Detector-Specific Quality Assurance Plan For Hadronic Calorimeter Tile Production For the sPHENIX Project

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sPHENIX Project DETECTOR-SPECIFIC QUALITY ASSURANCE PLAN

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Detector-Specific Quality Assurance Plan

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1.1	4/16/2019	Megan Connors	Applied G. Young's comments
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2.0	5/20/2019	James Mills	Assigned Document Number

LIST OF ACRONYMS AND ABBREVIATIONS

BNL	Brookhaven National Laboratory
CD	Critical Decision
DOE	Department of Energy
DQAP	Detector-Specific Quality Assurance Plan
ES&H	Environment, Safety and Health
GSU	Georgia State University
L2	Level 2
L3	Level 3
PHENIX	Pioneering High-Energy Nuclear Interacting Experiment
QA	Quality Assurance
QAP	Quality Assurance Plan
RHIC	Relativistic Heavy Ion Collider
SiPM	Silicon PhotoMultiplier
SBMS	Standards-Based Management System
WBS	Work Breakdown Structure

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1 INTRODUCTION

The sPHENIX Project is a project to upgrade the Pioneering High-Energy Nuclear Interacting Experiment (PHENIX) detector at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). This upgrade brings exciting new capability to the RHIC program by opening new and important channels for experimental investigation and utilizing fully the luminosity of the recently upgraded RHIC facility. It enables a compelling jet physics program that will address fundamental questions about the nature of the strongly coupled quark-gluon plasma discovered experimentally at RHIC to be a perfect fluid. The project is funded by the U.S. Department of Energy (DOE), RIKEN and other organizations.

A key component of sPHENIX is the Calorimeter system, which is composed of an electromagnetic calorimeter (EMCal) and Hadronic calorimeter (HCal). The EMCal is used to detect photons, electrons and positrons and determine their energies and the positions at which they strike it. The HCal, which has two segments, the Inner HCal and Outer HCal, serves a similar function for protons, charged pions and heavier ions. The EMCal is positioned inside of and supported by the Inner HCal, which in turn is supported just inside the superconducting solenoid magnet of the experiment. The Outer HCal is located just outside the solenoid magnet and serves as the flux return for the magnetic field.

Each sPHENIX HCal covers 2π in azimuthal angle and pseudorapidity η between -1.1 and 1.1. The flux return is composed of steel plates, which are tilted in azimuth. Scintillator tiles are inserted between the steel plates, which measure the energy traversing particles. Each tile is coupled to a silicon photomultipler (SiPM) to read out the energy. There are scenarios in which the full scope of the inner HCal is not built. This has no impact on the tile QA procedures as the tiles are built individually.

Tiles are made from extruded polystyrene (doped with 1.5% PTP and 0.01% POPOP dyes by weight to yield a 2-component Stokes shift of the primary light in to the visible wavelength region). This scintillating material is covered in a reflective coating to trap light within the tile. The light is then guided by fibers embedded into the tiles in a reentrant pattern to an optical sensor readout. The fibers are placed within a grove that is cut into the tile and fed through a light blocker, which prevents light from tile from traveling directly to the sensors. Finally the tiles are wrapped in a layers of Tyvek and Tedlar to contain the produced light within the tile as well as to block ambient light.

The tiles are made in 12 distinct shapes for each HCal layer in order to accommodate the increasing tilt in polar angle needed as they are placed along a cylindrical surface to keep them oriented towards the cylinder's central point, which is the interaction point. Each unique tile shape has its own fiber routing designed to maximize uniformity of light collection throughout the tile.

The production plan for the HCal tiles includes the plans and procedures described in this document, the Detector-Specific Quality Assurance Plan for the HCal tile production.

1.1 Purpose

The purpose of this Detector-Specific Quality Assurance Plan (DQAP) is to establish the Quality Assurance (QA) requirements for HCal Tile production for sPHENIX and describe how the requirements will be met, using a graded approach. This plan describes the HCal Tile production project's QA activities, which are conducted largely at the vendor's production site such as Uniplast in conjunction with the Physics Department of the Georgia State University (GSU) and BNL, and is implemented via processes described herein that address specific quality requirements.

1.2 Scope

This DQAP provides requirements applicable to HCal Tile production for sPHENIX, encompassing all activities, including but not limited to fabrication and testing at Uniplast, and shipping to GSU/BNL. Specific QA procedures are described in the following for HCal Tile manufacturing, and testing prior to shipment to GSU/BNL. The production work to be done will be described in a Statement of Work (SOW) issued by BNL/sPHENIX and incorporated into a subcontract between BNL and Uniplast.

1.3 Approach

GSU Physics will be the responsible organization for ensuring the QA requirements are met for all HCal Tile production activities from completion of tile production, testing and subsequent shipments.

