Presheath/Sheath structure for grazing incidence magnetic field

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Stangeby's model

Chodura : potential drop in the Chodura Sheath (transition from field aligned to normal to wall (super)sonic flow)

$$\frac{e\Delta\phi_{CS}}{k_B T_e} = \ln \sin \alpha \tag{1}$$

Divergence when $\alpha \to 0$.
Chodura : independance in α for the floating wall case

$$\frac{e\Delta\phi_{\text{floating}}}{k_B T_e} = \frac{e(\Delta\phi_{CS} + \Delta\phi_{DS})}{k_B T_e} = 0.51 \ln \left[\left(\frac{2\pi m_e}{m_i} \right) \left(1 + \frac{T_i}{T_e} \right) \right] \tag{2}$$

Stangeby statement : for small α, as $\Delta\phi_{\text{floating}}$ is finite, (1) and (2) are incompatible. There exists some critical angle $\alpha^\star$ for which the DS disappears.

$$\Delta\phi_{DS} = 0 \to \alpha^\star = \sin^{-1} \left\{ \left[\left(\frac{2\pi m_e}{m_i} \right) \left(1 + \frac{T_i}{T_e} \right) \right]^{\frac{1}{2}} \right\}$$

Stangeby's model

Similar to Chodura/Riemann for CS

- no collisions, no collisional presheath, assumption of sonic/superonic flow at CS entrance.
- fluid ions, isothermal closure ($T_i = cst$, $\gamma = 1$)
- Boltzmann electrons
- strongly magnetized electrons ($\rho_e \ll \lambda_D$) $\rightarrow$ α-independence of $\Delta\phi_{\text{floating}}$
- test-cases : $m_i = 1, 2, 2.5 m_H$, $\alpha^\star = 4.746°, 3.354°, 2.999°$.

