ARAMyS Source Plate Calibration Study

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Previous work with manual source plate calibration at Brandeis and using ARAMyS to examine source plate calibrations on a test beam at CERN had indicated the possibility of a systematic error in CMM measurements of source plates leading to an observed increase in source separation (at least on an image sensor). The original hypothesis was this error was due to some optical effect which possibly caused the position of the point sources on the source plates to be inset into their ferrules, rather than at the surface, as originally thought.

In order to test this hypothesis, we developed a script which would edit the source plate calibration database and shift the calibrations of source plates so that the effective source position moved along the axis of the ferrules (z-axis). We note that this shift is positive on one side of the plate (positive z side) and negative on the other (negative z side). This has the effect of stretching (or compacting) the source plate along the z-axis, rather than simply translating the source plate in the z-direction (which would be the case if both sides were shifted in the same direction). Using this script, we incrementally displaced the source calibrations of source plates in some system (either on the CERN source plate test beam or on nSW side A) and used these shifted calibration to produce a best fit of the system in ARAMyS, and compare how these fits differ as the source plate calibration changed.

The first tests performed in this way were with readouts from nSW side A with small sector bars and sector A12 installed (work not shown here). The subsequent tests were performed on the source plate test beam at CERN, which had two mirrored BCAMs on either side of a source plate. These tests were performed using 25 source plates and produced results consistent with the test with nSW-A.

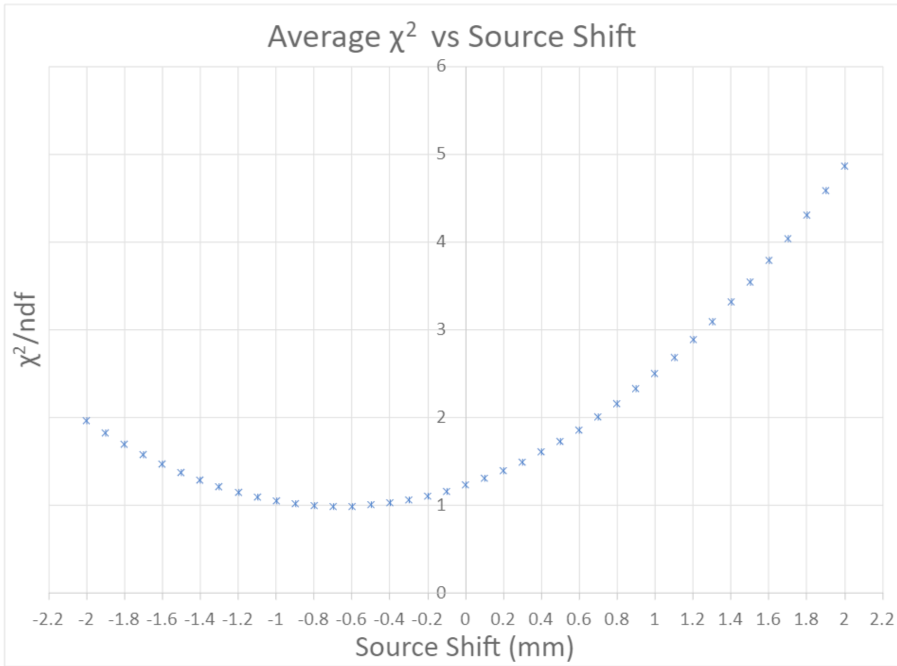


Figure 1. Average of χ^2 per number of degree of freedom (ndf) over 25 source plates for different values of relative source shift. Sources on the SP test beam were shifted in the z-axis (relative to their orientation as described in the text above).

The average over source position shift giving the optimal χ^2 for each source plate was -0.66 mm (recessed into the ferrules) with a standard deviation of 0.12 mm. This would appear to support the hypothesis of an optical effect shifting the effective source positions.

However, follow up work applying the same procedure on nSW-A with small sector bars and sectors A12 and A14 installed yielded very different results. Subsequent work attempting to recreate the original trend found both on the test beam and on nSW-A with A12 found that the fit quality as a function of source shift likely changed due to updated surveys of the small sector bars and differences in alignment system readouts. We were not able to reproduce the results of the original test with nSW-A, however, we found similar trends for the fit quality versus source shift by weighting in the fit source plates on only A12, only A14, and on both A12 and A14.