The procedures described here are based on experience gained during production of tiles at Uniplast for previous HCal prototypes. Additional HCal production QA procedures will be developed, as necessary, if early production experience indicates they are warranted. Similarly, the QA procedures listed herein may be modified or improved, as experience dictates. All such additions and modifications will be captured in a formal revision to this DQAP.

1.4 Graded Approach

This DQAP embodies the concept of graded approach; that is, selecting and applying an appropriate level of analysis and controls to work activities, equipment, and items commensurate with the potential for environmental, safety, health, radiological, or programmatic impact.

1.5 Definitions

The following is a list of definitions for terminology used in this plan:

Hadronic Calorimeter (HCal)– Device composed of alternating layers of scintillator tiles and steel plates for measuring the energy of particles striking it, which will be installed in the sPHENIX detector.

Hadronic Calorimeter Tile (HCal Tile) – A basic construction unit of Hadronic Calorimeter. The tiles are made of extruded plastic with a layer of reflective coating. Charged particles traversing the scintillating fiber lose energy which appears as optical light. Fiber is installed in a grove in the tiles, which feeds the light produced in the tile to the optical sensing elements, specifically SiPMs for read out. Tiles are wrapped in layers of foil, plastic and Tyvek.

Wavelength Shifting Fiber – An active sensing material used in an HCal Tile and which consists of a thin 1 mm diameter extruded plastic filament which is doped with typically 1% of organic dye. Light emitted by the HCal tiles are shifted in wavelength and conducted to an end of the fiber, which in turn couples to an optical sensing device.

Wrapping – The HCal tiles are wrapped to prevent light from escaping the tiles. The wrapping includes layers of TYVEK and TEDLAR. HCal tiles are fully wrapped before final testing at the manufacturer.

Measuring and Test Equipment (M&TE) - Devices or systems used to calibrate, measure, gauge, test, inspect, or control to acquire research and development, test, or operational data to determine compliance with design, specifications, or other technical requirements

Quality (Q) - The condition achieved when an item, service, or process meets or exceeds the user's requirements and expectations.

Quality Assurance (QA) - All actions and controls necessary to provide confidence that quality is achieved.

QA Plan (QAP) - The document describing the QA program requirements that the project will implement.

QA Program - The overall program or management system established to assign responsibilities and authorities, define policies and requirements, and provide for the performance and assessment of work.

2 QUALITY ASSURANCE PROGRAM

The HCal Tile production is included in the sPHENIX project's Work Breakdown Structure (WBS) under section WBS 1.04.02.03 and includes therein all preproduction and production steps together with an enumeration of the delivered objects, the HCal Tiles.

2.1 Responsibility for Managing

The sPHENIX L3 Managers are responsible for constructing specific items of apparatus, such as the HCal Tiles, following a DQAP developed for the specific item, and reporting their QA issues to their respective L2 manager and as needed to the sPHENIX Project Director.

The tile production will be carried out by a vendor such as Uniplast. The QA of the HCal tiles will be monitored by GSU Physics during production. Any quality problems identified will be resolved by consulting with sPHENIX project management at BNL.

2.2 Organization and Level of Authority and Interface

This DQAP for HCal Tile Production defines the responsibility, authority, organization and interrelation of personnel who manage, perform, and verify work that affects HCal Tile quality.

The vendor is responsible for the quality of the work that they perform and/or supervise for HCal Tile production. The L3 Manager for the HCal Tile production is responsible for monitoring the acceptance of tiles and documentation of the QA tests of the tiles. Management at each level is responsible for evaluation of quality through management assessments; however, independent assessments may be requested by sPHENIX management.

3 PERSONNEL TRAINING AND QUALIFICATION

The vendor is responsible for ensuring its members are trained and qualified to perform their assigned work effectively and safely.

The L3 Manager for HCal Tile production is responsible for ensuring that the QA is monitored through out production and that all those staff members assigned by universities or BNL are trained and qualified to perform their assigned work effectively and safely.

Before personnel are allowed to work independently, the L3 Manager for HCal Tile production is responsible for ensuring personnel have the necessary experience, knowledge, skills, and abilities. Personnel qualifications are based on factors such as:

- Previous experience, education, and training
- Performance demonstrations or tests to verify previously acquired skills
- Completion of training or qualification programs
- On-the-job training.

All project participants are responsible for ensuring that their training and qualification requirements are fulfilled.

The Nuclear Physics group at Georgia State University has experience building detectors for nuclear physics experiments. Assistant Professor Megan Connors, the L3 Manager for HCal Tile production, has been serving as the HCal prototype manager since 2015 and oversaw the successful prototype used in beam tests (Ref.1). Assembling this prototype exercised all aspects of tile production and testing needed for construction of the HCal prototype. The successful performance of the HCal prototype, including in particular its acceptable energy resolution, uniform spatial response and linear energy response in beam tests, validates the overall approach to qualifying components for use in the HCal.

Connors will train and supervise the student workers. They will ensure that all safety requirements are met and that the training records kept are accurate and up to date.

