Decay ring design status

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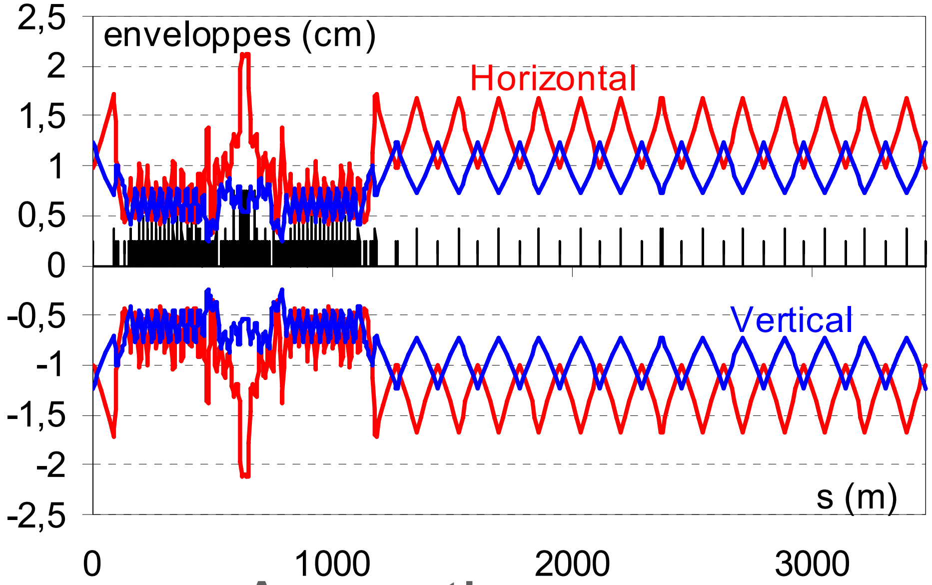
Outline

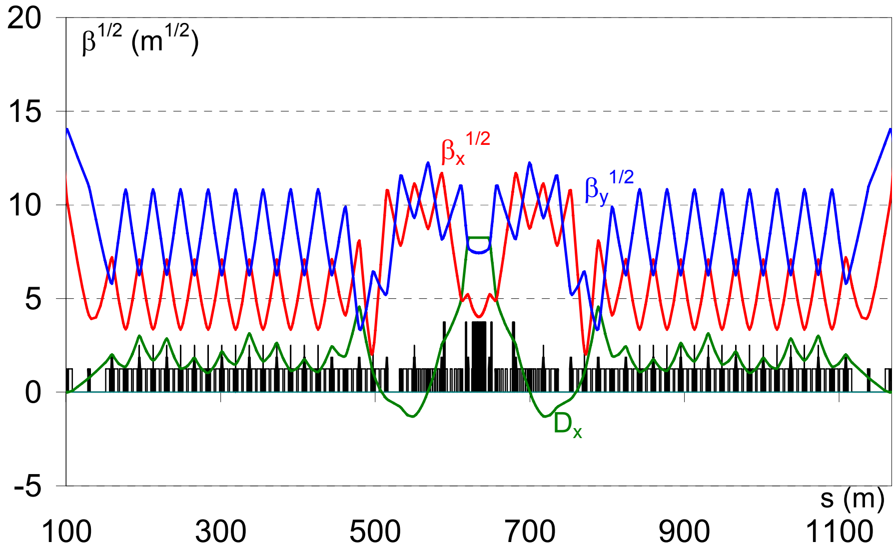
- Decay ring design in April 2005
- New changes in the lattice
- Beam sizes in the decay ring
- Deposits of the losses in the decay ring
- Collimation of the beam

Old lattice : Decay ring structure in April

Beam envelopes



Arc optics



In the straight sections, we use FODO cells. The quadripoles are not superconducting and are 1 m long

The arc is a 2π insertion composed of regular cells and an insertion for the injection

There are 489 m of 6 T bends with a 5 cm half-aperture

The arc length is about 1060 m

At the injection point, dispersion is 8.25 m while the horizontal beta function is as 21.2 m

The injection septum is 18 m long with a 1 T field

With the new values

The relative momentum spreads of the stored and injected beams have increased : they are respectively 2.5 ‰ and 0.4 ‰

