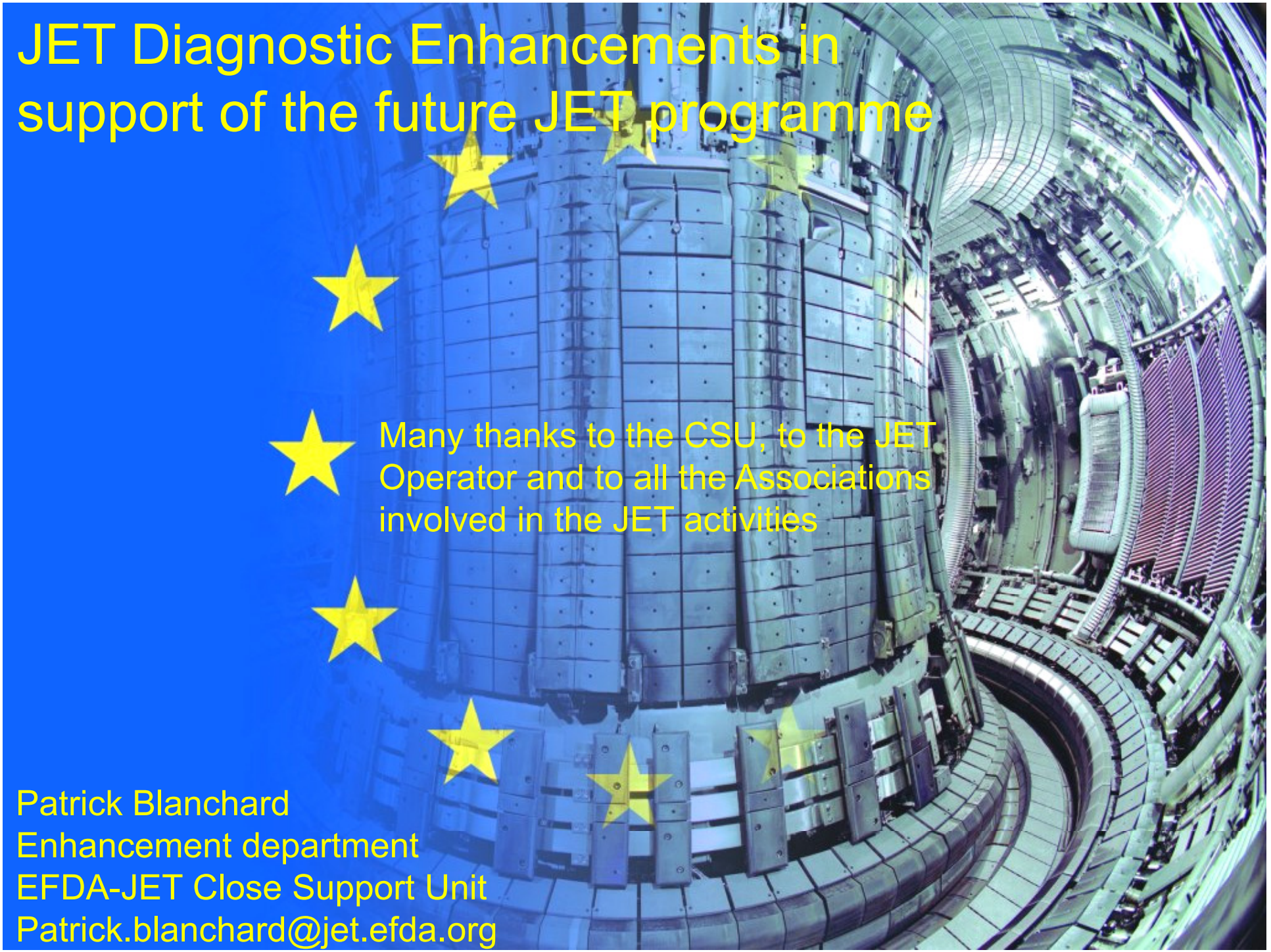
JET Diagnostic Enhancements in support of the future JET programme



Many thanks to the CSU, to the JET Operator and to all the Associations involved in the JET activities

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Overview

- JET EP2 Enhancement programme
- JET new metallic wall
- EP2 Diagnostic Enhancements at JET
  - Spectroscopy
  - New Divertor Endoscope
  - Infrared Camera for tile 5
  - Gamma-Ray Spectrometers
  - Gamma-Ray Camera: neutron attenuators
  - DAQ systems for n and γ Diagnostics
  - Tandem Collimator for gamma-ray spectroscopy
- Conclusion

ITER-like wall

Replacement of all the CFC tiles with mix of Be and W tiles to provide experimental information on a C-free tokamak operation

Neutral Beam Enhancement

Upgrade of the heating power and pulse length to increase the operational space and to fully exploit the total pulse length capability of JET

Plasma Control Upgrade

Upgrade of the FRFA and VS controller to allow large ELM study

High-Frequency Pellet Injector

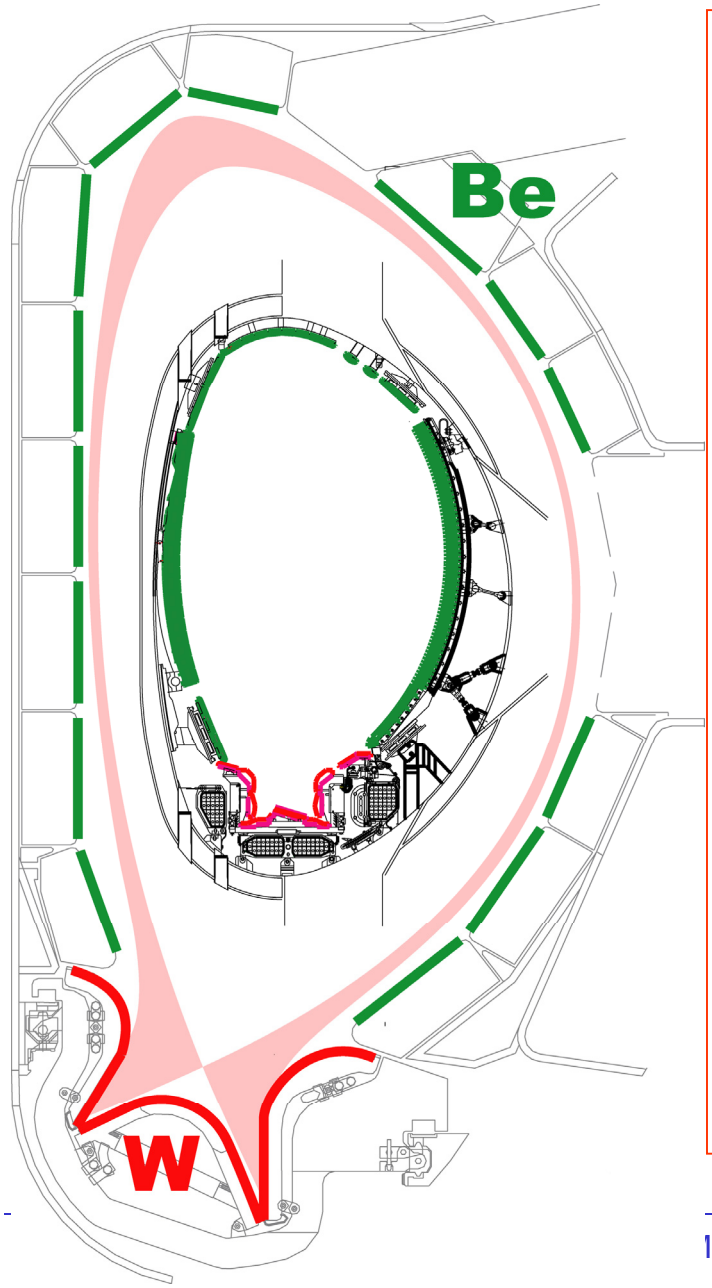
Up to 50 Hz with high fuelling capability to confirm the ELM-pacing technique and deep fuelling experiments

