Wendelstein 7-X

IPP Max-Planck-Institut für Plasmaphysik

Report: Sensitivity Analysis of Radiation Distributions in W7X

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EUROfusion

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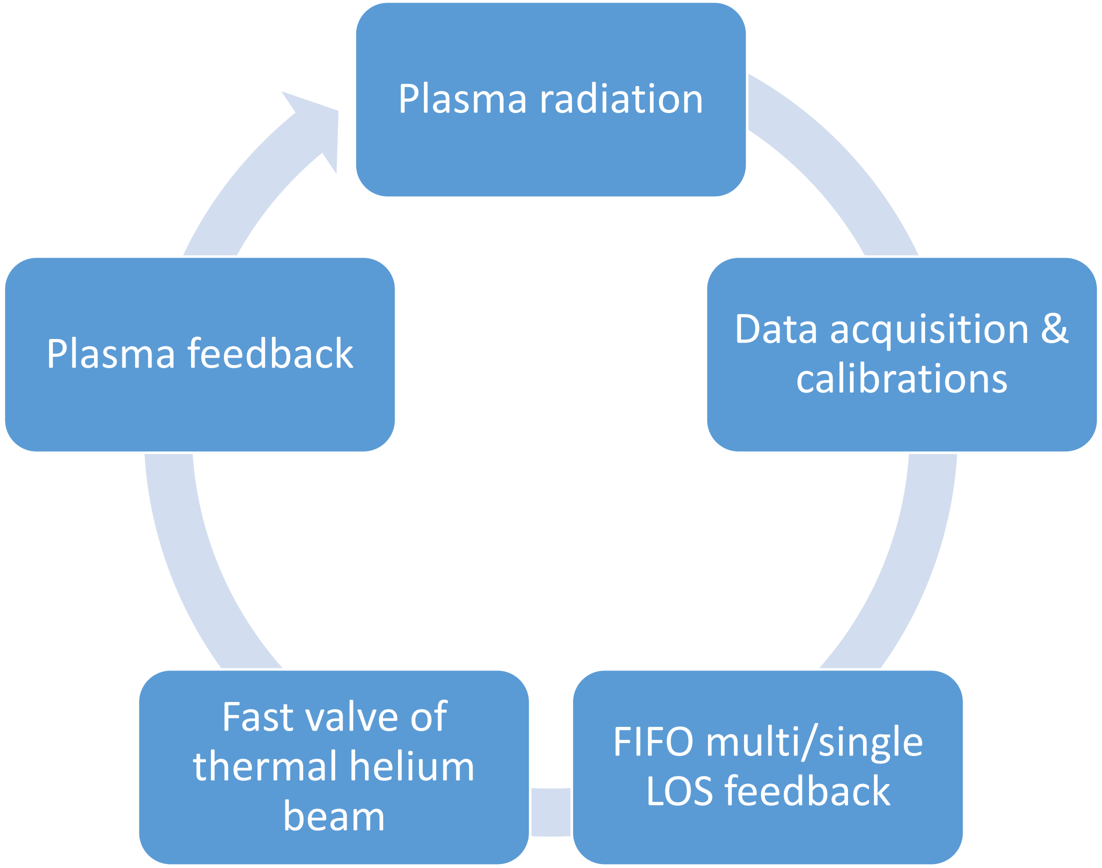
Background & Motivation

We try to use the Bolometer to control the plasma based off of information on the radiation distribution.

1) adjust heat loads, investigate radiation regimes, maybe improved detachment

2) investigate radiation (scaling), i.e. importance of intrinsic/extrinsic impurities



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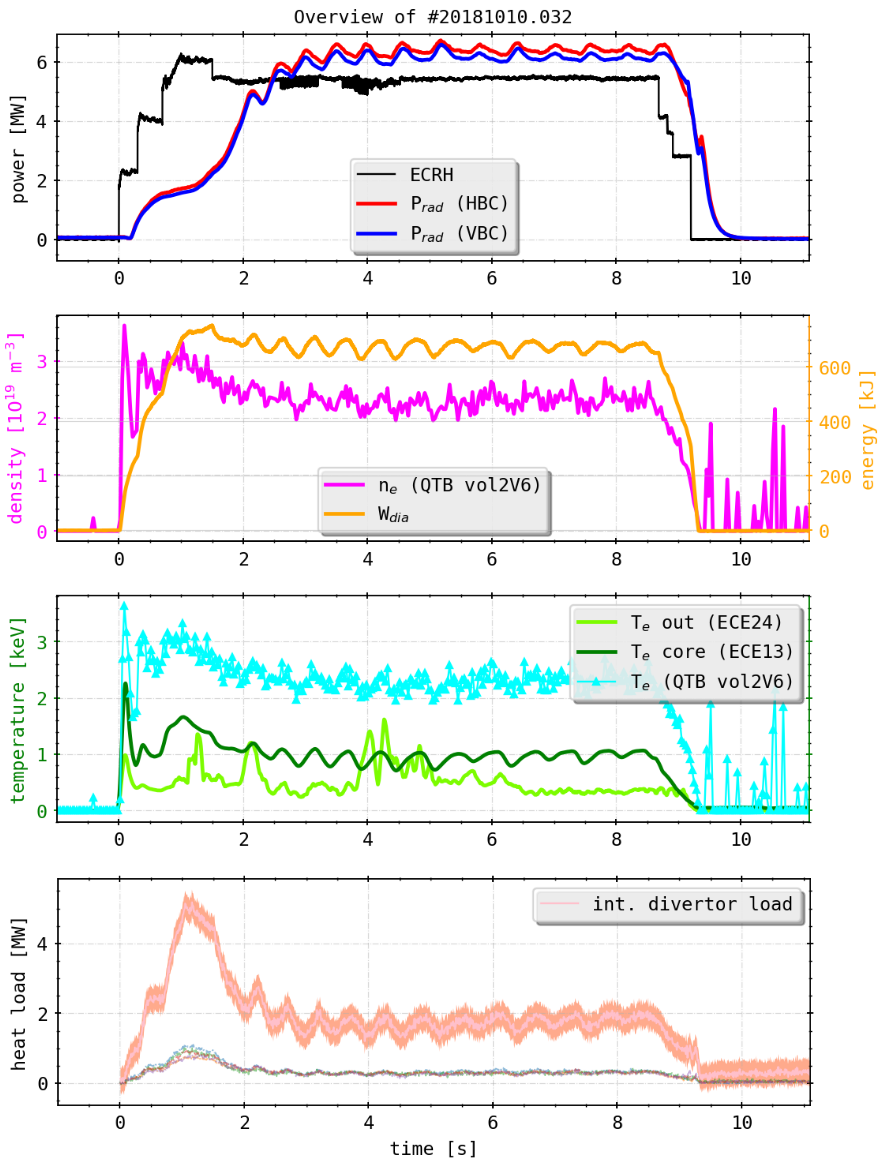

