THE TANDEM INJECTOR FOR THE SUPERCONDUCTING CYCLOTRON AT L.N.S.

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Abstract

At the L.N.S. the transport line for the radial injection of the Tandem beam in the Superconducting Cyclotron has been totally assembled. Different ion beams delivered from the Tandem have been transported. Extensive tests of the diagnostic elements and control system have been performed. The Tandem is now able to operate at a maximum voltage of 14 MV with a meanlife of the belt charging system of more than 5000 hours. In order to guarantee the operation of the accelerator up to 15 MV, the accelerating tubes number 1, 4 and 5 will be extended and modified according to our beam optic simulations.

1.Introduction

A heavy ion facility is in progress at the L.N.S. in Catania [1] and it consists of an SMP Tandem coupled to a K=800 Superconducting Cyclotron (S.C.) [2]. This facility will deliver ion beams with energies up to 100 Mev/amu for lighter ions and 10 Mev/amu for uranium. Nowadays the iron magnet and the RF power amplifiers of the S.C. are at the L.N.S., and the RF cavities, the cryostat, the power supplies and all the other equipments will be shipped from Milan in the next months.

The Tandem now works at a maximum voltage of 14 MV with no troubles but efficient operation of the booster requires an upgrading in order to guarantee a reliable voltage of 15 MV.

Different beams delivered from the tandem has been transported along the radial injection line of the S.C.. These operations allowed an extesive test of the main magnetic elements, of the beam diagnostic devices and of the computer control system. The following describes the major improvements of the Tandem and the results obtained during first tests on the beam injection line.

2. Tandem upgrading

The Tandem has been operating since 1984. During 1986÷1988 some improvements were implemented to obtain a continuous running of the machine at 13 MV. In June 1988, by introducing a ^{137}Cs radioactive source of 2 Ci, a maximum voltage of 14 MV was reached, but at this high gradient the mean life of the belt decreases about at 1500 h. In order to solve this problem, at the beginning of the 1989, we modified the so called "structure" around the belt and to introduce the down-charge system. The old half-open structure with the spacers placed down the belt has been replaced by a new "triangular" structure with the spacers alternatively placed up and down around the belt [3]. The accelerator worked very well at maximum operating voltage of 14 MV in this new configuration by April 1989. We can't test the accelerator with heavy ion because the vacuum system of the gas stripper at the high voltage terminal was out of order. The tandem operations for the last 30 working weeks has been as follows:

- unscheduled accelerator maintenance	1 week
- unscheduled injector maintenance	2 days
- conditioning	2 weeks
- accelerator studies with beam	2 weeks
- beam available for experiments	25 weeks

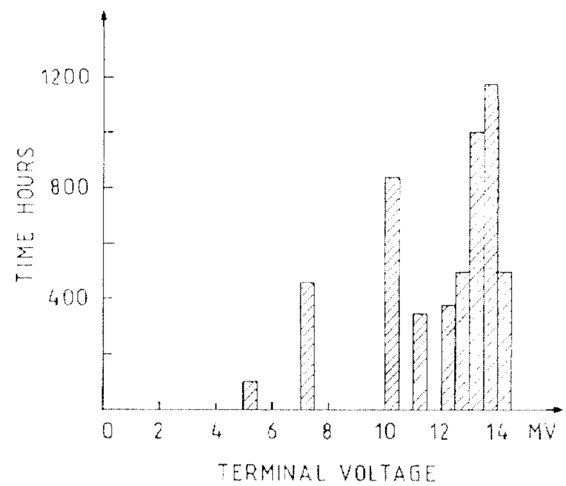

Fig.1 Operating voltage for the experiments.

In fig. 1 is shown the operating voltage for the experiments. The life of the belt is now of 5000 hours but according to the results of the future Tandem operations we hope to increase it more eventually making some minor modifications of the "structure".

The installation of the S.C. requires a tandem upgrading to reach a maximum voltage of 16 MV and reliable operations at 15 MV with the higher possible beam transmission.The desired conditions require to lenghten the accelerator tube number 1 up to 92" and the tubes number 4, 5 up to 84", and to install a second radiactive source.

The first tube is the most critical element for the maximum possible voltage and for the transmission. We will have at the entrance a shortened straight circular section (all at half resistor) followed by a 7° inclined electrodes section to guarentee a high electrical suppression (see fig. 2). This configuration requires only small beam steerers corrections also with low injection energy. The optics starting from the source placed on the new 450 KV platform [4] has been recalculated (see fig. 3) and to increase the transmission the beam astigmatism has been minimized.

