R & D Efforts on Nb Superconducting RF Cavity at IHIP of Peking University

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ABSTRACT

In the fall 1988, a superconducting RF cavity project was funded and started at Institute of Heavy Ion Physics of Peking University, as the first step to master or develop superconducting RF technology in China.

A pilot cavity with spherical geometry was designed after extensive computing studies on the field distribution of fundamental mode, high order modes (HOM's) as well as wake potentials using computer codes: Super-fish, URMEL, TBCI. An aluminum model cavity was machined accordingly to test the RF property at room-temperature. The postpurification of Nb surface is in progress. A cryostat for testing cavity is being manufactured. In order to facilitate the superconducting measurement, a pre-test 5.0 GHz Nb cavity was made.

INTRODUCTION

The research on Nb superconducting cavity in China was initiated by Prof. Ding Yu and his colleagues in early 1970's at the Institute of High Energy Physics, Beijing. A small cylindrical Nb cavity (TE011 Mode, F=9.2GHz) was constructed then. Unfortunately the project was stopped partialy due to the passing away of Prof. Ding in 1974. However there were extensive efforts abroad on the development and construction of super-conducting accelerators and significant technological progress has been achieved since then (1)(2). In order to accelerate high current electron beam with excellent quality, the cavity should have large aperture, high gradient and be able to run under the condition of CW. Such requirements can only be met by using superconducting cavities (3). To catch up the recent progress in the field of RF cavities, the research on superconducting cavity was renewed in the fall of 1988 at the Institute of Heavy Ion Physics, Peking University. As a start, a single cell resonator of L band is being studied. It is to be made of high purity Nb sheet and has a spherical geometry which should be effective in restraining electron multipacting effect(2).

DESIGN STUDIES

The fields of fundamental mode and high order modes in the cavity as well as the wake field potentials were studied using Superfish, URMEL and TBCI computing codes while designing.(5) The fundamental mode in the spherical cavity was compared with that in the conventional cavity with nose cones. The characteristics of both cavities are given in Table I and the surface electric and magnetic fields are shown in Fig. 1. The spherical cavity has apparently a reduced peak surface electric field and a lower shunt impedence. This is due to the elimination of the nose cones and having larger beam aperture. It is obviously more suitable for superconducting operation as reported by others(2)(4). High order modes, especially monopole, dipole and quadrupole modes, might cause extra energy spread, beam instability or spoil the beam emittance. They were computed and analyzed up to 10.0 GHz using URMEL on VAX 785. Typical results are given in Fig. 2 as an example.

As we are also interested in the beam induced effects,(6) the wakefield forces experienced by a relativistic electron bunch while traversing through a discontinuous cross section were studied with TBCI code. Fig. 3 shows typical results of a single bunch effect. The pictures depict the electric field in time sequence of a beam bunch traversing through a cavity. At present, analysis of HOM's as well as the wake fields are still in progress.

WORKING PROGRESS

Apart from the design studies mentioned above, we have been engaged in the construction of the Nb cavity and cryostat and the renovation of the room in the lab. as well. The main items are as follows:

1. Aluminum Cavity

A 1.3 GHz model cavity of aluminum alloy is constructed on the basis of the design studies. The total length of the cavity with beam tube is 267.4mm. The spherical cavity has the largest dimention of Φ 203 mm.

Eight probe holes are fixed around the cavity equator. The coupler and pick-up probe can be inserted from the end of the beam tube or in the ver -tical direction of the beam axis. Several diagnostic measurements can be carried out with this simple cavity and be compared with the design.

2. Cryostat

A cryostat for L-band Nb cavity is under construction. The sketch is shown in Fig. 6. The whole length is about 175 cm, and the diameter is Φ60 cm. To shield the cavity from dirt, the pumping pipe is in the form of over-head. Both coupler and pick-up probe are fixed in the pumping pipe. The cryostat tank and Nb cavity are to be evacuated seperately by TMP and ion pump. Liquid He is fed from the top. The cryostat is connected to a big Dewar by a transmission line. No HOM coupler and frequency tuner are provided at the moment. The outer magnetic shield is not shown in the figure.

