STATUS OF RF SUPERCONDUCTIVITY WORK AT CERN — LABORATORY TALK

W. Weingarten for the
superconductivity community at CERN[1]

Seventh Workshop on RF Superconductivity in Paris, October 1995

Abstract:
The main effort at CERN is concentrated towards three goals: the completion of the LEP2 upgrade energy programme, preparatory work for the future LHC SC cavities, and a deeper understanding of the physics of the niobium film.

I. INTRODUCTION

A development of superconducting (sc) cavities for more than 15 years bears its fruits with the gradual increase of the beam energy in LEP. The technique is based on thin niobium films on a copper substrate. The main advantage is a large reduction of the risk suffering from at thermal quench - particularly important in the harsh environment of a large electron accelerator. On the other hand, the Q-value of these cavities decreases faster with the RF power than with conventional niobium sheet cavities.

To obtain the largest energy possible and in view of future linear colliders it is worthwhile to exploit the big potential offered by this technology. Therefore, an R&D program to understand the physics of the coating has caught up speed again.

II. LEP2 UPGRADE PROGRAM

The LEP2 upgrade programme aims at a beam energy of about 91 GeV. The actual record energy is 70 GeV per beam and 68 GeV for physics.

The majority of the SC cavities (224) are of the Nb/Cu type. The present status is the following: 35 cryo-modules, each consisting of four individual four-cell cavities, are delivered and accepted. The average Q-value at 6 MV/m is $3.6 \cdot 10^9$, measured before the installation of the HOM and power couplers (Fig. 1). In total 15 modules are installed in

1
M. Barranco-Luque, C. Benvenuti, D. Bloess, D. Boussard, G. Bressani, P. Brown, O. C. Brunner, S. Calatroni, G. Cavallari, E. Chiaveri, E. Ciapala, R. Cosso, P. Darriulat, C. Durand, W. Erdt, K. Geissler, G. Geschonke, D. Güsewell, E. Haebel, C. Hauviller, N. Hilleret, H.P. Kindermann, D. Lacarrère, M. Marino, H. Nakai[1)], G. Passardi, E. Peschardt, J.M. Rieubland, V. Rödel, R. Russo, K. Schirm, M. Stirbet[2)], M. Taufer, J. Tischhauser, J. Tückmantel, J. Uythoven, V. Veshcherevich[3)], H. Wahl, W. Weingarten, C. Wyss — CERN, European Organization for Nuclear Research, 1211 Geneva 23, Switzerland -
[1)] Visitor from KEK, Tsukuba, Japan.
[2)] Visitor from Institute of Atomic Physics, Bucharest, Romania.
[3)] Visitor from Budker Institute of Nuclear Physics, Novosibirsk, Russia.

LEP (14 of the NbCu type), and have been running at or very close to their nominal field (6 MV/m) and with beam currents up to 7 mA.

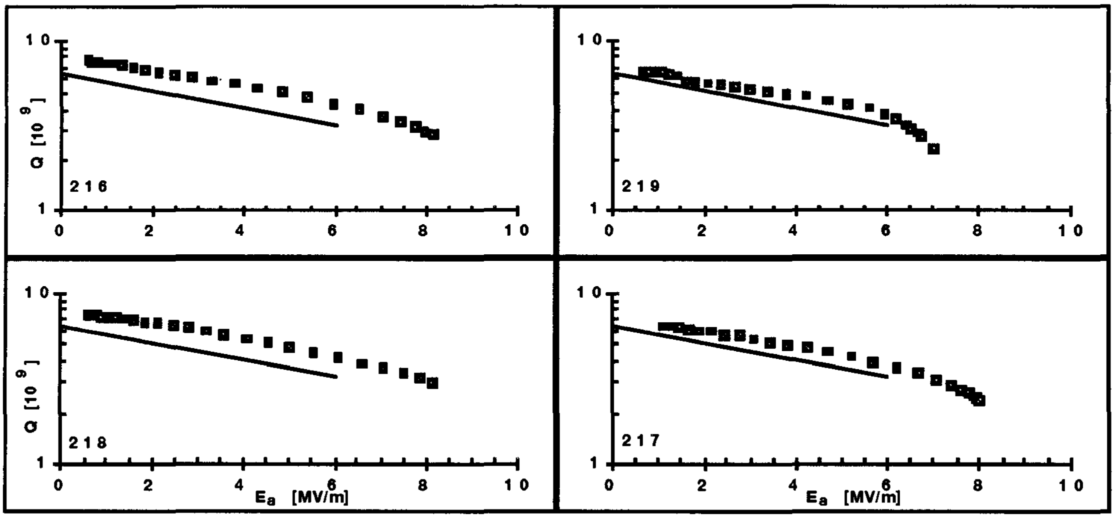

Fig. 1: Typical performance of the four NbCu cavities after assembly to a cryo-module (power coupler and HOM couplers not yet mounted). The gradient is limited by the available RF power.

