November 15, 2000
Version 0.00

First Level Analysis Results from the CERN ISR EMU Alignment Test in June 2000

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Abstract

This note summarizes results from the first level analysis of the data taken for CMS EMU alignment test. The test was conducted at CERN ISR in three periods approximately 1 week each (June, July/Aug, and Sept. 2000). The main focus of this analysis is to study the stability (short, medium and long terms) and to obtain an intrinsic resolution of the laser signals read out by ccd (COPS) sensors as well as the analog sensors. This note describes this first level analysis results in details. The resultant ccd centroid information is fed to COCOA reconstruction programs. Details of reconstruction result is summarized in a separate note. In this note, we summarize the main issues we learned from ISR test from the first level analysis and also from the COCOA reconstruction.

1 Introduction

At the ISR I4 CMS alignment laboratory, we have set up 13 sensors in total; 8 in the SLM line (es1, es2, es4, es5, es6, es7, es9, and es10) and 5 in the Transfer line (et0, et1, et2, et3, and et4). Each sensor has 4 CCD arrays with 2048 channels. The pitch of the CCD pixel is 14 μm. Fig. 1 shows the layout of the sensors at the ISR test. After the setup was complete, we have taken approximately 100 runs over a 4 day period in various conditions in June. We repeated the test in July/August and September together with the Link and Barrel alignment groups. IRS test information including run summary and the description of the raw data format can be found in a web page:

http://home.fnal.gov/˜maeshima/alignment/isr/isr.html.

The detail information on the DAQ program used for the test is in:

http://home.fnal.gov/~maeshima/alignment/daq/daq.html.

1.1 CCD profiles and Problem with Long Daisy Chain

In June data taking period, the majority of data were taken with all 13 sensors connected in series. This caused a problem in the last 2 sensors in the chain, namely et3 and et4 due to a voltage drop during readout. The "good" data for et3 and et4 can be found in runs in which we connected the 5 transfer line sensors only. Fig. 2 - Fig. 6 show typical laser signal profiles in each CCD from the 5 transfer line sensors (et0 - et4, respectively); from a "transfer line only" run. Fig. 7 - Fig. 11 show the same sensors' laser profiles from a run in which we connected all 13 sensors. Fig. 10 and Fig. 11 show corrupted data in et3 and et4. Fig. 16 through Fig. 19 show CCD profiles of 8 SLM line sensors from an event in run 379 from laser 302 (L302) and Fig. 20 through Fig. 27 show the same plots from laser 303 (L303). We note that this long chain problem is unique to June test at ISR only. We will not have this particular problem in the real CMS experiment environment, since we do not plan to have this type of long chain. In July/August and September alignment tests, we separated the 13 sensor read-out chain to two 8 and 5 sensor read-out chains to avoid the problem.

2 Analysis Steps

- **Fixing data format.**
  We found that the data coming from the DSP boards miss some lines/characters occasionally. This happens independent of what types of DAQ program we use. Because we read out each pixel in a measurement, the number of lines we read out to a raw data file is very large. The size of one event with 13 sensor read out is approximately 27,000 lines. On average we find a few random corrupted data lines in such an event. At the fundamental level, the problem must be fixed in the DSP software, improving the timing control of the data transfer. After the DSP internal fitting be implemented, there will be substantial reduction in data transfer to DAQ, and that would certainly help this problem in the future. However, randomly corrupted data is a serious problem in any case and must be fixed. For the time being to analyze ISR test data, we have fixed the data format basically by hand, which was a real pain.

- **Plotting and fitting**
  The FLAP (First Level Analysis Program) program is written to do this job. FLAP takes a raw data file as an input, plots CCD profiles from each sensor and

performs fitting to obtain the centroid of the laser beam signal for each event. The program is written in c++ runs on a unix/linux environment. ROOT[1] is used as a software analysis tool. FLAP makes a ROOT output file, which contains histograms and root ntuples for the ISR data analysis. (Eventually, FLAP will produce another output file which will be fed into the next level analysis program). The fitting procedure is the following:

  - First find the bin with the max. content and fit a gaussian around the max. bin.
  - Fit the background using a straight line for the entire range.
  - Fit the laser signal (gaussian) + background (straight line) function over the entire range using the results of above two fits as starting parameters and find the centroid of the laser signal.

- **Analyze fitted results over the runs**
  Taking the outputs of FLAP as inputs, analyze data for stability, abnormality, resolution, etc. for each sensor.

