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SDC
SOLENOIDAL DETECTOR NOTES

DECAY TIMES OF WAVELENGTH SHIFTING FIBERS AND SCINTILLATOR PLATES

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The decay times of several scintillator-fiber combinations have been measured. The decay times are dominated by the wave-length-shifting (WLS) fibers. The scintillator tile - WLS fiber combined decay times varied from 13 nsec down to 4 nsec. The fastest combinations were the new BICRON BC499-52 together with BICRON's G1 or G2 WLS fibers.

This study was undertaken to find the best commercially available tile-WLS fiber combination for the SDC calorimeter unit cell. Three types of scintillating tiles were investigated. These were Kuraray SCSN38 and SCSN81 and Bicron's new scintillator BC499-52. All of the tiles have blue emitting fluors with the SCSN81 emission spectrum about 30 nm longer than the other two. The six green WLS fibers measured were Kuraray Y7, Y8 and Y9 and Bicron BCF91A, G1 and G2. Kuraray Y11 is the same as the Bicron BCF91A because both use the K27 fluor. The scintillator-fiber combination used the "sigma" geometry shown in Figure 1. The decay times were measured either with a cosmic muon telescope or with the electrons from a Ruthenium-106 radioactive source.

The cosmic muon telescope used three scintillators coupled by a short light guide to a 10 stage Hamamatsu R2154 photomultiplier. In order to ensure minimum ionizing particles a 5 cm lead layer was inserted between the top and second scintillator. A triple coincidence denoted a minimum ionizing particle passing thru the muon telescope. The top scintillator of the telescope was delayed by 10 nsec to ensure that the time jitter of the start pulse was due to one scintillator element only. The tile-WLS fiber assembly was inserted between the top telescope element and the lead and connected to a 12 stage Hamamatsu R329 phototube that gave the stop signal. Several size telescopes were tried, from 2 cm x 2 cm to 4 cm x 4 cm and eventually 8 cm x 8 cm scintillators that were 1 cm thick. The telescope scintillators were made of NE110. The time jitter of the start signal was estimated to be negligible. In order to ensure only one photoelectron detection from the tile-WLS fiber system, a neutral density filter (Kodak Wratten #96) was placed between the fiber and the R329 phototube. This reduced the efficiency to about 15%, so that only one photoelectron was produced most of the time. A Monte Carlo calculation showed that even at this 15% efficiency, the measured decay time varied only 3%. First a Lecroy QVT and later a Lecroy 2228A TDC in a CAMAC crate connected to a 486 computer was used to collect data.

Figure 2 shows the schematic diagram of the cosmic muon telescope, where the "muon' signal was the start pulse and the signal from the "sample" was the stop pulse. The data taking rate with cosmic rays was very slow, even with the 8 cm x 8 cm telescope. A typical data run took 3 days! In order to speed the measuring rate, the electrons from a Ruthenium-106 radioactive source were used instead of cosmic muons. The top scintillator of the telescope alone was used for the start signal and the tile - WLS fiber gave the stop signal as before. The results from the cosmic muon and the Ru radioactive source were the same, so most of our measurements were continued this way with occasional checks with cosmic muons. A typical data run with the Ru source took only couple of hours.

Figure 3 shows a typical decay distributions. Each decay time distribution was fitted to an exponential function in the form:

$$y = A \exp(-t/t0)$$

where y is the number of counts, t is the time in nsec and t0 is the decay time. Repeating measurements typically gave variations of less that 10%. The fit was limited to the falling portion of the distribution. For all the fibers except G1 and G2 this was the full decay portion. The G1 and G2 fibers have a double exponential with the longer time exponential of approximately 12 nsec. Table 1 below gives the results of the measurements with various combinations of blue scintillator tiles and WLS green fibers.

Table 1. Decay times in nsec. Errors are about 10%. Also listed are the wavelengths of the emission spectrum peak. For fibers, the measurements are after 20 cm of length.
* G1 fiber does not couple with SCSN81.

Fiber		Scintillator		
	Emission peak-->	SCSN 81 466 nm	SCSN 38 435 nm	BC499-52 425 nm
BCF91A	495 nm	11.2	10.0	8.5
G1	475 nm	*	5.3	4.0
G2	506 nm	6.4	4.8	4.1
Y7	506 nm	10.0	11.0	8.6
Y8	533 nm	13.0	13.0	11.5
Y9	509 nm	5.9	5.9	4.7

The excitation of the fiber G1 has lower wavelength than the other fibers and does not couple with the scintillator SCSN81. The fastest decay times were obtained by BC499-52 coupled with the G1 or G2 fibers. Unfortunately the short decay time fibers are also more radiation soft. The light loss due to 1 Mrad irradiation is most for the fastest WLS fibers. In the SDC detector the typical length of the WLS fiber in the tile at shower maximum is about 40 cm long. Table 2 lists the light loss due to 1 Mrad irradiation.

