SDC-92-191

SDC
SOLENOIDAL DETECTOR NOTES

REVIEW OF RECENT R & D IN FIBER TRACKING

R. Ruchti
University of Notre Dame

January 30, 1992

REVIEW OF RECENT R & D IN FIBER TRACKING

R. RUCHTI
NOTRE DAME

FIBER TRACKING GROUP (FTG)

1-30-92

Conceptual Design
Scintillating Fiber Outer Tracking

Fiber Tracking Group (FTG)

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Presented to the SDC Collaboration
Tracking Review Committee
January 20, 1992

Compiled and Edited by
D. Adams, A. Baumbaugh, F. Bird, R. Chaney, C. Collins, K. Hess,
D. Koltick, R. Leitch, and R. Ruchti

TOPICS:

1. PHOTOSTATISTICS
2. RADIATION DAMAGE
3. VLPC R&D
4. BEAM TEST AT FERMILAB
5. PATTERN RECOGNITION

PHOTOSTATISTICS ISSUES

(1) η coverage $\Rightarrow$ scint $\lesssim 4.3$ m

(2) integration $\Rightarrow$ waveguide lengths $\lesssim 7$ m

(3) total fiber length $\lesssim 10$ m

Examine Data from UCLA bench tests with Cosmic Rays.

$\phi = 830 \mu m$

scint = 4 m

waveguide = 3m

one optical splice

Scale to SDC arrangement.

$\phi = 830 \mu m$

$\phi = 1000 \mu m$

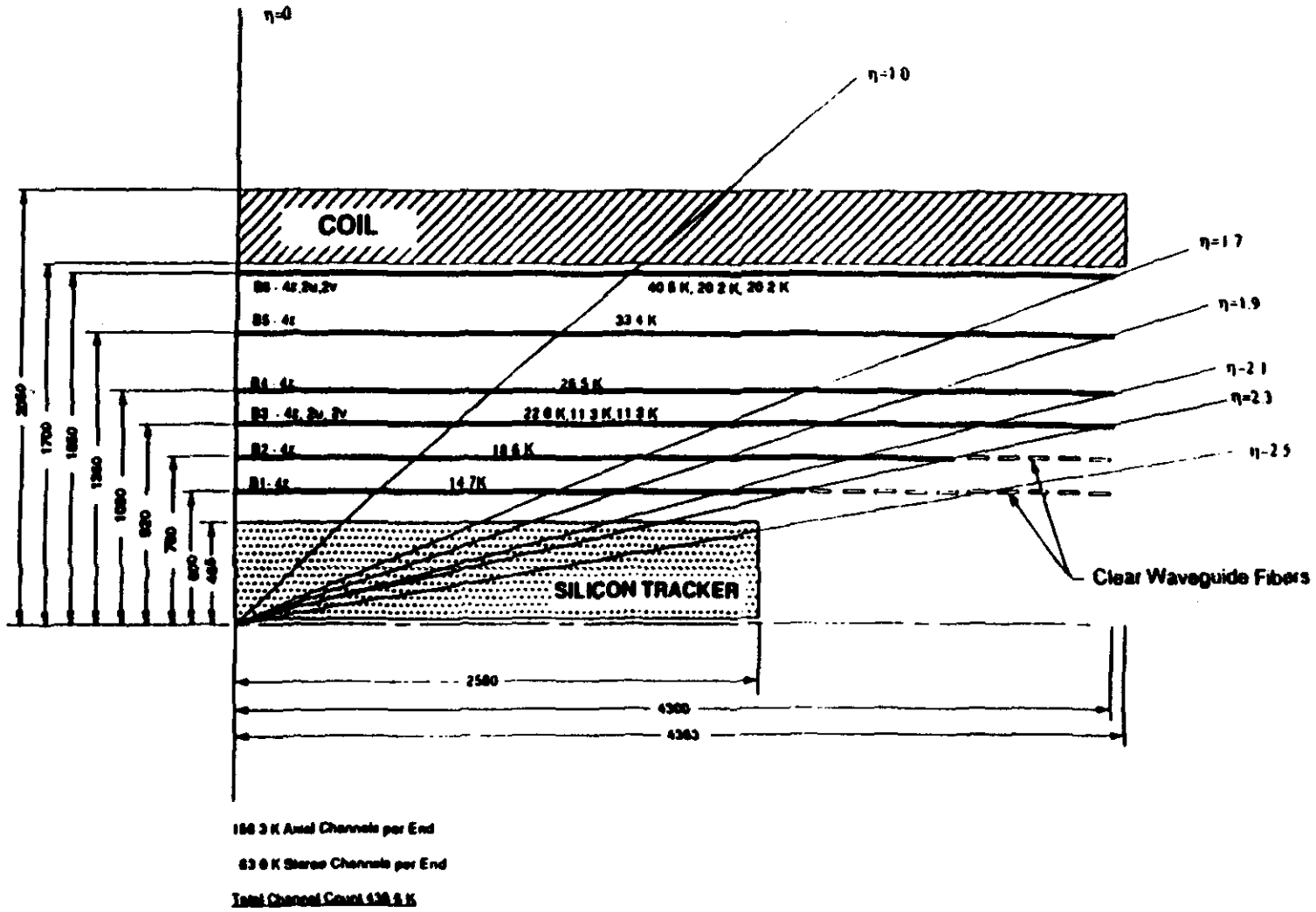
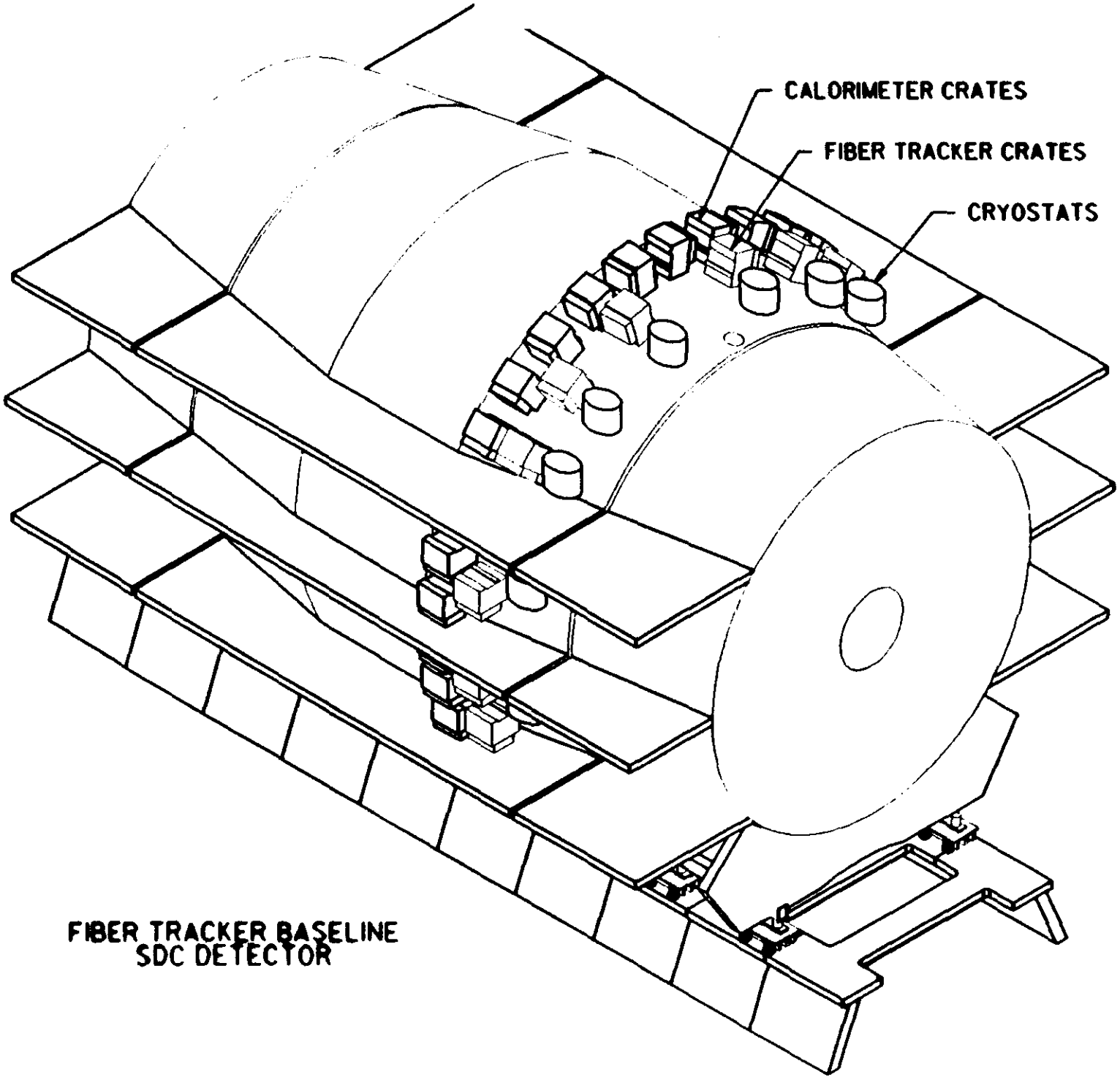
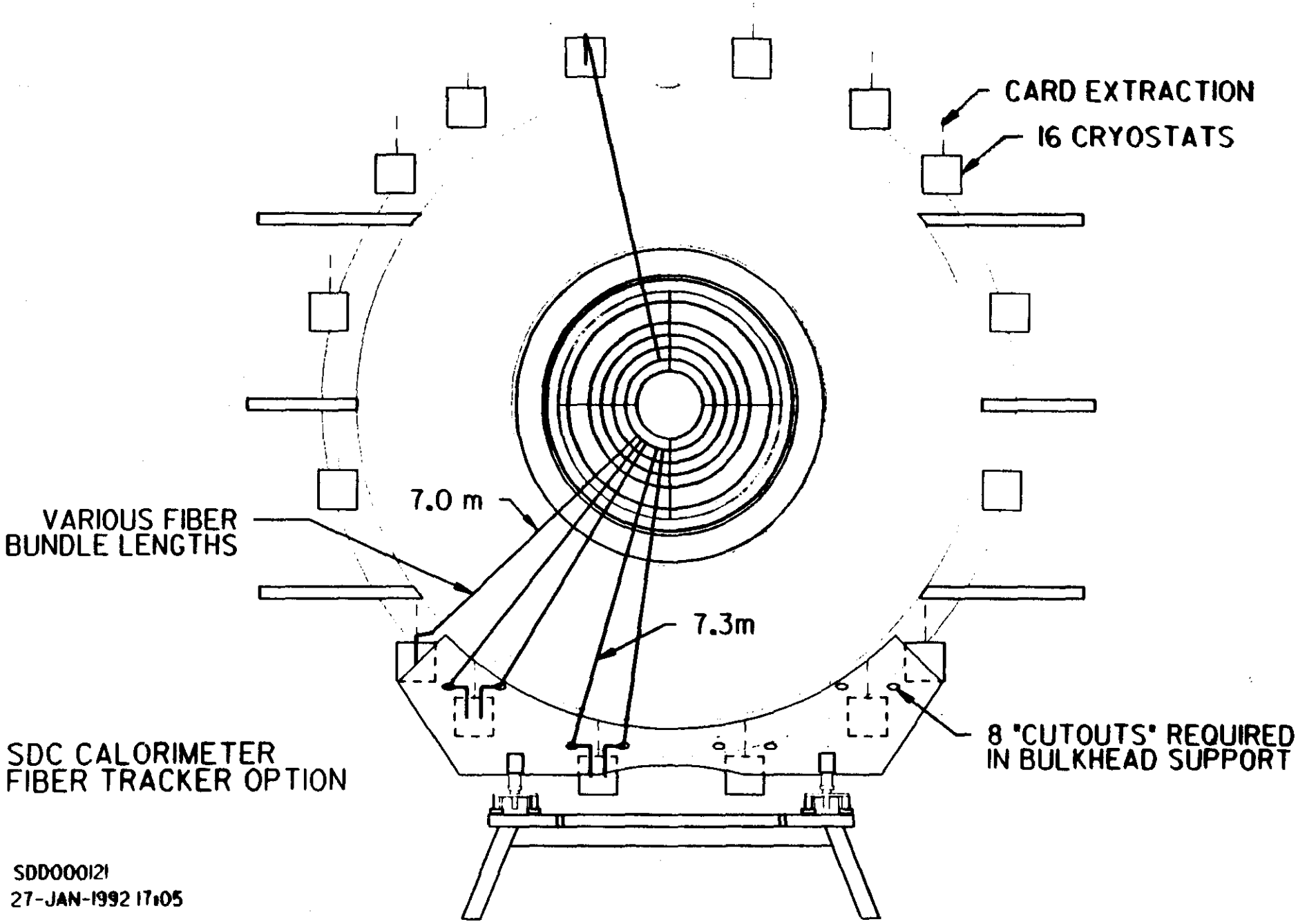
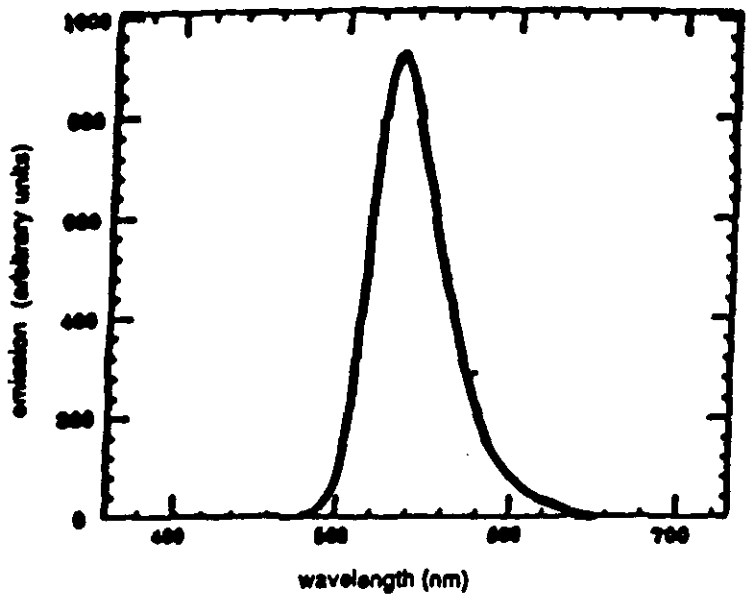


Figure 3.1-1. Schematic of the central tracker exhibiting the fiber superlayers.



FIBER TRACKER BASELINE
SDC DETECTOR


CARD EXTRACTION
16 CRYOSTATS
7.0 m
VARIOUS FIBER
BUNDLE LENGTHS
7.3m
8 "CUTOUTS" REQUIRED
IN BULKHEAD SUPPORT
SDC CALORIMETER
FIBER TRACKER OPTION
SDD000121
27-JAN-1992 17:05



Emission Spectrum

Figure 2.2-1 Absorption curve for polystyrene/PTP/3HF , reference-air. The vertical scale is in absorption units, AU=-log (I/I_O), path length = 1 meter

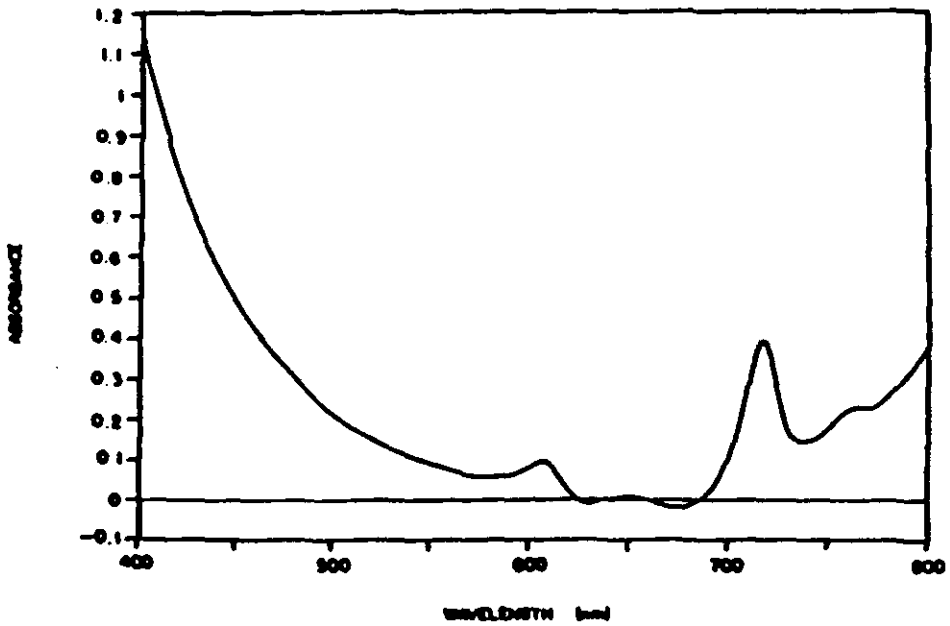
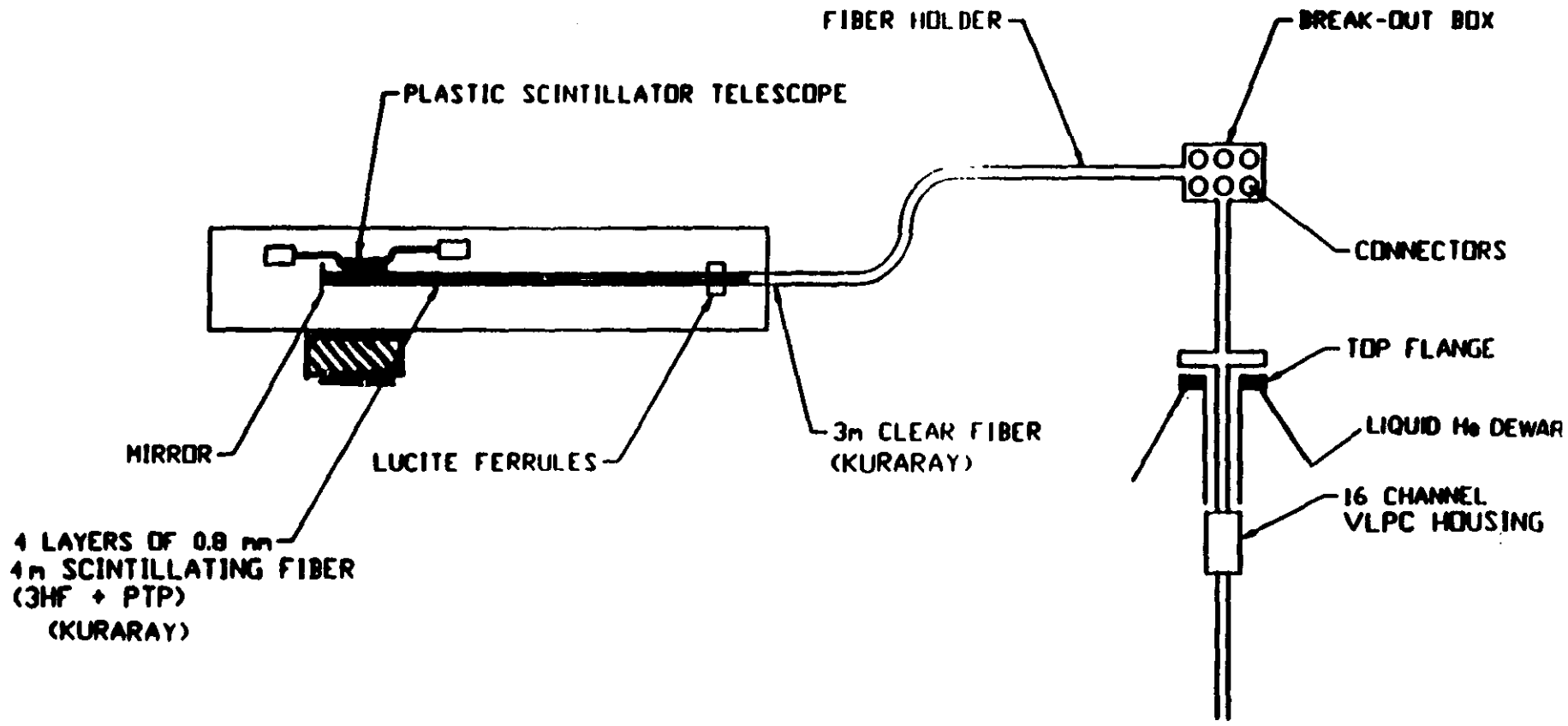


Figure 2.2-2 Absorption in unirradiated polystyrene as a function of wavelength.


