STATUS REPORT ON AXIAL INJECTION IN THE GRENOBLE CYCLOTRON

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ABSTRACT

The axial injection system has been used since 1969 for the experiments with a polarized proton or deuteron beam. We are now adding a system for the pulsation of the beam of a duoplasmatron. We plan to modify the system for the injection of multicharged heavy ions.

I - THE CHANNEL

Before the beam enters the channel, (see figure 1) it goes through a system of electric quadrupole and einzel lenses which match the emittances of the source and the channel. A 90 degrees bending magnet acts as a switch between the duoplasmatron and the polarized source.

The channel is installed in the upper axial hole of the magnet of the cyclotron, 75 mm (3 inches) in diameter. The guidance of the beam along the axis is achieved by means of a series of 22 magnetic quadrupoles. This optical system has, among other properties, periscopic stability, and its admittance is 1000 mm mrad [1, 2].

The inner tube for the passage of the beam has a diameter of 16 mm and a length of 1340 mm. After more than a year of operation since the last overhaul, the transparency of the channel, measured with a duoplasmatron beam, has decreased from 90 % to 50 %. The tube has been removed, cleaned and degassed at a temperature of 300 degrees C. The transparency is now back to the normal figure of 90 %.

Before putting the tube back in place, we made the following experiment : a diffusion pump was installed at one end of the tube and a vacuum gauge at the other. The gauge indicated a pressure of 2.10^{-6} torr. As the pressure decreases as the square of the length of the tube, we believe that this type of channel could be modified in a convenient way for the injection of heavy ions. A tube of greater diameter could be put in a vacuum of a few parts in 10^{-7} torr at both ends. A device should be installed to allow the periodic heating of the tube without mechanical intervention. The admittance of the magnetic system could be improved, as we dispose of space now occupied by an aluminum plug concentric to the axis.

II - THE ELECTROSTATIC INFLECTOR

The inflector in the center of the cyclotron has undergone no modification for the last three years [3, 4, 5].

The electrical and magnetic radii of curvature are respectively 32 and 16 mm. A beam power of one watt does not harm the inflector. R.F. shielding is an absolute necessity for damage avoidance.

The influence on the extracted beam of a variation of the energy of the injected beam is reasonable. The intensity of the beam has a variation of $\pm$ 5 % for a variation in energy of $\pm$ 1 %.

The ratio of the accelerated beam to the injected beam is as high as 30 % when the bunching is in use with of a deuteron beam.

III - THE BUNCHER [6]

If the buncher is put into service, the intensity of the accelerated polarized beam is multiplied by a factor of 3 ; for the duoplasmatron's beam, by a factor varying from 2 to 5 depending on beam intensity. The buncher consists mainly of an accelerating tube placed near a waist of the beam. Its diameter, 18 mm, is a compromise between the admittance of the system and the dispersion in energy produced by aperture effects. The buncher is located 1815 mm upstream of the inflector, this relatively long distance allows the use of low voltage : only 70 to 100 RMS volts are needed to operate the buncher.

IV - THE BEAM PULSER

We are presently experimenting with a beam pulser located between the duoplasmatron and the channel. The beam of the duoplasmatron is first focussed, then goes through 2 successive diaphragms, 5 and 6 mm in diameter, 210 mm apart, which delimit accurately the emittance of the outgoing beam. The beam is focussed again and then is swept by means of two successive pairs of deflecting plates, parallel to the same plane.

For very long pulses, a square wave voltage is applied on one pair of plates.

For pulses shorter than 0.5 microsec, a sine wave voltage is used, its frequency being a submultiple of the frequency of the cyclotron. And for very short pulses, both pairs of plates are used, the second one being fed with a voltage at the frequency of the cyclotron.

A diaphragm 7.5 mm in diameter is located 220 mm downstream of the deflecting plates. The beam can go through the diaphragm only when the deflecting voltages are at their maximum.

The conditions for the best efficiency of the system are described as follows.

If we consider, immediately downstream of the deflecting plates, two successive phase - space ellipses, at such a time interval that these two ellipses are tangential, and if we intend to put a diaphragm at some distance downstream, we must logically select for the location of the diaphragm the point where the tangent common to the two ellipses is parallel to the x' axis in the phase - space diagram.

