SDC-92-273

SDC
SOLENOIDAL DETECTOR NOTES

SCINTILLATING FIBER TRACKER
FUTURE R & D

May 6, 1992

David S. Koltick
Purdue University

Scintillating Fiber Tracker

Future R & D

D. Koltick May 6, 1992 SSCL

I. Status of VLPCs

- HISTE III
- Review of Project
- Prototype Cassette

II. BNL Beam Test

- Fibers
- Superlayers
- Trigger
- System Photo-electron yield

III. Mechanical

- Flat Panels
- Small Cylinders
- Fiber Ribbon Production
- Superlayer Production

IV. Status of Scintillating Fibers

-3HF Baseline

New Improved Dyes

V. Beam Test/Rad Damage Studies

T-851 and beyond

Environmental Effects

Future Beam Tests

VLPC Visible Light Photon Counter

A solid-state photomultiplier

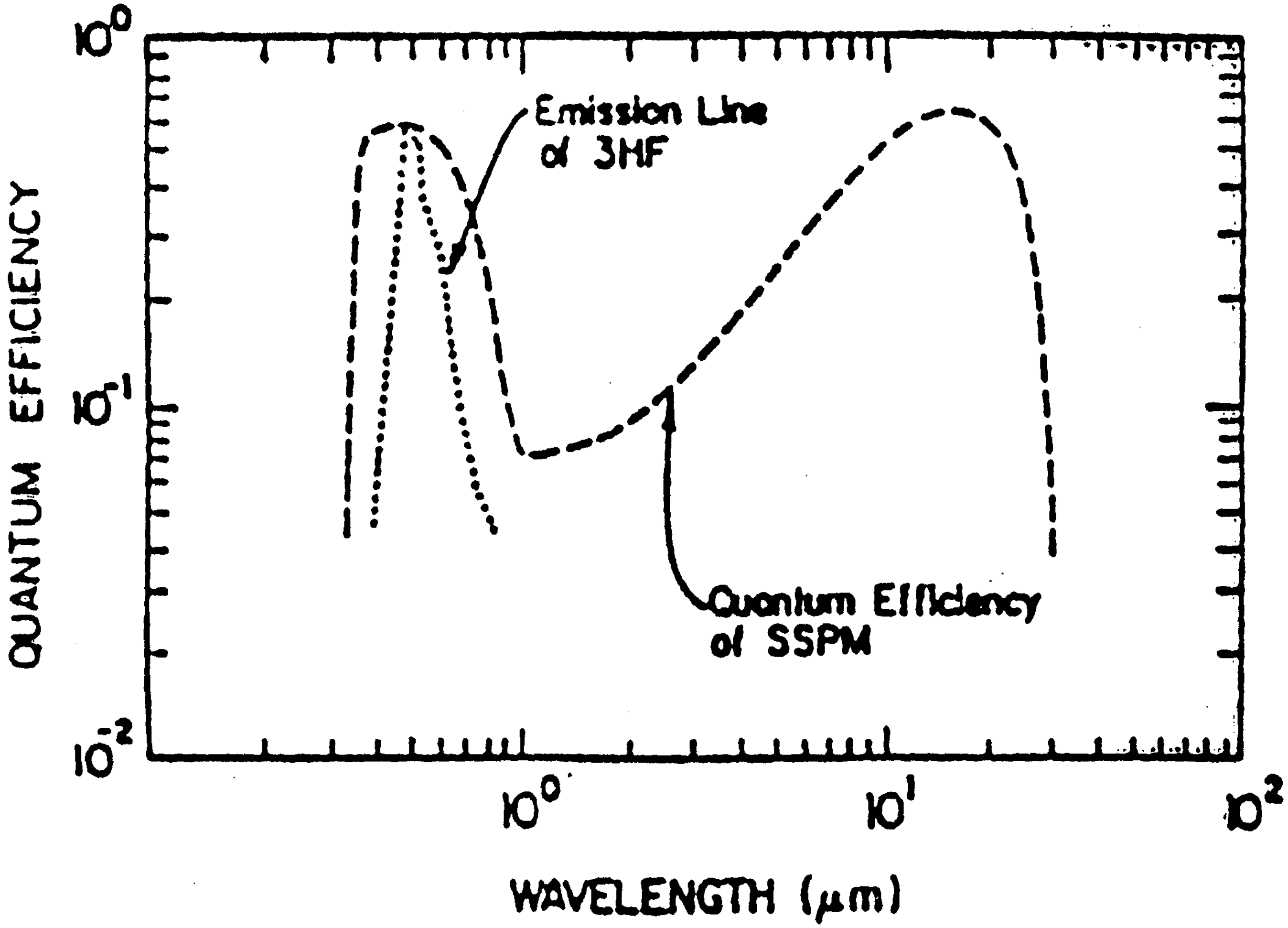
gain $\gtrsim 10^4$

Q. E. $\gtrsim$ 70%

(devices have achieved 85%)

Risetime < 8 η sec.

Cryogenic Operation ~7° k



QUANTUM EFFICIENCY
WAVELENGTH (μm)
Emission Line of 3HF
Quantum Efficiency of SSPM
10^0
10^-1
10^-2
10^0
10^1
10^2

Science Center
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P.O. Box 3105
Anaheim, California 92803-3105

Rockwell International

031-BC16

March 24, 1992

Prof. M. Atac
Department of Physics
University of California - Los Angeles
Los Angeles, California 90024

Dear Muzaffer:

The purpose of this letter is to update you on the status of Lot HISTE -III Visible Light Photon Counters (VLPCs).

VLPCs exhibiting very good performance have been obtained from lot HISTE-III. Wafer fabrication of this lot of devices was completed recently on the HISTE (High-Rate Scintillating Fiber Tracking Experiment) contract from UCLA.

The lot included three groups of wafers with different variations of material parameters; all three groups yielded operating VLPCs. Detailed evaluation of the best performing group has been carried out using dies of an 8-element line array from each of the three wafers in that group. Results to date are very positive and are summarized below.

Quantum efficiency in the visible and infrared spectral regions was measured on these devices and concurrently on a Solid State Photomultiplier (SSPM) fabricated earlier in lot HMC for checkout of a HISTE mask set. Table I summarizes the device quantum efficiencies estimated from these data. The estimated accuracy of these measurements is +5% to -15%.

TABLE I

	Quantum Efficiency* (%)	
Wavelength (μm)	**HMC Device**	**HISTE-III Device**
Visible - 0.55	85	80
Infrared -1.0 to 2.0	1	< 0.12
3.2	3	< 0.25
15	38	< 1.3
20	30	< 0.5

* These devices do not have the anti-reflection coating optimized for the visible spectrum.

Rockwell
International

It is clear that these HISTE-III devices combine high quantum efficiency in the visible spectrum with negligible quantum efficiency in the infrared. It should also be noted that these HISTE-III devices demonstrate a substantial performance improvement over the HISTE-II devices released for beam tests in December 1991 which had a visible spectrum quantum efficiency approaching 40%. The HISTE-III devices are Visible Light Photon Counters that could be made available for beam tests and other evaluations without the restrictions associated with SSPMs.

The dark count rate and biasing current of these HISTE-III devices are higher (factor of 2 to 4) than that of the best HMC devices. These can be reduced, if necessary, by tailoring the material parameters. Gain and gain dispersion have been observed qualitatively to be excellent, equivalent to or better than lot HMC devices. Quantitative data needs to be gathered.

HISTE-III VLPCs operate over a fairly wide temperature range (6 to 8.5K) with bias between 8.0 and 8.6V. Optimum performance is obtained at a temperature between 6.5 and 7K and at a bias of 8.2V, which is very comfortably below the breakdown voltage of 9.0 to 10.0V.

We plan to take data on additional devices. From past experience on impurity band conduction devices, we do not expect the variations from device to device on a wafer to be significant.

The VLPC refinement effort proposed for FY'92 funding will address adjustments between the various device performance characteristics (quantum efficiency, dark count, latchup, etc.) and material/process parameters (doping concentrations, layer thicknesses, AR coating) to provide optimization of the device performance and stability range for SSC requirements.

ROCKWELL INTERNATIONAL CORPORATION
SCIENCE CENTER - ANAHEIM

Paul Besser

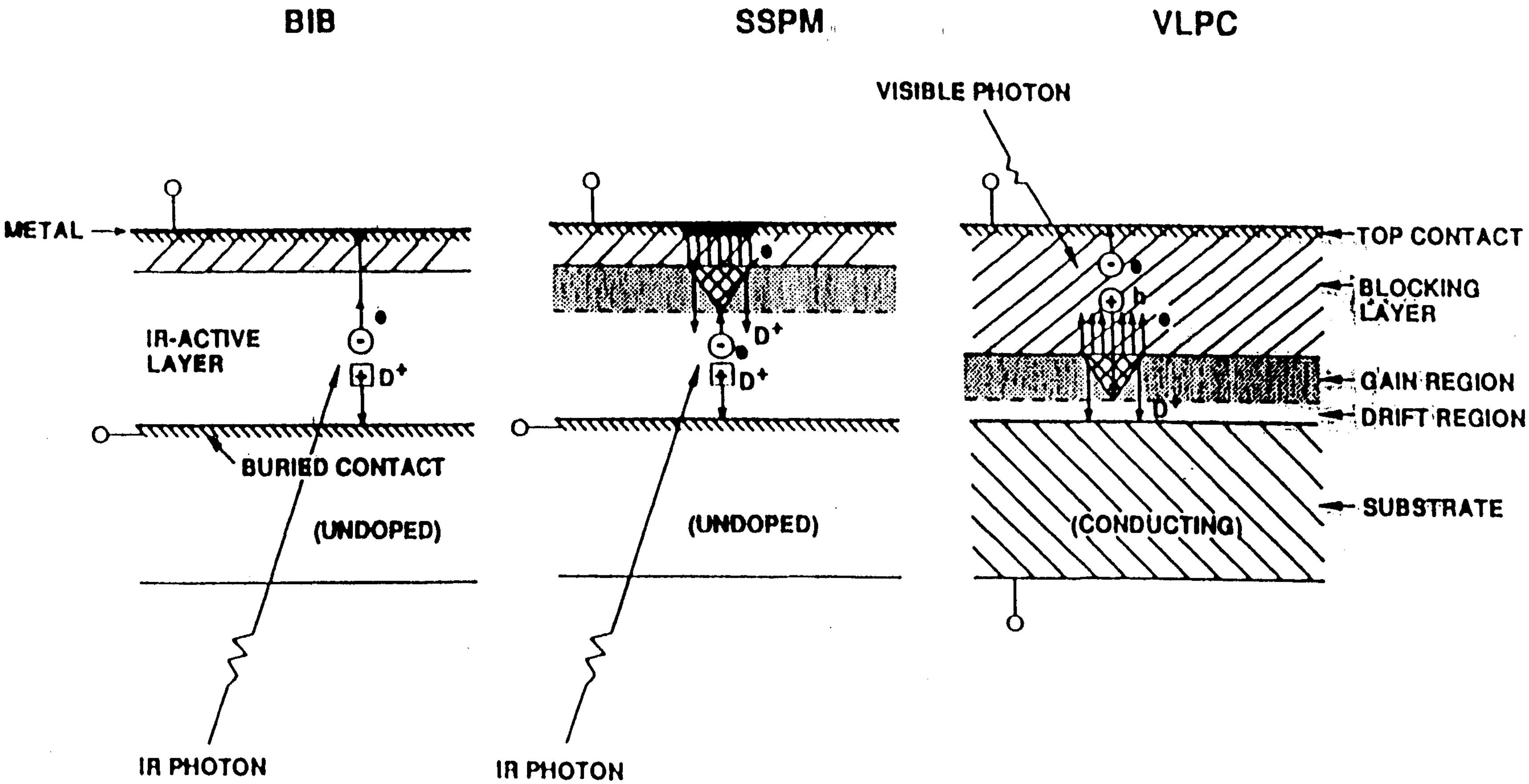
P. J. Besser
Manager
Silicon Programs

PJB:bc

IMPURITY BAND CONDUCTION DETECTORS

M. P[illegible]
M. A[illegible]

DEVICE STRUCTURES



Level 1

The production and operation of 8-channel arrays of VLPCs with accurate dimensions and uniform operating conditions within each element of the array. This step has been accomplished. See Figure 1.

Level 2

The production and operation of working sub-assemblies consisting of 4 arrays (32 channels) with high density packing and uniform operating characteristics for each of the VLPC channels. This step has been accomplished. See Figure 2.

Level 3

The production of integrated sub-assemblies into a high density 128-channel unit which can serve as a sub-module for a fully integrated cassette. A design now exists and is shown in Figure 3.

Level 4

The production and operation of a fully integrated 512-channel cassette containing sensitive high speed pre-amplifiers and low voltage digital line drivers. This cryogenics module will accept the light output from a group of scintillating fibers and output a digital signal to both a fast trigger system and a simple latch for storage to be read by the data acquisition system. A preliminary design of the cassette now exists and is shown in Figure 4.

Level 5

The production and operation of a 16 cassette system (~8,000 channels) as is shown in Figure 5. This is the highest level of integration that is necessary for the SSC. This is the eleme that will be replicated to form the opera system.

