EUROPEAN SPALLATION SOURCE

Studies into beam loss patterns at European Spallation Source

Michał Jarosz

ESS AD Retreat

2013-12-11

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- Born in Warsaw, Poland

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- Working with ESS since 2009, officialy joined Beam Diagnostics in 2012 as a Marie Curie oPAC project fellow

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oPAC Project

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- The **o**ptimisation of **p**article **ac**celerator network

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- Part of the Marie Curie Initial Training Network scheme funded by the EU
- Consists of an international consortium of more than 30 partner organizations including universities, research centres and private companies working in the field of accelerators

Why is beam loss monitoring important?

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5 MW proton beam

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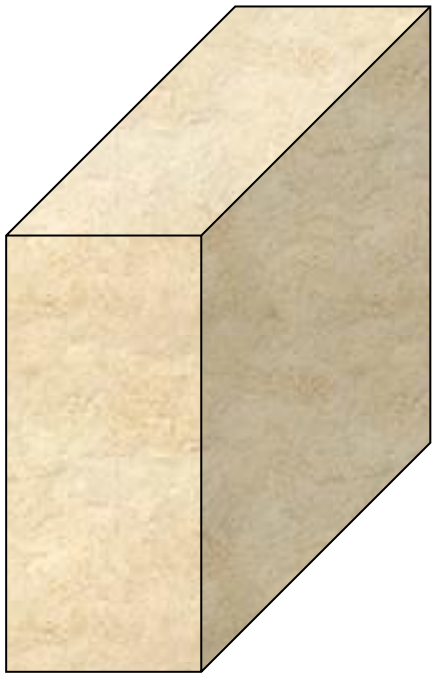

330 km/h

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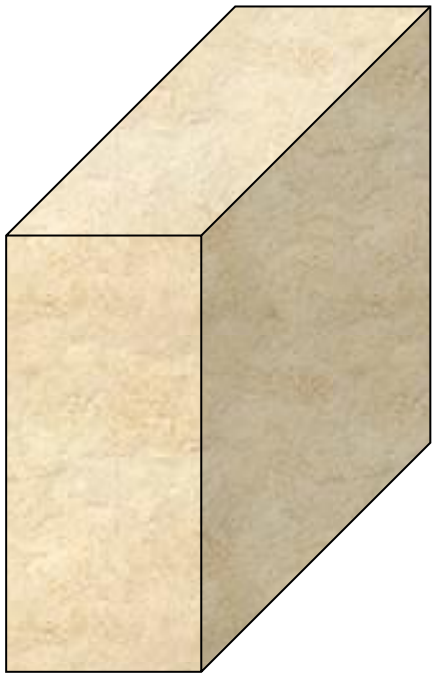

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Beam loss monitoring goal is to detect the loss as fast as possible to minimize the damage.

Why is beam loss monitoring important?

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- People (both ESS workers/employees and general public)
- Machines (preventing radiation fatigue/damage and activation)

Beam loss monitoring goal is to detect the loss as fast as possible to minimize the damage.
It should also provide the precise information about the location of the loss to help trace the faulty element.

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Beam Loss Studies

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Beam Loss Studies

- Creating a coherent model of the whole accelerator facility for various purposes connected with the radioactive beam transport

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Accelerator Model

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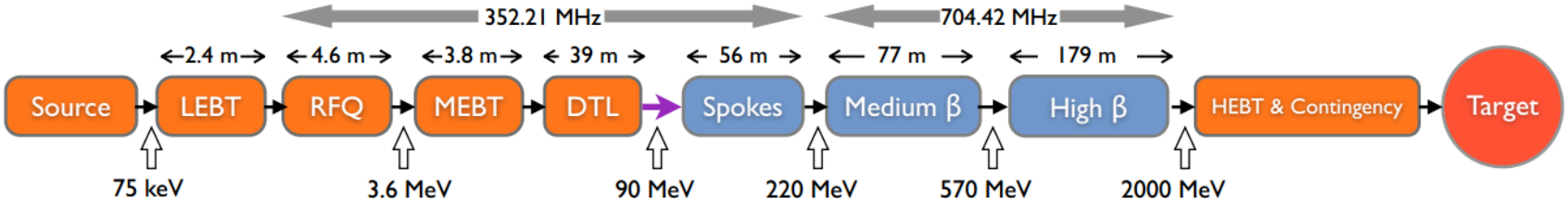
Accelerator Model



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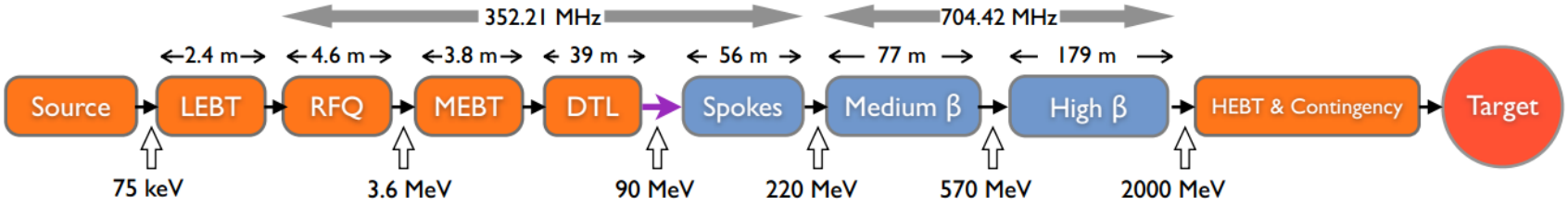
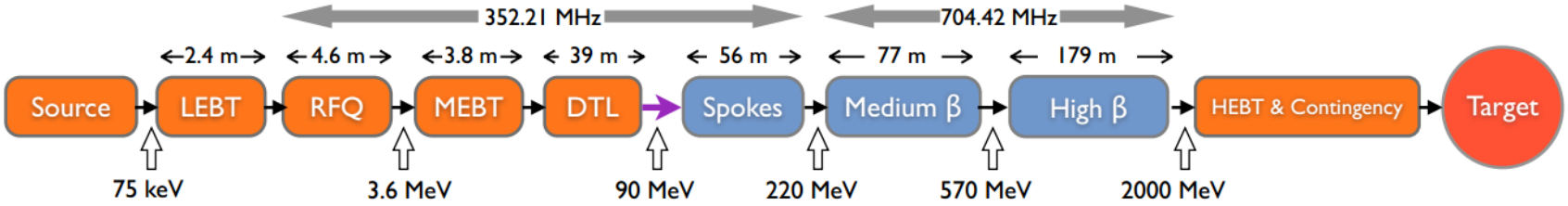


How about something more in-depth and useful ?

Accelerator Model

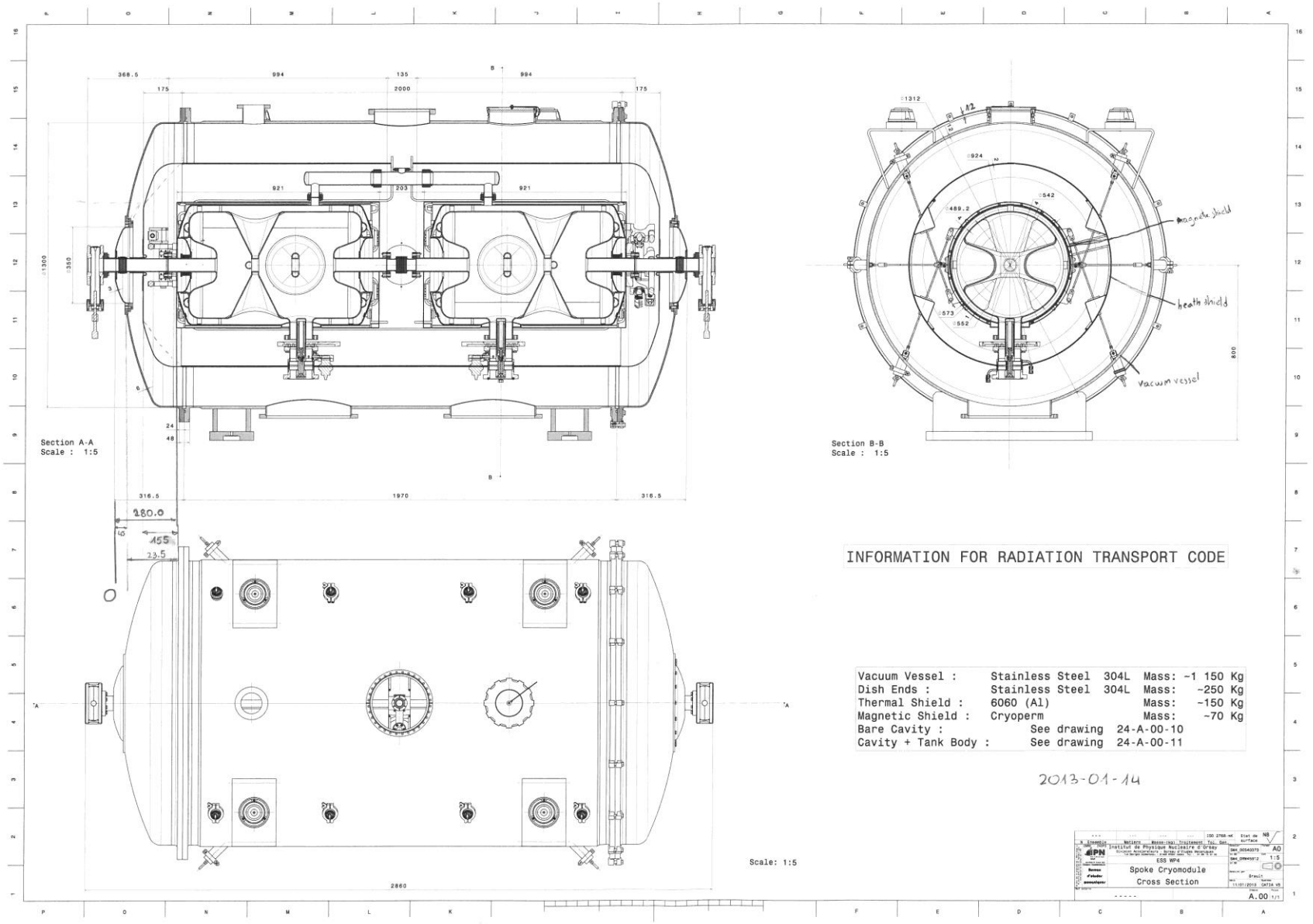


A low-level model in a simulation code:

- Very useful in the design phase
- Could remain useful during the operation
- Can be started early as rough estimation and then updated regularly as more detailed information about the machine parts become available

Coherence – one model utilizing the whole machine; whith strict rules and common depository; modular build

Accelerator Model



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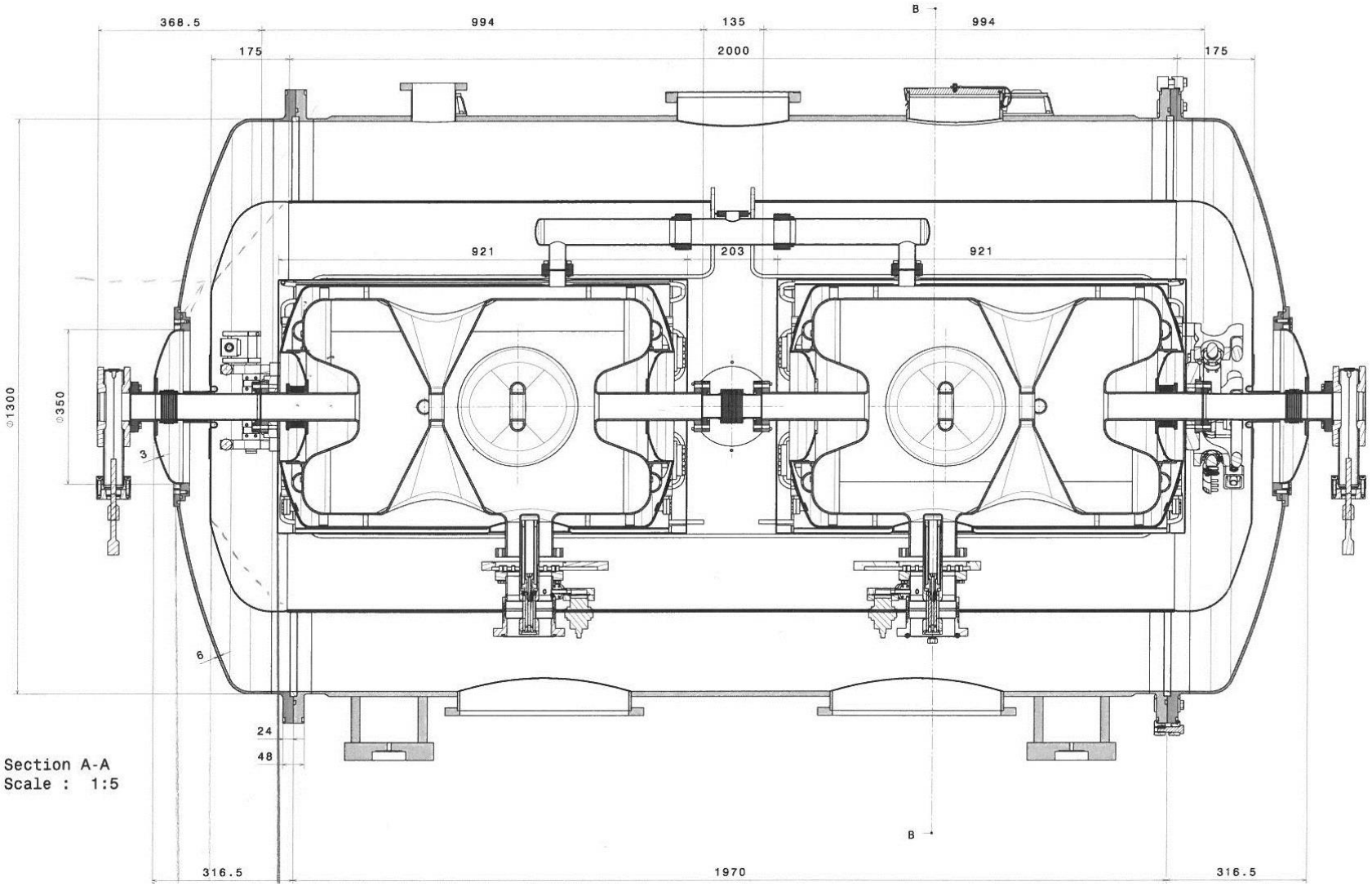

