LHCb 2001-122
HCAL
15 September 2001

# The Hadron Calorimeter Module-0 Construction

*R.Dzhelyadin, A.Kobelev, A.Konoplyannikov, V.Matveev, V.Novikov and V.Obraztsov.*
*(IHEP, Protvino, Russia)*

ABSTRACT

The construction experience of the LHCb Hadron Calorimeter Module-0 is being described in this note. All related tooling and assembly area in the IHEP workshop were constructed, checked and used as an important step toward serial production of modules. The optics component preparation and assembly also described. The attention is paid for the quality control checks during the assembly chain. The readiness for mass production of the HCAL modules is shown.

# 1. Introduction

The purpose and design of the LHCb Hadron Calorimeter has been described elsewhere (Note LHCb 2000-45). In brief it has been designed as two symmetrical parts of 52 modules in total stacked on top of each other with weight of the module around 9.4 tons.

Here we describe the experience in construction of the Module-0 and the quality check procedures have been done during the assembly.

# 2. Iron plates

All masters and spacers for Module-0 have been milled on the machine. This was a reason why those plates undergo the input check procedure before gluing. Main attention has been paid to the key dimensions of 80 mm that define the relative alignment of plates during sub-module gluing. In the Fig.1 two typical measurement results are shown.

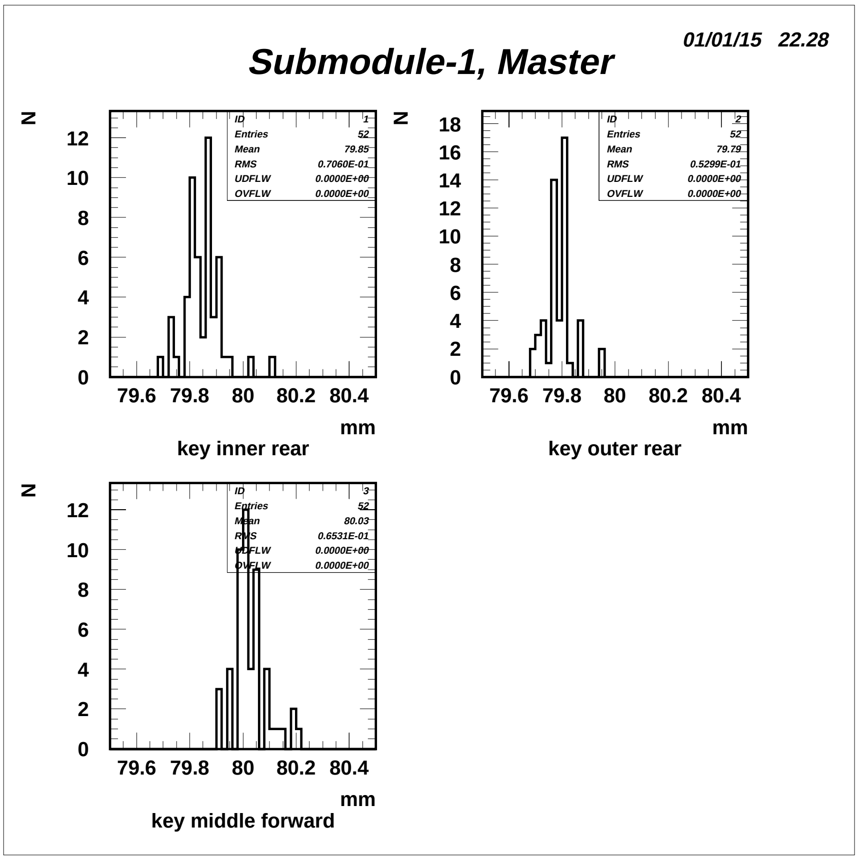


**Fig.1** In the histogram the results of the key measurement are presented. Only one measured distance out of three corresponds to required tolerance of (80.05 ±0.05) mm.

Up to 15% of the total amount of master plates and 18% of spacers containing the end-plug key have not been pass the measurement check and have been corrected on the digital mill machine. Analyses show that error appear mainly because the systematic deviations in the key position for the set of plates (typically for set of one half of needed for sub-module).

The results of this analysis convinced us that the production technology for both masters and spacers has to guarantee the identity of the plates. This means the production has to be done either by computer controlled laser cut or punching using die. Currently both of them are considered as a solution for the production of the masters and spacers.

# 3. Tooling and assembly area

Assembly of sub-modules has been done in the IHEP workshop. The set of needed tools has been designed and constructed. The main purpose of constructing Module-0 was to check those tools and get experience for the mass production. All tools have been tested and accepted without any significant modification. In the table below the set of tools is being listed.

