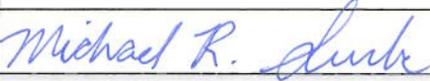


| PAYLOAD FLIGHT HAZARD REPORT | | a. NO: | AMS-02-F16 |
|---|--|--|---|
| b. PAYLOAD | Alpha Magnetic Spectrometer-02 (AMS-02) | | c. PHASE: III |
| d. SUBSYSTEM: | Optics, Materials | e. HAZARD GROUP: | Impact/Collision, contamination, Injury/Illness |
| g. HAZARD TITLE: Shatterable Material Release | | f. DATE: | August 4, 2010 |
| | | i. HAZARD CATEGORY: | CATASTROPHIC X CRITICAL |
| h. APPLICABLE SAFETY REQUIREMENTS: NSTS 1700.7, NSTS 1700.7B ISS Addendum, 200.3, 206, 209, 215 | | | |
| j. DESCRIPTION OF HAZARD: The breakage of glass or other frangible material can results in contamination/damage of space suits (EMU, Orlan) or the generation of debris of sufficient size to cause a released mass hazard. | | | |
| k. CAUSES | | | |
| (list) 1. Release of shatterable materials | | | |
| o. APPROVAL | PAYLOAD ORGANIZATION | SSP/ISS | |
| PHASE I | | | |
| PHASE II | | | |
| PHASE III |  TREN T MARTIN 8/5/10 |  Michael R. Durk 8/6/10 | |

A.16-1

JSC 49978C

| | | | |
|---|---|-----------|----------------|
| PAYLOAD FLIGHT HAZARD REPORT | | a. NO: | AMS-02-F16 |
| b. PAYLOAD | Alpha Magnetic Spectrometer-02 (AMS-02) | c. PHASE: | III |
| 1. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS) | | | OPS CONTROL |
| 1. CAUSE: Shatterable Material Release | | | |
| <p>1.1 CONTROL: The TOF and ACC Photomultiplier Tubes (PMT) are vacuum tubes, and have a reduced interior pressure. All photomultiplier tubes are sealed within PMT housings with potting used to protect the high voltage circuitry also preventing any potential broken glass from the rear of the assembly. The glass body of the PMT is covered with conductive paint and a protective coating that will protect and contain the glass in the event of a breakage. The glass front of the PMTs is covered with a polymer optical coupling/pad that will contain any fragments and preclude migration of glass. The PMTs are enclosed by an aluminum housing to additionally contain any fragments and preclude migration of fragments. Beyond the optical coupling/pad is the PMT support and the light guides that are sealed to the TOF PMT housing and within the housing for the ACC light guides. Additionally, an ACC PMT is sealed within a cover that is vented through a filter.</p> <p>1.1.1 SVM: Review of Design.</p> <p>1.1.2 SVM: Inspection of as built hardware.</p> <p>1.1.3 SVM: Qualification of TOF & ACC PMT designs (vibration testing).</p> <p>1.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0016, "AMS-02 Photomultiplier Tube Safety Controls," dated April 3, 2009</p> <p>1.1.2 STATUS: Closed. Review of LTOF, UTOF and ACC Acceptance Data Package by Jacobs AMS-02 Project Manager confirms inspections documented. Confirmed in email "PMT Review" sent October 6, 2009 From John C. Tutt to Leland D Hill. ADPs on file in AMS-02 Project Archive.</p> <p>1.1.3 STATUS: Closed. ACC PMT Vibration Testing has been documented in the ACC ADP to validate PMT vibrational design compatibility. ADP Posted March 9, 2009 to AMS-02 Project Archive.</p> | | | |
| <p>1.2 CONTROL: The RICH and ECAL Photomultiplier Tubes (PMT) are vacuum tubes, and have a reduced interior pressure. All photomultiplier tubes are sealed within PMT housings with potting used to protect the high voltage circuitry and preventing any potential release from the rear of the assemblies. The glass body of the PMT is covered with conductive paint and a protective coating that will protect and contain the glass in the event of a breakage. The glass front of the PMTs is covered with a polymer optical coupling/pad that will contain any fragments. The ECAL front face is additionally optically sealed to the ECAL lead optical fiber sandwiches to preclude any release path. The RICH polymer optical coating is compressed by the light guides held in place with nylon wires.</p> | | | |

A.16-2

JSC 49978C

| PAYLOAD FLIGHT HAZARD REPORT | | a. NO: AMS-02-F16 |
|-------------------------------------|---|-------------------|
| b. PAYLOAD | Alpha Magnetic Spectrometer-02 (AMS-02) | c. PHASE: III |
| | <p>1.2.1 SVM: Review of Design.</p> <p>1.2.2 SVM: Inspection of as built hardware.</p> <p>1.2.3 SVM: Qualification of PMT designs (vibration testing).</p> <p>1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0016, "AMS-02 Photomultiplier Tube Safety Controls," dated April 3, 2009</p> <p>1.2.2 STATUS: Closed. Review of RICH and ECAL ADP for certification of as built design by J. C. Tutt documented in email "RICH and ECAL ADPs," dated July 12, 2010.</p> <p>1.2.3 STATUS: Closed. ECAL Vibration Testing conducted at SERMS in Terni Italy November/December 2003, reported successful results to AMS-02 Collaboration on January 08, 2004 by Catherine Adloff.</p> | |
| | <p>1.3 CONTROL: All fiber optics cables (glass and polymer) are constructed to retain fibers within the cables and connectors by bonding the fibers or by sealing the end of the cables. Use of fiber optic cables are within the TAS and avionics integration hardware.</p> <p>1.3.1 SVM: Review of Design.</p> <p>1.3.2 SVM: Inspection of as built hardware.</p> <p>1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0025, "Integration Cables Shatterable Materials Containment," dated May 4, 2009. "AMS-02 Tracker Alignment Control System (TAS)... response to information request #51..." From W. Wallraff, RWTH Aachen, November 30, 2004</p> <p>1.3.2 STATUS: Close to SVTL. NOTE: ESCG Internal email summarizing review of ADPs for TAS, ECAL and ACC for proper design of the fiber optics cables. Email between John C. Tutt (AMS-02 ESCG Project Manager) and Leland D. Hill (AMS-02 Safety Engineer) October 8, 2009, titled "TAS ADP." ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, "TAS Inspection," dated July 15, 2010. ADPs in Project File. Verification open pending KSC integration fiber optic cables inspection after final installation.</p> | |
| | <p>1.4 CONTROL: The ACC fiber optic connectors must distribute the fibers (non-glass, non-frangible) to specific connector locations from the ACC panel cables ("Y" connector) and to the ACC PMT. The connectors utilize a free volume to route the individual fibers. This free volume is vented through filters to contain any possible broken fibers.</p> <p>1.4.1 SVM: Review of Design.</p> <p>1.4.2 SVM: Inspection of as built hardware.</p> | |

A.16-3

JSC 49978C

A.16-4

| PAYLOAD FLIGHT HAZARD REPORT | | a. NO: AMS-02-F16 |
|---|---|-------------------|
| b. PAYLOAD | Alpha Magnetic Spectrometer-02 (AMS-02) | |
| <p>1.4.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.</p> <p>1.4.2 STATUS: Closed. ACC Acceptance Data Package, Posted March 9, 2009 to AMS-02 Project ADP repository.</p> | | c. PHASE: III |
| <p>1.5 CONTROL: Fiber optics are used within the Tracker Laser Alignment System laser source boxes that are contained within the structure of the box and a simple sheath and the 50 micron sized box vents preclude the release of any possible generation of glass particulates that get by fiber optics covering.</p> <p>1.5.1 SVM: Review of Design.</p> <p>1.5.2 SVM: Inspection of as built hardware.</p> <p>1.5.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.</p> <p>1.5.2 STATUS: Closed. TAS Acceptance Data Package, Sonia Natalie, October 8, 2009 and confirmation of final construction inspection by Prof. em. Dr. Klaus Luebelsmeyer, RWTH Aachen on 11/4/2009. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, "TAS Inspection," dated July 15, 2010</p> | | |
| <p>1.6 CONTROL: The Tracker Silicon Wafers are glued to a flexible metalized film that will retain fractured pieces. The film is Upilex which is supported (adhered to) on 5 mm Airex Foam. The foam is glued to a carbon fiber layer which is glued to the aluminum ladders that support the sensors as a whole. In addition, the light tight air vents have been fitted with a mesh screen to preclude the release of any particles.</p> <p>1.6.1 SVM: Review of Design.</p> <p>1.6.2 SVM: Inspection of as built hardware.</p> <p>1.6.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009. ESCG Memorandum ESCG-4295-ADV SY-MEMO-0017, "New Tracker Planes on AMS-02," dated July 12, 2010</p> <p>1.6.2 STATUS: Closed. Installation of Tracker Silicon Wafers and light tight air vents visually confirmed by a designated verifier (DV), T. Martin on September 25, 2007 and documented in correspondence to Safety Engineer on that same date. Tracker Planes 1N and 6 visually confirmed by ESCG/P. Mott, DV, confirmed by email "Verification Activity Request", dated 7/26/2010</p> | | |

