Decay Ring optics, injection/collimation layout

A. Chance

CEA Saclay DSM/DAPNIA/SACM

Top parameters

	$^{6}He^{2+}$	$^{18}Ne^{10+}$
γ	100	100
T/ion (GeV)	555	1660
$t_{repetition}$ (s)	6	3.6
Number of injected ions	$9.05\ 10^{12}$	$4.26\ 10^{12}$
Injected beam energy (MJ)	0.82	1.13
Lost power by decay (injected beam) (W/m)	1	0.68
Number of stored ions	$9.71\ 10^{13}$	$7.4\ 10^{13}$
Stored beam energy (MJ)	8.7	19.9
Lost power by decay (stored beam) (W/m)	10.8	11.8
Energy to collimate between 2 injections (MJ)	**≈ 0.5**	**≈ 1**

To avoid the quenching, we must avoid deposition peaks in the magnetic elements. The design must consider the both species for the decay losses: we cannot optimize the absorber positions for only $^{6}He^{2+}$ or $^{18}Ne^{10+}$.

We have to do the design of a momentum collimation section. Not possible to use superconducting magnets near from this section.

Space charge effects due to the high intensities

Laslett tuneshift

$$\Delta \nu = -\frac{3}{4}\frac{Z^2}{A}\frac{r}{\beta^2\gamma^3}\frac{R}{L_b}\frac{N}{\varepsilon/\pi}$$

In the baseline we have L_b = 1.65 m, R = 1100 m

	Max $^{6}He^{2+}$	Max $^{18}Ne^{10+}$
γ	100	100
Nb of ions/bunch	4.8 10^{12}	3.4 10^{12}
ε_x (π mm.mrad)	0.11	0.11
ε_y (π mm.mrad)	0.06	0.06
$\Delta\upsilon_x$	-0.02	**-0.14**
$\Delta\upsilon_y$	-0.04	**-0.26**

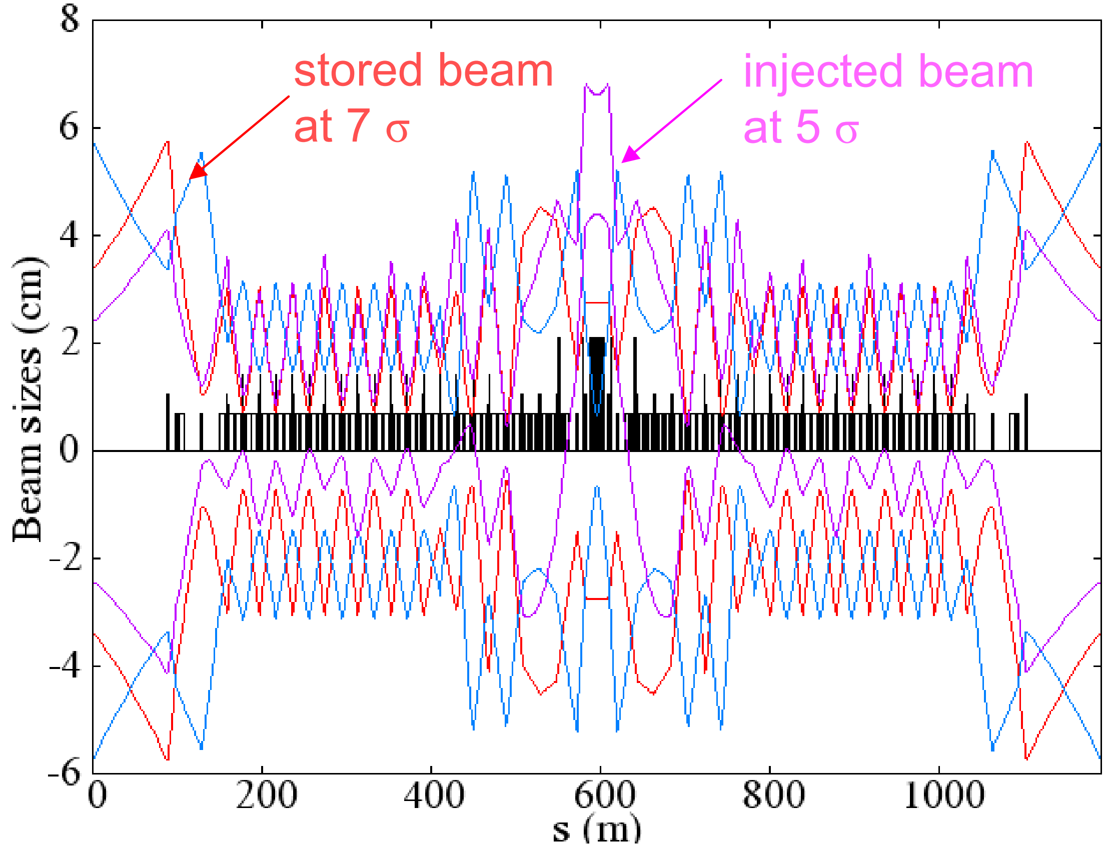
The tuneshift is too high for $^{18}Ne^{10+}$ in the both planes.

To decrease it without increasing the number of stored bunches, we must enlarge the rms emittance until 0.22 π mm.mrad in the Neon case.

