Operational domain for the new 3MW/1000s ECRH System on WEST

*T. Fonghetti, R. Dumont, G. Giruzzi, J.-F. Artaud J.-M. Bernard, F. Bouquey,
C. Bourdelle, L. Delpech, J. Hillairet, P. Maget, P. Manas, P. Mollard,
J. Morales, V. Ostuni, B. Robinet, and the WEST team*

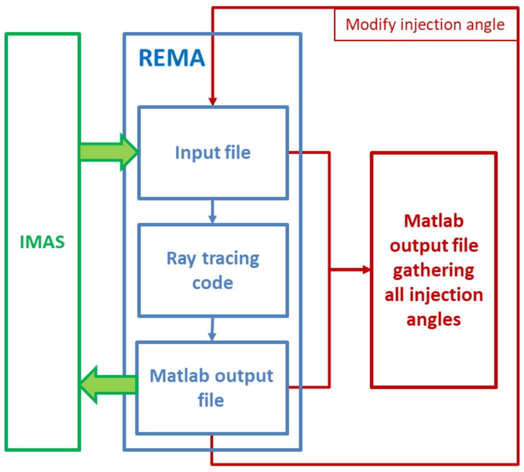
CEA, IRFM, F-13108 Saint Paul-lez-Durance, France.

INTRODUCTION

A new ECRH system is expected to start on WEST for 2023 in order to:
- increase margins with respect to H-mode access
- provide additional flexibility in terms of achievable scenarios using heavy impurity accumulation and/or MHD control

As a preparation, several developments have been performed:
- IMAS interface for the EC wave ray-tracing code REMA
- Determination of the operational domain in terms of injection angles
- First integrated modelling simulations for plasma control

IMAS interface for the ray-tracing REMA code



Modify injection angle

IMAS

REMA

Input file

Ray tracing code

Matlab output file

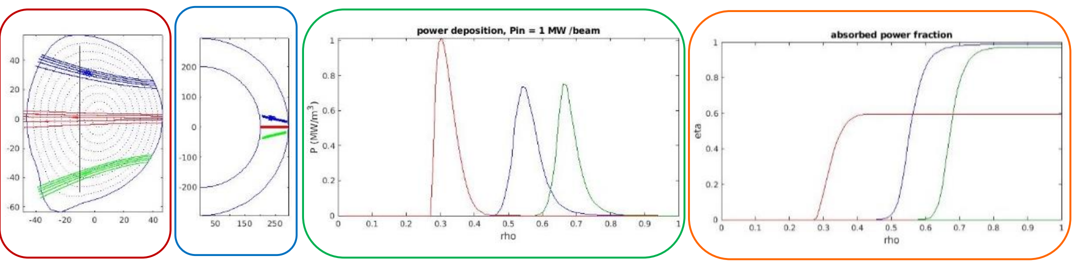
Matlab output file gathering all injection angles

Developments of the ray-tracing code REMA:

1 Interface with IMAS database → possibility to run REMA for any WEST shot

2 General simulations sweeping the mechanically reachable injection angles

Ray tracing outputs made available for data analysis and simulations
- EC rays propagation (poloidal and toroidal projections)
- power density and absorbed power profiles

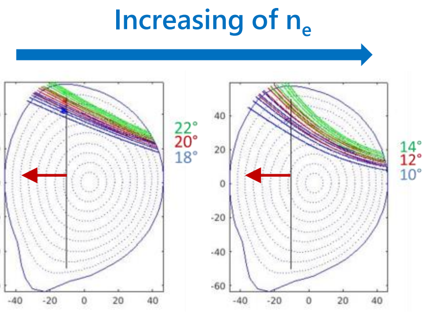


Determination of the absorption limits for the ECRH antenna

Context

- Tore Supra ECRH antenna updated to meet WEST specifications
- Absorption limits necessary for defining the mechanical limits
- Outside these limits, EC waves not well absorbed by the plasma

Absorption and propagation properties depend on the plasma conditions
→ Necessary to determine plasma conditions that maximize the limits



● Increasing the density means increasing the refraction
→ Same absorption location obtained for different injection angles

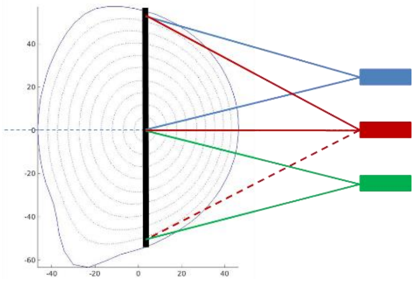
● Decreasing the magnetic field results in moving the resonance location towards HFS

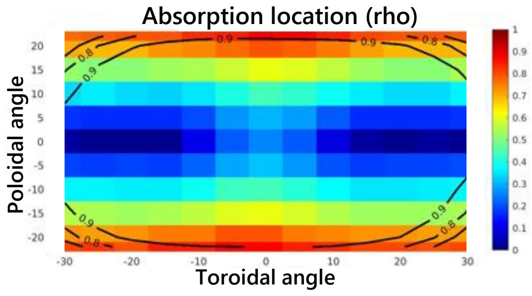
● Increasing the temperature increases the absorption rate

Widest domain that includes any plasma condition: low-density ($\bar{n} = 2.10^{19} m^{-3}$), high temperature ($T_{e_0} = 6keV$) and nominal magnetic field ($B_0 \sim 3.7T$)

Determination of the limits ?

