lation. Each assembled wall weighs about 30 tons, and is rigid enough to form a virtually solid block of calorimetry that can be lifted, handled, and supported as a unit.

Mass Production, Assembly, and Quality Control

Major components of the PbSc calorimeter are to be produced and preassembled at the Institute for High Energy Physics (Protvino, Russia). Among the operations involved are:

- Tooling for scintillator production and stamping of lead and reflecting paper.
- Injection molding scintillator tiles.
- Painting tile edges using high reflectivity white paint.
- Control of scintillator quality.
- Lead and reflective paper stamping, production of construction elements.
- Stacking and bench testing modules.
- Preassembling supermodules.

Stacking

The PbSc calorimeter module stacking procedure, designed to produce a totally self supporting mechanical unit, was tested. To assure easy insertion of the fibers during module assembly, a simple alignment fixture is used to line up the lead plate edges and pass a few locating rods through the stack. After stacking, the whole assembly is put under a controlled compressive force of about 150 kg. After a period of time needed for the lead plates and paper to stabilize the compression force is checked, and the 0.2-mm thick stainless steel side covers is tack welded to the front and back plates. It is calculated and confirmed by tests that if the module is held horizontally, supported only by its back plate, then its front surface will sag by a few tenths of a millimeter. Such displacements could cause the module weights to combine along the vertical column (if the wall is held vertically), thereby developing a pressure equal to approximately half the weight of the column (as much as 360 kg total or 1 kg/cm^2), which is comparable to the axial pressure applied to the module while stacking. Experience with injection molded polystyrene based scintillator showed no effect on the scintillator surface quality when held under similar pressure for many years. Nevertheless, to avoid pressing the scintillator tiles on their edges, the modules are locked over the front plate only. The geometrical depth of the module must be kept within specifications. If, after stacking, a module depth differs too much from the design value, then an extra layer of passive material will be added in front of the last plate prior to welding.

Fiber Installation

WLS fibers are installed following the pattern corresponding to a front loop radius of 13 mm. This may require preheating the bend area in a hot water bath before bending. To facilitate the insertion, fiber ends are tapered by cutting the fibers at an angle. When inserted, the fibers are grouped within towers, partially covered with epoxy glue and inserted into a positioning tube. The module is held in a vertical orientation with the PMT side down during epoxy hardening. The extra fiber length protruding from the positioning tube is then trimmed, the fiber bundles are fine polished, then cleaned and protected from damage with temporary protective covers. The module assembly is completed when the central positioning rod is extracted and replaced with a quartz rod to bring light from a UV laser to the scintillation tiles.

Supermodule Assembly

There are a few factors like the thickness of the aluminized mylar used to improve light reflection on the tile edges, tack welding of the skins, and production tolerances which could slightly influence the final module size. It is expected that prior to the serial production of the supermodule backplanes, a sufficient number of modules will be built to check the dimensions. At least one preproduction prototype supermodule will be assembled. During assembly of the supermodule, the backplane is positioned horizontally on the support frame to provide access to the tie-bolt fasteners. Individual modules are installed from above making sure the tie-bolts are properly engaged. A temporary stiffening crate put over the 8×8 matrix of modules helps to ensure correct positioning of the modules with respect to each other and simplifies the insertion of locking keys. The locking keys keep the individual modules from being displaced while handling the supermodule. Tightening the tie-bolts completes the assembly of the supermodule. To make the supermodule both a light-tight and a dust-proof rigid body, 0.5-mm thick sheets of stainless steel are tack welded to the supermodule back plane over the whole supermodule perimeter and are welded to the outer edges of the outermost modules. The sheets extend 5 cm above the surface formed by the front plates, thus providing a common enclosure for the fiber loops. After the quartz fibers distributing the laser light to individual modules are routed and connected, the enclosure is sealed from light with a thin plastic cover.

Production Quality Control

The quality control procedures to be followed while building the PbSc calorimeter are designed around two major goals: (1) to assure the uniformity of the calorimeter response; and (2) to assure the geometrical dimensions of individual modules so the assembly phase will proceed without major flaws. Given the uniformity of the sampling media, uniform light yield is the intrinsic feature of the PbSc calorimeter design. Care is taken to avoid mixing tiles with different response within a single tower. This is done through strict control of the scintillator composition, obligatory light yield measurements made on a few samples from each bunch of tiles, and detailed production travellers.

After assembly each module is subjected to a uniformity test in which a linear radioactive source or UV light source is scanned through the channel penetrating the whole module depth at its center. Large differences in the light yield from individual towers signifies a problem and tags that module for further testing and probable reassembly. After the monitoring fibers are installed, a similar procedure is used for the wall assembly.

