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CMS FORWARD DETECTORS METROLOGY ANALYSIS

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Abstract

This report is presenting an analysis of the geometrical parameters of the CMS Forward silicon detectors, as measured on dummy detectors used for assembling procedure tests. Alignment crosses' coordinate, microstrips' angle, cut edges' angle, and detectors' height measurements were in detail analyzed. It was found that measurement set-up is introducing measurement errors mainly because of the camera and light cables, weight and fixing position on machine's arm. Two measurements programs for metrology analysis were written. Measurement procedure and accompanying detectors' data sheets were established.

- Technical Report -

CMS FORWARD DETECTORS METROLOGY ANALYSIS

- Technical Report –

Introduction

This report is presenting an analysis of the geometrical parameters of the CMS Forward silicon detectors, as measured on dummy detectors used for assembling procedure tests. The dummy detectors were produced at IMT Bucharest. The measurements were done using a DEA Brown&Sharp coordinate measurement machine at INFN Florence. We aimed to investigate the metrology parameters of the single side ϕ-type silicon forward detectors for the CMS experiment.

Measurement procedure

We measured 18 detectors of F1- and 19 detectors of F2-type. The measurement programs for the two-type detectors were wrote in the DEA Part Programming Language (DEAPPL) under TUTOR for WINDOWS and consist in following main steps:

- definition of a reference system;
- measurement of different elements of the silicon detector;
- data saving into a file and printing on a data sheet.

Figures 1 and 2 present the elements measured on F1- respectively F2-type detectors. The numbers associated represent memory location numbers of different measured elements.

The reference system is defined measuring two alignment crosses located on the long base of trapezoidal shaped detectors. The Y-axe is defined by these crosses (6 and 11 respectively 8 and 9) and the origin of the system, for symmetry reasons, was imposed at half distance's between these crosses.

First elements measured were crosses coordinates. We will refer in following at these values as *cross N - C* where *N* is the memory location number (from 5 to 12) and *C* is the coordinate type (X or Y).

Next the two outer-most inclined strips are defined by measuring two points on each strip. Since we are interested only in the correct inclination of these strips (37 and 38) we registered only their angle with the X-axe and also the angle in-between; we refer to these as *left_strip*, *right_strip* and *angle_strip* respectively.

The cut edges are defined at the end by measuring two points on each edge. Since also here we are interested only in the inclination of cut edges (39, 40, 41 or 43 and 42 or 44) with respect to our reference system, we registered that as *left_*, *right_*, *upper_* and *botom_cut* respectively. We also registered the angle in-between left_ and right_cut as *angle_cut*.

Apart from the above parameters, the program calculates also the detector height (47 or 48) named as *height* and also the distance (48) from the alignment crosses 6 (F1-case) or 7 (F2-case) to the adjacent cut line, referred as *dist_to_cut*.

In this way the measurement of one detector is done and data saving into a file and printing out of the data sheet complete the measurement.

