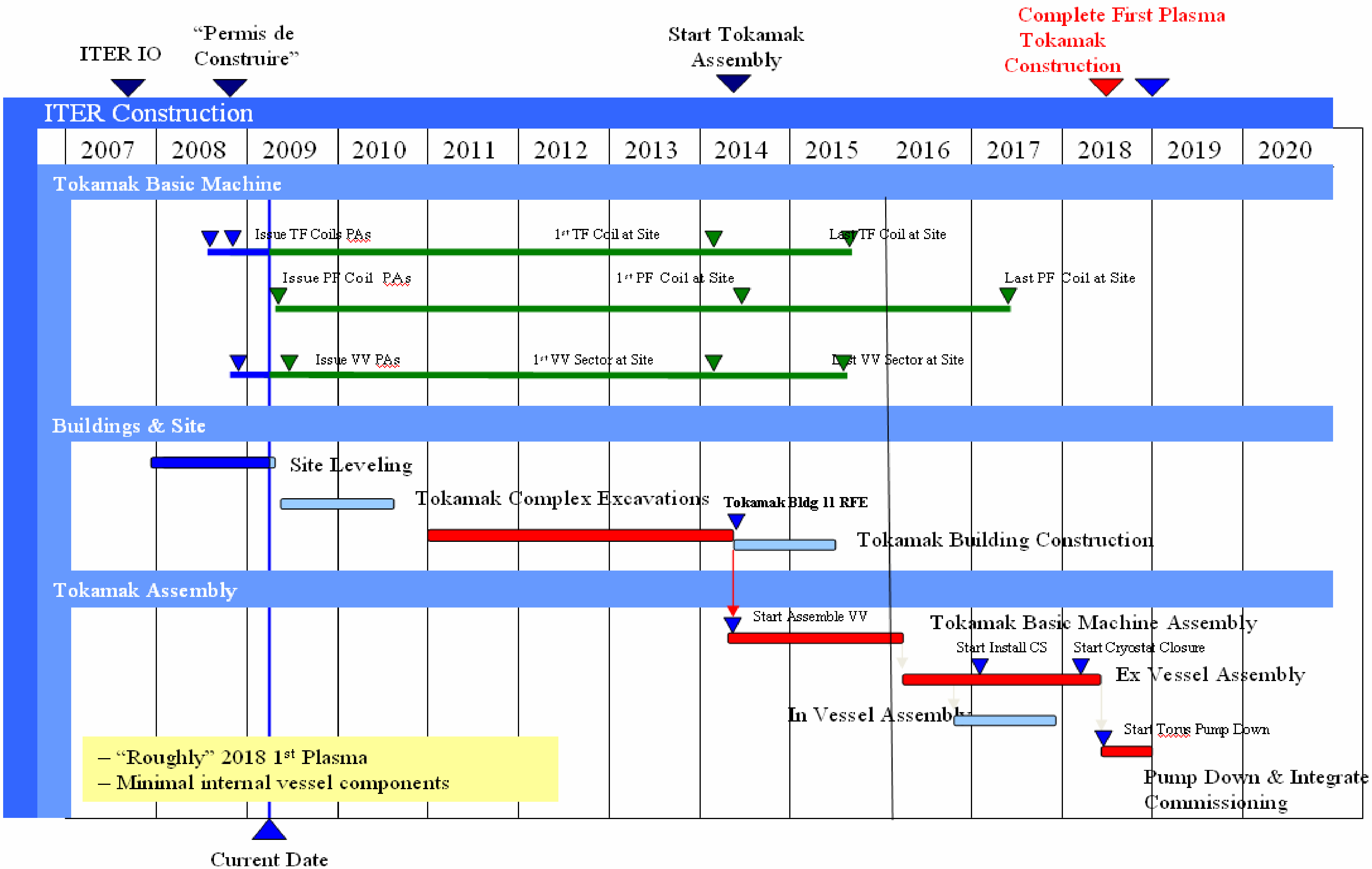
FUSION FOR ENERGY

ITER Parameters

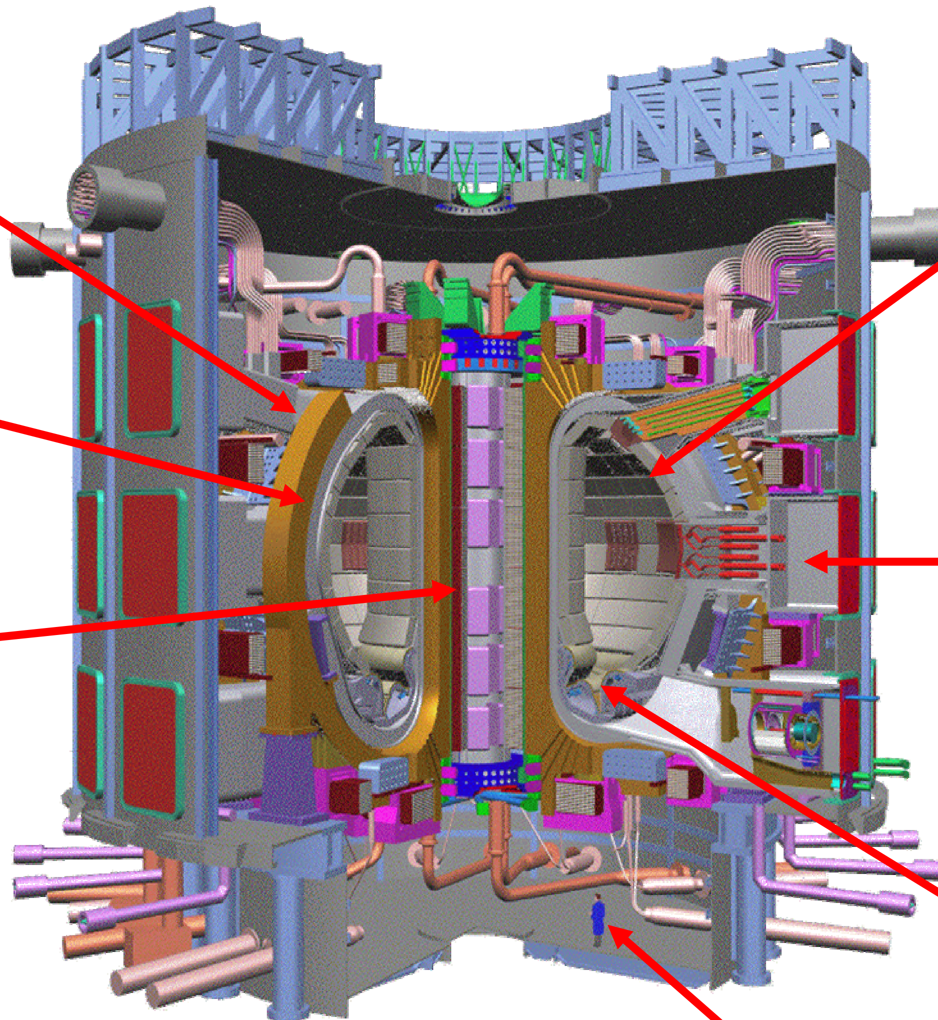
Plasma Current (MA)	15
Toroidal Magnetic Field on Axis (T)	5.3
Machine Height (m)	26
Machine Diameter (m)	29
Plasma Volume (m^3)	837

