Experiences in fusion - participation in big science

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EURATOM and fusion research

The EURATOM program is one of the first organizations of the EU:

→Collaboration in nuclear research and radiation protection

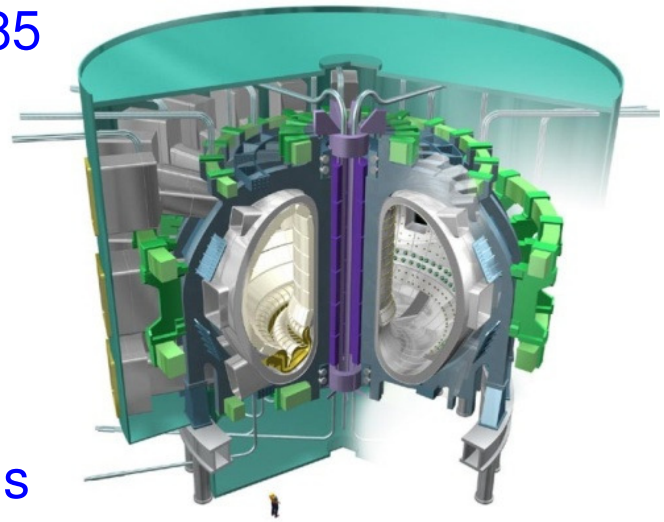
Since the last decade the largest part of EURATOM resources are devoted to the development of fusion energy:

• Inexhaustible nuclear energy source, similar to the Sun
• Uncontrolled reaction, runaway is impossible
• Little and short-lived nuclear waste
• Concept and nuclear reactions are known since the 1940's

Although in theory fusion energy is the optimal solution to energy problems in practical terms it could not be demonstrated yet:

• Needs confinement of 100 million C deuterium-tritium ionized gas mixture: plasma
• Heat loss from plasma should be sufficiently low, so as heating power is small compared to energy from fusion
• Basic technologies have been demonstrated around 2000, but energy balance is negative due to "small" size of devices
• Special physics and technology can be developed hand-in-hand only
• Extremely special high-tech, big-science field.

The environment and Hungarian fusion research in FP6

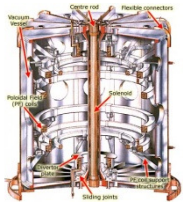


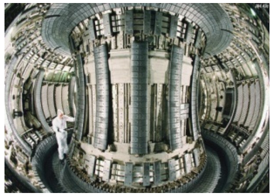
The next step fusion experiment has been planned since 1985

International Thermonuclear Experimental Reactor: ITER

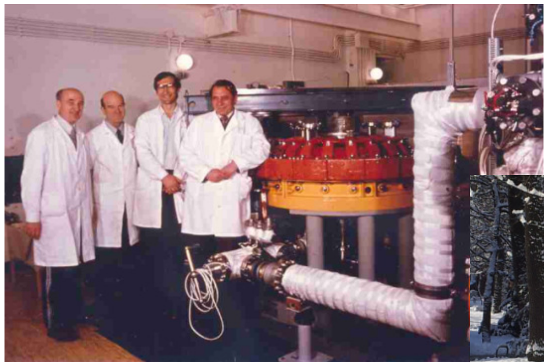
- 10 Billion EUR class device
- EU-Japan-USA-Russia-China-Korea-India collaboration

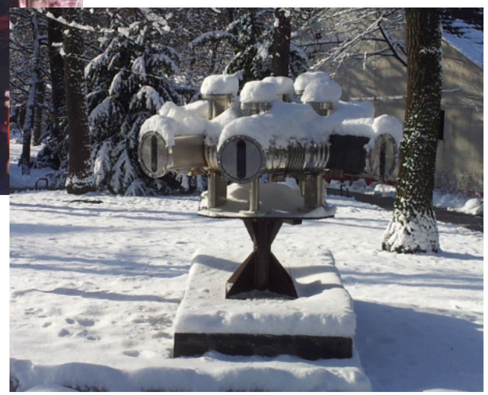
Strong EU fusion programme with well established institutions and large experiments





Hungary had a small fusion activity between 1978-1998





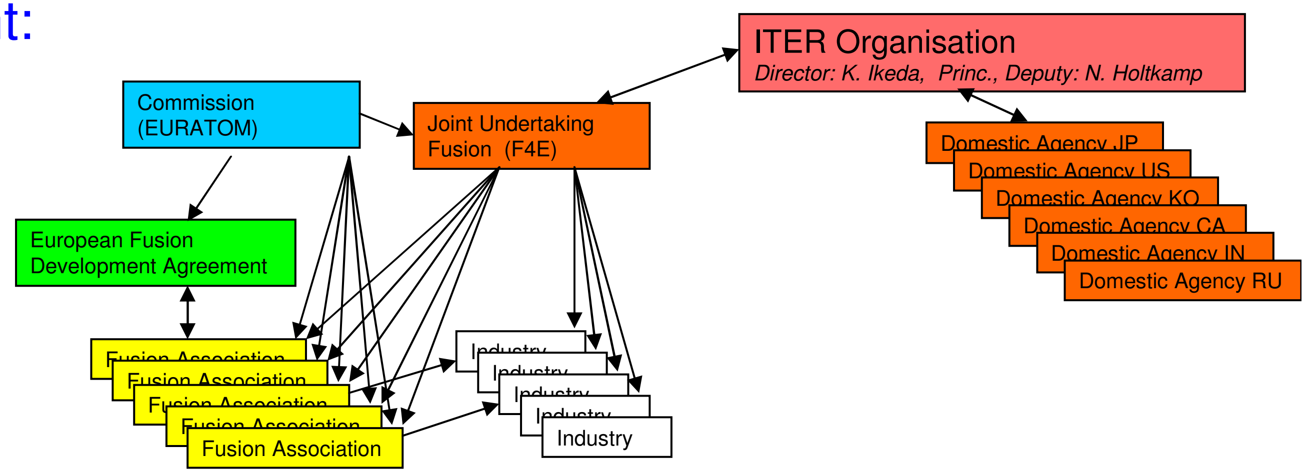
Hungary joined EURATOM in 2000:

- Small physics research activity with ~5 people
- No engineering and little technical background
- No students

The EURATOM fusion programme: HU opportunities

The EURATOM fusion programme has an extremely complex organization as a result of 50 year of organic development:

- Only 20% EU support
- Mobility programme
- Need to involve more researchers and engineers



Hungarian situation in FP6

Strengths:

- Some fusion physics background
- Some connections to German laboratories
- Competitive manpower cost
  → Started to build fusion diagnostic devices for large labs

Weaknesses and reactions:

- No students: → Start University lectures at BME
  → Joint Czech-Hungarian practical training course
- No HU funds: → Use existing manpower resources and invest EU support in infrastructure and training
  → Extensive use of EURATOM mobility
- No engineering: → Provide young engineers for EU labs
  → Seek funds to recruit engineers

Adaptation to future trends

In ~2004 it bacame clear that ITER is going to be a completely different environment:

→No chance without engineering, technology

In 2005 NKTH awarded a grant to

"Technology development for new nuclear energy production methods"

- Fusion and fission technology development
- Fusion aims:
  - Establishing an engineering group and infrastructure
  - Development of a key diagnostic system for a large experiment
  - Development of technologies for a selected diagnostic method
  - Participation in the preparation of ITER diagnostics

The project reached all its aims

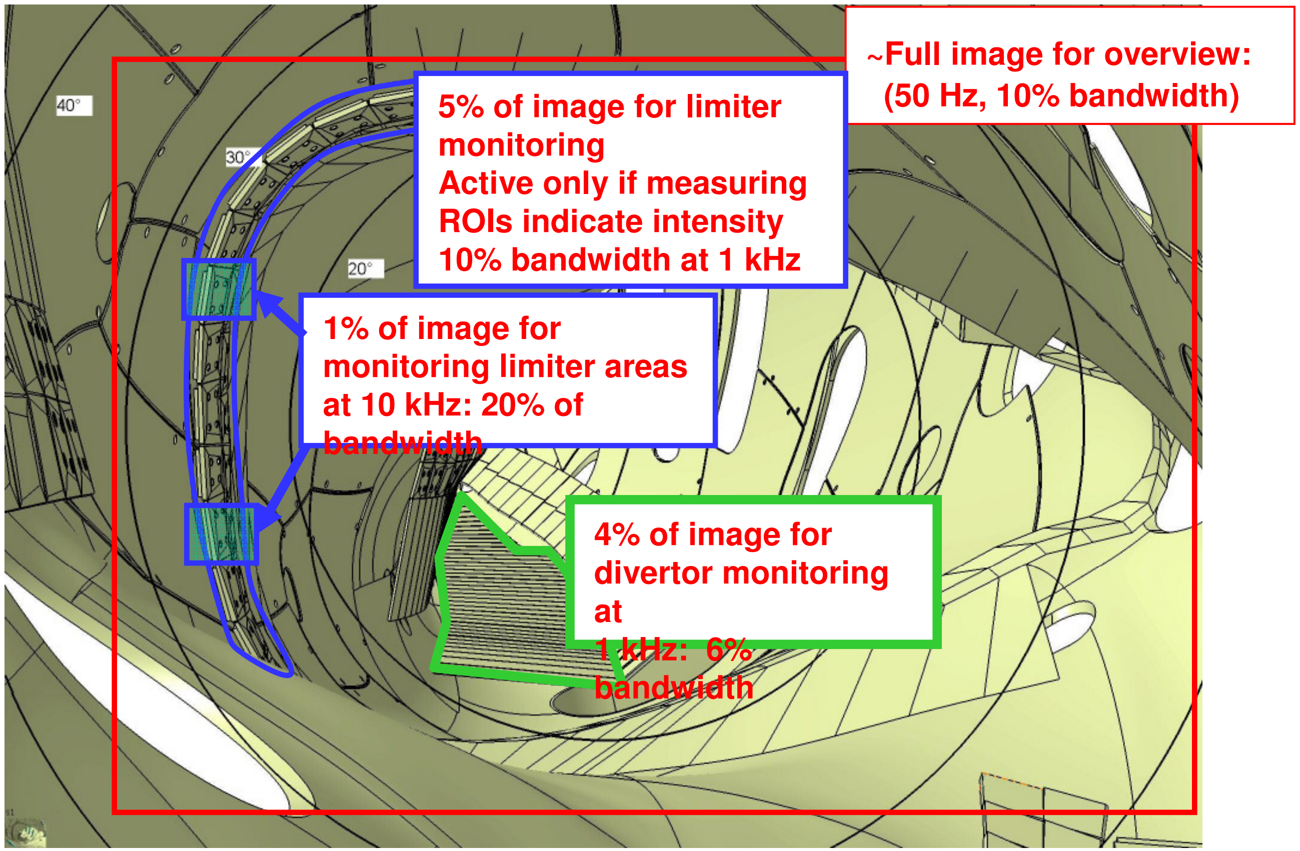
- By 2008 ~15 engineers worked on fusion projects
- Participation in many EU experiments, increasing funds from western labs
- New technologies for Beam Emission Spectroscopy diagnostic
- Elements of 10-camera video survey system for Wendelstein 7-X experiments (to be installed in 2014)
- Participation in 4 ITER diagnostic projects + test tritium module consortium