Table 2. Light loss due to 40 cm fiber due to 1 Mrad radiation

WLS Fiber:	BCF91A	G1	G2	Y7	Y8	Y9
Light loss	6%	14%	24%	10%	8%	27%

The fibers used were WLS for BCF91A, G2 and Y7. The other three fibers were of the scintillating type that were used as WLS. For the three non-WLS fibers, the radiation damage in table 2 may be an overestimate.

The light output of various combinations are also different and depend on the phototube used. The BCF91A fiber gave the most light output, while G2 was about 20% lower and G1 was lower by a factor of 2. Y7, Y8 and Y9 were also lower than BCF91A by approximately 20%, 40% and 30%. These numbers are approximate as it varies with the scintillator as well as the quantum efficiency of the phototube.

There is no best scintillator tile - WLS fiber combination at this time. If radiation damage is a consideration, then the BCF91A is the best WLS fiber. If pileup is the critical factor, then G2 is almost as bright but much faster. What is needed is a fiber with the speed of G2 and radiation resistance of the BCF91A. The BC499-52 is the best tile, except that it is a very new product and has no track record.

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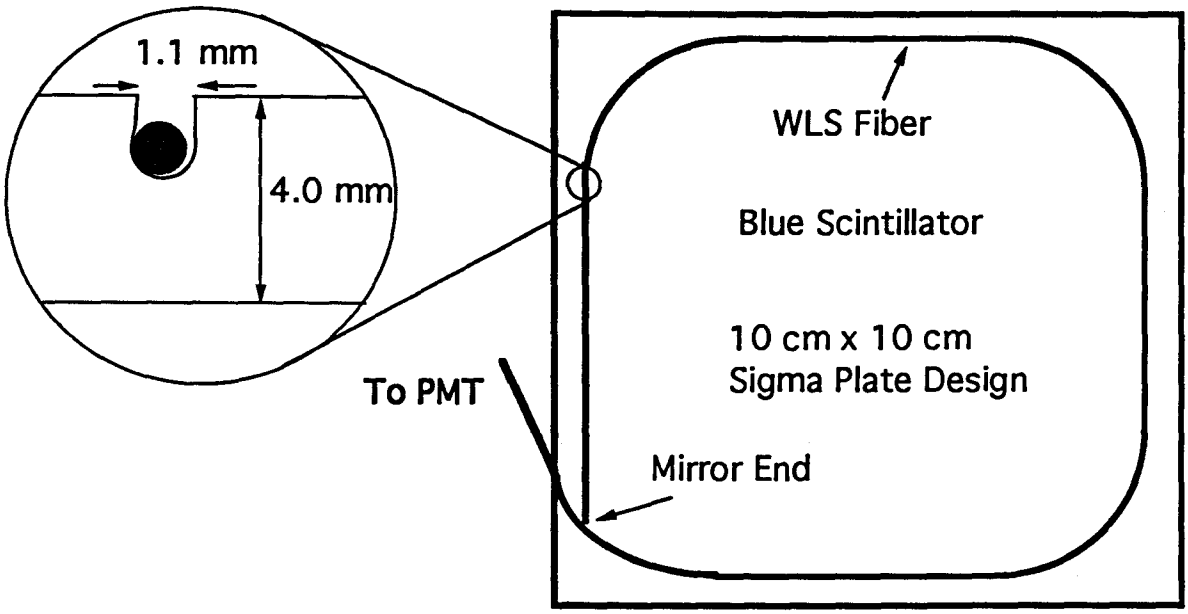

Fig. 1 The SDC Calorimeter Tile-Fiber unit.