**Table 1**. The incomplete list of the tools designed and constructed for the Module-0 production chain

| N | Item | Desing |
|---|---|---|
| 1 | Master/spacer washing tool | B-1609 |
| 2 | Master/spacer drying tool | B-1647, B-1650 |
| 3 | Sub-module assembly table | 10.2547 |
| 4 | Sub-module lifting tool | 10.2575 |
| 5 | Sub-module rotating tools | P-2979-00/01 |
| 6 | Sub-module welding tool | K-1999-00-00 |
| 7 | Sub-module painting set-up | P-3156-00-00 |
| 8 | Slits cleaning tool | B-1649 |
| 9 | Module assembly facility | 10.2554 |
| 10 | Module lifting tool | 10.2594 |
| 11 | Module optics assembly tool | 10.2574 |
| 12 | Module transporting tool | 10.2593 |

Three last items listed in the table has been moved to CERN with Module-0 to allow tile insertion and fiber routing during optics assembly.

For the gluing we use the modified automatic machine used previously for the ATLAS TileCal sub module construction. The machine has been cleaned up after three years of use, rubber joints and guides replaced and the routing program on the EPROM modified. Fig.2 show the sub-module gluing area during production.

**Fig.2.** The sub-module assembly area in the IHEP workshop. The gluing tool seen on the left. The gluing automatic machine seen on the back covered by the air exhaust.

# 4. Sub-module assembly check

Eight sub-modules have been glued for Module-0. Typically one sub-module assembly takes three days. The procedure includes the following steps:

- **Day-0, morning**. Pick-up the masters and spacers, visual inspection;
- **Day-0, afternoon**. Washing and drying set for sub-module;
- **Day-1, morning**. Gauge test of parts, preparing for gluing;
- **Day-1, afternoon**. Gluing and rest stressed for a night for hardening;
- **Day-2, morning**. Weld side bars, release stress, move to rotating tool and final welding;
- **Day-2, afternoon**. Perform check measurements, move to painting vessel, paint and dry. Mark the serial number. Fill up the protocol.

During the serial production most steps are overlapped, resulting in typical production rate of 4 sub-modules per week.

Both being glued and welded sub-modules are twice measured for the height deviation at 10 points. Fig.3 show the layout of those points.

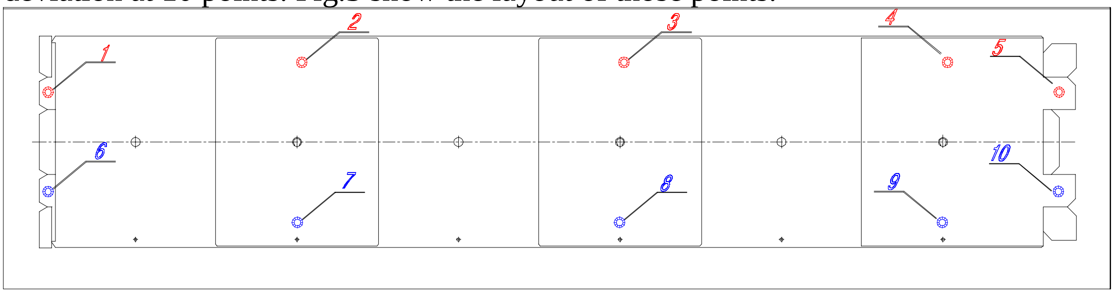


**Fig.3.** The layout of the height measurement points on the top of sub-module after gluing and welding.

The results of the measurements are shown in the Fig.4. All results are well within allowed ±2 mm.

