F4E needs (facilities and expertise) for ITER construction

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EU Workshop
on Fusion Roadmap for FP8 and beyond

IPP - Garching
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Introduction

- A number of relevant fusion technology testing facilities have been used extensively in Europe in the past to conduct the required R&D for the ITER project.
- To complete the needed ITER R&D and to support the qualification and the manufacturing phases some of these facilities are still needed, in additions to others that are planned to be built.
- Some facilities are also required on the ITER site and are needed for acceptance tests and tests of component during the operation phase.
- Complementary to the exploitation of these facilities, expertise existing in Laboratories is also required in support to ITER design, R&D and construction in some areas (e.g., Magnets, Vacuum Pumping, Tritium, Instrumentation and Control).

ITER Magnet Testing Programme

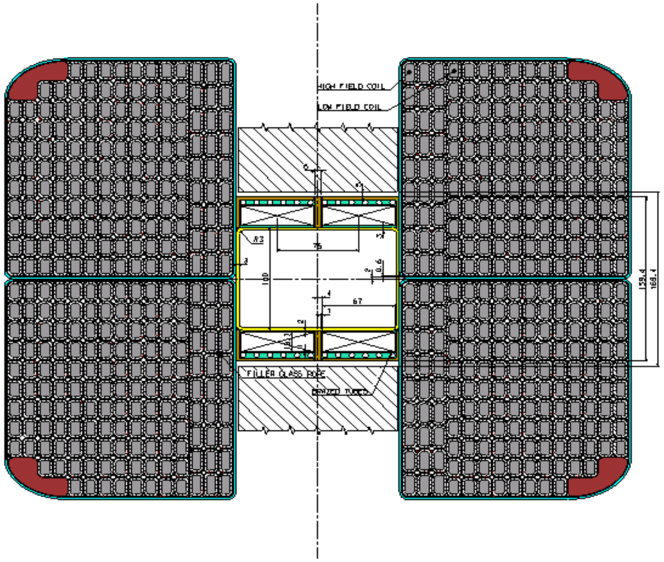
- **Strand qualification** and tests during fabrication: critical current and AC losses (strand characterization at Durham Walter Spring (UKAEA)) and strain sensitivity (Durham Walter Spring (UKAEA), Tarsis (FOM)).
- **Jacket material qualification**: test facility at KIT.
- **Conductor qualification** and test during fabrication (Twente press (FOM) for strain sensitivity, Sultan (CRPP), and Dipole (CRPP))

EU Dipole (EDIPO) for the QC of the ITER superconducting cables

Main parameters:

a) Max magnetic field 12.5 T

b) Test volume
1200x150x100 mm



Due to be installed at CRPP Villigen in the second half of 2011

Magnet Cold Tests

The test of coils at full performance (B, I) is difficult and very expensive. A reasonable programme supported by EU DA in line with IO is as follows:

- Perform cold test of **TF winding packs** prior to insertion in the coil cases at a temperature of LN_2 for high voltage and leak test

  → Cold test facility on firm premises

- Perform cold test of the **PF coils** in a temperature of LN_2 for high voltage and leak test

  → Cold test facility on ITER site

- Local thermal shocks with LN on the cooling circuit of the coil case.

- A local leak and high voltage test, also in Paschen-minimum conditions of coils terminal area at RT.

  → Facility on firm premises

ITER facilities for PFC qualification, fabrication, acceptance tests

High heat flux tests

Divertor: **a few 1000 cycles up to 20 MW/m^2 for CFC and for W armors**

- **EU facilities: FE 200** (AREVA-CEA), **GLADIS** (IPP-Garching) for HHF tests of CFC and W clad components. Identification of defects in CFC/Cu joints in **SATIR** (CEA) facility.
- Qualification tests and acceptance tests on final manufactured Plasma Facing Units planned to be done in **Russia** in a facility being modernized (e.g., **TSEFEY-M**) or new to be built in Russia in the frame of an ITER PA with RF.

