# LIMITED STREAMER TUBES QUALITY CONTROL AND TEST PROCEDURES

The BaBar LST Group

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# INTRODUCTION

In this document we describe the Quality Control (QC) procedures that are being developed for the BaBar Limited Streamer Tube (LST) detector. It will consist of four main stages:

- **QC at the production site** will be principally focused on monitoring each stage of the production process. It will include checks of the mechanical and electrical properties of the tubes, their gas tightness and HV capabilities. The plateau curves of all tubes will be measured, and a long term test will make sure that the detectors behave reliably in time. The detailed history of each tube will be collected in a database.
- **QC at Ohio State University (OSU) and Princeton** will concentrate on carrying out more detailed measurements on the tubes. After checking for possible damages which might have occurred during transportation, studies will include signal shape tests, tube efficiency measurements and rate studies using a radioactive source. The plateau curve measurements will be repeated and further long term tests will be performed with the tubes assembled into modules.
- **QC at SLAC** will be focused on checking for damages from transportation and on the measurement of properties not tested earlier, such as measuring the detector efficiencies using cosmic rays.
- **QC during installation** will aim at finding problems as modules are being installed, so that they can be repaired and/or replaced while it is still easy to do so.

In the following sections each of the four stages outlined above will be discussed in detail.

# QC AT THE PRODUCTION SITE

## Introduction and System Requirements.

Quality Control (QC) procedures at Pol.Hi.Tech.(PHT) have been discussed and defined in several meetings with the company. For some of the procedures described below the equipment will be provided by INFN. Acceptance criteria for the various stages have been established in agreement with the company.

The main goals of QC during production are:

- To establish and monitor the qualitative standard of the materials used and of the manufacturing procedures.
- To be able to detect problems early on in the production chain, in order to be able to give a positive feedback on the production itself.
- To test and certify the detectors, before they are accepted and shipped to the U.S.
- To create a database with the detailed history of each detector.

Several constraints must be taken into account when designing a QC system to be installed at the production company:

- Any interference or added operation resulting in a slowing down of the production, as planned by the company, translates into an extra-cost.
- QC procedures and equipment must be compatible with the production flow as established by the company.

- QC procedures and equipment must be easy to understand and to operate by PHT personel.
- QC procedures and equipment must be approved by the company, and acceptance criteria must be established in agreement with the company.

In addition to that, experience suggests to use, whenever possible, automated (computer-based) systems for data entry and data organization.
A close cooperation between BaBar and PHT has been established in order to develop the QC procedures described below. For each QC step we are working together with PHT to establish the correct procedure.
In what follows we will first give a description of the general infrastructure, followed by an overview of the production chain and QC procedures. Each QC step will then be described in greater detail.

## General Infrastructure

QC data and any other relevant information will be collected by hand or, whenever possible, automatically, by means of DAQ stations located on site. In order to make data entry easier and quicker, barcode labels will be used to identify the various parts and components, as well as some QC tests (e.g. the quality of the graphite coating, see below).
Unless otherwise specified QC operations will be carried out by PHT personnel. Furthermore BaBar will organize shifts to guarantee the presence of the appropriate number of BaBar people during the production of the detectors (probably 2-3 each day). BaBar will designate a person in charge of production and QC, who will act as the primary link with PHT.
The DAQ stations will be connected with each other by means of a wireless Local Area Network. The output of the DAQ stations will be simple text files reporting a common reference record (e.g. the barcode of the tube under construction) plus all the relevant quantities related to the test underway (e.g. the resistivity values). The text file approach is system independent, i.e. it is a standard starting point for any database we might need (both on site and off site); moreover it makes it possible for anybody to look at the data of interest in a fast, easy way. At the end of each test the station(s) will send the files to a central server which will then put this information in the "local production database".
At the end of each day, all data files will be sent to a server outside the production site, to be imported in the "official" (off-site) LST database. To this end, a (maybe slow) connection with the internet will be available.

**Production Server.** A dedicated PC (the production server) will be used for:

- Network management.
- Backups.
- Data collection from DAQ stations and forms.
- Local production database development, running and browsing.
- Data transfer to a server outside the production site.

**DAQ and Test Stations.** There will be four DAQ/test stations dedicated to the following tasks:

- Measurement of the resistivity of the graphite-coated profiles.
- Wire/tube association.

- HV conditioning and plateau measurements
- Long range tests.

In addition there will be several general purpose, portable stations which will be used for other operations such as reporting the results of the visual inspection of the graphite coating, the gas tightness tests and the capacitance measurements. All these operations will be described below.
The DAQ software will be written using Labview.