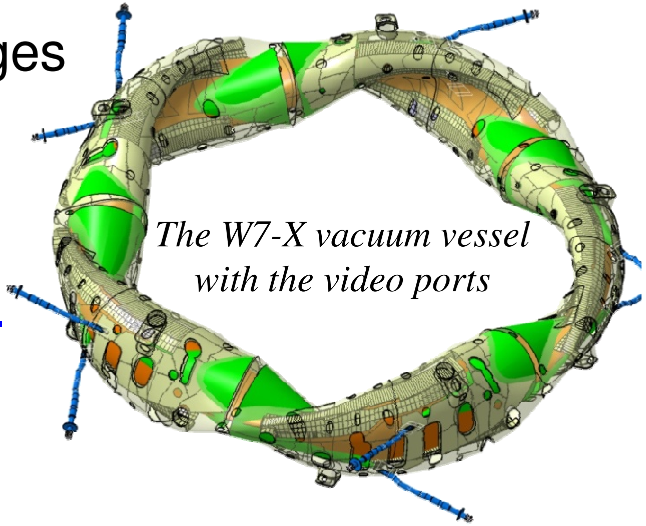
Video survey system for the W7-X stellarator

Wendelstein 7-X is a large optimized stellarator device being built in Greifswald, Germany. Wigner RCP is responsible for construction of a 10-camera video survey system:

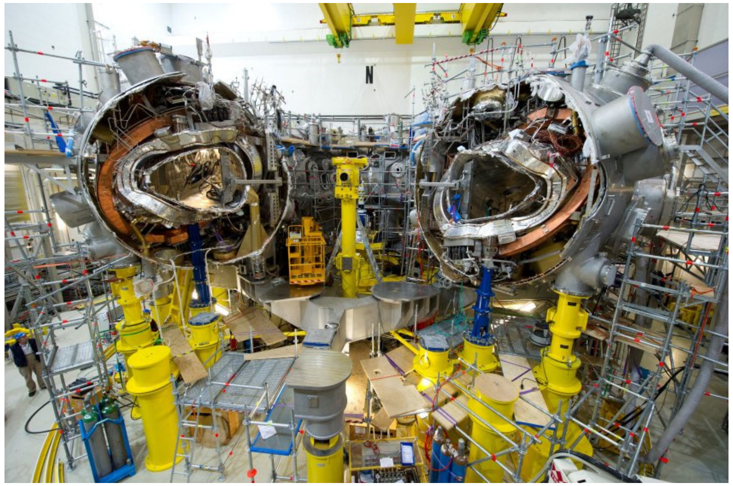
- Conflicting requirements: overview with long exposure images
- Fast detection of plasma-wall interaction
- Optimal use of sensor and data storage

A special video camera has been developed for the purpose.





