

Core-edge transition region - Boundary conditions for core transport

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09? 14? 07.2026 TWG W7-X Strategy 2035



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 $\nabla T/T \rightarrow T_0$ depends very strongly on T_{edge} . e.g. for Squid- τ [G. Plunk et al]:

- 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.

- $Q_{\text{GB}} \equiv n T_i c_s \rho_s^2 / a^2$, $\hat{Q} * Q_{\text{GB}} * \text{Area} = P_{\text{tot}}$

- Power balance at the edge/core boundary gives Temperature scaling: $T \sim (P_{\text{tot}}/n_e)^{2/5} B^{0.8}$

- With this boundary condition we can obtain profiles for different scenarios, densities, types of heating etc.

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

$$\tau_{E,\text{ISS04}} = 0.134 a^{2.28} R^{0.64} n_e^{0.52} I^{0.41} B^{0.84} P^{-0.61}$$

$$f_{\text{ren}} = \tau_E / \tau_{\text{ISS04}}$$

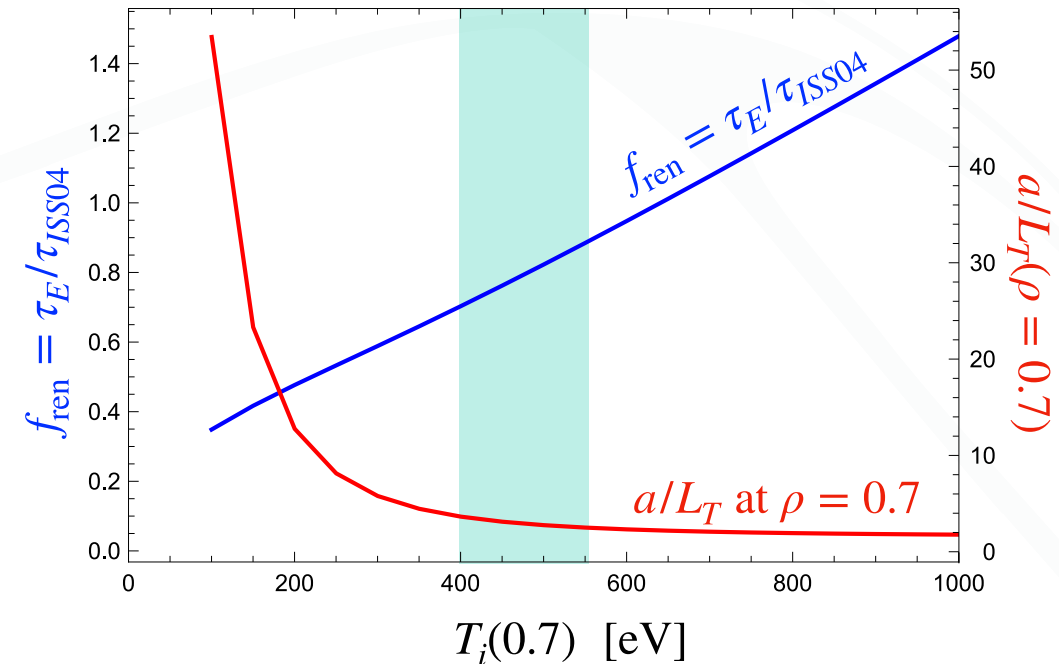
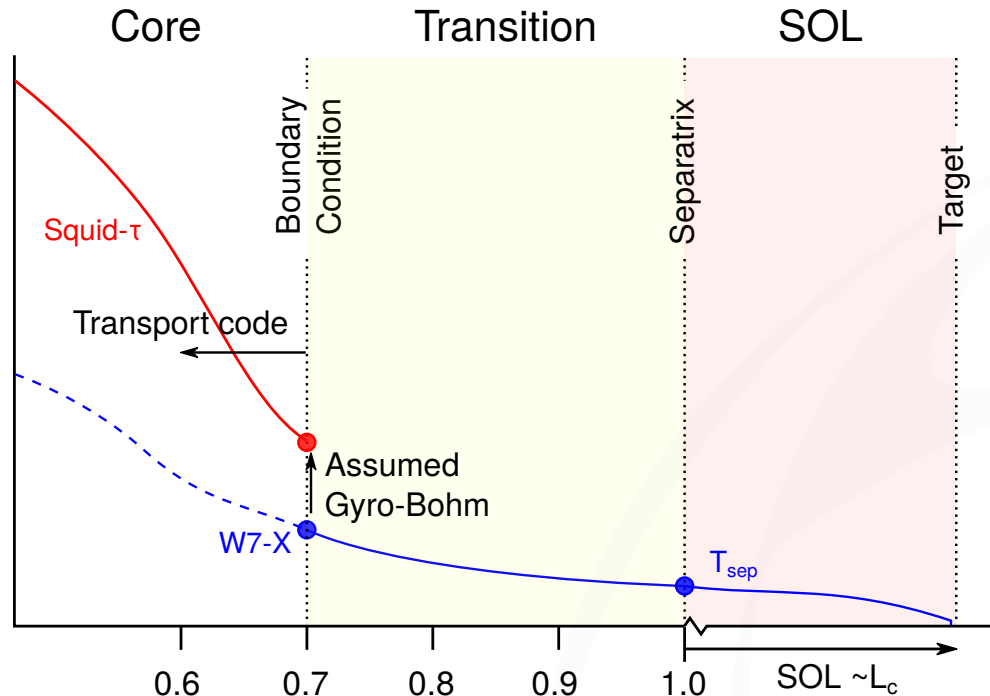


