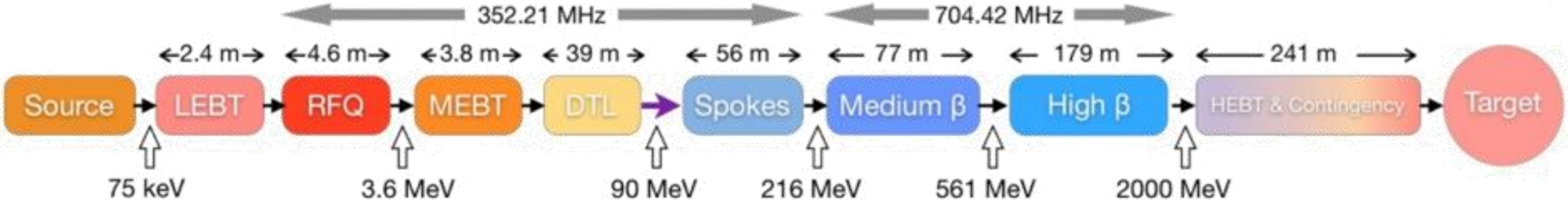
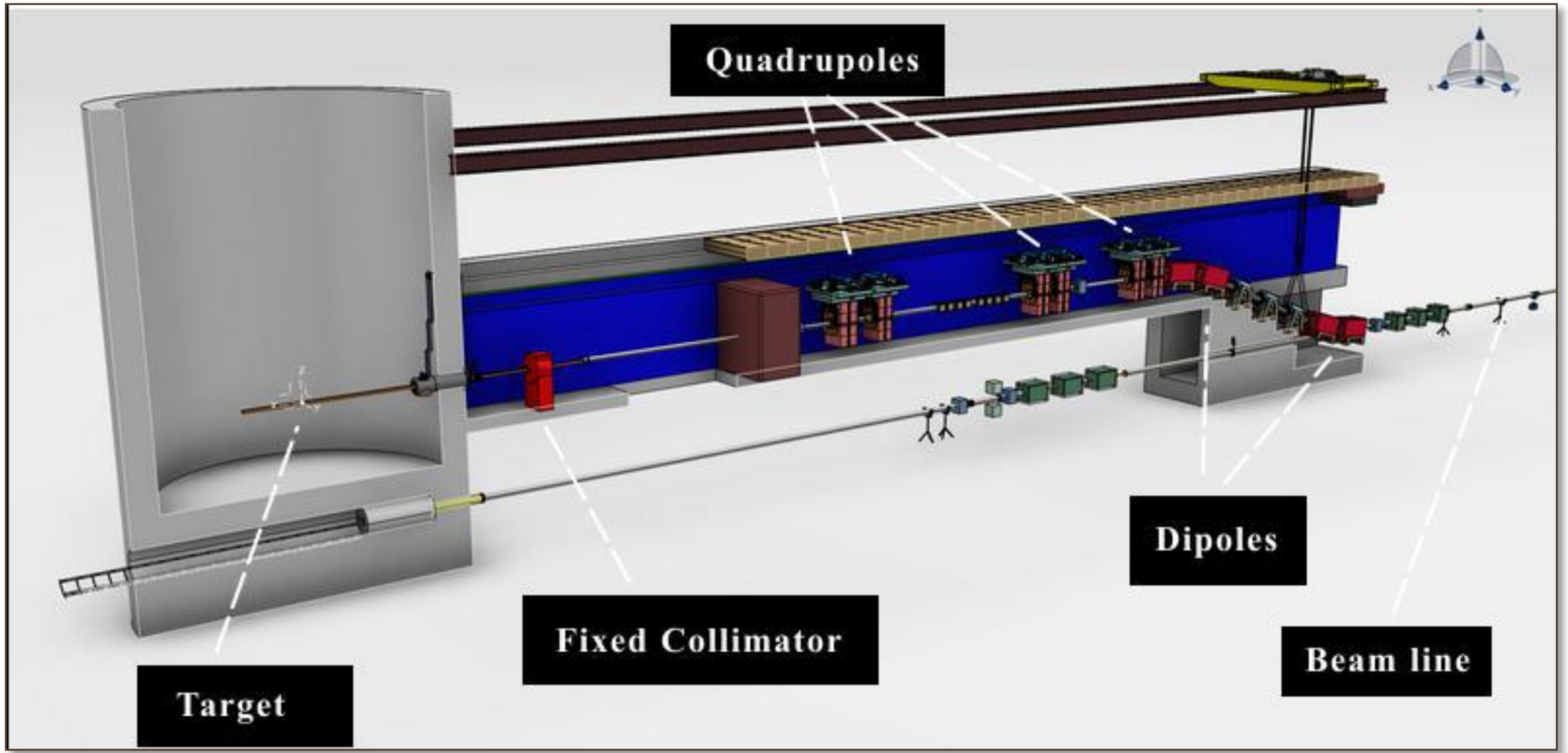
Fixed collimator

Lund
14.05.2014
Karol Szymczyk
Karol.Szymczyk@ncbj.gov.pl

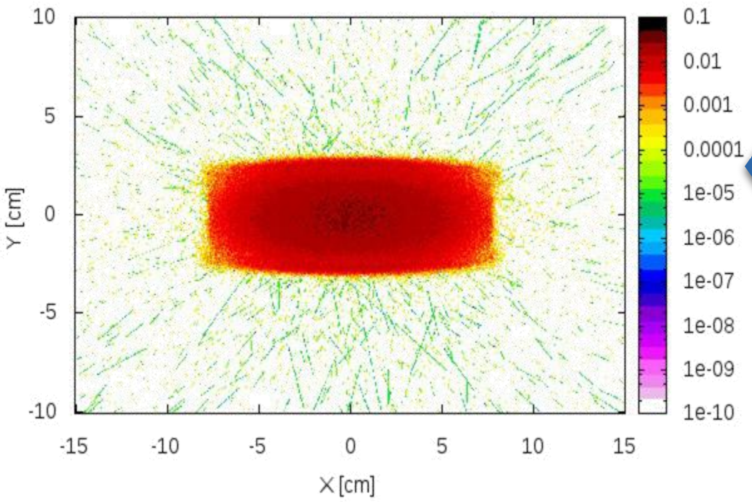
Schematic layout of HEBT





Two scenarios of collimator designing

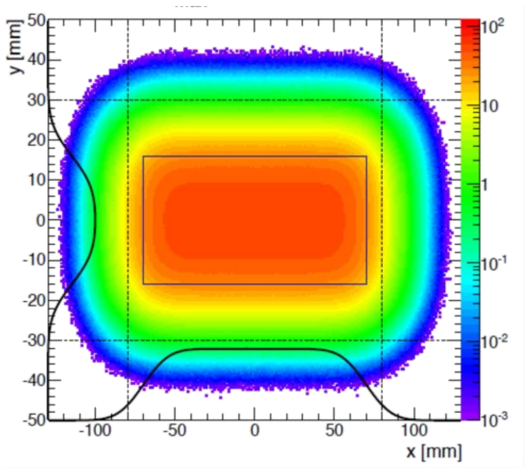
The beam generation system is determine the purpose and the way to design collimator



Proton flux XY on the target

non-linear beam expander system

linear raster system



Proton flux XY on the target

The main role a collimator should play in the ESS project is to protect the target

Used tools:

TraceWin

FLUKA

ANSYS®

Used tools:

- TraceWin: Proton beam distribution
- Fluka Program: dose, material, and activation simulation
- Ansys program: temperature simulation and cooling system simulation

karol.szymczyk@ncbj.gov.pl

Layout with non-linear beam expander system

karol.szymczyk@ncbj.gov.pl

Assumptions

- Collimator located between the last magnetic elements and the PBW
- **The main role that collimator should play in ESS project is to protect the PBW and the target**
- **Fixed collimator should ensure a beam foot print on the target surface of 160 mm horizontally and 60 mm vertically**
- **Collimator should cut tails and back scattering**
- Collimator should be able to absorb 25 kW
- Collimator should have a sufficient thickness to absorb more than 99% of proton range
- Lifetime, if possible about 45 years

Main parameters of the nominal ESS beam:

Beam energy 2.5 GeV

Beam power 5 MW

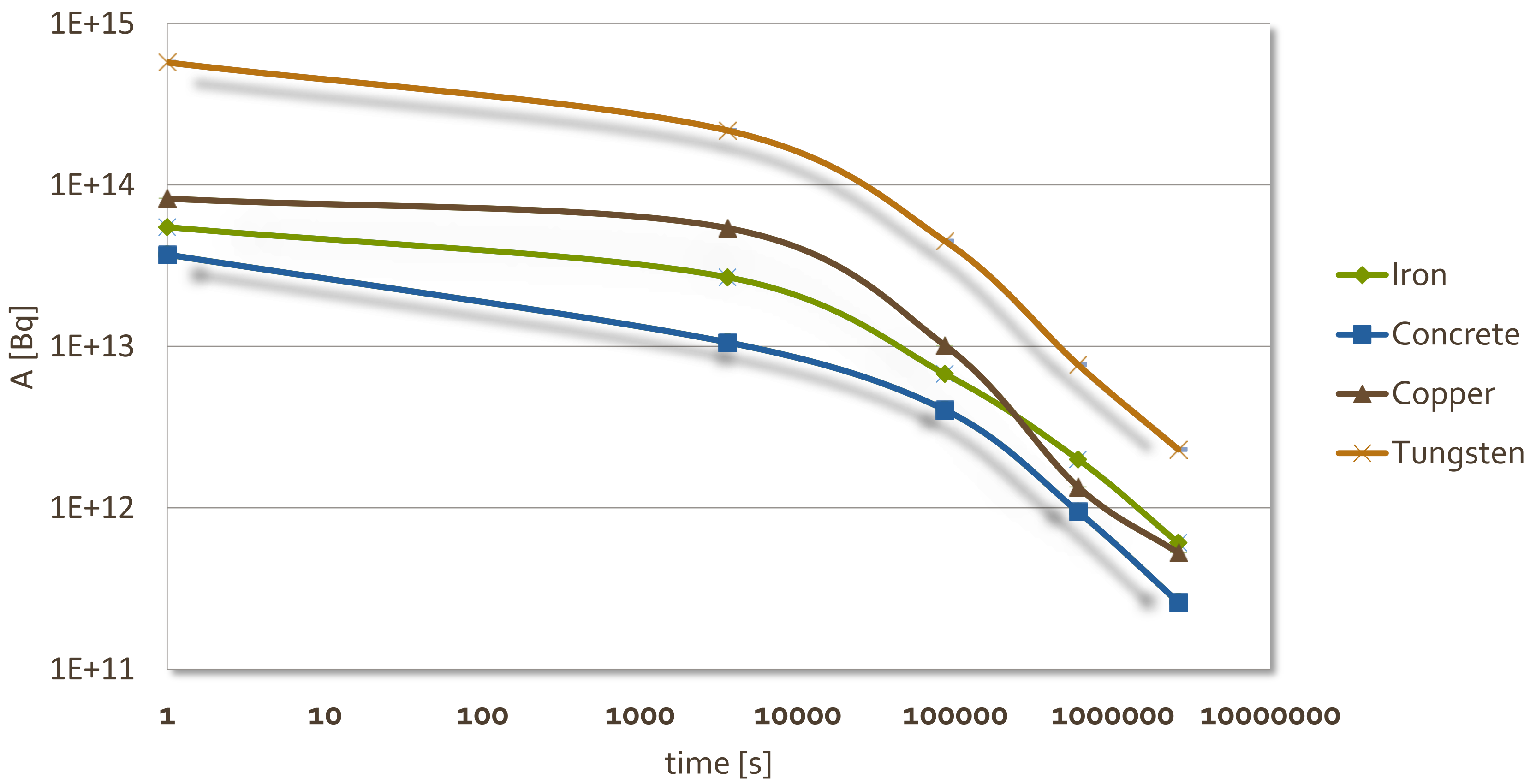
The beam flux $1.248 \cdot 10^{16}$ p/s

The beam current 2 mA

karol.szymczyk@ncbj.gov.pl

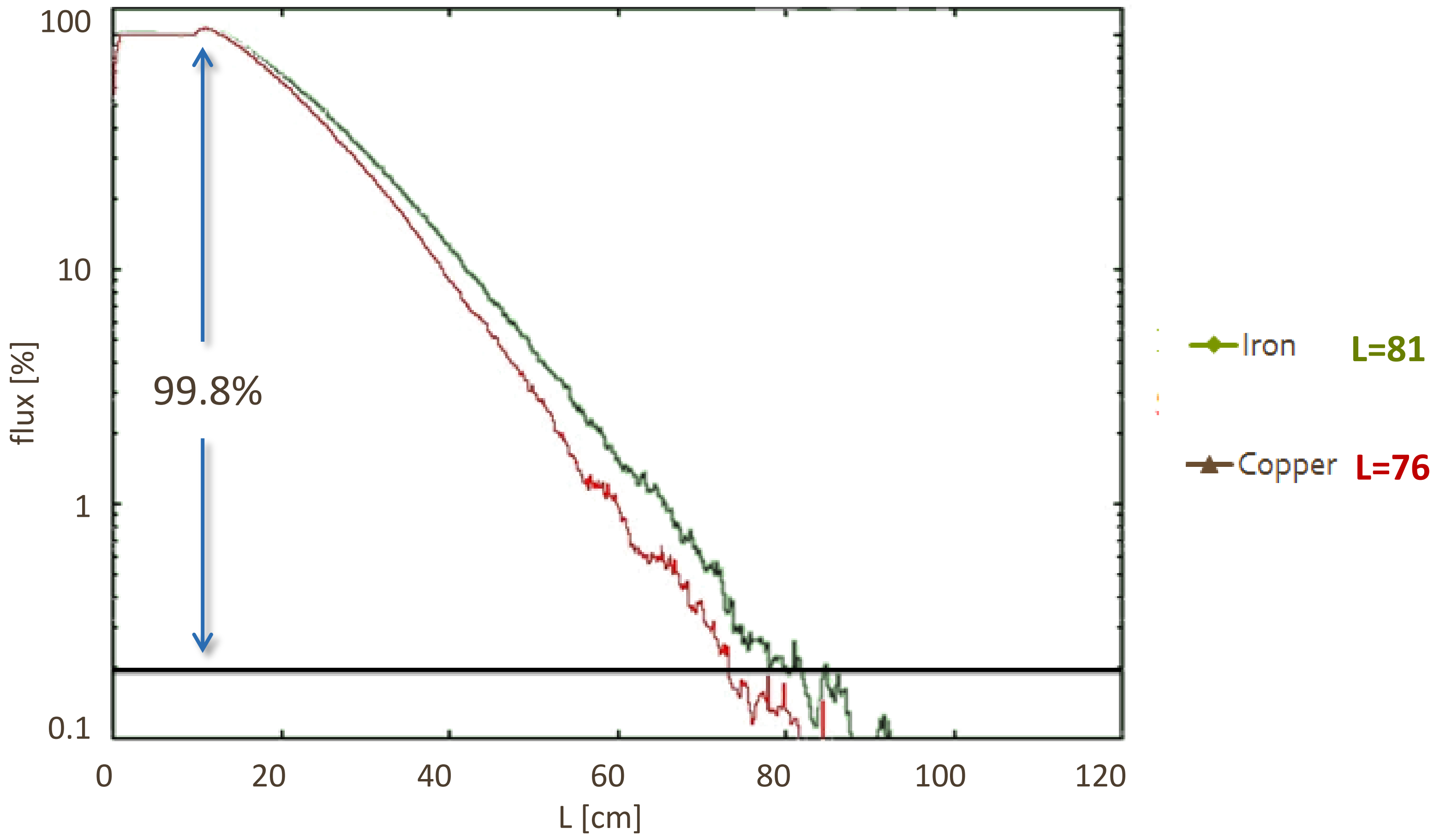
Material choice - deactivation as a function of time.

