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MECHANICAL DESIGN OF CDF END PLUG OPTICAL SYSTEM

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ABSTRACT

The CDF End Plug at Fermilab is being upgraded to optical fiber technology. Fibers must extend from individual EM, Hadron and Shower Max pans within the plug to photomultiplier tubes mounted on the plug face. The entire system involves the organized splicing, coupling and routing of over 24000 optical fibers and 2000 source tubes per plug. Routing paths, methods of coupling and attachments of the fibers to the pans and plug are shown.

1. Fiber Routing Within Pans

There are three types of detectors within the end plug; Electromagnetic (EM), Position Detector (Shower Max) and Hadron.[1,2] The EM section consists of 23 layers. Each layer contains 24 pans. An individual pan encompasses a 15 degree "pie shaped" section of the plug and includes 18-20 separate tiles. Each tile in an EM pan is individually attached to a layer of polystyrene (white plastic) by 2 dowels made of scintillator. Fiber grooves are cut into each tile in a form resembling the Greek letter sigma. 0.83 mm diameter green "wavelength shifting" fibers are spliced to clear fibers of the same diameter within the pan. The fibers are routed into each of the fiber grooves, then rise above the scintillator into mating grooves in the white plastic layer. Figure 1 shows the fiber as it enters the white plastic sheet in an EM pan. From here the fiber is routed into an optical connector mounted near the perimeter of the pan. Cables consisting of 0.9mm diameter fibers are connected to the pan to pass the signal on to photomultiplier tubes. Hadron pans each contain a "megatile" made from a single sheet of scintillator. The individual "tiles" are optically separated by grooves and white epoxy. Each pan contains either 36 or 38 tiles and encompasses a 30 degree section of the plug. There are 22 layers. Each layer includes towers in the same projective positions as in the EM section. As a result, there are approximately as many fibers and source tubes needed to be routed from the hadron section as from the EM. Hadron fiber assemblies are routed from the tiles into the white plastic sheet in a way similar to that done in EM pans. Fibers are routed within each pan to four optical connectors located at the perimeter of each pan At the optical connectors the .83mm diameter individual fibers are coupled to cables made from .9mm diameter fibers.

The Shower Max Detector (or position detector) requires the routing of approximately 160 fibers in every 15 degree section. Fibers will exit the detector in bundles of 80, twice every 15 degrees. Cables identical to the ones used for EM fibers will be used to route the fibers to the rear of the plug. Shower Max pans each encompass a 45 degree section of the plug and are placed between the 4th and 5th EM layers. Long thin strips of scintillator, each containing one fiber, are placed side by side within the pan. The fibers exit the strips near the perimeter of the pan and go directly into connectors.

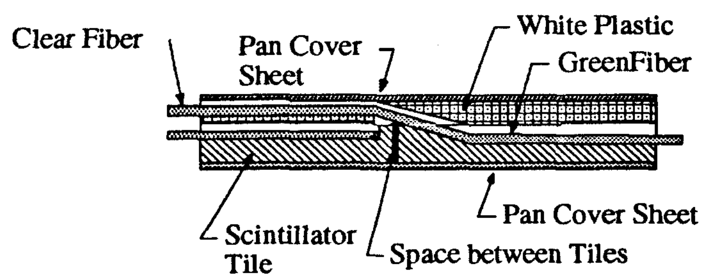

Figure 1. EM Fiber Entering Tile

Pans from all three detectors contain source tubes. Source tubes must be made available to calibrate the plug both when it is removed for servicing and when it is inserted into the detector. The tubes are placed inside grooves cut into the white plastic. Two types of source tubes exist. Most tubes are terminated at the perimeter of the pan by "funnels" as shown in Figure 3. These are accessible only when the plug is removed from the detector. Some (approximately 20% for EM and Hadron and 100% for Shower Max) are routed all the way back to the plug face. They will be used for periodic calibration while the plug is inserted.

2. Optical Connectors

All fibers are attached to optical connectors mounted at the perimeter of the pans.[3] There are two types of connectors. Those used inside the EM pans are 3.2 mm thick x 28 mm wide x 26 mm long. They are closed by using specially machined shoulder screws which provide both the clamping force and the necessary location. They are attached to the top surface of the white plastic sheet by clamping. A small L shaped "hold down clamp" is screwed to the pan and holds down the connector. The connector is set into the pan at a depth which allows the fiber bending radius to be sufficiently large and still remain within the confines of the light tight cover.