The W7-X vacuum vessel with the video ports

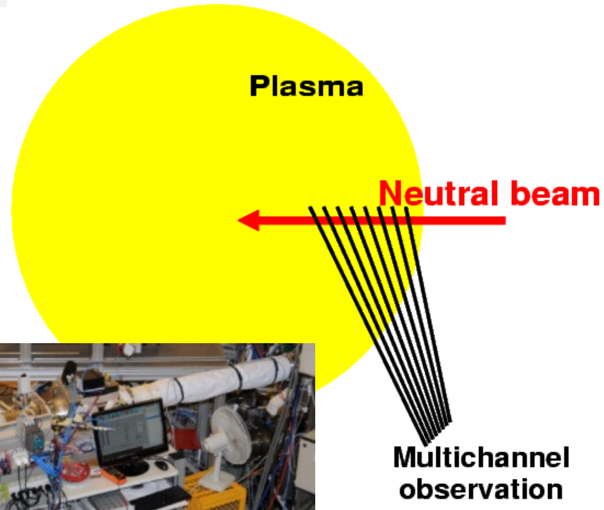


The W7-X device in 2012

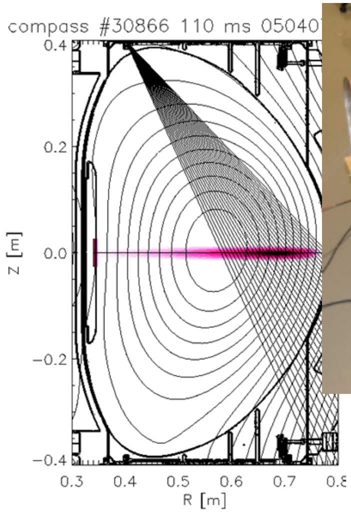
Beam Emission spectroscopy

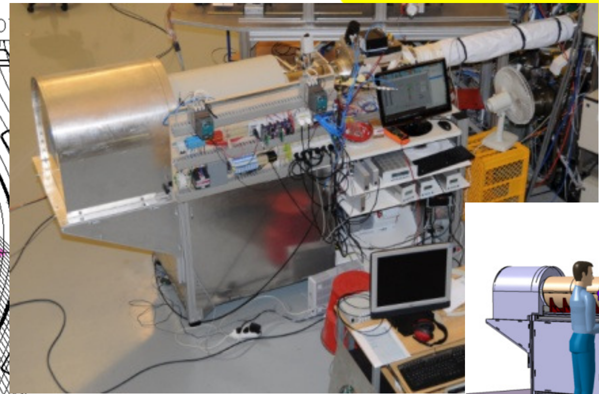
Injecting a neutral atomic beam into the plasma and observing its light emission:

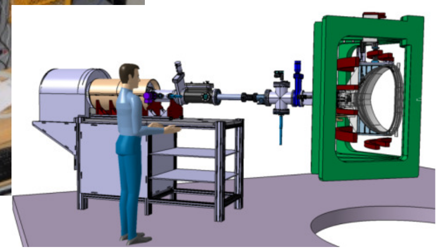
→ information on plasma density, turbulence, flow, ...

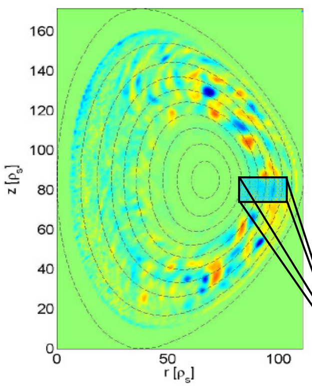


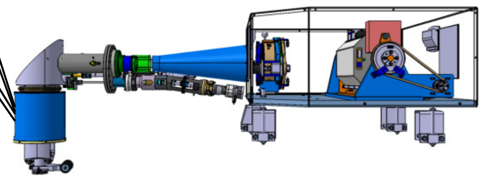
Beam can be either a heating D beam or diagnostic beam, typically Lithium

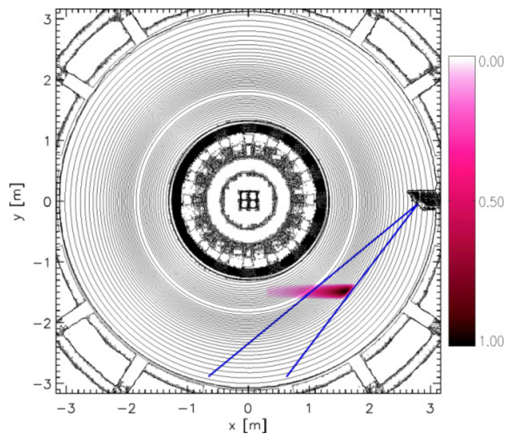


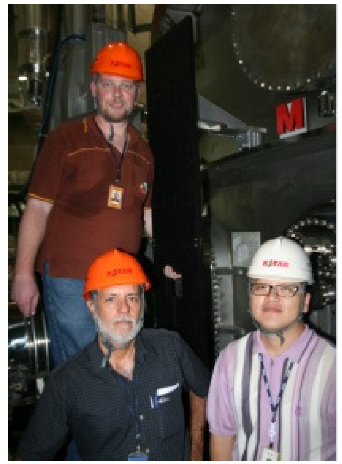












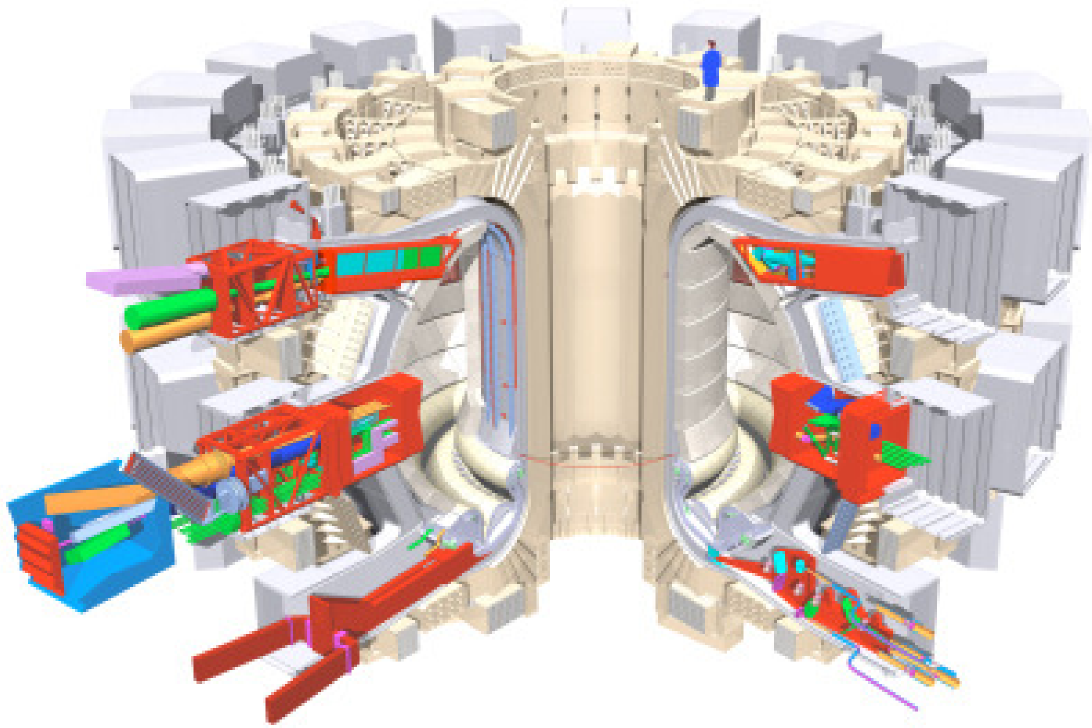
Hungarian BES systems specialize on plasma turbulence measurements

