200 MHz Superconducting Cavity Development

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Background

Fermilab NUFACT design study calls for
200 MHz RF for Linac and first RLA, >500 cells ≈ LEP-2

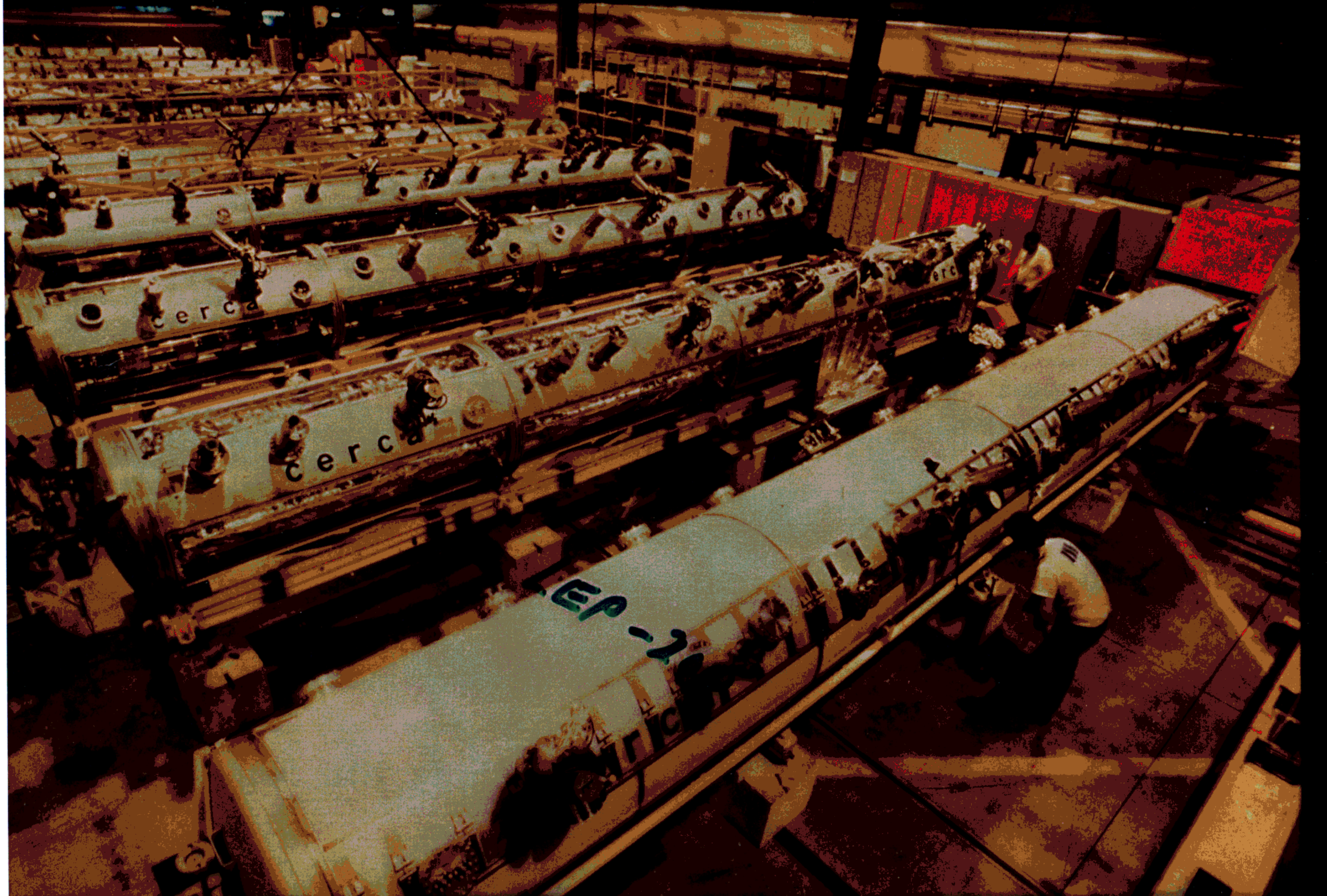
400 MHz for 2nd RLA, 1500 cells >LEP-2

Development pressure is on the 200 MHz system

RLA 1 If Muon storage ring built at < 15 GeV, need 200 MHz system
200 MHz is lower than lowest frequency ever for SC (350 MHz)

RLA 2 400 MHz system very similar to LEP-II except we need to increase gradient from best
10 to 15 MV/m in 4-cell cavities

LEP-II 288 cavities × 4 cells
= 1152 cells @ 350 MHz


cerca
cerca

Installed in SPS @ CERN

Eacc 5.5 MeV/m Q ~ 2x10^9

PROTOTYPE CAVITY FOR LEP II 100 GeV + 100 GeV

350 MHZ

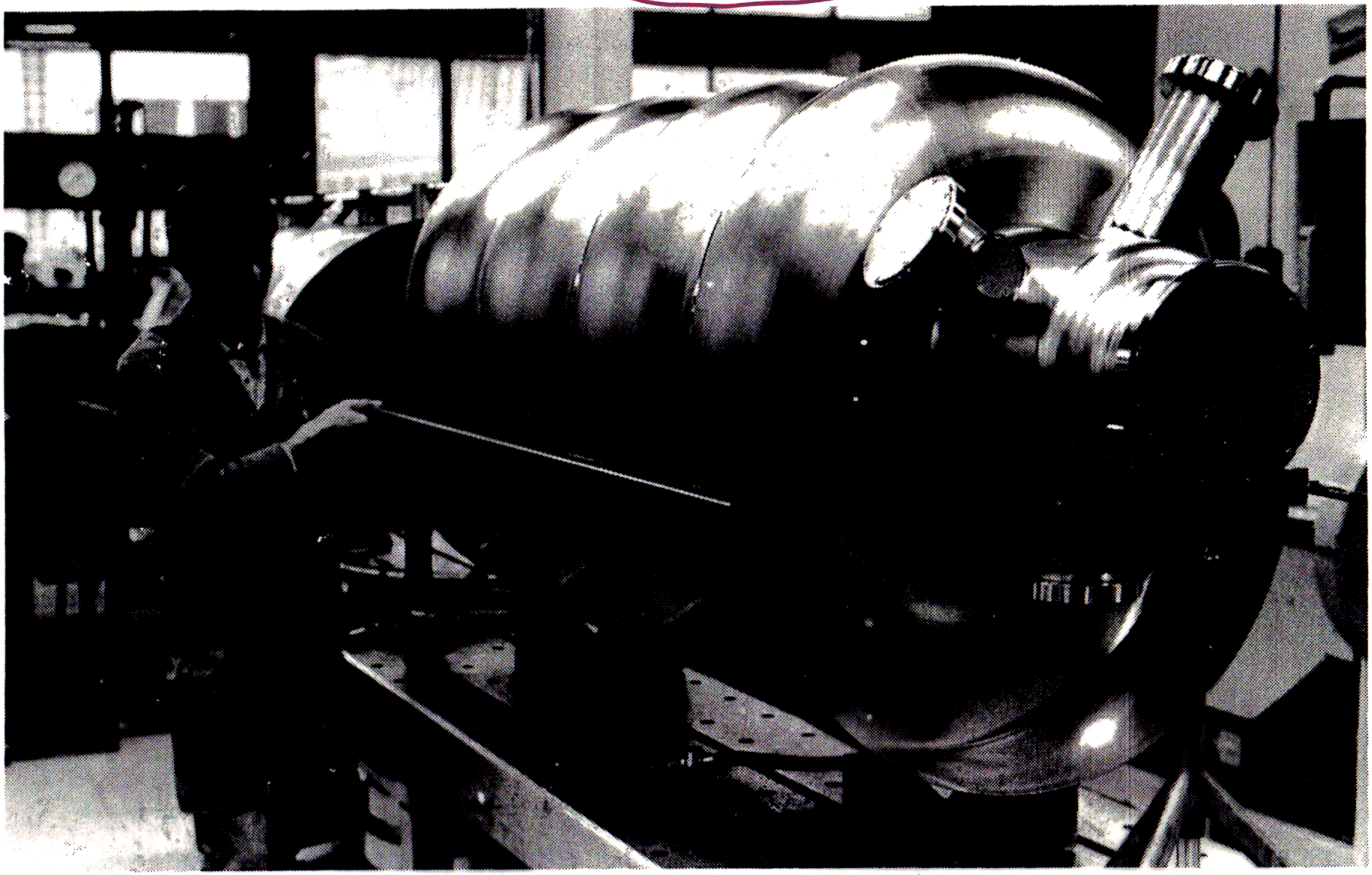
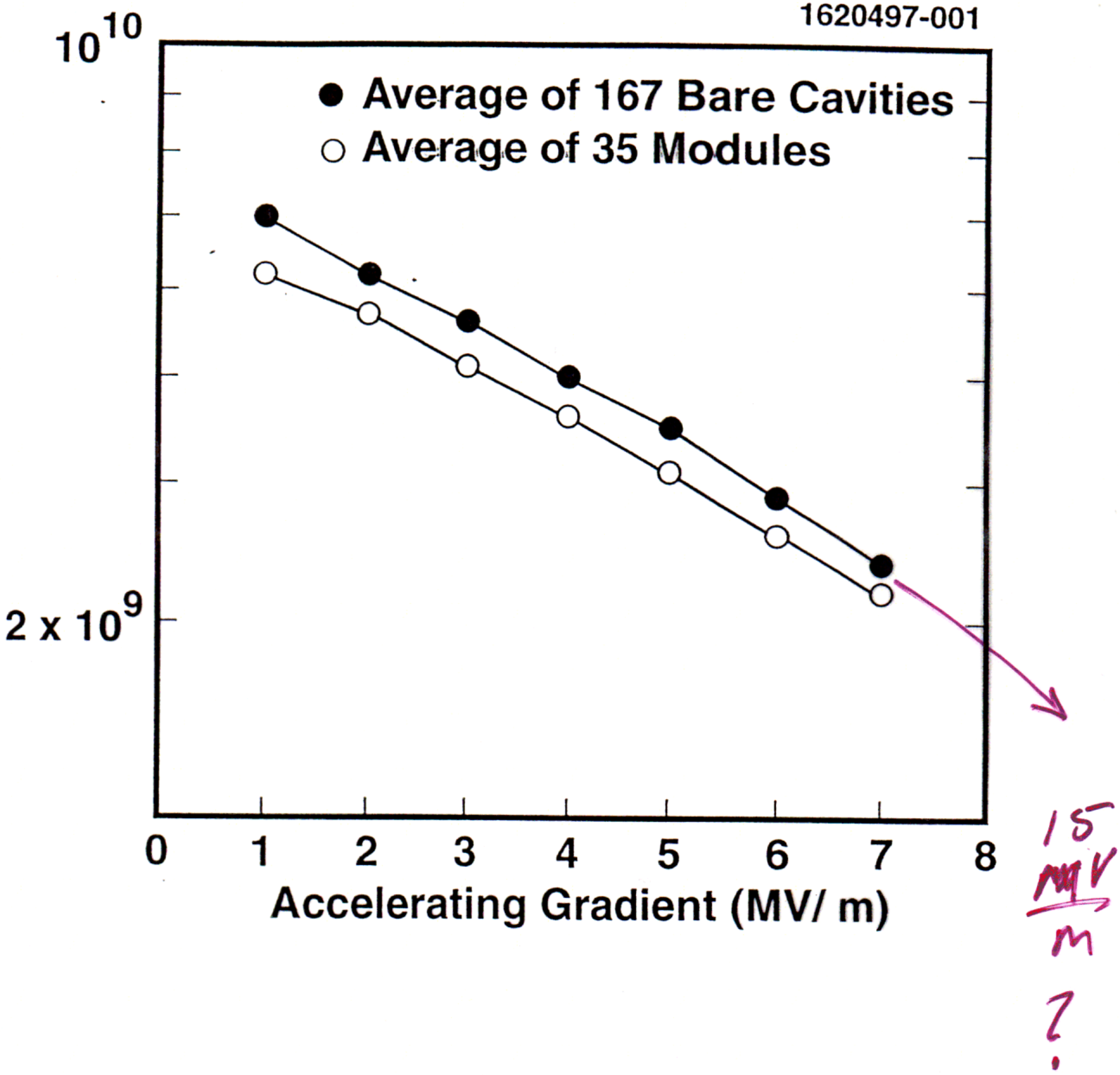


