ALICE - Stations 3-4-5 :

Validation tests of the slats positioning system with photogrammetric measurements

Tests made in February 12th-14th 2002 at Saclay

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Abstract *:*

The slats of Stations 3-4-5 of the ALICE Dimuon Arm need to be localized in the three directions with a very good precision (x, y ~ 50 µm, z ~ 100 µm). It could be useful to apply some angular corrections in the slat positioning and a special mechanical device has been designed and realized for that. It allows small adjustments of each slat from 0.1 mm to 2 mm in each direction.

This document presents the slats positioning system, its mechanical design, its working principle and all the tests performed with the system on a mock up of the central part of Station 5. The mechanical validation of the positioning system is done at first with a comparator and then with photogrammetric measurements. The results are discussed and conclusions on the device efficiency are given.

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1 Introduction

The slats of Stations 3-4-5 of the ALICE Dimuon Arm need to be localized in the three directions with a very good precision (x, y ~ 50 µm, z ~ 100 µm). The control of these positions, after slats mounting on support, will be done by photogrammetric measurements, in the pre-installation building SXL2 at Point 2 at CERN. This technique allows to reach the required precision in the three directions.

The knowledge of the pads coordinates, which are on the Printed Circuit Boards, is crucial for physics ; it is done in two steps :

During the slat assembly, the position of the pads is well known and given by two calibrated holes at each extremity of the slat. Inserts, placed in the panel support, are used to position precisely the slats. Of course, these inserts are out of the detection area. Two centering calibrated axis, adjustable and drilled for survey targets, are foreseen to receive each slat.

During the mounting of the slat on its support, the reference is always the two centering axis. It could be useful to apply some angular corrections, for each slat individually, and a special mechanical device has been designed and realized to allow very small adjustments of each slat : from 0.1 mm to 2 mm. In order to test this slat positioning system, an Aluminum mock up of the central part of Station 5 has been built with 5 slats (at scale 1), and the efficiency of the device has been tested with a comparator and with a campaign of photogrammetric measurements.

2 Principle of the Slats Positioning System

The slat positioning system is divided in 4 pieces, shown in Figure 1 :

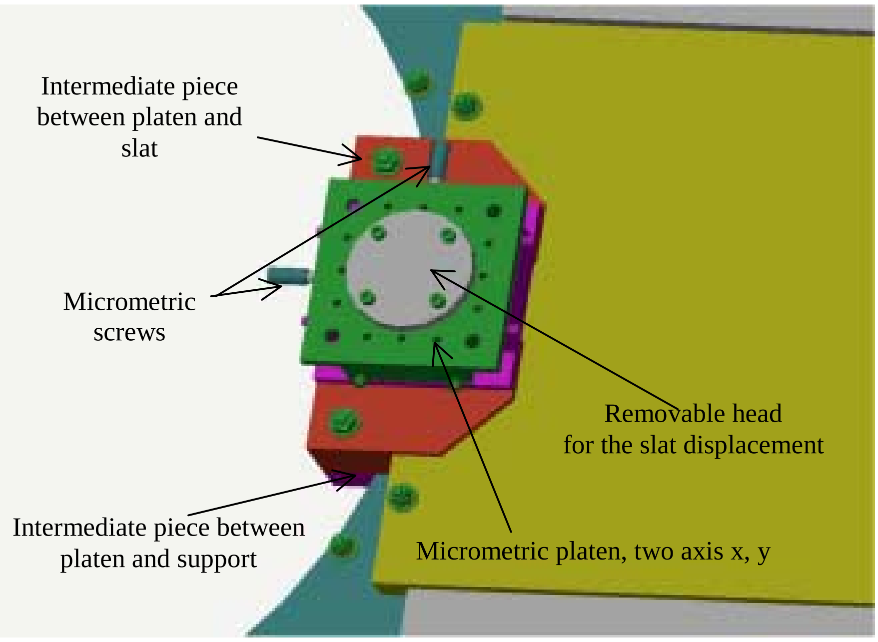
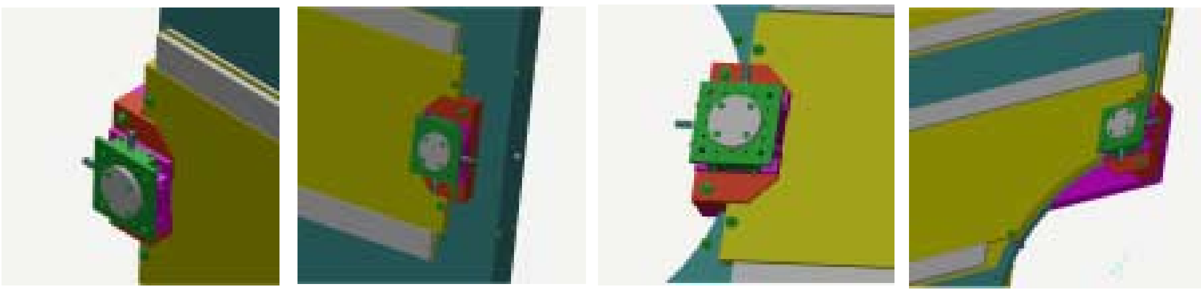


Figure 1 : Drawing of the slat positioning system composed of 4 main pieces. This present configuration is made to use the system for the central circular slat of Station 5 (beam shield side).

The functions of the different pieces of the system are the following :

- A micrometric platen, with two axis x - y and its micrometric screws, allows precise adjustments of the slat in x and y up to 2 mm, with steps of 10 µm.
- A removable head is connected to the micrometric platen and introduced in the slat centering axis, without any constraint for the slat. This part allows the displacement of the slat in x and y through the platen.
- An intermediate piece is used between the platen and the slat. This piece is only a support for the platen, there is no load on the slat.
- Another intermediate piece between the last piece and the panel support maintains the device, applying the load of the device only on the support. The design of this last piece depends of the position of the device on the panel support : in total, 4 pieces are necessary (circular part, straight part, etc …).

The different configurations of the system are shown in Figure 2, and the mechanical principle of the removable head introduced in the platen is shown in Figure 3.



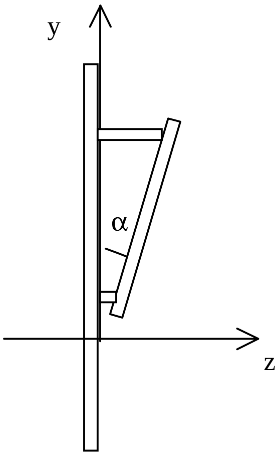
(a) (b) (c) (d)

Figure 2 : Four configurations are necessary to use the slat positioning system, with its four intermediate pieces between platen and panel support (a : internal straight border, b : external straight border, c : circular part, d : rounded part of the panel support).