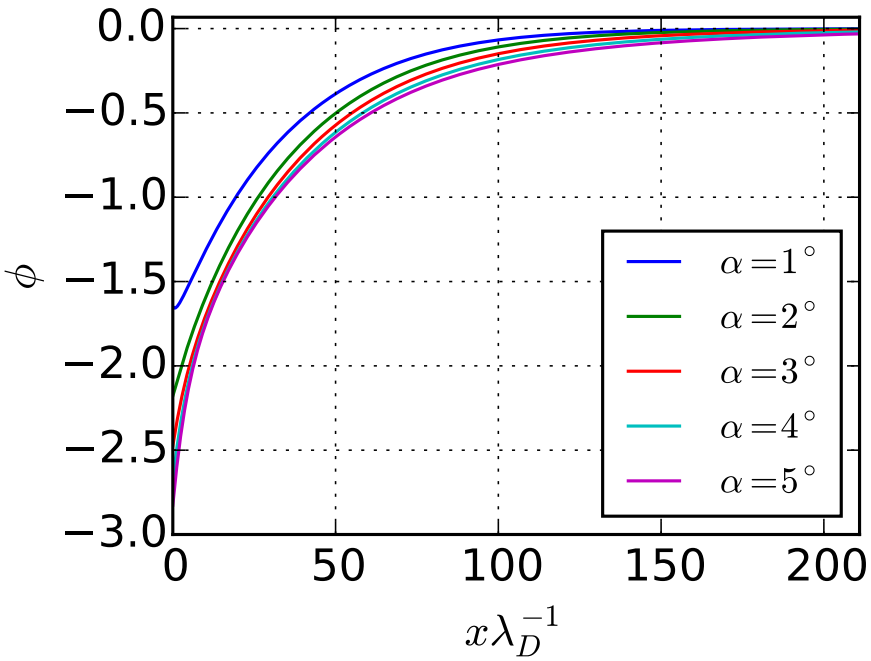
Open questions

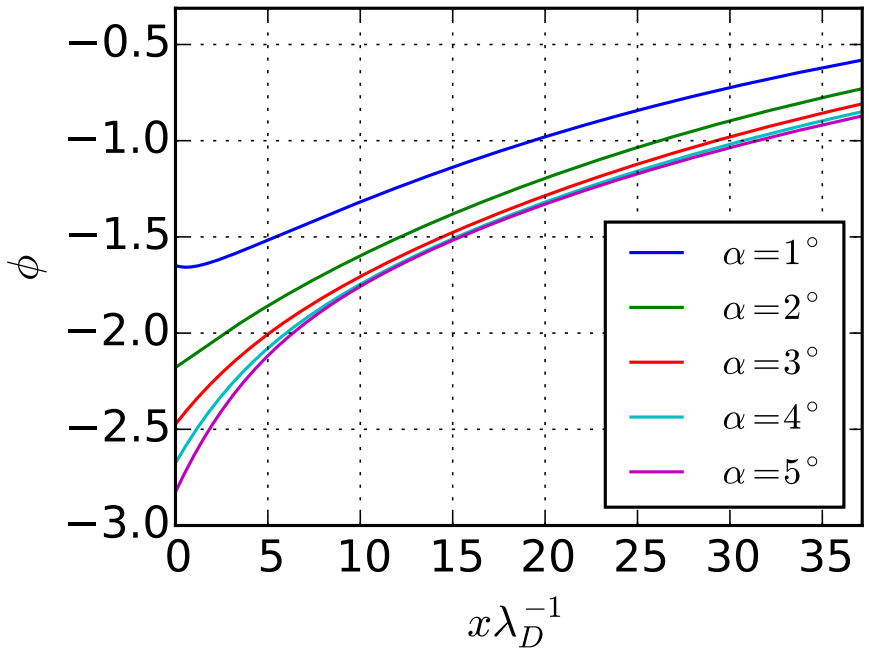
- kinetic model for ions
- collisions
- FLR effects for electrons
- full kinetic electrons

Simulation Parameters

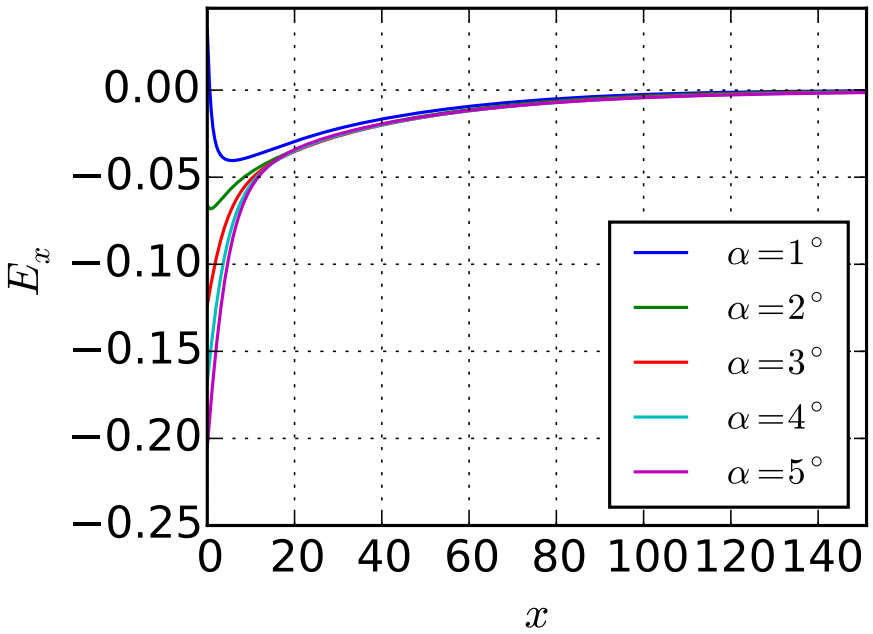
- deuterium plasma $m_i/m_e \approx 3680$, $\alpha^\star = 3.354°$ in Stangeby's model.
- kinetic ions
- Boltzmann electrons, $T_{e0} = T_{i0} = 5\text{eV}$.
- Magnetic field : $\omega_{CI} = 0.05\omega_{pi}$, $\alpha \in \{1°, 2°, 3°, 4°, 5°\}$
- simulation grid $(n_x, n_{v_x}, n_{v_y}, n_{v_z}) = (256, 120, 120, 120)$.
- space domain $[0, L = 5000\lambda_D]$. Δx ranges from $0.1\lambda_D$ to $80\lambda_D$.
- BC , absorbing plate at $x = 0$, plasma bulk (Maxwellian) at $x = L$.
- velocity space $[v_{max}, v_{min}] = [-6v_{thi}, 6v_{thi}]$.
- relaxation rate $\nu_{bgk} = 2.0 \times 10^{-3}\omega_{pi}$.
- $\Delta t = 0.1\omega_{pi}^{-1}$, 16000 steps, $\omega_{pi}t_{end} = 1600$, $\nu_{bgk}t_{end} \approx 3$ (a bit low)