Diagnostics

To support the future JET programme

To test ITER-relevant diagnostics at JET

The New JET metallic wall



Carbon: -Robust (no melting) ✓
-Good to explore operation boundaries ✓
-T retention: not acceptable in a reactor X

=>solution: **metal wall at JET** as
-enough energy to cause melting
-can inject Tritium
-more flexible than ITER

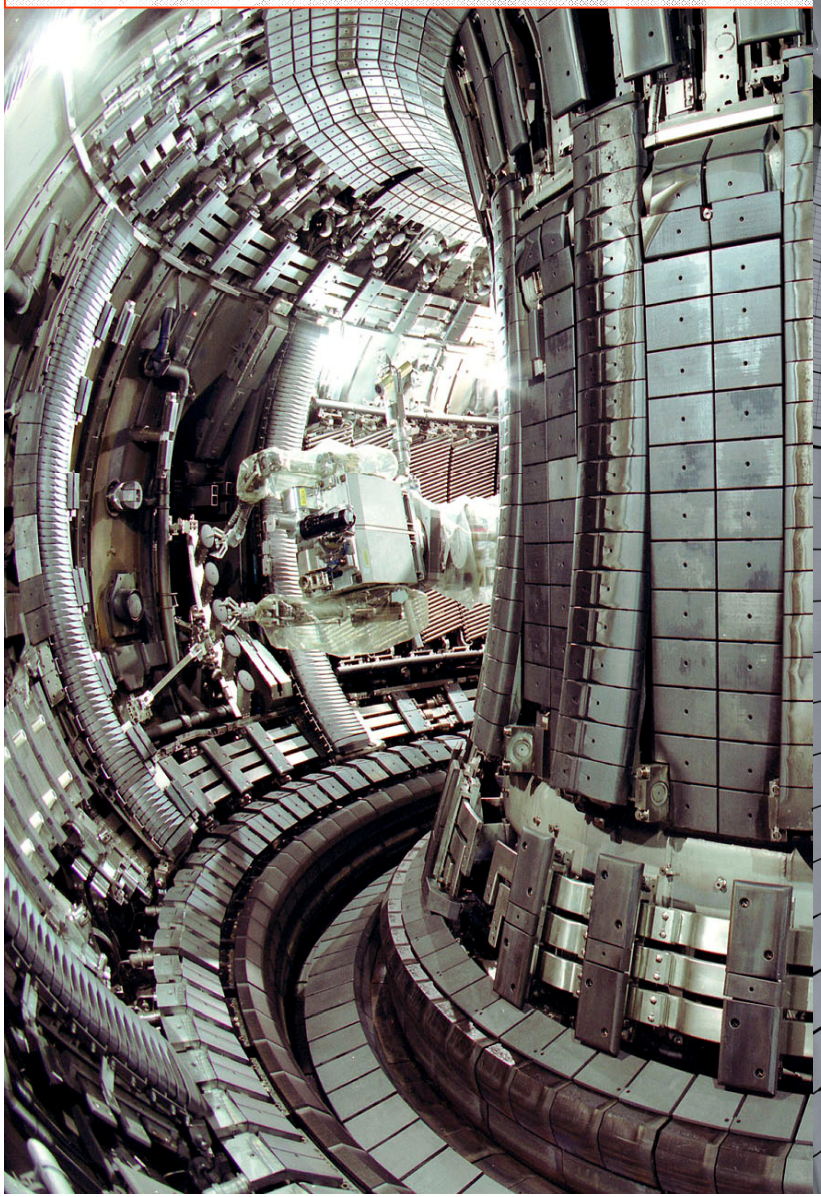
Scientific objectives:

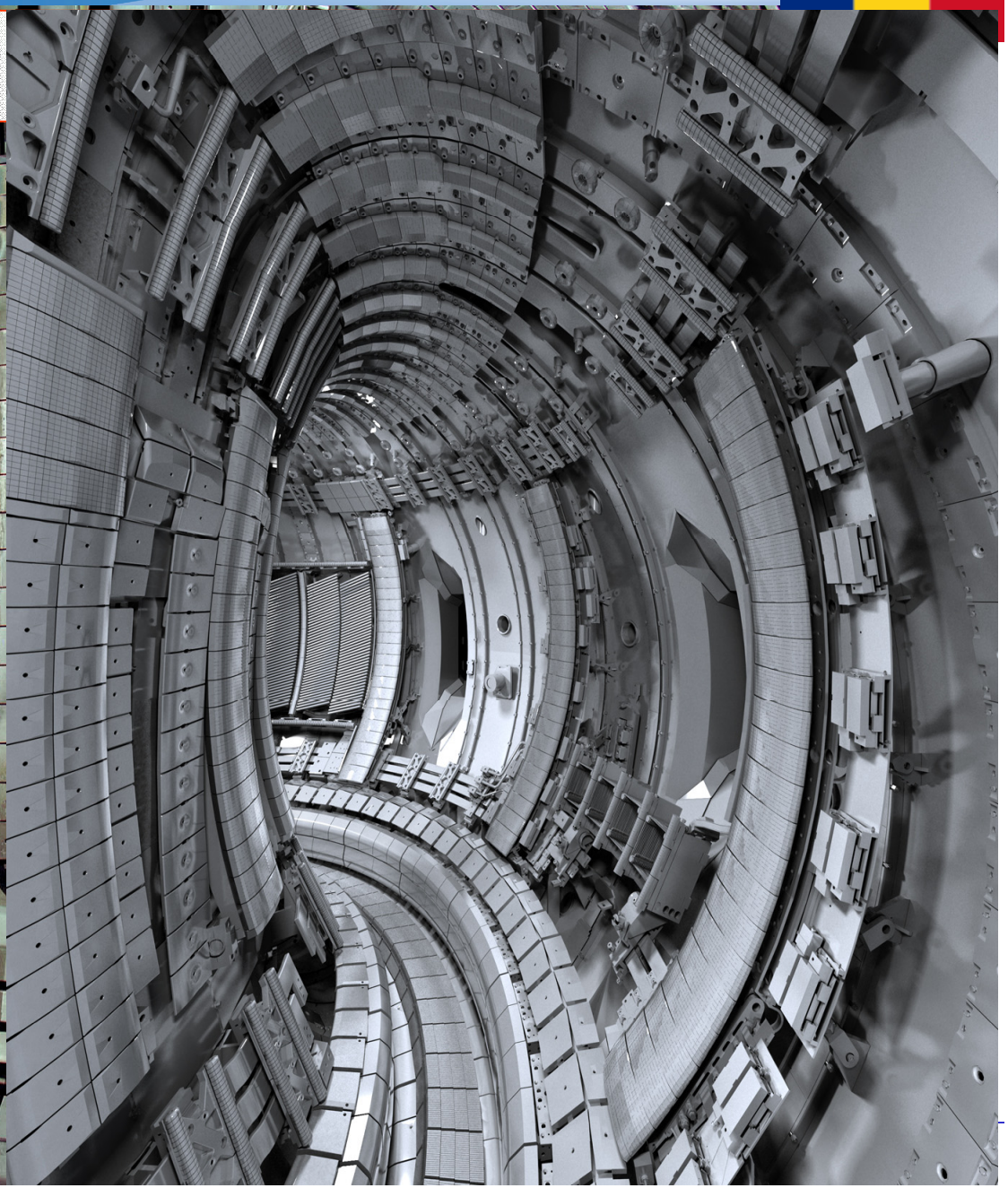
To gain operational experience with:
-ITER relevant mix of materials
-steady and transient conditions

Plasma Wall interaction: T retention, Be & W erosion and migration, damages

The New JET metallic wall

More than 4400 tiles





EP2 Diagnostic Enhancements

In 2005 and 2008, it was decided to launch a series of diagnostic enhancements and new diagnostic developments in support of the new ILW

About 25 projects involving more that 10 Association (MEdC, FZJ, VR, TEKES, HUN, CIEMAT, IST, CEA, IPP, UKAEA, IPPLM) + **JOC** have been launched

- Diagnostics in support of the new wall
- Diagnostic with strong In-Vessel and Vacuum-boundary implication
- Improved Profiles and Detection & test of techniques