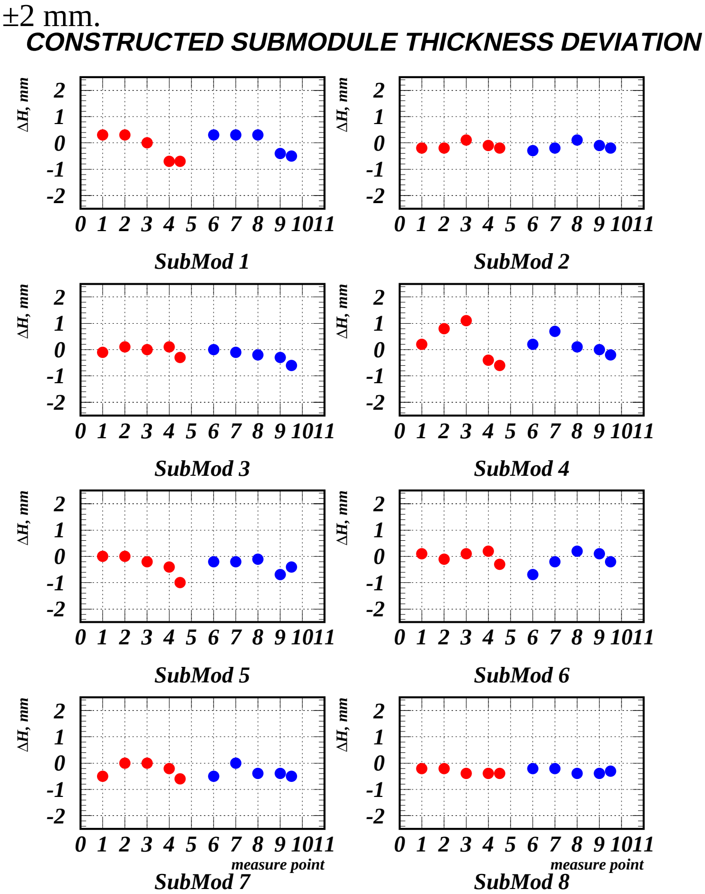


**Fig.4.**The measured sub-modules thickness results.

We investigate the possible barrel-type shaping of the sub-module that results in after the welding the bars on the corners due to bar stretch. Fig.5 show the measurement results averaged along sub-module axis.

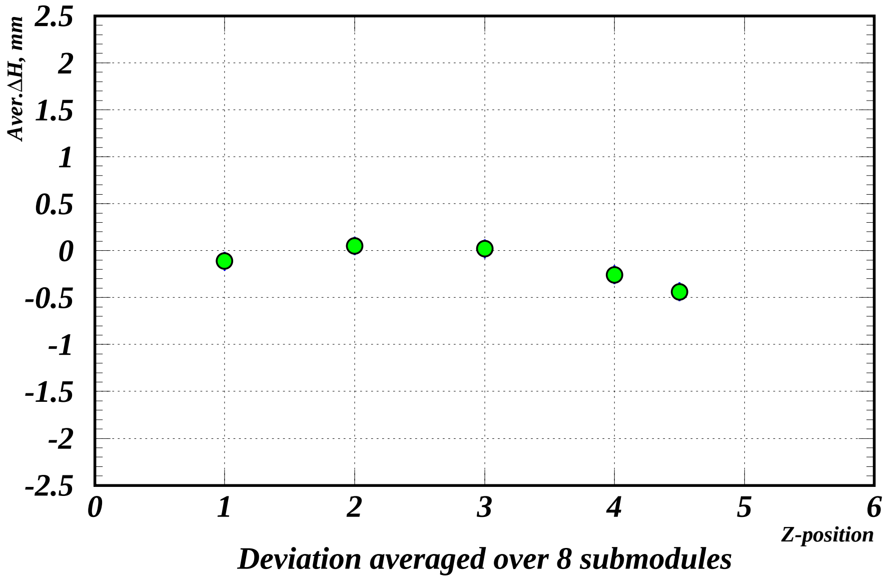


**Fig.5.**The evidence for the barrel-type shape of sub-modules. The sagitta of less then 0.5 mm seen.

The small sagitta of less than 0.5mm is well below required tolerance of ±1.4mm and does not influence on the detector performance. This is a result of long term study of the sub-module welding procedure on the rotating tool shown in the Fig.6.

