THE ALPI PROJECT AT LEGNARO NATIONAL LABORATORY

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The conceptual design of a superconducting (linac) booster (named ALPI PROJECT) for the 17 MV XTU-TANDEM of Laboratori Nazionali di Legnaro has been recently accepted by the National Institute of Nuclear Physics as one of the leading projects to be funded in the next five year plan. Money for resonator and cryostat prototypes is already available and the building is going to be funded next January.

The project aims at a machine capable of accelerating all the stable isotopes up to Uranium at energies above the Coulomb barrier of every possible ion-ion interaction with beam quality comparable to that of d.c. accelerators.

With such a machine, in fact, we want to keep up the long tradition[1)] of the laboratory in fields like nuclear spectroscopy, quasi-elastic collisions and their interplay with fusion around and below the Coulomb barrier, deep inelastic and quasi-fission regimes in ion-ion collisions, accelerator mass spectrometry, interaction of ions with solids and biological samples. The experience with ATLAS at ANL and SUNYLAC at Stony Brook over thousands of hours of running time, has demonstrated that the Tandem (injector) - superconducting linac (booster) combination allows easy and continuous energy variability and transverse and longitudinal beam emittances of few tens of π mm·mrad $\mathrm{MeV}^{-1/2}$ and of keV·nsec respectively[2)].Moreover the continuous duty cycle and the natural availability of beam time structures in the 100-200 ps range make these machines particulary attractive for exclusive and crucial experiments in the fields mentioned above.

ATLAS and SUNYLAC machines are mainly limited in the heavy beam production by the Tandem injectors both working at maximum terminal voltages of 9 MV and using stripper-foils in the terminal. With such injectors the beam intensity drops down to small fractions of pnAmp already for ions with $A \approx 100$ and the ATLAS URANIUM upgrading program, now in progress at ANL is aiming at accelerating, for the first time, high quality very heavy ion beams with intensity up to hundreds of pnA.

At LNL we will take the advantage of coupling the linac postaccelerator to the 17 MV XTU Tandem which is able to produce even the very heavy beams with reliable intensity and velocities $\beta \geqslant 0.04$ which can be matched by superconducting resonators feasible with the present available technology.

As accelerating structures in the ALPI project we have chosen straight line quarter wave resonators (QWR) on the basis of their intrinsic mechanical stability and broad velocity acceptance (two gap resonator) particularly important for a national facility like ALPI which is expected to produce as many different beams as possible.

We have chosen lead as superconductor on the basis of the following considerations:

i) lead technology being much more applied for QWR resonators than the Nb one can be easier and faster introduced in a Nuclear Physics Laboratory without any experience in the field;

ii) the performances of SUNYLAC have demonstrated that our initial goal of reaching accelerating gradient of 3 MV/m is feasible;

iii) the difficulty in fabricating the OFHC copper base of the resonators (number of EB welds, joints) is relatively modest if compared wiht the solutions involving Nb as superconductor.

The linac architecture

The linac architecture (number of resonators, number of sections with different optimum β-values) has been fixed taking into account the following requirements:

a) possibility of accelerating all the beams (30<A<238) produced by the Tandem injector operating at terminal voltage up to 17 MV. Starting from ions with A=120, the gas stripper is employed;

b) average accelerating field for the resonators (QWR type) should be of the order of 3 MV/m;

c) the beam energies would cover the range between 6 MeV/amu for Uranium up to 20 MeV/amu for light ions like Silicon and Sulphur (see fig. 1);

d) the machine optimization (TTF as close as possible to the maximum value through all the resonators) is done for beams with A around 120÷150.