In the following, the z axis is taken parallel to the beam, and axis x, y are taken orthogonal to the beam. The principle of working of the device and the supports are explained in [1].

<u>Positioning in z</u> :

The slat comes in contact to the support on four pins. The slat is maintained on these pins by screws and spring disks (these latest avoid any constraint on the slat).



The four pins of one slat are in a plane with a flatness of 0.5 mm and all the pins, in the whole support (5.70 m maximum), are in a plane within 2 mm. This area of 0.5 mm of flatness on 300 mm in height guarantees an angle in z equal to 0,095° at maximum. This maximum angle is considered as negligible and consequently, there is no adjustment foreseen in z for the slats.

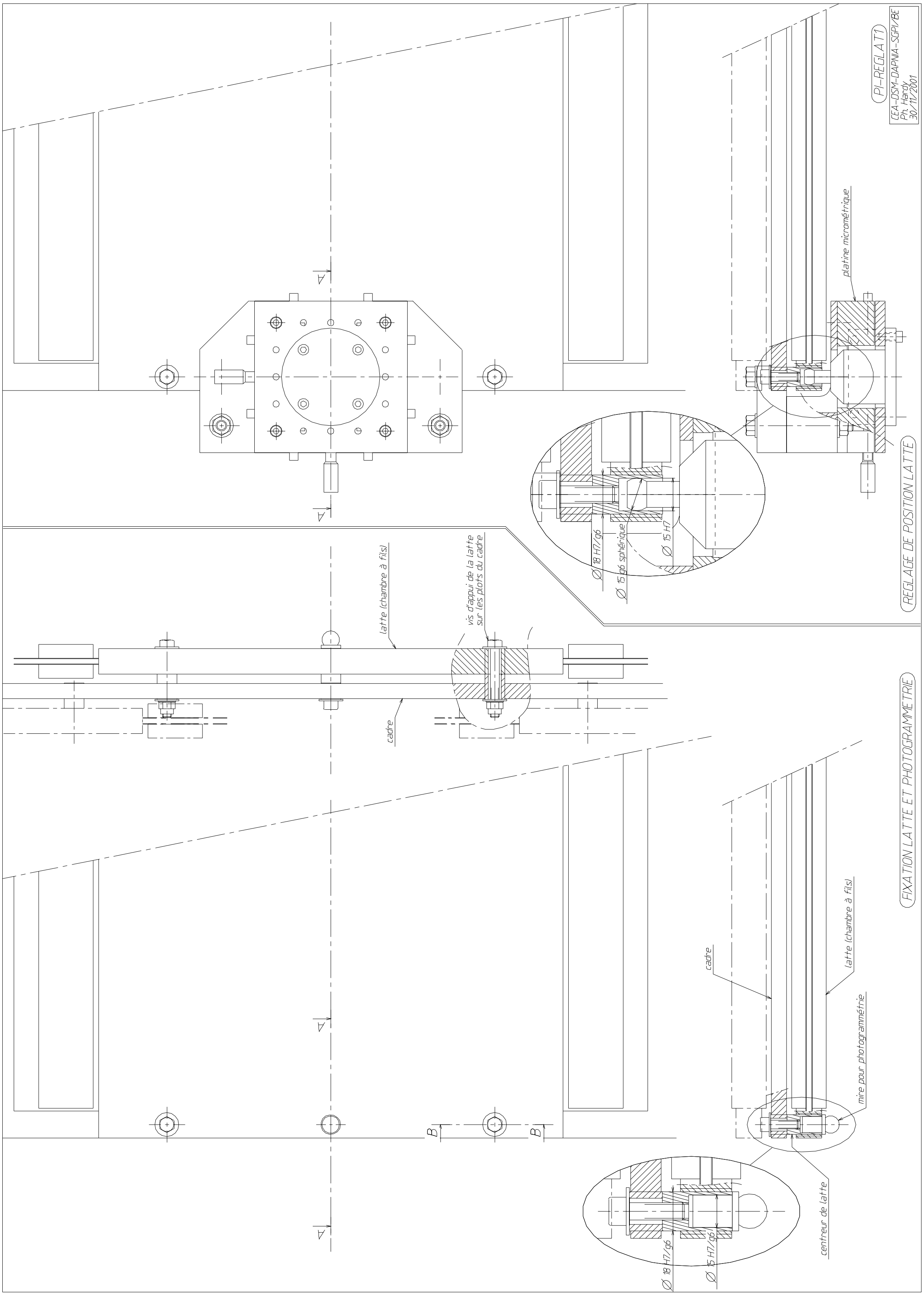


Figure 3 : Detailed drawings of the mechanical positioning system. The removable head is mechanically detailed.

Positioning in x and y :

The right position in x and y is assured by the two adjustable centering axis (adjustment of ± 1,5 mm) on the panel support. Each slat is mounted on these two axis. Both axis are then overtightened on the support.

The position in x of the slat is assured by the adjustment of the first centering axis, the second one is free in an oblong groove. The position in y is ensured by the adjustment of the two centering axis.

3 Mock up of the central part of Station 5 (at scale 1)

In order to test the mechanical device, Saclay has built a mock up of the central part of Station 5 (Aluminium sandwich with a Rohacell foam core), with 5 slats (3 slats on face called "Front", 2 slats on face called "Back"). Figure 4 shows the photograph of the complete mock up (left) and the attachment of the slat positioning system (right).

