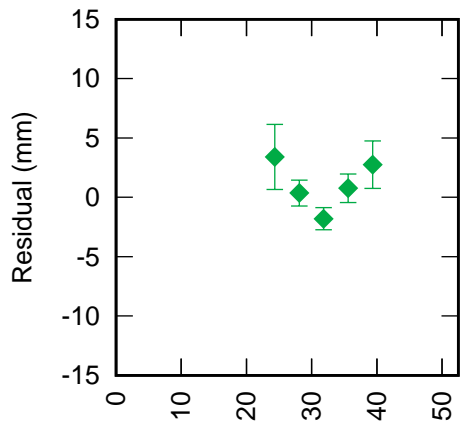
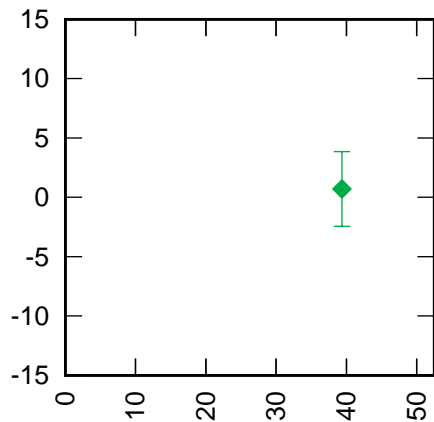


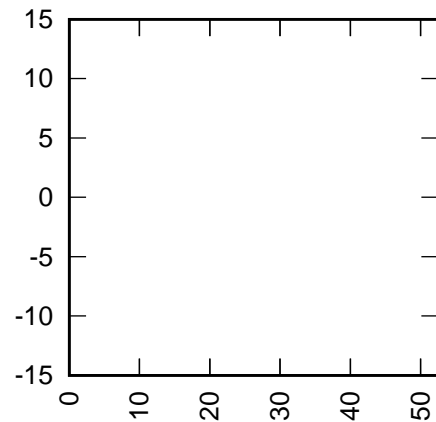
Komsomolsk 1868 LAG1+LAG2
(CoM 248 mm) RB 3.7 mm +



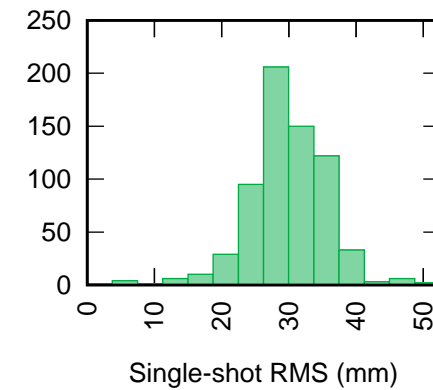
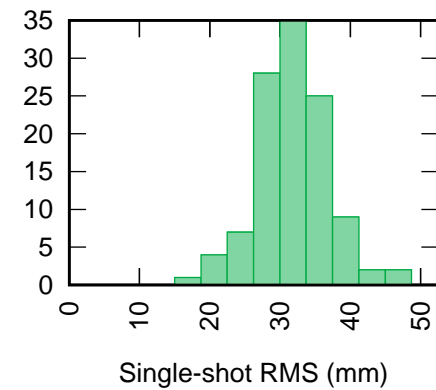
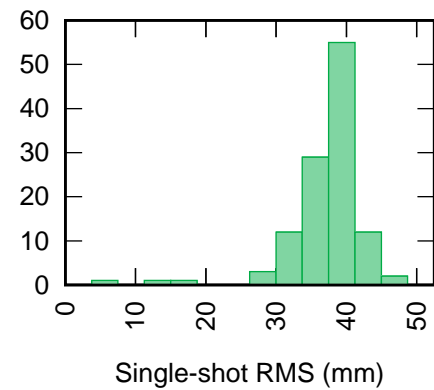
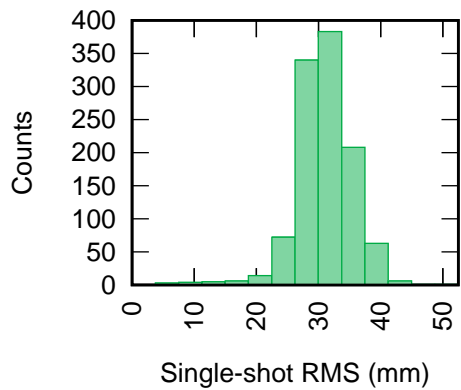
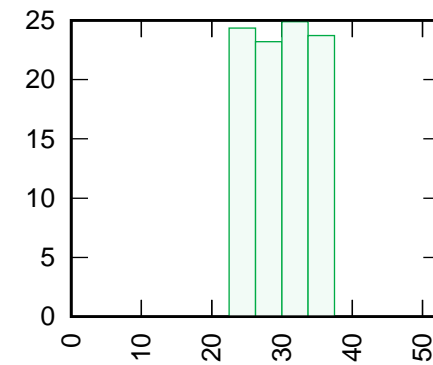
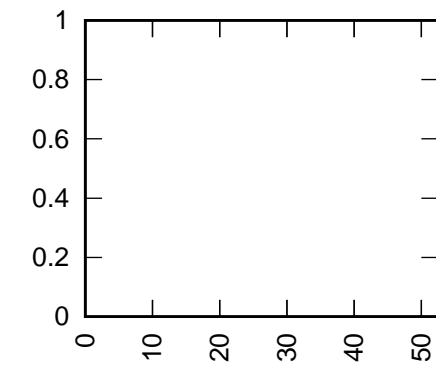
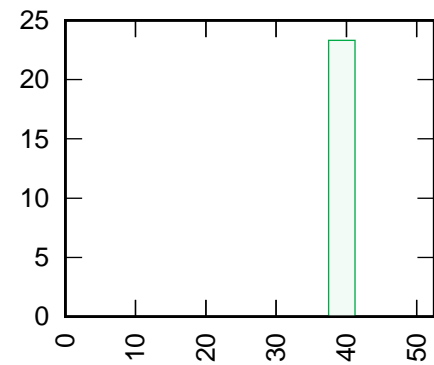
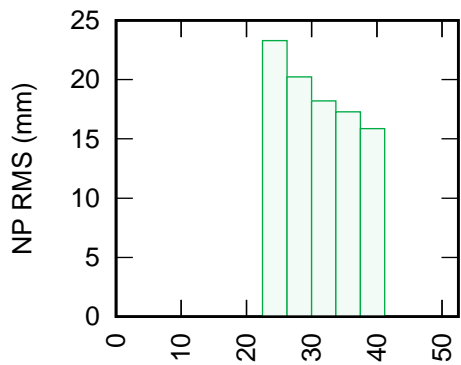
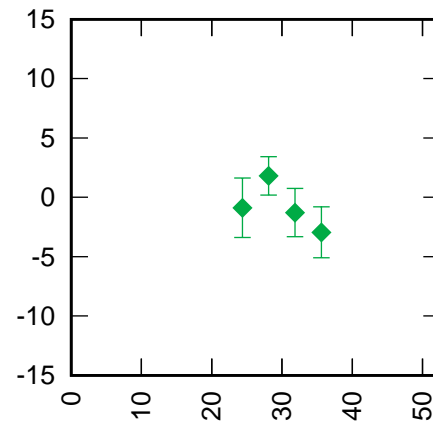
Komsomolsk 1868 AJI
CoM (CoM 1013 mm) RB 14.8 mm +



Komsomolsk 1868 STRL+STEL
(CoM 75 mm) RB -27.7 mm +



Komsomolsk 1868 LARS
CoM (CoM 133 mm) RB -8.2 mm +



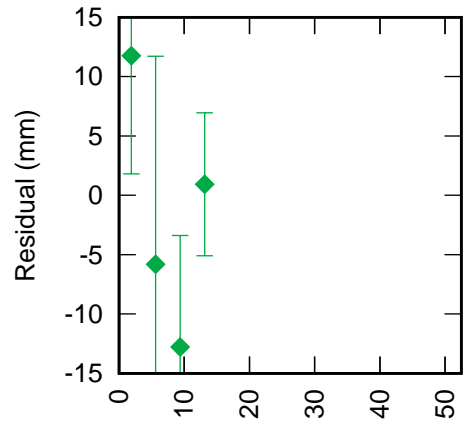
Single-shot RMS (mm)

Single-shot RMS (mm)

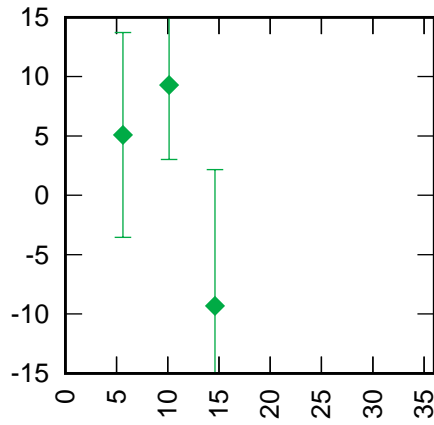
Single-shot RMS (mm)

Single-shot RMS (mm)

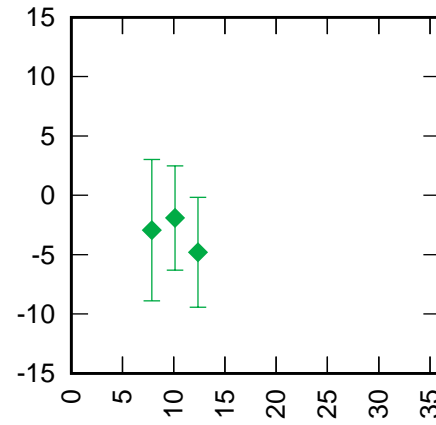
Simeiz 1873 LAG1+LAG2
(CoM 246 mm) RB 3.0 mm +



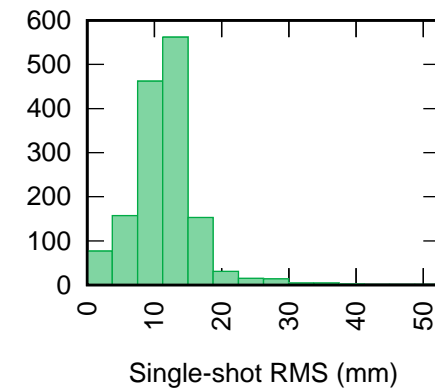
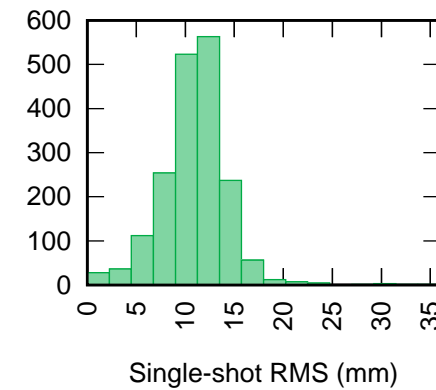
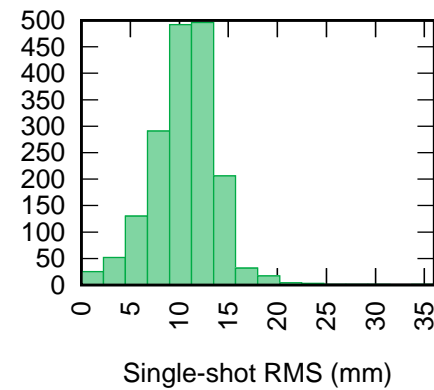
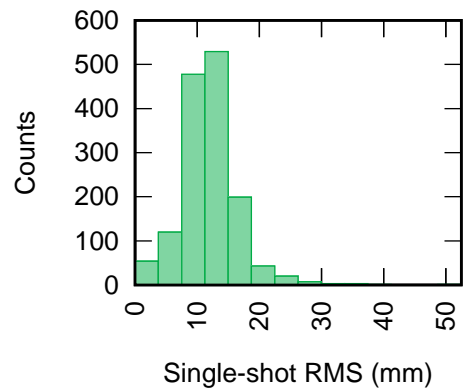
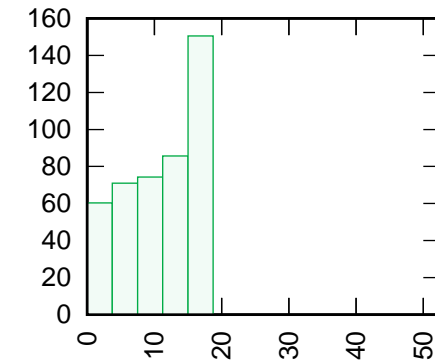
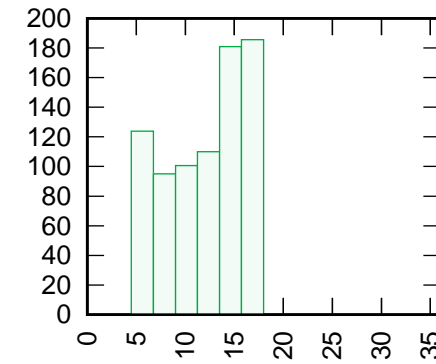
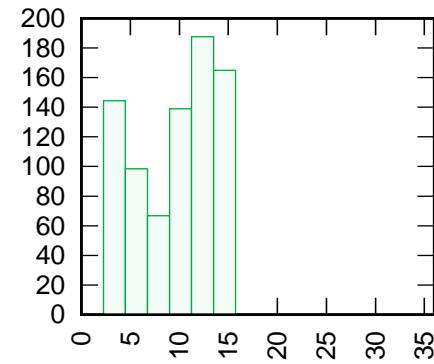
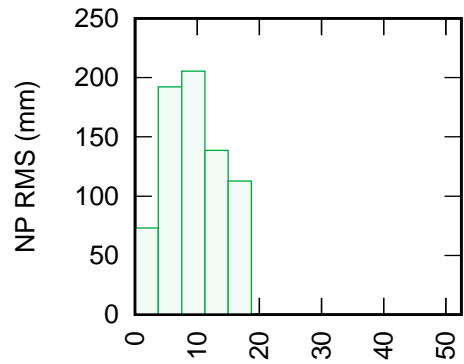
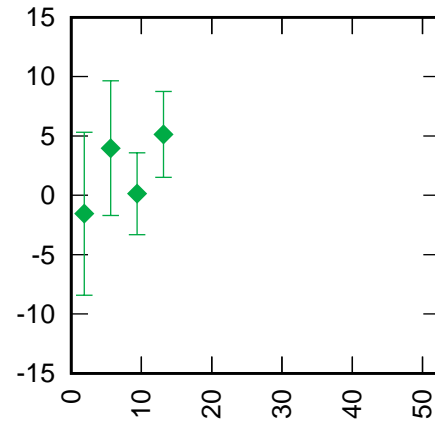
Simeiz 1873 AJI
CoM (CoM 1009 mm) RB 10.1 mm +



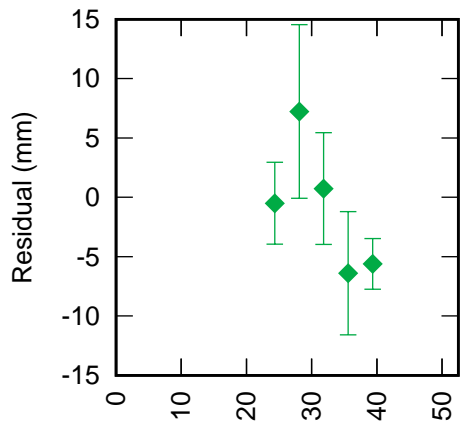
Simeiz 1873 STRL+STEL
(CoM 75 mm) RB -10.3 mm +



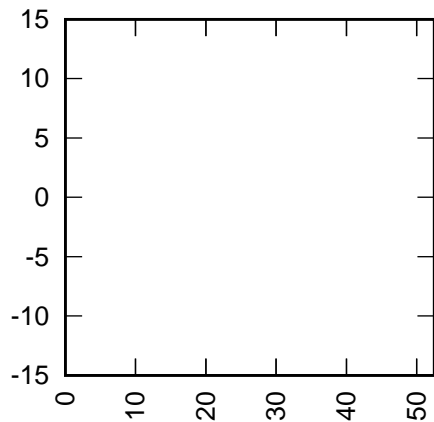
Simeiz 1873 LARS
CoM (CoM 133 mm) RB 20.1 mm +



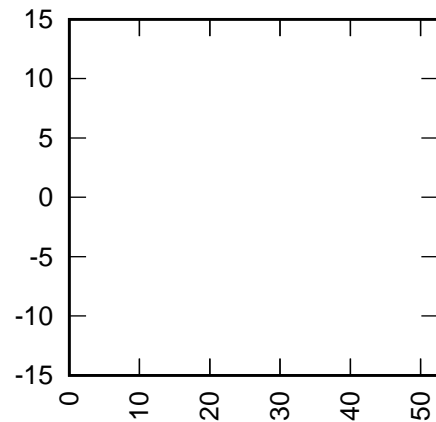
Altay 1879 LAG1+LAG2
(CoM 251 mm) RB 58.9 mm +



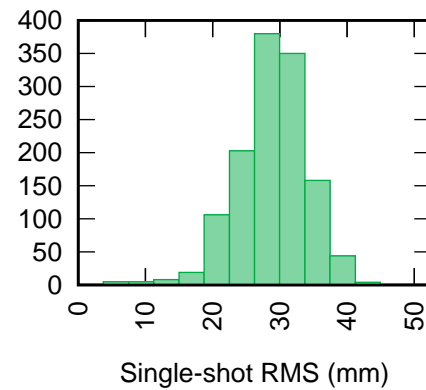
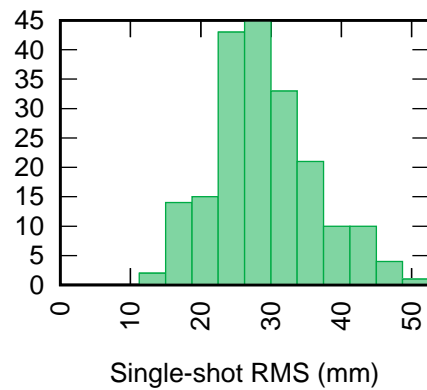
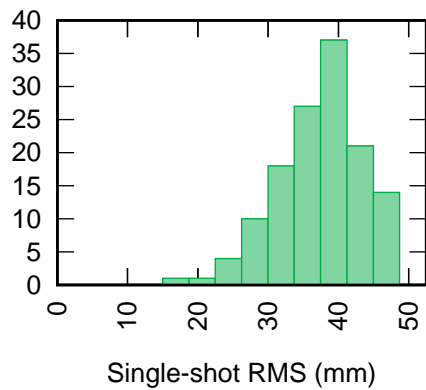
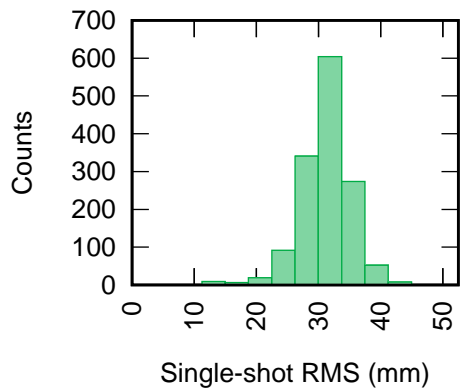
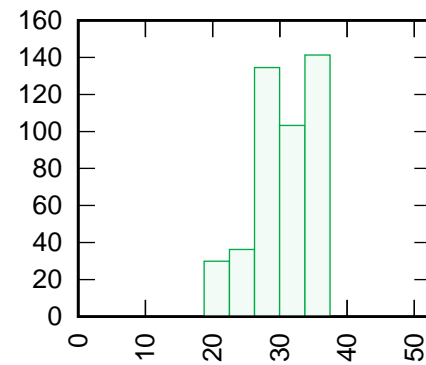
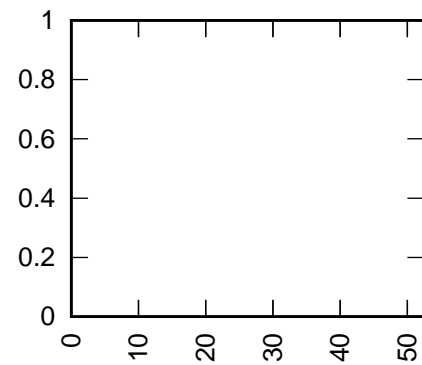
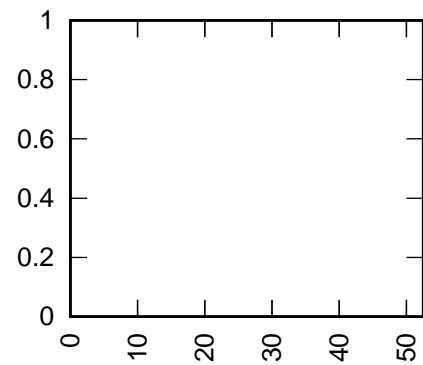
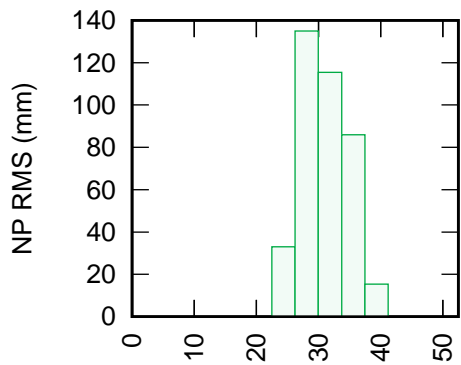
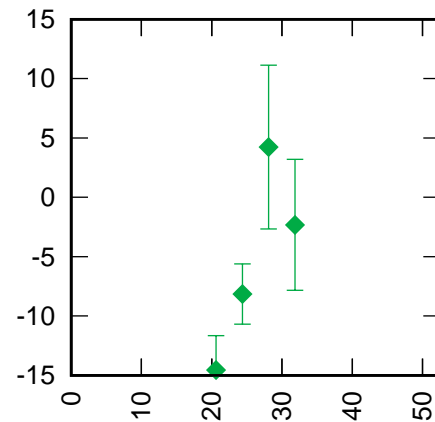
Altay 1879 AJI
(CoM 1013 mm) RB 60.2 mm +



Altay 1879 STRL+STEL
(CoM 75 mm) RB 30.2 mm +



Altay 1879 LARS
(CoM 133 mm) RB 53.9 mm +



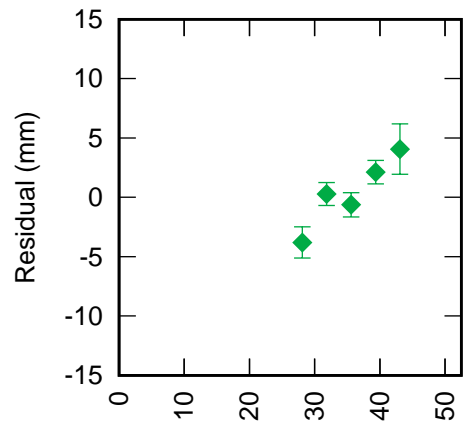
Single-shot RMS (mm)

Single-shot RMS (mm)

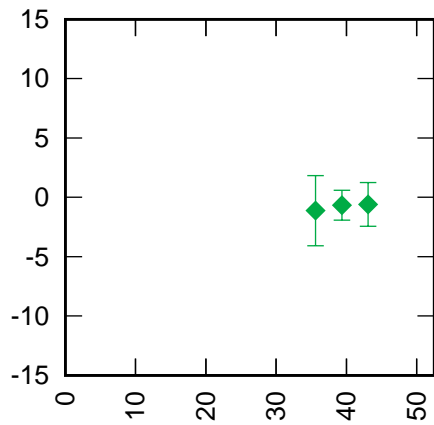
Single-shot RMS (mm)

Single-shot RMS (mm)

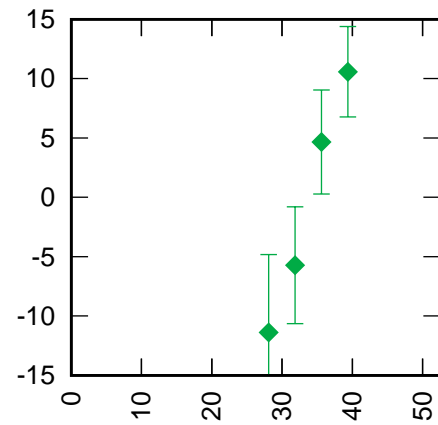
Arkhyz 1886 LAG1+LAG2
(CoM 248 mm) RB -84.5 mm +



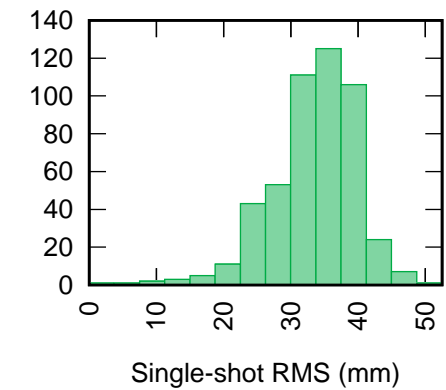
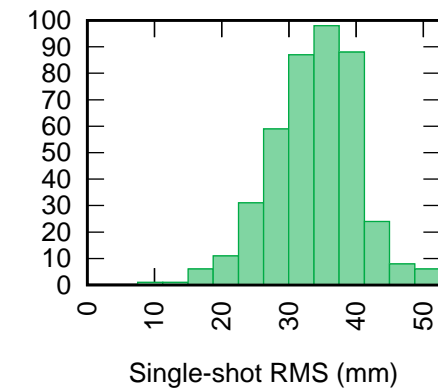
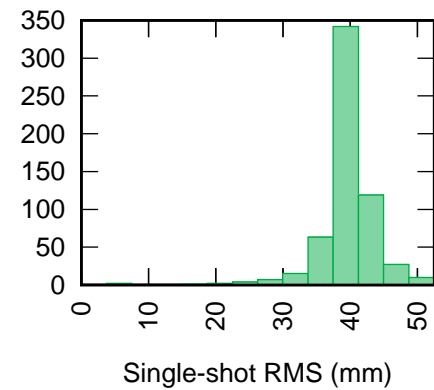
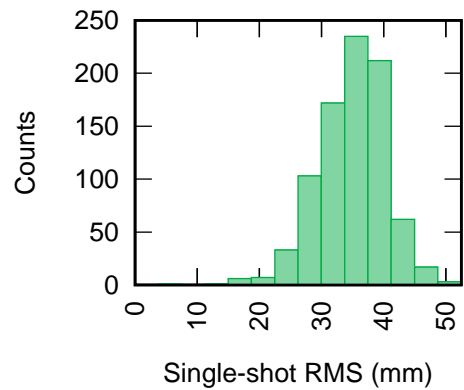
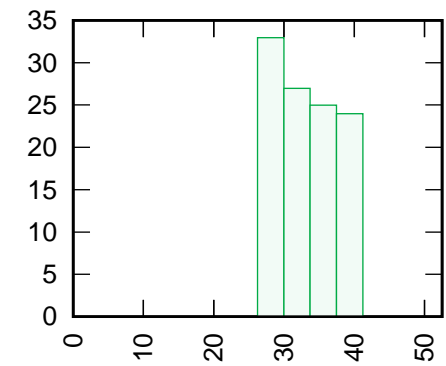
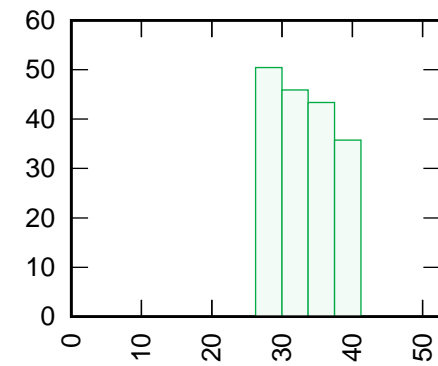
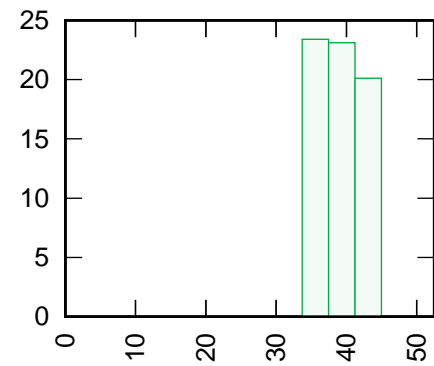
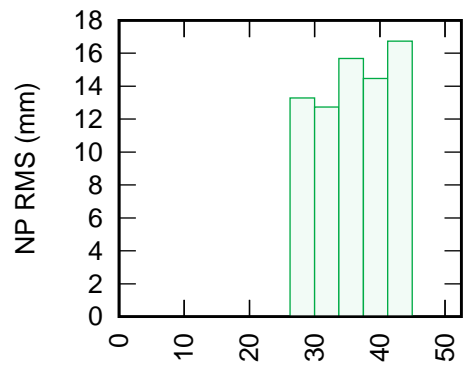
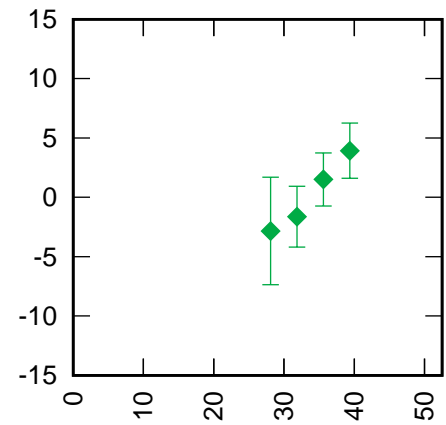
Arkhyz 1886 AJI
(CoM 1009 mm) RB -68.4 mm +



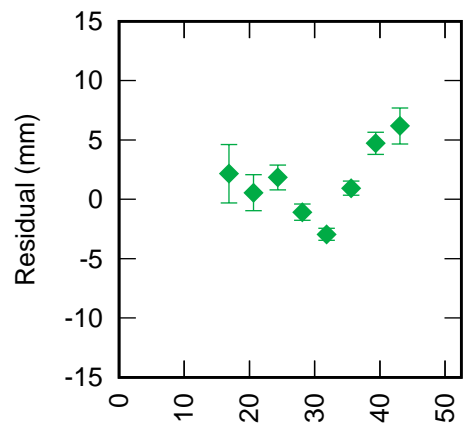
Arkhyz 1886 STRL+STEL
(CoM 75 mm) RB -100.5 mm +



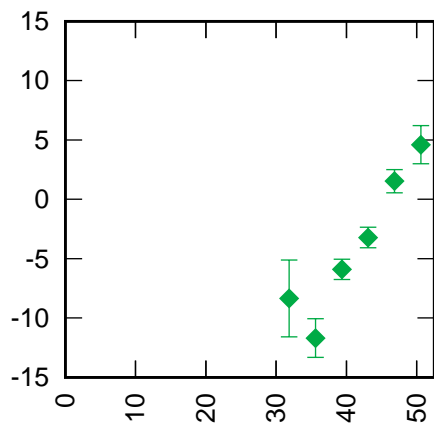
Arkhyz 1886 LARS
(CoM 133 mm) RB -84.0 mm +



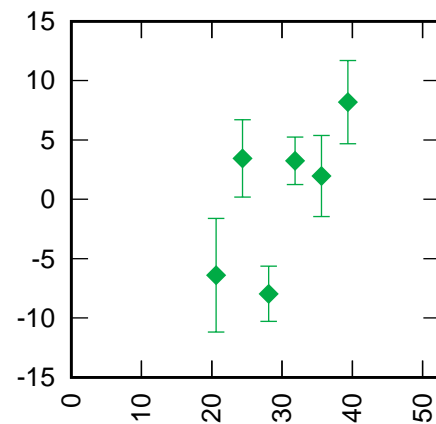
Svetloe 1888 LAG1+LAG2
(CoM 248 mm) RB 5.8 mm +



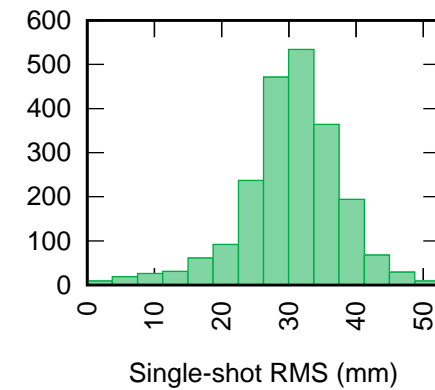
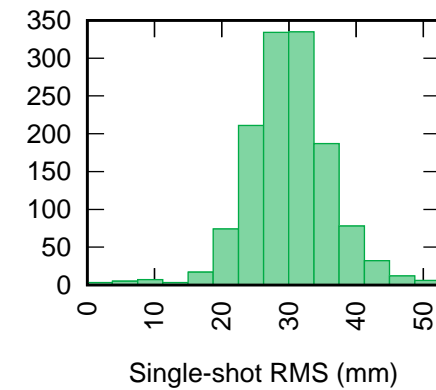
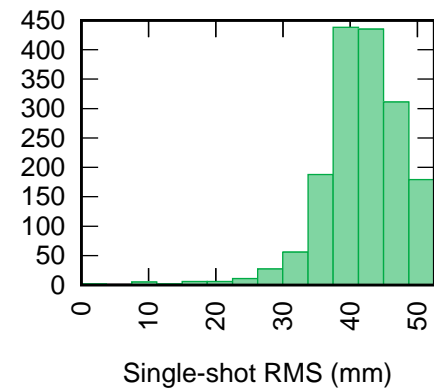
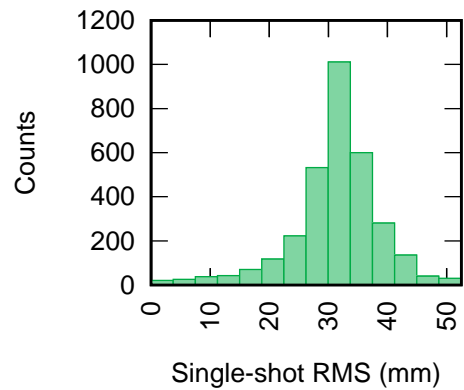
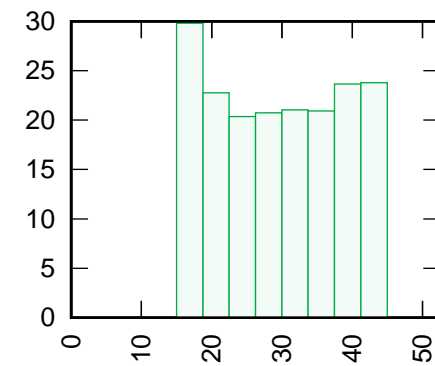
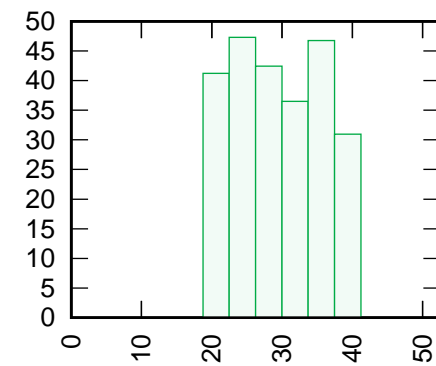
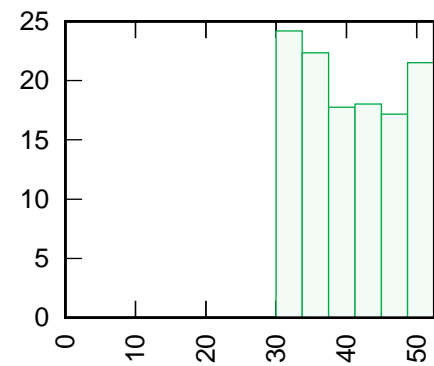
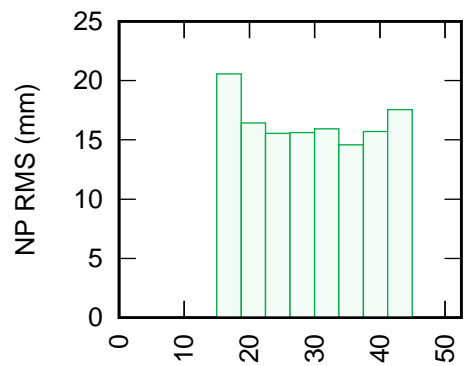
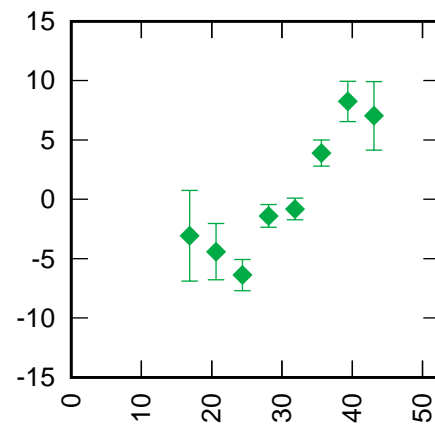
Svetloe 1888 AJI
(CoM 1009 mm) RB 30.2 mm +



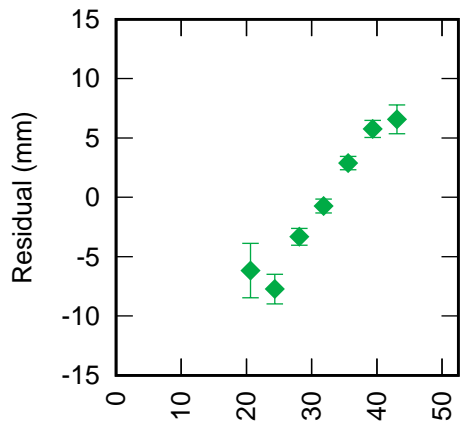
Svetloe 1888 STRL+STEL
(CoM 75 mm) RB 1.4 mm +



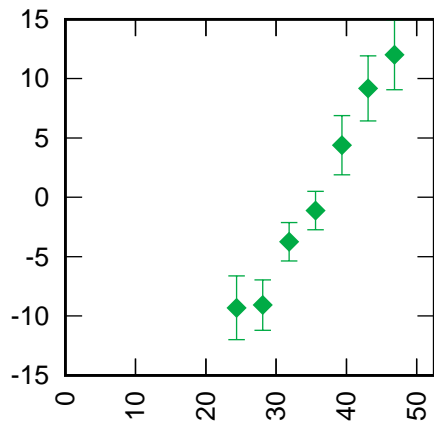
Svetloe 1888 LARS
(CoM 133 mm) RB 8.1 mm +



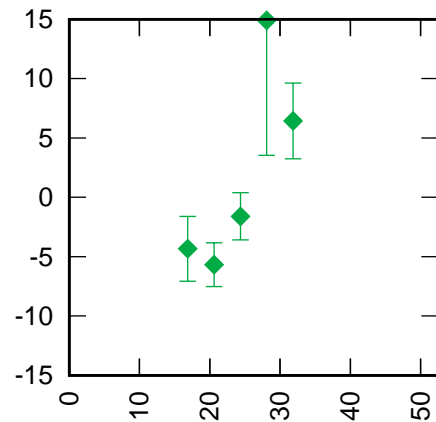
Zelenchukskya 1889 LAG1+LAG2
(CoM 248 mm) RB 17.9 mm +



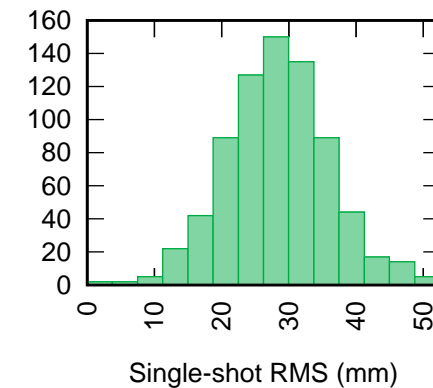
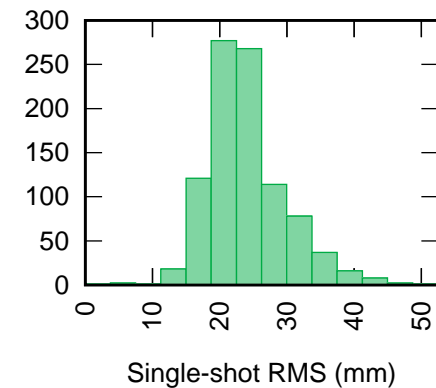
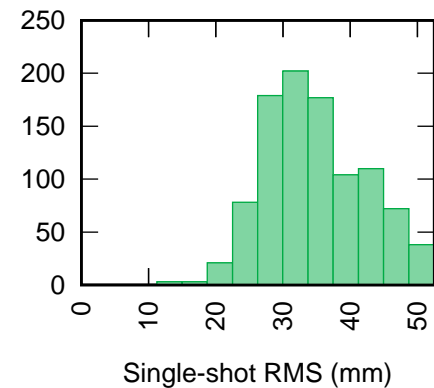
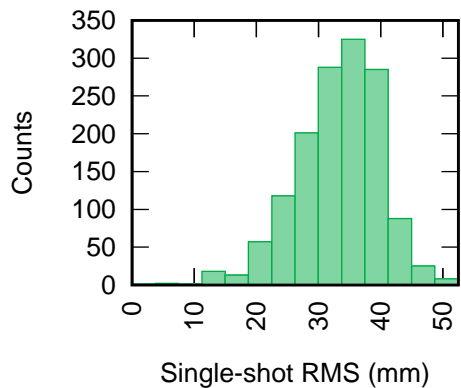
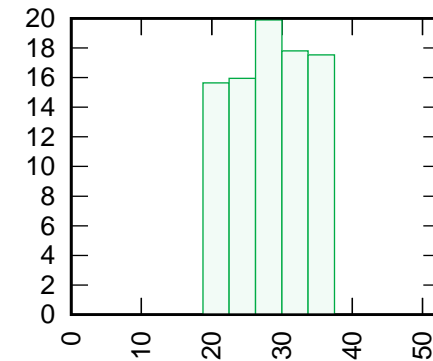
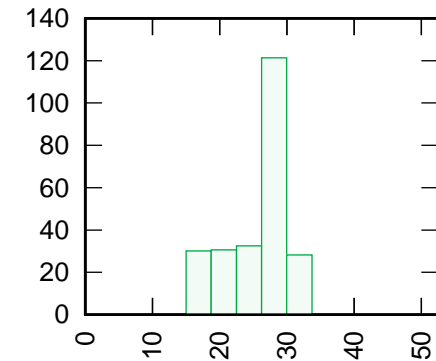
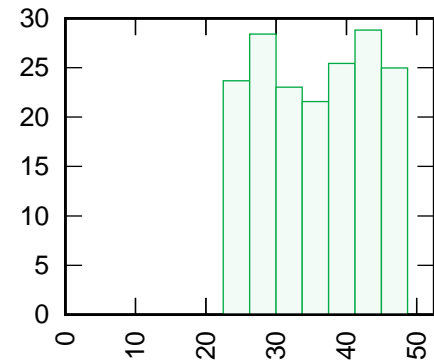
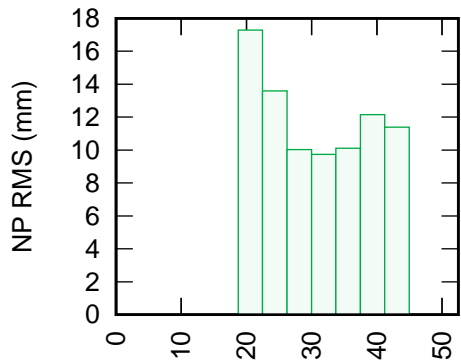
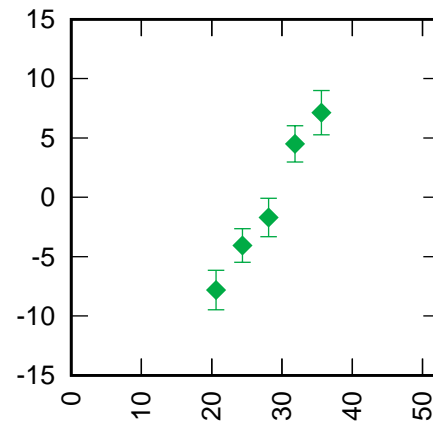
Zelenchukskya 1889 AJI
CoM (CoM 1009 mm) RB 34.1 mm +



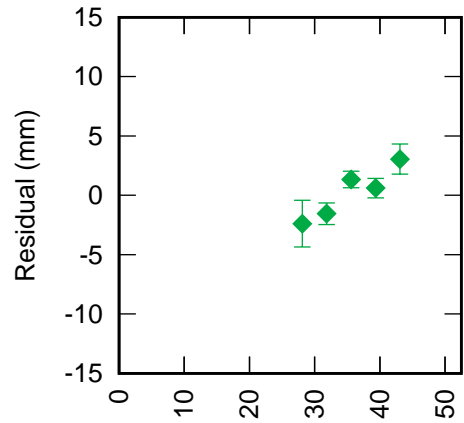
Zelenchukskya 1889 STRL+STEL
(CoM 75 mm) RB 4.3 mm +



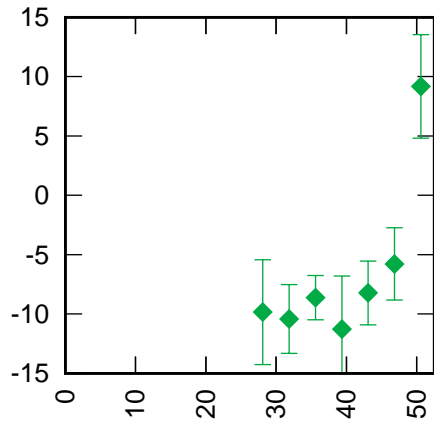
Zelenchukskya 1889 LARS
CoM (CoM 133 mm) RB 15.8 mm +



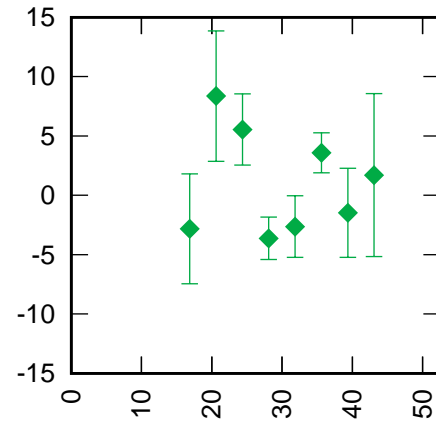
Badary 1890 LAG1+LAG2
(CoM 248 mm) RB 12.1 mm +



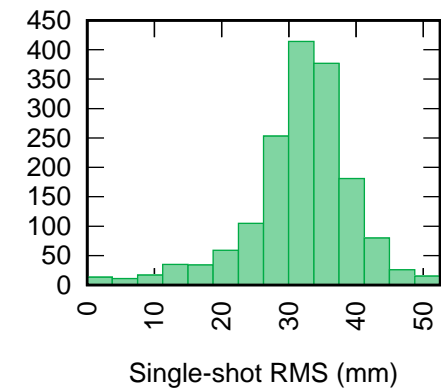
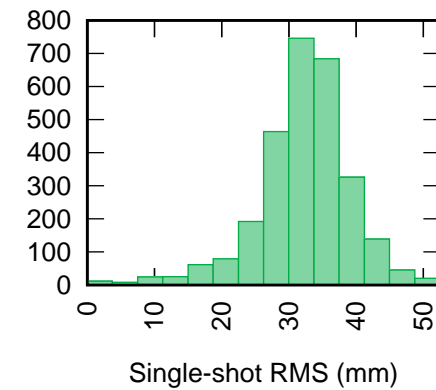
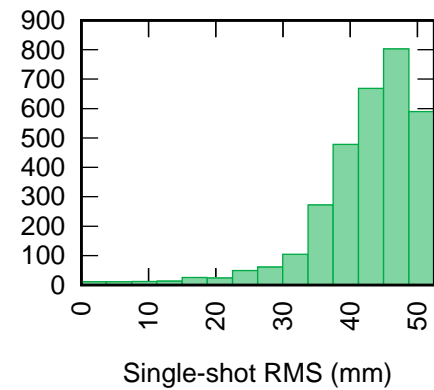
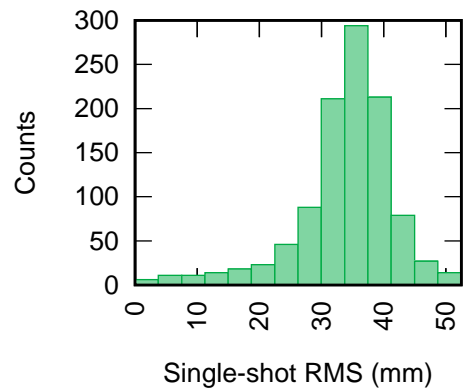
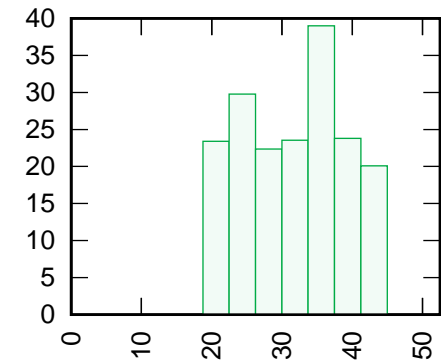
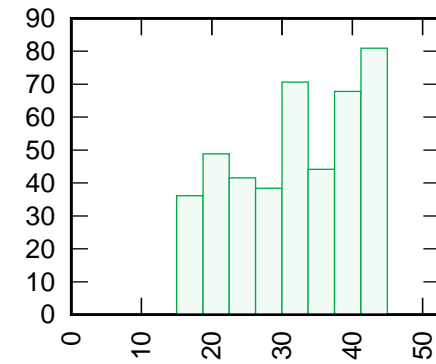
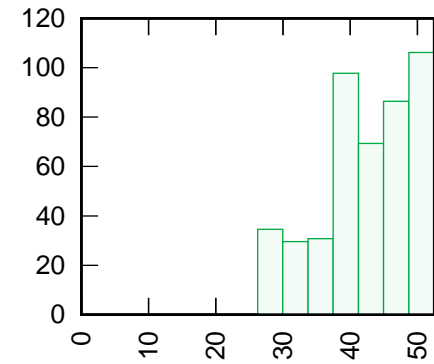
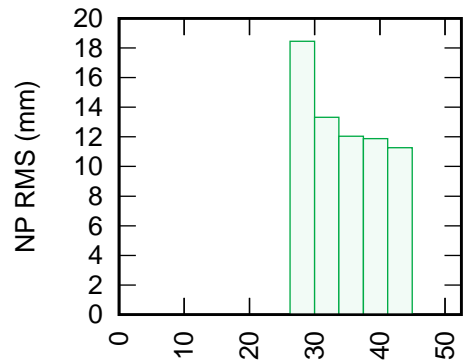
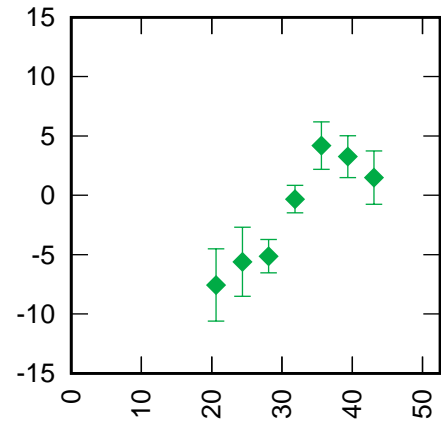
Badary 1890 AJI
(CoM 1009 mm) RB 35.7 mm +

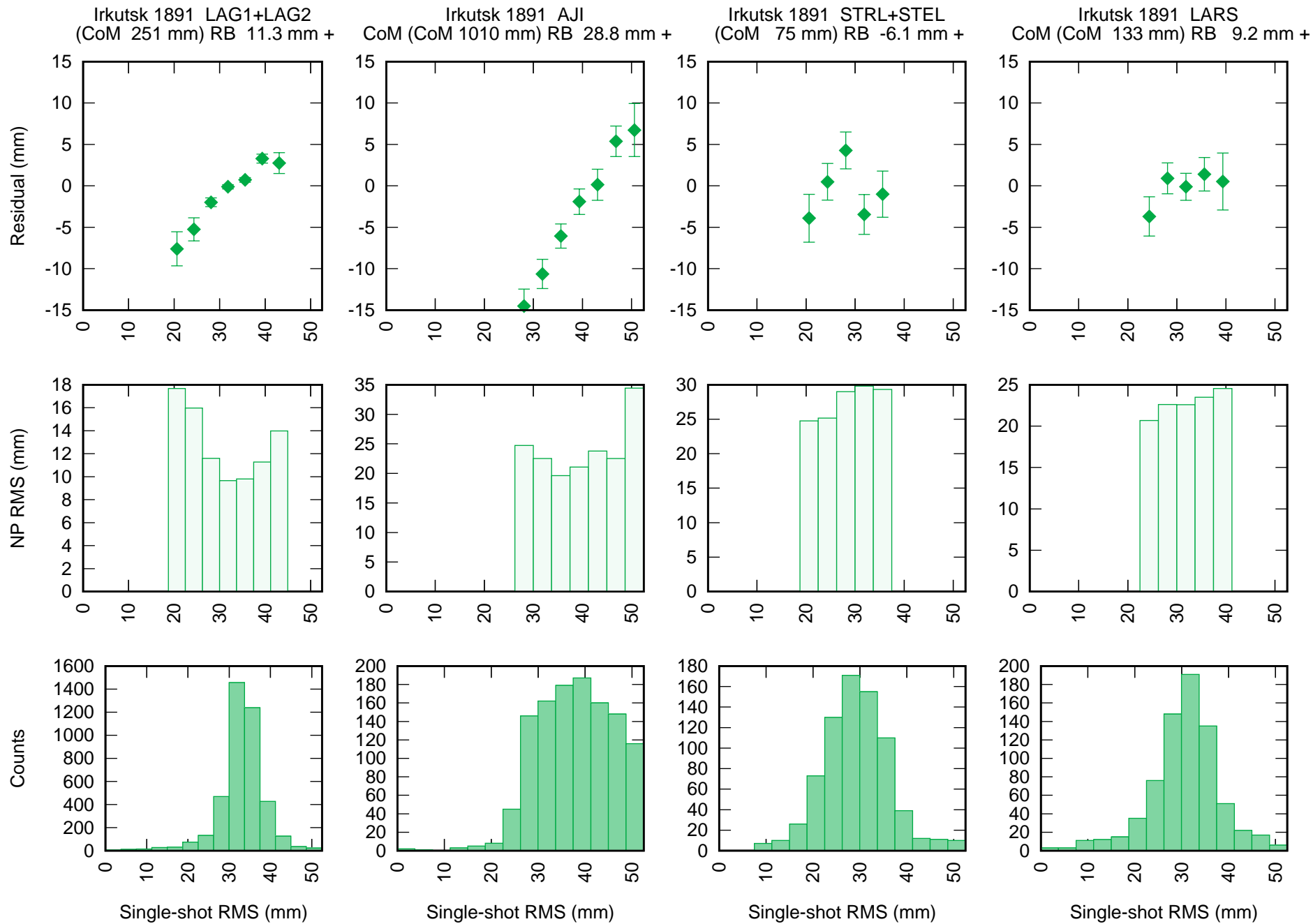


Badary 1890 STRL+STEL
(CoM 75 mm) RB 0.3 mm +

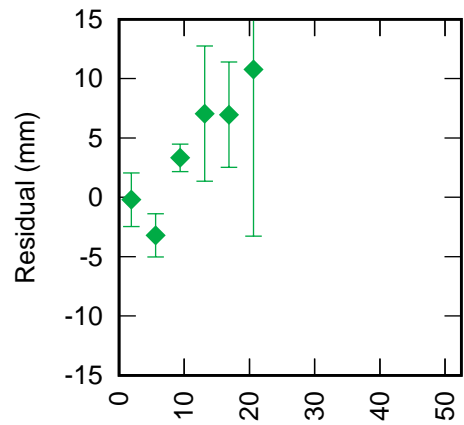


Badary 1890 LARS
(CoM 133 mm) RB 11.4 mm +

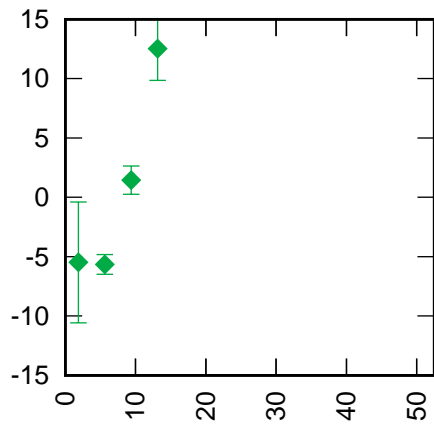




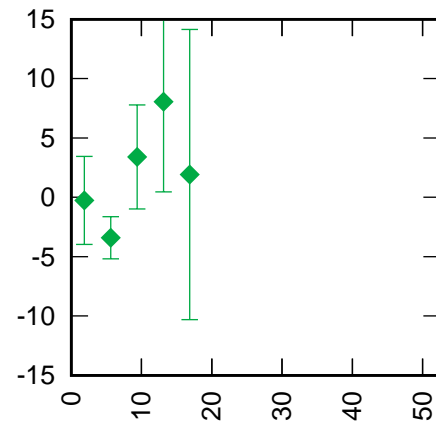
Katzively 1893 LAG1+LAG2
(CoM 246 mm) RB -46.5 mm +



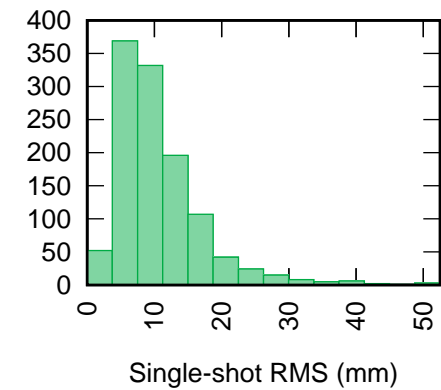
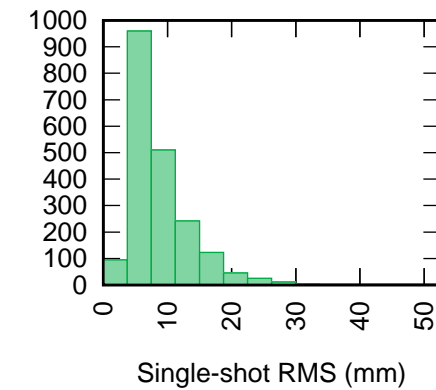
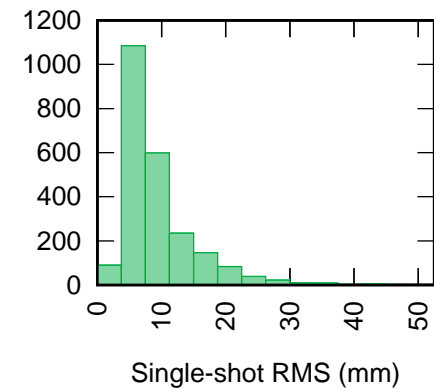
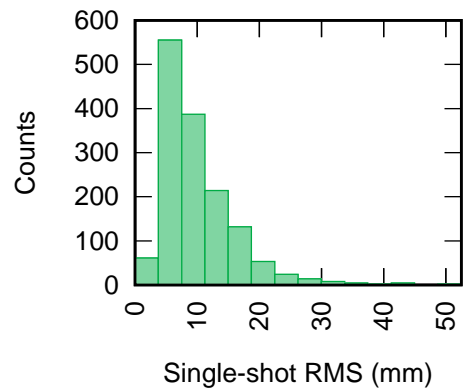
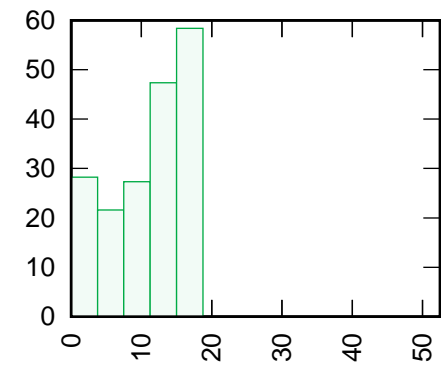
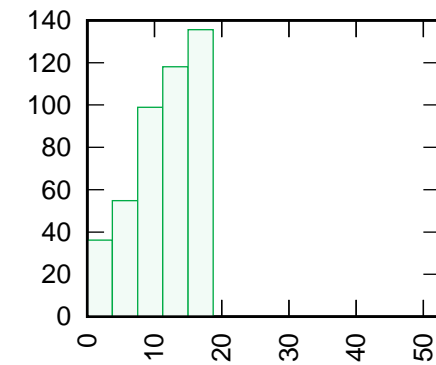
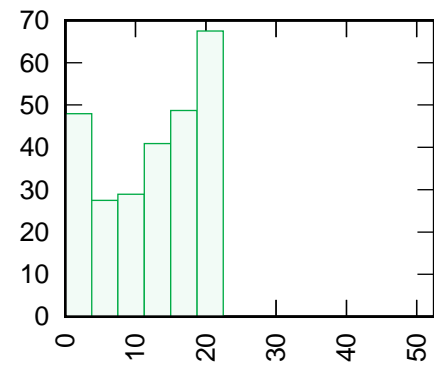
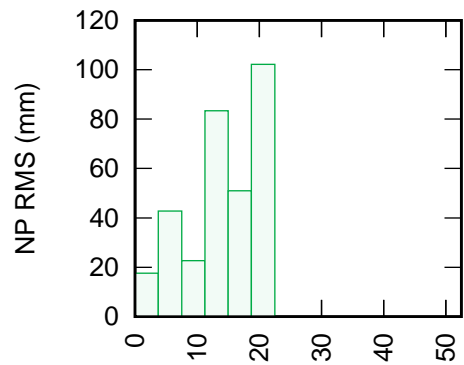
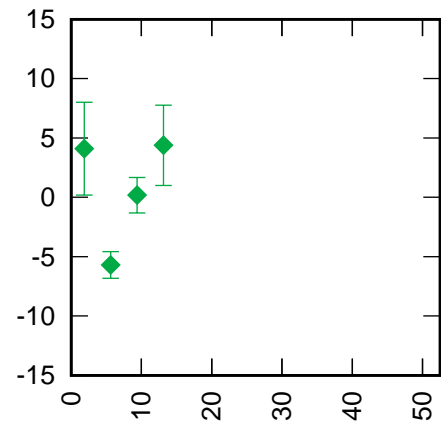
Katzively 1893 AJI
CoM (CoM 1009 mm) RB -33.9 mm +

