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INSTYTUT FIZYKI PLAZMY I LASEROWEJ MIKROSYNTEZY
IM. SYLWESTRA KALISKIEGO

Contribution of Polish research units in fusion technology programme

Monika Kubkowska

Superconductivity & Particle Accelerators conference, SPAS 2026
22.10.2026, Kraków

Polish Fusion programme

- In 2005, the EURATOM-IPPLM Association was established in Poland to coordinate activities within the framework of EFDA. IPPLM as a coordinator.

- 2005-2013: EFDA (European Fusion Development Agreement)

  Agreement between European research institutions and the European Commission (representing EURATOM) to strengthen their coordination and cooperation and their participation in joint activities in the field of fusion research.

- In 2013 publication of the European Fusion Roadmap, followed by an update in 2018. Roadmap - EUROfusion

Polish Fusion programme

- 2014-2025 (2027): EUROfusion consorcium

  29 member institutes, 2 associated partners (Ukraine and Switzerland), and 171 affiliated entities from across Europe.

- In 2014, the New Energy Technologies Research and Industrial Centre was established in Poland, CeNTE. Currently, Cente's units are involved in implementing the EUROfusion programme, which is divided into scientific and technological components.

- Fusion research in Poland is also carried out independently by individual institutions under contracts awarded by F4E or ITER.



EUROfusion - Realising Fusion Energy

CENTE

AGH

AKADEMIA MORSKA SZCZECIN

BIMO TECH

IFPiLM

Instytut Geofizyki Polskiej Akademii Nauk

PhoTECH INNOVATION PHOTONICS TECHNOLOGY

INTiBSPAN

IPPT PAN

Łukasiewicz IMiF

NCBJ

PK Politechnika Krakowska im. Tadeusza Kościuszki

PŁ Politechnika Łódzka

Politechnika Poznańska Poznan University of Technology

Politechnika Warszawska Warsaw University of Technology

Politechnika Wrocławska

PCSS

SPETECH

Universitas Cardinalis Stephani Wyszyński Varsoviae

Uniwersytet Mikołaja Kopernika w Toruniu

unipress

Uniwersytet Opolski Universitas Opoliensis

Uniwersytet Szczeciński

VoiceLab

WPT Wrocławski Park Technologiczny

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

Polish Fusion programme

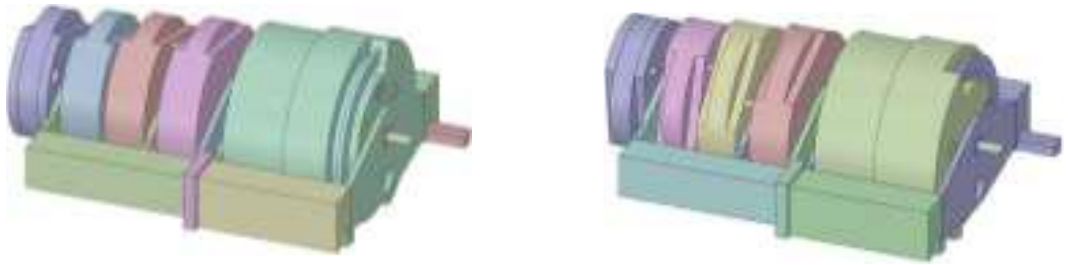
Fusion technology programme under several Work Packages:

- Early Neutron Source -> DONES
- Magnets
- Balance of Plant
- Remote Meintenence
- Diagnostics
- …..

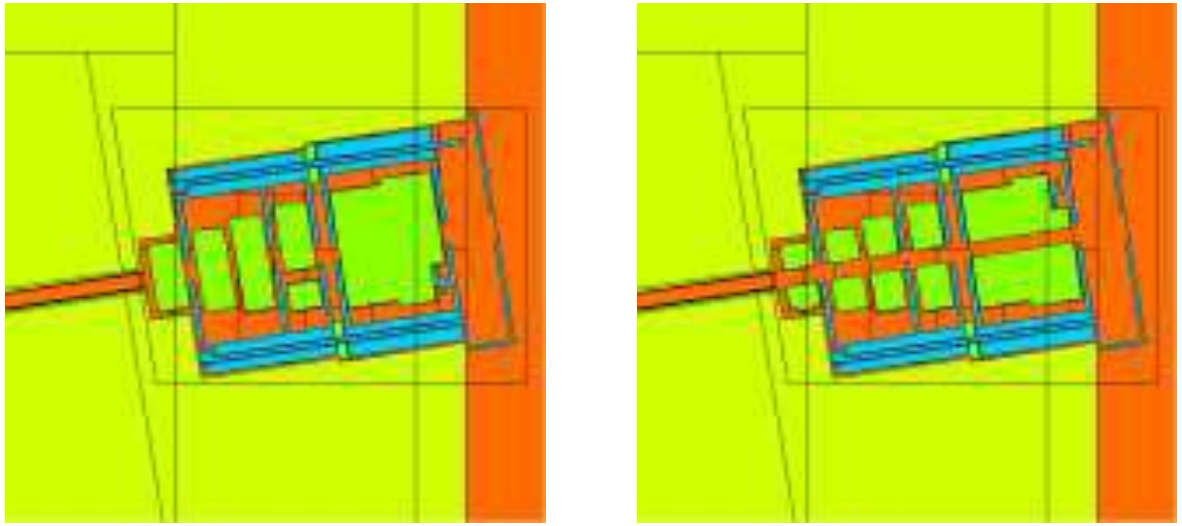
Involvement in IFMIF-DONES project under WPENS

One of the important systems of the IFMIF-DONES device will be the neutron beam line. It will guide the neutrons from the Test Cell (TC) to the Complementary Experiments Room (CER). The neutron beam from the Test Cell (TC) to the Central Experimental Hall (CEH) will be controlled by a neutron beam shutter (NBS) installed in the wall separating the two rooms. The system requires the development of general technical solutions to ensure that radiation protection requirements are met in the first place. Hence, before proceeding to the next phases of design work, it is extremely important to perform calculations verifying the correctness of the postulated solutions in terms of radiation protection. The neutron beam line consists of a neutron tube and a beam shutter. Shutter main task is to provide protection against radiation that will allow it to meet the relevant standards.

MCNP calculations of radiation transport, in particular neutron and gamma rays, in the designed neutron beam shutter were performed.



