

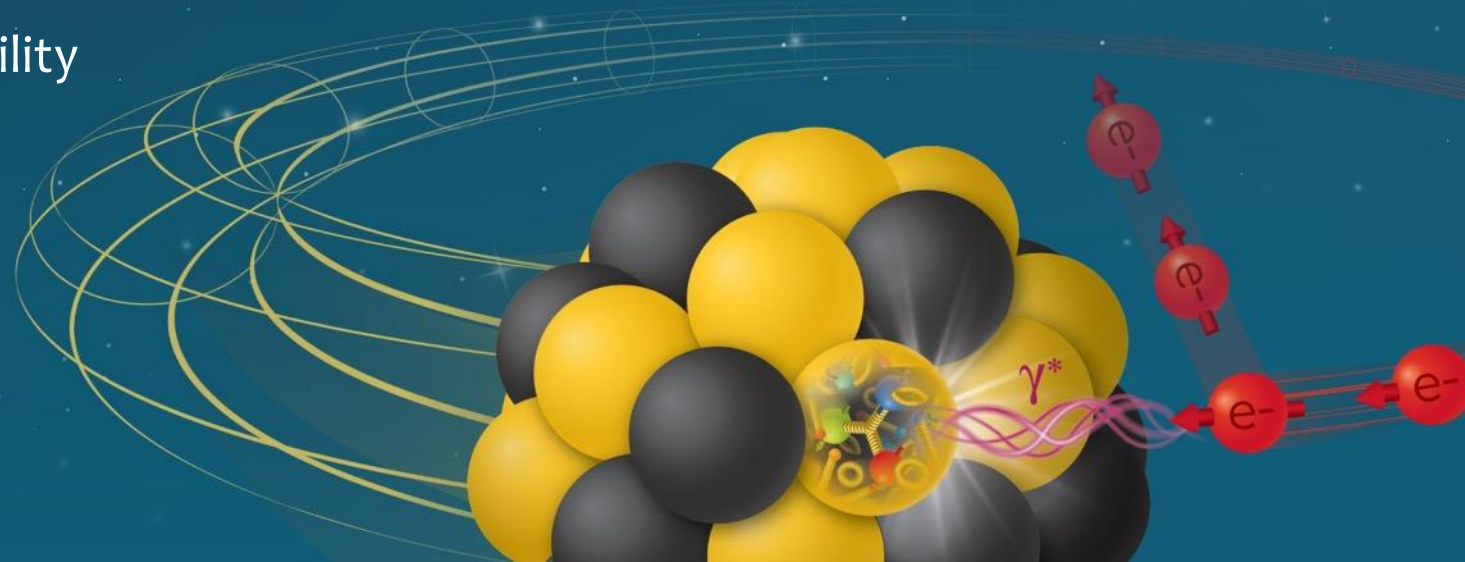
Quality Assurance Planning Documents

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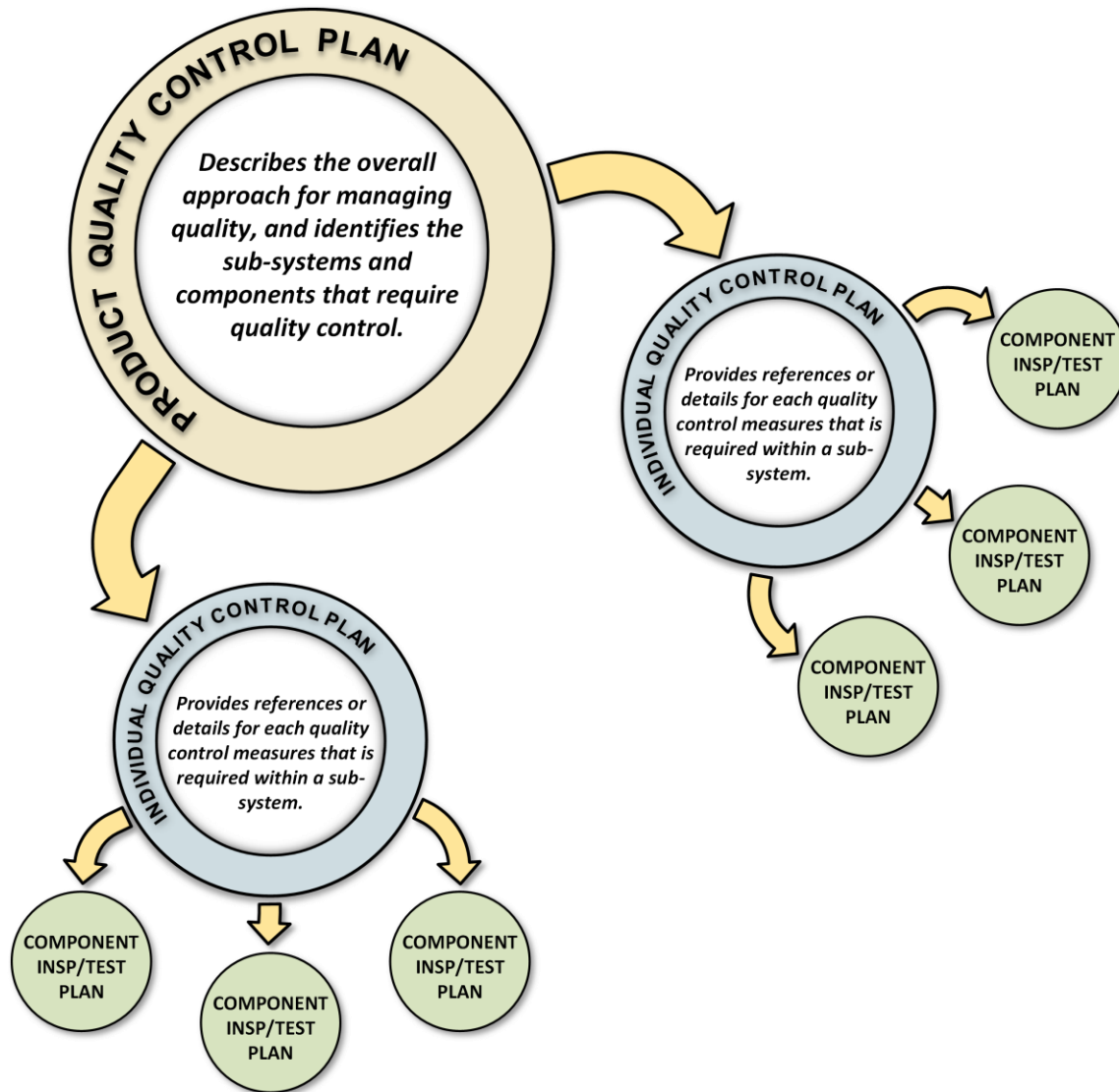
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Hierarchy of Quality Assurance Documentation



Quality assurance planning documents exist in a hierarchy, where the highest level documents provide general guidance and lower level documents become increasingly specific.

1. Product Quality Control Plan

Describes the overall approach for managing quality assurance issues, and identifies the systems, sub-systems, and components that will require quality control measures.

