DEMO diagnostic development (WPDC): *Studies on the architecture, system design and integration of ECE diagnostics for mode detection and electron temperature measurements*

M. Zerbini, M. Alonzo & G. Rocchi

WIP 021 Giugno 2022, Frascati

PROLEGOMENON:
ciclo informativo WIP's PLAS

- Risultati diagnostiche THz, Enabling Research, collaborazione Clarendon *(fatto: Febbraio 2020)*
- Collaborazione con DIII-D San Diego (*fatto: 21 Febbraio 2022*)
- JET 1999-2002: dal Michelson ECE al Real Time Control (04 Aprile 2022)
- *ECE DEMO (WPDC) (oggi)*

Task Specification (TS)

TS Title:	DEMO diagnostic development: Studies on the architecture, system design and integration of ECE diagnostics for mode detection and electron temperature measurements		
TS Ref. Nr.:	DC-S.01.06-T002	Task coordinator:	Marco Zerbini
Status:	Accepted	Date:	06-May-2022

Technical Specification:

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DEMO diagnostic development: conceptual studies on the architecture, design, feasibility, lifetime and measurement performance of diagnostics, their components and subsystems; support the studies on diagnostic integration in DEMO; in particular related to the development of ECE diagnostics for mode detection and electron temperature measurements on DEMO:

General topics:

- Review the results from previous studies, in particular the pre-conceptual work status achieved in WPDC from 2015-2020, assess which results are still valid and analyse what are the main gaps in the current development status.
- Update/revise the design description document (DDD) for ECE on DEMO, summarising the current design status in a documented and traceable way (full results in the DDD, or specific references to other relevant documents on IDM), based on the DDD version from 2021.
- In close collaboration with MHD mode control group: Perform wave propagation simulations and antenna design studies to define the number and locations, and to optimise the layout and performance of the ECE diagnostics on DEMO related to the main targets mode detection and measurement of the electron temperature profile.
- In close collaboration with the WPDC system engineers, contribute to the design integration into the DEMO baseline, and to the definition and updating of system requirements.
- Conduct urgent specific studies upon request by the PL and review documents (e.g. DDDs or final reports) from other WPDC tasks upon request by the PL.
- Frequent communication with the project leader and with participants in WPDC; regular participation in relevant technical meetings.
- Writing the final report on 2022 work, covering the points of the technical specification of this task (referring to technical contents of the DDD, not to be repeated).

Priorities 2022:

- CAD design of ECE in-vessel components and their arrangement in DEMO, number and position of channels, and overall space allocation, integration

with ECRH and other diagnostics, vacuum interfaces.

- Waveguides material opto-mechanical characteristic, characteristics of inner surfaces (corrugated, smooth, level of finishing, possible coating)
- Choice of curvature methods: bends, mirrors, suitable angles, solutions for ECE radiation receiving components (simple truncated waveguide, cones, non-imaging concentrators)
- Final choice of ECE diagnostics type, number, calibration systems and methods.
- Study of thermal loads, cooling systems, components lifetime due to neutral particle fluxes & radiation exposure studies.
- R&D laboratory and machine tests for the validation of the design above described (budget 10 keuro for 2022).
- Develop a maintenance approach (in close collaboration with the WPDC system engineers), assess the compatibility to remote handling, and perform quantitative analyses to predict the measurement performance of the ECE system.

Perspective topics (to be addressed in full in 2023):

- Development of concepts for system commissioning, (in-situ) calibration, signal quality and data validation.
- Contribution to writing and updating a risk register. Development of specific risk mitigation strategies.
- Liaise with IST, to provide inputs for detailed neutronics studies to be conducted by IST.
- Liaise with control experts within WPDC, to define SMART requirements for ECE measurements in support of control simulation studies and control system design.

Deliverables of the task:

Deliverable	Description
DC-S.01.06-T002 - D001	
DC-S.01.06-T002 - D002	

Allocated resources:

ID	Title	Start Date	End Date	RU	Del. Owner	AWP2022	
						PM 50% standard	Eq./OGS 40% standard
DC-S.01.06-T002 - D001	Revised DDD for ECE measurements on DEMO	01-Jan-22	30-Jun-22	ENEA	Marco Zerbini	2.000	10.000
DC-S.01.06-T002 - D002	Final report on conceptual studies for ECE diagnostic design, covering the technical specification of this task specification (technical contents of the DDD not to be repeated here)	01-Jan-22	31-Dec-22	ENEA	Marco Zerbini	2.000	
					TOTAL:	**4.000**	**10.000**

Acceptance criteria for this task:

- The task shall be carried out along the lines defined in the technical specification.
- Achieved Deliverable(s) to be reported and approved through EUROfusion IDM (https://idm.euro-fusion.org)
- *further criteria as required*

Timeline ECE DEMO WPDC

- Started 1.1.2021
- Intermediate Meeting 15/9/2021
- *Topical meeting microwave diagnostics 23/11/2021*
- *Final review meeting 18/1/2022*
- *WPDC kickoff meeting 1/4/2022*
- *NEXT: Topical meeting microwave diagnostics 27/07/2022*

Summary of essential system engineers information on ECE diagnostics characteristics

- **How to integrate the diagnostic system and the Lines Of Sight?**

Quartz vacuum window(s) 20 mm thick, diameter 150 mm, wedged shape. Optical matching box outside the machine 80x50x30 cm^3.

- **Main components of the diagnostic system**

- internal waveguides and antennae
- external waveguides, in excess of 10 m runs
- vacuum windows and optical boxes [+ calibration systems]
- spectrometers (4 to 8), both quasi-optical and electronics

Heterodyne radiometers: 15 to 20 channels, bandwidth ($\Delta\nu$ ~ 100 MHz), frequency range 125-270+ GHz, time resolution (~2ms)

Fourier Transform Spectrometers, broadband (100-1000 GHz), lower temporal resolution (>10ms)

- power supply, data acquisition and control systems for all the above

Control role of ECE/ECRH

The ECE diagnostic development work is being coordinated with the ECRH and Control groups (Alessi et al.)

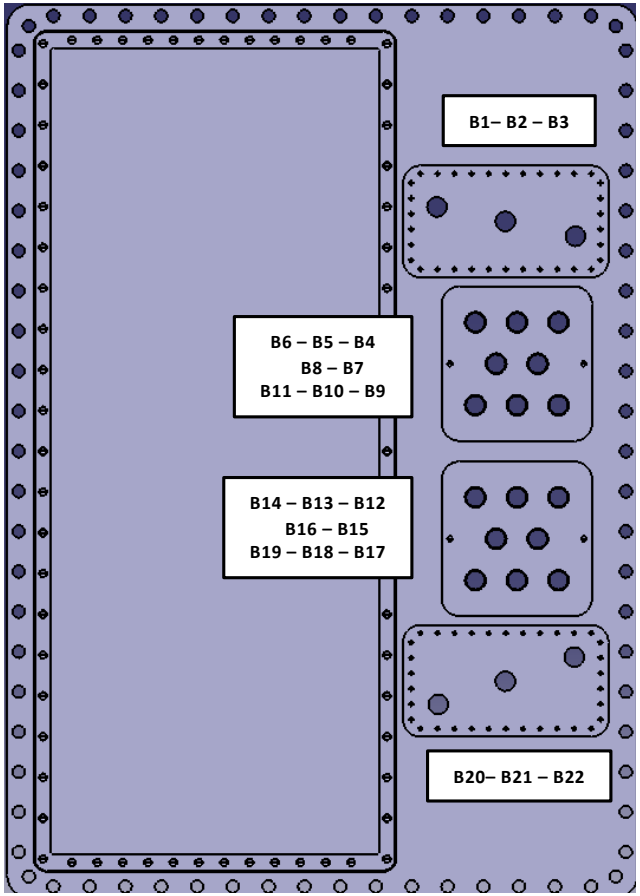
Reminder: Neoclassical Tearing Mode (NTM), are driven by the "loss" of boostrap current while a magnetic island is present. ECRH will target the islands in real time to control, by using ECE inputs, the plasma equilibrium and stability.

