UPGRADE OF THE TRASCO SC LINAC DESIGN @ 700 MHZ

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Abstract

We present an upgrade of the design of the high energy superconducting part of the TRASCO Linac. The RF frequency of the three section linac has been set to 704.4 MHz, in order to reduce the linac length and to benefit from the outstanding results of bulk niobium SC cavities driven by the TESLA Collaboration. The revised design takes into account the demanding linac reliability requirements, crucial for its application as a driver for a nuclear waste transmutation system. This design, that integrates the option of pulsed operation, is a step towards a common design with the French ASH project. A coordinated R&D program for the development of the major critical components has already started and the INFN part of this activity is also outlined in the following paragraphs.

1 THE TRASCO PROGRAM

The TRASCO Program for R&D activities on components of an accelerator driven system (ADS) for nuclear waste transmutation is completing its first two year phase. In this period the objectives of the studies for the high energy superconducting part of the accelerator were the experimental tests, in collaboration with CERN, of the feasibility of producing and operating a reliable high beta (β=0.85) multicell cavity based on the LEP2 sputtering technology [1,2], and the development of a sound conceptual design for a 100-1600 MeV linac at the LEP2 frequency of 352.2 MHz [3]. The program is now being extended for an additional two years period, and is being revised in order to join the European and international effort on high power proton accelerator R&D activities.

Starting from the beginning of 1999 a MOU between INFN, CEA and IN2P3 has been signed for the collaboration on the ADS driver design and on the superconducting accelerator technology development. While starting from different funded R&D programs (ASH in France and TRASCO in Italy), the very fruitful collaboration established suggested us to move rapidly in the process of converging on a common reference design, in order to take advantage of the complementary experiences and competences of the groups.

The recent proposal of a European-based collaboration group for the study of a multi-application facility based on a high power proton linac will probably give a wider perspective to our collaboration work [4].

2 THE SCALING TO 700 MHZ

The original choice of the 352.2 MHz LEP2 frequency is still an attractive option for a conservative machine ready to be built in a short time with a minor R&D effort, because all the ancillary components (klystrons, power couplers, tuners, RF controls and cryostats) exists at CERN and are compatible with the ADS linac requirements. A higher frequency (for example 704.4 Hz, twice the operation frequency of the lower parts of both the TRASCO and ASH accelerator schemes, i.e. RFQ and DTL/ISCL) will require a few years of wider R&D effort on components, but definitely gives more freedom for the choice of machine parameters and more possibilities for improvements, as driven by the ongoing worldwide R&D programs on SC cavities, that now includes SNS.

Even if our tests with CERN demonstrated the feasibility of reaching the nominal values for the high-beta cavities with the “cheap” sputtering technology, there are still unknowns on the practical feasibility of efficient low beta cavities, and mainly the machine cost estimation has motivated the convergence to the 704.4 MHz frequency of the TRASCO scheme.

On the basis of the experience gained as active subjects on the TESLA cavity development [5], more performing cavities can be realized at this frequency and they can be treated and tested in our Laboratories. Indeed, as part of the TRASCO extension, a test bench for 704.4 MHz cavities is being set up in the LASA Laboratory in Milano. This facility, that includes a clean room for the cavity assembly and a high pressure rinsing station, will be compatible with the existing facilities in CEA/Saclay, to allow exchange of test cavities. Moreover, the presently envisaged time schedule of the ADS demonstrator gives margin for the development of the ancillary components and the cryomodules.

3 SC LINAC LAYOUT

At present, different options of beam energy and current are being considered in the ADS community, and the interest for a multipurpose, pulsed, facility is growing. To take advantage of the SC linac potentialities, we decided, in collaboration with the French group, to study a modular accelerator with a final energy ranging from 1 to 2 GeV while the current has been set to 20 mA. This set of parameters represents, in this phase, a reasonable compromise between the linac efficiency, which increases with current, and the ADS actual requirements for a single user demonstration plant. This general reference choice is considered adequate for the preliminary prototyping activities.

Table 1 summarizes the main parameters for the linac layout, for the full energy of 2 GeV, assuming a starting energy of 85 MeV, that we consider as the minimal capture energy with the five-cell β=0.5 structures.

By shortening the higher beta section of the linac, where each four-cavity cryomodule gains approximately 50 MeV, any linac energy below 2 GeV can be chosen. The overall linac length will range from 320 m (1 GeV) to 500 m (2 GeV).

Table 1: Linac parameters at 2 GeV, 20 mA.

	S 1	**S 2**	**S 3**
Section β_S	0.50	0.68	0.86
Section Length [m]	84	124.2	297.5
Input Energy [MeV]	85	200	500
Focussing Period [m]	4.2	4.6	8.5
# Focussing Periods	20	27	35
Max Gain/Cavity [MeV]	3.3	6.0	11.4
Max Eacc [MV/m]	8.5	10.2	12.3
# Cells/Cavity	5	5	6
# Cavities/Section	40	54	140
# Cavities/Cryomodule	2	2	4
# Cryomodule/Klystron	1	1	1
Max RF/Coupler [kW]	66	120	228

The beam dynamics studies of the linac are under investigation both at CEA/Saclay and Milano with the codes available to the collaboration [6, 7]. Separate contributions to these Proceedings will discuss the simulation activities [8, 9].