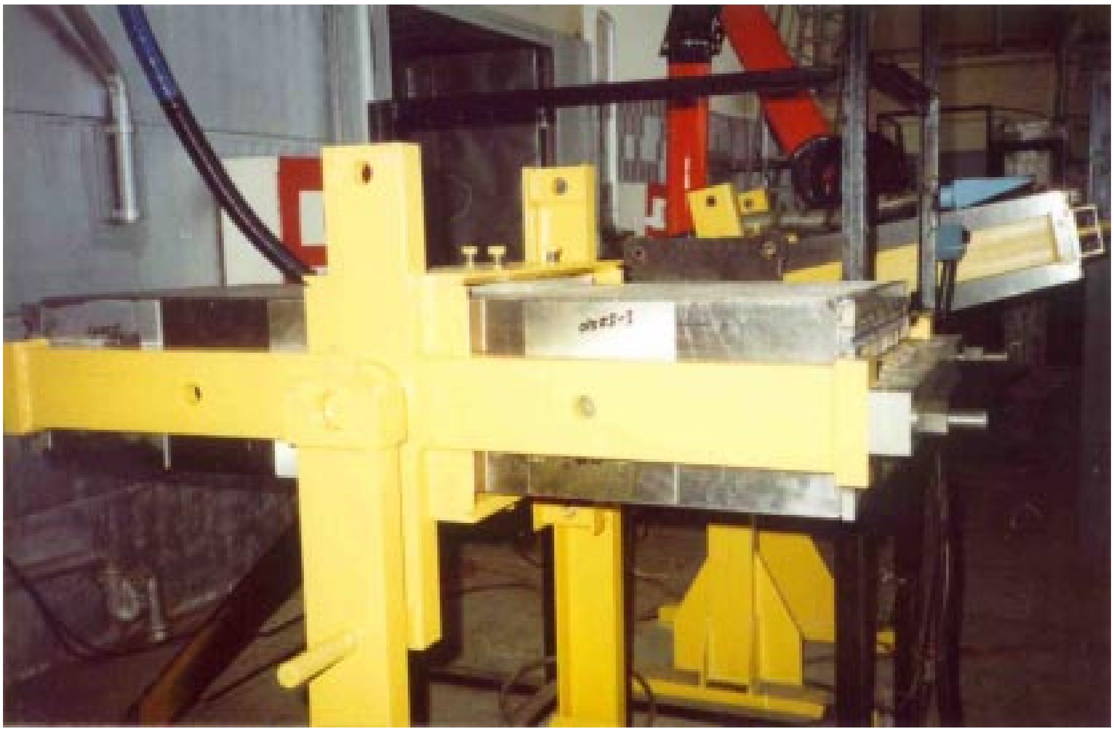

**Fig.6.**The rotating tool for sub-module final welding. To minimize the stretch of the welded bar the special procedure has been developed like a dash-line simultaneously on all bars.

After welding sub-modules pass the slit cleaning procedure. A special tool mentioned under point 8 in Table 1 is used to remove the possible excess on the glue.

Then sub-modules are paint with a water-soluble protective black paint inside the specially designed vessel. Being filled by pump the paint level decrease of one centimeter per minute allows reduce the excess of the paint in the slits. The slit gap is then checked by the set on gauge with different thickness of 3.55, 3.65 and 3.75 mm to ensure the tile wrapped in TYVEK envelope of maximal thickness 3.48 mm will fit in the slit.

## 5. Module assembly

After the completion of eight sub-modules they are join together in module and so called “back-holder” is being attached with bolts. On the Fig.7 the frame of this huge tool is shown. The tolerances required for the assembly of the module are being granted by the precisely machined surfaces, seen on the frame. Back-holder to be screwed to module is temporarily located on the supports, seen on the right.

**Fig.7.**The frame of the module assembly tool.

After the welding of sub-modules together with joining bars the back-holder has been attached without any problem. Several reference marks are foreseen to be applied to the serially assembled module on the same tool to easy the further detector installation and survey.

# 5. Transport to CERN

The assembled Module-0 has been placed on the transport tool and delivered to CERN. The specific feature of the transport support is that on the truck the module is being rest on three points, allow a floor of the panel truck to be screwed during the movement. In Fig.8 an installation for check of the Module-0 on to the transporting tool is shown.

