Contributions to the Joint European Torus fusion research work programme

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Outline

JET: Introduction

JET Experiments

Diagnostics developments

The ITER-Like Wall

JET future

Dedic aceasta prezentare memoriei lui

Teodor Ionescu-Bujor (Dudu).

Este un modest omagiu pentru o munca imensa si pentru imaginea unui om deosebit , pentru un coleg si prieten greu de inlocuit.

Fara munca istovitoare depusa de Teodor Ionescu-Bujor pentru Asociatia Romana de Fuziune, multe dintre cele prezentate mai jos nu ar fi fost infaptuite.

JET: Introduction

-The largest controlled nuclear fusion facility in the world.
-Operated, used and developed by the European fusion community working under the European Fusion Development Agreement (EFDA).
-Contributions of the Romanian Fusion Association to the JET research programme during the last 5-6 years

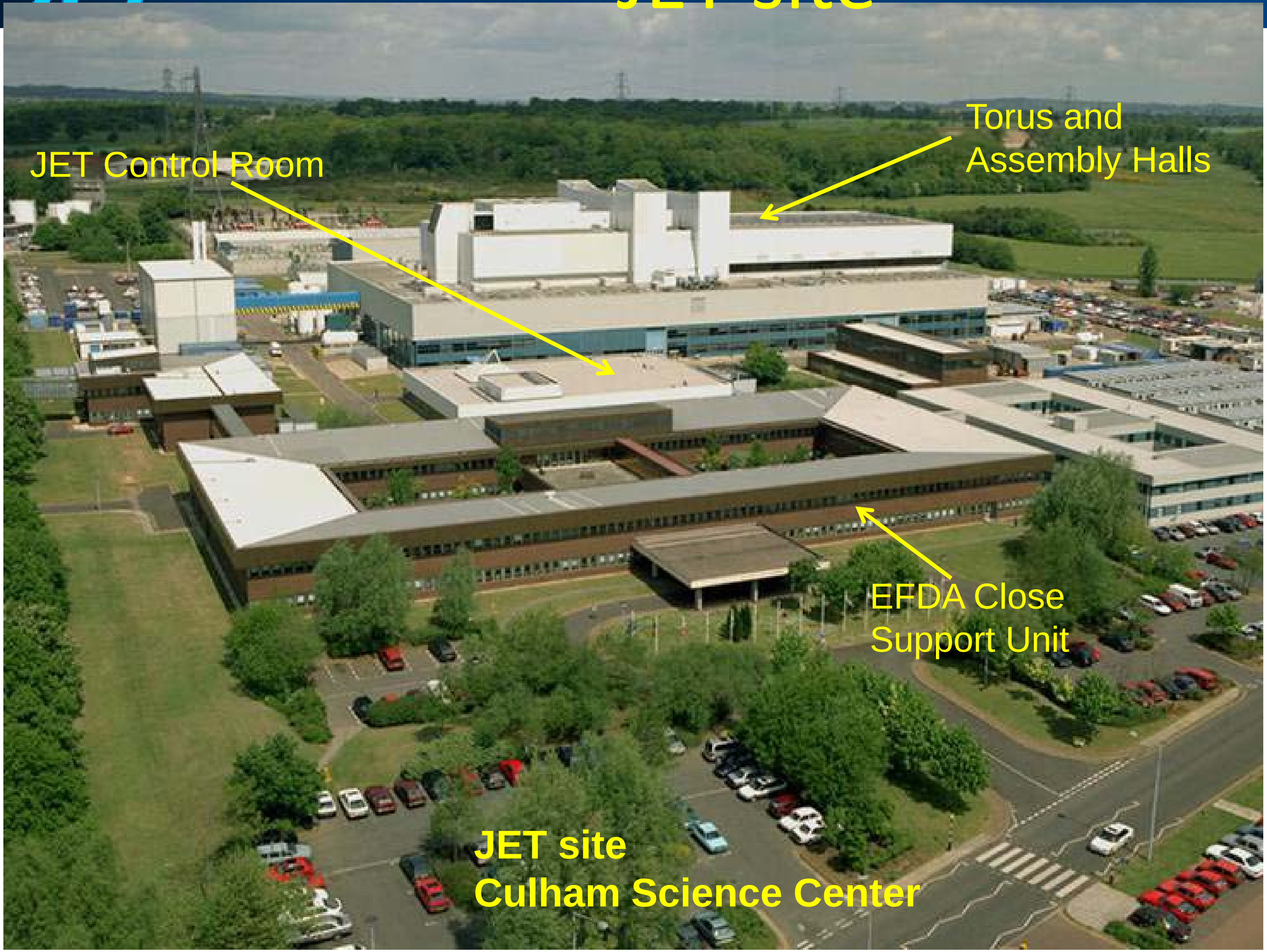
- -development of new technologies, components and devices, as well as by participating in JET experiments.

-A review of some of the activities in which the author has been directly involved.
-It will focus on the impact and significance of these contributions to the JET work programme, rather than on the technical details of the particular activities.
-Examples of contributions to JET (in a chosen order)

- -JET experimental campaigns
- -diagnostics systems for gamma-ray imaging and gamma-ray spectroscopy
- - tungsten and beryllium coatings for the JET wall tiles

-Particular attention to the contribution of the Romanian scientists and engineers to the recently completed “ITER-Like Wall” project
-At various points, some lessons learned will be presented

JET site


JET Control Room
Torus and
Assembly Halls
EFDA Close
Support Unit
JET site
Culham Science Center

JET

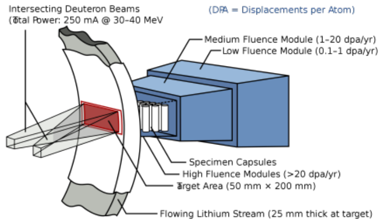
Joint European Torus (JET)

The largest operating controlled fusion device with magnetic plasma confinement with capability of operation with the deuterium-tritium (D-T) mixture.

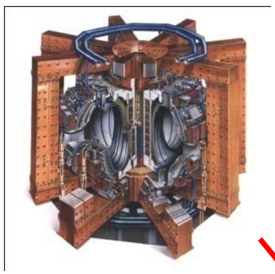
The scientific mission of JET is to optimise plasma operation scenario for a reactor-class machine, ITER, the next step in fusion reactor development.

Significant developments during the last 5-6 years prepared JET for achieving its scientific mission before being closed down.
These include:
- -A new wall: the ILW
- -Increased NBI power
- -New advanced diagnostics techniques

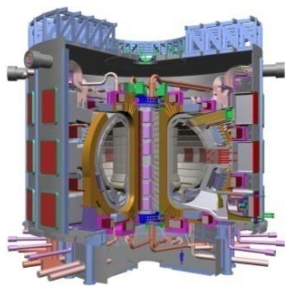
JET & ITER



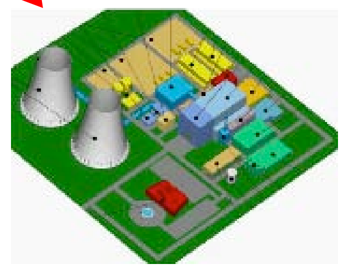
IFMIF



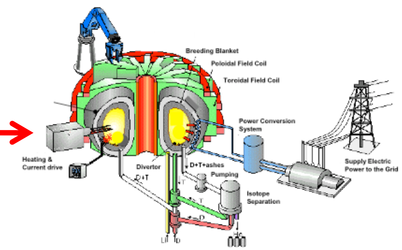
JET



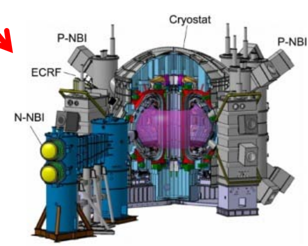
ITER



DEMO



Fusion Power Plant

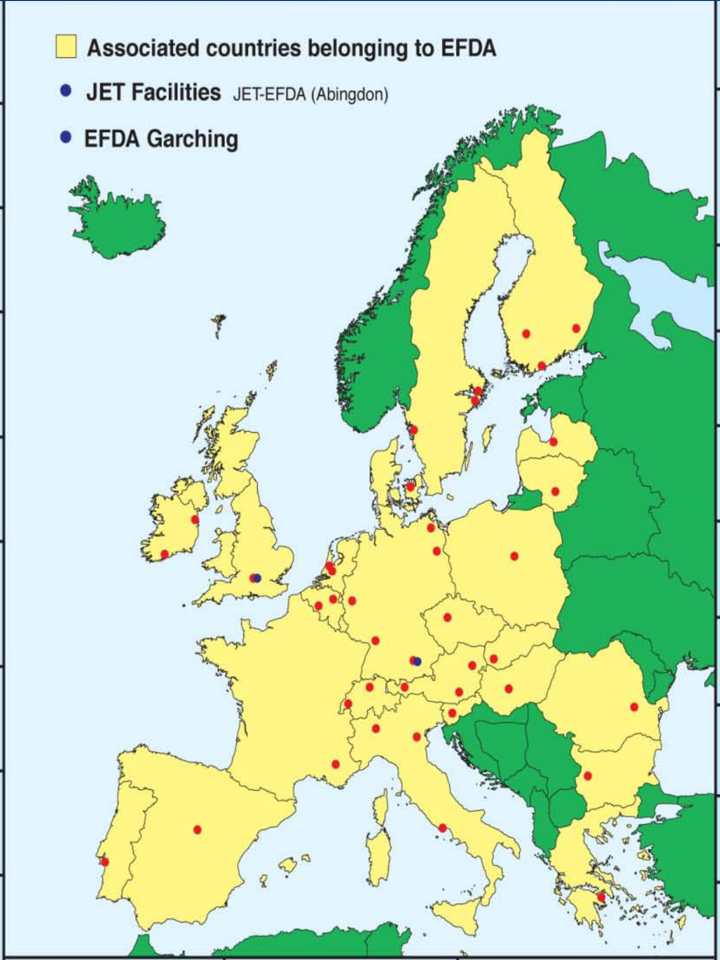


JT-60SA

European Fusion Development Agreement

26 EFDA Associations involved fully and collectively in the exploitation and development of JET

- **Euratom - Belgian State** (Brussels) - (Mol)
- **Euratom - CEA** TORE SUPRA (Cadarache)
- **Euratom - CIEMAT** TJ-II (Madrid)
- **Euratom - Conf. Suisse** TCV - SULTAN (Lausanne) - (Villigen)
- **Euratom - DCU** (Dublin) - (Cork)
- **Euratom - ENEA** FTU - RFX (Frascati) - (Milan) - (Padua)
- **Euratom - FOM** (Petten) - (Nieuwegein)
- **Euratom - FZJ** TEXTOR (Julich)
- **Euratom - FZK** TOSKA (Karlsruhe)
- **Euratom - Greece** (Athens) - (Heraklion) - (Ioannina)



- **Euratom - LEI** (Kaunas)
- **Euratom - CU** TOSKA (Bratislava)
- **Euratom - MHST** (Ljubljana)
- **Euratom - IPPLM** (Warsaw)
- **Euratom - INRNE** (Sofia)

- **Euratom - HAS** (Budapest)
- **Euratom - IPP** Asdex Upgrade - Wendelstein 7-AS Wendelstein 7-X (Garching) - (Greifswald) - (Berlin)
- **Euratom - IPP.CR** CASTOR (Prague)
- **Euratom - IST** ISTTOK (Lisbon)
- **Euratom - Latvia** (Riga)
- **Euratom - MEC** (Bucharest)
- **Euratom - ÖAW** (Vienna) - (Graz) - (Innsbruck)
- **Euratom - RISØ** (Roskilde)
- **Euratom - TEKES** (Helsinki) - (Tampere) - (Lappeenranta)
- **Euratom - UKAEA** MAST - JET (Culham)
- **Euratom - VR** EXTRAP T2R (Stockholm) - (Lund) (Gothenburg) - (Studsvik) - (Uppsala)

JG03.241-7c

Organisation & Management

EFDA Associations + European Commission

Steering Committee

↓ ↑

EFDA Associate Leader for JET

Head of Close Support Unit (CSU) Culham

Francesco Romanelli

Responsible for use of JET facilities: Scientific Programme, Enhancements, JET Operation Contract (JOC) management for the European Commission, International Collaborations

↓ ↑

OPERATION
CCFE / JOC
(400-500 personnel)
Responsible for operations, safety, plant protection…

PROGRAMME, ENHANCEMENTS, JOC MONITORING
CSU JET Department
(~35 staff)

SCIENTIFIC WORK
Associations
(~350 scientists)
International
(~150 scientists)

JET tokamak

JET load assembly

Vacuum vessel

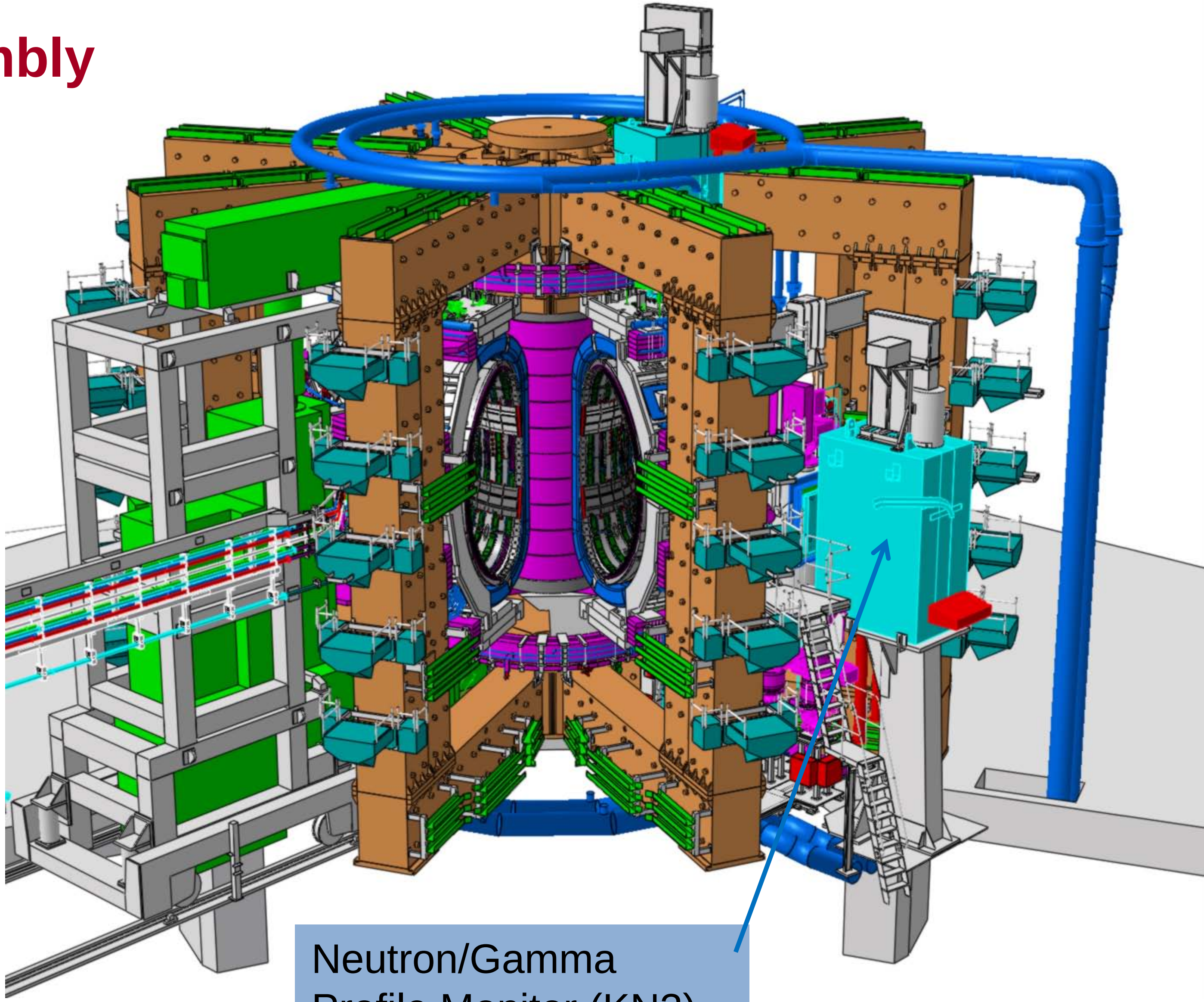
TF coils

Support
structure

PF coils

Transformer
Iron limbs

other



Neutron/Gamma
Profile Monitor (KN3)

JET Experiments: Campaigns Management

JET Experimental Campaigns

Task Forces

- -Task Force Leaders
  - -EALJ proposal
  - -EFDA/EC approval
  - -TFL's: for each Experimental Campaign (group of campaigns)
- -Present:
  - -TF E1 (Experiments: commissioning the ITER-Like Wall)
  - -TF E2 (Experiments: exploration of the ITER-Like Wall)
  - -TF FT (Technology)

Workprogramme Headlines

- -CSU proposal
- -EFDA SC approval

Associations

- -Proposals
  - -Two page document
- -Working Groups
  - -Analysis of proposals

JET Experiments

Campaigns

General Planning Meeting

- Evaluation of proposals
- Experiments timeline

Call for participation

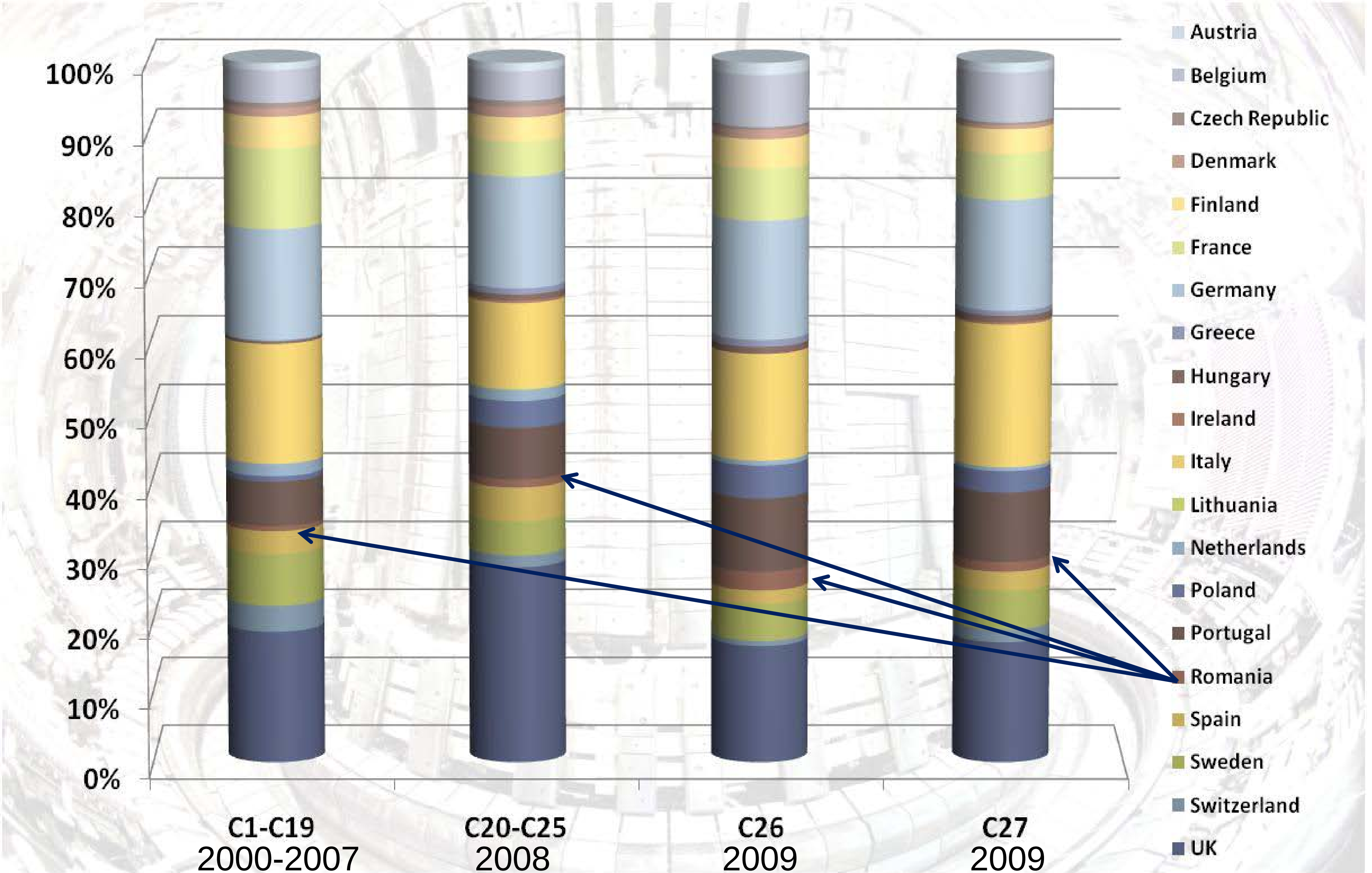
- List of experiments
- Workprogramme headlines
- List of competencies

CSU & TFL's

- Proposals for Scientific coordinators

The Scientific Coordinator is responsible for the overall coordination of an Experiment, including physics integration, session preparation, documentation, analysis and reporting. In these duties he is assisted by the key personnel with relevant scientific expertise that make up the Experimental Team. Additionally the SC (or Deputy in cases with double sessions) covers the Control Room SC duty. The Scientific Coordinator is not necessarily the proposer of the Experiment, nor by default the first author of any resulting publications.

