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ICD Tile Module Assembly for the DØ ICD in Run II

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The Inter Cryostat Detector (ICD) is a scintillating tile based detector array which augments the DØ liquid argon calorimetry in the region between the central and end cryostats, improving missing transverse energy and jet energy resolution. The motivation and design of the Run II ICD is fully described in the ICD Technical Design Report [1]. The purpose of this note is document the ICD tile module production procedure, not included in the TDR.

Contents

1 Introduction

The active element in the Run II DØ Inter Cryostat Detector (ICD) is an array of scintillating tiles. Charged and neutral particles produce light in the tiles. WLS (wavelength shifting) fibers laid in grooves in the scintillating tiles bring the light signal to a connector at the edge of each tile module. A 12 channel ICD tile module unit includes scintillating tiles, WLS fibers and fiber connectors enclosed in white reflective paper wrapped in black paper with an outer silvered coating. The wrapped unit is contained within a light tight custom aluminum enclosure with external slots for fiber connectors. This note describes the assembly of an ICD tile module unit.

NOTE: Clean cotton gloves should be worn while handling the scintillating tiles as well as the WLS fiber assemblies. The exposure of both tiles and fibers to light, dust and human contact must be kept to a minimum during all of these procedures.

2 Scintillator Unit Production

2.1 Fermilab: scintillator cutting/epoxy

Forty pieces of Bicron BC400 Scintillator measuring 22″ square (1/2″ thick) is shipped directly from Bicron to Lab 8 at Fermilab. Each piece is used to make a single tile unit containing 12 optically isolated tiles.

The scintillator is cut using the Thermwood routing machine in Lab 8. First, isolation grooves are cut, as indicated by the straight lines inside the trapezoidal tile unit boundary of Figure 1. These grooves are 1/16″ wide and 490 mils deep, leaving about 10 mils of

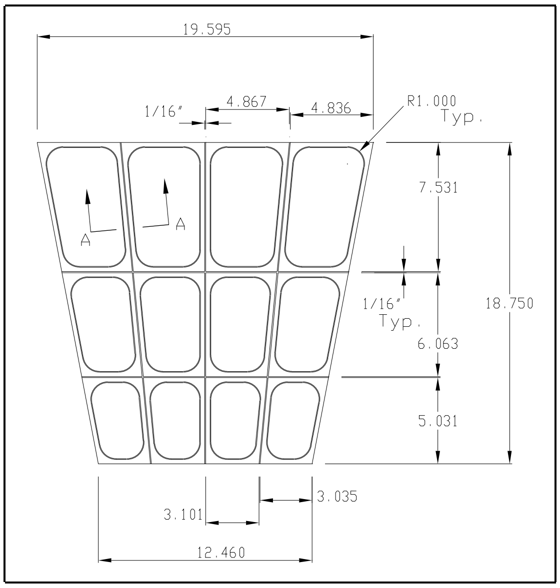

Figure 1: Schematic of the cut scintillator in an ICD tile module. Each module contains 12 tiles covering 0.3×0.4 in η and ϕ. Straight lines indicate the isolation grooves. WLS fibers are placed in the curved grooves.

material for mechanical stability during the epoxying process. These grooves are filled with a reflective white epoxy as described in DØ note 2976 [2]. By hand, any gaps in the epoxy are filled with either more white epoxy or Bicron (BC 620) white reflective paint.

After the isolation grooves have been cut and filled with epoxy, the 12 fiber grooves are routed and the outer edges of the scintillator unit is cut out. These cut out tile units are shipped to UTA for tile module assembly.

2.2 Arlington: final tile unit preparation

Before fiber insertion, a few final steps must be performed to complete preparation of the tile unit. NOTE: Clean cotton gloves should be worn while handling the scintillating tiles as well as the WLS fiber assemblies.

