DEMO Toroidal Field Coil Fast Discharge Unit Integration Studies

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Challenge

Introduction

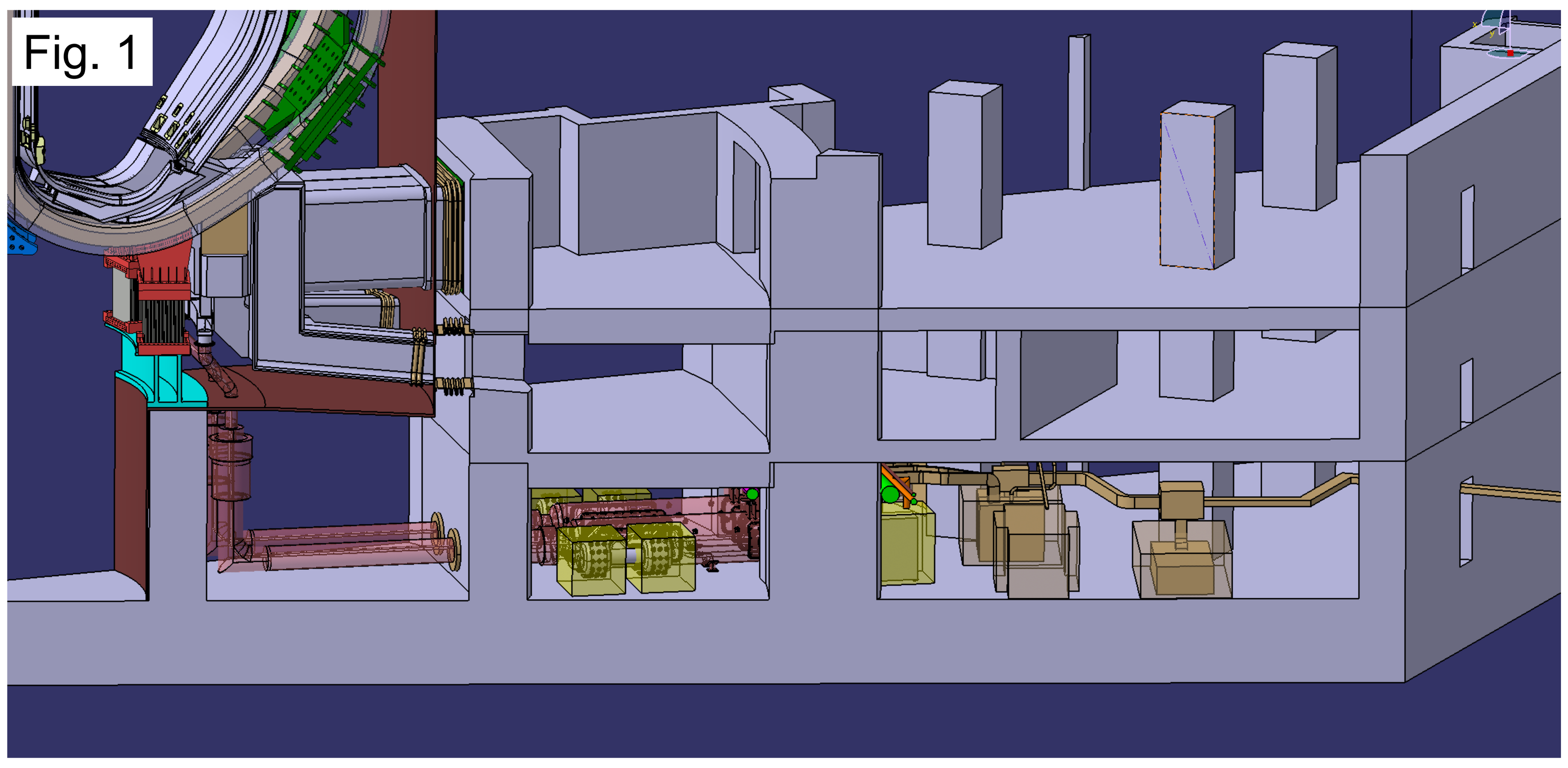
- The fast discharge units (FDUs) shall allow the safe and fast discharge of the superconducting magnet coils in case of any failure event which could lead to their destruction (quench) [1]. FDUs are safety important class (SIC) components,

- A neutronics study has started which is still running to show the shielding issues of sensitive electronics and possible solutions. In ITER the shielding could not be added anymore, in DEMO we have still the option to optimize the shielding design.