Associates Participation in Experiments



Participation in JET experiments

Participation as

- -Member of the Control Room Experimental Team
  - -Session Leader
  - -Scientific Coordinator
  - -Diagnostics Coordinator
  - (Engineer-in-Charge: Operator)
- -Experiments
  - -Scientific coordinator
  - -Member of an experimental team
  - -Expert (competencies)

MEdC Association participation

- -Well below possibilities and opportunities
- -Participation: fully funded by EC

Why?

- -One reason: the salary payment issue
- -?

JET Experiments: JET operation

JET discharge (pulse)

Plasma discharge evolution

(Torus interior lit by D_α plasma light)

Make gas break-down at bottom

Shift plasma up,
dwell on inner-wall guard limiter

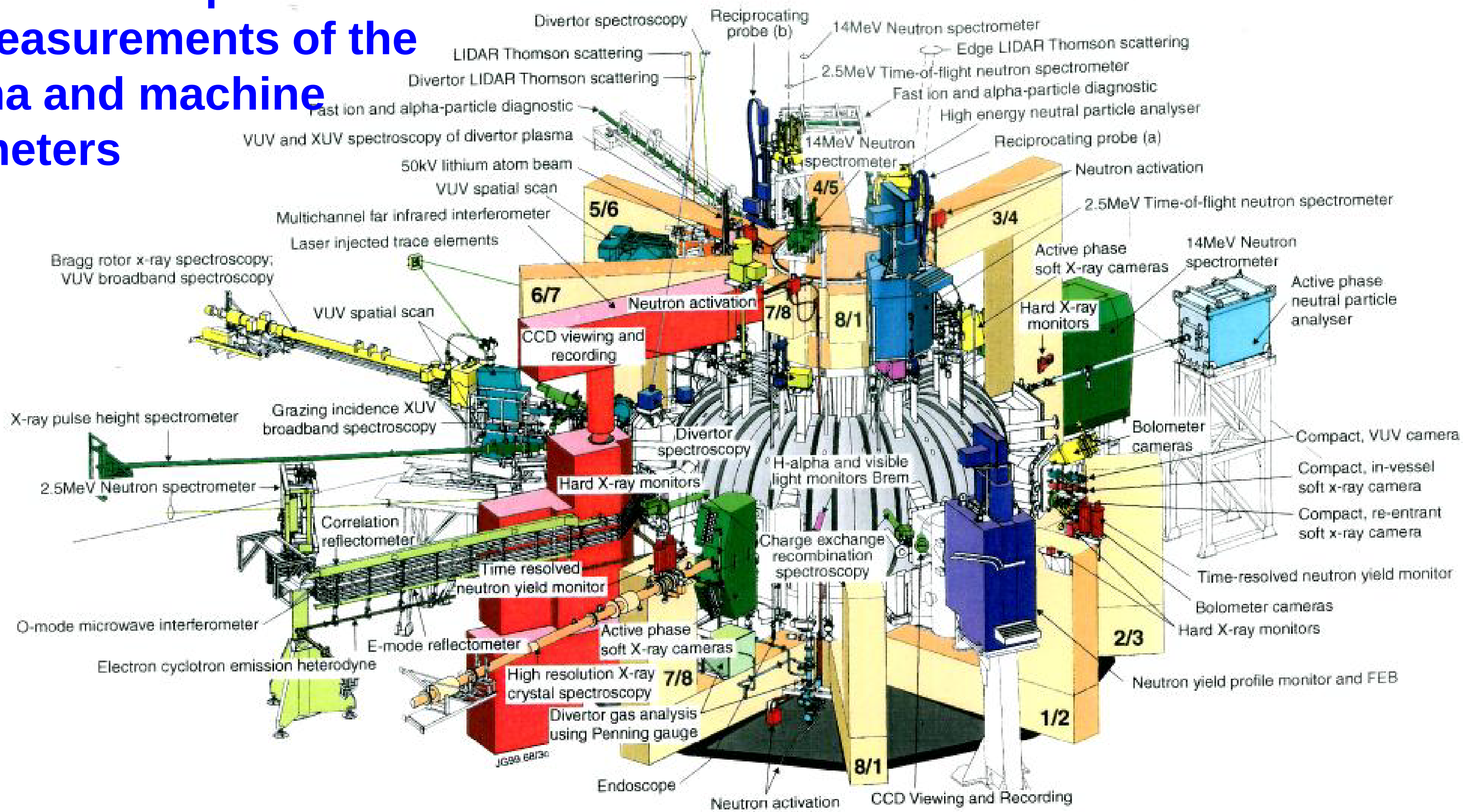
Create poloidal divertor

Apply heating...

Plasma dies on inner-wall guard limiter

JET diagnostics

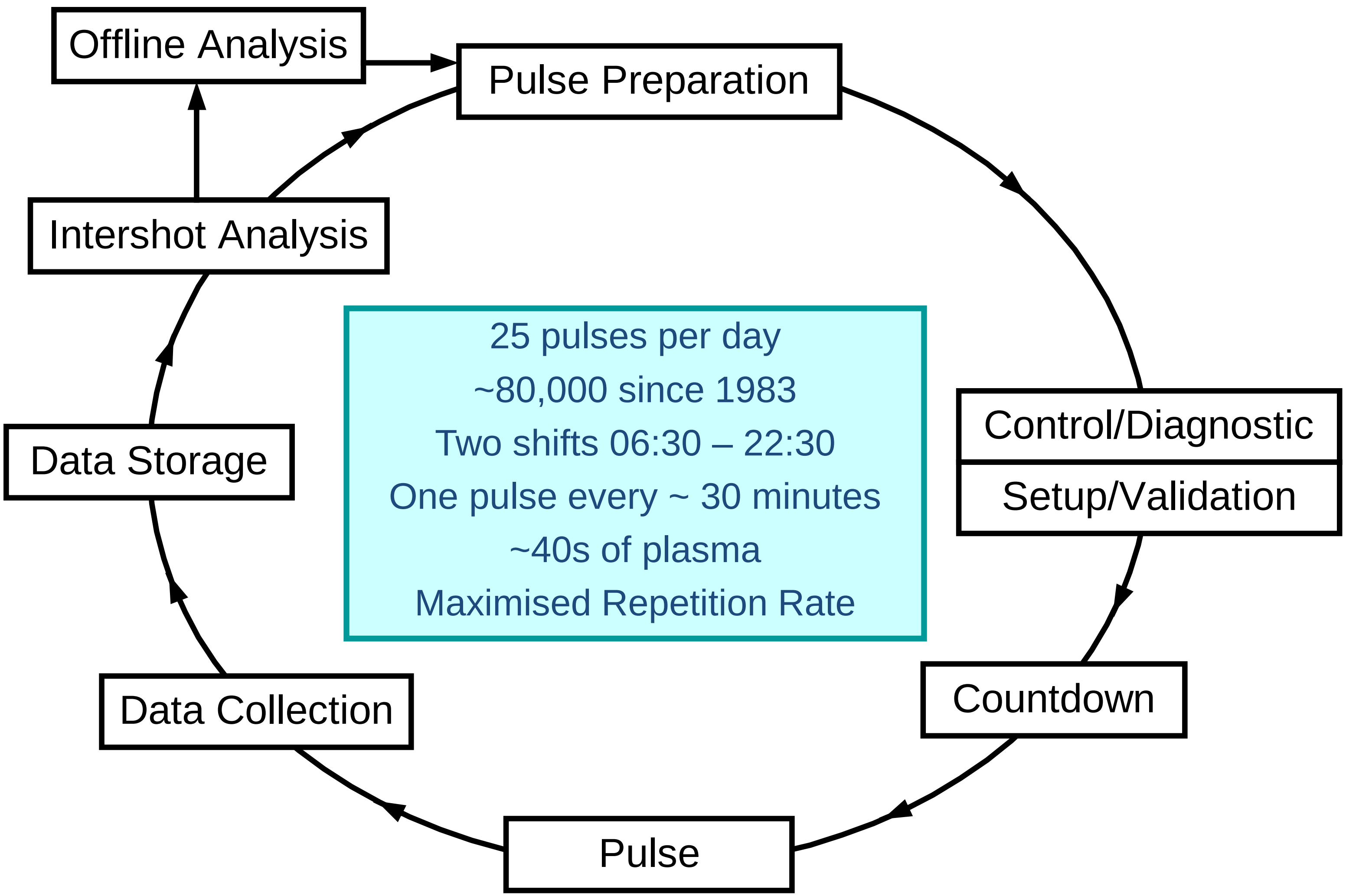
JET diagnostics: Over 80 techniques for the measurements of the plasma and machine parameters



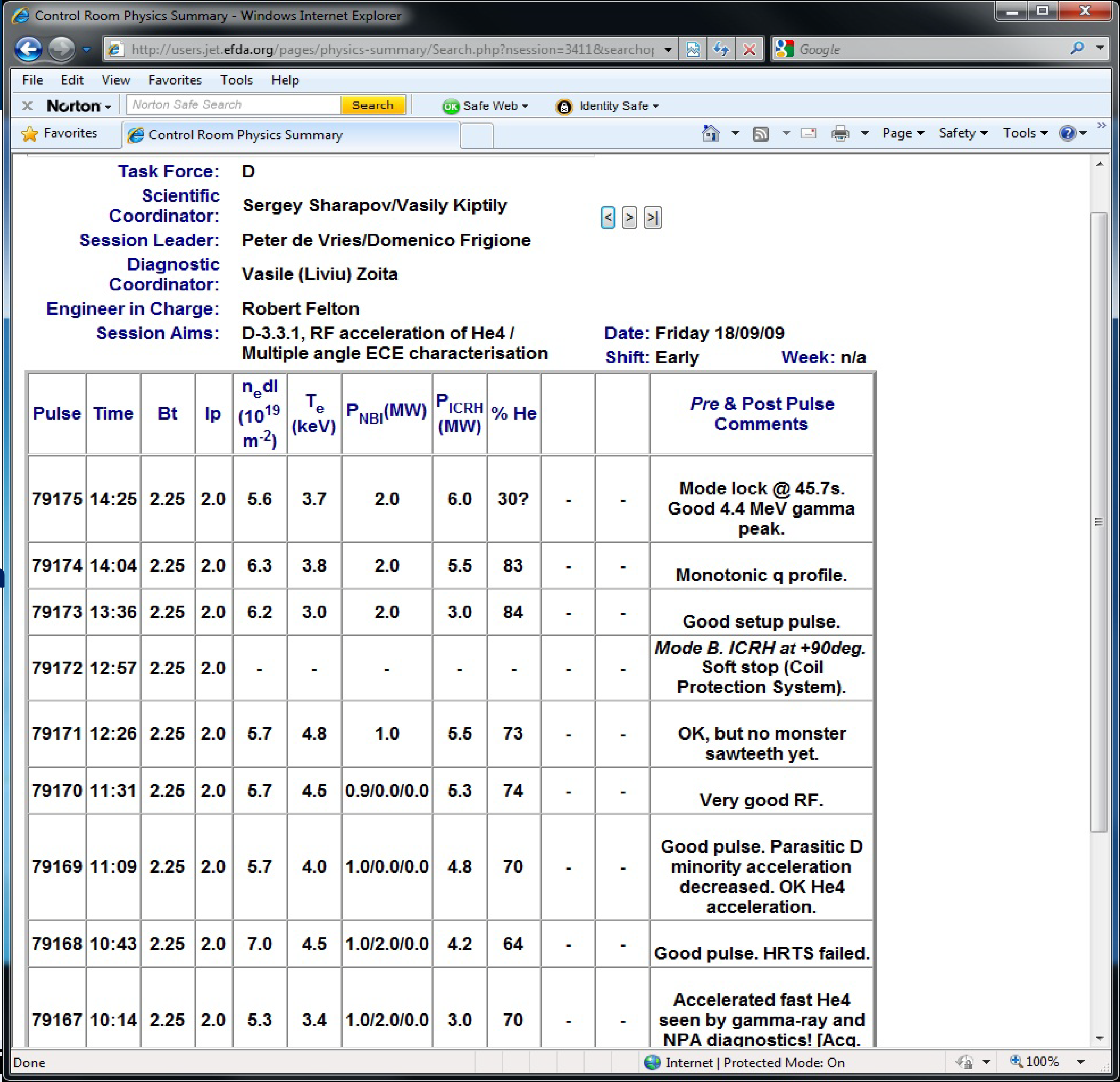
CODAS - Control and Data Acquisition System

- 25 Subsystem control computers + 150 analysis computers
- Control of JET via 20,000 “Level 1” parameters
- Monitoring via ~1000 mimics and ~8000 plant alarms
- Data Acquisition from ~80 diagnostics
- CAMAC, VME and PC based diagnostic systems
- ~15Gbytes of data per pulse ~ 0.4Tbytes a day

CODAS - control of JET pulse cycle



JET Experiment
Control Room Team
and
Control Room Physics Summary



Task Force: D
Scientific Coordinator: Sergey Sharapov/Vasily Kiptily
Session Leader: Peter de Vries/Domenico Frigione
Diagnostic Coordinator: Vasile (Liviu) Zoita
Engineer in Charge: Robert Felton
Session Aims: D-3.3.1, RF acceleration of He4 / Multiple angle ECE characterisation
Date: Friday 18/09/09
Shift: Early **Week:** n/a

Pulse	Time	Bt	Ip	$n_e dl$ (10^{19} m^{-2})	T_e (keV)	P_{NBI}(MW)	P_{ICRH} (MW)	% He			*Pre* & Post Pulse Comments
79175	14:25	2.25	2.0	5.6	3.7	2.0	6.0	30?	-	-	Mode lock @ 45.7s. Good 4.4 MeV gamma peak.
79174	14:04	2.25	2.0	6.3	3.8	2.0	5.5	83	-	-	Monotonic q profile.
79173	13:36	2.25	2.0	6.2	3.0	2.0	3.0	84	-	-	Good setup pulse.
79172	12:57	2.25	2.0	-	-	-	-	-	-	-	*Mode B. ICRH at +90deg.* Soft stop (Coil Protection System).
79171	12:26	2.25	2.0	5.7	4.8	1.0	5.5	73	-	-	OK, but no monster sawteeth yet.
79170	11:31	2.25	2.0	5.7	4.5	0.9/0.0/0.0	5.3	74	-	-	Very good RF.
79169	11:09	2.25	2.0	5.7	4.0	1.0/0.0/0.0	4.8	70	-	-	Good pulse. Parasitic D minority acceleration decreased. OK He4 acceleration.
79168	10:43	2.25	2.0	7.0	4.5	1.0/2.0/0.0	4.2	64	-	-	Good pulse. HRTS failed.
79167	10:14	2.25	2.0	5.3	3.4	1.0/2.0/0.0	3.0	70	-	-	Accelerated fast He4 seen by gamma-ray and NPA diagnostics! [Acq.

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JET Experiment: a very simple example (the only one we have!)

Determination of neutron field characteristics for high performance discharges (JET Experiment D-1.5.2) (C20-C26)

Objectives of Experiment

-Determine the neutron field parameters (yield, fluence, energy distribution) at a specific location on JET (end of the KM11 line-of-sight).

-Apply simultaneously different neutron measuring techniques (bubble detectors, activation, time-of-flight) and compare the results.

-Compare experimental results with MCNP calculations

Determination of neutron field characteristics for high performance discharges (D-1.5.2)

The bubble detector array configuration operates like a **neutron pinhole camera**

Confirmed by (independent) MCNP calculations

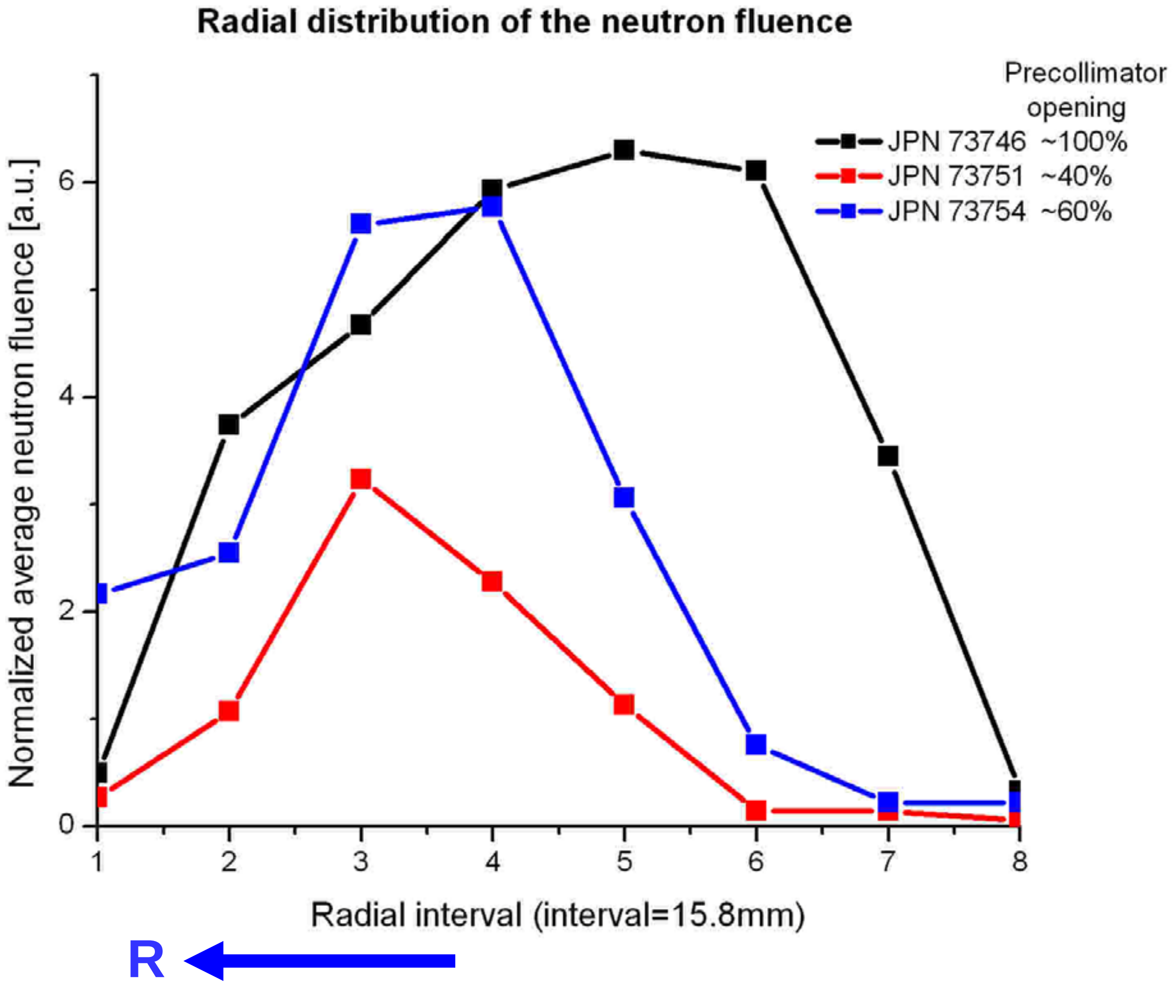


Figure
Radial distribution of the neutron fluence

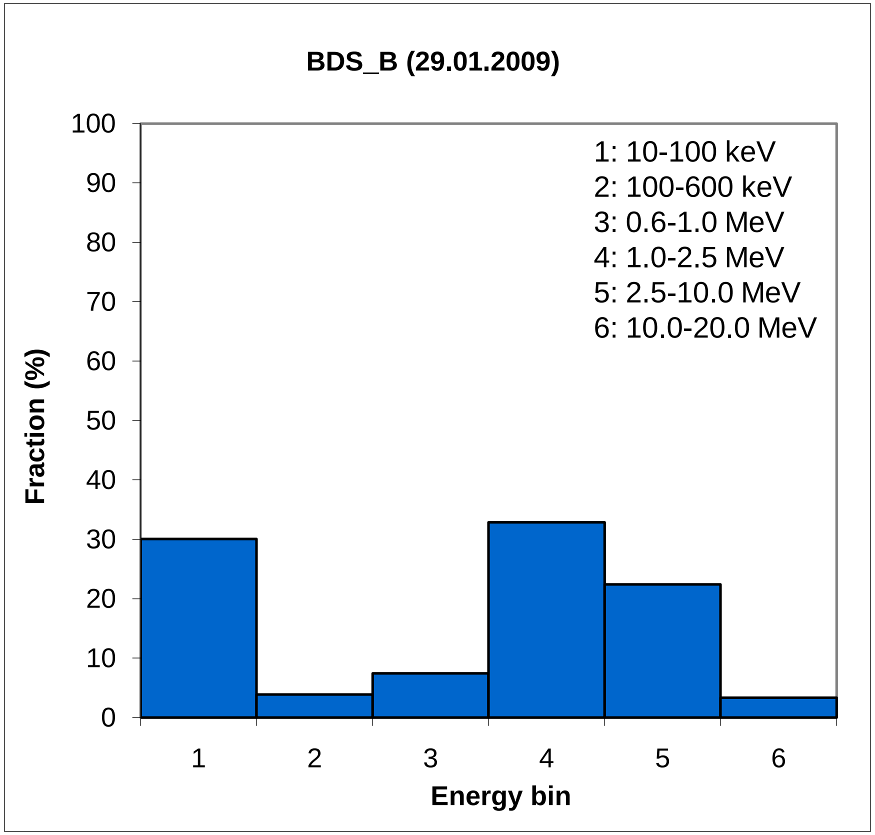
Neutron energy distribution

Eb4 & Eb5: DD fusion

Eb2 & Eb3: scattered neutrons

Eb6: Triton burn neutrons (TBNs)

Eb1: Photo-neutrons? Disruption



Large amount of experimental data still to be processed

Determination of neutron field characteristics for high performance discharges

Objectives of Experiment

- -All objectives achieved
- -All capabilities of the new technique independently demonstrated
  - -Spatial resolution (order of cm)
  - -Broadband energy coverage (10 keV -10 MeV), with reasonable energy resolution
  - -Time resolution (10's ms)

But

- -With a minimum impact

Why?