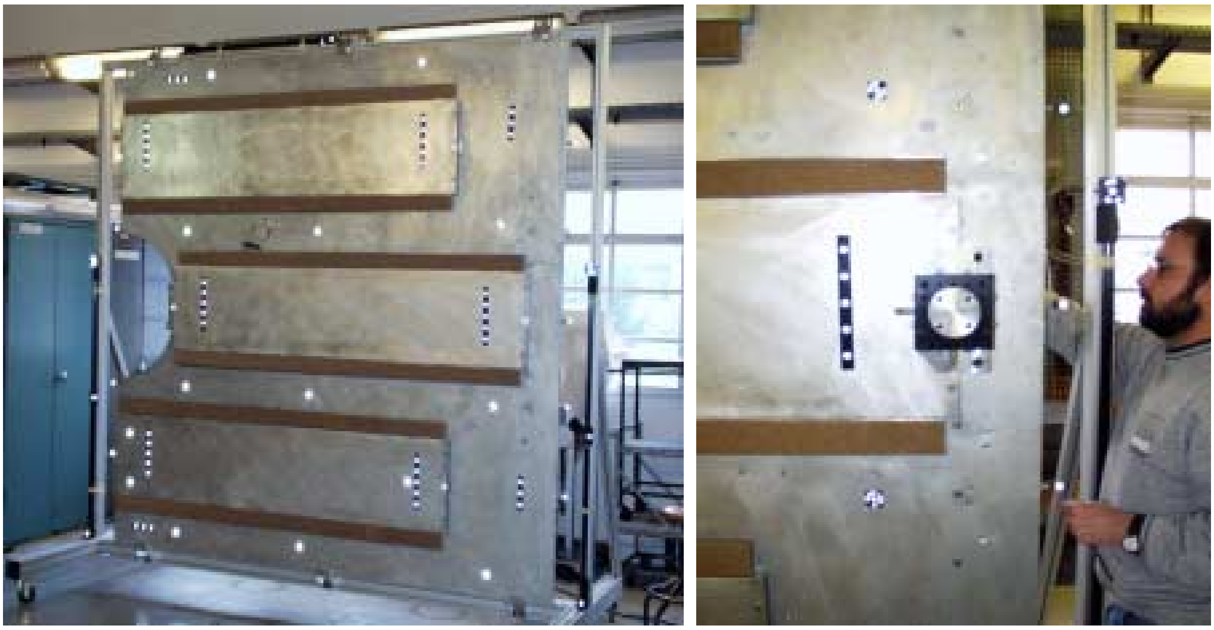


Figure 4 : Left : Aluminum mock up of the central part of Station 5 (at scale 1). The different types of surveyor's target are shown. Right : Tuning of the slat positioning system on the panel support.

Dimensions of the mock up are : 2500 mm × 2600 mm, with a thickness of 15 mm. The weight of the panel is about 60 kg. The Aluminum slats have the same weight and size than the future final ones (P~7 kg per slat ; L = 2400 mm and H = 585 mm for the biggest one).

Two holes ϕ18H7 are foreseen at each extremity of the slat as centering axis and for the spherical surveyor's target. Nine other identical holes are foreseen also on the panel support edges for the spherical targets (4 in the internal part –beam shield side- and 5 in the external part). Other smaller holes are used to place the slat positioning system.

4 Tests of the slat positioning system with a comparator

A first set of tests is made with a simple comparator. Indeed, we want to check the real displacement of our slats when we use the slat positioning system. In other words, when the slat is moved by 0.2 mm with the micrometric screw of the mechanical device, in Y for example, how many millimeters the slat has been displaced in reality ?

Many measurements of displacement have been performed in X, Y upward and Y downward for each slat. The results are shown in Figure 5, Figure 6 and Figure 7 : red triangles represent the value of the displacement of the slat, made with the mechanical device (the reading of the value is made on the micrometric screw) and the blue squares represent the value of the displacement read directly on the comparator.

Except the first two measurements (number 2 and 3) of Figure 5, the difference between the two values, in the X direction, is very small : 20 µm to 30 µm in maximum.

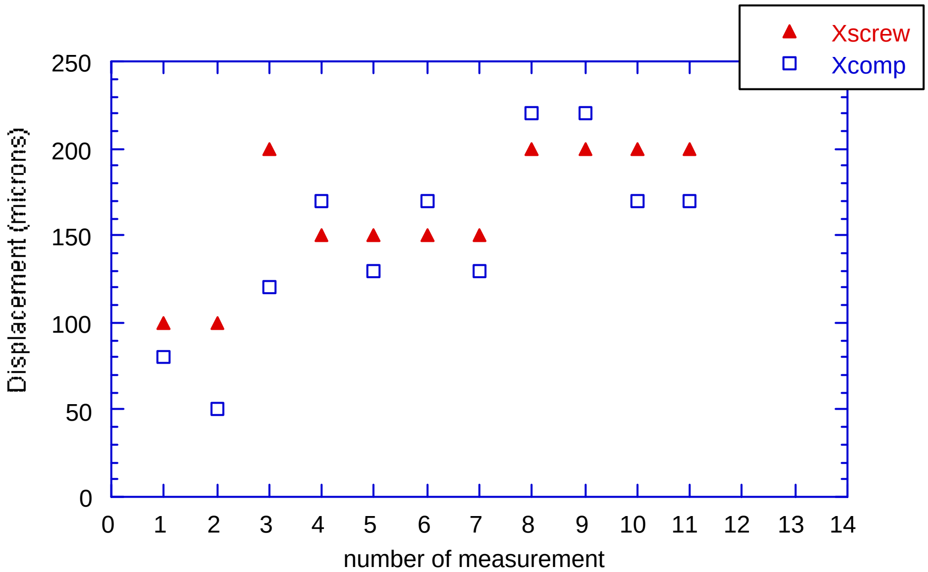


Figure 5 : in the X direction, comparison between the value of displacement given by the mechanical device and the effective value given by the comparator, and for several measurements.

The comparison is better in Figure 6, in the Y downward direction, where the difference (when it exists) is in the order of 10 µm to 20 µm in maximum. Same kind of results is obtained in Figure 7, for the Y upward direction.

Conclusion : these tests have allowed to check the efficiency and the precision of the slat positioning system. Displacement can be very precise, with help of micrometric screws in X and Y. The whole system is mechanically correctly designed, as the effective value of displacement is always practically equal to the value given by the micrometric screws (by 10 µm or 20 µm in maximum). Notice that the photogrammetric technique is not able to see such a small difference.

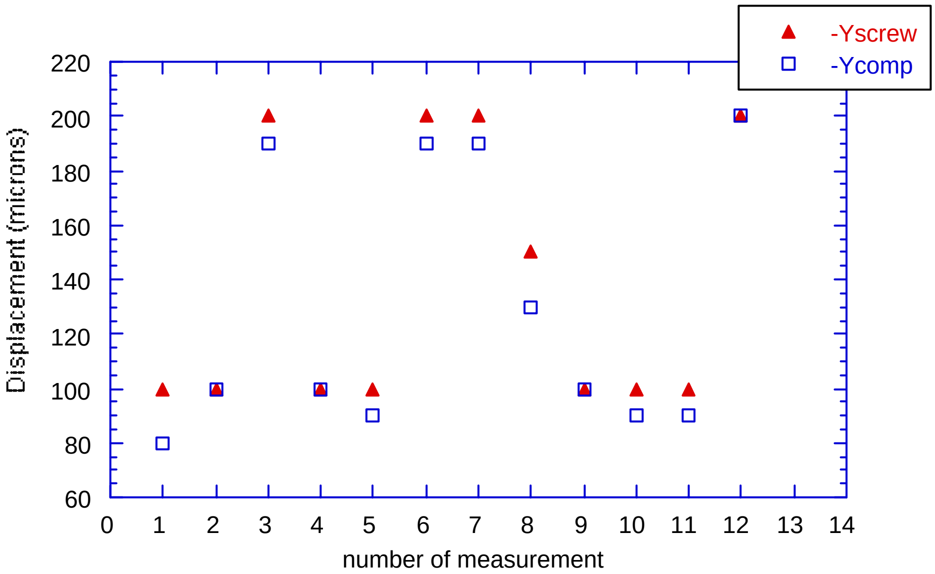


Figure 6 : in the Y downward direction, comparison between the value of displacement given by the mechanical device and the effective value given by the comparator, and for several measurements.