Final Assembly and Installation

Each calorimeter wall is transported fully assembled to the major facility hall assembly area and lifted into the detector support structure (see Fig. 9.1). Each wall is attached at three or four adjustable attachment points. Adjustment of the attachment points facilitates alignment of the walls both with each other and with the other detector elements.

9.2.2 Lead-glass Electromagnetic Calorimeter

The fourth sector of calorimetry for PHENIX is the 10,000 module PbGl photon detector of the WA80 and WA93 heavy ion experiments at CERN. Approximately 4000 of these modules were used successfully in the WA80 and WA93 experiments. Additional modules were added for use with the WA98 experiment, which was approved recently for the Pb beams at CERN. In preparation for the Pb-beam experiment, the 10,000 PbGl modules are being repackaged in permanent supermodule units of 24 modules arranged in a 4×6 module geometry. The supermodule construction follows a definite sequence. First, the PbGl modules are prepared with their plastic photomultiplier housing epoxied to the back of the PbGl. Next, each module is individually wrapped in aluminized mylar and encased in thin shrink-tube which is tightly fitted by heat shrinking for protection and optical isolation. Then, the 4×6 modules comprising a supermodule are wrapped with a fiberglass cloth, and the entire supermodule is potted in epoxy and oven-cured. The epoxy is forced to flow between all modules to eliminate isolated points of contact so that the supermodules may be safely stacked upon one another. The final supermodule geometry is shown in Fig. 9.5. Aluminum side panels are fixed to the supermodule with the fiberglass wrap and epoxy. The side panels are used to form a shielded box which encloses the photomultipliers and high voltage bases.

A light calibration distribution system will be fixed to the front of each supermodule. All modules will be reinstrumented with new HV-generating bases and readout systems with analog delay and ADC. The full detector system will be calibrated in preparation for the WA98 running in 1994. The PbGl system will be brought fully calibrated to be redeployed within the PHENIX detector. The supermodule units allow rearrangement of the detector geometry, as required for PHENIX, while preserving the individual module calibrations. The only necessary modifications needed before using the PbGl within PHENIX are changes in the module readout to allow for the collider time structure and for the PHENIX trigger requirements. Otherwise, the PbGl will be available with only the expense of transportation and installation.