First Wall & ICRH antenna: a few 1000 cycles up to 3-5 MW/m^2 for Be-coated components)

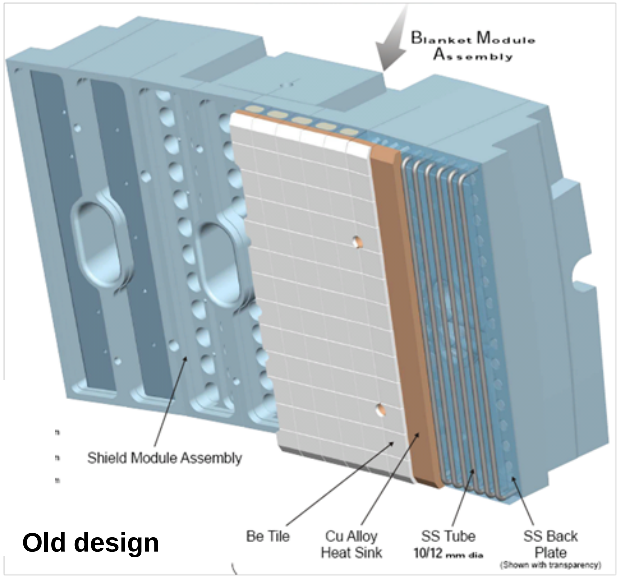
- **mock-ups and semi-prototypes in** JUDITH I & II (FZJ)
- Acceptance tests of final manufactured Be first wall **panels to be done in a EU facility (to be built).**

ITER FW test facilities for series production depend on final design of first wall

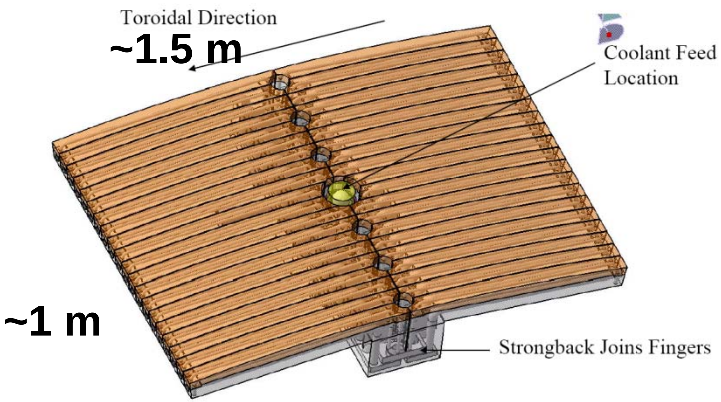
- Ongoing effort (IO/DA) to redesign the FW to address the concerns identified in the course of the Design Review. Four times larger FW panels (1 per module) to be tested.

- EU DA in charge of the procurement of the low HF FW panels and of ICH antenna requiring Be-compatible high heat flux test facilities.

- Testing for acceptance of manufacturing series would require in EU an e-beam test facility capable to test large numbers of FW panels for short time.



Old design



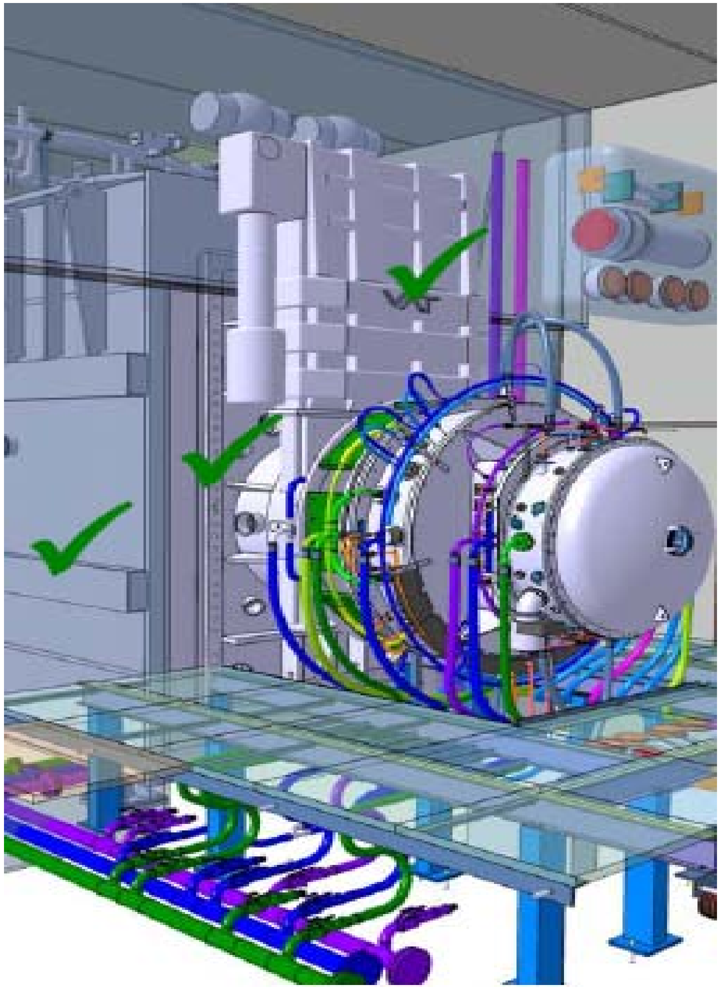
New design (tentative)

