ID	Posternumber	Title	Topic	Pesenter first name	Presenter last name
53	P1a.101	Magnetic reconnection rate during sawtooth crashes in ASDEX Upgrade	Magnetic Confinement Fusion	Oleg	Samoylov
94	P1a.102	A new equilibrium solver for the Fenix flight simulator	Magnetic Confinement Fusion	Emiliano	Fable
102	P1a.103	Possibility for neutral density measurements with beam emission spectroscopy	Magnetic Confinement Fusion	Örs	Asztalos
130	P1a.104	Investigation of q-profile and normalized beta control in JT-60SA using reinforcement learning	Magnetic Confinement Fusion	Takuma	Wakatsuki
132	P1a.105	Energetic particle driven instabilities during the L-H transition in ASDEX Upgrade	Magnetic Confinement Fusion	Philipp	Lauber
134	P1a.106	Investigation of the poloidal asymmetries on the radial electric field in FELTOR gyro-fluid simulations	Magnetic Confinement Fusion	Raúl	Gerrú Migueláñez
153	P1a.107	Towards a fully 3D MHD plasma-structures model: Coupling JOREK and CARIDDI	Magnetic Confinement Fusion	Nicola	Isernia
157	P1a.108	Kinetic modeling of bifurcation conditions of resonant magnetic perturbations in ASDEX Upgrade experiments	Magnetic Confinement Fusion	Markus	Markl
183	P1a.109	Computation of neoclassical toroidal viscosity with the account of non-standard orbits in a tokamak	Magnetic Confinement Fusion	Rico	Buchholz
245	P1a.111	Improvement of plasma position control by decoupling of Fast Plasma Position Control coil control and Poloidal Field coil control on JT-60SA	Magnetic Confinement Fusion	Shinichiro	Kojima
285	P1a.112	Gyrokinetic simulations of anisotropic energetic particle driven geodesic acoustic modes in tokamaks	Magnetic Confinement Fusion	Brando	Rettino
299	P1a.113	NBI ion losses at energy E0/2 driven by NTMs	Magnetic Confinement Fusion	hugo	ferrari
305	P1a.115	Experimental helium exhaust studies in the full-W ASDEX Upgrade	Magnetic Confinement Fusion	Antonello	Zito
334	P1a.116	Simulation of multi-modes in ASDEX-Upgrade	Magnetic Confinement Fusion	Hao	WANG
402	P1a.117	SOL modelling of the JT-60SA tokamak initial operational scenario using SOLEDGE3X-EIRENE code	Magnetic Confinement Fusion	Krzysztof	Gałązka
411	P1a.118	Ideal core MHD stability in operational scenarios in JT-60SA	Magnetic Confinement Fusion	Rui	Coelho
412	P1a.119	Inner-outer midplane density asymmetries and the link to the HFSHD close to double null at ASDEX Upgrade	Magnetic Confinement Fusion	Daniel	Hachmeister
457	P1a.120	Analysis of pellet ELM triggering potential in different ASDEX Upgrade plasma scenarios	Magnetic Confinement Fusion	Gabor	Kocsis
467	P1a.121	An efficient zero-order analysis of resonant effects on fast ion losses.	Magnetic Confinement Fusion	Panagiotis	Zestanakis
447	P1a.123	Tokamak GOLEM for fusion education - chapter 13	Magnetic Confinement Fusion	Petr	Macha
244	P1a.202	Avalance effect :The necessary condition for auto-sustained fusion process in Hydrogen-Boron fuel	Beam Plasmas and Inertial Fusion	Chrysovalanti	Daponta
258	P1a.203	Preliminary study of early time dynamics during pulsed laser interaction with a CH ablator target	Beam Plasmas and Inertial Fusion	Evaggelos	Kaselouris
333	P1a.205	Influence of the solid-to-plasma transition on the laser energy deposition in targets and subsequent hydrodynamics for direct drive inertial confinement fusion	Beam Plasmas and Inertial Fusion	romain	liotard
345	P1a.206	Study of cross-beam energy transfer in spherical strong shock polar directdrive experiments at the NIF	Beam Plasmas and Inertial Fusion	Diego	Viala
350	P1a.207	Effects of non-Maxwellian electron distribution functions on properties of hot under-dense gold plasmas	Beam Plasmas and Inertial Fusion	Christophe	Blancard
524	P1a.209	Study of laser plasma instabilities on their suppression and simulation methods	Beam Plasmas and Inertial Fusion	Ma	Hanghang
538	P1a.210	The influence of a strong external magnetic field on laser-plasma interaction	Beam Plasmas and Inertial Fusion	Ondrej	Klimo
34	P1a.301	Ion-Sound Waves in UHF Discharge Plasma Injected in Open Magnetic Trap	Low Temperature and Dusty Plasmas	Irakli	Nanobashvili
101	P1a.303	Electron swarm parameters for Alcohols plasma by using electron collision cross – sections	Low Temperature and Dusty Plasmas	Marcelo	Silva
580	P1a.304	Structure and Mechanical Properties of TaN and Ta2O5 Coatings Prepared by Sputtering Using Non-Self-Maintained gas discharge	Low Temperature and Dusty Plasmas	Anton	Taran
111	P1a.401	Nonlinear properties of the Kelvin-Helmholtz instability in compressible plasmas	Basic, Space and Astrophysical Plasmas	Zhiru	Li
328	P1a.402	Nonlocal thermal transport in magnetized plasma along different directions	Basic, Space and Astrophysical Plasmas	hanzhi	zhao
471	P1a.403	Simulation of the Formation and Structuration of a Diamagnetic Cavity in a Magnetosphere Barium Cloud	Basic, Space and Astrophysical Plasmas	Benoît	Bernecker

Magnetic reconnection rate during sawtooth crashes in ASDEX Upgrade

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Sawtooth instability is characterised by fast redistribution of the plasma core temperature during a crash phase. The radial velocity of the plasma core during the crash phases has been measured with ECEI diagnostic for the first time. These measurements introduce a novel approach for studying magnetic reconnection during sawteeth since the radial velocity characterises the rate of the reconnection.

In addition, the observed crash times have been compared with nonlinear two-fluid MHD simulations and with Kadomtsev model as shown in figure 1. The comparison reveals good qualitative and quantitative agreement, which indicates that two-fluid effects (inertia and pressure gradient of electrons) are sufficient for the correct prediction of the experimental results. Contrarily, the crash time of the Kadomtsev model, which is based on a single-fluid picture of magnetic reconnection, disagrees completely with the experimental results.

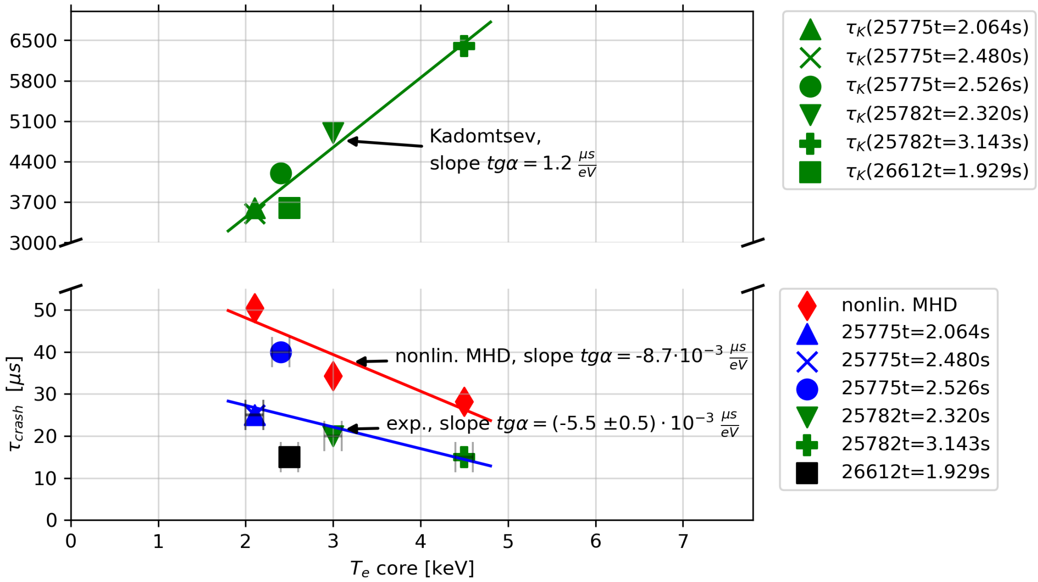

Figure 1: *The dependence of the duration of observed sawtooth crashes τ_{crash} on the plasma core electron temperature T_e^{core}. Both the experimental and the MHD simulation data are used. Kadomtsev times of the crashes τ_K are calculated using the experimental parameters from the six crashes. Straight lines represent a linear fit to the data. Slopes of the fitted lines of the Kadomtsev times are significantly different and the values are two orders of magnitude higher compared to the experimental results and the MHD simulations. To show all data, the upper part of the plot has a different time scale than the lower part.*

