Decay Ring Collimation Study and Energy Deposition on Surrounding Magnets

E. Bouquerel, CERN (EN-STI-EET)

9th Beta Beam Task Meeting
27th March 2009, CERN

- Need for collimation in Beta Beam
- Placement and size of the collimators (ACCSIM & FLUKA)
- Implementation of the Straight Section and the Bumps with quadrupoles and dipoles in FLUKA
- Energy deposition in the implemented Straight Section and first estimations of the power deposited in the surrounding magnets
- Use of absorbers to protect magnets

Need for collimation in Beta Beam

- After the injection, longitudinal merging is mandatory for success of Beta Beam concept (stacking improves the neutrino rate) [S. Hancock, CERN]
- After 15 (20) merges 50% (70%) of the injected 6He (18Ne) ions of the 'oldest' bunch are pushed outside the longitudinal acceptance.

  -> Momentum collimation is needed for cleaning

- Momentum collimation at/after merging process:
  - Cycle average: 62 or 230kW (6 resp. 3.6s)
  - Process average: 1.2 or 2.8 MW (0.3s, continuous collimation during bunch compression)

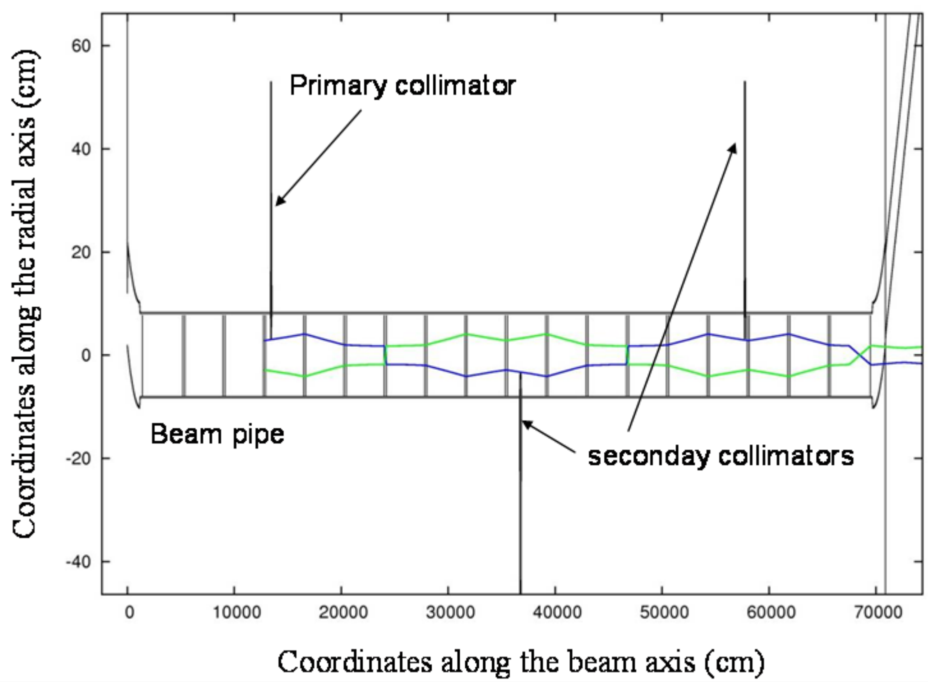
Momentum collimation (reminder…)

- High normalized dispersion is needed
- High intensities to collimate implies:
  – Not possible use of superconducting magnets
  – A multistage collimation (if possible): insertion of secondary collimators after the primary collimator
- Best place for momentum collimation is in one of the two straight sections:
  – No superconducting magnets
  – Enough space

[A. Fabich; Eurisol Town Meeting, Nov 2006]

Placement of the collimators

- Placement of the primary collimator as defined by A. Chancé in the lattice (according to the beam enveloppe at δ=2.5‰)
- Condition $\frac{D'}{D} = -\frac{\alpha}{\beta}$ has been verified [B. Jeanneret et al.]
- Collimator element ±X under ACCSIM [F. Jones, TRIUMF] has been modified/corrected and validated
- Loss maps were created and adapted for an easy use under FLUKA



Due to the presence of injected beam in the ring the primary collimator can not stand in the regions of 'positive energies' [A. Chancé]

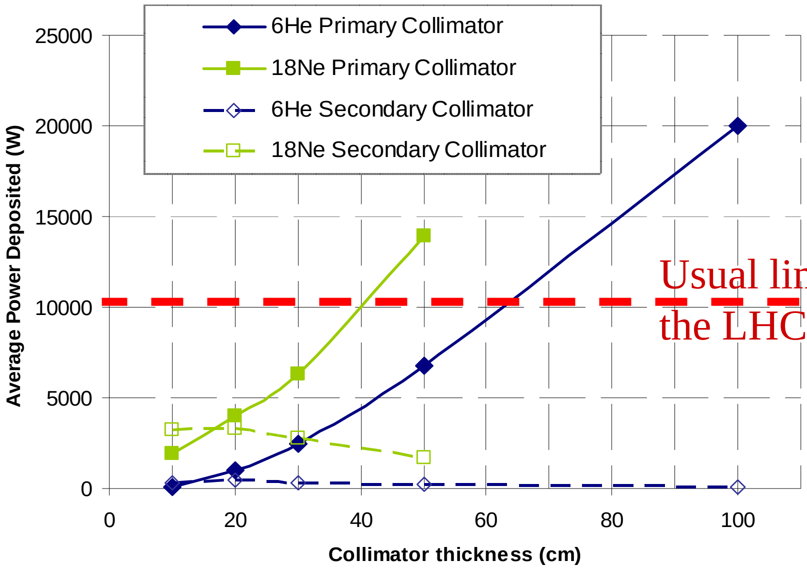
Beam enveloppe: $X_{max} = D\delta_{max} + X_{\beta max}$

$$= D\delta_{max} + \sqrt{\frac{\varepsilon\beta}{\pi}}$$

δmax=-2.5‰

ε=2.6p.mm.mrad (100%)

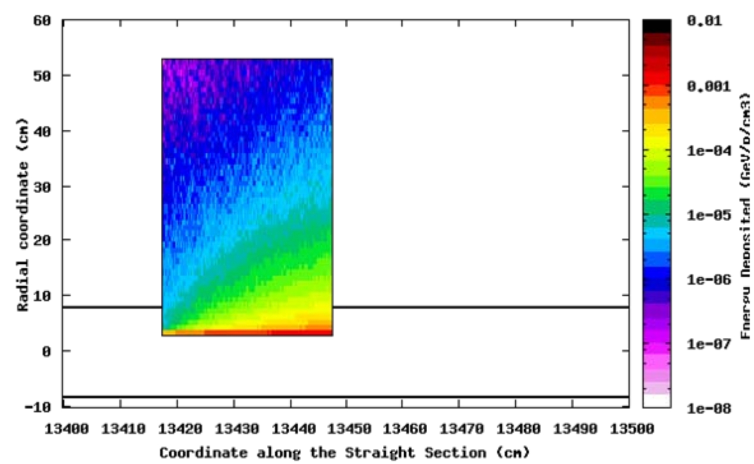
Primary & Secondary Collimator Materials/Thickness



Usual limit for the LHC collimators

Carbon as material gives 6kW (18Ne) and 2.5kW (6He) as average power deposited
for a thickness of 30cm (FLUKA)

Average deposited power x25 when using Cu as Material for the Primary Collimator!!