**Local Production Database.** The local production database records and archives the history of each detector. It stores all data coming from the various tests and measurements carried out during QC on the basis of which the person in charge of production and QC certifies each detector as “good”. The local production database will be populated by automatic insertion of data produced by the DAQ stations, as well as by data typed in manually by operators, whenever necessary. The database will reside on a central server, which will also be used for network management and for backups. The relational database mySQL will be used.

## Clean Room

It is considered very important that the tubes contain as little (dust, small hair, ...) dirt as possible. Dust, and especially small hair, are potential sources of continuous discharge which may happen on a long time scale. The processing of the profiles (coating, stringing and storage until the profiles are inserted in the jackets and thus isolated from the atmosphere) shall take place in a controlled atmosphere in a clean room of class no higher than 100000. The enclosures where such atmosphere is provided can be made of plastic sheets. They will have a system of air recirculation through absolute filters which provides clean air over the region of the profiles. In the enclosures a small overpressure will be maintained with an appropriate procedure of blowing clean air inside and letting air out through calibrated vents. An entry room will be provided where people can wear appropriate attire, i.e. overshoes, hair retaining hats and coats, all of the type developed for clean rooms. Mouth masks are not required for cleanliness purposes.
Stacks of profiles can be covered while being moved from one clean room to the other. Should any dust deposit during this short passage, it will be removed by vacuum cleaning done during stringing.

## Overview of Procedures

An overview of the production chain at Pol.Hi.Tech. is shown in Fig. 1. After being checked for mechanical integrity the comb-shaped profiles are painted with graphite (A). At this point two barcode labels with the profile ID are glued on the two sides of the profile. The quality of the graphite coating is then checked (B) and its resistivity measured (C). These procedures are carried out in a clean room.
The profiles accepted by the resistivity test are then moved to a second clean room where they are strung (D). The wires used to string the profiles are previously checked, and a sample of wire from each new spool is sent to Princeton to be tested. After stringing, a check is made that the wires are correctly positioned in the wire holders.
The circuit cards are then installed and the completed profiles are then inserted into their jacket; the tubes are then closed by glueing the two endcaps (E). All parts have

been previously checked for mechanical integrity. The jacket is identified by the same barcode ID used for the profile; the appropriate barcode labels are glued to the two endcaps.
The tubes are then moved to the water pool where they undergo the gas tightness test (F). At this point, the tubes are ready for HV conditioning, which takes place in appropriate racks (G). After one week of electrical conditioning, a single rate plateau curve will be measured for each tube.
The tubes are then moved to the shipping boxes (H). Here a capacitance measurement is made in order to check that no wires are broken or loose (I). Finally the tubes undergo long term tests for a period of one month.