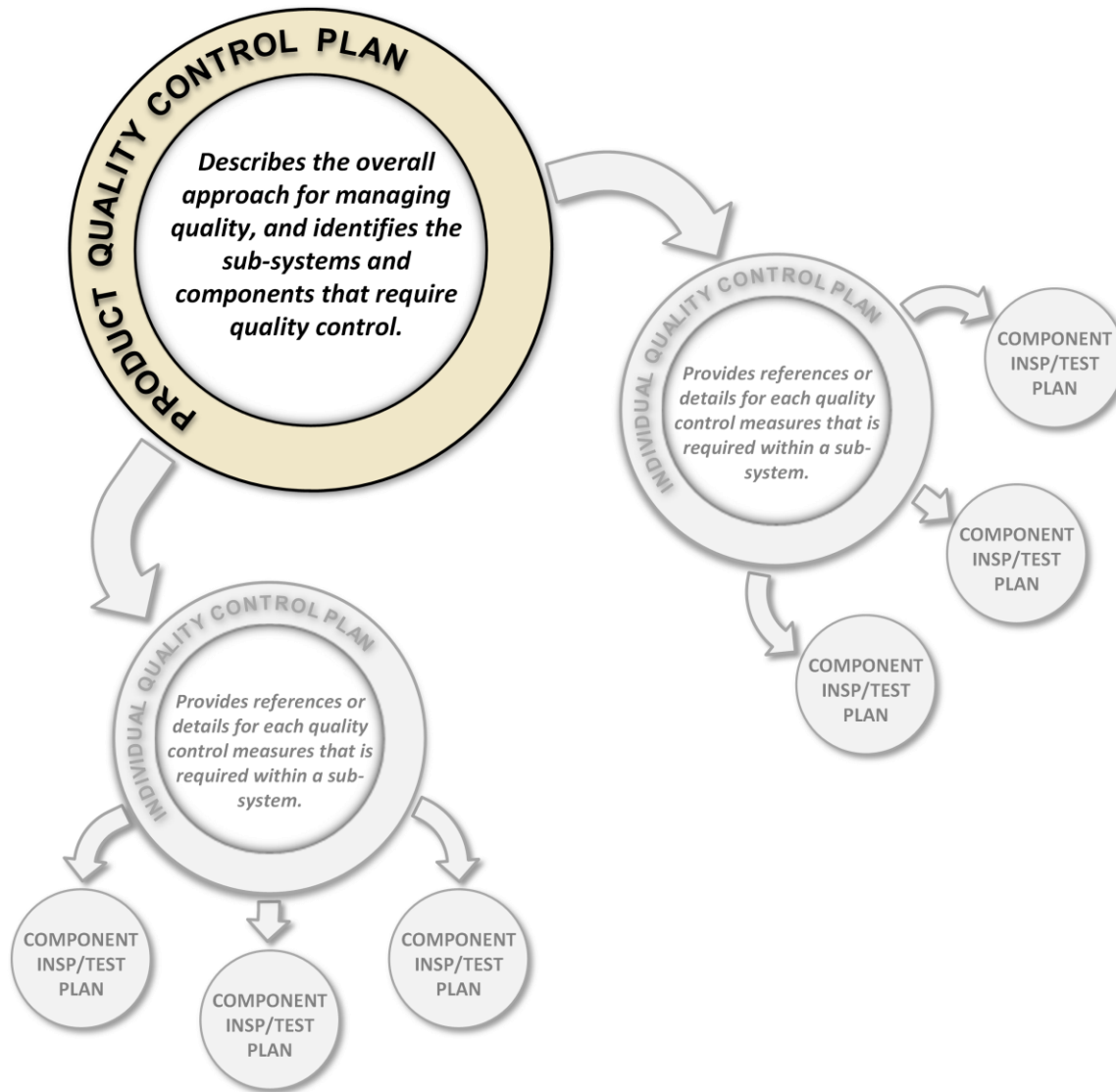
2. Individual Quality Control Plan

Provides references (or details) for each quality control measure that is required by within a sub-system or collection of components.

3. Component Inspection & Test Plans

Provide detail methods, measures, and processes for assuring quality control for individual components throughout their development lifecycle.

