Modelling of neutral penetration through the SOL

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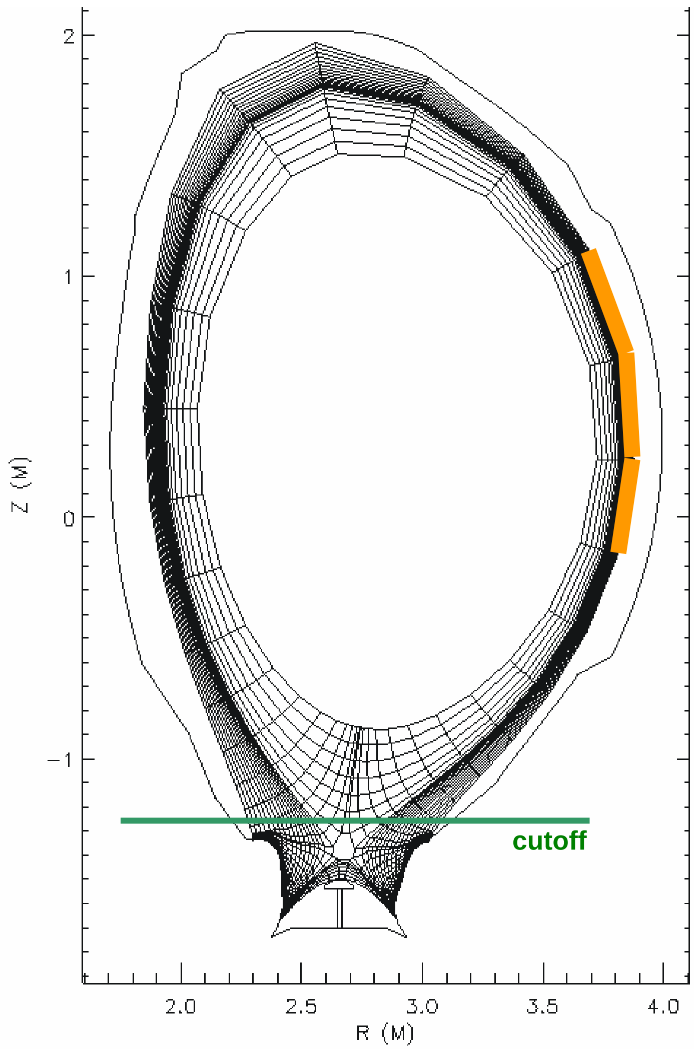
Motivation

A clear understanding of the neutral transport processes in SOL:

- LH-transition threshold (D. Kalupin: steepening of ped.gradient due to incr. of neutral ionisation, stronger radial heat convection: decreases P_{th})
- neutral transport across the SPX, pedestal-structure (Mahdavi-model)
- fuelling for ITER (gas-puff and/or NBI?, A. Loarte, P. Tamain)
- ELM-mitigation via gas-puff (exp. seen: frequency increase, amplitude decrease)
- …

2D-problem: numerical investigation by density scans w/ EDGE2D + neutral transport model NIMBUS (now also: EDGE2D/EIRENE)