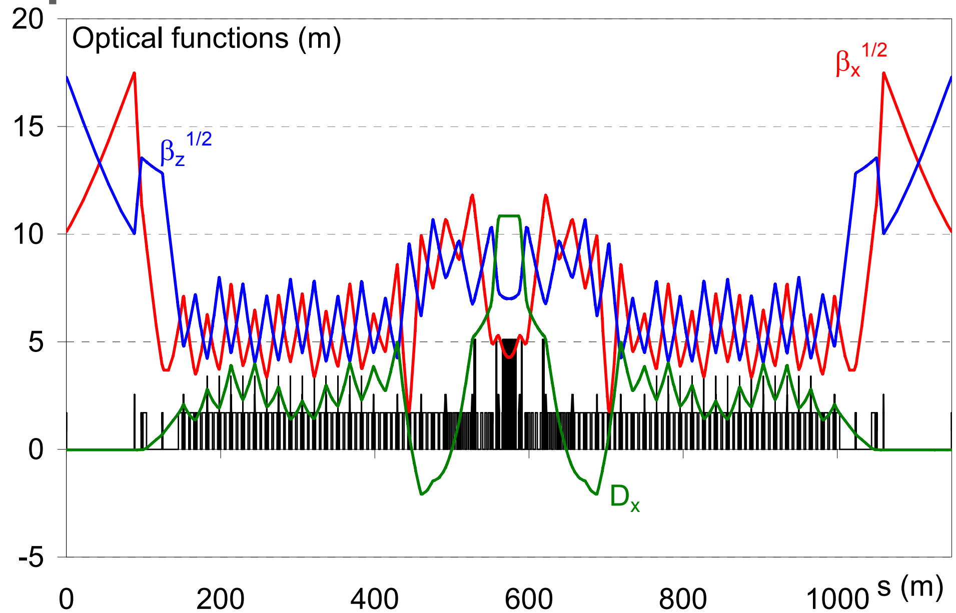
The beam horizontal emittance after the SPS is much higher than calculated one by simple scaling : its value is up to 9 µm (at 3σ)

Horizontal betatron amplitude function, β	21.2	m
Horizontal dispersion function, D	8.25	m
Horizontal emittance (at 3σ), ε	9	µm
Relative momentum spread, $\Delta p_{incoming}/p$	± 0.4	10^{-3}
Relative momentum spread, $\Delta p_{circulating}/p$	± 2.5	10^{-3}
Relative momentum separation, $\delta p/p$	6.2	10^{-3}
Beam size, $\Delta x_{incoming}$	± 14	mm
Beam size, $\Delta x_{circulating}$	± 25	mm

⇒The dispersion must be increased or the beta functions must be decreased

⇒The quadripole fields have increased : superconducting quadripoles are needed. The arc is designed again in that way

Optical functions in the arc



Superconducting magnets

2π insertion

Arc length decreased by 90 m (about 973 m now).

Energy difference between the both beams is acceptable for the RF system

At the injection point

Horizontal betatron amplitude function, β	22.7	m
Horizontal dispersion function, D	10.85	m
Horizontal emittance (at 3σ), ε	9	μm
Relative momentum spread, $\Delta p_{incoming}/p$	± 0.4	10^{-3}
Relative momentum spread, $\Delta p_{circulating}/p$	± 2.5	10^{-3}
Relative momentum separation, $\delta p/p$	**5.3**	10^{-3}
Beam size, $\Delta x_{incoming}$	± 15	mm
Beam size, $\Delta x_{circulating}$	± 31	mm

