Collimators in Ess -

(1/2) - Movable collimators system

Lund,
11 December 2013

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SPALLATION
SOURCE

General assumptions connected to the movable collimators:

Function:

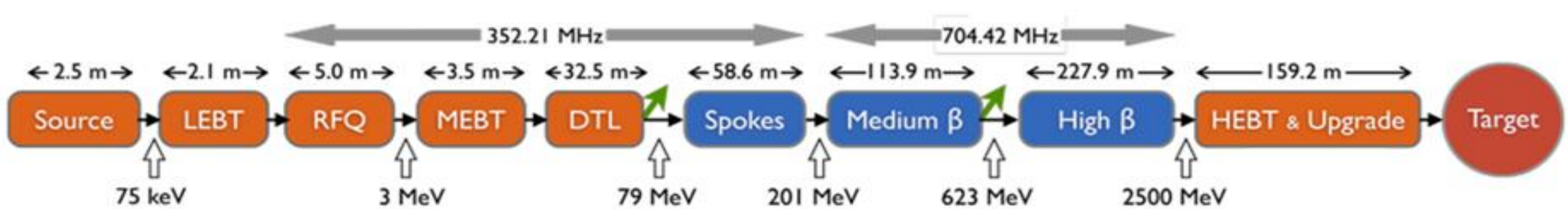
- Reduction of the HALO
- Protection of more sensitive linac parts
- Diagnostics – measuring losses and beam deviations

Optimalisation points:

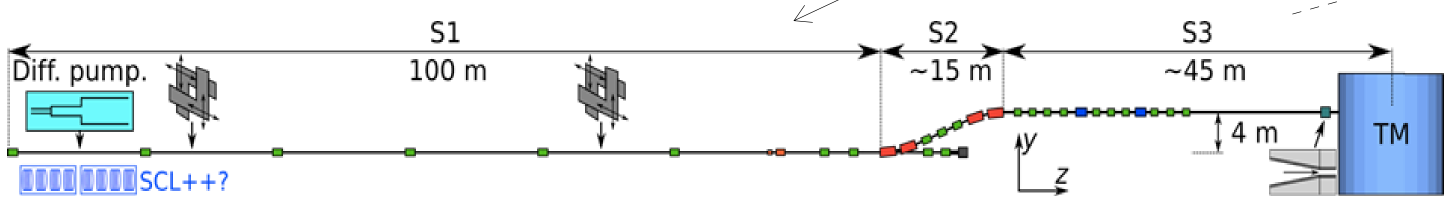
- Minimal cost
- Appropriate dimensions and weight (material)
- Acceptable dose distributions around MCS

ESS:


Science for Society


352.21 MHz
704.42 MHz
2.5 m
2.1 m
5.0 m
3.5 m
32.5 m
58.6 m
113.9 m
227.9 m
159.2 m
Source
LEBT
RFQ
MEBT
DTL
Spokes
Medium β
High β
HEBT & Upgrade
Target
75 keV
3 MeV
79 MeV
201 MeV
623 MeV
2500 MeV

Karol


S1
100 m
S2
~15 m
S3
~45 m
Diff. pump.
4 m
TM
y
z
SCL++?

Where MCS will be placed?

-	1.	2.	3.	4.	5.	6.
Z[m].	11.32	12.82	36.88	38.38	62.44	63.94
Period:	2	2	5	5	8	8

Used tools:

is a particle physics Monte Carlo simulation package. FLUKA a tool for calculations of particle transport and interactions with matter, covering unextended range of applications spanning from proton and electron accelerator shielding to target design, calorimetry, activation, dosimetry, detector design.

is a tool for an engineering simulation solution sets in engineering simulation that a design process requires. It was used to simulate thermal distribution and total deformation of designed collimators.

Few words about my data:

- This talk is based on movable collimator intermediate report, where the data from TDR (January 2013) was used. Our studies are based on 'old' layout (This year has brought some changes, for example: beam expander system → raster scanning stystem).

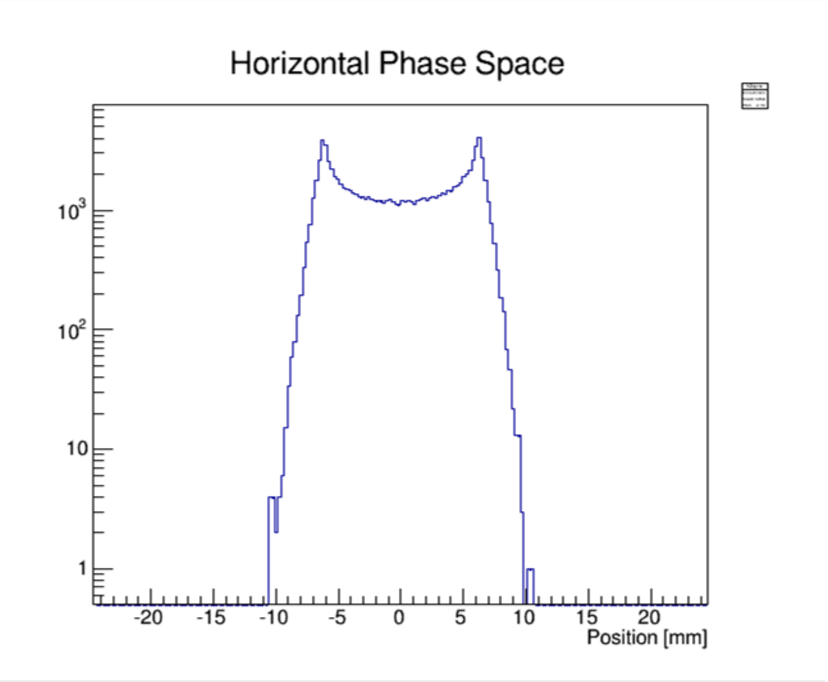
- Beam parameters:

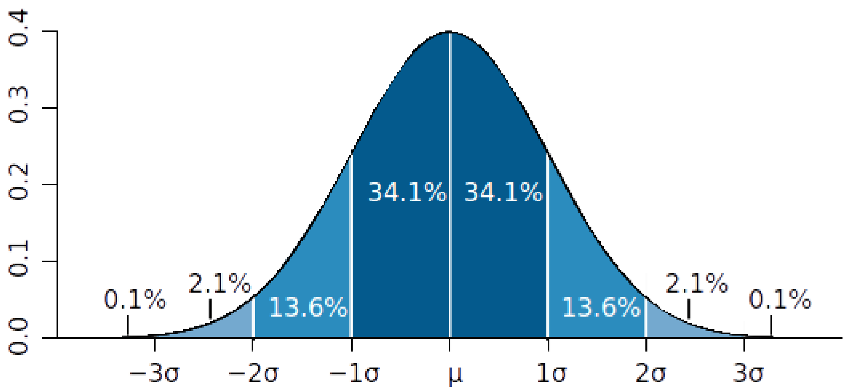
E[GeV]:	Duty Cycle [%]:	I(peak) [mA]:	I(avg) [mA]:	P(avg) [MW]:
2.5	4.0	50.0	2.0	5.0

- Simulations parameters: Statistics of 3E5-3E6 particles (sufficient in various simulations)

- Simulations were based on the 'special' input file.