CAD models of a neutron shutter: (a) a closed position; (b) an open position

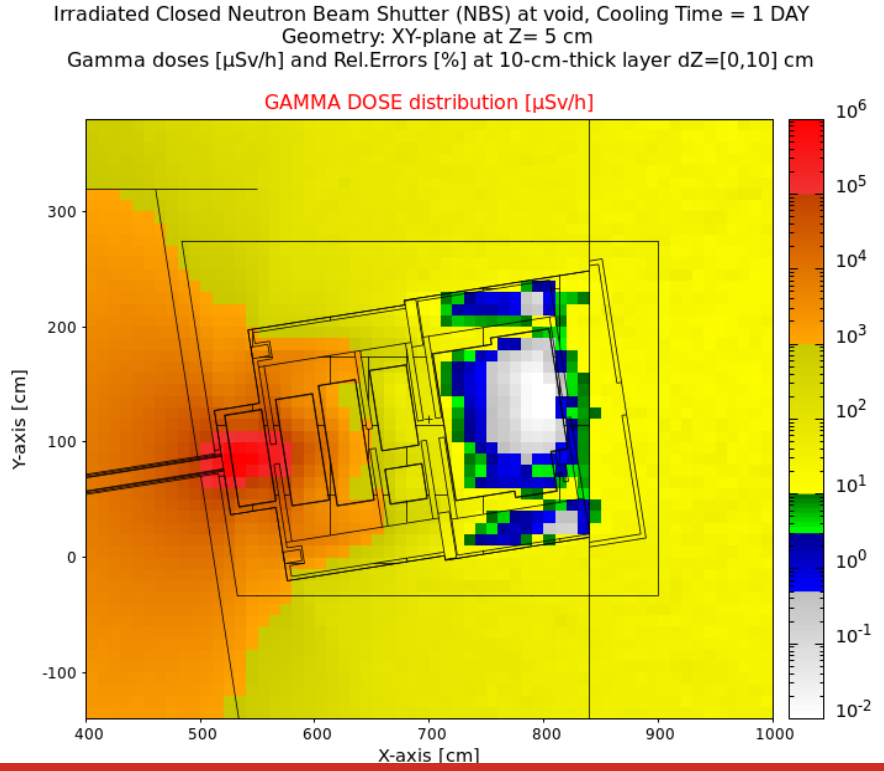


MCNP Shutter Models: (a) a closed position; (b) an open position

Involvement in WPENS – IFMiF-DONES project

Shutdown dose analysis for the neutron beam shutter (NBS) during maintenance

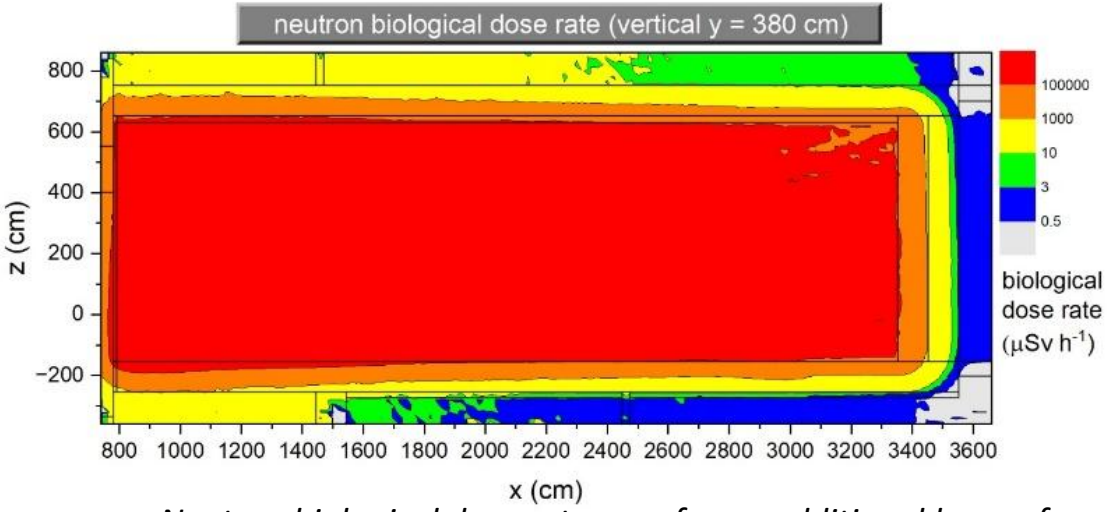
Shutdown dose rate calculations for the NBS following the termination of operation of the DONES neutron source were performed using the Rigorous Two-Step (R2S) method. Under giving operating condition, activation of the device and consequently the resulting radiation dose rates, is expected to be the highest. An irradiation period of 20 Full Power Years (FPY) was assumed.



Dose space distribution from gamma radiation in the NBS area after 1 day after stopping operation of DONES.

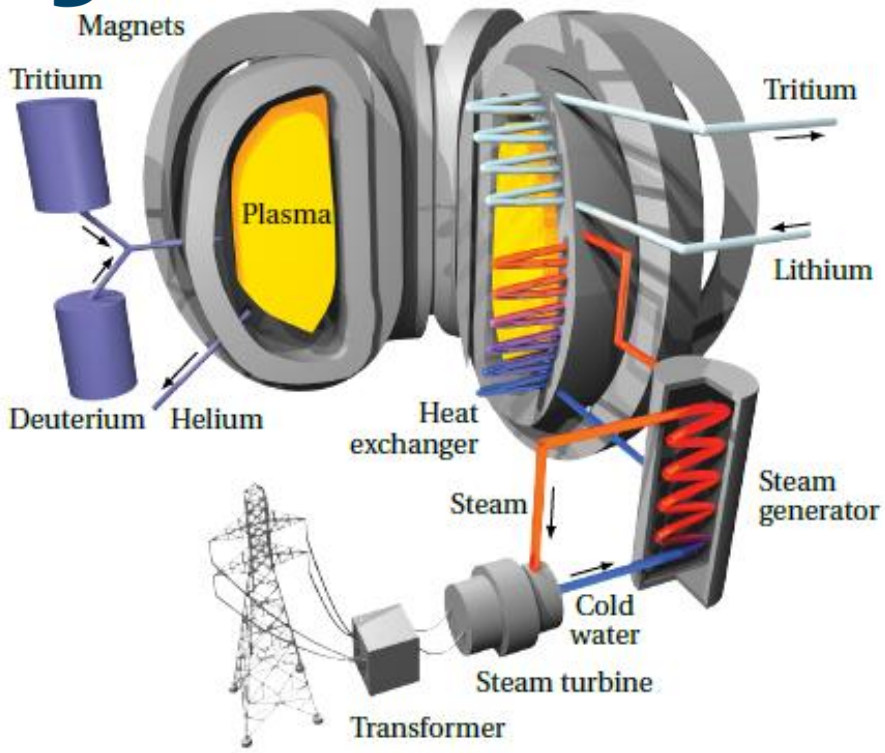
Consolidation of shielding approaches for the complementary experimental room (CER) during operation

The optimization of the shielding for Complementary Experimental Room (CER). A series of calculations were performed using the MCNP6 code. The calculations showed that the biological dose rate in the corridor decreased to below the specified limit for the green zone. However, dose rates in the Access Cell (AC) remained too high. The results indicated that additional shielding of the CEH ceiling would be necessary to reduce dose rates in the AC. The minimum calculated thickness of the polyethylene shielding, however, would make the structure excessively heavy, potentially creating safety issues and increasing costs. Therefore, it is necessary to identify an optimal material for the CEH walls by testing different types of concrete.



Neutron biological dose rate map for an additional layer of borated polyethylene on the ceiling (50 cm).

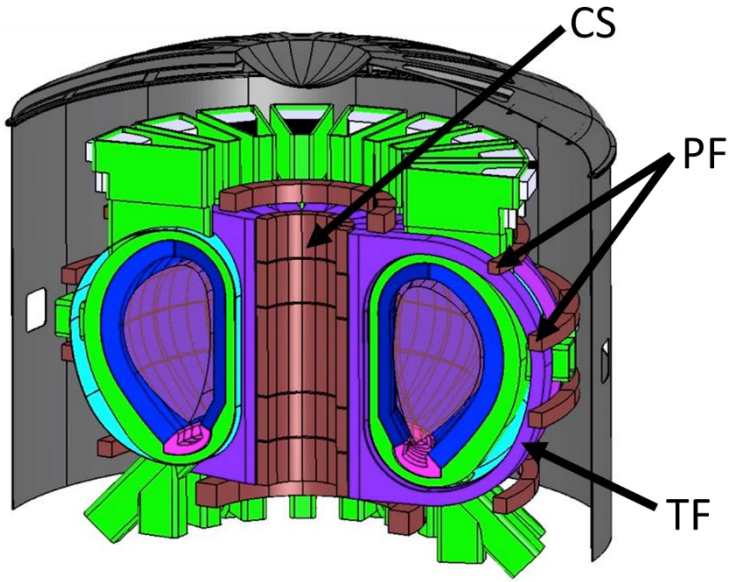
EU – DEMO and its magnet system



EU - DEMO – European DEMOnstration fusion power plant based on the tokamak concept with fully superconducting magnet system [1] was being designed in the scope of the **EUROfusion** project.

[1] Fusion Engineering and Design 174 (2022) 112971
[2] B. Meszaros, H. Hurzlmeier, EU DEMO1 2015 - DEMO_TOKAMAK_COMPLEX

View of the DEMO coils: CS, PF and TF [2]



- Step between ITER and a commercial power plant
- Net electricity production of a few hundreds MW
- Achievement of tritium self-sufficiency
- Attaining proper availability (up to several full-power years)
- Minimization of radioactive wastes

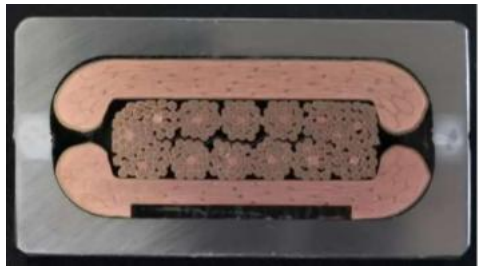
Analyses of superconducting coils designs

The EU-DEMO magnet system was being designed in the scope of the **EUROfusion Work Package Magnets (WPMAG**).

