SDC-93-432

Photoelectron Yield

Scintillating Fiber Tracking System for the Superconducting Super Collider

Solenoidal Detector Collaboration
Fiber Tracking Group
February 3, 1993

PHOTOELECTRON YIELD FOR THE SCINTILLATING FIBER OUTER TRACKER

FIBER TRACKING GROUP

PRESENTED BY:

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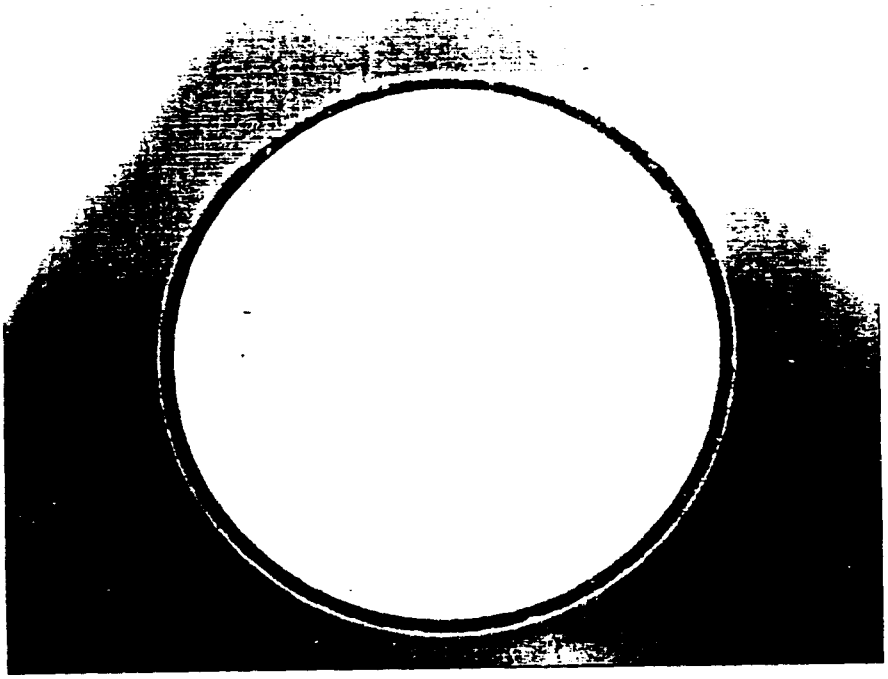
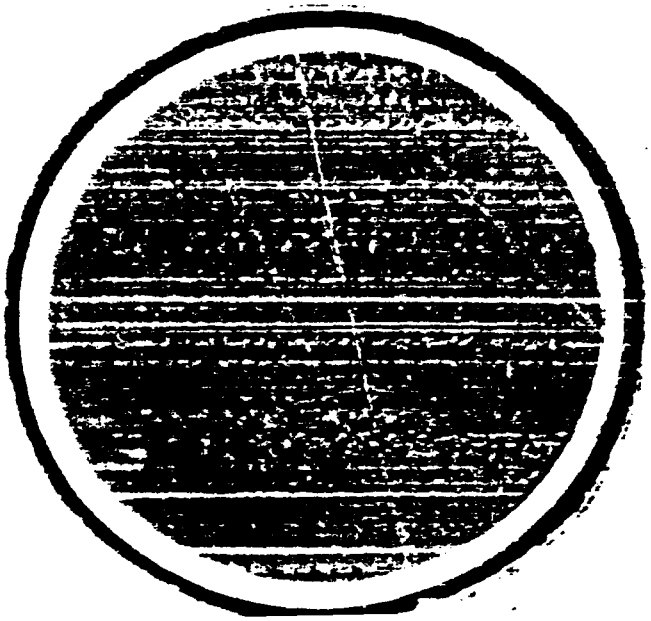
NOTRE DAME
2-6-93

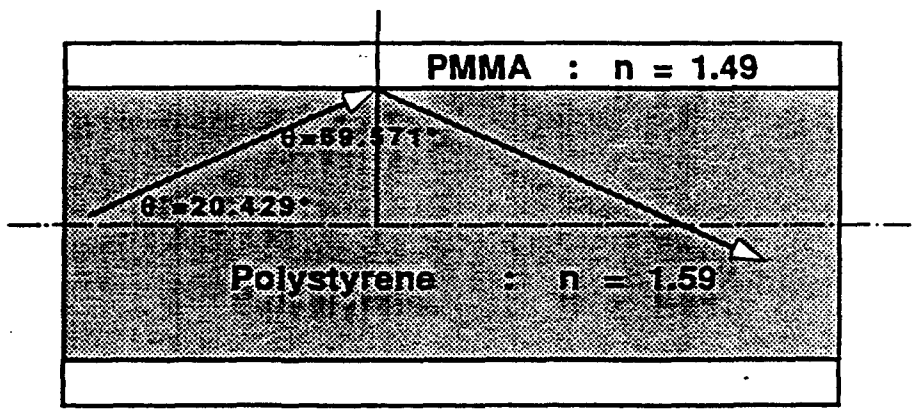




MULTI-CLAD FIBER DEVELOPMENT

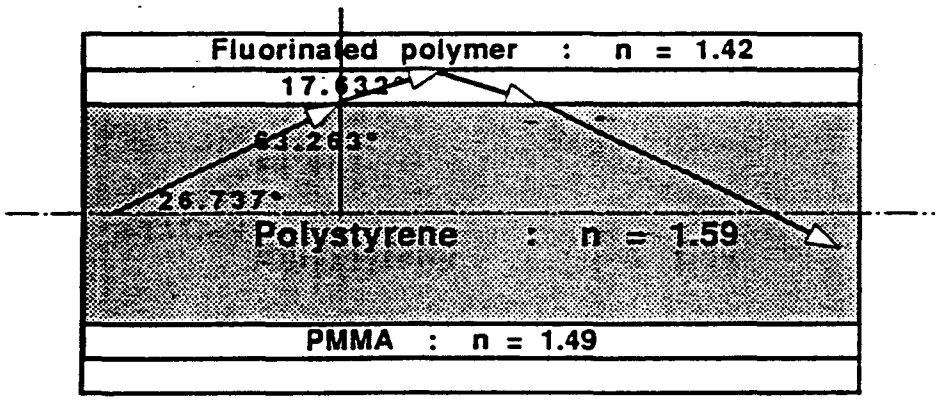
Single Clad Fiber Properties:

Outer diameter	835μm
Core	polystyrene + PTP +3HF
	n=1.59
	active diameter 785μm
Clad	PMMA
	n=1.49
	thickness 25μm
Scintillator	PS + PTP + 3HF (1500ppm)
Trapped light	3.14%



Multiclad Fiber Properties:

Outer Diameter	835μm
Core	Polystyrene
	n=1.59
	active diameter 735μm
Clad 1	PMMA
	n=1.49
	thickness 25μm
Clad 2	Fluoropolymer
	n=1.42
	thickness 25μm
Scintillator	PS + PTP + 3HF (1500ppm)
Trapped light	5.34%



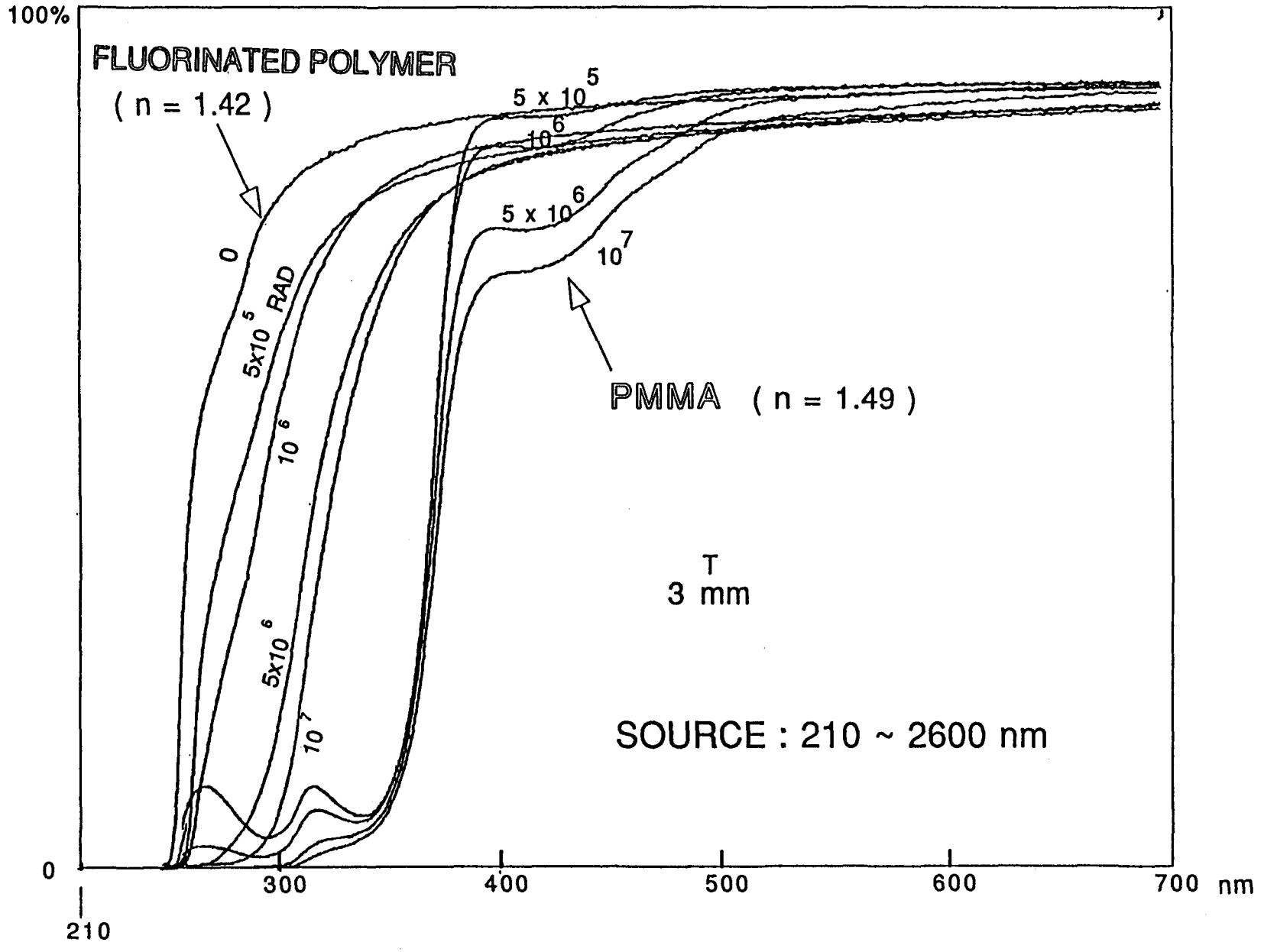


Figure 2.1.2-8 Optical transmission in fluorinated polymer and PMMA as a function of wavelength for various applied radiation doses, indicating good performance for both, but clearly superior performance for the fluoropolymer.

