CLAS-NOTE 2002–010

Drift Chamber Alignment

Straight track analysis of data taken in Fall 2001

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Abstract

Straight track electron data runs 30910 and 31486 were taken in Nov '01 and Jan '02. The data of run 30910 were used in an alignment study. Existing codes and procedures were used in the analysis. Fits, to the region 3 chambers only, were found to give alignment to within $\sim 60\mu m$. Subsequent fits, to the region 2 chambers only, were found to worsen the alignment. (In total 4 fits were made and the results of fit 2 have been used as the final offsets.) It is noted that only the chambers in region 3 were moved since the last alignment study. The new offsets are valid for the run groups g8a, g6c, e1–6a, e6.

Contents

1 Introduction

This note describes the analysis of straight data taken in Nov '01 for the purpose of aligning the CLAS drift chambers. Data were taken with no torus current, providing straight tracks through the 3 drift chamber regions. The data are in run 30910 which was taken during e1–6a run (Nov '01), These data were taken with an electron beam, an empty target cell [1], a mini–torus current of 2000 A (the mini–torus current was not turned off completely in order to shield the region 1 chambers) and a torus current of 0 A. Approx. 1,000,000 events were accumulated. A DC calibration has been performed on the run. This was not done in previous alignment studies and represents an improvement in the technique as the straight track data are very much more sensitive to their DC calibration than normal data.

In addition, data of run 31486 were also taken with ∼350,000 events. These data were taken at the end of the e1-6a run period (30 Jan) when the target cell had been pumped empty. This ensured that only events from the target cell walls contributed. A completely empty target cell was desired in order to select elastic events originating from the target cell's walls. This data run, however, was not used in the present study, only the data of run 30910 were used here.

The present analysis used the codes and procedure developed by Feuerbach [1]. These were already fully documented and operational at the time of this study. The general procedure makes a series of assumptions. Firstly, it is assumed that the chambers are rigid bodies, in other words each one is considered to move around as a whole unit. In addition, the alignment which is made is an intra–sector alignment only, i.e. chambers of one sector at a time are aligned with respect to one another. Finally, in the current study region 3 has been aligned assuming that the other 2 regions were already well aligned. This is considered a reasonable assumption because, since the time of the last alignment study, only the region 3 chambers have been moved.

[1] The target cell temperature was increased to reduce the pressure, however it was not pumped empty and therefore residual gas was still present, and contributed to scattering events.

2 Alignment technique

The geometry of each of the chambers is characterized by a set of 6 offsets;

- 3 translational (dx,dy,dz),
- 3 rotational (θx, θy, θz).

A set of these offsets is held for each of the 18 chambers. The values themselves are stored in the CalDB or in a Map file, under the system 'DC_GEOM' and subsystem 'dc'. In DC_GEOM the offsets are stored in the Hall Sector Coordinate system (HSCS) [2]. In this system;

- x is along the ideal mid–plane of a drift chamber sector, pointing radially outwards,
- z is horizontal along the beam axis and in the beam direction,
- and y is constructed such as to make a right–handed set with x and z.

The 3 translational offsets, (dx,dy,dz), give the displacements of each chamber in the directions (x,y,z) respectively. The 3 rotational offsets, (θx, θy, θz), are simply rotations about the 3 Cartesian axes (x,y,z) respectively.

The values (stored in units of cm and rad) are the offsets relative to the ideal positioning of the chambers, as if they were positioned exactly as in the engineers' drawings. Therefore they give the displacement or rotation needed to move the object in question from its ideal location to its measured location in the HSCS [2]. Non–zero offsets account, in the off–line analysis of data, for the non–perfect positioning of the chambers. This is necessary since the chambers cannot feasibly be positioned to within the few hundred μm accuracy required for calibrations.

In the procedure to be described, "alignment" of the chambers is taken to mean determining how well the chambers are presently aligned, i.e. the finding of a set of offsets which best describes the current position of the chambers in the hall. The subsequent DC calibrations will take into account the offsets found in this analysis.

The alignment procedure was performed in order to account for distortions in measured particle momenta. These distortions have two causes; firstly, mis–alignment of the chambers themselves and secondly, the lack of knowledge of the torus magnetic field strength at any given position in space. An independent determination of the alignment therefore allows to separate these two effects. To do this consistently the procedure for alignment should be independent of any knowledge of particle momentum.

The optimal offsets are found through a minimization technique. By allowing the offsets (of the chamber being aligned) to vary, the following quantity is minimized

$$\chi^2 = \Sigma_{tracks}\Sigma_{hits}\frac{(|D_{track,hit}| - |D_{hit}|)^2}{(\sigma^2_{track,hit} + \sigma^2_{hit})}$$

where

- $D_{track,hit}$ = DOCA (Distance Of Closest Approach) to the wire of the fitted track (also known as FITDOCA),
- D_{hit} = calculated DOCA from x vs t function (also known as CALCDOCA),
- $\sigma_{track,hit}$ = uncertainty in track position,
- σ_{hit} = time–based resolution of the hit.

The quality of a new alignment is determined by looking at the "spatial residual". The spatial residual is defined as

$$SRESI = D_{track,hit} - D_{hit}$$

where the $D_{track,hit}$ and D_{hit} are as defined before.

An independent method of determining the alignment may be made using optical techniques. These optical "surveys" use points on objects known to be fixed, like pillars in the hall, as references against which to measure shifts in the position of chambers. The position of cross–hairs, which have been placed on the outside of the region 3 chambers of each sector, are measured relative to the known fixed points. This procedure provides a set of measurements for each of the marks (the results are quoted in a Cartesian reference frame; the Hall Coordinate system (HCS) [2]) relative to its position as of the previous survey. In the HCS reference frame; x is horizontal towards beam left; y is vertical, opposite to gravity; and z is horizontal along the beam axis and in the beam direction. In order to be compared with the DC_GEOM offsets, these numbers must be transformed into the HSCS reference frame. The surveyors quoted an accuracy of ~500 μm on their offsets for this particular survey (however higher accuracy is possible) [3].

3 Analysis

3.1 Main codes

The main codes to be used are `user_align` and `aligndc` [1], which may be found in the CVS repository under;

`calib/dc_cal/aligndc` and `calib/dc_cal/user_align`.

It is also important to make sure that you are using the most up–to–date versions of the following files (under packages in CVS);

- `dc/dc_tcl_init.F`
- `dc/dc_set_def.F`
- `include/dc_tcl.h`
- `include/dc_tcl.inc`
- `trk/trk_dtime.F`
- `trk/trk_run_control.c`

3.2 Procedure followed in the present analysis

In the present study the following steps were taken to analyze the data of run 30910;

1. Run `user_align`. This is an altered version the program `user_ana` and performs the tracking of the straight tracks through the drift chambers and produces an Ntuple of useful quantities. The Ntuple resides in the directory ALIGN of the output `.rzn` file. It also produces a BOS file which will be used as input to the next stage of analysis. To run this program, use the command

   ```
   user_align -t <tcl file>.tcl
   ```

   as would be done with `user_ana`. See Appendix A for a sample `.tcl` file.

   Additionally, plots are saved automatically in the hbook file of SRESI and SRESI vs layer no.. Running this command once, before starting the fitting procedure, and viewing these plots, shows how well the chambers are aligned relative to the existing offsets. This shows straight away which sectors require attention in the analysis.

2. Calibrate the run using the procedure outlined previously. Run `trk_mon` on the BOS file output of `user_align`, using the command

```
trk_mon -N -Cchisq.lt.3.0 -A1l-28.0 -A1u-20.0 -A2l-19.0 \
-A2u-15.0 -A3l-15.0 -A3u-10.0 -ct0 -cm2000 \
-o<outputfile>  <bosfile>
```

   note, no PROTON cut is used. Then calibrate the run with DC3 as for a regular data run.

3. Run `user_align` with a multiplier of 50 for the region in need of alignment (only one region at a time should be aligned). This means that, for the denoted region, $\sigma_{hit} = \sigma_{hit}/50$. It is advisable to run ~80,000 events since it was observed that too many events caused a crash when running with this multiplier value on the JLab farm, due to the Ntuple becoming too large. If this occurs try running with a smaller no. of events.

4. Run `aligndc` to perform the fitting on the straight tracks, (which are read in from the BOS output of `user_align`, created in step 3). The command line used should look something like

```
aligndc -o<output offset file> -i<input offset file> \
-s<no. of the sector being aligned> \
-n<no. of events> \
-d123 -l3 -rf3 -w350. <input BOS data file>
```

   Below is a description of the command line options. See [1] for more details.

   - `-o` the name of a (new) text file to which to write the new offsets,
   - `-i` text file holding the existing offsets,
   - `-s` the no. of the sector being aligned,
   - `-n` the no. of events to be processed,
   - `-d` the dimensions to be fitted, where; 1=dz, 2=dx, 3=θ_y, 4=θ_x, 5=dy and 6=θ_z); i.e. in the example 123=(z, x, θ_y),
   - `-l` the type of superlayer to fit, where 1=axial, 2=stereo or 3=both. In this analysis, option 3 was chosen to fit both the axial and stereo superlayers.
   - `-rf` the region to be fitted, (1,2 or 3); 3 in the example above,
   - `-w` the σ multiplier used in `user_align` (which must match the value used in step 3 above), with the region it was applied to.

In the above example a sigma of 50 was applied to region 3, the other 2 regions had sigma=1.

- `-M` the maximum number of permitted holes in a given SL, i.e. to say that SL 1 may be allowed up to 4 layers without a hit, use `-M14`. (This is not shown in the example above.)
- final argument; the BOS file which holds the tracking banks.

Practical notes;

(a) For sector 6 also use the flag `-M14` since S6SL1 has a large dead region at present.

(b) At the present time of writing, for use with CalDB, it is necessary to use an input offset file with the option `-i`. Omitting this option and reading the input offsets directly from CalDB, as stated in [1], causes an error.

(c) The following is a small note to make entering the constants into the CalDB easier with the scripts provided. It is desirable, when aligning more than one sector that the final offset file should hold the new offsets for all sectors. However only one sector may be aligned at a time with the `-s` flag. Therefore, for each sector aligned, use the newly created output offset file as the input file when aligning the next sector. This way the final file holds all offsets, and may be easily written to the CalDB in one step using the script described in section 3.4.

5. Using the alignment offsets found in step 4, run `user_align` again with the sigma values set to 1. Then view the SRESI and SRESI vs layer no. plots again to see if the alignment has improved.

6. Make diagnostic plots of SRESI vs layer no.; SRESI with double Gaussian fits; means vs SL; tables of offsets and tables of rms's by running the command shown in section 3.4.

7. If the fitting has found large shifts for the chamber positions, then verify that the calibration made in step 2 is still valid. If not, re–do the calibration before continuing.

8. Repeat steps 3–5 for each region and set of offsets to be fitted.

   The example command line in step 4 showed fitting for the offsets (dz, dx, θy). It is not feasible to let all 6 parameters in the fit vary at once, as they are too many. In order to limit the number of free parameters in the fit during this analysis, only the offsets (dz, dx, θy) were let vary in the first iteration. As described above, this was done with the flag `-d123`. (These offsets were chosen as they are the ones to which the axial wires are most sensitive.) After convergence was found with these parameters they were held fixed and steps 3–5 were repeated, letting the offsets (dy, θx) vary, using the flag `-d45`.

3.3 Fits made in the present analysis

In the present analysis 4 sets of fits were made. These are summarized here;

- fit 1 – fit to region 3 varying only the dimensions (dx,dz,θ_y),
- fit 2 – fit to region 3 varying only the dimensions (dy,θ_x), the (dx,dz,θ_y) were fixed to the values found in fit 1,
- fit 3 – fit to region 2 varying only the dimensions (dx,dz,θ_y),
- fit 4 – fit to region 2 varying only the dimensions (dy,θ_x), the (dx,dz,θ_y) were fixed to the values found in fit 3.

3.4 Useful codes

In addition to the main programs mentioned in section 3.1, there are a few codes in the CVS repository which are useful for viewing offset values, dealing with the CalDB (reading and writing operations) and producing diagnostic plots. These are;

- `mapdiff`; takes 2 text files of offsets in a particular format. A new set of offsets is produced (and written to standard output) of the difference $<file1> - <file2>$.
- `map2latex`; takes a text file of offsets in the same format used by `mapdiff` and writes a latex formatted table to the standard output.
- `caldb_print_dcgeom.pl`; prints a set of offsets to standard output in the format used by `mapdiff`. The options are;

```
caldb_print_dcgeom.pl r=<run no.> it=<run index table> \
t=<time of validity of the constants> \
help=<non-zero for help message>
```

- `caldb_write_dcgeom.pl`; reads the offsets from a formatted file, the kind produced by `mapdiff`, and writes them to the database. The options are;

Table 1: *History of chamber movements since last straight track study.*

Date	Chamber	Run periods affected by this study
9/01/98	reg3 sec5	–
6/11/99	reg3 sec5	–
1/18/00	reg3 sec2	–
4/27/01	reg3 sec4	–
5/09/01	reg3 sec3	g8a, g6c
9/26/01	reg3 sec2	e1–6, e6

```
caldb_write_dcgeom.pl \
c=<comment> f=<file with constants> \
[srmin=<source run min>] [srmax=<source run max>] \
[it=<run index table>] \
[hostname=<hostname of db server>] [help=<non-zero>]
```

- Kumacs for producing monitoring plots. Open the hbook file produced by running `user_align` and cd into the ALIGN directory. Then execute the macro `dcalign_mon.kumac <basename for output files>` This will produce the following files
  - `<basename>.tex` – latex table of rms's.
  - `<basename>.eps` – plots of rms vs SL.
  - `postscript/<basename>.*.eps` – postscript files of SRESI, SRESI vs layer no..

4 History of chamber movements

Until this study, all cooking was made using offsets from the Oct '98 alignment analysis [1]. These offsets were stored under run number 10. For a summary of the chamber movements since September '98 see table 1. Offsets from the current study are relevant for the g8a, g6c, e1–6a and e6 run groups. (With the exception of the offsets found for sector 2. This sector was moved in Sept '01 and therefore its offsets are not valid for g8a and g6c.)

5 Results

Diagnostic plots were made using the offsets which existed before any fitting was made (Run 10) and are shown in figures 1–5. They show that the spatial residual is off–centered for many superlayers (this is especially noticeable when a breakdown is made into angular bins of θ) and it is worst in sector 4.

Note that these off–centered distributions also appear in regions 1 and 2, while it is know that region 3 was the only one to have been moved. This does NOT necessarily imply that the other regions are also mis–aligned. It is interpreted as an artifact of the tracking; when the straight tracks are fitted the tracks get biased by the chamber which is mis–aligned (in this case region 3) and this causes all the chambers in a sector to look "off–centered". This interpretation was borne out by the fact that gross mis–alignments in all superlayers (see sector 4) have been fixed by changing the offsets for the region 3 chambers only.

To show how the alignment was before the present study, figure 6 gives the mean of the spatial residual distribution vs SL no. for each of the 6 sectors. The 4 panels show the means calculated in 3 different ranges of θ, the polar angle, as well as for the whole θ range. These plots show that the chamber alignment was worse than $100\mu m$ in all θ ranges before the present study.

