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# Tungsten surface temperature calculated by means of PIC simulations: bifurcation and space charge limited regime

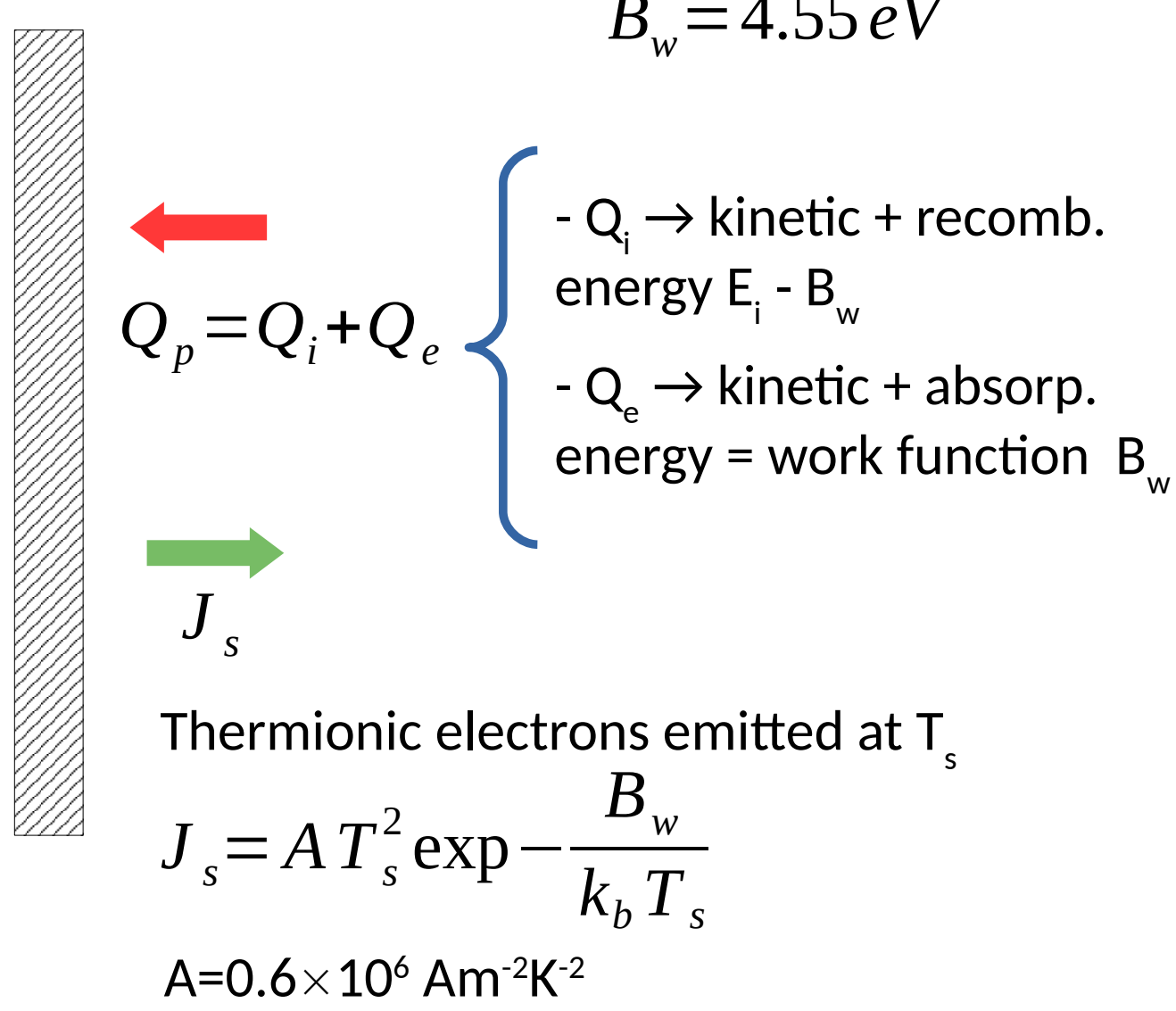
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## Context of the Simulations

- 1d/3V PIC simulations ( $L=100L_d$ )
- Tungsten surface with  $\epsilon=0.25$   
 $B_w=4.55\text{ eV}$