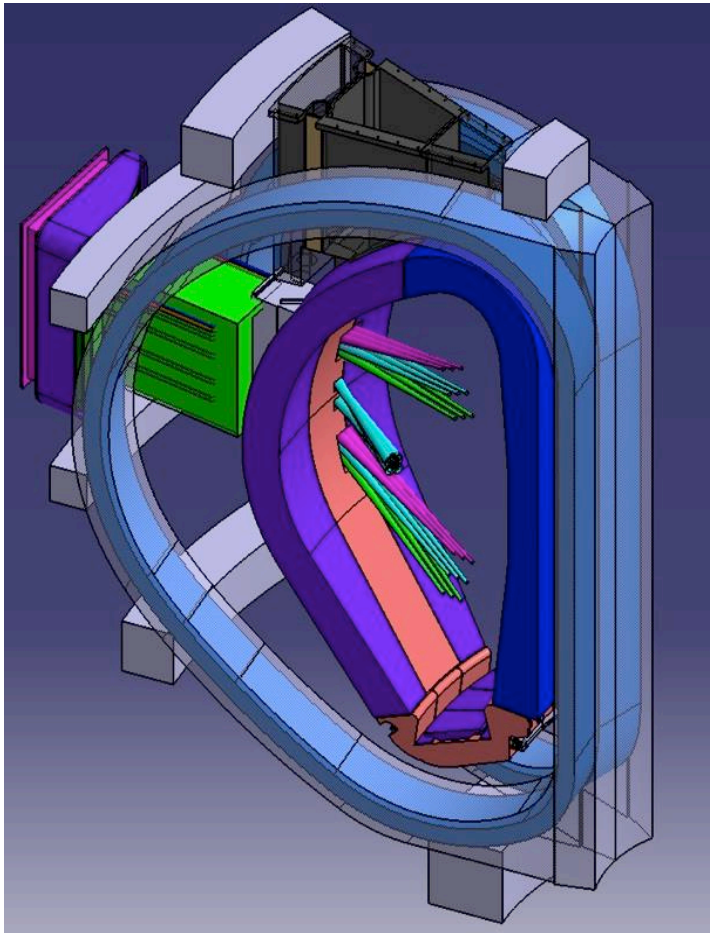
ECE antennae position and viewing angle will match the ECRH launchers, to ensure geometrical correspondance between detected islands and power launch to dispers it.

Presently, of DEMO foreseen **16 sectors ECRH** requested the even-numbered: 10-12-14 and mirrored ones. ECE line of sights will be accommodated accordingly.

Port Configuration

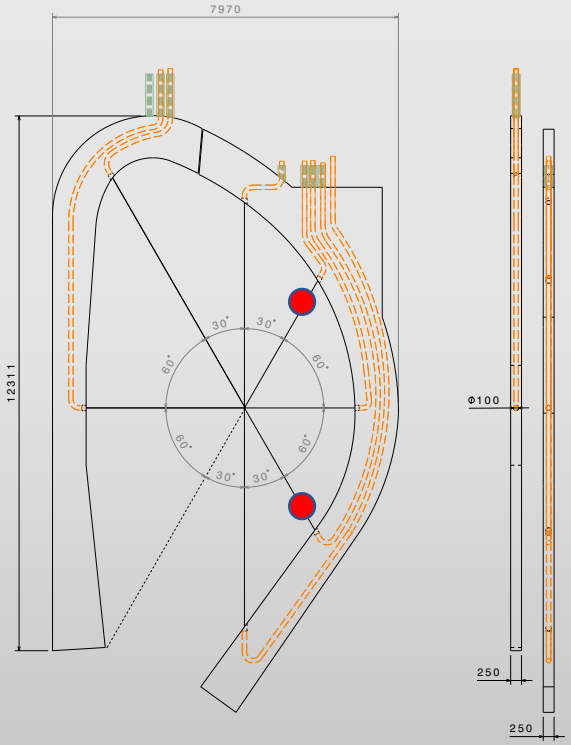
- https://idm.euro-fusion.org/?uid=2MJCQV

