WP-DTT1-ADC Technical Meeting on Physics and Engineering 2019

Fulvio Militello and the WP-ADC team

Abstract:
This document summarizes the main discussions and decisions taken at the Technical meeting on Physics and Engineering held in March 2019.

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Purpose of the meeting

The meeting was held to address engineering and physics problems that were still outstanding from 2018. In particular, the main points to discuss were: 1) the consistency of the structural calculation in the TF coils between WP-ADC and WP-MAG; 2) The feasibility of internal coils to further optimize the configurations; 3) the physics approach and the set-up of the simulations for multiflid-codes.

People attending:

Day 1 – F. Militello; S. Merriman; D. Marzullo; R. Ambrosino; P. Fanelli; G. Rubino; G. Calabro'; R. Kembleton; V. Corato (R); M. Biancolini (R); D. Boso (R); F. Girorgetti (R).
Day 2 - F. Militello; S. Merriman; R. Ambrosino; P. Fanelli; G. Rubino; G. Calabro'; R. Kembleton; Andrew Wilde (R).
Day 3 (morning) - F. Militello; S. Merriman; P. Fanelli; G. Rubino; G. Calabro'; A. Herrmann; W. Suttrop
Day 3 (afternoon) – F. Militello; F. Subba; S. Varoutis; D. Coster; D. Moulton; M. Wensing; T. Lunt; M. Wishmeier; L. Aho-Mantila (R);
Day 4 – F. Militello; F. Subba; S. Varoutis; D. Coster; D. Moulton; M. Wensing; T. Lunt; M. Wishmeier; L. Aho-Mantila (R);
Day 5 – F. Militello; F. Subba; D. Coster; D. Moulton; M. Wensing; T. Lunt; M. Wishmeier; L. Aho-Mantila (R);

Structural calculation in TF coils

During day 1 we discussed a number of issues relevant to the alignment of the TF coil structural calculations in WP-ADC with those in WP-MAG.
WP-MAG is working on the 2015 DEMO design with 18 coils. Detailed calculations include the full description of the winding pack, including insulator and jackets. A simplified calculation is carried out by smearing the internal structures of the winding pack and creating 6 macroscopic radial layers characterized by different mechanical structures.
WP-ADC is using only the latter approach, employing exactly the same material characteristics as WP-MAG. Similar boundary conditions are used by both groups on the internal wedge, where cyclic conditions, representing toroidal symmetry are employed. However, the contact between winding pack and casing is considered frictionless or with a friction coefficient of 0.3 by WP-MAG and bonded by WP-ADC. To assess the difference between the two cases, an ANSYS simulation was carried out, resulting in relatively minor differences, although the stress intensity in the bonded case was sometimes smaller in peaks (potentially by a factor almost two). Completely frictionless cases discussed by the group should lead to results similar to the 0.3 friction case.

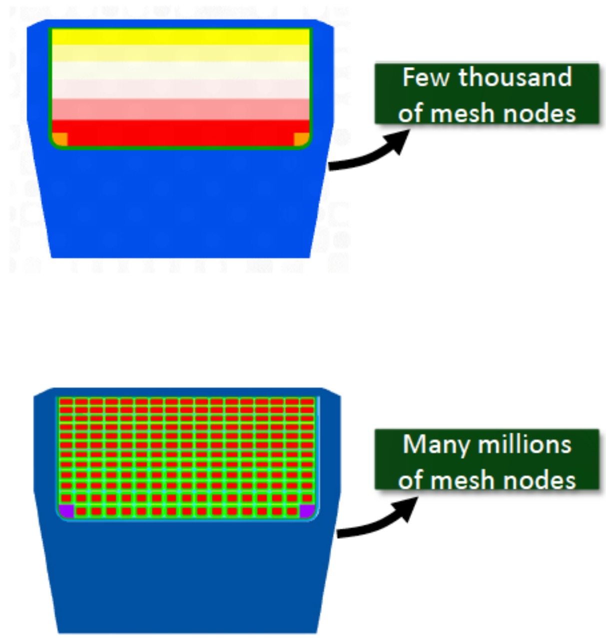


Figure 1: difference between smeared and detailed calculation

Failure criteria were discussed at length as the two groups used different assumptions.
The procedure for WP-ADC was as follows: 1) after the calculation of the principal stresses (σ_{11}, σ_{22}, σ_{33}), a stress intensity was evaluated with the following formula:

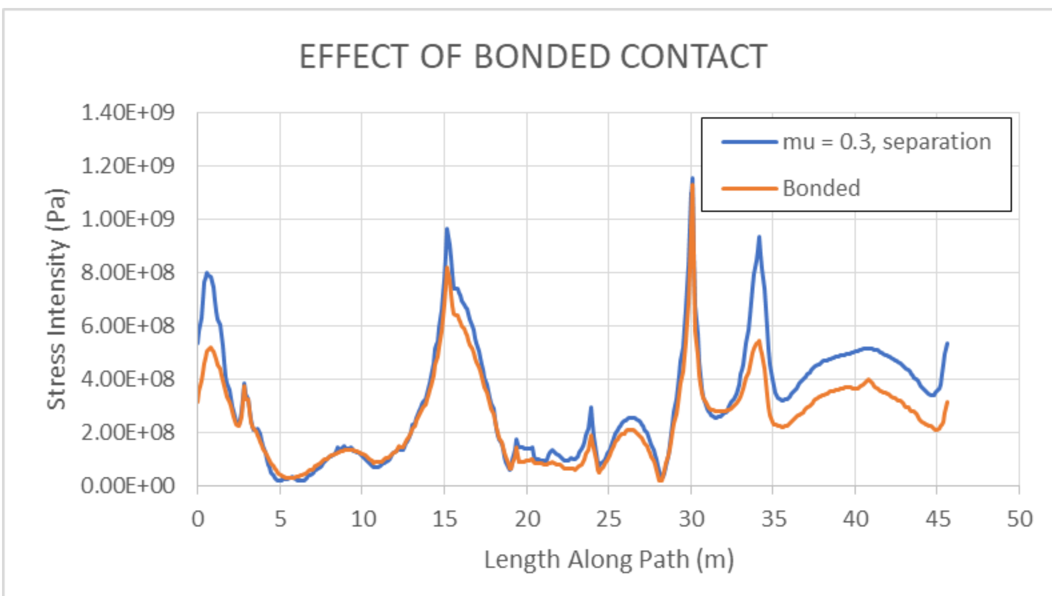


Figure 2 Stress intensity as a function of the length along a poloidal path in the TF coil for bounded and friction=0.3 cases.

$$\sigma = \mathrm{MAX}(|\sigma_{11} - \sigma_{22}|, |\sigma_{11} - \sigma_{33}|, |\sigma_{33} - \sigma_{22}|)$$

next, 2) the stress intensity is compared against S_{max}, where $\sigma=2S_{max}$, which represents the maximum shear stress that is realized at a given point by rotating the local coordinate system; 3) the maximum shear stress that leads to yield was fixed to 660 Mpa and if the stress intensity exceeded this value anywhere in the coil, the coil was said to fail. This is equivalent to satisfying the Tresca criterion.

The procedure for WP-MAG was instead: 1) calculate the principal stresses; 2) linearize them through the thickness of the component by splitting the actual stress/position function into a peak (maximum), a membrane (average) and a bending component (linear fit corresponding to the equivalent torque); 3) application of Tresca criterion on the membrane with failure limit of 660 MPa and on the membrane + bending with failure limit of 870 MPa.

Therefore, the WP-ADC criterion is more stringent since it is looking only at the peak value and with a lower failure limit.

We discussed about the possibility that the low operating temperature (-4K) might induce in the structural material a ductile to brittle transition, thus leading to different failure criteria (maximum stress). However, evidences were shown that even at low temperature the structural material retains sufficient plasticity (which is good for many reasons, among which the fact that this allows stress linearization and simplifies the analysis).

Related to this point, there was discussion about the fact that the WP-MAG limit was much higher than the WP-ADC limit. This comes from ITER steel characteristics, as tabulated in ITER's magnet structural design guidelines, which give a Yield Strength of 1000 MPa (2/3 of which gives the membrane limit in our calculations and 1.3*(2/3) gives the membrane plus bending limit according to WP-MAG practice and ITER criteria). The material is an aged variant of the 316LN steel alloy, probably corresponding to FMJJ1 (need to check properly).

Material	Yield Strength at RT [MPa]	Ultimate Strength at RT [MPa]	Yield Strength at 4K [MPa]	Ultimate Strength at 4K [MPa]	Fracture Toughness at 4K [MPa√m]
FMJJ1	300	620	1000	1450	>200
FM316LNH	280	580	900	1430	>200
FM316LNM	245	550	700	1385	>200
FM316LNL	210	520	500	1340	>200
316LN (PF/CC Structures)	245	550	700	1385	>150
Inconel 718	1000	1200	1350	1600	>75
Nitronic 50 or B4565	480 420	780 850	1350 1350	1740 2150	>180

One of the results of WP-ADC's studies was that regions of high stress occurred mainly because of Out of Plane (OoP) forces and because of compressional forces in the inner leg of the divertor. The former observation is quite important because it implies that a Princeton D-shape, aimed at minimizing the bending stresses related to the hoop force, is not a necessary requirement. Also, the second observation is quite important because these stresses are related to the high magnetic field / high current at the high field side. This might be induced to the fact that the current 16 coil design requires higher coil currents to obtain the same performance (ripple constraints require bigger coils and therefore farther away from the plasma and therefore more powerful).

There was discussion about the possibility of strengthening the inter-coil structures to stiffen the system and reduce the stresses caused by the OoP forces. At the moment the maximum thickness for the inter-coil structures is 20cm, but it is unclear how this limit was imposed by WP-PMI. Small inter-coil structures maximize the port space, but they also reduce the rigidity of the TF coil cage. A possible way to address this problem is by doing a scoping study where the characteristics of the inter-coil structures are varied, e.g. their thickness or poloidal extension. In addition, it will be useful to assess the effect of the out of plane forces with respect to the hoop force by artificially eliminating the contribution of the former from the electromagnetic loads. This will allow to clarify what is causing the highest stresses in the coil.

The TF coils will undergo fatigue effects due to the cyclic loads they are subject to. While the TF coils are likely to be on continuously, the poloidal magnetic field will not and will undergo ~20000 repetitions over the DEMO lifetime. By removing the OoP loads associated with the poloidal field, one can assess also how much the stresses would vary during the cyclic loads.

It was agreed to establish a reference simulation based on the 2015 design (since WP-MAG is focusing on this), with WP-MAG passing to WP-ADC the equilibrium (.eqdsk file), the PROCESS run used to determine the winding pack and the geometric details. Once the WP-ADC simulations will be completed, we will check that EM forces are compatible, as well as stresses in the coil. In order to determine the possible failure of the coil, WP-ADC will also need to understand the linearization technique used by WP-MAG, in particular, how to determine the linear part (e.g. how many notes are excluded after a hot spot?). In addition, a few other technical questions were identified during the discussion session, and we report here the questions that were not already addressed above:

- Could you provide more explanation of the application of cyclic symmetry and the sliding effect in the noses?
- Outer Intercoil Structure design, are they straight or do they follow the curvature of the TF?
- Is there a reference on the failure limits (807MPa for membrane + bending etc.)
- The calculation of the winding pack thickness for ADC within KDI-3
- Does the Insertion Gap and/or ground insulation get included within the graded winding pack or are they extra components?
- Is the comparison between the results of the different modelling strategies (smeared/fully detailed etc.) in the Francesco's Thesis?
- What boundary condition exist in the axial orientation?