- If it has not already been completed, gaps in the white epoxy in the isolation grooves must be filled with either more white epoxy or Bicron (BC 620) white reflective paint. Let dry/cure.
- The 4 sides of the scintillator unit edge must be painted with Bicron white reflective paint.
- If necessary, wipe the tile unit clean with 50/50 (50% isopropyl alcohol and 50% water) and a clean cotton cloth.
- Turn the unit over. Using a black marker, draw lines covering the scintillator backing the isolation grooves. This will reduce cross talk between adjacent channels in the unit.
- Gently wrap the unit to prevent damage from dust and light until you are ready for tile wrapping (Section 5).

3 Fiber Pigtail Production

The ICD fiber *pigtail* is the assembly of WLS fibers that carry the light signal from the tiles to a connector interface on the tile module outer radial wall. This section describes the construction of these pigtails. The total path length of WLS fiber in any groove is less than 0.5 meters. The current design includes two WLS fibers in each fiber groove.

3.1 WLS fiber polishing/mirroring

Production begins with WLS fiber processing, performed at Lab 7 at Fermilab. Spooled Bicron BCF 91A WLS fibers (diameter of 0.9 mm) were shipped directly to Lab 7 at Fermilab from Bicron, where the cutting, polishing and mirroring is performed. Over 1000 WLS fiber were cut from the spools in lengths slightly longer than 36″ (a few inches longer than the longest fiber needed). These fibers were polished on one end using the ice polishing technique described in DØ note 3390 [3]. Polished ends were mirrored using an aluminum sputtering technique. These cut/polished/mirrored fibers were shipped to UTA for pigtail assembly.

At UTA, the mirrored ends of the WLS fibers should be coated with a thin layer of Elmer's Glue [4] in order to keep the mirrored end from flaking off. Let the glue dry thoroughly.

3.2 Epoxying Fibers into Connectors

The ICD group has decided to use precision injection molded connectors distributed by DDK Electronics, Inc. used by CDF in their end plug hadronic calorimeter. A drawing of a connector assembly is shown in Figure 2. They are modular and are available in the

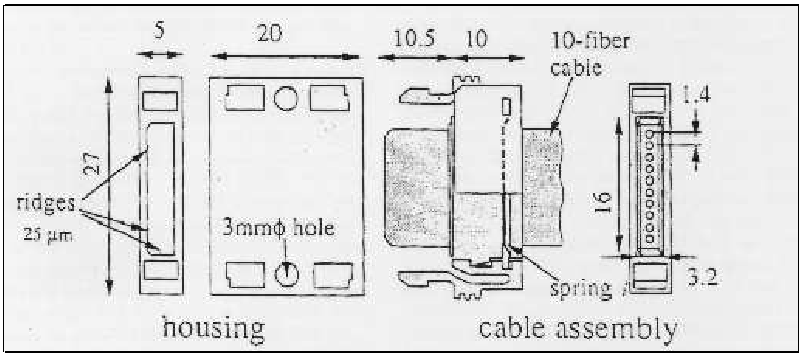

Figure 2: Fiber ribbon cable connector.

appropriate sizes for ICD fiber diameters (0.9 and 1.0 mm). Since they are only available only in 10-channel models, only 6 channels will be utilized.

Supplies needed to complete the pigtail production process are:

- A flat surface large enough to lay the fiber template.
- At least 6 WLS fibers which have been polished, mirrored and glued.
- Clamp assembly for holding connectors upright for epoxying while supporting the fibers along their length.
- DDK connectors: both the ten hole piece for 0.9 mm diameter fibers and the spring assembly.
- Bicron 600 24-hour optical epoxy, scale, calculator, mixing tool (ie tongue depressors), plastic cups, syringe for epoxy application with needle dispensing tip.
- Fibers to be connectorized, at least 4 spare 2″ pieces of fiber, black tubing fitting the WLS fiber diameter and a sharp razor blade or scissors.

The steps below describe how to epoxy fibers into the connectors with 24 hour Bicron 600 optical epoxy.

1. Place the fiber template on a flat surface.
2. Insert fibers one at a time into the grooves of the fiber template:

- Select a mirrored fiber with no visible flaws.
- Lay the fiber on a flat surface. Note the curvature of the fiber. When inserting the fiber into the template groove, try to allow the natural curvature to follow the curvature of the groove.
- Insert the mirrored end first, lining up the end with the predetermined stopping point marked on the template. Take care not to stress the mirroring or the fiber itself.
- Gently press the fiber down into the groove toward the connector edge of the template.
- If the fiber will not stay in the groove, constrain it using a small piece of kapton tape.