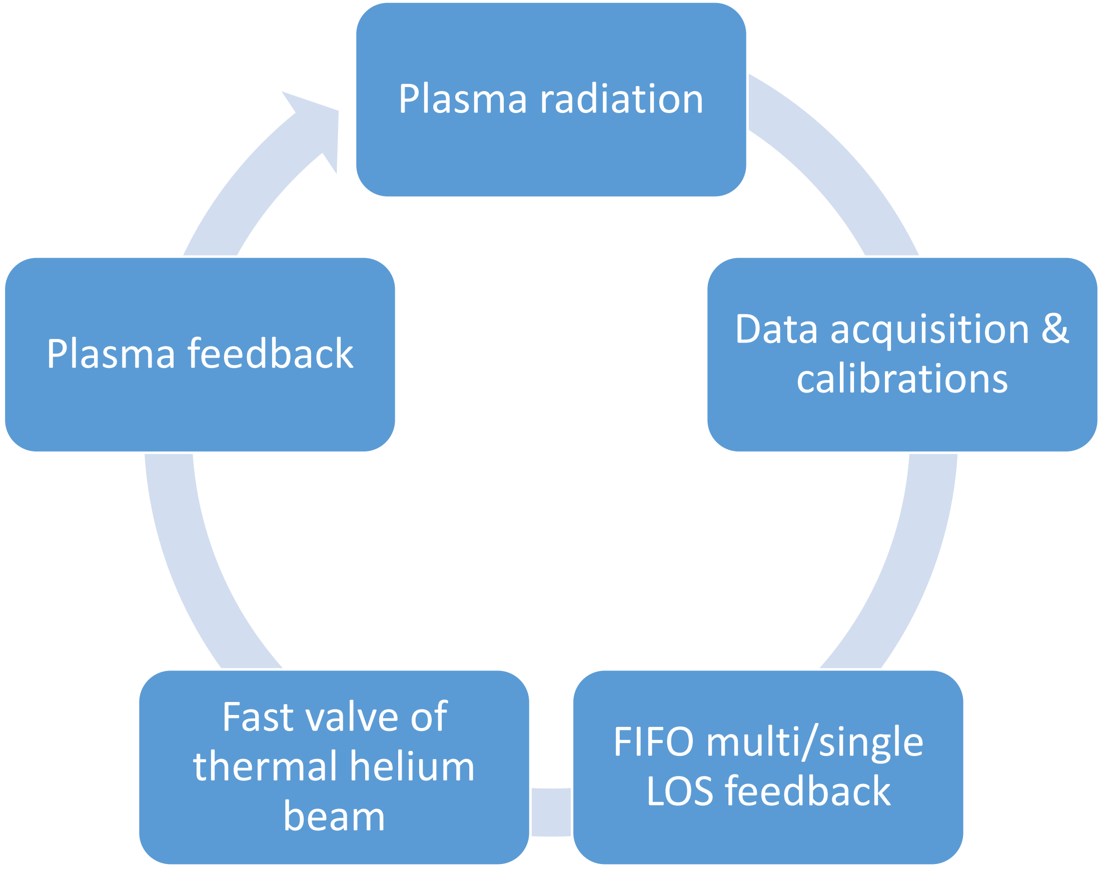

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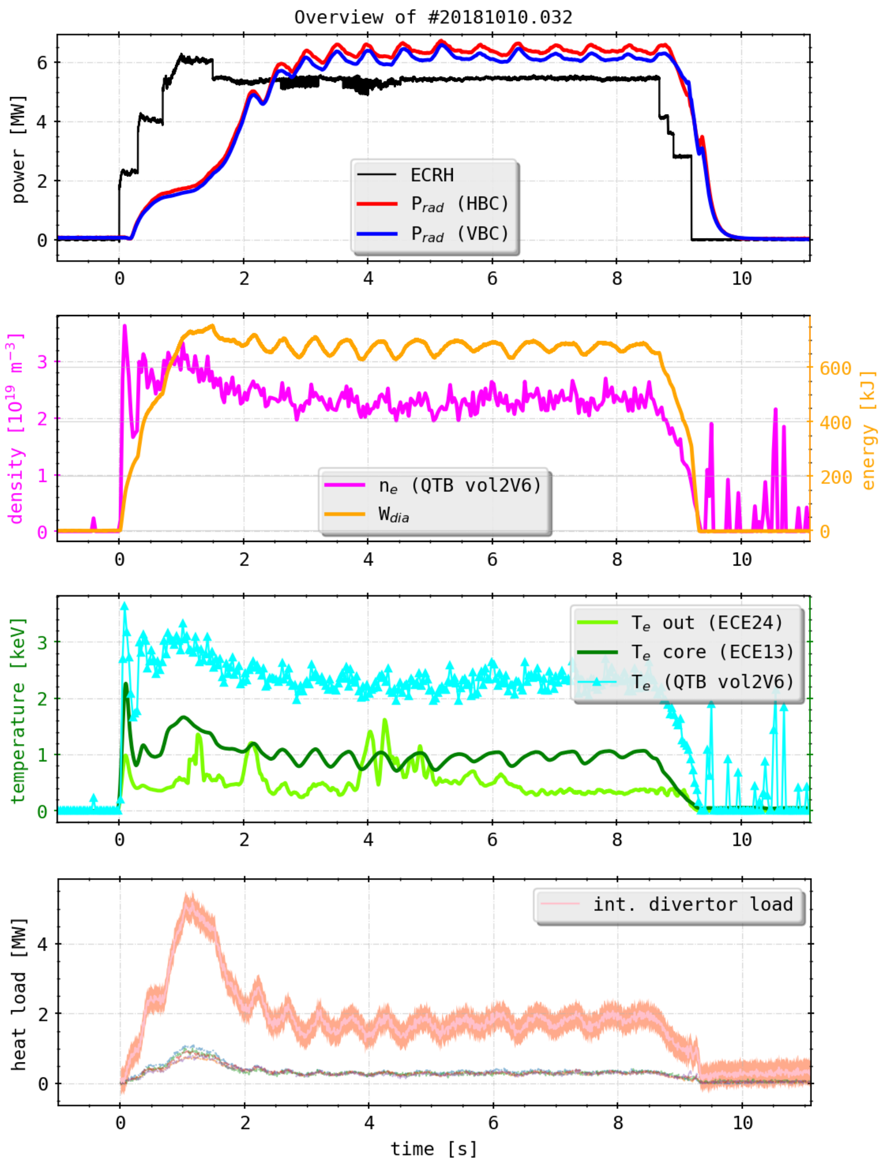

- increasing power loss fraction (f_{rad}) by radiation through evaluation of the radiation distribution
- initial ramping phase by gas puffing from thermal helium beam until target f_{rad} or P_{rad}
- fast valve is opened & closed according to feedback aiming for radiation loss equal to input power
- relatively constant W_{dia}, line int. electron temperature/density while target load is greatly decreased and f_{rad}~0.9 … 1.0

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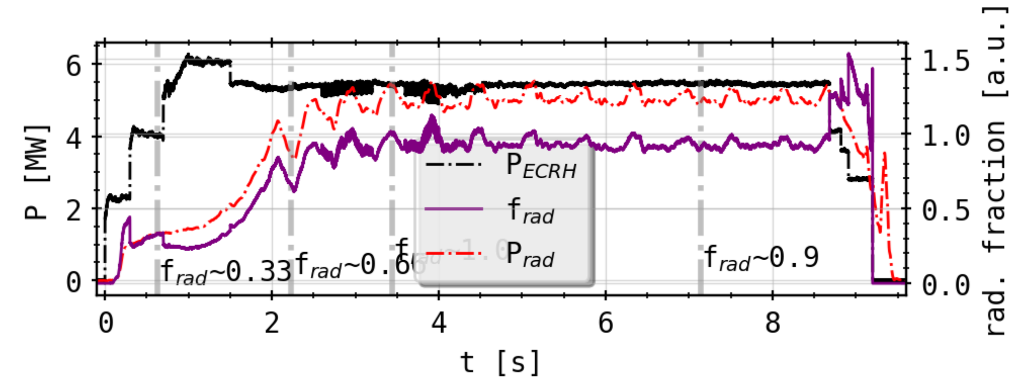

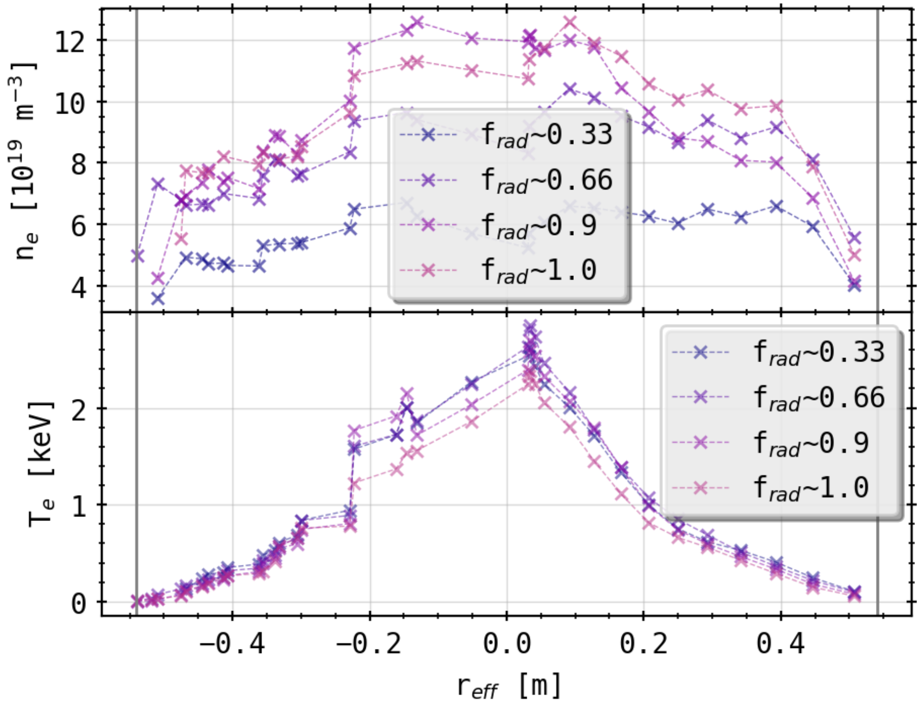

- overall increasing (Thomson scattering) n_e until $f_{rad} = 0.6$
- beyond: smaller changes in absolute value, edge profile shape (gradient and level)
- electron temperature decreases slightly with greater radiation fraction
- edge profile of T_e close to unchanged

➢ plasma irradiates more energy, conclusively lowering temperature while maintaining or increasing the density

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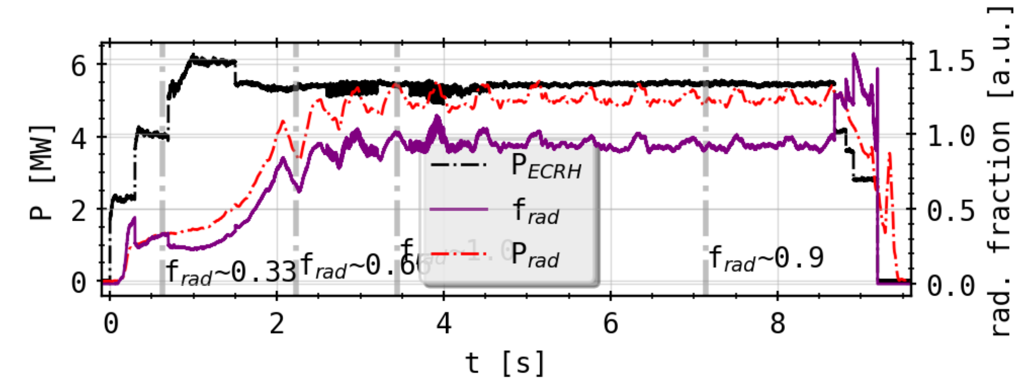