FIBER HOLDER
BREAK-OUT BOX
PLASTIC SCINTILLATOR TELESCOPE
CONNECTORS
TOP FLANGE
LIQUID He DEWAR
3m CLEAR FIBER
(KURARAY)
MIRROR
LUCITE FERRULES
16 CHANNEL
VLPC HOUSING
4 LAYERS OF 0.8 mm
4m SCINTILLATING FIBER
(3HF + PTP)
(KURARAY)

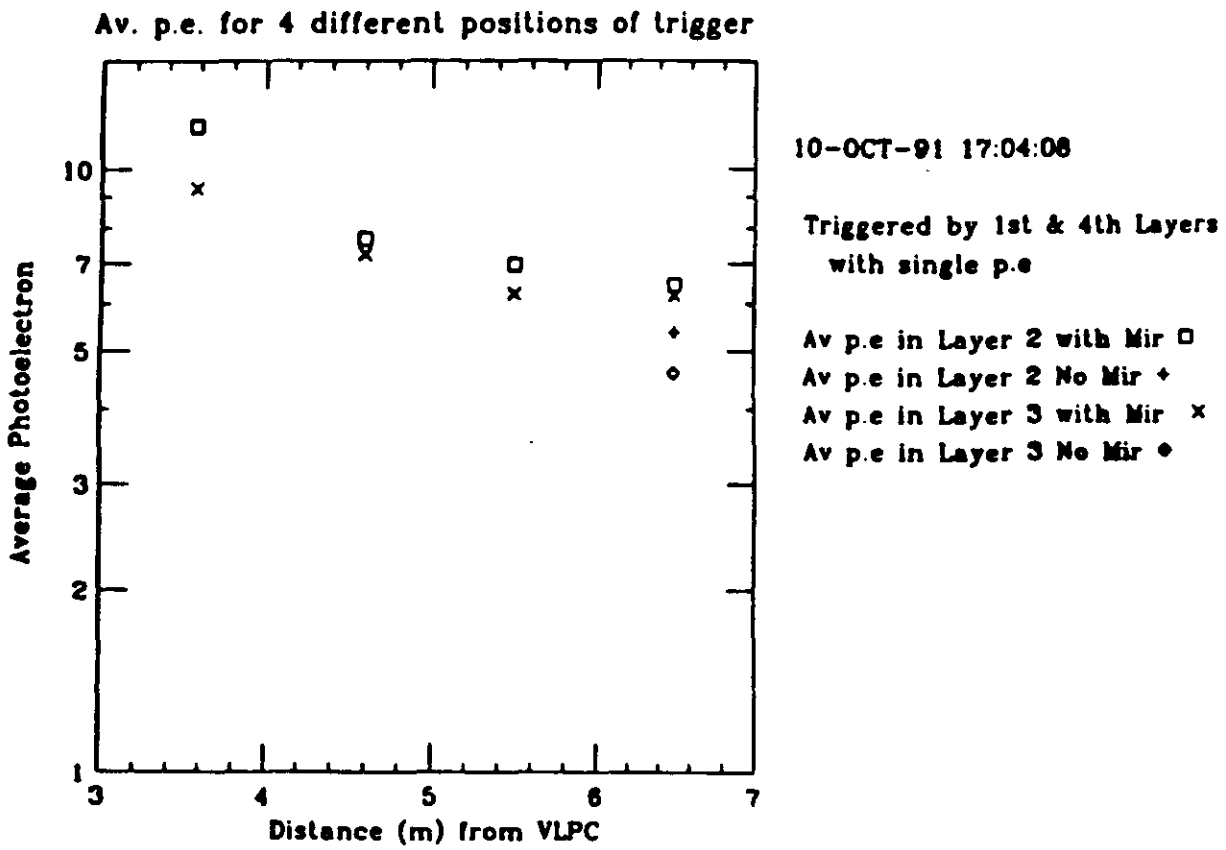


Figure 2.2-11 Average number of detected photoelectrons per fiber layer in the cosmic ray tests using HMC VLPC photodetectors. Distance indicates the physical separation of the trigger counter telescope from the VLPCs, and includes 3 meters of clear fiber-optic waveguide, an optical splice, and then up to 4 meters of scintillating fiber.

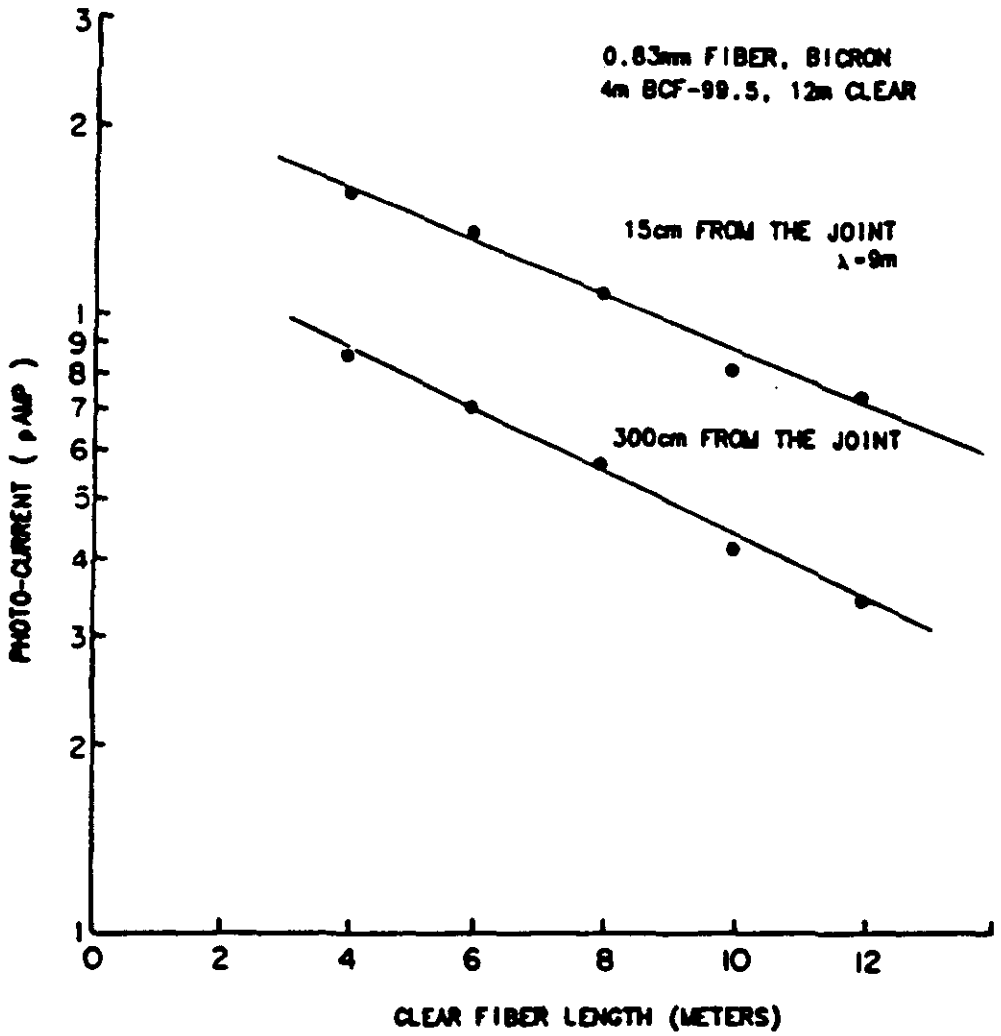


Figure 2.2-12 Attenuation length of clear waveguide fiber of 830μm diameter. Source is UV excitation. Photodetector is a silicon photodiode, which has spectral response similar to the VLPC.

Table 2.2-1

Photoelectron Yields in the Scintillating Fiber Tracker

Fiber Super Layer	Scifi length	Wave-guide length	Total fiber length	Correct-ion factor from data from Fig. 2.2-11	Corrected p.e. for 830μm diameter (η =0)	Scale up to 1mm diameter	Expected p.e. for 1mm diameter (η =0)
B1	3.00m	6.93m	9.93m	.61	3.4	1.47	5.0
B2	3.65m	6.12m	9.77m	.67	3.4	1.46	4.9
B3	4.30m	5.31m	9.61m	.73	3.3	1.46	4.8
B4	4.30m	5.15m	9.45m	.75	3.4	1.45	4.9
B5	4.30m	4.87m	9.17m	.77	3.5	1.44	5.0
B6	4.30m	4.58m	8.88m	.80	3.6	1.44	5.2

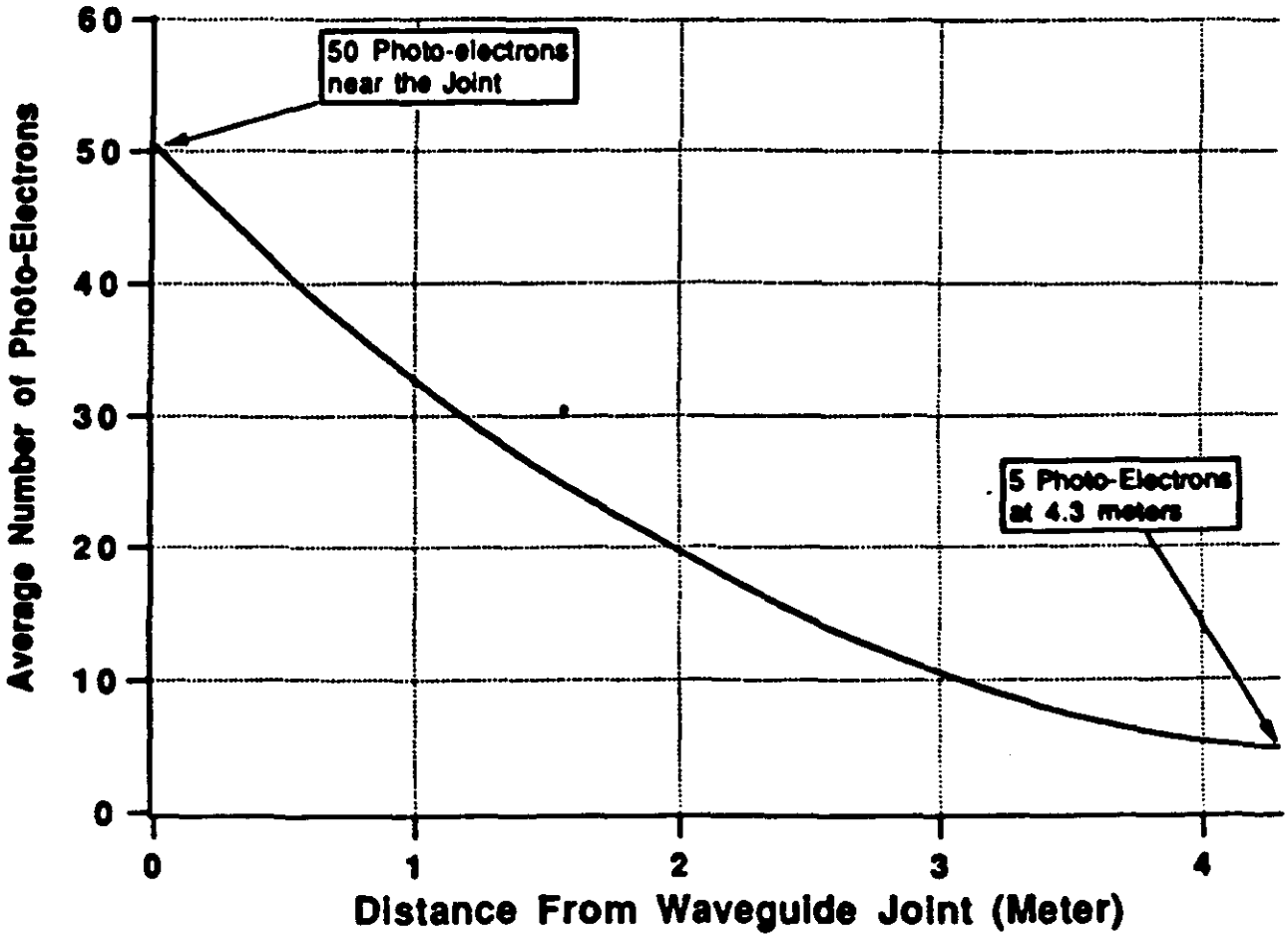


Figure 5.3.3-1 Mean detected photoelectron yield as a function of position along a scintillating fiber in layer B3 of the tracker

RADIATION DAMAGE EFFECTS PS/PTP/3HF

HIGH DOSE ^{60}Co 1 MRad - 10 MRad
HIGH DOSE RATE

VARIOUS ATMOSPHERES
ANNEALING
SAMPLES: 10cm LENGTH

LOW DOSE RATE TEVATRON CØ AREA 15KRad - 120KRad

T851
VARIOUS ATMOSPHERES
ANNEALING
SAMPLES: FIBERS

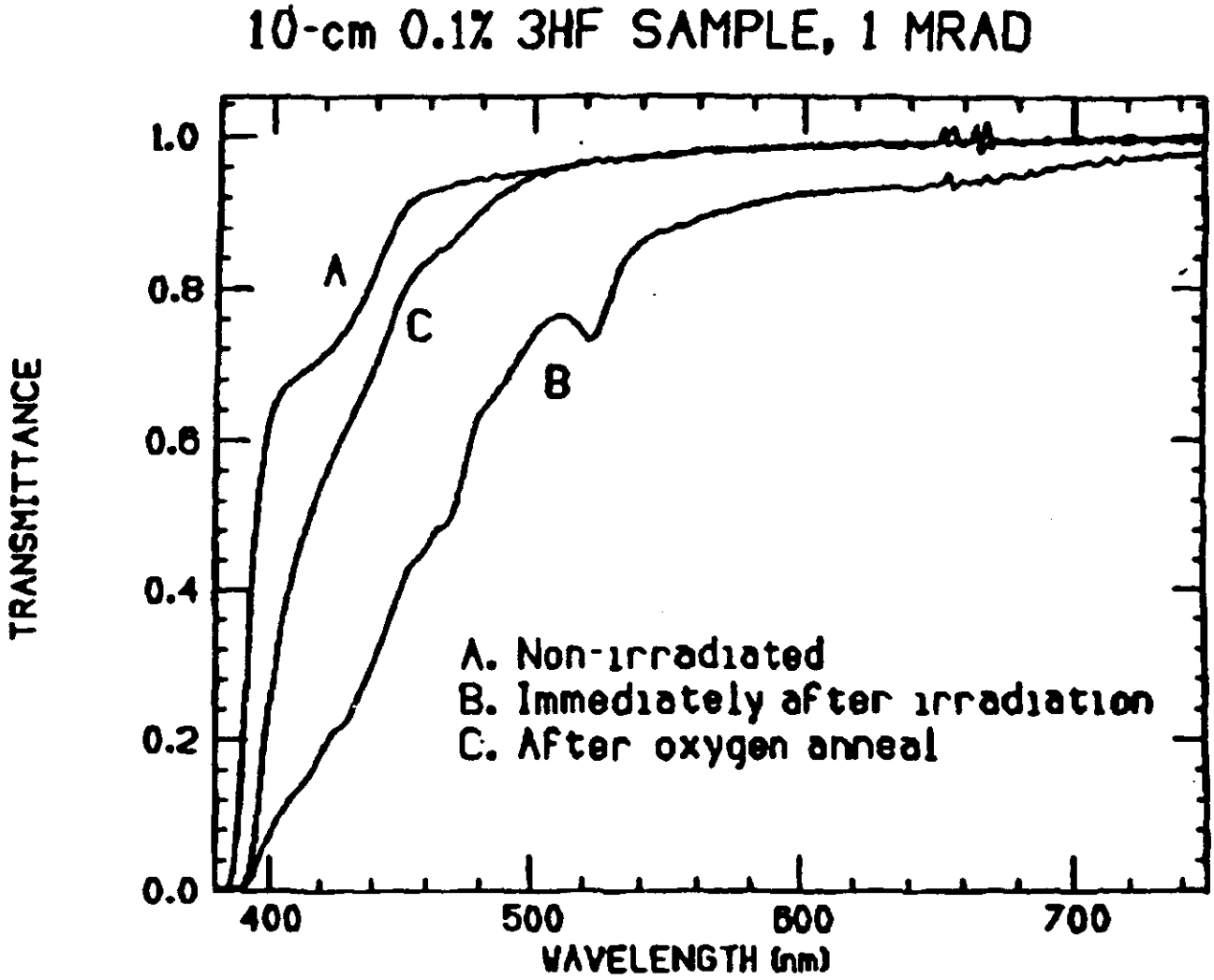


Figure 5.2-1 Transmission in polystyrene/PTP/3HF scintillator as a function of wavelength. Before and after irradiation by ^{60}Co to 1 MRad, and after annealing.