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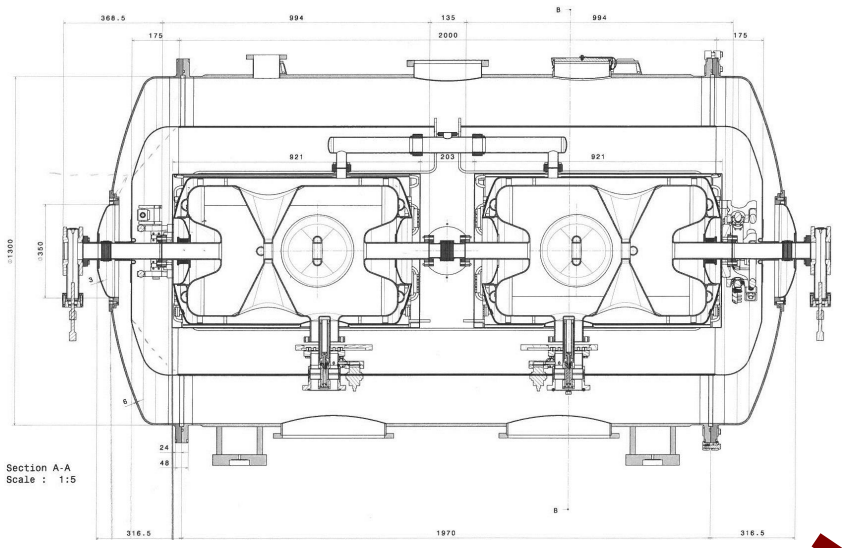
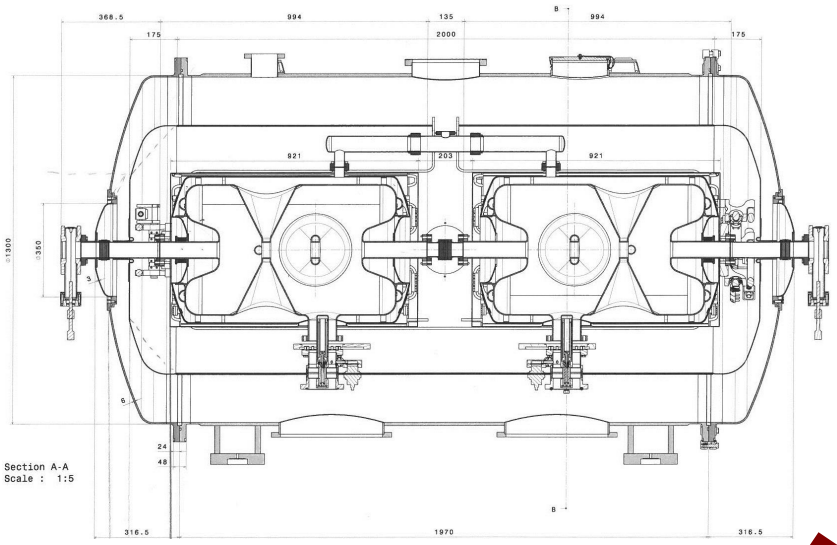


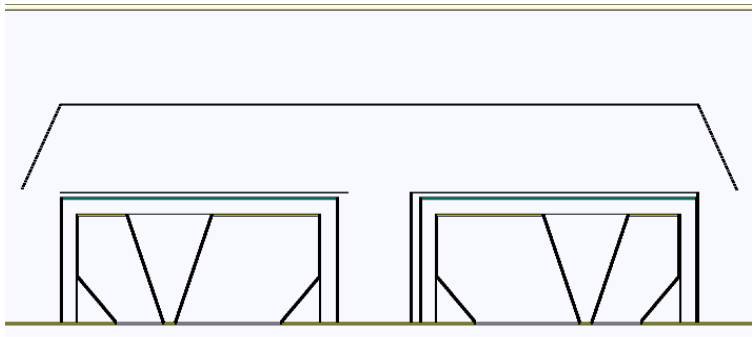

```
heltankm  2 0 2     0. 0. 19.6    20.9   21.4   92.6  !middle part of helium tank
helcovl   2 0 2     0. 0. 19.6     9.1   21.4   0.5   !helium tank left cover
helcovr   2 0 2     0. 0. 111.7    9.1   21.4   0.5   !helium tank right cover

magshld   2 0 8     0. 0. 19.45    24.25  24.4   92.9 !magnetic shield over
cavities
magshll   2 0 8     0. 0. 19.45    9.1  24.25  0.15   !magnetic shield left cover
magshlr   2 0 8     0. 0. 112.2    9.1  24.25  0.15   !magnetic shield right cover

termshld  2 0 9     0. 0. 0.      47.25  47.4   131.8 !thermal shield around
```

Accelerator Model





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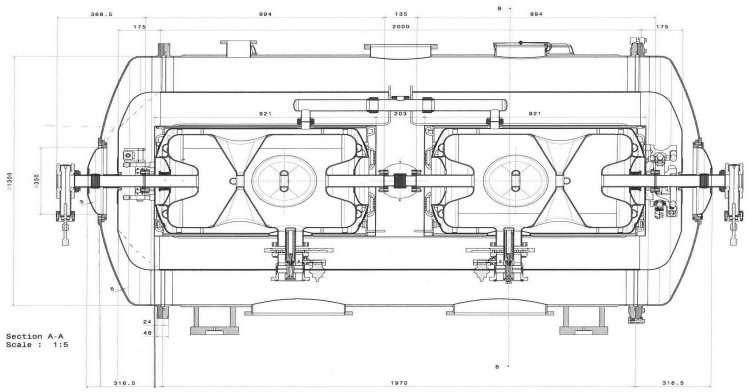
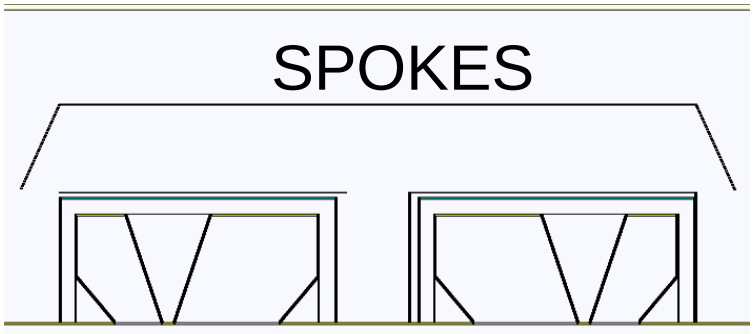
Accelerator Model





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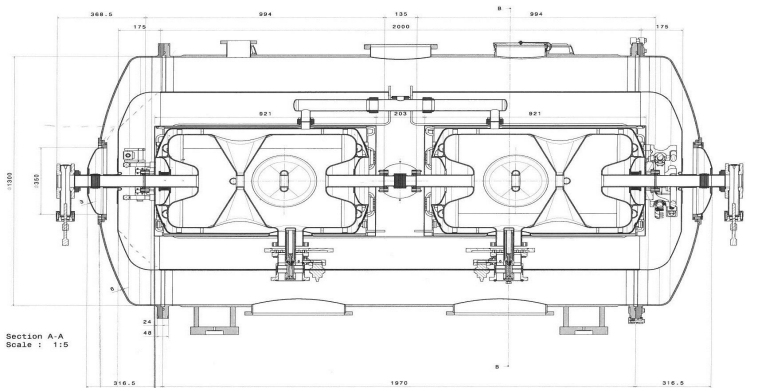

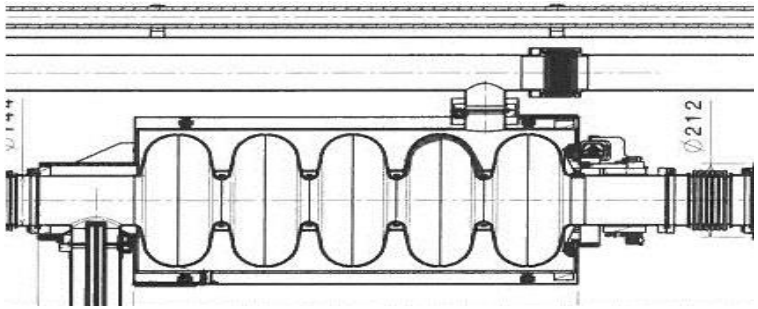

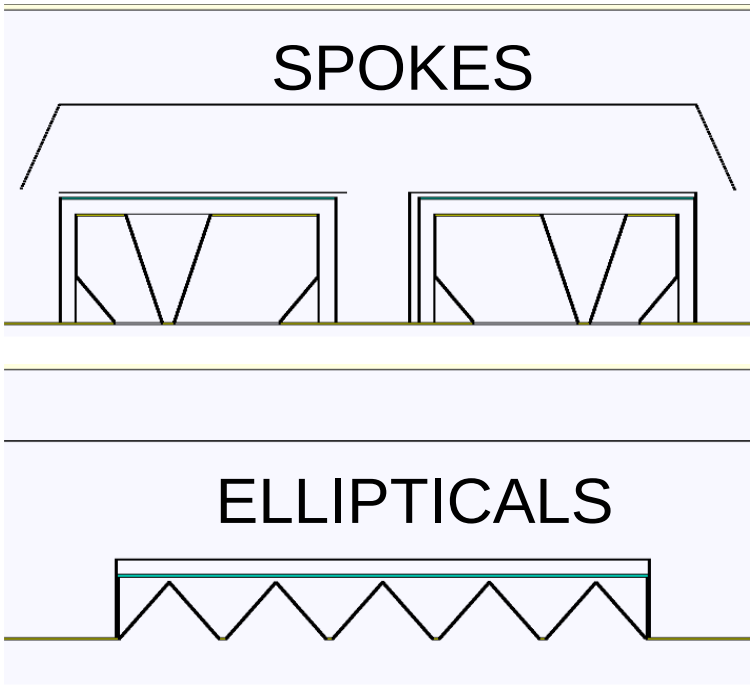

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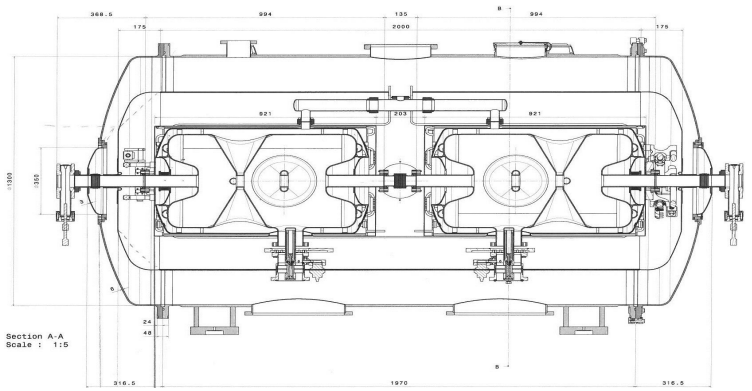

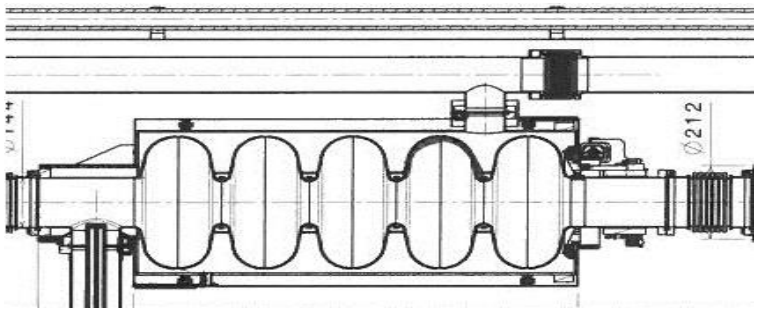

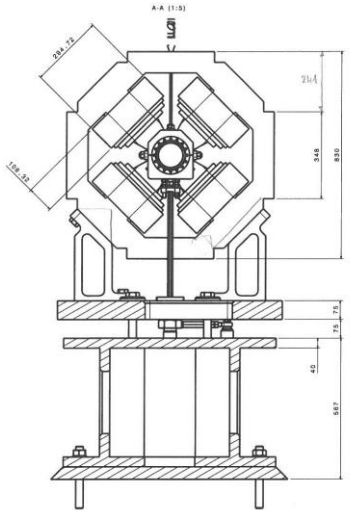

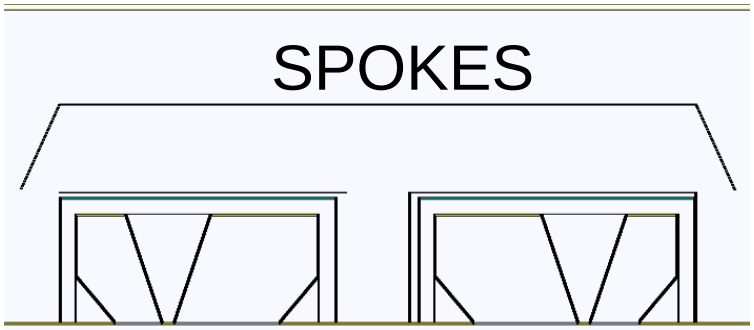

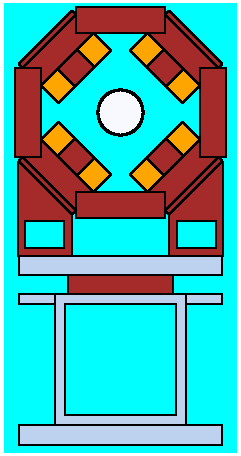

QUADS

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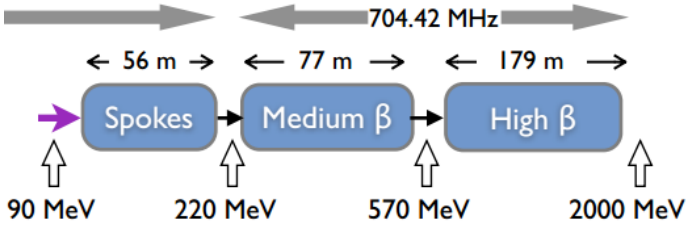
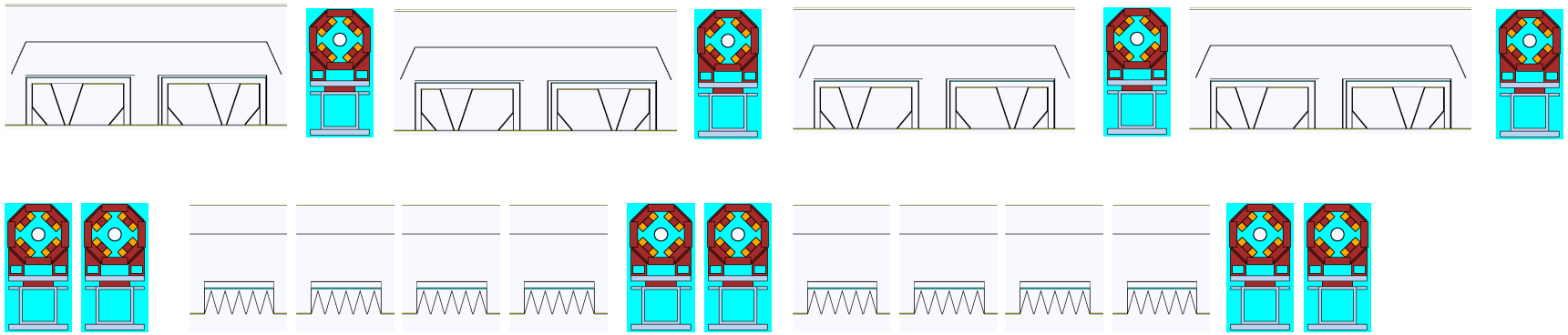
Accelerator Model