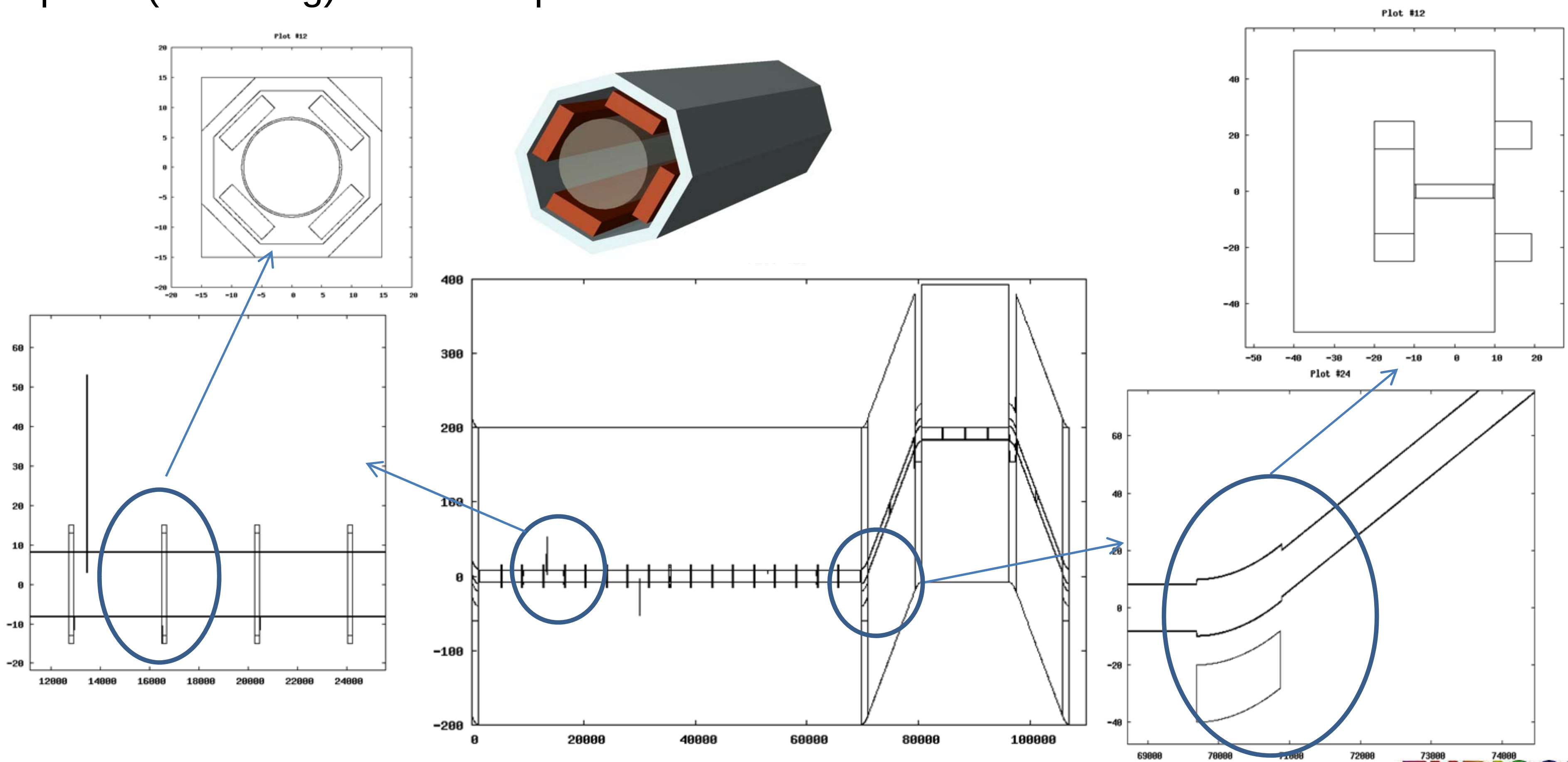


- Primary Collimator in Carbon of 30cm thick is the most suitable

[P. Delahaye, GANIL]

Implementation of the geometry of the Straight Section in FLUKA

Addition of 17 warm quadrupoles (2m long each) in the Straight Section and 5 warm dipoles (12m long) in the bumps



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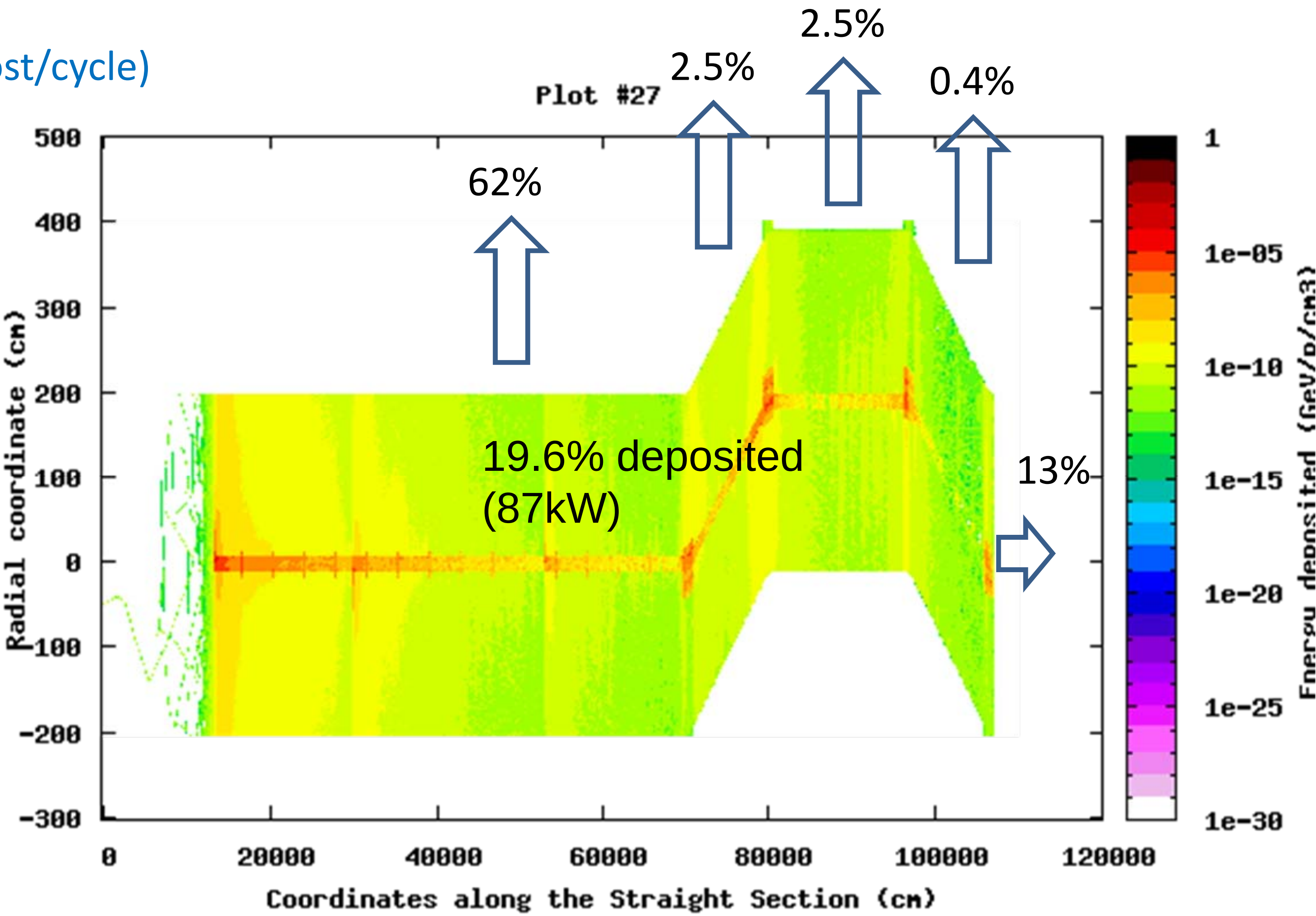
Energy Deposited in the Straight Section (FLUKA)

