MST1 High Level Topics

Each year, a EUROfusion Annual Work Plan 2017[1] is defined by the Projects Leaders, Task Force Leaders and by the Programme Management Unit. Each Work Package has the duty to define three top objectives (TO). For WP MST1 in 2017, there are:

- TO1: Explore the applicability of type-II/grassy and RMP suppressed ELM regimes as well as I-mode and QH mode to ITER and DEMO with respect to SOL density, collisionality, metal wall compatibility and target heat and particle loads.
- TO2: Increase understanding, efficiency and portability of methods for disruption mitigation and avoidance and runaway electrons control
- TO3: Explore alternative scenarios making use of novel divertor configuration to reach high P_{sep}/R with acceptable power and particle loads.

In parallel, a targeted list of 25 High Level Topics (HLT) has been predefined by the MST1 Task Force Leader and Deputy Leaders. These HLTs were presented at the Annual Work Plan 2017 preparation meeting held mid-July 2016. For each topic, the main objectives are clearly identified. HLTs contributing directly to the top three objectives will be allocated the majority of resources, but other proposals can still be made.
For each HLT listed next, we give:

- The expected numbers of years to reach the objectives.
- The Roadmap Missions headlines it relates to and if relevant, the number of the top three deliverables, it will contribute to
- The MST1 TFLs that should be contacted in case of questions.
- The main objectives to be reached.

So as to ensure that the process is not overly restrictive, there will still be some room in the call and programme for novel bright ideas that are outside the high level topics. These proposals are self-contained i.e. they will be either accepted as full or rejected. However, only a smaller fraction of the programme will be dedicated to these proposals.

[1] The Annual Work Plan 2017, will be distributed after formal approval by the GA mid -October

Topic 1: Impact of low momentum input, dominant electron heating, impurity seeding and fuelling on the ITER operational scenarios

Duration: 2017–2018
Headlines: 1.1, 2.1, 1.5, 1.6
TFL: H. Meyer, S. Coda
Main objectives:

1. Extend ITER base-line scenario to low momentum input (pure wave heating) and quantify stability limits at q95=3 and q95=3.6.
2. Investigate the impact of dominant pellet fuelling in the ITER base-line scenario.
3. Complete the studies of JET/AUG improved H-mode identity experiment and ρ* scaling.
4. Assess the impact of core MHD on particle and impurity transport.

Topic 2: ITER/DEMO compatible integrated impurity seeded scenarios development by optimisation of pedestal performance, divertor cooling and core radiation maintaining $H_{H(98,y2)} \geq 1$ in conjunction with high radiation fraction studies.

Duration: 2017-2018
Headlines: 1.1, 2.1, 1.2 / **Top deliverable:** TD3
TFL: H. Meyer, S. Coda
Main objectives:

1. Support JET DT scenario development by characterising the operational space without N_2 seeding.
2. Study the effect of multiple seeding species avoiding core dilution.
3. Assess the effect of He ash.
4. Characterise the operational space towards high Greenwald density and assess the type-I to type-III ELM transition.
5. Assess the ELM target heat loads in impurity seeded scenarios.

Topic 3: Validation of analysis techniques to determine the intrinsic torque in order to provide a robust scaling with ρ* and quantify sources contributing to intrinsic rotation.

Duration: 2017.
Headline: 1.1
TFL: H. Meyer, S. Coda
Main objectives:

1. Investigate the sensitivity of intrinsic torque determination on plasma shape with respect to the previous results of the dimensionless ρ* scan.
2. Validate experimental and analysis techniques by modelling of synthetic data and assess the sensitivity to measurement errors.
3. Study the impact of edge conditions (e.g. fuelling, ELM behaviour etc.) and core MHD activity on intrinsic torque determination and the intrinsic rotation.

Topic 4: Assessment of the applicability of type-I ELM suppression by resonant magnetic perturbations to ITER.

Duration: 2017-2018.
Headlines: 1.2, 1.7 / **Top deliverable:** TD1
TFL: H. Meyer, T. Bolzonella
Main objectives:

1. Characterise the 3D pedestal parameters, target and first wall heat loads in ELM RMP supressed regimes including fast ion losses and explore ITER relevant heat load mitigation techniques (e.g. mixed n spectra and rotating fields).

2. Characterise the operational space in density/collisionality, plasma shape and plasma rotation of full ELM suppression.
3. Work towards predictive modelling capability for ELM suppressed operation with RMPs including modelling the effects of RMPs on density and confinement properties
4. Demonstrate the compatibility of ELM suppressed regimes with shallow ITER like pellet injection.
5. Optimize the confinement in RMP driven ELM regimes with acceptable heat loads for ITER/DEMO.
6. Develop full ELM suppression on MAST-U.