Repeat until at least one set of six grooves in the template are filled.

3. With scissors or a razor blade, cut the ends of the fiber hanging beyond $2''$ past the template edge.

4. With a NEW SHARP razor blade, cut six $1 - 3''$ lengths of black plastic sleeve, one for each transmitting fiber to be epoxied into the connector (cut the sleeve at an angle on one end to make it easier to slide that end over the fiber). Place a sleeve over each fiber end and slide it temporarily up the fiber at least $4''$ from the fiber end.

5. Slide the spring assembly over all fibers to be epoxied in the same order as they should ultimately be in the connector with the fins pointing DOWN.

6. Hold a connector with the beveled edge upward and the 10 holes furthest from the template. Stick the fiber ends into the appropriate connector holes, skipping a single hole between each pair of fibers (and leaving the outermost holes unfilled).

7. Use a $2''$ piece of kapton tape to hold the 6 fibers in place above and below the connector: Fibers should extend $1''$ below the connector bottom.

8. Gently pull the connector upward, pulling the fibers out of the template grooves. The kapton tape must hold the fibers fixed in length and orientation relative to the connector.

9. Place a connector piece in a vice with the 10 holes pointing downward. Support the fibers along their length so that they don't twist or pull out of the connector. Be aware: dripping epoxy may spill onto the area below.

10. Put dummy $3''$ length fibers into the 4 vacant connector holes (in the current scheme, only 6 of the 10 fiber holes in the connector will be filled leaving 4 empty slots). These dummy fibers prevent epoxy from flowing directly through the connector and dripping excessively out the bottom.

11. Mix Bicron epoxy according to manufacturer directions in a plastic cup. Mix thoroughly. Pour into a syringe and attach a dispensing tip. Bend the tip to make it easier to drip the epoxy into the connector. Fill the connector end with epoxy. If the epoxy is viscous, slight back and forth vertical movements of the fibers in the connector will deliver epoxy more uniformly down to the connector face. Epoxy should be pooled up at the connector open end (top).

12. Slide the black plastic sleeves down the transmitting fibers into the pool of epoxy on the connectors as far as they will go. These sleeves prevent cross talk within the connector and provide strain relief.

13. Apply more epoxy after 20 minutes if the level is reduced below the top of the connector.

14. Wait at least 24 hours for the epoxy to cure.

15. Remove connector from the vice and label it to indicate which phi sector within the module it is for.

3.3 Polishing Connector Ends

The ends of the connectors containing epoxied fibers must be polished. The procedure for polishing a DDK connector holding epoxied fibers is fully described in DØ note 3390 [3]. Inspect the pigtail assembly for possible flaws and store it in a dark clean cool location until it is time to insert it into a tile.

4 Insertion of Fiber Pigtail into Tile

This section defines the procedure for inserting each of the 4 WLS fiber pigtail assemblies into the scintillating tile. NOTE: Clean cotton gloves should be worn while handling the scintillating tiles as well as the WLS fiber pigtail assemblies.

- At this point, the 12-channel scintillator unit will have been through the following processes:
  - Isolation grooves have been routed and filled with white epoxy.
  - Bicron (BC 620) white reflective paint has been painted along the 4 sides of the scintillator edge.
  - The base of isolation grooves are marked with black marker to reduce cross talk between channels.
- Insure that the scintillator is clean and dry. Note any scratches or defects. If necessary, wipe with 50/50 (50% isopropyl alcohol and 50% water) and a clean cotton cloth, taking care not to disturb the black markings.
- Place the tile with the fiber grooves opening upward on a flat clean surface.

