Core-edge transition region -
Boundary conditions for core transort

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Boundary conditions for transport modelling

- Predictions for next-step devices are based on core-transport (NC, turbulence etc) and cannot handle edge.
- Turbulence codes predict $\nabla T/T$ ---> T_0 depends very strongly on T_{edge}. e.g. for Squid-τ [G. Plunk et al]:

--> Core performance strongly depends on BC, e.g. $T(\rho=0.7)$

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- Instead of fixing Temperature at the boundary, we fix $a/L_T = -d\ln T/d\rho$.
  - Why? Gyro-Bohm scaling of stellarator experiments (ISS04) implies self-similarity of plasma profiles.
    - $Q_{\mathrm{GB}} \equiv nT_i c_s \rho_s^2/a^2$, $\hat{Q} * Q_{\mathrm{GB}} * \mathrm{Area} = P_{\mathrm{tot}}$
    - Power balance at the edge/core boundary gives Temperature scaling: $T \sim (P_{\mathrm{tot}}/n_e)^{2/5}\mathrm{B}^{0.8}$
  - With this boundary condition we can obtain profiles for different scenarios, densities, types of heating etc.

--> Core performance strongly depends on BC, e.g. T(ρ=0.7)

$$\tau_{E,\mathrm{ISS04}} = 0.134\ a^{2.28} R^{0.64} n_e^{0.52} \iota^{0.41} B^{0.84} P^{-0.61}$$
$$f_{\mathrm{ren}} = \tau_E/\tau_{\mathrm{ISS04}}$$

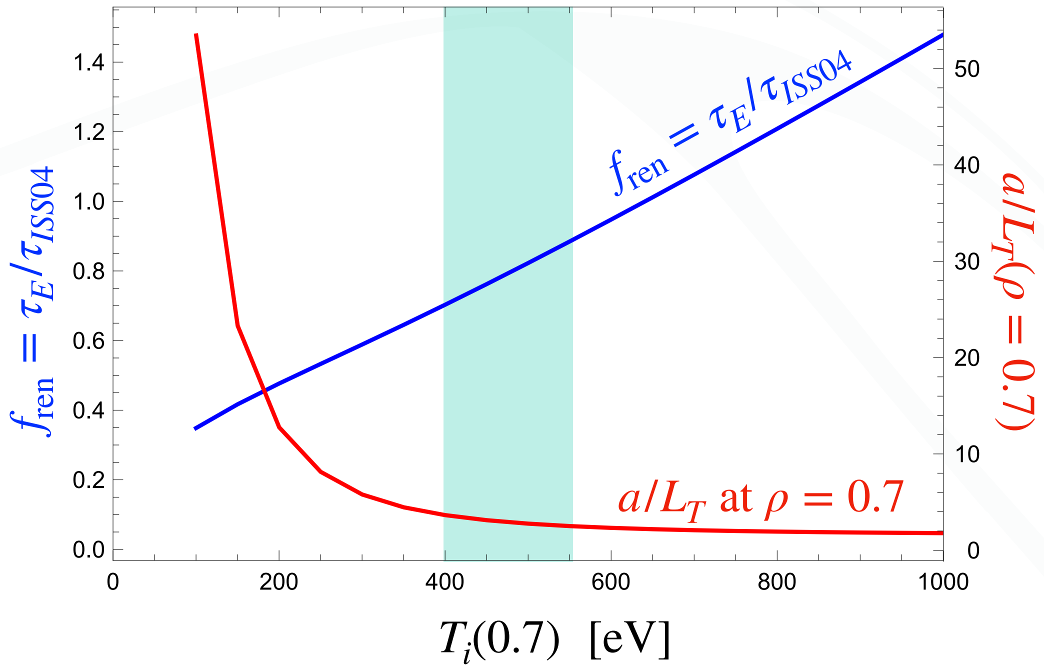
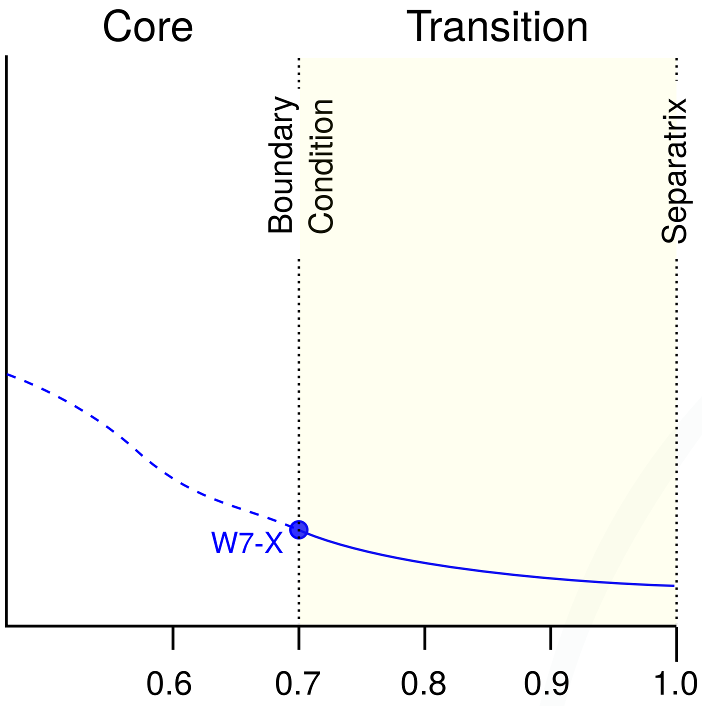


Fig.: Sensitivity of predicted performance to edge/core boundary conditions (SQuID-τ).

Separatrix temperature

- Assume $T \sim (P_{\mathrm{tot}}/n_e)^{2/5}$, but what value?



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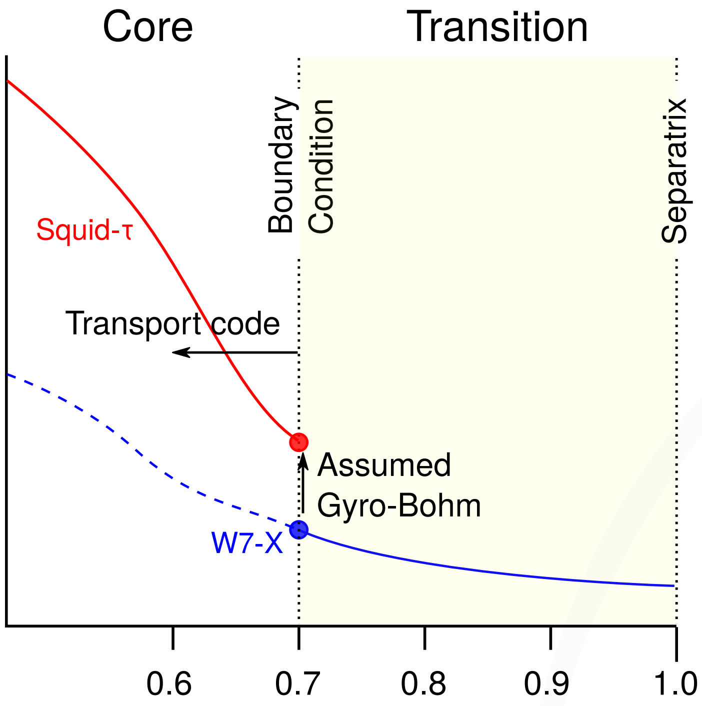