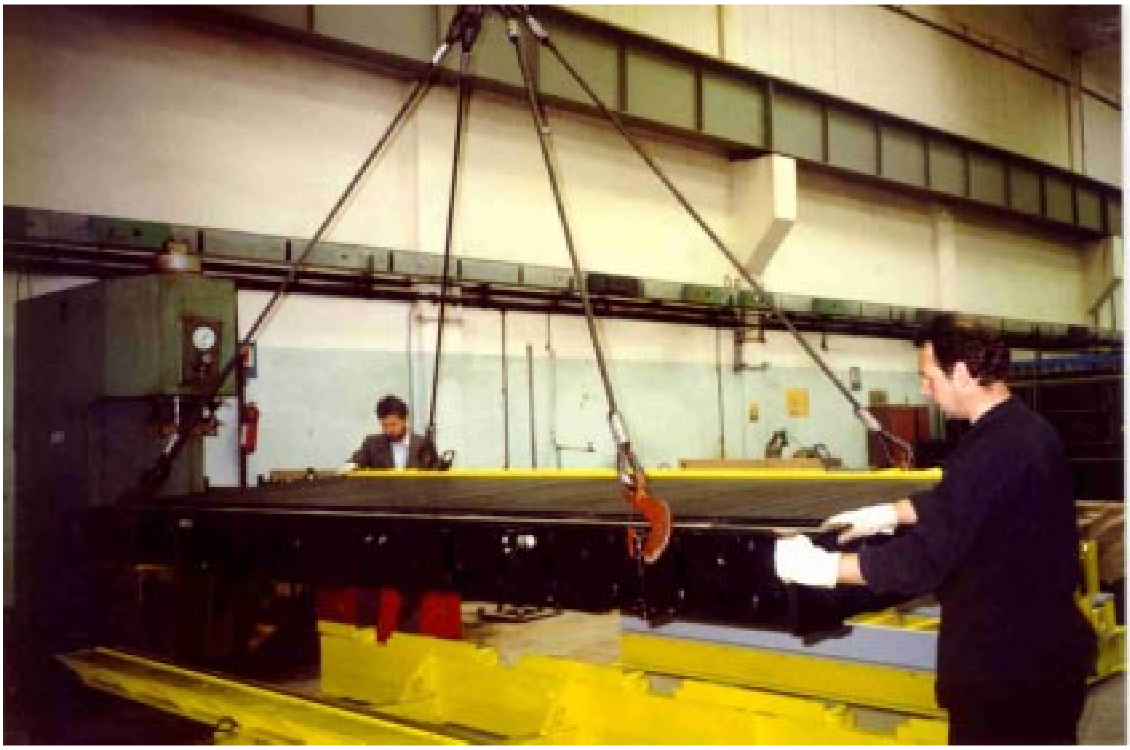

**Fig.8.**Installing the Module-0 on to the transport tool for the check in the IHEP workshop.

Along with Module-0 both the lifting and the optics assembly tool have been delivered. The Fig.9 show the procedure of rotating the Module-0 to the vertical position at the CERN Assembly Hall just after arrival.

Special attention has been paid to the redundant safety margin of the all parts manipulating the module of 10 ton. Many ANSYS calculation at the design stage followed by the overload test after construction convinced in secure use of the tooling in use.

**Fig.9.** Rotation the Module-0 to the vertical position.

# 6. Scintillating tile production

The scintillating tiles have been produced by the productive casting-in-mold technique. The mold design has been done by the “LUTCH” enterprise in Podolsk, Moscow region and constructed at VNIIEF institute, Sarov, Gor’kii region, Russia, undet the ISTC Project 1610. The quality of tiles is defined by the surfaces of the mold. After special treatment of those surfaces they appear to be excellent quality of 14-th class of purity. Fig.10 show the sample of tiles without envelope.

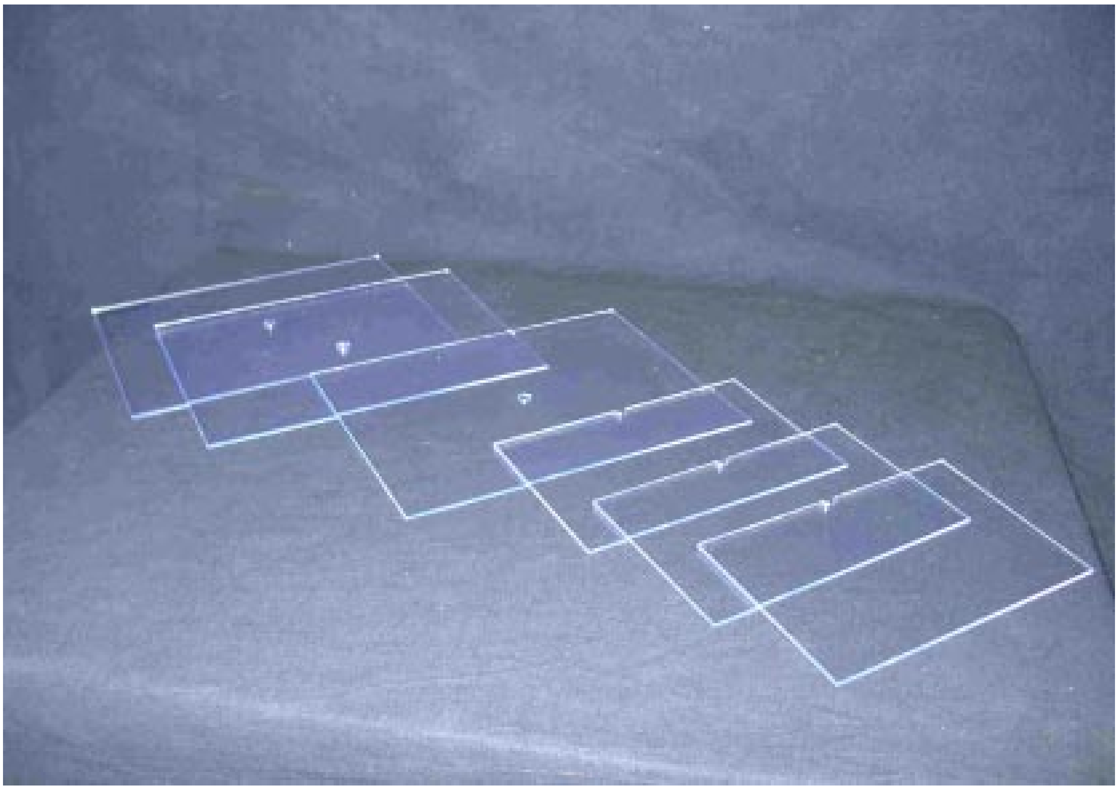

**Fig.10.** The scintillating tiles of full and half size.

In total 1500 tiles have been produced in several days at “LUTCH”. Components used were granulated polystyrene of type BASF 165 H with PTP and POPOP as a primary and secondary dopant. The concentration of the dopants was chosen for PTP 1.75% to polystyrene by weight and POPOP/PTP=1/36.For small samples of 80 tiles the concentration varied for PTP within 1.4-1.8% for further light yield study. The ratio of POPOP to PTP was kept unchanged in this study. All tiles have been wrapped in the TYVEK envelope just after production.

