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Preliminary analysis of density dependence of carbon radiation in Wendelstein 7-X

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Outline

- Introduction: Understanding the carbon source and transport in the SOL
- Experimental Set-Up
- General behavior of carbon radiation with density
- Impact of carbon source on radiation behavior
- Discussion and Future work

Plasma surface interaction combined with SOL impurity transport determine the intrinsic impurity source

- Carbon introduced into the plasma via chemical and physical erosion[1]:

$$\Phi_C \approx (Y_{chem} + Y_{phys})\Phi_H = \left(\frac{Y_{low}(E, T_{surf})}{1 + \left(\frac{\Phi_H}{6.0\mathrm{E}21}\right)^{.54}} + Y_{phys}\right)\Phi_H + Y_{imp}\Phi_{imp} \cdots$$

- Two source regions: divertor (small area, receives large heat and particle flux) and first wall (large area, receives small heat and particle flux)

[1] Roth et al, *Nucl. Fusion* **44** (2004)
[2] Stangeby, *Plasma Boundary of Magnetic Fusion Devices,* IOP Publishing Ltd. (2000)

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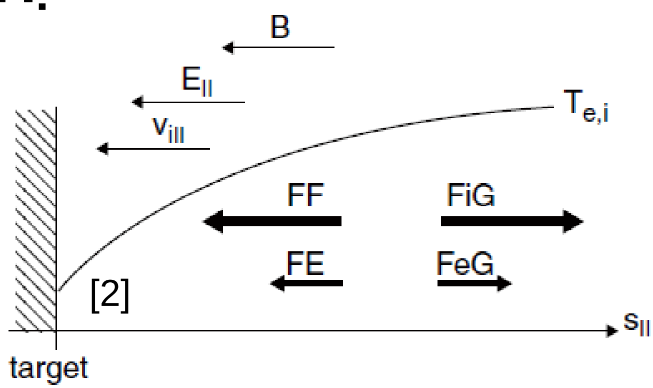
- Two source regions: **divertor** (small area, receives large heat and particle flux) and **first wall** (large area, receives small heat and particle flux)

- Once eroded and ionized, a balance of the parallel friction and ion thermal forces determine the transport in the SOL[2]:

$$F_Z \approx \overbrace{m_Z \frac{(v_i - v_Z)}{\tau_s}}^{\text{Friction}} + \underbrace{\beta_i \frac{d(kT_i)}{ds}}_{\text{Ion Temperature Gradient}}$$



- Plasma surface interaction and force balance can be **interlinked**

- **Essential to monitor both carbon erosion and its transport in the SOL**

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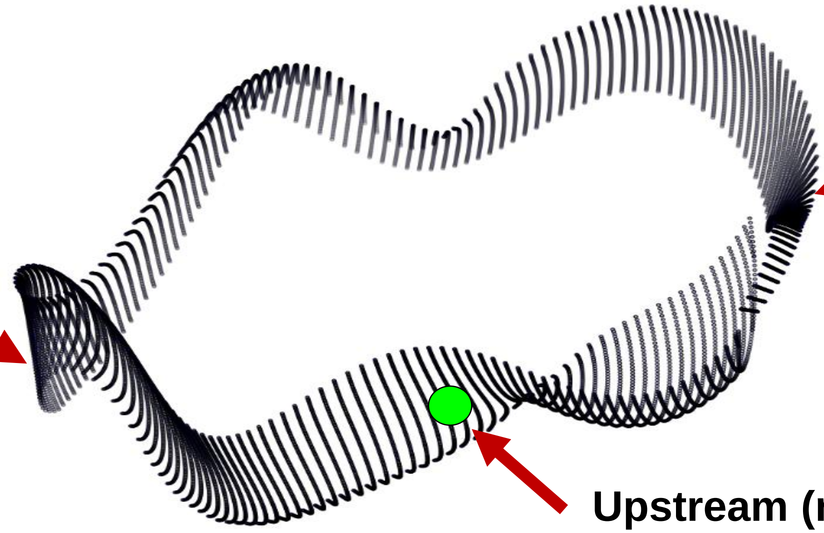
[2] Stangeby, *Plasma Boundary of Magnetic Fusion Devices,* IOP Publishing Ltd. (2000)

Puffing a known amount of methane from a downstream location helps separate source and transport behavior

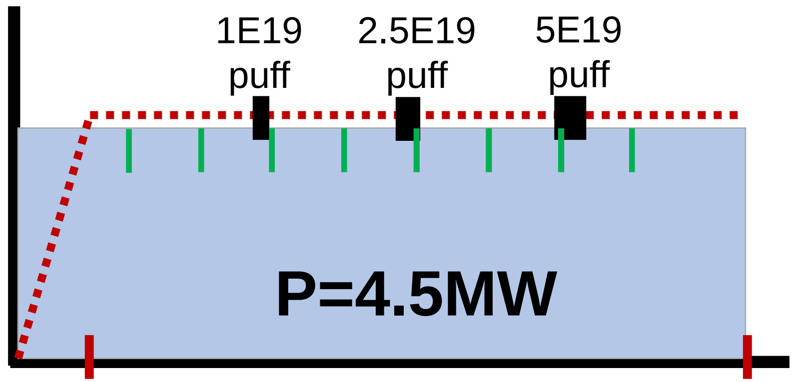
Spectroscopic observation system (C lines, He-beam) in magnetically connected lower divertor in Module 3