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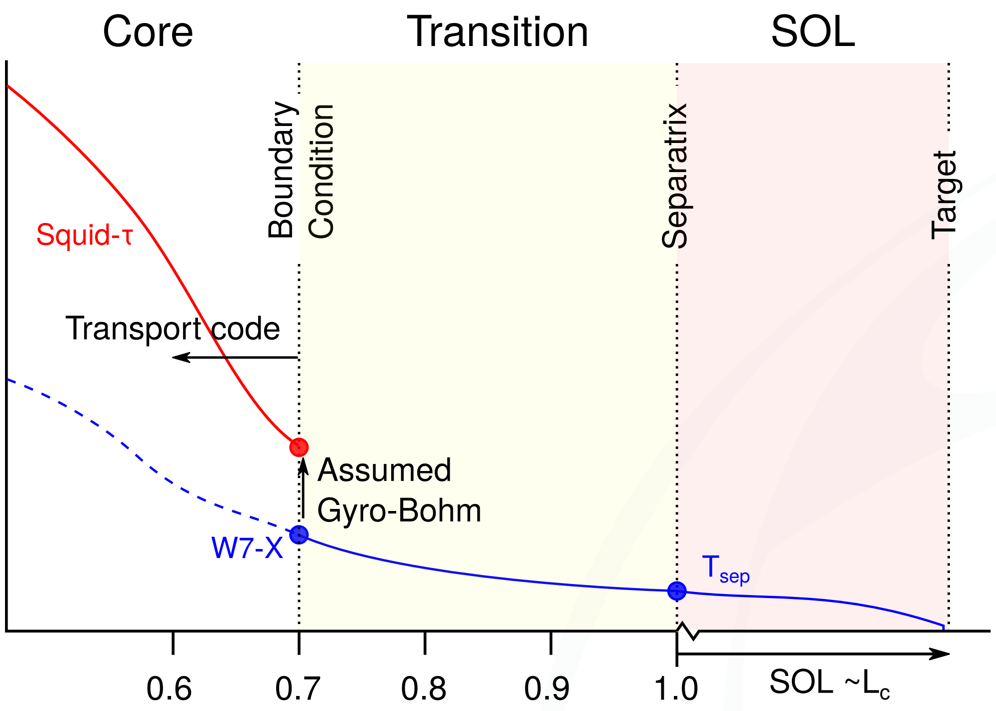
- What determines *T(ρ=0.7)*?



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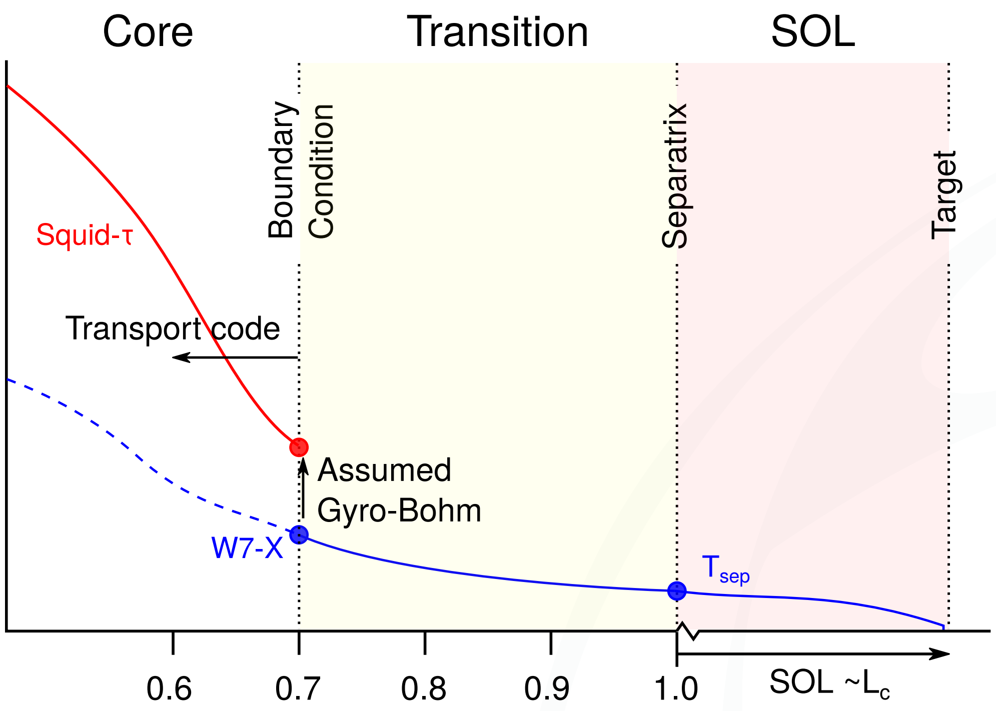

1) T_{sep} determined by SOL physics, e.g. 2-point model:

$$T_{sep} = T_{targ} + (7\, q_{//}\, L_c/2\kappa)^{2/7} + \ldots$$

No |B| scaling!

Perpendicular transport
Maybe |B| *effects*??

Might be very different in next step-machines.
Scaling |B| not expected!

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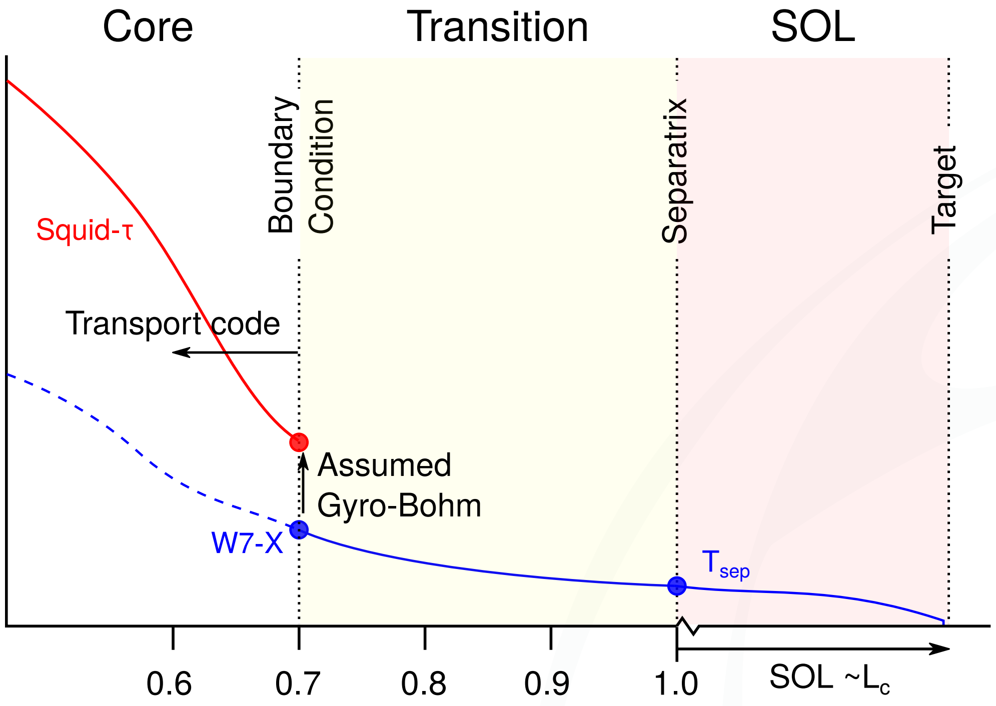

