A RFQ FOR THE DECELERATION OF ANTIPROTONS

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Abstract

A RFQ which is designed for the deceleration of antiprotons extracted from LEAR (CERN) at 2.0 MeV down to 0.2MeV is being built by groups of CSNSM Orsay and IAP Frankfurt and CERN. The design of this RFQ system, which should improve the counting rate by a factor of up to 10^3 in comparison with the energy degradation technique and the status of the project will be reported.

Introduction

RFQs have been built for various applications namely high current proton injectors for synchrotrons, accelerators for polarized ions, for heavy ions, and also industrial use. RFQs are unique for low energy acceleration because of the strong electric focusing with rf quadrupole fields[1,2]. Even the design is somewhat complicated the RFQ is a compact structure which is simple to operate. The input and output energies are fixed and emittance growth can be made very small.

The low injection energy at relatively high operating frequency is very important. The ion source can be close to ground potential, thus allowing the use of bulky and complex ion sources which would be difficult to operate on a high voltage platform concerning the space needed and the power consumption. These are sources for heavy ions, for high charge states or high currents as well as for polarized beams and clusters. They are especially difficult for a higher duty cycle..

The same is true for post acceleration or deceleration of heavy ion beams[3] which have been stripped at high energies or for antiprotons which have been stored and cooled in a synchrotron ring[4,5]. In this context the heavy ion prestripper accelerator and LEAR are bulky ion sources which have to be on ground potential for which RFQs can provide efficient post acceleration or deceleration with strong focussing and little emittance growth.

Several proposals to provide 0.2 MeV Antiprotons to the CSNSM Orsay experiment: "Antiproton - Proton mass comparison with a radio - frequency mass-spectrometer "(PS189)[6,7] by deceleration were not realized because of complexity and the costs involved[5,8]. In a new effort work was concentrated on the reduction of costs e.g. by a pulsed mode RFQ deceleration with a less complex RFQ structure and simpler bunching schemes.

Other important points were the change of the data taking mode at the experiment and success of the LEAR team in decelerating the $\bar{p}$ beam from 6.0 to 2.0 MeV with an ejection lasting 0.5 msec. A layout of experiment PS189 is shown in Fig.1.

The aim of the experiment is the reduction of the present upper limit on a hypothetical CPT theorem violation in baryon-antibaryon pairs. The experimental set-up is a specially designed radiofrequency mass spectrometer of L.G.Smith type. It has been installed at CERN at the LEAR (low energy antiproton ring) experimental area in order to make a comparison of the charge to mass ratio of an antiproton and a proton by measuring the cyclotron frequencies of antiprotons and H^- ions rotating in the same very homogenous magnetic field. The physical parameters are fitted to reach a mass resolving power of 5×10^5, enabling a mass comparison accuracy of 5×10^{-9}.

The acceptance of the spectrometer is extremly low: $\alpha_H = 1\pi$ mm mrad, $\alpha_V = 2\pi$ mm mrad (not normalized) , $\Delta T/T = \pm 6$ eV and the kinetic energy of the particle is not allowed to exceed 0.2 MeV. The deceleration with the RFQ has to be optimized for the transmission to the spectrometer. The overall transmission is planned to be 10^{-5} to gain at least 10^2 in comparison with an energy degrading process using a foil coupled with a bunching-debunching technique.

Design considerations

A RFQ decelerating system has to match the spectrometer and has to be compact and relatively simple. A short RFQ requires a high electrode voltage and therefore a large aperture. The rf power requirement is no problem for the CERN Linac frequency of 202.5 MHz, because a Linac transmitter can be provided. The large aperture would be advantageous for a standard RFQ but the spectrometer accepts only the core of the phase space of the beam.

That means that usual RFQ design procedures aiming at high transmission have to be revised[8] Adiabatic bunching for a decelerating RFQ would require a RFQ of appr. 20m length and would not increase the transmission of the spectrometer.