- Heat flux balance at the wall at each iteration

$$Q_p = Q_c$$

$$\text{With [1]} \quad Q_c = J_s (2k_b T_s + B_w) + \epsilon \sigma T_s^4 + \frac{\kappa}{l} (T_s - T_0)$$

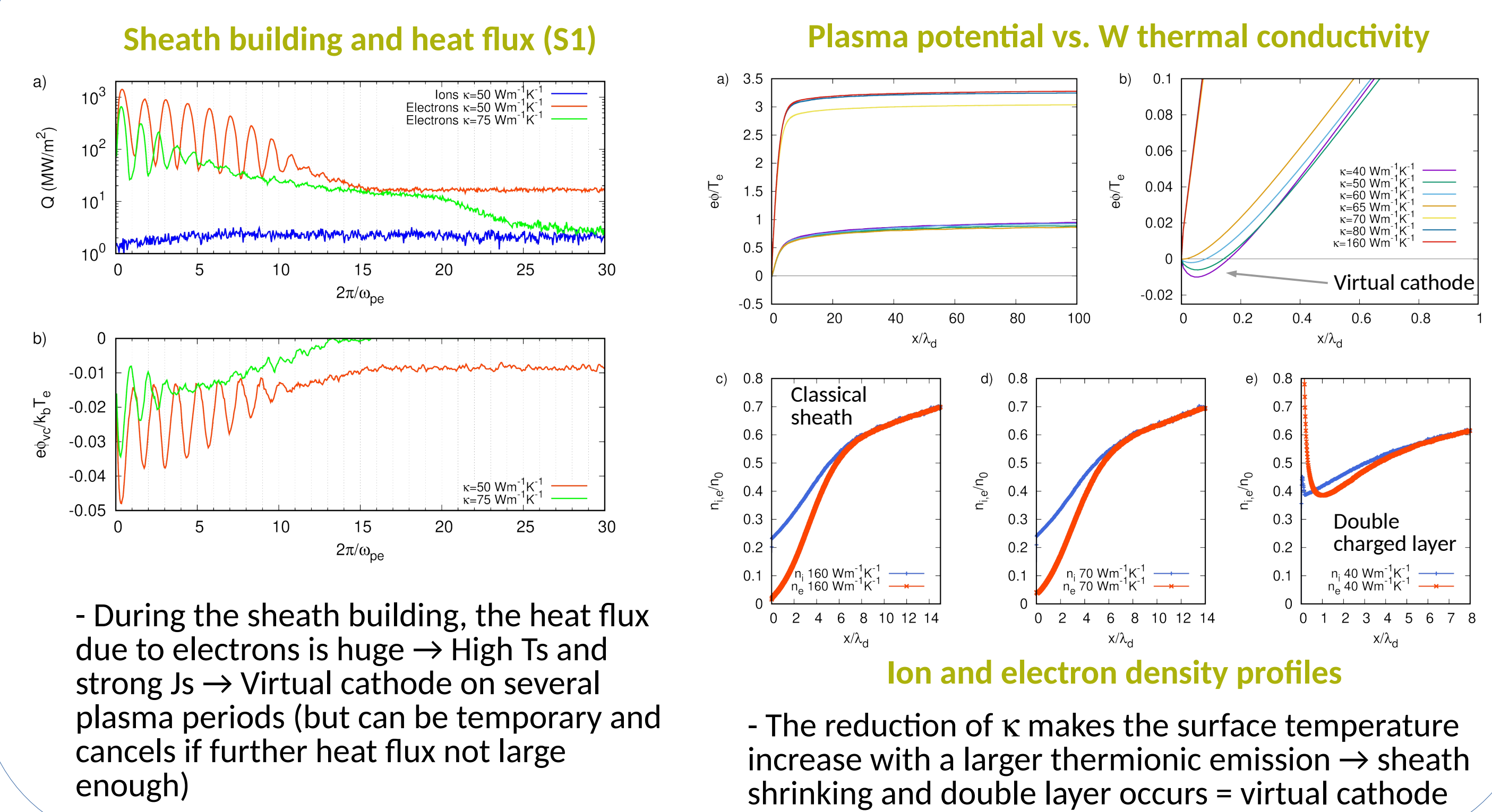
→ gives  $T_s$  and then  $J_s$  to be injected + loop until the steady state ( $T_0 = 300\text{ K}$  and wall thickness  $l=1\text{ cm}$ ).