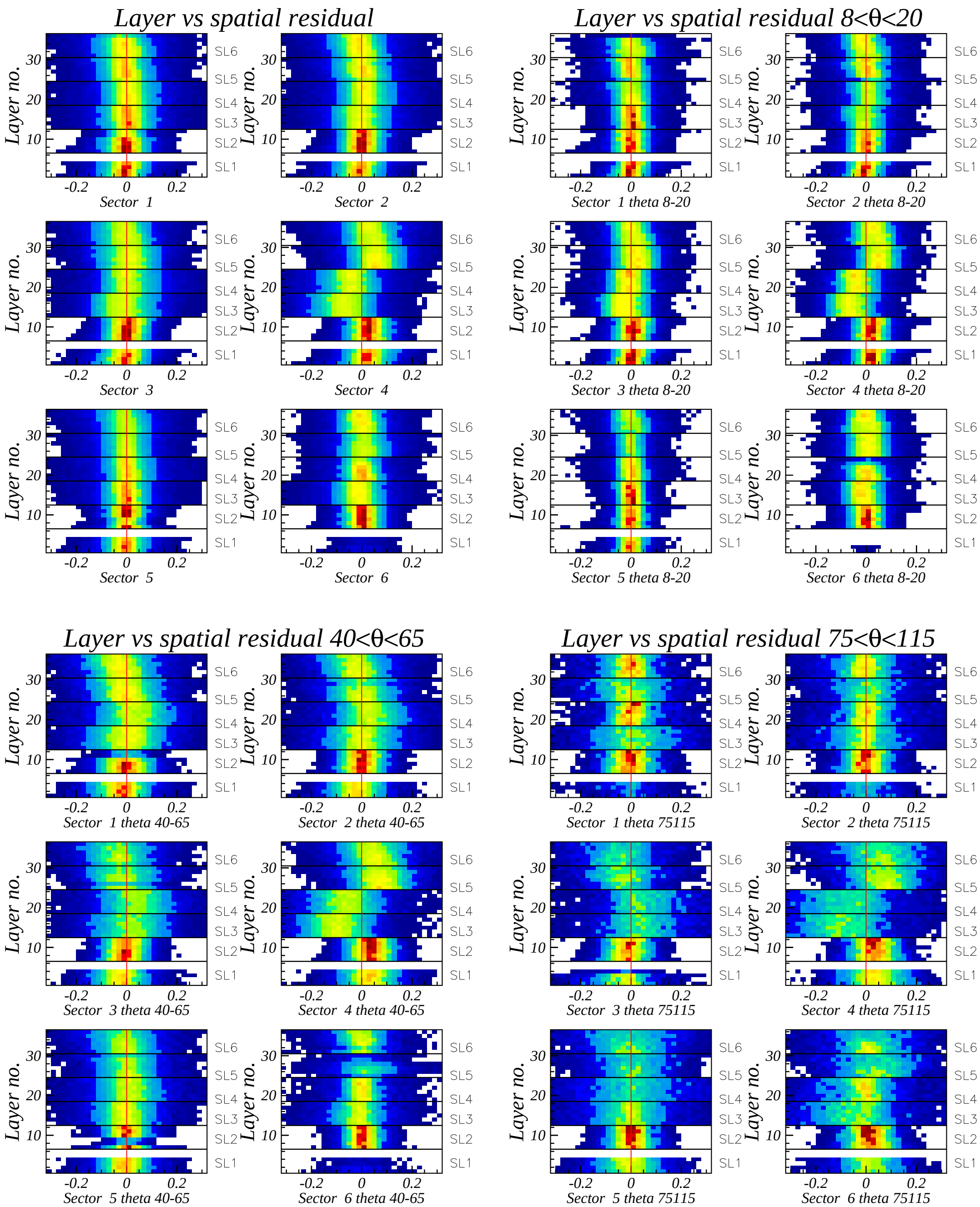

Figure 1: *Spatial residual distributions v's layer no., using the Oct '98 offsets.*

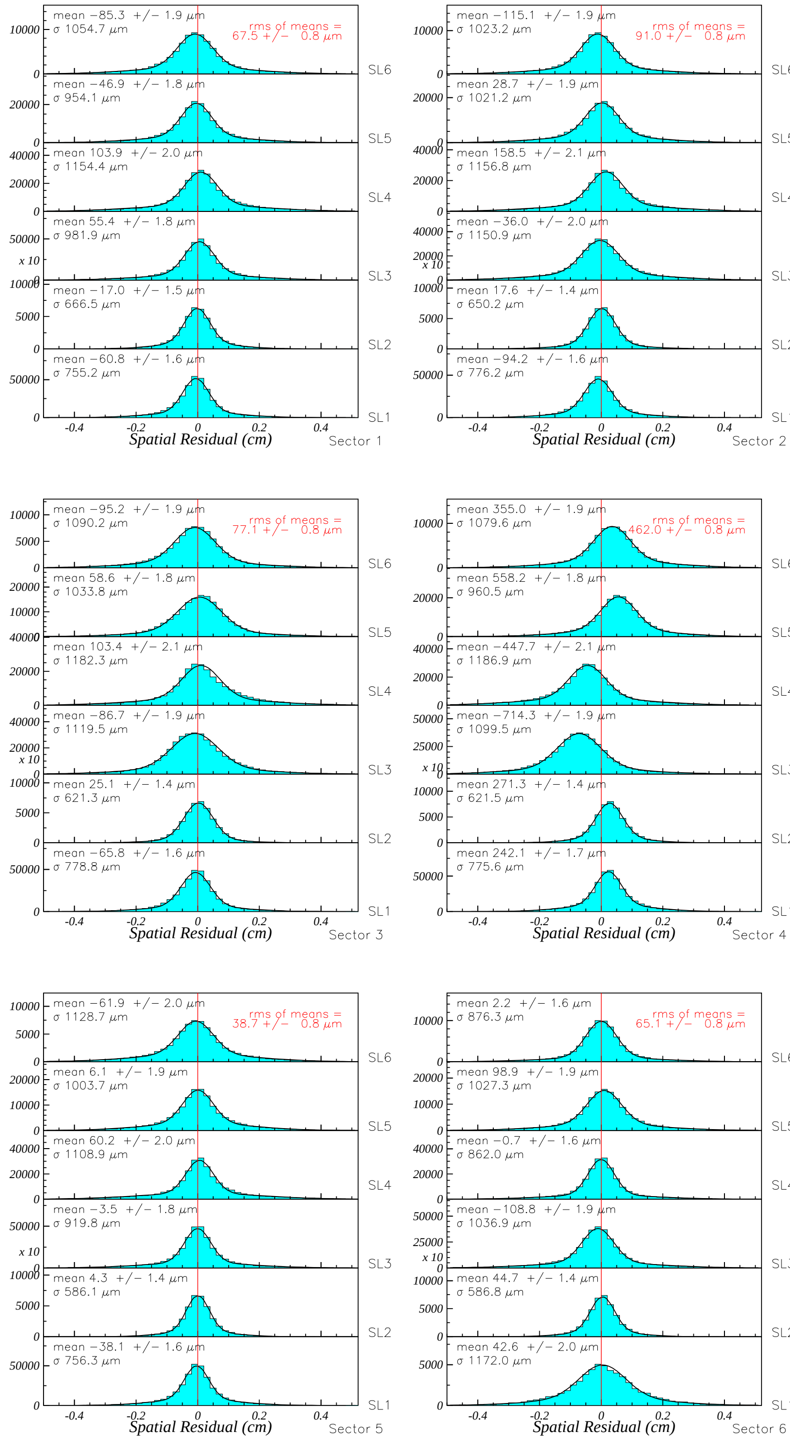

Figure 2: *Spatial residual distributions, using the Oct '98 offsets, for the entire θ range.*

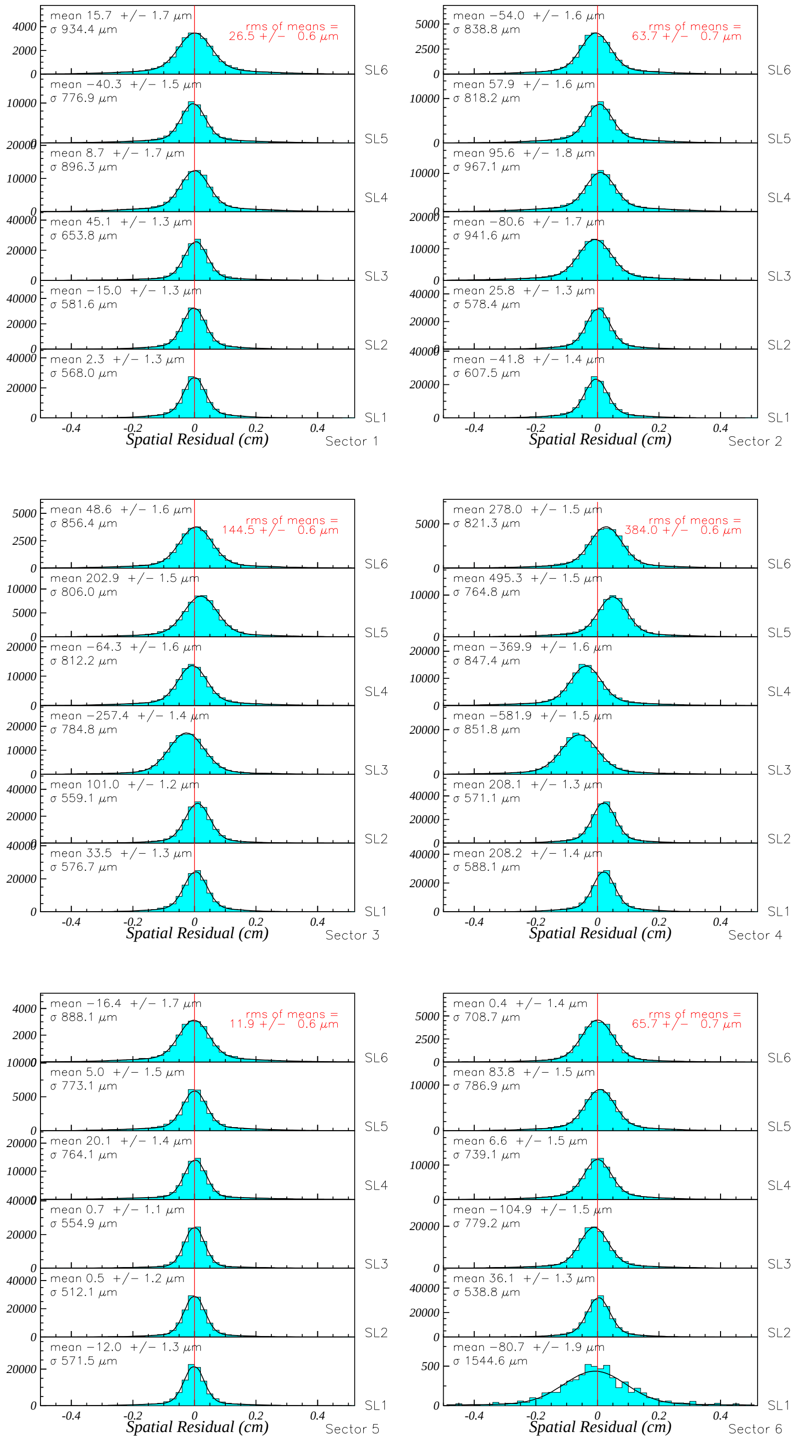

Figure 3: *Spatial residual distributions, using the Oct '98 offsets, for the θ range 8< θ <20.*

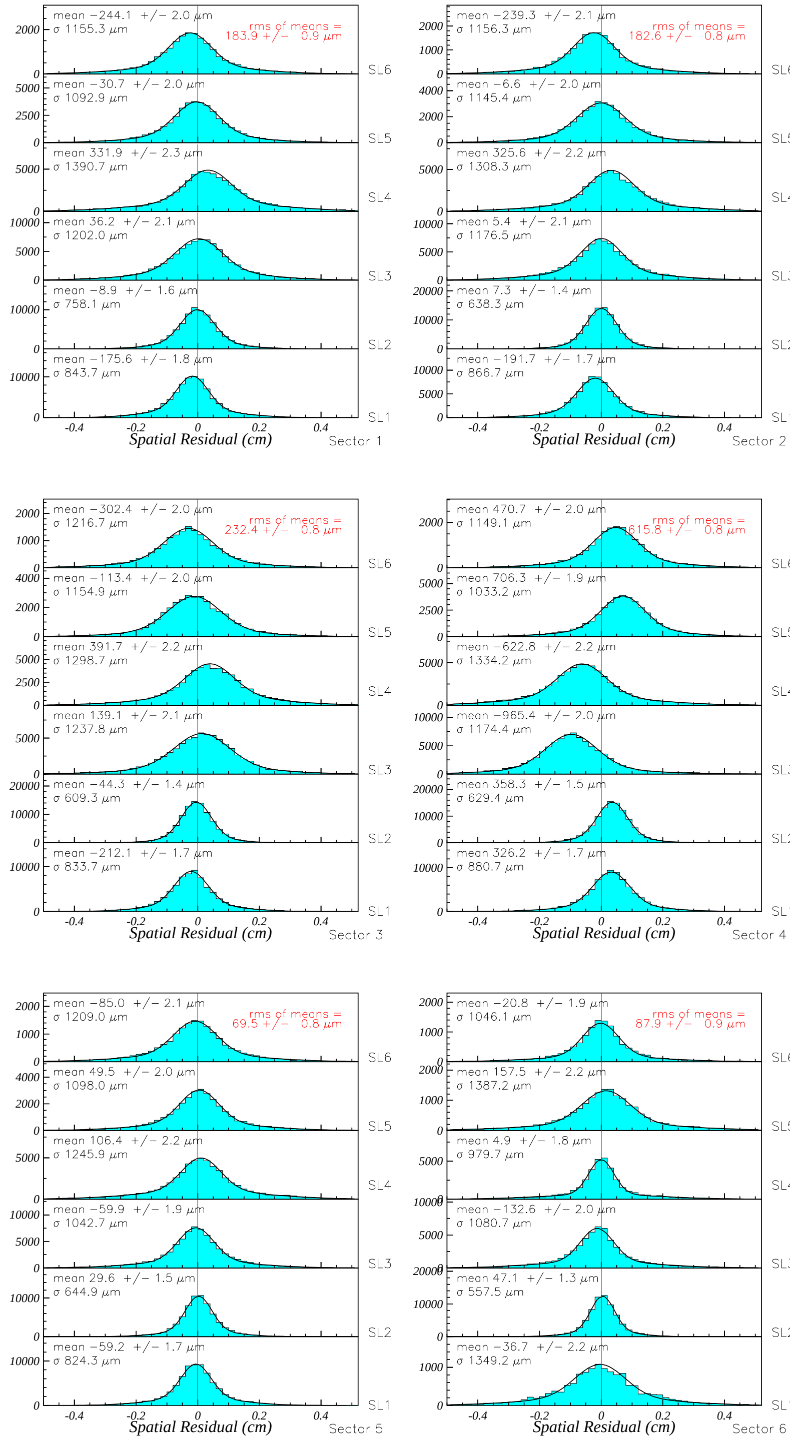

Figure 4: *Spatial residual distributions, using the Oct '98 offsets, for the θ range 40< θ <65.*

Table 2: *Rms of means (μm) using the Oct '98 offsets, separated into 3 angular ranges in θ.*

	Angular range			
Sector	all θ	$8< \theta <20$	$40< \theta <65$	$75< \theta <115$
1	67.5 ± 0.8	26.5 ± 0.6	183.9 ± 0.9	50.0 ± 0.9
2	91.0 ± 0.8	63.7 ± 0.7	182.6 ± 0.8	62.7 ± 0.8
3	77.1 ± 0.8	144.5 ± 0.6	232.4 ± 0.8	353.8 ± 0.9
4	462.0 ± 0.8	384.0 ± 0.6	615.8 ± 0.8	644.4 ± 0.9
5	38.7 ± 0.8	11.9 ± 0.6	69.5 ± 0.8	66.5 ± 0.9
6	65.1 ± 0.8	65.7 ± 0.7	87.9 ± 0.9	67.5 ± 0.8

It was desired to have a single quantity which could be used as a gauge of how well the alignment had been made. For this reason, the RMS of the means, for all of the 6 superlayers, in each sector has been calculated and is used to quote how well an alignment was made. Table 2 shows the RMS of the means calculated using the Oct '98 offsets. The alignment of sector 4, for example, was only accurate to $\sim 460\mu m$, when considering the average over the whole θ range.

In the following sections the results from fits 1–4 are shown in sections 5.1–5.4, respectively.