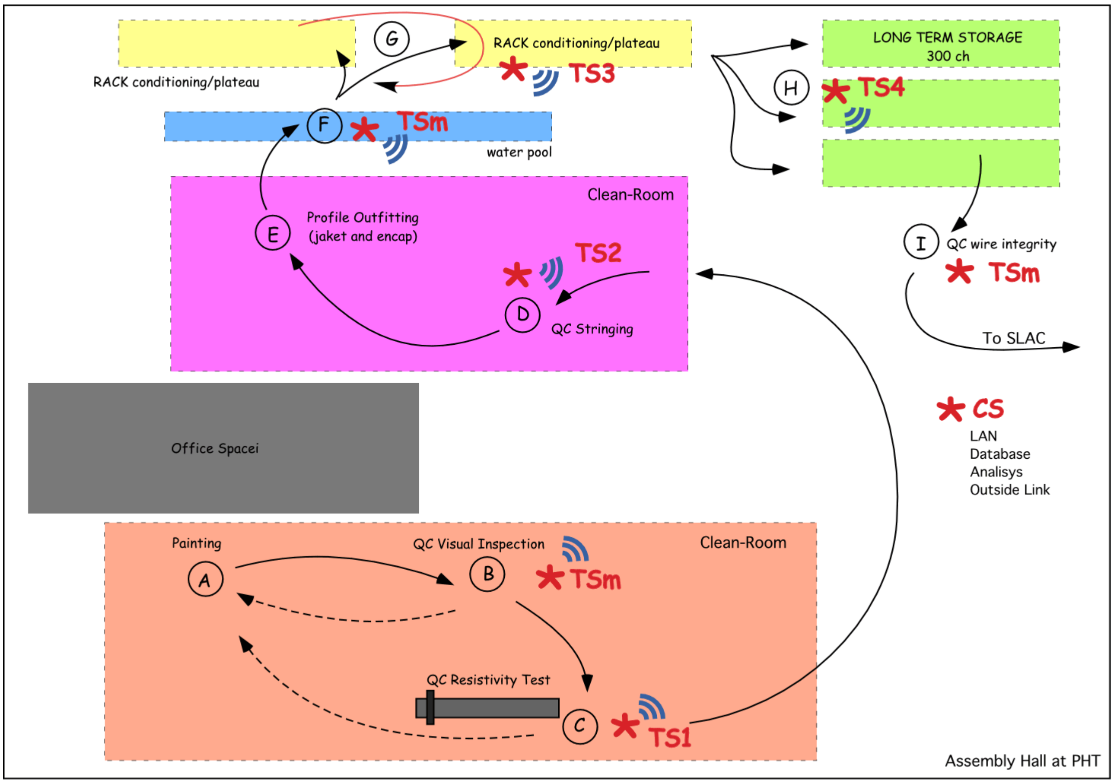



*Fig. 1 Assembly Hall at Pol.Hi.Tech. and overview of the QC procedures.*

## Identification of the Profiles

Each profile will be assigned a unique barcode ID. Two barcode labels with the profile ID will be glued on the two sides of the profile itself, one at the backward and one at the forward end. The backward label will be marked with a black dot and it will identify the backward/left end of the profile. This means that the position along the profile (z-coordinate in the BaBar reference system) will be measured starting from this end, and the profile cells will be numbered from 1 to 8 starting from this end.
The assembled tube will be identified with the same barcode ID of the profile it contains. Two labels with the appropriate barcode ID will be glued on the two endcaps, to make identification of the profile easy in all conditions of installation.
Each profile will be subdivided, along its length, in 8 zones (each identified by a barcode), as shown in Fig. 2.

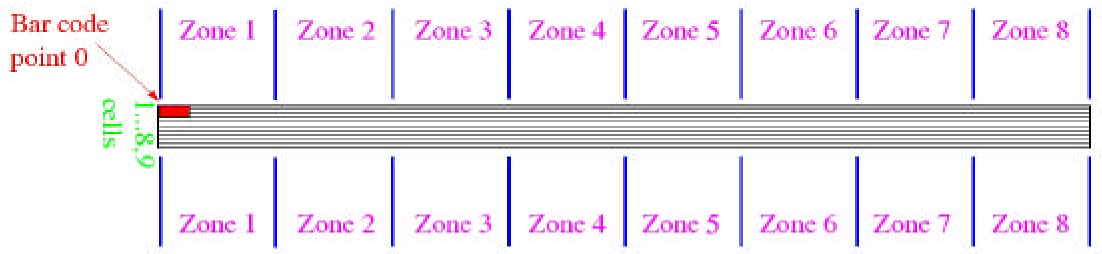



*Fig.2 Subdivision of a tube in zones.*

## Inspection of Comb Shape Profiles

**Extrusions.** Before the final production of the extruded profiles, the quality of the extrusion will have to be certified by BaBar people. Extrusion samples will be visually inspected to make sure that there are no defects and will be measured to make sure that their dimensions are correct within the specified mechanical tolerances (±0.5 mm on the width and ±0.2 mm on the height, see below).

**Mechanical.** Every profile shall be visually inspected to make sure there are no observable bents, dents, cracks. The required mechanical tolerances are: ±0.5 mm on the width, ±0.2 mm on the height, ±2 mm on the length.

After delivery, profiles will be measured on a sampling basis, to make sure that their dimensions are within the required mechanical tolerances.

In order to look for possible defects, a profile sample will be sent to Padova for optical inspection. The profile sample (0.5 %) will be extracted by Pol.Hi.Tech. upon delivery of the production batch, cut in 1 m long pieces and sent to Padova.

**Graphite Coating.** After coating, all profiles will be visually checked. Big defects, incompatible with the correct functioning of the detector, will be corrected (e.g. type C, see below); smaller, acceptable defects will be recorded together with their position along the tube (e.g. types A and B, see below).

The procedure developed for the graphite coating inspection allows us to record an arbitrary number of pre-coded defects and the zones and cells in which the defects are found. For each defect a record will be generated with the two barcode entries: one will contain the zone and defect type, the other will have the zone and cell; the relative data will be entered by means of a barcode reader.

