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Fiber instrumentation of the Barrel and Extended Barrel Modules 0

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Contents

List of Tables

List of Figures

1 Introduction

We report here on the method used in the optical fiber instrumentation of the Tilecal Barrel and Extended Barrel Modules 0, respectively in 1998 and in 1997. The method was developed in 1996 for the first instrumentation of the Barrel Module 0 [1], and some improvements were introduced. An estimative of the light output for each tile of a cell was calculated in order to choose the routing that provides the best uniformity and the maximum light output (light budget calculations [2]). The cell configurations of both Barrel and Extended Barrel modules were extensively discussed in 1997, as well as possible alternative ways to rout the fibers to the PMT's [3].

2 Configuration of the Extended Barrel Modules 0

Two Extended Barrel Modules 0 were instrumented in 1997, one at ANL (Argonne, USA), and the other at IFAE (Barcelona, Spain).

The geometry chosen for the Extended Barrel Modules is the so called "3-4-4" geometry [4, 3], shown in Fig. 1, with the first sampling composed by 3 different sizes of tiles and the other 2 samplings composed of 4 different sizes of tiles each one. In the case of the Barrel Modules, described in section 3, the geometry is the so called "3-6-2" geometry [3], shown in Fig. 2, with 3 different sizes of tiles in the first sampling, 6 sizes of tiles in the second sampling and only 2 sizes of tiles in the third sampling. The BC cells (cells of the second sampling of the geometry "3-6-2"), are read out by fibers with four different lengths, forcing an adequate choice of the location of the PMT's for each cell, in order to get the combination of fiber lengths that corresponds to the best uniformity.

In the case of the Extended Barrel Modules, each cell is read out only by fibers with two different lengths and the non-uniformity inside each cell is not an issue[3]. With this simplification, the choice of the configuration is based essentially in the maximization of the light output, that is equivalent to the minimization of the fiber lengths. This is done assigning to each cell the girder hole nearest to the center of the cell, and in case of conflict, priority is given to the A cells, then to the balance of the number of fibers at left and right of the PMT, then to B cells and finally to D cells. The ITC cells and the small cells C9 have lower priority in the choice of the location of the respective holes. The geometry of the Extended Barrel implemented in the Barcelona Module 0 is shown in Fig. 1, and the distribution of PMT holes for both sides is listed in table 1.

The fiber lengths for the Extended Barrel Modules 0 built in Argonne and Barcelona are given in table 2. The number of profiles with the same fiber lengths are listed in table 3, for the Extended Barrel Module 0 built in Barcelona.

3 Configuration of the Barrel Module 0 in 1998

The optics of the Barrel Module 0 was reinstrumented in 1998 with new tiles and new fibers. Relative to the instrumentation of 1996, the cell geometry was changed allowing to decrease the cost by the suppression of one cell per module (two channels) [3], and to take into account the light output of the new tiles and fibers used. Some definitions relative to the labeling of the cells and PMT holes are described bellow, as well as the tile-fiber light budget calculations.

Review and location of the module in the assembly hall

Figure 3 represents the girder of the Barrel Module 0 as it was in the assembly hall in building 867 at CERN. The small circles represent the holes for the PMT's, the upper ones located at "SALEVE" side (side 2) and the lower ones at "JURA" side (side 1). The numbers represented are associated to the holes (PMT's).

The module has 2 faces (face looking at JURA and face looking at SALEVE), and each face is divided in 2 halves. The half side which contains the special wider submodule (half side located at "north" or "Gex") was instrumented 2 years ago [5], and was arbitrary chosen to be at negative η values. The respective cells are labelled A-1, A-2, ..., D-2, D-3. The other half corresponds to positive η values, and the cells are labelled A+1 (or A1), A+2 (A2), ... D+2 (D2), D+3 (D3). The central cell of sampling D is labelled D0.

The holes for the PMT's in the girder are counted from the center of the module, with negative numbers in the negative η side, and positive numbers in the other side. The 2 holes nearest to the center are the holes number 1 and -1, that define the ODD quarters of the module, as it is represented in the previous drawing. Using this convention (the same used in 1996), in the negative η side ("north") the ODD holes are in the "SALEVE" face and the EVEN holes are in the "JURA" face. In the positive η side is the opposite.

For the 1998 test beam the module was sandwiched between the 1 m prototypes exactly as in the 1996 test beam. On the scanning table the upper face of the Barrel Module 0 was the "JURA" face and the "SALEVE" face was down.

3.1 Light budget and choice of configuration for the Barrel Module 0 in 1998

In the case of the barrel modules (Fig. 2), the situation is quite different from the extended barrel, due to the BC cells of the second sampling which group 6 tiles read out by 4 WLS fibers.

The configuration was chosen using the same guidelines as in the 1996 instrumentation [2], mainly trying to get the best uniformity within each cell, and to get the maximum light output. In the end some lengths were rounded up to decrease the number of fiber lengths. The light output was obtained using parameterizations of the tile and fiber responses. The tile parameterization was obtained from the quality control data taken during the production of the tiles. The tiles were not wrapped and were measured along the central line in 2 points, located 1.5 cm far from the ends of the tile. The sum of both values was used as a rough estimative of the light output of the tile. The data available at the time to estimate the parameterization was obtained from 2 plots received in a fax[1], so the values were not very accurate. Two slightly different parameterizations were obtained from the same plots[2]:

I(tile)=152+2594 / tile length

I(tile)=142+2823 / tile length

Both parameterizations give in general similar results. The tile length is the length at the center of the tile and is the same as the ratio (tile area) /

[1]Fax sent by V.Lapin to M.Nessi

[2]The first one was obtained in Lisbon, the second one was obtained at CERN, and the difference comes from the uncertainty when reading the plots in the fax

(tile width) used in previous notes ([6], [2], etc). For the wrapped tiles, due to the better effective attenuation length, of the order of 50 cm compared with about 30 cm for unwrapped tiles, the decrease of the tile light output with the tile length is expected to be smaller than the decrease obtained in the parameterization used.

The parameterization used for the fibers is a sum of 2 exponentials [7] with the respective reflection. The parameters are listed in table 4. For the Bicron fibers, the parameters were obtained measuring 1.5 m long BCF91A MC fibers without Ultra Violet Absorber (UVA) [8], and for the Pol.Hi.Tech fibers the parameters were obtained for the "higher" concentration of UVA, i.e., 200 ppm [9].

The module is also equipped with Pol.Hi.Tech fibers with smaller concentration of UVA (100 ppm) and BCF99-28 fibers with 60 ppm of UVA, but the small number of fibers and the respective locations in the module do not justify the use of their parameterizations in the calculation to get the best configuration.

When compared with the responses of the tiles and fibers used in 1996, the light output of the tiles now decreases slower with increasing tile length, and the fiber response changes with fiber length in the same way as it was in 1996. So, for the typical lengths of the fibers in the configuration used in 1996, the global response of tile plus fiber decreases slower when the dimensions of the tiles become larger, leading to large non-uniformity inside BC cells. This means that to keep the BC cells uniform, the fibers that read the B subcell should now be as short as possible, and the fibers that read the C subcell should be increased. The other source of changes relative to the configuration of 1996, are the D cells, that now have a cell centered at η=0 (cell D0), to allow the saving of 2 PMTs per Barrel Module.

The configuration used in 1998

The new configuration that was found in the conditions described above is shown in figures 4, 5, 6 and 7, each figure showing one quarter of the module. The lengths of the fibers for the "short" and "long" fibers of each cell, the number of fibers per cell and the cell labels are shown inside the boxes of the cells. In the girder region, at the top of the figures, it is shown the position of the PMT holes and the cell to which they correspond.

The uniformity within each cell can be seen in tables 5 and 6 for the 2

ODD quarters of the module (the EVEN quarters give similar values). In these tables, within each cell, the light output is normalized to the first tile of the cell. Inside each cell, the spread in light output among different tile sizes is smaller that 10%, and the values are quite similar for the Bicron and Pol.Hi.Tech fibers.

The fiber lengths for the Barrel Module 0 are given in tables 7 and 8. The distribution of the profiles is given in tables 9, 10, 11 and 12.

4 Preparation of the Barrel Module 0 for the 1998 optics instrumentation

The preparation of the module for the optics instrumentation consists in a set of operations to allow an efficient insertion of the tiles and fibers and to ensure the best performance. With the experience from the past obtained in the instrumentation of the three Modules 0 in 1996 and 1997, all the required operations were identified. These operations should be done before the installation of the profiles with the fibers in the modules.

The operations are here divided in 2 groups. The first group corresponds to the first 3 items of the list bellow, and should be done during the mechanics instrumentation phase. The other operations should be part of the optics instrumentation phase.