ITER diagnostics

ITER has a comprehensive diagnostic set with ~40 systems. They are integrated into a difficult engineering environment.

Situation is completely different than on present-day devices.

However, diagnostics on present day devices + engineering make the Hungarian fusion team well prepared for ITER diagnostics.



Some of the ITER diagnostic port plugs

Europe has 25% of ITER diagnostics

Tomography

Tomographic measurements are common in fusion:

•Line integral radiation data are obtained (visible, X-ray, neutron,...)

•2D radiation source should be determined from limited number of measurements

•Good design and modeling is extremely important

Several ITER tomographic diagnostics has been modeled by Hungarian researchers:

•Bolometer tomography (total radiation profile)

•Neutron cameras (neutron source)

•X-ray tomography: plasma shape

The ITER bolometer tomography diagnostic is a German-Hungarian project:

• ~450 lines of sight

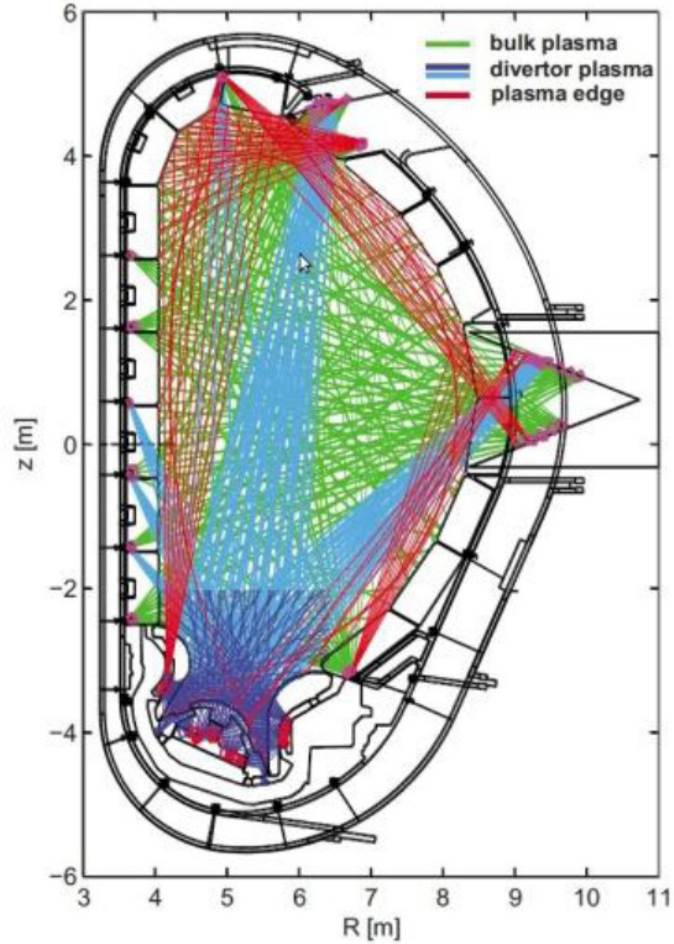
• small cameras integrated into various locations

Hungarian contribution:

• Tomographic analysis, optimal placement of views

• Integration of equatorial port cameras

• Irradiation testing in the Budapest research reactor



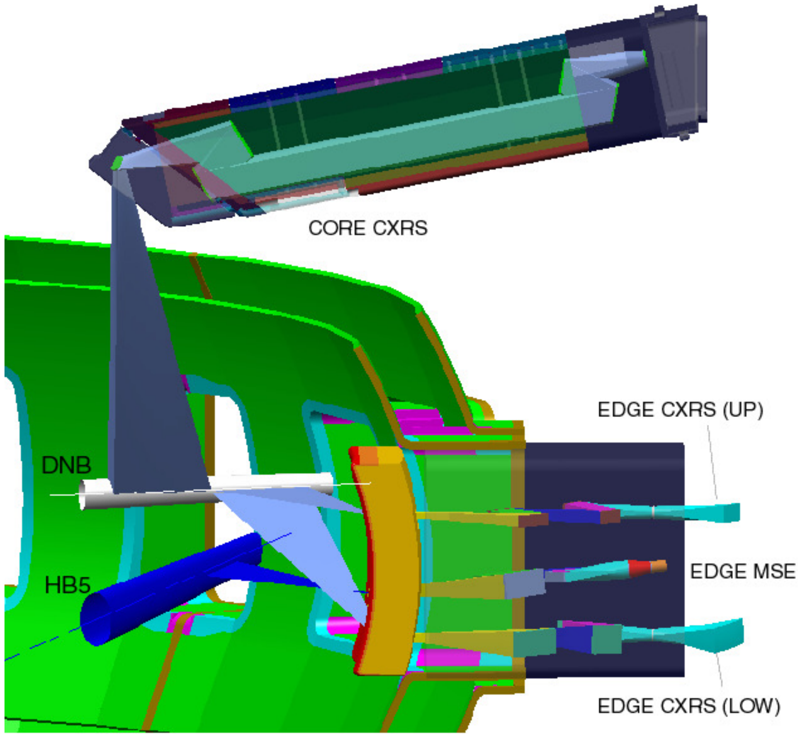
Current arrangement of the ITER bolometer sightlines