Recently, new diagnostics projects are being launched in relation of the Protection of the ITER-Like Wall

Closed projects

- **Edge LIDAR Upgrade**
- **Divertor IR Camera**
- **KK3 Heterodyne radiometer**
- **UV and n^o measurements using CVD**
- **CNN application to IR thermography**
- **Multi-band sweeping reflectometer**
- **Fast Visible Camera**

To be closed in 2010

- **Radiation Hard Hall probe**

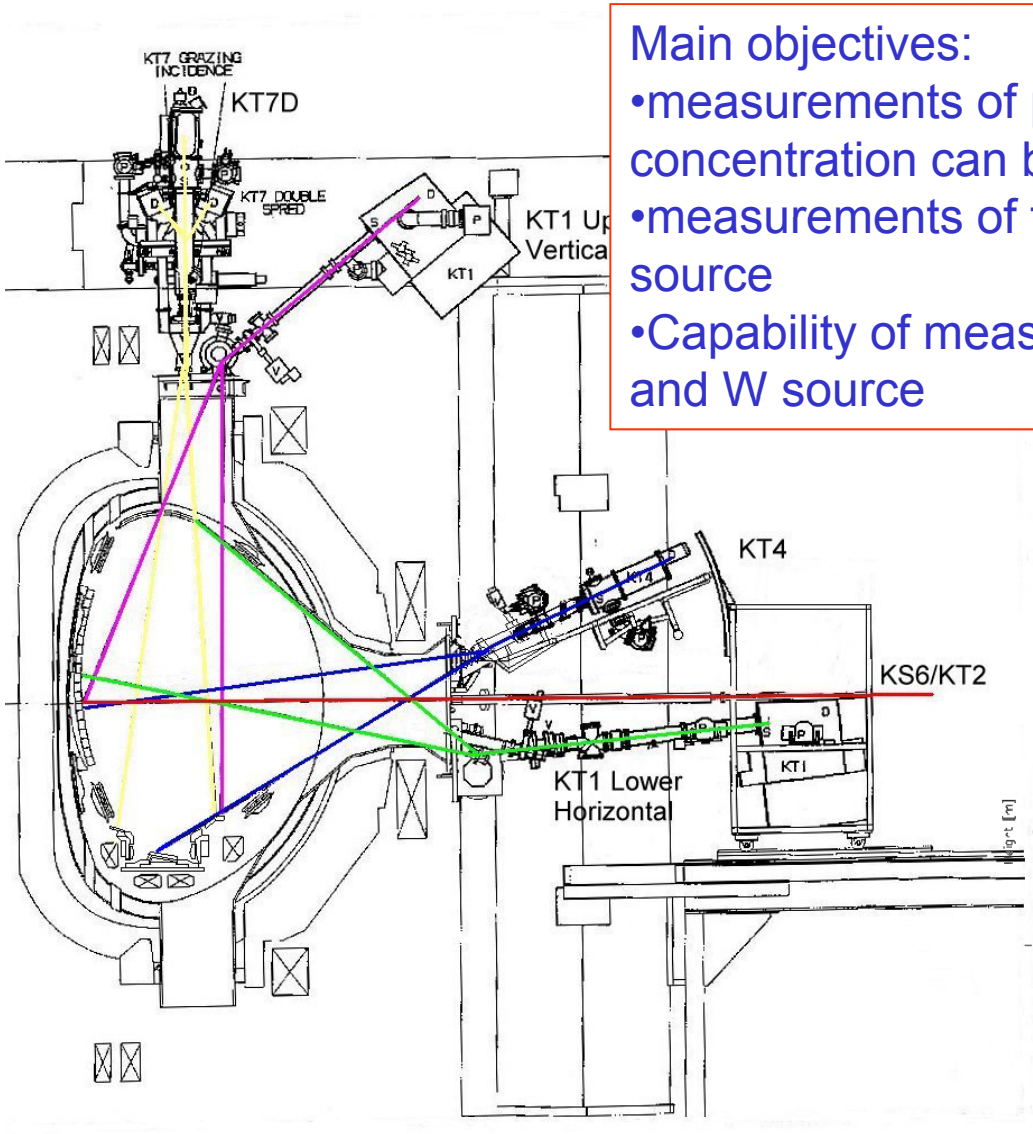
Projects to be closed after ILW installation

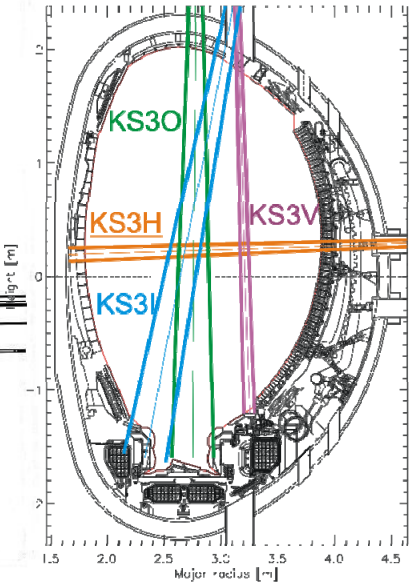
- **Spectroscopy for the ILW**
- **Gamma ray spectroscopy**
- **DAQ for neutrons**
- **DAQ for gammas**
- **Upgrade of the Li beam intensity**
- **Upgrade of the γ ray cameras: NA**
- **Erosion Deposition Probes**
- **Tandem Collimator for γ Spectroscopy**
- **RT measurement and control**
- **Compact neutron spectrometer**
- **KL1 spectroscopy upgrade**
- **New pressure gauges**
- **NPA upgrade**
- **Divertor view KL11 Endoscope**

Spectroscopy for the ITER-Like Wall

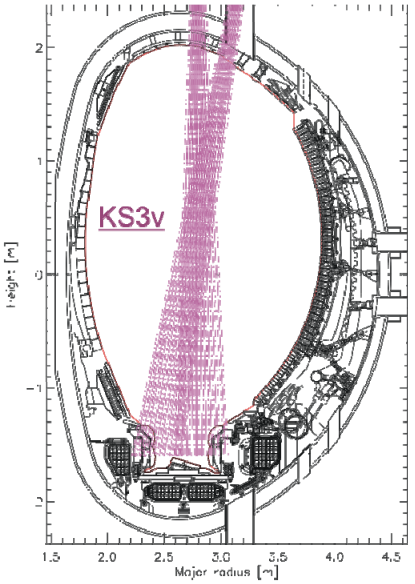
Main objectives:

- measurements of photon flux from which core W concentration can be derived
- measurements of the poloidal distribution of Be, C and W source
- Capability of measuring in RT transients events in Be and W source