A new equilibrium solver for the Fenix flight simulator

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<u>*Abstract*</u>

In this work, a new fast equilibrium solver has been developed to be used into the Fenix tokamak flight simulator [1,2,3]. Fenix is based on the coupling between Simulink™ and the ASTRA transport solver [4]. The flight simulator main purpose is to perform pre-discharge checks like: 1) show that the programmed feed-forward and feed-back time traces have been implemented as desired; 2) show that the discharges physics goals develop as planned, or if not, allows one to understand why and eventually correct the trajectories or modify the purpose; 3) show that the operational and physics limits are not overrun, otherwise one needs to modify the programmed trajectories.

In order to achieve these goals, the complete tool has to run in a reasonable time scale, e.g. a typical full ASDEX Upgrade 15+ s discharge scale has to be simulated in less than 5 minutes (the faster, the better). The main bottleneck of this computational time requirement is the equilibrium solver (2D Grad—Shafranov equation solver + circuit equations solver) because of the non-linear nature of this system of equations. Moreover, the equilibrium solver has to provide a smooth transition between the pre-plasma phase (during which coils are being charged) and the plasma phase (breakdown, ramp—up, ramp—down, plasma termination).

The newly developed equilibrium solver has been written specifically to be both fast and flexible in the choice of the operational mode, such that transition from the pre-plasma to the plasma phase is accomplished in the smoothest and most reasonable way possible. In this respect, it distinguishes itself from existing equilibrium solvers, which typically model the developed plasma phase only (i.e. the existence of stable closed field lines is assumed). In this work the details of the new code are presented and discussed, and application to both ASDEX Upgrade and DEMO machines are presented.

Lastly, the new code exploits a modernization of the ASTRA transport solver, which has been rewritten in Fortran 90 [5], and its also used in this work.

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Possibility for neutral density measurements with beam emission spectroscopy

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A sought after and yet quite an elusive measurement on magnetically confined plasma devices is the assessment of neutral particle densities and their profile outside of the plasma boundary. Our work aims to assess the applicability of beam emission spectroscopy (BES) for neutral density measurements.

BES is an active plasma diagnostic employed to measure plasma density, featuring as a standard diagnostics method on many fusion devices. A high energy neutral beam injected into the plasma suffers collisional events with charged plasma particles resulting in photon emission. The emission is used to reconstruct plasma density profiles [1].

Based on previous work, establishing the classical trajectory Monte Carlo method as a viable tool for generating neutral beam atom impact cross-sections with plasma neutral particles [2], we have generated a novel set of Li and H beam projectile cross-sections with neutrals.

The cross-sections were used to augment existing nl-resolved collisional radiative models (CRM) [3] used for plasma density reconstruction. The impact of neutral gas on beam emission was assessed and established as non-negligible for realistic neutral densities. The nHESEL scrape-off layer turbulence code [4] was used to generate various neutral and corresponding plasma density profiles, which resulted in a realistic test set for neutral gas-induced emission on the plasma edge and SOL that was subsequently analysed using the augmented CRM.

Finally, we adapted the CRM to an existing plasma density reconstruction code [5] in an effort to establish a plasma to neutral ratio as a threshold for the viability of neutral density reconstruction.

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Investigation of q-profile and normalized beta control in JT-60SA using reinforcement learning

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Real time control of a safety factor (q) profile and a normalized beta (β_N) has been studied in various tokamaks because they strongly affect the confinement performance and MHD stability of fusion plasmas. In this work, an integrated q profile and β_N control is developed using reinforcement learning. In order to control the q profile and β_N according to the plasma confinement characteristics, a neural network whose input is the state vector $\boldsymbol{s}_i = [t_i, q(\rho, t_i), q(\rho, t_i\text{-}1), T_e(\rho, t_i), \alpha(\rho, t_i), P_{heat}(t_i), P_{heat}(t_{i-1}), \beta_N(t_i), \beta_N(t_{i-1})]$ (α : normalized pressure gradient, P_{heat}: heating power of each actuator) and output is the heating and current drive power $P_{heat}(t_i+1)$ has been constructed and optimized.

The integrated transport code RAPTOR is used since RAPTOR can solve the transport very fast. It has the advantage to do more than one million trials. By randomly changing the parameters which give the thermal diffusivity, plasmas with various confinement characteristics have been simulated and used for training. This parameter randomization allows the neural network to adapt to a wide range of transport characteristics. The neural network has learned to achieve a flat q profile with a minimum value of q_{min} greater than 1, aiming to achieve both high confinement and good MHD stability while β_N is controlled to 2.4.

The trained control system has been verified using another integrated transport code TOPICS. While the heating and current drive profiles of each NBI and ECH beam are prescribed in the training using RAPTOR, the heating and current drive profiles are calculated considering the plasma parameters at each time step in the validation using TOPICS. In addition, CDBM model is used for thermal diffusivity in TOPICS, which is different from the model used in training. With this setup, the applicability of the trained control system to the plasma different from the ones simulated in training has been checked. As a result, it has been confirmed that q profile and β_N can be controlled. This result indicates that the control can be performed even when there is a finite modeling error.

Energetic particle driven instabilities during the L-H transition in ASDEX Upgrade

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Traditional experiments on present day devices face the difficulty that the redistribution of energetic particles (EPs) due to instabilities in the low-toroidal-mode number regime lead either to substantial losses or to a re-deposition of EPs close to the plasma edge where the slowing down times decrease considerably, and other transport effects such as 3D perturbations are present.This means that the influence of the redistributed particles on the background plasma is usually negligible and not measurable. This will be different in burning plasma experiments at ITER, where redistributed EPs by core-localised instabilities are expected (and required) to be well-confined, broadening the alpha-particle heating profile. Depending on the intermittency of the core-transport mechanisms, interesting multi-time-scale self-organisation processes may be expected.
This paper reports experiments on ASDEX Upgrade (AUG) trying to mimic part of the physics described above. In order to avoid the complications due to edge losses, an off-axis-peaked EP distribution is generated by 2.5-5MW NB-heating, leading to inwards-directed EP transport. Modes with positive mode numbers in fig. 1 are driven by the positive radial EP gradient, propagating in the electron diamagnetic direction with an $n = 2$ TAE (yellow color) as the most unstable mode observed. Discharge #39681 was designed to have stable L-mode (before $3.0s$) and H-mode (after $3.7s$) phases, and most interestingly a slow L-H transition at constant heating power. This phase is modelled with the recently developed Energetic Particle Stability Workflow (EP-WF) [V.A. Popa, 4th IAEA TCM on Fusion Data Processing, (2021)], based on IDA data [R. Fischer et al, Fusion Sci. Technol. 76, (2020)] and the AUG-IMAS interface TRVIEW [G. Tardini, (2022)]. High-resolution equilibrium reconstruction, local and global linear gyro-kinetic LIGKA runs are automatically performed for 160 time slices during the transition. The results (fig. 1, right) do not only explain many details of the underlying EP physics, but they open the possibility for the application of various EP transport models and rigorous uncertainty quantification, as pursued in the EUROfusion enabling research project ATEP and TSVV#10.