Charge-exchange recombination spectroscopy (CXRS)

CXRS is one of the largest diagnostic systems involving a 25x5x5 m, 700 ton diagnostic beam injector:

- Injector to be provided by India
- Core observation system is EU responsibility
- 2 edge observation systems to be provided by RU

The diagnostic beam and observation systems in ITER



A grant application for the core CXRS diagnostic has just been submitted by a German-Dutch-Hungarian-Spanish-British consortium.

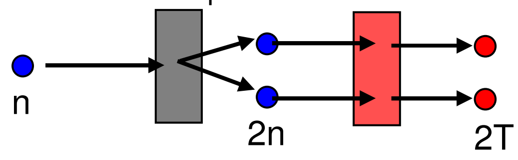
Hungarian involvement is proposed in optical and engineering design, data acquisition modeling.

Tritium breeding

ITER will not prepare its Tritium, but will test two blanket concepts for DEMO.

The fusion blanket has dual role:

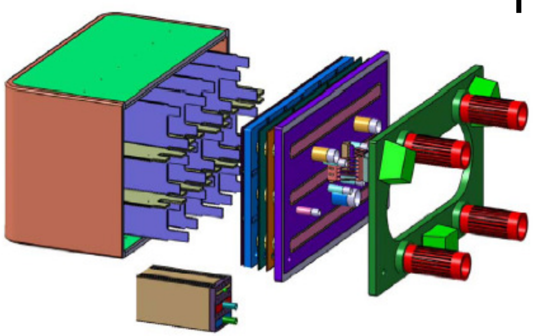
- Breeding Tritium from Lithium
- Extracting the power from neutrons and radiation



Two EU concepts:

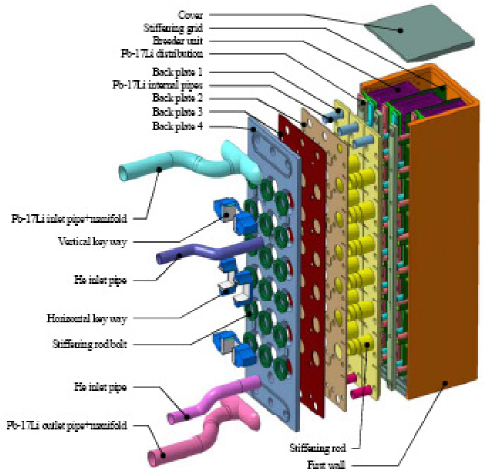
Be multiplier → Be + Li ceramics pebbles with He gas cooling

HCPB



Pb multiplier → liquid PbLi alloy with He gas cooling

HCLL



Hungarian engineers contribute to the ITER TBM development through engineering design, thermal, mechanical and thermohydraulic modeling.