$\Rightarrow$Tune shift of -0.07 in the both planes

Repartition of the losses in the decay ring

Beam sizes for $^{18}Ne^{10+}$



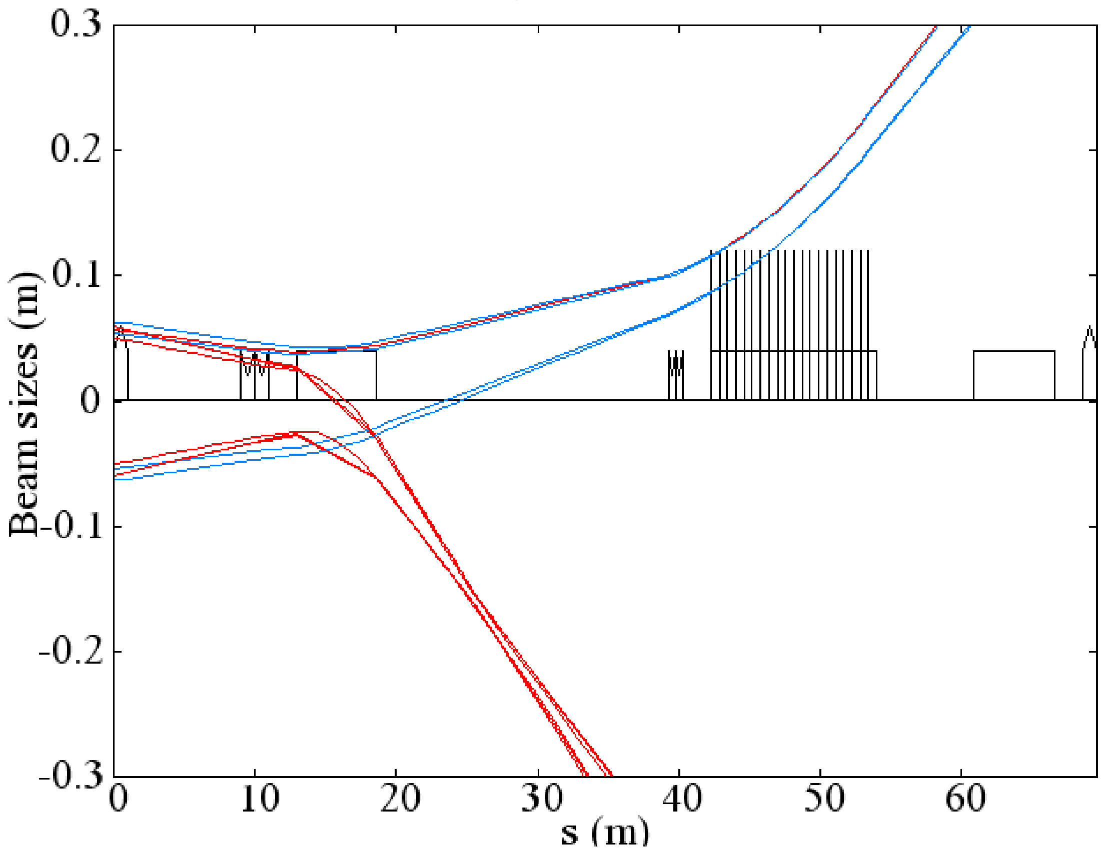
The momentum collimation is made at $\delta = 2.5\ 10^{-3}$

$\Rightarrow \Delta = 5\ 10^{-3}$ for a 15 mm thick septum with its guard

Absorbers at 4 cm from the axis in the FODO lattices

at 4.5 cm in the injection insertion

Extraction of the decay products



The beam sizes are at 7 σ In red: Helium, in blue Neon

The extraction septum is 12 m long with a magnetic field of 0.5 T

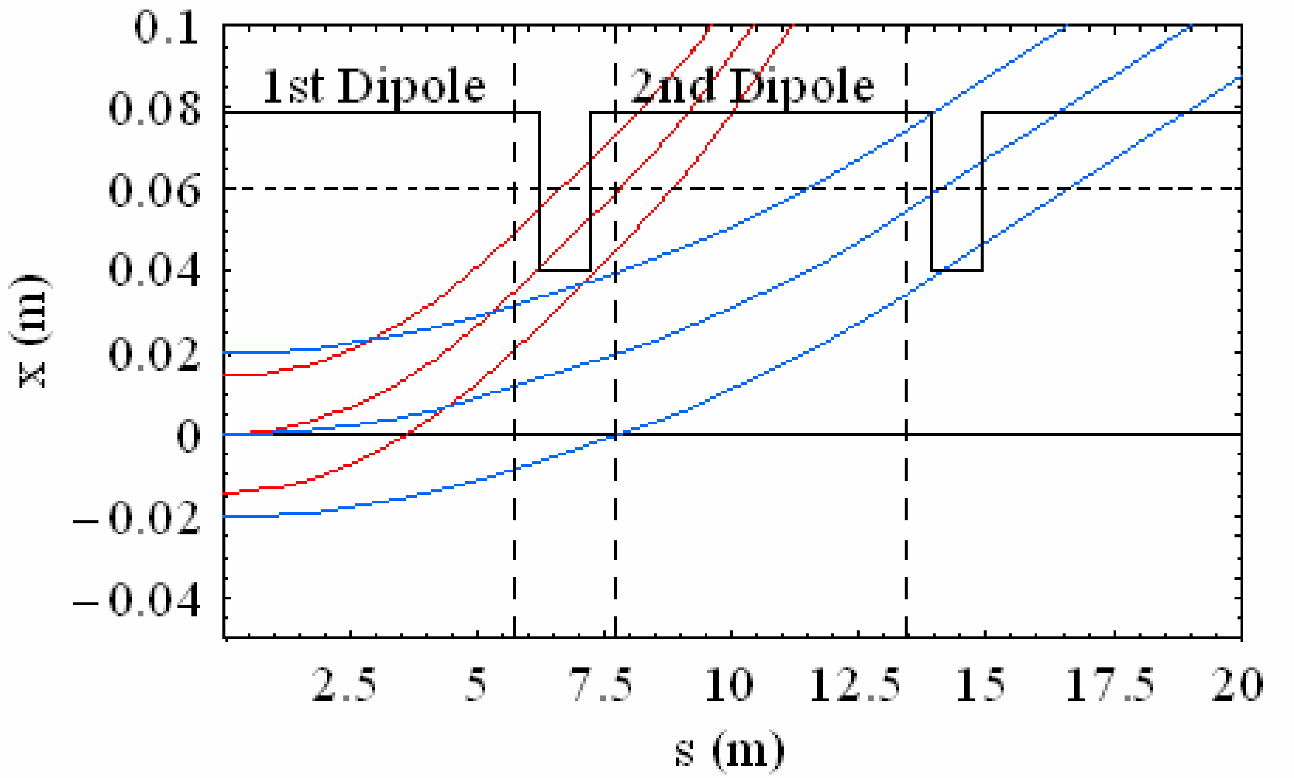
Despite the increase of the emittance, the decay products coming from the long straight sections can be extracted without hitting the magnet elements

Needed physical aperture in the dipole: 7 cm

Magnetic elements in the ring

Outside the injection section, the lattice is always the same.

