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ID: EXP3-13

The Role of Edge Plasma Parameters in H-mode Density Limit on the JET-ILW

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ABSTRACT

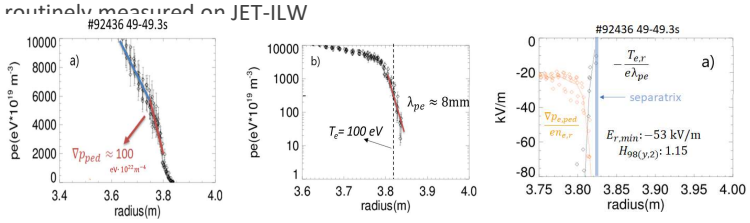
- JET-ILW plasmas stay in dithering phase after reaching MHD limit, associated with a higher (≈20%) HDL than JET-C equivalents.
- A new, reliable estimator for JET Er has been derived by combining HRTS measures of pedestal and SOL regions
- JET-ILW radial Er ETB wells are in the range -15 to -60 kV/m in H-modes. A higher positive E×B shear plays a role in sustaining a marginal phase.
- SOL broadens at high collisionality and a hypothesis for the dithering H-mode phase is proposed.

BACKGROUND

- The high-density plasma is desirable for fusion power and reducing the exhausting power
- The H-mode cannot be sustained when the density approaches the H-mode density limit (HDL)
- The studies of the HDL in JET-ILW have excluded excessive radiation, MARFE and divertor detachment as the causes of HDL

EXPERIMENTAL METHODS AND ESTIMATION OF $E_{r,min}$

Assuming $T_i \approx T_e$ and $n_i \approx n_e$ for high density JET pulses, E_r can be estimated by $E_r \approx \nabla p_i/en_i \approx \nabla p_e/en_e$, where all the parameters are routinely measured on JET-ILW



Demonstration of the method for estimating the edge radial electric field minimum, $E_{r,min}$

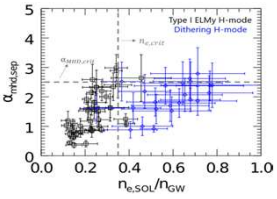
Experimental Results

CORRELATION WITH BALLOONING STABILITY AT THE SEPARATRIX

The ballooning parameter for the separatrix position, $\alpha_{MHD,sep}$, can be expressed as:

$$\alpha_{MHD,sep} = \frac{Rq_{95}^2 \nabla p_{sep}}{B_t^2/2\mu_0} = \frac{Rq_{95}^2}{B_t^2/2\mu_0} \cdot \frac{2p_{e,sep}}{\lambda_{p,SOL}}$$

$\alpha_{MHD,sep}$ increases almost linearly as $n_{e,sep}$ until the $\alpha_{MHD,crit} \approx 2.5$, when $n_{e,sep}/n_{GW} \approx 0.35$. The very large range of $n_{e,sep}$ with $n_{e,sep} >$ 0.35 implies that the HDL is NOT directly set by ballooning stability at the separatrix.



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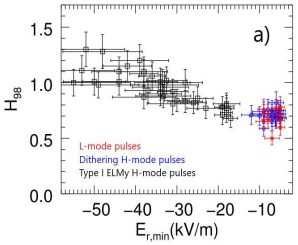
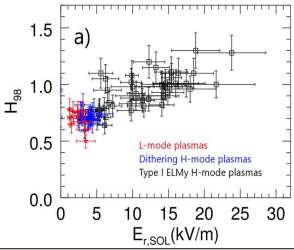
EXPERIMENTAL RESULTS

ROLE OF THE EDGE RADIAL FIELD FOR HIGH DENSITY PLASMA

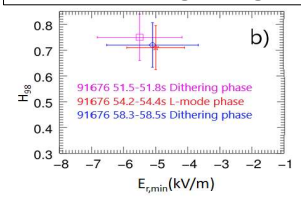
- $E_{r,min}$ are in the range -15 to -60 kV/m in H-mode, consistent with AUG[2].
- $E_{r,min}$ vary little between the L-mode and dithering phases, suggesting that HL transition is not due to a reduction of the inner E_r shear.

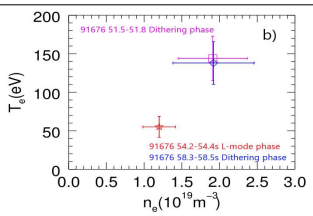




- The trend of $E_{r,SOL}$ against confinement is similar with that of $E_{r,min}$, the confinement increases as the absolute value of $E_{r,SOL}$ increase.
- $E_{r,SOL}$ decreases in dithering H-mode phase, but is generally higher than that in L-mode phase

The figures below for #91676, support that a higher positive Er shear plays a role in sustaining a marginal phase





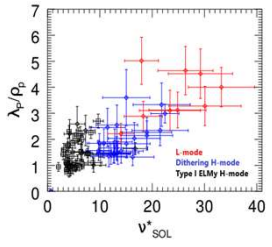
Discussion and summary

This two-parameter phase space in [3-5] can explain the edge plasma behaviour on JET-ILW.

- For low collisionality, the drift wave turbulence can be suppressed by $E \times B$ shear ($E_{r,min}$ threshold). Pressure gradient increases until the MHD stability limit.
- As collisionality increases, the perpendicular transport is enhanced by resistive modes and the confinement degrades even when α_{MHD} is well below MHD limit.
- The enhanced transport reduces the pressure gradient and cools down the plasma, corresponding to a decrease of $E_{r,min}$.

SOL width is found to increase with increasing collisionality, as AUG [6]. A hypothesis for the 'dithering' H-mode phase is proposed:

- n_e increases → $\nu_{*,SOL}$ increases → SOL broadens → E_r shear decreases → H-L transition;
- n_e decreases → $\nu_{*,SOL}$ decreases → SOL narrows → E_r shear increases → L-H transition.



- The JET-ILW results suggest that ITER could be operated in H-mode with higher density, but likely with a dithering phase plasma with lower confinement.

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.

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