- A task was launched under WPDES to study the effect of neutron shielding. In parallel in WPPES an R&D study is ongoing about fully mechanical solutions. Indeed, the trend in industry is (also in the HVDC transmission) to go to semiconductor solutions whenever possible and replace the mechanical solutions. Therefore, another tasks is launched in parallel in WPPES also to study solutions based on IGBT/IGCT.

Simplified CATIA model of the DEMO TF magnet feeders and FDUs

Fig. 1



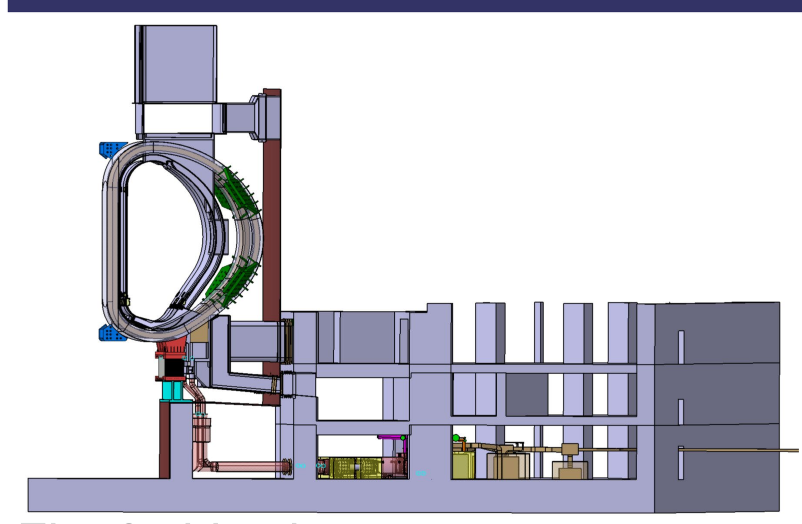


Fig. 2 side view

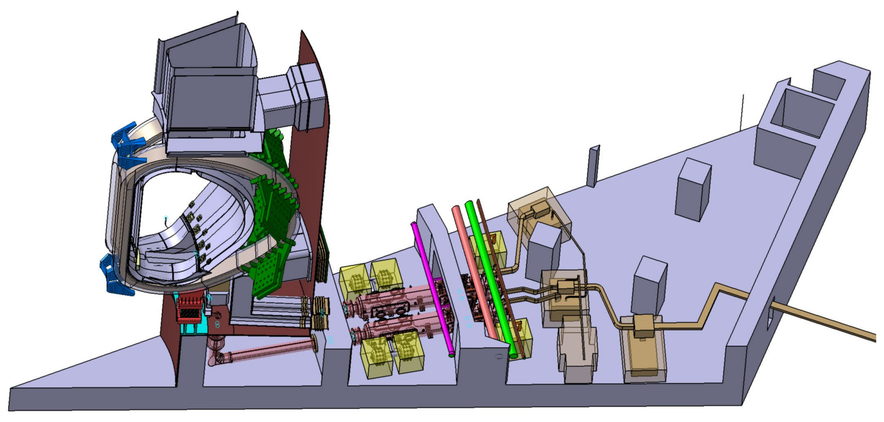


Fig. 3 top view

Shielding assessment (MCNP study at JSI)

Based on the CATIA input from PMU (DCT) an MCNP model was built with 2 cases, one case as direct interpretation of the CATIA model and one with more shielding by introducing a concrete ceiling above the feeder (to the cryostat):