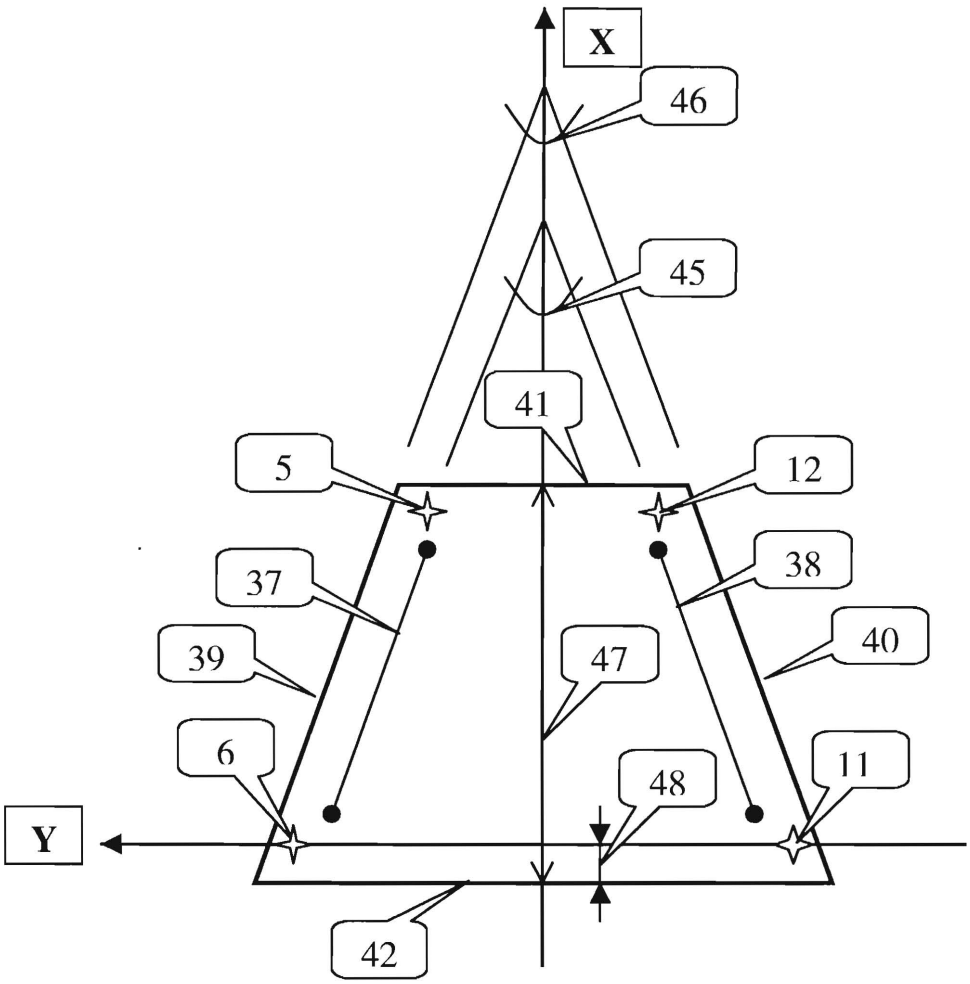

Figure 1. Measured and calculated elements for CMS F1-type detector

Data analysis

The following Excel sheets present the measured and calculated parameters, for each silicon detector. For statistical parameters' analysis the average and standard deviations were computed. We discuss next the metrology behavior of three parameters: the coordinates of the alignment crosses, the inclination angle of microstrips and cut edges and the detectors' height and distance to cut.

1. Alignment crosses. From the sheet 2 of data we can extract the following mean values and standard deviations of the alignment crosses' coordinates:
The measured crosses' coordinates for the F1-type detectors are:

Cross 5-X=63967.60±1.89μm
Cross 5-Y=26626.54±8.42μm
Cross 6-X=0.12±0.82μm
Cross 6-Y=32462.02±4.32μm

Cross 12-X=63971.54±2.84μm
Cross 12-Y=-26611.95±6.56μm
Cross 11-X=-0.12±0.99μm
Cross 11-Y=-32462.82±5.71μm

The measured crosses' coordinates for the F2-type detectors are:

Cross 7-X=54316.32±0.92μm
Cross 7-Y=32473.98±4.54μm
Cross 8-X=-0.18±0.93μm
Cross 8-Y=37480.74±1.81μm

Cross 10-X=54323.66±3.03μm
Cross 10-Y=-32445.78±4.9μm
Cross 9-X=-0.44±1.4μm
Cross 9-Y=-37481.97±1.14μm