At the production step each set of 25 tiles has been checked for light yield using simple radioactive beta-source illumination. The measurements show the tolerance within ±5% for the main batch. The transparency stability check procedure has been developed by the relative comparison of the light yield for two different points on the tile where beta source is attached.

A dozen of tiles have been scanned with beta source through whole surface. In the Fig.11 the typical scan result is shown. The light attenuation length was estimated in tile as better than 50 cm. In the detector we collect light from both sides of the tile, so the signal response is uniform for most of the tile surface except vicinity of the fiber. Nevertheless this effect compensates the non-instrumented zone between modules after final installation resulting in total uniformity in signal. It have been proved by the beam-test measurement with prototype (LHCb Note 2000-45).

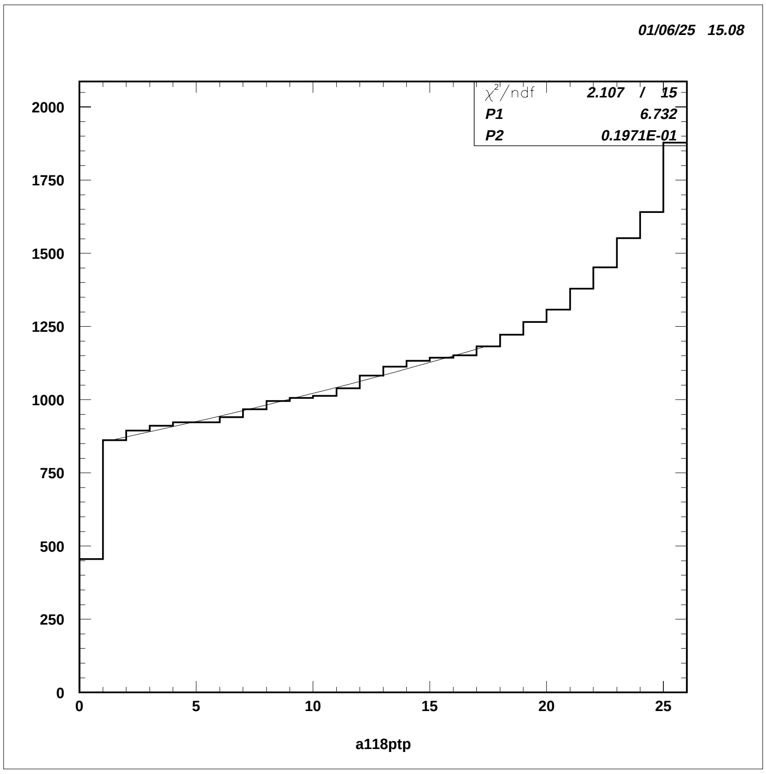


**Fig.11.** Scan results with beta source across tile. The fit show the attenuation length in tile is better than 50cm.

# 7. Wavelength shifting fiber aluminizing

A sample of two types of fibers has been prepared for use in Module-0: the BCF-92 of the BICRON Inc. the fast decay time fiber for periphery of the calorimeter and Y-11(MS250) of KURARAY Inc. for use in the central region of detector as more radiation hard one.

The fibers have been prepared in two steps:

- polishing of the fiber ends with couple of diamond cutter;
- aluminizing a mirror in vacuum with consecutive protective coating with $MgF_2$.

Cutting of the fiber ends has been performed using high-speed (up to 60 thousand rpm) rotating head for 25 fibers in the set. Observation of the machined surface demonstrate very high quality with purity substantially less than one micron level. The schematic view of the cutting head is shown in the Fig.12.

Aluminizing of thousand fibers has been done in sets of 200 fibers and took several days. Samples out of each batch were checked for reflectivity and attenuation length. The fit of the measured data with/without the mirror gave typical reflectivity factor within range 70-83%. In the future the non-destructive check for all aluminized fibers is foreseen. This method will be based on the comparison of the direct and reflected signal on the digital oscilloscope.

