Plasma Physics Group

Association EURATOM-ÖAW

Institute for Theoretical Physics
Graz University of Technology
Petersgasse 16, 8010 Graz
Austria

Dipl.-Ing. Dr.techn. Winfried Kernbichler
Tel: +43(316)873-8182
Fax: +43(316)873-8678
Email: kernbichler@itp.tu-graz.ac.at

Staff

Professors:

- Ass.-Prof. W. Kernbichler
- Ao.Univ.-Prof. M. Heyn
- Univ.-Prof. M. Heindler

Scientific Staff:

- Dr. S. Kasilov
- Dr. V. Nemov
- Dr. R. Kamendje

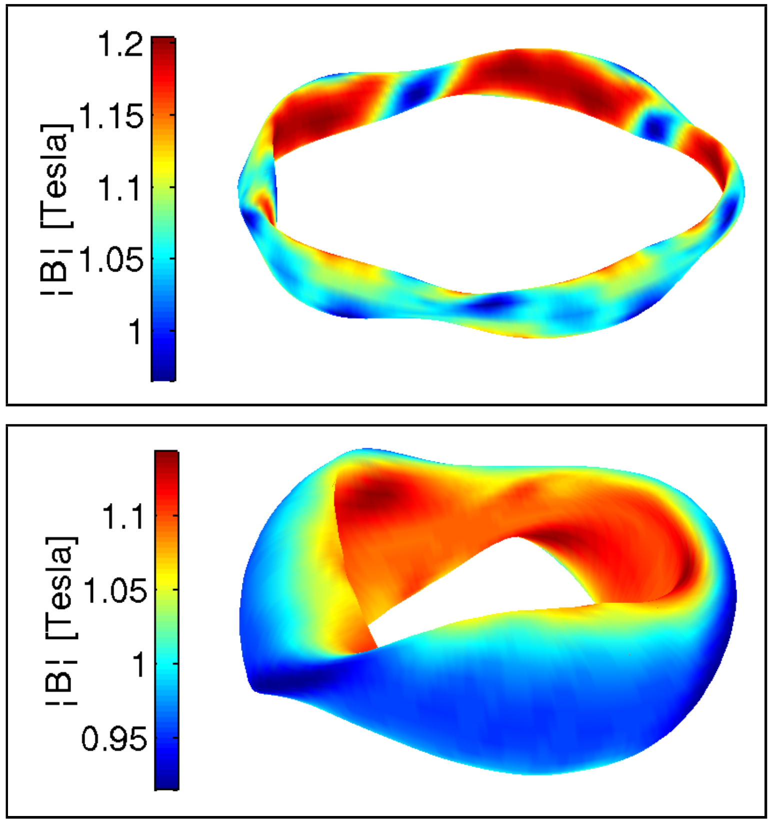
PhD Students and Undergraduate Students:

- DI Mag. B. Seiwald
- DI G. Leitold
- DI Ch. Eherer
- DI M. Baumann
- DI K. Allmaier

Neoclassical Transport

Generally speaking, there are three ways in which the charged particles that constitute a magnetized plasma can cross a magnetic field: (1) by virtue of collisions causing them to diffuse across the field; (2) as a result of drift motion arising from gradients and curvature of the magnetic field; and (3) because of electric fields. Such transport is termed *classical*. In case of toroidal configurations such as the tokamak or stellarator, transport is considerably increased. This so-called *neoclassical* transport is an essential consequence of the toroidal curvature of the confining magnetic field. Minimization of neoclassical transport is one of the key issues in stellarator optimization. The aim of our work is the development of novel and fast methods, both numerical and analytical, for the computation of the neoclassical transport coefficients and equilibrium plasma currents in stellarators with realistic magnetic field geometry. The newly developed codes and the results of our transport analysis are applied to existing configurations (e.g. W7-AS), to a configuration being build (W7-X), as well as to a variety of candidate configurations in international optimization studies (e.g. NCSX).

Neoclassical Transport



Magnetic flux surfaces from the stellarators W7-AS (Garching, top) and NCSX (Princeton, bottom).

Stellarator Optimization

The aim of this project is the development of a new and fast code for optimizing existing stellarators, based on the existing code for calculating neoclassical transport. The code is able to deal with realistic vacuum fields and the optimization can be done without any restrictions to the complexity of the field.