Things to do:

1) WP-MAG provides WP-ADC with the equilibrium, WP and geometry details for the comparison of the 2015 design;
2) We clarify the failure criterion, possibly discussing it also with WP-PMI;
3) Through this exercise, we establish how each group is setting up the simulations in detail, in other words, we answer the questions above and we provide information from WP-ADC as well.
4) We carry out FEM simulations within WP-ADC with stress linearization and check the sources of the failure points.

Internal coils

On Day 2 we tackled the issue of internal coils in our alternative configurations. We discussed the limits suggested by PPPT on the coils. The general recommendation is to: 1) keep the forces within reasonable limits (around 12 MN, but flexibility will be required in a preliminary assessment); 2) consider the total size of the coil, this will be proportional to the coil current; 3) make sure that the coils allow efficient remote maintenance operations through the ports. There is also a limit on the maximum current density, which is related with the capability of the coil to remove the Ohmic heating. This constrain, however, is not independent from the force and size considerations.

It was agreed that the best option is to have water cooled copper coils as superconducting coils would require joints that are not yet technologically mature, more shielding to prevent problems with the irradiation of the insulator and more complex cryogenic systems. Coils that can be separated in sections to make their remote maintenance possible were considered, although they will provide extra technical difficulties. Redundancy would be preferred as a back-up strategy.

We discussed the fact that the coils will likely to be bolted to the vacuum vessel (unless they'll have to be removed) and should not be placed close to the fixations of the divertor cassette. The force limit is related to the maximum forces on the bolts. There was also discussion on the possibility of simplifying the divertor cassette design by just providing replaceable armoured structures where the maximum loads create damages. Putting the strike point on the lower target would therefore allow easier extraction operations and make the divertor remote maintenance easier.

An element of uncertainty is the remote maintenance scheme for DEMO, which is not yet defined for the baseline solution, which implies that no general guidelines nor a comparator are available.

The old 2015 WP-DTT1 configurations with internal coils were reviewed. In that study, the external PF coils were used to constrain the shape of the plasma to make it compatible with the baseline SN solution, while the internal coils were used to create the alternative configuration. This led to very large currents in the internal coils, of the order of several MAs.

The new approach has a completely different philosophy. Given the already calculated configurations with external coils, small internal coils will be used to alleviate some of the critical problems (stresses on the TF coils; positioning of the PF coils to give more space to remote maintenance, optimization of the physics, in particular flux expansion and secondary X-point generation). It was agreed to use two classes of internal coils, one with a maximum of 1MA and one with a maximum of 0.5MA, to scope the potential advantages they could give. The study will first tackle the ADCs in double null configuration, starting from the baseline DN design (deadline July 2019). Next, the LSN configurations will be investigated, starting with the current 2018 ADC designs. Finally, possible hybrid solutions will be explored, including mixed solutions, potential disconnected double nulls with long leg on one divertor, etc.

Things to do:

1) Deliver (by June 2019) the DN alternative configurations with internal coils (0.5MA; 1MA) starting from the PPPT DN configuration and assess the potential benefit;
2) Produce configurations with internal coils (0.5MA; 1MA) in lower single null configuration starting from the 2018 configurations with external coils only;
3) Start discussing possible hybrid configurations, such as disconnected DN with a single SXD outer leg.

Report to the Engineering Advisory Group

Day 3 started with the discussion of the engineering results with the Engineering Advisory Group. A summary of the conclusions of the previous days and of the plan going forward was presented. The Advisory group notice that friction might play a role if the TF will not be perfectly toroidally symmetric, maybe due to manufacturing or assembly imperfections. There was a suggestion to validate the simplified smeared approach versus the detailed analysis. It was noticed that WP-MAG has already done this, and the differences were not massive. It was recommended to investigate the possibility to generate simple models to describe how different the detailed structural analysis is with respect to the smeared approach. This might allow to assess the robustness of our simplified TF analysis against future and more refined calculations.

Upon request, a recommendation was made to follow ITER failure criteria. After checking the ITER guideline on “Magnet Structural Design Criteria Part 1: Main Structural Components and Welds” it was found that the linear elastic approach and the membrane/membrane plus bending approach was the selected method, exactly the one followed by WP-MAG. The only remarkable difference was the design factor in front of the membrane+bending limit, which is 1.5 for ITER and 1.3 for WP-MAG. Following discussions with Christian Vorpal confirmed that these limits are defined in the WP-MAG “Outline Magnet Design Definition” document on IDM.

Regarding the internal coils, it was suggested to pair them in order and to have opposite currents flowing in them in order to balance the forces, as done in AUG. It was suggested to consider a hybrid maintenance solution (like ITER’s), with one redundant coil, so that operations can continue until a normal shut down of the machine, where the coil that failed could be repaired.

Control of the configurations was considered to be essential as small variations in the currents, including the eddy currents flowing the in the metallic structures surrounding the plasma, can lead to significant changes in the X-point position.

The lack of analysis of disruptions in the TF coil design was considered a major deficiency, since this was the design driving force in AUG. It was recommended to give some consideration to the problem, maybe just by checking how bad is the problem in the different configurations without redesigning them.

Considerations about cost were raised. The answer was that the ADC solutions are a last resort solution and the alternative is not a cheaper reactor, but no reactor at all.

