DEVELOPMENT OF A VARIABLE ENERGY RFQ FOR CLUSTER ACCELERATION[×]

A. Schempp, H. Deitinghoff, J. Madlung, U. Bessler, J. Friedrich, J. Dehen, R. Veit
Institut für Angewandte Physik, Univ. Frankfurt, D-6000 Frankfurt 11, FRG
H. O. Moser, Institut für Mikrostrukturtechnik,
Kernforschungszentrum Karlsruhe, Postfach 3640, D 7500 Karlsruhe, FRG
G. Hadinger, M.J. Gaillard, R. Genre, J. Martin,
Institut de Physique Nucleaire de Lyon, IN2P3-CRNS/Universite Claude Bernard,
43, bd du 11 Novembre 1918, F-69622 Villeurbanne Cedex, France

Abstract

A RFQ is being built as a postaccelerator for the cluster accelerator facility at the IPN Lyon. The 4-Rod RFQ resonator is designed for variable energy by means of a variable frequency of the resonator between 80 -110 MHz. The properties of the RFQ for the typical cluster mass ranges of up to 50u is discussed and the status of the project is reported.

Introduction

The Lyon cluster ion accelerator is used for a variety of experimental activities [1,2] which mainly deal with the interaction of clusters with matter and the study of the structure of clusters themselves. There are interesting collective effects and all components of material stopping power which are as important as sputtering, desorption, and the emission of photons and secondary particles.

The cluster velocity is a critical parameter which can help to solve the problems with resolution of measurements of these overlapping effects. Higher cluster energies are important for comparing clusters and heavy ions in respect to ion yields and stopping power. They allow also to study more complex reactions with clusters of molecules and solve critical target problems.

The cluster energies of the existing Cockroft-Walton accelerator are limited to approx. 700 keV. In order to widen the available range of beam parameters, and to improve the performance, an upgrading program was started, which includes, a RFQ postaccelerator and a new beam line to transport the beam from the exit of the acceleration gap to the target or the entrance of the postaccelerator. Rf-postacceleration allows for a high energy gain at low peak potentials but the limited focusing strength at low energies leads to bulky rf structures at low frequencies.

An advantage of the RFQ structure is the use of strong radiofrequency electrical quadrupole focusing, which solves the focusing problems and allows relatively high operating frequencies and compact cavities[3,4].

A postaccelerator for clusters has to be compared with a low current heavy ion RFQ. For ions with a low specific charge of the particles and no internal beam space charge forces. So in the particle dynamics design the strong rf defocusing at low velocities must be balanced by focusing forces. This leads to a typical RFQ design, a small accelerating field E_z at the low energies, which is smoothly increasing along the structure together with high focusing gradients e.g. high electrode voltages at minimum apertures[4,5].

The velocity of the clusters is given by the cluster energy in the preaccelerator and the masses of the clusters. The frequency will be chosen as high as possible to have a compact accelerator because of the most important boundary conditions of structure size and costs of the postaccelerator.