Fig.: Sensitivity of predicted performance to edge/core boundary conditions (SQUID- τ).

Separatrix temperature

- Assume $T \sim (P_{\text{tot}}/n_e)^{2/5}$, but what value? --> Use W7-X and scale.
- What determines $T(\rho=0.7)$?



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

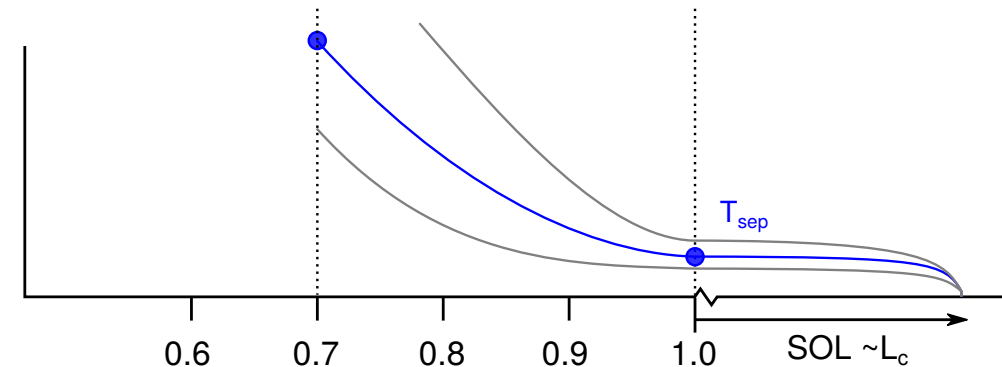
$$T_{\text{sep}} = T_{\text{targ}} + (7 q_{\parallel} L_c / 2\kappa)^{2/7} + \dots$$

No $|B|$ scaling!

Perpendicular transport
Maybe $|B|$ effects??