Fig. 2 A 4-cell 350 MHz Nb cavity for LEP with beam tubes and coupling ports. Below: one half of the He tank to be welded around the cavity.

CERN
LEP CAVITIES



name	F MHz	pulsew msec	MW per Linear_m	cells per klystron	Number cells	tot. installed Votage/GeV
preaccel.	200	2	0.55	10	320	3.6
RLA1	200	2	0.55	10	231	2.6
RLA2	400	2	0.2	60	1,511	8.5
total						14.7
name	Peak MW	ave Pwr kW /kly	no. of klystrons	Linear_m per kly	Linear_m	average rf P MW
preaccel.	8.25	247.5	32	15	480	7.9
RLA1	8.25	247.5	23	15	347	5.7
RLA2	9	270	25	45	1133	6.8
Total			80		1960	20.4

Table 8: Description of the power distribution for the superconducting accelerators.

No. of cells

200 MHz : 550

No. of 200 MHz Klystrons (≃ 10 MW)

55

200 MHz RF System Parameters

Single cells, cell length 0.75 m , Diameter ~ 1.5 m
Voltage = 11.3 MV
Total no. of cells needed = 320 + 231 = 551
LINAC RCA1

Peak RF power needed = 800 kW/cell
Total RF installation required 440 MW peak, 2 ms

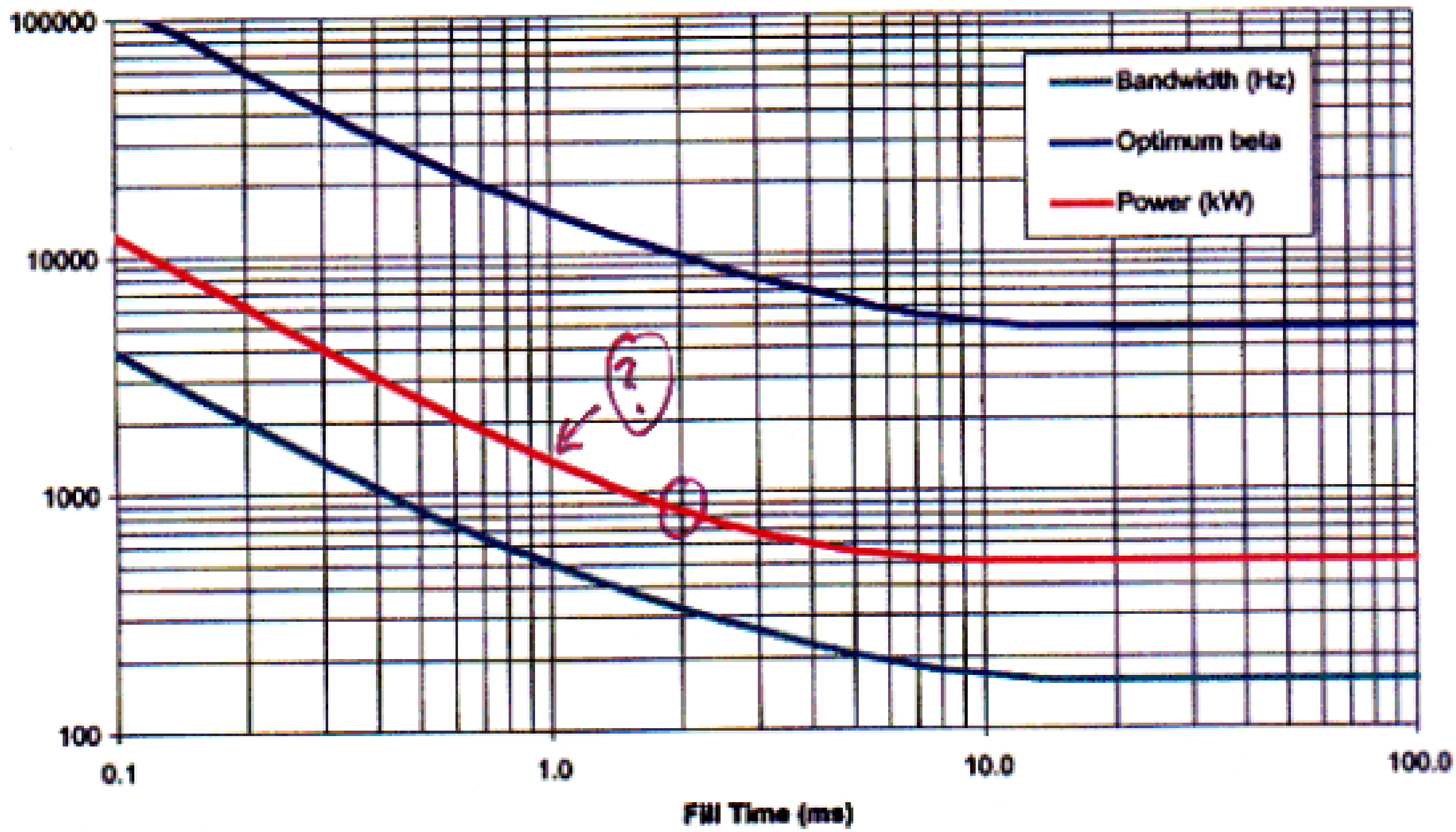
Dynamic heat load at Q = 6×10^9 = 6 W/m
Duty factor = 3%

Static heat load = 5 watts
Total heat load = 10 W per unit

⇒ Refrigerator ≈ 5 KW

Operating T = 2.5 → 4.5 ?

