Development and Fabrication of Superconducting Accelerator Modules and Systems

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I Introduction

Since more than 12 years the Accelerator and Magnet Technology Division of Interatom which has been incorporated into the Siemens AG on October 1, 1991 is working in the field of RF-superconductivity.

In the following an overview of projects and R&D work in the field of s. c. accelerator technology is given. These activities are carried out at Siemens by about 20 physicists/engineers and about 100 employees from our manufacturing department.

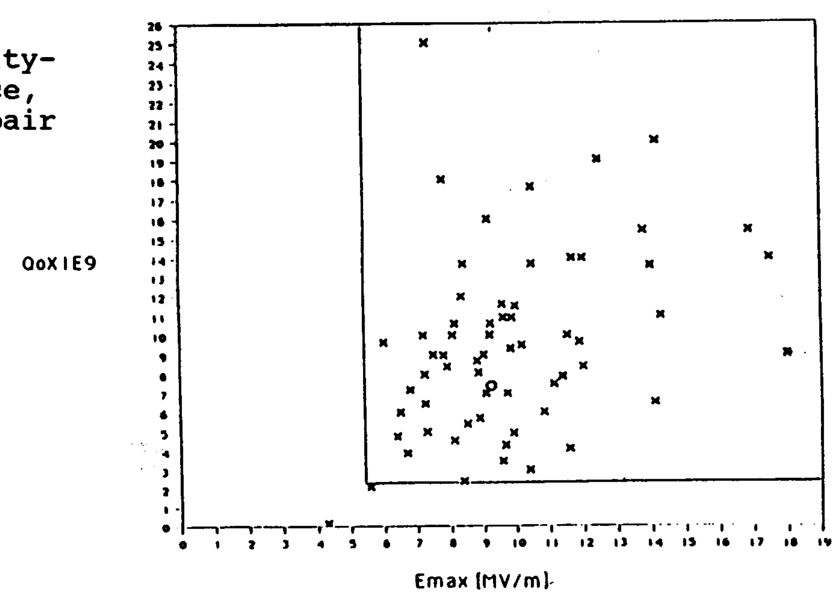
II Superconducting accelerator projects

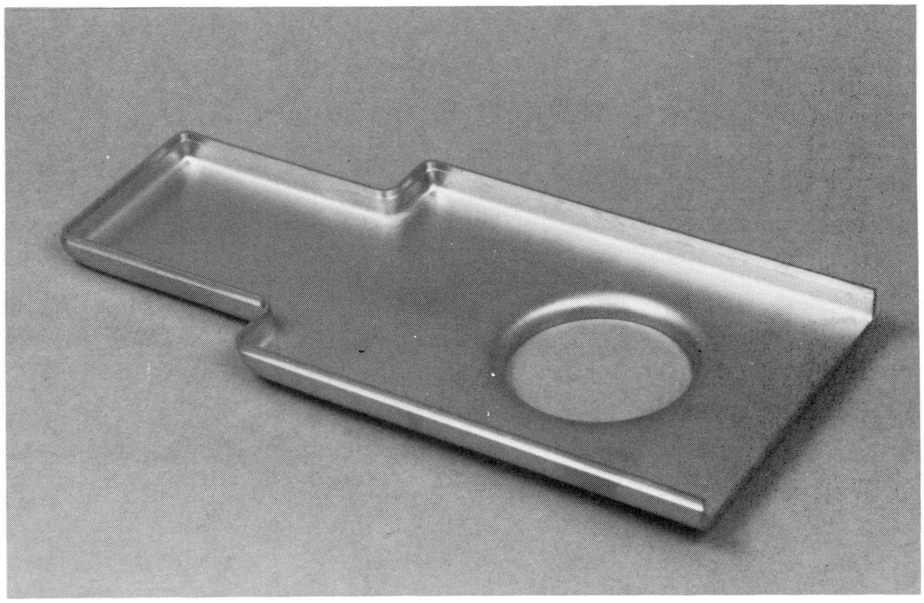
II.1 CEBAF: 360 1.5 GHz, 5-cell niobium cavities

Supplying all 360 Niobium cavities for CEBAF we now have delivered more than 180 Cavities about 40 of them having been tested and showing results exceeding the specification. Figure 1 shows the results achieved so far for the tested cavities. Maximum field values are 18 MV/m and the mean value of accelerating field is about 10 MV/m. [1]

During the start-up of fabrication intense development in deep drawing technique has been performed resulting in larger deep drawn pieces for the cavity couplers thus reducing the number of welding seams (see Figure 2).