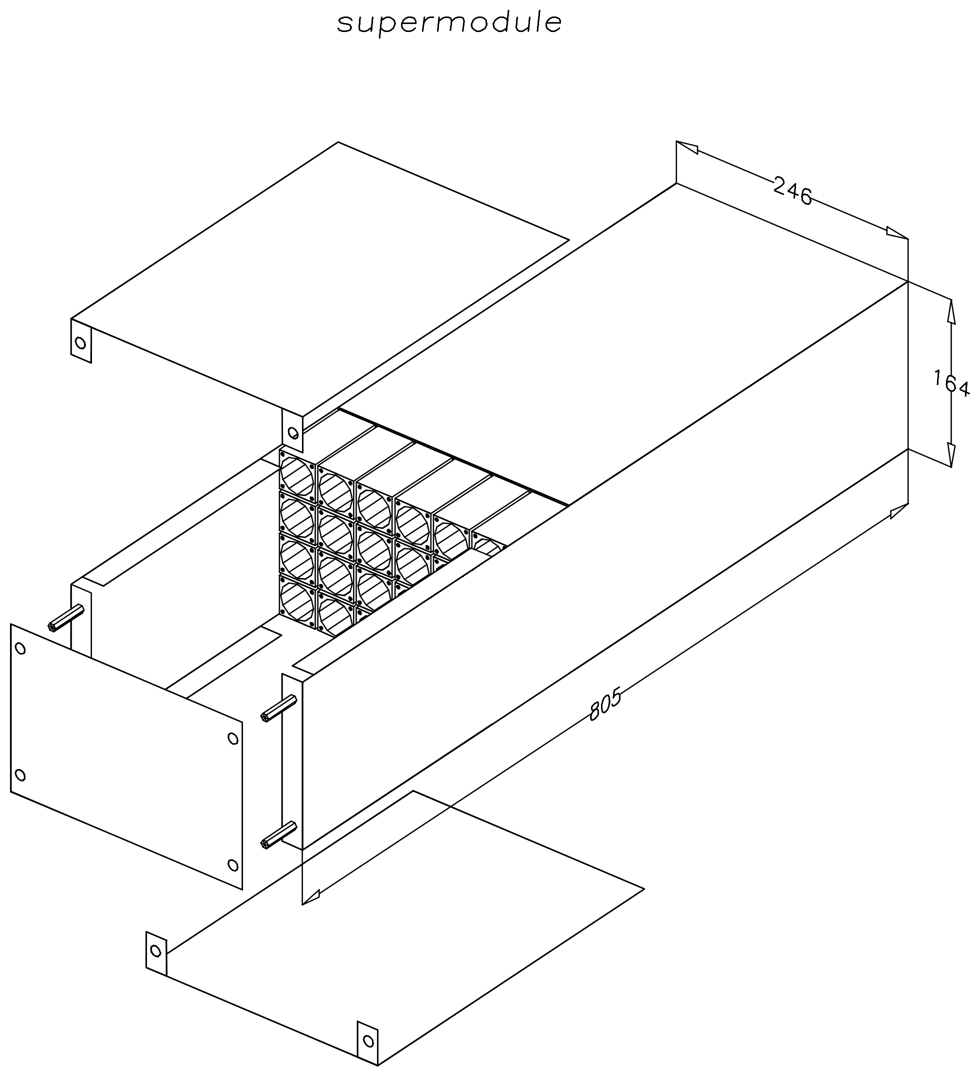

Figure 9.5: PbGl calorimeter supermodule.

9.2.3 Calibration and Stability Monitoring

The basic scheme for calibration and stability monitoring of the EMCal is described in the pCDR. Three independent yet integrated calibration systems, one for each of the EMCal subsystems (PbSc, PbGl and high resolution), comprise the EMCal. The main purpose of the calibration system is to provide a means to correct for time-dependent gain variations in the phototubes, which result from voltage drifts or temperature variations, and to provide a rapid and reliable means of checking the performance of each detector element in-situ once the full detector is assembled. A stable time calibration for measuring the stability of the time-of-flight resolution for the EMCal system is planned. The absolute conversion factors between pulse height and energy for each detector element will be preserved either through independent beam tests or by using additional on-line information, such as minimum ionizing particles or momentum analyzed electrons making a known energy deposit in each detector. Overall calibration factors may also be verified with actual data by requiring certain known particles or resonances (such as the π^0 , J/ψ, etc.) to have the correct mass.

The calibration system will utilize a number of pulsed nitrogen lasers to provide a set of calibrated light sources which will be used by each subsystem for monitoring in a slightly different way. The PbGl detector will use a modified version of the calibration system developed for WA98 and will follow the philosophy used successfully for other CERN experiments. First, UV light from the laser is used to excite a scintillator to convert the light to a wavelength which is better matched to the photomultiplier spectral sensitivity. Next, the light is distributed to the front of each PbGl block through a system of fibers which monitor the light transmission of the block along with the response of the photomultiplier tube. Because the PbGl blocks will be packaged in modules containing 24 detector elements, each module will have its own individual quartz fiber light distribution system. After being packaged into their permanent subunit modules, All 10,000 PbGl blocks will be calibrated in an electron beam prior to the 1994 run of WA98. The calibration system must therefore carry over the absolute calibration information from those beam tests to WA98, and eventually to PHENIX.

The calibration systems for the PbSc and high resolution calorimeters will be developed in parallel, providing the benefits of the high resolution system for the PbSc calorimeter for the initial stage of the experiment. If and when the high resolution upgrade is deployed, the calibration can be adapted easily for the high resolution detector (see Chapter 15). For the PbSc calorimeter, the UV light from the laser will be propagated down a system of quartz optical fibers to a set of distribution boxes, one for each supermodule (Fig. 9.6).

The output of the distribution box provides one fiber to each of the 64 individual modules which are coupled to a 2-mm diameter quartz rod passing down the central axis of the module. This rod has a diffusing surface which allows UV light to escape and excite each scintillator tile. The quartz rod can also be removed to allow insertion of a long, wire encapsulated radioactive source for preliminary testing of the module during assembly. The source can be easily withdrawn and may be reinserted for a rough gain equalization of each module prior to calibration in the test beam. The central hole can also be used to insert a special quartz rod that provides point source illumination and can be moved through the calorimeter stack to excite individual scintillator tiles. If necessary, this procedure can be used for detailed testing of certain modules during assembly. The distribution box is equipped with at least one additional fiber which goes to a separate photomultiplier tube that is used to monitor the intensity of the light injected into the distribution box. The gain of this phototube is independently monitored using a permanently mounted scintillator and radioactive source.

The light output from each nitrogen laser is directed into its own integrating sphere which acts as a diffuser and beam splitter. The interior surface of the sphere is coated with a highly reflective UV coating and is designed with several small ports for indirectly viewing the scattered light. One port is viewed by a biplanar phototube which monitors the light output of the laser on a pulse by pulse basis. The biplanar phototube (for example, the Hamamatsu R1328U) is a special type of vacuum photodiode designed to monitor laser light output power. It is inherently stable with unity gain and capable of delivering a very high