Upper divertor puff in Module 5 via divertor fueling system

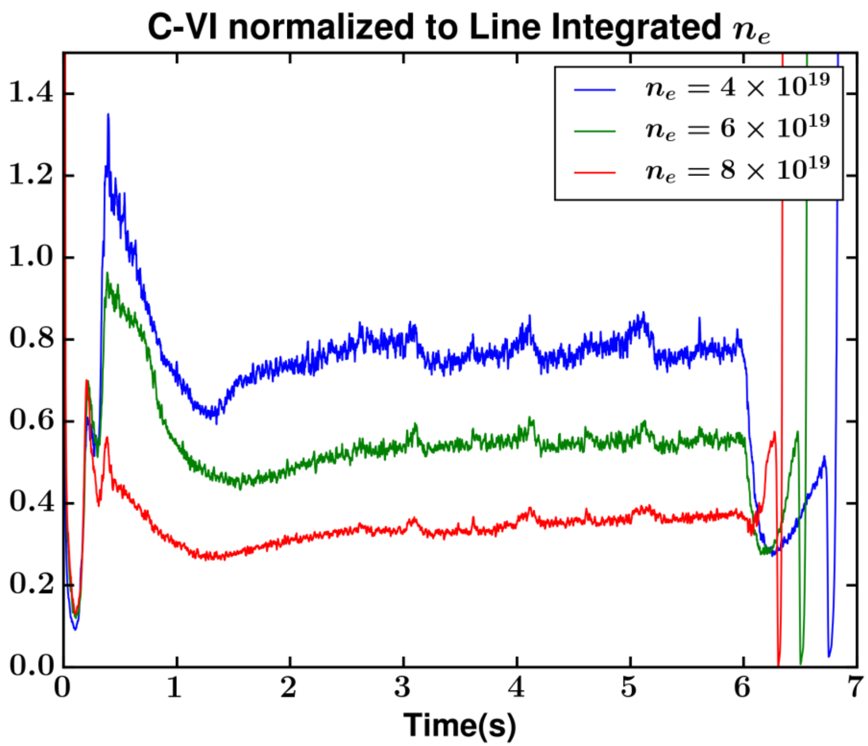


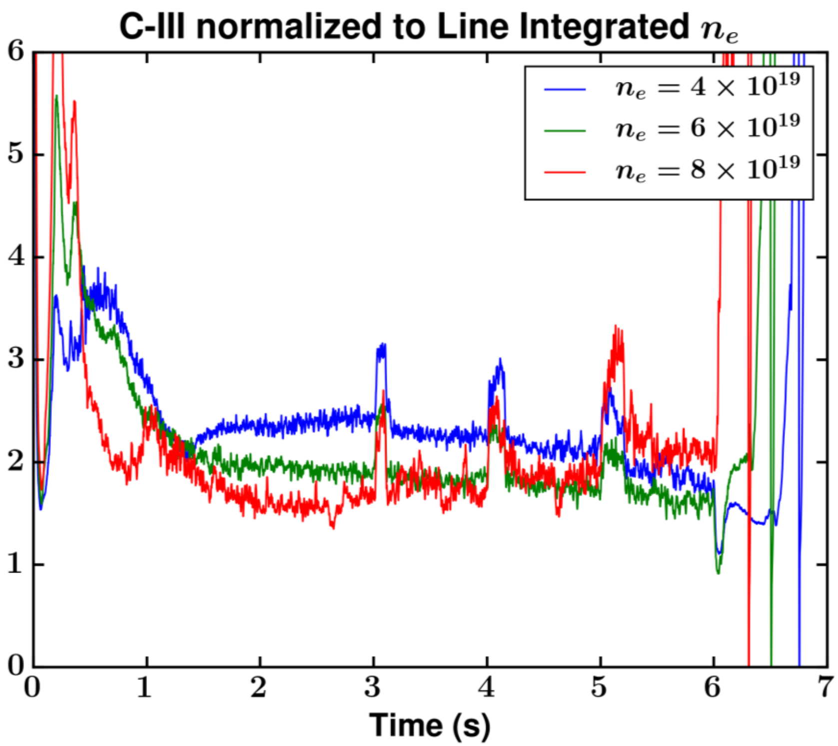
Upstream (midplane) filterscope observation