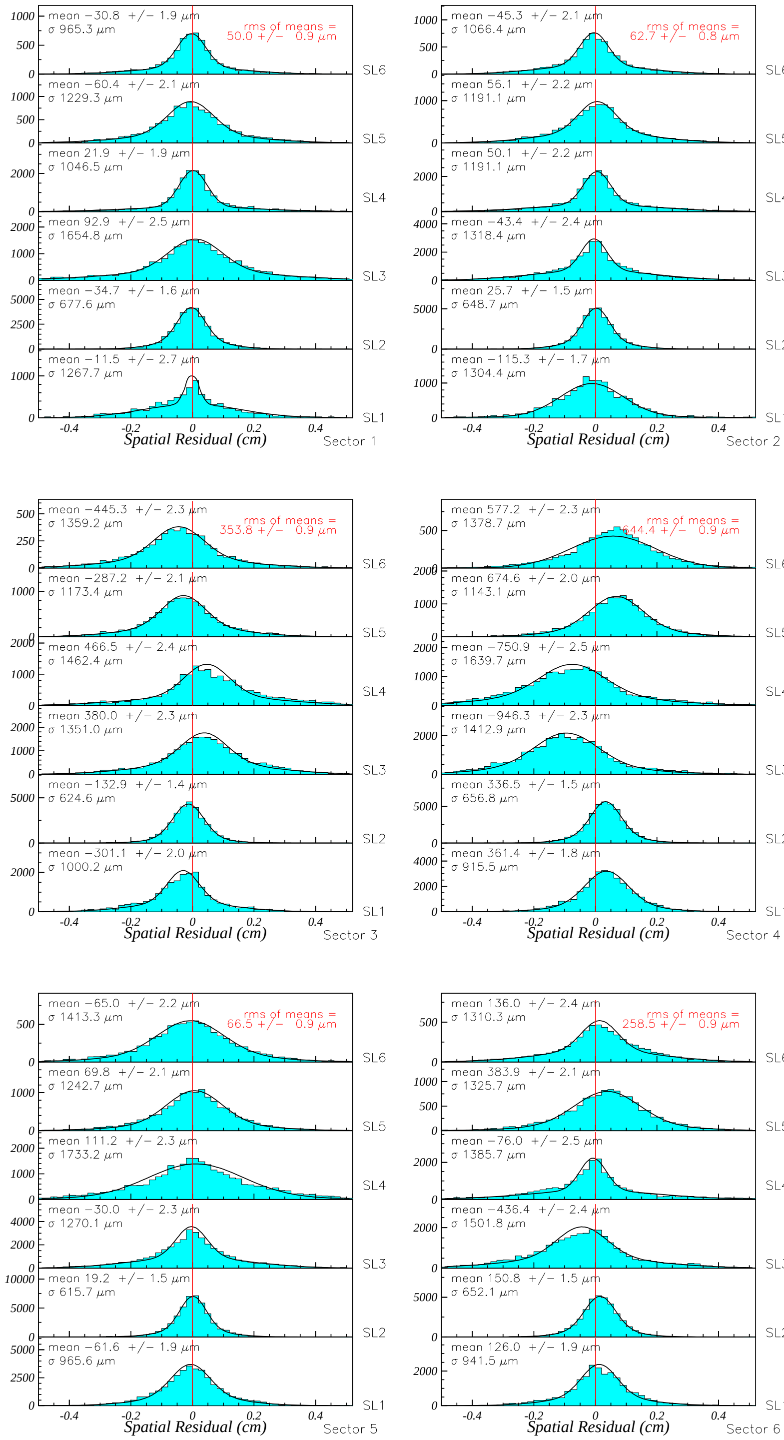

Figure 5: *Spatial residual distributions, using the Oct '98 offsets, for the θ range 75< θ <115.*

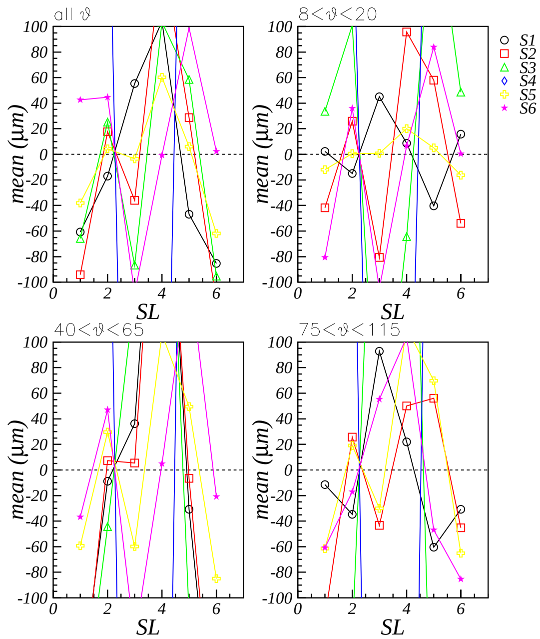

Figure 6: *Means vs SL no. for each sector, using the Oct '98 offsets.*

5.1 Results of fit 1

The following are the diagnostic plots found from the results of fit 1, the fit to region 3 for the offsets (dx,dz,θ_y).

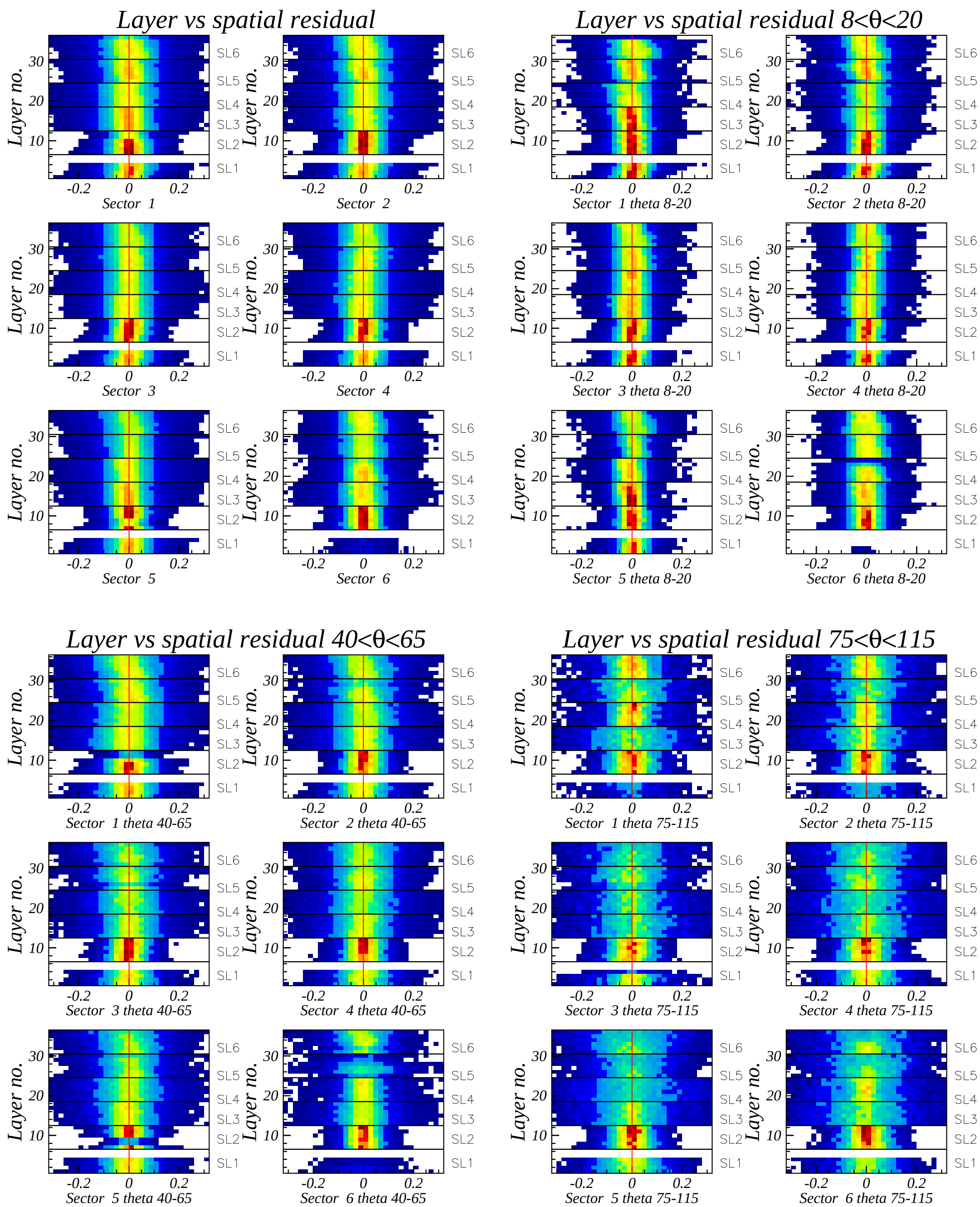

Figure 7: *Spatial residual distributions v's layer no., using fit 1 to dimensions* (dx, dz, θ_y) *region 3.*

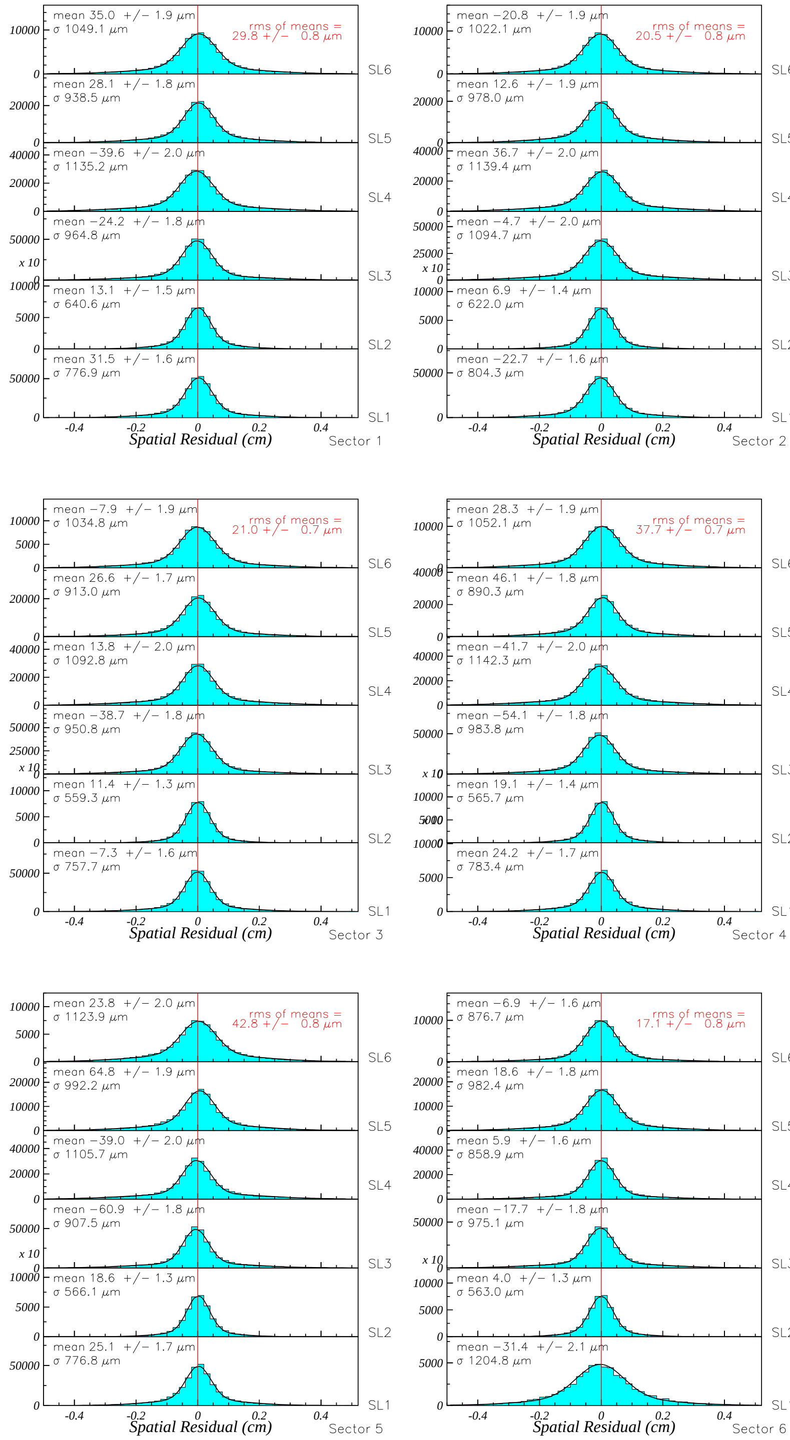

Figure 8: *Spatial residual distributions, using fit 1 to dimensions (dx,dz,θ_y) region 3 for the entire θ range.*

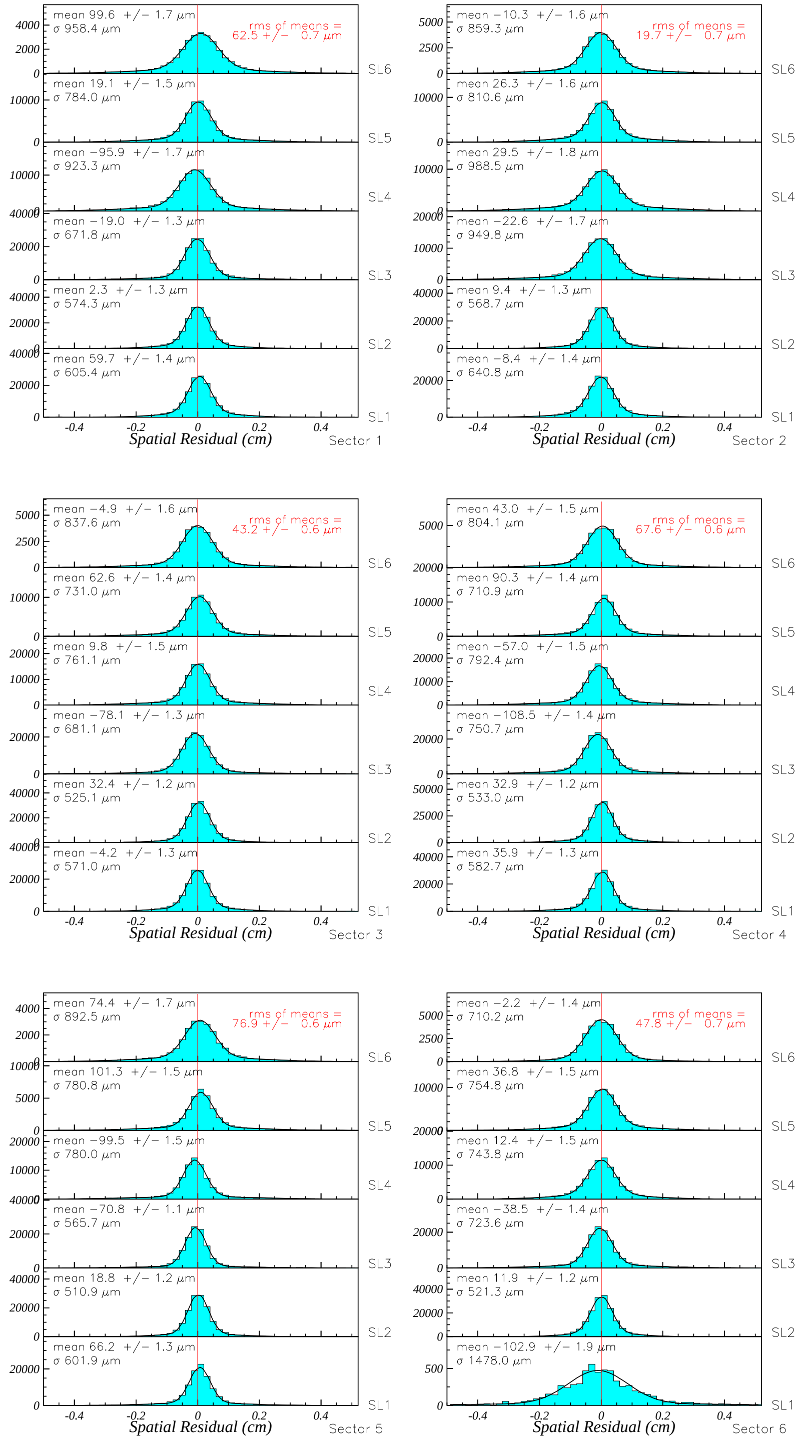

Figure 9: *Spatial residual distributions, using fit 1 to dimensions (dx,dz,θ_y) region 3 for the θ range 8°$< \theta <$20°.*