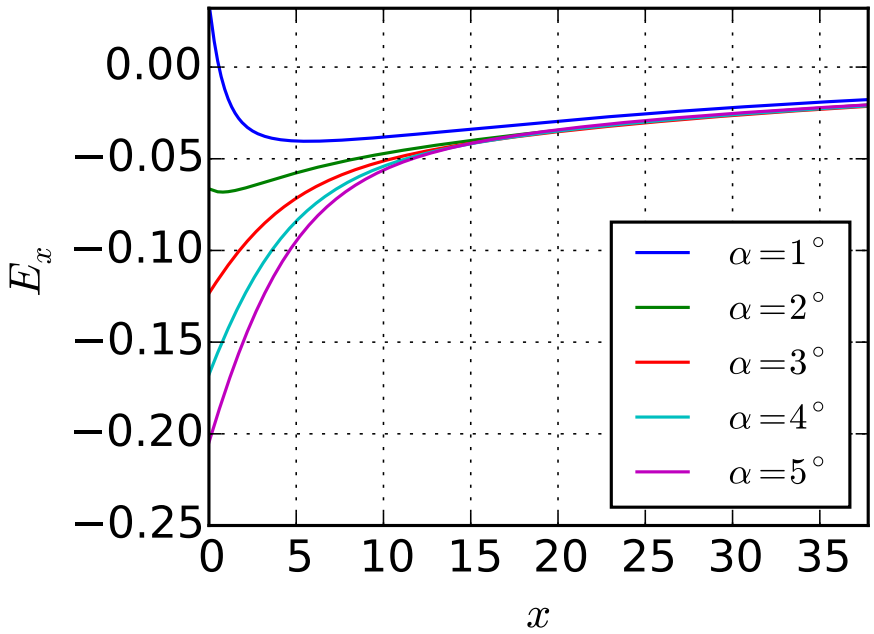
Potential profiles



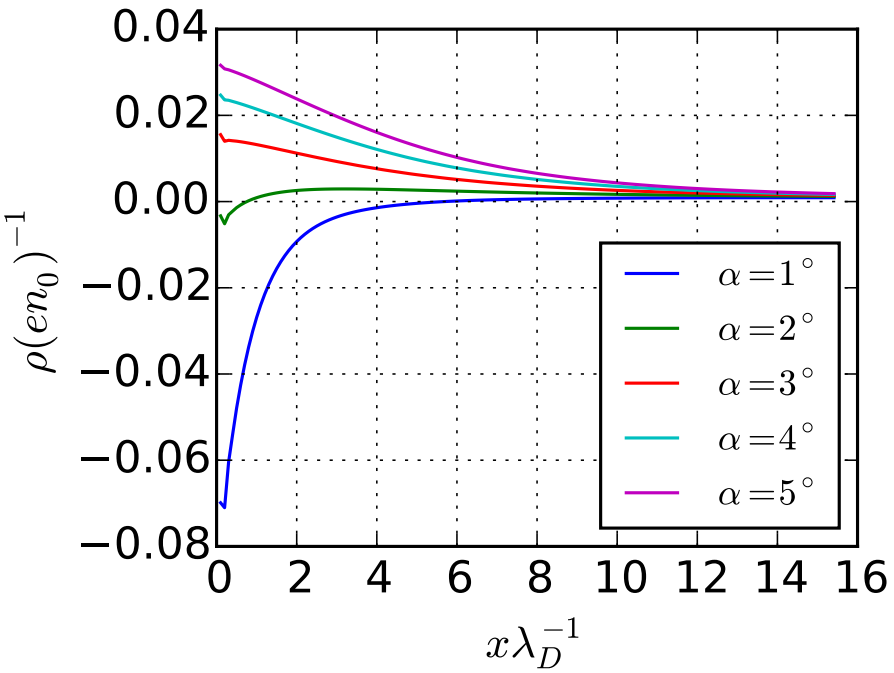


Electric Field