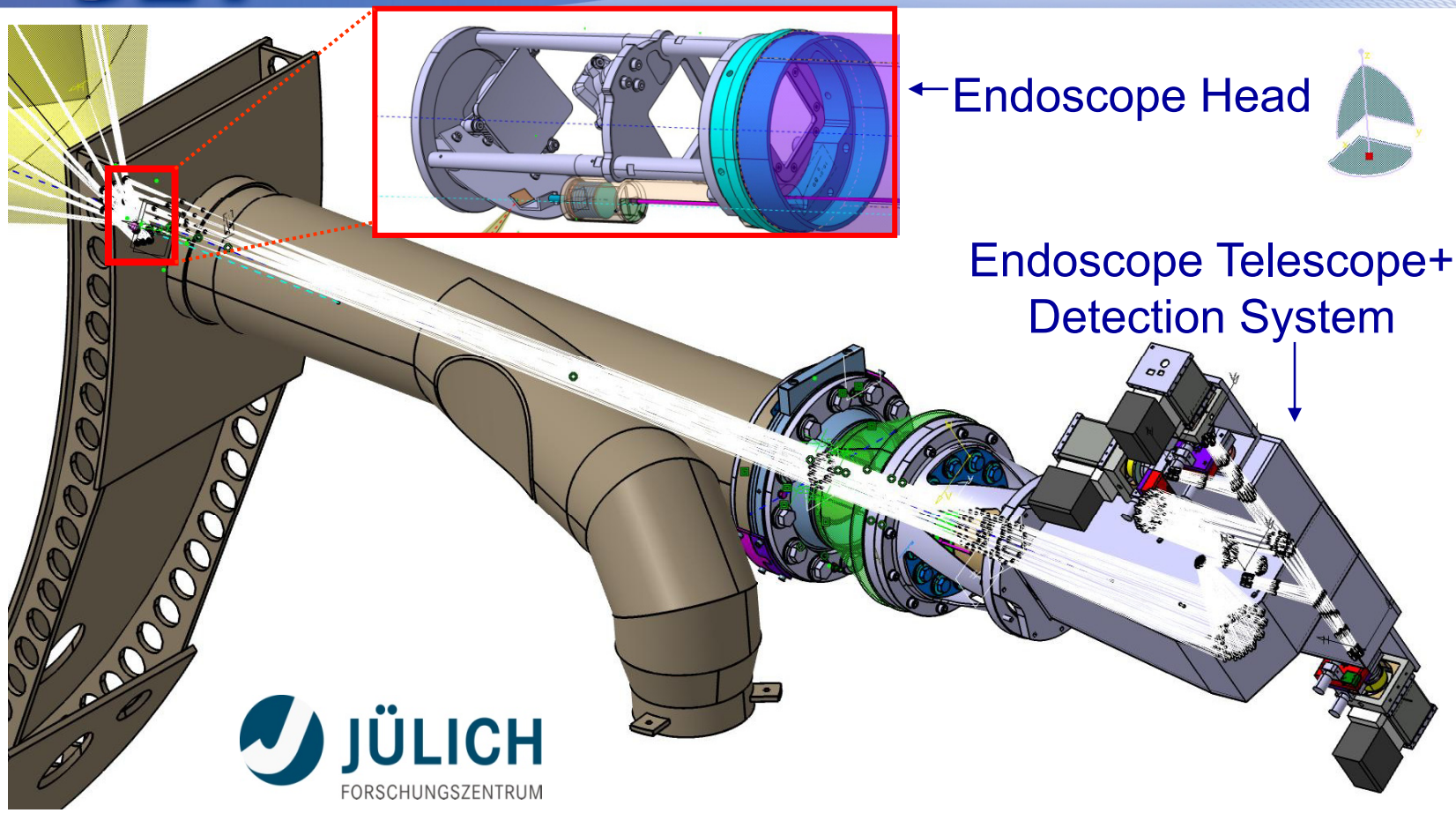


Global KS3 chords



KS3 divertor chords

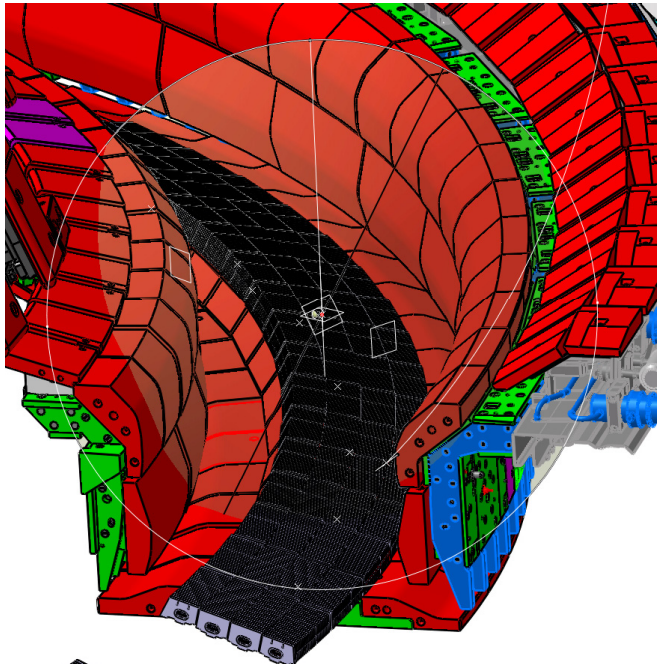
New Divertor Endoscope



- Measurement of W erosion yields in the full W divertor of JET
- Spectral range coverage from 350 nm to 1700 nm with optimised transmittance in the near UV/blue spectral region to detect W I emission at 400.8 nm
- Simultaneous detection of, Be II emission at 527 nm, C III emission at 465 nm and Dα emission at 656 nm (to provide effective yields)

New Divertor Endoscope

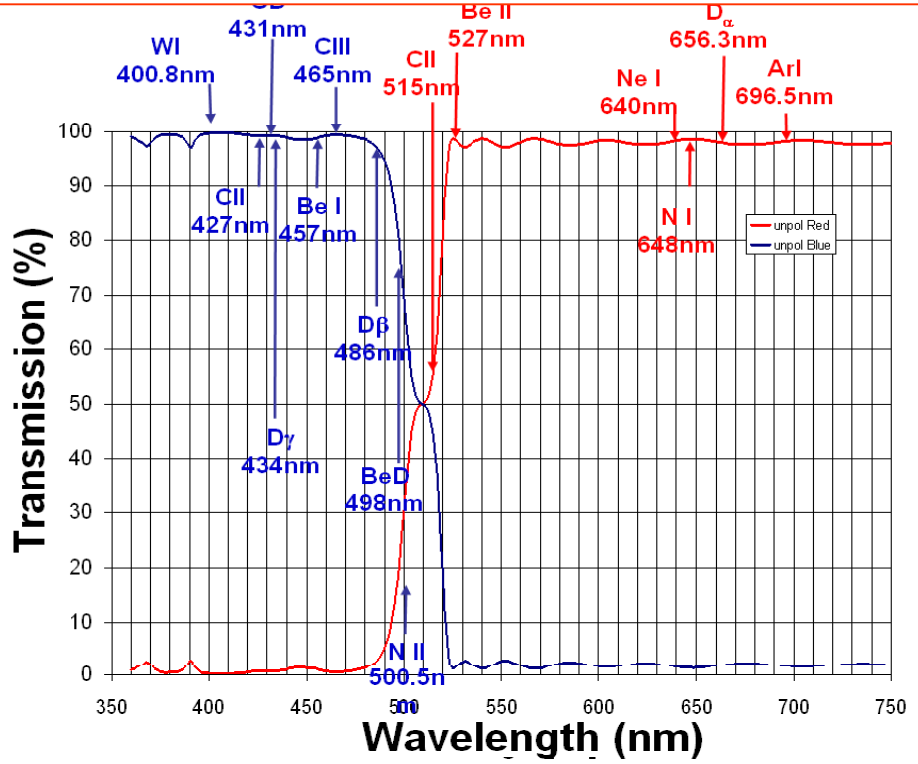
View into Octant 2



Detection system:

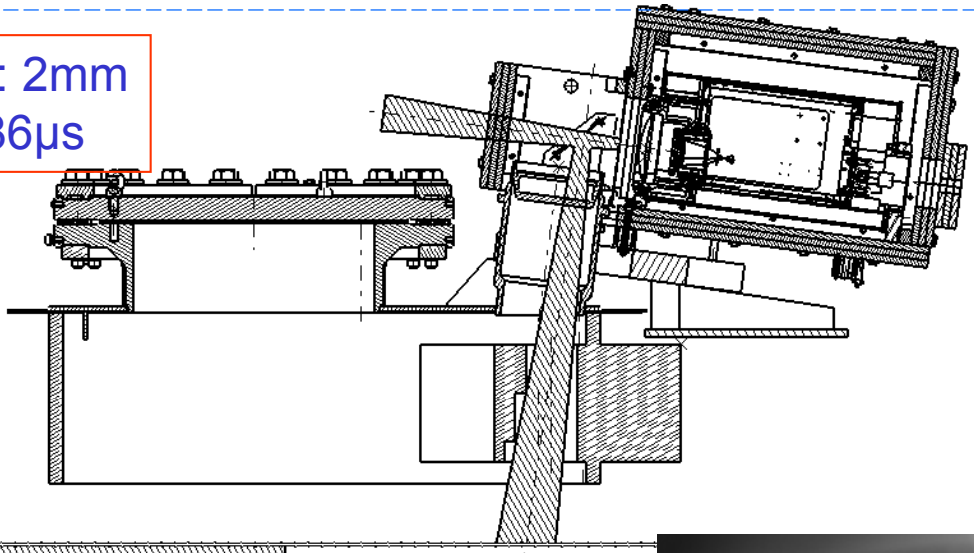
- Dichroitic mirrors for red/blue separation
- 4 CCD cameras with filter wheels for simultaneous observation
- 2 cameras (IR and visible) for protection
- 6 interference filters per filter wheel
- Time resolution: ~ 30 Hz