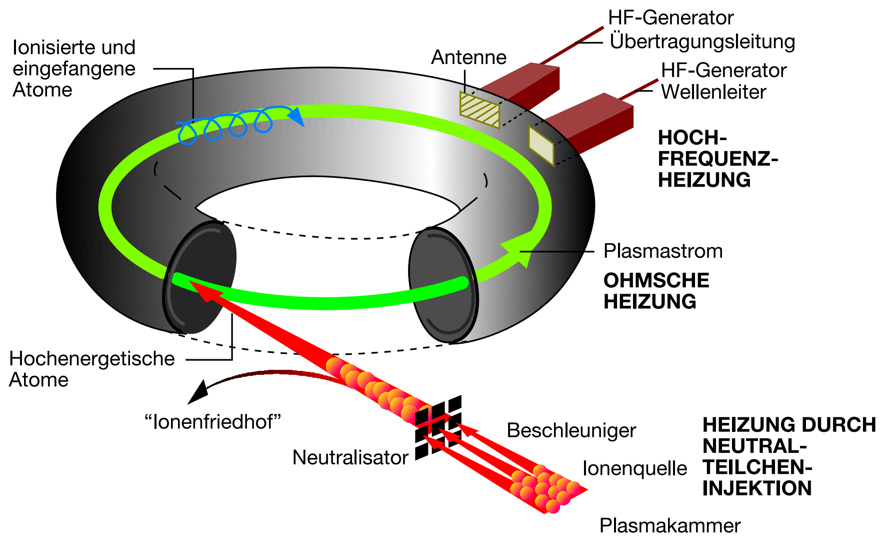
The simulation could show the amount of possible improvement of existing stellarators when modifying the currents or changing the position and angle of the coils. The proposed tool can find the optimal configuration with respect to neoclassical transport in the long-mean-free-path regime for existing experiments.

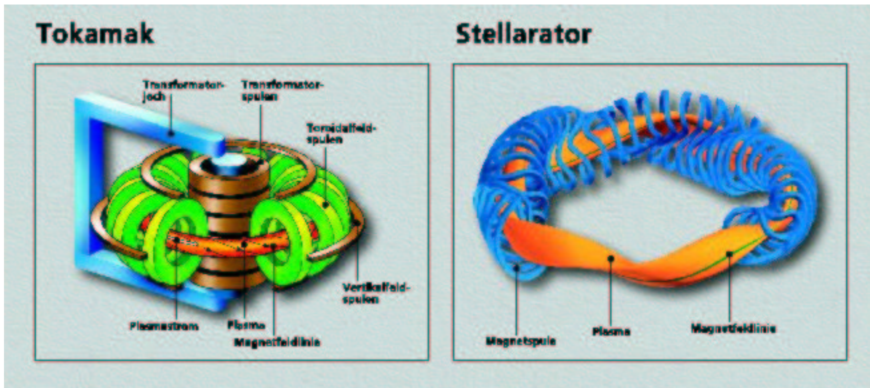
Another point is to show that it is possible to do such an optimization in a shorter time compared to the time which is needed by procedures, which are currently used and need an equilibrium solver. Parallelizing the program is the way to make a cheap cluster of PCs accessible for such a work. Therefore, there is no need to use expensive super computers for this purpose.

Radio Frequency Heating

In fusion experiments plasma is heated in various ways (see figure). Two of the heating mechanisms are very important. These are the Electron Cyclotron Resonance Heating (ECRH) and the Electron Cyclotron Current Drive (ECCD). The big advantage is the sharp localization of the wave particle interaction (very small wavelengths) which provides great flexibility of the special distribution of energy deposition and allows therefore control of the current profiles. The aim of this project is the modeling of wave particle interactions for various values of a nonlinearity parameter in the frame of Hamiltonian mechanics. A combination of this model with modeling of Coulomb interactions is used to numerically determine important quantities like the electron distribution function, the absorption profile and the current drive efficiency. The kinetic equation is solved in the frame of the “stochastic mapping technique”, which has been developed in the Graz plasma physics group. Among others, Monte Carlo algorithms are used for the numerical treatment.

Plasma Heating





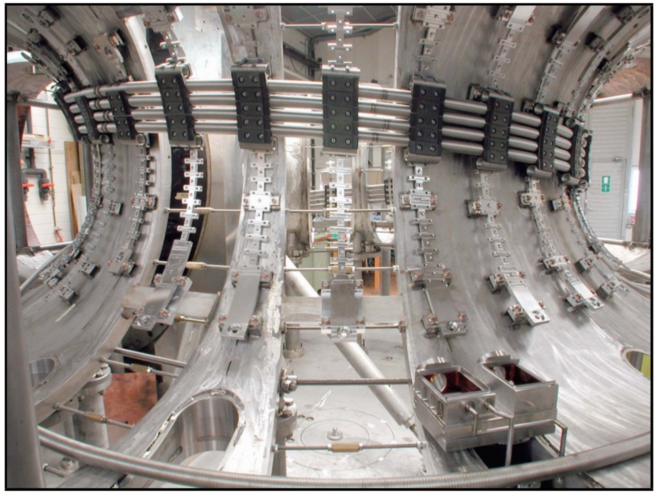
DYN. ERGOD. DIVERTOR (DED)