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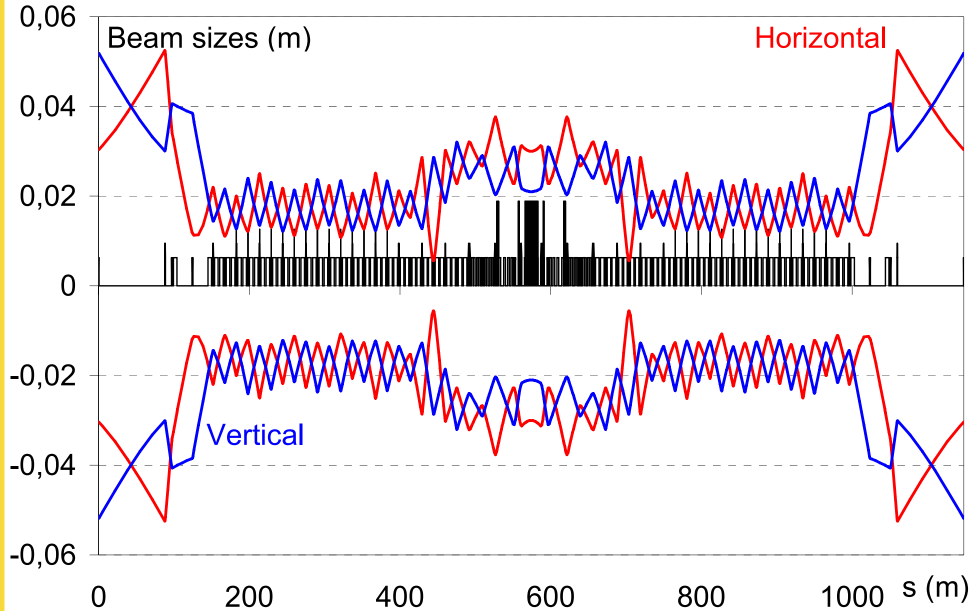
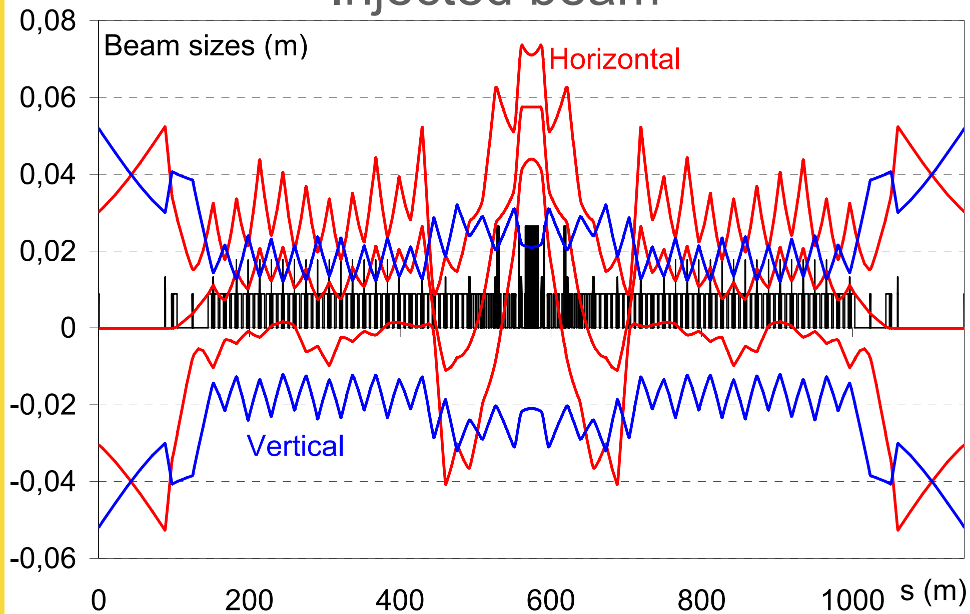
Envelopes in the arc

