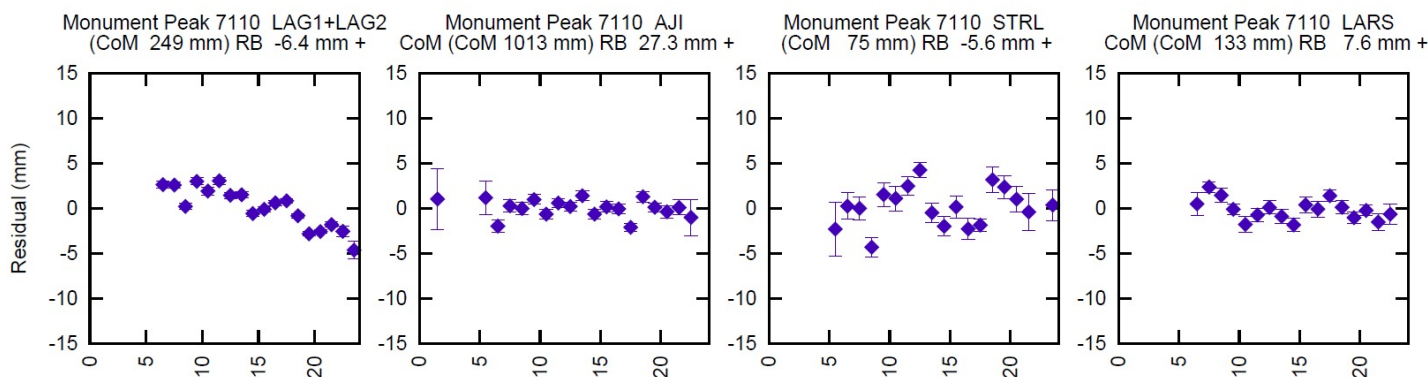




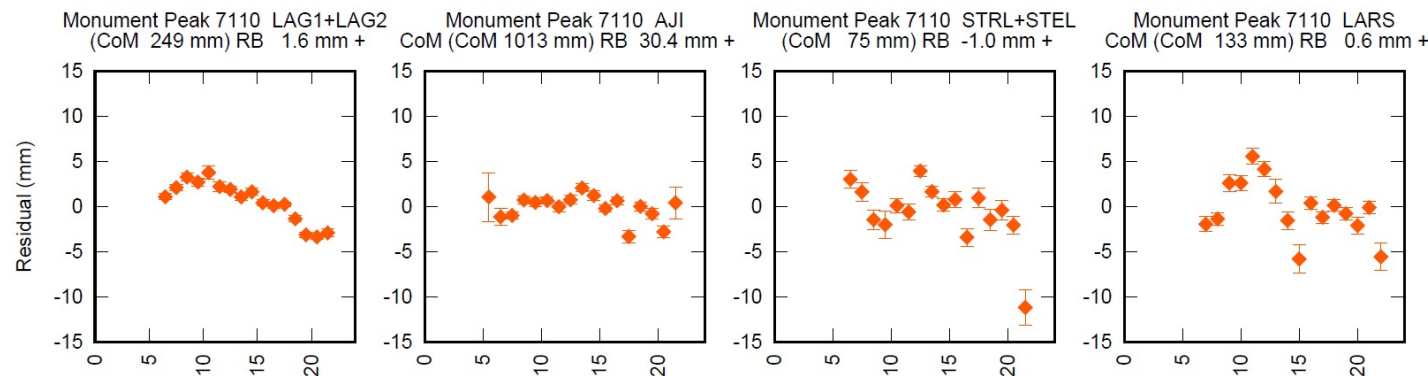
Toshi's 7110 MONL Yearly Aggregate Analysis