At the moment three types of defect are coded (both others are possible):

- type A: small point
- type B: rough surface
- type C: unpainted spot (to be painted again)

**Resistivity Measurement.** The surface resistivity is monitored by measuring the resistance between a pair of appropriate electrodes. A first measurement will be made 24 hours after painting, to check the uniformity. The final measurement is made 72 hours after painting. The resistivity shall be measured in an automatized way at 50 cm intervals along the tube's length, for each of the 8 cells, on the bottom of the cell and on the two cell sides. The resistivities of the graphite-coated profiles will meet the following requirements:

- For the measurements on the bottom of the profiles the average values will be between 200 kΩ/sq and 450 kΩ/sq. Tubes for which more than 2 % of the resistivity measurements yield values below 200 kΩ/sq or above 800 kΩ/sq will not pass the test. Tubes for which 2 or more resistivity measurements within one cell yield values above 1000 kΩ/sq will not pass the test and will have to be repainted.

- For each resistivity measurement yielding a value above 1000 kΩ/sq, the profile will be set aside and the relevant regions will be visually inspected (for defects in the graphite coating) and re-measured.
- Tubes for which 2 or more resistivity measurements within one cell yield values below 80 kΩ/sq will be rejected.
- For the measurements on the sides of the profiles (taken at half height) the resistivity values will be between 200 kΩ/sq and 4000 kΩ/sq.

The equipment to measure the resistivity will be provided by INFN. Here is a brief description of the procedure.
A bridge, carrying the resistivity probe, moves along a 5 m long support table. Every 0.5 m the bridge stops and releases the probe on the profile. The resistivity measurement takes place in parallel for all 8 cells. Once all data is recorded and checked for consistency by the data entry manager the bridge lifts the probe and heads for the next point to be measured. The single data acquisition will take approximately 60 seconds, while the bridge can move as fast as 1 meter/minute. It will take 9 stop-and-acquire cycles to measure a full tube: the total time for this operation will be less than 15 minutes. Once the rest position at the other side of the table is reached the system is ready for a new measurement with the bridge moving in the opposite direction (i.e. the measurements can be carried out with the bridge moving in either direction). Before the bridge starts the operator reads, with a barcode reader, the profile ID on the label closer to the rest position of the bridge. Since the ID code comes in two flavors (Forward and Backward) this solves any ambiguity on the measurement position. At the end of the measurement the data entry manager issues a quality flag for the tested profile. Depending on the flag the tube either passes the test or it is put away for further investigations or repairs.

## Inspection of Parts

**Jackets** will be checked visually for mechanical integrity. Measurements will be made to make sure that they have the correct dimensions and that they are straight (the sagitta must be smaller than 1.5 mm).

**Endcaps.** The electrodes and the gas inlet and outlet are visually inspected to insure they are in good integrity and there is no crack in the endcaps.

**Circuit Cards.** The solder joints are visually inspected to check for cold solder joints and for sharp wire ends. The entire circuit is then checked for proper continuity.

The jackets and endcaps will be checked by PHT. As for the circuit cards, a first check will be made by the company which manufactures them; a second check will be carried out upon installation of the cards themselves.

## Gas Tightness

The gas leakage test is performed by completely submerging the tubes in water at 15-20 mbar overpressure in a “knife edge” fashion. Less than 1 small bubble per minute is required. Leaking tubes are fixed with PVC glue if possible and tested again. If accepted, the information that the tube has been repaired will be registered and the position in which the repair has occurred will be clearly marked. Tubes exceeding the 1 small bubble per minute limit will be rejected.

## Wire Check

**Wire Quality.** At the beginning of each new spool a sample of wire will be sent to Princeton to be checked (mechanical check, diameter measurement). Before the wire is installed it is checked visually to make sure that there are no defects (e.g. oxidation). A wire sample from each spool will be kept and appropriately identified, in order to keep track in which tubes it is used. To this end a dedicated DAQ station will register, for each tube, the 8 spools whose wires are used to string the tube.
The innermost layers of wire in each spool will not be used.

**Wire Position.** Each strung profile shall be visually inspected, to make sure the wires are correctly positioned in the wire holders.

**Wire Connection.** Tests and measurements shall be carried out to ensure that no wires are broken and that they are all connected. To this end the capacity between pin and ground at one end of the chamber will be measured.

## Electrical conditioning and Plateau measurement

An **electrical conditioning** is performed for each tube for a minimum of 7 days (even if the drawn current becomes acceptable in less than 7 days). A current limiting power supply will be used. The tubes will be fluxed with a ternary gas mixture (89 % $CO_2$, 8% Isobutane, 3 % Argon, the so-called Zeus gas mixture).