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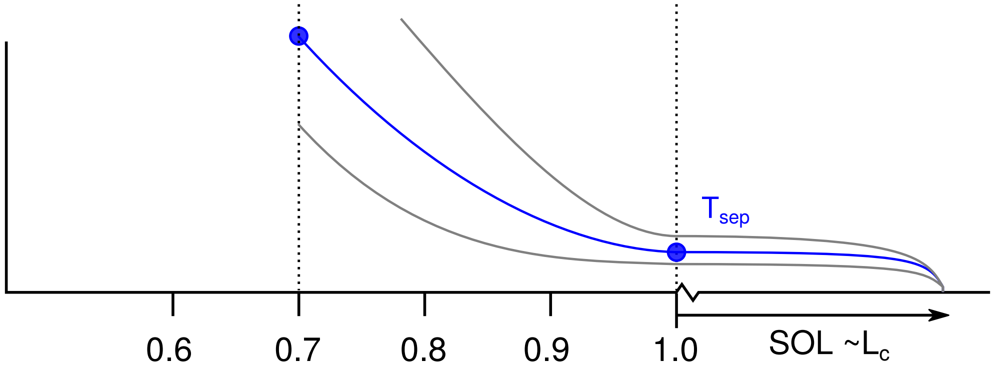
Even if dominant ΔT in transition region , T_{sep} still critical.



Transition region

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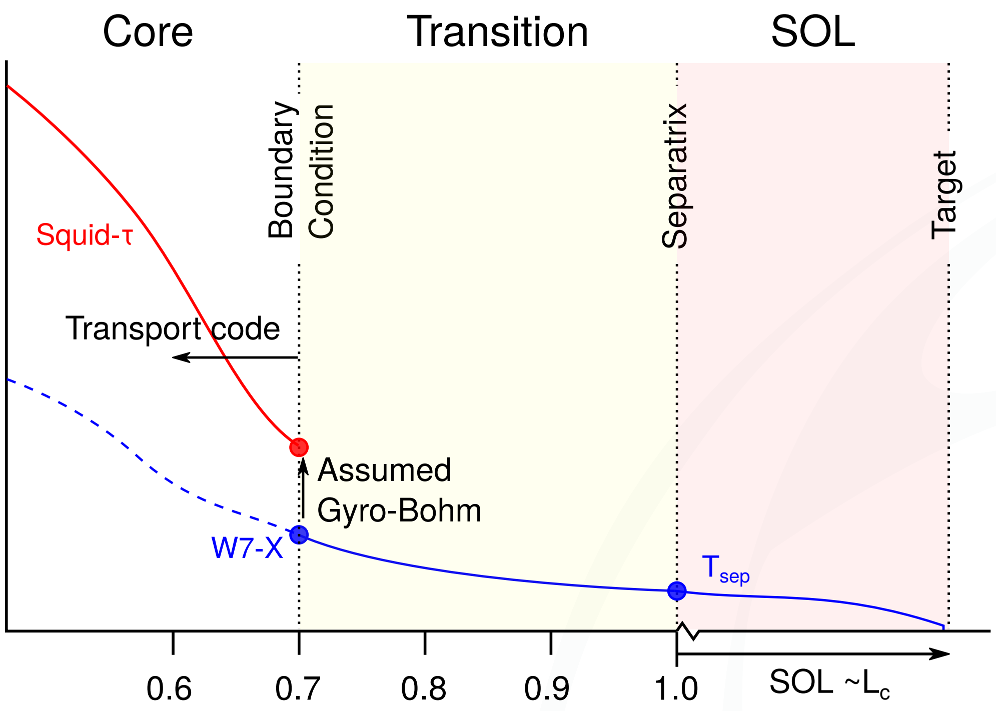


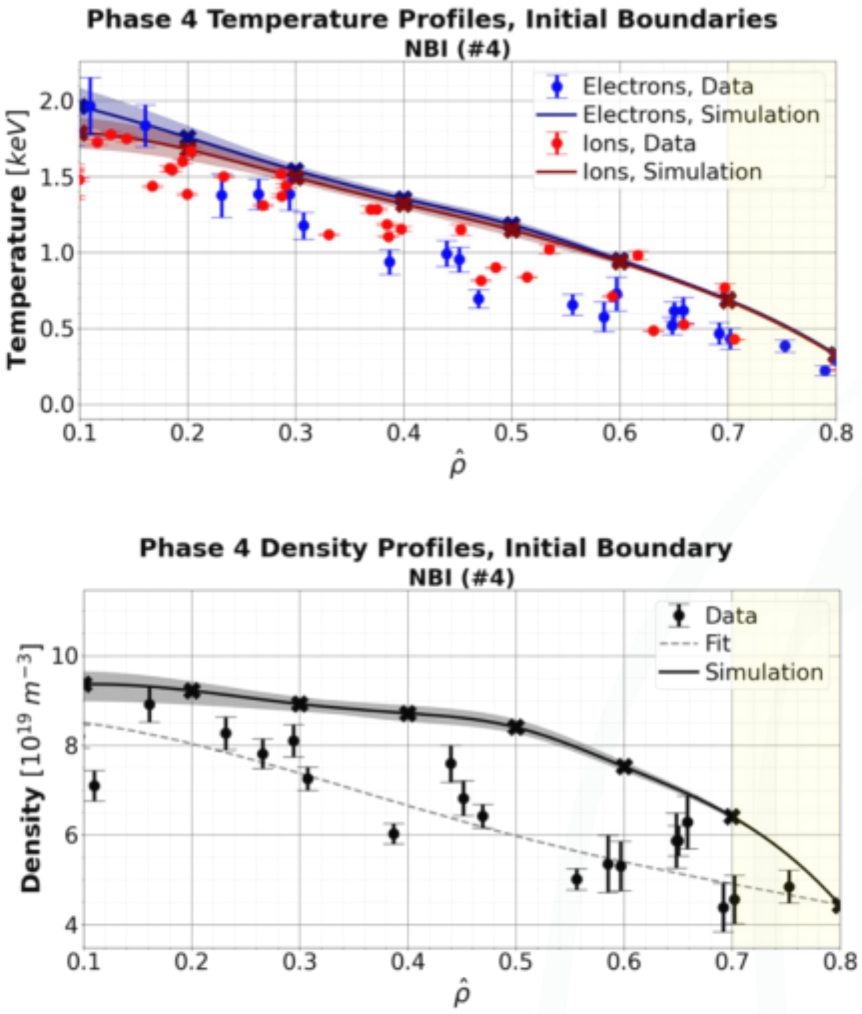
2) Even if T_{sep} scaling were known, can we assume
$T(\rho=0.7) - T_{sep}$ ~ Gyro-bohm?

Transition region:
- Assumptions break-down.
  - Gyrokinetics ...
  - Neoclassics ...
- Strong radiation
- Strong neutral effects (depends on divertor)

In W7-X: Region is relatively moderately diagnosed and very rarely analysed.