Muon Telescope

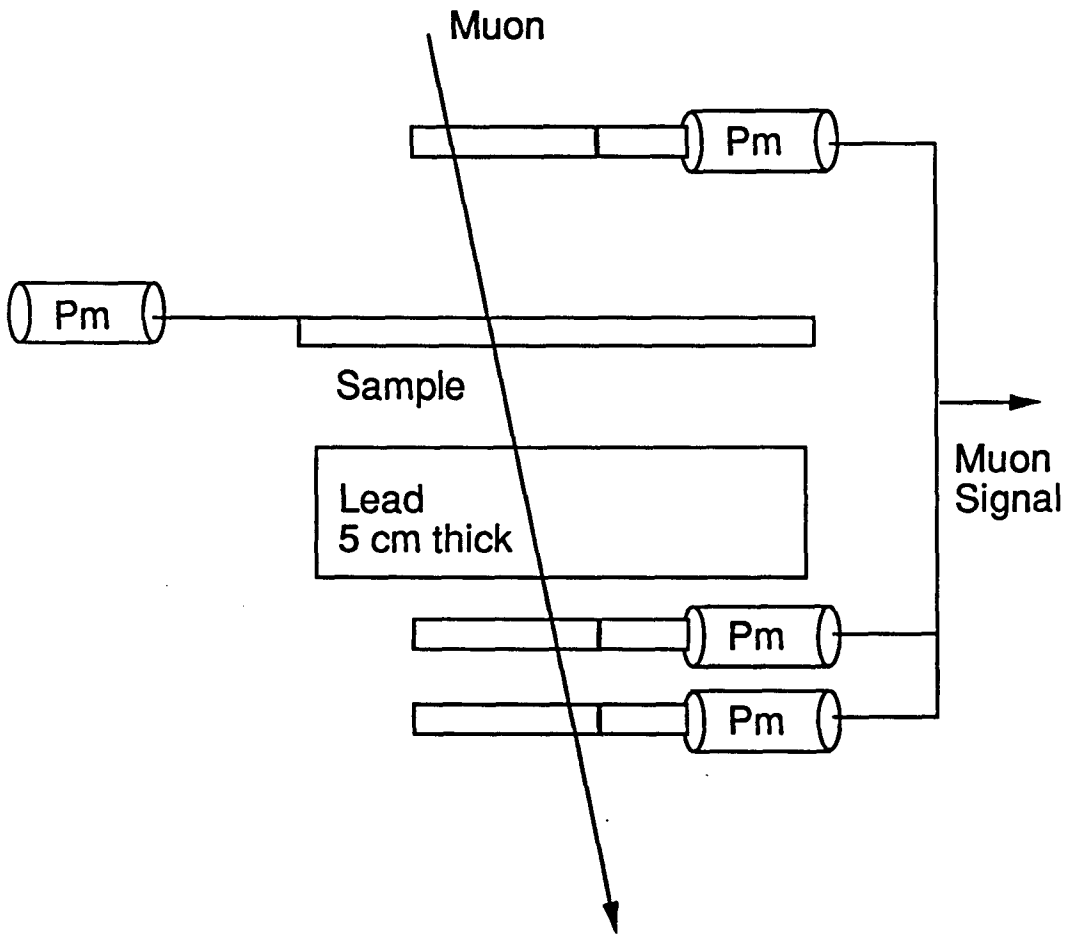

Fig. 2 The cosmie ray muon telescope

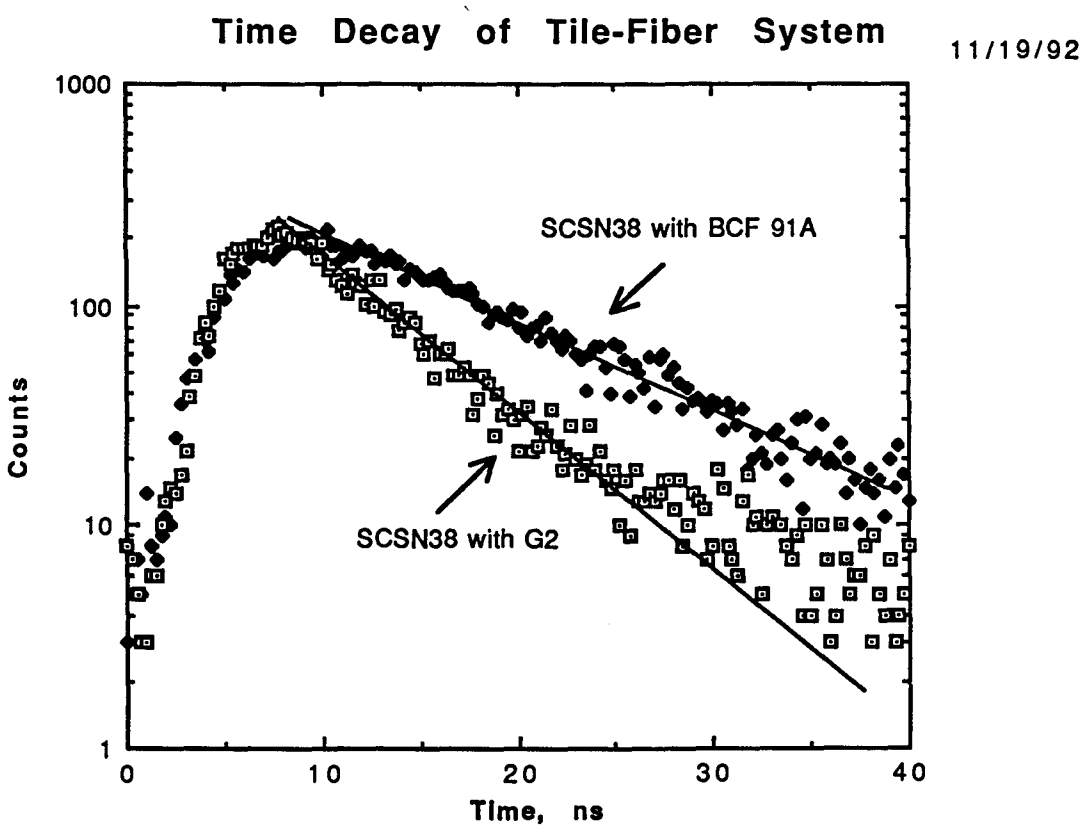

Fig. 3 Time distribution of pulses from tile fiber system. Decay time constants for SCSN38 plus BCF91A is 11.2±1.1nsec and for SCSN38 plus G2 is 6.4±0.7nsec