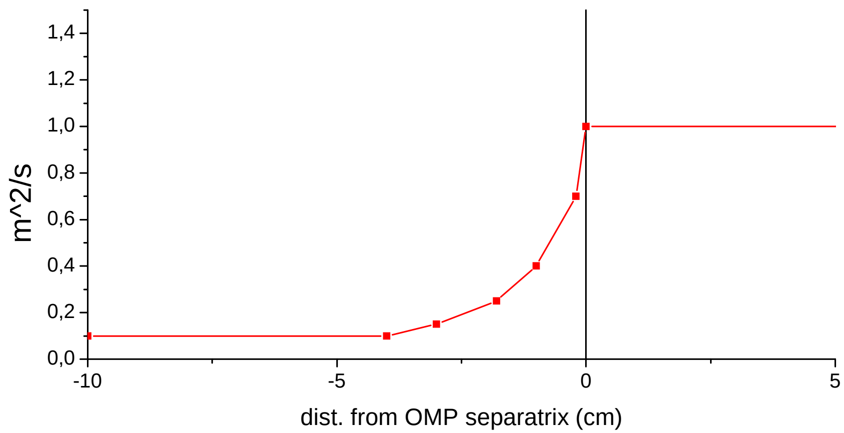
EDGE2D JET #53140

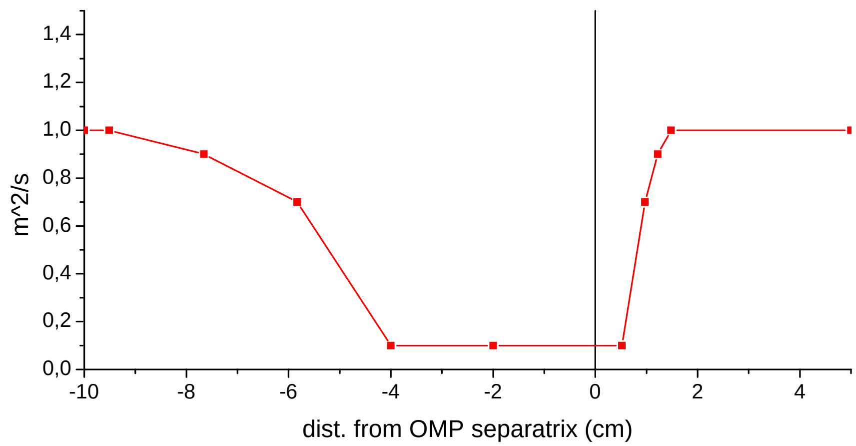


- vertical target + septum
- P_{SOL} = 3.7MW (shared between els.+ions)
- D-puff from OMP
- no core particle fuelling
- no impurities/no drifts
- steady state simulations until convergence

