STAR NOTE SN0333

Light Yield Measurements for Different Tile/Fiber Optical Read-out Schemes

O.Grachov*
Wayne State University
Department of physics and astronomy,
666 W.Hancock, Detroit, MI 48201

13 April 1998

Abstract

In this Note we presented results of light yield measurements for different tile/fiber optical read-out schemes. We compered tiles with α - and σ - grooves . The light from tile was collected by a different types of WLS fibers with diameter 1 mm and 0.83 mm. Our results of tile/fiber optimization show, that for relatively small sizes of scintillating tiles with σ - groove, the Russion extrusion PS scintillator is good choice.

*Visitor from Institute for High Energy Physics, Protvino, Russia.

Introduction

The tile/fiber sampling technique is chosen for Barrel EMC design. EMC requires a total of 90,800 scintillating tiles. The cost per tile is an important parameter in the choice of the tile material. This issue has led us to the choice of PS extrusion scintillator. The most important problems of optical system on the base of PS extrusion scintillator were to achieve a minimum light yield so that the resolution of EMC is not compromised by a lack of photostatistics. However, requiring light yield from tile more than 2 photoelectrons/MIP, it is possible to use this material, but at the expense of optimization of all components of optical system. This optimization include the following:
- studies of the dependence of the light output of the tiles on the pattern of fiber groove:;
-selections in the optical read-out chains, which include choice of WLS and clear fibers.
The signal from the scintillating tile is readout with a WLS fiber embedded in a groove, which is mashined in the tile. The light re-emitted by the WLS(Wave Length Shifting) fiber is then transported directly by the WLS fiber or by the clear fiber thermally fused to a WLS fiber to the phototube located on the distance about 3 m from scintillating tile.
We have compered the absolute light yield of eleven different tile/fiber systems using α- and σ- grooves. Fig.1 shows the principal scheme of read-out chain for tile with α - and σ - pattern of fiber groove. Extrusion PS scintillator and BICRON BC404A scintillator of 5 mm thickness were used.

Tiles fabrication.

Extrusion technique developed at IHEP[1] is used for scintillator production. Commercially available optically transperent granulated polystyrene (PS, the grain size about 3mm) is used as a scintillation matrix base. Polystyrine is mixed with finely dispersed scintillation dopants, most commonly used are 0.75% - 2% of paraterphenyl(pTP)$^{(1)}$ and 0.01% - 0.04% of POPOP$^{(2)}$. One production batch of scintillation tiles, 26 tiles (PSM-115 + 1% pTP + 0.01% POPOP) with dimensions: 1600 mm x 300 mm x 5 mm were done at UNIPLAST for bench test in 1997. The sample tiles are fabricated by WSU Department of Physics and Astronomy group. A peripheral groove was mashined in the tile, where WLS fiber was embedded. The groove has rectangle shape with width 1.25 mm. The distance of the groove from the tile edge was 1.5 mm. The depth of groove was 2 mm. Each sample tile have narrow notch[2] or slot for fiber routing. The non-polished tile edges are painted white with Bicron reflective paint[3]. White paper is used on both sides of the tile as reflector[4].
For our measurements we have used Bicron standard cladded and Kuraray multiclad fibers.

$^{(1)}$- pTP - para-terphenyl, λ_{abs} = 275 nm, λ_{em} = 340 nm
$^{(2)}$- POPOP - 1,4-bis-[2-(5-pheniloxazolyl)]-benzene, λ_{abs} = 365 nm, λ_{em} = 420 nm

Measurements

The description of the experimental setup can be found in our previous Note[5]. The fiber was coupled to PMT with optical grease through hole 1.5 mm diameter in rubber holder. Light from fiber was detected a 10-stage R580-17 green extended PMT. The signal is amplified by 10 times using a LeCroy PMT amplifier. We run the PMT at a high voltage 1550 v.
We determined the number of photoelectrons using the weighted mean method. The center poin of tile/fiber assembly is illuminated by penetrating 3 MeV β-rays from a Ru^{106} source. The charge from the PMT is measured by an ADC. The single photoelectron charge is determined by reducing the detection efficiency to approximately 0.1 so that the contribution of 2 photoelectrons was made negligibly small. The ratio of the average charge to that of single photoelectron gives the number of photoelectrons[6]. For the uncertainty in the number of photoelectrons we avalueted effect of the reproducebility of measurements due connection fiber to PMT. This uncertainty is not more than 10%.
Figure shows a schematic diagram of different optical read-out schemes and number of photoelectrons/MIP for Bicron BC404A scintillator(BC) and PS extrusion scintillator(PS).