### - 2 Simulation scenarios:

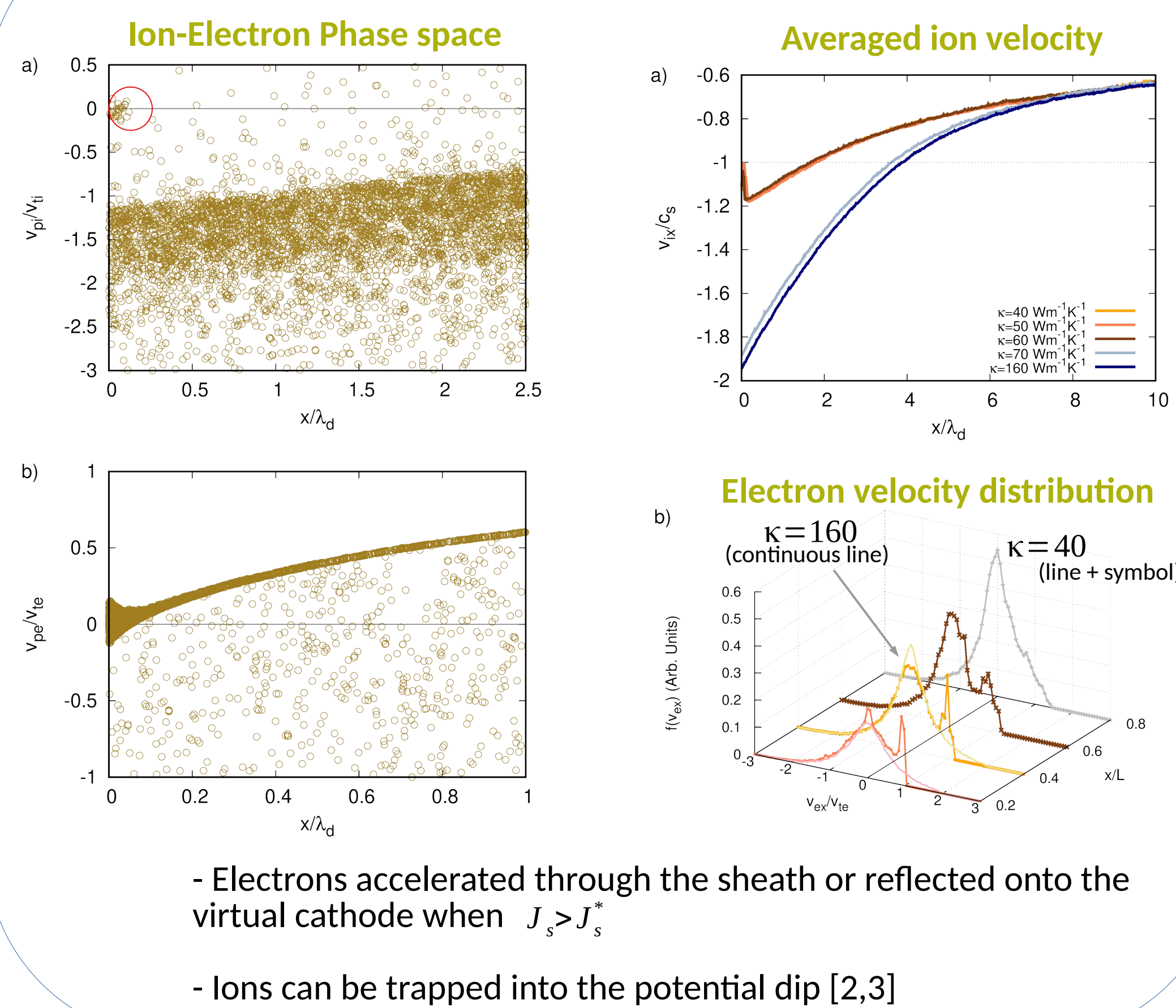
S1: The routine calculating  $T_s$  and  $J_s$  is run at the beginning of the simulations. During the establishment of the sheath, the surface receives a very large heat flux due to the electrons → high  $T_s$ . Then the wall eventually cools down to the steady state.