- ❑ A scan of line integrated density was performed (4-8E19m^{-2})
- ❑ At each density level, 3 methane puffs of different sizes were used to determine source and transport characteristics
- ❑ <u>Hypothesis</u>: As density is increased, SOL retention of carbon increases due to increased friction force



Overview HEXOS observation shows relative decrease of C-VI line emission with density, while C-III remains constant

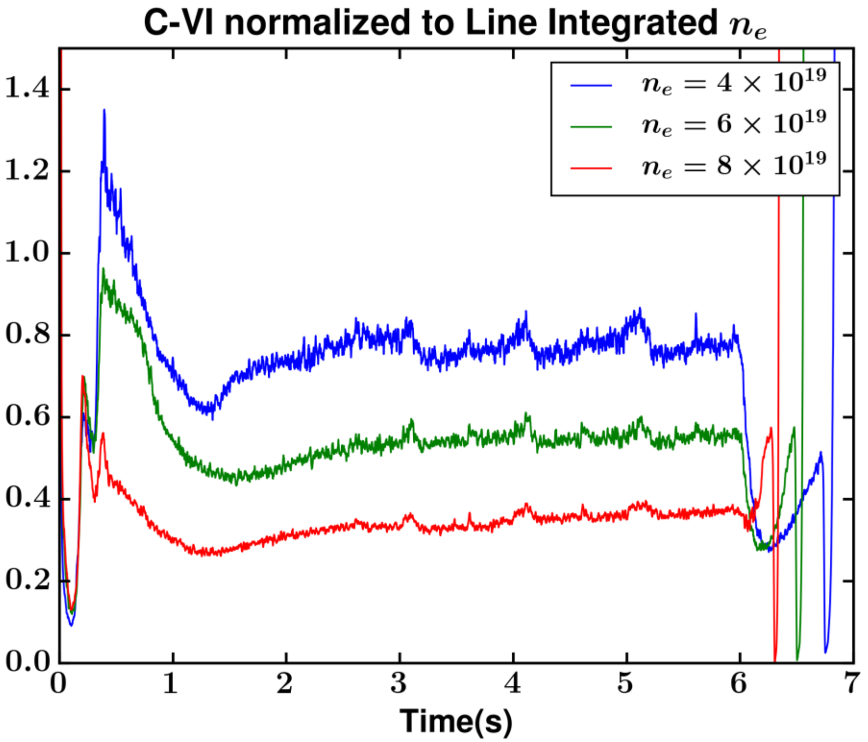


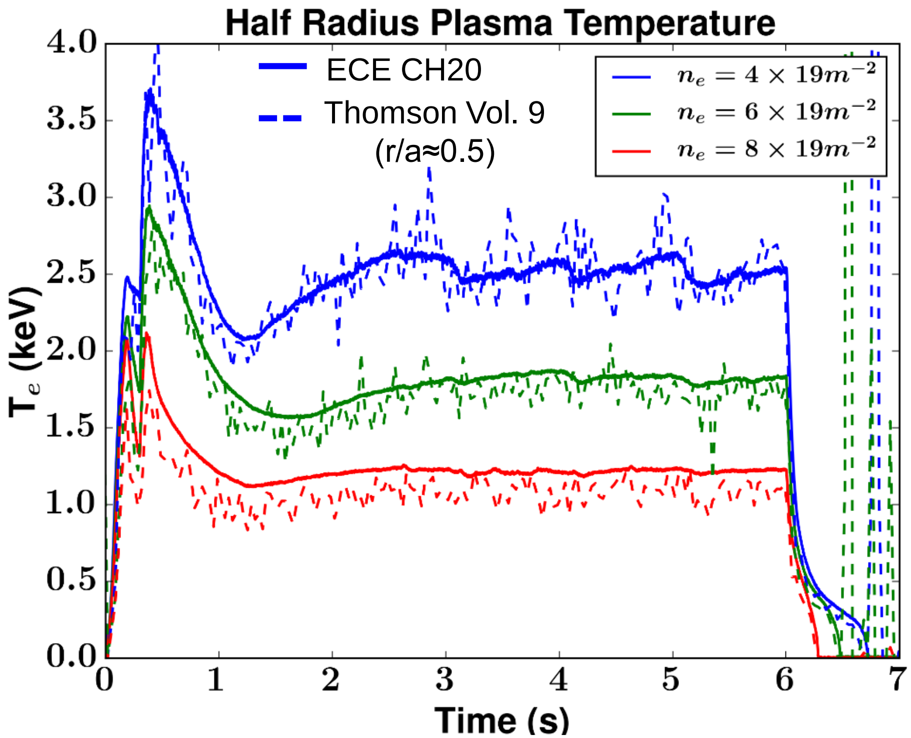


- ❑ **Overall line emission of C-VI (3.37nm) is decreased, while C-III (117.5nm) emission remains relatively unchanged**

- ❑ **Lowered C-VI emission could be:**
  - ❑ **Emission effect (due to lowered temperature)**
  - ❑ **Source effect (lowered erosion)**
  - ❑ **Transport effect**