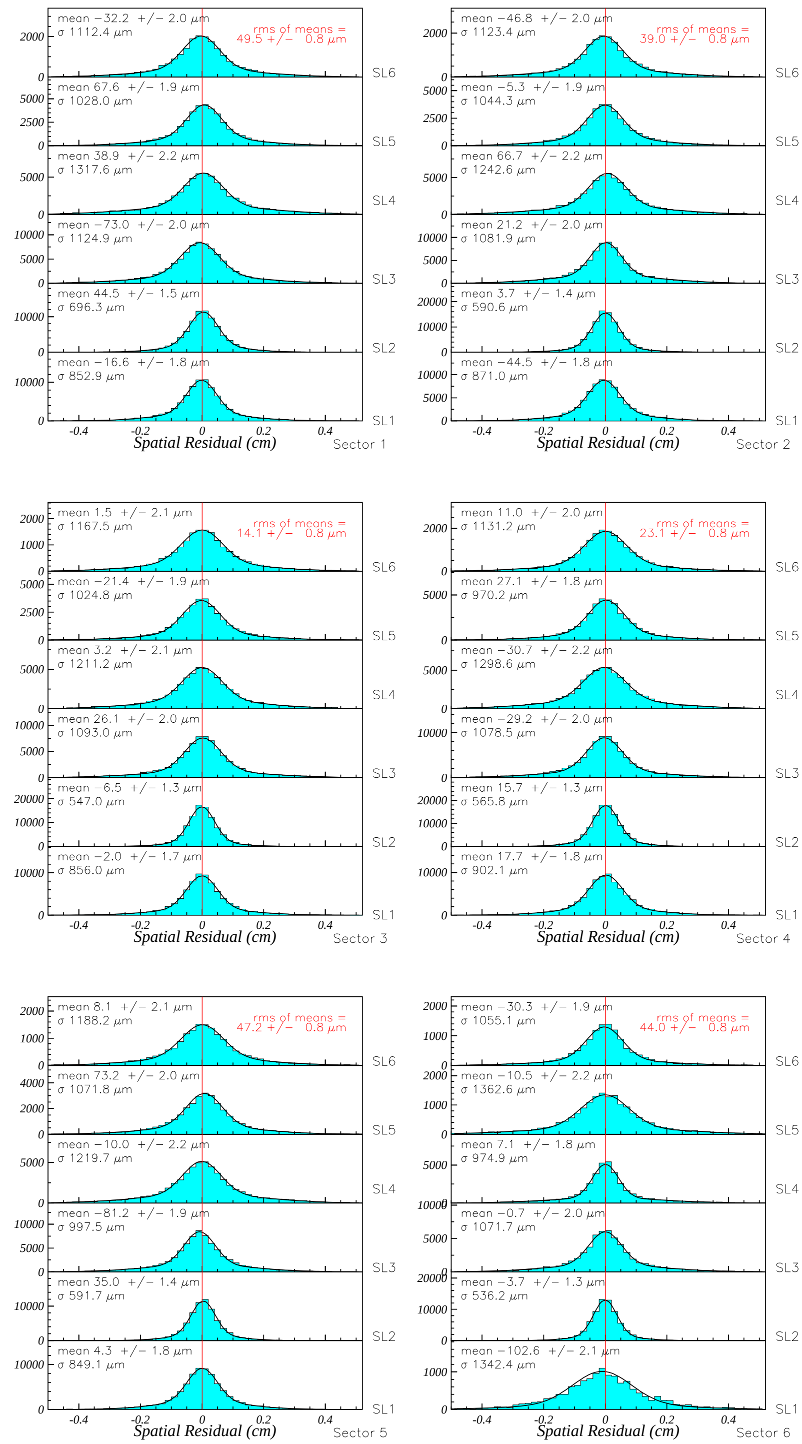

Figure 10: *Spatial residual distributions, using fit 1 to dimensions (dx,dz,θ_y) region 3 for the θ range 40°< θ <65°.*

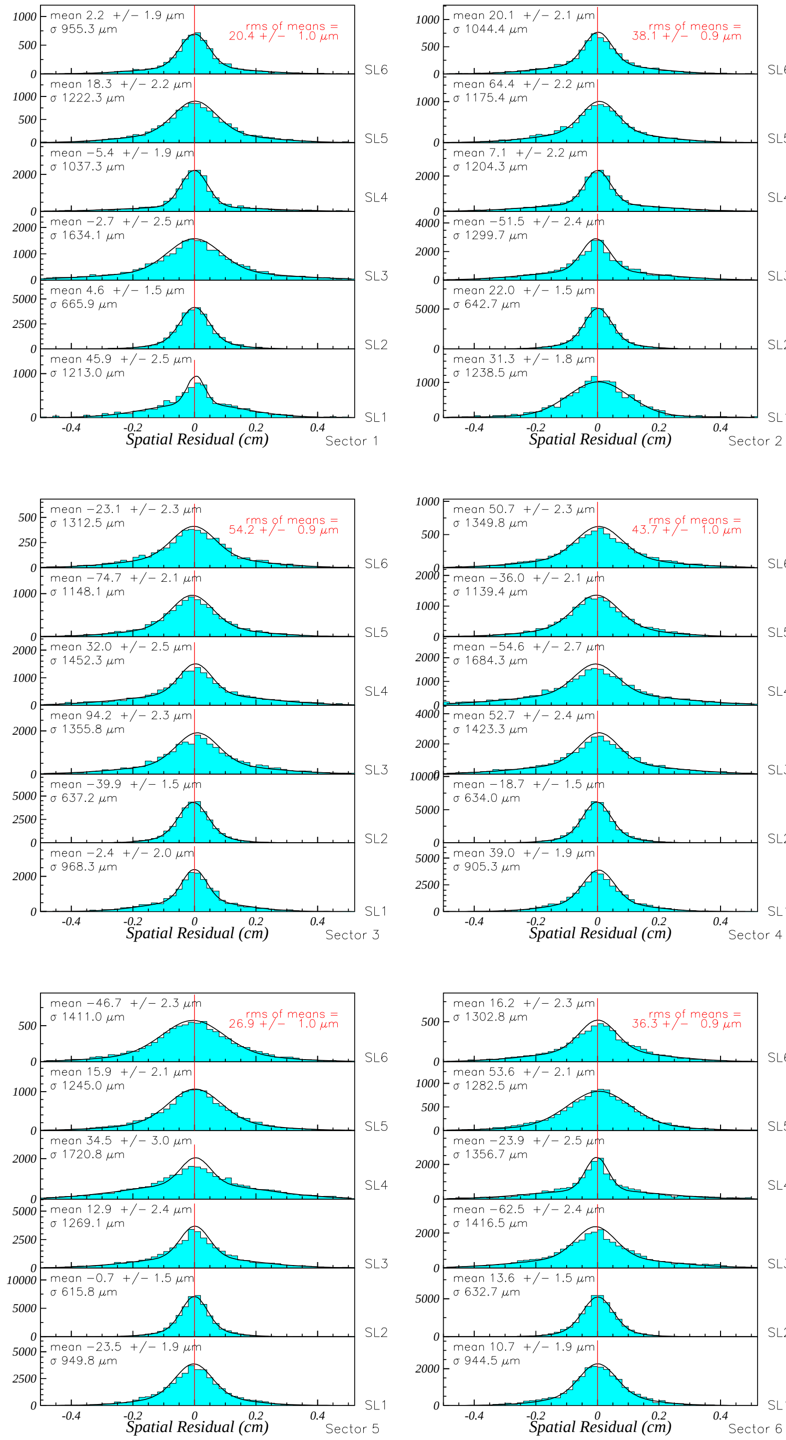

Figure 11: *Spatial residual distributions, using fit 1 to dimensions (dx,dz,θ_y) region 3 for the θ range 75°< θ <115°.*

5.2 Results of fit 2

The following are the diagnostic plots found from the results of fit 2, the fit to region 3 for the offsets (dy,θ_x).

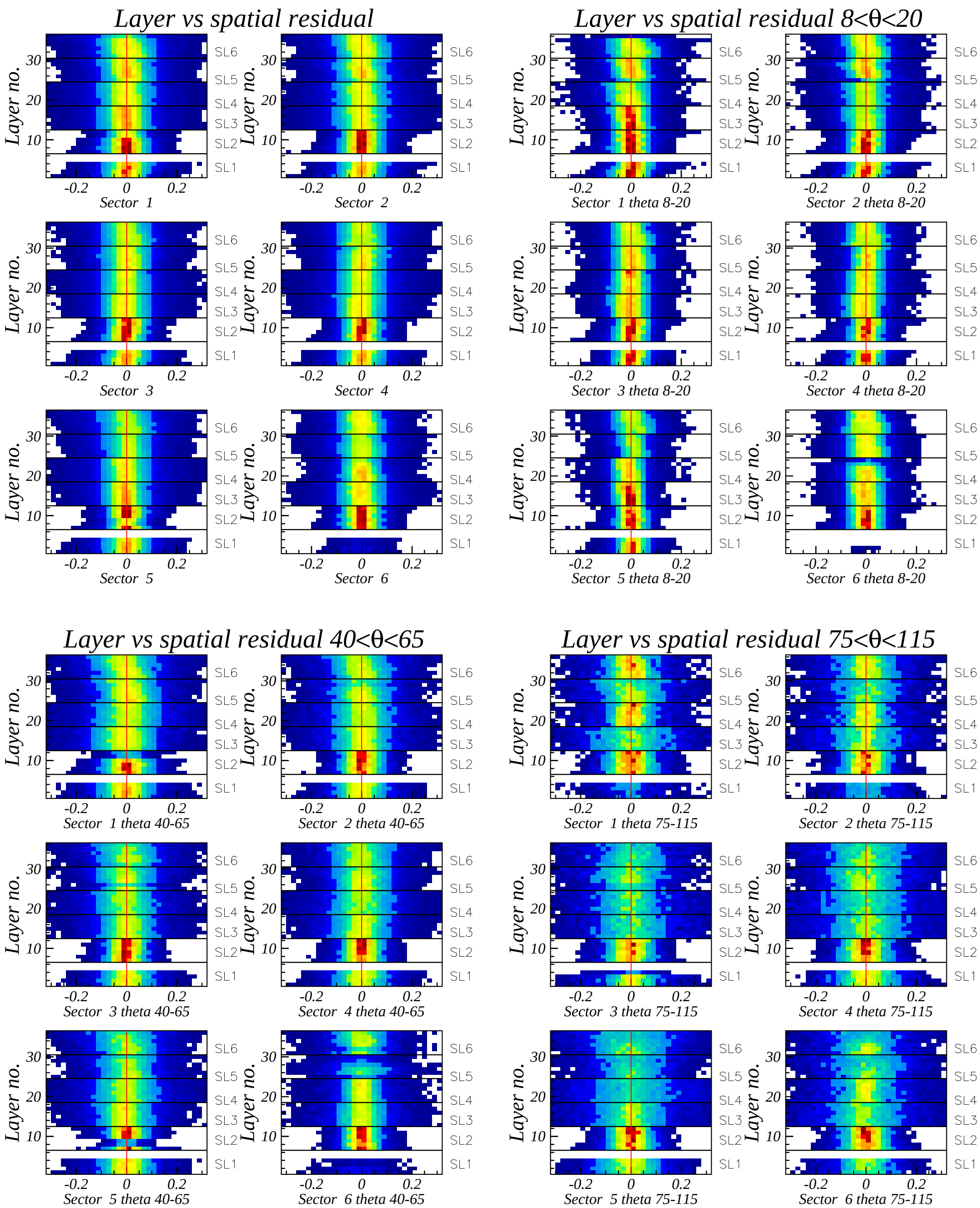

Figure 12: *Spatial residual distributions v's layer no., using fit 2 to dimensions (dy,θ_x) region 3.*

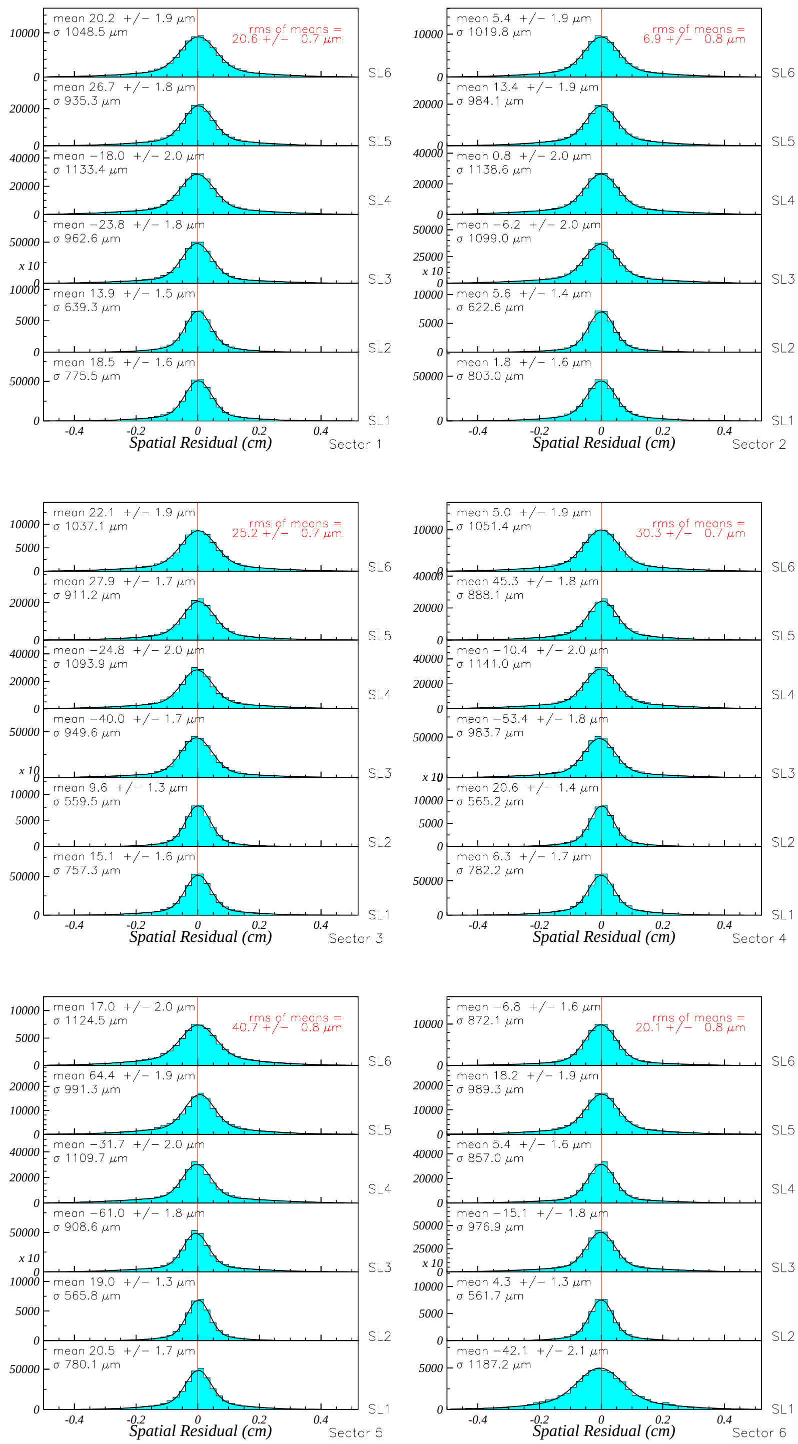

Figure 13: *Spatial residual distributions, using fit 2 to dimensions (dy,θ_x) region 3 for the entire θ range.*

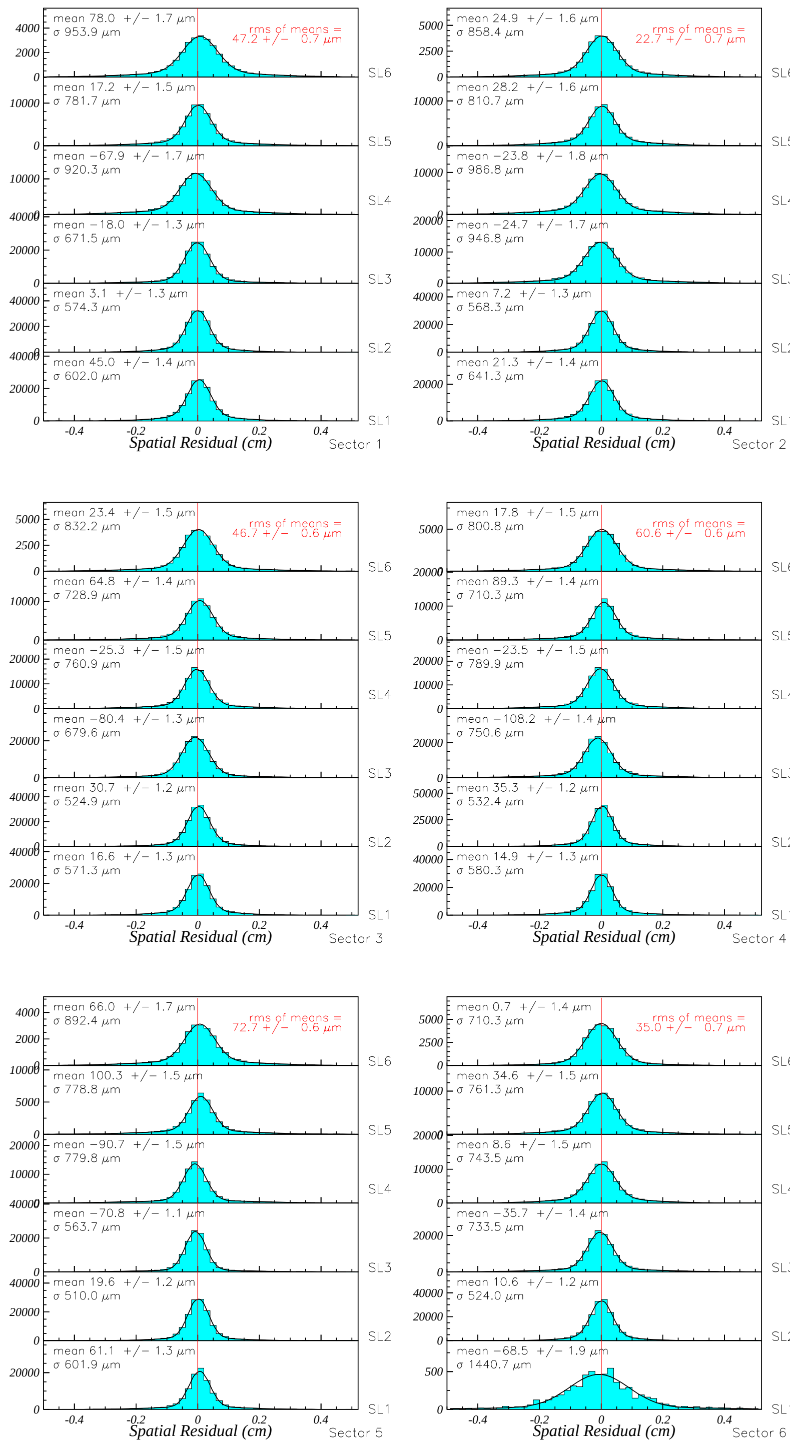

Figure 14: *Spatial residual distributions, using fit 2 to dimensions (dy,θ_x) region 3 for the θ range 8°< θ <20°.*