S2: The routine calculating  $T_s$  and  $J_s$  is launched after 10 plasma periods (*waiting time*) for the sheath to be established. The cathode can then be cold before the steady state is reached contrary to scenario 1.

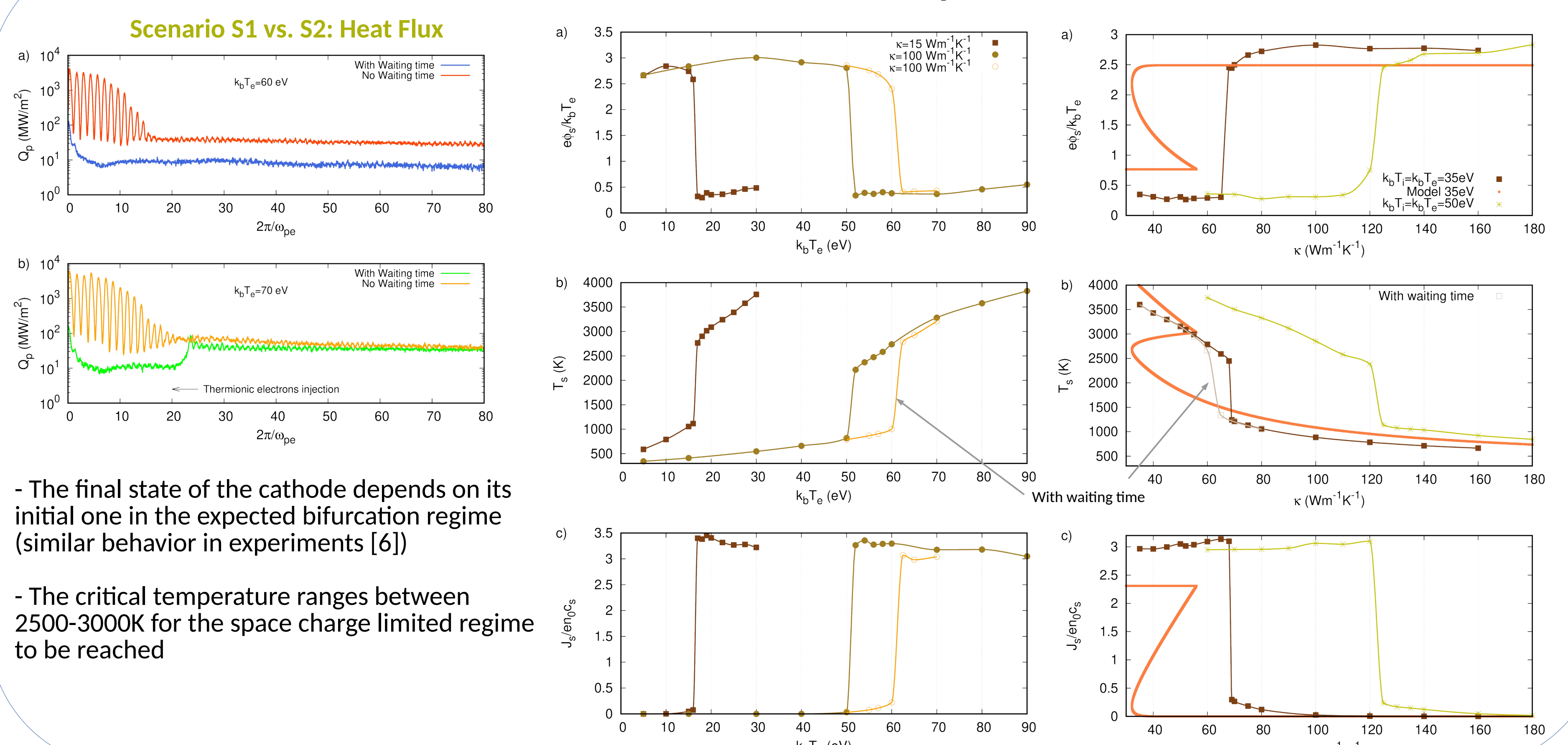
## Sheath building & Space potential + plasma density



