5.6 TIME-OF-FLIGHT (TOF) SCINTILLATOR COUNTERS

The TOF serves to a) be a fast trigger to the experiment for traversal of a particle across the bore of Cryomagnet and Silicon Tracker, b) measure the particles traversing the detector to a resolution sufficient to distinguish between upward and downward traveling particles and c) measure the absolute charge of the particle. Particles that pass through the scintillators generate photons as they pass through the counter paddles, these events detected by groups of two or three sensitive photomultiplier tubes (PMT) on either end of the detector element, the counter paddles.

The TOF is composed of four planes of detectors, two atop the AMS tracker, two below as shown in Figure 5.6-1. Numbered from the top down, detector assemblies 1, 2 and 4 have eight detector paddles per plane and detector assembly 3 has ten. The pairs of detector assemblies are oriented 90° to each other, shown in Figure 5.6-2. This configuration gives a 12 x 12 cm2 resolution for triggering particle events over the 1.2 m^2 area the TOF covers.

Each individual detector paddle is made of polyvinyl toluene (a Plexiglas-like material) that is 12 cm wide and 10 mm thick. End paddles of each layer are trapezoidal with a width of 18.5 to 26.9 cm. Each detector paddle is wrapped in aluminized Mylar and enclosed in a cover made of carbon fiber. As the construction is presented in Figure 5.6-3 each detector paddle includes a depressurization pipe to allow for pressure equalization. In the center of each detector is an LED that is used for calibration and testing. At the ends of each panel are light guides which direct the light of scintillation to photo multipliers. These light guides are curved to orient the photomultiplier tubes within the AMS-02 magnetic field for minimum impact to photomultiplier operations.

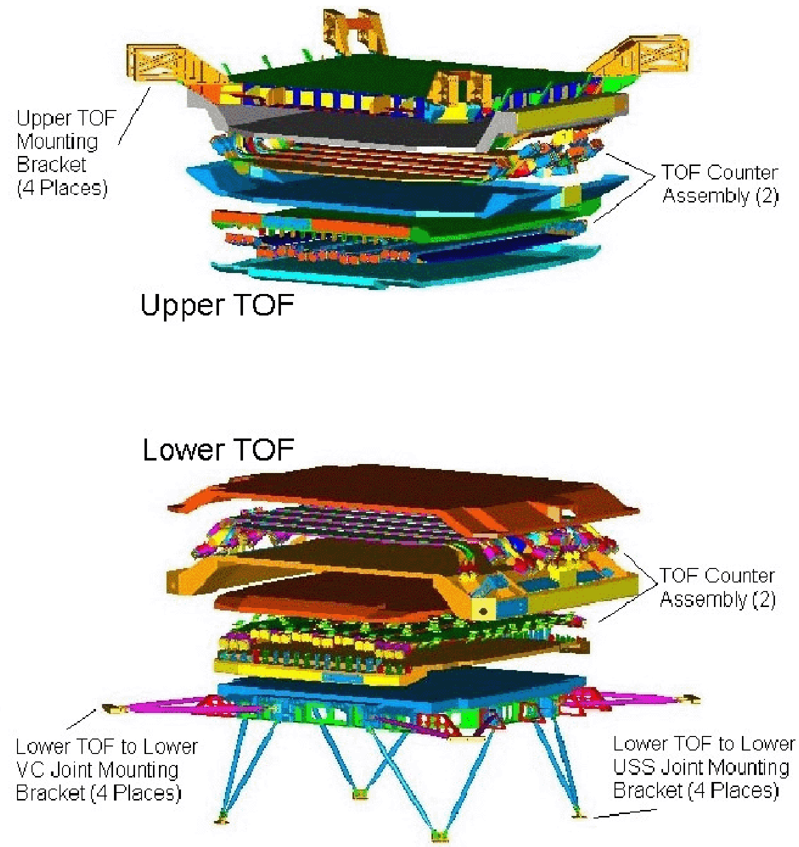

Figure 5.6-1 Time of Flight Counter Construction

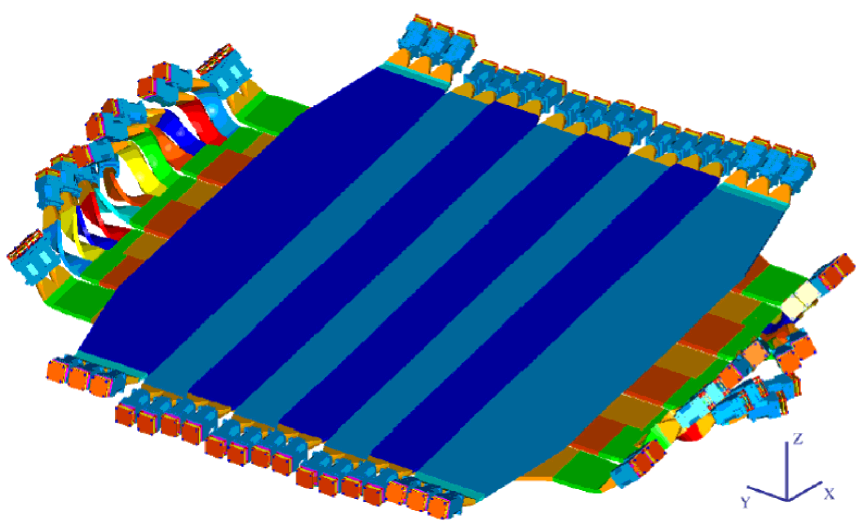

Figure 5.6-2 TOF Detector Paddles Orientation

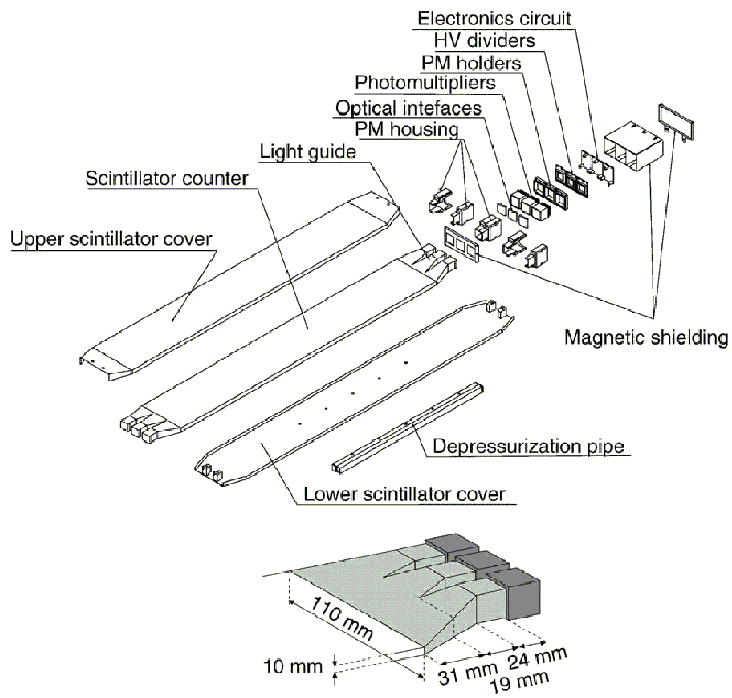

Figure 5.6-3 TOF Detector Paddle Construction

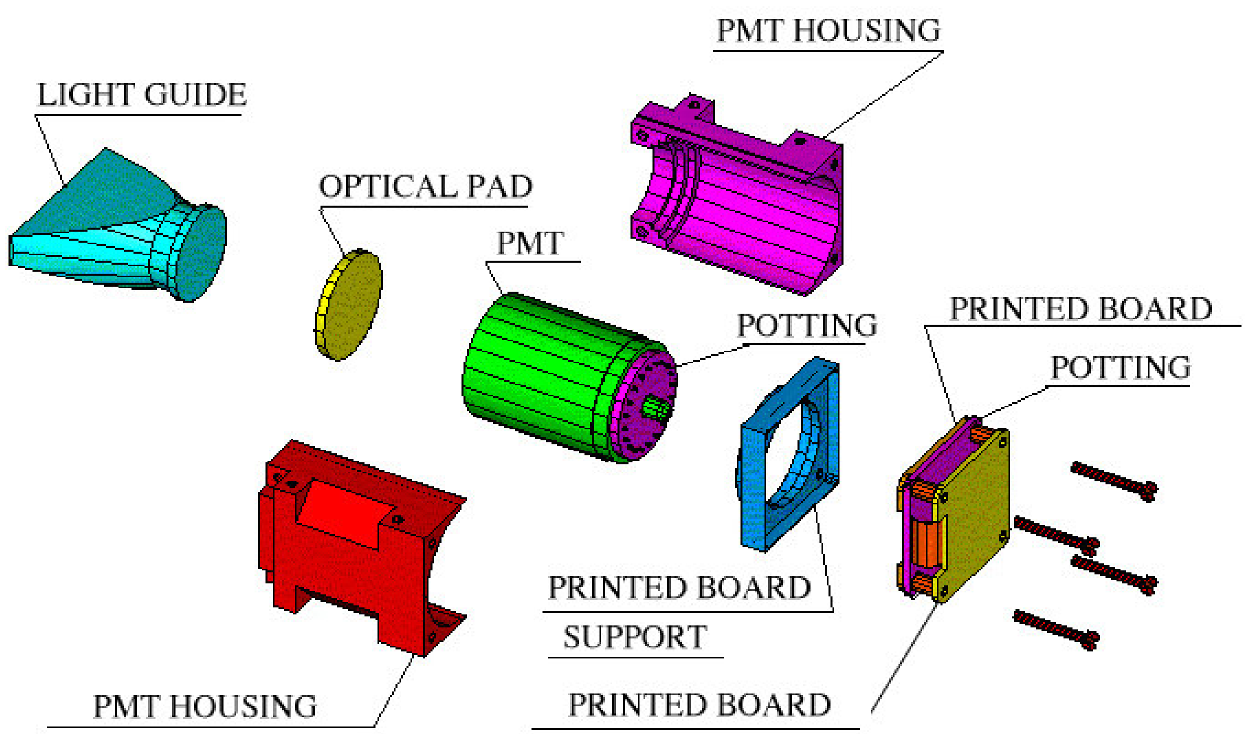

Figure 5.6-4 TOF PMT Exploded View

The TOF is instrumented with 144 Hamamatsu R5946 photomultipliers, used to detect the scintillating light. The PMT operated with a 700-750 Vdc voltage that is supplied by the SHV Crates. Each plane has two printed circuit boards that provide the high voltage sources for the detectors. The design of the TOF has considered the potential of discharge of high voltages at low atmospheric pressures and has implemented potting and coating of the PMT and high voltage interfaces. Access to the insulated and potted high voltage sources by an EVA crewmember is restricted as the TOF are under thermal blankets/MLI. The output from the PMTs on each end of the TOF detectors are summed to provide the necessary triggering signal that is provided to the four S Crates for data processing.