The Product Quality Control Plan



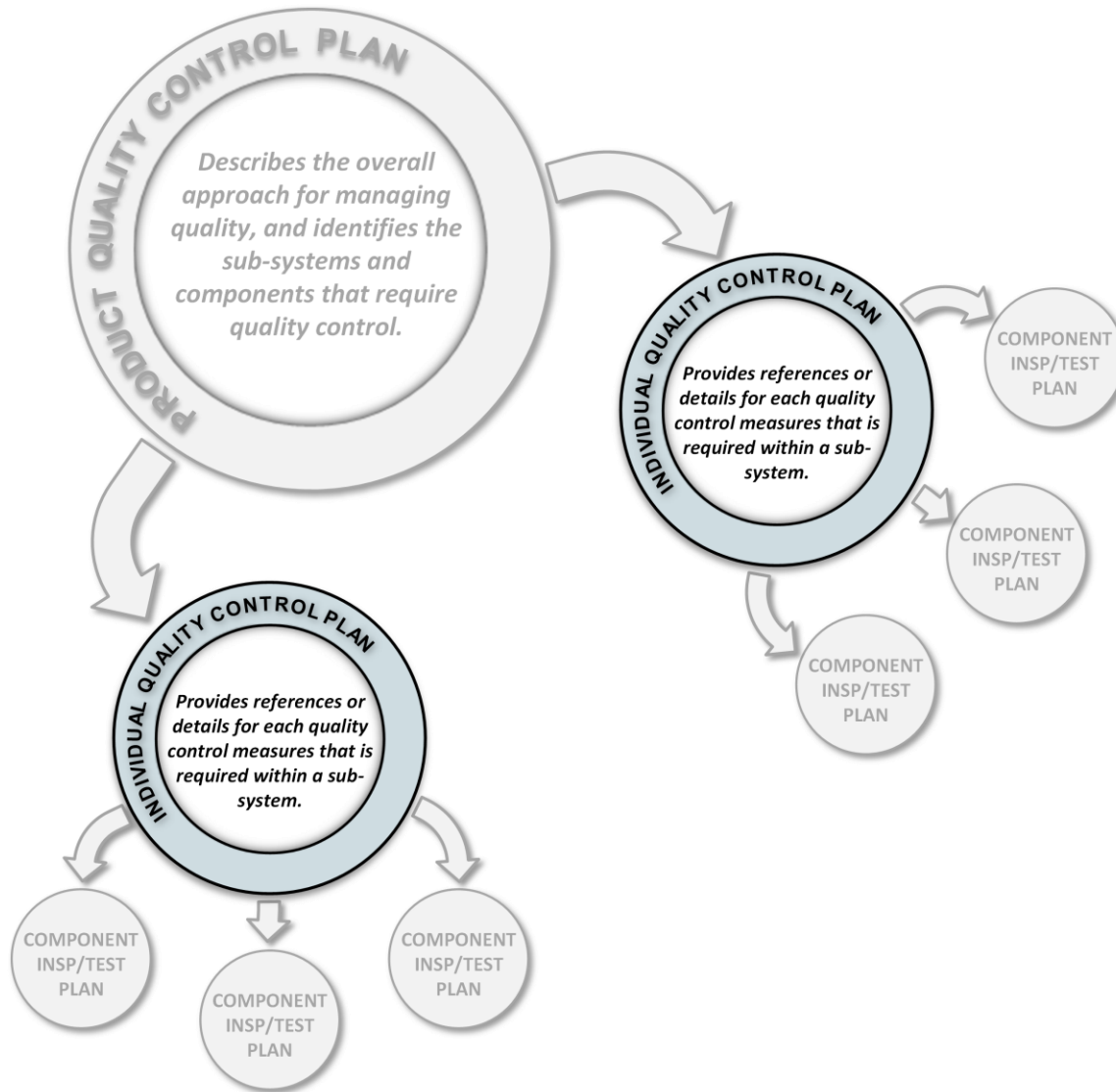
The Product Quality Control plan typically refers to a single Level-2 WBS (system) and performs the following functions:

- 1. Establishes General Quality Assurance Requirements**
Provides the governing definitions that are used throughout subsequent plans, including: scope definition, categories of providers, effected sub-systems and components, and requirements traceability.
- 2. Defines Specific Quality Control Measures**
Identifies and defines each of the specific quality control measures that must be addressed in the subsequent documents.
- 3. Identifies Components Requiring Quality Control**
Examines the system at the Level-3 or Level-4 sub-detector level, and identifies each component that will be subject to quality control measures.
- 4. Establishes Expectations for Quality Control Measures**
Establishes the expectations for how each quality control measure must be addressed, and identifies assumptions and constraints that exist within the larger system.

