PROGRESS REPORT ON THE HEAVY ION FACILITY AT LNS

E.Acerbi, F.Alessandria, G.Baccaglioni, G.Bellomo, C.Birattari, A.Bosotti,
F.Broggi, L.Calabretta, G.Ciavola, G.Cuttone, C.DeMartinis, M.DiGiacomo,
E. Fabrici, A.Ferrari, D.Giove, P.Gmaj*, P.Michelato, C.Pagani, G.Raia,
L.Rossi, G.Varisco, S.Zhou**

Istituto Nazionale di Fisica Nucleare - LNS (Catane) - LASA (Milan)

* Heavy Ion Laboratory, Warsaw - Poland
** Institute of Modern Physics, Lanzhou - China

Abstract: The Milan K = 800 superconducting cyclotron is transferring and installing in the Laboratorio Nazionale del Sud (LNS) in Catane. The test of the machine will be carried out by midplane injection in the cyclotron of ion beams delivered by the 15 MV Tandem. The paper will present an overview of the facility by describing the main components and the project status.

Introduction

The initial program of the superconducting cyclotron project has been changed in consequence of the successful operation of the magnet and the good performances of the measured magnetic field [1] obtained in the last year. In order to reduce the delays arising by a full test of the cyclotron at LASA (Laboratorio Acceleratori e Superconduttivita' Applicata) in Milan, the transfer of the cyclotron has been anticipated in comparison with the previous schedule. The final magnetic measurements and the injection, acceleration and extraction tests will be carried out at LNS by coupling the 15 MV Tandem with the superconducting cyclotron.

The layout of the heavy ion facility at LNS is shown in Fig. 1. Negative ions from a suitable source are accelerated by means of an electrostatic platform to 450 keV and bunched before injection into the Tandem. The beam is rebunched before the midplane injection in the cyclotron and it is stripped by a carbon foil near the cyclotron center. Three dees operating at a maximum voltage of 100 kV accelerate the beam up to an average radius of 0.86 m where the beam is extracted by two electrostatic deflectors and by a set of passive magnetic channels. A conventional transport system distributes the extracted beam to the various experimental areas.

This paper presents the status of the major components of the injector system and of the superconducting cyclotron.

Injector system

Tandem

The Tandem is in operation since 1984, when the machine was able to reach 13 MV but not without some problems. Several improvements in the last years have allowed to increase the maximum operating voltage up to 14.0 MV [2]. Notwithstanding this the Tandem, as injector for the superconducting cyclotron, needs to be upgraded in order to work in a stable way at 15 MV and to deliver heavy ion high charge state beams. The following improvements are now in progress:

- modification of the stainless steel screen of the belt charge to obtain an uniform deposit and collection of the charge on the belt;

