AWP 2022

Title: Coordination of In-Vessel Coils Design and Analysis work 2022
IMS task ID: DIV-IDTT.P.1-T019

Title: In-vessel coils Design and Analysis 2022
IMS task ID: DIV-IDTT.S.07-T005

DIV-IDTT.P.1-T019 Del. Owners: Mauro Dalla Palma, Tommaso Bolzonella, Giuseppe Ramogida

DIV-IDTT.S.07-T005 Del. Owners: Roberto Ambrosino, Tommaso Bolzonella

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This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Outline

- Coordination of In-Vessel Coils Design and Analysis work 2022: deliverables and allocated resources
- In-Vessel Coils Design and Analysis work 2022: deliverables and allocated resources
- Activities and synergies among the systems within In-Vessel Coils:
    - stabilizing plates (STP)
    - in-vessel coils axial symmetric (ICA)
    - in-vessel coils not axial symmetric (ICN)
- Locations of joints in ITER
- Requirements of coil cable and joint
- Main characteristics of coil cable and joint

Coordination of In-Vessel Coils Design and Analysis work 2022

DIV-IDTT.P.1-T019 deliverables and allocated resources:

ID	Title	Start Date	End Date	RU	Del. Owner	AWP2022
						PM 50% standard
DIV-IDTT.P.1-T019 - D001	Coordination of the Design and Analysis of In-vessel Coils 2022 – Lead Engineer	01-Jan-22	31-Dec-22	ENEA	Mauro Dalla Palma	2.000
DIV-IDTT.P.1-T019 - D002	Coordination of the Design and Analysis of In-vessel Coils 2022 – Deputy Engineer	01-Jan-22	31-Dec-22	ENEA	Tommaso Bolzonella	2.000
DIV-IDTT.P.1-T019 - D003	Coordination of the Design and Analysis of In-vessel Coils 2022 – Deputy Engineer	01-Jan-22	31-Dec-22	ENEA	Giuseppe Ramogida	2.000
					TOTAL:	**6.000**

In-Vessel Coils Design and Analysis 2022

DIV-IDTT.S.07-T005 deliverables and allocated resources:

ID	Title	Start Date	End Date	RU	Del. Owner	AWP2022 PM 50% standard
DIV-IDTT.S.07-T005 - D001	Design, analysis, and integration of stabilizing plates	01-Jan-22	31-Dec-22	ENEA	Roberto Ambrosino	7.000
DIV-IDTT.S.07-T005 - D002	Design, analysis, and integration of axial symmetric in-vessel coils	01-Jan-22	31-Dec-22	ENEA	Roberto Ambrosino	15.000
DIV-IDTT.S.07-T005 - D003	Design, analysis, and integration of not-axial symmetric in-vessel coils	01-Jan-22	31-Dec-22	ENEA	Tommaso Bolzonella	15.000
					TOTAL:	37.000

Working Team:

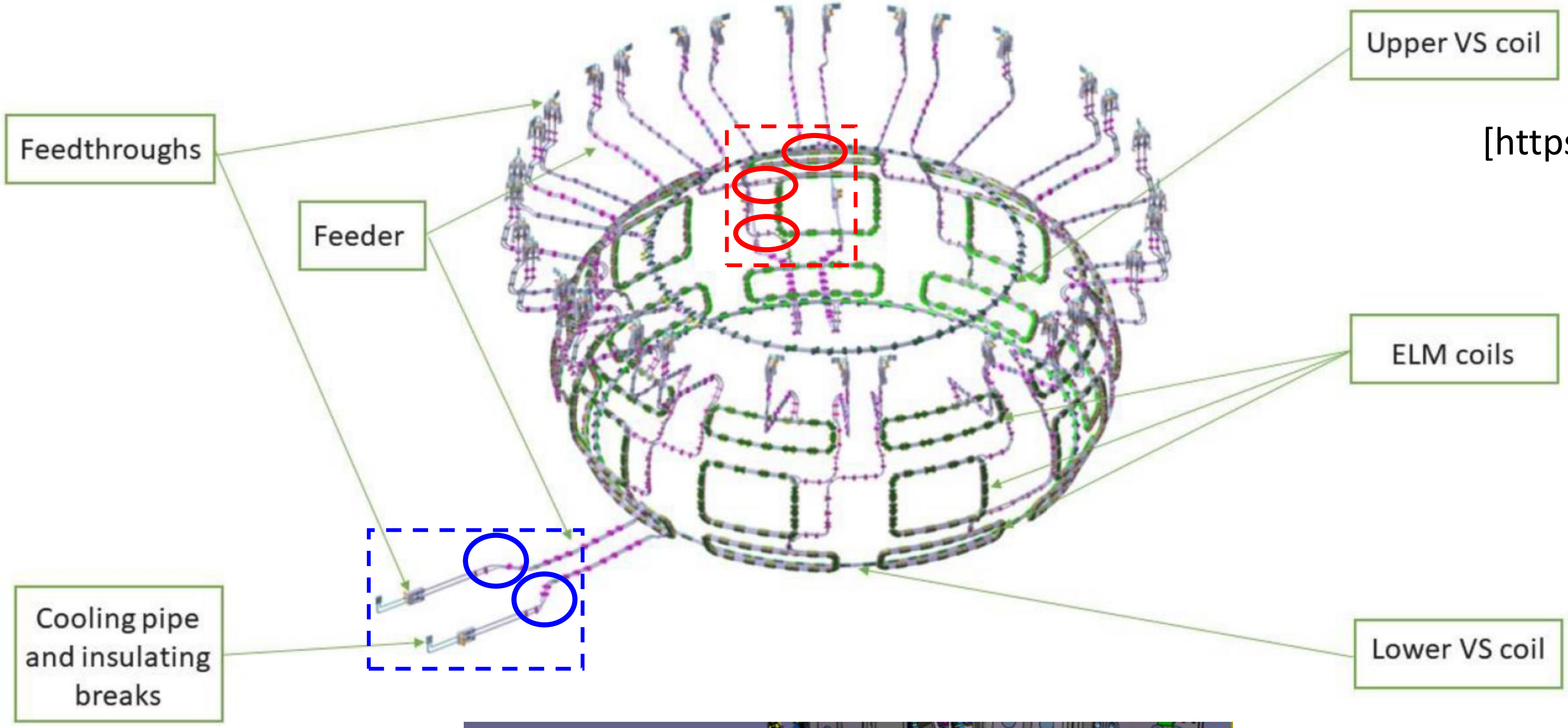
Institution	Activity
Consorzio RFX	Conceptual design
Create M&C	Electromagnetic and control specification including disruption analyses Design and position of the coils including thermal analysis of the in-vessel coils
PoliTo	Joining and testing of multi-material components
Uni Tuscia	Mechanical design & electromagnetic loads specification
Uni Tor Vergata	Static thermo-structural analyses on in-vessel coils under EM loads Engineering design of the in-vessel coil attachments to the vacuum vessel Engineering design of the in-vessel coil feeders

In-Vessel Coils Design and Analysis - activities

- Activities:
  A. Revision of System and interface requirements
  B. Electromagnetic (EM) and control specification including disruption analyses (revision of plasma equilibrium)
  C. Design and position of the in-vessel coils including thermal analysis of the in-vessel coils (duty cycle)
  D. Joining and testing of multi-material components (coaxial configuration with inner fluid bulk, copper conductor, electrical isolation, steel jacket as vacuum boundary)
  E. Mechanical analyses and verifications
  F. Engineering design with thermo-structural analyses and verifications, applying EM loads, of:
     - attachments to the vacuum vessel
     - feeders
  G. Verification of interfaces, in particular with the other in-vessel components, the vacuum vessel, and the power supply

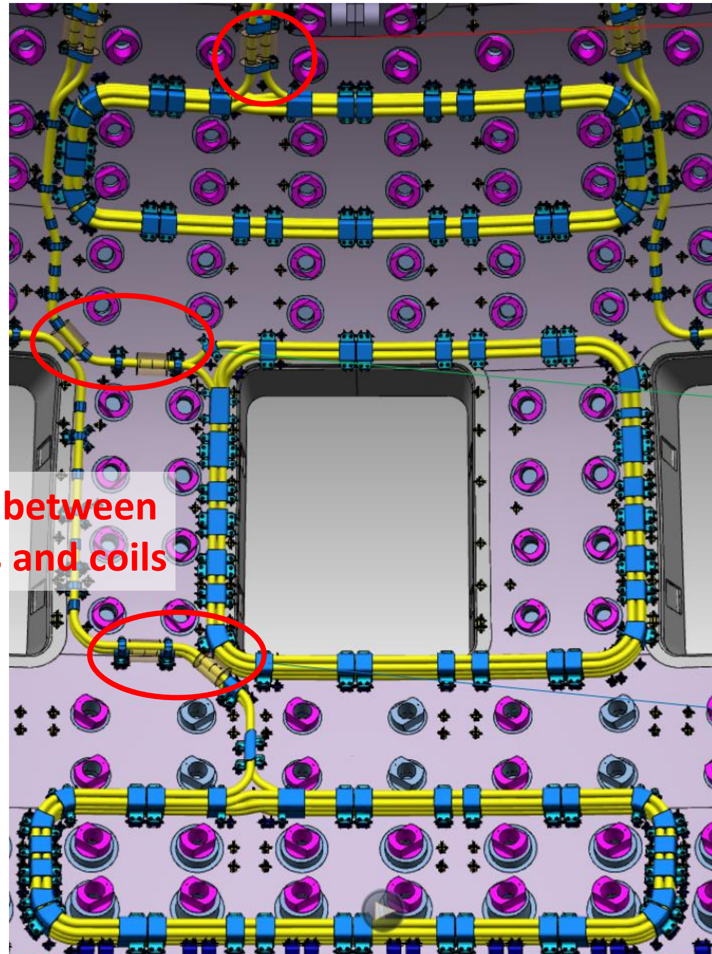
- Synergies among systems and Teams:
  - Sharing of resources and activities among STP, ICA, ICN (working Team presented in the previous slide)
  - Collaboration with IPP Team that is integrating similar in-vessel coils in ASDEX Upgrade

