Construction of the Modules

Standard calorimeter modules, shown schematically in Fig. 9.2 and with parameters given in Table 9.2, have transverse dimensions of 10.5×10.5 cm^2 and a depth of $18X_\circ$. They are constructed from alternating layers of 1.5-mm thick lead, white reflecting paper, and 4.0-mm thick injection molded polystyrene-based scintillator tiles.

Injection molding of the scintillator plates helps to decrease drastically the amount of manpower and time involved in scintillator production at the expense of only a slight loss in light yield. A dry mixture of polystyrene granules and two wave-shifting colorants (1.5% p-terphenyl and 0.5% POPOP) is preheated to 170–210 °C and then injected into the mold at a pressure of 150 kg/cm^2. One cycle takes only about two minutes [5]. Due to the high surface quality of the mold thus produced, the scintillation plates do not need additional treatment (except edge-mirroring) before being suitable for assembly. Earlier tests demonstrated that the light yield variations are within $\pm 10\%$, when mechanical tolerances on the tile sizes are 0.1 mm. The light attenuation length measured by exciting the scintillator with a ^{90}Sr radioactive source was 70–90 cm for 5-mm thick tiles. Finally, the wavelength of the scintillator peak emission is at about 420 nm and has a decay time constant of 3.5 ns.

As indicated schematically in Fig. 9.2, the injection molding device and lead-and-paper stamping devices incorporate a 1.2 mm diameter hole pattern on a 8.6-mm grid. The holes allow the WLS readout fibers to be inserted into the assembled modules. The currently favored WLS fiber is the Bicron BCF-99-29a with 1.0-mm diameter, 2.8-ns decay time, and 500-nm peak emission. To compensate for the light loss in reflections at the tile edge, the distance from the last row of fibers to the tile edge is reduced. The optimal reduction appears to be 0.5 mm less than half the fiber-to-fiber step.

The design granularity of 5.25×5.25 cm^2 is reached by assembling each scintillating layer out of four identical injection molded scintillator tiles. Light containment is achieved by painting the edges with reflective paint. The complete stack is held in compression by the 0.2-mm thick stainless steel side covers that are pretensioned and welded to both the front (5-mm thick) and back (8-mm thick) stainless steel plates. This technique was developed in IHEP, Protvino, Russia. The PbSc module, shown in Fig. 9.2, comprises a total of 36 fibers collecting light from an individual tower, which are bundled together, glued, cut and polished, and held fixed inside a short circular tube precisely positioned with respect to the tower axis.

Phototransducer

The phototransducer converts light collected inside the calorimeter tower into an electrical signal. A conventional photomultiplier (PMT) is used. A radioactive source and electron beam calibration are used to set the initial gain; however, the time dependent gain variations intrinsic to this kind of phototransducer make continuous gain monitoring mandatory. This requirement sets stability as a primary design goal both for PMTs and amplifiers. Another important consideration is the dynamic range and maximum current which can be drawn linearly from the PMT.

The upper end of the dynamic range is determined by the maximum energy per channel

