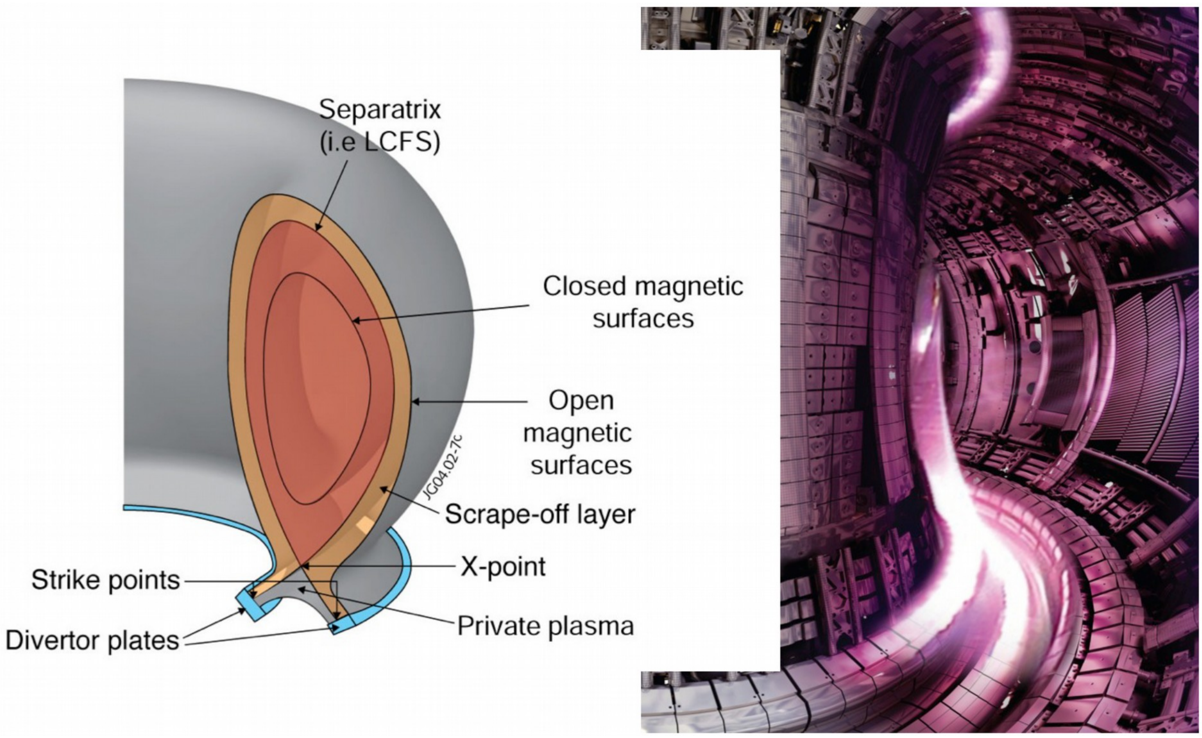
Fusion and plasma physics – summer project proposals

The Fusion and Plasma Physics research group is seeking to recruit interested and motivated students for the summer 2020 period. We offer topics suitable both for Bachelor's theses and special assignments, potentially leading to Master's theses. Further information about the group itself can be found from our website: https://www.aalto.fi/department-of-applied-physics/fusion-and-plasma-physics.

An info session about fusion and plasma physics summer project proposals will be held on Wed, Jan 22, at 16:15 in Vaaksa (room Y338b) in the Undergraduate Centre.



Impact of neutral density on detachment in tokamaks (contact: Vladimir Solokha)

Present fusion reactor design calls for more than 85% of the thermal power to be dissipated before reaching the plasma-facing surface. Present tokamak experiments showed that in diverted fusion devices 90% of input power can be exhausted by operating in detached divertor plasma conditions. The window for achieving detachment is described by the thermal front analytical model promoted by Lipschultz, Hutchinson and Parra [*Nucl. Fusion (2016) 56*]. The proposed project has two goals: The first goal is to use the numerical code SOLPS in a 2D slab geometry to assess the applicability of the thermal front model. The second goal is to extend the analytical model to investigate the impact of the distribution of neutral particles on the detachment window. The topic is suited for both Bachelor and Master level students. The successful applicant is expected to be familiar in Python programming.

