ID	Posternumber	Title	Topic	Pesenter first name	Presenter last name
18	P4a.101	Nonlinear interaction between toroidal Alfvén eigenmode and tearing mode on HL-2A tokamak	Magnetic Confinement Fusion	Peiwan	Shi
74	P4a.102	Detachment control with feedback impurity seeding and ECRH injection in LHD	Magnetic Confinement Fusion	Masahiro	Kobayashi
75	P4a.103	Characteristics of electron temperature profile stiffness in electron heating dominant plasmas on EAST	Magnetic Confinement Fusion	Jianwen	Liu
77	P4a.104	Improvement of electron temperature and density evaluation in the 20 kHz Thomson scattering diagnostics on LHD	Magnetic Confinement Fusion	Hisamichi	Funaba
147	P4a.107	Optimization of pressure gradient driven modes and Alfven Eigenmodes stability by the neutral beam current driven in LHD plasma	Magnetic Confinement Fusion	Jacobo	Varela Rodriguez
171	P4a.108	Self-induced transport barrier in the helium plasma on the tokamak GOLEM	Magnetic Confinement Fusion	Petr	Macha
208	P4a.109	Bifurcated magnetic flux consumption during current ramp-up	Magnetic Confinement Fusion	Qi	Zhang
210	P4a.110	Upgrade of the gas puff imaging system by developing a relay optical system and its application in EAST	Magnetic Confinement Fusion	Shaocheng	Liu
211	P4a.111	Characterization of Pedestal Burst Instabilities during I-mode to H-mode Transition in the EAST Tokamak	Magnetic Confinement Fusion	XiaoMing	Zhong
241	P4a.112	Experimental observations of RMP induced toroidal rotation accelerations on EAST	Magnetic Confinement Fusion	Yifei	Jin
306	P4a.113	Alpha Particle Confinement and Losses in JET's Tritium Campaign	Magnetic Confinement Fusion	Philllip	Bonofiglo
317	P4a.115	Parametric Dependence of Sawtooth Crash Time in EAST Tokamak	Magnetic Confinement Fusion	Ziwei	Qiang
340	P4a.116	Study on impurity suppression using resonant magnetic perturbations and on-axis electron cyclotron resonance heating in EAST	Magnetic Confinement Fusion	liang	he
390	P4a.119	The properties of supersonic molecular beam injection in H-mode, L-mode and I-mode plasmas	Magnetic Confinement Fusion	jing	chen
416	P4a.120	Impact of ICRF heating on core impurity transport in NBI-heated LHD plasmas	Magnetic Confinement Fusion	Naoki	Tamura
109	P4a.123	An interpretable, transferable and real-time disruption predictor in HL-2A based on deep learning	Magnetic Confinement Fusion	Zong Yu	Yang
353	P4a.124	Potential profiles and transient response in H and D plasmas of the LHD	Magnetic Confinement Fusion	Masaki	Nishiura
609	P4a.125	Quasi-static modeling of two-dimensional adiabatic compression of FRC plasmas	Magnetic Confinement Fusion	Abba	Alhaji Bala
385	P4a.201	Optimization of γ-photon sources using near-critical density targets towards electron-positron pairs generation through the linear and nonlinear Breit-Wheeler processes	Beam Plasmas and Inertial Fusion	Iuliana-Mariana	Vladisavlevici
431	P4a.202	Sources of electrons, positrons and gamma-rays from lasers within plasma channels	Beam Plasmas and Inertial Fusion	Marija	Vranic
441	P4a.203	Conditions for QED cascade development in counter-propagating Laguerre-Gauss beams	Beam Plasmas and Inertial Fusion	Anthony	Mercuri-Baron
455	P4a.204	Probing Strong Field QED in beam-plasma collisions	Beam Plasmas and Inertial Fusion	Aimé	Matheron
485	P4a.205	Concepts for studying strong-field QED using laser-electron colliders	Beam Plasmas and Inertial Fusion	Christoffer	Olofsson
504	P4a.206	Positron acceleration in plasma waves driven by non-neutral fireball beams	Beam Plasmas and Inertial Fusion	Thales	Silva
286	P4a.207	Deterministic and Stochastic Radiation Reaction in Focused Laser-Electron Scattering	Beam Plasmas and Inertial Fusion	Oscar	Amaro
395	P4a.301	Volatile Organic Compounds deplation by Surface Dielectric Barrier Discharge	Low Temperature and Dusty Plasmas	Cecilia	Piferi
465	P4a.302	Can we study turbulence in fluid complex plasmas?	Low Temperature and Dusty Plasmas	Prapti	Bajaj
470	P4a.303	Step- and pulse excitation methods for the characterization of a dust particle confined in a RF plasma	Low Temperature and Dusty Plasmas	Armin	Mengel
29	P4a.402	Sandpile on a network as a model for geomagnetic activity	Basic, Space and Astrophysical Plasmas	ALEJANDRO	Zamorano
56	P4a.403	Using wavelet analysis to scale plasma fluctuations in the MHD range of solar wind turbulence seen by Parker Solar Probe	Basic, Space and Astrophysical Plasmas	Xueyi	WANG
256	P4a.404	How flux rope heating affects solar prominence formation	Basic, Space and Astrophysical Plasmas	Nicolas	Brughmans
274	P4a.405	Coronal Magnetic Field Extrapolation Using a Specific Family of Analytical 3D Magnetohydrostatic Equilibria — Practical Aspects	Basic, Space and Astrophysical Plasmas	Lilli	Nadol
297	P4a.406	Impact of trapped particles on the plasma sheath around infinitely-long electron-emitting objects in Maxwellian plasmas	Basic, Space and Astrophysical Plasmas	Luca	Chiabò
332	P4a.407	Localization of 3-D kinetic Alfven wave and turbulent spectra in the solar corona region	Basic, Space and Astrophysical Plasmas	Garima	Patel
445	P4a.408	Inference of physics state variables from simulations. A new paradigm	Basic, Space and Astrophysical Plasmas	Richard	Marchand
479	P4a.409	Force-free Collisionless Current Sheets: A Systematic Method for Adding Asymmetries	Basic, Space and Astrophysical Plasmas	Lilli	Nadol
612	P4a.409	Plasma density depletion caused by inhomogeneous stochastic electric fields	Basic, Space and Astrophysical Plasmas	Dmitry	Chibisov
605	P4a.411	Expanding Hydrogen plasma in diverging Magnetic fields in an ECR based Large Volume Plasma System	Basic, Space and Astrophysical Plasmas	Shweta	Sharma

Nonlinear interaction between toroidal Alfvén eigenmode and tearing mode on HL-2A tokamak

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Experiments related to nonlinear interaction between toroidal Alfvén eigenmodes (TAEs) and tearing mode have been carried out on HL-2A tokamak. On one hand, it is found that nonlinear mode coupling between the two modes results in the generation of other Alfvénic sidebands with toroidal mode numbers of $n = 0, \pm1, \pm2$ ... Then two deuterogenic modes with a same mode number but propagating in different diamagnetic directions couple together and contribute to the excitation of an axisymmetric mode with frequency in the ellipticity-induced Alfvén eigenmode (EAE) frequency region [1]. Direct evidence suggests the axisymmetric modes play an energy transfer channel role during the nonlinear procedure and cause the growth of magnetohydrodynamic instability with finite toroidal mode number via beating with tearing mode. On the other hand, Off-axis sawtooth oscillations during the presence of nonlinear coupling between TAE and tearing mode are firstly observed in the plasma without two q = 2 rational surfaces [2]. The low frequency oscillations always take place during the nonlinear interaction processes and the off-axis features have been confirmed by multiple diagnostics, such as soft x-ray arrays and electron cyclotron emission imaging systems. A possible physical mechanism is proposed for interpretation of those off-axis oscillations. That is, nonlinear interaction between TAEs and tearing mode causes significant losses of fast ions though the spacial overlapped global mode structures, then makes a drop in torque and leads to rotation braking or even mode locking. When magnetic fluctuation becomes large enough during braking or locking, the resulting high amplitude saturated mode leads to subsequent or immediate collapse at the q = 2 rational surfaces.