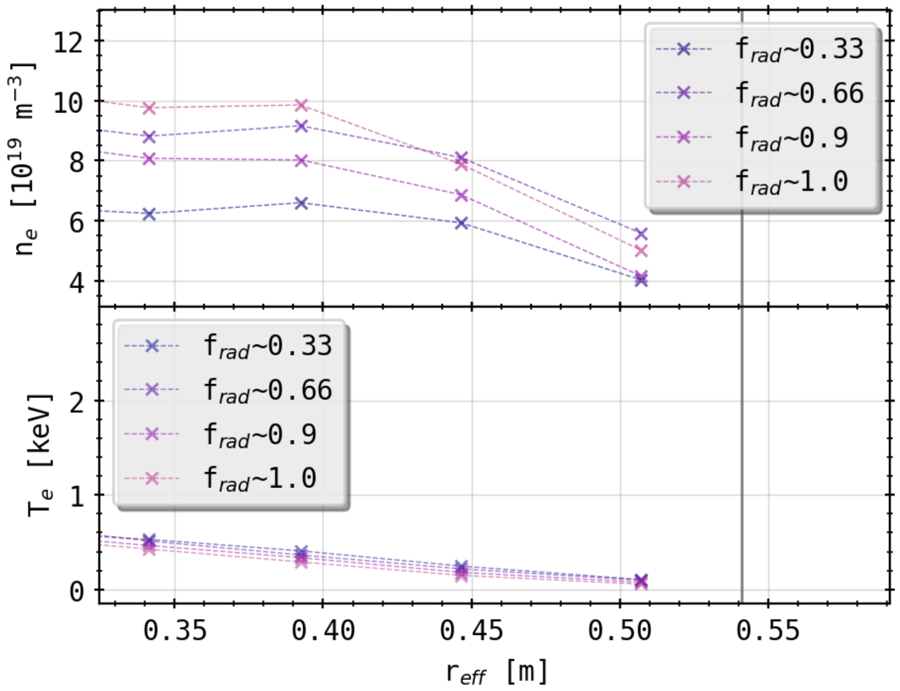

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Feedback Evaluation

- limited set of LoS possible for fast feedback calculations (e.g. 3-5 channels)

➢ Which channel yields most (important) information on plasma radiation?

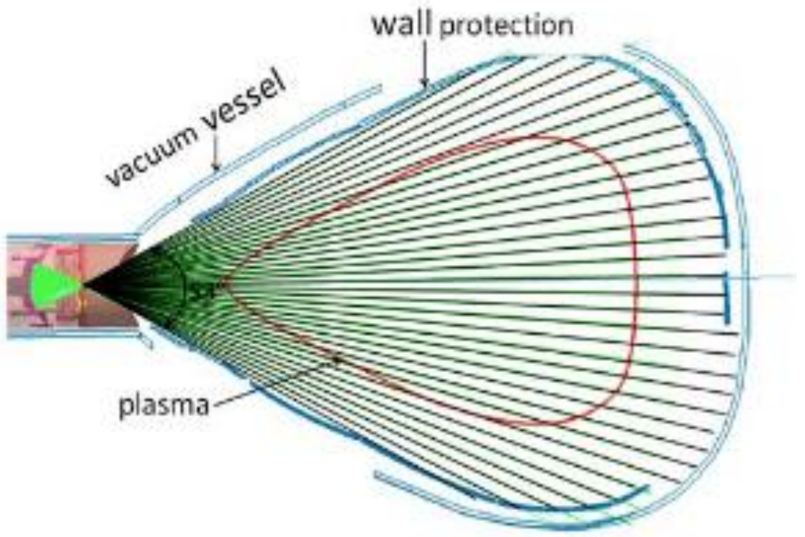
- Create measurement tools to decide on ‘best’ possible detector combination for estimation of P_{rad} during experiment:

Example:

$$d_{diff}(t) = \|P_{rad}(t) - P_{prediction}(t)\|$$

$$\varepsilon(t) = \left\{ \begin{array}{ll} 1 - \frac{d_{diff}(t)}{P_{rad}(t)} & , \; d_{diff} < P_{rad} \\ 0 & , \; \text{else} \end{array} \right\}$$

$$\vartheta = \overline{\varepsilon(t)}$$



AEU30
horizotal bolomter camera (HBC)

Feedback Evaluation

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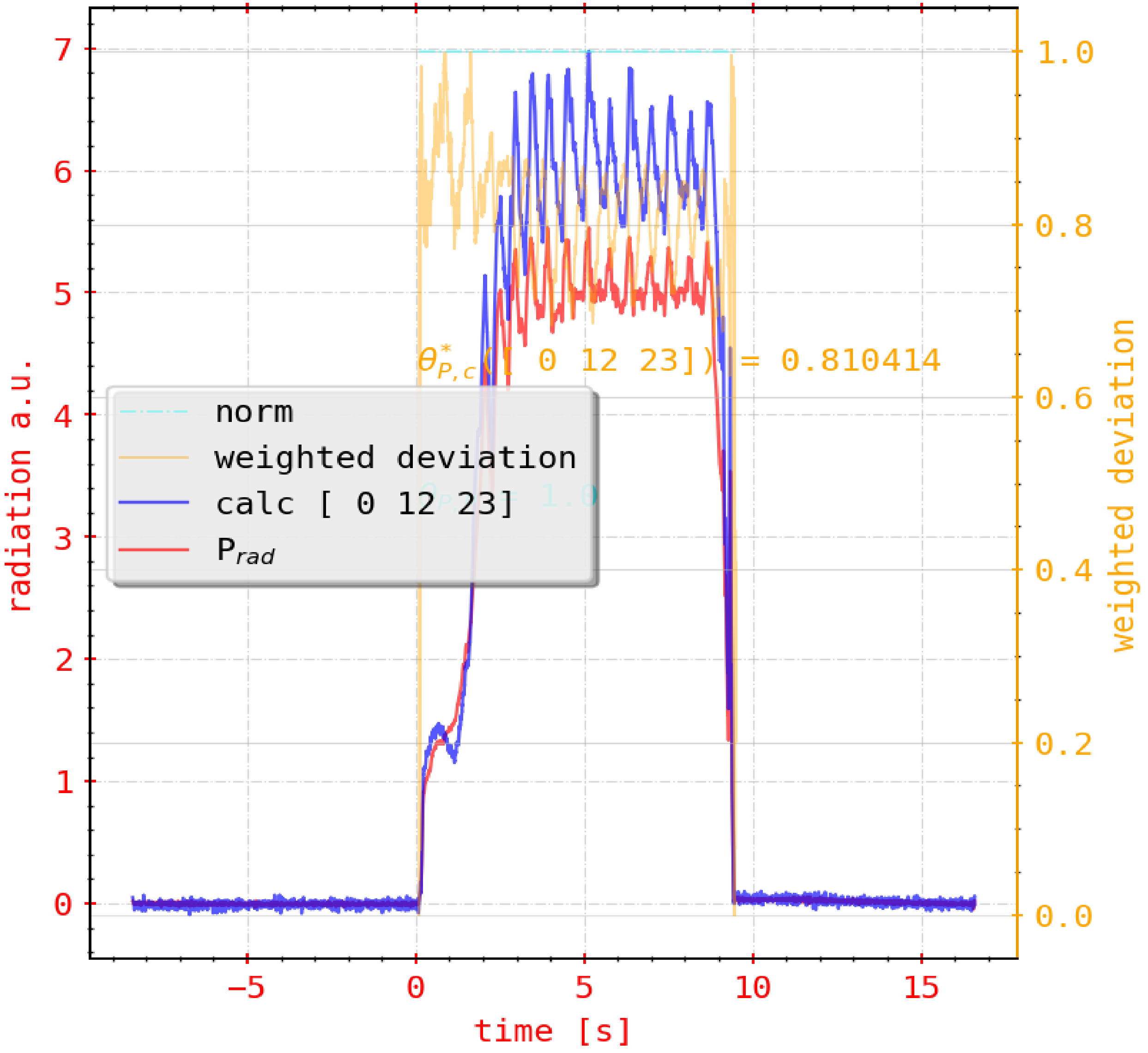
- done for >1e4 combinations of cameras and channels
- + 8 different sensitivity metrics (e.g. self correlation, coherence, convolutional)
- + multiple experiments