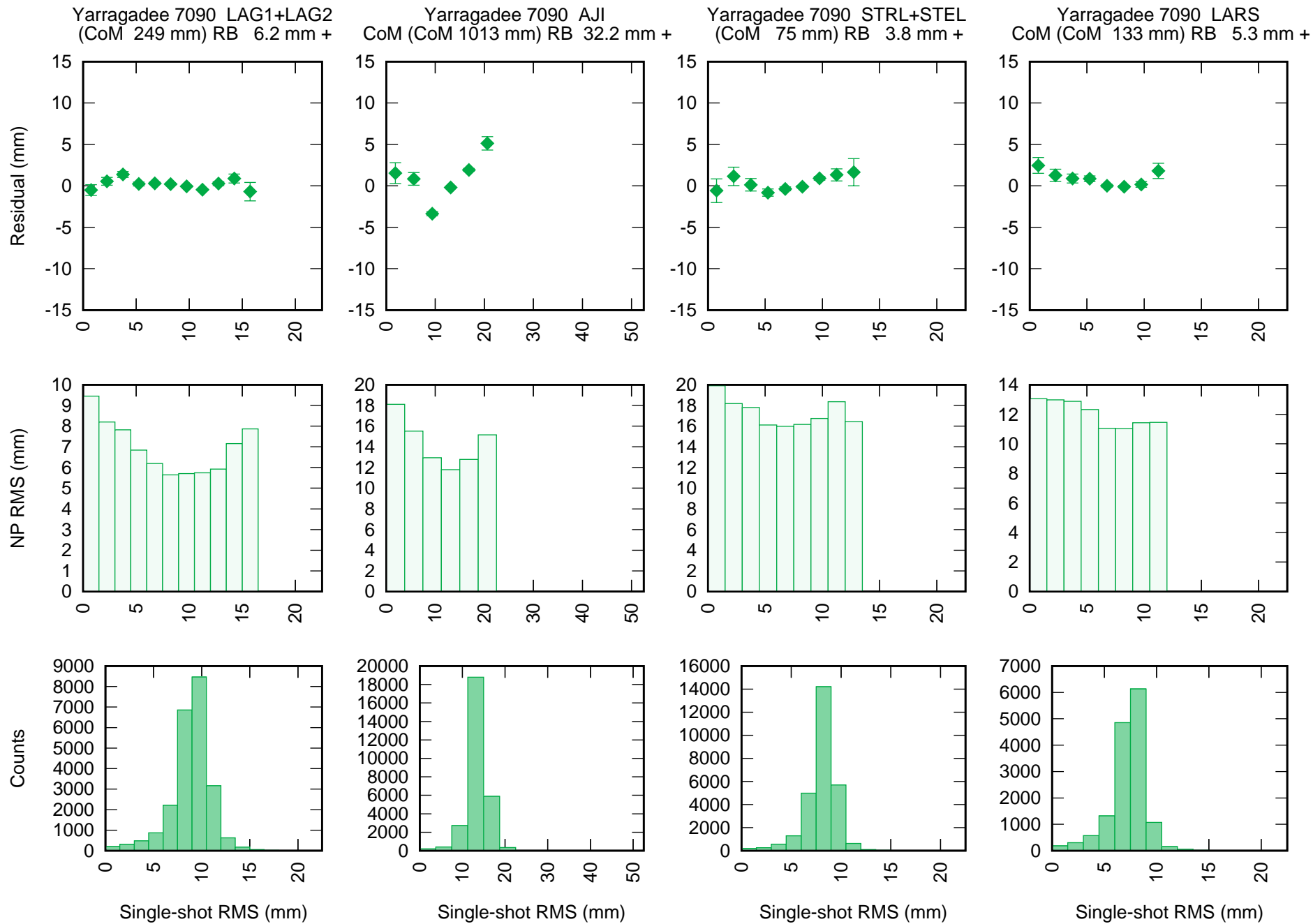


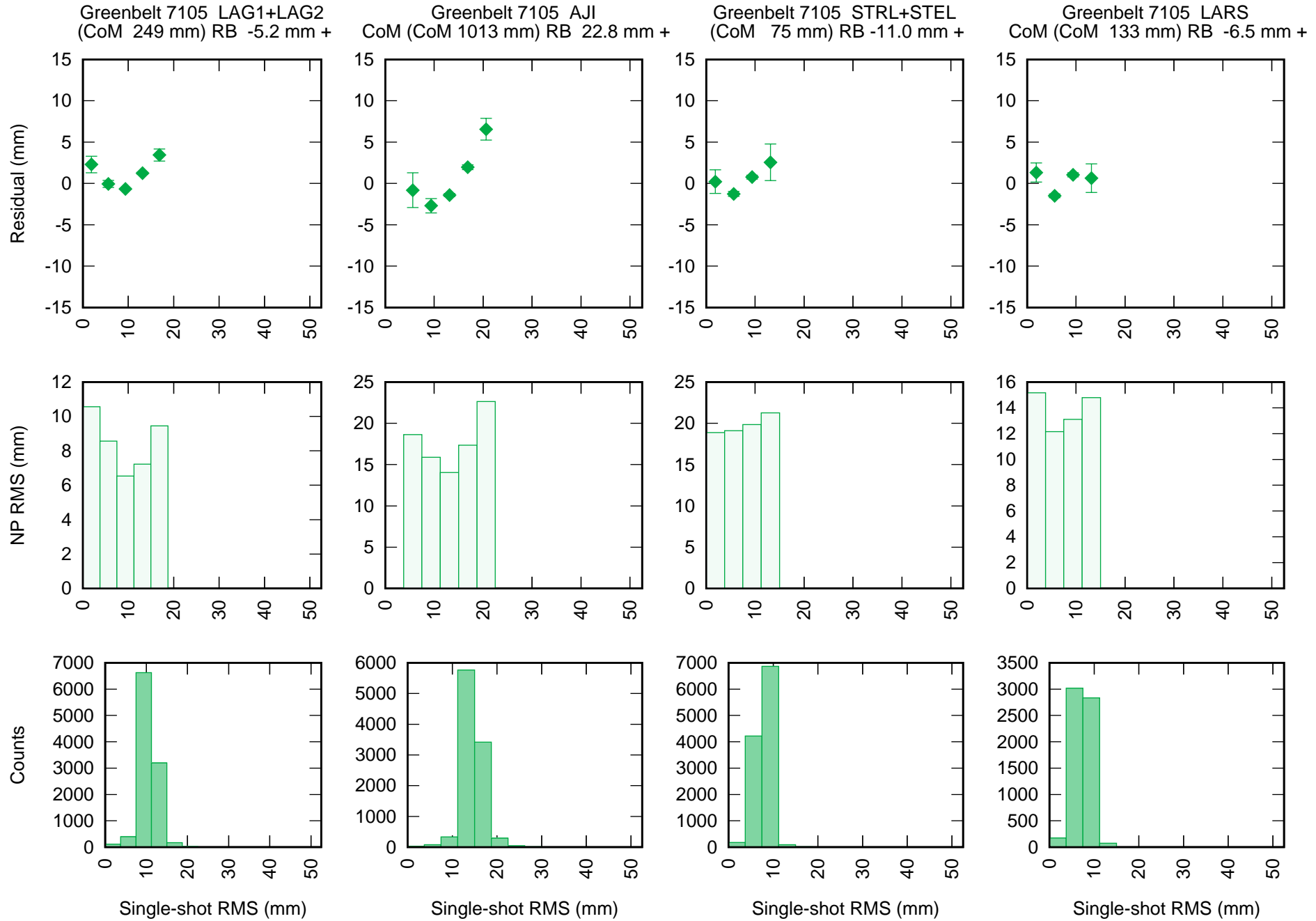
Katzively 1893 STRL+STEL
(CoM 75 mm) RB -54.5 mm +



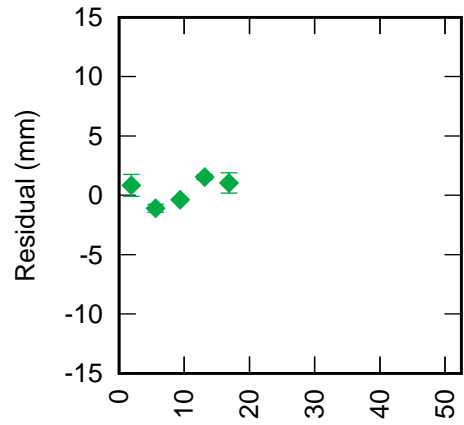
Katzively 1893 LARS
CoM (CoM 133 mm) RB -44.5 mm +



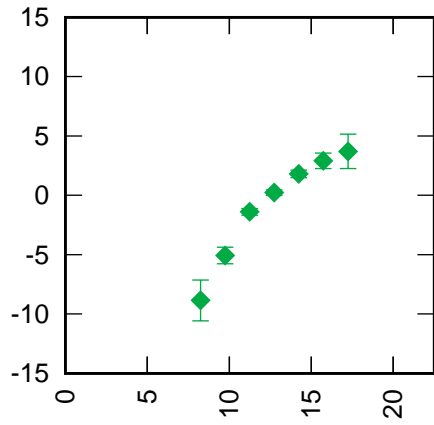




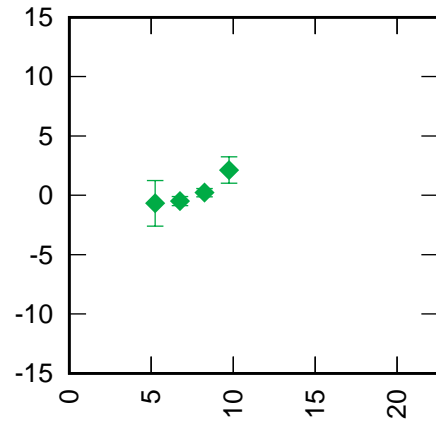
Monument Peak 7110 LAG1+LAG2
(CoM 249 mm) RB 2.3 mm +



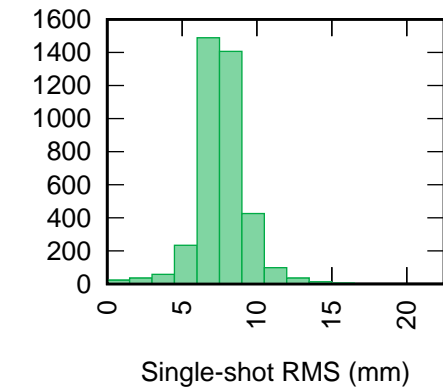
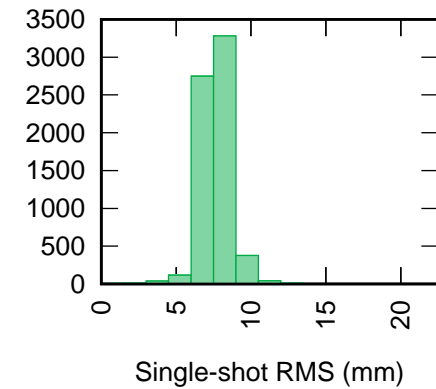
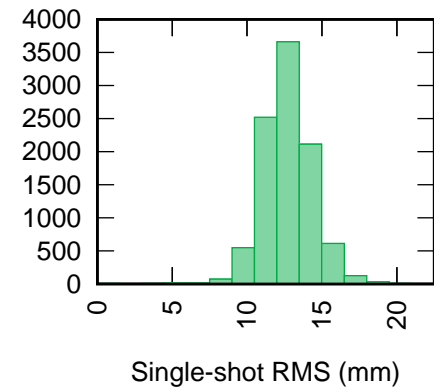
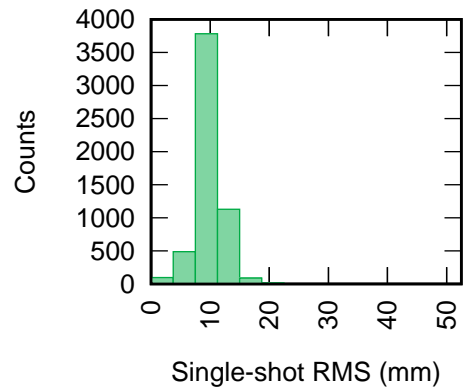
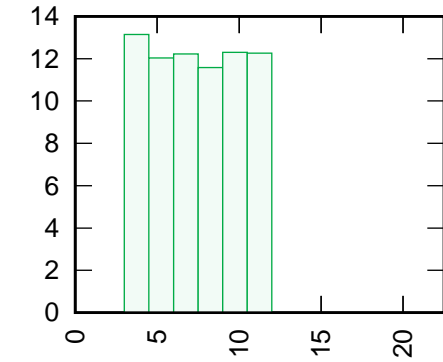
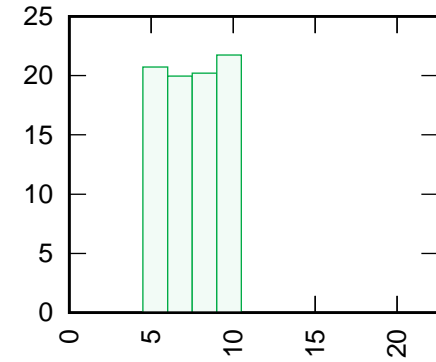
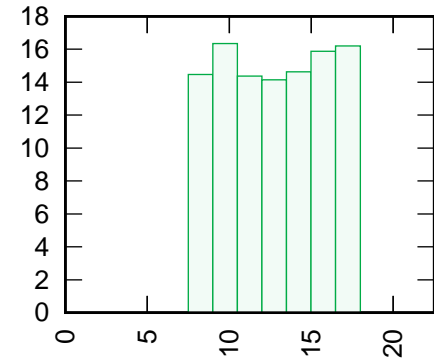
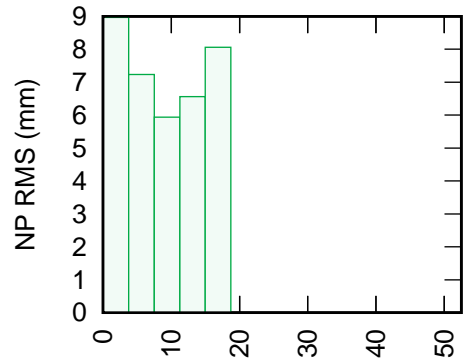
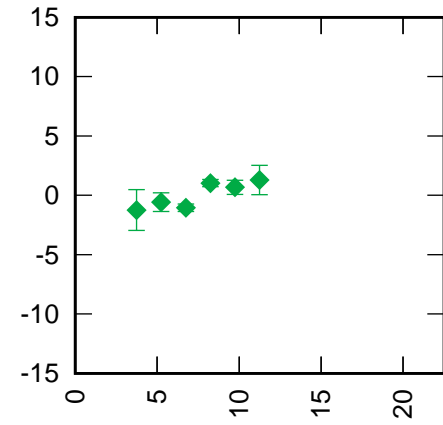
Monument Peak 7110 AJI
(CoM 1013 mm) RB 31.9 mm +

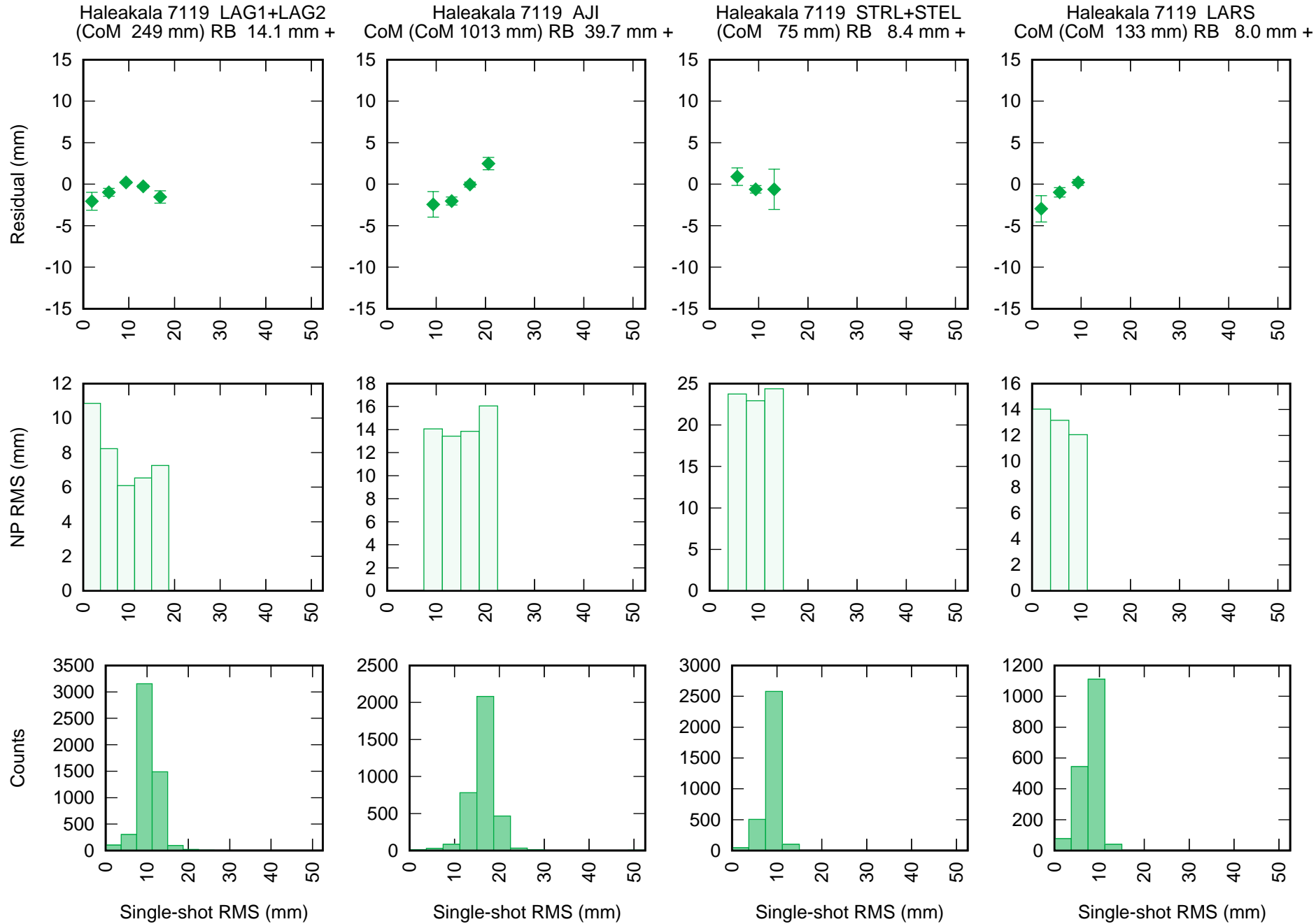


Monument Peak 7110 STRL+STEL
(CoM 75 mm) RB -0.3 mm +

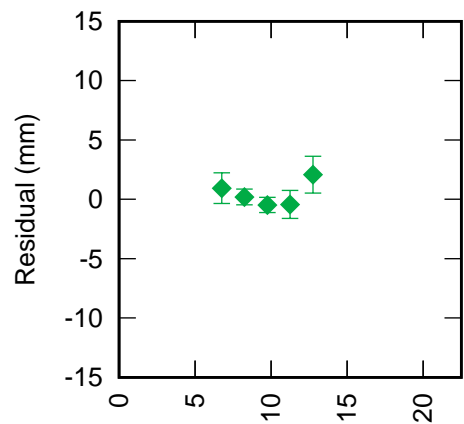


Monument Peak 7110 LARS
(CoM 133 mm) RB 3.8 mm +

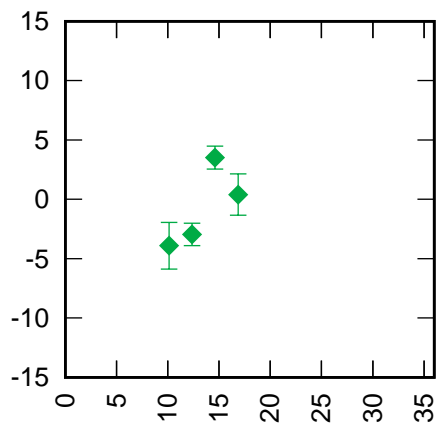




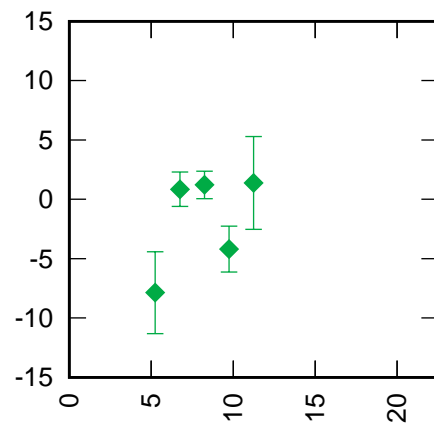
Tahiti 7124 LAG1+LAG2
(CoM 249 mm) RB -0.6 mm +



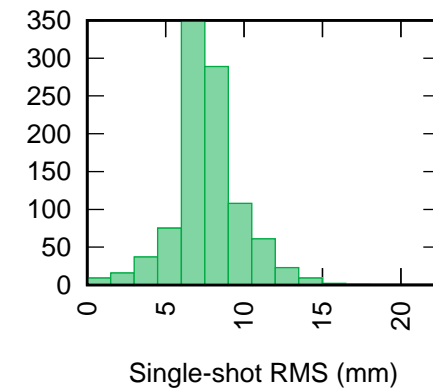
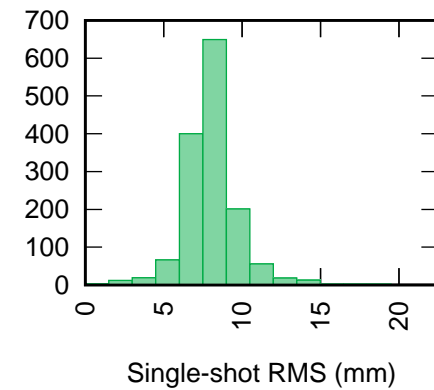
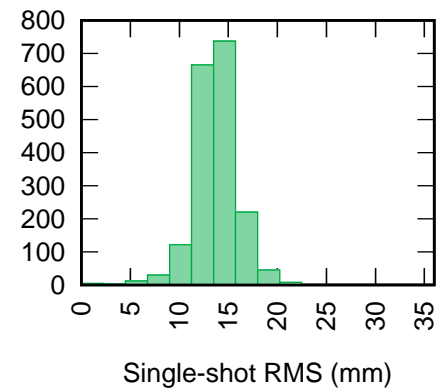
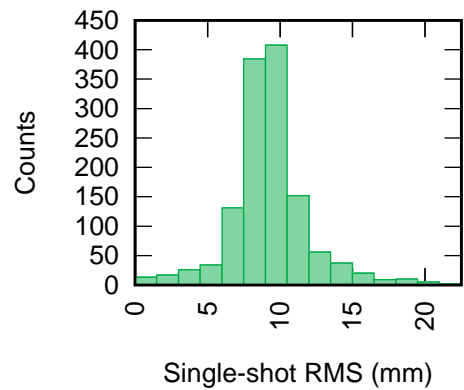
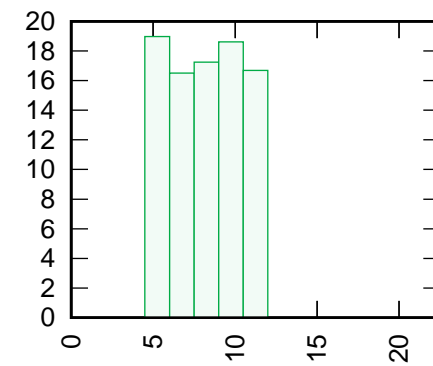
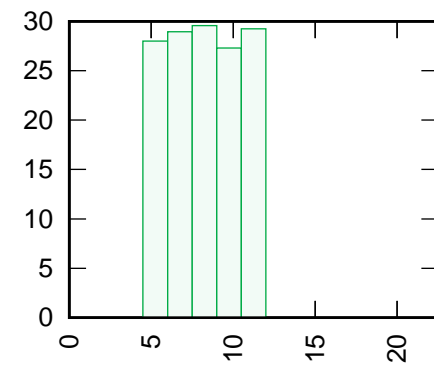
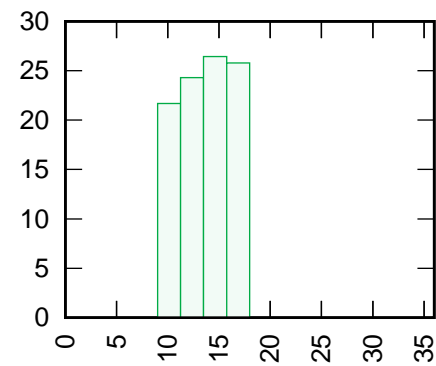
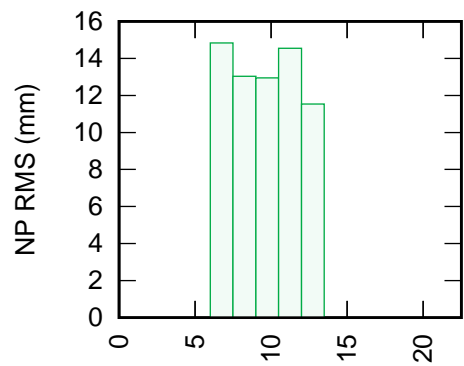
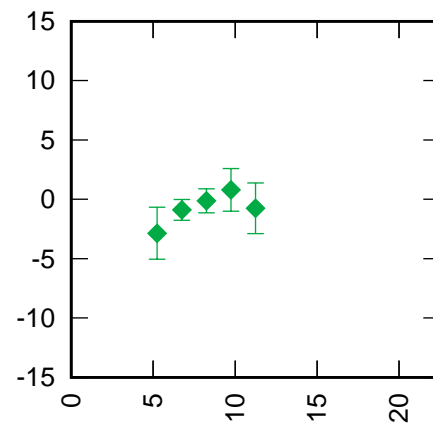
Tahiti 7124 AJI
CoM (CoM 1013 mm) RB 30.1 mm +



Tahiti 7124 STRL+STEL
(CoM 75 mm) RB -3.6 mm +



Tahiti 7124 LARS
CoM (CoM 133 mm) RB -4.6 mm +



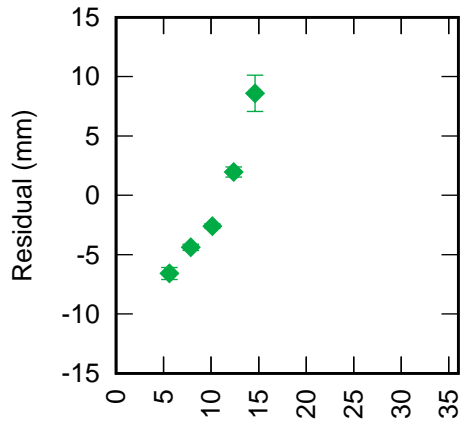
Single-shot RMS (mm)

Single-shot RMS (mm)

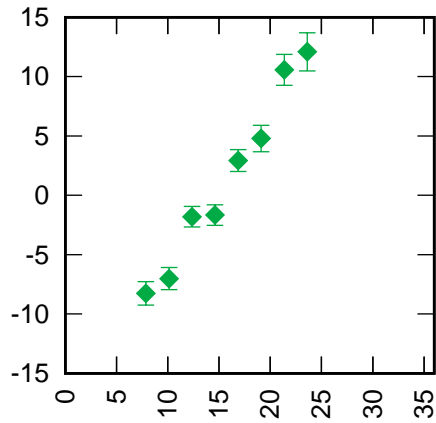
Single-shot RMS (mm)

Single-shot RMS (mm)

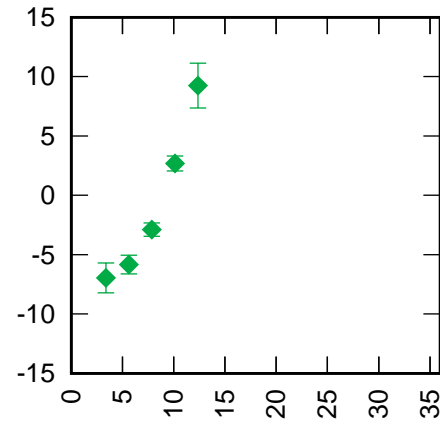
Changchun 7237 LAG1+LAG2
(CoM 252 mm) RB 11.7 mm +



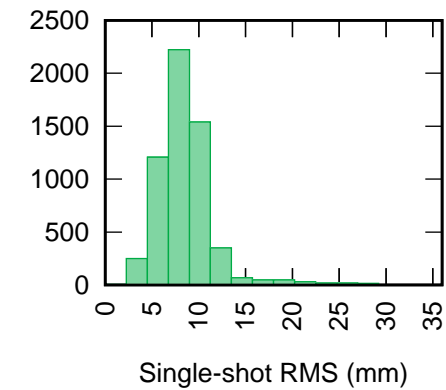
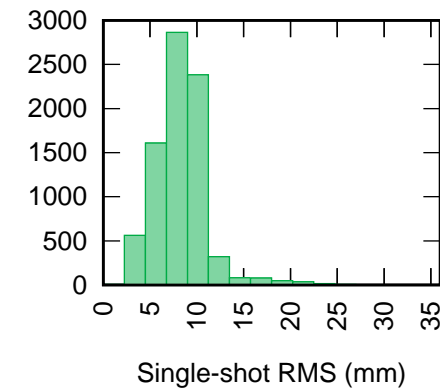
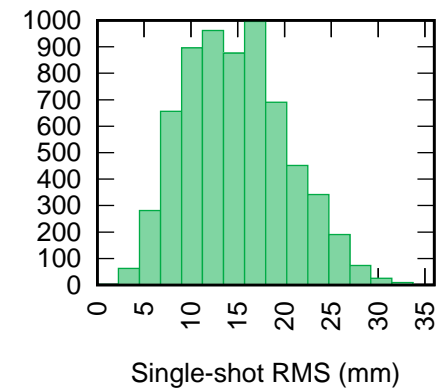
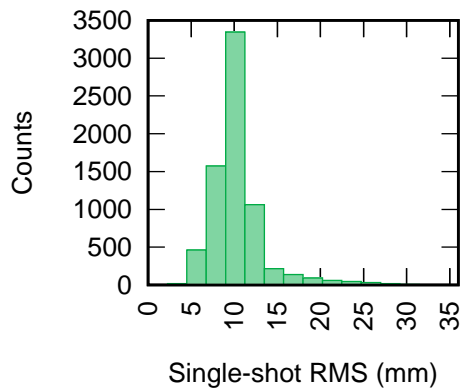
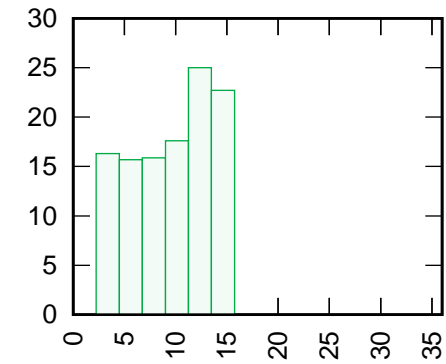
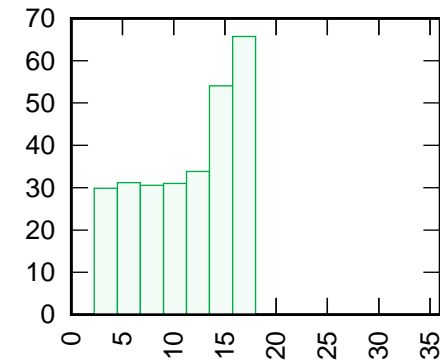
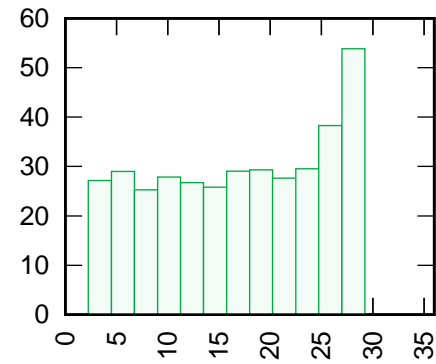
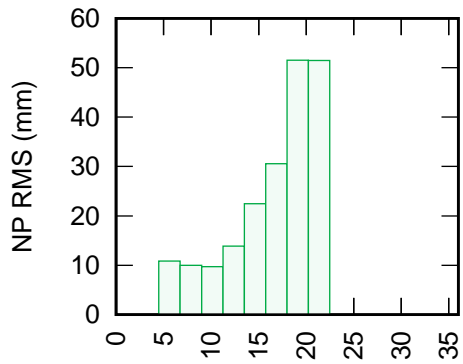
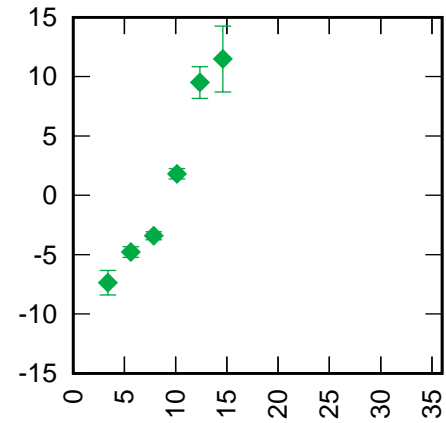
Changchun 7237 AJI
(CoM 1004 mm) RB 6.5 mm +



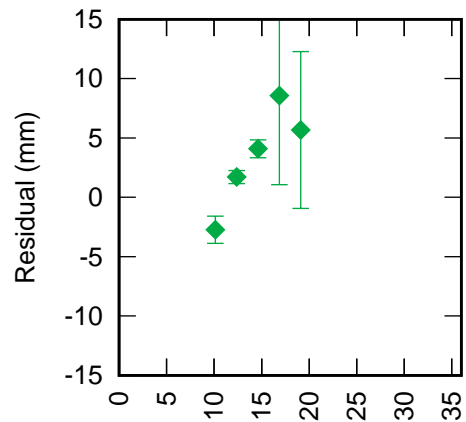
Changchun 7237 STRL+STEL
(CoM 75 mm) RB 3.2 mm +



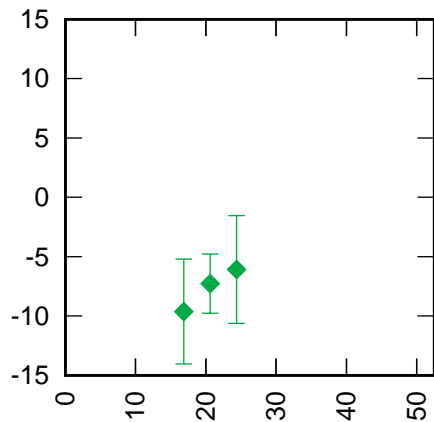
Changchun 7237 LARS
(CoM 133 mm) RB 9.3 mm +



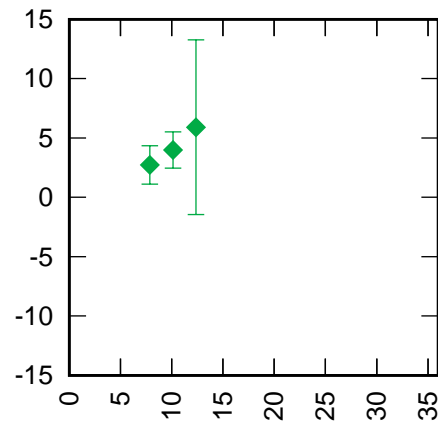
Beijing 7249 LAG1+LAG2
(CoM 252 mm) RB -10.4 mm +



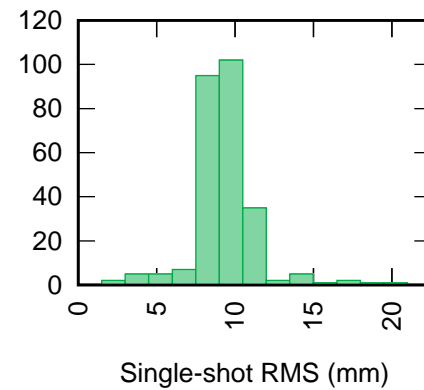
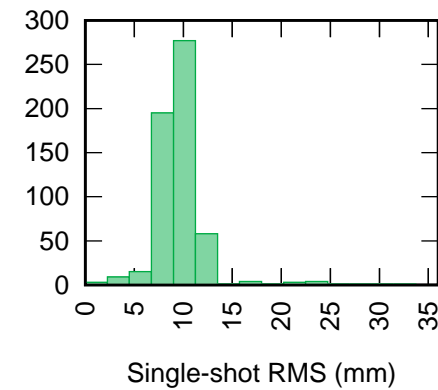
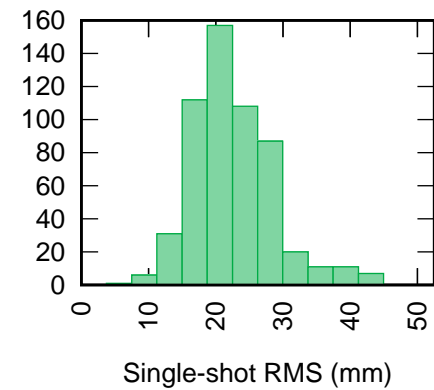
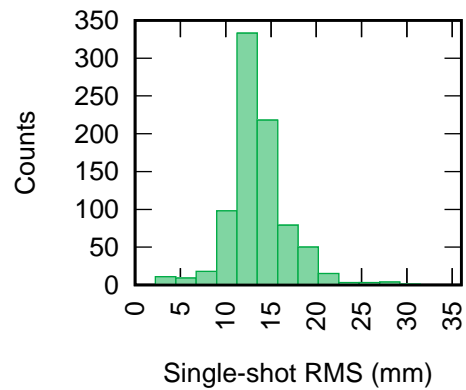
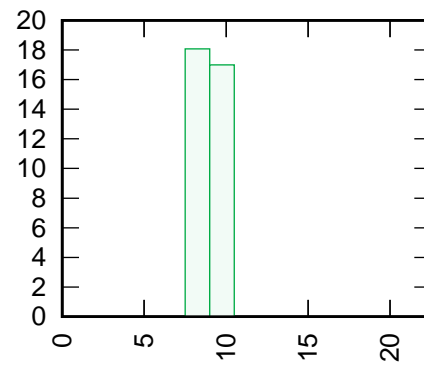
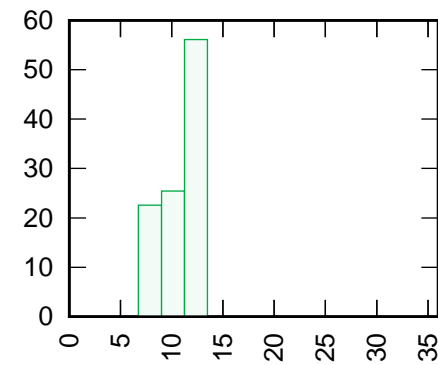
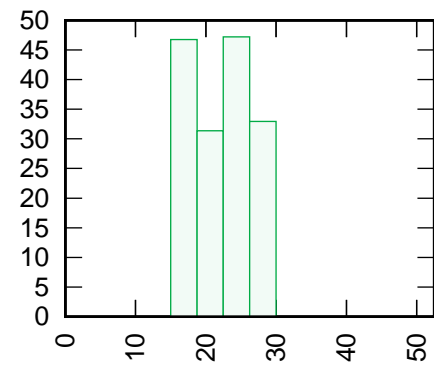
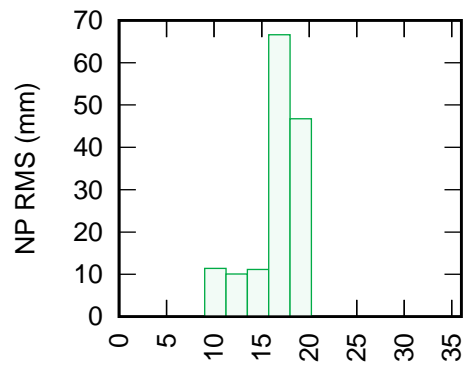
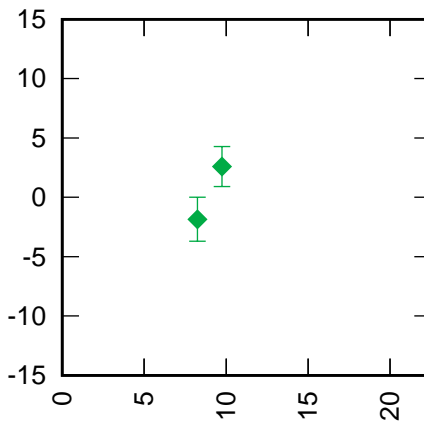
Beijing 7249 AJI
CoM (CoM 1004 mm) RB -6.3 mm +



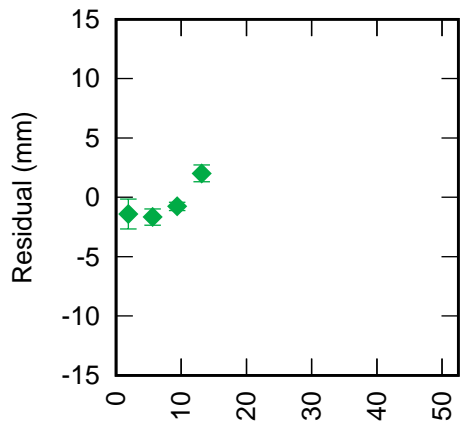
Beijing 7249 STRL+STEL
(CoM 75 mm) RB -19.0 mm +



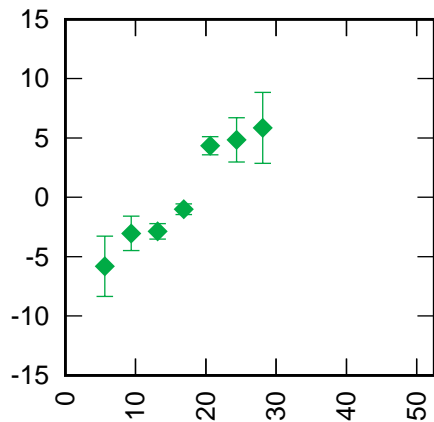
Beijing 7249 LARS
CoM (CoM 133 mm) RB -10.5 mm +



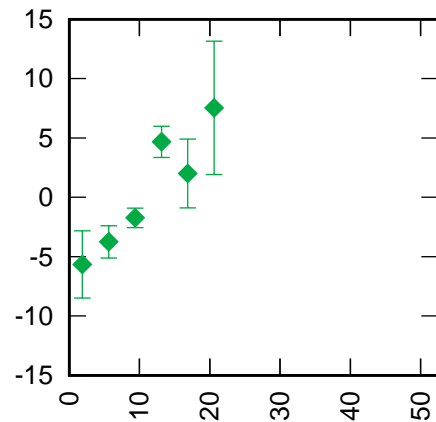
Arequipa 7403 LAG1+LAG2
(CoM 249 mm) RB 18.9 mm +



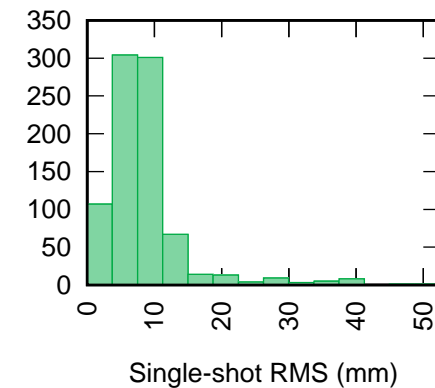
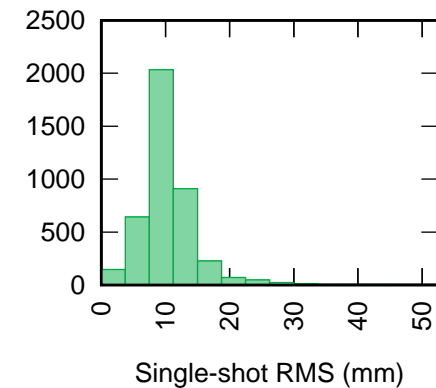
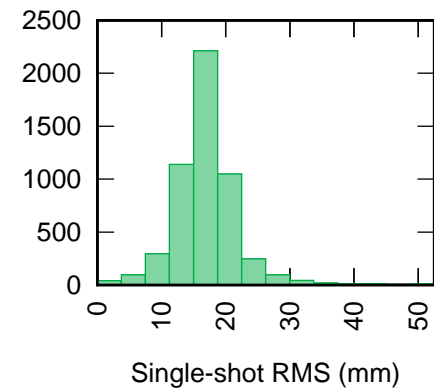
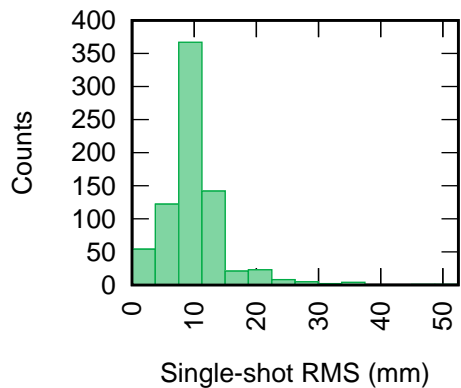
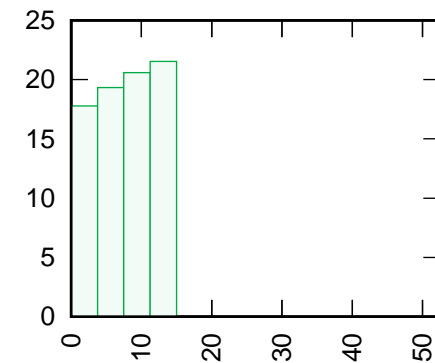
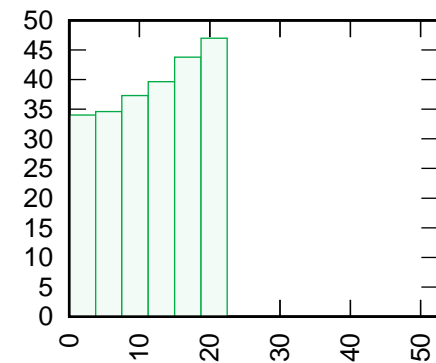
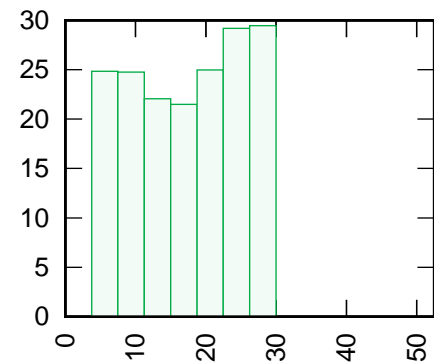
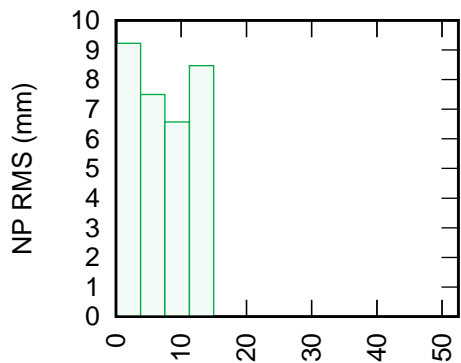
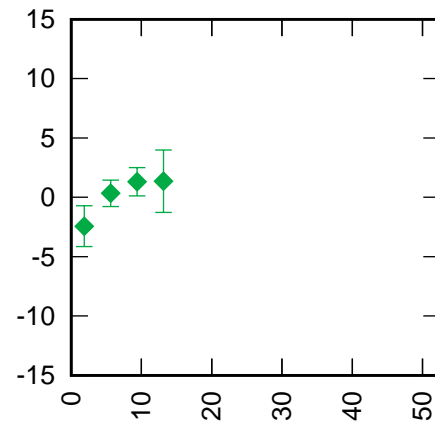
Arequipa 7403 AJI
CoM (CoM 1013 mm) RB 40.3 mm +

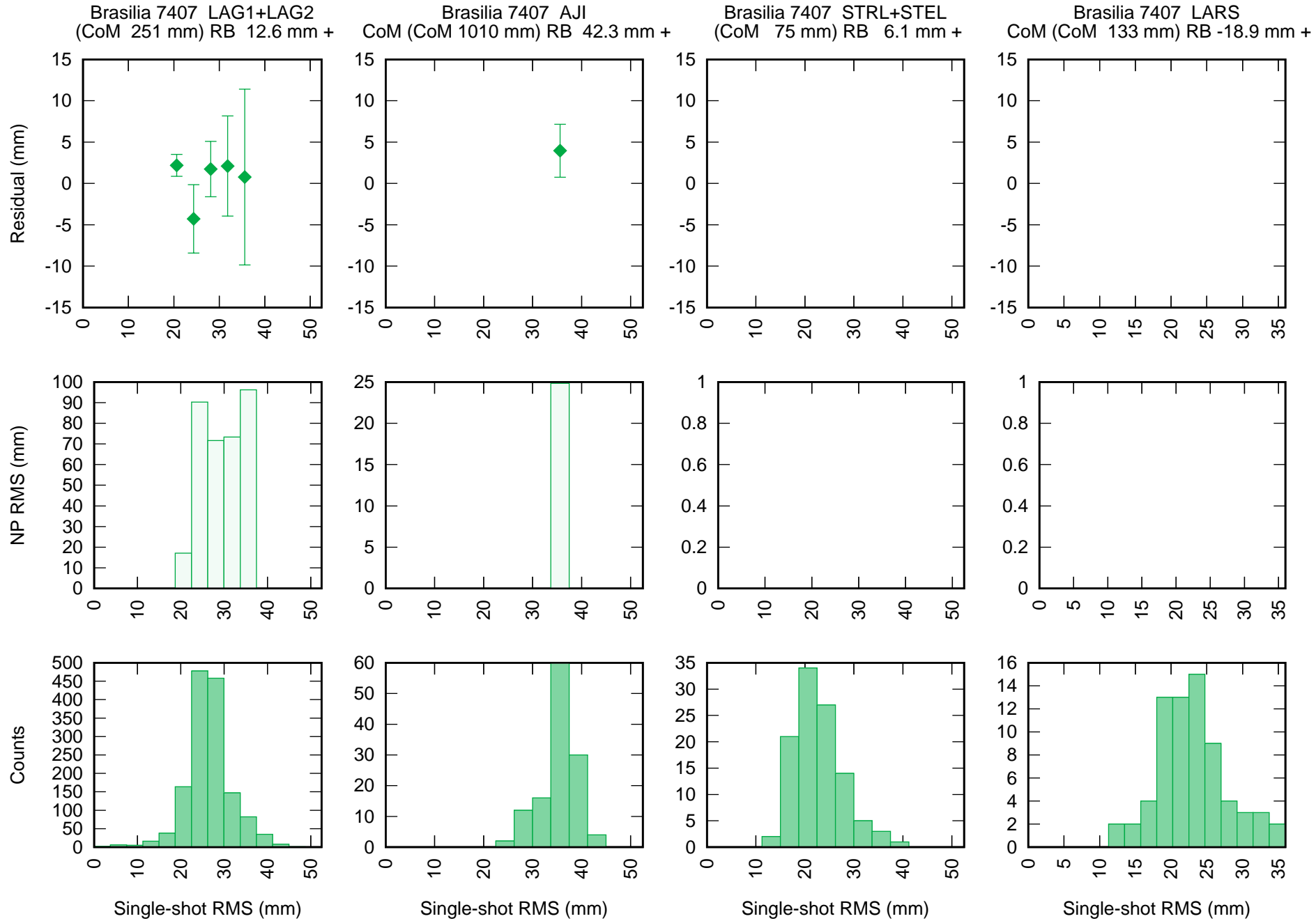


Arequipa 7403 STRL+STEL
(CoM 75 mm) RB 12.3 mm +

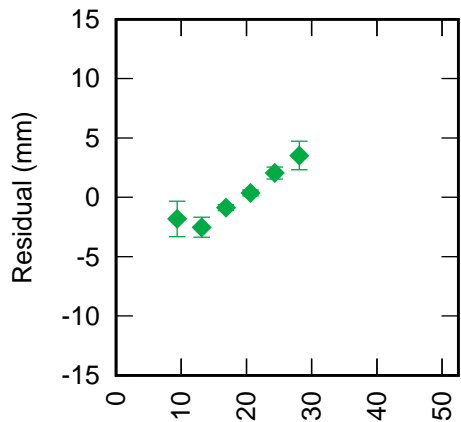


Arequipa 7403 LARS
CoM (CoM 133 mm) RB 10.4 mm +

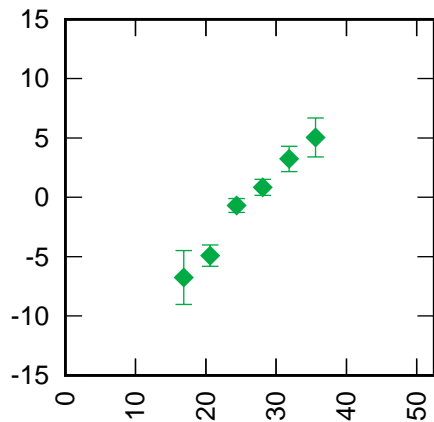




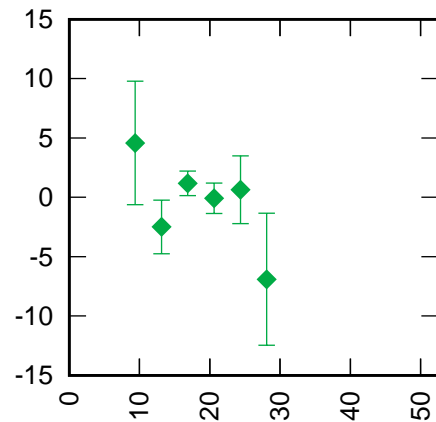
Hartebeesthoek 7501 LAG1+LAG2
(CoM 247 mm) RB 5.1 mm +



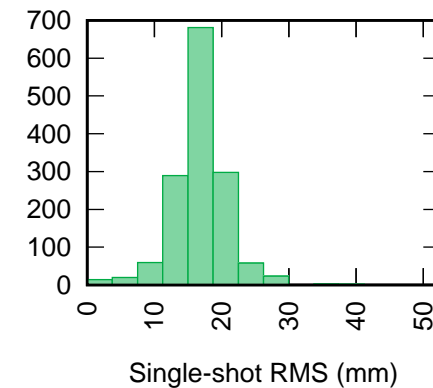
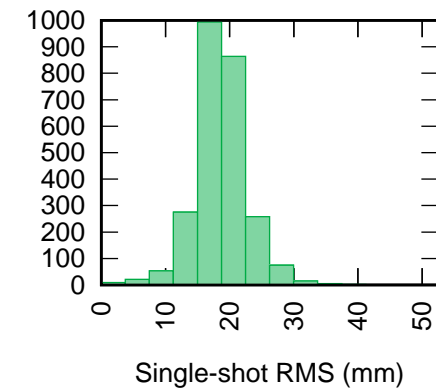
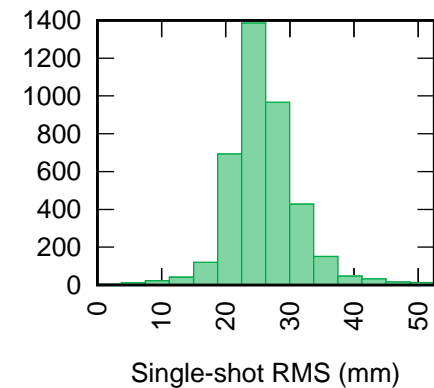
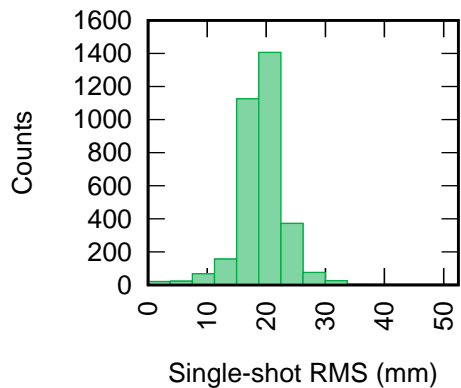
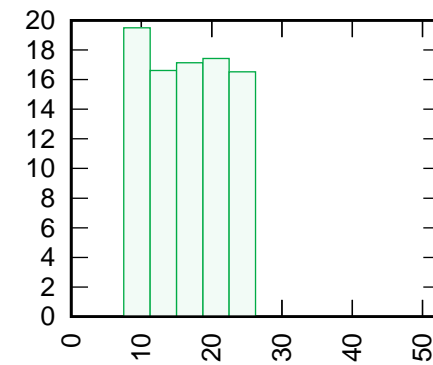
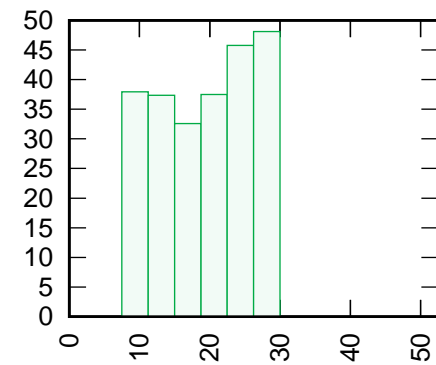
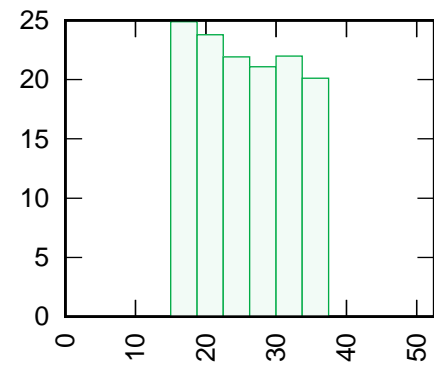
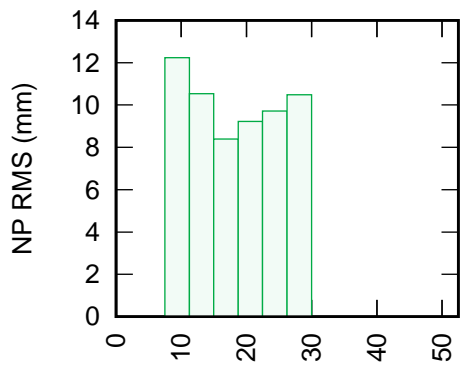
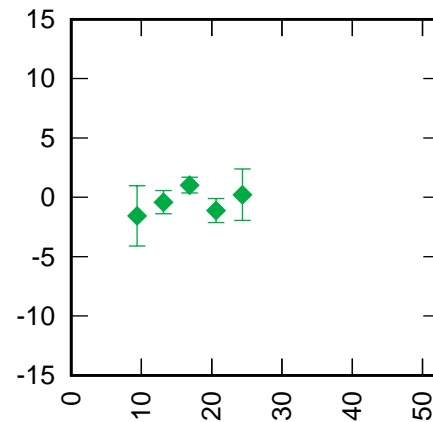
Hartebeesthoek 7501 AJI
CoM (CoM 1013 mm) RB 36.3 mm +



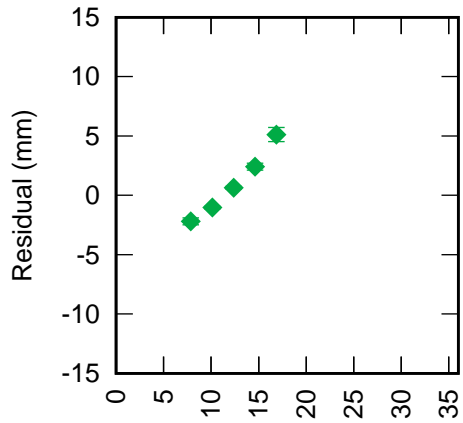
Hartebeesthoek 7501 STRL+STEL
(CoM 75 mm) RB 3.8 mm +



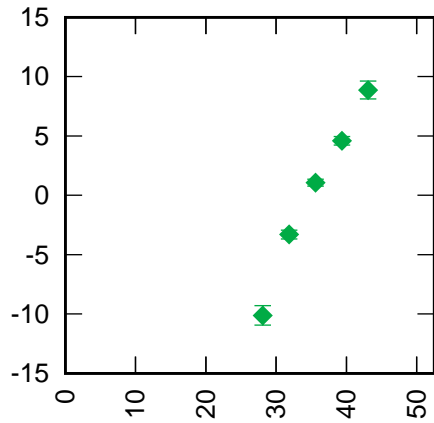
Hartebeesthoek 7501 LARS
CoM (CoM 133 mm) RB 10.3 mm +



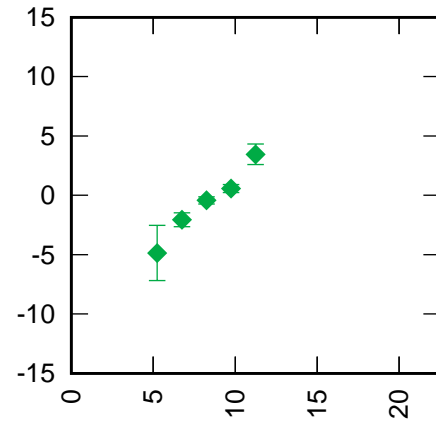
Zimmerwald 7810 LAG1+LAG2
(CoM 249 mm) RB 3.0 mm +