28h beam on. Activity controlled after: 1s, 1h, 1d, 1w, 1m of cooling.

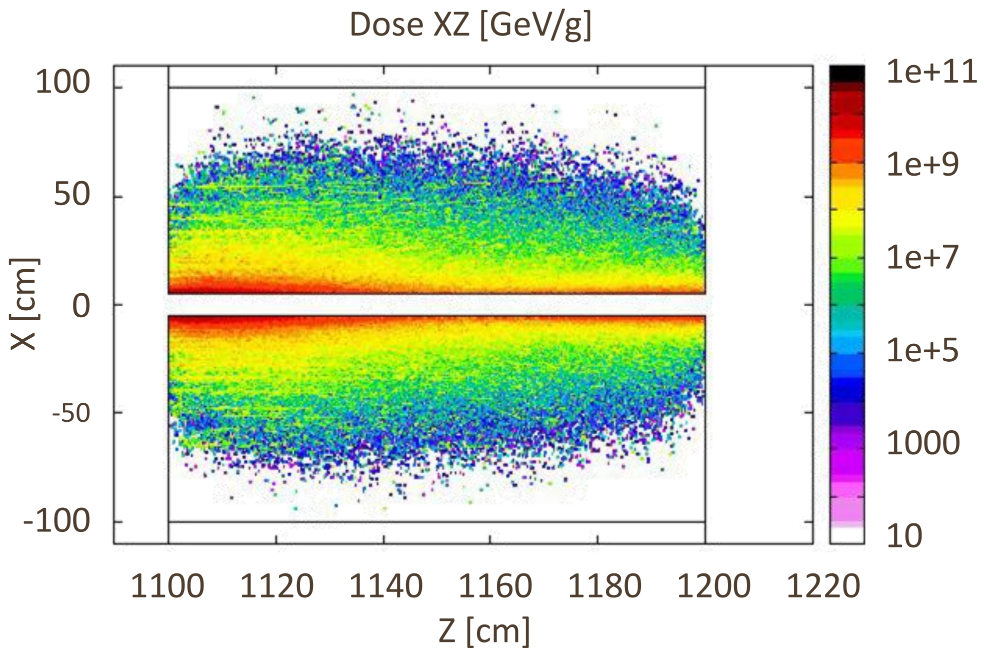


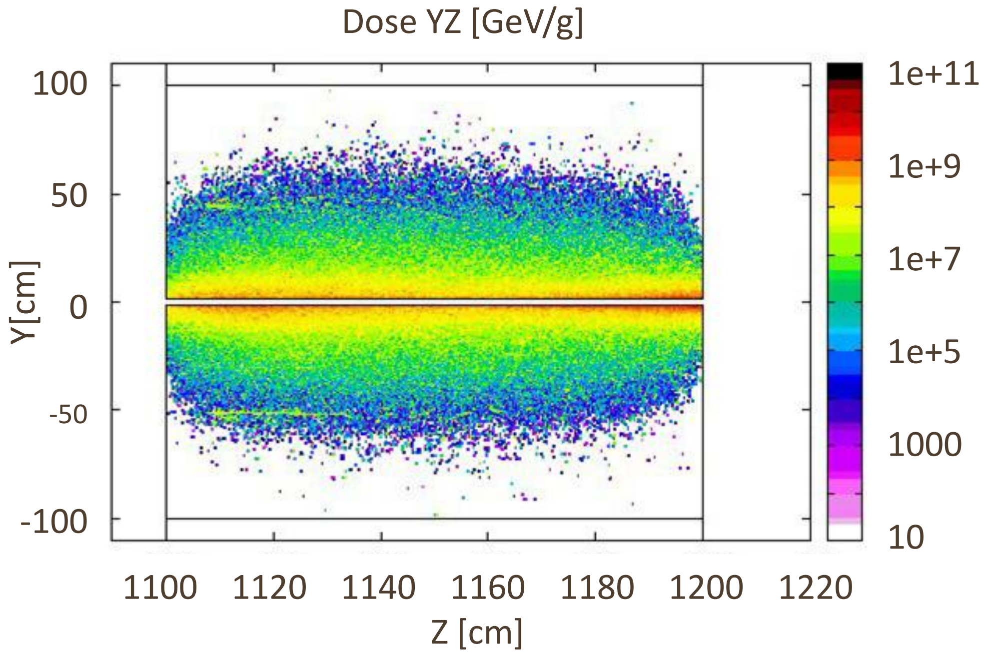
Material choice

Comparison of the proton range in copper and iron collimator.



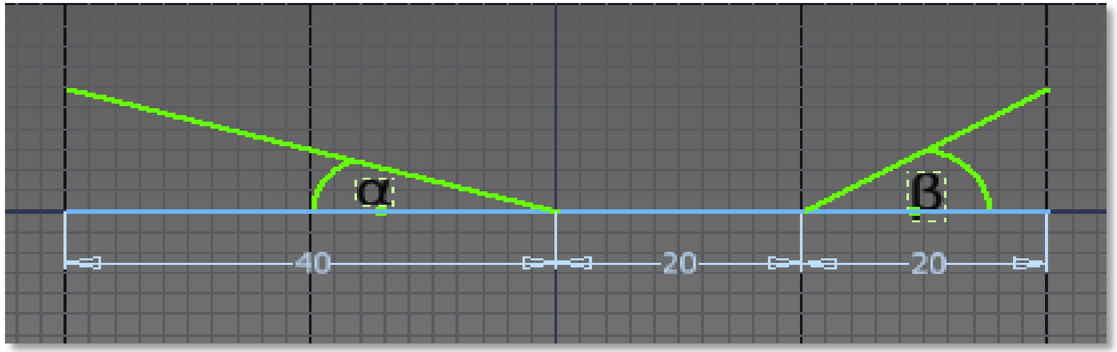
Shape of collimator : collimator with parallel jaws





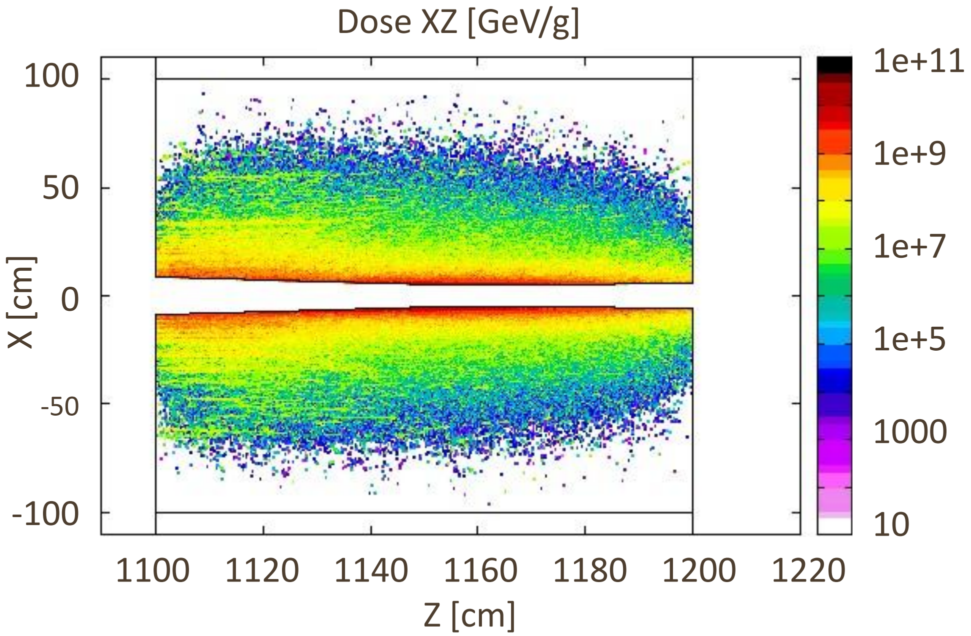
Distribution of the absorbed dose in the X,Y axes for parallel collimator jaws. Hot centres can be seen at the beginning and at the end of jaws.