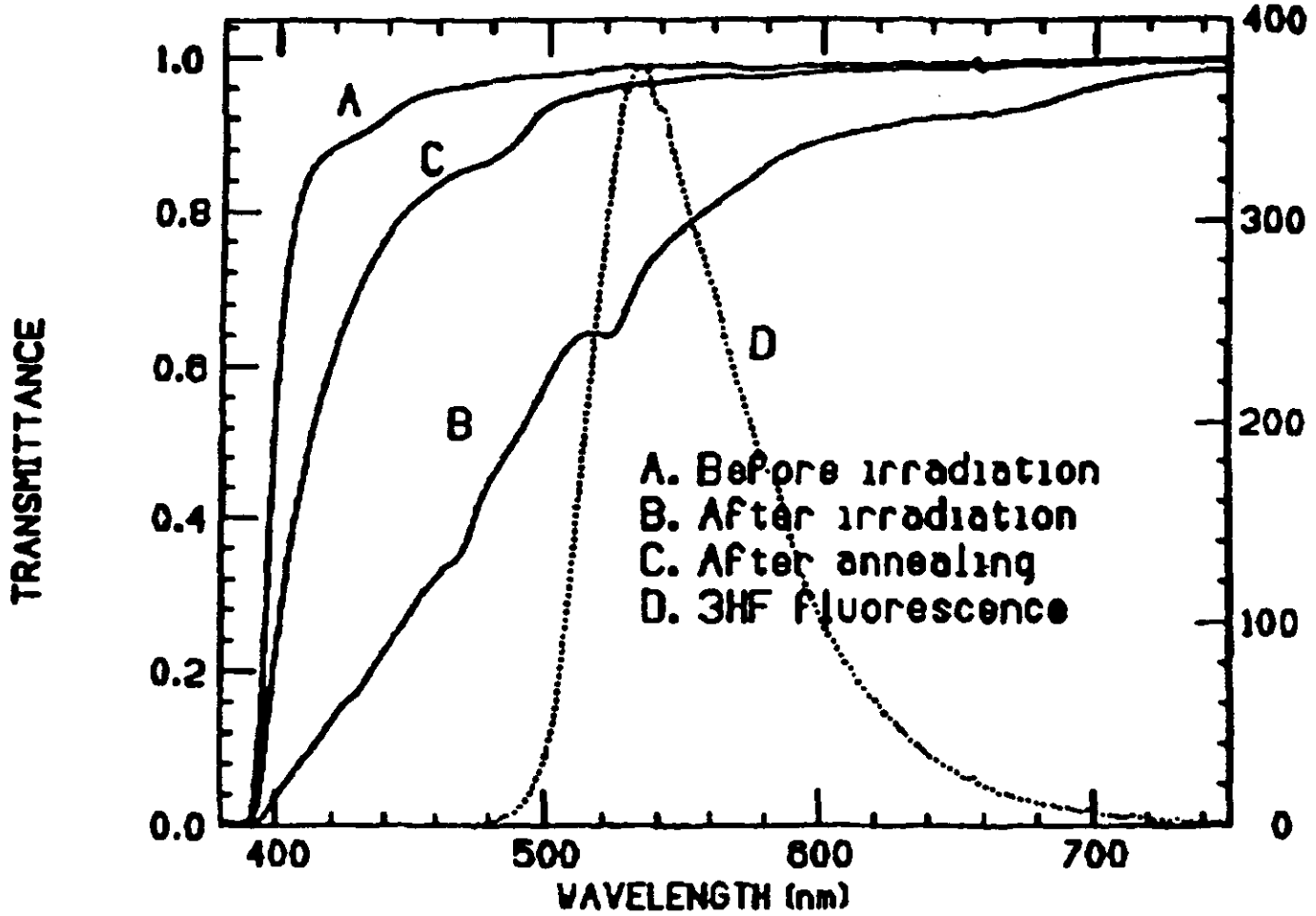
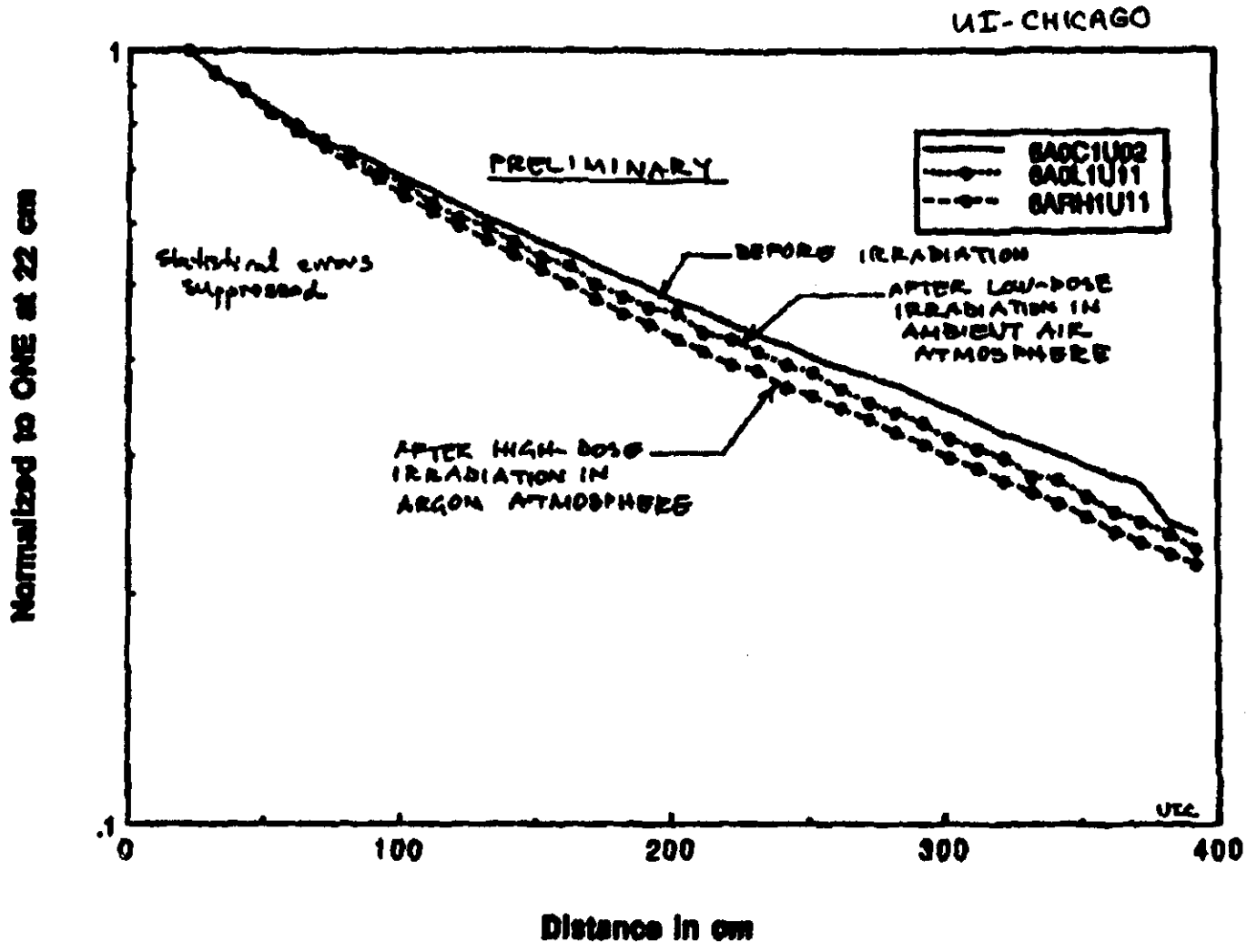


Figure 5.2-2 Transmission in polystyrene/PTP/3HF scintillator as a function of wavelength. Before and after irradiation by ^{60}Co to 10 MRad, and after annealing.



pT + 3HF

FIBER TRANSMISSION BEFORE IRRADIATION, AFTER LOW-DOSE IRRADIATION IN AMBIENT AIR, AND AFTER HIGH-DOSE IRRADIATION IN ARGON ATMOSPHERE. (ARBITRARY NORMALIZATION AT 22 CM.)

VLPC Developments

1. HISTE - II Declared "ITAR - free"
   Letters to Peoples and Schwitters

2. Beam test of 32 channels - HISTE-II + FAST PREAMPS
   96 channels - MAPMT

3. HISTE - III Characterization by end of Feb. 92

4. CANISTER CONCEPTUAL Design Report 2-17-92, presented at Fermilab.

Science Center
Rockwell International Corporation
3370 Miraloma Avenue
P.O. Box 3105
Anaheim, California 92803-3105

Rockwell International

Mail Stop: 031-BC15

November 27, 1991

Dr. John Peoples
Director
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, IL 60510

SUBJECT: Visible Light Photon Counter

Dear Dr. Peoples:

I am happy to inform you that there have been some very positive developments on the Visible Light Photon Counter (VLPC) recently at Rockwell International's Science Center. As you may recall from my communication in July 1991, we have been endeavoring to optimize the VLPC for reduced infrared response while providing adequate quantum efficiency in the visible spectrum. The VLPC work aimed toward high energy physics applications is being done under the High-Resolution Scintillating Fiber Tracking Experiment (HISTE) contract from UCLA.

Tests on our recently fabricated VLPCs (in a lot designated HISTE II) show that the infrared response of these devices is negligible. Thus, these devices are not subject to ITAR (International Traffic in Arms Regulations) restrictions. The peak quantum efficiency of these devices in the visible spectrum is about 40%. While this is quite good and, as I understand, should be adequate for some of the high energy physics experiments, we believe that significantly higher quantum efficiency (over 70%) will be obtained in the near future. We have another lot of devices (designated HISTE III) in fabrication to accomplish that objective while maintaining negligible infrared response. Characterization of those devices should be completed by January 1992. We expect the availability of those devices to the high energy physics community to be also free of ITAR restrictions.

Rockwell International

With our success in producing good-performance devices that are free of ITAR restrictions, we would like to see them put to good use in the high energy physics field as quickly as possible. As I indicated to you in my earlier letter, disposition of the devices fabricated under the HISTE contract is determined by UCLA.

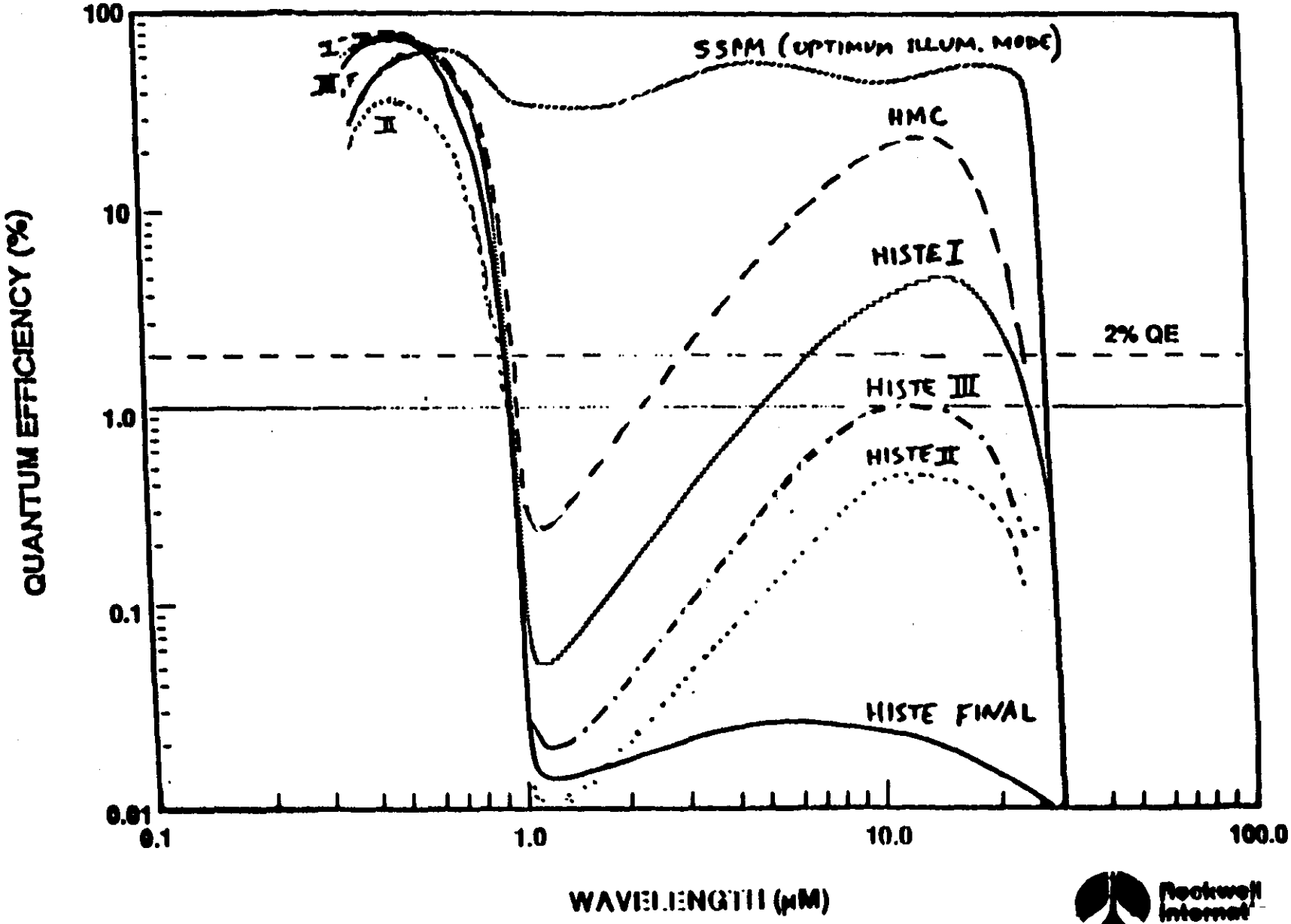
I hope that this information will help in your plans for the use of VLPCs in high energy physics experiments. If you have any questions or if we can be of any help, please feel free to contact me by telephone at (714) 762-1460 or telefax at (714) 762-0844.

R. Sharat

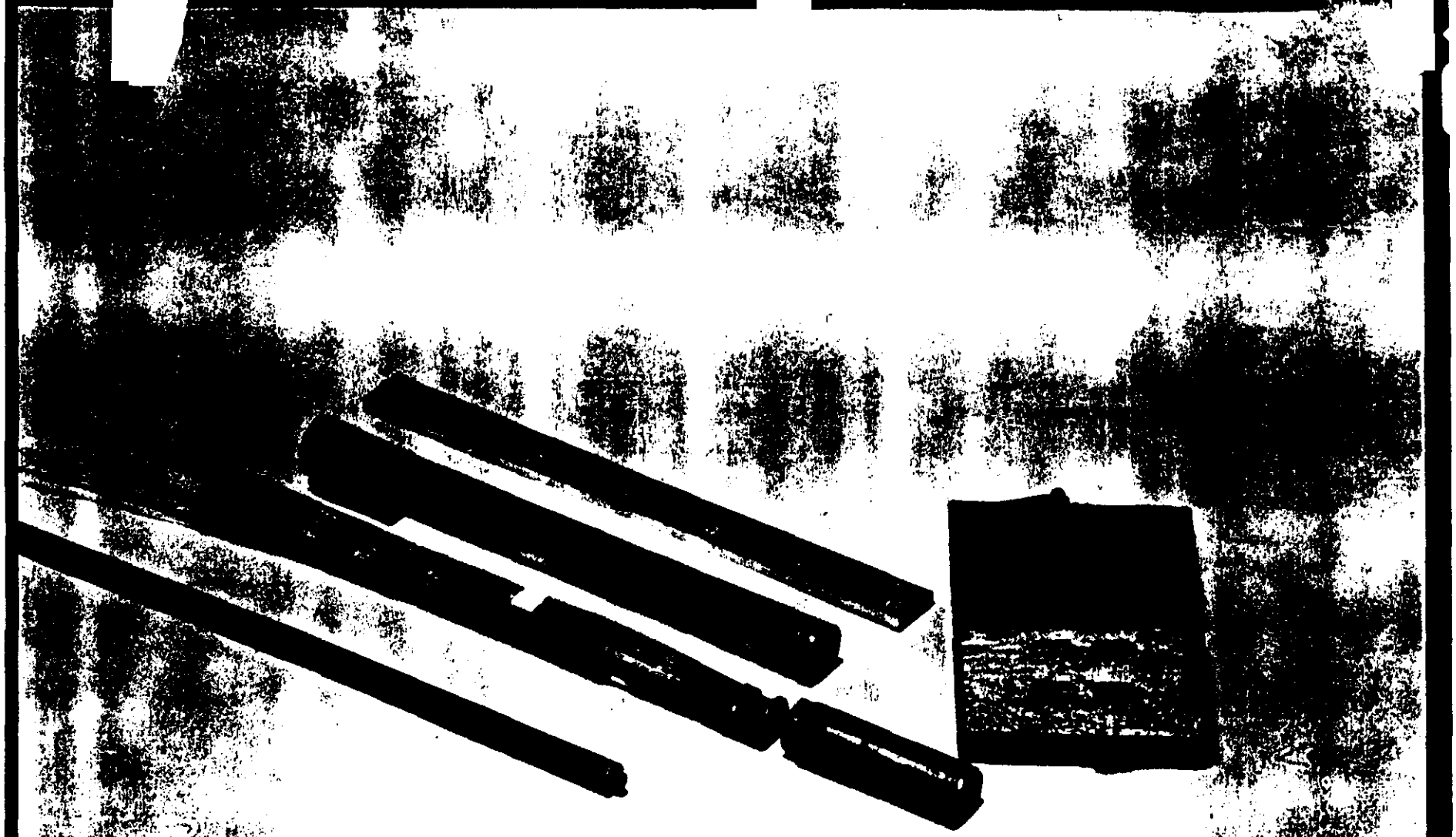
R. Sharat
Director
Silicon Devices

cc: M. Atac
D. Koltick
K. Montgomery
R. Rubinstein
R. Ruchti
K. Stanfield
G. Trilling

