Latest results from fusion research in Europe and plans for the future [[1]](#endnote-1)\*)

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EUROfusion is planning DT experimental campaigns in 2020 on JET with the ITER-Like Wall (DTE2) to address key physics and technological issues for the DT experiments in ITER. This paper will review the key elements developed for DTE2 preparation, which includes DT operation scenario and the fusion power predicted with first-principle modeling, isotope effect studies, and technological hardware improvements for DT plasma operation. To achieve the scientific objectives in DTE2, JET operation should demonstrate 15MW of fusion power for 5 seconds stationary state, a performance never attempted before in fusion-research history. For optimized operation in DTE2, the isotope effects and DT scenarios have been further exploited in the DD and TT campaigns for 2019~2020. This paper will also introduce the JET programme for Shattered Pellet Injector test, which is ITER’s main strategy to mitigate disruption and runaway electrons. Two complementary integrated scenarios are being developed to aim at high sustained DT fusion performance with fusion power Pfus=15 MW for 5 seconds. They both rely on H-mode confinement at high input power but differ in the plasma parameter space they explore. The baseline scenario (normalised beta βN~1.8 and normalised confinement factor H98~1.0) concentrates mainly on achieving high confinement and fusion reactivity by pushing the operation towards high plasma current with a relaxed current profile. Hybrid scenarios (βN~2-3 and H98>1.0) exploits the advantages of operating at higher normalised beta with a shaped current profile such that the safety factor q (the number of toroidal circuits made by a magnetic field line in one poloidal circuit) in the plasma core is above or close to unity. Encouraging results, very similar in the two scenarios in terms of extrapolated DT fusion power, were achieved in previous JET DD campaigns.

A different plasma scenario has been developed with qmin~2, for fusion alpha-particle studies, relying on short, 1-2 seconds, burst of high fusion performance. Extrapolation from the results obtained so far in DD confirm the potential to observe alpha-particle effects, such as induced TAE activity in the after-burn phase after the additional heating is switched off. The new 3-ion ICRH scenario has been further explored in JET and has led to a set of new and interesting results using the D-(DNBI)-3He scenario to further accelerate 120 keV DNBI particles to MeV range energies.

A summary will be given on the results of the last experimental campaigns of Wendelstein 7-X the largest stellarator in operation in the world, optimized to demonstrate good energy and fast particle confinement at Te=Ti~ 6 keV, n>1020 m-3, and a volume averaged β ~ 5 %. Stable ECRH operation at high density was achieved with 2nd harmonic ECRH X-mode, which is a necessary condition to realise high plasma densities in Wendelstein 7-X. Divertor detachment can be realized at sufficiently high densities, and, thus, the integrated operation with high power output and tolerable exhaust seems possi- ble. Three scenarios in the density range 8 1019 - 2 1020 m−3 are compared: ECRH heated plasmas with edge gas fuelling, predominantly NBI heated plasmas and discharges with central pellet fuelling. Gas fuelled discharges with ECRH heating are characterized by flat density profiles, ion temperatures below about 2 keV and the energy confinement time close to (but mostly lower than) the ISS04 scaling due to a significant turbulence fraction. This turbulence is generated by ITG modes when using large amounts of ECRH only as heating system and has limited the ion temperatures reached. This can be solved using NBI or pellet injection, leading to a stabilization of the ITG Modes. NBI heated plasmas exhibit a pronounced density peaking and a particle barrier at the half radius. In pellet fuelled discharges, transient phases with the improved energy confinement, ion temperatures as high as 3.5 keV.

EUROfusion is setting out the plans for the next Framework Programme, FP9. The focus will shift to the preparation of the experimental work on ITER (with foreseen start end 2025) and the preparative work for the design of DEMO. Plans consist to establish a stronger central DEMO design team, increase funding for technology development, integrate DEMO physics with the ITER physics programme, consolidate international collaborations. A shift in culture is required to convert the traditional R&D mind-set to a project-oriented approach in Europe.

1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/XLVII/R/ru/LB-Ongena.docx) [↑](#endnote-ref-1)