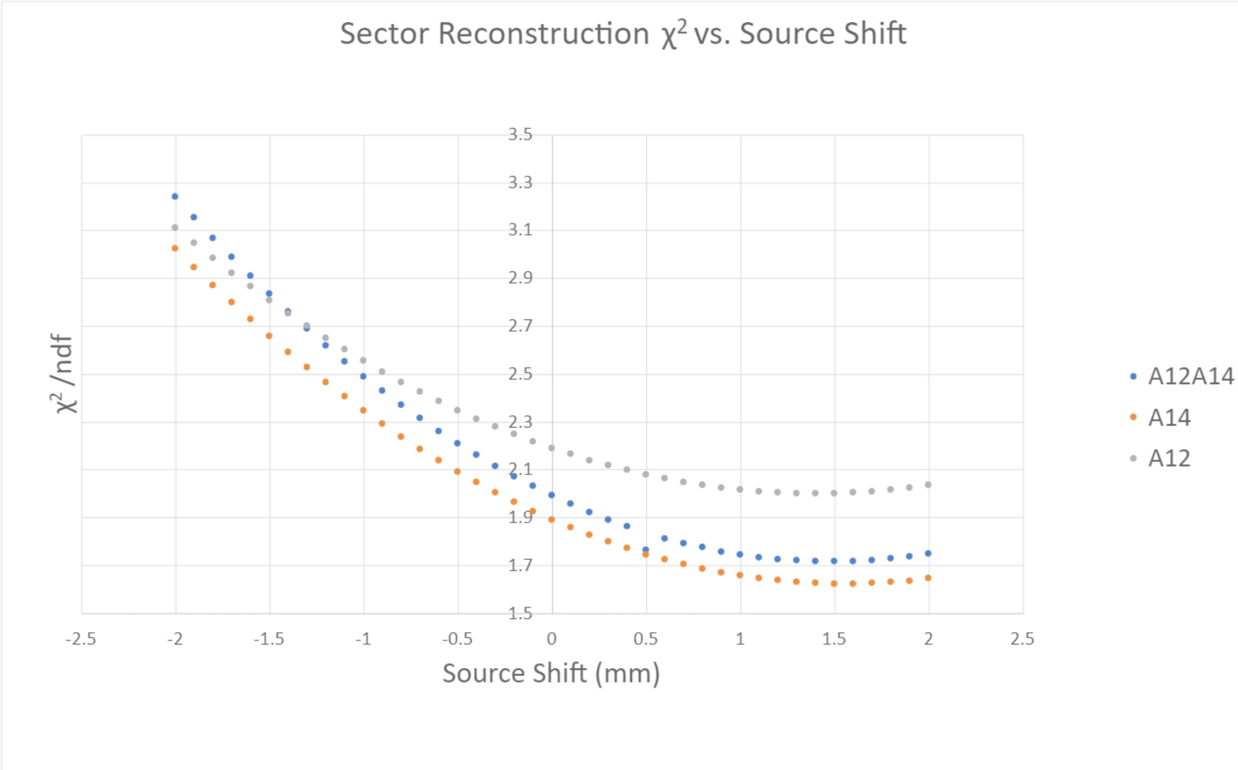
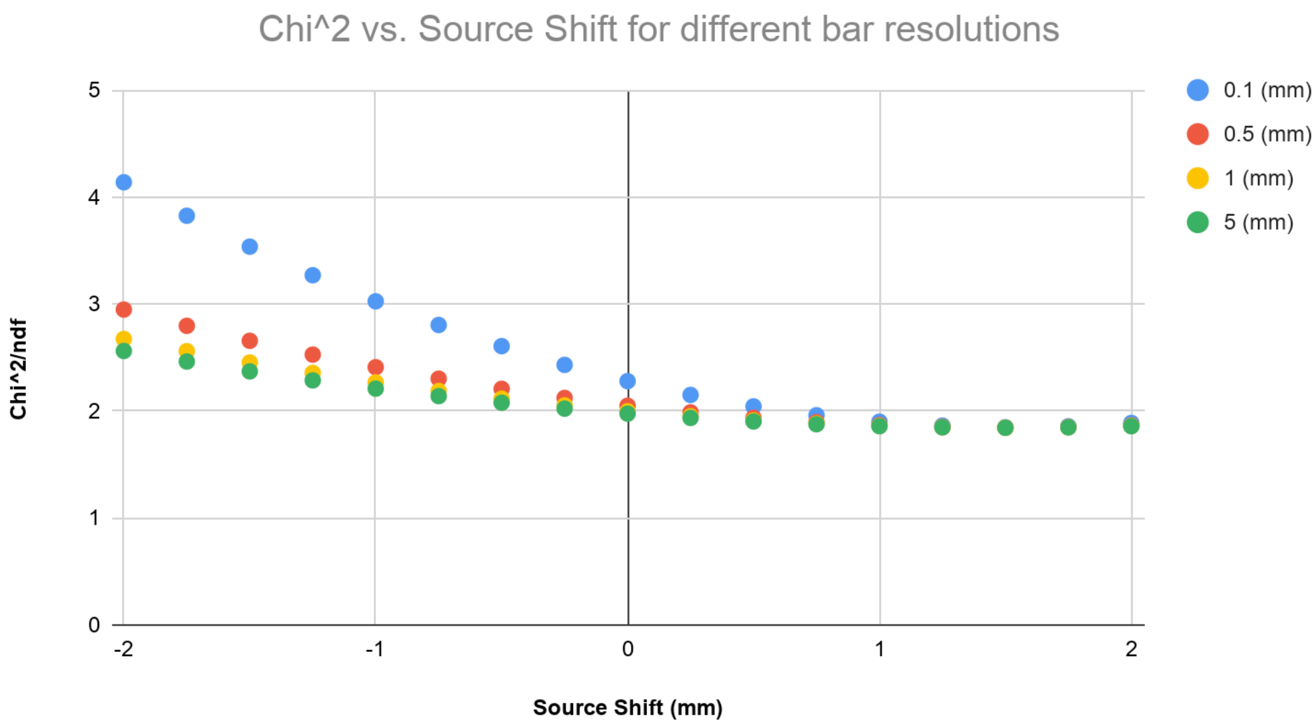