6He (5.10^{12} particles lost/cycle)

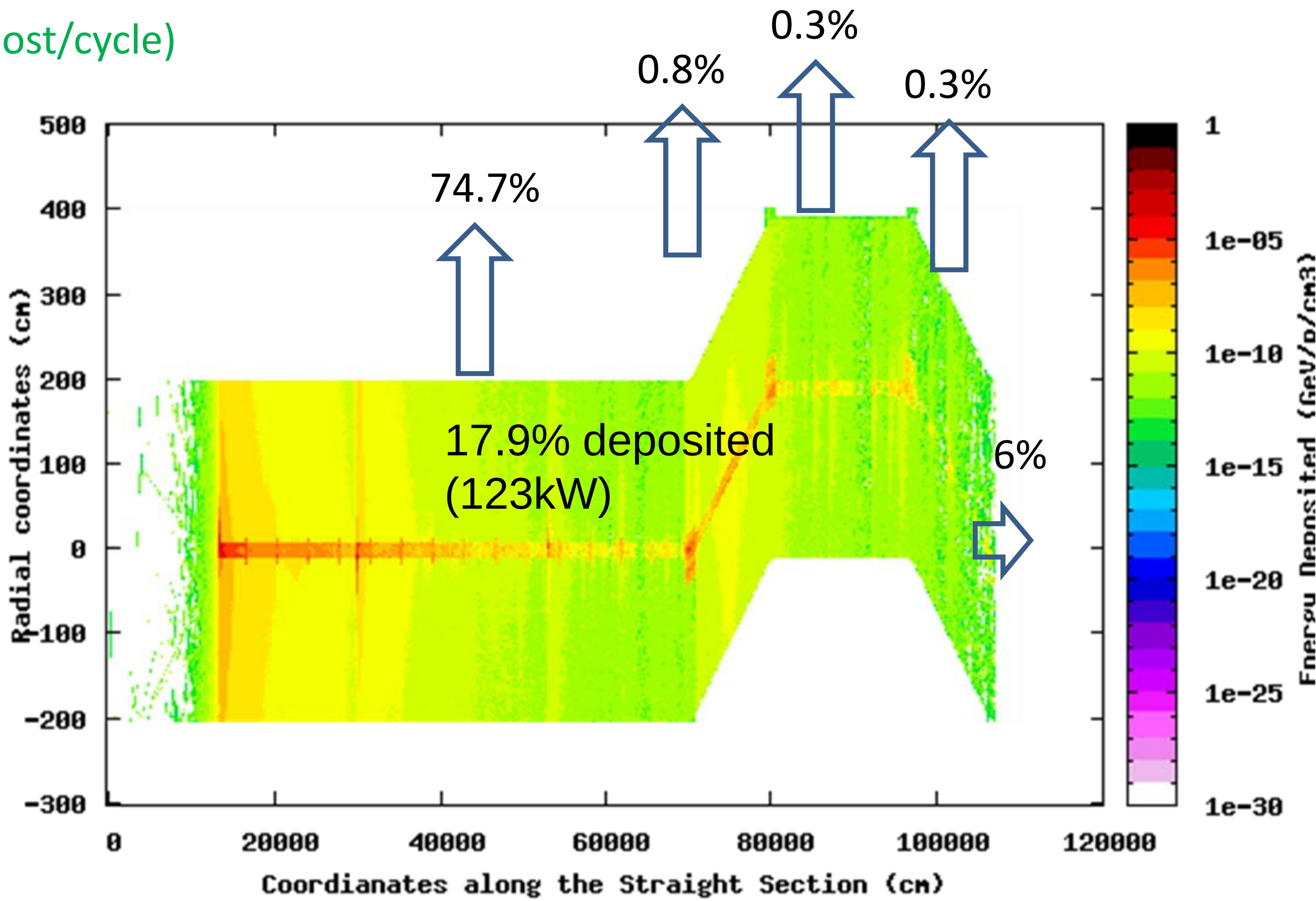
19.6% of the incoming energy is deposited into the system (17% directly in the Straight Section) which corresponds to 87kW



Energy Deposited in the Straight Section (FLUKA)