4 QUALITY IMPROVEMENT

Processes to detect and prevent quality problems will be established and implemented, including:

- Inspection and testing
- Work planning
- Assessments

Item characteristics, process implementation, and other quality-related information will be reviewed, and the data analyzed to identify items and processes needing improvement.

Problems identified by assessment, test, inspection, and other means will be controlled and corrected using the graded approach described in this plan. Where appropriate, the cause(s) of the problem will be identified and corrected to prevent recurrence.

Several QA checks have been identified through experience during prototype production. However, to promote continual improvement, suggestions for process improvement will be gathered throughout the duration of the HCal Tile production. These will be communicated to sPHENIX project management.

Project participants are encouraged to identify problems or potential quality improvements.

5 DOCUMENTS AND RECORDS

Documents will be prepared, reviewed, approved, issued, used, and revised to prescribe processes and specify requirements, and to fabricate, and review, the HCal Tiles.

Project management and the L3 Manager for HCal Tile Production are responsible for identifying the records to be preserved. Records that show evidence or proof that a decision was made, or an action taken, will be part of the records submitted. Records for the HCal Tile production project will be kept in a database for the project located in https://docs.google.com and keyed specifically to this project. This guarantees regular archiving (backups) of the data are made and also enables remote access under permission control.

The L3 Manager for HCal Tile production is responsible for bringing to the attention of project management any deficiencies in documentation that compromise the performance and reliability goals for the HCal Tiles.

Tile identification and key manufacturing parameters to be recorded are noted here.

Each HCal Tile will receive a database number DBN. The DBN will be associated with both the tile characteristics (type of tile), but also with the batches of raw materials, which were used to fabricate the tile. This information will be tracked in a computer-based Traveler as the tile is produced. An index of all Travelers will be kept in a summary Spreadsheet. The Travelers and summary Spreadsheet with be archived on a regular basis. The Spreadsheet provides a compact way of keeping track of the over 6000 Travelers for individual Tiles.

The fields in the Traveler will be: tile batch, results of light transmission tests, thickness measurements before and after wrapping and results of cosmic ray response.

The tile itself will have the DBN clearly labeled along with a QR scan code.

The final designs of the HCal Tiles were prepared by BNL, and the final drawings of all tile types to be manufactured are archived at BNL.

Remote access to the tile Travelers and Spreadsheet noted above will be provided to the vendor, BNL and those monitoring the QA.

6 INSPECTION AND ACCEPTANCE TESTING

Inspection and testing of HCal tiles will be conducted using established acceptance and performance criteria, and equipment used for inspection and tests will be calibrated and maintained.

The finished HCal tiles are judged and accepted based on the following criteria:

- dimensional compliance
- response to comic rays

The final decision on the tiles is based on meeting the dimensional requirements, having good light transmission, and a response to cosmic rays within the acceptable range.

The measurement dimensions are included in the drawings in the appendix. The thickness of the unwrapped tile must be 7.0 ± 0.1mm and the wrapped tile must be pass the 8.0mm gauge.

The manufacturer will be responsible for recording the thickness of each tile in a database and will use the BNL supplied device for quickly testing that the wrapped tiles will fit between the steel plates. The thickness of the wrapped tiles can be tested at the manufacture and confirmed by the receiving institution.

Tiles, which pass the QA requirements, will be shipped to GSU for a final round of QA tests. Dimension testing at GSU will be performed with a 8.0mm thickness gauge and stencils to check the tile shape. The response of the tiles to cosmic rays will be measured. The most probable value from the landau distribution of each tile will be compared to a set of reference tiles. Tiles whose light response is greater than 80% of the reference measurement will be accepted and grouped into towers. Tiles not satisfying this requirement will be retested. Finally the tiles will be shipped to BNL where they will be assembled into sectors. The tiles will be wrapped and shipped in appropriate containers using standard shipping services.

Non-conforming items

Individual tiles that do not satisfy the size specifications or light emission criteria will be rejected at GSU and replaced by the vendor in accordance with the contract. A tally of non-conforming tiles and the non-conforming specifications will be kept by GSU.

Designated inspection/tests will be performed using equipment that is calibrated and maintained. The calibration status will be readily discernible and associated calibration procedures, documentation, and records shall be prepared and maintained. Calibrated equipment will be properly protected, handled, and maintained to preclude damage that could invalidate its accuracy.

All inspection and acceptance testing results will be maintained as project records.

The L3 Manager for HCal Tile production is the responsible person to determine whether a given HCal tile approved by the vendor is accepted or rejected and will communicate these decisions to the manufacturer and sPHENIX project management.

7 REFERENCES

[1] C. Aidala et al., Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes. Submitted to: *IEEE Trans. Nucl. Sci.,* 2017. arXiv:1704.01461.1

[2] sPHENIX Collaboration. URL: https://indico.bnl.gov/conferenceDisplay.py?confID=3854