- shimming of the grooves between submodules (this shimming is required to keep the profiles and tiles in place, and to ensure a correct tile-fiber coupling). In the Argonne Extended Barrel Module 0 the shimming was done using mylar strips and epoxy plates, while in the Barcelona Extended Barrel Module 0 and in the Barrel Module 0 the shimming was done using stainless steel strips (Fig. 8);

- make the holes and respective screw thread in the girder to install "curtain" rails to hold the fiber bundles;

- installation of the girder rings (done by the Clermont-Ferrand group using specific tools);

- insertion of the bundle tubes (and covers for the unused holes). This operation may require tools to enlarge the girder rings and install the bundle tubes as tight as possible;

- drawing of the borders of the cells in the module;
- labelling of the PMT holes with the respective cell label;
- installation of the rails to fix the fiber bundles;
- installation of the fiber separator (Fig. 9): structure with ropes that run along the module, like a loom, at the level of the bottom of the girder, used to separate the fibers by samplings;
- installation of the fibers for the laser calibration. The fibers should come organized in cables, and they should run in such a way that their interaction with the path of the WLS fibers bundles is minimum;
- protection with tape (aluminium or other soft adhesive tape) of any sharp corners of the girder that may be in contact with the WLS fibers. In general, it is the top edge of the girder that needs to be covered with tape.

5 Insertion of the tiles and calibration tubes

The wrapped tiles are the first optical component to be installed in the module. It is a manual operation, and its efficiency depends very much on the quality of the assembled modules and of the wrapping of the tiles. The dimensions of the holes where the tiles are inserted in general show fluctuations in heigth and thickness (in most of the cases due to the presence of epoxy inside the hole), and the insertion of the tile may not be possible without cleaning the hole. The wrapper around the tile should have the correct dimensions and be tight and well ajusted to the tile to avoid sliding during the insertion.

After the insertion of the tiles, it is necessary to insert the cesium source calibration tubes that run along the holes of the tiles, and prevent the tiles to get out to one side or to the other (with a tolerance of about 1 mm).

5.1 Remarks on tile quality control

During the insertion of the profiles in the 1998 Barrel Module 0, it was noticed that several tiles were dark, showing a bad transparency. It happened in special in some groups of tiles #8, and more seldom in tiles #7 and #6. The tiles that were clearly less transparent were replaced by "normal" tiles.

6 Insertion of the fibers into the profiles

The insertion of the fibers into the profiles is an operation that is intended to be done automatically. The robot to do the insertion was still being developed, so the insertion of the fibers in the profiles for the Extended Barrel Modules 0 (1997) and Barrel Module 0 (1998) was done by hand.

6.1 Fiber cutting

The fiber cutting was done using paper cutters with sharp blades to grant proper cutting without bending or damaging the fiber ends. A 2.5 m long plate was required to keep the fibers straight while cutting. To store the fibers separated, several trays are required.

6.2 Insertion of the fibers into the profiles

The fibers were inserted manually into the profiles and after the insertion they were glued to the profiles near the aluminized end, about 5 mm far from the end.

Experience with the Extended Barrel Modules 0 The glue used in the Extended Barrel Modules 0 was a standard glue for plastics, "UHU all-past". The main drawback of this glue is the curing time of the order of a few minutes.

The insertion of the fibers in the profiles for the Extended Barrel Modules 0 did not show significative problems. The channels for the fibers were large enough to insert the fibers with very little pressure. In some profiles, the fibers could pass from one lateral channel of the profile to the central one or even to the opposite side, but in general, the insertion of the subsequent fibers would correct the situation. In some cases it was required to correct the insertion, removing the fiber and inserting it again.

Experience with the Barrel Module 0

The glues used in the Barrel Module 0 in 1998 were cyanoacrylate gels (Loctite GelMatic and Loctite 454), which cure much faster than the standard glues. The light losses due to these glues are smaller than 5% [10]. The reason to change from the "standard" glues to the cyanoacrylates is that for the mass production the time of cure is one of the key parameters in the fiber insertion operations. For the manual insertion it was chosen the gel, to allow the best control of the glue drops.

After the gluing, the profiles were stored in groups on storage trays with divisions. The number of profiles in each division was variable (3 to 30). Even using the cyanoacrylate glues, it was found that some profiles glued to the neighbours when they were put together in the storage trays, so it is recommended that in the future, the profiles with fibers and glue curing are kept well separated for several minutes before storing them in the trays, even if it is possible to move and handle the profiles with care just a few seconds after the gluing.

The insertion of the fibers in the profiles used in the Barrel Module 0 in 1998 showed several problems. Some of the channels for the fibers were very tight, some other channels were not symmetric, and some of the drilled holes where the fibers move inside the channels were tight and not perfect, so it was difficult to make the insertion of the fibers. In the most extreme cases it was impossible to insert the fibers. Despite of the channels being tight, in some cases, the fibers were still able to cross from the lateral channels of the profile to the central one.

7 Insertion of the profiles in the modules

The insertion of the profiles in the modules proved to be a fast operation, taking about 1 to 2 minutes per profile, plus some time for the checking of the fiber lengths before the insertion.

A special teflon tool (zip), shown in Fig. 10, was designed and built to insert the profiles in the modules.

Before the insertion of each profile, the width of the groove where it is going to be inserted should be checked by eye observation. If it seems to be very narrow, it should be checked with a gauge, to decide if the profile will be inserted with the normal zip, or with a special zip for narrow grooves.

The insertion of the profile consists of the following steps:

- insert the upper end of the profile in the zip and let it pass through by about 2 or 3 cm;
- put the upper end of the profile in the upper end of the groove and press the inserted upper end of the profile with one finger against the module;
- slide the zip downwards through the groove, keeping the zip pressed against the module, and at the same time keep the profile also pressed with the finger in a position where it is already inserted to avoid the sliding of the profile downwards with the motion of the zip;
- special care should be taken at the down end of the groove to avoid pressing the zip against the iron, which could scratch or break the fibers;
- after the insertion of each profile, the fibers are distributed by the slots of the fiber separator at the girder level, in a pre-defined sequence. The sequence is A (inner), B, C, D (outer) for the Barrel Modules and B (inner), A, D (outer) for the Extended Barrel Modules.

Keeping the profiles inside the grooves

The insertion of the profiles is done only in one side of the module at a time. After the first side is finished, aluminium adhesive tape is used to keep all the profiles of that side in place. Magnetic rulers (e.g., magnetic strips used in refrigerator doors) may be useful to keep the profiles in place while manipulating them, before the application of the aluminium adhesive tape. The tape thickness should be of the order 0.05-0.1 mm, and it should be at least 5 cm wide. Experience advises to use at least one tape per tile, plus one tape in the bottom of the profiles at 1 cm of the end. The tapes should be pressed against the steel of each master to guarantee a good adhesion to the module. For this operation leather gloves are useful, or it can also be used the back edge of the teflon zips used in the insertion of the profiles.

When the insertion of the profiles in the second side of the module is finished, aluminium adhesive tape is applied as in the first side.

Experience with the Modules 0

In the Extended Barrel Module 0 instrumented at ANL, the majority of the profiles inserted in the grooves of the first side that was equipped, were able to keep inside the grooves by themselves. During the insertion of the profiles of the first side, the tiles were free to move about 0.7 mm and were pushed to the opposite side, that had no profiles. When inserting the profiles of the second side, the profiles of the first side were already inserted but not taped with the aluminium adhesive tape, so a huge fraction (about 90%) of them went out of the grooves in the position corresponding to tiles #1 to #3, and about 50% of the profiles went out in some other places. When this behaviour was noticed, it was corrected using aluminium adhesive tape to glue the profiles to the masters.

In the Barcelona Extended Barrel Module 0 this problem was avoided taping the profiles of the first side just after insertion and before starting the insertion of the profiles of the opposite side.

After the insertion of the profiles it was noticed that the profiles were slightly out of the envelope of the masters in some places in both Extended Barrel Modules 0. The position where it was more visible, was at tile #3, where the profiles could be out of the masters by about 0.5 mm. For tiles larger than tile #3 the height of profile out of the envelope of the masters was smaller, being more evident only in very narrow grooves.

In the Barrel Module 0, the problem was even worse than in the Extended Barrel Modules 0. The tiles from #1 to #3 were longer than the corresponding tiles of the Extended Barrels by about 0.5 to 1 mm, so more profile was out of the envelope of the master plates.

Changes of dimensions for the future modules

The behaviour described from the experience with the Modules 0 results mainly from a lack of depth in the grooves for the profiles. The factors that contribute to the small depth of the grooves are the following:

- groove design depth was very small to minimize the crack between modules, mainly in the zone of tiles #1 to #3, where the profile had to be cut remaining very fragile;

- tiles were 0.6 mm longer than spacers by design. This feature caused problems and was more evident in small tiles where the depth of the groove was very small and the profiles were fragile;
- the front surface of the masters is not flat. Due to the dye punching cut, the masters are shorter than the nominal dimension at least in one of the sides.

Other important factor is the tolerance of the order of 1 mm that the tiles can have in lateral motion.

Some of these features in the tiles dimensions (and depth of the grooves) are already optimised in the design for the future modules. The spacer length is decreased mainly in the three smaller tiles to avoid the cutting of one side of the profiles in that region, and the difference in length between tiles and spacers is reduced from 0.6 mm to 0.4 mm.

7.1 Profiles and cell correctness in the Extended Barrel Modules 0

In the Extended Barrel Modules 0 the profiles were white with a transparency that was found to be of the order of 30%, so the checking of the correctness of the cells could be done using a lamp, and the checking of the lengths before insertion of the profiles was less important because any error would be detected before gluing, in time to allow a correction. This light check is also possible with the grey profiles used in small regions of the Barrel Module 0. These grey profiles have a transparency of the order of 1% or less.