Topic 5: Further characterization of "natural" no-ELM regimes at low collisionality.

Duration: 2017-2018.
Headlines: 1.2, 1.1 / **Top deliverable**: TD1
TFL: H. Meyer, S. Coda
Main objectives:

1. Extend I-mode operation towards high Greenwald fraction and low momentum input.
2. Assess the impact of divertor conditions (e.g. closed versus open, pumping) and characterise the target and first wall heat loads.
3. Develop I-mode and QH-mode scenarios in TCV and MAST-U.
4. Assess the compatibility of QH-mode operation with full metal walls.

Topic 6: Extrapolation of small ELM regimes at high density towards ITER and DEMO conditions.

Duration: 2017-2018.
Headlines: 1.2, 1.1, 2.2 / **Top deliverable:** TD1
TFL: H. Meyer, S. Coda
Main objectives:

1. Improve the understanding of SOL density/collisionality to pedestal stability with respect to type-II ELM regimes.
2. Model type-II ELM stability with 3D resistive MHD codes.
3. Develop stable operating scenarios close to the H-mode density limit with small ELMs and quantify the target heat loads.
4. Develop type-II ELM regimes on TCV and MAST-U.

Topic 7: Disruption prediction, routine avoidance and mitigation in a broad set of scenarios.

Duration: 2017-2018.
Headlines: 1.3, 1.4, 1.8 / **Top deliverable:** TD2
TFL: T. Bolzonella, S. Coda
Main objectives:

1. Improve the understanding of Massive Gas Injection (MGI) for disruption mitigation with experiments in AUG and TCV and with modelling, aiming at extending the efficiency and applicability of the method to the broadest set of high performance scenarios.
2. Demonstrate routine and robust disruption real-time avoidance via ECRH/ECCD (in AUG and TCV) and via applied magnetic perturbations (in AUG) with reliable triggers.
3. Bring the use of the RAPTOR suite as disruption avoidance suite to maturity.
4. Improve tools for disruption prediction and exploitation for real-time control.

Topic 8: Demonstrate post-disruption runaway electron beam control and extend the understanding of the runaway electron physics and of their interaction with injected gas and magnetic perturbation.

Duration: 2017-2018.

Headlines: 1.3, 1.4 / **Top deliverable:** TD2
TFL: T. Bolzonella, S. Coda
Main objectives:

1. Execute post-disruption runaway electron experiments in AUG and TCV to fully document the phenomenology of mitigation via MGI and provide a basis for modelling.
2. Advance the study of run-away electron mitigation with magnetic tools, in particular via applied magnetic perturbations (AUG) and via control of the Ohmic circuit (TCV). Exploit voluntary contribution from non-MST devices.
3. Broaden the study of runaway electrons via development and benchmarking of modelling tools, in particular in connection with mitigation experiments.

Topic 9: Assess plasma stability performance and stability control in high-beta and advanced tokamak regimes.

Duration: 2017-2018.
Headlines: 1.4, 1.8, 1.9
TFL: T. Bolzonella, S. Coda
Main objectives:

1. Adapt existing plasma stability control schemes to high-beta, advanced-tokamak regimes close to stability limits and document in particular the interaction of magnetic perturbations – especially error fields - with the plasma.
2. Document physics processes, which control MHD stability and dynamics in hybrid regimes.
3. Explore interaction between 3D magnetic field and plasma stability, in particular in in high-beta and advanced tokamak regimes.
4. Bring ECCD based NTM control to full maturity, aiming at routine application in the broadest set of scenarios.

Topic 10: W transport studies under ELM-mitigated and no/small-ELM regimes to allow mitigation of W accumulation in the core

Duration: 2017-2018.
Headlines: 1.5, 1.1, 1.4 / **Top deliverable:** TD1
TFL: A. Hakola, T. Bolzonella
Main objectives:

1. Continue and possibly extend to MAST-U the 2014-2016 experiments on AUG and TCV and determine the role of plasma heating scheme, shape, and configuration in the accumulation of W and seeding impurities.
2. Determine the effect of collisionality, plasma density, seeding, and source strength on impurity accumulation.
3. Determine the effect of poloidal asymmetries and 3D fields on impurity accumulation and couple the work with MHD stability analysis to allow mitigation of W transport.
4. Understanding the obtained results by modelling.

Topic 11: W sputtering in ICRF-heated plasmas

Duration: 2017-2018.
Headlines: 1.5, 1.1, 2.2
TFL: A. Hakola, H. Meyer
Main objectives:

1. Characterise the release of W when using the three-strap ICRF antennas of AUG.
2. Develop models for the RF sheath to explain the obtained results.

Topic 12: Throughput and pumping of particles and plasma fuelling in ITER-relevant detached plasma scenarios.