The controlled removal

- of plasma impurities (e.g. atoms from the reactor wall) and
- of fusion products generated in the inner sections of the plasma

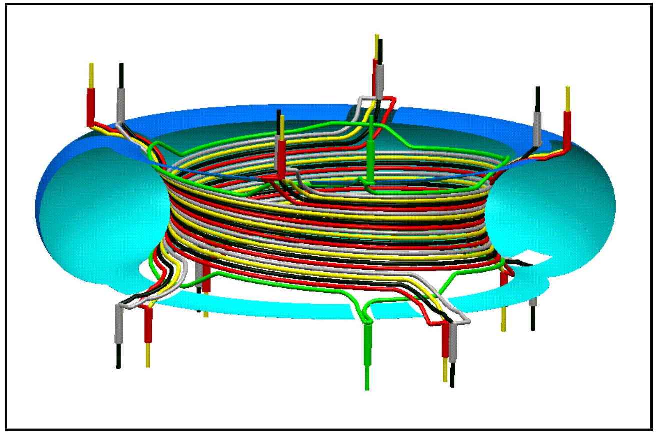
plays an essential role for the operation of a fusion reactor. Both impurities and helium ash stop the burning process. X-point-divertors are used in the present generation large tokamaks (JET, ASDEX-Upgrade). We investigate a novel concept, the dynamic ergodic divertor (DED), which is currently built for TEXTOR-94 in Jülich. Using special electromagnetic perturbative fields, which are generated by external coil systems, the topology of the magnetic field in the edge plasma is changed to get the desired effects. The goal is to model the problem physically and numerically, starting from the Maxwell equations and a suitable description of the plasma dynamics.

DYN. ERGOD. DIVERTOR (DED)



Prototype of the DED for TEXTOR (FZ Jülich)

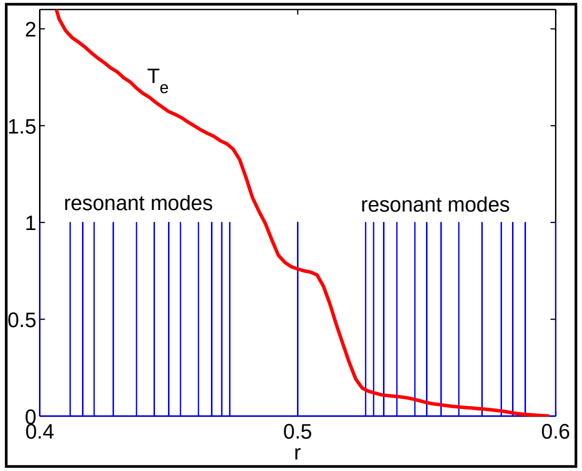
Sketch of the DED (FZ Jülich)



TRANSPORT BARRIERS

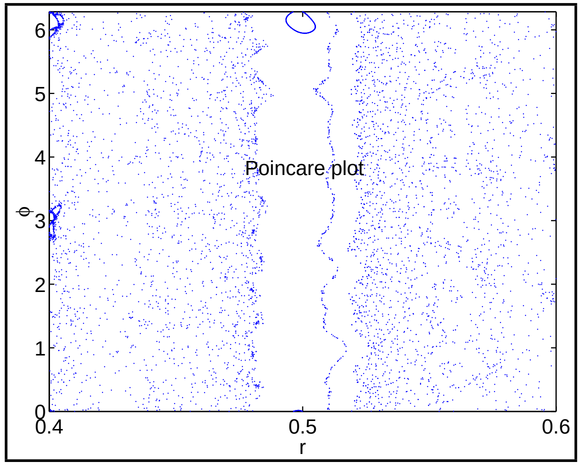
Tokamak experiments show the formation of radially extremely localized transport barriers with strongly reduced heat transport and high temperature gradients. The preferred appearance of those barriers near flux surfaces with low poloidal and toroidal mode numbers is explained within the frame of Hamiltonian perturbation theory by broad perturbation spectra; flux surfaces are destroyed and island structures appear whose overlap lead to field line diffusion. An overlap criterion can be defined for the formation of barriers which also allows for the determination of amplitude and spectral width of the experientially observed magnetic disturbances. The results are consistent with turbulent skin depth theory. The theoretical results are in agreement with numerical results from the independent MHD Monte Carlo transport code E3D developed in collaboration with FZ Jülich.