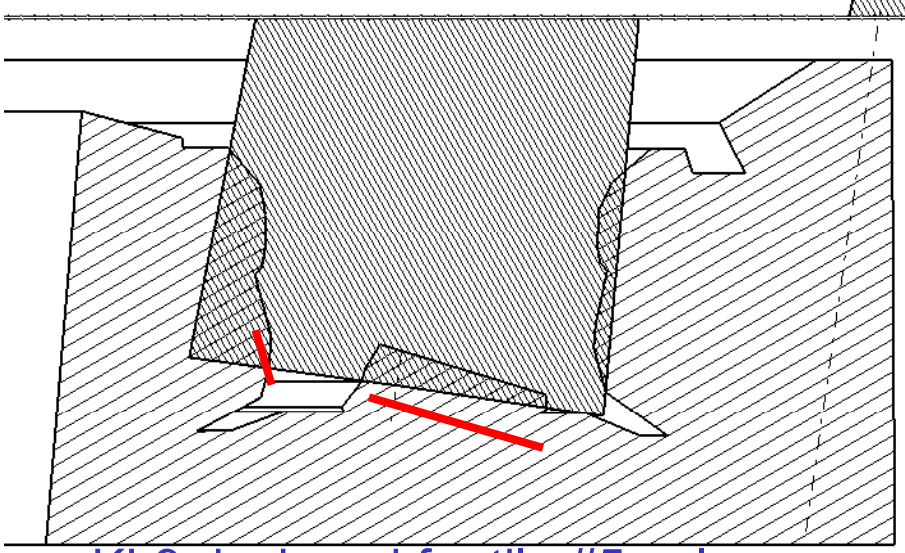
- Spatial resolution ≤ 3 mm at the object plane
- Suitable for 2D reconstruction
- Suitable for impurity radiation pattern in the divertor



Infrared Camera for tile 5

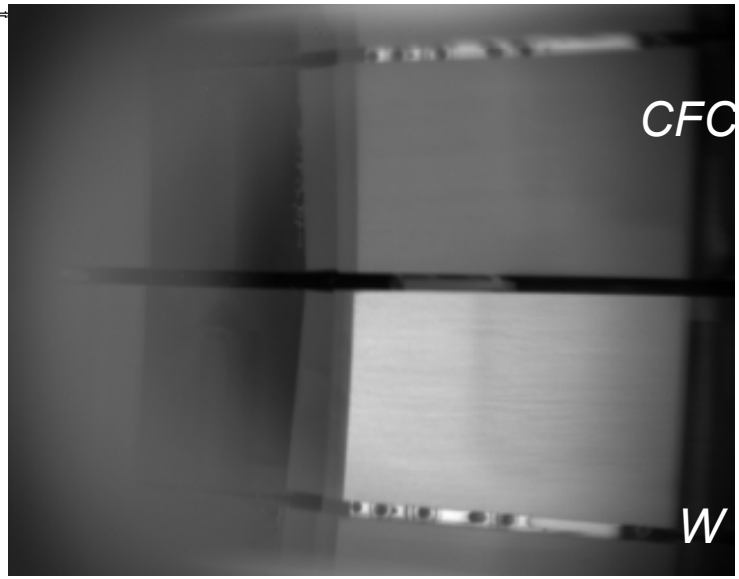
Spatial resolution: 2mm
Time resolution: 86µs





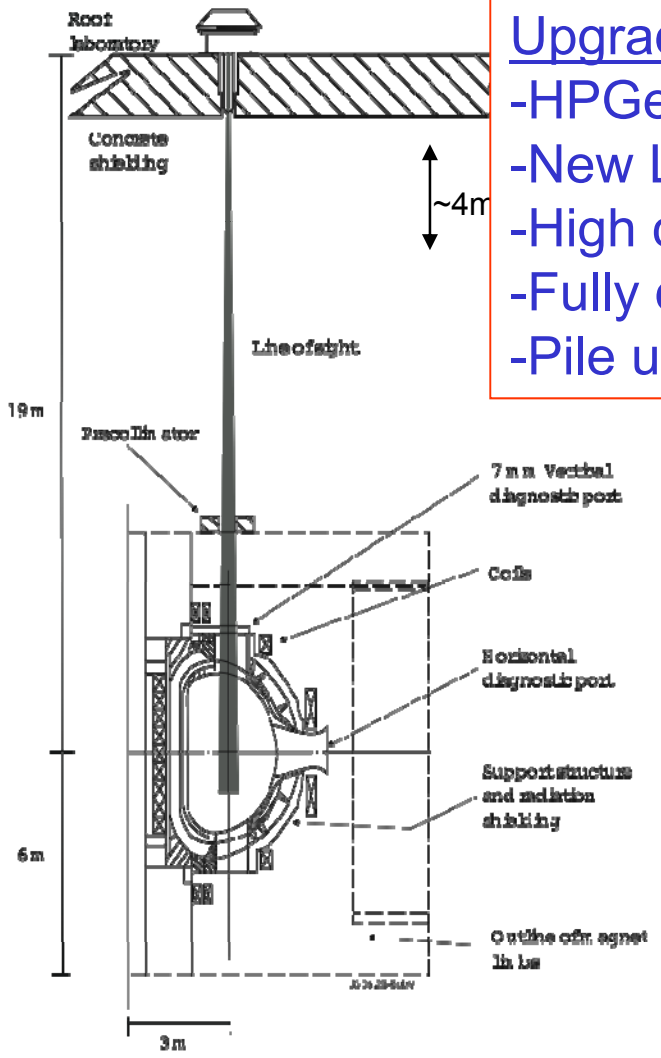
KL9 designed for tile #5 only

- Heat fluxes
- Power loads
- Decay length
- ELM studies



Calibration of the W emissivity to be done in Romania

Gamma Ray Spectrometers at JET



Upgrade:

-HPGe semiconductor spectrometer:$\Delta E/E<0.2\%$@660keV

-New LaBr3 scintillator detector with $\Delta E/E<3\%$ @ 660keV

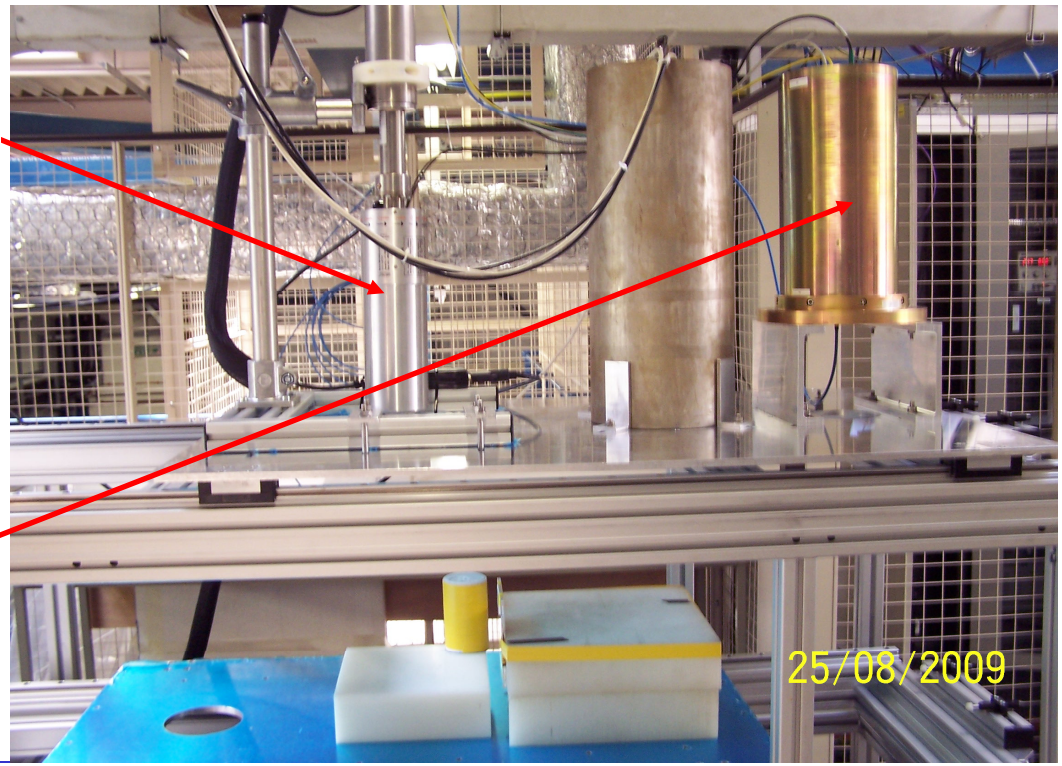
-High count rate detector system >0.5MHz