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Beam Loss Studies

- Creating a coherent model of the whole accelerator facility for various purposes connected with the radioactive beam transport
- Performing beam loss simulations

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Beam loss simulations

Identifying beam loss patterns

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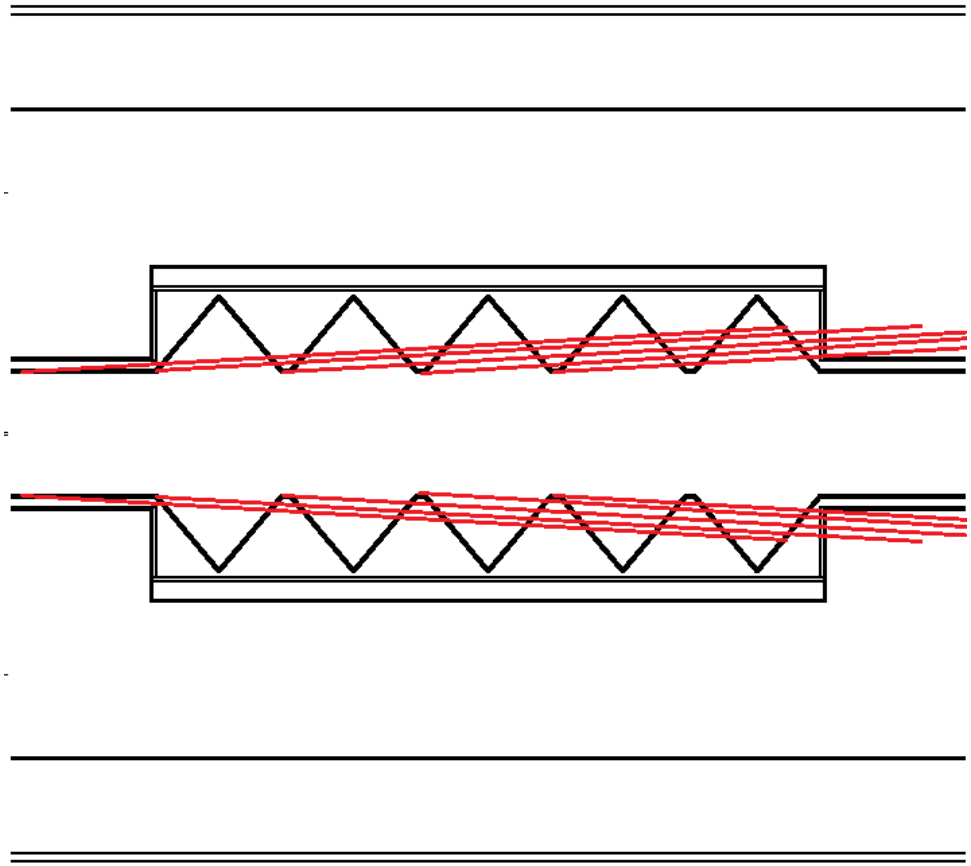


1 W/m loss distributed evenly along the machine (> ~50 MeV)

value coming from the limit for the hands-on maintenance

no hot spots

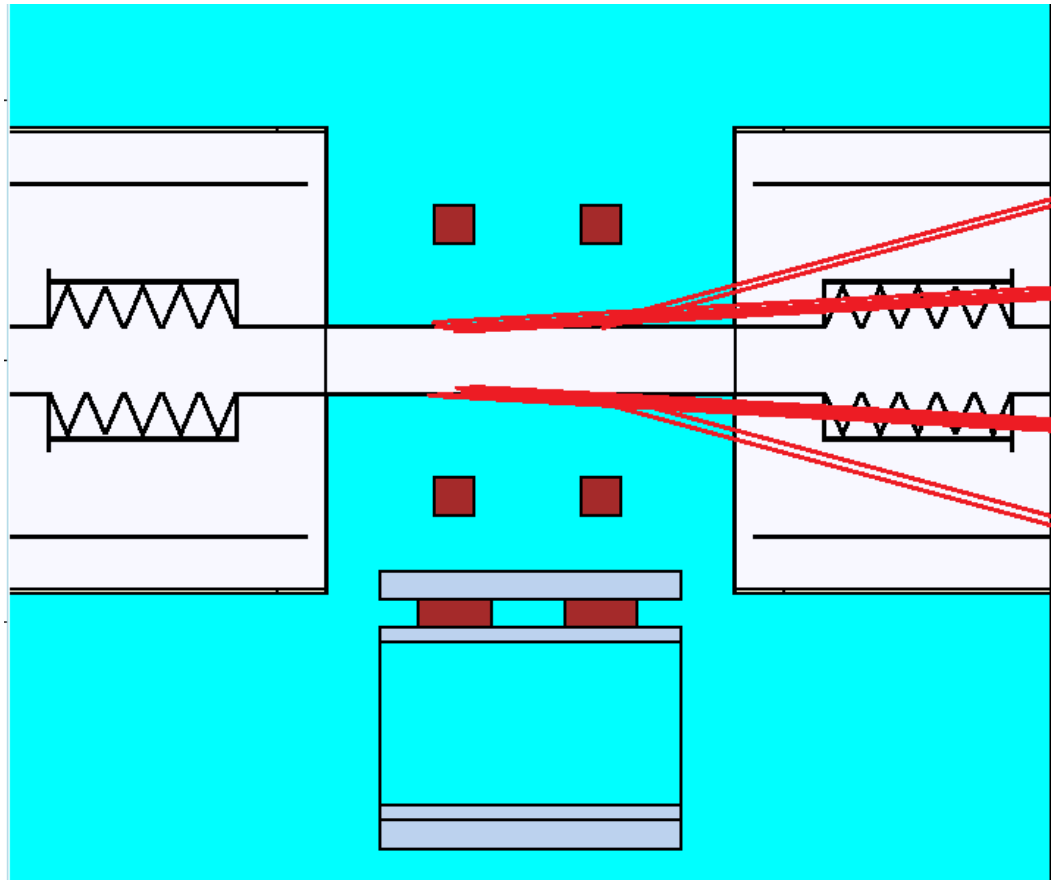
most probably nonrealistic

good approximation for the simulations of the further surrounding (i.e. shielding)

Beam loss simulations

Identifying beam loss patterns

First try: 1 W/m „golden rule”
More realistic pattern (focused close to quadrupoles?) to be determined

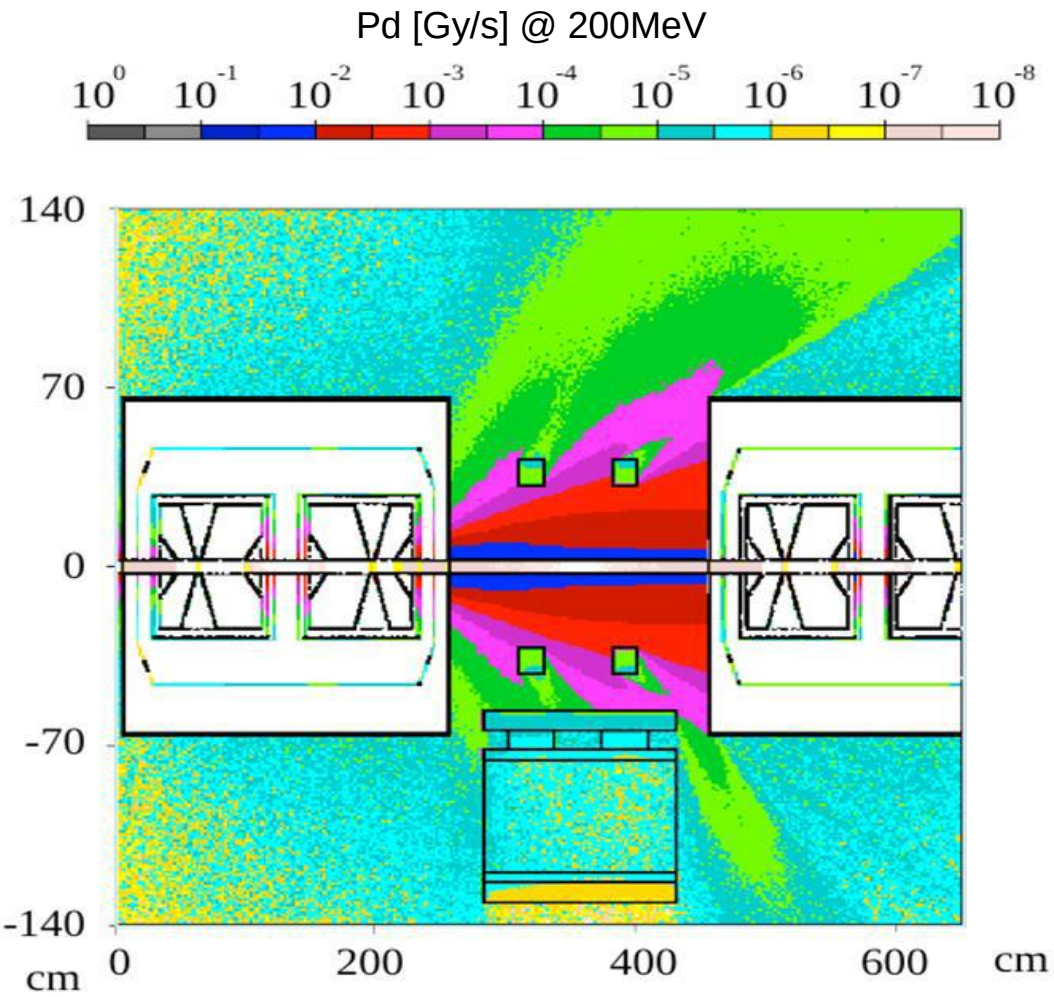


„true” pattern (or at least for sure more realistic)

needed for the studies of the near neighbourhood of the beampipe (material studies etc.)

Beam loss simulations

First approximates: power density distribution in the cold section of the linac for the uniform beam loss pattern.



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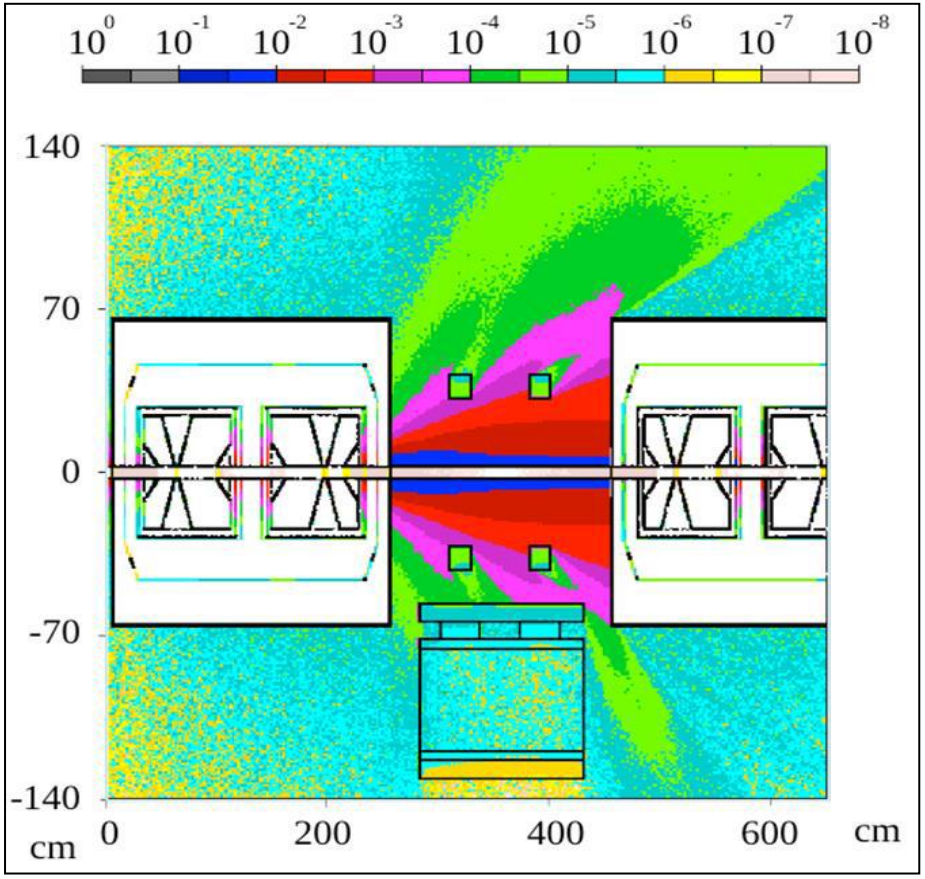
Pd [Gy/s] @ 200MeV



