Activities during last months

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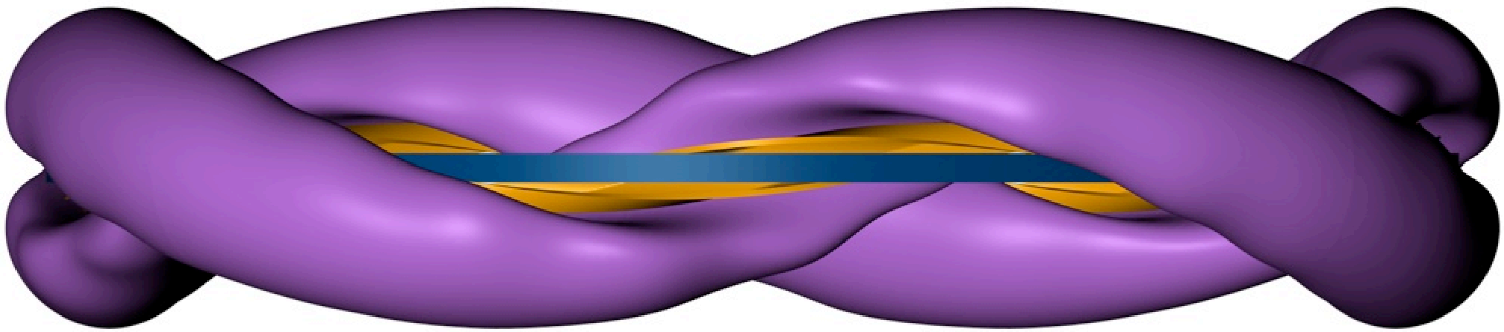
3rd Kinectic Workshop, Graz

Contents

- Global Neoclassical Fluxes with Er≠0
- Electric Field Resonances (ion transport)
- Bootstrap calculations for TJ-II

Neoclassical Global Fluxes



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Global Neoclassical Fluxes

- *"The linear drift kinetic equation with or without bounce average is intrinsically incompatible with large orbit size regardless of its fraction"*

- *"The authors neither solve for the equilibrium distribution function to show that it is a Maxwellian, nor show that the relaxation rate of the plasma profiles is slower than that of the distribution function"*

- *"The zero order equation for f_0 in linear drift kinetic theory is not valid for large orbits. Thus, using a Maxwellian distribution for f_0 is incorrect"*

Global Neoclassical Fluxes

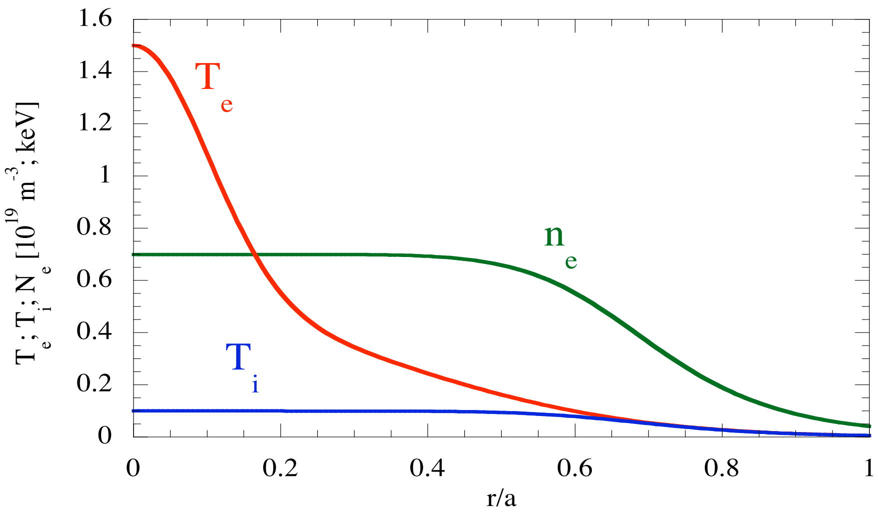
- What to do **without** the local approach?
  - Under *real* conditions in **real** devices
  - Without really solving the 5D DKE

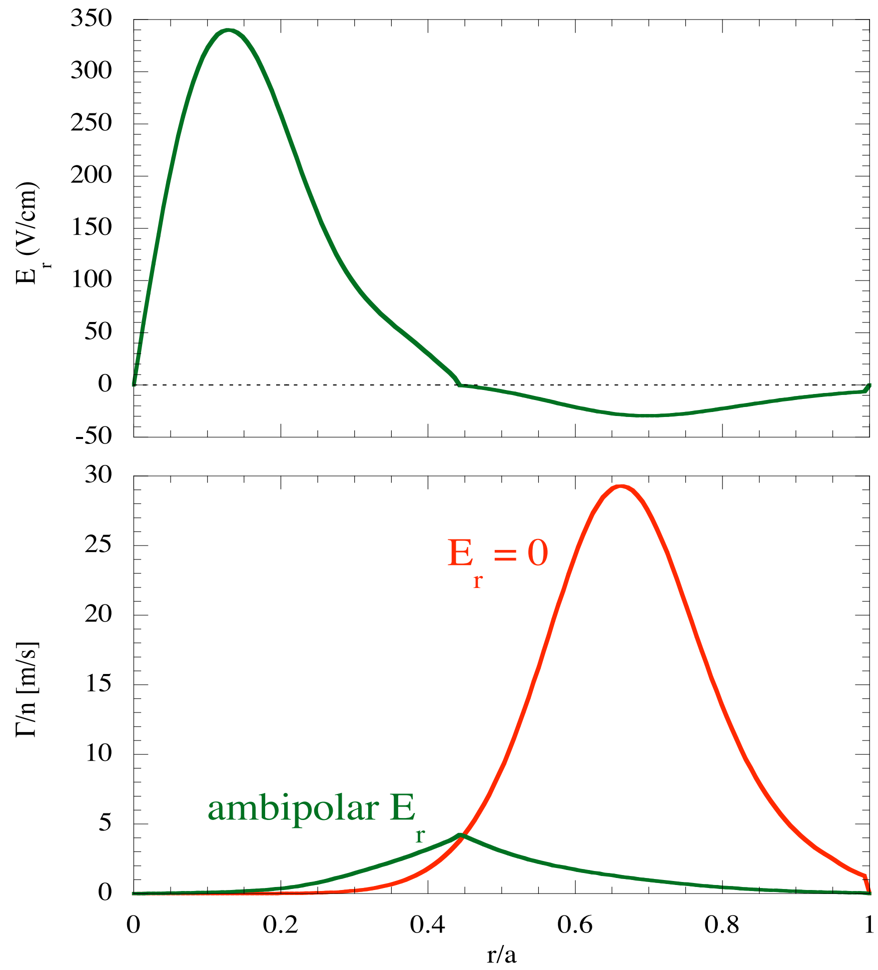
✓ Check the local approach with E_r=0

⟹ Include electric field effects

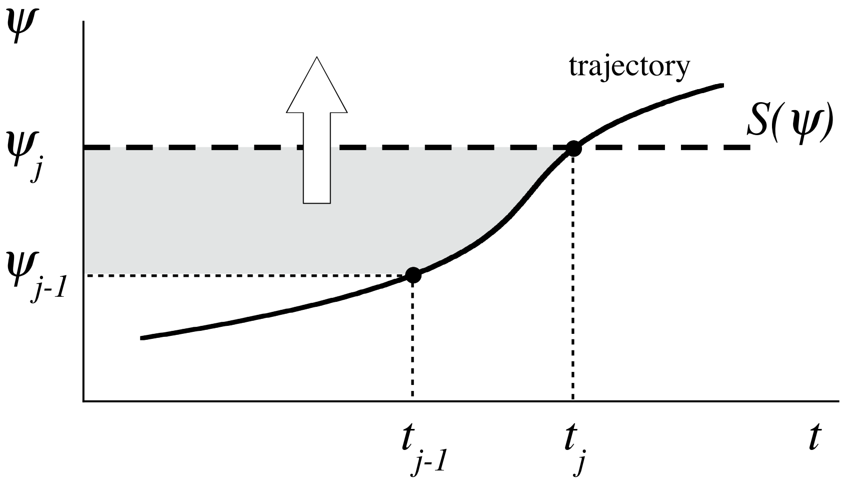
Global Neoclassical Fluxes

Common local approach based on monoenergetic coefficients





Global Neoclassical Fluxes



$$\Gamma_i(\psi_j) = \frac{N(\psi_j)}{tS(\psi_j)} = \frac{2\pi^2 R a^2 \int_{\psi_{j-1}}^{\psi_j} f(\psi) d\psi}{4\pi^2 R a \sqrt{\psi_j}(t_j - t_{j-1})}$$

$$\langle \Gamma(\psi, v) \rangle = \langle D^0(\psi, v) \rangle f(\psi, v) + \langle D^1(\psi, v) \rangle \frac{df}{d\psi} + ... + \langle D^n(\psi, v) \rangle \frac{d^n f}{d\psi^n}$$

$$\langle D^n(\psi, v) \rangle_{p.t} = \frac{(-1)^n}{(n+1)!} \frac{a}{2\sqrt{\psi}} \frac{1}{N_p N_t} \sum_{i=1}^{N_p} \sum_{j=1}^{N_t} \frac{\psi_j - \psi_{j-1}}{t_j - t_{j-1}} (\psi_j - \psi_{j-1})^n$$