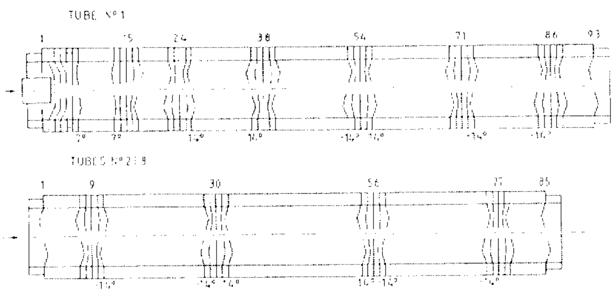

Fig.2 Section of the accelerating tubes.

The Tandem activity for 1990 has stopped. At january the tubes were sent to Vivirad-High Voltage to be rebuilded and lenghtened. At the end of August 90 they will be available in our laboratory. Until that time we are realizing a lot of internal minor mechanical and electronic modifications of the accelerator to improve all the maintenance operations. The console of the tandem has been moved from its temporary position, inside the accelerator room, to its final position in the control room together with the S.C. console. We are also adjusting the vacuum system of the gas stripper at the high voltage terminal. At the end of the year we plan to have the tandem in operation for experiments.

3.Bunching system

The bunching system of the Tandem-Cyclotron complex consists of a low energy buncher (LEB) and of a high energy buncher (HEB) located rispectively at the Tandem entrance and midway between the Tandem and the Cyclotron. The LEB produces a time focus at the tandem stripper to minimize the longitudinal phase space growth produced by the energy straggling at the stripper. The pulse length after the Tandem is roughly by ± 10° RF due to the spread source energy, wave shape and grids. By the HEB a final time focus at the cyclotron stripper of 3° RF is feasible.

The two cavities of the LEB were already tested and in the next months it will be installed in front of the tandem. The rebuncher is also ready and we have to test it before the installation on the beam transfer line. The prototype of the phase amplitude control loop for bunching system has been developed. The final realization of the component of the control loop is now in progress and the interface to the computer control too.

4.The beam transfer line.

The beam transfer line between the Tandem and the S.C. has been designed in a modular way to decouple the two machines in transversal longitudinal phase space [5]. It consists of three sections: analysis, achromatism and matching. The setting and the tuning of the beam line will proceed according to the modular design of the system; slits, faraday cups, beam profile monitors and emittance meters, are used. The setting of the analysis section is obtained by maximizing the transmission between the object slit and the image slit with the help of a beam profile monitor to check the size of the beam. The acromatism is guaranteed by the simmetry of the transfer line. A double waist (DW) at the end of achromatic section is obtainable for a large range of initial conditions. An home made emittance meter is used to check the presence of the DW.

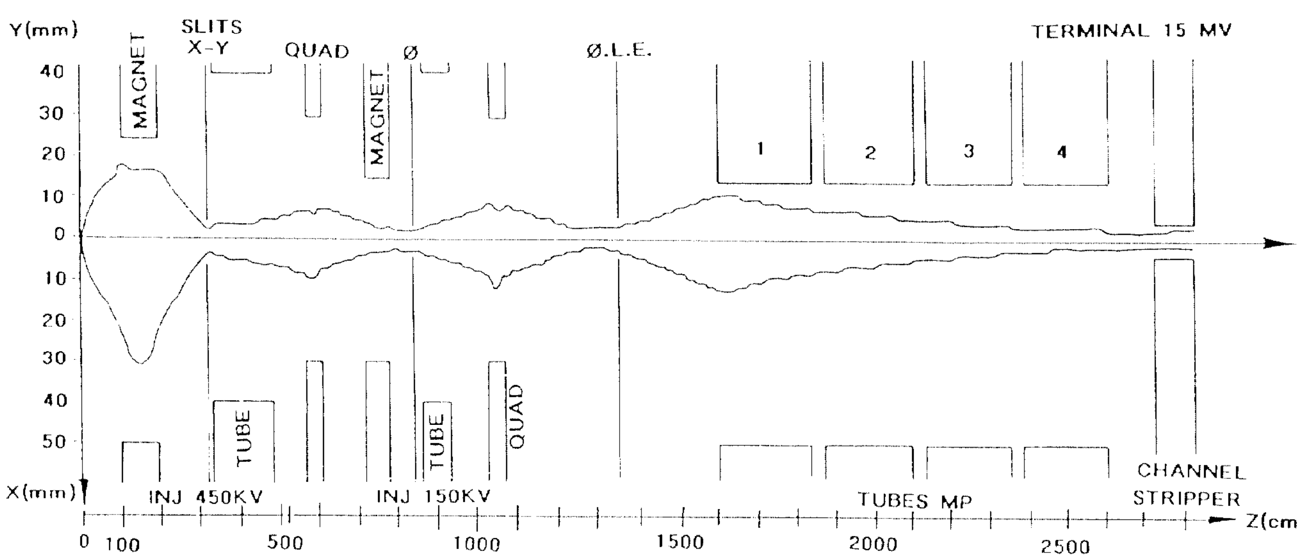

Fig.3 Tandem beam optic.