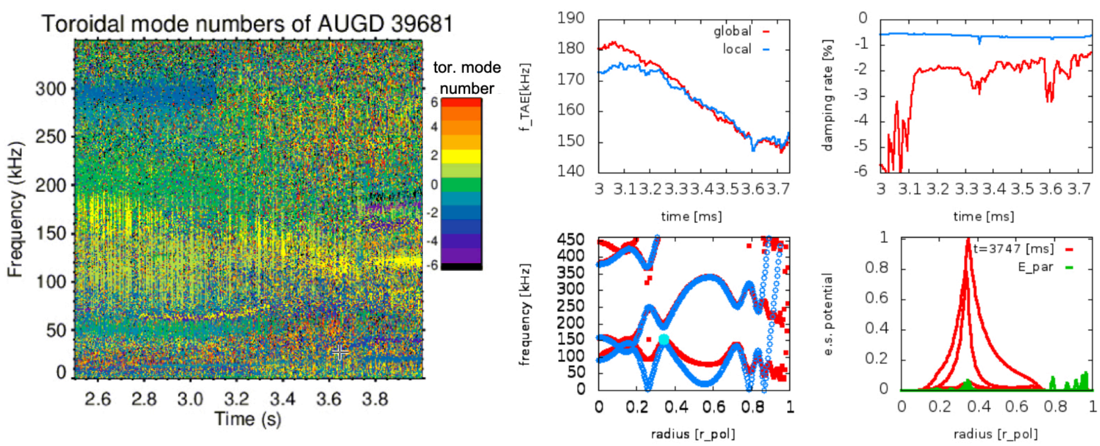

Figure 1: *Left: toroidal mode number spectrum as measured by the magnetic pick-up coils during a slow L-H transition (∼3.0-3.8s) for AUG discharge #39681. Right: the results of the automated EP-stability workflow for the toroidal mode number $n = 2$, summarising local and global mode frequency (top left), damping rate (top right) as a function of time, MHD and kinetic continuous spectra (bottom left, with TAE gap marked in light blue) and global mode structures of electrostatic potential (two main pol. harmonics) and parallel electric field for the last time point of this series of linear runs.*

Investigation of the poloidal asymmetries on the radial electric field in FELTOR gyro-fluid simulations

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Recent studies have investigated the role of the ExB flow and its shear in the transition from L to H mode in tokamak devices [1,2]. Understanding the sources of the radial electric field in the edge of the plasma is crucial to produce a theoretical model that can reproduce the L-H transition.

Some of the experimental observations of the radial electric field present the diamagnetic flows, with the radial force balance, as the most important mechanism to explain the edge radial electric field and the profiles in the region [3,4].

However, the radial electric field and thus the electrical potential are usually computed in fluid codes by the so-called “vorticity equation”. This equation is in reality the conservation of currents, as presented in our recent publications [5,6]. In these references, it is presented that the radial electric field is locally driven by the balance of the polarization current with the rest of the currents present in the plasma (mainly the parallel and the curvature currents). As this equation give a local description, it is possible that poloidal asymmetries in the currents can drive poloidal asymmetries of the polarization current and therefore, on the radial electric field.

In this contribution, we will present the preliminary analysis of the poloidal distribution of currents and radial electric field in the edge and SOL of tokamak plasmas done with the gyro-fluid code FELTOR [7]. We will present the relative relevance of each current in the conservation of current equation and the poloidal asymmetries that can arise from it.

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Towards a fully 3D MHD plasma-structures model: Coupling JOREK and CARIDDI

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Passive conductors represent an essential element of all existing tokamak devices, since eddy currents slow down Alfvénic instabilities to the electromagnetic time scale [1]. Shared currents between plasma and conductors, defined as *halo currents*, have also been routinely observed during *disruptions* of experiments [2]. The 3D features of conducting structures affect plasma vertical stability properties [3] and can be responsible for mode locking or breaking. Consequently, realistic macroscopic simulations of tokamak plasma dynamics require to capture the mutual interaction of a 3D plasma model with an accurate 3D model of conducting structures. However, complete 3D extended-MHD models generally use a simplified description of passive conductors (*e.g.* 2D or thin), and detailed 3D models of conductors are self-consistently coupled only to simplified MHD plasma models [4].

Here we illustrate a coupling scheme, based on the Virtual Casing principle, for the self-consistent integration of the 3D non-linear extended-MHD model of the JOREK code [5] with the fully 3D volumetric model of conducting structures in CARIDDI [6]. An equivalent current distribution, circulating at the MHD domain computational boundary, reproduces the same magnetic field as the plasma in the outer domain. The magnetic field produced by the equivalent currents is tested successfully. The coupling is illustrated both in the no-wall limit and with eddy currents.First test cases and benchmarks to JOREK-STARWALL [7] are shown. An outlook on the inclusion of halo currents in the coupling scheme and further developments is given.

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Kinetic modeling of bifurcation conditions of resonant magnetic perturbations in ASDEX Upgrade experiments

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One experimentally verified way to mitigate or suppress edge localized modes (ELMs) in tokamaks is the application of resonant magnetic perturbations (RMPs). Although the plasma response usually shields small perturbations, RMPs with high enough amplitudes can bifurcate into unshielded states. As shown with a fluid model and experimental measurements in DIII-D in Ref. [1], the bifurcation of RMPs at the pedestal top correlates with the suppression of ELMs.

In this work, necessary conditions for the bifurcation of RMPs and their correlation with ELM suppression in ASDEX-Upgrade (AUG) are studied within the quasilinear kinetic cylinder model established in Ref. [2] coupled with the linear ideal MHD solver GPEC [3] to account for realistic device geometry (in part, similar to [1]). Bifurcations are studied by following the quasilinear evolution of plasma parameters (density, temperature, toroidal rotation velocity) during the ramp-up of the RMP coil current and comparing the results with an approximate, but numerically efficient criterion, which poses a sufficient condition for a bifurcation. Additionally, the effect of the electron fluid resonance on the threshold is inspected, where the resonance includes a kinetic shift with respect to MHD predictions. A positive scaling of the bifurcation threshold with the plasma density sets the upper density limit for the bifurcations which correlates with the upper density limits also seen in ELM suppression experiments. Based on the above modeling, analysis of experimental time evolution of plasma parameter profiles in AUG shows that the ELM suppression phase correlates with the approximate bifurcation condition for the poloidal RMP mode resonant at the pedestal top. Simultaneously, it correlates with the capture of the electron fluid resonance by this mode, where the resonance is computed assuming a plateau on the electron temperature profile in the resonant layer of that mode.

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Computation of neoclassical toroidal viscosity with the account of non-standard orbits in a tokamak

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Neoclassical toroidal viscous (NTV) torque from internal and external non-axisymmetric magnetic field perturbations is usually computed using a local approach where toroidal torque density is directly related to local, gradient-driven neoclassical particle fluxes via an algebraic flux-force relation. Validity of this approach requires that the radial orbit width is small compared to both, radial perturbation scale and distance to the magnetic axis. For the typical medium-range tokamak parameters, both conditions may be violated for the ion plasma component. In particular, this concerns the radial scale of resonant magnetic perturbations (RMPs) used to mitigate edge localized modes at the plasma edge. The code NEO-RT [1] computes ion NTV in the most typical "collisionless" resonant plateau regime using a Hamiltonian approach. Taking finite orbit width into account showed that the local model correctly predicts the order of magnitude of the torque from RMPs but the profile of torque density is modified [2]. For the externally driven and internal kink-like perturbations localized near the axis, conditions for both radial perturbation scale and distance to the magnetic axis are usually violated. This may lead to a significant overestimation of the ion torque. In the present report, a modified, fully non-local version of NEO-RT code is presented. Besides the standard, passing and banana particle orbits, the underlying model takes into account all other possible types of non-standard orbits. The later orbits (e.g. "potato" orbits) form additional classes separated in the phase space by homoclinic orbits with infinite bounce time. More orbit classes are created near the magnetic axis when a weak radial electric field is present. When the field can not be treated as weak, there can be arbitrary many classes. In this report, results of this fully non-local NTV model are compared to local models for the resonant plateau regime [1] and general collisionality regimes [3].