1. 1α: WLS fiber (BCF-91A, 1 mm diameter) was laid in the fiber groove. Two ends of WLS fiber was spliced to 3 m long clear fibers (BCF-98, 1 mm diameter) which was connected to PMT.

2. 1α: WLS fiber(BCF-91A, 1 mm diameter) was laid in the fiber groove and two ends of 3 m lenght each was connected to PMT.

3. 2α: WLS fiber(BCF-91A, 1 mm diameter) in two loops was laid in the fiber groove and two ends of 3 m lenght each was connected to PMT.

4. 1σ: WLS fiber (BCF-91A, 1 mm diameter) was laid in the fiber groove. One of the ends of WLS fiber was spliced to 3 m long clear fiber (BCF-98, 1 mm diameter). The other end of the WLS fiber was mirrored and terminated inside tile.

5. 2σ: WLS fiber (BCF-91A, 1 mm diameter) was laid in two loops in the fiber groove. One of the ends of WLS fiber was spliced to 3 m long clear fiber (BCF-98, 1 mm diameter). The other end of the WLS fiber was mirrored and terminated inside the tile.

6. 2σ: WLS fiber (BCF-91A, 1mm diameter) was laid in two loops in the fiber groove. One of the ends (3 m long) was connected to PMT. The other end of WLS fiber without mirroring was terminated inside the tile.

For schemes 1-6, 10, 11 we have used tile with dimensions: 125 mm x 132 mm.

On the base results of SDC and CDF group for our next measurements we have used Kuraray multiclad fibers with different dye concentration and tile with σ groove. Dimensions of tile are 123 mm x 186 mm. This tile had a slot for fiber exit.

7. 1σ: WLS fiber (Y11, diameter 0.83 mm, multiclad S-type, 150ppm) was laid in the fiber groove. One of the ends of WLS fiber was spliced to 3 m long clear fiber (Clear Y11, diameter

0.83 mm, multiclad) and connected to PMT. The other end of the WLS fiber was mirrored and terminated inside tile.

8. 2σ: WLS fiber (Y11, diameter 0.83 mm, multiclad S-type, 150ppm) in two loops was laid in the fiber groove. One of the ends of WLS fiber was spliced to 3 m long clear fiber (Clear Y11, 0.83 mm diameter, multiclad) and connected to PMT. The other end of the WLS fiber without mirroring was terminated inside tile.

9. 2σ: WLS fiber (Y11, diameter 0.83 mm, multiclad S-type, 200 ppm) was laid in two loops in the fiber groove. One of the ends of WLS fiber was connected to PMT. The other end of the WLS fiber without mirroring was terminated inside the tile.

10. 1α: WLS fiber(Y11, diameter 0.83 mm, multiclad S-type, 200ppm) was laid in the fiber groove and two ends of 3 m lenght each was connected to PMT.

11. 2α: WLS fiber(Y11, diameter 0.83 mm, multiclad S-type, 200ppm) in two loops was laid in the fiber groove and two ends of 3 m lenght each was connected to PMT.

Summary

The main results of these measurements for PS extrusion scintillator indicate:

- optical schemes: 7,8 and 11(1σ, 2σ and 2α) met design criteria that the light yield should be more than 2 ph.e./MIP;

- the highest light yield corresponds to the α-groove with two loops of WLS fibers (scheme 11) and σ-groove with mirrored multiclad WLS fiber spliced to clear multiclad fiber (scheme 7);

- the light yield of the tile (σ- or α- groove) with two loops of WLS fibers embedded in one groove is 1.8 times higher than the light yield of the tile with one loop (schemes: 2,10-3,11 and 4-5);

- comparison of the single ended aluminazed σ-groove read-out (scheme 4) vs. α- groove read-out (scheme 1) have shown that 1.47 times the light is recorded with the latter;

- the use of a Kuraray multiclad Y11 WLS fiber spliced to a multiclad Kuraray clear fiber increases the light yield in 2.8 times, compared for Bicron standard cladded WLS fiber spliced to standard cladded Bicron clear fiber (schemes: 4,7);

- comparative light yield measurements for the Bicron BC404A scintillator and PS extrusion scintillator (PSM115+1%pTP+0.01%POPOP) showed that the Bicron 404A scintillator yields a factor of 1.6;

- test comparing the light collection efficiency from PS scintillator tiles with both Bicron and Kuraray multiclad Y11(200 ppm) WLS fiber show that the Kuraray improves the light yield by a factor of 1.6.