JSC 49978C

| PAYLOAD FLIGHT HAZARD REPORT | | a. NO: AMS-02-F16 |
|--|---------------|-------------------|
| b. PAYLOAD | c. PHASE: III | |
| <p>1.7 CONTROL: The Laser Diodes and optics are mounted within the Tracker Laser Alignment System laser source boxes and are contained within the structure of the box. Fiber optics within the box are contained within jackets and are contained by structure of the enclosure in the event of breakage.</p> <p>1.7.1 SVM: Review of Design.</p> <p>1.7.2 SVM: Inspection of as built hardware.</p> <p>1.7.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.</p> <p>1.7.2 STATUS: Closed. TAS Acceptance Data Package, Sonia Natalie, October 8, 2009 and confirmation of final construction inspection by Prof. em. Dr. Klaus Luebelsmeyer, RWTH Aachen on 11/4/2009.</p> | | |
| <p>1.8 CONTROL: The ACC imbeds a polymer (non-glass, non-frangible) fiber optics in the BICRON BC 414 scintillator panels using optical cement (BC 600) to retain the fibers in place.</p> <p>1.8.1 SVM: Review of Design.</p> <p>1.8.2 SVM: Inspection of as built hardware.</p> <p>1.8.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.</p> <p>1.8.2 STATUS: Closed. ACC Acceptance Data Package, Posted March 9, 2009 to AMS-02 Project ADP repository.</p> | | |
| <p>1.9 CONTROL: The ECAL is constructed using layers of grooved lead (lead-antimony alloy) with doped polystyrene fibers (PolHiTech 0046) strands (non-glass, non-frangible) placed in the groves. The layers of lead and the fibers are assembled together using optical cement. The fibers are retained by the tight tolerance construction and adhesive.</p> <p>1.9.1 SVM: Review of Design.</p> <p>1.9.2 SVM: Inspection of as built hardware.</p> <p>1.9.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.</p> <p>1.9.2 STATUS: Closed. ECAL Acceptance Data Package, Posted March 9, 2009 to AMS-02 Project ADP repository.</p> | | |

A.16-5

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| PAYLOAD FLIGHT HAZARD REPORT | | a. NO: AMS-02-F16 |
|------------------------------|---|-------------------|
| b. PAYLOAD | Alpha Magnetic Spectrometer-02 (AMS-02) | c. PHASE: III |
| A.16-6 | <p>1.10 CONTROL: RICH aerogel and sodium fluoride blocks are adhered to the “upper” structure of the RICH, a volume which is vented through filters. The aerogel and sodium fluoride blocks are covered by a Plexiglas plane that is sealed to the block support structure. This volume is vented through filters to contain released particles.</p> <p>1.10.1 SVM: Review of Design.</p> <p>1.10.2 SVM: Inspection of as built hardware.</p> <p>1.10.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, “Frangible Materials in the AMS-02 Detectors,” dated April 7, 2009.</p> <p>1.10.2 STATUS: Closed. RICH ADP/ Ciemat Log Sheet/Historical Record for RICH Aerogel Assy, Assembly P/N 11-RICSYS-10.000 dated June 19, 2007</p> | |
| | <p>1.11 CONTROL: The construction of the Star Tracker Lenses and filters are provides vent paths around the optics to preclude pressure loading of the optical components. The lenses are secured using standard optics interfaces without glue or potting compounds. No optical component of the Star Tracker exceeds 0.25 pounds; the heaviest glass component is approximately 55 grams.</p> <p>1.11.1 SVM: Star Tracker Lenses will be vibration tested to flight levels and inspected for damage.</p> <p>1.11.2 SVM: Star Tracker Lenses will be pressure decay tested to confirm venting performance without damage or release.</p> <p>1.11.3 SVM: Review of Design to confirm mass of optical components.</p> <p>1.11.1 STATUS: Closed. Vibration Test Report, VIBRPT30_S0100R_24JAN2K6.doc, dated 26 January 2006, from Laboratorio per lo Studio degli Effetti delle Radiazioni sui Materiali per lo Spazio, confirms no damage to optics or released masses.</p> <p>1.11.2 STATUS: Closed. Report AMIF/LETV/1/A, Issue 1, dated 23 October 2006 from Center for Advanced Research in Space Optics, documents the successful thermal vacuum testing of the lenses without damage or released masses.</p> <p>1.11.3 STATUS: Closed. Communications from Paolo Trampus, Star Tracker Project, confirmed mass of optical components individually under 0.25 pounds. Email dated 31 March 2006 addressed to AMS-02 Safety Engineer Leland Hill, Titled “Safety Issue”. File transmitted to AMS-02 Safety Verification Records.</p> | |
| | 1.12 CONTROL: The construction of the AMS-02 does not present any frangible material exposure to established EVA | |

| | | | |
|--|---|-----------|------------|
| PAYLOAD FLIGHT HAZARD REPORT | | a. NO: | AMS-02-F16 |
| b. PAYLOAD | Alpha Magnetic Spectrometer-02 (AMS-02) | c. PHASE: | III |
| <p>translation paths or work sites. Neither EVA Crew contact or EVA tool contact can result in the generation of frangible material debris.</p> <p>1.12.1 SVM: Review of AMS-02 Design to confirm no frangible materials in EVA translation paths and around EVA work sites.</p> <p>1.12.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0043, "EVA Shatterable Material Release," dated July 1, 2009.</p> | | | |
| Notes: | | | |

ACRONYMS

| | |
|---|--|
| °C – Degrees Centigrade (Celsius) | F – Fluoride |
| °F – Degrees Fahrenheit | Na – Sodium |
| ACC – Anti-Coincidence Counter | PFTE - Polytetrafluoroethylene |
| AMS-02 – Alpha Magnetic Spectrometer - 02 | PMT – Photomultiplier Tube |
| CFRC – Carbon Fiber Reinforced Composite | RICH – Ring Imaging Cherenkov (detector) |
| ECAL – Electromagnetic Calorimeter | TOF – Time of Flight |
| EMU – Extravehicular Mobility Unit | UMA – Umbilical Mating Assembly |
| EVA – Extravehicular Activity | DV – Designated Verifier |

A.16-7

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A.16-8

| Frangible Material Source | Application | Description | Control | |
|------------------------------|--|--|--|---|
| Photo Multiplier Tubes (PMT) | Electromagnet Calorimeter (ECAL) | Hamamatsu R7600-00-M04 | Potted into PMT housing with glass front covered with optical coupling/pad. | Vibration testing of design. Thermo-Vacuum Testing |
| Photo Multiplier Tubes (PMT) | Ring Image Cherenkov Counter (RICH) | Hamamatsu R7600-00-M16 | Potted into PMT housing with glass front covered with optical coupling/pad. | Vibration testing of design. Thermo-Vacuum Testing |
| Photo Multiplier Tubes (PMT) | Time of Flight (TOF) Upper and Lower Untis | Hamamatsu R5946 | Potted into PMT housing with glass front covered with optical coupling/pad. | Vibration testing of design. Thermo-Vacuum Testing |
| Photo Multiplier Tubes (PMT) | Anti-Coincidence Counter (ACC) | Hamamatsu R5946 | Potted into PMT housing with glass front covered contained by fiber optic connector that is vented through filter foam. Four PMT are enclosed within sealed volumes with filtered vents. | Vibration testing of design. Thermo-Vacuum Testing |
| Silicon Wafers | Tracker | Silicon wafers are bonded to metalized Upilex film which is bonded to 5 mm AIREX foam which is bonded to a carbon fiber layer and finally to a 5 mm aluminum ladder. | Silicon is adhered and retained to the Upilex film. | Vibration testing of design. Thermo-Vacuum Testing |
| Laser Tracker Optics | Tracker Alignment | Reflective interface to | Reflective surfaces are | Review of Design |