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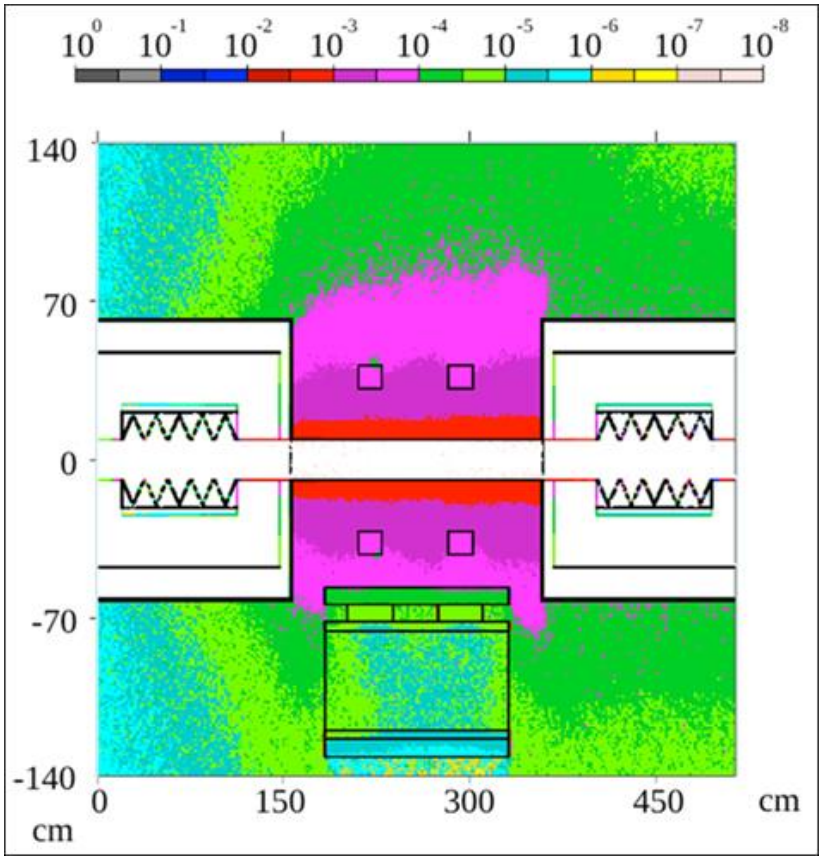

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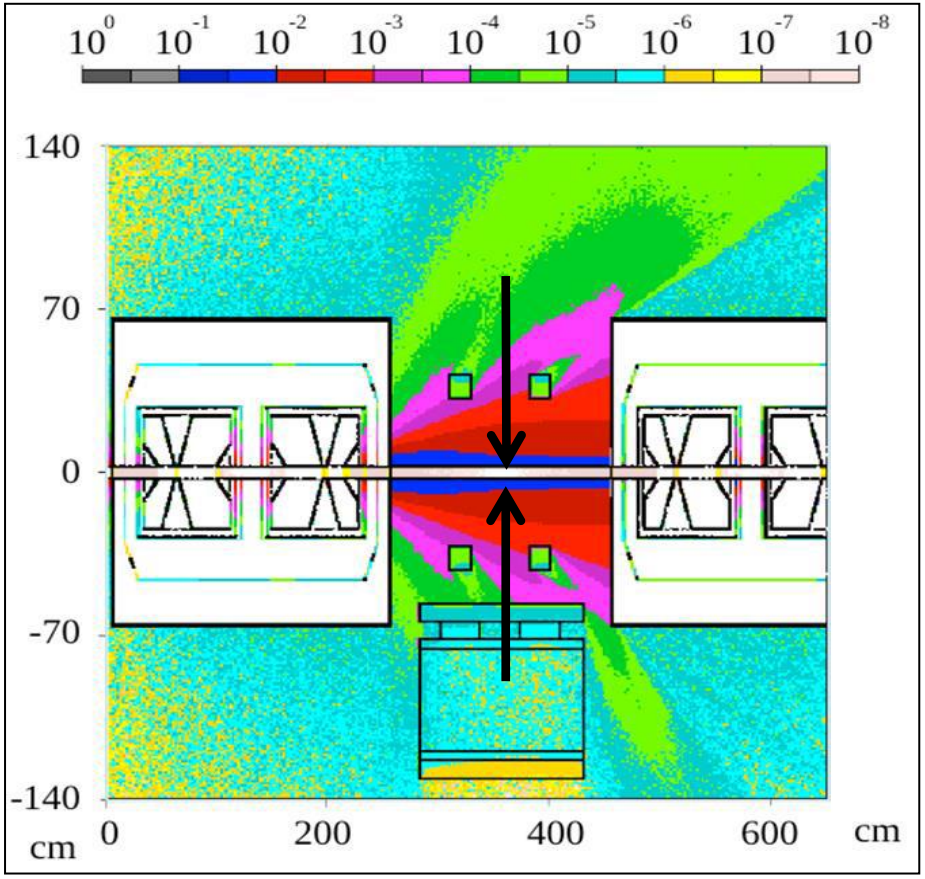

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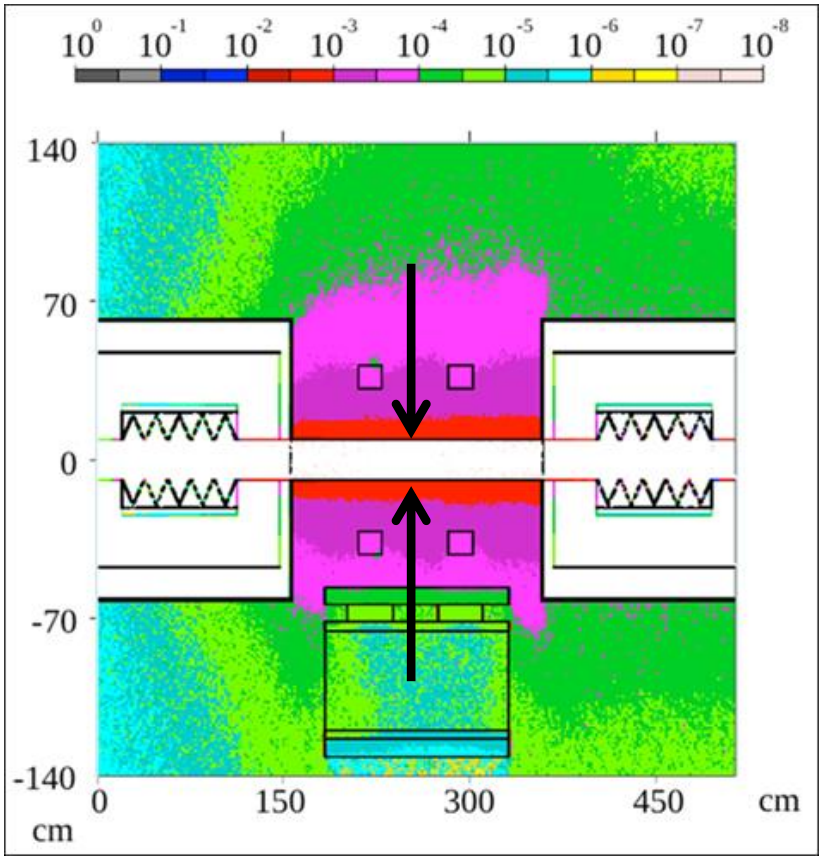

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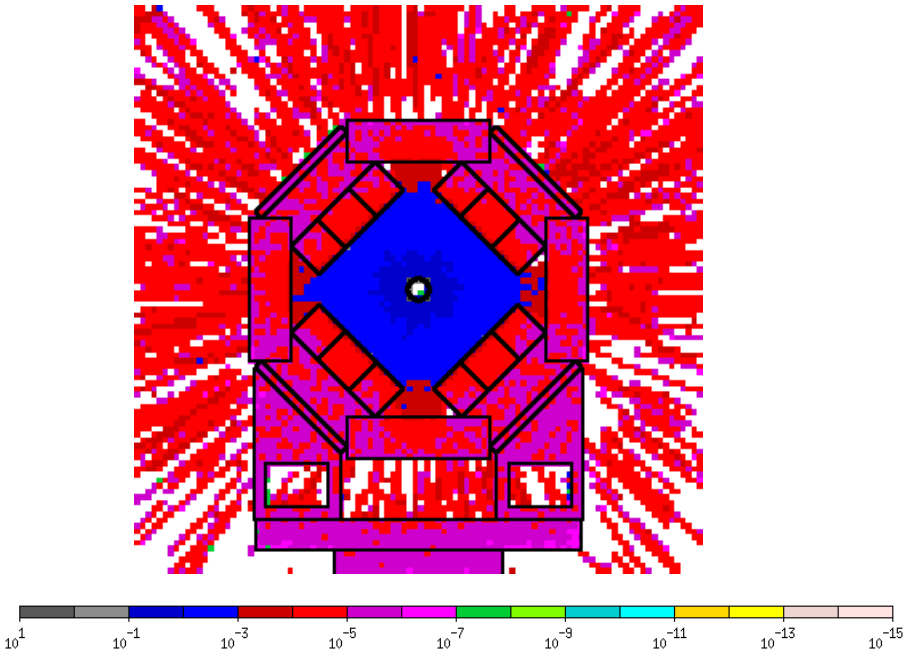

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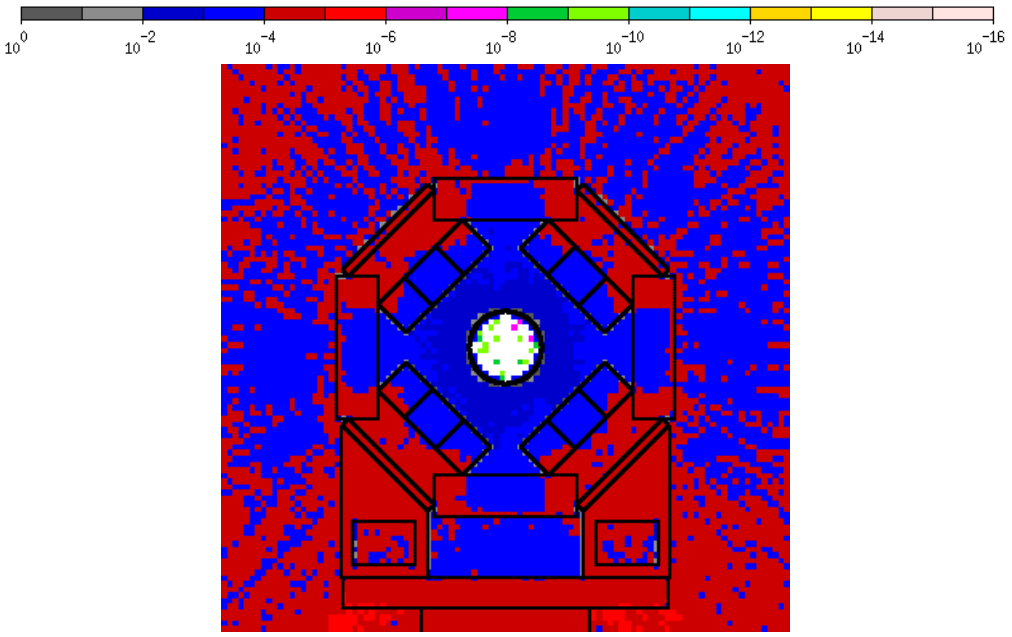
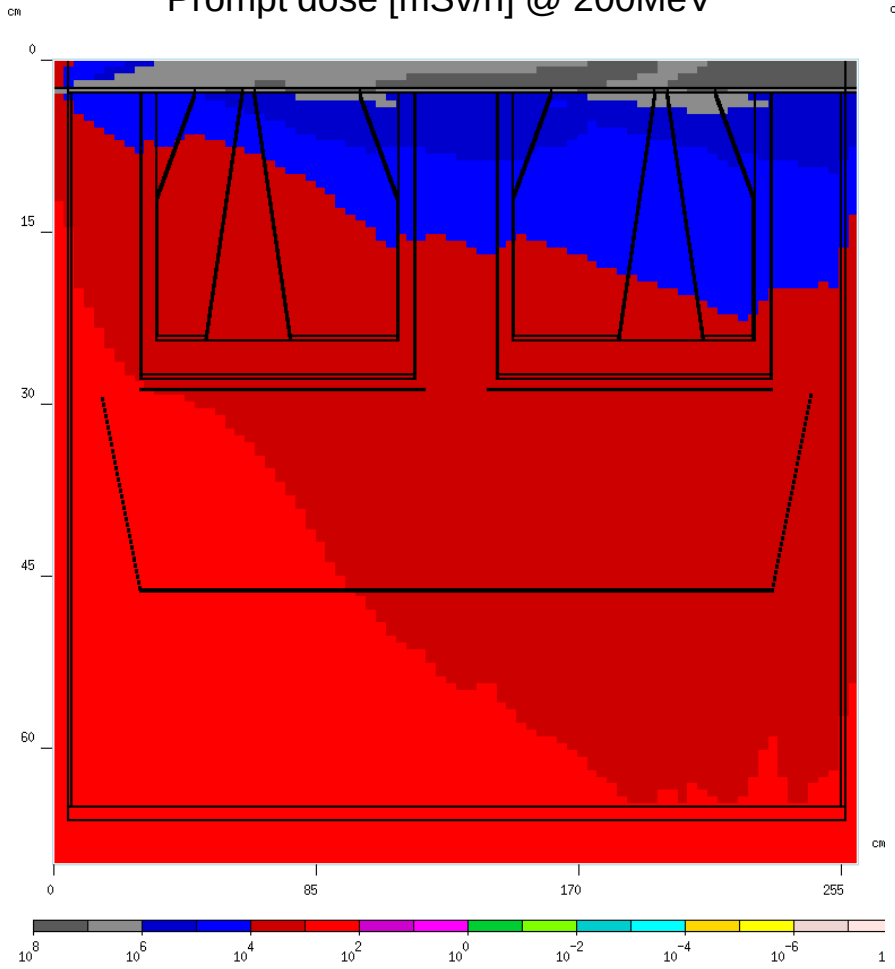