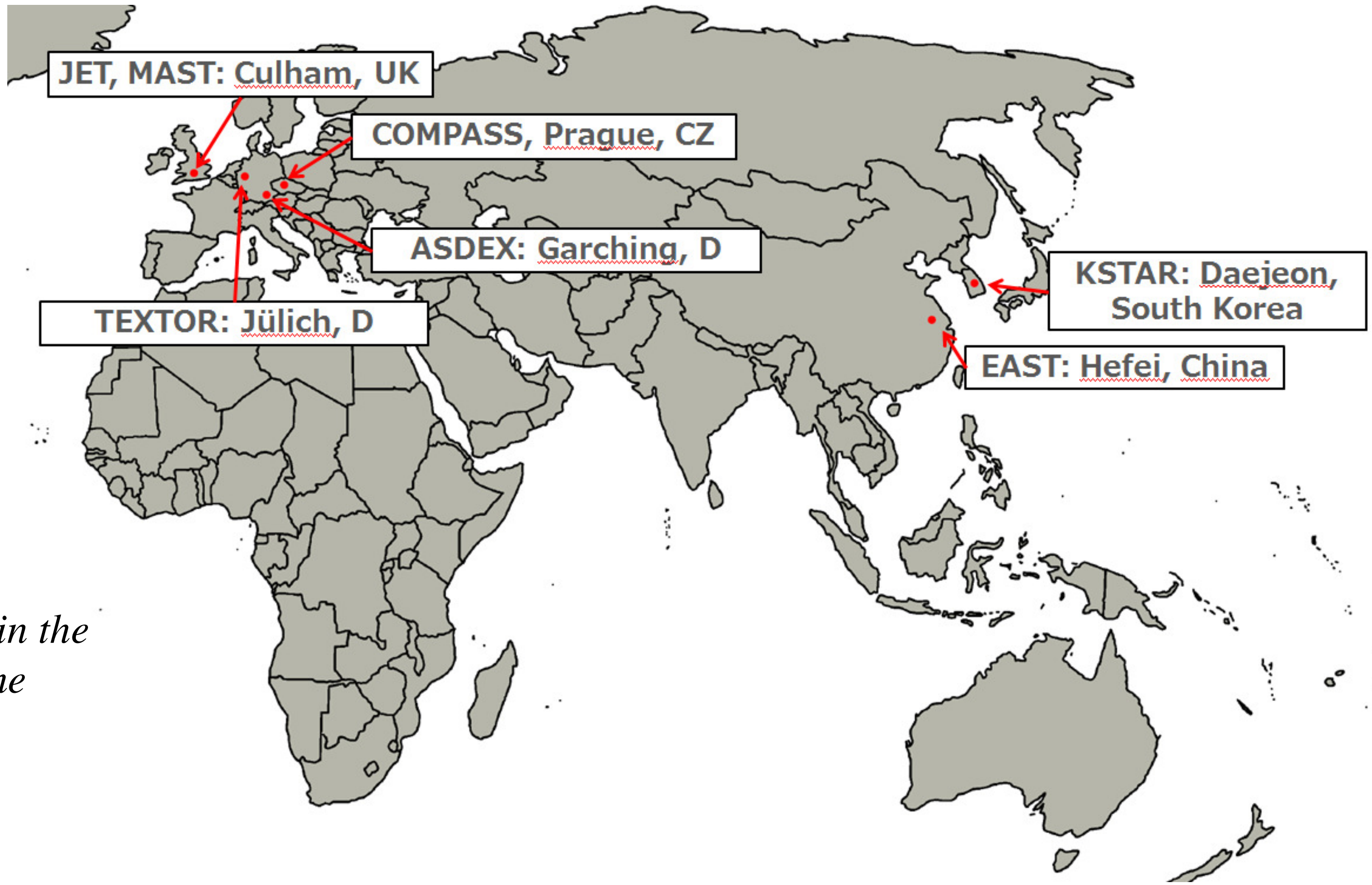
The tritium breedeing capability of the DEMO blanket is being assessed by the Budapest University of Technology and Economics.

At the end of FP7

The funding gradually moved from NKTH+FP7 to FP7 and external sources:

Annual resources:

- EURATOM: 200 kEUR (+300 kEUR mobility)
- ITER grants: ~700 kEUR
- Direct contracts with EU and Asian fusion experiments: ~300 kEUR
- HAS matching fund: variable



Hungarian collaborations in the world fusion programme

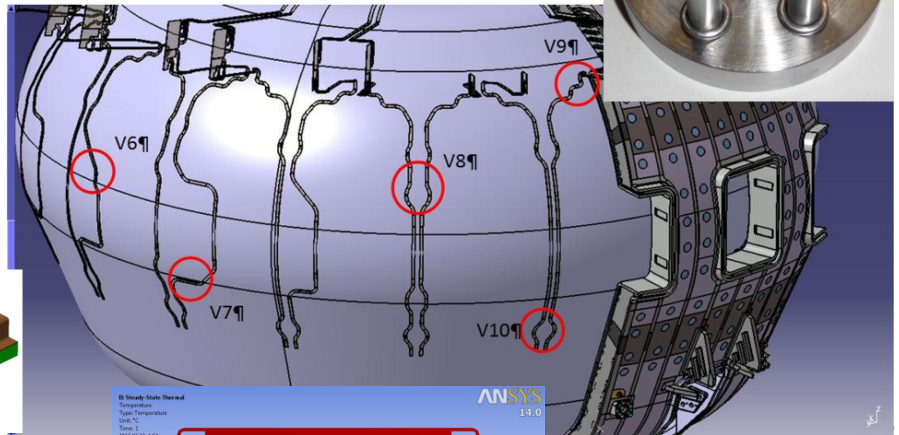
A HU-lead ITER project: Tokamak Services

The strong Hungarian engineering background made it possible to apply for one of the core services in ITER:

- In-vessel cabling technology development
- Vacuum feedthrough design and testing
- Remote handling compatible connectors, cable holders

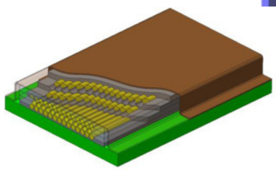
Although looks simple such a task is not trivial in a tokamak environment:

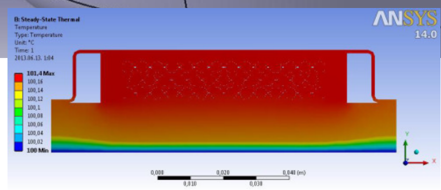
- High heat loads
- Electromagnetic forces during normal and plasma disruption conditions
- Complex environment, collaboration across 3 continents
- Radiation effects on cables, signals, mechanical structures
- High reliability need



A Consortium of Hungarian institutions won the Tokamak services grant:

- Wigner RCP
- Centre for Energy Research
- Budapest University of Technology and Economics





The ITER Tokamak Services project is a major engineering contribution to ITER.

