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Metrological inspection of modules of hadron calorimeter for ATLAS detector.

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1. Introduction and statement of a problem.

After assembly of the masters and spacers into a submodule, and submodules in a module, it is necessary to measure the deviations of the real module form from the required one. This is very important, since the assembly of a calorimeter toroid from 64 modules will be a very complicated technological process, in which the position of each module should be determined beforehand. A gap between the neighbouring modules is as small as 1 mm, therefore the deviation from the theoretical dimensions must not exceed 500 microns. If some modules have large deviations, then having information about all modules, one can arrange them to preserve the required geometry of the calorimeter. Other equipment of the module must also be mounted with regard to a particular module position .

The equipment for determining the form of the module should have the necessary accuracy and be able to measure the module for one working day. The data acquisition and processing should be automated as much as possible.

It is important to single out a module element with respect to which the measurement will be carried out. As the most accurately manufactured module element is the girder, and as it is an element, through which the modules are connected to each other, as it is convenient to use it as the basis of measurements.

Thus, it is necessary to measure deviations of the real dimensions of the module from the theoretical ones in system of co-ordinates, formed by the longitudinal axis of the girder and two orthogonal axes of its cross section. The errors in determination of the deviations must not exceed 50 microns. Measurements must be carried out in the course of assembling the module, after welding and finally after transportation to the calorimeter assembly place.

2. Principle of module measurements.

The measurements are based on the straight-line property of a laser beam in space and a possibility of determining the distance from the surface to the centre of the laser beam with a required accuracy. The schematic diagram of the measurements is shown in Fig. 1.

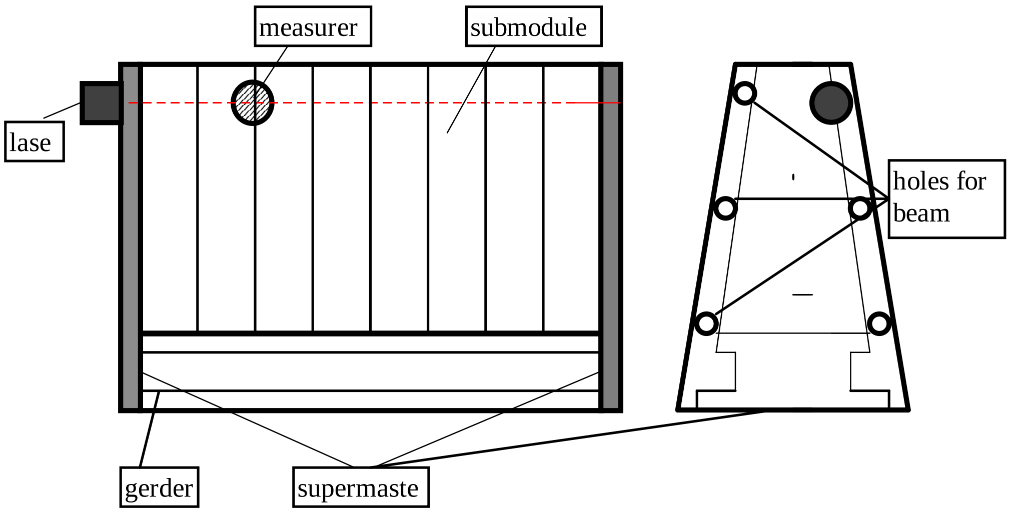

Figure 1. The scheme of the module size measurement.

A collimated laser beam is placed parallel to the side surface of the module. The distance from the centre of the beam to the side surface of the module is measured with a special device, described in item 3. The measurements will be carried out at several points over the length of the module. Thus we obtain a section of the module surface in the plane of the laser beam perpendicular to the module side surface . Next it is necessary to determine the exact position of the beam relative to the girder. Two special details, "supermasters", precise established on the ends of the girder, serve for this purpose. Having measured the position of the beam relative to the supermaster, we obtain the section of the module surface in the system of girder co-ordinates .

We repeat the module surface section measurement procedure at points at different height (for example, top, bottom and middle). As a result, having measured the section of the module surface at various heights, we restore the real form of the module.

3. Measuring device.

The scheme of the device for measurement of the distance from the surface to the centre of the laser beam is shown in Fig. 2.

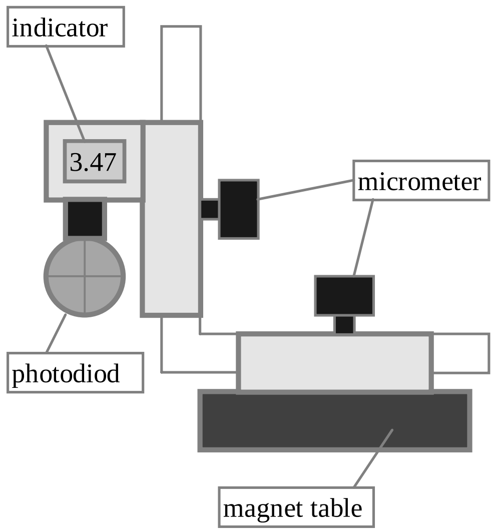

Figure 2. The device for beam-surface distance measurement.