VLPC SPECTRAL QUANTUM EFFICIENCY



Rockwell Internat
Science C

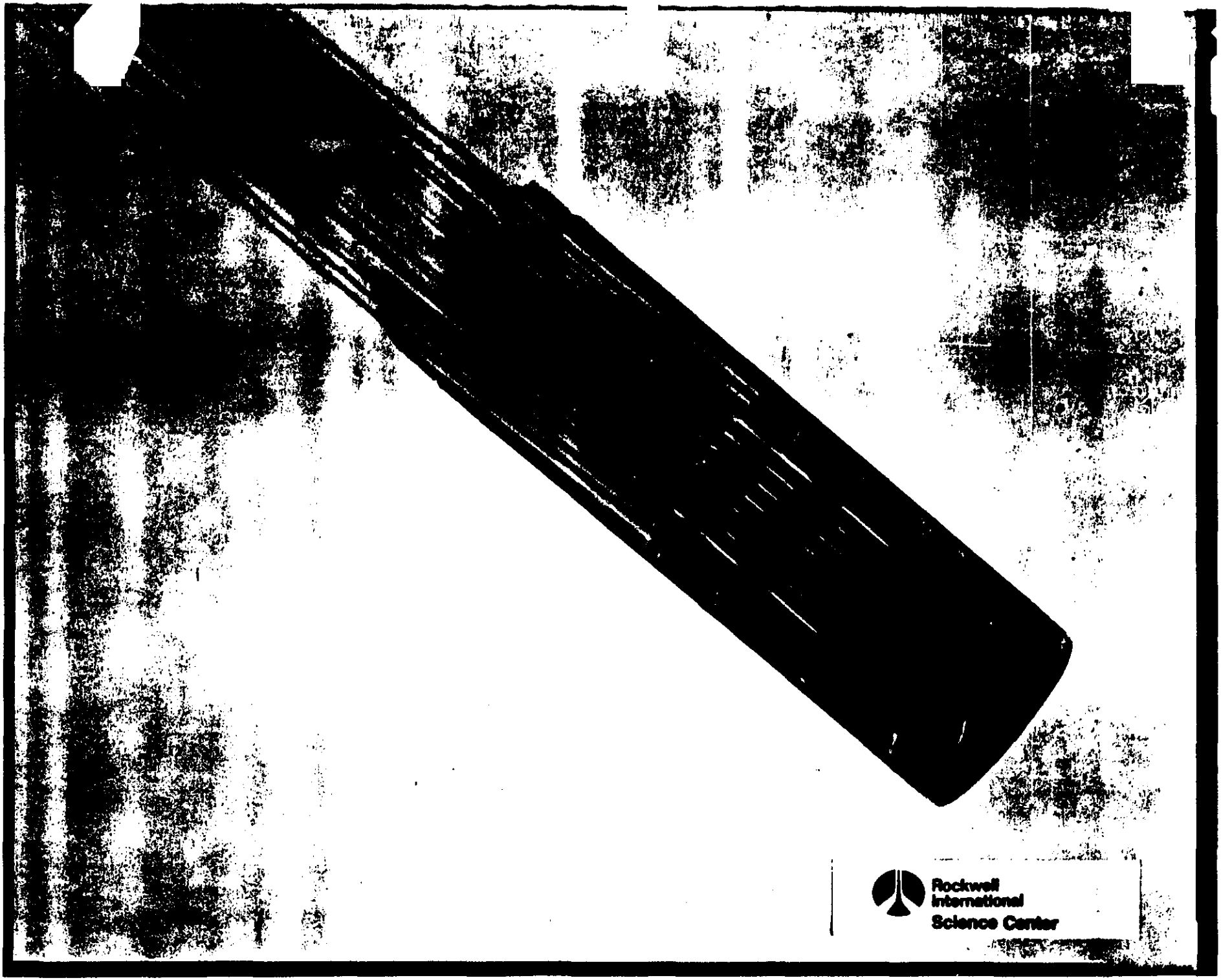


32 CHANNEL VLPC CASSETTE

Rockwell International Science Center

32 CHANNEL VLPC CASSETTE

Rockwell International
Science Center



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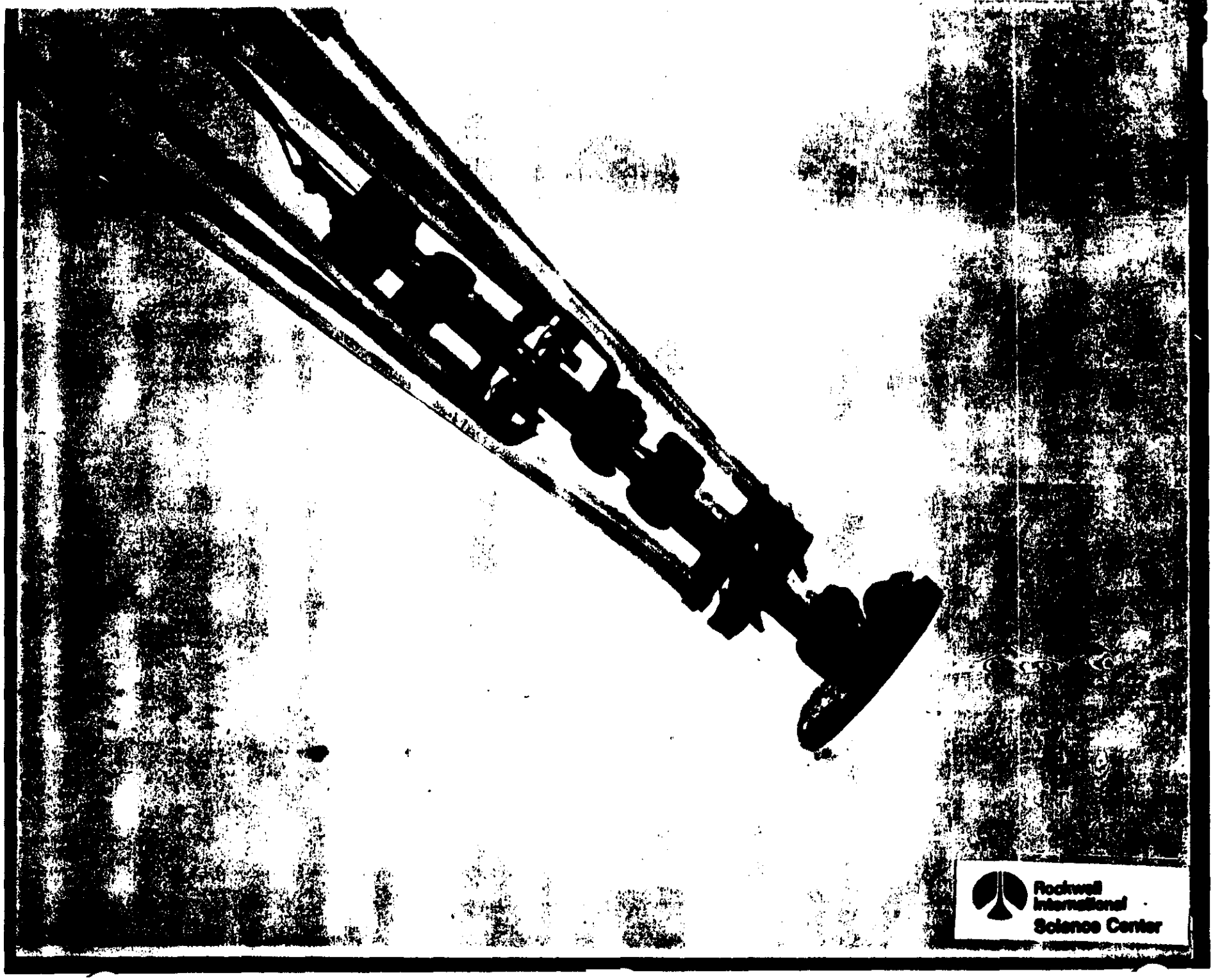
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Figure 7. Helium Bottle for Multiple Channel VLPC Cassette

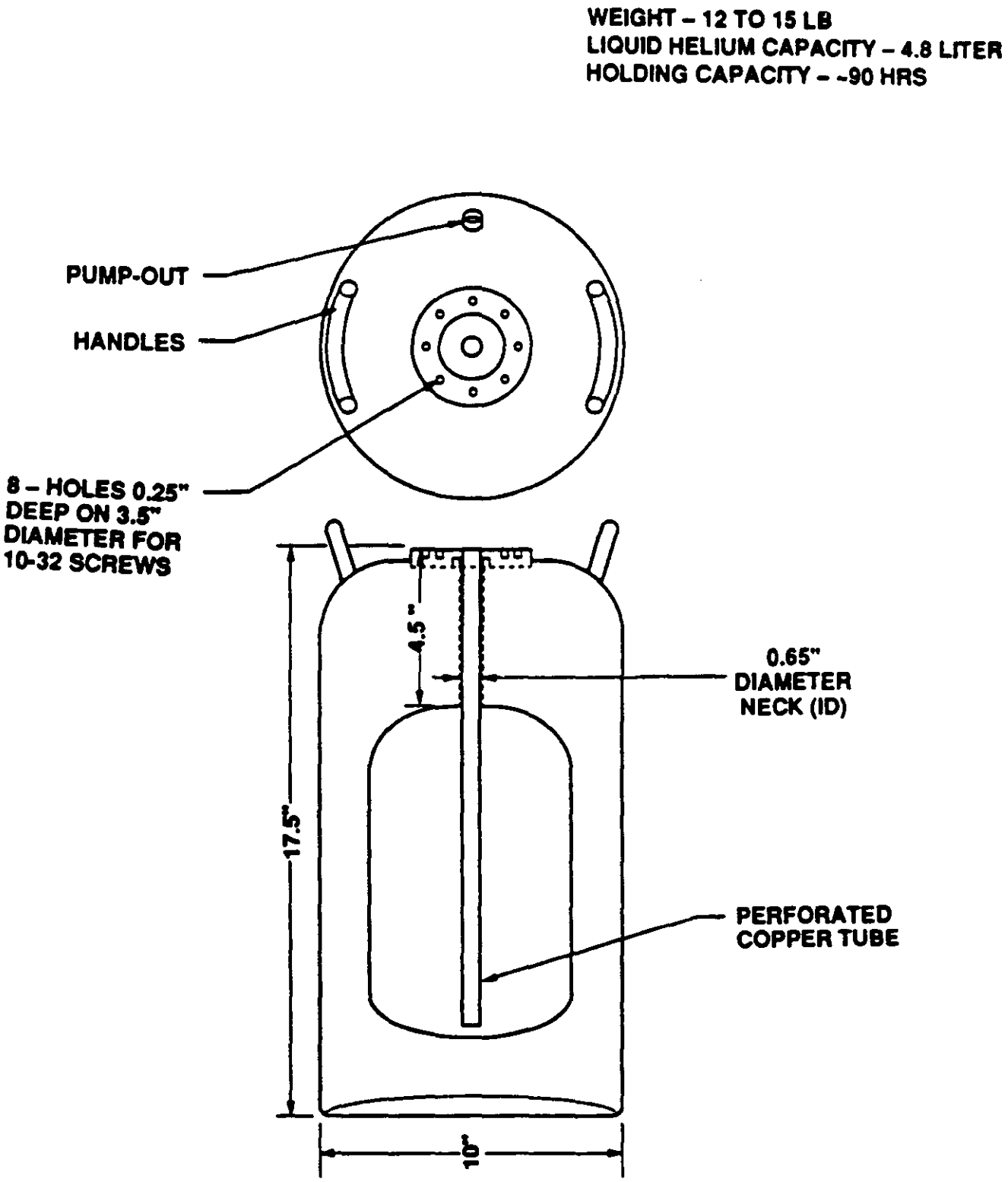
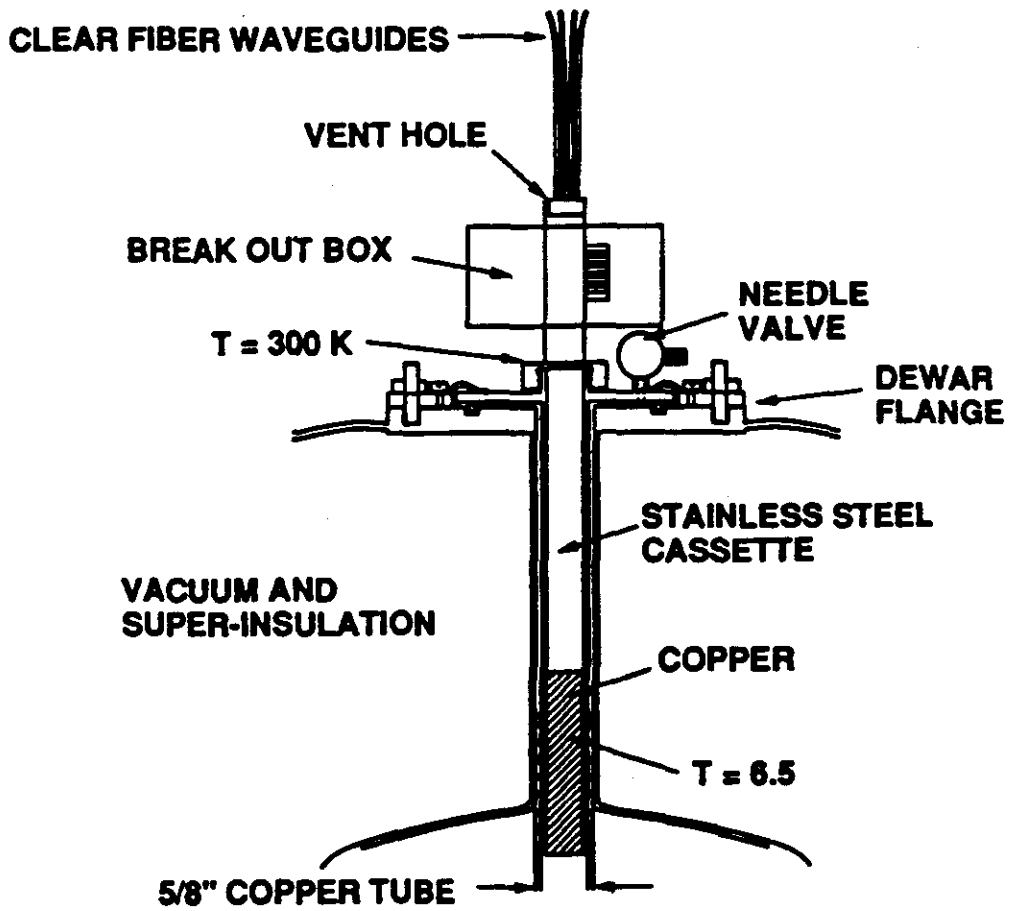
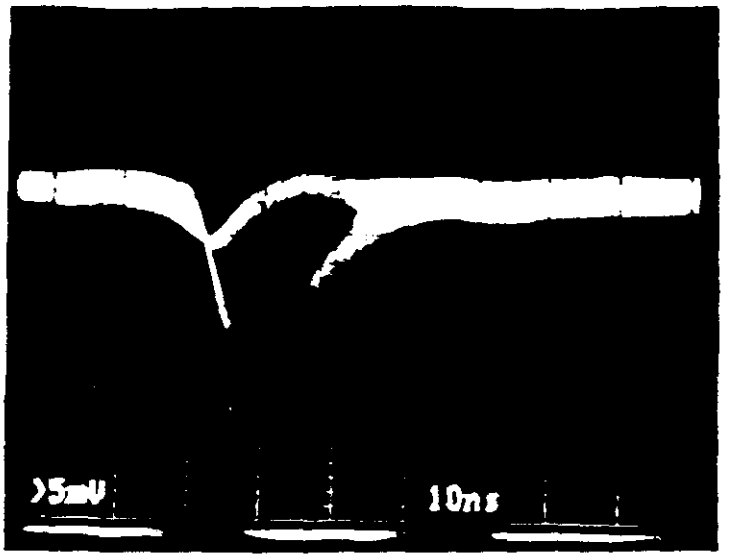


Figure 8. Multiple Channel VLPC Cassette Installed in Helium Bottle.





1/2/1992

Tests with HISTE-II VLPCs

Using VTX amplifiers

Bias Voltage : 7.8 volts

Temperature: 9.5 K

Looking at thermal electron pulses

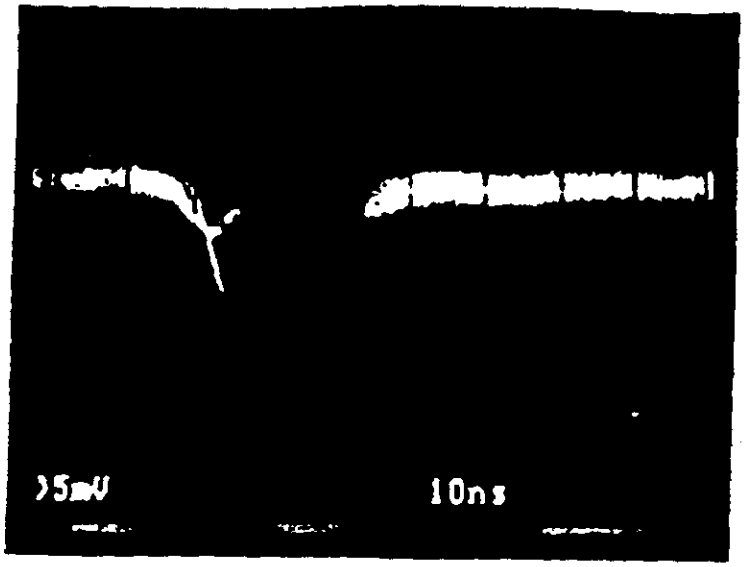


Figure 2.2-14 Typical signal from the HISTE-II/VTX system operating in the test beam at Fermilab, indicating a clear single-photoelectron line above noise and a pulse rise of less than 5ns. As displayed, the signal has received additional amplification in an LRS 612 preamplifier as was the case prior to data recording in the LRS2880 ADC system.