7.2 Profiles and cell correctness in the Barrel Module 0

In the Barrel Module 0 most of the profiles were black and opaque, so it was impossible to check the correctness of the cells using light to check the ends of the fibers. In order to minimize the occurrence of errors, the profiles of the combination of cells to be inserted ($\mathrm{A}_i\mathrm{B}_j\mathrm{C}_k\mathrm{D}_l$) were displayed in a empty tray nearby the module. The number of short and long profiles was checked as well as the respective fiber lengths, comparing with the values in the profile insertion tables (tables 9, 10, 11 and 12).

8 Fiber bundling and routing

After the insertion of the profiles in the modules, the bottom ends of the fibers have to be inserted in the bundle tubes, grouped in bundles of fibers belonging to the same cell.

8.1 Fiber bundling

The fibers separated by samplings through the fiber separator are first grouped in sub-bundles and later inserted in the respective bundle tubes. Several approaches have been used in the Barrel and in the 2 Extended Barrel Modules 0.

Experience with the Extended Barrel Modules 0

In the Extended Barrel Module 0 made at Argonne, it was used the technique described in the note [4] to make the bundles. The number of fibers in each sub-bundle was well defined, as well as the respective routing. The routing of each sub-bundle was specified as a sequence of curvatures. The final result was nice, as can be seen in Fig. 11, but the manipulation of the bundles to prepare for gluing was not easy. As additional drawbacks, the number of curvatures of some sub-bundles and the length of the majority of the fibers were excessive.

In the Extended Barrel Module 0 made in Barcelona the sub-bundles were done using the following technique: rubber bands with several loops were put around 1 cm diameter plastic tubes, then the fibers of each sub-bundle were inserted in the plastic tubes, and the tubes were removed leaving the rubber bands around the fibers. The number of fibers in each sub-bundle was chosen in the following way: each of the outermost bundles had 5 fibers; the inner bundles had 10 fibers each, with the exception of the bundles close to the PMT position - these bundles were adjusted in the range from 5 to 15 fibers, keeping the fibers located at the right of PMT in sub-bundles at the right, and fibers located at the left of the PMT in sub-bundles located at the left. The final result can be seen in Fig. 12.

Experience with the Barrel Module 0 In the Barrel Module 0, for each cell, in general 4 sub-bundles were made, two with the fibers located at the left of the bundle tube and the other two with the fibers located at right.

The two sub-bundles with the fibers of both ends of the cell had only 6 fibers. If the number of fibers in one of the sub-bundles was very small (typically smaller than 6), that sub-bundle might be eliminated and the fibers joined one of the neighbour sub-bundles.

8.2 Routing of the fiber bundles

The sequence of insertion in the bundle tubes is the sequence of the samplings, that is from A (first) to D (last) in the Barrel Modules and B, A, D in the Extended Barrel Modules.

After the first bundling, it is necessary to make corrections in the path of the bundles, to ensure that the paths of the bundles will keep the minimum curvature when the fibers are restrained to be within the girder boundaries. These corrections are done bundle by bundle, and have to take into account the clearance required for the gluing operations. It is a operation done by eye, taking into account the experience of the previous modules, and for which there are not very clear rules. In the instrumentation of the Barrel Module 0 in 1998 it was tried to use photos from one side to make the routing corrections in the other side, but the help of the photos is reduced due to the lack of the third dimension (depth) in the photos. For the future production of the modules, mock ups will be done and used by the technicians to implement the same routing in all the modules.

8.3 Checking the bundles

Before gluing the bundles of fibers, the correctness of the bundles has to be checked, i.e., it has to be checked if they have all the fibers of the respective cell and no fibers of the neighbour cells.

In the Extended Barrel Modules 0, this test was done in a similar way to the procedure described in section 7.1.

In the Barrel Module 0 the test done in the Extended Barrel Modules 0 was impossible, as it is described in section 7.2. In this case the number of fibers in each bundle was counted after the bundle making procedure. This procedure is not as safe as the check with the light source. In fact, later it was found that 2 fibers were in the wrong bundles, as it is described below in section 8.6.

8.4 Gluing the bundles of fibers

Before the gluing, each bundle of fibers needs to be completed with small dummy fibers to fill completely the bundle ring. When complete, 2 fibers are removed to allow the later insertion of 2 clear fibers for the laser calibration. The fibers are adjusted in such a way that their ends do not differ by more than 2 mm. A dentist mirror may be used to help looking at the end of the bundle of the fibers. After, a sponge is put around the bundle of fibers to protect them, about 4 cm out of the bundle ring, and the fibers are tightly tied with a cable tie. The 2 calibration fibers are then inserted in the bundle ring, out of the cable tie.

After the preparation of all the bundles following the procedure described above, the bundles are ready to be glued.

The glue used is Bicron BC 600, prepared in plastic cups with a mixture of resin and hardener (28% of the resin in weight - a balance with a precision of 0.1 g was used). In normal conditions it should be put in the syringes after being well mixed, the syringes are kept in vertical position to get rid of the air bubbles, and the glue is injected about 45 minutes later. The injection is done using wide needles connected to 1 mm diameter teflon tubes.

After the injection of the glue in each bundle, more dummy fibers should be inserted if glue is seen escaping by the middle of the fibers.

In the Barrel Module 0, the amount of glue that escaped was not negligeable. The zones of the fiber bundle in contact with the glue became hard and non-flexible “rocks” of fibers mixed with glue. These “rocks” could be as long as 5 cm, making difficult to bend the bundles of fibers, and easy to break them.

When the glue is cured (in general after two days), the dummy fibers are cut.

8.5 Mechanical flexibility of fibers and bundles

The bundles of fibers in general are very flexible and allow an easy routing within the available space of the girder as it was found in the instrumentation of the Barrel Module 0 in 1996 and of the two Extended Barrel Modules 0 in 1997. But that was not the case in several bundles of the Barrel Module 0 in 1998.

Experience with the Barrel Module 0 in 1998

If there is glue in the middle of the bundle of fibers (glue that escaped from the bundle tube during the gluing procedure), it makes the bundle hard and non-flexible, as it happened in some bundles of the Barrel Module 0 in 1998. In most of the cases, it was possible to separate the glue from the fibers of the bundles and the bundles recovered the flexibility. The risk of this operation is not negligeable, and it is possible that it results in broken fibers, as it happened some times.

During the operation of cutting the dummy fibers in the Barrel Module 0, it was found that the fibers break easily. In general, edge effects in the glued zone of the fiber were responsible for the breaking, but some fibers that were not in the edges broke also easily. After the discovery of this unusual feature of the fibers, a fast test was done with a few samples of Bicron, Kuraray and Pol.Hi.Tech fibers. The test consisted in bending the fibers until they break, or up to 180 degrees. The qualitative result of the test was the following:

- Bicron BCF91A from Module 0 of 1998 and old Kuraray Y11(200)MS fibers taken out from Module 0 of 1996:

  In general the fiber would not break up to 180 degrees. Only in a few cases the fiber would break.

- Pol.Hi.Tech S250 fibers from Module 0 of 1998:

  In general the fibers would break at angles as small as 90 degrees. In a few cases they would not break up to 180 degrees. Along one fiber it was possible to find regions of breaking and not breaking behaviours alternating.

This test shows that some fibers of the Pol.Hi.Tech production for the Barrel Module 0 of 1998 had some mechanical problems.

8.6 Reparation of broken fibers and routing errors

In the first instrumentation of the Barrel Module 0 and in the Extended Barrel Modules 0 there were no fibers broken in the preparation for the gluing or after the gluing of the bundles. A total of 5 fibers were broken in the second instrumentation of the Barrel Module 0 in 1998.

One of the fibers was broken at 2 cm from the end, so the respective path was changed to allow it to go straight to the PMT, requiring no further repair. The other 4 broken fibers were polished in the end and connected to the spare clear fibers of the respective bundles. The connection was done using plastic tube with a inner diameter of 1 mm to guide the fibers, which were glued one to the other with Bicron 600 glue. After the gluing, the connection seemed to be mechanically hard enough.

The list of connected fibers is shown in Table 17.

It was found during the calibration with the cesium source that there was an exchange of two fibers between cells B-2 and B-3, in the JURA side. The last fiber of cell B-3 was routed to the bundle of B-2, and the second fiber of cell B-2 was routed to the bundle of cell B-3. Both fibers were cut, polished and connected to the spare clear fibers of the respective bundles, eliminating the routing error.

The list of repaired fibers due to routing errors is shown in Table 18.

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Cell	PMT hole (Odd side)	PMT hole (Even side)
A12	7	8
A13	11	12
A14	21	22
A15	29	30
A16	41	42
B11	9	10
B12	15	16
B13	23	24
B14	33	34
B15	43	44
C9	5	6
D5	3	4
D6	17	18
D7	37	38

Table 1: Hole numbers of the PMT's, for each cell of the EB Modules 0 made at Argonne and Barcelona. Holes 1, 2, 13 and 14 will be used by the ITC scintillators.