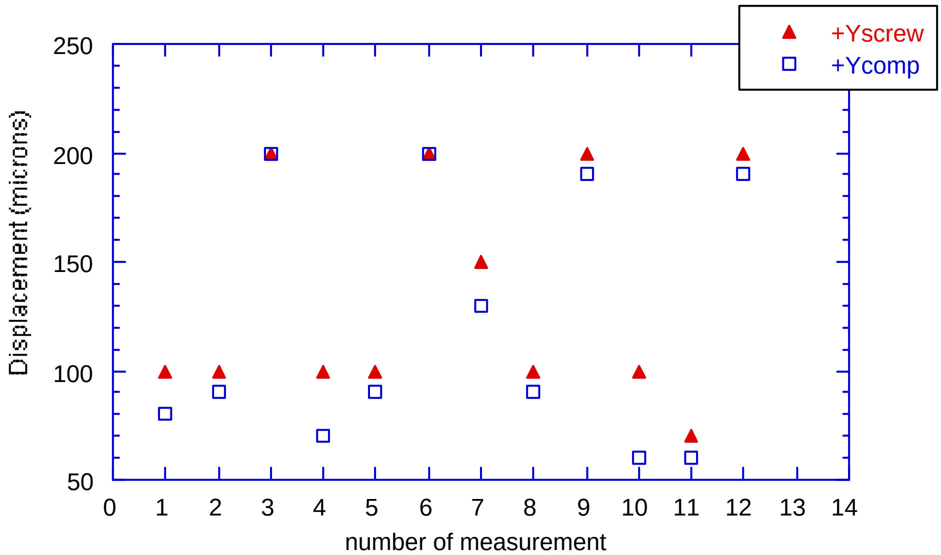


Figure 7 : in the Y upward direction, comparison between the value of displacement given by the mechanical device and the effective value given by the comparator, and for several measurements.

5 Photogrammetric measurements and results

5.1 *Targets and mock up equipment :*

Surveyor's targets are installed on different places on the panel support and on the slats (in the centering axis). Four different types of targets have been used : 25 coded-stickers (on the surface of the panel), 10 button targets (to equip the reference points on the 5 slats), 9 spherical targets (on the panel support edges) and 78 non-coded targets. These last targets have been used for the transformation calculations and have been placed on slats and support. In addition, three standard bars are placed at each side and at the top of the panel in order to give the scale.

Figure 8 shows all the non-coded targets and button targets on the two faces, which are identified by numbers (essential during calculations). Collection of positions in x, y and z is done with photographs of all these targets (122 in total).

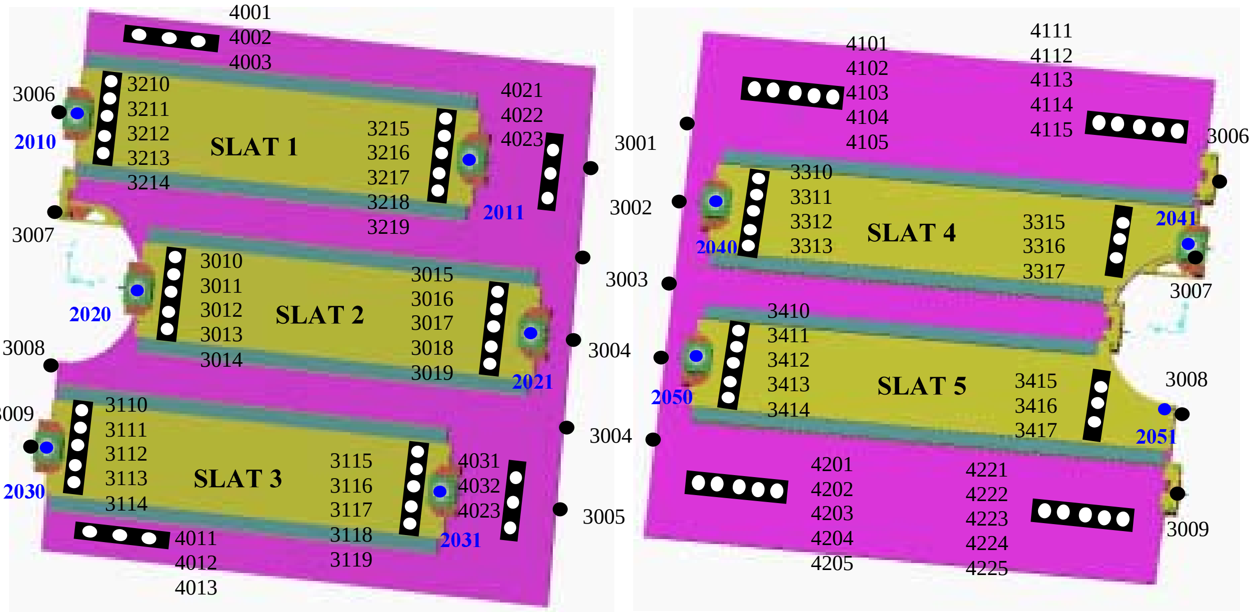


Figure 8 : Left : Distribution of points on face " Front ". Right : Distribution of points on face " Back ". These points are used for all calculations made by the surveyor.

The camera, used during all measurements, is a DCS 460 Digital camera, 18 mm × 27 mm (3000 × 2000 9 µm-pixels), and with a focal of 24 mm.

To take good photographs, an important condition for the surveyor is to have enough room to move back. Indeed with this focal, the minimum distance is 3 m from our object (height of the panel support is 2.5 m). Moreover, the surveyor needs a lot of free space around the object too (around 1 m minimum), without any other things that can obstruct the line of sight.
These conditions are essential to get the best precision for the measurements (1σ ~ 50 µm).

5.2 Principle of the measurements

The slat is mounted to its theoretical position as well as possible. A first collection of photographs is done. In function of the results obtained, the slat is mechanically positioned again in x and y with the platen system.