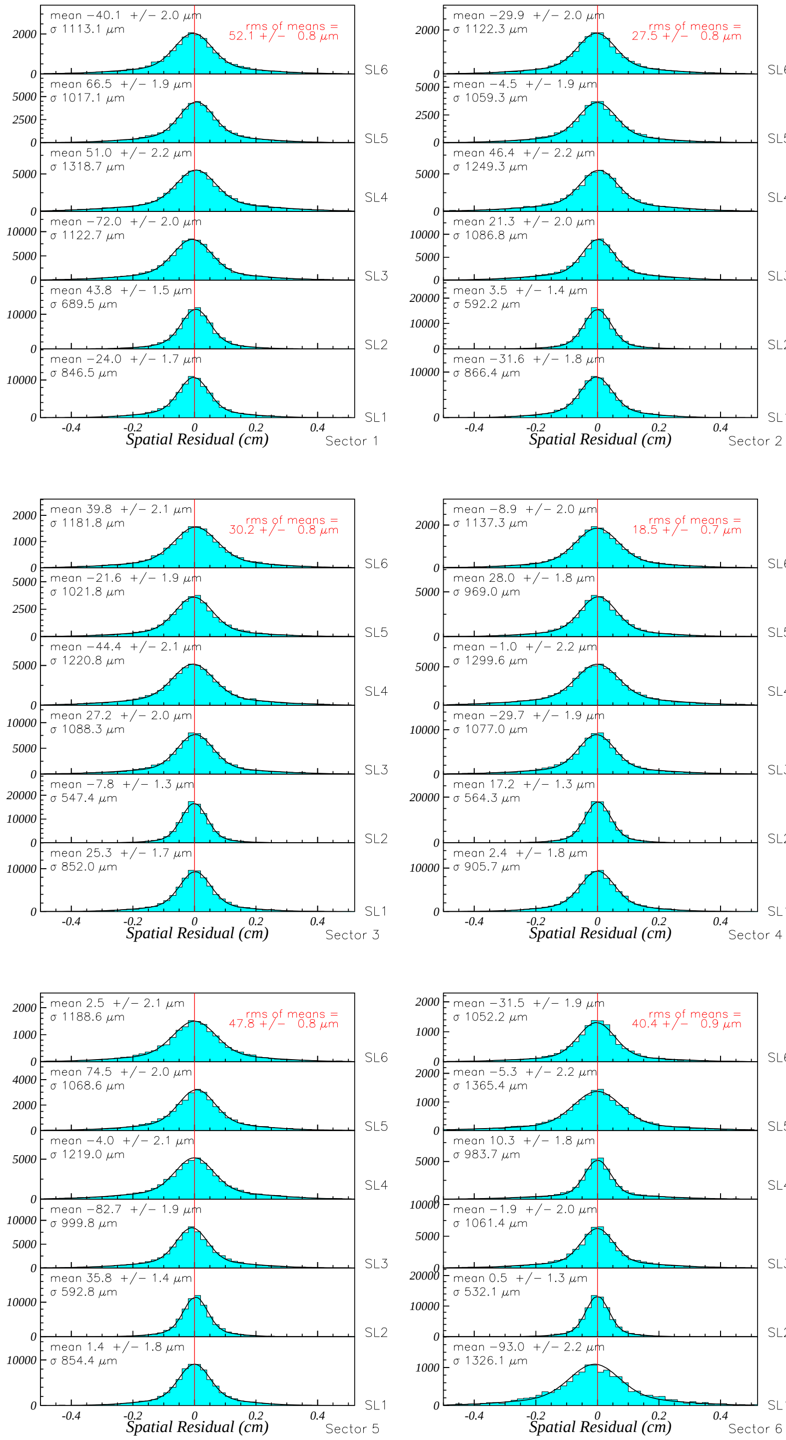

Figure 15: *Spatial residual distributions, using fit 2 to dimensions (dy,θ_x) region 3 for the θ range 40°< θ <65°.*

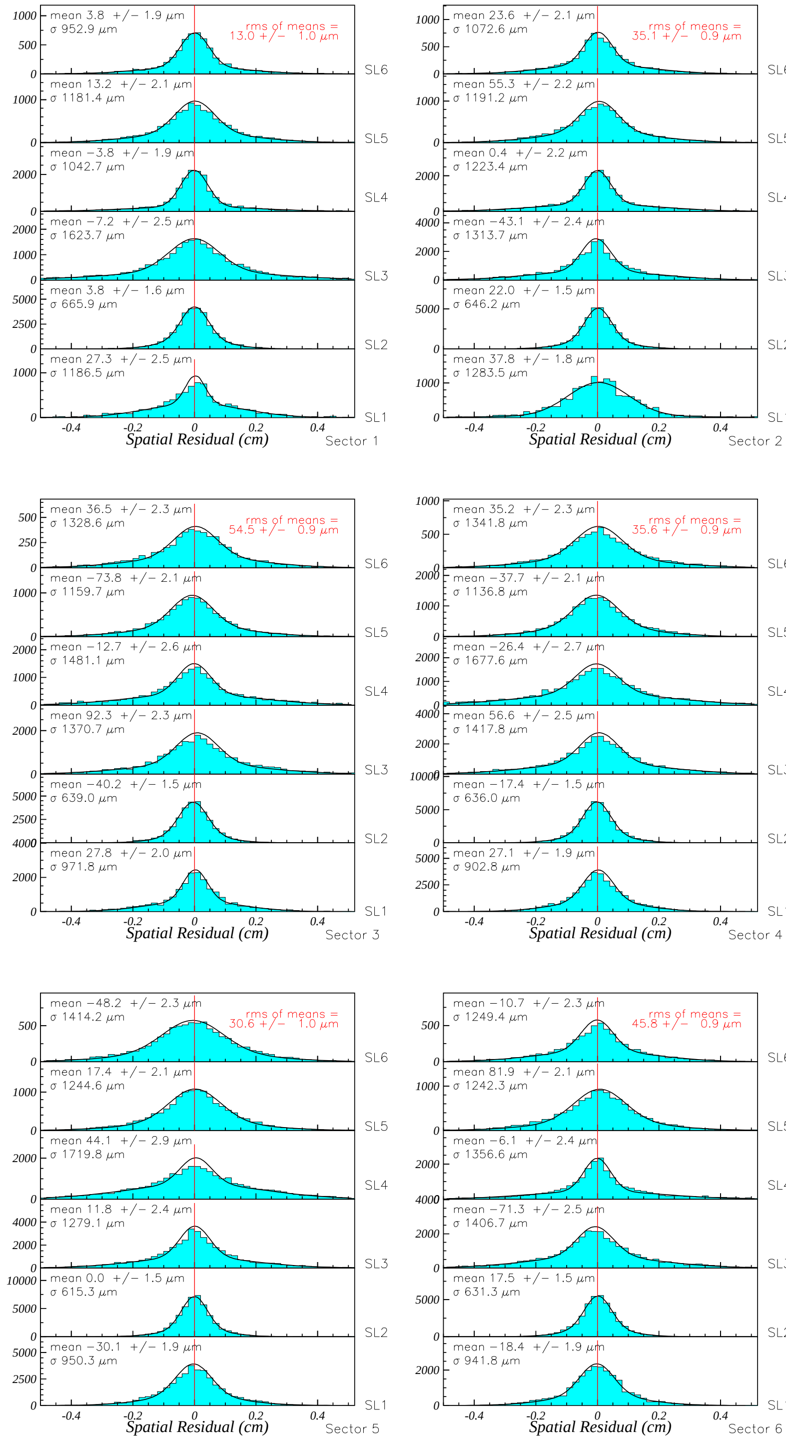

Figure 16: *Spatial residual distributions, using fit 2 to dimensions (dy,θ_x) region 3 for the θ range 75°< θ <115°.*

5.3 Results of fit 3

The following are the diagnostic plots found from the results of fit 3, the fit to region 2 for the offsets (dx,dz,θ_y).

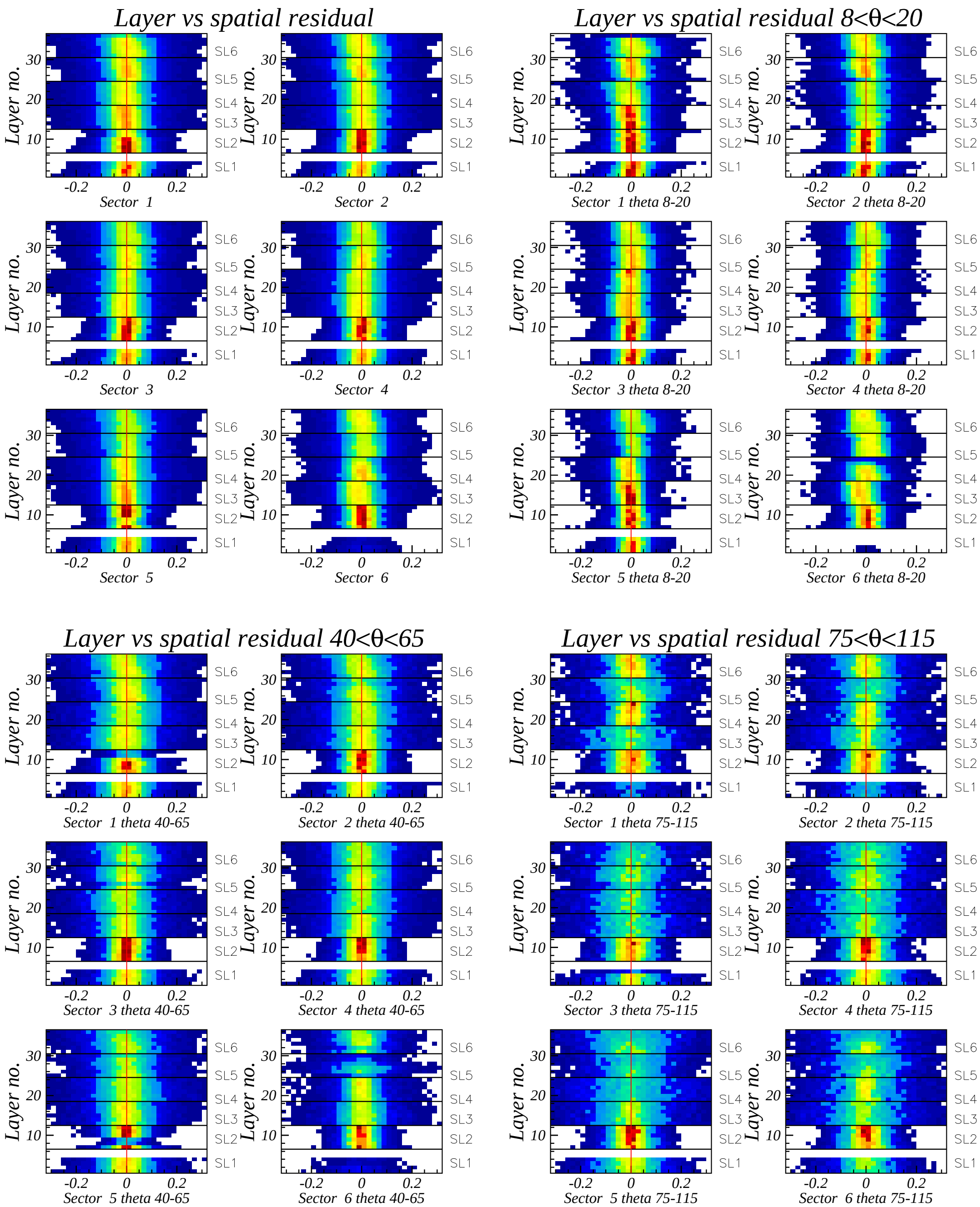

Figure 17: *Spatial residual distributions v's layer no., using fit 3 to dimensions* (dx, dz, θ_y) *region 2.*

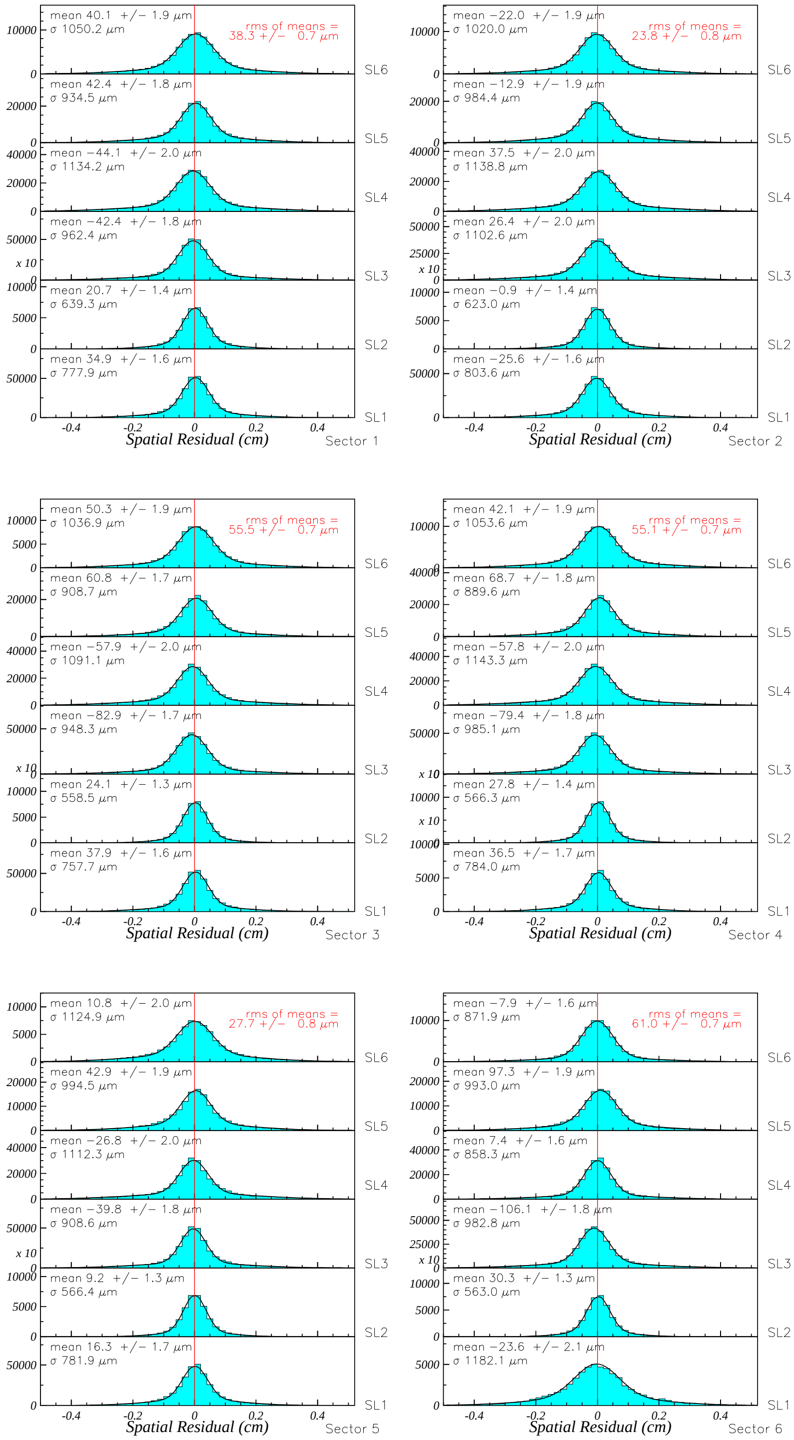

Figure 18: *Spatial residual distributions, using fit 3 to dimensions (dx,dz,θ_y) region 2 for the entire θ range.*