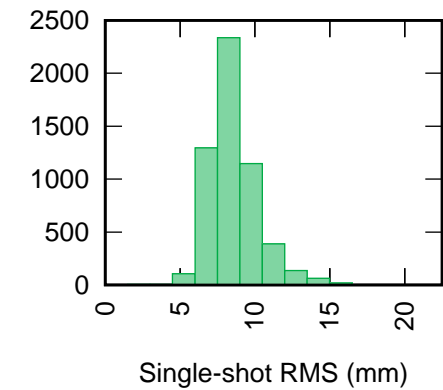
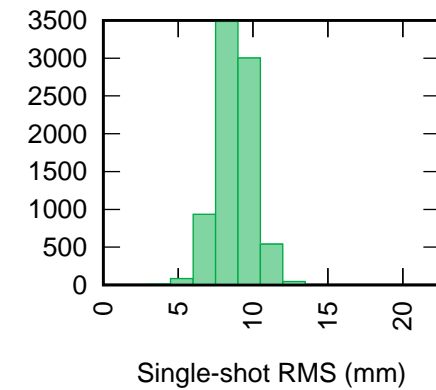
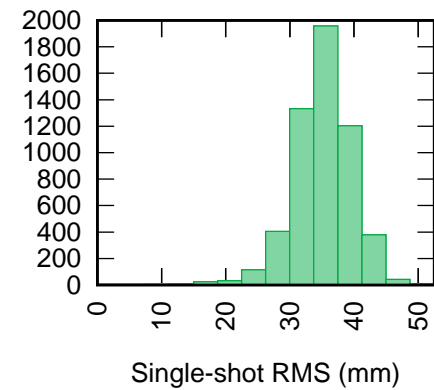
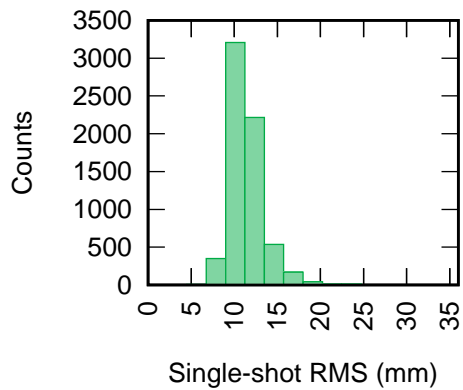
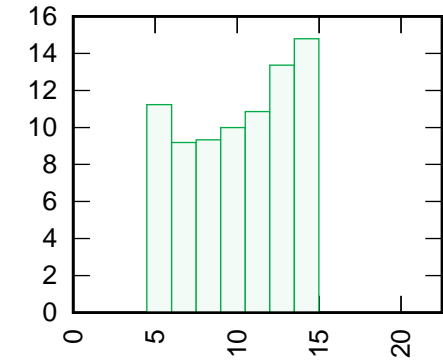
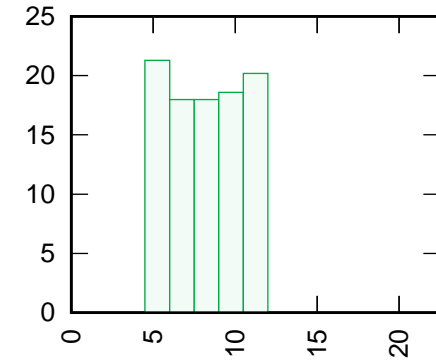
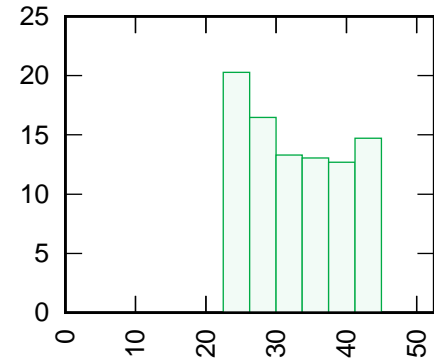
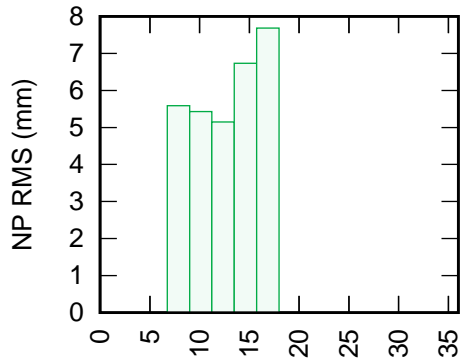
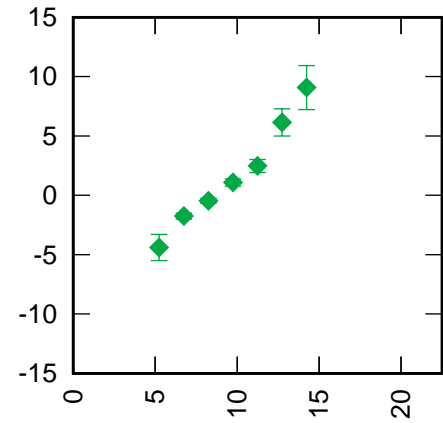
Zimmerwald 7810 AJI
(CoM 999 mm) RB 17.3 mm +

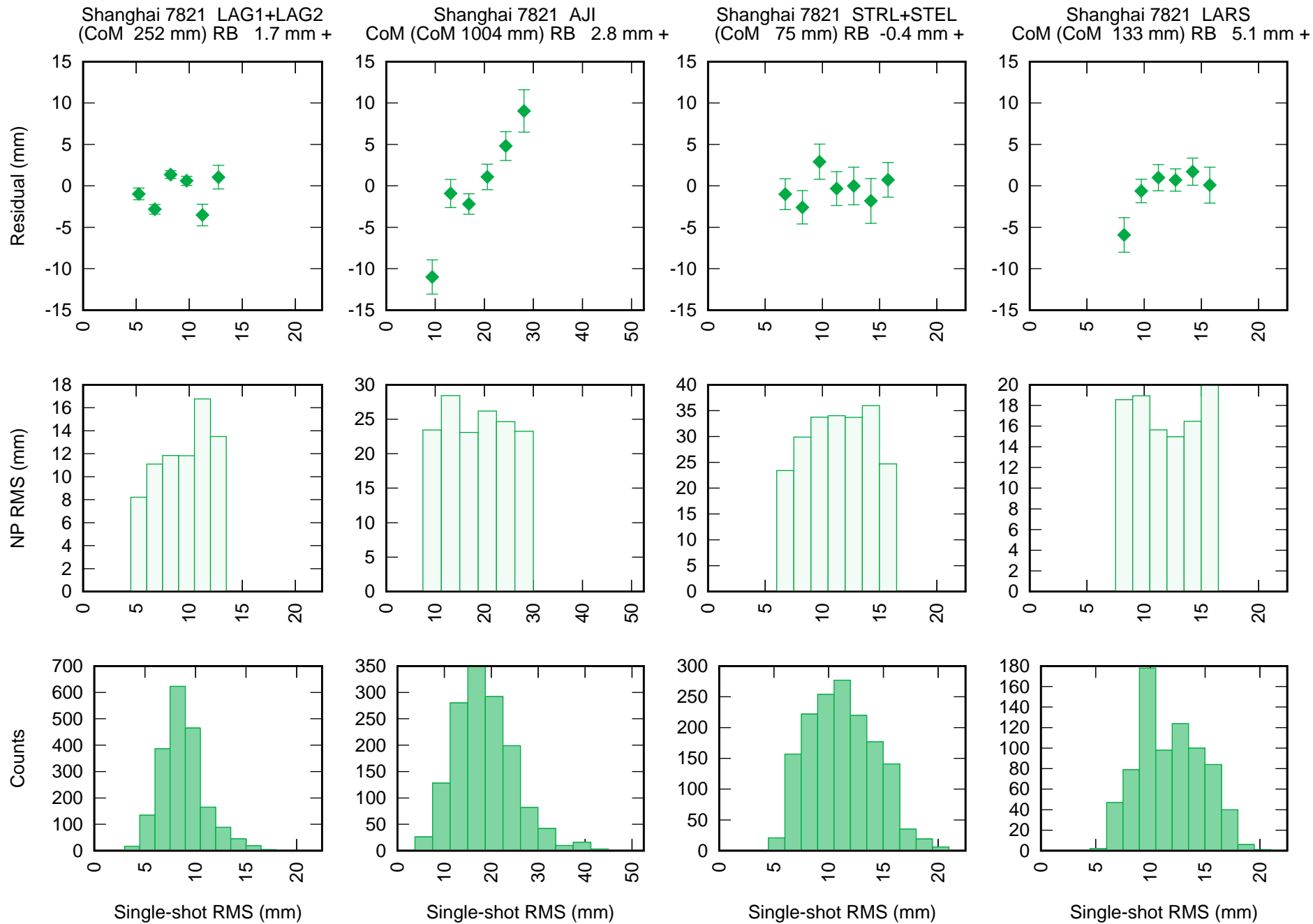


Zimmerwald 7810 STRL+STEL
(CoM 75 mm) RB -0.8 mm +

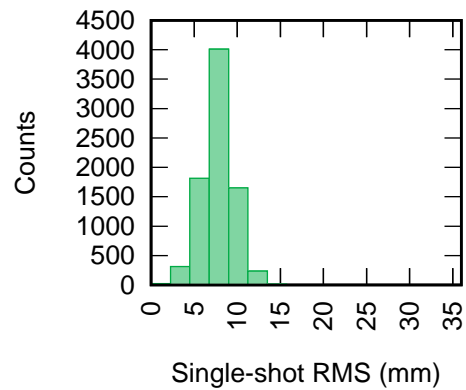
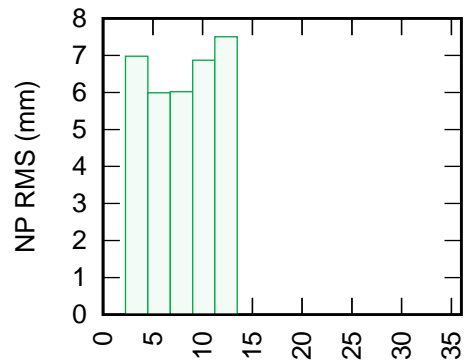
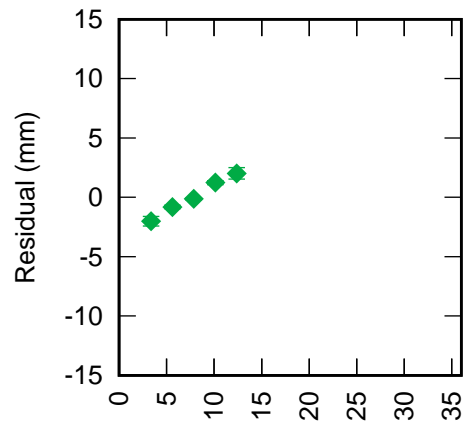


Zimmerwald 7810 LARS
(CoM 133 mm) RB 5.1 mm +

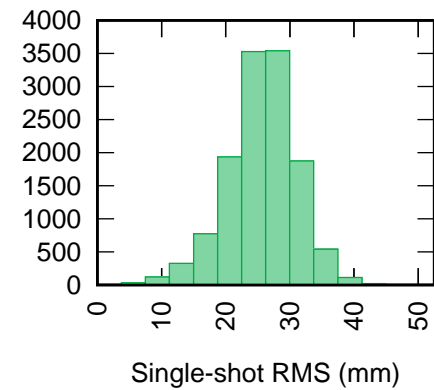
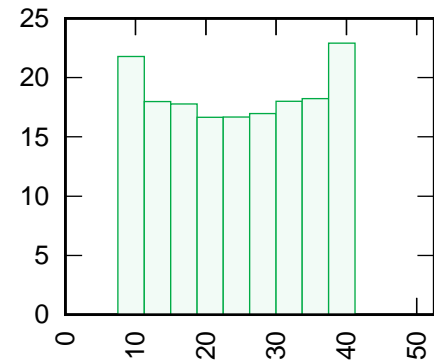
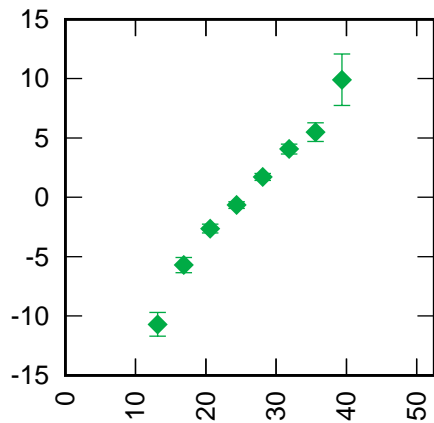




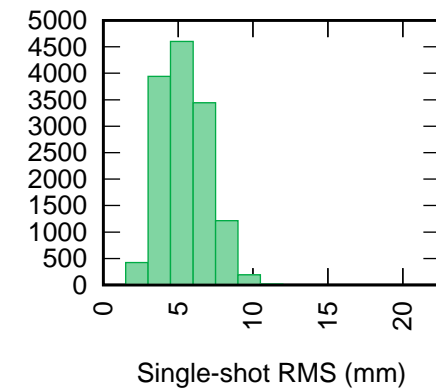
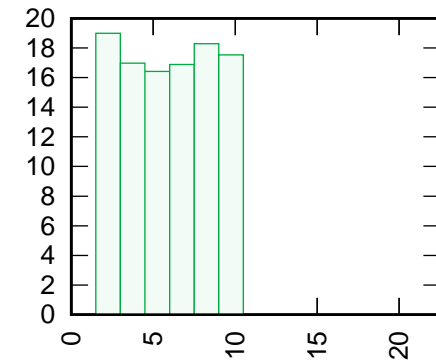
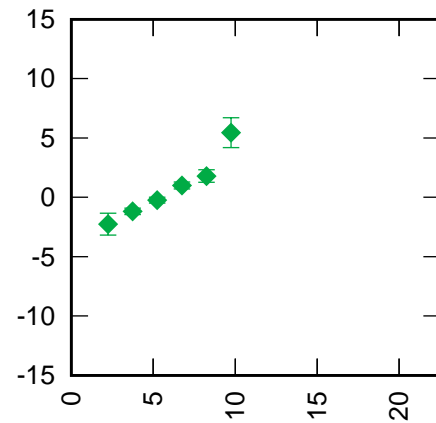
Mt Stromlo 7825 LAG1+LAG2
(CoM 252 mm) RB 10.0 mm +



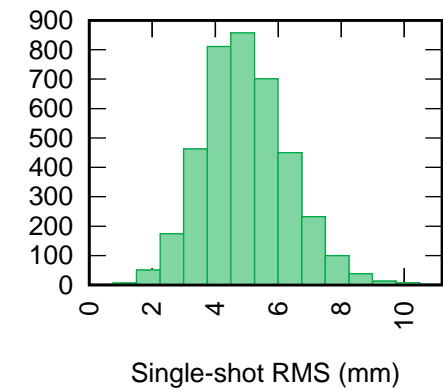
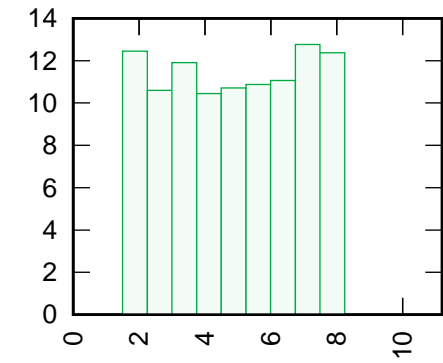
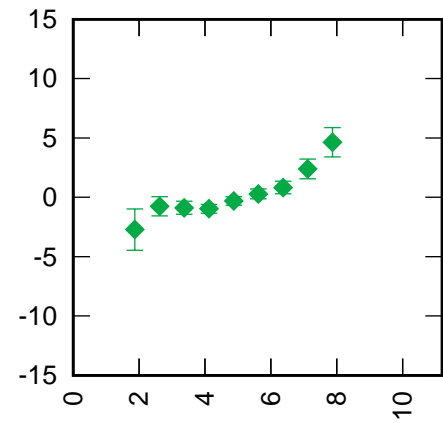
Mt Stromlo 7825 AJI
CoM (CoM 1004 mm) RB 13.7 mm +



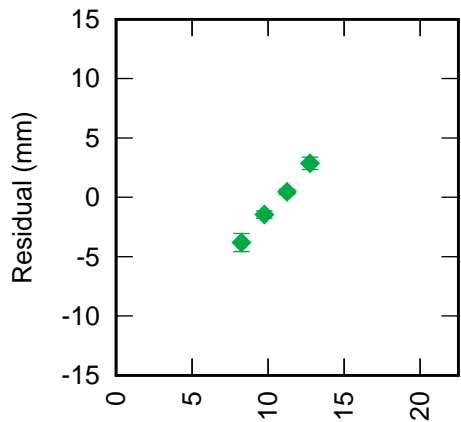
Mt Stromlo 7825 STRL+STEL
(CoM 75 mm) RB 2.5 mm +



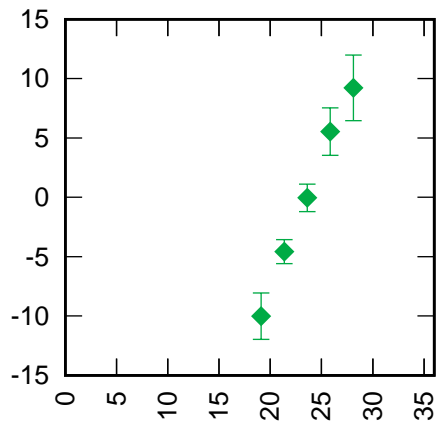
Mt Stromlo 7825 LARS
CoM (CoM 133 mm) RB 7.2 mm +



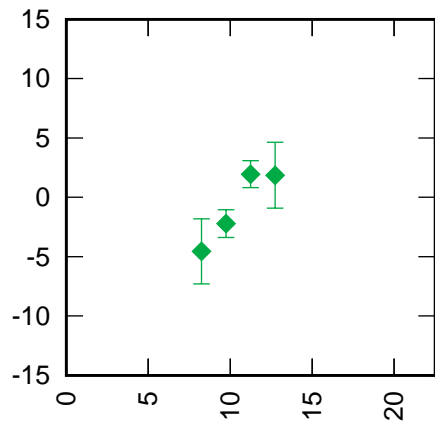
Wettzell 7827 LAG1+LAG2
(CoM 251 mm) RB 8.3 mm +



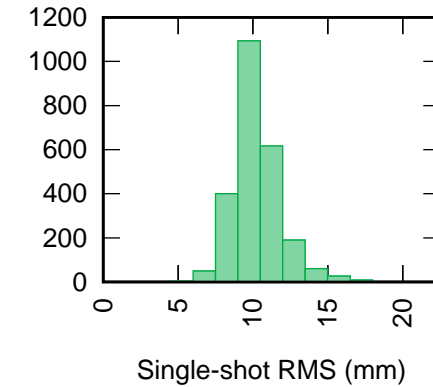
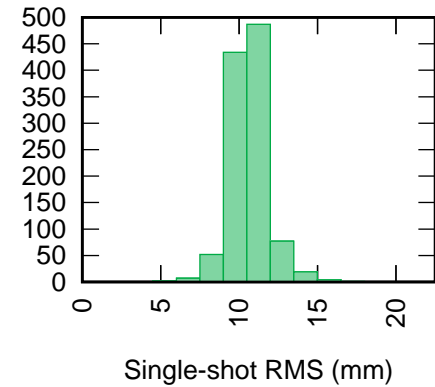
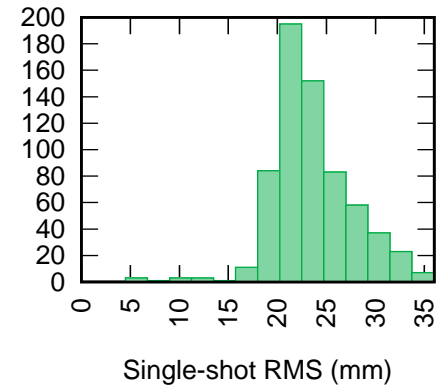
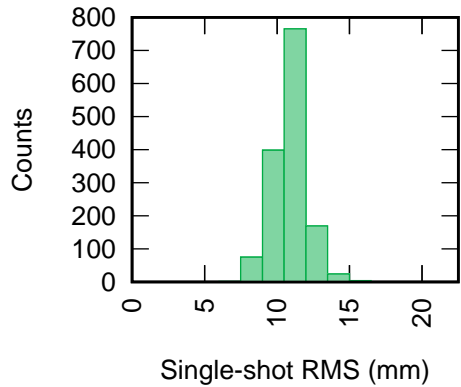
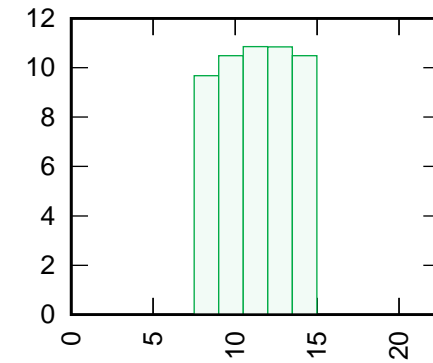
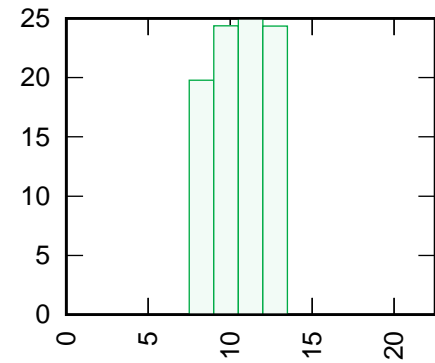
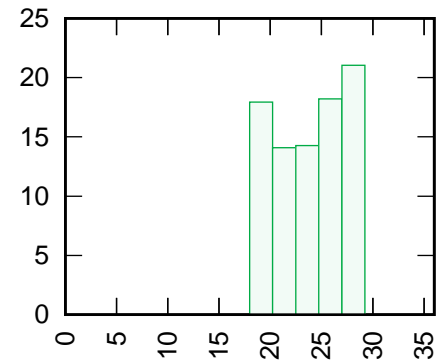
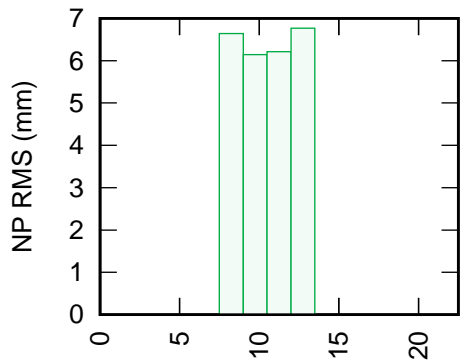
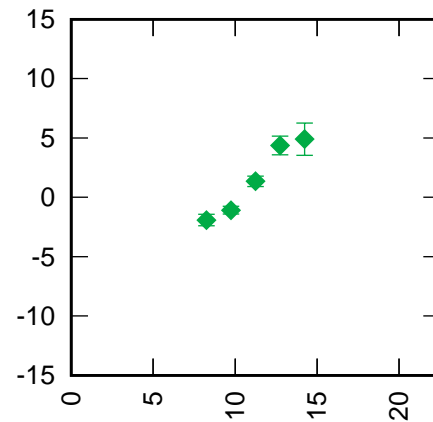
Wettzell 7827 AJI
(CoM 1010 mm) RB 25.4 mm +

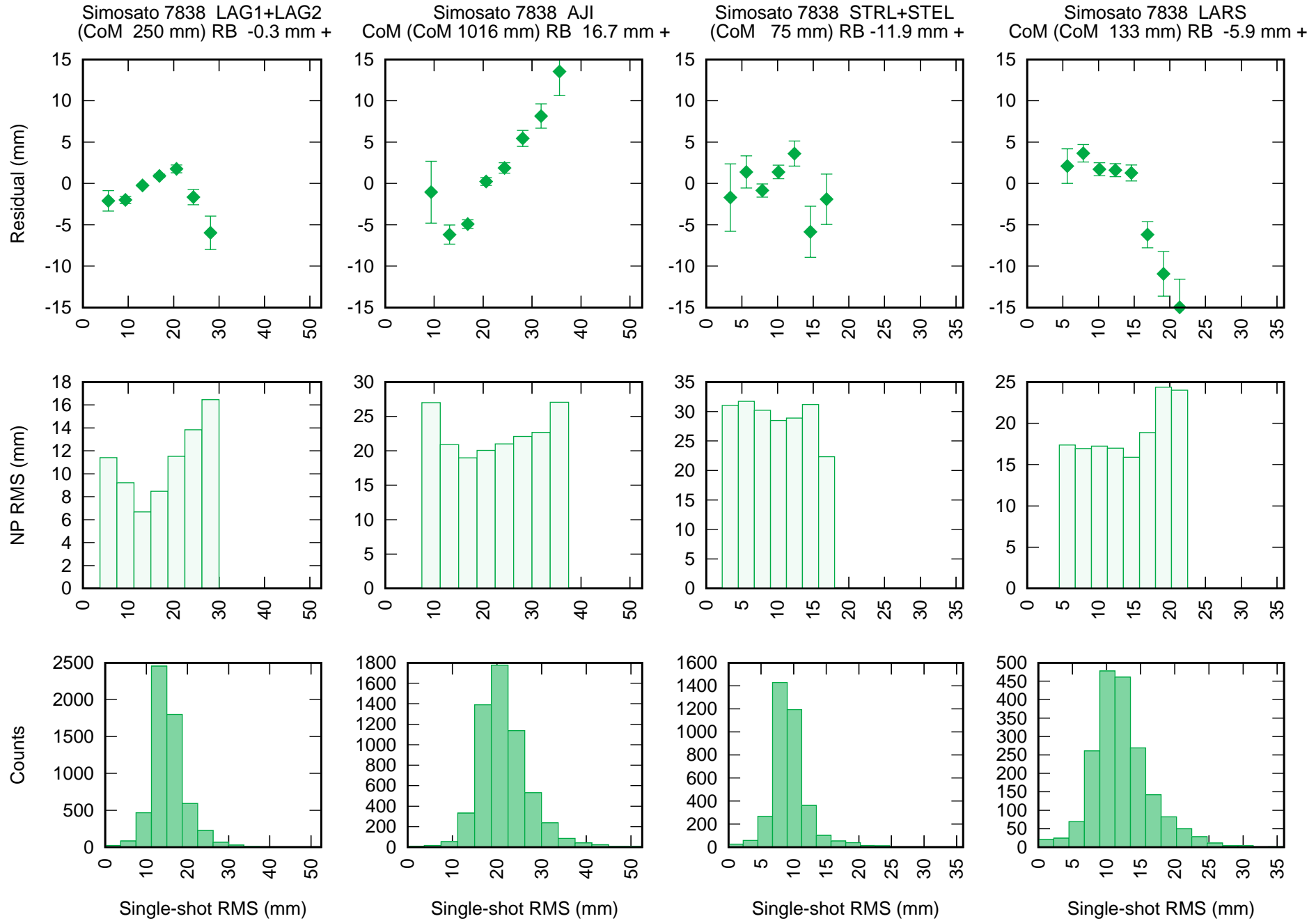


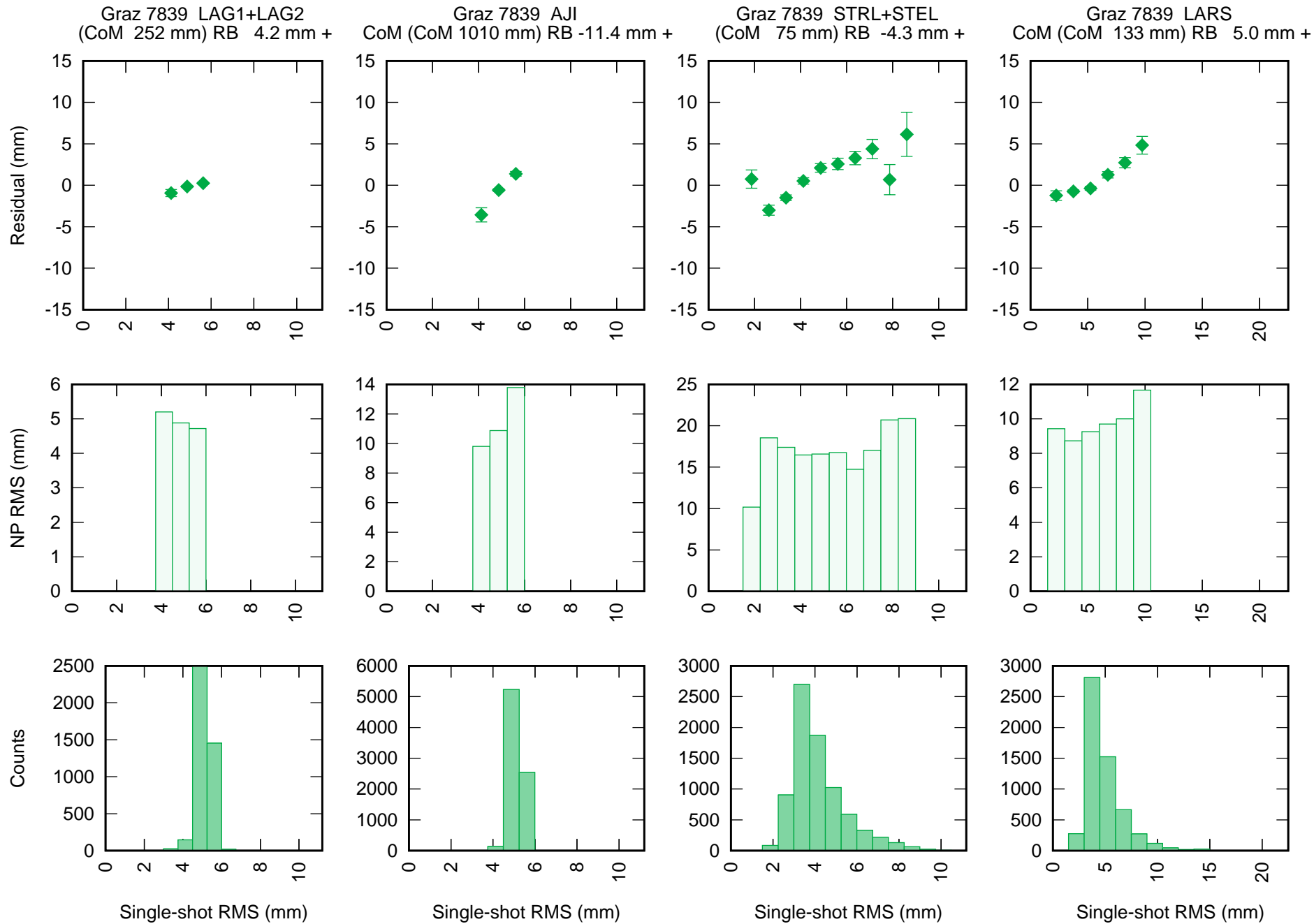
Wettzell 7827 STRL+STEL
(CoM 75 mm) RB 5.4 mm +



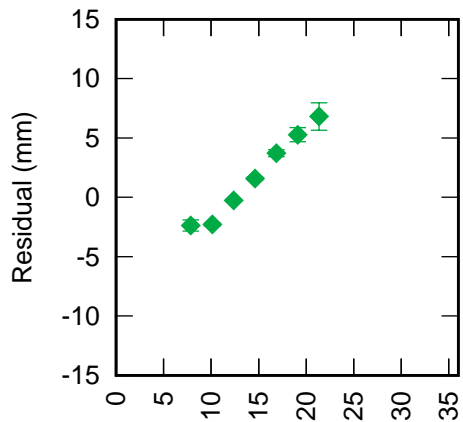
Wettzell 7827 LARS
(CoM 133 mm) RB 10.9 mm +



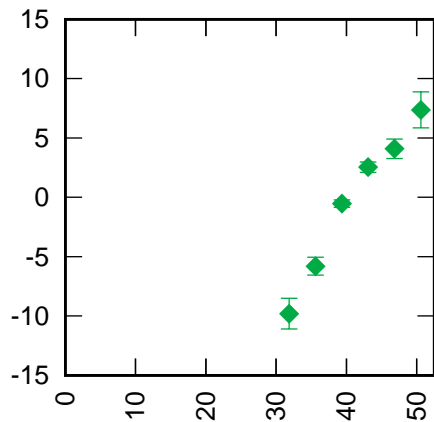




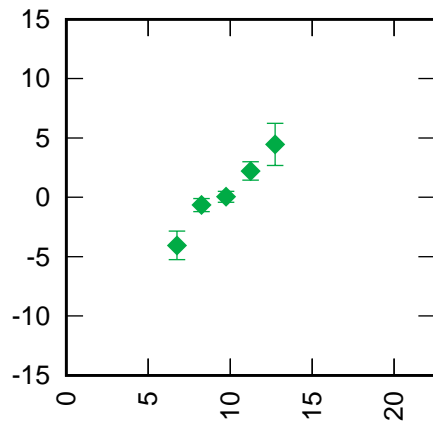
Herstmonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -0.8 mm +



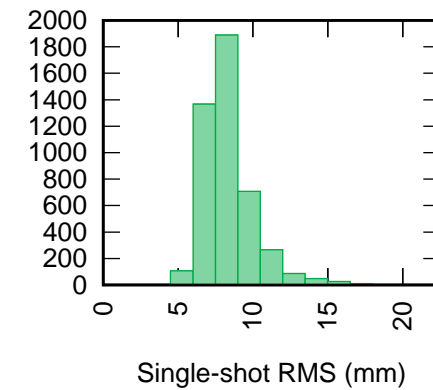
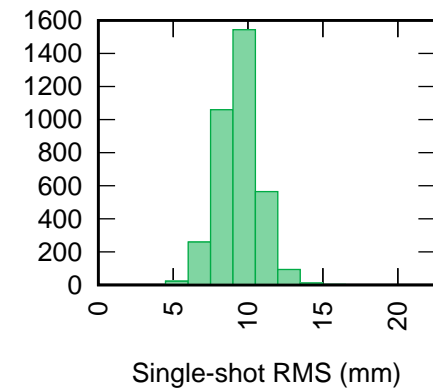
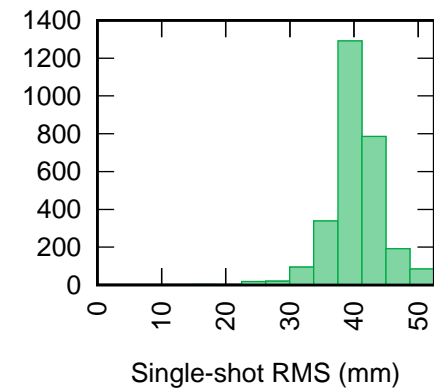
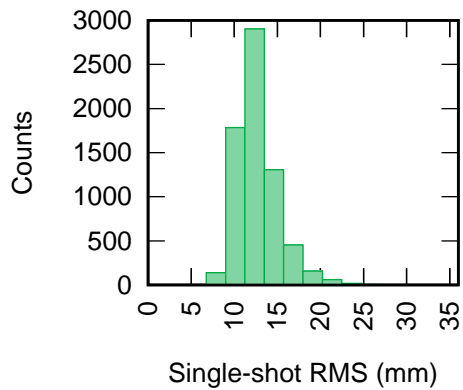
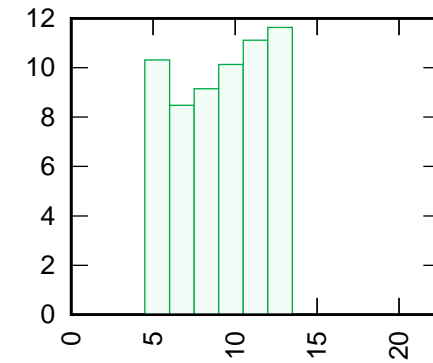
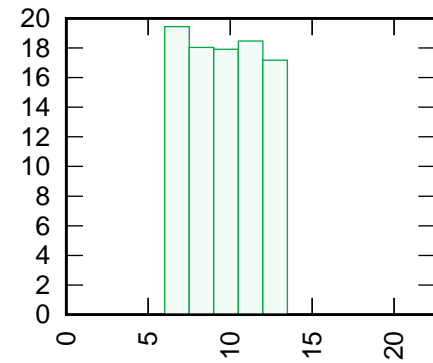
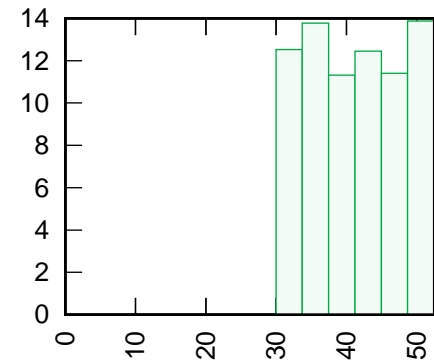
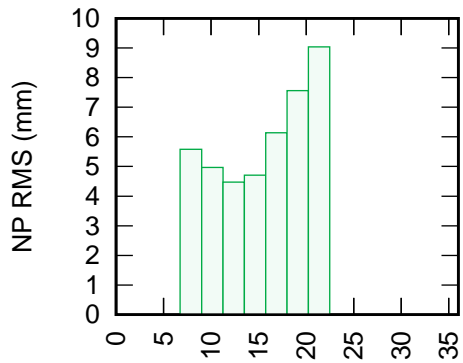
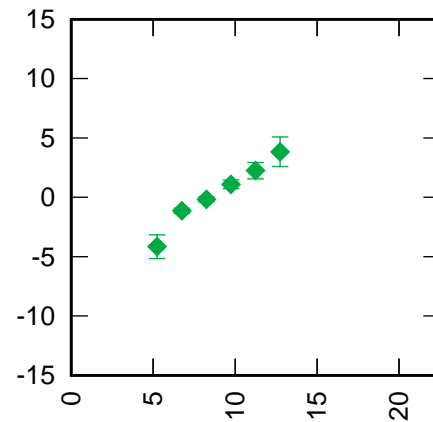
Herstmonceux 7840 AJI
CoM (CoM 982 mm) RB 5.5 mm +



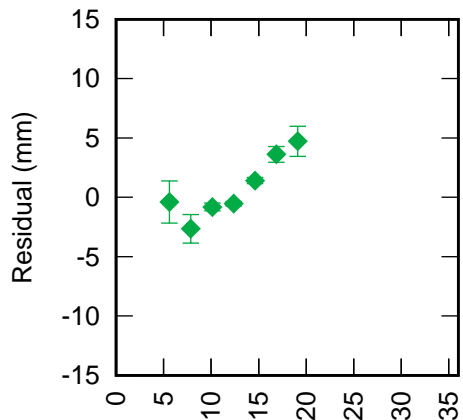
Herstmonceux 7840 STRL+STEL
(CoM 75 mm) RB -2.8 mm +



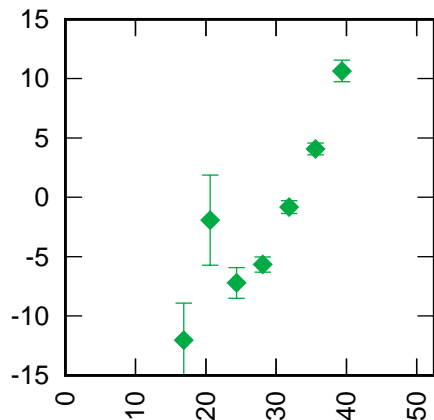
Herstmonceux 7840 LARS
CoM (CoM 133 mm) RB 3.8 mm +



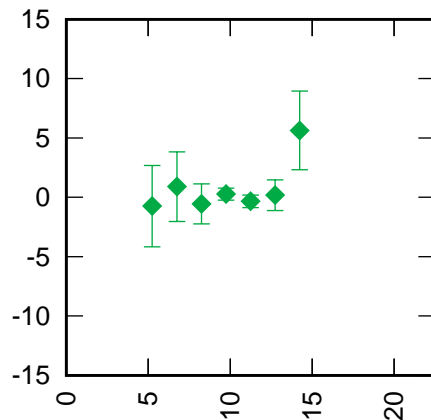
Potsdam 7841 LAG1+LAG2
(CoM 245 mm) RB -0.9 mm +



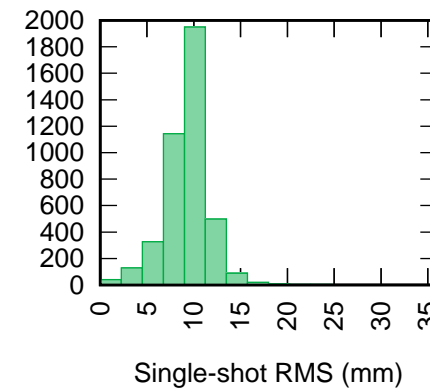
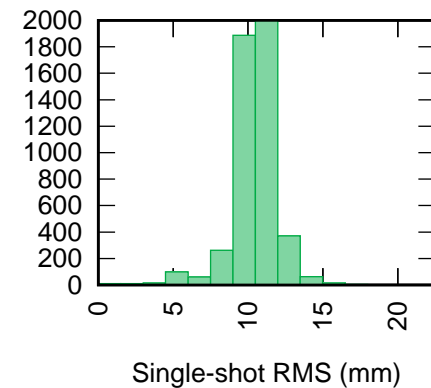
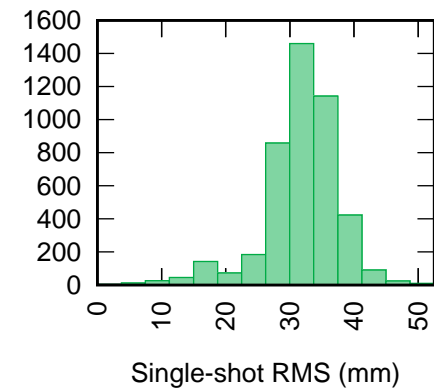
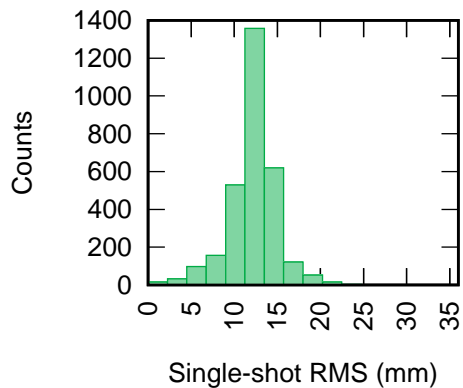
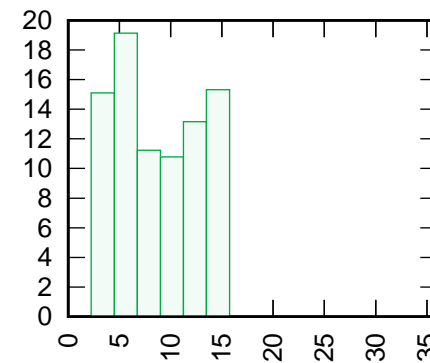
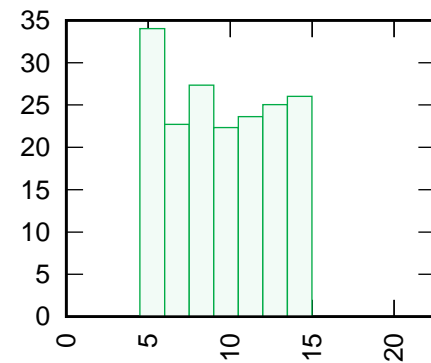
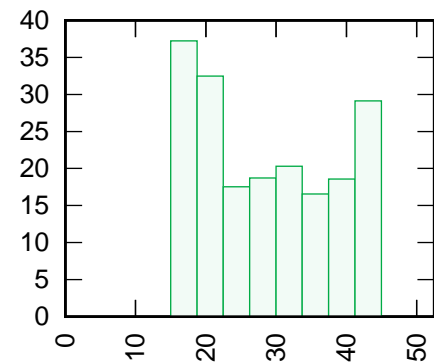
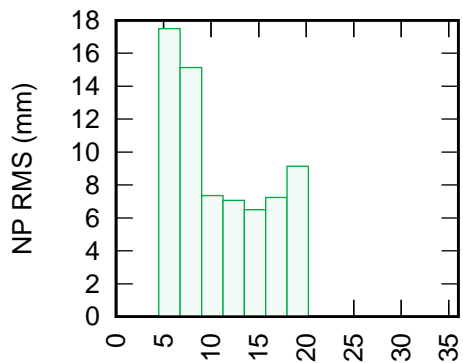
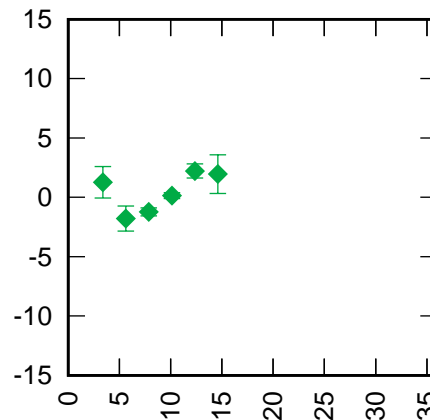
Potsdam 7841 AJI
CoM (CoM 995 mm) RB 11.1 mm +



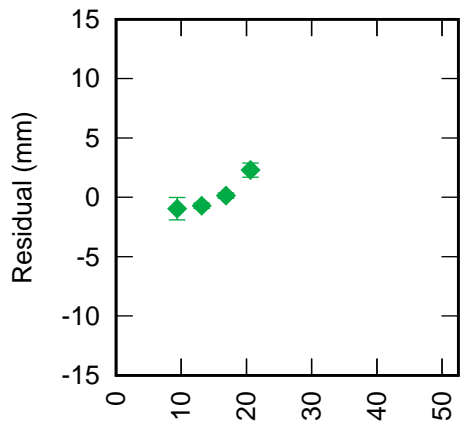
Potsdam 7841 STRL+STEL
(CoM 75 mm) RB -1.2 mm +



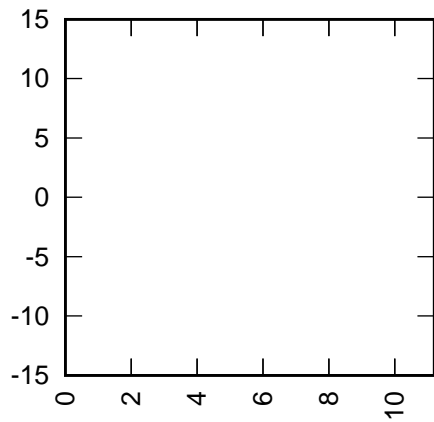
Potsdam 7841 LARS
CoM (CoM 133 mm) RB 5.8 mm +



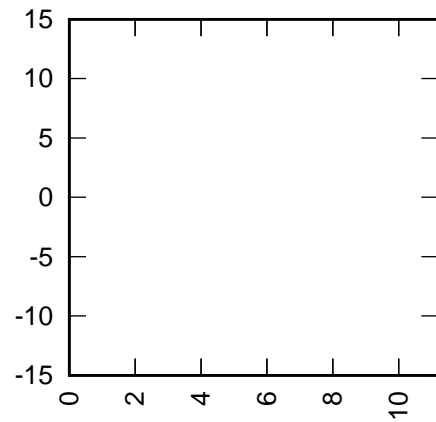
Grasse 7845 LAG1+LAG2
(CoM 251 mm) RB -0.1 mm +



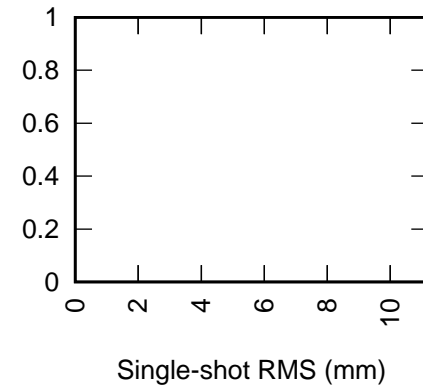
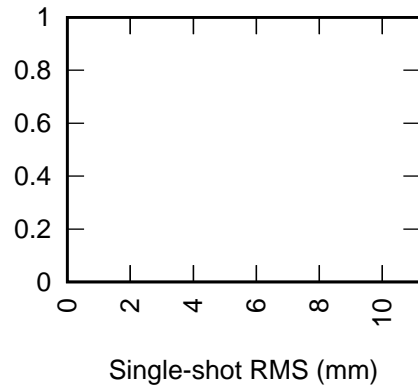
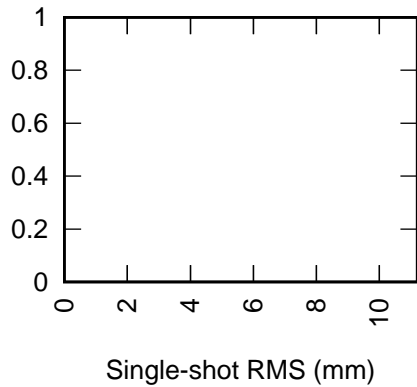
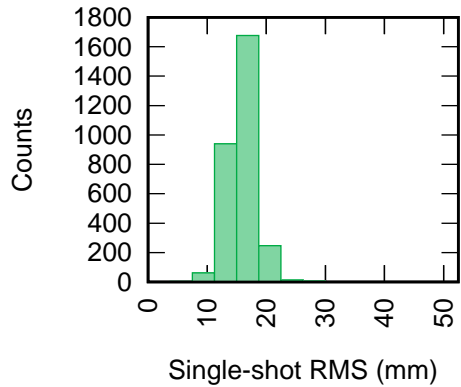
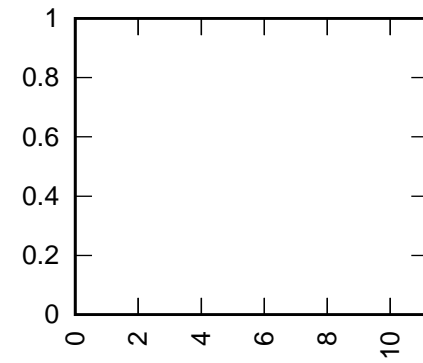
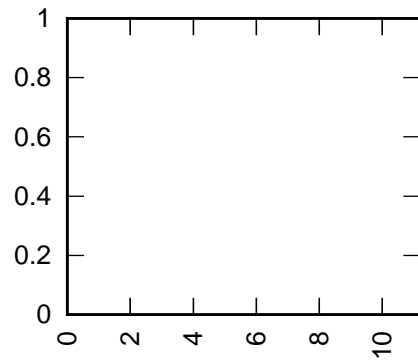
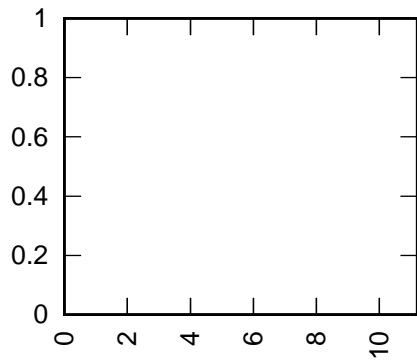
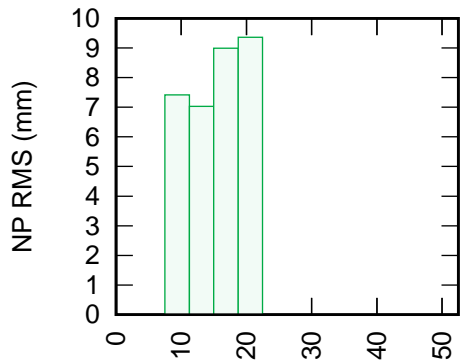
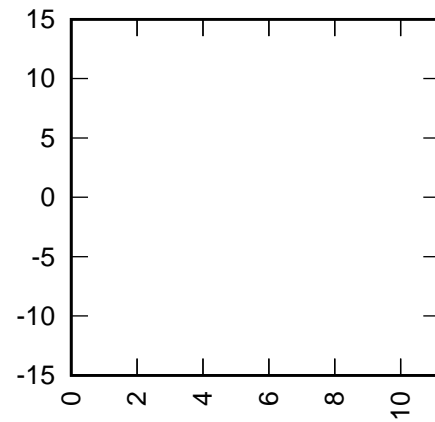
Grasse 7845 AJI
CoM (CoM 1004 mm) RB 0.0 mm +



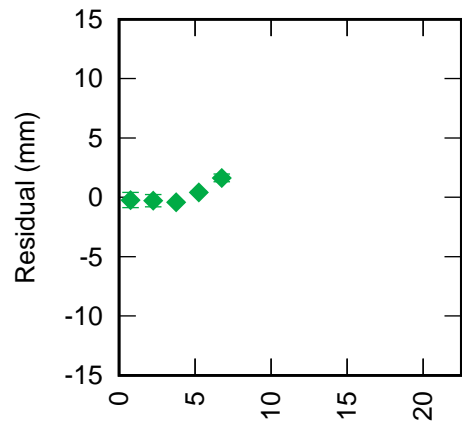
Grasse 7845 STRL+STEL
(CoM 75 mm) RB 0.0 mm +



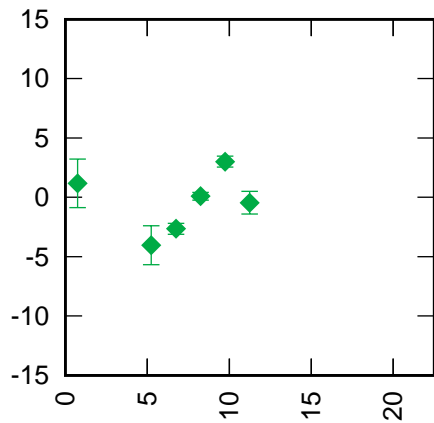
Grasse 7845 LARS
CoM (CoM 133 mm) RB 0.0 mm +



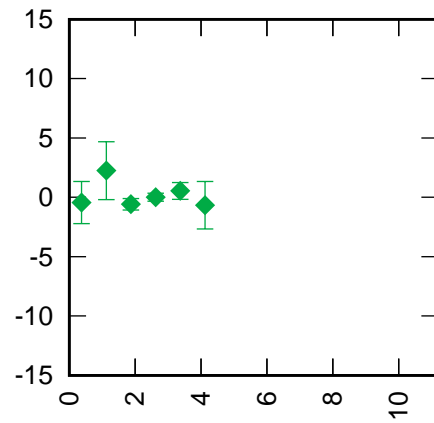
Matera 7941 LAG1+LAG2
(CoM 250 mm) RB -2.5 mm +



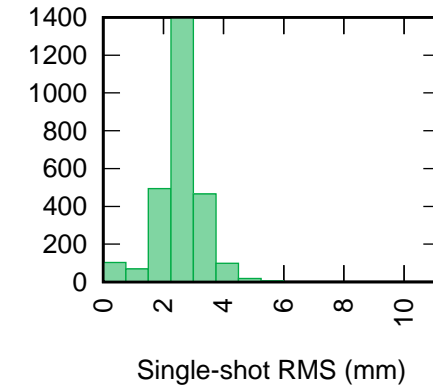
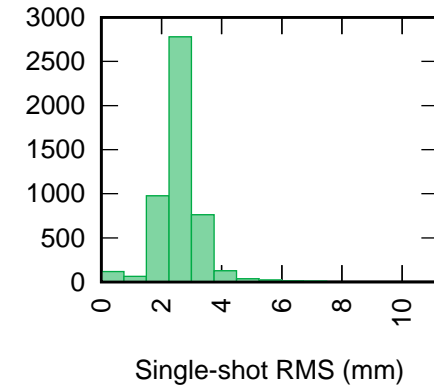
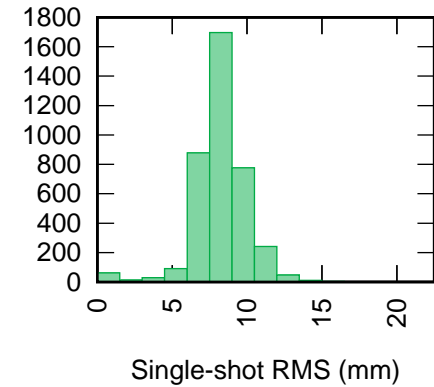
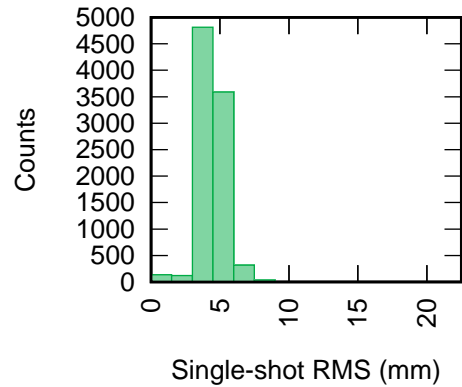
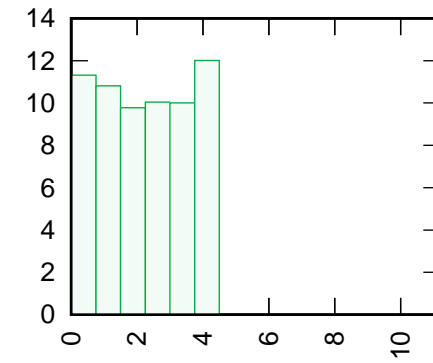
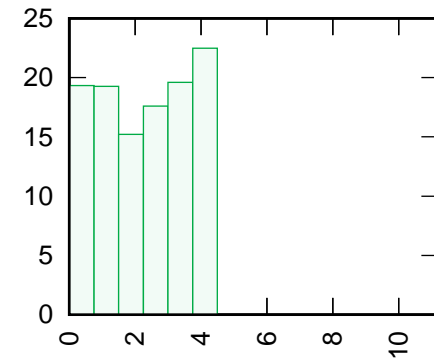
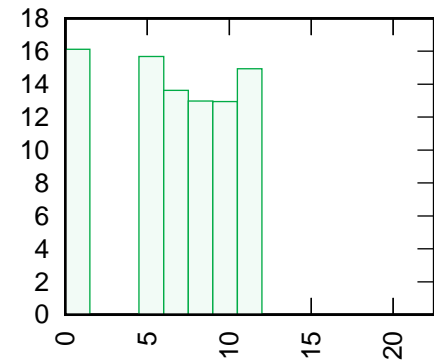
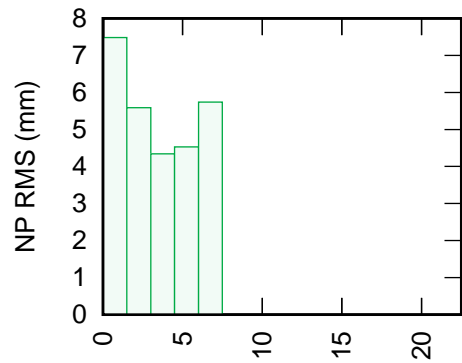
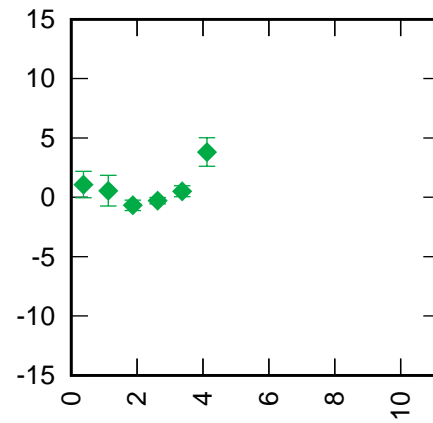
Matera 7941 AJI
CoM (CoM 1020 mm) RB 25.0 mm +



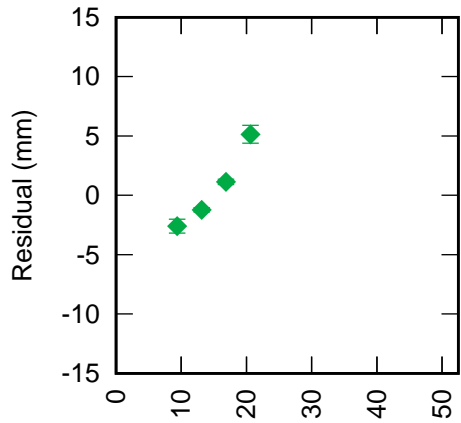
Matera 7941 STRL+STEL
(CoM 75 mm) RB -5.7 mm +



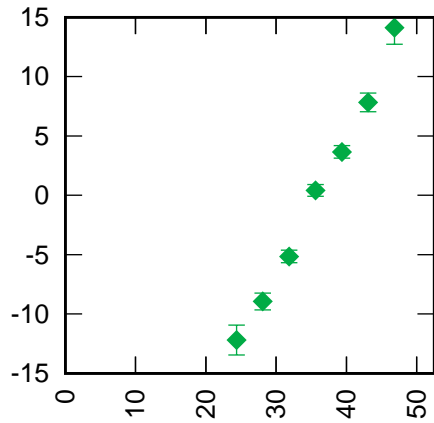
Matera 7941 LARS
CoM (CoM 133 mm) RB -2.3 mm +



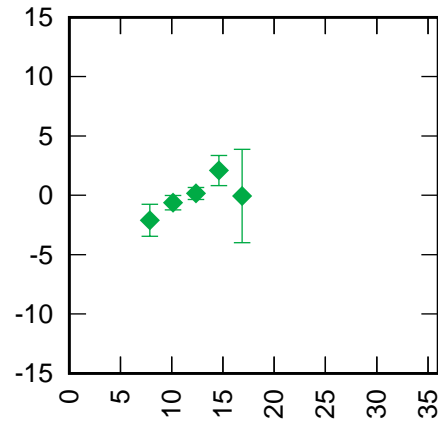
Wetzell 8834 LAG1+LAG2
(CoM 250 mm) RB -19.0 mm +



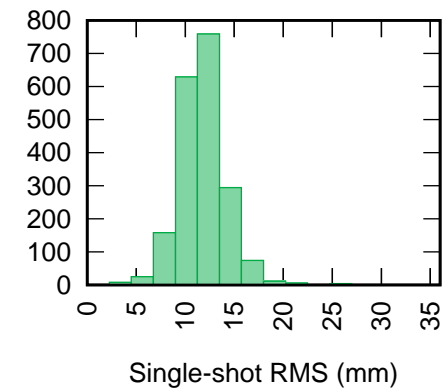
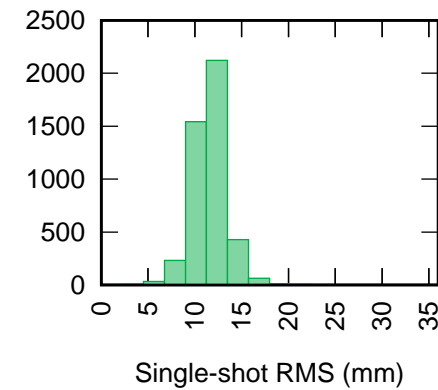
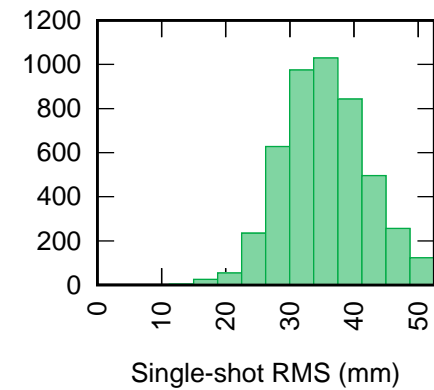
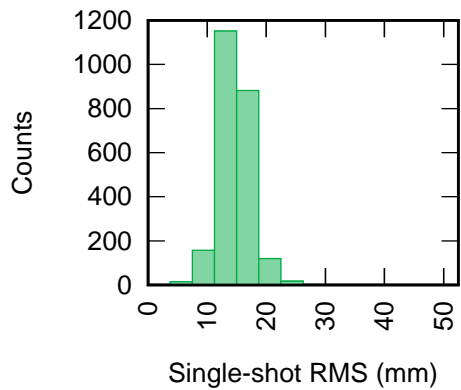
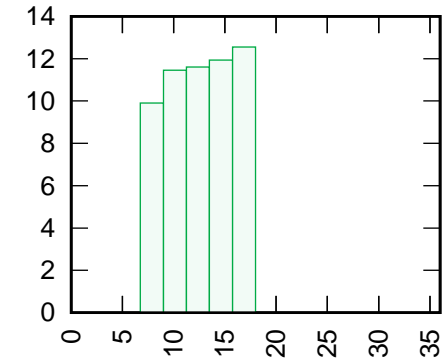
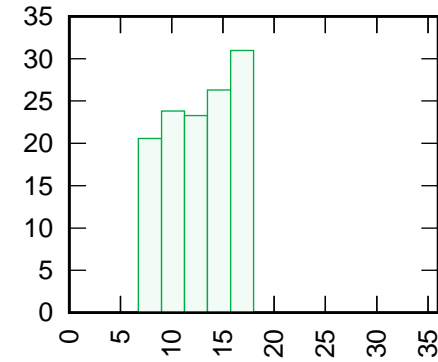
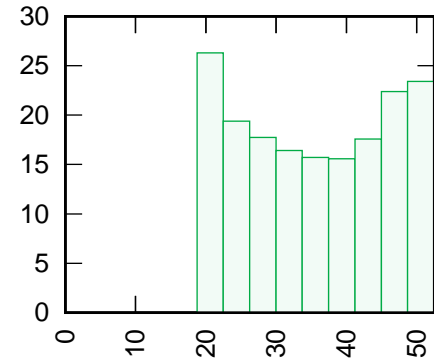
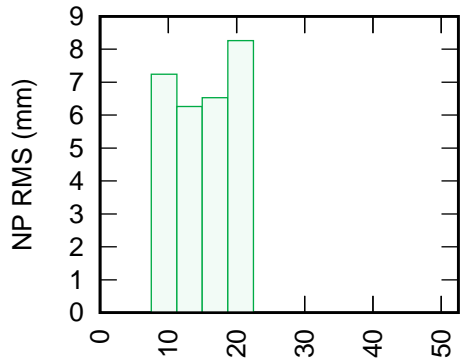
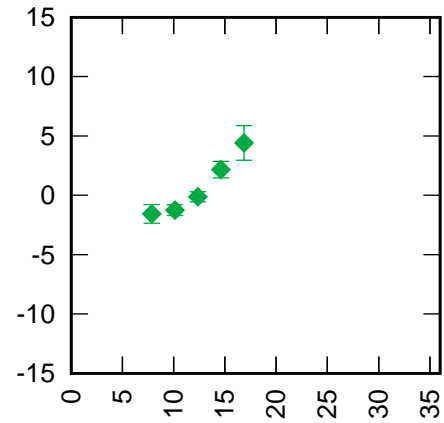
Wetzell 8834 AJI
CoM (CoM 1020 mm) RB 17.5 mm +