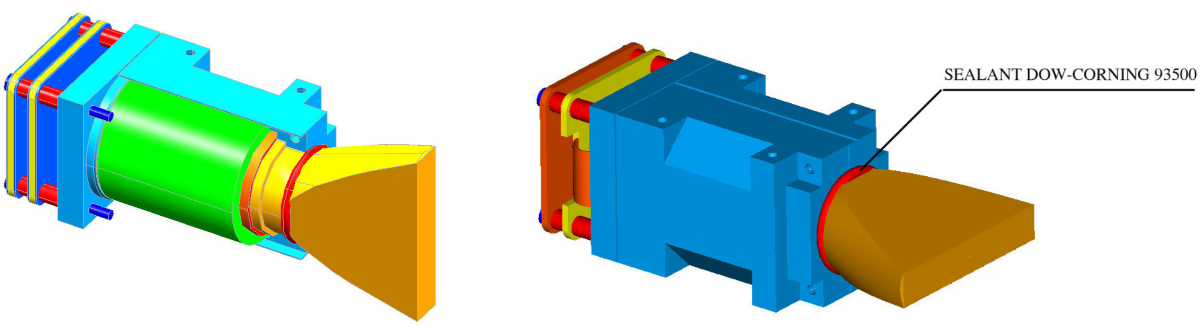

Figure 5.6-5 TOF PMT Construction

The Hamamatsu R5946 PMT is within a PMT housing, shown in Figures 5.6-4 and 5.6-5, made of black polycarbonate that is potted in place. The PMT is pressed into the light guides with an optical pad assuring optical transmission and providing a containment plane for the PMT tube itself.

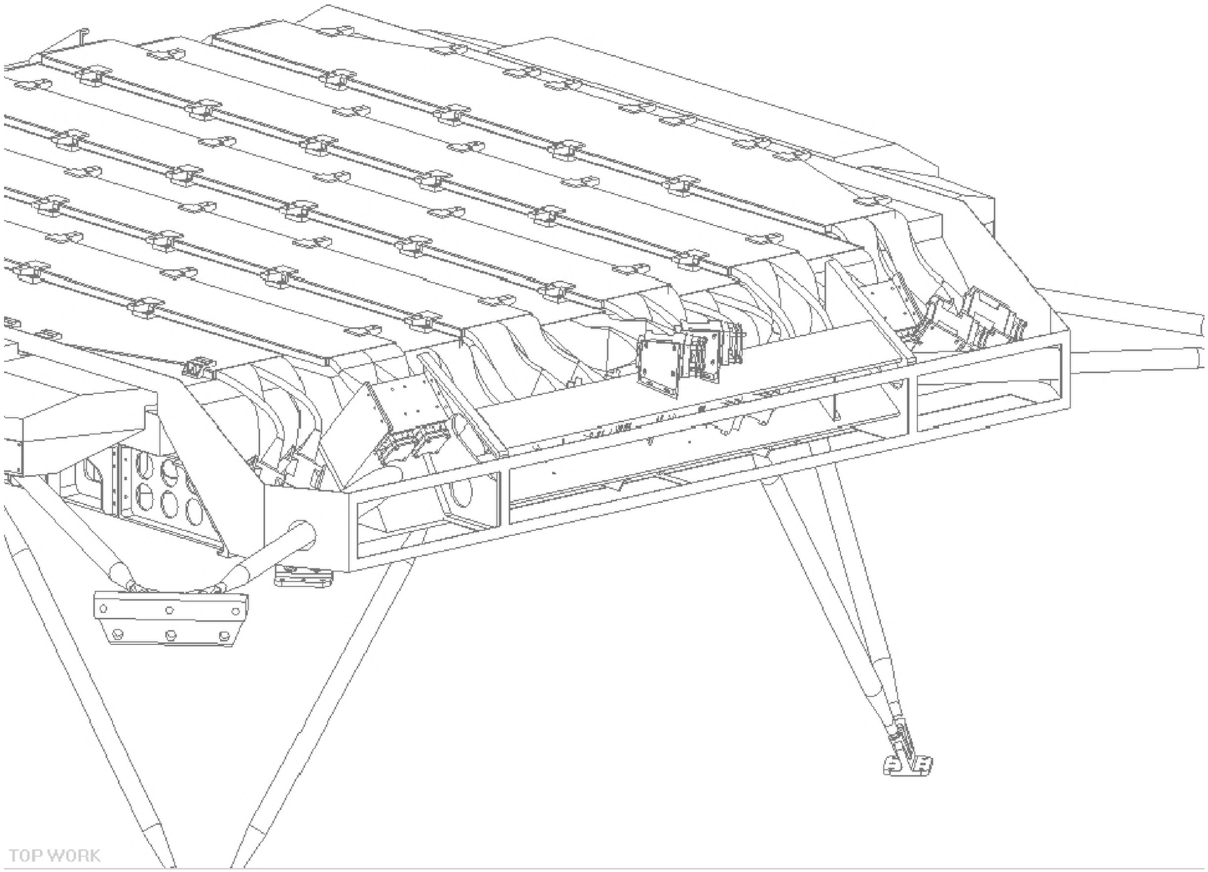

Figure 5.6-6 Mounting of TOF PMT and Detector Paddles

The PMTs are mounted to the TOF structure at orientations that minimize the impact of the magnetic fields on the PMT operations. These orientations can be seen in Figure 5.6-6. Light guides have complex curves to orient the light from the paddles into the carefully oriented PMTs.

Two large flat aluminum honeycomb panels are used to support the scintillator counters. The upper TOF attaches via brackets to the TRD corner joints which hard-mount to the USS-02 upper corner joints (Figure 5.6-7). The lower TOF honeycomb is supported to the lower USS-02 (Figure 5.6-8). The honeycomb panels are roughly circular with a 60.6 inches (1540 mm) equivalent outside diameter. The thickness of the honeycomb aluminum core is 1.97 inches (50 mm) and the aluminum skin is 0.04 inch (1 mm) thick.