Jul 2014 to Jun 2015



Jul 2016 to Jun 2017



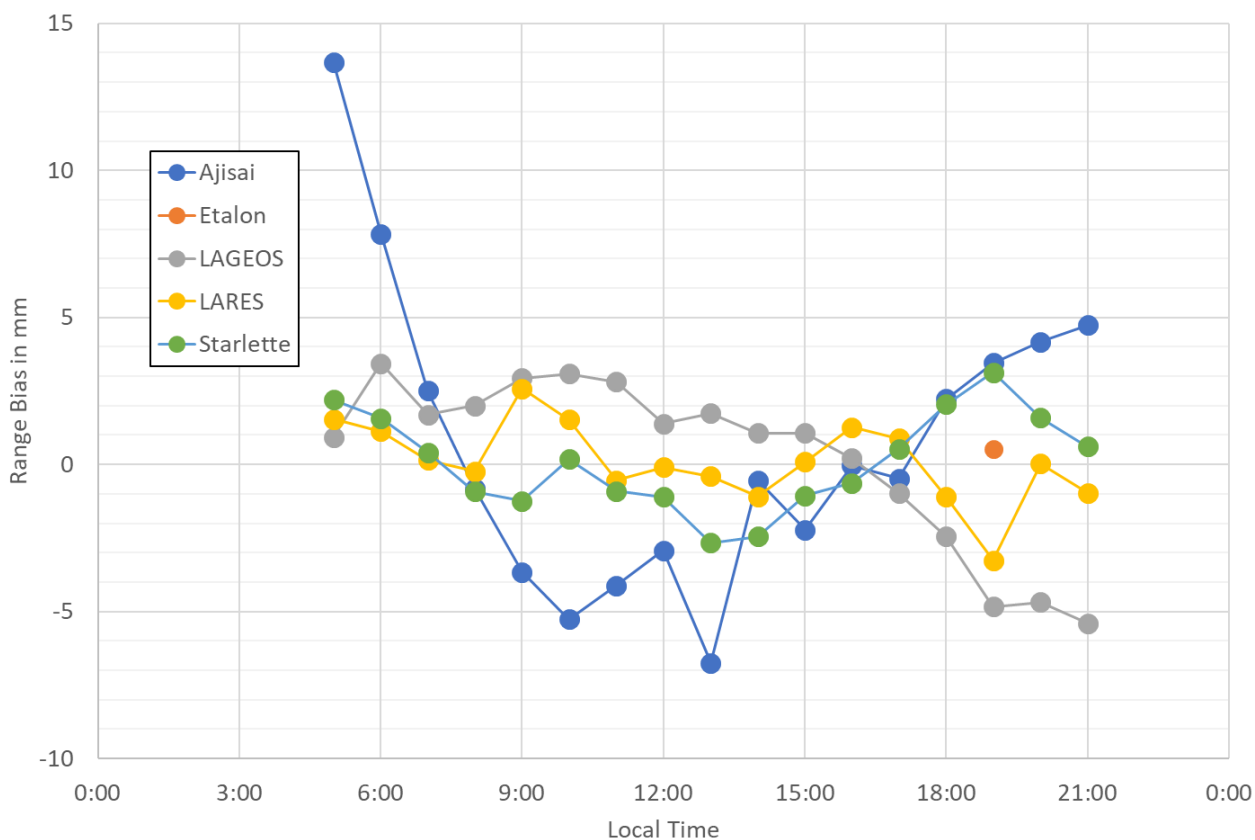
- ◆ Here are 2 sets of 7110 charts from Toshi's yearly aggregate analysis as a function of local hour.
- ◆ There appears to be a consistent 7 to 8 mm diurnal drift in the LAGEOS range biases.
- ◆ No noticeable trends on the other geodetic satellites.