Cell	length (BCN)	length (ANL)
A12	195	207
A13	210	253
A14	210	253
A15	210	253
A16	230	253
B11	175	224
B12	180	224
B13	180	224
B14	185	224
B15	190	224
C9	125	139
D5	90	124
D6	170	170
D7	170	170

Table 2: Fiber lengths for each cell of the Extended Barrel Modules 0. BCN - Barcelona, ANL - Argonne. Fiber lengths in cm.

Name	Profile	number	A	B	D
A12B11	long	9	195	162	155
A12B11	short	8	186	175	170
A13B11	long	7	210	162	155
A13B11	short	7	201	175	170
A13B12	long	18	210	167	155
A13B12	short	19	201	180	170
A14B12	long	9	210	167	155
A14B12	short	8	201	180	170
A14B13	long	19	210	167	155
A14B13	short	19	201	180	170
A15B13	long	10	210	167	155
A15B13	short	11	201	180	170
A15B14	long	19	210	172	155
A15B14	short	19	201	185	170
A16B14	long	13	230	172	155
A16B14	short	13	221	185	170
A16B15	long	35	230	177	155
A16B15	short	35	221	190	170
ITC	Profile	number		C	D
C9D5	long	5	–	125	71
C9D5	short	5	–	110	90
D5	long	12	–	–	90
D5	short	12	–	–	71

Table 3: Number of profiles and fiber lengths for the Extended Barrel Module 0 built in Barcelona. The cells D6 and D7 do not appear in the labelling because both have the same fiber lengths. The number of half-periods is 128 for cell D6 and 150 for cell D7. Fiber lengths in cm.

Fibers	L_{att}^{short}	I_0^{short}	L_{att}^{long}	I_0^{long}	R
Bicron BCF91A MC	23 cm	0.58 a.u.B.	345 cm	0.75 a.u.B.	0.75
Pol.Hi.Tech S250 MC	27 cm	0.9 a.u.P.	323 cm	1.1 a.u.P.	0.50

Table 4: Fiber parameters for the tile-fiber light budget of the Barrel Module 0 of 1998. The arbitrary units used (a.u.B. and a.u.P.) for I_0 are not the same for the Bicron and Pol.Hi.Tech fibers. R is the reflection coefficient. The Bicron BCF91A MC fibers had no UVA, while the Pol.Hi.Tech S250 MC had 200 ppm of UVA.

SAMPLING 1						
cell	tile 1	tile 2	tile 3			
A1	1	1.01	0.98			
A2	1	1.01	0.98			
A3	1	1.01	0.98			
A4	1	1.01	0.98			
A5	1	1.01	0.98			
A6	1	1.01	0.98			
A7	1	1.01	0.98			
A8	1	1.01	0.98			
A9	1	1.01	0.98			
A10	1	1.01	0.98			
SAMPLING 2						
cell	tile 4	tile 5	tile 6	tile 7	tile 8	tile 9
BC1	1	1.02	0.98	1.06	1.09	1.05
BC2	1	1.02	0.98	1.04	1.07	1.03
BC3	1	1.02	0.98	1.03	1.05	1.01
BC4	1	1.02	0.98	1.01	1.04	1.00
BC5	1	1.02	0.98	1.01	1.04	1.00
BC6	1	1.02	0.98	1.03	1.05	1.01
BC7	1	1.02	0.98	1.02	1.05	1.01
BC8	1	1.02	0.98	1.02	1.05	1.01
SAMPLING 3						
cell	tile 10	tile 11				
D0	1	1.05				
D1	1	1.05				
D2	1	1.05				
D3	1	1.05				

Table 5: Light budget for the Barrel Module 0 in 1998, using Bicron BCF91A MC fibers. Values of relative light output for the negative η side and PMT's with odd numbers. All the values are normalized to the first tile of each cell.

SAMPLING 1						
cell	tile 1	tile 2	tile 3			
A1	1	1.01	0.99			
A2	1	1.01	0.99			
A3	1	1.01	0.99			
A4	1	1.01	0.99			
A5	1	1.01	0.99			
A6	1	1.01	0.99			
A7	1	1.01	0.99			
A8	1	1.01	0.99			
A9	1	1.01	0.99			
A10	1	1.01	0.99			
SAMPLING 2						
	tile 4	tile 5	tile 6	tile 7	tile 8	tile 9
BC1	1	1.02	1.00	1.07	1.11	1.08
BC2	1	1.02	1.00	1.05	1.09	1.06
BC3	1	1.02	1.00	1.03	1.07	1.05
BC4	1	1.02	1.00	1.02	1.05	1.03
BC5	1	1.02	1.00	1.02	1.05	1.03
BC6	1	1.02	1.00	1.03	1.07	1.04
BC7	1	1.02	1.00	1.03	1.07	1.04
BC8	1	1.02	1.00	1.03	1.07	1.04
SAMPLING 3						
	tile 10	tile 11				
D0	1	1.07				
D1	1	1.06				
D2	1	1.06				
D3	1	1.06				

Table 6: Light budget for the Barrel Module 0 in 1998, using Pol.Hi.Tech S250 MC fibers. Values of relative light output for the positive η side and PMT's with odd numbers. All the values are normalized to the first tile of each cell.

	Long Fibers			Short Fibers		
cell	# fib.	ODD	EVEN	# fib.	ODD	EVEN
A-1	13	205	200	13	196	191
A-2	13	205	200	14	196	191
A-3	14	200	200	14	191	191
A-4	14	212	200	14	203	191
A-5	15	200	200	14	191	191
A-6	15	200	200	16	191	191
A-7	17	205	205	16	196	196
A-8	17	205	205	17	196	196
A-9	18	212	212	19	203	203
A-10	16	205	205	16	196	196
B-1	15	170	170	15	157	157
B-2	16	170	170	15	157	157
B-3	15	170	170	16	157	157
B-4	16	170	170	16	157	157
B-5	17	170	175	17	157	162
B-6	18	175	175	17	162	162
B-7	18	180	180	19	167	167
B-8	20	180	180	19	167	167
B-9	18	175	175	18	162	162
C-1	17	135	135	18	120	120
C-2	18	140	140	17	125	125
C-3	18	145	145	18	130	130
C-4	18	150	150	19	135	135
C-5	20	150	160	19	135	145
C-6	20	150	150	20	135	135
C-7	21	155	155	22	140	140
C-8	20	155	155	20	140	140
D-0	20	105	105	19	86	86
D-1	40	116	116	41	97	97
D-2	43	112	112	42	93	93
D-3	50	125	120	50	106	101

Table 7: Number of fibers and fiber lengths for the Barrel Module 0, "north" side (negative η), Bicron fibers. Fiber lengths in cm.

	long fibers			short fibers		
cell	# fib.	ODD	EVEN	# fib.	ODD	EVEN
A1	13	205	200	13	196	191
A2	14	205	200	13	196	191
A3	14	200	200	14	191	191
A4	14	212	200	14	203	191
A5	14	200	200	15	191	191
A6	16	200	200	15	191	191
A7	16	205	205	17	196	196
A8	17	205	205	17	196	196
A9	19	212	212	18	203	203
A10	16	205	205	16	196	196
B1	15	170	170	15	157	157
B2	15	170	170	16	157	157
B3	16	170	170	15	157	157
B4	16	170	170	16	157	157
B5	17	170	175	17	157	162
B6	17	175	175	18	162	162
B7	19	180	180	18	167	167
B8	19	180	180	20	167	167
B9	18	175	175	18	162	162
C1	18	135	135	17	120	120
C2	17	140	140	18	125	125
C3	18	145	145	18	130	130
C4	19	150	150	18	135	135
C5	19	150	160	20	135	145
C6	20	150	150	20	135	135
C7	22	155	155	21	140	140
C8	20	155	155	20	140	140
D0	19	105	105	20	86	86
D1	41	116	116	40	97	97
D2	42	112	112	43	93	93
D3	50	125	120	50	106	101

Table 8: Number of fibers and fiber lengths for the Barrel Module 0, "south" side (positive η), Pol.Hi.Tech fibers.

name	profile	number	A	B	C	D
A1B1C1D0	short	13	191	170	120	105
=	long	13	200	157	135	86
A2B1C1D0	short	2	191	170	120	105
=	long	2	200	157	135	86
A2B2C1D0	short	3	191	170	120	105
=	long	2	200	157	135	86
A2B2C2D0	short	2	191	170	125	105
=	long	2	200	157	140	86
A2B2C2D1	short	7	191	170	125	116
=	long	7	200	157	140	97
A3B2C2D1	short	4	191	170	125	116
=	long	4	200	157	140	97
A3B3C2D1	short	4	191	170	125	116
=	long	5	200	157	140	97
A3B3C3D1	short	6	191	170	130	116
=	long	5	200	157	145	97
A4B3C3D1	short	5	191	170	130	116
=	long	6	200	157	145	97
A4B4C3D1	short	7	191	170	130	116
=	long	7	200	157	145	97
A4B4C4D1	short	2	191	170	135	116
=	long	1	200	157	150	97
A5B4C4D1	short	5	191	170	135	116
=	long	6	200	157	150	97
A5B4C4D2	short	2	191	170	135	112
=	long	2	200	157	150	93
A5B5C4D2	short	7	191	175	135	112
=	long	7	200	162	150	93