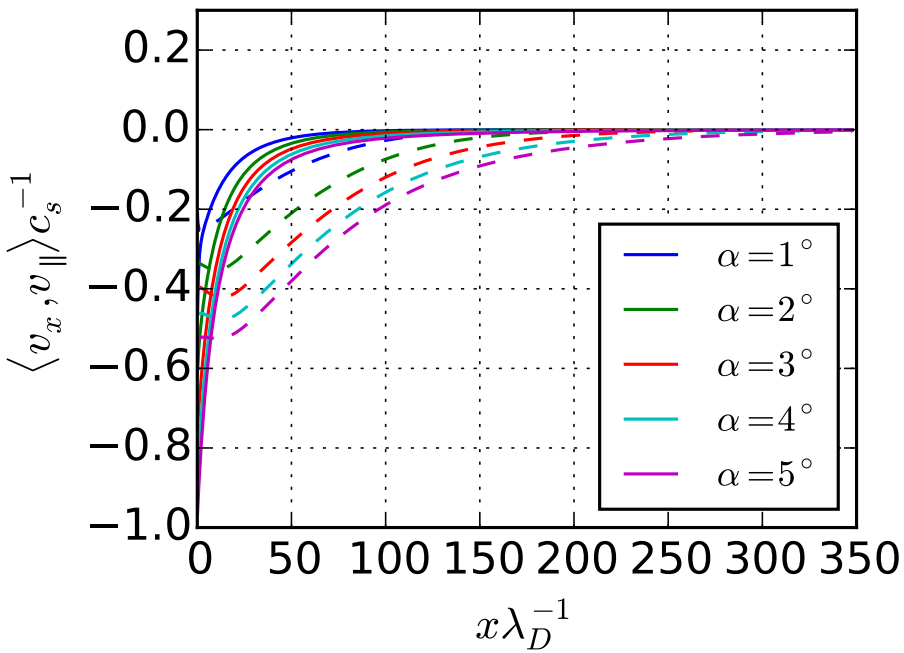


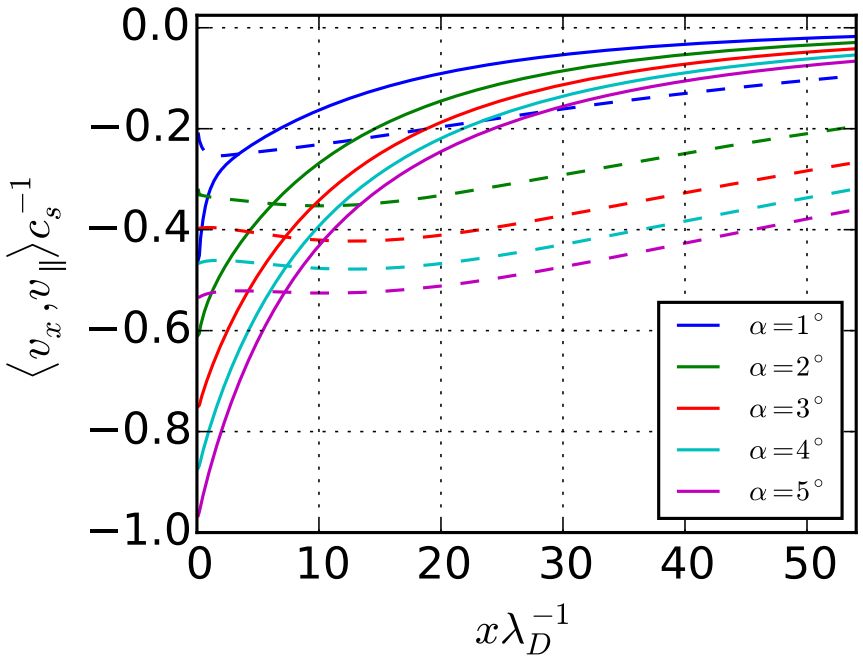
Charge separation



Transition seems to be between 3° and 2°.