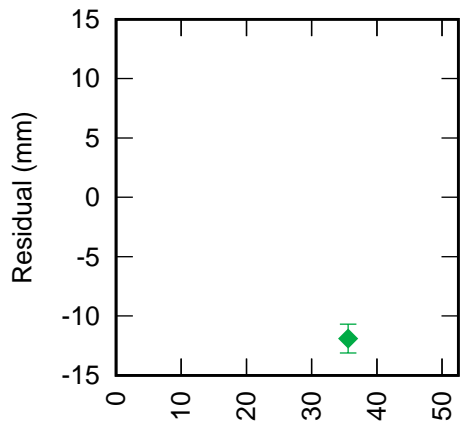
Wetzell 8834 STRL+STEL
(CoM 75 mm) RB -28.6 mm +



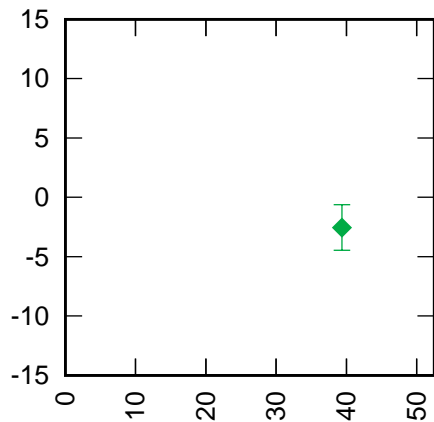
Wetzell 8834 LARS
CoM (CoM 133 mm) RB -21.1 mm +



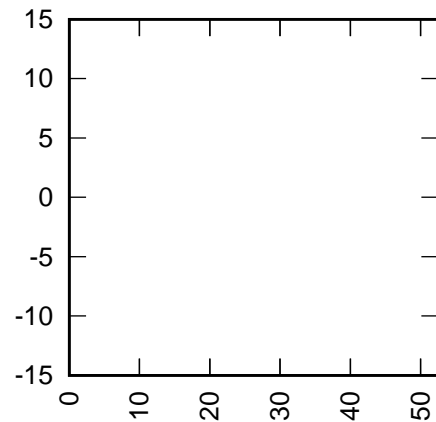
Komsomolsk 1868 LAG1+LAG2
(CoM 248 mm) RB 36.0 mm +



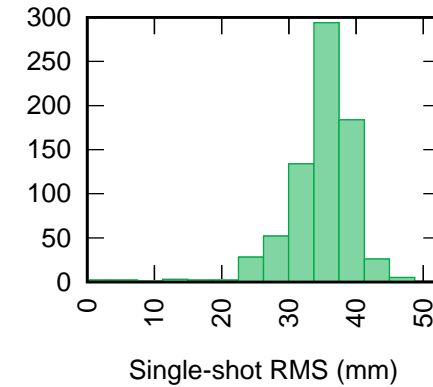
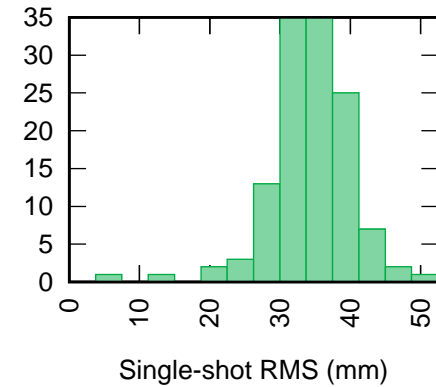
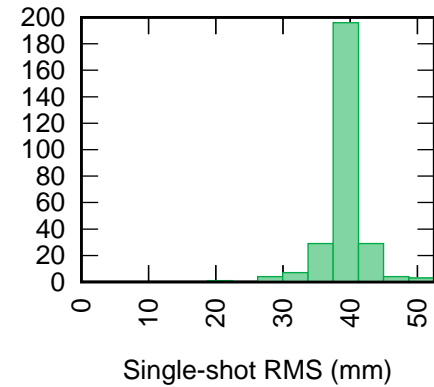
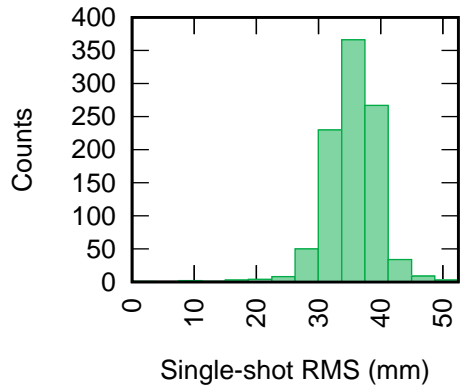
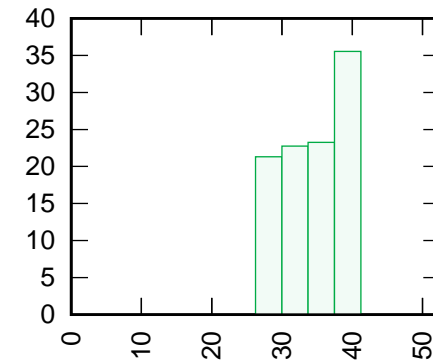
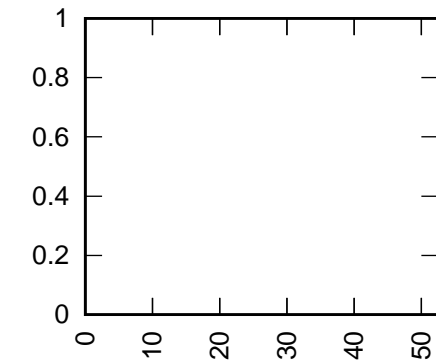
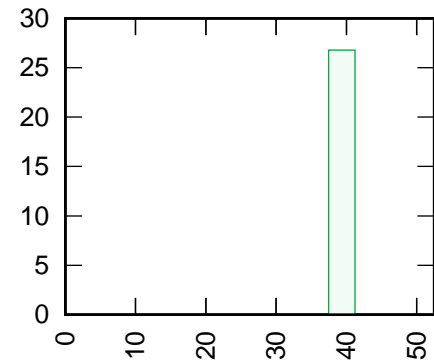
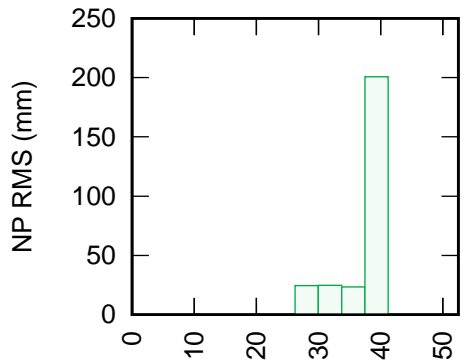
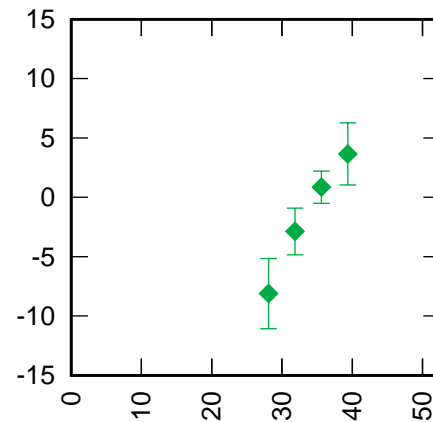
Komsomolsk 1868 AJI
(CoM 1013 mm) RB 33.6 mm +



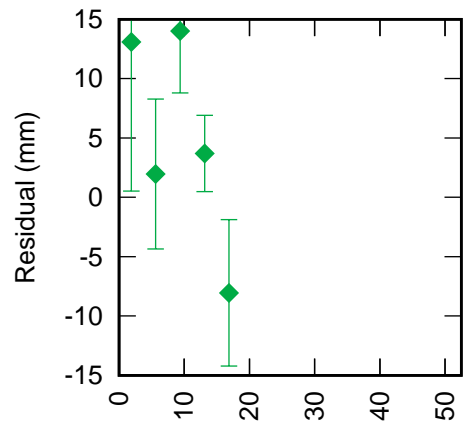
Komsomolsk 1868 STRL+STEL
(CoM 75 mm) RB 0.6 mm +



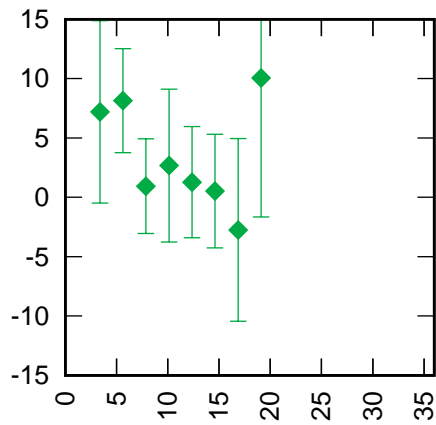
Komsomolsk 1868 LARS
(CoM 133 mm) RB 14.8 mm +



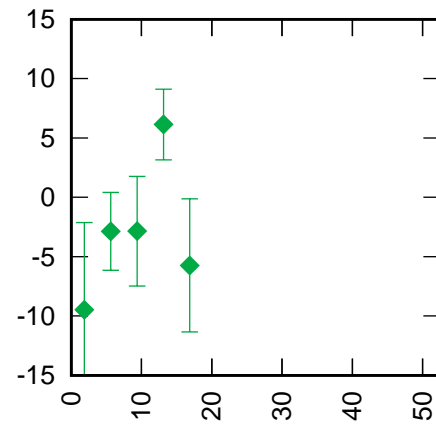
Simeiz 1873 LAG1+LAG2
(CoM 246 mm) RB 9.0 mm +



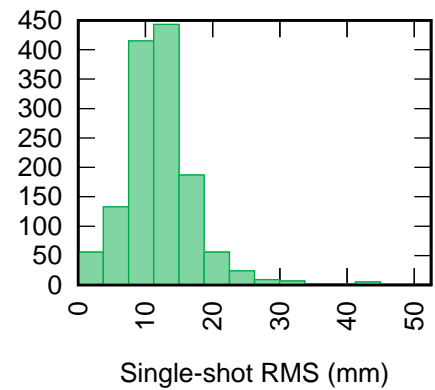
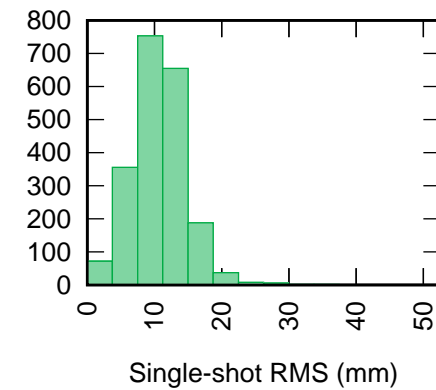
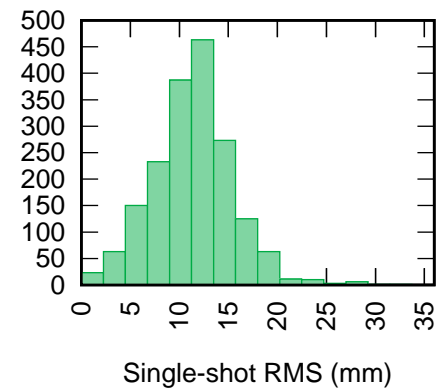
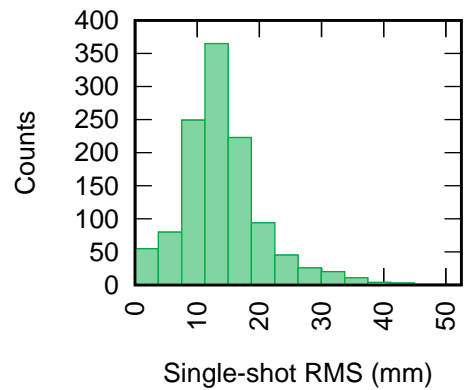
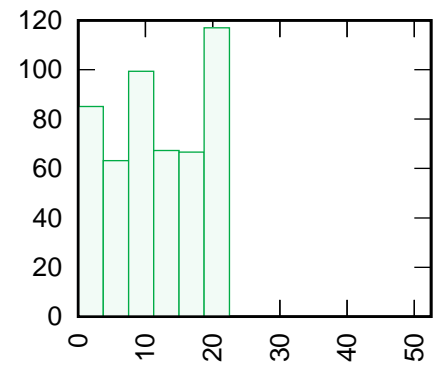
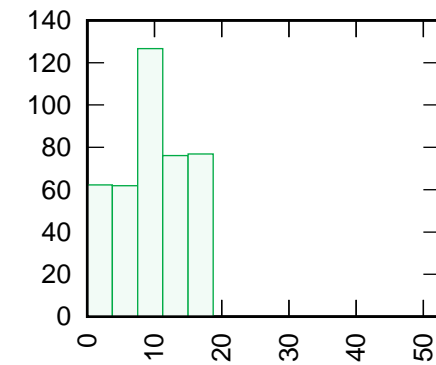
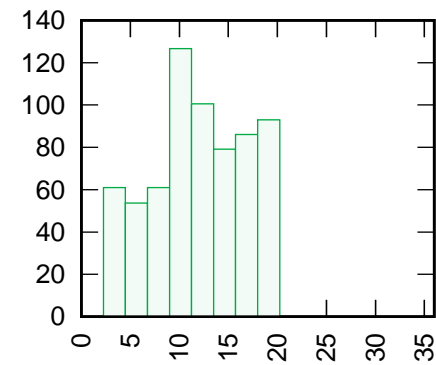
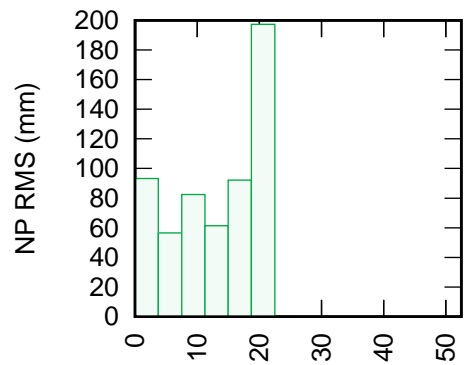
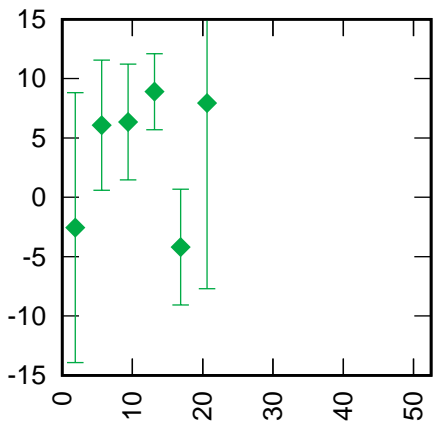
Simeiz 1873 AJI
(CoM 1009 mm) RB 41.7 mm +

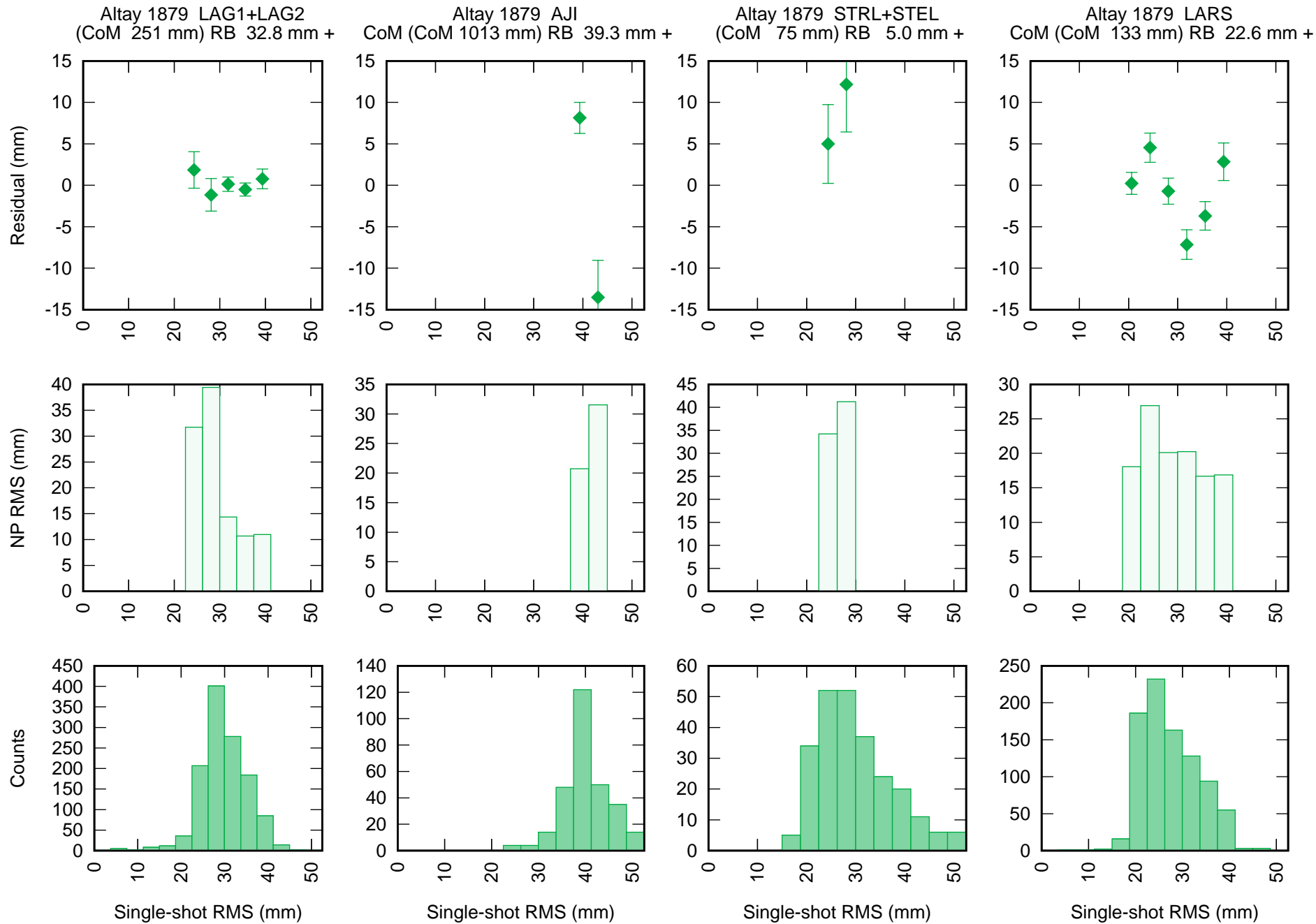


Simeiz 1873 STRL+STEL
(CoM 75 mm) RB 14.8 mm +

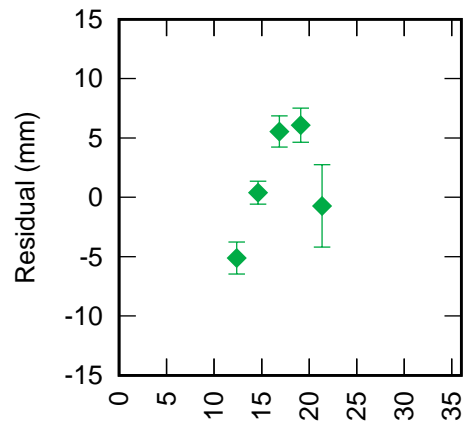


Simeiz 1873 LARS
(CoM 133 mm) RB 14.0 mm +

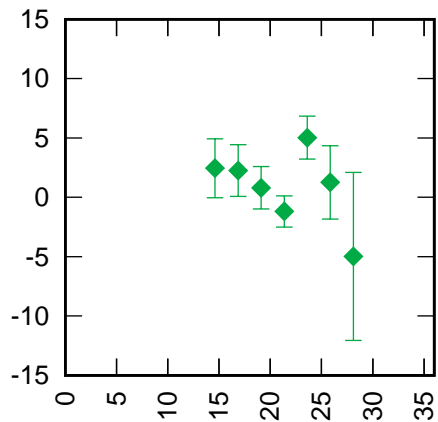




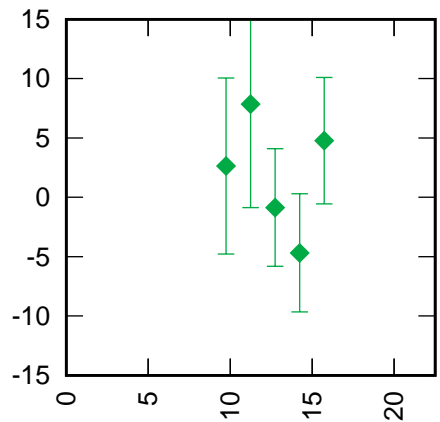
Riga 1884 LAG1+LAG2
(CoM 250 mm) RB 184.0 mm +



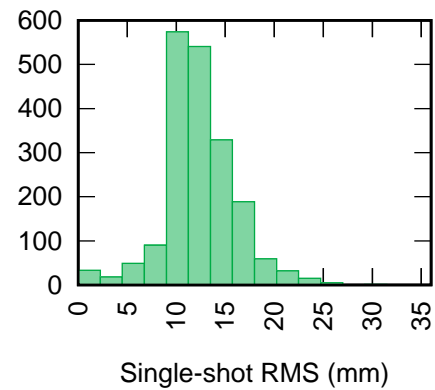
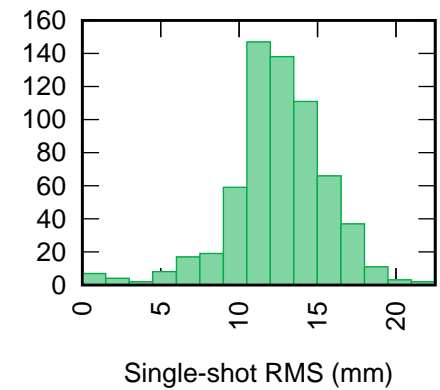
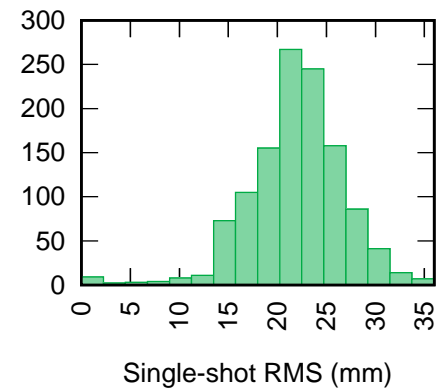
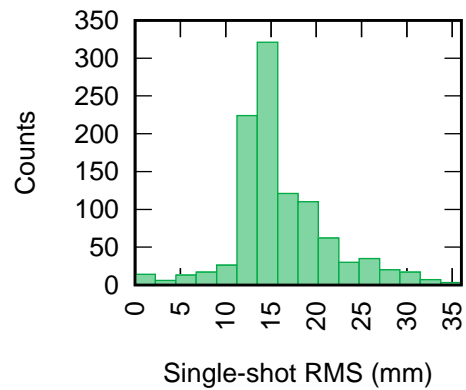
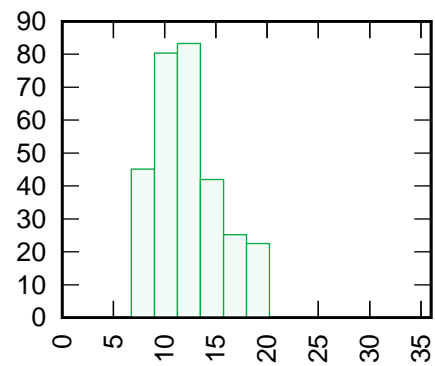
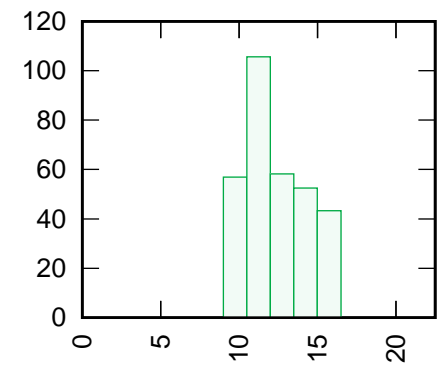
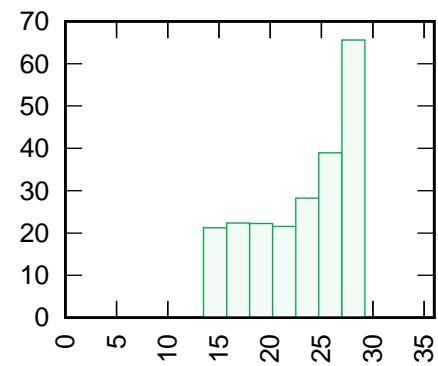
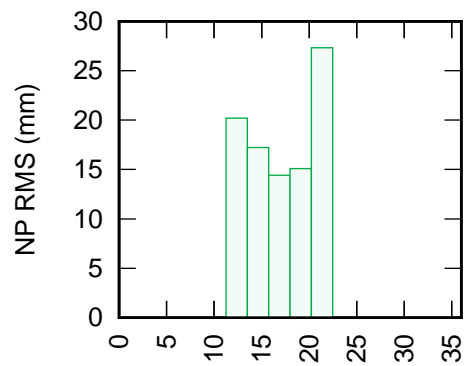
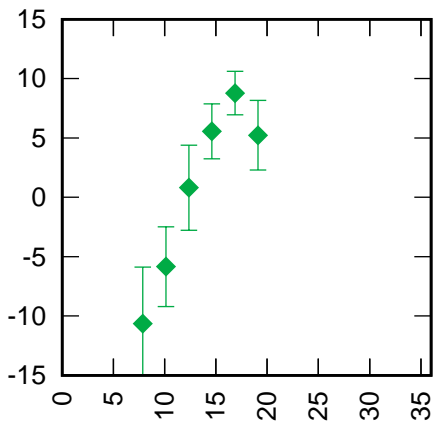
Riga 1884 AJI
CoM (CoM 1013 mm) RB 213.2 mm +



Riga 1884 STRL+STEL
(CoM 75 mm) RB 198.2 mm +



Riga 1884 LARS
CoM (CoM 133 mm) RB 189.7 mm +



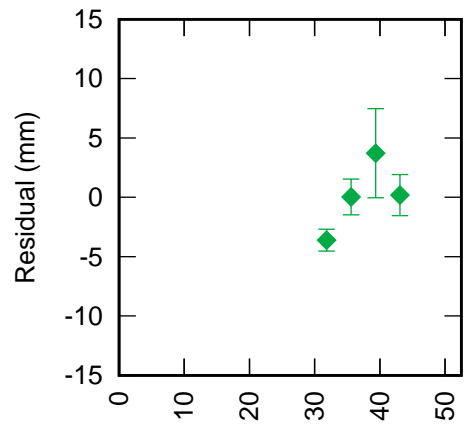
Single-shot RMS (mm)

Single-shot RMS (mm)

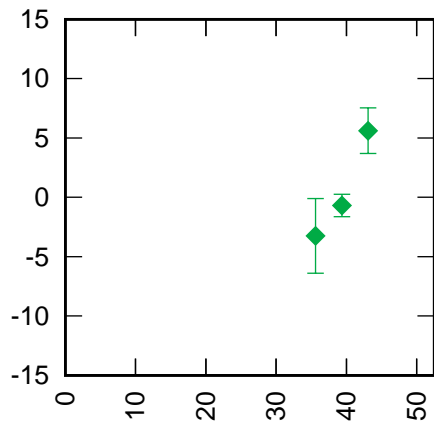
Single-shot RMS (mm)

Single-shot RMS (mm)

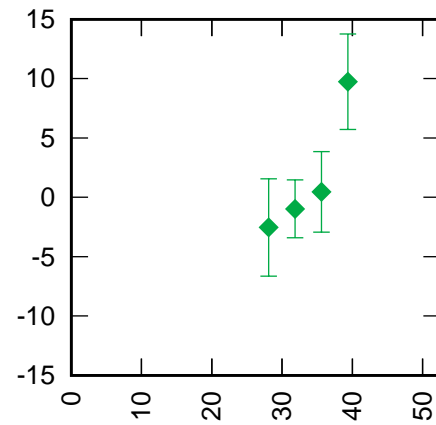
Arkhyz 1886 LAG1+LAG2
(CoM 248 mm) RB -80.3 mm +



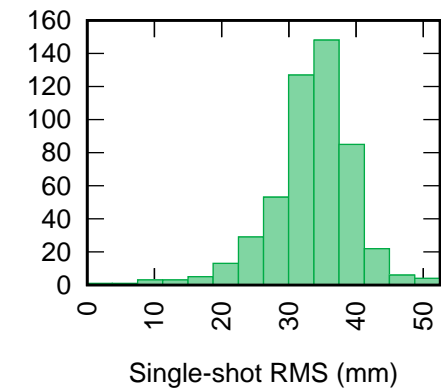
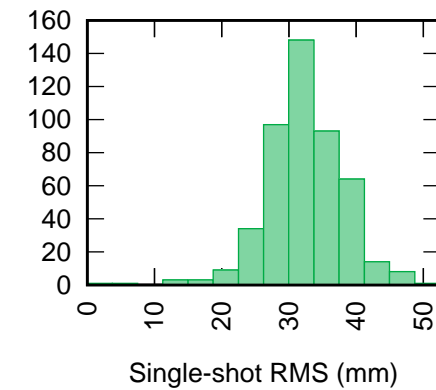
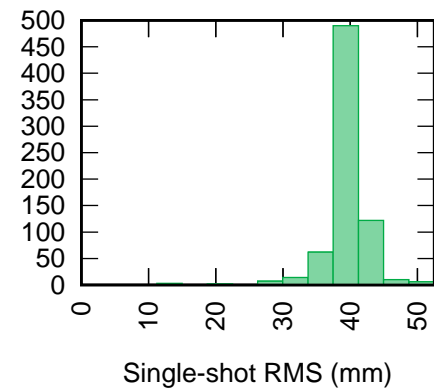
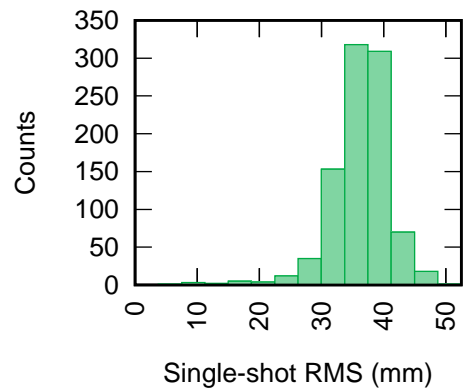
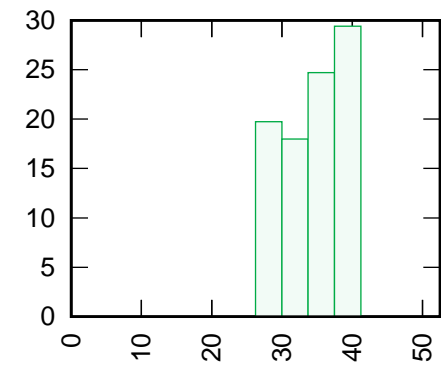
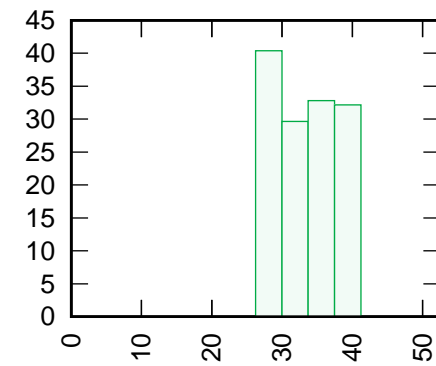
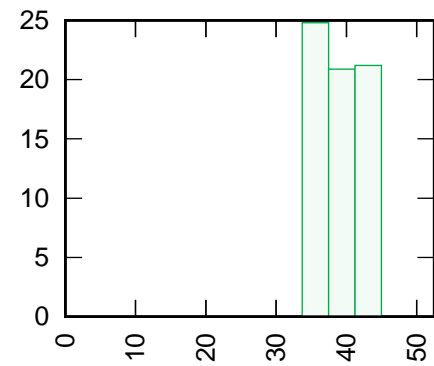
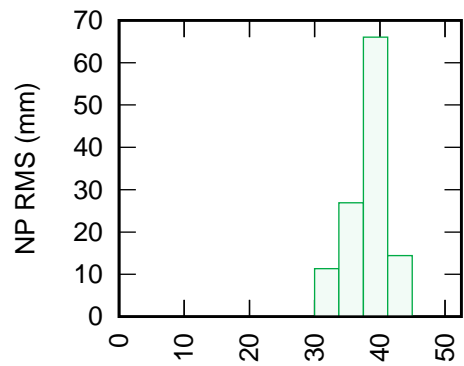
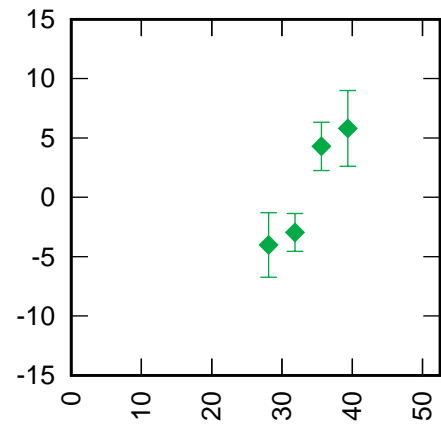
Arkhyz 1886 AJI
(CoM 1009 mm) RB -70.5 mm +



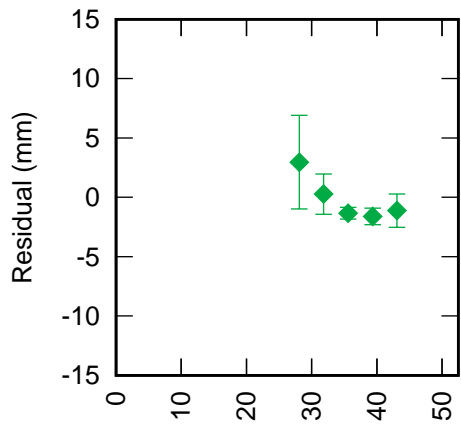
Arkhyz 1886 STRL+STEL
(CoM 75 mm) RB -99.9 mm +



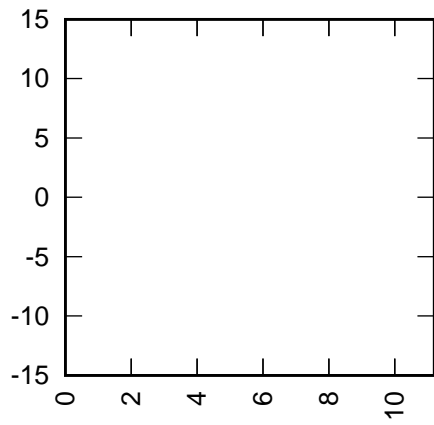
Arkhyz 1886 LARS
(CoM 133 mm) RB -88.3 mm +



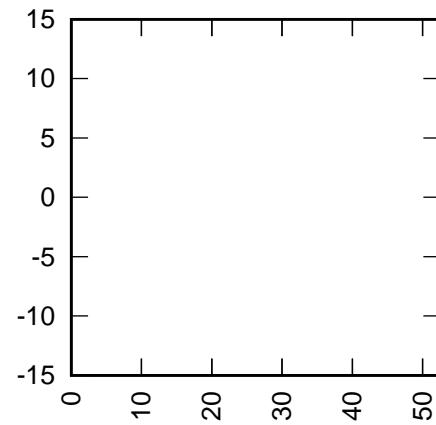
Baikonur 1887 LAG1+LAG2
(CoM 248 mm) RB -15.2 mm +



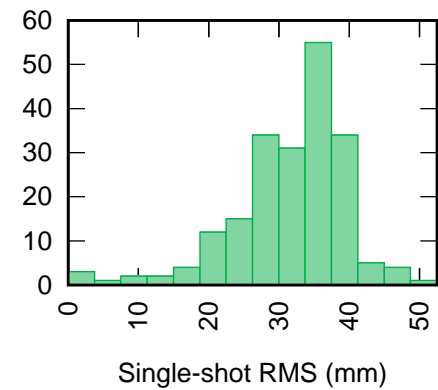
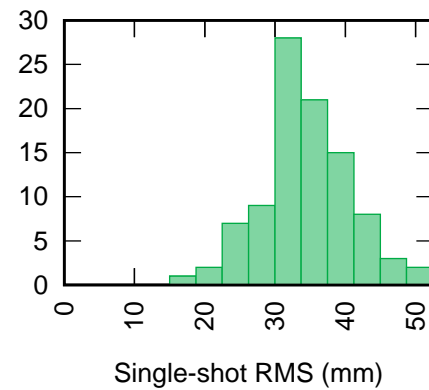
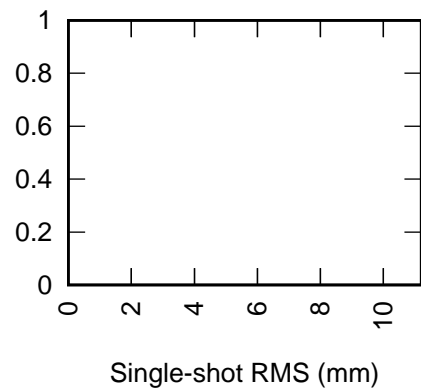
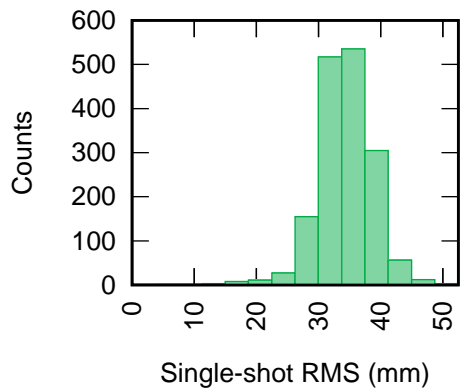
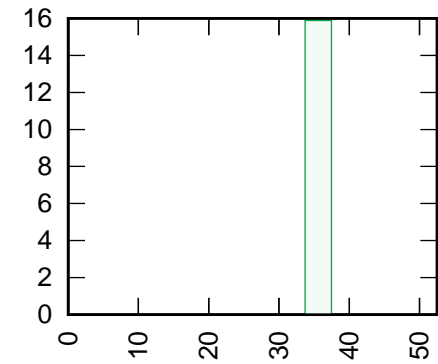
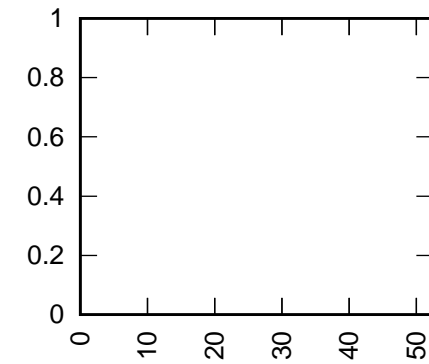
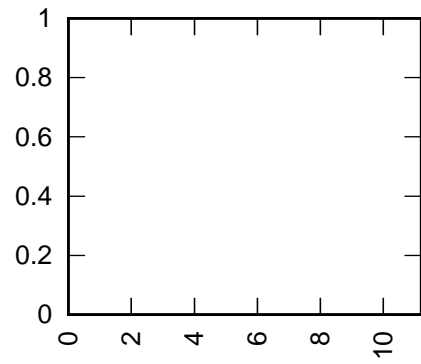
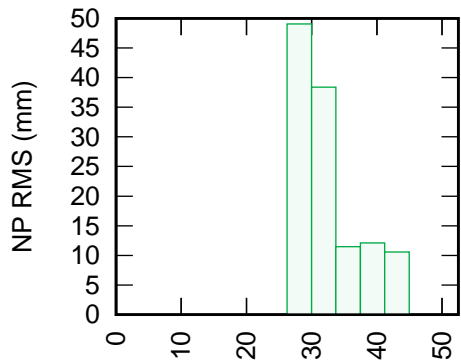
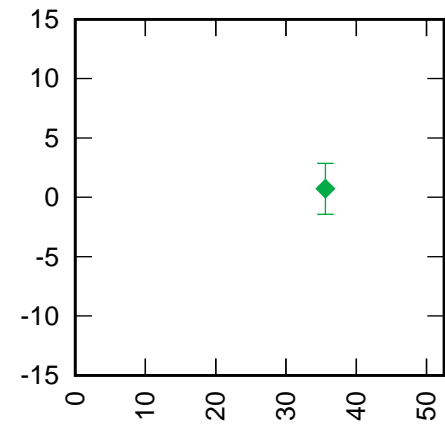
Baikonur 1887 AJI
CoM (CoM 1009 mm) RB 0.0 mm +



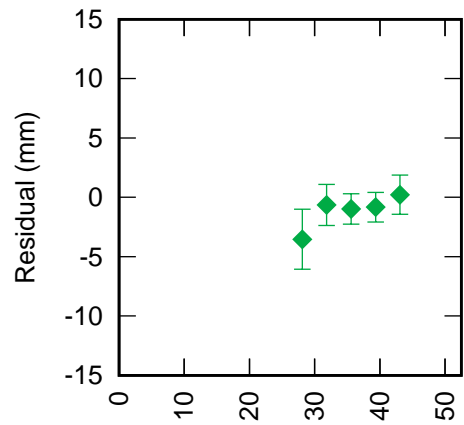
Baikonur 1887 STRL+STEL
(CoM 75 mm) RB -17.4 mm +



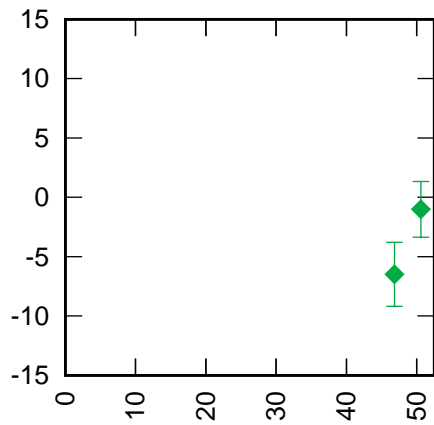
Baikonur 1887 LARS
CoM (CoM 133 mm) RB -20.4 mm +



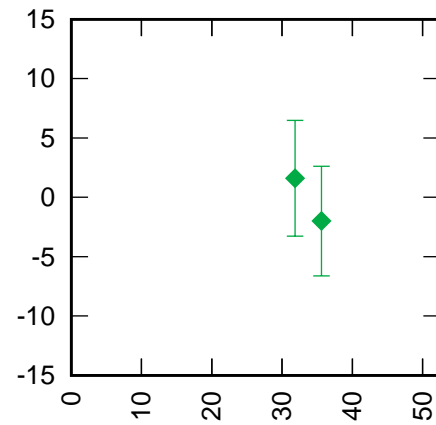
Svetloe 1888 LAG1+LAG2
(CoM 248 mm) RB 10.8 mm +



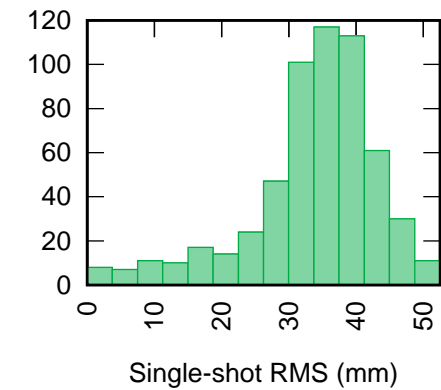
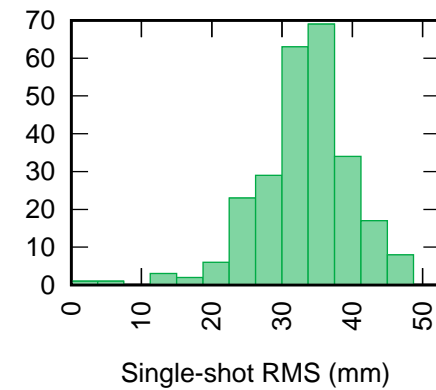
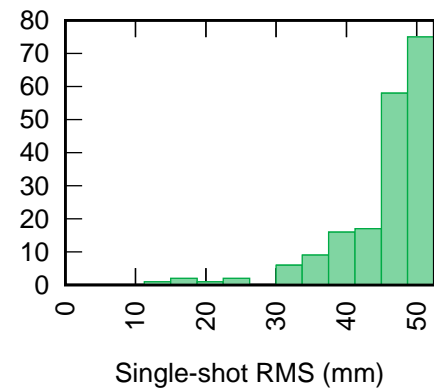
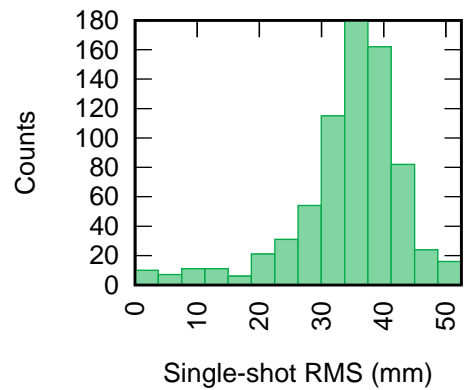
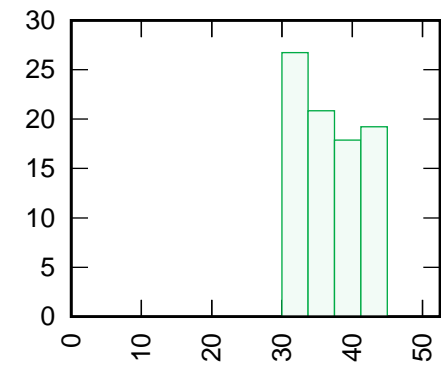
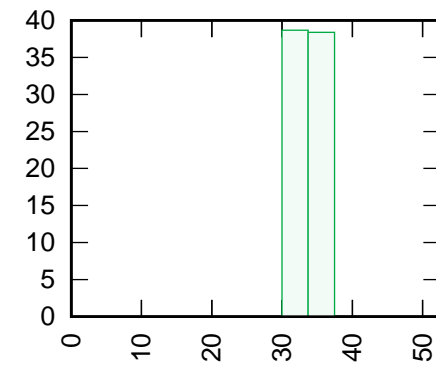
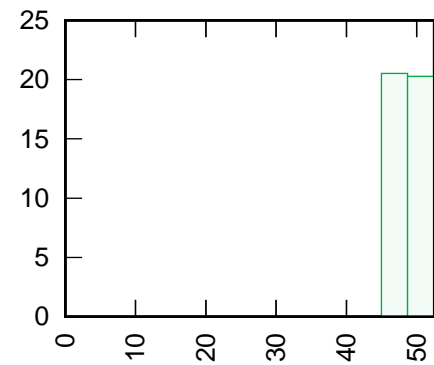
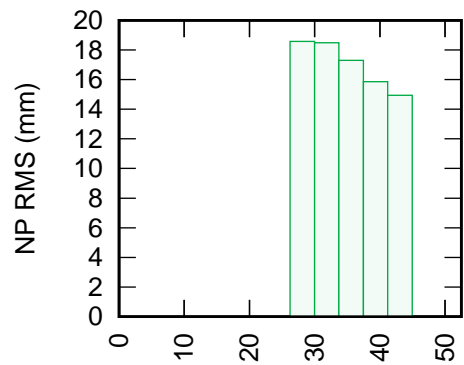
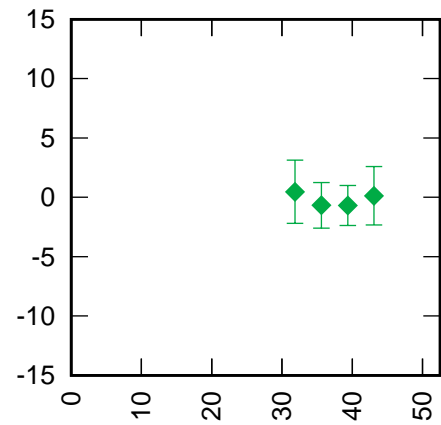
Svetloe 1888 AJI
(CoM 1009 mm) RB 44.9 mm +



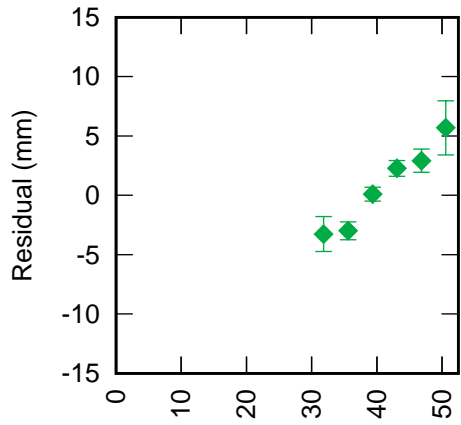
Svetloe 1888 STRL+STEL
(CoM 75 mm) RB 9.1 mm +



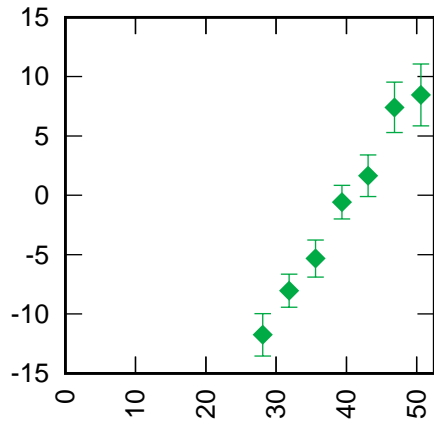
Svetloe 1888 LARS
(CoM 133 mm) RB 14.5 mm +



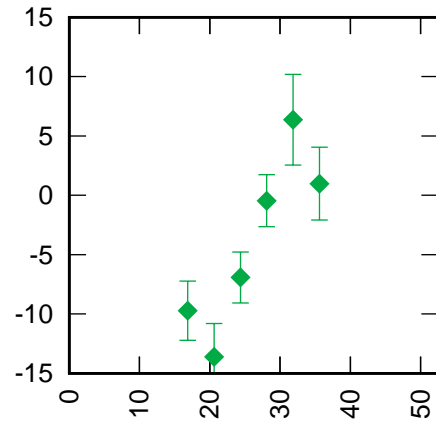
Zelenchukskya 1889 LAG1+LAG2
(CoM 248 mm) RB 18.5 mm +



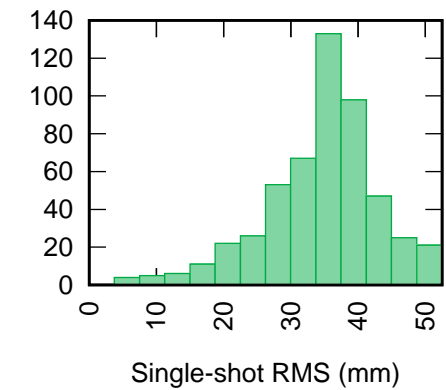
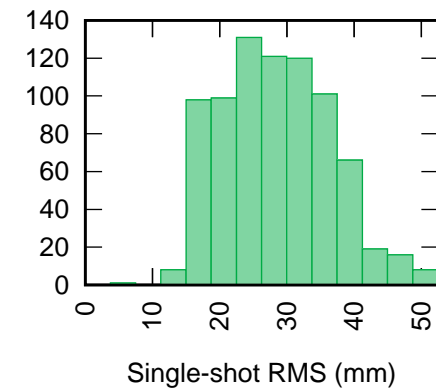
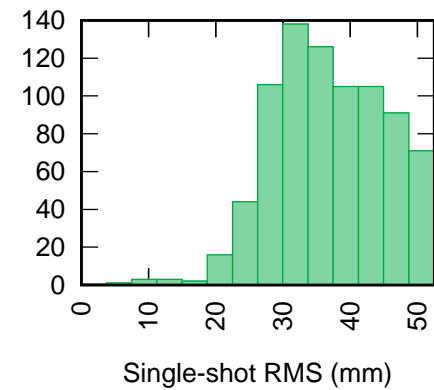
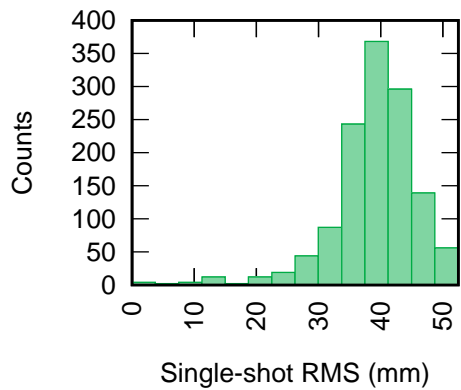
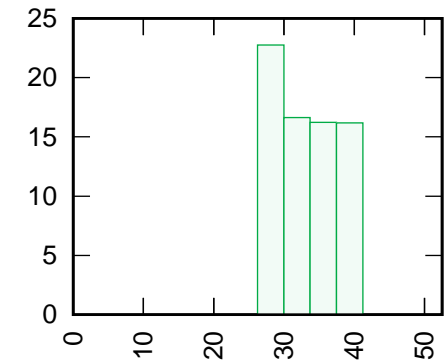
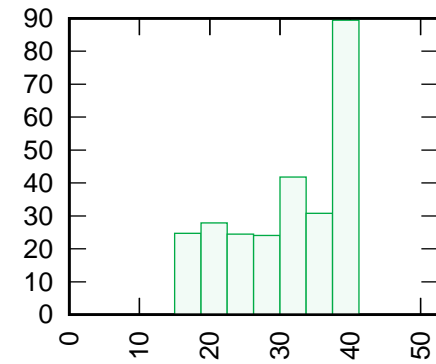
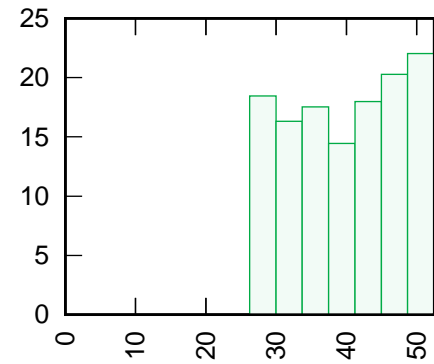
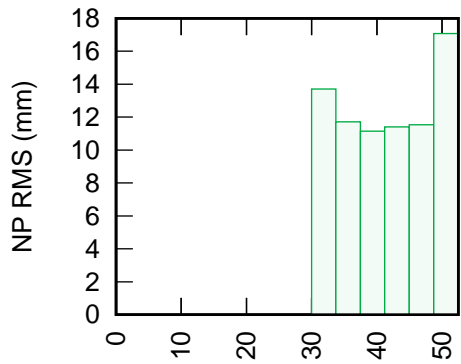
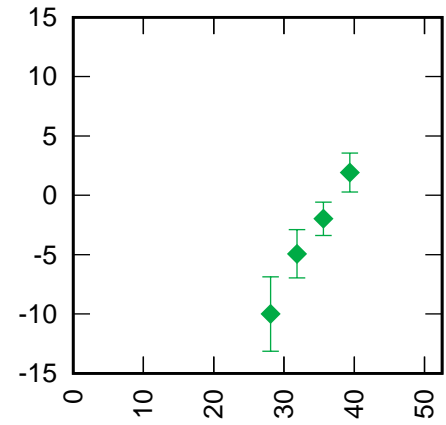
Zelenchukskya 1889 AJI
CoM (CoM 1009 mm) RB 36.4 mm +



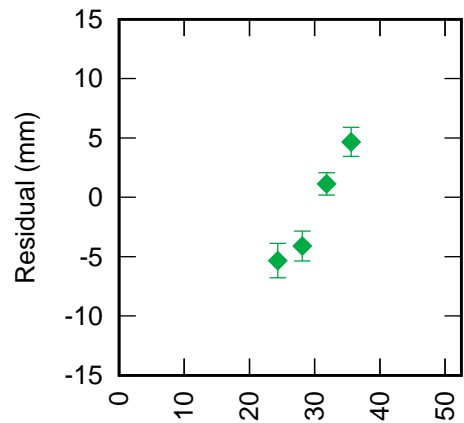
Zelenchukskya 1889 STRL+STEL
(CoM 75 mm) RB 4.0 mm +



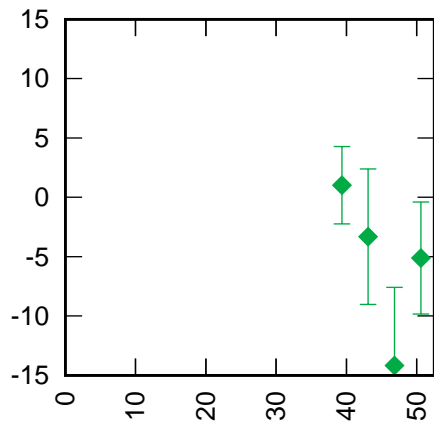
Zelenchukskya 1889 LARS
CoM (CoM 133 mm) RB 15.9 mm +



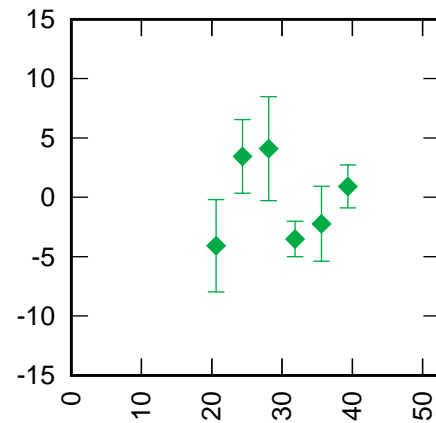
Badary 1890 LAG1+LAG2
(CoM 248 mm) RB 3.5 mm +



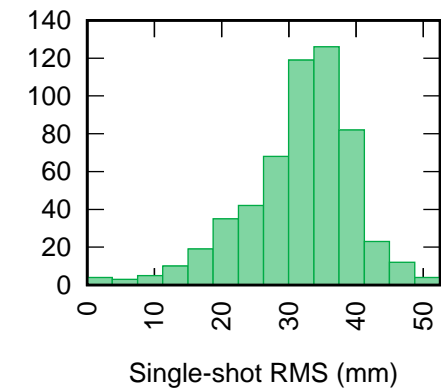
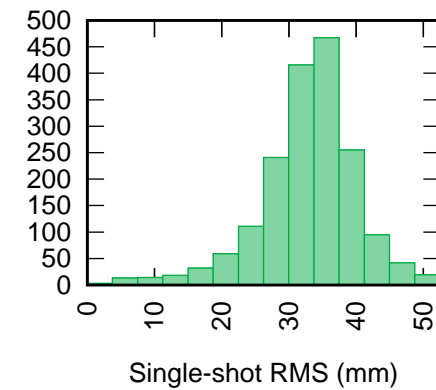
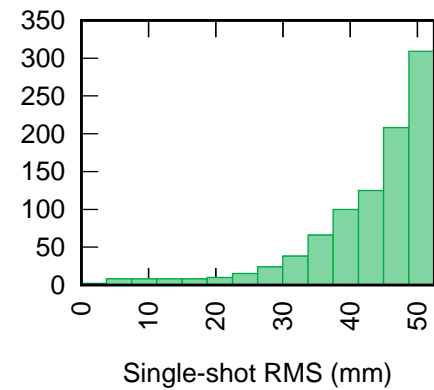
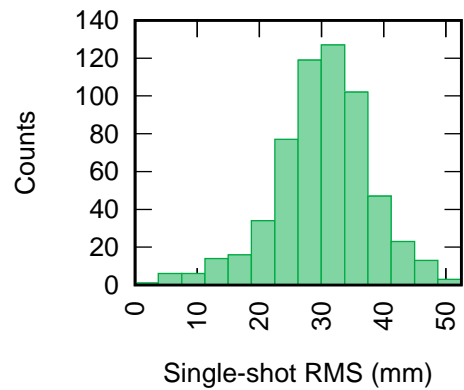
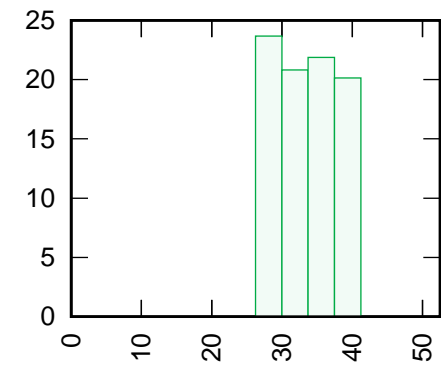
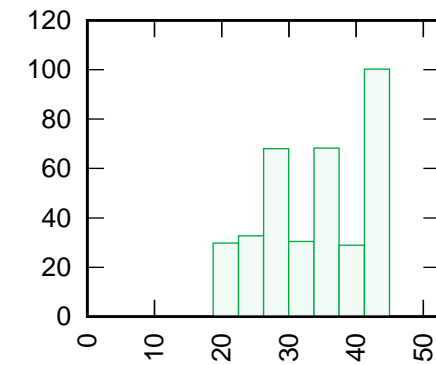
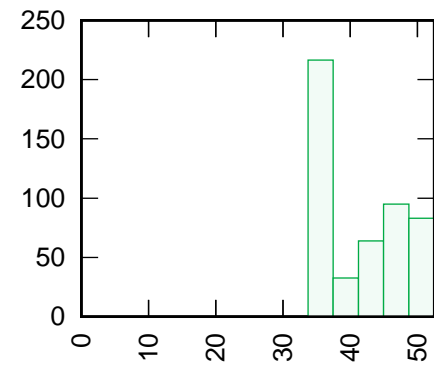
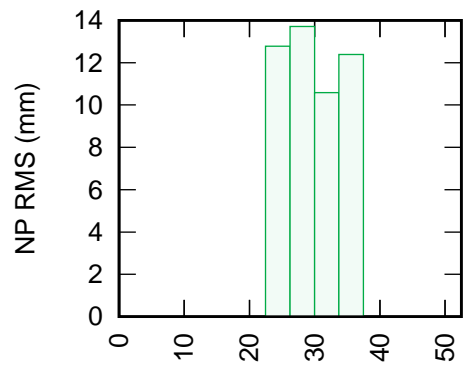
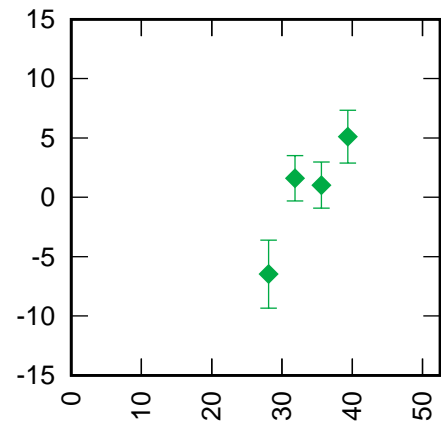
Badary 1890 AJI
CoM (CoM 1009 mm) RB 26.2 mm +