Figure 2. χ^2 per number of degree of freedom (ndf) versus relative shift of sources in z-direction relative to their orientation. The three different datasets weigh only certain source plates in the fit; those only on A12, those only on A14, and lastly all source plates (those on both installed sectors).

This data was not in support of the hypothesis that an optical effect was responsible for the observed increase in source separation, as the optimal fit in each case is at a positive shift (meaning the effective point source lies outside of the ferrule) and would not lead to an increased observed separation.

Following this, we checked if changing the resolution of placing the small sector alignment bars viewing the installed sectors in the reconstruction of nSW-A could change this trend (as this resolution was one significant change between changing the bar surveys, and thus between different results). We found that increasing the bar resolution for these bars changed the fit quality (especially at negative shifts), but not to the overall trend of the dataset. The optimal shift to the source positions was still positive and around the same magnitude as before.

Figure 3. χ^2 per number of degree of freedom (ndf) versus relative shift of sources in z-direction relative to their orientation. Each data set represents fits using different values for the resolution of the SURVEY instrument in ARAMyS for small sector bars 11, 13, and 15.



At this point, our attention shifted to looking at how these systematic errors in the source plate measurements would affect the ARAMyS reconstruction, rather than what the systematic error may be (at this point in time, further work with manual source plate calibration showed agreement with CMM measurements). To do this, we compared ARAMyS reconstructions, with all degrees of freedom fixed (not allowed to move or deform), with the small sector bars released (with movement and deformation of the small sector bars allowed), and with everything released (both bars and sectors allowed to move and deform) with the exception of QS1s on sectors A14 and A12. These reconstructions were done for different shifts of source positions in z, and found that all three datasets very closely followed one another. This would indicate that when everything is allowed to deform and move in the reconstruction, the best fit is highly similar to the case where nothing is allowed to move in response to the changing source positions. We can then conclude that the alignment system is not sensitive to these systematic errors in source plate calibration.