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- 1. In-Process Inspection and Test**
Inspections and tests that will be performed on components that are built in-house.
- 2. Outsourcing: Vendor/Partner/Contributor In-Process**
Inspections and tests that will be performed on components that are built by others.
- 3. Incoming Inspection and Acceptance Tests**
Inspections and tests that will be performed when components are received.
- 4. Travelers, Procedures, and Checklists**
Documentation that must be delivered with manufactured components.
- 5. Verification Plans: Methods and Activities**
Methods that will be used to ensure that the component meets critical performance parameters.
- 6. Deliverable Documentation and Records**
Documentation that must be delivered for inclusion in the project documentation.
- 7. Associated Equipment**
Additional equipment that will be required for measurements and calibration.
- 8. Calibration Plans**
Any requirements for calibration of components and/or tools associated with testing.
- 9. Serialization and Material Traceability Requirements**
Requirements for serializing components for identification and tracking.
- 10. Planned Partner and Vendor Communication & Visits**
Requirements for scheduled visits with partners and vendors to assure quality production.
- 11. Control of Nonconformances**
How deviations from quality expectations will be addressed.
- 12. Packaging/Transportation/Shipping**
Requirements for packing, shipping, and transporting manufactured components.

The Individual Collective Quality Control Plan



Individual Product Quality Control Plans (IQCP) typically refer to a single Level-3 or Level-4 WBS sub-system (as categorized in the L2 product quality control plan) and provide references or details for how the quality control requirements in the Product Quality Control Plan will be satisfied. These plans are:

1. Auto-Generated Where Possible

Whenever possible, the IQCP will be auto-generated using a spreadsheet that provides details about the components that are included in the plan, and references to external Inspection and Test Plans.

