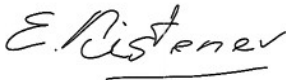





**Specification Control Document (SCD)**  
**for the**  
**sPHENIX Outer Hadronic Calorimeter (HCal)**  
**Installation-Ready Scintillating Tiles**

QA Category: A-3

|                   |   |                        |
|-------------------|---|------------------------|
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**REVISION CONTROL SHEET**

| REVISION | DESCRIPTION  | DATE       | AUTHOR                  | APPROVED BY     |
|----------|--|------------|-------------------------|-----------------|
| A        | Draft  | 04/26/2018 | E. Kistenev<br>D. Lynch | See cover page. |
| B        | Final – Update Drawing rev and remove text on pilot production | 02/11/2019 | E. Kistenev             | See cover page. |

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## TABLE OF CONTENTS

|     |                                |   |
|-----|--------------------------------|---|
| 1   | SCOPE .....                    | 1 |
| 1.1 | Background.....                | 1 |
| 1.2 | Definitions/Acronyms .....     | 1 |
| 1.3 | Description: .....             | 1 |
| 2   | APPLICABLE DOCUMENTS.....      | 2 |
| 3   | REQUIREMENTS.....              | 4 |
| 3.1 | Material Specifications: ..... | 4 |
| 3.2 | Tile Fabrication .....         | 5 |
| 4   | Quality Control: .....         | 6 |

## 1 SCOPE

This Specification Control Document (SCD) supplements the drawings listed in section 2.0 of this SCD. Installation-Ready Scintillating Tiles will convert ionization energy of particles propagating through the Calorimeter into scintillation light pulses which are recaptured by wave shifting fibers and further converted into electrical pulses by silicon photomultiplier (SiPM) optical sensors coupled to fiber ends in places where the fibers exit tiles. Black nontransparent stray light blockers are embedded into tiles at fiber exits to protect SiPM's from direct exposure to the light propagating inside the tile body, and to couple the tiles to SiPM's and LED light distributing fibers in accordance with the specifications and drawings listed in section 2 of SOW. This document outlines the Contractor's responsibilities and obligations necessary for completing the requirements as set forth herein.

### 1.1 Background

The sPHENIX Calorimeter experimental concept includes the design, construction, installation, and commissioning of hardware, civil construction, and facilities required to produce upgraded experimental equipment with new detection capabilities. The concept includes several detector subsystems and a superconducting solenoid magnet which will track and characterize properties of particles generated by heavy ion and/or polarized proton collisions.

### 1.2 Definitions/Acronyms

|      |  |      |                                 |
|------|--|------|---------------------------------|
| ASME | American Society of Mechanical Engineers | MRB  | Material Review Board           |
| BNL  | Brookhaven National Laboratory           | MRP  | Material Requirements Planning  |
| BSA  | Brookhaven Science Associates            | QA   | Quality Assurance               |
| HCal | Hadronic Calorimeter                     | RHIC | Relativistic Heavy Ion Collider |
|      |  | SOW  | Statement of Work               |

### 1.3 Description:

The typical scintillating tile for the sPHENIX project is a large piece of quadrilateral-shaped polystyrene based scintillator, 7mm thick with a continuous groove of constant width and variable depth on one surface. A wave length shifting (WLS) fiber is embedded and epoxied into the groove and coupled to an optical sensor (Silicon Photo Multiplier Hamamatsu S12572-015) via a custom built optical block (Stray Light Blocker) embedded into tile. Each tile is double layer wrapped to improve scintillation light containment and to protect the tile from ambient light and mechanical damage.

There are a total of 12 unique tile designs in the Outer HCal Detector.

## 2 APPLICABLE DOCUMENTS

In the event of a conflict between the Technical Drawings and this SCD, the drawings will take precedence.