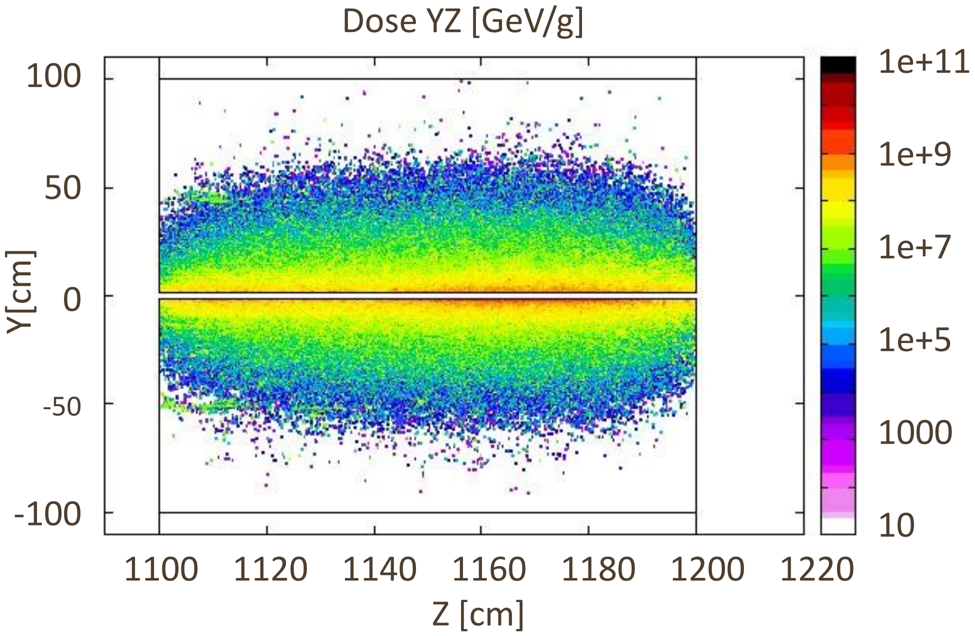
Shape of collimator : collimator with changed jaws shape



In X axis:
α = 4°
β = 1°

In Y axis:
α = 0°
β = 1°





Residual dose equivalent rate

Zones:

Supervised radiation areas; <3 μSv/h

Controlled radiation area blue; <25 μSv/h

Controlled radiation area yellow; <1000 μSv/h

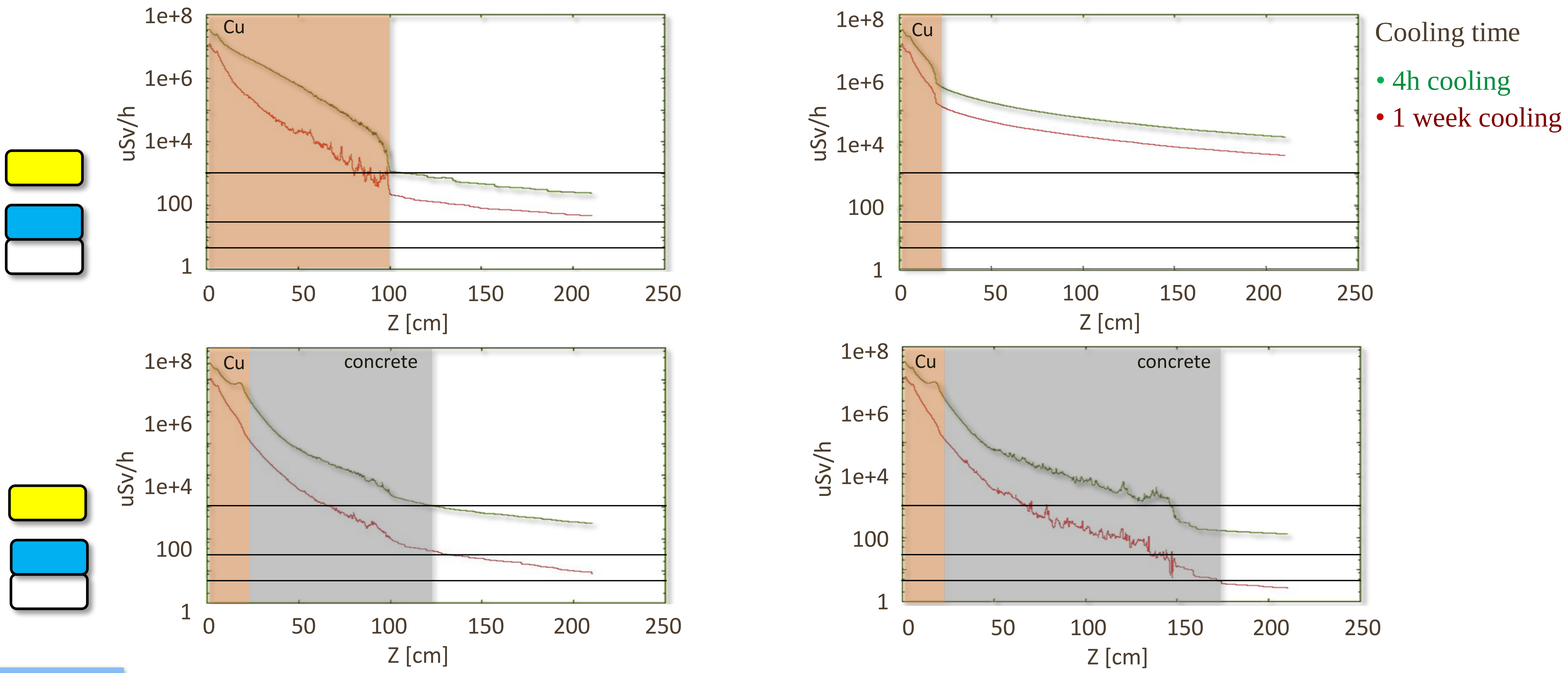
4 weeks of exposure and :

- 4 hours of cooling
- 1 week of cooling

for different collimator's radii :

- R = 20cm
- R = 1m
- R = 20 cm of copper + 80 cm of concrete
- R =20 cm of copper + 1.3 m of concrete