Transport model

Assumptions for: $D_\perp / \chi_\perp$





$P_{heat} < P_{th}^{LH}$

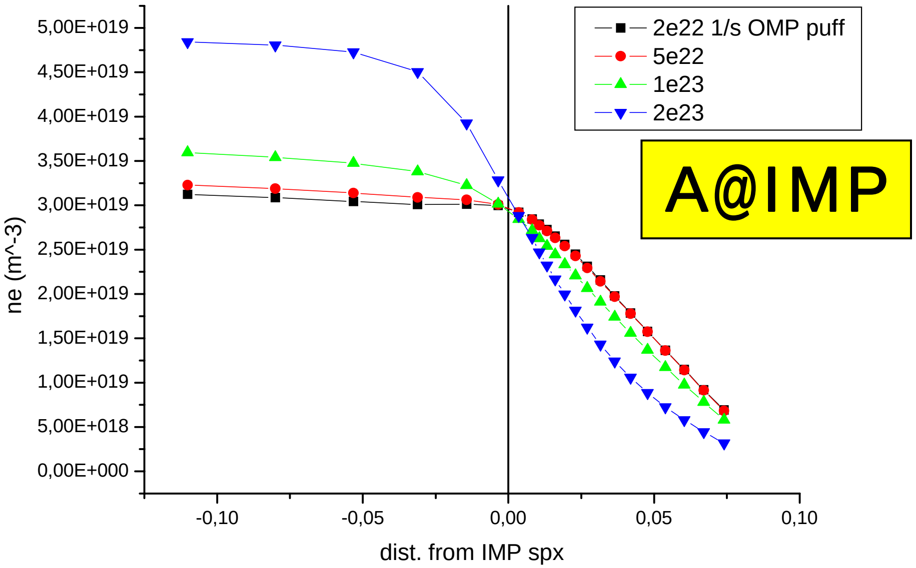
$P_{heat} > P_{th}^{LH}$

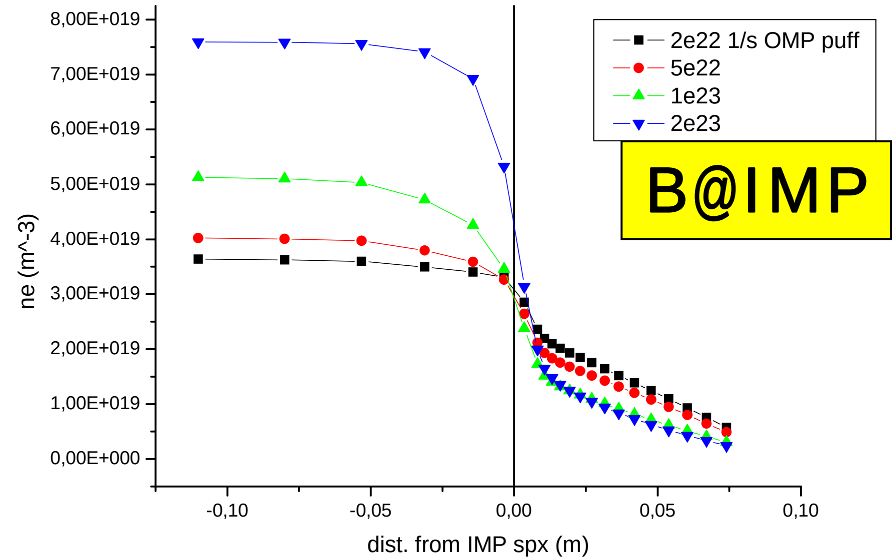