- Each tube will be kept one day (24 H) under the ternary gas mixture flux for at least 6 volumes exchanges.
- Each tube will take a minimum of 1 hour and a maximum of 24 hours to reach 2500 V; they will take a minimum of 18.5 hours and a maximum of 48 hours to go from 2500 V to 5000 V. They will take a minimum of 9 hours and a maximum of 16 hours to go from 5000 V to 5450 V. They will take a minimum of 8 hours and a maximum of 16 hours to go from 5500 V to 5850 V. Thus the total time to reach 5850 V will be a maximum of 104 h.
- Tubes which at the end of each of the time periods given above are not able to keep the specified voltage drawing a current smaller than 5 µA will be rejected.
- The tubes are kept at 5700 V for a minimum of 3 days, so that the total conditioning period will be of 1 week. The current limit will be 2 µA for the first day and for the remaining days according to the following table.

| Type of Tube | current limit |
|---|---|
| 8-cell long | 250 nA |
| 8-cell short | |
| 7-cell long | |

The current will not go above the values given in the table for more than 2 minutes.

**Plateau.** For each tube the plateau will be measured using the ternary gas mixture. For each plateau the following three quantities will be calculated:

- Plateau slope S: the slope of a linear fit to the data points in the plateau region;
- Plateau range $\Delta V$: the high-voltage range in which the relative deviation of the data points from the fitted curve is less than 5%;
- $R_{mean}$: the mean value of the cosmic ray counting rate within the plateau range.

The tube will be accepted if the following three criteria are satisfied:

- $S < 0.1$ Hz/V
- $\Delta V > 300$ V
- $R_{mean} = (44 \pm 4)\times L$ Hz, where L is the tube length in meters.

In order to be accepted a tube must satisfy all three criteria.

## Scan Test with radioactive source

- This test consists of producing a high rate using a radioactive source. This results in a high rate of charge exchange on the cathode which will allow us to identify non-uniformities in the graphite coating, in particular so called bald spots or graphite islands.
- For the radioactive source test we will use a 300 µCi $^{90}Sr$ source.
- The source will be moved above each pair of cells in every tube at a rate of approximately 2 cm/second at a height low enough to achieve a tube current of ~600 nA at 5600 V.
- While the source moves over the cells the tube current is monitored and the values are recorded by a computer and eventually stored in the QC database. This requires an HV power supply with fast current monitoring.
- Tubes with currents above 4 µA will be rejected. Tubes with selfsustained charges will be rejected.

## Long Term Tests

Each tube will be kept at 50 V below the maximum voltage on the plateau for a period of thirty days, during which the current drawn by the tube must not exceed normal current values of the order of 100 nA for more than 5 % of the time it is monitored The exact values of the current limits will be established once the final gas mixture has been chosen. The long term tests will be carried out by BaBar people at PHT.

# QC PROCEDURES AT THE MODULE ASSEMBLY SITES (OHIO STATE UNIVERSITY AND PRINCETON)

## Introduction and System Requirements

This document outlines the quality control procedures and tests we will perform at the Ohio State University and at Princeton University before and after the limited streamer tubes are assembled into modules. We have defined a very detailed set of quality control procedure that is designed to find defective components as early in the assembly process as possible. Tubes and phi-strips will be shipped from Italy and our first tests check for any damage during transport. Tubes are then placed under gas and high voltage for a period of at least seven days. During that time a plateau curve is measured for each tube. Before a tube is used in a module it will be scanned with a radioactive source following a procedure that was developed by the OPAL collaboration and that is designed to find defects in the graphite coating. Completed modules will be placed under gas and high voltage for at least seven days before they are sent to SLAC. Data taken throughout these test procedures will be recorded electronically and stored in a database. Information from the production site (Pol. Hi. Tech) will be transferred to the same database. A set of web-based tools will be developed to allow remote access and viewing of this information. The use of bar-codes to identify system component will continue. In the following we describe the tests and QC procedures in greater detail. Since we are still evaluation the large cell prototypes some test parameters are not yet finalized.

## Inspection of Shipping Boxes

- Every shipping box will be visually inspected for any transport damages.
- The bar code tag on the shipping box will be scanned and the appropriate information in the QC database will be updated (arrival time, location, possible damage etc).

## Tube resistance and capacitance

With the tubes still in the shipping box but with the box endplates removed we perform the following tests on each tube.

