PS/GP/nc

PS/LIN/Note 76-1
8 January 1976

THE POSSIBLE APPLICATION OF THE CERN MACHINES TO IONS

G. Plass

It is the purpose of this brief note to give a very crude outline of the principal possibilities and main limitations of using our machines with heavy ions. The question of intensity has not been discussed in detail. It can be discussed more fruitfully when some results of the present study on ion sources [10] are available and in the light of specific experimental requirements.

1. Storage in the ISR

The ISR can store any kind of particle the PS can accelerate [1]. Vacuum conditions are of course excellent; there exists, however, one limitation : storage below the ISR transition energy is difficult, requires modification of the RF system, and has not been tried. Transition occurs for deuterons at 16.4 GeV/c; the minimum momentum for storage [2] would hence be near 17 GeV/c (8.5 GeV/c per nucleon) for deuterons and other symetrical [*] nuclei (and somewhat higher for heavier nuclei).

2. Acceleration

Acceleration of heavy ions in the CERN accelerators is only possible with fully stripped ions for two reasons. In the synchrotrons, the high cross-section for further stripping at the available vacuum pressures (10^{-8} or 10^{-7} Torr) makes acceleration of ions other than fully stripped ones impossible (and changing the vacuum systems is very difficult if not impossible). In addition, the particular acceleration mode in the Linac is restricted to charge-to-mass ratios near 0.5.

The accelerators introduce a lower limit in accelerated intensity : beam detection systems require currents of 10^{10} or, better, a few 10^{10} charges per pulse to produce useful signals.

----

*) "Symmetrical" is used for nuclei with $N_p = N_N$.

2.1 SPS

The SPS can accelerate symmetrical nuclei from the normal injection momentum of 10 GeV/c after some minor improvement of the RF system [3]. The method could be extended to heavier nuclei.

If the method ran into unexpected difficulties, the PS could accelerate to higher momenta (e.g., 20 GeV/c for symetrical nuclei) and trapping in the SPS would take place at the same particle velocity as normally with protons. The strength of the new components of the transfer system would have to be increased, whereas those used in common with transfer towards ISR are dimensioned for 28 GeV/c anyway.

2.2 PS

As the linac provides ions at only half the velocity of protons an RF acceleration frequency below the limit of the RF system would be required. The difficulty can be overcome by trapping first at twice the normal harmonic number (40 bunches instead of 20) and debunching and retrapping at $h = 20$ at an appropriate moment. The procedure has been successfully simulated with protons [4].

2.3 Linac

While the CERN linacs - old and new - are designed primarily for protons, they can also accelerate nuclei which are fully stripped or very nearly so. Synchronism with the accelerating fields in a proton Alvarez structure can be obtained for these nuclei at half the speed of protons in the so-called "4π mode", the particles entering an accelerating gap only during every other RF cycle [5],[6]. (In the NAL 200 MeV linac synchronism is lost beyond approximately 60 MeV proton energy [7].) During short tests with the CERN Linac currents of deuterons of 8 mA [5],[8] and of He^{++} of 0.8 mA [8] have been accelerated, which would correspond to a few 10^{11} and around 10^{10} particles per pulse from the PS respectively. How large a deviation from charge-to-mass ration 0.5 (symetrical nuclei) is possible, i.e., the limit in the mass number which can be accelerated, depends on details of the structure design and must be evaluated separately for the two linacs.

3. Ion sources

The He^{++} have been produced in the standard duoplasmatron source. It is being investigated whether this is the highest atomic number obtainable.

The only type of source reputed to produce heavier fully stripped nuclei is the electron beam source proposed by Donets [9] from which N^{7+} has been obtained. Ionisation occurs in it by electron-electron collision rather than by collision with ions. An experimental source of that type is now being set up at CERN [10].

The "classical" method to obtain heavier nuclei would be to produce partially stripped ions e.g., in a PIG-type source, to accelerate them to a few MeV and strip before tank 2 and possibly again after tank 3. A convenient arrangement of that type would be to replace the present Tank 1 by a structure suitable for slower particles and to accelerate in Tanks 2 and 3 in the mode described above [10]. The energy at the input of Tank 2, 2.5 MeV/N, would be sufficient for single stripping up to nitrogen. Double stripping would yield useful intensities certainly up to Argon.

4. Conclusion

It becomes clear that the most difficult problems and limitations occur at the input end of our machines : ISR could store at between 8.5 and 15.5 GeV/N and PS and SPS could accelerate any nucleus to full energy (respectively 12 and 200 GeV/N!) once it is available fully stripped.

If fully stripped ions were available at low energy, the linac would permit to go a fair piece of way along the atomic mass scale, beyond Argon, and it is not clear yet how far. If almost fully stripped ions were presented at the input of tank 2, the linac would still transmit them and the limit for full stripping at the linac output would be in region of Argon.

In the study [10] ways to provide fully stripped ions are sought. At this moment, deuterons and He^{++} can be readily provided. It is worth noting that with moderate investment and effort CERN could create facilities that are unique and unrivalled for some time to come.

I thank P. Germain, D. Möhl, P.H. Standley and D. Warner for discussions and comments.

REFERENCES

1) H.G. Hereward, Possibility of polarized protons in the ISR, CERN/ISR-DI/74-42.

2) K. Hübner, Performance of the ISR with deuterons, Note for open ISRC, 25 April 1975.

3) C. Zettler, How to accelerate deuterons and heavier particles in the SPS, Lab. II/RF/CZ/Note 75-32.

4) O. Barbalat, E. Brouzet, Machine Development Summary No. 39, MPS/DL/Note 75-18.

5) Th. Sluyters, A theoretical and experimental comparison of proton and deuteron acceleration in the CERN Linac, CERN 64-22 (1964).

6) H. James, D. Warner, Deuteron acceleration in the new linac, MPS/LIN/Note 74-24.

7) S. Ohnuma (NAL), Th. Sluyters (BNL), Limitations of acceleration of deuterons in Alvarez-type linacs, Proc. LAMPF Conference on Proton Linacs (1972).

8) H. Haseroth, private communication (1975).

9) E. Donets, Review of the JINR electron beam ion sources, Dubna preprint (1975).

10) Proposal for a two-year study, CERN/MPS/DL 75-1.