Stored beam



Injected beam



The momentum spread of the injected and stored beams increased

The energy difference between the injected and stored beams increased

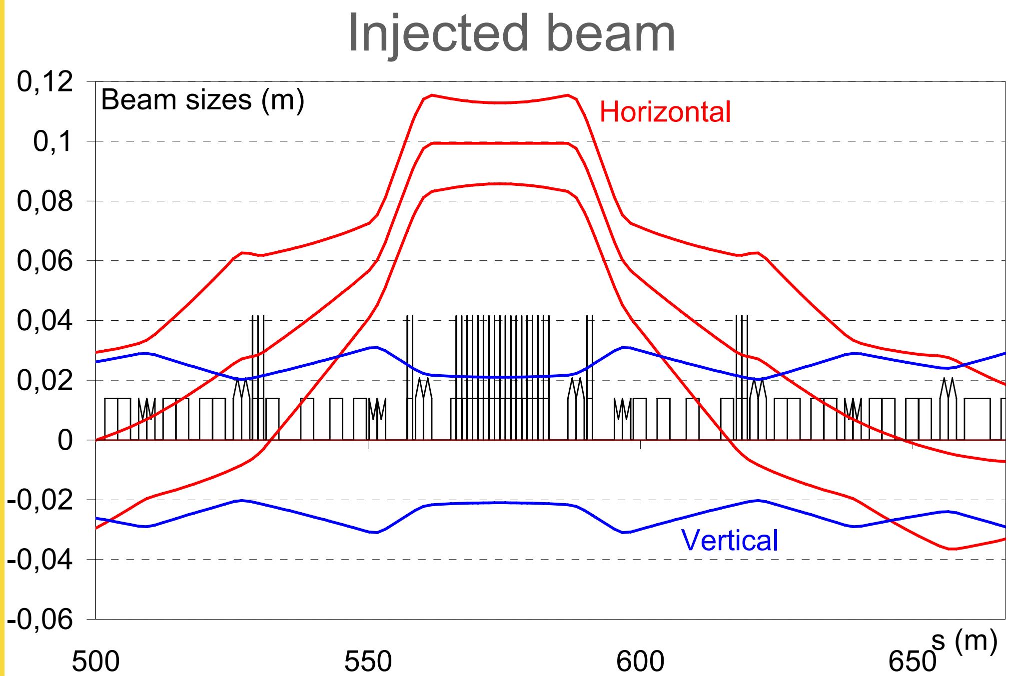
The horizontal emittance is higher

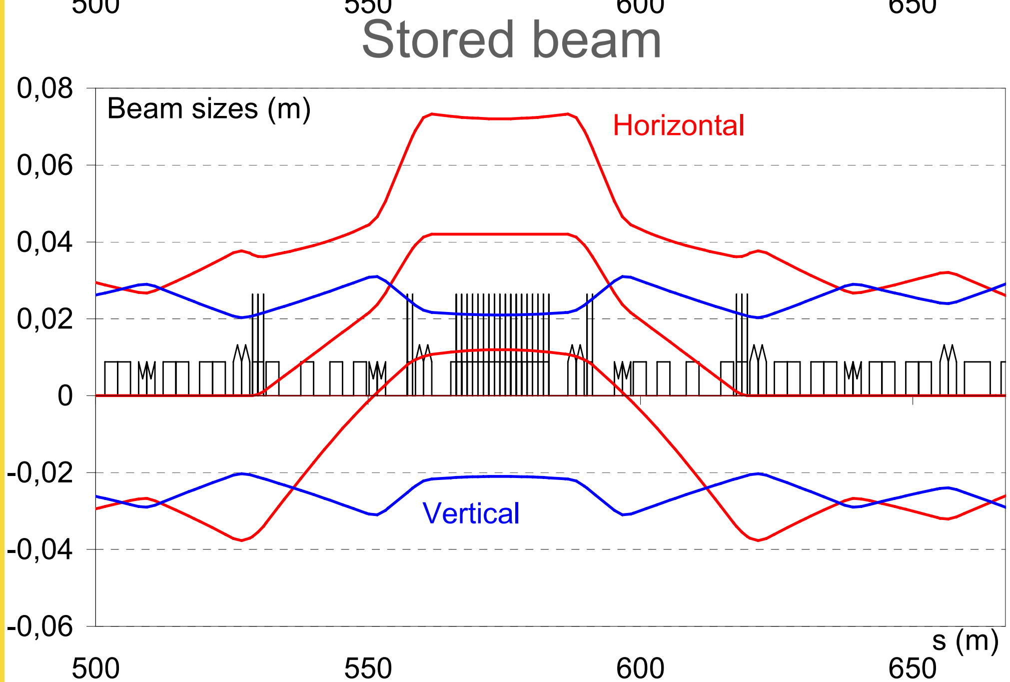
$\Rightarrow$The magnet half-apertures increased in the decay ring (5-6 cm in the FODO lattices)

With 1 m long quadripoles, the fields in the FODO cell quadripoles are about 4T with a 6 cm half-aperture!

The gradients in the quadripoles become strong and they may be lengthened to keep reasonable fields

Injection section





The beam bump is about 4.2 mm

Kicker half-apertures enlarged: 11 cm. Their field has increased (0.3 T)

Some magnet apertures are quite large : we need a 8 cm half-aperture just after the injection section. Special magnet at this point?