- -Insufficient resources
- -The next level would have involved at least one order o magnitude in resources

The next level

- -Multichannel (space and energy) time-resolved spectrometer with absolutely calibrated neutron detectors

ITER calibration test on JET?

The case for neutron calibration in a fusion device
(JET Workgroup on the DT campaign)

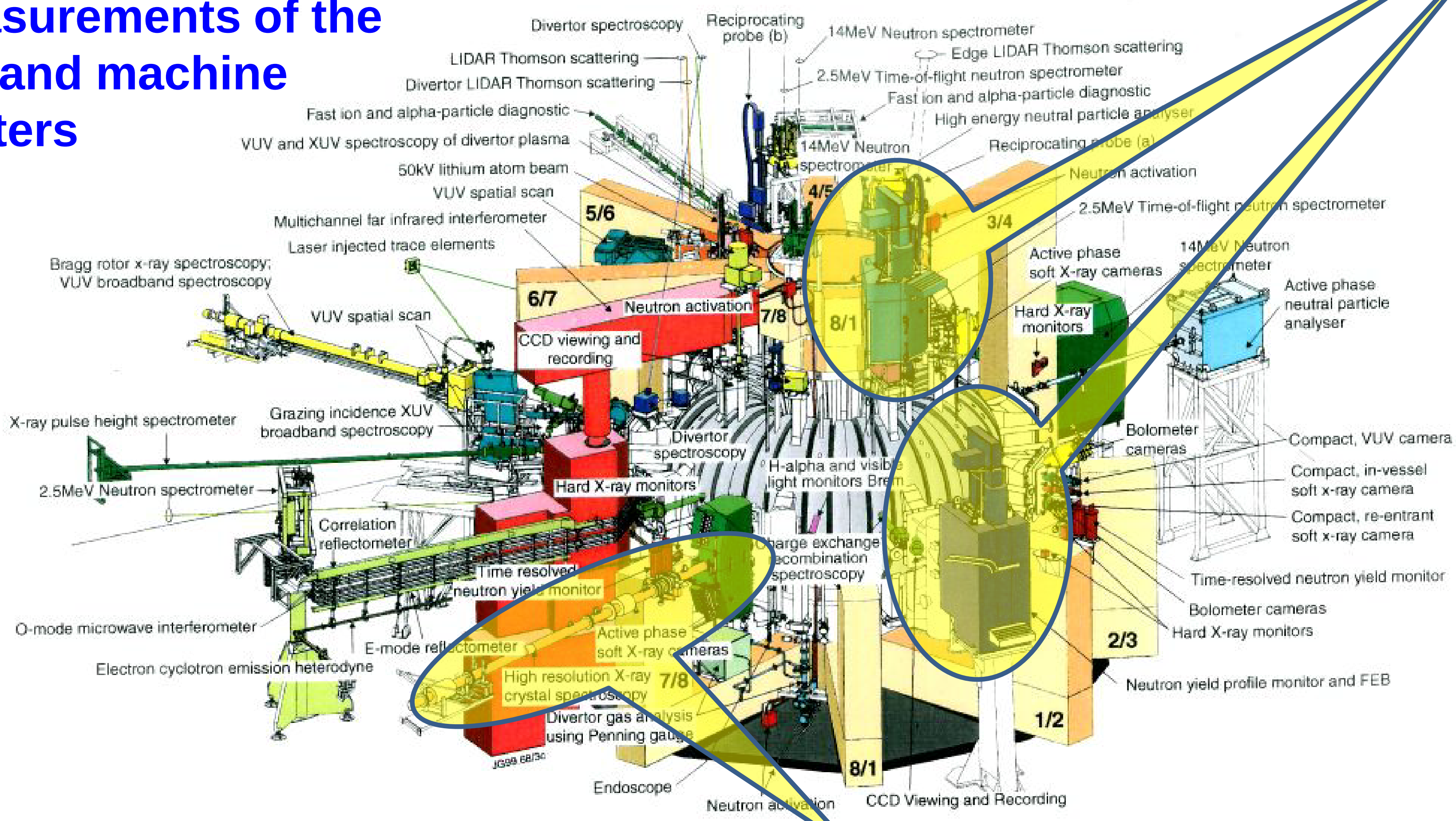
- ITER neutron calibration concept is complex, time consuming and will rely heavily on MCPN computations to take into account non-ideal calibration.
- ITER neutron calibration concept is unproven and risky, especially usage of D-T neutron generator
- It is not clear if usage of D-T neutron generator is feasible and if feasible, if it will bring added value compared to ‘lighter’ methods.
- If D-T generator proves impossible or impracticable, alternatives must be developed and validated.
- ITER neutron calibration is **TOO IMPORTANT TO FAIL**
- JET DT workgroup recommended, as one of the selling points:
  ITER concept for neutron diagnostic calibration should be tested, validated, developed on JET.

Diagnostics development

JET diagnostics

JET diagnostics: Over 80 techniques for the measurements of the plasma and machine parameters

(KN3) Gamma-Ray Cameras



(KM6T) Tangential Gamma-Ray Spectrometer

Neutron and Gamma-Ray Diagnostics

Neutron (and gamma-ray) filtering and collimating techniques have been developed both for the JET gamma-ray cameras and the (tangential) gamma-ray spectrometer.

Two JET diagnostics enhancements projects:
-"Upgrade of the Gamma-Ray Cameras – Neutron Attenuators" (GRC) addresses the following physics item:
Determination of the spatial distribution of the tokamak plasma gamma-ray emission (fusion plasma gamma-ray imaging)

-"Tandem Collimators for the gamma-ray Spectrometer" addresses the following physics item:
Determination of the spectral distribution of the tokamak plasma gamma-radiation emitted as a result of the interaction of fast particles with plasma impurities (fusion plasma gamma-ray spectrometry)

Neutron and Gamma-Ray Imaging

Top

- 14MeV neutron emission profile during trace T experiment (2003)

  Left: using normal NBI (mostly trapped)

  Right: using tangential NBI (passing)

Bottom

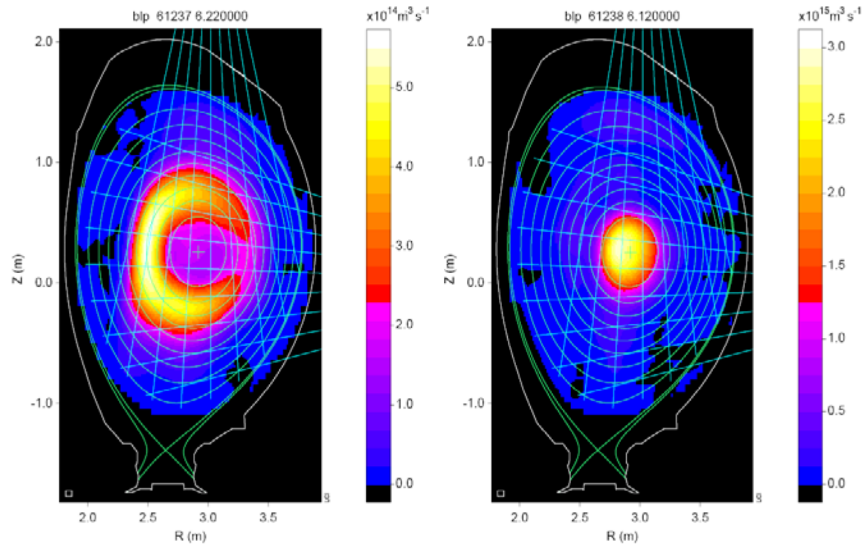
- Fast ion profiles inferred from gamma rays produced by RF accelerated fast ions and impurities:

  Left: 4.44MeV γ-ray emission from the reaction $^{9}\mathrm{Be}(^{4}\mathrm{He},n\gamma)^{12}\mathrm{C}$

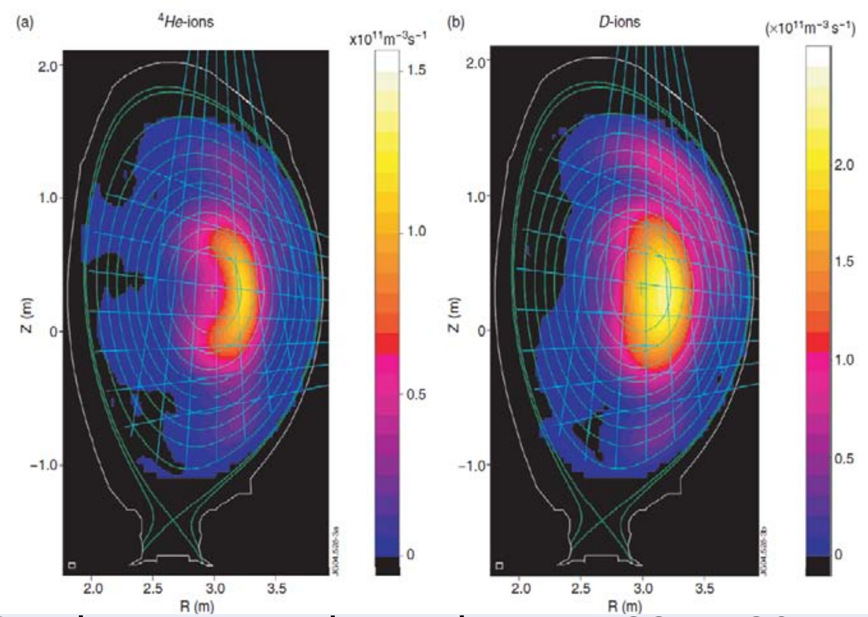
  Right: 3.09MeV γ-ray emission from the reaction $^{12}\mathrm{C}(\mathrm{D},p\gamma)^{13}\mathrm{C}$

Issue: High power (high neutron yields) D and DT discharges: need of neutron/gamma filters

14-MeV neutron emission



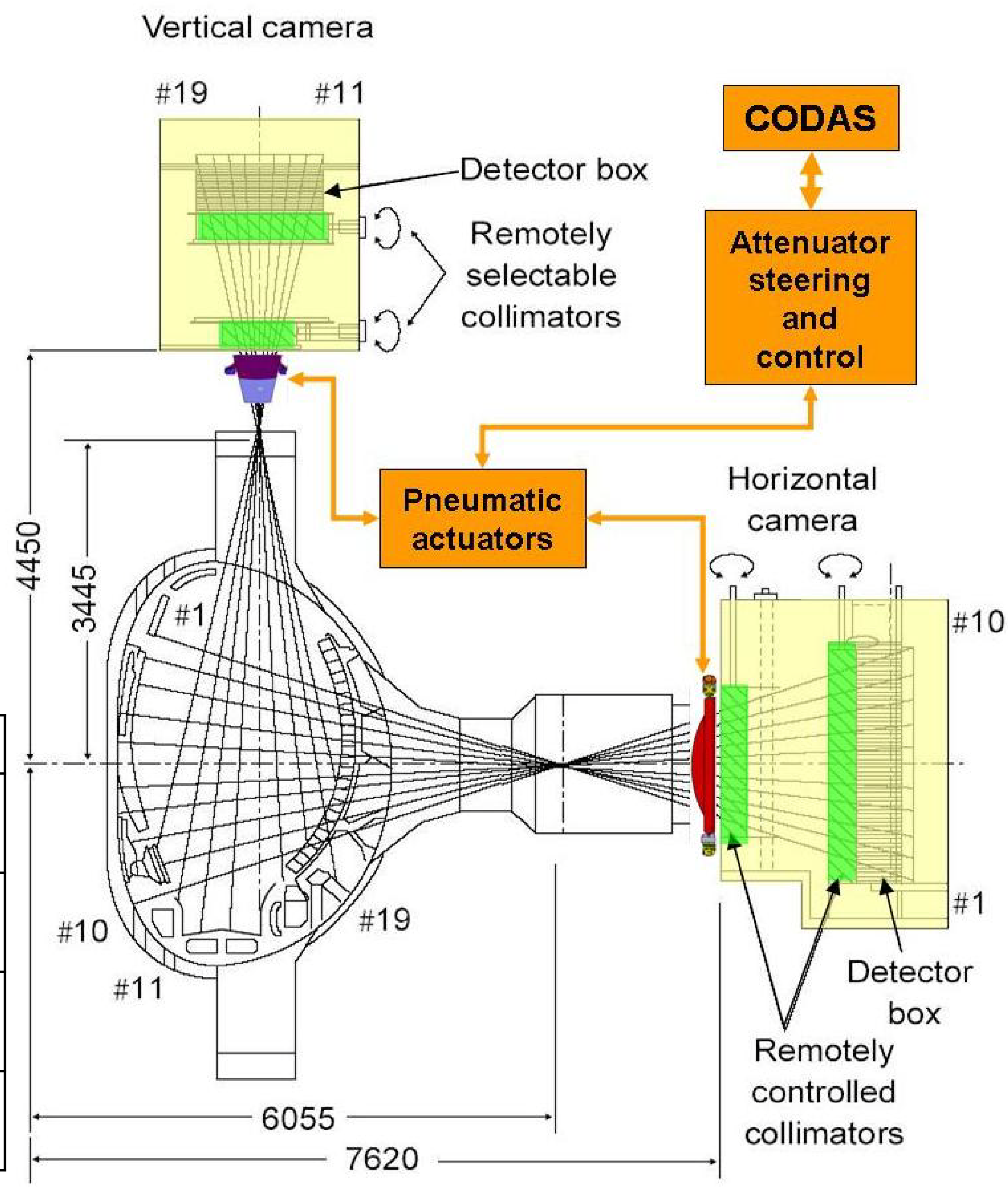
Off-axis 300ms T-blip @ 46s. Slice: 46.22 – 46.27s
On-axis 300ms T-blip @ 46s. Slice: 46.12 – 46.17s



Schematic representation of the KN3 Gamma-Ray Camera neutron attenuator assembly

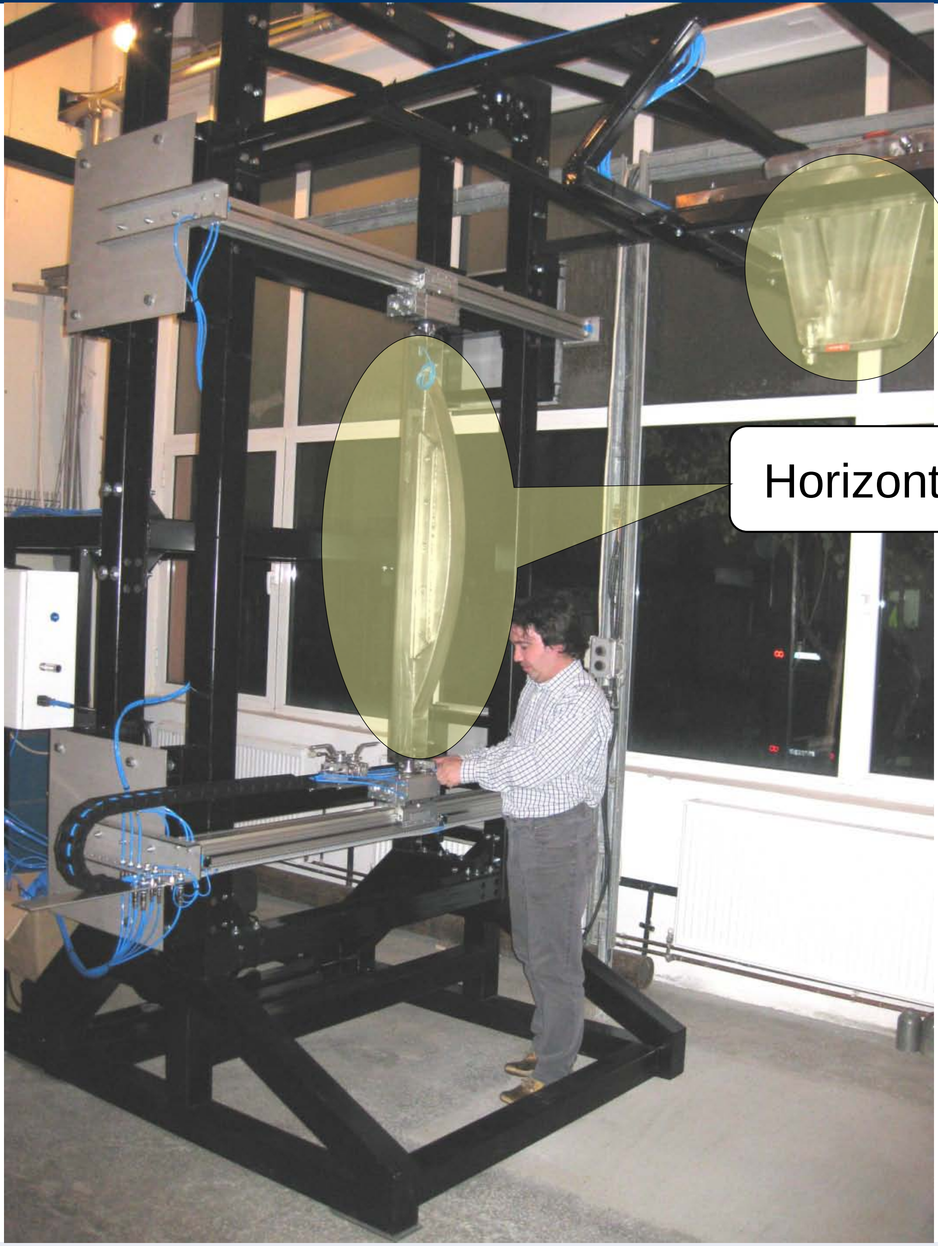
Approximate attenuation factors attainable within the project constraints

Neutron attenuator	Material	Neutron energy	
		2.45 MeV	14.1 MeV
KN3-HC-NA	H_2O	$2x10^2$	15
KN3-VC-NA (Short)	H_2O	$2x10^2$	15
KN3-VC-NA (Long)	H_2O	10^4	10^2



KN3-NA Construction

Neutron attenuators:



HC-NA installation at JET

Upgrade of the Gamma-Ray Cameras – Neutron Attenuators (GRC)

Objectives of Enhancement project

- -All objectives have a good chance of being achieved
  - -Waiting for plasma commissioning (beginning of 2012)

- -No such a system designed and built so far
  - -New concepts, new approach

Impact

- -Significant

Next step

- -Re-design and construct the DT version of the vertical attenuator

The next level

- -Develop the same system for ITER
- -Unfortunately, no body had the initiative for such a proposal