Mach numbers

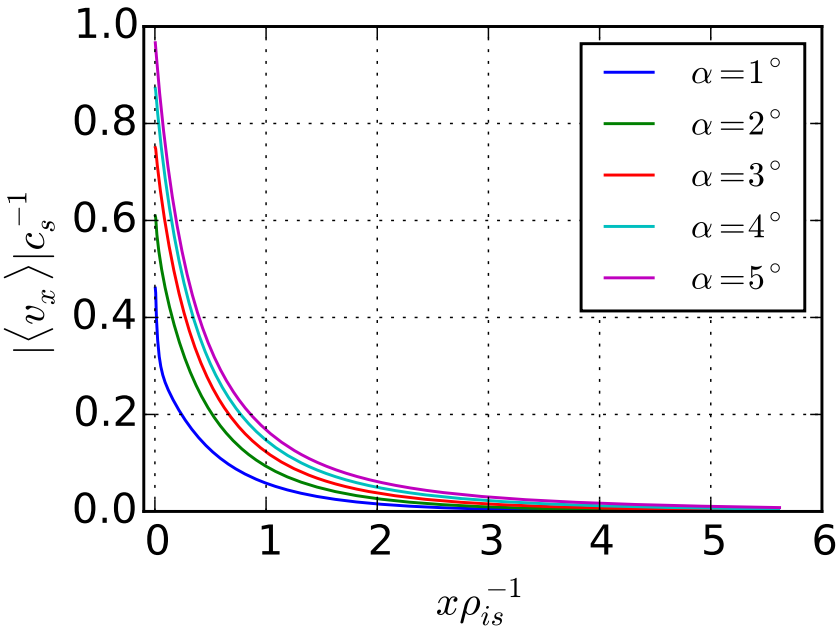


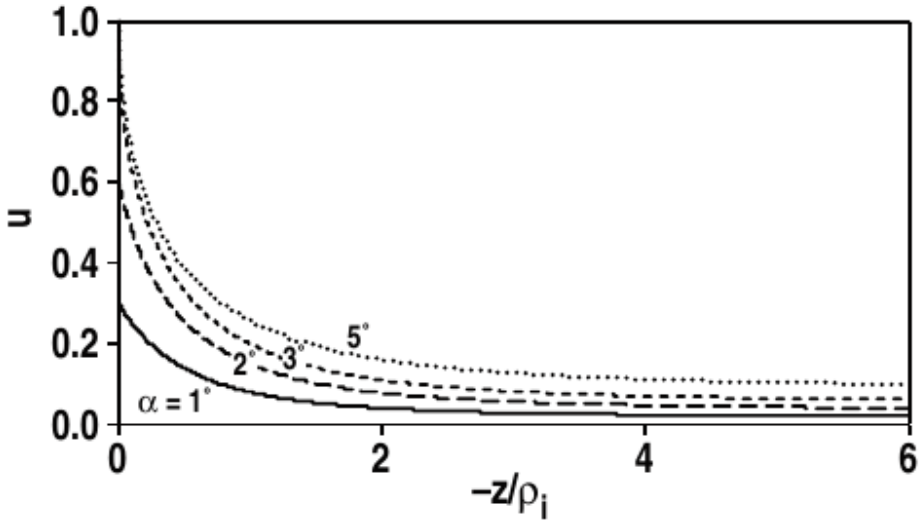


(continuous : v_x, dashed $v_\parallel$).