## Phase space and Velocity distribution

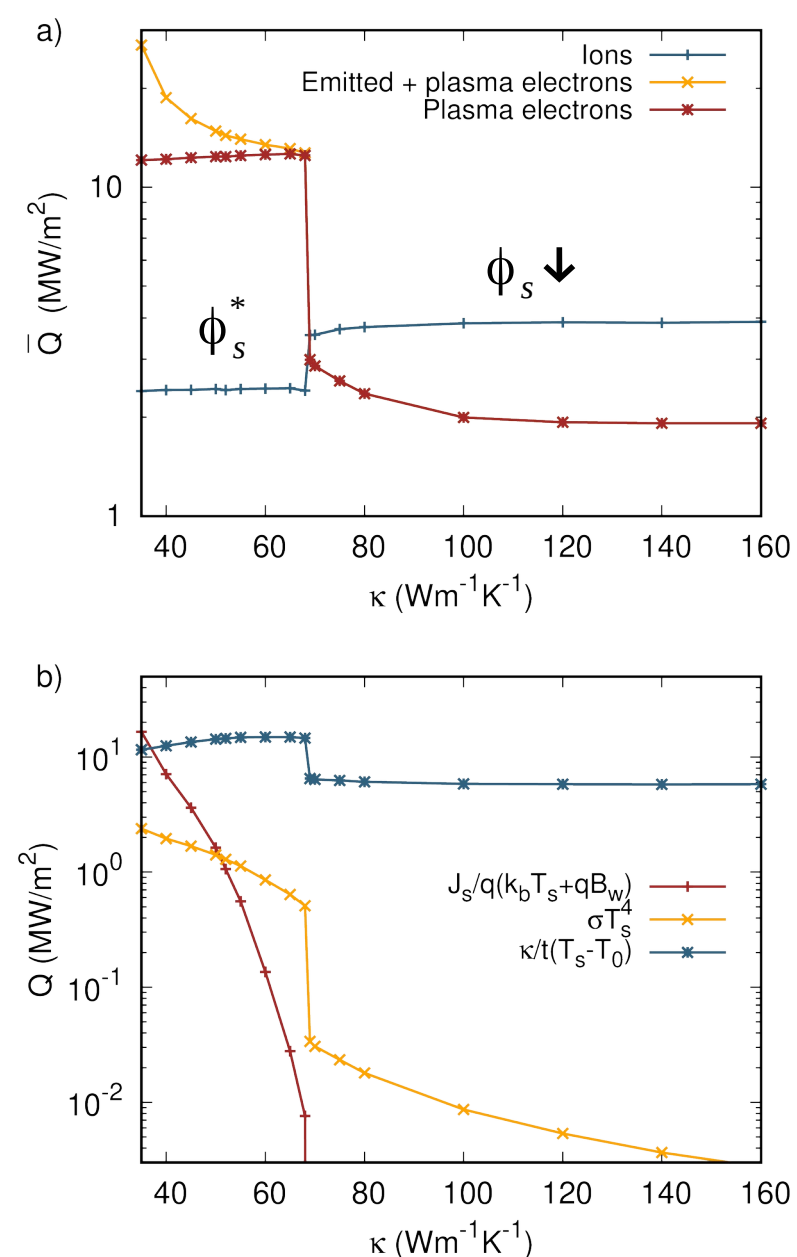


## Parametric studies & hysteresis



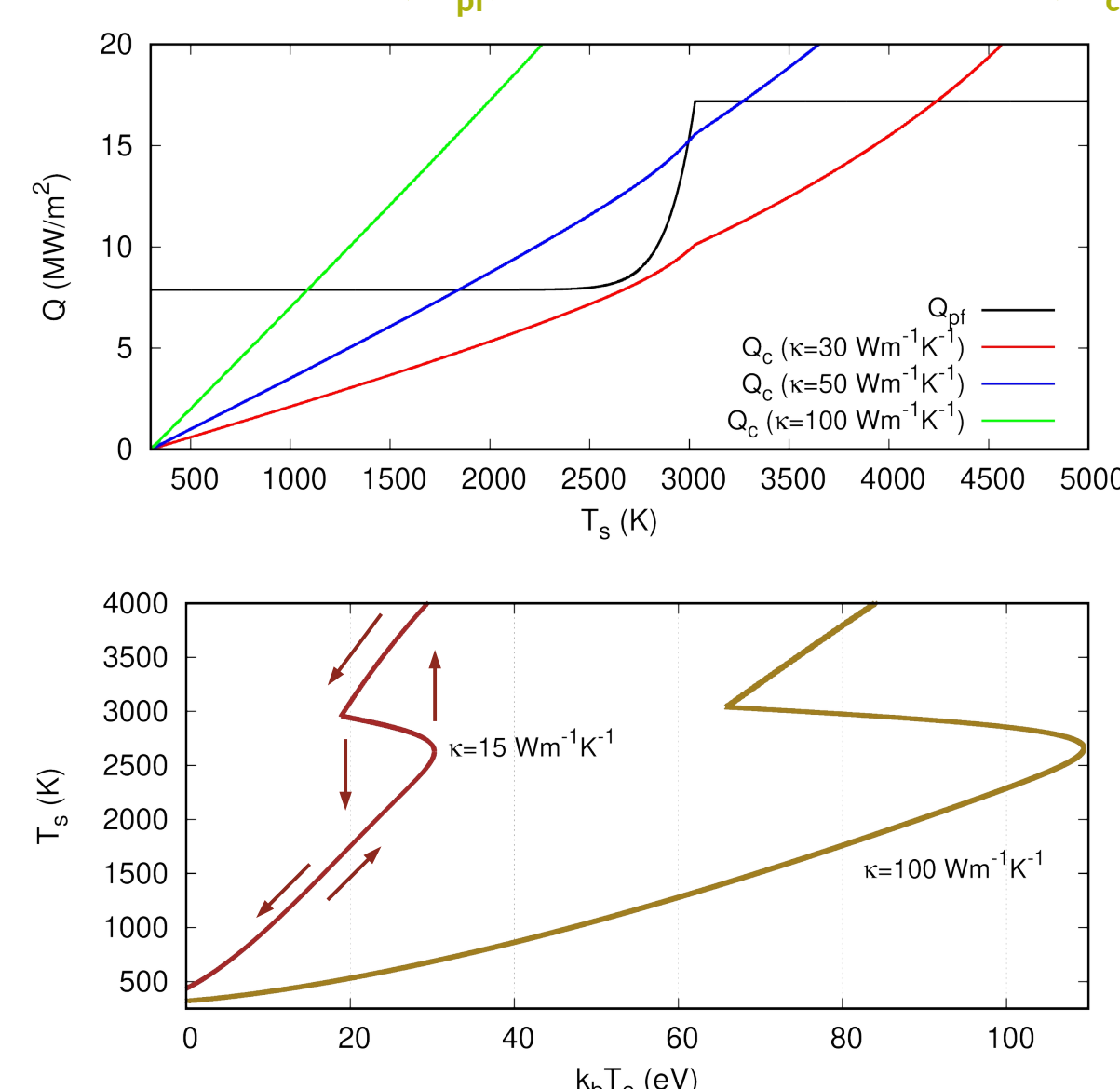
## Heat Flux & Fluid Approach and bifurcation

### PIC Heat flux to the surface



- The heat flux on the surface depends on the sheath potential.
- In the strong emission regime, the current is limited + reflected electrons increase the heat flux
- The heat flux carried away from the surface → mostly conduction for all the range of  $\kappa$  investigated

### Heat flux to ( $Q_p$ ) and from the surface ( $Q_c$ )



$$Q_c = J_s (2k_b T_s + B_w) + \epsilon \sigma T_s^4 + \frac{\kappa}{l} (T_s - T_0)$$

$$Q_p = n_s c_s (2k_b T_i + E_i - B_w + e \phi_s) + \frac{n_s c_e}{4} \exp\left(-\frac{e \phi_s}{k_b T_e}\right) (2k_b T_e + B_w)$$

$$e \phi_s = e \phi_f - k_b T_e \log\left(1 + \frac{J_s}{e n_s c_s}\right) \text{ until the electric field at the surface cancels [4,5] then } J_s = J_s^*, \phi_s = \phi_s^*$$

- There is a regime of the thermal conductivity where a bifurcation occurs → the final temperature of the surface depends on its history = hysteresis phenomenon

- The history in the PIC simulation is related to the scenario run → coming from a high or a low temperature before reaching the steady state

## References:

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