Duration: 2017.
Headlines: 1.6, 2.1, 1.1 / **Top deliverable:** TD3
TFL: A. Hakola, H. Meyer
Main objectives:

1. Investigate the compatibility of the pumping schemes with the operational window for detachment.
2. Validate improved models for neutral pressure transport under high-density conditions of a detached divertor.
3. Extend the studies to helium transport.
4. Compare shallow pellet fuelling with gas fuelling.

Topic 13: Effect of ECCD/ECH and RMPs on TAE stability and fast ion confinement.

Duration: 2017
Headlines: 1.7, 1.2 / **Top deliverable:** TD1
TFL: S. Coda, H. Meyer
Main objectives:

1. Further develop TAE suppression with ECCD/ECH and RMPs.
2. Quantify the fast-ion losses due to RMPs in ELM suppressed regimes.

Topic 14: Effect of fast-ion driven instabilities and turbulence on current drive and fast ion transport.

Duration: 2017-2018.
Headlines: 1.7, 1.4, 1.9
TFL: S. Coda, H. Meyer
Main objectives:

1. Based on existing non “fully” non-inductive MHD quiescent scenarios assess the impact of fast-ion driven instabilities on neutral beam current drive and fast ion redistribution by controlled variations of the fast-ion distribution.
    a. E.g. change of beam deposition (on/off axis, passing/trapped fraction, beam energy).
    b. Use of ICRH fast particle acceleration.
    c. Controlled modification of q-profile by ECCD.
2. Conclude the quantification of He slowing down and the confinement highly energetic particles.
3. Test the impact of turbulence on fast ion redistribution by varying E/Te.

Topic 15: Integrated control of multiple key reactor-performance quantities and entities in specific ITER scenarios.

Duration: 2017-2018.
Headlines: 1.8, 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 2.4
TFL: S. Coda, T. Bolzonella
Main objectives:

1. Include both diagnostic observers and real-time modelling.
2. Introduce and test appropriate supervisory algorithms and scarce resource allocation algorithms.
3. Incorporate feedback controlled free boundary transport simulator if available.
4. Demonstrate successful application of model-based control design techniques within an appropriate supervisory environment.
5. Apply control tools specifically to ITER discharge development, including start-up, flat top and termination for different foreseen regimes.

Topic 16: **Extension of the operating space of fully non-inductive scenarios on AUG and TCV towards higher $\beta_N \gtrsim 2.5$ and/or stationary or quasi-stationary operation.**

Duration: 2017.
Headlines: 1.9, 1.4, 1.7
TFL: S. Coda, T. Bolzonella
Main objectives:

1. Quantify the global MHD stability limits of the fully non-inductive scenarios in AUG and TCV and the interaction of plasmas with 3D fields.
2. Document performance (beta) improvement with NBH in fully non-inductive, (ECCD-driven), stationary scenarios on TCV, with and without ITBs.
3. Develop and demonstrate performance and stability control in advanced tokamak scenarios in AUG and TCV.

Topic 17: **Optimisation of seeded detachment regimes with multiple species towards high confinement, high radiation and robust control using ITER/DEMO relevant observers and actuators**

Duration: 2017 - 2018.
Headlines: 2.1, 2.4, 1.1, 1.2, 1.8, 1.6 / **Top deliverable:** TD3
TFL: H. Meyer, A. Hakola
Main objectives:

1. Explore detachment at high P_{sep}/R level (seeded assisted detachment) by impurity seeding.
2. Study simultaneous efficiency of mantle and core radiators to reach partial detachment at high density and high confinement.
3. Assess control of detachment front by use of standard diagnostics such as Bolometry and Spectroscopy or others.
4. Compare to alternative scenarios, i.e. Snowflake minus (SF-) and Super-X, to understand potential advantages of secondary X-point for radiation control.
5. Benchmark codes to predict ITER and DEMO detachment, particle and power loads, for integrated D and He plasmas scenarios including impurity seeded ones.
6. Document detailed conditions to reach detachment at highest available P_{sep}/R and close to H-Mode density limit and quantify particle and power loads to the main chamber.

Topic 18: **Heat and particle loads to the first wall characterization in detached H-mode regimes during transient events and in the presence of ELM mitigation/suppression techniques.**

Duration: 2017 - 2018.
Headlines: 2.1, 1.1, 1.2, 2.2, 2.4 / **Top deliverable:** TD3
TFL: H. Meyer, A. Hakola
Main objectives:

1. Study effects of divertor geometry on power spreading S and compare inboard / outboard heat fluxes in order to understand the transport setting the near SOL width.
2. Compare detachment in the presence of 3D fields for ELM mitigation/suppression with detachment fields.
3. Compare first wall loads and SOL width between attached and detached conditions by using upstream measurements.
4. Investigate ELM heat loads under detached conditions (reduction of ELM energy fluence due to buffering).
5. Extend studies of (4) towards SF- or other alternative concepts.

