DECELERATION OF ANTIPROTONS WITH A RFQ

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Abstract

A 4-Rod-RFQ is being 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 measurement of protons and antiprotons (PS189). The design of the RFQ system, which should improve the counting rate by a factor of up to 10^3 and the status of the project will be reported.

Introduction

The CSNSM Orsay experiment: "Antiproton - Proton mass comparison with a radio - frequency mass-spectrometer "(PS189)[1,2] aims at 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}.

Several proposals for rf - deceleration to provide 0.2 MeV Antiprotons for the spectrometer e.g. with help of a small synchrotron, a cyclotron or a RFQ were not realized because of complexity and the costs involved[3,4,5], but the RFQ system proposed was the least complex one.

Deceleration is an new application for RFQs, which has been proposed for highly stripped heavy ions and for antiprotons, which have been stored and cooled in a synchrotron ring[3,6]. In this context LEAR is a bulky ion source.

RFQs are unique for low energy deceleration because of the strong electric focusing with rf quadrupole fields[7,8]. The low final energy in case of a decelerator at relatively high operating frequency is very important, because the structure is compact and the $\bar{p}$ are slowed down efficiently and with little emittance growth.

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Design considerations

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 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.

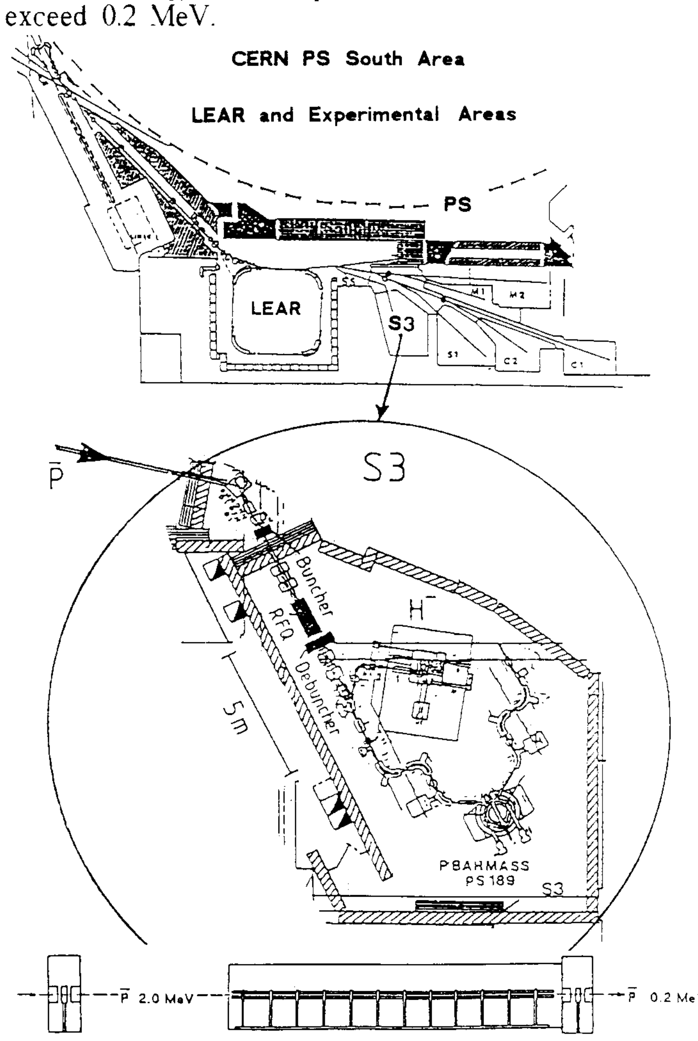

Fig. 1 Layout of the experiment PS 189

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.
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 high rf power, which is no problem for the CERN Linac frequency of 202.5 MHz, because a Linac transmitter will be used.

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[9]. Adiabatic bunching for a decelerating RFQ would require a RFQ of appr. 20m length and would not increase the transmission of the system.

The output emittance is sensitive to the electrode voltage, the buncher voltage and possible energy variations of the beam. It will be fine tuned with the help of a debuncher cavity attached directly to the low energy end of the RFQ as shown in fig. 2. This additional degree of freedom allows both a precise orientation of the output ellipse and some energy variation.

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 202.5 MHz in LEAR[10]. The gain in transmission does not pay off because the phase space dilution.

RFQ Design

The 4-Rod RFQ resonator design is based on the structure operated successfully at DESY[11,12]. 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 beam dynamics design of the RFQ which determines the variation of modulation, aperture and cell length along the structure is characterized in fig. 3.

The bunchers will be spiral loaded cavities which are efficient and compact. They have been developed for application in post-accelerators[13] and have been built e.g. for GSI and DESY for use as linac bunchers[14].

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. 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