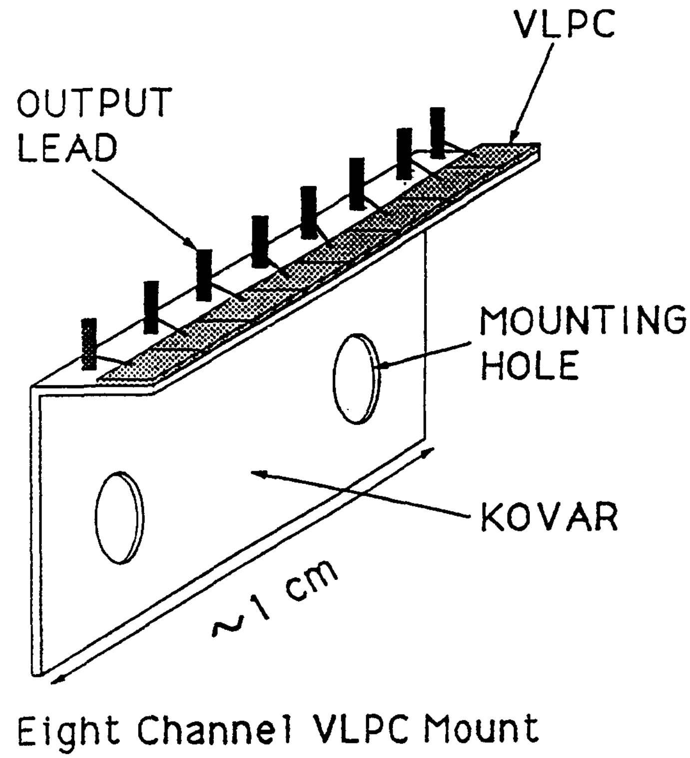
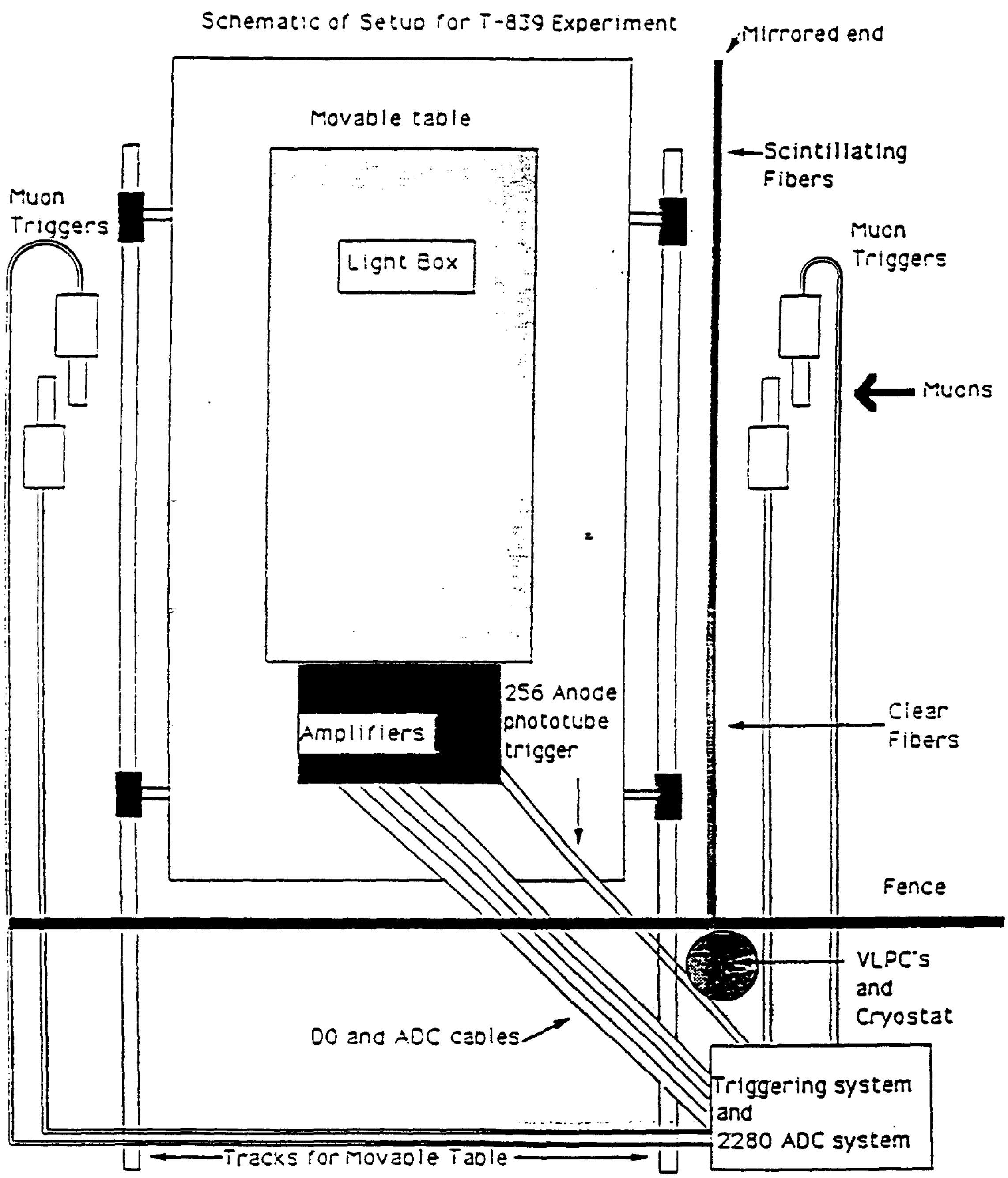
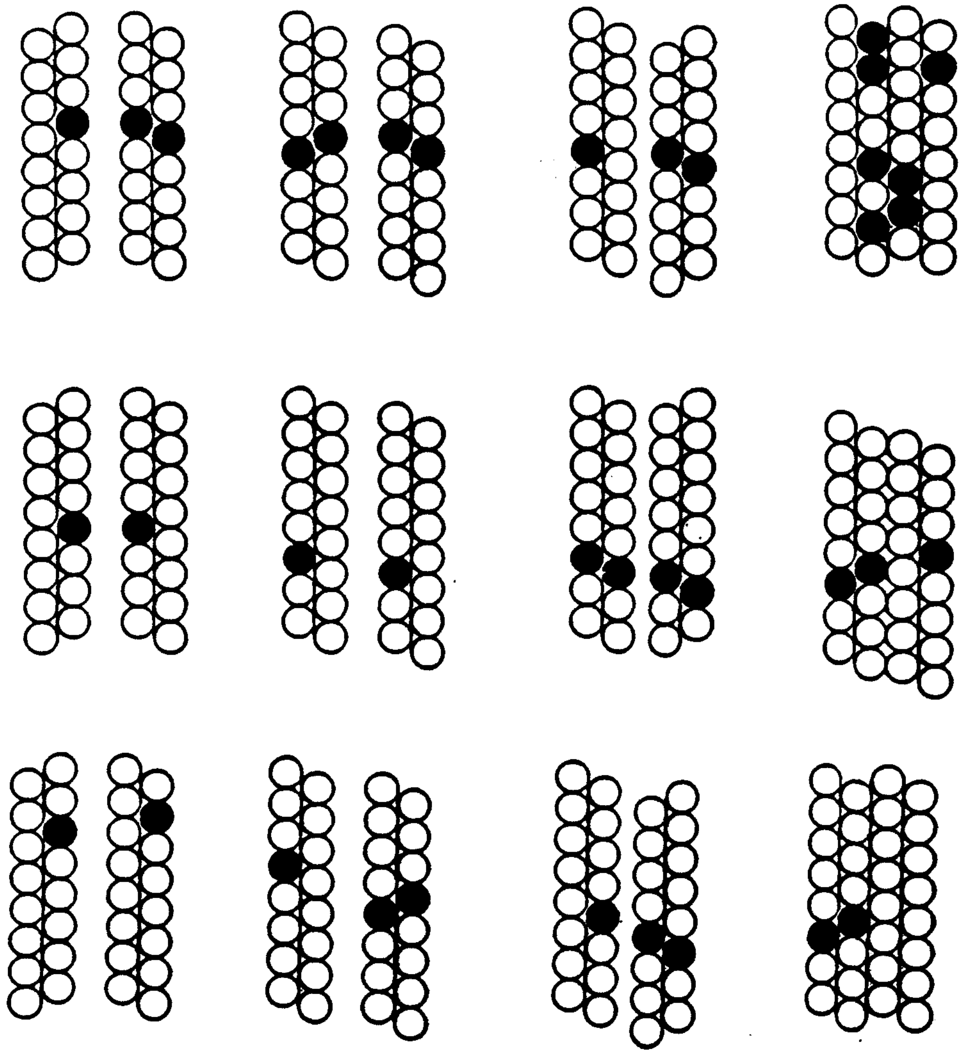
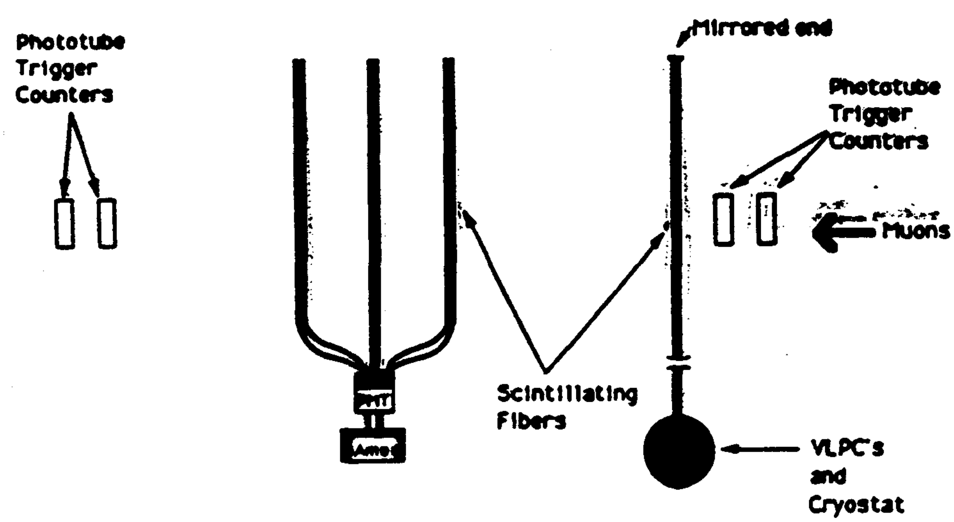


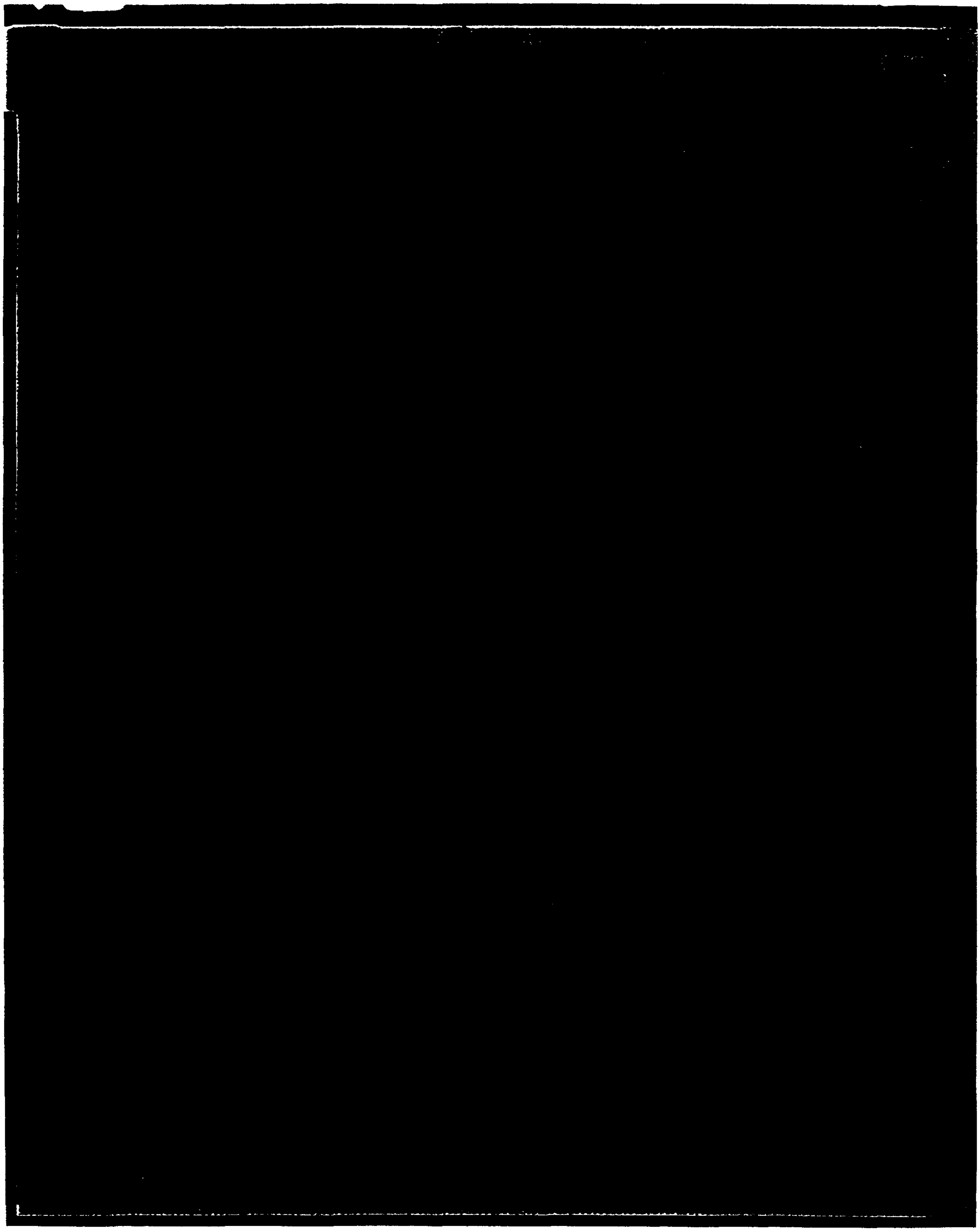
Fig. 1 An 8 channel VLPC array, wire bounded and placed unto a Kovar Mount. New mounts will be made of Invar. The new pixels will be 1 mm in diameter, round to eliminate cross coupling. These have been successfully operated.