- subsonic flows

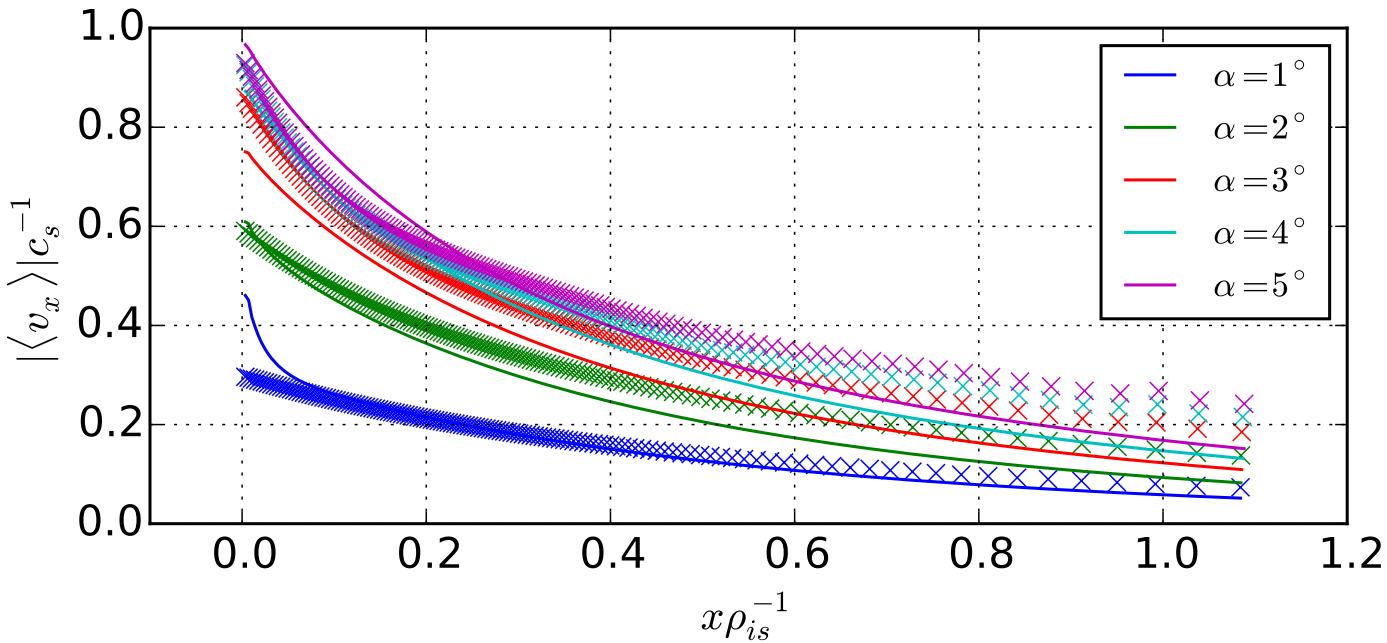
Mach numbers ⊥ to wall only





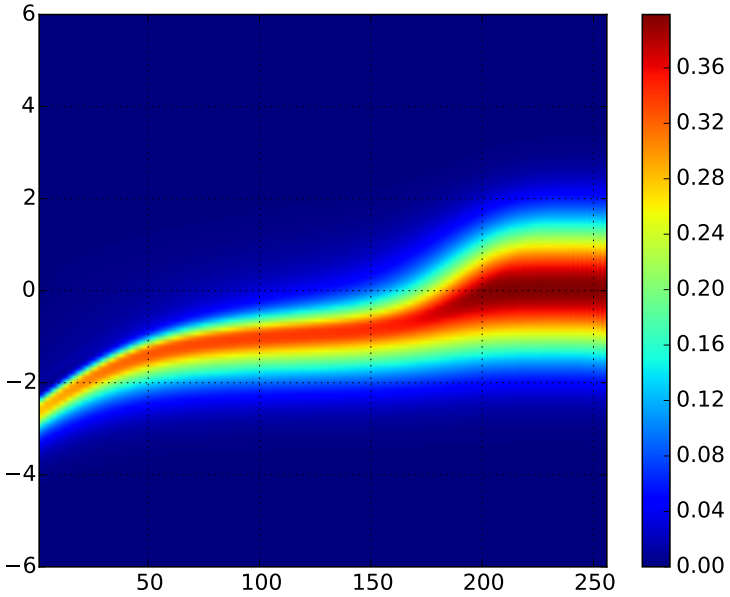
- WARNING : no DS in Stangeby's plot : $z = 0$ is the DS entrance.
- Stangeby bc : $v_{||} = c_s$ at entrance of CS, here $v_{||} < c_s$=> different initial condition, cannot match mach number profile (not counting collision effects

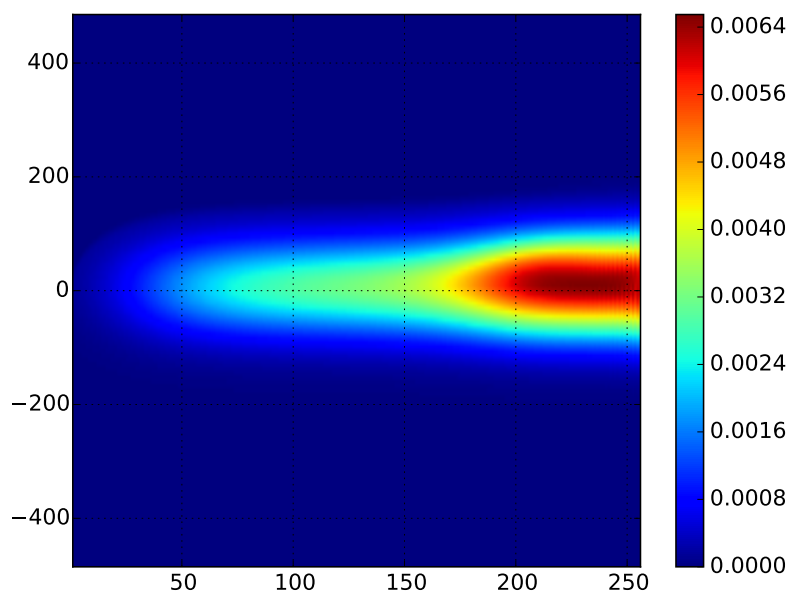
Mach numbers $\perp$ to wall only, comparison with Stangeby polynomial fit for $u = v_x / c_s$