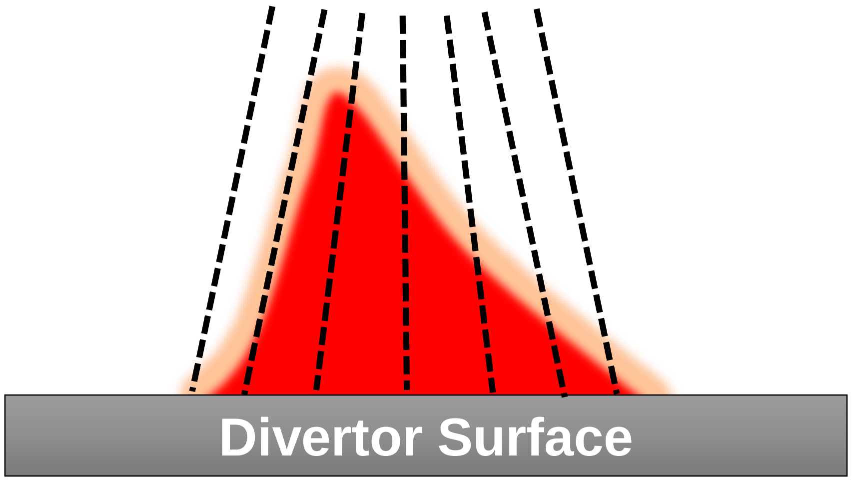
Half radius ECE measurement shows a decrease of T_e on the same order of magnitude as C-VI decrease



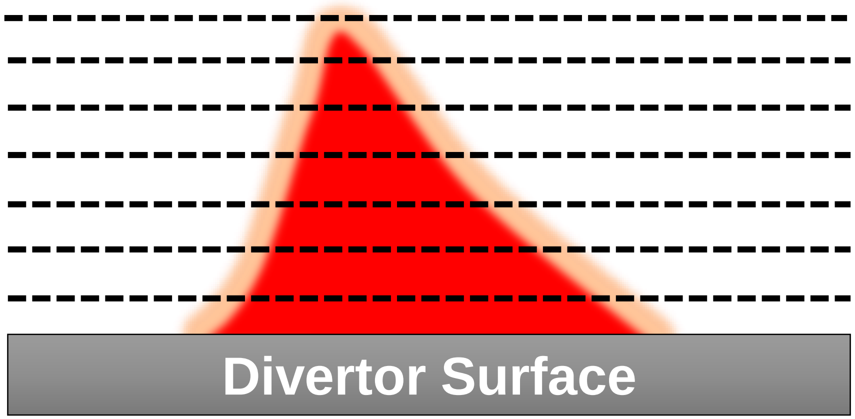


- ❑ A decrease of electron temperature around the same order of magnitude as the decrease in C-VI
  - ❑ Likely emission effect
  - ❑ Ionization rates need to be checked
- ❑ Still important to check source effect/transport effect from methane puffing

Assessment of carbon source requires full photon source + local plasma parameters