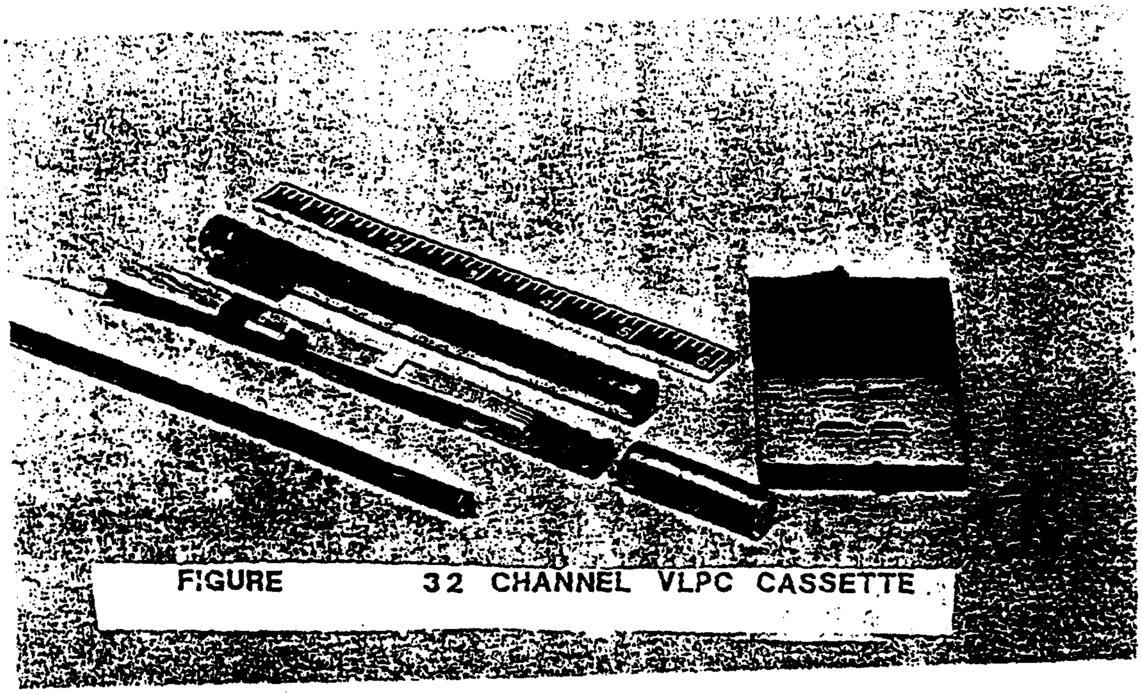

Schematic of Setup for T-839 Experiment
Mirrored end
Movable table
Scintillating Fibers
Muon Triggers
Light Box
Muon Triggers
Muons
Amplifiers
256 Anode phototube trigger
Clear Fibers
Fence
VLPC's and Cryostat
D0 and ADC cables
Triggering system and 2280 ADC system
Tracks for Movable Table



Schematic of T-839 Experiment







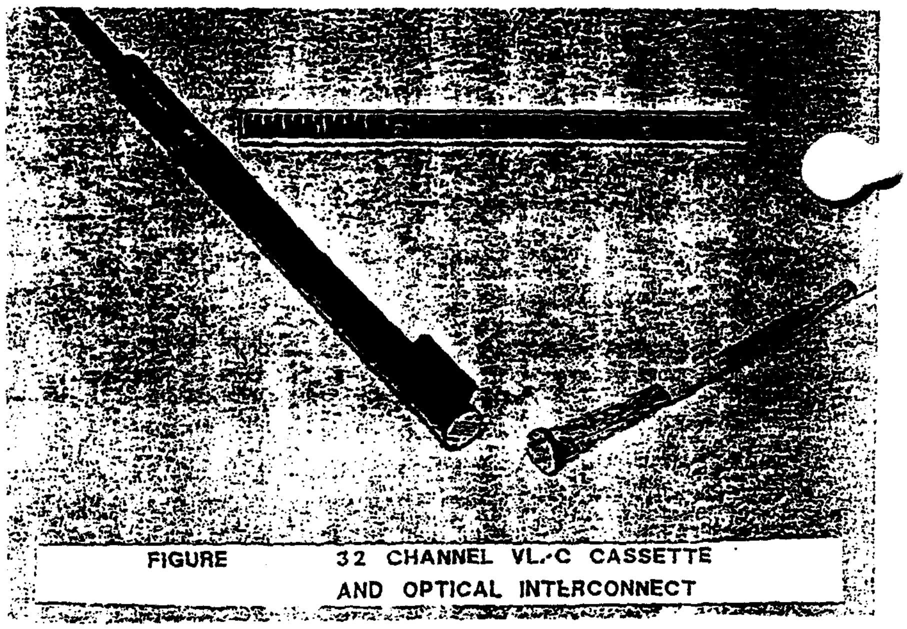


Fig. 2 A 32 channel VLPC cassette. Successful operation of this device has been carried out in Fermilab Beam Test T-839. The present cassette works using the "boiling cryostat" technique.

128 CHANNEL VLPC MODULE

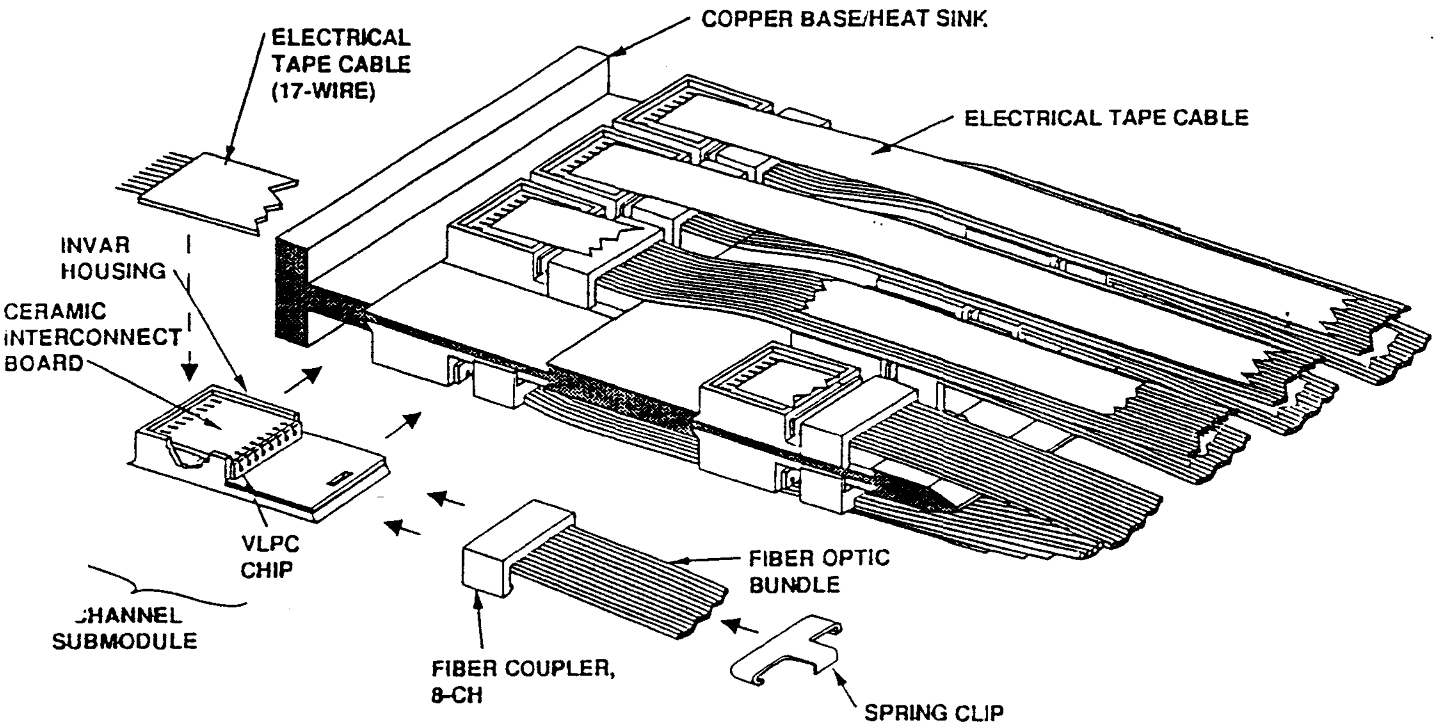


Fig. 3 Present preliminary design of a 128 channel VLPC module. There are many aspects of this design that need detailed analysis and critical review before prototype production can proceed.

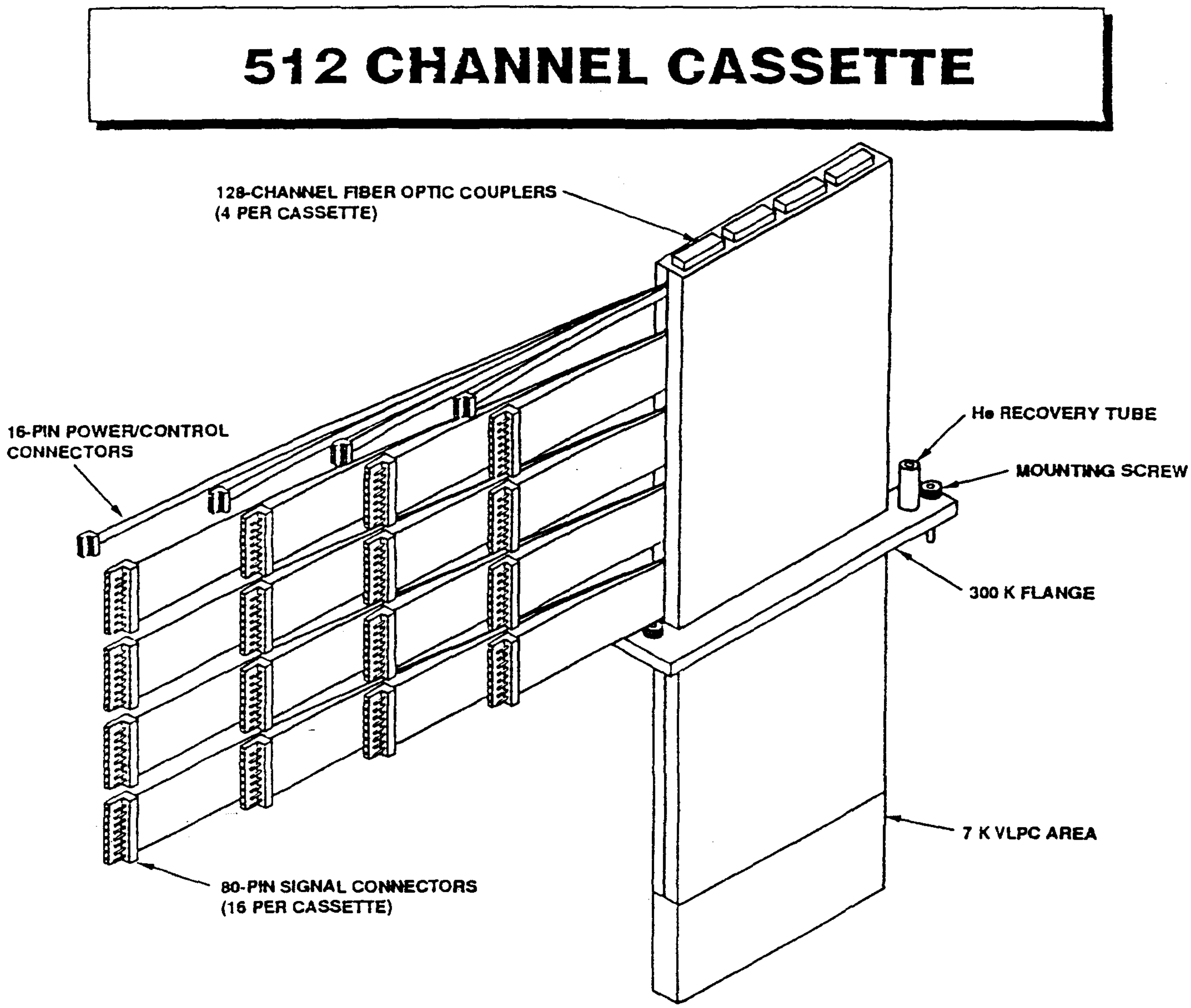


Fig. 4 Conceptual design of a 512 channel VLPC cassette. The funding request is aimed at building two of these cassettes and operating them by the end of 1992 or early 1993.