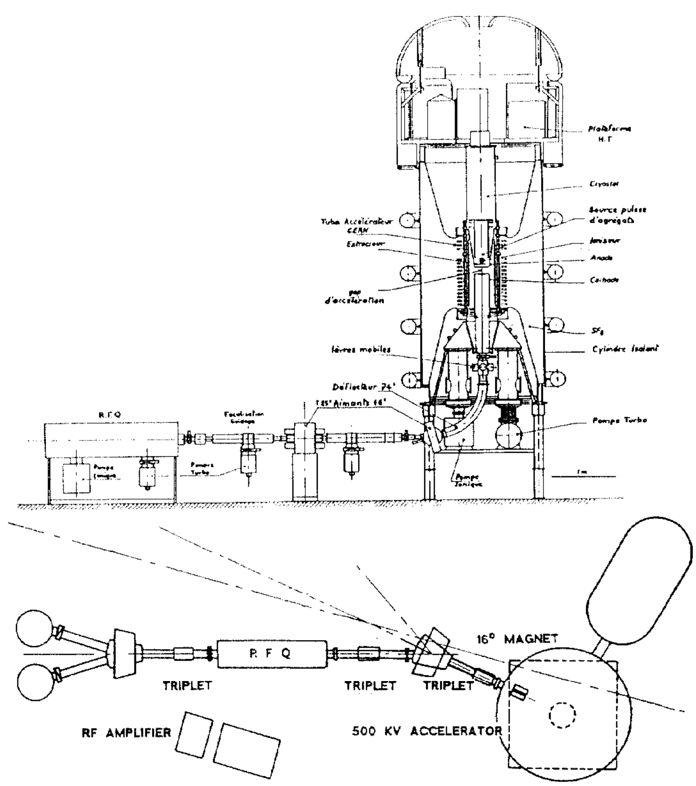

Fig. 1 Layout of the Lyon cluster accelerator

[×] Work supported by CEC under contract no. SC1 0333-C(EDB) and BMFT under contract nr. 60F186I

For the Lyon postaccelerator an upper frequency of 110 MHz could be used because of the relatively high preaccelerator voltage of 500 kV and the restriction to cluster masses of 30u resp. 50u.
The upgrading of the Cluster Facility is beeing performed in a collaboration between IPN Lyon, KfK Karlsruhe and IAP Frankfurt[6,7]. The RFQ for postacceleration of clusters is designed for 500 keV (10 keV/u) injection energy and up to 3 MeV (100 keV/u, for m=30u, 5MeV for m=50u) final energy.
The postaccelerator will be placed in the horizontal beam line of the existing 0.5 MeV C.W. accelerator. A layout of the cluster accelerator is shown in fig.1 . The beam is accelerated vertically, then bent into the horizontal direction by a cylindrical electrostatic deflector and a bending magnet which provides mass selection. The beam transport and matching into the RFQ is done by electrostatic quadrupole triplets, which are very effectiv at the low cluster velocities. Fig. 2 shows a beam envelope as an example for the low energy beam transport line and the matching to the transverse beam input emittance of the RFQ [8,9,10]

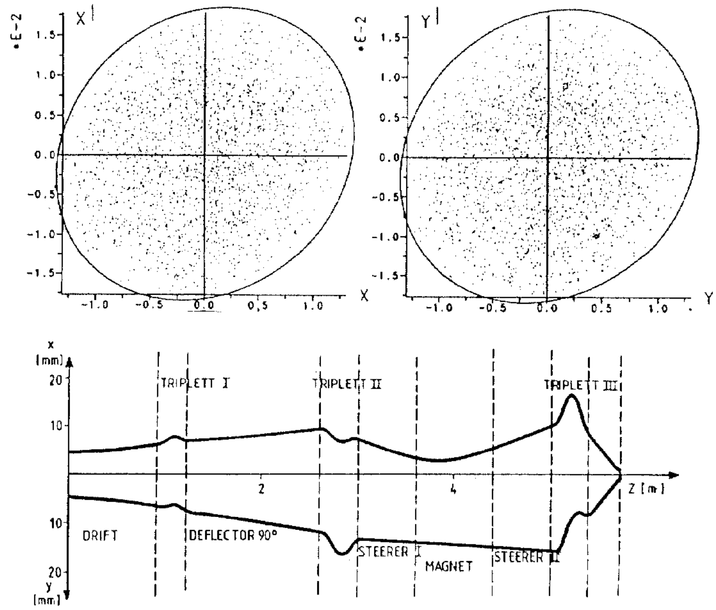

Fig.2 Beam enveloppe of the low energy beam transport line together with matched RFQ input distributions.