Let the emittance of the beam, immediately after the pulser, satisfy the equation

$$\beta x^2 + 2 \alpha x x' + \gamma x'^2 = \epsilon$$

and let the transfer matrix of the system between the pulser and the diaphragm be :

$$\begin{vmatrix} a & b \\ c & d \end{vmatrix}$$

Then $$\frac{a}{b} = \frac{A \alpha + \gamma}{A \beta + \alpha}$$

"A" being the slope of the line along which the phase - space ellipses are displaced by the sweeping voltages, at the point immediately downstream of the deflecting plates.

Another condition for clean operation is that the parameter "A" stays constant as long as the beam is in the vicinity of the hole of the diaphragm. This condition implies, in the case of a sine wave voltage, that the system should be tuned in such a manner that the beam goes through the diaphragm only when the voltages are at their maximum (or minimum).

Ultimately, it can be proved [7] that the best efficiency of the sweeper itself is obtained if the coefficients of the outgoing phase - space ellipse α, β, γ, and the parameter "A" are choosen in order to minimise the following function "F".

$$F = \frac{A^2 \beta^2}{(\alpha + A \beta)^2 + 1}$$

In this case, the beam should be convergent if A is positive.

On a test bench, using a proton beam at 10 keV and the two pairs of deflecting plates, we have measured, after the diaphragm, pulses of 10 nanosec of duration every 0.2 microsec, without bunching. The deflecting voltages had a value of 200 RMS volts.

The experiment with the cyclotron is underway.

We have observed an amplitude modulation of the beam bursts extracted from the cyclotron, using a diffusion process on a target.

The intermediate bursts are fully suppressed only if the sweeping frequency is more than 5 times slower than the frequency of the cyclotron. This phenomenon is mainly caused by the multiturn extraction.

V - COMPATIBILITY WITH AN INTERNAL SOURCE

For light ions, a conventional internal source is normally used. It gives a beam of poorer emittance, but with a greater intensity than the duoplasmatron especially with helium. Also, the internal source is easier to handle.

The axial injection system is elaborate, but once it has been put into service it can be used for many days on the same settings without any particular supervision.

Before switching from internal to external source, and in order to save time, the different power supplies of the axial injector can be put into service. The different settings are repetitive and can be automatically printed for verification.

The withdrawal of the internal source and the introduction of the axial inflector takes a few minutes.

The different high tension power supplies necessary for the axial injector can be adjusted altogether by means of a common electronic divider, when it becomes necessary to make small adjustments of the energy or of the bunching. The voltage stability must be of the order of 3.10^{-4}.

VI - PERFORMANCES

The internal polarized beam averages 0.3 microamp. The corresponding extracted beam can go up to 0.125 microamp and the normal polarization is 80 % .

With the duoplasmatron the internal beam is between 10 and 20 microamp. The extracted beam averages 5 microamp.

REFERENCES

1. G. Bagieu, Thesis I.S.N. Grenoble.
2. R. Gouiran, Rapport CERN MU/EP 67-4.
   Ann. Phys. 1968 t.3 pp.67-87.
3. J. L. Belmont et al., IEEE Trans. N.S. 13-4 pp191.
4. J. L. Pabot, Thesis, Rapport CEA R 3729
5. J. L. Belmont - J. L. Pabot, Rapport interne 1966 n° 3 et N° 4.
6. J. L. Belmont et al., Rapport interne 1970 N° 2.
7. J. L. Belmont, Rapport interne 1972 N° 2.