8192 CHANNEL CRYOSTAT BASELINE DESIGN

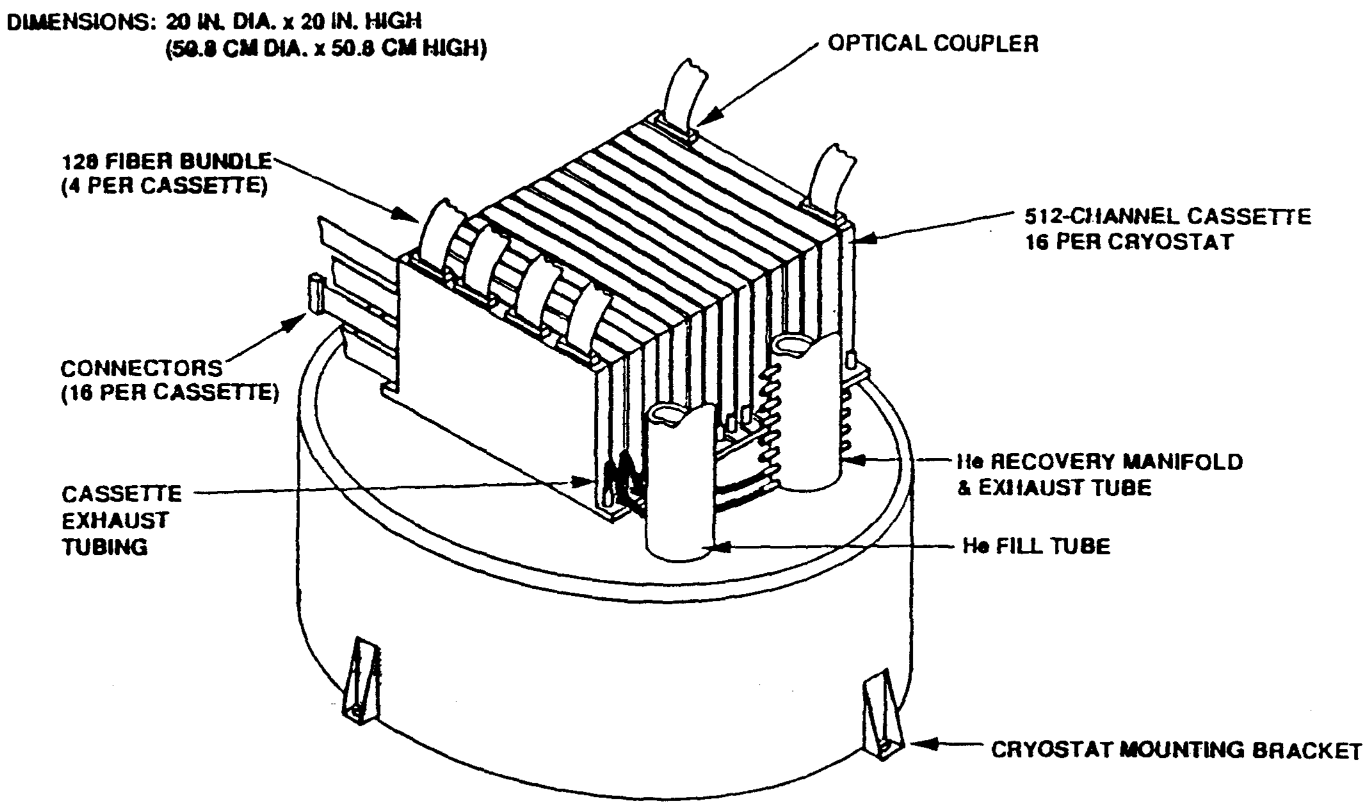
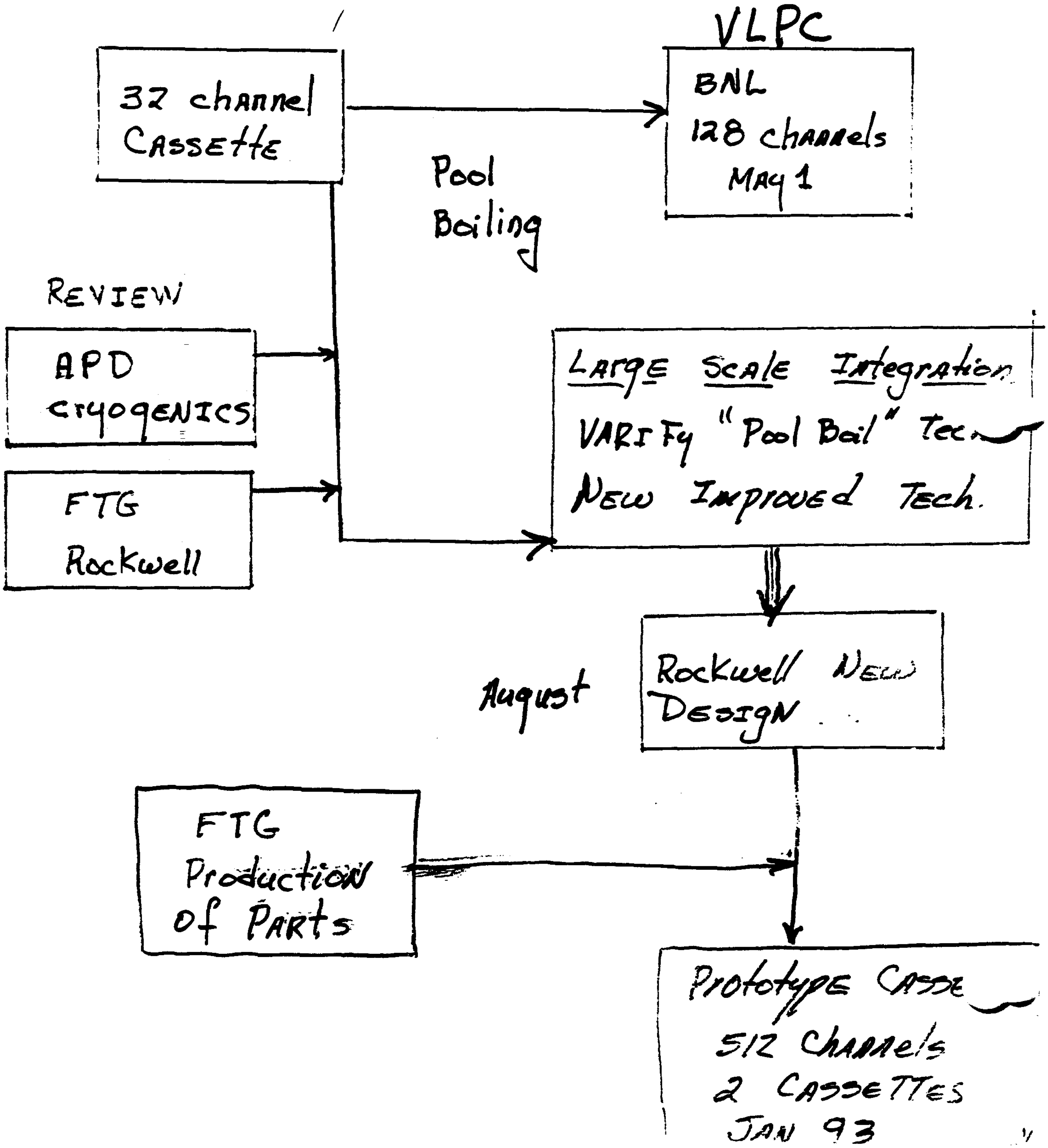


Fig. 5 Conceptual design of a 16 cassette cryostat. The funding request proposes only to build a cryostat capable of holding two cassettes. This will be adequate for verifying the design.

VLPC - Cryogenics



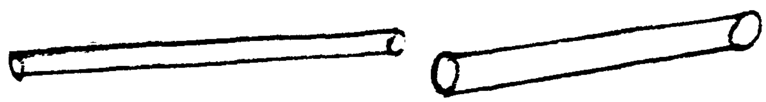
VLPC - Development

HISTE - III Excellent

November 1 HIST - III

Anti-Reflective coating Si_3N_4

New Mask Set 1mm



Characterize one lot of HIST IV Range of Materials

November 1, 1992 (start)

Final VLPC Design Optimization of SSC.

Contact Resistance

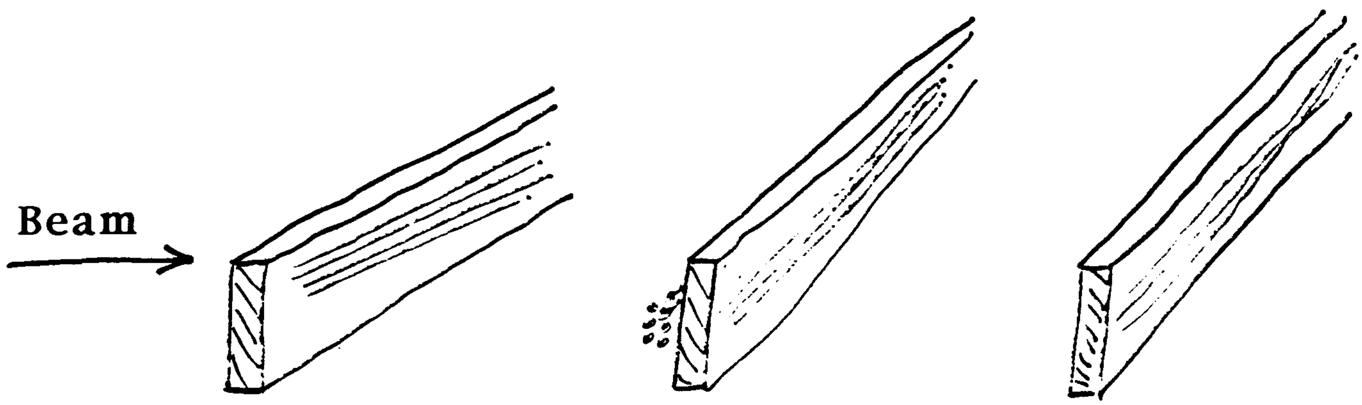
Latch-up Suppression

Fully Optimized Q. E.

July 1993 (start)

Production of 10,000 channel lot of VLPCs

BEAM TEST AT BNL



Ribbons accurately placed on flat 4.3 m x 1.6 cm boards

Readout with HISTE III VLPC

Custom made cryostat (design by Rockwell)

- 128 VLPC channels (min)
- 3 double sided superlayers
- 830 μm 3 HF fibers (1000 ppm)
  (Bicron order has been placed)
- 2 x 10 doublet ribbons

Goals of the BNL Beam Test

Start May 1992

Operation of 128 channel system

Produce accurate ribbons

Bicron
Kuraray
FTG

Light yield from 4.3 meter fiber with SDC length waveguides

Measure resolution
checks fiber placement

Stability of system for 1 month run

Self Trigger (3 superlayer trigger)

Accurate Ribbon Fabrication

SSC Quality Ribbons

$<$ 25 μm — { center to center misplacement; 100 x 2 doublet ribbons }

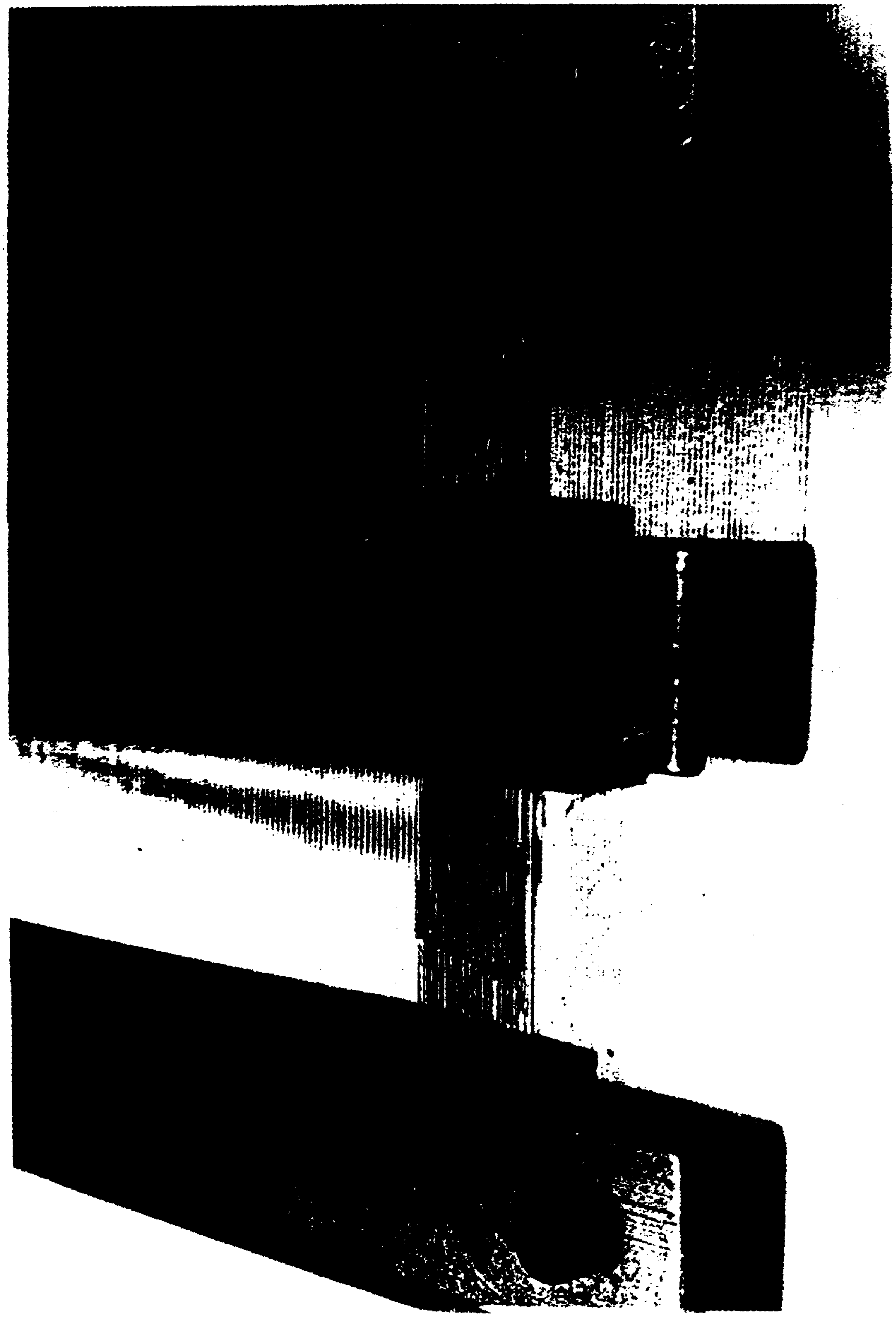
Attempt 512 x 2 doublet ribbons

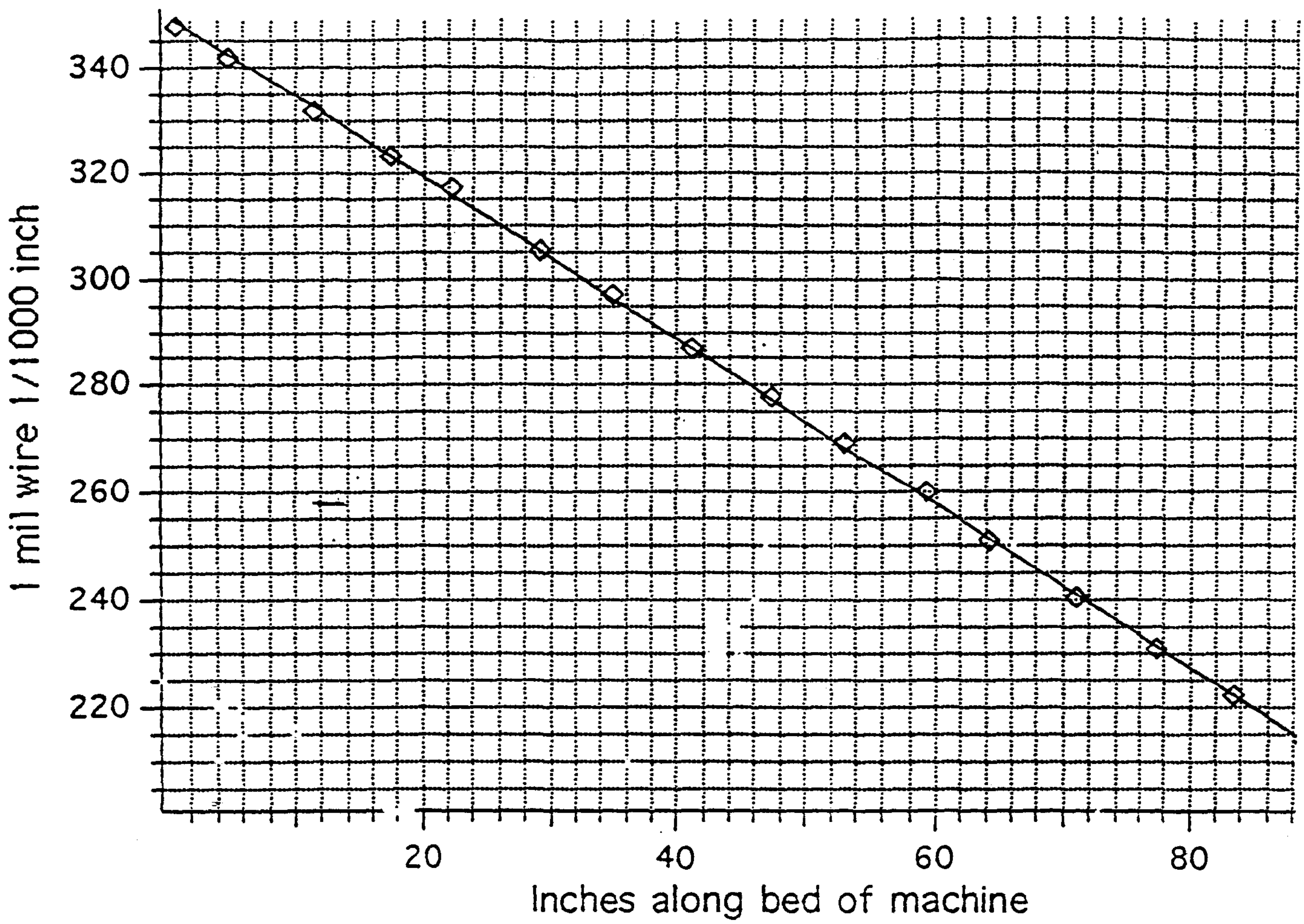
4.5 m ribbons with 10 cm free ends

Ribbon fab at Bicron with FTG participation

- check environment
- quality of product
- material for ribbons
- refinement to process