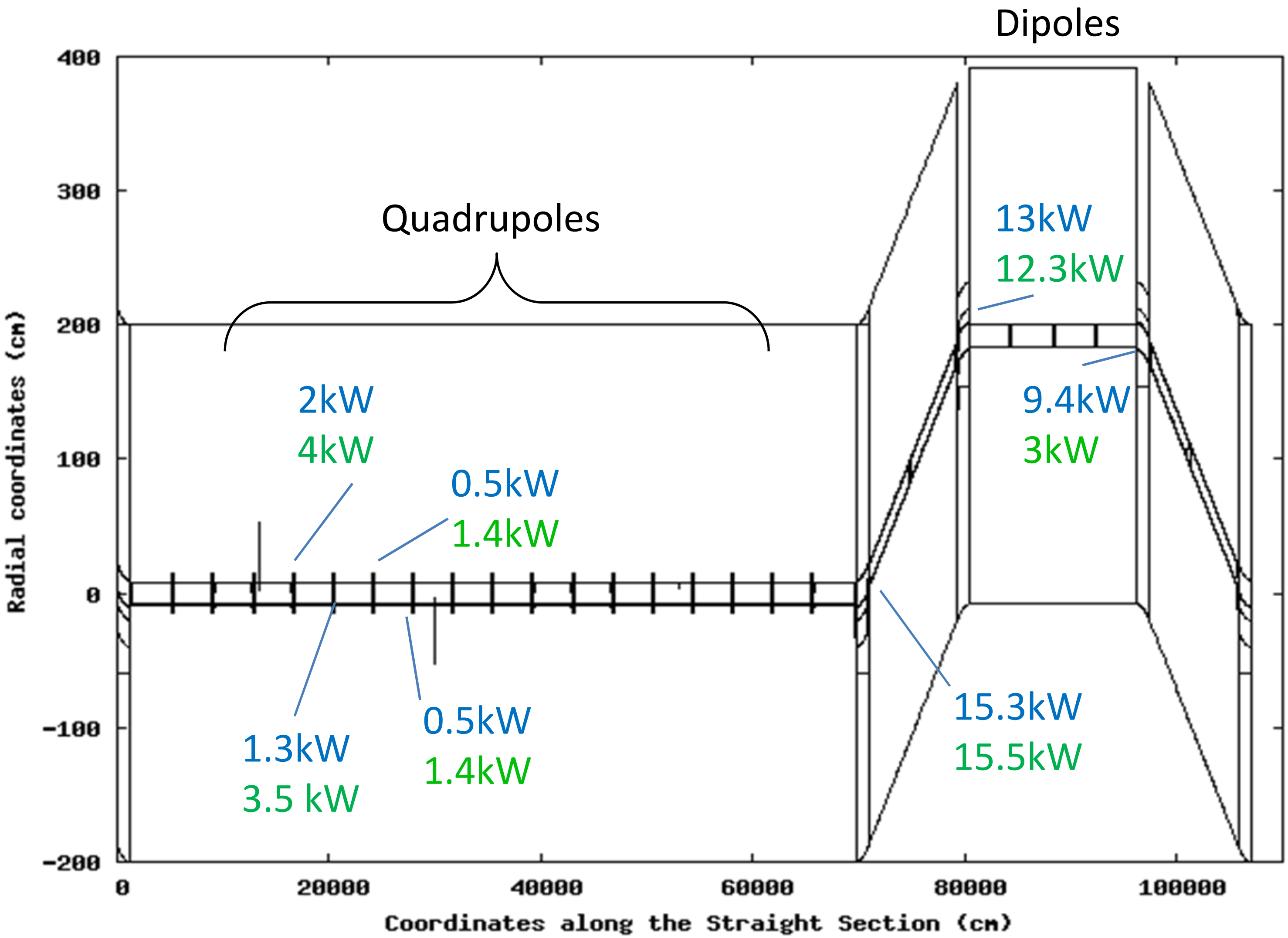
18Ne (3.4.10[12] particles lost/cycle)

17.9% of the incoming energy is deposited into the system (14% directly in the straight Section) which corresponds to 123kW



Average Power deposited in the Qdrup. & Dipoles. (FLUKA)

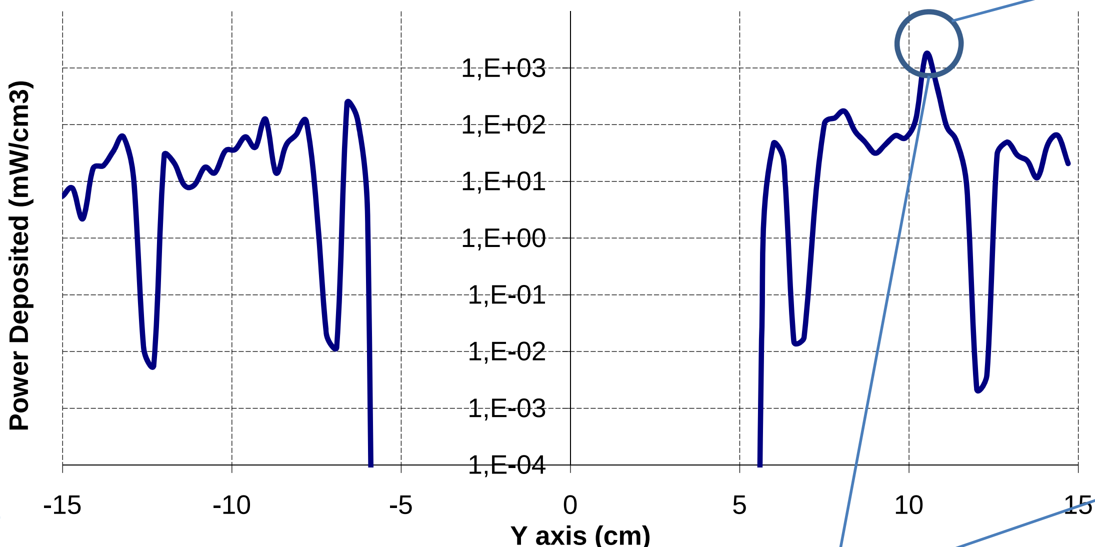
6He
18Ne



Peaks of Power deposited in the Magnets (FLUKA)

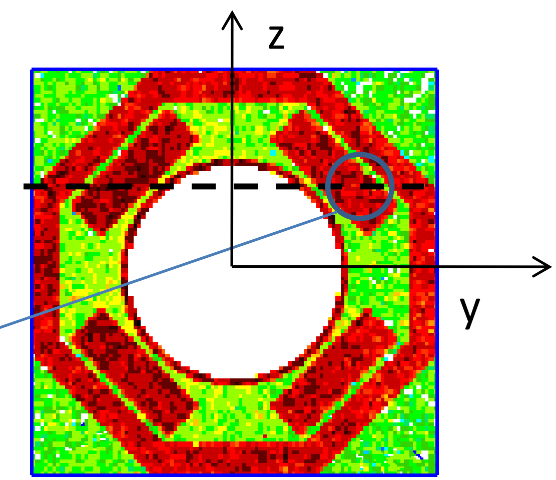
6He

First quadrupole after the Primary Collimator



6He

FLUKA Coordinates:
X= 16502 cm
Y= 10.5 cm
Z= 5.1 cm



Binning size:
0.9 mm² (ZY plan)

<1.5W/cm³ in the magnet
(recommended limit value 4.3mW/cm³)

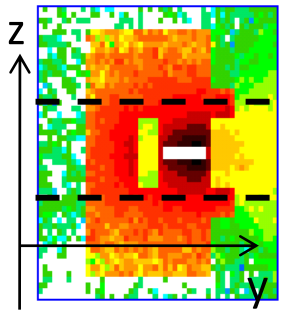
<0.98 W/cm³ in the magnet for 18Ne

Peaks of Power deposited in the Magnets (FLUKA)