Global Neoclassical Fluxes

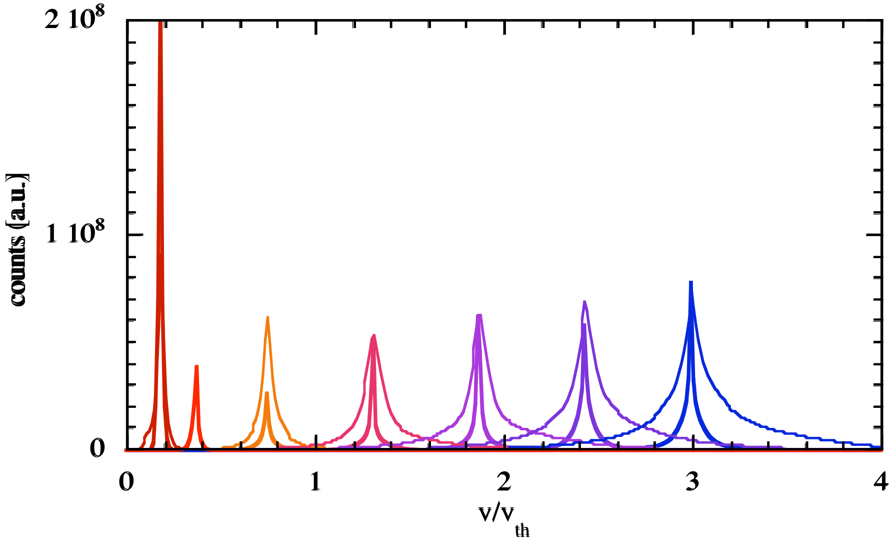
- Dealing with the radial electric field
  - Kinetic energy is not conserved
    - Monoenergetic approach dubious
  - Appearance of electrostatic barriers
  - Ambipolarity becomes highly non linear
- Compute fluxes for the local ambipolar Er

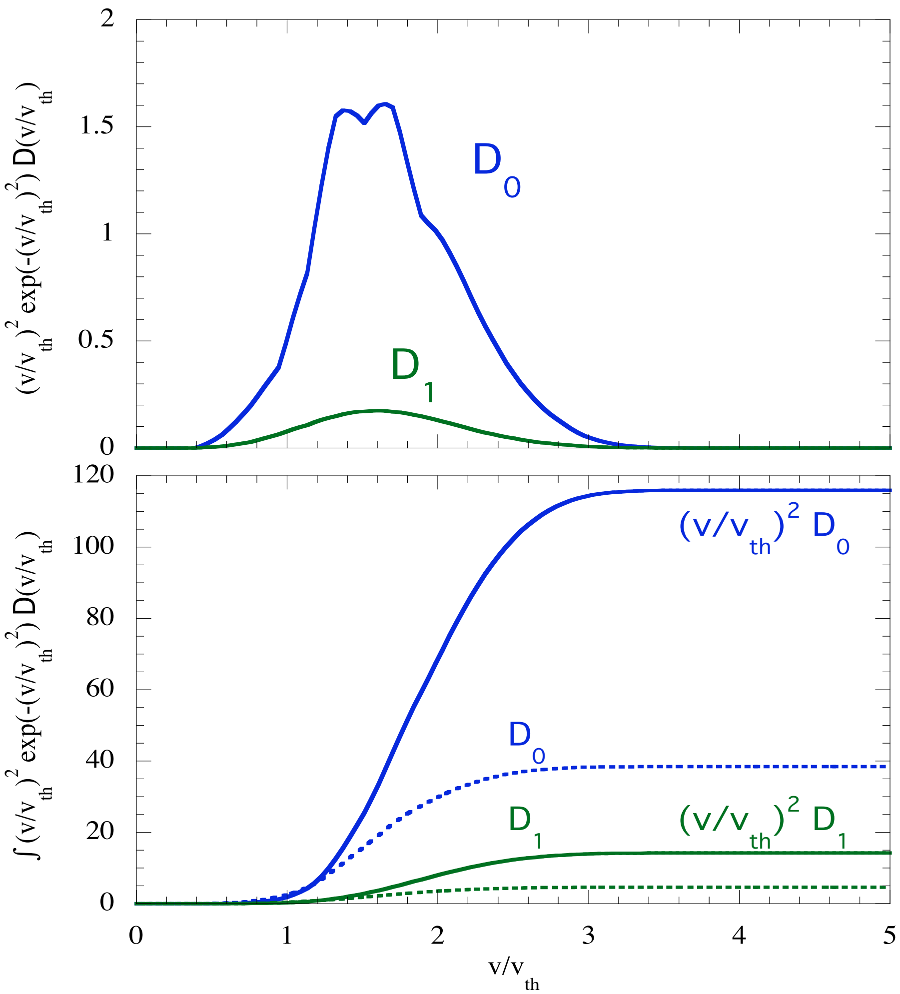
Global Neoclassical Fluxes

$$\Gamma^n(\psi) = \frac{4}{\sqrt{\pi}} \int_0^\infty \langle D^n(\psi, v)\rangle_{p,t} \, (\nabla_\psi) \, f_{Max}(\psi, v) \, v^2 dv = -\langle D^n(\psi)\rangle_v (\nabla_\psi)$$