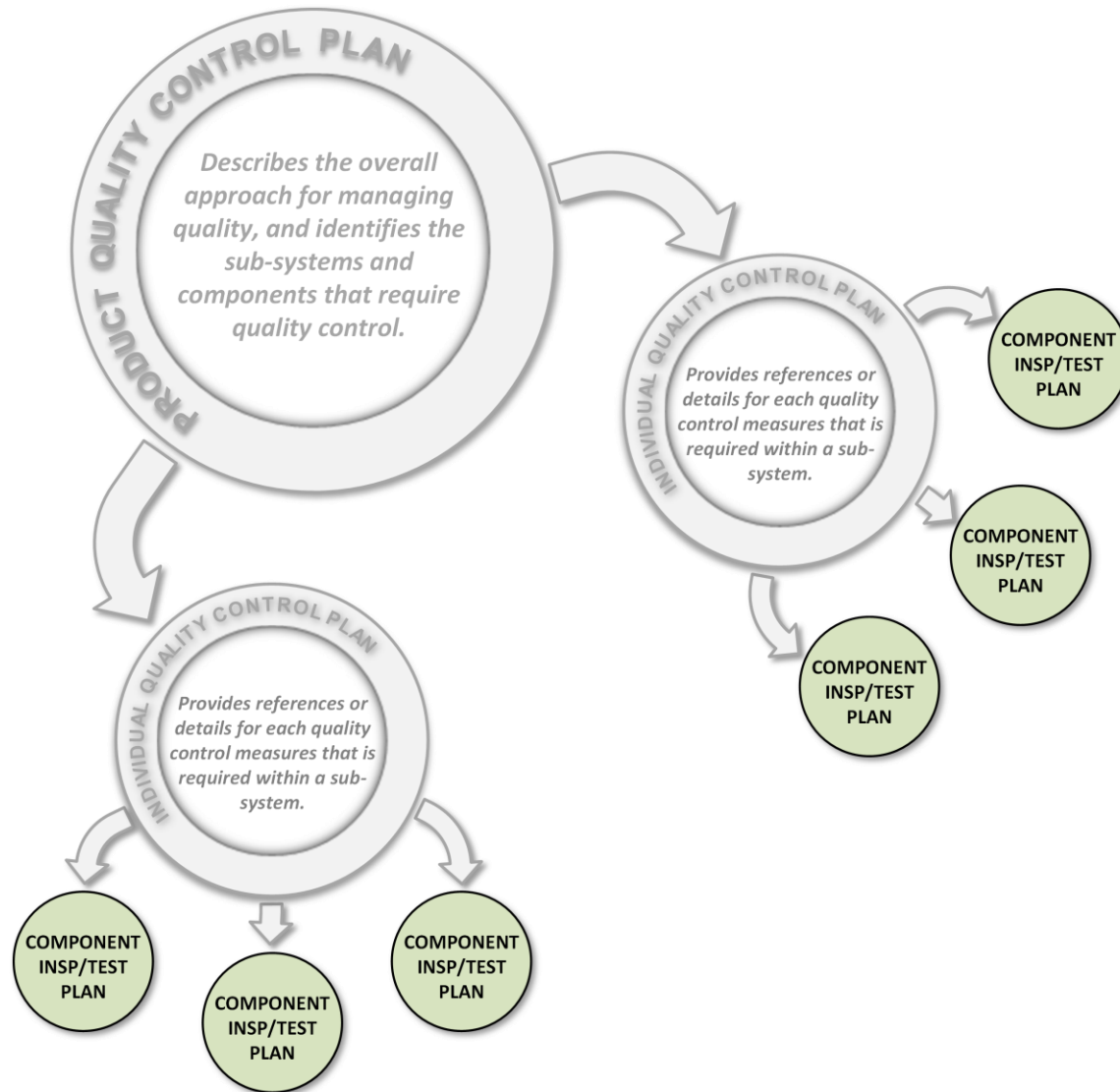
2. Detailed Where Necessary

For details that are not provided in an existing Inspection and Test Plan, it may be necessary to provide specific detailed information within the IQCP.

3. A Roadmap for Reviewers

The IQCP provides a standard format for reviewers to use to find documentation that may exist in numerous locations and various formats.

The Inspection and Test Plan



Inspection and Test Plans are stand-alone documents that provide quality assurance information for individual components and parts. They are *highly specific, functionally formatted, and developed/maintained by systems experts*.

These documents are the heart of our quality control program and may include:

- **Material Properties**
- **Test Setups and Plans**
- **Matrices of Component Quality Data**
- **Required Environmental Conditions**
- **Testing Resource Requirements**

The Inspection and Test Plan Example - Aerogel

1 Aerogel Tile Properties

Aerogels are widely used in Cherenkov detectors due to their unique optical properties and lightweight nature. To ensure optimal performance in these detectors, aerogel must exhibit several key properties:

- **Refractive Index:** This parameter is crucial as it determines the Cherenkov threshold, the minimum velocity a particle must have to emit Cherenkov radiation.
- **Transparency:** High transparency is essential to minimize the absorption and scattering of Cherenkov light. This ensures that the light can travel through the aerogel with minimal loss, maintaining its intensity and clarity.
- **Density:** Aerogels are characterized by their very low density, typically between the order of $\sim 10^{-4} - 10^{-3} \text{ g/cm}^3$. This property minimizes the material's interaction with particles other than Cherenkov radiation, preserving the detector's accuracy.
- **Homogeneity:** Uniform refractive index and density across the aerogel are important for consistent Cherenkov light production and propagation. Variations can lead to inaccuracies in particle detection.
- **Hydrophobicity:** Hydrophobic aerogels are preferred because they resist absorbing moisture from the air. Moisture can degrade the aerogel's optical properties and mechanical integrity.
- **Thickness:** The thickness of the aerogel layer needs to be optimized to produce a sufficient number of Cherenkov photons while allowing enough path length for particle detection. This typically ranges from a few millimeters to a few centimeters.