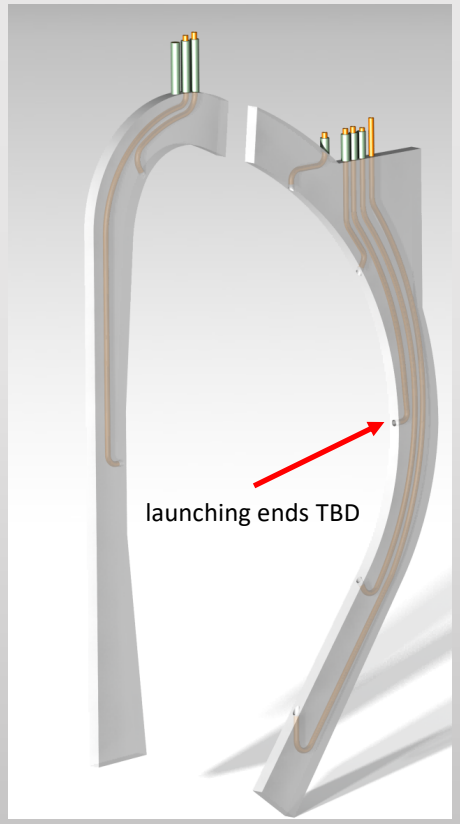


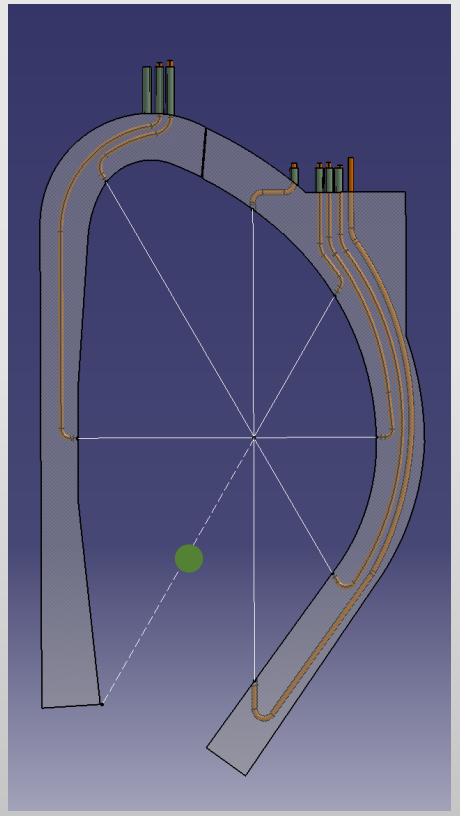


Waveguide integration in a DSC system

(8 LOS on one sector at present)



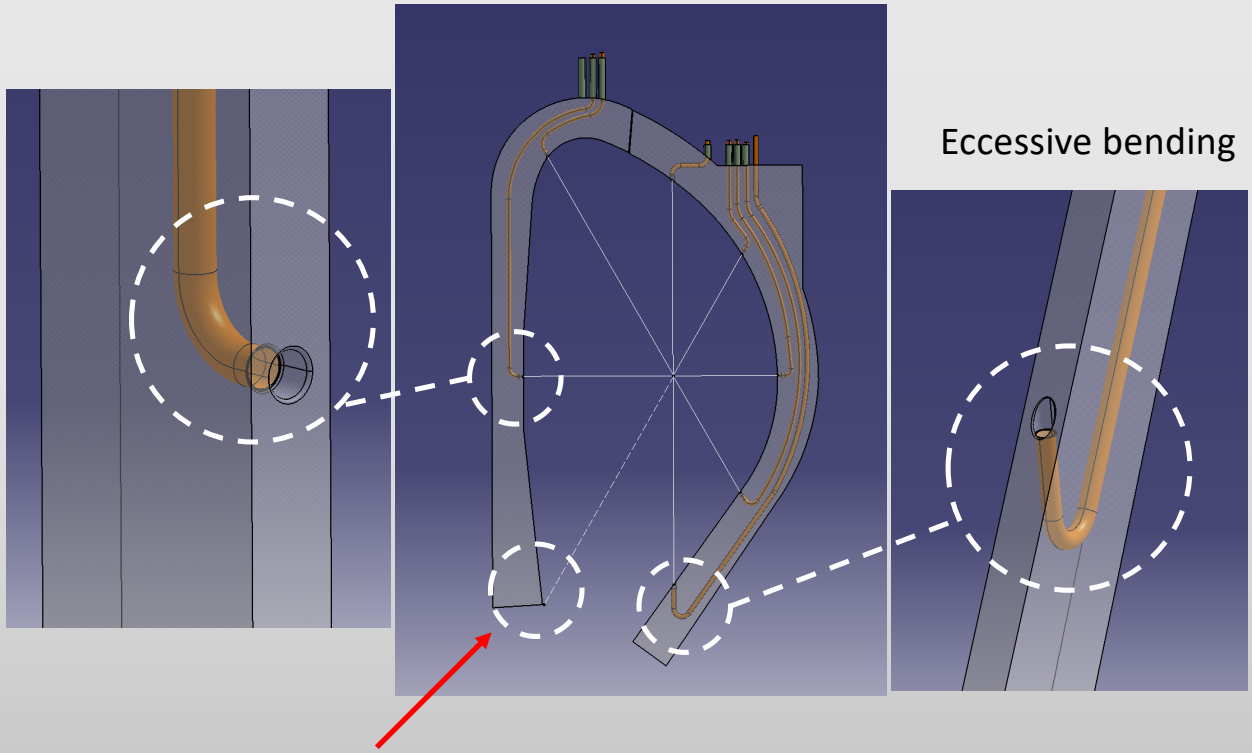




● =ECRH launcher angle

● LOS out of the DSC

Waveguide integration in a DSC system:
Choice of LOS and related issues



per concludere:

il task WPDC-ECE e’ una grande opportunita’ per mettere a frutto le competenze di Frascati su questa diagnostica, accedendo a risorse disponibili in un quadro internazionale di alto livello, con una ulteriore possibilita’ di crescita e sviluppo per il laboratorio.