4 SC CAVITIES DESIGN

One of the first necessary steps for the definition of the common design was to set the geometries of the 704.4 MHz superconducting cavities, in order to maximize the benefits of the prototype production foreseen by the two national programs.

A description of the guidelines and the tools used for the cavity design can be found in Ref. [10] and in a separate contribution to these Proceedings [11], it is however worth to summarize the main guidelines in the following:

- The energy range will be covered with three sections.
- The transition energies for the three sections have been loosely set to 85, 200 and 500 MeV.
- The number of modules in each section has been derived using a conservative value of 50 mT for the peak surface magnetic field.
- The number of cells per cavity has been chosen to be 5 in the two lowest beta sections and 6 in the highest beta section.

5 ACTIVITIES ON PROTOTYPES

The TRASCO program involves industrial partners for the developments of prototypes of the accelerator components. The Italian company Zanon, which is fabricating all the cryomodules and part of the niobium cavities for the TESLA Test Facility (TTF), will deliver the first prototype β=0.5 single cell cavity (with low grade RRR=50 niobium) by the end of June 2000. The niobium half-cells have already been drawn (see Fig.1), the tooling has been already fabricated and the cavity is being welded. This cavity will be chemically treated and tested in Saclay, and used to qualify the cavity test bench in Milano (see Fig. 2) by Fall 2000. A scaled (1400 MHz) single cell model, shown in Fig. 1, has been welded and is under test in Genova.

Figure 1. A 700 MHz beta=0.5 niobium half-cell deep drawn by Zanon, ready for welding, and a scaled (one half) single cell cavity.

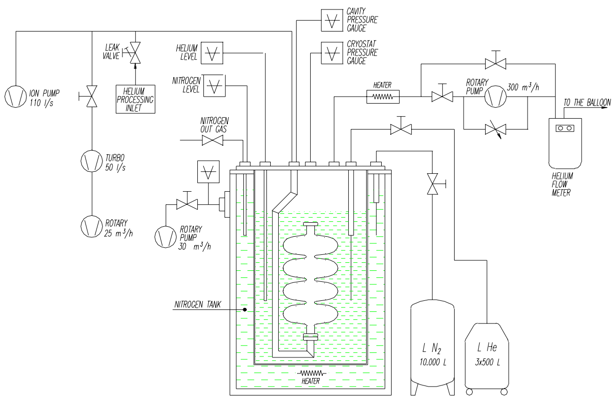

Figure 2. Block diagram of the RF test facility being set-up in LASA.

We have planned to produce additional single and two-cell cavities, including stiffening rings, to set the cavity fabrication technology. A complete five-cell cavity with high quality niobium is planned as conclusion of this prototyping activity.

A conceptual design of the linac cryomodules has been investigated, on the basis of the guidelines described in a separate contribution to these Proceedings [12]. The design is based on the TTF experience, with some modifications imposed by the typical ADS requirements.

6 OTHER R&D ACTIVITIES

While our cavity design is fully consistent with CW operation, as the TRASCO and ASH designs, in the case of the proposed pulsed operation for a multipurpose machine [4], the Lorentz force detuning coefficient of the lowest beta cavity is probably too high [11]. As for TESLA [5], an improvement of this crucial parameter is strictly related to the machine cost because of the impact on the RF power distribution and the low level RF controls.

Along the path set by the French colleagues in Orsay [13], and in the framework of the MOU between INFN, CEA and IN2P3, in collaboration with the CESI laboratories in Milano we are studying and analysing the thermal and mechanical characteristics of bimetallic niobium-copper samples produced with different deposition techniques and thermal treatments. The sample thermal conductivity (parallel and normal to the deposition direction) has been tested at room and at cryogenic temperatures. Values as high as 238 W/m·K @ 77 K have been measured on samples produced with a modified arc technique, called "Pure-Coat". This result is very promising because, in principle, it could provide enough conductivity, at least for the proton cavity parameters.

The mechanical properties (Interface cohesion, Young modulus, yield stress and elongation) have been measured using different techniques (pull out, four point bending, Brinnel hardness test, thermal shock). The Young modulus and yield stress (21 GPa and 130 MPa, respectively) of the last samples are compatible with the required stiffening material specifications. The initial problem of an extreme brittleness of the deposited copper, showing an elongation before rupture of less than 0.2%, is being solved through a well-calibrated heat treatment under vacuum. A value of 2% has already been measured on the treated samples.

The technological analyses are crosschecked with physical tests (SEM, Auger and XPS), to obtain a correlation between the material structure, its composition and the physical behaviour [14]. The results of the analysis are fed back for the optimisation of the deposition procedures and of the surface treatments [15].

7 CONCLUSIONS

The TRASCO program ended its first phase, aimed at the demonstration of the feasibility of an ADS driver based on the "cheap" LEP2 niobium sputtered on copper technology. A two years extension of the program has just started, focussed on a 700 MHz solution, studied in collaboration with CEA/Saclay and IN2P3/Orsay. An RF test bench for 700 MHz cavities is being set-up in Milano and an R&D activity on prototypes is in progress.

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