3. 5.0 GHz Cavity

In order to facilitate the test on a superconducting Nb cavity, a small cylindrical cavity with a resonant frequency of 5.0 GHz was machined. It was made of high purity Nb refined by electron beam. Its chemical analysis and photoelectron energy spectrum are shown in Table II and Fig. 4.

4. 1.5 GHz Dornier Cavity

Recently, a 1.5 GHz cavity made by Dornier was kindly presented to us by Dr. D. Proch of DESY so as to help us speeding up our measurements on superconducting cavities. Its spherical part is made of high RRR (300) niobium sheet while its size and shape are similar to those original Cornell resonators. The RF coupler and pick-up probe are to be fixed at the end of the beam tube. Fig. 5 is the picture of the cavity. We shall do the final cleaning procedure by ourself and carried out the measurements by the end of this year. It is expected that a lot can be learnt from this cavity and hence it will certainly help us constructing and developing new cavities in China.

5. Laboratory Renovation

The room in the lab. was renovated so as to create an environment suit -able for the processing and assembling of superconducting cavities. Fig.7 shows the layout of our lab.. It is to be a clean room of good quality.

At the super clean bench, where the surface treatment and cavity assembling will be done, a class 100 standard can be achieved.

ACKNOWLEDGMENT

We've been receiving generous support on this research project from Dr. D. Proch (DESY) since his visit to Peking University. Dr. H. Padamsee (Cornell Univ.) also offered to loan a 1.5 GHz single cell cavity to help us start the first step. Dr. T. Weiland provided us with code URMEL and TBCI. We also have useful and informative discussions with Dr. G. Neil (TRW). Hereby, we take the opportunity to express our heartfelt gratitude for their efforts they put on our work. Their kindness and assistance are highly appreciated.

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(4) H. Schwettman et al., IEEE Trans. Nucl. Sci. NS-32, 2927 (1985)

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Table I: Parameters of 1.3 GHz Cavity

(Normalization (E0=1.0 MV/m))

Data	Spherical	Normal
R/Q (Ω/m)	1921.7	2512.9
R (MΩ/m)	57.02	62.39
Q	29672	24828
Beam Aperture (cm)	3.17	1.765
Peak Surface Electric field (MV/m)	1.925	4.811
Peak Surface Magnetic field (KA/m)	3.047	3.388
Total Power (W)	1753.63	1398.14