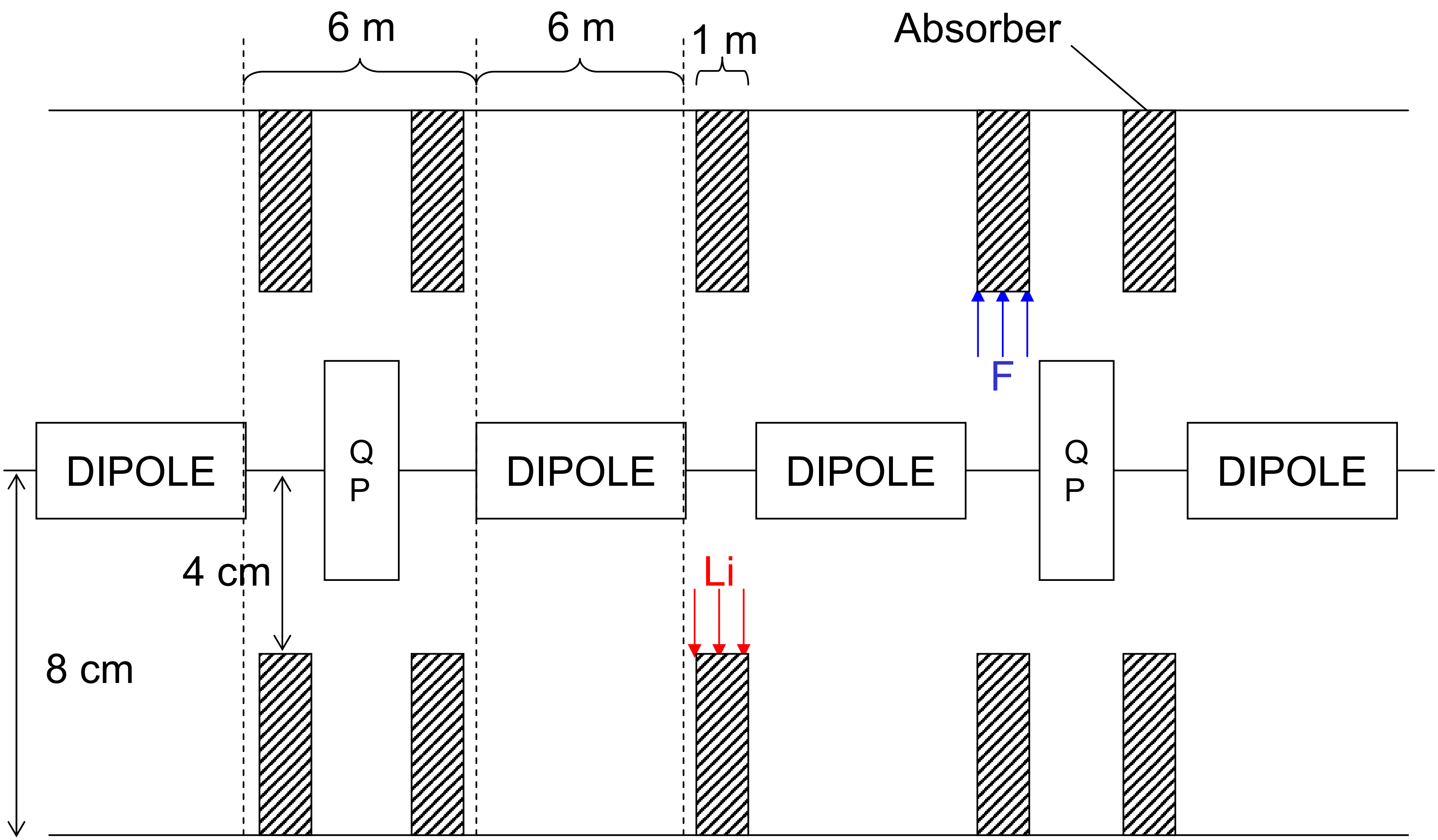
Beam sizes for the decay products at 4 σ on the figure below



For $^{18}Ne^{10+}$, we need half-apertures of 8 cm in the dipoles to avoid the deposition of the decay products.

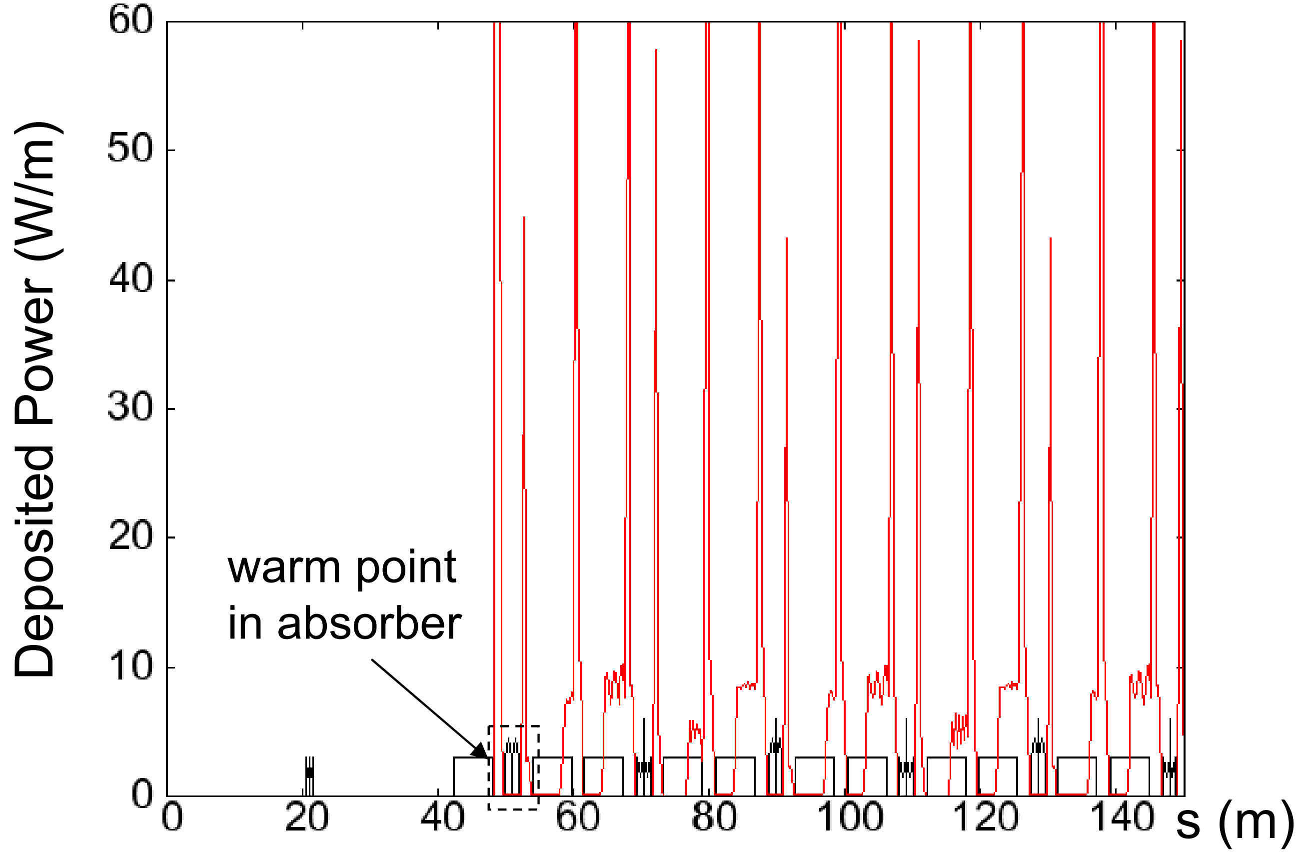
Not necessary to have a good field outside the region +/- 6 cm