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Improvement of plasma position control by decoupling of Fast Plasma Position Control coil control and Poloidal Field coil control on JT-60SA

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The plasma position and shaping, and the plasma current are controlled by poloidal field (PF) coils consisting of superconductor, and the fast plasma postion change is controlled by in-vessel coils consisting of normal conductor on recent tokamaks. The coil current response for the voltage command value depends on the time constant of the coil. The in-vessel coils have a much faster coil current response than PF coils due to the short time constant. Therefore, the decoupling control between in-vessel coils and PF coils respecting each coil current response must be established. In this study, we introduce the issues given by the coupling of in-vessel and PF coils controls and demonstrate the improved control by the decoupling. In JT-60SA, two in-vessels coils which are called the fast plasma position control (FPPC) coils are going to be installed [1], and the control logic for FPPC coils has been developed [2]. Each coil is connected to the power supply so that the coil voltage could be controlled individually. Thus, the plasma shape/plasma current controller employs the ISO-FLUX scheme so that the magnetic fluxes on the controlling point could be identical to the reference value. In the ISO-FLUX scheme, FPPC coils can control not only the vertical direction but also the horizontal direction.

The two control methods of proportional (P) control and the differential (D) control were applied for FPPC coil control in the plasma current ramp-up as shown in Figure. 1. P control can rapidly reduce the error at the initial, whereas it causes the coupling with PF control by the differential of response. On the other hand, D control slowly reduces the error, whereas it enables FPPC coils to decouple from PF coils. In order to take advantage of the strength of P component for fast position control, and ease of decoupling by D control, FPPC coils should control the high-frequency part of the P component. We will explain in the conference that high-pass P control combined with D control accomplishes the decoupling and works better for control than the conventional P or D control only.

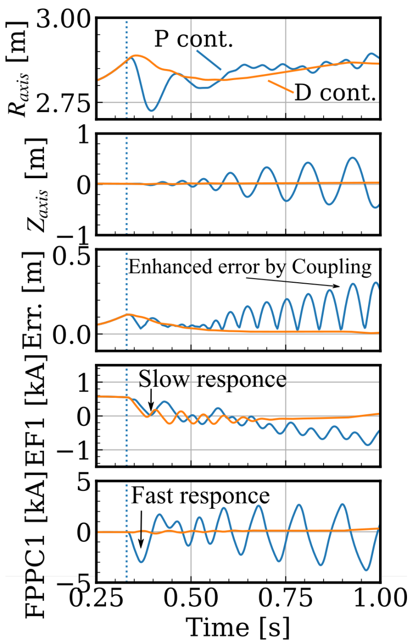

Figure 1: *The time evolution of R, Z of magnetic axis, the error length between LCFS, PF, and FPPC coil current.*

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Gyrokinetic simulations of anisotropic energetic particle driven geodesic acoustic modes in tokamaks

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Abstract

Energetic particles produced by neutral beams are known to excite energetic-particle-driven geodesic acoustic modes (EGAMs) in tokamaks. We study the effects of anisotropy of distribution function of the energetic particles on the excitation of such instabilities with ORB5, a gyrokinetic particle-in-cell code. Numerical results are shown for linear electrostatic simulations with ORB5. The growth rate is found to be sensitively dependent on the phase-space shape of the distribution function. The behavior of the instability is qualitatively compared to the theoretical analysis of dispersion relations. Realistic neutral beam energetic particle anisotropic distributions are obtained from the heating solver RABBIT and are introduced into ORB5 as input distribution function. Results show a dependence of the growth rate on the injection angle. A qualitative comparison between the numerical results and experimental measurements in ASDEX Upgrade is presented. An explanation for the remaining quantitative difference is proposed.

NBI ion losses at energy $E_0/2$ driven by NTMs.

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Energetic ion losses due to neoclassical tearing modes (NTM) have been reported in ASDEX U [1]. We have used a full orbit code [3] that includes the time dependent perturbed electric and magnetic fields to study this process. The perturbed fields were calculated employing the experimental information available and the method proposed in [4].

In a previous work we reported an increase in ion losses when the frequency of the NTM matches the precession frequency of the trapped particles (f ~ $\sqrt{E}$) [2]. In the ASDEX U experiment the frequency of the NTMs was 6 kHz and the precession frequency of the injected ions (at 93 KeV) was f_p ~ 8kHz. For the ions with E0 = 93keV the losses ~~are~~ increased by a factor 2, from 2% in the static case to 4% in the rotating case.

Since a fraction of the injected neutral atoms (~ 1/3) have an energy equal to half the maximum value (46.3 keV~~s~~) it is also important to study NTM induced losses at this energy. The 46.3 keV ions have an average precession frequency similar to the measured NTM frequency and the strong resonance results in a 23% loss of the trapped ions. These results show the importance of including the full time dependency of the perturbation.

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Experimental helium exhaust studies in the full-W ASDEX Upgrade

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In future fusion devices helium will be generated in the core of a burning plasma as a product of the D-T reaction. In order to avoid fuel dilution and not degrade the confinement properties, the core helium concentration must be kept within tolerable values [1]. It will be therefore mandatory to efficiently remove helium ash from the plasma, which imposes constraints on edge and divertor conditions and requires an adequate design of the pumping systems.

An experimental investigation of helium recycling and pumping has been performed at the ASDEX Upgrade (AUG) tokamak. This is an ideal test environment thanks to the ITER-like plasma geometry and the presence of PFCs made of tungsten, which is a fusion-relevant wall material. The time evolution of helium following a small injection during otherwise steady-state deuterium discharges was measured spectroscopically in the plasma with CXRS [2][3] and in the exhaust gas using in-vessel Penning gauges [4]. Applying simple analytical multi-reservoir particle balances, the decay of the helium content in the plasma was interpreted by means of a pumping efficiency, limited by the technical capability of the pumping system, and a divertor compression efficiency, which quantifies helium transport in the edge and retention in the divertor plasma. Distinct decay times were fitted to separately characterize the two processes.

In all scenarios the limited performance of the AUG pumping system was identified as the main bottleneck for an efficient exhaust. This is mainly due to the fact that helium is not pumped by the installed in-vessel cryopump. The influence of helium retention in the W-wall was also identified to play a non negligible role in the decay dynamics. It was found that helium compression in the divertor strongly depends on the plasma scenario. In attached H-modes plasmas, helium compression was found to greatly increase with increasing divertor neutral pressures, with a resulting decay time in the plasma decreasing roughly linearly with increasing neutral pressure. On the other hand, the exhaust efficiency was seen to degrade with the divertor entering a detached state in L-mode, in line with past observations at AUG with C-wall [5].

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Simulation of multi-modes in ASDEX-Upgrade

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Recently, a series of experiments demonstrated the coexistence of Alfvén eigenmode (AE), energetic particle driven geodesic acoustic mode (EGAM), and energetic particle driven mode (EPM) in ASDEX-Upgrade tokamak[1-3]. A hybrid simulation is conducted with the code MEGA to investigate the mode properties and the resonant particles. The simulation is based on realistic experimental parameters with slowing-down energetic particle distribution.

In the simulation, AE, EGAM, and EPM, are reproduced in the same run. The mode numbers m/n are 2/-1 and 3/-1 for AE, m/n = 0/0 for EGAM, and m/n = 2/-1 for EPM. AE and EGAM are located around r/a = 0.5∼0.6, while EPM is located in core region around r/a = 0.1. The frequencies of AE, EGAM, and EPM are 103 kHz, 42 kHz, and 145 kHz, respectively. In nonlinear saturated stage, the frequency of AE chirps down, and the frequency of EPM chirps up. By contrast, the frequency of EGAM keeps constant.

The resonant condition of AE is $\omega_{AE} = n\omega_\phi + L\omega_\theta$, where ω_ϕ and ω_θ are particle toroidal and poloidal frequencies, respectively, n is toroidal mode number, and L is an arbitrary integer. In the present simulation, it is found that L is 1 for the above resonant condition. The resonant condition of EGAM is $\omega_{EGAM} = L\omega_\theta$. In the present simulation, the resonant particles with L = 1 are dominant, and also, some particles resonate with L = 2. In addition, fractional resonance (L = 1.5) also exists.

The resonant particles are analyzed in both (ω_ϕ, ω_θ) space and (Λ, E) space where Λ is pitch angle and E is energy. In linear growth stage, resonant particles of EGAM are located in low frequency and low energy region, by contrast, resonant particles of AE are located in high frequency and high energy region. There is an obvious gap between this 2 kind of particles. In nonlinear saturated stage, with time evolving, more and more particles fill into the gap and the gap becomes difficult to identify.