But here: P_{heat} kept constant

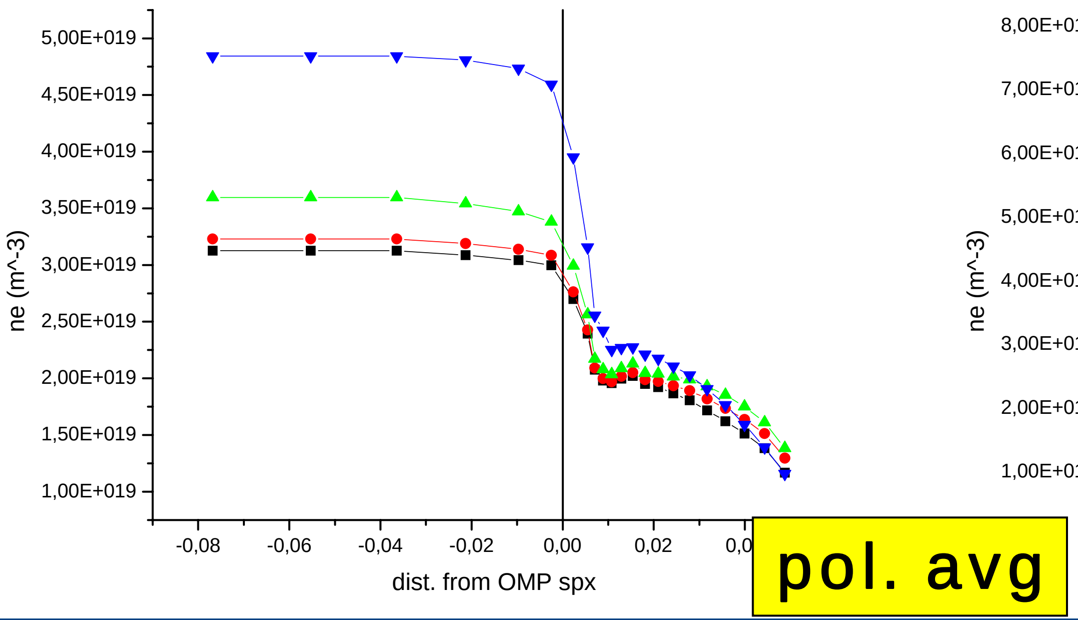
Model A

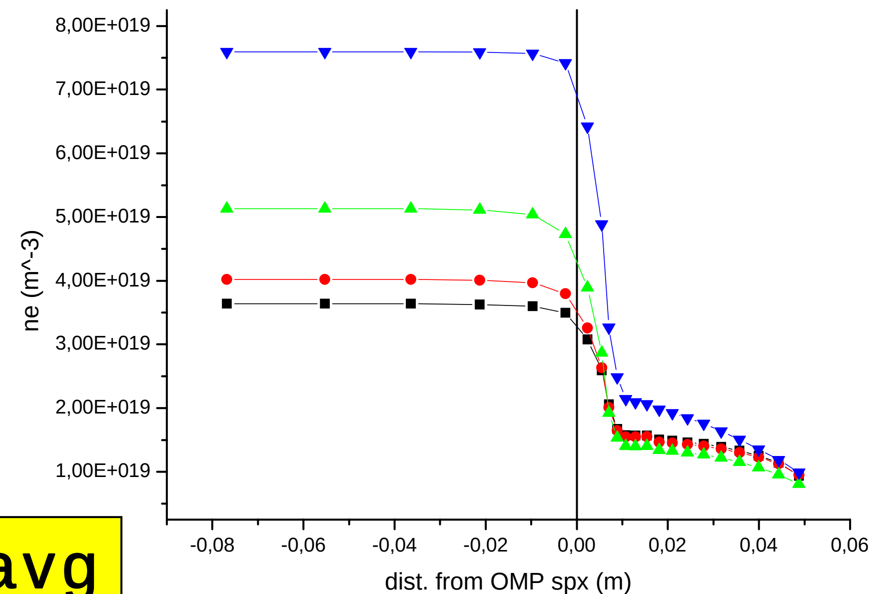
Model B

Radial n_e (OMP puff)