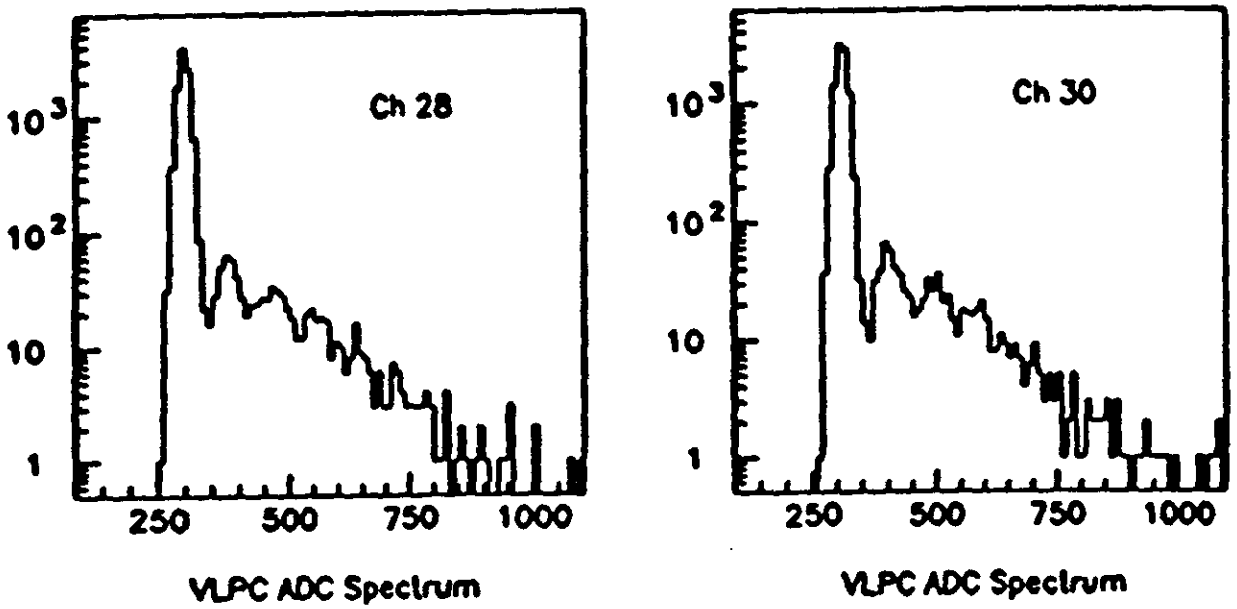


Figure 2.2-15 A typical pulse height spectrum observed in the fiber/HISTE-II/VTX system recorded during the beam tests at Fermilab and exhibiting characteristic photopeaks.

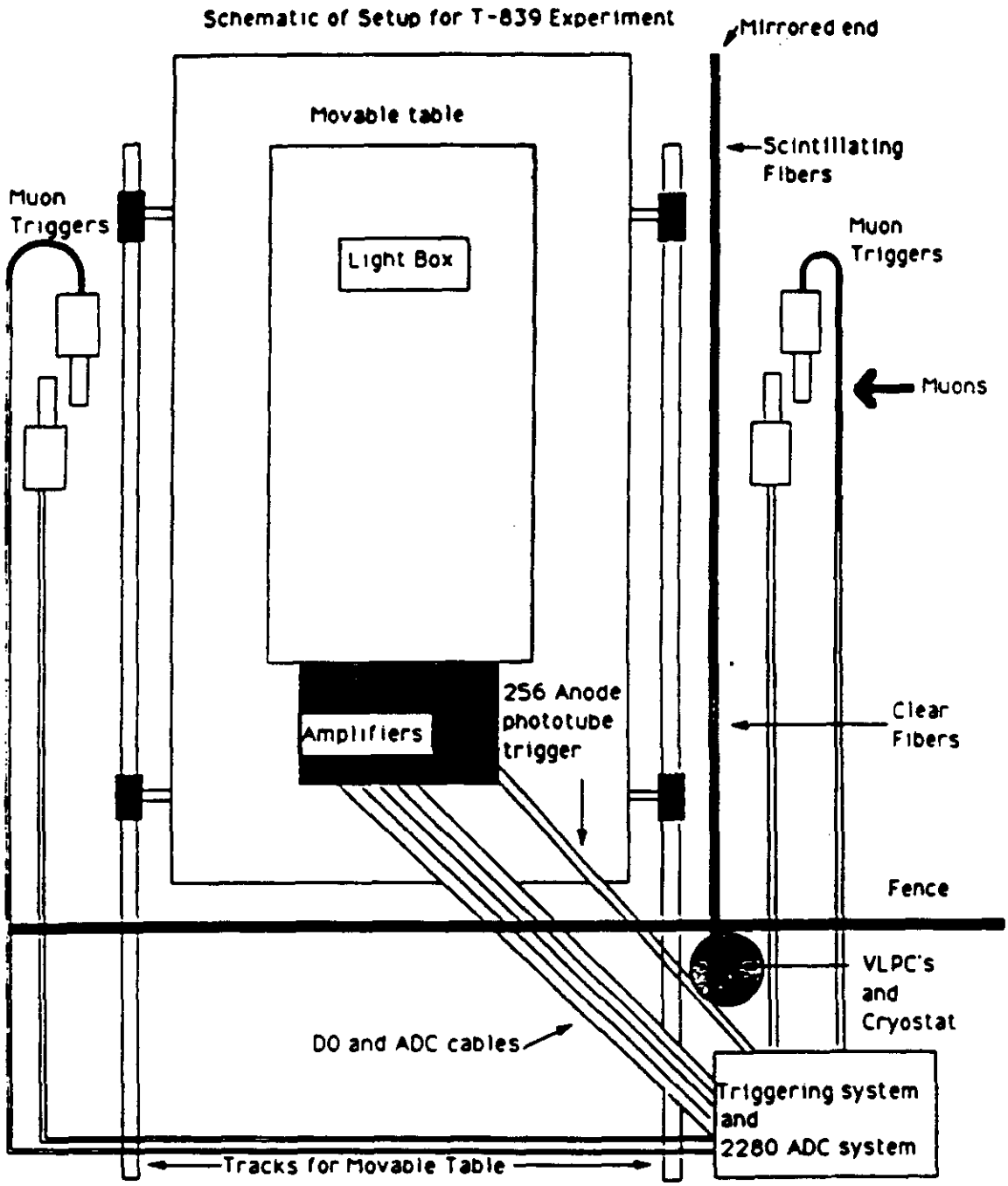
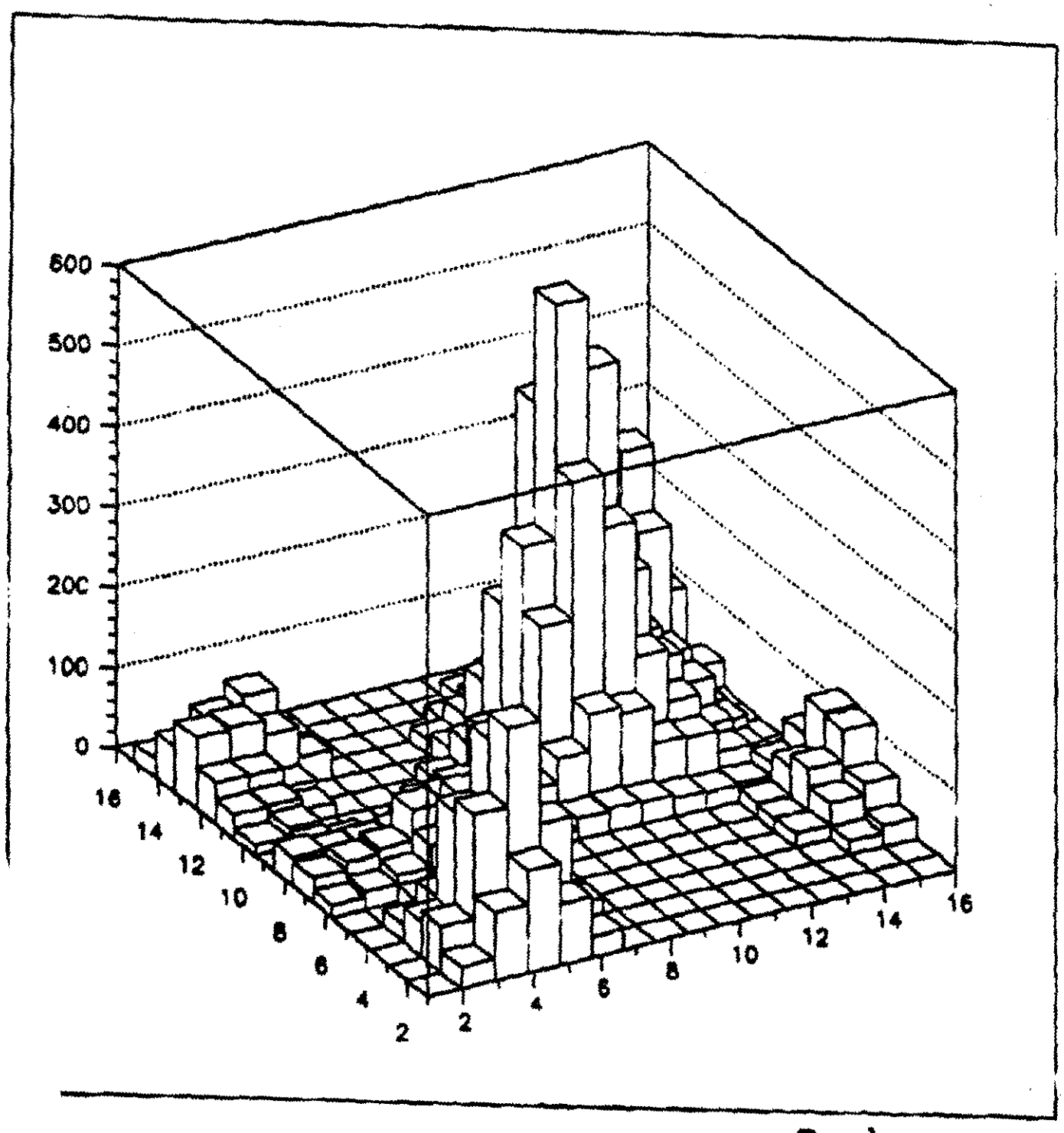
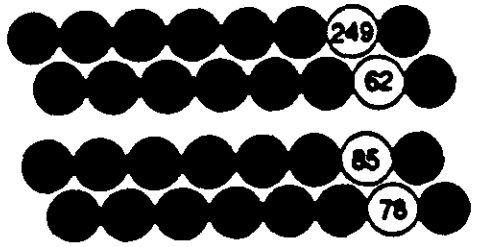


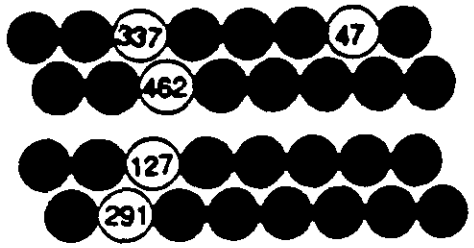
Figure 2.2-13 Schematic of the arrangement of detectors in the NM (muon) beam at Fermilab.



Purdue



Event 13



Event 14

Figure 2.2-16 Typical particle tracks seen in the 32 element scintillating fiber array readout with HISTE-II VLPCs. Two different events are shown. (Beam is incident from above.) White circles represent fibers hit.

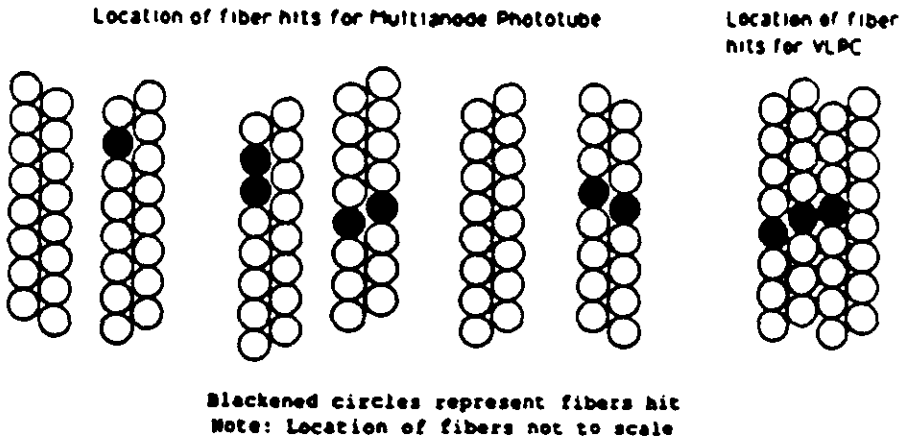
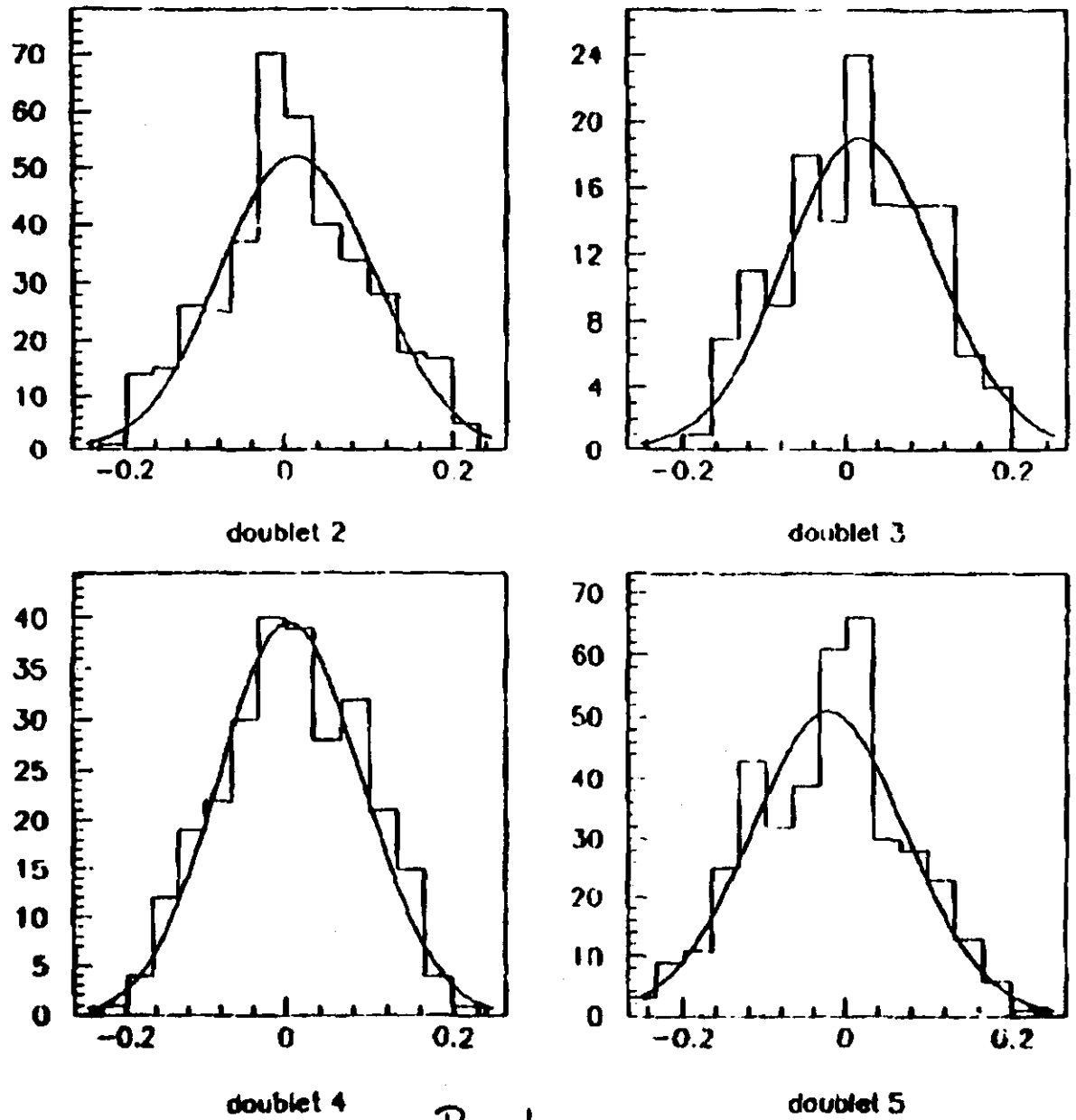


Figure 2.2-17 Typical particle track passing through all four fiber superlayers. The superlayer on the right hand side was readout with the HISTE-II VLPCs. (Beam is incident from the right.)

Test Beam T-637



Purdue

BEAM TESTS – RESULTS/ACCOMPLISHMENTS

1. HISTE-II VLPCs – 32 CHANNELS IN THE NM LAB/FNAL!

2. NEW COMPACT CRYOSTAT (5ℓ DEWAR)
   - SHORT STEM LENGTH ~ 1/2 ft
   - LOW CAPACITANCE STRIP CABLE 6 pF/ft

   - RAPID COOLDOWN 5-10min to 9K
   - STABLE OPERATION UP TO TWO DAYS.

3. MULTIANODE PMT – 96 CHANNELS.
   - OPERATIONAL

4. FAST PREAMPS USED WITH HISTE-II (VTX – 32 channels)
   - FAST PULSE RISE $\lesssim$ 5ns.
   - WILL WORK FOR SDC!

5. BEAM TEST ESSENTIAL RATHER THAN COSMIC RAYS TO ASSESS SYSTEM PERFORMANCE.

UPDATE ON PATTERN RECOGNITION STUDIES USING THE FIBER TRACKER

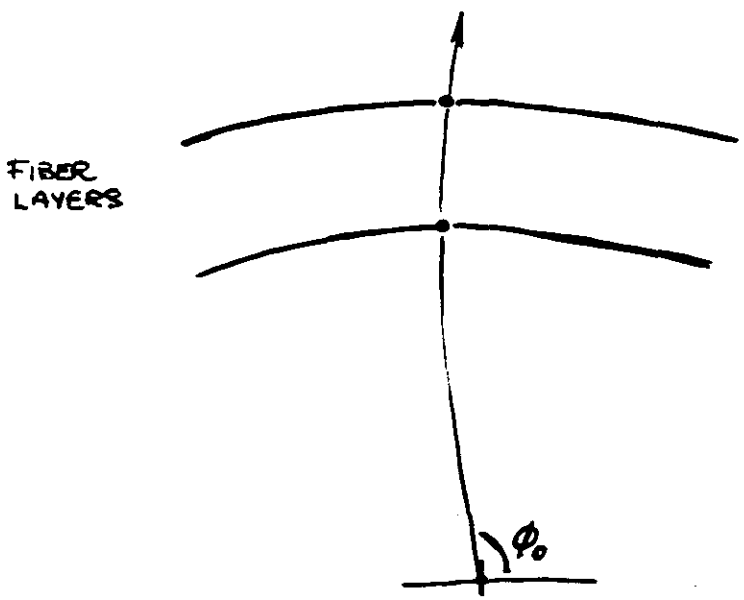
(J. Hylen, Fermilab)

1. FIBER TRACKER SUPERLAYERS WERE POSITIONED AS IN THE CDR.

2. THE 5 LAYERS OF AXIAL FIBERS WERE DOUBLETS IN THE SIMULATION STUDY, RATHER THAN QUADRUPLETS IN THE ACTUAL CDR DESIGN.

3. THE CODE USED WAS PATTERN RECOGNITION OPTIMIZED FOR SILICON STRIPS.

4. A TRACK IS RECOGNIZED AS A CLUSTER OF VECTORS IN (ϕ,k) COORDINATES. THERE ARE FOUR VECTORS AVAILABLE FROM THE FIBER TRACKER IN THE CDR CONFIGURATION.

