Predictive dynamics of Tearing Modes for plasma stability in DT and TT scenarios considering JET Baseline and Hybrid discharges with mixture of isotopes

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ABSTRACT

- Studies of the effects of Hydrogen (H) isotopes are an important issue on achievement of high performance in the next Deuterium-Tritium (DT) and Tritium-Tritium (T) high beta operations at JET
- Experiments with mixed H-D plasmas were recently performed at JET to understand the dependence on confinement of these isotopes [1]
- Since strong dependence on confinement has been found in mixed plasmas close to pure H or D and no dependence for other values of mixtures, while opposite behavior is expected for any DT composition, presence of MHD instabilities could play a key role in confinement loss
- Particularly, NTMs are responsible of a decrease of performances leading in some cases to disruptions
- The goal of this work is to predict the effects of isotopes mixtures on NTMs onset and dynamics for plasma stability, depending the modes appearance on the isotope ion mass mi

BACKGROUND

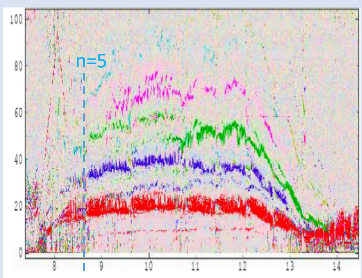
- In JET plasmas most detections of NTMs at low poloidal (m≤5) and toroidal ($n \leq 4$) numbers have been observed typically for $\beta_N < 2.2$ in Baseline and for $\beta_N > 2$ in Hybrid scenarios [2].
- Predictions of different isotope mixture on NTMs onset are provided modelling the mode amplitude with a Generalized Rutherford Equation (GRE) [3] integrated in the NTM module in the European Transport Simulator (ETS) [4] . In GRE bootstrap J_{bs} and ion polarization current contain the m_i/m_p dependence (m_p being the proton mass)
- Simulations of HD and HDT plasmas, extrapolated from high power and neutron rate discharges, have been provided [5]

EFFECTS OF ISOTOPES IN DT AND TT PLASMAS

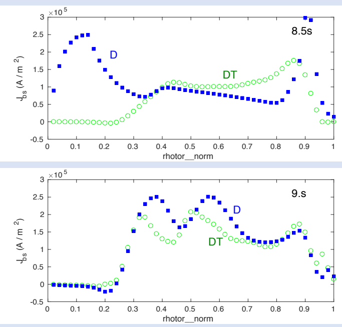
- First predictions of NTMs onset, allowed by high J_{bs}, have ben provided considering the JET Baseline pulse #92436 (2.8T, 3MA, 28MW NBI, 6 MW ICRH) with the rate of fusion rate and the hybrid pulse #97781 (3.4T, 2.23MA, 30MW NBI, 3.3 MW ICRH) with a record neutron rate over 5s.
- TM n=5 and n=3 of small measured amplitude (0.2-0.5G corresponding to 2-5cm) appear in the final ramp-up of the heating phase.
- It was investigated which isotopes mixture could increase the mode width up to a non negligible loss of confinement

RESULTS FOR BASELINE PULSE #92436

- First NTM n=5 is triggered by Sawteeth (ST) at 8.6: the aim is to investigate if different mixture of isotopes can increase the mode size neglecting isotopes effects in the plasma core and edge
- Comparing in ETS the Baseline D reference pulse with 98%D, 2%H and the predictive DT case with 38%D, 57%T, 5%H [6], the DT scenario seems more prone to the mode avoidance (J_{bs} (DT) $\lesssim J_{bs}$ (D) as shown for the n=5 onset time 8.5 and 9s, so in DT no effects on NTM are found



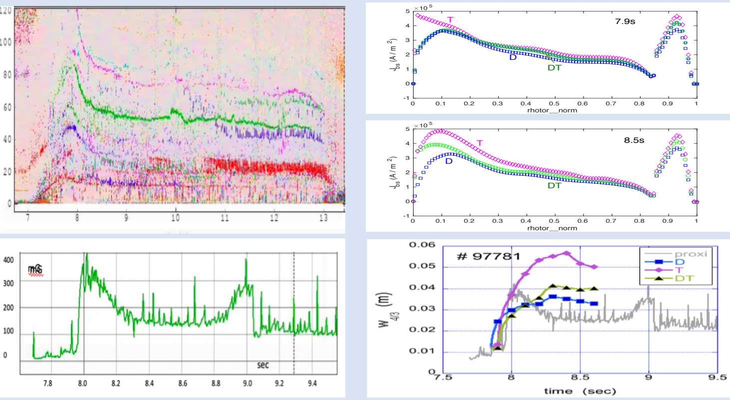
#92436 spe ctrogram from 'Modeanalysis' code by E. Giovannozzi



J_{bs} for D and DT case at 8.5s and 9s

RESULTS FOR HYBRID PULSE #97781

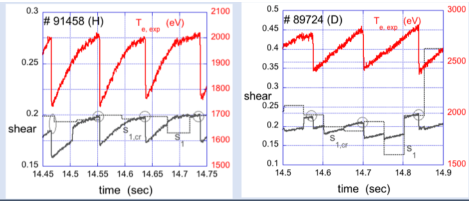
- First TM n=3 is triggered at 7.9s
- Predictions have been provided in ETS with profiles scaled to follow an advanced pedestal modelling [7] fixing the position of the boundary condition at $\rho_{t,norm} = 0.85$. TGLF code used for the turbulent transport model
- D, DT, T scenarios are considered.
- As the ion/electron pressure and J_{bs} are larger in T plasma, an important effect on the mode size can be predicted.



(top) Spectrogram and J_{bs} at the n=3 onset 7.9s and at 8.5s. (bottom) measured n=3 in mG and simulations in ETS of mode evolution in D,DT,T with comparison with a proxi estimate [8].

DEPENDENCE OF SAWTOOTH ON ISOTOPES

- As the NTM onset can be associated with the occurrence of a long ST period, the dependence of ST on isotopes is important for plasma stability in D, DT, T
- As ST crash happens when at q=1 location the magnetic shear s_1 is larger than a critical value [9] $s_{1,cr} \div ((mi/mp)^{0.5})^{1/3}$, $s_{1,cr}(H) < s_{1,cr}(D)$ as observed in isotope identity experiments [10] where #91458 is in H (1.74T, 1.44MA) and #89724 in D (2.95T, 2.46MA) and simulated in good agreement
- We can foresee that NTM destabilization should be more favourable in T plasma than in D because $s_{1,cr}(D) < s_{1,cr}(T)$



Calculated time evolution of s_1 and $s_{1,cr}$ and experimental electron temperature for pure H plasma and pure D The modelling is in good agreement with the observed ST periods

CONCLUSION

- Effects of H isotopes, D and T, are an important issue on achievement of high performance in the next DT and TT high beta operations at JET
- For different fraction of the H-D-T isotopes in the same scenario, neglecting other isotopes effects in the plasma core and edge and considering the total pressure as constant sum of different fraction of isotopes, the Jbs changes are negligible (≤1%)
- Effects of different isotopes are found in plasmas with profiles scaled to follow an advanced pedestal modelling, fixing the position of the boundary condition for temperatures and densities at the a given minor radius. As the ion pressure and the bootstrap current are larger in T plasma, an important effect on the mode size can be predicted with effect on transport and loss of confinement. Modelling of NTM evolution in D, DT and T plasmas has been done using the General Rutherford Equation integrated in the NTM module in ETS transport code
- Effects of isotopes on ST crashes are important because the onset of NTM can be associated with the occurrence of a long ST crash. Modelling of the crash condition in terms of s1,cr has been applied and found in agreement with experiments

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