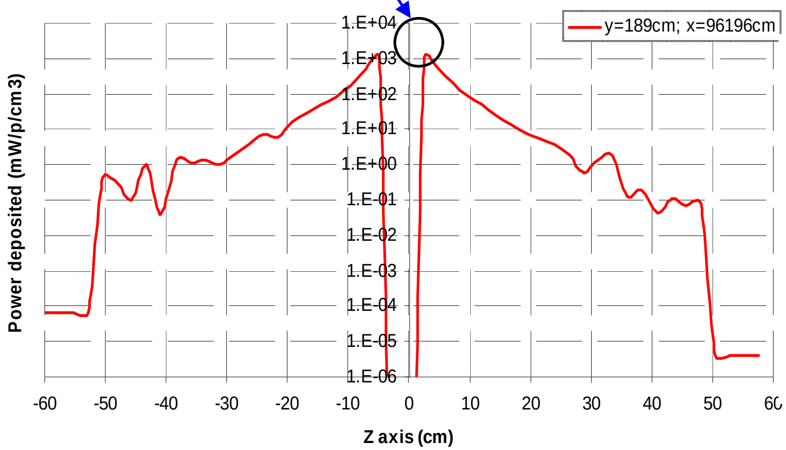
6He

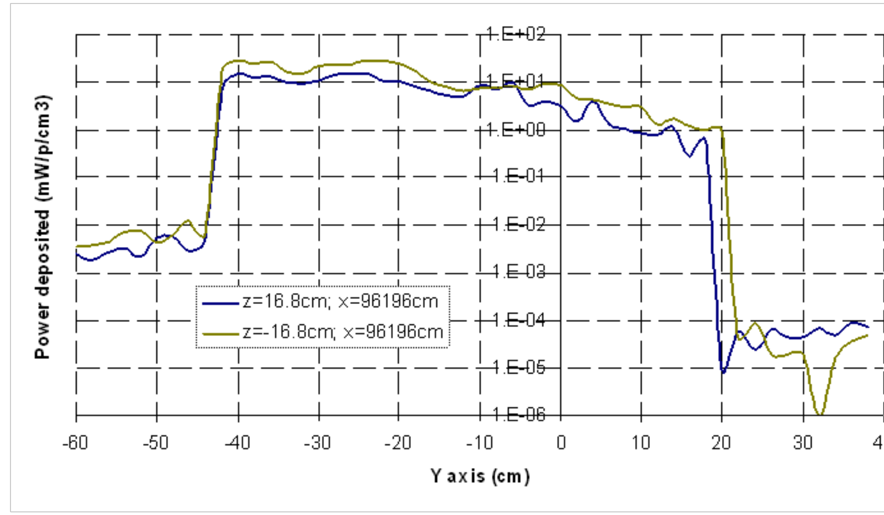
First warm dipoles of the 2nd bump

<12mW/cm^3 in the magnets



<1W/cm^3 in the yoke

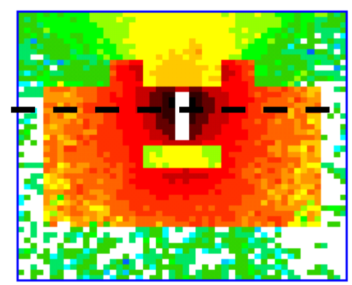




Binning size:

1 cm^2 (ZY plan)

…to be improved



18Ne

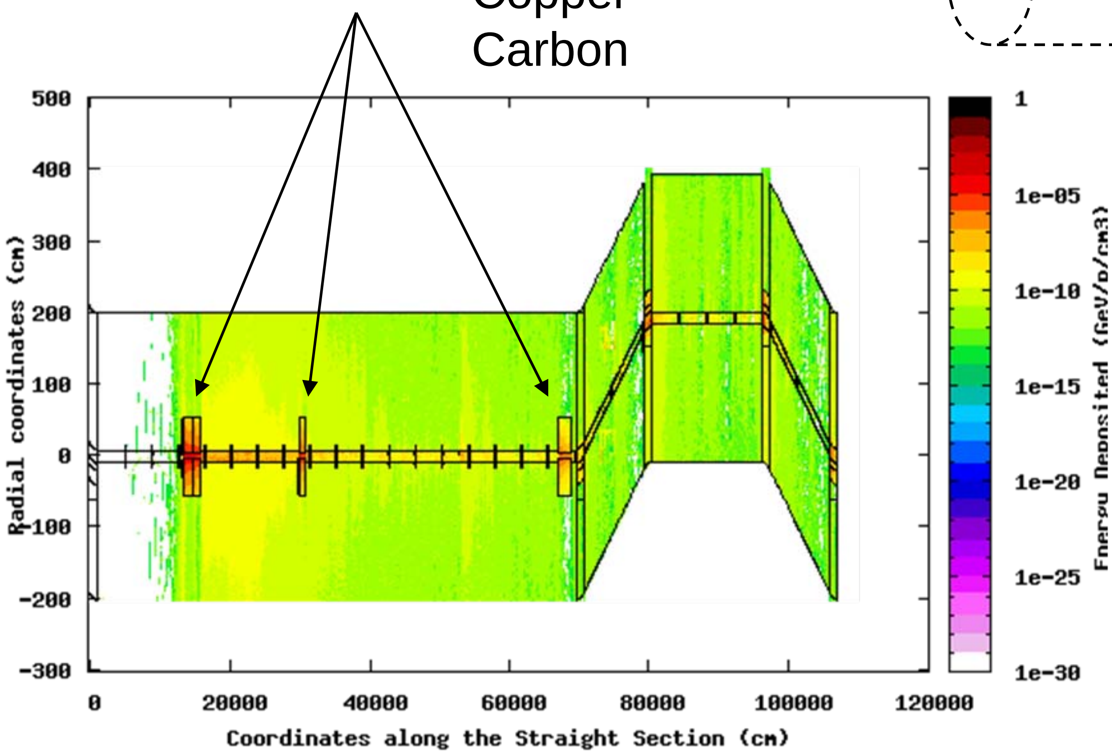
<20 mW/cm^3 in the magnet and

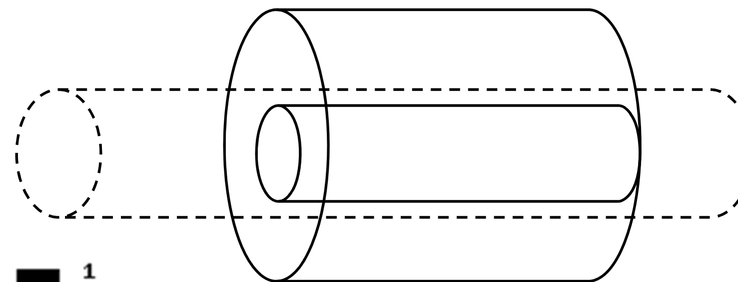
<1.54 W/cm^3 in the yoke

Profile along the beam axis gives a too high power deposited → need to use absorbers to protect magnets.