Operation Phase: about 20 years

ITER Updated Schedule

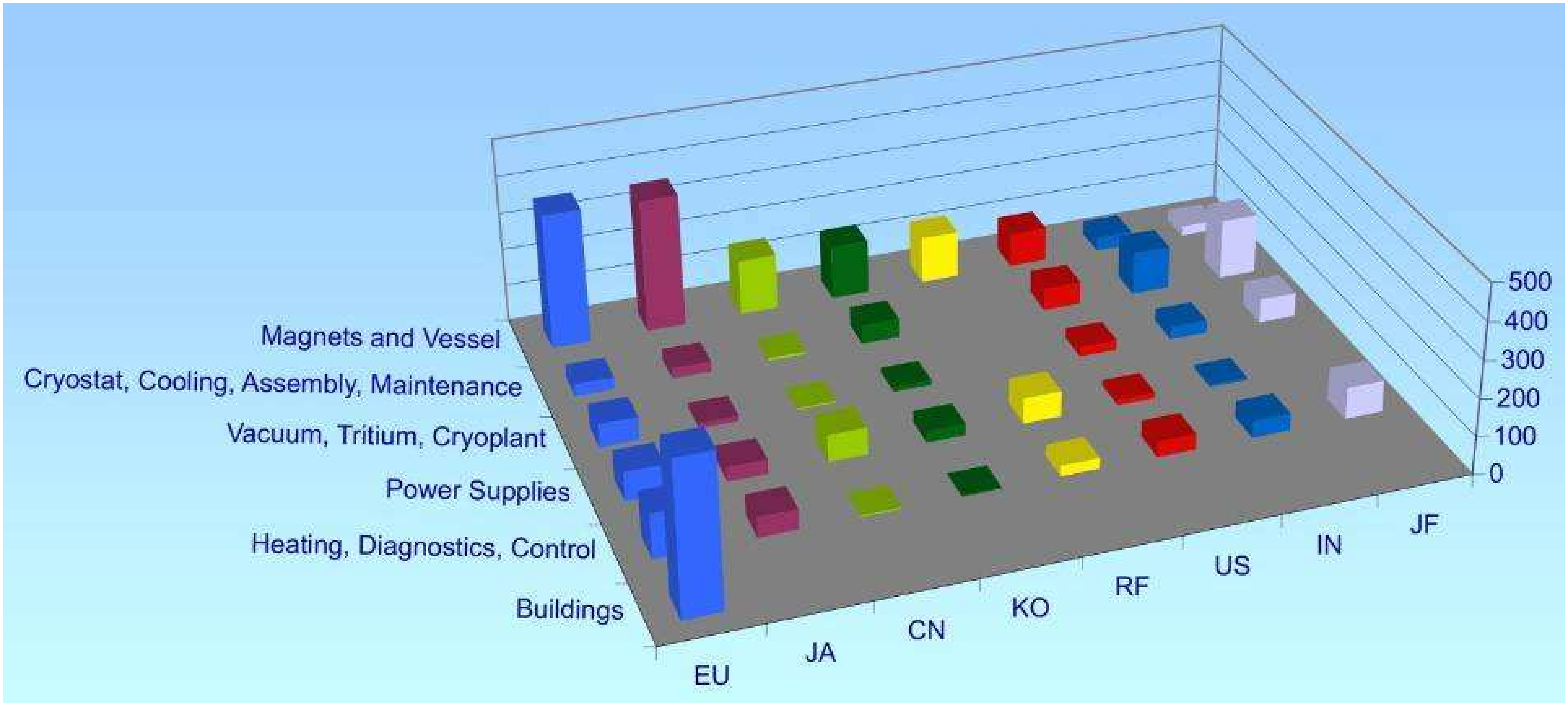


EU Main Components for ITER



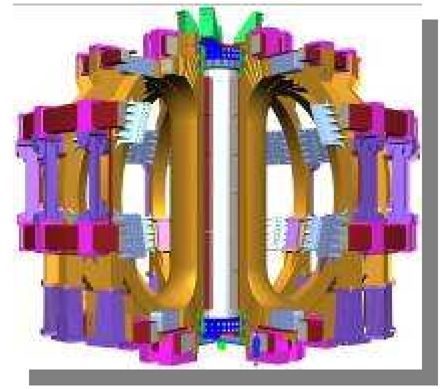
Construction Cost Sharing

Some procurement packages will be shared among several Parties:



Magnets: Procurement

		EU Share	kIUA*
Magnets	Toroidal Field Magnet windings	100%	85.2
	Toroidal Field Magnet Structure: 12 fiberglass rings	10%	5.14
	Poloidal Field Magnet 1 & 6	50%	6.8
	Poloidal Field Magnet 2 to 5	100%	33.6
	Toroidal Field Magnet Conductors	20%	43
	Poloidal Field Magnet Conductors	13%	9.653



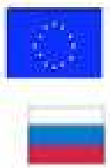
***1kIUA = approx. 1.5 MEUR (2009 value)**

FUSION FOR ENERGY

Magnets: Achievements

TOROIDAL FIELD MODEL COIL

Height 4 m
Width 3 m
B_{max}=7.8 T



Courtesy of ENEA

