ZDC-HCal: Fabrication and Assembly Plan

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Abstract

This document describes the construction of the ZDC-HCal SiPM-On-Tile boards. Production steps for the boards and associated electronics are described. ES&H concerns during construction and installation are also discussed.

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1. ZDC-HCAL SIPM-ON-TILE INTRODUCTION

The Zero-Degree Calorimeter - Hadronic Calorimeter (ZDC-HCal) is used to measure particles in ePIC with very high pseudorapidity. It consists of scintillating layers using a SiPM-On-Tile design, wherein Silicon Photomultipliers (SiPMs) are embedded inside individual tiles of the scintillating layers. These layers are staggered within the detector to provide greater measurement resolution.

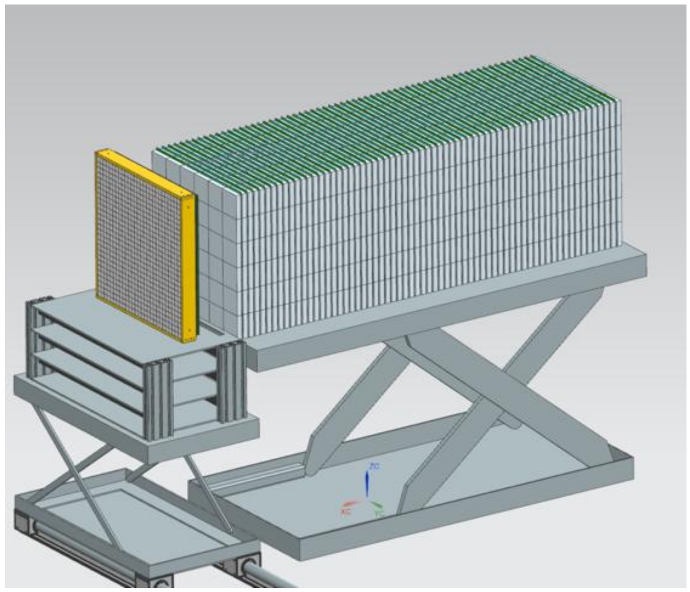

Figure 1. ZDC-HCal Tile Assembly CAD model. (Courtesy of Yulia Furletova)

2. MODULE PRODUCTION PROCESS

2.1 ESR Foil Fabrication

A sheet of ESR foil is prepared by removing the protective plastic film from one side and fully covering that side with black ink from an expo marker. The sheet is then cut to fit inside a 400 cm × 400 cm CNC 500 mW laser cutter shown in Fig. 2, with the black side facing up. The CNC machine can process foils for up to 16 tiles at a time.