Kinetic energy is not conserved

Monoenergetic approach *acceptable*

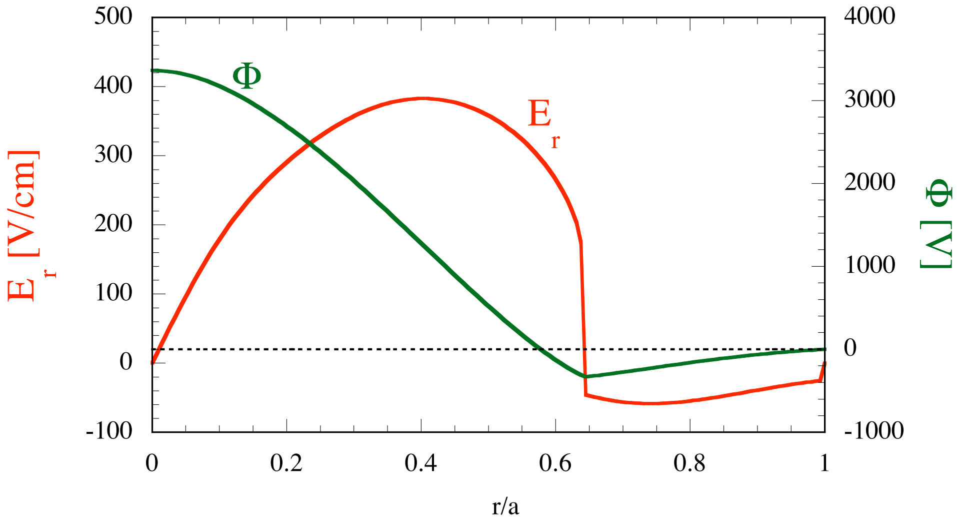


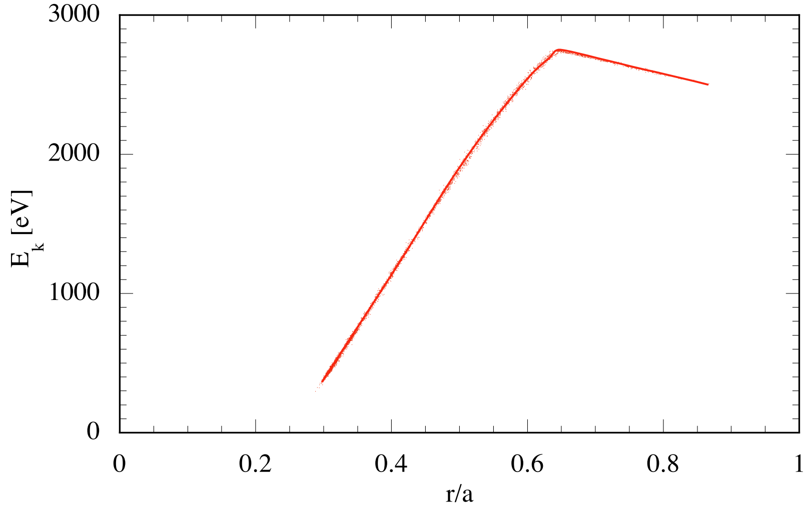


Global Neoclassical Fluxes

Appearance of electrostatic barriers

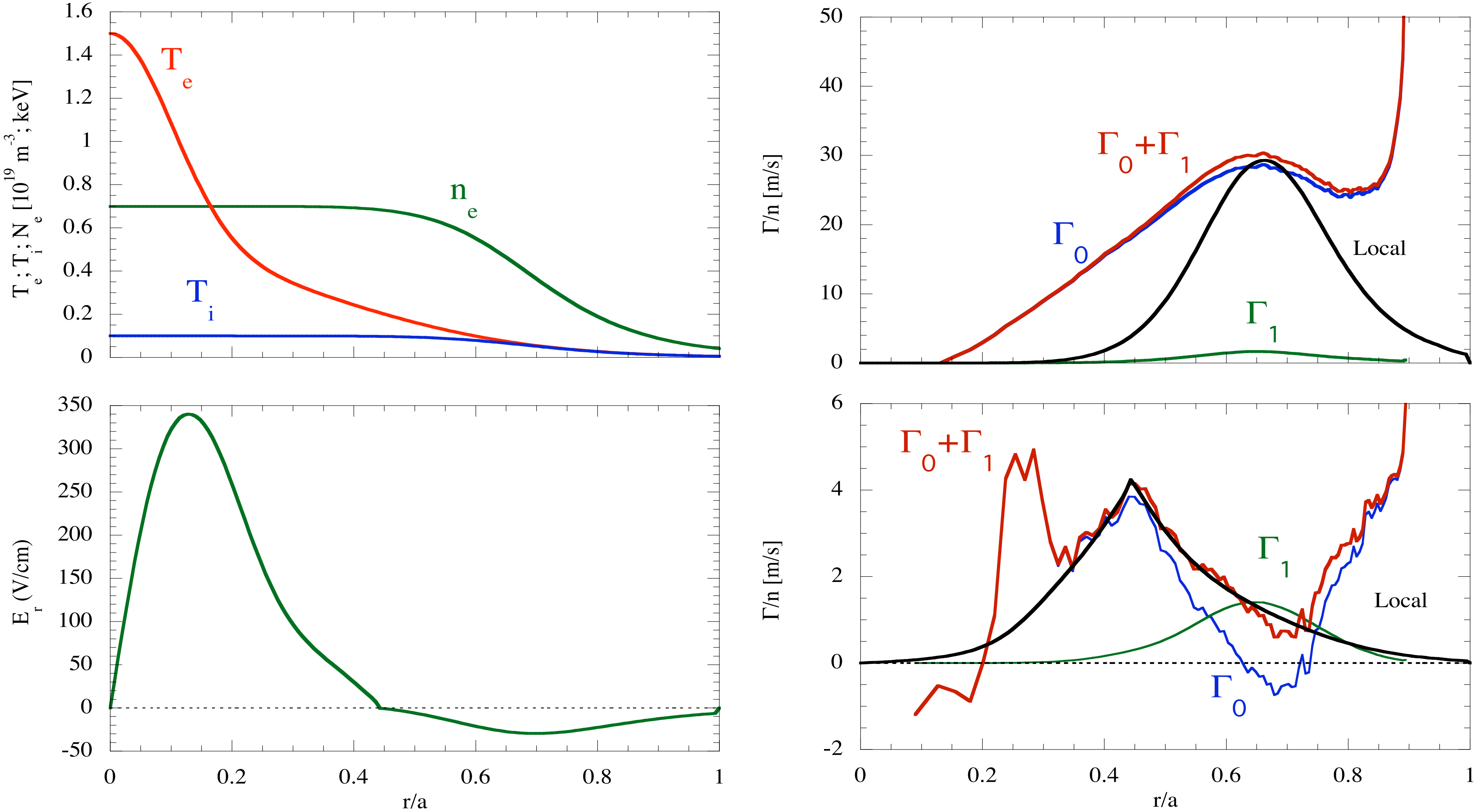
funny trajectories





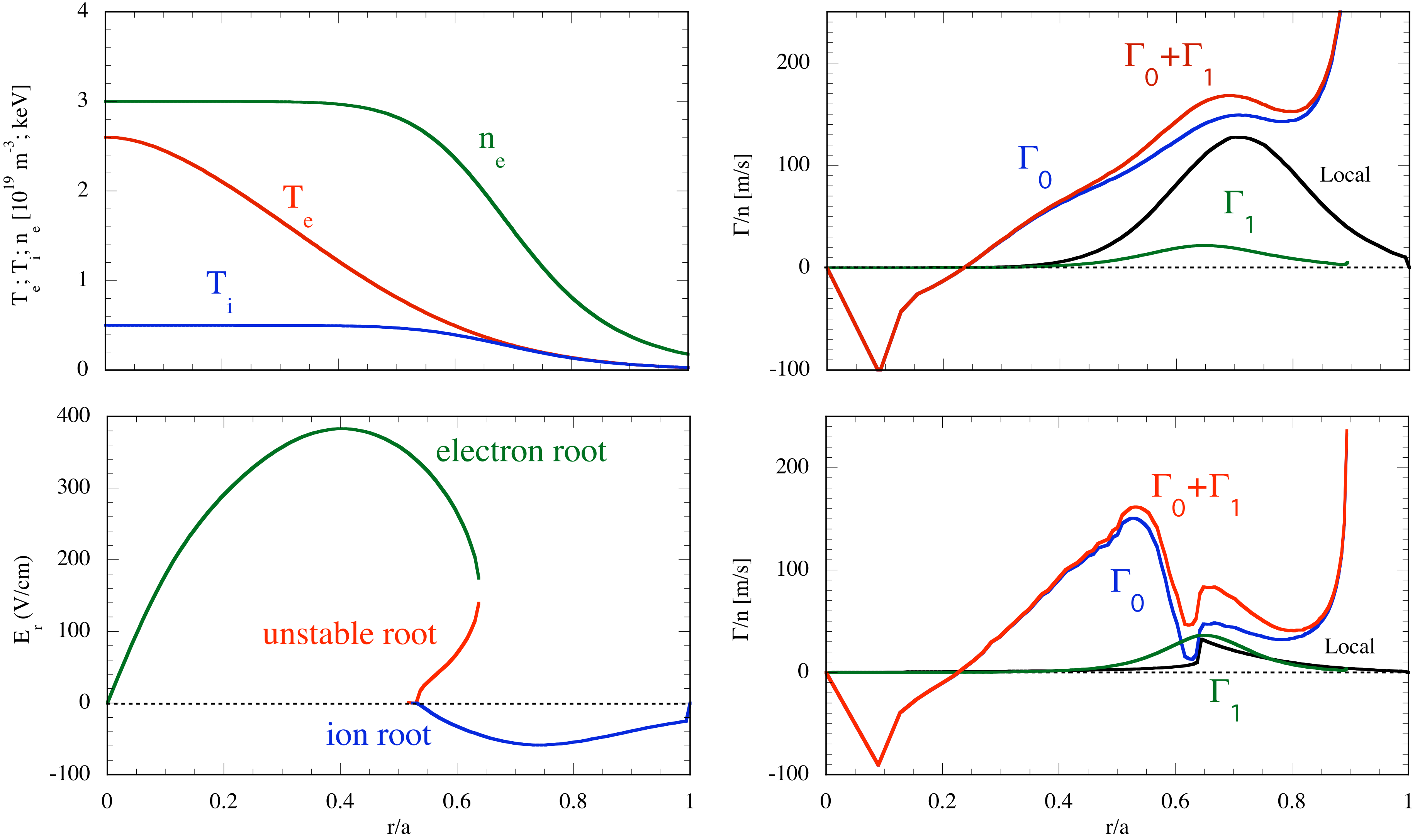