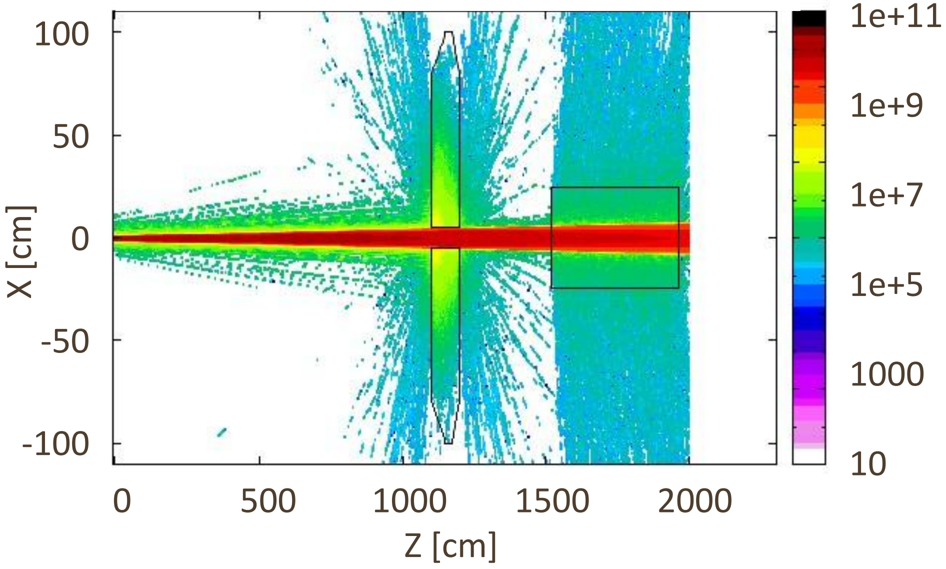
Residual dose equivalent rate after 4 weeks of exposure



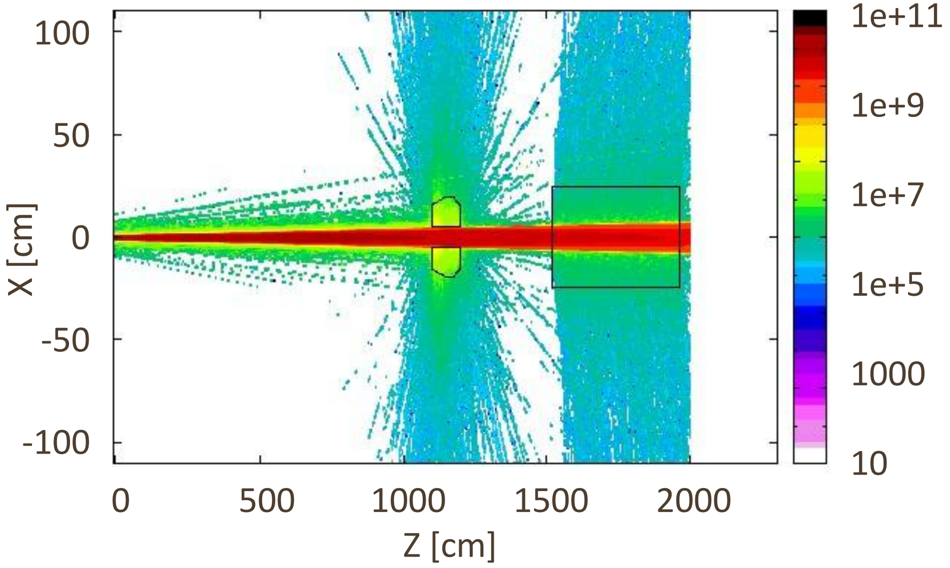
Protection the PBW

- Decreasing radius of the collimator does not affect the safety of PBW
- Backscattering is mainly perpendicular to the proton beam