References

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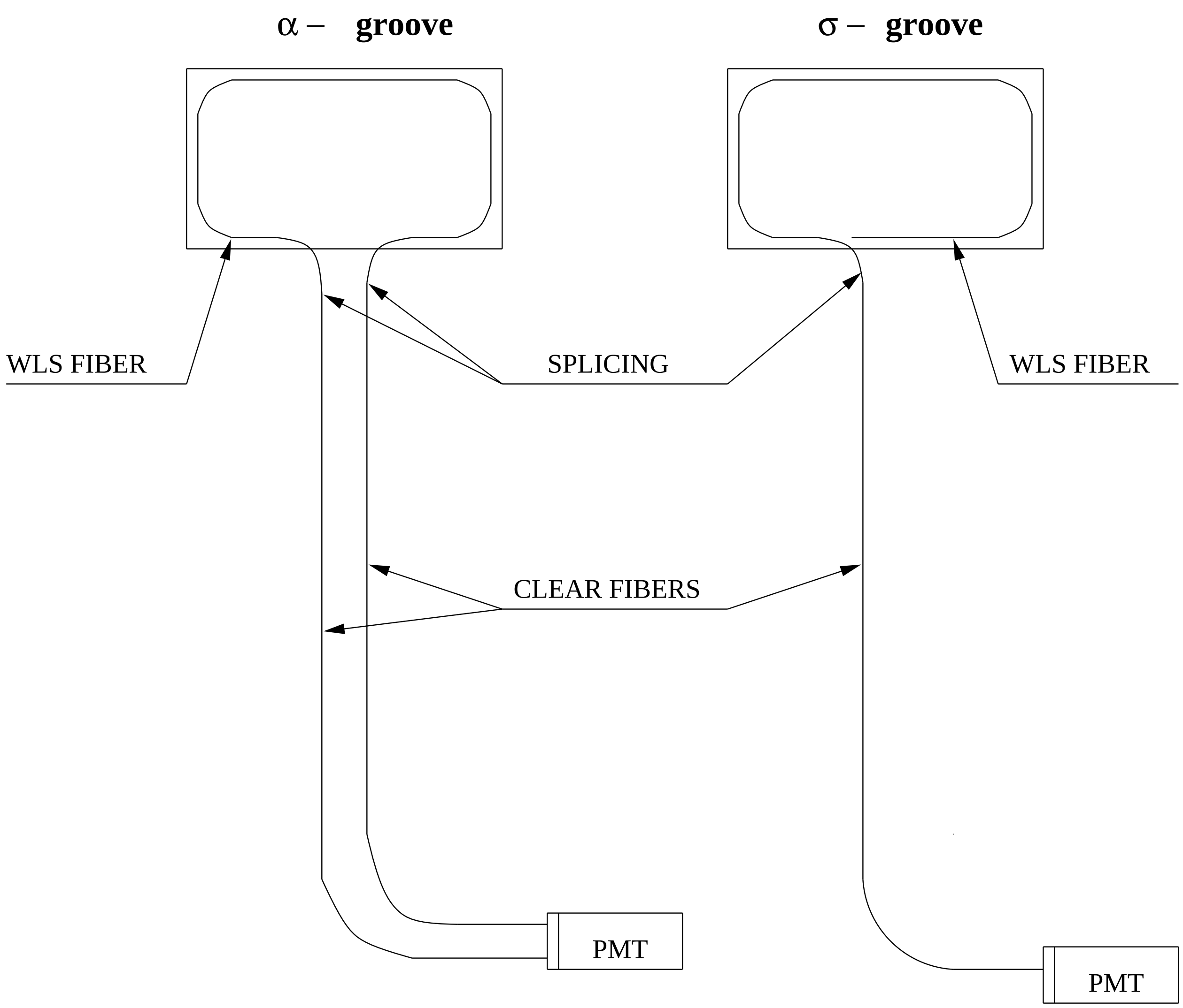
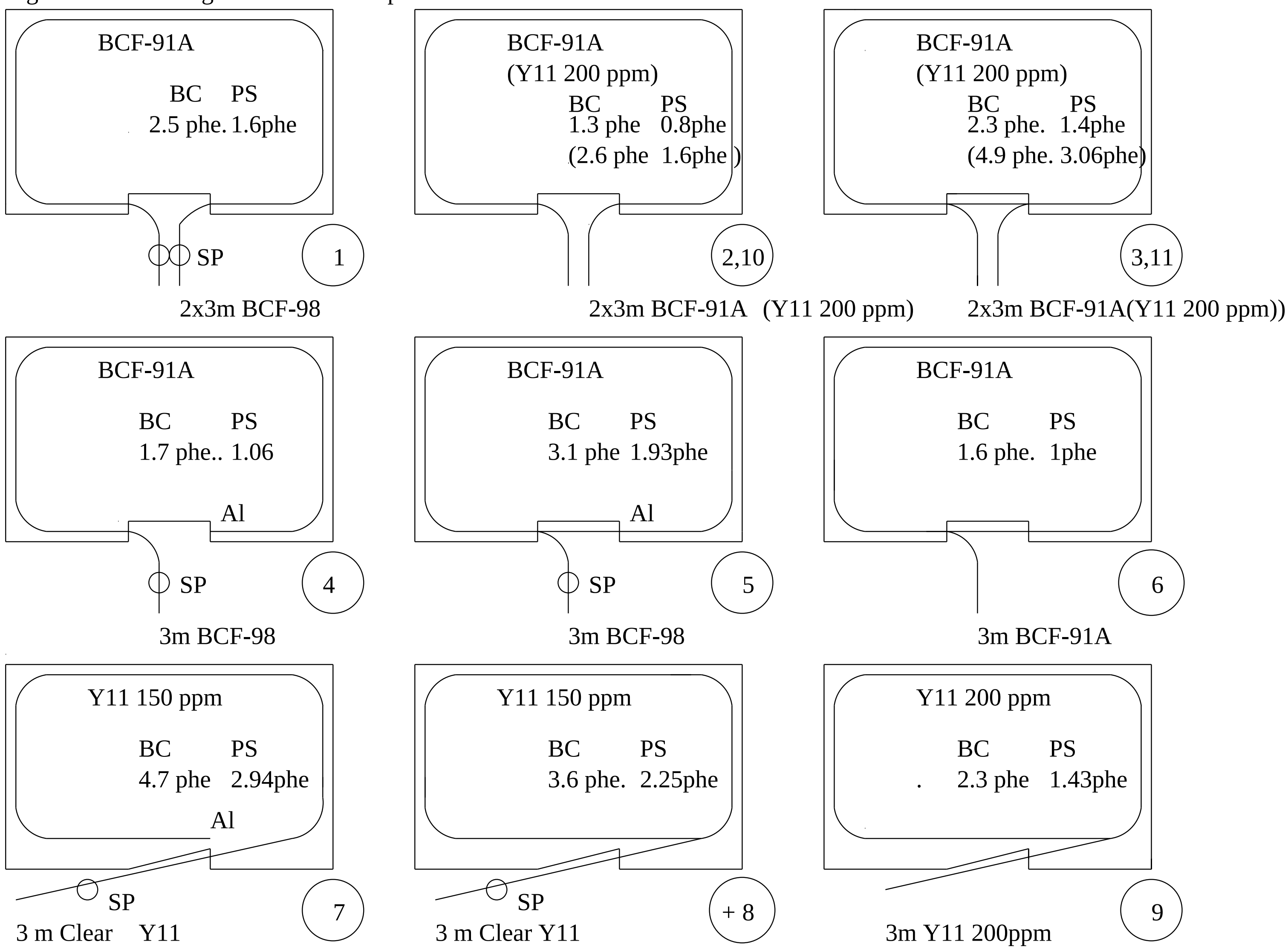


Fig.1 Principal scheme of read-out chain for tile with σ – α– pattern of fiber groove.

Fig.2 Schematic diagram of different optical read-out schemes.



(Bicron)BCF-91A - green WLS fiber.

(Bicron)BCF-98 - clear fiber.

(Kuraray)Y11 150 ppm(200 ppm) - multiclad S-type green WLS fiber (ppm - the numbers in the parentheses . correspondent to number of parts per million by weight of fluorescent dye in the fiber core.

(Kuraray)Clear Y11 - multiclad clear fiber.

Al - aluminum mirroring.

SP - splicing.