In summary, aerogel designed for Cherenkov detectors need to balance multiple properties, including a low and controlled refractive index, high transparency, low density, homogeneity, mechanical stability, hydrophobicity, and appropriate thickness. These characteristics ensure that the aerogel can effectively produce and transmit Cherenkov light, enabling accurate and reliable particle detection in high-energy physics experiments.

2 Process and Procedures

2.1 Refractive Index

The refractive index n can be measured using the so-called prism method. The prism method is a straightforward and precise technique for determining the refractive index of transparent materials, including aerogel tiles. It involves measuring the angle of deviation of light passing through a prism-shaped aerogel tile. Figure 4 shows the experimental setup used for measuring the refractive index. The aerogel tile is placed on a turntable and light from a laser source is incident on the tile. The tile is rotated until the deflection angle θ_{def} reaches a minimum. When at the minimum deflection angle, the refractive index is given by:

$$n = \sin\left(\frac{\theta + \theta_{\text{def}}}{2}\right) / \sin\left(\frac{\theta}{2}\right). \quad (1)$$

2.4 Homogeneity

The homogeneity of the aerogel can be assessed through its transmittance and refractive index uniformity. How the transmittance varies across the aerogel surface can be assessed using the LED transmittance setup described in Sec. 2.2. This allows us to study how the transmittance at each wavelength varies over the aerogel surface. Monitoring the refractive index gradient over the aerogel surface allows for an assessment of the refractive index uniformity. The setup for this measurement is currently under investigation.

2.5 Hydrophobicity

The aerogel tiles are hydrophobic and should be resistant water and moisture. However, we will store aerogel tile in a humidity controlled dry box.

3 Experimental Setup

3.1 Refractive Index: Prism Method

The setup used to measure the refractive index via the prism method is detailed in Sec. 2.1 and shown in Fig. 4. A 800nm laser, with a beam spot of about 2mm was placed 20cm from the aerogel tile, which was placed on a turntable. The deflected light was measured on a screen placed about 2m from the aerogel. The aerogel was rotated to find the minimum deflection relative to the beam spot position where no aerogel sample is present. Figure 4 shows the laser passing through a corner of the aerogel sample during a refractive index measurement. These measurements can also be done using an available 635nm laser.

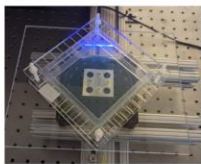


Figure 3: 800nm laser passing through the corner of an aerogel tile during a refractive index measurement via the prism method.

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where θ is the angle making up the corner of the aerogel tile ($\approx 90^\circ$). The deflection angle is determined by measuring the laser spot displacement x a distance L from the aerogel. The refractive index is measured using each of the four aerogel corners and then averaged together for a final nominal value.

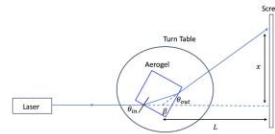


Figure 1: Block diagram of refractive index measurement via the prism method.

The prism method can only be used if the aerogel tiles have optical quality edges. However, it is anticipated that the final ePICH production tiles will be water-jet cut from a bulk aerogel piece, resulting in non-optical quality edges and rendering the prism method non-applicable. Another method, which exploits the correlation between refractive index and density is being investigated as a way to determine the bulk refractive index.