Fig. 1
CEBAF cavity-performance, vertical pair tests [1]





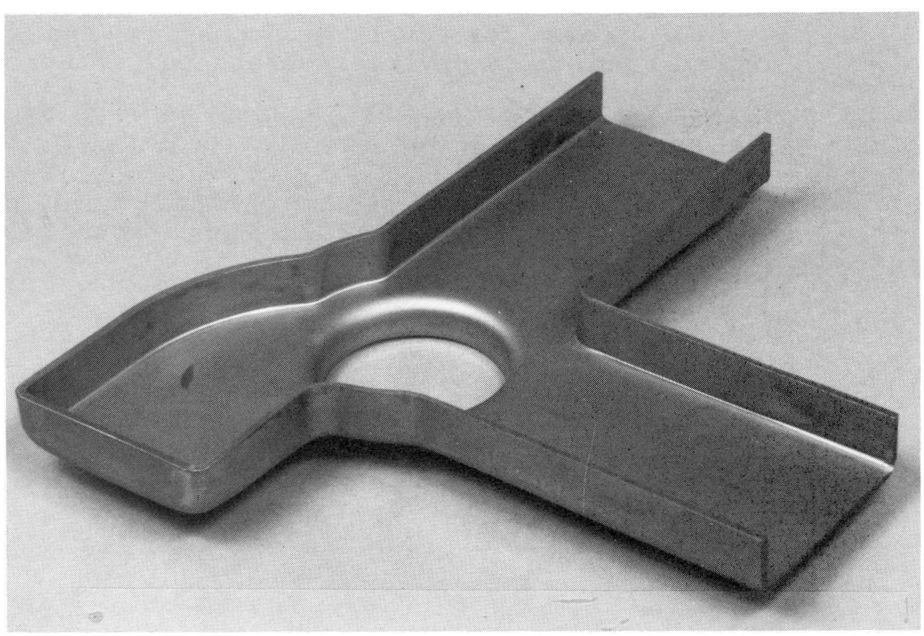


Fig. 2
Parts of the main coupler waveguide (upper photo) and the HOM waveguide (lower photo) deepdrawn from Niobium sheets

II.2 CERN: 52 Superconducting Accelerator Modules for CERN in Niobium Sputter Technique

CERN has subcontracted with Siemens the production of 52 complete superconducting Accelerator Modules. The 350 MHz 4-cell cavities are fabricated from copper and afterwards coated with a thin (~ 1μm) Niobium layer inside. [2, 3]

In order to apply this technology of cavity manufacture an intense cooperation and technology transfer is established between CERN and Siemens.

Since January 1991 all the special equipment necessary to do the manufacturing steps have been installed and are ready for operation since July 1991.

These equipments are:

- special electron beam welding gun to perform welding of Cu-cavities from inside
- dedicated automatized system to perform degreasing and chemical polishing of the complete cavities before coating
- UHV system and power supplies for magnetron sputtering
- clean rooms for dustfree mounting and ultrapure water rinsing of cavities before and after coating
- clean areas for final assembly of complete modules are under preparation.

As of today all necessary installations for the production have been established and tested.

Coatings have been performed by

- Coating samples in a special cavity (for details of the results see figure 3 and table 1).

- The very first chemically processing and coating of a complete cavity (350 MHz 4 cell cavity) fabricated by CERN. The results obtained are: Starting with $Q > 8 \cdot 10^9$ at low field ($E_{acc} \approx 0{,}1$ MV/m) the Q dropped due to a blister. The field was limited by electron loading at about 4 MV/m. RF or He-Processing was not performed.

