COREDIV
Physical Model

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Small modification Roman Stankiewicz

In order to treat simultaneously core and edge plasma regions, the COREDIV code was developed

COREDIV = 1D transport in the core self-consistently coupled to 2D model in the SOL

Continuity of the values and fluxes

- It follows our experience with simpler self-consistent models (0D + 1D) successfully used to simulate FTU plasmas

- Aims at steady state description of plasmas with impurities

Physical Model – Core Plasma

1D transport in the core self-consistently coupled to 2D model in the SOL = COREDIV CODE

1D transport of particles (n_i) and energy (T_e, T_i):

$$\frac{\partial n_i}{\partial t} + \frac{1}{rg_1}\frac{\partial}{\partial r}\left[rg_2\left(-D_i\frac{\partial n_i}{\partial r} + w_i n_i\right)\right] = S_i(r) = S_i^0 \times P(r)$$

S_i^0 iterated to have constant <n_e>

$$\frac{3}{2}\frac{\partial n_i T_i}{\partial t} + \frac{1}{rg_1}\frac{\partial}{\partial r}\left[rg_2\left(-k_i\frac{\partial T_i}{\partial r} + \frac{5}{2}\Gamma_i T_i\right)\right] = P^i_{AUX} + Q_{ei}$$

$$\frac{3}{2}\frac{\partial n_e T_e}{\partial t} + \frac{1}{rg_1}\frac{\partial}{\partial r}\left[rg_2\left(-k_e\frac{\partial T_e}{\partial r} + \frac{5}{2}\Gamma_e T_e\right)\right] = P_{OH} + P^e_{AUX} + P_\alpha - P_B - P_{lin} - Q_{ei}$$

- P_α accounts self-consistently for impurity transport: dilution, radiation

Quasineutrality: $n_e = n_i + \sum_j n_j$ $\quad < n_e >= const.$

g_1, g_2 – metric coefficients

j(r) – given function (no current evolution)
Plasma rotation neglected

Background ions

Physical Model - Core Plasma

Anomalous transport described by simple model:

F(r) – profile function

$$\chi_e^{an} = C_e \frac{a^2}{\tau_E} F(r)\ \mathbf{FSB(r)}$$

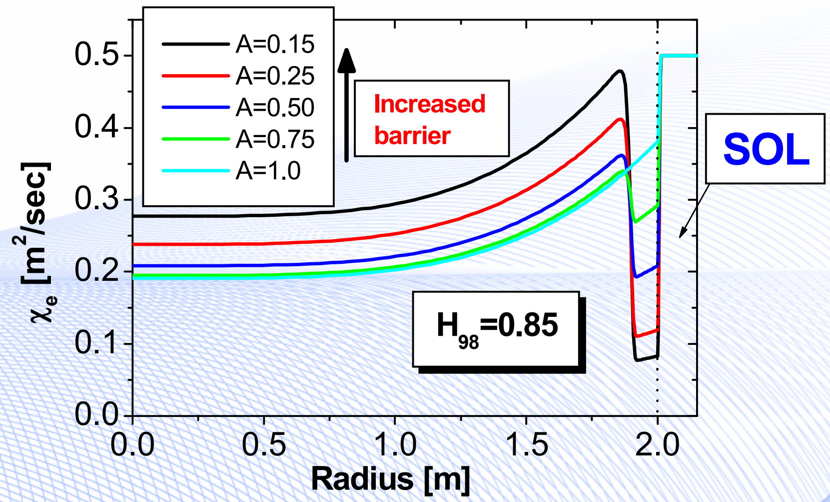
$$F(r) = \left(1 + \left(\frac{r}{a}\right)^4\right)$$

τ_E from experimental ELMy H-mode scaling

$$\chi_i^{an} = \chi_e^{an} \qquad D_i^{an} = 0.35\chi_e^{an}$$

FSB → Transport Barrier Possible

C_e – adjusted iteratively to keep prescribed confinement



Neoclasical ion heat conductivity
Anomalous pinch $V_{pinch}/D_i \sim r/a^2$,

Background ions

Physical Model - Core plasma

•Different types of impurities are treated simultaneously and self-consistently

$$\frac{\partial n_j^k}{\partial t}+\frac{1}{rg_1}\frac{\partial}{\partial r}\left(rg_2\Gamma_j^k\right)=n_e\left[n_{j-1}^k\alpha_{ion,k}^{j-1}-n_j^k(\alpha_{ion,k}^j+\beta_{rec,k}^j)+n_{j+1}^k\beta_{rec,k}^{j+1}\right]\quad j=1,\ldots Z_k$$

$$\Gamma_j^k=\Gamma_j^{nc,k}+\Gamma_j^{an,k}$$

Pfirsch-Schlüter contribution

$$\Gamma_j^{nc}=-D_j^{PS,k}\partial n_j^k/\partial r+n_j^kW_j^{PS,k}=\left(1+q^2\right)\rho_k^2\nu_j^k\left[-\frac{\partial n_j^k}{\partial r}+Z_j\left(\frac{1}{n_i}\frac{\partial n_i}{\partial r}-\frac{1}{2T_i}\frac{\partial T_i}{\partial r}\right)\right]$$