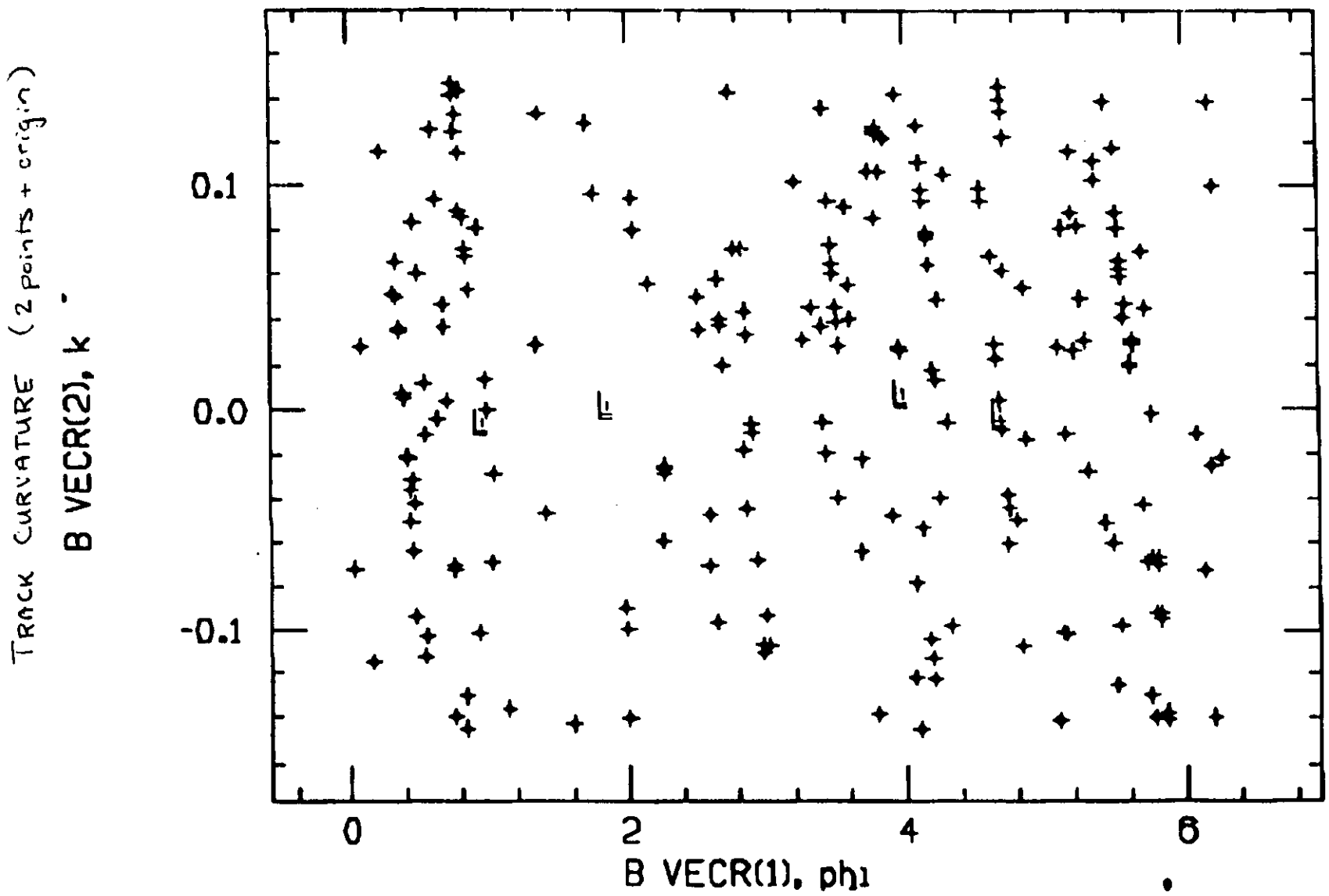


2 HITS + ORIGIN DETERMINE A CIRCLE

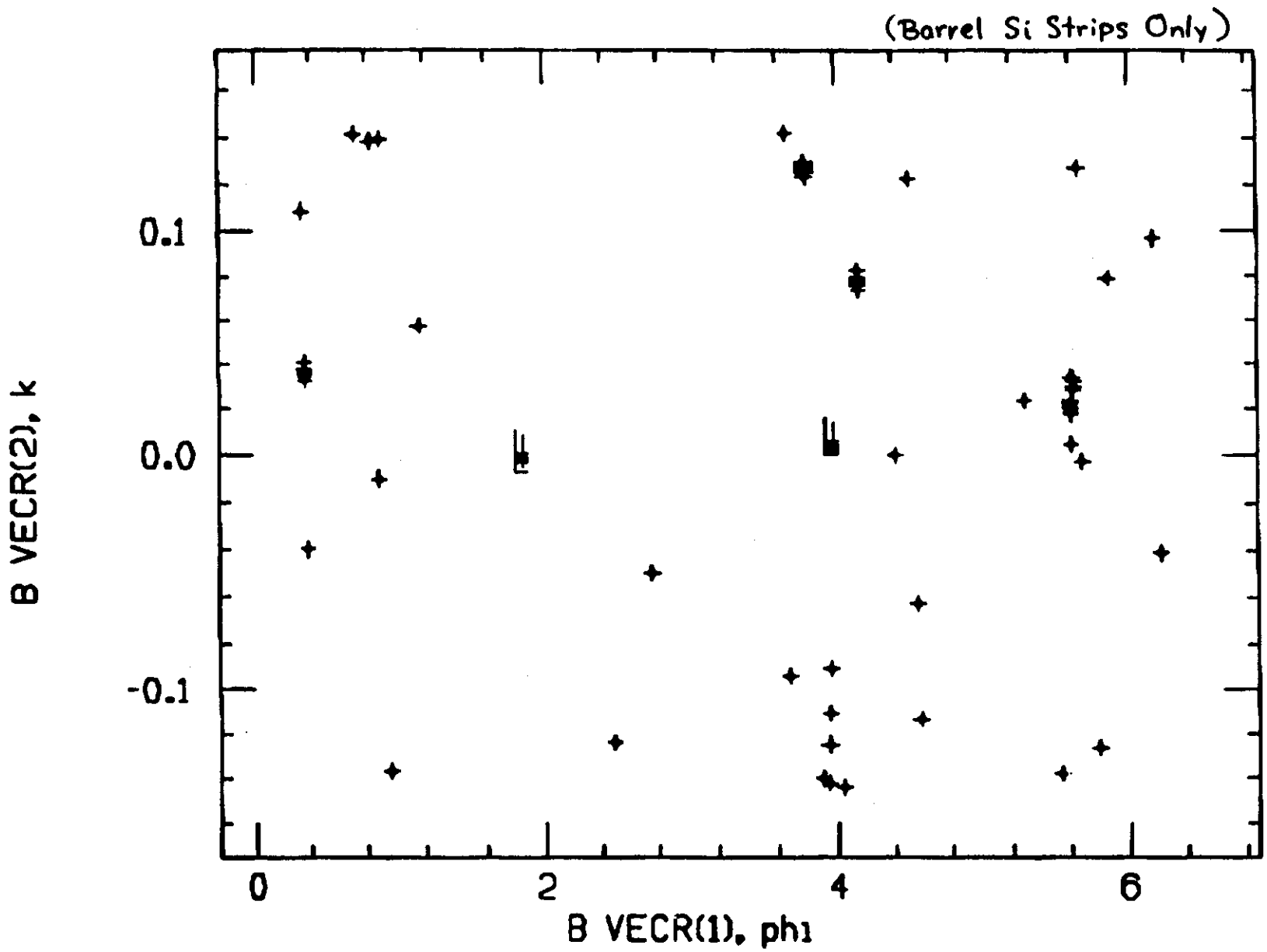
ϕ_0 = LAUNCHING ANGLE

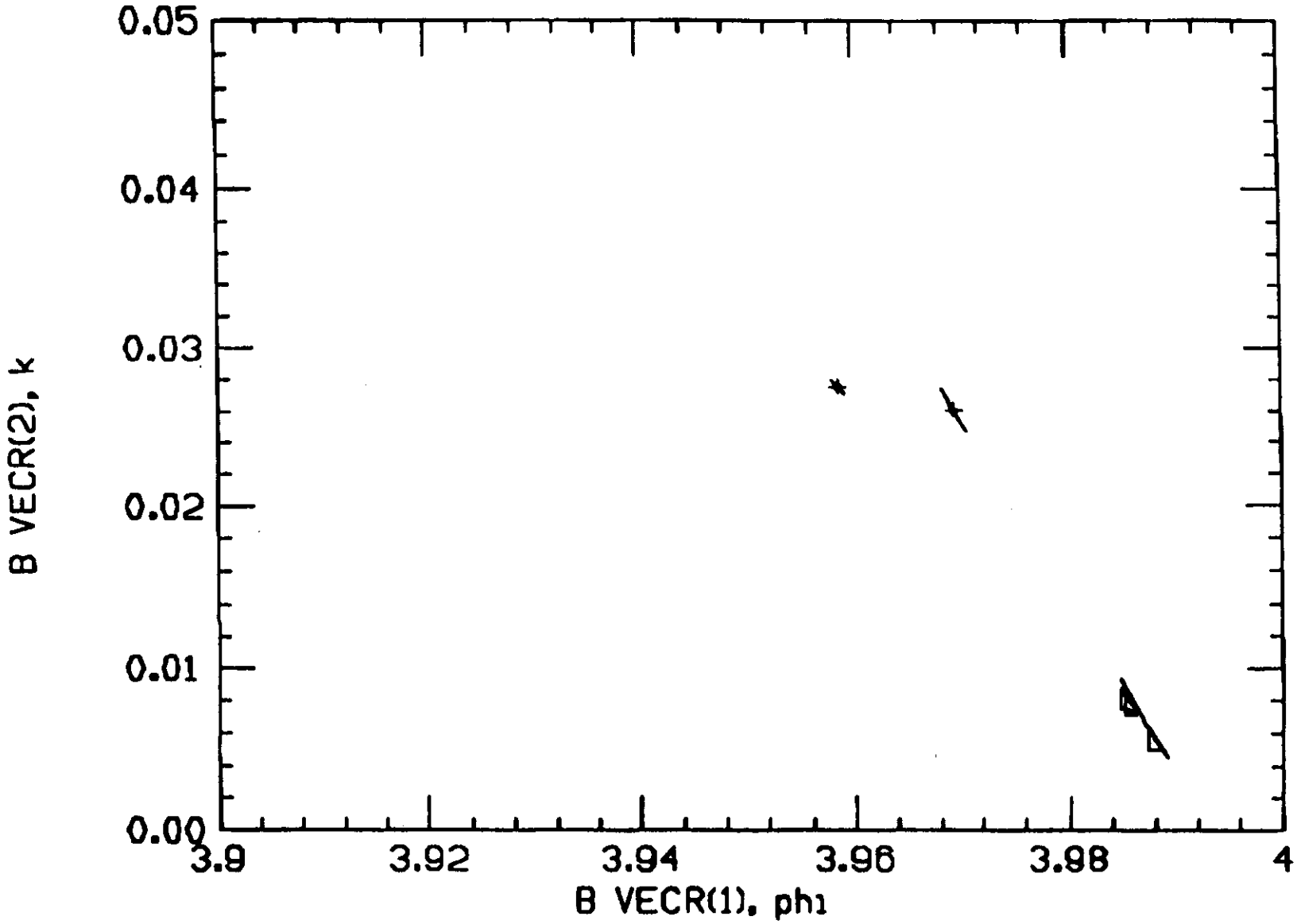
k = TRACK CURVATURE

400 GeV/c² Higgs 4 leptons (Fibers Only)



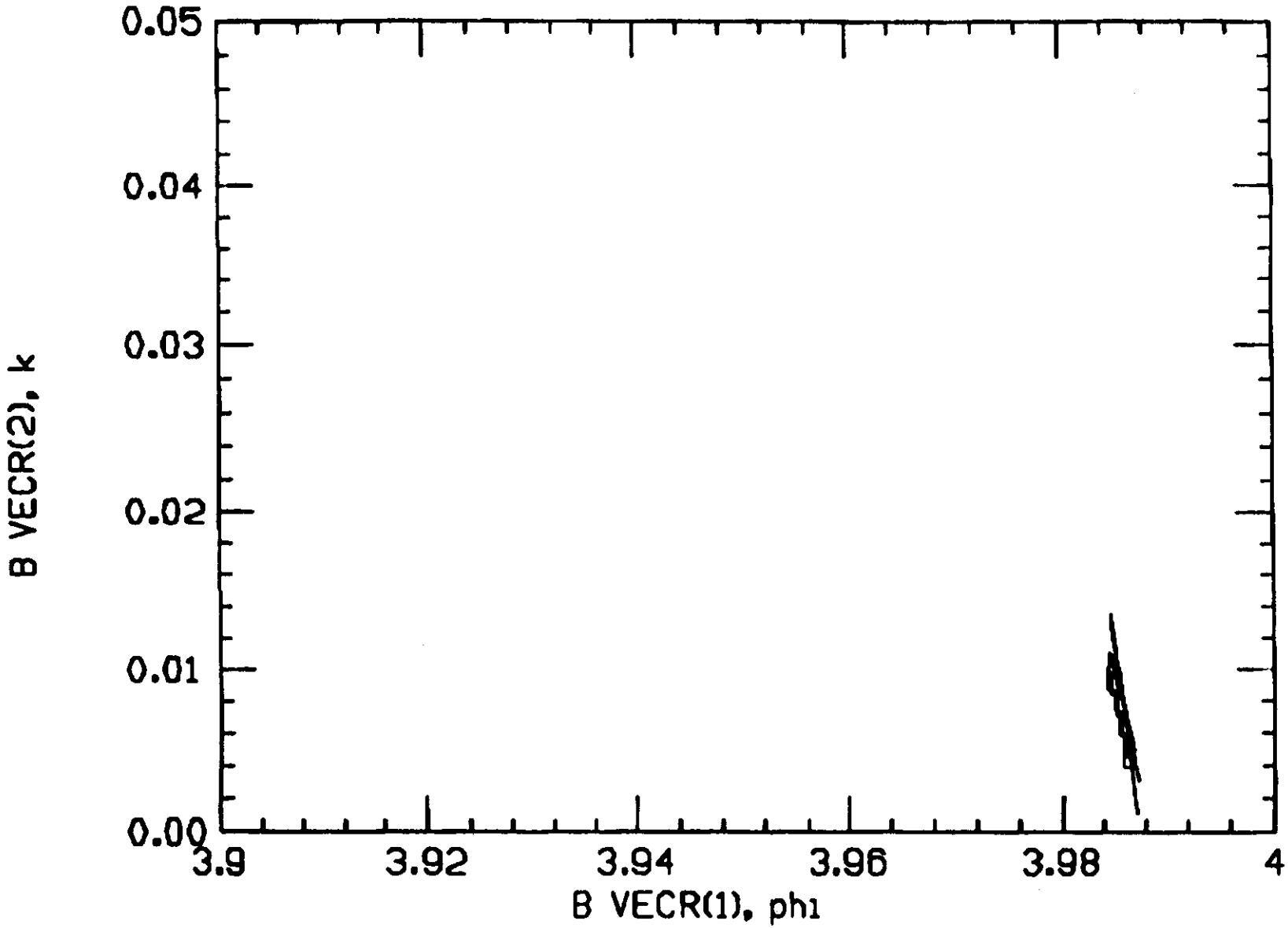
EXTRAPOLATED ϕ, AT ORIGIN


(Barrel Si Strips Only)
0.1
0.0
-0.1
B VECR(2), k
0
2
4
6
B VECR(1), phi

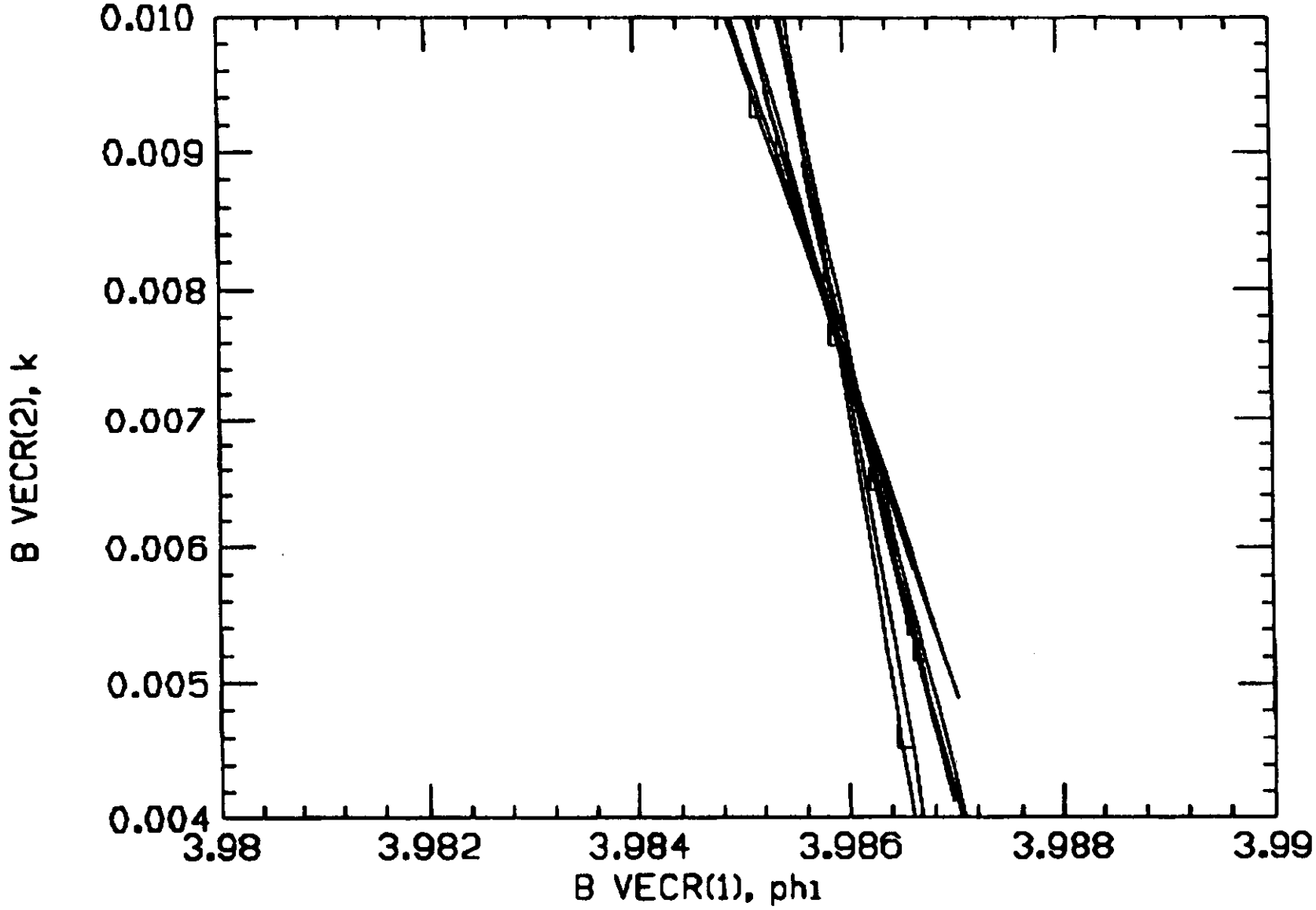

0.05
0.04
0.03
0.02
0.01
0.00
B VECR(2), k
3.9
3.92
3.94
3.96
3.98
4
B VECR(1), ph1