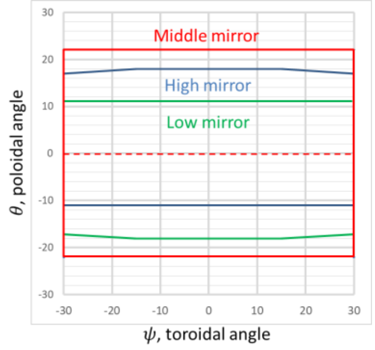
- General first limit is determined mechanically from the antenna
- Define the range for which the wave is absorbed from the core to the separatrix for every mirror





Location of the absorption for the middle mirror

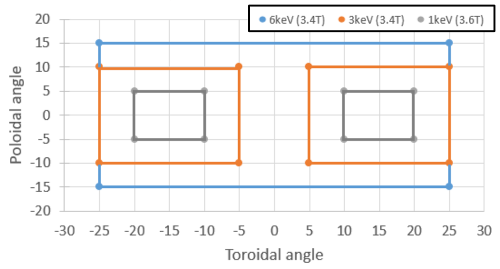
- Absorption takes place in the whole mechanical domain
- Possibility to refine the limits with simple REMA simulations



- Repeat the process to determine limits for every mirror
- Limits are shown on the adjacent figure.

What if plasma conditions are worse ?

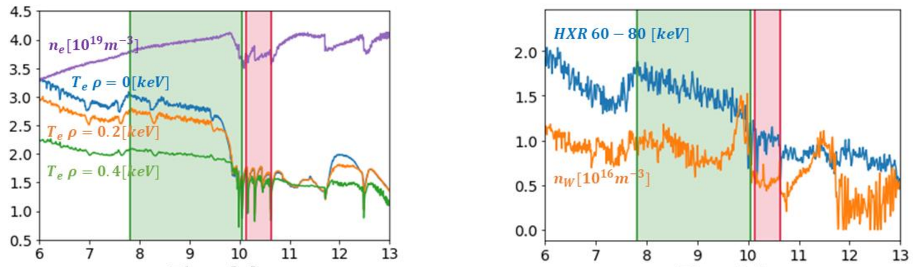
Additional investigations



- Set the electron temperature to low, medium and high
- Determine the magnetic field limit
- Consider low and high density (extreme conditions)
- Determine the combined domain for which the absorption is sufficiently high (> 70%)

The figure gives a global view of acceptable injection angles in terms of absorption rate, at the magnetic field limit and depending on the electron temperature

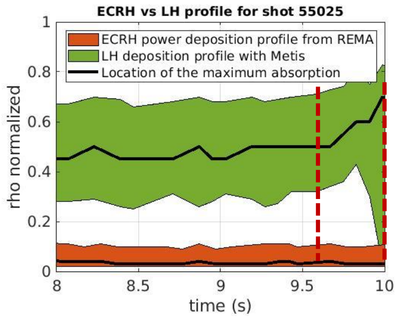
Integrated modelling of ECRH in WEST



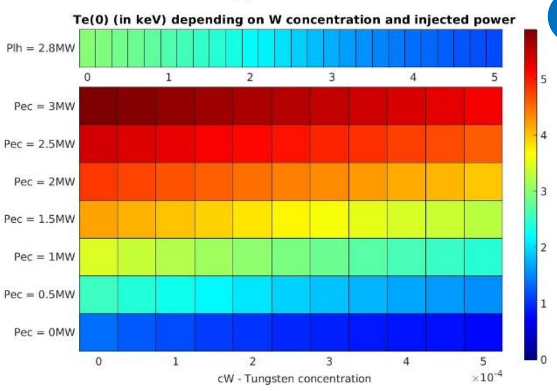
Ostuni V., EPS (2022)

Radiative collapse in WEST shot 55025:
- Insufficient electron heating from LH in the core (when T_e decreases, LH deposition moves further off-axis)
- Tungsten accumulation and radiation peak

How could ECRH be beneficial ?



1 Comparison between simulated LH profile from METIS [Artaud NF 2018] and ECRH profile coming from REMA
- EC absorption remains central even if T_{e0} decreases
- Power deposition remains narrow → EC absorption stays localized



2 Comparison between electron heating from LH or ECRH systems
- RAPTOR [Felici NF 2012] simulations using Bohm - Gyrobohm transport model and IMAS data for shot 55025 at t=8s
- For the same injected power, T_{e0} is twice larger with ECRH

- Less ECRH power is necessary to obtain the same heating : 2.8 MW of LH power is equivalent to approximately 0.7MW of ECRH at low W concentration and even less (< 0.5MW) at higher concentration

WEST ECRH system should prevent radiative collapse in these conditions