Physics questions and strategy

The afternoon of day 3 involved a detailed discussion on how to deliver physics results as soon as possible and in a as complete as possible way.

The group was informed that we will try to align as much as possible to the physics questions required by DEMO design, among which those identified by PPPT: first wall loads (in P-2) and reattachment. The latter will require to properly define detachment characteristics for all configurations in a comparative way. Detachment should be seen as a complex event that induces a roll-over of the ion flux at the target, a low temperature and a pressure loss between midplane and target. In order to properly assess these features, the study of isolated simulations is not the best approach. Instead a programme of systematic scans can allow a deeper exploration of the detachment properties (onset, depth, window, stability), similar to what is done in experiments.

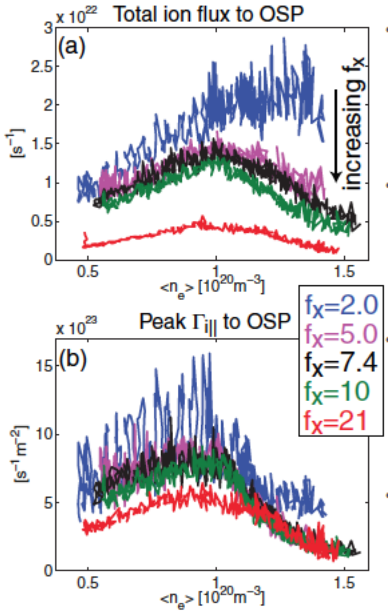


Figure 3 target ion flux rollover at different flux expansions in TCV [Theiler2017]

Due to the challenging nature of the DEMO simulations, and in particular their computational cost and length, a different approach is required to these scans. They cannot be performed serially, gradually adjusting the aim from one simulation to the next. Instead, a simulation plan needs to be carefully prepared and once it is, a set of simulations must be launched in parallel and reevaluated only once it is completed to prepare a second iteration.

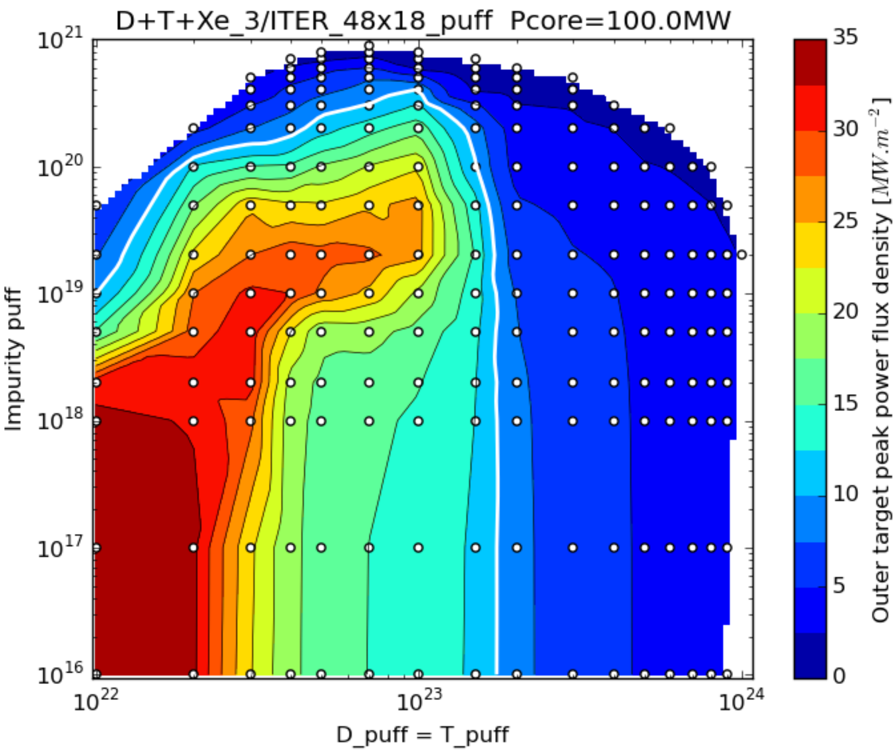
As a consequence of the need for this approach, the discussion concentrated on: 1) which methodology to use; 2) which specifications to use for the simulations (set-up, parameters, sources, etc); 3) which output to analyse and how to present it.

The methodology that was agreed is the following:

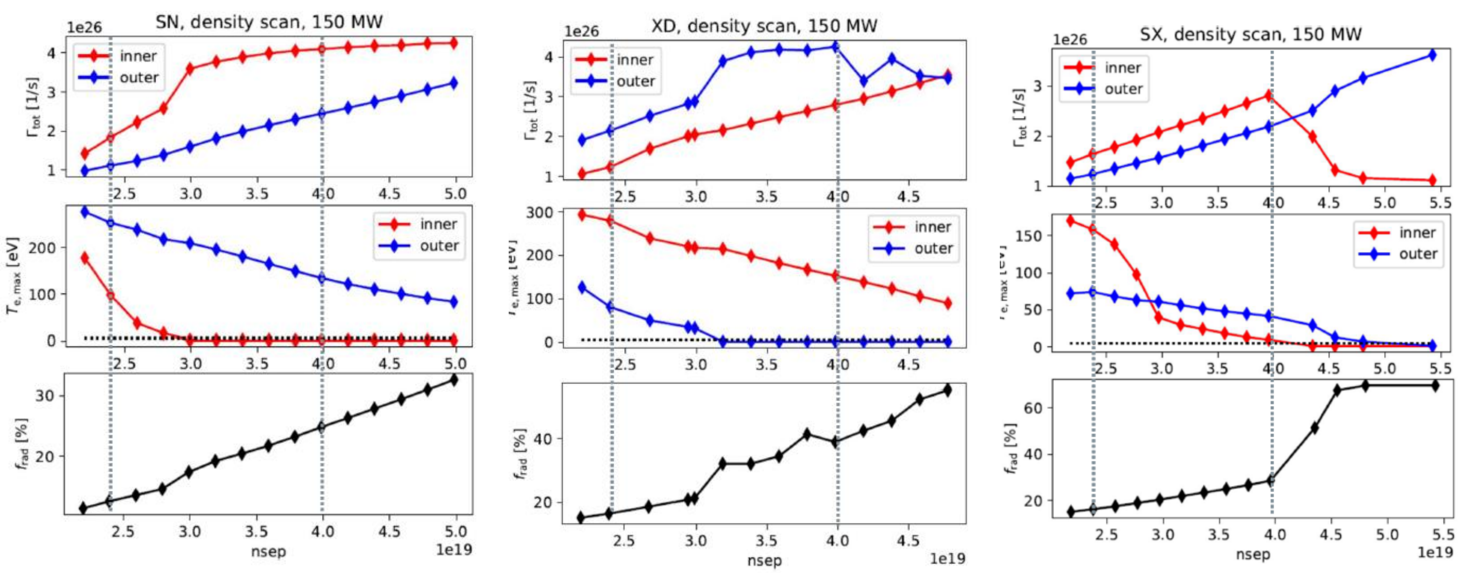
1) the first step is to generate proper meshes for all the configurations. These will include SN, DN, SXD, XD and SF-.
2) Once the meshes are ready (at the moment only SN and XD are ready, but they might need revisions) one simulation will be performed for each configuration using fluid neutrals.
3) Also, one simulation in the most challenging mesh condition should be performed with kinetic neutrals in order to understand the possible difficulties associated with this approach.
4) Once there is sufficient confidence in the fluid simulations, two or three parameters (e.g. D and impurity flux, power…) will be varied systematically to explore the features of the individual alternative configurations and to compare them on an equal basis.
5) Finally, guided by the fluid simulations a reduced number of kinetic simulations will be carried out in order to confirm (or not) the trends observed in the matrix scan approach.

One of the possible issues with the meshes is the need to use non-orthogonal cells, which should anyway be treatable with SOLPS. This is true if the conditions are not too extreme, such as in sharp corners.

The matrix scan approach was well illustrated by previous ITER simulation scans carried out by David Coster and shown in the figure below:



Leena showed the results of some fluid simulations she already performed with fluid neutrals. Ideally, these results would correspond to a slice of a figure like the one above and show that such a systematic scan is possible, useful and meaningful:



The first step will be to identify the axes of the scan, i.e. which variables need to be changed. These will likely include the fueling and impurity seeding influx and the power crossing the separarix. Due to the need to work as a team and to report to or inform external parties, it was agreed to create specification documents to track the methodology and the specifications of the simulations to be carried out.

A number of issues were raised regarding the possible set-up of the simulations (i.e. the specifications) and they will be explored more deeply in the following days. Among these issues, the way the plasma is fueled (from where, with which scheme) should be considered carefully. Also, the depth of the mesh in the core, which will affect how large of a volume will be available for radiation. In this respect, there was discussion on whether the radiation would not go anyway at the X-point, which is where sufficient resolution should be available. The appropriate impurity mixture was briefly examined, with Ar as the main SOL radiator and possibly Kr or Xn as the core radiators. It was not completely clear whether Ar alone could be sufficient, as suggested in some publications [Wenninger2015], since the high temperature peak might be emitting outside the pedestal, see figure to the right.

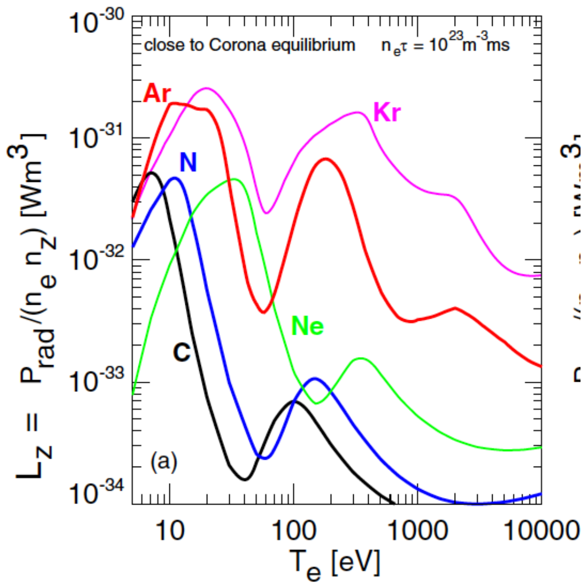


Figure 4 Radiative loss parameter as a function of the electron temperature for different impurities

Anther mesh relevant specification is the resolution, which needs to properly capture the heat flux decay length (~5 points in the first λ_q~3mm) and that needs to assure sufficiently weak numerical dissipation. Leena showed previous simulations that clarify that the heat flux spreading due to the flux expansion is captured sufficiently accurately for the resolution currently used (96x36):

