The TRASCO Project

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Abstract. TRASCO is a joint INFN/ENEA program, started in 1998, aiming at the design and the technological investigation of the main components of an accelerator driven system (ADS) for nuclear waste transmutation. The proposed 30 mA, 1 GeV, proton linac (TRASCO-AC) is briefly outlined, together with the ongoing R&D work on several key components.

INTRODUCTION

The disposal of radioactive waste represents a problem that is not yet fully solved, especially in terms of environmental and social acceptability. By using partitioning and transmutation technologies the most hazardous materials could be separated (partitioning) from the nuclear wastes and, then, converted to shorter-lived elements (transmutation). Transuranic elements would be transmuted by fission and Fission Products by neutron capture and beta decay.

Accelerator Driven Systems (ADS) are generally believed to be particularly suited for assessing the transmutation of nuclear waste and have become a major R&D topic in Europe [1].

Important ADS activities are also going on or are being planned outside Europe e.g., in Japan (the JAERI/KEK Joint Project), in USA (the AAA project) and in Korea (the KOMAC Project).

TRASCO PROGRAM OUTLINE

On the basis of a growing interest on the ADS concepts in Italy, the basic R&D program TRASCO has been funded in 1998 by the Ministry of the University, Scientific and Technological Research, and has been followed by an industrial program, in which major Italian research institutions and industries are involved [2]. TRASCO aims to study the physics and to develop the technologies needed to design an ADS for nuclear waste transmutation.

The TRASCO program consists of two main parts, regarding, respectively, the accelerator and the sub-critical system. The first part falls under the competencies of INFN and the second under those of ENEA, which are the two institutions jointly responsible of the TRASCO activities, which include also Italian industrial partners.

The program covers all the main subsystems of an ADS (accelerator, window/target, sub-critical reactor). However, due to the limited available financial resources, all the efforts are concentrated on starting a few significant and qualified experimental activities, in view of the goal of a future participation in an International project dedicated to the study and construction of an ADS prototype, like, for example, the PDS-XADS program of the 5th framework programme of the European Commission.

Reference Accelerator Parameters

The TRASCO accelerator program [2] is focussed on the conceptual design and the realization of prototypical components for a 30 MW (1 GeV, 30 mA) CW proton linear accelerator, which is the candidate for an industrial size transmuter with a thermal power in the range of 1500 MW.

The coupling of the accelerator with the subcritical system leads to rather tight requirements on the accelerator reliability and availability. This reliability issue therefore is at the base of the linac design, leading to conservative choices on all components with respect to the "state of the art" technologies, and to an appropriate amount of redundancy in the system, in order to increase the tolerance to component faults and to achieve beam delivery to the target in the presence of faulty components, in the time between regularly scheduled maintenance periods.

General layout

The linac consists in a microwave discharge proton source, operating at 80 kV, capable of providing 35 mA of CW proton beam, followed by a 352.2 MHz RFQ up to 5 MeV. A 352.2 MHz superconducting linac with independently phased resonators brings the energy to approximately 100 MeV, and the beam is finally brought to the nominal energy of 1 GeV by a

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three section superconducting linac that uses multicell elliptical cavities at 704.4 MHz.

The main objectives of the TRASCO program are:

- The conceptual design of the whole linac;
- The design and construction of the proton source and of the RFQ pre-accelerator;
- The design, construction and test of prototypes of the superconducting cavities, mainly for the high-energy linac.

A schematic layout of the TRASCO linac is presented in Figure 1.

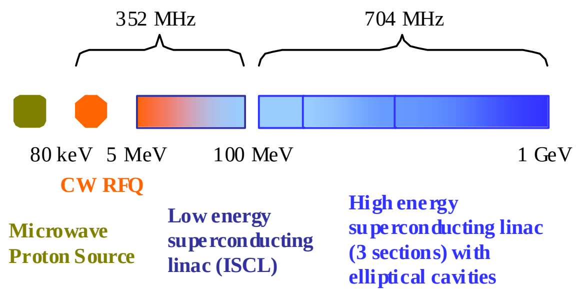

FIGURE 1. The schematic layout of the TRASCO linac.