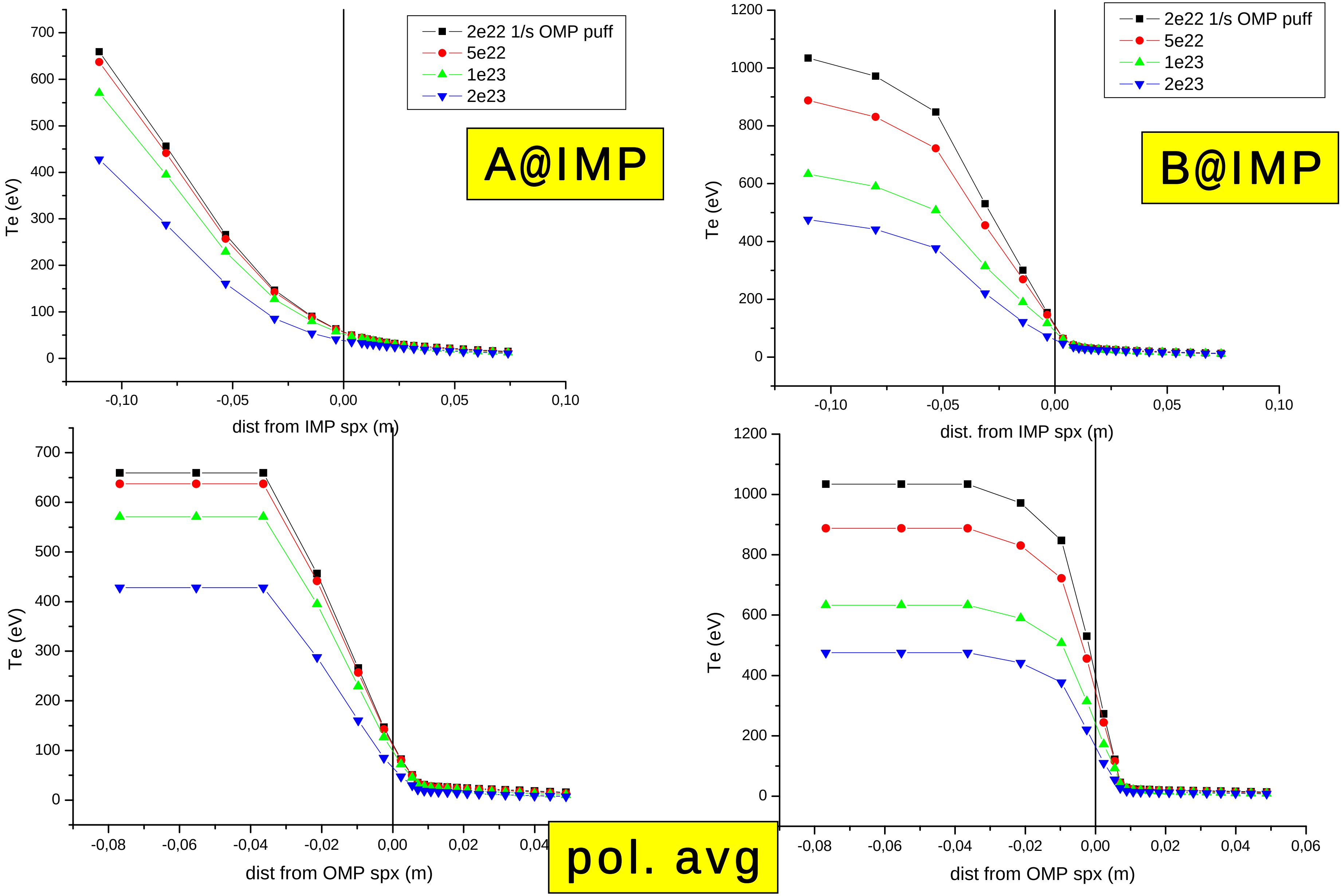




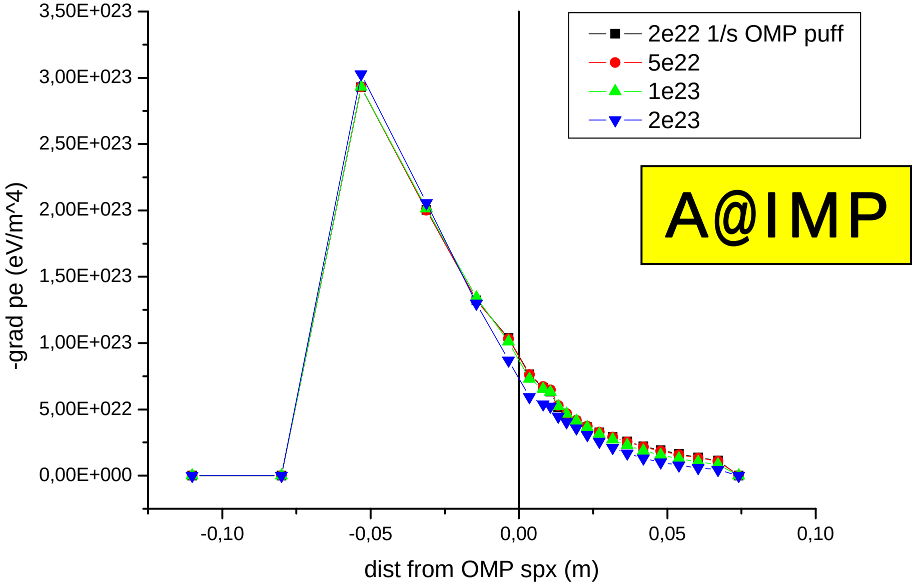


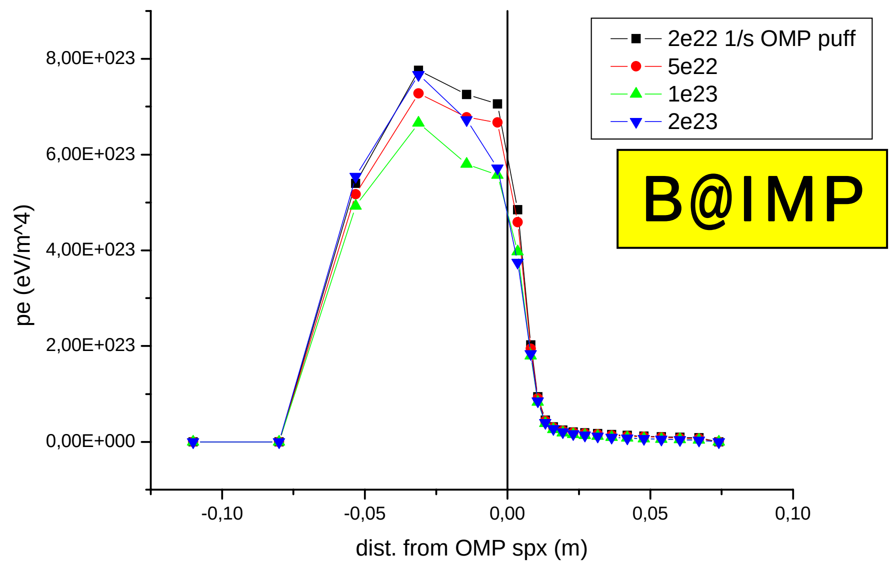


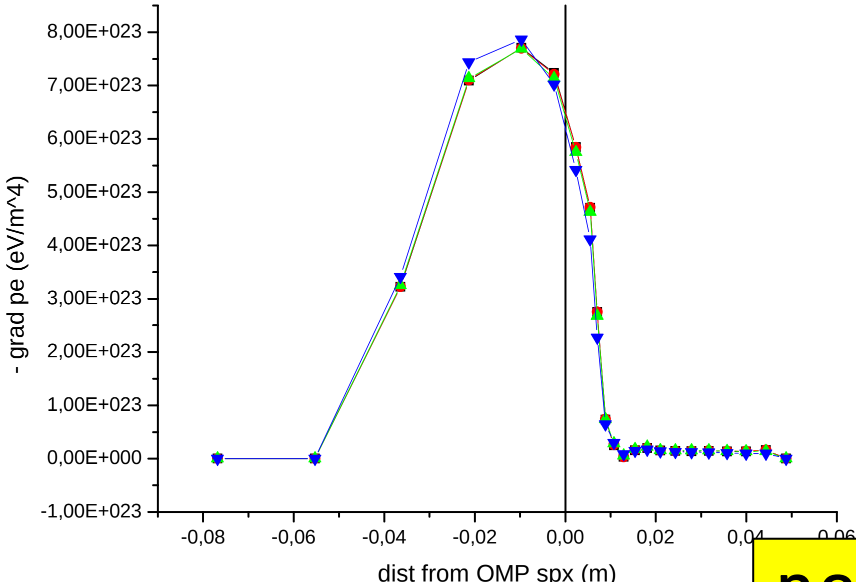
Radial T_e @ IMP (OMP puff)

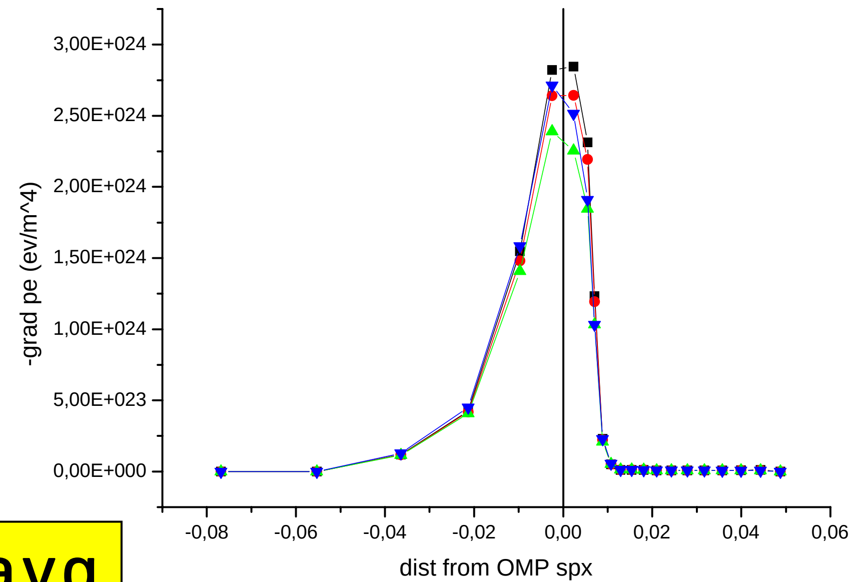


p_e gradient @ IMP (OMP puff)









pol. avg

Characterization of pedestal ne-profile

Steady-state balance between diff. particle outflux and atomic influx

$$D\frac{\partial n}{\partial r} = n_0 v_0$$

1D-solution by Wagner & Lackner (1986):

$$n_e(r) \propto \tanh(ar+b) \qquad\qquad n_0(r) \propto \left[\cosh(ar+b)\right]^{-2}$$

Wagner-Mahdavi model (1)

Mahdavi (2002): additional approx. for flux-expansion correction incl sources

$$\nabla\cdot\left(-D\nabla n_e+n_e\vec{v}_e\right)=n_e n_{0\theta}\langle\sigma v\rangle_{ion}\qquad \nabla\cdot\left(n_{0\theta}\vec{v}_0\right)=-n_e n_{0\theta}\langle\sigma v\rangle_{ion}$$

$$n_e(r)=n_e^{ped}\tanh\left(n_e^{ped}A\cdot r+C\right)$$

$$n_{0\theta}(r)=n_{0\theta}^{sep}\left[\frac{\cosh^2(C)}{\cosh^2\left(n_e^{ped}Ar+C\right)}\right]^{1/E_\theta^{eff}}$$