Table 9: Number of profiles and fiber lengths for the Barrel Module 0, "north" side (negative η), Bicron fibers, EVEN holes. Fiber lengths in cm.

name	profile	number	A	B	C	D
A6B5C4D2	short	3	191	175	135	112
=	long	2	200	162	150	93
A6B5C5D2	short	7	191	175	145	112
=	long	8	200	162	160	93
A6B6C5D2	short	6	191	175	145	112
=	long	5	200	162	160	93
A7B6C5D2	short	6	196	175	145	112
=	long	7	205	162	160	93
A7B6C6D2	short	6	196	175	135	112
=	long	5	205	162	150	93
A7B7C6D2	short	4	196	180	135	112
=	long	5	205	167	150	93
A8B7C6D2	short	2	196	180	135	112
=	long	1	205	167	150	93
A8B7C6D3	short	8	196	180	135	120
=	long	9	205	167	150	101
A8B7C7D3	short	4	196	180	140	120
=	long	4	205	167	155	101
A8B8C7D3	short	3	196	180	140	120
=	long	3	205	167	155	101
A9B8C7D3	short	10	203	180	140	120
=	long	9	212	167	155	101
A9B8C7D3	short GREY	5	203	180	140	120
=	long GREY	5	212	167	155	101
A9B8C8D3	short GREY	2	203	180	140	120
=	long GREY	2	212	167	155	101
A9B9C8D3	short GREY	2	203	175	140	120
=	long GREY	2	212	162	155	101
A10B9C8D3	short Black	8	196	175	140	120
=	long Black	8	205	162	155	101
A10B9C8D3	short GREY	8	196	175	140	120
=	long GREY	8	205	162	155	101

Table 10: (continuation of table 9) Number of profiles and fiber lengths for the Barrel Module 0, "north" side (negative η), Bicron fibers, EVEN holes. Fiber lengths in cm.

name	profile	number	A	B	C	D
A1B1C1D0	short	10	196 -UVA	170 -UVA	120 -UVA	105 -UVA
=	long	10	205 -UVA	157 -UVA	135 -UVA	86 -UVA
A1B1C1D0	short	3	196 -UVA	170 -UVA	120 -UVA	105
=	long	3	205 -UVA	157 -UVA	135 -UVA	86
A2B1C1D0	short	2	196	170 -UVA	120 -UVA	105
=	long	2	205	157 -UVA	135 -UVA	86
A2B2C1D0	short	2	196	170	120 -UVA	105
=	long	3	205	157	135 -UVA	86
A2B2C2D0	short	2	196	170	125	105
=	long	2	205	157	140	86
A2B2C2D1	short	7	196	170	125	116
=	long	7	205	157	140	97
A3B2C2D1	short	4	191	170	125	116
=	long	4	200	157	140	97
A3B3C2D1	short	5	191	170	125	116
=	long	4	200	157	140	97
A3B3C3D1	short	5	191	170	130	116
=	long	6	200	157	145	97
A4B3C3D1	short	6	203	170	130	116
=	long	5	212	157	145	97
A4B4C3D1	short	7	203	170	130	116
=	long	7	212	157	145	97
A4B4C4D1	short	1	203	170	135	116
=	long	2	212	157	150	97
A5B4C4D1	short	6	191	170	135	116
=	long	5	200	157	150	97
A5B4C4D2	short	2	191	170	135	112
=	long	2	200	157	150	93
A5B5C4D2	short	7	191	170	135	112
=	long	7	200	157	150	93
A6B5C4D2	short	2	191	170	135	112
=	long	3	200	157	150	93

Table 11: Number of profiles and fiber lengths for the Barrel Module 0, “south” side (positive η), Pol.Hi.Tech fibers, ODD holes. Fiber lengths in cm.

name	profile	number	A	B	C	D
A6B5C5D2	short	8	191	170	135	112
=	long	7	200	157	150	93
A6B6C5D2	short	5	191	175	135	112
=	long	6	200	162	150	93
A7B6C5D2	short	7	196	175	135	112
=	long	6	205	162	150	93
A7B6C6D2	short	5	196	175	135	112
=	long	6	205	162	150	93
A7B7C6D2	short	5	196	180	135	112
=	long	4	205	167	150	93
A8B7C6D2	short	1	196	180	135	112
=	long	2	205	167	150	93
A8B7C6D3	short	9	196	180	135	125
=	long	8	205	167	150	106
A8B7C7D3	short	4	196	180	140	125
=	long	4	205	167	155	106
A8B8C7D3	short	3	196	180	140	125
=	long	3	205	167	155	106
A9B8C7D3	short	9	203	180	140	125
=	long	10	212	167	155	106
A9B8C7D3	short GREY	5	203	180	140	125
=	long GREY	5	212	167	155	106
A9B8C8D3	short GREY	2	203	180	140	125
=	long GREY	2	212	167	155	106
A9B9C8D3	short GREY	2	203	175	140	125
=	long GREY	2	212	162	155	106
A10B9C8D3	short Black	8	196	175	140	125
=	long Black	8	205	162	155	106
A10B9C8D3	short GREY	4	196	175	140	125
=	long GREY	4	205	162	155	106
A10B9C8D3	short GREY	4	196 -UVA	175 -UVA	140	125
=	long GREY	4	205 -UVA	162 -UVA	155	106

Table 12: (continuation of table 11) Number of profiles and fiber lengths for the Barrel Module 0, "south" side (positive η), Pol.Hi.Tech fibers, ODD holes. Fiber lengths in cm.

name	profile	number	A	B	C	D
A1B1C1D0	short	10	191 -UVA	170 -UVA	120 -UVA	105 -UVA
=	long	10	200 -UVA	157 -UVA	135 -UVA	86 -UVA
A1B1C1D0	short	3	191 -UVA	170 -UVA	120 -UVA	105
=	long	3	200 -UVA	157 -UVA	135 -UVA	86
A2B1C1D0	short	2	191	170 -UVA	120 -UVA	105
=	long	2	200	157 -UVA	135 -UVA	86
A2B2C1D0	short	2	191	170	120 -UVA	105
=	long	3	200	157	135 -UVA	86
A2B2C2D0	short	2	191	170	125	105
=	long	2	200	157	140	86
A2B2C2D1	short	7	191	170	125	116
=	long	7	200	157	140	97
A3B2C2D1	short	4	191	170	125	116
=	long	4	200	157	140	97
A3B3C2D1	short	5	191	170	125	116
=	long	4	200	157	140	97
A3B3C3D1	short	5	191	170	130	116
=	long	6	200	157	145	97
A4B3C3D1	short	6	191	170	130	116
=	long	5	200	157	145	97
A4B4C3D1	short	7	191	170	130	116
=	long	7	200	157	145	97
A4B4C4D1	short	1	191	170	135	116
=	long	2	200	157	150	97
A5B4C4D1	short	6	191	170	135	116
=	long	5	200	157	150	97
A5B4C4D2	short	2	191	170	135	112
=	long	2	200	157	150	93
A5B5C4D2	short	7	191	175	135	112
=	long	7	200	162	150	93
A6B5C4D2	short	2	191	175	135	112
=	long	3	200	162	150	93

Table 13: Number of profiles and fiber lengths for the Barrel Module 0, "south" side (positive η), Pol.Hi.Tech fibers, EVEN holes. Fiber lengths in cm.

name	profile	number	A	B	C	D
A6B5C5D2	short	8	191	175	145	112
=	long	7	200	162	160	93
A6B6C5D2	short	5	191	175	145	112
=	long	6	200	162	160	93
A7B6C5D2	short	7	196	175	145	112
=	long	6	205	162	160	93
A7B6C6D2	short	5	196	175	135	112
=	long	6	205	162	150	93
A7B7C6D2	short	5	196	180	135	112
=	long	4	205	167	150	93
A8B7C6D2	short	1	196	180	135	112
=	long	2	205	167	150	93
A8B7C6D3	short	9	196	180	135	120
=	long	8	205	167	150	101
A8B7C7D3	short	4	196	180	140	120
=	long	4	205	167	155	101
A8B8C7D3	short	3	196	180	140	120
=	long	3	205	167	155	101
A9B8C7D3	short	9	203	180	140	120
=	long	10	212	167	155	101
A9B8C7D3	short GREY	5	203	180	140	120
=	long GREY	5	212	167	155	101
A9B8C8D3	short GREY	2	203	180	140	120
=	long GREY	2	212	167	155	101
A9B9C8D3	short GREY	2	203	175	140	120
=	long GREY	2	212	162	155	101
A10B9C8D3	short Black	8	196	175	140	120
=	long Black	8	205	162	155	101
A10B9C8D3	short GREY	4	196	175	140	120
=	long GREY	4	205	162	155	101
A10B9C8D3	short GREY	4	196 -UVA	175 -UVA	140	120
=	long GREY	4	205 -UVA	162 -UVA	155	101

Table 14: (continuation of table 13) Number of profiles and fiber lengths for the Barrel Module 0, "south" side (positive η), Pol.Hi.Tech fibers, EVEN holes. Fiber lengths in cm.