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SOL modelling of the JT-60SA tokamak initial operational scenario using SOLEDGE3X-EIRENE code

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JT60SA is a tokamak constructed in Naka, Japan to support the operation of the ITER reactor [1]. In the initial research phase the device will be equipped with a full carbon first wall with no active cooling. For this reason, the preparation and assessment of the full inductive scenario with 26.5 MW of input power (the maximum available during this phase) is particularly challenging. The main aim of this work is to assess the realistic heat loads on the first wall of the vessel and to check the overall compatibility of the scrape-off layer plasma (SOL) regime with the desired core performance. To achieve this scope, the entire SOL volume within the vessel and the subdivertor region is simulated by the fluid transport code SOLEDGE3X [2], which uses a mesh extended up to the first wall and can besides handle the secondary X-point situated at the top of the tokamak vessel. Depending on the regime of operation, the interplay between the transport and atomic processes (ionization/recombination) makes this area interesting from the point of view of energy dissipation. The neutrals playing a key role in the process of detachment are treated kinetically by EIRENE Monte Carlo code [3] including additional reactions involving D_2 molecules (charge exchange and elastic collisions) [4,5]. A scan on the input power is performed to estimate the maximum total power that can be handled by the divertor targets (maximum power density 10 MW/m^2) and other plasma facing components: the dome (10 MW/m^2), baffles (up to 1 MW/m^2) and the rest of the wall (0.3 MW/m^2), as specified in the Plant Integration Document. It is found that in certain areas a substantial fraction of the deposited power is delivered by the neutrals (up to 40%). This leads to the assesment of the desired range of radiated power fraction by intrinsic carbon or possible seeded impurities with respect to the mentioned material limits and H-mode operation requirements (power through separatrix $\geq \sim$10 MW) [6]. The results are compared with the previous simulations of the nominal fully inductive scenario (auxiliary heating power 41 MW) with Ar and Ne seeding [7].

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Ideal core MHD stability in operational scenarios in JT-60SA

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The scientific work programme of the JT-60SA foresees several operational scenarios at normalised plasma beta close or larger than 3, ranging from full Ip inductive at 41MW heating power with different heights in the pedestal density, hybrid like scenarios with 37MW of heating power and strongly reversed shear scenarios (heating power larger than 30MW) in a full non-inductive current operation.

Considering the large operational plasma beta it is essential to infer the MHD stability of the core/pedestal plasma. While on the pedestal it is largely anticipated that all scenarios are peeling-ballooning (PB) unstable, the core MHD stability is less straightforward except when the plasma scenarios are sawtoothing. In particular, large pressure gradients may give rise to local ballooning-infernal or kink modes resonant with magnetic surfaces close to the q=1 magnetic surface or possible minima in the safety factor q-profile.

In this work we investigate the ideal core MHD stability of the foreseen scenarios and present a comprehensive analysis of the MHD spectra characteristic from each scenario. The background plasma and equilibria stem from modelling done using the CRONOS suite using dedicated models for core particle and heat transport e.g. GLF23 and CDBM [1,2]. Such models lack of some characteristics expected to be important in JT-60SA, e.g. the impact of electromagnetic effects on turbulence, and yet they were used as a first step towards a full prediction of scenarios in JT-60SA. It is found that while the fully inductive scenarios are mostly kink unstable at the q=1 surface (though the n=1 mode is not necessarily the most unstable mode), as large pressure gradients become more evident in the advanced scenarios, ballooning-infernal like modes become strongly unstable, with occasionally more than one unstable branch being inferred.

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Inner-outer midplane density asymmetries and the link to the HFSHD close to double null at ASDEX Upgrade

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Research at ASDEX Upgrade (AUG) has reported the formation of a high-field side high density (HFSHD) front in the divertor region associated with the inner divertor detachment [1]. The dynamics of the midplane edge electron density profiles and its link to divertor detachment have been previously studied on AUG, taking advantage of the high-resolution HFS/LFS O-mode reflectometry diagnostic [2]. It has been shown that the formation of a high-density region in the midplane in front of the inner wall leads to strong poloidal asymmetries in the scrape-off layer density [2]. Building on these results, this work details the divertor detachment and HFSHD formation in highly shaped plasmas - close to double null (DN) configuration - characteristic of many reactor concepts.

For this purpose, we performed plasma configuration scans from lower single null (LSN) to upper single null (USN) passing through DN configuration. These scans were performed in both L- and H-mode at different fuelling and seeding levels to vary the detachment state and overall plasma density. During the transition from LSN to USN, we measured: (i) the inner and outer divertor density and temperature using Thomson scattering and stark broadening spectroscopy; (ii) the target density and temperature using Langmuir probes; (iii) the scrape-off layer density at the inner and outer midplane using O-mode reflectometry. These measurements allowed us to monitor the detachment state and the magnitude and location of the HFSHD during the LSN to USN transition.

While moving from LSN to DN, the HFSHD moves from the far-SOL to the X-point region as the HFSHD becomes increasingly disconnected from the LFS. Interestingly, the HFS density even increases when approaching DN despite the reduced magnetic connection to the LFS. In the midplane scrape-off layer, the LFS density experiences little change going from LSN to USN, but the HFS density - dominated by the midplane HFSHD front - is significantly lower in the USN case. This highlights the importance of the ExB drift in the divertor in establishing the HFS density since the drift points inwards in LSN and outwards in USN [3].

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Analysis of pellet ELM triggering potential in different ASDEX Upgrade plasma scenarios

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Cryogenic pellet edge localised mode (ELM) triggering was proposed decades ago to shorten the time elapsed between successive ELMs and therefore to reduce the ELM caused heat loads on first wall elements. Pellet ELM pacemaking was successfully demonstrated on several tokamaks increasing the ELM frequency substantially [1][2]. However, it has also been discovered that this technique cannot increase the ELM frequency arbitrarily. It was found that the probability of a pellet triggering an ELM is dependent on the time elapsed since the previous ELM and even "lag times" were observed where this probability drops to zero [3]. Recent nonlinear MHD simulations of ELM triggering by pellets (ASDEX Upgrade scenario) confirmed the existence of the lag time and investigated its dependence on the different pellet and plasma parameters giving clear parametric trends [4].

Since the discovery of ELM pecamaking, there have been several experiments on ASDEX Upgrade tokamak in which cryogenic pellets were shot into H-mode plasmas. Some of these were aimed at investigating the ELM triggering itself, some of them served a different purpose, but independently of the original aim, the efficiency of pellet ELM triggering can also be examined in these discharges. Accordingly, the aim of our study presented in this contribution is to systematically investigate the occurrence of lag time and its dependence on pellet (speed, mass, etc.) and plasma parameters (e.g., pedestal pressure, first wall material, etc.) and to compare the obtained results with the predictions of the MHD simulations [4].

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An efficient zero-order analysis of resonant effects on fast ion losses.

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Fast ion (FI) losses may compromise the performance of the fusion reactor by transporting energetic particle bursts on the plasma facing components of the wall. Such losses often occur due the interaction of the fast ion population with MHD modes [1, 2] or as a result of synergetic effects between FI and magnetic perturbations (MPs) and FI and neoclassical tearing modes (NTMs). Numerical simulations have shown that application of MPs can lead to significant fast ion losses in ITER [3] and have highlighted the role of resonances at FI transport [4].

In this work, we propose a zero-order analysis of the fast ion dynamics which aims at providing insight on the effect of resonances on fast ion losses. Our analysis is carried out in the unperturbed phase space of the single particle gyrocenter in a background equilibirum magnetic field. The key contribution is the introduction of the *resonance index*, a quantity which models the susceptibility of the gyrocenter phase space to the effect of specific external perturbations.

The value of the *resonance index* depends on the number of resonant orbits in the vicinity of a phase space point as well as the distance of these resonant orbits from the vessel wall. Conceptually, the result is a function of phase space which quantifies the probability that an elementary volume in phase space may yield escaping orbits in the presence of specific MHD modes and magnetic perturbations by the mechanism of resonance overlap. Finally, we propose a recipe of mapping the *resonance index* to the plane of the scintillator of the FILD detector. We demonstrate a remarkable similarity between the mapped resonance index profile and the FILD detector signal for selected shots in ASDEX upgrade.