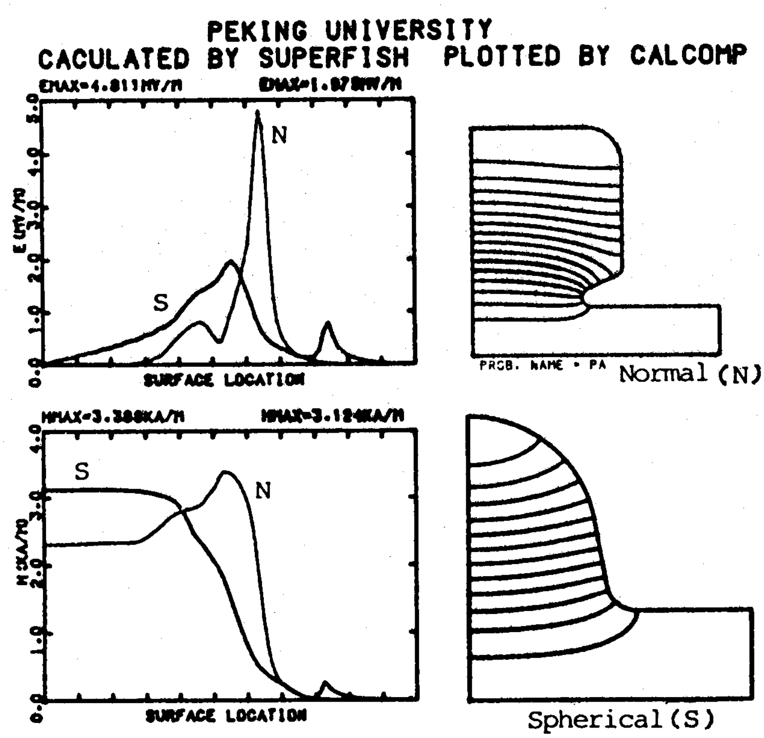

Fig. 1 - Peak Surface Electric and Magnetic Field

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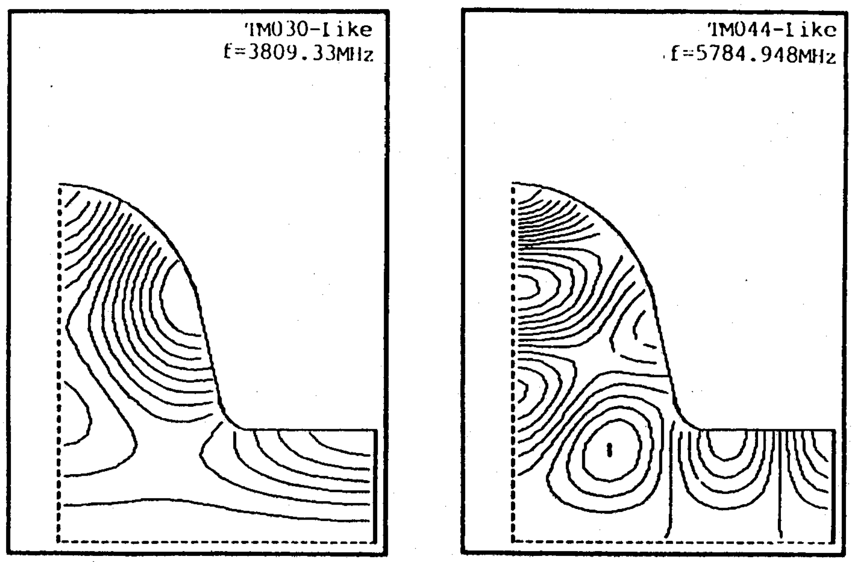