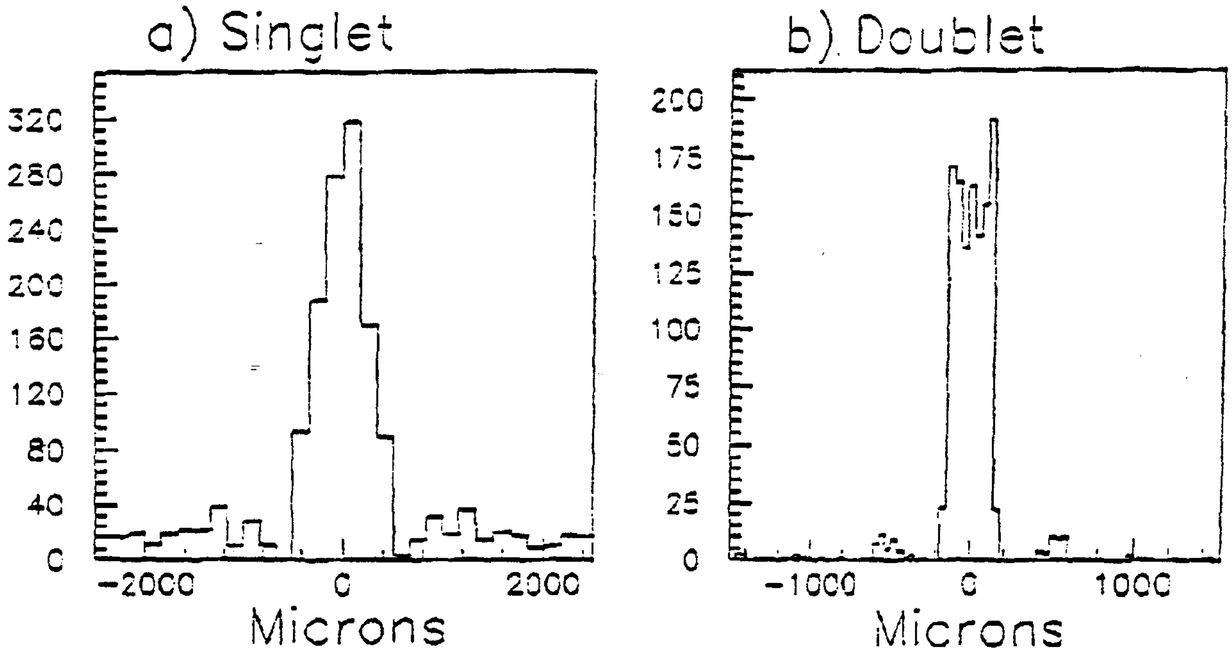
Kuraray Ribbons





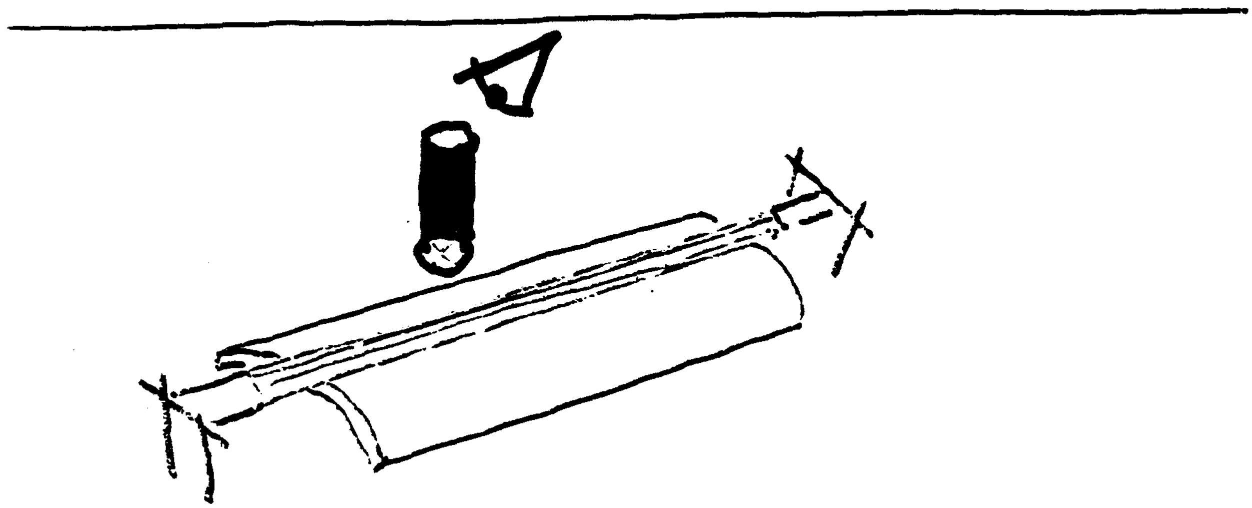
$\sigma \leq 12 \mu m$ Error consistant with measuring error.

Ribbon
Making Jig.



Resolution measured in test beam experiment T-831.
A) A single layer ribbon
B) A double layer ribbon.

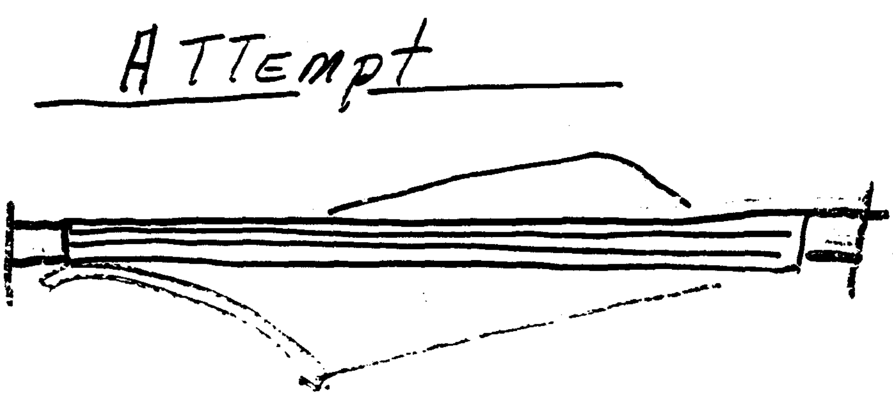
Accurate placement of ribbons on
curved surface



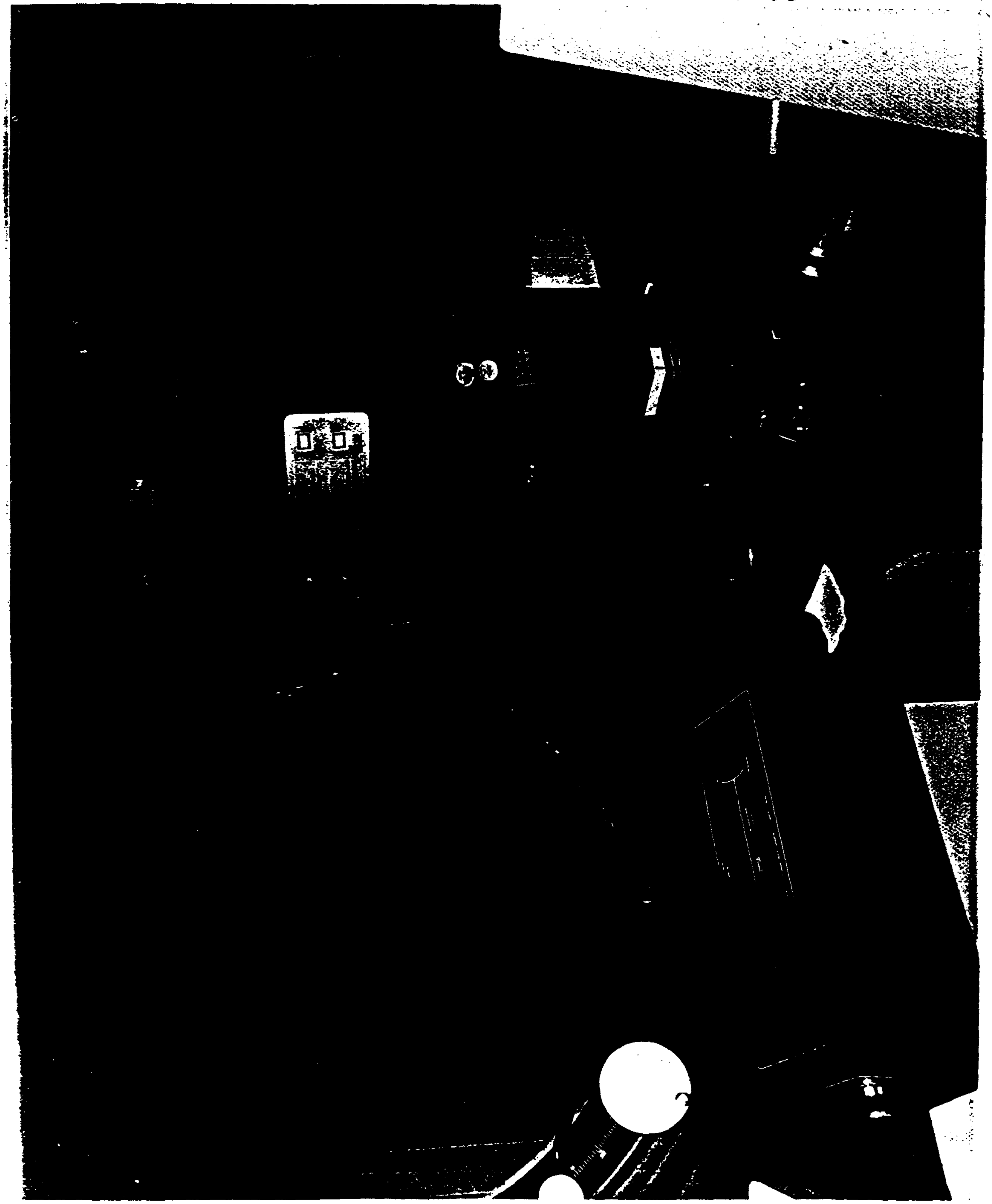
Development of placement technique

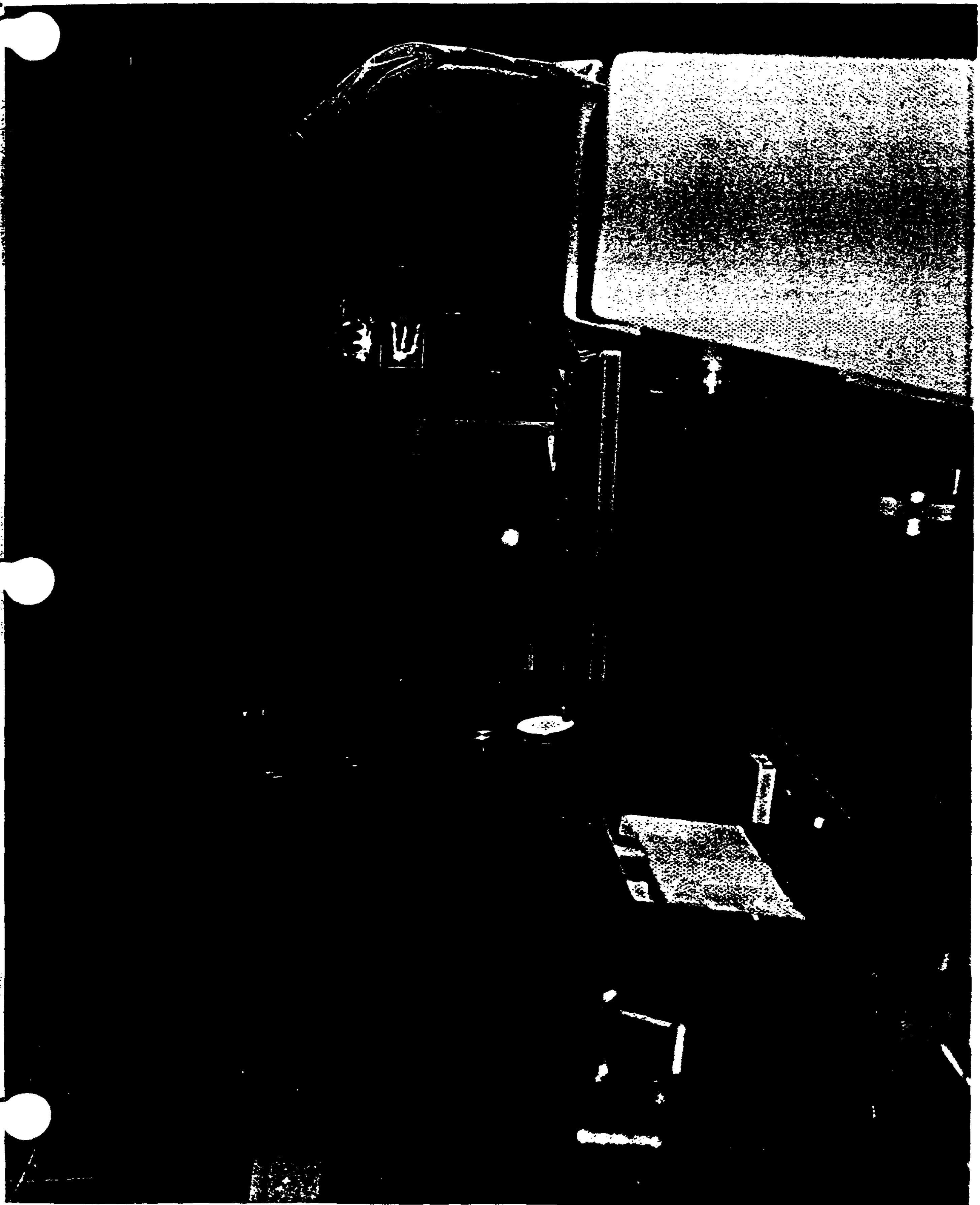
Check of placement of fibers on curved surface