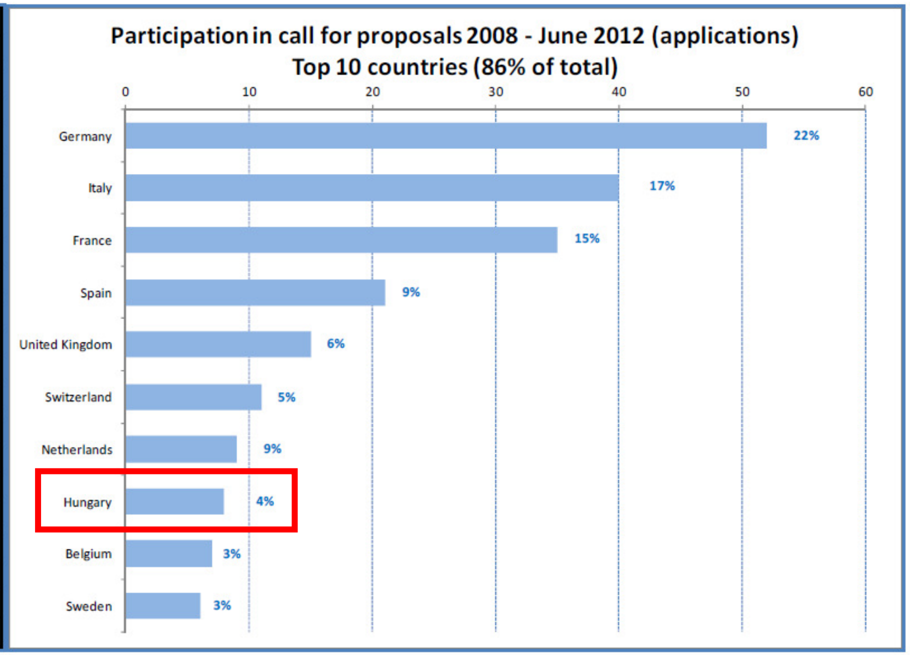
Hungarians are one of the leading developers of ITER diagnostics

H·a·S EURATOM ASSOCIATION

Fusion for Energy
Grant statistics, 2012 december

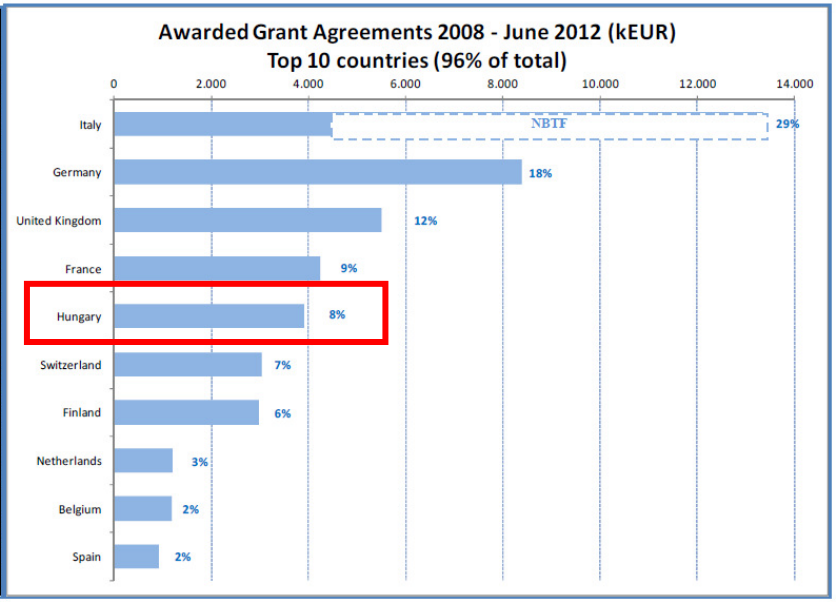
Summary of Grant Participation

Country	Applications
Austria	3
Belgium	7
Czech Republic	4
Finland	4
France	35
Germany	52
Greece	3
Hungary	8
Italy	40
Latvia	4
Netherlands	9
Poland	3
Portugal	5
Romania	3
Slovenia	4
Spain	21
Sweden	6
Switzerland	11
Third country (Canada)	1
United Kingdom	15
Grand Total	238



Summary of Grant Funding Distribution

Sum of Max F4E Contribution (kEUR)	
Country	Total
Austria	118
Belgium	1.179
Czech Republic	162
Finland	2.985
France	4.239
Germany	8.389
Greece	176
Hungary	3.919
Italy	13.355
Latvia	58
Netherlands	1.207
Poland	43
Portugal	226
Romania	190
Slovenia	99
Spain	920
Sweden	605
Switzerland	3.031
Third country (Canada)	39
United Kingdom	5.491
Grand Total	46.429



The success of the Hungarian fusion programme relies on a few features:

- Combination of resources (EURATOM, NKTH, HAS, external orders)
- Long term view, adaptation to environment
- Investment in manpower and infrastructure

There are threats during H2020:

- All grants rely on national matching funds
  - At present 2 sources: HAS matching fund + external projects
  - Both sources are prone to fluctuation
- Physicist staff is HAS employee, but all engineers are paid by projects

  Lack of funds

  → reduction of engineering background

  → reduced capability to acquire projects
- Low salaries
  - Although the projects are international and the HU fusion community is world leading in some fusion diagnostics there is no way to recruit non-Hungarian staff
  - Flow of young researchers/engineers is unidirectionl: Hungary → World