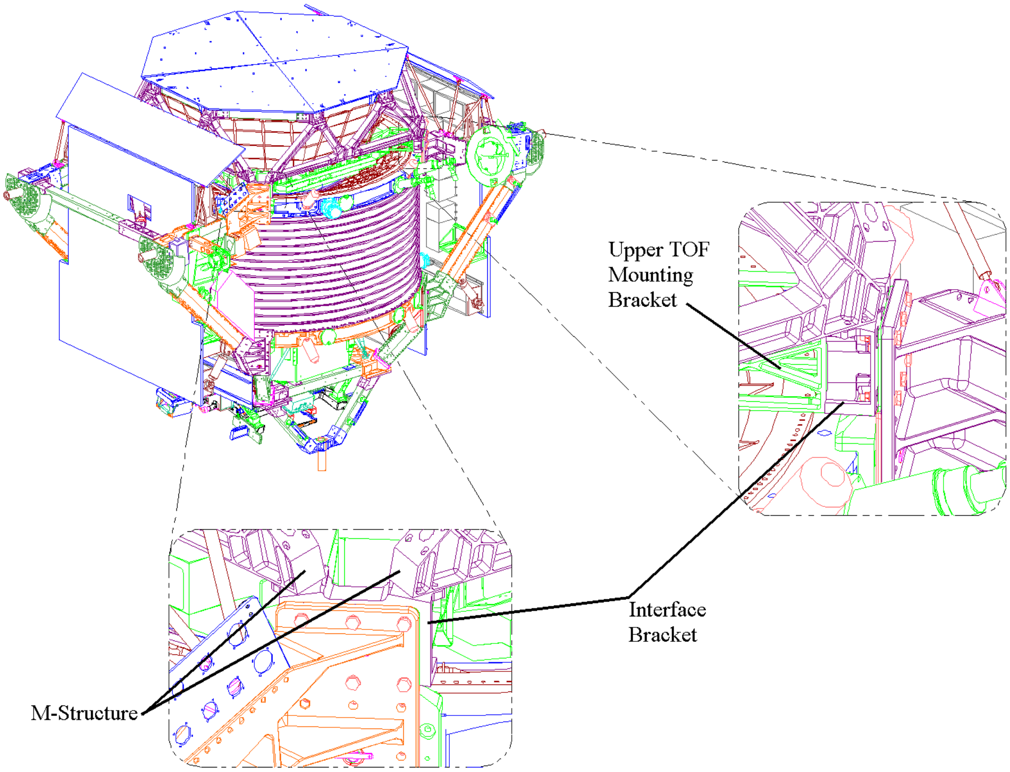

Figure 5.6-7 Structural Interfaces for the Upper TOF

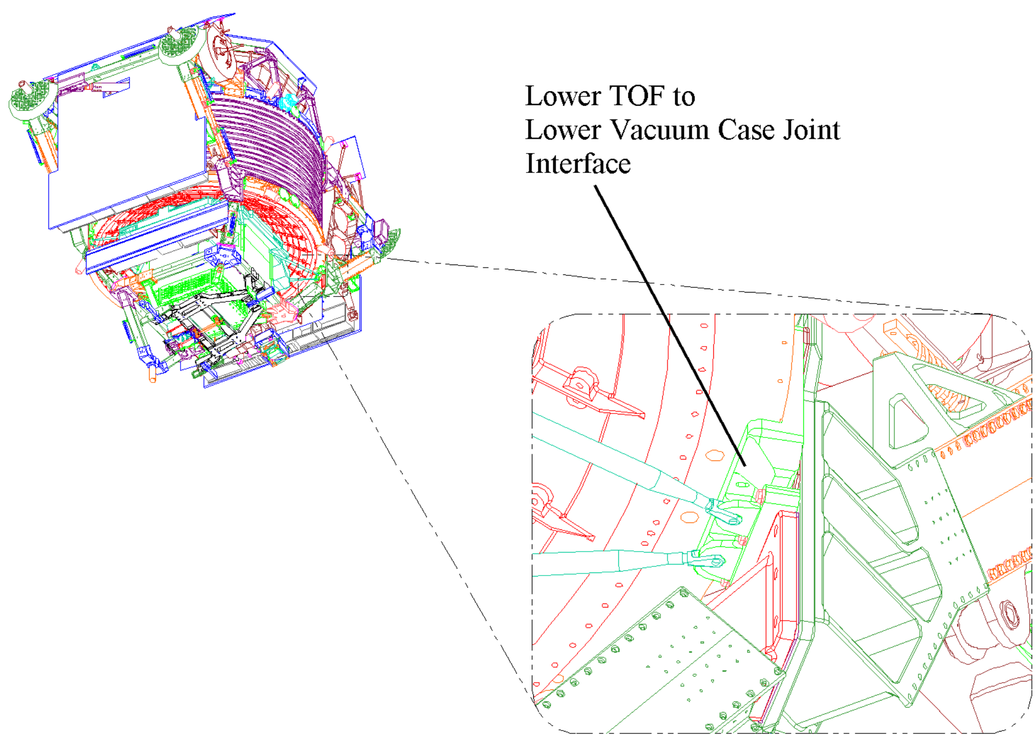

Figure 5.6-8 Structural Interfaces for the Lower TOF

5.7 STAR TRACKER

The Space Station, which is large and fairly flexible, cannot measure its own position with a high degree of accuracy and thus cannot directly tell the AMS-02 where it is exactly and where it is pointing. To optimize science from the Tracker detector carried by AMS it is important to have the capability to determine accurately the position of the AMS payload at the exact time that an event occurs. To accurately determine its position, AMS carries a Star Tracker called AMICA (for Astro Mapper for Instrument Check of Attitude). AMICA is equipped with a pair of small optical telescopes (AMICA Star Tracker Cameras or ASTCs). The ASTCs are mounted to the upper Vacuum Case Conical Flange on opposite sides of AMS to increase the probability that one has a clear view of the stars (Figure 5.7-1 and 5.7-2). The positioning of the Star Trackers while in the Shuttle Payload Bay does not place the ASTCs within nominal EVA translation paths. The location atop of the tracker places the ASTCs outside of EVA translation paths on the ISS and EVA operations that may be performed on the AMS-02 are not in proximity of the Star Trackers.

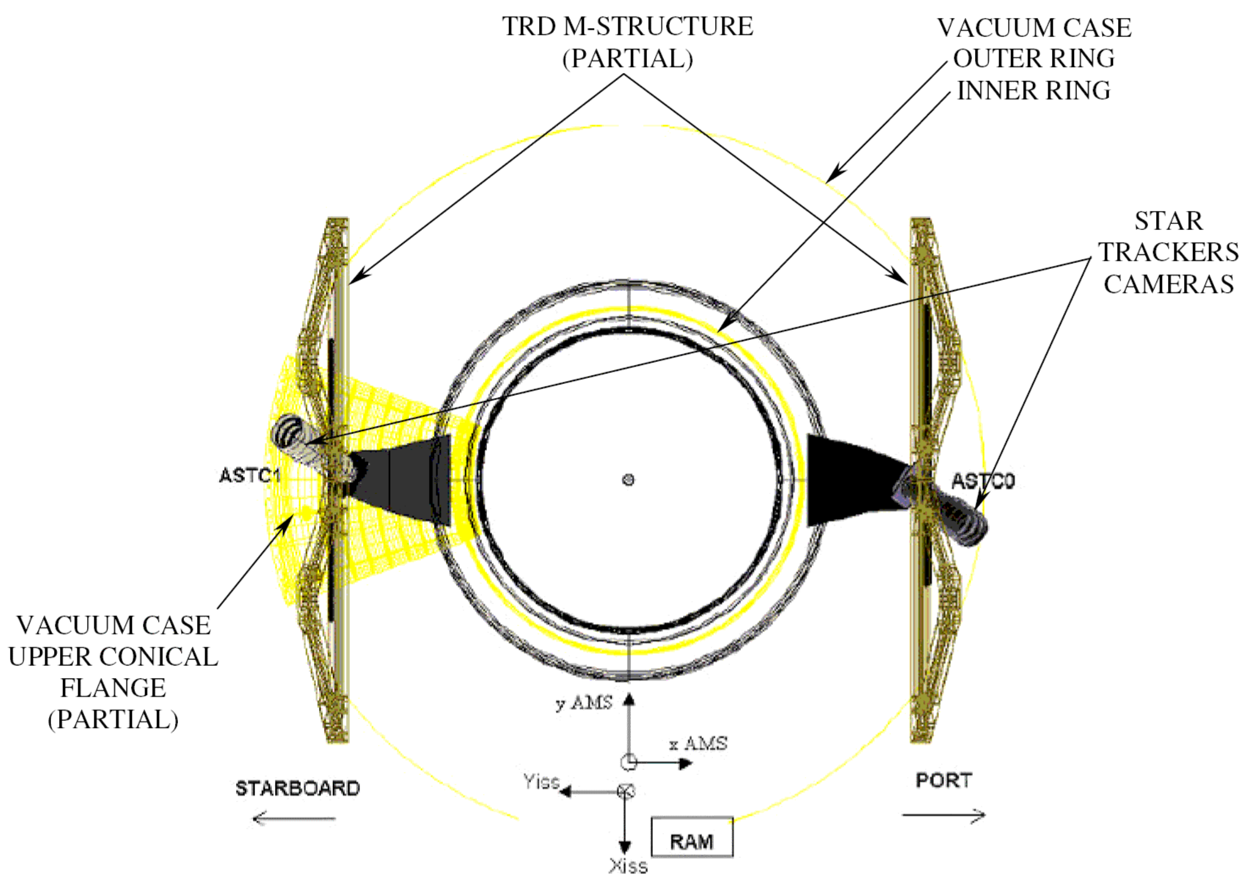

Figure 5.7-1 Star Tracker Position on the AMS-02

Each camera acquires an image of the stars with a Charged Coupling Device (CCD) detector and compares the resultant image to an on-board sky map. With this information, the attitude of AMS can be determined within a few arc-seconds (arc-sec) accuracy.

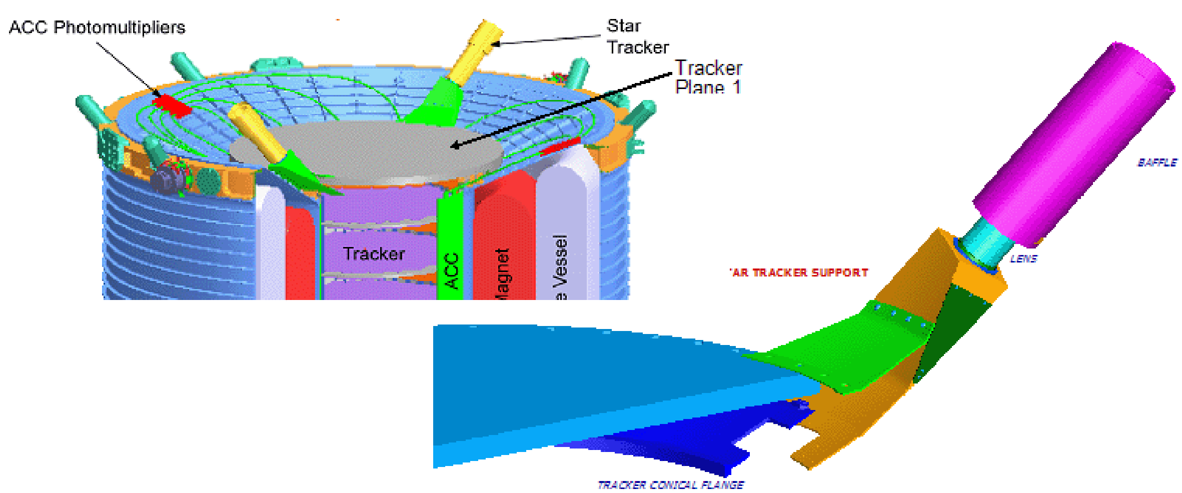

Figure 5.7-2 Star Tracker Mounting on the AMS-02

The hardware consists of an optics system [f/1.25 lens with 75 mm focal length and a 6.3° X 6.3° field of view (FoV)]; a lens cover containing a 3 mm thick blue filter and a 2 mm thick red filter; a low noise frame-transfer CCD (512 X 512 pixels); and a baffle to limit the stray light intrusion to the optics. The baffle is made of black anodized aluminum Al 6061 that is 1 mm thick. The Star Tracker optical components are shown in Figures 5.7-3 and 5.7-4. The baffle is not mechanically connected to the lens assembly and is supported independently by a bracket mounting the baffle to the M-Structure, the configuration allowing for relative motion between the baffle and the lenses without leaking light into the optical path. The interface between the baffle and the lens assembly is made light tight by a fabric MLI cover.