Concerning the quadripoles in the injection section, the fields are quite reasonable (less than 1.5 T with a 6 cm radius)

Injected and stored energies

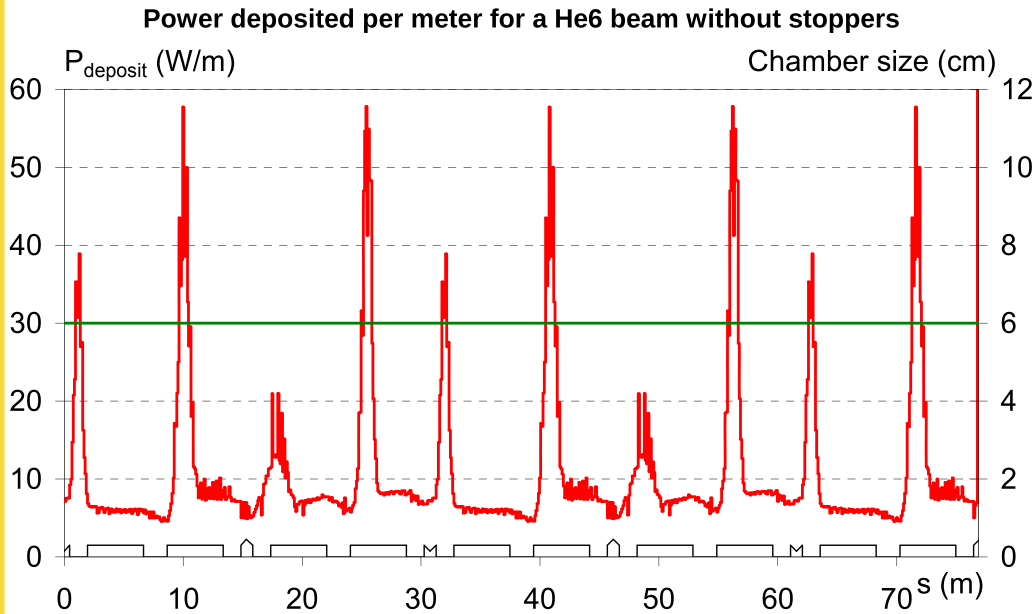
	He^6	Ne^{18}
gamma	100	100
T/ion (GeV)	561	1680
$t_{repetition}$ (s)	6	7.2
Injected intensity	$9.05\ 10^{12}$	$1.79\ 10^{11}$
Injected beam energy (kJ)	820	48.7
Lost power (injected beam) (W/m)	1	0.03
Stored intensity	$9.71\ 10^{13}$	$3.11\ 10^{12}$
Stored beam energy (kJ)	8800	846
Lost power (stored beam) (W/m)	10.8	0.5

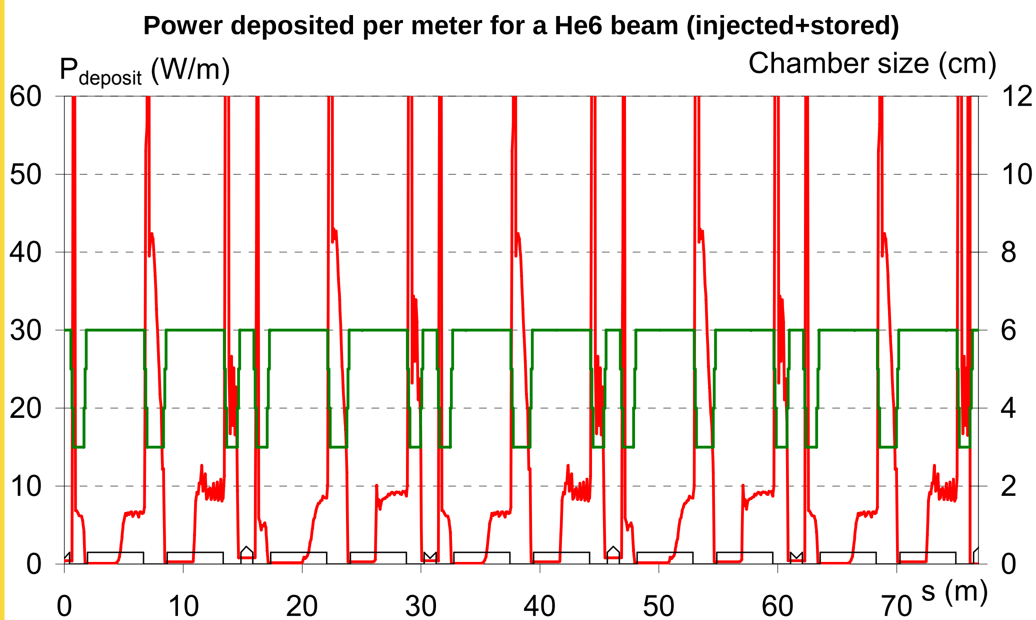
The Neon beam power is negligible compared to the Helium beam