R&D on sub-scale pre-compression ring successfully completed.
Tests show rupture stress of ~1,400 MPa, well above the limit required by ITER

Courtesy of JAEA

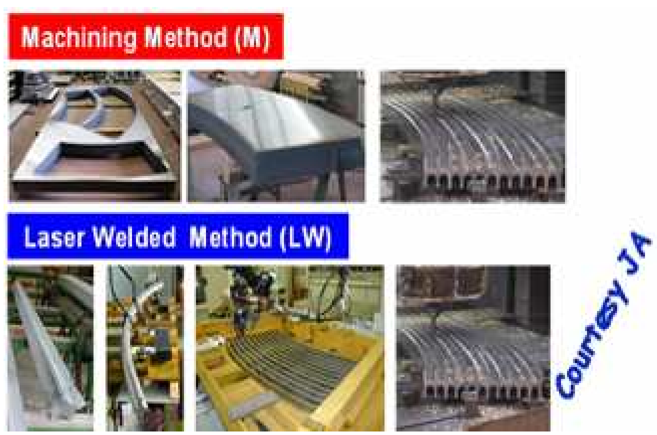
The Poloidal Field Coil Insert successfully tested in Naka (J). Stable operation of the test coil up to 52 kA at 6.4 T and 4.5 K.

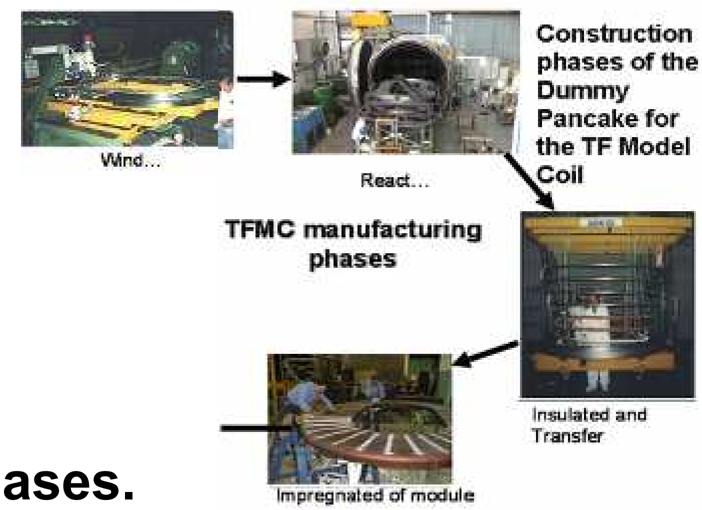
Magnets: Next steps in Work Programme 2009

Procurement strategy developed in order to reduce risks and costs: manufacturing of prototypes for TF winding packs and radial plates

- **World wide call for tender to manufacture 1 or 2 radial plates full scale prototypes to demonstrate the manufacturing feasibility and find the cheapest fabrication route.**

The activity should be carried out in parallel with the JA Domestic Agency;