Use & effect of Absorbers to protect magnets

4 cylindrical absorbers added
2 materials studied:
- Copper
- Carbon





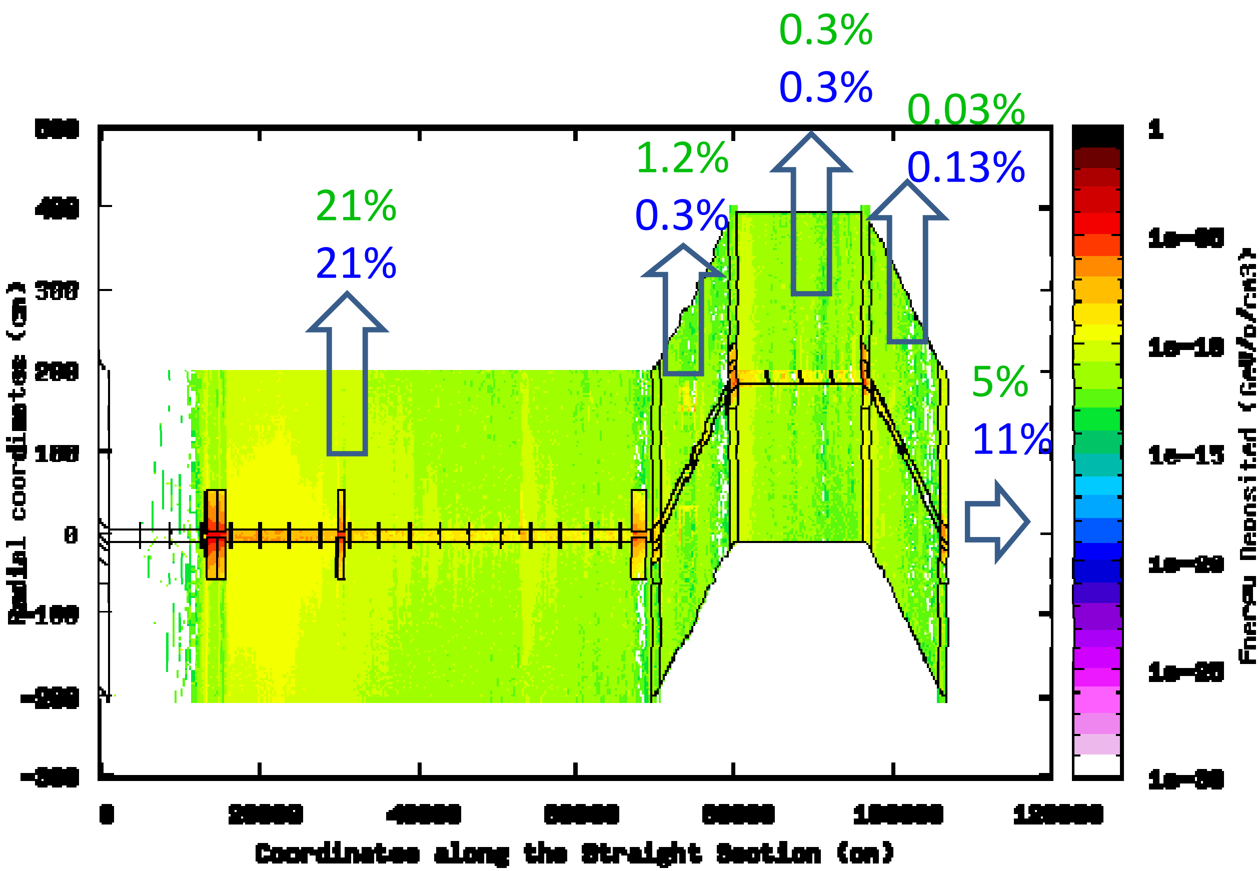
Preliminary dimensions:
Length: 10m
Ext. Radius: 30cm