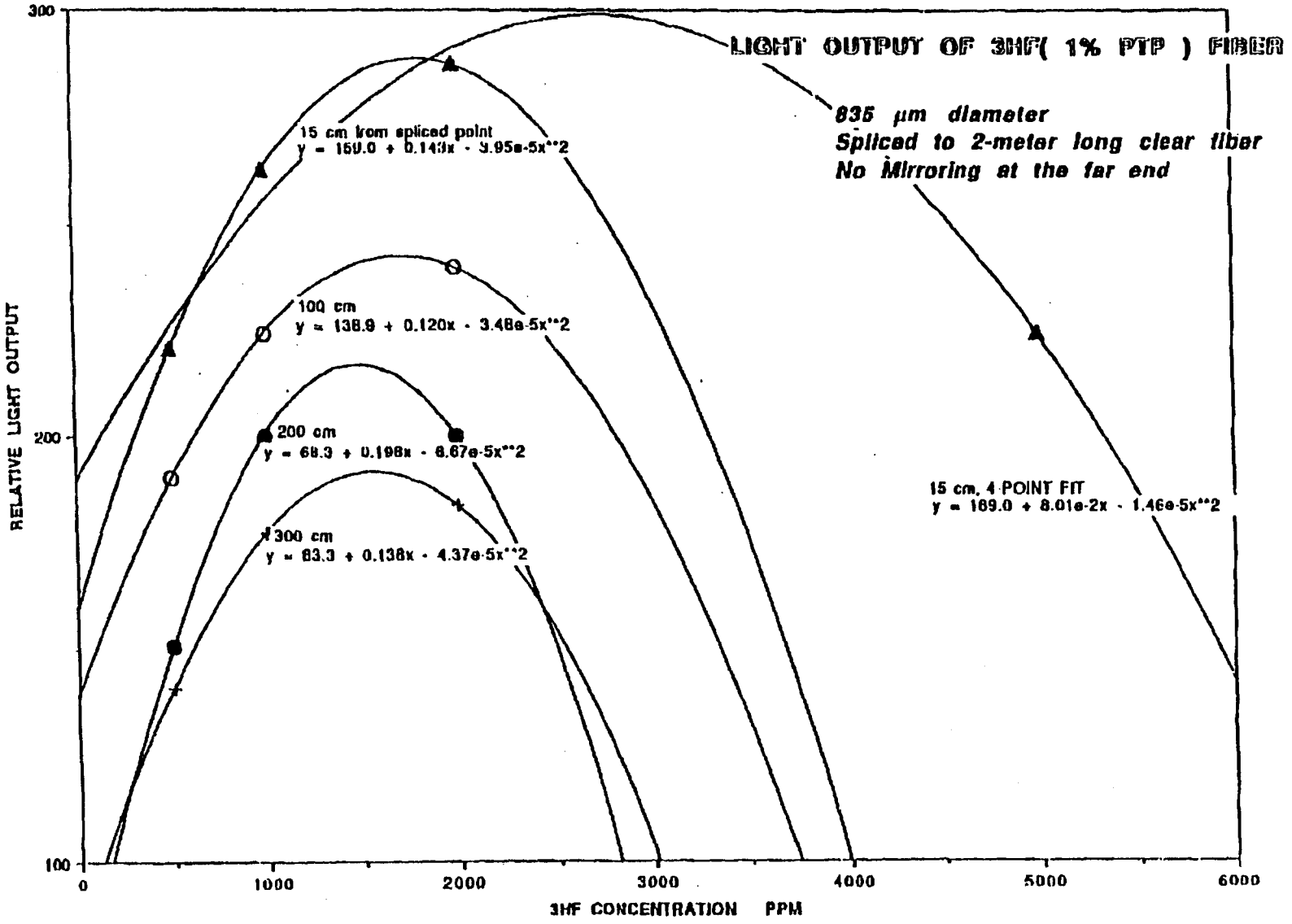


Figure 2.1.2-6 Optimization study of the 3HF concentration in the standard scintillator. indicates that for long lengths of fiber, ~1500ppm is optimal.