Problems encountered in the past during operation, such as discharges in the power couplers and RF amplitude modulations observed above 4 MV/m accelerating gradient, have been analyzed and solutions have been found. The origin of the discharges was found in one-side electron multipactoring in the coaxial extension located between the warm RF window and the cold cavity. It is suppressed by imposing a DC voltage between central and outer conductor. The amplitude variations are the result of cryogenic fluctuations or ponderomotive instability at the mechanical cavity resonances. Their effect could be minimized by tuning the resonant frequency of the cavity nearer to the RF klystron frequency at a (modest) expense of more RF power.

Power couplers have been tested up to 280 kW in transmission.

The production in industry of the cavities and modules is proceeding smoothly. More than 170 individual cavities have been received and are within the specified performance ($Q = 4 \cdot 10^9$ at 6 MV/m and 4.2 K). The success rate for the first coating increased from about 20 % in the initial phase of the project to 70 % today, mainly due to modifications in the copper substrate treatment and sputtering conditions.

Modifications in the HOM and power coupler designs have been developed to cope with the more demanding operation conditions (increased beam intensity).

Four LEP type cavities are installed in the SPS ring (5 MV/m in routine operation and pulsed mode). The injection energy into LEP has been increased from 20 to 22 GeV.

III. SC CAVITIES FOR THE LARGE HADRON COLLIDER

Single cell 400 MHz copper cavities with an Nb film have been developed as preliminary prototypes for the LHC RF system. One cavity is installed in the SPS accelerator (Fig. 2) and has been tested with beam for the first time last October. It operated with a circulating proton current of about 60 mA, at half its design field of 5 MV/m. Present limitations come from the sophisticated beam manipulations necessary to bring the beam frequency close to the cavity resonance, but not from the cavity performance.

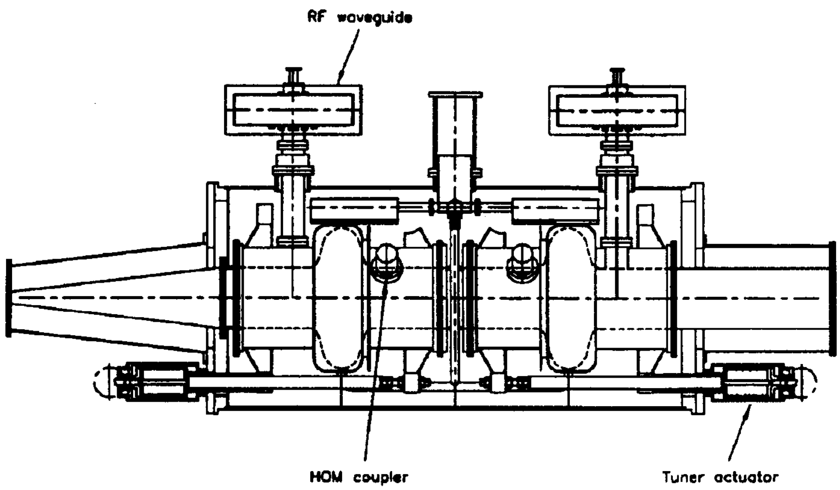

Fig. 2: Schematic layout of sc mono-cell cavities for the Large Hadron Collider LHC.

IV. THE PHYSICS OF THE NIOBIUM LAYER

The 1500 MHz cavity program launched some years ago brought its first conclusions. The study aimed at the more than quadratically growing losses with RF amplitude. Evidence is increasing that magnetic flux penetration into the surface is the cause.

Nevertheless, technical improvements are not yet in sight. Therefore, the physics of the niobium layer is being studied with emphasis on impurities and grain size. Coating process parameters such as layer thickness, noble gas mixture, coating temperature, substrate treatment and cathode pre-cleaning are studied, as well as new fabrication techniques (galvanoplastic forming) for the copper substrate. A Laser gun for post-annealing of the niobium layer is under construction.

Experimental tools to qualify the coating and the substrate are available or under development: RF tests on cavities in the 350 to 3 GHz frequency range, optical and scanning Auger inspection of cavities and low frequency low temperature RF tests of the bare copper cavity (in coaxial set-up) for impurity analysis. Cavity tests are backed up with sample tests: RF (triaxial cavity), SEM, SIMS, TEM, scanning Auger, RRR, T_c and AFM analysis.