SOLPS5 modelling of the ELMing H-mode on TCV

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Tokamak à **C**onfiguration **V**ariable

R=0.875 m, a=0.25 m, Bφ = 1.43 T

All-graphite machine

Number of open diverted configurations

Standard operating mode with reversed toroidal field Bφ

=> ion B x ∇B drift direction upwards

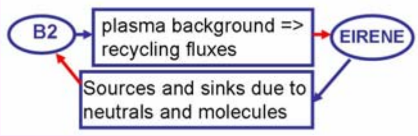
Scrape-**O**ff **L**ayer **P**lasma **S**imulation

SOLPS 5 = coupled EIRENE + B2.5

Suite of codes to simulate transport in edge plasma of tokamaks

B2 - solves 2D multi-species fluid equations on a grid given from magnetic equilibrium

EIRENE - kinetic transport code for neutrals based on Monte - Carlo algorithm



B2

plasma background => recycling fluxes

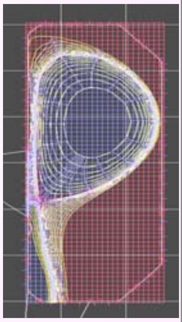
EIRENE

Sources and sinks due to neutrals and molecules

TCV simulation mesh

72 grid cells **poloidally** along separatrix

24 grid cells **radially**



Main inputs: magnetic equilibrium
$P_{sol} = P_{heat} - P_{rad}^{core}$ experimentally measured
upstream separatrix density n_e

Parameters: cross-field transport coefficients ($D_\perp$, $\chi_\perp$, $v_\perp$)
systematically adjusted
until agreement of simulation with experiment is achieved

Inter-ELM simulation Ansatz

SOL radial **heat flux**:

$$q_\perp = -(n\chi_\perp \frac{dT}{dr} + 5T(D_\perp \frac{dn}{dr} + \cancel{nv_\perp}))$$

SOL radial **particle flux**:

$$\Gamma_\perp = -D_\perp \frac{dn}{dr} + \cancel{v_\perp n}$$

Cross-field radial transport in the main SOL-complex phenomena

$$\Gamma_\perp = -D_\perp^{eff}(r).\nabla n$$

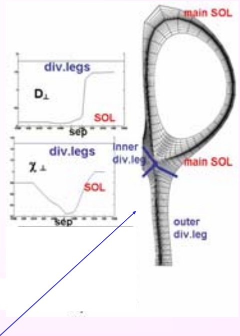
diffusion ($D_\perp$) + convection ($v_\perp$)

Direct measurements of turbulent driven ExB radial fluxes using turbulent code ESEL predict very small values of $D_\perp$
=> More appropriate approach would be ‘convective’

(with $D_\perp = D_\perp^{collisions}$ and variation of $v_\perp$)

However only the value of flux matters for the code and thus we can neglect convective term of equation for simplification and assume **$v_\perp = 0$**

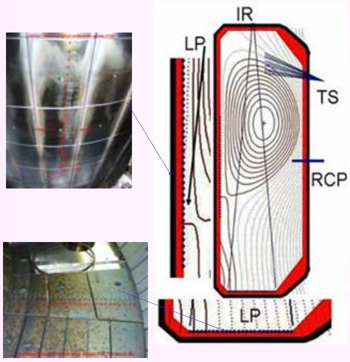
Assumption: $\chi_{\perp_i} = \chi_{\perp_e}$



Ansatz: $D_\perp$, $\chi_\perp$ - variation
radially – transport barrier (TB)
poloidally – no TB in divertor legs

Transport is specified differently in the main chamber SOL and divetror regions

Edge diagnostics in TCV



Targets

LP : Langmuir probes
⇒ j_{sat}, T_e, n_e at the targets

IR: fast Infrared thermographic camera
⇒ perpendicular heat flux at outer target

Upstream

RCP: fast reciprocating Langmuir probe
⇒ T_e, n_e upstream

TS: edge Thomson scattering system
⇒ T_e, n_e upstream

Typical ELMing H- mode

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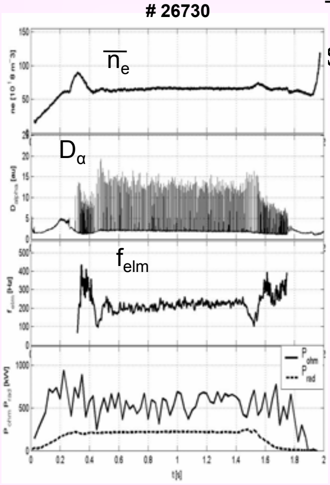