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A.16-9

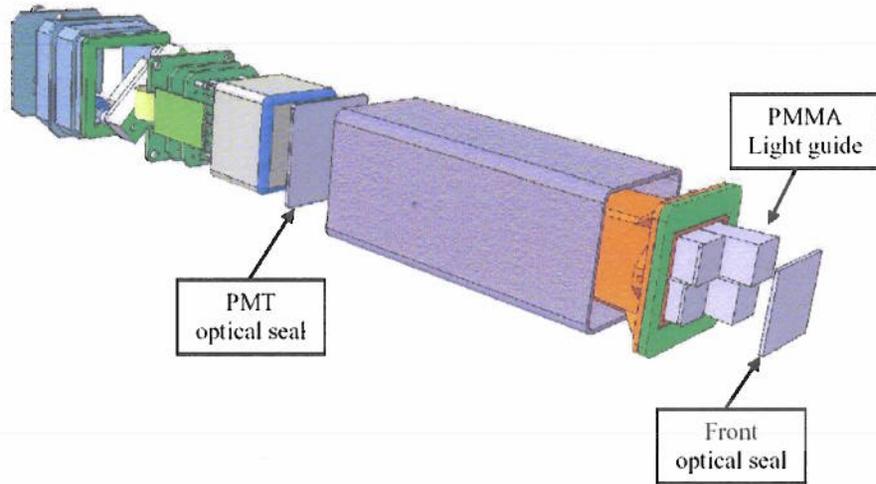
| Frangible Material Source | Application | Description | Control | |
|---------------------------------------|---------------------------------|--|---|---|
| | System | take fiber optics laser energy and directing through Tracker | glued to housing. | Inspection of as built hardware Thermal-Vacuum Testing |
| Laser Diodes, Optics and Fiber Optics | Tracker Alignment System | Laser Diodes, Splitter, fiber optics | Laser Diodes, Optics and Fiber Optics are properly mounted and contained in laser source boxes contained by structure and 50 micronvent. Fibers are cladded and jacketed. | Review of Design Inspection of As-built hardware. |
| Fiber Optics Cable | Tracker Alignment System | Fiber optics that carry photons from sensitive sensors or avionics data. | Fiber optics utilizes standard fiber optic techniques of bonding fibers/sealing cables. | Thermo-Vacuum Testing |
| Fiber Optics Cable | UMA-EVA Connector | | | |
| Fiber Optics Cable | EVA Panel to Avionics box | | | |
| Avionics | Fiber Optics data cable | | | |
| Fiber Optics Cable | Anti- Coincidence Counter (ACC) | Fiber optics collect photons from collectors to PMT | Fibers are non-frangible polymer not glass. Contained in cables. Fibers in connectors are contained by connector housing and filters in housing vents. | Review of Design Inspection of as built hardware |
| ACC Sensor Fibers | Anti-Coincidence Counter (ACC) | Strands of fiber optic collect photons from energetic radiation passing through ACC. | Fibers are polymer and not glass and non frangible. Fibers are bonded into the ACC Scintillator Panels | Review of Design Inspection of as built hardware |

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A.16-10

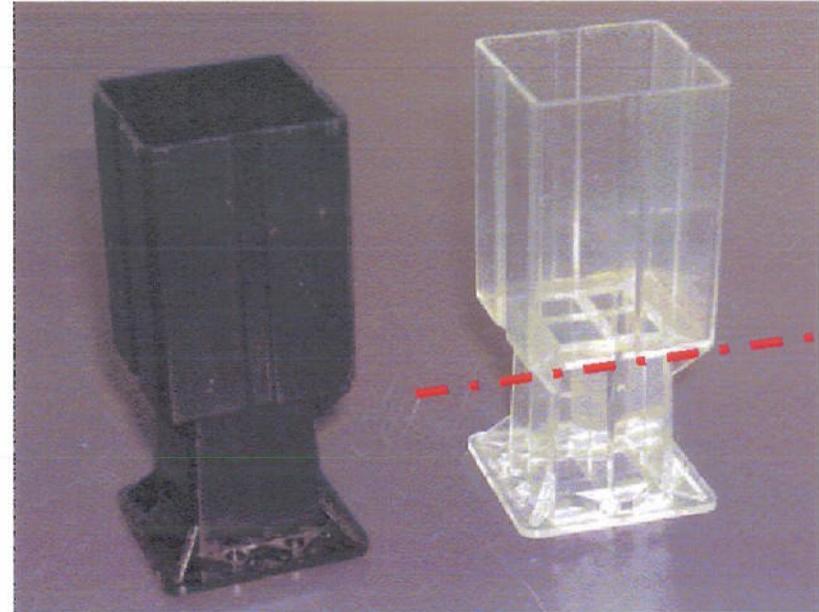
| Frangible Material Source | Application | Description | Control | |
|-----------------------------|-------------------------------------|--|--|---|
| | | | (BICRON BC 414) with Optical cement (BC 600) | |
| ECAL Sensor Fibers | Electromagnet Calorimeter (ECAL) | Strands of fiber optic collect photons from energetic radiation passing through ECAL | Fibers are polymer fibers (doped polystyrene) contained within the lead layers of the ECAL. The lead has been machined to accept the fibers. Epoxy retains the fibers and layers in place. | Review of Design Inspection of as built hardware |
| Aerogel | Ring Image Cherenkov Counter (RICH) | Silica Aerogel | Aerogel is contained within RICH Structure and plexiglass cover. Structure is vented through filters and cover is sealed in place. | Review of Design Inspection of as built hardware |
| Crystalline | Sodium Fluoride Blocks | Solid NaF Crystal | NaF is contained within RiCH Structure and plexiglass cover. Structure is vented through filters and cover is sealed in place. | Review of Design Inspection of as built hardware |
| Optics (Lenses and Filters) | Star Tracker | Standard Optical components, lenses, filters. | Star Tracker optics are vented through mounting methodology and carry no appreciable pressure load. | Vibration testing of design. Thermo-Vacuum Testing |

JSC 49978C



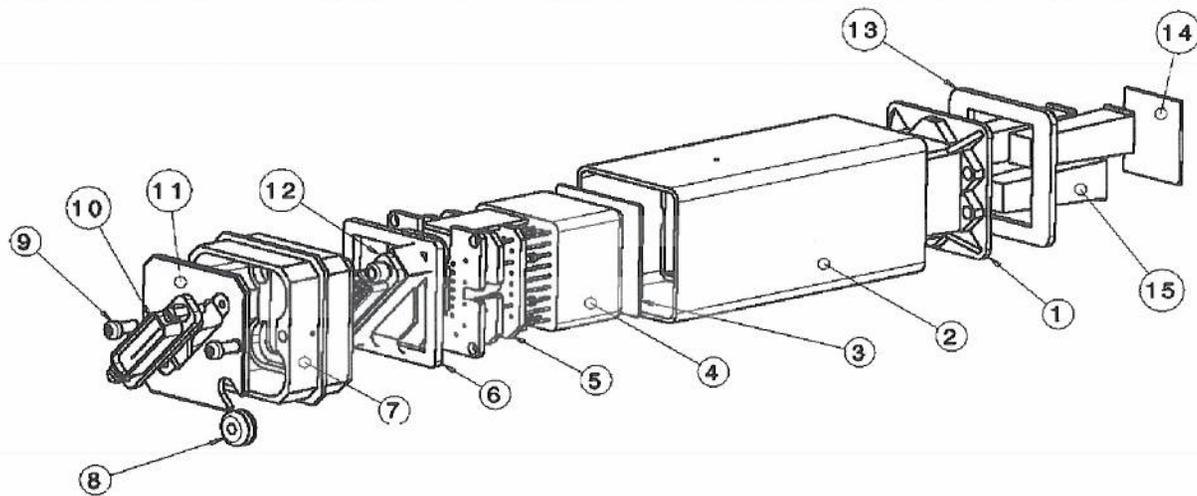
ECAL PMT Assembly

RICH is similar but uses a 4 x 4 light guide assembly and not 2 x 2 and no front optical seal.