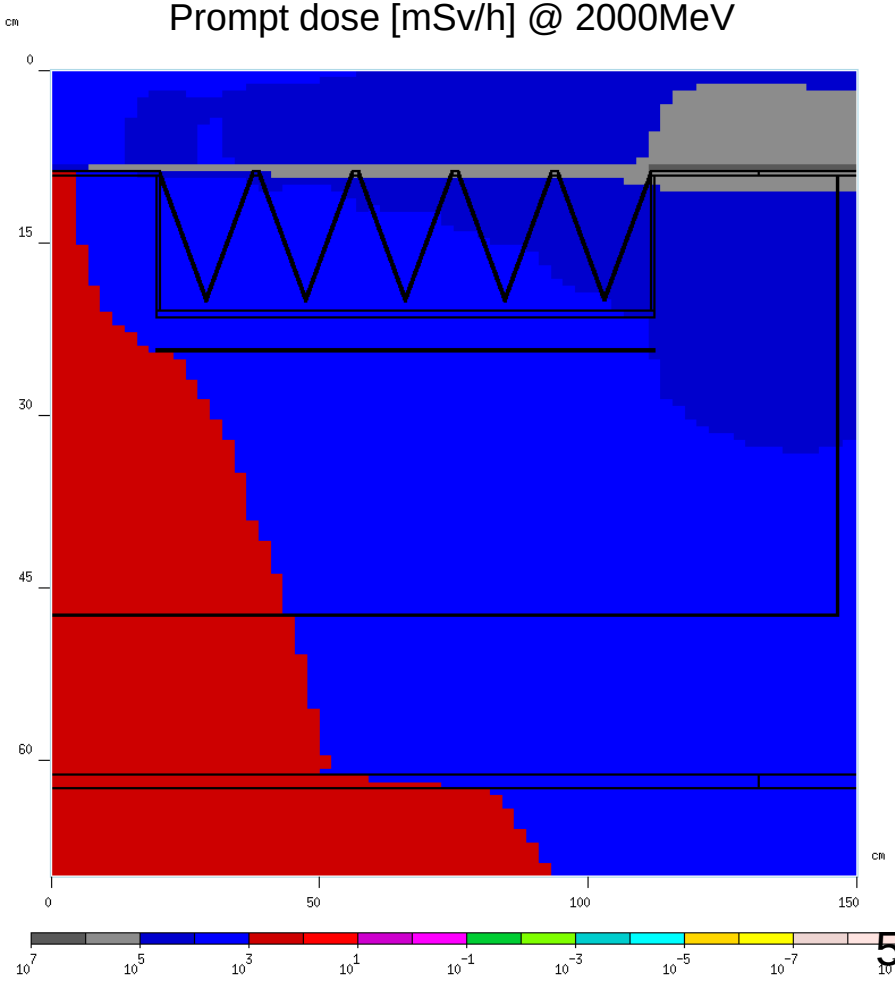
Beam loss simulations

Other results examples: prompt dose

Prompt dose [mSv/h] @ 200MeV



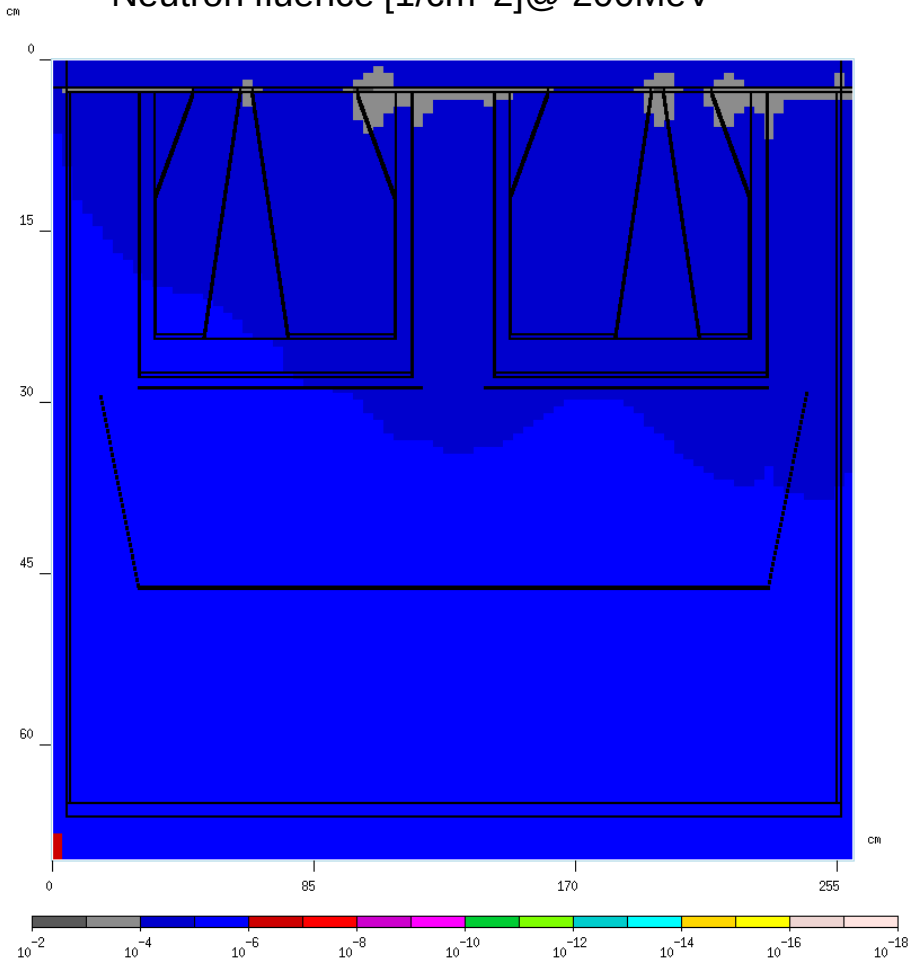
Prompt dose [mSv/h] @ 2000MeV



Beam loss simulations

Other results examples: particle flux

Neutron fluence [1/cm^2]@ 200MeV



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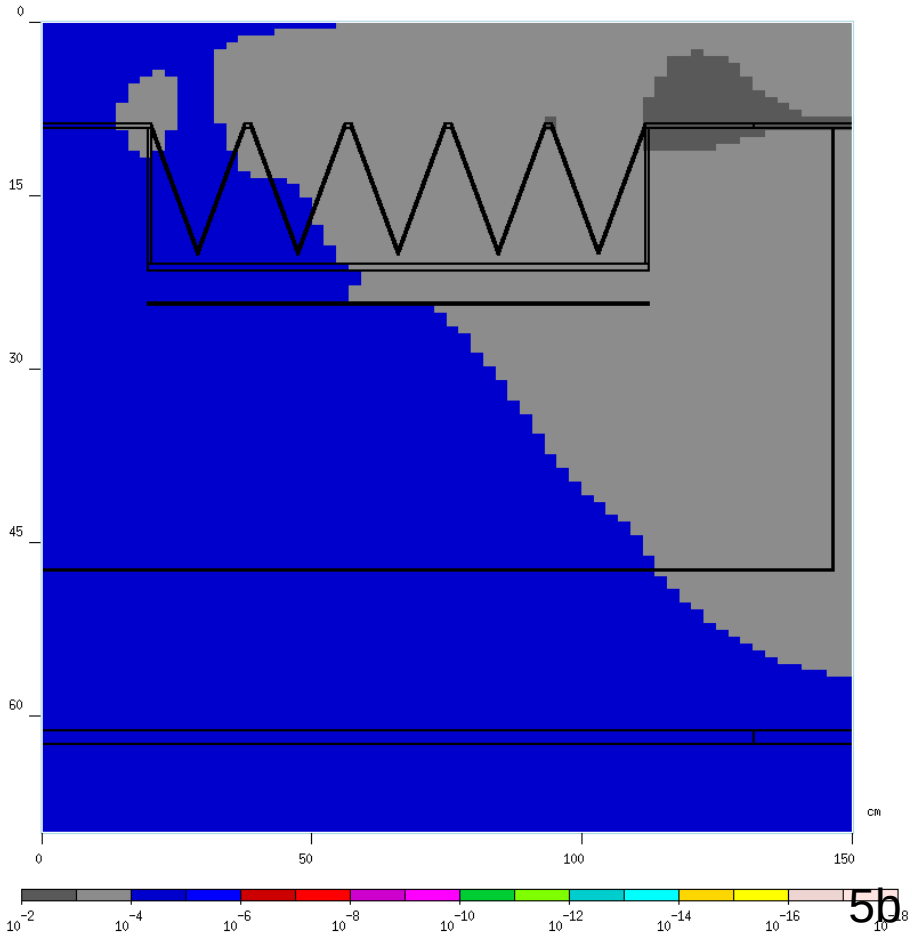

Beam loss simulations

What else the model can be used for ?

Activation of the machine components
Irradiation of the surrounding
Radiation mechanical damage of the equipment
...
...

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Beam Loss Studies

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- Optimizing the number and position of the beam loss monitors (radiation detectors)

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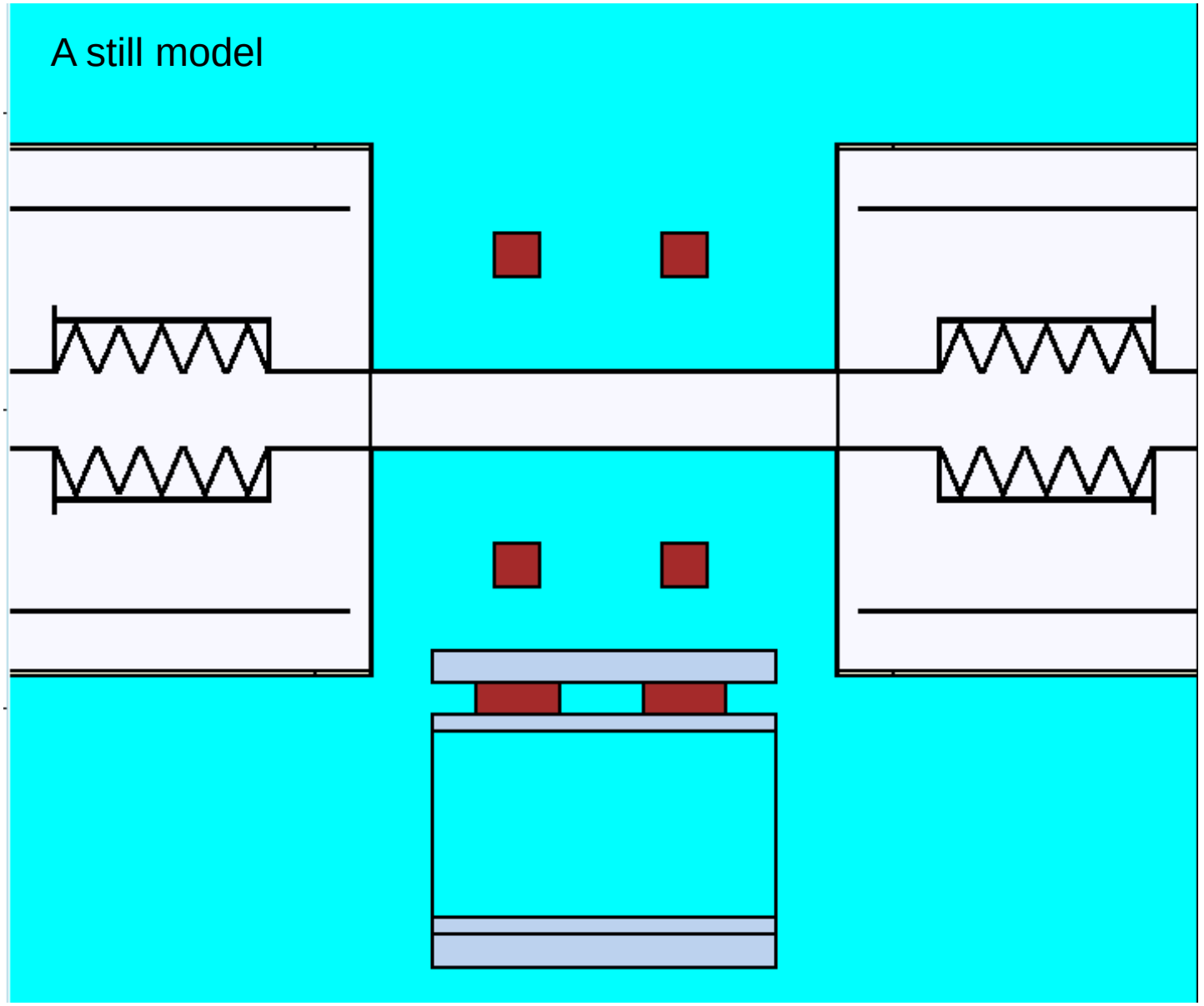
BLM optimization