- Chemically processing and coating of the first complete cavity fabricated by Siemens.

Table 1
Results of samples which are coated inside a 350 MHz 4-cell cavity

Location	RRR value measured		/ expected	Thickness (μm) measured
Cut-off tube upper side	8,1		< 10	0,7
Cell 1	13.0	15.0	14 - 18	1.43
Cell 2	16.3	14.9	14 - 18	1.24
Cell 3	17.8	17.2	14 - 18	1.24
Cell 4	14.1	13.3	14 - 18	1.28

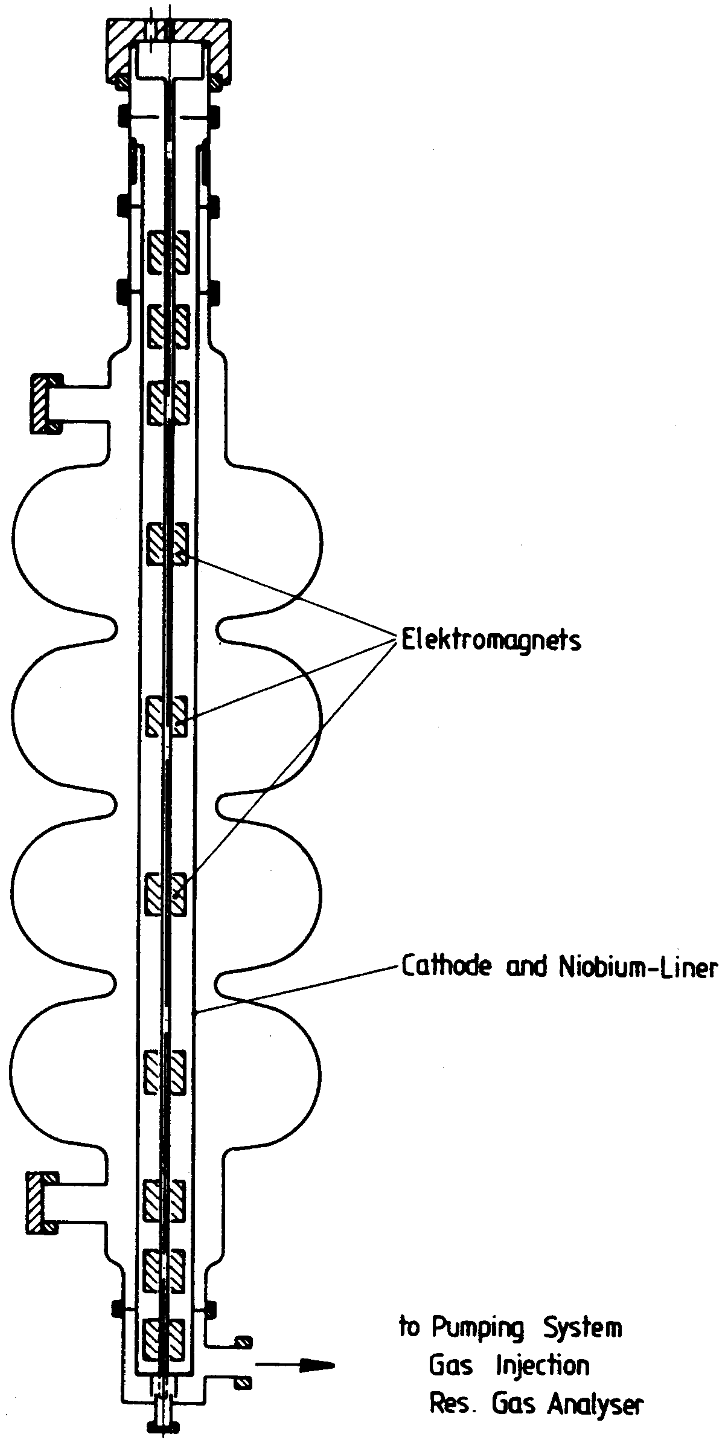


Fig. 3
Schematic view of the 4-cell cavity with the Nb-cathode inside the cavity and the arrangements of the magnets

