Final Report on Deliverable

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PMU Approver	**Denis Kalupin (RO ENR)**

[1]Report must be uploaded by the deliverable owner to the specified folder, PMU RO must be chosen as report approver

Purpose and use of the report

This report is to report the achievements on project objectives after the final year, to justify payment.

A brief summary of the scientific highlights in 2018 is requested. While the report will be available to STAC the performance will be assessed by the PMU unless there are issues which require the advice of STAC.

Please indicate if there are outcomes of the project, that can contribute or deserve the attention of main Work Packages, this information will be communicated to Project Leaders.

The reports should be as brief and clear as possible, referring to publications and other information for details. However there should be enough information to support statements that deliverables have been achieved. As an indication the full ***report should not exceed 5 pages excluding this title page****. Please keep to the report format and do not attach additional information. If there are one or two particularly significant figures that are needed to demonstrate the results, these can be included in the tables.* ***This report is to be uploaded and approved through the document management system https://idm.euro-fusion.org (exact folder link is specified above).***

1. Main scientific output - summary

In 2018 the NAT team [0] continued to explore the interaction of Alfvénic modes and turbulent spectra via the generation of zonal structures (ZS) in an integrated fashion: on all fronts (analytical framework, the construction of simplified models, the hierarchical application of different non-linear codes in various geometries and the development of advanced diagnostics applicable to code output and experimental data) considerable progress is reported within this document. The links between the 6 work packages (WPs) have continued to grow resulting in various publications with common authorship from different WPs [e.g. 1-6,12,13,15,16,24-27]. These cross-WP activities can be separated in three groups: firstly, the combined effort for building reduced models [11,21,23,53] and improving the numerical tools [6,28] while checking their validity with analytical theory [5,11,28]; secondly, the acquisition and analysis of experimental data [7,12,26,27], and finally the application of toolsets for experimental analysis [26,27] to code output, i.e. synthetic diagnostics developments (see 'Final review meeting', Dec 2018 [0]). Based on these links the NAT team reached most of its envisaged milestones and deliverables in 2018, as documented in the reports below.

WP1: The complete theoretical framework describing the nonlinear dynamics of phase space zonal structures was presented at the NAT review meeting (Feb. 27th, 2018) and provided the basis for the plenary invited talk (F. Zonca et al [39]). Two journal papers are expected in 2019 from this research activity [48,49], which has produced published cross-WP results with WPDTT1/DTT2 [15,16], ER17-ENEA-10 [17,18] and ER17-CIEMAT-03 as well as MST1 Campaigns on Medium-Sized Tokamaks-6 [14,19,20,40]. The impact of these activities on the broader plasma physics research is demonstrated by the application of the theoretical framework [18] to whistler chorus emission in the Earth's magnetosphere [48]. A Vlasov-Poisson diagonally reduced model has been successfully tested against fully non-linear N-body bump-on tail (BoT) simulations. The reduced system can be described in the form of a Dyson-like equation and the shortcomings of this approach (related to the loss of self-consistency) have been outlined [21], together with a re-analysis of the quasi-linear theory and its features [22]. For the ITER 15MA baseline scenario [M.Schneller et al. PPCF 58, 014019 (2016)] EP transport and spectral evolution have been properly reproduced [50] by means of a local (linear) map between the reduced radial dimension and the velocity space of the BoT paradigm. The analysis underlines avalanches and convective spectral transfers of the addressed system. Specific features of the beam-plasma system [23,51] have been also successfully applied for the prediction of the non-linear velocity redistribution related to the EGAM dynamics [5].

WP2: The HAGIS 3-wave interaction model has been implemented in the existing code and has been successfully tested. Thanks to the new AUG data (dedicated shots on the request of NAT team), previously unreported experimental findings (interpretation of the overall plasma scenario, mode-mode coupling/triggering) were modelled and interpreted for the first time [12,53,54]. Detailed EGAM/BAE/TAE analysis employing the LIKGA code had to be performed as input to the HAGIS model. In the presence of a highly anisotropic distribution function (off-axis NBI) the modelling - including also kinetic electrons (as discussed in WP4) -turned out to be challenging [12]. The LIGKA calculated mode structures were used in 3-wave coupling HAGIS runs. First proof-of-principle results were obtained (see final review meeting [0]) and analyses with the NTI wavelet tools (see WP6) were performed. Benchmarks with XHMGC are on the way.