TRANSPORT BARRIERS



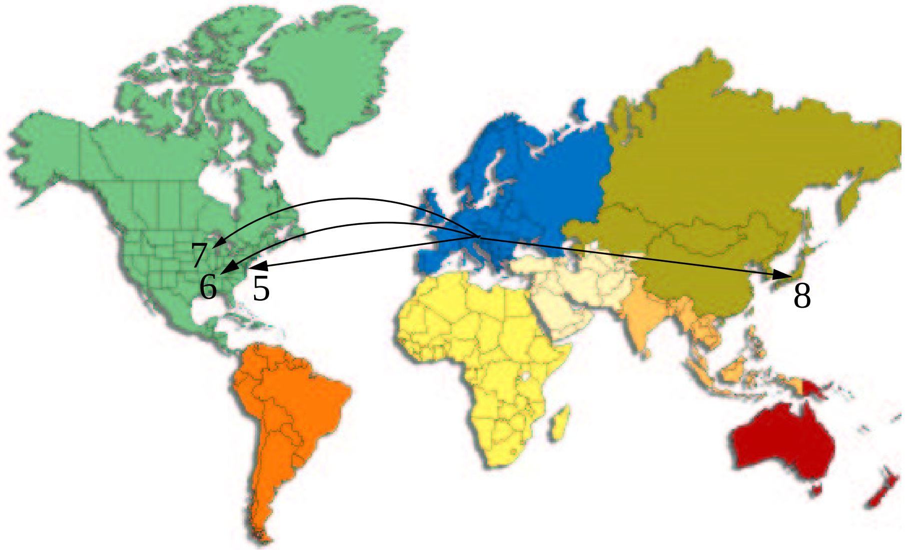
Transport barrier at a resonant surface $r = 0.5$ (RTP, Rijnhuizen)

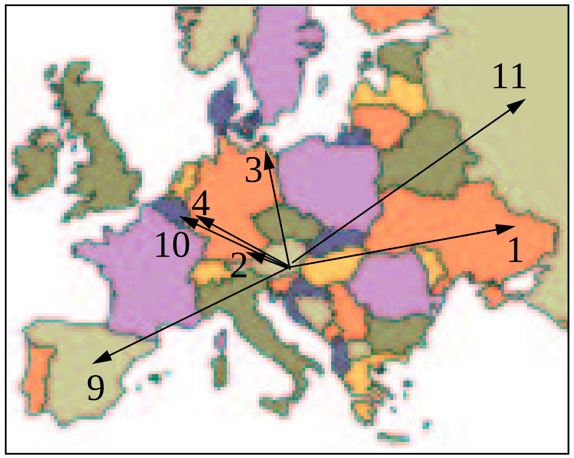
Results from the E3D Monte Carlo Transportcodes (RTP, Rijnhuizen)



Energy from Nuclear Fusion

Commercial energy from nuclear fusion is the ultimate goal, long-term research and development in the field of physics and technology is the road to go, funding is almost exclusively from public sources. As a consequence, socio-economic, safety and environmental aspects increasingly influence decisions on the future of the fusion programme as well as on short-term decisions such as the siting of ITER. In response, the European Union has started, in 1997, the complementary programme *SERF (socio-economic research on fusion)*. Currently SERF is its third phase, covering the refinement of previous studies (in particular on direct and external costs of energy from fusion, on fusion power as a part of the energy system, on fusion and the public opinion) and the EU's participation to the *IEA Implementing Agreement on ESE (Environmental, Safety and Economic) Aspects of Fusion Power*. The ITP Plasma Physics Group supports the Austrian participation to the SERF programme, contributes to several SERF studies and assists the STC (Scientific and Technological Committee) in advising the European Commission - EURATOM.





Cooperations

1	IPP, Kharkov, Ukraine
2	IPP MPI, Garching, Germany
3	IPP MPI, Greifswald, Germany
4	FZ, Jülich, Germany
5	PPPL, Princeton, NJ, USA
6	ORNL, Oak Ridge, TN, USA
7	Univ. of Wisconsin, Madison, WI, USA
8	NIFS, Toki, Japan
9	CIEMAT, Madrid, Spanien
10	Univ. Libre de Bruxelles, Brussels, Belgium
11	“Kurchatov Institute”, Moscow, Russia

Financial Support

EURATOM, FWF, ÖAW

Pictures:
Pictures for DED and plasma heating are kindly permitted by FZ Jülich.