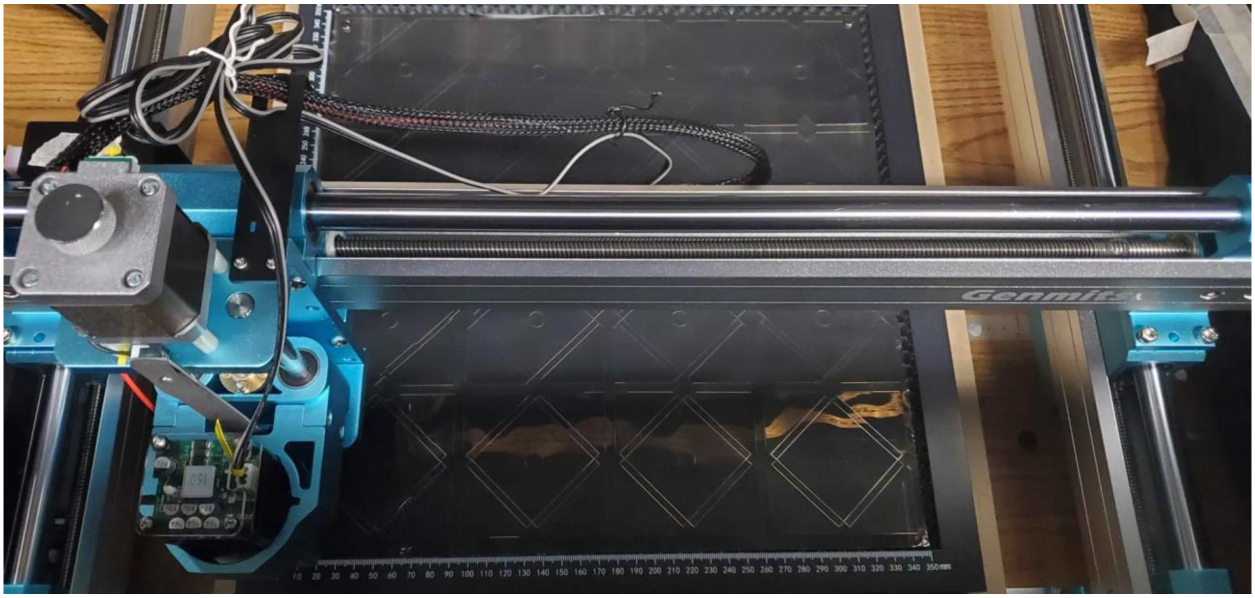

Figure 2. CNC 500 mW Laser Cutter, cutting a 400 cm x 400cm sheet of ESR Foil

The cut foils are carefully lifted from the plastic backing and folded around tiles with the aid of a 3D-printed fixture shown in Fig. 3. A sticker is then used to secure the foil in place. To manufacture foils for 16 tiles, the entire process requires approximately:

- 10 minutes for foil preparation,
- 30 minutes for cutting,
- 40 minutes for wrapping tiles.

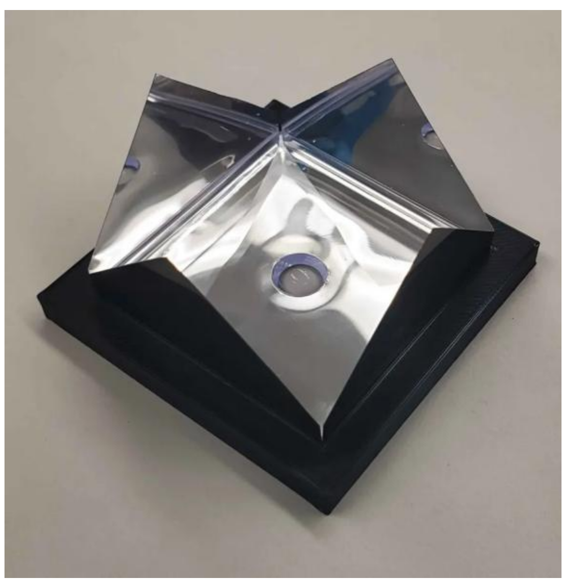

Figure 3. 3D-Printed Fixture used to fold ESR Foil around scintillating tiles

2.2 Layer Assembly

Each layer consists of three custom PCBs manufactured by JLCPCB. The assembly steps are as follows:

1. Verify pad continuity with a multimeter to detect manufacturing defects.
2. Solder two plastic edge card connectors to the PCB and check for shorts with a multimeter.
3. Apply solder paste to the SiPM pad locations using a stencil.
4. Place 3-mm SiPMs on the designated pads using plastic tweezers.
5. Reflow the PCB by applying heat below each channel via a hot air gun to solder the SiPMs.
6. Perform an IV scan on each channel using a custom "IV board" and a Keithley 2450 unit for quality assurance (QA).
7. Conduct a second QA check by placing wrapped scintillating tiles on the PCB and connecting the board to a CAEN DT5202 unit biased to 43 V. Using the DAQ software Janus, allow self-triggering and record cosmic ray events for at least 10 minutes. Channels should exhibit events significantly above the pedestal, consistent with the beginning of a Landau curve.

A SiPM can be replaced by applying heat from a hot air gun directly underneath the SiPM for approximately 30 seconds, after which the solder will have melted and the SiPM can be removed via tweezers. With heat still being applied underneath and the solder is still liquid, a new SiPM can be placed on the pads using plastic tweezers. This procedure is best performed with two people. After all channels are confirmed nominal, tiles can then be affixed to the board.

1. Place the tiles on the board and align them to the printed grid.
2. Apply masking tape to the corners of each tile to hold them in place relative to each other, and on the bottom two corner tiles to hold them in place relative to the PCB.
3. Fold the first row of tiles down, and place pieces of double-sided tape on the PCB between the SiPMs and the upper boundary of the grid.
4. Fold the first row of tiles back up and press them to the board, then remove the masking tape connecting the first row of tiles to the second.
5. Repeat the process for the remaining rows of tiles.
6. Once all the tiles have been placed, a sheet of polyimide film is placed on the front and back of the layer as a protective coating.

2.3 Cable Assembly

The following assembly instructions are relevant to the cable system.