GENE-Tango simulations

- GENE-Tango used to simulate out to ρ = 0.8. Also strongly affected by edge and transition region assumptions:
  [D. Fernando et al. https://doi.org/10.1063/5.0267879]



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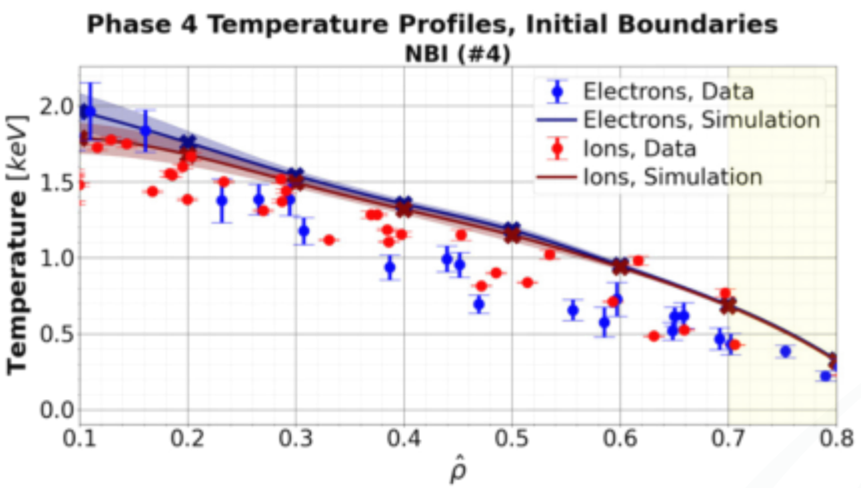
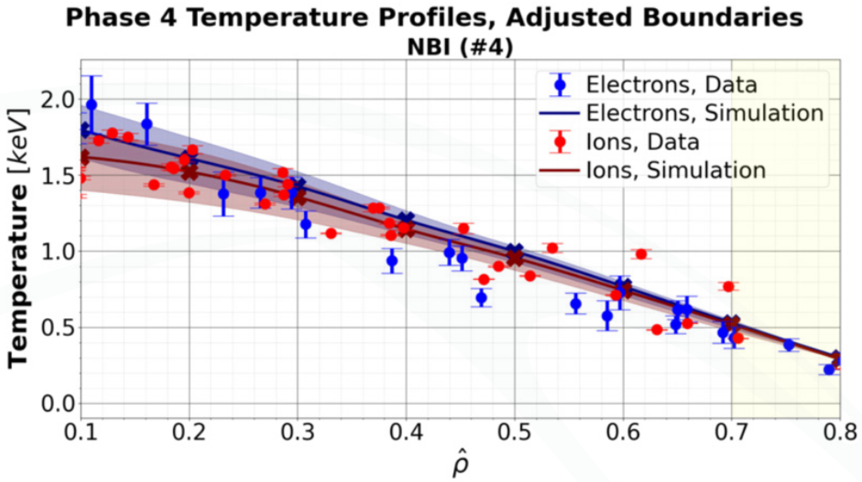
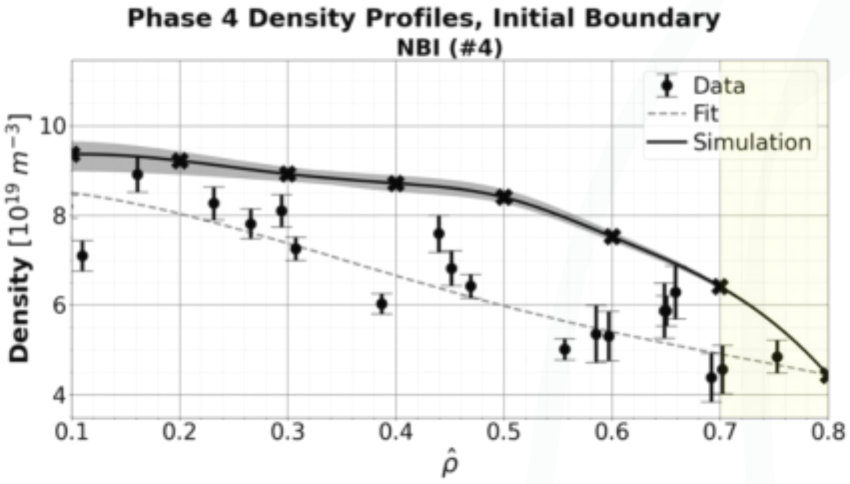
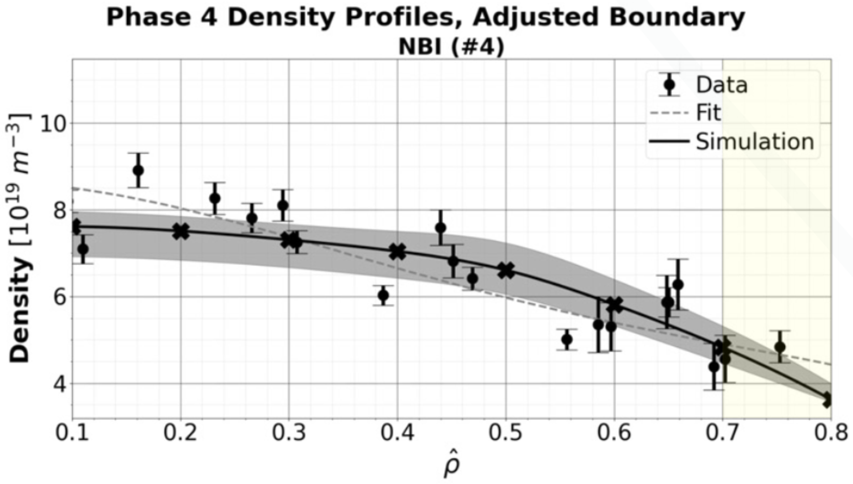




Adjust boundary and n_e, T_e. to obtain match.





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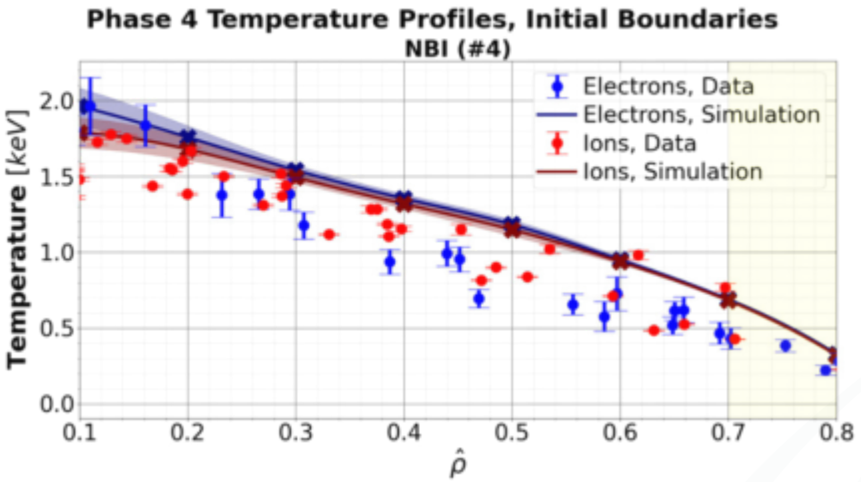