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Tokamak GOLEM for fusion education - chapter 13

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The GOLEM tokamak is the oldest operational tokamak worldwide. Currently it serves mainly as an educational device. GOLEMs most unique feature is its remote-control system [1]. This contribution is devoted to the current experimental projects of students.

A new motorized manipulator allowing both the radial and angular profile measurements is installed at the GOLEM tokamak. A scan of ion saturation current flows at various angles with respect to the magnetic field is performed and measured using double tunnel probe. Results are compared with existing measurements based on a Gundestrup probe. **A new external plasma stabilization system** was installed at the GOLEM. Compared to the previous one, the new stabilization windings have more turns per coil to create a stronger magnetic field. New fast cameras have also been added, which can now be used to reconstruct the plasma position and compare it with the position obtained from the data from the Mirnov coils. **The electron temperature is estimated based on the expanded calibration database of 2D3V PIC code of the tunnel probe.** By the interpolation of current ratio measured experimentally, the electron temperature can be calculated with a high temporal resolution. The results are cross-checked by a comparison with other electron temperature measurement methods. **Visible plasma tomography** is being implemented on the GOLEM tokamak using a newly installed pair of fast cameras. The camera setup is currently undergoing calibration. The goal is to achieve partial automation of tomography measurements that can be performed remotely. Relationship between macroscopic plasma parameters and **magnetic islands generation** is studied. Strong correlation with plasma current is observed. **Runaway electron studies** using semiconductor detectors and calorimetric probe. **A video about the GOLEM tokamak vacuum system**is being created as the first in a newly emerging series of methodological materials for tokamak technology relevant educational purposes

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Avalanche effect: The necessary condition for auto-sustained fusion process in Hydrogen-Boron fuel

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Abstract

The main goal of the present work is the investigation of the "chain reactions" effect occurring during the $p^{11}B$ (Hydrogen-Boron) nuclear fusion process, in two different schemes (a non-thermal and a thermal one). The main advantage of the Hydrogen-Boron ($p^{11}B$) fusion [1] is the production of three alphas with total energy of 8.7 MeV, which could enhance the alpha heating effect of the species (protons, Boron) and allow the development of "clean" devices for power generation, avoiding neutron radiation. The "chain reactions" effect described also as the avalanche effect [2] is the necessary condition for "fast ignition enhancement" of fusion process in the medium by continuous elastic central collisions, where proton and ^{11}B particles gains energy from the produced alpha particles. This alpha heating effect increases the medium species energy in an auto-sustained operation, as well as the gain of the output fusion power.

The "chain reactions" effect in the non-thermal scheme [3, 4], is ignited by energetic protons (~10^9 cm/sec) interacting with a low temperature Hydrogen-Boron medium. The produced alpha particles from the nuclear fusion reaction, transfer energy to the low energy particle of the medium and generate relatively high energy protons with energies corresponding to the maximum $p^{11}B$ fusion cross section (~ 600 keV). This process improves the fusion reaction probability and produces a new cascade of energetic alphas. The protons energy losses due to frictions with the medium electrons (stopping power) is sustained up to 600 keV, applying a periodical pulsed external electric field. Evaluation on the stooping power enables the optimization of the fusion power as a function of the medium electron density. The result of the aforementioned operation is an important enhancement of the alpha particle production and consequently of the energy transfer to protons which in turn improves the fusion energy output.

In the thermal scheme the "chain reactions" effect is investigated numerically, calculating the temporal evolution of the $p^{11}B$ plasma parameters (density, temperature and reaction rate) with initial density ~ 10^{19} $m^{-3,}$ and relatively low initial temperature of the order of 30 keV, using a multi-fluid, global particle and energy balance code [5, 6], including collisions between all species (p, B, e, alpha). The code allow to study the temporal production of alphas in the $p^{11}B$ plasma, as well as the temporal energy transfer from the alphas to the plasma ions. The latter increases the ions (p, ^{11}B) initial temperatures to values corresponding to the optimum value of the cross section (600keV) and maximizes the reaction rate (RR). The temporal evolution of the RR enables the definition of the necessary time interval for the appearance of strong alpha heating effect, which generates a "fast ignition enhancement" of fusion process, until the fuel depletion. An important numerical result is that the effect of the "fast ignition enhancement" of the RR, is initiated when the density of the produced alphas in the plasma is approximately one order of magnitude lower than the initial plasma ion density.

The analysis of the two above mentioned schemes shows important physical process similarities with emphasis on the "chain reactions" effect [or avalanche effect] which is proved to be the necessary condition to ignite an auto-sustained fusion process in the $p^{11}B$ fuel. The important increases of the alpha density enables to overcome the energy losses of the species in the fusion medium through the increase their temperature up to the optimum cross section values for fusion

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Preliminary study of early time dynamics during pulsed laser interaction with a CH ablator target

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It is well known that a critical area of concern to inertial confinement fusion (ICF) is target nonuniformities due to their unstable growth. In direct-drive ICF experiments, the process starts when a low intensity pulse illuminates the ablator [1,2]. Three-dimensional Multiphysics finite element modelling and simulation [3] has been recently carried out to explore the influence of the thermoelastoplastic (TEP) and melting phases during the ablator's heating considering its intrinsic real TEP properties. In this work, to simulate the initial phases of solid-to-plasma transition, a ns pulsed laser interacts with a polystyrene (CH) target-sample. A 3-mm diameter 100-μm-thick planar disk of CH polymer is irradiated by a single laser beam using a pulse of 6 ns duration. The sample geometry is similar to the work in [4], where direct-drive measurements of laser-imprint-induced shock velocity nonuniformities are performed. To simulate the hydrodynamic response of the target, the first-principles equation of state (FPEOS) of polystyrene is used [5]. For the TEP mechanical response of the heated solid an accurate strength material model is considered coupled with the EOS. The results of this study aim to contribute towards the comprehension of the transition from solid to plasma phase of the target. The simulations were performed in the National HPC facility—ARIS—using the computational time granted from the Greek Research & Technology Network (GRNET) under project ID pr011027—LaMPIOS.

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Influence of the solid-to-plasma transition on the laser energy deposition in targets and subsequent hydrodynamics for direct drive inertial confinement fusion

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Inertial Confinement Fusion (ICF) is a method of achieving nuclear fusion reactions by bringing a small mass of combustible material at high densities with the desired thermodynamic properties. To achieve this goal, high power laser beams are used to implode a spherical shell constituted of gaseous DT fuel surrounded by solid DT and a plastic ablator. The laser ionizes the ablator which is ablated and the target implodes due to the rocket effect. In radiation-hydrodynamics codes modeling this process, the plastic ablator is supposed opaque to the laser radiation, which is only the case when it is already in plasma state, where the laser field is reflected at the critical density. However, the mechanisms that lead to the transition from solid state to plasma state of the ablator are not modeled in the aforementioned codes, whereas they may have an important role in implosion symmetry, target compressibility, shock timing, and hydrodynamic instabilities.

This work focuses on the introduction of a solid-to-plasma transition model in a 3D radiation hydrodynamics code, in order to study such an influence on direct-drive implosions. It is based on a recent physical model developed in Ref. [1, 2] which describes the solid-to-plasma transition of polystyrene step by step (most of ICF ablators are composed of polystyrene). The hydrodynamic code is a numerical tool coupling the 3D laser propagation code IFRIIT [3] with the 3D Eulerian hydrodynamic code ASTER [4]. Simulations with a single beam have confirmed the validity of the implementation, and have provided information about the dynamics of the transition: the ablator undergoes the solid-to-plasma transition, i.e. transforms from transparent to reflective optical state, on a timescale of 50ps. Simulations are then applied to the 60 laser beams configuration of the OMEGA laser facility. Test simulations conducted on warm targetsshow a modification in the spherical harmonics mode distribution of the target areal density (ρR), where the volume heating during the solid to plasma transition is then to smooth the predominant OMEGA modes. They also shows a slightly modification of shock velocity in the target, probably due to the preheating of the inner ablator. We will also present results for cryogenic cases at different adiabats and consider other applications such as modeling of foams for the Dynamic Shell design or the Spherical Strong Shock experiments conducted on the NIF.