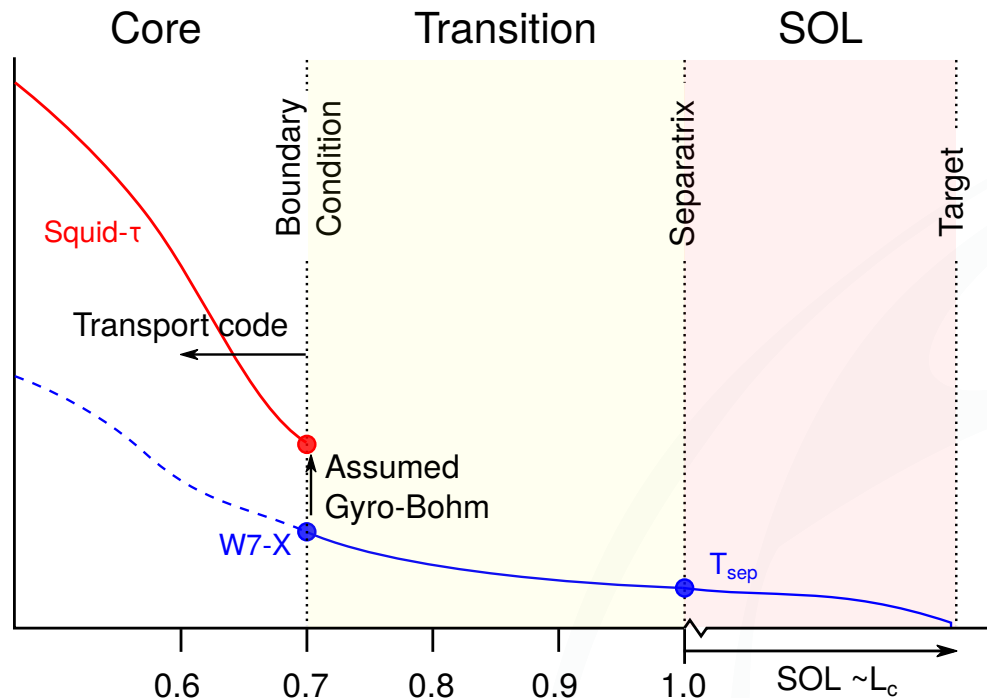
Might be very different in next step-machines.
Scaling $|B|$ not expected!

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



Transition region

- Assume $T \sim (P_{\text{tot}}/n_e)^{2/5}$, but what value? --> Use W7-X and scale.
- What determines $T(\rho=0.7)$?



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

Transition region:

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

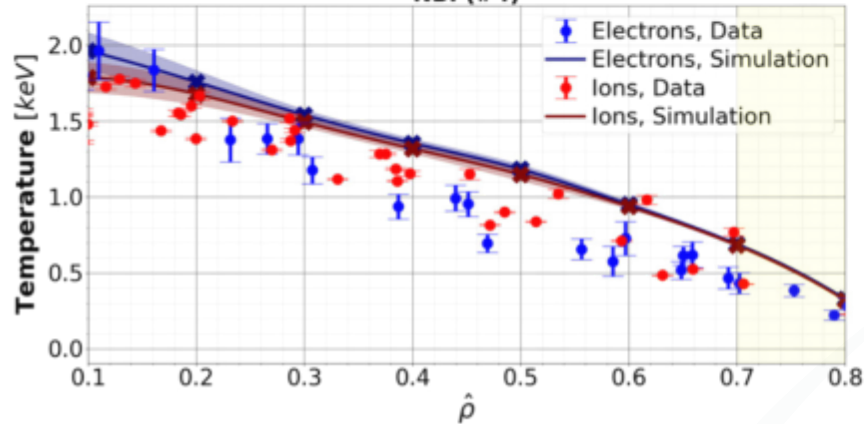
In W7-X: Region is relatively moderately diagnosed and very rarely analysed.

GENE-Tango simulations

- GENE-Tango used to simulate out to $\rho = 0.8$. Also strongly affected by edge and transition region assumptions:

[D. Fernando et al. <https://doi.org/10.1063/5.0267879>]

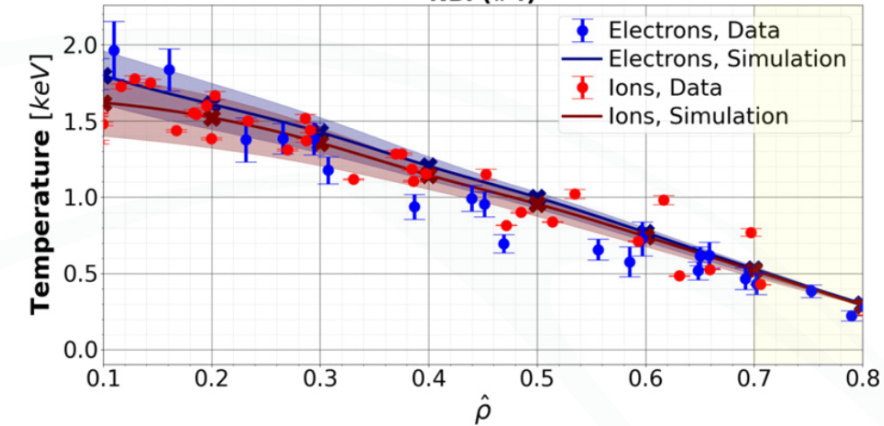
Phase 4 Temperature Profiles, Initial Boundaries
NBI (#4)



