Studies into beam loss patterns at European Spallation Source

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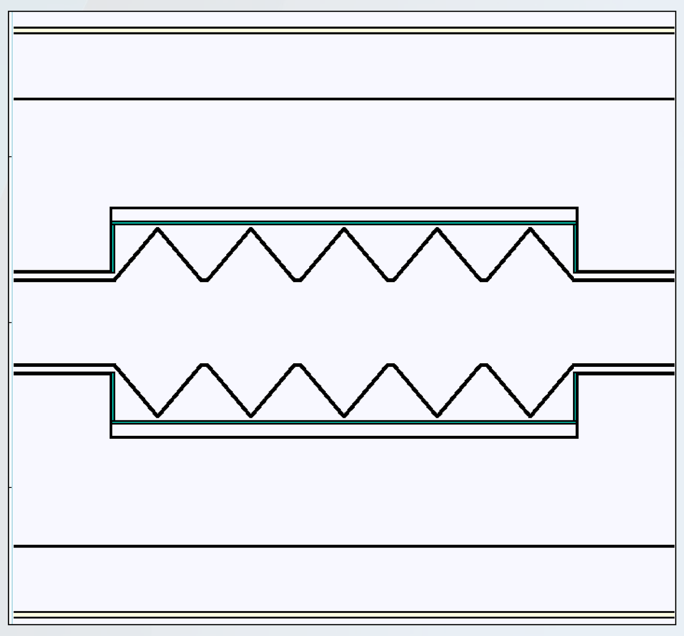
The understanding of beam losses is essential for high energy, high intensity accelerators. This project focuses on the studies into beam loss patterns at European Spallation Source with the aim to optimize the distribution (location and type) of beam loss monitors and improve the interpretation of the BLM data. Project's main goal is to develop a full ESS accelerator's model in the Monte-Carlo simulation codes (FLUKA and MARS) and use it to study the optimal location of loss monitors and develop algorithms to analyze the measured spatial loss profile. The model starts as a rough estimation of the foreseen machine and will become more detailed as more information about the accelerator's components become available. The simulations performed using it will also bring answers to the questions concerning the activation of machine's components and surrounding, radiation mechanical damage and heating.

Phase one: creating a model of the machine

Creating a complete and coherent model of the machine is crucial for many aspects of the design phase of the high energy accelerator and can also benefit the users later during the operation phase. Monte Carlo particle transport simulations performed with this kind of model might bring answers to the questions raised by the machine and radiation protection issues and cooperate with beam physics particle tracking works. By treating results given by the latter as an input for the beam loss simulation it is possible to track the impact of loss occurring in a specific point on the whole machine. Secondary particles produced as a result of the loss could be afterwards treated themselves as input files for another beam tracking simulation, creating a chain of operations resulting in accurate beam loss pattern information.

Monte Carlo particle transport codes demand huge amount of time spent on creating the geometrical description of the accelerator's components. It is therefore important to coordinate the work and ensure that all created models are coherent with each other and when put together in one of the codes (i.e. MARS, FLUKA) represent accurately the machine. This can keep the time consumed by creating the geometry to minimum and prevent doubling of work by avoiding the need of rewriting the code.

MARS



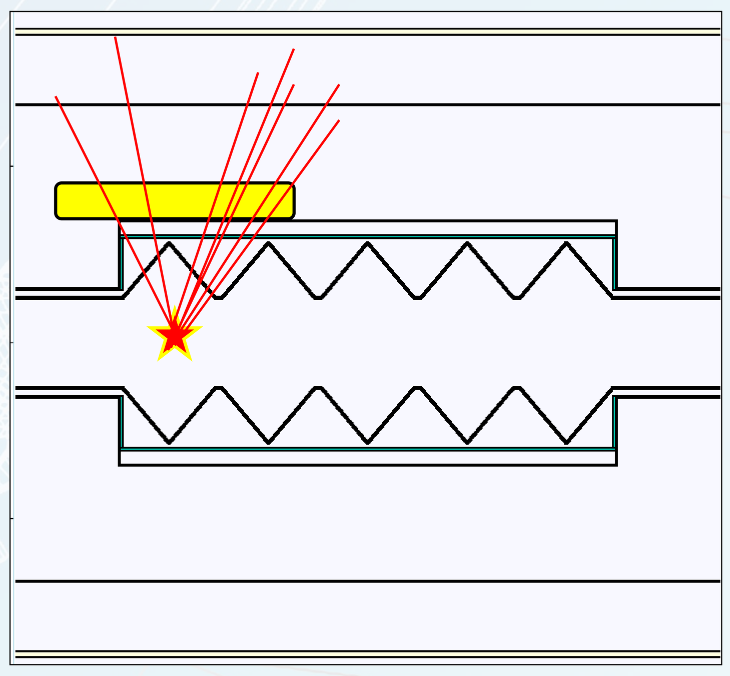
Top: MARS Code System logo
Right: cross section of the rough model of the ESS eliptical cavity

The tool selected finally for this task at ESS is MARS Code System developed at Fermi National Accelerator Laboratory. Current works involve translation of the CAD drawings of the machine's components provided by the Design Group into a code readable by MARS geometry compiler.