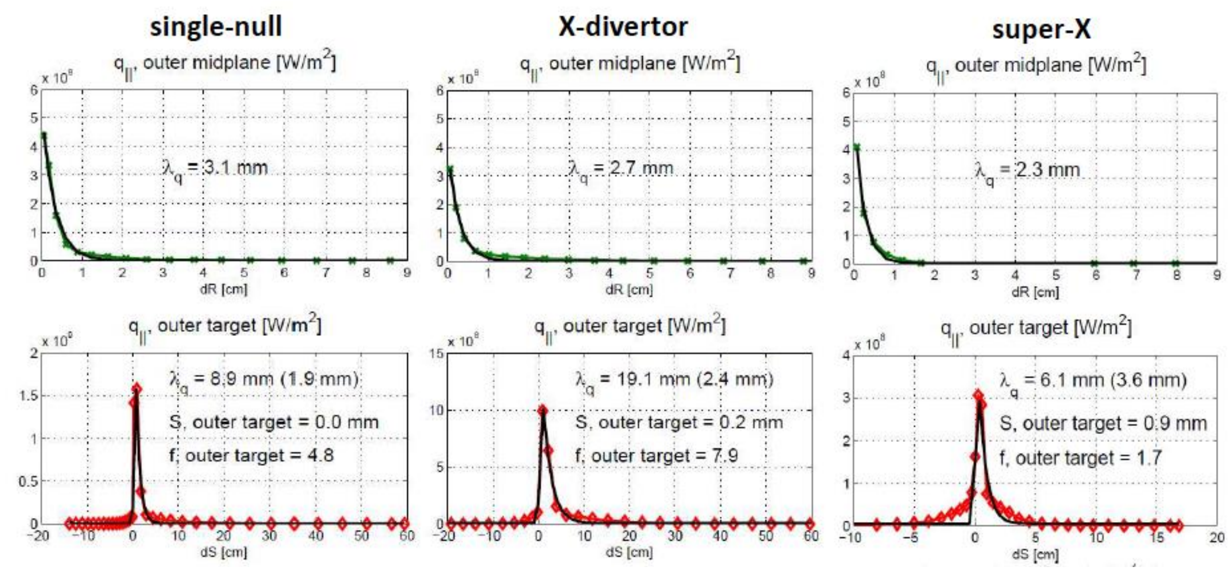


Figure 5 projection of the midplane profile to the target in SOLPS simulations

Meshes and Specifications

Day four and five were devoted to work on the mesh and the specifications of the simulations. We went systematically through input parameters and possible issues with the simulations.
The code used to generate the grid is DivGeo (DG), which is the standard tool for SOLPS meshing. During the meeting it was remarked that attention has to be paid to redef_pbs, in order to avoid mysterious spikes to appear in the simulations (unresolved bug).
Starting from the mesh, it was decided to use the 96x36 grid point SN configuration generated by Fabio as a reference for alternative configurations. Meshing the SX and DN configurations was attempted during the meeting itself. It was agreed to have the mesh done by the person that will work on the configuration, with Leena providing review for all the meshes generated in order to ensure consistency of all simulations. Soon it was realized that the reference grid files need to be on a machine that is easily accessible to all members of the team (at the moment the AUG cluster, hopefully soon MARCONI). This is because the make heavy use of symbolic links, which are accessible only if on the same filesystem [correct?]. It was decided have centralized SN input files that are used as reference. These SN input files should be fully compatible with specifications given below. Each person responsible for the work on the different ADCs will copy those files for their own branch without changing anything. Any deviation from the standard approach should be discussed by the group.
The upstream heat flux decal length, λ_q, will be set to 3mm in the SN configuration. This is not based on physical scalings, which are not available for completely detached divertors and radiative core conditions, but on the fact that we need a reasonable reference for a fair comparison between configurations. The way to set this SOL width will be discussed in the following, here the emphasis is on the resolution of the mesh, and on the fact that the decay length needs to be resolved by at least 3 poloidal grid points. The reference grids will have 18 points inside the separatrix and 18 outside. Using a variable resolution grid with a factor ~1.07 increase of dr between two points [$\sum_{k=0}^{N-2} \delta^n \lambda_q = (1-\delta^{N-1})\lambda_q/(1-\delta)$, with δ=1.07 and N=18] this gives a total gridded SOL width of ~30λ_q, corresponding to roughly 8-9cm at the upstream midplane (delta1=0.001 and delta2=0.15 in DG). This is actually the value currently used in the SN simulations. The outer limit is given by the beginning of the wall shadow (first interaction point close to the secondary X-point on top of the machine). At the moment we will keep 18 points in the core, although this might be too much. An assessment will be carried out after the first simulations to determine if we want to go to 12+18 rather than 18+18 cases to reduce the computational cost. This would also affect the resolution in the PFR.
Again on the SN, it is not clear if the vertical tiles connecting to the wall in the outer divertor can be optimized and smoothed as in the ADC configurations (at the moment they are just formed by three straight lines, which create problems with the meshing).
In ADCs, the resolution upstream, downstream and at the X-point should be maintained more or less the same, which means that the number of grid points can be increased to accommodate the different magnetic geometry. Unfortunately, the SF configurations will not be able to satisfy these conditions, considering that the flux expansion at the X-point is significantly different from other designs.
The depth of the grid in the core should be around 15-20 ion Larmor radii, around 10cm in order to allow for future pedestal studies. The depth of the grid in the PFR, instead, should be roughly determined by the radial width of the SOL in the main SOL at the level of the X-point. Fabio's SN grid already respects this criterion.

Regarding the EIRENE's mesh, it was agreed to use larger cells at the midplane and finer in the divertor region in order to properly resolve the mean free path of the neutral/neutral interactions, which shortens in the high-density region.

The SF- grid will be the most challenging due to the topological complexity and the fact that few simulations have been attempted in this geometry. The mesh obtained by Tilmann and Mirko has 600 poloidal points, which will need to be significantly reduced to allow efficient computation. Also, the preliminary choice of the midplane separation between the two separatrices is 1mm, but this is a somewhat arbitrary number that keeps part of the heat flux channel between separatrices and some in the main SOL. Mirko will perform dr_sep scans for TCV and can inform us of the result.