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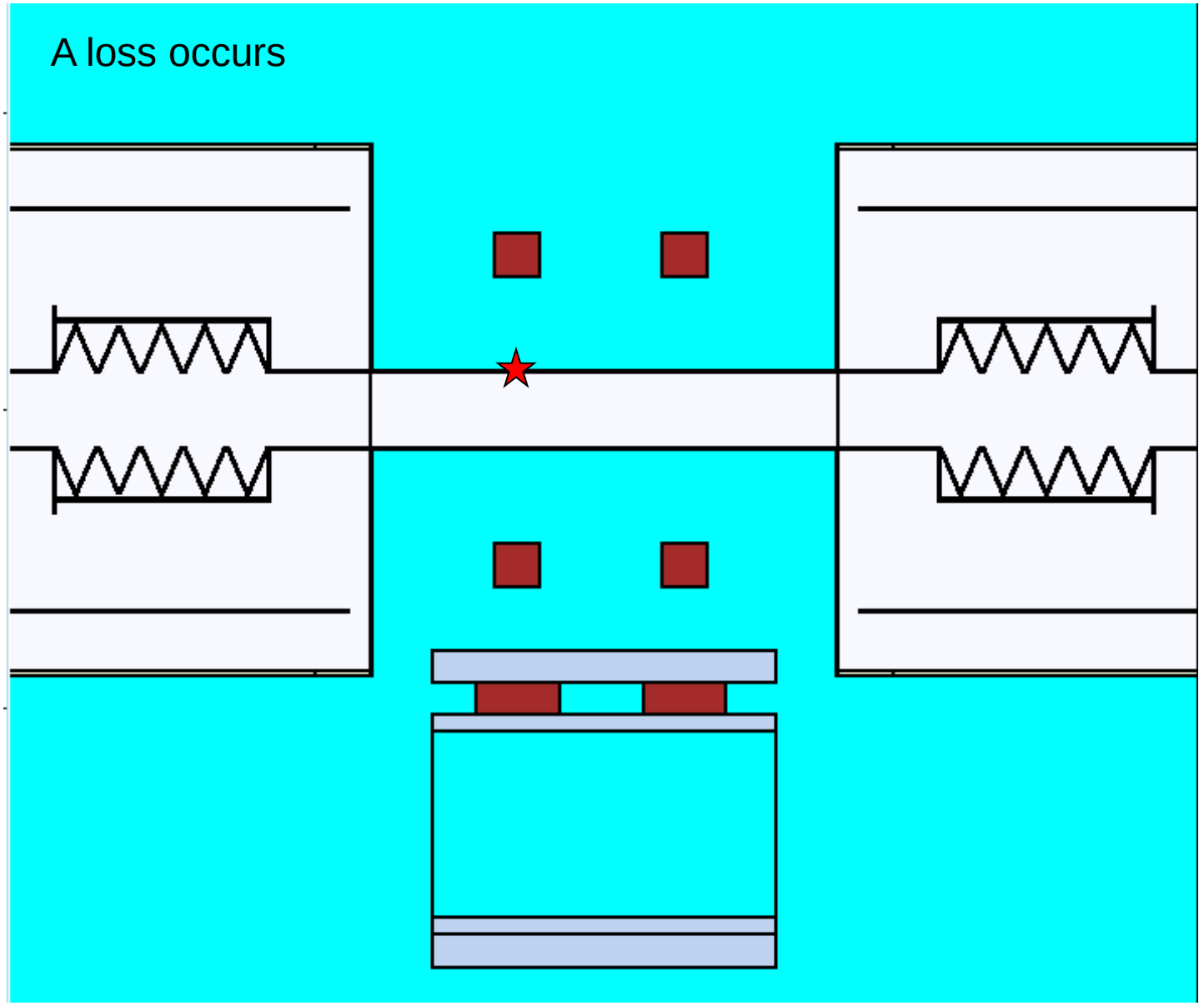

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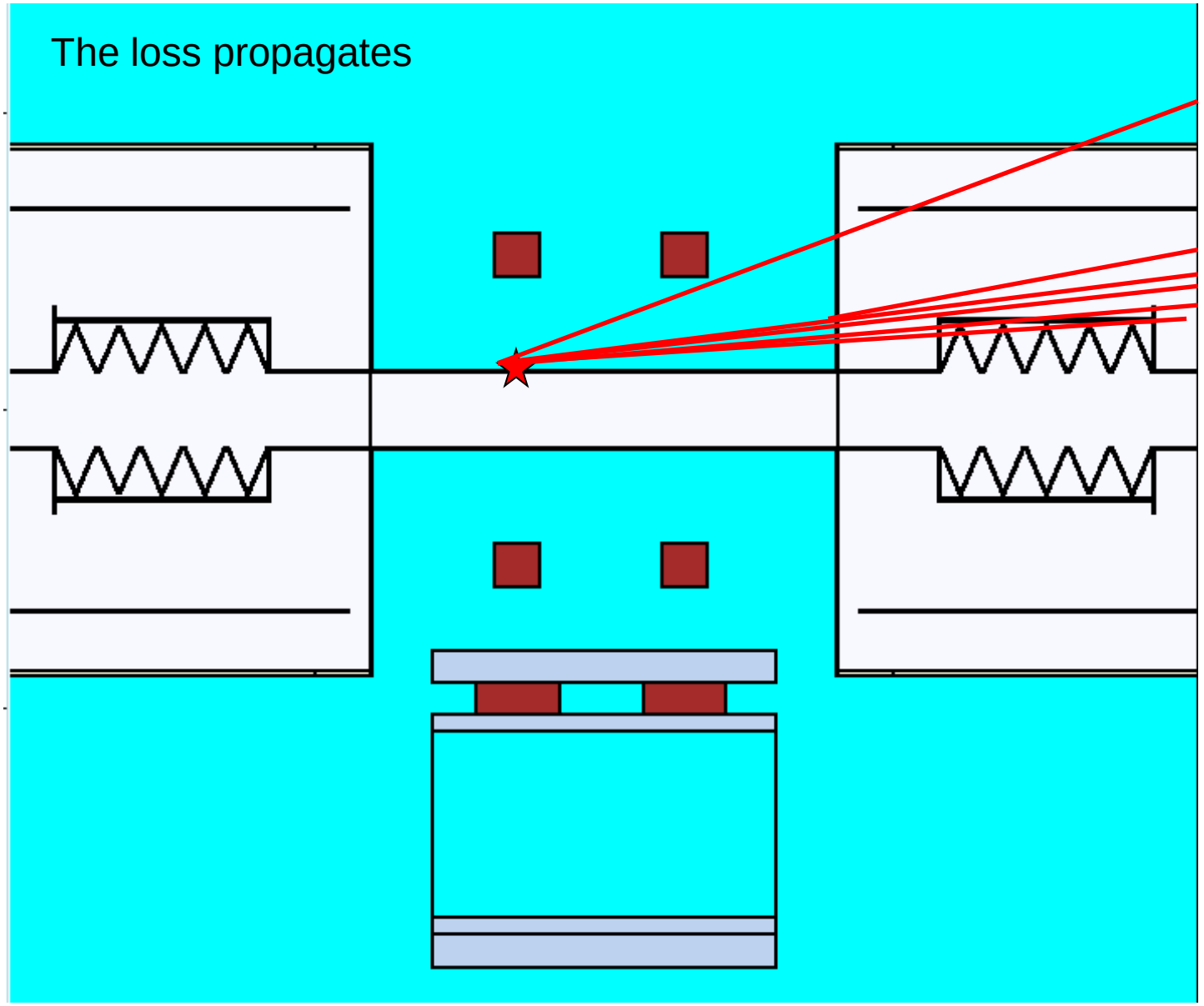

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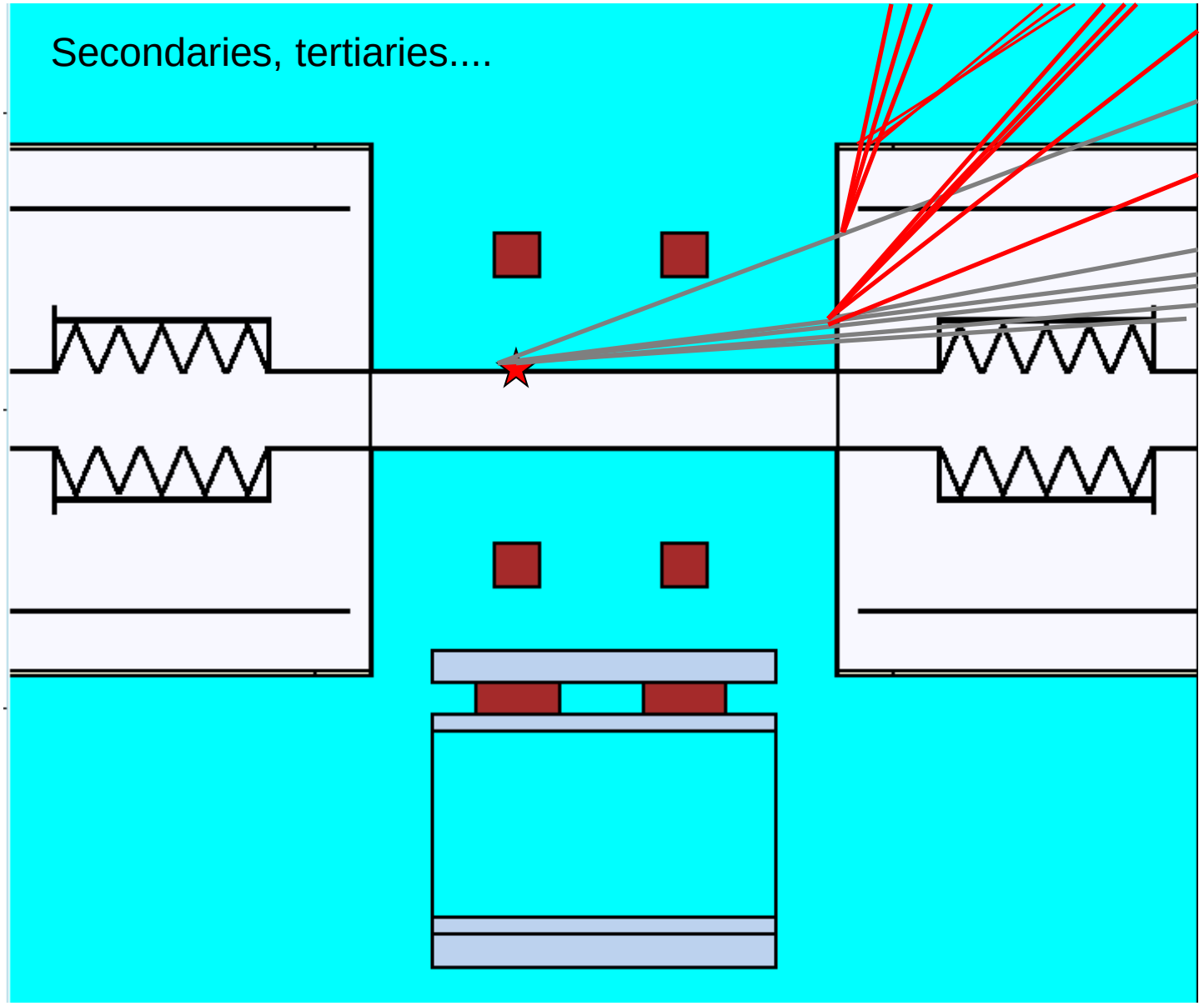

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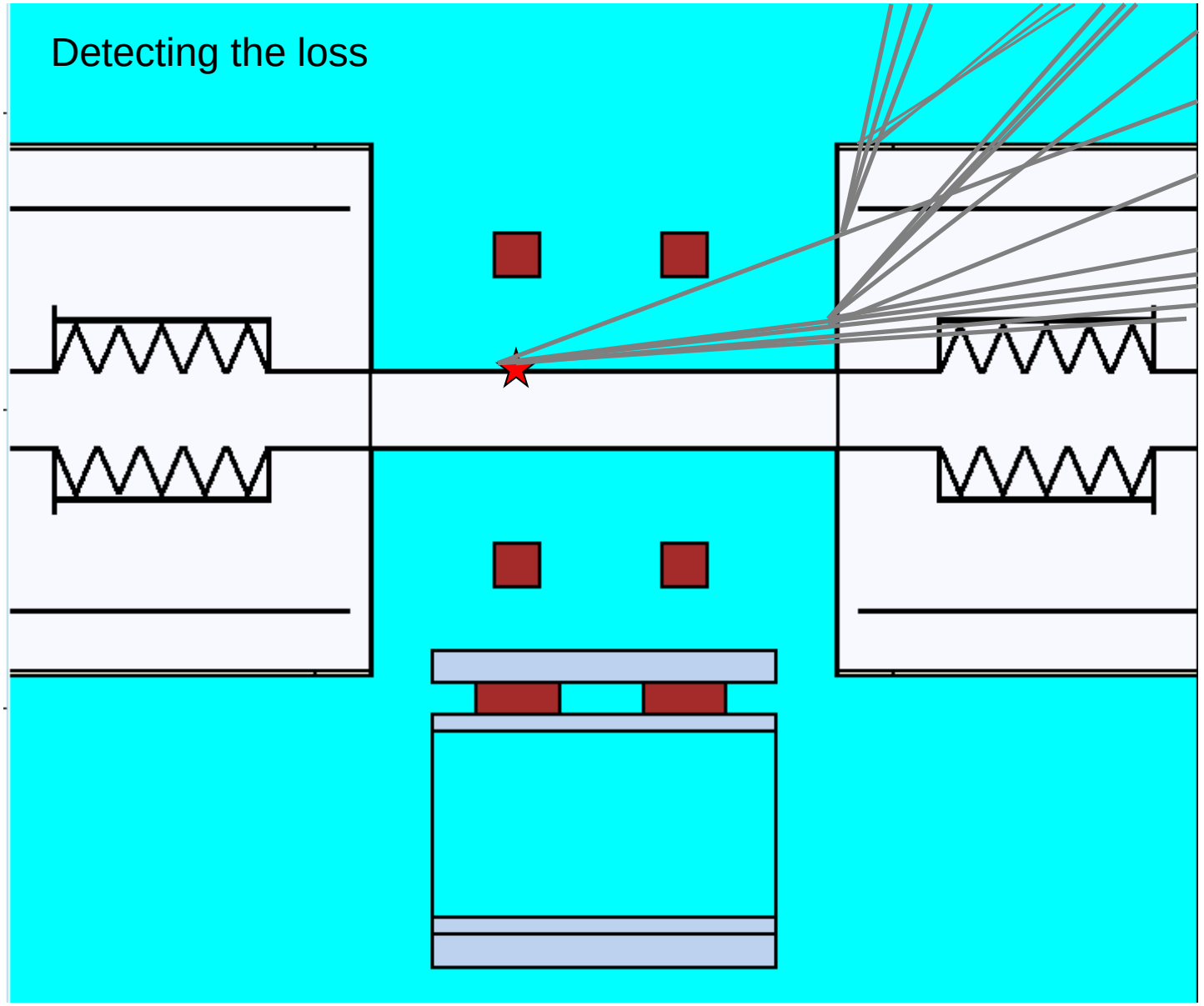