Global Neoclassical Fluxes

TJ-II

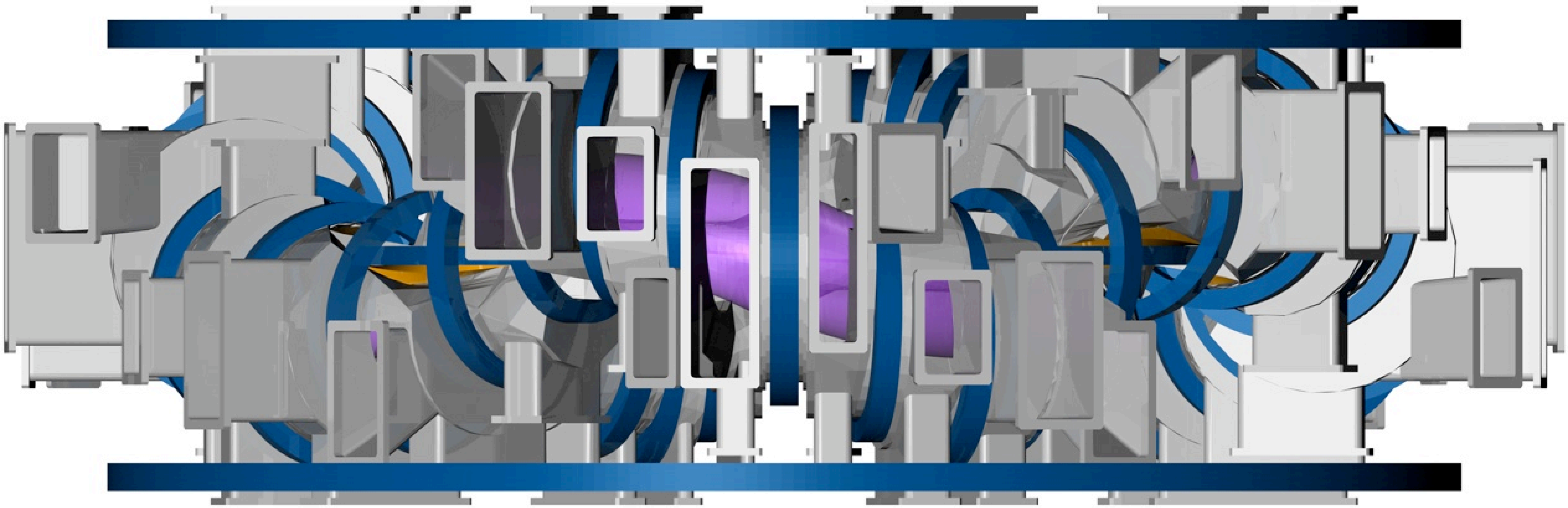


Global Neoclassical Fluxes

TJ-II



Electric Field Resonances



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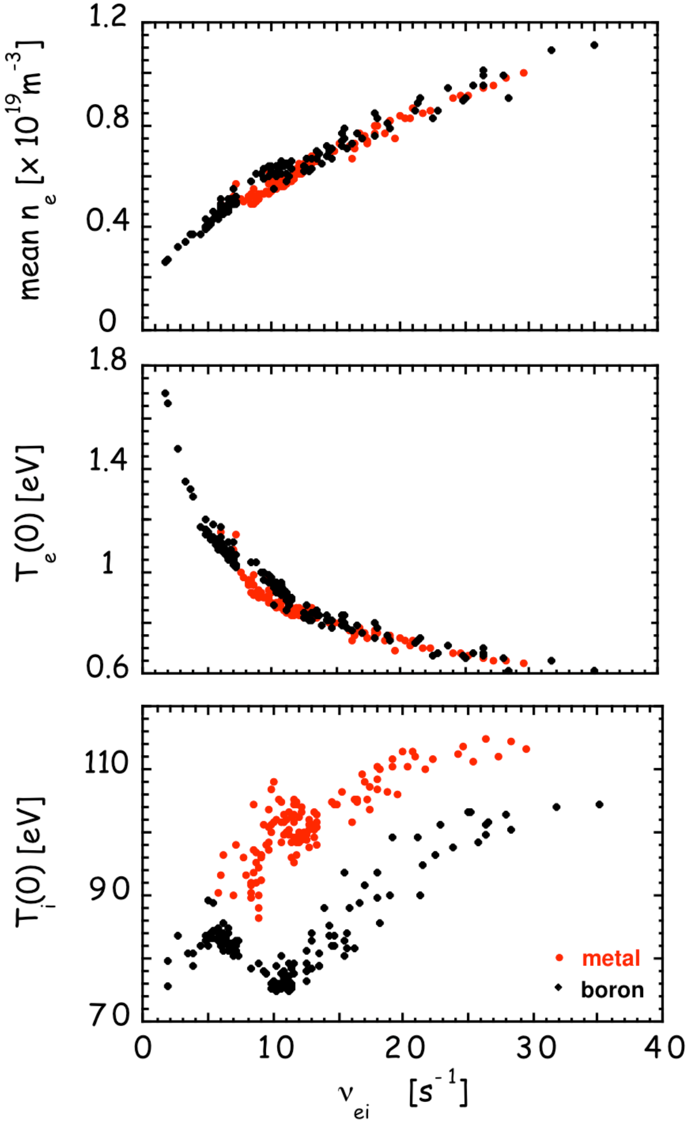
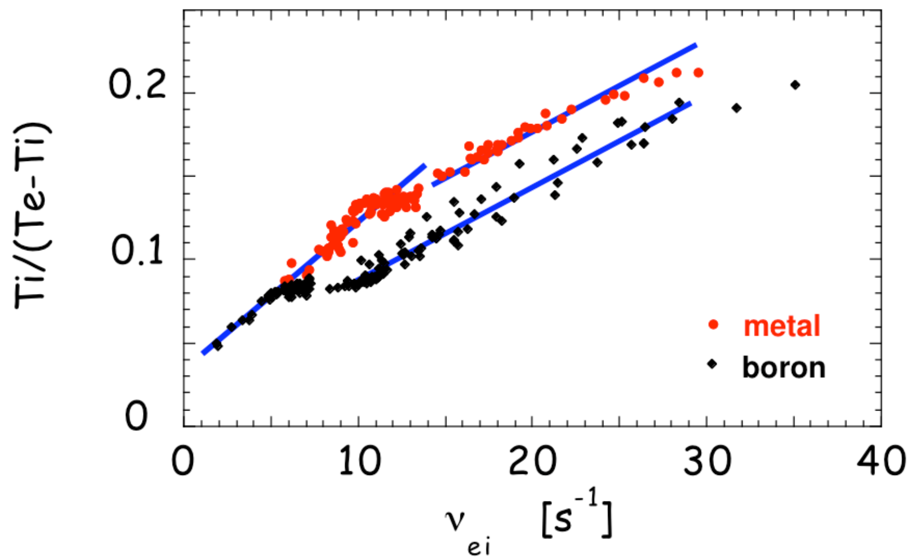
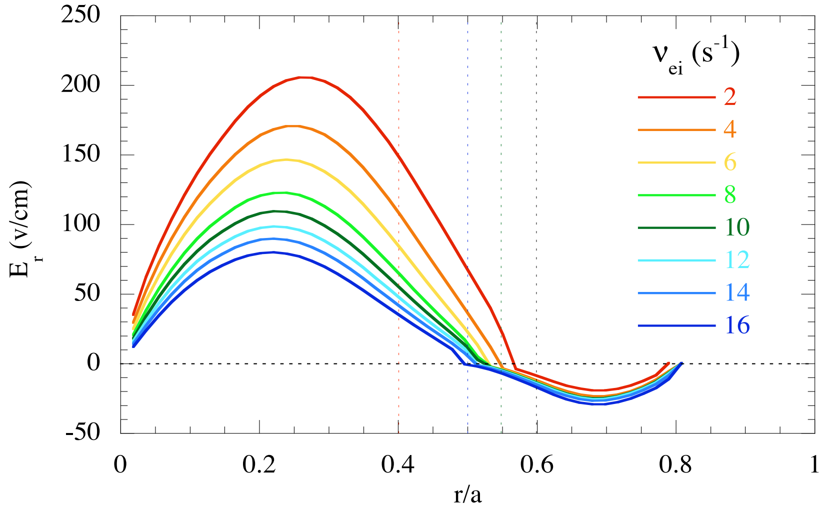
Electric Field Resonances