EXPERIMENTS ON THE PERFORMANCE OF MULTICLAD FIBER

1. Relative Performance of Clear Waveguide
   (Multi vs Single Clad)

   UV lamp excitation

Y11 waveshifter fiber	835μm	pigtail
Clear waveguide fiber	835μm	lengths ≤ 12m

2. Relative Performance of Scintillating Fiber and Waveguide
   (Multi vs Single Clad)

   UV lamp excitation

3HF scintillating fiber	835μm	length 4.3m
Clear waveguide fiber	850μm	length 6m

3. Relative Performance of Scintillating Fiber and Waveguide
   (Diameter Study of Multiclad Fiber)

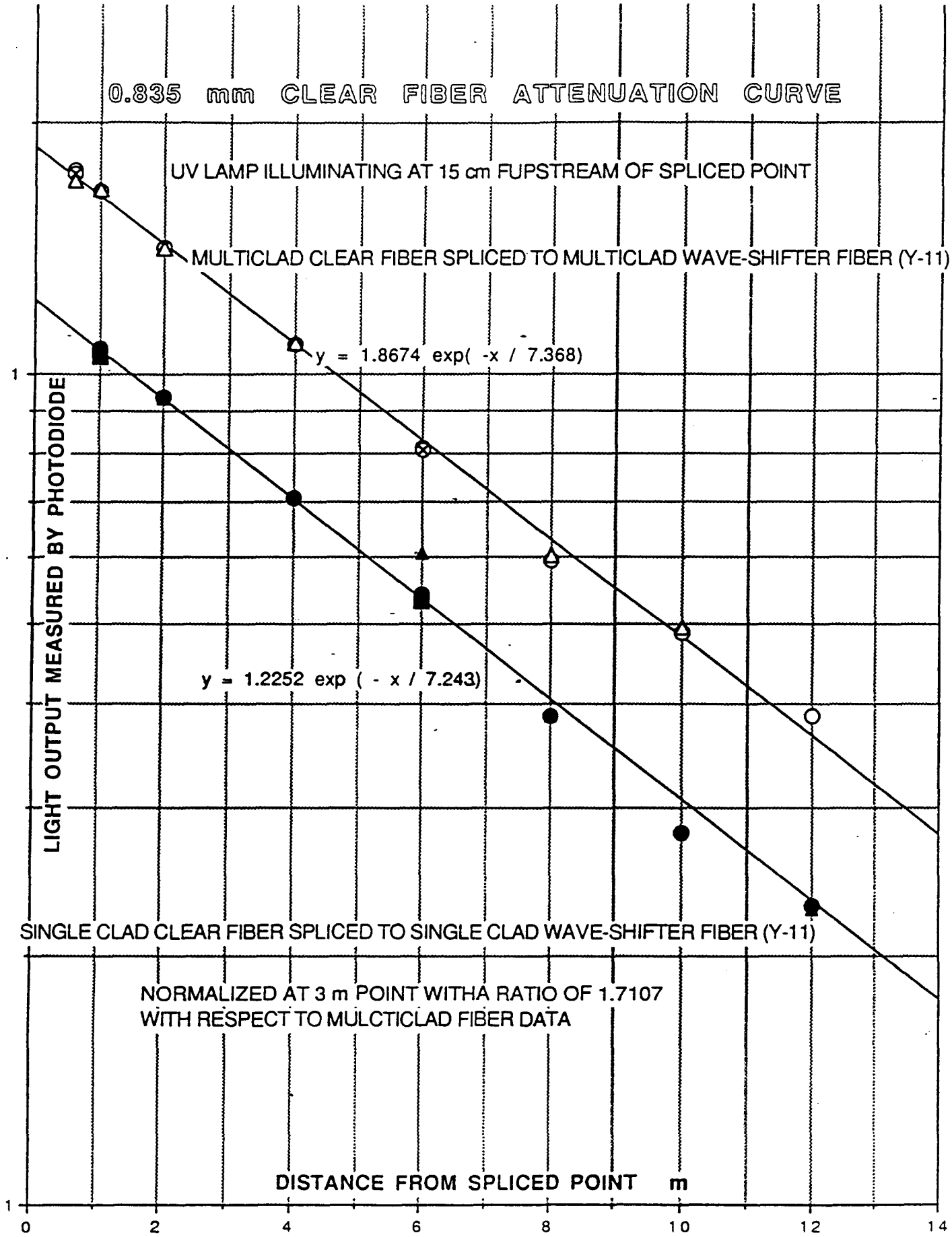
   UV lamp excitation

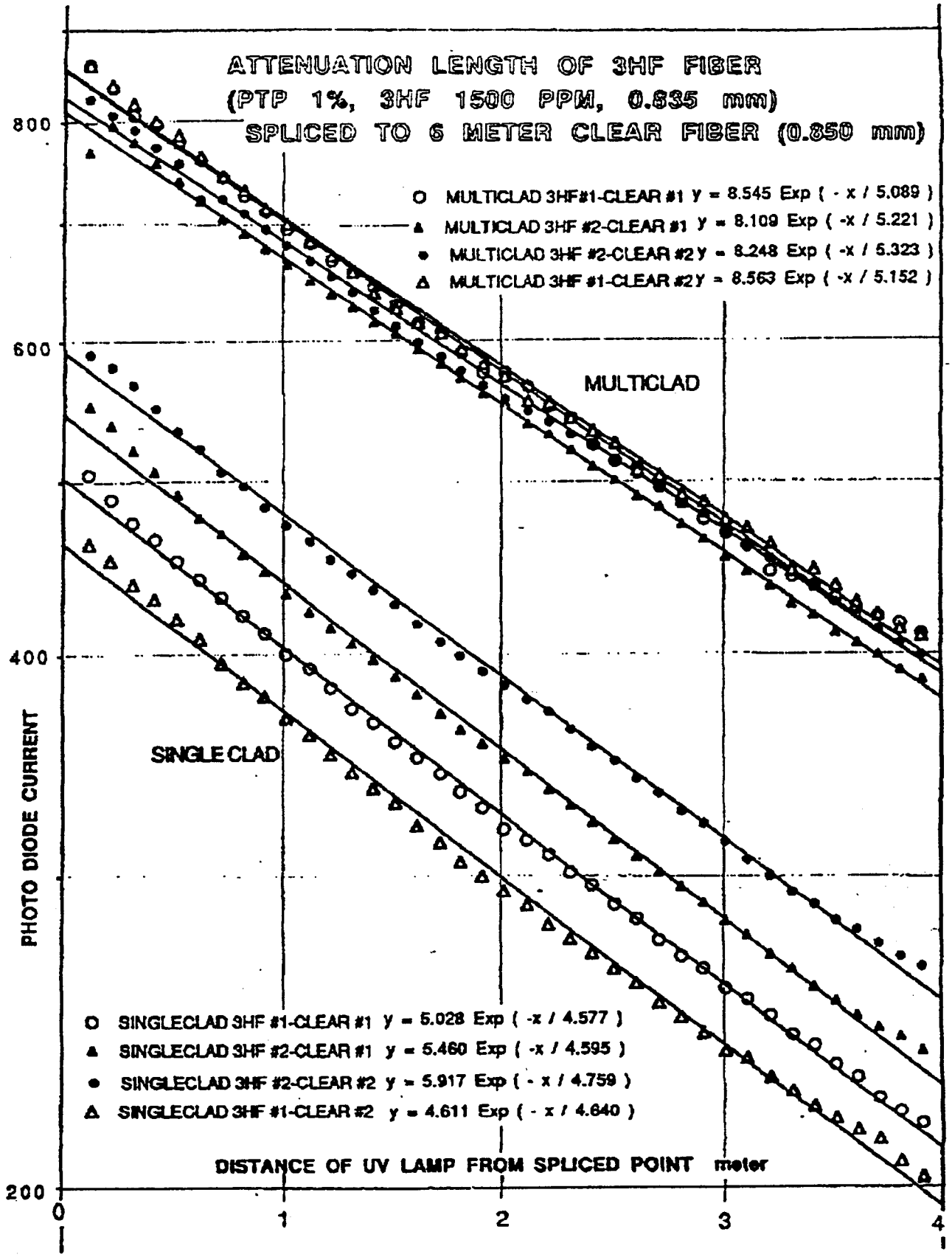
3HF scintillating fiber	835μm	length 4.3m
Clear waveguide fiber	850μm	length 6.0m
vs		
3HF scintillating fiber	925μm	length 4.3m
Clear waveguide fiber	960μm	length 6.0m

