A MINIMUM SPIRALLING SOLUTION UPGRADING THE CAPABILITIES IN LIGHT IONS ACCELERATION OF A SUPERCONDUCTING ISOCHRONOUS CYCLOTRON

A. Laisné
Institut de Physique Nucléaire, B.P. n°1 91406 Orsay Cedex (France)

Summary

The proposed solution consists in setting the working magnetic field range just above the lowest possible level which keeps still saturated the iron of the hills. This level is, to our opinion, equal to 1.7 Tesla. Moreover it has been found useful and possible to dig a little valley in the middle of each of the 3 hills. The valleys have an opening of 30% of the hill azimuthal angle.

1. Introduction

The present solution has been proposed in 1982 for the superconducting cyclotron which is at the basis of the "Project of a new accelerator facility" for the Institut de Physique Nucléaire d'ORSAY[1].

Because the scientifical program developped for this new facility strongly emphasized the use of light particles in the 200 MeV region, acceleration of these had to be taken into account in the beginning of the studies.

We limited our investigations to compact isochronous superconducting machines with three fold symmetry. The inherent difficulties of the light particle acceleration came upon quickly.

These are of two kinds :

a) Difficulties connected with the high working magnetic induction level. If the later lies beyond 2.2 Tesla , we can mention :
   - the frequency of the RF system which should reach 75. MHz because h = 2 is at least needed for insuring a good turn separation,
   - problems with centering the h = 2 accelerated orbits in the central region, from an axial injection using possible vertical electrical field component in excess of 25 kV/cm in the inflector,
   - problems with high value of the spiralling if constant Archimede Spiral is used as in K800 MSU machine, giving very long accelerating electrodes in the transverse direction with respect to the waves.

b) Difficulties connected with vertical and horizontal stabilities.
   - In a three-fold symmetry machine, the natural horizontal stop-band is $\nu r = 1.5$. Due to the increase of νr with γ willing to reach 200 MeV protons, for which $\gamma = 1.213$, means that ν_r will ly in the 1.25 - 1.5 range.

II - Proposed Solution

In order to minimize the difficulties of the first kind, we proposed to lower the working magnetic induction nearby the minimum which keeps the soft iron of the hills saturated. This minimum has been theoretically calculated and found to be equal to 1.7 T. This theoretical approach is reported in another paper presented at this conference[2].

So we suggest to operate the magnetic field just above 1.75 Tesla.

The R.F system, thus limited in frequency to 62 MHz, is being thought feasible.

The vertical component of the electrical field in the mirror for axial injection is limited to 25 kV/cm, value which has been proved to be realistic[3].

We also proposed to reduce the spiralling of the machine to a minimum, by departing from a constant Archimede Spiral, and by assigning a constant minimum value of $\nu_z = 0.1$ to the He_3^{++} particle during the whole acceleration.

In order to minimize the difficulties of the second kind that is to say, those related to the location of all the working points in the stability diagram $\nu_z = f(\nu_r)$, I suggested to dig out of the hills and in the middle of them a little valley having 30% of their azimuthal opening as it is shown on fig.1.

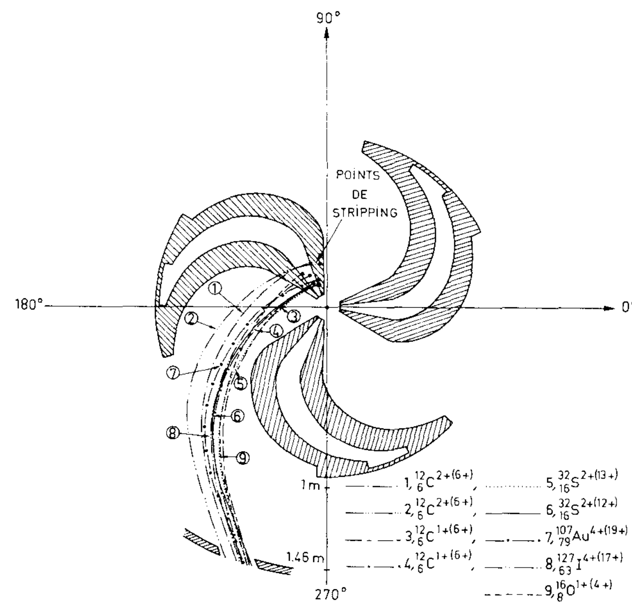

Fig.1 - Plan view showing the hills with the little valleys and the radially injected beams trajectories.

At the origin of this proposal there has been a study on magnetic field maps created by hills and valleys having elliptical profiles. In these specific maps, all the harmonic amplitudes are either increasing or constant with the radius. Because it has been thought that there exist a connexion between the scaloping of the closed orbit and the shifting sensitivity of "ν_r" in the neighbourhood of the stop band, I introduced the little valley which reduces the scaloping and permits to solve the stability problem on these maps. After what we went to more realistic hills profiles (constant gap equal to 7 cm) and found that it is useful for technology reasons to maintain the little valley.

The corresponding stability diagram for the extreme particles is shown fig.2.

As it is shown on fig. 1, one advantage of introducing such a little valley could be to simplify the introduction of the stripping foils for radial injection mode.

A second advantage is to offer some room for locating non-destructive R.F pick-up electrodes.