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Detachment control with feedback impurity seeding and ECRH injection in LHD

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Divertor detachment operation is foreseen as a scheme to mitigate divertor heat load in future reactors. During the detachment phase, the impurity radiation layer is usually unstable and is needed to be stabilized to ensure safe divertor operation. In LHD, a detachment control system has been developed by using impurity gas puff and ECRH injection. The bolometer raw signal is sampled with 50kHz by cRIO-9035 (National Instruments), and the raw signal is processed by NI Linux Real-Time LabView 2019 and FPGA (Xilinx Kintex7) to be converted to radiated power. Two thresholds are defined for the impurity puff and the ECH injection, respectively. The impurity is seeded with several millisecond pulses with 5 to 10 Hz until the radiated power reaches the first threshold. The 154GHz gyrotrons are operated in a boost injection mode and injected when the radiated power exceeds second threshold to supress the radiation power and thus to avoid radiation collapse.

In NBI heated plasmas, stable divertor detachment was sustained with Ne seeding and ECH injection in the feedback-controlled mode until the end of the NBI. The achieved steady sate radiated power was 36%, while the radiation collapse occurs around 40% without the ECH feedback injection. The detachment feedback control was attempted also with Ar seeding, where the steady state radiation was 42%, which is slightly higher than the Ne seeding case. The divertor heat flux decreased at all toroidal sections. It is found that the ECH deposition at the peripheral region ($\rho = r_{eff}/a_{99} \sim 0.9$) is more effective to recover the edge temperature, and thus to avoid radiation collapse.

When we tried higher radiation fraction beyond 40%, divertor re-attachment occurred during the ECH injection phase, and the re-attachment lasted about one second until the detachment is recovered. This is considered caused by a feedback loop between the ECH injection and turn-off of impurity seeding because of the elevated radiation power due to the increased input power by addition of ECH. At the conference, dynamics of impurity radiation obtained by spectroscopy and plasma response, and a future plan of the system upgrade are presented.

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Characteristics of electron temperature profile stiffness in electron heating dominant plasmas on EAST

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In future fusion plasmas, since the birth energy of alpha particles is typically 2 orders of magnitude higher than the temperature of the DT fuel ions, they will be predominantly slowed down on electrons, so the core alpha particle heating of electrons is expected. Therefore, electron heat transport characteristics in plasmas with a core electron heating dominated are crucial for the study of magnetic confinement fusion.

Recently, a very high core electron temperature (T_e~10 keV) has been achieved using pure radio frequency (RF) waves heating in a low density plasma (central line averaged density $<n_e>$ = $1.8\times10^{19}m^{-3}$) on EAST. Due to the strong synergistic effect between two on-axis ECRH (2 × 0.4 MW) and LHW (1.8 MW), the core T_e profile becomes rather peaked. The ratio of $T_{e0}/T_{e0.8}$ after the second ECRH injection is by a factor of 2 larger than that with LHW heating only. The dependence of electron heat flux (q_e^{GB}) on the normalized electron temperature gradient (R/L_{Te}), which yields the slope of straight line to represent the profile stiffness, has been investigated. The result shows that the increase of ECRH power can increase significantly of the normalized T_e gradient at the plasma core region ($\rho < 0.6$), but does not change the T_e profile stiffness. Furthermore, a slow density ramp-up from $1.5\times10^{19}m^{-3}$ to $3.3\times10^{19}m^{-3}$ has been performed in the target plasma dominated by LHW and ECRH synergistic electron heating on EAST. According to the plasma transport analysis, three distinguishable stages, characterized with different T_e profile stiffness, in the time evolution of the plasma density climb can be identified. A stronger T_e stiffness at ρ=0.3 has been observed in the second stage, where the LHW power deposition moves away from the plasma core region following the n_e increases. A formation of internal plasma density transport barrier at ρ=0.6, accompanied by a sudden drop in core T_e and a rise in both of core density and ion temperature, has been observed for the first time during the transition from the second stage to the third stage when the central line-averaged plasma density reaches a threshold of $2.2\times10^{19}m^{-3}$. It also turns out that the density transport barrier at ρ=0.6 can be stably sustained even with a higher plasma density of $3.3\times10^{19}m^{-3}$.

Improvement of electron temperature and density evaluation in the 20 kHz Thomson scattering diagnostics on LHD

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Operation with a high-repetition-rate Nd:YAG laser started in the recent diagnostics of Thomson scattering system on the Large Helical Device (LHD) [1] in order to study fast changes of electron temperature, T_e, and electron density, n_e, profiles. This laser works in the "pulse-burst" [2] operation and in two modes of the repetition rate, one of which is 1 kHz with 30 pulses and the other is 20 kHz with 100 pulses. The scattered signals are acquired by new multi-channel fast digitizers of the switched-capacitor type, which can acquire the data with the time interval of 50 μs. Figure 1 shows an example of the data of Thomson scattering (green) which is acquired by the new digitizer. When the time-integration for evaluating of the intensity is made simply by summation, it is made between the two vertical dotted lines in Fig. 1. The background noises which are caused by the fluctuation of the light from the plasma or the reflection from the wall are observed. Moreover, a spike which is generated by the digitizer is found in the region of the time-integration. Although some large spikes can be removed by a calibration, it is difficult to remove such small spikes which appear near the signals. Therefore, as one of approximation methods, the "model fitting" method [3] is applied in order for evaluating the signal intensity. In this method, an ideal signal shape is derived by averaging of many signals from the same laser and in the same channel assuming that the signal shape doesn't depend on the intensity. In Fig. 1, the signal is well fitted with this method as shown by the red curve. In this study, improvement of the error and the scattering of the data in T_e and n_e profiles using this method is evaluated.

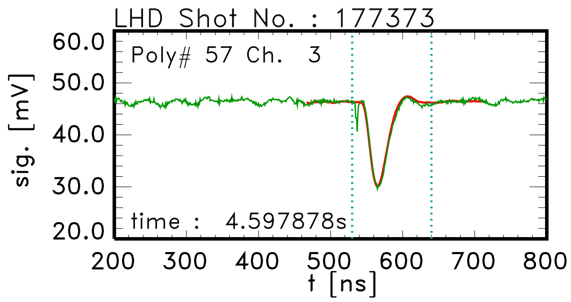

Figure 1: *An example of Thomson scattered signals (green) on LHD and approximation by the "model fitting" method (red).*

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Optimization of pressure gradient driven modes and Alfven Eigenmodes stability by the neutral beam current driven in LHD plasma

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The study consist in a set of experiments performed in the 22nd and 23nd LHD campaigns dedicated to analyze the effect of the neutral beam current drive (NBCD) on the stability of pressure gradient driven modes (PGDM) and Alfven Eigenmodes (AE) for inward shifted configurations. The NBCD modifies the iota profile, leading to the stabilization or further destabilization of the PGDM and AE. The iota profile is measured using Motional Stark Effect (MSE) and the plasma stability is analyzed using the code FAR3d [1, 2]. Discharges with large co-NBCD (Fig. 1, panel b) and high thermal β (panel a) leads to the stabilization of $n/m = 1/2$ PGDM (panel c and d) because the rational surface $1/2$ is non resonant (panel e), although the mode $3/2$ PGDM at the plasma periphery is further destabilized (panel c and d). In the discharges with large ctr-NBCD (data not shown), $1/2$ PGDM and AEs are further destabilized because the $1/2$ rational surface resonates in the plasma core, the magnetic shear is weaker and the EP β threshold decreases. FAR3d simulations reproduce the plasma stability during the discharges: $1/2$ PGDM stabilization during the iota profile up shift induced by the co-NBCD, stabilization of $1/1$ – $1/2$ Toroidal AE due to slender AE gaps and an enhanced continuum damping.