Locations of joints in ITER

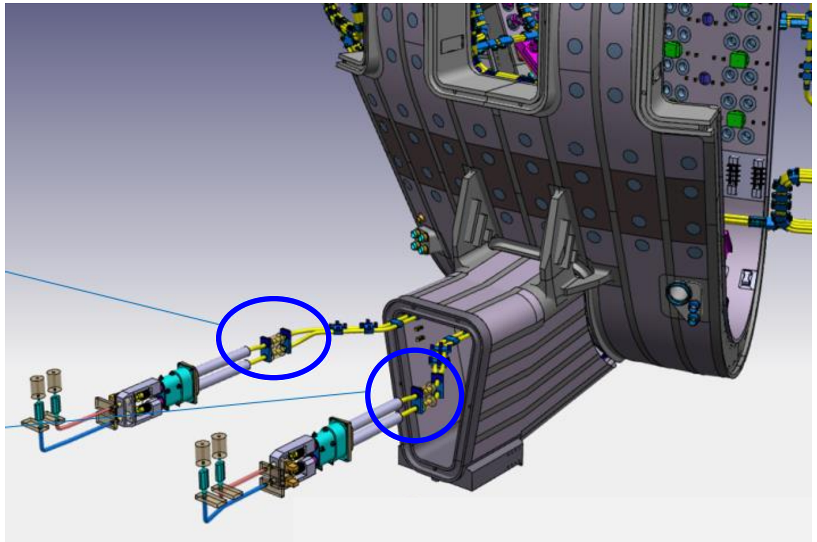


[https://doi.org/10.1016/j.fusengdes.2021.112527]

In-vessel joints between feeders and coils



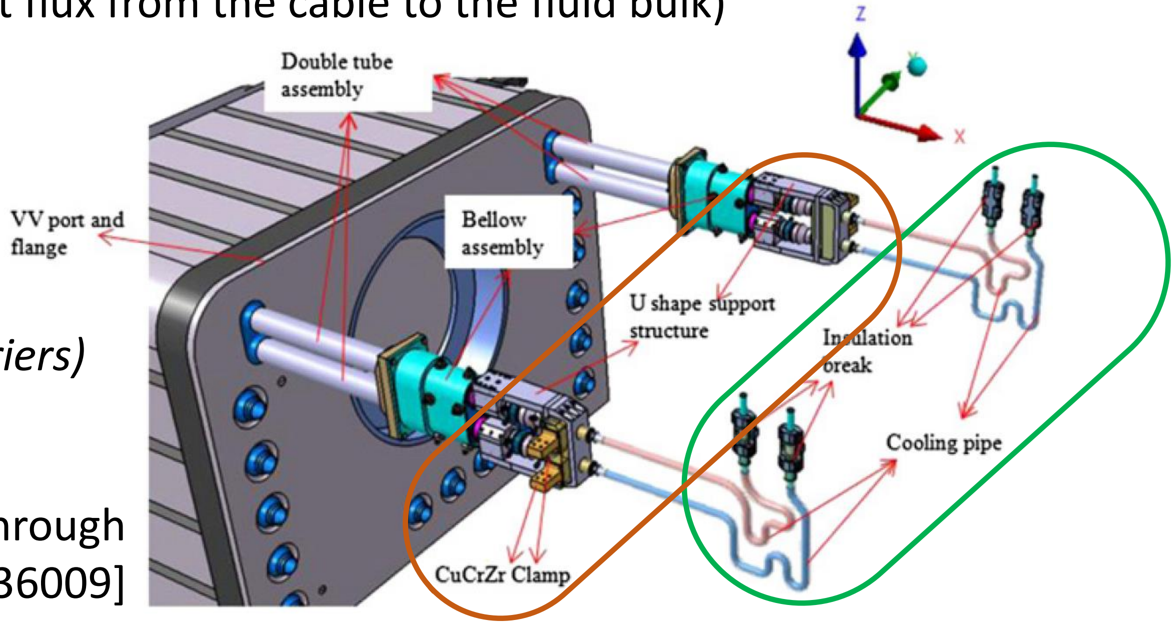
Ex-vessel joints between feeders and feedthroughs