- **Winding full scale production in phases.**

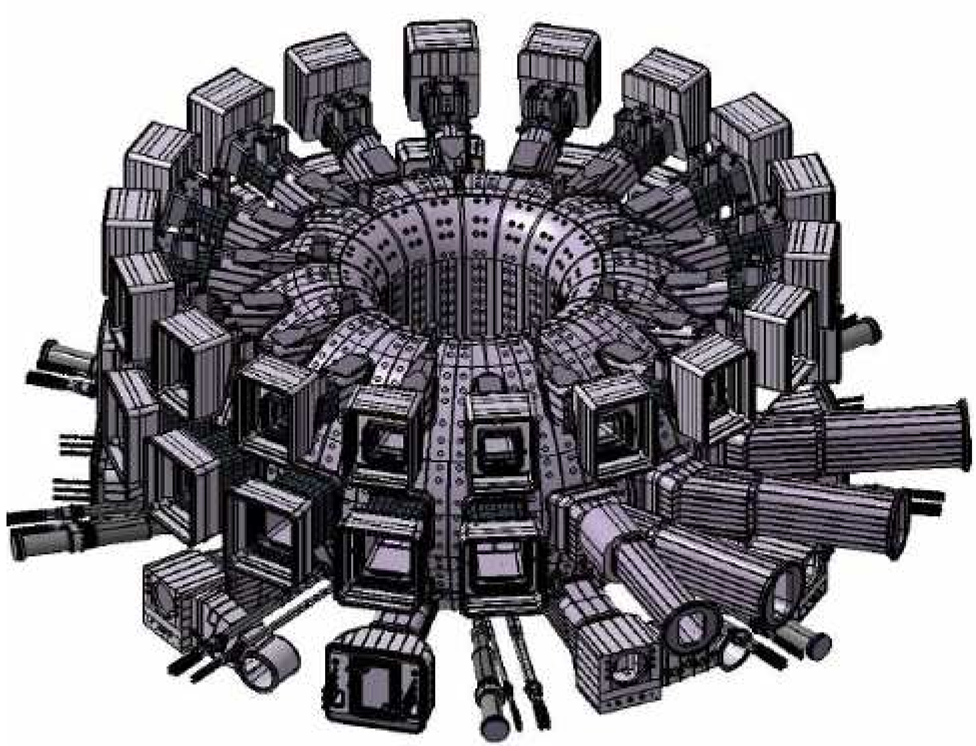
The first phase includes two years of R&D with the manufacture of a full scale dummy double pancake.

Vacuum Vessel: Procurement

		EU Share	kIUA*
Vacuum Vessel	Main Vessel including Blanket Manifolds and Hydraulic Connectors	80%	99.36

*1kIUA = approx. 1.5 MEUR (2009 value)

The ITER Vacuum Vessel Torus consists of 9 Sectors, each of 240 ton, 13 metres high and 6 metres wide, made from 60 mm thick Stainless Steel plates and with a double-wall with an additional 250 tons of bolted neutron shielding plates.

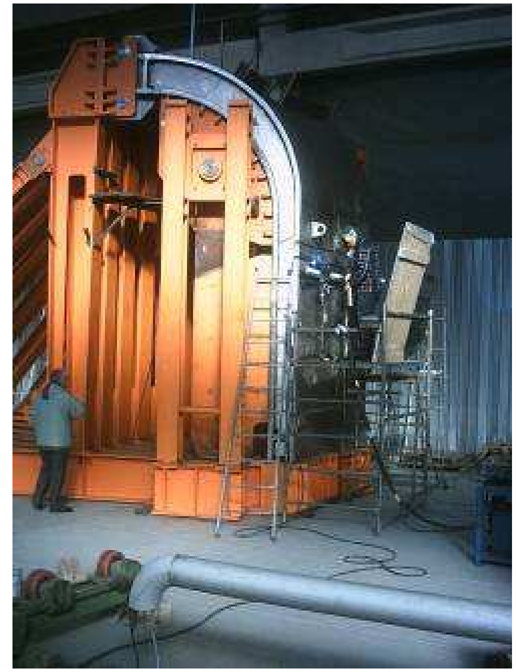


Vacuum Vessel: Achievements

FUSION FOR ENERGY

Construction of a full-sized, 20 Tons VV Poloidal Sector Prototype successfully completed within required VV tolerances (+/- 10 mm) and using conventional manufacturing methods. It should be noted that arc welding produces distortions that are difficult to keep under control.

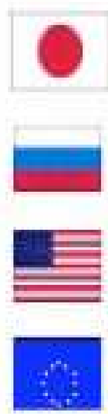
A novel technique of fabricating some VV straight parts using only e-beam welding has also been demonstrated for a full-representative mock-up.



Courtesy of Ansaldo

VACUUM VESSEL SECTOR

Double-Wall, ± 5 mm

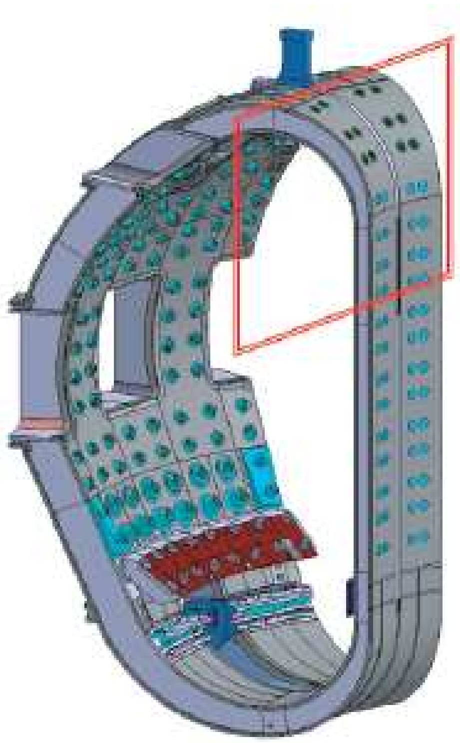


6.2 metre long e-beam welds successfully completed

Courtesy of DCNS

Vacuum Vessel:
Next steps in Work Programme 2009

Procurement of the 7 sectors is planned as soon as the VV design will be defined. This Procurement will also include the engineering and manufacturing design for all sectors and the following development activities:



***EB welding system development;**

***qualification of ultrasonic tests;**

***weld distortion control analysis.**

In-Vessel Components: First Wall / Blanket - Procurement

		EU Share	kIUA*
Blanket System	Blanket First Wall	30%	26.1
	Blanket Shield	10%	5.8

***1kIUA = approx. 1.5 MEUR (2009 value)**

The design is at a very early stage;

The new strategy foresees a first wall separated from the shield module. This approach will allow dismantling of these 2 parts inside the vacuum vessel instead of in the hot cell.

In-Vessel Components: First Wall / Blanket: Next steps in Work Programme 2009

High heat flux and thermal fatigue testing of FW mock-ups;

Be/CuCrZr joining development;

CuCrZr power-solid HIP development;

Irradiation and testing of blanket material (powder HIPed SS) and joints;

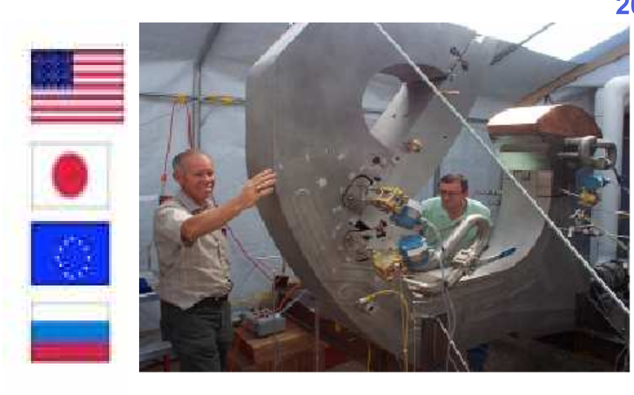
In-Vessel Components: Divertor - Procurement

		EU Share	kIUA*
Divertor	Cassette Integration	100%	11.2
	Inner Target	100%	20.2

***1kIUA = approx. 1.5 MEUR (2009 value)**

DIVERTOR CASSETTE AND PFCs

20 MW/m²

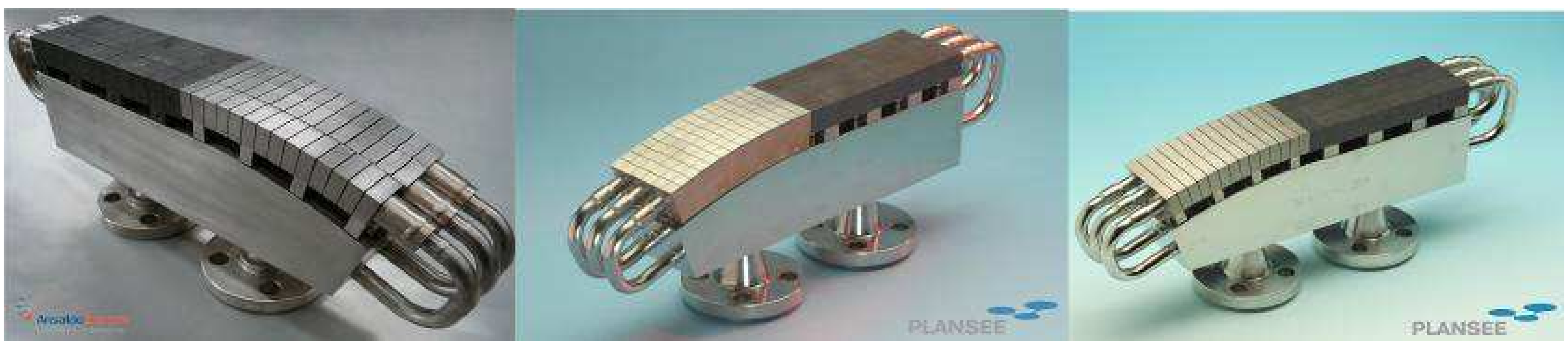


In-Vessel Components:
Divertor:
Next steps in Work Programme 2009

Procurement of the CFC material for the prototype;

Preparation of Mock-ups in CFC and W;

Qualification of repair technologies;



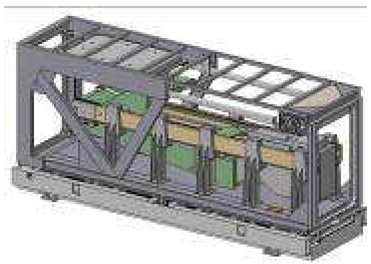
Courtesy Ansaldo

Courtesy Plansee

Remote Handling (RH) Procurement

		EU Share	kIUA*
Remote Handling	Divertor RH Equipment	100%	12
	Transfer Cask System	50%	8.2
	Viewing/Metrology System	100%	6.8
	Neutral Beam RH Equipment	100%	6

