Confinement studies in OP2.1 and OP2.2

Confinement related studies can be broken into the following groups:

- development of experimental methods for assessing FI confinement from available diagnostic data
- slowing-down physics
- influence of MHD instabilities on FI confinement
- FI confinement in different magnetic configurations
- scaling of FI confinement with field
- FI confinement improvement with $\beta \rightarrow$ explicit high level objective

Main Objectives Task Force I

Main Objective	Scientific Goal	Measures of success / deliverables
Exploration of reduced turbulence / high performance scenarios w.r.t. stationary plasma conditions, kinetic-, density-, and impurity-profile control	▪ Demonstrate steady-state viability of increased performance scenarios after pellet / impurity injections as well as low ECRH/NBI heated plasmas ▪ Qualify actuators for the control of profiles and impurities	▪ High plasma performance in the order of seconds, including • T_i above clamping limit (1.5 keV) • τ_E equal or better to ISS04 scaling ▪ Avoidance of impurity accumulation ▪ Assess density profile control
Exploration of heating scenarios using upgraded plasma heating capabilities (ECRH, NBI, ICRH)	▪ Extension of NBI operation space and preparation of fast ion diagnostics ▪ Observation and prediction of fast ion losses for machine safety and validation of simulations tools	▪ Demonstrate effective ion heating ▪ Exhaustive operational map of the W7-X configuration space incl. operation limits ▪ Safe operation w.r.t. NBI/ICRH induced fast ion losses ▪ Validation of fast ion loss simulation tools
Develop high beta plasma scenario by means of low field operation	▪ Development of a plasma startup scenario @ B=1.7 T employing X3 / ICRH / NBI heating ▪ Fast ion confinement at high plasma-beta	▪ Reliable plasma startup scenario @ 1.7 T ▪ Demonstration of improved fast ion confinement of W7-X at high beta ▪ Develop capability to extrapolate B-field dependency to high-field reactor operation

Connection to the high-level objectives

The final aim of FI studies is to demonstrate success of the FI optimization in W7-X, i.e. to demonstrate improvement of FI confinement with plasma pressure. However, this final step, explicitly reflected in the high-level objectives, relies on several components that should be prepared before. Thus, proposals in the following categories are implicitly connected to the same aim:

- development of high-β scenarios (TG Profiles and Scenarios)
- development of FI generation scenarios (NBI and ICRH operation), including low-field operation
- development of diagnostic methods and their use for confinement studies
- validation of FI models

Besides, though influence of MHD modes on FI confinement is not explicitly mentioned, it is a reactor relevant aspect.

Proposals 1

Proposal	Main idea and requirements	Proponent
Tomography for confinement studies	Use FI tomography to reconstruct FI distribution function, compare to modeling and conclude about confinement. Use FIDA, CTS, etc.	D. Moseev et al.
Measurement of slowing-down time	Compare slowing-down time with simulations. Scan of plasma parameters. Use NBI blips of variable length.	D. Moseev
Effect of ECCD crashes	ECCD crashes with long period. Compare FI population before and after crashes. Use FIDA, FILD detectors.	S. Bozhenkov, D. Moseev et al.
FI confinement in scenarios with AEs	Measure effect of AEs on FI distribution. Use one of established AE scenarios. FIDA and CTS to diagnose the distribution function.	S. Bozhenkov, C. Slaby et al.
Effect of core islands	Special configurations with core islands (e.g. FOM003) Vary island size with trim and control coils.. NBI blips for FI.	S. Lazerson, D.Kulla et al.
FI confinement with NBI blips	NBI blips@2.5Hz, 50% duty. Configurations: EIM, AIM, KJM, FTM, KJM001 Diagnostics? Plasma parameters scan?	S. Lazerson, D.Kulla et al.

Proposals 2

Proposal	Main idea and requirements	Proponent
FI confinement in He plasmas	NBI blip technique. Configurations: EIM, AIM, KJM, FTM, KJM001. Various levels of H/He ratio.	S. Lazerson, D.Kulla et al.
Scaling of confinement with field	Compare FI population at low and full fields. ECRH plasmas with NBI/ICRH for FI generation. Compare distribution functions and validate modelling.	?
Configurations optimized for FI	Compare good and bad configurations for FI confinement. Verify models and measurement techniques. Comparison of distribution functions and losses.	?
Effect of density peaking	Large $\|\beta'\|$ reduces prompt losses. KJM is preferred, EJM for comparison. ICRH/NBI blips in phases with peaking. 3 proposals: pellets, NBI + ECRH, peaked NBI scenarios.	J.L.Velasco, S.A. Bozhenkov et al.
FI confinement at high-β	High-performance scenario. High-mirror configuration, 1.7 T NBI-blips for FI generation.	S. Bozhenkov, et al.

Effect of density peaking on fast ion confinement (TG FI)

Main idea	• **Large |β'| should reduce prompt losses of fast ions even at *low* <β> in:**
	  • **High performance during/after pellet series injection.**
	  • **High performance in NBI plasmas with additional ECH.**
	  • **NBI plasmas with strong core density peaking.**
	• **NBI / ICRH *blips* during phase of density peaking.**
	• **<u>Experimental validation of β' effect</u>: compare (w.r.t. phase without peaking) population/losses of fast ions of energy close to their birth energy.**
	• **Analyses need to account for changes in fast ion generation, E_r effects…**

Relevance for the high level objectives	Demonstration of improved fast ion confinement of W7-X at high β (TF I) *Also: exploration of reduced turbulence scenarios (TF I)*
Magnetic configurations	KJM if possible (β' effect is stronger) and EIM
Required heating systems	ECRH / NBI + { NBI / ICRH blips }
Required diagnostics	Interferometry, TS, ECE, CXRS, energy-resolved Fast Ion Loss Detectors
Involved scientist (list incomplete and in no particular order, <u>possible proponents</u>)	<u>J. L. Velasco</u>, S. Bozhenkov, I. Calvo, O. Ford, S. Lazerson, S. Mulas…
Possible number of proposals	3