Interpretive ERO modelling of beryllium migration in the JET divertor (contact: Henri Kumpulainen)

The Joint European Torus (JET), the world's largest operational tokamak, uses beryllium and tungsten as wall materials. Plasma-wall interactions inevitably result in some erosion of wall materials, which are transported in the plasma and deposited elsewhere onto the vacuum vessel. Since the transport of beryllium has implications for the lifetime of the wall components and for the contamination of the fusion plasma, understanding these processes and predictive capabilities of present tools is necessary.

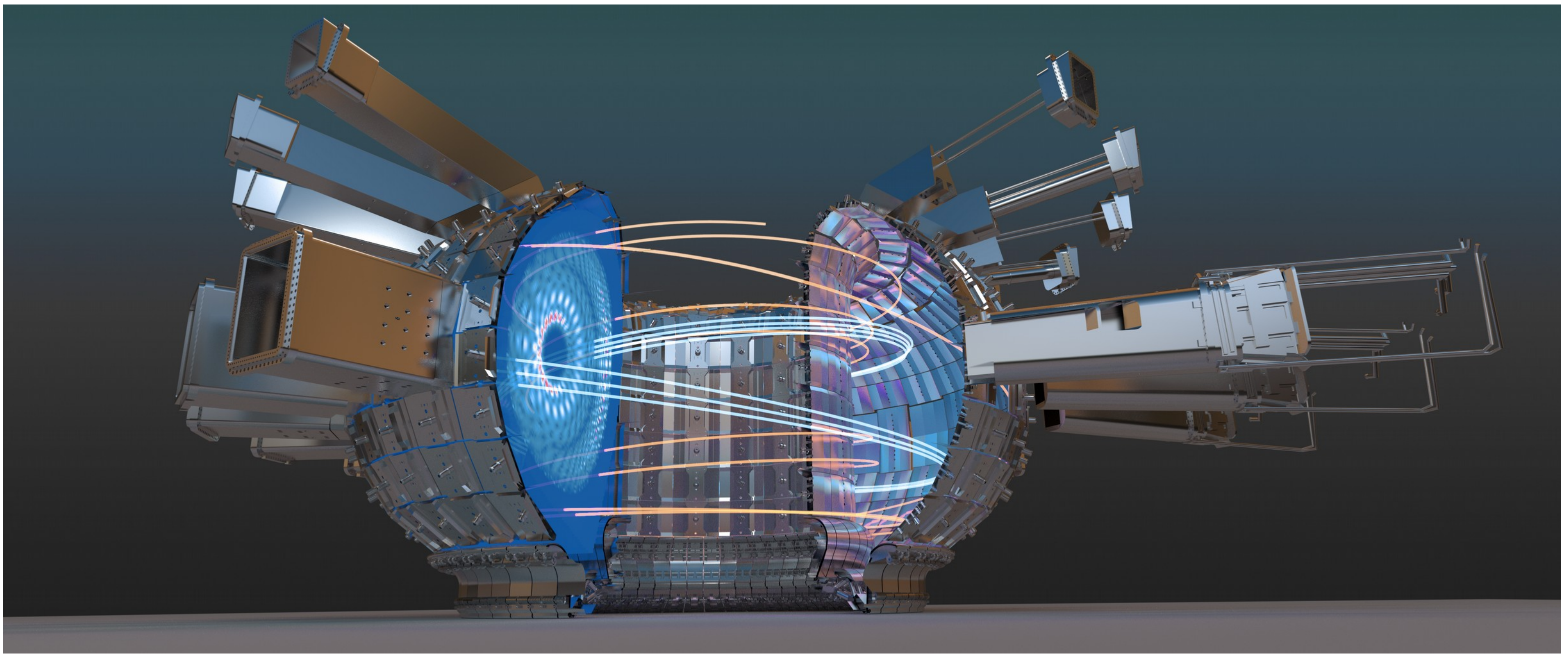
The proposed project will use the Monte Carlo simulation code ERO to perform interpretive modelling of beryllium migration, deposition and re-erosion from tungsten surfaces in the JET divertor. The goal is to find the range of input settings and parameters which predict experimental data from actual JET plasmas and post-mortem tile analysis. The project will give insight on which physical processes are expected to be the most relevant and how much of the beryllium observed in the divertor plasma can be explained by re-erosion as opposed to migration. The topic is suited for both B.Sc and M.Sc level students with an interest in computational physics.

