

Inspection QA Plan for PbWO₄ Crystal Tests in the ZDC EMCAL

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Abstract

This Inspection, Test, and Plan (ITP) document describes the quality assurance (QA) plan for PbWO₄ (PWO) crystals intended for the ZDC Electromagnetic Calorimeter (ZDC EMCal). It identifies the crystal properties to be verified as part of the ZDC EMCal QA process and defines the scope of this document.

Since the measurement methods, instrumentation, and test procedures are largely identical to those developed for the EEEMCal PWO crystal QA plan, they are not repeated here. Instead, this document highlights only the modifications and additional requirements specific to the ZDC EMCal. Unless otherwise specified, all other procedures and acceptance criteria follow the EEEMCal QA documentation.

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1. PWO CRYSTAL PROPERTIES

The crystal properties are identical to those described in the EEEMCal document [1].

2. PROCESS AND PROCEDURES

2.1. Visual Quality

The visual quality inspection procedure and acceptance criteria are identical to those described in the EEEMCal QA document [1] and are therefore not repeated here.

For the ZDC-EMCal PWO crystals, the visual quality inspection will be carried out at RIKEN, Japan, and Academia Sinica (AS) and National Central University (NCU), Taiwan. Each crystal will undergo a detailed visual inspection to verify its external surfaces, mechanical features, and internal characteristics. The inspection is intended to identify defects that may affect the optical performance of the crystals, including surface scratches, surface pitting, chips, internal bubbles, and other visible imperfections.

The inspection results will be documented and used to determine whether each crystal satisfies the visual quality requirements for detector installation.

2.1.1. In-Process Testing

Prior to shipment and throughout the manufacturing process, CRYTUR performs visual inspections of the crystals to ensure that no nonconforming crystals are shipped.

2.1.2. Incoming Inspections or Acceptance Testing

Upon completion of the visual inspection of the entire crystal lot, the lot will undergo an initial acceptance by the designated inspectors at RIKEN, AS, and NCU. Following the initial acceptance, all of the crystals in each lot will be selected for further testing of the quality parameters described in this document.

2.1.3. Verification Testing

During the crystal wrapping stage of the detector assembly process, and prior to final assembly, the crystals will undergo a final visual inspection to verify that no damaged crystals are installed in the detector.

2.1.4. Failures and Non-Conformances

If any of the tested PbWO₄ crystals are found to be outside the limits defined in the specification, the crystals will be returned to the manufacturer for replacement. For any nonconformances identified by RIKEN, AS, or NCU, concurrence on the disposition by the ZDC-EMCal QA authority shall be required.

2.2. Mechanical Dimensions

The mechanical dimensions of all crystals will be measured after the visual inspection process has been completed. The measurements will be performed in the same area where the visual inspections are conducted.

The PbWO₄ crystals are square prisms with nominal dimensions of approximately $2.05 \times 2.05 \times 7.00$ cm (dimensions may occasionally be reported in millimeters (mm), in which case the units will be clearly indicated).

The purpose of the mechanical dimension measurements is twofold. First, they serve as a quality control (QC) check to verify that all crystals meet the specified dimensional requirements. Second, they provide the mechanical dimensional data required for detector assembly and integration.

The measurements will be performed using a digital height gauge on a granite surface plate to accurately determine the crystal dimensions. Since the crystals are stacked in the detector, dimensional accuracy is critical to ensure proper alignment and assembly. Crystals that are either oversized or undersized may lead to mechanical assembly issues and could adversely affect detector performance.

Details of the mechanical dimension measurement procedure are provided in Section 3.

2.2.1. In-Process Testing

The mechanical dimension measurement procedure, measurement criteria, and acceptance requirements are identical to those specified in the EEEMCal QA document and are therefore not repeated here. The dimensional data provided by CRYTUR and the measurements performed as part of the ZDC-EMCal QA process will be recorded as part of the ZDC-EMCal QA documentation.

2.2.2. Test Conditions

Mechanical dimension measurements will be conducted after the visual inspection and initial acceptance of the crystals have been completed.

2.2.3. Failures and Non-Conformances

If any of the tested PbWO₄ crystals are found to be outside the limits defined in the specification, the crystals will be returned to the manufacturer for replacement. For any nonconformances identified by RIKEN, AS, or NCU, concurrence on the disposition by the ZDC-EMCal QA authority shall be required.

2.3. Optical Transmission

The optical transmission measurement procedure, measurement criteria, and acceptance requirements are identical to those specified in the EEEMCal QA document and are therefore not repeated here.

