PEP-37 Effect of low-Z impurity on pedestal and global confinement

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| **TG priority:** High | **Start date:** 2015 | **Status:**  On-going | **Personnel exchange:** |
| **IO priority:** | **End date:** | **Motivation:** | |

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| **Device /**  **Association** | **Contact**  **Person** | **TG Request** | **Activity (from JEX/JA spreadsheet)** | | |
| **2015** | **2016** | **2017** |
| JET | C. Giroud | Desirable | Committed |  |  |
| CEA | M. Becoulet | Desirable |  |  |  |
| EUROfusion | M. Beurskens | Desirable |  |  |  |
| AUG | M. Dunne | Desirable |  |  |  |
| TCV | B. Duval | Desirable | Committed |  |  |
| KTH/JET,AUG | L. Frassinetti | Desirable |  |  |  |
| EAST | X. Gao, G. Zuo | Desirable |  |  |  |
| ITER | G. Huijsman,  A. Loarte | Desirable |  |  |  |
| C-Mod | J. Hughes | Desirable | Considering |  |  |
| York/JET, DIII-D | M. Leyland | Desirable |  |  |  |
| NSTX-U | R. Maingi | Desirable | Committed |  |  |
| DIII-D | T. Osborne | Desirable | Considering |  |  |
| MAST | S. Saarelma | Desirable |  |  |  |
| JT-60U | H. Urano | Desirable | Analysis |  |  |
| AUG | E. Viezzer | Desirable | Committed |  |  |

**Background and Previous Results**

H-mode energy confinement in metal-walled devices can be adversely affected with respect to that in devices with a carbon wall. This is partly caused by the requirement of high fuelling in order to avoid high-Z metal accumulation in the core plasma, but the decrease in low-Z impurity content may also play a role in the reduced confinement. Reintroducing low-Z impurities such as carbon (in the form of CD4), nitrogen and neon can help recover the thermal stored energy. This recovery is largely due to a recovery of the pedestal pressure, which propagates to the core through profile stiffness. In JET this has so far been investigated in low N<1.5 plasmas at both low (~0.2) and high triangularity (~0.4) where with N2 seeding the pedestal pressure (and mainly temperature) was increased by 10% and 40% respectively. In AUG seeding N2 and CD4 in high N>2 plasmas lead to a pedestal pressure improvement of up to 40% whether at low or high plasma triangularity. In Alcator C-Mod impurity seeding with N2 or Ne also increases confinement in EDA H-mode plasmas (N~1.3). In devices with C-wall and high intrinsic content of C impurity such as DIII-D, there is no benefit of N2 and Ne impurity seeding on the plasma confinement, consistent with earlier findings in JET with a carbon wall. The plasma content of low-Z impurity either intrinsic in a C-wall device or seeded in a metal-wall device has an impact on confinement but characteristics differ depending on the devices, the impurity and operating conditions.

The first experimental results were attempted in Alcator C-Mod in 2015, but definitive results were not obtained. The other programs deferred the joint experiments from 2015 to 2016.

**Outline of Proposed Experiments, Purpose and Goals**

In light of understanding the possible beneficial effect of low-Z impurity in ITER we propose both a joint experiment and joint modelling activity:

Aim of joint experiment:

* Test leading explanations for confinement improvement via impurity seeding from metal-walled devices AUG, JET, Alcator C-mod, EAST.
* Test leading explanation for effect of impurity seeding in C-walled devices DIII-D, NSTX-U, MAST and TCV with high intrinsic impurity content.

*Key experimental goals in ELMy H-mode plasma at nped/ngw~0.5-1.0*

* Two N values: N~1. and N~2 for Ne and N
* Two plasma triangularities: ~0.2 and ~0.4 for Ne and N
* Various low-Z impurity with different edge radiating location for the considered device: N, Ne, B, O, C, Ar, He in order of importance. At least 2 impurities should be considered.
* Determine impact of gas on pedestal structure and interaction with impurity seeding: low and high gas injection rate for two impurities.

Aim of joint modelling activity:

* Improve the modelling of both linear (e.g. ELITE/MISHKA) and non-linear (e.g. JOREK) MHD stability as well as divertor (EGDE2D/SOLPS) modelling to provide initially accurate pedestal boundary conditions such as Tsep, nsep, n0 and further impact of divertor physics.
* Improve the calculation of bootstrap current profile in the pedestal region in the presence of impurities and compare with the measurements where possible

The key question to be addressed is whether the differences in confinement benefit of impurity seeding is due to the access to the linear peeling ballooning stability diagram of the various plasma regimes influenced by effective plasma charge Zeff and impurity composition or whether the situation is more complicated and also linked to divertor/xpoint radiation or divertor physics. Other areas that will be addressed in this study are the change with impurity content in the Type III to Type I ELM transition, and the presence of slow (possibly resistive) ELMs as well as quasi-coherent fluctuations in metal devices. The experiment aims are to provide a controlled variation of key plasmas parameters with different levels of beta, triangularity, and Greenwald density fraction and determine the impact of various low-Z impurities in combination with gas (D2) have on pedestal and core confinement and ELM behaviour. Ideally the devices would explore the seeding regimes up to partial detachment or loss of H-mode. If possible, Alcator C-mod would conduct the experiment with Type I ELMy H-mode plasmas. These experiments should be well diagnosed for core, pedestal and divertor conditions: Te, Ti, ne, impurity content and profiles, radiation profiles, pedestal current profiles, turbulence measurement and divertor power load, target conditions. Li experiments are currently not part of this proposed joint experiment but can be part of the joint modelling activity.