In the following sections the status of the design of the components of the TRASCO linac will be outlined, together with the R&D ongoing activities.

TRIPS: TRASCO Intense Proton Source

High intensity proton sources of several tens of mA already exist but additional R&D efforts are still necessary for ensuring the availability and reliability required by the ADS system. TRIPS design is based on the principle of microwave discharge, off-resonance, and it is a modified version of the source SILHI operating at CEA/Saclay since several years.

With respect to that source some things have been changed and some new features have been added. Mainly the efforts have been concentrated on the design of a new extraction system with the aim to increase the source availability and reliability, in order to meet the requirement of a driver for an ADS system.

RFQ and low energy linac

The TRASCO RFQ has been designed with the constraints of low beam losses (less than 4%), the use of a single LEP type klystron (1.3 MW nominal power) and a Kilpatrick factor of 1.8 (corresponding to a 33 MV/m surface electric field). Table 1 summarizes the main parameters of the TRASCO RFQ.

The RF structure is split in three resonantly coupled segments (similar to the LEDA design). The vane tips have a fixed transverse radius of 2.93 mm, and the vane voltage is kept constant along the structure, to reduce power dissipation. A cold 3 m aluminium model has been built and has demonstrated the capability of field stabilization. Tests of the fabrication technology have been performed on a short model and the full RFQ structure is now under fabrication.

TABLE 1. TRASCO RFQ Parameters.

Beam Current	30	mA
Beam Emittance	0.2 π	mm mrad
Output Energy	5	MeV
Total Length	7.13	m
RF Input Power	850	kW
Peak Electric Field	33	MV/m

For the low energy linac several options have been investigated: a normal conducting DTL, and a few superconducting linac options based on different types of independently phased resonators (single gap reentrant cavities, half wave resonators and more recently spoke cavities, with one or two spokes).

The choice of a superconducting linac with independently phased cavities seems the most attractive both in terms of power consumption and in terms of reliability. Spoke cavities can allow a large beam aperture and can be divided in few families, as done for the elliptical cavities in the high energy part

The high energy linac

From energy of about 100 MeV the technology of elliptical superconducting cavities represents the most efficient and cost effective one to accelerate the beam to higher energies. The RF frequency has been set to 704.4 MHz (twice that of the RFQ and low energy linac) to use the bulk Nb technology for cavity fabrication, which can now guarantees outstanding performances, thank to the work done in the past years in the framework of the TESLA/TTF Collaboration. In order to cover the desired energy range (from ~100 MeV to 1 GeV), three different linac sections are required and sufficient, with the cavity betas set respectively to the values of: 0.47, 0.65 and 0.85. These beta choices, while efficient, leave a large margin for energy ugrade (ut to 2 GeV). Table 2 summarizes the main parameters of the three sections.

TABLE 2. TRASCO 704.4 MHz SC Linac Params.

Section #	1	2	3
Section Geometrical β_g	0.47	0.65	0.85
Input Energy [MeV]	90	190	480
Output Energy [MeV]	190	480	1000
Lattice Period [m]	4.2	5.8	8.5
# Lattice Periods	14	16	12
# Cells/Cavity	5	5	6
Cavity Eacc [MV/m]	8.5	10.3	12.3
# Cavities/Cryomodule	2	3	4

A set of multicell cavities for all three linac sections has been designed, taking into account both the optimization of electromagnetic performances (in terms of peak fields on the surface) and mechanical performances (stability under vacuum load, stiffness for microphonics and Lorentz forces excitation). Conservative values with respect to the state of the art technology of the TTF cavities have been used in terms of maximum peak design electrical and magnetic fields on the surface (set to < 30 MV/m and < 50 mT), in order to increase the reliability of the proposed technology.