ITER NBI Development Facilities

- The Radio Frequency ion source was successfully developed in the IPP facilities (BATMAN, MANITU and RADI) and became the reference design for ITER.

- **ELISE test facility (IPP-Garching)**
  - Provide important input for the ion source design
  - main objective: **<u>extraction uniformity</u>** → ½ size ITER ion source

Isotope	H, D
Extraction Area	1000 cm^2
Total Voltage	60 kV
Extraction Voltage	12 kV (→ 20 kV)
Ion Current	20 A
RF Power	2 x 180 kW cw
Pulse Length:: Plasma Extraction	3600 s 10 s every 180 s



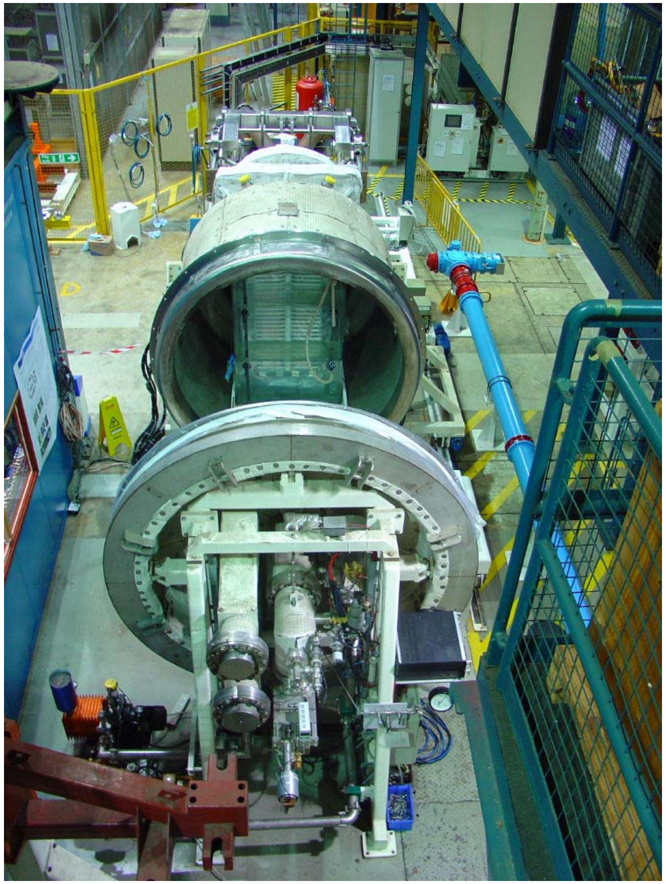
Neutral Beam Test Facility

- Develop the NB Injectors that meet ITER specs. (power coupled to plasma=16.5MW, ion current (D) =40A, voltage=1MV, pulse length =3600s)
- Provide a test bed for the RH tools
- Provide a supporting laboratory for NBI operation in ITER.
- Continue system upgrades aimed at improving reliability and efficiency.

The Neutral Beam Test Facility Building (architectural view)

ICRH Test Facilities

- Test high voltage full pulse length operation of one antenna module (1/4th of the antenna,) as part of risk minimisation strategy.
- Several relevant facilities are available in EU (JET, CEA, IPP-Garching)
- It is also planned to construct a facility for port plug basic testing like dimensional, water and vacuum leak, electrical testing.