WP3: Within the NAT project, multiple-n simulations were performed using the hybrid gyrokinetic-MHD code XHMGC. Progress was achieved with respect to the understanding of different nonlinear coupling mechanisms, i.e. the nonlinear coupling through the kinetic EP pressure term and/or MHD wave-wave coupling. The simulations for a set of Alfvénic instabilities have shown that the EP pressure term is the dominant nonlinear coupling mechanism, which is consistent with the HAGIS-LIGKA model. Meanwhile such simulations offer useful datasets w.r.t. WP6 within the NAT framework. Another achievement is that the nonlinear generation of zonal flows is for the first time successfully simulated by a hybrid code including kinetic thermal ion effects. The zonal flow generation simulations of XHMGC can thus be compared to the HAGIS-LIGKA model.

WP4 has focused on the study of the nonlinear dynamics of zonal structures (ZS) in the presence of turbulence and energetic-particle driven instabilities. In 2018, the linear and nonlinear dynamics of ZS, i.e. GAM/ZFZF has been further investigated, both in the absence and in the presence of turbulence, and both in the absence and in the presence of Alfvénic instabilities. The following main achievements have been obtained: GAM dynamics in the presence of energetic particles (linear and nonlinear) has been studied, with particular attention to the linear properties of EGAMs and the saturation of EGAMs due to the wave-particle nonlinearity. The results have been published in [5,7,0]. An antenna, i.e. a forcing term in the gyro-kinetic equations, has been implemented in ORB5, for the study of the 3-wave interactions [8]. A dedicated PhD project (Ivan Novikau), has been started in Oct. 2016 on the topics of turbulence and ZS. So far, the linear GAM dynamics in realistic tokamak configurations, with kinetic electrons, and GAM/EGAM wave-particle resonances (with a new diagnostics