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Study of cross-beam energy transfer in spherical strong shock polar direct drive experiments at the NIF

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When the interaction parameter $I\lambda_L^2$ crosses the threshold of $\sim 10^{14}$ W μm^2/cm^2, the laser plasma interaction becomes prone to numerous couplings between electromagnetic and plasma waves [1]. Most of these additional processes have non-linear behaviors and are in general harmful to the implosion in inertial confinement fusion. It is notably the case of the cross-beam energy transfer (CBET), a non-linear laser/plasma coupling effect that is paramount in ICF implosions. CBET can lead to a net transfer of energy between incoming and outgoing beams that affects both the symmetry of the implosion and the laser-target coupling [2].

In this talk, I will present 3D simulations of Polar Direct Drive (PDD) experiments [3] carried out on the NIF. These experiments aimed to study the efficiency of the laser energy coupling to a spherical target with beam intensities close to the SI regime. Two series of shots were simulated: N190204 (a 1100 μm CD+CH radius target with 3.0×10^{15} W/cm^2 peak intensity and 5 *ns* pulse) and N210519 (a 1050 μm radius CH target with 8.0×10^{14} W/cm^2 peak intensity and 7 *ns* pulse) [4]. These shots are simulated with and without CBET to investigate its influence on compression and coupling efficiency using the IFRIIT + ASTER [5] coupled codes.

We observe that with CBET, there is a large loss of total energy absorbed for both shots. The energy absorption decreases from 85% energy absorption without CBET to 40-60% absorption (and drops at 30% relative absorption during spike) with CBET. These energy losses occur mainly around the equatorial plane, where the overlap between the beams is much more extreme therefore inducing more CBET. This results in an inhomogeneous compression that is much stronger at the poles, leading to the creation of a pancake-shaped shock, and to several *ns* delays regarding the convergence time. We present comparisons of these results to angularly-resolved density profiles extracted from radiography data.

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Effects of non-Maxwellian electron distribution functions on properties of hot under-dense gold plasmas

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A lot of studies in plasma physics are performed assuming that the electron distribution functions (EDFs) are Maxwell-Boltzmann distributions. However, this assumption appears to be not valid in various situations. For example, solar flares or laser-produced plasmas at ultra-high intensities are known as media where the EDFs are characterized by overpopulated high-energy tails compared to Maxwell-Boltzmann distributions [1, 2]. Another example is the laser-produced plasmas where the inverse Bremsstrahlung process is the dominant heating mechanism. In this case, it has been predicted that the EDFs can be described as super-Gaussian distribution functions [3]. Recently, such flat-top electron distributions and their effects on crossed beam energy transfer and on the laser heating have been measured [4, 5].

In the present study, the effects of non-Maxwellian EDFs on properties of hot under-dense gold plasmas are numerically investigated in conditions existing in laser-heated hohlraums. The EDFs are assumed to be super-Gaussian distribution functions which are used both in a collisional-radiative atomic kinetic model to compute the atomic state populations and to evaluate spectral emissivities. Calculations are done for a 10 mg/cc gold plasma at electron temperatures ranging from 0.3 to 4 keV and including, or not, a radiation field described by a Planckian distribution with a radiative temperature equal to 100 or 300 eV. The effect of the super-Gaussian exponent on the charge state balances and on the relative intensities of the N-, M-, and L-shell emission spectra are presented.

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Study of laser plasma instabilities on their suppression and simulation methods

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Laser plasma instabilities (LPIs) are one of the most critical and fundamental problems to be mitigated to achieve inertial confinement fusion ignition. LPIs not only scatter away a considerable proportion of the laser energy out of the fusion pellet, but also produce harmful hot electrons that affect compression and implosion efficiency. In this study, we propose a new strategy to suppress LPIs by sunlight-like lasers, which can be generated by coupling two broadband laser beams with different random phase-frequency spectra and orthogonal polarizations. Particle-in-cell (PIC) simulations are carried out to verify the suppression of LPIs by sunlight-like lasers.It is found the sunlight-like lasers have much stronger suppression effects on LPIs than the broadband lasers under same bandwidths. Namely, the application of sunlight-like lasers in the ICF experiments may greatly reduce the requirement of bandwidth of broadband lasers for the suppression of LPIs.

Besides of the suppression of LPIs, numerical simulation of LPIs also poses a big challenge. Generally, the simulation of LPIs may be carried out either by kinetic codes or fluid codes. The kinetic codes, i.e., PIC codes or Vlasov codes, can give a detailed description of LPIs at the expense of huge simulation costs, which makes it hard to simulate the LPIs under large scale and long time conditions. The fluid codes, either based on the enveloped three wave coupled equations or Zakharov equations have much lower simulation costs and faster calculation speeds. However, the fluid codes ignore a series of nonlinear effects of LPIs and are unable to describe the kinetic effects self-consistently. In this study, we firstly establish a set of full-wave fluid equations including both SRS and SBS instabilities. The physical model is then solved by particle-mesh method and a one-dimensional PM1D code is finally developed. Compared with the PIC codes, our PM1D code has a much faster calculation speed while keep the kinetic effects as well. Comparing with the fluid codes, the PM1D code can give a more detailed description of LPIs .

The influence of a strong external magnetic field on laser-plasma interaction

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The influence of a strong external magnetic fields on the interaction of a laser pulse with plasma has recently gained attention both in connection with new possibilities of generating such very strong field and in connection with potential applications such as the development of innovative sources of energetic particles and radiation or the inertial thermonuclear fusion. For example, the MagLIF concept [**?**] relies on strong external magnetic field of the order of ten Tesla to help reduce the thermal energy transport thus decreasing the required parameters which have to be achieve for ignition of thermonuclear fusion, while a high energy laser is used to preheat the fuel. However, the question of how such strong magnetic field may influence the interaction of the laser beam with the underdense plasma is not fully understood so far. A recent study [2] demonstrates that the magnetic field strength of 12 Tesla has already a significant influence on laser propagation and interaction with underdense plasma.

The interaction of a sub-relativistic multi-picosecond laser beam with the wavelength $\sim 1\mu$m and the intensity $\sim 10^{16}$ W/cm^2 with an underdense plasma is investigated via two-dimensional Particle-in-cell simulations using the code EPOCH [3]. An external magnetic field with the field strength of the order of few tens of Tesla is included in the simulation box. The simulations concentrate in particular on the interaction in front and around quarter critical density and on the laser absorption, filamentation and parametric instabilities. In particular the filamentation process which takes place on the picosecond time scale is influenced by the external magnetic field. This process is indeed important for the long term evolution of the interaction and the coupling of the laser field to hot electrons.

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Ion-Sound Waves in UHF Discharge Plasma Injected in Open Magnetic Trap

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Different methods of filling open magnetic trap with plasma are used in various experiments. Contactless methods are used most frequently and lately ultra-high frequency (UHF) methods of plasma accumulation in a trap were most widely applied. As a rule, plasma formation takes place in the trap itself in the electron cyclotron resonance (ECR) regime. However, this method has various disadvantages. In particular, the range of magnetic field variation in the trap is strictly limited by the existence of an UHF discharge in the magnetic field. Together with a change of magnetic field, discharge regime and plasma parameters change. The most important disadvantage is that the ”hot” region of UHF wave absorption in the plasma is in the trap itself, which is often undesirable. Therefore, the application of an independent plasma source with controllable parameters located far from the trap and from which the ”target” plasma is injected in the trap is of great interest.

The present work deals with this new application. The independent stationary UHF plasma source and its characteristics are described. The possibility of filling an open magnetic trap with uniform field by plasma injected from the source as well as the properties of plasma and its low frequency (LF) oscillation characteristics in the trap are investigated.

Experiments showed that plasma which is formed in an independent stationary UHF source in the ECR regime for pressure $\boldsymbol{p} < 1\cdot10^{-3}$ Torr, magnetic field in the trap $\boldsymbol{H_t} > 400$ Oe and distance between the plasma source and solenoid $\ell < 80$ cm, fills the trap very efficiently. As a result, plasma with controllable density within the range $10^8 \div 10^{12}$ cm^{-3} and temperature $2 \div 3$ eV is accumulated in the trap. Near the UHF plasma source and also in the trap first, second and third harmonics of the ion sound wave together with ion cyclotron oscillations are reliably detected.