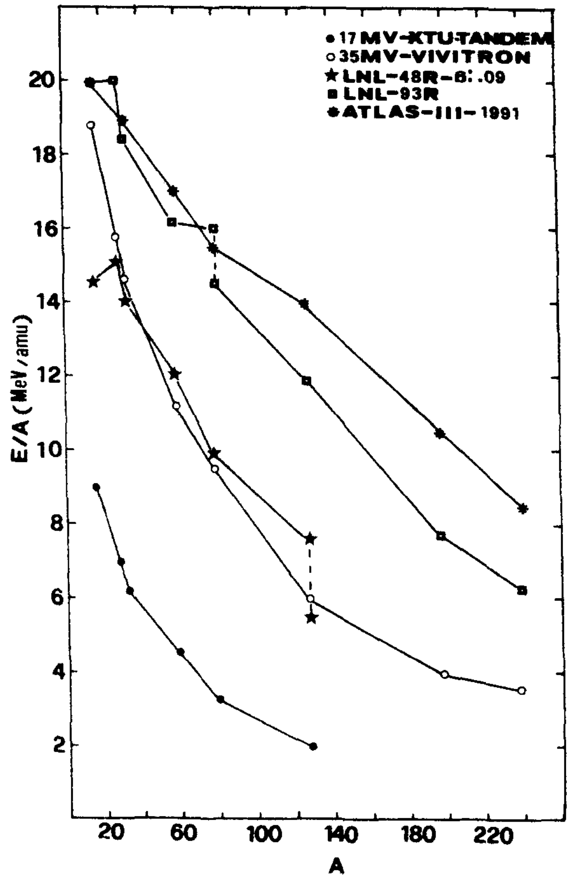

Fig. 1. - Energy performances of the LNL Tandem + Linac accelerator in the initial (48 resonators β_{opt}=0.09) and final configuration (93 resonators). The average accelerating field is assumed to be 3 MV/m. As reference accelerators have been taken the upgraded XTU Tandem, the Vivitron Tandem in construction at Strasbourg and the ATLAS Linac in phase III of Argonne National Laboratory (ANL).

In this way we get a machine configuration which consists of twenty-four β=0.055, 100 MHz QW-resonators (low β-section), fourty-eight β=0.09, 150 MHz QW-resonators (medium β-section) and twenty-one β=0.15, 150 MHz QW-resonators (see fig. 2).