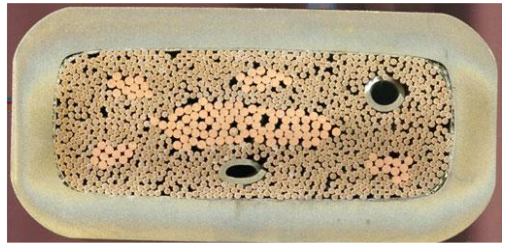
Numerous design concepts of the DEMO coils and conductors have been proposed by involved research units from EPFL-SPC (Switzerland), CEA (France), KIT (Germany), ENEA (Italy), Twente University (Netherlands). All candidate designs are subjected to comprehensive analyses:

- electromagnetic
- mechanical
- thermal - hydraulic

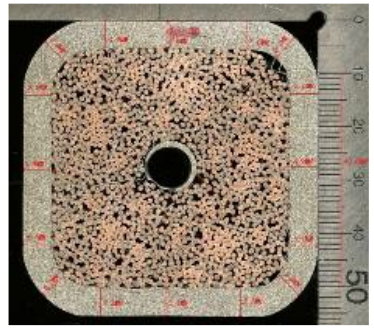
in order to verify if the proposed coil designs fulfill the acceptance criteria and to provide the information for further optimization of the conductors' dimensions and layouts.



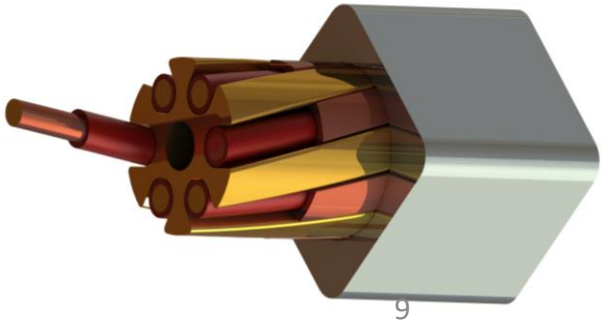
DEMO TF WP#1



DEMO TF WP#2



DEMO TF WP#3



DEMO CS, CORC HTS, TU design

Contribution of the WPUT/IFJ teams to thermal-hydraulic analyses of DEMO cables designs

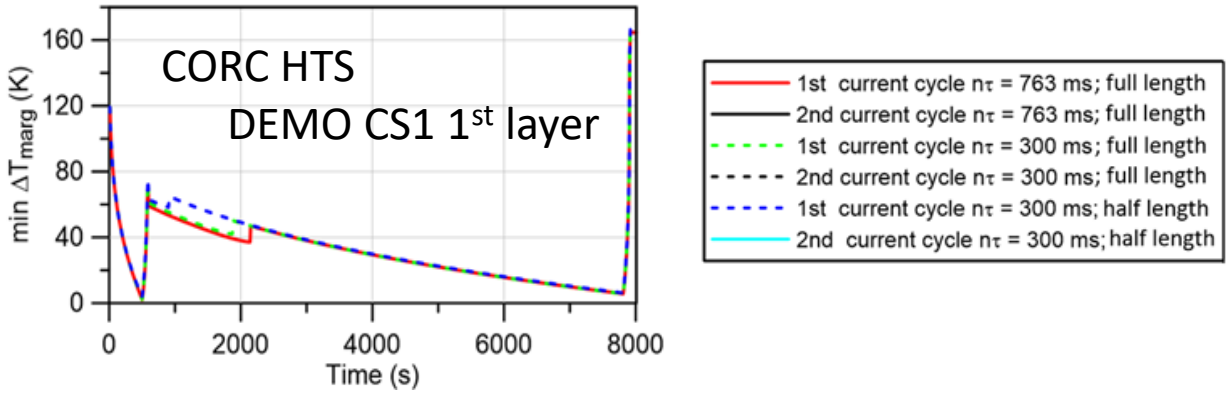
- Estimation of the maximum He mass flow rate in a coil (useful information designers of the DEMO cryogenics system)
- Verification if the minimum temperature margin in all conductors at operating conditions is sufficiently large (Fus. Eng. Des. 136 (2018) 1597):

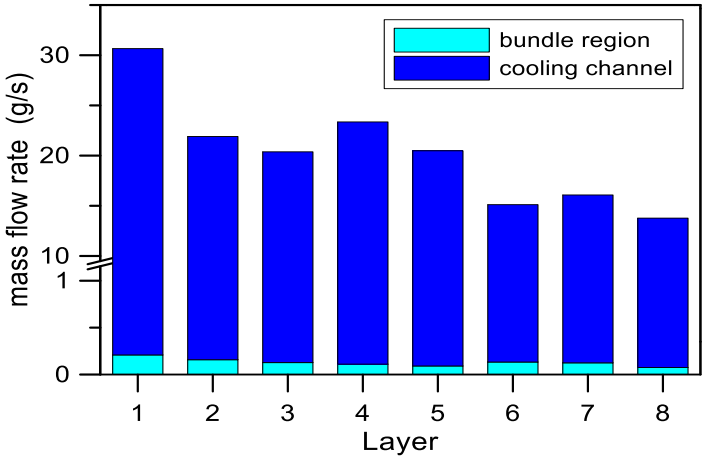
$$\textbf{minimum } \Delta T_{marg} = T_{cs}(x,t) - T_{sc}(x,t) > 1.5\ \text{K}$$

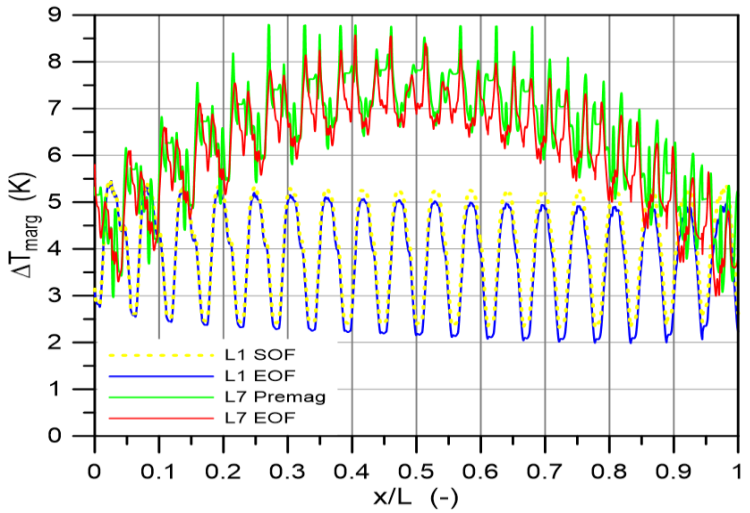
Verification if the maximum temperature during quench is sufficiently low:

$$\textbf{max } T_{jacket} < 150\ \text{K}$$

Analysis and interpretation of the results of SULTAN experimental tests of superconducting cables, aimed at tuning the parameters in numerical models.