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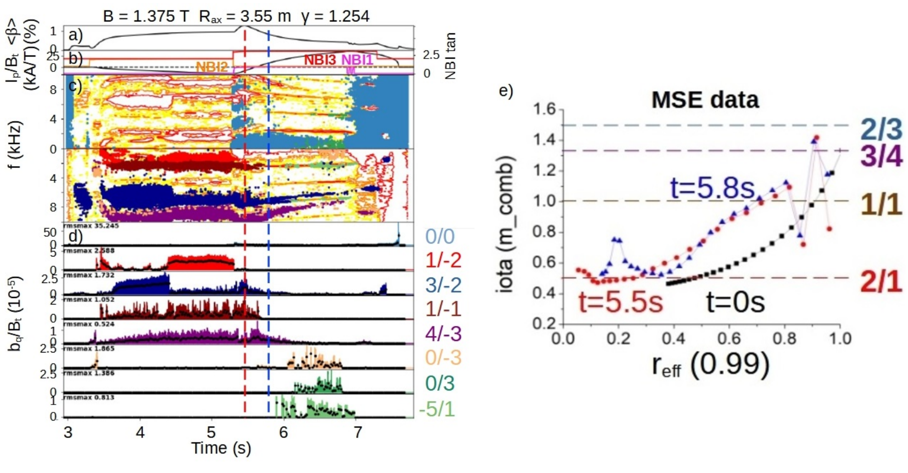

Figure 1: *(a) Averaged plasma β. (b) Plasma toroidal current and NBI heating pattern. c) PGDM frequency d) Poloidal magnetic field perturbation dominant modes. e) Evolution of the iota profile measured by MSE diagnostic.*

Self-induced transport barrier in the helium plasma on the tokamak GOLEM

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The edge transport barriers play an important role in plasma particle and energy confinement and stability in tokamaks. Therefore, the investigation of its formation is of high importance for current and future devices. There are, in general, two major ways of transport barrier formation. First, mostly in tokamaks with limiter configuration, is based on the plasma polarization by the external electric field using biasing electrode.

The second one, mostly in tokamaks with divertor configuration, relies on self-induction due to several physical processes occurring in the plasma. These processes are described in many scientific publications, but still not yet fully understood. It plays a crucial role to achieve H-mode in tokamaks with divertor configuration. In this work, we present a unique observation of the spontaneous formation of the transport barrier in helium discharge on the GOLEM tokamak. The tokamak GOLEM is a small fusion facility with limiter configuration, used primarily for plasma edge and RE studies, with remote control system [1]. The transport barrier forms a steep gradient of the electron temperature associated with a gradually increasing of the radial electric field in the narrow region in the edge plasma. The electron temperature and the plasma potential as well as the electric field are obtained using probe system on shot-to-shot basis with 5 mm of radial resolution and microsecond temporal resolution. The measurements are based on the combined ball-pen and Langmuir probe head. The calibration of ball-pen probe in helium plasma is an integral part of the work. The ball-pen probe [2] is commonly used for the plasma potential measurements at different tokamaks. The combination of the ball-pen and Langmuir probe allows us to measure both the electron temperature and plasma potential simultaneously. The additional diagnostic, double Langmuir rake probe, and the ring of Mirnov coils are also used for further fluctuation analysis of both the floating potential and the magnetic oscillations.

The process of the spontaneous formation of the transport barrier is investigated and the impact on turbulent transport is discussed in the paper. The suppression of low frequencies and decoherence of signals is observed.

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Bifurcated magnetic flux consumption during current ramp-up

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In inductively start up tokamak, limited magnetic flux from primary transformer drives the toroidal plasma current providing the confining poloidal magnetic field (inductive consumption) and ohmic heating (resistive consumption), and the remnant determines the duration for the pulse discharge. On EAST, the superconducting tokamak, ECE imaging system is adopted to trace MHD modes and the safety factor profile and furtherly current profile can be inferred during current ramp-up whose condition is poor for other current diagnostics. The flux consumed by forming poloidal magnetic field and heating the plasma can be evaluated by current profile and temperature profile evolution respectively. It is observed that the portion of flux consumption follow bifurcated paths under the same macroscopic operation condition, and discharges with different flux allocation shows various MHD stabilities features and achievable kinetic parameter. Low inductive flux consumption shapes current profile as a hollow distribution which is unstable for MHD activities, and the existence of MHD activities take up resistive consumption and restrain the thermalization.

Upgrade of the gas puff imaging system by developing a relay optical system and its application in EAST

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Abstract

The gas puff imaging (GPI) system on EAST was developed in 2012 and upgraded in 2021. A new relay optical system, consisting of a front reflecting prism, a series of lenses and a filter, is developed for the GPI diagnostic. At the end of the relay optical system, the rays are focused on a thin image surface, which is captured by the sensor of a high-speed camera. In contrast with the previous optical system of GPI in which a coherent glass fiber bundle is used to transmit the image from the end of a telescope inside the vacuum vessel to the outside, the new relay optical system has much lower light loss, i.e., the emission intensity on the image plane is much higher in the new optical system. In consequence, the temporal resolution of GPI diagnostic on EAST can be raised significantly. The analysis of the optical design denotes that the imaging quality is high enough to ensure a spatial resolution of 2 mm on the objective plane. In the spring experimental campaign of 2021, the upgraded GPI system was commissioned in EAST. Clear poloidal and radial propagations of the edge fluctuations are measured directly by GPI with a high sampling rate of 530 kHz. The poloidal and radial velocities of the edge fluctuations are derived by the time-delay cross-correlation method, with the radial velocity propagating outward, and the poloidal velocity propagating in the ion-diamagnetic drift direction in the SOL and in the electron-diamagnetic drift direction inside the LCFS.

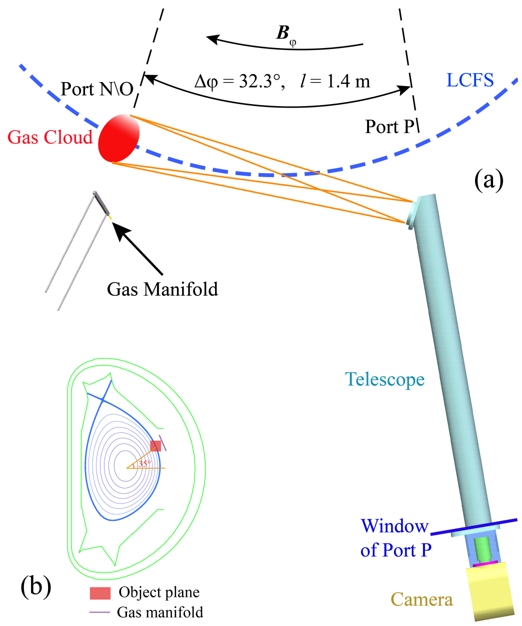

Figure 1 (a) The toroidal layout of the GPI on EAST viewed from the top; (b) poloidal layout.

Characterization of Pedestal Burst Instabilities during I-mode to H-mode Transition in the EAST Tokamak

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I-mode, featuring high energy confinement comparable to H-mode and moderate particle confinement comparable to L-mode, can be a potential candidate for future fusion devices. In EAST, the stationary I-mode regime has been identified [1]. However, it could be found that I-mode could transit to H-mode with the increase of the auxiliary heating power. Quasi-periodic pedestal burst instabilities (PBIs), which features alternative turbulence suppression and bursts, have been clearly observed by various edge diagnostics during I-H transition. The radial distribution of the phase perturbation caused by PBI shows that PBI is localized in the pedestal. Prior to each PBI, a significant increase of density gradient close to the pedestal top can be clearly distinguished, then the turbulence burst is generated, accompanied by the relaxation of the density profile, and then induces an outward particle flux. The relative density perturbation caused by PBIs is about 6 - 8%. Statistics analysis show that the pedestal normalized density gradient R/L_n triggering the first PBI has a threshold value, mostly in the range of 22-24, suggesting that a PBI triggering instability could be driven by the density gradient. These results suggest that PBIs and the density gradient prompt increase prior to PBIs can be considered as the precursor for controlling I-H transition.

Key Words: EAST, I-H transition, pedestal burst instabilities, density gradient

Reference：

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Experimental observations of RMP induced toroidal rotation accelerations on EAST

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The neoclassical toroidal plasma viscosity (NTV) effects induced by the RMP systems are shown to efficiently drive plasma rotations in recent experiments. Theory predicts that in the low-collisionality case, where the electron fulx is dominant, the NTV effect could drive co-current plasma rotations with positive "offset" rotation values [1]. These phenomena are also observed at KSTAR. As shown in the Ref. [2], the RMP systems can drive substantial rotations before the mode lock. Recent experiments on EAST show that even with mode lock occurring, RMPs can still drive co-current plasma rotations in some situations. The toroidal MHD mode spectrum are shown in Fig. 1.

It can be seen that after RMPs coil current ramp up to a threshold value, a new pattern of about 15 kHz shows in the spectrum which corresponds to the mode lock process. After the mode lock occurs, the toroidal rotation angular frequencies $V_{tor}/2\pi R$ (dot lines) increase for approximately 1.5 kHz, which is around 17 km/s on EAST. There are remarkable rotation increments in the whole region $\rho = 0.14$ to $\rho = 0.4$. Further comparisons of the experimental observation are shown in the poster. The experimental results show that RMP-induced NTV torque can act as an efficient momentum source to drag the toroidal rotations to the positive "offset" rotation values.