The dimensional specifications, fiber embedding pattern for each of the 12 scintillating tile designs for the sPHENIX Outer Calorimeter and specifications for dimensional tolerances after wrapping are in the attached drawings as follows::

| Document Number       | Document Title        |
|-----------------------|-----------------------|
| 205-0100-0021, Rev. F | Outer HCAL Tile 1     |
| 205-0100-0022, Rev. F | Outer HCAL Tile 2     |
| 205-0100-0023, Rev. F | Outer HCAL Tile 3     |
| 205-0100-0024, Rev. F | Outer HCAL Tile 4     |
| 205-0100-0025, Rev. G | Outer HCAL Tile 5     |
| 205-0100-0026, Rev. F | Outer HCAL Tile 6     |
| 205-0100-0027, Rev. F | Outer HCAL Tile 7     |
| 205-0100-0028, Rev. F | Outer HCAL Tile 8     |
| 205-0100-0029, Rev. F | Outer HCAL Tile 9     |
| 205-0100-0030, Rev. F | Outer HCAL Tile 10    |
| 205-0100-0031, Rev. F | Outer HCAL Tile 11    |
| 205-0100-0032, Rev. F | Outer HCAL Tile 12    |
| 205-0100-0125, Rev. B | Tile Assembly Details |

In addition, the following are the drawings for matching plastic components of the compound optical block used to couple individual Tiles to the sPHENIX Data Acquisition System and matching components of the sPHENIX HCal LED light distribution system used in the assembly of the tiles. The block is functionally comprised of Stray Light Blocker (above) and SiPM holder. The LED system includes fiber terminators, fiber bundles and Light Distribution Cups. Retaining clips are used to locate and hold tiles in the active gaps of the Outer Hcal calorimeter. One retaining clip is to accompany each individual Tile.

| Document Number       | Document Title                             |
|-----------------------|--|
| 205-0150-0034, Rev. B | Stray Light Blocker                        |
| 205-0150-0033, Rev. B | SiPM Holder – Snap In                      |
| 205-0150-0036, Rev. B | Monitoring Fiber Male Connector/Terminator |
| 205-0150-0037, Rev. B | Fiber bundle (assembled)                   |
| 205-0150-0039, Rev. C | Light Distribution Cup.                    |
| 205-0150-0038, Rev. B | Outer HCAL Tile Retaining Clip             |
| 205-0150-0040, Rev. B | Fiber Plug                                 |

Figure 1 illustrates these components and their relation to the Tile Assemblies. Shown are the Stray Light Blocker, SiPM Holder, SiPM carrier board (not included in the drawings, above, separately procured), terminated monitoring fiber, LED Distribution Cup and Retaining Clip. The machined groove on tile surface contains embedded (epoxied) WLS fiber with both ends fed through the stray light blocker. Exiting fibers are viewed by SiPM optical sensor installed on a small carrier board. A clear plastic fiber is connected to the tile through optical coupler built into the body of the blocker. This latter fiber is used to deliver fixed amplitude light pulses from LED light source (colors are for viewing only).