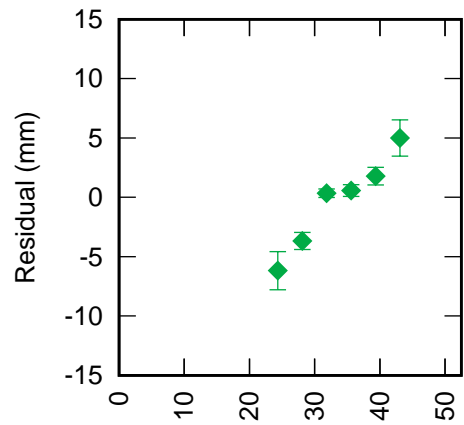
Badary 1890 STRL+STEL
(CoM 75 mm) RB -4.2 mm +



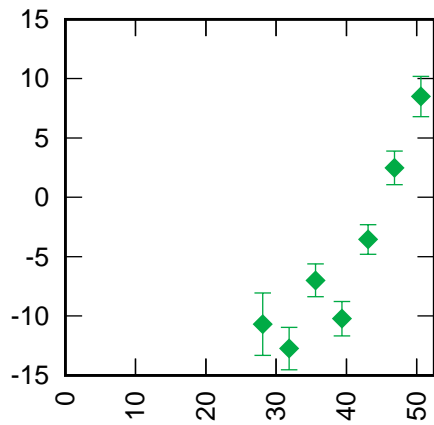
Badary 1890 LARS
CoM (CoM 133 mm) RB 13.9 mm +



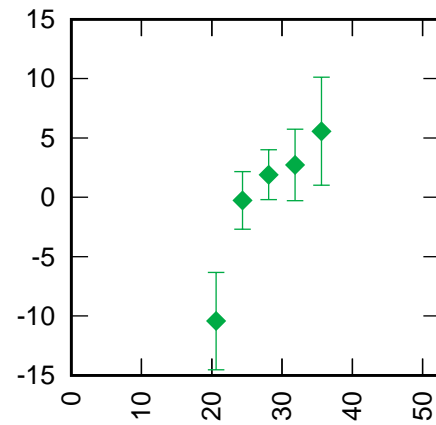
Irkutsk 1891 LAG1+LAG2
(CoM 251 mm) RB 26.6 mm +



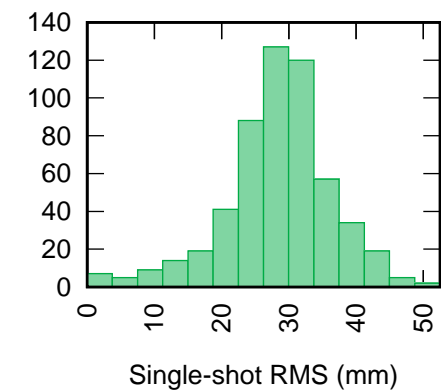
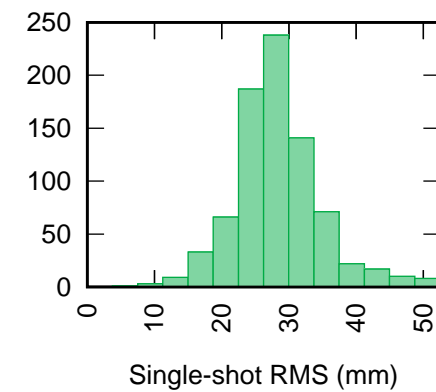
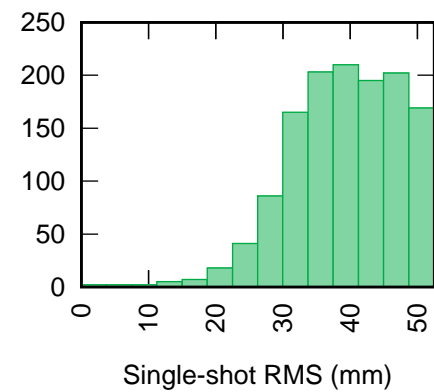
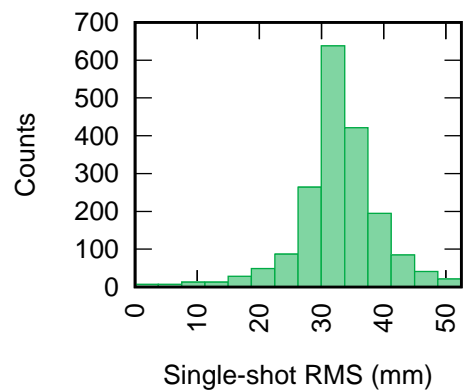
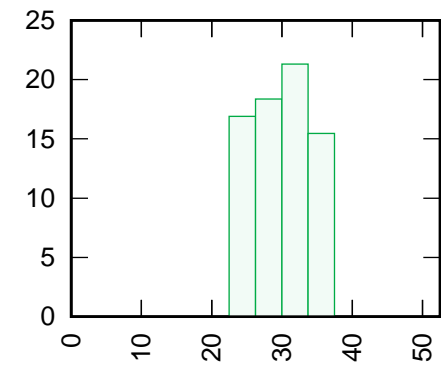
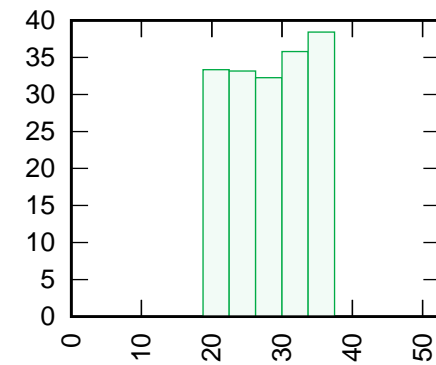
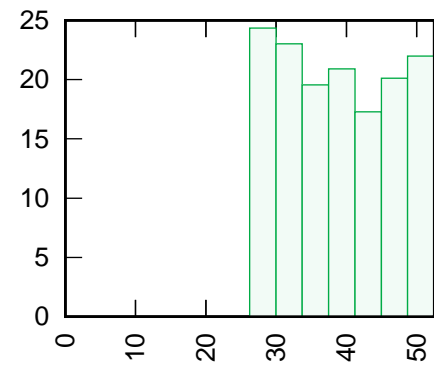
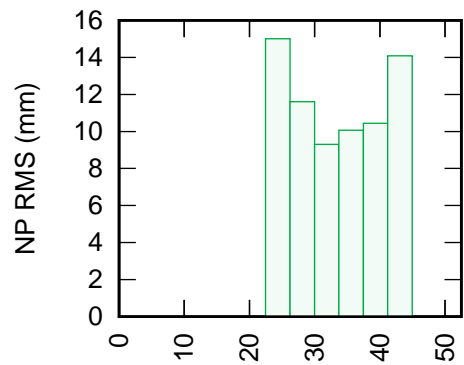
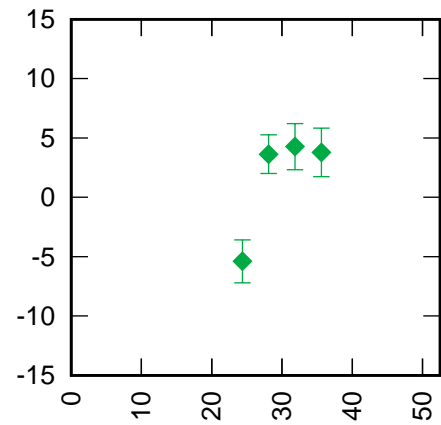
Irkutsk 1891 AJI
CoM (CoM 1010 mm) RB 46.4 mm +



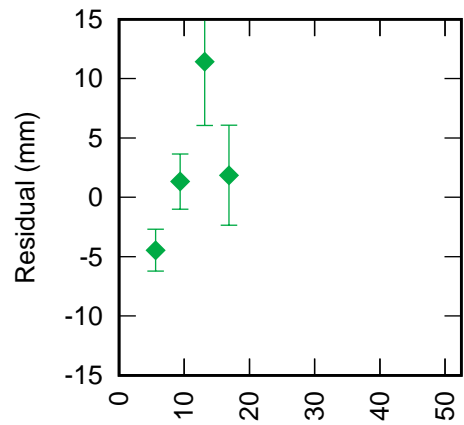
Irkutsk 1891 STRL+STEL
(CoM 75 mm) RB 9.1 mm +



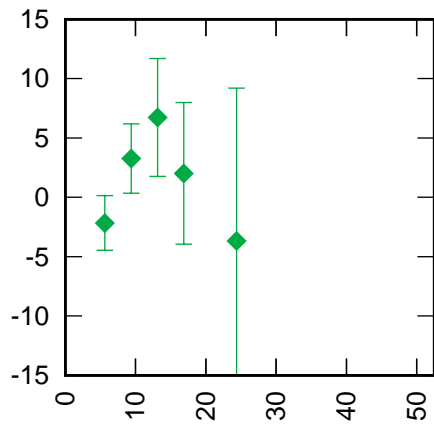
Irkutsk 1891 LARS
CoM (CoM 133 mm) RB 16.1 mm +



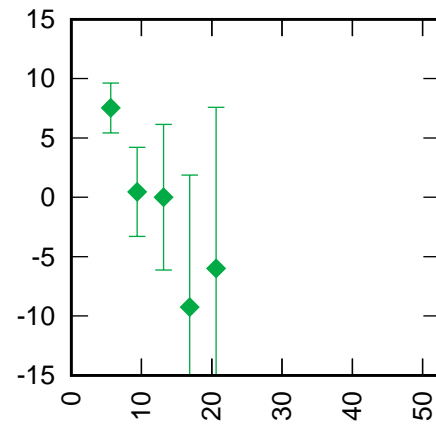
Katzively 1893 LAG1+LAG2
(CoM 246 mm) RB -48.4 mm +



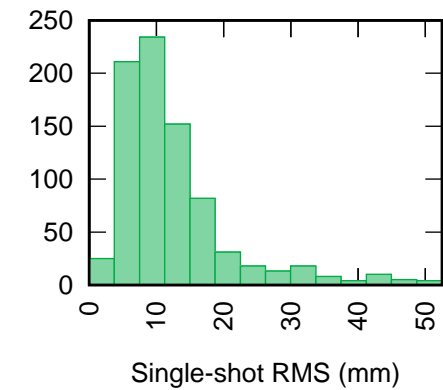
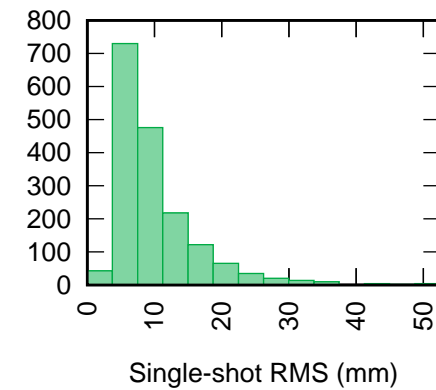
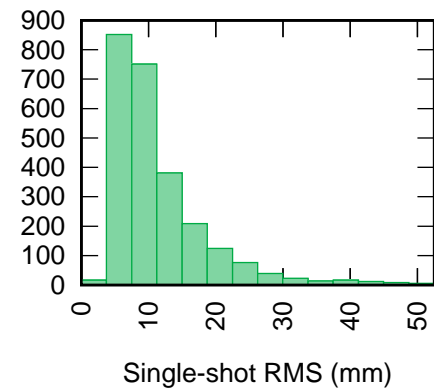
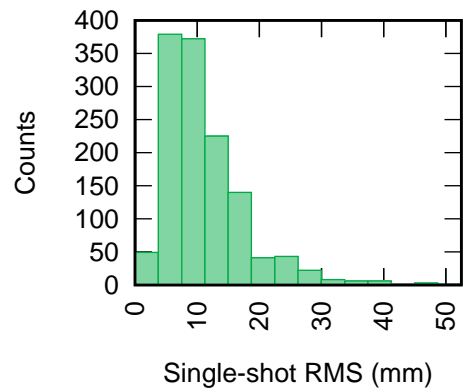
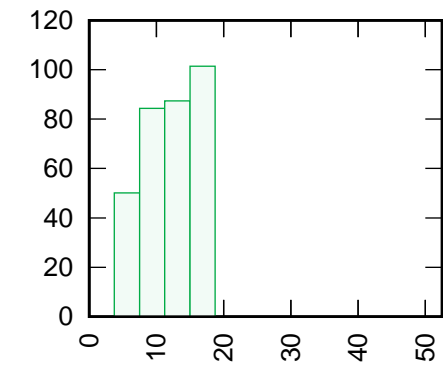
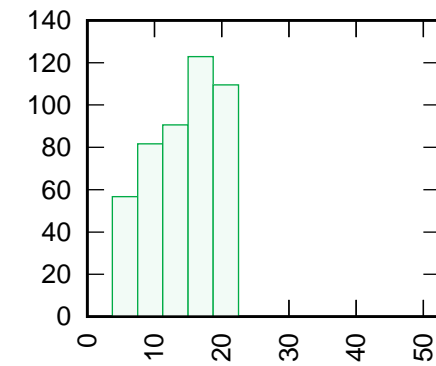
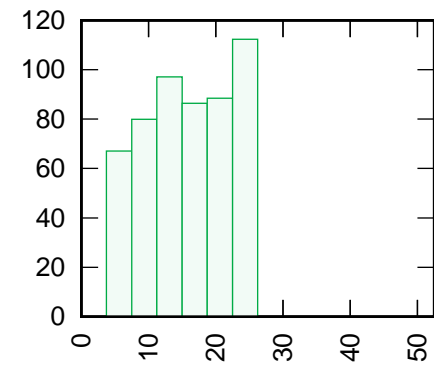
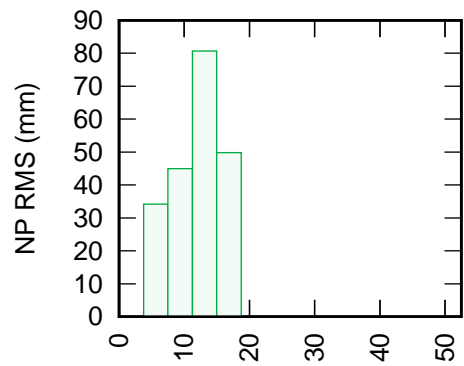
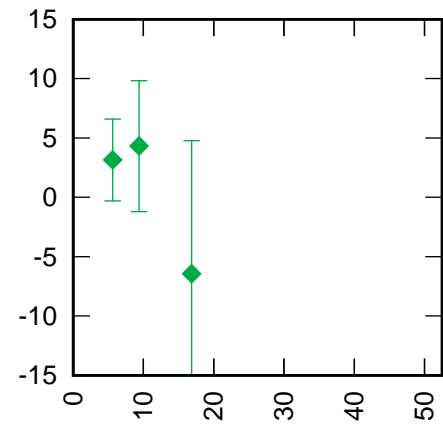
Katzively 1893 AJI
CoM (CoM 1009 mm) RB -51.0 mm +

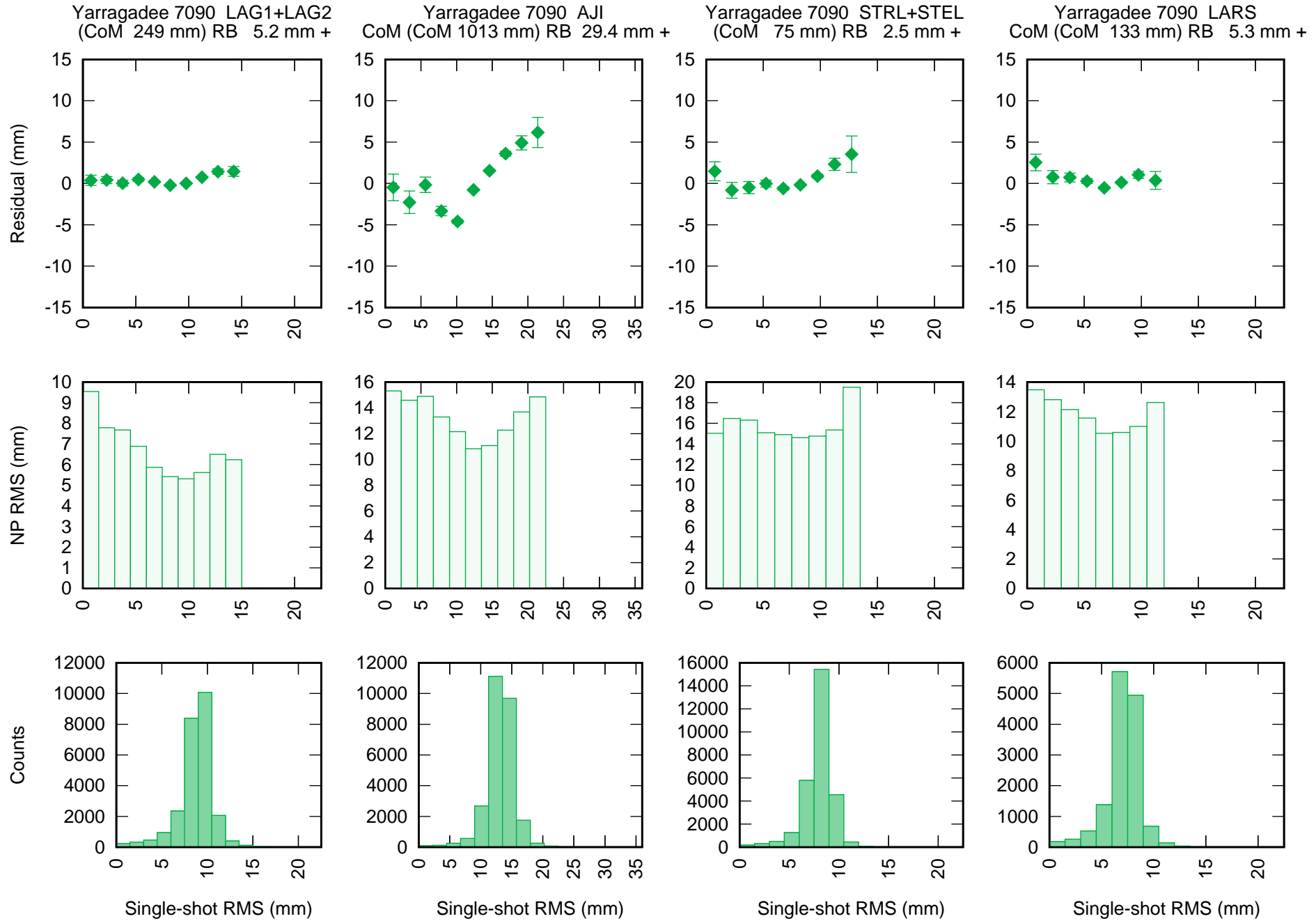


Katzively 1893 STRL+STEL
(CoM 75 mm) RB -86.7 mm +

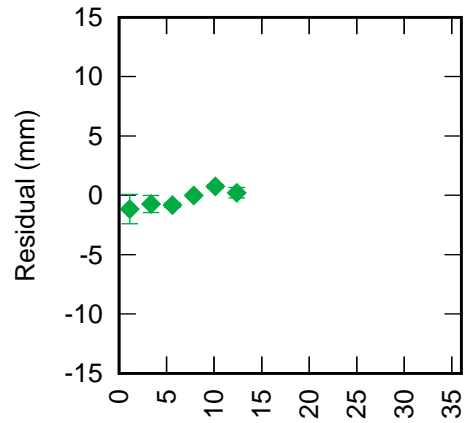


Katzively 1893 LARS
CoM (CoM 133 mm) RB -73.0 mm +

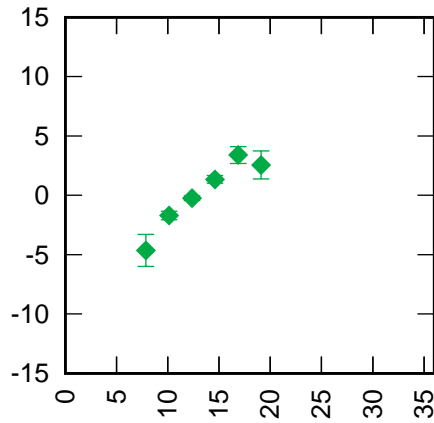




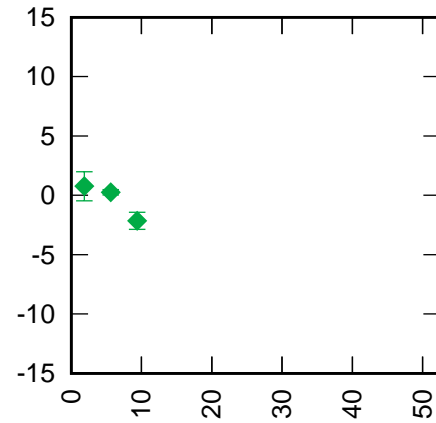
Greenbelt 7105 LAG1+LAG2
(CoM 249 mm) RB -2.0 mm +



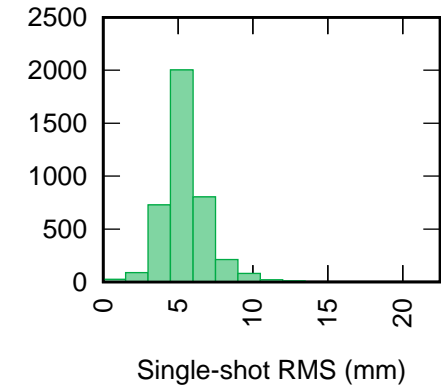
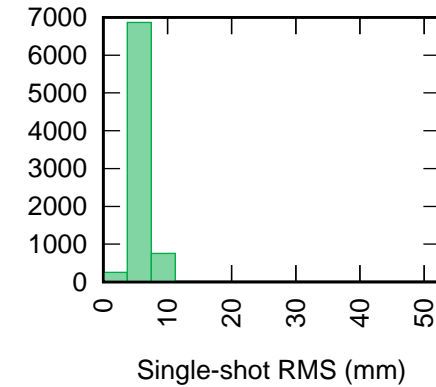
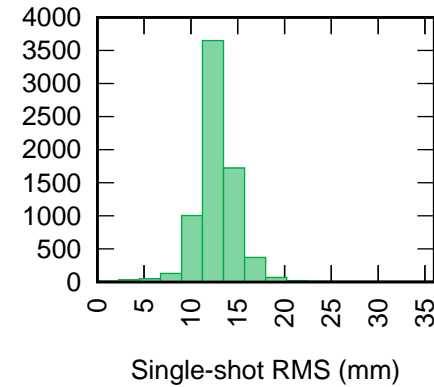
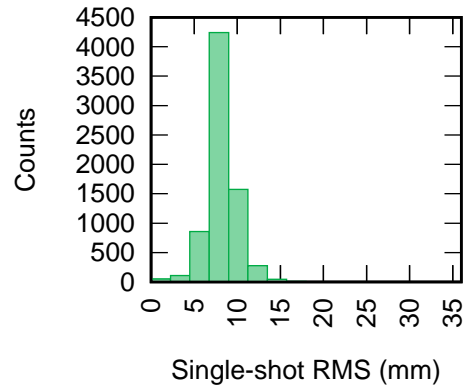
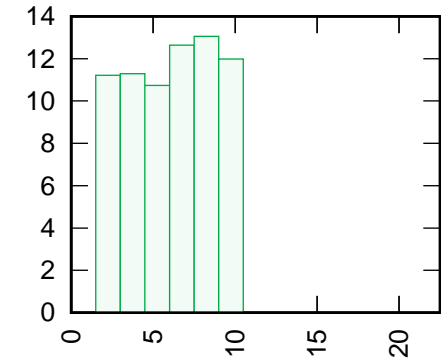
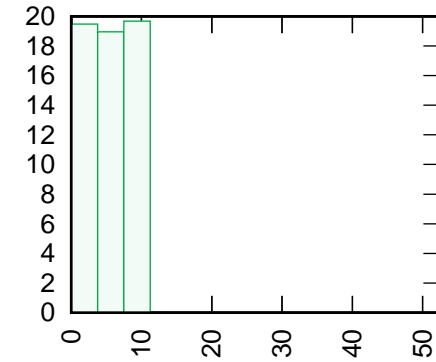
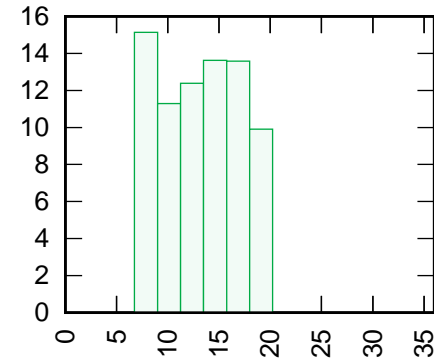
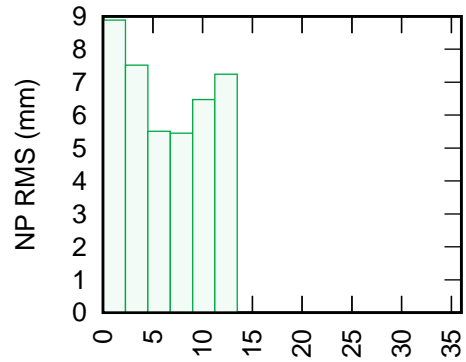
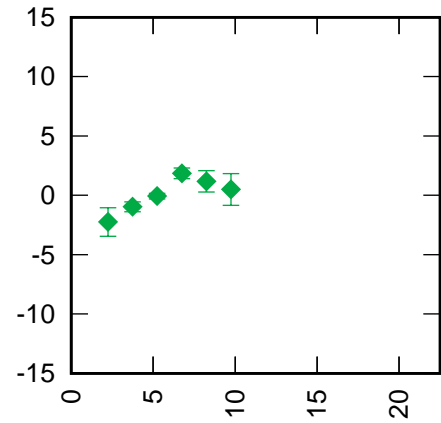
Greenbelt 7105 AJI
CoM (CoM 1013 mm) RB 25.0 mm +



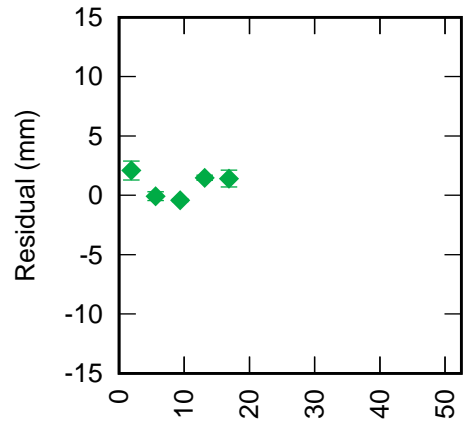
Greenbelt 7105 STRL+STEL
(CoM 75 mm) RB -7.3 mm +



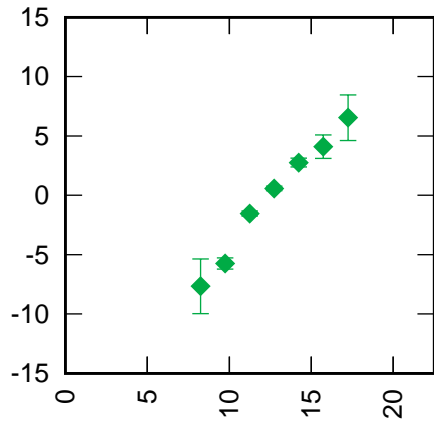
Greenbelt 7105 LARS
CoM (CoM 133 mm) RB -4.3 mm +



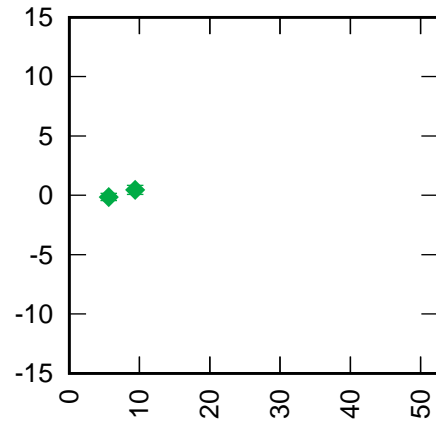
Monument Peak 7110 LAG1+LAG2
(CoM 249 mm) RB 1.6 mm +



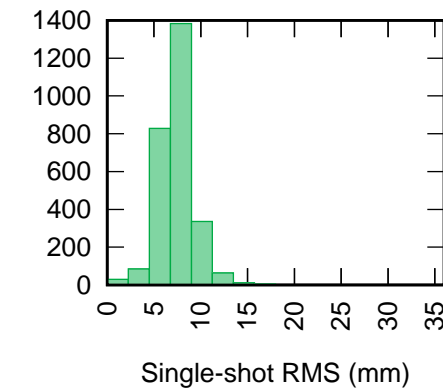
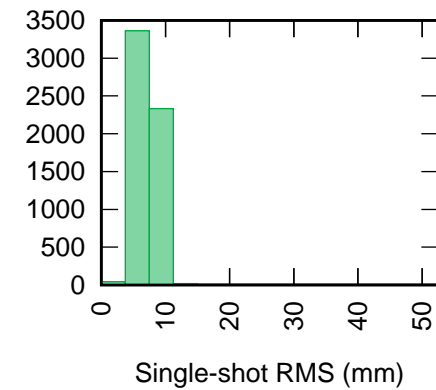
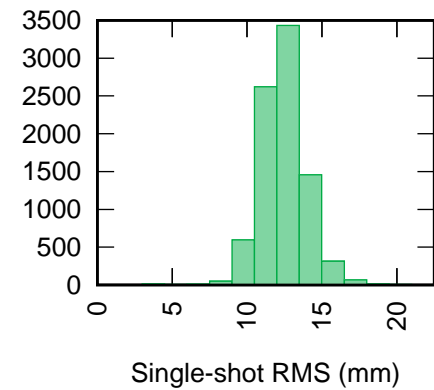
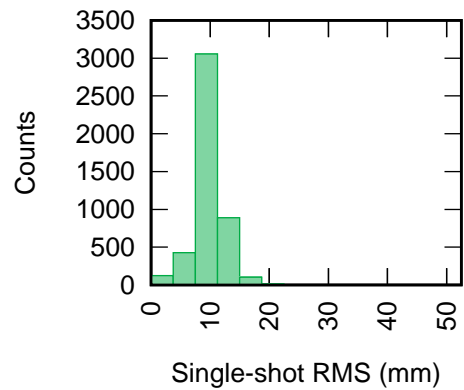
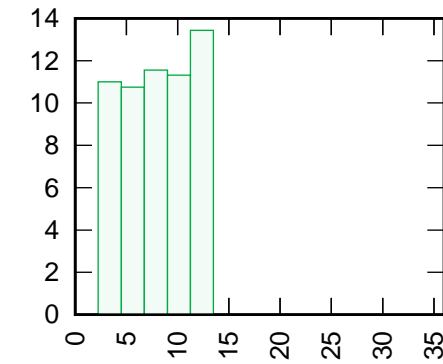
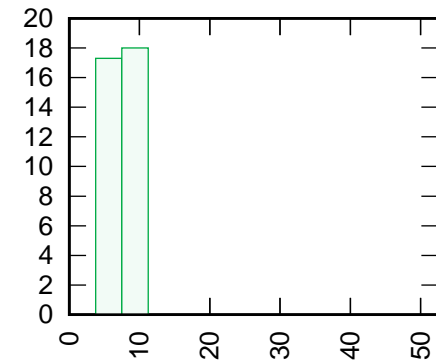
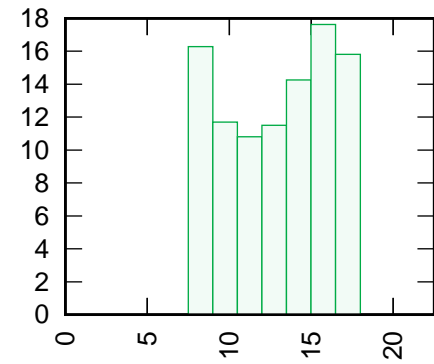
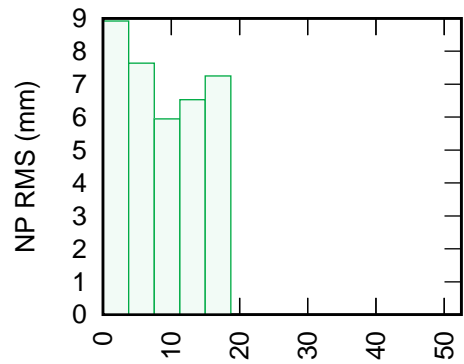
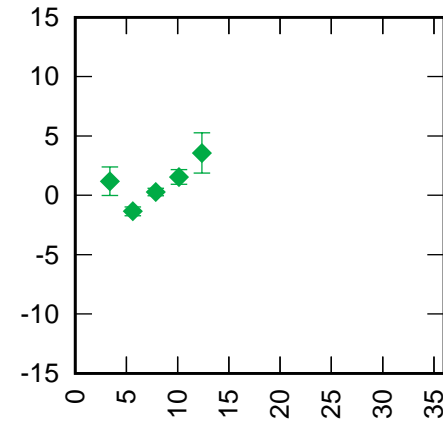
Monument Peak 7110 AJI
(CoM 1013 mm) RB 30.4 mm +



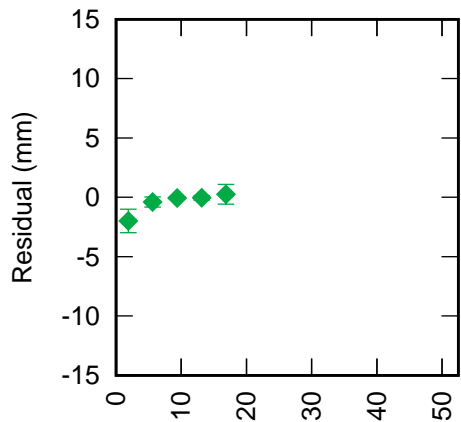
Monument Peak 7110 STRL+STEL
(CoM 75 mm) RB -1.0 mm +



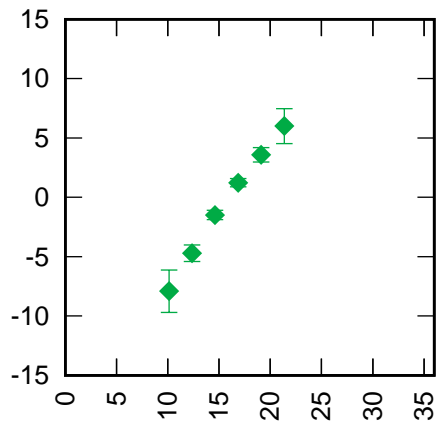
Monument Peak 7110 LARS
(CoM 133 mm) RB 0.6 mm +



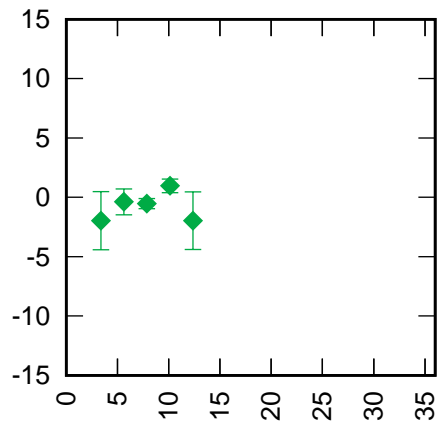
Haleakala 7119 LAG1+LAG2
(CoM 249 mm) RB 14.8 mm +



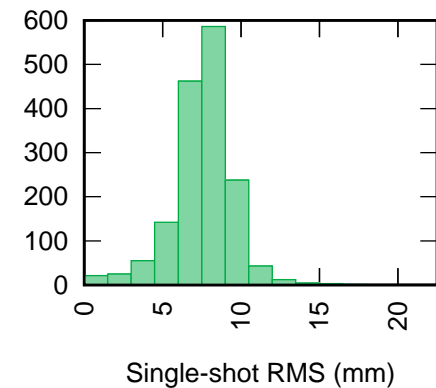
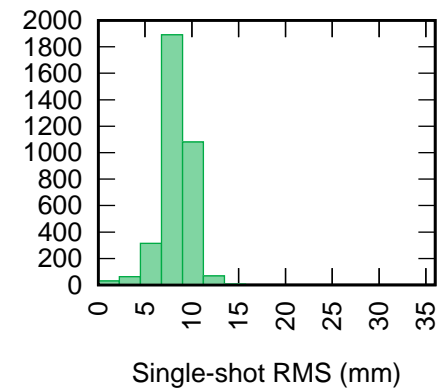
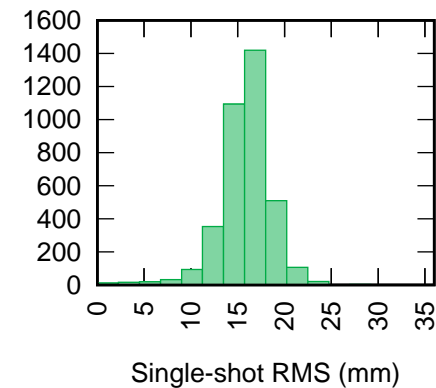
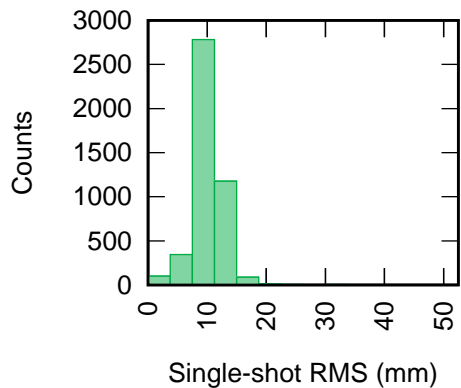
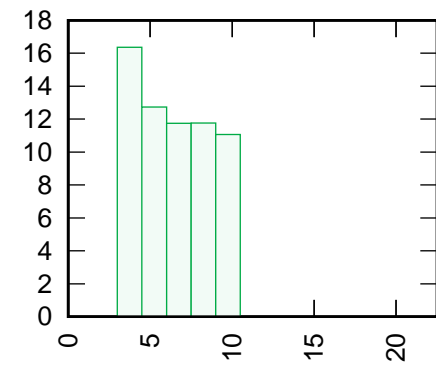
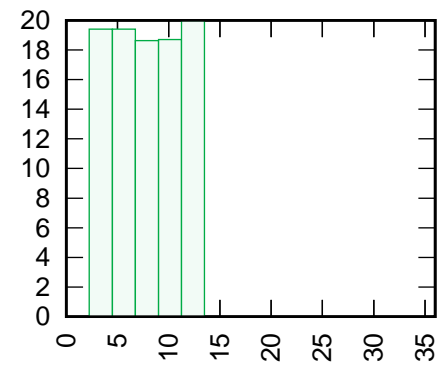
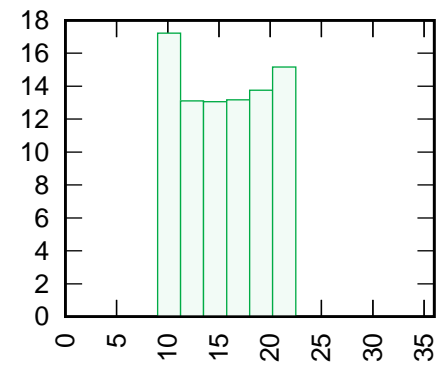
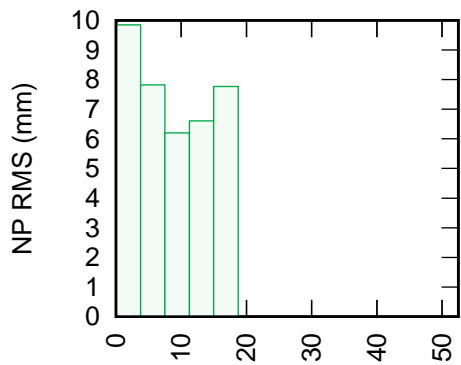
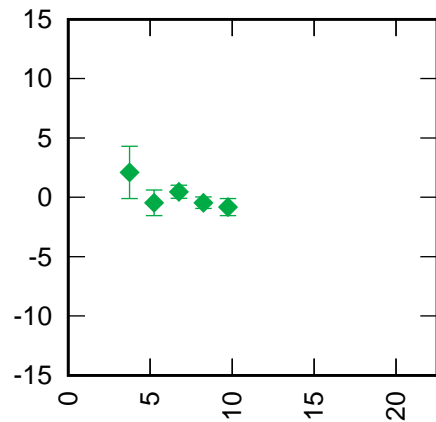
Haleakala 7119 AJI
CoM (CoM 1013 mm) RB 41.5 mm +



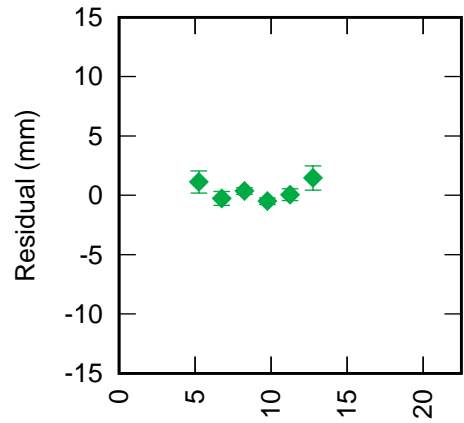
Haleakala 7119 STRL+STEL
(CoM 75 mm) RB 9.2 mm +



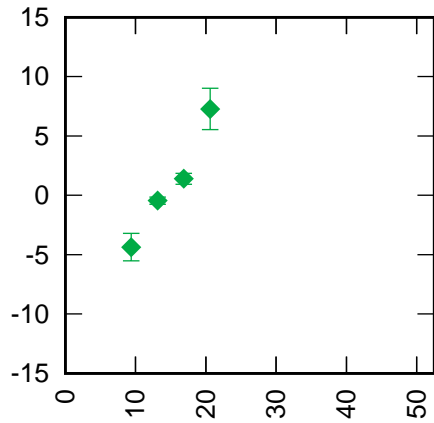
Haleakala 7119 LARS
CoM (CoM 133 mm) RB 13.0 mm +



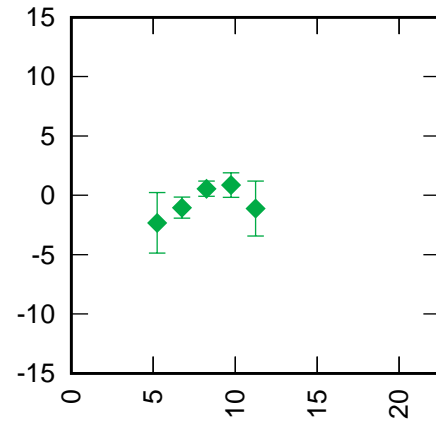
Tahiti 7124 LAG1+LAG2
(CoM 249 mm) RB 2.8 mm +



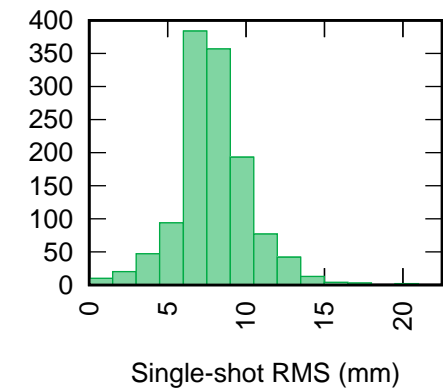
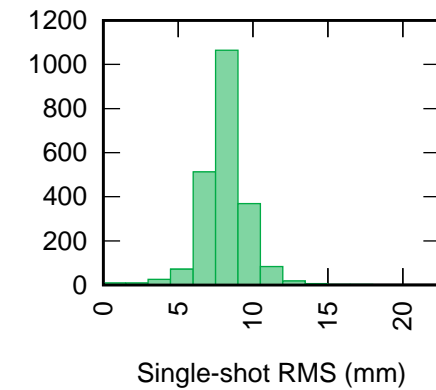
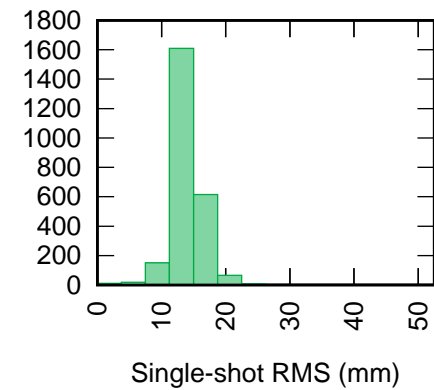
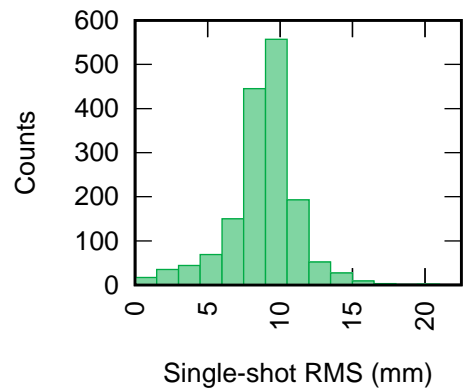
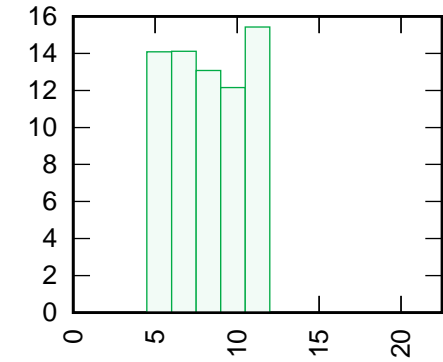
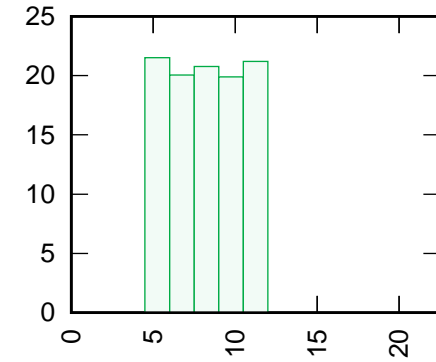
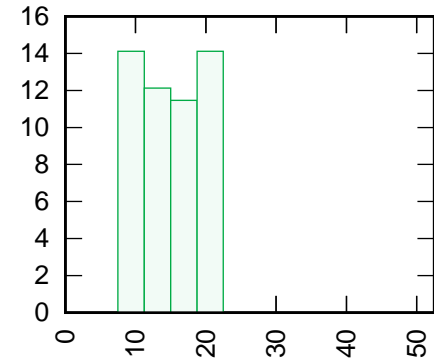
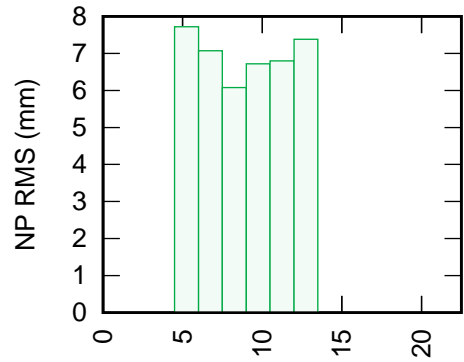
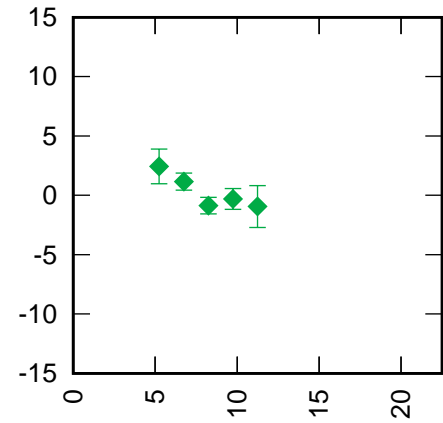
Tahiti 7124 AJI
CoM (CoM 1013 mm) RB 29.1 mm +

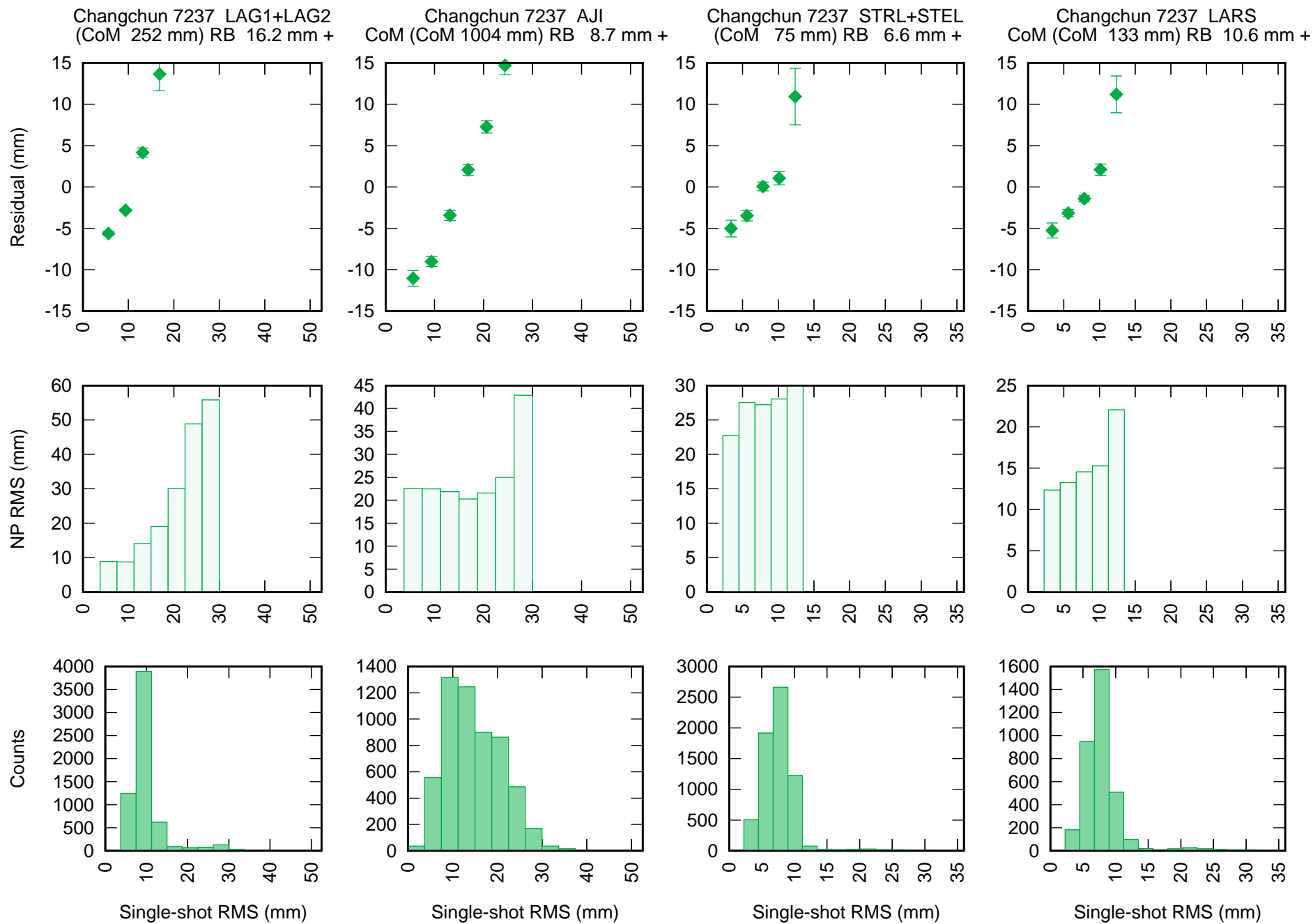


Tahiti 7124 STRL+STEL
(CoM 75 mm) RB -3.7 mm +

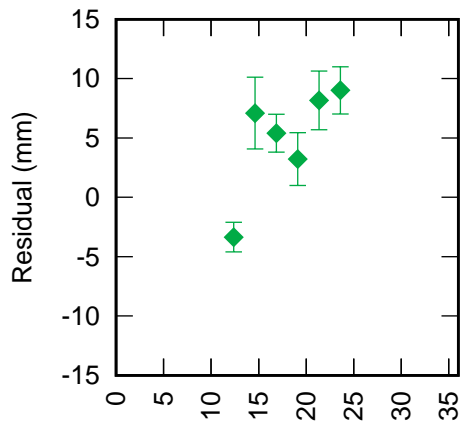


Tahiti 7124 LARS
CoM (CoM 133 mm) RB -1.6 mm +

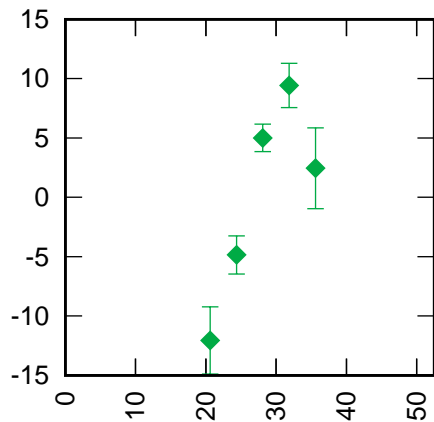




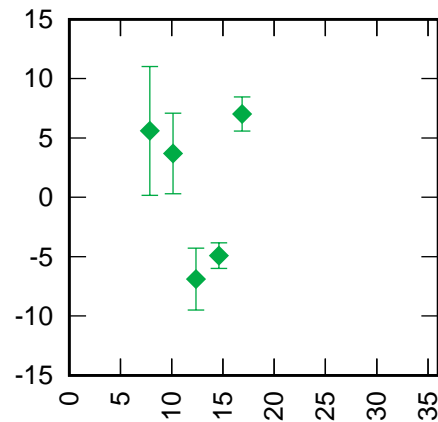
Beijing 7249 LAG1+LAG2
(CoM 252 mm) RB -2.3 mm +



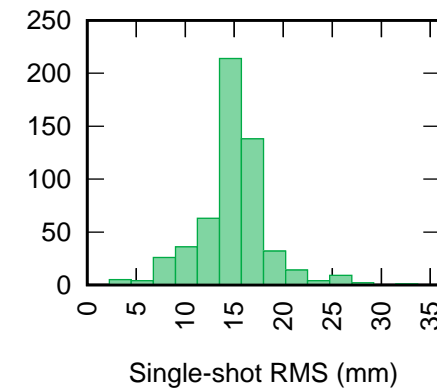
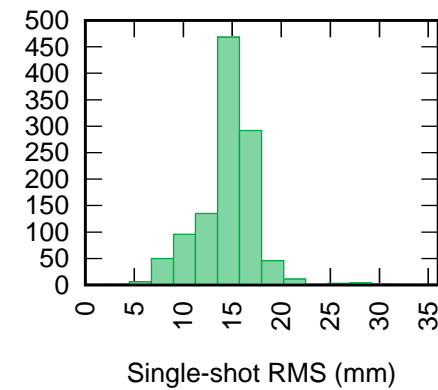
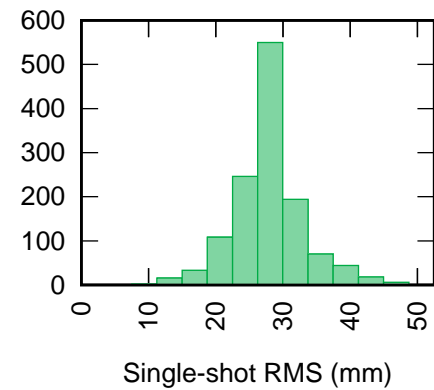
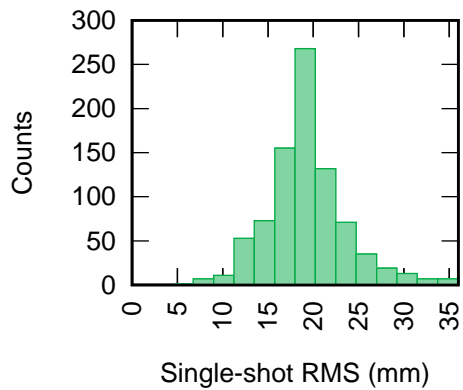
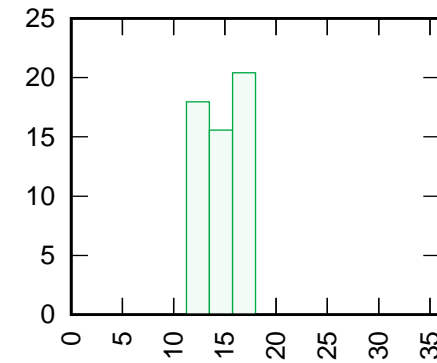
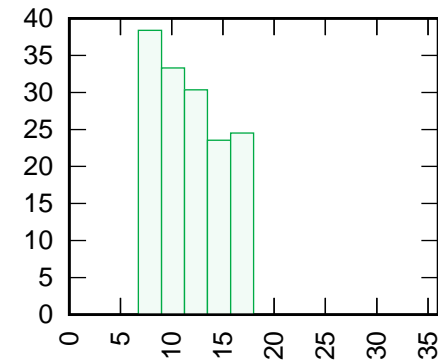
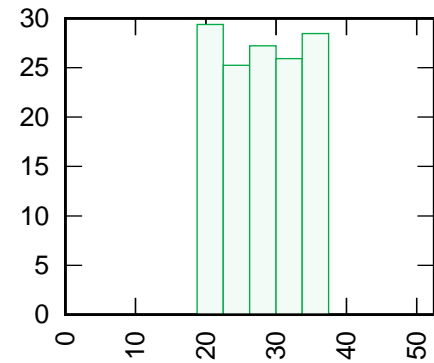
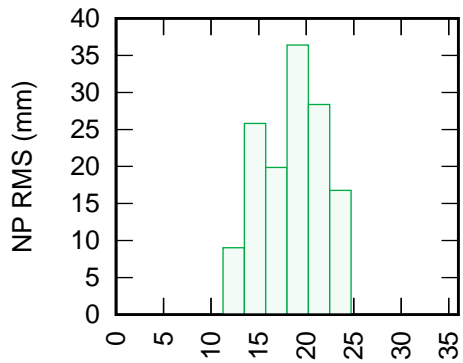
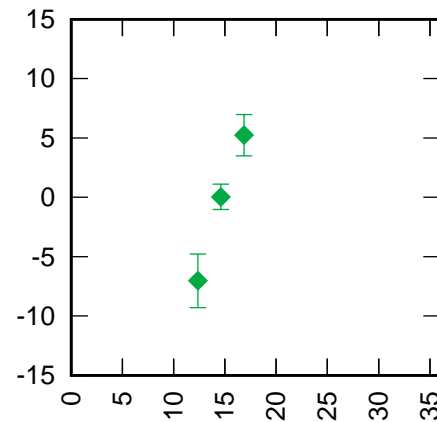
Beijing 7249 AJI
CoM (CoM 1004 mm) RB 4.9 mm +



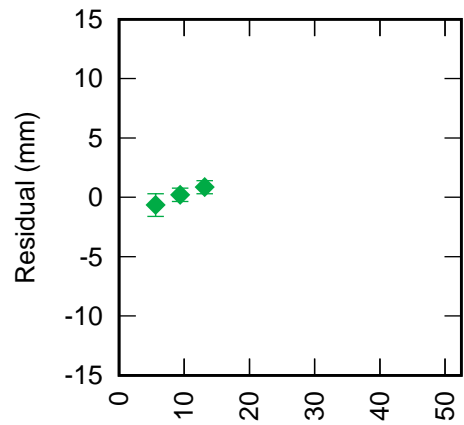
Beijing 7249 STRL+STEL
(CoM 75 mm) RB -8.7 mm +



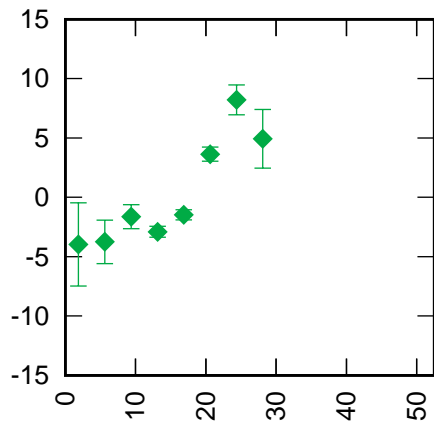
Beijing 7249 LARS
CoM (CoM 133 mm) RB -0.7 mm +



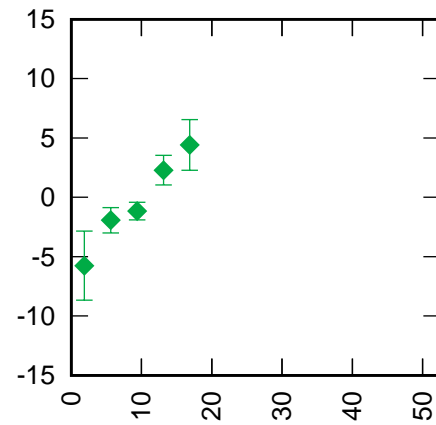
Arequipa 7403 LAG1+LAG2
(CoM 249 mm) RB 15.5 mm +