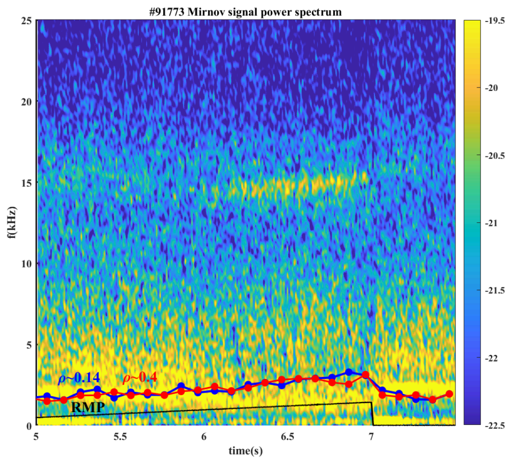

Figure 1: *Toroidal MHD mode spectrum derived from the toroidal Mirnov coils signals.*

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Alpha Particle Confinement and Losses in JET's Tritium Campaign

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JET's 2021 tritium campaign provides interesting energetic particle scenarios in which to study fast ion confinement, transport, and heating. In particular, the production of alpha particles in T-T fusion reactions presents opportunities for comparison studies against JET's recent DT-campaign. This presentation will focus on fast ion confinment and transport in a discharge from JET's T-campaign. The analysis will encompass both measurement and integrated modeling with the TRANSP [1] and ORBIT-kick [2] codes. Energetic tritons and alpha particle loss measurements will be presented and compared against a synthetic loss model [3] to study the confinement properties against an observed long-lived mode. The spatial and energy sensitivity of the losses will be detailed. Lastly, the impact of the alpha particles on the neutron rate will be briefly discussed and considered for future analysis. Additonal work will include neutron and gamma ray measurements to provide further details on the alpha and beam-born distributions.

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Parametric Dependence of Sawtooth Crash Time in EAST Tokamak

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One of the recuring problems in sawtooth oscillation is the nature of sawtooth crash. Yet, there's no research explaining the variability of sawtooth crash time: Sawtooth crash time changes with different plasma scenarios; even during the current flat top phase in a single discharge, sawtooth crash time is not constant. To explain this variability, the parameters who contribute to this variability are waiting to be found out; also, the dependence of sawtooth crash time on these parameters needs to be analysed. The electron cyclotron emission imaging (ECEI) system armed on experimental advanced superconducting tokamak (EAST) has 384 channels by 24 (vertical) × 16 (horizontal); with so many channels it can cover a two-dimensional observation area containing almost entirely of the region inside the q=1 surface of EAST. Taking the advantage of this large observation area, a method to estimate sawtooth collapse time statistically is introduced. Utilizing this method, based on a large data set, the effects of various plasma parameters on sawtooth crash time are investigated. Through analysis, the negative dependence of sawtooth crash time on heat flux ran out of q=1 surface has been observed in more than one discharge. The dependence of sawtooth crash time on Lundquist number and other plasma parameters is still under investigation.

Study on impurity suppression using resonant magnetic perturbations and on-axis electron cyclotron resonance heating in EAST

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Impurity accumulation in core of fusion plasma can cool down the plasma. For ITER, W concentrations above ~10^{-4} may lead to unacceptable radiative cooling. Therefore, how to control the concentrations of impurity in the core of plasma is crucial issues for future fusion devices. On-axis electron cyclotron resonant heating (ECRH is a proved effective method to suppress impurity accumulation. Besides, in previous study, it is also found that the impurity is suppressed with the application of resonant magnetic perturbations (RMP) in EAST [1]. Therefore, in this study, the impurity transport study by combination of RMP and on-axis ECRH. It has been found that there is a synergistic effect of RMP and on-axis ECRH for the impurity suppression. In order to obtain an optimized RMP configuration for impurity suppression, the impurity behaviours are studied with different toroidal mode number of RMP, RMP coil current, and the phase difference between upper and lower RMP coil assembly. The experimental results are also analysis in detail for different RMP configuration.

Keywords: impurity suppression, on-axis ECRH, RMP

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The properties of supersonic molecular beam injection in H-mode, L-mode and I-mode plasmas

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Supersonic molecular beam injection (SMBI) is one of the important fuelling method in fusion plasma. In this paper, the properties of SMBI in L-mode, H-mode and I-mode plasmas are studied by using BOUT++ code. The properties of SMBI with different injection parameters in L-mode and H-mode plasmas are firstly studied. And to compared the results of molecular injection depth and injection efficiency, the results show that the injection depth and injection efficiency of L-mode are significantly larger than that of H-mode. Here, the injection efficiency is defined as the ratio of the total increment of ion density to molecular injection flux. This is because that both the temperature and density in pedestal of H-mode plasma are very high which can significantly enhance the molecule dissociation rate and the charge exchange collision rate of atom and suppress the molecule injection. Therefore, for H-mode plasma SMBI is difficult to penetrate the pedestal to the core region. But are both the density pedestal and temperature pedestal the key factions to suppress the SMBI injection? The case with only temperature pedestal, which is so-called I-mode, and the case with only density pedestal are studied. It is found that in I-mode plasma, molecule injection is slightly shallow than that in the case with only density pedestal. This reveals that the plasma temperature is the more important factor to suppress the molecular injection. All these results are helpful to deeply understand the physical process of SMBI and help people to know the properties of SMBI in different confinement mode plasmas.

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Impact of ICRF heating on core impurity transport in NBI-heated LHD plasmas

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The impurity accumulation towards the plasma centre has become a severe concern in magnetic confinement fusion devices, especially in stellarators, because it can cause significant degradation of fusion reactor performance and lead to a radiative collapse of the discharges. Therefore, it is essential to develop an efficient way of controlling the number of impurities in the core plasma, especially removing the impurities from the core plasma. In LHD, we have demonstrated the mitigation of the core impurity accumulation in high-density NBI-heated plasmas by applying an additional electron cyclotron heating (ECH, P_{ECH} ~ 1.5 MW at f = 154 GHz) [1, 2]. In this contribution, we report the impact of an additional ion cyclotron resonance frequency (ICRF) heating on the core impurity transport in NBI-heated LHD plasmas. Here, we have utilized the new type of TESPELs containing an inorganic compound [3] (in particular, lithium titanite (Li_2TiO_3: Z=3, 22 and 8), silicon hexaboride (SiB_6: Z=14, 5), sodium chloride (NaCl: Z = 11, 17), and calcium aluminate ($CaAl_2O_4$: Z = 20, 13 and 8)) for studying the behaviours of low- and mid/high-Z impurities simultaneously. Line emissions from the highly ionized impurities derived from the TESPEL were measured basically with EUV/VUV spectrometers. Further, the spatio-temporal behaviours of some of those impurities can be measured using a charge exchange spectroscopy (CXS) technique. The experiments have been performed in high-density (as line-averaged electron density of ~ 5 x 10^{19} m^{-3}) NBI-heated plasmas, where the impurity accumulation has been observed. When the ICRF heating (P_{ICRF} ~ 3 MW at f = 38.47 MHz) was applied just after the TESPEL (tracer impurity) injection, the decay times of the intensities of line emissions from the tracer impurity ions became shorter, compared to the cases without the ICRF heating. However, after the ICRF heating was switched off, the intensities of line emissions from the tracer impurity ions were slightly recovered. This result indicates that ICRF power of more than 3 MW is needed to mitigate core impurity accumulation completely in the high-density NBI-heated LHD plasmas.

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An interpretable, transferable and real-time disruption predictor in HL-2A based on deep learning

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A disruption predictor based on deep learning is developed in HL-2A. It has an accuracy of 96.1% on Shot Nos. 32000-36000. Novel 1.5-D CNN + LSTM structure is used to get such a high accuracy. [1] In recent years, further investigations and updates are carried out on the basis of the original algorithm, which bring it interpretability, transferability and real-time capacity.

For the interpretability, HL-2A's algorithm give saliency maps indicating the correlation between the algorithm's input and output. The distribution of correlations shows good coherence with the disruption causes. A disruption recognizer can be realized by using Bayes theorem to inference disruption reasons by correlations distributions. [2]

For the transferability, a preliminary disruption predictor is successfully developed in HL-2M, a newly built tokamak in China. Although only 44 shots are used as the training set of this algorithm, it still gives reasonable outputs with the help of data from HL-2A and J-TEXT.