7110 MONL Aggregate Diurnal Analysis



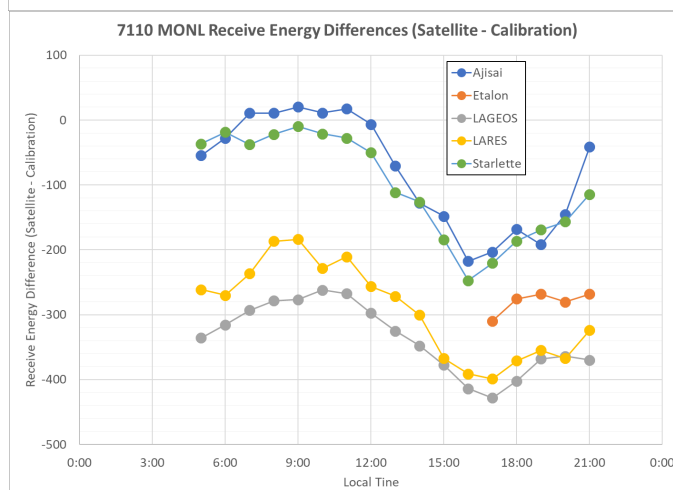
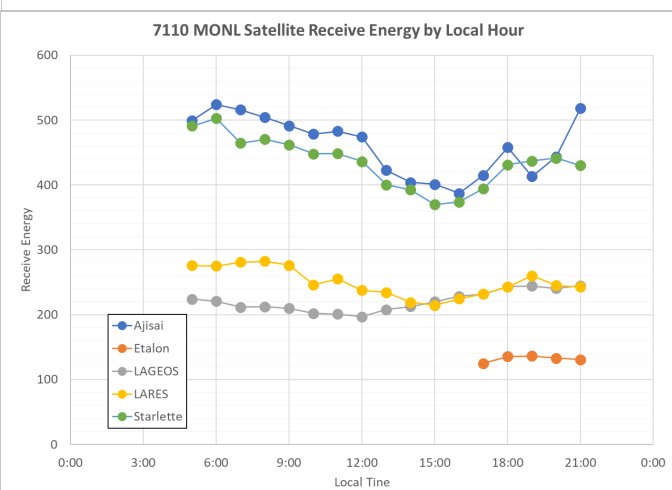
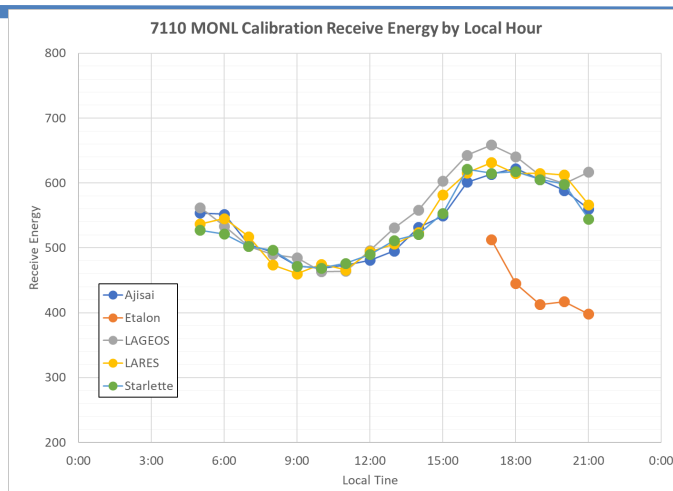
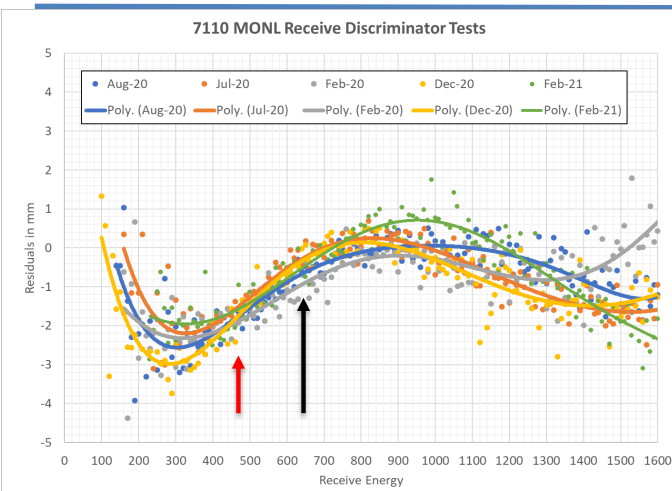
7110 MONL HITU Normalized Range Biases vs Local Time



- ◆ This chart is an aggregate (9+ years) of pass-by-pass range bias estimates by local hour from (Jan '12 to Feb '21).
- ◆ LAGEOS results still show the same 7 to 8 mm diurnal trend as Toshi's yearly aggregate analysis.
- ◆ Ajisai and Starlette appear to have a U-shaped pattern.