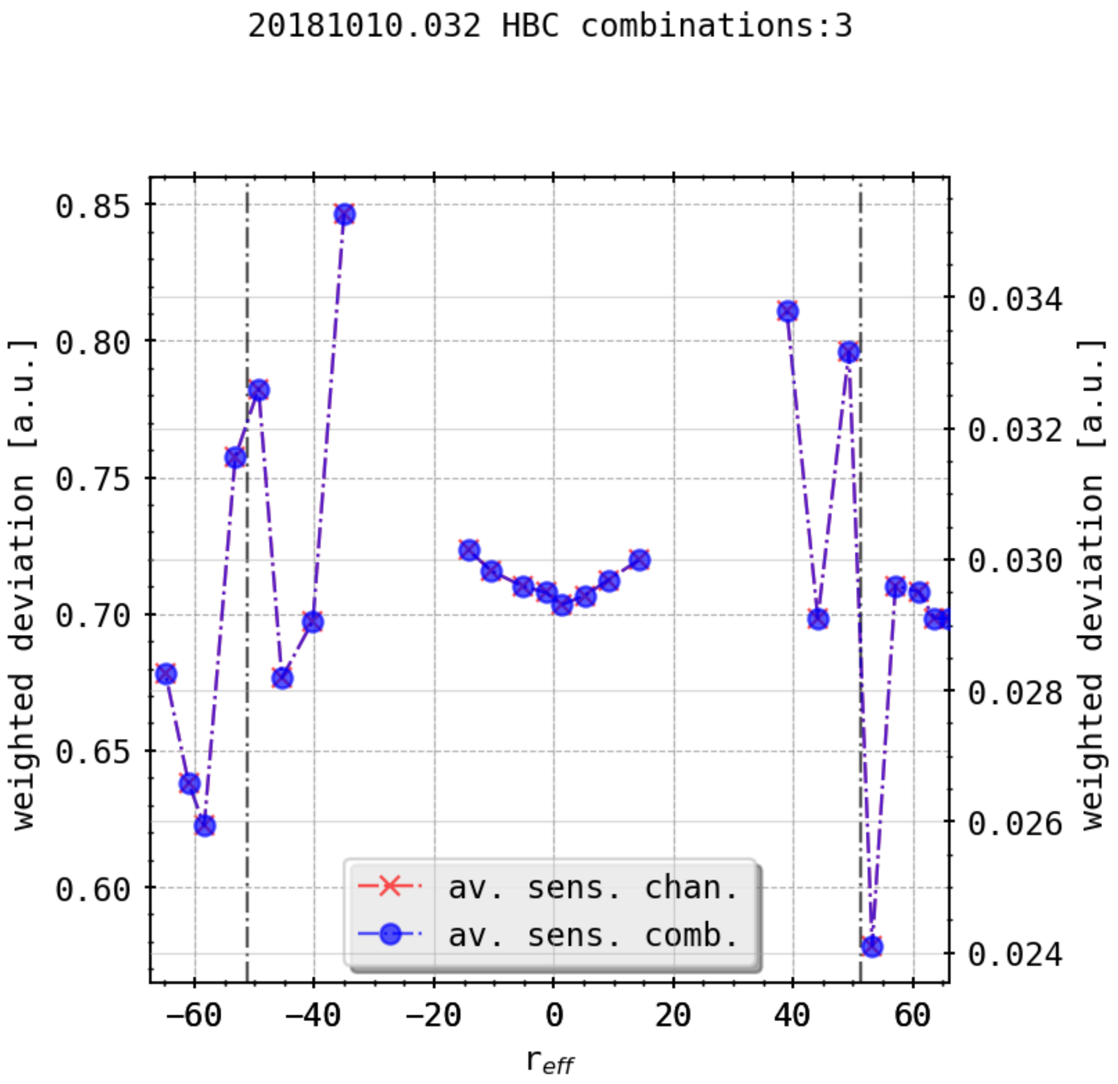
Feedback Evaluation

- all evaluation methods and camera/subset combinations show roughly same behavior:

➢ detectors viewing tangential to the LCFS/SOL or along island chains are capable of (at all times) representing >60% of the plasma radiation

➢ lines of sight along the LCFS + slightly inwards are most sensitive to changes in the plasma radiation regime

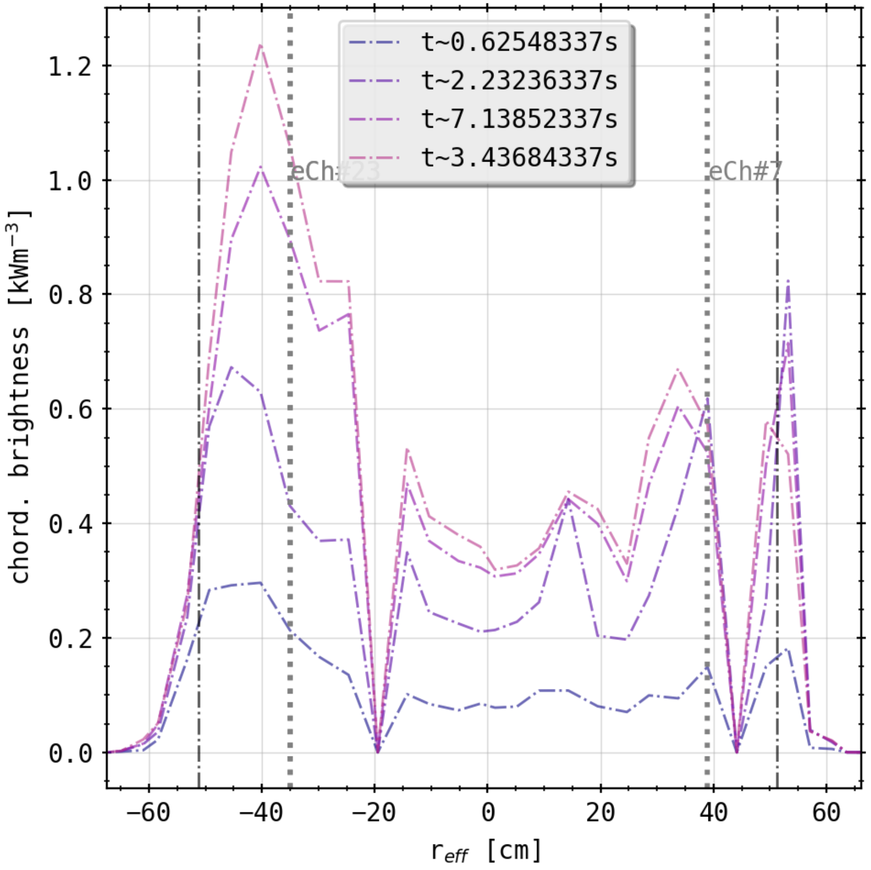
➢ a well picked subset of 3 detectors can reflect the total plasma radiation with up to 90% accuracy (!)



Feedback Evaluation

- majority of radiation comes from edge region or close to SOL
- with increasing radiation fraction chordial brightness shifts inwards away from LCFS
- core radiation rises relative uniformly according to f_{rad}
- greatly increasing fraction of radiation from confined region

➢ radiation source responsible for shift given the previous plasma profiles? (decreasing T_e, intrinsic impurities …)