Chamber geometry



The absorbers are 1 m long: we have kept a drift of 0.5 m between the absorber and the magnetic element.

Deposition in the ring for $^6He^{2+}$



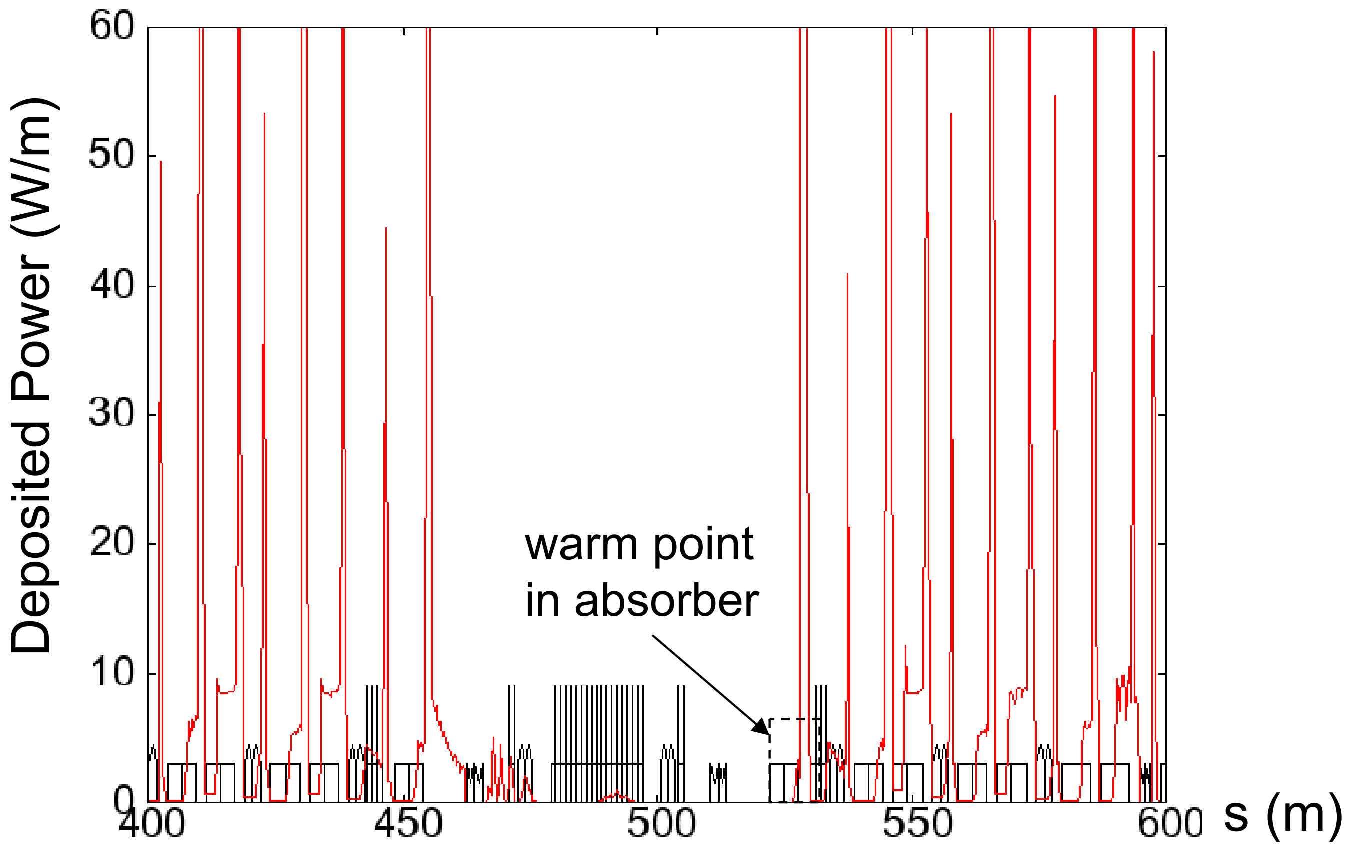
The absorbers are quite far from the axis.

⇒We have still some deposition in the dipoles

Quenching?

Due to the long drift before the second dipole in the arc, the deposition peak in the absorber is high (several hundreds of watts). How long must the absorber be? 1 m may be not enough.