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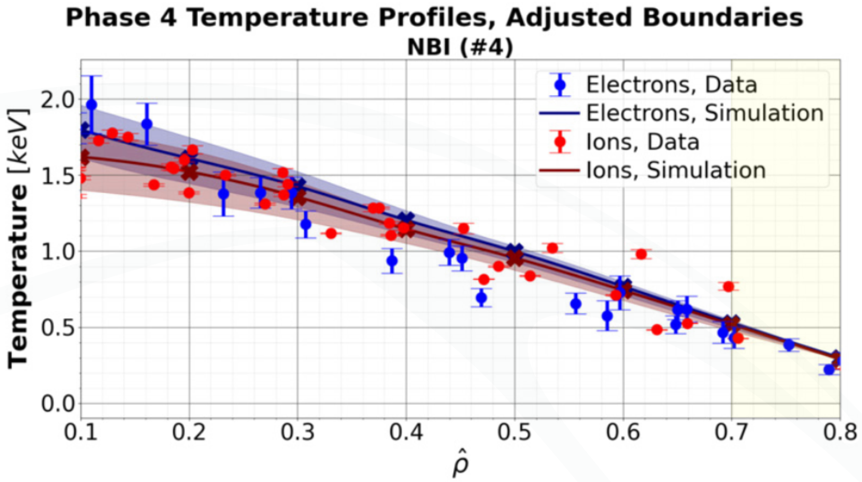
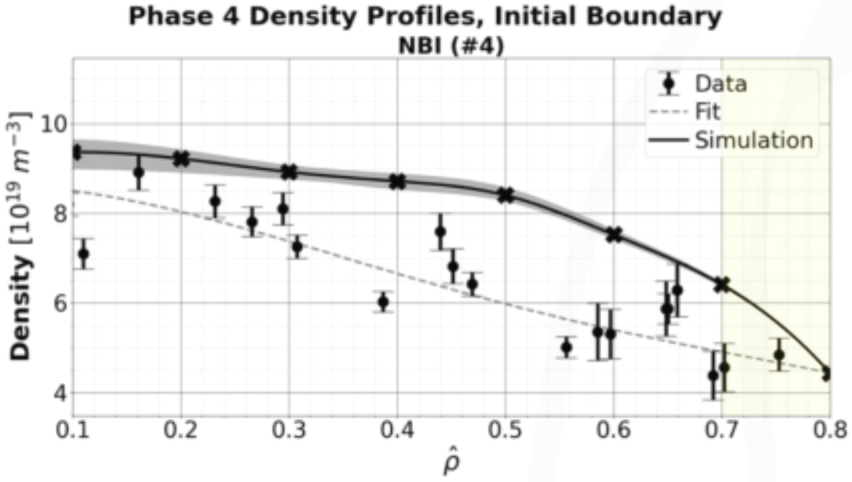
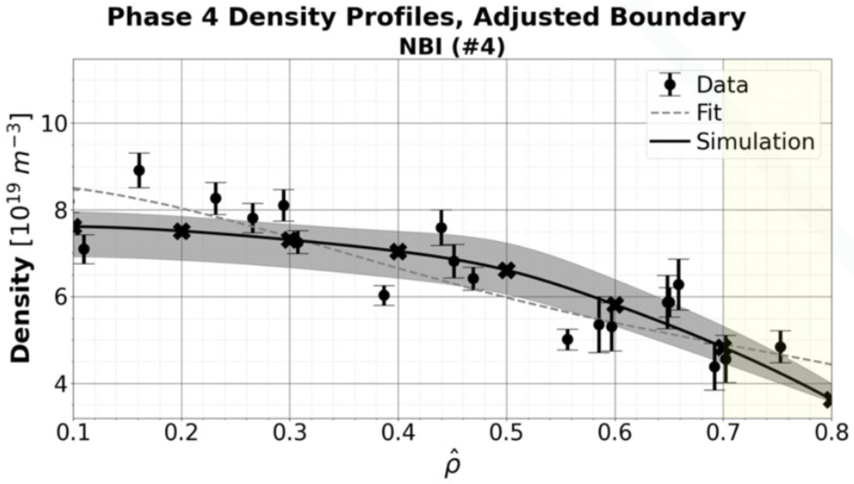




Also:

Good match of fluxes near edge require adjusting of n_0 for non-NBI cases.



Scaling in W7-X

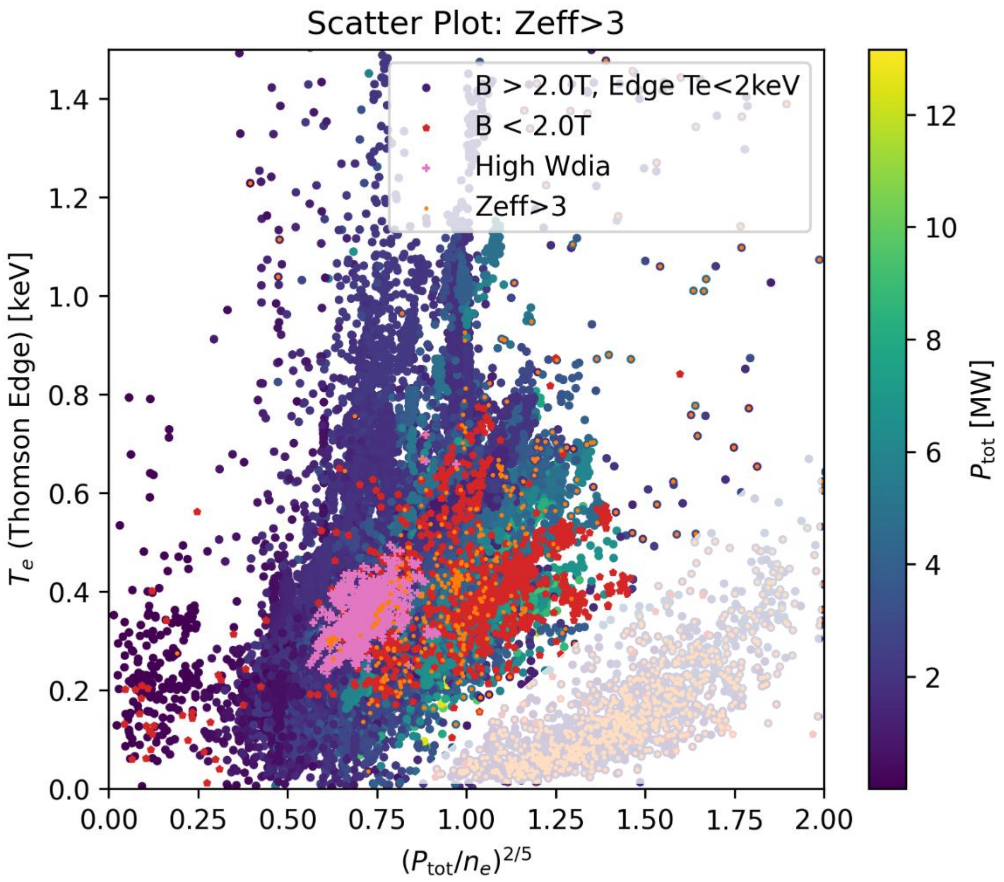
- Look at Juice DB to see what scaling within W7-X shows [D. Kulla]:

- P/n term from GB scaling:

$$T \sim P_{in}^{0.4} n^{-0.4} B^{0.8} (a/R)^{0.4}$$

- Low-field (B<2.0T) points have **lower measured edge Te than expected** from GB term