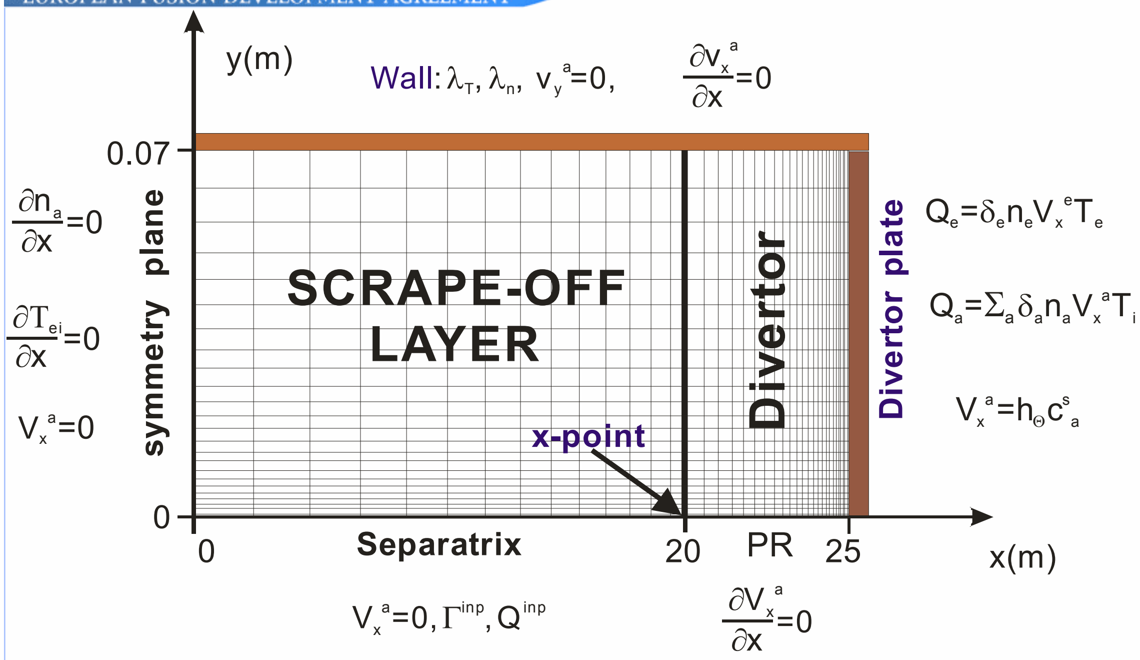
Anomalous contribution

$$\Gamma_j^{an,k}=-D_j^{an,k}\partial n_j^k/\partial r+n_j^kV_j^{pinch,k}\qquad V_j^{pinch,k}\propto -D_j^{an,k}r/a^2$$

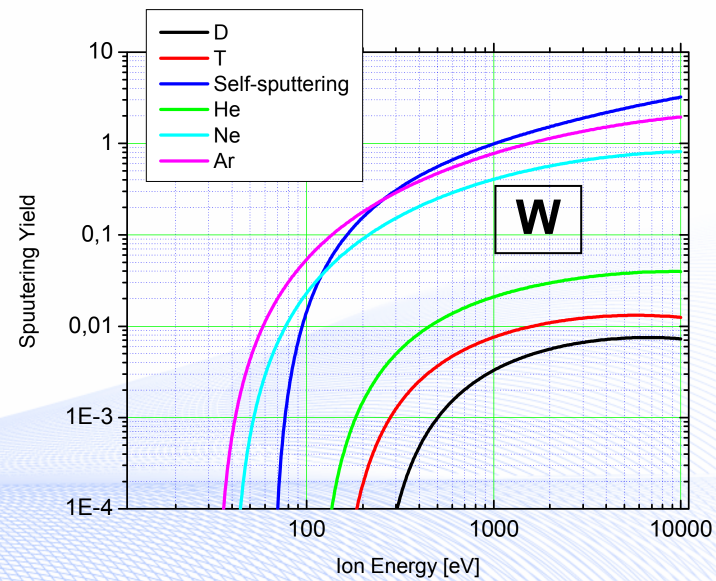
Anomalous transport same as for background plasma (ambipolarity) $D_j^{an,k}=D_i^{an}$