Beam dynamics analysis and simulations

The whole linac has been designed using high current beam dynamics criteria aimed at minimizing the occurrence of beam emittance growth and particle losses. In particular structure and tune resonances, and strong tune depression, have been avoided in the design and a smooth variation of all linac parameters has been guaranteed. Proper adiabatic matching procedures, have been developed and employed at the section interfaces [4]. The validity of the design has been assessed by means of multiparticle simulations with standard beam dynamics codes.

R&D ON LINAC COMPONENTS

In addition to delivering a conceptual design report for an ADS driver, the TRASCO program foresees the realization of prototypical activities on critical components of each section of the proposed linac. The most representative examples of these activities are described in the following paragraphs. More information on the status of the different components can be found in [4] and in the references there quoted.

TRIPS operation

The TRIPS source has been assembled in LNS-Catania in May 2000, commissioned in January 2001 with a 20 mA beam at 60 kV and finally achieved 55 mA of beam current with 90% of proton fraction during beam tests in August 2001 [4].

Fabrication of the TRASCO RFQ

The RFQ design has been engineered, in collaboration with the industrial partners and the full structure is now in the fabrication stage [4]. Special attention during the design has been dedicated to the optimisation of the cooling channels.

SC cavities for the high energy linac

A single gap SC re-entrant cavity (at the 352.2 Mhz frequency) has been designed and manufactured. A report of the performances obtained is found in ref [4].

A total of four β=0.47 single cell cavities have been built with the TRASCO industrial partners, two of which using low grade niobium sheets (RRR>30) and two using high purity sheets (RRR>250). The vertical tests were very successful in all four cases. Both the cavities produced with low quality, and cheap, niobium exceeded the design parameters, showing a hard quench at an accelerating field value of 10-11 MV/m. The best of the other two cavities (Z104) reached the record accelerating field of 22 MV/m, the Q staying above 10^{10} up to > 20 MV/m. The other (Z103) was limited to 20 MV/m by field emission.

In Figire 2 the test results on the two best cavities are presented, showing also the corresponding values of the peak electric and magnetic fields. Treatments and tests were performed at TJNAF and CEA-Saclay.

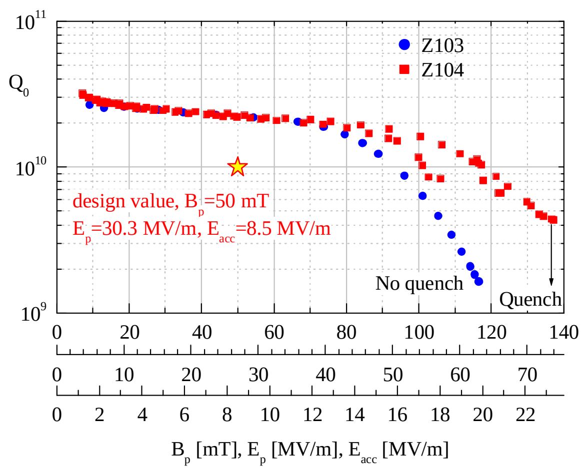

FIGURE 2: RF tests of the Z103 and Z104 cavities, made with high quality niobium (RRR > 250).

On the basis of this experience the construction of two complete five cell cavities has been launched. A more complete description is given in ref [4].

REFERENCES

[1] EU Tech. Working Group on ADS, "A European Roadmap for Developing Accelerator Driven Systems (ADS) for Nuclear Waste Incineration", April 2002, http://www.neutron.kth.se/TWG22/default/index.html.

[2] TRASCO Partners for the accelerator program are: INFN and the Italian companies HITEC, CINEL, Saes Getters, CESI and ZANON.

[3] The TRASCO_AC Group, "Status of the High Current Proton Accelerator for the TRASCO Program", INFN Report INFN/TC-00/23, December 2000, available from http://wwwsis.lnf.infn.it/pub/INFN-TC-00-23.pdf.

[4] Papers THBLA002, TUPLE121, WEPLE109, THPDO022, THPDO023, THPLE083 are being presented at EPAC2002 and will be in its Proceedings.