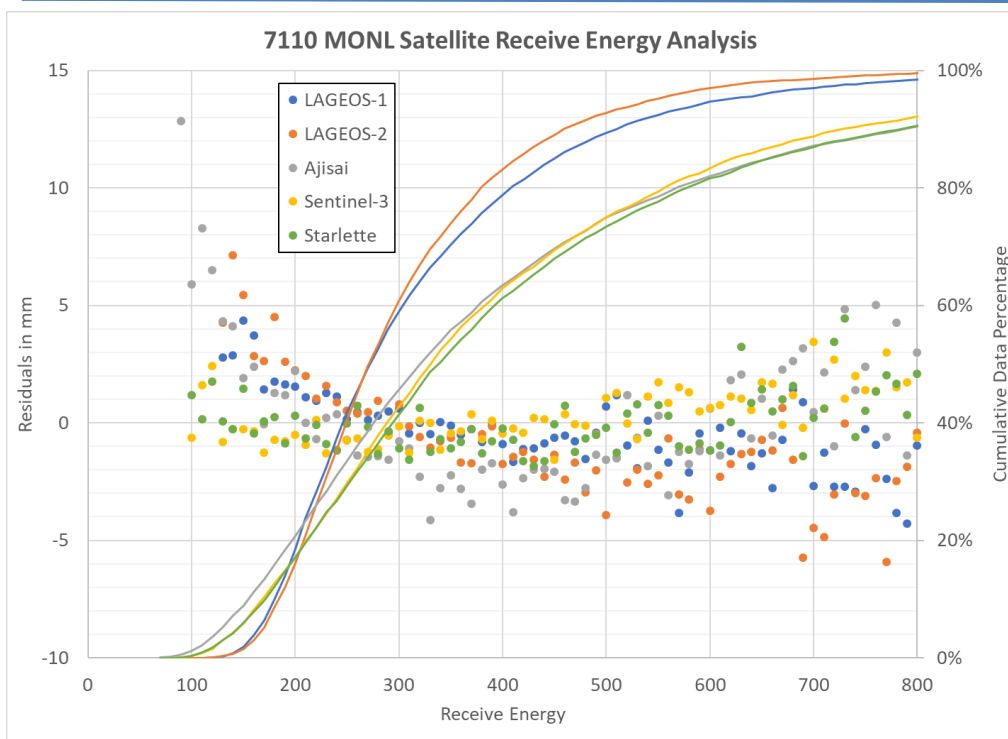
7110 MONL Receive Energy Analysis



- ◆ The top left chart are plots of monthly 7110 receive discriminator tests
- ◆ Top right, bottom left and bottom right charts are the aggregate (9+ years) calibration receive energies; satellite receive energies and the differences in receive energy by hour; respectively.
- ◆ The calibration receive energies, which are larger at night, can explain ~ 1.5 mm/20% of the 7 to 8 mm diurnal range bias variations. See the black (nighttime) and red (daytime) arrows on the discriminator curve to determine the differences in system delay between day and night calibrations.



7110 MONL Satellite Receive Energy Analysis



Sentinel-3: 7 retroreflectors



Starlette: 60 retroreflectors



LAGEOS: 426 retroreflectors

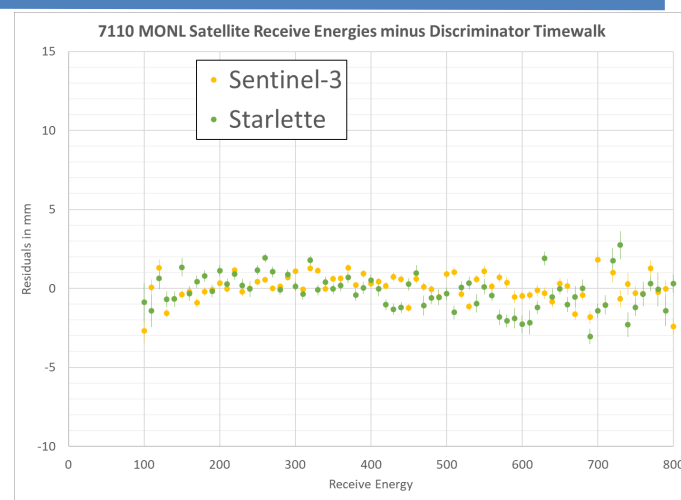
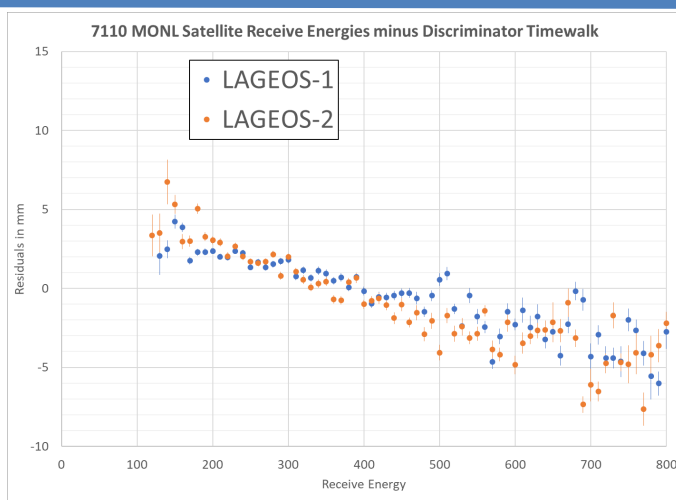
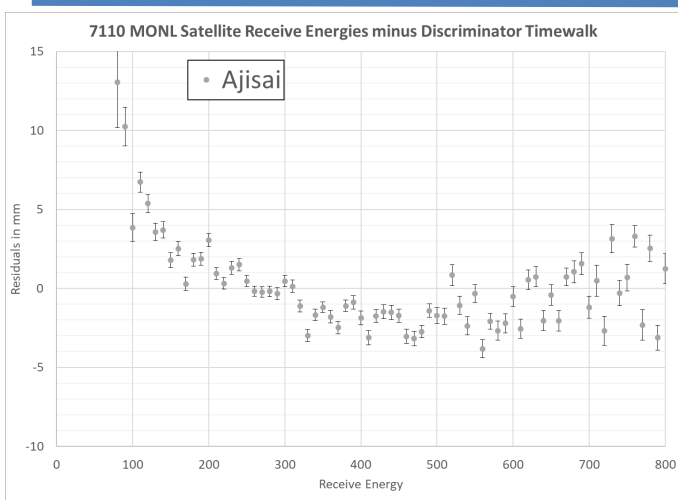


Ajisai: 1436 retroreflectors

The chart displays 7110 satellite receive energy variations on the left axes and their cumulative receive energy distributions on the right axes from a sampling of 3 to 4 robust nighttime passes. MONL LAGEOS and LEO data were taken at 5 and 10 Hz; respectively. Greater than 90% of LAGEOS and LEO data have receive energies less than 600 and 800; respectively. On the right are the four satellite retroreflector arrays and their number of retroreflectors.



