Monitoring of Detector Structures at the CERN ALICE Experiment

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Abstract. *One of the four CERN LHC (Large Hadron Collider) experiments is ALICE, short for "A Large Ion-Colliding-Experiment", a detector consisting of multiple layers of sub detectors around the collision point to detect different types and properties of particles created in the collision [1] [2] [3]. The sub detectors are held in place by a structure called 'Spaceframe'. It has a cylindrical 18 - sided geometry with a length and diameter of 8 m. The weight of all the sub detectors, about 80 tons on the whole, will deform the Spaceframe in radial direction. For obvious reasons these deformations have to be monitored. This paper presents results from the deformation analysis during a magnetic field test and the installation of detector modules.*

Keywords: Laser Alignment, Detector Monitoring, BCAM, Structure Alignment

1. Introduction optical deformation monitor

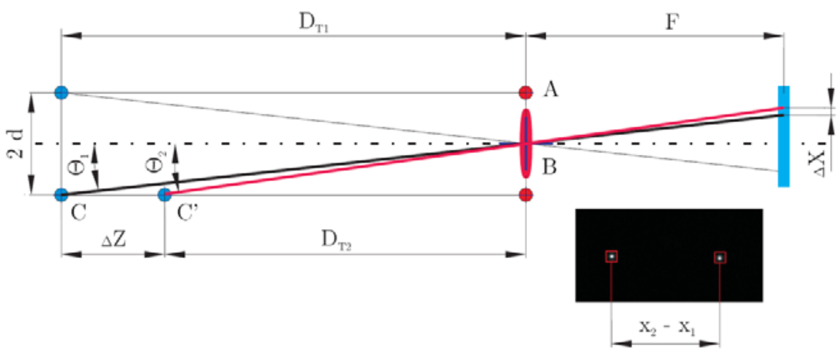

Fig. 1. Principle of the BCAM Operation

The BCAM is a simple optical device which has been developed by Brandeis University for the LHC ATLAS experiment End - Cap Alignment system [10]. The principle of Measurement is presented in Figure 1. A BCAM consists of an electronic camera and a pair of light sources (see Fig. 1. A, B), all integrated into a single enclosure kinematically mounted on three steel balls. The camera contains a CCD (Charge Coupled Device) image sensor and a lens with a focal length F of 75mm. Its field of view is 40mrad horizontally and 30mrad vertically to its mounting plane. The CCD provides an array of 344 by 244 pixels, serving as a two - dimensional coordinate system. A pixel measures 10µm square. The light sources of the BCAM are red laser diodes, treated as being point - like. Each laser transmits at $\lambda = 650$nm in a rectangular cone that measures 75mm by 25mm on a screen at a distance of 100mm from the BCAM. Lasers and CCDs can be controlled via an RJ - 45 sockets. The centers of the steel balls on which the BCAM is mounted in a local BCAM - coordinate system. All relevant BCAM - parameters, e.g. the center of the lens or CCD rotation, can be related to this local coordinate system by a calibration procedure. Thus one only needs to know the position of the centers of the steel balls in a global coordinate system to know the position and orientation of the BCAM - coordinate system. Figure 1 shows the principle of a standard BCAM alignment based on the example of a longitudinal movement. As can be seen, a small displacement ΔZ is limited by the angular BCAM resolution of 5 μrad defined by $\varphi_2 - \varphi_1$ according to the following equation (1), [6]:

$$Z = \frac{D_T^2\,\varphi}{d + D_T\,\varphi} \approx \frac{D_T^2\,\varphi}{d} \qquad (1)$$

DT	Distance between lens pivot point of the BCAM A and the light source of BCAM B
φ	Angular resolution of the BCAM system in μrad
d	Distance between the two light sources
Z	Accuracy

2. The ALICE Spaceframe

The monitoring system of the ALICE spaceframe structure has to determine all the corner positions to an accuracy of better than 500μm. The BCAM system is implemented to the Spaceframe by fixing a mounting plate holding two BCAMs on each corner. The 18 corners of the Spaceframe show relative movements within a few millimeters for the entire detector load. Measuring the relative angles of all BCAMs the 18 internal angles of the space frame are monitored. In summer 2005 a load test was performed to verify the expected deformations [7]. Different load conditions were measured by the SMS and with external survey done by the CERN survey group [4]. Both results were compared and showed that the SMS could reconstruct the positions of the 36 vertices on both sides of the Spaceframe for every load condition within the expected 500μm of their actual position.