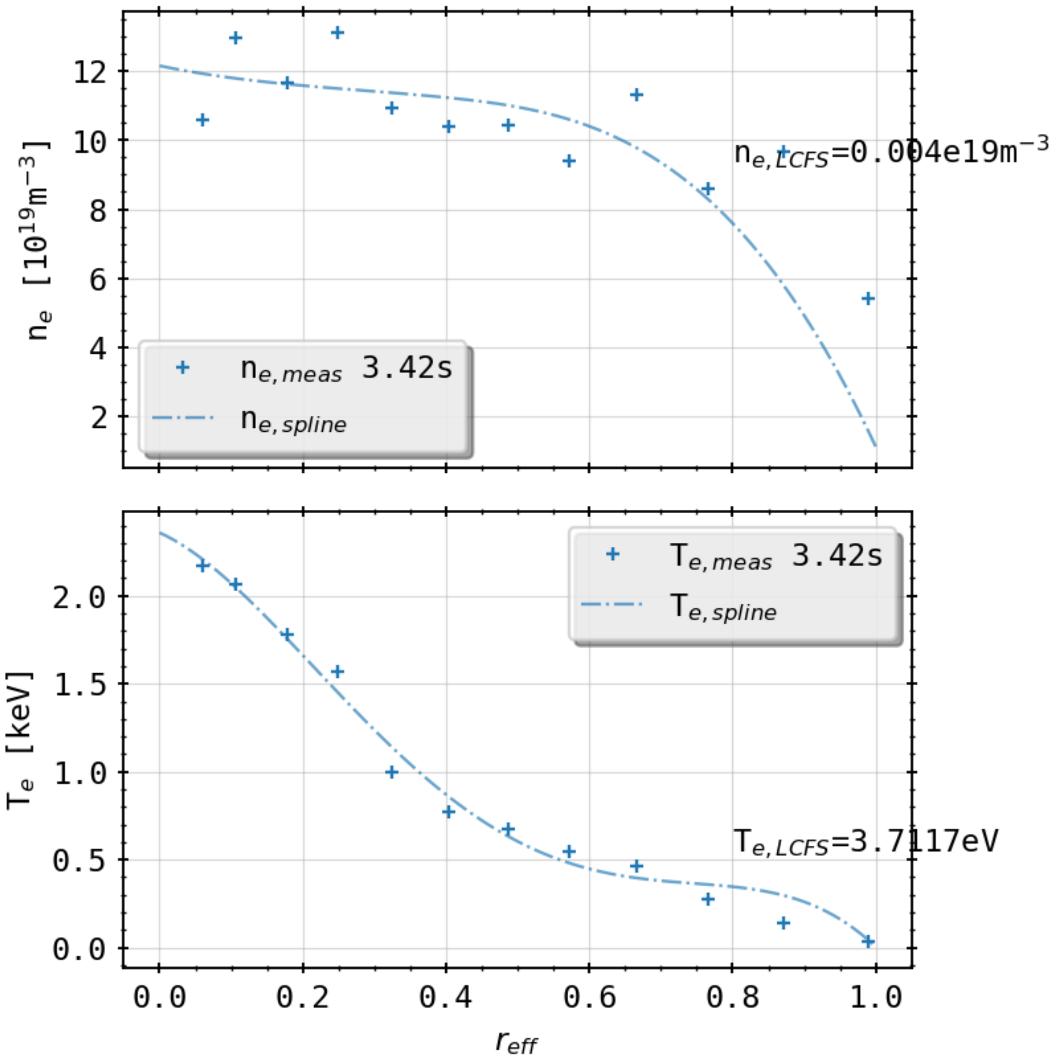


chordial profiles of the previously discussed f_{rad}

STRAHL Simulations of Carbon Radiation

- assuming 1D distribution given the chordial profiles, i.e. radiation coming from inside the LCFS
- investigating main intrinsic impurity carbon (i.e. lines measured also by HEXOS)

- using TS profiles from radiation feedback controlled plasma
- scale values of electron density and temperature at the SOL, i.e. $r_{eff} = 1.0$ since TS is least accurate
- 4th order spline interpolation for smoothness (k=3 leads to rising edge T_e



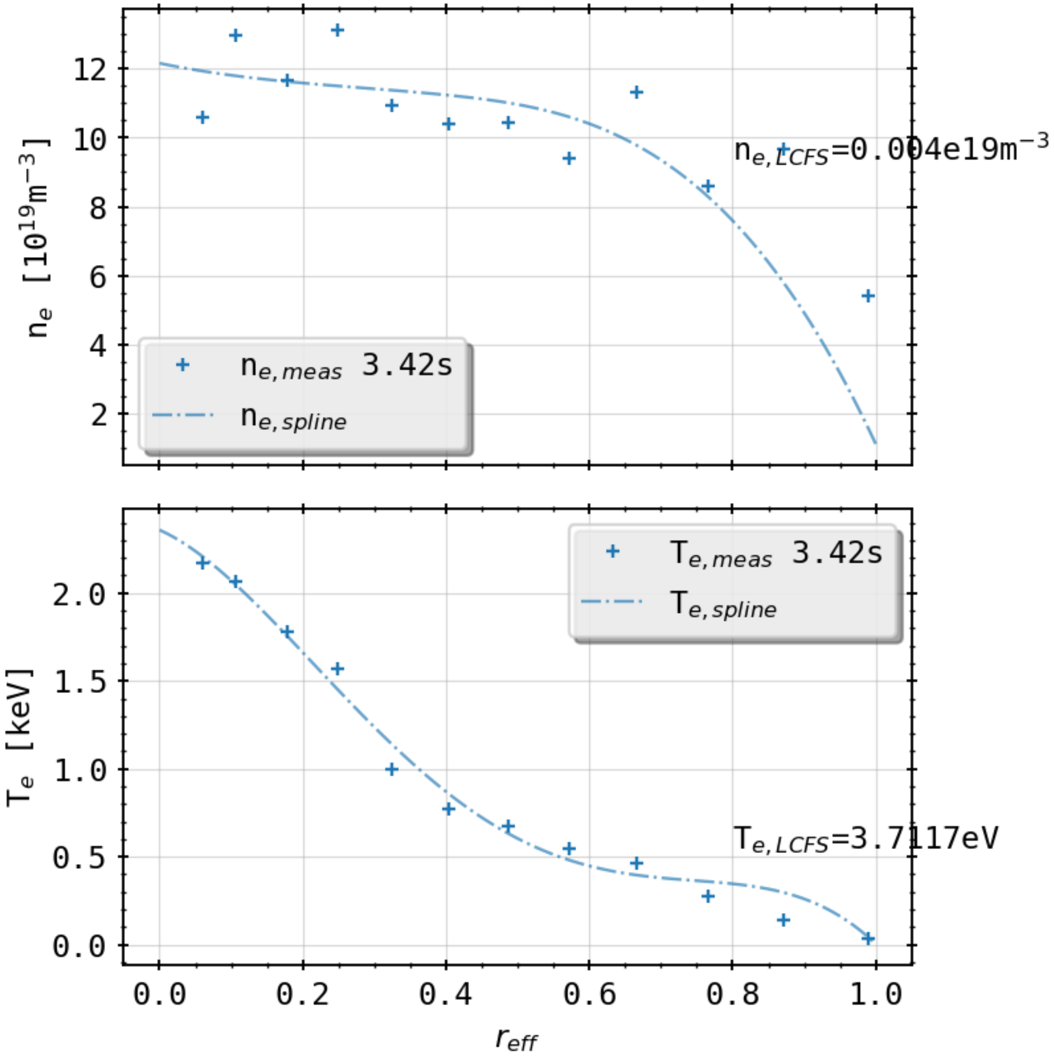
TS profiles (+) and STRAHL profiles for $f_{rad} = 1.0$

STRAHL Simulations of Carbon Radiation

- transport: $D = 0.1\,\frac{m^2}{s}$ at the center, $5\,\frac{m^2}{s}$ at $r_{eff} = 0.6$ and $0\,\frac{m^2}{s}$ at the LCFS

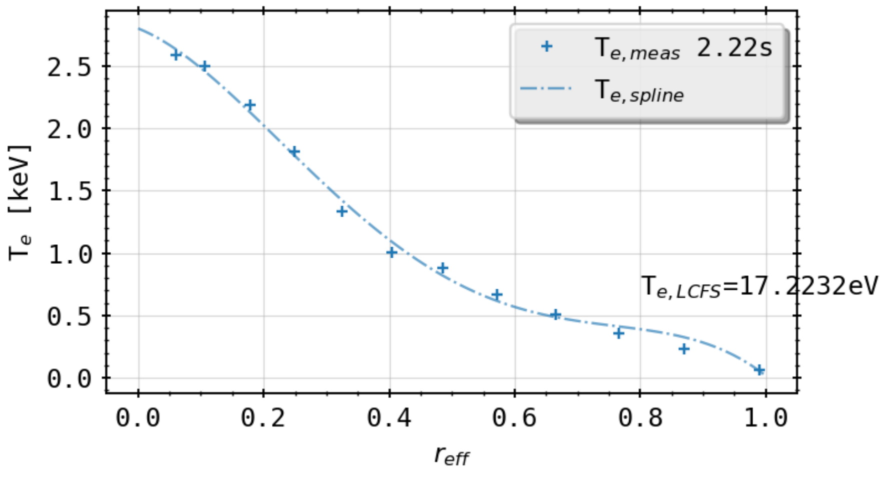
- decay length of temperature and density $\lambda = 5cm$, mimicing island chain regions

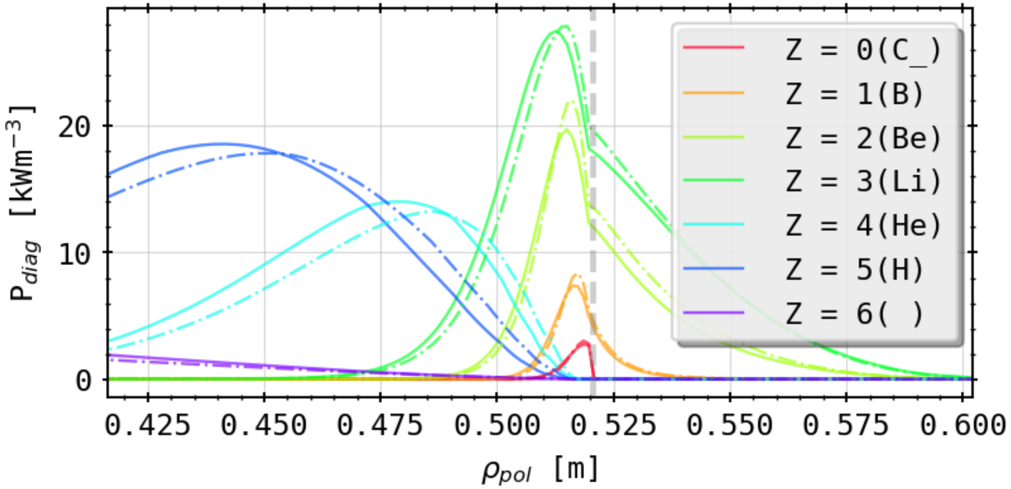
- source of carbon at the SOL with $10^{21}s^{-1}$