1. Cut straight across all conductors in the cable in one pass so the cable end is perpendicular to the conductors.
2. Locate the polarity/keying feature on the 5-104892-5 housing and match it to conductor 1 on the cable (typically marked with a colored stripe).
3. Both 104891-5 covers are symmetrical. Start each cover partially into the housing (upper and lower) before you position the cable
4. With the covers started but not seated, lay the ribbon cable squarely across the IDC contact area, aligned so each conductor sits directly over its corresponding contact slot.

5. Using the arbor press or hand tool, press the upper and lower covers together in one continuous, even stroke. This drives the insulation-displacement blades through the cable's insulation and into the conductors, and simultaneously locks the covers (and cable) mechanically into the housing.
6. After pressing, confirm both covers are fully flush and latched to the housing, with no visible gap. The cable should not pull out of the connector with light tension. Visually check that no conductors were pinched, cut through, or pushed out of alignment during the press.
7. Before final installation, ring out continuity pin-to-pin (or use a cable tester) to catch any missed or shorted IDC terminations before the assembly goes into the system.
8. Once terminated, the 5-104892-5's latch mates to the corresponding board-mounted header. Align by the polarization feature and press straight on until the latch clicks/engages.

2.4 Iron Structure Assembly

The iron structure of the detector follows a modular block-and-pin design, which is assembled by doing the following:

1. Position pins in the bottom aluminum plate.
2. Stack absorber blocks in three-row sections, inserting pins at each level.
3. Place a thin aluminum sheet on the top of each layer using the pins.
4. Once several layers have been assembled, place a thin aluminum sheet on the sides using the pins.

Two people are able assemble 15 layers in approximately 20 minutes. A partially assembled iron structure is shown in Fig. 4.

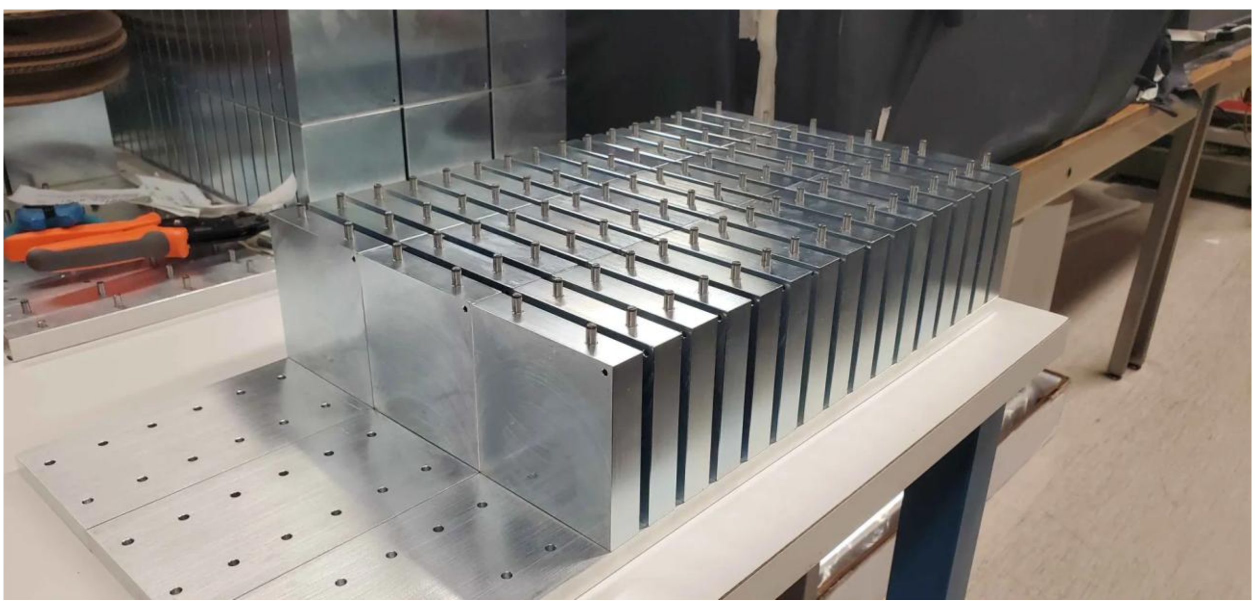

Figure 4. Partially assembled iron structure for slotting scintillating layers

3. PRELIMINARY INSTALLATION PLAN

3.1 High Level Installation Steps

1. Assemble the HCAL iron structure in place according to the "Iron Structure Assembly" instructions above.
2. Slide the assembled PCB layers into their respective slots from above.
3. Use electrical tape to provide a light-tight seal between the PCB layers and the iron structure
4. Connect the readout / bias ribbon cables to their respective PCBs