***1kIUA = approx. 1.5 MEUR (2009 value)**



Divertor cask

Remote Handling (RH): Next steps in Work Programme 2009

Basic activities:

- **Engineering support activities for studies in general areas;**
- **Qualification of radiation hard components (motors, sensors, etc).**

•**Specific activities:**

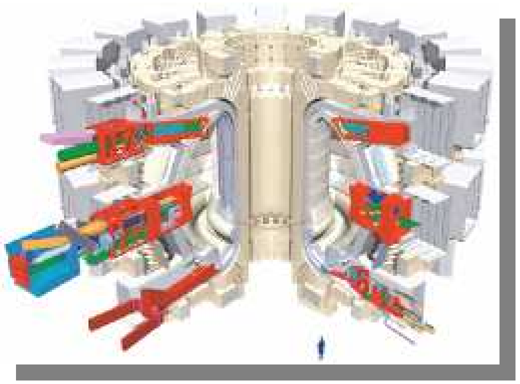
- **Neutral Beam RH: design activities in view of the Procurement Arrangement signature;**
- **Study on Transfer Cask path in the ITER buildings;**
- **In-Vessel Viewing System (IVVS): detailed design;**

Courtesy of Telstar

Diagnostics - Procurement

		EU Share	kIUA*
Diagnostics	Magnetics	25%	0.825
	Neutron Systems	25%	2.525
	Optical Systems	25%	6.425
	Bolometry	25%	1.675
	Spectroscopic	25%	5.625
	Microwave	25%	4.425
	Operational Systems	25%	2.75
	Standard Diagnostics	25%	10.125

***1kIUA = approx. 1.5 MEUR (2009 value)**



F4E is responsible for the procurement of 9 diagnostic-related systems for ITER (and enabling of a further 3).

Diagnostics
Next steps in Work Programme 2009

Activities launched in the diagnostic area during this Work Programme will focus on completion of the designs for the diagnostics and associated port plugs in the 9 diagnostic procurement packages for which the EU is responsible, to the level appropriate for a conceptual design review.

The activities will include:

- **Design and engineering studies of each diagnostic system;**
- **System-level optimisation;**
- **Prototyping and testing of relevant components;**
- **Assessment of the technical specifications.**

Ion Cycloton H&CD Antenna (ICH), Electron Cyclotron Upper Launcher (EC-UL), Electron Cyclotron Power Sources (EC-PC): Procurement

		EU Share	kIUA*
Ion Cyclotron Heating & Current Drive	IC Antenna	88%	3.96
Electron Cyclotron Heating & Current Drive	Upper Launcher	88%	7.832
	RF Power Sources	31%	10.075
	Power Supplies	92%	12.788

***1kIUA = approx. 1.5 MEUR (2009 value)**

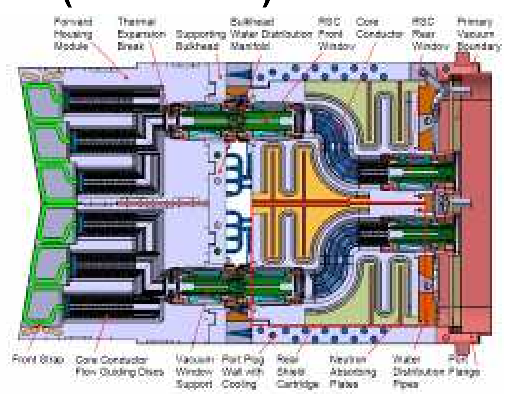
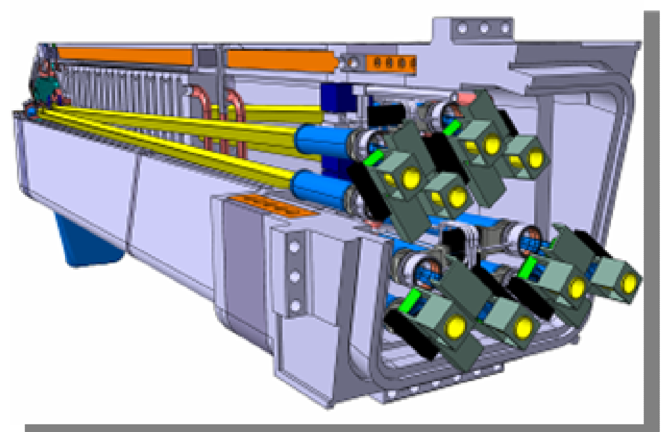
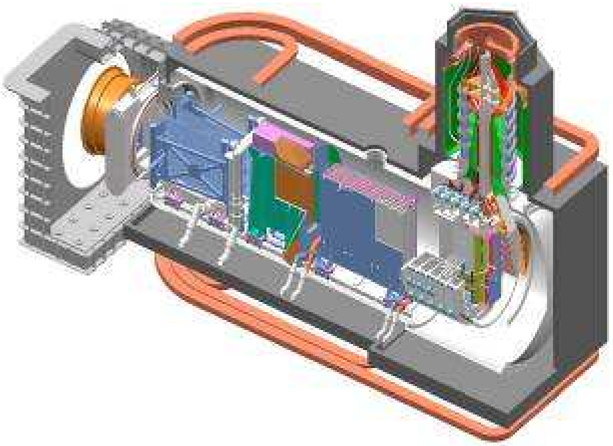
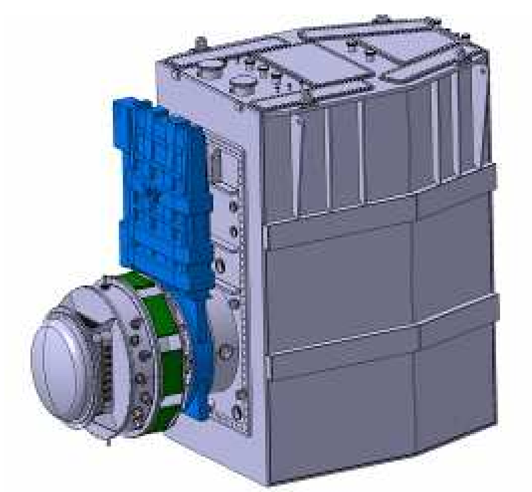