-Fully digitized DAQ based on FPGA technology

-Pile up recognition software

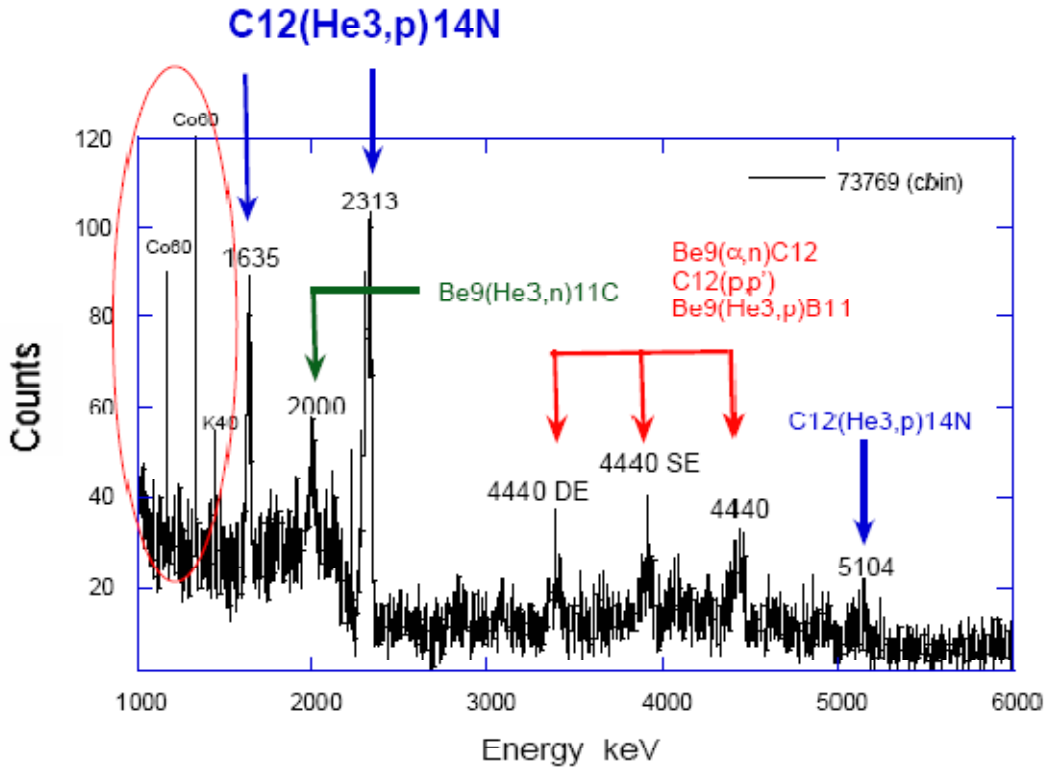
HpGe

$LaBr_3$

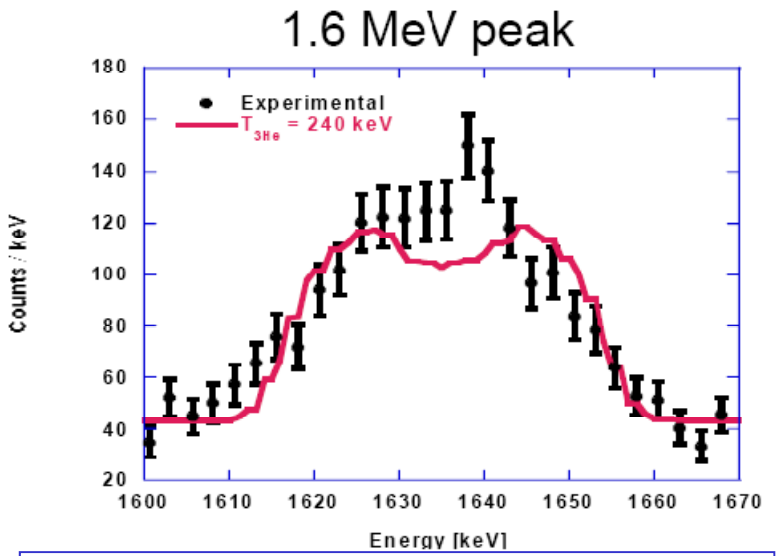


Detector characterisation took place Magurele accelerators

HPGe Gamma Ray Spectrometers



γ spectrum of a JET D(^{3}He) discharge with ICRH @ $\omega=\omega_{C3He}$



Agreement of the Doppler broadening simulation with the data achieved for **T=240±40 keV**

New HPGe spectrometer has measured for the first time with high resolution the gamma ray Doppler broadening of 3He and 4He ions