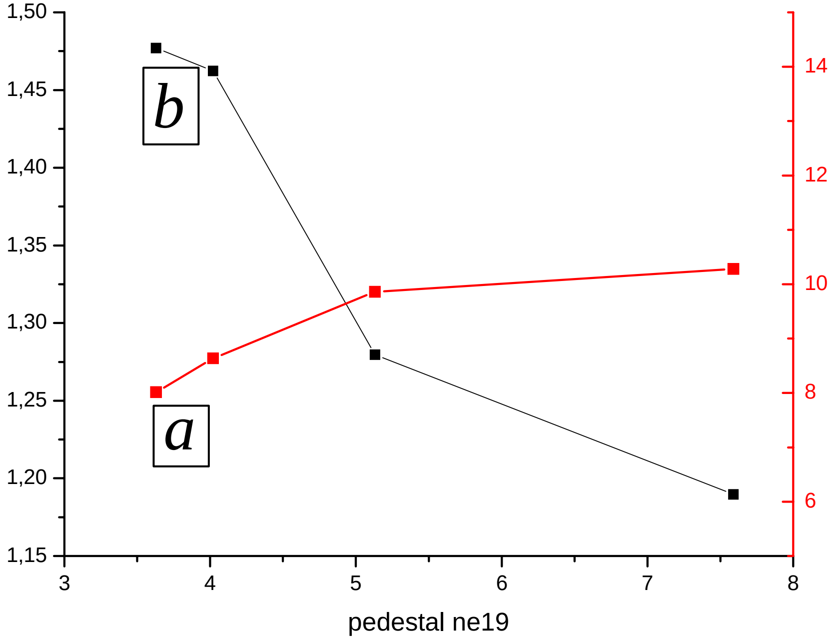
$$A(\theta)=\frac{E_\theta^{eff}\langle\sigma v\rangle_{ion}}{2v_{0\perp}}\qquad C(\theta)=\frac{1}{2}\sinh^{-1}\left[D\sqrt{\frac{\tau_\parallel^{SOL}}{D^{SOL}}}\frac{E_\theta^{eff}\langle\sigma v\rangle_{ion}}{v_{0\perp}}n_e^{ped}\right]$$

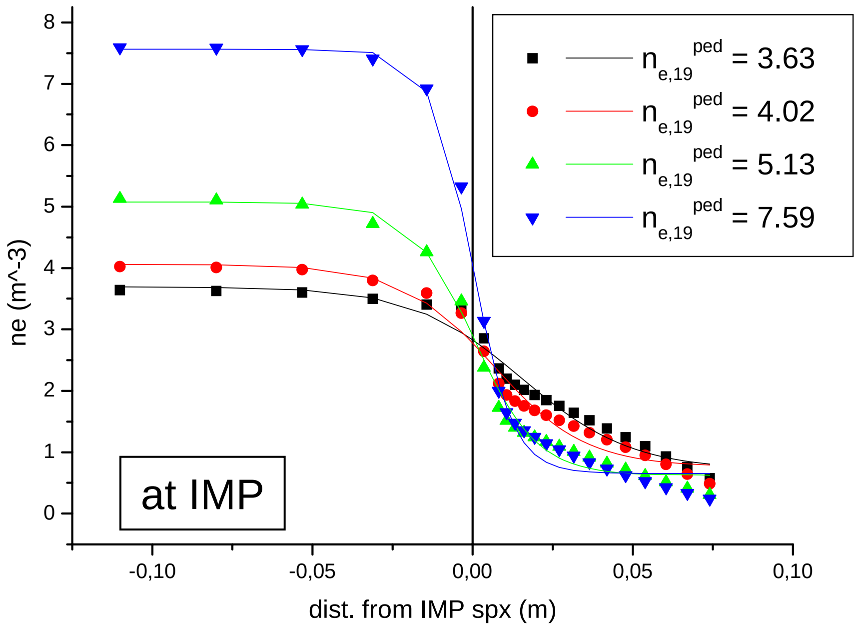
A(θ) should be almost constant at fixed poloidal position (assume: no CX & perpendicular neutral velocity const.)

