Deceleration of Antiprotons with a RFQ

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Abstract

A 4-Rod-RFQ has been built for the deceleration of antiprotons which will be extracted from LEAR at 2.0 MeV and injected at 0.2 MeV into the rf-mass spectrometer built by CSNSM, Orsay for the high precision mass comparison of protons and antiprotons (PS189). The properties of the RFQ system, which should improve the counting rate by a factor of up to 10^3, the status of the project will be reported.

I. 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. Input and output energies are fixed and the emittance growth can be made very small [1,2,3].

The ion source can be close to ground potential, thus allowing the use of bulky and complex ion sources like for high currents or for high charge states as well as for polarized beams and clusters. A heavy ion prestripper accelerator and e.g. LEAR (the "low energy antiproton ring" at CERN) represent bulky ion sources for which RFQs can provide efficiently post acceleration or deceleration with strong focusing and little emittance growth [4,5].

The first proposals for the deceleration of antiprotons were not realized because of the complexity and the costs involved [6,7]. A new effort by CSNSM Orsay employed a less complex RFQ structure, simpler bunching schemes, and uses only fast extraction from LEAR, thus avoiding changes in LEAR. The optimization was done for their specific experiment "Antiproton-Proton mass comparison with a radiofrequency mass- spectrometer"(PS189 [8,9]). A layout of experiment is shown in Fig.1.

The aim of the experiment is the reduction of the present upper limit on a hyphothetical CPT theorem violation in baryon-antibaryon pairs. The experimental set-up is a specially designed radiofrequency mass spectrometer of L.G.Smith type which has been installed at the LEAR 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 comparison accuracy of 5×10^{-9} [10]. The radial acceptance of the spectrometer is extremly low: $\alpha_H = 1.$, $\alpha_V = 2.\pi$ mm×mrad and the energy spread must be smaller than $\Delta T/T = \pm 6$ eV. 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.

II. THE DECELERATOR SYSTEM

The RFQ decelerating system has to match the spectrometer, it has to be compact and to give a high transmission to the spectrometer.

A small radial emittance growth is always important but maximizing the transmission of the RFQ in the usual way may even dilute the effective phase space. There is a buncher 1.5m

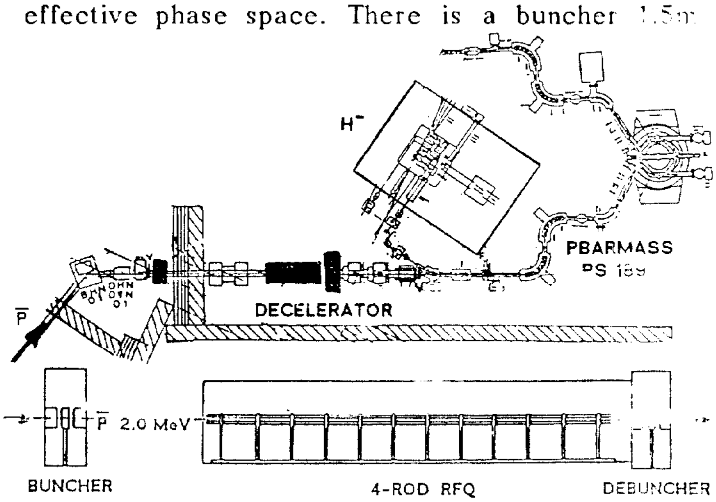

Fig.1 Layout of the experiment PS189

[x]now at SSC, Waxahachie, Tx

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infront of the RFQ to give a time focus at the first RFQ cell with a small energy spread. 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 because the orientation of the output ellipse is sensitive to the electrode voltage, the buncher voltage and possible energy variations of the beam. These additional degrees of freedom allow both a precise orientation of the output ellipse and some energy variation [11].

The 4-Rod RFQ resonator [12] uses an array of flat stems on a common base plate supporting the four electrodes which have a periodically changing diameter. The resonant 4-Rod insert is surrounded by a copper plated vacuum tank and driven by one loop and tuned with one plunger. Rf-stabilization is not neccessary.

A short RFQ has been designed [13] with a high electrode voltage and without an adiabatic bunching scheme, because the spectrometer accepts only the core of the beam. The beam dynamics design of the RFQ, which determines the variation of modulation, aperture and cell length along the RFQ, is characterized in fig. 2, table I gives characteristic parameters.

The bunchers are spiral loaded cavities [14]which are efficient and compact. They have been developed for application in postaccelerators and are based on $\lambda/4$ coaxial resonators in which the inner conductor is wound up to a spiral. It carries a drift tube at the open end which together with the drift tubes of a pill box cavity form two accelerting gaps for $\beta\lambda/2$-mode operation. Fig.3 shows a scheme of the spiral cavity and the the field distribution in the debuncher, table II summarizes the properties.