Scrape-off layer plasma reconstruction using the Onion-Skin Model approach (contact: Mathias Groth, Henri Kumpulainen, Antti Hakola)

The lifetime of wall structures in fusion reactors is largely impacted by the erosion of these materials due to bombardment of plasma and impurity particles. The Onion-Skin Model approach, promoted by Stangeby et al. [*The Plasma Boundary in Magnetic Fusion Devices*], is one of the most direct methods to predict the plasma conditions adjacent to the material surfaces. In the proposed project, the scrape-off layer plasma in the JET and ASDEX Upgrade tokamaks is predicted using the Onion-Skin Model and compared to predictions using the analytic two-point model equations. Through this project the student will become familiar with the physics of this important region of a fusion device and aquainted with the most basic scrape-off layer plasma simulation tools. The project is intended either for B.Sc. or early-phase M.Sc. students having introductory-level understanding of plasma physics and fusion. The successful applicant is expected to be familiar in Python programming.

Effects of turbulence on bootstrap current (contact: Timo Kiviniemi)

The bootstrap current plays an important role in the pedestal stability and transport. In a pedestal with steep gradients the global effects become important. These can be studied using the global full-f code ELMFIRE developed in Aalto University. Steep gradients also drive turbulence which may cause new current components in addition to neoclassical bootstrap current. A recent work by McDevitt [Phys. Plasmas 24 (082307) 2017] has identified several mechanisms through which electrostatic microturbulence can directly impact the electron current, including a turbulent analogue of the bootstrap current. In this project the aim is to quantify the effect of turbulence on the tokamak pedestal. Preferably JET tokamak pedestal parameters are used but simulations are very heavy so some compromises are needed to stay within available HPC resources. The existing code version is used and the results compared to published results.



Effect of charge exchange reactions on fast ions in the TCV tokamak (contact: Patrik Ollus)

When simulating fast-ion transport, several difficulties that are faced elsewhere in plasma physics can be eliminated, since the fast ions are often well decoupled from the main plasma. However, interaction between the fast-ion species and the bulk plasma has to be properly modeled. One often neglected interaction is the charge exchange (CX) process. There is experimental evidence and numerical simulations showing that these CX reactions are essential under certain plasma conditions and need to be included in the numerical models. In recent years, such a model has been implemented in the ASCOT code. Within this proposal we use this model to carry out predictive simulations for the TCV tokamak, where CX processes are known to be important.

Estimating fast-ion losses in ITER using reduced numerical model (contact: Lucia Sanchis, Antti Snicker)

Using a full numerical simulation model to estimate fast-ion losses in ITER plasmas is computationally a rather expensive task. Nonetheless, there are cases where estimates are needed for large scans. A good example is the operational space of the so called ELM control coils (ECC), where currents in each individual coil can be chosen (almost) arbitrarily. To tackle this problem, we have developed a reduced model to estimate the fast-ion losses in a CPU-friendly manner. Within this project, the student will apply such a model for the ITER

ECC problem, and verify the most the important results by running the full numerical model using the ASCOT code.

Numerical simulations and coding work using the ASCOT5 code (contact: Antti Snicker, Seppo Sipilä, Joona Kontula, Taina Kurki-Suonio)

The ASCOT code is one of the most comprehensive simulation packages for fast-ion transport studies for fusion devices. The code, developed here at Aalto since the early 90's, is currently running its fifth generation. This recently developed version, ASCOT5, has made an international breakthrough in the field. Currently, over ten institutions around the globe are using the code. We offer various topics, ranging from developing new numerical models, such as the influence of turbulent fluctuations on fast-ion transport, to more straightforward simulations using existing models for various experimental machines (including W7-X Stellarator). Being part of the developer group gives an overview on how large numerical software development works. This includes obeying coding style, usage of issue tracker, generation of documentation, providing user guidande and instructions for collaborators, and running simulations for the largest fusion experiments in Europe.