Single-cell 200 MHz



800 KW/cell BW = 300 Hz, 2 ms

1500 KW/cell BW ~ 500 Hz, 1 ms

Challenges

Fabrication of large scale 200 MHz structure

Mechanical properties,
resilience against microphonics @ 300 Hz B.W
esp. in pulsed operation

High Field, high Q performance
Eacc = 15 MV/m, Q = 6 x10^9 ← ACTIVE GRADIENT

One MW pulsed operation
Input power capability one MW @ 2ms fill time

What is the best fill time, loaded Q and power level?

Operating temperature?

2.5K or 4.5K

Aim: Cornell R&D Program 5-year goal

* Develop, design, fabricate and high power test one 200 MHz single-cell cavity cryomodule.

Determine best fabrication techniques.
Determine best fill time, loaded Q and input power level

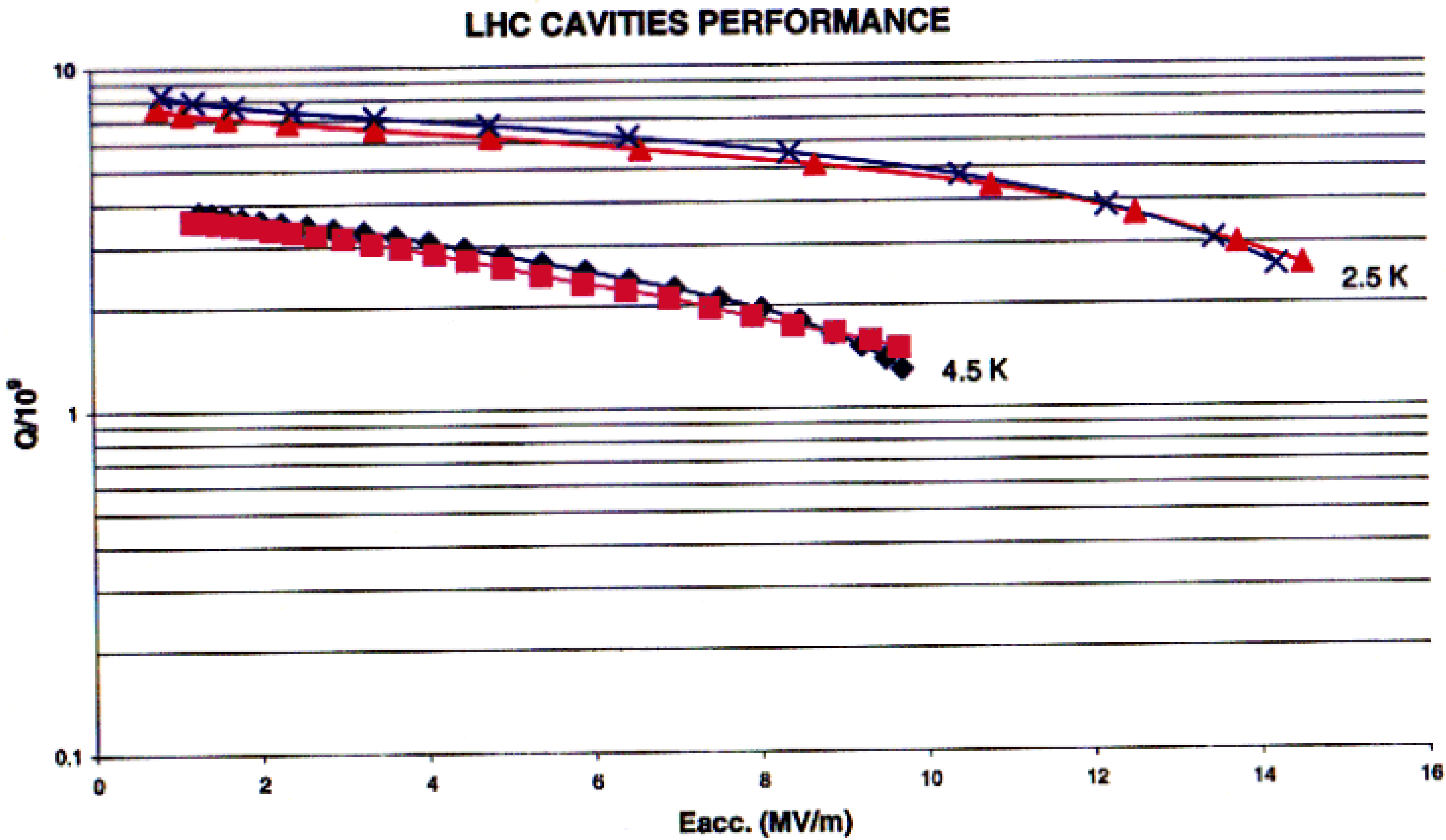
Approach: Nb/Cu suitable for 200 MHz WHY?

1) Significant savings in material cost
If made from Nb sheet, 6 mm thick,
Nb cost for 500 cells will be 70 M$ ($200 per pound)

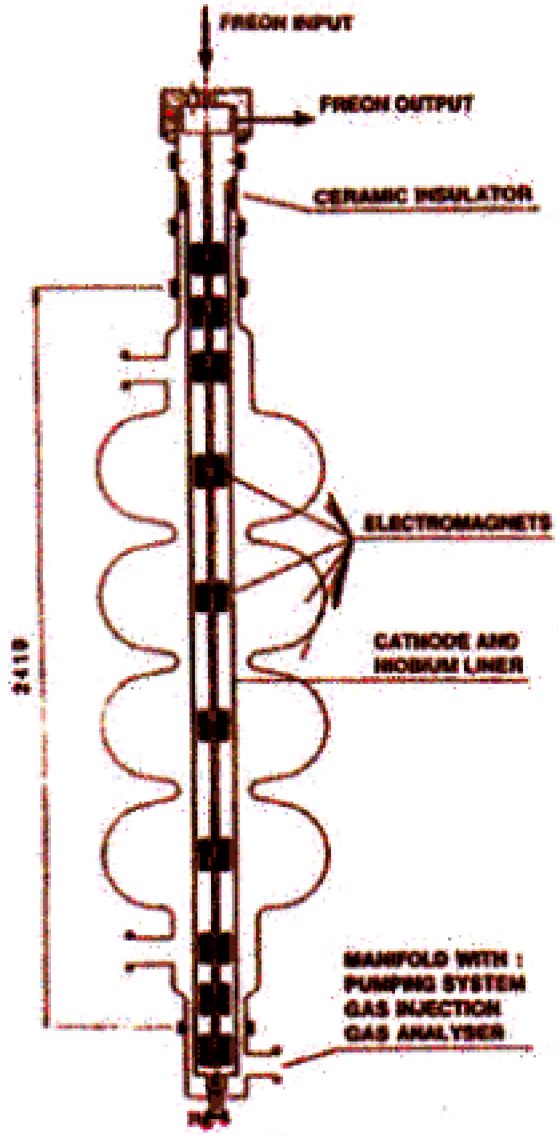
Copper base cavity will cut material cost by x 10 - x 100

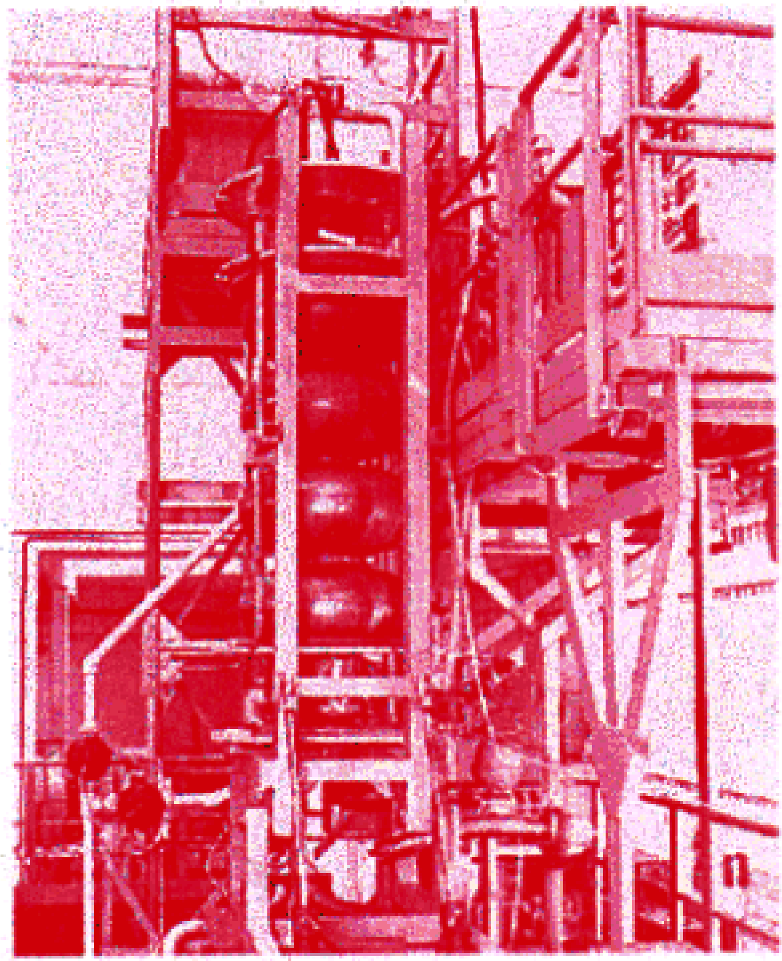
2) Quench resistance (one kJ stored energy)
   copper wall can be made thicker for stiff cavity against microphonics

