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PC BASED CONTROL SYSTEM OF A CALIBRATION BENCH FOR THE ATLAS EXPERIMENT

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Abstract

ATLAS is a particle detector that will be built at CERN in Geneva on the LHC accelerator. In the barrel, it is constituted of 600 chambers of few square meters, amongst other things. The relative position of a chamber within a triplet must be known with a spatial resolution of 30µm. To fulfil these requirements, different alignment systems have been designed. The PRAXIAL sensor that we have developed at Saclay is one of them and its goal is to measure the relative position of a chamber with respect to the neighbouring chambers.

In order to reach the required precision, each PRAXIAL sensor must be individually calibrated. Since a chamber must be equipped with four (half) sensors, the total number of PRAXIAL to be calibrated will be 1250.

After a short introduction on the experiment, the second part of this paper is devoted to the PRAXIAL alignment. The last part is related to the calibration bench: the hardware part and its associated software.

1 ATLAS, THE MUON DETECTOR AND THE ALIGNMENT PRINCIPLE

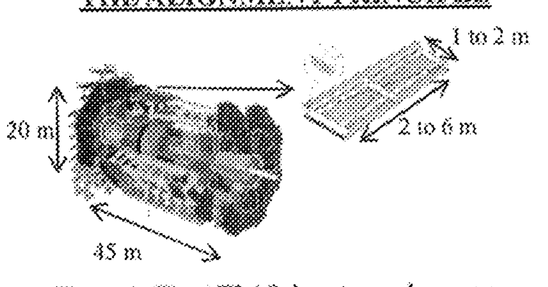

Figure 1: The ATLAS detector and a muon chamber

The ATLAS experiment, see Fig. 1, is a detector that will be installed on the LHC accelerator [1, 2, 3] at CERN [4]. The LHC will provide proton-proton interactions with a centre of mass energy of 14.10^{12} eV. One of the physics goals of the experiment is to detect the Higgs particle. Despite the fact that its existence is crucial for the particle physics Standard Model, it has not yet been observed.

The higgs particle may decay through two Z^0 particles each decaying into two leptons: e.g. muons or electrons. Thus the muon channel is of particular importance. The momentum measurement in the ATLAS muon spectrometer aims at a precision of the order of 10% for muons of momentum 1 TeV. It proceeds from a sagitta measurement using triplets of precision drift chambers with a mean inter chamber distance of 5 meters. The target degree of accuracy for the precision chamber alignment is such that the alignment contribution to the final sagitta measurement error stays below the intrinsic chamber measurement error which contributes at a level of 50 µm.

To fulfil this global precision one of the key element of the alignment system is the PRAXIAL system. Its measuring accuracy should be 30µm in translation and 50µrad in rotation. The initial positioning of the chambers and the possible chamber displacements during the life of the experiment drives the measuring range of each PRAXIAL sensor: ±5mm and ±5mrad.

2 PRAXIAL ALIGNMENT

We will now detail the PRAXIAL sensor. First we will explain the RASNIK optical system, which is the basic sensor for the PRAXIAL sensor.

2.1 The Rasnik sensor

This sensor has been developed by the NIKHEF institute in Amsterdam [5]. It is called RASNIK for Relative Alignment System from NIKhef. It measures the relative position between three elements: a coded mask lightened by a set of infrared LED, seen by a camera through a lens (see Fig. 2).

This optical system is able to measure four coordinates: i) and ii) the 2D transverse position with a resolution of ~2µm, iii) the mask magnification on the camera with a resolution below 10^{-4} and iv) the angle between the mask line and the pixels line of the camera with a resolution of ~150µrad.

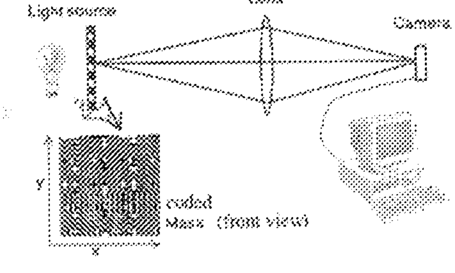

Figure 2: The RASNIK sensor.

NIKHEF has also developed a readout electronic system together with an image analysed software called ICARAS.

ICARAS drives a multiplexer in order to operate the infrared LEDs and the camera, through a RS232 device. An image of the coded mask as seen by the camera is digitised through a frame-grabber card. Finally, the four reconstructed coordinates are stored in a file.

2.2 The praxial sensor

The PRAXIAL sensor that has been developed at Saclay is composed by two crossed RASNIKs (see Fig. 3, bottom part). The optical components are mounted on two mechanical elements each installed on two neighbouring chambers.

The principle of the sensor is to take the four coordinates of each RASNIK in order to calculate the six parameters, three translations and three rotations, describing the relative position of one element with respect to the other one.

As it is impossible to mount all optical components on the platforms with the required accuracy, we have to perform a calibration of our PRAXIAL sensors (see section 3).

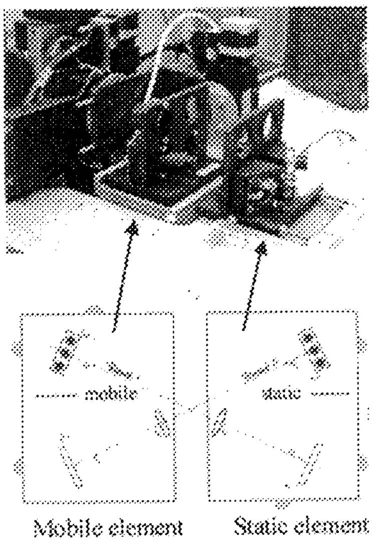

Figure 3: The Praxial system (bottom) and the Praxial sensor installed on the Caliprax calibration bench (top).