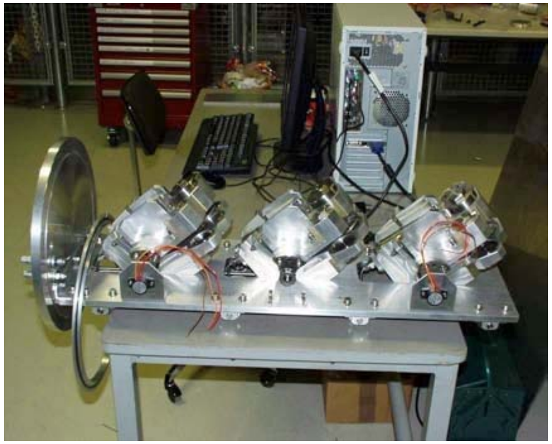
Jet RF test bed

ITER ECRH Test Facilities

EC Test Facility in CRPP, Lausanne

- The development tests (and later the pre-delivery tests) of the EU Gyrotrons (2 MW or 1 MW) for ITER are performed at CRPP and KIT.
- First prototype tested. New tests on refurbished gyrotron in 2nd half of 2011.

Short-pulse pre-prototype gyrotron, KIT

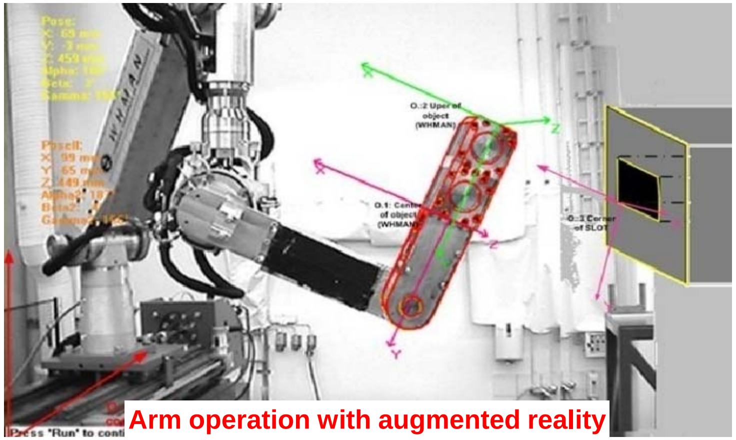


'Cold Test' set up, KIT, Karlsruhe

ITER Test Facilities for Remote Handling
Divertor RH

- **ITER Divertor:**
  - (DTP2 VTT/TEKES) + hot cell refurbishment (DRP ENEA)
- **RH for divertor:**
  - Radial and toroidal movement of cassettes along the divertor level RH ducts using the Cassette Multifunctional Mover and the Cassette Toroidal Mover (hosting on board manipulator arm and tooling).