Use & effect of Absorbers to protect magnets

Absorber material: **carbon**

18Ne

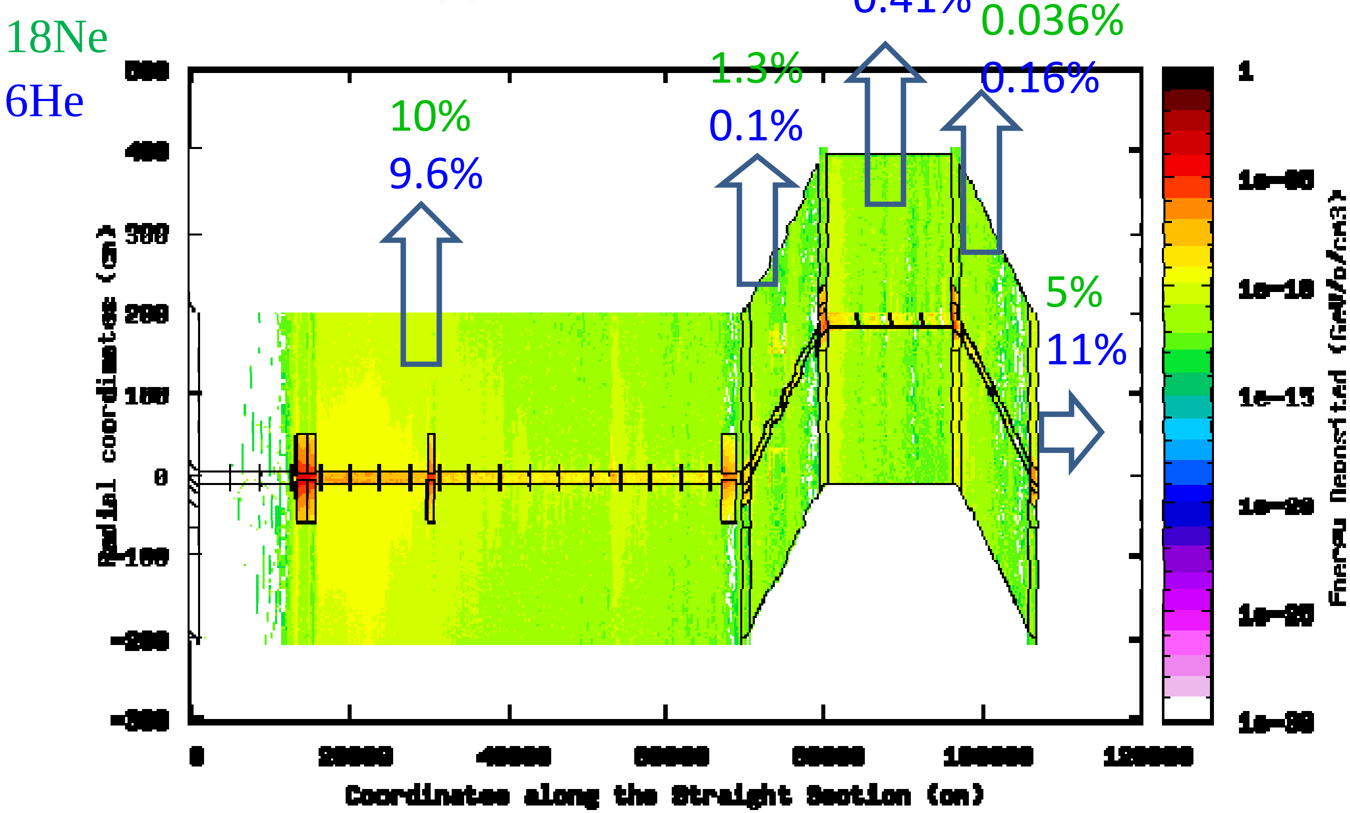
6He



53.7% (41%) of the incoming energy is deposited in the absorbers of the straight section from collimation which represent 369kW (181kW)

Use & effect of Absorbers to protect magnets

Absorber material: ***copper***



64.7% (52.4%) of the incoming energy is deposited in the absorbers of the straight section from collimation which represent 444kW (232kW)

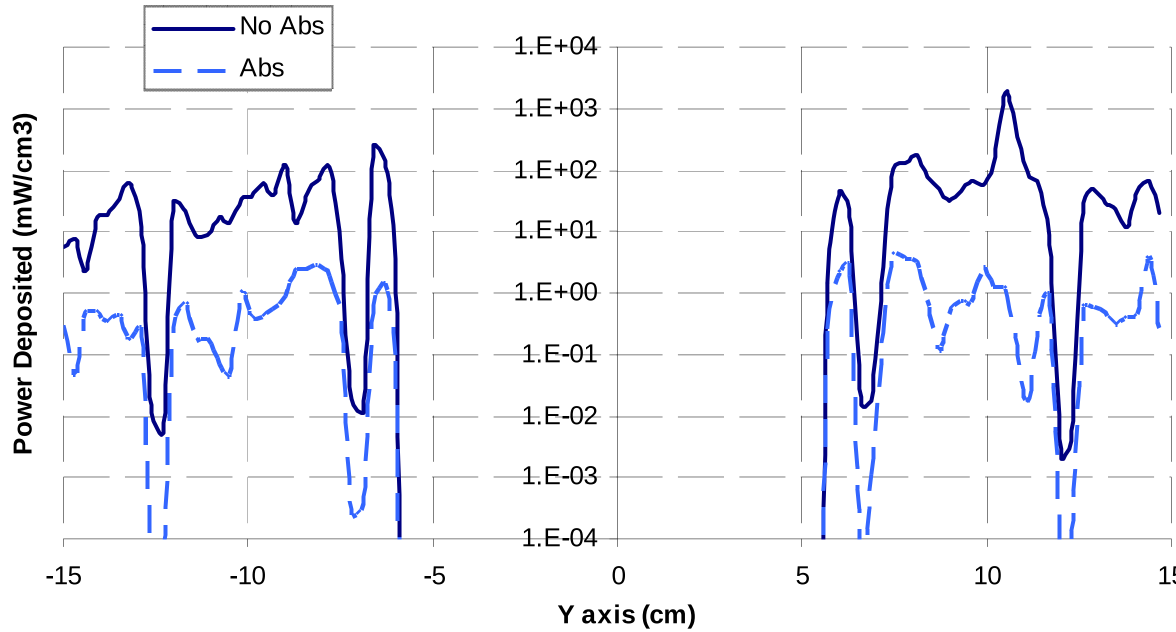
Copper absorbs 11% more incoming energy than using Carbon for the absorber materials

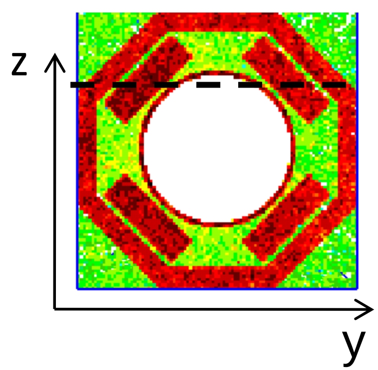
Effect of Absorbers on magnets: Quadrupoles

6He, 18Ne

- General decrease of the average power deposited of factor 4 in all quadrupoles located after the primary collimator

- Significant decrease of the peak of power deposited in the magnets of 3 orders of magnitude
→1.5mW/cm^3
(1.7mW/cm^3)





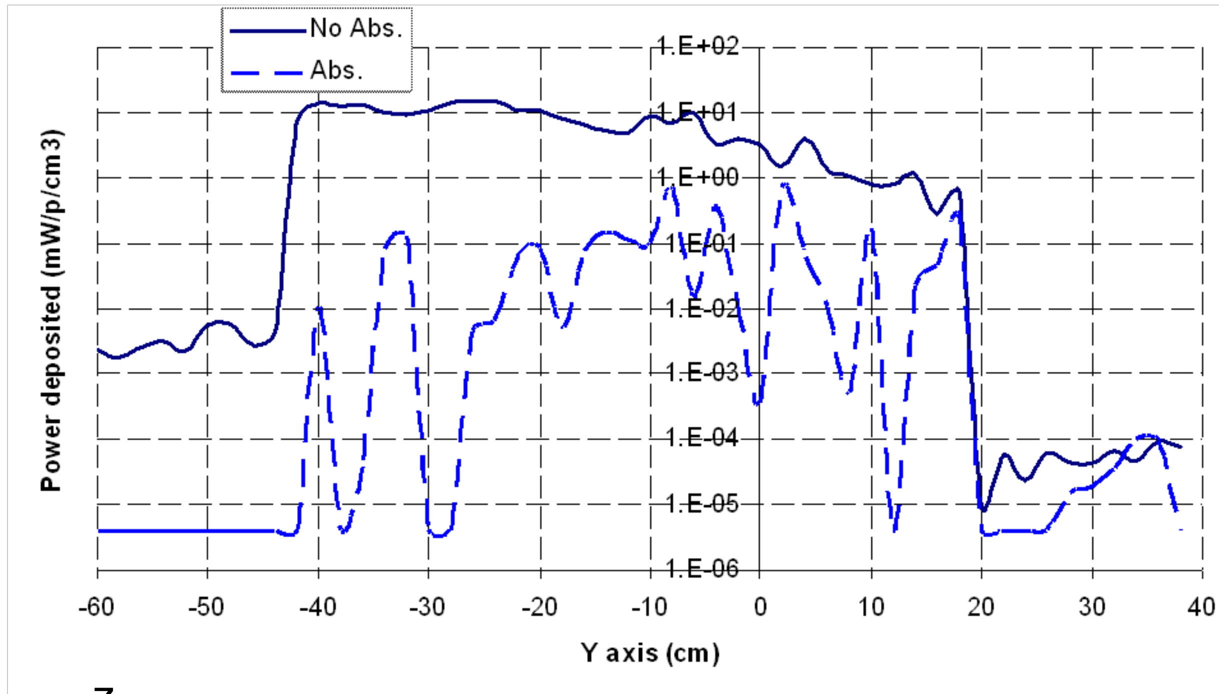
Binning size:
0.9 mm^2 (ZY plan)