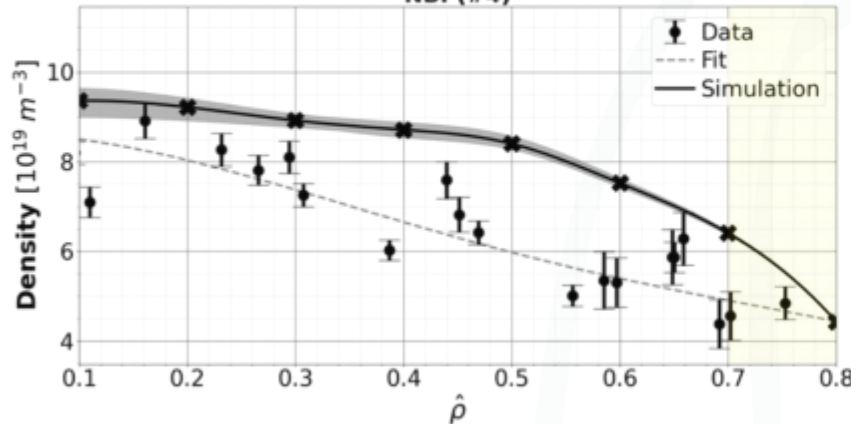
Adjust boundary
and n_e , T_e . to
obtain match.



Phase 4 Temperature Profiles, Adjusted Boundaries
NBI (#4)

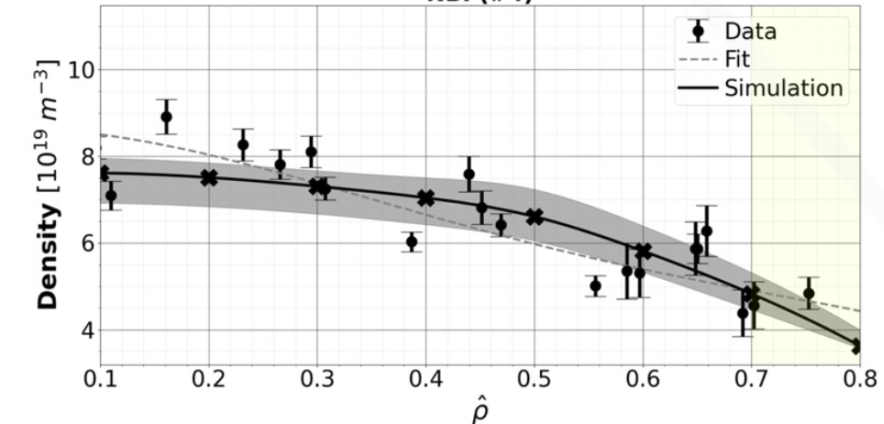


Phase 4 Density Profiles, Initial Boundary
NBI (#4)



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

Phase 4 Density Profiles, Adjusted Boundary
NBI (#4)

