PROJECT OF A SUPERCONDUCTING RF ELECTRON LINAC AT FRASCATI INFN LABORATORIES

A.Aragona, C.Biscari, R.Boni, M.Castellano, A.Cattoni, V.Chimenti, S.De Simone, S.Faini, U.Gambardella, S.Guiducci, S.Kulinski*, L.Maritato,G.Modestino, P. Patteri, M.A.Preger, C.Sanelli, A.Savoia, M.Serio, B.Spataro, S.Tazzari, F.Tazzioli and M. Vescovi

presented by F. Tazzioli

INFN-LNF, C.P. 13, 00044 Frascati (Roma), Italy
*On leave from Institute for Nuclear Studies, Swierk, Poland

1. Introduction

A program of construction of a test superconducting linac with low emittance, high peak current and low energy dispersion is in course at Frascati INFN laboratories. This program is motivated by the consideration that RF superconductivity is very promising in the effort to achieve the break through in ideas and techniques that seems necessary to implement new very high energy accelerators.

For electron machines in the TeV range the future is certainly connected with linear colliders. Actual ideas on the implementation of these can be subdivided in two main lines, one employing fully superconducting accelerating structures[1], and the other based on the two-beam accelerator concept that uses superconducting resonators on the auxiliary beam line for power generation[2].

Moreover,superconducting cavities are now considered the structures of choice for high energy CW electron accelerators for Nuclear Physics[5].

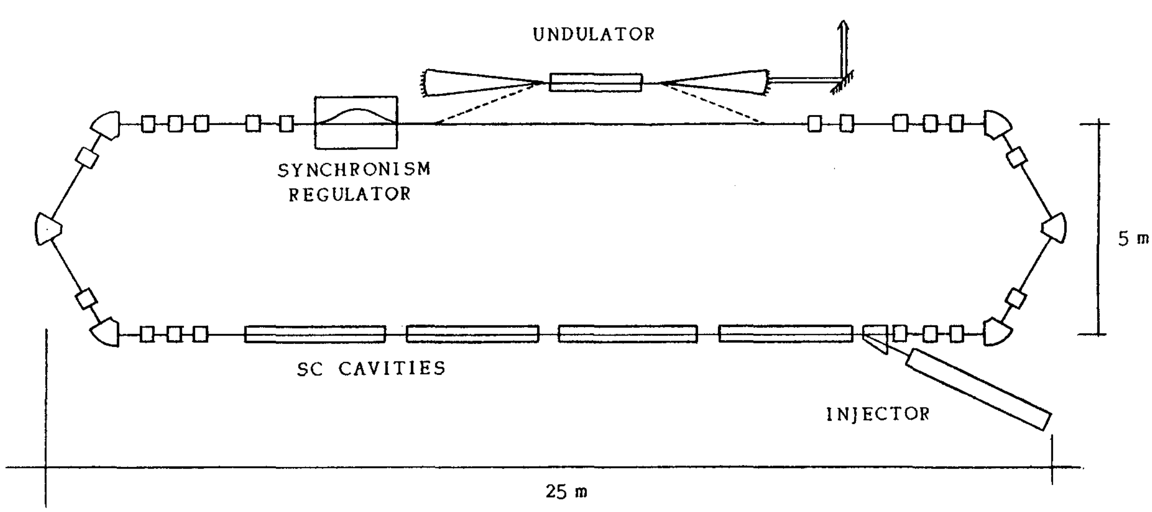

FIG. 1 - Schematic machine layout.-

An immediate application of this test accelerator, of energy between 25 and 73 MeV, is the implementation of a Free Electron Laser in the infrared wavelength region. Such an FEL has applications in molecular physics and medicine.

2. Actual situation of facilities

At Frascati Labs investments have already been made since several years for projects that use superconducting technologies. Among these are to be mentioned a superconducting wiggler magnet and a microwave undulator which are in course of implementation.

For these we have already set up a liquefier/refrigerator capable of cooling a 60 W thermal load at 4.6°K. This is completed by a system for recovery and recompression of He gas and a centralized vacuum system.

Clean air and water facilities are in course of preparation.

3. Project LISA (Linear Superconducting Accelerator)

The structure of the test accelerator complex is shown schematically in Fig. 1. It consists of:

- A 1 MeV injector at normal temperature.
- 4 multicell superconducting cavities with an overall 4.8 m useful accelerating length.
- Recirculation channel.
- Refrigeration and power plants.

The accelerator will be able to deliver a beam of energy between 25(49) and 36(73) MeV depending on the maximum gradient achieved in the cavities.