Flux all particles XZ - 1m radius of copper

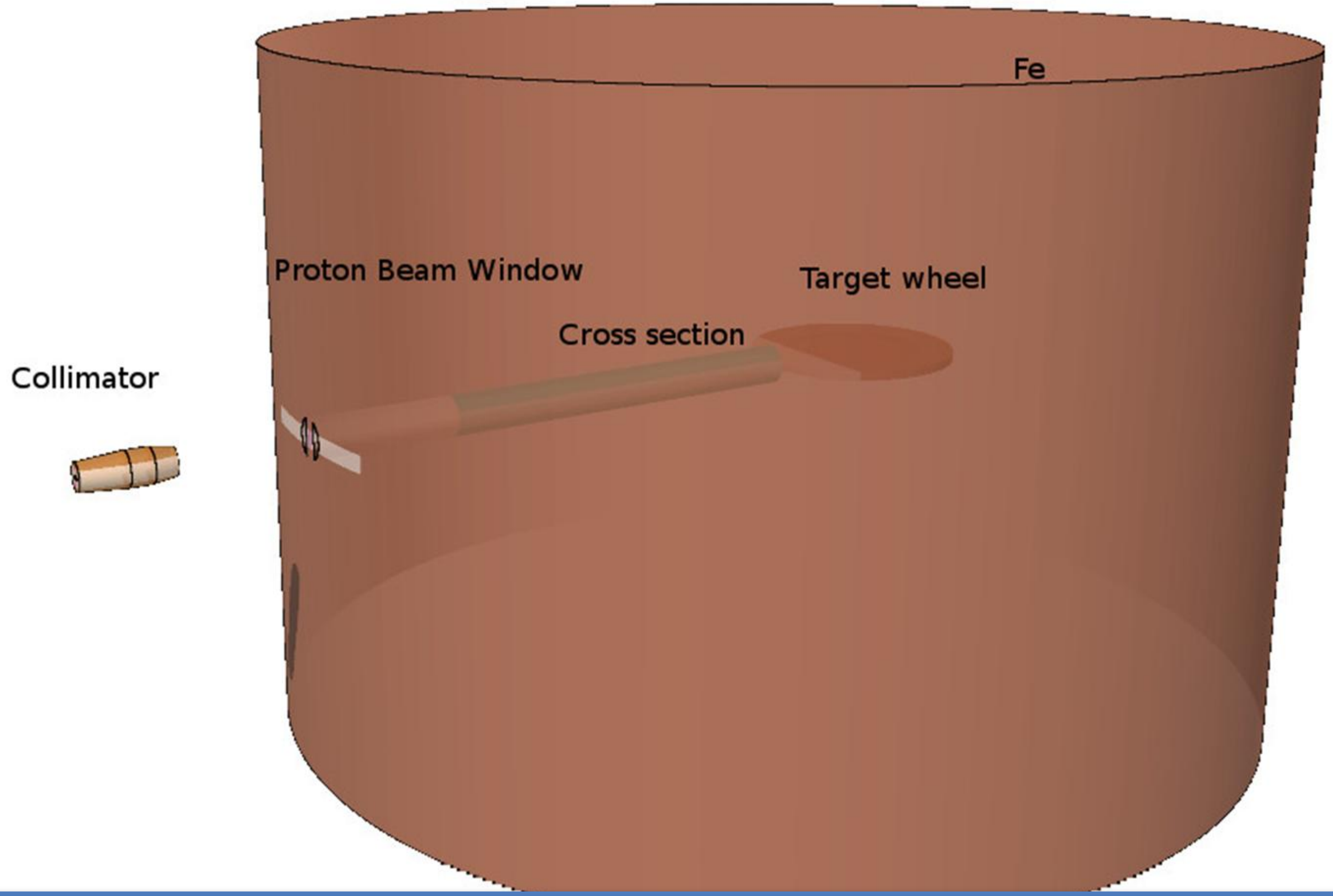


Flux all particles XZ – 0.2m radius of copper

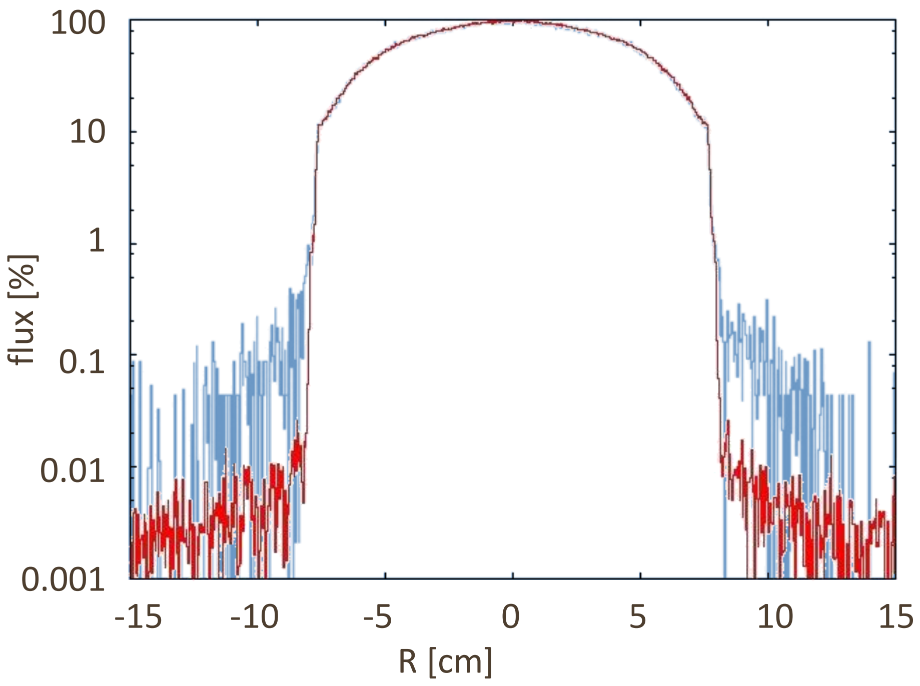


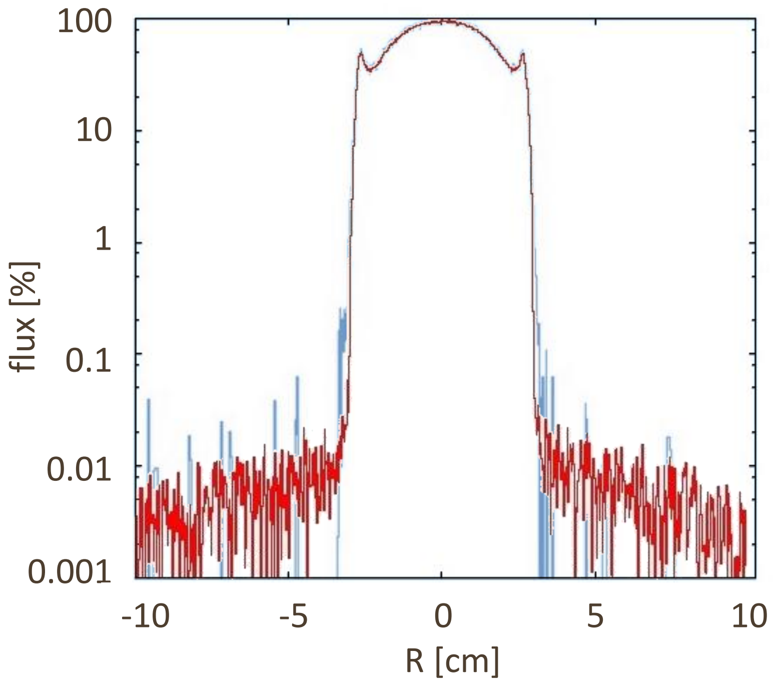
Collimator with Target section, with 3D visualization

The whole scheme of the Target was modelled, for more realistic simulations of HEBT.



Footprint on the Target





Protons flux projection on X-axis on the target, without the collimator

Protons flux projection on X-axis, before the target, with the collimator

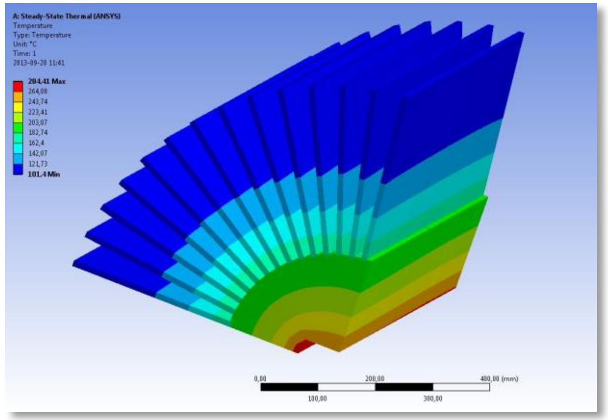
Protons flux projection on Y-axis on the target, without the collimator

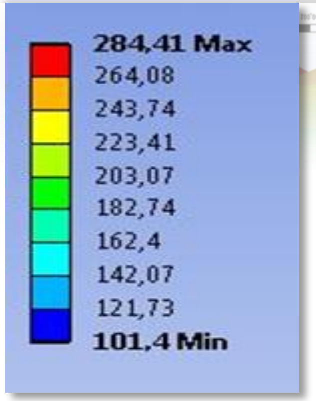
Protons flux projection on Y-axis, before the target, with the collimator

Cooling system

Air-cooled Steel 316 collimator

Energy lost in Collimator E=25kW





Max 284°C

Air-cooled system

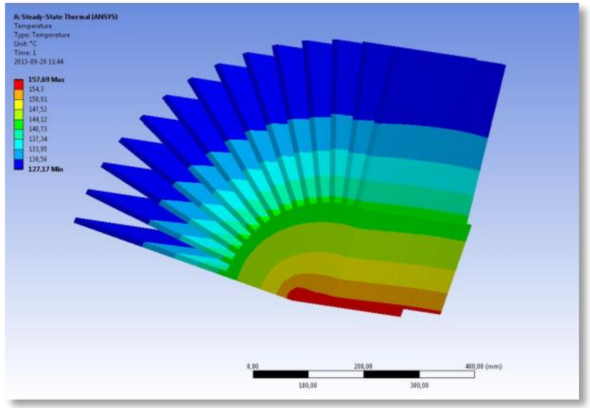
- Thickness of ribs = 1 cm
- 56 ribs
- Collimator radius R = 20 cm
- Depth of ribs = 30 cm
- Air Pump with 2500 m^3/h

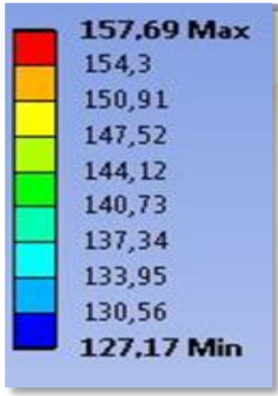
Air cooling:

- safer and simpler to implement,
- active water is not produced

Air-cooled copper collimator

Energy lost in Collimator E=25kW

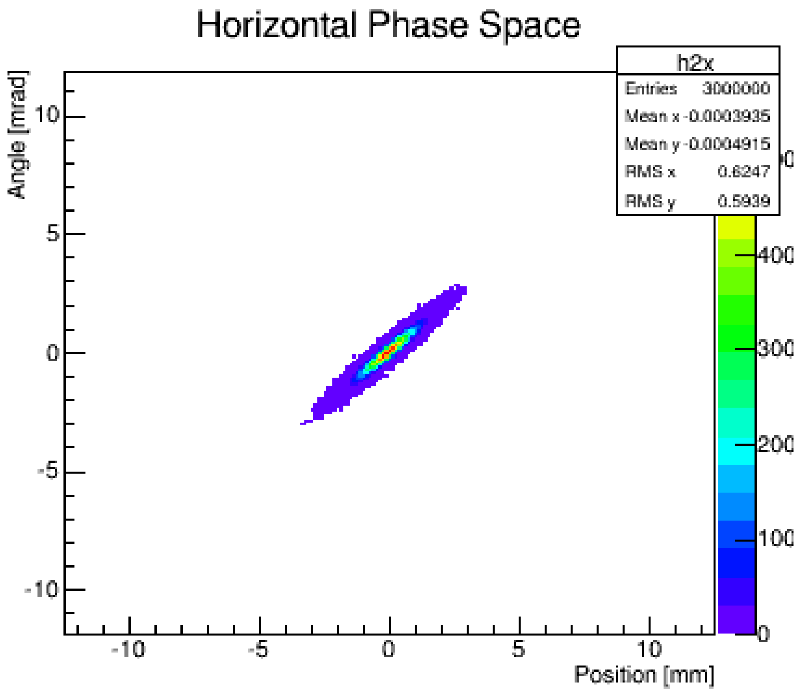


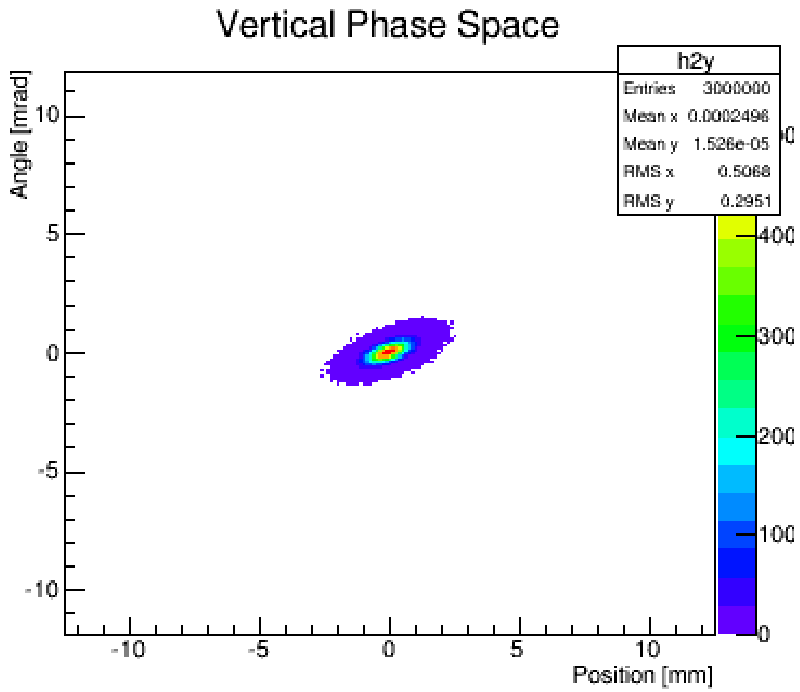


Max 158°C

Rastering system

Assumptions : new beam definition





Main parameters of the nominal ESS beam:

Beam energy 2GeV

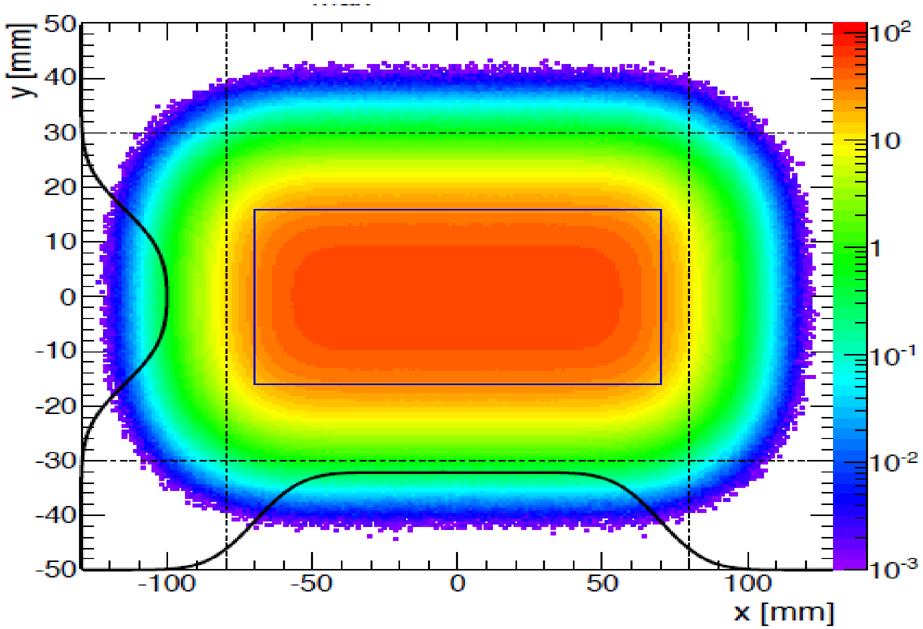
Beam power 5 MW

Beam flux $1.562 \cdot 10^{16}$ p/s

Beam current 2.5 mA avarage

The full beam was generated using the TraceWin code including 3D space charge to get realistic beam input files.

Assumptions : new beam definition



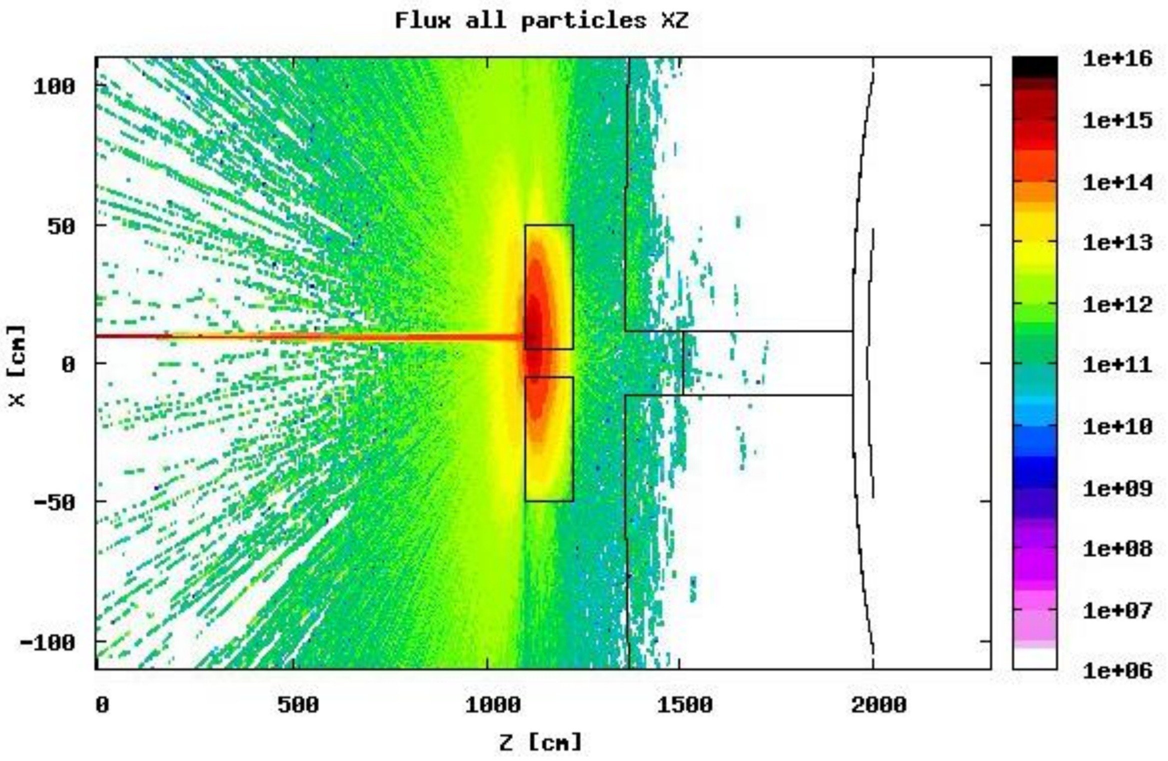
Proton flux XY on the target

New task for collimator - machine protection system!