The diagnostics of the matching section is critical mainly as a result of difficulties in placing diagnostic devices close to the cyclotron because of the fringing field that could be as high as 2 Kgauss. The possibility of placing an emittance meter just at the end of the matching section, at a distance from the cyclotron center of 2.5 m, is studying.

The beam line has been completely assembled up to the last dipole magnet. Tests of the analysis and achromatic sections for carbon ions at different energies were performed. Horizontal beam sizes of 1.8 mm were measured near to the analysis slits assuming a dispersion R_{16} =30 mm/% for the 60° analysis magnet a resolving power of about 1666 is available agreeing with the expected values of 1875. The preliminary test with beam showed a transmission along the beam line about 100%. Unfortunately was not possible to transport heavy ions beacuse of the Tandem gas stripper was out of order. The field values of the dipoles and quadrupoles are in good agreement with the values obtained by simulations accomplished by using "TRANSPORT" code.

5. Beam diagnostic and control system

The main beam diagnostic elements in the transfer lines are beam profile monitor (BPM) and emittance meter (EM). The features of these devices was reported elsewhere [6]. The elements of the beam line (diagnostic devices, magnetic elements and actuators) are computer controlled by means of a high speed serial bus of microcontrollers based boards [6] and all the operations are performed by a prototype console based on two PCs. One of these is devoted to controlling the power supplies of the magnetic elements (dipoles, quadrupoles and steerers) and the magnetic measuraments system while the second allows to operate on the beam diagnostic devices (BPM, EM, faraday cup and slits).

During the test of the radial injection line a position resolution 0.2 mm and a current resolution of 10 pA was measures for the BPM. The total beam scanning time is about 1 sec. and the reconstruction and graphic display of 150 different acquisitions of the 3 wires is about 1 sec. The reliability and repeatability of the BPM during the beam line operation are now quite satisfactory. These devices are also working on negative ions without troubles.

A prototype of the EM has been tested on the 150 KV preinjector of the tandem with a ^{32}S beam delivered from a sputter ion source Iconex mod. 834 at an energy of 100 Kev and with total current of 2 μA. In fig. 4 is shown a typical beam emittance shape and its value is 9 π*mm*mrad*$\sqrt{Mev}$. The main constraints of the system is the total measuring time (about 6 minutes). We are now realizing a final version of the EM changing some mechanical parts in order to allow an emittance measurement in 90 sec. maximum. It will be tested before the end of the year.

The long-time beam stabilization procedures of the transport lines require to implement a closed-loop control of the dipole power supplies to correct the magnetic field instabilities. Our control of dipole magnetic field is based on the Scanditronix system NMR 751-27 able to measure up to 27 field using NMR method. The system is already integrated in our control system by means of standard Bitbus cards. It was successfully tested. A dedicated software has been developped implementing as major task an automatic research of the resonace and an easy interface to the operator. The test on the sofware implementing the closed loop for the automatic correction of the long term instabilities of the power supplies is now in progress.

The final goal of the beam transfer lines control system is to achieve automatic procedures to set and optmize all their parameters. We are planning to develop a dedicated beam transport computing and displaying program by using the first order matrix formalism. In order to implement this tool a workstation with good performance either as number crunching or as graphic capability (DEC 3100) will be dedicated to this specific task.

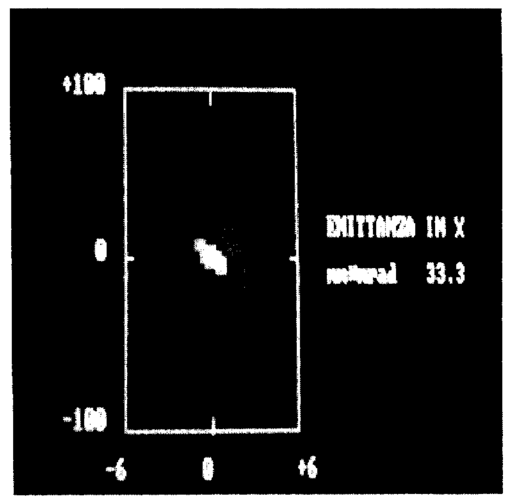

Fig.4 Beam emittance shape.

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