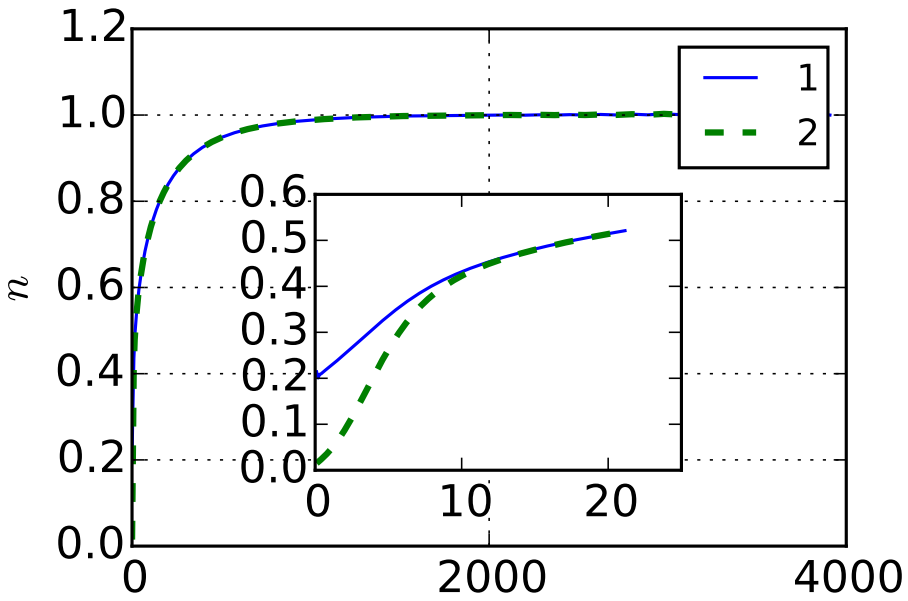


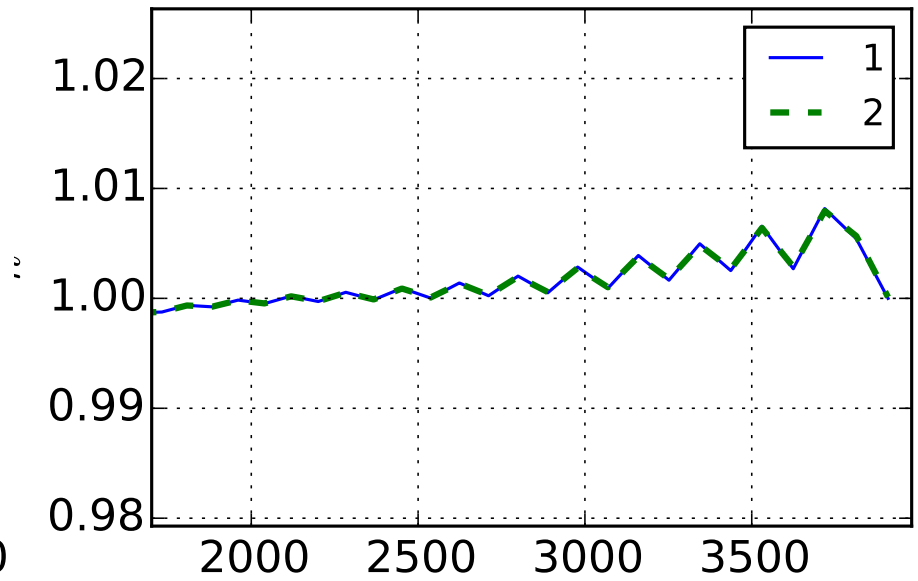
- stangeby bc : $v_{||} = c_s$ at entrance of CS