A small emittance growth is always important but an optimized transmission of the RFQ may even dilute phase space. The orientation of the longitudinal output ellipse will be fine tuned with the help of a debuncher cavity attached directly to the low energy end of the RFQ. There are RFQs which incorporate a debuncher but this is rather uncritical for the high energy end of a structure[10].
In case of the decelerator the orientation of the output ellipse is sensitive to the electrode voltage, the buncher voltage and possible energy variations of the beam. So the additional degrees of freedom allow both a precise orientation of the output ellipse and an energy variation.
The matching of the beam from LEAR and the energy spread of the RFQ beam are better for a small buncher voltage e.g. the drift space beween the buncher and the RFQ should be as long as possible. But simplicity of the system restricts the length of the drift to about 3.5m because a buncher infront of the last bending magnet would introduce chromatic errors. The same argument works against a scheme with a prebunching at a frequency of 202.5MHz in LEAR[11]. The gain in transmission does not pay off because the phase space dilution.
The 4-Rod RFQ resonator design is based on the structure operated successfully at DESY[12,13]. It consists of an array of flat stems on a common base plate supporting the four electrodes which have a periodically changing diameter. Fig. 2 shows a scheme of the 4-Rod RFQ structure. Changes have been made for the improvement of alignment, vacuum, and rf-efficiency.
The resonant 4-Rod insert will be cooled efficiently by water tubes in the base plate. The structure has been operated already with much higher duty cycles e.g. rf-losses up to 20kW/m and electrode voltages up to 150 kV. These values are clearly higher than the design values for the decelerator which are summarized in Table I.
The bunchers will be spiral loaded cavities which are efficient and compact. They have been developed for application in postaccelerators[14] and have been built e.g. for GSI and DESY for use as linac bunchers[15].
The beam dynamics design of the RFQ which determines the variation of modulation, aperture and cell length along the structure is characterized in fig. 3 . Fig. 4 shows results of simulations with PARMTEQ for the deceleration of a $\bar{p}$ beam with LEAR parameters.

Beam transport

The small acceptance of the PS189 spectrometer requires a careful design of the antiproton beam transport in order to optimize the particle transmission through the system.

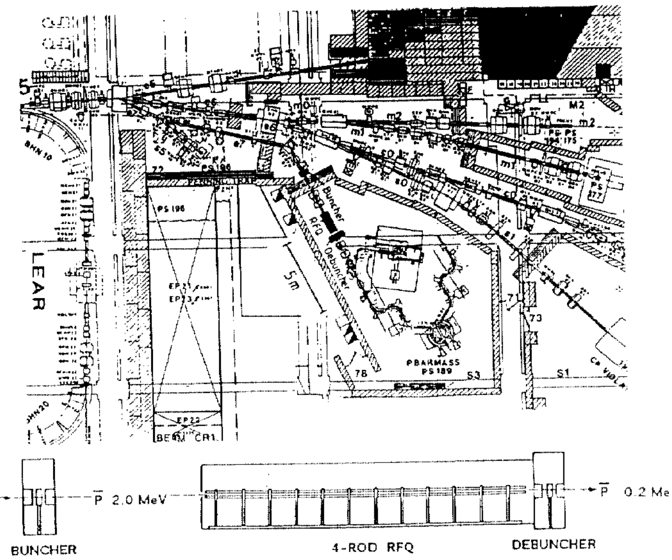

Fig. 1 Layout of the experiment PS 189

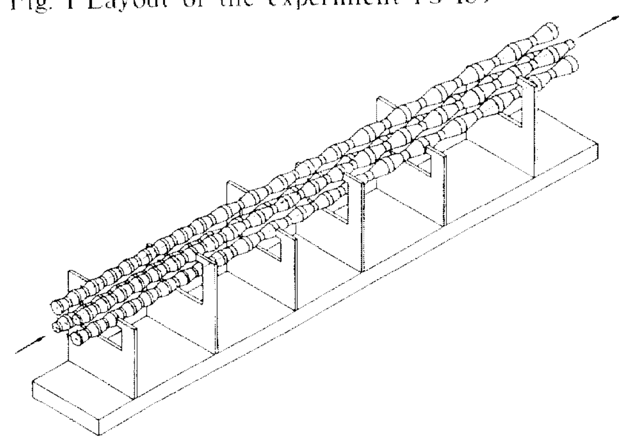

Fig. 2 Scheme of the 4-Rod RFQ

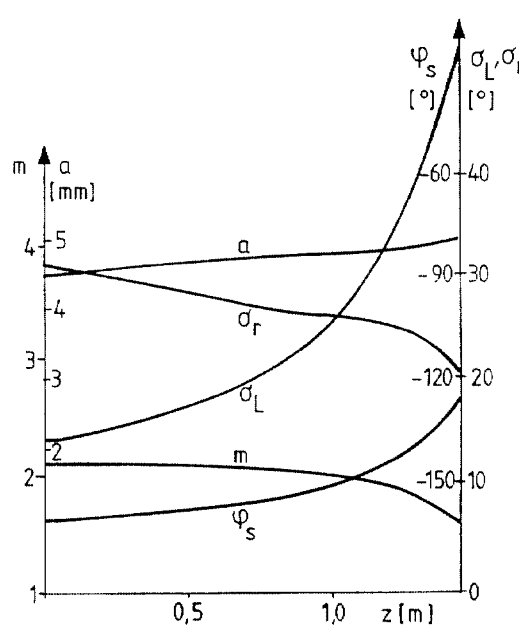

Fig. 3 Electrode design of the decelerating RFQ

The beam transport is divided into the high- and the low energy beam lines. The high energy beam line with a length of 30m transports the $\bar{p}$ beam from LEAR to the entrance of the RFQ. Practical aspects like sharing the first part of the beam line with other experiments restrict changes to the part after the bending magnet. A design for a line able to match different RFQ input conditions is shown in Fig. 5.