Fig. 2 - HOM Electric Field Profiles

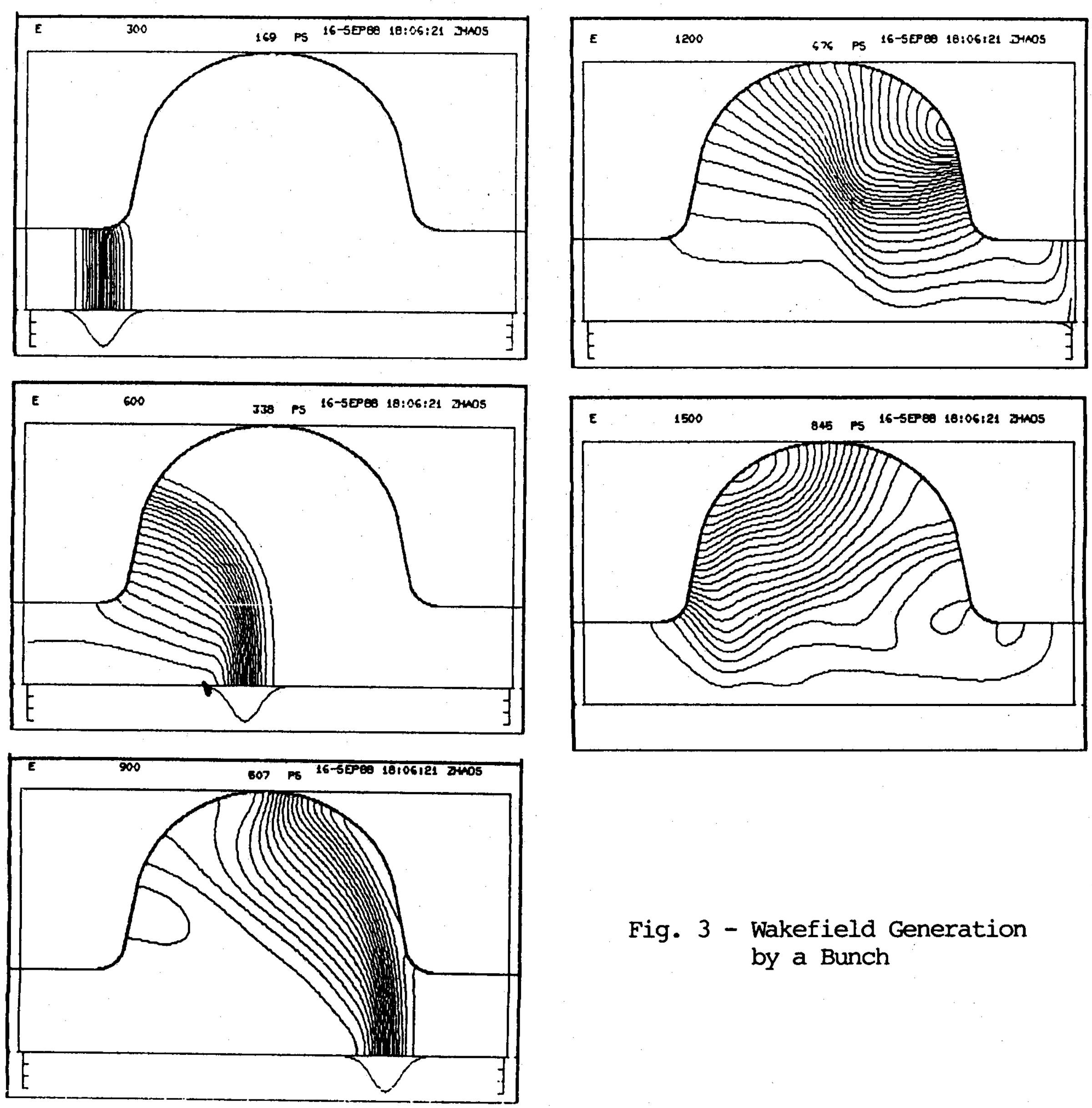

Fig. 3 - Wakefield Generation by a Bunch

Table II: Chemical Analysis of Nb

Sample #1

Ni	Zr	Rh	Sn	Tl
0.001%	0.003-0.01%	0.01%	0.001%	0.001%
Ta	Mg	Pt	Ti	
0.1%	0.001%	0.002%	0.001-0.01%	