ECAL Interior Housing Structure (dark flight, clear used for potting procedure)

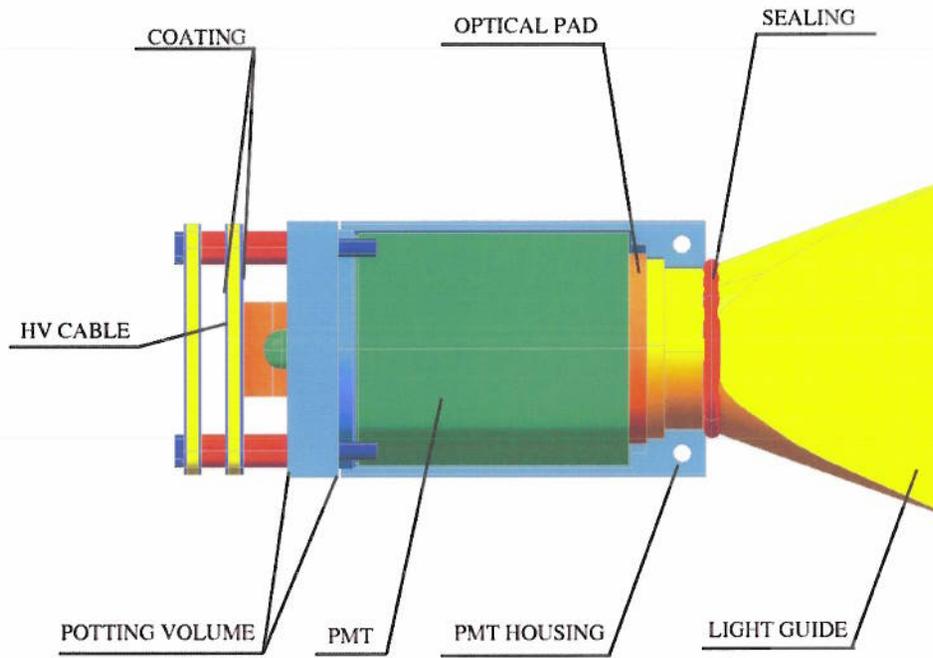
RICH uses a 4 x 4 light guide assembly and not the 2 x 2 assembly of the ECAL



| Part number | Description | Material | Processing | Mass per unit (gr.) | Exposed Surface (cm ²) | Coating |
|-------------|------------------------------|------------------------|-------------------|---------------------|------------------------------------|---------------|
| 1 | PMT Box | Black Poly carbonat | Injection | 14 | 0 | No |
| 2 | Magnetic Shielding | Soft Iron | Bending / welding | 68 | - | Nickel plated |
| 3 | PMT optical coupling | DC 93-500 | Moulding | 0.3 | 0 | No |
| 4 | Photomultiplier multi anodes | R5900U-00-M4 | Hamamatsu process | 24 | 0 | No |
| 5 | Electronics divider + EFE | PCB + Potting DC93-500 | - | 15 | 0 | DC 93-500 |
| 6 | Back seal | Therm-a-gap A274 | Cutting out | 2 | 0 | No |
| 7 | End cap | Al. 7075T7351 | CNC Milling | 9 | - | Alodine 1200 |
| 8 | Grommet | Black Silicone | Injection | 0.4 | 0 | No |
| 9 | M2.5 CHC Screw | Stainless steel 304 | Standard | 0.3 | | No |
| 10 | 25 p Connector - EIB | GLENAIR M83513/03-D11N | | 8 | 0 | |
| 11 | Connector plate | Al. 7075T7351 | CNC Milling | 4 | - | Alodine 1200 |
| 12 | 25 p Connector - FEE | GLENAIR M83513/04-D11N | | 10 | 0 | |
| 13 | Front seal + reflective foil | Therm-a-gap A274 | Cutting out | 8 | 0 | No |
| 14 | Front optical coupling | DC 93-500 | Moulding | 0.3 | 0 | No |
| 15 | Light guides | PMMA transparent | Injection | 1.9 | 0 | No |

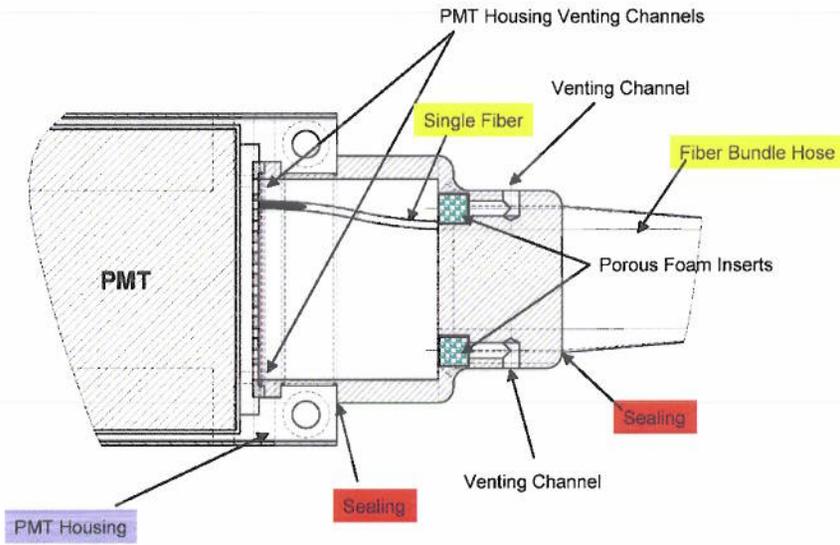
ECAL PMT Construction

RICH construction similar but uses a 4 x 4 light guide assembly, Hamamatsu R5900U-00-M16 and no front optical seal

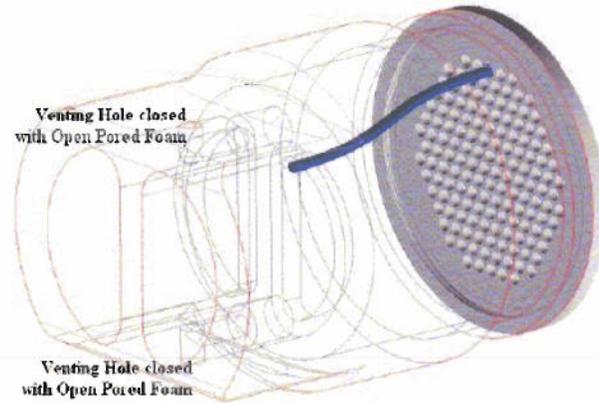


TOF Cross Section for PMT Glass Containment
ACC similar design except for Light Guide design and optical pad.
ACC Differences follow.

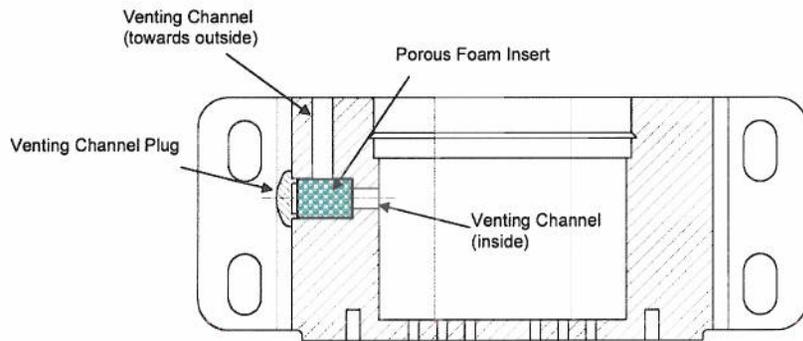
A.16-14



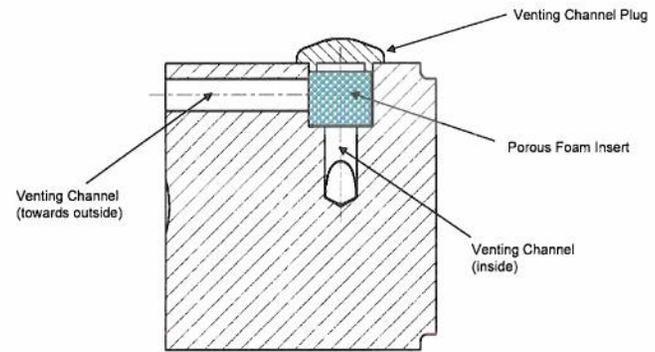
ACC PMT Construction Detail (Variance from TOF design)