name	profile	number	A	B	C	D
A1B1C1D0	short	13	196	170	120	105
=	long	13	205	157	135	86
A2B1C1D0	short	2	196	170	120	105
=	long	2	205	157	135	86
A2B2C1D0	short	3	196	170	120	105
=	long	2	205	157	135	86
A2B2C2D0	short	2	196	170	125	105
=	long	2	205	157	140	86
A2B2C2D1	short	7	196	170	125	116
=	long	7	205	157	140	97
A3B2C2D1	short	4	191	170	125	116
=	long	4	200	157	140	97
A3B3C2D1	short	4	191	170	125	116
=	long	5	200	157	140	97
A3B3C3D1	short	6	191	170	130	116
=	long	5	200	157	145	97
A4B3C3D1	short	5	203	170	130	116
=	long	6	212	157	145	97
A4B4C3D1	short	7	203	170	130	116
=	long	7	212	157	145	97
A4B4C4D1	short	2	203	170	135	116
=	long	1	212	157	150	97
A5B4C4D1	short	5	191	170	135	116
=	long	6	200	157	150	97
A5B4C4D2	short	2	191	170	135	112
=	long	2	200	157	150	93
A5B5C4D2	short	7	191	170	135	112
=	long	7	200	157	150	93
A6B5C4D2	short	3	191	170	135	112
=	long	2	200	157	150	93

Table 15: Number of profiles and fiber lengths for the Barrel Module 0, "north" side (negative η), Bicron fibers, ODD holes. Fiber lengths in cm.

name	profile	number	A	B	C	D
A6B5C5D2	short	7	191	170	135	112
=	long	8	200	157	150	93
A6B6C5D2	short	6	191	175	135	112
=	long	5	200	162	150	93
A7B6C5D2	short	6	196	175	135	112
=	long	7	205	162	150	93
A7B6C6D2	short	6	196	175	135	112
=	long	5	205	162	150	93
A7B7C6D2	short	4	196	180	135	112
=	long	5	205	167	150	93
A8B7C6D2	short	2	196	180	135	112
=	long	1	205	167	150	93
A8B7C6D3	short	8	196	180	135	125
=	long	9	205	167	150	106
A8B7C7D3	short	4	196	180	140	125
=	long	4	205	167	155	106
A8B8C7D3	short	3	196	180	140	125
=	long	3	205	167	155	106
A9B8C7D3	short	10	203	180	140	125
=	long	9	212	167	155	106
A9B8C7D3	short GREY	5	203	180	140	125
=	long GREY	5	212	167	155	106
A9B8C8D3	short GREY	2	203	180	140	125
=	long GREY	2	212	167	155	106
A9B9C8D3	short GREY	2	203	175	140	125
=	long GREY	2	212	162	155	106
A10B9C8D3	short Black	8	196	175	140	125
=	long Black	8	205	162	155	106
A10B9C8D3	short GREY	8	196	175	140	125
=	long GREY	8	205	162	155	106

Table 16: (continuation of table 15) Number of profiles and fiber lengths for the Barrel Module 0, “north” side (negative η), Bicron fibers, ODD holes. Fiber lengths in cm.

side	cell	fiber type	fiber #
Jura south	A5	Pol.Hi.Tech	15
Jura north	B-3	Bicron	16
Saleve north	A-10	Bicron	1
Saleve north	A-9	Bicron	5

Table 17: Broken fibers in the Barrel Module 0. The fiber number is counted from the beginning of the cell, from the center of the calorimeter to the outside.

side	cell	fiber type	fiber #
Jura north	B-2	Bicron	30
Jura north	B-3	Bicron	2

Table 18: Fibers repaired in the Barrel Module 0 due to a routing error. The fiber number is counted from the beginning of the cell, from the center of the calorimeter to the outside.

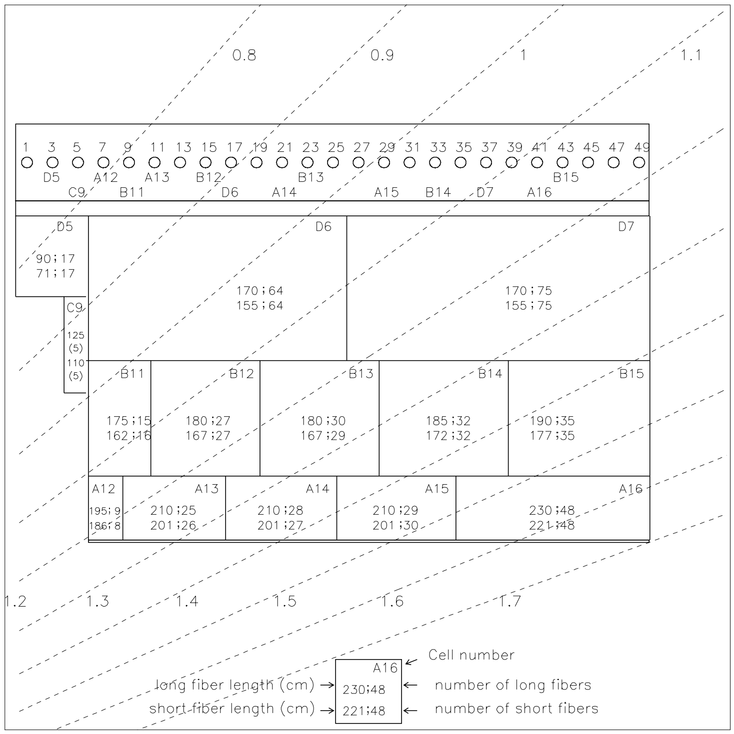


Figure 1: Configuration of the Extended Barrel implemented in the Barcelona Module 0. The side shown has 24 holes in the girder (even side). The lengths and number of fibers in each cell are shown inside the cell boxes. The dashed lines are η lines spaced by $\Delta\eta$=0.1. In the case of the Argonne Extended Barrel Module 0, the fiber lengths are different, as it is shown in table 2.

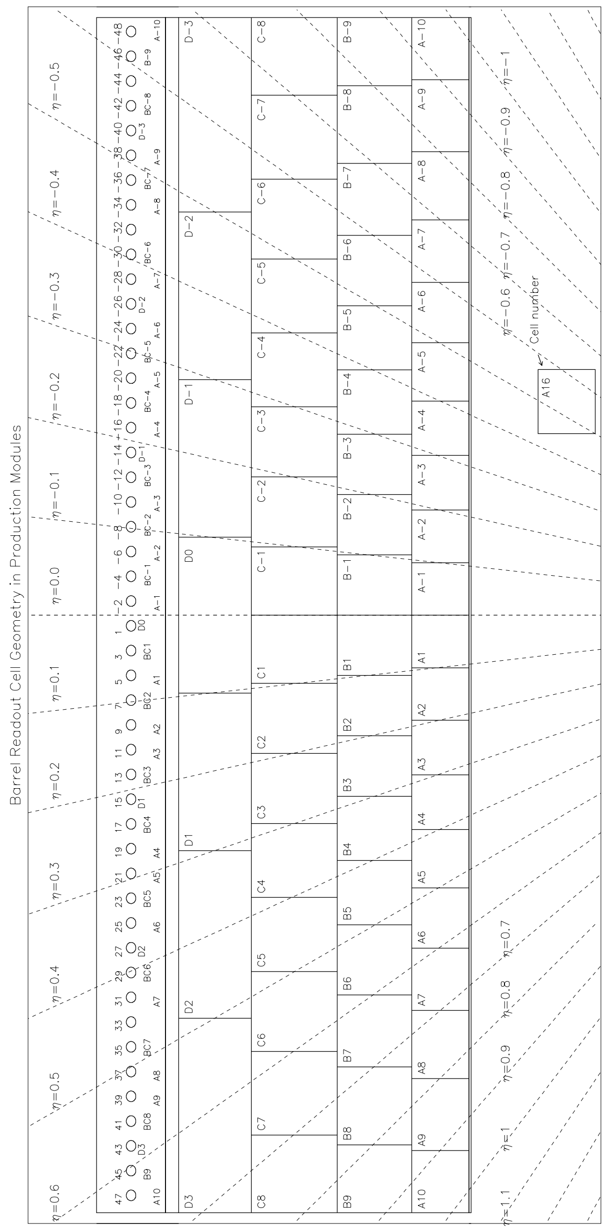


Figure 2: Cell geometry of the Barrel Module 0 in 1998.

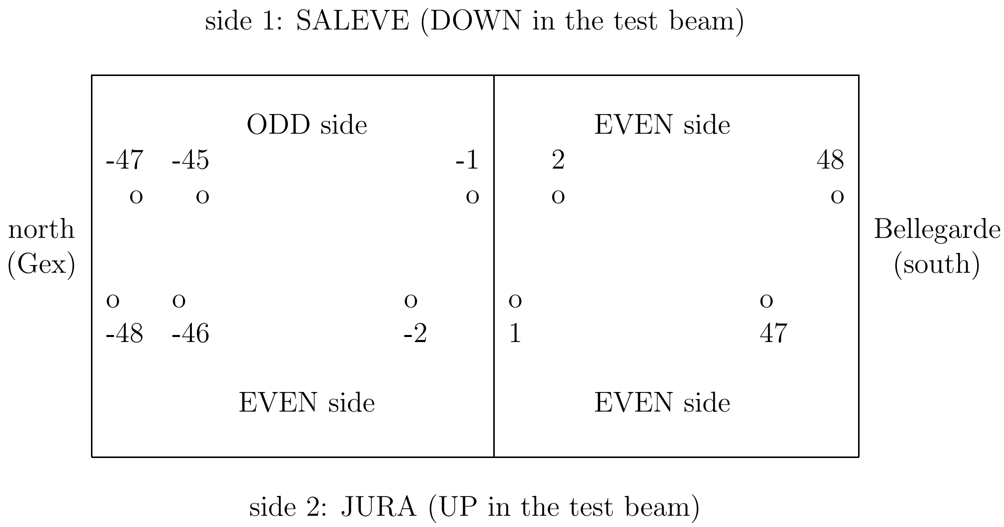


Figure 3: Representation of the girder of the module 0 as it was in the instrumentation hall in building 867 at CERN.