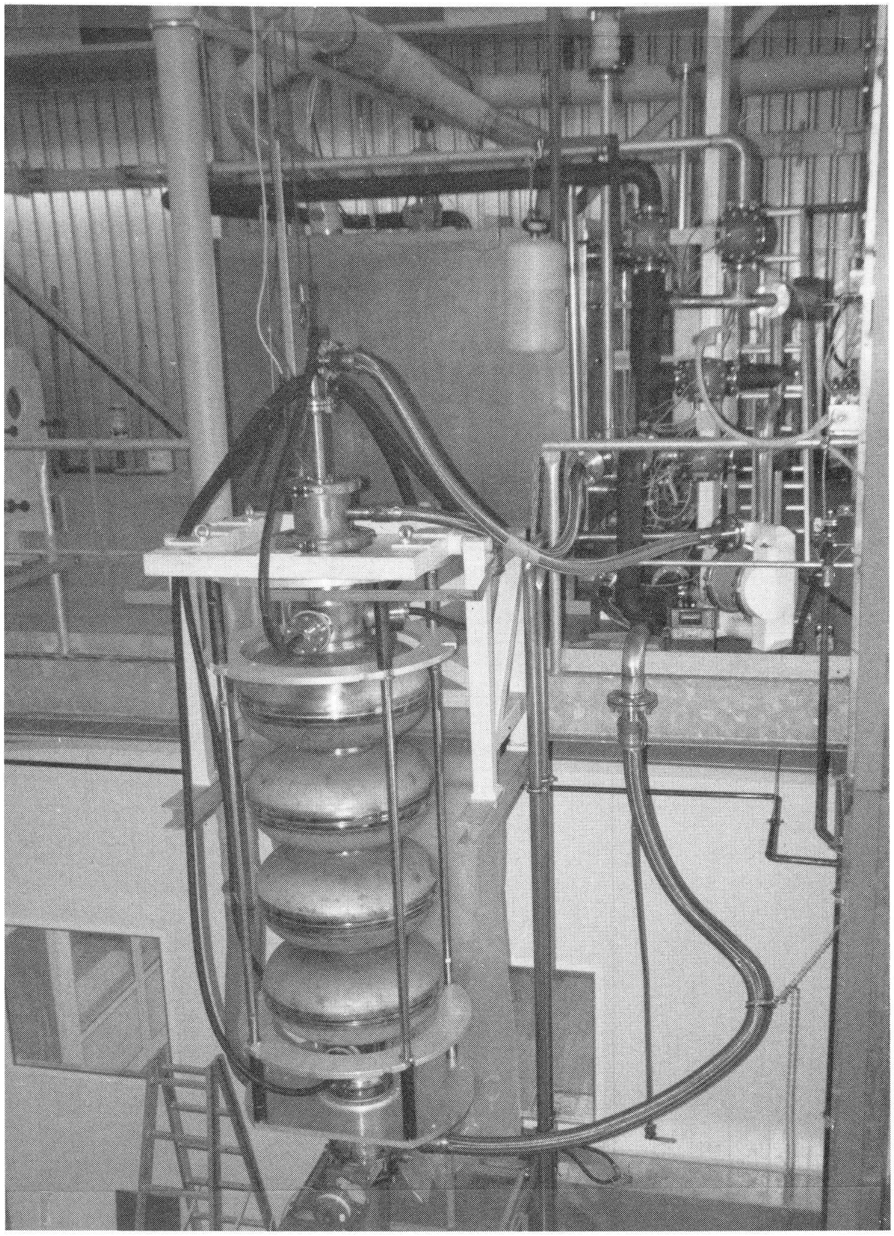


Fig. 4
CERN 350 MHz 4-cell cavity assembled and connected ready for chemical processing

II.3 INFN: 4 complete superconducting Accelerator Modules for LISA

We have delivered the 4 completely tested 500 MHz 4 cell Accelerator Modules to INFN. All cavities have been tested at Siemens and have exceeded the design field (5 MV/m). The quality factor is still below design value due to electron loading. RF processing was performed only to a small extend due to the limited refrigerating power presently available at our test area. In the meanwhile the modules have been put into place at INFN. RF processing will be done with the cooling capacity of the refrigerator available. Figure 5 shows the 4 modules aligned in the Linac hall.