Upgrade of γ Ray Cameras: Neutron Attenuators

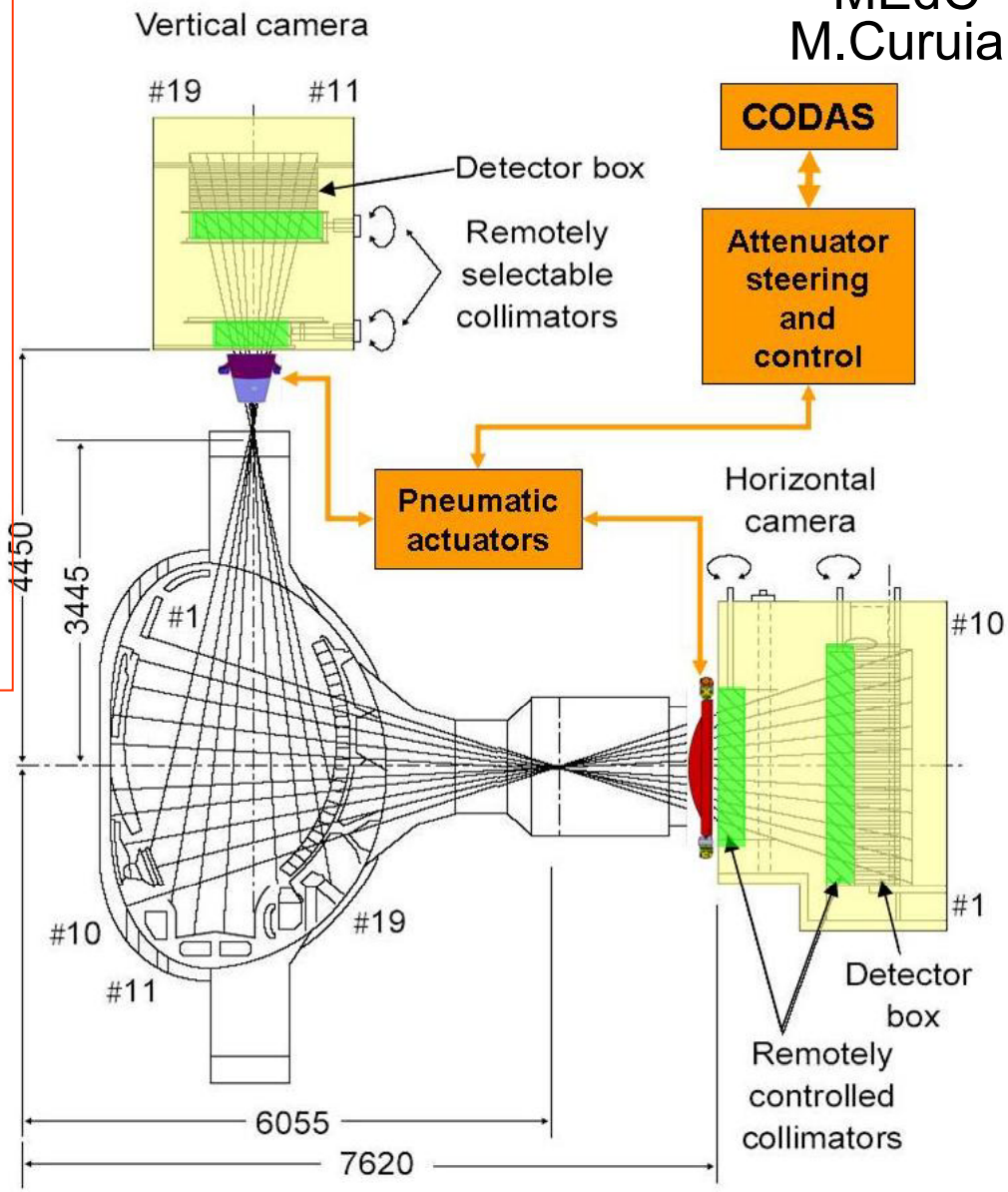
MEdC
M.Curuia

Main objectives:

- Providing neutron attenuators for the two subsystems of the gamma-ray imaging diagnostics:
  a) gamma-ray horizontal camera
  b) gamma-ray vertical camera

This diagnostics upgrade should:

- Make possible gamma-ray imaging measurements in high power deuterium JET pulses, and eventually in D-T discharges.



Approximate attenuation factors attainable within the project constraints

Neutron attenuator	Material	Neutron energy	
		2.45 MeV	14.1 MeV
Horizontal	H_2O	10^2	15
Vertical (Long version)	H_2O	10^4	10^2
Vertical (Short version)	H_2O	10^2	15

DAQ for n and γ Diagnostic Enhancement

Upgrade:

- Increase count rate up to MHz range
- n & γ PHS for each los
- Pile-up control
- RT output could be used for control

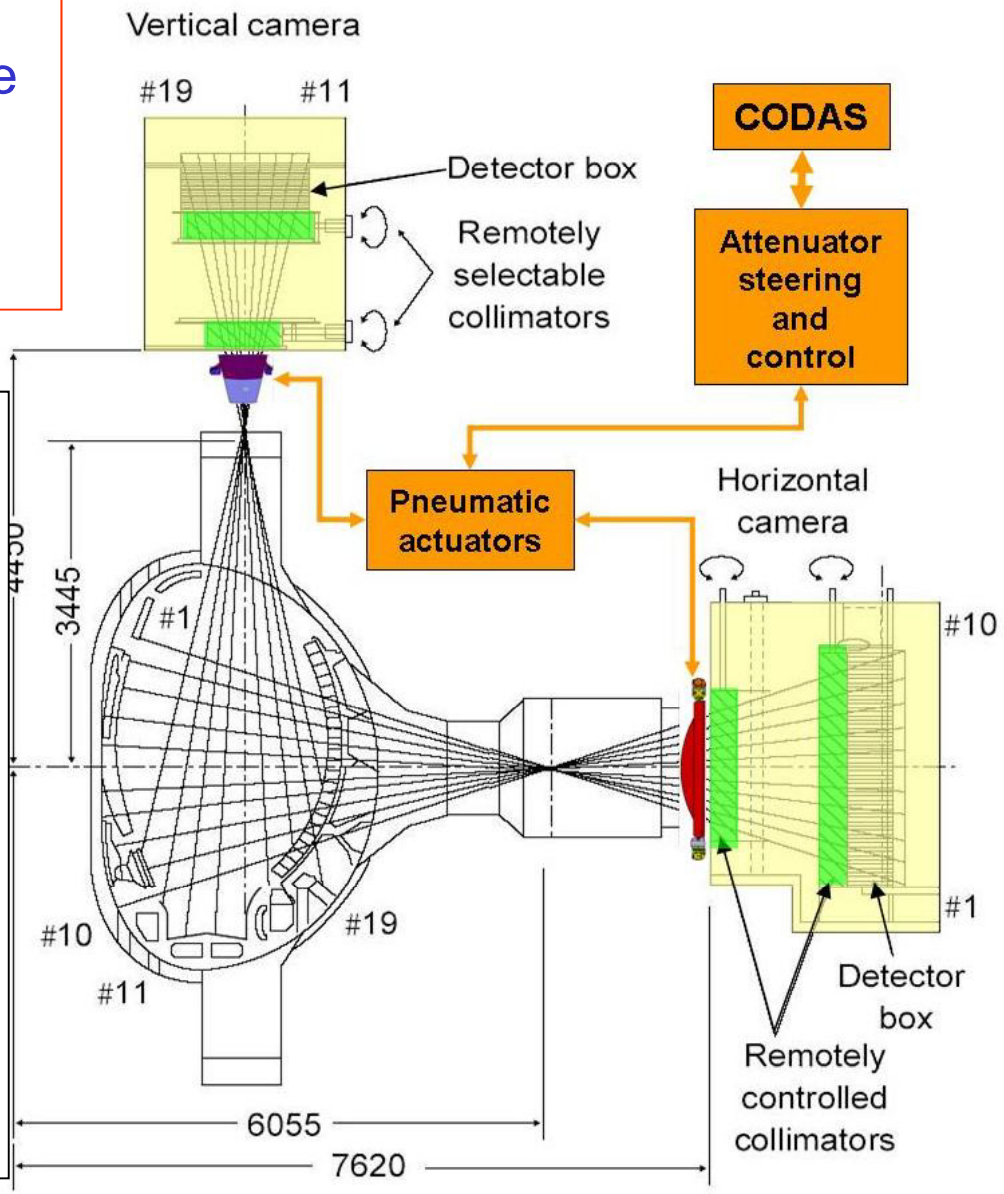
Two cameras:

Vertical: 9 lines-of-sight

Horizontal: 10 lines-of-sight

Absolutely Calibrated Detectors:

- NE213 liquid scintillators (2.5 and 14 MeV) + PSD;
- Plastic Bicron418 scintillators (14 MeV)
- CsI(Tl) photodiodes (Hard X rays and γ emission 0.2<Eγ<6 MeV).