Typical set-up



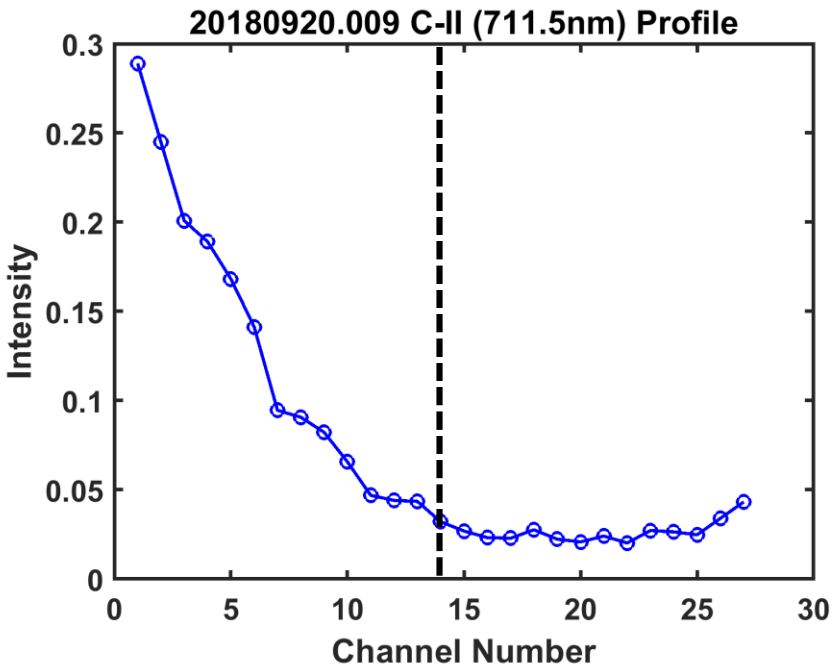
Available calibrated set-up

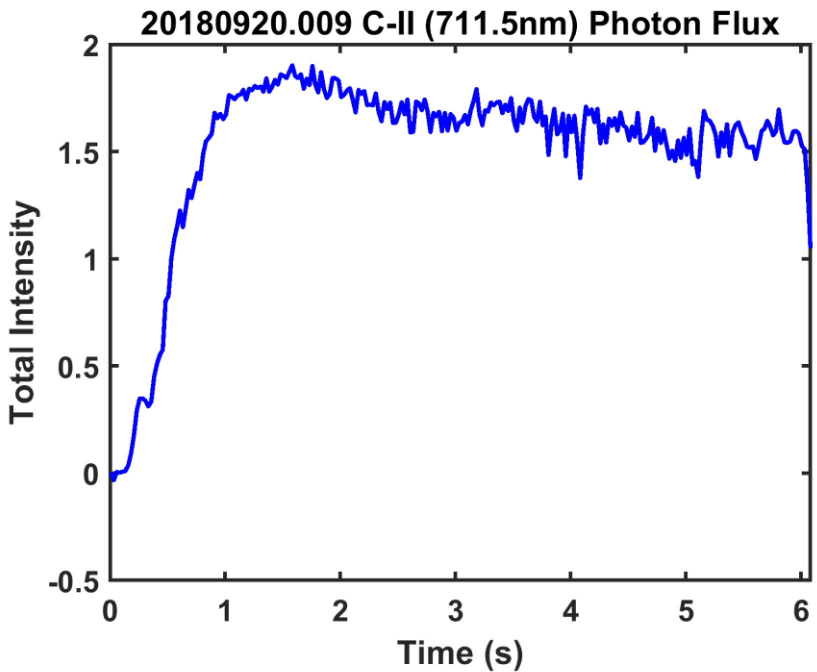
- **Assessment of carbon source from photon flux requires full photon flux source**
- **Typical set-up captures full source as distribution in space**
- **Set-up has no spatial resolution on divertor surface, but full photon source can be found with enough channels**
- **LoS parallel to the divertor is used also by He-beam – local measurement of n_e, T_e**

QSS He-beam system has enough channels to fully capture C-II photon source

- C-II photon intensity distribution shows emission above background up to channel 14