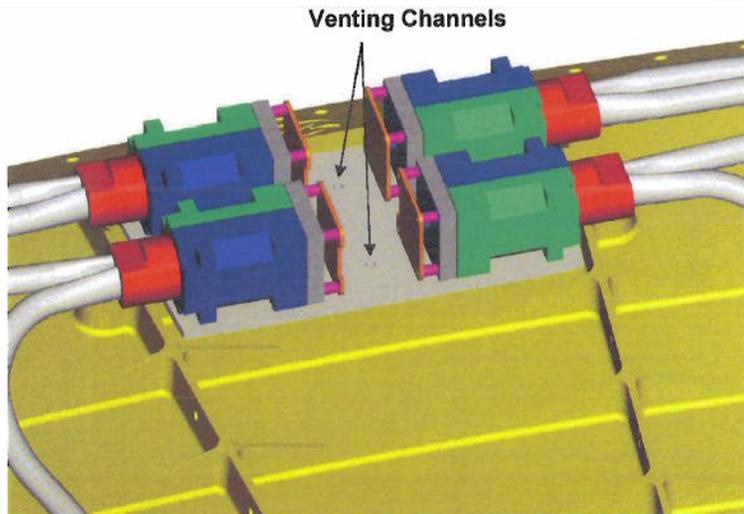
ACC PMT Fiber Routing and Vent Location



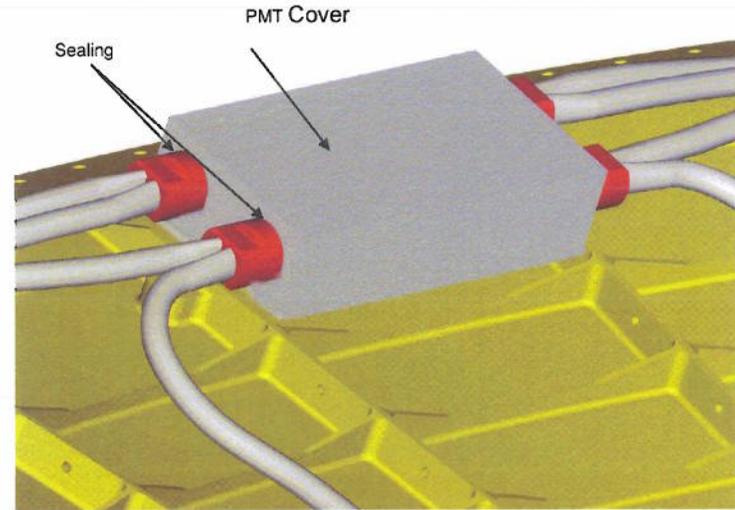
ACC PMT and Fiber Containment



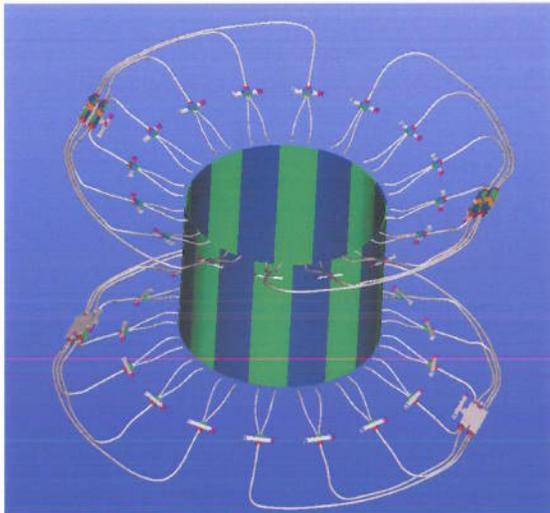
ACC Fiber "Y" Junction Connector Venting Detail



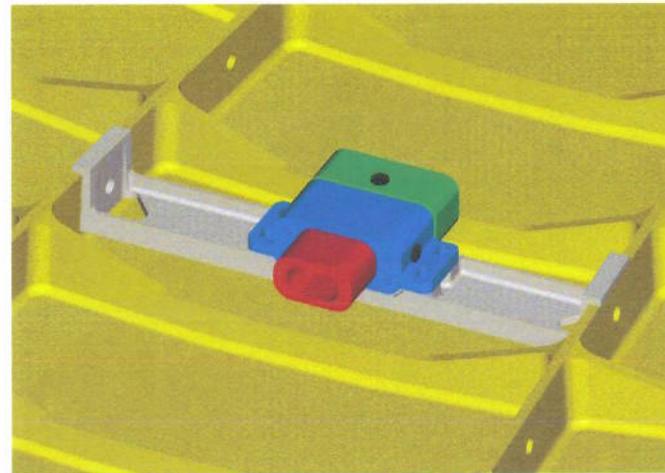
ACC PMT Mounting Enclosure (Cover Removed)