BLM optimization

CERN-type BLM

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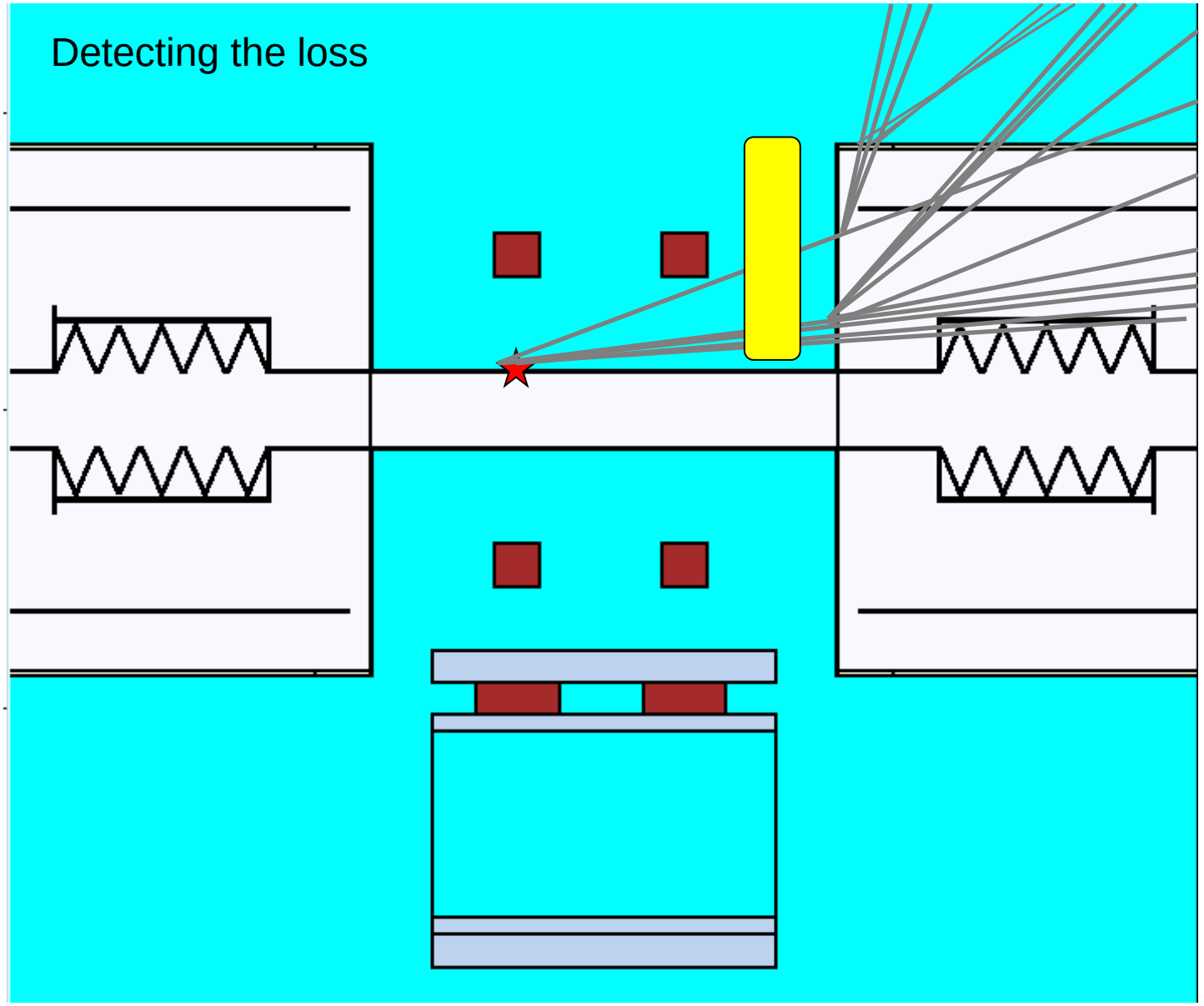

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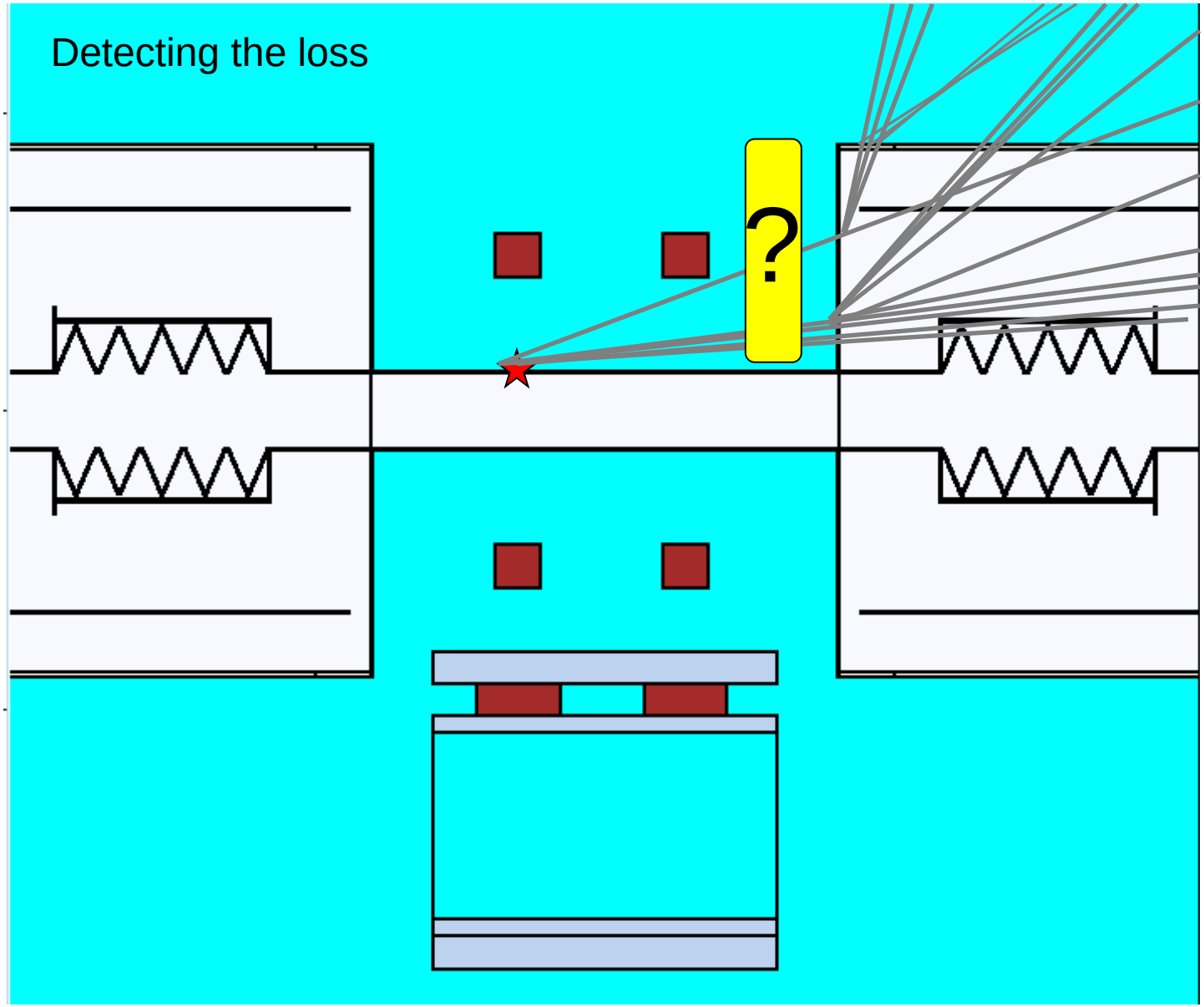

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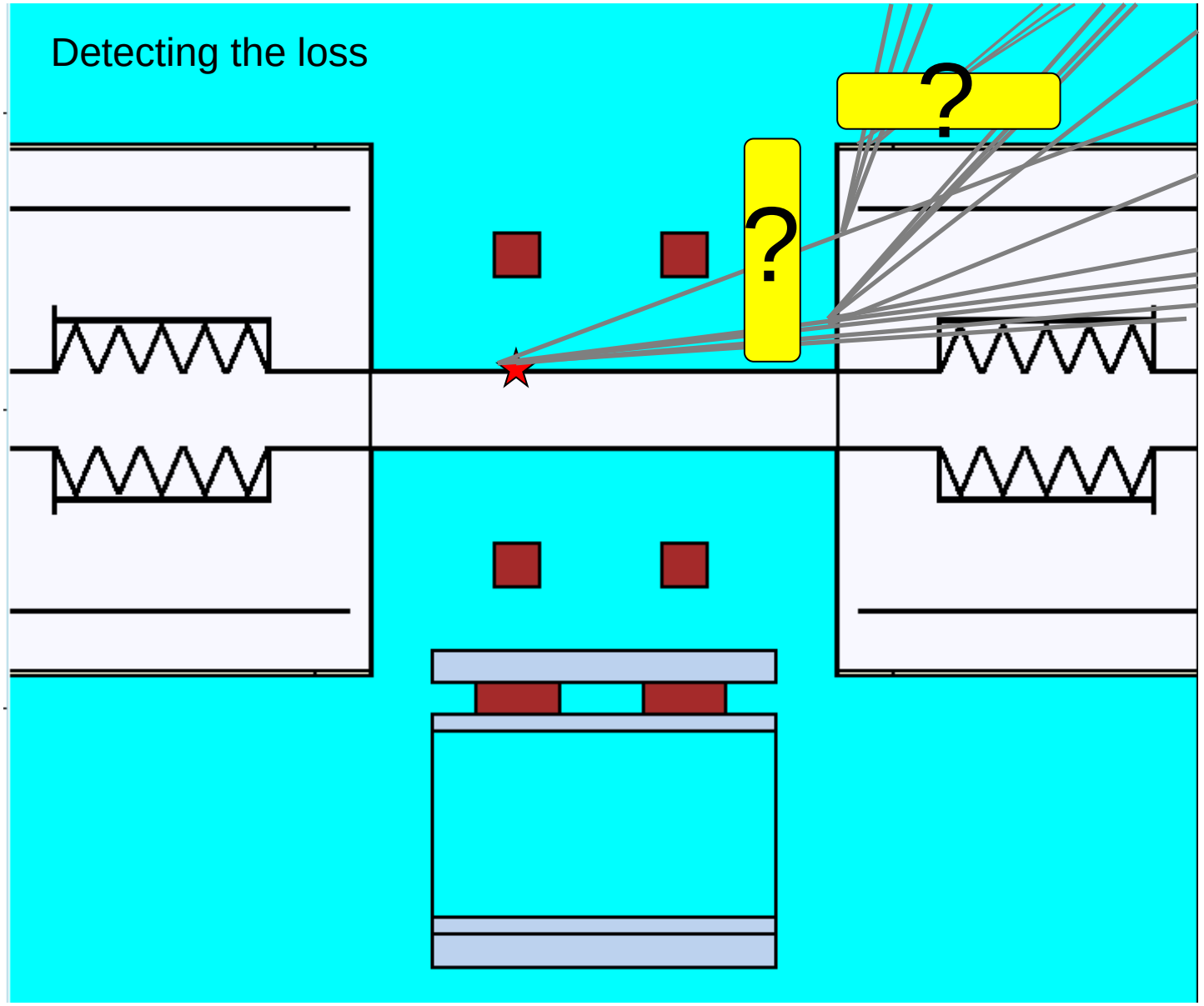

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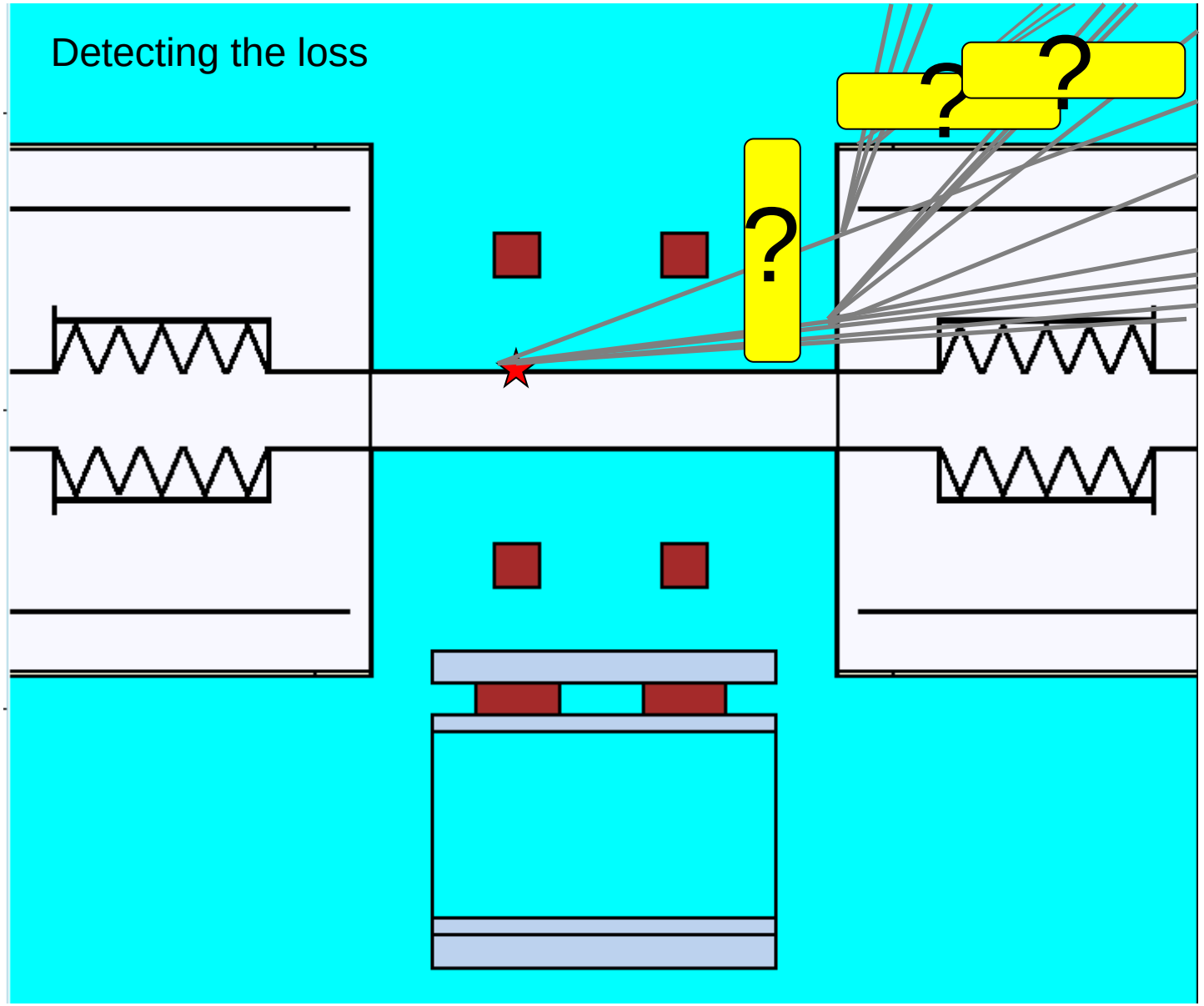