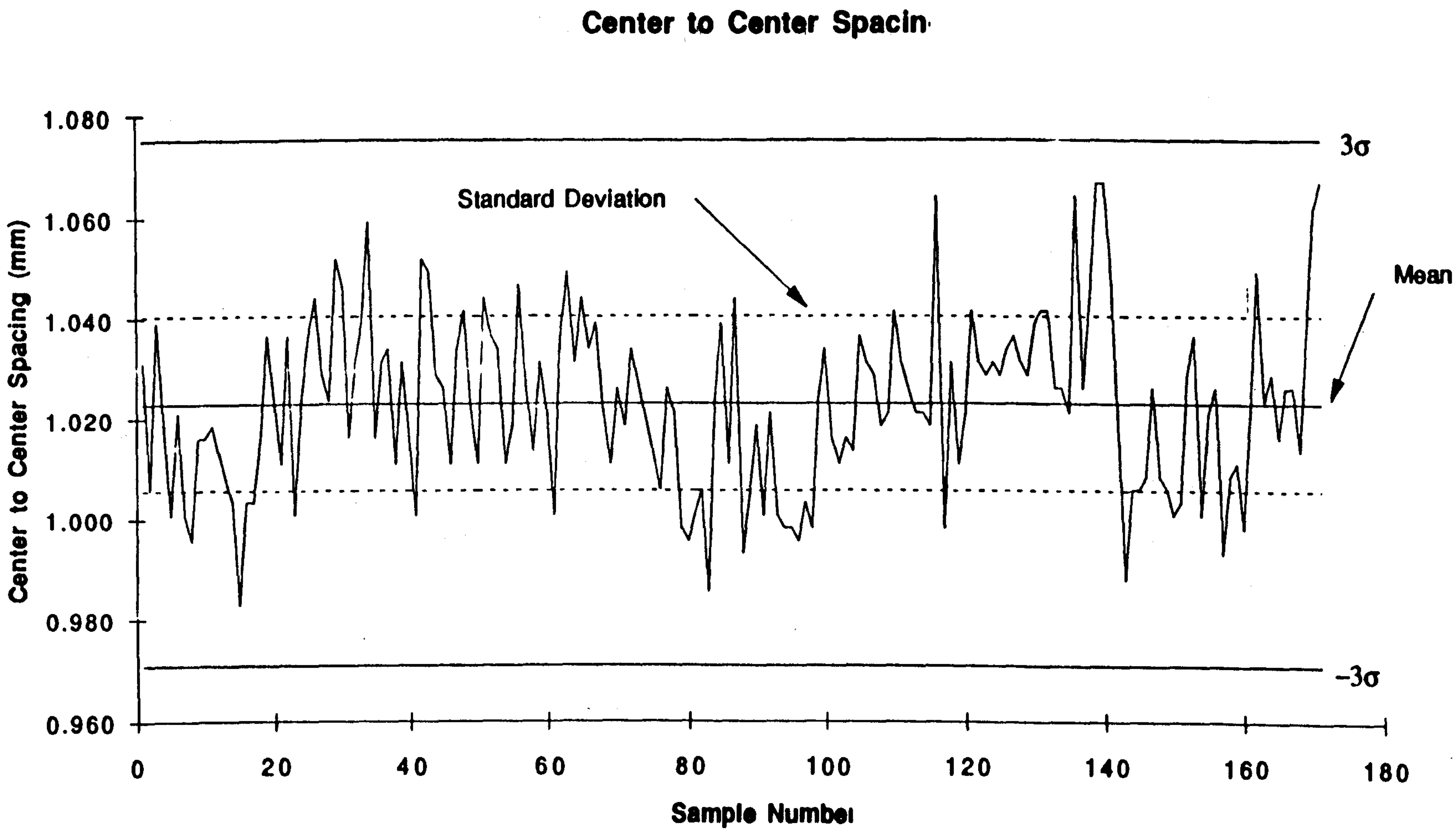
Placement of fibers on curved surface



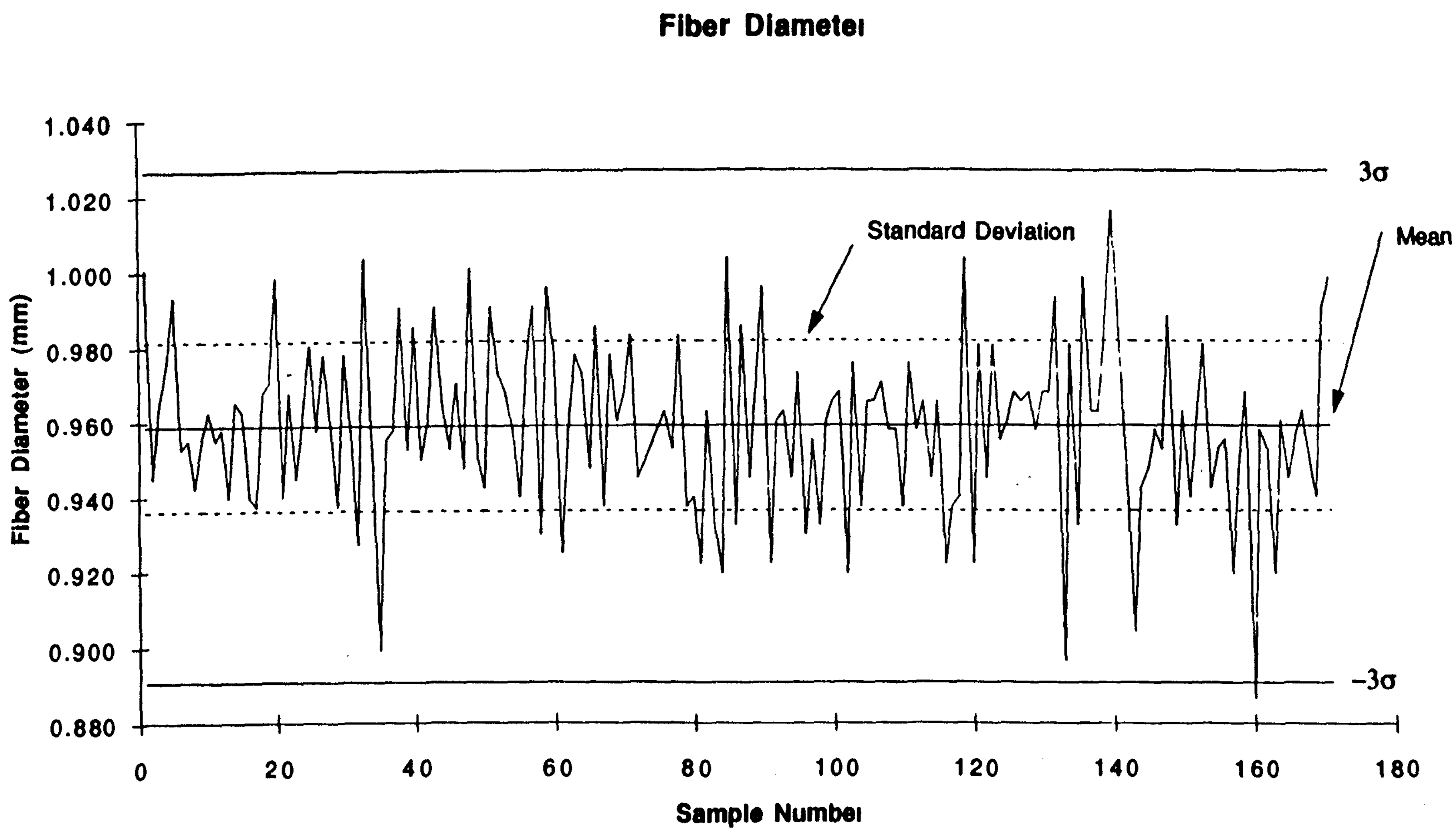
Stereo placement of ribbons

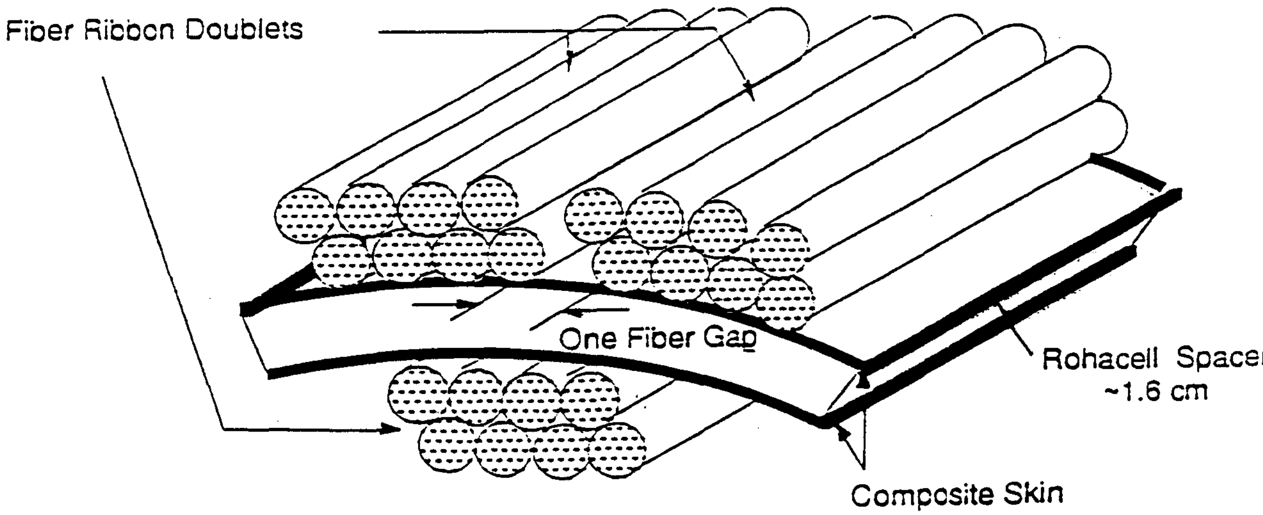






Center to Center Spacin
Standard Deviation
Mean
3σ
-3σ
1.080
1.060
1.040
1.020
1.000
0.980
0.960
Center to Center Spacing (mm)
0
20
40
60
80
100
120
140
160
180
Sample Numbei


Fiber Diametei
1.040
1.020
1.000
0.980
0.960
0.940
0.920
0.900
0.880
Fiber Diameter (mm)
3σ
Standard Deviation
Mean
-3σ
0
20
40
60
80
100
120
140
160
180
Sample Numbei



Composite Cylinders

Carbon fiber epoxy skins ~ 10 mills thick

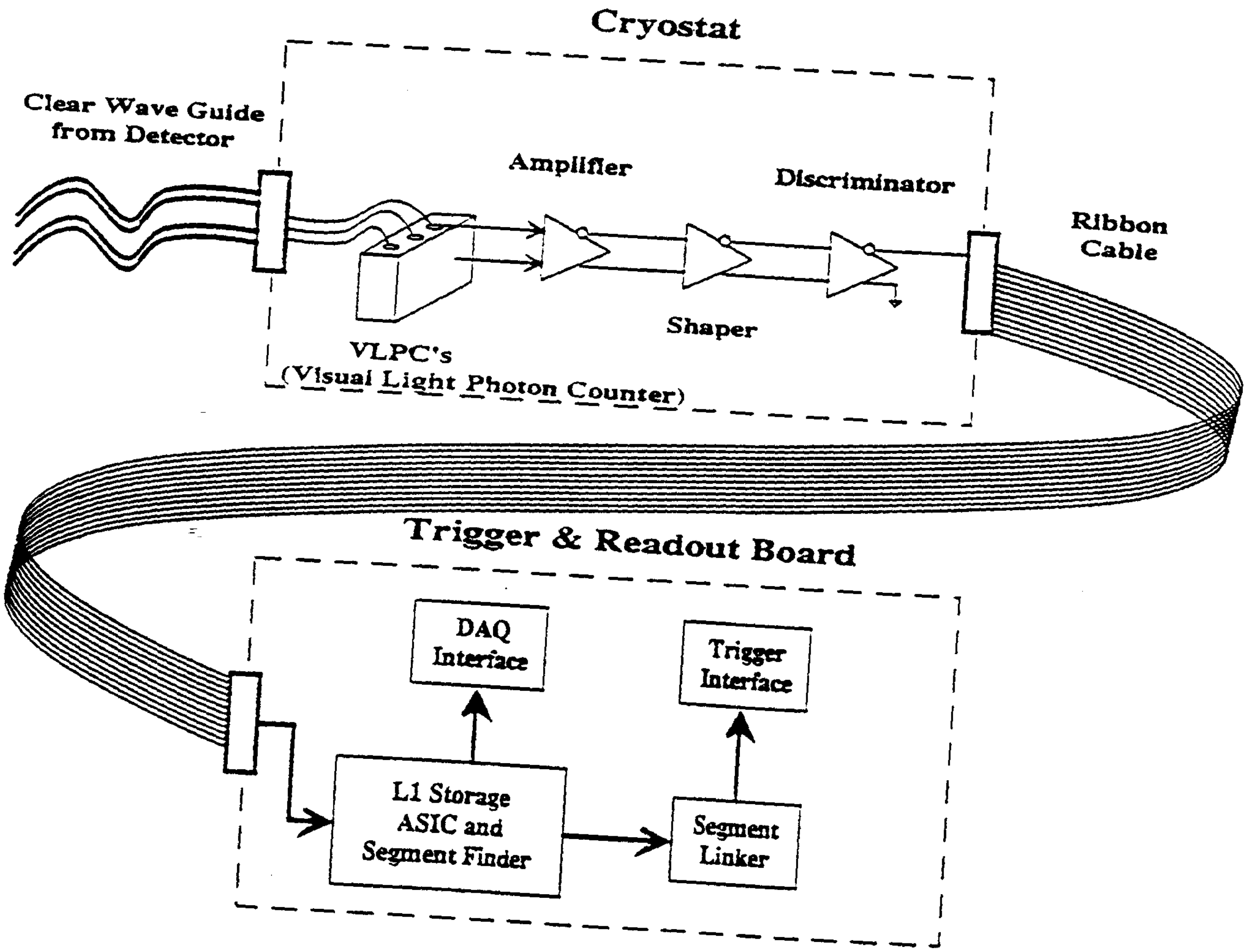
First flat panel boards
    4.3 m x 1.5 cm x 1.6 cm
    (in hand for BNL)