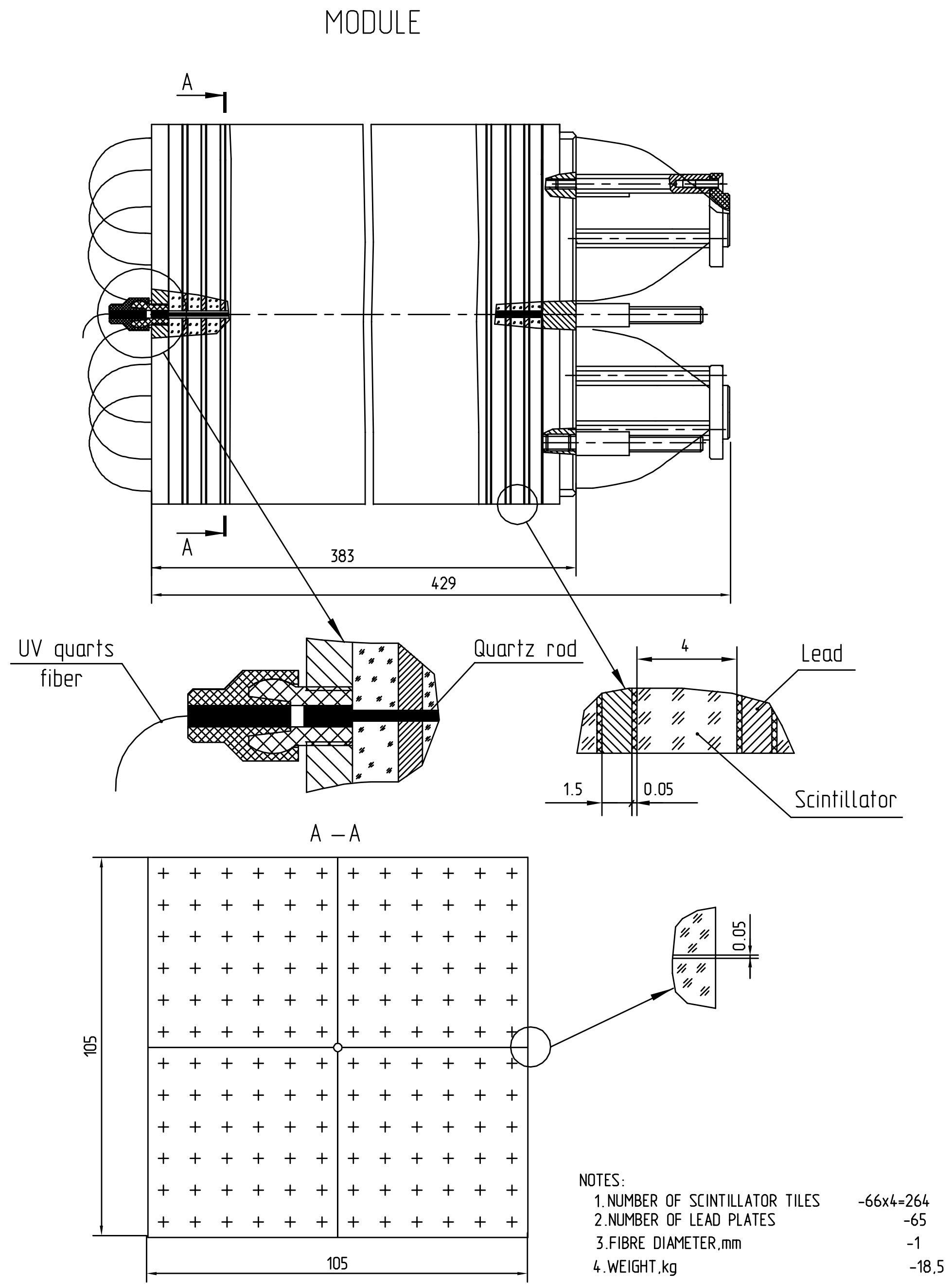

Figure 9.2: Lead-scintillator (shish-kebab) calorimeter module.

Table 9.2: Lead-Scintillator Calorimeter Parameters

Item	Dimension
Lateral segmentation	5.25×5.25 cm^2
Absorber layers	66
Scintillator thickness	4 mm
Absorber	Pb, 1.5 mm
Cell thickness	5.6 mm (0.277 $X_\circ$)
Front plate	Stainless steel, 5 mm
Last plate	Stainless steel, 8 mm
Active depth	370 mm
Total depth (without PM)	550 mm
Number of WLS fibers per tower	36
Fiber diameter	1 mm
Fiber bundle diameter	7 mm

Table 9.3: Phototransducer for PbSc Calorimeter

Item	Description
PMT type	FEU115M
Manufacturer	MELS, Moscow, Russian Federation
Photocathode	Sb-K-Na-Cs
Photocathode diameter	25 mm
External PMT diameter	30 mm
PMT length	90 mm
Luminous sensitivity	≥ 80 μa/lm
Rise time (20%–80%)	≤ 5 ns
Voltage divider	resistive, type B

deposited by high p_T particles and low multiplicity jets. As much as 40 GeV should be measurable in order to do jet studies with leading particles. In general the dynamic range is limited by the maximum linear pulsed current which can be delivered by the PMT. Our collaboration studied a number of relatively inexpensive phototubes available from the PMT manufacturers in Russia. The best choice appears to be the Moscow MELS factory product FEU115M (Table 9.3), which was developed at our request to improve an older fast, but nonlinear, FEU115 phototube.