2.1 Fitting Procedure and Problems Associated with Tape Filters

Fig. 2 through Fig. 20 show the laser beam profiles together with fit results for typical events. Most of the profiles fit well with this method. However, some CCD peak distributions do not fit well. At the ISR test, we have used 3M tapes of various color as a filter material as a temporary filter solution. This method of filtering has multiple problems. Some of these problems are:
1) It does not filter the background light well enough so that the data were very sensitive to the background lighting conditions. At the ISR test, we were only able to take meaningful data with the ceiling lights off (or with cardboard boxes over the sensors) as a result.
2) The tape defuses the laser signal and makes a much wider distribution than the intrinsic laser signal shape. (We have tested with a laser guard filter, which indicates the tape filiter width is nearly twice as wide as the laser gurd filter we tested.) This makes it more difficult to keep an entire signal profile and dynamic range within the range of CCD pixels. The setup for the physical placement of the sensors was more difficult and fitting results are less reliable (See, for examples, Fig. 18 CCD1 and CCD3 profiles).
3) The non uniform way of applying tape (so that a CCD is not saturated by the background lights; by putting black tapes here and there, etc.) caused strange looking background profiles and causes the fitting to be very difficult (for example, see a profile of es10, CCD3 in Fig. 19).
4) The whole process of trying to make the right kind of colored tape combinations

for each sensor consumed much time which reduced data taking at the ISR lab (see Section 4).
5) Tape would likely start peeling with time and is not a long term solution for the experiment.

Since the shapes of the CCD laser beam profiles critically depend on how tapes were placed and by varying background conditions, the job of determining how to do the “fitting” became non-trivial. We have 84 CCD profiles to fit even in steady conditions; but here, we have over 100 runs in varying conditions. The total CCD profile count of 84 comes from 8 SLM bi-directional sensors with 4 CCD’s each with data taken from opposite end of line lasers 302 or 303 (see Fig. 1) lasers plus 5 transfer line sensors with 4 CCD each with laser 301. A significant amount of time was spent investigating the fitting process. Several different types of functions were tried to fit the odd shaped profiles better. With more time/effort/parameters, we could always find a better customized fit for a particular profile; however the fitting process then became very complex and unstable. The fitting process we use, as described in the previous section (gaussian + straight line), is a compromise solution between the goodness of fit and an automated stable procedure to deal with the vast amount of profiles to be fit. It is not appropriate to invest much more time to find a better fitting procedure for this temporary sub-standard filtering system. It is critical to have a proper filter developed in short time, and when that is in place, the fitting procedure should be re-evaluated. Only after that, the final fitting scheme should be implemented into the internal DSP software.

3 Short Term Stability

In general, the laser beam centroid position from the fit in each CCD seems to be quite stable on a short time scale. With the current DSP read out scheme, it takes ≈ 3 seconds to digitize all the sensors at once, and it takes additional ≈ 7 seconds to read out each sensor from a DSP card. Therefore, it takes ≈ 1.5 min to read out an event which contains all 13 sensors. The bottom 4 plots of Fig. 49 through Fig. 61 show distributions of laser beam centroid positions from the fit for 12 consecutive events from Run 401. This run was taken during the early morning (3 am on) of June 21 with all the ceiling lights off. The 13 figures correspond to the 13 sensors and each figure contains 4 plots from 4 CCDs in a sensor. Except for those “known to be bad” CCD’s (see Appendix B List of Bad CCDs), the figures show that the RMSs of the distributions of individual centroid are generally quite stable and the rms is less than 1 pixel width (14 μm). The top 4 plots of Fig. 49 through Fig. 61 show the differences in the centroids between “signal only” fit and “signal + background” fit. When a fit is bad or the background shape is strange, this difference is often very large.

We also have looked at short term stabilities in other runs and found that the distributions are stable in the short term like run 401. However, we did observe significant jumps in the CCD distribution centroids in a short time interval in the SLM line sensors when we were conducting "motion test" using L302. Cause of this behavior is found to be "laser jumping" which will be described later in this note. This caused analysis of "motion test" to be difficult and extremely confusing.

4 Medium and Long Term Stability

4.1 Quick summary of ISR test runs from June, July/Aug and Sept runs

We staged the June ISR test from June 14th till late evening of 21st. The main part of the hardware setup work had been already done in the previous weeks. Setting up cross hair lasers, sensor positions, and filter tape configurations were the main tasks before we were able to take analyzable data. The transfer line was setup first, then the SLM line. The analyzable transfer line data were taken between run 347 (June 18th, late afternoon) and run 456 (June 21st, late evening) which spans $\approx$ 80 hours in total. However, for et3 and et4, the last analyzable run is run 380 (June 20th, 7 pm) due to the 13 sensor long daisy chain problem as described in section 1.1. The SLM line setup was finished on the night of 19th June and analyzable runs are between run 379 (long overnight run started late 19th June) and run 456 (June 21st, late evening) which spans $\approx$ 50 hours. Hence, here, "medium term" corresponds to a 2 - 3 day time period for the June testing period.