There is not enough room within the 8.8 mm (.346 in.) space allotted for the EM pans to include both the pans and the connectors. The lead plates must therefore be cut away locally to create the necessary space for the connectors. Small pieces of tungsten replace the lead in these areas. These tungsten pieces, although thinner than the lead, are thick enough to provide approximately the same total interaction and radiation lengths as the lead they replace, thereby rendering the cut away section "invisible".

The Shower Max pans will use connectors identical to those used in the EM pans. They are placed near the perimeter of the pan, some facing radially and some facing at 45 degree angles to the plug surface.

Additional space in the hadron pans makes it possible to use a connector thicker than the one used for the EM and Shower Max detectors. The Hadron connector includes a spring clip assembly making connection and disconnection more convenient. The main features are shown in Figure 2. Both connectors have been developed at DDK Co. in Japan in conjunction with Tsukuba University and Fermilab and tested both at DDK and Fermilab.

Connectors are fastened to Hadron Pans as shown in Figure 3. An injection molded "connector tray" is attached to the pan by sandwiching between the scintillator and white plastic. The connector housing fits into the connector tray and is positioned by two holes. A cover (not shown) is screwed onto the tray, enclosing the connector housing. Cable assemblies then fit into the housing.

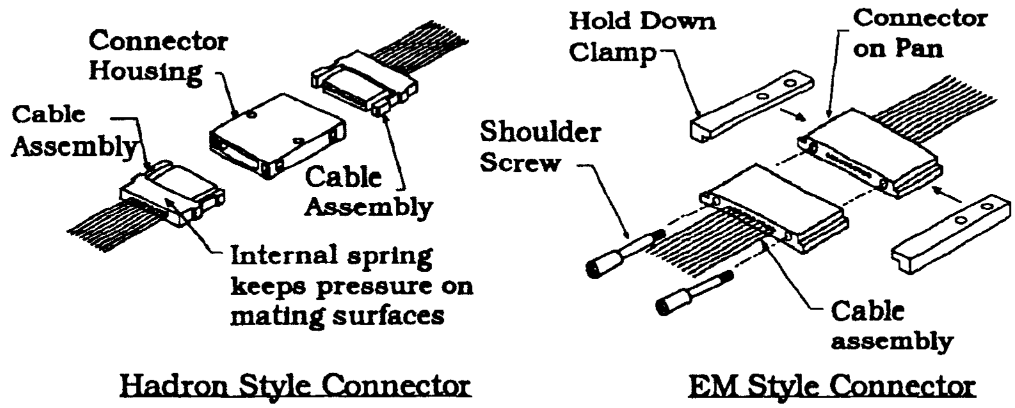

Figure 2. Optical Connectors

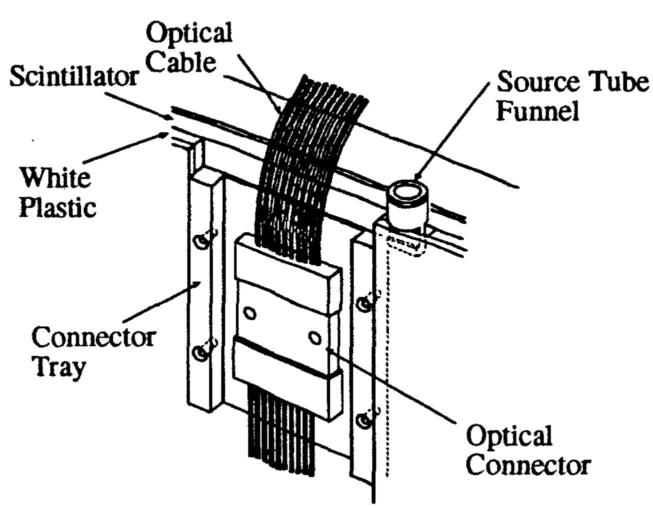

Figure 3. Hadron connector in Pan

3. Optical Cables

All fibers are routed by using optical cables as shown in Figure 4. Cables can consist of either 8,9 or 10 separate .9mm diameter fibers, depending on the position within the detector. The fibers are sandwiched between two layers of thin film. Prototypes have used 38 micron thick Tedlar, which has sufficient light blocking properties. Cables will connect to the pans on one end and "light sorter boxes" which contain the photomultiplier tubes on the other. They are terminated at the light sorter box by Hadron style connectors and at the pan end by either EM or Hadron style connectors, depending on the detector.