The RFQ structure

RFQs are accelerator structures, which use electrical rf-quadrupole fields for focusing and acceleration of low energy ion beams. They have been developed especially for the replacement of Cockroft-Walton-preaccelerators for synchrotron injectors (short pulses, high currents). The features are acceleration directly from ion source potential, a compact structure with spatial homogenous[3] strong focusing and excellent beam quality.
A new feature, the possibility to vary the final energy has been included in the Lyon project. Up to now, RFQs have been fixed energy(velocity) accelerators and energy variation could only be done by additional rf cavities[11].
For energy variation in case of the RFQ the 4-Rod RFQ structure[12] which has been developed in Frankfurt, has been modified so that it can be tuned within an appreciable range to scan e.g. the FM range from about 80 MHz to 110 MHz corresponding to an energy change by a factor of approximately two[13,14].
Fig.3 shows a scheme of the variable energy (VE-) 4-Rod RFQ structure. Fig. 4 shows the frequency and the impedance R as function of the position of the tuner. The focusing strength is decreasing with operating frequency[15] so the impedance at highest frequency and the maximum field strength which can be applied determine the heaviest particle resp. the minimum charge to mass ratio q/A necessary for acceleration. Taking this "design particle" as reference better q/A ratios or acceleration to lower energies requires a lower voltage: $U \sim A/q \times f^2$.

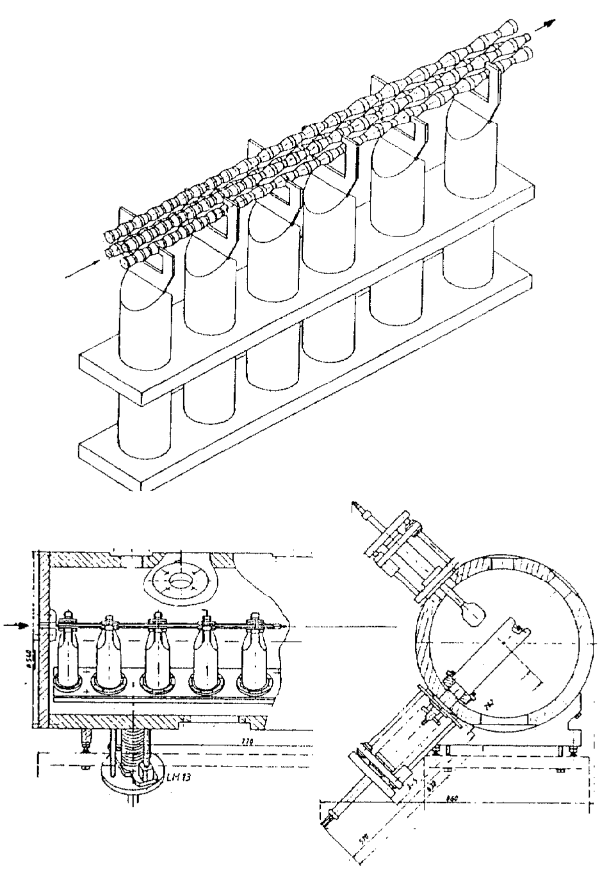

Fig.3 Scheme of the variable frequency 4-Rod RFQ

The particle dynamics design is characterized by Fig. 5. Compared to other RFQ designs[16] the adiabatic buncher has been skipped. One result is a very effective acceleration, e.g. an average accelerating field strength of up to 2.5 MV/m, which is even higher than in classical ion accelerators, which is on cost of a relatively small transmission of appr. 25%. Fig.6 shows the particle energy T as function of the frequency f for different cluster masses.

Status

The work on the Cluster injector and the beam lines is in progress. The RFQ is behind schedule, due to delays in delivery of the parts. After completion of assembly and tuning the transport to Lyon is scheduled for July and first beam experiments are planned for September.

References

1. M. Chevalier et al., ISSPIC 4, Aix en Provence 1988
2. J.P. Thomas et al., J. Physique. 50-C2 (1989) 195
3. I.M. Kapchinskiy and V. Teplyakov, Prib. Tekh.Eksp. 119, No.2(1970) 17,19
4. K.R. Crandall, R.H. Stokes, T.P. Wangler, Linac79, BNL-51143 (1980) 20
5. A. Schempp. EPAC 88, World Sci. (1989) 464
6. H. O. Moser, A. Schempp, NIM B24/25 (1987) 759
7. A. Schempp, H.O. Moser, J. Physique50-C2 (1989)205
8. G. Hadinger, priv. comm.
9. J. Dehen, Univ. Frankfurt, IAP Int.Rep.90-6, 1989
10. H. Deitinghoff, Univ.Frankfurt, IAP Int.Rep. 90-16
11. T. Weis et al., NIM B24/25 (1987) 787
12. A. Schempp et.al., NIM B10/11(1985)831
13. R. Hamm, Linac86, SLAC-303(1986)33
14. A. Schempp, NIM B40/41 (1989) 937
15. A. Schempp, NIM B50 (1990) 460
16. A. Schempp, Linac 88, Cebaf Rep.89-001(1989) 460