In order to move the slat, the two targets, which are in the centering axis, are removed. The head of the device, connected to the platen, is introduced and allows to adjust the slat in x and y.

The position z is given by the assembly and is well sufficient for the physics.

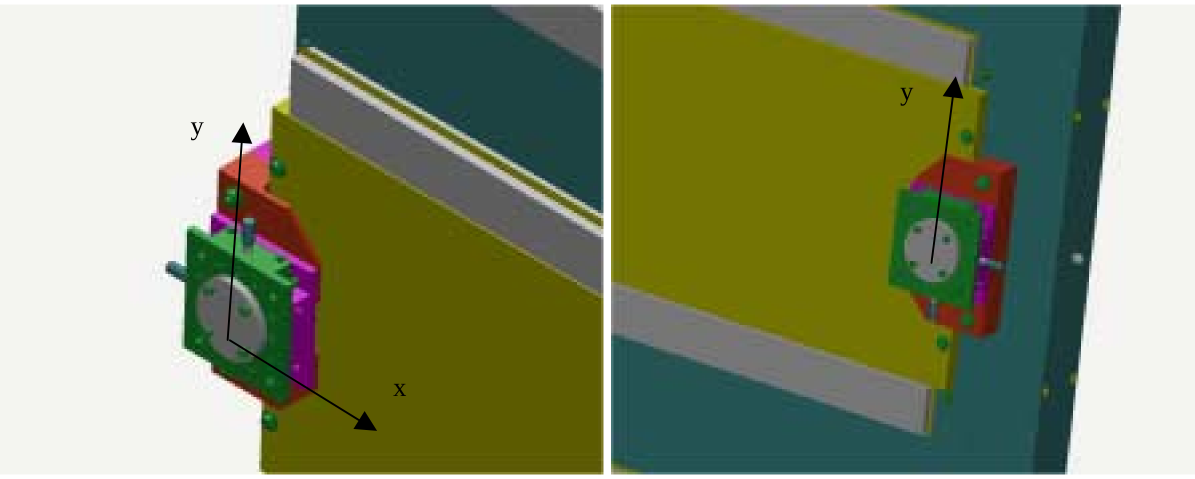


Figure 9 : Left : adjustment of the first centering axis in x and y (beam shield side). Right : adjustment of the second centering axis in y only (external side).

Slats adjustment steps :

1. All slats are mounted as well as possible, in the middle of their adjustment range.

2. Slats are fixed and a first set of photographs is taken to locate the positions of the targets in comparison with reference points placed on the panel support.

3. 1st point of adjustment : the positioning system is placed on the first centering axis (closed to the beam-shield) and we can tune in x and y, according to the results of the photogrammetry.
The second axis, mounted in an oblong groove and not jammed, can follow the displacement in x of the first axis.

4. The first point is jammed in position, once adjusted.

5. The positioning system is placed on the second centering axis, and the oblong groove is not jammed. The adjustment of the second point in y can be performed. The groove is then jammed.

We try to adjust x and y in a range of ± 1,5 mm at maximum.

6. We check the right position of the slats by a last set of photographs.

5.3 Measurements and results

The photogrammetric measurement gives the 3D position of target points on the surface of the panel and the slats. In the following, it has been decided to use the panel as reference to detect any movement.

During three days, we took 12 sets of ~15 photographs each (including the first measurement taken as the initial reference). All the tables, corresponding to each measurement, are detailed in [2], available on the web at the address : *http://edms.cern.ch/document/338330/2*.

For all measurements, the coordinates have been transformed using a 7-parameters transformation (3 rotations, 3 translations and 1 scaling factor) on the previous measurement to detect the recent movement of the different slats (ex : measurement 2 on measurement 1, measurement 3 on measurement 2, etc …).

For time reasons, the following measurements and results come from the face "Front" only, where 3 slats have been studied. Of course, same kind of results is expected from the second face called "Back".

Results :

In the following figures : black circles represent the displacement applied on Slat N, in X and Y direction, made with the micrometric screws of the positioning system (error bars are not visible, because the order of magnitude is very small : 10 µm). Red triangles represent the displacement of the same Slat N, detected by photogrammetry (error bars are taken at 50 µm). These latest values are averaged by all the tapes targets.

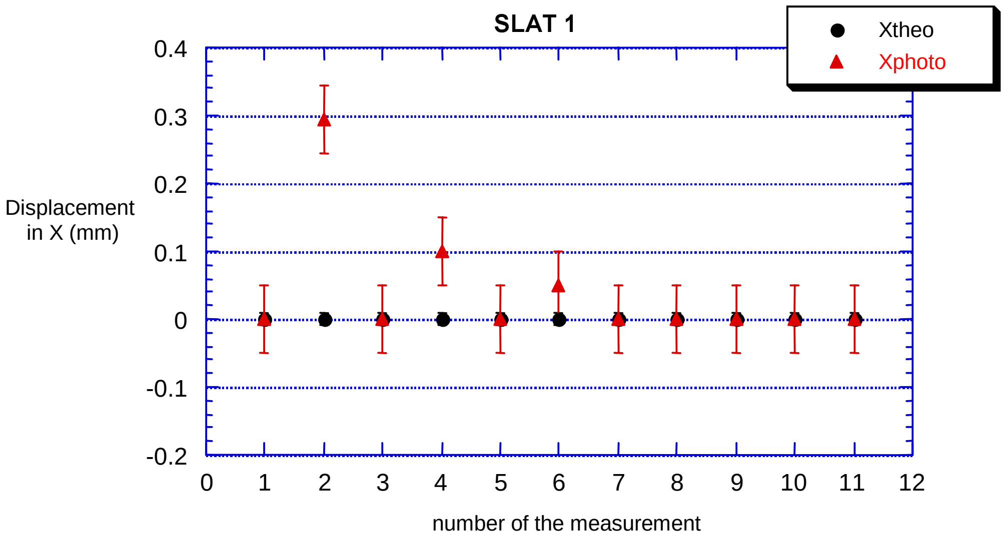
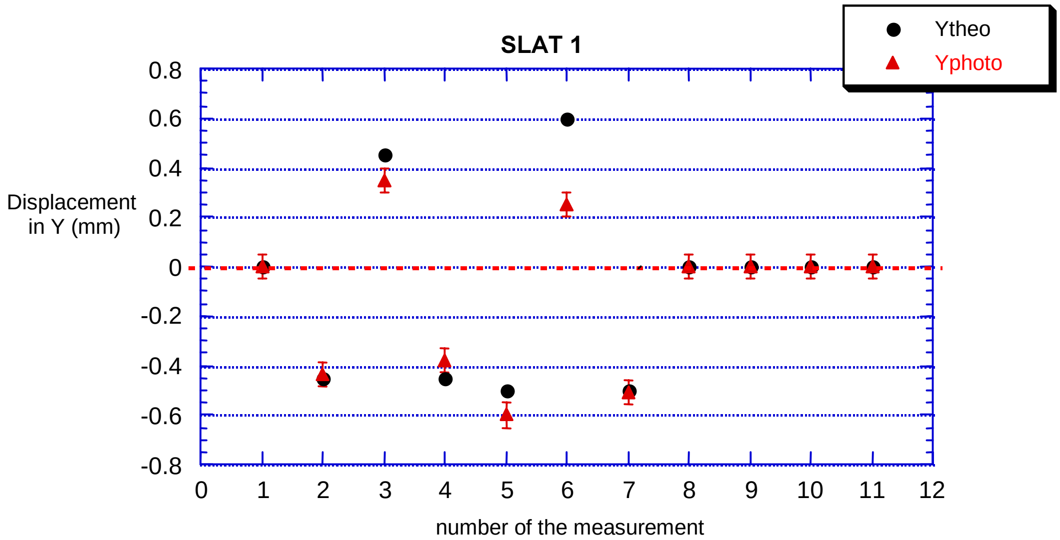