- Low-field points have **higher P/n values** in relative terms



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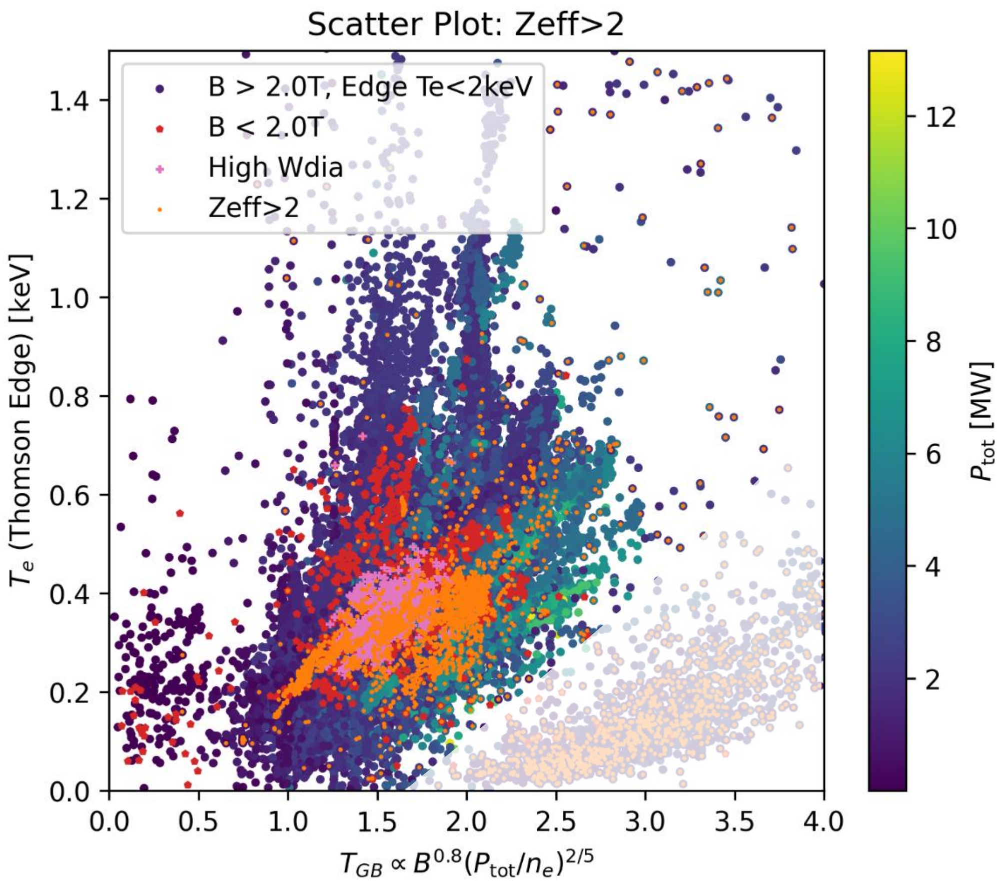
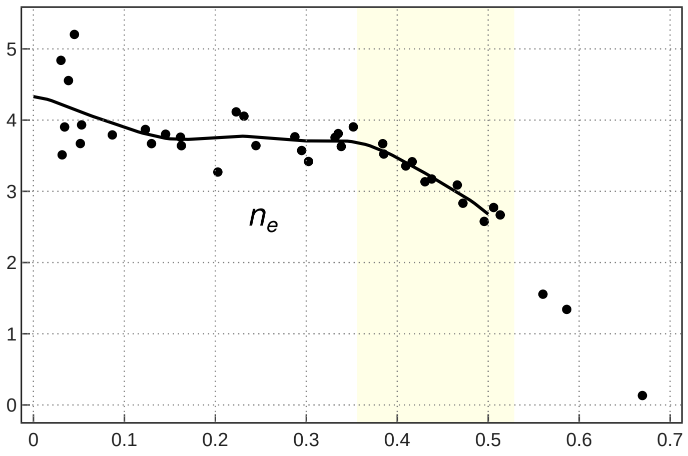
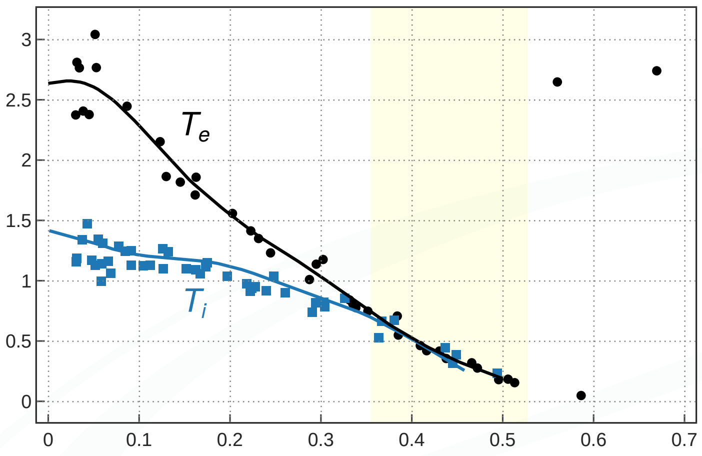
- Low-field (B<2.0T) points have **lower measured edge Te than expected** from GB term
- Low-field points have **higher P/n values** in relative terms
- Including B term from GB scaling:
  - Higher P/n of low-field points is compensated by low B, resulting in **similar edge T_e**
  - Few low-power, low-field phases have higher edge T_e



Diagnostics in transition region

- Profile diagnostic coverage in transition region is moderate (n_e, T_e, T_i):





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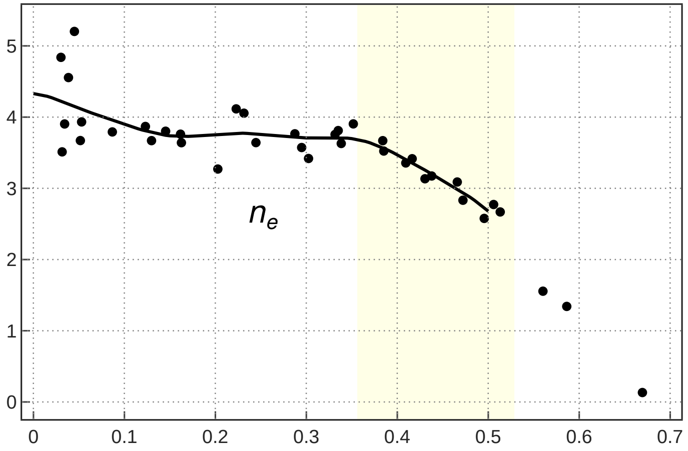