Type III ELMing H-mode target discharge

Single Null Low configuration

I_p = 430 kA

f_{elm} = 230 Hz

$\overline{n}_e = 6 \times 10^{19}$ m^{-3}

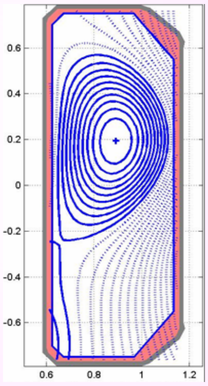
κ_{95} = 1.65

δ_{95} = 0.4

q_{95} = 2.5

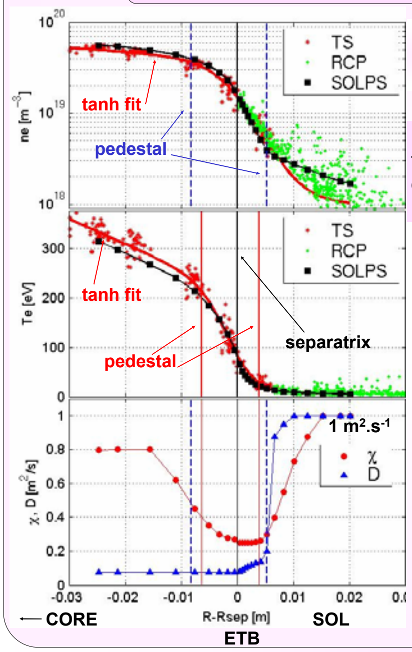
n/n_{GW} ~ 0.3

E_{stored} ~ 20kJ



$P_{SOL} = P_\Omega - P_{RAD}$ = 275 kW

SOLPS vs experiment upstream



Pedestal width (n_e) = 0.0136 m

Pedestal height (n_e)=3.6x 10^{19} m^{-3}

RCP data multiplied by factor of **0.5** to account for the overestimation due to Larmor radius effects increasing projescted area of the LP

Pedestal width (T_e)= 0.0102 m

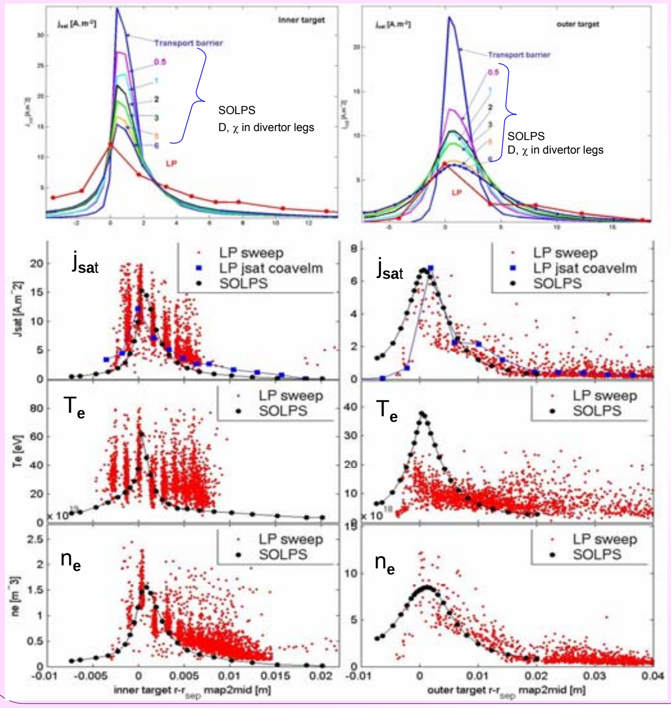
Pedestal height (T_e)= 179 eV

Excellent agreement

Foot of electron transport barrier (ETB) extends into SOL

SOLPS5 modelling of the ELMing H-mode on TCV

SOLPS vs experiment at the targets

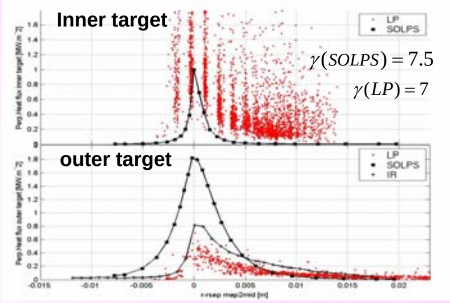


- Match is obtained only by “switching off” the transport barrier in divertor regions and increasing D, χ in divertor legs from 1→ 6 $m^2.s^{-1}$ (cf. $1m^2.s^{-1}$ in main chamber SOL). Increase of D, χ in inner leg doesn’t matter much

- SOLPS models inner target well because it’s there probably dominated by geometry of TCV

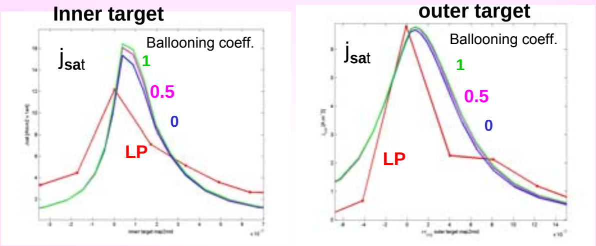
- Discrepancies at outer target might be explained by the fact that **DRIFTS** are **not included** in simulations yet