- For each of the four high voltage segments in a tube we measure the resistance between anode and cathode. A small value indicates a broken wire or a similar problem.
- For each of the four high voltage segments in a tube we measure the capacitance between anode and cathode. While a study showed that this will not be sensitive enough to control wire tension this test will help to find tubes where one or more wires are not properly connected to the HV pc board. For a 3.7 m long tube the capacitance for a single HV segment is around 75 pF or 300 pF for the entire tube.

## Long term test, burn in

The shipping box design allows the connection of HV and gas lines while the tubes are still in the box. We will use this feature to perform a long term/burn in test that begins with a LST - HV training session. All tests will be performed with the ZEUS Ar:Isobutane:$CO_2$ (3:8:89) gas mixture.

- Flush for one day and about 10 volume exchanges
- Turn on HV and monitor tube current. Since we don't know how well the tubes survived being shipped across the Atlantic we assume here that a few

days of HV conditioning/burn in will be required. This will follow the same procedure developed for LST conditioning at Pol.Hi. Tech.

- Tubes that don't reach 5800 V after 48 hours drawing a current smaller than 5 μA will be rejected.
- Tubes are kept at 5700 V for four days (96 hours). The current drawn must not exceed 2 μA for the first day and 100 nA for the remaining 3 days. Tubes failing these tests will be rejected.

## Signal Shape Test

- The (anode) pulse shape of each HV segment (i.e. two wires) of each tube will be studied with an oscilloscope.
- Pulses should be ~40 ns wide and 30 – 50 mV high.
- Rejection criteria: anomalously shaped pulses or no pulses at all.
- We are still investigating if pulse shapes (or the average over several pulses) should be recorded in the QC database. It might be sufficient to just record the average pulse height.
- This test will be performed with the tubes in the shipping box and at a voltage of 5700 V.
- Shielding either integrated in the box or around it will be required.

## Plateau Curves

- For each HV segment in each tube the plateau curve will be measured using the singles rate of the anode wires.
- The plateau length should be at least 300 V with the ternary gas mixture (Ar: Isobutane:$CO_2$ ) (3:8:89).
- The counting rate at the plateau region should be fairly stable (this needs to confirm). Once the average counting rate for a test site has been determined we can use deviations from this value to identify tubes with bad cells.
- The plateau curves will be measured without a pre-amplifier and with a discriminator threshold of 30 mV and a pulse width of 1000 ns.
- This test will be performed with the tubes in the shipping box.
- For each tube the plateau curve(s) and the counting rate(s) will be recorded in the QC database.

## Tube Efficiency

- For this and the following QC tests and of course for the module assembly the tubes have to be out of the shipping box. Careful handling guidelines will be established once we gain experience with the prototypes.
- For a sample of tubes we will determine the efficiency using a cosmic ray telescope (about 10%).
- The results will be recorded in the QC database.

## Scan Test with radioactive source

- This test consists of producing an exceptionally high rate using a radioactive source. This results in a high rate of charge exchange on the cathode which will allow us to identify non-uniformities in the graphite coating, in particular so called bald spots or graphite islands.
- For the radioactive source we are planning to use several 5 μCi $^{137}$Cs sources. A 1 mCi $^{90}$Sr source is also available. (OPAL used 10 μCi (or 370 KBq) $^{60}$Co)
- The source will be moved above each cell in every tube at a rate of approximately 10 cm/second at a height low enough to achieve a tube current of ~300 nA.
- While the source moves over the cells the tube current is monitored and the values are recorded by a computer and eventually stored in the QC database. This requires a HV power supply with fast current monitoring.
- Following the OPAL procedures we will classify the test results in 6 categories:
    a. Perfect behavior
    b. No peaks exceeding 1 μA.
    c. No more than 2 peaks exceeding 1 μA; no peaks above 2 μA.
    d. More than 2 peaks exceeding 1 μA or duty factor > 50%; no peaks above 2 μA.
    e. Worse than (d) but current returns to normal level spontaneously when the source is removed.
    f. Non-self extinguishing discharges.

- Only tubes with a grade of (c) or better were accepted by OPAL. We will
- adjust these criteria once we gain experience with our prototypes.

## Inspection of f strips

- Visual inspection. Look for bents, cracks, and transport damage.
- Measure resistivity (to find shorts) and capacitance between ground and signal traces.

## Inspection of Modules

After passing the tests listed above two or three LST tubes and a phi strip flexible circuit board will be assembled into a module. After the epoxy has cured for 20 hours we visually inspect each module and check the mechanical tolerances before the module is stored in the shipping box.

## Module Long Term Test

Back in the shipping box the module is connected to high voltage and gas.