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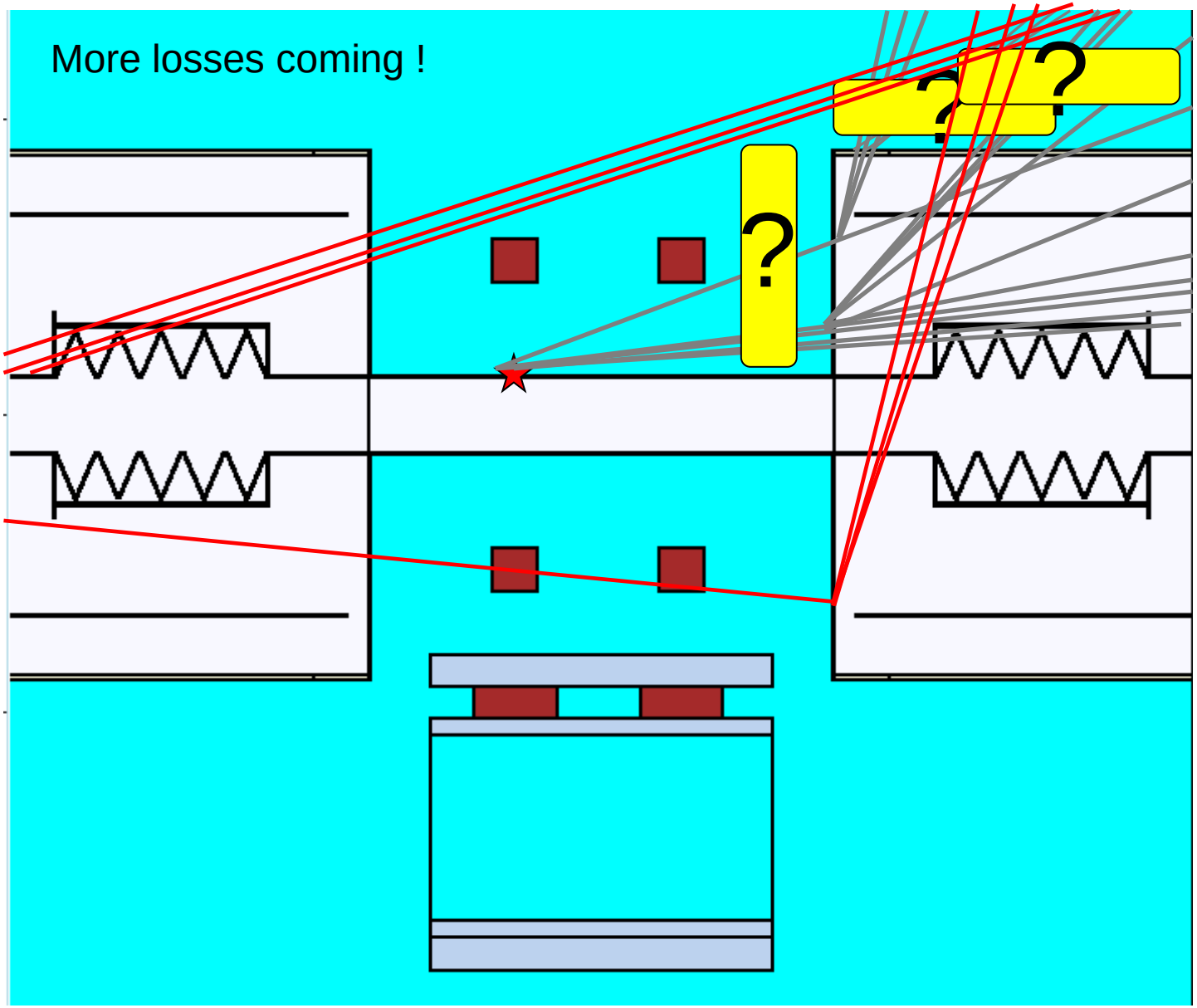

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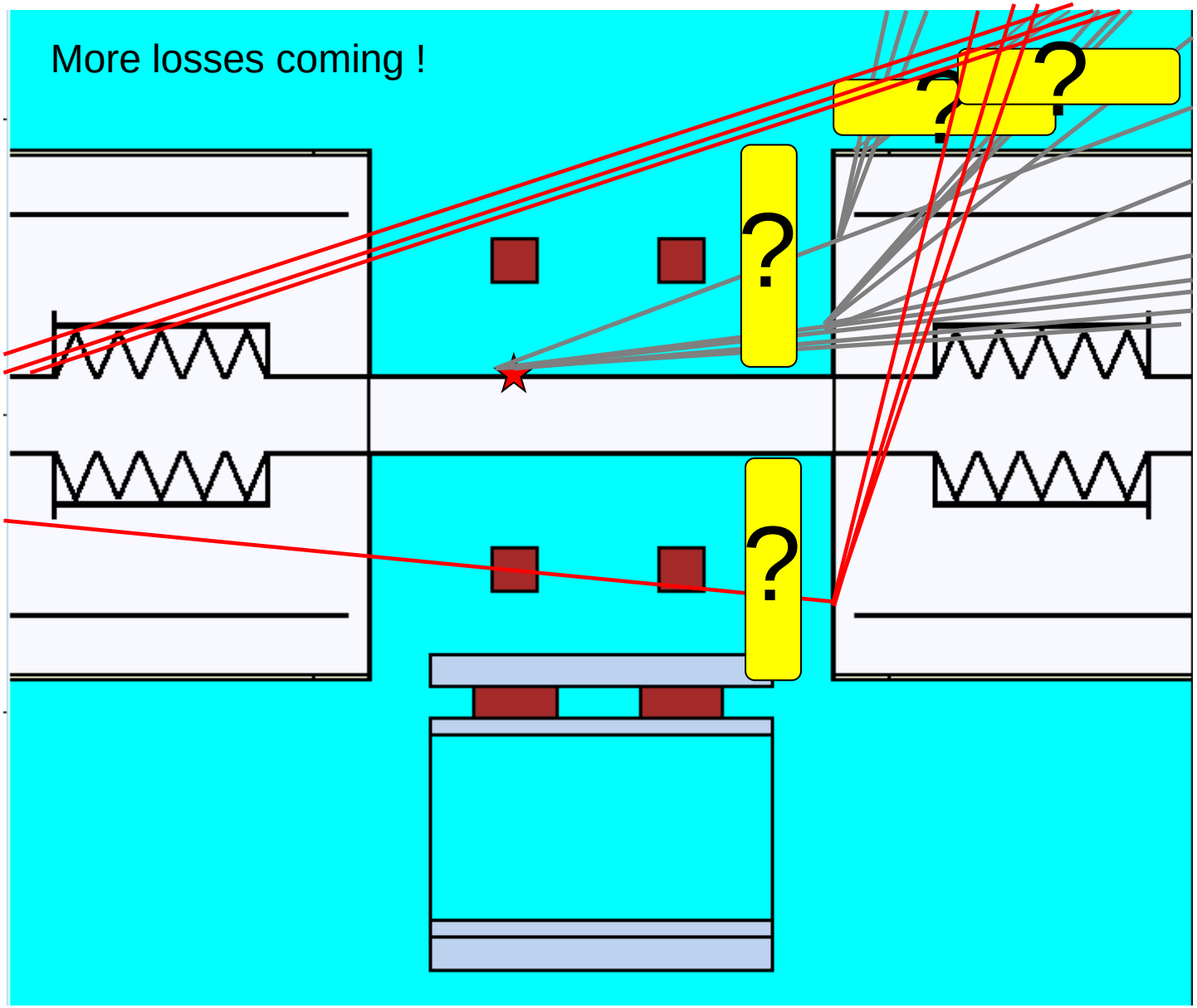

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Beam Loss Studies

- Creating a coherent model of the whole accelerator facility for various purposes connected with the radioactive beam transport
- Performing beam loss simulations
- Optimizing the number and position of the beam loss monitors (radiation detectors)
- Creating a novelty system for automization of the data processing using an artificial neural network

Neural Network Data Processing

Simulations generate a huge amount of data needed to be processed.

The data represent an optimisation problem that is multidimensional and nonlinear – cannot be described by the finite mathematical function, therefore requires special treatment.

Also, the data provide multiple sets of coherent input (detectors responses) and output (loss parameters – point, magnitude, direction etc.) vectors.

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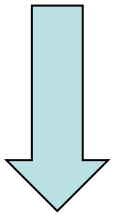
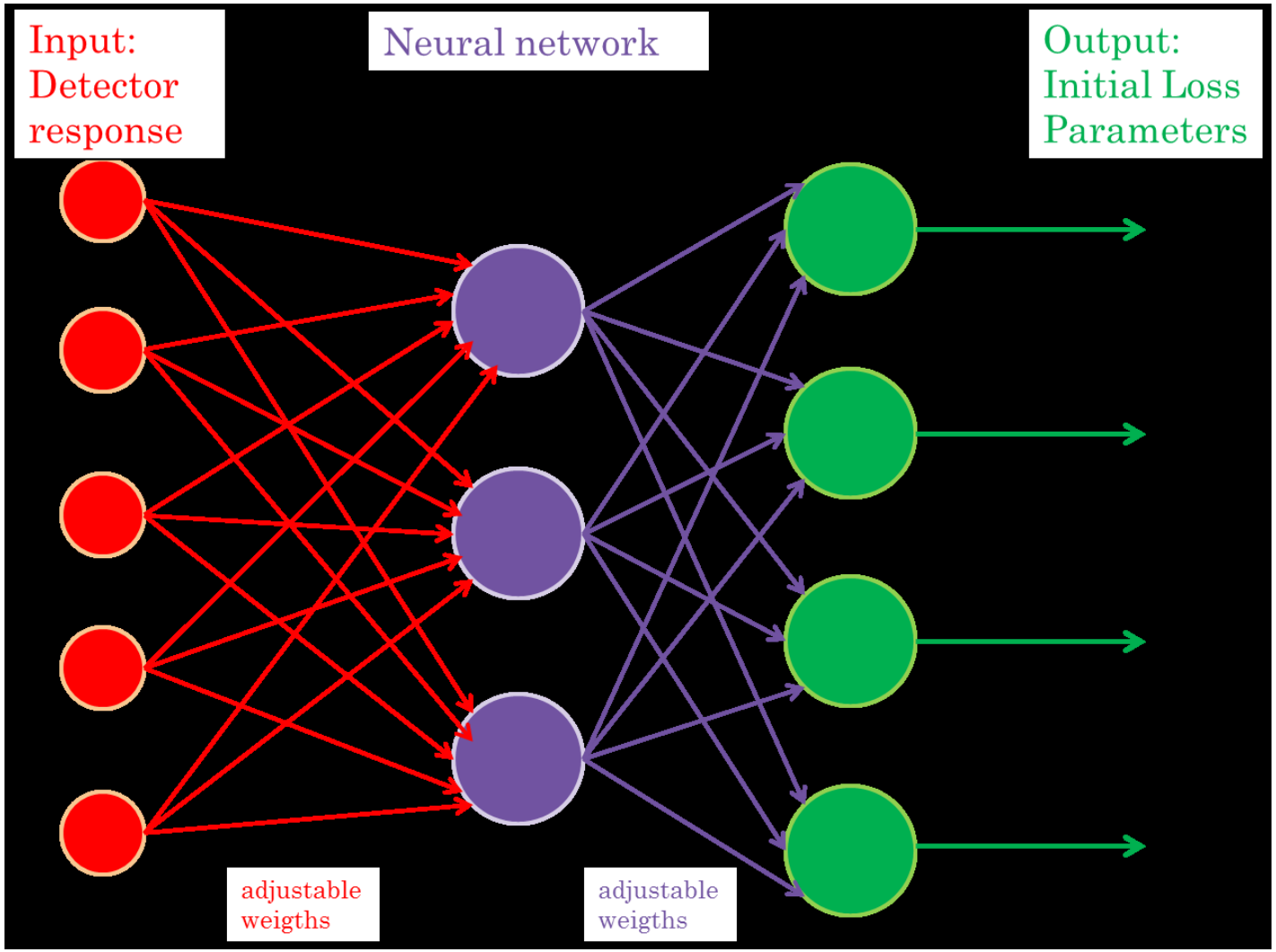
The data represent an optimisation problem that is multidimensional and nonlinear – cannot be described by the finite mathematical function, therefore requires special treatment.

Also, the data provide multiple sets of coherent input (detectors responses) and output (loss parameters – point, magnitude, direction etc.) vectors.



Seems like a perfect field for neural network processing

Neural Network Data Processing



Beam Loss Studies

- Creating a coherent model of the whole accelerator facility for various purposes connected with the radioactive beam transport
- Performing beam loss simulations
- Optimizing the number and position of the beam loss monitors (radiation detectors)
- Creating a novelty system for automization of the process using an artificial neural network
- Public outreach – a series of lectures on basics of accelerator science for high school students

EUROPEAN SPALLATION SOURCE

Thank you for attention