We have to minimize the losses in the magnetic elements

We have made a first study of the losses by decay but it will be completed thanks to Accsim developed by TRIUMF

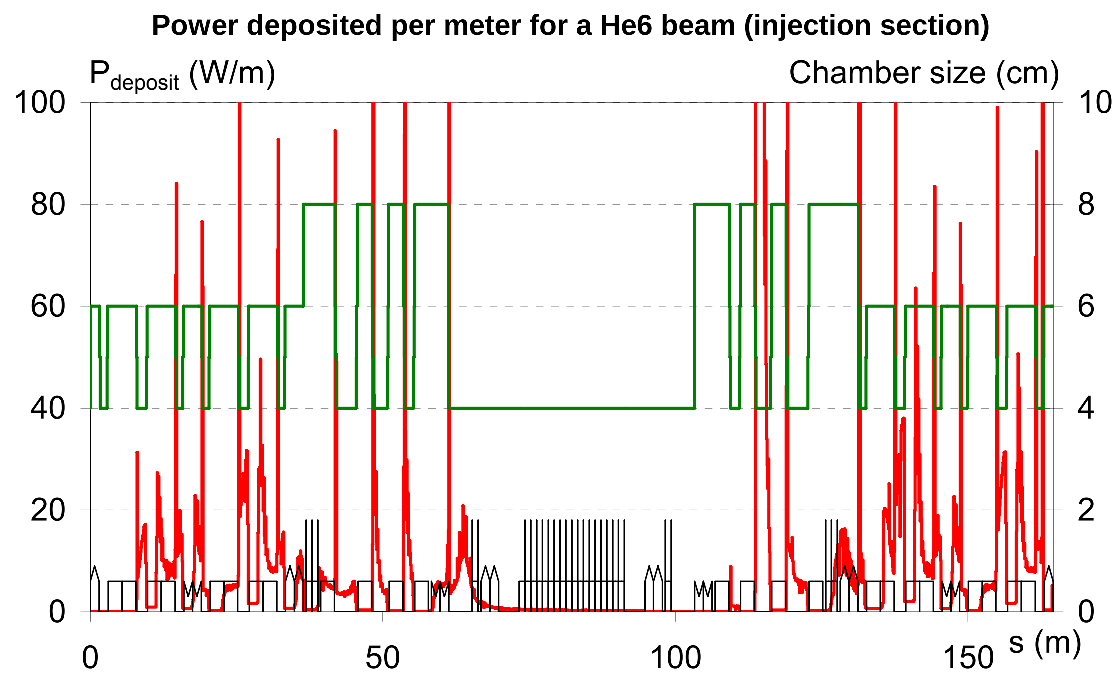
Losses in the regular lattice for the He6 beam





- The decay products of the Helium (Li^{3+}) are always deviated towards the negative x by the dipoles
- We have to put stoppers in the negative area : without stoppers, we have peaks in the magnets
- Fortunately, the injected beam is situated in the positive area
- Are these losses acceptable for the magnetic elements (radioprotection, heating,…)?
- Is there enough space to insert stoppers with 1.5 m between the magnetic elements?
- If it is not possible, the lattice must be designed again.