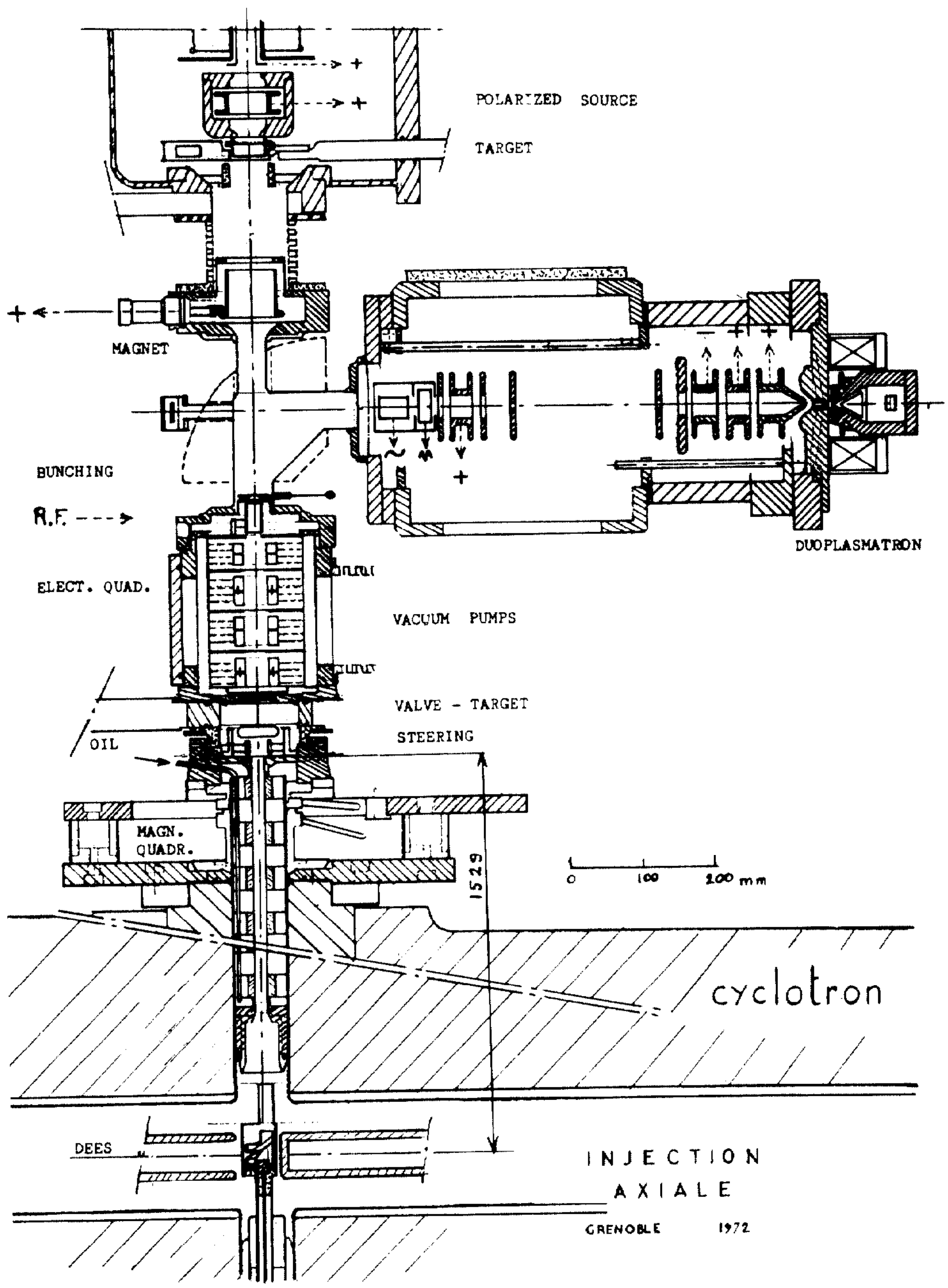
POLARIZED SOURCE
TARGET
MAGNET
BUNCHING
R.F.
ELECT. QUAD.
VACUUM PUMPS
DUOPLASMATRON
VALVE - TARGET
STEERING
OIL
MAGN.
QUADR.
1529
0
100
200 mm
cyclotron
DEES
INJECTION
AXIALE
GRENOBLE 1972

Figure 1

DISCUSSION

DUTTO: Could you tell us something about the matching between injected beam and the cyclotron?

FERMÉ: The matching of the axial injection and the cyclotron is actually good. Measurements of the efficiency show that there are no losses of particles injected within the phase acceptance angle of the machine. Consequently, the radial and axial acceptances of the cyclotron are believed to be at least 1000 mm-mrad at 10 keV.