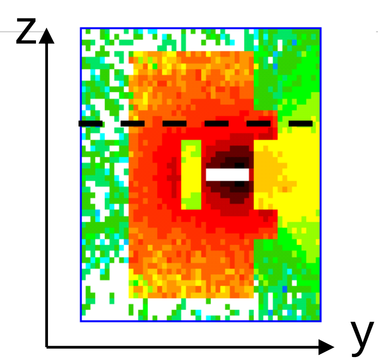
Effect of Absorbers on magnets: Dipoles

6He, 18Ne

- General decrease of the average power deposited in the dipoles of the 2nd bump: factor 20 less in the 1st dipole

- Significant decrease of the power peaks in the magnets of the dipoles → 0.9mW/cm^3 (2mW/cm^3) and 10mW/cm^3 (19mW/cm^3) in the Yoke

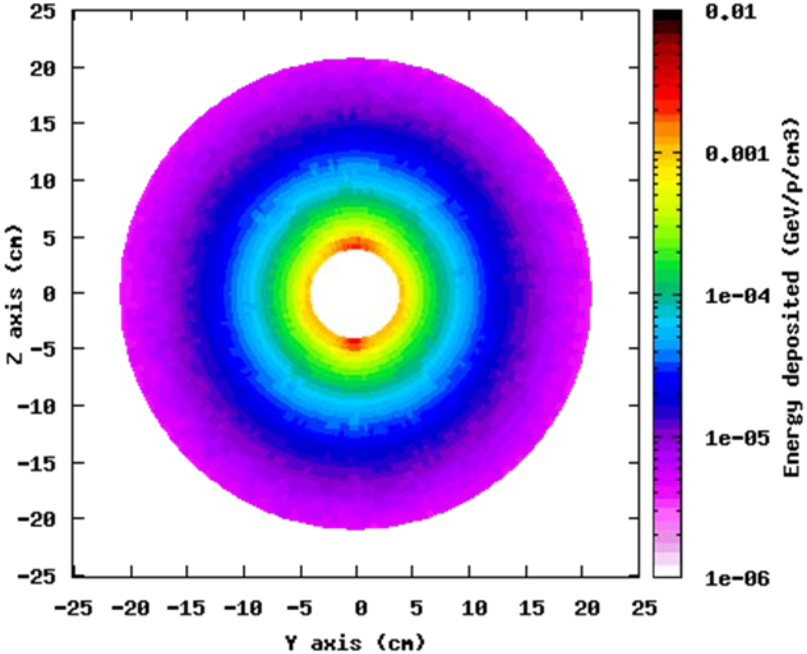




Binning size:
1 cm^2 (ZY plan)

Peaks of deposited power in the Cu & C absorbers

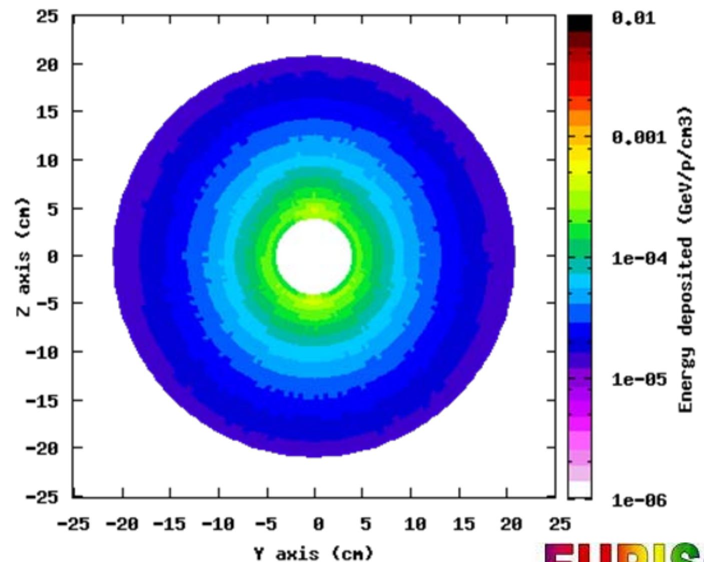
Cu



	6He		18Ne	
Absorb. Mat.	**Avg. Power (kW)**	**Peaks (W/cm³)**	**Avg. Power (kW)**	**Peaks (W/cm³)**
Cu	**70**	**4.0**	**156**	**1.5**
C	**64**	**1.8**	**144**	**0.7**

Binning size: ½ cm²
(ZY plan)

Carbon



Power values deposited in the absorbers too high!
→ need to design absorbers consisting of several modules able to share all this power (to ease their cooling)

Summary

- FLUKA preliminary implementation with quadrupoles and dipoles has been done on the Collimation Straight Section
- Placement of the primary/secondary collimators in ACCSIM and FLUKA
- 30cm thick Carbon collimator more suitable than Copper
- Power deposited above the recommended limit value in the magnets
- Need the use of absorbers to reduce the power deposited in the magnets
- Cu or C as absorber materials lead to a decrease in the energy escaping to the tunnel and a significant decrease in the peaks of power deposited in the surrounding magnets

What next?

- Addition of more details in the design of the magnets and improve the binning for a better accuracy in the deposition values within FLUKA.
- Study of the dose rate in the magnet (coming soon…)
- Need for a better design of the absorbers to ease the heat dissipation
- (Further investigations in the possibility of giving an angle in the primary collimator to compare the collimation efficiency)

References…

• F.W. Jones, G.H. Mackenzie, and H. Schonauer, "**ACCSIM** – A Program to Simulate the Accumulation of Intense Proton Beams," *14th Int. Conf. on H. E. Accelerators*, Tsukuba, Japan, 1989, in *Particle Accelerators* 31:199 (1990).

•*"The **FLUKA** code: Description and benchmarking"* G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fasso`, J. Ranft, Proceedings of the Hadronic Shower Simulation Workshop 2006, Fermilab 6--8 September 2006, M. Albrow, R. Raja eds., AIP Conference Proceeding 896, 31-49, (2007)

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• **SimpleGeo**, Theis C., Buchegger K.H., Brugger M., Forkel-Wirth D., Roesler S., Vincke H., "Interactive three dimensional visualization and creation of geometries for Monte Carlo calculations", Nuclear Instruments and Methods in Physics Research A 562, pp. 827-829 (2006).

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