For the ZDC-EMCal project, approximately 20% of the crystals in each lot will be selected for optical transmission measurements. The measurements will be performed at the RIKEN/AS/NCU Laboratory, and the results will be recorded as part of the ZDC-EMCal QA documentation.

2.3.1. In-Process Testing

The in-process optical transmission measurements performed by CRYTUR are identical to those described in the EEEMCal QA document. The transmission data provided by the manufacturer will be retained as part of the ZDC-EMCal QA documentation and used for comparison with the measurements performed during the incoming QA process.

2.3.2. Incoming Inspection or Testing

Following the completion of the visual inspection and mechanical dimension measurements, approximately 20% of the crystals in each lot will be selected for optical transmission measurements at the RIKEN/AS/NCU Laboratory. The measurement results will be documented and incorporated into the ZDC-EMCal QA records.

2.3.3. Failures and Non-Conformances

If any of the tested PbWO₄ crystals are found to be outside the limits defined in the specification, the crystals will be returned to the manufacturer for replacement. For any nonconformances identified by RIKEN, AS, or NCU, concurrence on the disposition by the ZDC-EMCal QA authority shall be required.

2.4. Light Yield

The light yield measurement procedure, measurement criteria, and acceptance requirements are identical to those specified in the EEEMCal QA document and are therefore not repeated here.

For the ZDC-EMCal project, light yield measurement systems will be established at the RIKEN/AS/NCU Laboratories. All of the crystals in each lot will be selected for light yield measurements, and the results will be recorded as part of the ZDC-EMCal QA documentation.

2.4.1. In-Process Testing

The in-process light yield measurements performed by CRYTUR are identical to those described in the EEEMCal QA document. The light yield data provided by the manufacturer will be retained as part of the ZDC-EMCal QA documentation and used for comparison with the measurements performed during the incoming QA process.

2.4.2. Transportation and Handling

The transportation and handling procedures are identical to those specified in the EEEMCal QA document and are therefore not repeated here. During transportation between the RIKEN/AS/NCU Laboratories, all crystals shall remain in their original manufacturer-provided packaging to minimize the risk of damage. Following detector assembly, appropriate protective measures shall be implemented to ensure the safe transportation of the detector.

3. EXPERIMENTAL/TEST SETUPS

The experimental setups, testing procedures, equipment, test conditions, and measurement methods described in the EEEMCal QA document are adopted without modification for the ZDC-EMCal project and are therefore not repeated in this document.

For the ZDC-EMCal QA program, the corresponding measurement systems will be established at RIKEN and AS/NCU. Visual inspection, mechanical dimension measurement, optical transmission measurement, and light yield measurement will be carried out following the same procedures and acceptance criteria as those defined in the EEEMCal QA document. All measurement results will be documented as part of the ZDC-EMCal QA records.

Details of the experimental setups, testing procedures, equipment, test conditions, and measurement methods are provided in Ref. [1].

4. ENVIRONMENT, SAFETY & HEALTH CONSIDERATIONS

All inspection and testing activities shall be carried out in accordance with the applicable Environment, Safety, and Health (ES&H) policies and regulations at the respective laboratories.

For the ZDC-EMCal QA program, all work performed at RIKEN and AS/NCU shall comply with the local ES&H requirements and established laboratory safety procedures.

The following personal protective equipment (PPE) shall be used during crystal handling and inspection:

- Powder-free nitrile gloves.

For visual inspection of internal bubbles, a Class 2 green laser shall be used to illuminate the crystals, providing clear visualization of internal defects while minimizing laser safety risks.

5. RECORDS AND DOCUMENTATION

5.1. Manufacturer/Producer Records

The manufacturer/producer records, documentation requirements, and record management procedures are identical to those specified in the EEEMCal QA document and are therefore not repeated here. All manufacturer inspection records, measurement data, and supporting documentation shall be maintained in accordance with the EEEMCal QA procedures.

5.2. Deliverable Documentation and Records

The deliverable documentation, quality records, and documentation management procedures are identical to those specified in the EEEMCal QA document and are therefore not repeated here. All inspection results, measurement records, and QA documentation generated during the ZDC-EMCal QA process shall be maintained in accordance with the EEEMCal QA procedures.

For detailed descriptions of the manufacturer/producer records, deliverable documentation, and record management procedures, refer to Ref. [1].

6. REFERENCES

[1] J. Crafts, B. Fraisse, T. Horn, C. K. Tam, Inspection QA Plan for PbWO₄ Crystal Tests in the EEEMCal.