- Flush for one day and about 10 volume exchanges
- Turn on HV and monitor current in each tube.
- Modules that include tubes that don't reach 5800 V after 48 hours drawing a current smaller than 5 μA will be rejected.

- Modules are kept at 5700 V for five days (120 hours). The current drawn by each tube must not exceed 2 µA for the first day and 100 nA for the remaining 4 days. Modules failing these tests will be rejected.

# QC AT SLAC

## Introduction and System Requirements

Quality Control procedures at SLAC are based on the premise that modules have been tested at PHT, and OSU and Princeton, and are therefore focused on

1. Damage from transportation, and
2. Properties not tested earlier.

The first test is similar to that at upstream production sites, and will utilize the same test stations.

- Inspect shipping box exterior for damage.
- Inspect endcap pieces for damage.
- Measure R and C between external connections to check for broken wires, shorts, open circuits, etc.
- Perform leak check.
- HV conditioning.
- Confirm HV plateau.
- Assemble and test z strips.

The second test is to measure efficiency using cosmic rays. Modules will be kept under HV all the time in order to weed out infant mortality. Both tests will be performed with the module in the shipping box for physical protection. In the following sections, we will discuss the QC steps that are different from upstream production sites.

## Measure Resistance and Capacitance

We plan to fabricate a custom wire harness that connects simultaneously to all the external electrical connections of a module such as HV and Φ strip signal. The QC test station will make measurements between all pairs of points automatically. The purpose is to identical broken connections as well as shorts. Acceptance criteria will be developed based on prototype modules. Bad modules will be flagged. The results will be saved.

## Leak Check

It is not practical to put the module under water and look for bubbles as done at PHT. The module will be filled to a slight over-pressure (roughly 1” water equivalent), and the input disconnected. A differential pressure gauge will be read periodically by the QC test station, and the data will be recorded.

A measurement precision of 0.05” water equivalent and a 20-minute test duration are sufficient to set an upper bound on the leak rate of 1% per hour. We have identified pressure transducers, and will be testing them shortly. The acceptance criteria will have to be defined.

## Z Strips

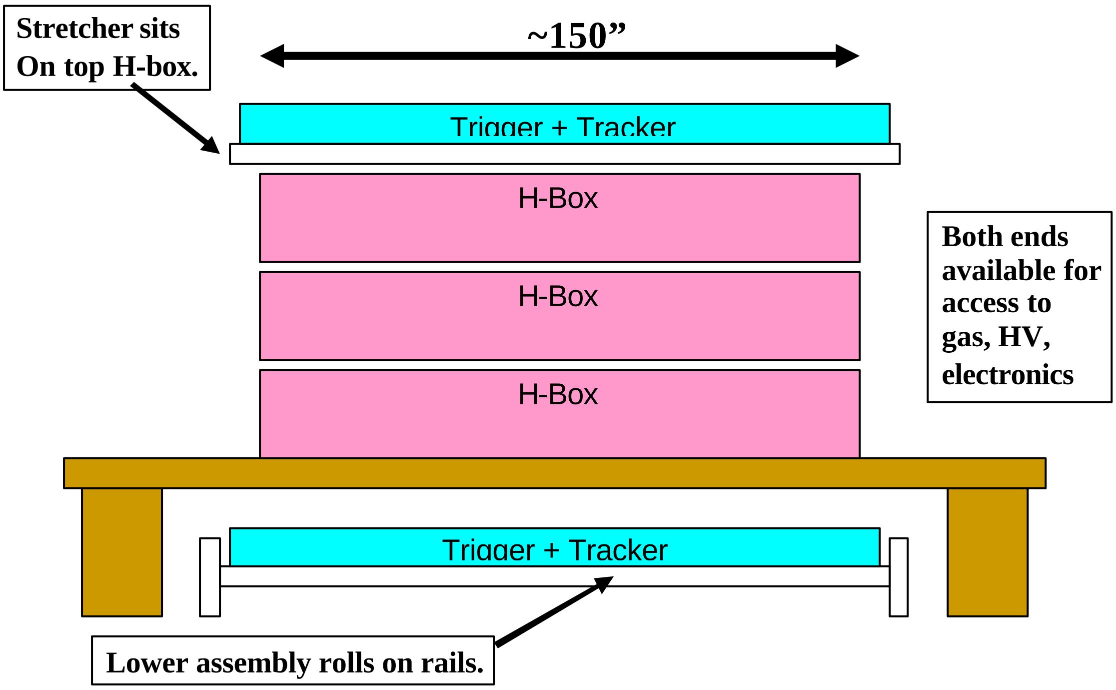
Each z strip is made up of three sections that have to be mechanically and electrically connected together. Each section will be tested for proper continuity. We will then assemble the full z strips and re-test. External mechanical constraints in the bottom sextant prevent the installation of fully assembled z strips, hence those sections will be joint together and tested during installation.