In the earlier part of July/August test, significant amount of time was spent trying to make the 3 serial port read-out to work in order to split a single daisy chain of 13 sensor read-out to two lines (axial and SLM) read-out. The 3rd port is used to read-out analog sensors. The analyzable data from July/August run were taken between run 564 (started 14:55 Aug. 1st 2000) and run 481 (21:43 Aug. 3rd). Here, again, "medium term" corresponds to approx. 50 hours for the July/August testing period.

The September data were taken between run 485 (20:48 Sept. 17th) through run 514 (21:46 Sept. 24th), which corresponds to 7 day time interval.

4.2 Medium and Long Term Stability

Fig. 62 through Fig. 82 show the distributions of means of fitted laser beam centroids as a function of time (in sec) for the July/August runs. Fig. 83 through Fig. 103 show the same distributions for the September runs. Basic behaviours of the June distributions are very similar to the other periods.

These figures show that during these 'medium' time period, the measured transfer line positions and SLM line sensor positions from L303 were relatively stable (typical rms of less than one pixel width), while many of the SLM sensor centroids from L302 had jumped by a few hundreds pixel width which is an order of 1mm in a few days. (see for example, Fig. 74). This is discussed more in the next section.

Fig. 104 through Fig. 124 attempt to show the longer term affect showing the same distributions for June, July/August, and September runs. Due to various distracting factors (data format corruption still there somewhat, laser jumping which is described below, some sensors are moved and exchanged, laser L302 is replaces, etc., etc....), it is hard to observe the exact nature of the long term stability from most of the plots. However, L303 results of es4 - es10 indicate somewhat promising stabilities. Of course, in theory, the laser position is arbitrary and reconstruction results supposed to be independent of the laser movement. However, in practice, that is not the case (discuss later).

5 Study of SLM line 'jumps' from L302

Fig. 125 shows magnitude of centroid shift (in pixel counts) from each sensor (from the bottom horizontal CCDs of the SLM line) as a function of the distance from L302 to the corresponding sensor. This jump corresponds the first major jump in July/August run. A straight line fits very well. Direction of the shift in each sensor are consistent. This plot clearly indicates these large jumps in the centroid distributions are due to the laser motion, rather than random motion of individual sensors.

6 Summary

Main items we have learned from ISR test are followings:

- Daisy chain of 13 sensors does not work (not a problem).
- Better Filter solution must be found.
- DSP readout error must be fixed.
- Better quality laser which does not shift mode should be obtained.
- Short and medium term stability seems to be good (within 20 μm in rms of centroid distribution) as long as we use a stable laser.

7 appendix A: List of Bad CCDs

from run 347
et2: ccd2 (hopeless)
et3: ccd4 (ok but not a good fit)
et4: ccd1(hopeless) and ccd2 (hopeless)

from run 379
(L302)
es1: ccd2 (flaky looking)
es2: ccd4 (hopeless)
es10: ccd1 (not so hot), ccd3 (bad), ccd4 (hopeless)
(L303)
es1: ccd3(hopeless) and ccd4(hopeless)
es2: ccd4(hopeless)
es4: ccd4(hopeless)
es9: ccd3 (not a good shape, fitting is ok)
es10: ccd3 (not a good fit)

from run 514 et2: ccd2 (hopeless)
et3: ccd1 ((hopeless), ccd4 (ok but not a good fit)
et4: ccd1(hopeless) and ccd2 (hopeless)
(L302)
es1: ccd3 (flaky and very bad fit)
es5: ccd2 (wimpy, but there)
es10: ccd4 (hopeless)
(L303)
es1: ccd3(hopeless) and ccd4(hopeless)
es2: ccd4(hopeless)
es4: ccd4(hopeless)
es7: ccd3(should have been ok, but not good fit, format error)
es9: ccd3 (not a good shape, fitting is ok)
es10: ccd2,3,4 (not a good fit, shifts in peak positions)

8 Acknowledgement

We especially thank our collaborators of Northeastern University (J. Moromisato, Eb vonGoeler, R. Terry) who built the mechanical parts, calibrated and filtered the DCOPS sensors, and worked with us in the development, setup, and some execution of the tests. We also thank S. Hanson, E. Cowden, J. Lofgrin, R. Martin (Fermilab PPD Electronics group) and V. Sknar, E. Orischin (Petersburg Nuclear Physics Institute) for their development, construction, testing,DSP programming, etc. of the DCOPS sensor and electronics for the ISR I4 tests.