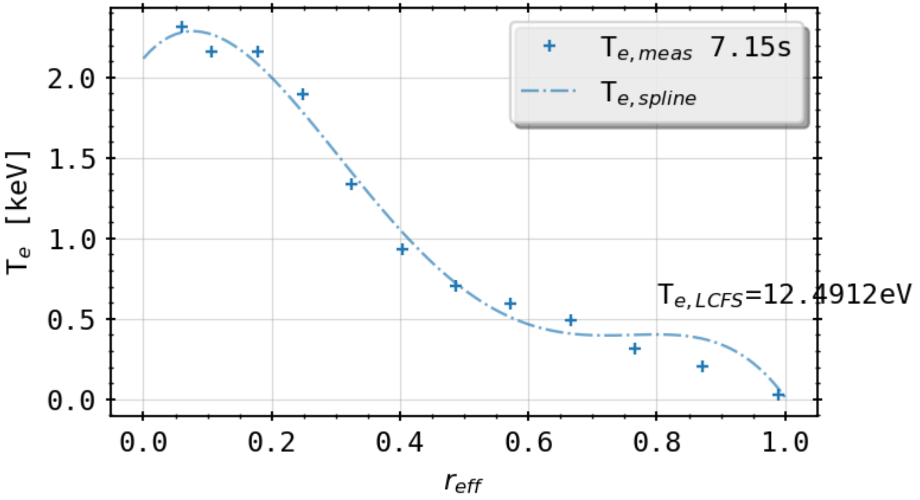


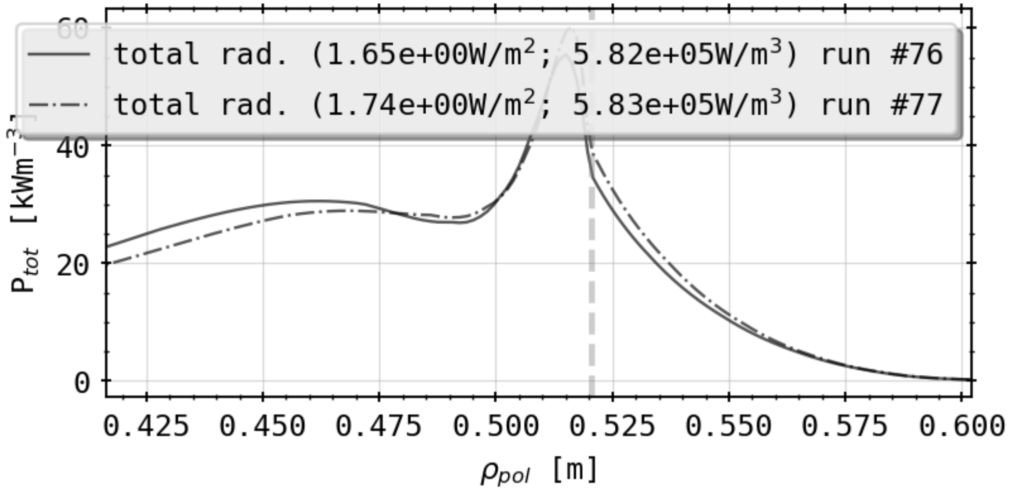
TS profiles (+) and STRAHL profiles for $f_{rad} = 1.0$

STRAHL Simulations: 60% v 90%









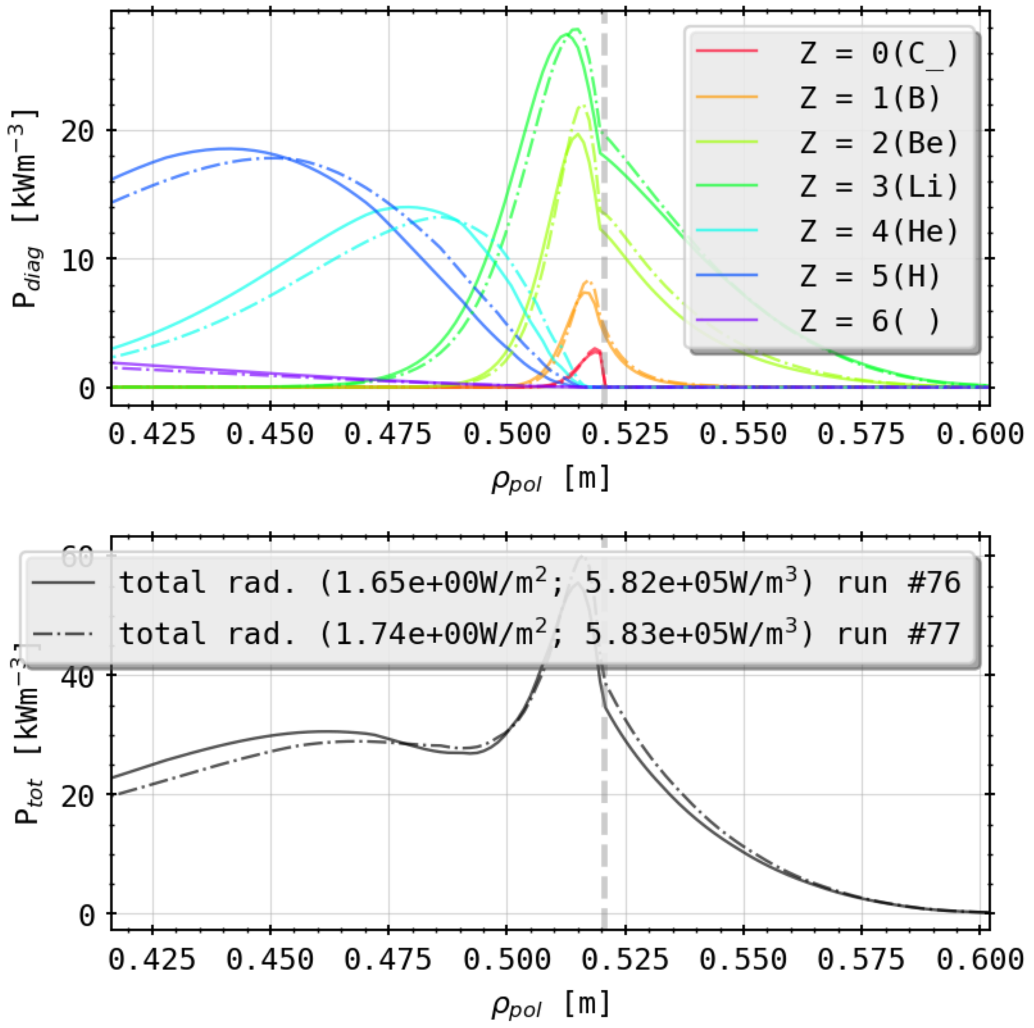
TS profiles (+) and STRAHL profiles for $f_{rad} = 0.6, 0.9$

coronal equilib. line radiation profiles for $f_{rad} = 0.6, 0.9$

STRAHL Simulations: 60% v 90%

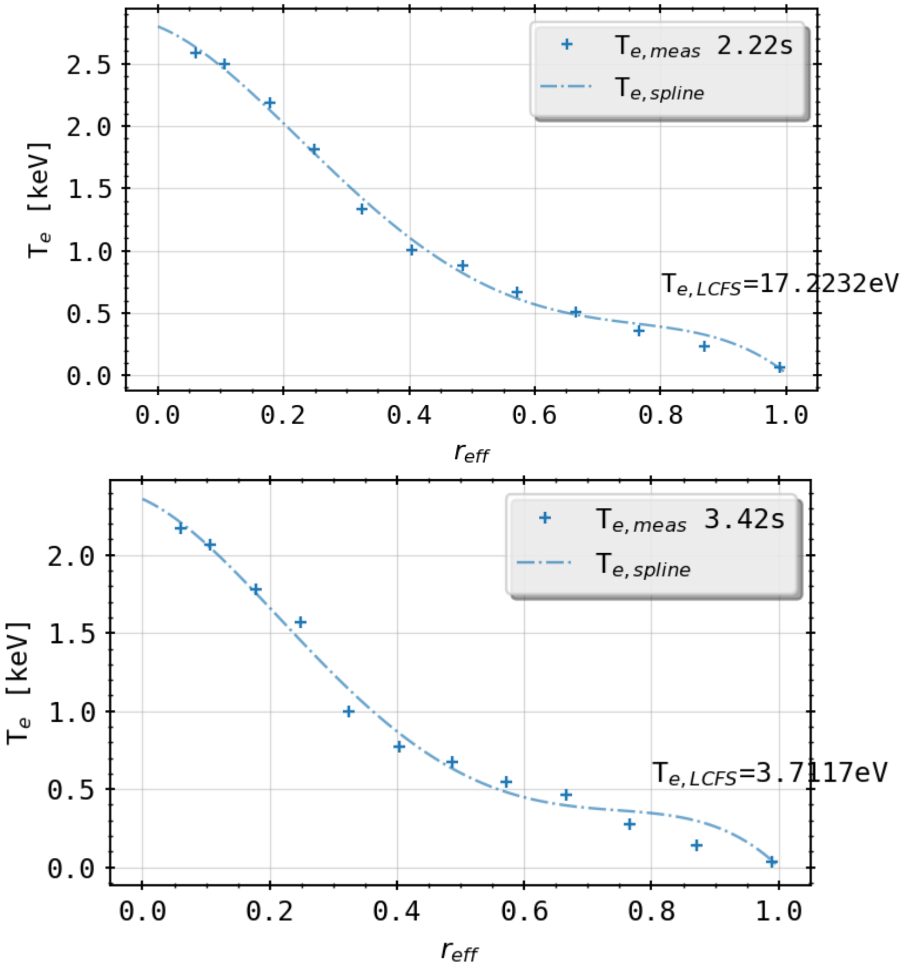
- minimal inward shift of all ionization stages inconclusive for Bolometer, since spatial resolution is 5cm
- slight change of radiation fraction between core and SOL