implemented in ORB5, see the dedicated slides by I. Novikau in NAT meeting July 2018 [0]) have been investigated. Moreover, the excitation of ZS by ITG modes was studied in the first pseudo-linear phase of turbulence simulations, when one ITG is dominant [13,25].
The nonlinear excitation of ZS by ITG turbulence (second deliverable) has been investigated firstly with electrostatic simulations, without EPs (see dedicated slides by I. Novikau in NAT meeting Feb 2018 [0]). The nonlinear interaction of ZS and ITG turbulence has also been investigated, in a second phase, in the presence of EPs. In this case, the EGAM dynamics in the presence of turbulence has been studied [25]. Finally, the nonlinear interaction of ZS and ITG turbulence has also been studied with electromagnetic simulations, in the presence of EPs, where both Alfvén modes and turbulence compete to excite the zonal structure [13].
A crucial numerical development of ORB5 which has made the previous simulations possible has been the implementation of the pull-back scheme, allowing for numerically more stable electromagnetic simulations [6].
WP5: In this subproject, GAMs have been studied in W7-X, HSX, LHD and QuASDEX geometries. It has been found that they are strongly damped in W7-X and HSX geometries for realistic rotational transform profiles and ion-to-electron temperature ratios. If the iota profile is strongly reduced in the W7-X, the GAM activity can be observed in the simulations. Unfortunately, these strongly reduced iota profiles would not be possible without a strong current drive in the W7-X. In the HSX, we could observe GAM activities only after a strong reduction of the ion-to-electron temperature ratio. Such conditions may occur in the electron-root regime if a strong ECRH heating is applied. In helical (LHD) and quasi-axisymmetric (QuASDEX) configurations, the GAM damping is much weaker. The oscillations can clearly be seen in simulations for experimentally relevant rotation transform and temperature profiles. The main reason for this is much smaller rotation transforms in the core regions of these configurations. This implies that the GAMs are more pronounced in the core of helical or quasi-axisymmetric plasmas and are damped stronger towards the plasma edge (opposite to Tokamaks).
Given the strong GAM damping in stellarator plasmas, we performed our fast-particle studies using low-mode-number shear Alfvén waves. We had been able to calculate fast particle driven Alfvén waves with n=1 and a realistic electron ion mass ratio in LHD. Those modes are numerically delicate as they are global (i.e. extending from the very center to the edge) and as there is an m=0 component present. The agreement with GTC and MEGA is satisfying if the approximations those codes make are taken into account. In the fully gyro-kinetic simulations, we find an EPM and an EAE mode simultaneously, while with a bulk-fluid model also present in EUTERPE, we find an odd TAE [0,45].
For non-linear calculations we engaged so far the fast CKA-EUTERPE code which calculates the mode amplitude resulting from the wave-particle power transfer for a fixed MHD mode structure (experimental W7-X application planned). Several types of collision operators and realistic distribution functions have been added to the code [28]. The dependence of the saturation level and dynamics of a single mode on collisions has been further investigated [30]. First results from the multi-mode version of CKA-EUTERPE have been obtained.
WP6: Apart from the implementation of new algorithms for poloidal mode number determination, the NTI wavelet tools have been extensively used to interpret experimental ASDEX Upgrade data, and in particular the 'AUG-NAT-EP supershot' #34924. Several time slices have been analysed in detail, showing mode-mode interaction with and without bicoherence signatures. Whereas mode-mode interaction without bicoherence could be explained by non-linear phase space triggering (BAE-EGAM-TAE), cases with significant bicoherence require large amplitudes and an exact resonance match. So far, anomalous heating or ZF-turbulence interaction could not be directly found in the available data, however, near-threshold experiments were planned and successfully proposed for further experimental studies.
The NTI tools have been used to analyse the output of HAGIS-3W and XHMGC (ORB5 in preparation). This is a crucial step for the interpretation and comparison of modelling data with the experiment. Resonance detuning and the effect of different types of non-linearities have been studied (WP2,3; final review meeting, 2018 [0]).
Outreach: Inspired by the overall research goal of this project and by the analysis of previous ASDEX Upgrade data within the NAT and NLED, a new stable high-radiation scenario has been developed on ASDEX Upgrade (Oct 2017) that is dominated by NBI-driven AEs and EGAMs. Due to the large ratio of $ß_{EP}/ß_{thermal}$, the modes exhibit large amplitudes and non-linear dynamics. This is an excellent (and to our knowledge presently the only) opportunity to validate codes for non-linear EP dynamics in NBI-driven, conventional tokamak scenarios. The discharges also attracted interest from other groups such as PPPL (M. Schneller, GTS code), NIFS (H. Wang, MEGA code), QST (A. Bierwage) and within IPP (GENE, A. di Siena[7]).
In addition, several past and present MST and ENR projects profit from the development and application of analytical theories [14,19,20,18,22] within NAT. Considerable NAT-related code developments and improvements will impact the modelling efforts on various present and future fusion devices.
Finally, comparing the complexity of experimental conditions to various limitations of present codes (magnetic axis, edge region, localised structures, coupling to vacuum region) motivated the development on unstructured mesh methods (NAT Seminar, Oct. 2018 [0]).