3) CERN has made substantial headway in Nb/Cu technology
   - low frequency cavities, 350 MHz, 400 MHz
   - large number of cavities
   - Need to improve Q slope.
   - 14 MV/m proof of principle exists at 400 MHz

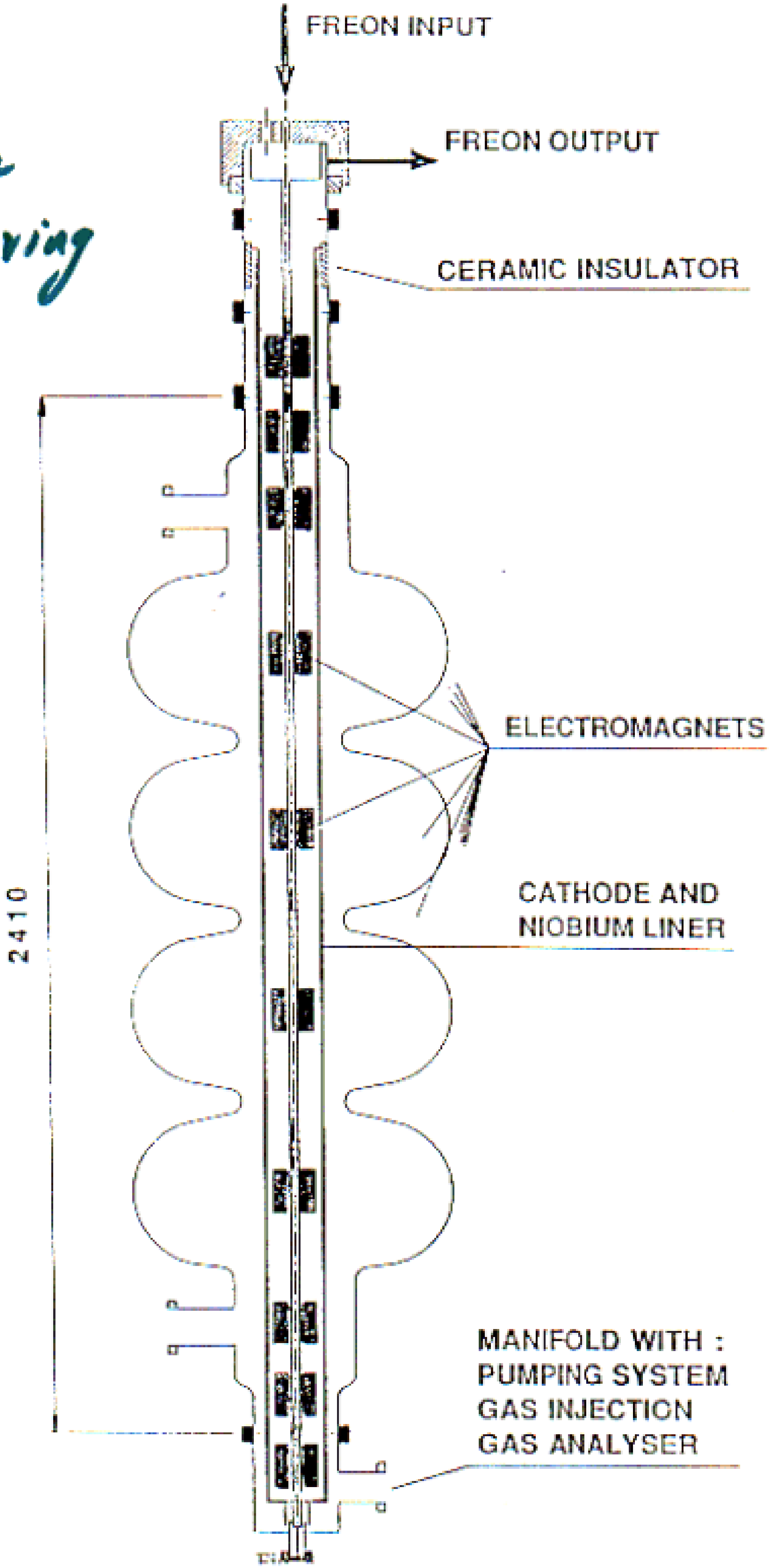


LHC CAVITIES PERFORMANCE
10
1
0.1
Q/10^9
0
2
4
6
8
10
12
14
16
Eacc. (MV/m)
2.5 K
4.5 K


FREON INPUT
FREON OUTPUT
CERAMIC INSULATOR
ELECTROMAGNETS
CATHODE AND
NIOBIUM LINER
MANIFOLD WITH :
PUMPING SYSTEM
GAS INJECTION
GAS ANALYSER
2419



CERN
Nb/Cu
Sputtering



YEAR 1

R&D Plan for Muon Acceleration
2000 - 2001

(4 parts)

I. Design Work

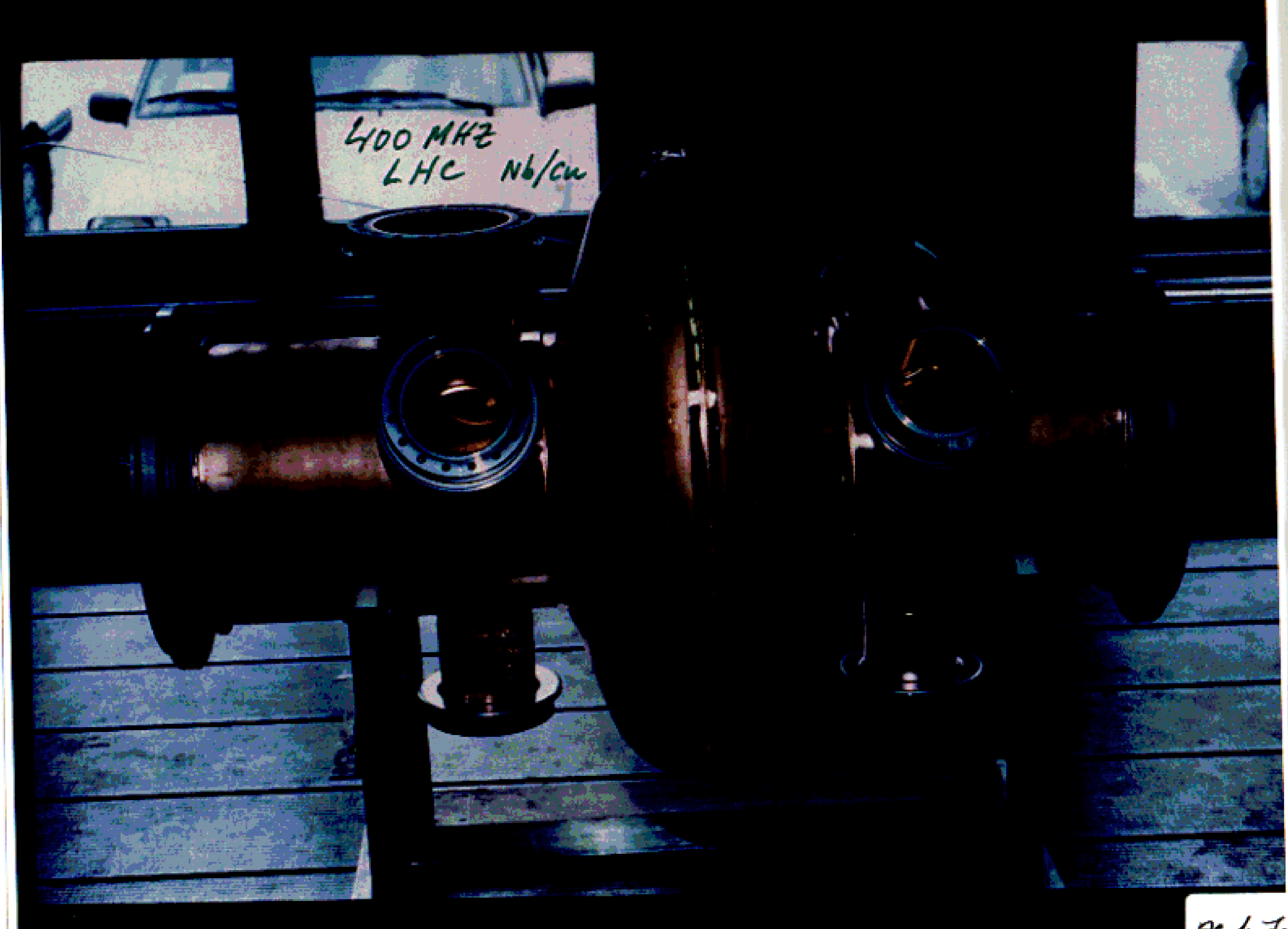
Design 200 MHz single cell cavity with input coupler port