Its principle of operation is as follows. The basis of the measurer is established on a surface. If the surface tilted, magnetic fastening is used. The photoreceiver is located on a mobile carriage, which can be moved with the help of two micrometric screws perpendicularly to and along the basis. The photoreceiver consists of four identical segments, connected into a balance circuit. Moving the carriage with the photoreceiver by the micrometric screws, one must bring the centre of the laser beam into coincidence with the centre of the photoreceiver (point of connection of all segments). Thus the signals from all segments are equal, i.e. the output of the balance circuit is zero. The indication of the micrometric screw, perpendicular to the basis, is the distance from the surface to the centre of the beam.

It is convenient to use a digital calliper as vertical micrometer. Obviously, the measurer should be previously calibrated, i.e. if the centre of the photoreceiver is on the surface under measurement, the indications of the vertical micrometer should be zero. A special procedure is envisaged for this purpose (it is not described).

Another posibility to measure beam-surface distance is to use a CCD matrix. In this case no moveable parts are necessary.

4. Measurement errors.

The total measurement error consists of the following basic errors:

- Error of installation of the supermasters on the girder;
- Error of manufacturing of the supermasters;
- Error of determination of the beam position with respect to the supermaster;
- Error of measurement of the distance from the module surface to the beam;
- Error due to the girder curvature;
- Error of calculations.

The tentative estimation of all kinds of errors shows that the given measurement technique provides the required accuracy (50 microns). For experimental estimation of the laser measurer sensitivity, measurements with the prototype were carried out. The results are presented in the next subsection.

5. The prototype laser measurer.

The schematic diagram of the prototype laser measurer module is shown in Fig. 3. The stabilised He-Ne laser LGN-302 was used. The laser beam was collimated and directed parallel to a large aluminium plate. The measurements were carried out over the length of 6 meters.

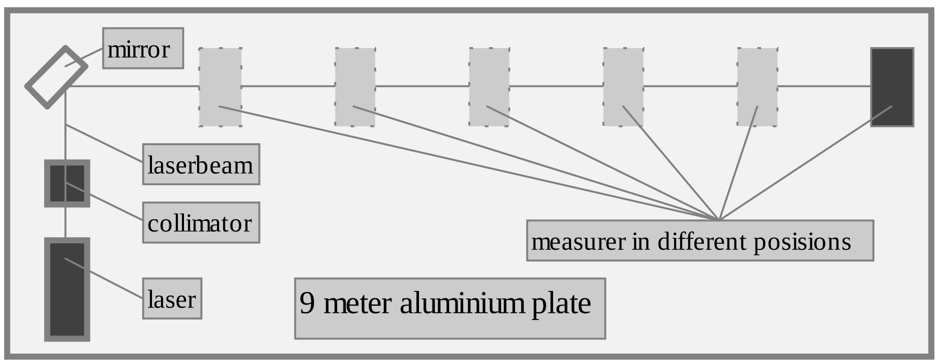

Figure 3. The scheme of the module measurer prototype.

A photodiode with a sensitive area greater than the laser beam spot (beam diameter about 3 mm) was used as the photoreceiver. Half of the sensitive area (bottom part) was closed by a mask. With the help of the micrometric screws (least division 10 micron) the photoreceiver was adjusted to the beam so that the signal from it was equal to half of the signal from the total laser power. In this position the indications of the micrometer were fixed.

A few measurement runs were carried out at various distances from the laser to the photoreceiving device. Repeatition of results in 6 different runs was investigated. Then the error of measurements at different distances was calculated. The results are displayed in Fig.4. The histogram shows the greatest deviations from the average indications of the measurer (in microns).

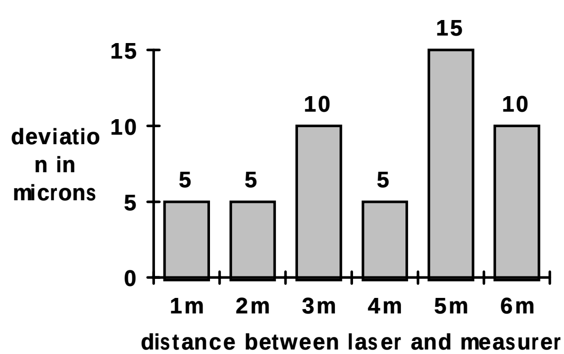

Figure 4. The maximum deviations at different laser-measurer distances.

The basic kind of noise in the given prototype are air density fluctuations on the way of the beam. A smaller contribution to the error comes from the laser power instability, laser beam jitters (lateral and angular), the error of installation of the measuring device in one place and errors of the micrometer. In the projected working version of the measurer the laser power instability will not give an error, since the balance receiver will be used.

Nevertheless, even in the present version of the measurer its sensitivity quite satisfies our requirements.