Figure 4: ICRH EX-Vessel Antenna General Layout



Neutral Beam System (NBS) Procurement





		EU Share	kIUA*
Neutral Beam Heating & Current Drive	Assembly & Testing	100%	3.8
	Beam Source and High Voltage Bushing	41%	4.75
	Beamline Components	100%	1.95
	Pressure Vessel, Magnetic Shielding	76%	5.95
	Active Correction and Compensation Coils	100%	6.1
	Power Supply for Heating Neutral Beam	31%	23.75

***1kIUA = approx. 1.5 MEUR (2009 value)**

Neutral Beam System (NBS)
Next steps in Work Programme 2009

ELISE experiment preparation;

Design of the “NB components outside the scope of the NB Test Facility”, (beam line and beam source vessels, passive magnetic shield, drift duct, active correction and compensation coils and fast shutter);

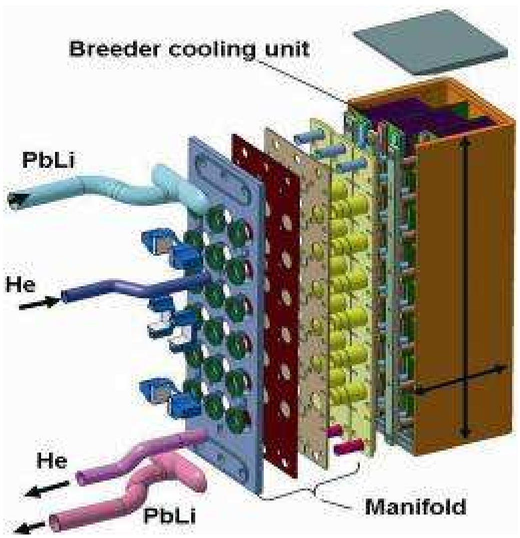
The detailed design and technical specifications of the components and infrastructure of the NBTF;

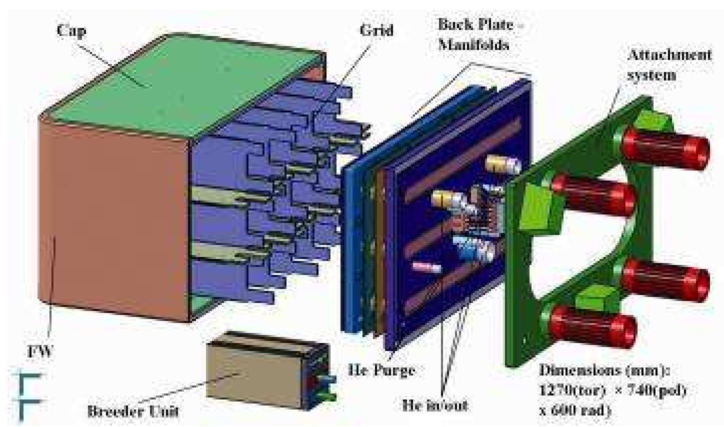
Procurement of hardware for the Ion Source Test Facility first phase;

Procurement of infra-structure for the NBTF first phase;

Test Blanket Modules (TBM) Activities

ITER Test Blanket Module (TBM) programme is a key step in the blanket development to test prototypes in a tokamak environment and validate the design codes. EU is developing HCLL (He-cooled Lithium-Lead) and HCPB (He-cooled pebble bed) concepts adopting as structural material the DEMO-relevant “9CrWVTa” reduced activation ferritic martensitic steel EUROFER.