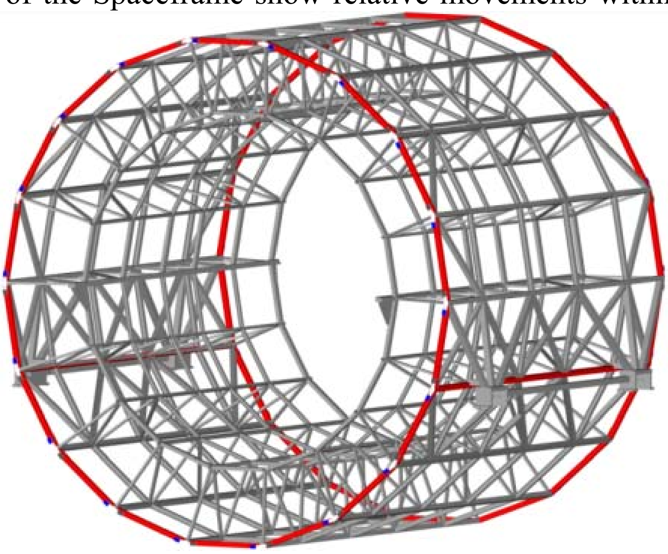

Fig. 1. ALICE Spaceframe - diameter: 8.5 m, length: 7 m, weight: 10.5 tons; Monitored surfaces are highlighted in red

3. Magnetic Field Mapping

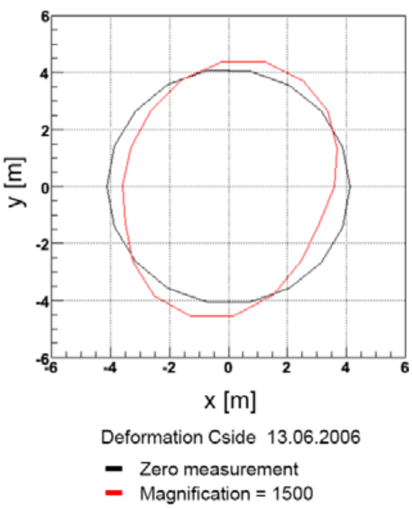

Fig. 2. Spaceframe deformation due to magnetic field influence (exaggerated)

After the primary installation and load test verification in the installation hall, the frame was transferred to the cavern and installed into the L3 magnet in early 2006 [6]. After this installation a magnetic field tests was performed in order to verify the field stability [11]. During this period it was decided to operate the spaceframe monitoring system verifying deformation levels due the field influence. In order to calculate and reconstruct the deformed shape of the spaceframe, a least square adjustment was implemented [12]. The Least Square Adjustment method was implemented in a program based on C++ and Root [13]. All calibration constants of the BCAMs and zero measurements of coordinates are stored in external files accessed by the program during runtime.

Figure 2 presents an exaggerated plot for reconstructing the spaceframe deformation during the described magnetic field test. As can be seen, the fit represents one face of the spaceframe. The start up of the ALICE magnet to the nominal current of 30000A (0.5T) showed a maximum deformation of 0.9mm vertically and 0.86mm horizontally. The shutdown of the magnet results in a residual deformation of 0.3mm in the vertical and 0.35mm in the horizontal direction. A first analysis of the resulting deformation of the spaceframe due to magnetic field influence has shown that the iron joke deformation is transmitting deformations to the spaceframe support rails. In order to monitor the spaceframe rail deformation an additional monitoring system based on a BCAM – retroreflector application will be installed [5].