Figure 10 : Comparison between the displacement of the slat 1, in the X direction, made with the mechanical device (Xtheo) and the displacement measured by photogrammetry (Xphoto), versus the number of the measurement.

In Figure 10, no displacement is applied in the X direction (all black circles Xtheo stay at zero), but we exchanged slat reference targets for the positioning system. We observed sometimes a difference from 0.1 mm up to 0.3 mm (measurement number 2 and 4).

Figure 11 : Comparison between the displacement of the slat 1, in the Y direction, made with the mechanical



device (Ytheo) and the displacement measured by photogrammetry (Yphoto), versus the number of the measurement.

In Figure 11, displacements are applied on Slat 1 in the Y direction upward (positive values) and downward (negative values). Except the measurement number 6, all measurements give a rather good agreement between values given by the positioning system and those by photogrammetry, within 100 µm. It seems that comparison is worse in the Y upward direction. This point is confirmed by following figures with Slat 2 and Slat 3.

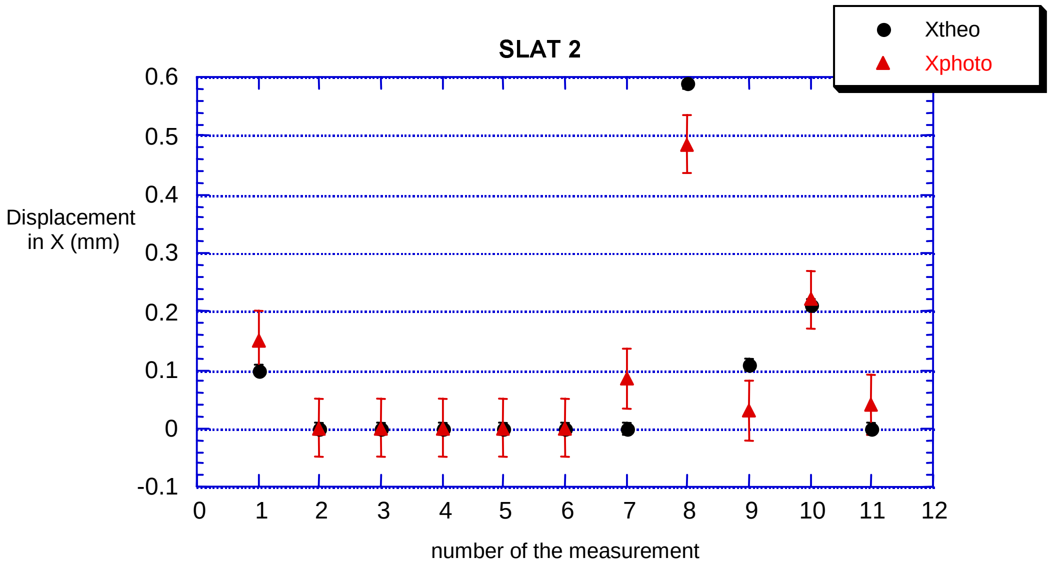


Figure 12 : Comparison between the displacement of the slat 2, in the X direction, made with the mechanical device (Xtheo) and the displacement measured by photogrammetry (Xphoto), versus the number of the measurement.

In Figure 12, displacements are applied on Slat 2 in the X direction. The difference between both values stays within 2σ (100 µm).

In Figure 13, only few displacements are applied on Slat 2 in the Y direction, upward and downward. There is a very good agreement on measurements number 3 and 11 in downward direction. Otherwise, no displacement is applied during the other measurements (all black circles Ytheo stay at zero). This time we do not exchange reference button targets for the positioning system. Of course, we observed the same values equal to zero.

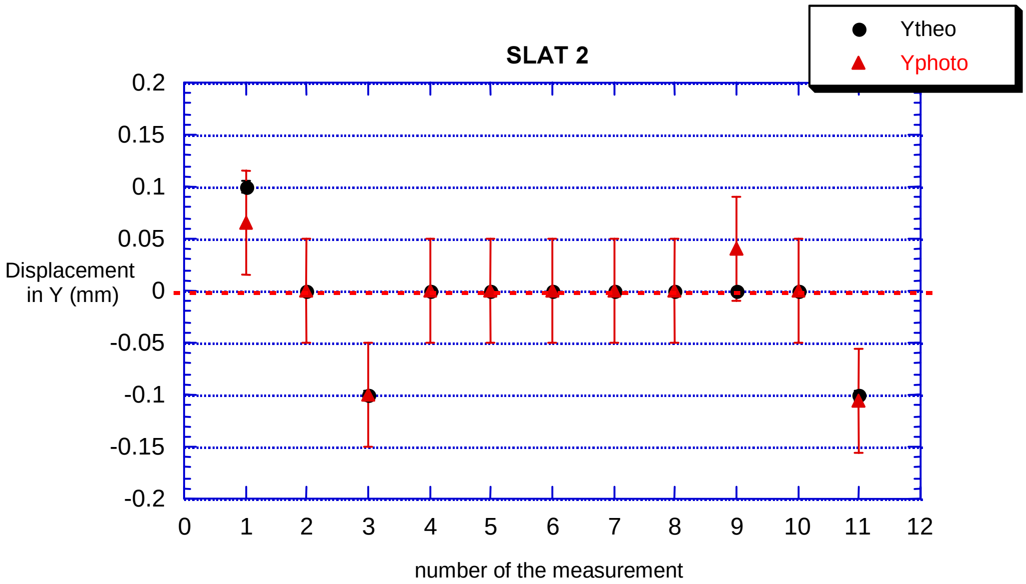


Figure 13 : Comparison between the displacement of the slat 2, in the Y direction, made with the mechanical device (Ytheo) and the displacement measured by photogrammetry (Yphoto), versus the number of the measurement.