- Using compressed air, blow out any dust or cutting debris from the fiber grooves.
- For each of the 4 pigtails in the tile module:
  - Using an anti-static gun and/or a cotton cloth, eliminate any dust that may be clinging to the WLS fibers or connectors.
  - Clamp or hold the connector end of the pigtail assembly on the tile in its designated position. The shortest fibers should be to the right side of the connector and the beveled edges of the connector should be facing upward.
  - Start with the longer of the shortest pair of fibers. Push the fiber into the groove, starting at the connector end. When the longer fiber is inserted, push the shorter fiber in the same groove on top of the longer fiber.
  - Repeat this process for the medium length pair of fibers, then the longest length pair.
  - Place a piece of kapton tape on the connector to hold it in place on the scintillator edge.
  - Kapton tape may be used temporarily to hold the fiber within the groove (if the keyed groove fails to capture the fiber in the groove). A drop of epoxy should be used to hold the fiber in the groove ONLY after the tile has been tested and the tile/fiber meets the yield criteria !
- Gently wrap the tile/pigtail unit to prevent damage from dust and light until you are ready for tile testing or tile wrapping (next section).

5 Tile Module Wrapping

Each channel in the tile/fiber assembly should be tested in the UTA tile module teststand before the final wrapping is performed.

The tile/fiber unit must be kept as light tight as possible inside the custom aluminum box. First, the tile/fiber unit is wrapped in Tyvek white paper which acts to reflect light from a tile back into the tile. The unit is then wrapped in EMI paper, which is black on the inside, silvered outside. The black side acts to absorb light escaping from the wrapped tile or entering from the exterior. The EMI paper's reflective silver coating on the outside reflects external light.

The box is designed with very tight tolerances, so excess wrapping bulk, especially at edges and corners would prevent the tile from fitting within the box. The *Tyvek template* is a flat piece of white plastic cut at Lab 8 at Fermilab. It is intended to be used as a cookie cutter to cut out pieces of Tyvek and EMI paper to wrap the tile units without excessive folds that might add bulk.

- Place the template over the piece of Tyvek or EMI paper to be cut on a flat cutting surface. Using a razor blade or exacto knife, cut the paper around the edges. One piece of both Tyvek and EMI paper are required for each tile module.

- Wrap the tile in Tyvek, allowing the connectors to poke through the designated slots. Secure it with kapton tape, keeping the tyvek as tight about the tile as possible. The light yield is known to increase with a minimized air gap between the scintillator and the Tyvek.

- Now wrap the unit in EMI paper, again allowing the connectors to poke through the designated slots. Secure it with a single strip of electrical tape along all seams keeping the paper as tight about the unit as possible.

- Slide the tile/fiber/tyvek/emi unit into the base (bottom) of the aluminum box.

- Mount the fiber connector bulkheads onto the box top (outer radial edge of the box) applying RTV or an equivalent material to insure the bulkhead connections are light tight.

- Plug the fiber connectors onto the box top bulkheads and screw the box top into position on the box base.

- Affix the box cover.

- Check for light leaks, applying RTV or electrical tape at trouble spots.

You may choose to test the tile at any stage in this assembly procedure.

6 Acknowledgements

The design of the Run II ICD for DØ is based on established technology developed in the construction of similar scintillating tile/fiber detectors. We'd like to acknowledge members of the Rochester group and the CDF and CMS experiments for their careful R&D contributions to the tile/fiber technology. Specifically we thank Howard Budd and Dan Ruggiero for their openness and helpfulness in relaying countless details in design, testing, and construction.

References

[1] H. Lee Sawyer, *et al.*, "Technical Design Report for the Upgrade of the ICD for DØ Run II", DØ Internal Note 2686 and FERMILAB-TM-2041, June, 1997. `http://www-hep.uta.edu/~gallas/icd_tdr.ps`.

[2] E. Gallas, "Optical Isolation of Scintillating Tiles Using TiO2 Doped Epoxy for the DØ ICD in Run II", DØ Internal Note 2976, in preparation. `http://www-d0.fnal.gov/hardware/upgrade/icd/white_epoxy.ps`.

[3] E.Gallas and J.Li, "Polishing Optical Fibers for the DØ ICD in Run II ", DØ Internal Note 3390, FERMILAB-TM-2062, November, 1998. `http://www-d0.fnal.gov/hardware/upgrade/icd/polish.ps`.

[4] Don Lincoln, physicist at large. Private communication.