Fig. 4 Case 1

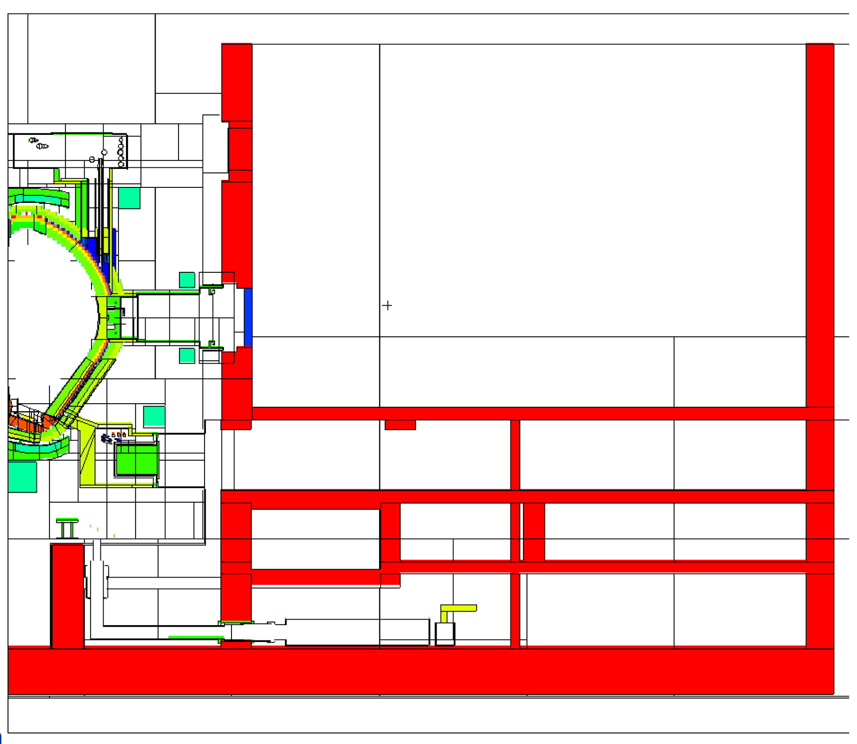
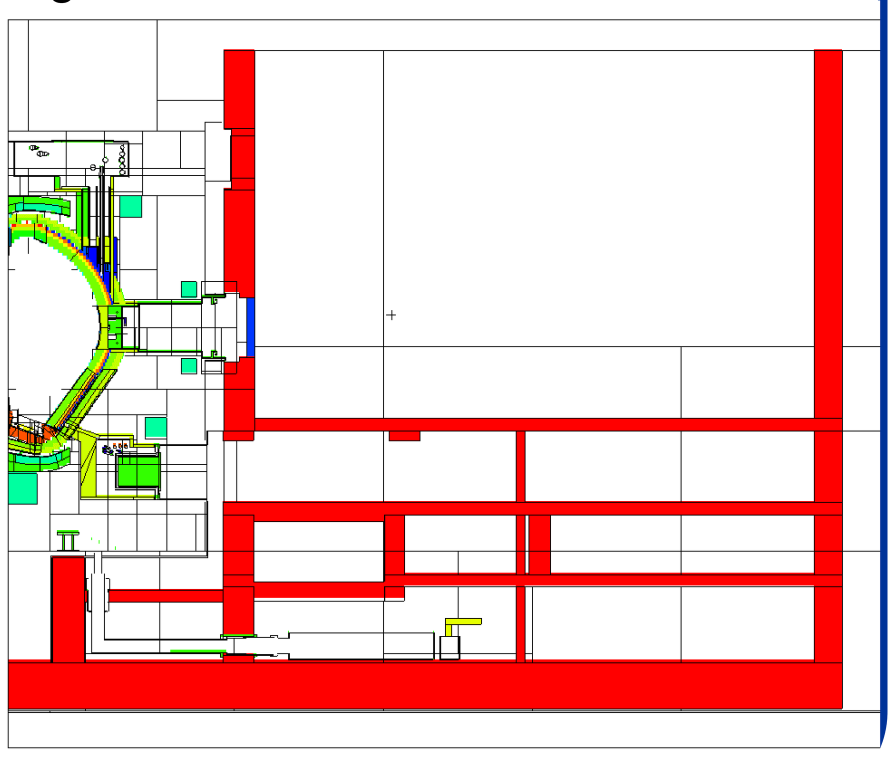


Fig. 5 Case 2



First Study Results

Results

The results shown in the study results are the first results of an ongoing study. The absolute values for the 2 cases are still just indicative, here we only are interested in the relative changes between the 2 options.