Sample #2

Hf	Zr	Tl	Al	Pt
0.01%	0.003%	0.001%	0.003%	0.001%
Cu	Ti			
0.001%	0.003%			

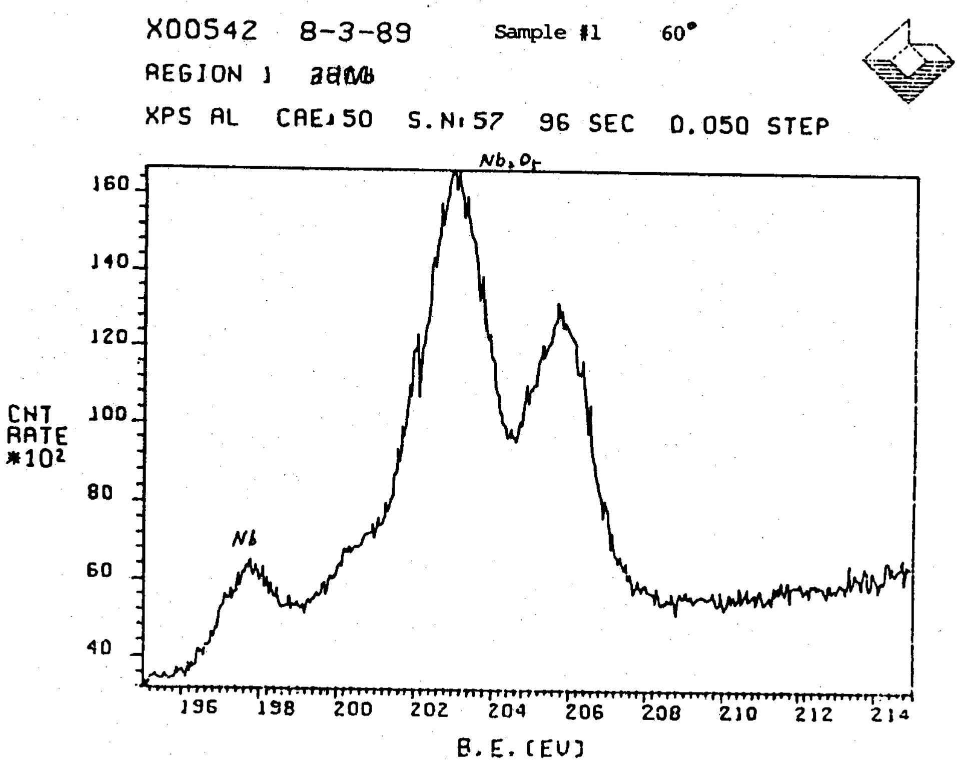

Fig. 4 - Photoelectron Spectrum of Nb Surface

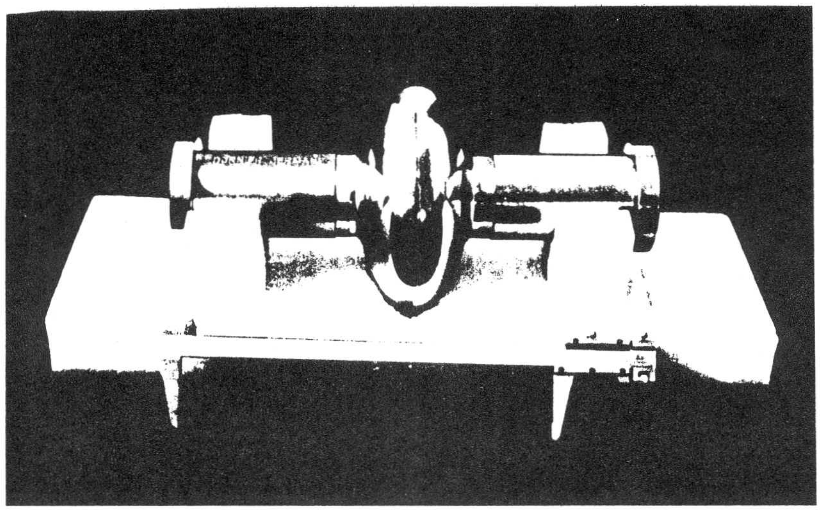

Fig. 5 - 1.5 GHz Nb Cavity