Electric Field Resonances

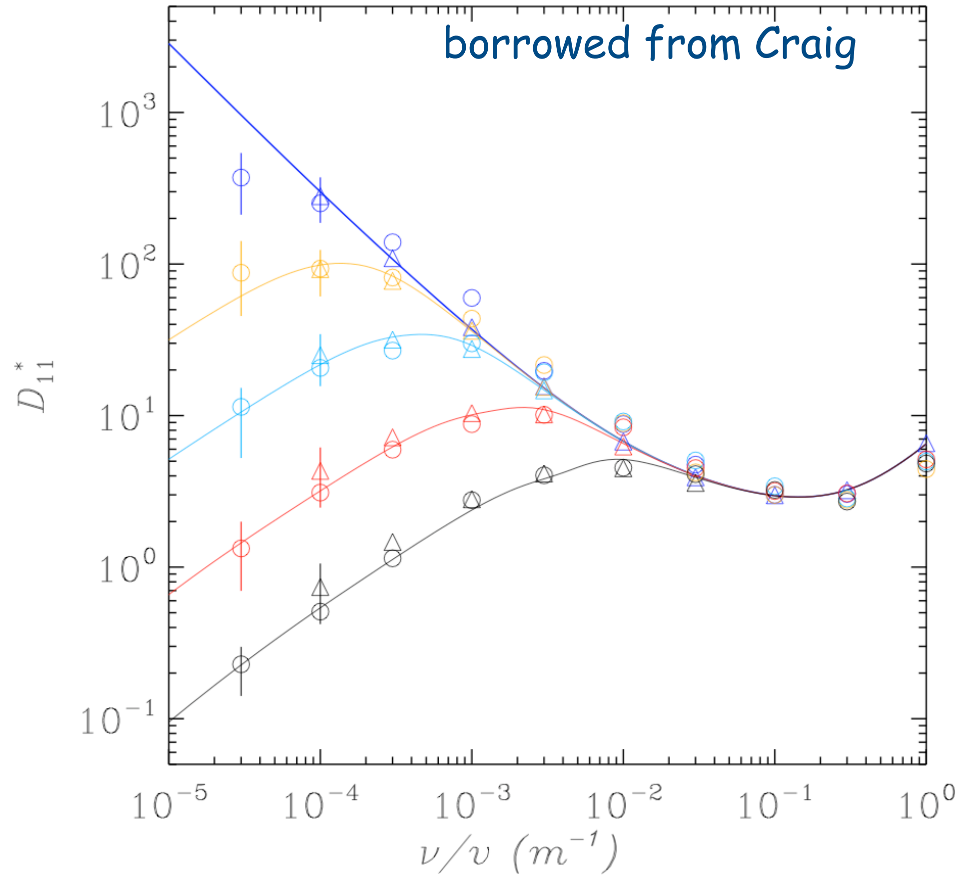
In the monoenergetic approach resonances appears at high values due to TJ-II's high iota (0.9 < ι < 2.2)

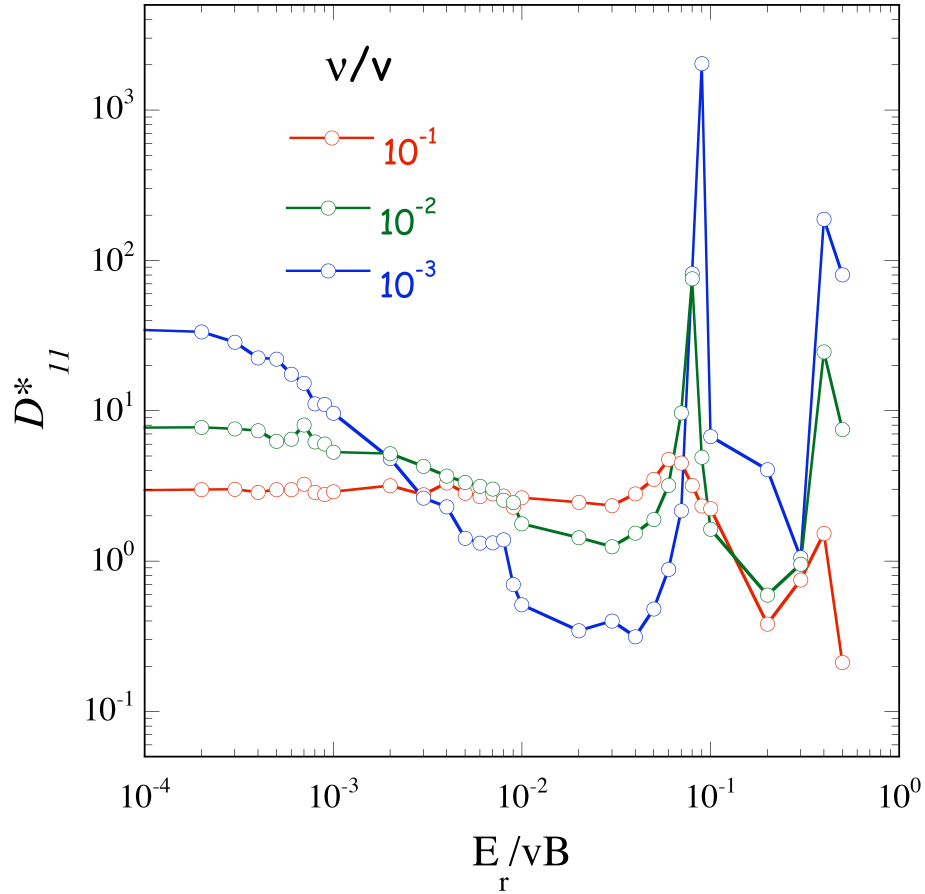
$$E_{res} = \iota v B \frac{r}{R}$$

However for low density ECRH plasmas E_r can be very high, and Ti very low.

Electric Field Resonances

TJ-II at r/a = 0.5



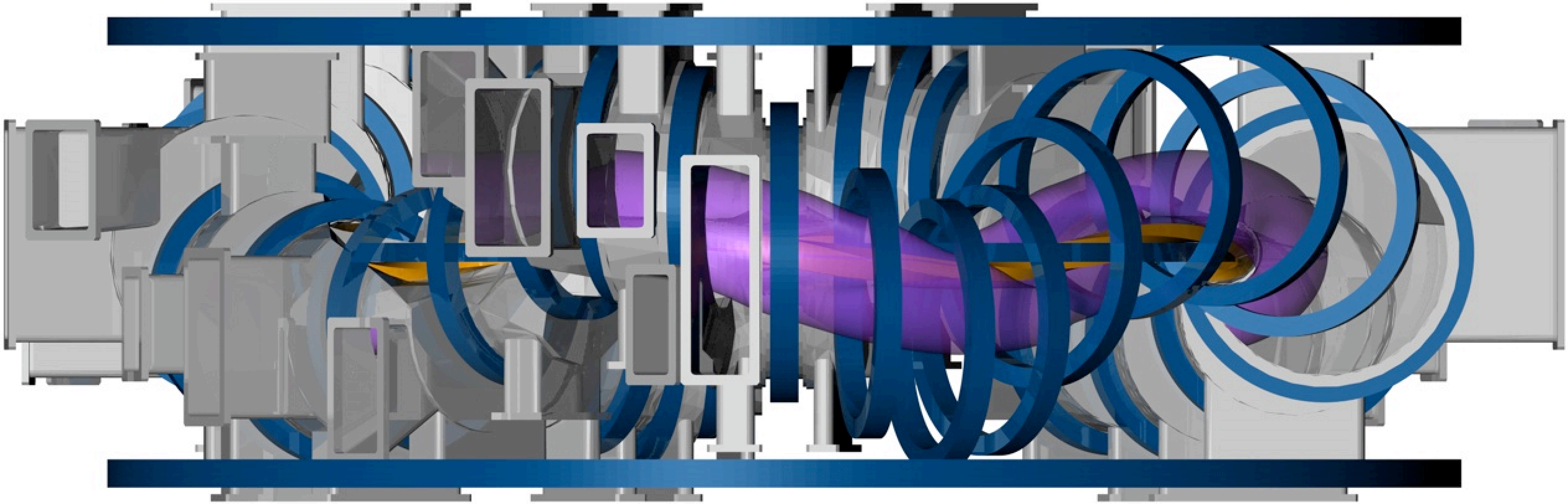


$|E|/vB_0 = 3\times10^{-3}$, 1×10^{-3}, 3×10^{-4}, 1×10^{-4}, 3×10^{-5} *and zero*.