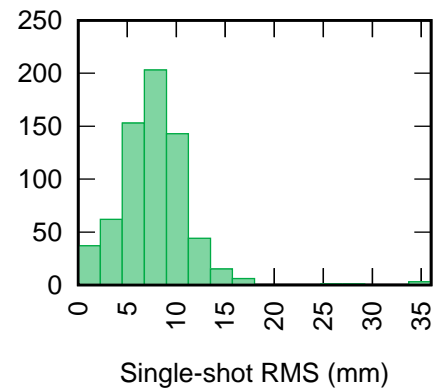
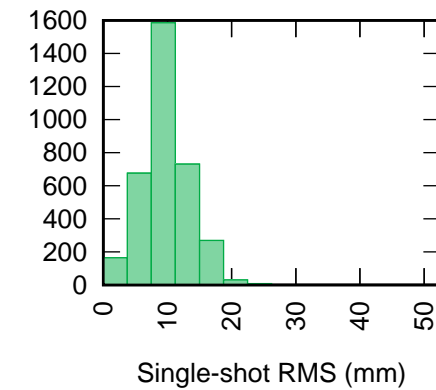
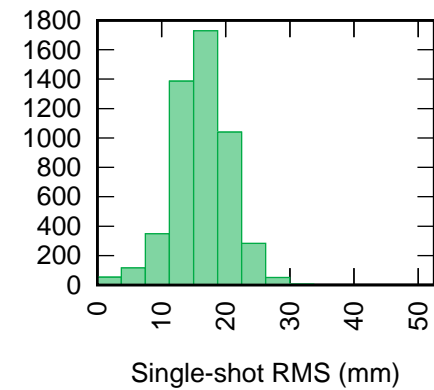
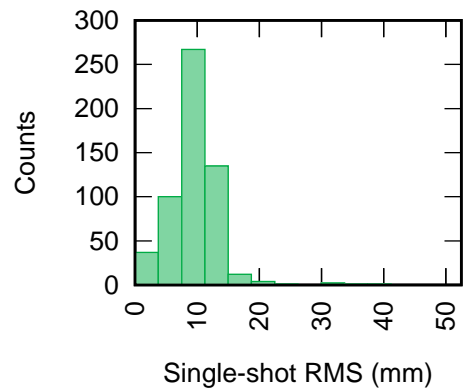
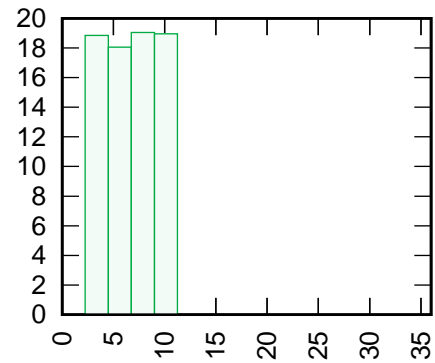
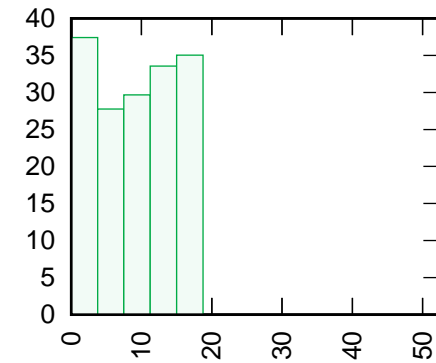
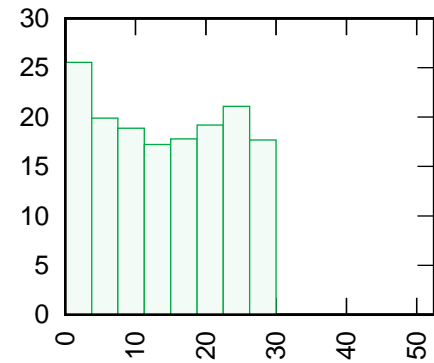
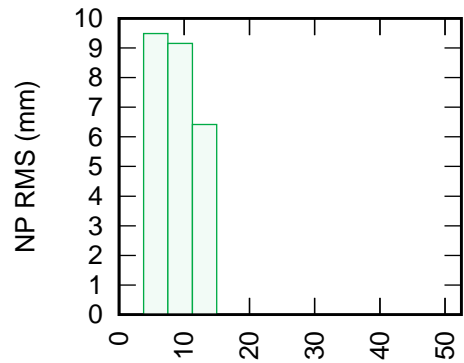
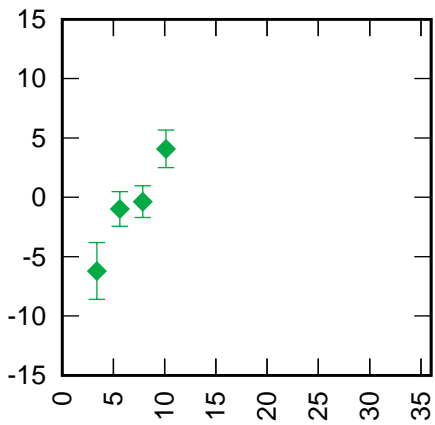
Arequipa 7403 AJI
CoM (CoM 1013 mm) RB 39.1 mm +



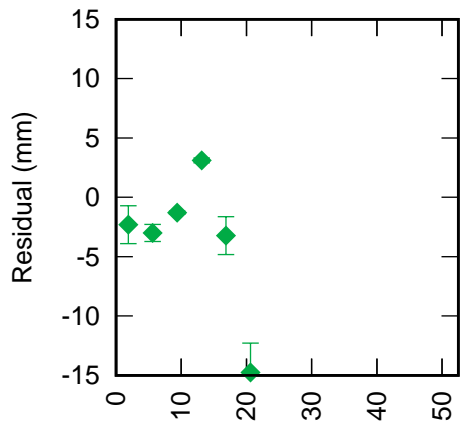
Arequipa 7403 STRL+STEL
(CoM 75 mm) RB 13.2 mm +



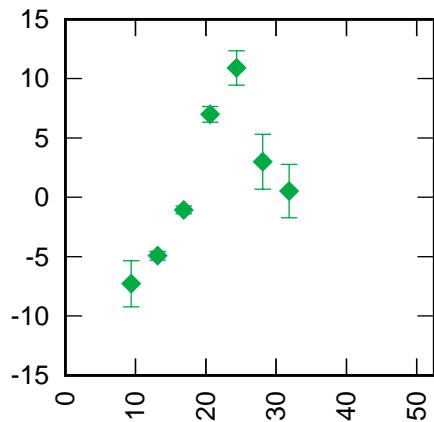
Arequipa 7403 LARS
CoM (CoM 133 mm) RB 11.2 mm +



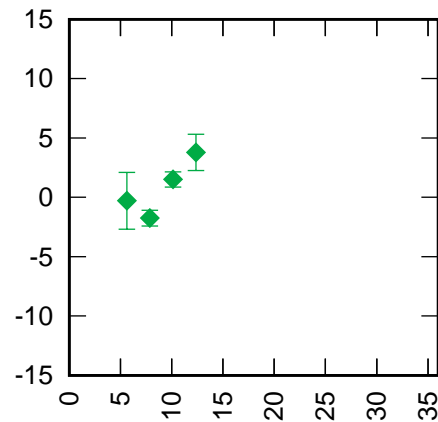
Hartebeesthoek 7501 LAG1+LAG2
(CoM 247 mm) RB 5.6 mm +



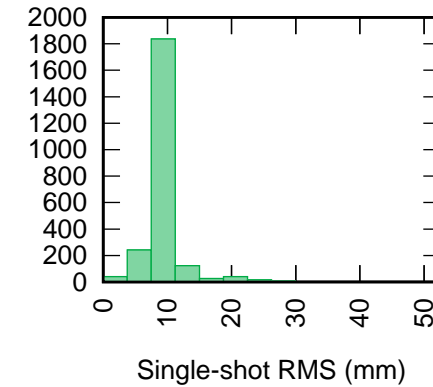
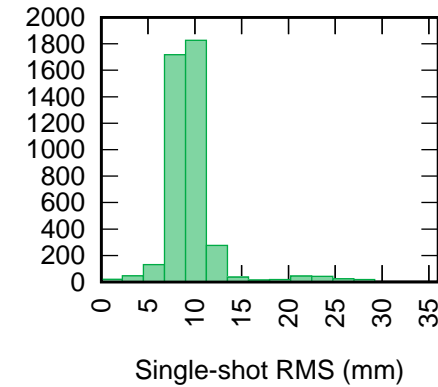
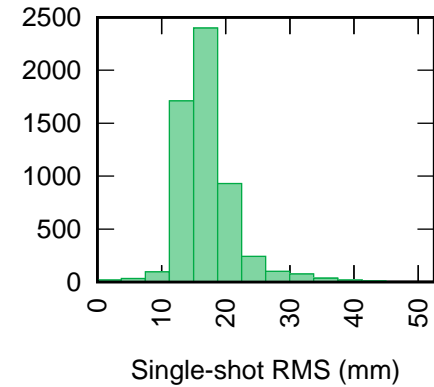
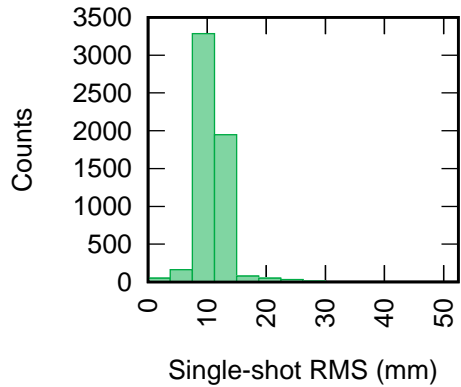
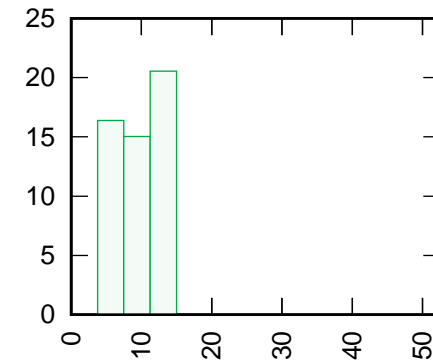
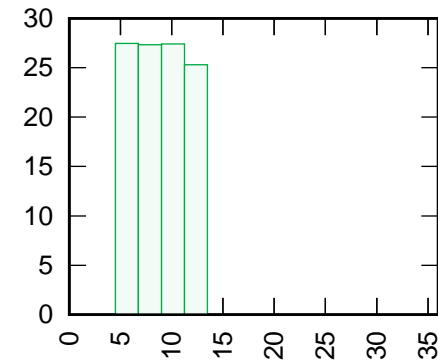
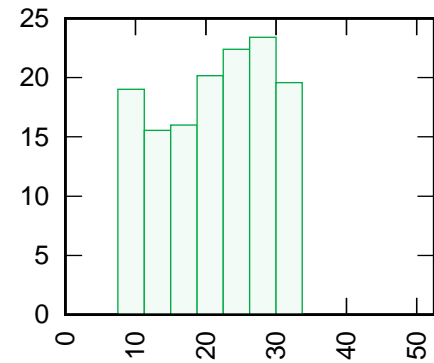
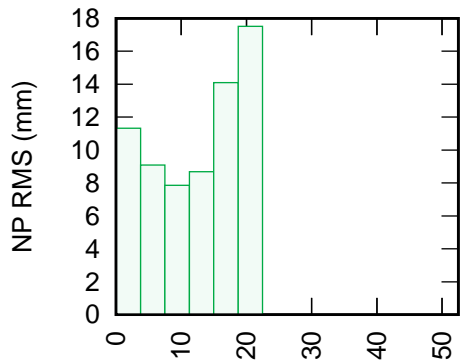
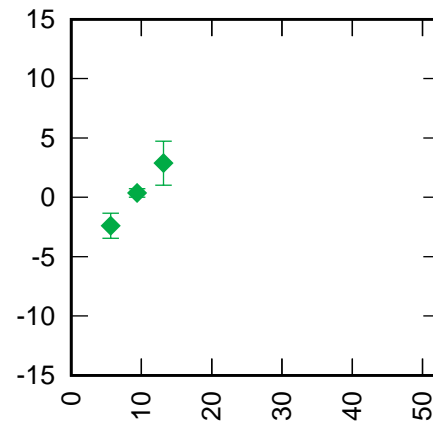
Hartebeesthoek 7501 AJI
CoM (CoM 1013 mm) RB 30.8 mm +



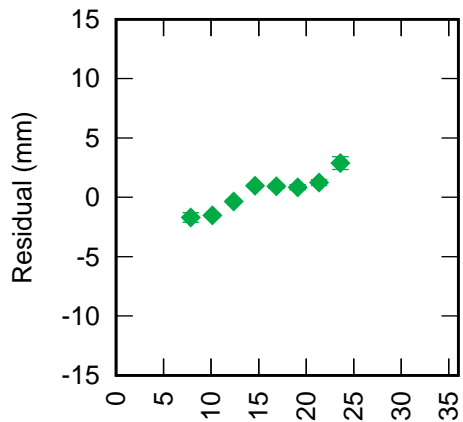
Hartebeesthoek 7501 STRL+STEL
(CoM 75 mm) RB -1.8 mm +



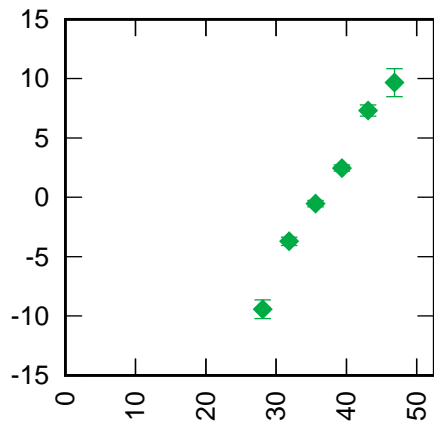
Hartebeesthoek 7501 LARS
CoM (CoM 133 mm) RB 3.2 mm +



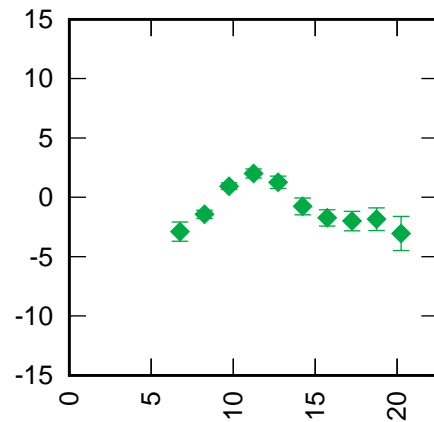
Zimmerwald 7810 LAG1+LAG2
(CoM 249 mm) RB 11.4 mm +



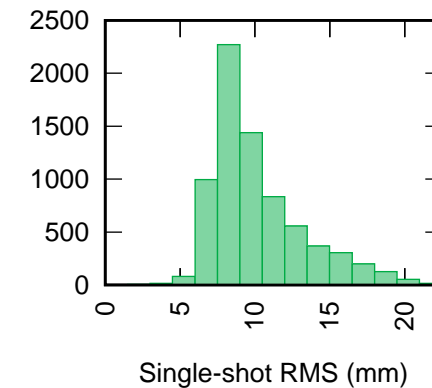
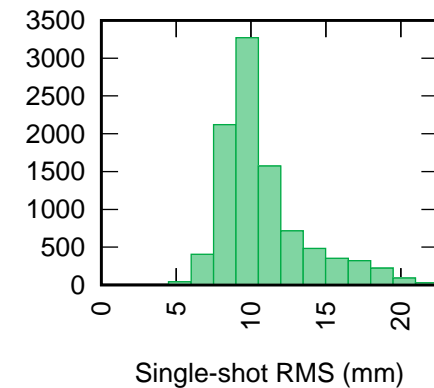
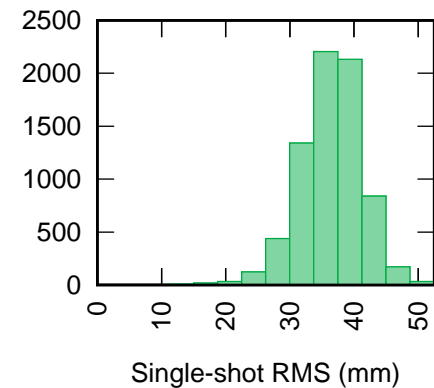
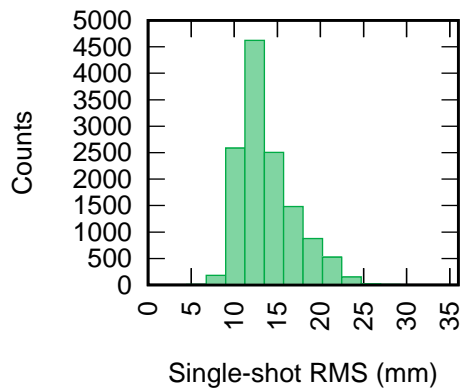
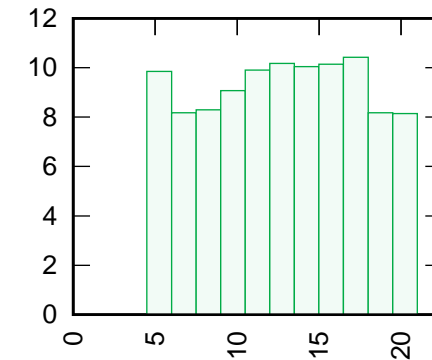
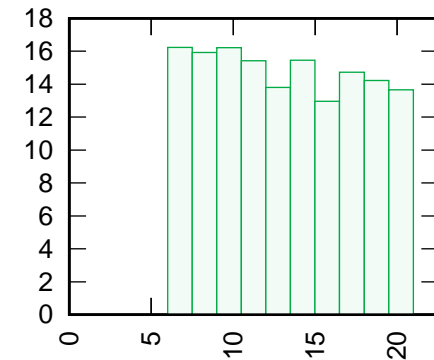
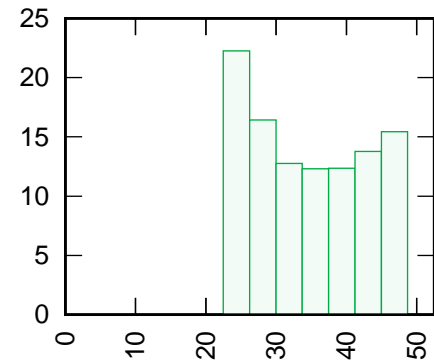
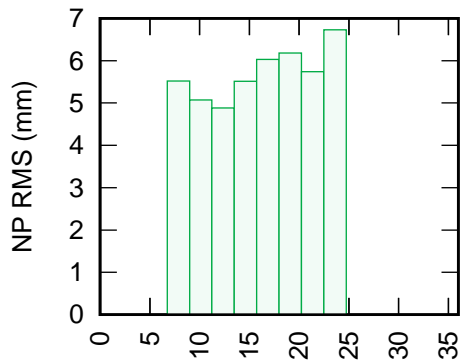
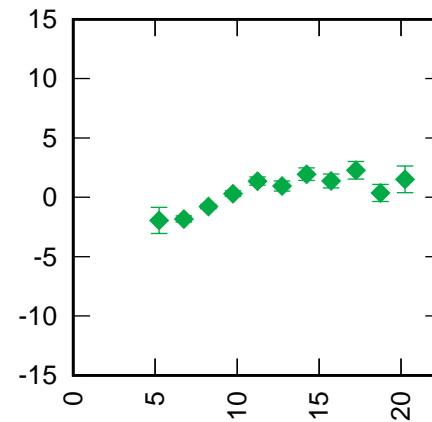
Zimmerwald 7810 AJI
CoM (CoM 999 mm) RB 25.2 mm +



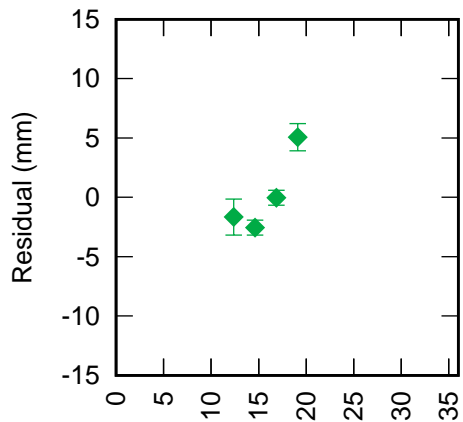
Zimmerwald 7810 STRL+STEL
(CoM 75 mm) RB 6.3 mm +



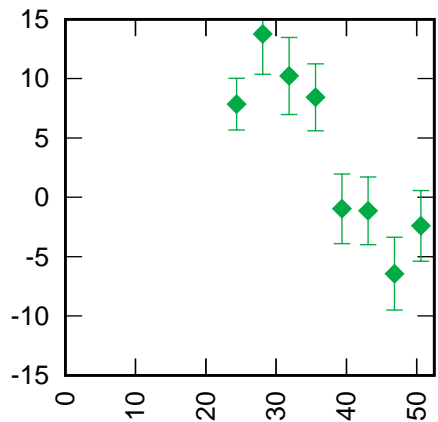
Zimmerwald 7810 LARS
CoM (CoM 133 mm) RB 10.9 mm +



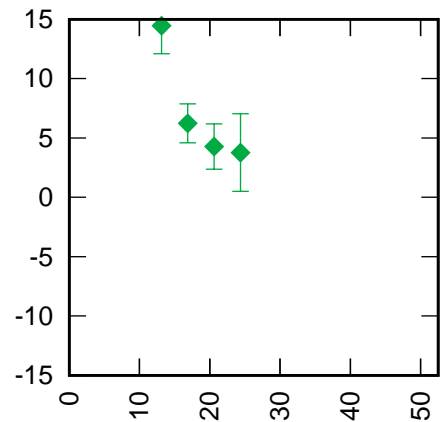
Borowiec 7811 LAG1+LAG2
(CoM 253 mm) RB 4.6 mm +



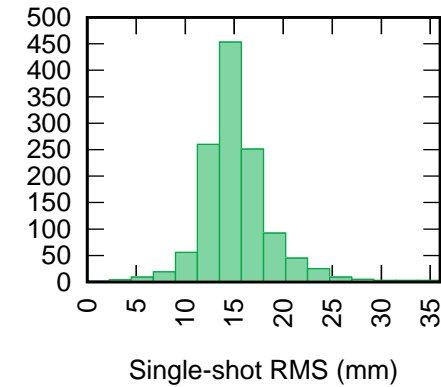
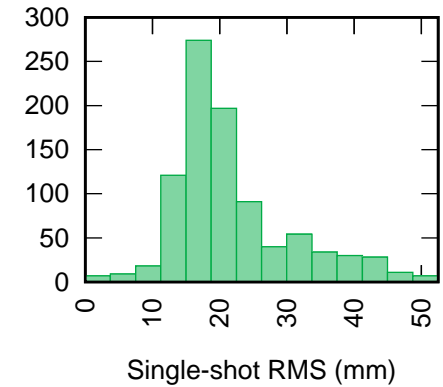
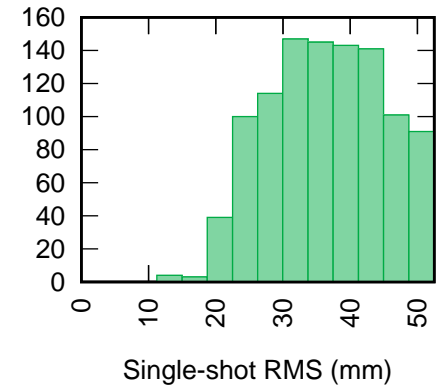
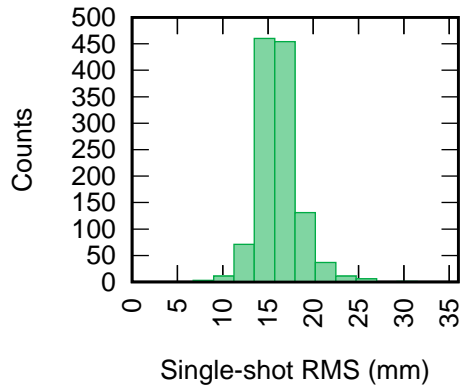
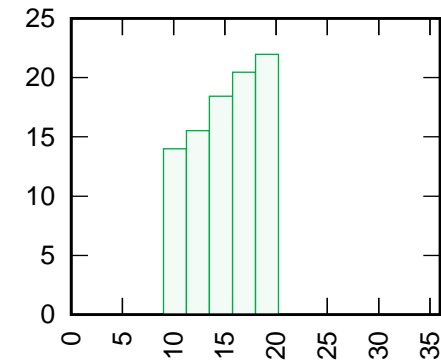
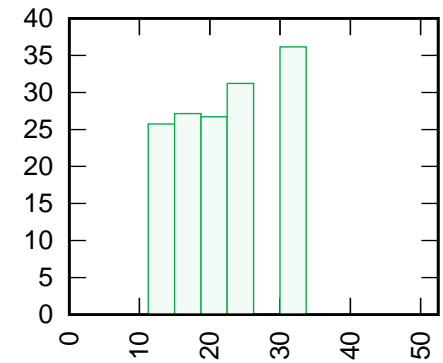
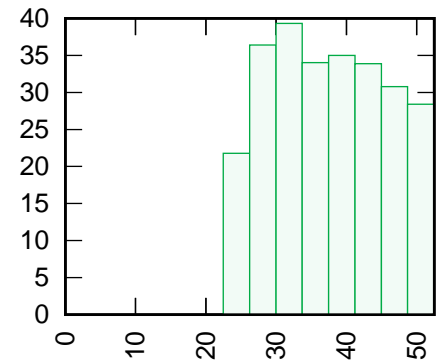
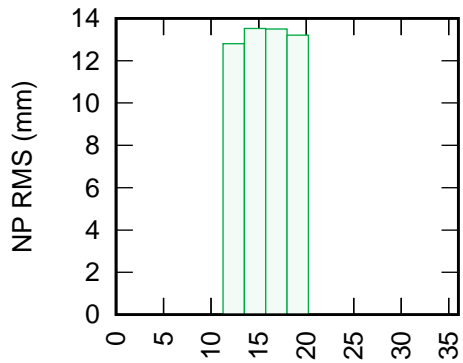
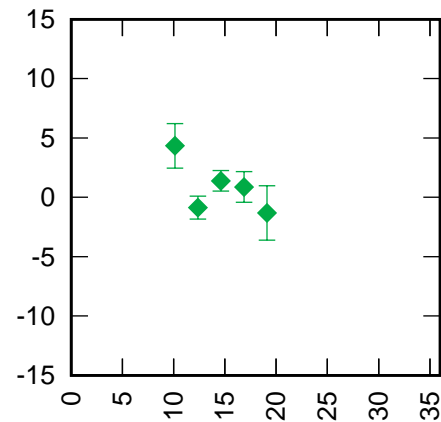
Borowiec 7811 AJI
CoM (CoM 1020 mm) RB 0.8 mm +

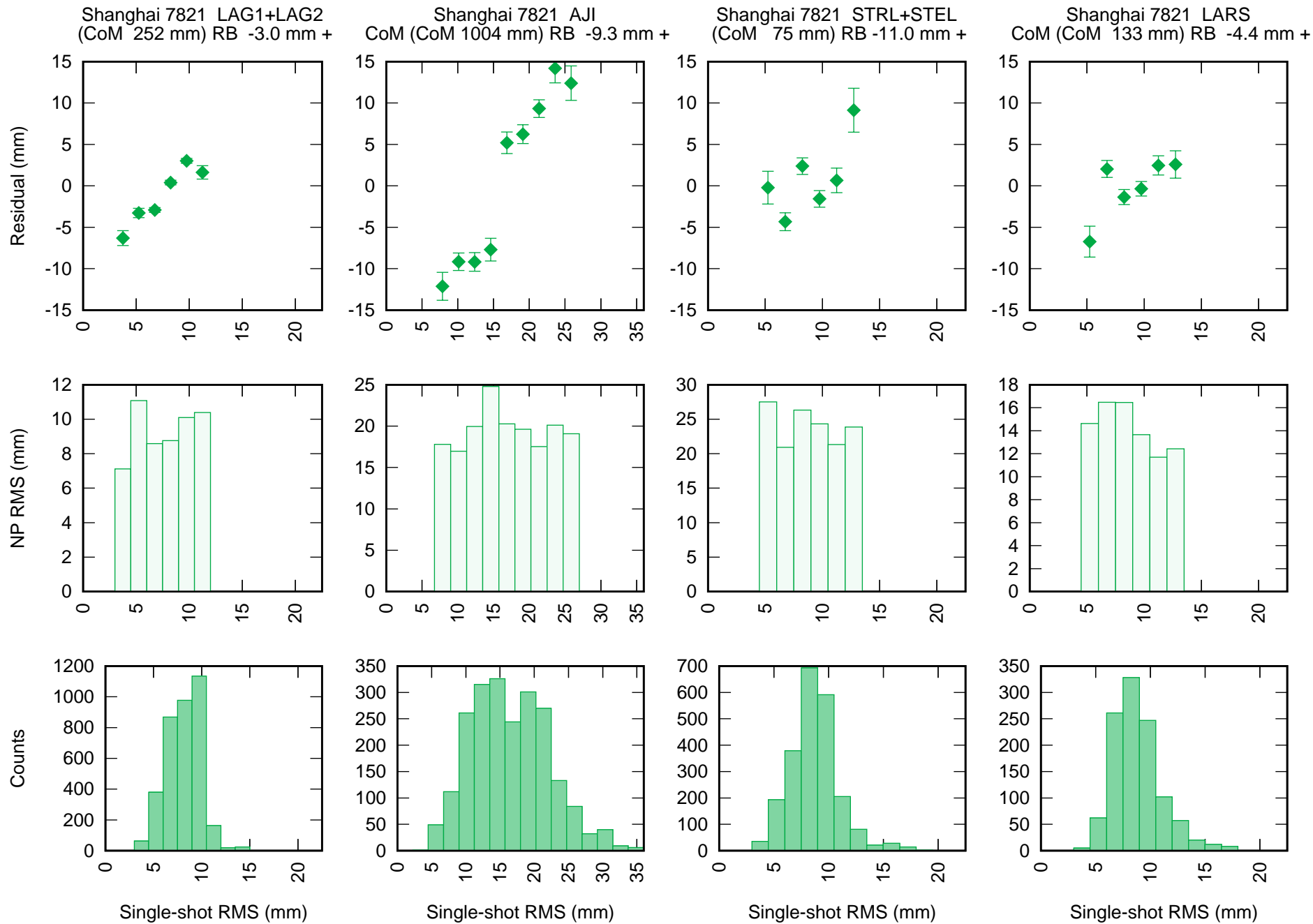


Borowiec 7811 STRL+STEL
(CoM 75 mm) RB -18.8 mm +

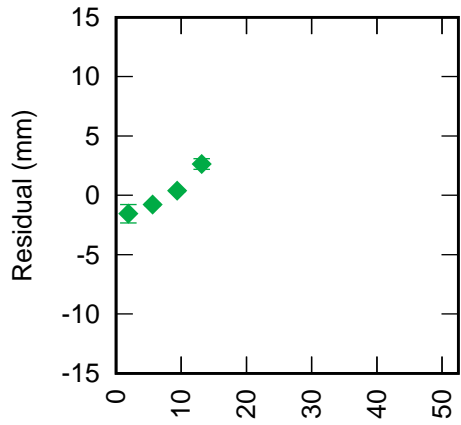


Borowiec 7811 LARS
CoM (CoM 133 mm) RB -2.8 mm +

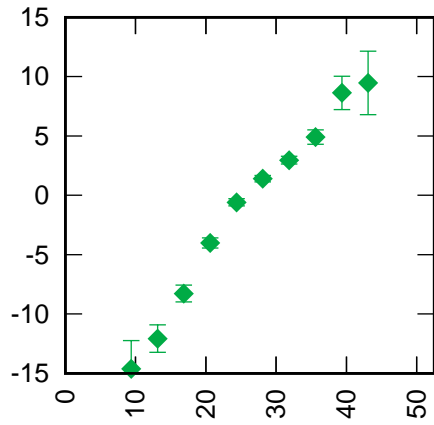




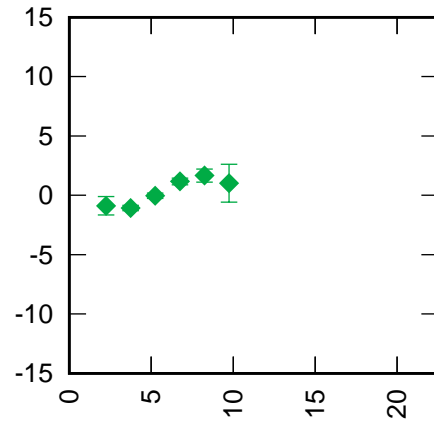
Mt Stromlo 7825 LAG1+LAG2
(CoM 252 mm) RB 11.3 mm +



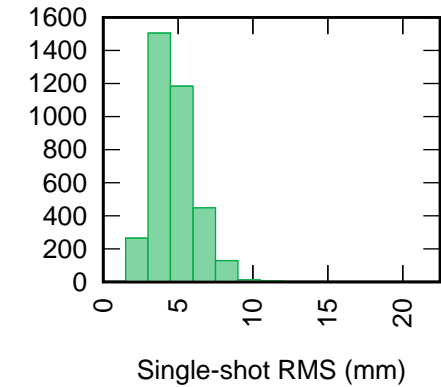
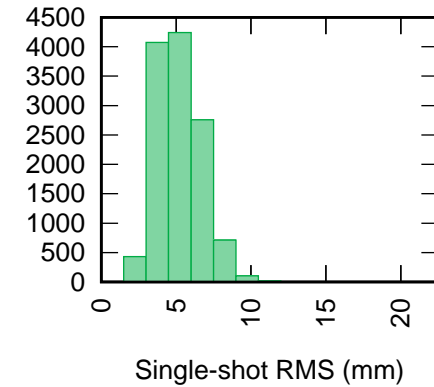
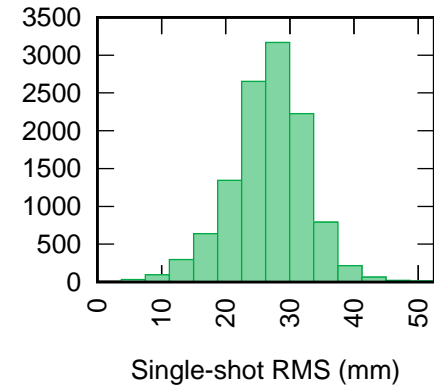
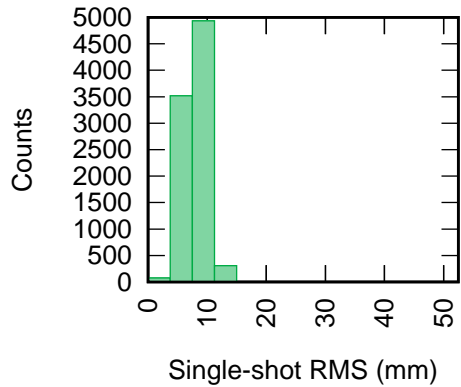
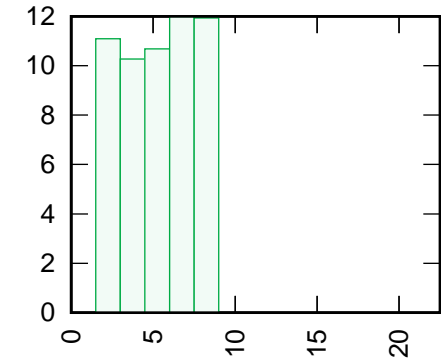
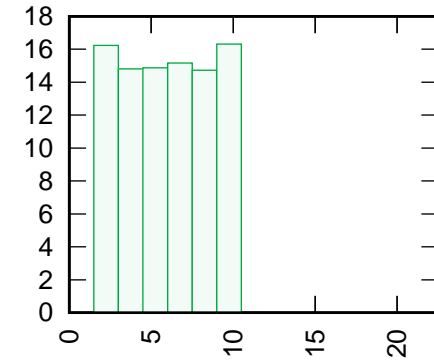
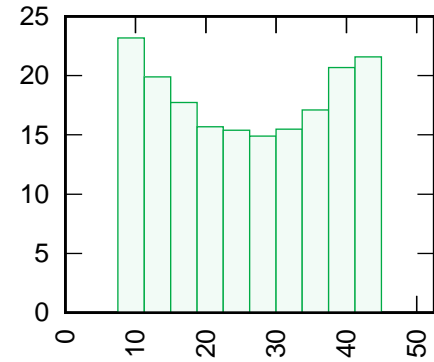
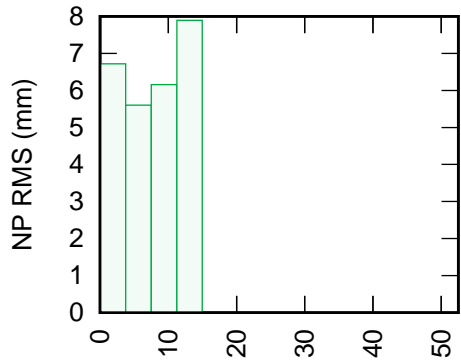
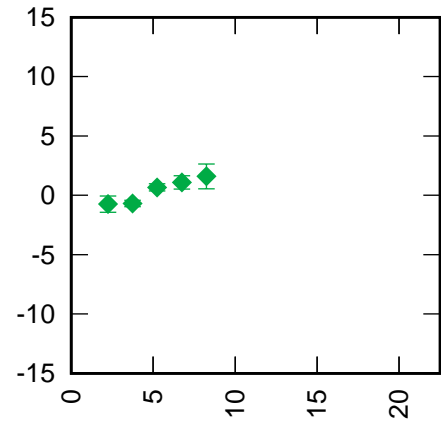
Mt Stromlo 7825 AJI
CoM (CoM 1004 mm) RB 16.1 mm +



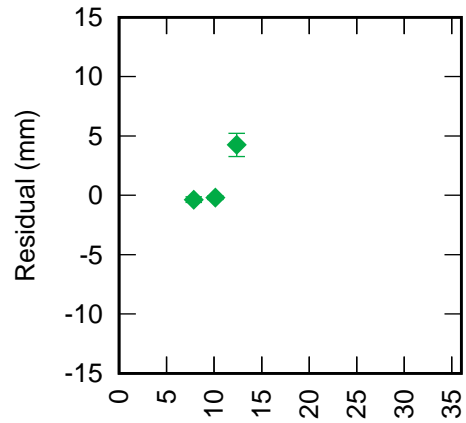
Mt Stromlo 7825 STRL+STEL
(CoM 75 mm) RB 3.8 mm +



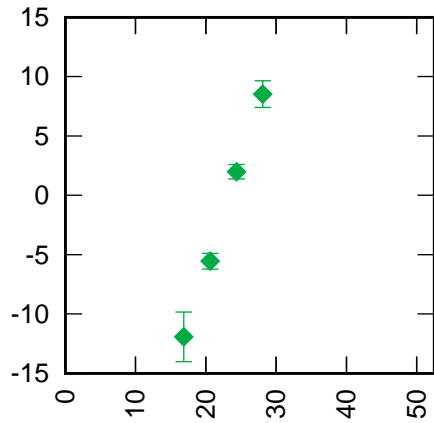
Mt Stromlo 7825 LARS
CoM (CoM 133 mm) RB 9.9 mm +



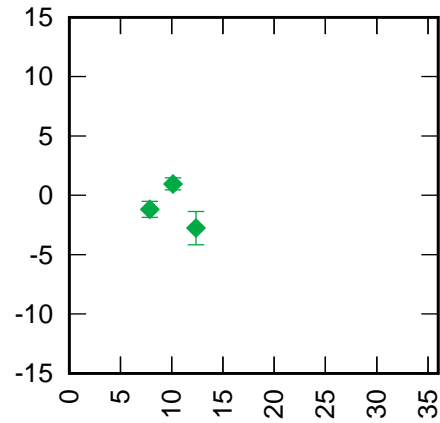
Wettzell 7827 LAG1+LAG2
(CoM 251 mm) RB 1.1 mm +



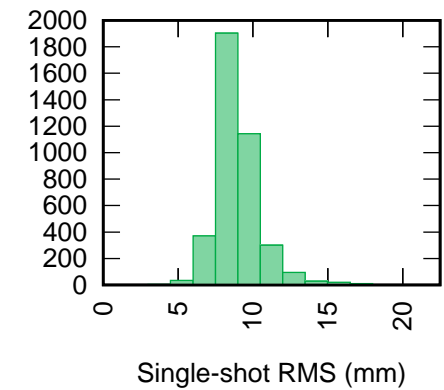
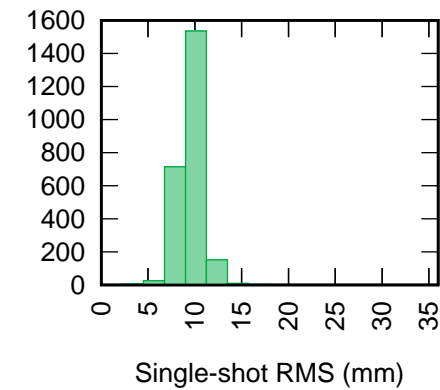
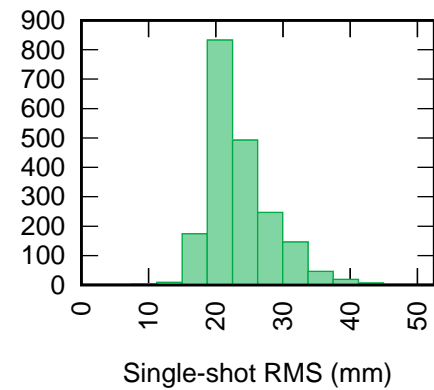
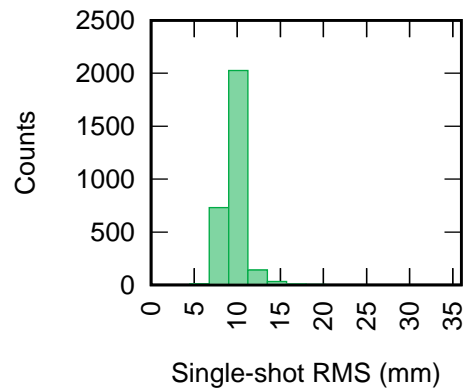
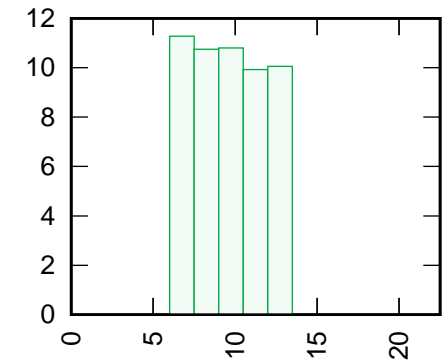
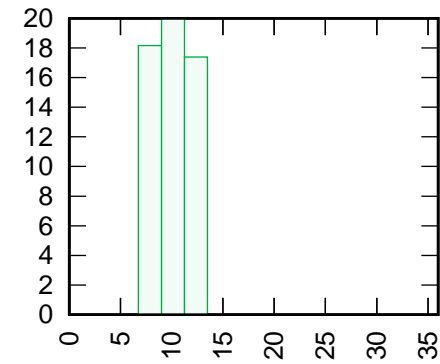
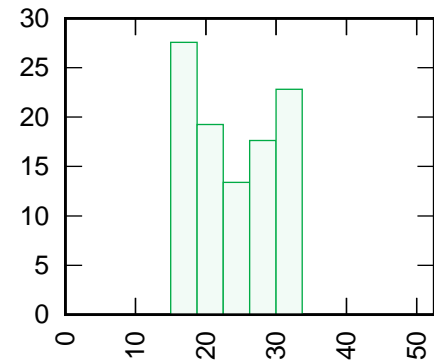
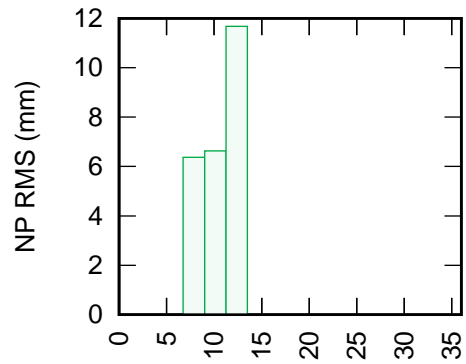
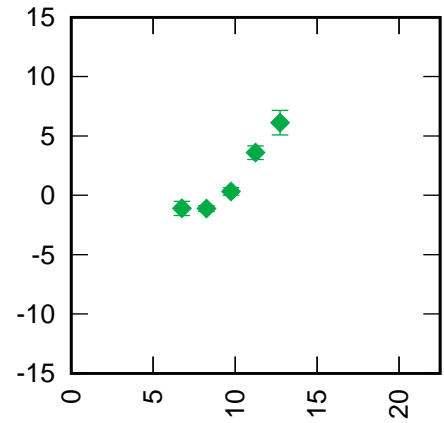
Wettzell 7827 AJI
(CoM 1010 mm) RB 17.4 mm +



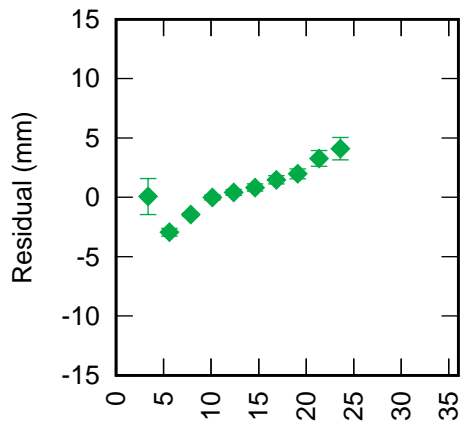
Wettzell 7827 STRL+STEL
(CoM 75 mm) RB -0.6 mm +



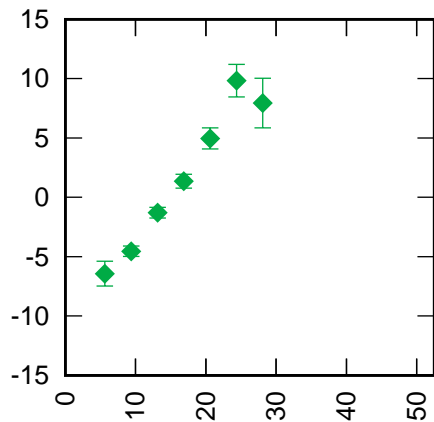
Wettzell 7827 LARS
(CoM 133 mm) RB 2.5 mm +



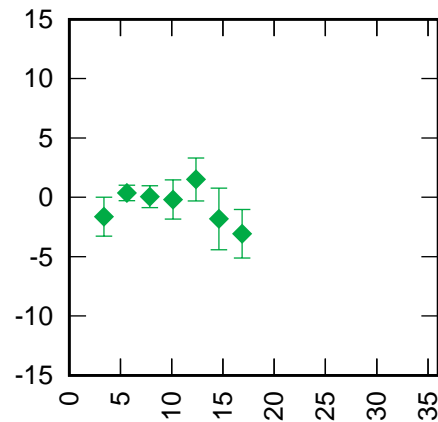
Simosato 7838 LAG1+LAG2
(CoM 250 mm) RB -3.8 mm +



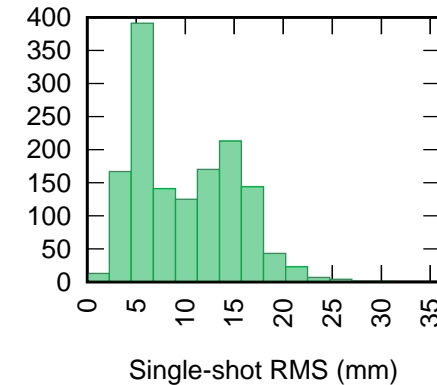
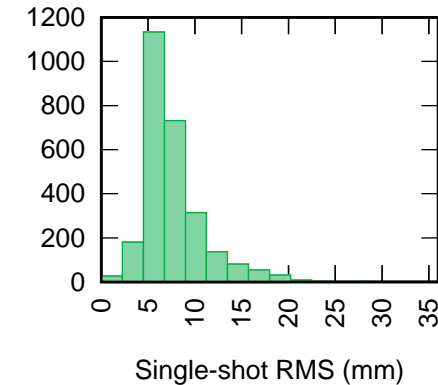
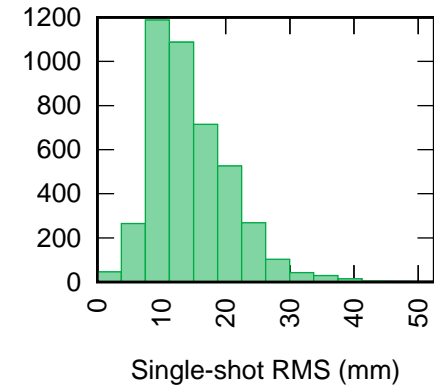
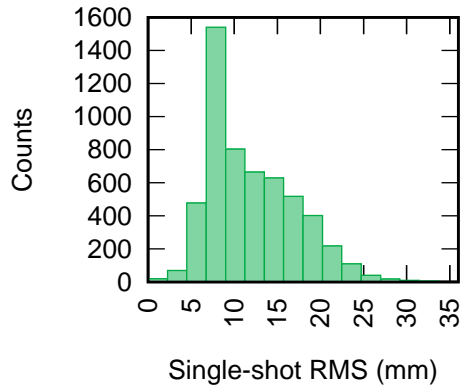
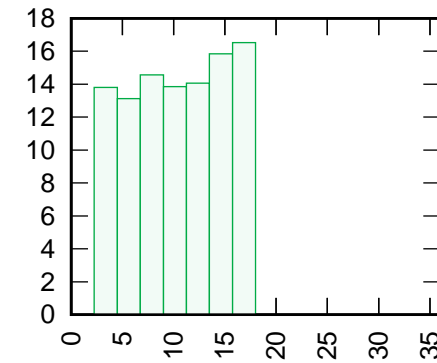
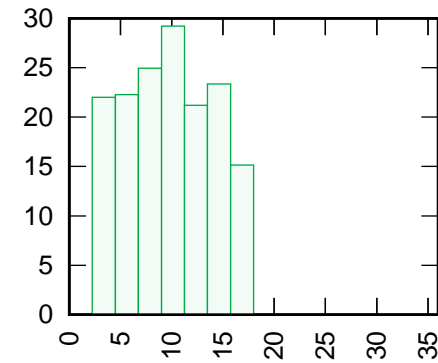
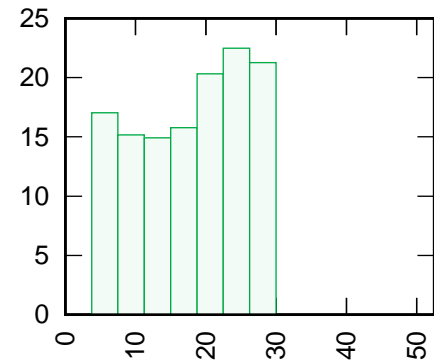
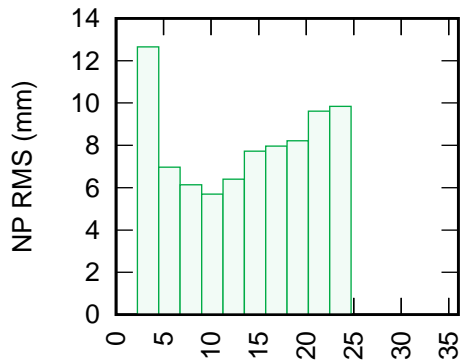
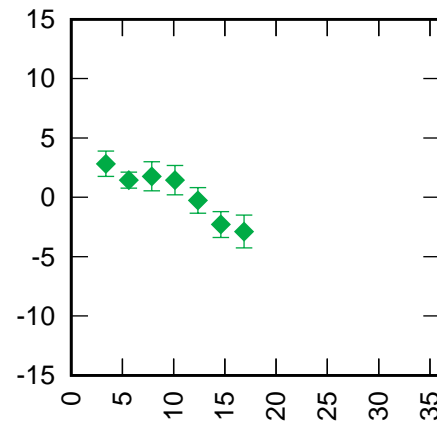
Simosato 7838 AJI
CoM (CoM 1016 mm) RB 14.1 mm +



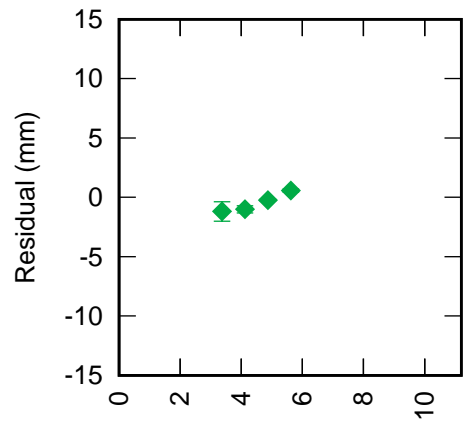
Simosato 7838 STRL+STEL
(CoM 75 mm) RB -11.0 mm +



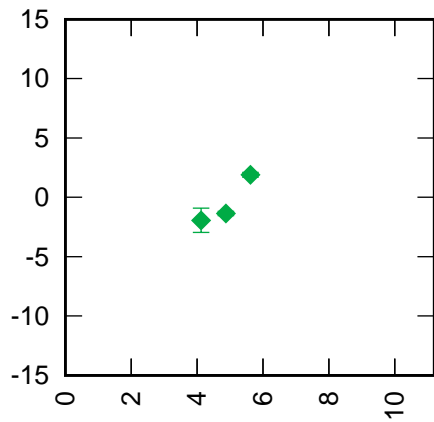
Simosato 7838 LARS
CoM (CoM 133 mm) RB -7.3 mm +



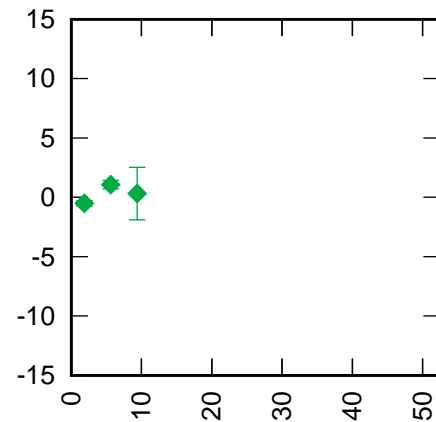
Graz 7839 LAG1+LAG2
(CoM 252 mm) RB 6.3 mm +



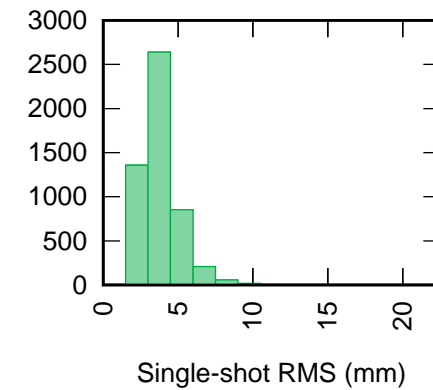
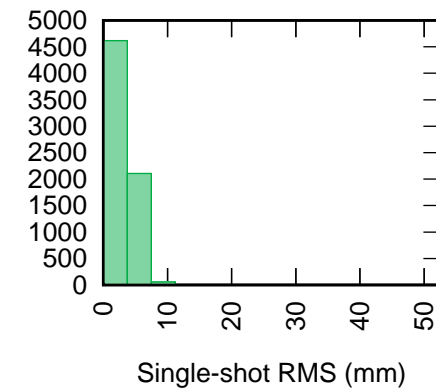
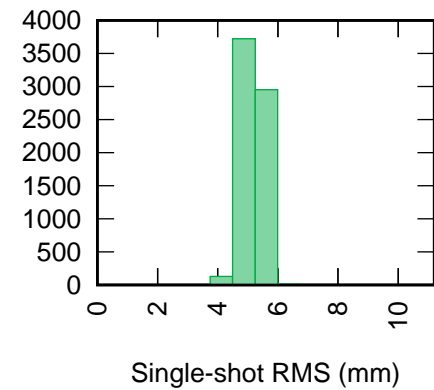
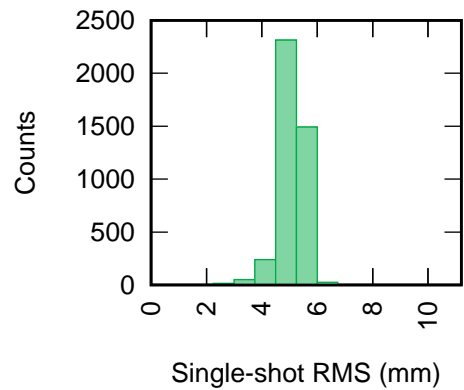
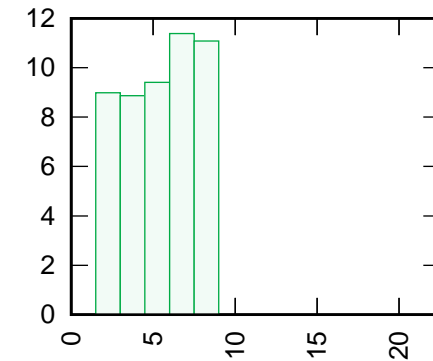
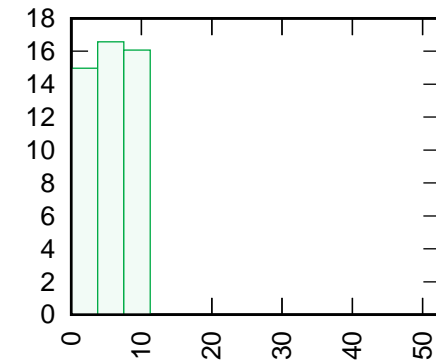
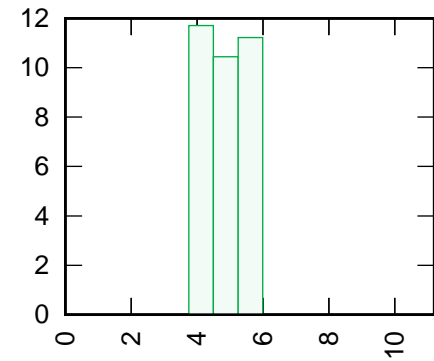
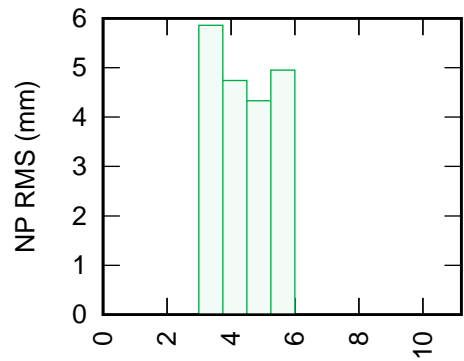
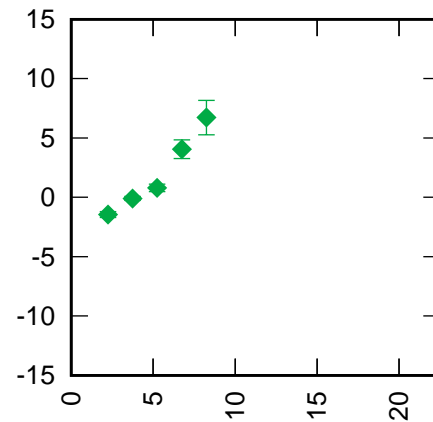
Graz 7839 AJI
CoM (CoM 1010 mm) RB -7.2 mm +

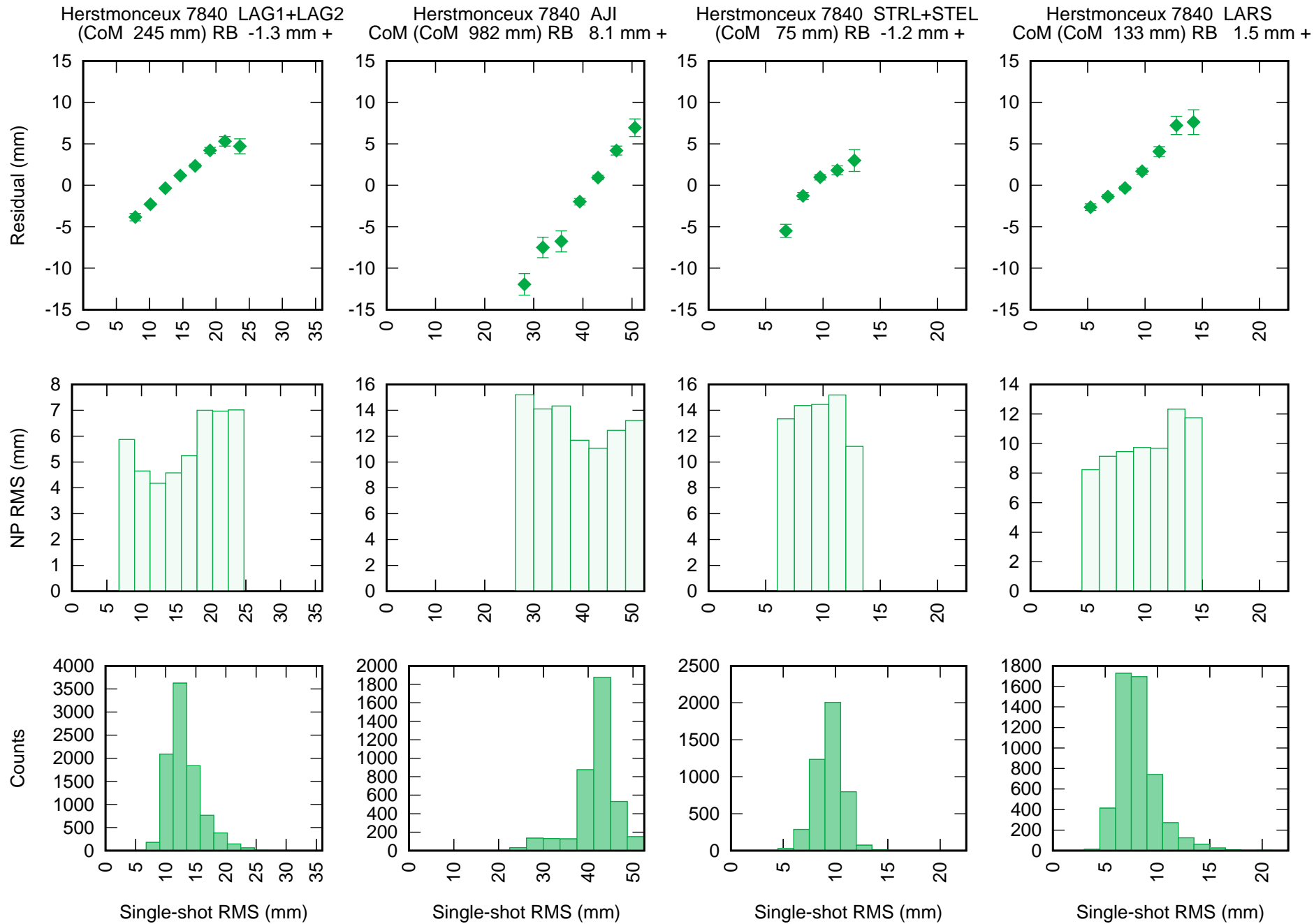


Graz 7839 STRL+STEL
(CoM 75 mm) RB -0.5 mm +

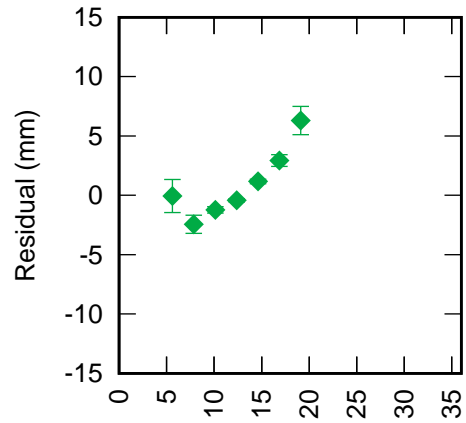


Graz 7839 LARS
CoM (CoM 133 mm) RB 6.0 mm +

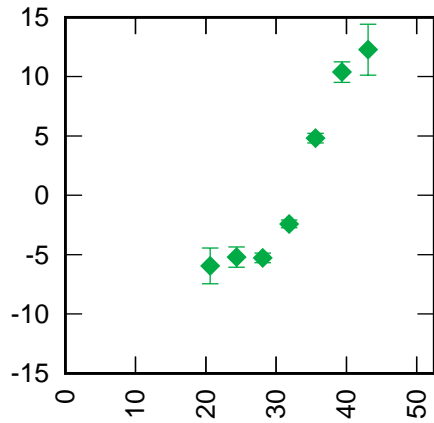




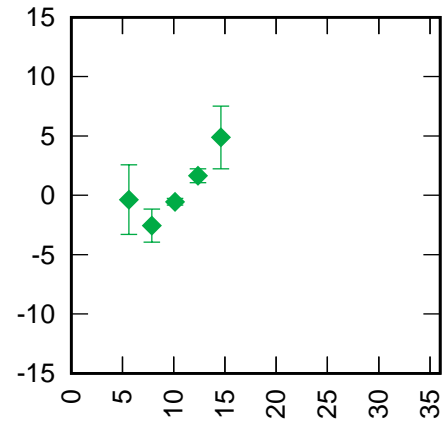
Potsdam 7841 LAG1+LAG2
(CoM 245 mm) RB 0.5 mm +