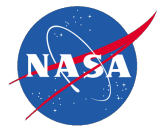
7110 MONL Satellite Receive Energy Analysis



Here are three charts of 7110 satellite receive energies after removing the receive discriminator timewalk based on the Dec '20 ground test. The resultant trends from these satellite are different based on the complexity of the retroreflector arrays.

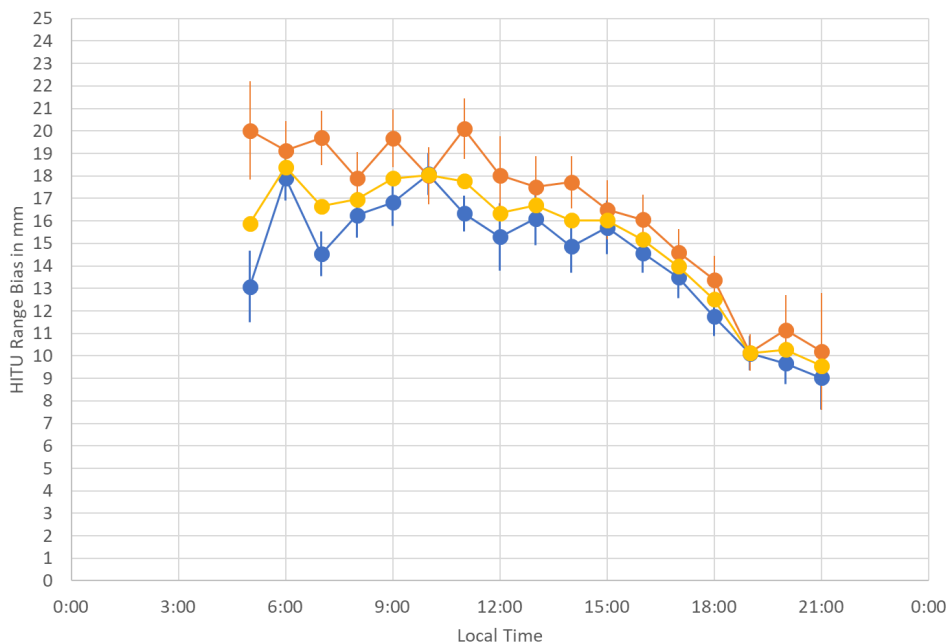
By design, the NASA SLR primary receiver system is considered leading edge detection. There are two cascading constant fraction receive discriminators with the threshold of the 1st discriminator set at 50 millivolts (mv). Any returns less than 50 mv in the primary receiver chain will **NOT** be recorded. The receive energy measurement is relative and represents the area under a curve.

It appears that Ajisai and LAGEOS spacecraft center of mass corrections are dependent upon the measured receive energy.