2. Scientific deliverables (Fully achieved deliverables from 2017 are omitted.)

Scientific deliverable *(2018 deliverables as specified in the Task Agreement)*	**Achieved: Fully/Partly/ Not**	**Evidence for achievement, brief reason for partial or non-achievement**
WP1, 2017: Derivation of nonlinear model equations for the self-consistent evolution of SAW/DAW and ZS/PSZS for the "fishbone paradigm"; generalization of resonance broadening theory **2018:** Numerical solution of model equations in the uniform plasma limit and V&V against numerical solution of Hamiltonian formulation of the "bump-on-tail paradigm". Solution of model equations in non-uniform plasmas("fishbone paradigm") and applications to ITER and DEMO	Fully/Fully	**2017:** The complete theoretical framework was presented (NAT meeting, Feb. 27th, 2018 [0]) and provided the basis for the plenary invited talk [39]. Two journal papers are expected in 2019 from this research activity [48,49], which has produced published cross-WP results with WPDTT1/DTT2 [15,16], ER17-ENEA-10 [17,18] and ER17-CIEMAT-03 as well as MST1 Campaigns [14,19,20,40]. The impact on the broader plasma physics research is demonstrated by the application of the theoretical framework [18] to whistler chorus emission in the Earth's magnetosphere [48]. **2018:** Vlasov-Poisson diagonal reduced model has been successfully tested against fully non-linear N-body BoT simulations [21], together with a re-analysis of the quasi-linear theory and its features [22]. For the ITER 15MA scenario [M. Schneller et al. PPCF 58, 014019 (2016)] EP transport and spectral evolution have been reproduced [50]. Specific features of the beam-plasma system [23,51] have been also successfully applied for the prediction of the non-linear velocity redistribution related to the EGAM dynamics ([5], with WP 4)
WP2, 2017: Formulation of the extension of HAGIS model for three-wave interaction; implementation into the existing code **2018:** Test implementation, benchmark in simple situations to other codes and apply to multi-mode TAE problem	Fully/Partly	**2017:** The 3-wave interaction model has been derived and implemented in the HAGIS code (NAT meeting, 13.12.2018 [0]). **2018:** The implementation has been tested, the output connected with the tools of WP6 (NAT meeting, 13.12.2018 [0]). A comparison with HMGC (WP3) has been started [0] but not yet completed [53]. An unexpected additional ENR NAT contribution was the dedicated AUG experiment [12,36] and the detailed kinetic modelling [10,11] in order to prepare experimental validation data for all models [12,47].
WP3, 2018: Benchmark with other models within the project, study importance of kinetic thermal ion response in comparison to MHD for the zonal dynamics	Partly	**2018:** benchmarks between codes are not yet complete (see also WP2), will continue [52]; instead, in addition: considerable effort on multiple-n simulations for understanding different coupling mechanism [41,42], as well as offering datasets to WP6 (NAT meeting, 13.12.2018 [0])
WP4, 2017: study three-wave interaction of a non-zonal instability with a ZF (ITG, Alfven mode) with ORB5, compare to analytical and simpler models **2018:** Extend study to simultaneous ITG/Alfvén/ZF dynamics and explore other turbulence regimes (KBM, TEM)	Fully/Partly	**2017:** GAM dynamics in the presence of energetic particles investigated [7,5,0]. An antenna for the study of the 3-wave interactions [8] and diagnostics for GAM/EGAM wave-particle resonances have been implemented in ORB5 [0,34]. Simulations on the excitation of ZS by ITG modes were performed [13,25]. **2018:** Non-linear interaction of ZS and ITG turbulence has been investigated in the presence of EP (electrostatic limit): EGAM dynamics studied [25]; electromagnetic studies in the presence of EPs, Alfvén modes, ITG turbulence and ZS have been performed [13]. Implementation of pull-back scheme in ORB5 [6] was crucial element to facilitate em. simulations with ORB5.
WP5, 2018: Study effects of the fast particles on the GAMs in W7-X and LHD	Fully	**2018:** study of GAM dynamics in W7-X, LHD and ‚QuASDEX' geometries [45,0]; study of Alfvén dynamics in LHD and W7-X [33] with global ZS structures present; benchmarks with GTC and MEGA[0]. Collisions and realistic distribution functions added to CKA-EUTERPE [28,29,30,32,43,44,45], multi-mode calculations started [0].
WP6, 2017: Develop a standard set of tools for the linear characterization of chirping modes, comparison to simulations; linear characterization of chirping modes on AUG **2018:** Characterize the non-linear interactions by higher order spectra and band-power; comparison to simulations; quantitative study of non-linear interactions of transient modes for detecting wave-wave coupling	Fully/Fully	**2017:** toolset successfully applied for the analysis of various AUG discharges (EGAMs, BAEs, TAE) [26,27] and the output of various codes (HAGIS/XHMGC, see NAT meeting, Dec. 13th, 2018 [0]) **2018:** Detailed bicoherence study of 'AUG-NAT-EP' super-shot (#34924); stationary and non-stationary modes investigated with clear signatures of significant bicoherence [12,36,47,54]; comparisons with code output (see above)

3. Publications/presentations: Work that have had a substantial component (>20%) from the project, marking those which are predominantly (>50%) from the project.

Publications and Conference Contributions with Proceedings in 2018:

[0] ENR NAT Team website: http://www2.ipp.mpg.de/~pwl/NAT/ENR_NAT.html
[1] Z. Lu et al, 'Mode structure symmetry breaking of energetic particle driven Beta-induced Alfvén Eigenmode', Phys. Plasmas 25, 012512 (2018)
[2] Z. Lu et al, 'Kinetic effects of thermal ions and energetic particles on discrete kinetic BAE mode generation and symmetry breaking', Nuclear Fusion, Volume 58, Number 8 (2018)
[3] Z. Lu et al, 'Theoretical studies and simulations of mode structure symmetry breaking in tokamak plasmas', Invited talk at THEORY OF FUSION PLASMAS JOINT VARENNA - LAUSANNE INTERNATIONAL WORKSHOP (2018)
[4] Z. Lu et al, ;Theoretical studies and simulations of mode structure symmetry breaking in tokamak plasmas in presence of Energetic particles', submitted to PPCF (2018)
[5] A. Biancalani, N. Carlevaro, A. Bottino, G. Montani, Z. Qiu, 'Nonlinear velocity redistribution caused by energetic-particle-driven geodesic acoustic modes, mapped with the beam-plasma system', J. Plasma Phys. 84, 725840602 (2018)
[6] A. Mishchenko, et al,'Pullback scheme implementation in ORB5', accepted for publication in Computer Physics Communications (2018)
[7] A. Di Siena, et al, 'Effect of elongation on energetic particle-induced geodesic acoustic mode', Nucl. Fusion 58, 106014 (2018)
[8] N. Ohana, et al, "Mode excitation by an antenna in global gk simulations", J. Phys.: Conf. Ser. 1125, 012017 (2018)
[9] A Medvedeva, et al. 'High frequency edge coherent modes studied with the ultra-fast swept reflectometer on ASDEX Upgrade', submitted to Plasma Physics and Controlled Fusion (2018)
[10] Ph. Lauber and Z. Lu, 'Analytical finite-Lamor-radius and finite-orbit-width model for the LIGKA code and its application to KGAM and shear Alfvén physics', Poster at THEORY OF FUSION PLASMAS JOINT VARENNA - LAUSANNE INTERNATIONAL WORKSHOP (2018)
[11] Ph. Lauber and Z. Lu, 'Analytical finite-Lamor-radius and finite-orbit-width model for the LIGKA code and its application to KGAM and shear Alfvén physics', Journal of Physics: Conference Series; 1124 (1) 012015 (2018)
[12] Ph. Lauber et al, 'Strongly non-linear energetic particle dynamics in ASDEX Upgrade scenarios with core impurity accumulation', Oral at the 27th IAEA Fusion Energy Conference, Ahmedabad, India, 22-27 October 2018, EX1/1 (100% NAT) Preprint: https://nucleus.iaea.org/sites/fusionportal/Shared%20Documents/FEC%202018/fec2018preprints/preprint0319.pdf
[13] A. Biancalani, et al, 'Self-Consistent Gyrokinetic Description of the interaction between Alfven modes and turbulence', Poster at the 27th IAEA Fusion Energy Conference, Ahmedabad, India, 22-27 October 2018, TH/P2-9; Preprint: https://nucleus.iaea.org/sites/fusionportal/Shared%20Documents/FEC%202018/fec2018-preprints/preprint0655.pdf
[14] J. Galdon-Quiroga et al., 'Impact of an edge resonant transport layer on fast-ion confinement in the ASDEX Upgrade tokamak', Poster at 27th IAEA Fusion Energy Conference, 22-27 October 2018, Gandhinagar, India
[15] T. Wang, Z. Qiu, F. Zonca, S. Briguglio, G. Fogaccia, G. Vlad and X. Wang, 'Shear Alfvén fluctuation spectrum in divertor tokamak test facility plasmas', Phys. Plasmas 25, 062509, (2018)
