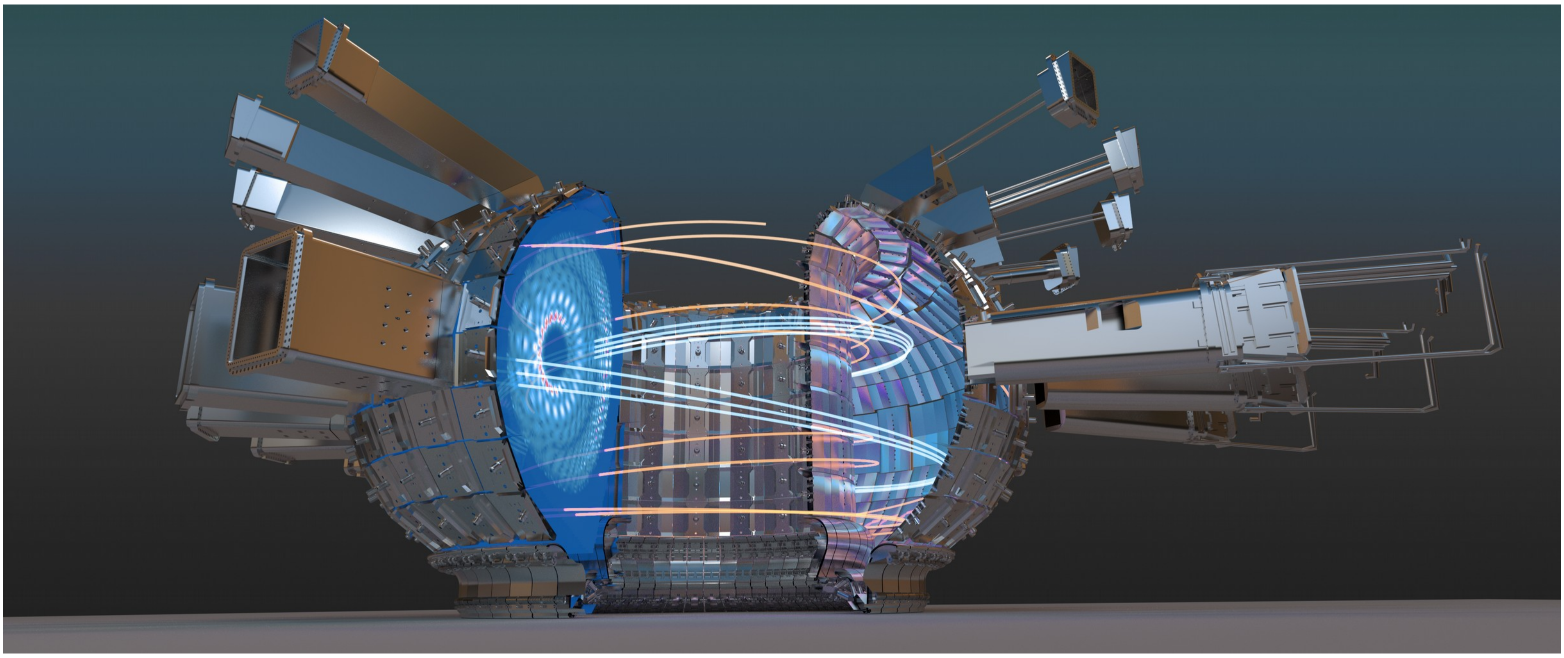
Fusion and plasma physics

The Fusion and Plasma Physics research group is recruiting motivated students to work within the three sub-groups during the summer 2018. It is assumed that either a Bachelor's thesis or a special assignment is produced during the projects.

Further information about the group itself can be found from our website: http://physics.aalto.fi/en/groups/fusion/



More detailed information about the group and, in particular, about the projects foreseen for the next summer will be given in the info session organized ***18th of January 2018, 14.15 o'clock, at Y338b (aka Vaaksa, 3rd floor Otakaari 1)***

Detailed description of the planned projects are given below. Depending on the funding situation and the number and type of applicants, 3-7 positions will be offered.

1. *Turbulence/MHD models in ASCOT5* (Antti Snicker, ASCOT group)

One of the fundamental properties of working fusion reactor is good confinement of fusion-born and other types of fast-ions. The fast-ion transport in fusion machines is solved using orbit-following codes, like the ASCOT code developed in Aalto. Typically the transport is resolved only to so-called neoclassical level, meaning that all exotic events that happen only under specific conditions will be omitted. However, it is foreseen that these conditions will apply at least to some extent in ITER plasmas. Namely, there will be a lot of MHD modes that will affect the fast-ion transport and evidence is growing that also small-scale turbulence will affect those fast-ions. To this end, we are developing our tools to account for these non-neoclassical phenomena. This project would include coding task, performing simulations and in particular getting educated about the subject.