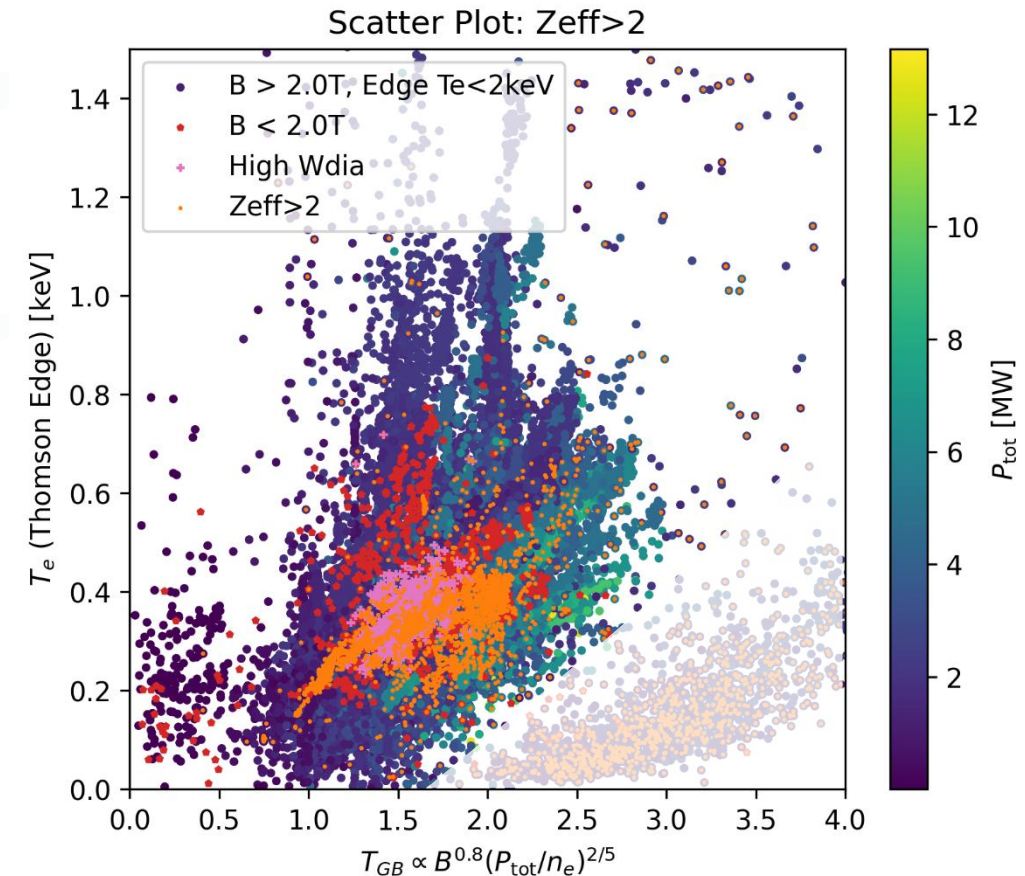


- Look at Juice DB to see what scaling within W7-X shows [D. Kulla]:

- P/n term from GB scaling:

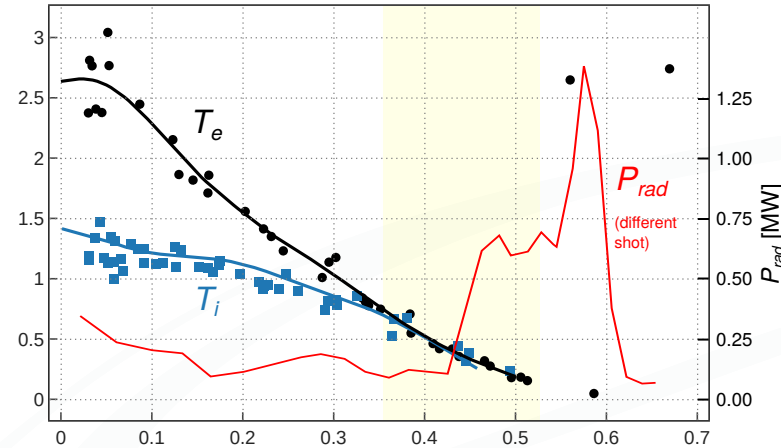
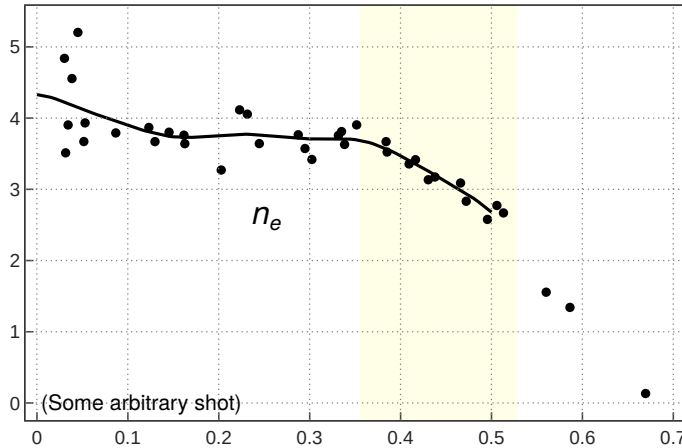
$$T \sim P_{in}^{0.4} n^{-0.4} B^{0.8} (a/R)^{0.4}$$