Tandem Collimators for Gamma Ray Spectroscopy

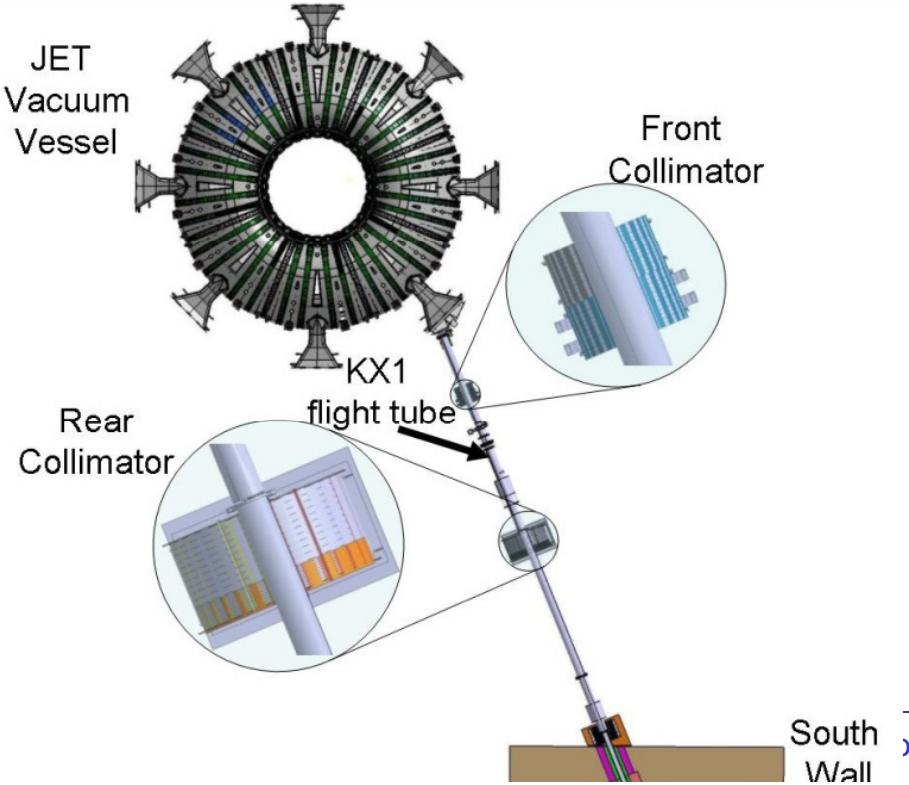
MEdC
S.Soare

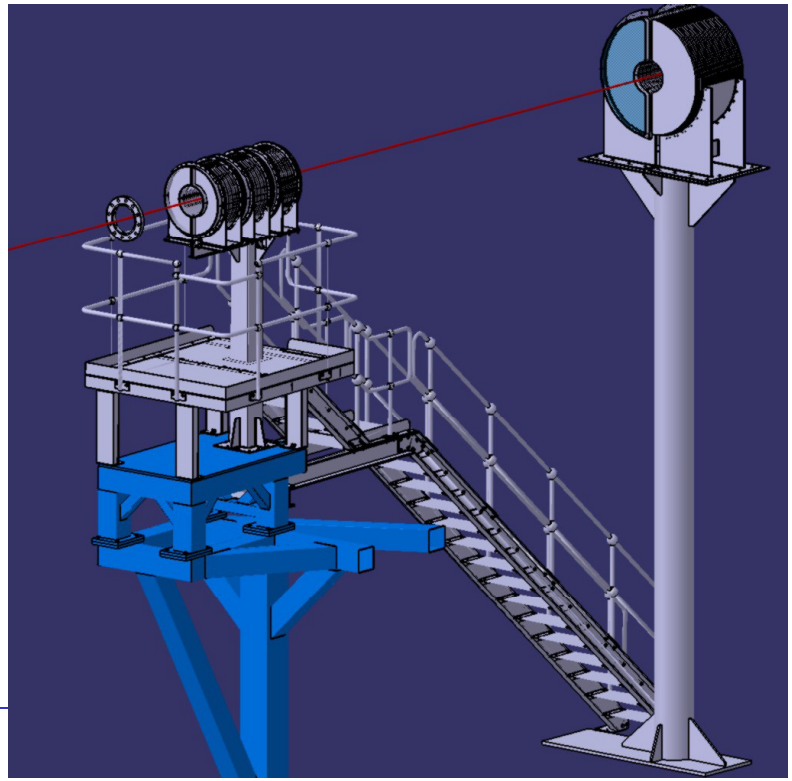
Main objectives:

- To provide two neutron/gamma collimators for the Tangential Gamma-Ray Spectrometer

This diagnostic upgrade should:

- Regain the capability of the diagnostic system for fast particle physics studies of JET plasmas
- Provide necessary conditions for the operation of the spectrometers in high performance deuterium and deuterium - tritium JET discharges





Conclusions

- More than five years after its launch, the EP2 Enhancement programme is now in its final phase and is progressing well according to the baseline shutdown plan

- After the actual shutdown, JET will have 100% metallic first wall and challenging new plasma control and operation are going to be implemented

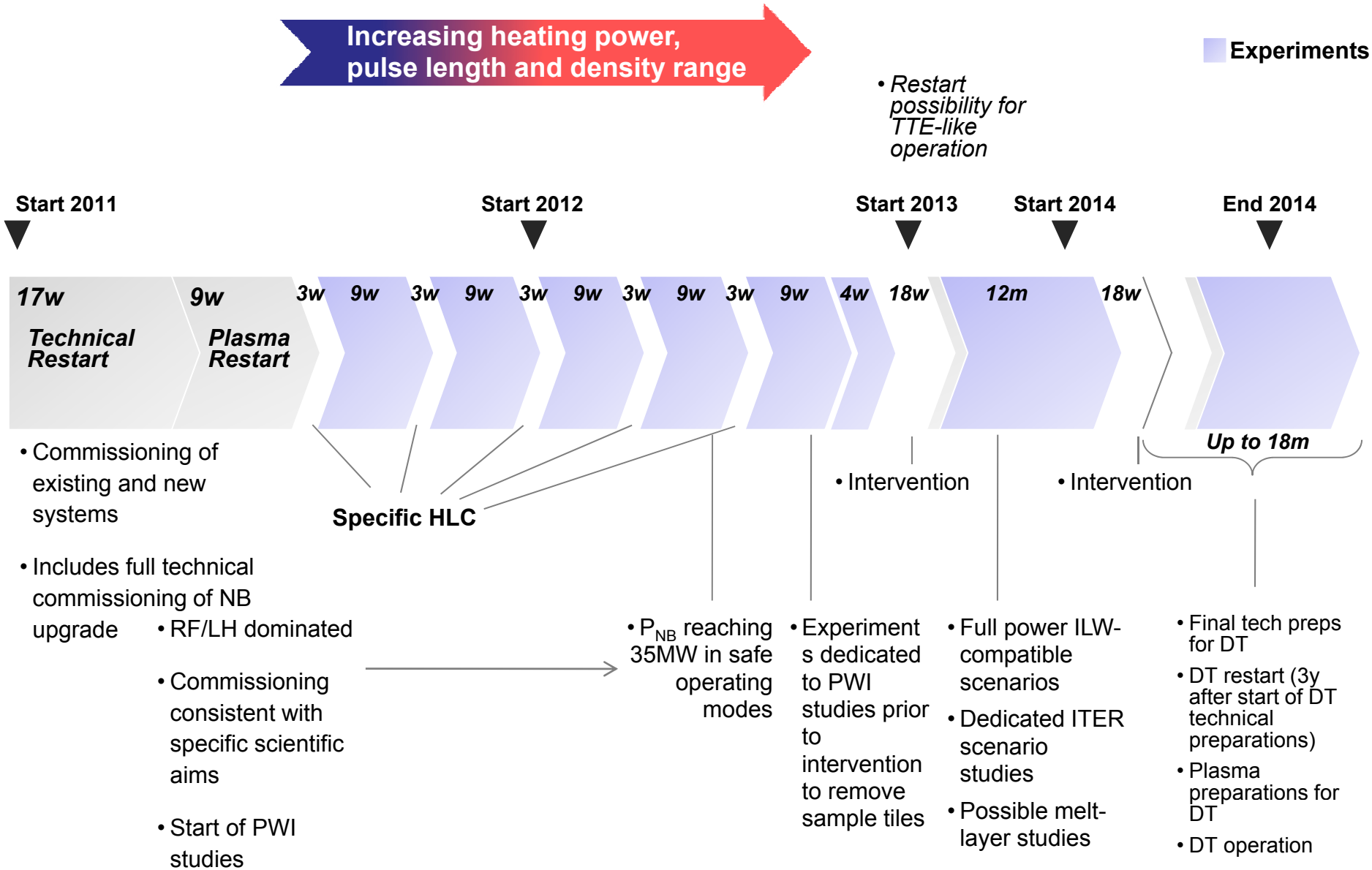
- Enhancement of more than 25 diagnostic systems have been launched since 2005 in support of the JET programme with an ILW

- More than half of them are in their final phase of implementation with final commissioning during the 2011 JET restart

- The Romanian Association has played and is still playing a key role in the EP2 programme

Thank you

Plan of JET Exploitation > 2010



Neutral beam enhancement

Increased power up to 35MW

- New “checkerboard” ion sources for more molecular ions and better neutralisation
- New 130kV power supplies for higher injection energies

Increased NBI pulse length up to 20s

- Actively cooled beam ducts and neutralisers