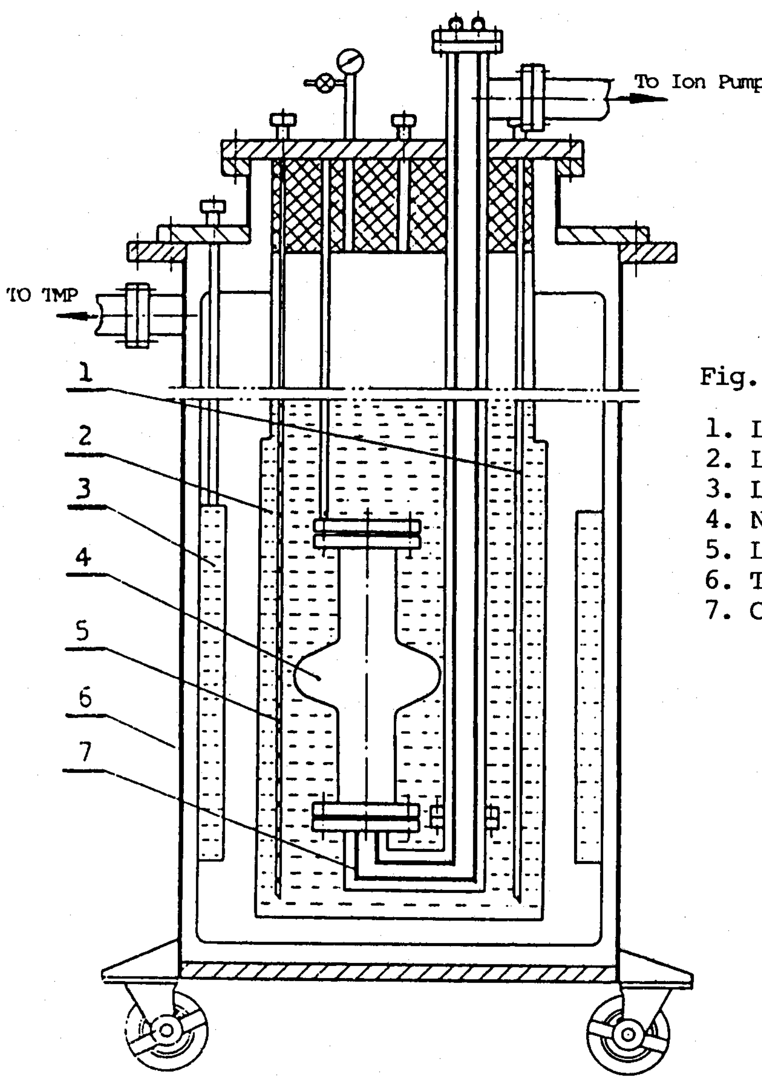

Fig. 6 - Sketch of Cryostat

1. LHe Transmission Line
2. LHe-Vessel
3. LN-Shield
4. Nb-Cavity
5. LHe Level Meas.
6. Tank
7. Coaxial Lines

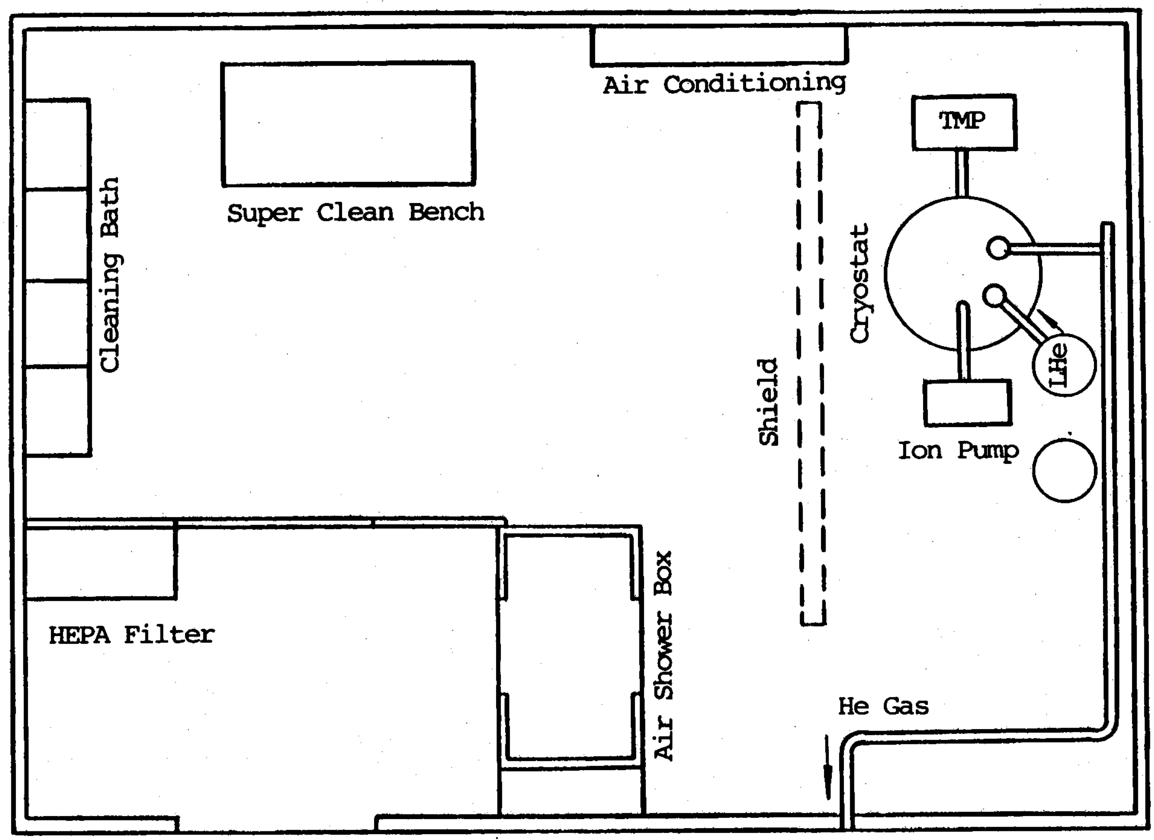

Fig. 7 - Layout of Laboratory