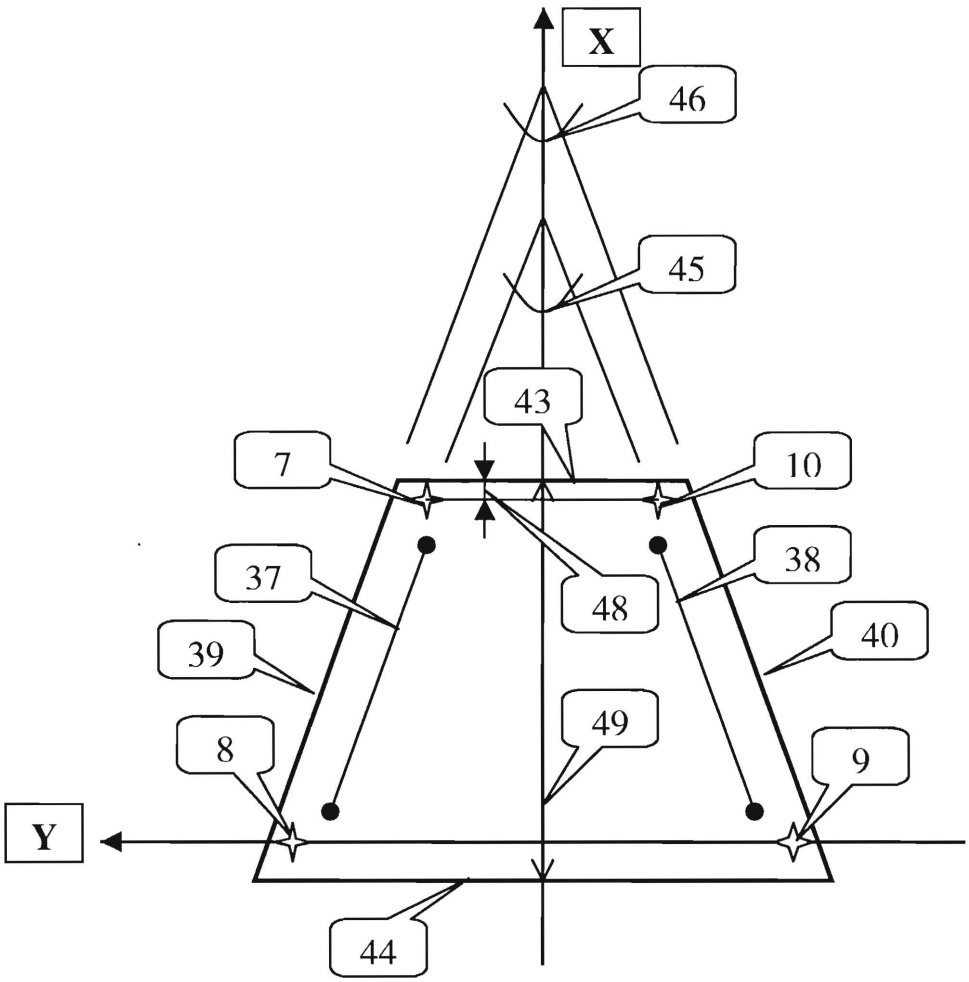

Figure 2. Measured and calculated elements for CMS F2-type detector

The following comments can be done for both detector types:

- The standard deviation is generally smaller for the X coordinate than for the Y coordinate. This can be a machine problem, but the high value of standard deviation (up to 6 microns) is caused by measurement's set-up. We observed during measurements that probe position is dependent on light cables' position. By fixing the cables some improvement was obtained but the point is

that TV camera fixing on machine arm is introducing inertial movements and rigidity of light cables is introducing uncontrollable microns' displacements. The change in set-up was made for F1 detectors 10 to 18.

- Upper crosses have larger deviation than lower ones. This can be explained by the above reasons (more tension introduced by cables). In particular the upper right cross always has larger coordinate deviation and seems to be not symmetrical with respect to the other crosses. We investigate that by calculating the difference of the coordinates of symmetrical crosses, obtaining the following results:

For the F1-type detectors	For the F2-type detectors
Xsim5-12=-3.94±3.97μm	Xsim7-10=-7.34±2.92μm
Ysim5-12=14.59±14.91μm	Ysim7-10=28.21±9.37μm
Xsim6-11=0.24±1.30μm	Xsim8-9=0.27±2.05μm
Ysim6-11=-0.79±2.02μm	Ysim8-9=-1.24±1.44μm

It is difficult to say now if the large asymmetry values obtained for the upper crosses are only caused by measurement set-up problems or also by a design placement error (especially on Y direction).

- The calculated distance between symmetrical crosses gave the following values:

For the F1-type detectors:	For the F2-type detectors:
dist5-12=53238.49±2.36μm	dist7-10=64919.76±1.24μm
dist6-11=64924.84±9.92μm	dist8-9=74962.71±2.67μm

This time the values have a smaller spread, except the bottom distance on F1 detector (dist6-11).

- Taking into account the first comment, we split the measurement data of F1 detectors in two parts: from detectors 1 to 9 and from detectors 10 to 18, last part being measured after a set-up adjustment of cables. After this arrangement, the parameters for this last batch only are improved as follows:

F1-type detectors betch1+2	F1-type detectors betch2
Xsim5-12=-3.94±3.97μm	Xsim5-12=-1.20±1.28μm
Ysim5-12=14.59±14.91μm	Ysim5-12=3.15±1.85μm
Xsim6-11=0.24±1.30μm	Xsim6-11=0.06±0.63μm
Ysim6-11=-0.79±2.02μm	Ysim6-11=0.50±1.37μm
dist5-12=53238.49±2.36μm	dist5-12=53236.52±1.01μm
dist6-11=64924.84±9.92μm	dist6-11=64916.62±0.56μm

It is evident now that the main cause of error is the measurement set-up. Also, because dist6-11=64916.62±0.56μm for F1 betch2 is practically equal with the corresponding distance on F2, dist7-10=64919.76±1.24μm we conclude that it's not a design placement error of crosses, but still a remaining error introduced by the measurement set-up.