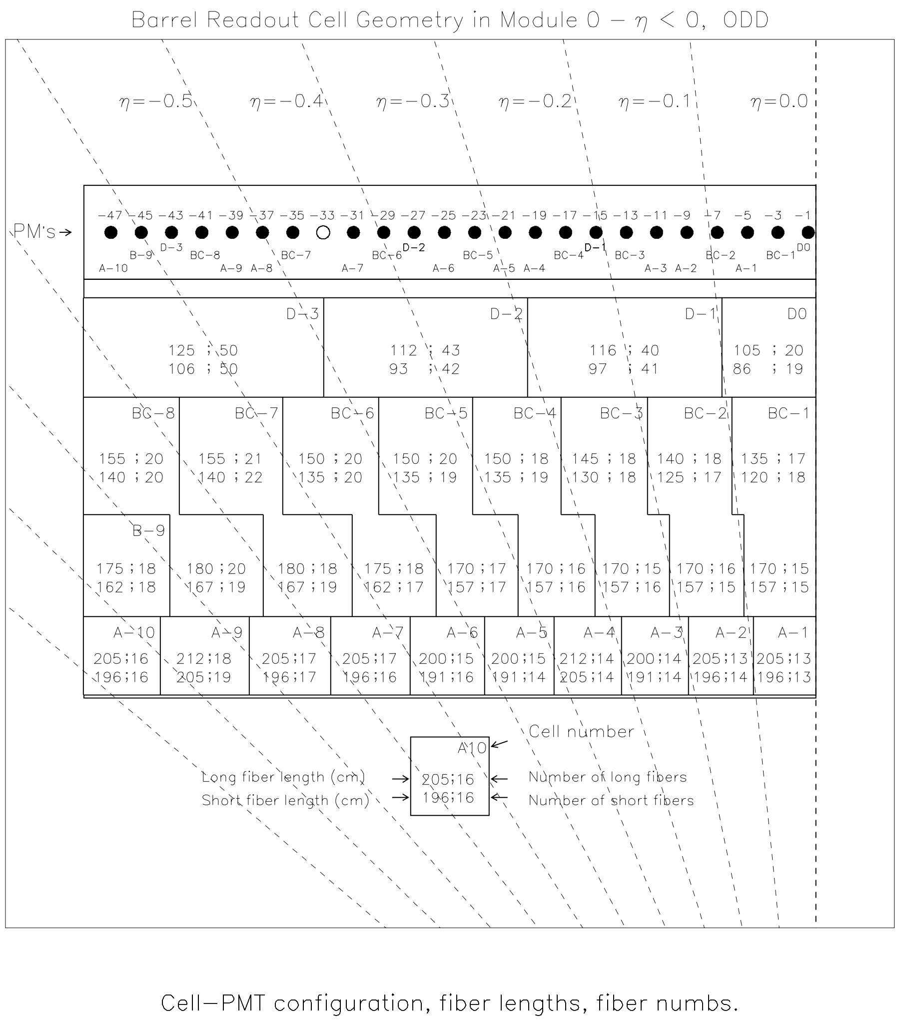


Figure 4: Configuration of the negative η side, PMT's with odd numbers. This side was equipped with Bicron fibers.

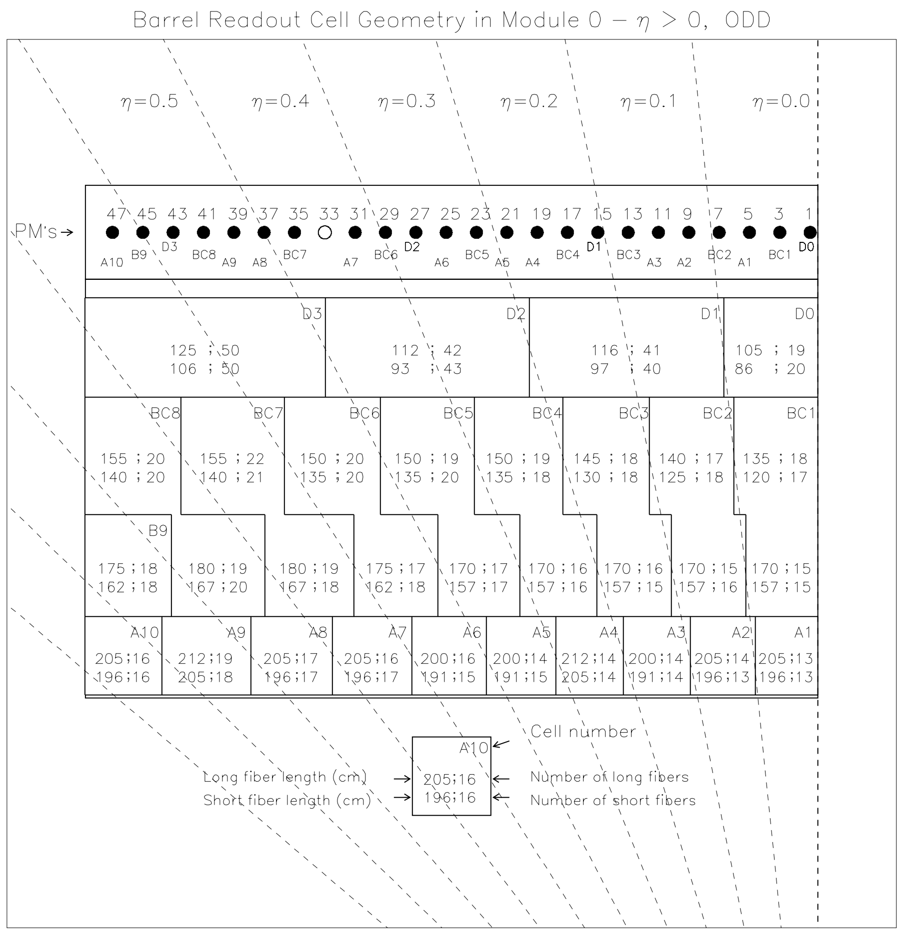


Figure 5: Configuration of the positive η side, PMT's with odd numbers. This side was equipped with Pol.Hi.Tech fibers.