The interior of the baffle is being considered sharp enough to cut EVA gloves, the interior of the baffle cannot be rounded to meet the sharp edge requirements without losing the optical properties of a baffle to limit stray light.

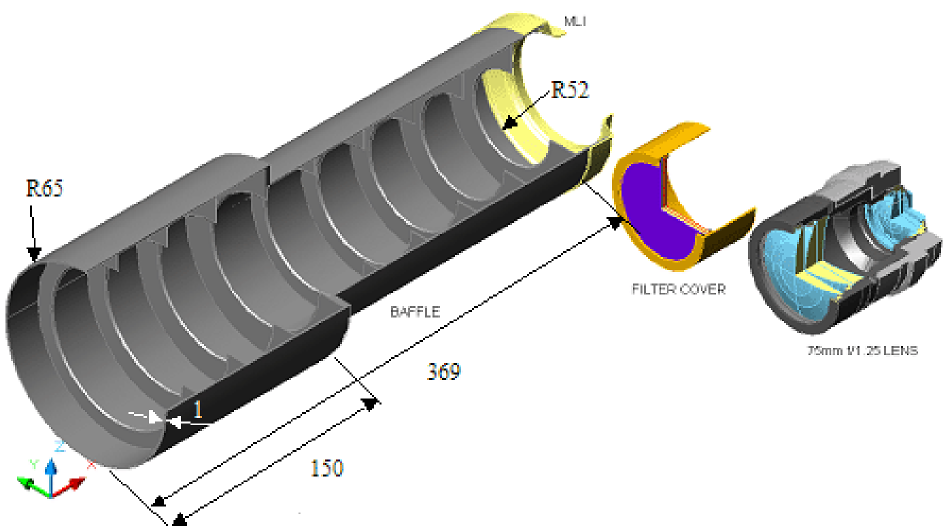

Figure 5.7-3 Star Tracker Optical Components

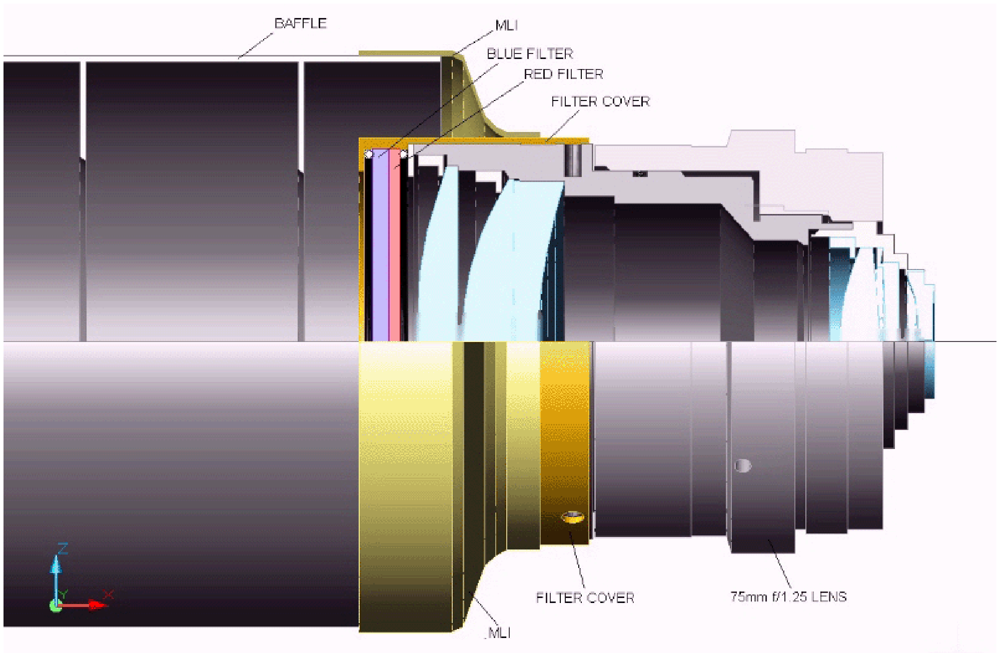

Figure 5.7-4 Star Tracker Optics

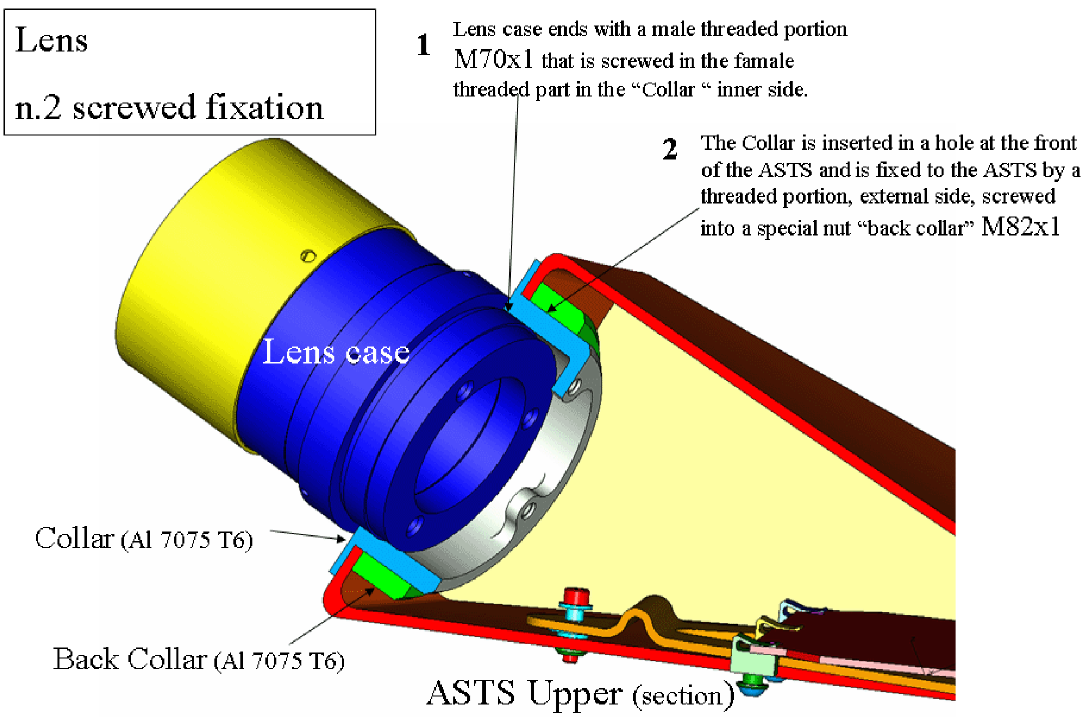

Figure 5.7-5 Star Tracker Lens Mounting

The AMICA lenses utilize standard optics mounting techniques (Figure 5.7-5) attaching to the housing body and in the construction of the lenses and filters. There is no specific venting paths provided for in the design of the lens assemblies, however the threaded body provides ample venting paths as shown during venting tests.

The enclosed volume of the Star Tracker is vented through the fastener access holes that are used for tool access when installing the Star Tracker to the AMS-02 as shown in Figure 5.7-6.

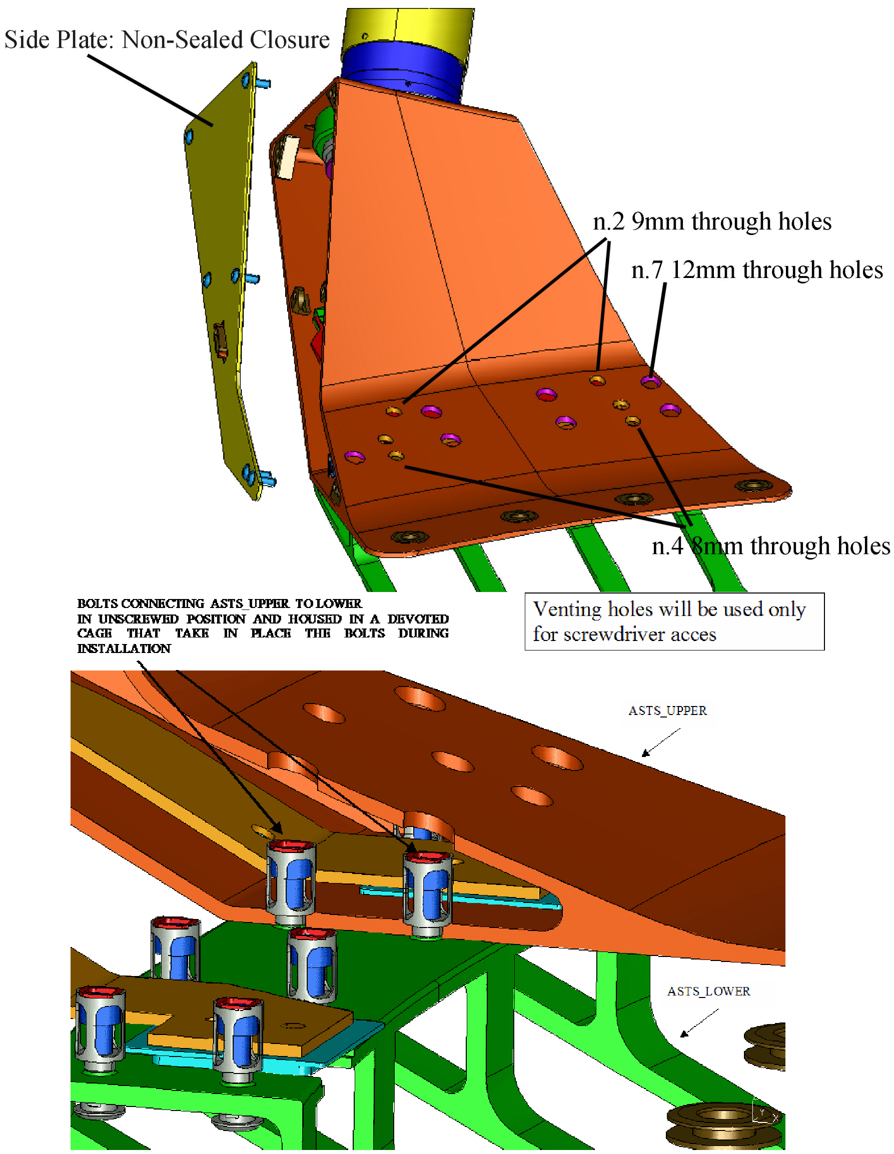

Figure 5.7-6 Star Tracker Assembly and Venting Paths

The AMICA operates on 28 Vdc and converts power internally to +35 V, +12 V, +7 V and +5 V distributed power. One small section of the circuitry operates at a maximum of