>A hard gained competency will be wasted

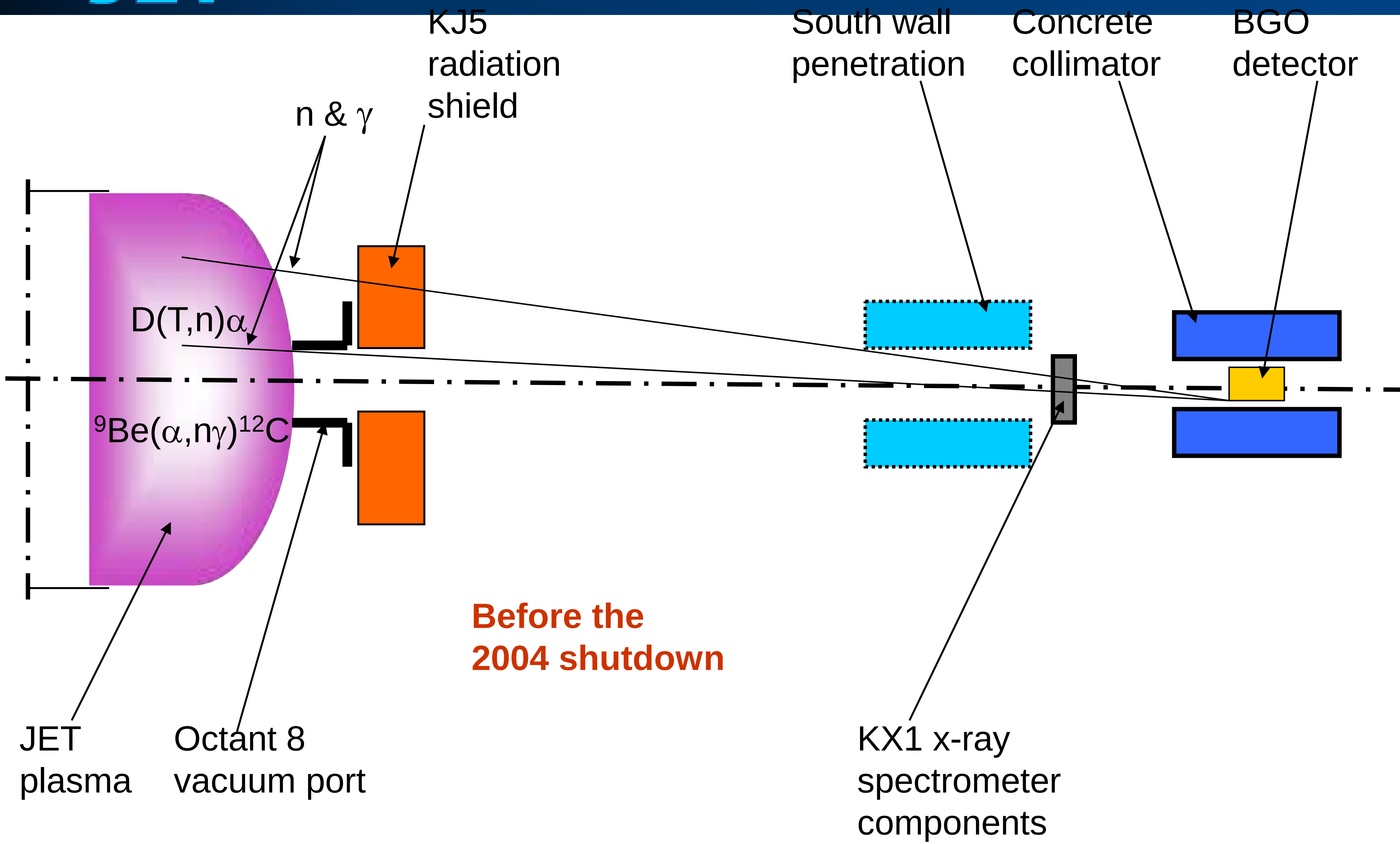
Upgrade of the Tangential Gamma-Ray Spectrometer (KM6T)

”Upgrade of the Tangential Gamma-Ray Spectrometer” addresses the following physics item:
Determination of the spectral distribution of the tokamak plasma gamma-radiation emitted as a result of the interaction of fast particles with plasma impurities (fusion plasma gamma-ray spectrometry)

KM6T tangential gamma-ray spectrometer:

Main goals of the upgrade:
- To re-design the KM6T gamma-ray spectrometer diagnostics
- To design and construct a suitable collimation and shielding system
- To design, construct and test a neutron attenuator system for the KM6T gamma-ray spectrometry diagnostics
- To develop and test design solution of relevance to ITER

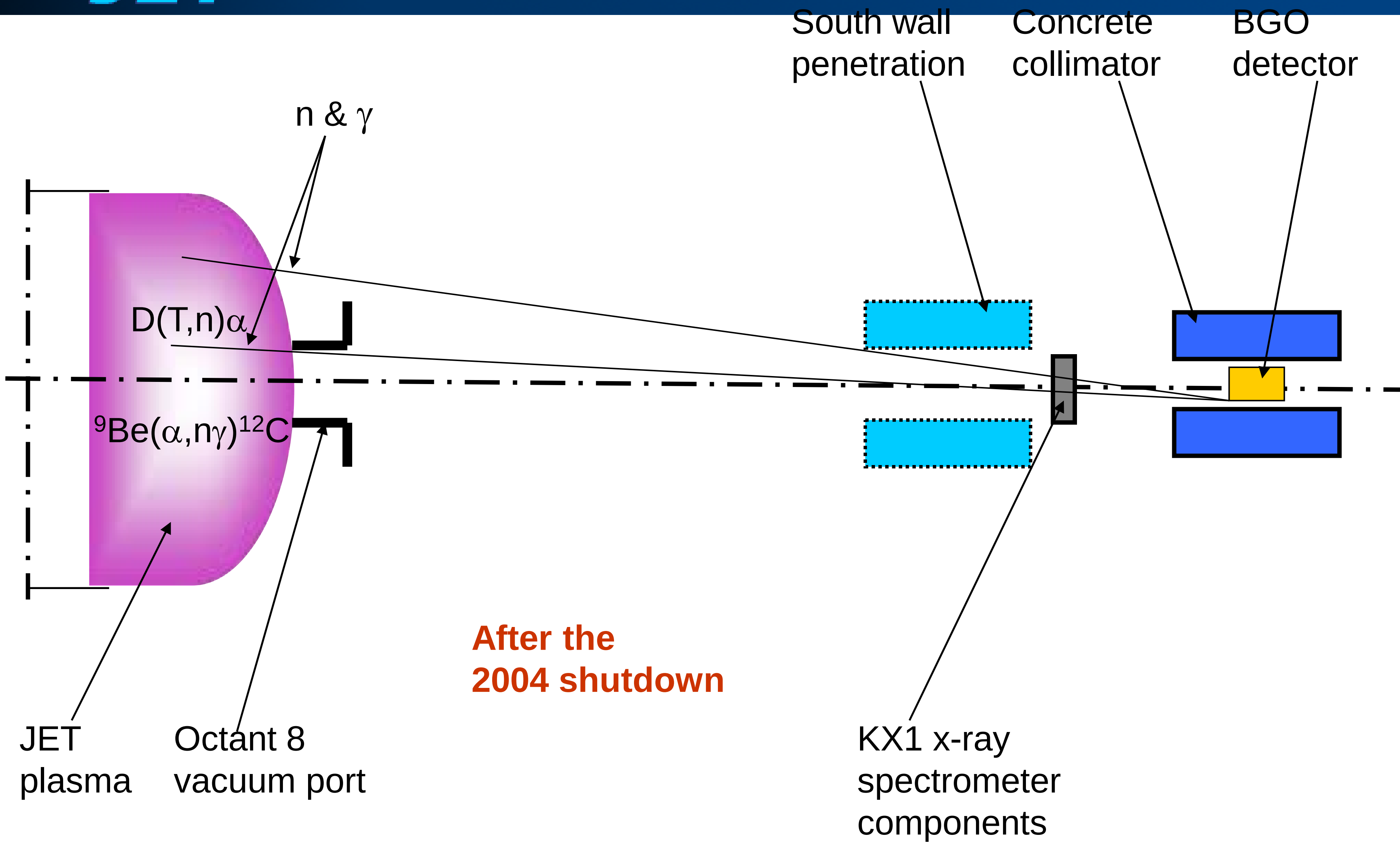
Old KM6T Tangential GRS



Before the 2004 shutdown

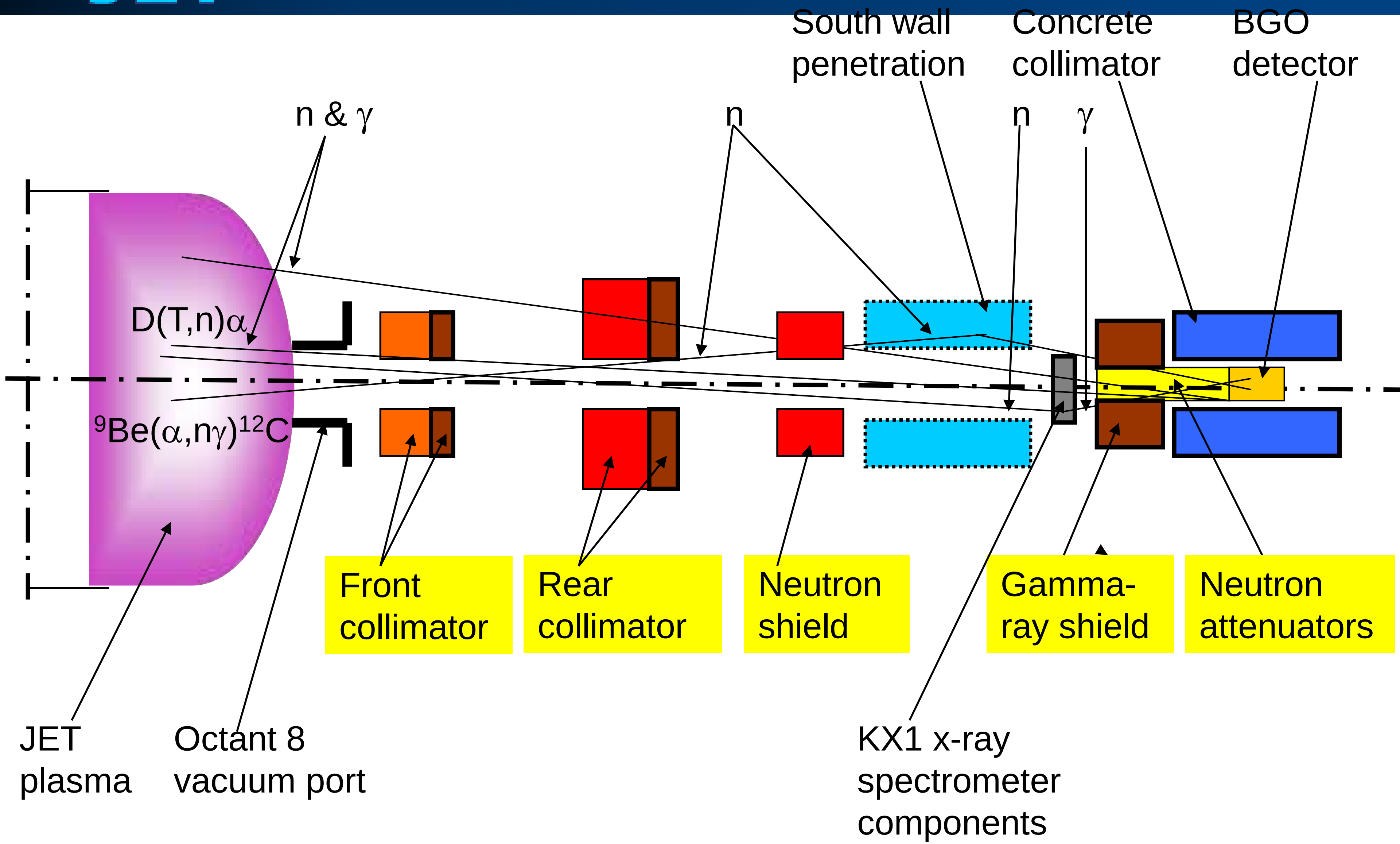
Schematic representation of the KM6T diagnostics

Old KM6T Tangential GRS



Schematic representation of the KM6T diagnostics

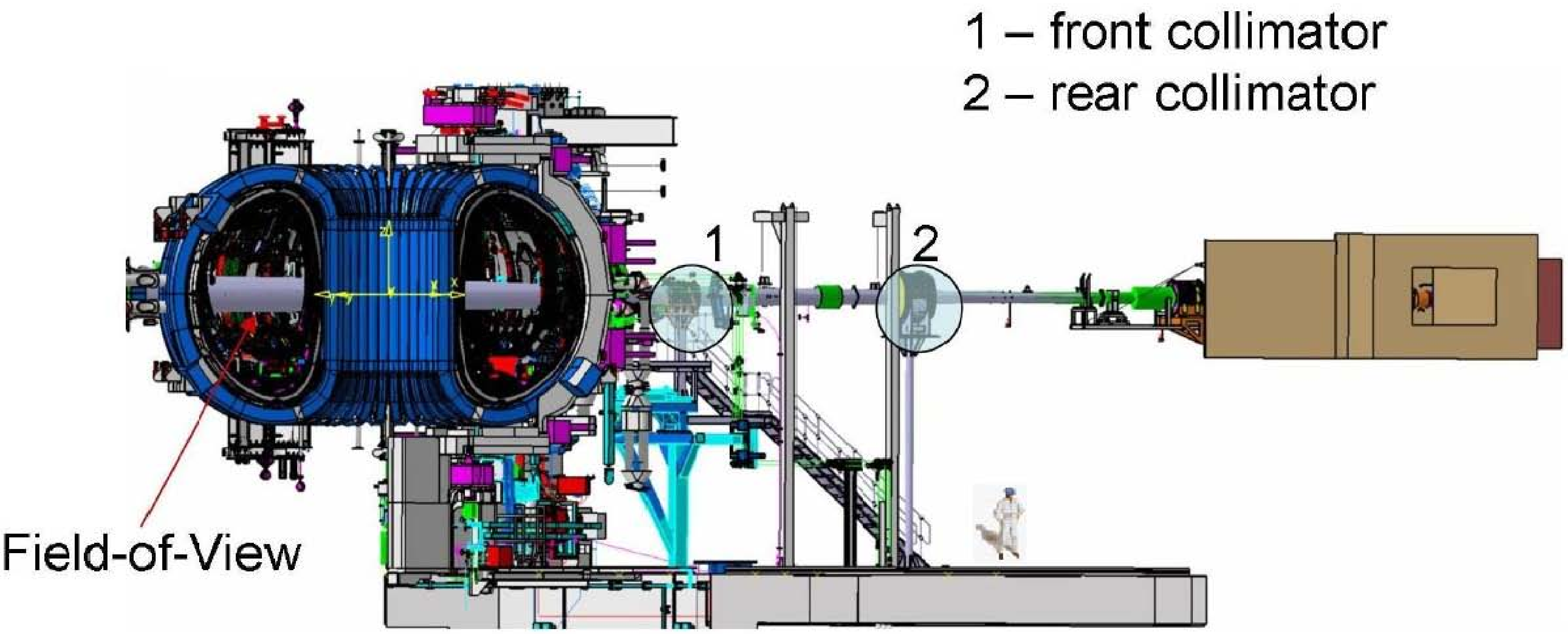
New KM6T Tangential GRS



Schematic representation of the KM6T diagnostics

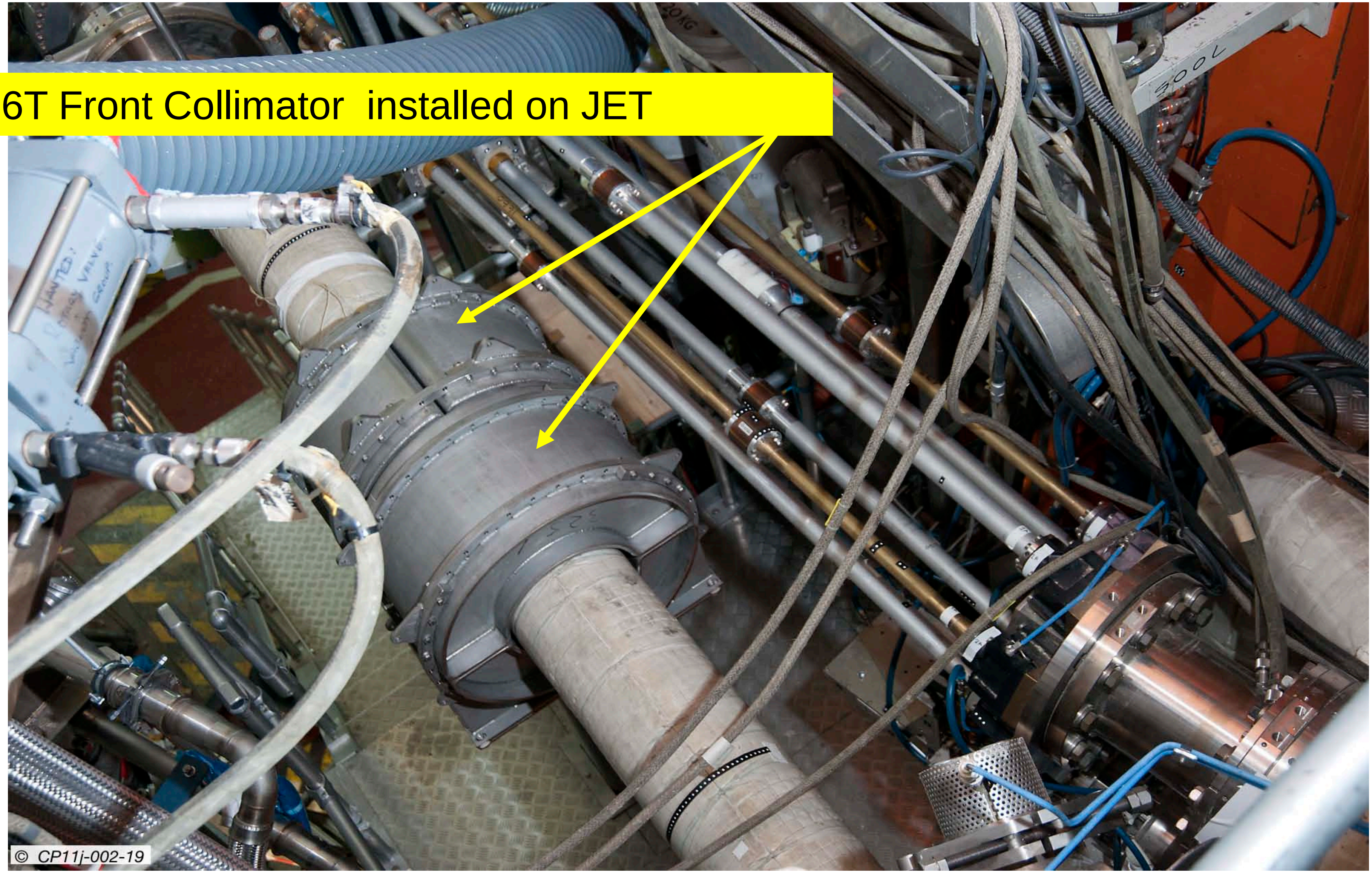
KM6T: Tandem Collimators within full system

Due to reduction in available resources, the initial project scope was reduced to the first two components: the tandem collimators.
Ongoing TCS project: Tandem Collimators for the gamma-ray Spectrometer



Gamma-Ray Spectrometer

KM6T Front Collimator installed on JET



Upgrade of the Tangential Gamma-Ray Spectrometer (KM6T)

Objectives of Enhancement project

- -Initial objectives have been reduced several times due to reduced resources
- -Status of the reduced project, Tandem Collimators
  - -Rear Collimator constructed and is to be installed before end of 2012
  - -Plasma commissioning (beginning of 2012)

Impact

- -Significant

Next step

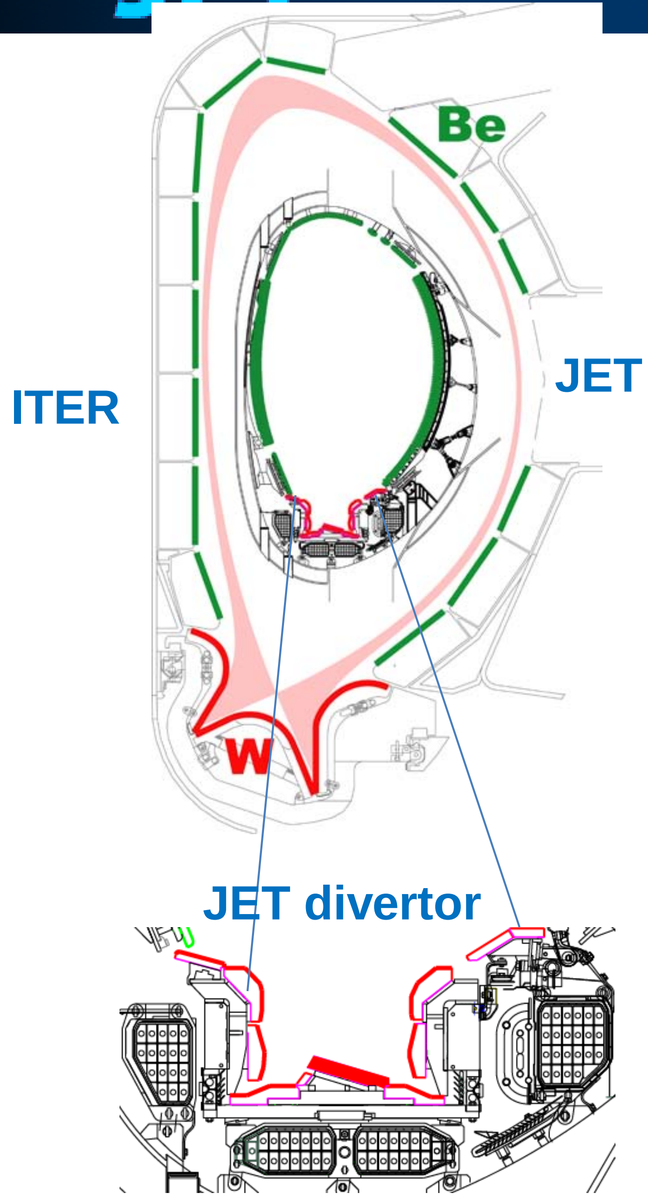
- -To develop the full diagnostics system in view of the JET DT campaign in 2015
- -Proposal was agreed in principle with the (MEdC) Association HRU

The next level

- -Develop a similar system for ITER?
- -So far no body had the initiative for such a proposal

ITER-Like Wall

ITER-Like Wall



ITER (start operation)

-Beryllium wall and carbon + tungsten divertor

Carbon: high tritium retention.