Losses by disintegration in the injection section



Very strong losses in the magnetic elements

The magnet apertures cannot be increased

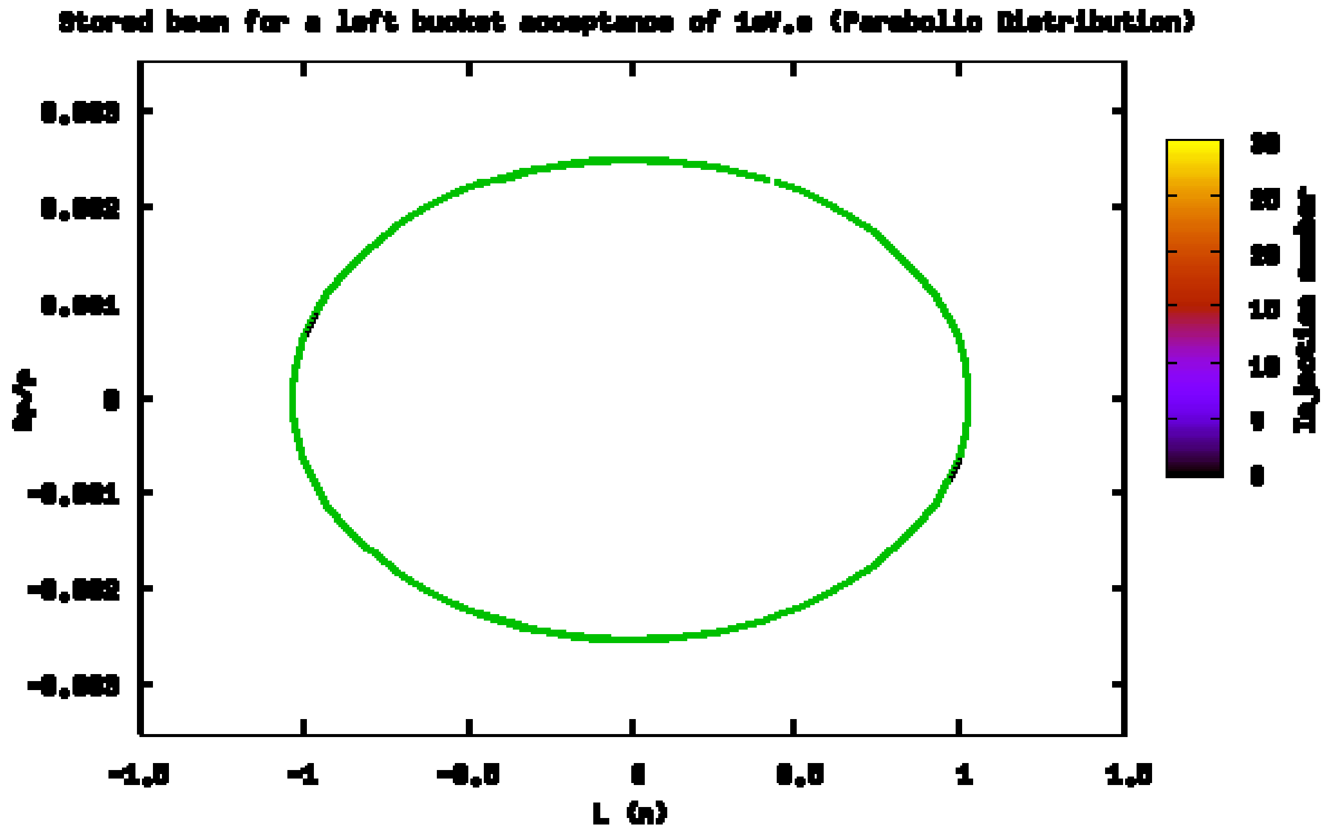
The stoppers cannot be nearer from the axis without losses of the fresh and circulating beams