+45 V. The boards are conformally coated to reduce any potential for high voltage effects. The ASTCs are interfaced to the M-crate located on the ram side by three cables, two 8 conductor 24 AWG shielded conductors to provide the SpaceWire Link for data and one three conductor 22 AWG cable for power. The thermal load from the Star Tracker CCD and electronics board inside the sensors is carried by a copper "bus" to the thermal blocks connecting to the Tracker Thermal Control System (Figure 5.7-7). The electronics unit is based on a VME bus, which contains the processor (DSP21020) and power switching boards. The CCD and power switching boards for each ASTC are contained in the AMICA Star Tracker Supports (ASTSs) that attach the instrument to the Tracker.

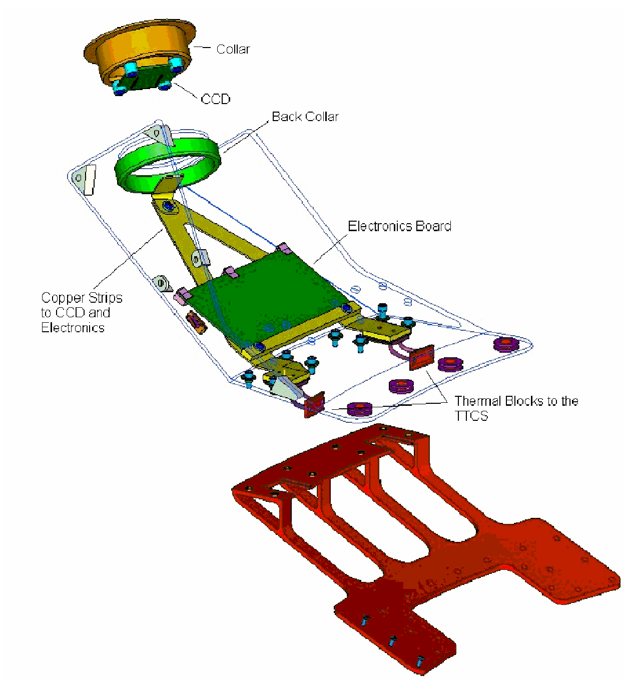

Figure 5.7-7 Star Tracker Thermal Interface and CCD Electronics

5.8 ANTI-COINCIDENCE COUNTERS (ACC)

The ACC is a single layer of scintillating panels that surround the AMS-02 Silicon Tracker inside the inner bore of the superconducting magnet (Figure 5.8-1). The ACC identifies particles that enter or exit the Tracker through the side, detecting particles that have not cleanly traversed the Tracker. The ACC provides a means of rejecting particles that may confuse the charge determination if they leave "hits" in the Tracker close to the tracks of interest.

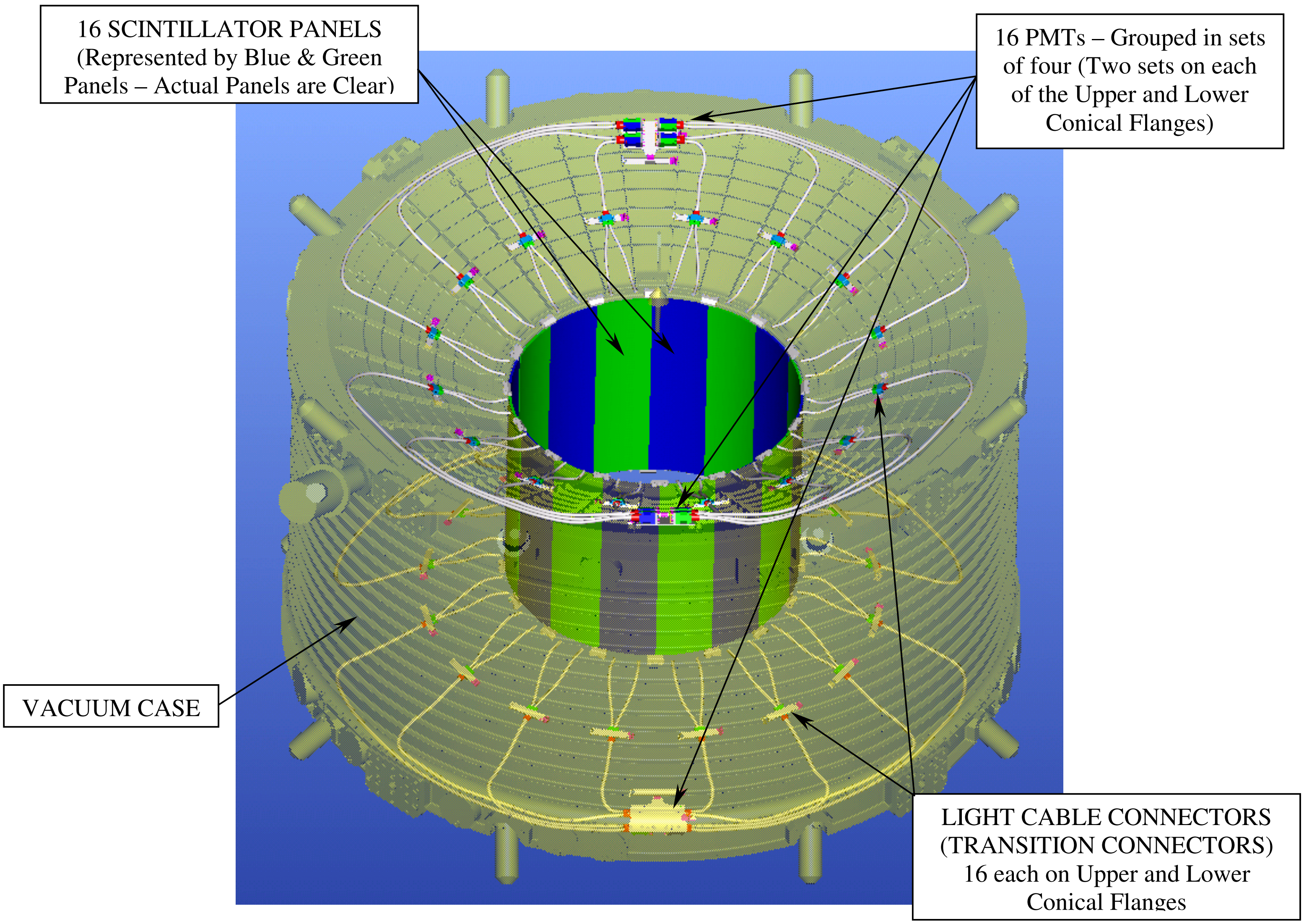

Figure 5.8-1 ACC Location Within the Inner Cylinder of the Vacuum Case

The ACC scintillating panels are fitted between the Tracker shell and the inner cylinder of the Vacuum Case, which contains the Cryomagnet system. The ACC is composed of sixteen interlocking panels fabricated from BICRON BC414 (Figures 5.8-2 and 5.8-3). The panels are 8 mm thick (as opposed to the 10 mm panels used for the AMS-01 ACC) and are milled with tongue and groove interfaces along their vertical edges to connect adjacent panels. This provides hermetic coverage for the ACC detection function around the Silicon Tracker. The panels are supported by a 33.46 in (850 mm) tall x .78 in (1086.7) diameter x 0.047 in (1.2 mm) thick M40J/CE Carbon Fiber Composite (CFC) Support Cylinder (Figure 5.8-4).