ITER (deuterium phase)

-Beryllium wall and full tungsten divertor

- This material mix has not yet been tested

JET is the only machine that can use Beryllium

ITER-like Wall (beryllium plus tungsten) has been developed and installed in JET, together with:

- Increased NB heating power: from 20MW (~10s) to 30MW (~20s)
- Improved control capabilities
- Improved diagnostics

> JET is the only fusion machine with the same plasma facing materials of ITER

ITER-Like Wall

Plasma-facing components of the JET wall have been fully restructured by replacing carbon cladding with beryllium (Be) in the main chamber and tungsten (W) in the divertor. (See ITER configuration).

The main components of the new JET wall are:

-Bulk W tiles for the load bearing plate in the divertor

-W coatings on carbon fibre composites (MEdC: main contribution)

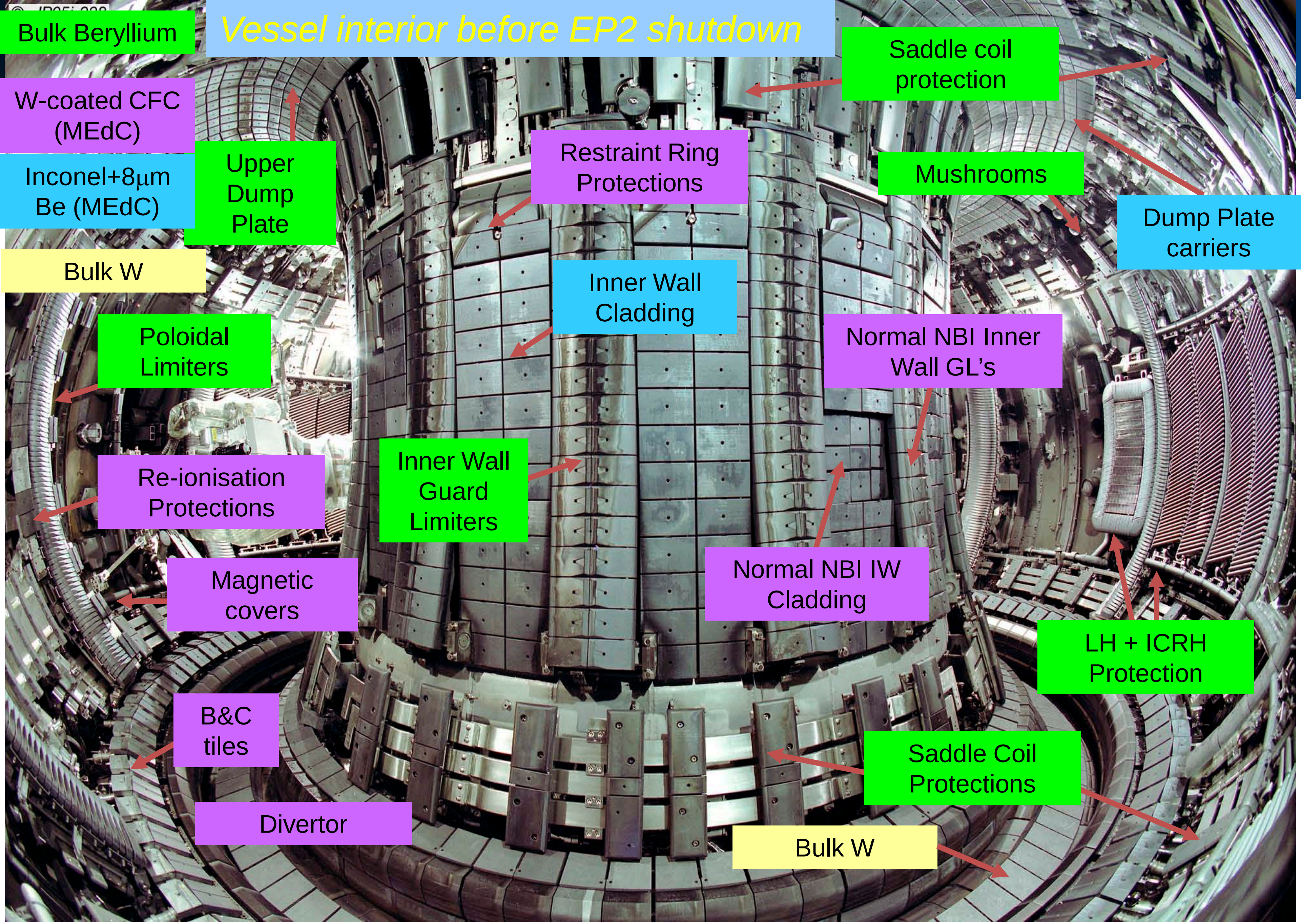
-Be-coated INCONEL plates for the inner wall cladding (MEdC : main contribution)

-Be bulk limiter tiles for the poloidal limiters

The ILW project included a set of diagnostic tools for erosion and deposition studies. (MEdC participation)

Marker tiles with special layers designed for the measurement of Be erosion from the wall (MEdC participation)

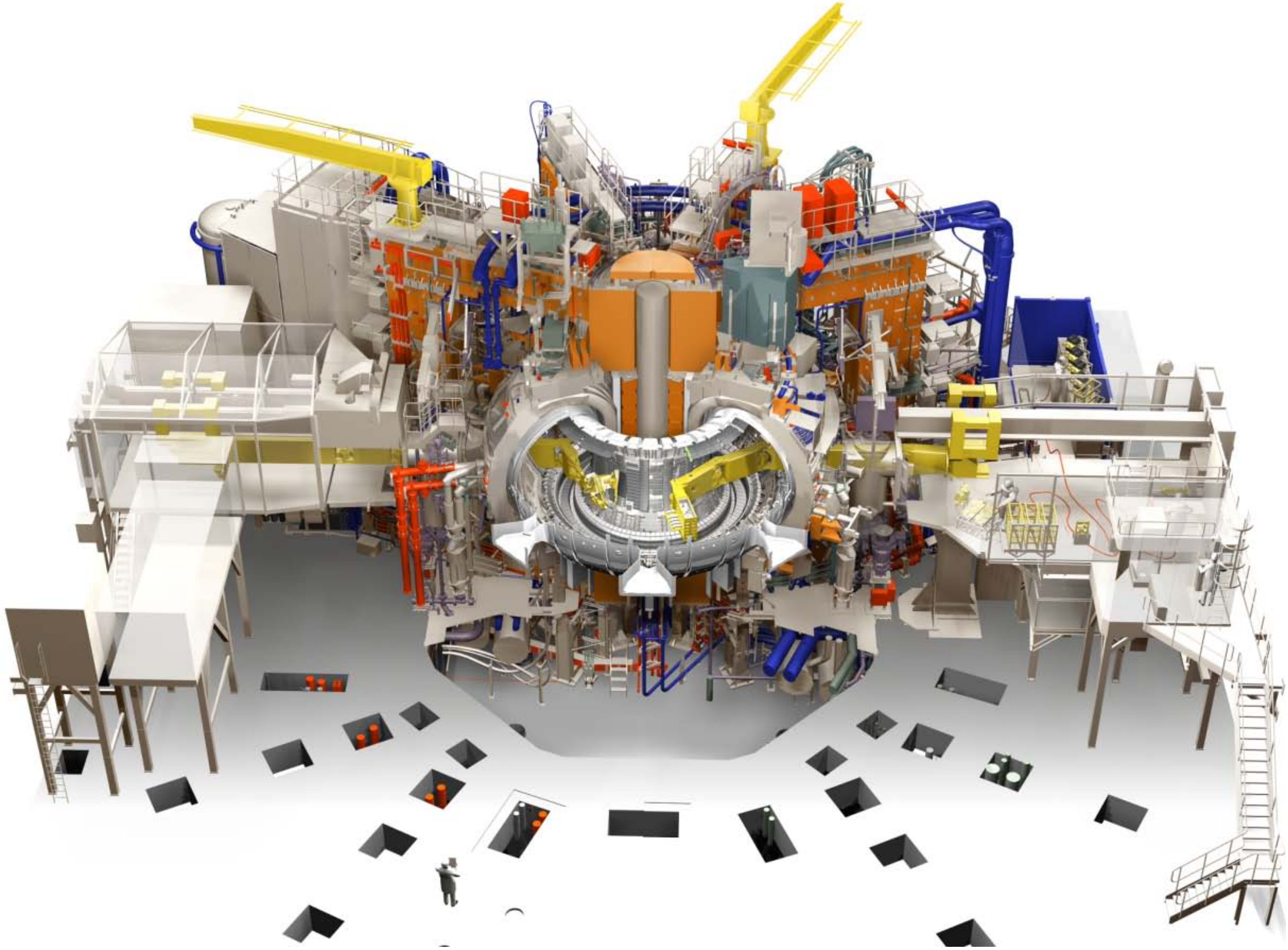
Vessel interior before EP2 shutdown



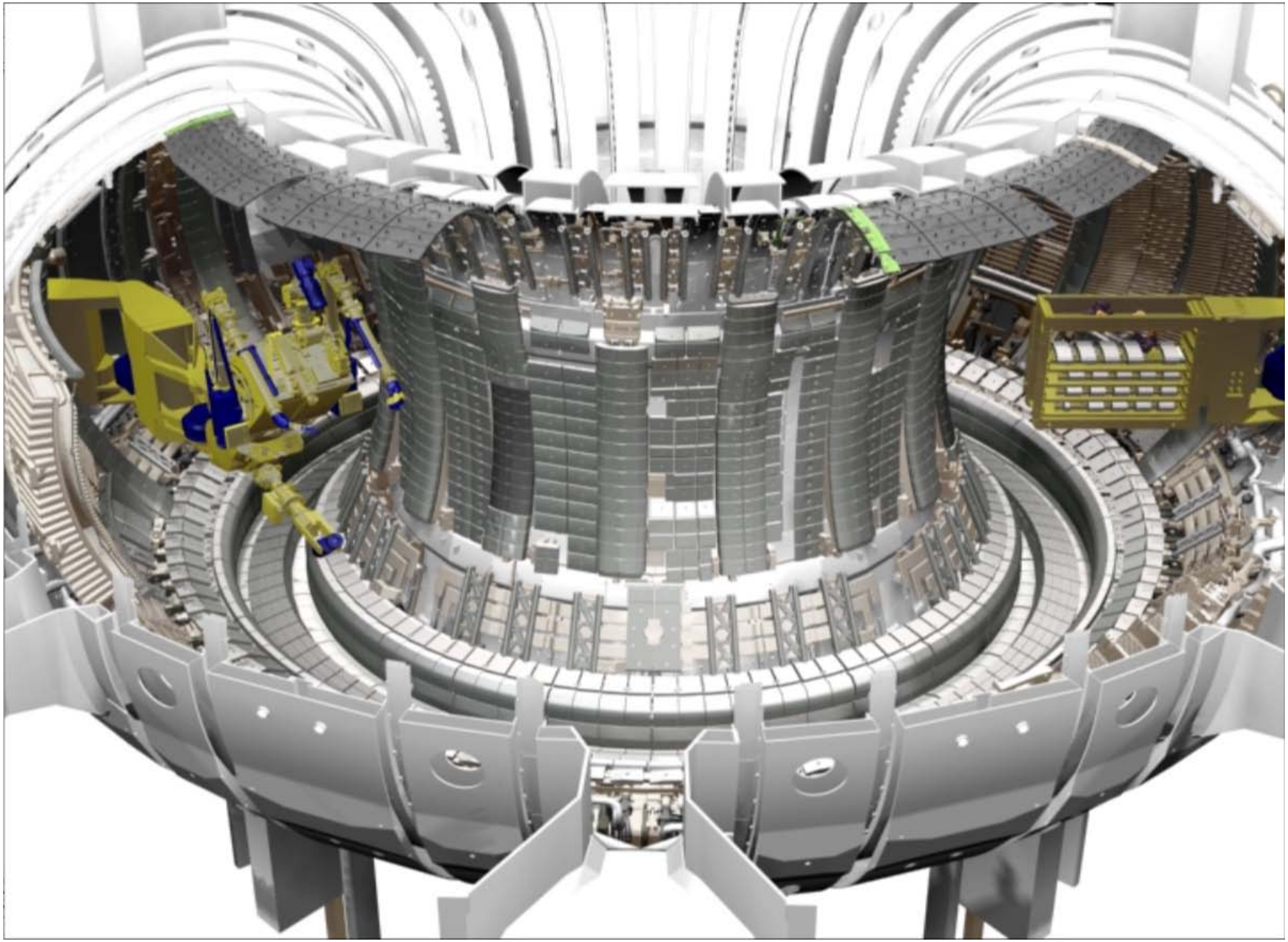
Number of installed assemblies	2,880
Number of individual tiles:	5,384 Be tiles (~2 tons Be / ~ 1m^3) 1,288 W-coated CFC tiles 9,216 W-lamellas (~2 tons W / ~ 0.1m^3) 15,828
Total number of parts:	82,273 counting bulk W modules as one part
Bulk W total parts:	191,664 including 100,080 shims
Total cost including manpower:	~60M€
Total work packages:	414

JET … (…)