- Use first 14 channels to deduce total photon source

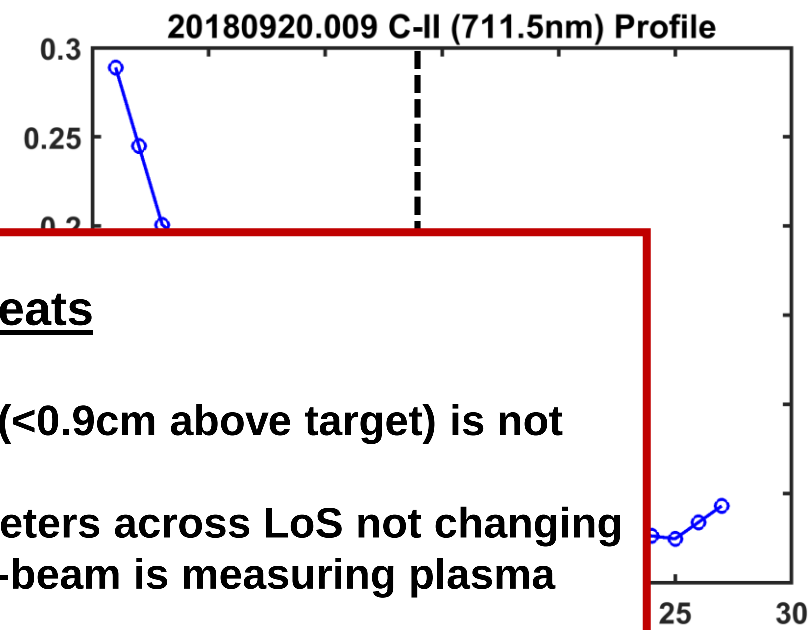




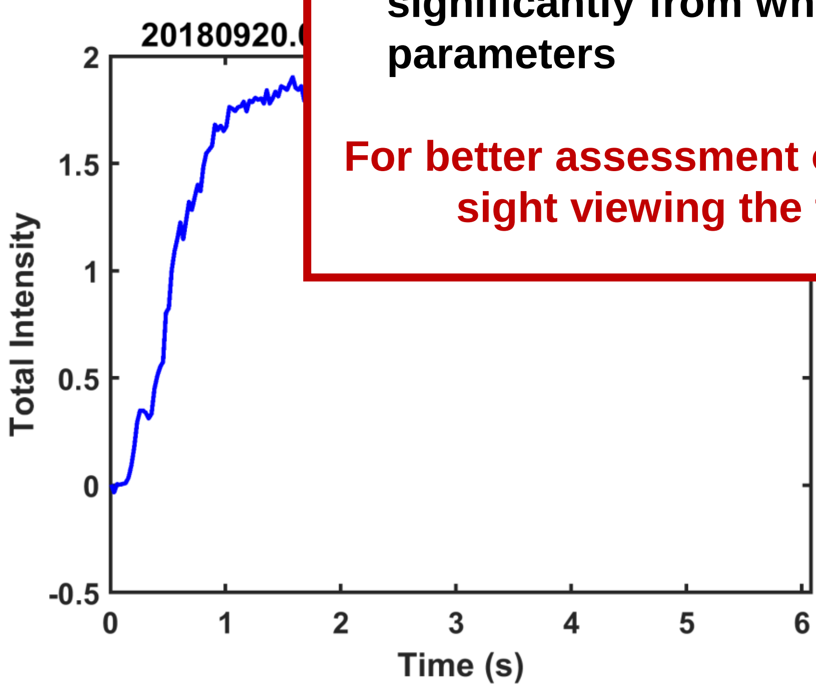
- Use photon flux and He-beam profiles to compute an „effective S/XB“

$$Photon\ Flux * \frac{S}{XB} \approx Particle\ Flux$$

QSS He-beam system has enough channels to fully capture C-II photon source



- C-II photon intensity distribution shows emission above background up to channe
- Use fir deduce



Caveats

- Emission before Channel 1 (<0.9cm above target) is not captured
- **Assumption:** Plasma parameters across LoS not changing significantly from where He-beam is measuring plasma parameters

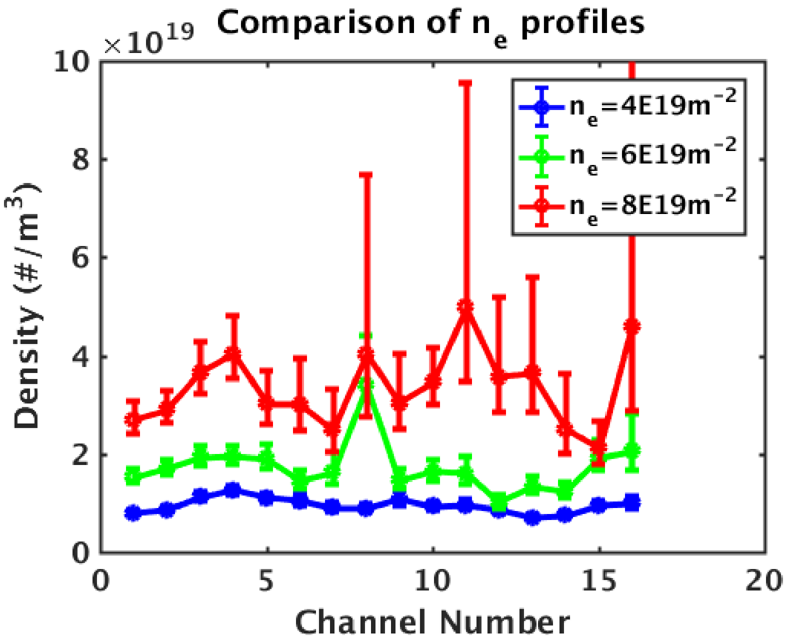
For better assessment of the source, a perpendicular line of sight viewing the target will be used in the future

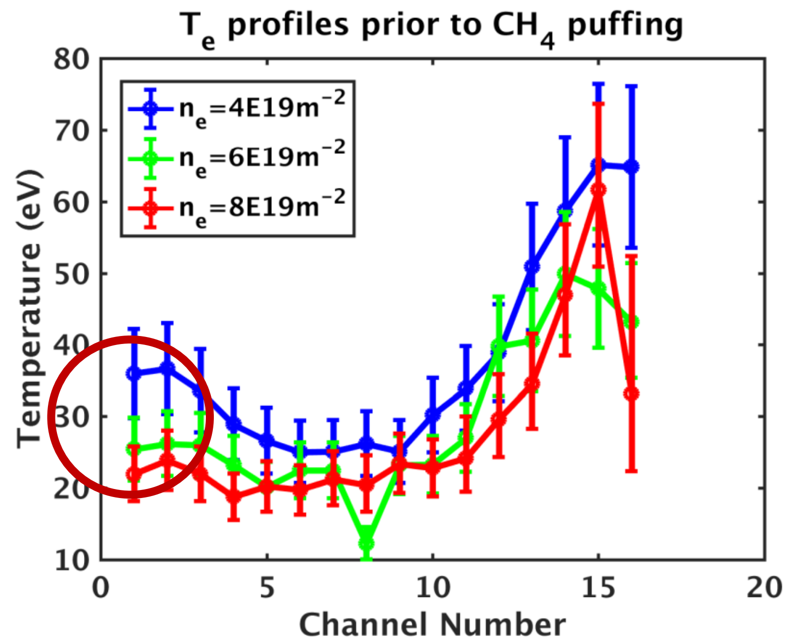
e-beam

„effective S/XB“

$$Photon\ Flux * \frac{S}{XB} \approx Particle\ Flux$$

He-beam profiles including high Rydberg states show change in T_e profiles as density is scanned