In the new layout beam is generated by raster system. The fixed collimator can protect target against a possible deviation of the beam.

Protect target against a possible deviation of the beam.

Single beam pulse hits the copper collimator



The flux of all particles with collimator during the bad scenarios.
Collimator length 1 m (10 cm deviation)

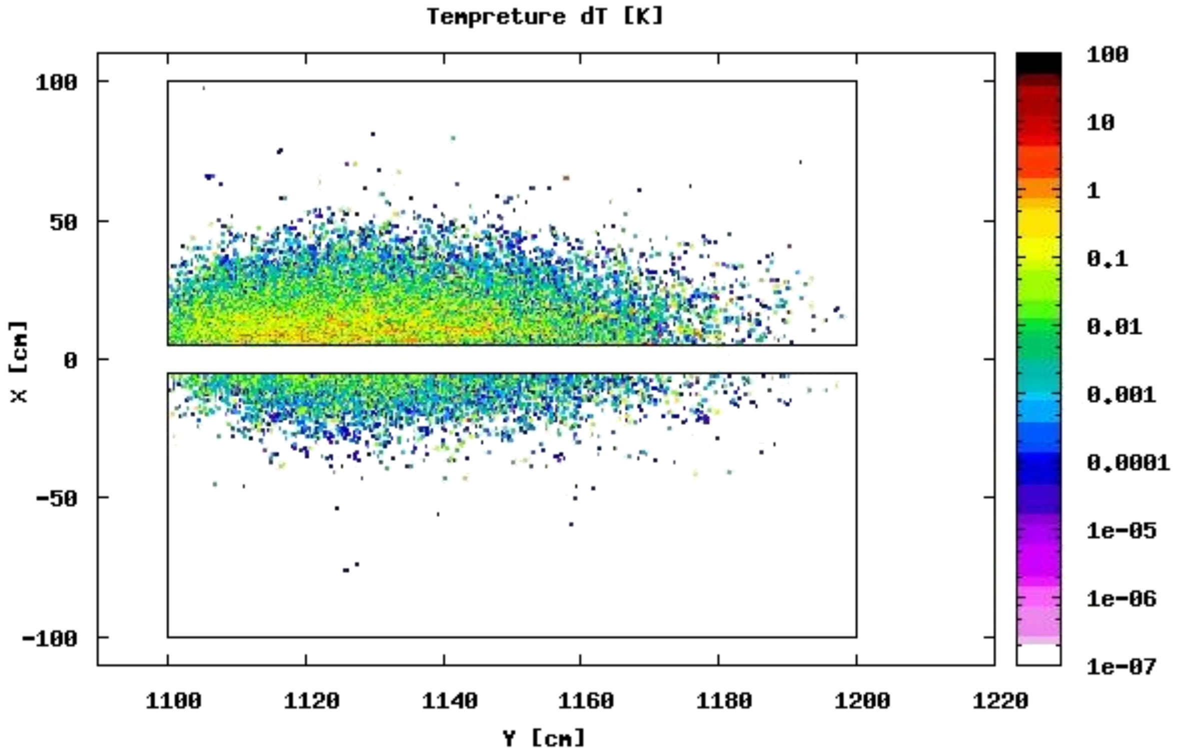
Normal conditions:

- 1 pulse: 2.86 ms
- 68 ms pause until the next pulse

The collimator must be resistant to the impact of single, 2.86 ms beam pulse (Next pulse inhibit)

Protect target against a possible deviation of the beam.

Temperature calculation of the collimator during one pulse in copper collimator.

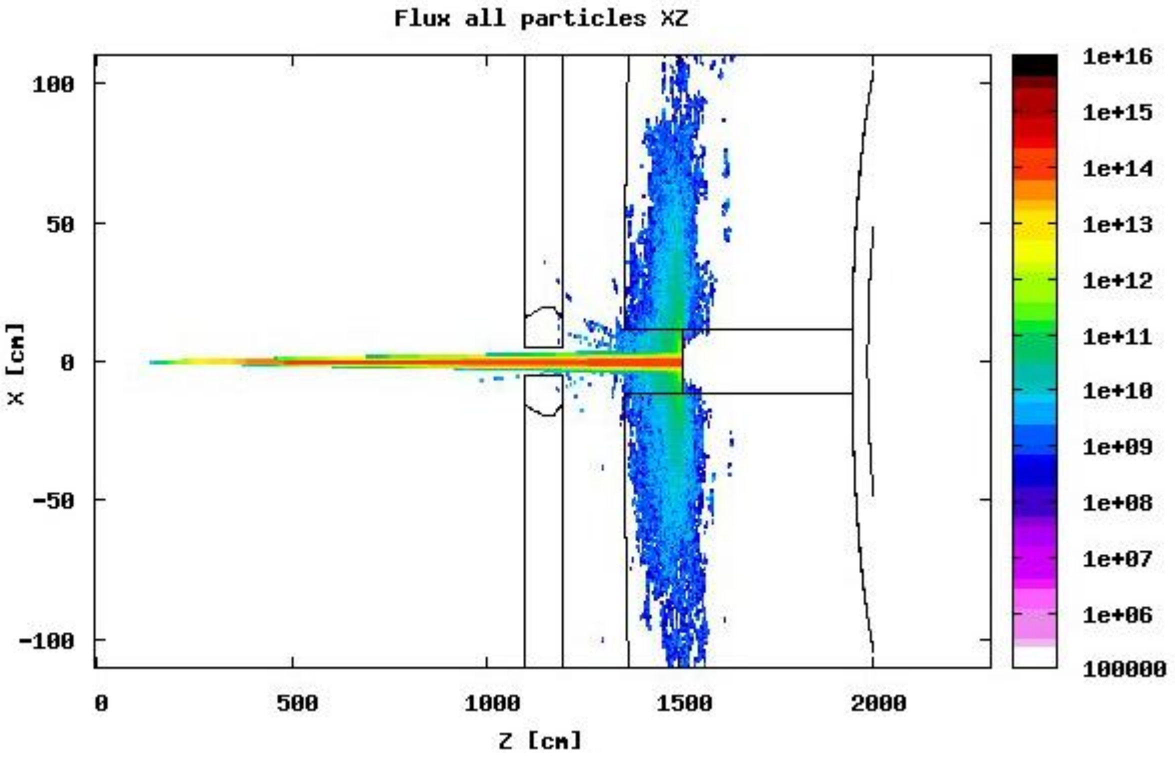


Distribution of the absorbed heat in the X axis for parallel collimator jaws.

The results show that the maximum temperature rise about 10°C.

Protect the Linac system from backscattering

Backscattering from PBW



Backscattering form PBW with the copper collimator

The interaction of the beam with PBW (Proton Beam window) is observed.
The collimator does not play an important role here, and its inner and outer shape can be omitted in favour of a simple block.

Summation

Collimator designed for two scenarios
Second scenario-early stage

Just prepared:

- Input Files for simulations
- Range of the particles inside some materials
- Selection of materials
- Appearance and shape of the collimator (for the first scenario)
- Activation levels
- Bad scenarios
- The idea of cooling system (for the first scenario)
- Several alternatives prepared.

Possibility of quick preparation of new scenarios

Plans for the next half a year.

- Bad scenarios
- Mechanical INVENTOR CAD design of the collimator-taking into account interfacing to vacuum chamber, including support stand and handling.
- Optimization and fine tuning of the above designs
- Procurement specifications written

Thank you for your attention