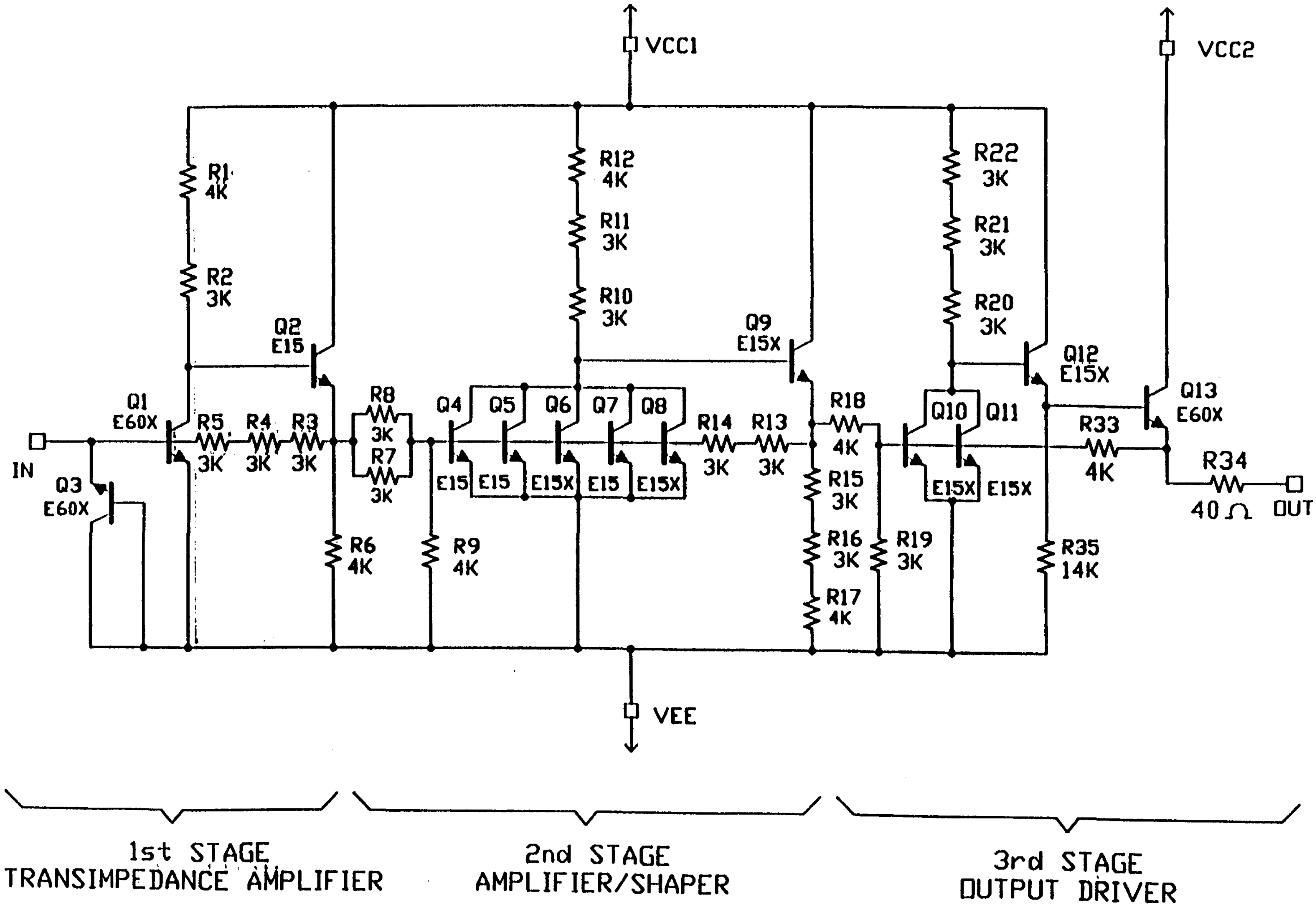
2 Prototype Cylinders
    Now in production at Hercules
    (expected finish: July)

    Test Stand at FNL (cosmic ray)

    Studies
    Accuracy
    Moisture test
    Radiation
    Temperature
    Surface

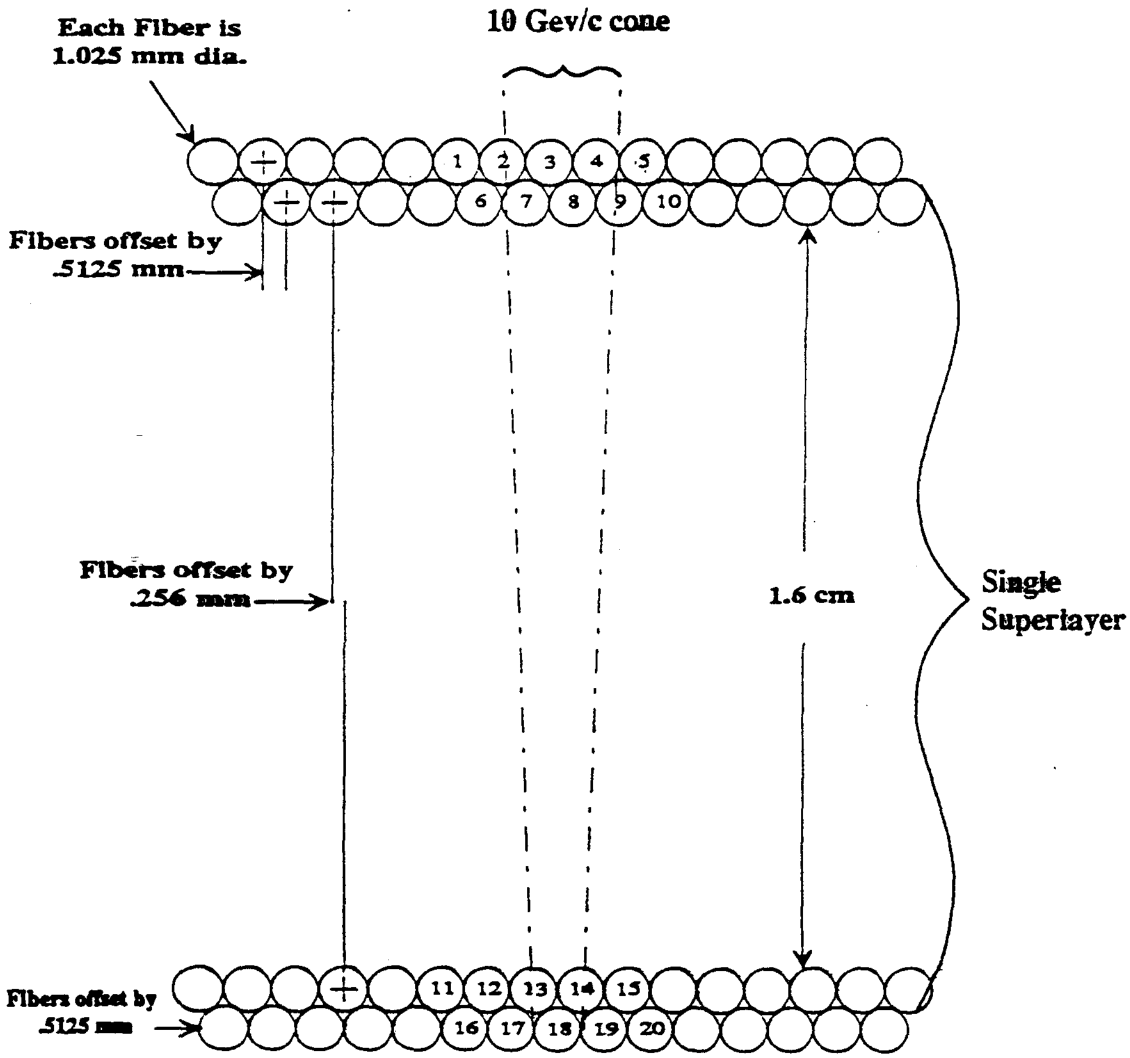
Scintillating Fiber Front End Electronics





VCC1
VCC2
R1 4K
R2 3K
Q2 E15
R12 4K
R11 3K
R10 3K
Q9 E15X
R22 3K
R21 3K
R20 3K
Q12 E15X
Q13 E60X
Q1 E60X
R5 3K
R4 3K
R3 3K
R8 3K
R7 3K
Q4 E15
Q5 E15
Q6 E15X
Q7 E15
Q8 E15X
R14 3K
R13 3K
R18 4K
Q10 E15X
Q11 E15X
R33 4K
R34 40 Ω
IN
OUT
Q3 E60X
R6 4K
R9 4K
R15 3K
R16 3K
R17 4K
R19 3K
R35 14K
VEE
1st STAGE
TRANSIMPEDANCE AMPLIFIER
2nd STAGE
AMPLIFIER/SHAPER
3rd STAGE
OUTPUT DRIVER

Track Segment Finding Algorithm



Acceptance cones for 10 GeV tracks
in single fiber bins

KLK
01/22/92

FLUORESCENT DYE DEVELOPMENT

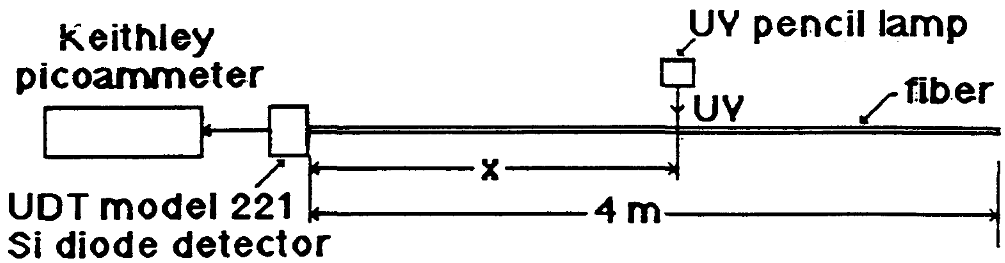
STANDARD MATERIAL

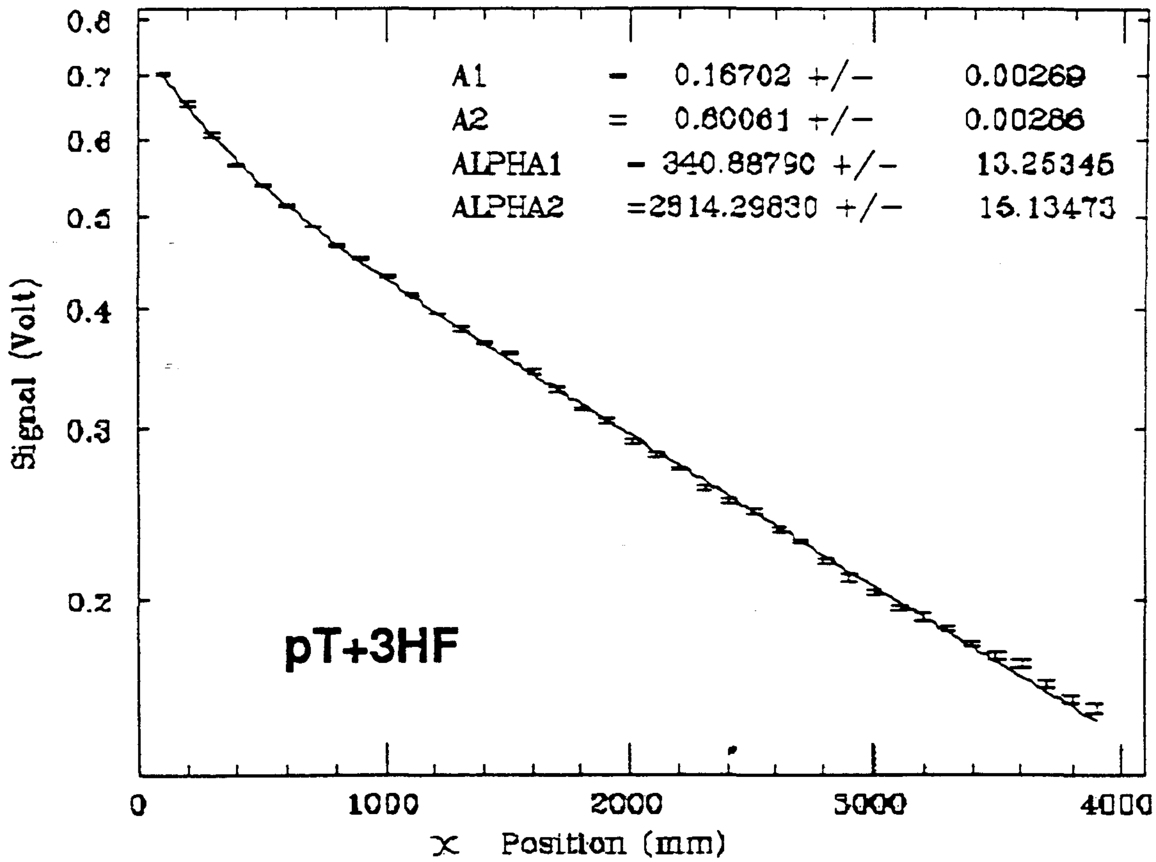
PS/PTP/3HF (KURARAY/BICRON) ~530 nm FIBER

FTGØ -	MOPOM/K27	~500 nm	FIBER
FTG1 -	DBTem-POPOP/K27		
FTG2 -	BC447	~540 nm	FIBER
FTG3 -	KAUFFMAN-A	~535 nm	
FTG4 -	KAUFFMAN-B	~535 nm	
• FTG5 -	BCF99-42	~530 nm	FIBER
• FTG6 -	KELLEY-A	~530 nm	DRAWING FIBER
• FTG7 -	KELLEY-B	~530 nm	PREFORMS
FTG8 -	KELLEY-C KAUFFMAN	PROPOSED FOR DELIVERY SUMMER 92	