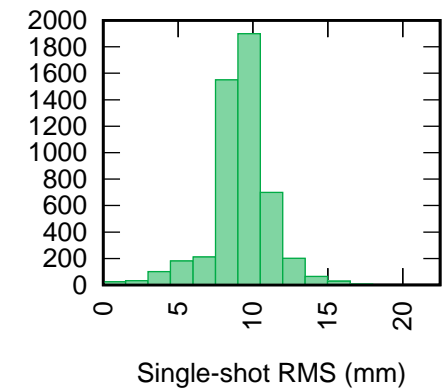
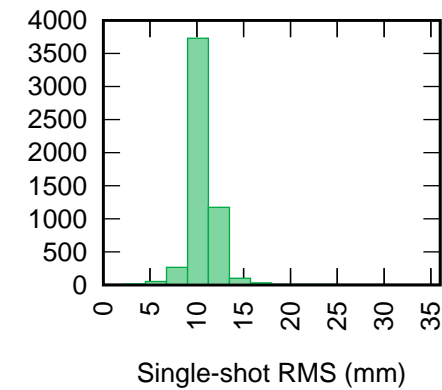
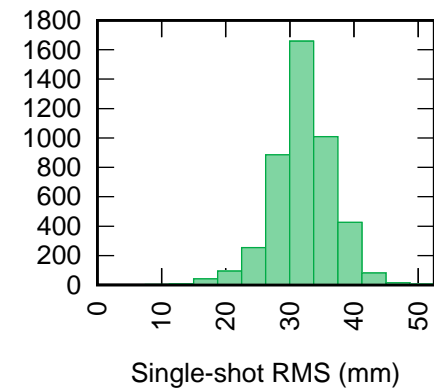
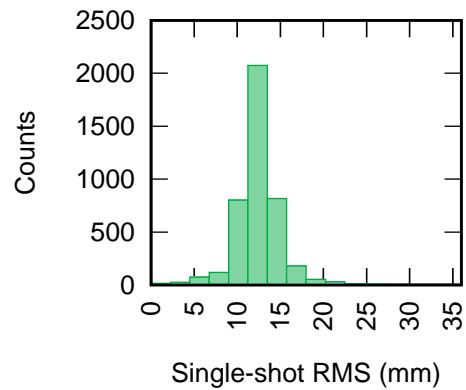
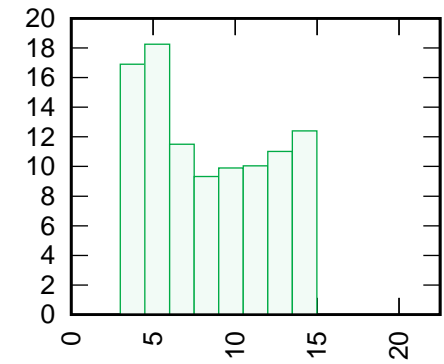
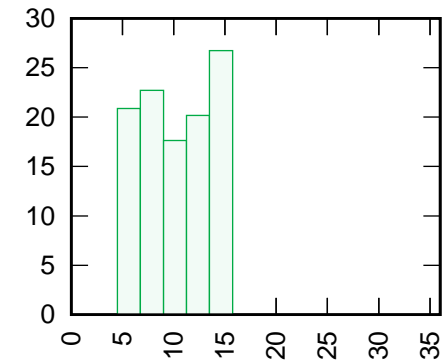
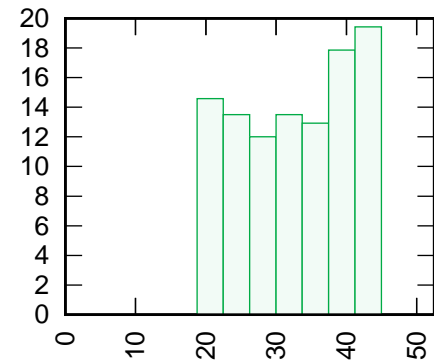
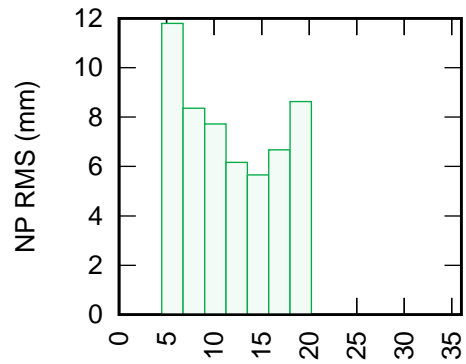
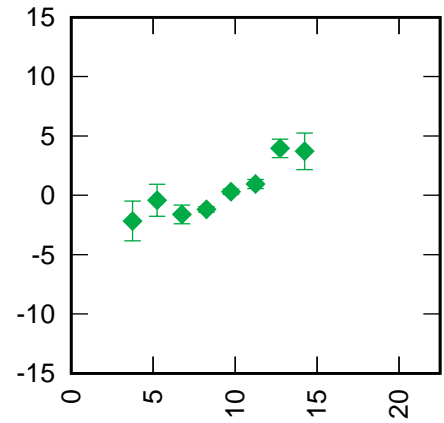
Potsdam 7841 AJI
CoM (CoM 995 mm) RB 13.0 mm +



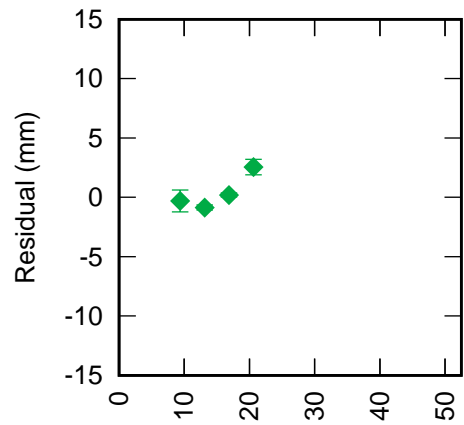
Potsdam 7841 STRL+STEL
(CoM 75 mm) RB 1.0 mm +



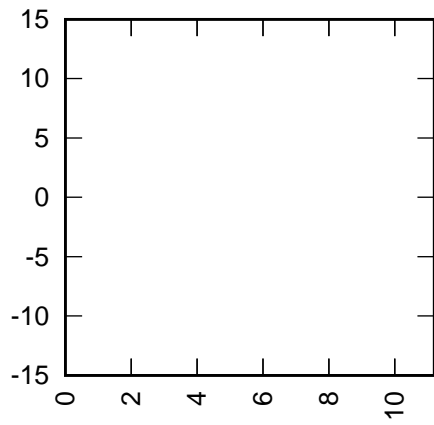
Potsdam 7841 LARS
CoM (CoM 133 mm) RB 5.0 mm +



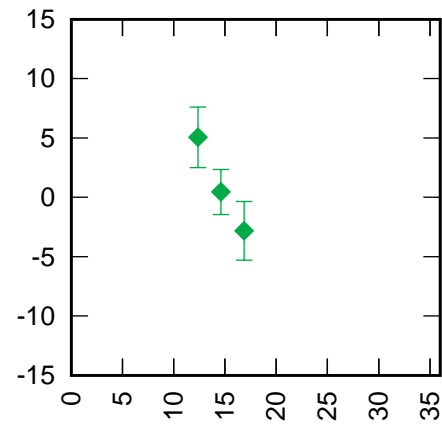
Grasse 7845 LAG1+LAG2
(CoM 251 mm) RB -5.5 mm +



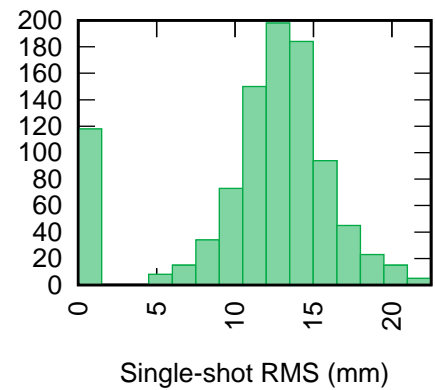
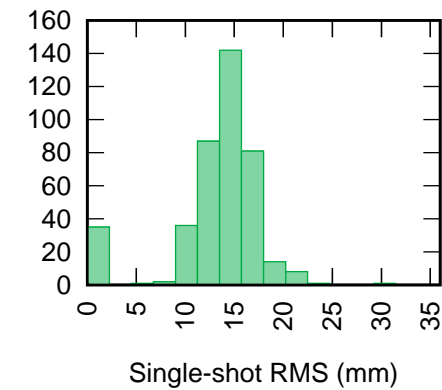
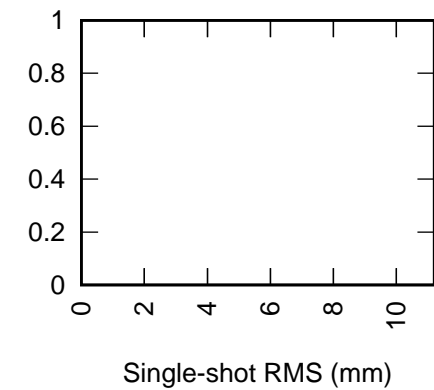
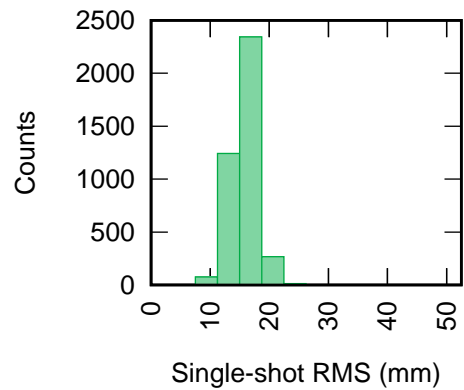
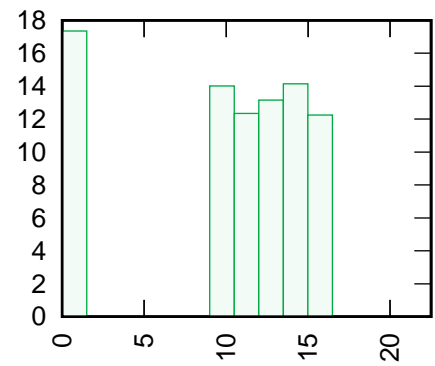
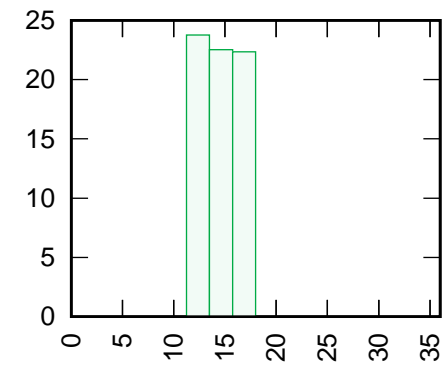
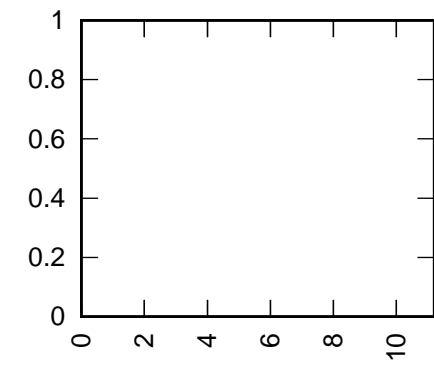
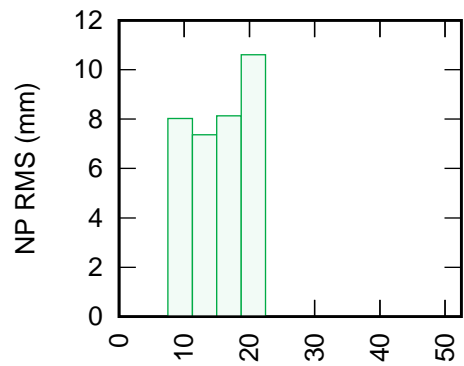
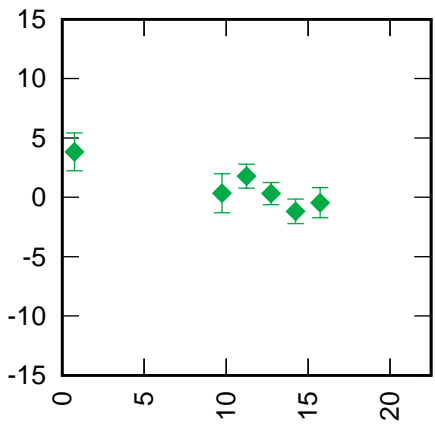
Grasse 7845 AJI
CoM (CoM 1004 mm) RB 0.0 mm +



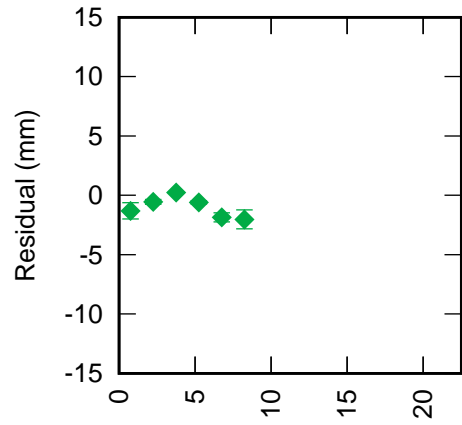
Grasse 7845 STRL+STEL
(CoM 75 mm) RB -13.2 mm +



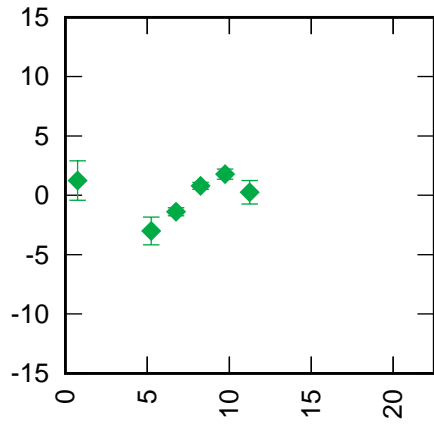
Grasse 7845 LARS
CoM (CoM 133 mm) RB -5.8 mm +



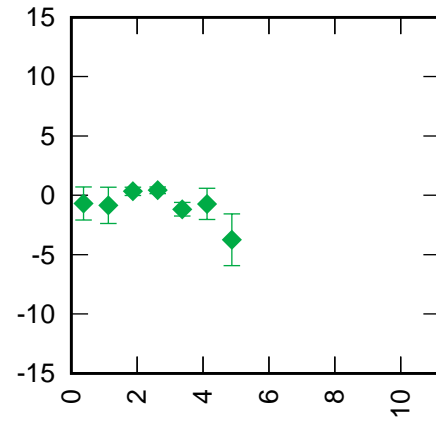
Matera 7941 LAG1+LAG2
(CoM 250 mm) RB -3.2 mm +



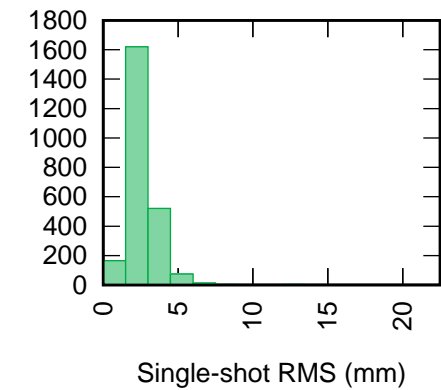
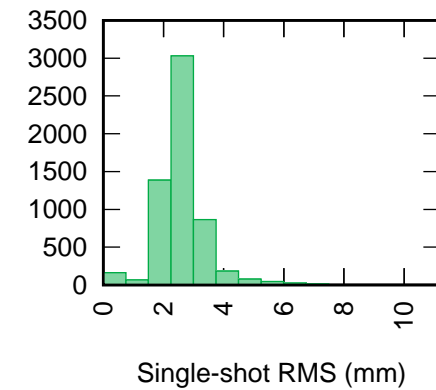
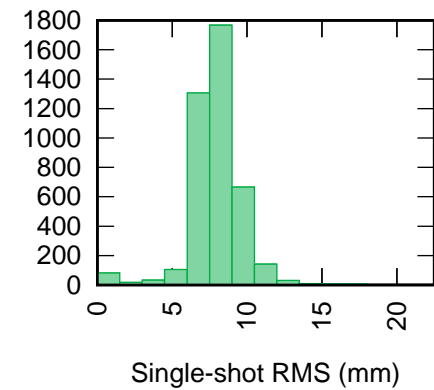
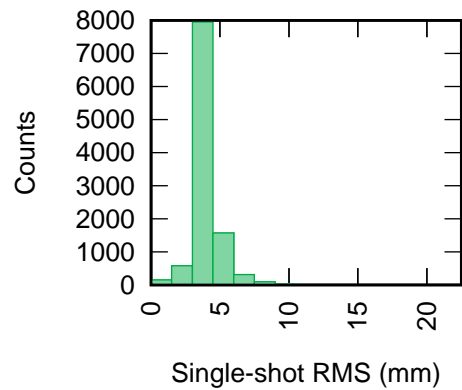
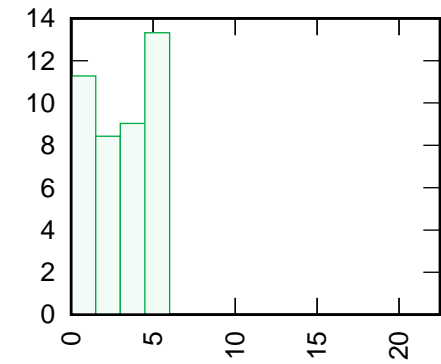
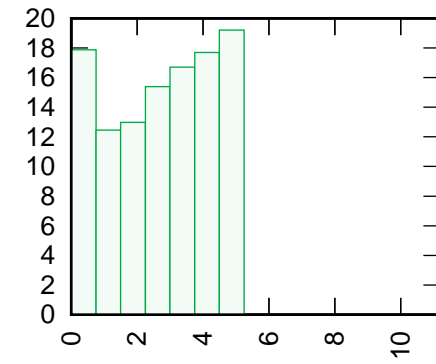
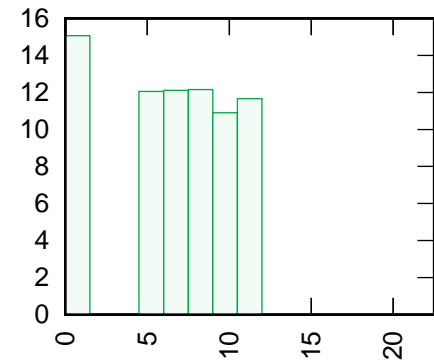
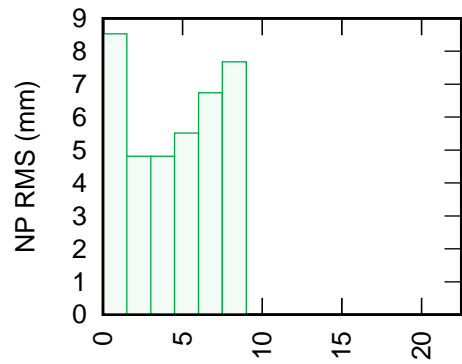
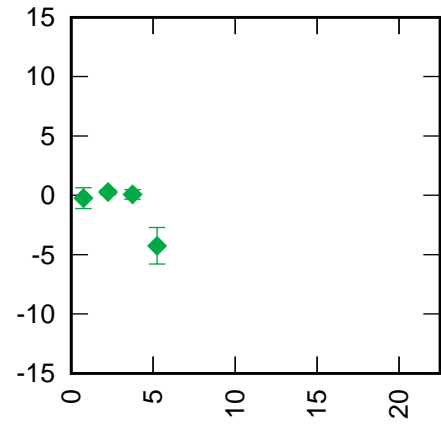
Matera 7941 AJI
CoM (CoM 1020 mm) RB 24.7 mm +



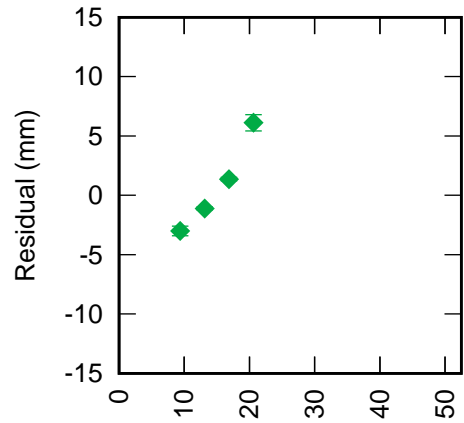
Matera 7941 STRL+STEL
(CoM 75 mm) RB -7.5 mm +



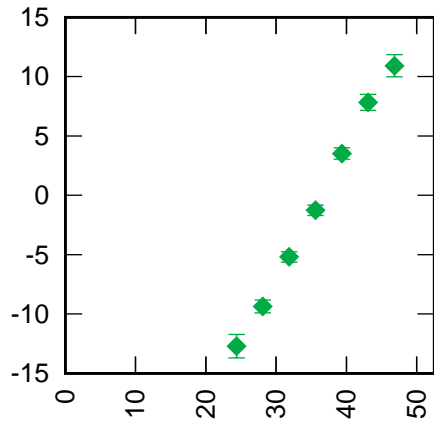
Matera 7941 LARS
CoM (CoM 133 mm) RB -4.5 mm +



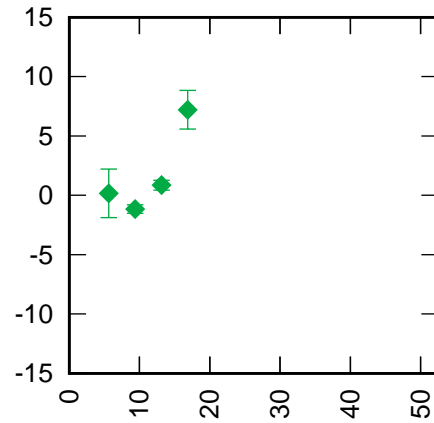
Wetzell 8834 LAG1+LAG2
(CoM 250 mm) RB -13.4 mm +



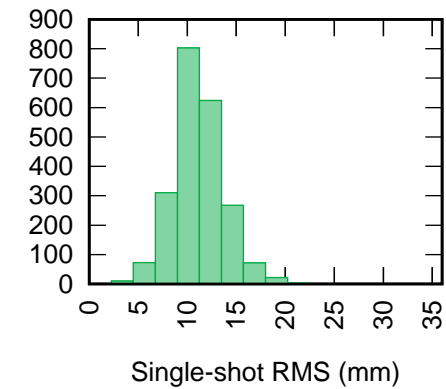
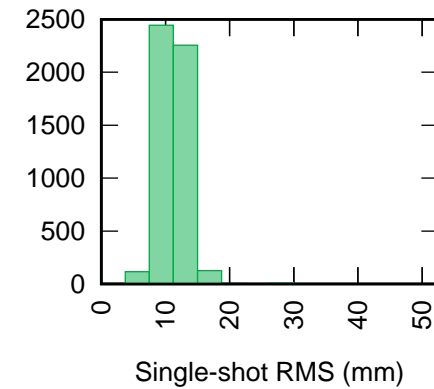
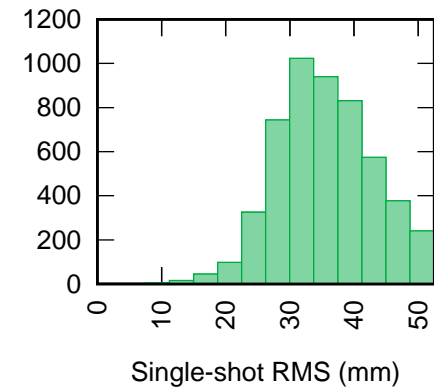
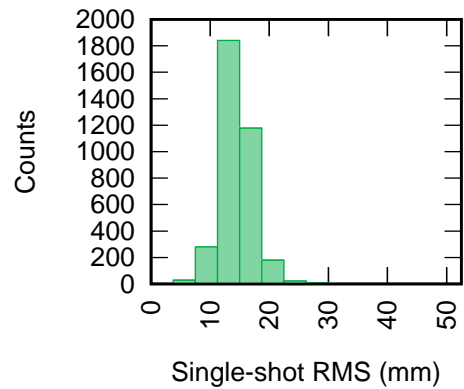
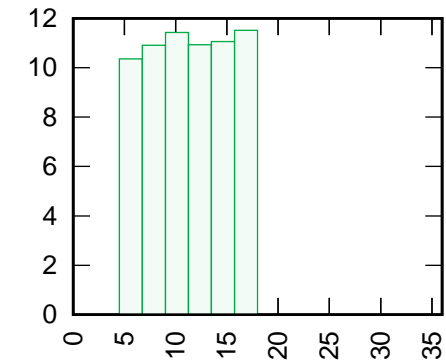
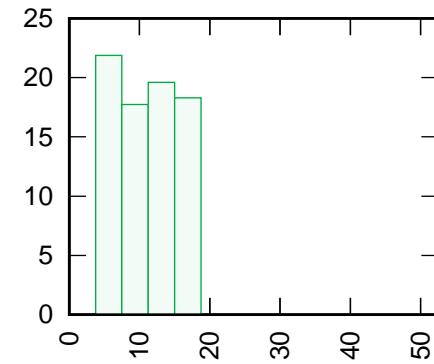
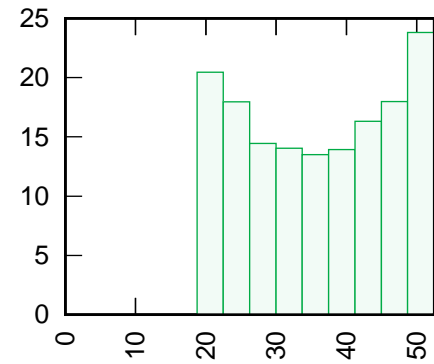
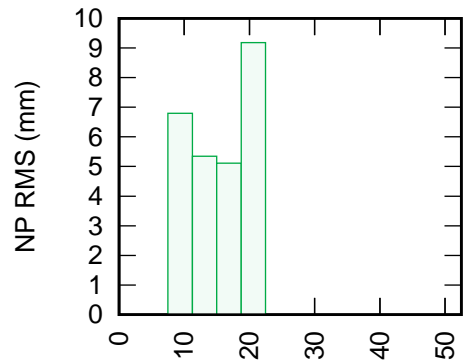
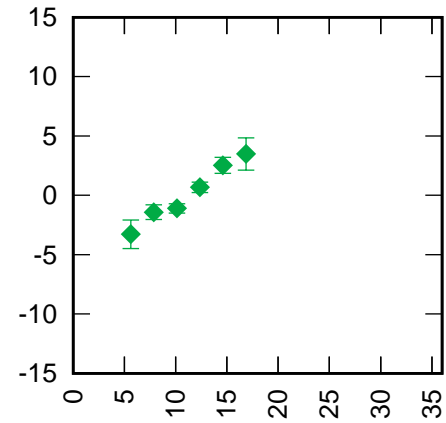
Wetzell 8834 AJI
CoM (CoM 1020 mm) RB 24.1 mm +



Wetzell 8834 STRL+STEL
(CoM 75 mm) RB -21.0 mm +



Wetzell 8834 LARS
CoM (CoM 133 mm) RB -16.8 mm +



Low-return Normal Point Analysis

John C. Ries
6/14/2021

ILRS NPT Guidelines

- *Daytime normal points - minimum 6 data points*
- *Night time normal points - minimum 3 data points*
- *Fewer data points would be acceptable on lower satellites (5-second normal points) from those ranging systems with lower pulse repetition rates where these minimum requirements are not practical.*
- What is the impact of making NPTS with as few as 1 return?
 - In the following, ‘low-return NPTs’ refers to NPTs with less than 3 returns, though the analysis was extended to ‘lower-return’ NPTs with less than 6 returns.

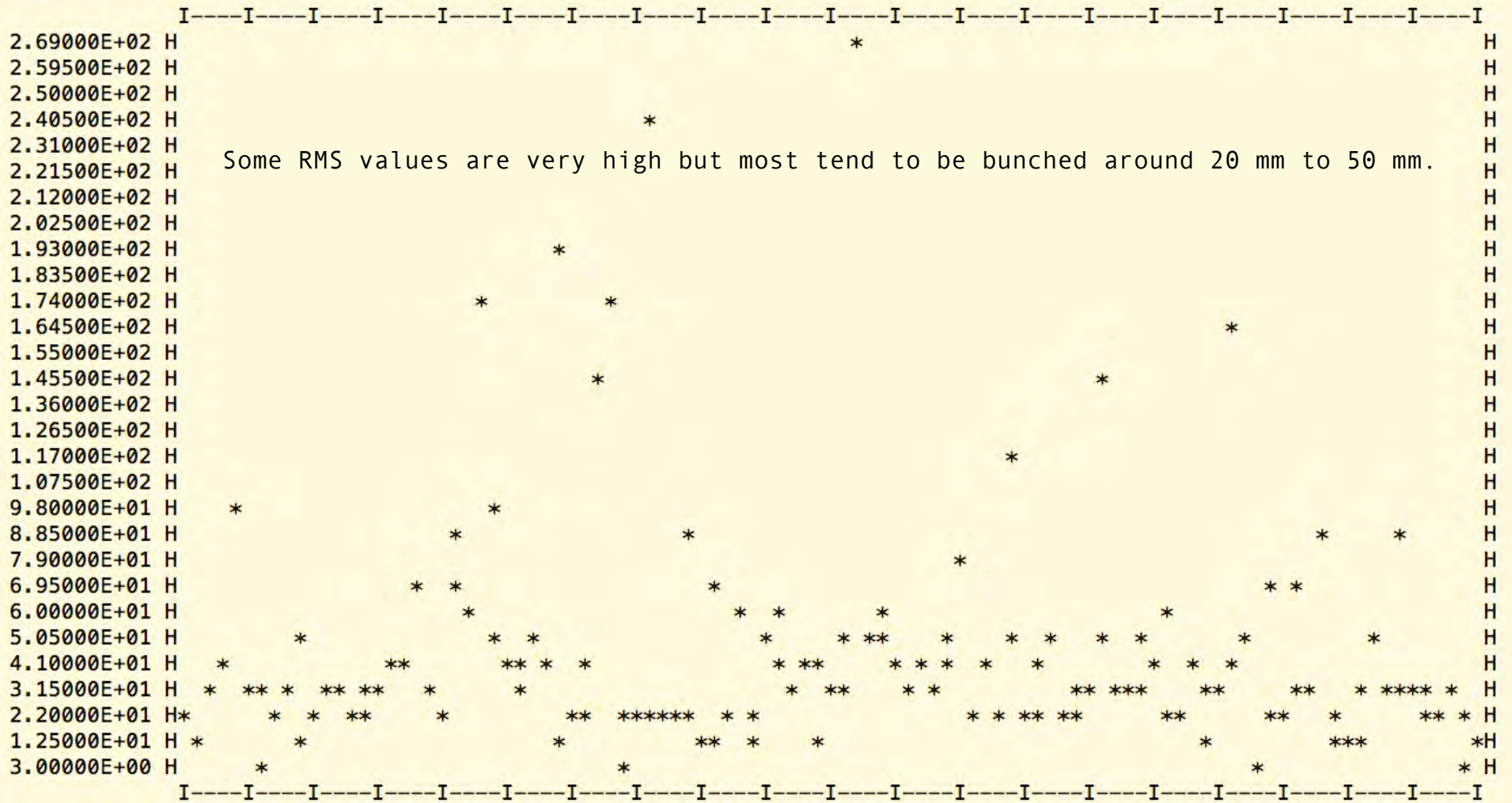
Breakdown of NPTS by number of returns (January 2020 for LAGEOS)

STATION	1SHOT	2SHOTS	3SHOTS	4SHOTS	5SHOTS	6+SHOTS
1873	4	5	5	4	2	28
1884	0	0	0	0	1	27
1888	0	0	0	0	0	45
1890	0	0	0	0	0	129
1893	5	6	4	5	4	47
7090	64	62	44	44	42	703
7105	3	4	4	6	6	268
7110	15	8	5	10	4	282
7119	7	7	4	3	3	101
7237	0	0	0	0	0	301
7249	0	0	0	0	0	17
7501	4	3	1	1	0	94
7810	0	0	0	1	5	1036
7811	0	0	0	0	1	97
7821	0	0	0	0	0	90
7825	0	0	0	0	0	44
7827	0	0	0	0	0	218
7838	3	2	5	7	8	216
7839	0	0	0	0	0	307
7840	0	0	0	0	0	478
7841	0	0	0	0	0	144
7845	0	0	0	0	0	392
7941	7	4	6	2	2	479
8834	0	0	0	0	0	230

A small number of stations are responsible for the low- and low-return normal points.

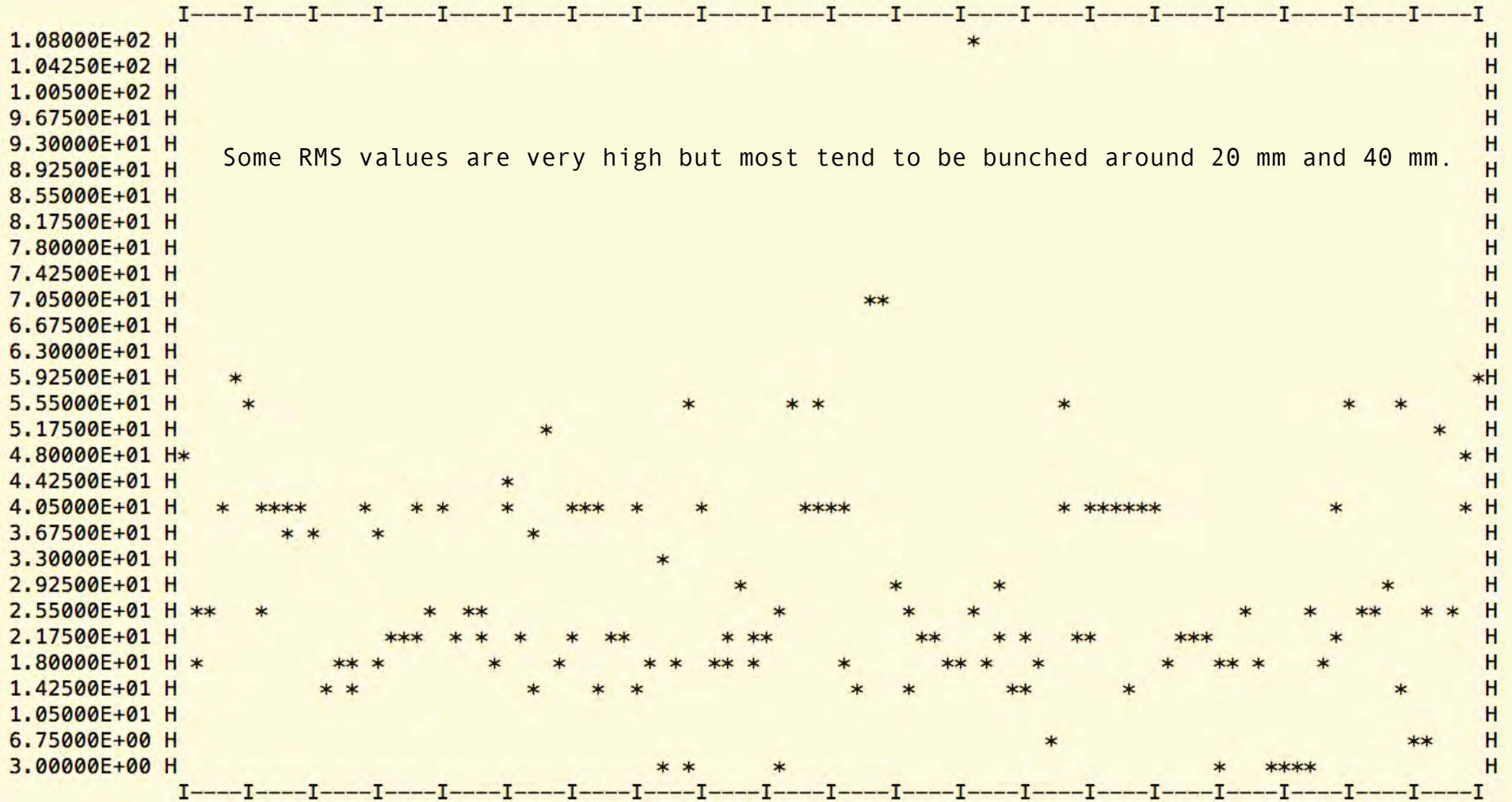
Look closer at Yarragadee to test impact of successively removing NPTS with only 1 shot, then 2 shots,...up to 5 shots, since it has the most low- and lower-return NPTS, and thus should be impacted the most.

Assigned NPT RMS for 2-return NPTs



Horizontal axis is simply the count; the 'ith' NPT based on 2 returns

Assigned NPT RMS for single-return NPTs



Horizontal axis is simply the count; the 'ith' NPT based on 1 return

Fit statistics for whole network

SLR data for all of 2020 fit using all available NPTs for 4 satellites at various altitudes. Residual RMS was computed for 7 cases: The reference fit RMS used all NPTs, then the RMS was computed for just the 6+ return NPTs, just the 5-return NPTs, just the 4-return NPTs, etc. down to the single-return NPTs.

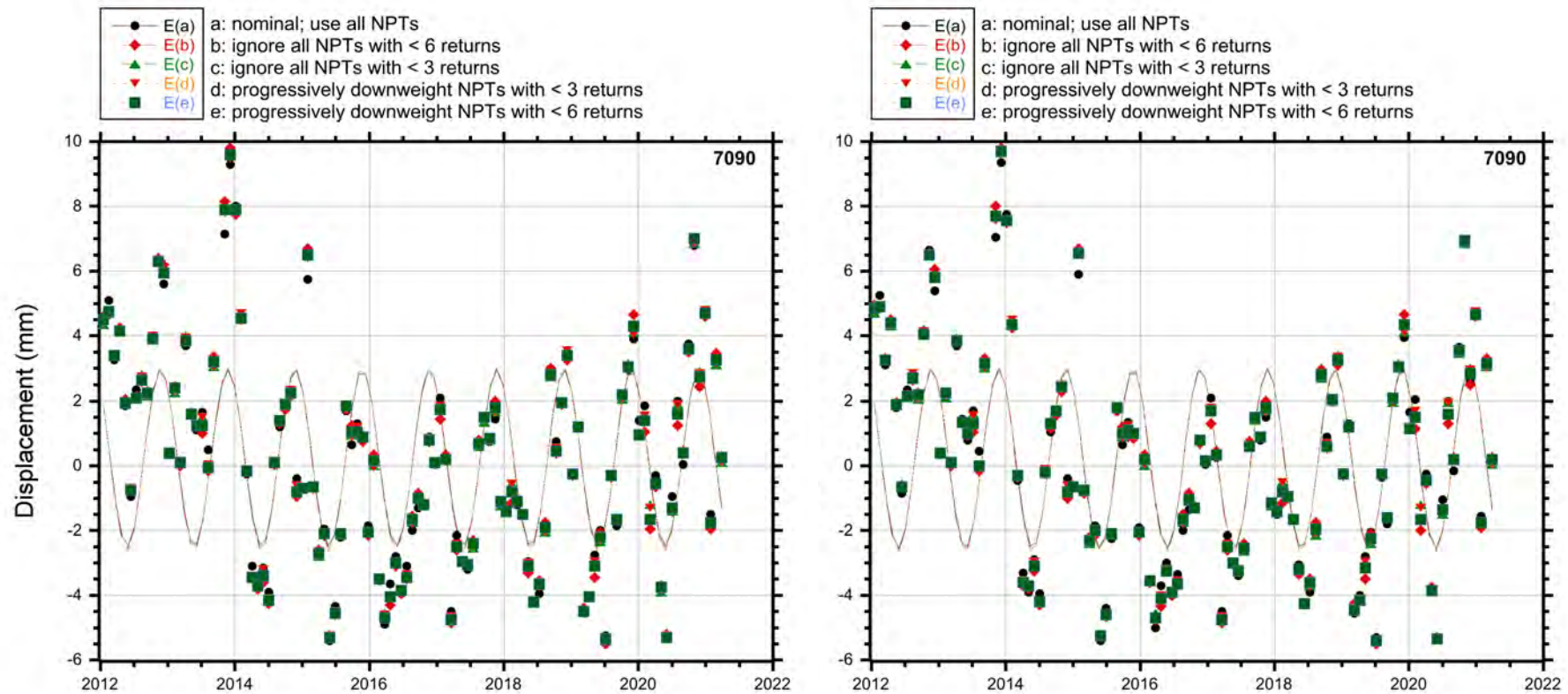
RMS	All NPTs	6+ Returns		5 Returns		4 Returns		3 Returns		2 Returns		1 Return		
	# NPTs	RMS (mm)	# NPTs	RMS (mm)	# NPTs	RMS (mm)	# NPTs	RMS (mm)	# NPTs	RMS (mm)	# NPTs	RMS (mm)	# NPTs	RMS (mm)
LAGEOS-1	61550	7.1	57708	6.9	634	8.7	645	8.8	727	8.7	834	9.6	1010	10.1
LAGEOS-2	55242	7.4	51002	7.2	738	8.4	711	8.8	811	9.4	895	9.1	1066	10.1
Starlette	83009	27.4	77999	27.0	693	29.2	797	28.3	909	28.5	1050	31.0	1358	31.1
LARES	70071	19.3	63811	18.5	839	21.8	987	21.7	1115	23.5	1369	24.6	1796	24.2
7105														
LAGEOS-1	2913	7.7	2656	7.2	42	9.5	34	10.6	43	12.6	65	11.0	64	11.8
LAGEOS-2	2786	7.1	2452	6.3	49	8.8	48	10.2	62	9.8	71	10.5	92	10.9
7090														
LAGEOS-1	7693	7.2	5870	6.8	275	7.9	316	7.8	333	8.0	388	8.3	506	9.1
LAGEOS-2	6999	7.2	5006	6.9	347	7.2	338	12.6	361	7.9	434	8.0	504	8.5
Range Bias	All NPTs	6+ Returns	5 Returns	4 Returns	3 Returns	2 Returns	1 Return							
LAGEOS-1	0.7	0.7	0.9	1.5	1.2	0.8	0.6	Range bias = network weighted average of residuals (mm) for January-November 2020						
LAGEOS-2	1.7	1.6	2.9	2.4	2.5	2.2	2.1							
Starlette	0.0	0.0	10.0	7.9	5.0	6.9	6.2	(SLRF2014 and ILRS 2013 station-dependent CoM used)						
LARES	-0.8	-0.4	-6.6	-4.1	-5.7	-3.9	-5.7	(7-day arcs for L1/L2/LARES, 6-day arcs for Starlette)						

There is a significant increase in the noise for all targets, with 1- and 2-return NPTs not surprisingly the worst. Effect was especially apparent for 7105.

For LARES and Starlette, the lower-return NPTs appear to be significantly biased compared to the 6+ return NPTs. No apparent issue for L1/L2.

Edit/Weighting Experiment (1)

The coordinates for 7090 were estimated every 30 days from 2012 to 2020, where the low-return NPTs were either edited or downweighted. However, it is difficult to see any impact on the quality of the time series, even though 7090 had the highest percentage of low-return NPTs.

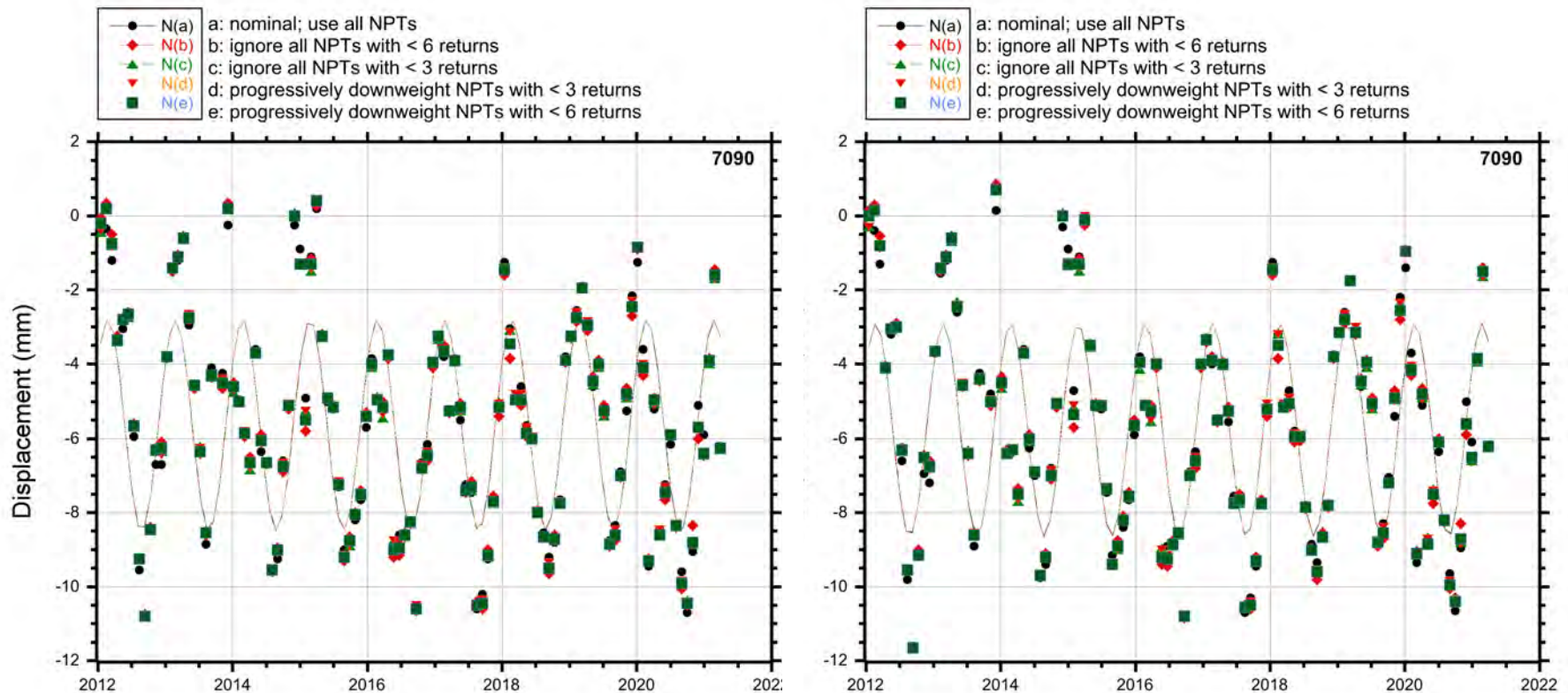


East component of 7090

(monthly bias was also estimated for figure on the right with 1 cm apriori)

Edit/Weighting Experiment (2)

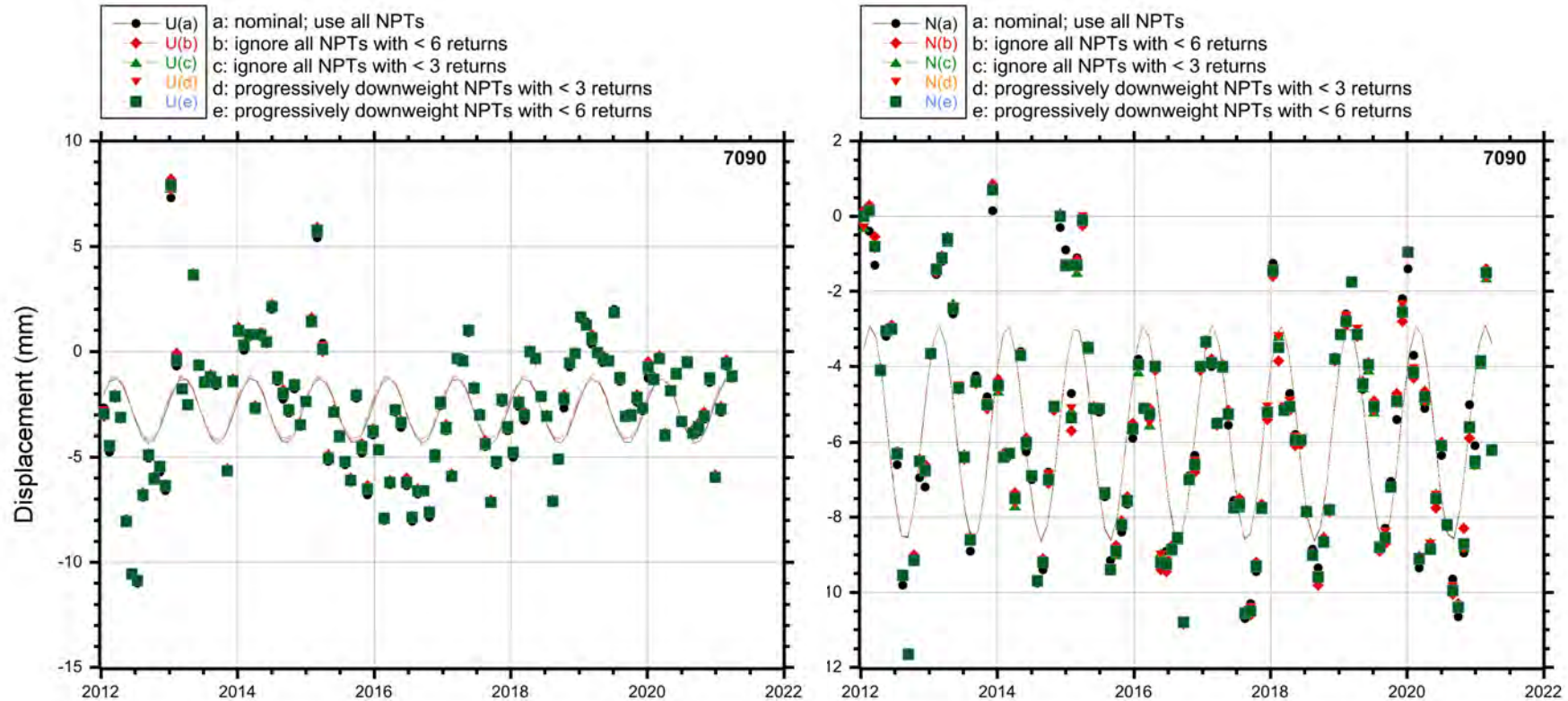
The coordinates for 7090 were estimated every 30 days from 2012 to 2020, where the low-return NPTs were either edited or downweighted. However, it is difficult to see any impact on the quality of the time series for either station, even though 7090 had the highest percentage of low-return NPTs.



North component of 7090
(monthly bias was also estimated for figure on the right with 1 cm apriori)

Edit/Weighting Experiment (3)

Unlike E and N, the Up component estimates improve considerably when biases are also estimated. However, the results are not significantly affected by the low-return editing/weighting choices. The offset from SLRF2014 increases by about 3 mm when estimating biases.



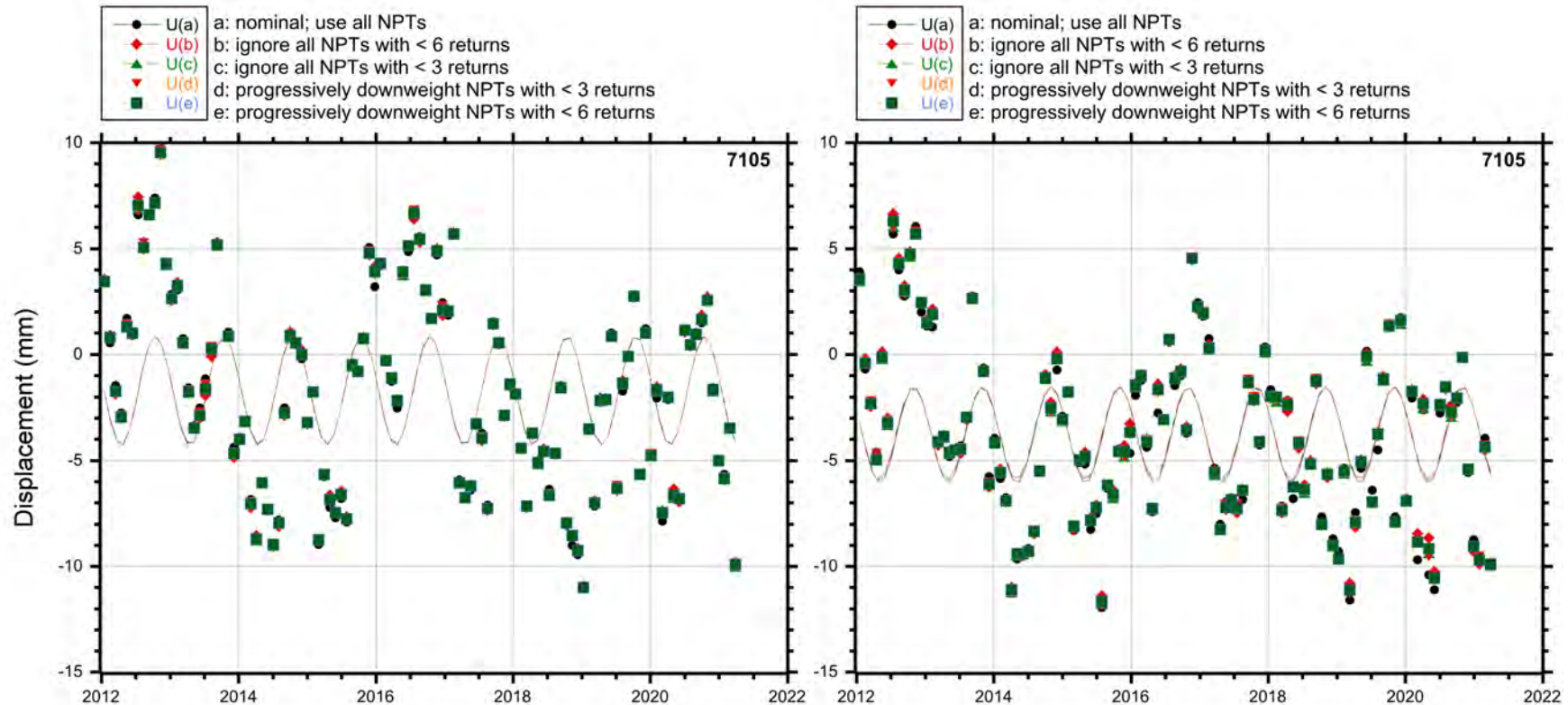
Up component of 7090

(monthly bias was also estimated for figure on the right with 1 cm apriori)

(note change in scale; estimating biases greatly improves recovery of the vertical)

Edit/Weighting Experiment (4)

The results were much the same for 7105. No significant difference in the estimates regardless of editing or weighting scheme. The estimation of biases improves the variability of the Up estimates, though not as much as for 7090. The offset from SLRF2014 is increased by about 2 mm with the estimation of biases.



Up component of 7105

(monthly bias was also estimated for figure on the right with 1 cm apriori)

(estimating bias improves recovery of the vertical somewhat, but a negative shift is apparent)

Conclusions (1)

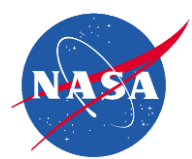
- The FIT RMS increases when low-return NPTs are included.
 - The low-return NPTs are clearly worse than NPTs with at least 6 returns, even in the case of 5, 4 or even 3-return NPTs.
 - For the two smaller (and lower) satellites looked at, a significant bias of 5-10 mm is introduced for NPTs with less than 6 returns.
- There seems to be some inconsistency in computing the RMS for low-return NPTs.
 - Since the uncertainty of a low-return NPT is large, the assigned RMS should probably be correspondingly large.
 - However, I suspect that the analysts do not generally use it to inform their data weighting, so there does not seem to be much point in trying to impose strict requirements on how to assign the RMS.

Conclusions (2)

- The geodetic impact of the low-return NPTs appears small, but analysts should consider the impact of including NPTs with less than 6 returns.
 - Analysts may want to test the impact of including/excluding any NPT with less than 6 returns, particularly for low satellites, to see the effect on the biases (e.g., Jason-3).
 - Some passes would be lost, but these are also clearly among the least reliable.
 - Where the tracking coverage is already weak, keeping the less reliable NPTs may be better. Keeping them but downweighting them may be reasonable.
 - This should become less of a problem with time as high-rep-rate stations come on line (7840, for example, had only a single NPT with less than 6 returns even when the test NPT software was run to allow for NPTs from as few as a single return).
- A possible analysis strategy would be to include NPTs with less than 6 returns, but downweight them progressively more severely as the number of returns gets smaller.
 - Preserves passes or low-elevation data that might otherwise be lost
 - However, impact on geodetic results seems to be minimal regardless of editing or weighting scheme.

Conclusions (3)

- While not the objective of this analysis, the tests where a monthly range bias was estimated showed some or significant improvement in the variability of the Up component estimates.
 - Though there is significant correlation between a range bias and the station height, that correlation is not so strong as to degrade the results; the opposite appears to be true.
 - The fact that for both test cases (7090 and 7105), the offset from SLRF2014 increased by a few mm suggests the possibility that the SLR estimates of the heights may be off by a similar amount because biases are not estimated simultaneously with the heights.
 - Determining changes in the biases as part of the apriori analysis is completely reasonable (and even necessary for the best SLR-based POD) as this can sometimes help in understanding the cause, but the only way to know the absolute bias is to let it adjust along with the heights.
 - If the bias changes are appropriately modeled apriori, then it may not be necessary to estimate the bias every week, month or year, but perhaps only a single global bias for each station.