No. of Module	Max. accelerating field, limited by field emission loading MV/m	Quality factor at 5 MV/m 10^9	Remark
1	5,8	1,1	Q_o dominated by electron field emission loading
2	6,1	1,5	
3	5,9	0,6	
4	5,3	1,0	

Table 2
Results of the 4 accelerator modules for LISA before processing at INFN

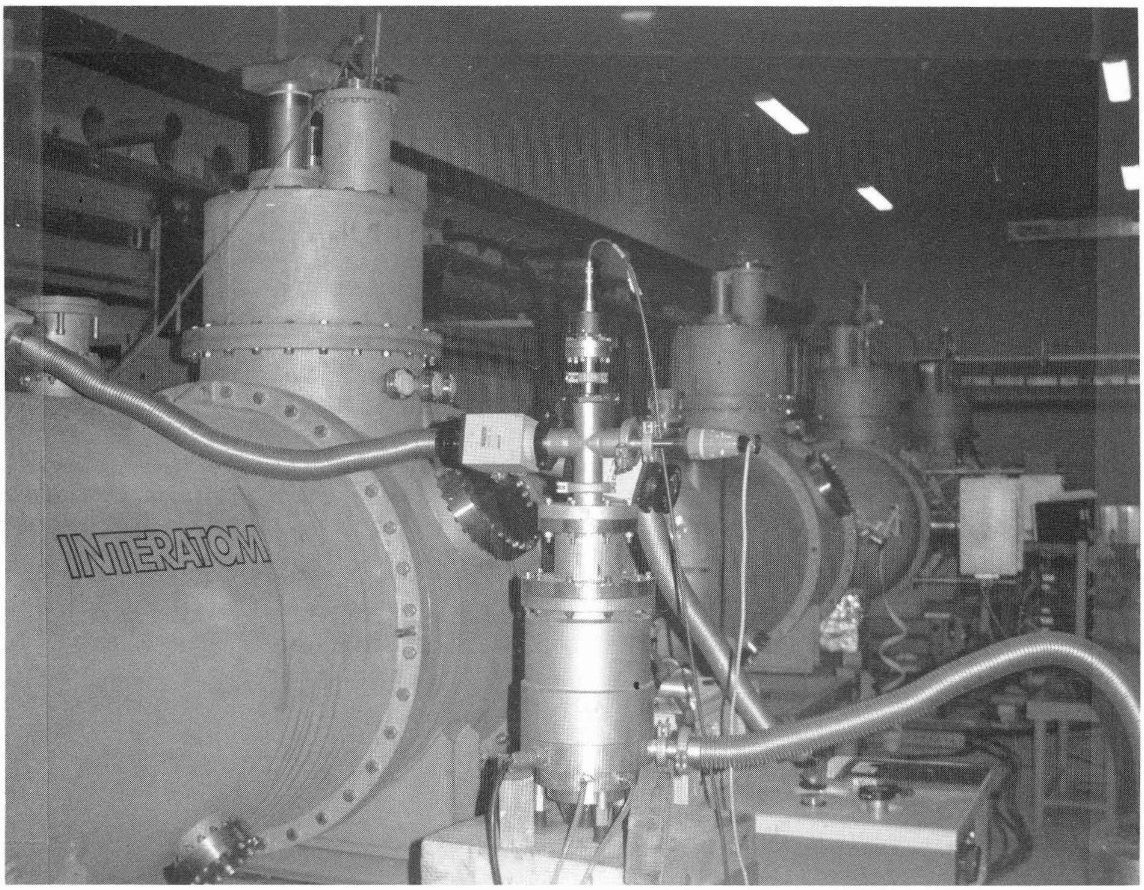


Fig. 5
The 4 accelerator Modules assembled in the linac hall
before connection of cryogenic and rf lines

II.4 Los Alamos: The scruncher, a 402 MHz pipe cooled single cell Accelerator Module

A single cell 402 MHz pipe cooled accelerator module was developed and delivered for Los Alamos to be used for manipulating the longitudinal phase space of a pion beam [4].