Requirements of coil cable and joint

- Amperturn (magnitude/effective value)
- Current and voltage at power supply interface
- Coil operational time related to pulse duration and duty cycle
- Electrical isolation
- Vacuum boundary at the cable jacket
- Fluid boundary at the copper conductor
- Material maximum allowable temperature compatible with:
  - Power exhausting through active cooling (convective heat flux from the cable to the fluid bulk)
  - Vessel baking temperature
- Separated ex-vessel interfaces:
  - Power supply (**clamps bolted onto copper conductor**)
  - Cooling supply (**pipes joined with copper conductors**)

  (conceptual layout, DTT design does not require double barriers)



[Structural integrity assessment for ITER lower VS coil feedthrough
Xuebing Peng et al 2021 Nucl. Fusion 61 036009]

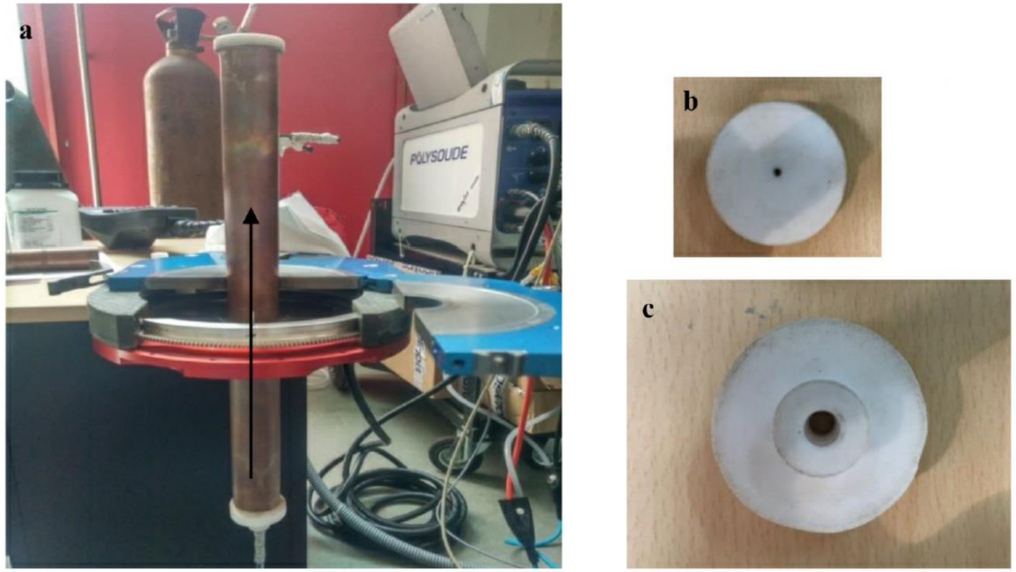
Characteristics of coil cable and joint

- Forming and integration of coils:
  - Coils and feeders will be formed at the supplier premises (ICN)
  - Coils will be field-formed inside the vacuum vessel (ICA)

  } Joints are made at the first installation and in case of maintenance/repair

- Main issues addressing the activities are:
  - Copper conductor welding with restoration of fluid boundary at the joints
  - Continuity of the electrical isolation at the joints (surface treatments to be studied, in particular using a technopolymer, in order to enhance adhesive bonding: chemical, mechanical, or both)
  - Jacket welding with restoration of vacuum boundary
  - Jacket non destructive testing [Xiao-Chuan Liu et al 2020 J. Phys.: Conf. Ser. 1559 012068]
  - Minimum bending radius [IEC 60702-3:2016]
  - Compatibility with geometrical/interface constraints and interfaced components

Orbital TIG welding of copper for high vacuum boundary applications [https://doi.org/10.1016/j.ijpvp.2020.104225]



(a) Purging gas supply from downward to upward (b) Teflon cap of diameter 1 mm at top (c) Teflon cap of diameter 6 mm at bottom.

Thank you for your attention and enjoy next presentations

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