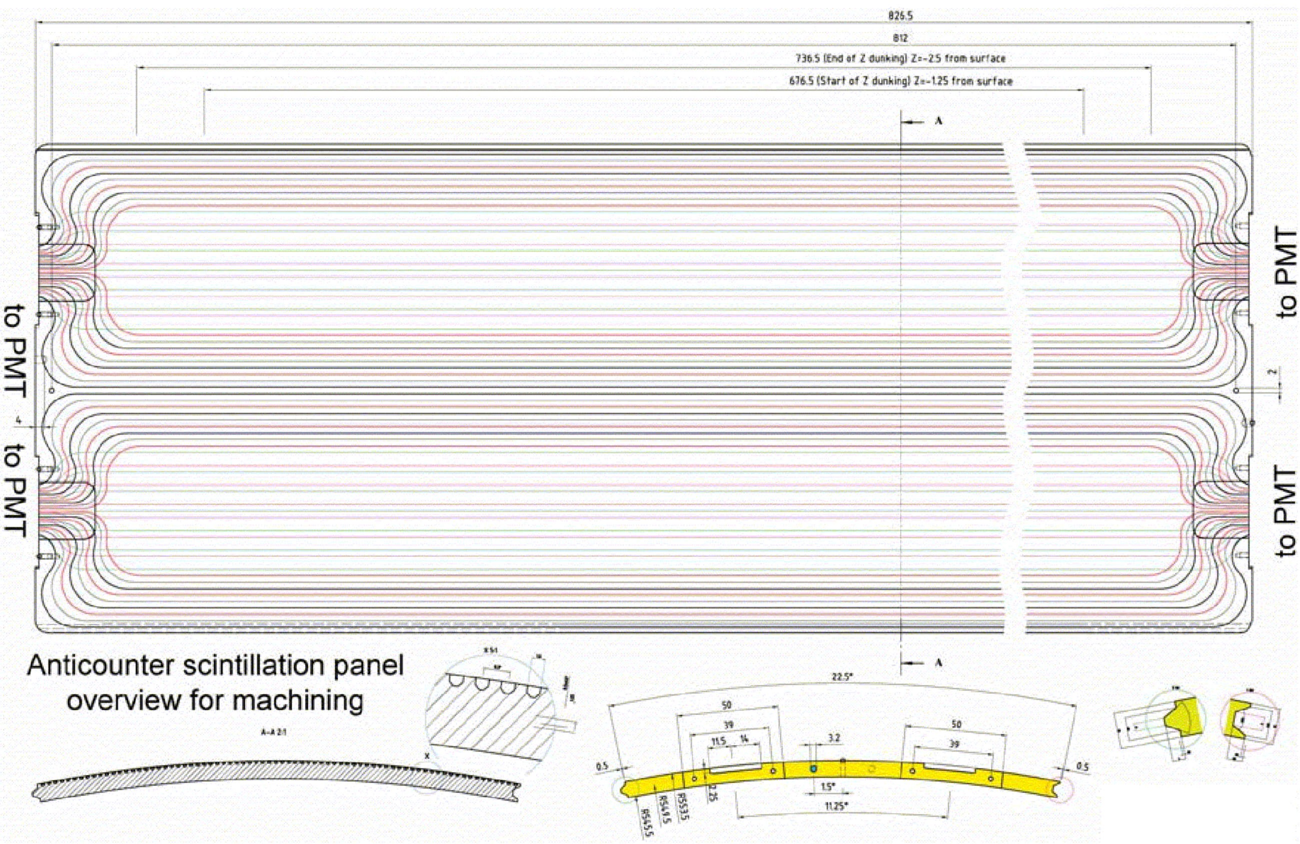

Figure 5.8-2 Design Details of an ACC Scintillator Panel

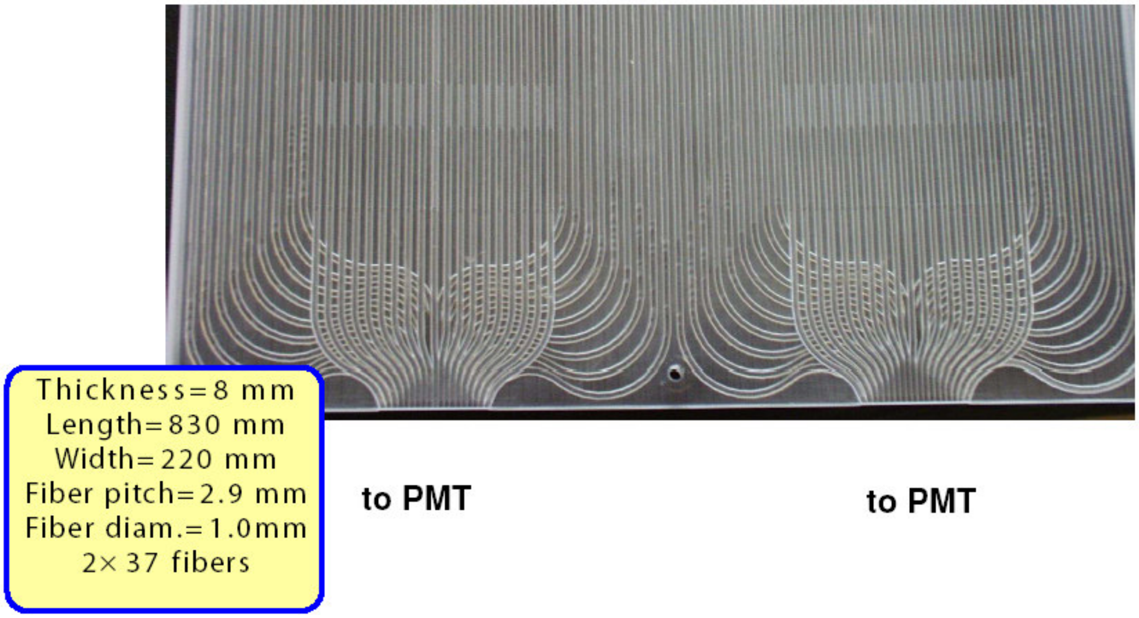

Figure 5.8-3 Finished End of an ACC Scintillator Panel

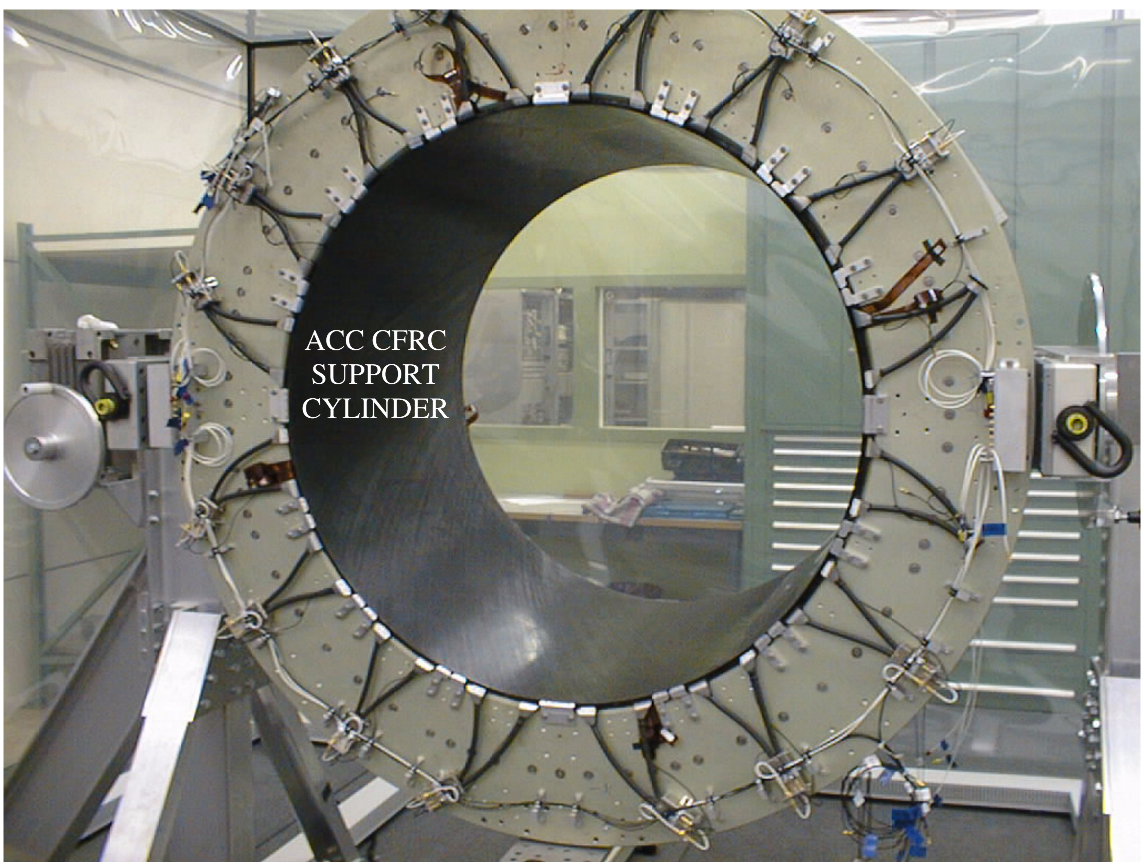

Figure 5.8-4 ACC Carbon Fiber Reinforced Composite Support Tube installed for AMS-01

The light of scintillation from particles passing through the panels are collected by 1 mm wavelength shifter fibers (Kuraray Y-11(200)M) that are embedded in groves milled into the panel surface. A panel has two collection arrays, each consisting of 37 fibers. The embedded fibers are collected into 2 output ports of 37 fibers each at both ends of the panel (Figures 5.8-2 and 5.8-5). For each panel there are two transition connectors (Figure 5.8-6), one each located on the upper and lower conical flanges of the Vacuum Case (Figure 5.8-7). From these transition connectors the light is routed through clear fibers up to PMTs mounted on the rim of the Vacuum Case (Figure 5.8-8).