The special features of this cavity are:

- fabricated from explosion bonded Niobium-copper-sandwich [5] with cooling pipes attached to the outer surface allowing for gravitional as well as forced flow LHe-cooling
- a new developed variable high power coupler allowing to adjust Q_{ext} for 3 decades (see figure 6)
- the application of a piezo-electric fine tuning system

The cavity with all its subsystems has been developed, fabricated, assembled, and tested at Siemens. In the initial test the cavity quality factor was dominated by electron loading. After transportation to LANL the cavity could be processed to reach the design values ($2 \cdot 10^9$ at 5 MV/m) and has since beginning of 1990 served many runs of experiments.

After cleaning following an accidental spoiling the cavity even showed improved results (see figure 7)

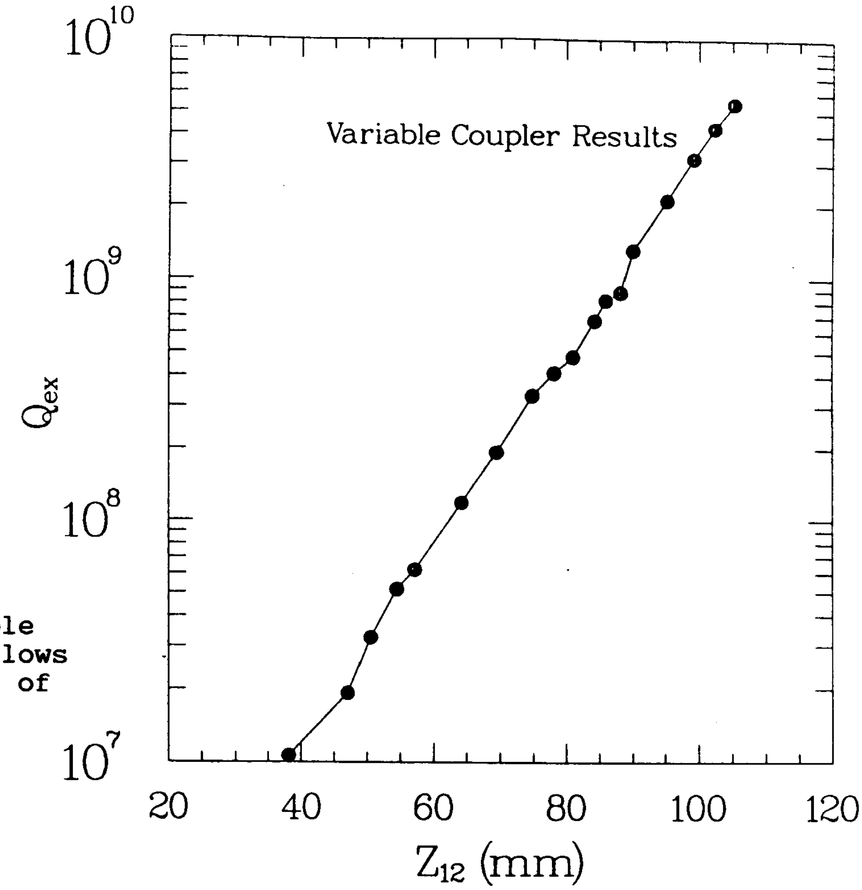


Fig. 6
The variable coupler allows adjustment of Q_{ext} by 3 decades

