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POST-DECELERATION OF THE LEAR BEAM BY A RADIOFREQUENCY QUADRUPOLE

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Introduction

The RFQ (Radio Frequency Quadrupole), as low energy particle accelerator, becomes more and more popular [1].

Following the proposal of the LEAR Group, we have begun to investigate a new application of this structure: the possibility of using an RFQ as post-decelerator after LEAR, to meet the requirements of antiproton physics at very low energy, especially of the p-$\bar{p}$ mass difference experiments (PS189) [2]. The main advantage with respect to an equivalent synchrotron is the lower cost. The fact that no adjustment is necessary after the initial tuning makes it particularly suitable to experiments which require fixed beam characteristics.

A preliminary study of this deceleration method is described in this paper. The results are summarized in two examples of RFQ structures decelerating the $\bar{p}$ from 1.3 MeV (50 MeV/c) or 5 MeV (100 MeV/c) to 200 keV (20 MeV/c).

A different system, which permits a tunable final energy, is being analysed at Los Alamos Laboratory and is presented in a separate contribution to this workshop [3].

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The RFQ project as decelerator

The specifications of the beam for the injection energy of 5 MeV and 1.3 MeV are summarized in Tables 1 and 2, respectively.

These preliminary beam parameters are determined assuming a special mode of extraction and strong cooling in LEAR, an ideal RFQ for deceleration and ideal debunching after deceleration[4].

	P=100 MeV/c T= 5 MeV	P=20 MeV/c T=200 KeV	
	At exit of LEAR beam bunched	After deceleration	After ideal debunching
ϵ_h [95%mm.mrad] ϵ_v	1π 3π	5π 15π	5π 15π
ΔP/P $\Delta\Phi_{rf}$ B_F^{-1}	$\pm 2\ 10^{-4}$ $\pm 18^{\circ}$ 10	$\pm 2.5\ 10^{-3}$ $\pm 40^{\circ}$ 4.5	$\pm 5.5\ 10^{-4}$

Table 1 : Parameters for deceleration from 100 MeV/c to 20 MeV/c

	P=50 MeV/c T= 1.3 MeV	P=20 MeV/c T=200 KeV	
	At exit of LEAR beam bunched	After deceleration	After ideal debunching
ϵ_h [95%mm.mrad] ϵ_v	2π 6π	5π 15π	5π 15π
ΔP/P $\Delta\Phi_{rf}$ B_F^{-1}	$\pm 4\ 10^{-4}$ $\pm 29^{\circ}$ 6.2	$\pm 2.5\ 10^{-3}$ $\pm 56^{\circ}$ 3.2	$\pm 7.810^{-4}$

Table 2 : Parameters for deceleration from 50 MeV/c to 20 MeV/c

The energy spread required for the decelerated beam is very small, so a smooth deceleration with small phase advances per period and therefore low fields is necessary to reduce strong oscillations inside the beam and to restrain the emittance growth in the longitudinal phase-space, during the transport along the structure. To reduce the dimensions and the cost, high frequencies can be used.

Figure 1 shows how the length and the mean aperture r_0 of the structure vary with frequency. These values are given for the injection energy of 1.3 MeV.

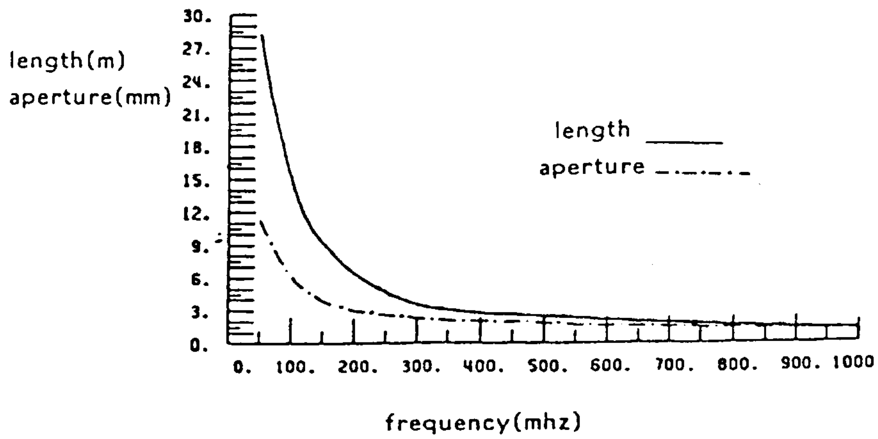

Figure 1 : Length and aperture versus frequency; Results computed for an initial energy of 1.3 MeV

The smallness of R_0 at high frequencies leads to the difficulty in the mechanical stability of a structure in which the ratio between the length and the aperture is of the order of 1000 to 1 and to the risk of exceeding the Kilpatrick voltage breakdown limit by a rather large factor, even if a low voltage is applied to the vanes.