The main characteristics of the electron beam supplied by the accelerator are given in Table I.

Table I - Characteristics of the beam

Energy	= 25 to 73 MeV
Average current on a 1 msec macropulse	= 13 mA (at 30 MeV)
Peak current in the micropulse	= 6 A (at 30 MeV)
Invariant emittance	$= \pi \times 10^{-5}$ m rads
Energy dispersion	$= \Delta E/E = 2 \times 10^{-3}$.

4. Accelerating structure

The frequency of the accelerating cavities has been chosen after an international discussion meeting[3] that took place in Frascati in October 1986.

The frequency of 500 MHz is a compromise between the necessity of large stored energy and low beam loading for all possible applications (colliders, FEL, nuclear physics) and the increasing cost with dimensions. At this frequency there are proven designs and the cavities can be ordered directly to industry.

The accelerating structure for LISA is made of multicell cavities of massive Niobium with high degree of purity (RRR=180). It is subdivided in 4 cryostats in each of which is placed a 4 cell cavity having the geometry of the DESY-HERA design[4]. The main characteristics of the cavity are given in Table II.

Table II - Characteristics of the cavities

Frequency	= 500 MHz
r/Q_o	= 383 Ohm/m
Number of cells	= 4
Useful length	= 1.2 m
Accelerating field	= 5 MV/m
Q_o	= 2×10^9 at 4.2 °K.

The contour of the single cells is studied so as to avoid multipacting discharges and all the structure is supported in the cryostat with a mechanical system that allows tuning to the right frequency against thermal variations. We are studying for the cryostat a solution, different from the DESY one, that will not use massive Aluminium blocks but lighter bodies to reduce the Helium volume, CERN style. This will allow easier cool-down and warm-up phases. Another difference will be the implementation of an independent cryostat for each four-cells cavity. This will favour the handling of the module and flexibility of operation of the accelerator in case of trouble in only one of the modules, with only a modest loss in effective accelerating length per unit mechanical length.

The power loss per unit length on the cavity walls is

$$P_o = E_a^2/(r/Q_o)\ Q_o$$

where E_a is the accelerating field, r/Q_o is the geometrical characteristic impedance of the structure, Q_o is the unloaded quality factor.

In our case (r/Q_o)=383 Ohm/m, so for E_a=5 MV/m and $Q_o=2\times10^9$ at 4.2 °K the power loss per unit length results

$$P_o = 33\ \text{W/m}$$

To this we must add at least 2 W/m of static cryostat loss, so for an overall useful length of 4.8 m and an effective cryostat length of 10 m the expected power loss is about 180 W.

A 400 W refrigerator is necessary to run the machine at full energy.

We intend to buy the superconducting cavities and cryostats from industry, that has to deliver them after complete chemical and mechanical cleaning. The only surface treatments that are foreseen in our Labs are washing with ultrapure (18 MOhm cm) water and He-ion processing.

5. Machine problems

Having chosen, as a first approach, a 100 KV thermal gun, it is better to pre-accelerate the particles with a normal conducting structure until they are well relativistic before injection into the superconducting structure.

The recirculation channel has been designed achromatic and isochronous for energy doubling. It has been shown instead that for energy recovery after interaction with the undulator in the lasing process (that gives an energy spread of a few %) a non isochronous channel gives better performance.

Energy recovery brings also the problem of low beam loading and small generator coupling and consequent greater sensitivity to the bath pressure fluctuations.

Beam break-up does not seem a very serious problem at the envisaged 13 mA current level, given the large iris opening of the cavities and the suppression of high order modes.

6. Status and time schedule

Funds have been granted for years 1987 and 1988. Preliminary design of the injector is complete. Offerts for the superconducting cavities are being examined and orders will be emitted within this year.

Clean water and air facilities will be installed within this year. We intend to use them immediately to study and develop prototype single cell superconducting cavities obtained by deposition of Niobium film on Copper.

Plans for the buildings are in course and works will be given out within this year.

We plan to assemble the machine in two years from the date of emission of the first orders.

References

1. U. Amaldi, C. Pellegrini: CERN-CLIC Note 16 (1986).
2. W. Schnell: CERN-CLIC Note 13 (1986).
3. Proceedings of "SC Linear Accelerator - Discussion Meeting", Frascati 13-14 October 1986.
4. D. Proch: 1987 Particle Accelerator Conference, Washington.
5. C.W. Leeman: The CEBAF Superconducting accelerator, Proceeding of 1986 Linac Conference.