Table 1. Vertical and horizontal elastic deformation due to the magnetic field influence

	Solenoid current [A]	ΔV [μm]	ΔH [μm]
02.06.2006	0	0	0
08.06.2006	0	1.7	3
13.06.2006	30000	902.8	860.2
14.06.2006	0	307.4	343.3
20.06.2006	0	303.5	350.6

4. Detector Installation

In early 2009 one module of the Transition Radiation Detector (TRD) was installed into the Spaceframe (Fig. 3.). In parallel, the entire data acquisition was implemented to the detector control system which allows to the read measurement system remotely. The analysis of the raw data taken before and after the detector installation showed that the spaceframe was deformed according to the exaggerated blue curve in Fig. 3.

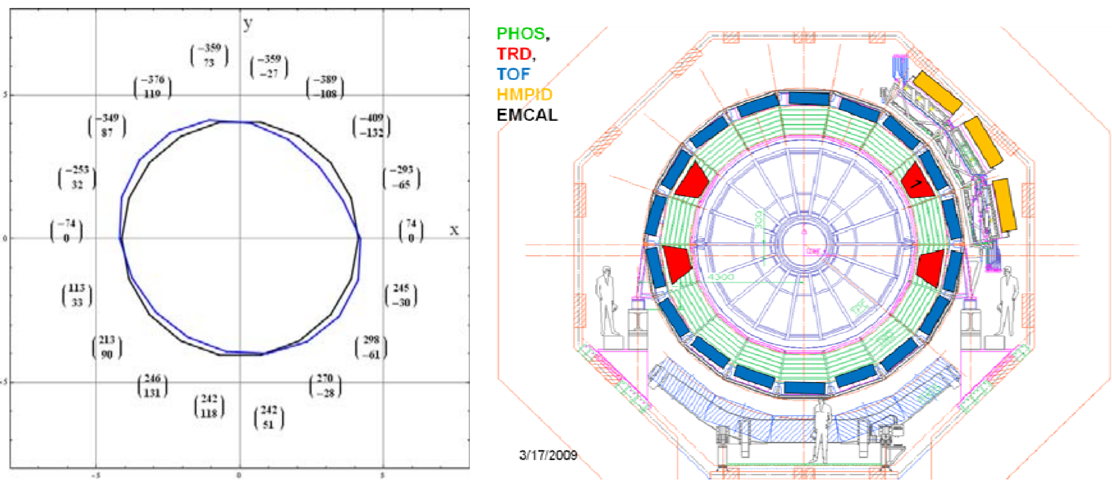

Fig. 3. Left: Deformation due to the TRD module installation. The black curve represents the zero measurement whilst the blue curve shows the deformation after the installation. The curve is drawn with an exaggeration factor of 1000. Right: ALICE Detector layout; (1) installed detector module.

As can be seen, the installation of the 1300kg detector module deforms the spaceframe structure locally by a maximum value of 132μm in vertical and 400μm in the horizontal plane. The implementation and automatic analysis of the monitoring system via the detector control system will allow encountering critical deformations during delicate detector operations in shutdown periods. Furthermore the system will give additional information during the entire life cycle of the ALICE experiment.

5. Discussion and Conclusion

The spaceframe detector structure in the CERN LHC ALICE experiment has to be monitored during the entire lifecycle. This is partly given by the required high precision and the tight clearances in order to install and handle detector structures, but also because the status and long term mechanical stability of the entire experiment is depended on the spaceframe structure. The paper showed first results of the analyzed raw data taken during a magnetic field test and the installation of detector modules. The successful measurements during the magnetic field test showed a deformation of 0.9mm vertically and 0.86mm horizontally on one spaceframe surface. The installation of one TRD module deformed the spaceframe elastically by 132µm in vertical and 409 µm in the horizontal plane. Currently the integration of the monitoring system into the ALICE detector control system is near completion. The implementation of further monitoring systems based on the optical device is foreseen in order to get more detailed information of deformations and small movements of the spaceframe with respect to an external reference.

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