The beam transport system has been optimized to the small acceptance of the PS189 spectrometer. The high energy beam line with a length of 30m transports the $\bar{p}$ beam from LEAR to the entrance of the RFQ. Changes have only been made to the part after the bending magnet to avoid emittance dilution by the chromaticity. The design which can be adopted to different RFQ input matching conditions is shown in Fig.4.

The low energy beam line is about four meters long. Critical points are the transverse emittance increase of about a factor three caused by the deceleration process and the final energy spread of roughly 4%. The orientation of the longitudinal $\Delta\varphi-\Delta T$ ellipse can be changed by the debuncher, placed as close as possible to the RFQ. Fig. 5 shows results of calculations with PARMTEQ for the deceleration of a $\bar{p}$ beam with LEAR parameters which give a transmission of 1×10^{-5} for the overall system.

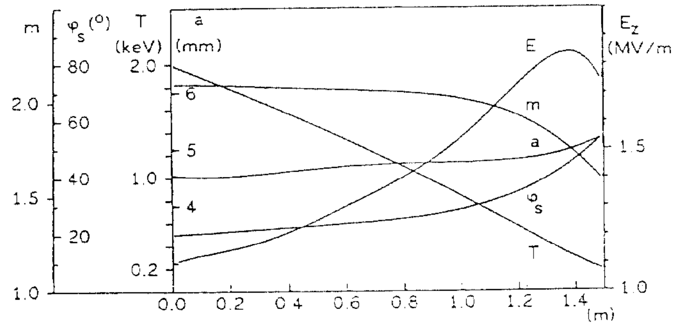

Fig.2 Electrode design of the decelerating RFQ

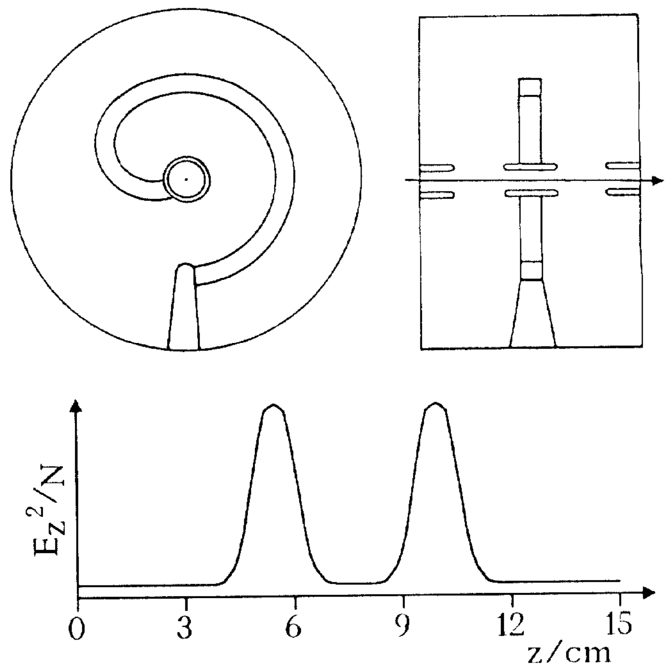

Fig.3 Scheme of spiral cavity and axial field distribution of the spiral debuncher

Table I Parameters of the decelerating RFQ

Frequency	202.5 MHz,	Electrode voltage	111kV
Input energy	2.0MeV,	Output energy	0.2MeV
Length	1.49 m,	Number of cells	46
Phase	-160 - -126°,	Aperture	4.5-5.25 mm
Modulation	2.1-1.6,	Max. field	35MV/m
Impedance R_p	57 kΩ,	Rf-power	220 kW
normalized transverse acceptance			5.0 πmmmrad

TableII Parameter of the spiral buncher/debuncher

Frequency	202.5 MHz,	Input energy	2.0/0.2MeV
Length	0.2/0.15 m,	Impedance R_p	6/4.9 MΩ
Q	4100/3900,	Aperture	25/20 mm
Rf-power	1/0.25 kW,	cavity voltage	80/35 kV

III. STATUS

The experimental set up is now near completion. The RFQ and the bunchers have been built and tuned. The RFQ-impedance has been measured to 57 kΩ and the field flatness is better than 3% which are close to theoretical values. The decelerator has been shipped to CERN and is currently being installed in the PS189 beam line. Rf-tests will be done in the first weeks of June after which a first antiproton data taking run is planned.