2.2 Transparency

The aerogel's transmittance is measured across the ultraviolet (UV) and visible (Vis) spectrum. The transparency is quantified by the percentage of light transmitted through the aerogel at various wavelengths. A fiber optic cable is coupled to each of the narrow wavelength LEDs and serves as the input light source. Light from the LEDs is incident on the face of the aerogel tile and the transmitted light then passes into an integrating sphere. The integrating sphere collects the light into a fiber optic that is connected to a UV/Vis spectrometer where the light intensity is measured as a function of wavelength, I_{out} . The aerogel is placed on a stage which can move horizontally and vertically relative to the incident LED light, allowing for transmittance measurements across the surface of the aerogel. Both the aerogel, its transmission stage, and integrating sphere are contained within a dark box. The LED transmittance measurement setup is shown in Fig. 2. The measurement is repeated for each LED without the aerogel present to obtain a reference intensity, I_{ref} . Finally, a background intensity is measured by running the spectrometer with the LED sources powered off, I_{bgd} . The transmittance for each LED is given by:

$$T_{\lambda} = \frac{I_{\text{out}} - I_{\text{bgd}}}{I_{\text{ref}} - I_{\text{bgd}}} \quad (2)$$

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Equipment Below is a detailed list of the equipment used in the refractive index prism method measurements:

- Thorlabs Laser PL255: Compact laser module with USB connector, 800nm, 45mW
- Thorlabs Laser PL252: Compact laser module with USB connector, 635nm, 45mW
- Rotation Stage (RPV0): 4in Manual Rotation Platform

3.2 LED Transmittance Setup

The transmittance was measured using a four LED system constructed at Tripple University. The measurement procedure is described in Sec. 2.2 and a block diagram of the setup is shown in Fig. 2. The setup consists of four LEDs of different wavelengths (380nm, 405nm, 500nm, and 625nm) providing four discrete transmittance measurements. Each LED has its own power supply and LED driver unit. The LED light is transported through a 900um diameter fiber optic cable, with one end coupled to the LED and the other to a collimating lens. The collimated light is incident on an aerogel sample that is placed about 5cm from the lens and has a beam spot of about 10mm. The transmitted light has a beam spot diameter of about 10mm when it enters the integrating sphere positioned about 12cm from the aerogel. The integrating sphere inner walls are highly reflective PTFE material and has an opening port diameter of about 2.5cm. The light entering the integrating sphere reflects off the inner walls until it enters a 200um diameter fiber optic that couples the integrating sphere to a UV/Vis spectrometer. The spectrometer is connected to a PC via usb cable for analysis. The aerogel tile sits on a platform that is mounted to a vertical A1 extrusion that is able to slide along the extrusion. The vertical A1 extrusion is mounted to a slide stage that is installed on a horizontal A1 extrusion, which allows aerogel to move perpendicular to the beam direction. This setup allows measurements to be carried out over the area of the aerogel for uniformity studies. The collimator lens, aerogel and its translation stages, and integrating sphere are contained inside of a dark box to minimize ambient light and other possible external light sources that could impact the measurement.

Equipment Below is a detailed list of the equipment used in the LED transmittance measurements:

- Thorlabs 625nm LED: 625nm, 13.2mW (Min) Fiber-Coupled LED, 1000mA, SMA
- Thorlabs 500nm LED: M380F3 - 500nm, 6.5mW (Min) Fiber-Coupled LED, 1000mA, SMA
- Thorlabs 405nm LED: M405F1 - 405nm, 5.3mW (Min) Fiber-Coupled LED, 500mA, SMA
- Thorlabs 380nm LED: M380F1 - 380nm, 0.45mW (Min) Fiber-Coupled LED, 600mA, SMA
- Thorlabs CPLED USB-Controlled LED Driver: 1.2A Max, 8V Max

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The Aerogel Test Stand Quality Assurance and Quality Control Procedures for the ePIC Detector RICH Sub-Systems provides the following details:

1. Aerogel Tile Property Definitions

- Refractive Index
- Transparency
- Density
- Homogeneity
- Hydrophobicity
- Thickness

2. Processes and Procedures for Each Tile Property

3. Individual Experimental Setups, including

- Diagrams
- Equipment Lists

4. Record Keeping Requirements

See <https://eic.jlab.org/Detector/#QUASet> for examples of all documents



Questions?