3. CALIPRAX BENCH

As we have to calibrate 1250 PRAXIAL sensors, we have built a PC controlled calibration bench. It has been installed in an air-conditioned room to avoid thermal variation during calibration.

3.1 Principle

The principle of the calibration is to scan all the active working space of the sensor (±5mm and ±5mrad) and to determine the transfer function of the sensor. To do that, we fixed one of the two elements on a static support and the other one on a mobile support. Then we move the mobile element approximately one hundred times. For each position we record and reconstruct the RASNIK images. Using this set of coordinates and knowing each element position thanks to mechanical displacement probes we can calculate the transfer function of the sensor.

3.2 Hardware

The mechanics of the calibration bench is very important. It is composed of four distinct components (see Fig. 3, top part and Fig. 4):

1. *Mobile support*: it is made up six displacement stages (three translations and three rotations).
2. *Static support*: it has precise support in order to position the static element in a reproducible manner.
3. *Mechanical interface*: it is an interface in-between the mobile element and the stages. This piece has to have geometry precisely known (<10µm).
4. *Support of the mechanical probes*: it has eight adjusted holes in order to fix the eight mechanical probes on it. It is mechanically linked to the static support. The probes measure the mobile platform position with respect to the static one relatively to the first movement. We used eight probes for redundancy (only six are needed). Each probes has a translation resolution of 1µm.

The bench stays on a concrete block to ensure stability. The required accuracy imposes to work with a stable temperature close to the operating one. The operating temperature is 20°C ± 0.5°C. In order to monitor the thermal effect, we have installed five PT100 probes.

Finally, to have an *absolute calibration*, we have built a mechanical support with a known geometry with an accuracy of 5µm. This system is called ZEROPRAX and is used to define a common mechanical frame for both PRAXIAL elements.

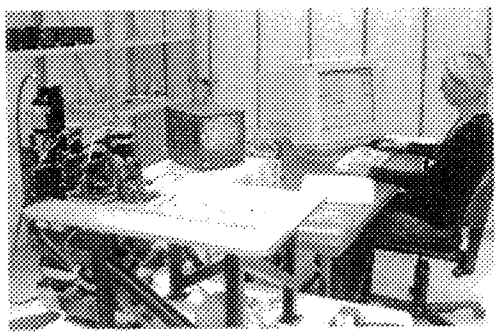

Figure 4: Overview of the calibration bench.

3.3 Software

For cost consideration, we decided to use a computer equipped with PCI and ISA cards.

Two C++ applications have been written to control the bench: i) a set-up program and ii) a main program. We developed and wrote both programs in our institute. In addition we use ICARAS. Thus the three software programs are:

1. the set-up program allows:
   - the configuration of the mechanical parameters of the bench: e.g. the dimensions of the mechanical interface,
   - the definition of the electronic parameters of the measurement channels, the gain, the conversion coefficient and the alarm thresholds.
2. *ICARAS*: this program performs the acquisition and reconstruction of both RASNIK sensors. It is triggered by the main program.
3. the main program: it controls all the calibration operations. It is the main software part of the bench since each function can be executed and seen separately in a dedicated window.

Let us now detail the six different calibration operations needed to calibrate a PRAXIAL sensor:

1. *Initialisation*: it consists in:
   - verifying the electronics of the sensor to be calibrated, reading and verifying the bar code using the database,
   - measuring hall temperature.
2. *Starting point search*: the first position is adjust in order to find the reference position as given by the ZEROPRAX mechanic.
3. *Data acquisition*: up to now the exact number of movements necessary to obtain the correct calibration is not fixed. Nevertheless, a Monte-Carlo simulation shows that hundred movements is a maximum. In order to synchronise the following actions a "task sequencer" is realised.
   - 3.1. *Motion of the mobile platform*: The software controls the motorised stages through a RS232 protocol following a list of pre-defined movements.
   - 3.2. *Alarm temperature*: this task consists in reading five probes to secure the process.
   - 3.3. *Reconstruction of the mobile platform position*: This module calculates the position of the mobile support with respect to the ZEROPRAX position reading the mechanical probes through a RS485 card and using a DLL calculation.
   - 3.4. *RASNIK acquisition*: it consists in triggering the ICARAS program to acquire RASNIK data.
   - 3.5. *Storage*: record all results.
4. *Analysis*: It determines the transfer function. Two methods can be used: a linearisation method or a geometrical method [6].
5. *Final validation*: This operation validates or refuses the analysis just realised. For this, the program starts again some known displacements and computes the theoretical position using the previously calculated transfer function. The error between these known positions and the computed positions must not exceed the required accuracy.
6. *Storage*: The results are stored in the ATLAS experiment database [7].

Finally, to calibrate these 1250 PRAXIAL sensors a quality control method has been established. We record all necessary information during all steps of the calibration. In particular, each element must be labelled with a unique bar code.

4 CONCLUSION

In this paper we have presented the software used to control the calibration bench of the ATLAS PRAXIAL sensors.

The bench now works correctly but still has to be improved in particular on what concerns the record procedure and the documentation. The resolution obtained on few PRAXIAL prototypes already fulfils the ATLAS specifications: 30µm in translation and 150µrad in rotation.

This bench is planed for two and a half years of operation and will start mid of 2003.

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