STUDIES INTO BEAM LOSS PATTERNS AT EUROPEAN SPALLATION SOURCE

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The linear accelerator of European Spallation Source will produce 5 MW proton beam. Beam of this power will likely generate significant losses along the beamline. To study these losses, a coherent model of the whole machine is being made using custom generator, DEIMOS. This model is used to perform Monte Carlo simulations of the propagation of the accelerated beam and the losses in the MARS code system. Preliminary simulations utilizing the uniform beam loss distribution were done. More detailed simulations based on the various different loss patterns focused around hot spots in magnets were also performed and their results compared. This confirmed the limit of 0.5 W/m average heat load on accelerating cavities foreseen by the cooling requirements. Additional studies investigated the dose absorbed by fragile cooling system's elements during the normal operation of the facility defining their radiation resistance to the levels of few kGy/y. Further simulations will also give the information about the expected beam loss detectors signal at possible locations. These data will be further analyzed using custom algorithms.

Beam loss monitoring at ESS

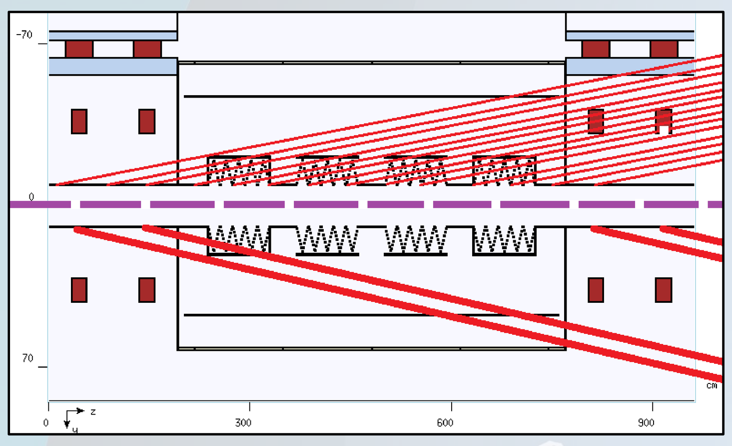
European Spallation Source will produce neutrons by irradiating the tungsten target using 5 MW proton beam (H+) at 2 GeV delivered by linear accelerator of around 600 m length [1]. Beam losses along the linac anticipated by the design of the facility are limited by 1 W/m which should allow the hands-on maintenance [2] [3]. To ensure that this limit is not exceeded during the normal operation of the machine and also to detect catastrophic events a beam loss monitoring system will be introduced. Additionally, the system will be also used to tune-up the machine by pointing the exact beam loss locations and providing feedback about the beam physics.

Figure 1: ESS Ionization Chamber with and without metal casing

The main detector chosen for the linac is CERN LHC type ionization chamber complimented by neutron detectors and scintillator-based fast loss monitors. The BLM system is designed to detect the losses as small as 1% of the limit (about 0.01 W/m) and as fast as 2 μs (to prevent destruction of elements during full beam loss) [1].

Beam loss patterns

Figure 2: Scheme comparing two loss patterns: uniform (top) and localized (bottom).



Due to the lack of detailed loss patterns provided, assumptions were necessary. The level of proton beam loss was set at 1W/m. Two different patterns were subject of investigation: a.) uniform losses along the whole model b.) losses localized in the quadrupoles (most probable loss points in the actual machine as the region where the beam is the largest) [1]. In both cases the losses propagate at a shallow angle of 0.05 degree in reference to the beam direction and very close to the beam pipe.

Accelerator modelling

Creating a complete and coherent model of the accelerator is crucial for many aspects of the design phase of the machine and can also benefit users during the operation phase. The tool selected for the task of modelling at ESS was MARS Code System [4]. This decision was supported by the features of overlapping and overwriting regions in the geometry which allowed easier automation of the model generating process. Most of work done up to date involved translation of the CAD drawings of the machine's components into a code readable by MARS geometry compiler. The parts treated in this way are grouped as blocks to be put in various places of the machine multiple times using the automated generator

DEIMOS Generator

All components of ESS linac are listed in the central Beam Line Elements Database (BLED), a system for central management of the data [1]. To ensure that the models used for the Monte Carlo simulations are consistent with the actual machine, a link between them and BLED have been established.

DEIMOS, an ESS Beam Line Generator for MARS is a program written in Python (running on Windows, Mac OSX and Linux-based systems for users convenience). As input file it reads the elements names and coordinates from BLED, processes them and outputs a complete accelerator geometry readable and processable by MARS.