Decay losses in the injection section due to $^{6}He^{2+}$



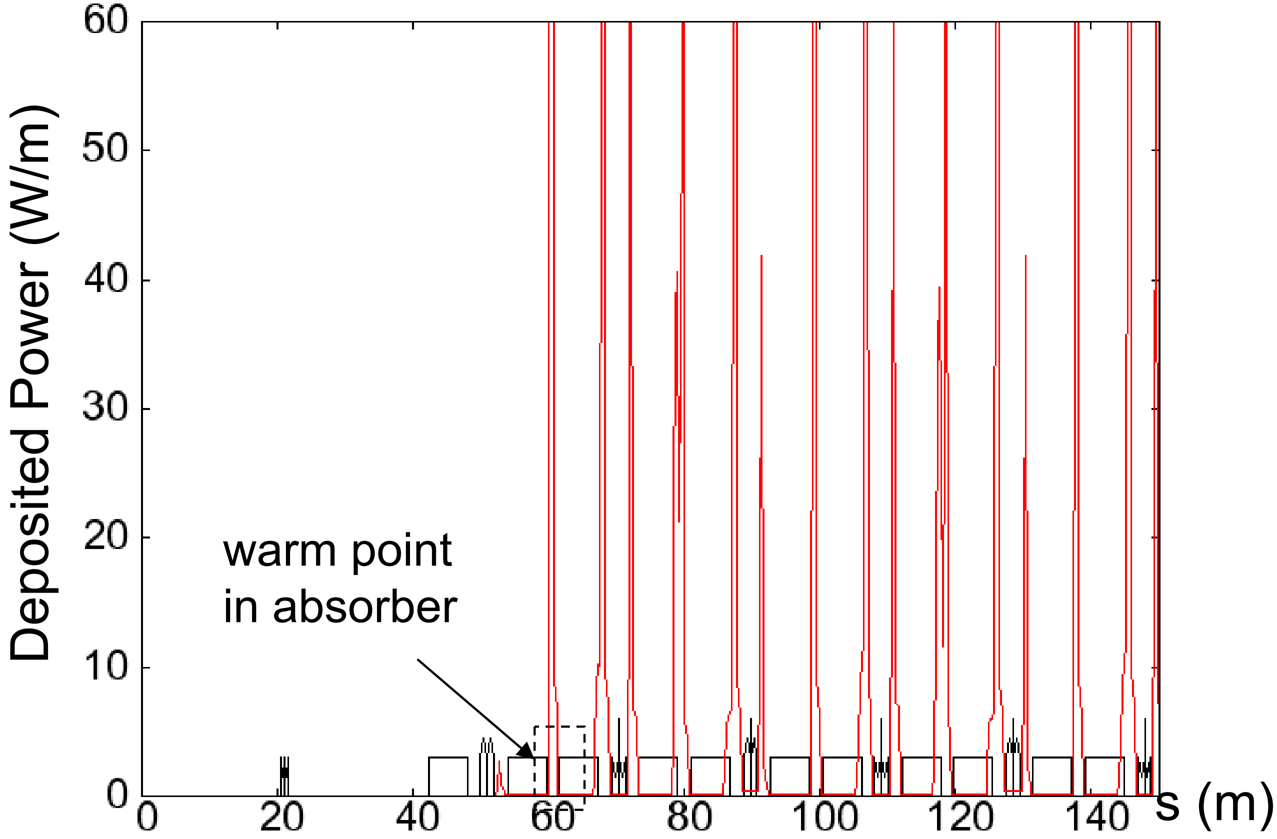
The absorber following the first dipole after the septum is a warm point. Several hundred of watts hit it continuously.

Absorbers at 4.5 cm from the axis seem to be sufficient in first order. But it is the limit: peaks begin appearing in the dipoles.

Use of an asymmetric chamber?

⇒Impedance budget

Deposition in the ring for $^{18}Ne^{10+}$



Same problem as for $^{6}He^{2+}$ for the absorber at the beginning of the arc

But the deposition in the dipoles is lower: a half-aperture of 8 cm is sufficient in the FODO lattice and the quenching problem is less likely than in the Helium case.

Momentum collimation section

Constraints on the collimation section

Momentum collimation

⇒High normalized dispersion needed

⇒Dispersion bump in the collimation section with dipoles

High intensities to collimate

⇒Not possible to use superconducting magnets

⇒Multistage collimation: insertion of secondary collimators after the primary collimator

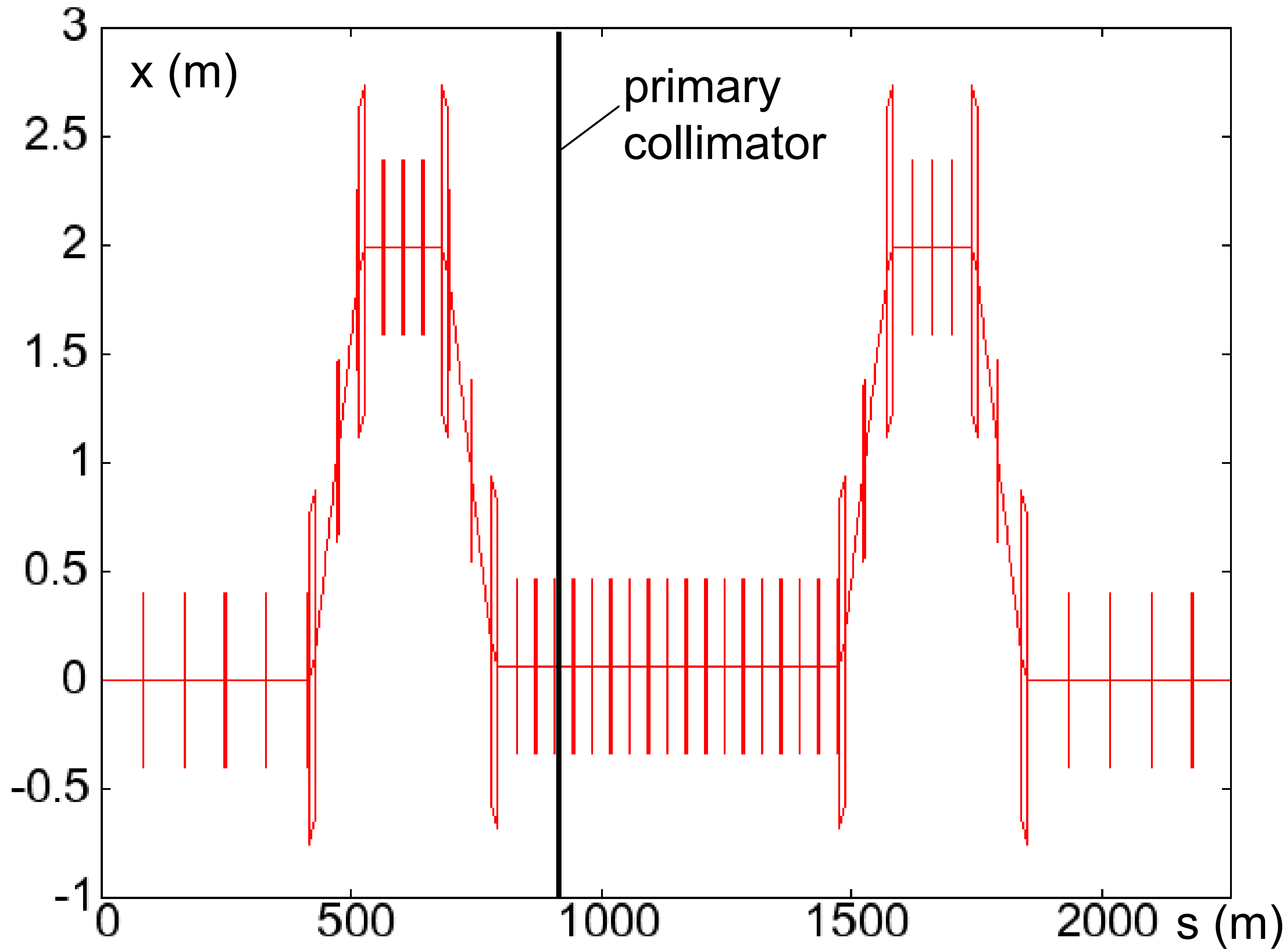
⇒We need a long drift after the primary collimator to collect the secondary particles