The low energy beam line is about four meters long. The beam from the RFQ-Debuncher system has a large divergence which can be matched to the spectrometer with a set of two quadrupoles close to the RFQ and a central triplet. The design of the low energy beam line is more difficult because of the transverse (absolute) emittance increase of about a factor three caused by deceleration. This corresponds to a 10% increase in normalized emittance only, the final energy spread being rougly 4% including the debuncher. The orientation of the longitudinal $\Delta\varphi$–ΔT ellipse can be changed by the debuncher, placed as close as possible to the RFQ.

The present design of the lines is consistent with an estimated transmission of 1×10^{-5} for the overall system. Final optimisation of the transport beam lines and the whole system is in progress.

Status

The preparation of the experiment is now near completion. The RFQ delivery should take place by the end of the year in order to test the equipment during next spring and to run data taking in 1991 and 1992

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Table I Parameters of the decelerating RFQ

Frequency	202.5 MHz,	Electrode voltage	115 kV
Input energy	2.0MeV,	Output energy	0.2MeV
Length	1.45 m,	number of cells	47
Phase	-160 - -126°,	Aperture	4.5-5mm
Modulation	2.1-1.6,	Maximum field	35 MV/m
Impedance R_p	60kΩ,	Rf-power	220 kW
normalized transverse acceptance	5.0 πmmmrad		

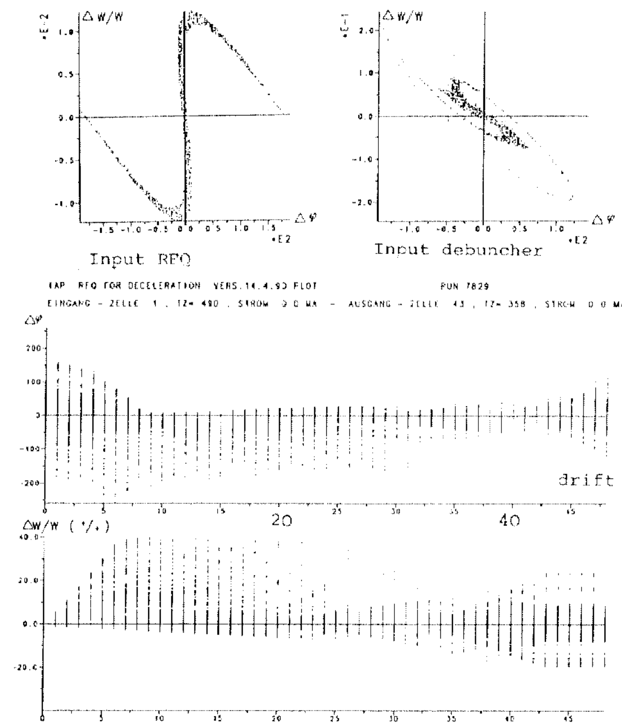

Fig. 4 Parmteq simultation of $\bar{p}$ deceleration

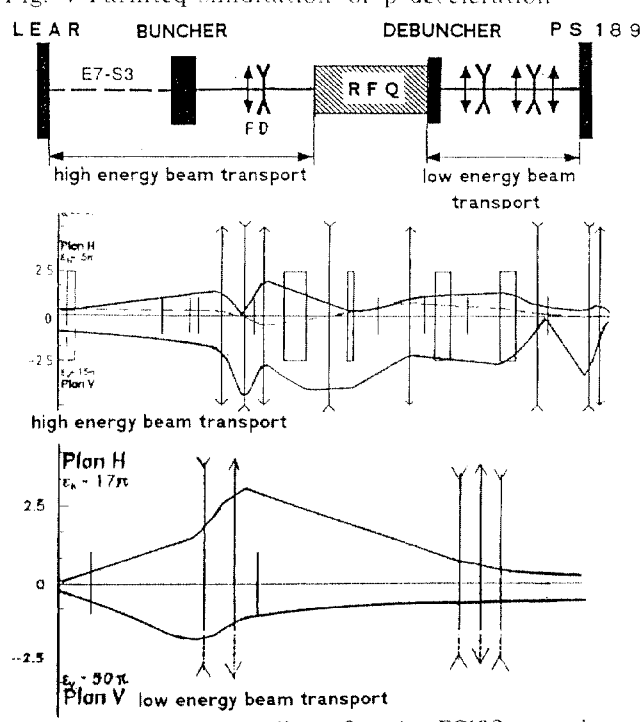

Fig. 5 Beam transport lines for the PS189 experiment