Electric Field Resonances

- The neural network method, in a first attempt, does not work very well for these kind of behaviors
- What is your experience ?
- Is it possible to incorporate resonances into Craig's formalism ?

Bootstrap Currents in TJ-II



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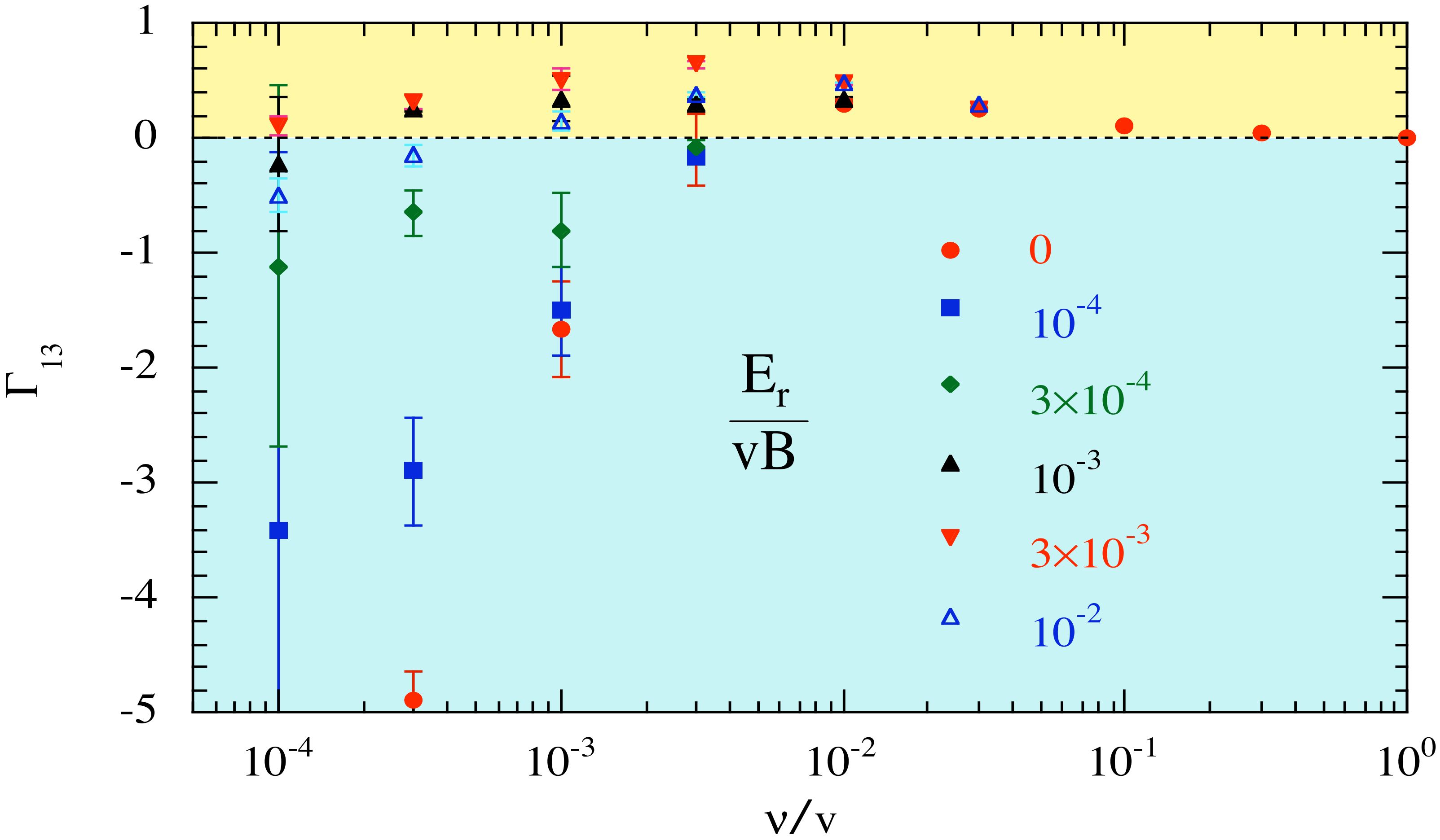
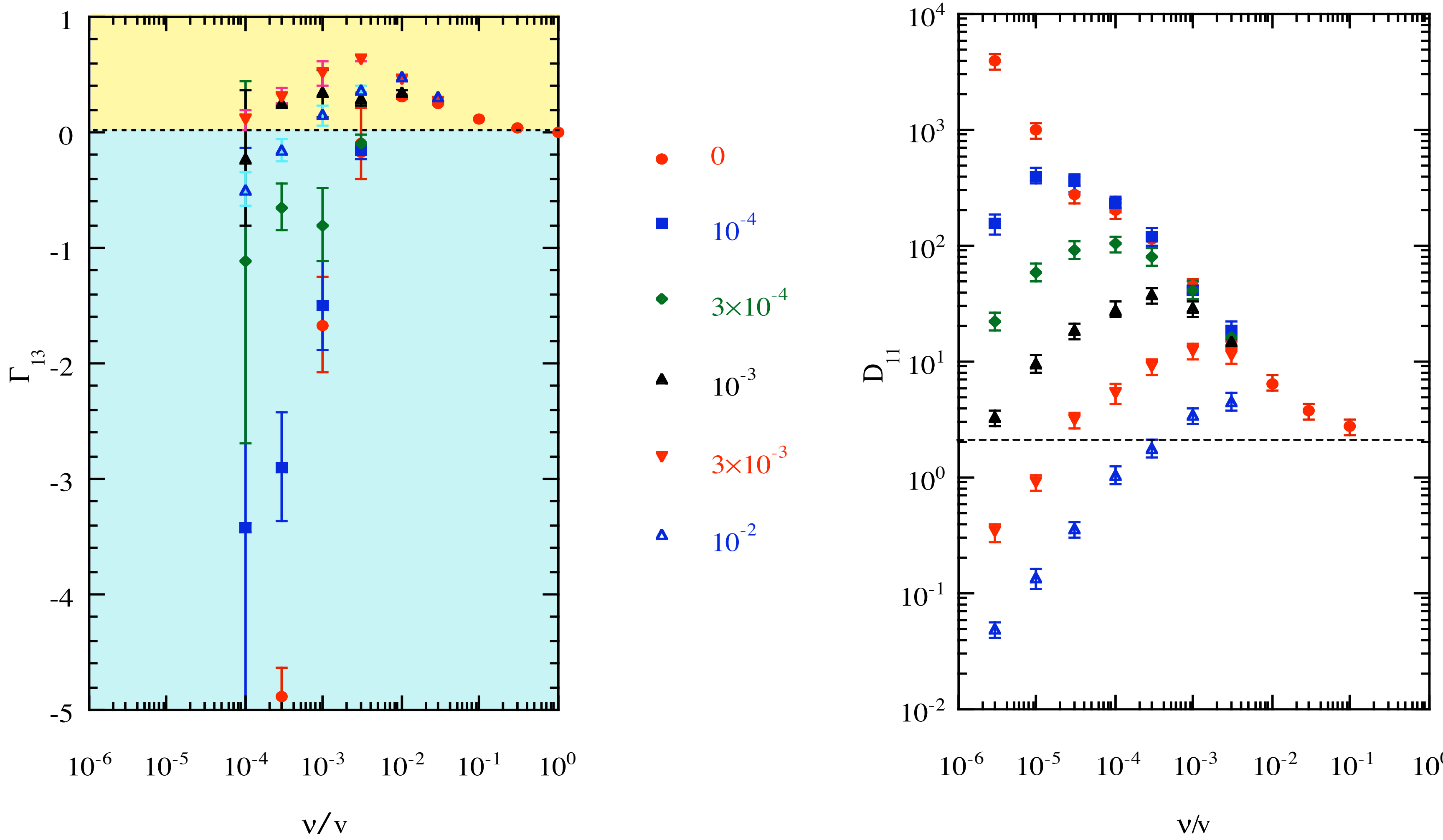
Bootstrap in TJ-II