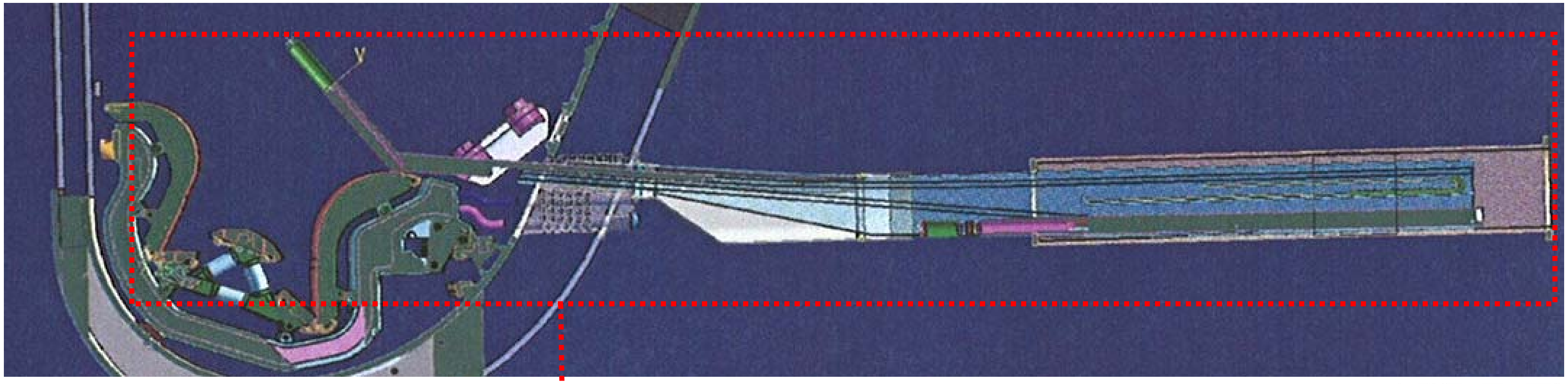

DTP2 remote control room


Arm operation with augmented reality


Cassette handling operation

ITER Test Facilities for Remote Handling

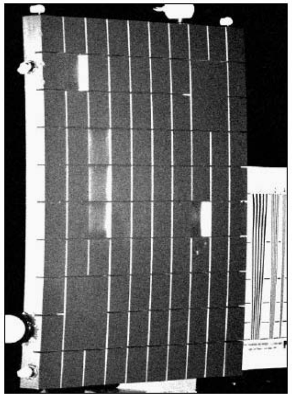
In-vessel viewing system



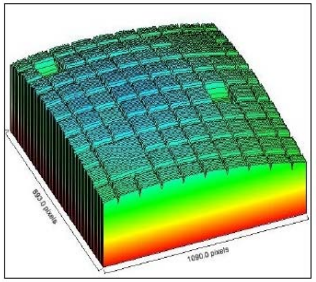
Laboratory tests so far have shown the potential of an inspection system for metrology and viewing, based on a remotely operated precision laser ranging system.

IVVS probe (ENEA Frascati)

viewing



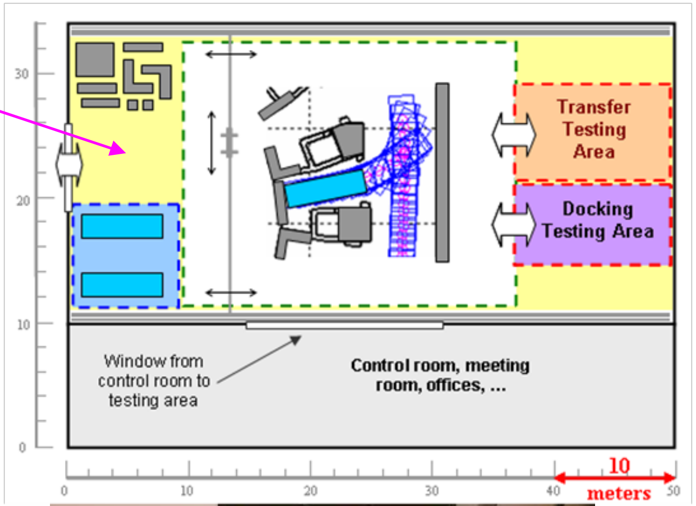
metrology



A full scale prototype should be tested in a facility reproducing vacuum, temperature and working environment

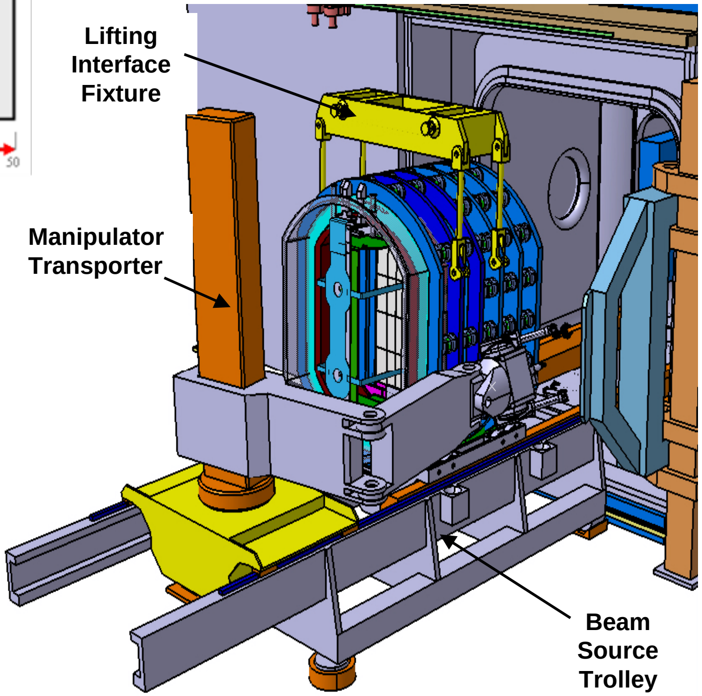
ITER Test Facilities for Remote Handling
Cask & Plug RH System (Transfer casks)
NBI RH

A full scale CPRHS test facility should focus on issues like path planning and navigation, obstacle avoidance, docking, handling, fail safeness, recovery/ rescue.