For the real-time capacity, the algorithm is accelerated to deal with an input slice within 0.3ms with the help of some adjustments on it and TFLite framework. It is implemented into the plasma control system and get an accuracy of 89.0% during online test. Figure 2 shows a demo shot where the algorithm predicted a disruption and triggered the SMBI to mitigate it. [3]

These three characteristics along with the high accuracy make the deep learning-based disruption predictor in HL-2A a new promising method for the disruption prediction in ITER.

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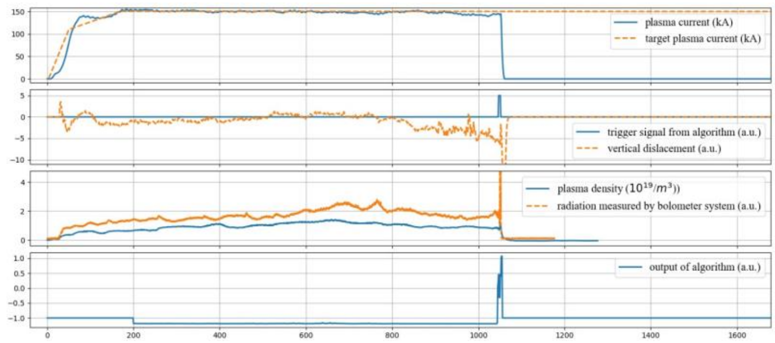

Figure 1. Demo shot for real-time disruption prediction and mitigation in HL-2A

Potential profiles and transient response in H and D plasmas of the LHD

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In laboratory plasmas, the importance of electric fields is widely appreciated for plasma confinement mechanisms. The electric field provokes the diverse phenomena; L-H transition, internal transport barrier and flow are observed in toroidal plasmas. The electric field and fluctuation can be obtained from a plasma potential and its profile measured by a heavy ion beam probe (HIBP) in the Large Helical Device (LHD). The impurity hole observed in the LHD was discussed with neoclassical theory [1]. Since the deuterium plasma experiments started in the LHD, the hydrogen isotope effect has been studied for transport physics. The isotope effect on H and D was observed with an input power per electron density P/n_e in the formation of electron transport barrier (e-ITB). The threshold of P/n_e for D plasmas was lower than that for H plasmas. In this report, the isotope effect on the potential formation and transient phenomena has been explored in farther parameter of P/n_e ~2 by the HIBP.

In a hydrogen or deuterium plasma, the electron cyclotron heating (ECH) modulated at 25 Hz is injected to produce plasmas with and without e-ITB, while the HIBP measures the time evolution of plasma potential and spatial profile under a fixed discharge condition. Above the threshold of P/n_e ~2 for the e-ITB transition observed in the LHD, the H and D plasmas have no clear difference in the potential profiles except for the decay phase after the ECH is turned off. The electron temperature from electron cyclotron emission decays faster than the local plasma potential in the core region. Inside the foot of e-ITB, the electric field does not change with and without m-ECH. On the other hand, outside that of e-ITB, the electric field increases with the ECH. The results and discussion will be presented in detail.

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Quasi-static modeling of two-dimensional adiabatic compression of FRC plasmas

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Adiabatic compression of field-reversed configuration (FRC) is among the promising paths to the compact, economical neutron sources and potential fusion reactors. The FRC equilibrium is essentially two-dimensional, however, previous theory models for FRC adiabatic compression often fail to take into account of the two-dimensional (2D) spatial and geometric features of FRC equilibrium. In this work, key scaling laws of the 1D quasi-static adiabatic compression of FRC plasma [1] are amended from 2D FRC MHD equilibriums numerically obtained using the Grad-Shafranov equation solver NIMEQ [2-3]. Based on the conservations of magnetic flux and entropy density, the quasi-static variation of the plasma pressure profile is obtained in the highly elongated FRC regime in a 1D approximation, which is then further used to construct the corresponding 2D FRC equilibriums and scaling laws for the quasi-static adiabatic compression of FRC. The amended 2D scaling laws are applied to the estimate of the upper limits of stable adiabatic compression ratio along with the empirical stability criterion for FRC.

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Optimization of γ-photon sources using near-critical density targets towards electron-positron pairs generation through the linear and nonlinear Breit-Wheeler processes

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At the interaction between an ultra-high intensity laser pulse (I > 10^{22} W/cm^2) with matter, the electrons will be accelerated up to ultra-relativistic velocities and will emit a copious amount of synchrotron gamma photons. For even higher intensities (I > 10^{24} W/cm^2), the emitted gamma photons can interact with the laser field and create electron-positron pairs by the nonlinear Breit-Wheeler process [1]. Due to the promising PW laser facilities such as APOLLON (Paris, France) and ELI-NP (Bucharest, Romania), various theoretical and numerical studies on these phenomena were performed in the last years. Studies on various absorption mechanisms using different target configurations, showed a conversion efficiency of the laser energy to gamma photons from 15% [2] up to 35% [3].

Our main goal is to investigate the high energy radiation emitted by electrons in the laser-plasma interaction, eventually leading to production of electron-positron pairs via the linear and nonlinear Breit-Wheeler processes. Through 2D Particle-in-Cell (PIC) simulations using SMILEI [4], we studied the case of an ultra-high intensity laser pulse interacting with a near critical density target. We studied the optimal parameters for the maximum conversion efficiency of the laser energy to gamma photons. In the optimal configuration, we analysed the total number of electron-positron pairs produced and the energy cut-off of the electrons, respectively positrons. We compared our results with the ones obtained by M. Lobet et al. [5][6] and we discuss their suitability for experimental campaigns.

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Sources of electrons, positrons and gamma-rays from lasers within plasma channels

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The next generation of pulsed lasers will have intensities in excess of 10^{23} $\mathrm{W/cm^2}$. While propagating through a pre-formed plasma channel, a laser of such intensity allows for direct laser acceleration (DLA) of leptons in the radiation reaction dominated regime. The DLA scheme has already been demonstrated to provide high-charge electron beams (at a $\sim$ nC level) with moderate laser intensities ($\sim 10^{20}$ $\mathrm{W/cm^2}$). In this work, we show what can be accomplished with near-future laser facilities.

We have found that increasing the laser power is bound to augment the charge content even further. The field structure formed due to electron beam loading allows for accelerating positrons. What is more, the interaction in the radiation dominated regime will provide a high flux of emitted photons, in hard x-ray and gamma-ray range. These photons can then be used as a seed for electron-positron pari creation, as well as a radiation source for applications.

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Conditions for QED cascade development in counter-propagating Laguerre-Gauss beams

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When a charge particle interacts with a laser pulse in the regime of strong field quantum electrodynamics, two main processes are of importance, hard photon emission by nonlinear Compton scattering, and electron-positron creation by nonlinear Breit-Wheeler. If the field is strong enough those two processes can in principle be coupled to achieve what is called a cascade, an exponential increase in the number of electron-positron pairs.

A recent work suggests that a cascade could be initiated with one laser pulse [1]. However the required intensity would be far beyond what is expected in the near future.

A more promising configuration involves two counter-propagating laser pulses, as discussed in several numerical and theoretical studies [2, 3, 4, 5]. However these works only consider Gaussian laser pulses. Here we present the result of 3D Particle In Cell simulations using the code SMILEI [6] in which we explore the optimal configuration to produce a cascade using Laguerre-Gauss (LG) pulses. We discuss the effect of polarisation and LG beam order in the field configuration, and study the role of the latter conjugated with the intensity in the triggering and efficiency of the cascade development.

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Probing Strong Field QED in beam-plasma collisions

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Strong Field Quantum Electro-Dynamics (SFQED) is a regime where charged particules experience very strong electro-magnetic (EM) fields leading to extreme quantum phenomena like Breit Wheeler pair generation or polarization of quantum vacuum [1]. The presence of quantum effects in these light-matter interactions becomes non negligible when the electric field experienced by charged particle in its rest frame is of the order of magnitude of the Schwinger field $E_{\text{Schwinger}} = 1.8 \times 10^{23}\,\text{V/m}$. This regime is still barely explored from an experimental point of view due to the need of extreme values of EM fields.