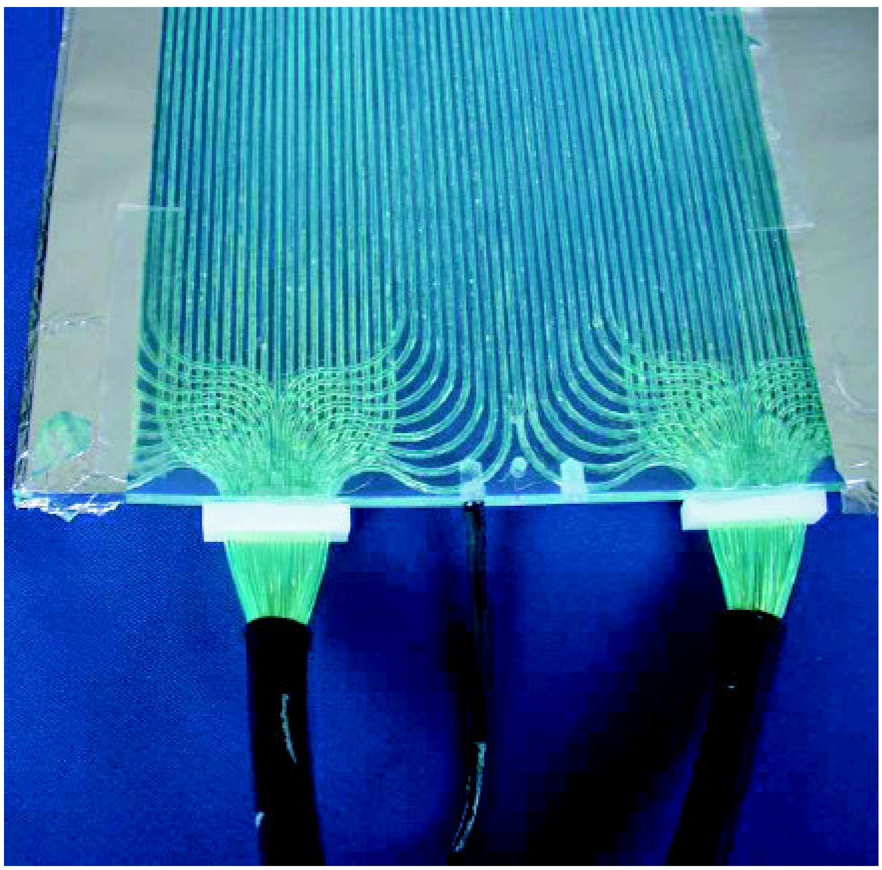

Figure 5.8-5 Fibers Collected at the End of an ACC Scintillator Panel

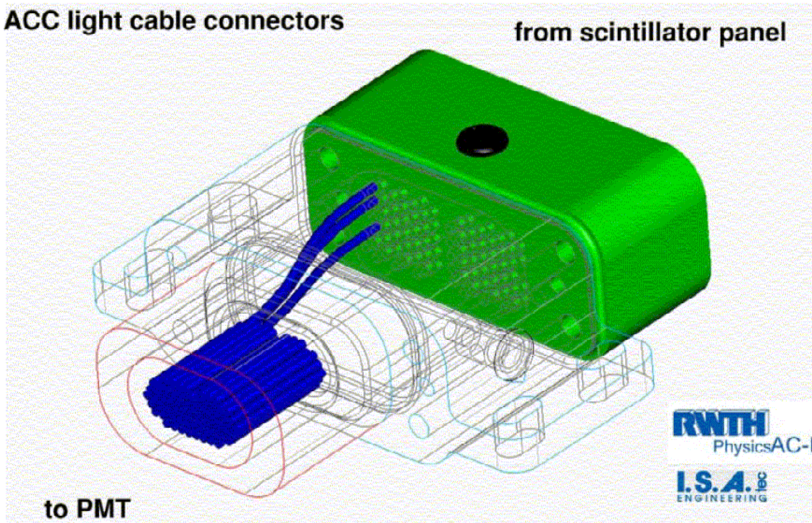

Figure 5.8-6 ACC Fiber Optic Transition Connector

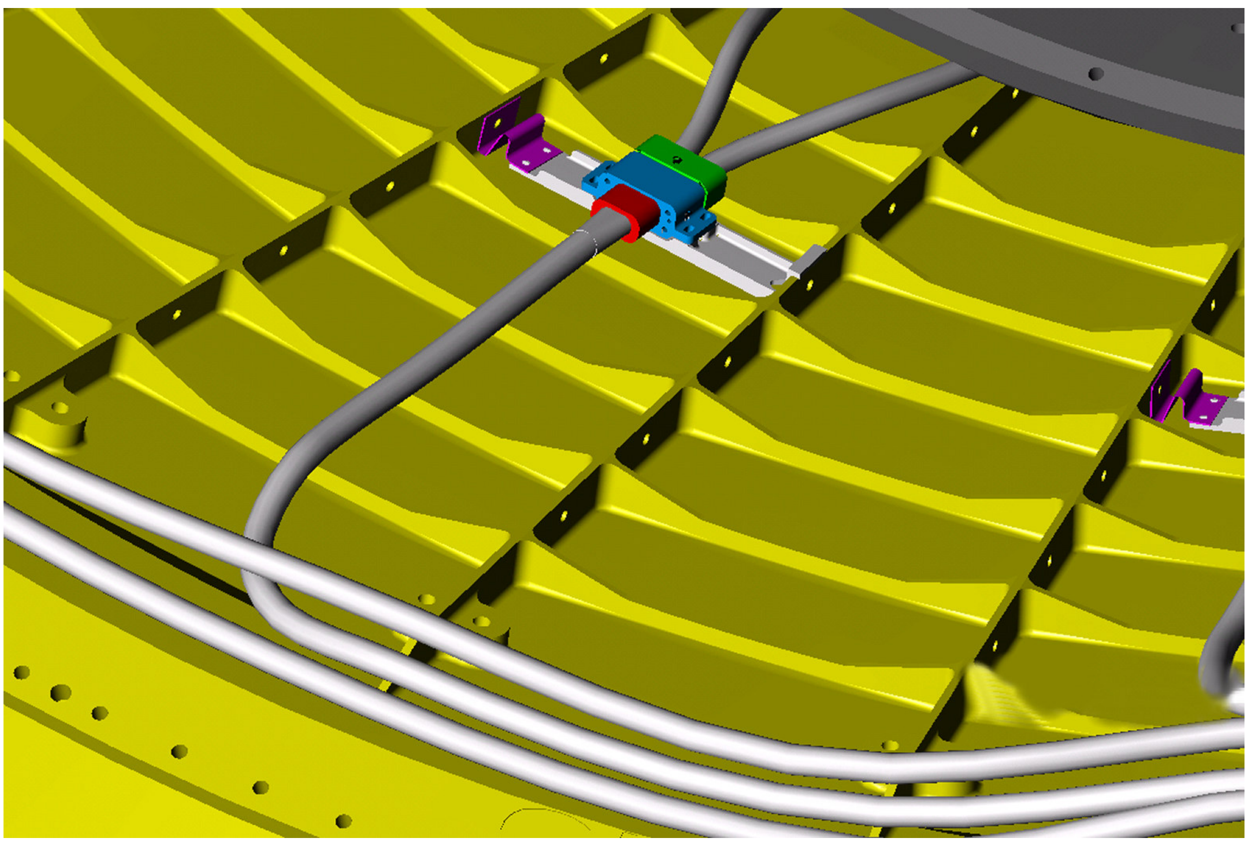

Figure 5.8-7 ACC Transition Connector Mounted to the Conical Flange

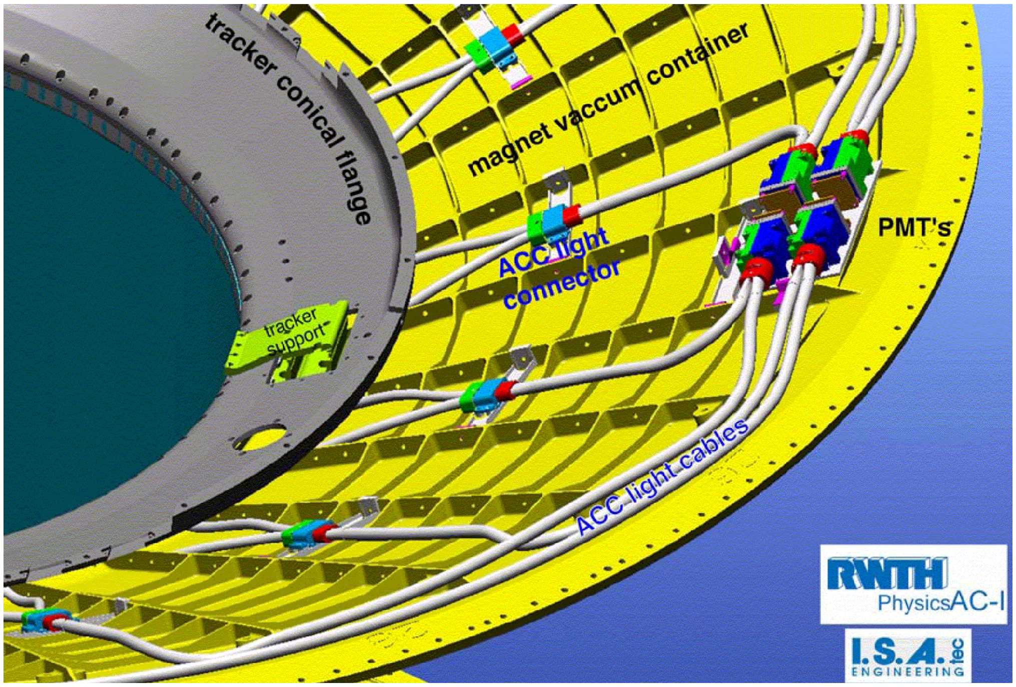

Figure 5.8-8 Routing of the Fiber Optic Cables from the ACC Scintillating Panels through the Transition Connectors to the PMTs