[16] T. Wang, X. Wang, S. Briguglio, Z. Qiu, G. Vlad and F. Zonca, 'Nonlinear dynamics of Shear Alfvén fluctuations in Divertor Tokamak Test facility plasmas', To be published in Phys. Plasmas, Jan. 2019
[17] M. V. Falessi and F. Zonca, 'Gyrokinetic theory for particle and energy transport in fusion plasmas', Phys. Plasmas 25, 032306 (2018)
[18] M.V.Falessi and F.Zonca, 'Transport theory of phase space zonal structures', subm. Phys. Plasmas
[19] L. Sanchis et al, Plasma Phys. Control. Fus. 61, 014038 (2019)
[20] M. Garcia-Munoz, 'Active Control of Alfvén Eigenmodes in Magnetically Confined Toroidal Plasmas', to be published in Plasma Phys. Control. Fus.
[21] N. Carlevaro, F. Finelli, G. Montani, 'Reanalysis of the beam-plasma instability using the Dyson-like equation formalism', submitted to EPL (2018)
[22] G. Montani, F. Cianfrani, N. Carlevaro, 'Quasi-linear model for the beam-plasma instability: analysis of the self-consistent evolution', submitted to Plasma Phys. Control. Fus. (2018)
[23] N. Carlevaro, G. Montani, F. Zonca, 'Resonance overlap and non-linear velocity spread in Hamiltonian beam-plasma systems', 45th EPS Conf. on Plas. Phys. 42A, P5.1067; http://ocs.ciemat.es/EPS2018PAP/pdf/P5.1067
[24] F. Palermo, et al., 'Complex-eikonal description of geodesic acoustic mode dynamics', 45th EPS conf. on Plasma Phys., Prague, Czech Republic, 2-6 July 2018, P1.1100, http://ocs.ciemat.es/EPS2018PAP/pdf/P1.1100.pdf
[25] A. Biancalani, et al, 'Nonlinear gyrokinetic investigation of energetic particle driven geodesic acoustic modes', 45th EPS conf. on Plasma Phys., Prague. Cz. Rep., 2-6 July 2018, P2.1003, http://ocs.ciemat.es/EPS2018PAP/pdf/P2.1003.pdf
[26] P. Zs. Poloskei, G. Papp, L. Horvath, G. Por, G. I. Pokol, 'Bicoherence analysis of nonstat. nl processes', JOURNAL OF IEEE TRANSACTIONS ON SIGNAL PROCESSING, submitted , 2018
[27] L. Horvath, G. Papp and G. I. Pokol, 'Reconstruction of Rapidly Changing Amplitude of Chirping Signals Using Time-Frequency Analysis', JOURNAL OF IEEE TRANSACTIONS ON SIGNAL PROCESSING, to be subm. 2018
[28] C. Slaby, A. Könies, R. Kleiber, and J. M. García-Regaña, 'Effects of collisions on the saturation dynamics of TAEs in tokamaks and stellarators' Nuclear Fusion, 58 (8) 082018 (2018)
[29] C. Slaby, A. Könies, R. Kleiber, S. Äkäslompolo, and J. Kontula. 'Parametric study of fast-ion-driven modes in Wendelstein 7-X', Journal of Physics: Conference Series, 1125 012019 (2018)
[30] C. Slaby, A. Könies, R. Kleiber, and H. Leyh, 'On non-linear frequency chirping in connection with collisions' submitted to Nuclear Fusion (2018)
[31] A. Könies, S. Briguglio, N. Gorelenkov, T. Fehér, M. Isaev, Ph. Lauber, A. Mishchenko, D.A. Spong, Y. Todo, W.A. Cooper, R. Hatzky, R. Kleiber, M. Borchardt, G. Vlad, A. Biancalani, A. Bottino and ITPA EP TG, 'Benchmark of gyrokinetic, kinetic MHD and gyrofluid codes for the linear calculation of fast particle driven TAE dynamics', Nucl. Fusion 58, 126027 (2018)
[32] C. Slaby, A. Könies, R. Kleiber, S. Äkäslompolo, and J. Kontula, 'Numerical investigation of fast-ion-driven modes in Wendelstein 7-X' (poster). 45th EPS Conference. 2-6 July 2018, Prague, Czech Republic
[33] Ralf Kleiber, Matthias Borchardt, Michael Cole, Tamas Feher, Roman Hatzky, A. Könies, A. Mishchenko, J. Riemann,