Several setups were proposed to reach such high values of EM fields : collision of two high-intensity laser pulses, collision of a laser pulse and an electron beam [2] and recently, collision between two highly compressed and focused electron beams [3]. In this last scenario, one uses the fact that each electron beam is a source of high EM fields. While the beam doesn't experience its own self fields, during the collision electrons from the first beam experience EM fields from the second beam and vice versa.

Here we propose a new concept to probe SFQED where a beam collides with a high-density plasma. The beam self fields are reflected and interact with the incoming beam as if the beam was experiencing fields coming from an "image" beam. This setup is particularly easy to implement experimentally since we only need one beam saving us from aligning two micrometer-scale beams. We demonstrate that we may be able to reach EM fields exceeding $E_{\text{Schwinger}}$ in the electron rest frame, thus creating copious amount of electron-positrons pairs that could be measured experimentally. We discuss several physical processes taking place during the beam-plasma collision such as field ionisation when starting from a solid state, plasma transparency when the bunch length is too small, excitation of a blowout cavity in the bulk of the plasma for overdense electron beams, and the influence of the beam shape on reflected fields.

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Concepts for studying strong-field QED using laser-electron colliders

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Current and upcoming laser facilities in combination with laser-driven or conventional electron accelerators open up an opportunity for probing and studying the processes of quantum electrodynamics (QED) in extreme regimes of strong electromagnetic fields [1, 2]. These regimes are characterized by the quantum nonlinearity parameter $\chi \gg 1$ and can reveal signatures of unexplored physics beyond the conjectured breakdown of perturbative methods at $\chi \gtrsim 1600$. Nevertheless, in the required range of field intensities and electron energies the interaction can lead to cascaded generation of electrons, positrons and photons at $\chi \lesssim 1$, which obscures the sought after signal. In our work we propose and assess optimised geometries and concepts that provide a way to differentiate and separate informative signals formed by electrons that have emitted only one high-energy photon and at $\chi \gg 1$ or by photons emitted by original electrons at $\chi \gg 1$ [3]. We analyse prospects for making statistical inferences and consider how machine learning methods can be used to reinforce the studies. Our analysis offers a framework for statistical studies of strong-field QED and outlines criteria for designing corresponding experiments at the existing and future facilities in a wide range of parameters, including electron energies from 100 MeV to 1 TeV and laser powers from 100 TW to 100 PW.

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Positron acceleration in plasma waves driven by non-neutral fireball beams

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Plasma-based positron acceleration is a long-standing challenge to the advanced accelerators community in the pathway to a compact electron-positron collider. Due to the electron and ion mass discrepancy, non-linear plasma waves are not symmetric concerning the acceleration of positive or negative charged particles; the ion column behind the plasma wave driver is focusing for electrons and defocusing for positrons. Possible solutions typically rely on changing the plasma or driver profile to drive topologically shaped plasma waves. Some of the most prominent solutions rely on hollow laser beams [1] or electrons beams [2] as drivers of the wakefield structure.

One concept that has recently drawn attention in the context of plasma micro-instabilities is the fireball beam [3], which consists of spatial overlap between an electron and a positron beam. This work shows that standard Gaussian, non-neutral fireball beams in certain conditions evolve self-consistently to a hollow shape electron beam with the positron beam focused on-axis, thus enabling the conditions for stable positron acceleration studied in [1, 2].

We use theory and particle-in-cell simulations to describe the physics behind the hollow beam formation. We also demonstrate stable positron acceleration with the scheme, perform a systematic tolerances study, and show the analogous system with a laser replacing the electron beam.

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Deterministic and Stochastic Radiation Reaction in Focused Laser-Electron Scattering

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The energy losses of electrons arising from the emission of radiation will be a standard feature in upcoming experiments using PW optical lasers. While several studies have addressed this issue in an idealized setting of scattering of electrons with a Plane Wave, few analytical models have been developed for the collision with focused laser pulses. In this case, not all electrons will interact with the same peak laser field due to spatio-temporal synchronization effects. However, it is possible to estimate the effective laser intensity of interaction for each fraction of electron ensemble. This allows the generalization of scaling laws previously derived in the context of a Plane Wave setup to more realistic geometries including 3D effects.

Recently, we have shown that the positron yield in focused laser-electron scattering can indeed be estimated by adapting a scaling law derived for Plane-Wave scattering [1].

In this work, we develop a semi-analytical model to predict the final electron distribution function using both Classical and Quantum Radiation Reaction description, including several non-ideal features such as offsets from the laser focus, interaction at an angle, non-monoenergetic beams, and focusing.

This model may be used to support experiments in the future, namely when searching for specific signatures of Quantum Radiation Reaction.

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Volatile Organic Compounds deplation by Surface Dielectric Barrier Discharge

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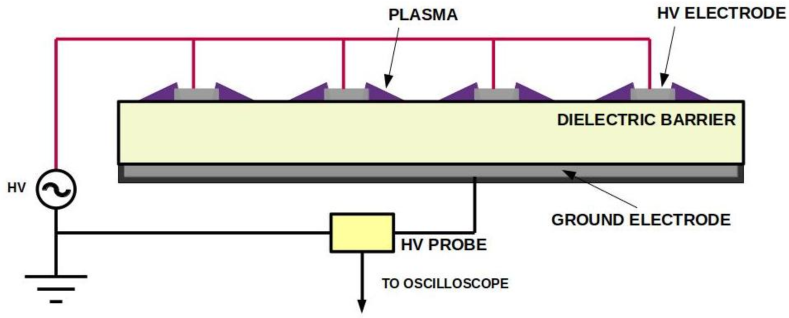

Figure 1: *Sketch of the modeled SDBD reactor.*

The use of Surface Barrier Dielectric Discharge (SDBD) is increasing in different application fields, such as the removal of volatile organic compounds or pathogenic organisms from air.

The aim of this work is to study the Volatile Organic Compounds (VOCs) depletion using a SDBD plasma device in asymmetrical geometry [1].

Further research is needed in order to understand which are the mechanisms responsible for the depletion processes and therefore being able to increase the abatement efficiency.

We evaluate VOCs decomposition efficiency as a function of plasma power, VOCs concentration and treatments time. We also studied the intermediate species produced by the primary VOCs and its interaction with the plasma.

The experiment is performed in order to study the chemical kinetics towards the chemical equilibrium of the VOC species.

We correlated the O_3 and NO_2 production gases with the VOCs depletion time rates during the treatment.

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Can we study turbulence in fluid complex plasmas?

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Turbulence is ubiquitous in nature and yet, it is far from being completely understood [1]. Complex plasmas are micrometre particles in a plasma environment of electrons, ions and neutral atoms. As they accumulate high negative charge due to higher mobility of electrons than ions, they interact with each other to produce collective behaviours, similar to many macroscopic systems. Thus, they provide a model system to study many fundamental problems like turbulence at a microscopic level. As these particles are relatively large and move comparatively slowly, we track them with high-speed imaging techniques of the ground-based PK-3 Plus laboratory [2] where our experiments are performed. We use dust acoustic waves, self-excited by the two-stream instability of ions moving past microparticles, to study turbulence. Due to considerable constant damping caused by the neutral drag force that slows down the microparticles as they collide with neutral atoms, it is necessary to study whether turbulence cascade can be observed before it is damped out. Here, we demonstrate that it is feasible to study turbulence in fluid complex plasmas even in the presence of constant background damping. In Fig. 1, an experimental snapshot is presented corresponding to the energy spectrum (red) in Fig. 2 with a power law of -1.3 (blue). In Fig. 2, we can also see that the cascade rate (green) is higher than the damping rate (pink) for a substantial range of wavenumbers, thus proving that it is possible to study turbulence as the background damping does not immediately damp out a developing energy cascade.