- Low-field ($B < 2.0\text{T}$) points have **lower measured edge T_e 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



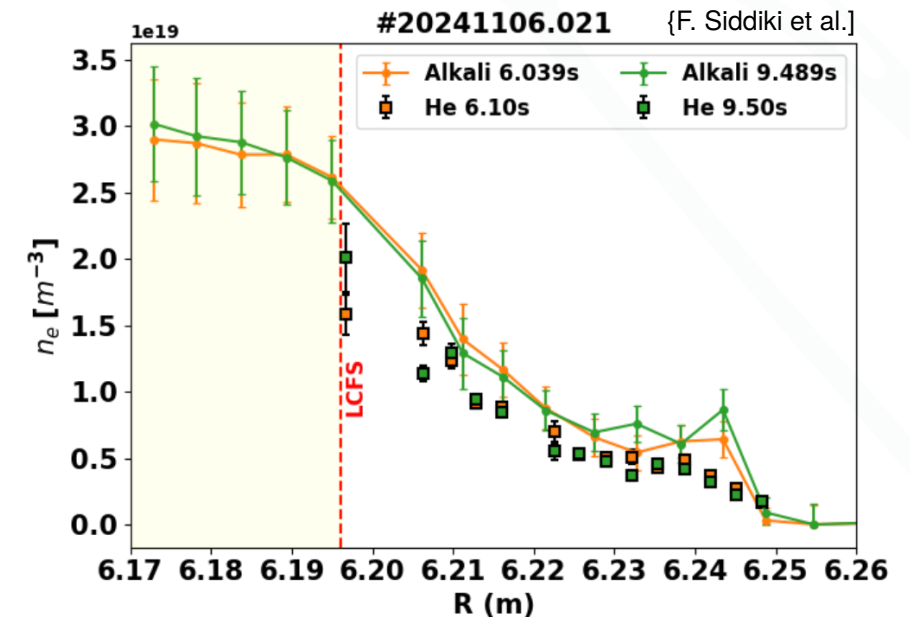
Diagnostics in transition region

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



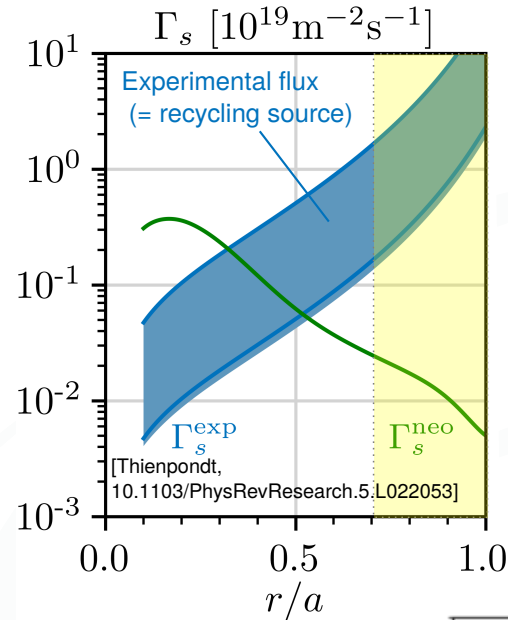
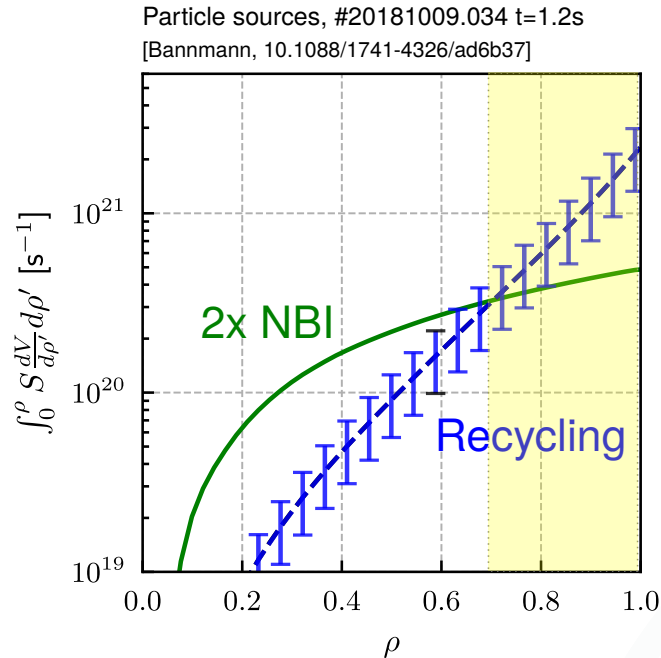
- P_{rad} often important to power balance. Bolometer inversions now relatively routinely provided.