The best place for a multistage momentum collimation is in one of the two straight sections:

_ No superconducting magnet

_ We have an ENORMOUS space to realize a chicane and the momentum collimation

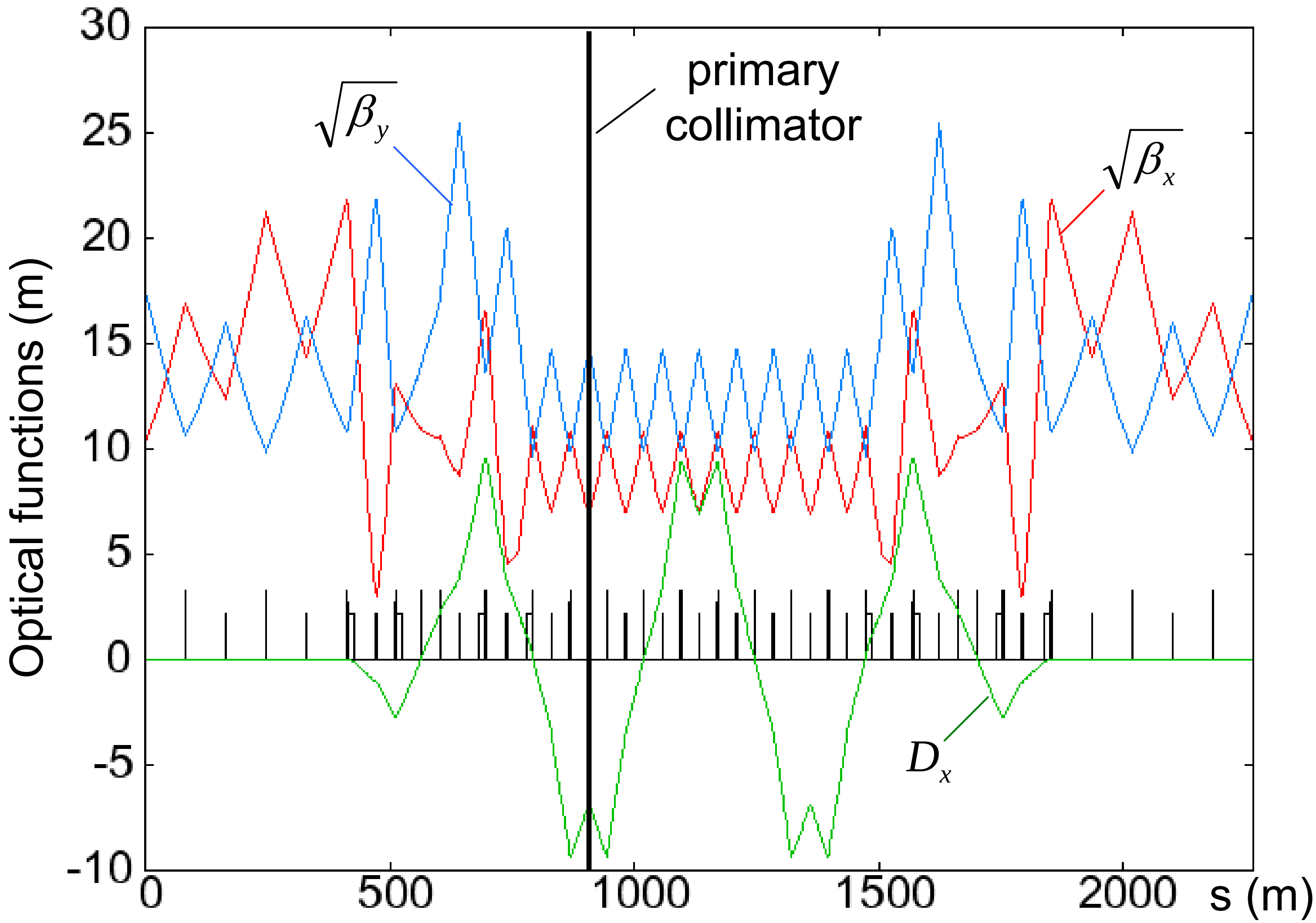
Synoptic



The collimation section is located in one of the long straight sections

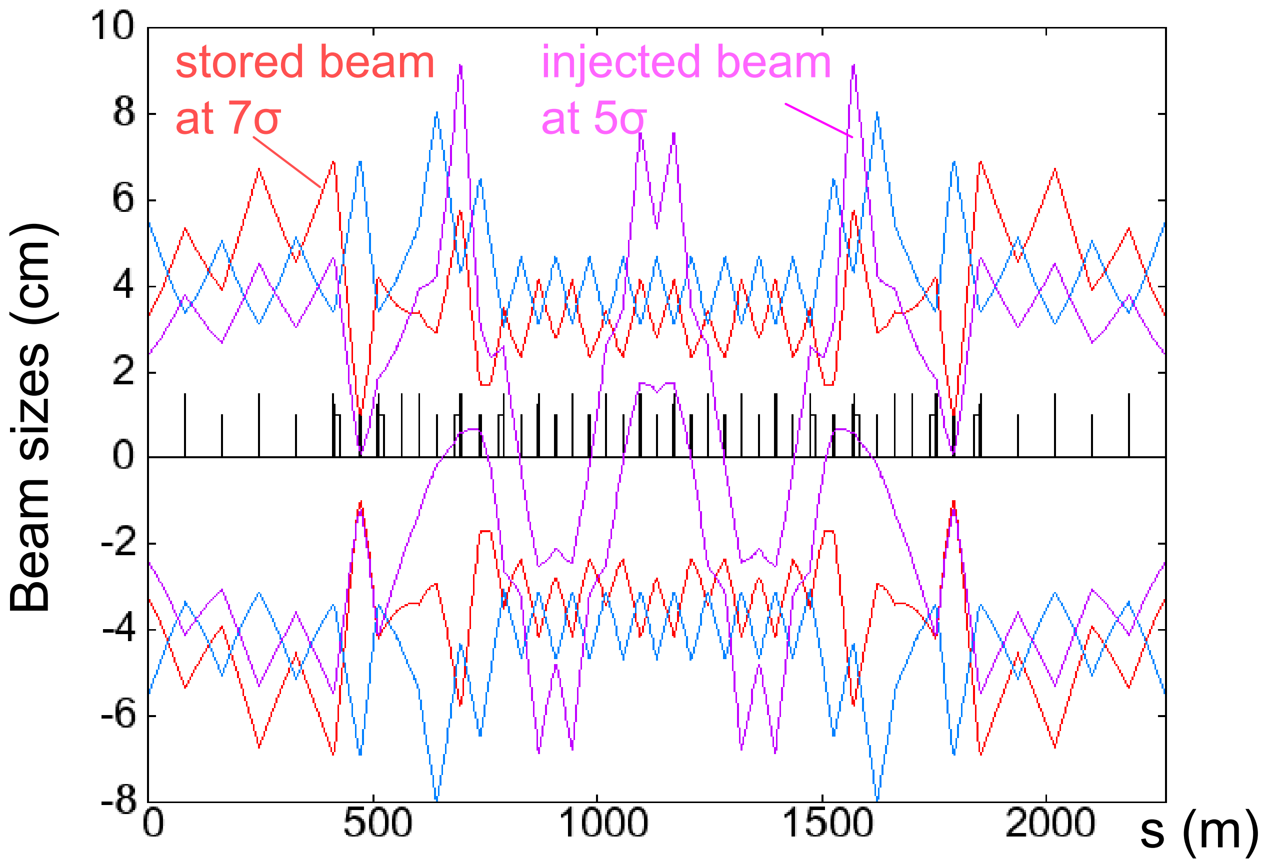
The dispersion bump is realized with 4 warm dipoles of 1.6 T