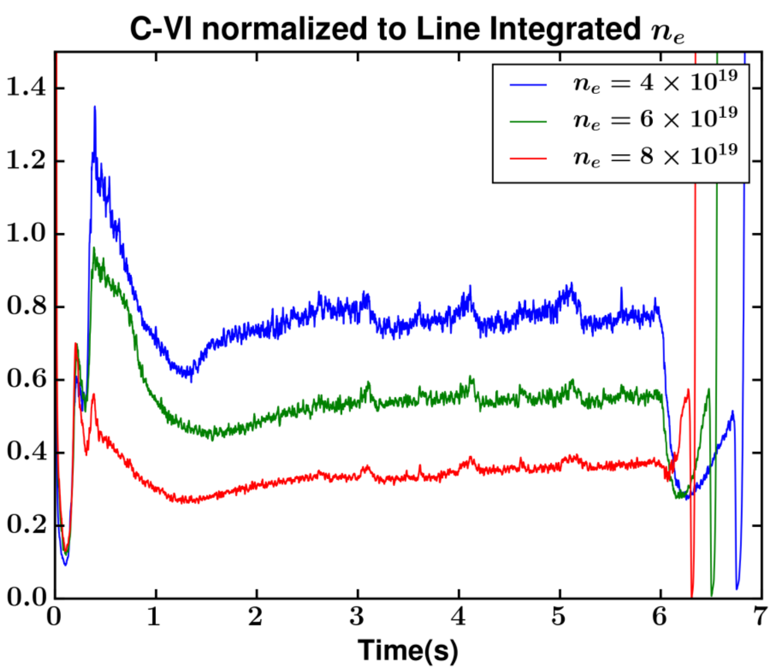


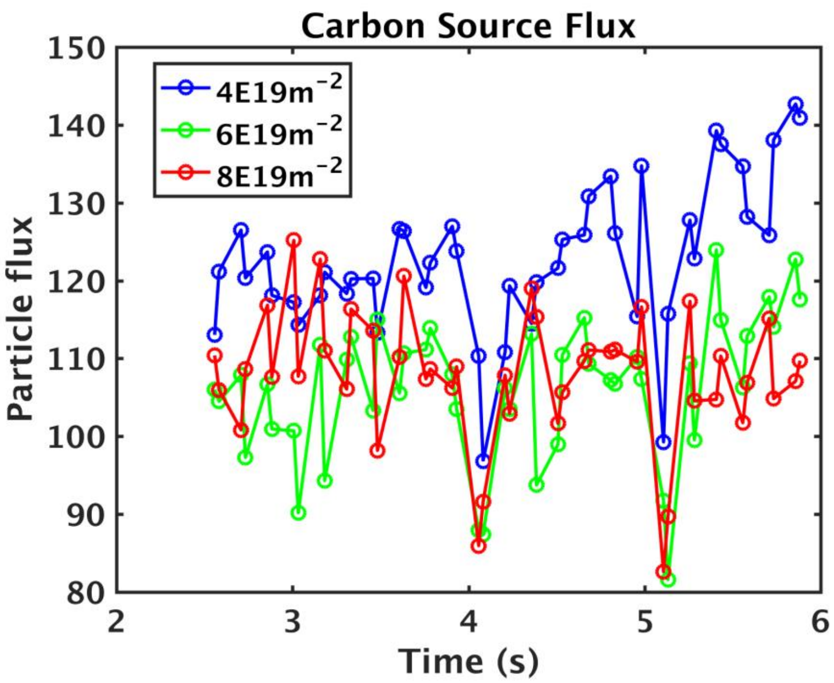


Data Provided by: T. Barbui

- **N_e profiles including high Rydberg states still show an increase of SOL density as the line integrated density is scanned**
- **Reduction of T_e near the divertor surface as the density is scanned– possible changes of background carbon source**