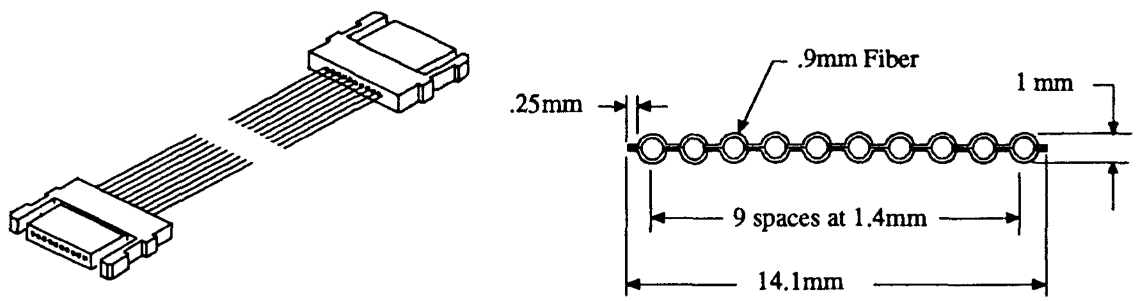

Figure 4. Optical Cable

4. Routing on Plug Surface

Fibers and tubes from the three detectors traverse the surface of the plug as shown in Figure 5. The pattern shown repeats every 15 degrees of azimuth. Fibers from each portion of the detector maintain individual paths. EM fibers are in the center surrounded by Hadron fibers, then Shower Max, with the source tubes from all detectors on the edges of each 15 degree section. There is a 5 centimeter wide "stay clear" region every 15 degrees to allow for structural brackets.

There is space for 10 rows of EM cables each 5 layers deep in the center. Since there are only 46 EM cables, there are 4 empty slots in the EM section which can be filled with cables for a proposed pre-shower detector. Hadron cables are stacked either 4 or 5 layers deep while Shower Max cables can be from two to four deep depending on their position. Stacks higher than 5 cables would result in fiber bending radii smaller than the self imposed 25mm specified for the design.

Cables must be held in place as they leave the pans and extend along the surface of the plug. Two preformed pieces of foam rubber will support he cables from above and below as they exit the pans. Studs will be tack welded to the surface of the plug, which will be used to attach brackets to hold down the fibers. The studs are internally threaded so light tight covers can be attached to them.

The entire plug surface must be covered, both to protect the fibers and source tubes and to provide a light tight enclosure. Covers will be made of .8mm stainless steel sheet and will each cover a 30 degree area. They will be attached to the ribs as shown in Figure 6.