2. *Optimizing the W7-X beams for fast ion confinement* and

3. *Phase-space loss map for W7-X beams* (Taina Kurki-Suonio, Joona Kontula, W7-X team, ASCOT group)

It has been a while since the last big fusion experiment was launched in the Europe. But just a few years ago a major installation started operating in Northern Germany. This machine, named W7-X, is a stellarator, an alternative reactor type to tokamaks. Since stellarators have been studied much less than tokamaks, many open issues are present and fast-ions are not an exception here. These two projects would be related to studying basic fast-ion properties in the W7-X stellarator. A significant source of fast ions in W7-X is the neutral beam injection (NBI) heating system. The aim of these projects is to gain more understanding of the NBI-born ion confinement in W7-X, with the work consisting mainly of carrying out numerical simulations and post-processing.

4. *Fusion product and neutron transport simulations in JET/JT-60SA* (Jari Varje, ASCOT group)

A working fusion reactor will produce neutrons, hopefully a lot of them. It is essential for the energy production to know the properties of these particles and how they are transported within the reactor. Finland is the flagship country for doing this kind of work, since we have a lot of experience both on calculating the source of the fusion products (using ASCOT and the related tools) and on calculating the neutron transport. This project would be mainly to run short simulations using several different numerical tools.

5. *Fast ion charge exchange losses in W-7X/JET* (Jari Varje, ASCOT group)

While calculating the fast-ion transport several difficulties that are faced elsewhere in plasma physics can be eliminated since the fast-ions are often well-coupled from the main plasma. However, interaction between the fast-ion species and the bulk plasma has to be properly modeled. One of the 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. This work would be to finalize the numerical model dealing with CX reactions and then utilizing this tool for plasmas where we have good measurements showing the effect of the CX reactions.

6. *W transport in the scrape-off layer in JET plasmas* (Mathias Groth, EDGE group)

Contamination of the core plasma with tungsten in fusion devices can significantly impact the performance of the device. Measurements of tungsten radiation were carried in the JET tokamak in the UK relating the sources at the wall to the tungsten concentration in the core. The proposed project encompasses simulations of the tungsten distribution in the scrape-off layer using the quasi-kinetic DIVIMP code and compare the predictions to previously established EDGE2D-EIRENE fluid code simulations. The student will become familiar with impurity transport in the scrape off layer and the primary simulation tools to address these issues. The project is intended for students with a Bachelor's degree and introductory-level understanding of plasma physics and fusion. The project is intended to be continued as a M.Sc. Thesis.

7. *Assessment of the 2-point model using edge fluid codes* (Andreas Holm, Ivan Paradela, Christos Stavrou, EDGE group)

The conditions in the scrape-off layer in tokamak fusion devices can be described by a reduced set of fluid equations relating the conditions near the core plasma to those at the material surfaces. The validity of the model will be assessed using more sophisticated models built into the the fluid edge codes SOLPS-ITER and EDGE2D-EIRENE. The project focus on analysing simulations by one of these codes for momentum and power losses in the scrape-off layer toward understanding of plasma transport, and atomic and molecular physics in plasmas. The project is set up for new students in the field of plasma physics toward a Bachelor's thesis.

8. *W erosion and re-deposition in different plasmas in the divertor region of ASDEX Upgrade* (Antti Hakola and Markus Airila from VTT, EDGE group)

The lifetime of wall structures in fusion reactors is largely influenced by their erosion by bombardment with plasma and impurity particles. The picture is additionally complicated by deposition of the eroded material together with radioactive tritium from the plasma fuel into new locations. Tungsten (W) is a very attractive wall material due to its low erosion yield, however, re-deposited W-containing layers may contain considerable T inventories. To this end, one needs to fully understand erosion and re-deposition characteristics of W in different plasma conditions. In the proposed project, erosion and re-deposition behavior of W will be numerically modelled using the Monte Carlo ERO code in the ASDEX Upgrade tokamak, where the entire wall directly facing the plasma is made of W. Different experimentally relevant conditions will be considered by varying the plasma gas (H, D, He), density and temperature, and impurity content. The student will become familiar with different plasma-material interaction processes and the primary simulation tools to model them. The project is intended either for B.Sc. or early-phase M. Sc. students having introductory-level understanding of plasma physics and fusion.

9. *Turbulent transport simulations of pellet injection in JET plasmas* (Laurent Chôné, ELMFIRE group)

Sustaining fusion reactions for power generation requires maximising the fuel density, temperature and energy confinement time. In magnetic fusion devices fuelling is achieved in part by hurling pellets of frozen fuel (hydrogen or its isotopes deuterium and tritium) towards the core where the fusion reactions occur. However the extreme temperatures mean that the pellets ionise before reaching reaching their target, making regimes where the deposited particles get transported by the plasma to the core ("inward pinch") very desirable. The student will learn the fundamentals of heat and particle transport in magnetised plasmas and apply them to investigate particle transport in numerical simulation data of tokamak pellet injection experiments.

10. *Energy confinement study for the FT-2 tokamak* (Susan Leerink, ELMFIRE group)

To produce electricity through fusion power, hydrogen, or its isotopes deuterium and tritium, need to be heated so that it becomes a plasma and then confined to continuously extract its energy. In this project, the student will learn the fundamentals of how heat is generated, transferred and lost in these blisteringly hot fusion plasmas. They will then apply the principles to post-processing and analyzing data from simulations of turbulent transport to determine the confinement time for FT-2 tokamak plasmas.