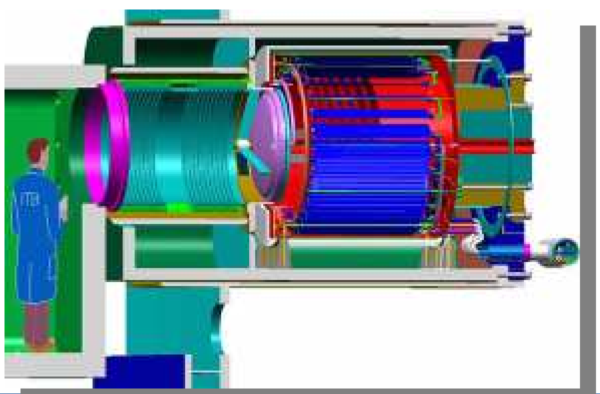


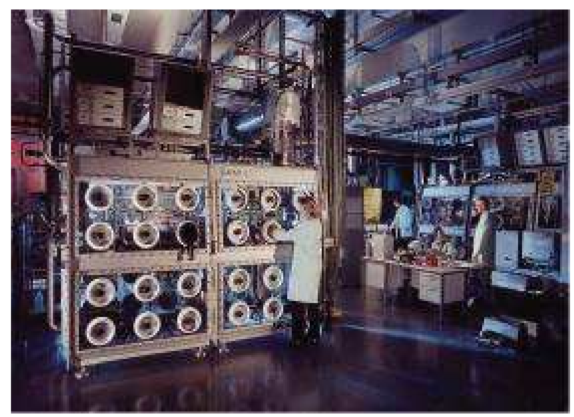


Fuel Cycle and Cryoplant Procurement

		EU Share	kIUA*
Vacuum Pumping	Cryopumps	88%	9.856
	Leak detection	88%	4.4
Tritium Plant Cryoplant	Hydrogen Isotopes Separation	88%	5.456
	Water Detritiation	88%	12.76
	Cryoplant	50%	31.5

***1kIUA = approx. 1.5 MEUR (2009 value)**





Fuel Cycle and Cryoplant
Next steps in Work Programme 2009

Cryopumps:

Completion of final design for the Prototype Torus Cryopump (PTC), upgrading of TIMO-2 facility and testing of PTC in TIMO-2 to qualify design ;

Manufacture of the PTC and Follow-up contract

Leak Detection:

Performance studies and conceptual design for leak detection system including proof-of-principle tests. Review of leak localization concepts and their possible realization

Cryoplant:

Optimisation of the design and specific analyses

Tritium Plant:

Finalisation studies of Isotope Separation System and Water Detritiation System

Buildings - Procurement

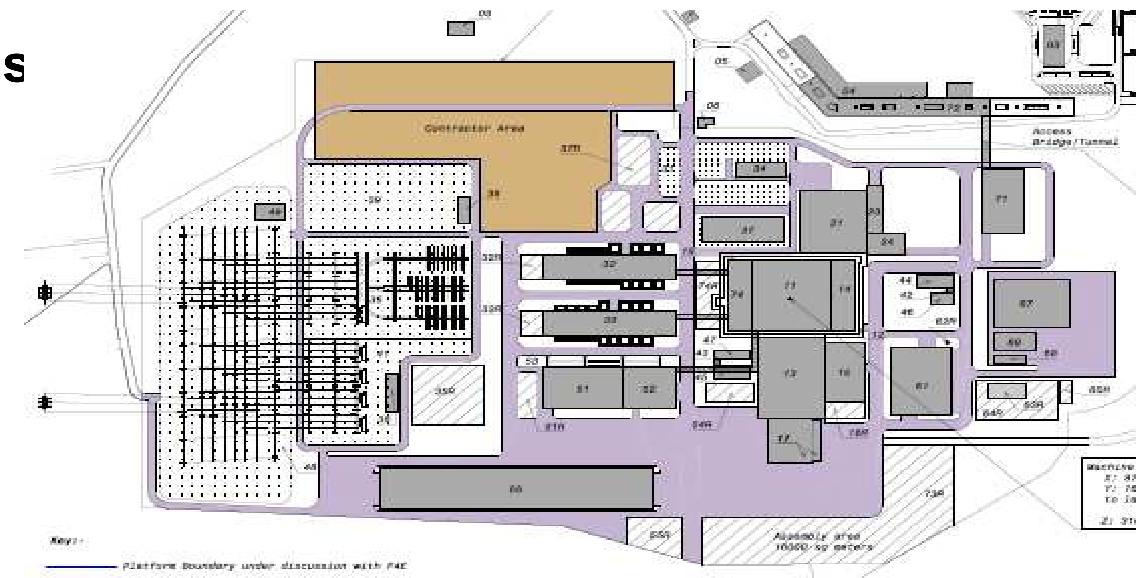
		EU Share	kIUA*
Buildings	Concrete Buildings	100%	323.5
	Steel Frame Buildings	100%	68.8

*1kIUA = approx. 1.5 MEUR (2009 value)

ITER Buildings form an integrated complex extending over an area of about 50 hectares, including 28 buildings.

Reinforced concrete buildings and selected infrastructure: 250.000 m³ of concrete, building volume 750.000 m³, foot print 21.000 m²;

Steel frame buildings: foot print 29.000 m².



Buildings - Achievements

Site Leveling: completed

Buildings
Next steps in Work Programme 2009

General Support-To-The-Owner Contract for the procurement of ITER buildings (follow-up of the call for tender, monitor the main contracts etc);

Architect/Engineer for the procurement of ITER buildings (detailed studies based on the preliminary technical specifications, prepare technical specifications for construction contracts);

General Health and Safety Coordination Protection for ITER buildings (prepare detailed rules, follow up the implementation).

Buildings
Next steps in Work Programme 2009

Main construction contracts:

- **Tokamak Complex Seismic Isolators Fabrication;**
- **PF Coil Fabrication Building Design-and-Build**
- **Excavation and drainage of the Tokamak Complex Foundations**

THANK YOU FOR YOUR ATTENTION