DKES (borrowed from Henning)



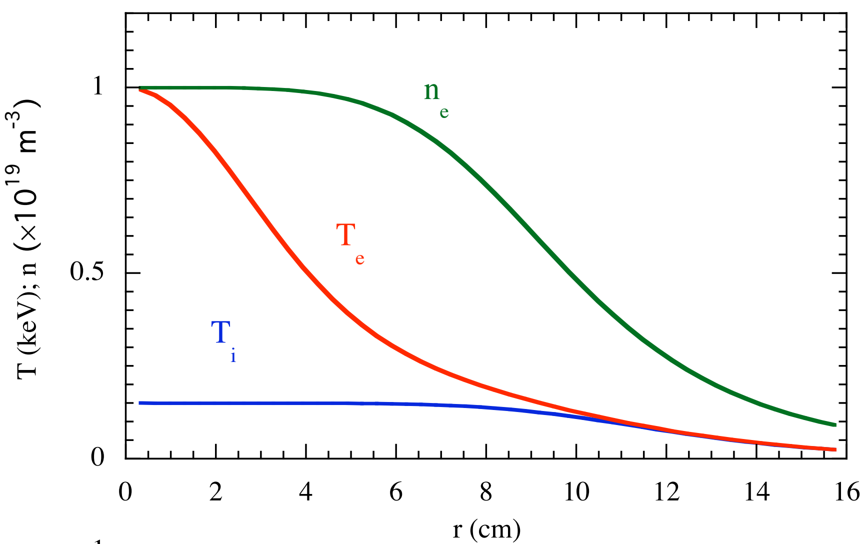
Convolutions

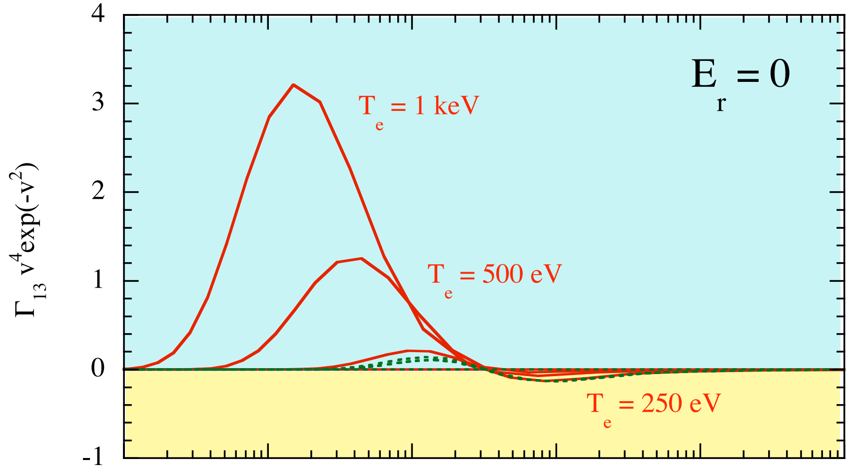
$$L_{1j} = \frac{4}{\sqrt{\pi}} \int_0^\infty D_{11}^*\left(\frac{r}{a}, \frac{\nu}{v}, \frac{E_r}{vB}\right)\left(\frac{v}{v_{th}}\right)^{2j} exp\left[-\left(\frac{v}{v_{th}}\right)^2\right]\frac{dv}{v_{th}} \qquad L_{j3} = G_b \frac{4}{\sqrt{\pi}} \int_0^\infty D_{13}^*\left(\frac{r}{a}, \frac{\nu}{v}, \frac{E_r}{vB}\right)\left(\frac{v}{v_{th}}\right)^{2(j+1)} exp\left[-\left(\frac{v}{v_{th}}\right)^2\right]\frac{dv}{v_{th}}$$

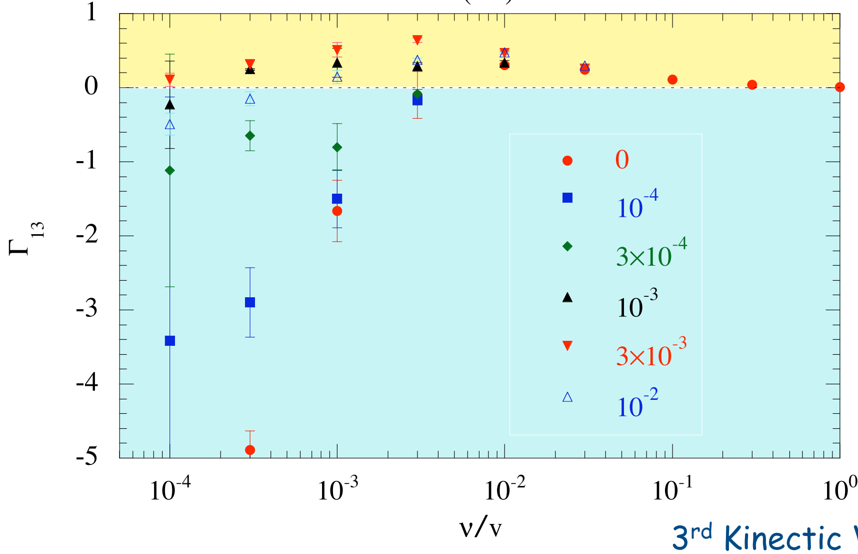


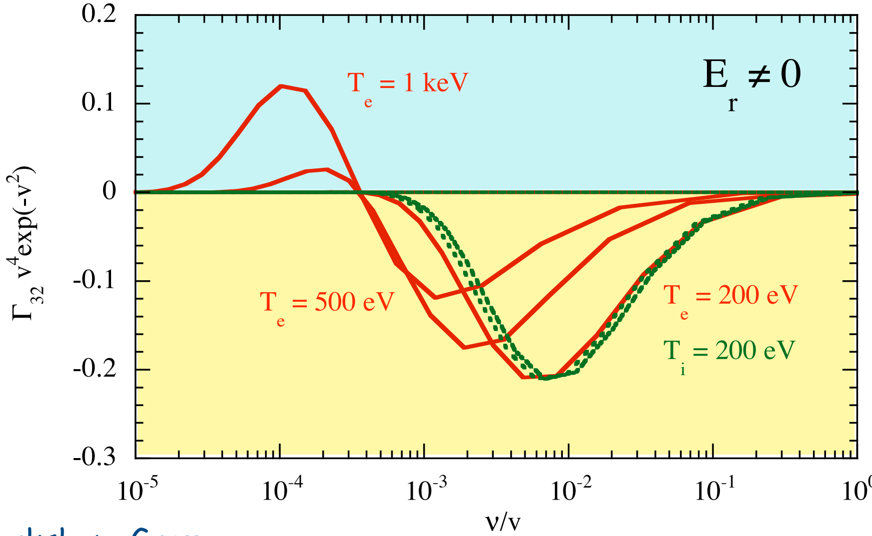
Results

$$L_{23} = G_b \frac{4}{\sqrt{\pi}} \int_0^\infty D^*_{13}\left(\cancel{\frac{r}{a}}, \frac{\nu}{v}, \cancel{\frac{E_r}{vB}}\right)\left(\frac{v}{v_{th}}\right)^4 exp\left[-\left(\frac{v}{v_{th}}\right)^2\right]\frac{dv}{v_{th}}$$