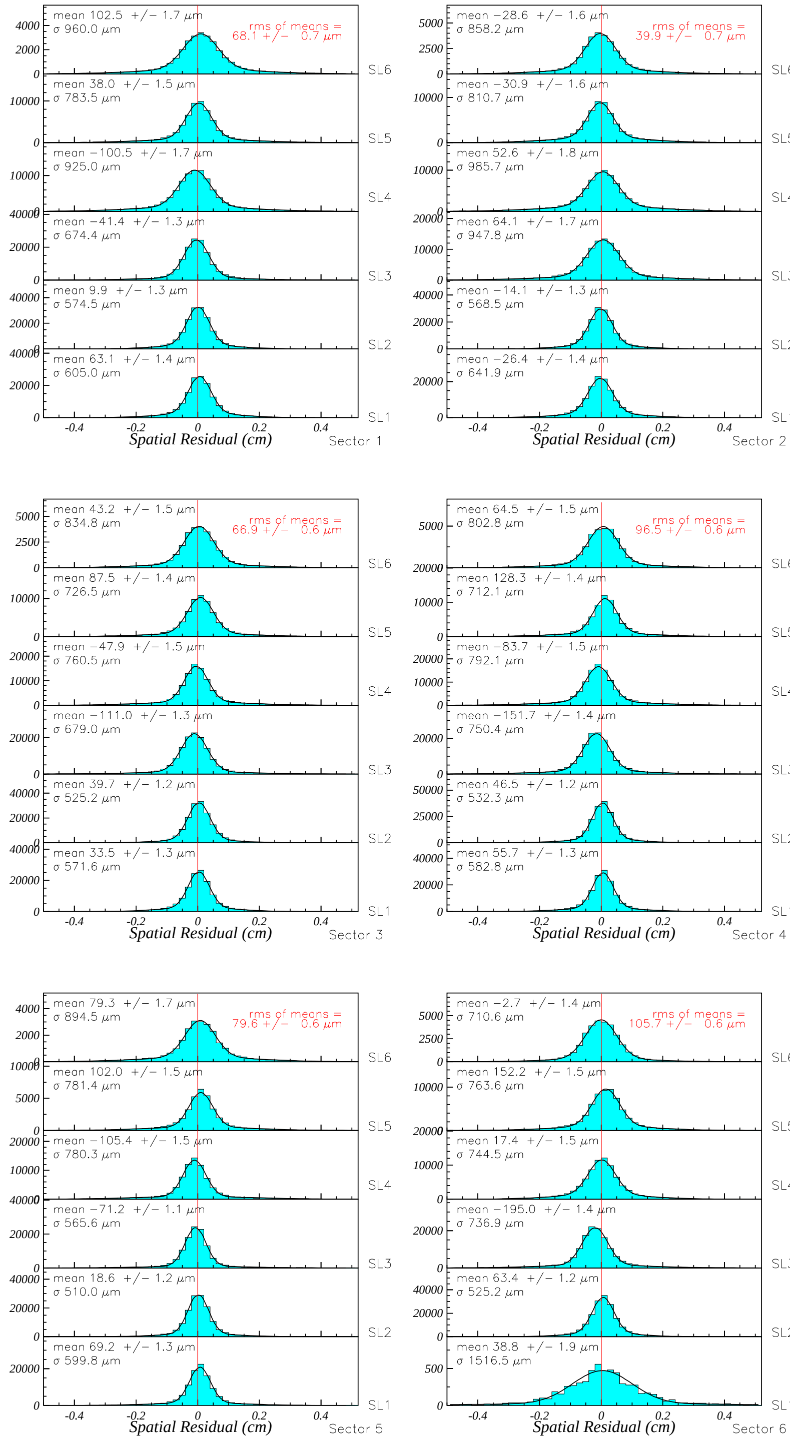

Figure 19: *Spatial residual distributions, using fit 3 to dimensions (dx,dz,θ_y) region 2 for the θ range 8°< θ <20°.*

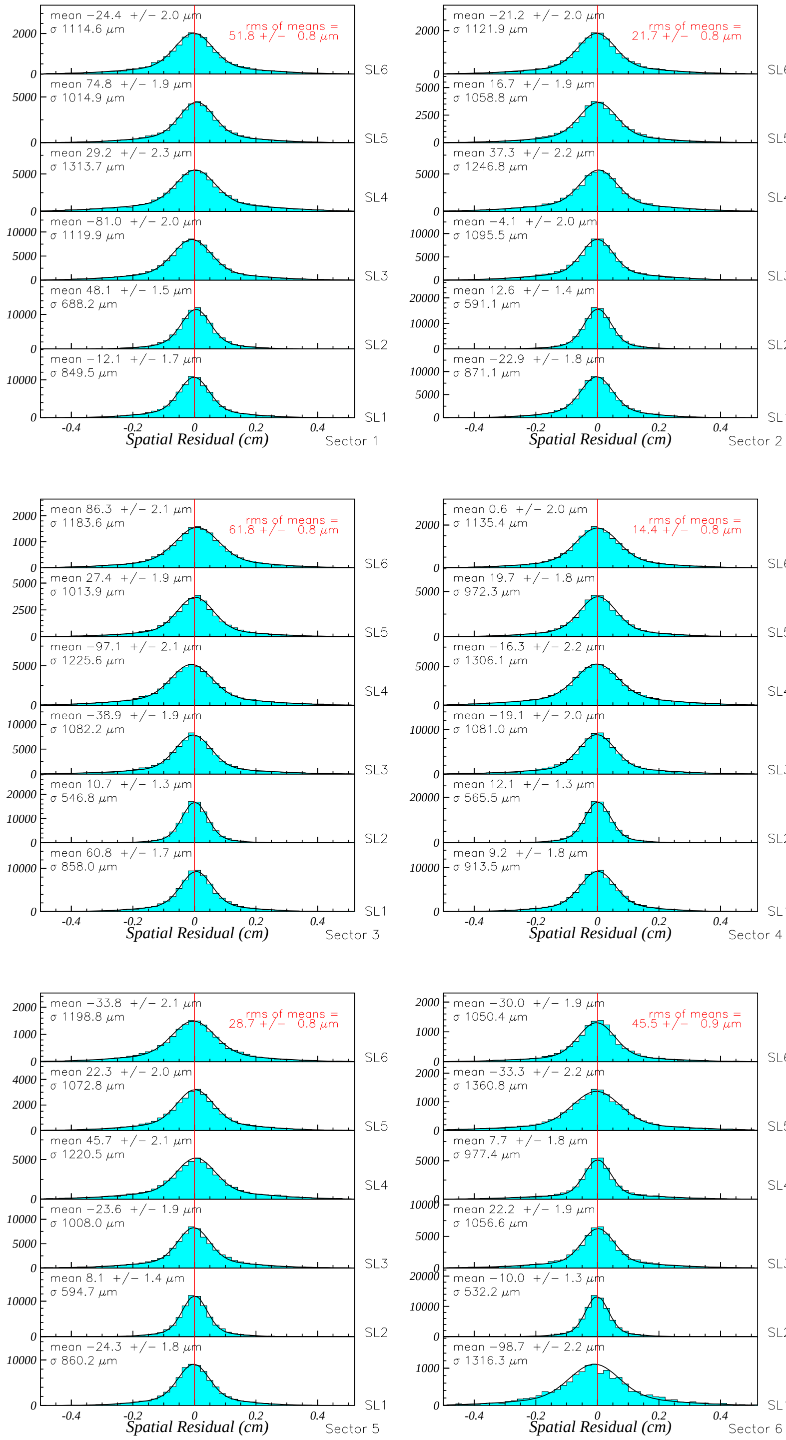

Figure 20: *Spatial residual distributions, using fit 3 to dimensions (dx,dz,θ_y) region 2 for the θ range 40°< θ <65°.*

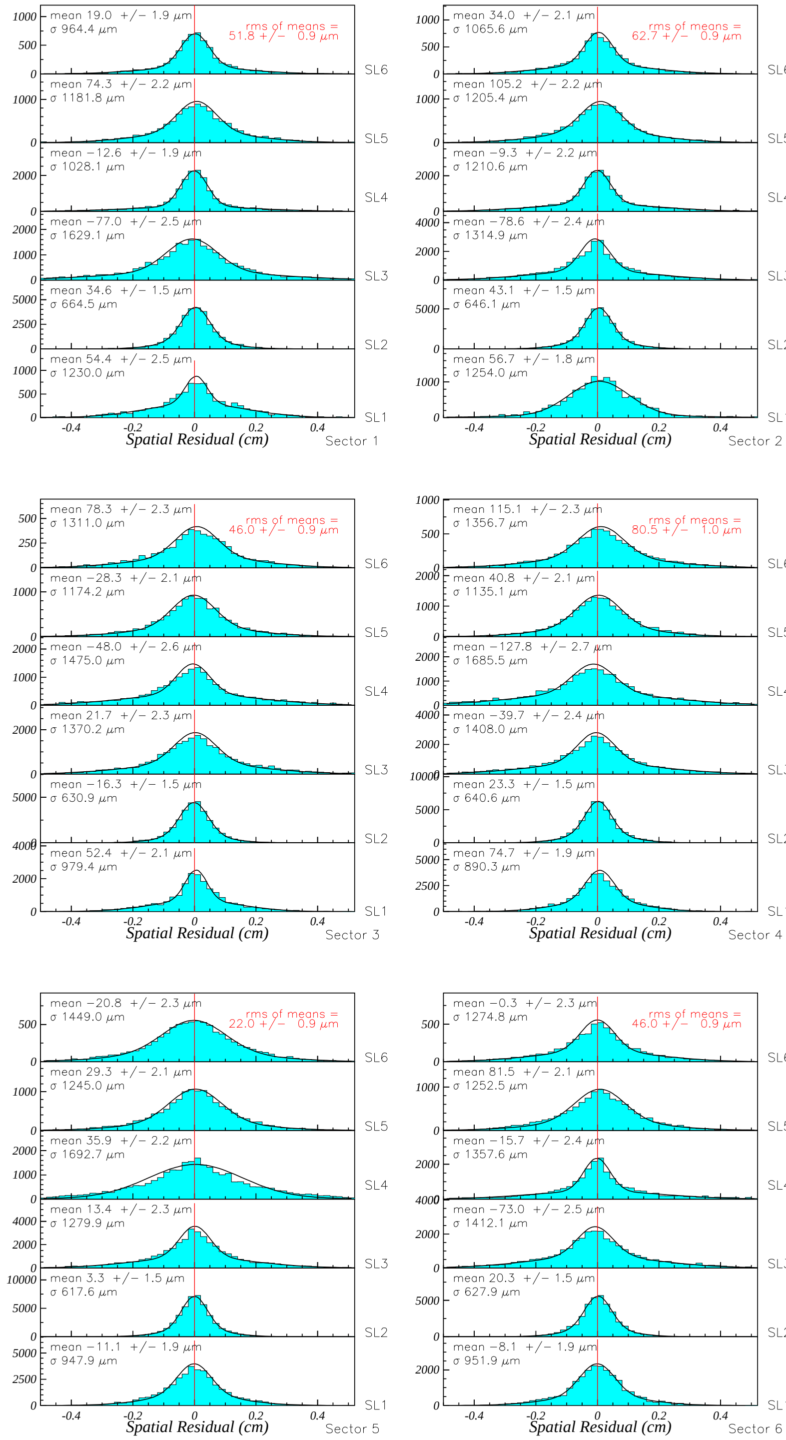

Figure 21: *Spatial residual distributions, using fit 3 to dimensions (dx,dz,θ_y) region 2 for the θ range 75°< θ <115°.*

5.4 Results of fit 4

The following are the diagnostic plots found from the results of fit 4, the fit to region 2 for the offsets (dy,θ_x).

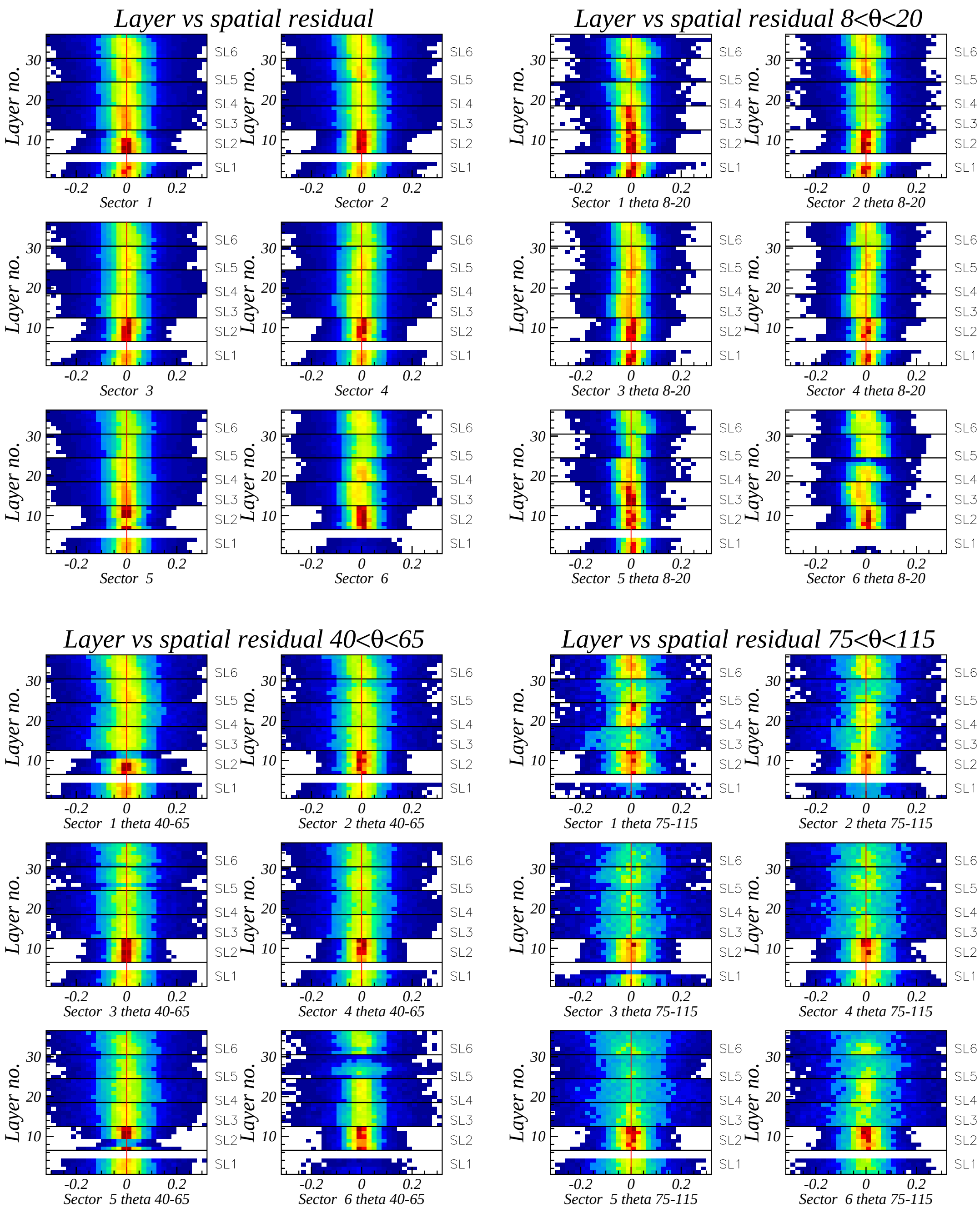

Figure 22: *Spatial residual distributions v's layer no., using fit 4 to dimensions (dy,θ_x) region 2.*