WP#1 DEMO TF, EPFL-SPC design

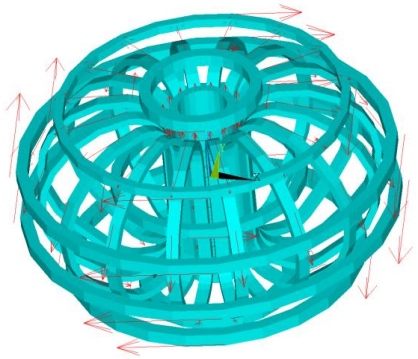
Selected reports: EFDA_D_2Q82VG - M. Lewandowska,et al., *Thermal – hydraulic analysis of the DEMO winding packs (2022)*
EFDA_D_2PG8C7 – M. Lewandowska, et al., *EU-CN Analysis of experimental results of quench test (2022)*
EFDA_D_2RCRJL - M. Lewandowska, A. Dembkowska, R. Ortwein, *Thermal – hydraulic analysis of the DEMO winding packs (2023)*
EFDA_D_ 2RCY8K - M. Lewandowska, R. Ortwein, A. Dembkowska, *EU-CN Analysis of AC losses and thermal – hydraulic simulations (2023)*

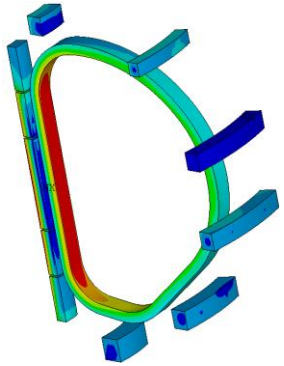
Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

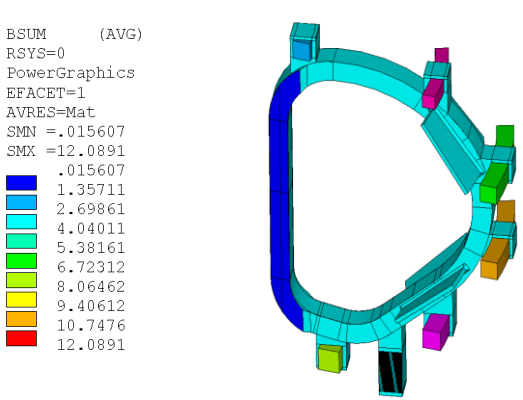
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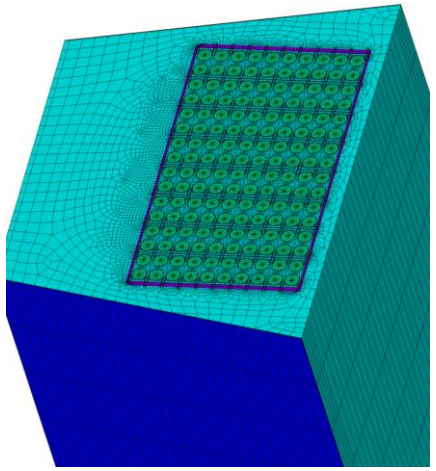
Contribution of the IFJ team to mechanical analyses of DEMO coils designs

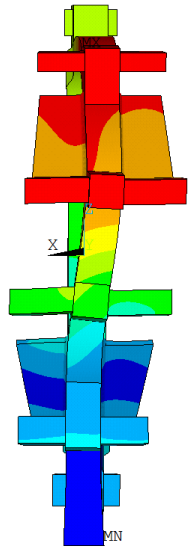
In this work the design of the TF coils was analysed from the mechanical point of view, assuming the CEA WP #4 coil design with circular superconducting cables and radial inserts. In order to obtain the electromagnetic forces acting on the coils a global electromagnetic model of the DEMO tokamak was built. The Ansys Mechanical APDL tool was used.

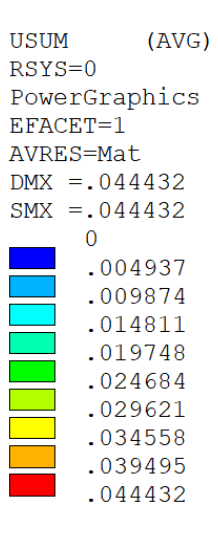








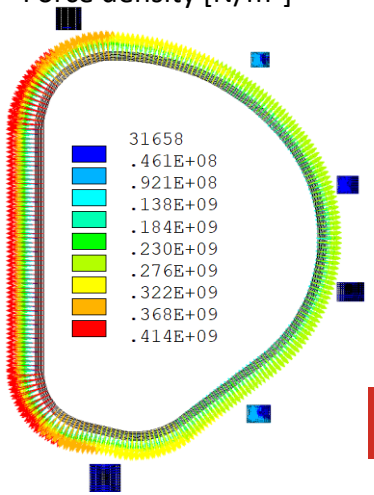


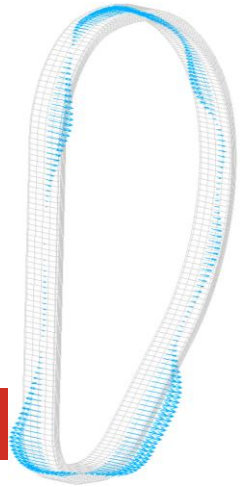


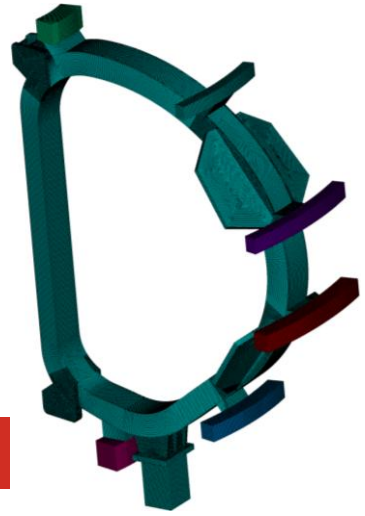
EFDA_D_2PFJQJ – R. Ortwein. Mechanical analysis of the TF WP#4 winding pack designed by CEA (2021)
EFDA_D_2Q7VLF – R. Ortwein. Update of the mechanical analysis of the TF WP#4

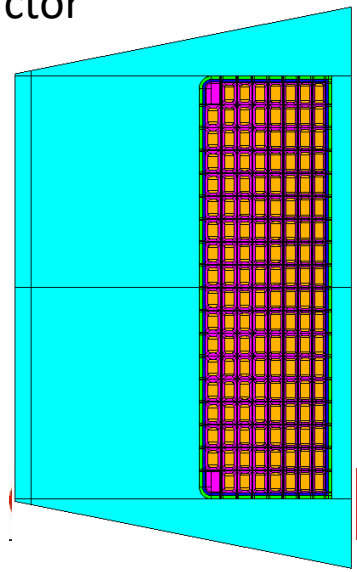
WP#1 EPFL-SPC design based on layer wound R&W conductor

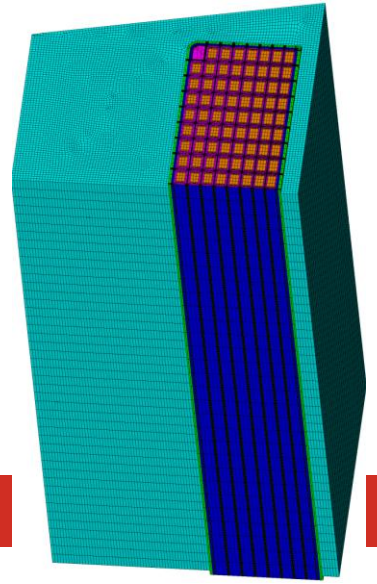
Force density [N/m^3]



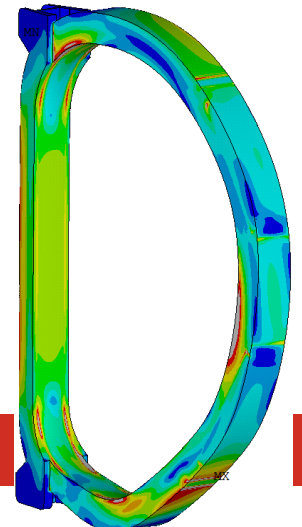


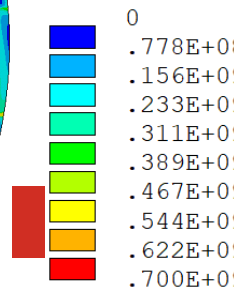






Tresca stress [Pa]



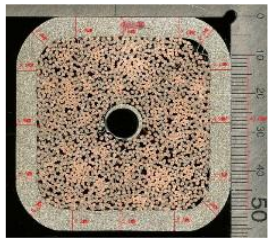


THETIS installation at West Pomeranian University of Technology

- The THETIS installation for hydraulic and thermal-hydraulic tests of superconducting cables or their components using demineralized water at various temperatures (from RT to about 60°C) was developed from scratch.

- The friction factor as a function of the Reynolds number (Re) was measured for several conductors or spiral ducts with geometries identical to those of Cable-in-Conduit Conductors (CICC) cooling channels. The results were used to develop friction factor correlations for thermal-hydraulic analyses.