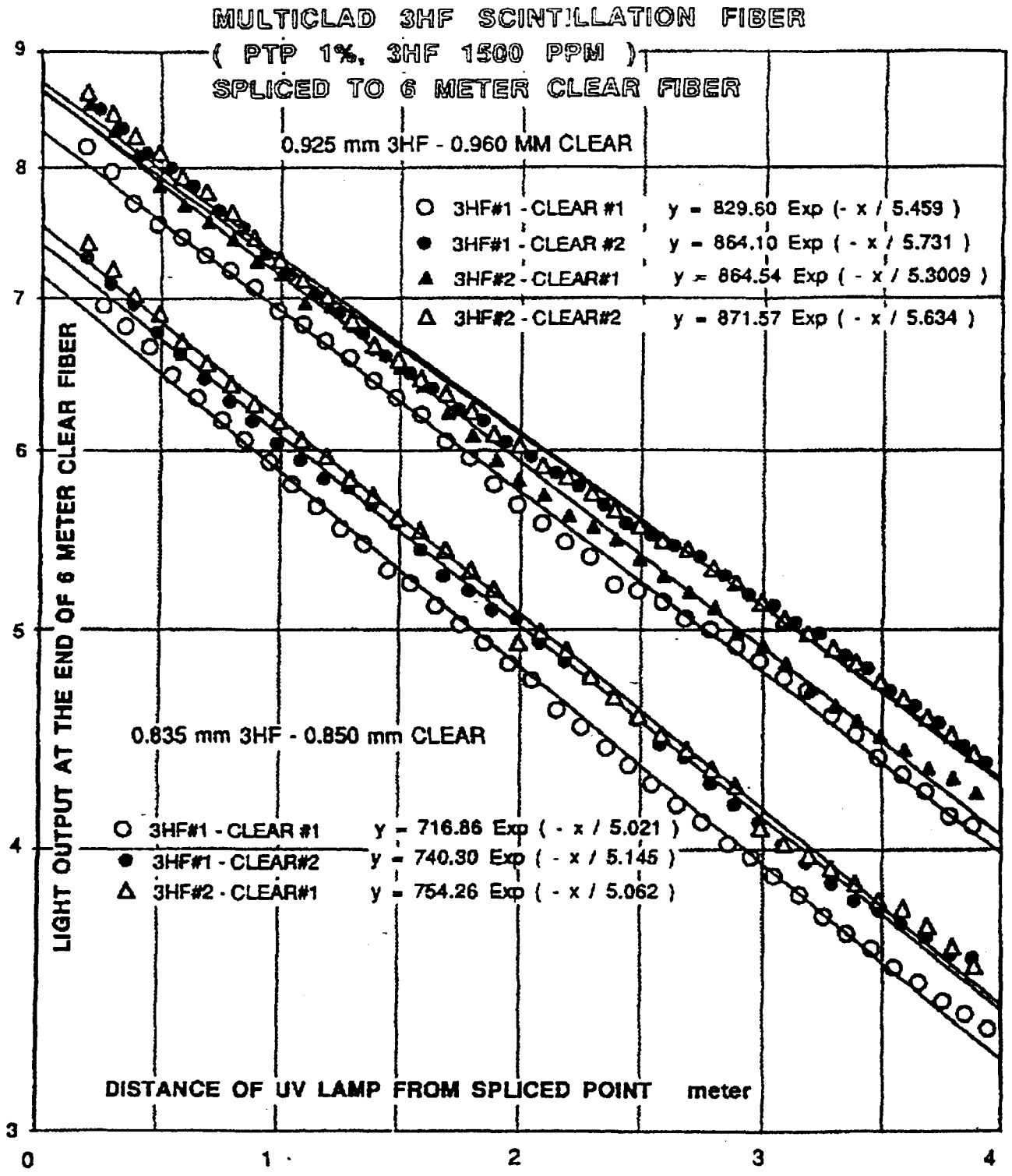
4. Relative Performance of Scintillating Fiber and Waveguide
   (Multi vs Single Clad)

   Bi 207 excitation
   HMC VLPC readout

3HF scintillating fiber	830μm	length 4.3m
Clear waveguide fiber	830μm	length 6.0m


0.835 mm CLEAR FIBER ATTENUATION CURVE
UV LAMP ILLUMINATING AT 15 cm FUPSTREAM OF SPLICED POINT
MULTICLAD CLEAR FIBER SPLICED TO MULTICLAD WAVE-SHIFTER FIBER (Y-11)
y = 1.8674 exp(-x / 7.368)
y = 1.2252 exp (- x / 7.243)
SINGLE CLAD CLEAR FIBER SPLICED TO SINGLE CLAD WAVE-SHIFTER FIBER (Y-11)
NORMALIZED AT 3 m POINT WITHA RATIO OF 1.7107
WITH RESPECT TO MULCTICLAD FIBER DATA
LIGHT OUTPUT MEASURED BY PHOTODIODE
DISTANCE FROM SPLICED POINT m
1
1
0
2
4
6
8
10
12
14