A third advantage is to reduce the pole tips mean

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Iron contribution to the magnetic field from $B_{iron}(r)=$ 1.3 Tesla for normal hills to 1.1 Tesla and thus oblige the main coils to a greater contribution which insures a better saturation.

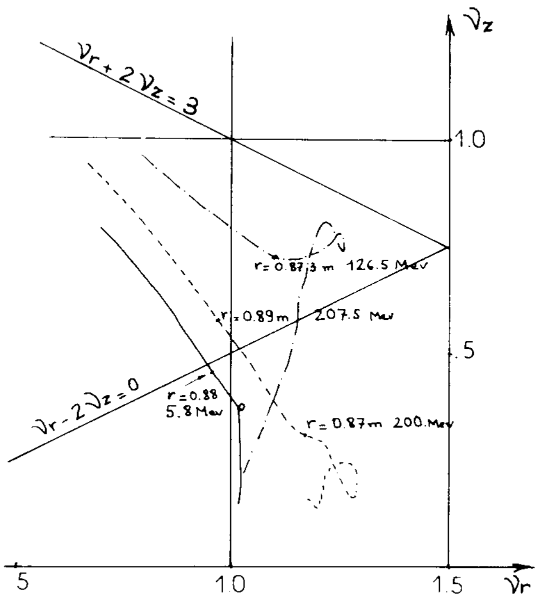

Fig.2 - Stability diagram for extreme particles
protons { ----- at maximum energy 207. MeV
{ —.—.—. at minimum energy 127. MeV
$238U^{23+}$ ——— at 5.6 MeV/n

A net drawback of this design is to reduce the effectivness of the trim coils which are planned to be wounded on the two remaining parts of the hills (fig.3). Thus the consumed maximum power increases from 20 KW for "fully covering the hills trim coils" to 51 KW. (See fig. 4)

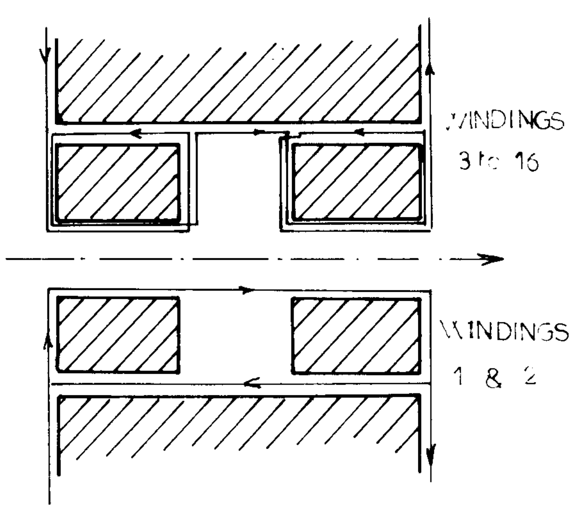

Fig. 3 - Sectional view of the windings for the n°3 to 16 trim coils. The windings of the trim coils n°1 and 2 overlap the little valley.

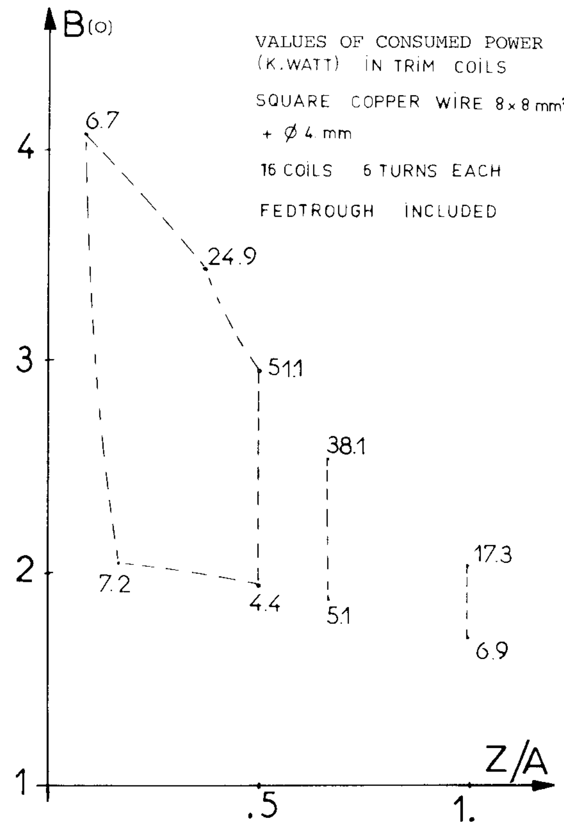

Fig. 4 - The numerical values noticed at the corners of the $B(o)_{Tesla} = f(Zi/A)$ diagram, are those of the consumed power in trim coils.

Acknowledgements

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References

1. Le projet de cyclotron à bobines supraconductrices d'Orsay et l'ensemble accélérateur associé, rapport final sur les études théoriques et techniques de faisabilité, report IPNO-GEPL June 1983
2. A. Laisné, D. Potaux, Possible pole geometry determination method for an isochronous superconducting cyclotron, IPN-Orsay, 91406 Orsay Cedex (France) at this conference
3. J.P. Schapira and P. Mandrillon, Axial injection in the Orsay project of a superconducting cyclotron and in the medical cyclotron MEDICYC, proceedings at this conference.