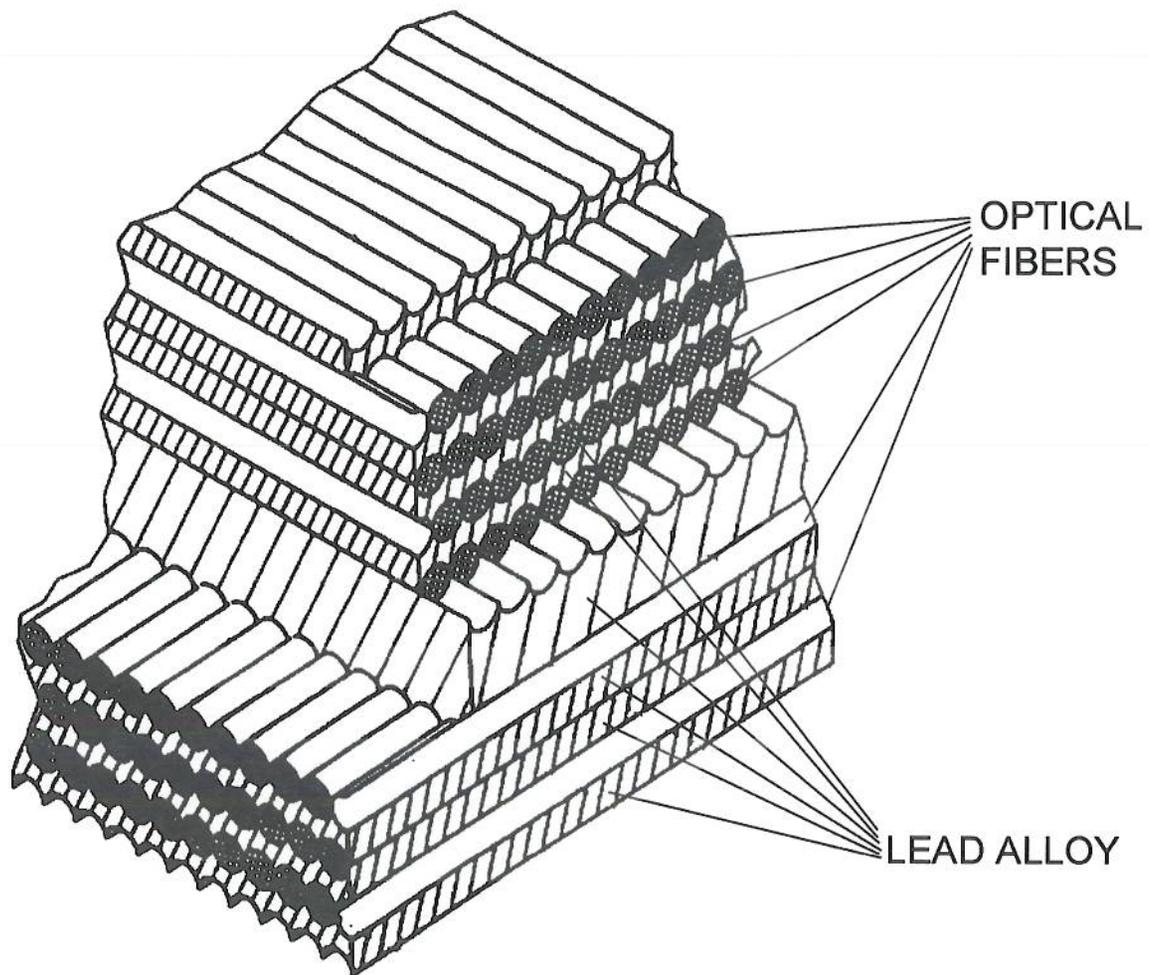
ACC PMT Mounting with Cover



ACC Fiber Optics and PMT Layout

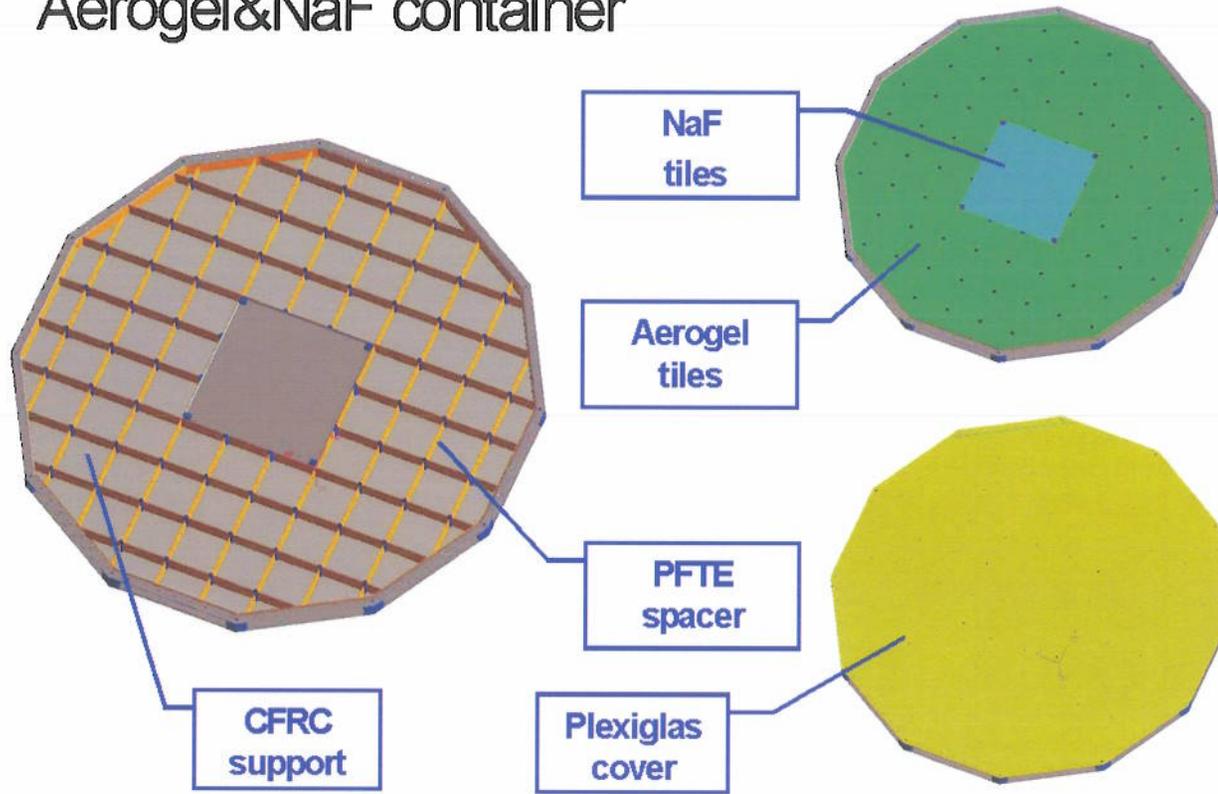


ACC Fiber Optics Coupler



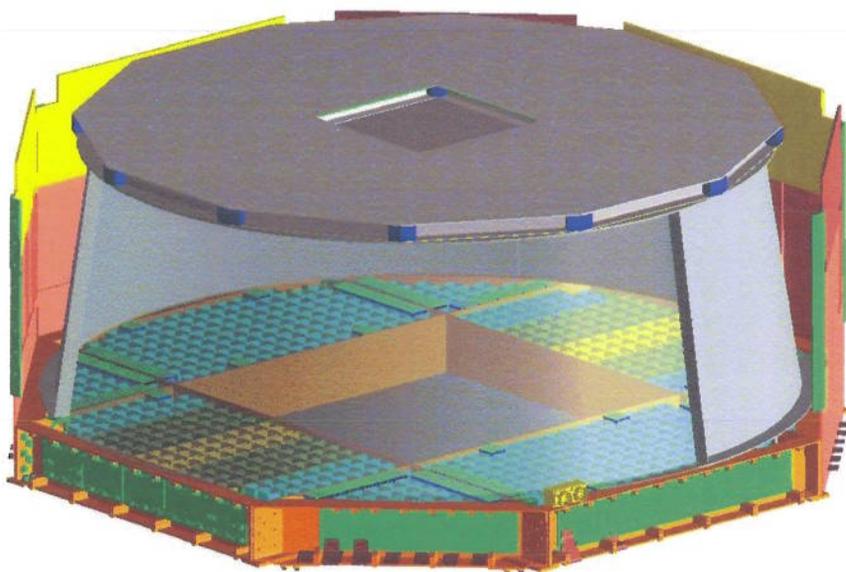
ECAL Lead-Fiber Sandwich

Aerogel&NaF container

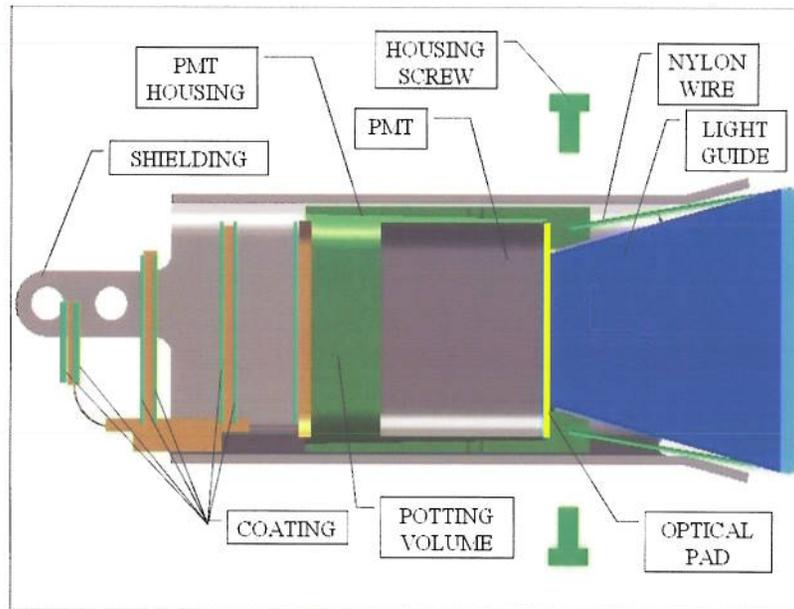


RICH Aerogel and NaF Containment

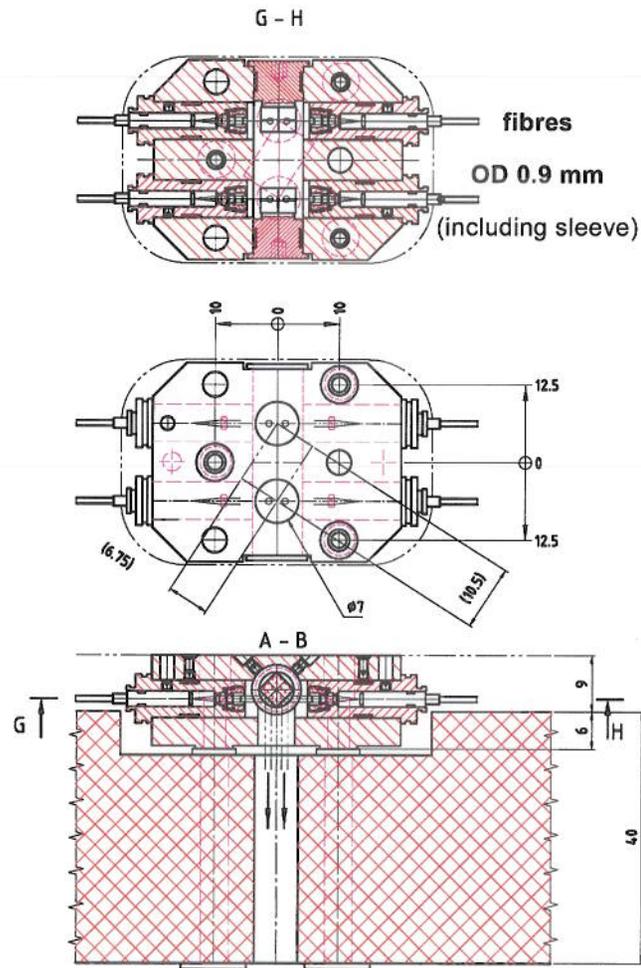
A.16-18