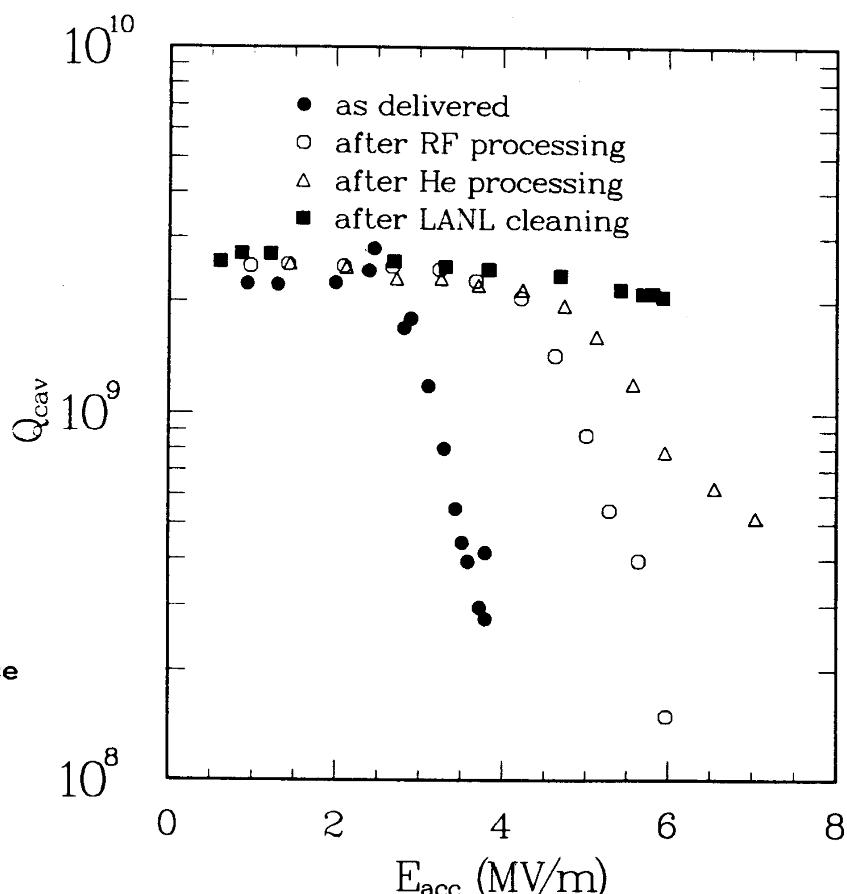


Fig. 7
Performance of the scruncher cavity

II.5 JAERI: 4 complete 500 MHz s. c. Module for a Free Electron Laser

For the JAERI Free Electron Laser Experiment the 4 Accelerator Modules (2 single cell 2 five cell 500 MHz Modules) will be delivered by Siemens by the end of 1992.

The design phase has been finished. Special effort has been undertaken to develop a variable High-Power-Coupler for 500 MHz cavities and to minimize the standby losses of the cryostat. In the JAERI FEL operation mode the cavities will be driven with a 1 - 2 % duty cycle thus having low cryogenic rf losses compared to the standby losses of the cryostat. Special care was given therefore to the cryogenic design. The cryostats have a duplex heat shield and are operated individually by closed loop refrigerators both for heat shield cooling (80 K, 20 K) and liquid Helium (4.5 K) (see figure 8).