Phase two: Monte Carlo simulations

Although the complete model can be used for simulations of various issues, this project focuses on using it to predict a beam loss pattern in order to optimize the numbers and positioning of the beam loss monitors. The simulations will be performed using the following scenario:

1. Look into the section of the linac.
2. Place detector(s).
3. Simulate a loss.
4. Gather the response.
5. Repeat 2-4 for different loss locations and detector positions.

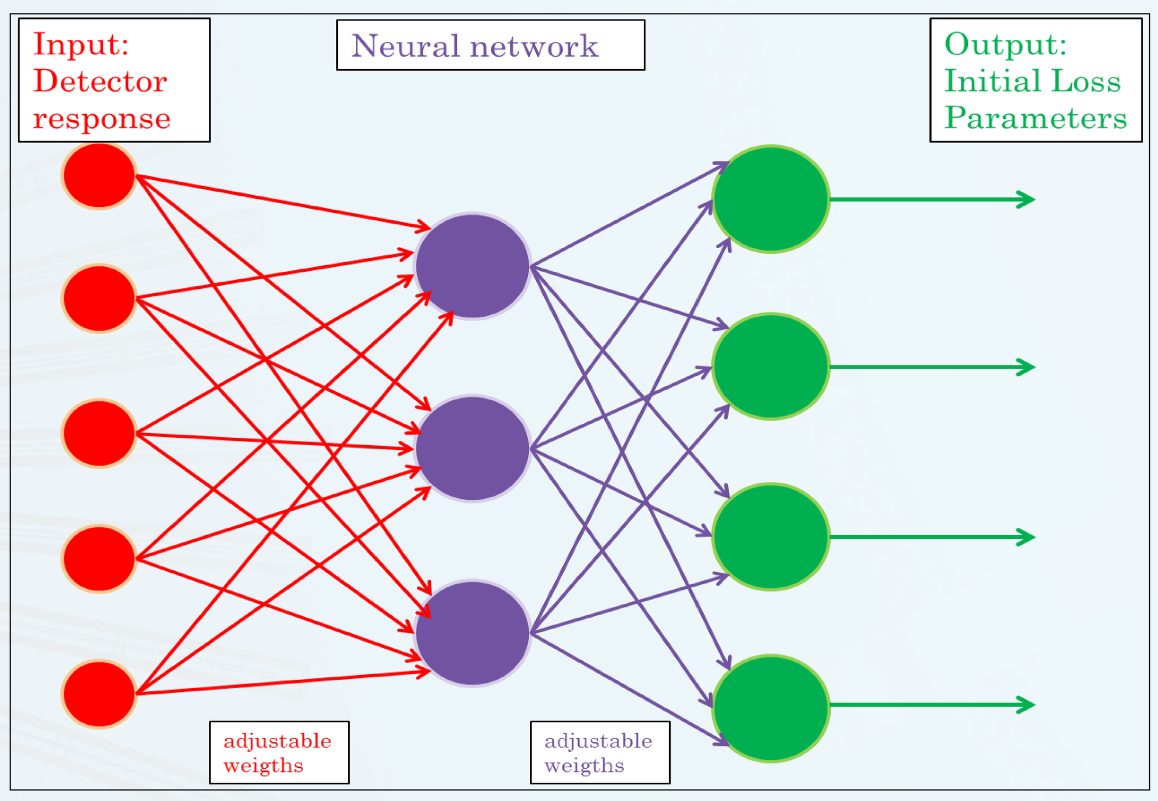


The results of the simulations (the responses of the detectors) will be stored in a database together with all of the initial conditions (location of the detectors, type and place of the loss) in order to be processed later.

Phase three: Data Analysis

The data stored in the database need to be interpreted to provide an answer to the question of the optimal number and position of the detectors. As that kind of optimization problem (multidimensional, nonlinear) cannot be described by the finite mathematical function and the procedure of simulations provide multiple sets of coherent input and output vectors, this project proposes to use neural network for the necessary data processing. Successful usage of similar techniques (i.e. genetic algorithms) in beam physics and the conditions above suggest that this approach is viable and worth deeper study.

Concept of the neural network to be used for the data processing



Most of the simulation results will be used as input data (the response of the detectors) and the answers (initial beam loss position and state) for the training of the neural network. Other sets of obtained values will be used to test the system's efficiency in detecting the loss. This will not only allow to pick an optimal case but will also provide a set of rules for loss detection during actual operation. So far this phase is only in the conceptual state.

Conclusions

In order to study the beam loss patterns in the accelerator one has to create a coherent model of the whole machine. The model might be used for many different applications, one of which is optimization of the beam loss monitors number and position. The results of the beam loss simulations performed while using it will be stored in a database together with the initial loss conditions. Data contained in the database will be processed using custom algorithms (proposal: neural network). Results of the data analysis will provide an optimal set of BLM parameters and will be used later as a reference during the operation phase of the machine.

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