Electron swarm parameters for Alcohols plasma by using electron collision cross – sections

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In the present work, are presented the transport coefficients of alcohols (methanol, ethanol, propanol, and butanol) widely used in areas like automotive, medicine, ecology and industry. The coefficients are calculated numerically using the two-term expansion of electron Boltzmann equation Bolsig+ and Monte Carlo collision code METHES, based on cross section sets obtained experimentally covering the interval of electron impact energy from 1 eV to 500 eV . The data obtained are compared with experimental values extracted from previous studies, such as effective ionisation coefficients and drift velocity. Results for the electron energy distribution function (EEDF), mean energy, reduced mobility and diffusion coefficient are also presented. For the purpose of calculations are used as parameters the temperature 300K and reduced fields E/N between $1 - 10^4$ Td (1Td = $10^{-21} Vm^2$) and Plasma density $10^{19} (1/m^3)$. We seek to bring results that are meaningful in swarm physics and can be used in plasma models.

Structure and mechanical properties of TaN and Ta_2O_5 coatings prepared by sputtering using non-self-maintained gas discharge

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Among the different transition metal nitrides (TiN, CrN, ZrN, etc.), tantalum nitride (TaN) is gaining increasing interest due to its excellent chemical and physical properties [1,2]. Ta_2O_5 coatings are used in medicine research as a new type of biomaterials. Ta_2O_5 coatings have an excellent biocompatibility, good dielectric properties, and high corrosion resistance [3]. It was reported in [4] that Ta_2O_5 coating promotes the biocompatibility, anticorrosion and antibacterial behaviors of NiTi substrate.

In the present research the TaN and Ta_2O_5 coatings have been deposited by sputtering using non-self-maintained gas discharge in Bulat-type facility. Non-self-sustained gas discharge, in which the additional charge carriers are produced by a vacuum-arc evaporator, is characterized by high values of current and degree of ionization [5]. Due to enhanced plasma density and degree of ionization, the processes of surface treatment in such gas discharge are much more intense than they are in a self-sustained glow discharge [5].

The surface topography of the coatings was studied using JEOL JSM-6390LV scanning electron microscope (SEM), chemical composition was examined using energy-dispersive X-ray analysis (EDX). The measurement of nonohardness was carried out with a Nanoindenter G200 nanoindentor from the USA, using Berkovich diamond triangular pyramid.

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Nonlinear properties of the Kelvin-Helmholtz instability in compressible plasmas

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Kelvin–Helmholtz (KH) instabilities, driven by sheared plasma flow, have been found to underlie various phenomena exhibited in many fields [1-4]. Influence of plasma flow on the Kelvin–Helmholtz (KH) instability is numerically investigated by using a compressible magnetohydrodynamics (MHD) model. It is found that the KH instability can be driven by sub-sonic shear flow and a fast reconnection process due to coupling of two KH modes has been explored. As shown in figure 1, the KH mode always dominates the dynamics process of instability, which suggests a crucial effect of the weak magnetic shear on formation of high mode harmonics.

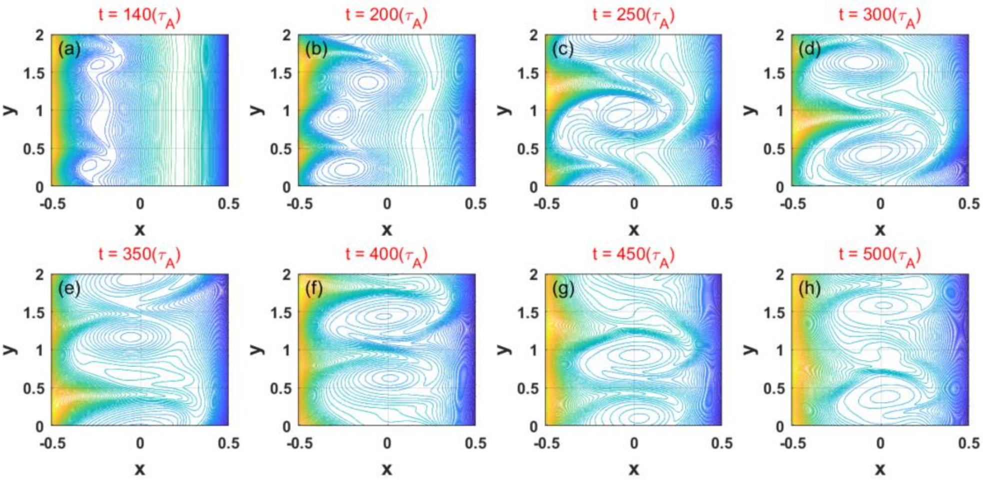

Figure 1 Time evolution of 2D structures of the total magnetic flux of the KH instability

In addition, the asymmetric forced magnetic reconnection configuration is well kept and it leads to locking of double KH modes. The interlocking process of the two KH instabilities may support a possible explanation for the mechanism of nonlinear fast reconnection in space or fusion plasma with weakly reversed magnetic shear.

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Nonlocal thermal transport in magnetized plasma along different directions

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Thermal transport plays a critical role in inertial confinement fusion, which leads to fusion target compression and heating. It is well-known that the classical Spitzer–Härm theory for thermal transport becomes invalid when steep temperature gradients are found in laser-produced plasmas, where the thermal transport is shown to be nonlocal. Nonlocal thermal transport is also widely found in other plasma systems, such as magnetic fusion devices, astrophysical environments and general laser plasma interaction. In magnetized plasmas, the transport coefficients appear as a tensor and they are classically given by the Braginskii theory. Generally, the magnetic fields tend to inhibit and divert the heat flux, and nonlocal thermal transport also takes place in magnetized plasmas with steep temperature gradients.

In this work, the nonlocal thermal transport in magnetized plasma is studied theoretically and numerically with the Vlasov-Fokker–Planck (VFP) model, where the magnetic field has components both perpendicular to and along the temperature gradient. Nonlocal thermal transport is found both in the longitudinal and transverse directions as long as the temperature gradients are sufficiently large. The magnetic field tends to reduce the non-locality of the thermal transport in the direction perpendicular to the magnetic field, i.e., the difference between the heat fluxes predicted by the Braginskii's theory and the VFP simulation decreases with the magnetic field strength. When the temperature gradient is steep, the contribution of higher-order terms in the spherical harmonic expansion of the electron distribution function becomes important, in particular, for the thermal transport in the direction perpendicular to the temperature gradient even for weakly magnetized plasma.

Simulation of the Formation and Structuration of a Diamagnetic Cavity in a Magnetosphere Barium Cloud

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The 3D multi-fluid magnetohydrodynamic code CLOVIS, is developed to investigate ionospheric natural disturbances like Equatorial Spread F or artificial events like barium cloud experiments. The model is based on Euler equations for the neutral fluid and Euler-Maxwell equations with the ideal MHD assumptions for the charged fluid. CLOVIS uses a Finite Volume method based on the Godunov's scheme with approximate Riemann solvers like ROE or HLLC for Euler equations and 8-wave or HLLD for ideal MHD equations [1].

The active experiments like barium releases, help to improve our understunding of ionospheric physics, magnetosphere-ionosphere coupling, and also cometary physics.The high altitude barium release experiment G-10 from the Combined Release and Radiation Effects (CRRES) mission shows the formation of a diamagnetic cavity and a structuration of the plasma [2]. The expansion of a sub-Alfvenic plasma through the magnetic field lines is known to form a diamagntic cavity where the total magnetic field almost vanishes. At the lower order, the radius evolution of the cavity can be estimated by equating the kinetic energy in the release to the swept-up magnetic energy.

The structuration results from the growth of the large larmor radius instability (LLR) which is similar to the Rayleigh-Taylor instability (RTI) but for unmagnetized ions [3]. The linear theory shows that the LLR instability developps faster than the RTI. Simulations initialized with the G-10 conditions have been performed with CLOVIS. The maximum radii from the experiment and from the simulations are in good agreement. The second order MUSCL-HANCOCK reconstruction associated with the HLLD solver, allows us to describe the evolution of plasma structures in the framework of the ideal MHD.

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