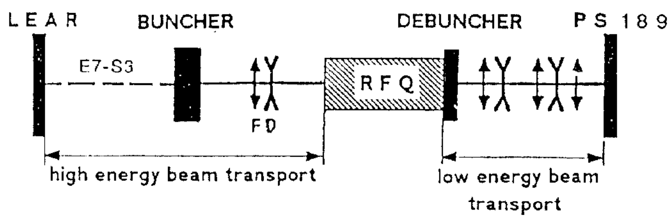

Fig. 4 Beam transport lines for PS 189

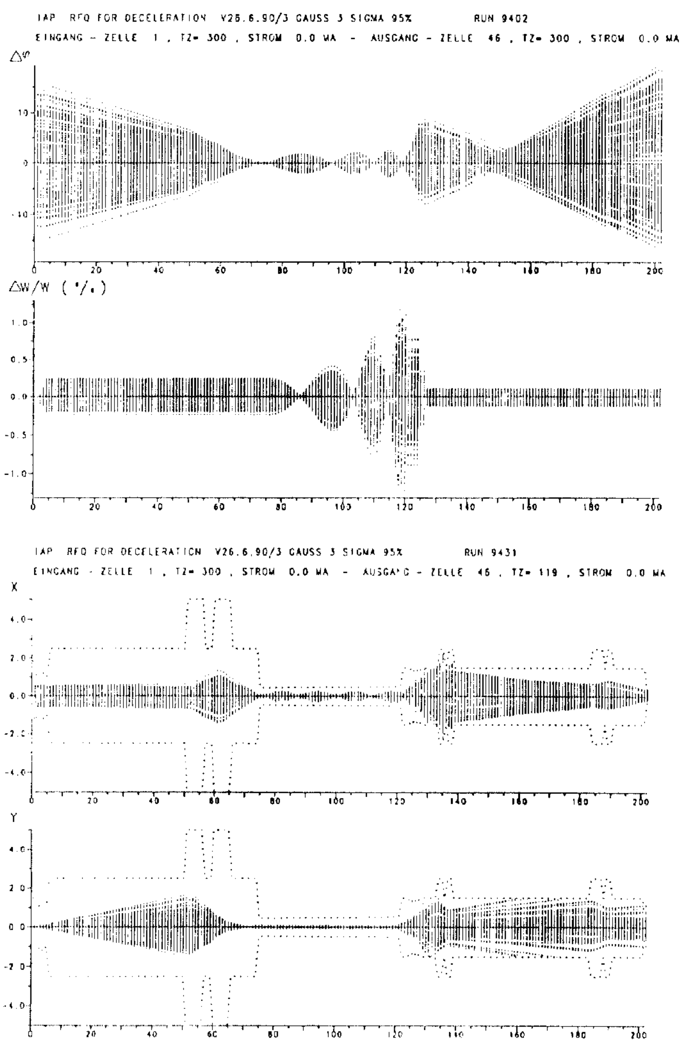

Fig. 5 PARMTEQ simulations of $\overline{p}$ deceleration

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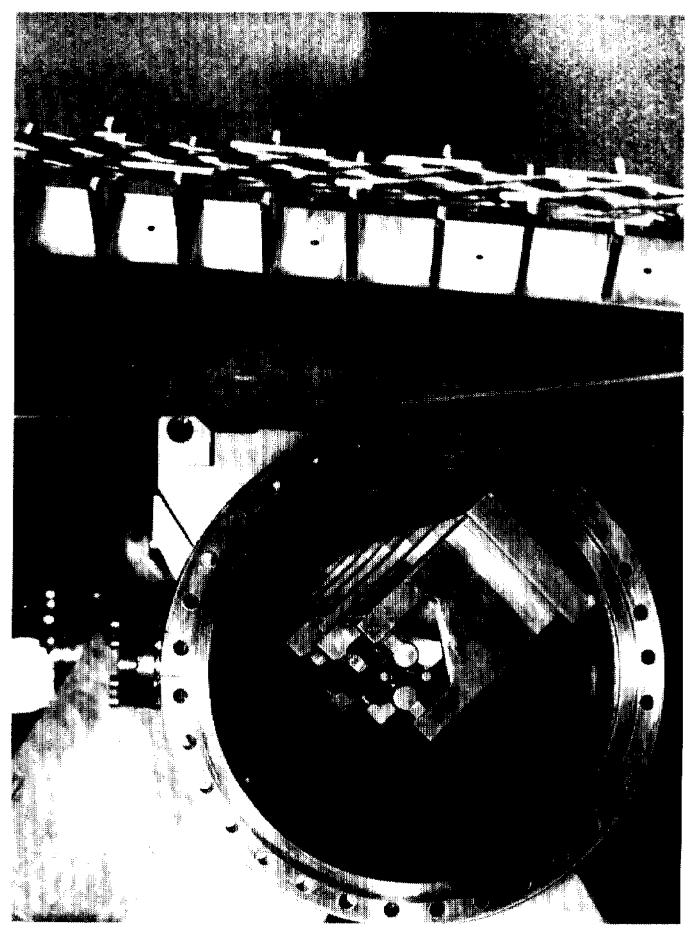

Fig. 6 Views of the decelerator RFQ