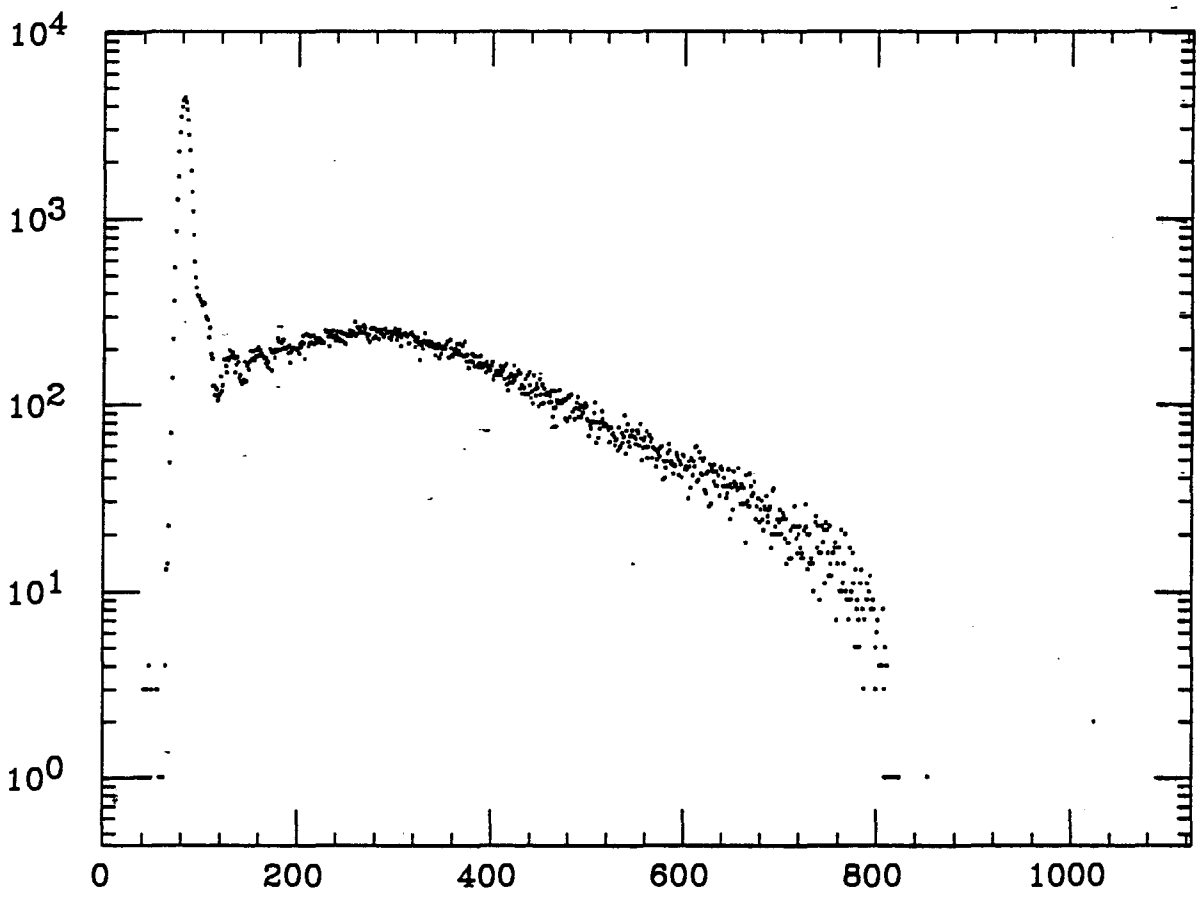

ATTENUATION LENGTH OF 3HF FIBER
(PTP 1%, 3HF 1500 PPM, 0.835 mm)
SPLICED TO 6 METER CLEAR FIBER (0.850 mm)
O MULTICLAD 3HF#1-CLEAR #1 y = 8.545 Exp (- x / 5.089)
▲ MULTICLAD 3HF #2-CLEAR #1 y = 8.109 Exp (-x / 5.221)
● MULTICLAD 3HF #2-CLEAR #2 y = 8.248 Exp (-x / 5.323)
Δ MULTICLAD 3HF #1-CLEAR #2 y = 8.563 Exp (-x / 5.152)
MULTICLAD
SINGLE CLAD
O SINGLECLAD 3HF #1-CLEAR #1 y = 5.028 Exp (-x / 4.577)
▲ SINGLECLAD 3HF #2-CLEAR #1 y = 5.460 Exp (-x / 4.595)
● SINGLECLAD 3HF #2-CLEAR #2 y = 5.917 Exp (- x / 4.759)
Δ SINGLECLAD 3HF #1-CLEAR #2 y = 4.611 Exp (- x / 4.640)
PHOTO DIODE CURRENT
DISTANCE OF UV LAMP FROM SPLICED POINT meter
800
600
400
200
0
1
2
3
4


MULTICLAD 3HF SCINTILLATION FIBER
(PTP 1%, 3HF 1500 PPM)
SPLICED TO 6 METER CLEAR FIBER
0.925 mm 3HF - 0.960 MM CLEAR
3HF#1 - CLEAR #1 y = 829.60 Exp (- x / 5.459)
3HF#1 - CLEAR #2 y = 864.10 Exp (- x / 5.731)
3HF#2 - CLEAR#1 y = 864.54 Exp (- x / 5.3009)
3HF#2 - CLEAR#2 y = 871.57 Exp (- x / 5.634)
0.835 mm 3HF - 0.850 mm CLEAR
3HF#1 - CLEAR #1 y = 716.86 Exp (- x / 5.021)
3HF#1 - CLEAR#2 y = 740.30 Exp (- x / 5.145)
3HF#2 - CLEAR#1 y = 754.26 Exp (- x / 5.062)
LIGHT OUTPUT AT THE END OF 6 METER CLEAR FIBER
DISTANCE OF UV LAMP FROM SPLICED POINT meter
9
8
7
6
5
4
3
0
1
2
3
4

MULTI CLAD FIBER

Bi 207 Source Response at the Near End of the Scintillator
HMC VLPC Readout

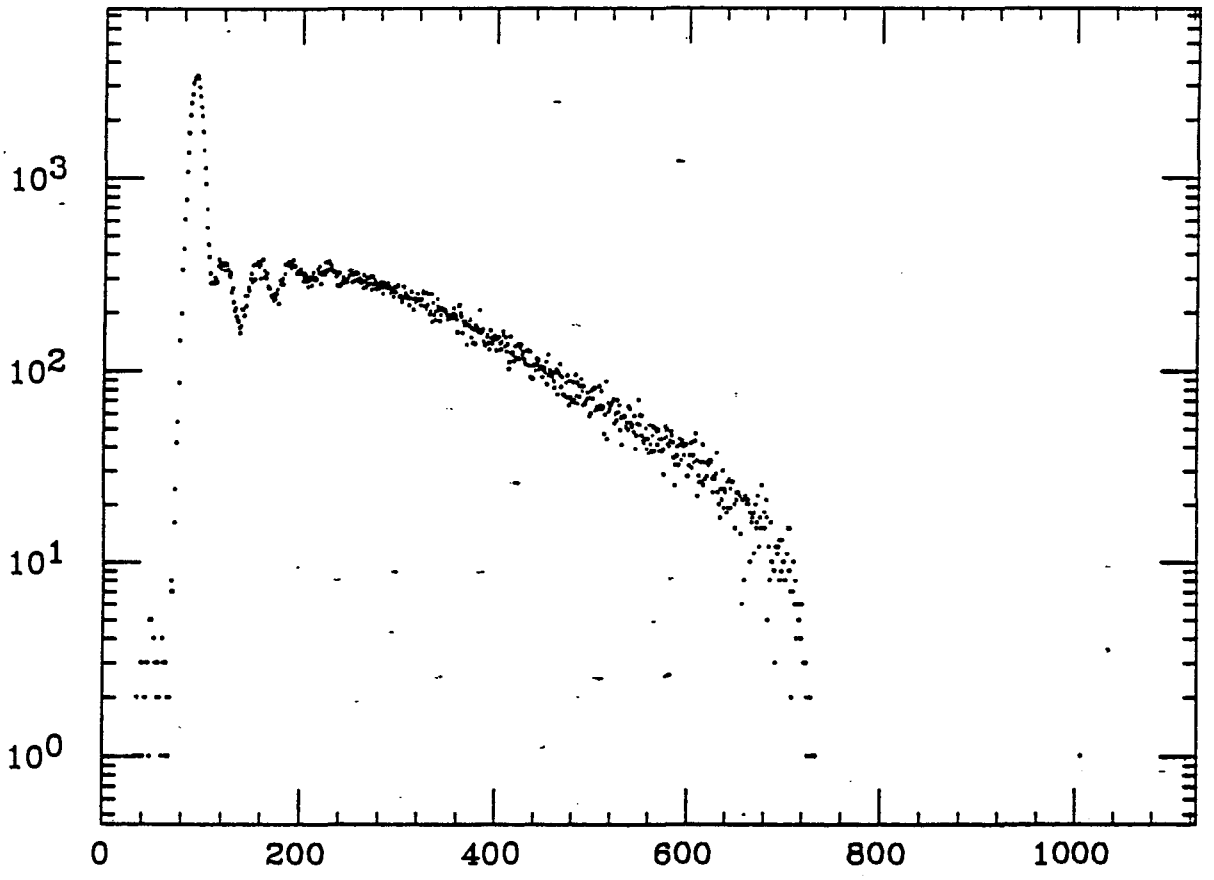
6m of waveguide fiber
2 optical splices/connectors