Recent tests demonstrated that these tubes deliver currents of as much as 100 mA in a linear mode, or approximately 150 pC of charge in a pulse of 30 ns duration (Fig. 9.3).

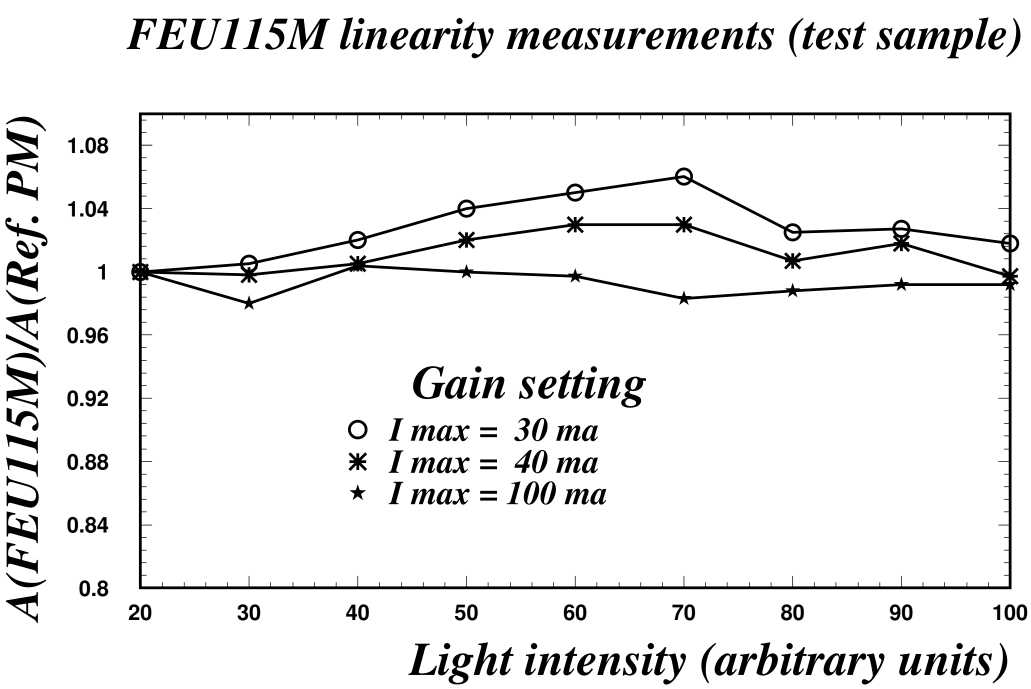

Figure 9.3: Dependence of the FEU115M response (normalized on the response measured with reference photomultiplier) on the light intensity for three different gain settings.

Compared to the expected number of photoelectrons per GeV of deposited energy in our calorimeter, this results in a photomultiplier gain in the range of $0.2 - 2.0 \times 10^6$ (depending on running conditions). This is well within the necessary PMT specifications. We are now working with a different PMT manufacturer in Russia to improve quantum efficiency for green light and to decrease sensitivity to Cherenkov light emitted when a charged particle crosses the entrance window.

Supermodule

The individual modules are attached to a 10-cm thick aluminum backplane to form supermodules, each consisting of 64 modules in a square 8×8 array. The cavities are cast or machined into the backplane at each module location, as shown in the Fig. 9.4, creating an "egg-crate" type structure. The cavities provide room for the grouped fibers, which are then accessible through holes in the backplane. Precise location of the individual modules is achieved by shaping the module back plates to fit into the grooves machined inside the backplane cavities.