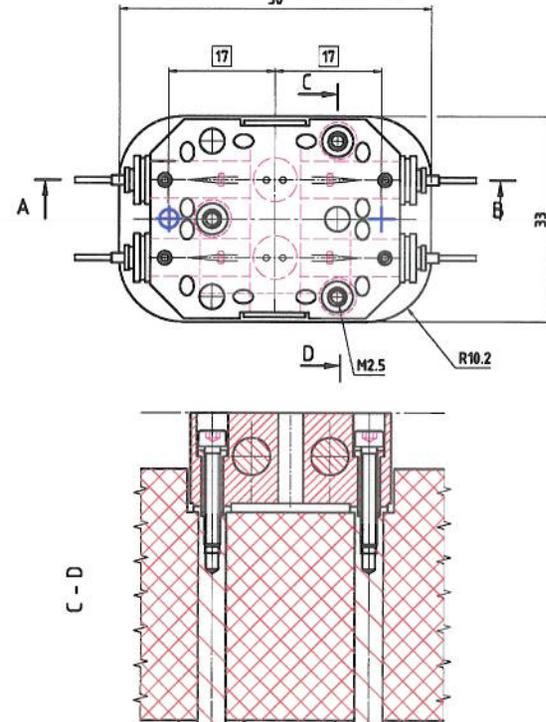
RICH Cutaway Diagram



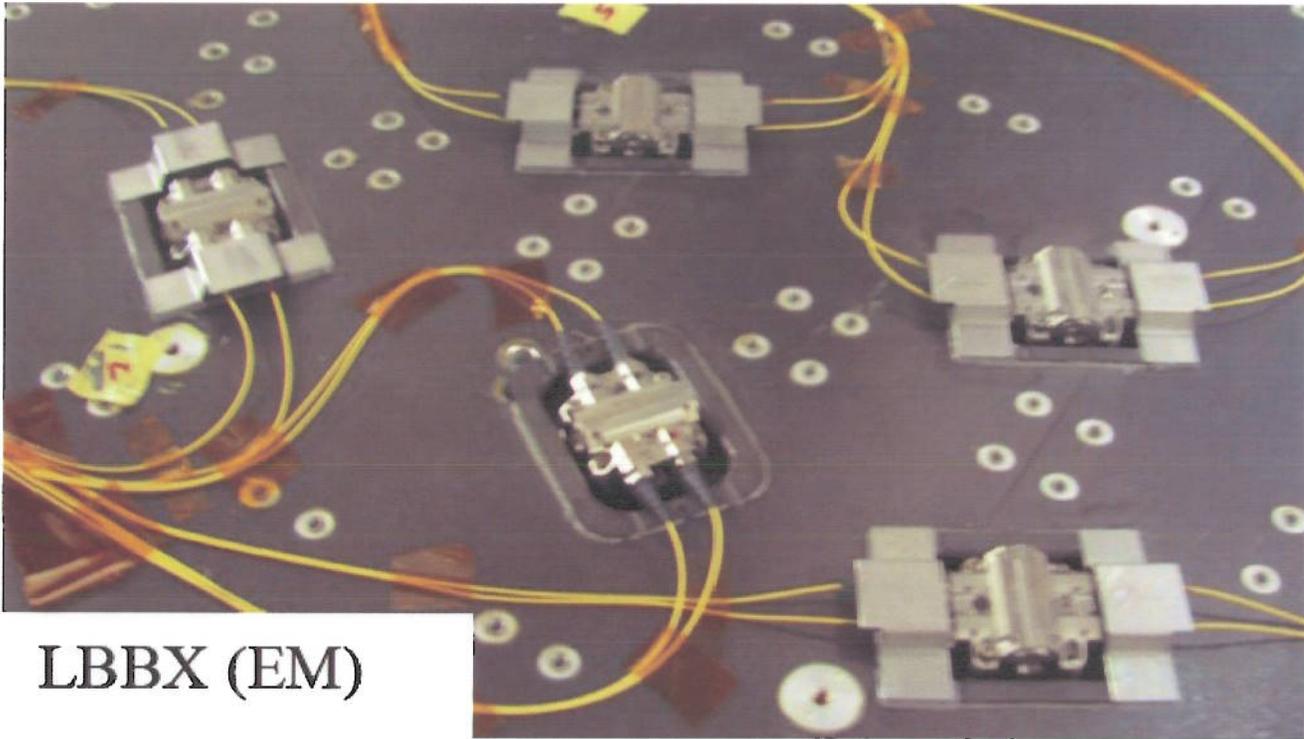
RICH PMT Construction



AMS **TAS** beamport boxes (**LBBX**)
4 fibres each
mounted on outer **tracker** plates (**1, 5**)
5 boxes / plate

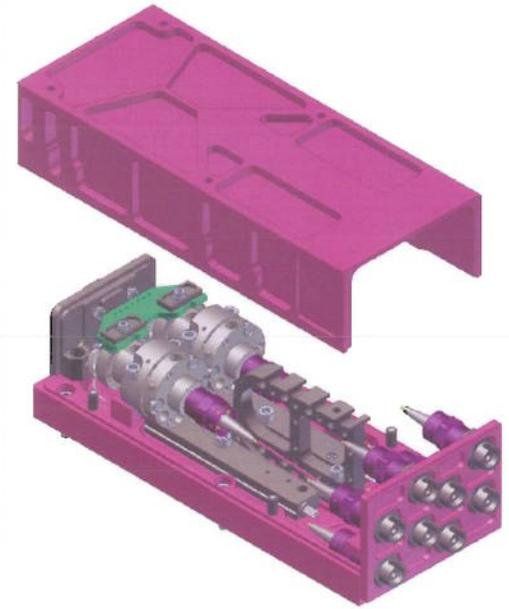
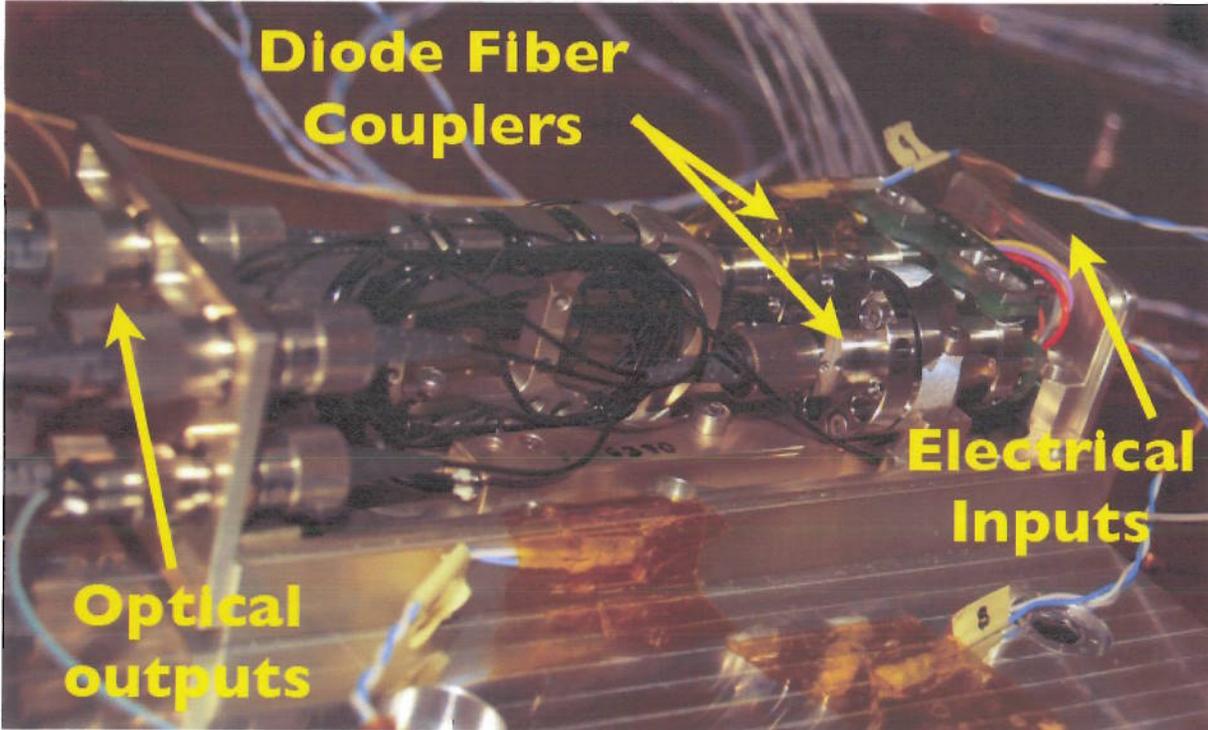


Tracker Laser Alignment System Beam Port Design

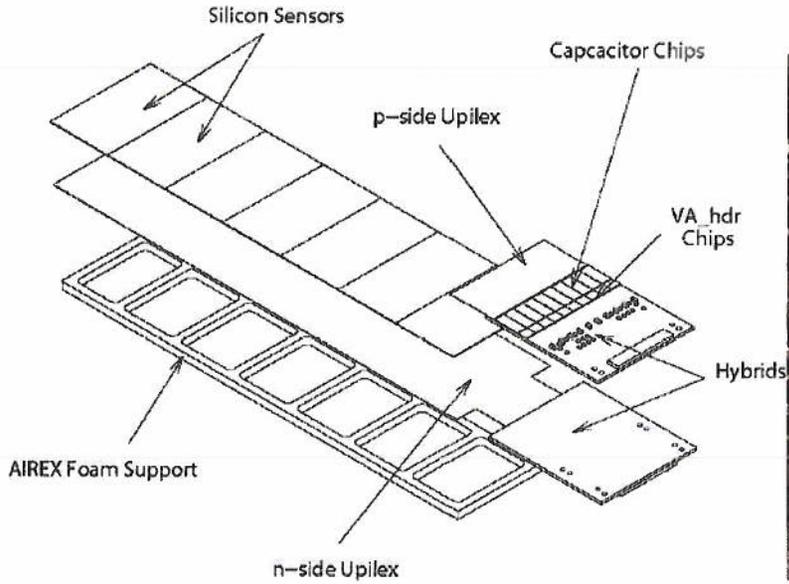


LBBX (EM)