## Cosmic Ray Efficiency Test

The upstream production sites will have measured the singles-rate plateau, and that counting rate has provided a first estimate of efficiency. We will perform a coincidence measurement to obtain a true efficiency for every module. We will have an external tracker to map the efficiency as a function of position.

**Infrastructure.** All the modules will be kept in the same location for the acceptance tests above and the efficiency test, in order to minimize movement of the modules and the need to disconnect and reconnect services. In the following, we describe one possible implementation. We expect the details to evolve as we optimize this operation.

Shipping boxes, measuring approximately 30” wide, 150” long and 8” high, will be stacked 3 or 4 high on a raised platform. They will be tested simultaneously. We will move the cosmic ray telescope, which has separate top and bottom components, to the modules. The bottom component can be pulled along a rail to position it below the boxes under test. The top part is a “stretcher”, and will be manually placed upon the uppermost box to be tested. Both pieces will have sufficiently long service loops to allow for this movement. The figure is a cross section of the platform.




**Trigger and External Tracker.** Any tracking device, e.g. scintillation hodoscope, PWC, drift chamber or LSTs, can be used to form the external tracker. We intend to use the first LSTs for several reasons.

- No additional infrastructure is needed, e.g. gas, readout electronics.
- It naturally has the appropriate dimensions.
- It can self trigger, and therefore avoid another triggering detector.

The normal z strips are the full width of an IFR gap, ranging from 1.9 m to 3.1 m. We can make narrower z strips by trimming the side without the external connections.

**Gas System.** Two gas mixing options are under consideration. One option is to clone the IR-2 LST system. The other is to use the one in IR-2, and pipe the mixed gas to the test location. The decision will be made based on practicalities and costs.

Other parts of the gas system, e.g. bubblers, will be the IR-2 production units. They will be moved back to IR-2 as the modules are installed.

**High Voltage.** We will use the production HV system, including power supplies and cables. They will be moved back to IR-2 as modules are installed.

**Electronics and DAQ.** We will use production equipment. The new LST FECs will be moved back to IR-2 as modules are installed. Other parts of the DAQ system, e.g. ROM, DAQ computer, have to be acquired. They are standard BaBar equipment, so no development is needed.

**Controls and Monitoring.** We intend to use the standard EPICS controls and monitoring system in BaBar.

**Efficiency Measurement.** We intend to take data for ~24 hours for each group of boxes. The data will be written immediately to disk at IR-2, and then backed up to tape. An offline program will reconstruct tracks with the external trackers. These tracks will be projected through the test modules to determine their efficiencies as a function of position. It may be necessary to perform a software alignment of the test modules relative to the external trackers. This is not expected to be a major issue given the coarse granularity of the strips. We have to develop this tracking program, and to establish acceptance criteria. Assuming a flux of 1 $cm^{-2}$ $min^{-1}$, we can reach a statistical precision of ~2.5% for each $cm^2$ region.

## Long Term Tests

Modules will be kept at the operating voltage indefinitely, and their currents monitored. We have to establish criteria for rejecting modules.

# QC DURING INSTALLATION

## Introduction

The goal of this QC step is to ensure that problems are caught early so modules can be replaced while it is still easy to do so, and this QC must not have a significant impact of the installation schedule. Specifically, we want to perform this QC for a layer before it is covered up by the services to many other layers. We expect to install all 12 layers in a sextant in about one week, the current plan is to perform the QC once a day at a time when the installation crew is not present.

## Test Procedure

Flushing the modules with LST gas and repeating HV training do not fit into the schedule; hence, the QC tests will not rely on the presence of streamers. We will test the integrity of all other parts of the system.

**Z Strips.** We will test each installed z strip by connecting to the signal connector, and measure the capacitance between traces. Since the connector is on the backward end of BaBar, i.e. away from the installation activities, we intend to do this in parallel with other LST work.

**Layer Tests.** We will connect a custom wiring harness to all the external electrical connections: HV, z strip and $\Phi$ strip, and measure their mutual resistances and capacitances. In addition, we will pulse the HV supply lines, and observe pulses on the strips. Both sets of tests will be run under computer control, the results recorded, and the failing channels flagged.