Input Beam – Core-less beam:





Zσ:	RMS [mm]:	Percent outside (-zσ, zσ):
1.0σ	2.25	68.27
2.0σ	3.50	95.45
3.0σ	6.75	99.73
3.3σ	7.43	99.90

7s = 0.000000000256%

To design movable collimators system it was needed to make additional assumptions:

- each collimation unit is able to accept up to 1kW

- direct handling of the collimators will be not needed during beam operation

- collimators should be able to stop 99% of the collimated particles power

- step of the collimator moving system should be not bigger than 0.01mm

- water cooling system should be avoided if possible, because of tritium production

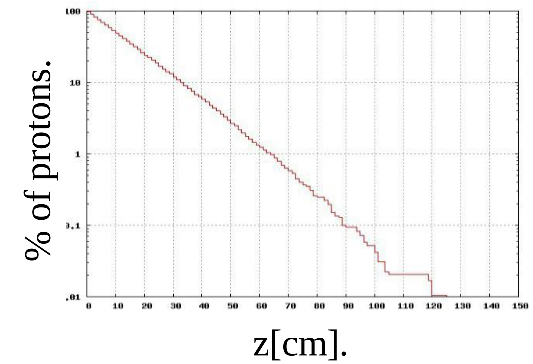
- all components of the collimators should be replaceable

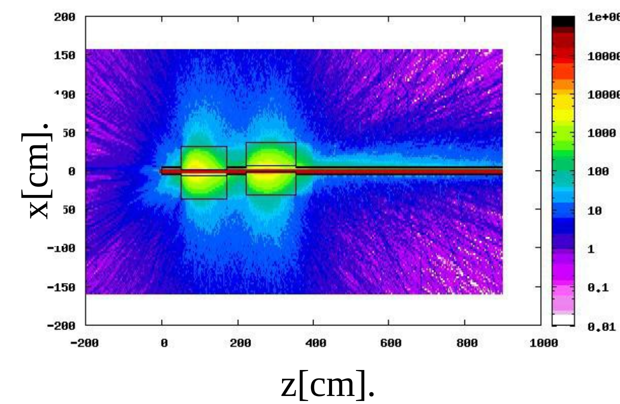
- in case of breakdown, collimators will have some time to cool down (residual dose rate)

What kind of studies has been done?

Simulations:

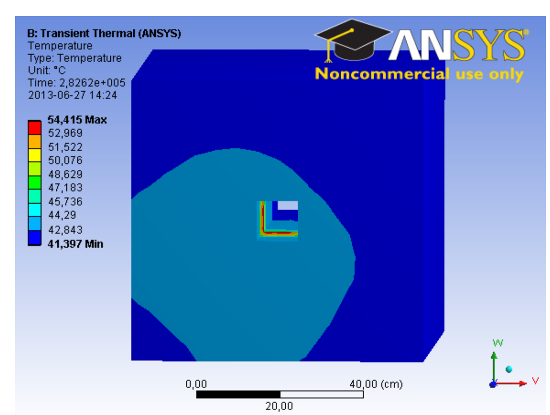
- production of secondary particles in function of angle
- 2.0 GeV proton in function of distance inside copper
- dose distribution during collimation
- activation of the collimators and the doses after specified tim
- energy deposition inside collimator
- heat distribution (with and without cooling)
- total deformation of collimator's material



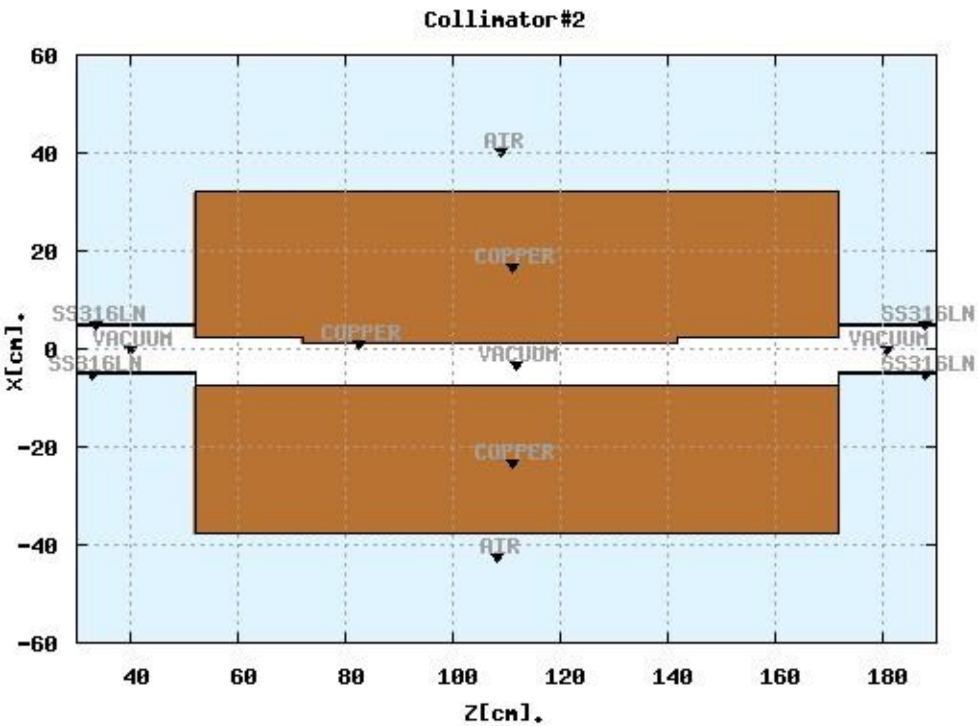


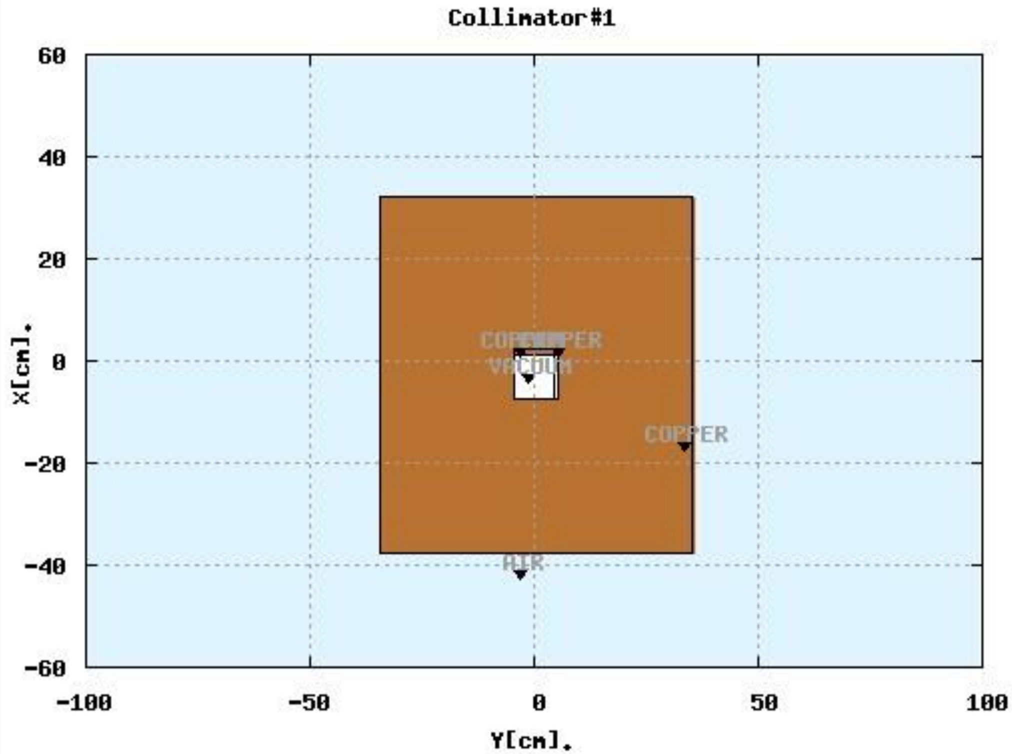
Other:

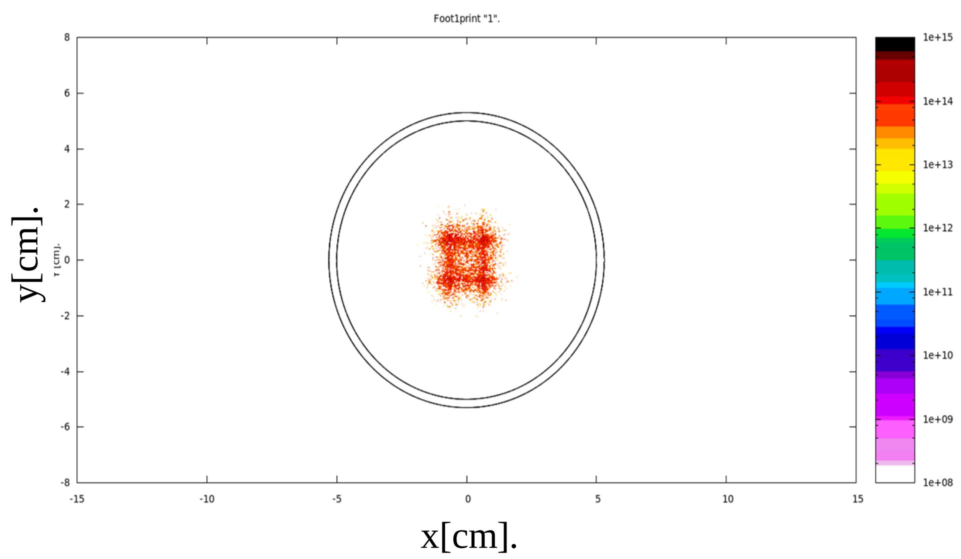
- catastrophically accident analysis
- need of extra shielding around collimators
- cooling system design (in progress)

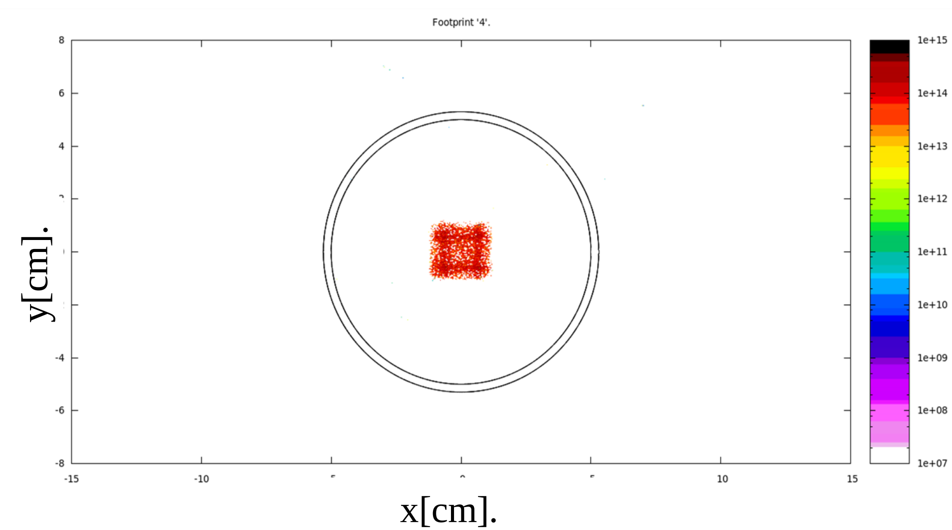


Designed collimators scheme:









- Due to the early stage of the studies, design of the collimators is still in phase of optimization and most parameters are changing during subsequent simulations.

- **Complete data analysis has been done!**

- **Thanks to my studies, it is possible to obtain new results in reasonably short time with modified beam parameters!**

Collimators in Ess -

(2/2) – The Fixed collimators

'old' layout with non-linear magnets

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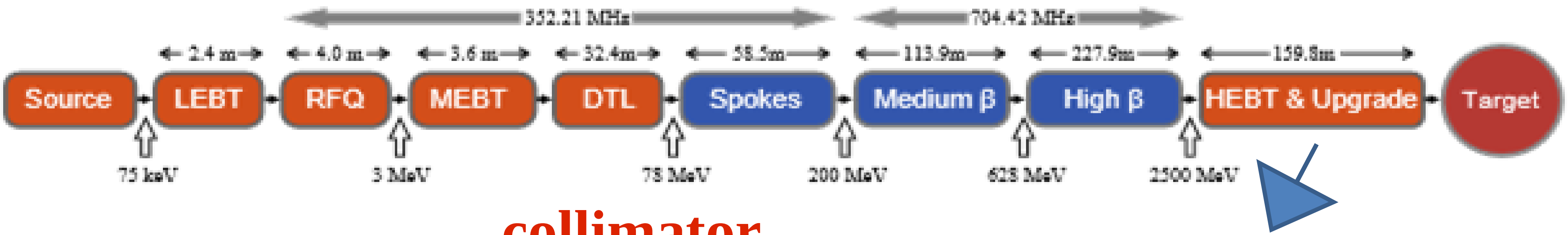
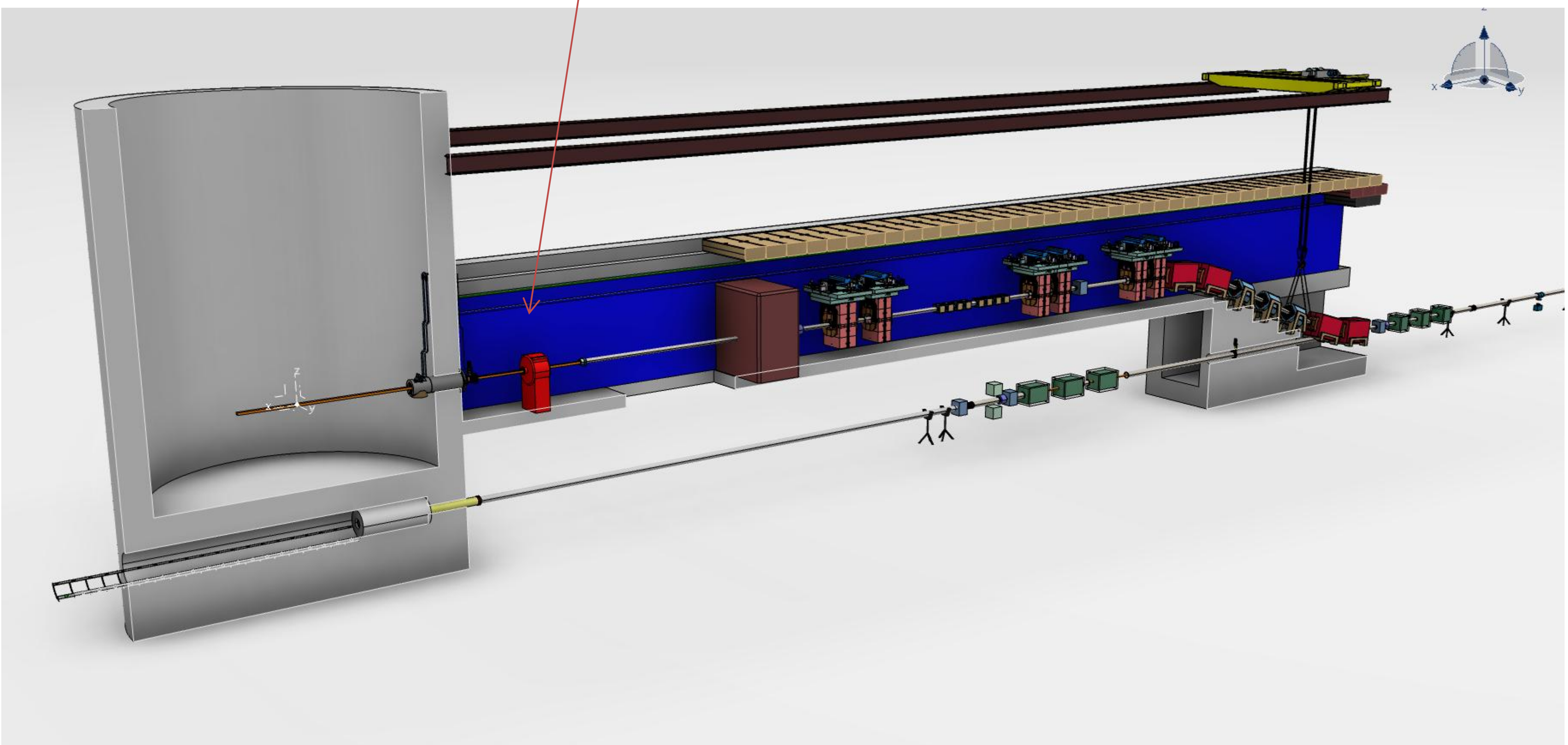
Schematic layout of the HEBT