➢ radiation peak inside LCFS



coronal equilib. line radiation profiles for $f_{rad} = 0.6, 0.9$

STRAHL Simulations: 60% v 100%



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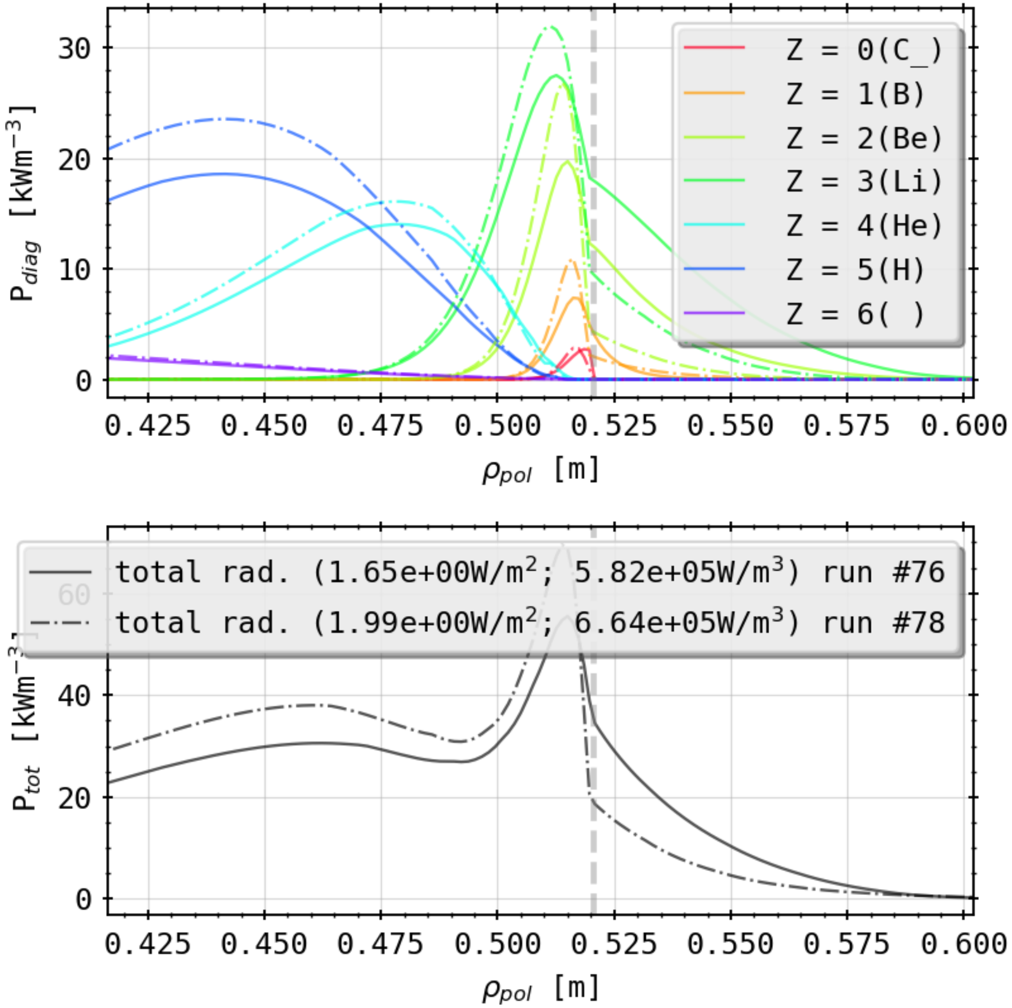


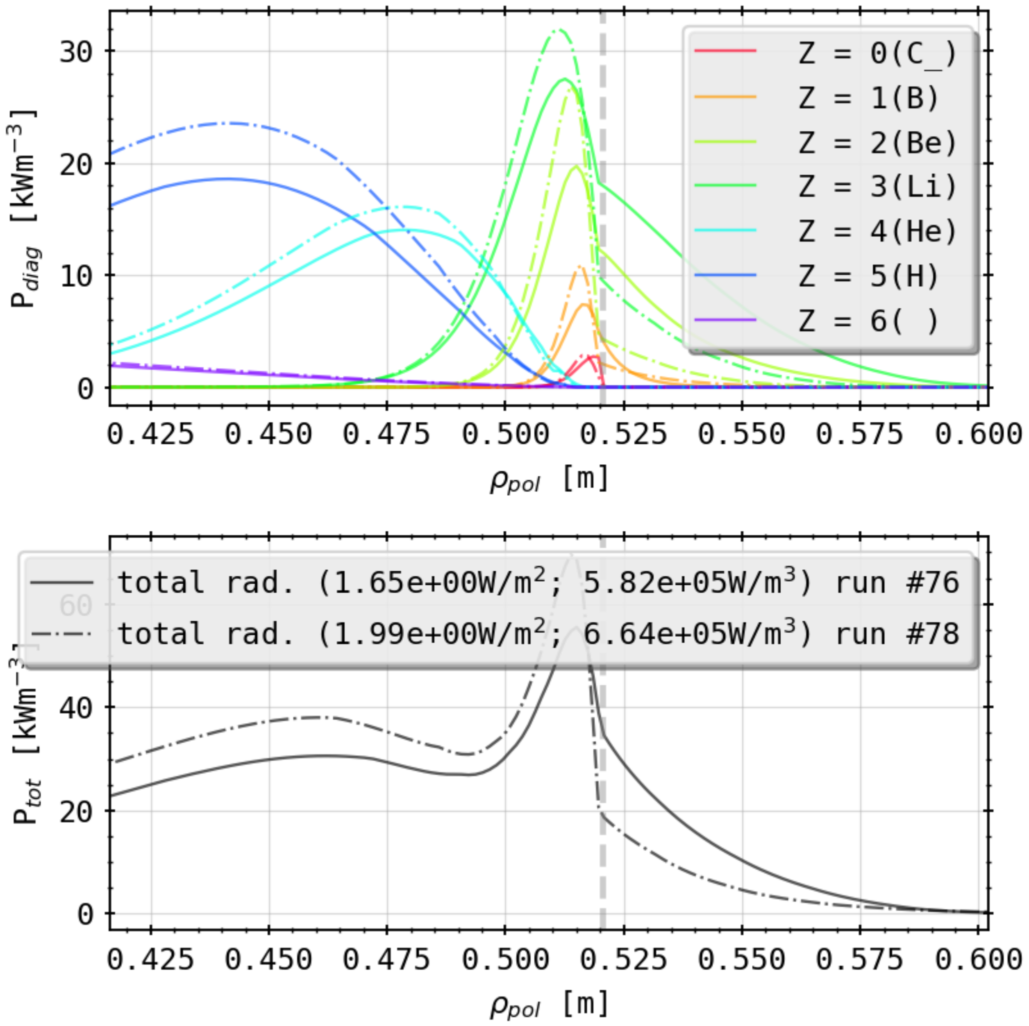
coronal equilib. line radiation profiles for $f_{rad} = 0.6, 1.0$

STRAHL Simulations: 60% v 100%

- very small temperature at LCFS (3eV) for 100% of irradiated power
- insignificant shift in position of ionization peaks

➢trend between SOL and core radiation changes >> strong core radiating carbon population

➢volume integrated radiation (for 30sqm of plasma volume) roughly matches experimental level