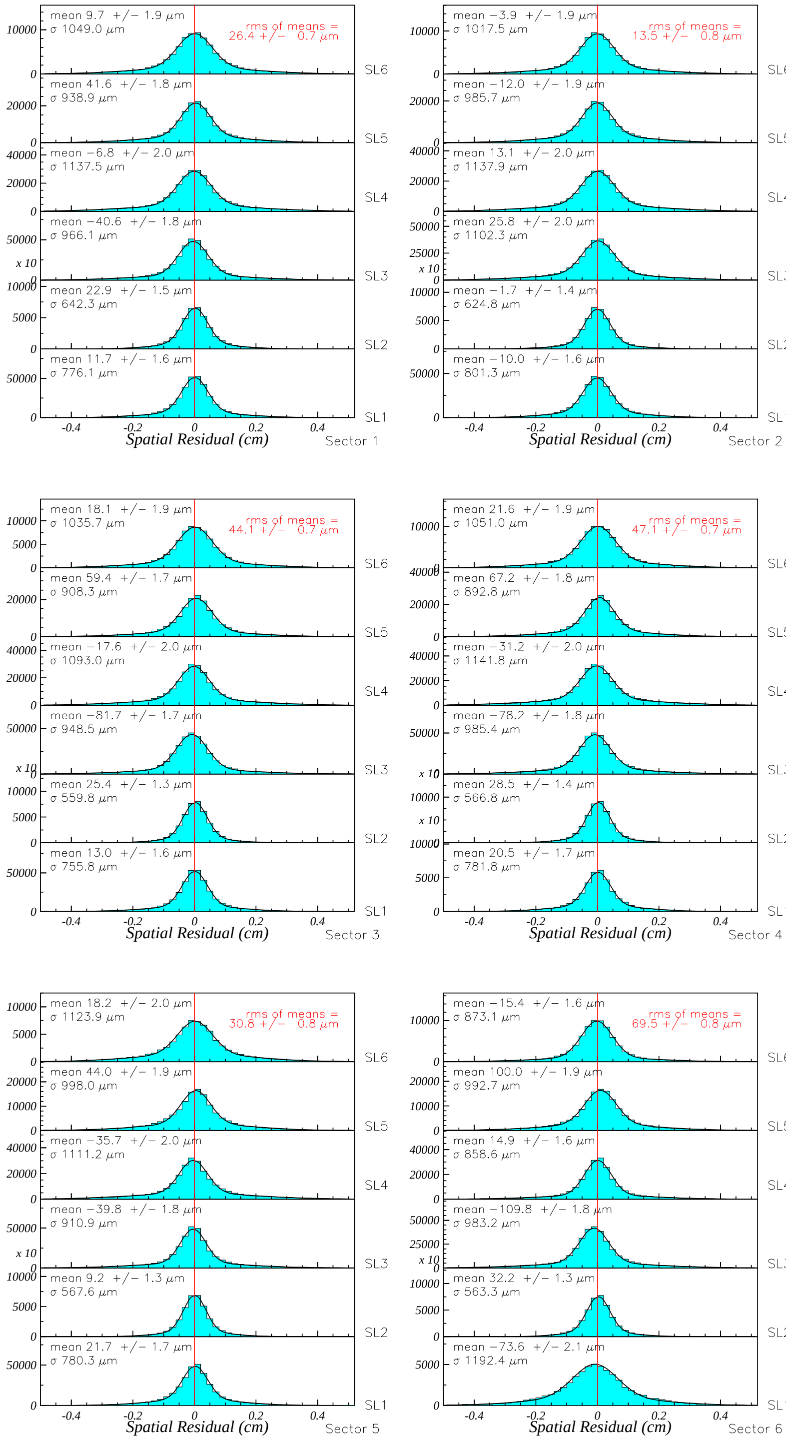

Figure 23: *Spatial residual distributions, using fit 4 to dimensions (dy,θ_x) region 2 for the entire θ range.*

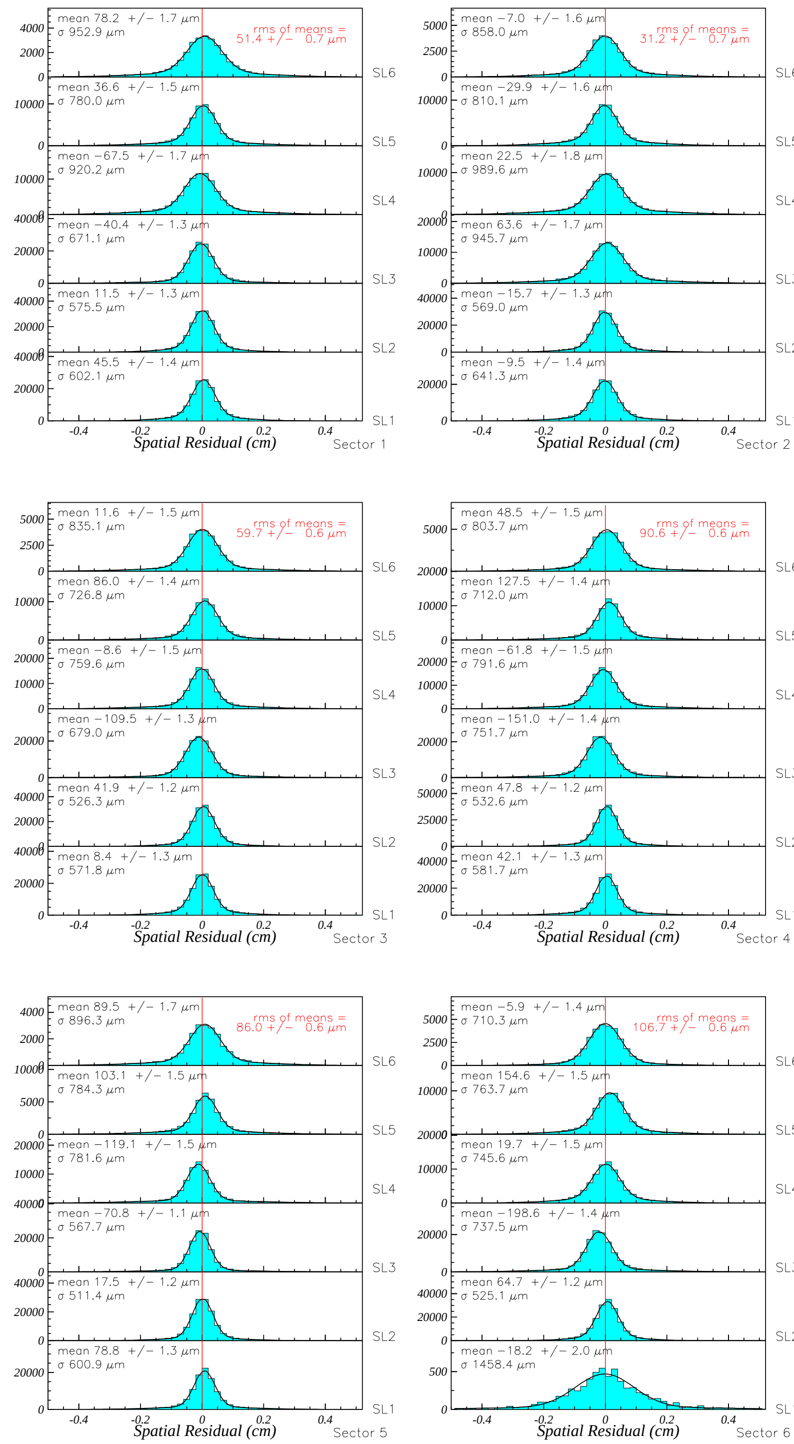

Figure 24: *Spatial residual distributions, using fit 4 to dimensions (dy,θ_x) region 2 for the θ range 8°< θ <20°.*

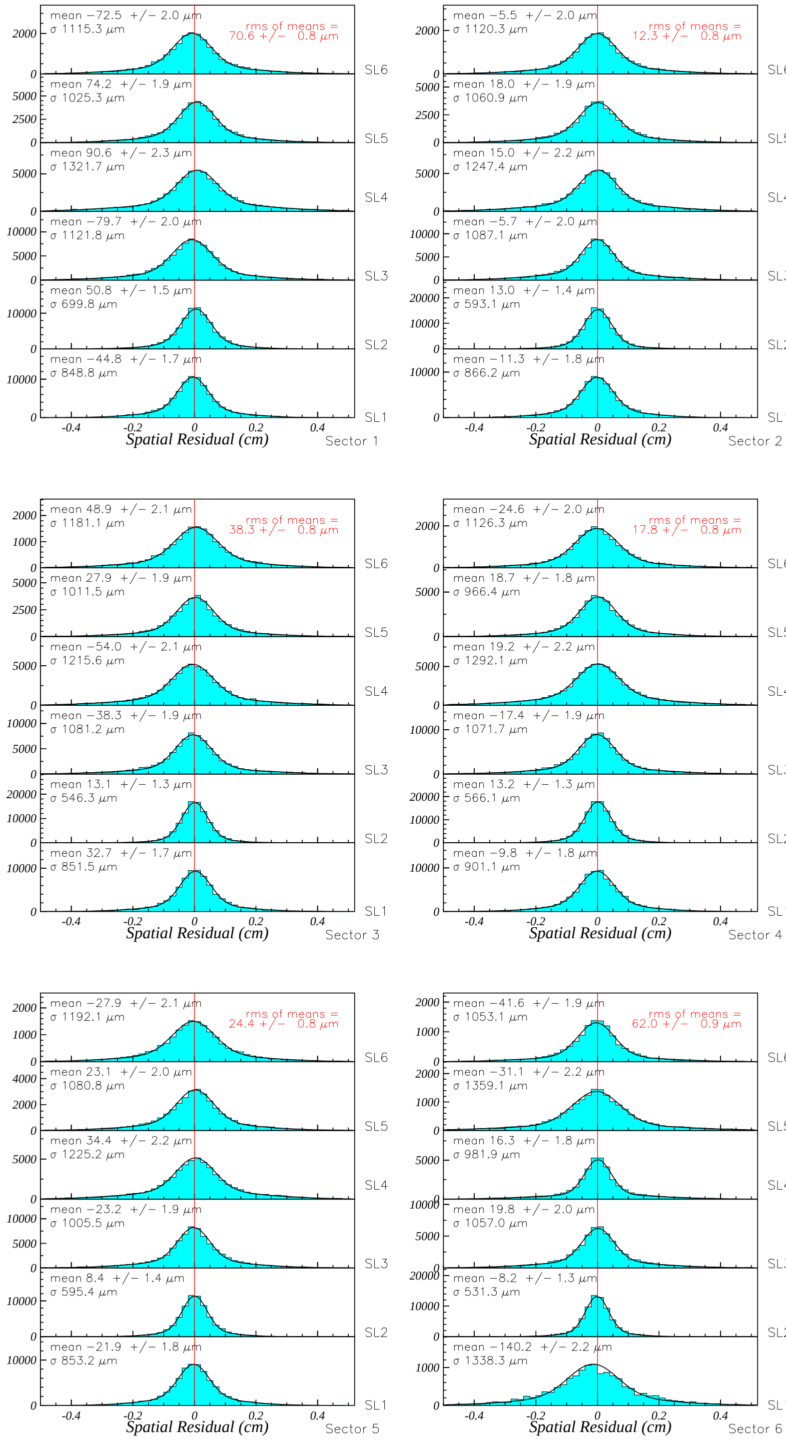

Figure 25: *Spatial residual distributions, using fit 4 to dimensions (dy,θ_x) region 2 for the θ range 40°< θ <65°.*

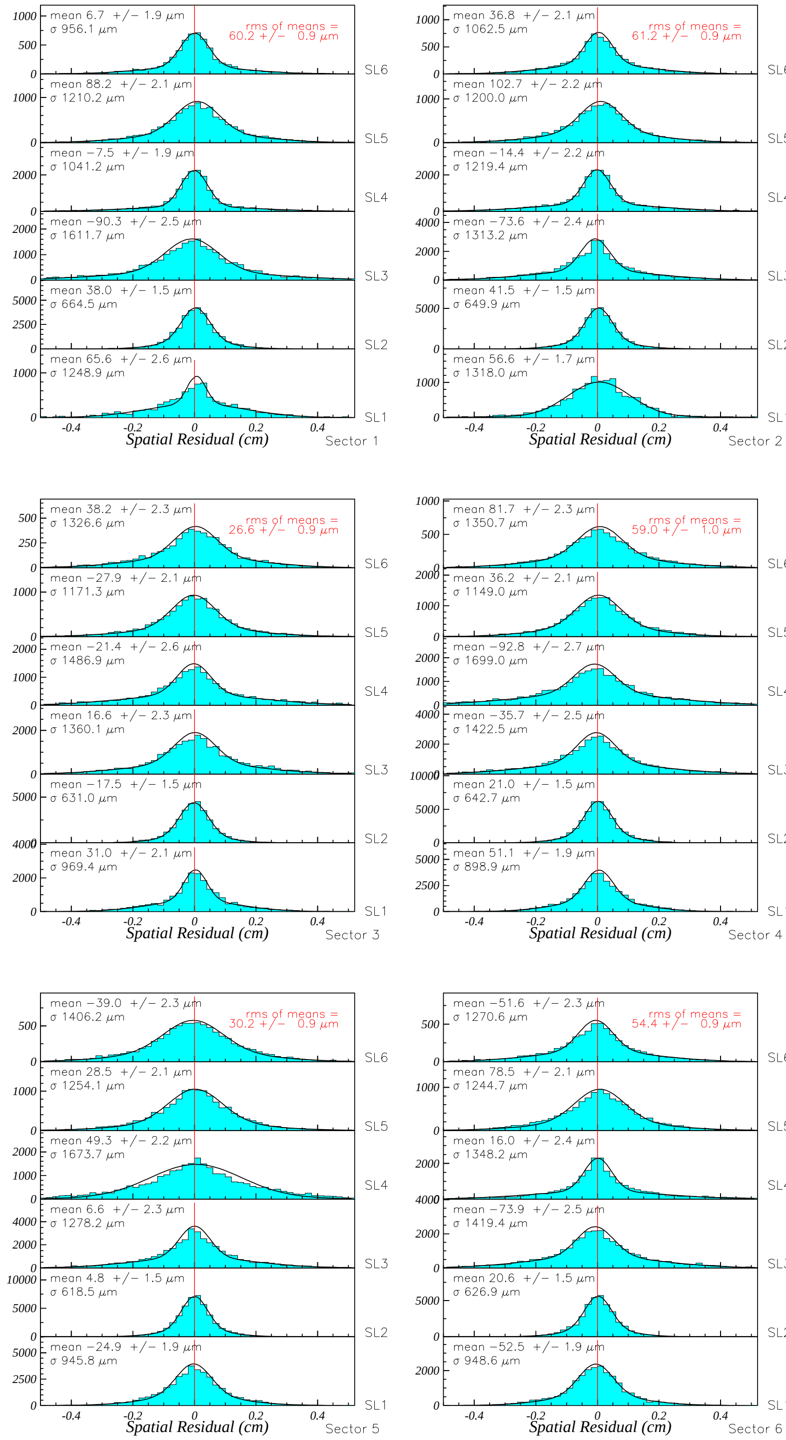

Figure 26: *Spatial residual distributions, using fit 4 to dimensions (dy,θ_x) region 2 for the θ range 75°< θ <115°.*

5.5 Discussion

Figures 27 and 28 show the mean values of the spatial residual distribution vs SL no. for each of the fits (1–4) mentioned above. The tables 3 to 6 show the RMS of the means for each sector in 4 θ ranges.

The tables 7 to 10 give the offset shifts (the difference between their present values and the Oct '98 values), showing how much the present fitting procedures have moved the chambers. The values are shown in cm and in rad, for the translational and the rotational offsets respectively. The largest offsets were found for sector 4, which had been replaced after its last movement, ~3mm (in the dz direction), away from where the Oct '98 offsets claimed it to be.

Fits 1 and 2 represent alignment of the region 3 chambers, assuming the other 2 regions to be well aligned and keeping them fixed. Fits 3 and 4 represent alignment of the region 2 chambers, keeping the region 1 and 3 chambers fixed. It was decided based upon the plots shown in figures 27 and 28 that the fitting of region 2 worsened the overall alignment. Therefore **the offsets found from fit 2 are those which have been used as the final result**. As a reminder, the fit 2 was a fit to region 3 varying only the dimensions (dy,θ_x), the dimensions (dx,dz,θ_y) being fixed to the values found in fit 1.

5.6 Where are the new constants?

The constants have been placed in the main run index `calib.RunIndex` of the CalDB under; system = DC_GEOM, subsystem = dc, item = (xyz)align and (xyz)rot, with the run range 28641 to 1000000, covering (at the time of writing) all run periods from g8a onwards.

6 Conclusions

Currently, the alignment of all sectors in region 3 has been updated and is now made to within ~60 μm, using the codes and procedure of Feuerbach [1]. The sector 4 results are in approx. agreement with the offsets estimated from the survey measurement. This gave encouragement that the systematics of the chamber movements was understood, since the survey measurements were added by hand from expected chamber movements, calculated from the results of the last survey measurement. The current offsets may be now used for cooking by the g8a, g6c, e1–6a and e6 run periods.