collimator



FIXED collimator

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 160mm horizontaly and 60 mm verticaly.
- •Collimator should cut tails and back scattering
- •Collimator should be able to absorb 25kW
- •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

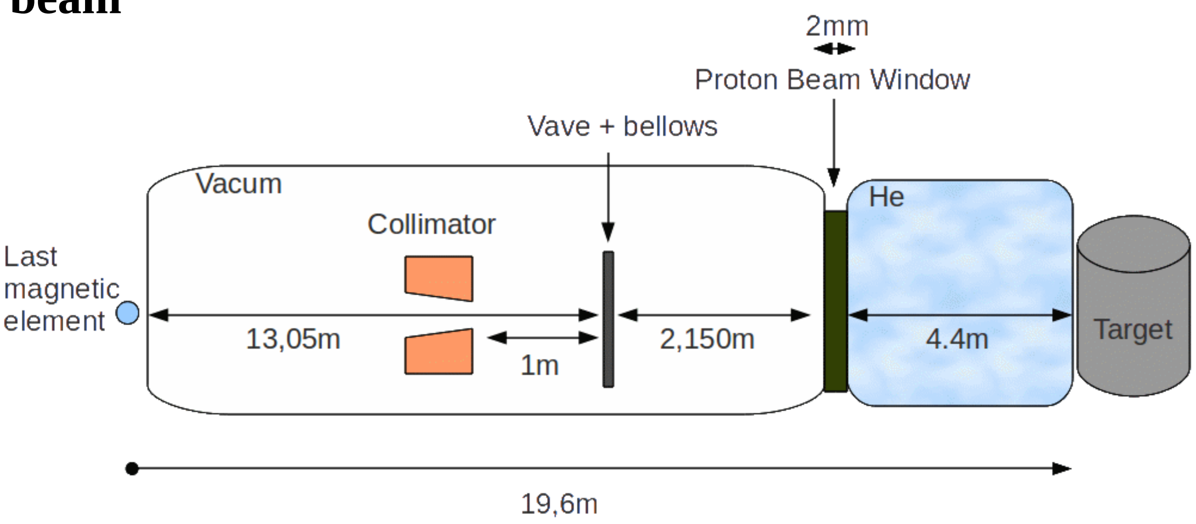
Beam energy 2.5GeV

Beam power: 5 MW

The necessary beam flux: $1.248 \cdot 10^{16}$p

The necessary beam current :

50mA (peak), 2 mA (average)