SINGLE CLAD FIBER

Bi 207 Source Response at the Near End of the Scintillator
HMC VLPC Readout

6m of waveguide fiber
2 optical splices/connectors



SUMMARY OF TEST RESULTS

1. Clear Fiber Waveguide (≤ 12m):

   Multiclad : Single clad = 1.7

2. Scintillating Fiber (4.3m) + Waveguide (6m):

   Multiclad : Single clad = 1.66 (min)
   = 1.76 (average)

3. Scintillating Fiber (4.3m) + Waveguide (6m):
   Bi 207 Study

   Multiclad : Single clad = 1.7

4. Scintillating Fiber (4.3m) + Waveguide (6m):

   Multiclad (925μm) : Multiclad(835μm) = 1.20

CONCLUSIONS:

FACTOR FOR MULTICLAD	1.7
FACTOR FOR DIAMETER INCREASE	1.2

Table 4
Extrapolation of the BNL Test Results to SDC Performance

Component	Status	Improvement Factor over BNL Test (Availability Date) 1/93	2/93	9/93
VLPC				
HISTE-III (QE=.55)	In hand/measured	1.0		
HISTE-IV (QE=.70)	Avail 2/93		1.27	
HISTE-IVR (QE=.85)	Avail 9/93			1.55
Scintillation Dye				
Standard Material	In hand	1.0		
Concentration Optimization	In hand/measured	1.1		
Refinement	In hand; avail in fiber form 2/93			1.21
Fiber Diameter (925μm vs 835μm)	Measured	1.11	1.20	
Scintillating Fiber/Waveguide FiberStructure				
Single Clad	In hand/measured	1.0		
Multi Clad	Measured	1.7	1.7	
Connectors (Two) (0.85 vs 0.75 for each)	Measured	1.28		
Improvement Factor over BNL		**2.7**	**3.6**	**4.9**
Photoelectron Yield per Fiber at $\eta = 0$ (worst case)		**3.2 pe**	**4.4 pe**	**5.9 pe**
Photoelectron Yield per Fiber (averaged over $0 \leq \lvert\eta\rvert \leq 2.3$)		**12.8 pe**	**17.6 pe**	**23.6 pe**

furnish the connector and the light yield was measured in a similar way. The light transmission is defined as the ratio of these two readings.

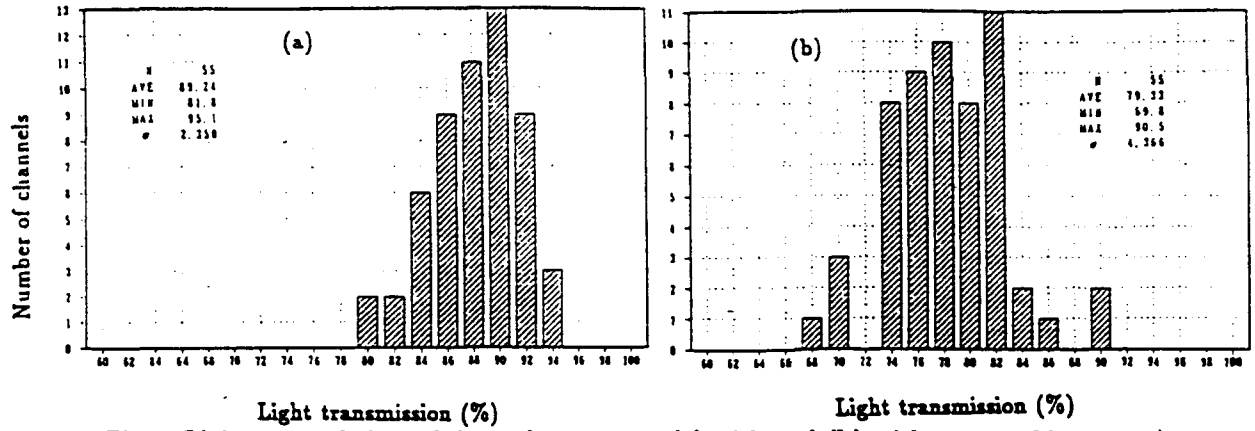


Fig. 3 Light transmission of the 8-ch connector (a) with and (b) without matching grease. The rms spread is wide as described in the text.

The average transmission is 89.2% (3.4% rms spread) with grease and 79.3% (4.4% rms spread) without grease for the 8-ch connectors. The matching grease increases the light transmission by nearly 10% and reduces its rms spread. peak-to-peak deviation with grease is +5.9% and −7.5%. The lids of the new connectors using 66PA were too tight to be pressed into so that each one of the two protrusions were trimmed. This repair caused the fiber axis to shift, and the rms spread of the light transmission increased. The rms deviation of the connector (C) was 2.6%. By using injection molding, the uniformity is expected to be about 2.6% or smaller.

Since the cross talk measured for the connector (C) was small, we have not repeated measurement for the new connectors (D). For the connector (C) the cross talk defined as the light yield when the light is input to the adjacent fiber is less than 0.11% and typically 0.06%, which is consistent with the background in the measurement.

The transmission for splicers is 94.5% in the average and 1.9% in the rms spread, as shown in Fig. 4. Here matching grease is used. The splicers may be used at the place where the fiber is bent at a certain curvature. We measured the effect of fiber bending. The fiber with a splicer (A), while one fiber end was kept fixed, was turned by 90° with a curvature of 30 mm. The light transmission was measured with changing the position of the splicer from the fixed end. Although the transmission increases gradually with increasing the splicer position from 15 mm to 45 mm, it agrees to within 1% for the four samples we measured.