Integrate with ANSYS calculations to push mechanical resonances to high frequencies

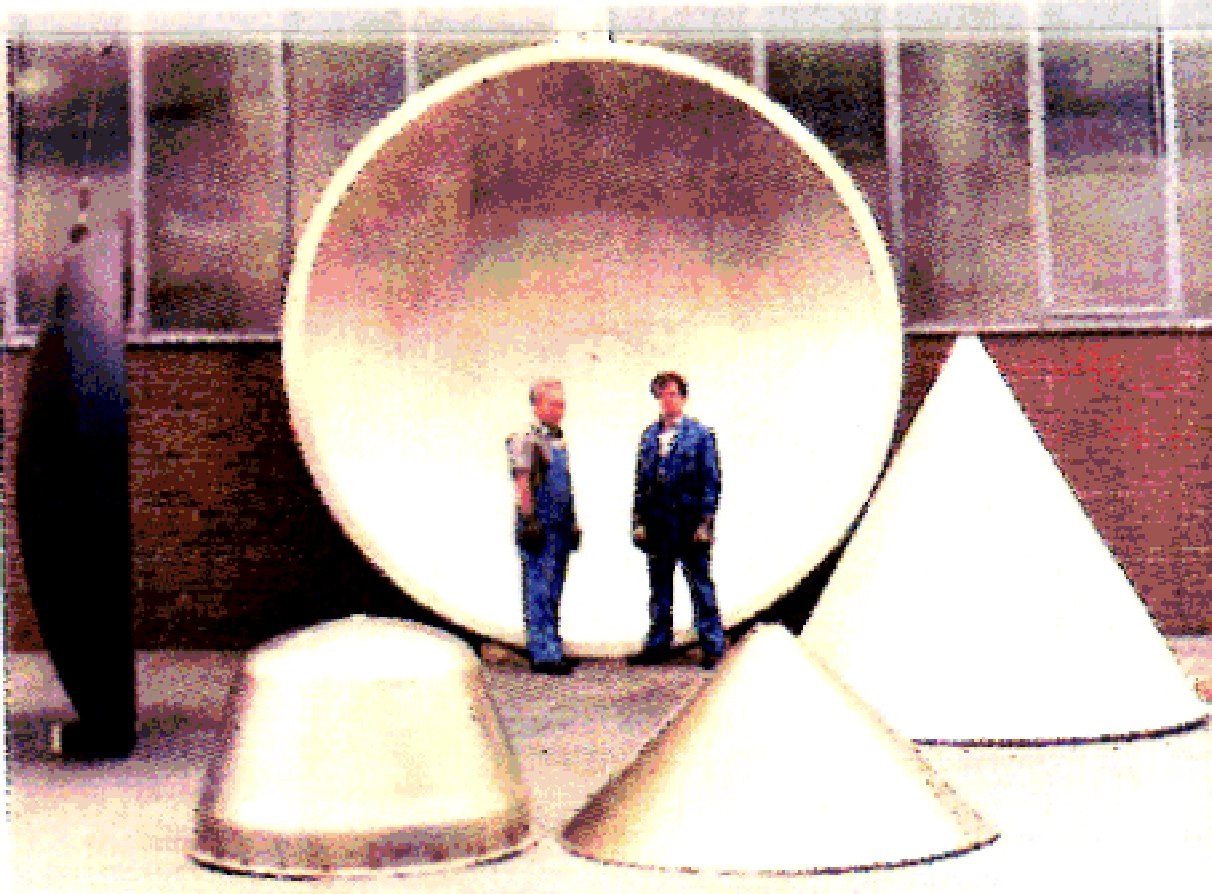
Determine cell shape and wall thickness for acceptable
mechanical resonant frequencies

Stiffeners ?

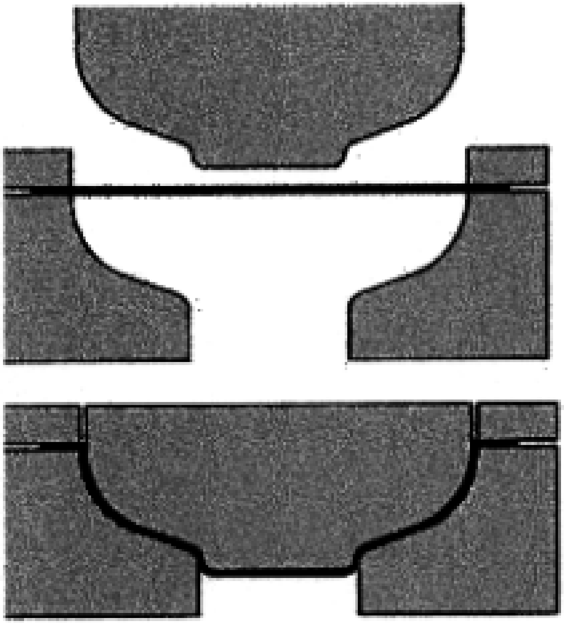
example: LHC single cell cavity

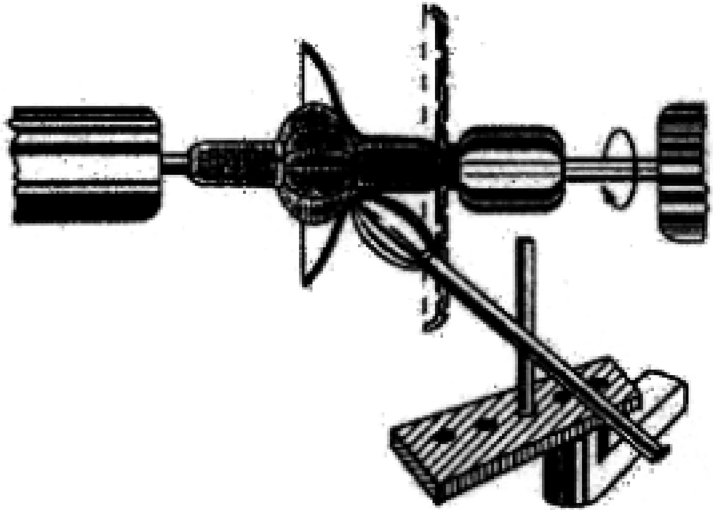


Ac 1. 7.



By Spinning





Spinning

YEAR 1

II. Model Cavities

Path One (Welded)

Acquire single-cell 200 MHz copper cavity from industry

Spin half-cells, eb weld, electropolish copper

Sputter coat with Nb at industry experienced with CERN techniques

*Path Two *

(No Welds - cost reduction, better performance)

\Spin single-cell copper cavity from one sheet

Collaboration with INFN

They have already spun 1300 MHz Nb and Cu cavities from single sheet

First stage, spin 500 MHz single cells later we may wish to explore spinnning from tube

