**TG Edge&Divertor**

**Subgroup Fueling & Exhaust**

**He exhaust**

**Team list:**

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**Questions:**

**He exhaust** –*Metrics* τα\*

* Is the current island divertor reactor relevant? τα\*/τE < 10-15
  + Configuration scan
  + Density scan
  + Power scan
  + Strike line/ Icc scan
  + Steep density gradient
  + Any changes when going to steady state? Possible H depletion from neutral reservoir
* What affects the He confinement time significantly? Can we control these processes?
* What scaling parameters for He exhaust allow an extrapolation to a reactor?
* What are the locally resolved confinement times in core/edge/divertor?
  + How can we distinguish them?
* Do we care about He compression?
  + Any limits to He in the main chamber as long as τα\* is feasible?
* How do we compare with tokamaks?
* Can we find a non-resonant configuration with the current target geometry?

**He removal** *– Metrics Seff,He, pHe,Divertor , ΓHe,Target*

* How can we increase the divertor neutral pressure?
  + Strike line/ Icc scan
  + Configuration scan
  + Density scan
* What are our effective pumping speeds for He?
* How can we increase the pumping efficiency of He?
* How can we increase the He neutral source in the divertor?
* What will Ar frosted cryo-pumps change?

**He retention in the SOL** *– Metrics*

* How can we retain He in the SOL?
* What is the He retention?
  + Density scan
  + Radiated power scan
  + OP1.2 results?
* What is the neutral transport after neutralization?
* How can divertor plugging be increased?
* What is the influence of CX and ionization processes on He
  + Fix temperature and try to scan density in the divertor? Fix σion, scan σCX
* What is the effect of He on sputtering? – Link to impurities

**He transport across the LCFS** *– Metrics*

* He exhaust and transport across LCFS vs. electron/ion root confinement
* What is the feasibility to measure He and other impurity densities with CXRS in the divertor?
  + What size of injection is needed for core diagnostics?
* Establish a scheme for core transport studies with He-Puff modulation
* Do we see He core accumulation in discharges with steep density gradients?

**He vs H enrichment – Route to decouple exhaust**

* Can we de-couple He from H (T) exhaust?
* What affects one but not the other?
* Is τα followingτH orτImpurities
* Differences in pumping efficiency between H and He?
* Can we increase He enrichment of pump gap vs divertor plasma ηgap/div
* Do we see changes in impurity source, with He enrichment?
  + Higher physical sputtering and higher C source?

**Tools and modeling**

* Use different gas inlet possibilities for short puff and decay measurement.
* What is the best proxy for a fusion born He particle?
* Does EMC3-EIRENE reproduce trends from power/density scans?
* Is NEOTRANSP applicable in the related collisionality regimes?

**Link to Subgroup Detachment**

* What is the influence of detachment on He confinement time and pressure?
* What is the influence of He on the achievement of detachment?
* Optimize He exhaust in detachment by control coil current

**Limits in EMC3-EIRENE modelling**

* Impurity neutrals are treated in a reduced manner compared to hydrogen neutrals in EMC3-Eirene. Helium neutrals are not treated by Eirene, only by EMC3. They are generated at a certain energy with a certain directional distribution and move in a straight line until they are ionized or they hit the wall. Since they are only treated by EMC3, they are located only in plasma grid cells. Therefore, any sort of subdivertor partial pressure measurement of Helium cannot be modeled in EMC3-Eirene (subdivertor is an Eirene-only domain). One can obtain a sort of pressure value of Helium close to the pumping gap, where plasma cells are still located. However, for Stepan's enrichment studies of the subdivertor region, a comparative enrichment factor could not be given by EMC3-Eirene. However, the information from modeling should still be useful - the larger the Helium density near the pumping gap, the more Helium we can assume would enter the pumping gap.
* Additionally for Stepan's discussion of the role of CX in keeping He neutrals close to the divertor: CX processes are not yet included in EMC3-Eirene for impurity transport. I think there is still an open question on whether they could be included only in EMC3 or whether it would have to be done by moving this to the Eirene side. There are also uncertainties in the atomic data, though I think for He CX with H there are some CX processes in the Eirene databases?
* With regards to modeling He-puffs: of course, the code is currently steady-state and therefore if one were to model the puff, the puff should be long enough to be in steady-state. For high recycling species such as Helium where we only puff shortly, we are typically assuming R=1, and thus in steady state the location information of the original puff is gone (that is, the code would not care where the Helium was puffed). One can look at the He radiation distributions with the code (keeping in mind other limitations such as no CX, no drifts, etc), but one could not get any decay times because the code is steady-state. (We plan to develop a trace time-dependent impurity transport module in the future, but this will not happen before OP2.1.)
* If we know the effective recycling coefficient of He, one could theoretically put a partial recycling coefficient in (which may not be the most applicable to He because it is more akin to wall pumping than pumping from some pumping port, as it is a probability for whether an impurity which hits the wall will be re-launched as a neutral). Then the equilibrium densities would be the steady-state puff combined with the distribution from "recycling". One could then look at changes to the radiation distribution if one were to change puffing location. But I think it makes sense to first perform the experiment and then determine if this is, in fact, needed.