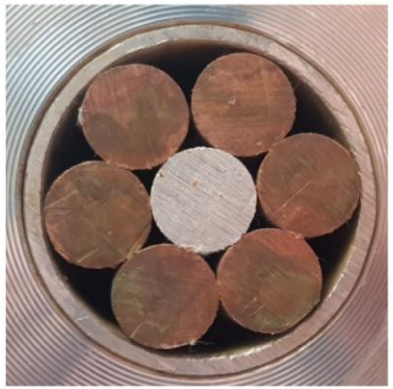
Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

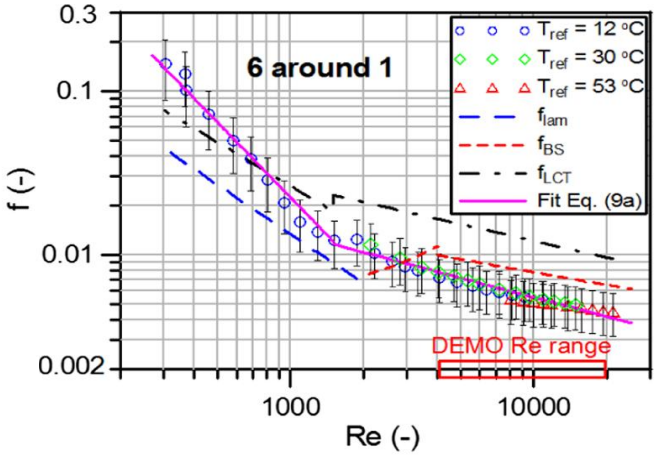
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THETIS installation at West Pomeranian University of Technology

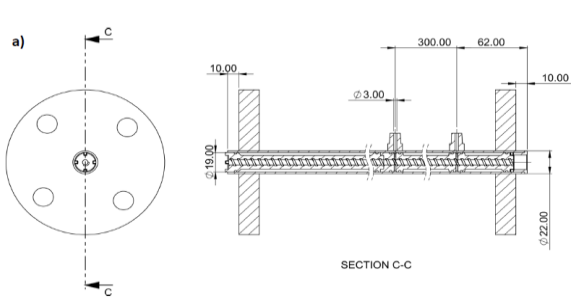
- The heat transfer coefficient between the CICC jacket and the flowing coolant was measured.

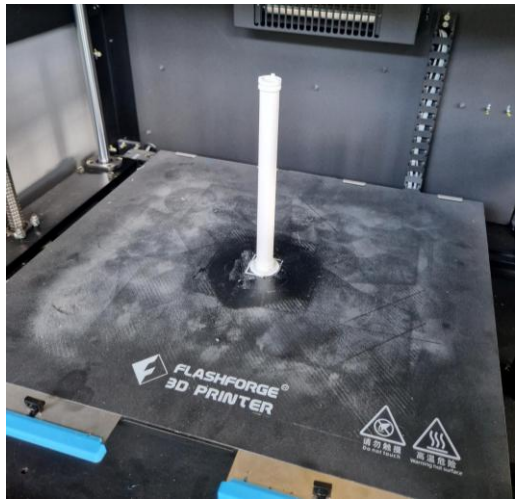
- New method of preparation samples with the same geometry as cooling channels in CICCs, suitable for hydraulic tests at THETIS, by 3D printing, was developed.

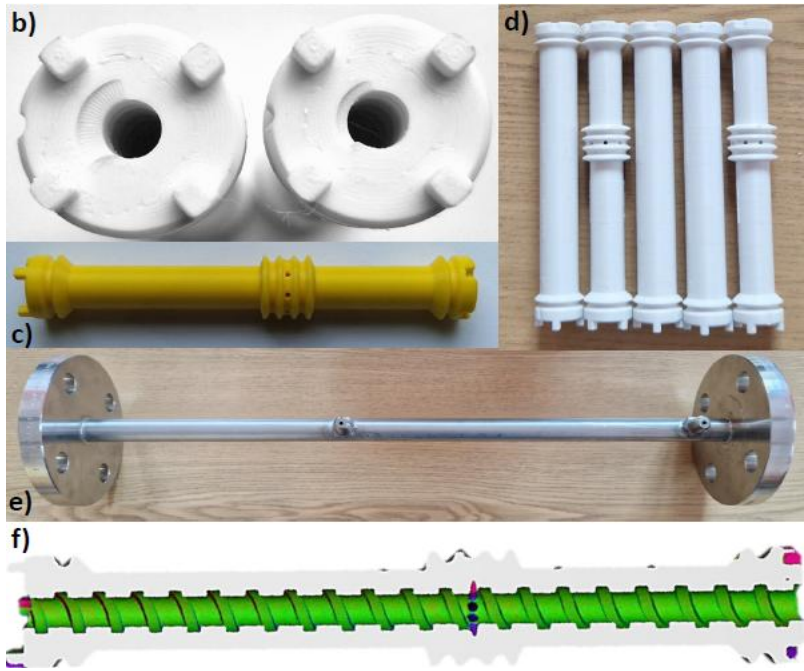




Cross section of one of tested samples and the results of its hydraulic test

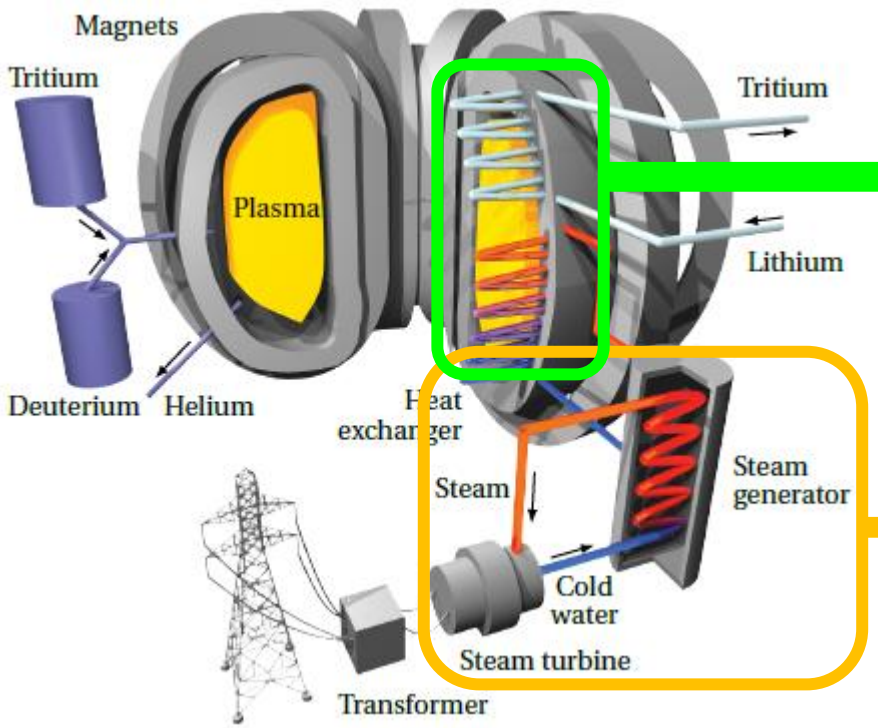






Sample preparation:
a) drawing and printing,
b)–c) details of the sample components,
d) printed components of the sample,
e) sample ready for the hydraulic test,
f) industrial CT scanner quality check of the sample

EU – DEMO Power Plant



Primary Heat Transfer System (PHTS)

Secondary Power Conversion System (PCS)

Various plant configurations and operational scenarios are being analyzed in the scope of the EUROfusion **Work Package Balance of Plant (WPBOP)** and their feasibility and cost are assessed.

