**Detachment introduction**

- **Detachment:** Simultaneous reduction $T_e$, $n_e$
- **Requires:**
  - Particle losses ($\text{ion sink/ power limitation}$)
  - Power losses
  - Momentum losses

**Density ramp**

- Analysis: Balmer n=5,6 atomic only
- $n_e$ ~ 1.6

**Particle balance**

- Power balance

**Power (kW)**

- $P_{\text{rec}}$
- $P_{\text{alpha}}$
- $P_{\text{ion}}$

**SOLPS (syn. diag)**

- Total (Attenuated, vib. states)
- Atomic
- Molecular (SOLPS)
- Molecular (AMUEL, vib. states)

**Da measurements**

- Measured
- Estimated (atomic)

**Post-processed SOLPS:** AMUEL (vib. states)

**Spectroscopic analysis**

- Assume all "missing" Da $\rightarrow$ plasma-molecule

**Molecular $\rightarrow$ Total - Atomic**

**Existing atomic/particle sink source analysis**

- **Balmer line ratio**
- **Ionisation rate**
- **Recombination rate**

**Molecular particle/power sink source analysis; with Yacara [4]**

- Separate mol. $	ext{De}$ in $\text{D}_1, \text{D}_2, \text{D}_3$ parts

**Iterative scheme**

- $	ext{De} \rightarrow \text{D}_1, \text{D}_2, \text{D}_3$
- 1 X rad./rec.
- per De photon ratios

**Estimation mol contributions; other Balmer lines**

**Preliminary results**

- Density ramp
- Spatial profiles ($n_e, n_{\text{ion}}$)

**Balmer order:**

- Ion target current
- Ionisation
- Recombination
- MAR $H^+_i$

**Particle losses**

- 10$^8$ ions/s

**Hydrogenic radiation (kW)**

- Total
- MAR $H^+_i$

**Break-down of Da**

- Fulcher (600-616 nm) emission ($\simeq$ 2 $10^9$)

**Core Greenwald fraction**

- Increased hydrogenic radiation (mostly $\text{D}_1^+$)
- Increased ion losses (MAR) (due to $\text{D}_1^+$ & $\text{D}_2^+$) - larger than electron/ion recombination (EIR)
- Ionisation - MAR/EIR $<$ ion target flux
- Onset of $\text{D}_1^+$ MAR near power limitation
- Detachment, followed by $\text{D}_1^+$ MAR and EIR
- Increase ion source (MAI $\text{D}_1^+$ & $\text{D}_2^+$) negligible

**Preliminary conclusion / DEMO implications**

- $\text{De}$ emission & anti-correlation $\text{De}$ & $\text{I}$, cannot be explained with atoms
- Additional $\text{De}$ could be due to $\text{D}^-$ (and/or $\text{D}^+$) - only high with $\text{CX}$ & vib. states
- Additional $\text{De}$ does not appear during $N_2$ seeding

- Particle/powers losses plasma-mol. interactions have been analysed experimentally
- Power losses: significant plasma-mol. rad. in hydrogen spectra during detachment (similar to atomic excitation radiation); losses mol. bands small [6];
- Particle losses/gains: significant MAR larger than EIR
- Plasma-mol. interaction can influence Balmer & Lyman series lines

- The inclusion of those losses in plasma-modeling codes may be limited
- Important for extrapolating to DEMO

**Emission / absorption**

- Ly$\alpha$ (~40%)
- Ly$\beta$ (~40%)

**Plasma-mol. implications for opacity**

- Different location Ly$\beta$, Ly$\alpha$ emission $\rightarrow$ opacity of both significant

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**Notes:**

1. K. Verhaegh et al. NF, 2019
2. K. Verhaegh et al. PFC, 2019

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**Additional notes:**

- Figure credits: CCFE/CCF
dna:

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**Keywords:**

- Molecular particle/power sink source analysis
- Balmer order
- Ly$\alpha$, Ly$\beta$
- Plasma-mol. implications for opacity
- Emission / absorption
- Power losses: significant plasma-mol. rad. in hydrogen spectra during detachment (similar to atomic excitation radiation); losses mol. bands small [6];
- Particle losses/gains: significant MAR larger than EIR
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