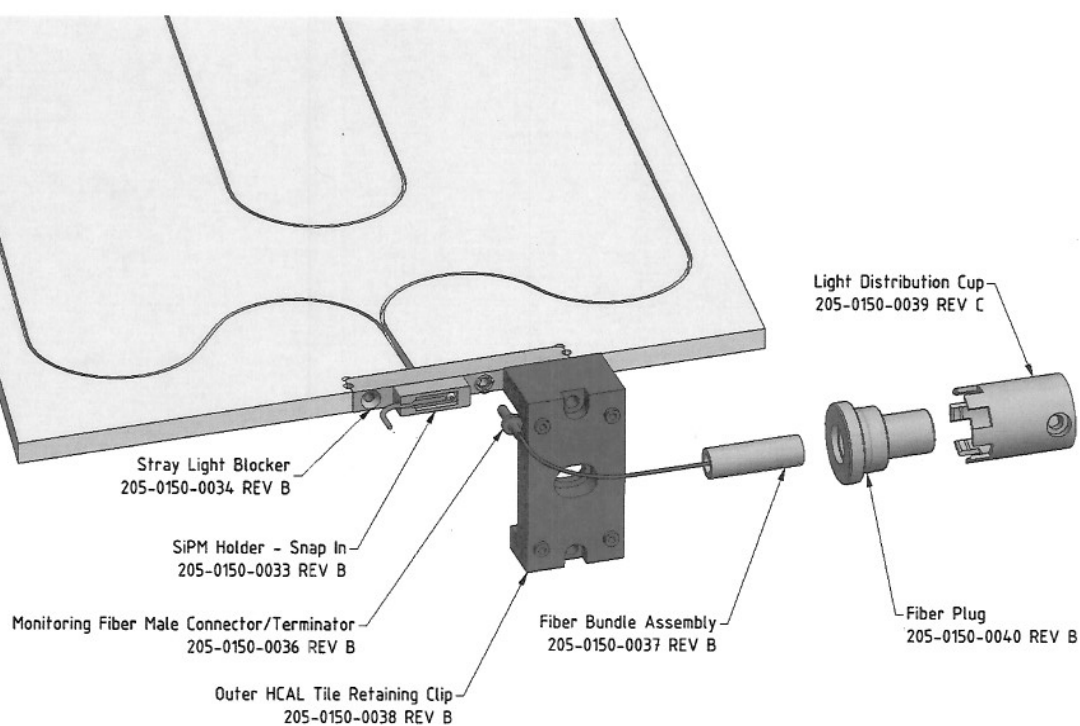


Fig. 1 Cut-off from the typical completed scintillating tile with matching plastic components for the sPHENIX Outer Hadronic Calorimeter.

### 3 REQUIREMENTS

In accordance with the applicable specifications, referenced documents, and instructions as defined in the Statement of Work, the Contractor shall be responsible for the purchase of all materials, build to print manufacturing, inspection, and delivery of 12 unique Outer HCal Scintillating Tile Assemblies with embedded WaveLength-Shifting fibers and Stray Light Blockers for the Outer Hadronic Calorimeter of sPHENIX Detector as defined by drawings 205-0100-0021 through 205-0100-0032 and general assembly details as defined in drawing number 205-0100-0125 and this Specification Control Document # sP-DS-OHC-001.

#### Material Specifications:

The scintillating tiles shall either be manufactured by polymerization from styrene monomer or by extrusion from the dry mix of optical quality polystyrene and phosphors.

The composition in the table below is tuned for dry mix extrusion process. The same table also includes the specifications for WLS fibers and optical cement for fiber and optical block embedding.

|                |                                    |
|----------------|------------------------------------|
| Polystyrene    | 98.46%,                            |
| Paratephenil   | 1.5%,                              |
| POPOP          | 0.04%                              |
| WLS fibers     | Y11, S-type, 1mm Ø, Kurarey,       |
| Optical cement | ELJEN 500, USA, ELJEN technologies |

The materials for two layer wrap around scintillating tiles are UV stabilized DuPont white TYVEK with thickness less than 0.15 mm and reflectivity in near UV (>400nm) better than 97% and DuPont carbon filled black PVF TEDLAR film of thickness less than 0.05 mm or equivalent.

Table below lists these components and estimated needs per 1000 Outer HCal tiles (based on computations and experience available to sPHENIX physicists).