Optical functions in the collimation section



At the primary collimator, the normalized dispersion must be as high as possible. We have reached the value $\frac{D}{\sqrt{\beta_x}} = 1\,\mathrm{m}^{1/2}$ by doing a dispersion bump in the straight section.

Beam sizes in the collimation section for $^{18}Ne^{10+}$



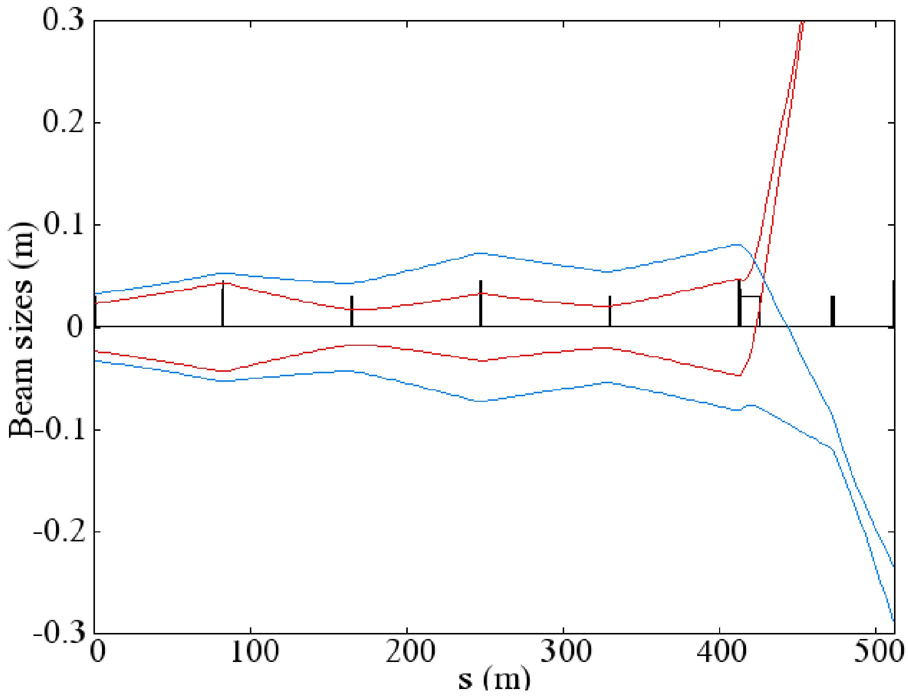
Large apertures needed for the dipoles and the quadrupoles