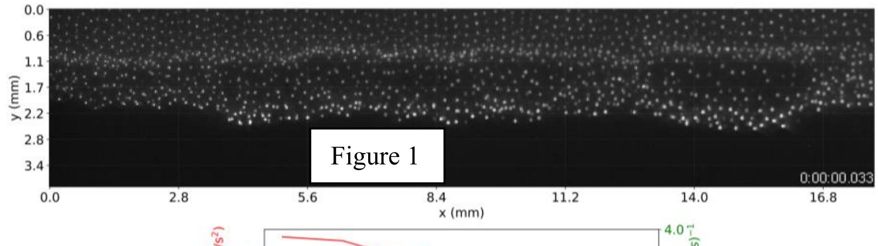
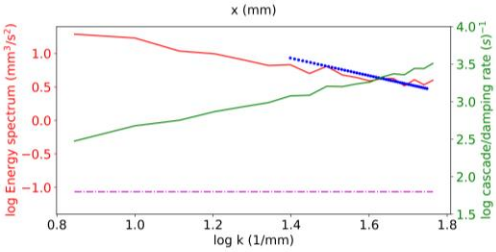


Figure 1

Figure 2



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Step- and pulse excitation methods for the characterization of a dust particle confined in a RF plasma

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The fact that a micrometer-sized dust particle trapped in the lower sheath of a RF plasma behaves like a damped harmonic oscillator is often employed for diagnostics of particle properties. Examples for such methods are the classical resonance method [1], the phase resolved resonance method (PRRM) [2], or the alteration of the particle's equilibrium position via RF power variation [3]. We present a new approach which involves only a small perturbation of the plasma parameters via an applied bias voltage on the lower electrode. This excitation signal is either a short pulse or a step, each resulting in a damped vertical oscillation (see Fig. 1) of the particle which can then be observed with a high-speed camera. From the well-known equation of motion, one can, using the system's Green function, derive the form of the particle response. This response function contains parameters such as the Epstein neutral drag γ or the eigenfrequency ω_0, which in turn contains the charge-to-mass ratio of the particle. Fitting the response function to the data yields said parameters. Implementing this method promises to yield results comparable in precision to the PRRM, which has a relative error of $< 0.1\%$ for the eigenfrequency ω_0, while being extremely fast (a few seconds per measurement).

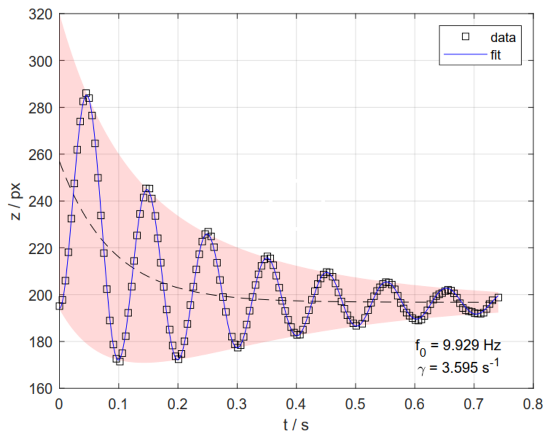

Figure 1: *damped harmonic motion of a particle*

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Sandpile on a network as a model for geomagnetic activity

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Various studies have pointed out that the Earth's magnetosphere exhibits self-organized critical (SOC) features, such as the power-law behavior of auroral indices and in-situ observations of the magnetic field in the Earth's geotail. [1] Indeed, the dynamics of the magnetosphere has the basic components expected in a SOC model: an external driver (the solar wind), slow accumulation of energy, and energy release in much shorter timescales (geomagnetic events such as substorms). Sandpile models [2] are a paradigmatic model for SOC behavior, and studies like Ref. [1] have used them to describe magnetopheric dynamics. Usually, sandpile models consider a grid of cells, and when load on a cell reaches a given threshold, it is redistributed on neighboring cells, until all loads are below the threshold, thus completing an energy release event (avalanche). However, several studies [3,4] have considered the generalized case of sandpiles on a complex network, whose nodes are loaded, and avalanches redistribute the load on their connections. Network topology modifies the SOC features, and thus it is interesting to study this in the context of magnetospheric physics, where magnetic field distortion and reconnection may modify the direction and intensity of energy release events. In this work we study a simple sandpile model as in [5,6] but now on a complex network that reconnects without breaking itself, as a first step for its application to magnetospheric dynamics.

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Using wavelet analysis to scale plasma fluctuations in the MHD range of solar wind turbulence seen by Parker Solar Probe

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The high Reynolds number solar wind flow provides a natural laboratory for the study of turbulence *in situ*. Parker Solar Probe provides opportunities to study how turbulence evolves in the expanding solar wind, and has to date executed nine sampling distances between 0.2 AU and 1 AU. We focus on data from the PSP/FIELDS [S D Bale *et al*., *Space Sci. Rev* **204**, 49 (2016)] and the PSP/SWEAP [J C Kasper *et al*., *Space Sci. Rev.* **204**, 131 (2016)] experiments, which provide magnetic field and plasma observations respectively at sub-second cadence. We have identified multiple intervals of uniform solar wind turbulence, selected to exclude coherent structures such as pressure pulses and current sheets, and in which the velocity of the primary proton population varies by less than 20% of its mean value. We focus on events of multiple-hour duration, which span the spectral scales from the approximately 1/*f* range at low frequencies, through the MHD inertial range of turbulence, and into the kinetic range which lies below the ion gyrofrequency. We perform a Haar wavelet decomposition [K H Kiyani *et al*., *Astrophys. J.* **763**, 10 (2012)] which provides accurate estimations of the exponents of these power-law ranges of the spectra, and of higher-order moments of the distributions of fluctuations, notably their kurtosis. This allows us to study how the spectral exponents may vary with distance from the sun and with solar wind conditions such as the plasma beta. We perform this analysis both for the vector components of the magnetic field and for its magnitude; these track Alfvénic and compressive turbulent fluctuations, respectively. At 1 AU, compressive fluctuations are known to exhibit scaling properties which differ from that of the individual magnetic field components [B Hnat *et al*., *Phys. Rev. E* **84**, 065401 (2011)]. Here we investigate this behaviour at different distances from the Sun, plasma beta, and proton density.

We acknowledge the NASA Parker Solar Probe Mission and the SWEAP team led by J Kasper and the FIELDS team led by S D Bale for use of data. This work received support from the RCUK Energy Programme grant no. EP/T012250/1. It was carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

How flux rope heating affects solar prominence formation.

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Prominences are cool, dense plasma clouds found in the optically thin solar corona, which makes them classical examples of condensations due to thermal instability. The levitation-condensation mechanism has been used in simulations to explain prominence formation in a flux rope, which is created through shearing and converging motions of coronal loop footpoints [1, 2]. These simulations employ two classes of background heating models for the solar corona: models based on scaling laws in which the heating rate depends on local parameters like density and magnetic field strength [3], and models with a steady background decaying exponentially with height. Two problems arise: heating based on local parameters only produces conditions favourable to in-situ condensations in case the flux rope is formed through anti-shearing motions, while an exponentially dropping heating rate ignores the complex flux rope structure consisting of field lines twisted around a central 'spine'.

We present a parametric study of these two different heating prescriptions in 2.5D simulations of prominence formation through levitation-condensation with the code MPI-AMRVAC [4]. Additionally, we propose a unified, new and dynamic heating model by identifying the flux rope during runtime and reducing the internal heating rate, as to mimic the 3D structure of the flux rope. The plane-projected flux rope structure is modelled as an ellipse centred in the flux rope centre, which is tracked using a method based on magnetic field curvature. It turns out that the two classes of heating models lead to morphologically distinct prominences. Furthermore, flux ropes with reduced heating rates produce considerably larger and more massive condensations, an essential ingredient to bridging the gap between simulation and observation. Finally, a look at the evolution of the phase space distribution provides insight in the condensation process and subsequent recovery of force balance.

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Coronal Magnetic Field Extrapolation Using a Specific Family of Analytical 3D Magnetohydrostatic Equilibria — Practical Aspects

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With current observational methods it is not possible to determine the magnetic field in the solar corona accurately. Therefore, coronal magnetic field models have to rely on extrapolation methods using photospheric magnetograms as boundary conditions. In recent years, due to the increased resolution of observations and the need to resolve non-force-free lower regions of the solar atmosphere, there have been increased efforts to use magnetohydrostatic (MHS) field models instead of force-free extrapolation methods. Although numerical methods to calculate MHS solutions can deal with non-linear problems and hence provide more accurate models, analytical three-dimensional MHS equilibria can also be used as a numerically relatively "cheap" complementary method.

We discuss a family of analytical MHS equilibria that allows for a transition from a non-force-free region to a force-free region. The solution involves hypergeometric functions and while routines for the calculation of these are available, this can affect both the speed and the numerical accuracy of the calculations. Therefore, we look into the asymptotic behaviour of this solution in order to numerically approximate it through exponential functions aiming to improve the numerical efficiency. We present an illustrative example by comparing field line profiles, density and pressure differences between the exact solutions, the asymptotic solution and a hybrid model where the use of the hypergeometric function is restricted to an area around the transitional region between the non-force-free and the force-free domain.