2. *Inclination angle of microstrips and cut edges.* From the sheet 3 of data we can extract the following mean values and standard deviations of the detectors' cut edge and microstrip angle, with respect to the Y-axe:

For the F1-type detectors:
left_cut=$4^0$57'24.12''±14.61''
right_cut=$4^0$58'48''±53.34''
top_cut=$0^0$0'24.61''±16.89''
botom_cut=$0^0$0'23.99''±16.83''
angle_cut=$9^0$56'12.19''±45.91''
left_strip=$4^0$57'16.02''±15.38''
right_strip=$4^0$58'13.70''±37.02''
angle_strip=$9^0$55'29.75''±22.56''

For the F2-type detectors:
left_cut=$4^0$56'56.72''±25.40''
right_cut=$4^0$59'48.88''±46.58''
top_cut=$0^0$0'36.42''±13.74''
botom_cut=$0^0$0'19.06''±18.75''
angle_cut=$9^0$56'45.60''±29.98''
left_strip=$4^0$56'57.66''±21.92''
right_strip=$4^0$59'10.74''±41.31''
angle_strip=$9^0$56'08.41''±20.79''

The following comments can be done for both detector types:

- The cut line's angle is fairly good considering the cut was done manually using the structure's guard ring. We can have an estimate of the manual alignment precision considering the differences between cut's angle and corresponding strip's angle (ideally this difference should be zero). This way the mean values of the manual alignment cut procedure's error are:
  For the F1-type detectors:
  left_side=$0^0$0'8.10''
  right_side=$0^0$0'34.30''
  top_side=$0^0$0'24.61''
  botom_side=$0^0$0'23.99''
  For the F2-type detectors:
  left_side=-$0^0$0'0.94''
  right_side=$0^0$0'38.14''
  top_side=$0^0$0'36.42''
  botom_side=$0^0$0'19.06''
  Overall these values give an alignment error around 23'', which for an alignment length distance of 5 cm means about 6 μm. This is fairly good considering the optics of the cut machine, where the cut well of approximately 80 μm width on the wafer is seen on the monitor about 1 cm width.

- An asymmetry in the left and right strip's angle on F1- and F2-type detectors can be observed; expressed in mean value difference, this asymmetry is 57.68'' and 2'13.08'' respectively. We consider it like a consequence of the measurement set-up problems.

- Dividing the angle strip value by 1023 (strip number minus one), an estimate of the angle between two strips can be made. We obtain (in terms of mean values) 34.926'' or 34.694'' for F1- respectively F2-type detectors which are in good agreement with the designed value. Nevertheless, a somehow bad conclusion can be drowned: the error in strip angle measurement is around the angle between two adjacent strips.

3. Detectors height and distance to cut values. From the sheet 3 of data we can extract the following mean values and standard deviations of the detectors' height and for the distance between cross 6 and lower cut line (for F1-type detectors) or between cross 7 and upper cut line (for F2-type detectors). We note that because of a cut error, some F1-type detectors were cut about 100 microns wider. Because of that we split the F1 measurements in two cases.

For the F1-type detectors
height1=64359.31±4.50μm
height2=64469.25±9.57μm

For the F2-type detectors
height=-54725.47±5.89μm
distance=201.09±3.44μm

distance1=196.15±3.72μm
distance2=254.63±7.25μm

We can observe that the standard deviation of detector's dimensions is less than 9.57 μm which is a somehow a large value. It is difficult to split this into the contribution of cut process and measurement set-up.

Conclusions

The main contributions of this work can be summarized as:

1. Two measurements programs for metrology analysis of CMS F1- and F2- type detectors using a DEA Brown&Sharp coordinate measurement machine were wrote. Measurement procedure and accompanying detectors' data sheets were established
2. Alignment crosses' coordinate, microstrips' angle, cut edges' angle, and detectors' height measurements were in detail analyzed.
3. It was found that measurement set-up is introducing measurement errors mainly because of the camera and light cables, weight and fixing position on machine's arm.

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