Finish 500 MHz cavities with beam tubes and eb welding

Electropolish copper cavity

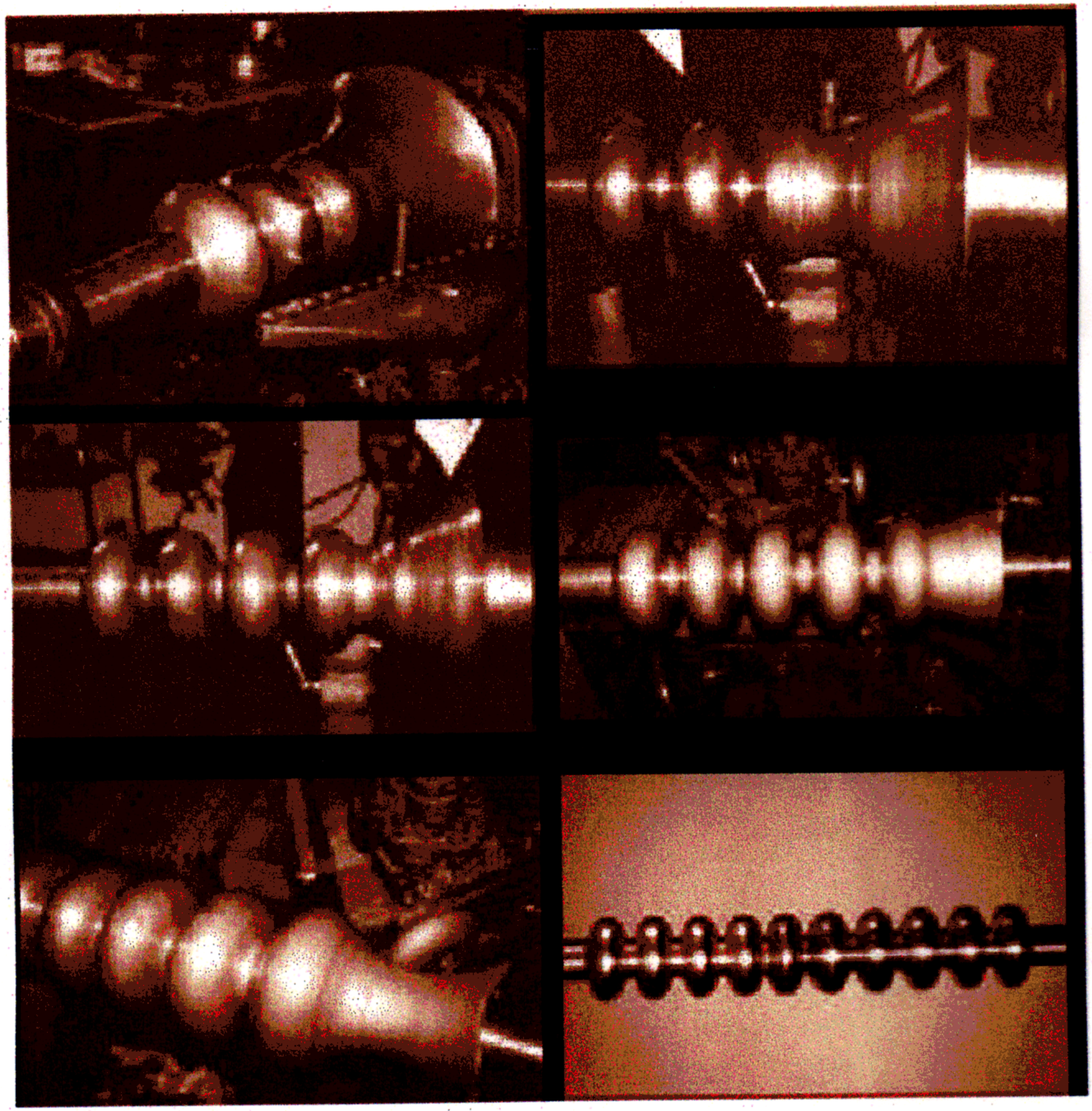
& Sputter Coat copper cavity

Collaboration with Industry

PATH II.

INFN

Spinning complete cavities



YEAR 1

III. Test Set-Ups

Infrastructure for final cleaning and testing 200 MHz single-cell cavities at Cornell *example*

Clean room, high pressure water rinsing, large dewar, dewar insert, test pit, radiation shielding

RF source, 2 kW+ amplifier

IV. R&D

(We may need to improve Nb/Cu technology)

Develop collaboration with coating laboratories to explore high energy niobium deposition.
small samples
    Dual ion beam sputtering
    Laser ablation, others?

Analyze film properties and
Test RF properties at 6 GHz
Host cavity available

YEAR 2

R&D Plan for Muon Acceleration 2001 - 2002

I. Testing Cavities

Test 200 MHz single-cell welded and coated Nb/Cu cavities

Test 500 MHz completely spun and coated Nb/Cu cavity

Recoat and test as necessary to get acceptable performance.

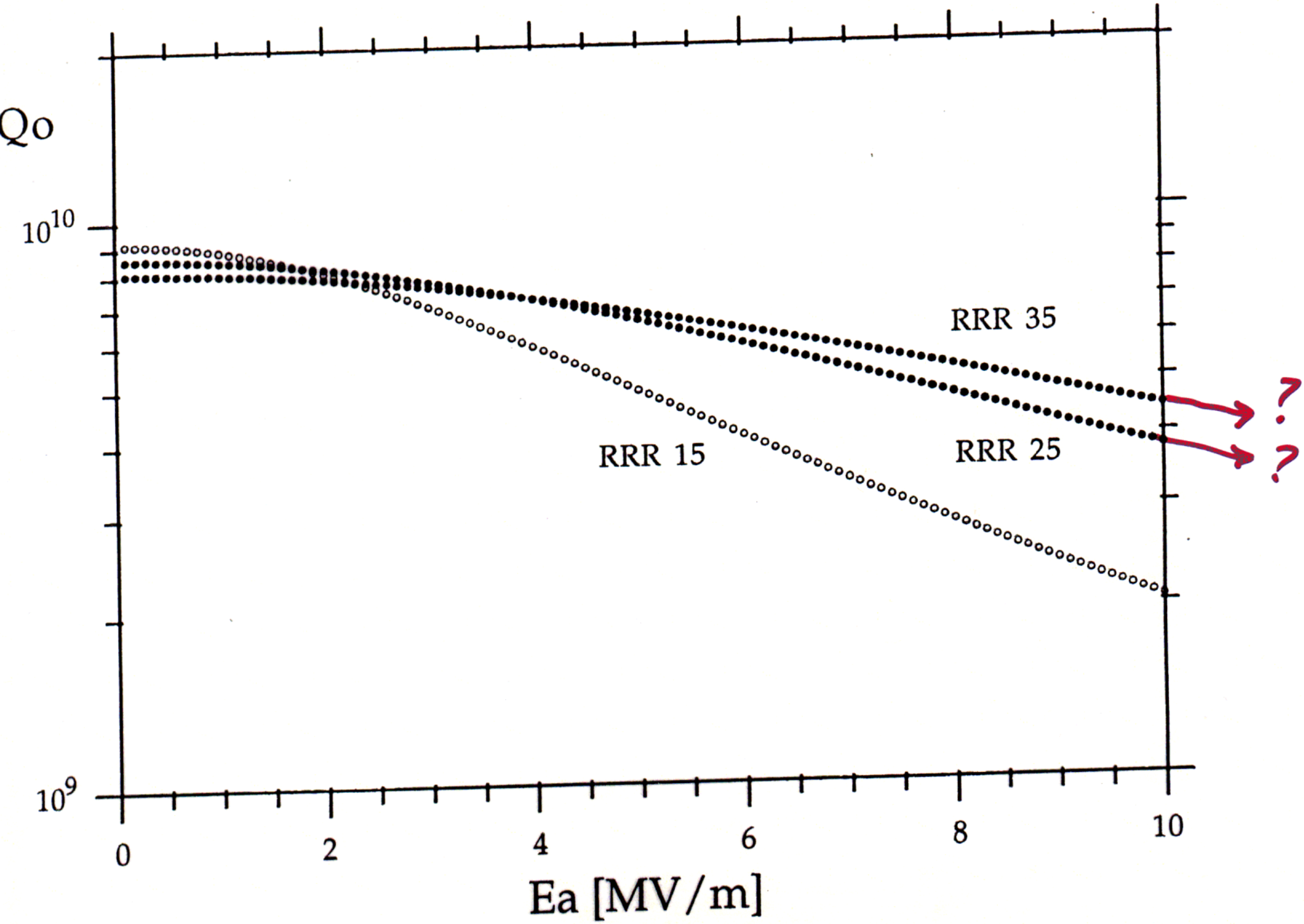
II. Design Couplers + Cryostat

Input Couplers, HOM couplers
Need input Qext variable to factor of 3
Set up collaborations (CERN? DESY?)

Coating modifications for coupler ports
Tuner
Horizontal cryostat for 200 MHz cavity
High power test facility for 200 MHz
Set up collaborations (CERN? BNL? LBL)