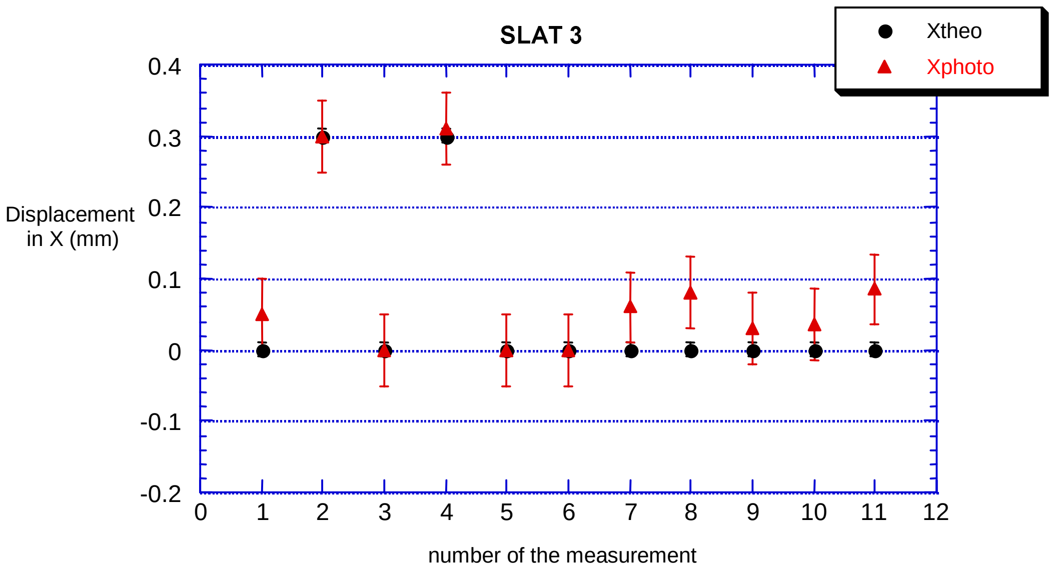


Figure 14 : Comparison between the displacement of the slat 3, in the X direction, made with the mechanical device (Xtheo) and the displacement measured by photogrammetry (Xphoto), versus the number of the measurement.

In Figure 14, displacements are applied on Slat 3 in the X direction. The first four measurements show a very good agreement between values obtained with the positioning system and the photogrammetry. During the following measurements, no displacement is applied (black circles stay at zero), but we exchanged reference button targets for the positioning system and inversely. Again, we observed some small deviations between both values. We conclude that the slat reference points (used for the reference survey targets) must not be used by the positioning device.

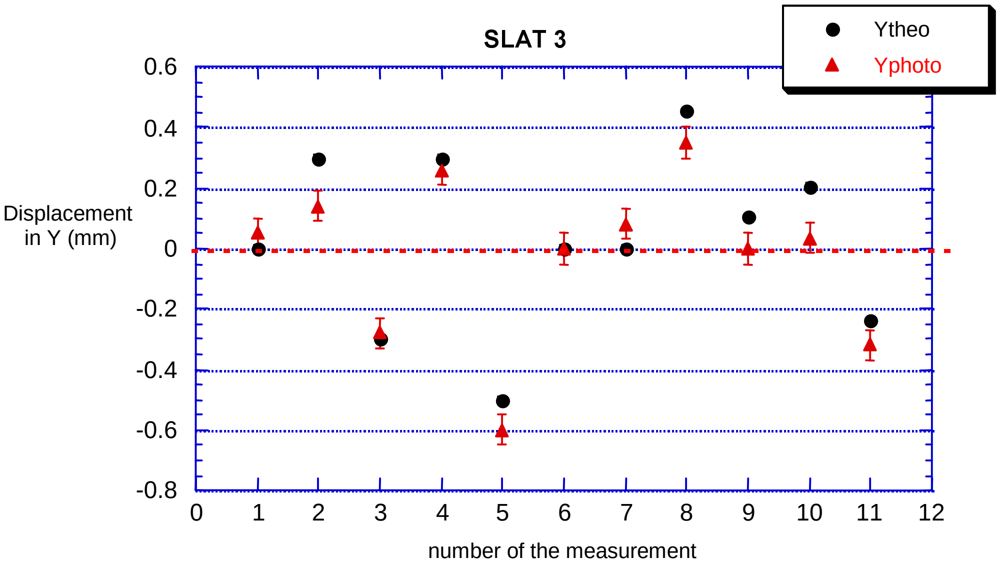


Figure 15 : Comparison between the displacement of the slat 3, in the Y direction, made with the mechanical device (Ytheo) and the displacement measured by photogrammetry (Yphoto), versus the number of the measurement.

In Figure 15, displacements are applied on Slat 3 in the Y direction, upward and downward. There is a good agreement on measurements in downward direction. In upward direction, some deviations between both values are observed.

This campaign of measurements can be summarized by histograms and it is illustrated on Figure 16. In these histograms, all the non-coded targets are taken into account in Face "Front".

An accumulation of points (or measurements) is done for always the same value of displacement. In other words, we try many times to move one slat always with the same value (with the positioning system), and we report each time, in the histogram, the real value given by photogrammetry. This way to proceed allows us to see the reproducibility of our displacements compared to reality, by looking at the standard deviation. Each time, we want to move one slat, we are making an error in the displacement equal to the standard deviation.

- In X : (top left of the figure), we try several times to move one slat by a value of Xtheo = 0.300 mm. The photogrammetry gives us a mean value of Xmean = 0.312 mm with a RMS value < 10 µm, which is a very good result.

- In Z : (top right of the figure), we did not move in this direction at all (Ztheo = 0), but during all our manipulations, we wanted to check if something has changed. We obtained Zmean = 0.011 mm with RMS ~ 35 µm.

- In -Y : (bottom left of the figure), we try several times to move one slat by a value of Ytheo = -0.500 mm. The photogrammetry gives us a mean value of Ymean = -0.501 mm with a RMS value = 65 µm. The mean value is really perfect and the deviation is greatly acceptable.

- In +Y : (bottom right of the figure), we try several times to move one slat by a value of Ytheo = +0.500 mm. The photogrammetry gives us a mean value of Ymean = +0.359 mm with a RMS value of 118 µm ! The mean value is very bad compared by the theoretical value and moreover the deviation is not acceptable in this case.