Therefore a compromise must be reached in the choice of the parameters.

In our study, we have assumed the division of the RFQ in four sections[5] (radial matching section, shaper, gentle buncher, and pure accelerating section); the space-charge forces are neglected because the beam intensity extracted from LEAR is low ($< 10^9$ particles/s).

The programs used in the calculations are:

- INPAR, to determine the main parameters of the structure;
- RFQIMS, to study the RFQ section by section;
- PARMTEQ, to study the beam dynamics and quality;
- OUTTEST, to obtain graphic results.

The three last programs were written at Los Alamos for an accelerating RFQ. We have made the necessary modifications to permit the study of a decelerating RFQ and a faster calculation.

Two preliminary results are described in Tables 3 and 4. The horizontal profile, the phase and energy spread of the beam inside the RFQ are represented in Figure 2.

Frequency (MHz)	500
Initial energy (MeV)	1.3
Final energy (MeV)	.2
Intervane voltage (kV)	28
Peak surface field (MV/m) = k_s*V/r_0	21
	(k_s = 1.5)
mean radial aperture (mm)	1.9
Minimum radial aperture (mm)	1.6
maximum modulation factor m	1.4
Initial synchronous phase (degrees)	-29
Length (m)	2.8
Total power (kW)	73
Output transverse emittance (π mm.mrad)	
ε_h	5
ε_v	16
Output longitudinal emittance	
phase spread ΔΦ (degrees)	±21
energy spread ΔE (keV)	±1.2
Transmission (%)	100

Table 3 : RFQ parameters for initial energy 1.3 MeV

Frequency (MHz)	400
Initial energy (MeV)	5
Final energy (MeV)	.2
Intervane voltage (kV)	82
Peak surface field (MV/m) = k_s*V/r_0	31
	(k_s = 1.5)
Mean radial aperture (mm)	4.1
Minimum radial aperture (mm)	1.8
maximum modulation factor m	3.1
Initial synchronous phase (degrees)	−18
Length (m)	4
Total power (kW)	630
Output transverse emittance (π mm.mrad)	
ε_h	5
ε_v	16
Output longitudinal emittance	
phase spread $\Delta\Phi$ (degrees)	±20
energy spread ΔE (keV)	±1.3
Transmission (%)	67

Table 4 : RFQ parameters for initial energy 5. MeV

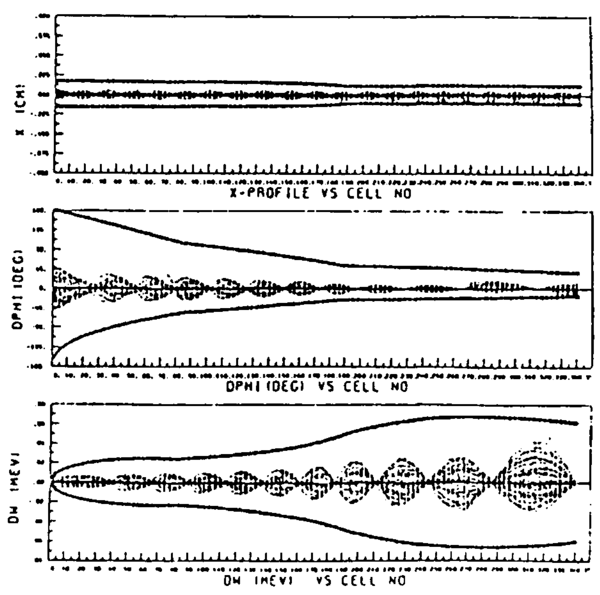

Figure 2 : Antiproton beam transport along the RFQ structure described in Table 4 (deceleration from right to left)

To improve the transmission, a matching cavity could be installed in the transport line between LEAR and the RFQ, to rotate the longitudinal emittance, matching it to the RFQ acceptance.

As the final aim of this project is to obtain a certain current with a small energy spread, it is possible also to decelerate a beam whose intensity is higher than the required one and to use from it after the deceleration only the dense core.

Conclusion

The results satisfy the required beam quality. But the mechanical tolerances are critical because the high frequencies used and the smallness of the RFQ aperture. After this first work, we will investigate the possibilities of the RFQ as decelerator in more details and study the feasibility of the whole system, starting at LEAR output and ending at the experiment.

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