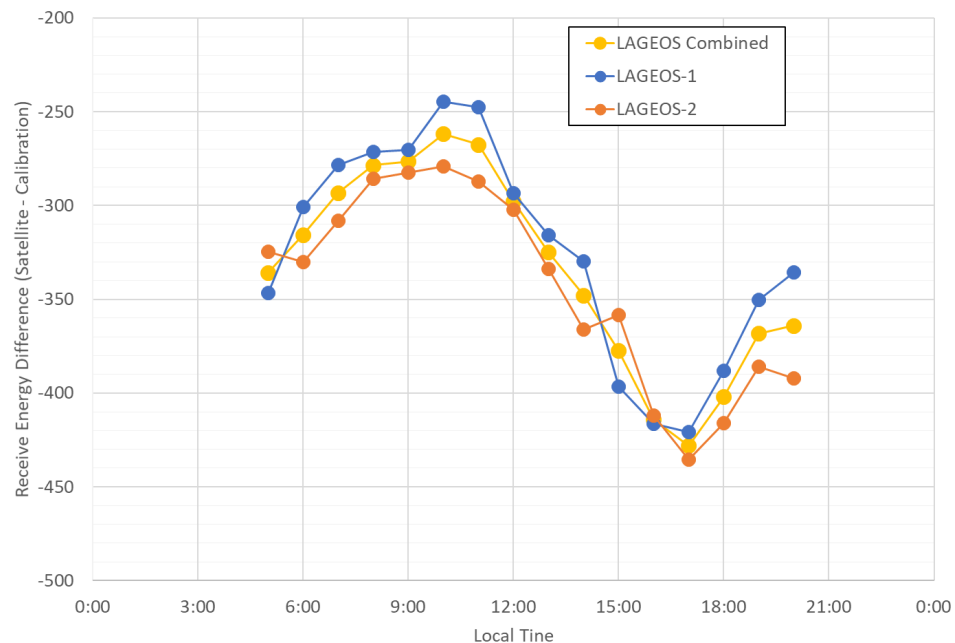


7110 LAGEOS Analysis (RB and Receive Energy)

7110 MONL HITU LAGEOS Range Biases vs Local Time

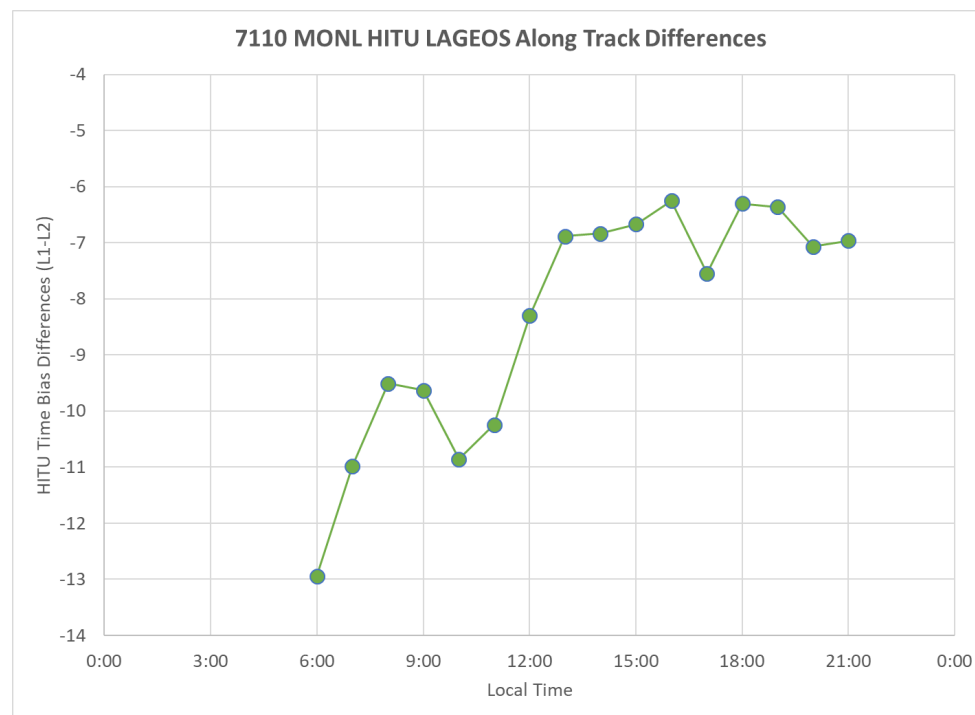
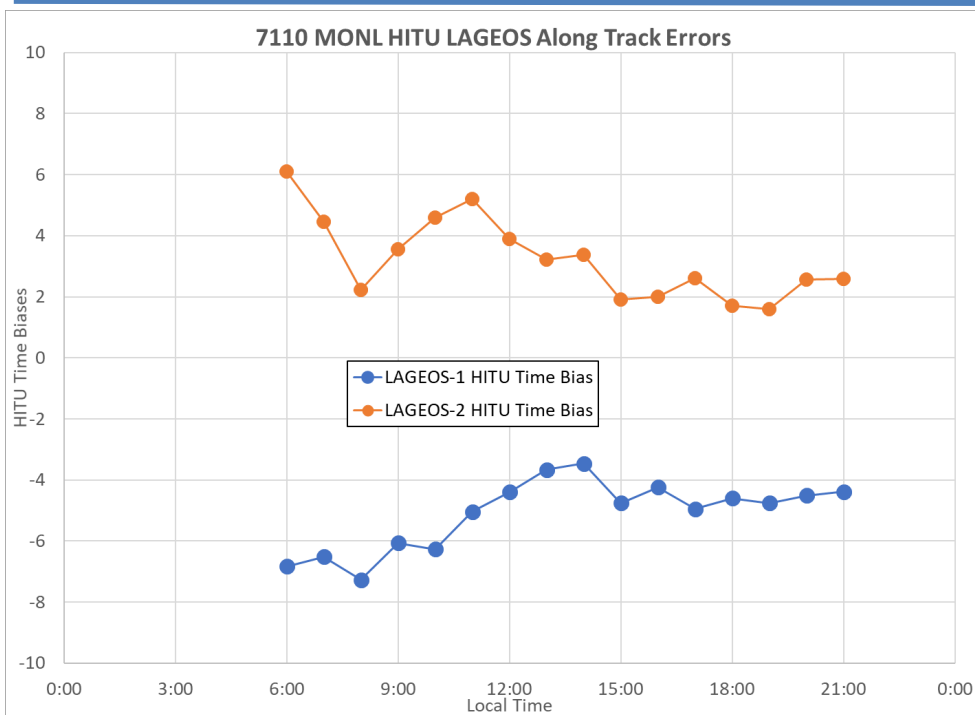