2. Attenuation lengths

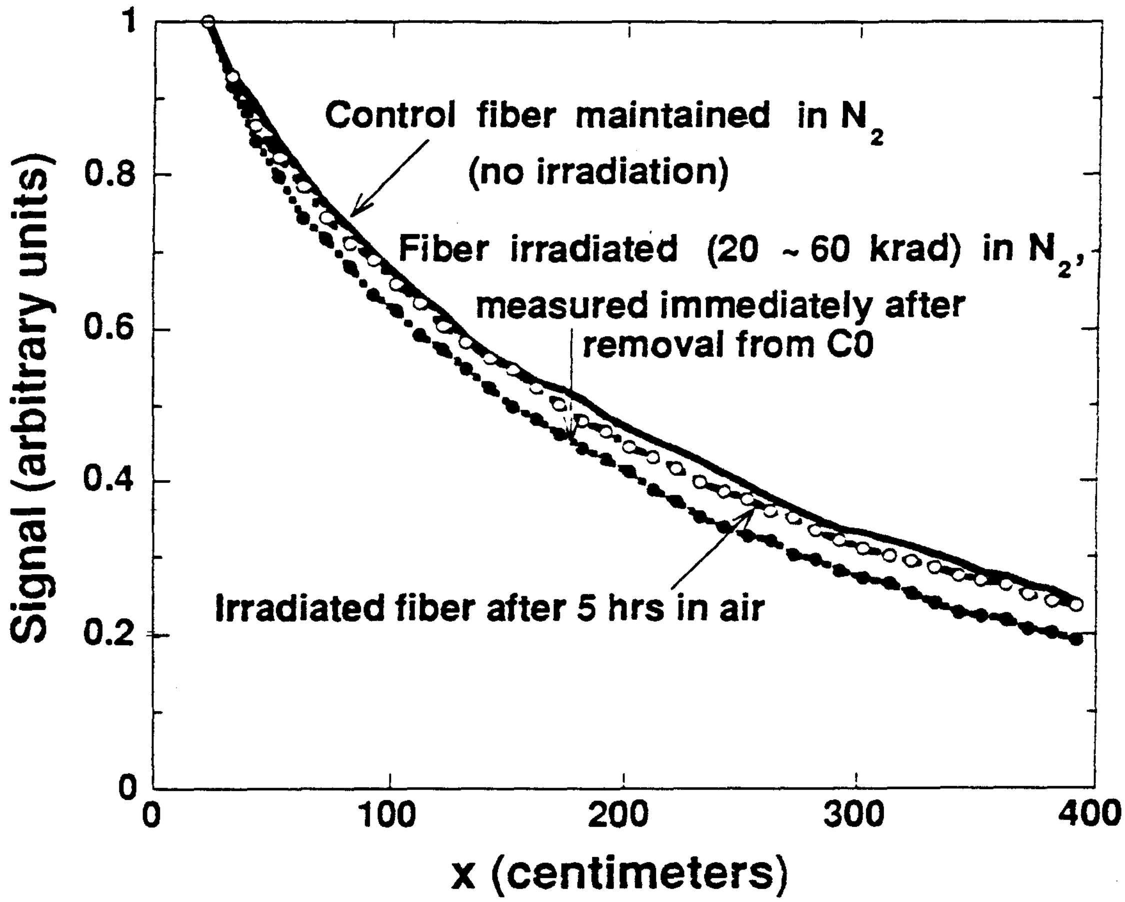
Measured by excitation with ultraviolet.





Typical transmission measurement for a fiber. The smooth curve is a fit using the sum of two exponentials.

RESULTS (pT+3HF)



Transmission curves
(normalized to unity at x = 22 cm)

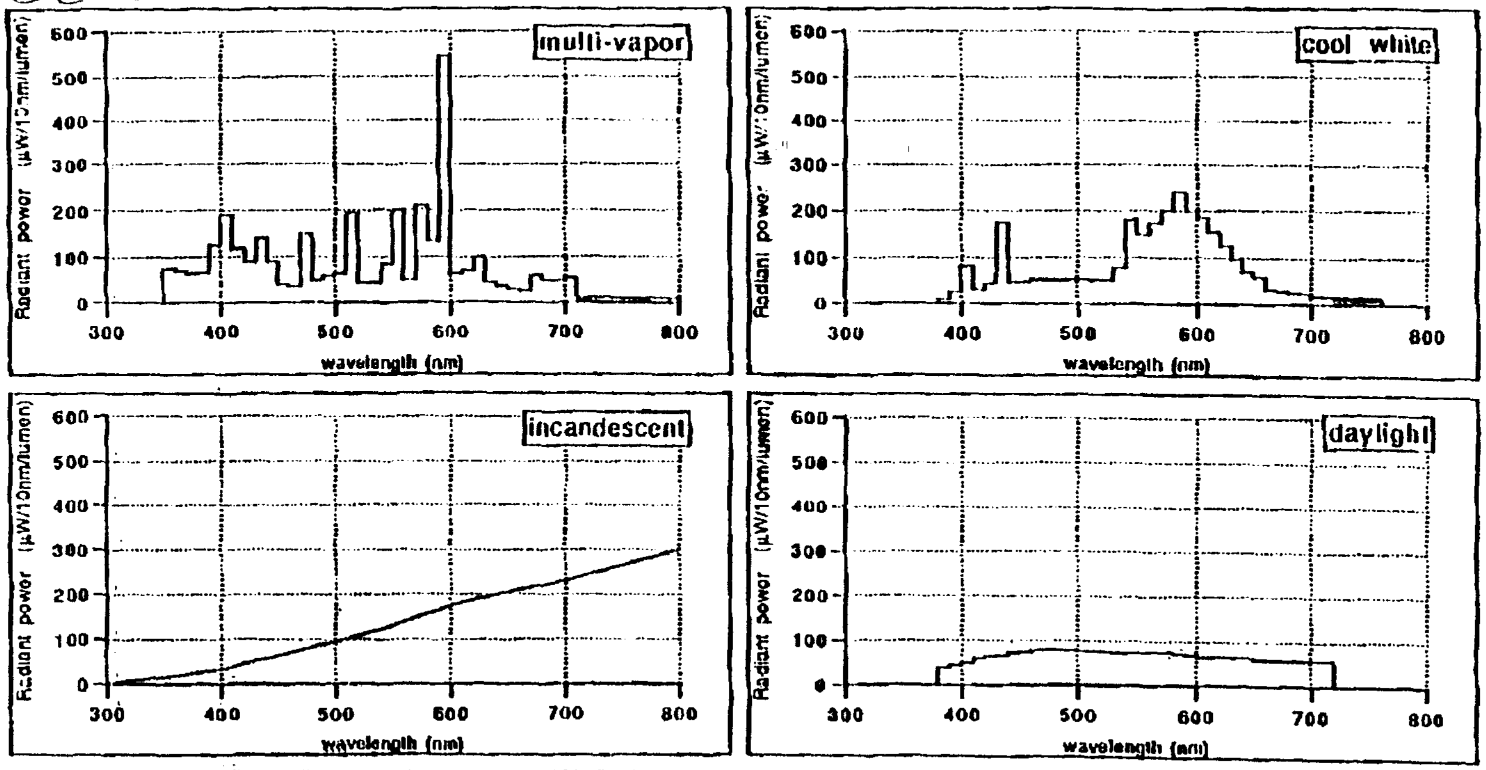
Long term test of environment and lighting on scintillating and clear waveguide fibers

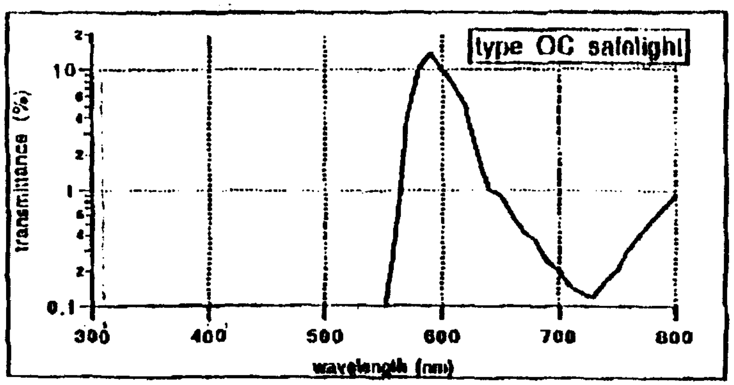
C. John Schmitz
Purdue University

4 March, 1992

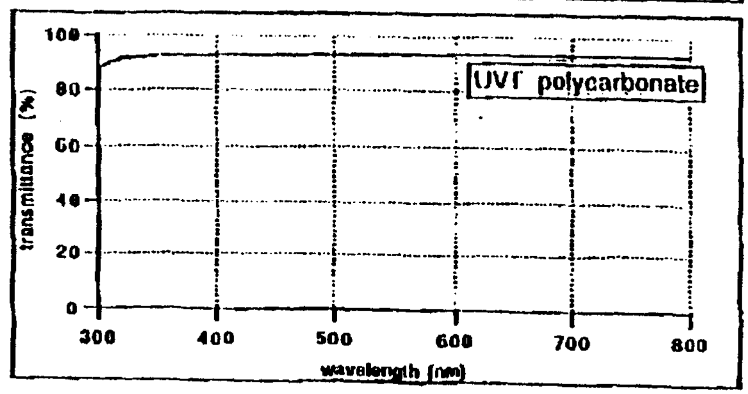
SOURCES:

GE LIGHTING APPLICATION BULLETIN





HANDBOOK OF KODAK PHOTOGRAPHIC FILTERS



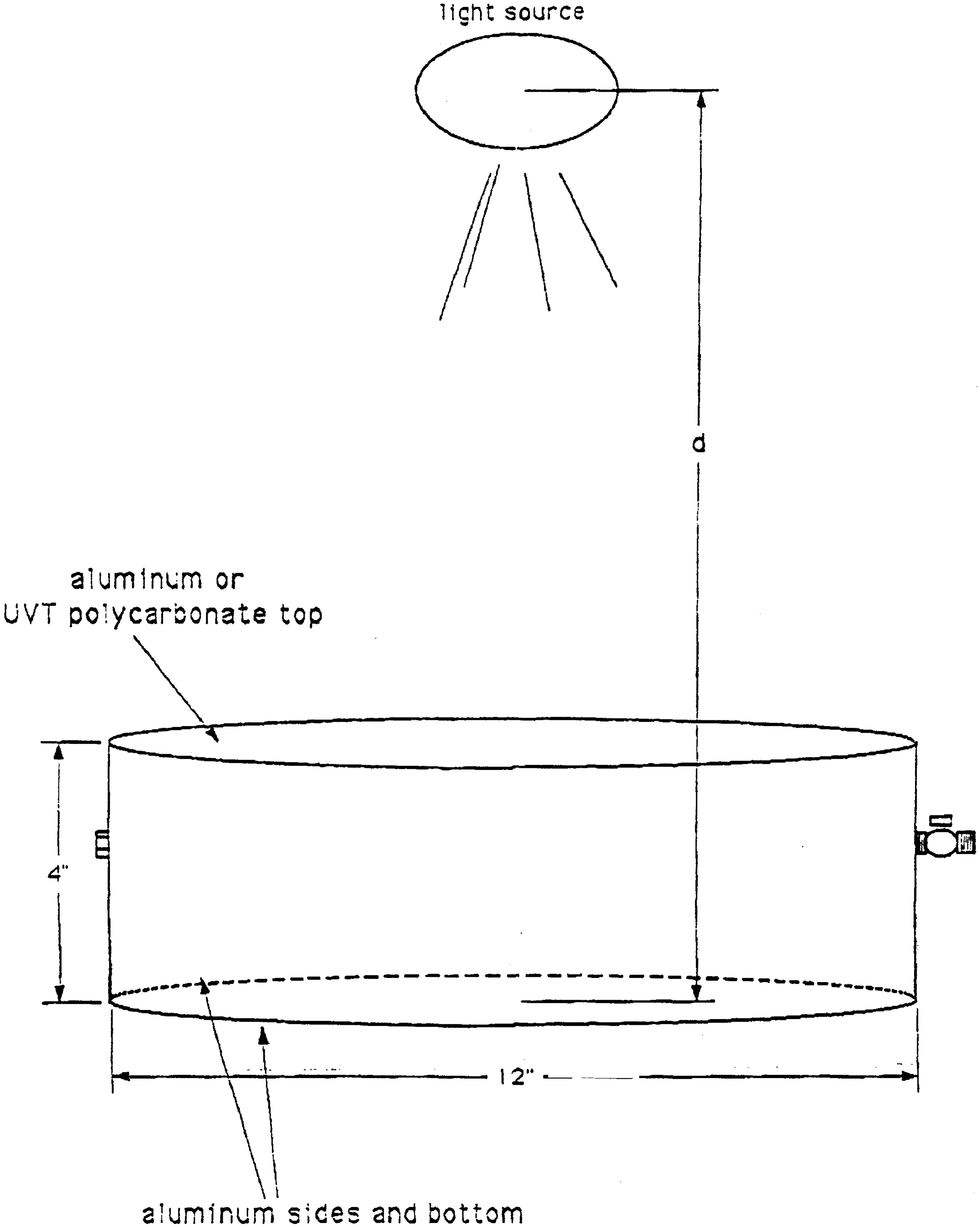
POLYCAST CORPORATION

TEST CONDITIONS

for clear and scintillating waveguides

environment	light sources: dark	cool white fluorescent	multi-vapor high-intensity discharge	incandescent	type OC photographic safelight
dry nitrogen	Al and UVT	UVT	UVT	UVT	UVT
dry air	Al	UVT	UVT	UVT	UVT
humid air	Al	UVT	UVT	UVT	UVT
distilled water	Al				
isopropyl alcohol exposure	Al				
body oils (hands)	Al				
epoxy	Al				

Al = aluminum lid
UVT = ultraviolet transmitting polycarbonate lid (Polycast SUVT-3)


light source
d
aluminum or
UVT polycarbonate top
4"
12"
aluminum sides and bottom

Goals of the Fiber Tracking Group in 1992

Beam Test of 3 superlayer prototypes at BNL

Accurate Ribbon Fabrication at Bicron and Kuraray

Accurate verfication of SDC quality ribbons

Accurate placement of ribbons on cured surface

Refinements to VLPC
(improve Q.E., contact ℓ, latch up . . .)

Brassboard (512 channels)

Warm Amp development