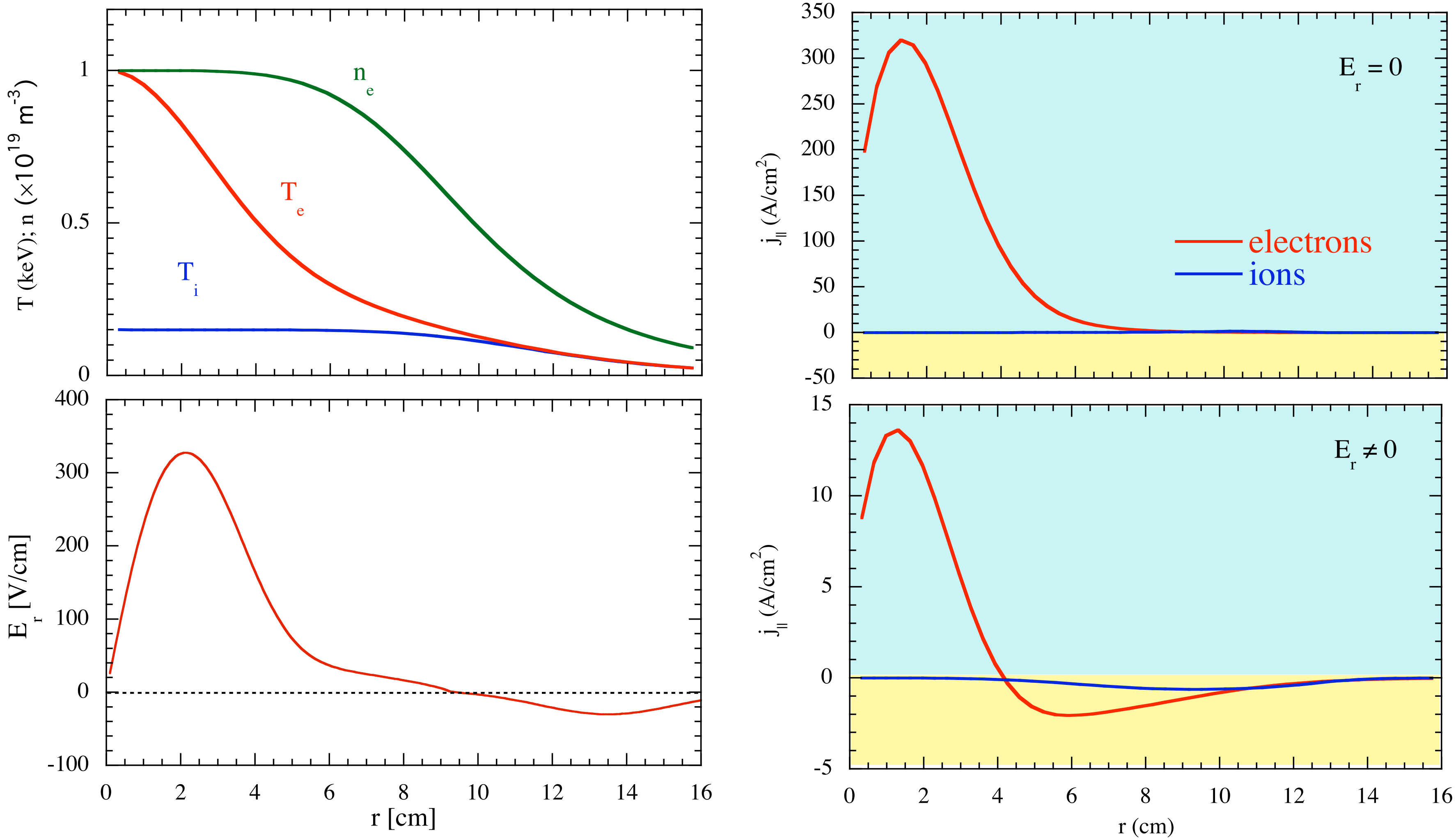






Results

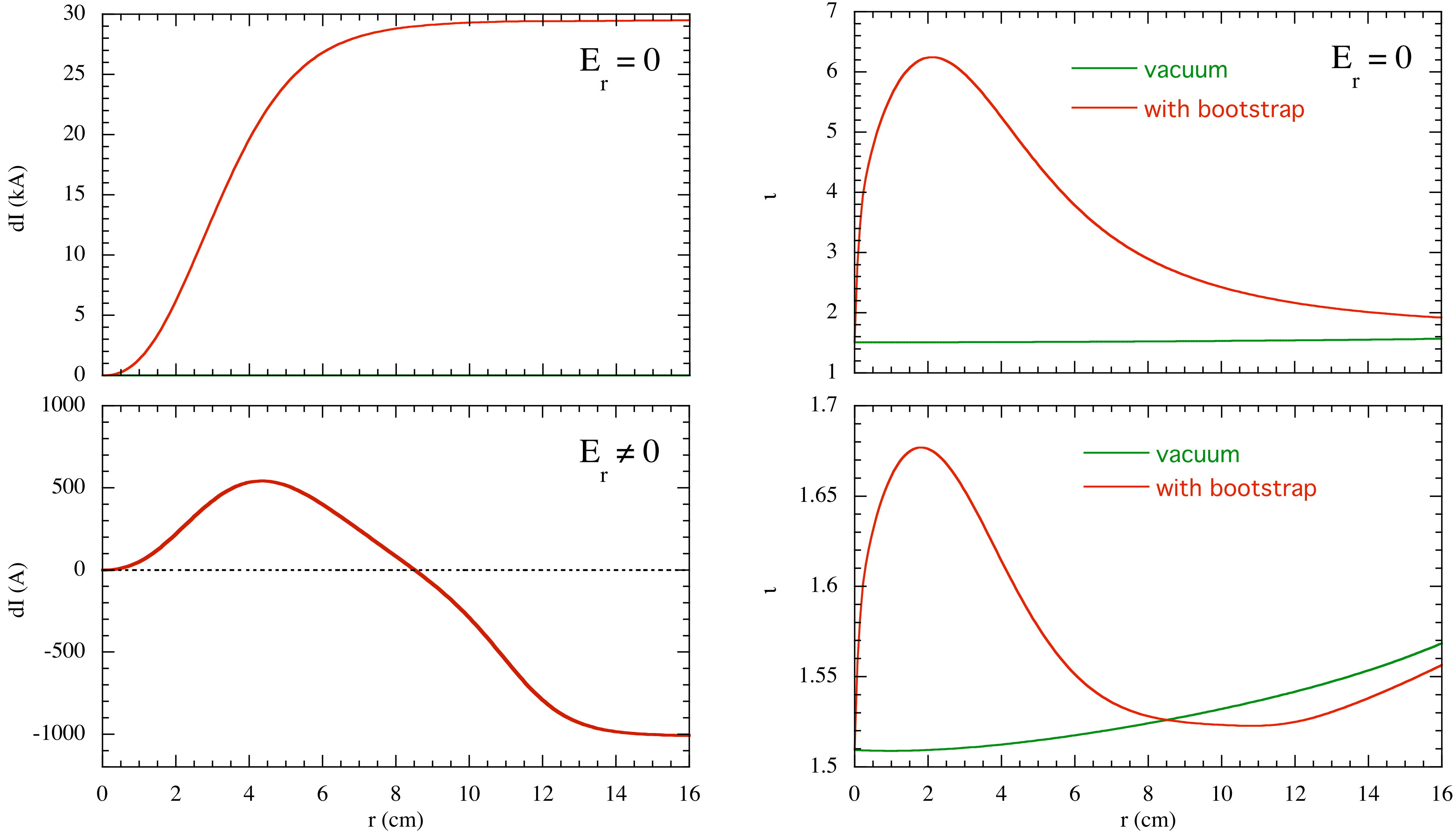
$$j_b^\alpha = -e n_\alpha \left[L_{31}^\alpha \left(\frac{n'_\alpha}{n_\alpha} - q_\alpha \cancel{\frac{E_r}{T_\alpha}} \right) + L_{32}^\alpha \frac{T'_\alpha}{T_\alpha} \right]$$



Results

$$dI = \int_0^r j_\parallel dS \approx 2\pi \int_0^r r' j_\parallel(r') dr'$$

$$\Delta\iota(r) \approx \frac{R\mu_0}{Br^2} \int_0^r r' j_\parallel(r') dr'$$



Future

- Global Fluxes
  - Publish the results (not successful so far)
- E_r resonances
  - Ion transport
- Bootstrap currents
  - Run DKES to account for the ambipolar E_r and r/a
  - Systematic error analysis
- Who can predict the future ?