#### Specialized materials used in sPHENIX Tile production.

| Item # | Name                 | Brand                              | Per 1000 Tiles            |
|--------|----------------------|------------------------------------|---------------------------|
| 1      | WLS fibers           | Y11, S-type, 1mm Ø, Kurarey, Japan | 4400 m                    |
| 2      | Clear Fibers         | 0.5mm Ø core                       | 3000 m                    |
| 3      | Reflective wrap      | TYVEC white                        | 600 m <sup>2</sup>        |
| 4      | Protective wrap      | PVF TEDLAR, black                  | 600 m <sup>2</sup>        |
| 5      | Optical grade epoxy  | EpoTec-301-2                       | 7000 mL (resin)           |
| 6      | PA SelfAdhesive tape | TekLine Gold Kapton Tape Polyamide | 100 rolls (36 yards each) |

### 3.1 Tile Fabrication

All tiles shall be cut to diamond cut edge surface quality from optical quality flat scintillating plates of 7mm thickness, chemically processed on all outside surfaces to develop mechanically stable diffuse reflective layer of modified polystyrene resulting in better than 97% reflectivity towards inside, grooved and blocker seat cut according to the pattern in the corresponding drawing.

Prior to grooving and shaping, tiles shall be thoroughly cleaned of chemically produced powder on all surfaces using compressed dry air. Tiles with visible damage to coating shall be rejected.

The matching plastic components (Stray Light Blocker, SiPM holder, Fiber Terminator, Fiber Bundle, LED Light Distribution Cup and Tile Retainer Clip) shall be manufactured of black ABS plastic, the body of light blocker shall be embedded into the tile at a time when fibers are embedded into the grooves using optical grade outgassed epoxy. (Epoxy mix shall be vacuum outgassed prior to use.)

Fibers shall be epoxied at the bottom of the groove and Blocker fiber exit aperture (outgassed epoxy required). Special care should be given to fiber insertion into Blocker exit channels to avoid damaging fibers in exit area. No air gaps, detectable air pockets or bubbles are permitted inside epoxy in grooves or exit channels of the optical block. Tiles showing signs of epoxy spreading outside the groove, bubbles, gaps, air pockets or polystyrene residue in epoxy in the groove, incomplete fill of the groove or uneven surface of the epoxy after polymerization shall be rejected.

After embedding, fibers (at exits from Blocker) shall be polished. To avoid damage to blocker body during polishing process, the blocker design shows an enhancement of 100  $\mu\text{m}$  height around fiber exits. That enhancement shall be taken away while polishing.

The tile shall be visually tested for damage in production by exposing grooved fiber to focused beam of blue light to detect localized light leaks and/or visual asymmetry in the light yield on two exiting ends of the fiber.

Each finished tile shall be further wrapped with layered light reflector / ambient light suppressor. The inner layer shall be of UV-stabilized diffuse reflective material with reflectivity above 400nm light wave length better than 97% (TYVEK). The outer layer is the ambient light suppressor (black PVF TEDLAR). Together the two layers of wrap shall create an ambient light barrier sufficient to extinguish ambient light down to a non-detectable level. The total thickness of wrap per large side shall not exceed 0.2mm. The overlaps (Tyvek-Tyvek-Tedlar-Tedlar) between individual top/bottom sheets of wrapping materials are allowed on tile edges only. The total thickness of the wrapping material shall not to exceed 0.4mm per tile edge. The light blocker on its side with attachments for SiPM holder, LED fiber and Retainer Clip shall be cleaned of any wrap or residue materials.



## 4 QUALITY CONTROL:

Quality Control of the tile assemblies and related components shall include:

- Tile labelling on the exposed tile edge next to the Stray Light Blocker.
- Tile mechanical dimension measurements and testing for compliance with design drawings.
- Tile bulk light attenuation length measurements in near UV light (before surface modifications and grooving) along longer dimension, shall be greater than 10cm.
- Tile compliance to final dimensional specification of wrapped-tile (shall pass insertion test in a go-no-go gauge set at 8.0 mm, maximum).
- Tile luminosity shall be measured as a response of tile to randomly penetrating cosmic muons. Tile shall be rejected if tile luminosity measured as the average number of pixels fired by light from passing muons on Hamamatsu S12572-015 SiPM's coupled to fiber exits is below 15 pixels/crossing.
- All test data for each tile shall be made available in printed and electronic media.