The modules are attached with tie-bolts (four per module) to the stainless steel endplate of the module. These tie-bolts are positioned on the periphery of the module to avoid interference with the fibers. The heavy sections of the back plate at the module corners provide room for threaded inserts to serve as the mounting and handling attachments for

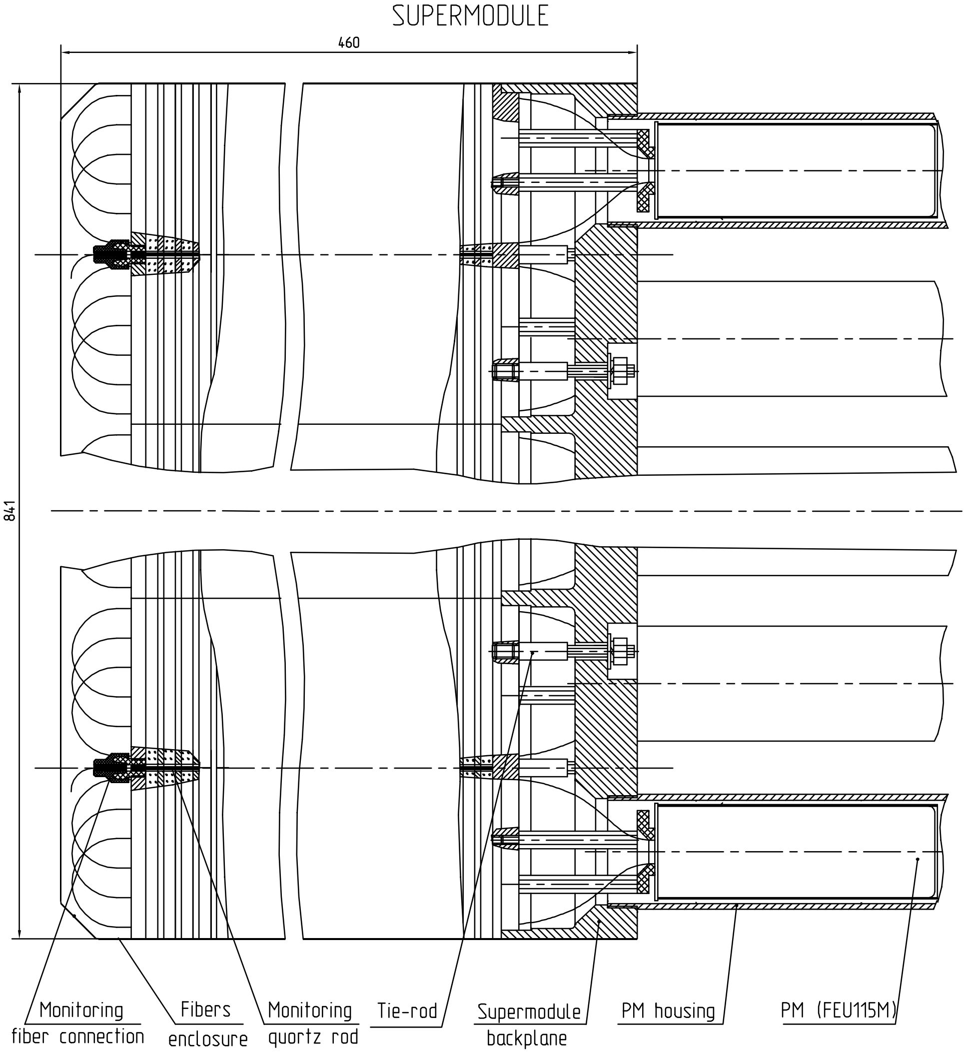

Figure 9.4: PbSc calorimeter supermodule.

the supermodules.

Calorimeter Wall

The supermodules are assembled into three calorimeter walls, each containing 25 supermodules, to form three of the four calorimeter sectors in the PHENIX detector. Each wall therefore has a 4.2×4.2 m live area facing the interaction region.

Ribbed standoffs, about 25-cm high, attach the supermodules to the calorimeter wall structure. The standoffs are required to provide room for the mounting of PMTs and electronics. Four standoffs are arranged on the edge of each supermodule. Figure 9.1 shows how the standoffs mount to vertical beams forming the backbone of the calorimeter wall, which is otherwise open to provide access for both maintenance and for PMT and electronics instal-