Coupling with the SOL plasma
through the boundary conditions at the separatrix: n_i, n_z, T_e, T_i – from SOL model

SOL Model



- 2D **multifluid** transport based on Braginskii equations (EPIT code
- Transport: parallel - classical, radial –anomalous
- Particle balance, parallel momentum, two energy equations



- Slab geometry (lack of PR), drifts neglected
- Atomic processes: ionization, recombination, excitation, charge exchange
- Analytical model for neutrals accounts for plasma recycling and impurity sputtering (also by seeded impurities). Recycling is an external parameter

- Boundary conditions: sheath, decay lengths; input fluxes from core part of the model
- Intrinsic and seeded impurities – gas puff at different positions

He, Li, Be, B, C, N, O, Ne, Si, Ar, Ti, Ni, Mo, W

$$\frac{\partial n_a}{\partial t} + \frac{1}{\sqrt{g}}\left(\frac{\partial}{\partial x}\frac{\sqrt{g}}{h_x} n_a v_x^a + \frac{\partial}{\partial y}\frac{\sqrt{g}}{h_y}\Gamma_y^a\right) = S_n^a$$

parallel momentum balance:

$$\frac{\partial}{\partial t}\left(m_a n_a v_{||}^a\right) + \frac{1}{\sqrt{g}}\frac{\partial}{\partial x}\left(\frac{\sqrt{g}}{h_x} m_a n_a v_x^a v_{||}^a - \eta_x^a \frac{\sqrt{g}}{h_x^2}\frac{\partial v_{||}^a}{\partial x}\right) +$$

$$\frac{1}{\sqrt{g}}\frac{\partial}{\partial y}\left(\frac{\sqrt{g}}{h_y} m_a n_a v_y^a v_{||}^a - \eta_y^a \frac{\sqrt{g}}{h_y^2}\frac{\partial v_{||}^a}{\partial y}\right) = -\frac{h_\Theta}{h_x}\frac{\partial p_a}{\partial x} + eZ_a n_a E_{||} + R_{||}^a + m_a S_{v||}^a$$

diffusion equation:

$$\Gamma_y^a \equiv n_a v_y^a = -D_\perp^a \frac{1}{h_y}\frac{\partial n_a}{\partial y}$$

ion energy balance:

$$\frac{3}{2}\frac{\partial}{\partial t}\left(\sum_a n_a T_i\right) + \frac{1}{\sqrt{g}}\sum_a\left[\frac{\partial}{\partial x}\left(\frac{\sqrt{g}}{h_x}\frac{5}{2} n_a v_x^a T_i + q_x^a\right) + \frac{\partial}{\partial y}\left(\frac{\sqrt{g}}{h_y}\frac{5}{2} n_a v_y^a T_i + q_y^a\right)\right]$$

$$+\frac{1}{\sqrt{g}}\sum_a v_x^a\left[\frac{\partial}{\partial x}\left(\eta_x^a \frac{\sqrt{g}}{h_x^2}\frac{\partial v_{||}^a}{\partial x}\right) + \frac{\partial}{\partial y}\left(\eta_y^a \frac{\sqrt{g}}{h_y^2}\frac{\partial v_{||}^a}{\partial y}\right)\right] = \sum_a v_x^a \frac{1}{h_x}\frac{\partial p_a}{\partial x} + \sum_a Q_{ea} + \sum_a S_E^a$$

electron energy balance:

$$\frac{3}{2}\frac{\partial n_e T_e}{\partial t} + \frac{1}{\sqrt{g}}\frac{\partial}{\partial x}\left(\frac{\sqrt{g}}{h_x}\frac{5}{2} n_e v_x^e T_e + q_x^e\right) + \frac{1}{\sqrt{g}}\frac{\partial}{\partial y}\left(\frac{\sqrt{g}}{h_y}\frac{5}{2} n_e v_y^e T_e + q_y^e\right) =$$

$$v_x^e \frac{1}{h_x}\frac{\partial p_e}{\partial x} - \sum_a Q_{ea} + S_E^e - \frac{j_P^2}{\sigma_P} - \frac{j_P}{e}\alpha_{th}\frac{h_\theta}{h_x}\frac{\partial T_e}{\partial x}$$