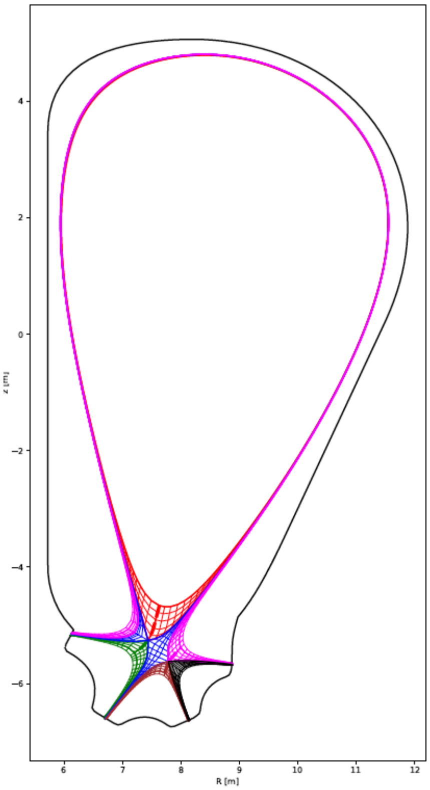


Figure 6 first attempt at a SF- grid

Regarding the simulation set-up, it was decided to use the same version of the code: SOLPS 3.0.6 develop. All problems with the code should be discussed via [Slack] and only one person (typically Leena) will contact Xavier Bonin and the SOLPS developers. A number of specifications were decided during the meeting. The simulations will be carried out both with fluid and kinetic neutrals, with the fluid neutral approach guiding the kinetic, with the caveat that the physics will not be equally realistic. All the simulations will use deuterium as the main fuel (tritium will be assessed in the future, but was deemed unimportant for the moment), He as an intrinsic impurity and Ar as a seeded impurity for divertor heat load control. Ar will be bundled in the fluid simulations and unbundled in the kinetic.

The procedure agreed was to proceed by doing a gas puff (12 points) and Ar seeding scan (16 points) and a coarser core rate scan (3 points), while coarse power and λ_q scans (3 points each) will be left for the future. The philosophy is to use engineering parameters without any sort of feedback. The logic behind the core rate scan is that the pedestal properties largely depend on the relative importance of gas puff and core fueling. A proper ½ day discussion (remote) should be held once the reference simulations are ready.

Each "matrix" scan will be preceded by a single fluid simulation per ADC, aimed at assessing the feasibility of the approach, the convergence of the code and the performance of the mesh. One kinetic simulation will also be attempted for the most challenging ADC (not all of them) to assess its feasibility. These initial fluid simulations will be performed at 150 MW of input power and $4\text{x}10^{19}$ separatrix density in density feedback.

The sources were calculated in the following way: assuming a 2GW reactor, the rate, α, at which He is produced is given and is: $2\times10^{9}\left[{}^{J}/_{s}\right] = \alpha\left[{}^{1}/_{s}\right]\times 2.8\times10^{-12}[J]$, where $2.8\text{x}10^{-12}$J is the energy released per reaction (17.6 MeV). It is therefore easy to see that the He production rate is around $7\text{x}10^{20}$ ions (α particles) per second. This is the value that will be used as core He rate in the simulations. For the Deuterium, we assume a factor 50 with respect to the He, and hence the core rate will be $3.5\text{x}10^{22}$ nuclei per second (see discussion below). The Ar seeding will be fixed at 0.1% of the total D rate (puff+core) and injected from the same midplane nozzle as the D puff (discussion with PPPT will give more details on the nozzle location). Finally, the D puff will be determined by feedback in order to get $4\text{x}10^{19}$ separatrix density. The puff location will be at the midplane in order to have a fair comparison between simulations, later on this could change. The loss rate of the pump will assume that there is a factor 10 enrichment on He in the divertor with respect to the core and that each He atom pumped, 10 of D will need to be pumped as well. This gives a factor 100 with respect to the core He rate and hence the pump rate will be $7x10^{22}$ nuclei per second. The He enrichment might be an output of the simulations in different ADC, thus will need to be reassessed. A potential concern is that usual interpretative modeling has a factor 10 smaller neutral pressure in the divertor than the actual experimental value when the puff rate is identical. Particular care has therefore to be used in the simulations.

As far as the dissipative coefficients are concerned, we will use ITER as a guideline for the modelling. In particular, ITER uses $\chi_e=\chi_i=1m^2/s$ and $D=0.3m^2/s$ in the SOL, dropping to $0.2m^2/s$ for all the coefficients in the core (the latter representing neoclassical values). The proposal (to be tested) is to start all the ADC simulations with $\chi_e=\chi_i=0.3m^2/s$ and $D=0.1m^2/s$ in the SOL, thus maintaining the same ratio as ITER, reducing the perpendicular transport to compensate the reduced parallel transport (due to longer connection length). This should give λ_q~3mm in SN, which will be used as a reference. For the same dissipative coefficients, the other ADCs will have slightly different decay lengths, but we see this as acceptable in the philosophy of the comparison. In the core, all the DEMO parameters will be reduced to $0.1m^2/s$ to simulate the pedestal region (which might be less evident in the density, consistently with the degraded confinement of I-mode or RMP based ELM control). Better values should come from the input of the turbulence activity P-2. The transition between the SOL and the core will be governed by a connecting function thus defined: the separatrix parameters will be the same as the SOL parameters; the transition region will cover 5 mm inside the separatrix; at -5mm, the core parameters will be used; at -2.5mm we will take the geometric mean between the core and SOL parameters (truncated to the first decimal), hence $\chi_e=\chi_i=0.17m^2/s$. For lack of a better estimate, the viscosity will be taken at $0.2m^2/s$, as in ITER. The heat flux decay length needs to be defined in an unambiguous way and will be evaluated a posteriori at the region of maximum flux (around the X-point) fitting an exponential behavior and then mapping to the midplane. If adjustments are needed in the in the dissipative parameters if λ_q is significantly different from 3mm in SN, further discussion will be needed.