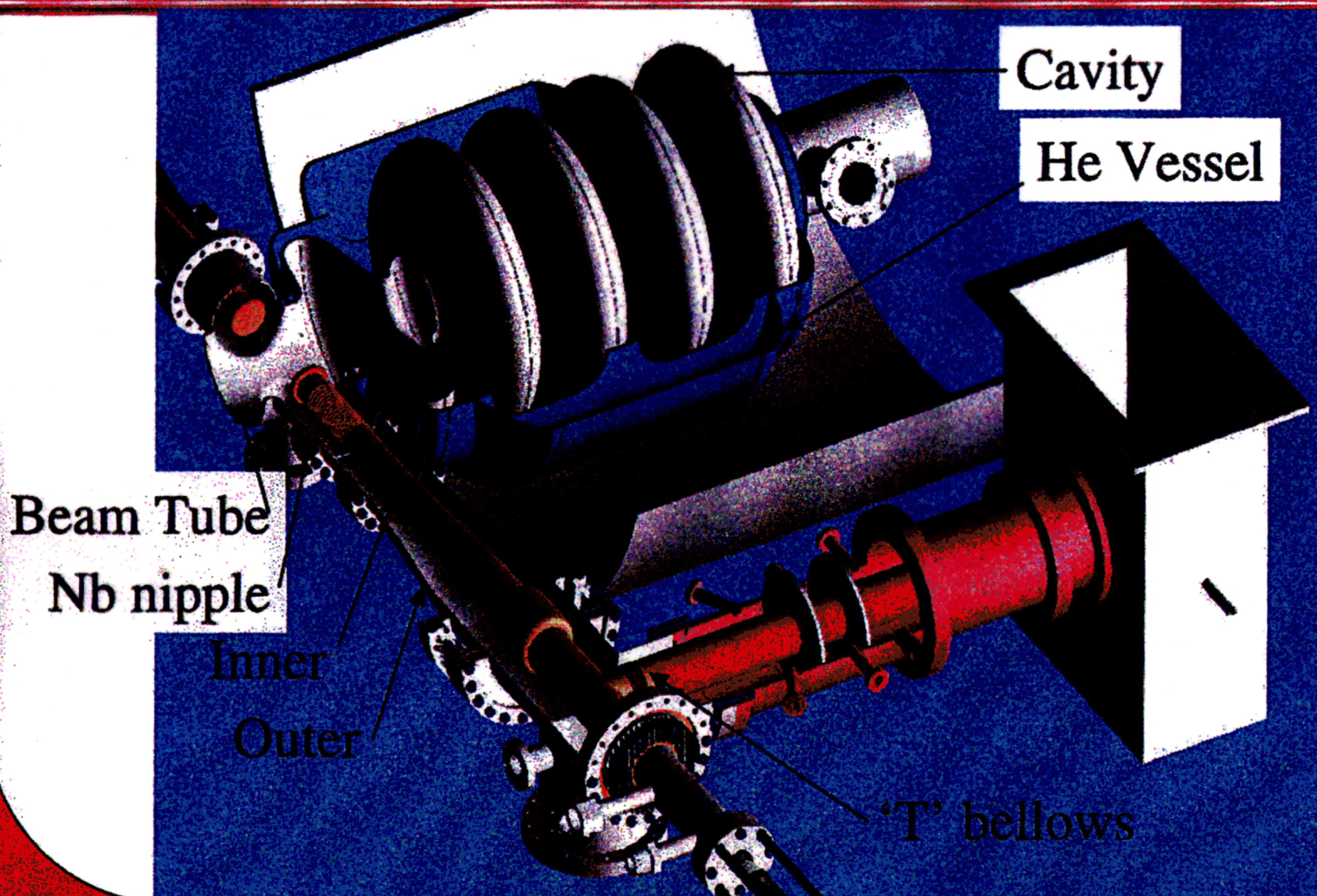
Secure one Mwatt+ pulsed RF source facility
Set up collaborations (CERN? BNL? LBL)
Goal: 5 msec pulse length

or: Does Q-slope depend on film purity?



CERN Results.