Improvements for the future may include selecting elastic events in the data sample. This will allow use of the vertex position as a constraint to the

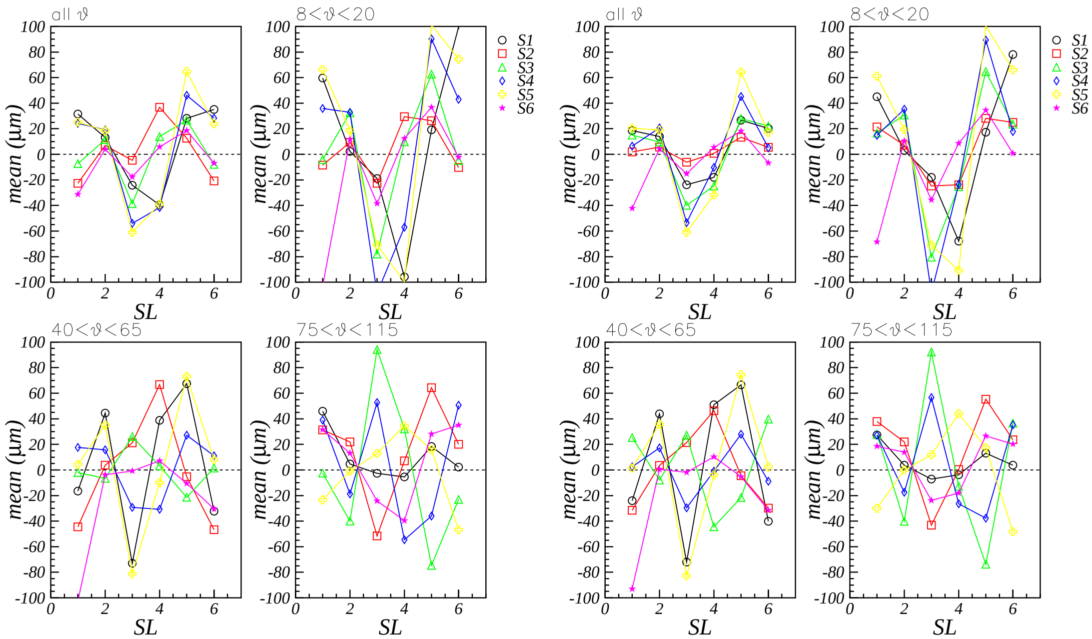

Figure 27: *Means vs SL no. for each sector, (left) after fitting region 3 (dx,dz,θ_y) and (right) after fitting region 3 (dy,θ_x). Each panel represents the data for a different range of θ.*

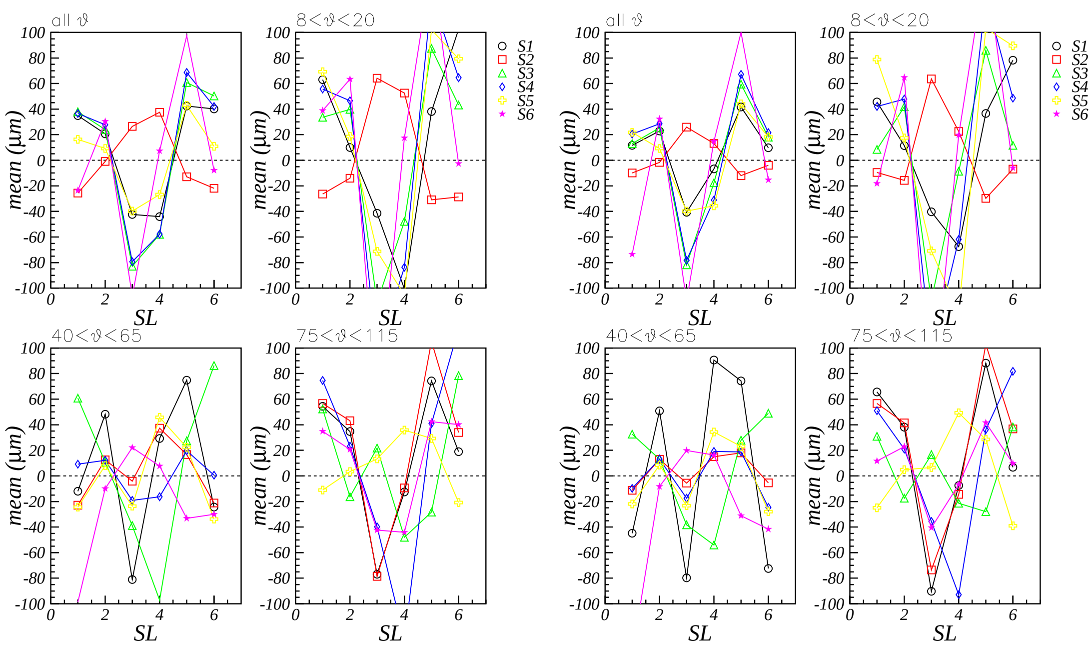

Figure 28: *Means vs SL for each sector, (left) after fitting region 2 (dx,dz,θ_y) and (right) after fitting region 2 (dy,θ_x). Each panel represents the data for a different range of θ.*

Table 3: *Rms of means (μm), for each θ range, after fitting the dimensions (dx,dz,θ_y) in region 3.*

Sector	Angular range			
	all θ	8< θ <20	40< θ <65	75< θ <115
1	29.8 ± 0.8	62.5 ± 0.7	49.5 ± 0.8	20.4 ± 1.0
2	20.5 ± 0.8	19.7 ± 0.7	39.0 ± 0.8	38.1 ± 0.9
3	21.0 ± 0.7	43.2 ± 0.6	14.1 ± 0.8	54.2 ± 0.9
4	37.7 ± 0.7	67.6 ± 0.6	23.1 ± 0.8	43.7 ± 1.0
5	42.8 ± 0.8	76.9 ± 0.6	47.2 ± 0.8	26.9 ± 1.0
6	17.1 ± 0.8	47.8 ± 0.7	44.0 ± 0.8	29.8 ± 0.8

Table 4: *Rms of means (μm), for each θ range, after fitting the dimensions (dy,θ_x) in region 3.*

Sector	Angular range			
	all θ	8< θ <20	40< θ <65	75< θ <115
1	20.6 ± 0.7	47.2 ± 0.7	52.1 ± 0.8	13.0 ± 1.0
2	6.9 ± 0.8	22.7 ± 0.7	27.5 ± 0.8	35.1 ± 0.9
3	25.2 ± 0.7	46.7 ± 0.6	30.2 ± 0.8	54.5 ± 0.9
4	30.3 ± 0.7	60.6 ± 0.6	18.5 ± 0.7	35.6 ± 0.9
5	40.7 ± 0.8	72.7 ± 0.6	47.8 ± 0.8	30.6 ± 1.0
6	20.1 ± 0.8	35.0 ± 0.7	40.4 ± 0.9	20.6 ± 0.7

Table 5: *Rms of means (μm), for each θ range, after fitting the dimensions (dx,dz,θ_y) in region 2.*

Sector	Angular range			
	all θ	8< θ <20	40< θ <65	75< θ <115
1	38.3 ± 0.7	68.1 ± 0.7	51.8 ± 0.8	51.8 ± 0.9
2	23.8 ± 0.8	39.9 ± 0.7	21.7 ± 0.8	62.7 ± 0.9
3	55.5 ± 0.7	66.9 ± 0.6	61.8 ± 0.8	46.0 ± 0.9
4	55.1 ± 0.7	96.5 ± 0.6	14.4 ± 0.8	80.5 ± 1.0
5	27.7 ± 0.8	79.6 ± 0.6	28.7 ± 0.8	22.0 ± 0.9
6	61.0 ± 0.7	105.7 ± 0.6	45.5 ± 0.9	38.3 ± 0.7

Table 6: *Rms of means (μm), for each θ range, after fitting the dimensions (dy,θ_x) in region 2.*

Sector	Angular range			
	all θ	8< θ <20	40< θ <65	75< θ <115
1	26.4 ± 0.7	51.4 ± 0.7	70.6 ± 0.8	60.2 ± 0.9
2	13.5 ± 0.8	31.2 ± 0.7	12.3 ± 0.8	61.2 ± 0.9
3	44.1 ± 0.7	59.7 ± 0.6	38.3 ± 0.8	26.6 ± 0.9
4	47.1 ± 0.7	90.6 ± 0.6	17.8 ± 0.8	59.0 ± 1.0
5	30.8 ± 0.8	86.0 ± 0.6	24.4 ± 0.8	30.2 ± 0.9
6	69.5 ± 0.8	106.7 ± 0.6	62.0 ± 0.9	26.4 ± 0.7

Table 7: *Offset difference between Oct '98 values and those of fit 1, after fitting the dimensions (dx,dz,θy) in region 3.*

Run 30910						
	dx (cm)	dy (cm)	dz (cm)	θx (rad)	θy (rad)	θz (rad)
Toroid	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:3 sec:1	-0.0431	0.0003	0.0660	0.0000	0.0001	0.0000
DC reg:3 sec:2	-0.0263	0.0001	0.0221	0.0000	0.0001	0.0000
DC reg:3 sec:3	0.0266	-0.0001	0.1692	0.0000	0.0002	0.0000
DC reg:3 sec:4	0.0123	0.0199	-0.3288	0.0006	0.0002	0.0000
DC reg:3 sec:5	-0.0498	0.0003	-0.0232	0.0000	0.0000	0.0000
DC reg:3 sec:6	-0.1662	0.0007	-0.0219	0.0000	0.0005	0.0000

Table 8: *Offset difference between Oct '98 values and those of fit 2, after fitting the dimensions (θx,dy) in region 3.*

Run 30910						
	dx (cm)	dy (cm)	dz (cm)	θx (rad)	θy (rad)	θz (rad)
Toroid	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:3 sec:1	-0.0432	-0.0401	0.0661	-0.0004	0.0001	0.0000
DC reg:3 sec:2	-0.0262	0.0360	0.0221	0.0006	0.0001	0.0000
DC reg:3 sec:3	0.0257	-0.2414	0.1692	-0.0003	0.0002	0.0000
DC reg:3 sec:4	0.0126	0.1048	-0.3288	0.0005	0.0002	0.0000
DC reg:3 sec:5	-0.0496	0.0354	-0.0232	0.0000	0.0000	0.0000
DC reg:3 sec:6	-0.1650	0.2984	-0.0219	0.0015	0.0005	0.0000

Table 9: *Offset difference between Oct '98 values and those of fit 3, after fitting the dimensions (dx,dz,θy) in region 2.*

Run 30910						
	dx (cm)	dy (cm)	dz (cm)	θx (rad)	θy (rad)	θz (rad)
Toroid	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:1	-0.0410	0.0001	0.0143	0.0000	0.0002	0.0000
DC reg:2 sec:2	0.0008	0.0000	-0.0308	0.0000	-0.0001	0.0000
DC reg:2 sec:3	0.0019	0.0000	-0.0139	0.0000	0.0000	0.0000
DC reg:2 sec:4	-0.0574	0.0002	0.0310	0.0000	0.0003	0.0000
DC reg:2 sec:5	-0.0416	0.0001	0.0331	0.0000	0.0002	0.0000
DC reg:2 sec:6	-0.0516	0.0002	0.0679	0.0000	0.0004	0.0000
DC reg:3 sec:1	-0.0432	-0.0401	0.0661	-0.0004	0.0001	0.0000
DC reg:3 sec:2	-0.0262	0.0360	0.0221	0.0006	0.0001	0.0000
DC reg:3 sec:3	0.0257	-0.2414	0.1692	-0.0003	0.0002	0.0000
DC reg:3 sec:4	0.0126	0.1048	-0.3288	0.0005	0.0002	0.0000
DC reg:3 sec:5	-0.0496	0.0354	-0.0232	0.0000	0.0000	0.0000
DC reg:3 sec:6	-0.1650	0.2984	-0.0219	0.0015	0.0005	0.0000

Table 10: *Offset difference between Oct '98 values and those of fit 4, after fitting the dimensions (θx,dy) in region 2.*

Run 30910						
	dx (cm)	dy (cm)	dz (cm)	θx (rad)	θy (rad)	θz (rad)
Toroid	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:1 sec:6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DC reg:2 sec:1	-0.0416	-0.1936	0.0143	-0.0005	0.0002	0.0000
DC reg:2 sec:2	0.0008	0.0155	-0.0308	-0.0002	-0.0001	0.0000
DC reg:2 sec:3	0.0014	-0.1047	-0.0139	-0.0001	0.0000	0.0000
DC reg:2 sec:4	-0.0578	-0.0945	0.0310	-0.0002	0.0003	0.0000
DC reg:2 sec:5	-0.0417	-0.0151	0.0331	-0.0002	0.0002	0.0000
DC reg:2 sec:6	-0.0523	-0.1998	0.0680	0.0000	0.0004	0.0000
DC reg:3 sec:1	-0.0432	-0.0401	0.0661	-0.0004	0.0001	0.0000
DC reg:3 sec:2	-0.0262	0.0360	0.0221	0.0006	0.0001	0.0000
DC reg:3 sec:3	0.0257	-0.2414	0.1692	-0.0003	0.0002	0.0000
DC reg:3 sec:4	0.0126	0.1048	-0.3288	0.0005	0.0002	0.0000
DC reg:3 sec:5	-0.0496	0.0354	-0.0232	0.0000	0.0000	0.0000
DC reg:3 sec:6	-0.1650	0.2984	-0.0219	0.0015	0.0005	0.0000

tracking, therefore improving the fit when the chamber positions are varied since one extra point along the track will be available. For this purpose, new alignment data will be taken during the e2b run with a CH target. This will provide real elastic events from a thin target, where the z position of the vertex is known to within micron accuracy.

A Sample tcl file

```
source /u/group/clas/builds/DEVELOPMENT/packages/tcl/recsis_proc.tcl;
# define packages

turnoff ALL;
turnon seb dc trk cc tof egn lac user pid;
global_section off;

set ltagger_do 0;
set lst_do      0;
set lrf_do     -1;
set lcall_do  -1;
set ltof_do    -1;
set lcc_do     -1;
set legn_do    -1;
set lec1_do    -1;
set llac_do    -1;
set ltrk_do    -1;
set lusr1_do  -1;
set lusr0_do  -1;
set lhbid_do  -1;
set lseb_do     1;

inputfile infile
outputfile bosfile
setc log_file_name logfile
setc chist_filename rznfile

setc outbanknames(1) "HEADTBIDTRKSTBERTBTRTGBITBLA";
#setc outbanknames(1) "all";

set trk_print(1) 1;
set trk_magtyp 5;

#level of analysis 0: raw  2: hbt 4: tbt
set trk_level 4;

# tbt stuff realistic curve for drift time to drift distance.
set dc_xvst_choice 2;
```

```
### For the ALIGNMENT, we want to be able to modify the
### SIGMA's for the track fitting
### by default, these are all =1.
### Default running conditions.
set dc_mult_Sigma(1) 1.0
set dc_mult_Sigma(2) 1.0
set dc_mult_Sigma(3) 1.0
set dc_mult_Sigma(4) 1.0
set dc_mult_Sigma(5) 1.0
set dc_mult_Sigma(6) 1.0

### Fit to Region 3 layers only.
#set dc_mult_Sigma(1) 1.0
#set dc_mult_Sigma(2) 1.0
#set dc_mult_Sigma(3) 1.0
#set dc_mult_Sigma(4) 1.0
#set dc_mult_Sigma(5) 50.0
#set dc_mult_Sigma(6) 50.0

### For empty target, use the cell walls to constrain the vertex
#set align_vert_cut 1;
#set trk_VXconstr 2;
#set target_wall 0.5;
#set dstmwall -1.5;
#set upstmwall -6.5;
#set dstmlen 1.0;
#set dstmlen 1.0;
#set TargetPos(1)  0.07;
#set TargetPos(2) -0.25;

# tell FPACK not to stop if it thinks you are running out of time
fpack "timestop -9999999999"

# do not send events to event display
set lscat $false;
set ldisplay_all $false;

#set nevt_to_skip  491826; # how many events to SKIP
#                            set to .le. 0 to NOT SKIP
## tell recsis to pause or go
```

```
go 100000
setc rec_prompt "align_recsis> "
exit_pend
```

References

[1] R. Feuerbach, "CLAS Drift Chamber Alignment Technique and Results: CMU Method (1998–1999)", **CLAS–Note 2001–22**, 18^{th} Dec 2001.

[2] R. Feuerbach *et. al.*, "Drift Chamber Alignment version 1.0", **CLAS–Note 98–002**, 26^{th} Jan 1998.

[3] K. Tremblay, "Jefferson Lab Alignment Group Data Transmittal", Private Communication, 13^{th} Aug 2001.