7110 MONL Receive Energy Differences (Satellite - Calibration)





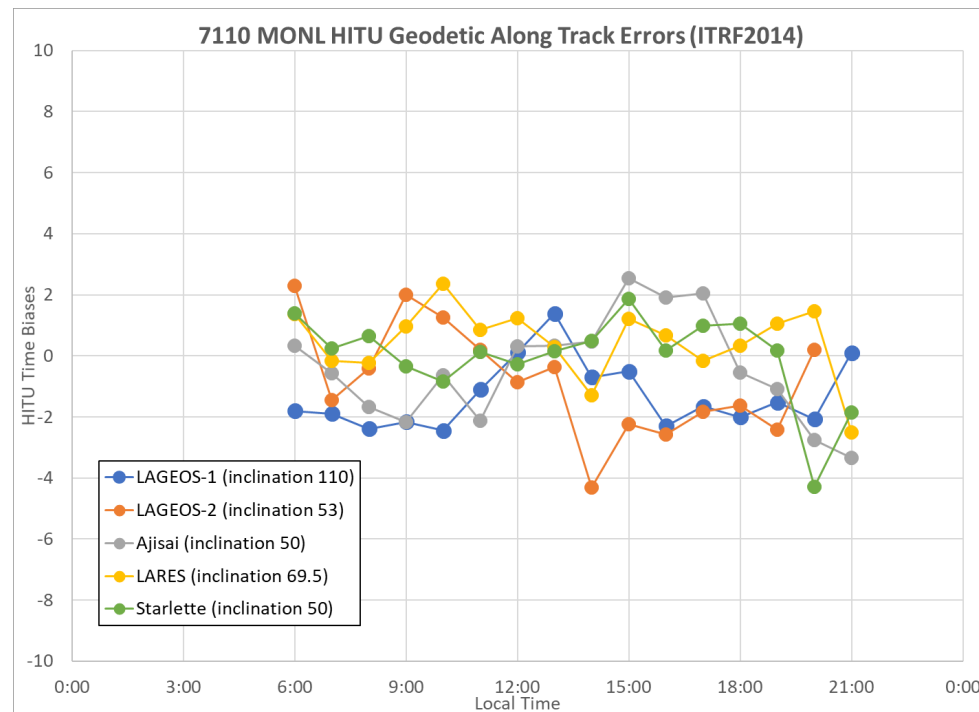
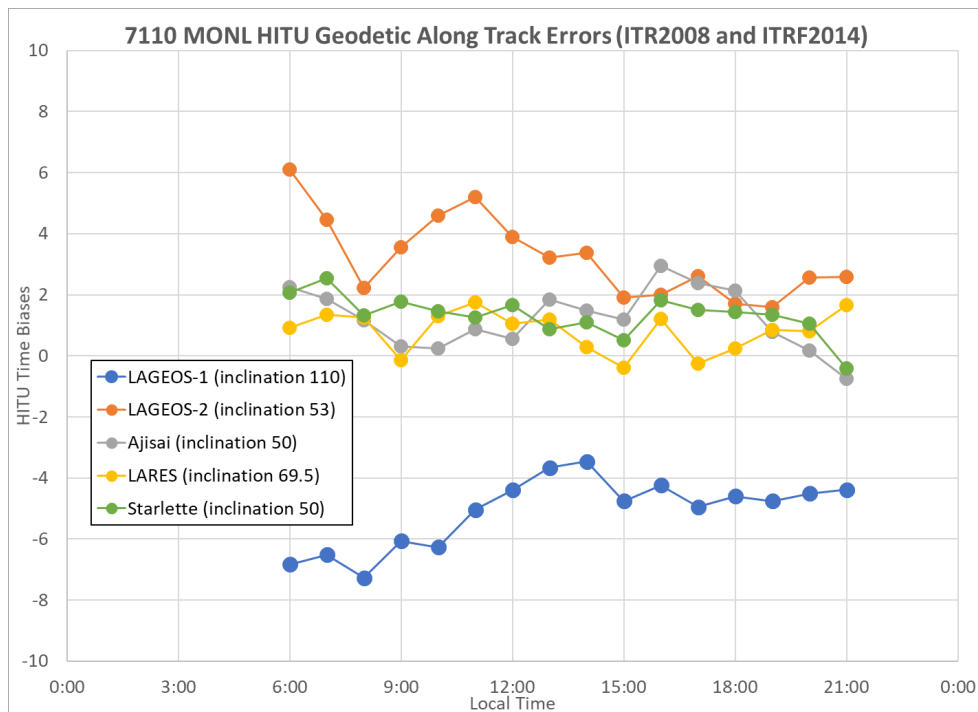
7110 HITU LAGEOS Time Bias Differences



- ◆ There is a large along track difference between LAGEOS-1 and LAGEOS-2. Is this due to a station position error?