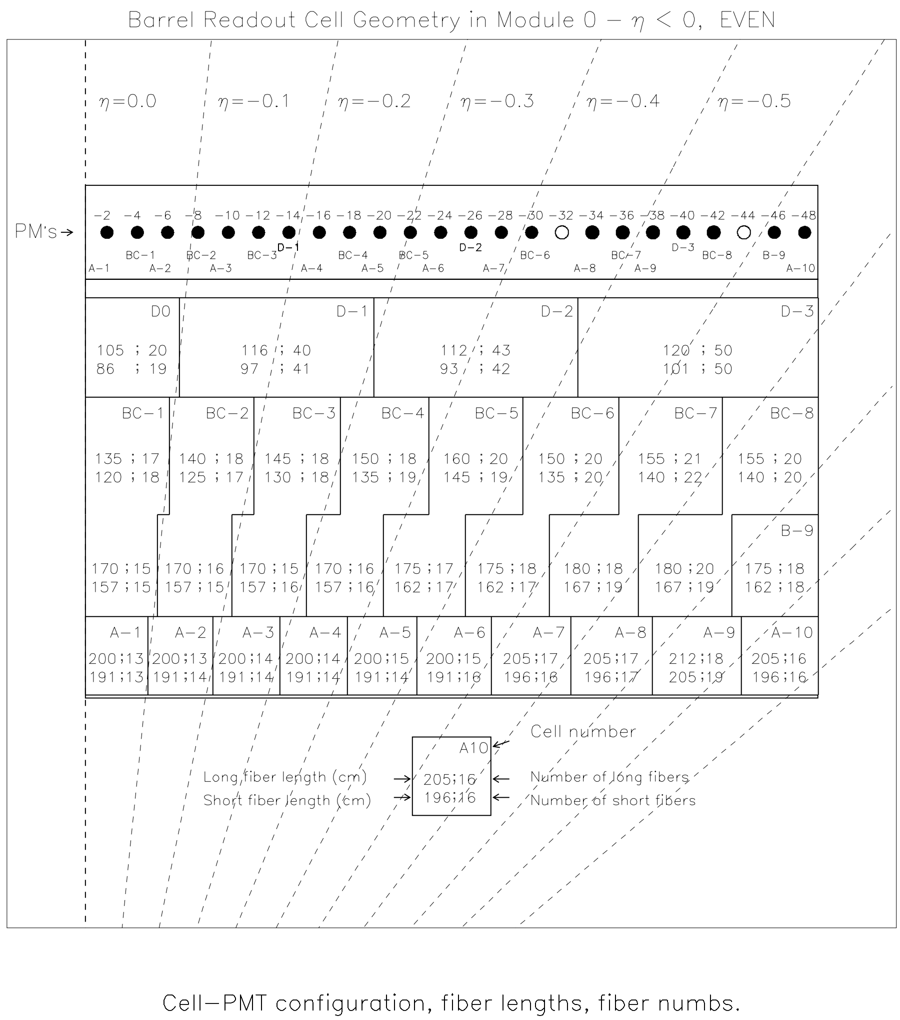
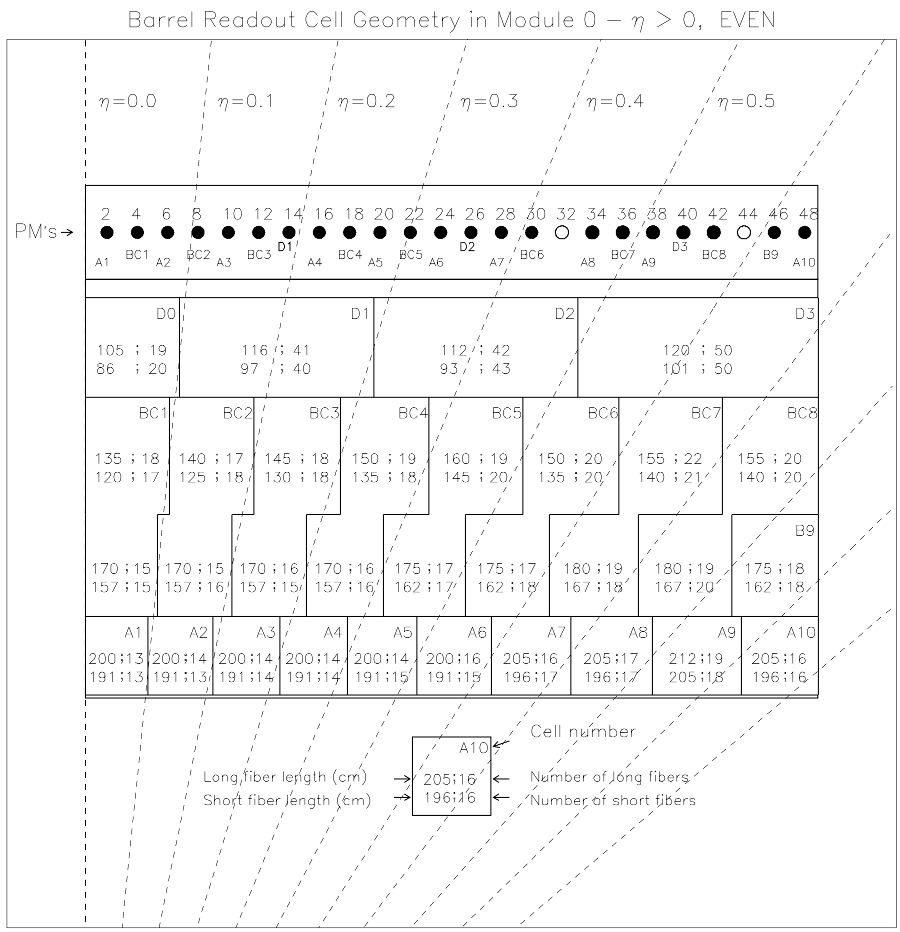


Figure 6: Configuration of the negative η side, PMT's with even numbers. This side was equipped with Bicron fibers.



Cell−PMT configuration, fiber lengths, fiber numbs.

Figure 7: Configuration of the positive η side, PMT's with even numbers. This side was equipped with Pol.Hi.Tech fibers.

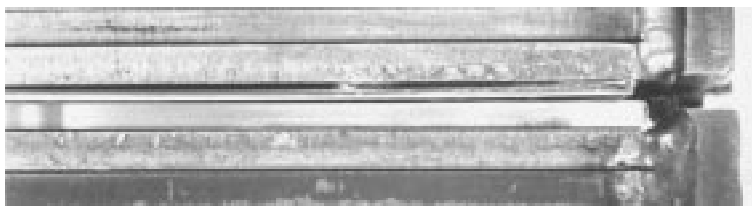


Figure 8: Detail of the shimming of the grooves between submodules using stainless steel strip (Barcelona Extended Barrel Module 0). From top to the bottom, in sequence: spacer, master, stainless stell strip, tile, master, spacer.

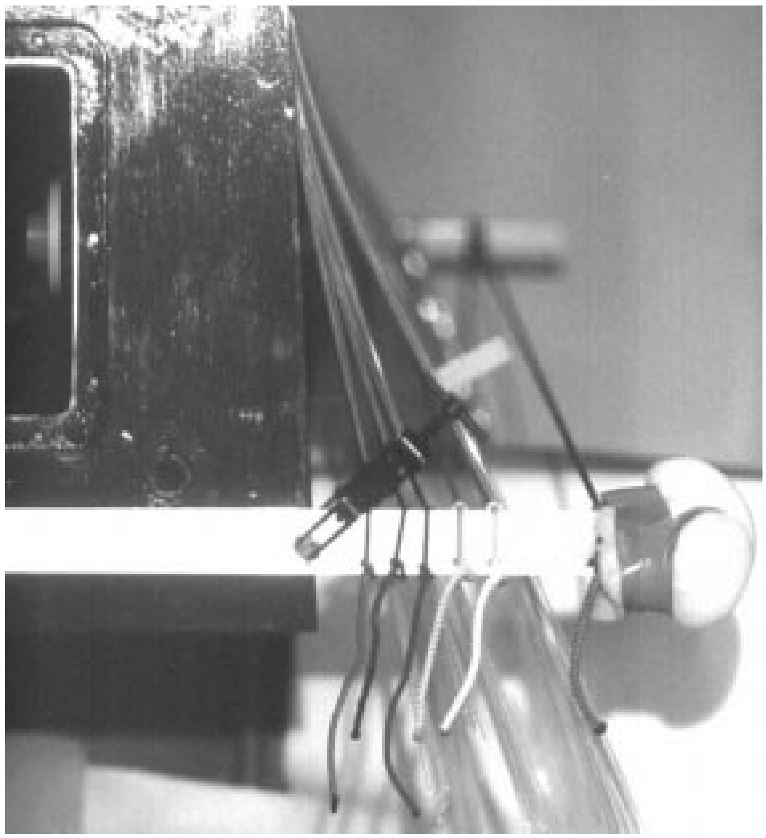


Figure 9: The fiber separator, used to separate the fibers by depth. In the photo, are visible 4 layers of fibers of the Barrel Module 0.

Figure 10: Photo of one of the “zips” used to insert the profiles in the 1997 and 1998 Modules 0.

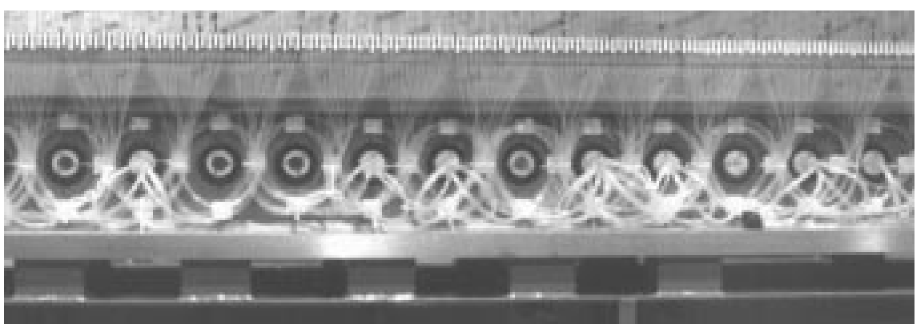


Figure 11: Detail of the routing of the fibers in the Argonne Extended Barrel Module 0. The loops made by the fiber bundles are visible.

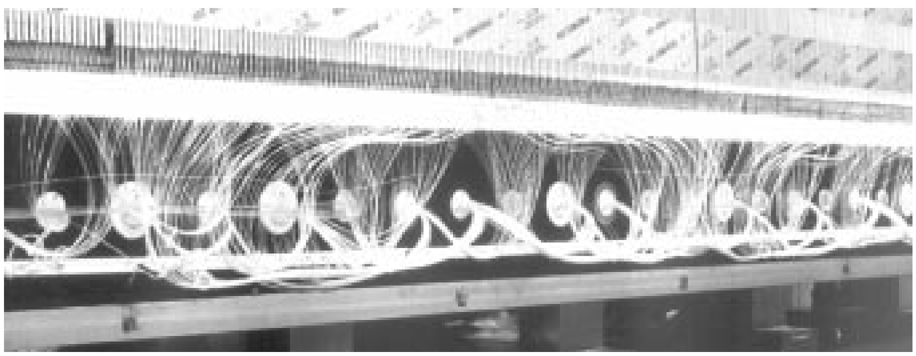


Figure 12: Detail of the routing of the fibers in the Barcelona Extended Barrel Module 0.