Challenge:
drastic drop of the reactor thermal power during the dwell phase (down to 1% of the nominal values)

In some concepts, an **Intermediate Heat Transfer System (IHTS)** featuring an **Energy Storage System (ESS)** with **Molten Salt (MS)** tanks is added between the PHTS and PCS

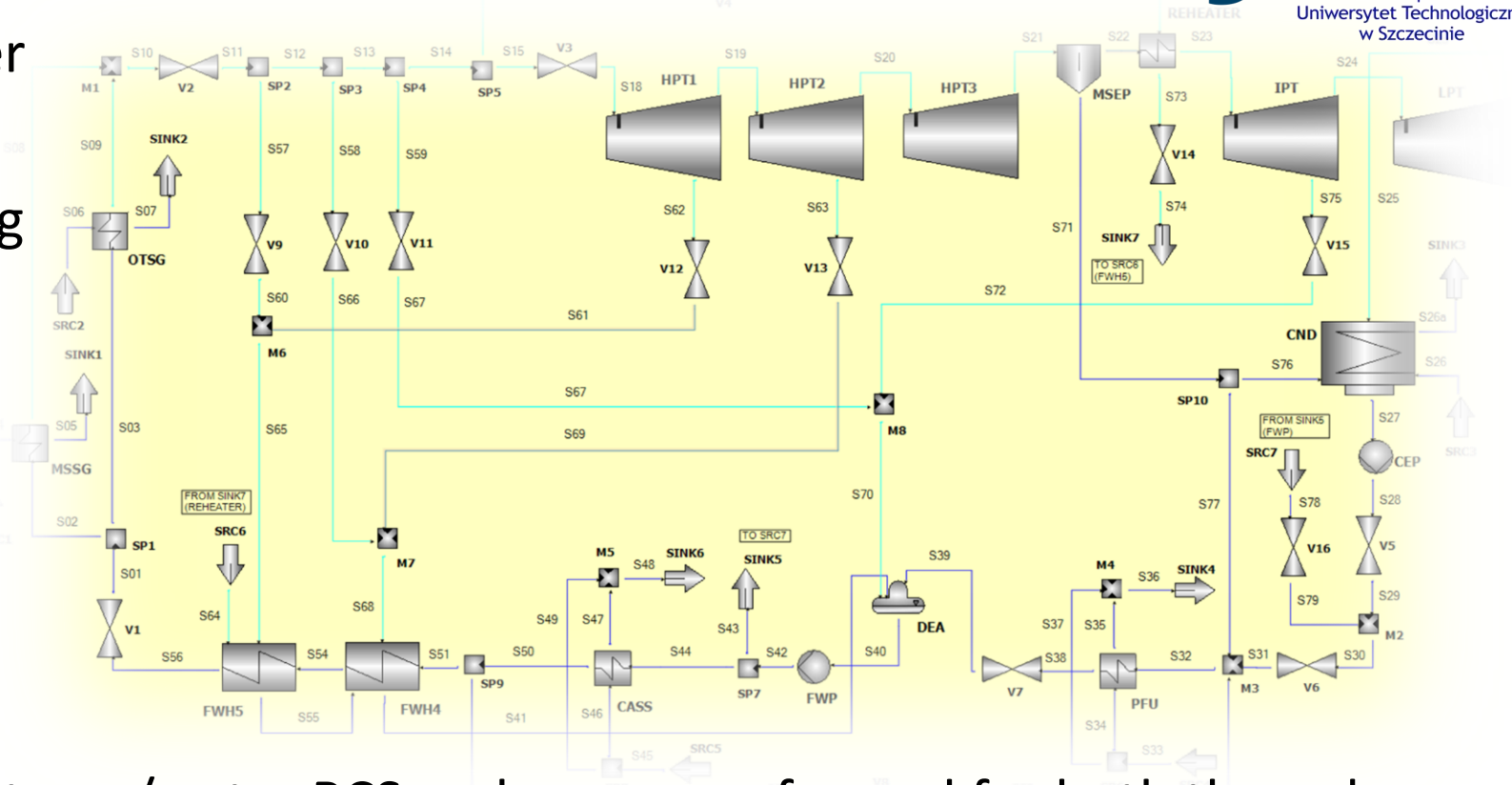
- **Pro**: almost constant production of electricity during pulse and dwell,
- **Con**: increased complexity and cost of the plant, integration and safety issues.

Other options featuring direct coupling between the PHTS and PCS, with a significant reduction of the net output in dwell, are being studied in parallel

WPBOP activities of the WPUT team

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

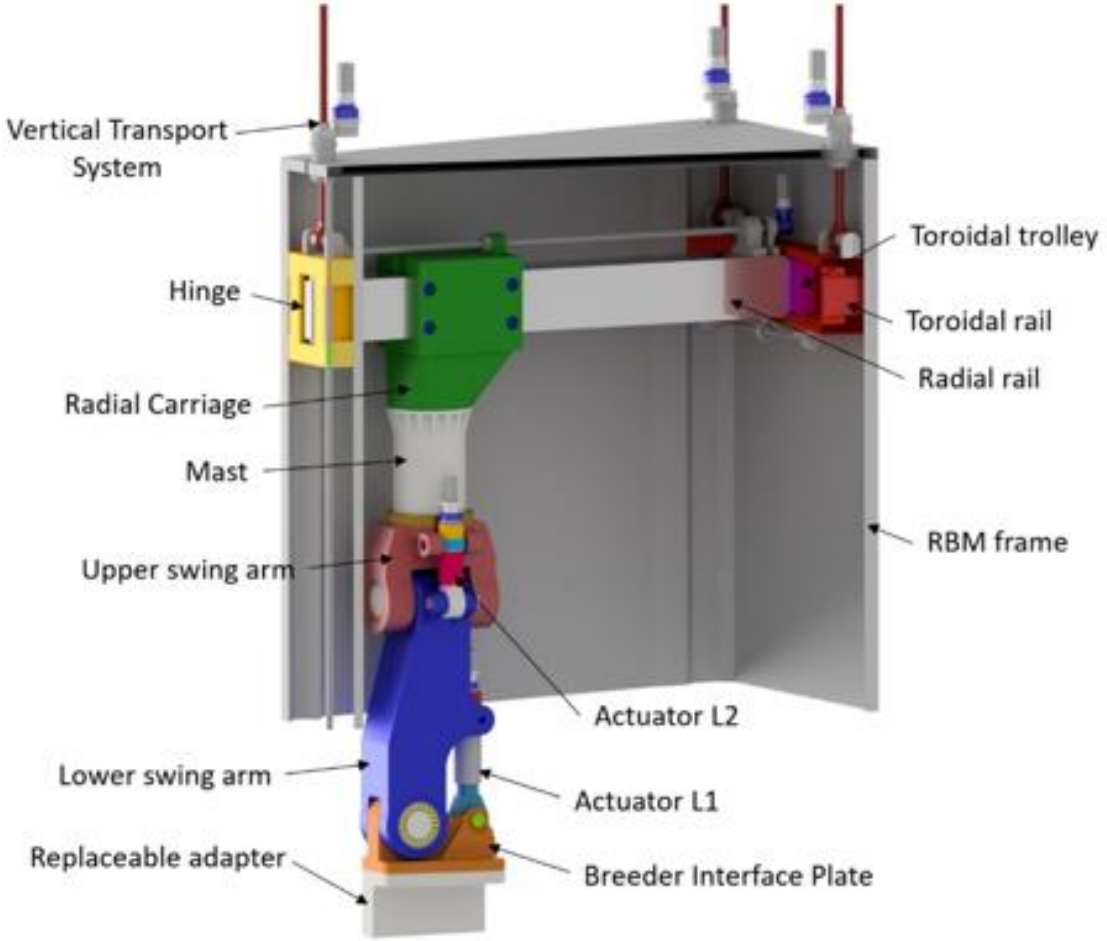
- Detailed models of several Power Conversion Systems circuit configurations were created using GateCycle software.
- Each model enabled preliminary design and sizing of the main circuit components.



- Steady-state simulations of the steam/water PCS cycle were performed for both the pulse and dwell phases.
- Electrical power output and efficiency were evaluated for various variants and operational scenarios of the DEMO power plant, confirming their potential feasibility.

NCBJ involvement In-Vessel Remote Maintenance Development

Task: develop the concept of the RBM (Rail Base Mover). Inside the Tokamak there are BB (Breeder Blankets) which have to be replaced remotely every few years.