3.2 ZDC-Table Mechanics

ZDC Distance from IP to ZDC- EMCAL = 35.58m. ZDC-HCAL detector overall Size: X= 57.6cm, Y = 58.8 cm, Z = 175.5cm. The table for ZDC-HCAL will be procured by a combination of vendor provided hydraulic lifting tables and onsite supports. Dimensions of the table are based on the vendor Southworth (provided by Gregory Poole Lift Systems)- (lowered) (X, Y, Z): 24" x 15" x 80" (Model: Custom LS8-48). Cost: $21,625 (including freight. Power: 115/Single Phase/60Hz, Hardwired

Recipient (Shop) will need to verify the make/model for the lifting tables are correct, and fabricate the support chocks as identified on the drawing package.

Pre-inspection – Ensure there are no hydraulic leaks prior to integration. Verify all electronics are connected and operational.

- Lifting/Lowering - The table must have the ability to raise up to 38" (min) and lower down to 15" (min).
- Dynamic Test – While lowered, place a 3.5-ton payload on the table surface. Secure payload using straps. Raise and lower payload to verify operation. Remove payload, visually inspect hydraulics for any leaks.
- Static Test – Raise table surface to maximum height, then install support chock. Place a 7ton (14,000lb) payload on table surface. Payload shall remain on table surface for 30-60 minutes. Remove payload. Visually inspect for any hydraulic leaks and damage. Raise table to maximum height, remove support chock, and lower table surface.
- Package associated support chocks along with each lifting table. Lifting tables shall remain in vendor freight, unpackaged and tested at BNL
- Once received at BNL, remove shipping material. Anchor the tables in position as identified on associated arrangement drawing(s). Test lifting tables in accordance with test procedure(s)

4. ENVIRONMENT, SAFETY & HEALTH CONSIDERATIONS

Environment, Safety and Health (ES&H) considerations during construction and installation are detailed below. Any other local restrictions or rules not detailed below should be adhered to at all times. E.g. Jefferson Lab or Brookhaven National Lab general work place risk assessments and procedures.

The ancillary sub-systems will strictly adhere to all Environment, Safety, and Health (ES&H) regulations to ensure the safety of personnel, the integrity of the equipment, and the protection of the environment throughout the construction and operation phases. Yulia Furletova has provided the following details.

4.1 Global for all Ancillary Detectors:

- The ancillary detectors are installed in the accelerator tunnel, where available space is limited and access is constrained.

- Radiation exposure is a key ES&H consideration, as components surrounding the system may become activated during beam operation. These conditions may require controlled access procedures and could limit maintenance activities following beam-on periods.
- Operation and maintenance activities must be performed in close proximity to accelerator magnets, requiring careful coordination and compliance to accelerator safety procedures.
- Operation and maintenance are also carried out adjacent to the accelerator vacuum system, necessitating strict controls to protect vacuum integrity and avoid interference with accelerator operations. Hearing protection will likely be needed if it is under vacuum and users are nearby.
- For operation with HV and cooling we will ensure that these are mechanically secure and not a trip hazard, have proper warning signs and follow the lab procedures for electrical safety.
- Space Constraints - ancillary detectors are positioned next or between the beamlines and space is relatively restricted in places.

4.2 Specific for the ZDC-HCal:

- Calorimeter blocks are quite heavy. Care will need to be taken when moving or handling Fe-Blocks. Total weight of the system is about 3.5 tons.
- Cables will be checked for flame resistance as a safety measure to avoid dangerous electrical fires during the running. 1 ft. of cable will be cut and turned over to the fire marshal to perform this safety test.

5. REFERENCES

Arratia, A., Preins, S., & et.al. (2024). *ZDC Engineering Test Module Report.* Riverside, CA: University of California Riverside (UCR).

EIC Systems Engineering Group. (2022). *Interface Management Plan.* Brookhaven, NY: Brookhaven National Laboratory.

EIC Systems Engineering Group. (2022). *Requirements Management Plan.* Brookhaven, NY: Brookhaven National Laboratory.

EIC Systems Engineering Group. (2022). *Systems Engineering Plan.* Brookhaven, NY: Brookhaven National Laboratory.