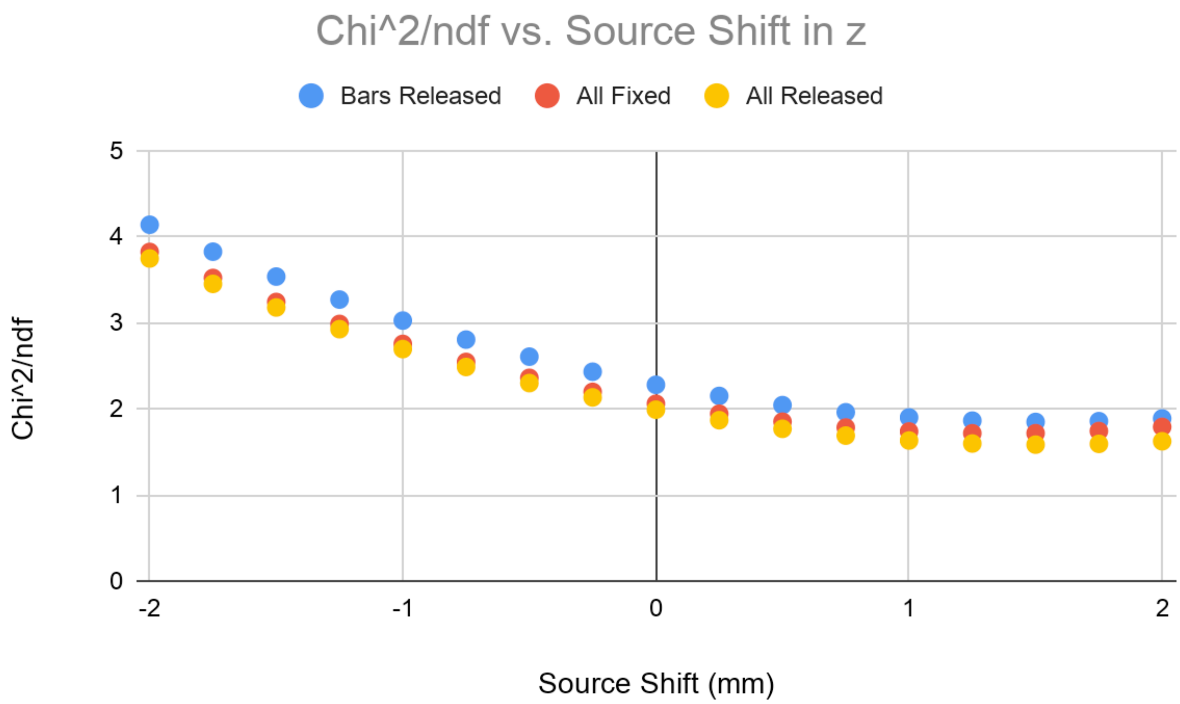


Figure 4. χ^2 per number of degree of freedom (ndf) versus relative shift of sources in z-direction relative to their orientation. Each data set represents ARAMyS reconstructions in which a) everything is fixed, only the source positions change relative to their nominals, b) source positions change and small bar positions and deformations are allowed to change in response, and c) both bars and chambers (with the exception of QS1s) are allowed to move and deform in response to changing source positions.

Similarly, we repeated this experiment in the case of changes in source position transverse to the axis of the ferrule along the alignment plane. So, instead of the source place (effectively) elongating along the axis of the ferrule, a positive shift corresponds to stretching the source plate transverse to the axis of the ferrule along the surface of the chamber it's installed on. The results very closely mirrored those with the shift along the ferrules, again indicating an insensitivity to this kind of symmetric error in source plate measurements.

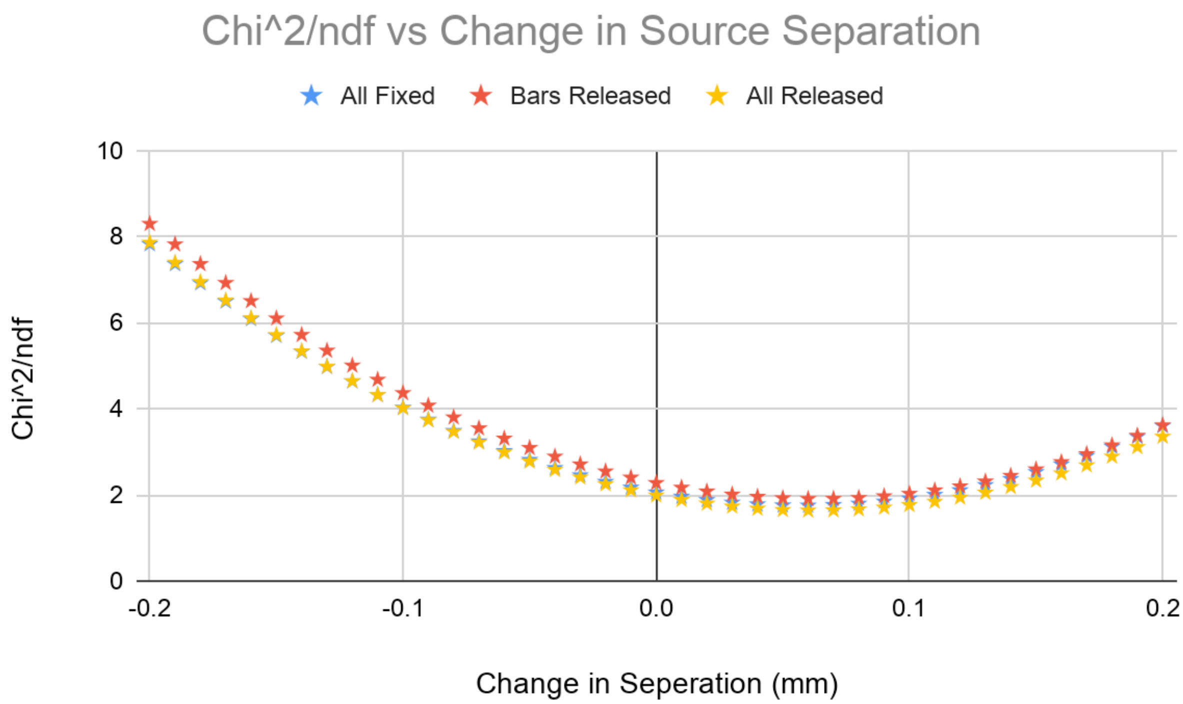


Figure 5. χ^2 per number of degree of freedom (ndf) versus change in source separation transverse to the axis of the ferrules. Each data set represents ARAMyS reconstructions in which a) everything is fixed, only the source positions change relative to their nominals, b) source positions change and small bar positions and deformations are allowed to change in response, and c) both bars and chambers (with the exception of QS1s) are allowed to move and deform in response to changing source positions.