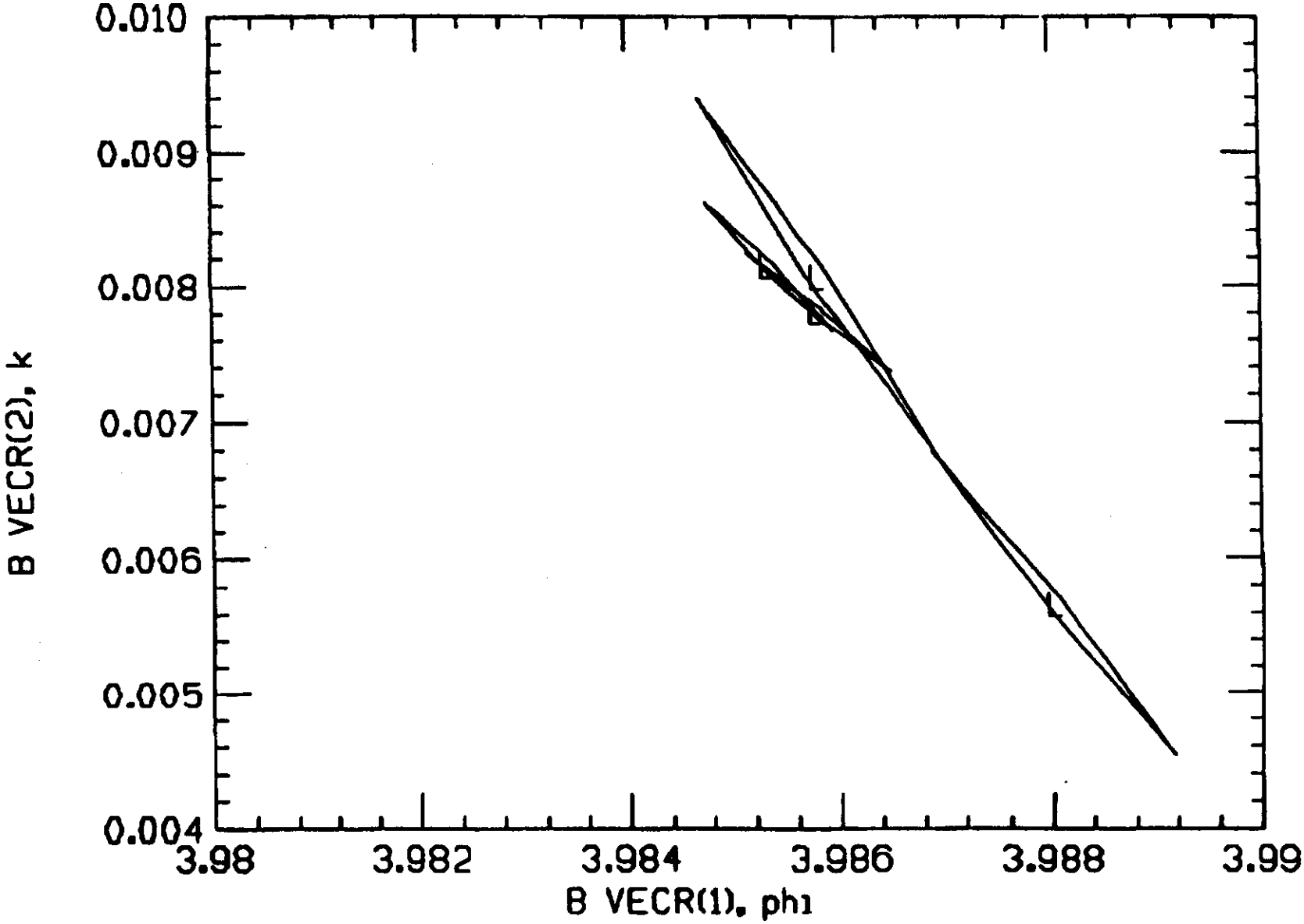
BARREL Si ONLY

(EXPANDED)

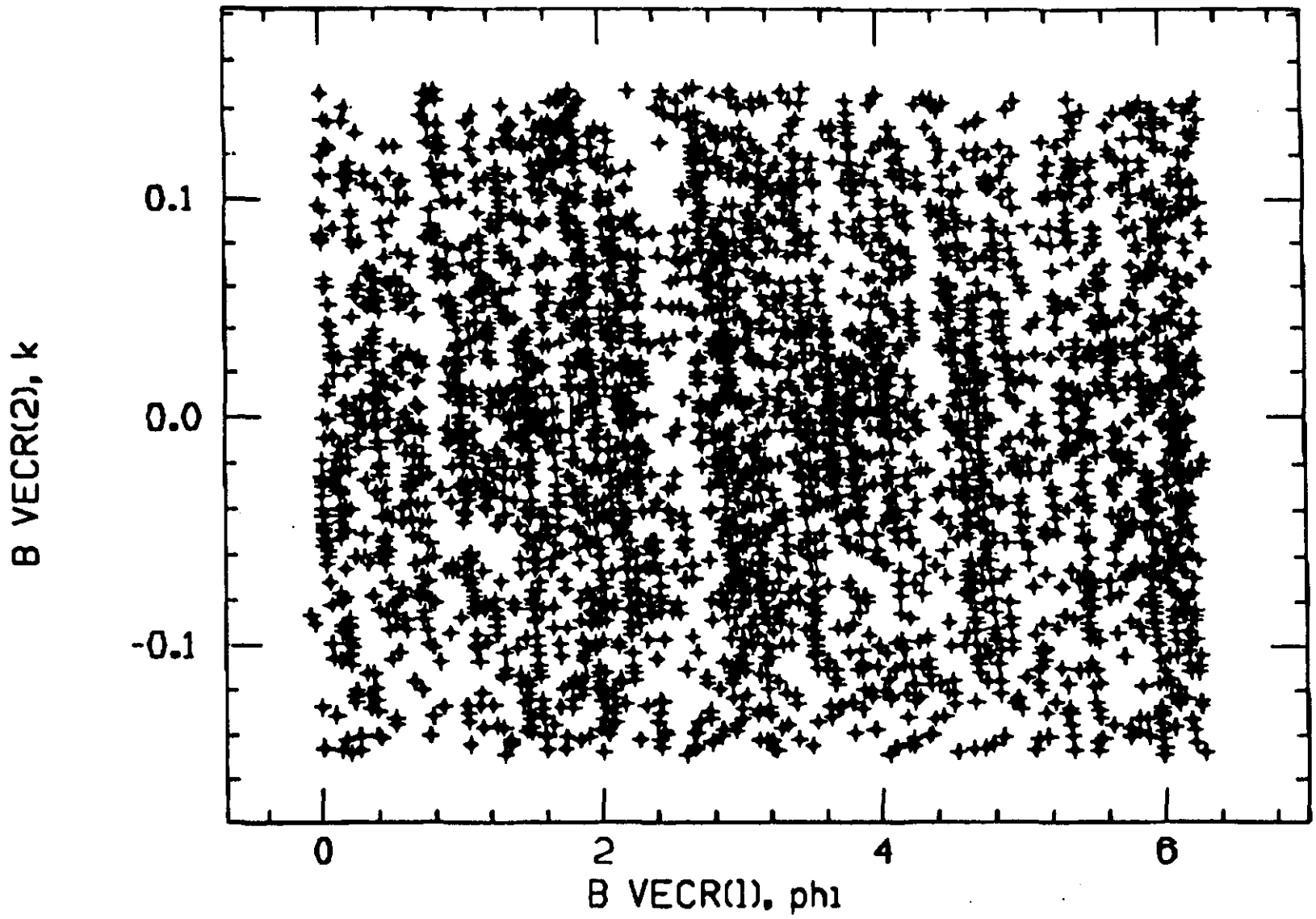


(BARREL Si ONLY-
HIGHLY EXPANDED)



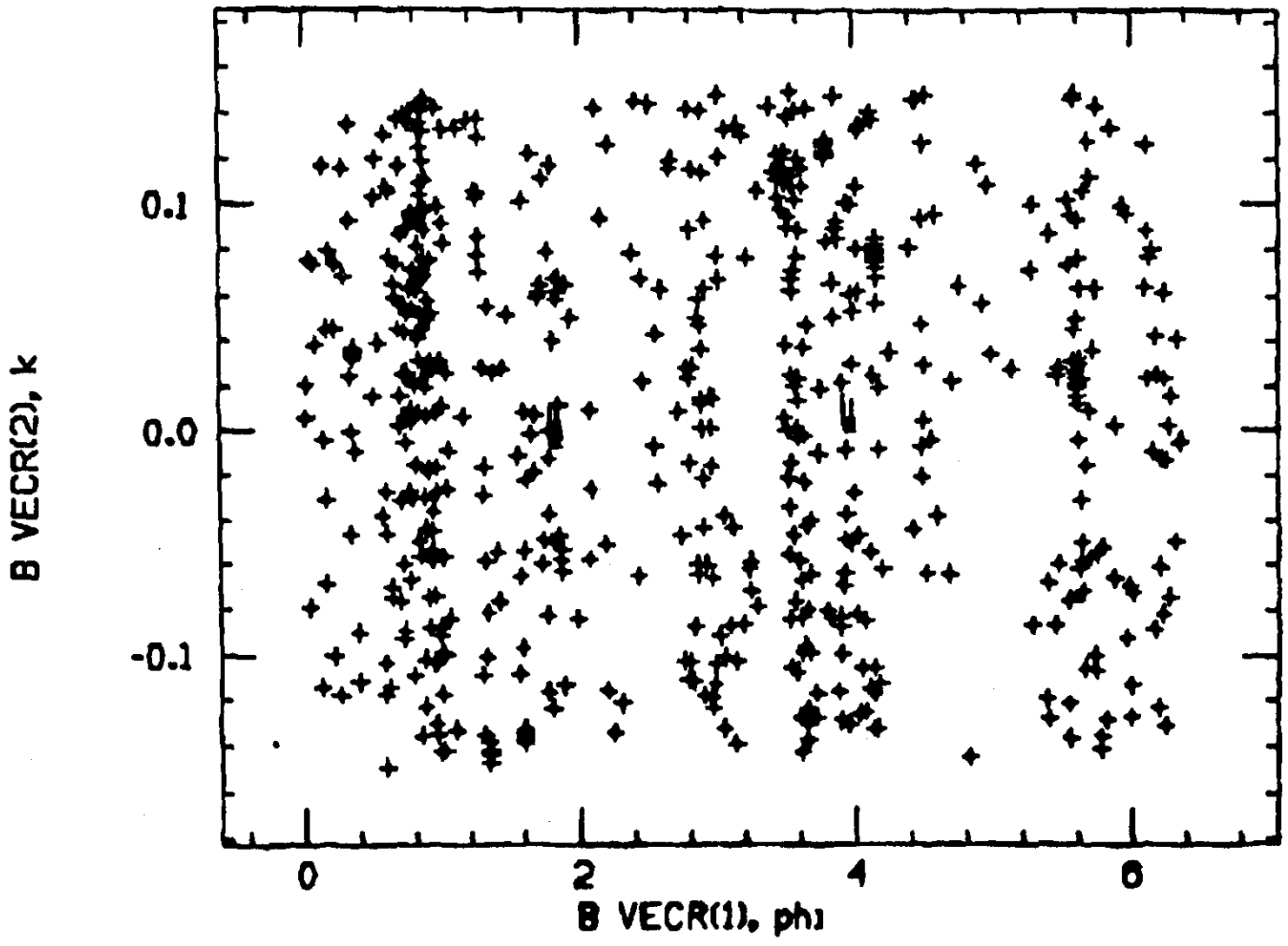

0.010
0.009
0.008
0.007
0.006
0.005
0.004
B VECR(2), k
3.98
3.982
3.984
3.986
3.988
3.99
B VECR(1), phi

400 GeV/c² Higgs → 4 lept (FIBERS ONLY)
+ 8 min-bias events



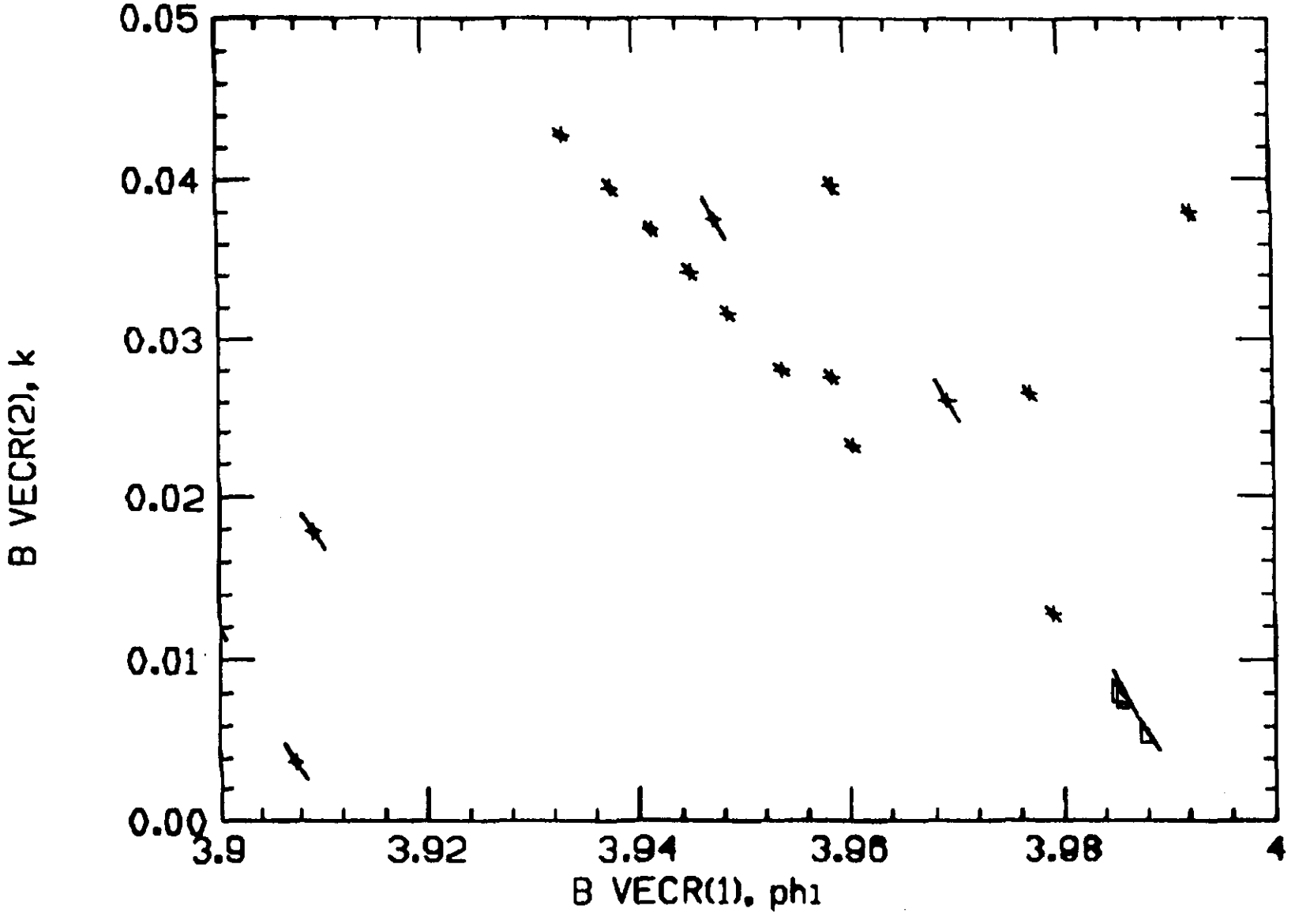
400 GeV Higgs → 4L
+ 8 min bias events

Barrel Silicon Strips Only



FIBERS ONLY
(EXPANDED SCALE)