Mountd LBBX on Tracker Plane



Tracker Alignment System Laser Fiber Coupler Box



Tracker Ladder Components

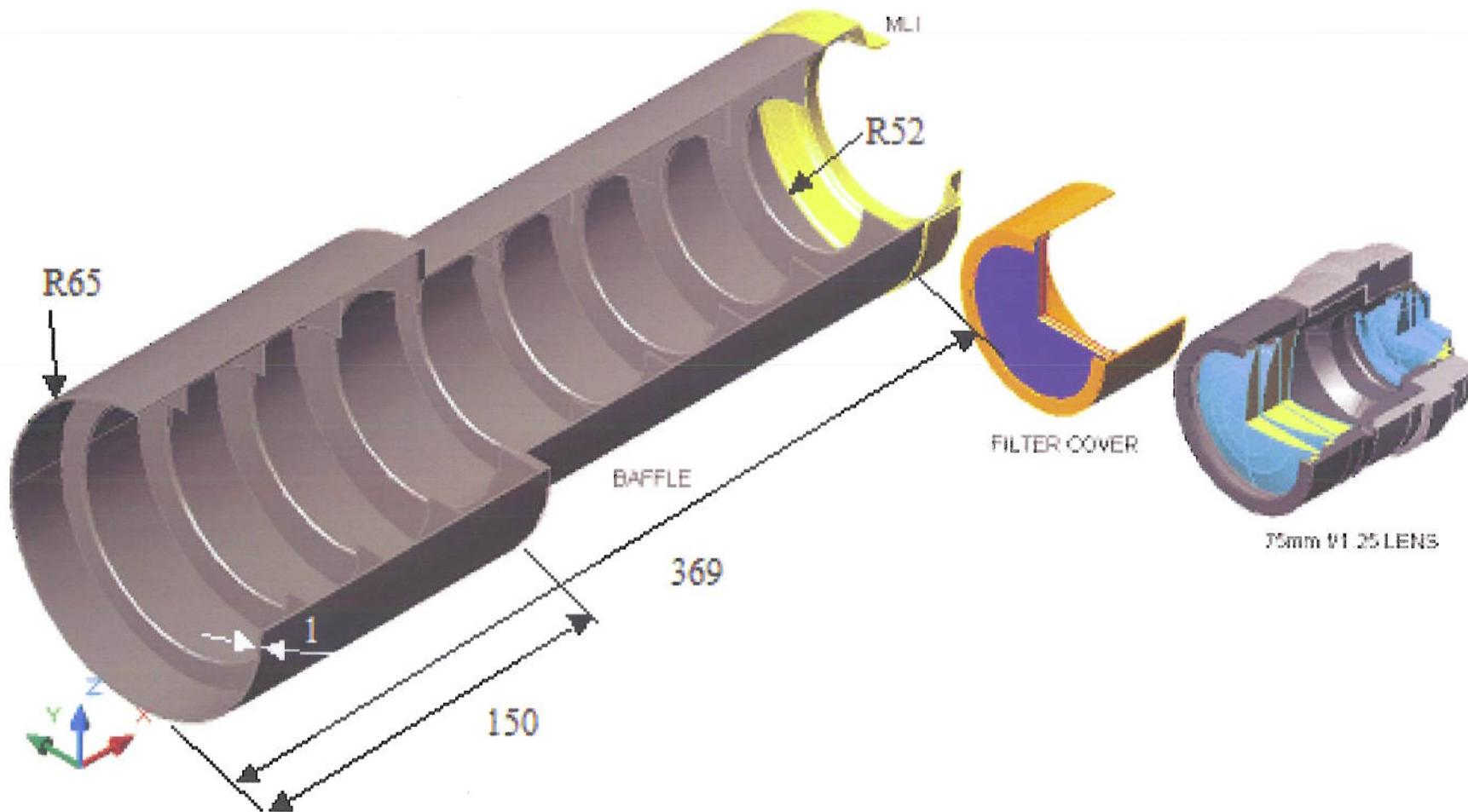


Tracker Ladders Installed, fully wrapped in shielding.

SILICON TRACKER LADDER Construction

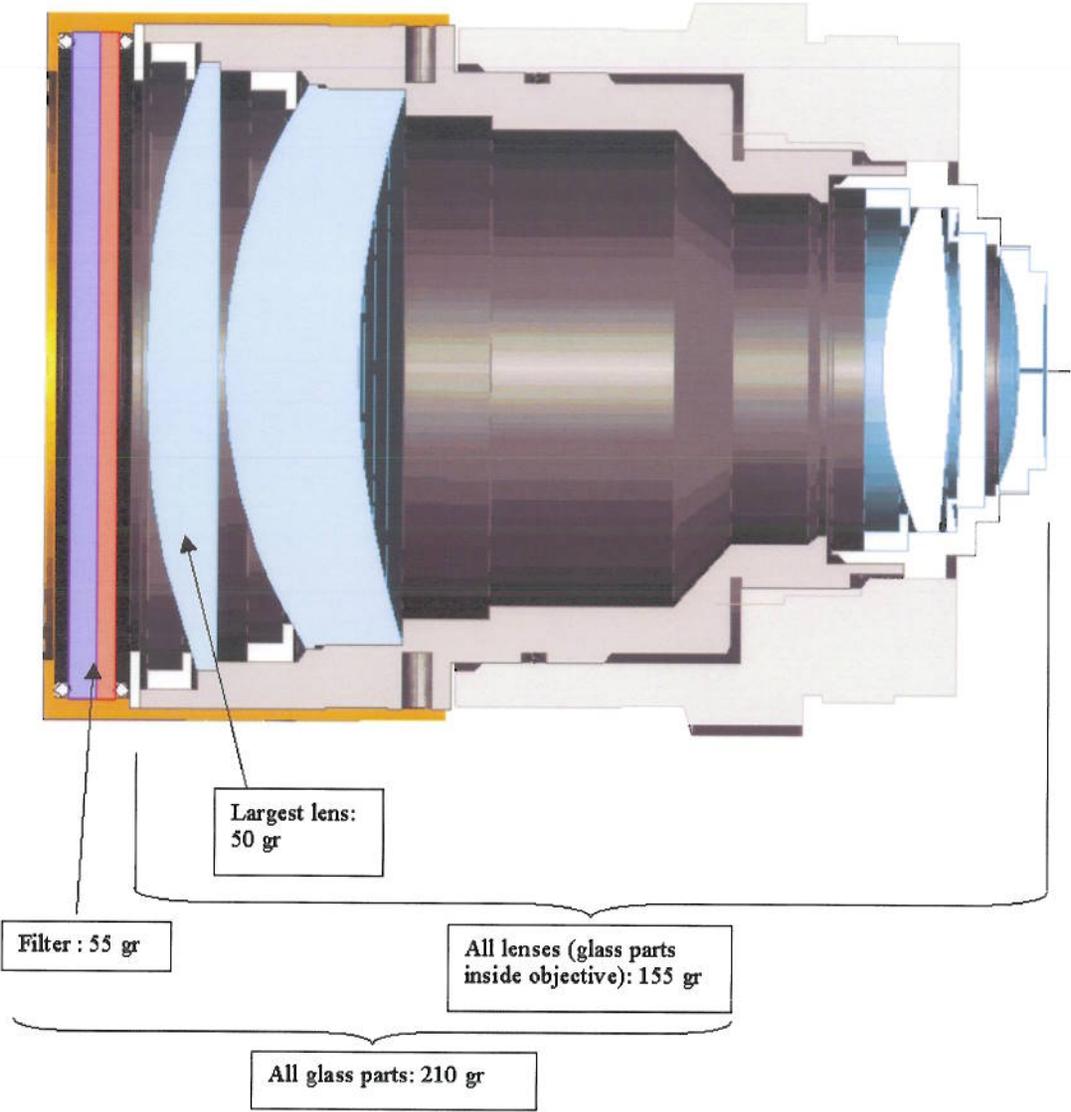
A.16-22

A.16-23



Star Tracker Optics

A.16-24



Significant Mass Characteristics of Star Tracker Optical Components