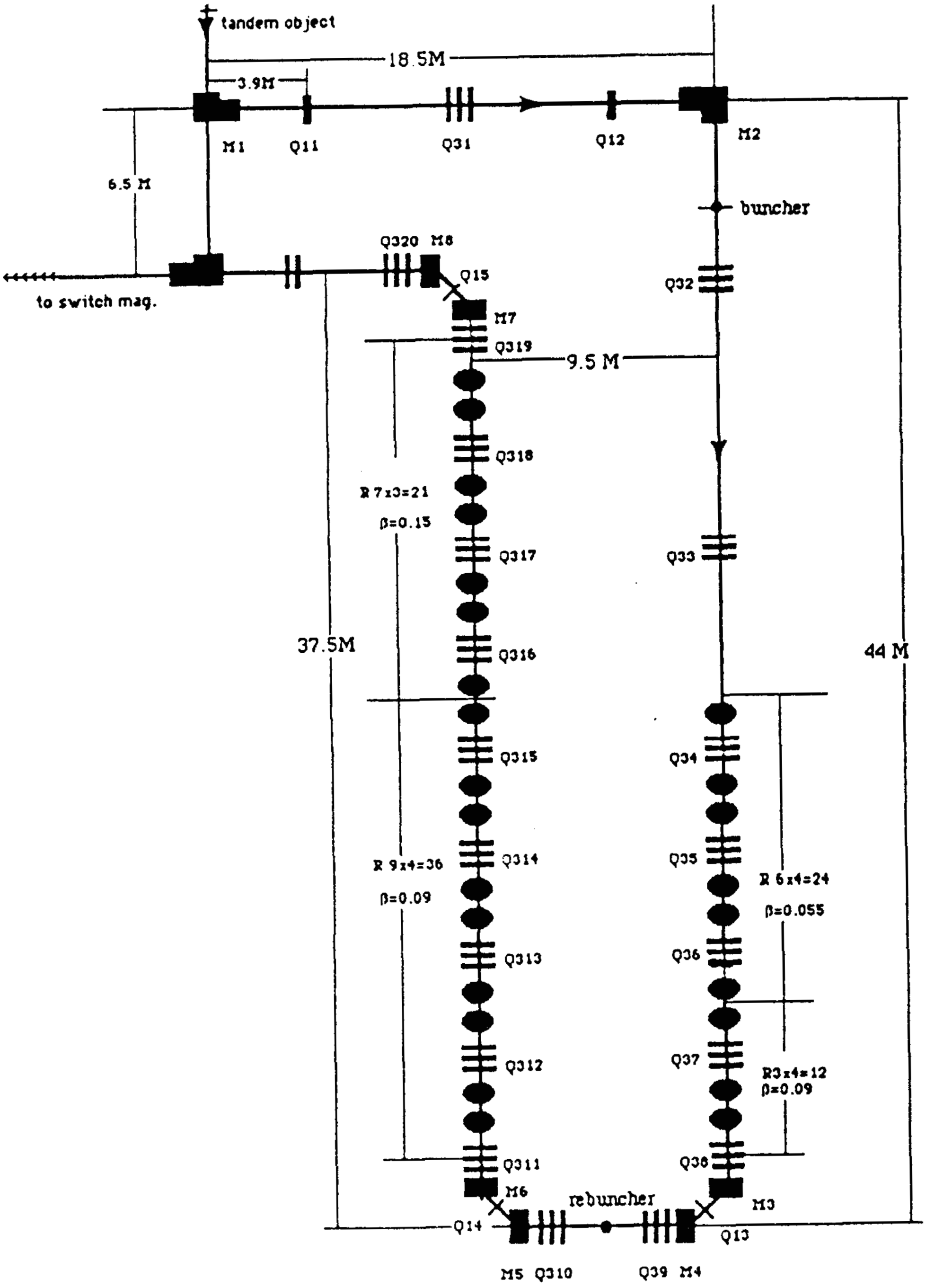

Fig. 2. - Schematic beam transport for the whole Linac configuration (93 resonators).

The core of the post-accelerator, namely the medium β-section will be built in the first phase of the project and at this stage the Legnaro machine will have the same energy performance of a 35 MV Tandem accelerator.

Using a computer program[3)] which is able to follow the beam optics through the whole LINAC, the base machine module consisting of a room temperature Q-triplet and two cryostats (every cryostat contains 3 or 4 resonators) has been chosen.

Such a module reduces the machine length and allows beam diagnostic boxes between the two cryostats extremely useful during the running operation.

The resonator prototypes

During the last half-year we have built four OFHC-copper resonators. The main difference between these resonators with the QWRs in operation at the Weizmann Institute of Science[4)] is the shape of the central conductor which in our case is not tapered. This shape suggested recently by I. Ben-Zvi and J.S. Sokolowski[5)] should reduce considerably electron multipactoring in the QWR.

The drift tube and the central conductor have been shaped by machining one forged piece (cylinder) thus avoiding an EB weld. The resonators consist of three basic parts namely the inner conductor, the outer conductor and either the top flange (first two prototypes - fig. 3a) or the top cylinder (last two prototypes - fig. 3b) which connect and shortcircuit the outer and inner conductors. When adopting the top cylinder solution a peripheral full penetrating EB weld is done and the internal weld area after further machining with special tools looks of better quality (free from crack and craters) than the cosmetic weld applied in the top flange configuration. The beam ports are brazed in a vacuum furnace concentrating the brazing fillet in a groove on the top of the beam ports.

The internal surfaces are polished with a tumbling step by step procedure which employs tumbling media (cones) of different weight, artificial and natural abrasive.

The final local roughness we get is of the order of 0.2÷0.5 μm. The lead plating and polishing techniques we use follow the experience of the Weizmann Institute of Science (Israel), the State University at Stony Brook[6)] and the University of Washington[7)]. After the surface finishing process, the cavity is treated with ultra-sound then washed and rinsed in manys steps using deionized water and citric acid (2‰ concentration). The plating process starts with a current shock of 7 Ampères for few seconds and then continues for ~4 h at a current of 1.3 Ampères. Every six seconds the electrode polarity is inverted for two seconds. Afterwards with fast operations the resonators is cleaned with deionized water, citric acid and then rinsed with ethilic alcohol. The resonators loading and unloading operations are done in a nitrogen controlled atmosphere.

We did some tests of lead layer samples obtained with the procedure above described and we got the following results:

1) thickness of ~5 mm
2) critical temperature of the superconductive state 7.20±0.02k
3) average grain size about 300Å
4) fairly good purity of the coating and uniformity of its crystalline structure.