We thank the CERN Laboratory EP/CMS (A. Ball, D. Arevalo, R. Riberio) for establishing the ISR I4 test area, utilities, supports; for survey services and Photogrammetry (C.Lasseur, C. Humbertclaude, D. Mergelkuhl, R. Goudard, J.Noel. Joux and crew- CERN Geodesy). We also thank the Fermilab Geodesy (J. Greenwood and crew) for Photogrammetry measurements of our sensor assemblies; and the Fermilab Technical Division for CMM measurements of brackets and the transfer plate.

References

[1] http://root.cern.ch.

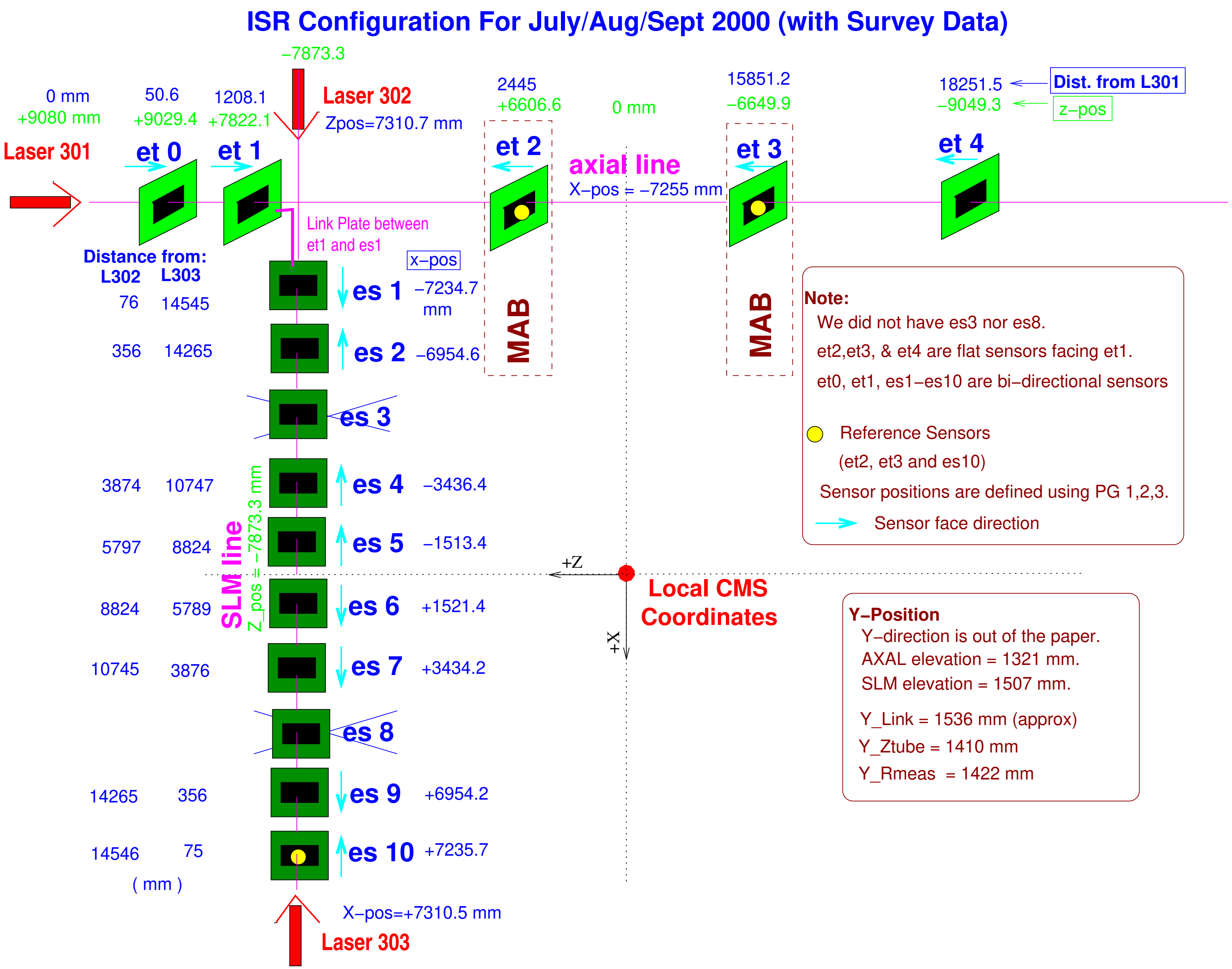

Figure 1: This figure shows the configuration for the June 2000 EMU alignment test at ISR.