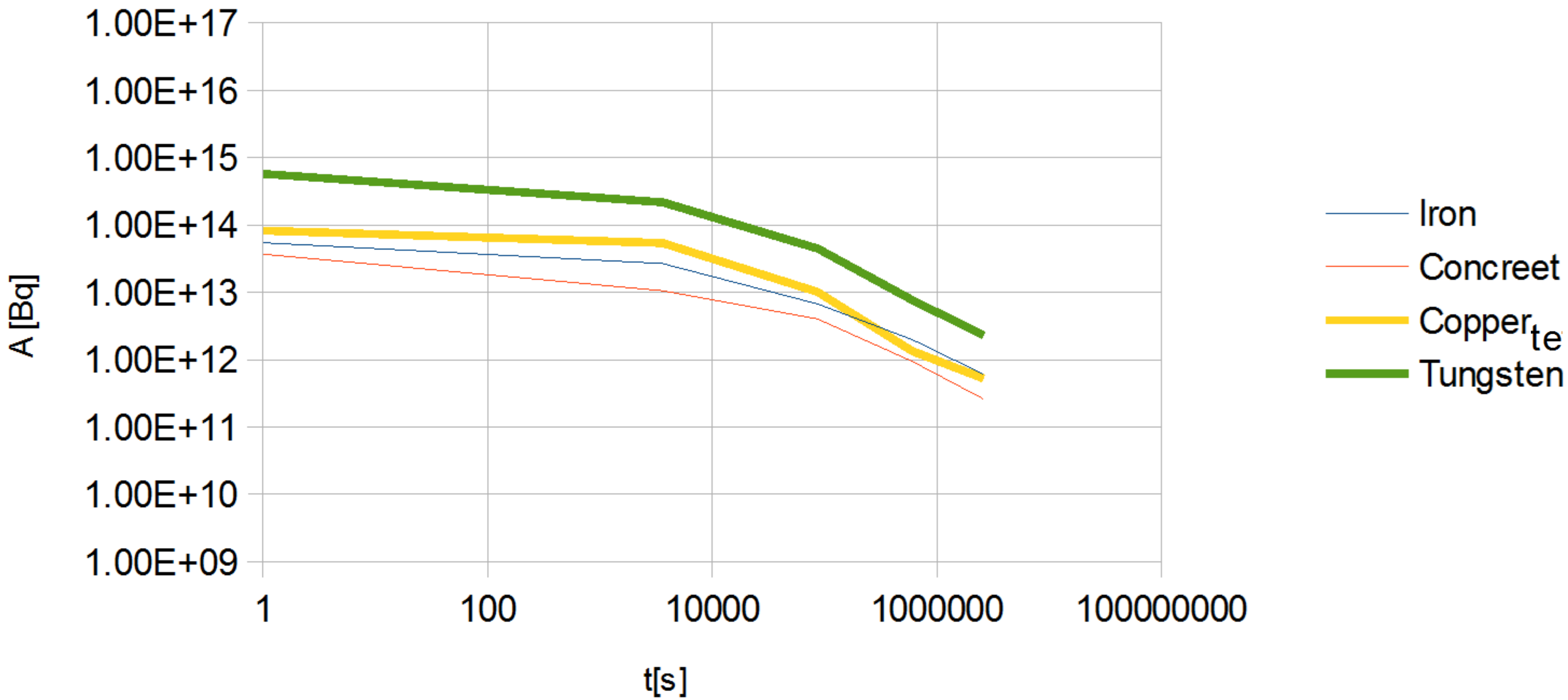


General info

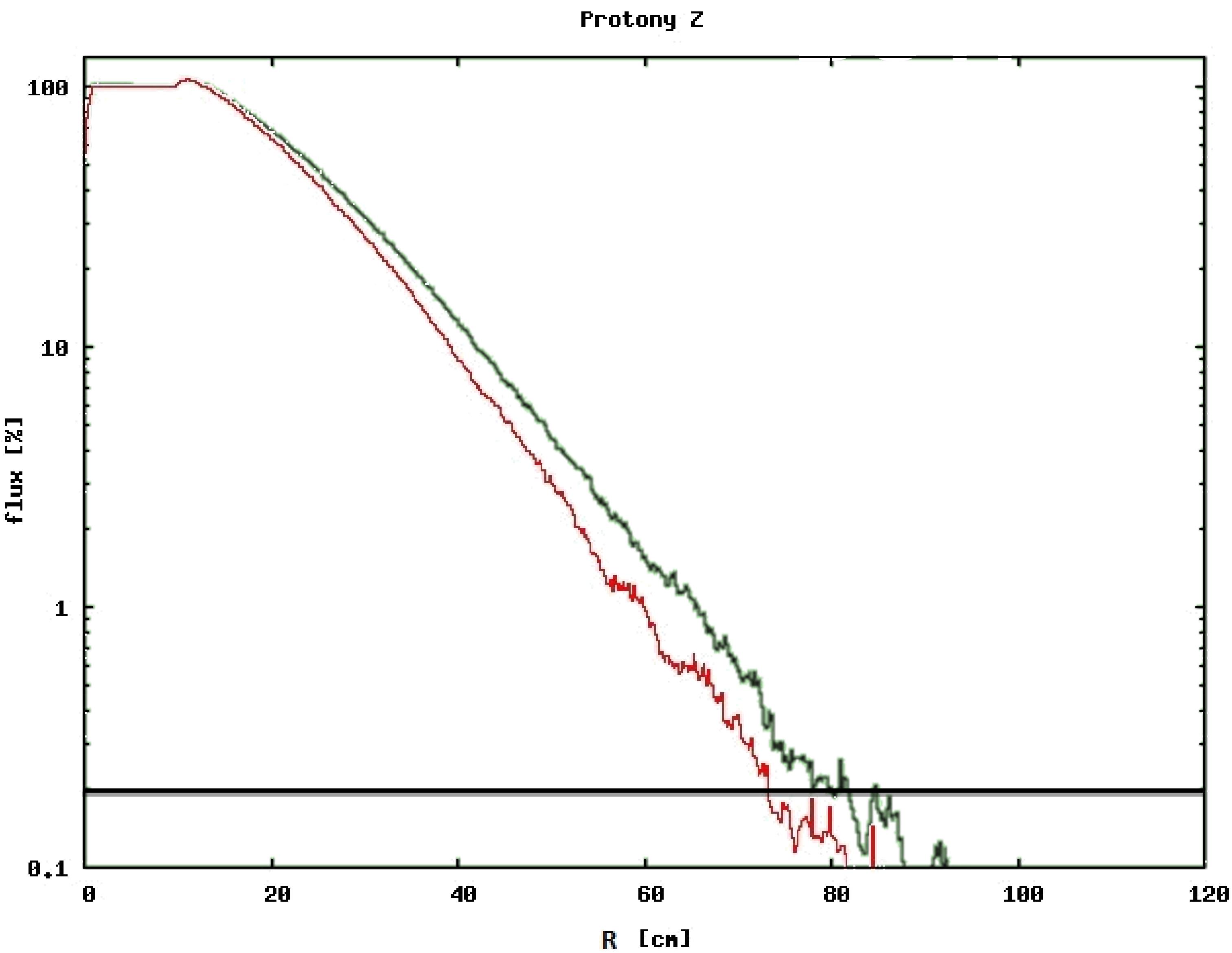
What I have done?