Kinetic electrons -1D tests

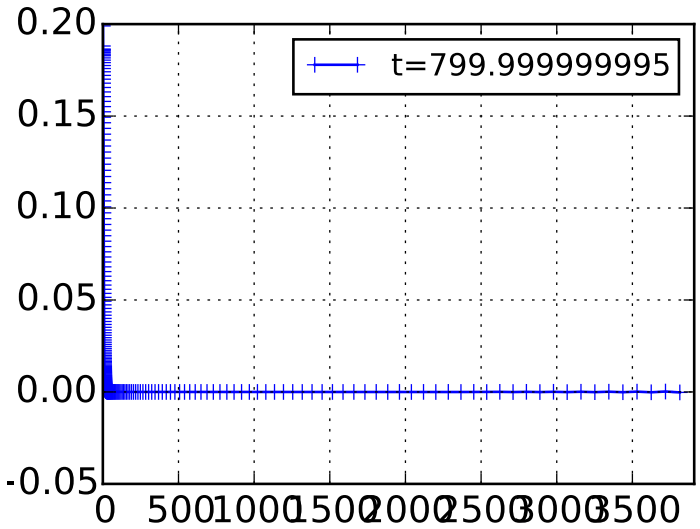


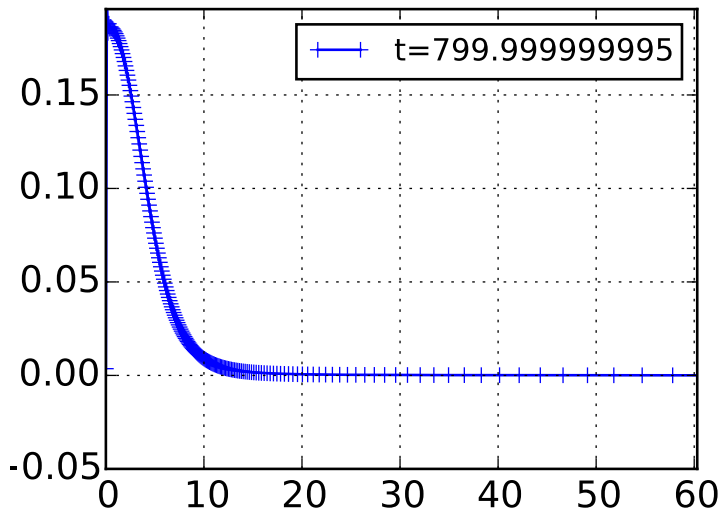


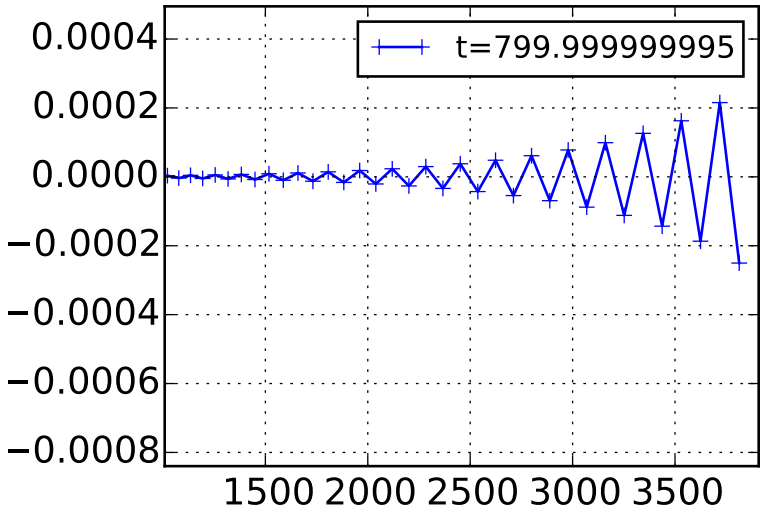


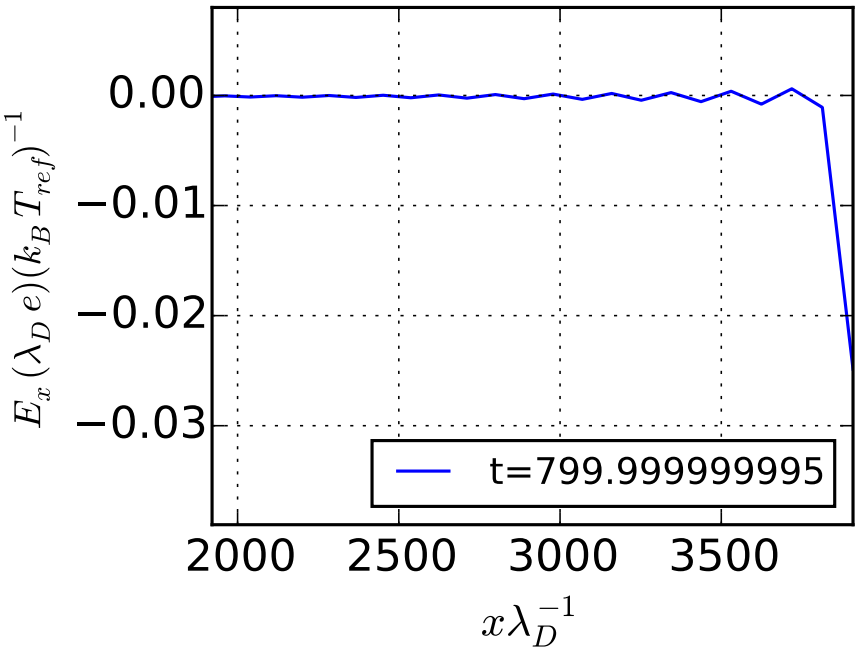


Kinetic electrons - 1D tests





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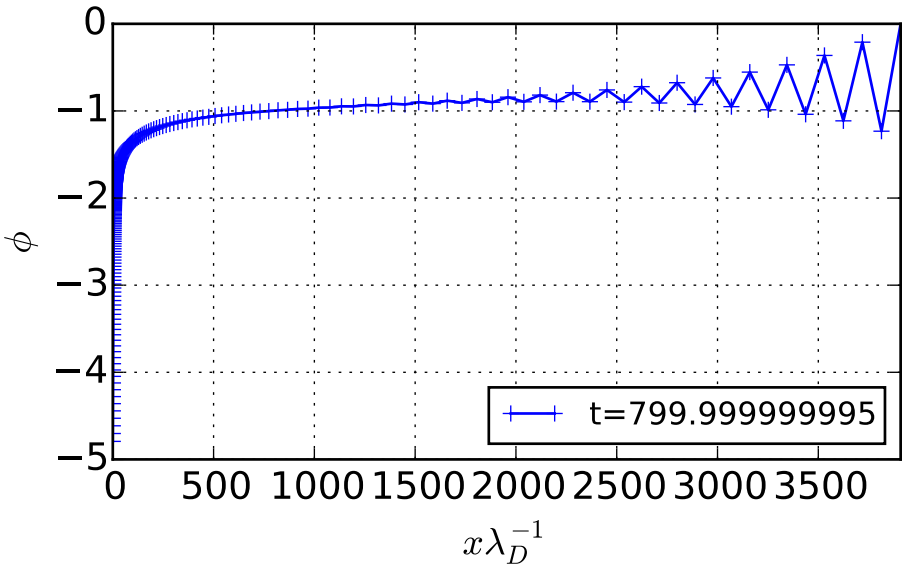
$E_x\,(\lambda_D\,e)(k_B\,T_{ref})^{-1}$
$x\lambda_D^{-1}$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