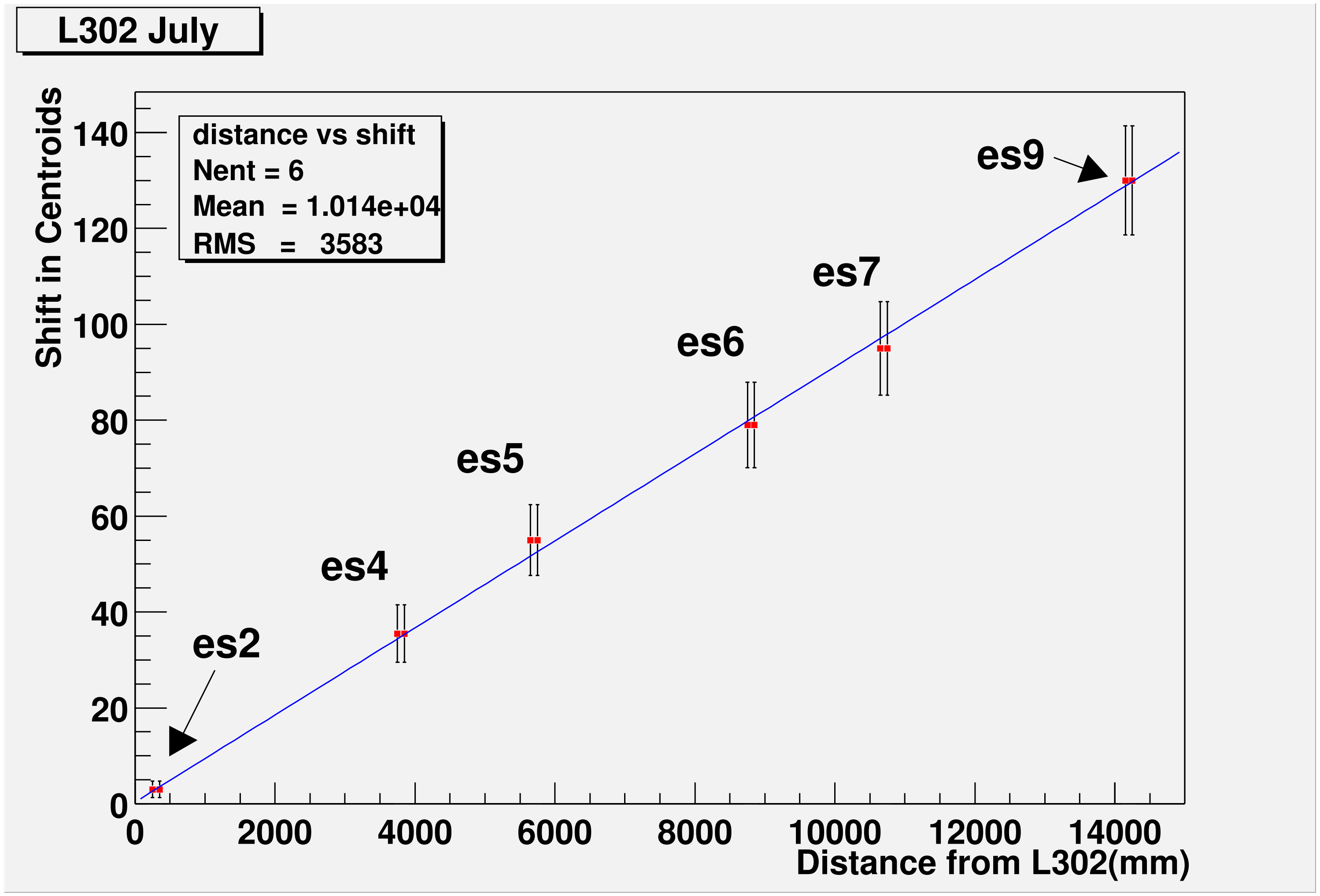

Figure 125: shift vs distance: The plots show the magnitude of centroid shift (in pixel counts) from each sensor (from the bottom horizontal CCDs of the SLM line) as a function of the distance from L302 to the corresponding sensor.