Perpendicular heat flux

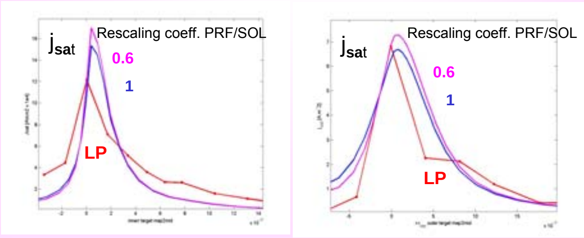


Sensitivity study

Ballooning effect

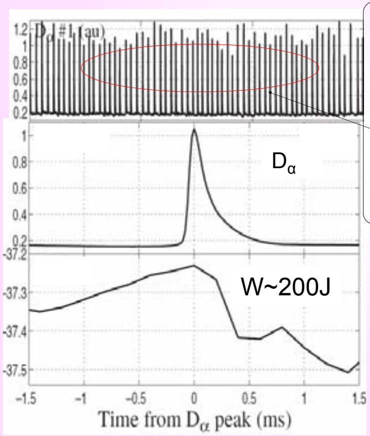


Private flux region vs. SOL



Edge localized mode (ELM) - Coherently averaged ELM

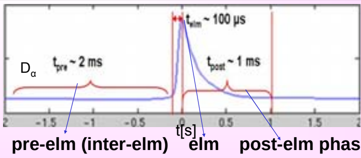
H-mode → Edge MHD instabilities →
Periodic bursts of particles and energy into the SOL
ELM leaves edge pedestal region in the form of a helical filamentary structure
localised in the outboard midplane region of the poloidal cross-section



Energy expelled by Type III ELMs at TCV ~ 200 J

ELMs - too rapid (frequency ~ 200 Hz)
for comparison on an individual ELM basis

Many similar events are **coherently averaged** inside the interval with reasonably periodic elms

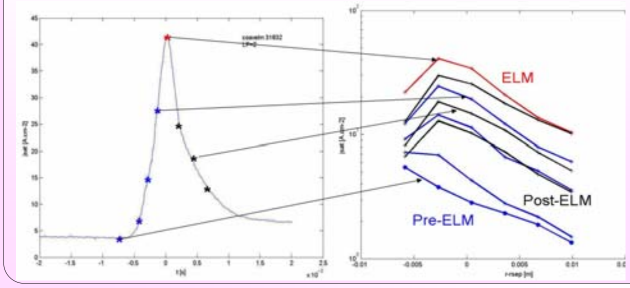


pre-elm (inter-elm) elm post-elm phase
as a base scenario for simulation

1.step: Inter-ELM simulation

Analysis of LP data based on coherently averaged elm method

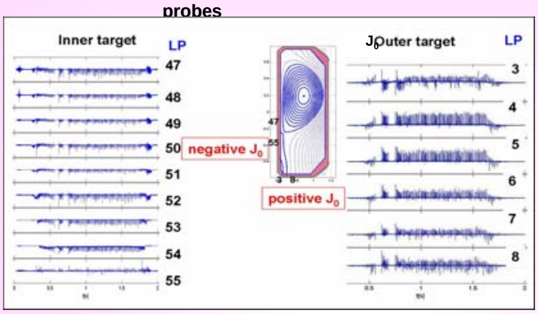
ELM-time evolution of j_{sat} at outer target



Simulation of ELM in progress…

Inner and outer target balance of J_0

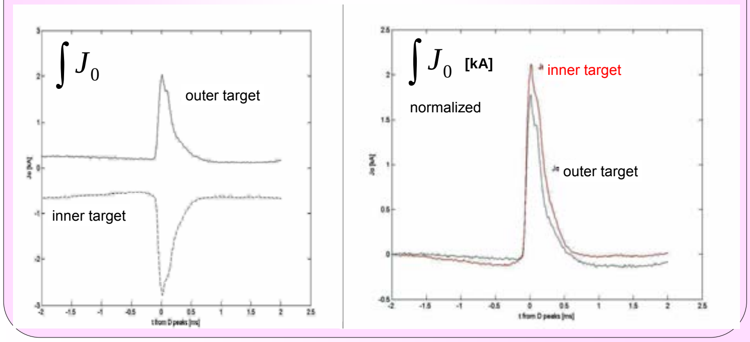
Voltage V=0 applied to Langmuir probes



Thermoelectric currents flow

from outer to inner (cold to hot) target

(see Ref.)



Ref. R. A. Pitts et al., Nucl. Fusion 43 (2003) 1145