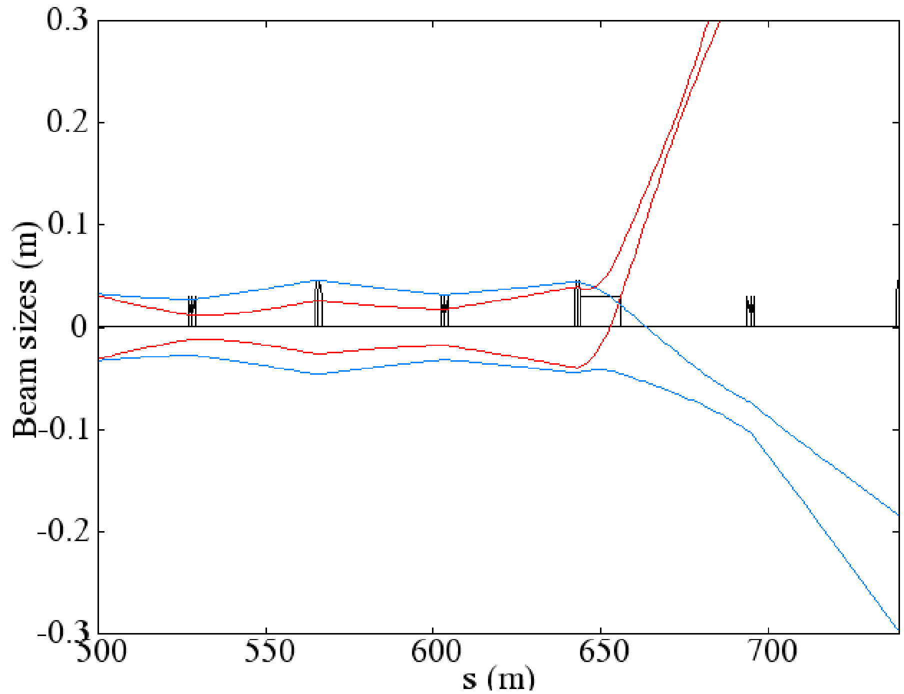
Limit for 1.6 T dipoles? Limit for quadrupoles of 15 T/m?

But long drifts between the dipoles

⇒Deposition peaks of the decay products of more than 6 kW

Extraction of the decay products coming from the collimation section





Left, beam of Li^{3+}(F^{9+}) between the arc and the first dipole of the chicane

Right, beam of Li^{3+}(F^{9+}) between the two chicanes

In red Lithium beam, in blue Fluorine beam

Possible to extract Lithium. More difficult for Fluorine (use of an extraction septum? of a dump?)

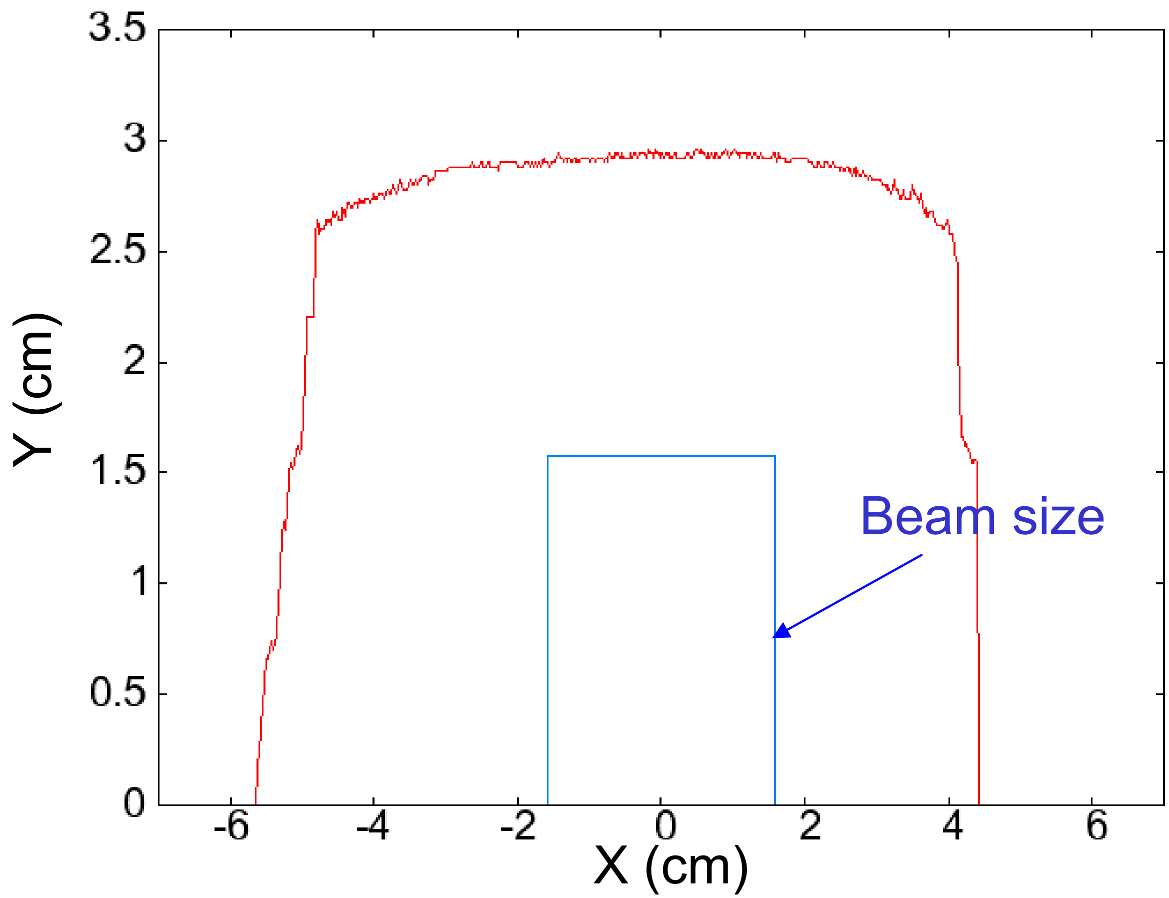
Dynamic aperture

The periodicity of the decay ring is only 1

⇒The beam is sensitive to every resonance

⇒The dynamic aperture is likely to shrink.

⇒We have inserted sextupoles in the arcs to correct the chromaticity and compensate the resonance effects



Summary

In first order, the decay losses seem to be manageable in the arc

BUT: _ Half-apertures of 8 cm for the dipoles

_ 1 m long absorbers between 2 successive magnetic elements in the whole ring

$\Rightarrow$Impedance budget

_ Activation of the absorbers

Due to the blow up in the longitudinal phase space after the merging, a momentum collimation section is needed. It is located in one of the long straight sections. The design was realized in first order.

BUT: _ Large apertures for the magnetic elements

_ Radioprotection

_ Betatron collimation in the same time too

How many ions are exactly deposited on the collimator?

Thank you for your attention