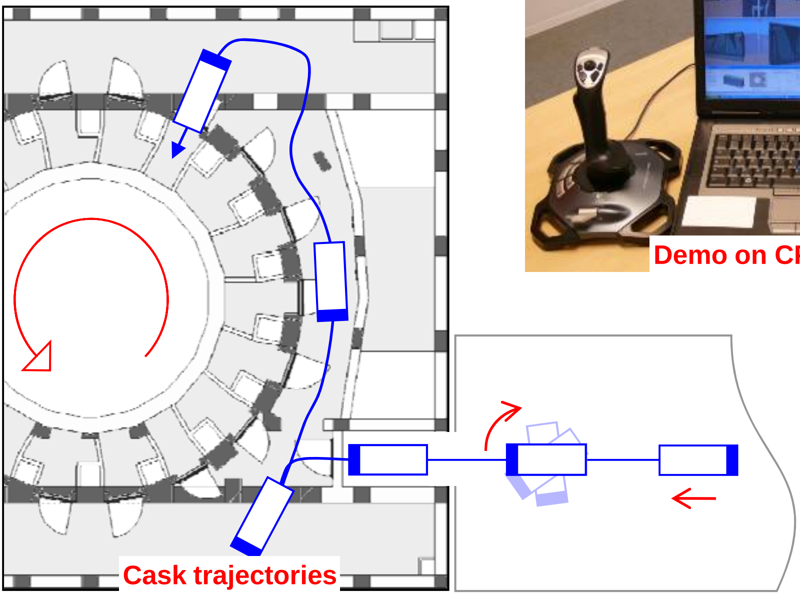


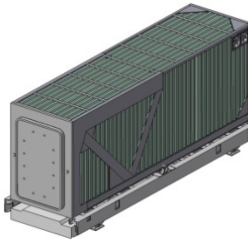
For NB RH, synergies are being established with NBTF (e.g. on source removal/installation, connection/ disconnection of supply lines, mechanical supports and interfaces)


Demo on CPRHS control



Beam source removal


Cask trajectories


CPRHS

Qualification of Fuel Cycle Technology

- The existing Tritium Laboratory at KIT has been intensively involved in both R&D and Design activities for ITER for testing tritium systems and components.

The existing facility TIMO (KIT) has been upgraded to TIMO-2 in order to perform the test campaign with 1:1 scale ITER Pre-Production Cryopump (PPC).

- Other laboratories with specific objectives: detritiation techniques, T-extraction studies (JET -AGHS).
- Some detritiation work (as service) possible (SCK.CEN).

Safety/ Management of in-vessel dust
(H_2/dust explosion risk)

In EU there are several relevant facilities:

- Determination of Gas/Dust mixture explosion indices: ➔**DUSTEX (KIT)**
- Characterization of flame propagation: ➔ **PROFLAM I&II (KIT)**
- Evaluation of mitigation methods:
  - gas mixing: nitrogen injection ➔ **MISTRA (CEA)**
  - early ignition➔ **A8 vessel (KIT**)
- To validate a safety code for H_2/dust explosion, integral tests (ITER relevant conditions) should be performed on a large scale facility➔ A2 vessel (220 m^3) in KIT could be a good candidate.

In order to be able to respond to specific requests from the safety authority the following experimental devices should be kept operational:

- Arc simulation behavior (busbar…), VACARC (KIT), LONGARC (KIT)
- Corrosion product release and transport (high Temp., high pressure and high velocities water). CORELE (CEA)

Plasma and First Wall Diagnostics

A number of facilities will be required for the development and qualification of diagnostic systems. In particular:

- Irradiation testing facilities (e.g., fission reactors, gamma-irradiation sources and 14-MeV neutron sources, e- and p- accelerators) for the development and qualification of sufficiently radiation-hard diagnostic components.
- Tokamak devices can be used for certain tests of new concept diagnostics as well as demonstrating components and alignment and calibration methods in a realistic environment.