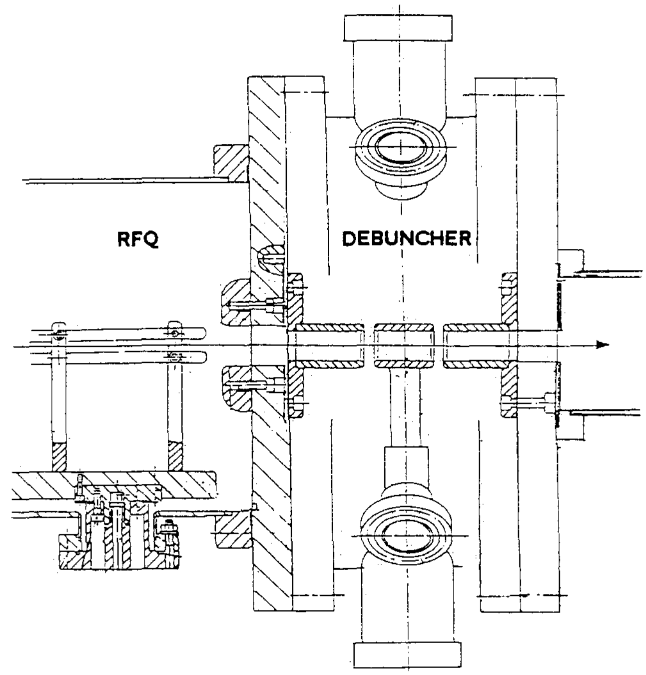

Fig. 2 Scheme of the low energy end of the RFQ

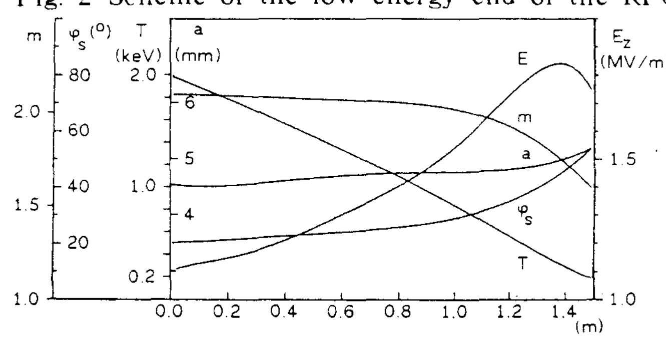

Fig. 3 Electrode design of the decelerating RFQ

Table I Parameters of the decelerating RFQ

Frequency	202.5 MHz,	Electrode voltage	111 kV
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,	Maximum field	35 MV/m
Impedance R_p	60kΩ,	Rf-power	210 kW
normalized transverse acceptance			5.0 πmmmrad

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. 4.

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. Fig. 5 shows results of simulations with PARMTEQ for the deceleration of a $\bar{p}$ beam with LEAR parameters.

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[15].

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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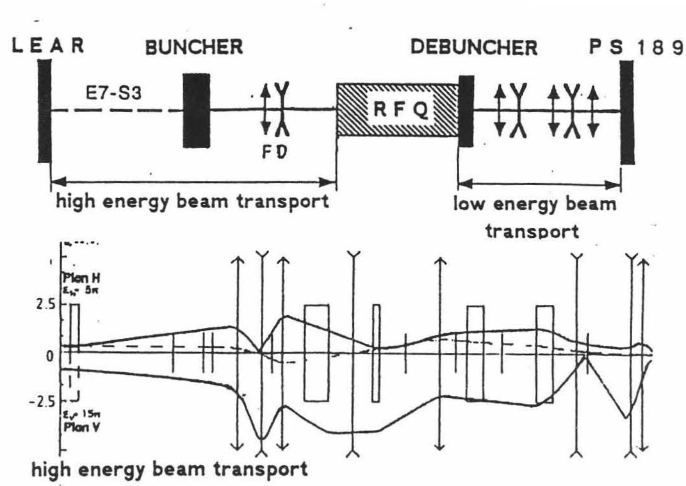

Fig. 4 HEBT for the PS189 experiment

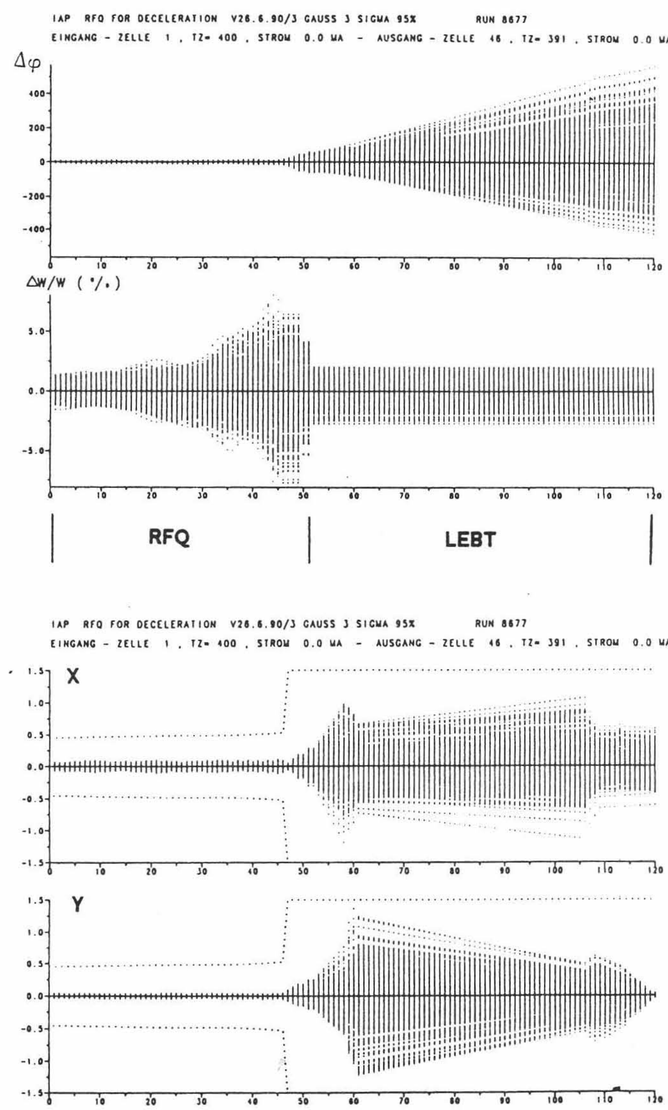

Fig. 5 Example of Parmteq simultation for RFQ and LEBT