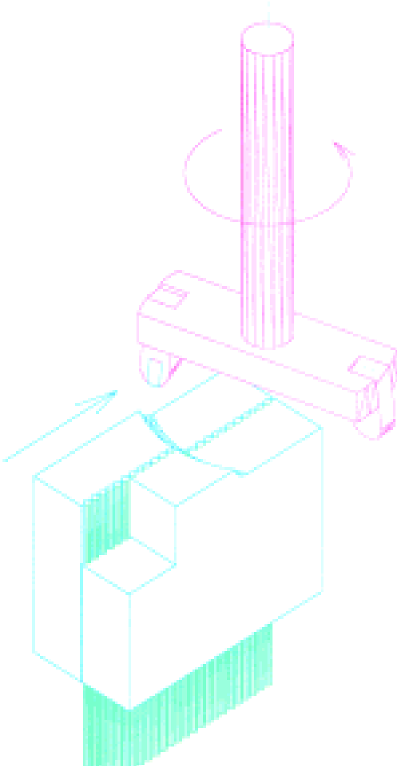

**Fig.12.**The fiber cutting head schematic view.

## 8. Optics assembly

After Module-0 arrival the tile and fiber routing has been performed. In the Fig.13 the details of the fiber routing is shown.

Along with WLS fibers each bundle include couple clear fibers for LED pulsing light supply. Several dummy teflon tubes have been inserted and glued in each bundle also to easier the possible further reparation of fiber in the bundle.

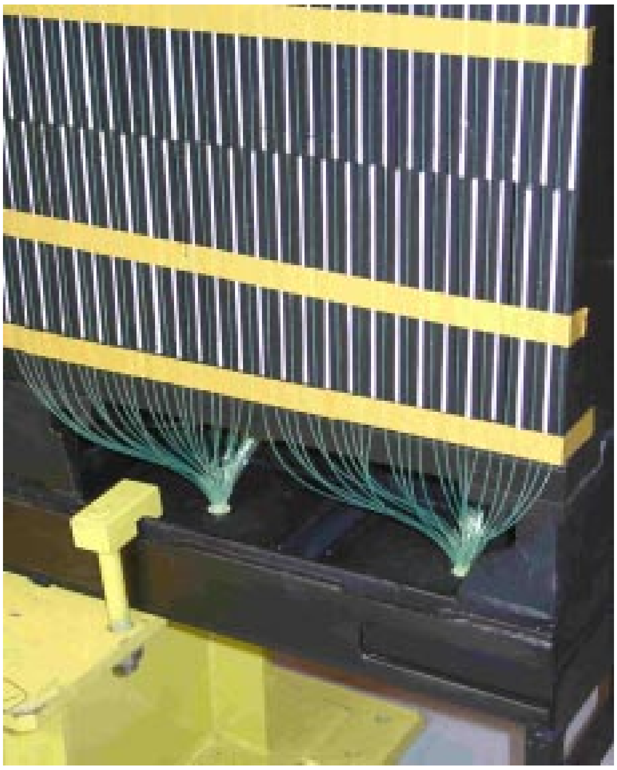

**Fig.13.** The fiber routing in bundles**.**

To compensate the light attenuation in the fiber the optical contact path between scintillating tile and fiber was reduced for bottom layers of tiles according to average measured value of 500cm for fibers with mirrors.

Fibers in 42 bundle (40 detection channel and 2 LED supply) were glued in the teflon cup.

After all, the module has been covered with thin maylar foil and black paper for the external light protection.

The general view of the assembled Module-0 is shown in the Fig 14.