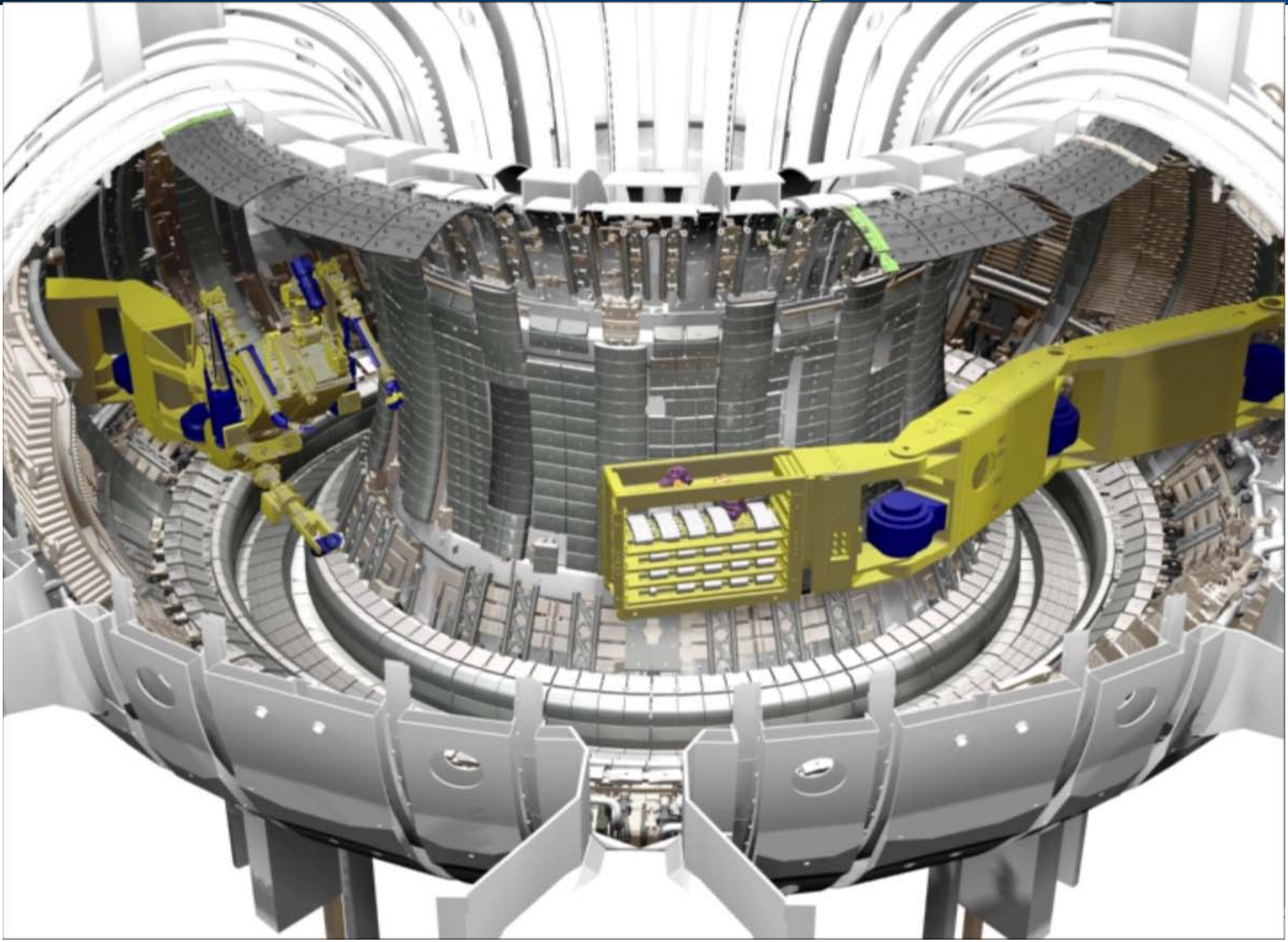
Remote Handling: Point of Installation



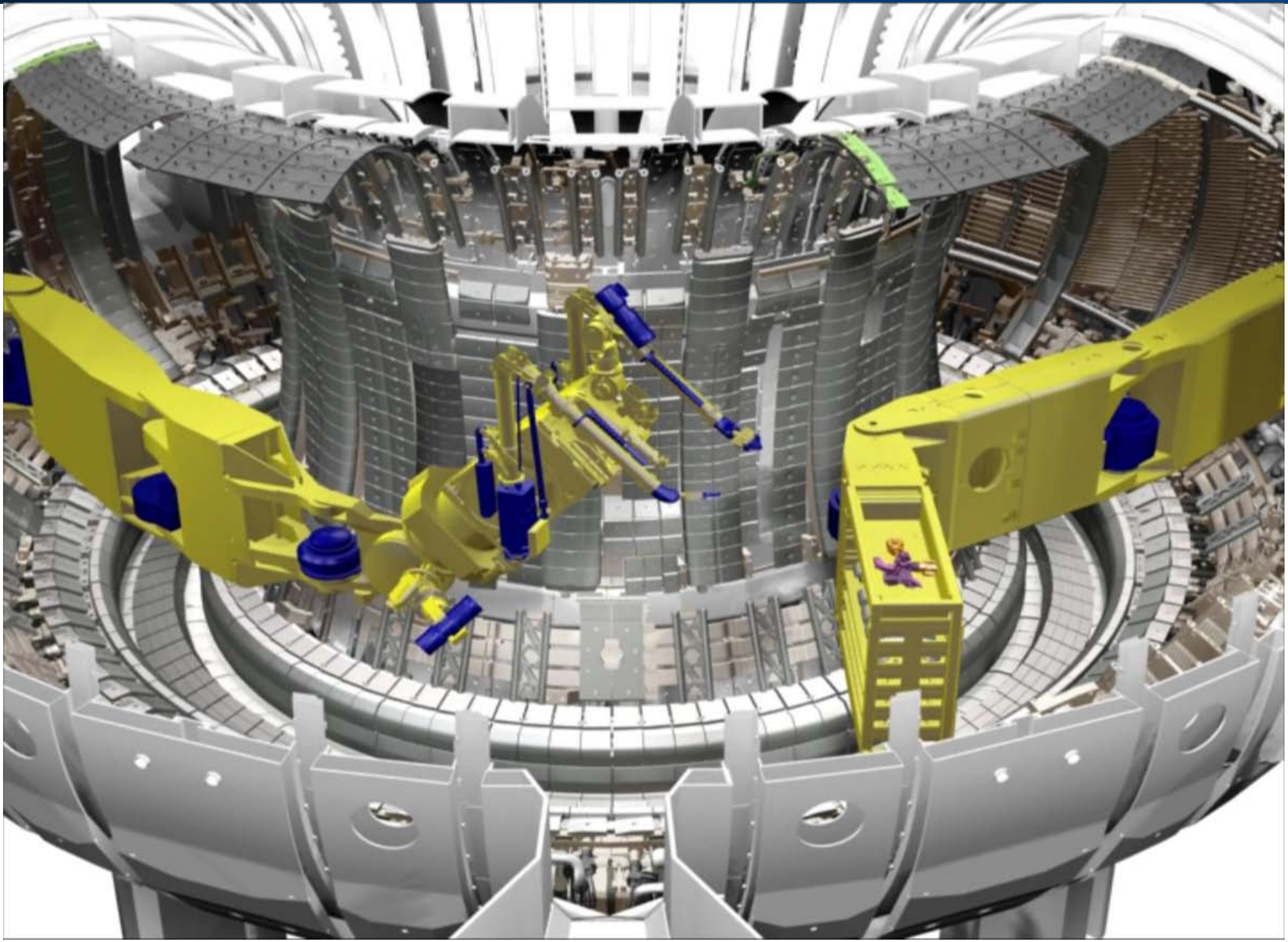
Remote Handling: tile Installation



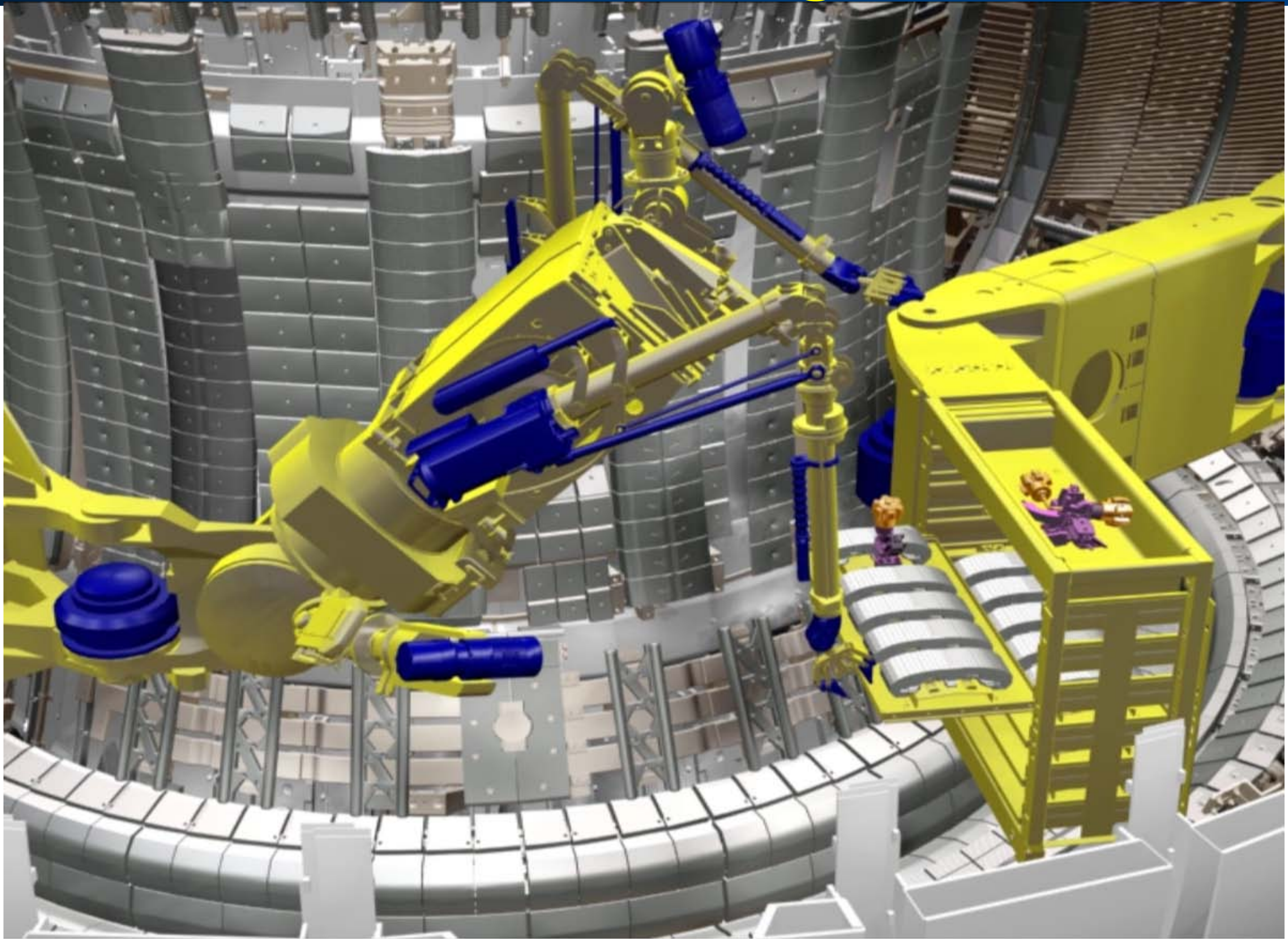
Remote Handling: tile Installation



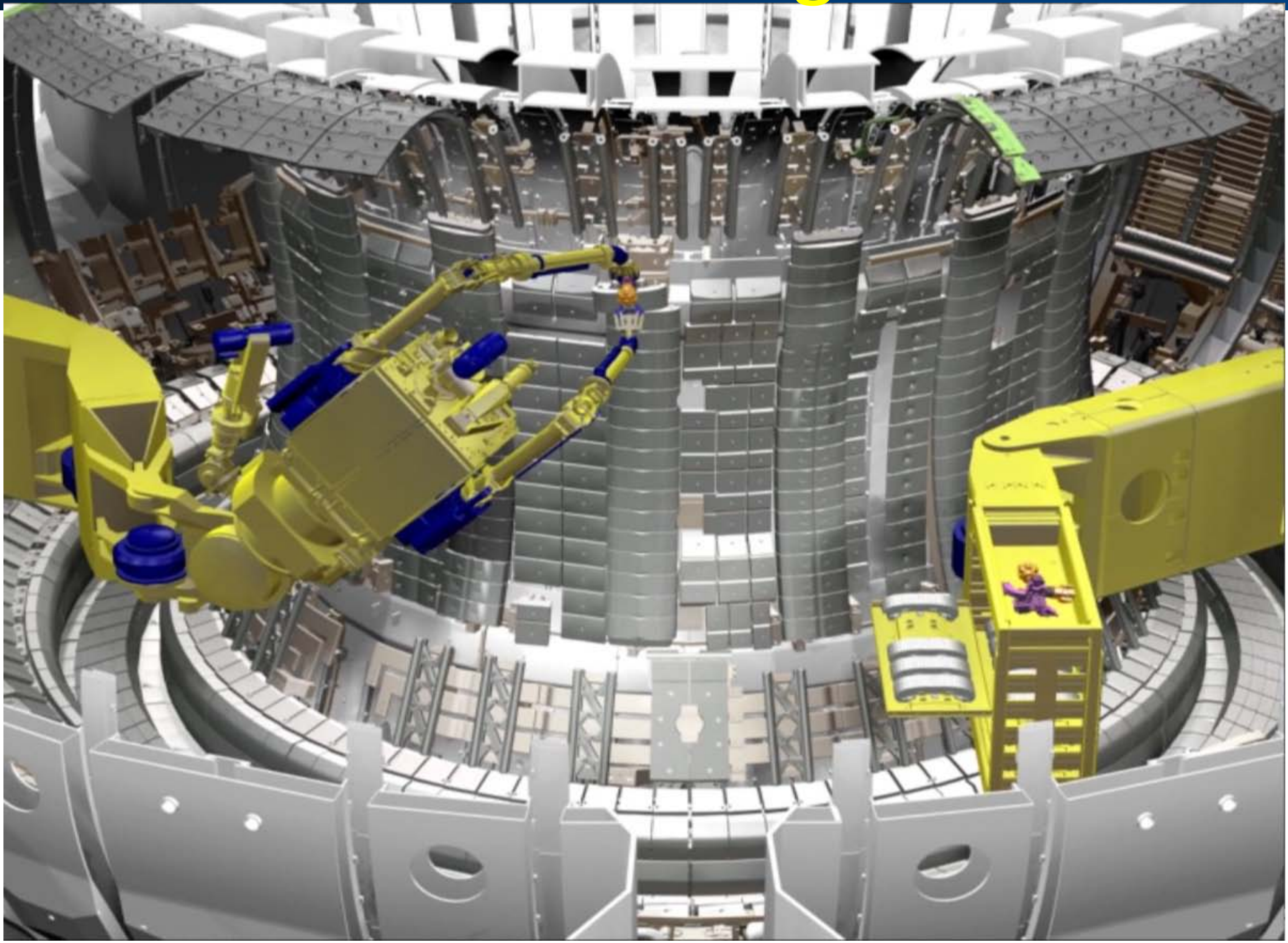
Remote Handling: tile Installation



Remote Handling: tile Installation

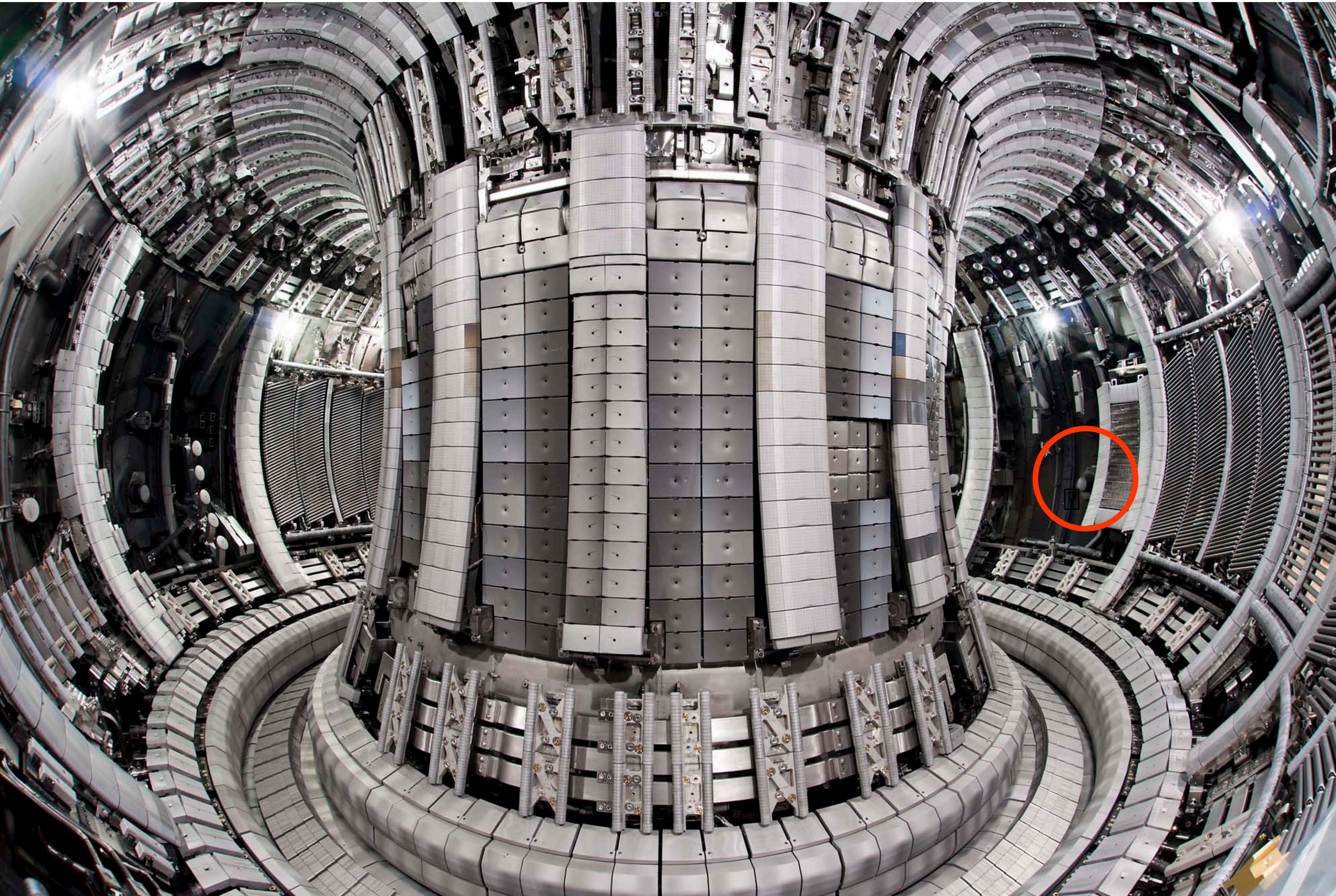


Remote Handling: tile Installation

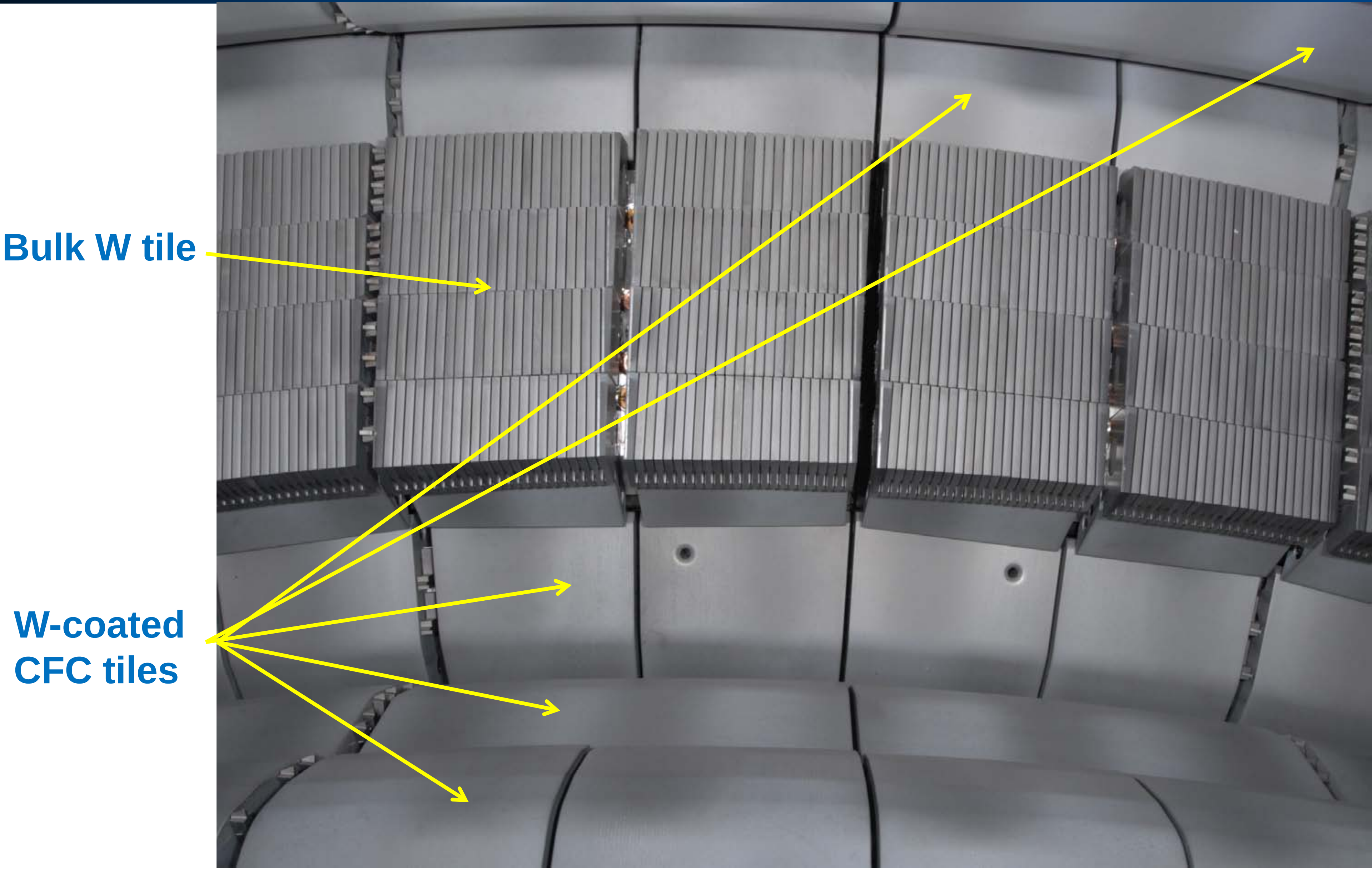


Remote Handling: tile Installation

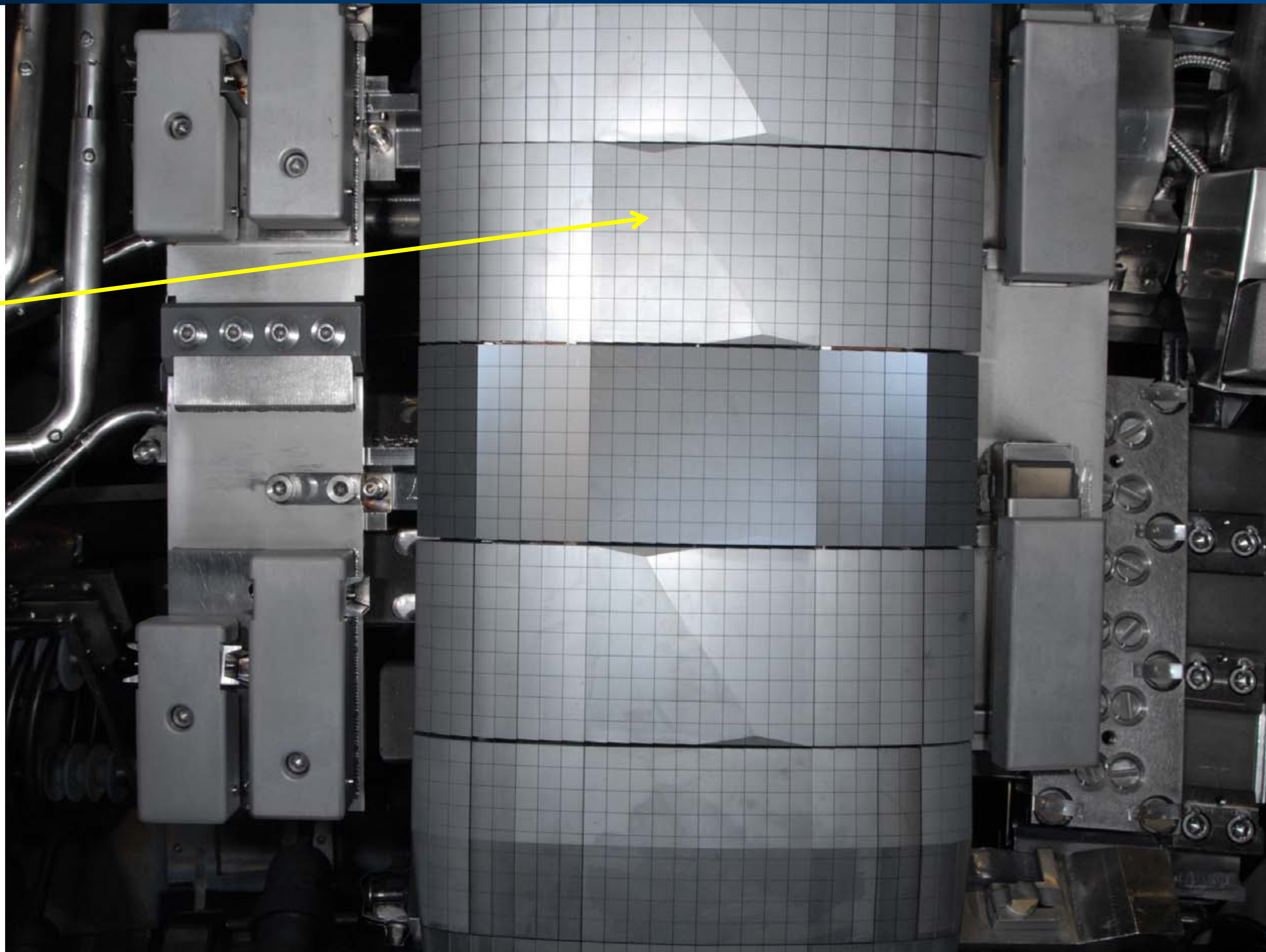
JET: the new wall



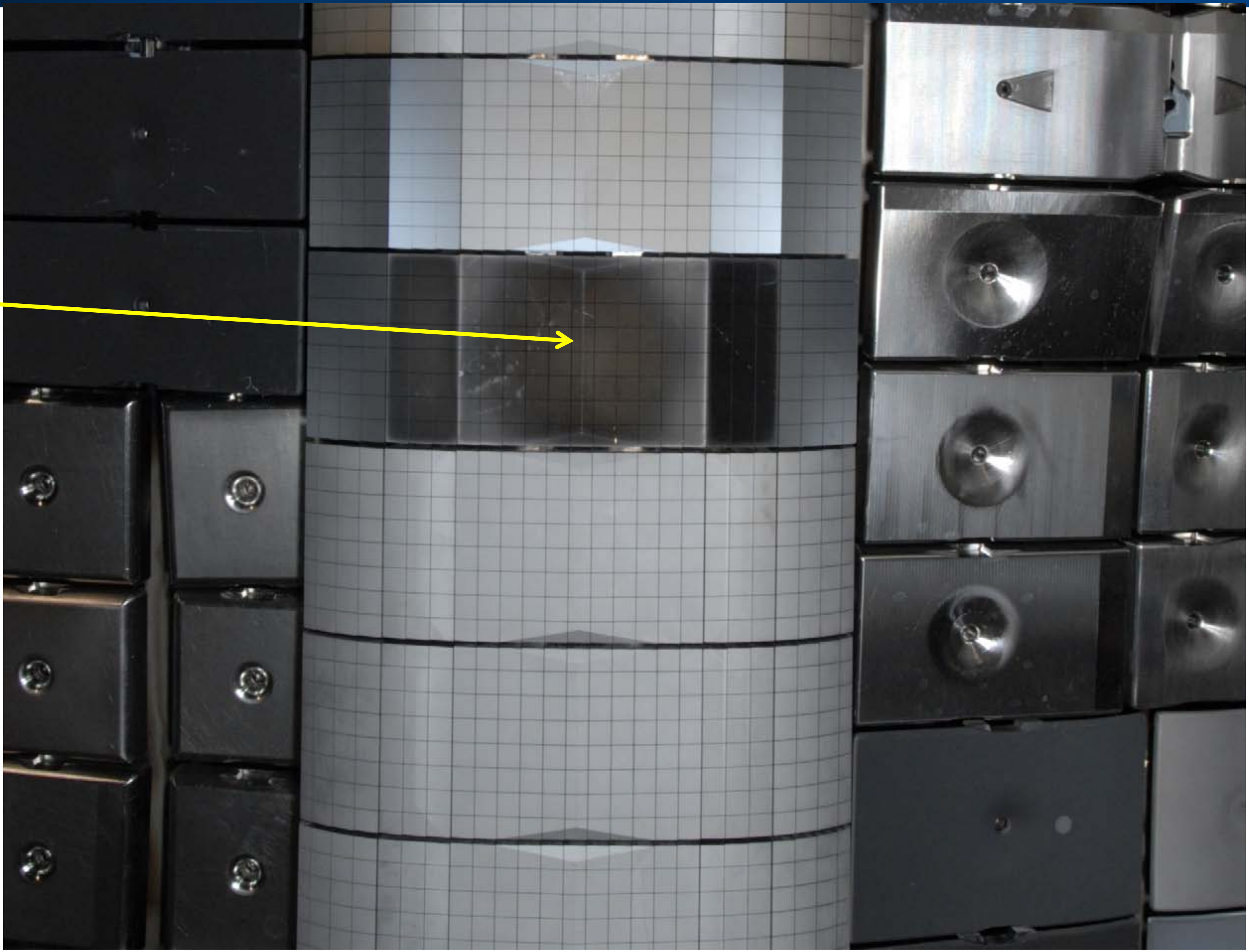
JET: the new divertor



Bulk Be limiter



Marker tile

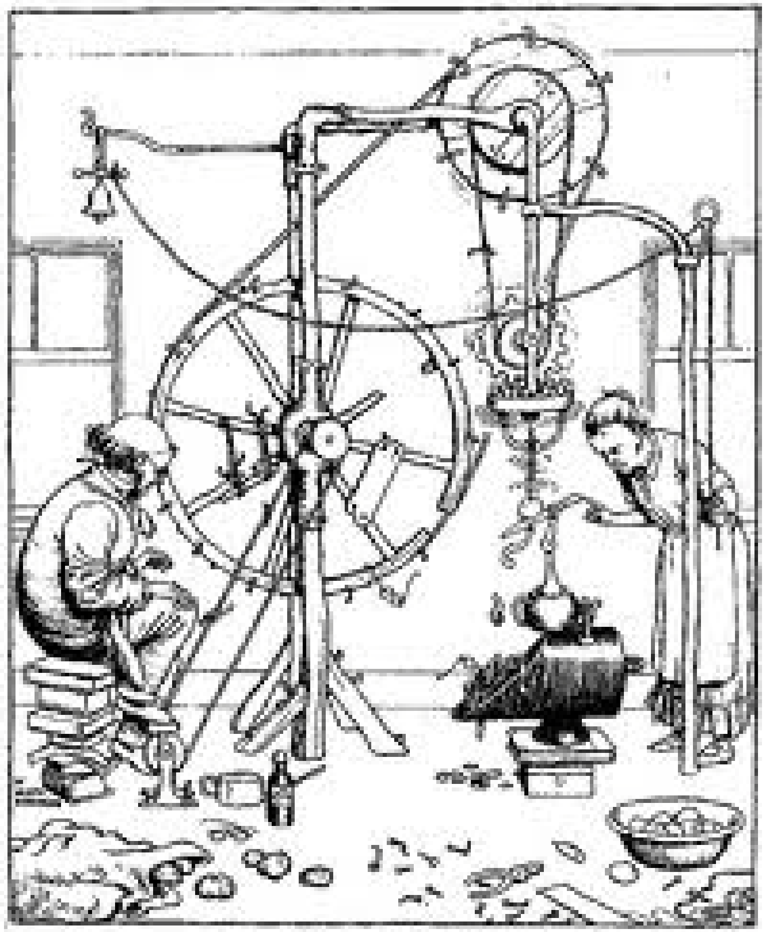


Scintillator Probe cap

W-coated
CFC

Mike Hill: The Wheel Re-invented