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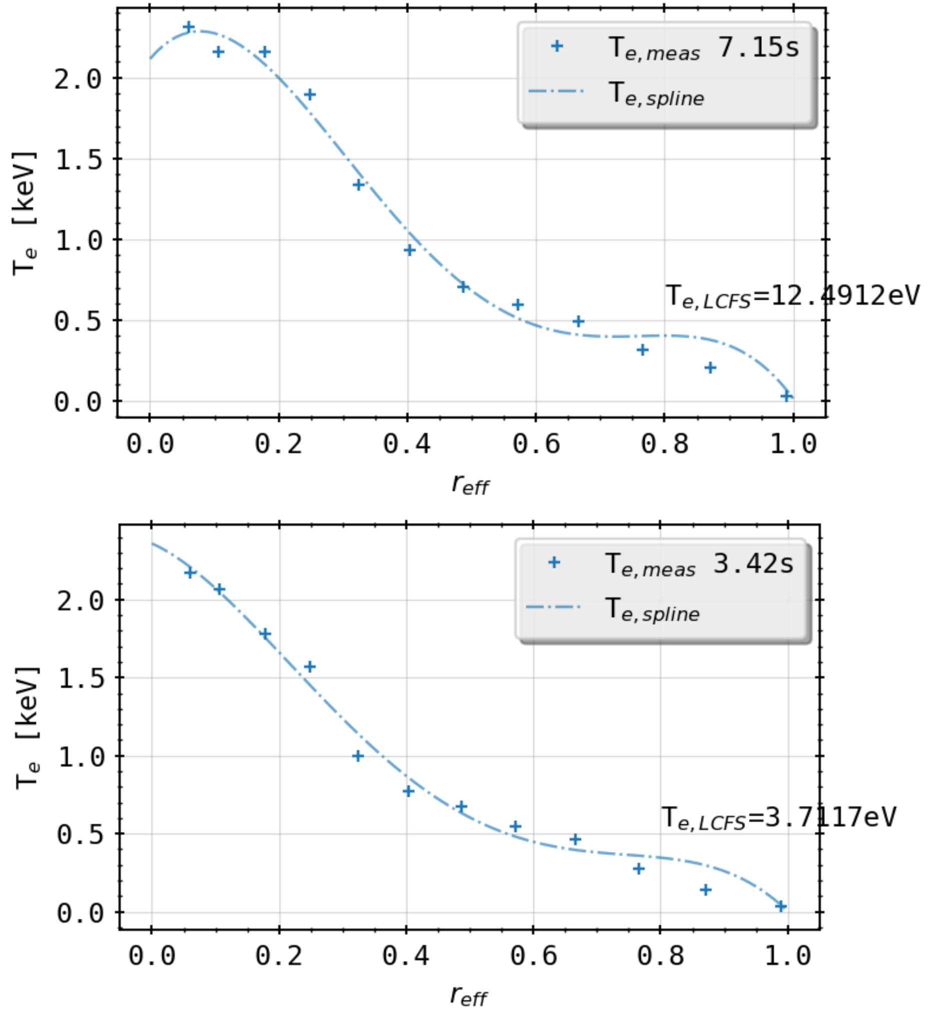
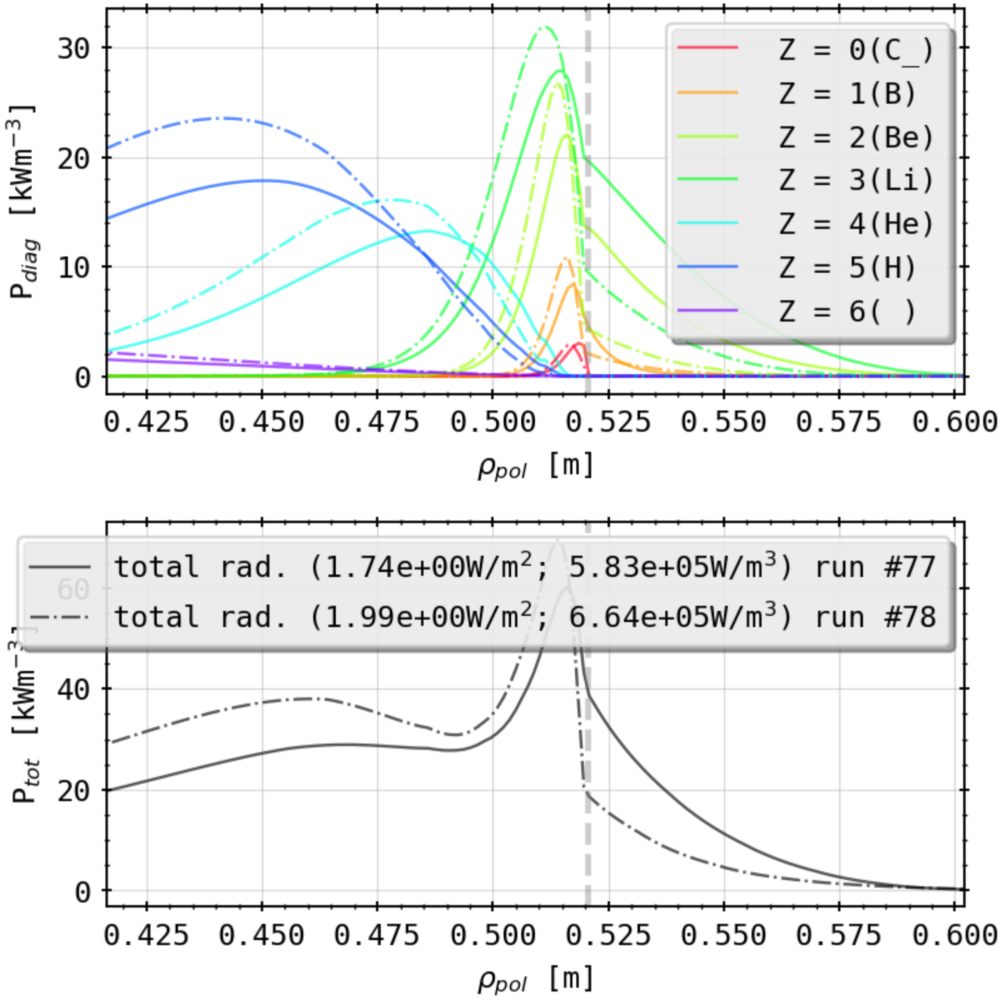


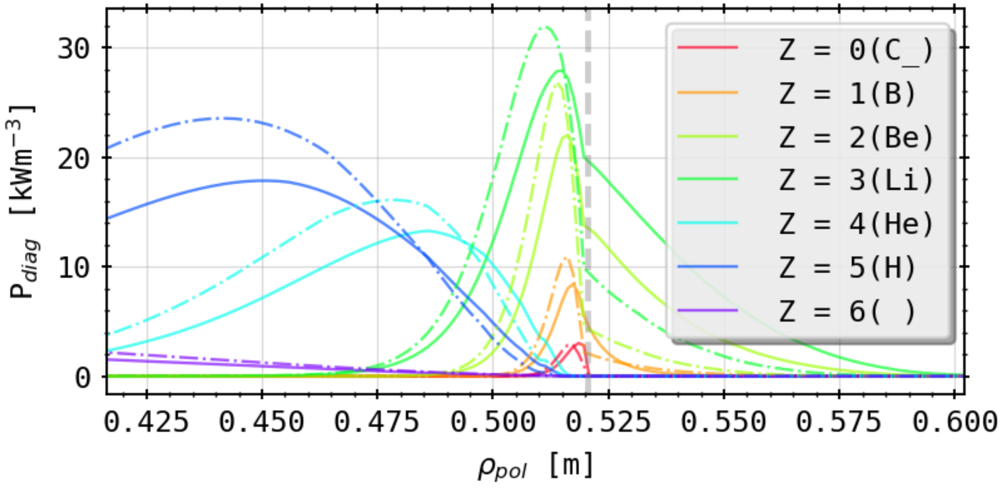
TS profiles (+) and STRAHL profiles for $f_{rad} = 0.9, 1.0$

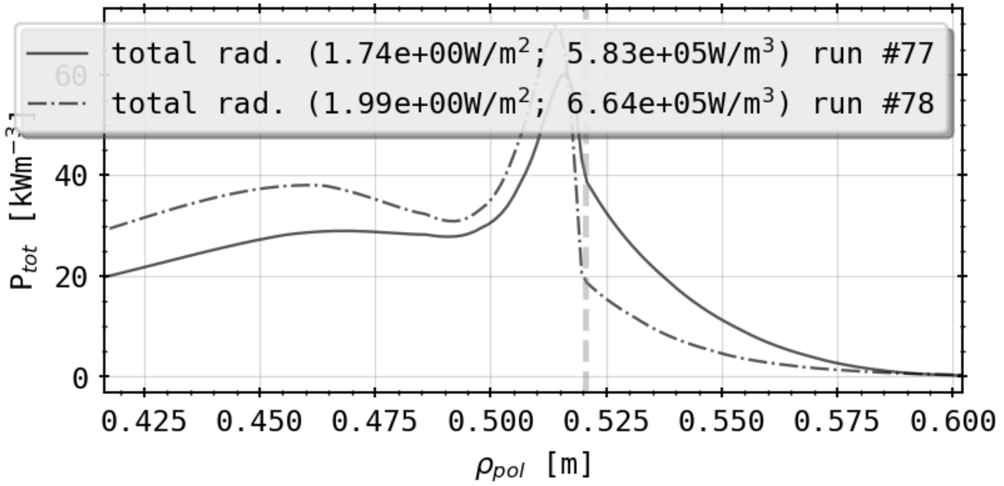


coronal equilib. line radiation profiles for $f_{rad} = 0.9, 1.0$

STRAHL Simulations: 90% v 100%

- measurable spatial shift, especially now in Be- and Li-like ion radiation peaks
- transition from bright to dark SOL from 90% to 100% of radiation power loss
- possible means for radiation regimes in detachment
- intrinsic impurity C main radiation source? (oxygen levels <1/3rd for same scenario)





coronal equilib. line radiation profiles for $f_{rad} = 0.9, 1.0$

Future Investigation

- directly compare line integrated STRAHL results for lines of sight geometry with chordial profiles
- measure SOL and core radiation in both STRAHL and Bolometer data
- extend simulation space to 2D inversion with MFR(Minimum Fisher Regularization)