Only when the model is more advanced the absolute values are considered.

Not considered is a possible contribution from activated water in cooling pipes or LiPb drainage tanks / pipes since not sufficient information were available from the tokamak layout when the task had started.

Neutrons

A first simulation was done to see the neutron radiation impact.

- The Case 2 provides a reduction of factor 50 for neutron shielding.

- all numbers are just indicative!

- ITER limits for SIC electronics [1], [2]:

- Accumulated dose 1 [Gy]

- Neutron Flux 10 E-2 [1/cm2 s]

- Accumulated Neutron Fluence 10E+8 [n/cm2]

Fig. 6

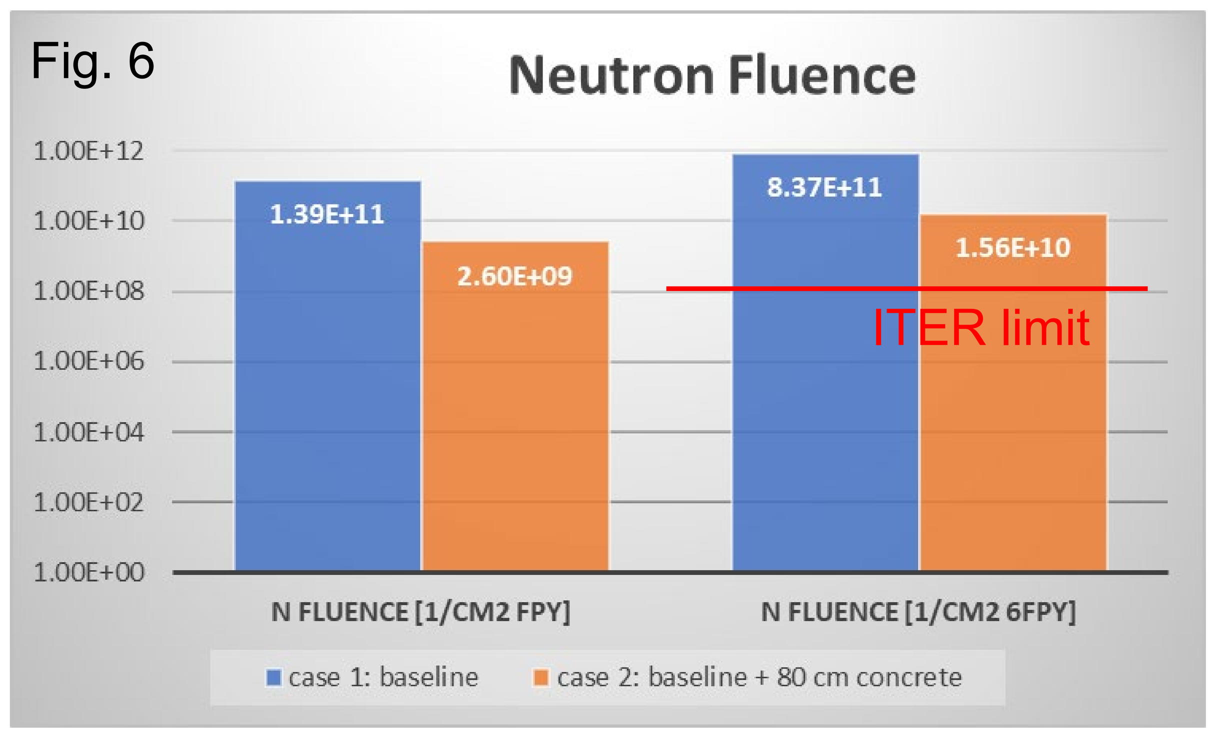
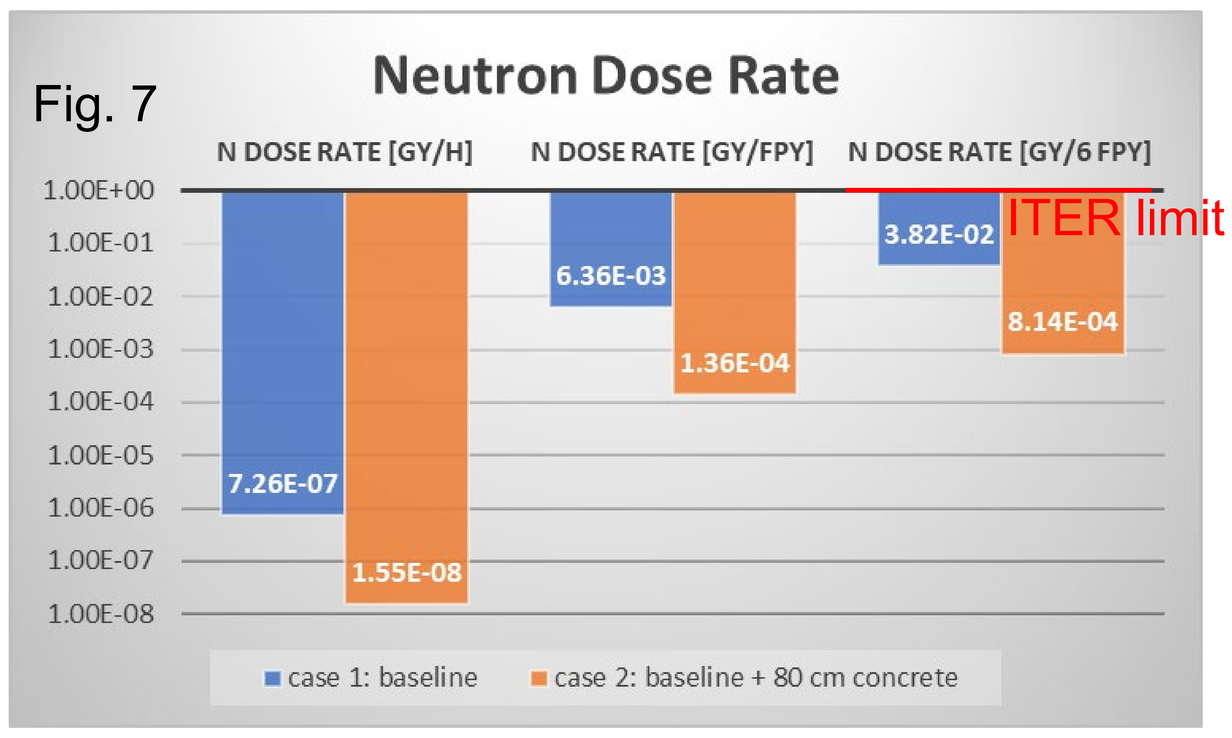