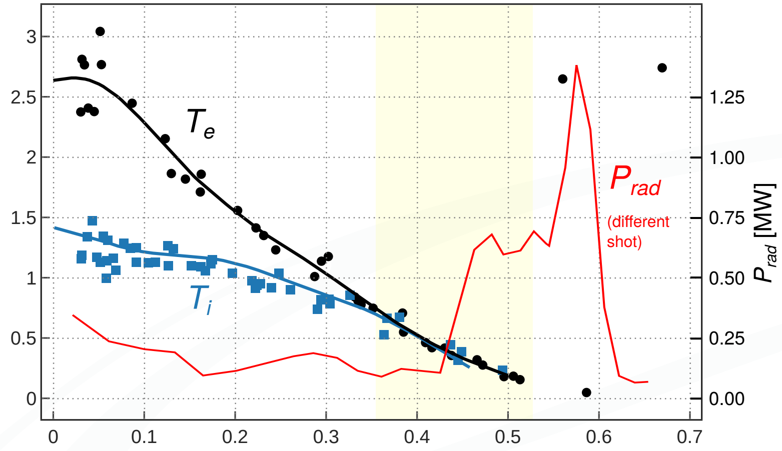

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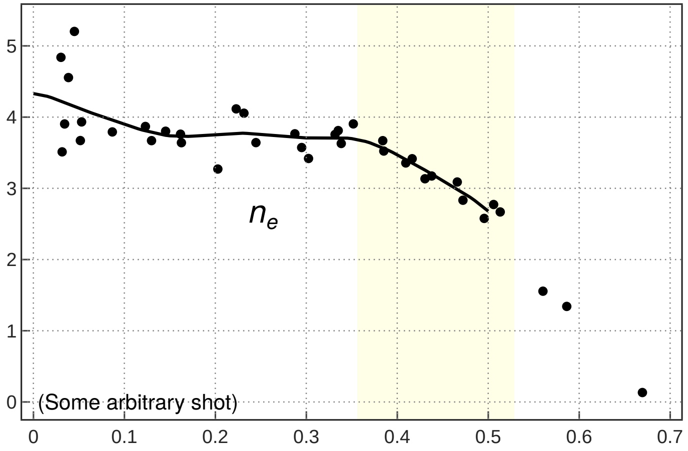

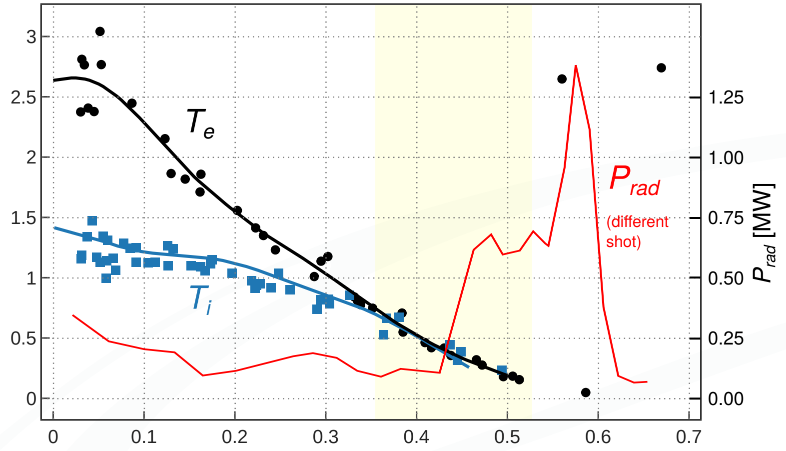

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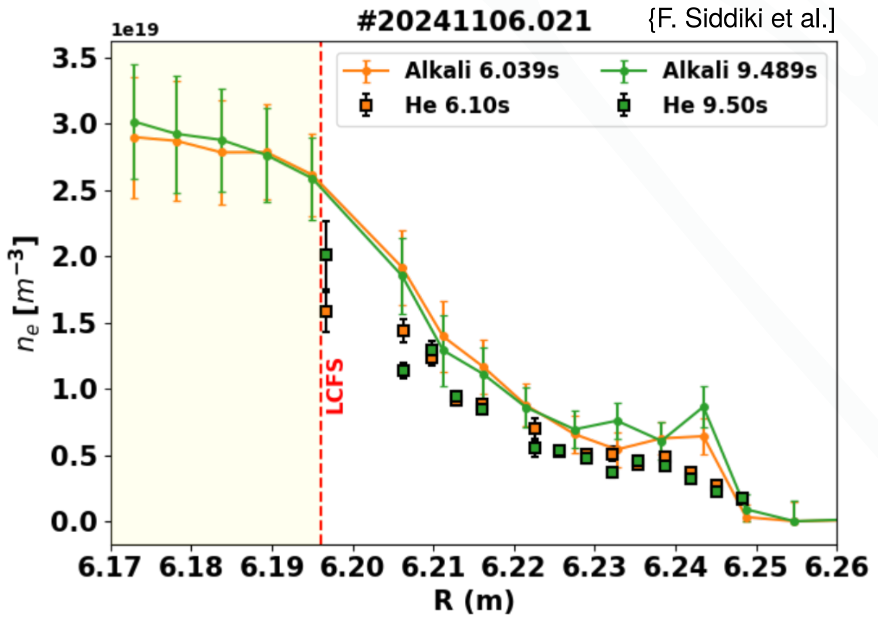
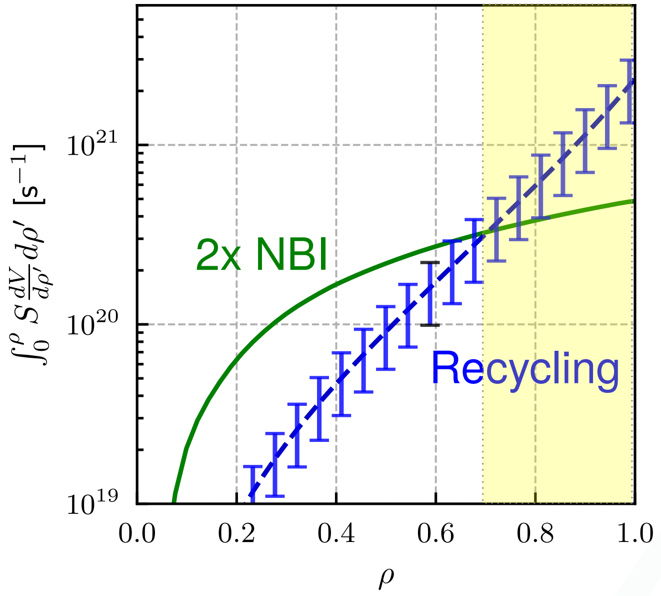
- Recently data from Alkali-beam (n_e) and upstream He-beam (n_e, T_e) in SOL. Integration/comparison with TS at LCFS would be helpful.



Neutral recycling source

- Neutral recycling is dominant source at edge, even with NBI:

Particle sources, #20181009.034 t=1.2s
[Bannmann, 10.1088/1741-4326/ad6b37]



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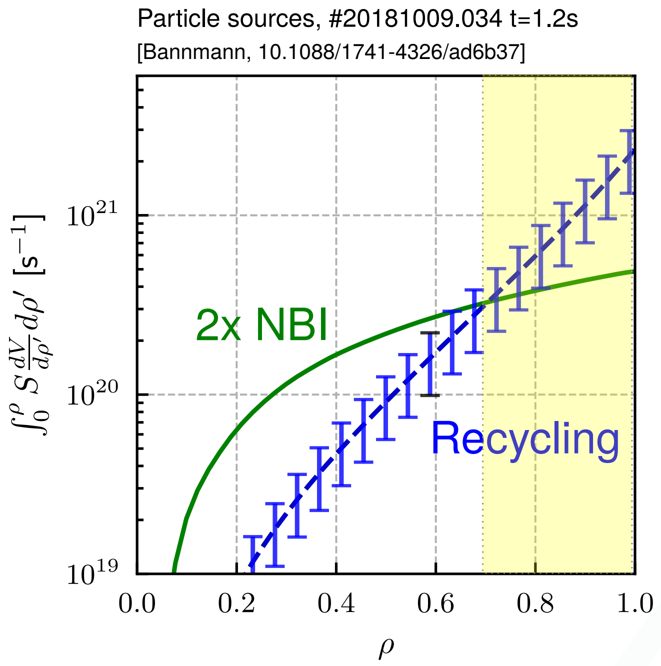