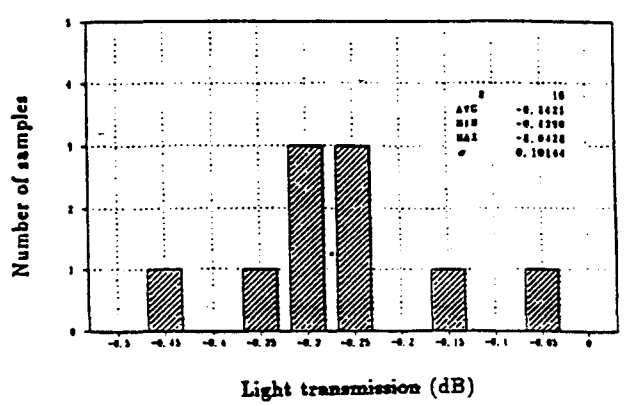
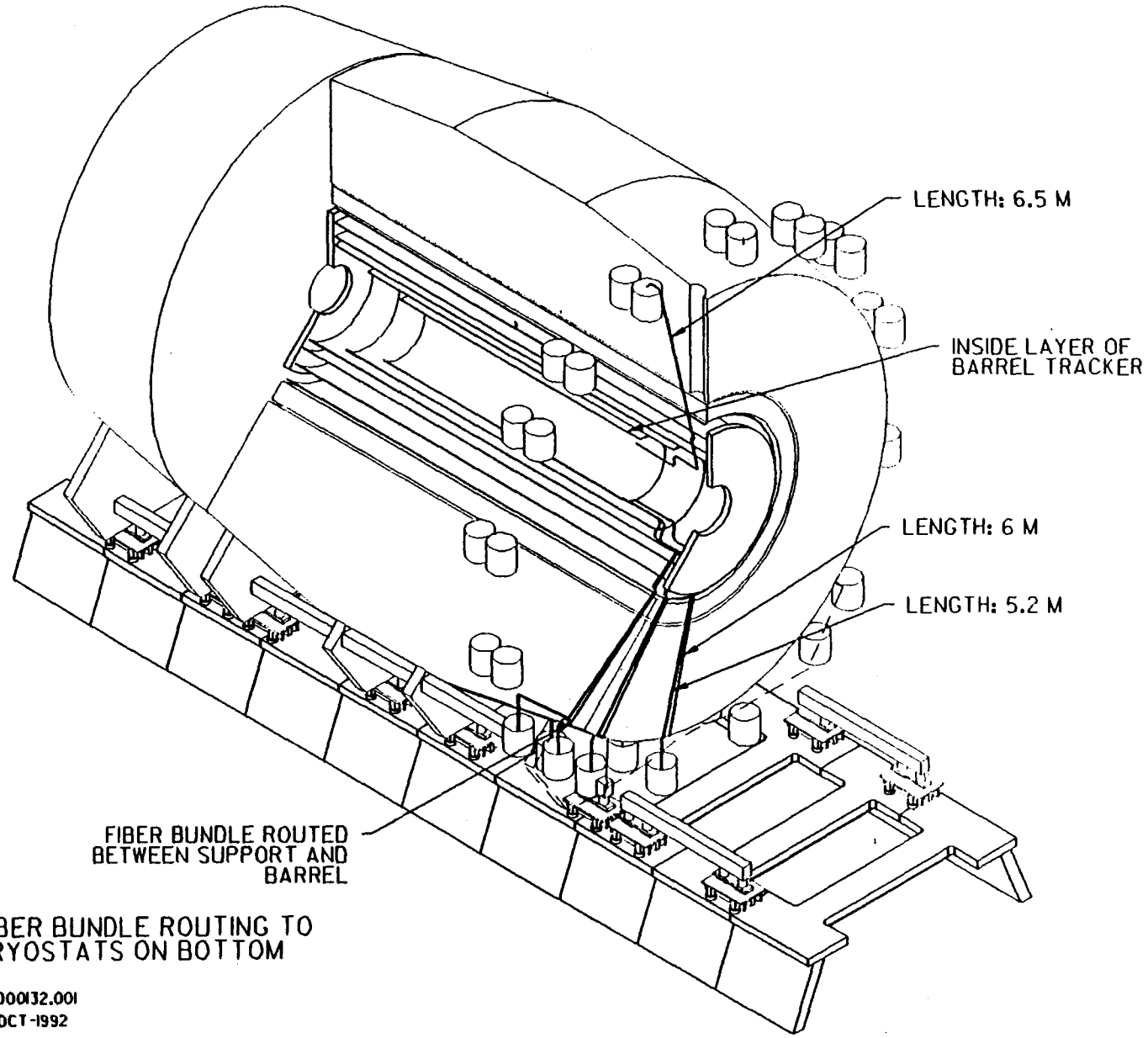


Fig. 4 Light transmission of the 1-ch splicers.

Table 5
Extrapolation of the BNL Test Results to SDC Performance

Additional Options (to improve light yield)	Status	Improvement Factor over BNL Test (Availability Date)		
		1/93	2/93	9/93
White Reflective Overcoating (Useful with low shifter dye concentration and to prevent crosstalk.)	Measured	1.1		
Mirroring of Fiber End				
White Diffusive Mirror	Measured	1.2		
Aluminum Specular Mirror	Measured	1.7		



FIBER BUNDLE ROUTING TO
CRYOSTATS ON BOTTOM

SDD00132.001
21-OCT-1992

Table 6
Parameters and characteristics of the superlayers of the scintillating fiber tracker

Layer	Radial Location (cm)	$\Delta\eta$ coverage	Scifi Length (m)	Waveguide Length (m)	Expected PE Yield (η=0)
B1	67	2.3	3.1	8.0	5.9
B2	79	2.3	3.7	7.3	5.6
B3	91	2.3	4.3	7.0	5.2
B4	109	2.1	4.3	7.0	5.2
B5	137	1.9	4.3	7.0	5.2
B6	164	1.7	4.3	7.0	5.2

SUMMARY

PHOTOELECTRON YIELD:

Needed for full efficiency	>2.4pe	
We have in hand		
	4.4pe	(η=0)
	17.6pe	($\lvert\eta\rvert \leq 2.3$)
We expect further improvement		
	5.9pe	(η=0)
	23.6pe	($\lvert\eta\rvert \leq 2.3$)

UNIQUE CAPABILITIES OF THE FIBER TRACKER:

Capable of successful operation up to the highest luminosity 10^{34}.

Uniform (seamless) coverage over the full interval $|\eta| \leq 2.3$ for tracking and triggering.

Good performance in track reconstruction under conditions of high local occupancy - such as jets. These can arise even under low luminosity conditions.

Excellent momentum resolution to highest luminosity operation.

Level 1 trigger coverage over the full range of η up to several times design luminosity. At high luminosity, trigger can be refined using more superlayers to maintain performance but with reduced η coverage.

Sharp trigger turn on for 10GeV/c. Good trigger turn on for 50GeV/c.

Detector has only passive elements in the tracking volume.

Insensitive to magnetic fields.

Photodetectors and electronics are located outside the calorimetry. This provides for relative ease of access and affords for staging options.

The overall cost of the fiber tracker is substantially less than that of the baseline system.