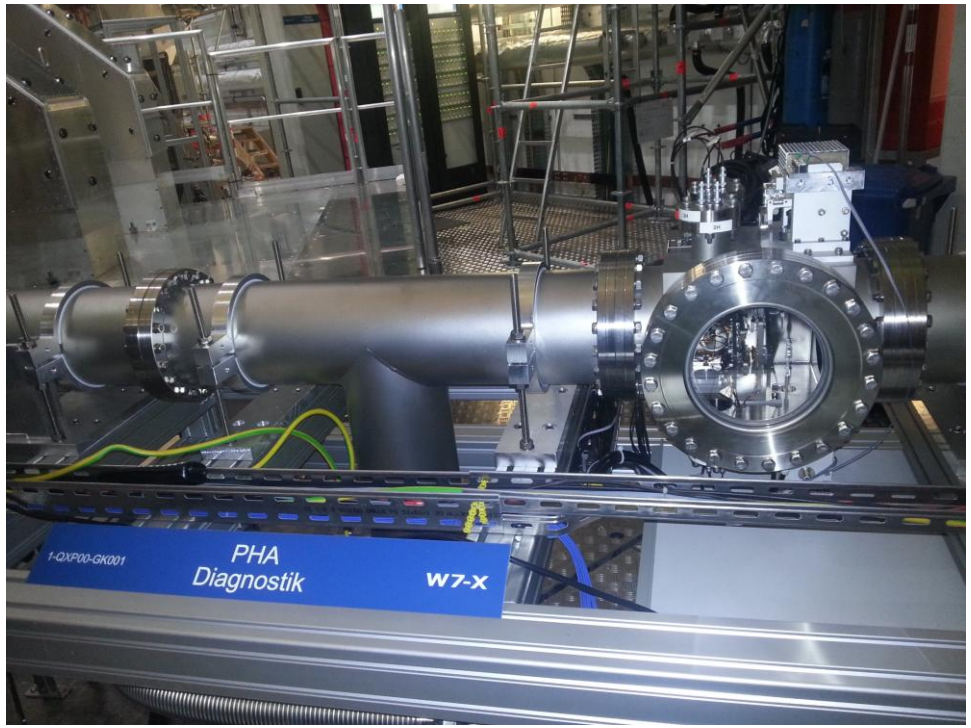
The RBM was designed to replace the BBs in the worst cases in the seismic environment. The initial strength calculations show that most of the structural components and components on the shelfs withstand these harsh requirements but at the expense of the large size and weight of the RBM elements.

RBM can be used for the first stage of replacement of BBs; kinematically feasible, structurally sound, but displacement during seismic events is a concern.

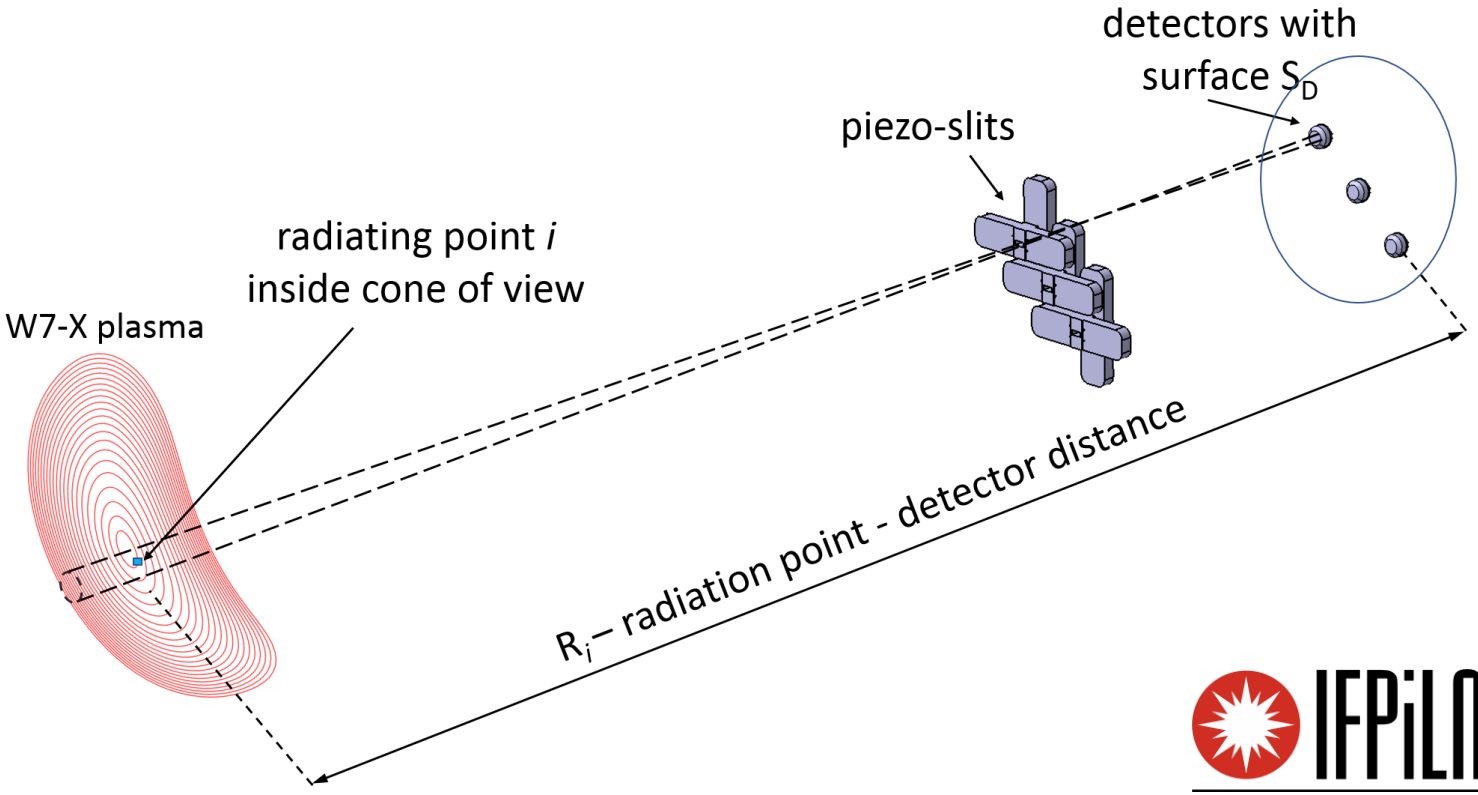
Involvement in diagnostic design and development

- Gas electron multiplier (GEM) detector for high resolution VUV cristal spectrometer at JET- KX1 diagnostic
- Pulse Height Analysis diagnostic for W7-X
- CO-monitor system for W7-X – diagnostic
- Cherenkov detectors for WEST, TCV
- Vertical Neutron Camera (VNC) for JT60-SA
- …..