Thierry:

* Is the He exhaust of the current island divertor reactor relevant? In what configuration?
* Can we de-couple He from H (T) exhaust? What affects only one but not the other?
* What physics or processes improve/hinder He exhaust? Can we control these processes?
* Do we care about He compression, or can we tolerate He in the main chamber as long as the overall effective confinement time is low enough?
* How can we retain He in the SOL?
* How can we increase the He neutral source in the divertor?
* Where do neutrals go after being neutralized? Plasma, Pumpgap, toroidal/poloidal neutral transport?
* How can we increase the exhaust of the neutral source from the strike line?

Dirk:

* What are the confinement times for helium and what parameters affect them significantly?
* What are the differences and their causes for the He confinement times in the different regions (core/edge/divertor)?
* As a tool we should use the different inlet possibilities (central gas inlet, divertor gas inlet, MPM, later He-NBI) and the different spectroscopy possibilities. Just let in a small amount of gas for a short time and follow the decay. And it would be great if we could predict and/or accompany such experiments with EMC3/Eirene calculations by Dieter.
* What is the dependence of the exhaust (He and fuel gases) on the strike line position (distance to pumping gap)?
* How we can increase the plugging of the divertor in order to prevent neutral gas leakage towards the main chamber along the baffles?

Victoria:

* What is the current compression/retention of Helium in the island divertor as seen in experiment (OP1.2b data from the WISP gauges available?)? Do we see any form of enrichment in the divertor or is Helium actually slightly de-enriched in the divertor? This is a question I hope could be partially scoped out prior to OP2.1 - we should have some data available I think.
* How does the retention of Helium in the divertor change as we move in density/radiated power fraction?
* What divertor optimization (not something that can be tested in W7-Xnecessarily) can be performed to minimize the loss of Helium compression (if it is compressed at all) as we move towards detachment?
* Is our Helium compression/exhaust capability comparable to that of a tokamak? (related to question 3, somewhat)
* Does EMC3-Eirene reproduce the trends with density/power we see in the experiment?

Dieter:

* How can we approximate in the best way the He exhaust from a DT reaction with He experiments in W7-X (which and where should He injection take place)?
* What is the influence of He on the achievement of detachment? Is this happening easier/more difficult/not?
* What is the effect of He on the neutral pressures. From one of the previous emails in this conversation I understood from Thierry that there are some neutral conductances known from the H experiments (or did I get this wrong?). What is the effect of He on these neutral conductances?
* Is there any difference in pumping efficiency between H experiments and He ones?
* What will be the effect of He on sputtering? (probably this is already (partially) known from tokamak experiments)

Felix:

* Establish a scheme for core transport studies with He-Puff modulation
* Assess feasibility to measure He (and impurity densities) with CXRS in the divertor using D (He gas puffs).
* Pumping efficiency of He.
* Identify relevant scaling Parameters for the He exhaust for extrapolation to a reactor.

Oliver:

* Effective confinement times for helium vs. energy confinement times, scaling with density and in how far can we increase density and improve this ratio
* Helium exhaust characteristics (enrichment, particle pressure, removal efficiency, effective helium confinement) vs. magnetic configuration, do we remove helium better in SDC (as we might hope)
* For a given configuration, e.g. SDC, can we optimize island shape and location by ICC to improve helium removal and still get detached plasma conditions?
* If we are able to find a non-resonant divertor mockup with the present baffle/target layout, how does helium exhaust compare to SDC?
* Helium exhaust and transport across LCFS vs. electron/ion root confinement
* Helium removal with Ar frosted cryo-pumps vs. TMP, can we simply scale to reactor relevant pumps?
* Helium exhaust and removal behavior on quasi-steady time scales, including the change of relative He/H fraction, i.e. possible H depletion from neutral reservoir
* If He enrichment occurs, do we see changes in impurity source (presumably higher physical sputtering and maybe a higher C source?)

Stepan:

* What is the He confinement time and how it can be influenced by:
  + Magnetic configuration
  + Island modification: width and position (Icc)
* The same for He pressure
* Can He confinement time be decreased more effectively than that of the fuel?  Can we increase He enrichment of pump gap vs divertor plasma eta\_gap/div?
* How is tau\_He related to the energy confinement time? Is it <0.1 of tau\_energy, as required for a reactor?
* What is the influence of detachment on He confinement time and pressure? Will it stay constant as P\_H?
* What is the influence of CX and ionization processes on He removal? (Can we fix temperature and try to scan density in the divertor  in order to  fix <sigma\_ion> and scan <sigma\_CX>? - recommended  by Felix)
* How to distinguish tau\_He\_1 vs tau\_He\_2 when He-NBI is available? What is the role of the 1st gen and 2nd gen He and how to simulate it with puffs/He-NBI?
  + Will cryo pumps increase eta\_gap/div in contrast to TMP only? What about Ar frosting?

Marcin:

* I would like to disentangle confinement time for helium in the plasma core with the recycling of He in the island divertor. Or to reformulate, how efficient is removal rate of He from the plasma edge.
* Is tau\_p for He following tau\_p of main species, impurities?
* How does these things change for three main configurations: standard, high-mirror, high-iota.

Thilo:

* What is the helium retention when puffing helium?
  + Connected to this. How much helium needs to be injected to ensure strong enough signals for the core diagnostics.
  + How does this scale with main plasma parameters.
* Only indirectly connected to exhaust. Do we see an accumulation of helium in the core in discharges with steep density gradients?
  + Connected to that. Is NEOTRANSP applicable in the related collisionality regimes.
  + How does this affect the confinement time of helium as a whole.
* Do parameter scans allow for an interpolation to a reactor, i.e. do they hint towards a regular behaviour.
* Is it feasible to have CXRS measurements using puffed helium.