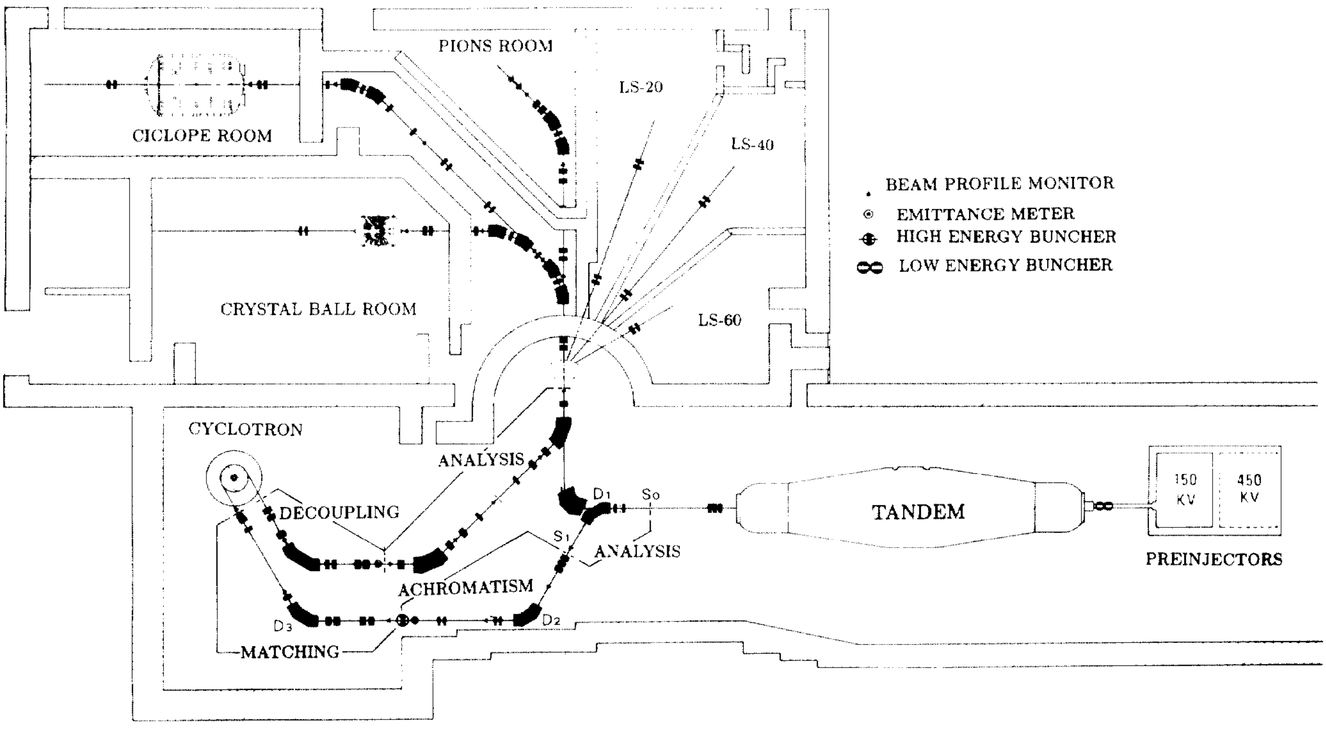

Fig. 1 Layout of the LNS with the Tandem, the superconducting cyclotron and experimental areas.

RF system

The RF system is almost completd and its transfer to LNS has started in November 1989, with the installation of the power amplifiers.

Electronic controls, fully computer assisted, for the three RF chains have been assembled and tested [9]. A 386 based PC computer, fully compatible with the general computer control is used for setting, monitoring and control of the system parameters.

The RF liners have been machined (Fig. 4) and are nearly completed. The fabrication of the dees presents some delay, with respect to the scheduled time, mainly due to the change in brazing technology necessary to improve the vacuum performances.

Computer control

The architecture of the computer control has been modified in few parts to take into account the requirements of the final installation.

New solutions, which take advantages from the available workstation technology and modern software standards, have replaced the old console structure based on specialized boards and dedicated programs. The new console consists of a Local Area Vax-Cluster based on a µVAX 3400, 3 VAX station 3100 and a µVAX II-GPX. A µVAX II provides a bridge between this structure and the other control networks. Efforts have been dedicated to the development of a general purpose X-Window program for operator interaction [10]. Personal computer have been integrated in the console for alarm recording and analysis and for the off-line management of all the informations related to the sensors and actuators of the cyclotron. An hypermedia software has been developed to provide tools as speech description of the action to be taken after a particular event along with the display of related drawing or pictures.

A modular, dedicated architecture is under development and test for beam diagnostic. Diagnostic devices are controlled by means of µcontroller based cards connected on Bitbus to a master unit, which will be a Personal Computer. The whole system will be based on 2 or 3 PC which will be able to exchange data on an Ethernet link to a VAX station dedicated to the display of beam characteristics.

Vacuum system

The vacuum system, extensively described elsewhere [12], is divided into seven subsystems.

Up to now some of these plants have been in operation in Milan, e.g. the cryostat vacuum system that has worked for more than one year. Moreover all the components have been tested in conditions similar to the operative ones: e.g. the split cryopumps have worked in the 5 T magnetic field during the magnetic field measurements.

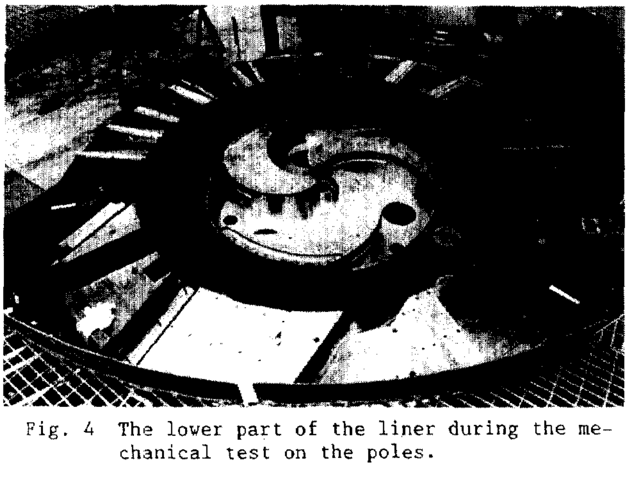

Fig. 4 The lower part of the liner during the mechanical test on the poles.