- 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.

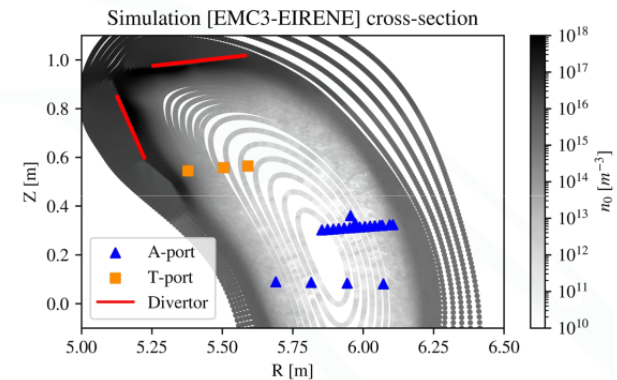


Neutral recycling source

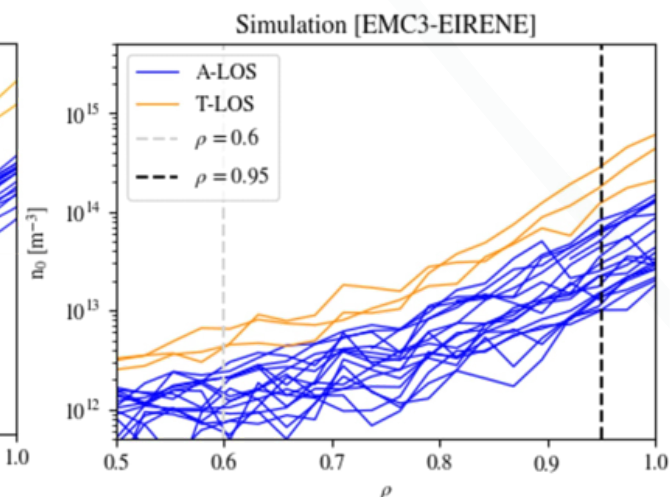
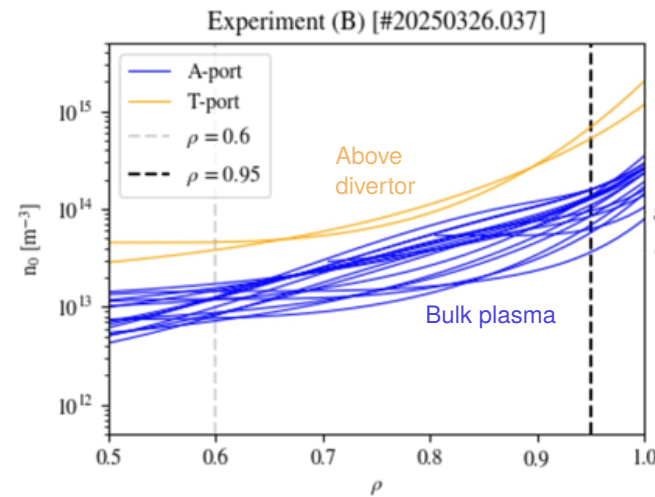
- Neutral recycling is dominant source at edge, even with NBI:



- Simple 1D models with $O \sim (10^1)$ uncertainties.



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



- 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"*).