Wagner-Mahdavi model (2)

fit function:

$$n_{19}^{ped} d\left[\tanh\left(n_{19}^{ped} ax + c\right) + b\right]$$

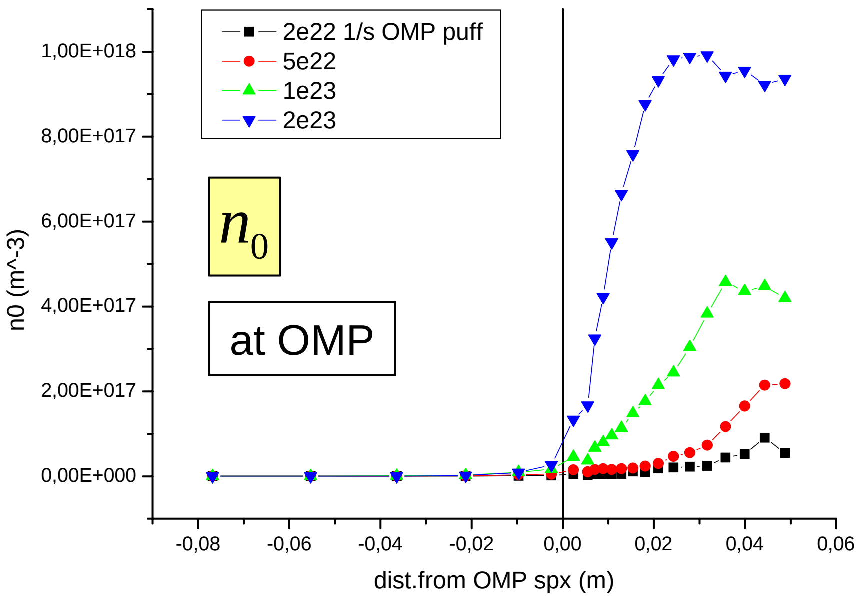


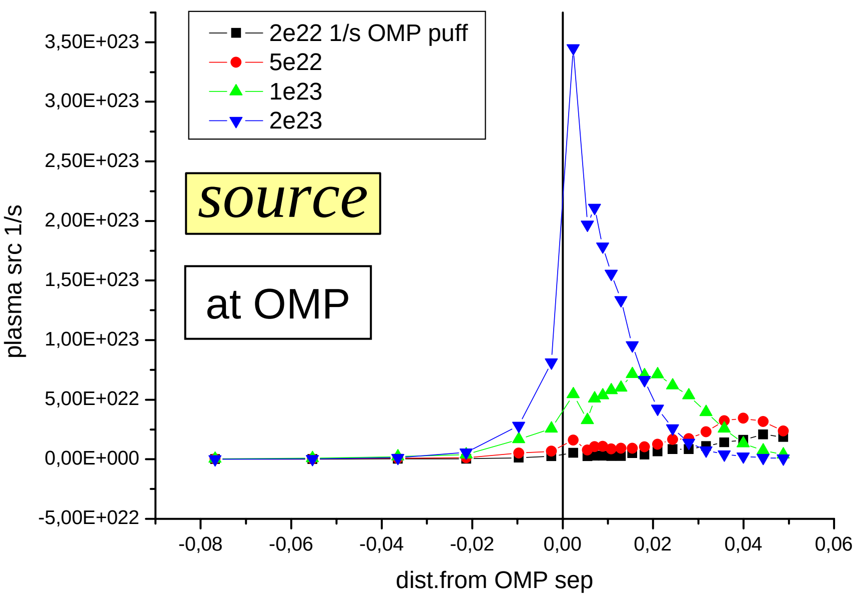


$$\Delta n^{ped} \propto \left(n^{ped} height\right)^{-1}$$

- **profile steepens as expected**
- **a: stays constant for large n_e^{ped}**
- **c: offset decreases**

neutrals / fuelling





With increasing puff-rate an increasing fraction of neutrals ionize in the edge region (fuelling)

Summary

- **density scans EDGE2D gas-puffing simulations resemble qualitatively pedestal characeristics**
- **LH-transition: with increasing pedestal density in transport “model A” the density gradient length decreases, ie: the convective heat transport fraction increases, the LH-power-threshold decreases (D.Kalupin)**
- **“model B”: at higher gas puffing rates, Wagner-Mahdavi model for ne-pedestal profile well reproduced**
- **also: pressure gradient increases slightly (ELM-mitigation)**
- **a significant amount of neutrals can travel across the SPX into the egde to fuel the core**

Future:

- **try to match experimental values**
- **puff from the top, include pellet-injection, etc...**
- **geometry-effect for LH-trans: switch from septum to SRP**
- **use EDGE2D/EIRENE and compare to EDGE2D/NIMBUS, Benchmark**