The vacuum control system is modular, it uses distributed µcontroller based cards, connected together by an high speed serial bus [13]. Microcontroller cards are located close to the instrumentation and interfaces have been designed for conditioning the signals coming from the plants. These interfaces are used also for local operation of the plants e.g. during the maintenance.

Such a modular structure is characterized by a great flexibility and by the possibility of easy future expansions. In fact the insertion in the control system of a new plant is simply performed adding a new microcontrolled board and the proper interface.

Health physics

Neutron and gamma spectra, fluxes and ambient dose equivalent, evaluated by using Montecarlo codes, have been reported in previous papers [6,7].

The calculated neutron spectra show that the high energy part is very important also outside the shielding. The available rem-conters (Andersson Braun or similar) normally used for the measurement of neutron equivalent dose, could understimate the cyclotron equivalent dose of 60%. The design and construction of a full-range rem-counter with the required sensitivity extending up to neutron energies of several hundreds MeV, is in progress.

The security system designed in order to rule the access to the bunker and to avoid any radiation hazard is composed by an access control system, a patrol system, an interlock system, an emergency system and acoustic and optic alarm devices. In particular the access system is based on radiofrequency operated proximity sensor, which recognize personalized badges.

References

Legenda: ICCA is for International Conference on Cyclotrons and their Applications.

[1] E.Acerbi et al. "The magnetic field measurements of the Milan Superconducting cyclotron" to be published in the Proc. of XII ICCA, Berlin (1989)

[2] L.Calabretta et al. "The Tandem injector for the superconducting cyclotron at LNS" presented at this Conference

[3] G.Bellomo et al. Proc. of XI ICCA, Tokyo (1987) p. 534

[4] E.Acerbi et al. Proc. of X ICCA, East Lansing (1984) p. 251

[5] E.Acerbi et al. Proc. of XI ICCA, Tokyo (1987) p. 168

[6] E.Acerbi et al. Proc. of EPAC, Rome (1988) p.323

[7] E.Acerbi et al. "Progress report on the Milan superconducting cyclotron" to be published in Proc. of XII ICCA, Berlin (1989)

[8] G.Bellomo et al. "Analysis of the magnetic field measurements of the Milan superconducting cyclotron" presented at this Conference

[9] A.Bosotti et al. "Tests of the computer controlled electronics for the RF system of the Milan superconducting cyclotron" presented at this Conference

[10] D.Giove, G.Cuttone "Man-machine interaction tools based on X-Window" presented at this Conference

[11] G.Baccaglioni et al. "The compact ECR Source and the axial injection line for the Milan Superconducting cyclotron" presented at this Conference

[12] P.Michelato et al. Proc. of EPAC, Rome (1988) p. 1278

[13] D.Giove et al. "Computer automation of the Milan superconducting cyclotron vacuum system" to be published in the Proc. of XII ICCA, Berlin (1989)

- installation of a second radiation source at the terminal;
- extension of the 1^{st}, 2^{nd} and 3^{th} acceleration tubes up to 92 inches.

It is planned that the Tandem will deliver beams for the experiments in January 1991 at an operating voltage of 15 MV.

Bunching system

The bunching system consists of a low energy buncher (LEB) and an high energy buncher (HEB) located respectively 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. Due to the source energy spread, wave shape, grids and debunching effects a pulse length after the Tandem of ± 10° RF is expected. By the HEB a final time focus at the cyclotron stripper of 3° RF is feasible.

The LEB is a double drift buncher consisting of two $\lambda/4$ cavities driven respectively in first and second harmonic. The cavities consisting of coaxial lines (77 Ω characteristic impedance) are tunable respectively in the 15-48 MHz and 30-96 MHz frequency ranges and operate at 1.5 kV. They are made of aluminum alloy, their shunt impedance is in the range 30-70 kΩ and the measured quality factors range, as expected, from 2000 to 900 for the first cavity and from 1000 to 1500 for the second one (Fig. 2). A phase control loop driving the sliding short is used to stabilize the resonance frequency of each cavity. This feedback loop has been tested and after warm up of the cavity automatic adjustments occur every ten minutes or more (the thermal phase shift during warming up is about 1° per minute). The amplitude control loop has been tested and a stability better than 0.1% measured.

The HEB is a $\lambda/4$ copper resonator with a drift tube working in the frequency range of 60-192 MHz. The drift tube length is 63 mm to match the average $\beta\lambda/2$ value of the injected beam. A quality factor Q = 5000 is expected and the peak voltage of 30 kV would be obtained by driving the HEB with a power of about 1 kW supplied by a broad band amplifier.