1)Material choice

Materials comparison-activity



Comparison of the Copper and Iron Solid Blocks



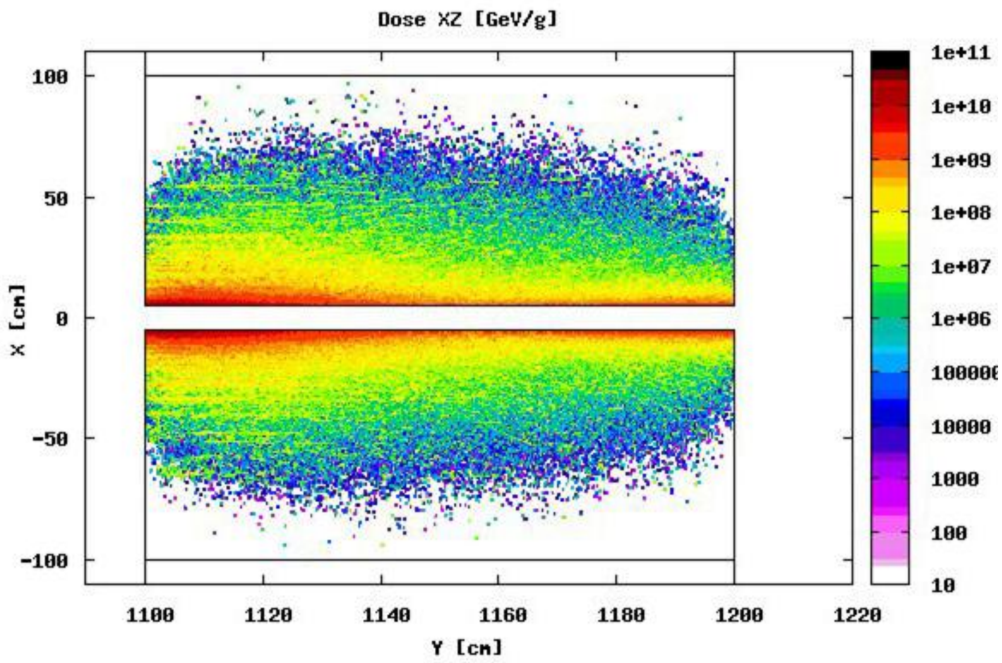
Iron, L=81

Copper, L=76

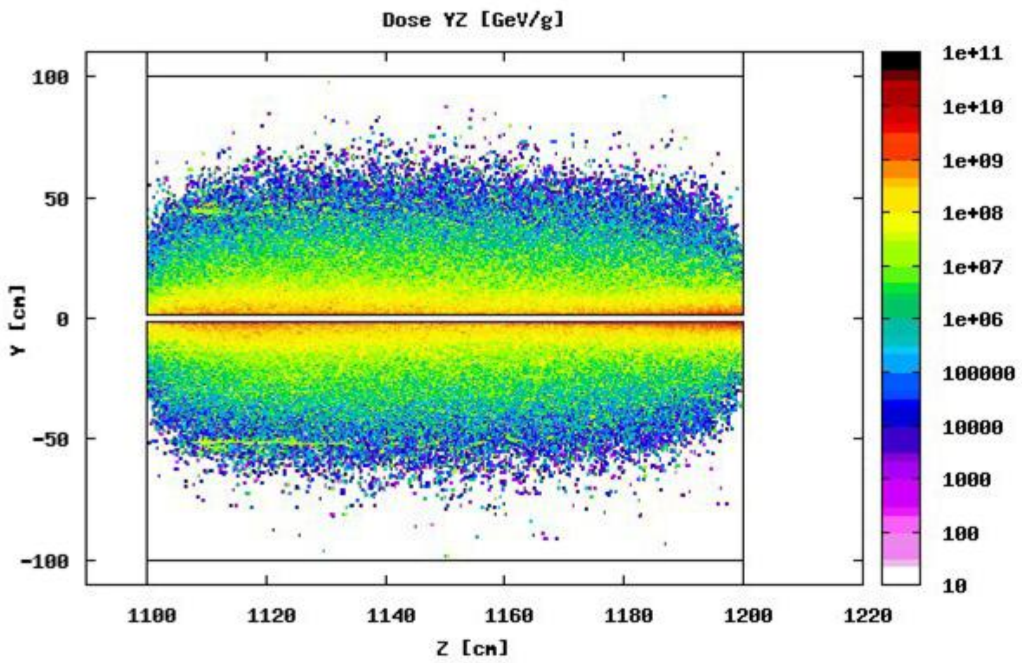
Material analysis

2) Shape of the collimator

Collimator with parallel jaws



X-axis parallel jaws- hot centres

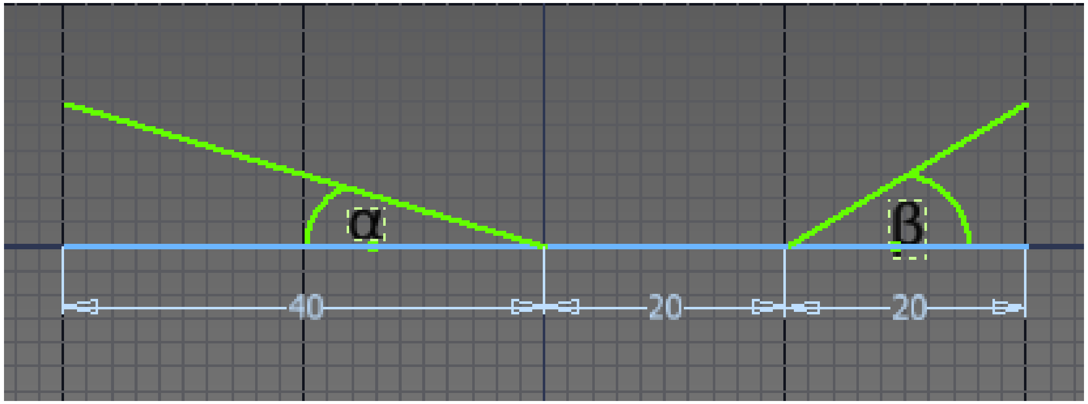


Y-axis parallel jaws- hot centres

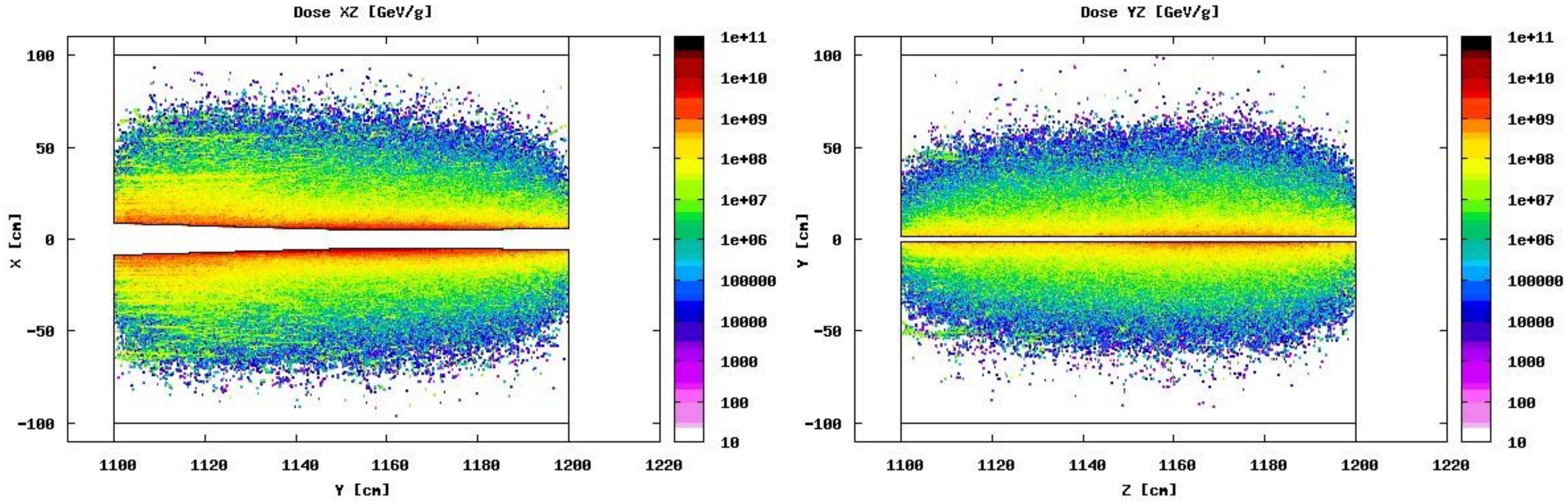
Distribution of the absorbed dose in the X,Y axes for parallel collimator jaws. Hot centres can be seen at the beginning and at the end of jaws.

Shape of the collimator

Modified shape of the collimator jaws



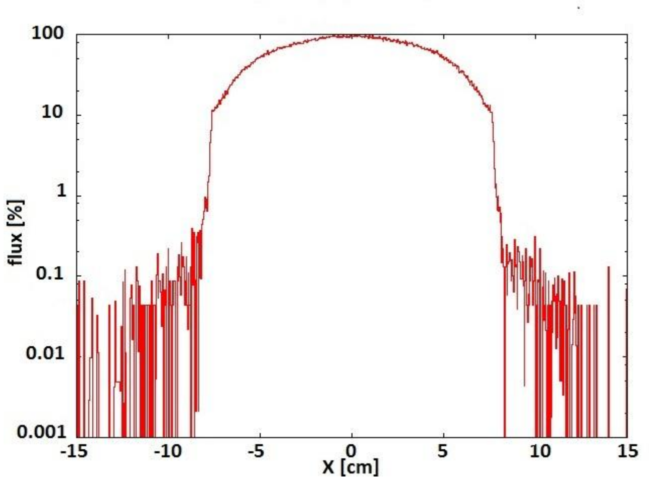
In X axis:
Z= 0 cm to 40 cm α = 4°
Z= 80 cm to 100 cm β=1°
In Y axis:
Z= 0 cm to 40 cm α = 0°
Z= 80 cm to 100 cm β=1°