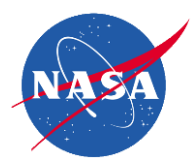


Graz Data Analysis

Van S Husson

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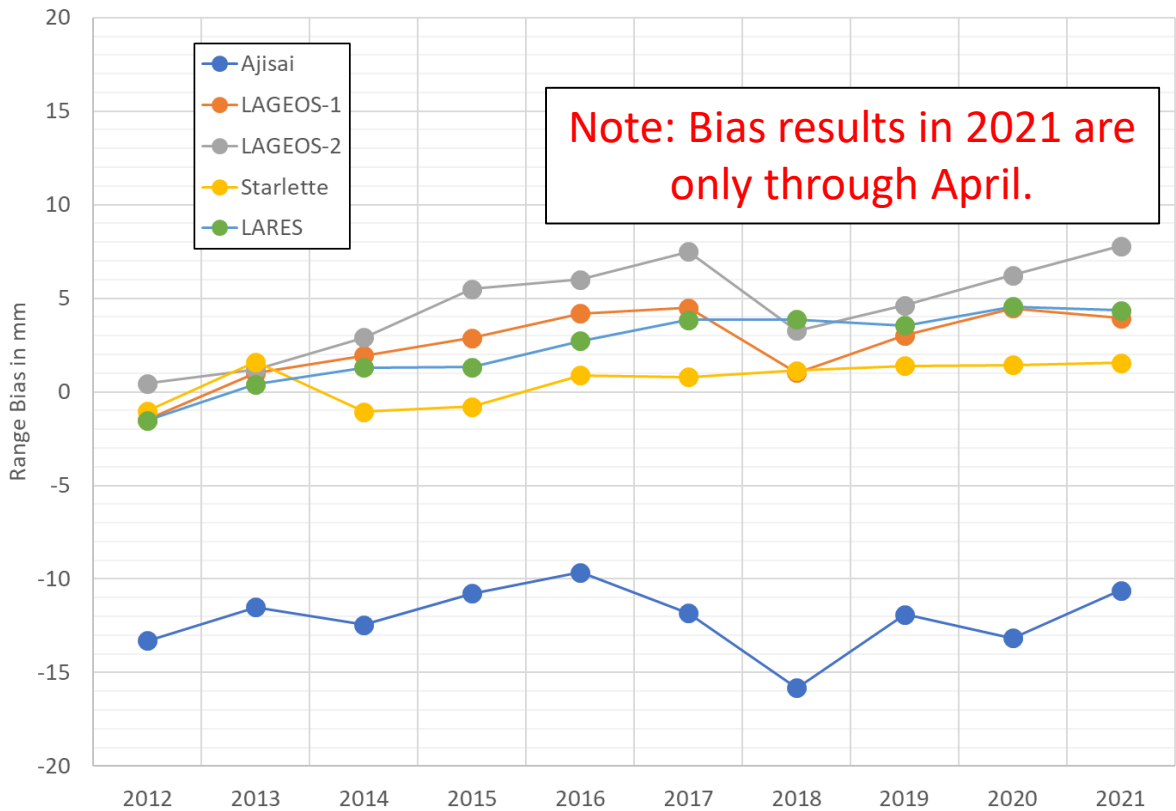
June 15, 2021



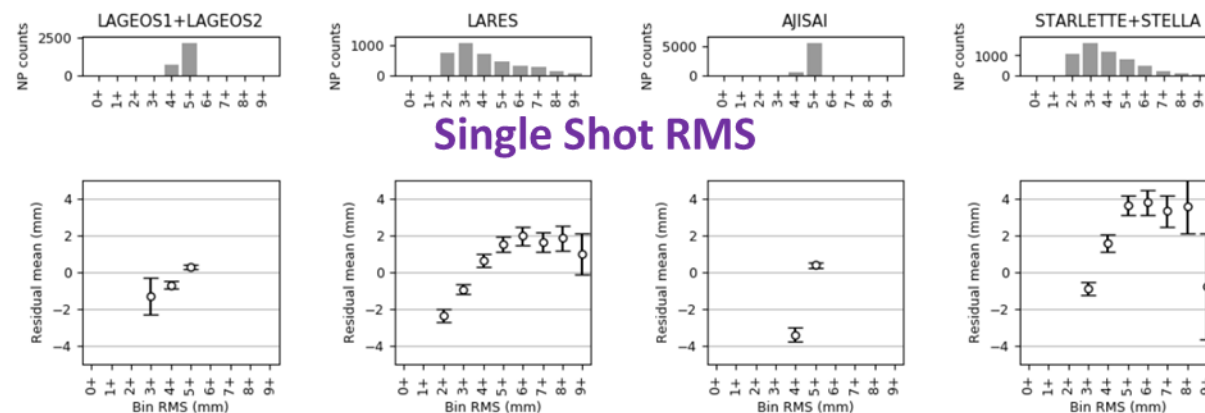
7839 Graz Range Bias Analysis (1 of 2)



7839 GRZL HITU Yearly Geodetic Range Biases



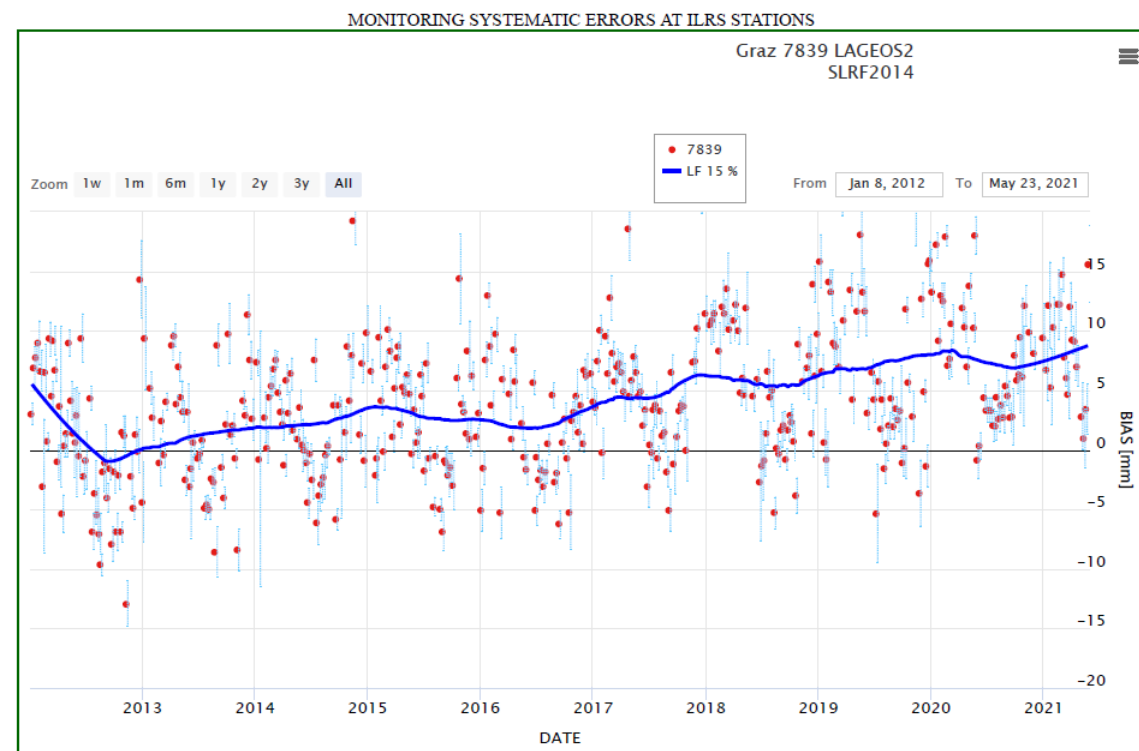
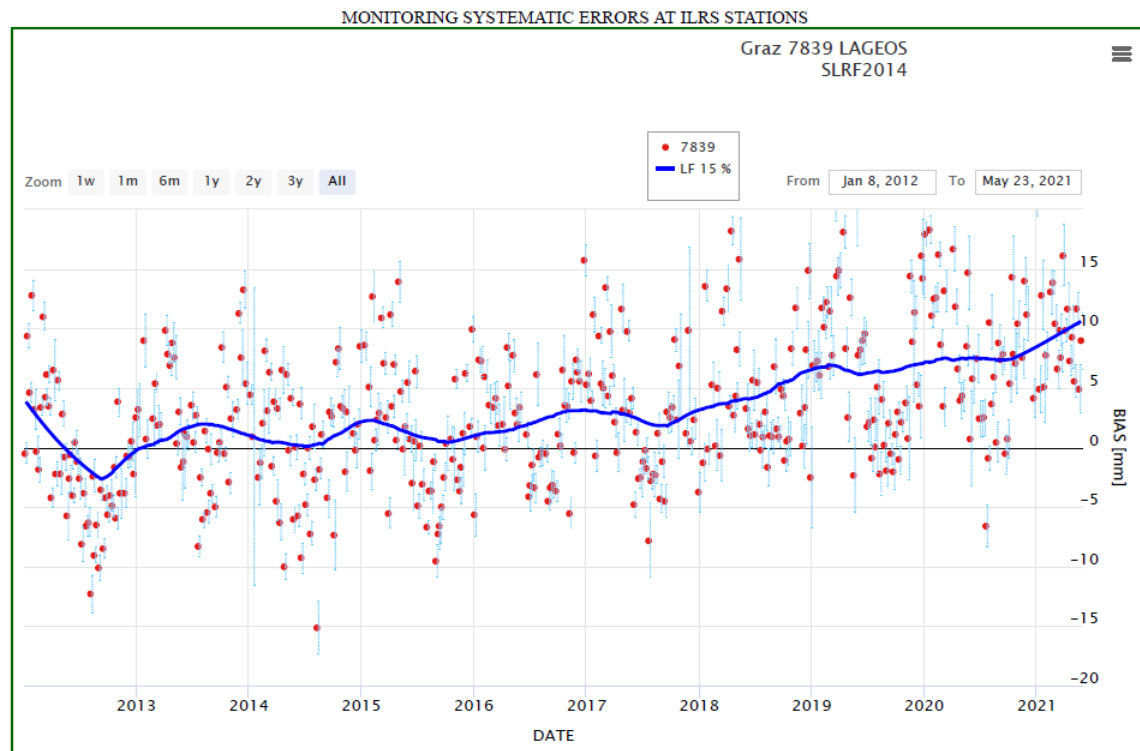
Toshi's 7839 Aggregate Analysis (Jul '17 to Jun'18)



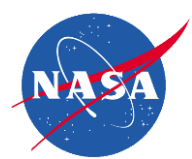
HITU updated the SLR coordinates to ITRF2014 in Jun '17, resulting in a 4.7 mm height change in Graz. In 2018 due to the Graz height change, there was a 3.5 to 4 mm drop in the LAGEOS-1, -2 and Ajsai range biases, but no change in the LARES and Starlette range biases. Based on the chart on the right; which is Toshi's aggregate analysis of Graz geodetic range biases between Jul '17 and Jun '18 as a function of single shot RMS; the large increase in LARES and Starlette RMSs in 2018 introduced a +3 to +4 mm range bias in those two satellites!



7839 Graz Range Bias Analysis (2 of 2)



Left and right charts are JCET LAGEOS-1 and LAGEOS-2 range bias estimates; respectively, since Jan 2012 using ITRF2014 coordinates. On the 10th of Dec 2020, Graz replaced their Paroscientific MET3A meteorological sensor with a Vaisala PTU300 eliminating a 1 millibar error. On the 26th of Mar 2021, the PTU300 was replaced a newer PTU300. The original PTU300 is being used as a redundant backup. Should we have seen a reduction in the bias by ~5mm post MET3A replacement? Since the Graz range biases have seasonal signals, do we need more data to see the impact or is there still a barometric issue?



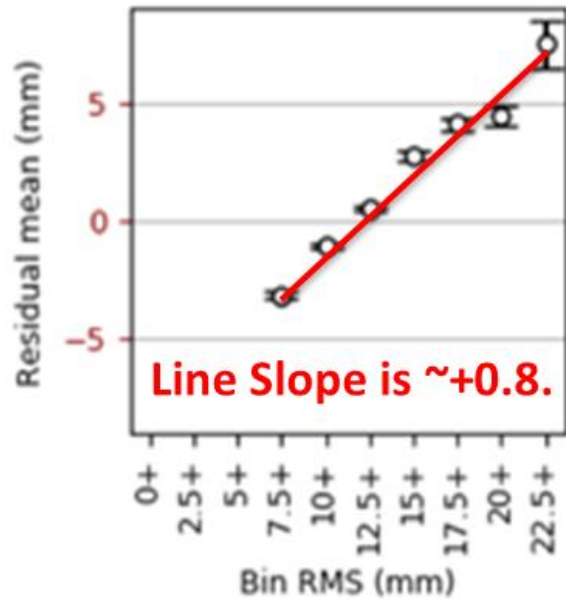
Herstmonceux Data Analysis

Van S Husson

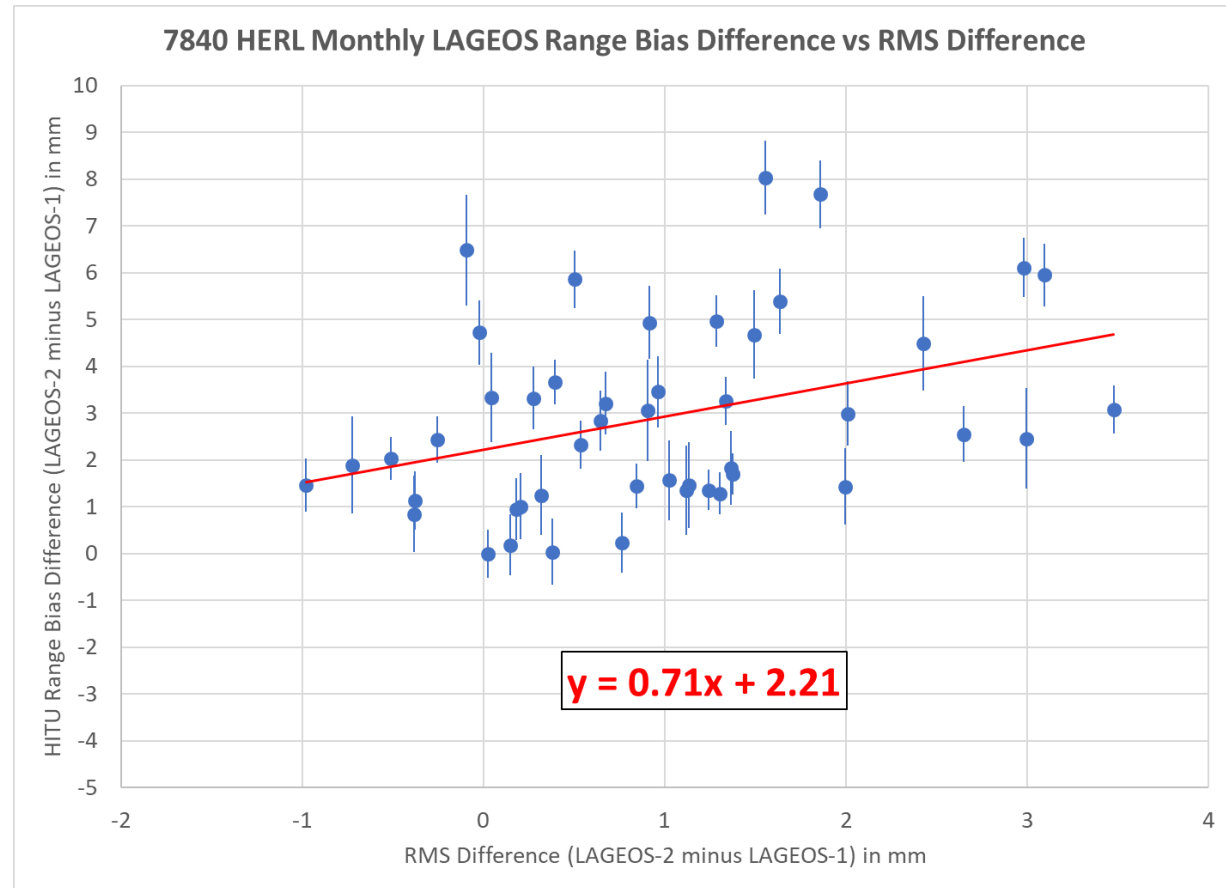
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Toshi's 7840 July 2017 to June 2018 LAGEOS Bin RMS Aggregate Analysis (LAGEOS 1 and 2 combined)



June 2017 to April 2021 LAGEOS Data Analysis

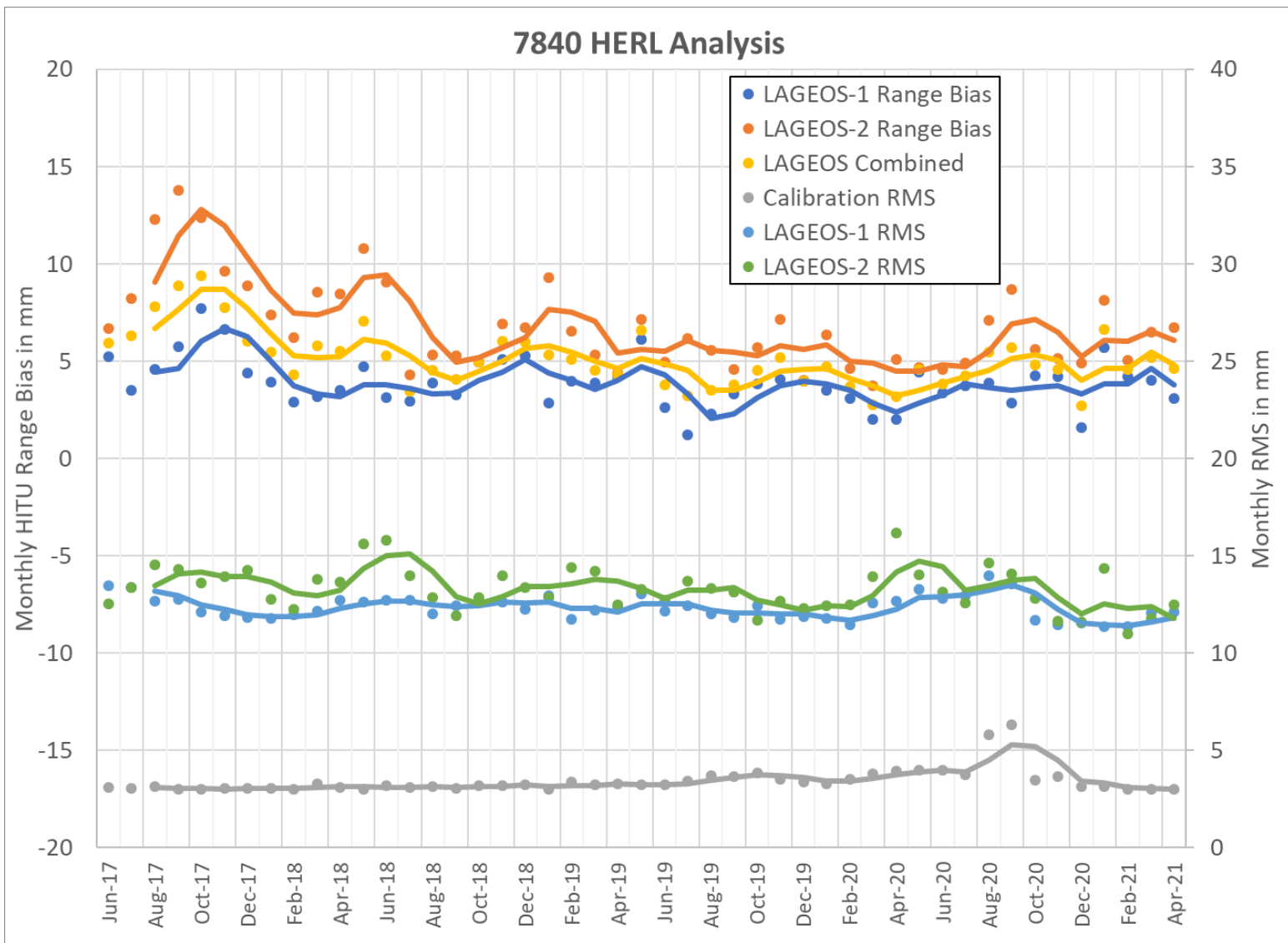


The chart on the left is a combination of LAGEOS data aggregated by bin RMS for one year. The chart on the right is monthly HITU LAGEOS range biases (L2-L1) differences vs monthly LAGEOS RMS differences. Both plots basically have the same slope. The differences in range bias between LAGEOS 1 and 2 can be explained in part by the RMS differences. See next slide.

Note: Toshi's analyses currently uses the same CoM for both LAGEOSs.



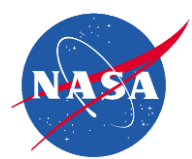
7840 HERL Performance Analysis



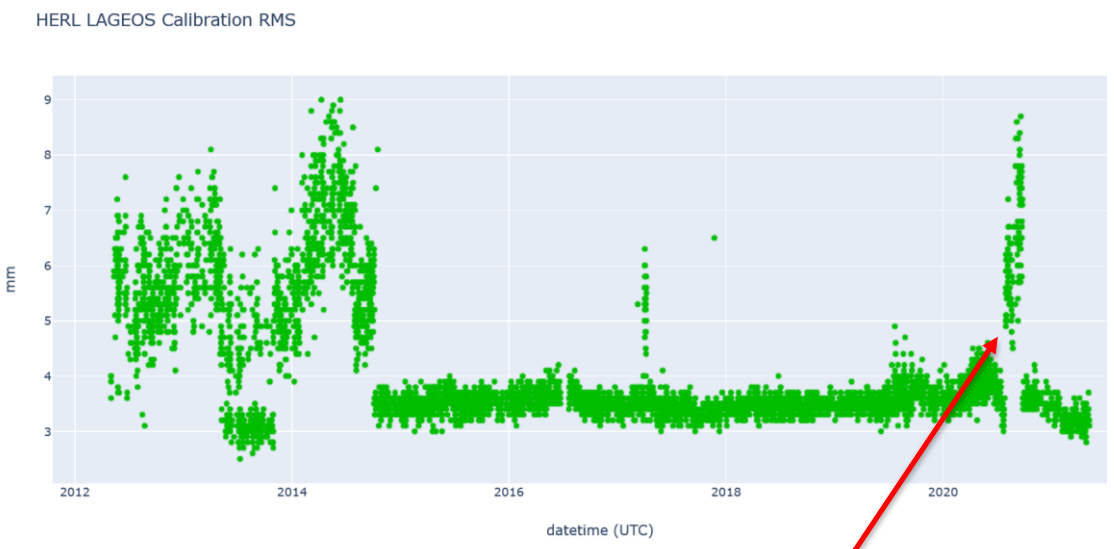
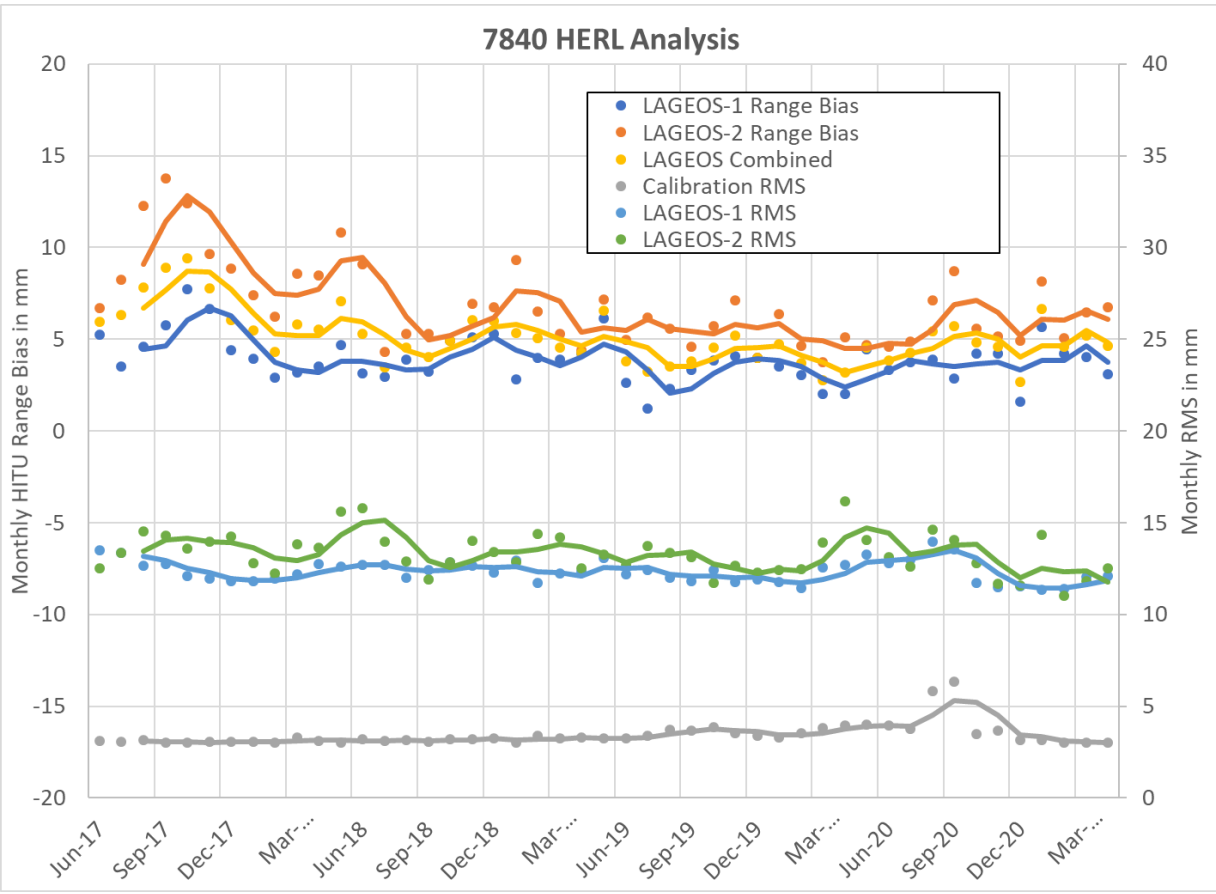
- ◆ This is time series of monthly LAGEOS-1 and -2 HITU Range Biases and RMSs including LAGEOS calibration data.
- ◆ Range biases are on the left axes and RMSs are on the right axes. The lines are 3-month running averages.
- ◆ There are more trends in the LAGEOS-2 RMSs than LAGEOS-1 RMSs. The range bias differences tend to converge as the RMSs converge.
- ◆ There was a blip in the calibration RMSs in the late summer of 2020 when there was a laser change. See the backup slides for more information.



BACKUP



7840 HERL Performance Analysis



When the old 7840 12Hz laser was installed on the 29th of July 2020, the calibration RMSs increased due to a longer pulse-width (81 vs 8 ps) and then the calibration RMSs decreased when the kHz laser was reinstalled on the 25th of September 2020. Did the laser change induce a few mm range bias in LAGEOS-2, but not LAGEOS-1? The HITU range bias difference between LAGEOS 1 and 2 was greater in 2017 then the past few years. Also, the LAGEOS-2 RMSs are typically higher than LAGEOS-1 RMSs and LAGEOS-2 RMSs have more variability.



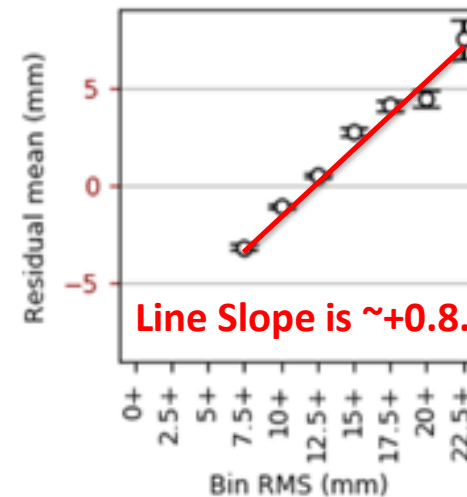
7840 2020 LAGEOS Analysis Summary



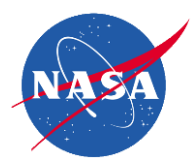
2020 LAGEOS-2										
Laser	Cal RMS in mm	Cal Skew	Cal Kurtosis	Cal Peak-Mean in mm	Sat RMS in mm	Sat Skew	Sat Kurtosis	Sat Peak-Mean in mm	CoM	HITU Range Bias (251mm CoM) in mm
1kHz	3.75	0.16	-0.29	-0.30	13.31	0.49	-0.42	-3.65	243.80	4.98
12Hz	6.26	0.21	-0.41	-1.10	14.50	0.36	-0.45	-4.19	243.10	7.64
Difference	-2.51	-0.05	0.12	0.80	-1.19	0.12	0.03	0.53	0.70	-2.66

2020 LAGEOS-1										
Laser	Cal RMS in mm	Cal Skew	Cal Kurtosis	Cal Peak-Mean in mm	Sat RMS in mm	Sat Skew	Sat Kurtosis	Sat Peak-Mean in mm	CoM	HITU Range Bias (251mm CoM) in mm
1kHz	3.73	0.16	-0.29	-0.29	12.26	0.53	-0.41	-3.41	244.50	3.14
12Hz	6.35	0.18	-0.41	-0.94	13.87	0.32	-0.42	-3.96	243.80	3.38
Difference	-2.62	-0.02	0.12	0.65	-1.61	0.21	0.01	0.55	0.70	-0.24

2020 LAGEOS-2 minus LAGEOS-1										
Laser	Cal RMS in mm	Cal Skew	Cal Kurtosis	Cal Peak-Mean in mm	Sat RMS in mm	Sat Skew	Sat Kurtosis	Sat Peak-Mean in mm	CoM	HITU Range Bias (251mm CoM) in mm
1kHz	0.01	0.01	0.00	-0.01	1.06	-0.04	-0.01	-0.24	-0.70	1.84
12Hz	-0.10	0.04	0.00	-0.16	0.63	0.05	-0.02	-0.22	-0.70	4.26



There is a 1.8 mm HITU range bias difference between LAGEOS-2 and -1 with the 1 kHz laser in 2020. The differences in center of mass can explain 0.7 mm. Based on Toshi's aggregate analysis there is a linear correlation between 7840 range bias and bin RMS on LAGEOS. The slope of this line is +0.77. So a 1 mm increase in LAGEOS RMS equates to $\sim +0.8$ mm change in range bias. Adding +0.7 mm (i.e. the differences in CoM) to +0.8mm (the range bias difference in LAGEOS-1, -2 based on RMS differences) is +1.5mm which is close to the +1.8mm difference in HITU LAGEOS-2 minus LAGEOS-1 range bias. Or is the difference in RMSs already accounted for in the differences CoM corrections?



Simosato Update

Van S Husson

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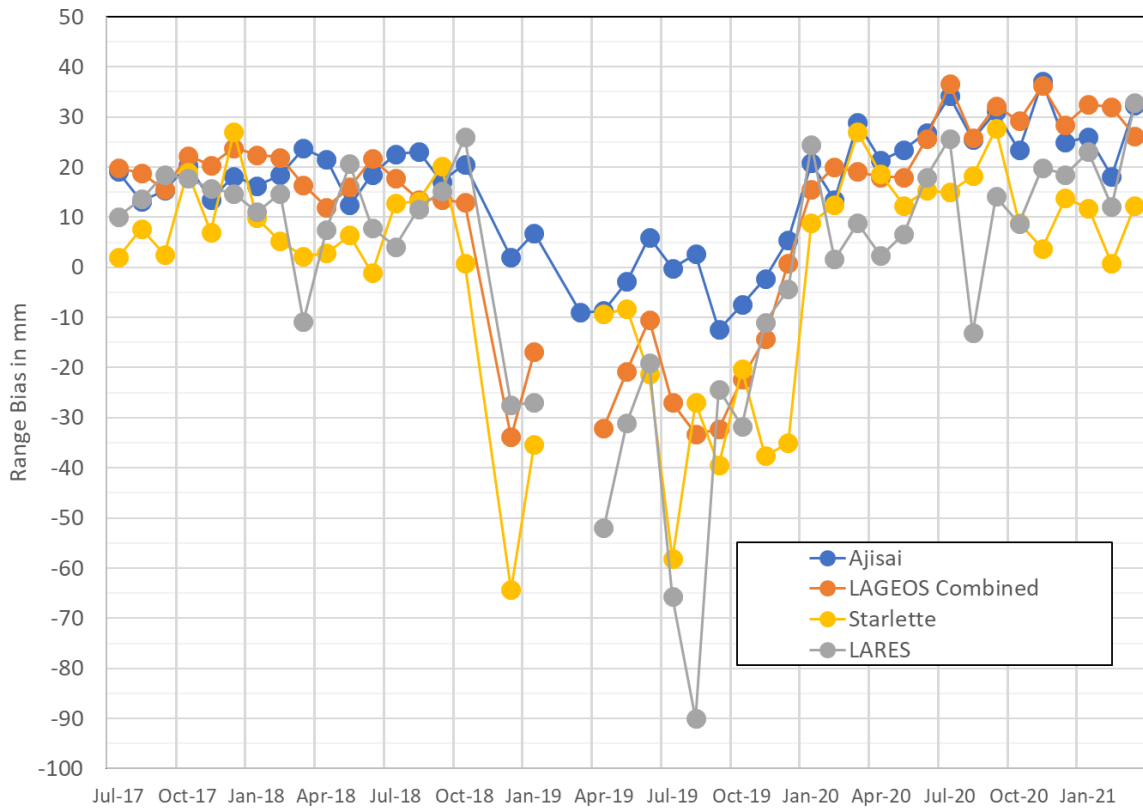
June 15, 2021



7838 SISL Data Analysis Update (1 of 2)



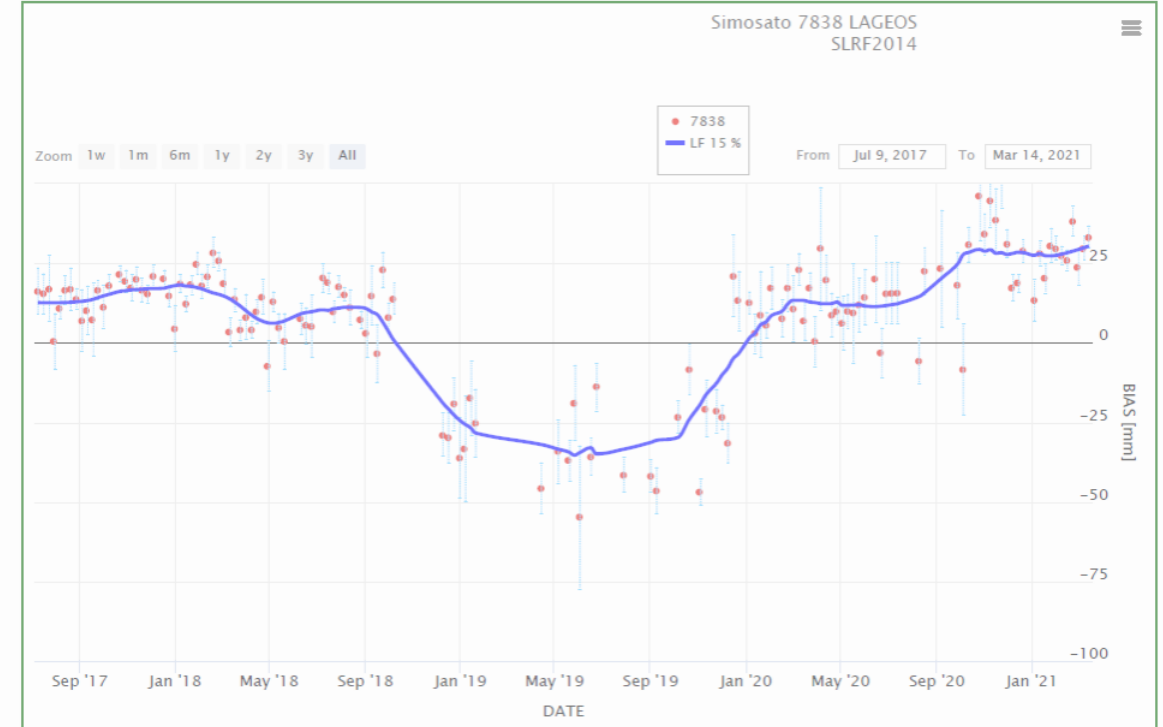
7838 Simosato HITU Monthly Geodetic Range Biases



3/28/2021

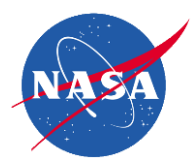
bias_H1_Simosato

MONITORING SYSTEMATIC ERRORS AT ILRS STATIONS



The 7838 LAGEOS HITU (left chart) & JCET (right chart) range biases appear to be growing since the beginning of 2020.

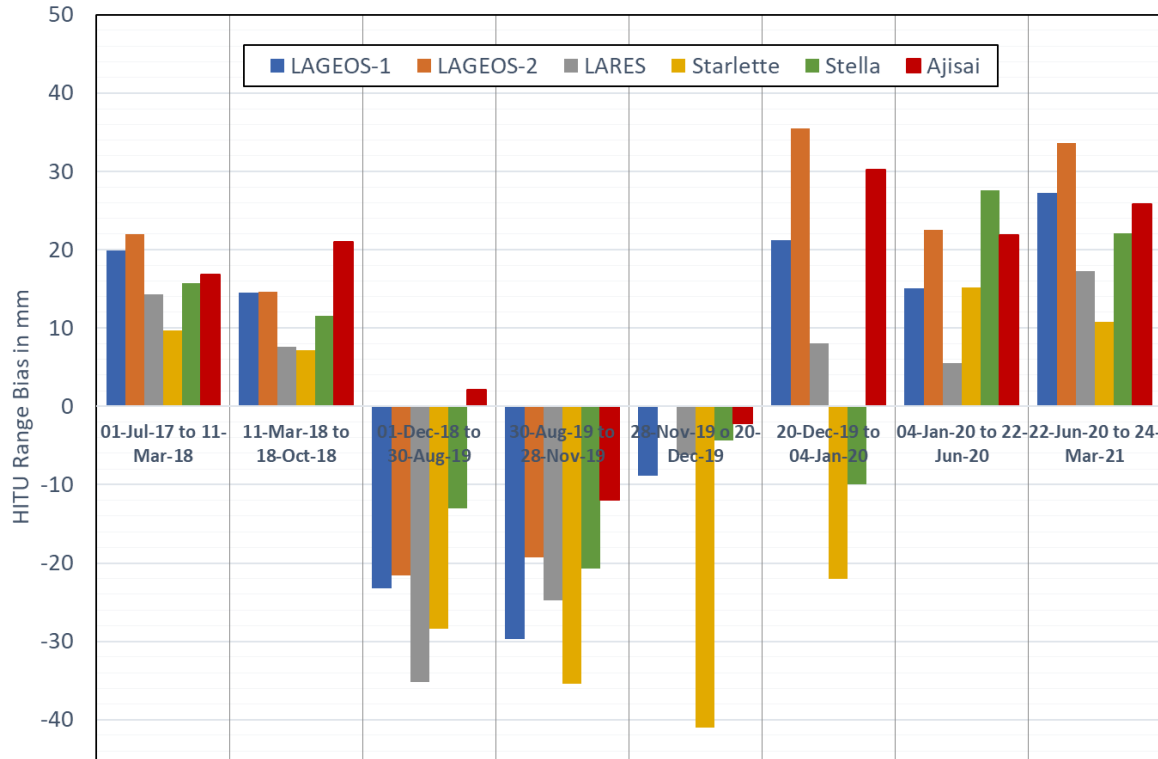
In ITRF2014, 7838's height rate is +3.3 mm/year (uplift). If in reality, the height rate is zero or negative (subsidence), this implies the range bias differences between 2017 and 2021 have grown more than indicated.



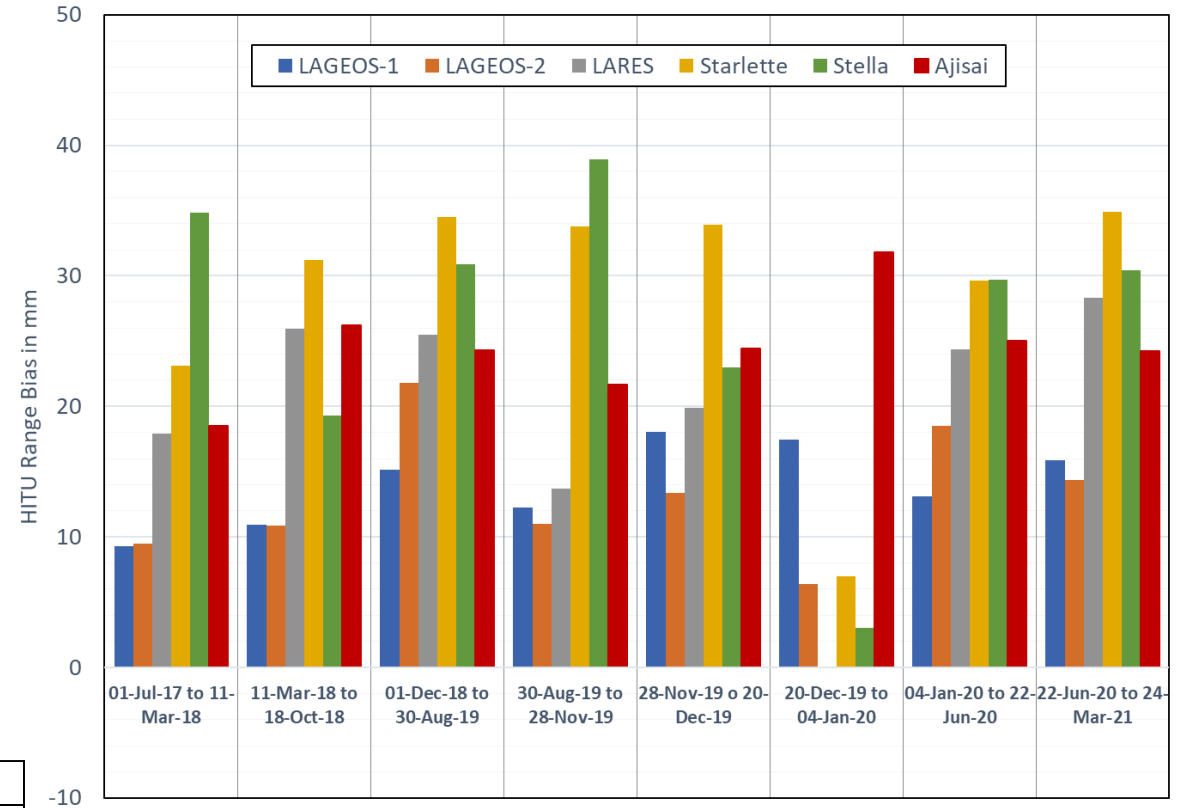
7838 SISL Biases by Period



7838 Simosato HITU Geodetic Range Biases

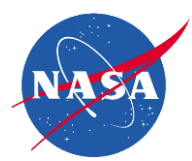


7838 Simosato HITU Geodetic Range Bias Stabilities



Period	Timespan	Change
1	01-Jul-17 to 11-Mar-18	Old laser, old MCP-PMT
2	11-Mar-18 to 18-Oct-18	New MCP-PMT
3	01-Dec-18 to 30-Aug-19	New 1 kHz laser
4	30-Aug-19 to 28-Nov-19	Disabled amplifier, cable change
5	28-Nov-19 to 20-Dec-19	Installed amplifier switch, enabled amplifier for HEOs
6	20-Dec-19 to 04-Jan-20	Changed the MCP-PMT gate width
7	04-Jan-20 to 22-Jun-20	Disabled amplifier
8	22-Jun-20 to 24-Mar-21	Cable change, installed Constant Mid-Signal Detection (CMD)

Average HITU range biases by period (left chart) and range bias stability (right chart). Period 1 had the best range bias stabilities.



◆ History Log Status

- Simosato, in December 2020, provided an updated history log starting with its second occupation of 7838
- Based on their site log, a few additional entries were added
- Added an entry for the first occupation of 7838
- Updated the data impact flags from an 'x' to an integer
- Recommend an independent review of my changes

◆ Site Log

- Site Log Sections 3, 5 (laser) and 6 (receiver) don't go back to the beginning of their first occupation of 7838 in 1982. Is that important?

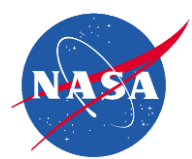


Single Shot RMS Dependencies in C-SPAD, APD, & SPAD Systems

Van S Husson

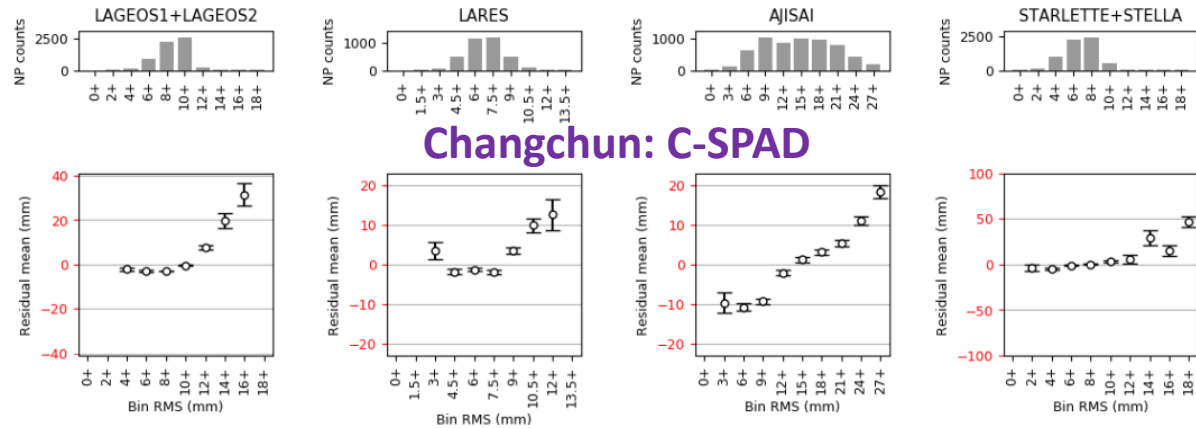
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June 15, 2021



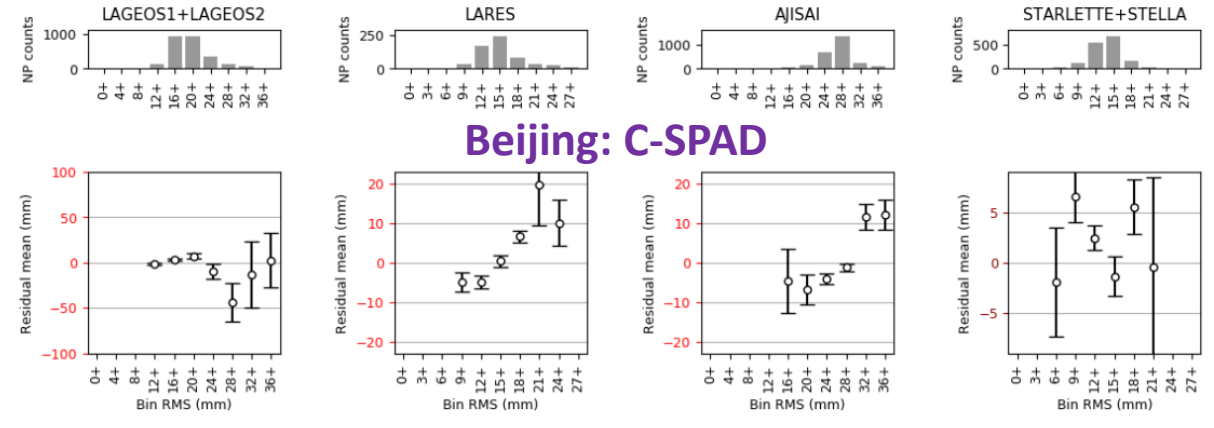
Range Bias and Single Shot RMS Dependency with SPADs

7237: wrt Single-Shot RMS



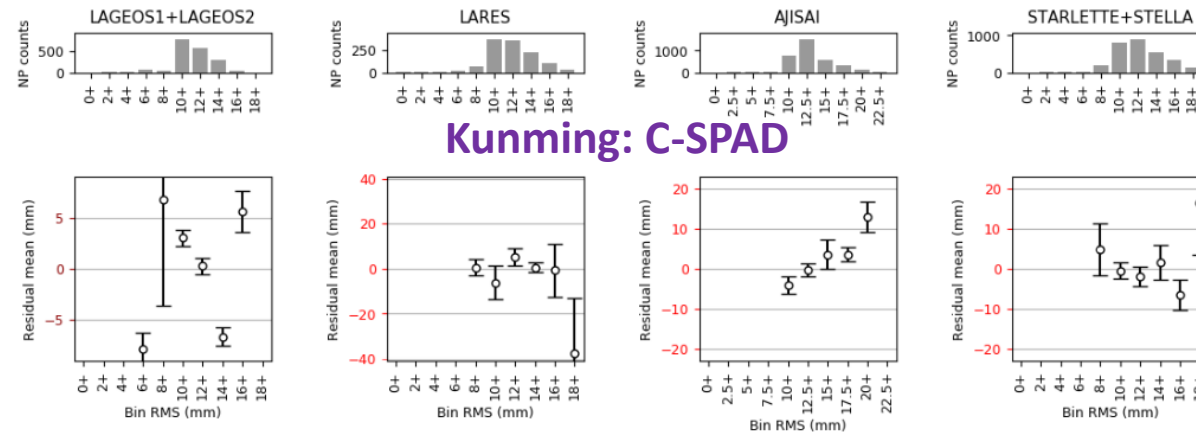
Changchun: C-SPAD

7249: wrt Single-Shot RMS



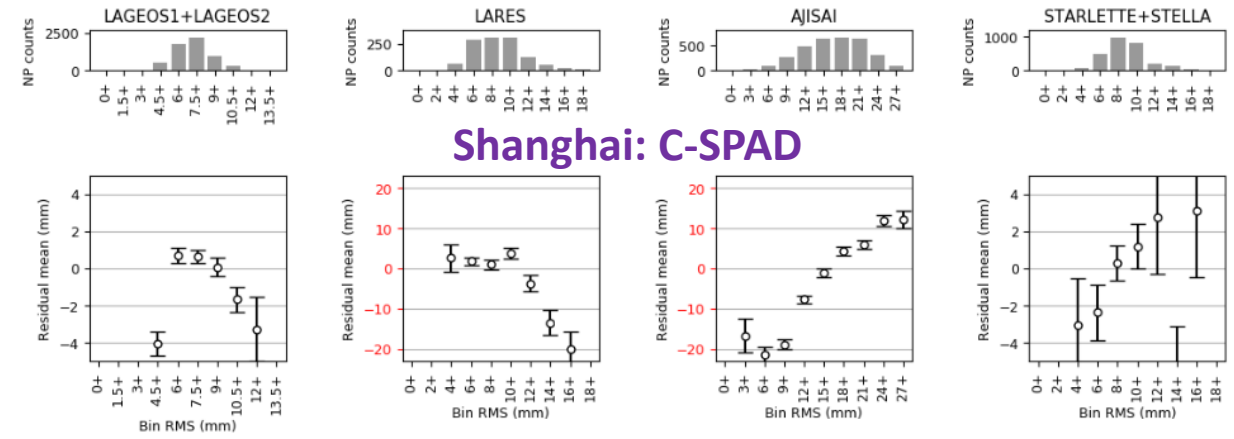
Beijing: C-SPAD

7819: wrt Single-Shot RMS



Kunming: C-SPAD

7821: wrt Single-Shot RMS



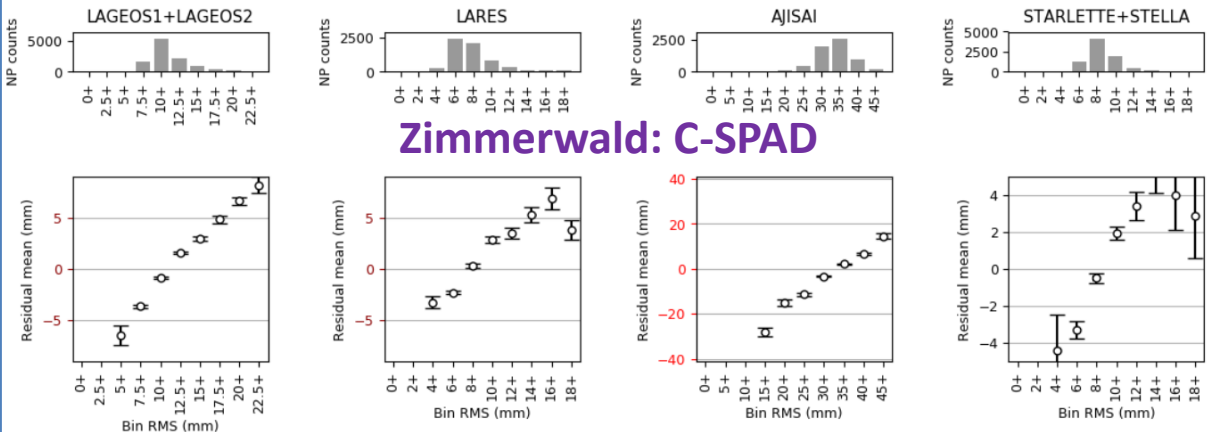
Shanghai: C-SPAD

Results of Toshi's last yearly aggregate analysis (data is from Jul 1, '17 to Jun 30, '18)
 All 4 Chinese systems have C-SPADs, but no consistent trend from one station and/or satellite to another.

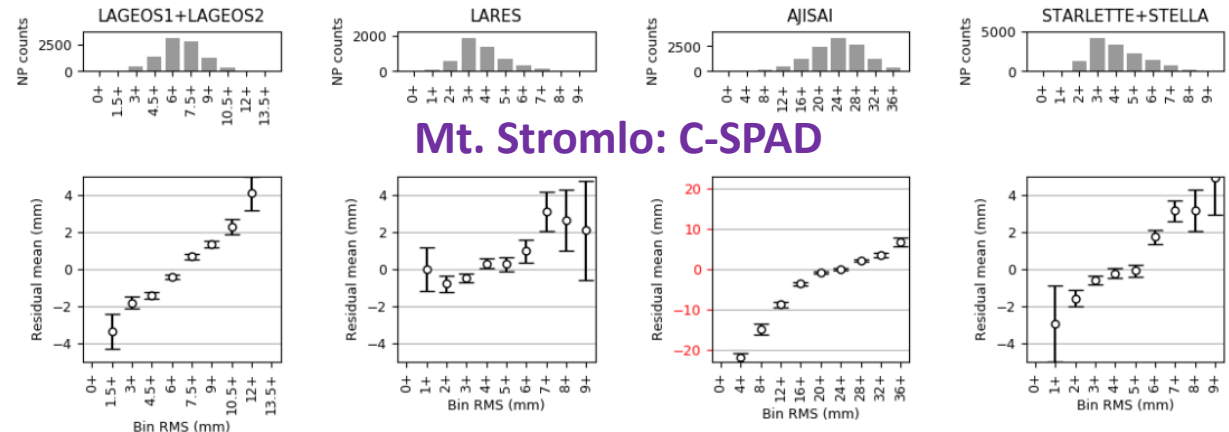


Range Bias and Single Shot RMS Dependency with SPADs

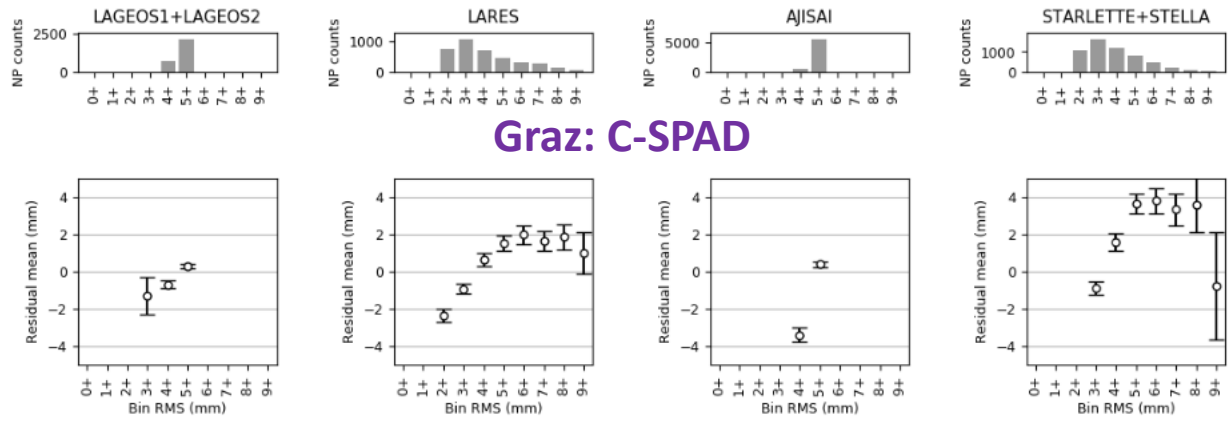
7810: wrt Single-Shot RMS



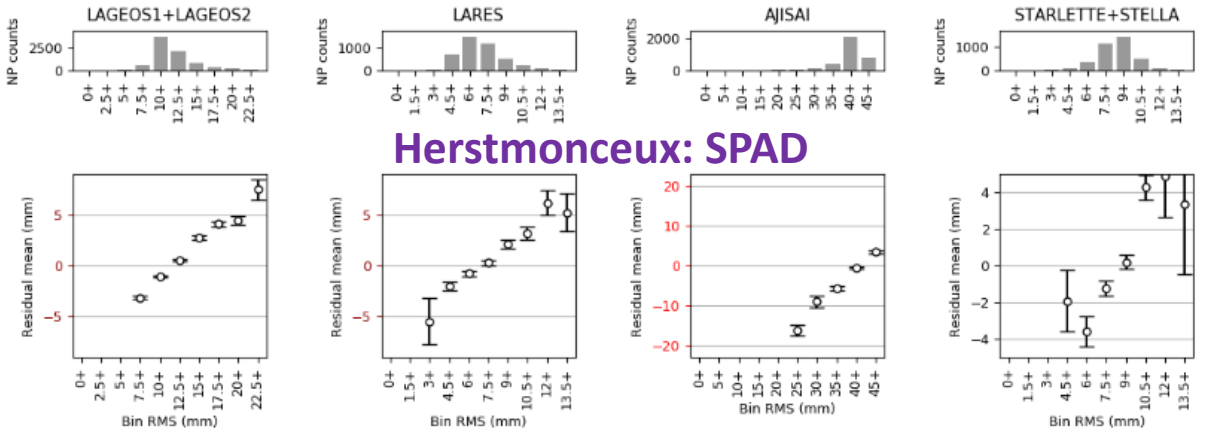
7825: wrt Single-Shot RMS



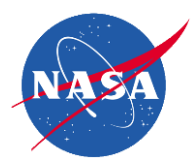
7839: wrt Single-Shot RMS



7840: wrt Single-Shot RMS

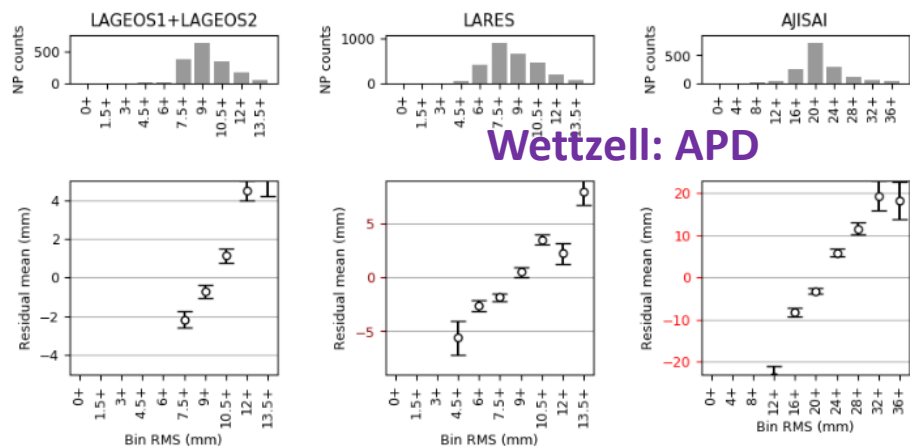


Zimmerwald, Mt. Stromlo, and Herstmonceux have linear trends on all 4 satellites. Graz trends are interesting and more on that later.

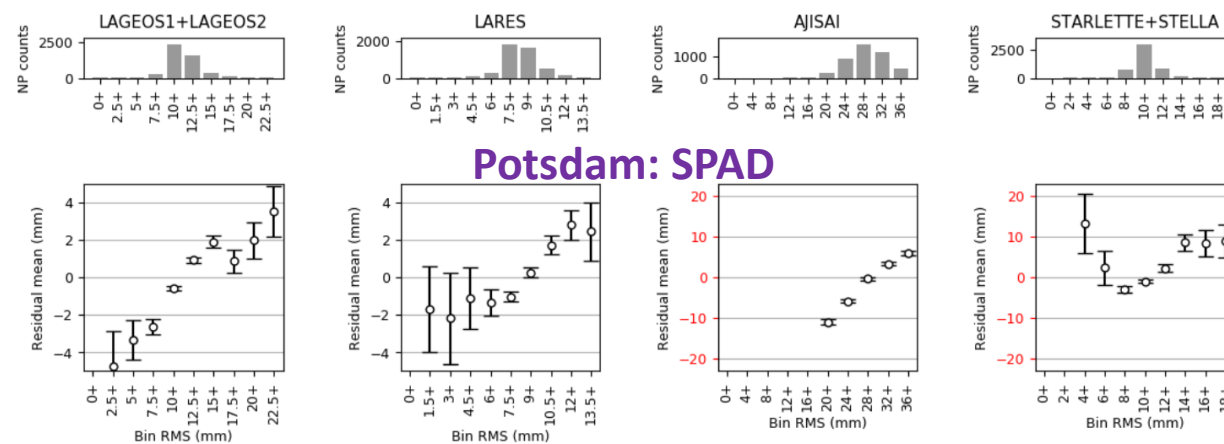


Range Bias and Single Shot RMS Dependency with SPADs

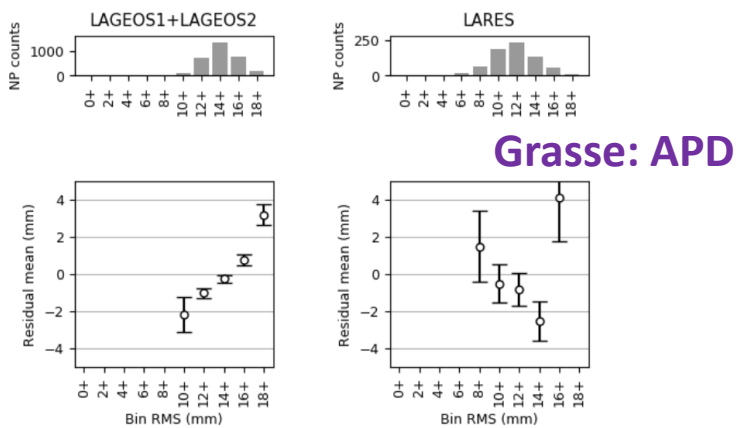
7827: wrt Single-Shot RMS



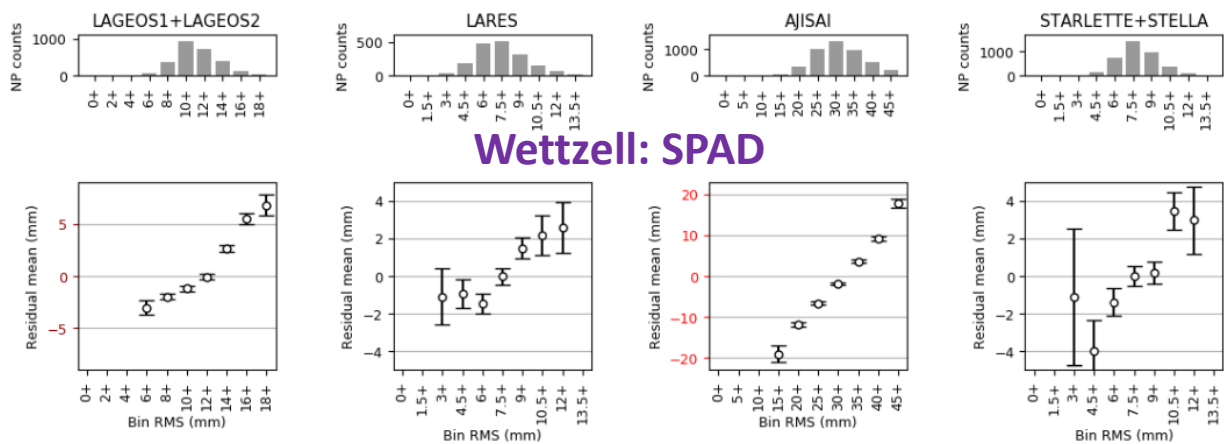
7841: wrt Single-Shot RMS



7845: wrt Single-Shot RMS



8834: wrt Single-Shot RMS



Both Wetzell systems and Potsdam have linear trends of range bias and single shot RMS. Grasse has linear trend on LAGEOS.

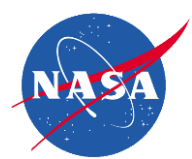


C-SPAD/SPAD/APD System Summary



Pad	Site	LAGEOS Range Bias/Bin RMS Slope	Detector	Return Rate	Satellite Sigma Edit	Calibration Sigma Edit
7237	Changchun	Non-linear	CSPAD	> 10%	2.5	2.5
7249	Beijing	Non-linear	CSPAD	> 10 %	2.5	2.5
7810	Zimmerwald	0.9	CSPAD	> 10 %	2.5	2.5
7819	Kunming	Non-linear	CSPAD	> 10 %	2.5	Manual
7821	Shanghai	Non-linear	CSPAD	> 10 %	2.5	2.2
7825	Mt Stromlo	0.7	CSPAD	> 10 %	2.5	2.5
7827	Wettzell	1.2	APD	< 10 %	2.0	2.0
7839	Graz	0.8	CSPAD	> 10 %	2.2 & Leading Edge	2.2
7840	Herstmonceux	0.8	SPAD	< 10 %	3.0	2.5
7841	Potsdam	0.4	SPAD	< 10 %	2.5	2.0
7845	Grasse (LLR)	0.6	APD	> 10 %	2.4	2.5
8834	Wettzell	0.8	SPAD	< 10 %	2.5 in 2018, now 2.2	2.5 in 2018, now 2.0

Legend: Single Photon systems in RED



Summary/Discussion

- ◆ Why don't the Chinese systems, which are similar to configuration to some of the European systems, show linear trends between range bias and RMS in 2017/2018? Is there some other systematic error in the system masking this trend?
- ◆ For SPAD systems, can the differences in LAGEOS RMSs explain part of the differences in their respective range biases or is this already taken into account by the latest CoM models?
- ◆ Matt, Georg and Stefan have presented approaches to clipping data based on the leading-edge-half-maximum, the front-edge and the Wiener filter; respectively.
 - Do these techniques totally eliminate the SPAD range bias dependency with RMS?
 - For systems with SPADs and kHz lasers, is one data clipping technique better than the other?
 - With either data clipping approach, does it matter if SPAD signal levels are controlled?
 - Are SPAD single shot RMSs elevation dependent? If they are, new data clipping approaches could improve SLR scale.
 - Should all stations compute normal point bin higher moments and peak minus mean?