'Global gyrokinetic multi-model simulations of ITG and Alfvénic modes for tokamaks and the first operational phase of Wendelstein 7-X', 27th IAEA Fusion Energy Conference - IAEA CN-258, 22-27 October 2018, Ahmadabad, India

Conference Contribuions (without Proceedings):

[34] I. Novikau, A. Biancalani, A. Bottino, G. D. Conway, P. Manz, P. Morel, O. D. Gurcan, E. Poli, 'Power balance analysis of the geodesic acoustic modes', at the Deutsche Physikalische Gesellschaft conference, 26.02. - 02.03.2018

[35] I. Novikau, et al, 'Linear and non-linear gyrokinetic simulations of zonal structures', Poster at the Joint Varenna-Lausanne international workshop, Varenna, Italy, 27-31 August 2018

[36] Ph Lauber, ASDEX Upgrade Programme Meeting, Ringberg 13.11.2018: Energetic Particle Physics at ASDEX Upgrade: new trends and opportunities (talk)

[37] Ph Lauber et al: 7th Research and Coordination Meeting JT60-SA Planning Meeting, Naka, 4.-8.6. 2018 (talk)

[38] Ph Lauber, et al, 'Low frequency EP driven modes in the BAE and BAAE frequency', 21th ITPA EP meeting , Lisbon, September 2018

[39] F. Zonca, L. Chen, M. V. Falessi and Z. Qiu, 'On the nonlinear dynamics of phase space zonal structures', plenary invited at the AAPPS2018 conference, Kanazawa, Nov. 12-17

[40] F. Zonca, L. Chen, M. García Muñoz and L. Sanchís-Sánchez, 'Nonlinear Wave-Particle Resonances due to Imposed Magnetic Perturbations', oral talk at the ITC27 conference, Toki, Nov 19-22

[41]X. Wang and S. Briguglio 'Progress on nonlinear dynamics of energetic particle driven Alfvén waves by (X)HMGC', 20th ITPA Topical Group on Energetic Particles Meeting 23 – 25, May 2018, ITER

[42] X. Wang, 'Update of XHMGC simulation results using DIII-D like profiles', 21st ITPA Topical Group on Energetic Particles Meeting 3- 5, September 2018, Lisbon

[43] C. Slaby, A. Könies, and R. Kleiber, 'Gyro-kinetic simulations of tokamaks and stellarators including collisions', Talk at DPG Spring Meeting. 5-9 March 2018, Erlangen, Germany

[44] C. Slaby, A. Könies, R. Kleiber, S. Äkäslompolo, and J. Kontula, 'Parametric study of fast-ion-driven modes in Wendelstein 7-X' (poster). Joint Varenna - Lausanne International Workshop on Theory of Fusion Plasmas. 27-31 August 2018, Varenna, Italy.

[45] A. Könies, A. Mishchenko, T. Windisch and the W7-X team, 'Gyro-kinetic bulk plasma effects in stellarators', 20th ITPA Topical Group on Energetic Particles Meeting 23 – 25, May 2018, ITER

In Preparation, NAT acknowledgement forseen (> 50% NAT contribution):

[46] F. Palermo, et al., 'Complex-eikonal and paraxial description of geodesic acoustic mode', to be submitted

[47] Ph. Lauber et al., 'Strongly non-linear energetic particle dynamics in ASDEX Upgrade scenarios with core impurity accumulation', to be submitted to Nuclear Fusion

[48] F. Zonca et al.,'Nonlinear dynamics and phase space transport by chorus emission', to be submitted to Rev. Mod. Plasma Phys. 2019

[49] F. Zonca et al.,'The fishbone paradigm: a reduced description for nonlinear dynamics and phase space transport in tokamaks', to be submitted to New J. Phys. 2019

[50] N. Carlevaro, G. Montani, F. Zonca, 'Mapping between the beam-plasma model and ITER relevant simulations for fast ions interacting with the Alfvénic spectrum', to be submitted to Phys. Plasmas (2018/2019)

[51] N. Carlevaro, M. Del Prete, G. Montani, F. Squillaci, 'Revised beam-plasma interaction: back-reaction on the thermal plasma and friction effects', to be submitted to Plasma Phys. Control. Fus. (2019)

[52] X. Wang et al, 'Multiple-n simulations of Alfvénic modes including zonal structures', to be submitted 2019

[53] Ph Lauber et al, 'A 3 wave interaction model for the HAGIS code and its application to strongly non-linear AE activity at ASDEX Upgrade', to be submitted 2019

[54] P. Zs. Poloskei, G. Por, G. Papp, L. Horvath, Ph. Lauber and G. I. Pokol, 'Experimental observation of the nonlinear interactions of fast-ion driven modes', to be submitted (2019)

4. Managerial aspects (optional)

Peter Poloskei left the official NAT team by January 2018; he started his PhD within the AUG team. Thus, he stayed connected to NAT project as an external collaborator. On his behalf, Gabor Por (Wigner RCP, Budapest) has joined the team (0.3ppy). He took over some of Gergo Pokol's responsibilities; Gergo Pokol's contribution decreased to 0.1ppy in 2018. The overall budget for Wigner RCP stayed constant in 2018. The use of EUROfusion Mobility in 2018 was less than expected, partially also due to the availability of mobility due to other resources (MST). Nonetheless, Mobility support was of crucial importance to facilitate and promote collaborative research activities.