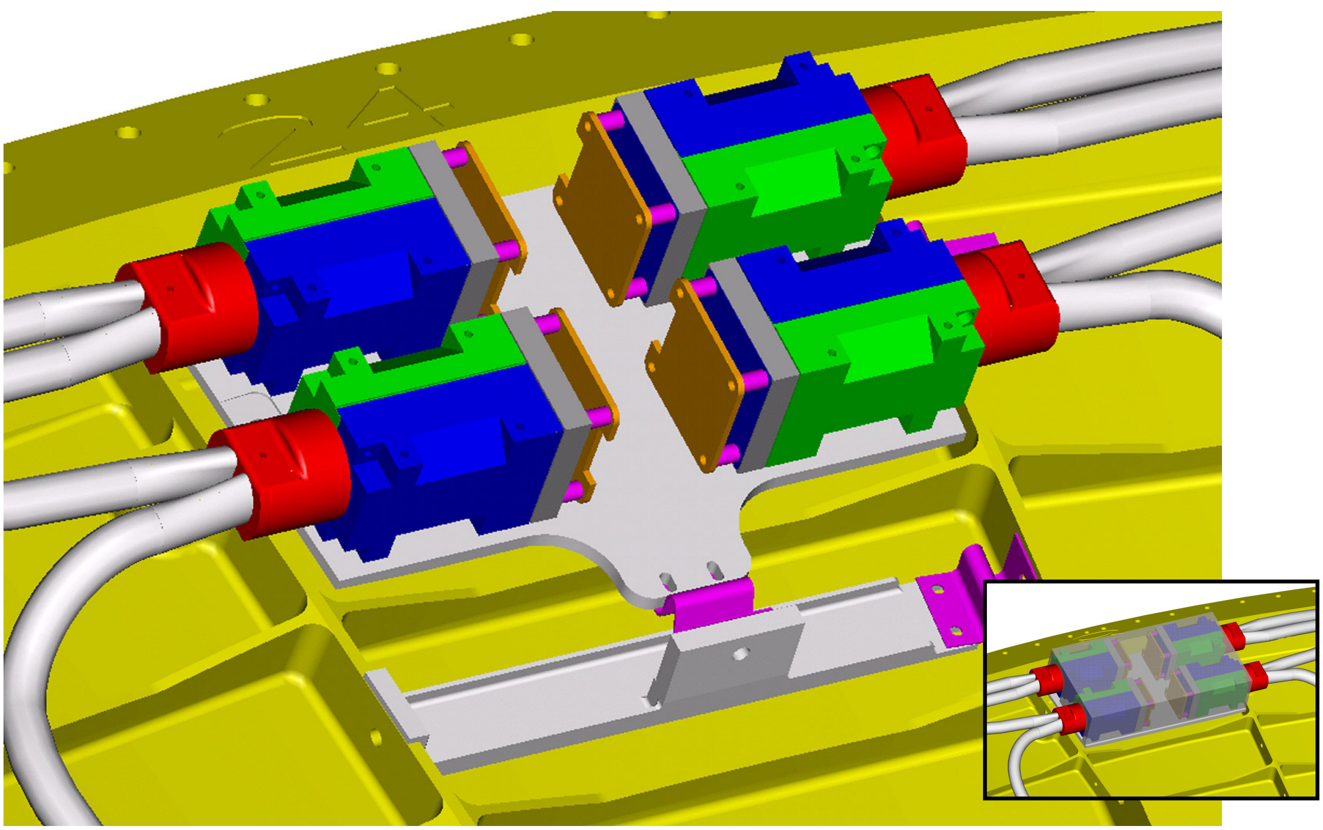

Figure 5.8-9 PMTs Mounted to the Conical Flange (Inset: PMT Set with Cover shown schematically)

The PMTs that record the light signals from the ACC panels are identical to the PMTs used in the TOF system (Hamamatsu R5946) (Figures 5.8-10 & 5.8-11). The ACC PMTs have to work in a moderate (~1.2 kG) magnetic field at locations on the top and bottom of the Vacuum Case, approximately 40 cm from the racetrack coils. To minimize the impact of this, the PMTs are oriented with their axes parallel to the stray magnetic field.

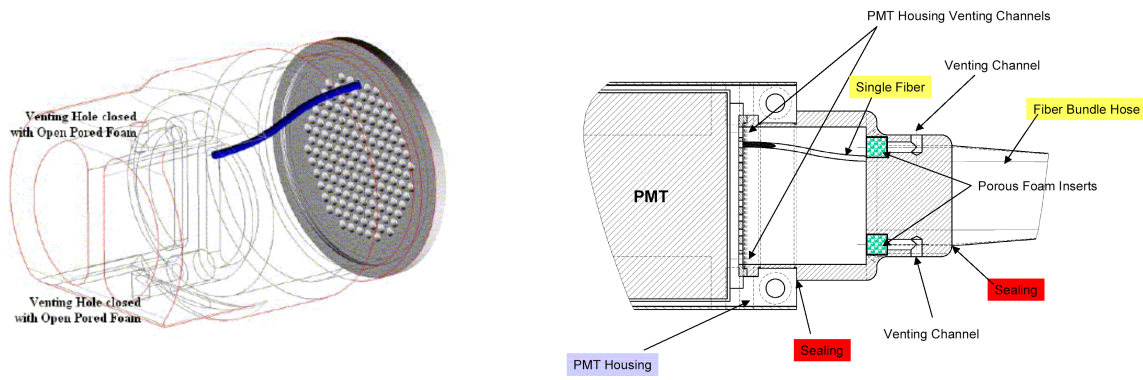

Figure 5.8-10 ACC PMT Fiber Optic Interface Construction

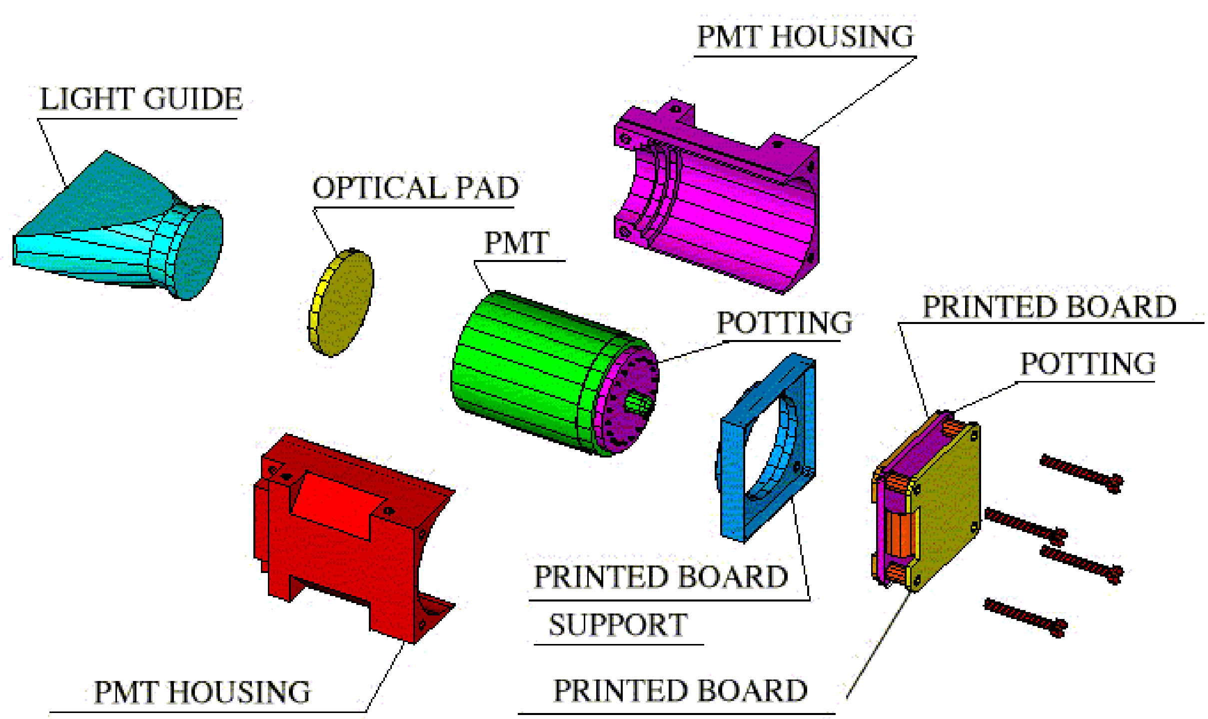

Figure 5.8-11 Basic Construction of ACC PMT is Similar to TOF Except for Fiber Optic Interface in lieu of Light Guide

The ACC also utilizes the same avionics architecture as the TOF to detect and interpret the passage of particles through the scintillating panels. Cables from the ACC PMTs are routed out from under the MLI covering the conical flanges to high voltage sources the S-Crate (Figure 5.8.12).

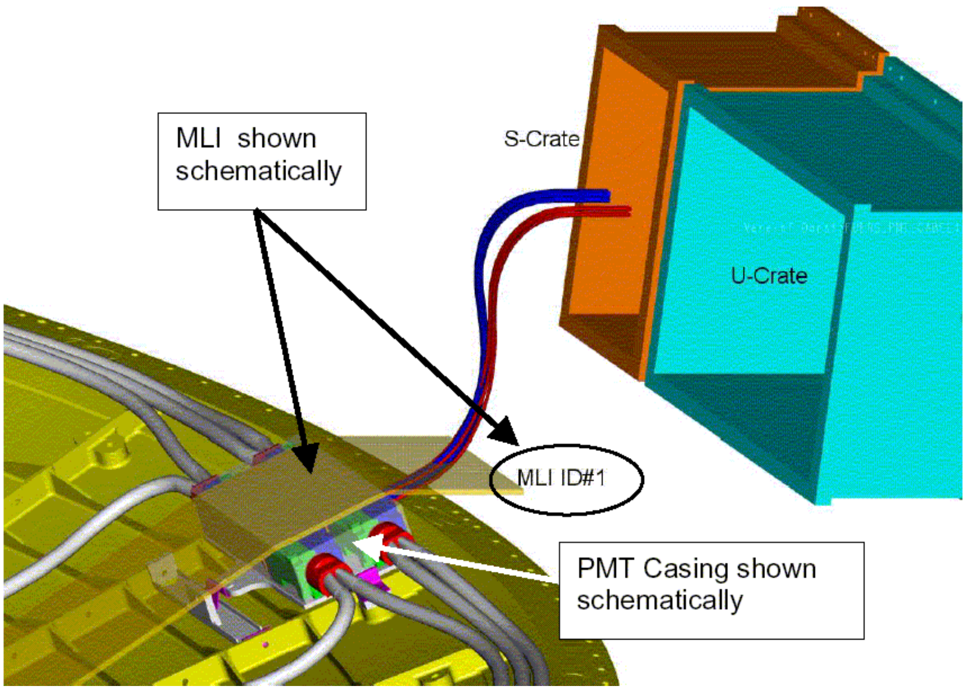

Figure 5.8-12 Wiring of the ACC PMTs to the S-Crate