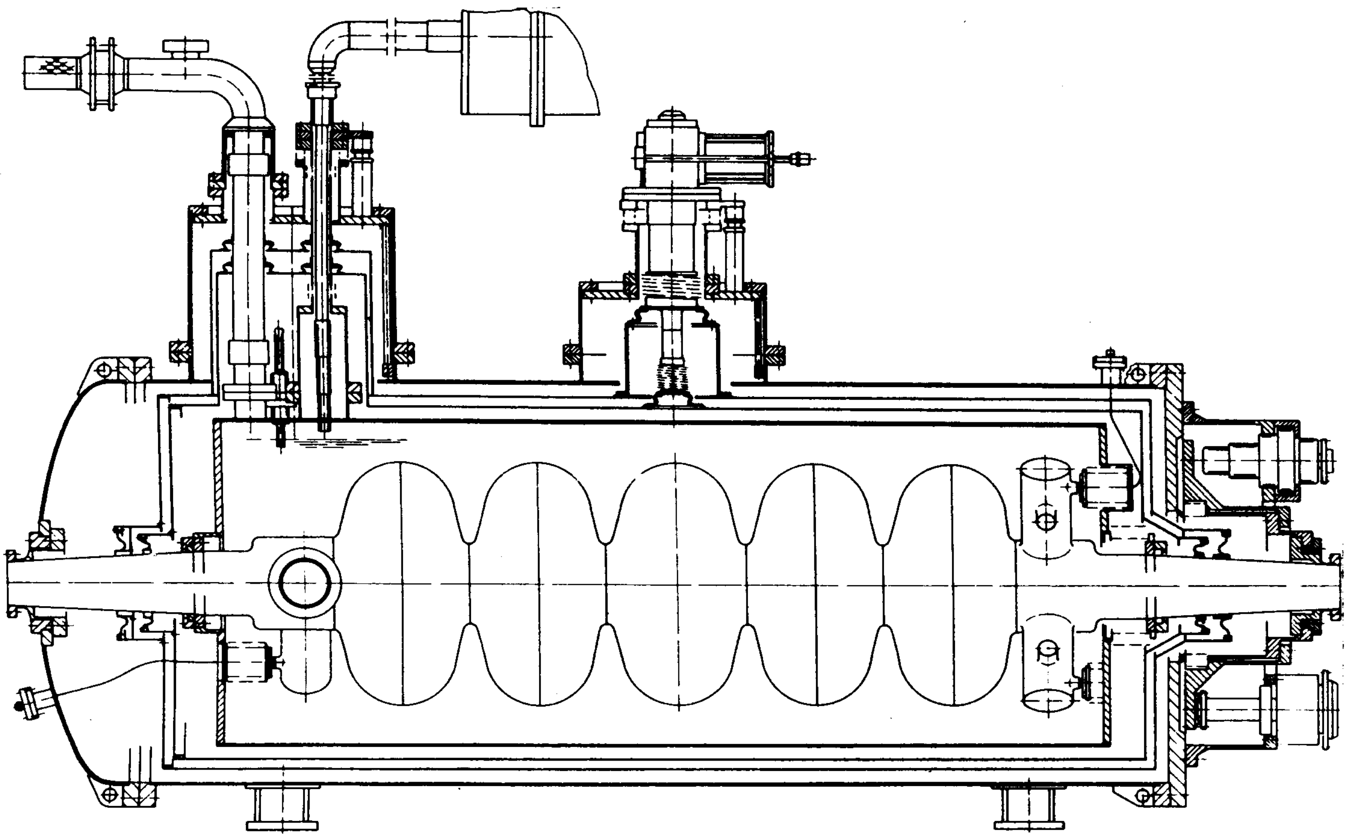


Fig. 8
Layout of the 5-cell accelerator module for the JAERI FEL

III R & D work in s. c. accelerator technology

Our R & D work in s. c. accelerator technoloy is directed in two main activities.

At first we are trying to optimize the technologies of s. c. accelerator modules in view of rf performance (e. g. main couplers, HOM couplers), cryogenic losses, manufacturing and assembly techniques and superconducting material (Nb, Nb_3Sn, high field, high Q)

On a more long range scale we are also investigating the potential of the new high temperature superconductors for application in accelerator technoloy.

All this work is performed in cooperation with the University of Wuppertal and with many other institutes and research centers.

Reference List

[1] Kneisel, this workshop

[2] Benvenuti et al.
Superconducting Niobium Sputter coated copper cavity modules for the LEP energy upgrade, PAC 1991, 5 - 9 May 1991, San Francisco/USA

[3] Cavallari, this workshop

[4] Davis et al.

A superconducting radio-frequency cavity for manipulating the phase space of pion beams at LAMPF

[5] Klein et al

RF superconductivity at Interatom, proceedings of the 4th workshop on RF superconductivity

[6] Thiessen

A reference design for PILAC, a pion linac facility for 1 GeV pion physics at LAMPF, LA-UR-91-869
Pilac Tech Note 13, March 6, 1991