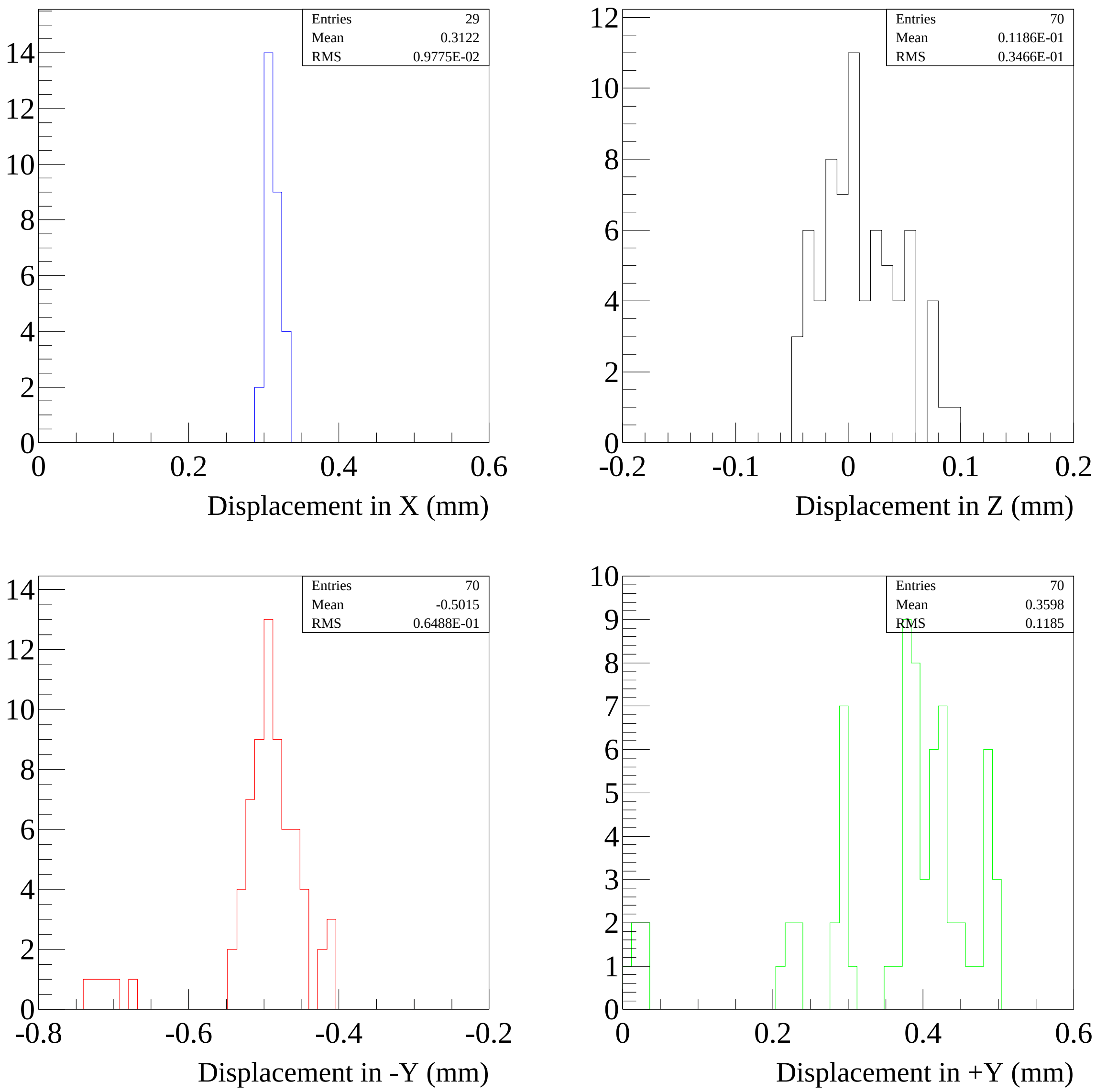


Figure 16 : Dispersion of the displacement obtained with the positioning system, for a given and fixed displacement value : in X (top left), in Z (top right), in Y downward (bottom left) and in Y upward (bottom right).

5.4 Conclusion on the photogrammetric measurements

Photogrammetric measurements are essential to give the complete set of slats coordinates in the 3 directions. In ideal conditions of room around the studied object, made at Saclay, the surveyor has obtained very good precision on photographs in the three directions : σ_x = 30 µm, σ_y = 30 µm and σ_z = 50 µm. In "ordinary" conditions, surveyors announce $\sigma_x = \sigma_y$ = 100 µm and σ_z = 200 µm. These differences come from the dimension of the object and the measurements conditions (environment).

During this campaign, we notice that the reference button targets must never move, otherwise an error of 100 µm can be detected without moving anything. In the future, the slat positioning device must take place in another hole specially dedicated for the displacement. This hole must be different from the one of the reference target.

6 General Conclusion

In average, all adjustments of slat in X are precise (Xmean = 0.312 mm for Xtheo = 0.300 mm) and can be very well reproduced (deviation equal to 10 µm).

In average, all adjustments of slat in Y downward are precise (Ymean = -0.501 mm for Ytheo = -0.500 mm) and can be well reproduced (deviation equal to 65 µm).

On the other hand, all adjustments of slat in Y upward are not precise and not reproducible. Indeed, the mean value is very bad compared by the theoretical value (Ymean = +0.359 mm for Ytheo = +0.500 mm) and moreover the deviation is not acceptable in this case (deviation equal to 118 µm).

This can be explained by mechanical reason : to move a slat in the upward direction, we need to compensate the weight of the slat with the micrometric screw before starting the displacement. This compensation (made by hand) is unfortunately approximate. This leads to non-negligible errors in our displacements. We cannot make mechanical corrections to this effect.

Notice that it is not the case in the downward direction, as the weight of the slat stands on the positioning system (i.e. the micrometric platen). In any case, in order to get a precise adjustment of slat in Y direction, we have to move the slats only in the downward direction. But finally, in the experiment, we do not plan to readjust the position of the slats after mounting, since the precision given by the photogrammetry technique is largely sufficient.

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[1] : " Supports des lattes des Stations 3-4-5 ", P. de Girolamo, P. Hardy, F. Orsini, Alice Dimuon Arm Saclay internal note, Ref : 6B3221T007DB02, February 2002.

[2] : " Alice tracking Chambers : Test of a prototype of the alignment tool ", D. Mergelkuhl, CERN/EST/SU internal note, EDMS Ref : 338330v.2, 20th February 2002.