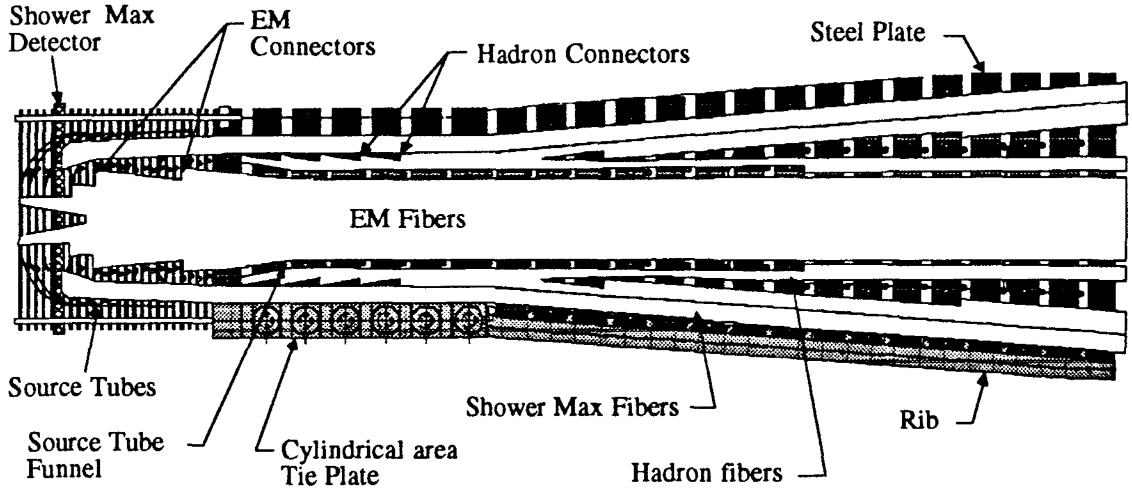

Figure 5. Fiber Routing Layout

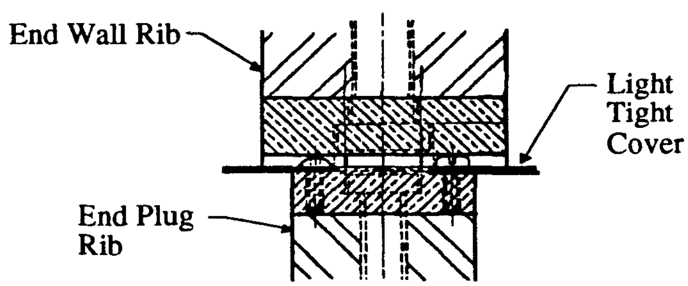

Figure 6. Light tight cover attachment

5. End Plug Face

Cables routed on the plug surface are organized "by pan", that is, one cable represents a group of tiles from an individual layer. A photomultiplier tube is designed to accept the fibers from a projective row of tiles, or "tower". A "light sorter box" is therefore needed which accepts cables by pan and sorts the fibers into groups representing individual towers. The light sorter boxes are being designed at Michigan State University. Light sorter boxes are modular assemblies containing inputs for 25 connectors and 10 phototubes. The box contains an internal array of fibers. They fit into larger photomultiplier tube boxes which are mounted onto the plug face. Figure 7 shows all the photomultiplier tube boxes mounted to the plug face.

6. Conclusion

The fiber routing system for the CDF end plug upgrade is well established. Fiber paths, connector and cable design are understood. Cables can be removed and replaced if damage is sustained on the plug surface. The system provides a relatively convenient, low risk method of routing fibers from the plug interior.

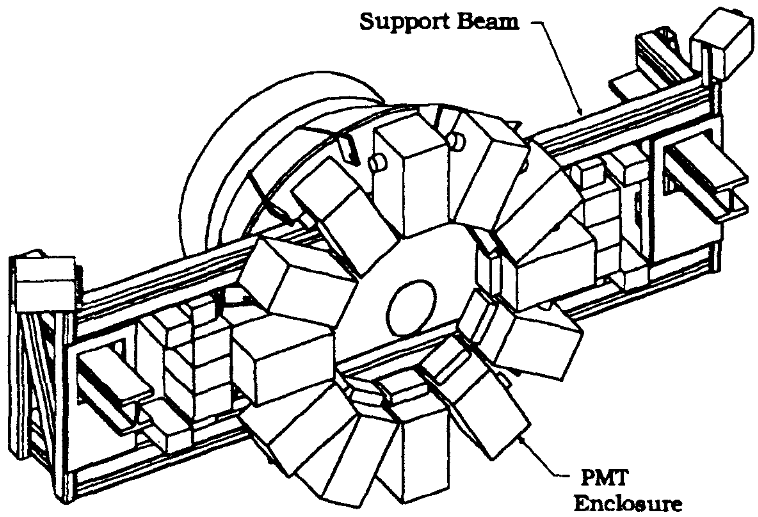

Figure 7. Photomultiplier Tube Box Layout on Plug Face

7. References

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2.) J. Kerby, et al., *CDF End Plug Upgrade Mechanical Design Report*, February 1993.

3.) M. Mishina, et al., *Development of Connector for Optical Plastic Fiber*, proceedings of the Workshop on Scintillating Fiber Detectors, October 24 - 28, 1993.