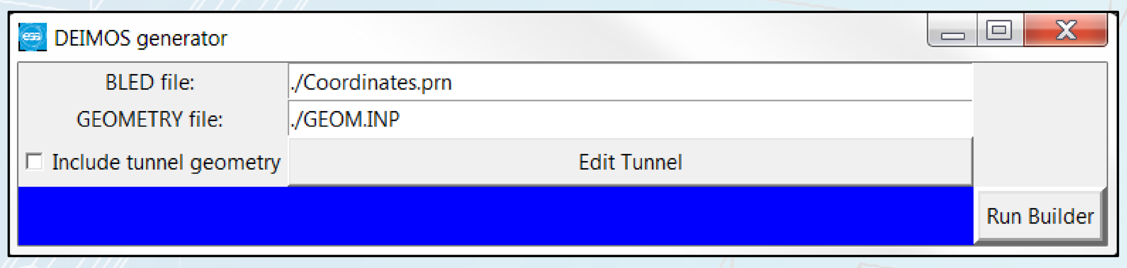


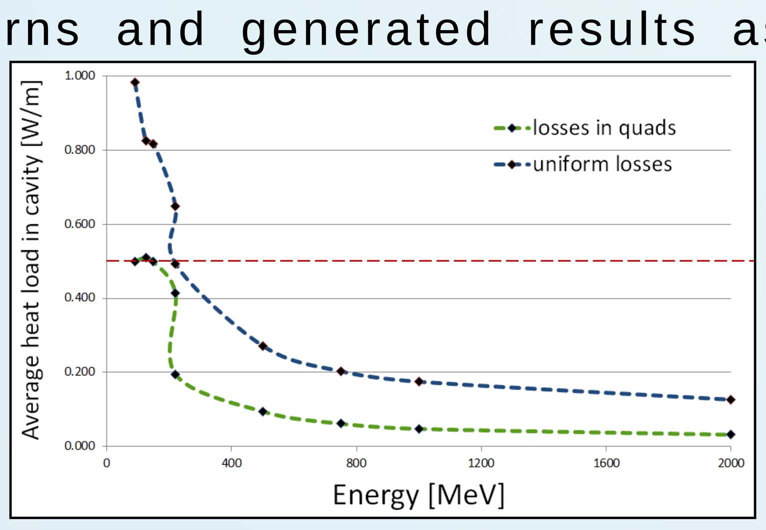
Figure 3: DEIMOS main window

MARS output file includes the accelerator tunnel with all the parts recognized in the BLED input. As every part is saved as separate module it is very easy to add new parts or edit existing ones, as well as update the layout based on the changes in BLED.

Heat loads in superconductive cavities

Inspection of the heat loads in the superconducting cavities of ESS linac were performed. Results covered the energy range from 90 MeV to 22 0MeV (spoke cavities) and from 220 MeV to 2 GeV (elliptical cavities). Estimating the heat loads was necessary to confirm or update the preliminary cooling requirements, previously established at 0.5 W/m averaged along all cavities. Simulations were performed for both loss patterns and generated results as follows:

Figure 4: Heat load predictions in superconducting cavities



One can observe that the heat load on cavity for lower energies gets close to the total beam loss (1W/m) – this is due to conservative assumptions (normalization to the maximum heat load absorbed in the cavity). Even with this overshoot the average heat load along the whole accelerator will be lower than expected 0.5 W/m (from the point of view of the cooling system this value is more important than the local excess of the limit).

Future work

More elements will be added to the DEIMOS library to eventually acurately cover all parts listed in BLED.

The model will be used to optimize the numbers and positioning of the beam loss monitors. The results of the beam loss simulations will be stored in a newly created database together with all of the initial conditions in order to be processed later [4].

The influence of the x-rays generated by the superconducting cavities on the detectors response and tunnel background will be investigated.

Beam losses in the low energy end of the machine will be specially emphasized as particularly hard to detect and localize.

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References:
[1] S.Peggs et al., "ESS Technical Design Report", Lund, 2013 [2] L. Tchelidze, "Beam spill limits during various event classes (for the ESS accelerator)", Lund, 2014 [3] T. Hansson "ESS Radiation Protection Strategy for Employees", Lund, 2013 [4] N. Mokhov et al., "The MARS Code System User's Guide Version 15", Batavia, 2014 [4] L. Tchelidze, H. Hassanzadegan, M. Jarosz, A. Jansson, "Beam loss monitoring at European Spallation Source", IBIC13