Fig. 7



The neutron fluxes are

Case 1	4.42E+03 [1/cm2 s]
Case 2	8.26E+03 [1/cm2 s]

Gammas

A new simulation was done and the dose rates for neutrons are from 1.4E-7 to 7.4E-7 Gy/h (+-7% in this new simulation) the dose rates for gammas are 2.1E-5 to 5.1E-5 Gy/h (+- 7%). This was done for the Case 1. With that the values for the accumulated dose will be slightly above 1 Gy and would need further optimization.

Summary

So far no real show-stopper was found, even if the limits for the neutron fluence still can be optimized. The neutron fluxes in ITER are set for natural background. For DEMO we don´t expect such limits therefore we consider here only the accumulated neutron dose and neutron fluence. If no solution can be found by shielding, new technical design is needed (R&D on fully mechanical solutions) or a re-position of part of the FDUs (most sensitive electronics) to more `quiet´ in terms of radiation (neutron, gamma) areas or even re-position the full FDUs to other levels with all the consequences of routing of busbars.

References (more in the paper)

[1] Gaio, E. et al., Status and challenges for the concept design development of the EU DEMO Plant Electrical System, https://doi.org/10.1016/j.fusengdes.2022.113052
[2] Hamilton, D. et al., Guidance for EEE in Tokamak Complex, ITER_D_7NPFMA
[3] Denatan, M. et al., Proposed Strategy for Electronics Exposure to Nuclear Radiation in ITER, ITER_D_QXPP97

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