Beam transfer line

The beam transfer line between the Tandem and the cyclotron has been designed in a modular way to decouple the two machines in transversal and longitudinal phase space [3]. It consists of three sections: analysis, achromatism, matching as shown in Fig. 1.

The setting and the tuning of the beam line will proceed in accordance with the modular design of the system. The setting of the analysis section is obtained by maximizing the transmission between the object slit S_0 and the image slit S_1 with the help of a beam profile monitor to check the size of the beam. The achromatism is guaranteed by the symmetry of the transfer line. A double waist (DW) at the end of the achromatic section is obtainable for a large range of initial conditions and will be checked by an emittance meter. The matching section will be checked by an emittance meter or by two beam profile monitors.

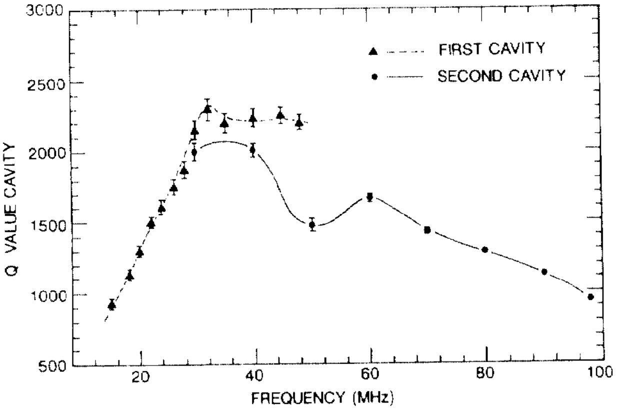

Fig. 2 Quality factors of the LEB cavities as a function of the operating frequency.

The beam line has been completely assembled up to the dipole magnet D_3. Tests of the analysis and achromatic sections for Carbon ions at different energies have been performed. The field values of the dipoles and quadrupoles have been in good agreement with the values obtained by the "TRANSPORT" code. The horizontal beam sizes of 1.8 mm, measured near the analysis slits, have confirmed the calculated resolving power (R = 1875) of the analyzing magnet. The transport of the beam along the line has been also a test of the diagnostic devices that have a 0.2 mm position resolution and a good signal to noise ratio.

Superconducting cyclotron

The main characteristics of the cyclotron have been described in several invited papers and progress reports [4-7]. A few technical papers on the various components of the machine are presented at this Conference [8-11]. For these reasons in the following only some aspects of the project will be presented.

Magnet corrections and improvements

The analysis of the magnetic measurements has shown that the average field requires only small corrections on the poles whereas the first harmonic in the extraction region requires suitable corrections shared between poles, coils, yoke and vacuum chamber.

The main correction of the average field (about 100 Gauss at the extraction radius) has been performed with 1.5 mm thick Armco plates extending from 0.83 m to 0.90 m and screwed on the hills.

The Fig. 3 shows for an high field map the single contributions to the first harmonic arising from different sources [8]. The coil first harmonic content will be reduced with stronger horizontal tie-rods, the yoke and vacuum chamber content will be reduced with iron slabs inserted in the yoke, the pole content will be corrected with harmonic coils and harmonic bars.

With these corrections the iron magnet has been completed and it has been transported and installed at LNS. The cryostat, after the magnetic measurements, has been disassembled to weld the injection, extraction and diagnostic penetrations in the midplane.

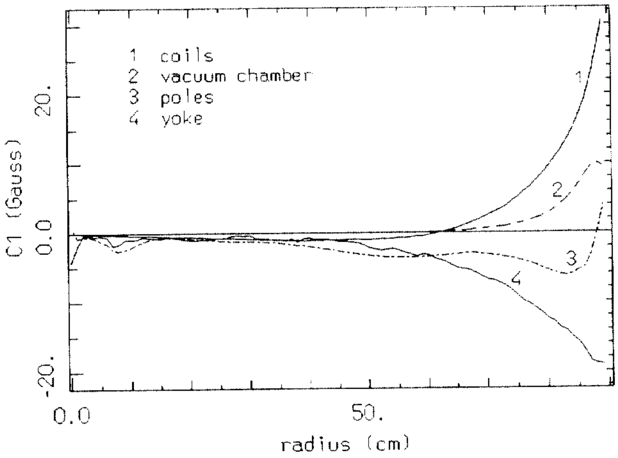

Fig. 3 First harmonic components of the measured magnetic field.