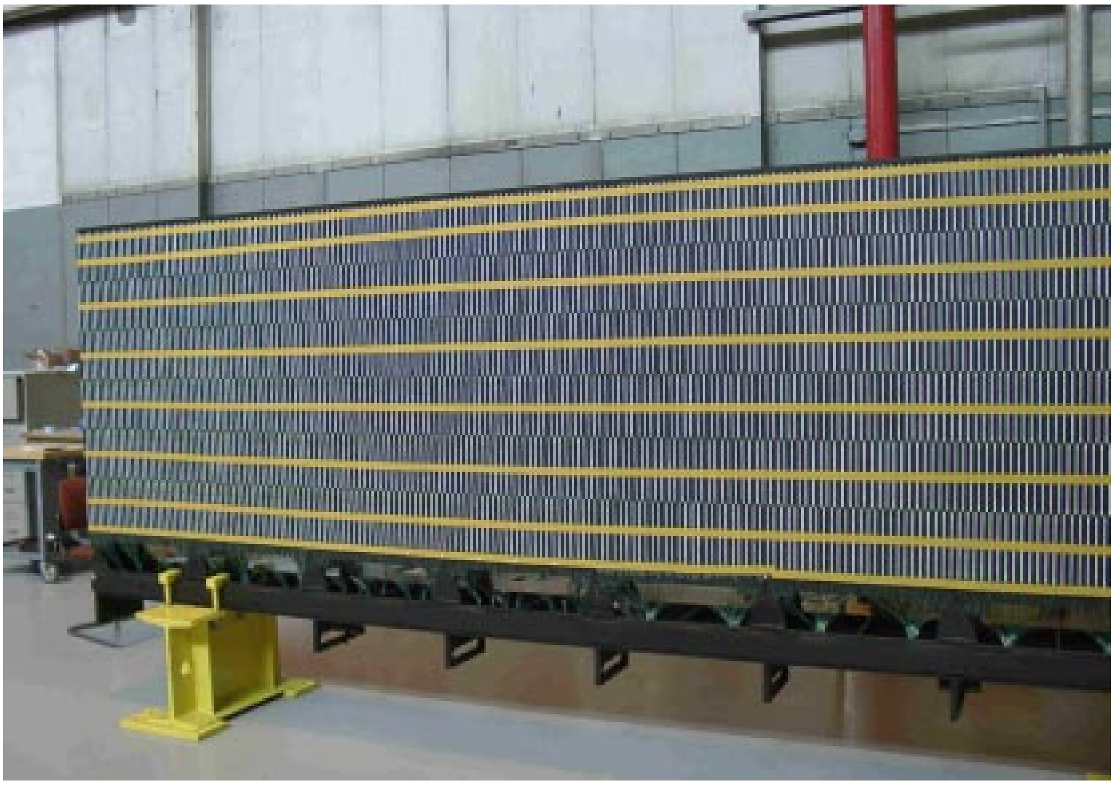

**Fig.14.** Module-0 with optics assembled.

# 9. Tests with radioactive source and beam.

Essential step in the quality control of the assembled modules is test with $^{137}$**Cs** radioactive source. An on-detector integrating electronics with CAN-bus interface to the PC computer has been developed and implemented. First data collected show the reliable performance of the CAN-bus interface at up to 1 Mbit/s transfer rate. Fully automated hydraulic subsystem integrated with SCADA interface allow run the measurement cycle in 3-5 min with recording the data on each tile and fiber in the module. Data collected in the first run are currently under study.

Module-0 after assembly has been moved successfully to the X7 beam line at SPS. The main aim of the coming run is to compare the light yield of the different fibers and tiles with different concentration of dopants. The particle induced pulse shape will be studied on the real-size detector as well. The LED induced pulse will be adjusted precisely to imitate the real signal.

In the Fig.15 an example of the performance of the monitoring system is demonstrated with the test-beam. The HCAL Module-0 was used as an 'luminosity' monitor. Each point corresponds to step of 4 ms for PMT current measurement integrated over 1 ms.

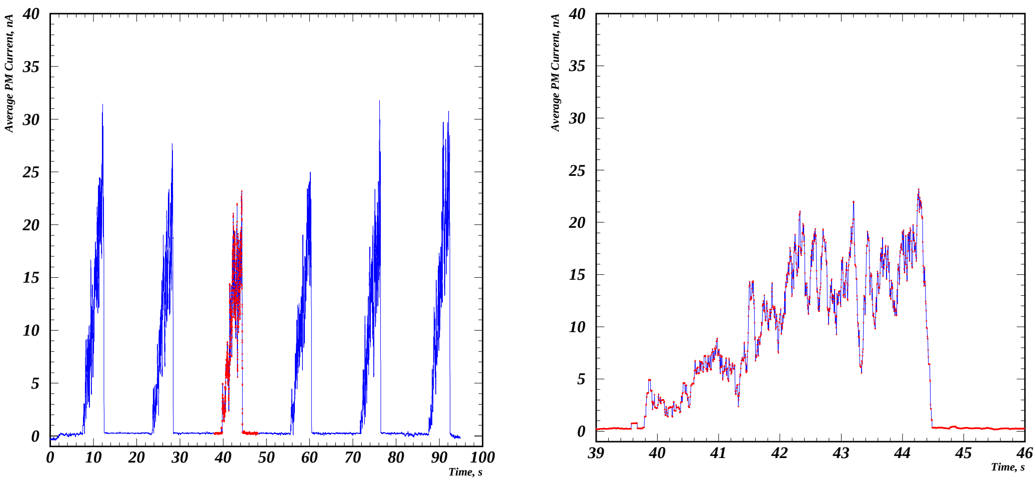


**Fig.15.** An example of the HCAL calibration system readout use for X7 test-beam intensity measurements. The SPS accelerator cycles seen clearly (left) as well as the beam structure during the spill(right figure, zoom of single cycle from left figure)

Results on the final tests will be used for the mass production of the HCAL modules scheduled for start in November 2001.