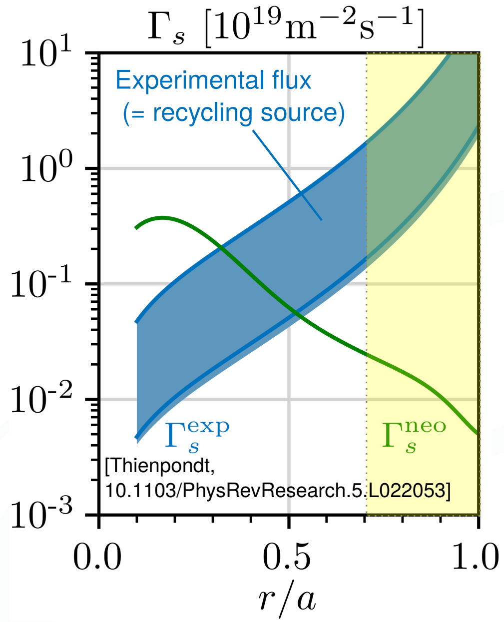

- Simple 1D models with O~(10^1) uncertainties.

Above
divertor

Bulk plasma

Neutral recycling source

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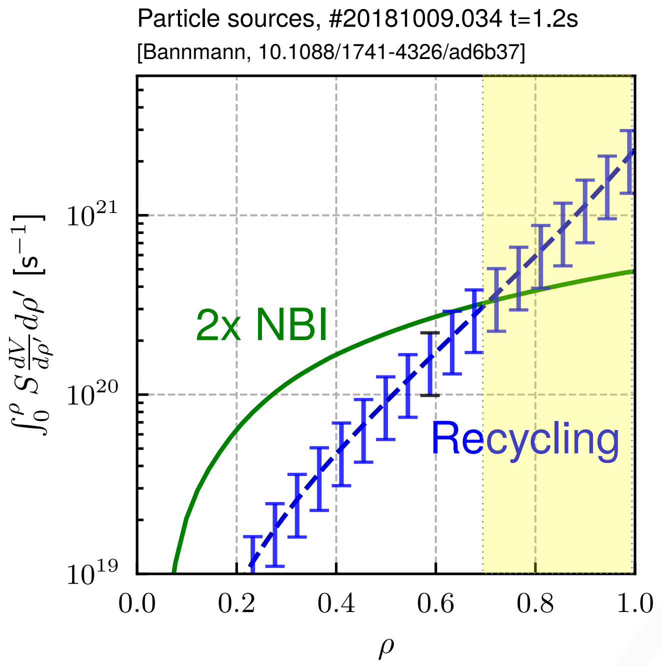

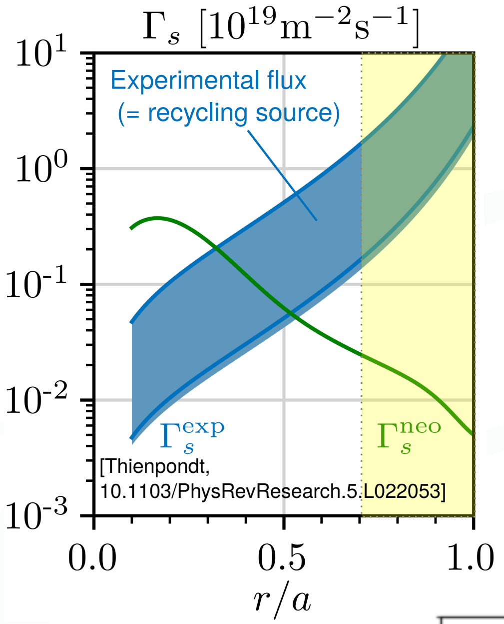

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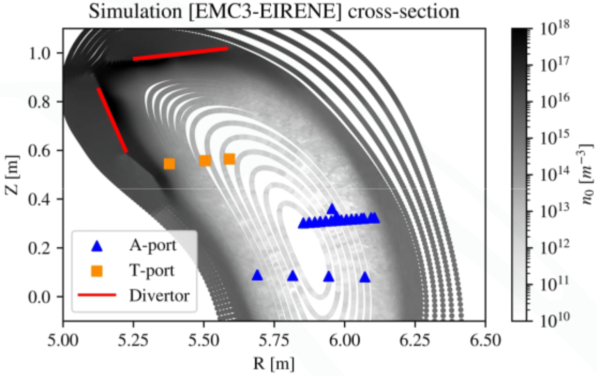
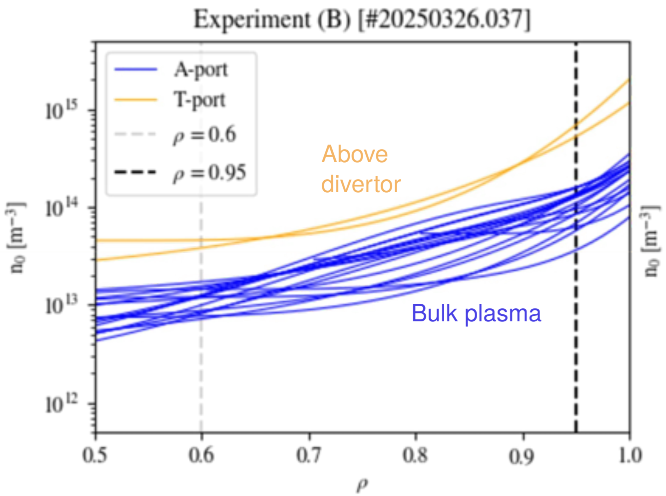
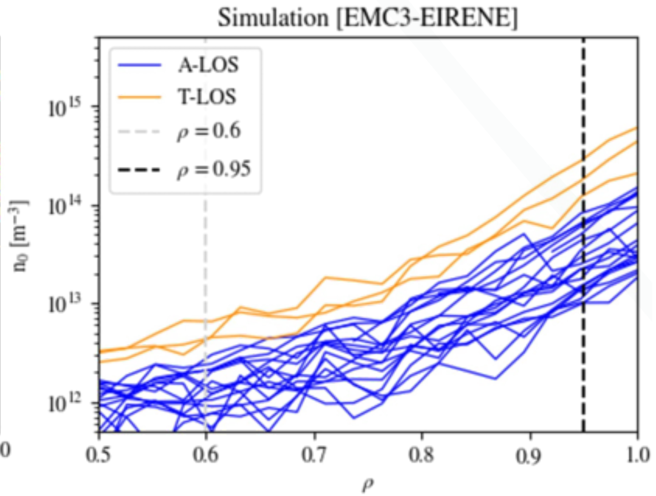


- **H$^\alpha$ filterscopes**: Data issure in OP2.3. 0D quantity.
- **H$^\alpha$ cameras**: Limited data availability due to technical issues in OP2. No routine data analysis.
- **Warm H$^\alpha$ spectroscopy** (n_0 inside separatrix). Some local measurements. No routine analysis.





Summary

- Performance of core entirely dependent on separatrix and transition region parameter.

- Scaling not clear from W7-X data.

- We have moderate diagnostic coverage, not optimised for this. Recycling source measurements are poor.

- Very little focus of analysis on core/edge physics (that's not the same as *"core-edge scenario integration"*).