Topic 19: Gross and net erosion balance of W PFCs in the divertor region and determination of W sources in the main chamber.

Duration: 2017-2018.
Headlines: 2.2, 1.1, 1.5, 2.1
TFL: A. Hakola, H. Meyer
Main objectives:

1. Continue migration studies initiated in 2014 on AUG by using novel sample geometries and specifications as well as better diagnostics coverage of the divertor manipulator for unambiguous determination of gross and net erosion of W.
2. Determine spectroscopically W and impurity fluxes in the main chamber.
3. Investigate the effect of N seeding on the divertor and main-chamber sources, ammonia production and tritium retention.
4. Determine under which SOL conditions outer strike point region turns from erosion dominated into deposition dominated.
5. Extend the studies to helium plasmas by studying the growth and evolution of fuzz on W surfaces.
6. Modelling of the obtained gross and net erosion patterns.

Topic 20: Effect of misaligned, pre-damaged, and rough surfaces on erosion and surface modification patterns on W PFCs.

Duration: 2017-2018
Headlines: 2.2, 1.5
TFL: A. Hakola, H. Meyer
Main objectives:

1. Expose pre-damaged W and Mo PFCs to plasmas on AUG, determine erosion of marker coatings on them and propagation of surface damage.
2. Expose misaligned W samples to plasmas on AUG, determine propagation of the melt front and, with the help of better diagnostics coverage, more reliably flash melting by ELMs.
3. Investigate the effect of shaping and shadowing on the resulting erosion and damage patterns.
4. Model the processes related to melting.

Topic 21: Filamentary transport in high-power H-mode conditions and in no/small-ELM regimes to predict heat and particle loads on PFCs for future devices.

Duration: 2017 - 2018.
Headlines: 2.2, 1.1, 1.5, 2.1
TFL: A. Hakola, H. Meyer
Main objectives:

1. Use the new HHF probe on AUG to study filamentary transport under high-power H-mode conditions and under different plasma configurations (SN, DN).
2. Study the role of ELM regimes, neutral compression, and particle density in filamentary transport and related shoulder formation.
3. Identify the contribution of collisionality and seeding on filamentary transport and related shoulder formation.
4. Extend the studies to quiescent H-modes as well as to other small-ELM regimes.
5. Determine the effect of filaments and shoulder formation on target heat loads in different H-mode plasmas.
6. Investigate the effect of plasma shape and configuration on ELM-induced heat loads.

Topic 22: Applicability of wall-conditioning techniques for cleaning vessel walls.

Duration: 2017.
Headlines: 2.2
TFL: A. Hakola, S. Coda
Main objectives:

1. ICWC cleaning in connection with He campaign to quantify D release.
2. ECWC experiments on TCV to determine optimal time to recover from disruptions.

Topic 23: Improvement of predictive capability of the effect of magnetic perturbations in the divertor and SOL.

Duration: 2017 - 2018.
Headlines: 2.3, 2.1, 1.2 / **Top deliverable:** TD2
TFL: A. Hakola, H. Meyer
Main objectives:

1. Provide 3D code for proper treatment of effects of Magnetic Perturbations, benchmark with 2D codes and validate on experiments.
2. Apply to partial and full detachment regimes with 3D fields.

Topic 24: Advanced divertor detachment studies in H-mode and higher P/R and comparison to single null.

Duration: 2017 - 2018.
Headlines: 2.4, 2.1, 2.2 / **Top deliverable:** TD3
TFL: H. Meyer, S. Coda
Main objectives:

1. Quantify H-mode access in snow flake and super-X divertor configurations.
2. Measure transient heat loads due to ELMs in advanced divertor configurations.
3. Assess the stability of advanced divertor configurations with ELMs and improve vertical control during transients.
4. Develop impurity seeded detachment regimes and investigate possible control parameters.
5. Work towards predictive edge modelling codes for advanced divertor configurations.

Topic 25: Comparisons between normal and advanced divertor configurations in L-mode discharges on MAST-U and TCV.

Duration: 2017 - 2018.
Headlines: 2.4, 2.1, 2.2 / **Top deliverable:** TD3
TFL: H. Meyer, S. Coda
Main objectives:

1. Develop conventional, advanced divertor configurations in MAST-U.
    a. Develop Super-X and snow flake configurations with different connection length and flux expansion.
2. Characterise the L-mode target heat and particle flux as function of connection length at different densities.
3. Compare MAST-U results with TCV studies and modelling predictions.