Main Components of PC



APT
Accelerator Production of Tritium

KEK-B

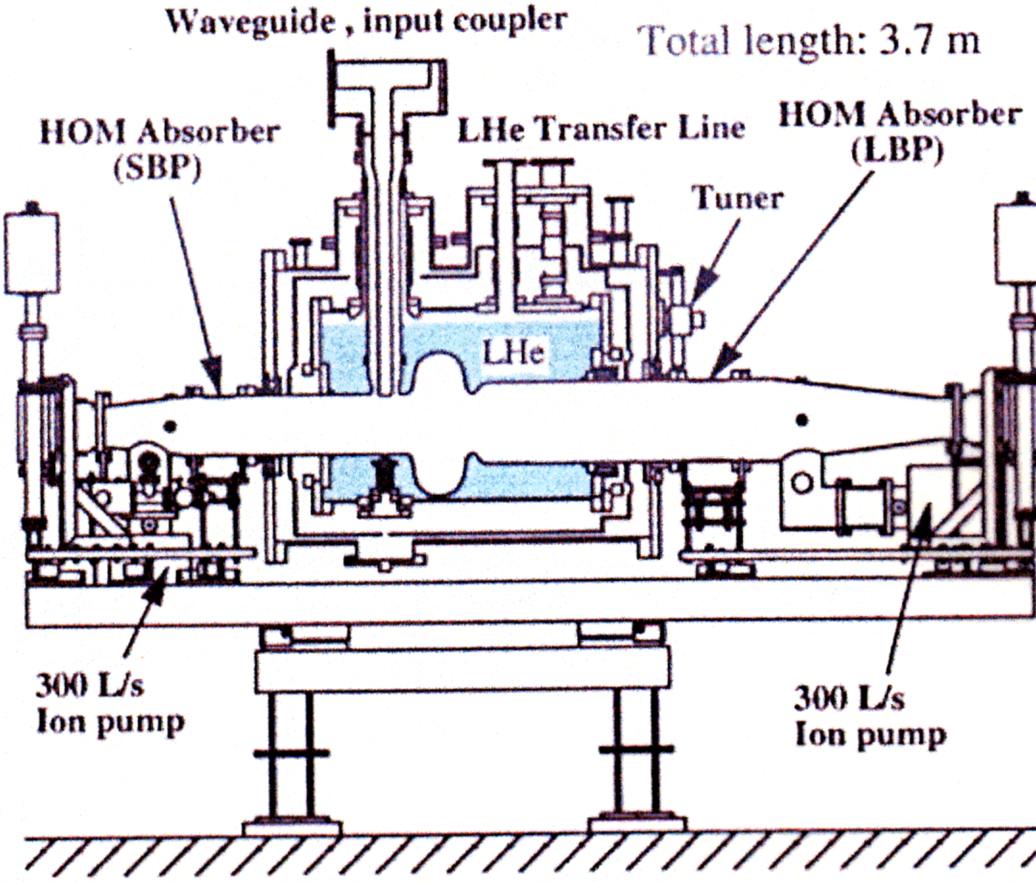


Figure 1: Superconducting cavity module for KEKB

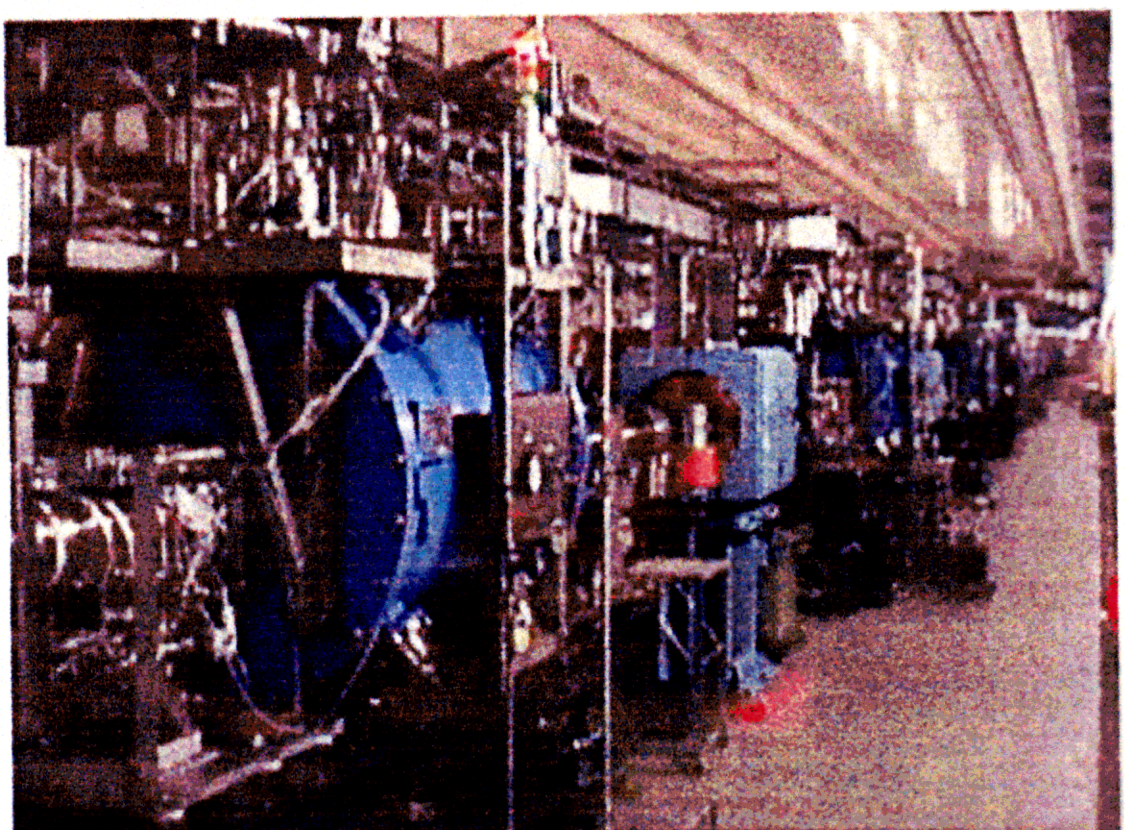
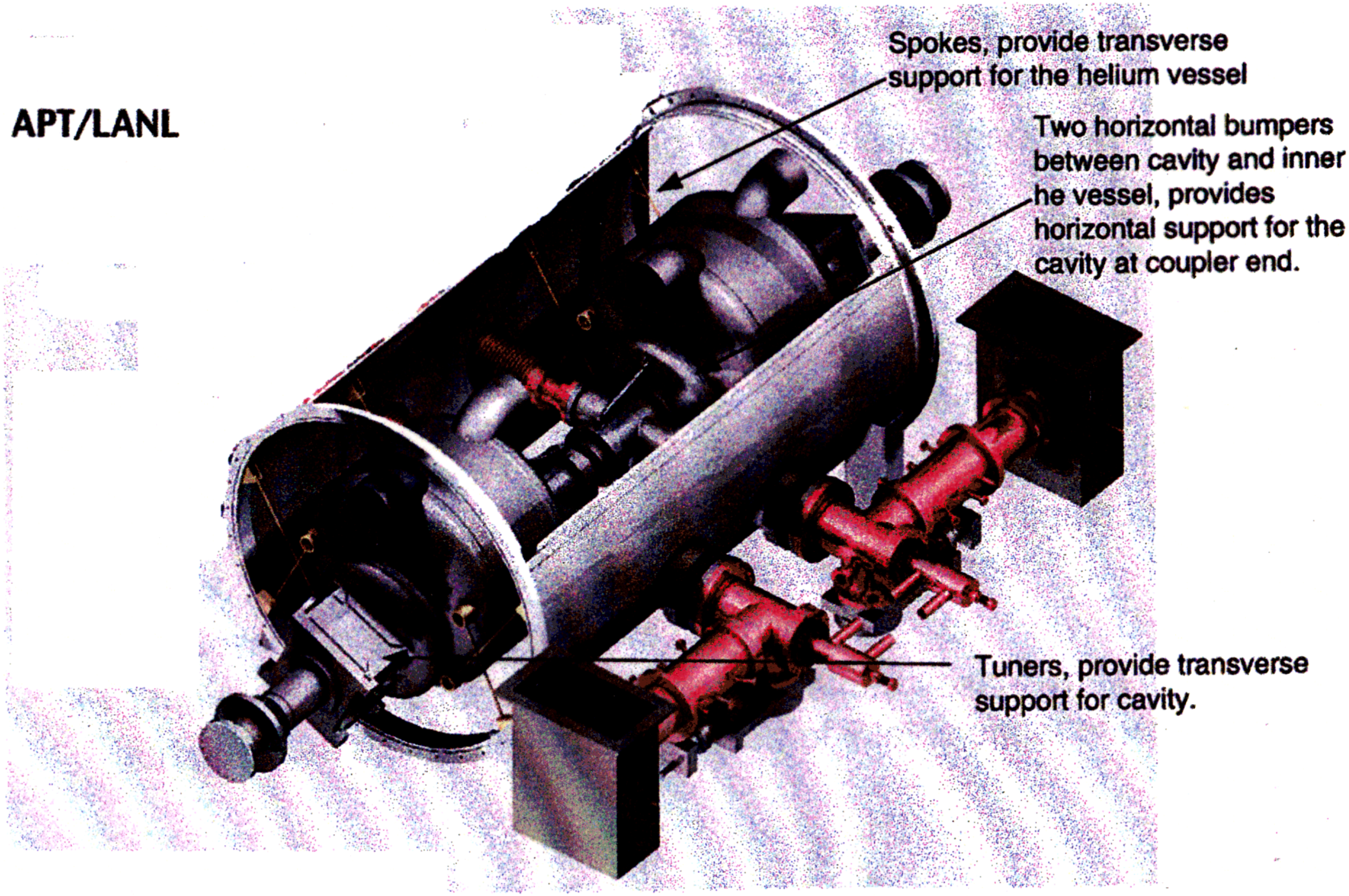


Figure 2: A picture of four SCC modules in Nikko-D11 tunnel

Possible Cryostat Design

ED&D **Cryomodule w/ Cavities and Power Couplers**

APT/LANL



YEAR 2

R&D Plan for Muon Acceleration 2001 - 2002 (continued)

III. Fabrication

Spin complete cell of 200 MHz copper cavity.
Collaboration with INFN

Finish cavity by welding beam tubes
Coat spun 200 MHz copper cavity
Industry

Strip 200 MHz copper cavity and add input and HOM coupler ports, He vessel attachments
Industry

Coat 200 MHz cavity with coupler ports
Industry

IV. R&D

Continue development/testing of improved coating methods

Extrapolate new coating techniques to large scale

YEAR 3

R&D Plan for Muon Acceleration
2002 - 2003

I. **Facilities**
Set up one MW test set stand for couplers and cavity

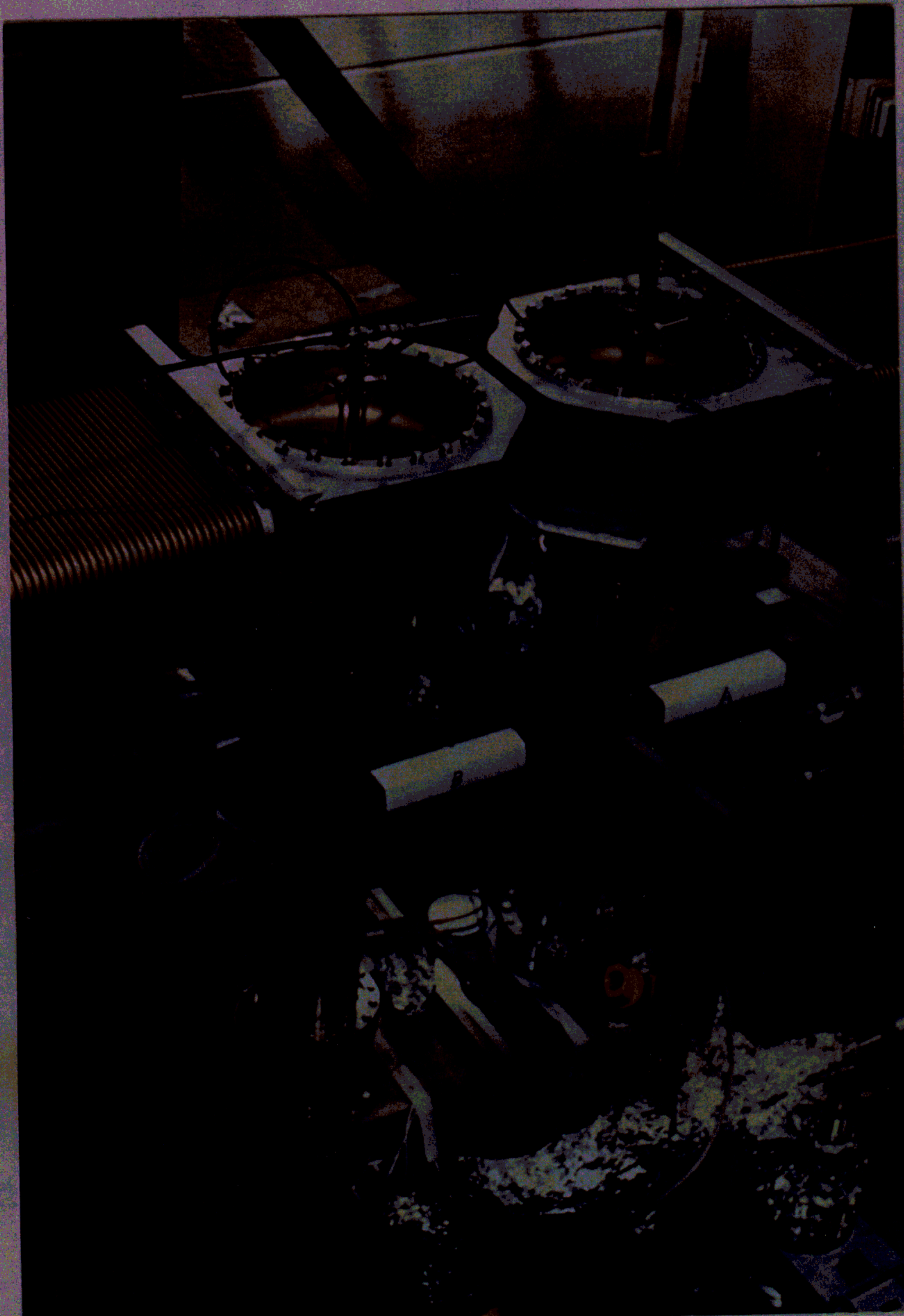
II. **Fabrication**
Procure two input couplers
Procure Cryostat, tuner

III. **Testing**
Continue testing cavities

High power test of couplers

IV. **R&D**
Coat full scale cavities with improved techniques if successful

KEK



YEAR 5

R&D Plan for Muon Acceleration
2003 - 2005

Assemble 200 MHz cryomodule
horizontal cryostat, best 200 MHz cavity, input coupler and tuner

Test 200 MHz cryomodule with one mwatt, 2 - 5 msec pulses
test microphonics vs Qext, and pulse length

Determine improvements necessary

Prepare for 2nd Generation module