HIGGS -> 4C + 8 minbins
LEPTON #1

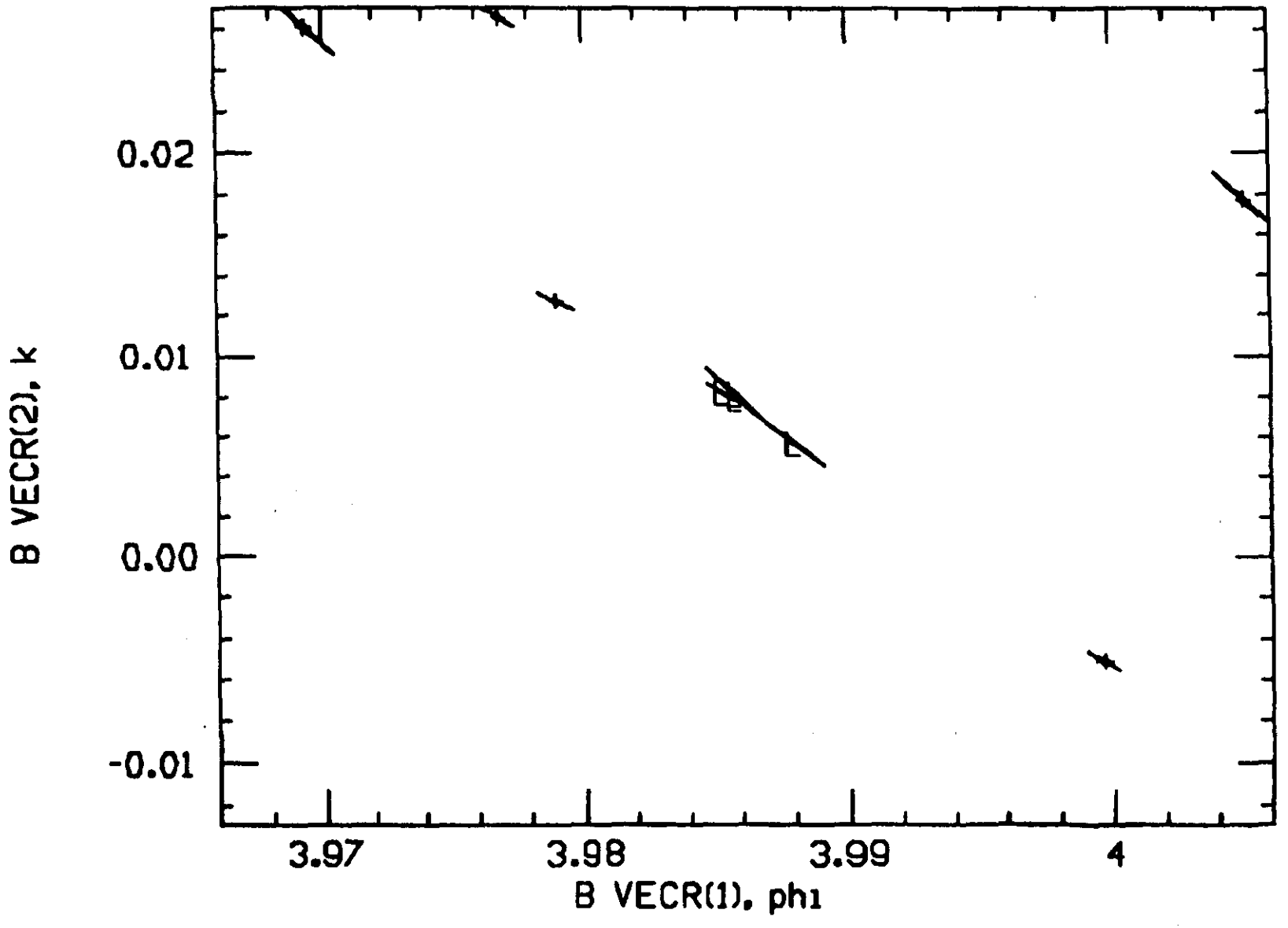


HIGGS → 4ℓ + 8 minbias

LEPTON #1

FIBERS ONLY

(HIGHLY EXPANDED)

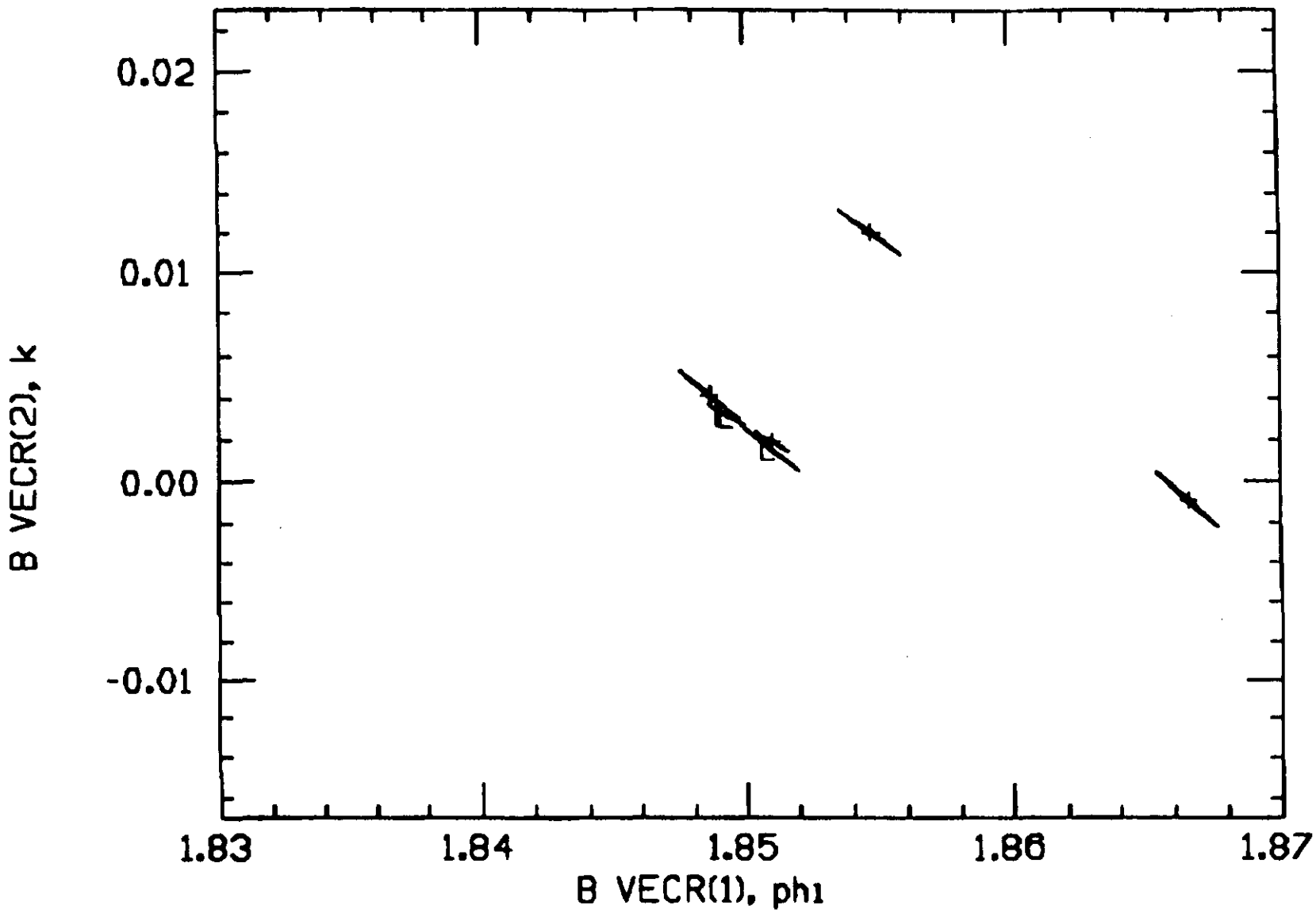


HIGGS -> 4ℓ + 8 minbias

LEPTON # 2

FIBERS ONLY

(HIGHLY EXPANDED)

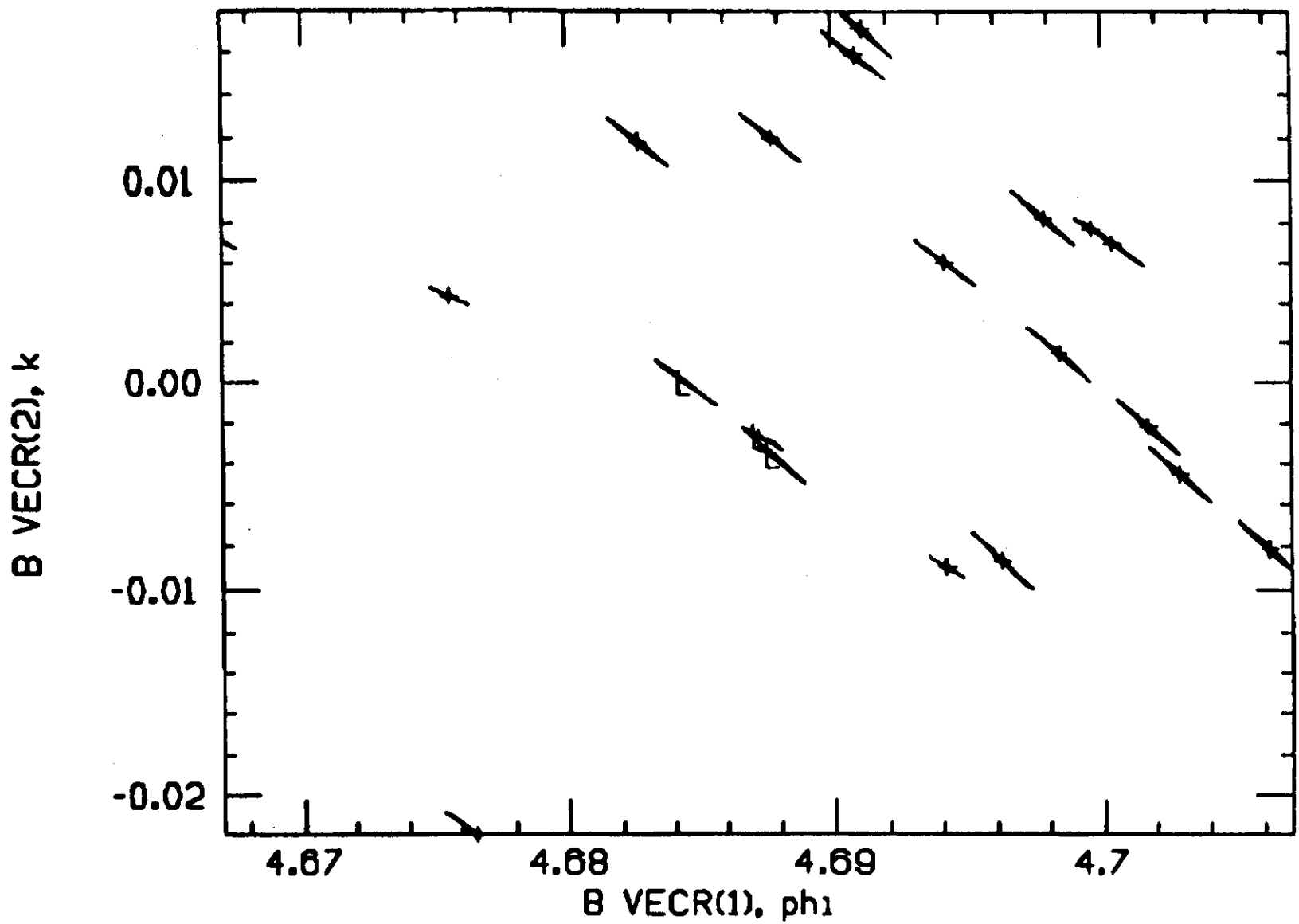


HIGGS → 4ℓ + 8 minbias

LEPTON # 3

FIBERS ONLY

(HIGHLY EXPANDED)

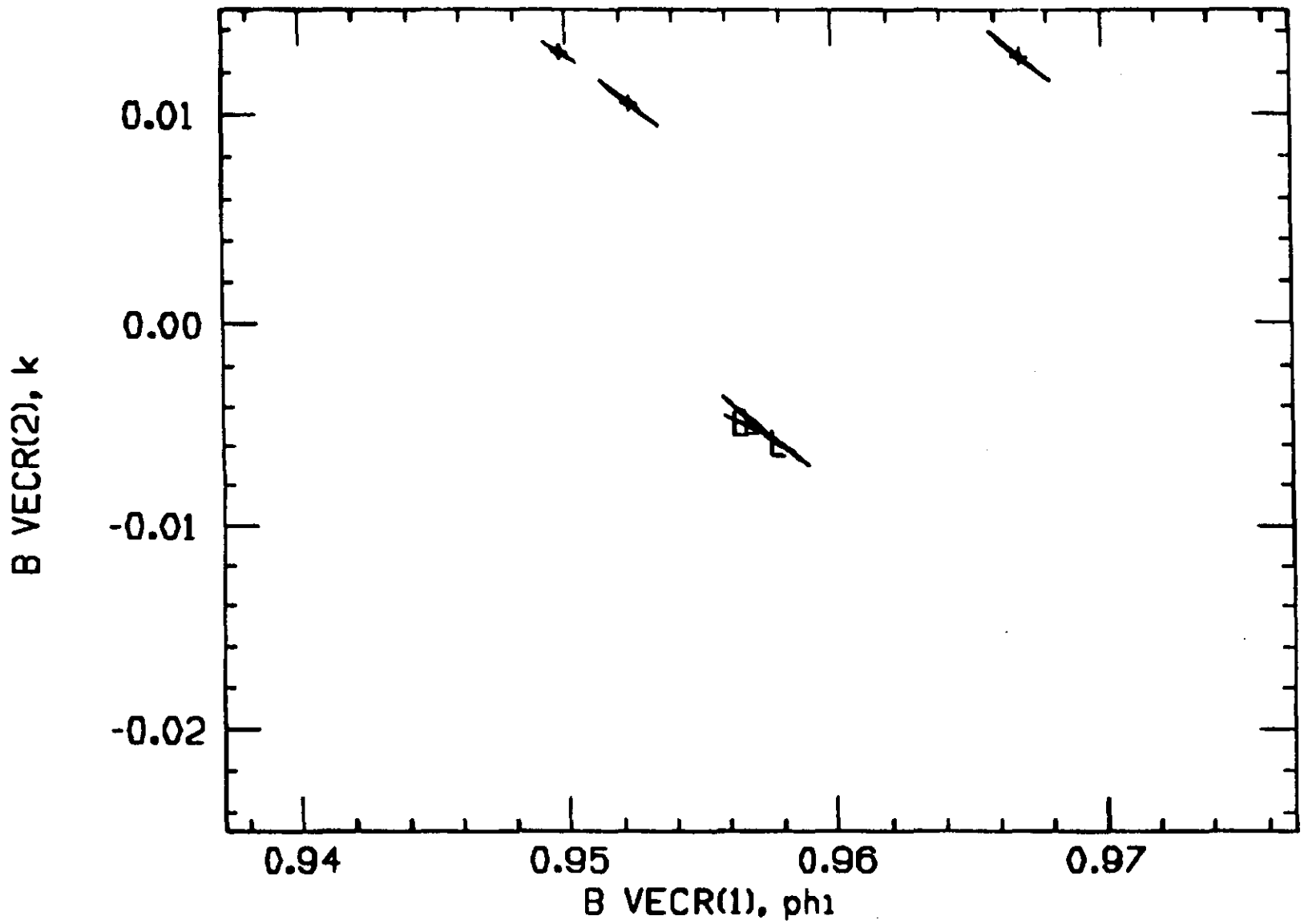


HIGGS → 4λ + 8 minbias

LEPTON # 4

FIBERS ONLY

(HIGHLY EXPANDED)



RESULTS:

1. FOR A 400 GeV/c^2 HIGGS - 4 LEPTON EVENT, THE FIBER TRACKER EASILY FINDS ALL THE LEPTONS.

2. THE SILICON BARREL HAS REDUCED η ACCEPTANCE, AND HENCE ONLY TWO OF THE LEPTONS ARE FOUND BY THE SILICON USING THIS PATTERN RECOGNITIONTECHNIQUE.

3. THE FIBER VECTORS ARE A GOOD MATCH TO THE SILICON VECTORS.

4. EVEN WITH 8 MINIMUM BIAS EVENTS SUPERIMPOSED ON THE EVENT CONTAINING THE HIGGS TO 4 LEPTON DECAY, THE FIBER TRACKER FINDS ALL OF THE LEPTONS WITHOUT THE SILICON.

CONCLUSION:

1. PATTERN RECOGNITION IS STRAIGHT FORWARD EVEN AT HIGH LUMINOSITY.

2. UNIFORM APPLICATION OF THE VECTOR CLUSTERING TECHNIQUE CAN BE UTILIZED EFFECTIVELY IN THE BARREL REGION FOR THE COMBINED SCINTILLATING FIBER/SILICON SYSTEM.

CONCLUSIONS OF RECENT DEVELOPMENTS

1. Ø = 1mm Fiber selected.

2. PS/PTP/3HF selected as "baseline" scintillator
   PS selected as "baseline" waveguide

   cladding is PMMA.

3. Radiation resistance – very good
   Low dose rate studies in progress.

4. Beam tests –

   successful/stable operation of HISTE-II
   VTX preamp shows pulse rise $\lesssim$ 5ns
   signal:noise excellent
   cooldown $\lesssim$ 10min to 9K.

   Tracks recorded.

5. PATTERN RECOGNITION FOR FIBER TRACKER IS SIMILAR TO SILICON IN (K, ϕ) SPACE. VECTOR CLUSTERING METHOD MAY BE APPLIED EFFECTIVELY TO BOTH SYSTEMS.

QUESTIONS FROM NOVEMBER

1. PATTERN RECOGNITION:
   - (a) SILICON-STYLE (κ, ϕ) ANALYSIS WORKS WELL.
   - (b) SEPARATED DOUBLETS ARE AN AID – USEFUL FOR TRIGGERING, ALSO IN PATTERN ANALYSIS
   - (c) UNIFORM APPLICATION OF VECTOR ANALSIS USING CYLINDRICAL GEOMETRY OVER η RANGE.
   - (d) WORKS INDEPENDENT OF SILICON; POWERFUL WITH SILICON

2. VLPC TECHNOLOGY:
   - (a) HISTE-II ITAR FREE
   - (b) BEAM TEST OF 32 CHANNELS
   - (c) WARM PREAMP 5ns PULSE RISE
     REDUCES SIGNIFICANTLY TECHNICAL RISK
   - (d) HISTE-III CHARACTERIZATION – FEB. 92
   - (e) CANISTER/CASSETTE CONCEPT. DESIGN – REPORT FEB. 12, 1992

(i) PRODUCTION QUALITY VLPCs IN MARCH
(ii) BEAM STUDIES OF 32-128 CHANNELS (SPRING 1992)
256 CHANNELS (SUMMER 1992)

(iii) RAD HARDNESS ("LOW" DOSE RATES) IN PROGRESS AND ANALYSIS
HIGH DOSE RATE SHOWS MINIMAL EFFECT.

(iv) CONFIRMATION WITH HMC DEVICES – BENCH
HISTE-III – BEAM

(a) in CDR: parametric resolutions
(b) simulations: in progress
(c) trigger performance – uniform to $|\eta| \leq 2.3$
retreat (or include additional layers) at higher luminosity.
(d) L1 fake rate is luminosity dependent, but low for fibers
(e) pattern recognition works w/w.o. silicon
(f) system as $L \to 10^{34}$: pattern recognition OK (κ, ϕ)
trigger – ok – use more layers if needed (reduced η coverage 2.0)
rad damage – in study but looks ok.