By Cristian Ruset



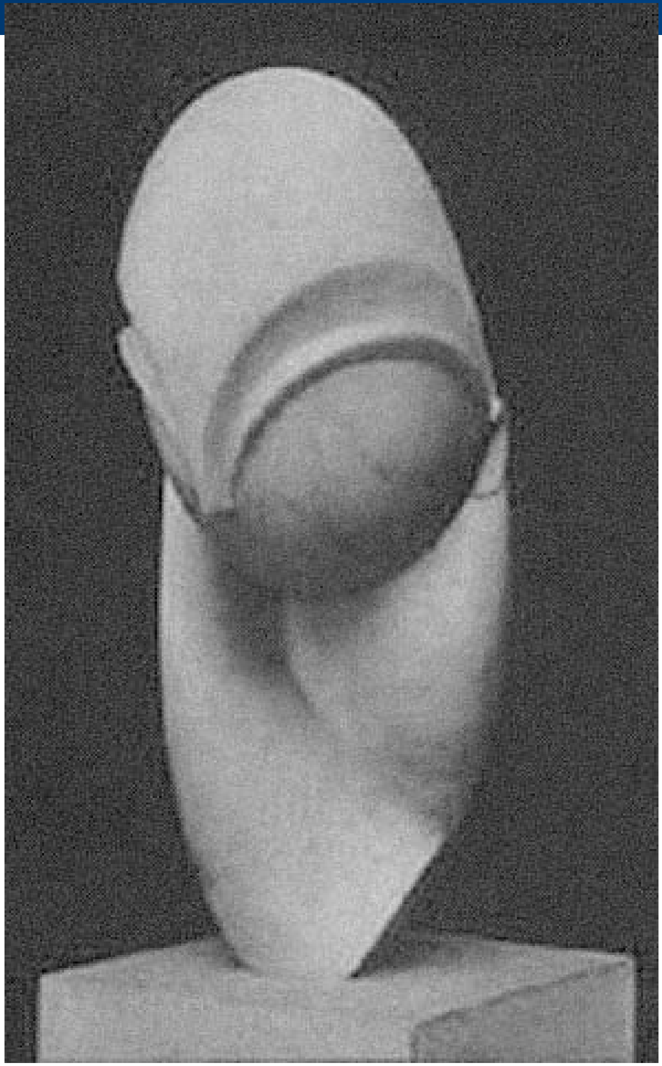
The Professor's invention for peeling potatoes.

By Heath Robinson

Technology versus Art

Scintillator Probe cap

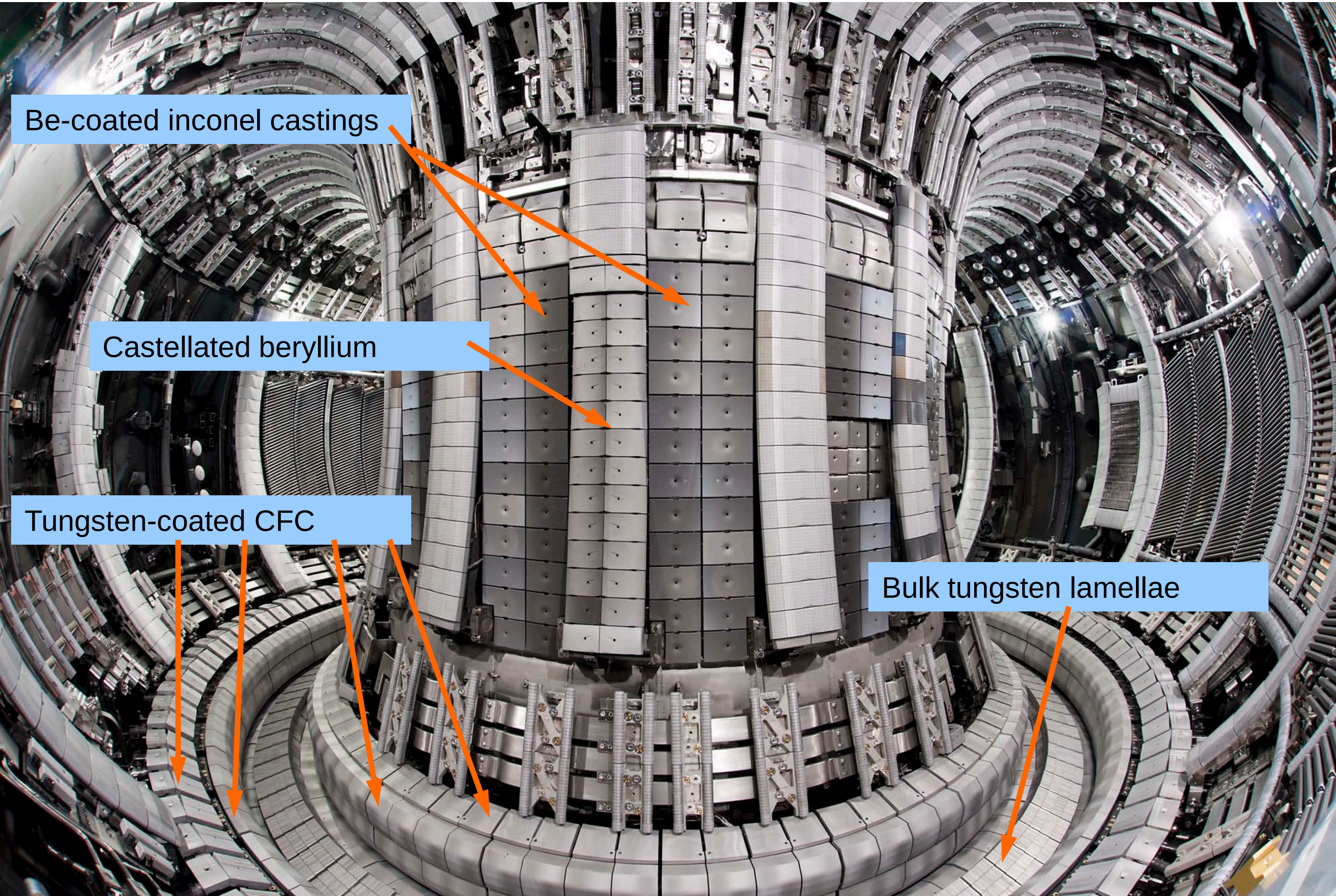
by Cristian Ruset



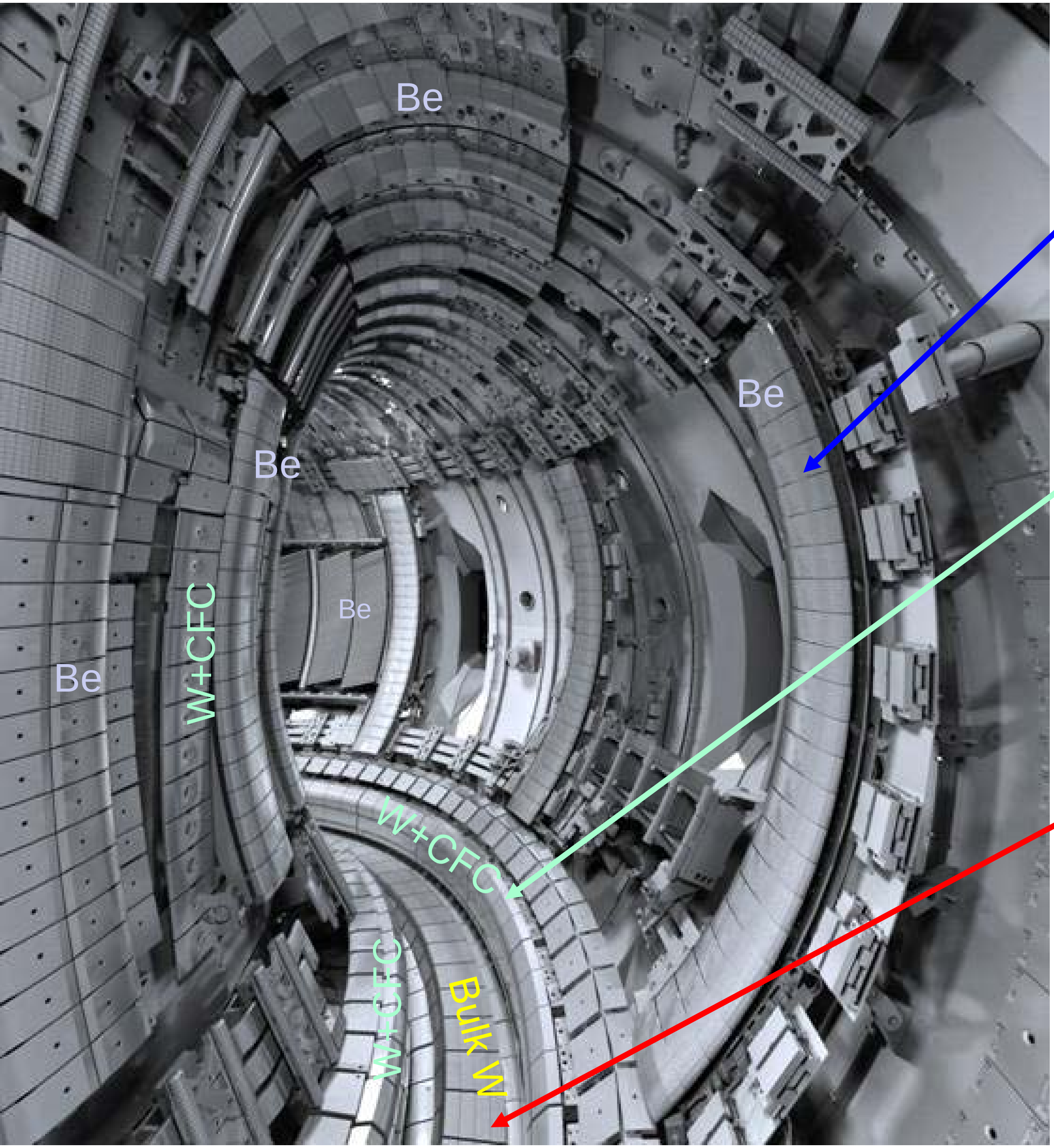
Mademoiselle Pogany

by Constantin Brancusi

Different materials for different power loadings



ILW: Test and Limitations



All tiles only inertially cooled

Solid Be limiters
Surface temperature < 900°C
$22 MJm^{-2}s^{-1/2}$

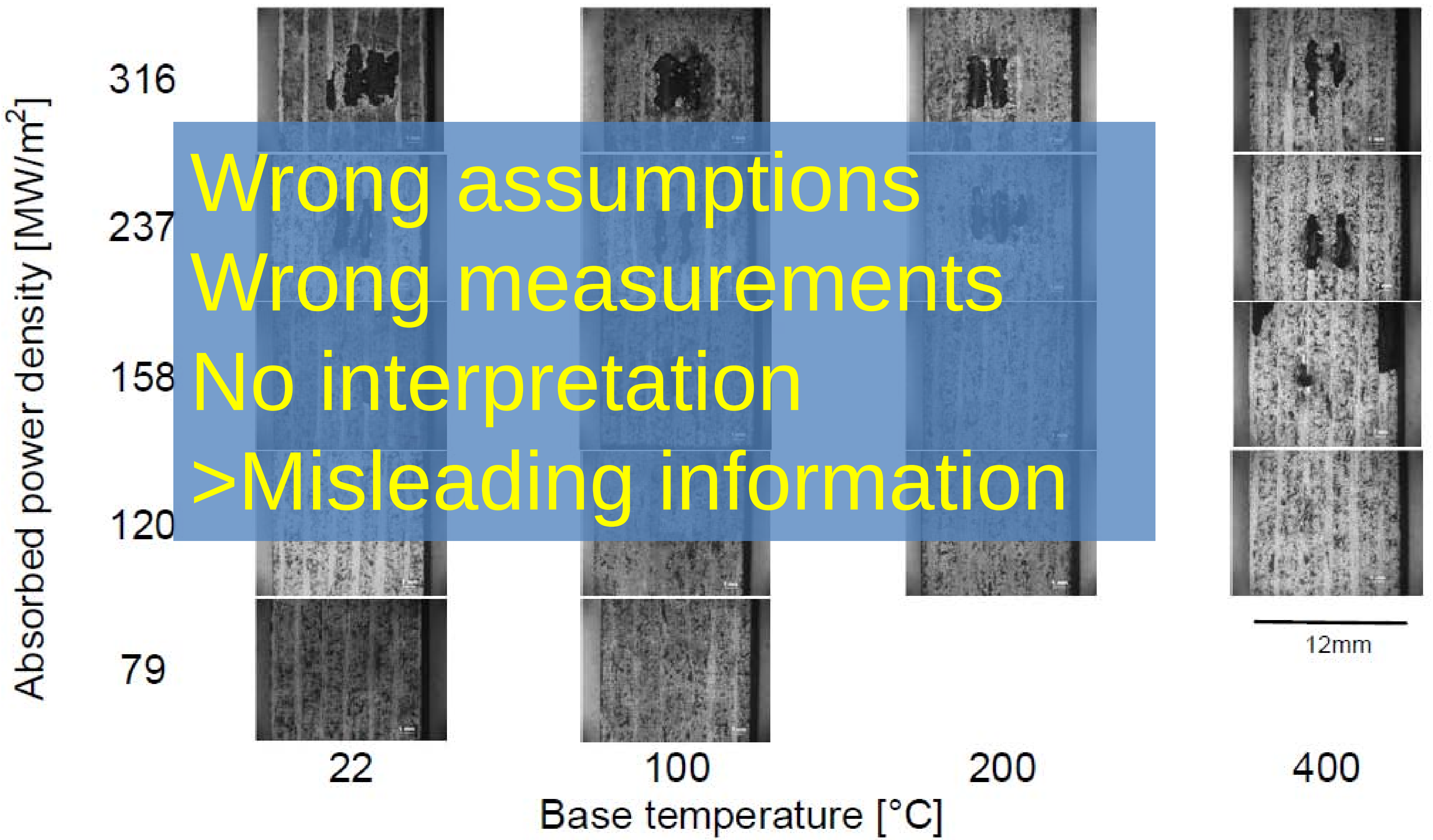
W-coating on CFC
Temperature <1200°C
ELMs: ~5 MW m^{-2} $s^{-1/2}$

W stacks
Surface temperature limit
< 2200°C
$20\text{-}35 MJm^{-2}s^{-1/2}$
Energy limit ~60MJ/m^2/stack

Testing of tiles in different facilities: ion beams, e beams plasma guns etc.