Impact of trapped particles on the plasma sheath around infinitely-long electron-emitting objects in Maxwellian plasmas

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The response of a collisionless, unmagnetised, Maxwellian plasma to the presence of an external electron-emitting object is a phenomenon appearing in many interesting applications. Emissive probes, charging of dust grains and current exchange at the cathodic segment of low work-function electrodynamic tethers (LWTs) are just a few examples. Simulation tools are essential to address the properties of the sheath and calculate macroscopic quantities such as collected and emitted currents, or the charge of the object. For infinitely long cylinders, stationary Eulerian Vlasov solvers based on Orbital Motion Theory (OMT) have been implemented successfully for this purpose [1]. However, stationary codes cannot provide the population of trapped particles that might arise during charging transients, and this population is typically neglected. Nonetheless, it was shown by using a non-stationary eulerian Vlasov-Poisson solver that trapped particles modify the steady-state structure of the sheath around the cylinder [2]. The present work expands the latter analysis to include electron emission. In particular, the impact of the trapped population on the Space Charge Limited (SCL) emission regime is investigated. The latter can have an important influence on the charging of an object and, under such circumstances, commonly implemented theoretical descriptions such as the Orbital Motion Limited (OML) theory become grossly inaccurate [3]. Results from a novel semi-Lagrangian Vlasov-Poisson solver are compared with a stationary Eulerian solver and verified against a well-tested PIC code for curvilinear geometries [4].

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Localization of 3-D kinetic Alfven wave and turbulent spectra in the solar corona region

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Abstract—

Magnetic reconnections and the Kinetic Alfven Waves (KAW) are expected to play important role in coronal heating but the proper methodology to describe the heating of solar corona is still being browsed by the Solar physicist. Different magnetic structures interact with the KAW to plays its role in the occurring of this dramatic Corona heating. We proposed a 3D model of Kinetic Alfven wave which is propagating in magnetic reconnection region encounters the Harris current sheet profile with taking into consideration of ponderomotive effects and non-linearity in the solar corona. This Model equation is solved numerically using the finite difference method in time and pseudospectral in spatial domain with the predictor-corrector method. The numerical simulation shows that the field structure feels a slow change without the nonlinearity whereas the presence of nonlinearity causes a rapid change. And approaching towards quasi-steady state, it generates a fully chaotic structure which are signals of turbulent filamentation with temporal evolution. We have also obtained the semi-analytical solution for these localized structures which shows the transverse scale size to be comparable to electron inertial length.

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Inference of physics state variables from simulations. A new paradigm

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For nearly a century, Langmuir probes have been the instrument of choice for measuring basic state plasma parameters, such as the density, temperature and plasma potential. In that time period numerous experiments and theories have been reported, with the objective of constructing better inference techniques for this apparently simple instrument. The number of studies made to better understand the physics of Langmuir probes speak to the importance of this diagnostic tool in lab, and more recently, in space plasma. The continuing work on this topic also speaks to the difficulty of accurately interpreting measurements made with this instrument in terms of physical parameters. The difficulties encountered here are easy to understand: Inference algorithms used so far are almost all exclusively based on analytic algorithms obtained from theoretical models. These models in turn rely on simplifying assumptions which are not fully satisfied in experiments. This then leads to inferences with uncertainties which, in the absence of independent accurate measurements, are difficult to characterize. An alternative approach which is being pursued, is to use computer models, capable of accounting for complex conditions and physical processes, which cannot be accounted for in theoretical models. Such an approach however, requires considerable computational resources, which makes it impractical in real-time applications. The solution presented here, consists of using advanced three-dimensional simulations to construct solution libraries, or synthetic data sets, from which inferences are made using adapted multivariate regression techniques. In this talk, this approach is explained and illustrated with applications to *in situ* measurements made with Langmuir probes mounted on satellites.

This work was supported by the Natural Sciences and Engineering Research Council of Canada, Compute Canada, the China Scholarship Council, the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 866357, POLAR-4DSpace), and the Research Council of Norway under grant agreements no. 275655 and 325074.

Force-free Collisionless Current Sheets: A Systematic Method for Adding Asymmetries

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Recent observations have shown that current sheets in the solar wind can have systematic spatial asymmetries in their particle density and temperature while the pressure remains constant. For one-dimensional current sheets the magnetic field has to be force-free, but known self-consistent equilibrium particle distribution functions for force-free current sheets usually lead to spatial density and temperature structures that are either constant or vary symmetrically in space. Using a specific ad hoc example, Neukirch et al. (2020) showed that it is possible to introduce spatial asymmetries into the density and temperature profiles without changing the magnetic field structure.

In this contribution, a systematic method will be presented that can in principle be used to construct particle distribution functions leading to density and temperature asymmetries of the form given in Neukirch et al. (2020). We will show how it explains why the known examples work and present some results of our attempts to find new examples.

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Plasma density depletion caused by inhomogeneous stochastic electric fields

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We consider the time evolution of the initially homogeneous spatial distribution of the plasma density in a magnetic field due to the effect of inhomogeneous turbulent electric fields. These fields in homogeneous plasma can arise as a result of the development of instabilities when nonuniform electron flows pass through the plasma. The emerging ponderomotive force pushes particles out of the region with an increased level of oscillations, which leads here to a depletion of the plasma density and cavity formation. This situation can occur both in laboratory and space plasmas. In particular, in the plasma of the ionosphere and magnetosphere of the earth, satellites and sounding rockets often observe the so-called lower hybrid cavities, axially symmetrical regions elongated along the magnetic field which are characterized by an increased level of oscillations in the region of the lower hybrid frequency, as well as a depletion of the plasma density. The study of the evolution of the plasma density distribution due to inhomogeneous electrostatic turbulence is carried out using the one-dimensional Fokker-Planck equation. The evolution of the density of ions and electrons, which are homogeneous in the initial state, is considered separately. The drift velocity and the diffusion coefficient of ions and electrons in Fokker-Planck equation are determined from the equation of motion of the particles, as averaged over a long time, the rates of the quasi-linear drift and the displacement velocity of the squared root-mean-square displacement. It is assumed that the frequency range of oscillations is near the lower hybrid frequency, so that the gyrofrequency of electrons is much higher, and the gyrofrequency of ions is much less than the frequency of plasma oscillations i.e. electrons are magnetized while ions are unmagnetized. It has been found that the drift velocity and the diffusion coefficient of guiding electron centers significantly exceed the corresponding values for ions. For a given envelope of plasma oscillations, the shape of the cavity is determined when a steady state is established. It is also shown that the formation of a plasma density cavity occurs if the particle drift velocity exceeds their thermal velocity.

Expanding Hydrogen plasma in diverging Magnetic fields in an ECR based Large Volume Plasma System

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Expansion of Hydrogen plasma from a compact μ-wave electron cyclotron resonance (ECR) based plasma source into a large volume expansion chamber was studied experimentally at different gas pressures and input powers. The compact ECR plasma source (CEPS) [1-2] is a portable cylindrical chamber (dia: 9.0 cm, length: 11.5 cm) which is enveloped by an axially-poled assembly of permanent ring magnets (NdFeB). It is mounted on the top of the large expansion chamber (dia ~ 100 cm & height ~ 100 cm) [3]. The magnet assembly generates a unique magnetic field profile inside the CEPS and a diverging field into the expansion chamber. A movable cylindrical Langmuir probe was scanned axially from the source to far downstream of the expansion chamber to study the effect of expansion on the plasma parameters, especially at the junction. Initial experiments were conducted with minimum μ-wave power ≈ 400W and at pressure of 1-5 mTorr. Uniform and moderate hydrogen plasma densities, n_e in the range of ~ 5 – 10 × $10^{10}/cm^3$ with electron temperature T_e ~ 0.5 - 3 eV, for the aforementioned pressure range, were observed, while a sharp fall in plasma potential V_p (~ 200 V in gap of 5 cm) were noticed at the junction of CEPS and expansion chamber. This steep fall is expected to accelerate ions to very high energy and overall lead to formation of a plasma beam. This feature became more visually evident when the power was increased beyond 600W. Separate plasma columns were seen to form inside the expansion chamber, rather than a diffuse flaring plasma along the diverging magnetic field, as observed at lower powers. A retarding field energy analyser (RFEA) measurement is currently underway to find the existence of these high energy ions.

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