Multipactoring levels of one resonator prototype have been conditioned at the nitrogen temperature and were overcome in two hours with average loading power levels between 10-50 Watts obtained in a pulsing mode operation with duty cycle between 10 and 20%.

This result could be an indication of the validity of the geometry we have chosen for the inner conductor.

Q-tests at the liquid-He temperature on the same prototype have been initiated but as we tried to increase the input power of the resonator the Q-value from $7 \cdot 10^7$ soon started to deteriorate. We associated this deterioration to the presence of a long crack in the inner conductor-top flange EB weld that was clearly evidence after the lead stripping, through and endoscope inspection. The repair of the crack is now in progress.

The resonator development program was initiated about one year ago, and in this period we have gained experience in most of the areas of resonator production, testing and control. We are about to have a cold test (in a few weeks) of our first prototype after its repair and we expect to reach this time good Q-value at high fields. During next year we plan to complete a 4-resonators module and then start with the machine construction.

We hope to have the building ready by the end of 1988, the first part of the linac (the 48 resonators) by the end of 1990 and the project completed in 1992.

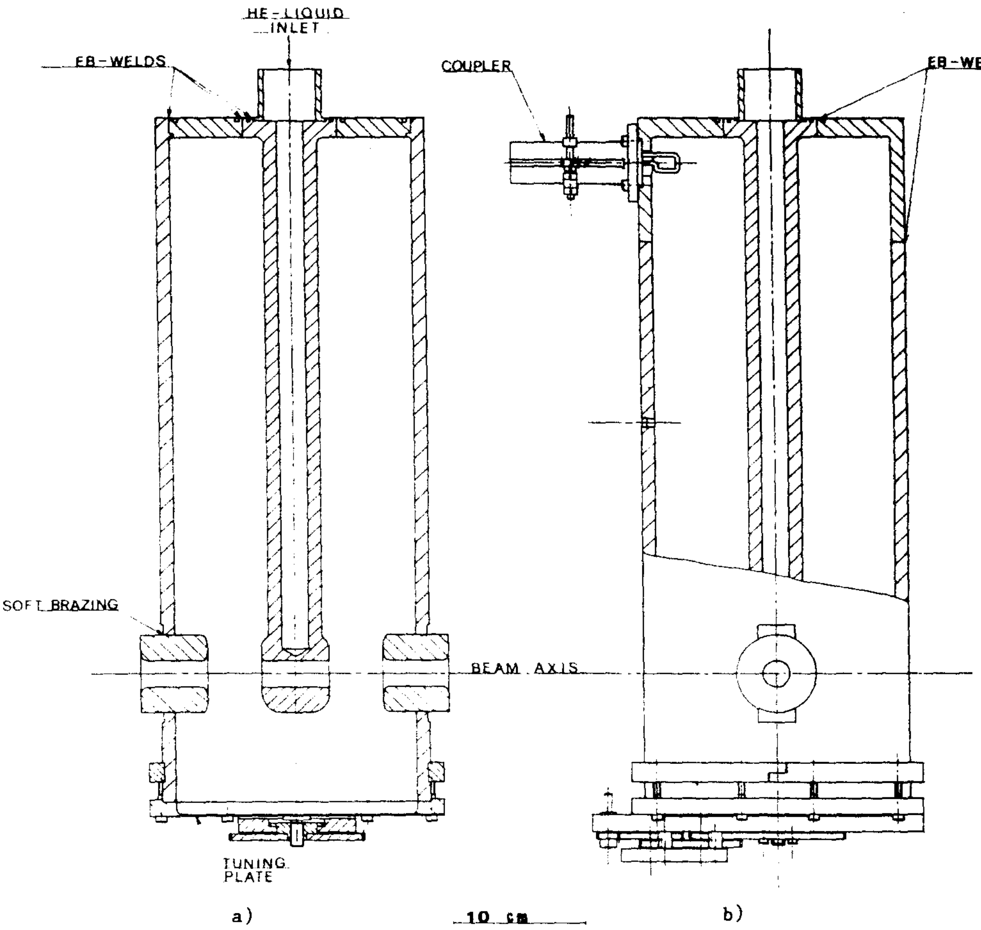

Fig. 3. - The prototype quarter-wave resonator.

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