Example Diagnostics
(Areas of Expertise/ Activities)

AREAS	EXPERTISE	REQUIRED ACTIVITIES
Plasma Position reflectometer **Charge Exchange** **Recombination Spectrometer** **Wide-Angle Viewing System & Radial Neutron Camera** **Core Thomson Scattering system** **Bolometers and pressure gauges** **Magnetics** **In-vessel and divertor thermocouples** **In-vessel services (cables, conduit, connectors & feedthroughs)** **Collective Thomson Scattering (enabling)**	**mm-waves;** **active & passive spectroscopy;** **IR thermography;** **neutron detection;** **magnetics sensors;** **image and tomographic inversion;** **equilibrium reconstruction;** **plasma-wall interactions;** **software writing & qualification;** **mechanical, electrical and electronic engineering;** **vacuum design;** **remote handling;** **optical design;** **radiation effects;** **hydraulic analysis;** **neutronic analysis;** **CAD;** **project management and QA**	**Port plugs and port-related structures: R&D, design and analysis;** **Functional testing of prototypes and mock-ups;** **Diagnostic systems: assembly and testing;** **Diagnostic systems: testing, commissioning and calibration;** **Technical and managerial supervision;** **Project Management;** **Planning and scheduling;** **Specific Manufacturing follow-up**

Typical facilities covering main test objectives of Breeder Blanket development and TBM qualification

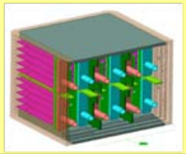
Facilities	Main objective/purpose	Status
MEKKA	MHD tests (NaK instead of PbLi)	Under operation (KIT)
TRIEX	Tritium recovery from PbLi	Under upgrade (ENEA funds) (ENEA)
DIADEMO	Thermo-mechanical tests of small-size components in PbLi environment and cooled by He	Under operation (CEA)
PICOLO	EUROFER corrosion in flowing PbLi	Under operation (KIT)
IPUL-MHD	Effect of magnetic field on EUROFER corrosion by PbLi	Under operation (Latvia)
HELOKA	He loop for TBM mock-ups testing up (1/1 TBM relevant Helium turbo-circulator has been commissioned)	Construction achieved; final commissioning planned 2011 (1:1 TBM relevant Helium turbo-circulator has been commissioned) (KIT)
EBBTF (HeFus3 + IELLLO)	EBBTF (European Breeder Blanket Test Facility, ENEA/Brasimone) = HeFus3: He loop for TBM mock-ups testing up to 1:1 TBM scale + IELLLO: PbLi loop for TBM mock-ups testing up to 1:1 TBM scale	-HeFus3 upgrade achieved (new 1:1 TBM relevant Helium turbo-circulator has been commissioned) - IELLLO constructed; final commissioning planned 2011 - HeFus3 + IELLLO (=EBBTF): Upgrade of a common DACS is on-going through F4E Grant

1. **Technologies development & qualification for sub-components**

e.g.: Cooling Plate test in DIADEMO

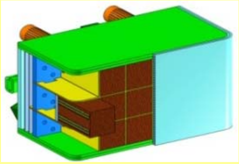
2. **Qualification of [1/4 – 1/3] TBM size mock-ups**
   Integrated functional tests: thermo-mechanics, -hydraulics, H permeation & extraction, etc

e.g.: 1/4 HCLL TBM



3. **Qualification of 1:1 TBM size prototypes**
   Full-size validation (risk limitation)

e.g.: 1/1 HCPB TBM



+ Fission reactors (& multiple beam irradiation facilities):
⇒ Irradiation of structural and functional materials

Proposed new EU ITER-relevant Technology Facilities

Magnet testing.	TF-PF windings cold tests at 77K.
High heat flux component testing	Beryllium-compatible HHFT for series production and acceptance tests of ITER FW panels
NBI system testing	Neutral Beam test Facility.
Divertor Test Platform (DTP2)	Simulation of divertor in-vessel maintenance operations using prototype divertor RH equipment in a full scale mock-up of ITER divertor region.
CPRHS test	focus on issues like path planning and navigation, obstacle avoidance, docking, handling, fail safeness, recovery/ rescue
In-Vessel Viewing System (IVVS) test facility	To test and verify visual and metrology capabilities of a full scale prototype of the IVVS in vacuum and temperature conditions close to the real ITER ones.