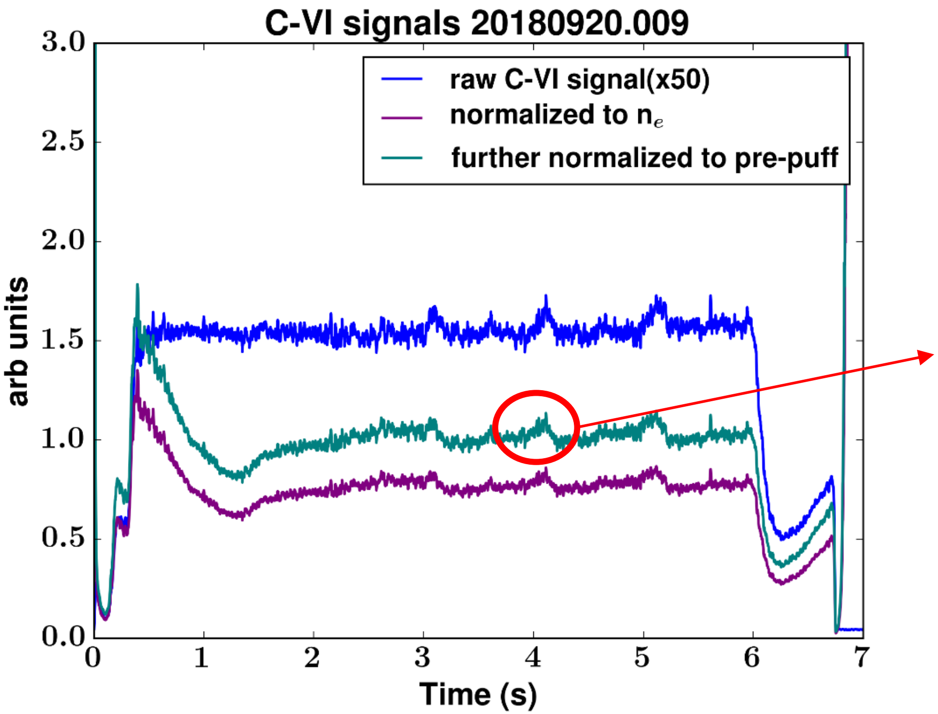
Using effective S/XB, one sees no significant change in the carbon source flux with density

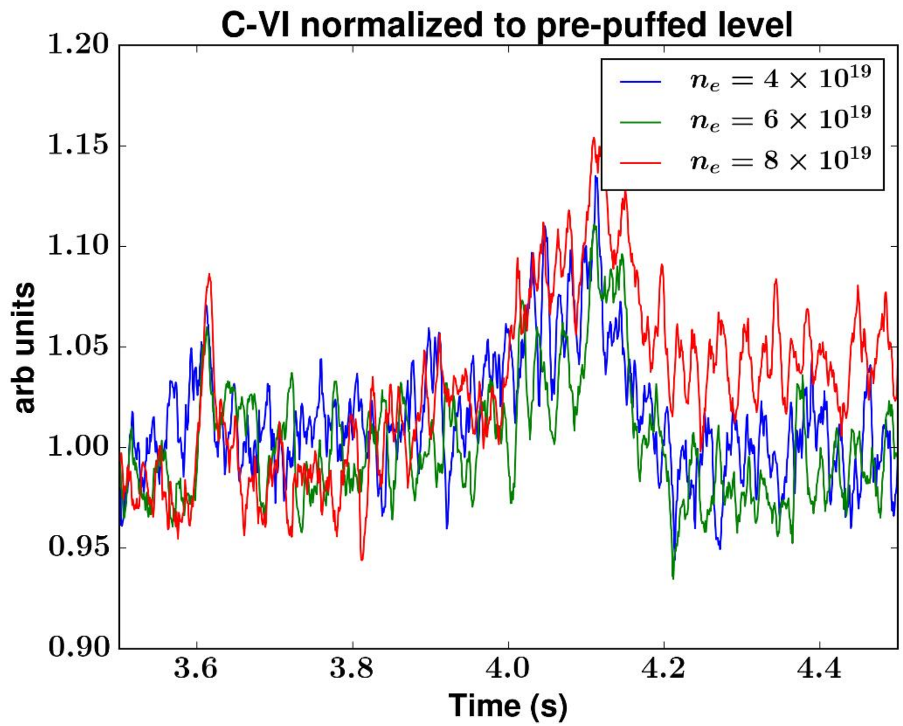




- ❑ **No significant change in carbon source flux as density is increased**
- ❑ **Overall decrease of C-VI likely not dominated by changing source**
- ❑ **Decrease of carbon particle flux during methane puff comes from large temperature decrease as measured by He-beam**

The percentage increase of normalized C-VI during methane puff is the same at all 3 density levels





- ❑ **Normalize raw C-VI signal to n_e/1E21**
- ❑ **Further normalize to C-VI value before methane puff level in each discharge**
- ❑ **At each density level, this percentage increase during the puff is the <u>same</u>**
  - ❑ **Likely similar transport processes at each density level**

Conclusions and Future Work

- An experiment to explore the carbon sourcing and transport in the SOL at different densities was performed

- Even without puffing, C-VI radiation was decreased as the density was increased
  - Preliminary carbon particle flux analysis shows a slight decrease in the source as the density is increased

  - Dominant effect modifying overall C-VI radiation could be emission changes from lowering T_e

- During methane puffs, the percentage increase of C-VI radiation is the same for all 3 density levels
  - Likely means transport processes were similar at all 3 density levels

- <u>Future Work</u>
  - CXRS profiles to determine the absolute carbon amount reaching the confined region
  - Better source calculation using perpendicular line of sight
  - Modeling of carbon migration from divertor puffing (FZJ)