Involvement in diagnostic design and development



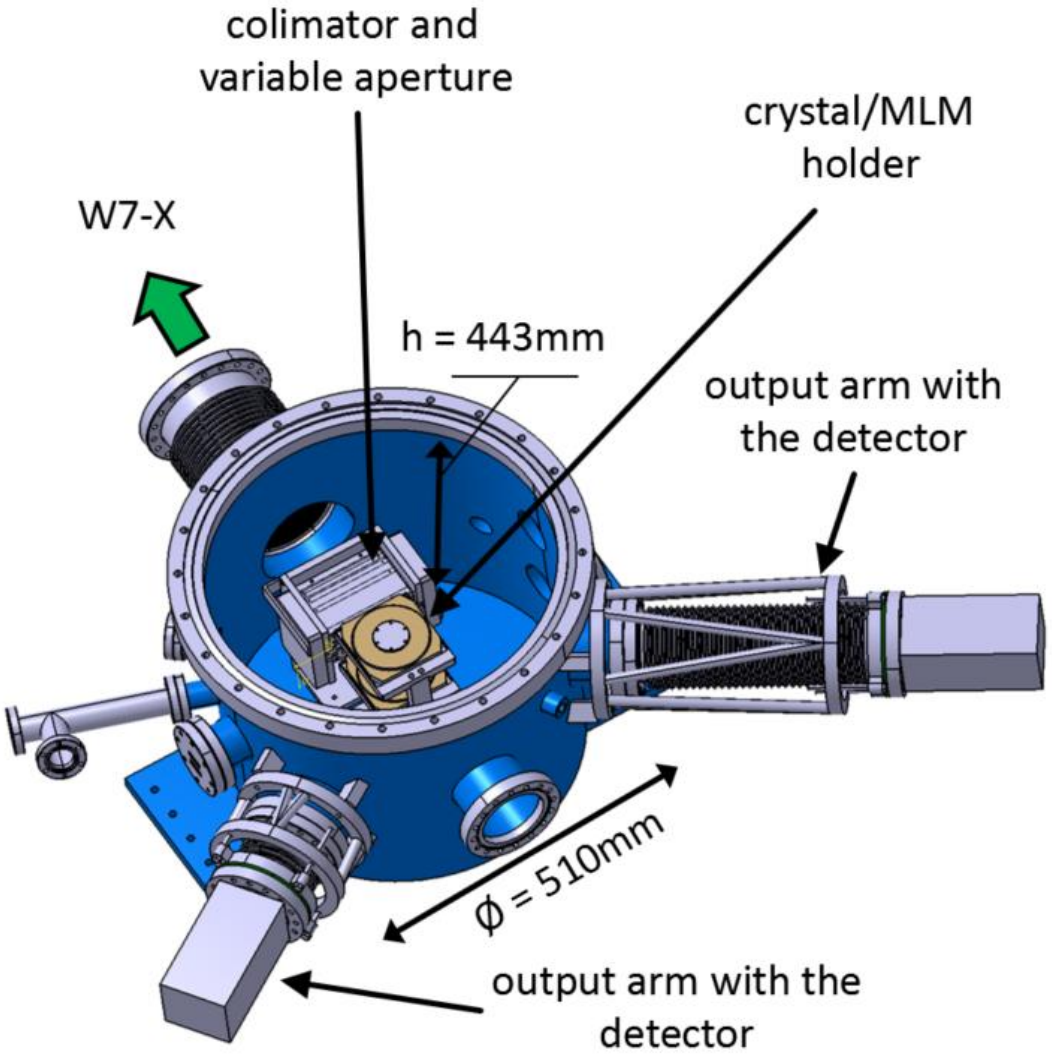
1. Design based on the simulations results – IPPLM dedicated code
2. Selection of the detectors
3. Selection of the materials



4. Manufacturing with the certificate of materials and leakage test
5. System in operation since first plasma in 2015

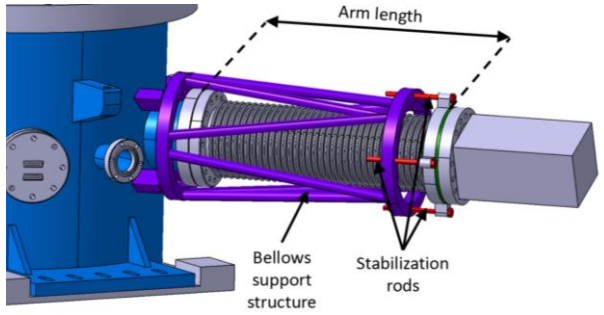
Involvement in diagnostic design and development

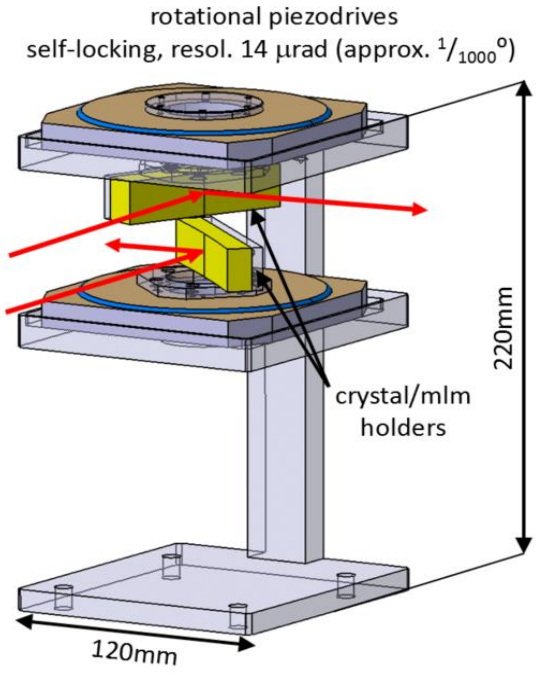
CO monitor system for W7-X



Crystal holder

- Adapted dispersive elements: MLM for C, B and N observation; TIAP for O;
- Piezoelectrical rotational drives;
- Ensures the fine-tunning of the angle of dispersive element;
- Once the position is set, it remains fixed;



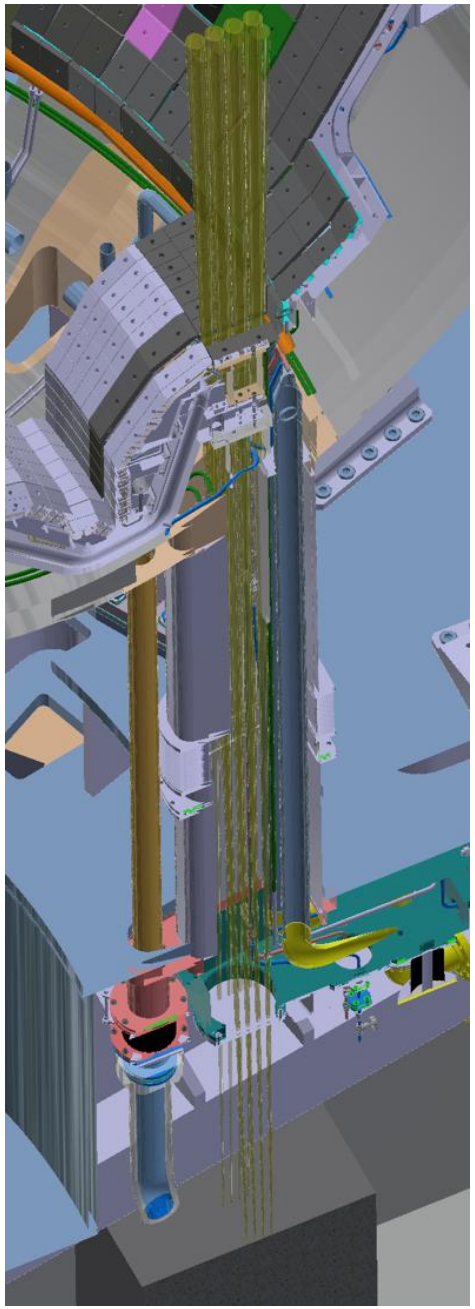


Involvement in diagnostic design and development

Feasibility study for installation of a Vertical Neutron Camera (VNC) for JT-60SA tokamak:

Based on the technical design, an assessment was conducted regarding the feasibility and potential placement of the VNC at several proposed locations. Taking into account the restricted field of view, caused by interference from structural components within the diagnostic channel and the size of the gap between the divertor panels above the port, the spatial and temporal resolution capabilities were estimated for selected scenarios. Preliminary neutron transport calculations were performed for various shielding thicknesses and collimator widths at the proposed location.

- detector requirements:
  - spatial resolution: < 20 cm
  - statistical accuracy: < 3%
  - temporal resolution: < 10 ms
- calculation of expected detector count rates for scenario S5-1:
- 25 mm thick organic scintillator → 20% det. eff. @ 2.45 MeV neutrons
- 10 mm diameter collimator → 10^5 cps → 1000 events / 10 ms
- 1.4 m collimator length → 6.8 mm spatial resolution (FWHM)



NCBJ

IFPiLM

Summary

- Participation in fusion technology activities covers a very broad range of topics, from hydraulic studies and materials to structural design, including the design of a movable arm for component replacement, as well as plasma diagnostics.

- Polish research units have experience in MCNP simulations, design and CAD drawing and modelling, as well as all related structural and mechanical strength analyses.

- In addition to a highly skilled engineering staff, we also have scientists working at fusion facilities around the world who use the designed components and diagnostic systems for the research.

Thank you for the attention!