“ELM simulation” on W-coated divertor tile

100x, 1 ms long, JUDITH HV EB pulses



Wrong assumptions
Wrong measurements
No interpretation
>Misleading information

ILW operation and coatings

Coatings (W & Be): initial information on behaviour in the JET tokamak environment

W coatings

- -Overall: very good behaviour
- -One tile started to develop defects
  - -Region was damaged slightly during installation

Be coatings

- -No effect on coatings observed so far

But we should wait

- -No high power discharges so far. No NBI. Only some RF (~4 MW)

ITER-Like Wall and the MEdC Association

The ITER-Like Wall project (closed officially on Oct. 6th, 2011) was a JOC project. JOC and CCFE had the most important contribution to the accomplishment of the largest single project EFDA has ever had.

Two other EURATOM Association contributed in a decisive way to the success of the ILW project. The first the MEdC Association for its development and implementation of the technologies for w and Be coatings.
The second is the FZ Julich Association for the design and management of the construction of the bulk W divertor tile.

There is however something else.
One of the contributions mentioned above had a dramatic impact on the fate of the ILW project and JET.
That was the W-on-CFC coatings.

ITER-Like Wall and the MEdC Association

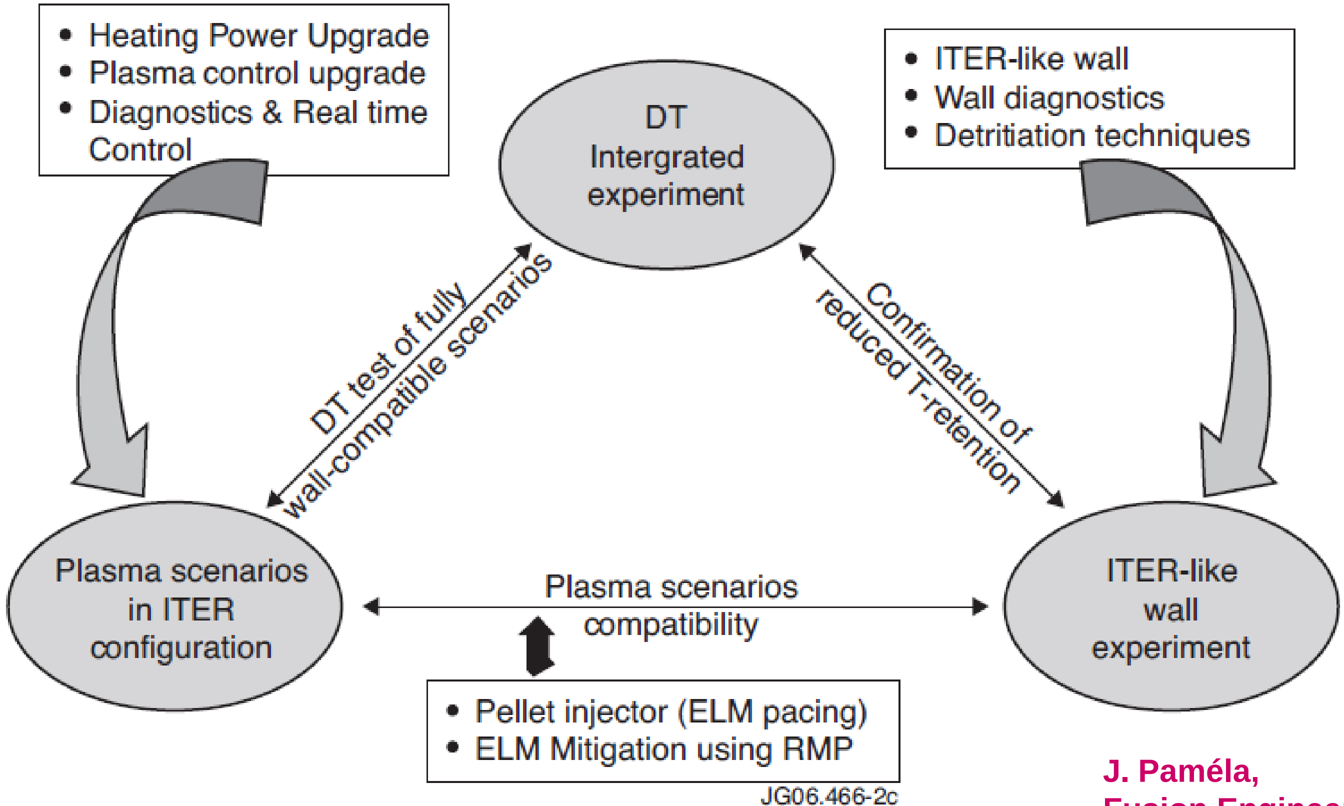
Francesco Romanelli, EFDA Associate Leader for JET
MEdC Association Days, 2009
“The W-coating technology developed by you saved the JET ILW project“

David Maisonnier, European Commission
Message to Florin Spineanu, at the end of his position as the HRU
“We do not know where JET would have been today without your contribution”

Guy Matthews, the ILW Project Leader, at the ILW Project Board meeting in March 2010.
“The W-on-CFC coatings technology developed by Cristian Ruset and co-workers is one of the success stories of the ILW project”

JET future

DT operation is the next step in the "JET Programme in support of ITER"



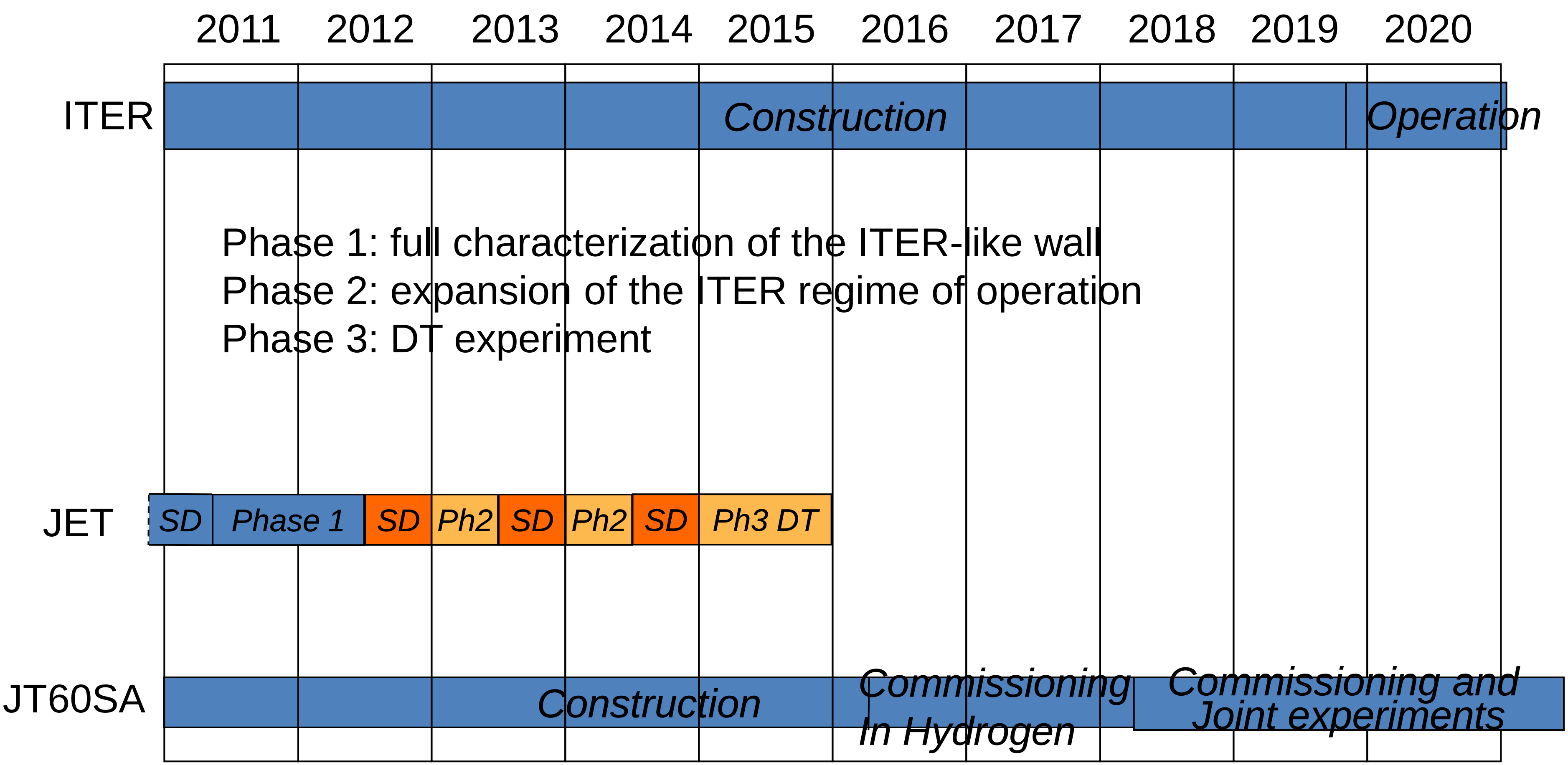
J. Paméla, Fusion Engineering Design, 2007

Coherent, phased approach:

1. Full characterisation of the ITER-like-Wall (2011-2012)
2. Develop ITER regimes of operation to their full performance (2013-2014)
3. Integrated experimentation in deuterium-tritium (2015)

Reference Scenario (2011-2015)

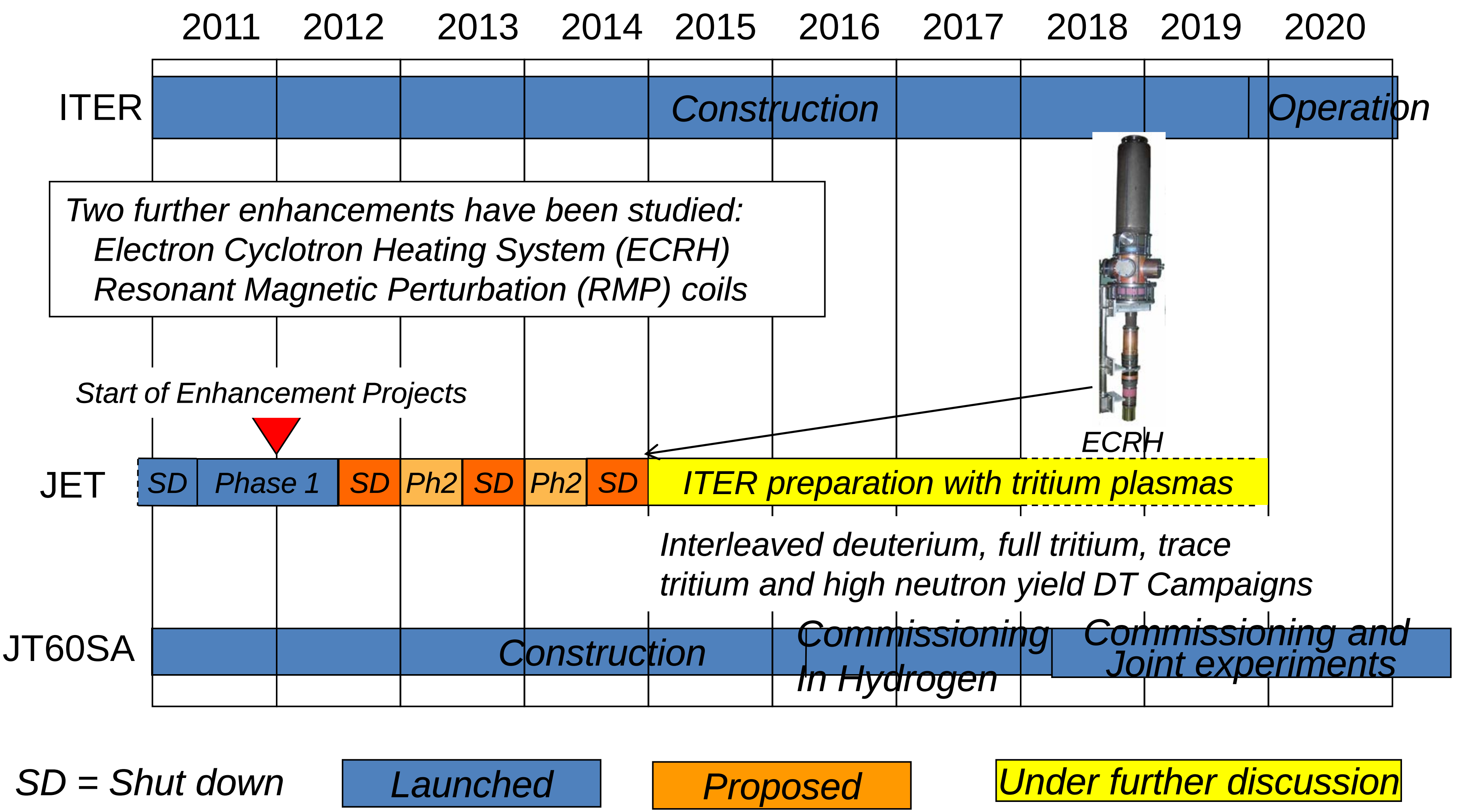
ITER-like wall exploitation and DT Campaign



SD = Shut down *Launched* *Proposed* *Under further discussion*

Alternative Scenario (2011-2018/20)

ITER preparation with all the control tools foreseen in ITER



Alternative Scenario (2011-2018/20)

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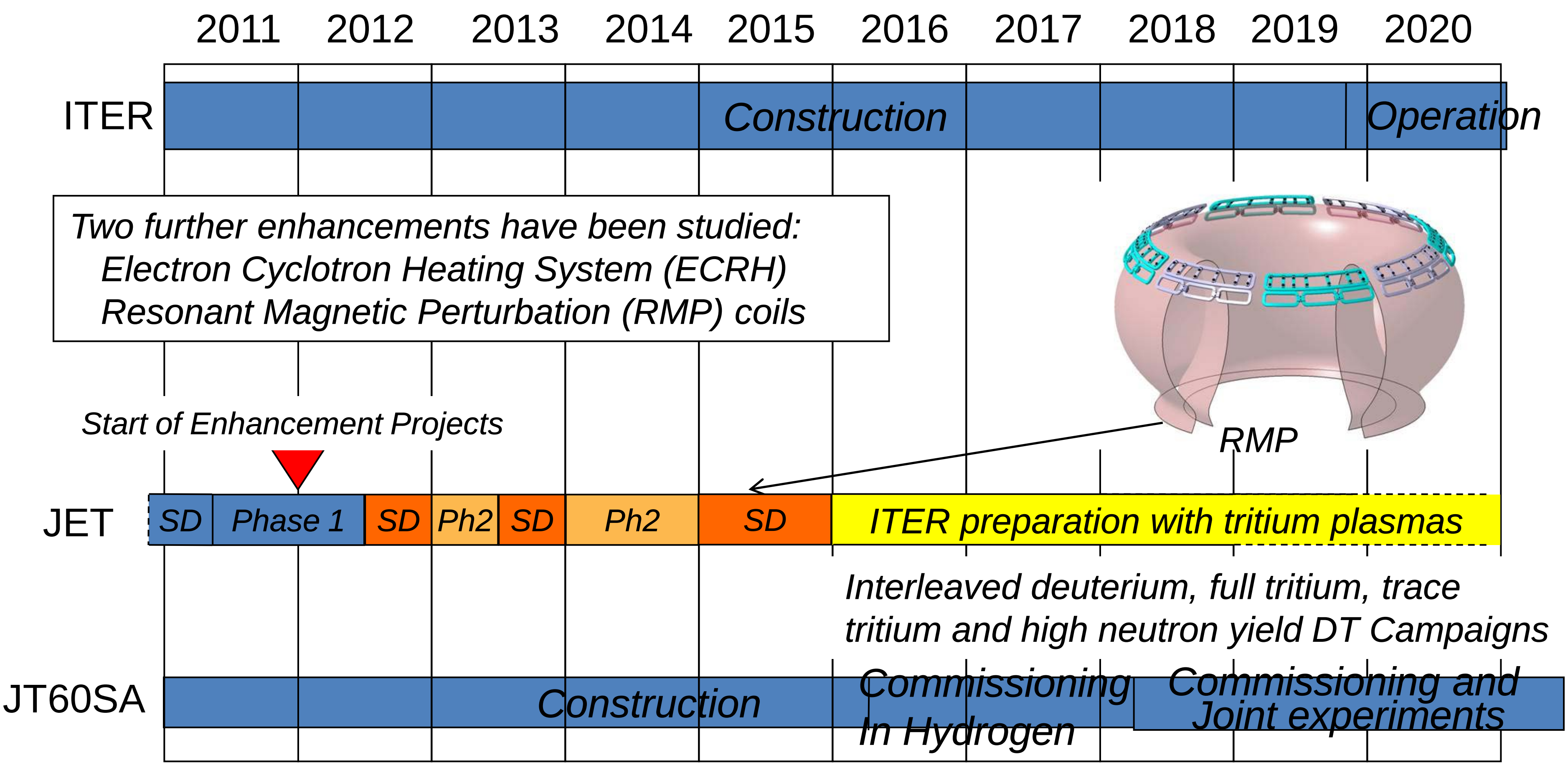

SD = Shut down | Launched | Proposed | Under further discussion

* *Exact duration to be quantified*

Training the scientists and the operators from the different ITER parties will put together the team that will exploit ITER

A convincing argument?

DT campaign assumptions

- A DT phase will be performed with a W/Be wall.
  Possible change out of solid W tile 5 to W-coated carbon tile in 2013/2014.
- NBI power: 35MW, ICRH power 5MW.
- High performance scenarios are developed in DD (3.5-5 MA), and are compatible with the ILW.
- Operation up to 4.1 Tesla (performance and ICRH heating schemes)
- LHCD can be used (in contrast to DTE1)
- Required tritium quantity:

  -For 100% tritium operation ~60g
  -For D:T operation ~40g

Of interest to the MEdC Association

DT campaign main physics objectives

ISOTOPE campaigns (D,H,T)

- **Assess effect of ITER-like shape and ILW on threshold and H-Mode access Investigate L-H transition and pedestal & ELM physics with previously unavailable diagnostics (edge CXRS, HRTS, profile reflectometer)**
- **Improve confinement physics basis for ITER prediction, extending to HYBRID and AT regimes**
- **Understand isotope scaling of pedestal & ELMs seen in DTE1 (1997)**
- **Develop and test effective ELM mitigation techniques in T, DT plasmas**

ICRH:

- **Qualify 2nd harmonic T scenario for application to ITER and develop T-rich scenario for easier H-mode access**

ALPHA PARTICLES

- **Establish/validate critical pressure for TAE's to appear for ITER scenarios**
- **Use TAE antennae to distinguish absence of TAE's from presence of stable TAE's**
- **Investigate alpha particle loss mechanisms**
- **Investigate alpha heating, revisit unexplained ion heating observations (alpha induced confinement improvement or ion cyclotron emission?)**

Of interest to the MEdC Association

In lieu of conclusions

Rezultatele prezentate mai sus au condus la formarea unei imagini extraordinare pentru comunitatea noastra de fuziune .
As vrea sa multumesc celor care au contribuit la aceasta imagine.

Cristian Ruset si colectivului pentru cel mai rasunator rezultat obtinut in domeniul nostru prin realizarea acoperirilor de wolfram pe CFC.

Cristian Lungu si colectivului, impreuna cu acei colegi inimosi de la FCN Mioveni pentru curajul de a se fi angajat in o activitate atat de riscanta ca depunerile de beriliu.

Marian Curuia, Sorin Soare si Teddy Craciunescu pentru contributiile lor la realizarea celor doua proiecte de diagnostica gamma.

Alexandra Pantea, Mihaela Gherendi si Teddy Craciunescu pentru participarea lor la primul experiment facut vreodata pe instalatia JET de catre o echipa din Europa Centrala si de Est.

Va multumesc!