The kinetic simulation will be carried out in the same way, although the loss rate will be replaced by setting up an albedo that gives the maximum engineering pumping speed [input required from Stylianos] and putting the pump in a recessed place in order to avoid the contribution of direct line of sight from the plasma, which could give unrealistic results due to the contribution of fast neutrals (which also introduce nonlinearities).

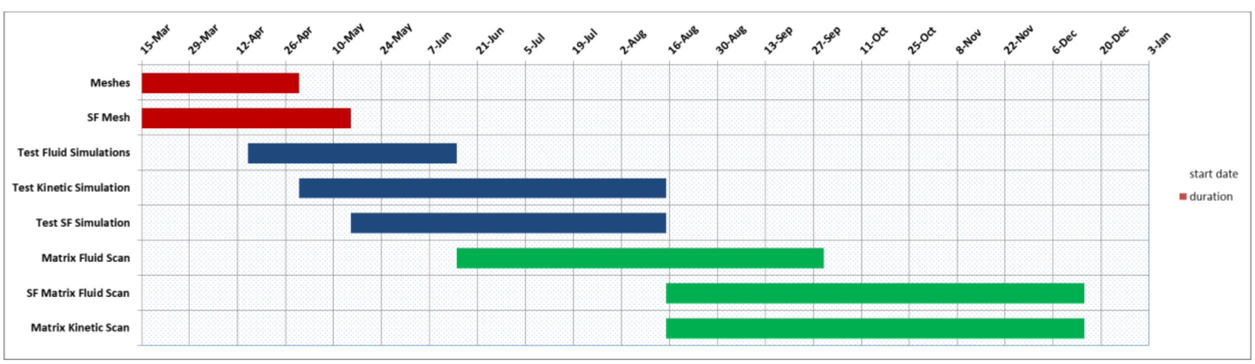
In the "matrix" scan, the upped gas puff rate will be limited by the Greenwald limit, although it is not completely clear how to determine it given a separatrix density. We estimate that $4x10^{19}$ separatrix density will be close to the limit, assuming $7x10^{19}$ Greenwald density, similar to ITER where it is $8x10^{19}$. Another (more complicated) option is to use the maximum pumping capability as the upper limit, and this will be required if this is smaller than the Greenwald limit.

The range of the Ar scan will be determined by Zeff in the core. Pragmatically, we can check its value in the reference discharges to be performed before the scans and readjust in such a way that we cover roughly two decades in the Ar puff rate. Similarly, also the range of the core D puff rate will be assessed as the reference simulations produce the first reliable output. Finally, the input power will be held fixed at 150MW for the moment, expecting roughly 10% of the input power to be radiated I the core, so that $P_{sep}\approx P_{input}$.

Other specifications are as follows. The initial conditions for the kinetic simulations will be based on the Fabio's 96x36 old simulations. The snowflake simulations will need to start from scratch as the SN case would not be transferable. For fluid cases we will start with flat initial conditions. The single test simulations developed first for each ADC will be used as initial condition for all matrix scan simulations in order to allow for parallel calculations. Neutral-neutral collisions will be on, and this will require a properly refined EIRENE grid in regions of high density. Photon opacity should be taken into account, but only after other groups will properly debug the code and provide reliable calculations. The SOLPS default settings for the wall temperature are 0.1eV (1000K) maxwellian behavior. However, this might be a bit too high for the walls. Considering that the W ductile/brittle temperature is around 700K, ~0.06eV, we will take this value for the walls and 0.1eV at the target (Maxwellian in both cases). The recycling coefficient in all simulations will be set to 1, as we are considering steady state conditions and saturated walls. Regarding kinetic corrections, we will take flux limiters for ions, electrons and neutrals. In particular, for lack of better models, we will use the values employed in ITER's simulations (Kukushkin): 0.2 for the electron heat flux, 10^5 for the ion heat flux and 0.375 for the viscosity. For the neutral fluid model, we will take 1, consistently with Dave's simulations (this number should be compared with the default value and possibly revisited). The neutral diffusivity is calculated by the code and the maximum and minimum values are bounded. Dave will send information on how he sets this up, together with Leena and Fabio.

We estimated the computational cost of the matrix scans. Each simulation should take between 1 day and 1 week and hence the scans must be run in parallel (i.e. many simulations at the same time). We have 150000 node hours on MARCONI and there are 48 processors each node. We would therefore need 12 nodes for each scan for one week (12x16x3), hence 60 nodes for each complete ADC run for one week. We therefore need 60 nodes x 7 days x 24 hours: 10080 node hours, which is barely 7% of the total allocation. Memory might be more of an issue as it will require 10 GB per simulation times 2880 simulations, giving ~30 TB for the complete analysis. We need to pack the serial jobs on MARCONI so that they fit on 48 processors at the same time. An alternative would be to request a big serial queue (now the serial queue is not charging, but it only lasts 6h and experiences only low usage). Fulvio will contact Richard Kamendje and the CPT (Core Programming Team) to find a solution.

This is a Gantt chart of the P-1 activity, to be approved with the members of the team:



Division of work for the simulations:

- Fabio (SN for PPPT; XD for WP-ADC)
- Leena (DN)
- Mirko, Tillman (SF-)
- Lingyan, David M. (SXD)
- David C., Marco (general set-up and meshing of the simulations, scripts and incredible SOLPS wisdom)