⇒The injection section must be designed again

⇒The compacity of the arc may be decreased

Merging step after step

Simulation without beam cleaning



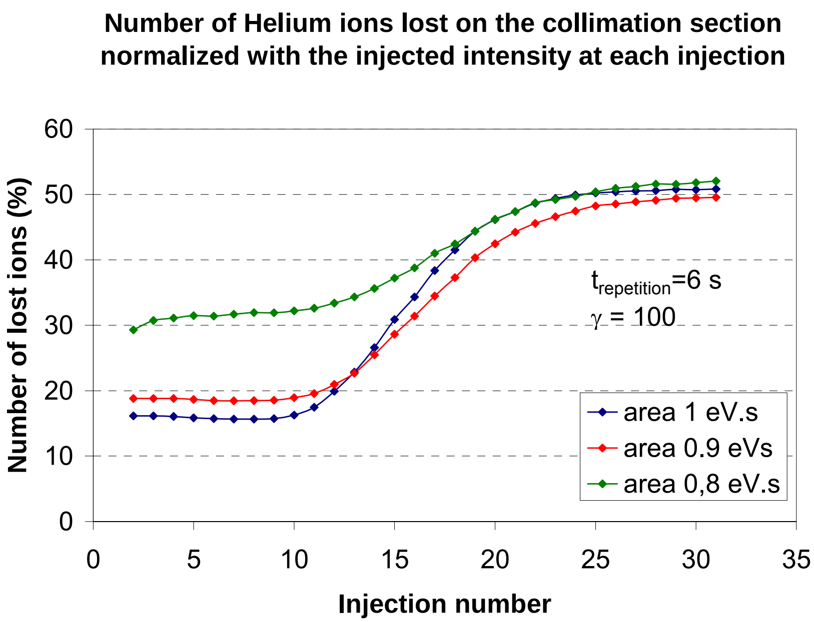
A part of the fresh beam is lost : some injected ions are not in the left bucket after a quarter synchrotron turn → they are in the halo around

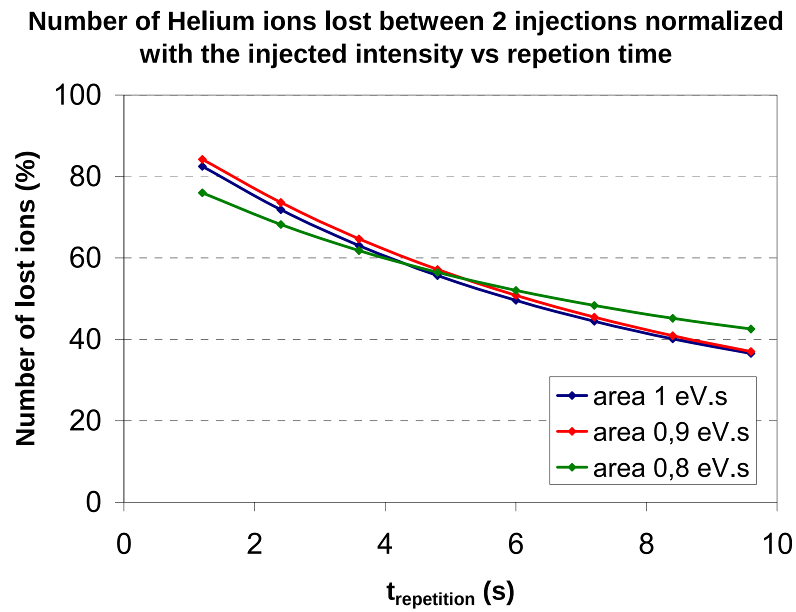
The stored beam is pushed away after each injection

A large part of the injected beam will be lost because of the physical longitudinal acceptance (the septum position imposes a 2.5‰ momentum spread)

Losses due to the RF system

Simulations for a parabolic distribution of the injected beam





Between 2 injections, we have to get out about 0.5 times the injected intensity

⇒E_{lost} ≈ 400 kJ every 6 s →P_{mean} ≈ 67 kW (2.7 kW/m for a 25 m available collimation section)

⇒Is it better to decrease the repetition time? For a 7.2 s repetition time, we lose 0.43 times the injected intensity

Conclusion

- The study is only at the first order. We do not take into account the emittance growth due to the instabilities, magnet and misalignment errors. But, the emittance and momentum spread values are already a problem

- At some points, magnet apertures are certainly too large. If we use 2 m long quadripoles, the fields are lower but are strong yet (until 3 T with a 6 cm radius). We must discuss with a magnet specialist about the feasibility of such elements. What is the maximum aperture with such fields and deposited powers?

- The kicker apertures are very strong with about 0.3 T fields

- The loss repartition shows 10 W/m losses in the magnets in the regular lattices. It has been studied in the injection section too. The collaboration with TRIUMF will enable to quantify it better

- The injection section will be designed again to face with the losses by decay

- The collimation section has to be designed for a high level of losses