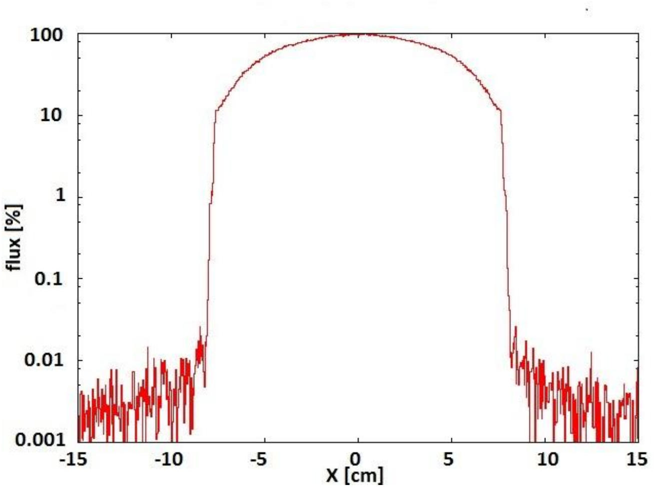
Distribution of the absorbed dose in the X,Y -axes with changed jaws shape

Shape of the collimator

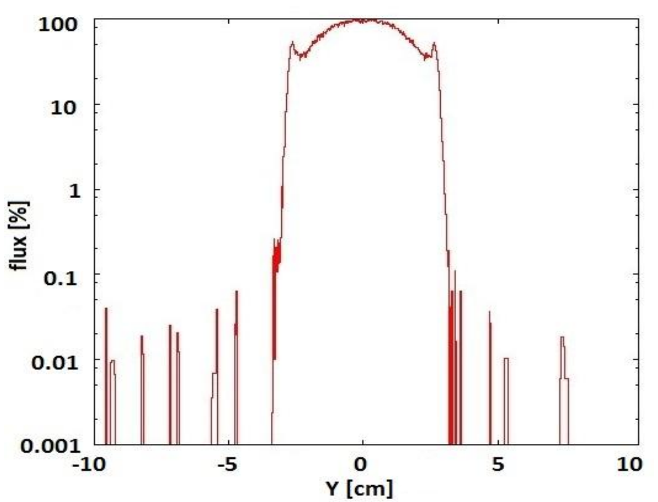
Footprint on the Target



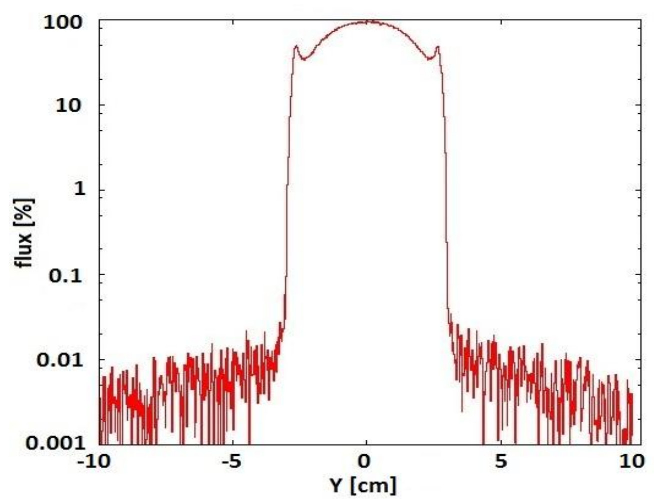
Protons flux projection on Xaxis on the target, without the collimator



Protons flux projection on Xaxis, before the target, with the collimator



Protons flux projection at Yaxis on Z =1960cm, before the target, without the collimator



Protons flux projection at Yaxis on Z =1960cm, before the target, with the collimator

Shape of the collimator

3)Residual dose equivalent rate.

Supervised radiation areas; <3μSv/h

Controlled radiation area blue; <25μSv/h

Controlled radiation area yellow; <1000μSv/h

Simulation of the residual dose equivalent due to activation were performed after 4 weeks of exposure and:

•4 hours of cooling;

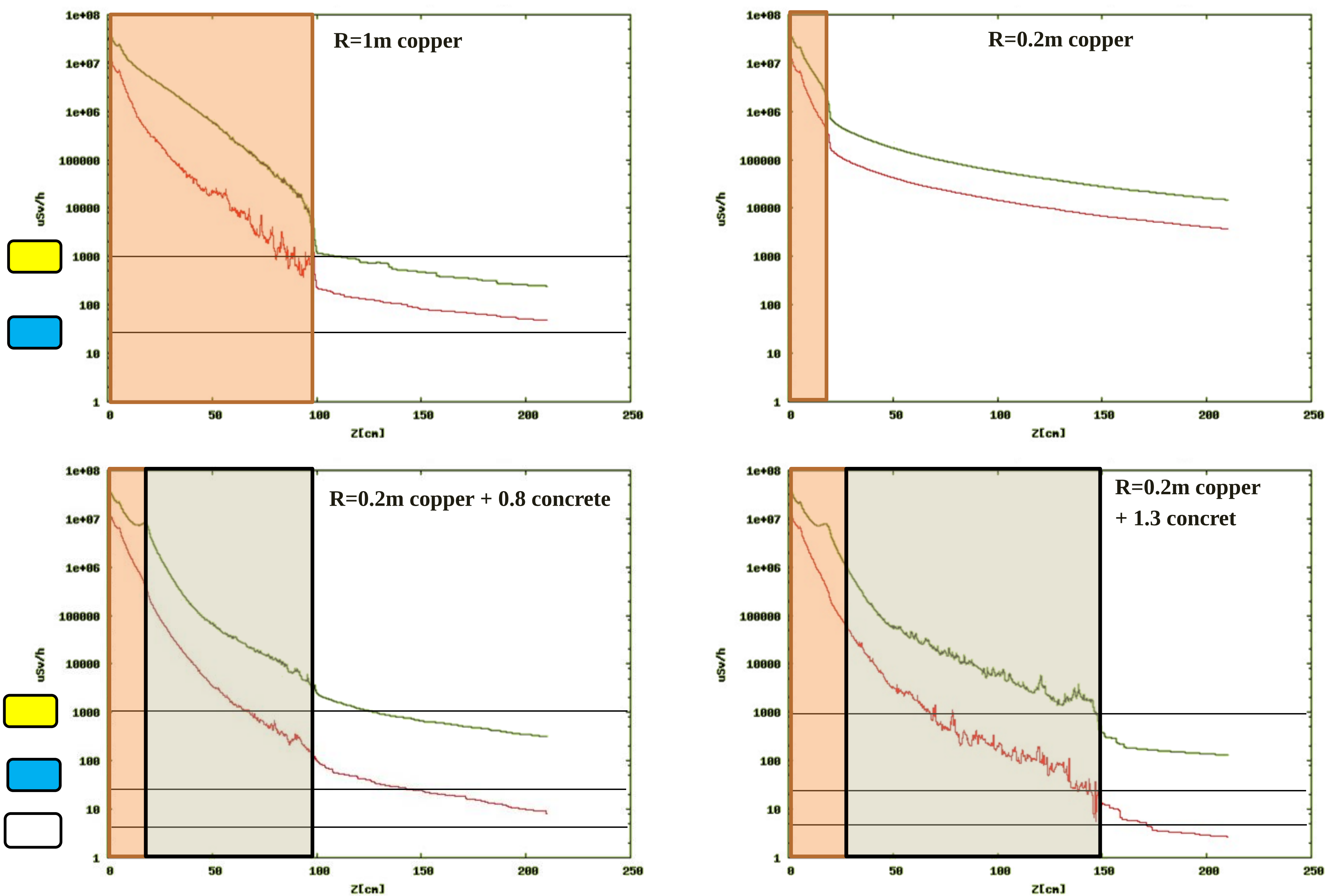
•1 week of cooling;

for diffrent collimator's radii:

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

Residual dose equivalent rate after 4 weeks exposure, and cooling time:

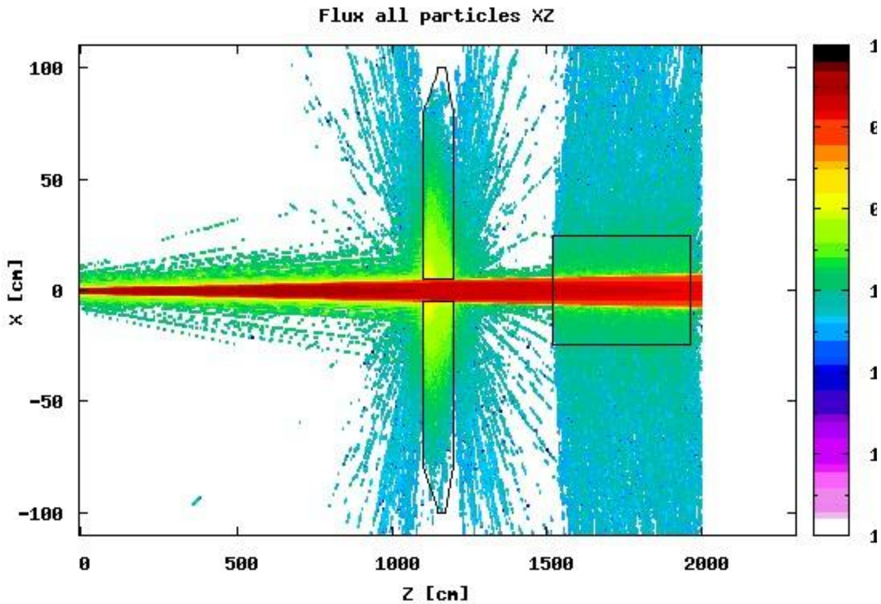
- 1 week cooling
- 4h cooling



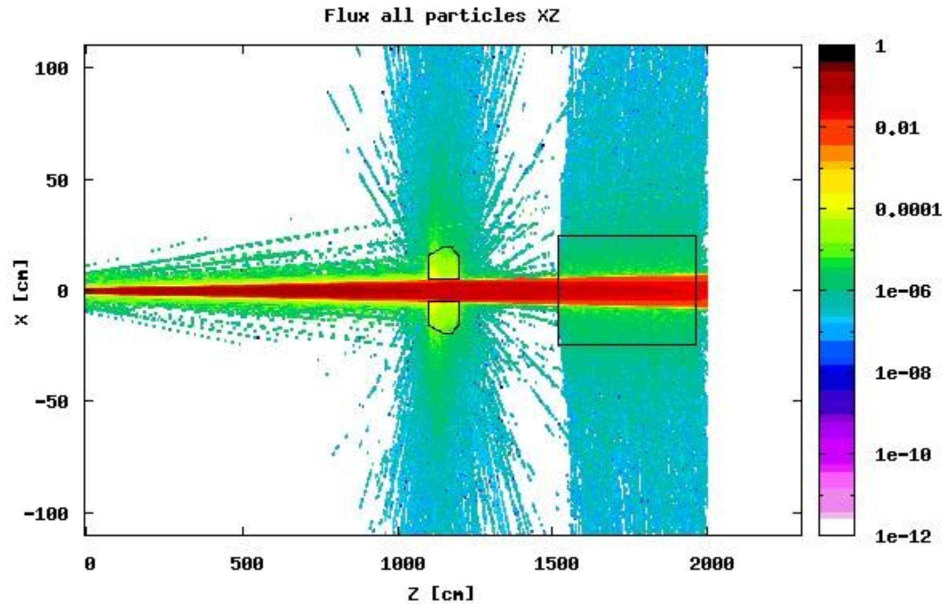
Protection the PBW

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

1m copper



0.2m copper



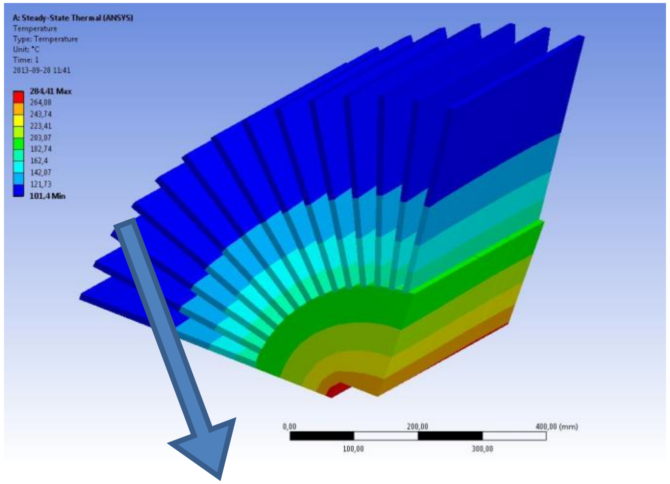
To get the same dose level at a distance of 2 meters from the beam:

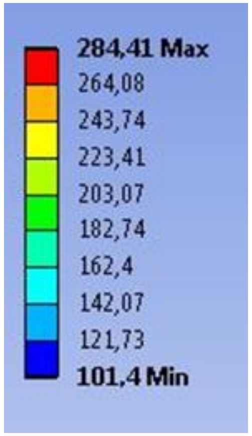
- 1m copper
- 0.2m copper + 0.8m concrete

Dose level study

4)Cooling System

Air-cooled Steel 316 collimator
Energy lost in Collimator E=25kW





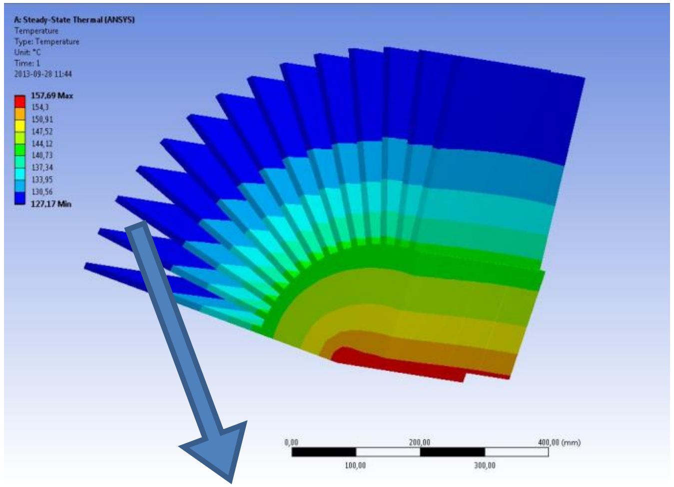
Max 284°C

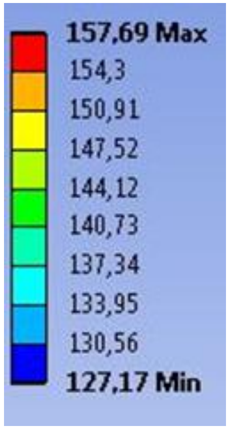
Cooling system

Air-cooled collimator
- Thickness of ribs = 1 cm
- 14 ribs
- Collimator radius R=20 cm
- Depth of ribs =30 cm
- Air Pump with 2500m^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 157°C

Summation

Just prepared:

•Input Files to simulation
•Range of the particles inside the some materials
•Selection of materials
•Appearance and shape of the collimator
•Activation levels
•The idea of cooling system
•Several alternatives prepaired.

Possibility of quick preparation of new scenarious

Thank You for Your attention