Table I VE-RFQ parameters

Max. initial/final kinetic energy	10/100 keV/u
Min. initial/final kinetic energy	5/50keV/u
Maximum kinetic energy for m=30u	3.0 MeV
Length of structure	2.0 m
aperture	3.1-2.5 mm
Number of cells	162
Initial length of cell $\beta\lambda/2$	6.3 mm
modulation of electrodes	1.1-1.98
Diameter of vacuum chamber (m)	0.5 m
Frequency	80-110 MHz
Peak voltage (kV)	80 kV
Maximum field strength (MV/m)	35 MV/m
Transverse phase advance per cell	8.2-7.2°
Synchronous phase	50-15.5°

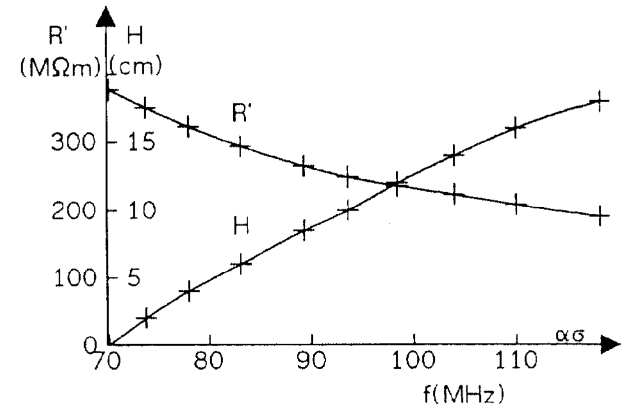

Fig.4 Frequency f and Impedance R as function of the tuner position

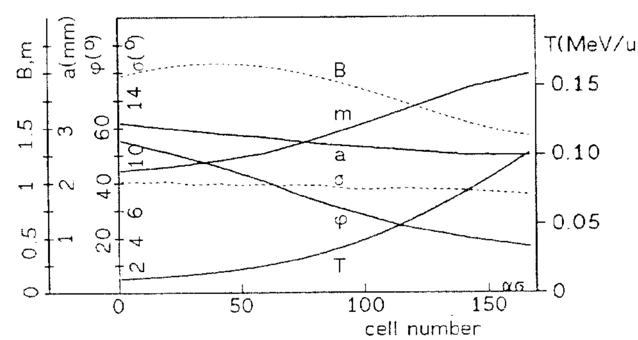

Fig.5 Electrode parameters along the RFQ structure

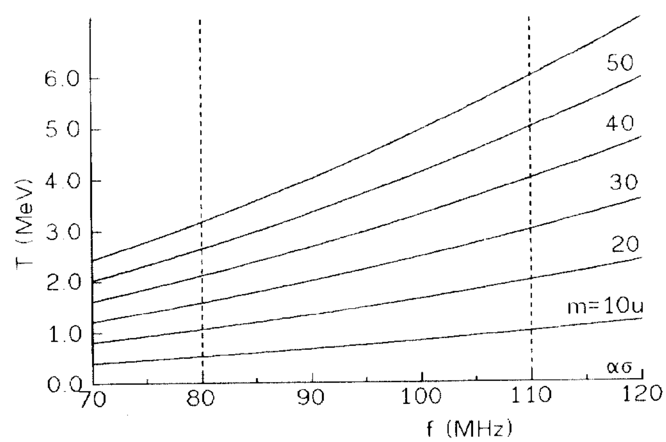

Fig.6 Energy variation of the cluster postaccelerator for different cluster masses m.