7110 MONL HITU Along Track Errors





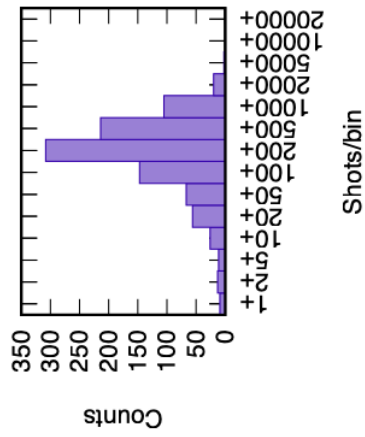
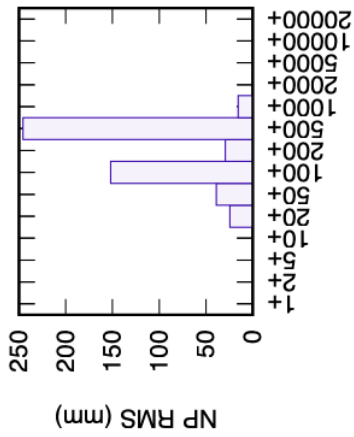
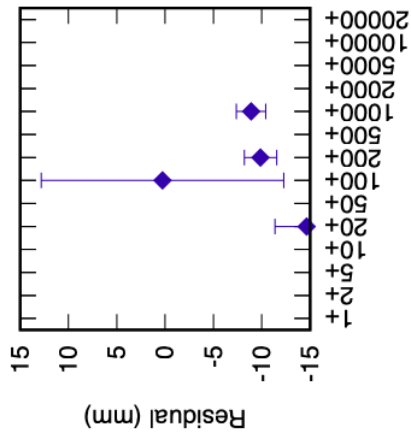
Comments on AWC charts presented on Oct. 5 2021 regarding the objective to process MCP multi photon data with a Wiener filter

1. In contrast to single photon data, recording the entire satellite response function, multi photon data is restricted to leading edge detection imposing stringent requirements on the definition of the leading edge with respect to the center of mass of the satellite.

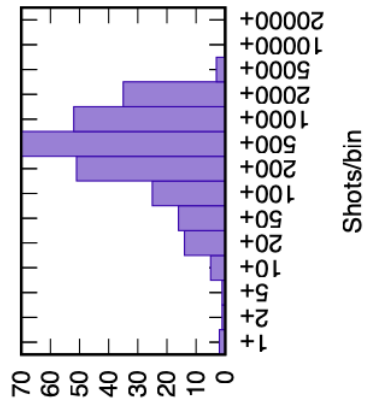
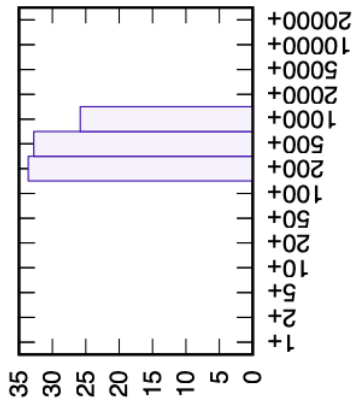
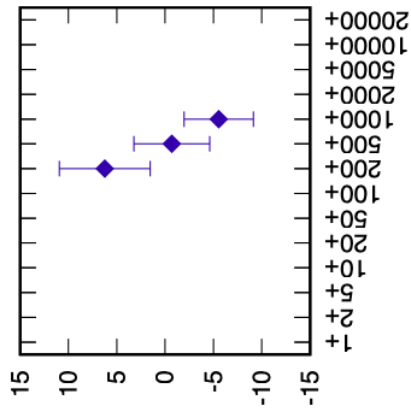
2. The periodically performed time walk measurements are a splendid tool to correct fullrate data in order to retain the remaining satellite signature effect involved in the detection process and pave the way for a spectral analysis of the residuals.

3. For improving intersystem consistency (single - multi photon detection) it may be helpful to derive center of mass corrections from a unified reflectivity function. With detailed information on calibration measurements, spectral characteristics of the residual distribution can be retrieved for multi photon systems.

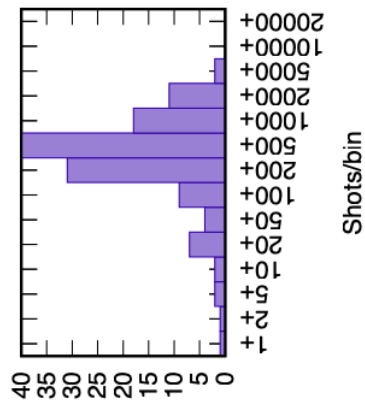
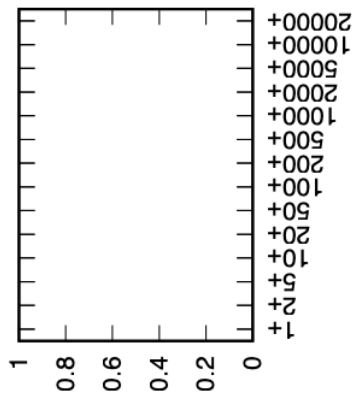
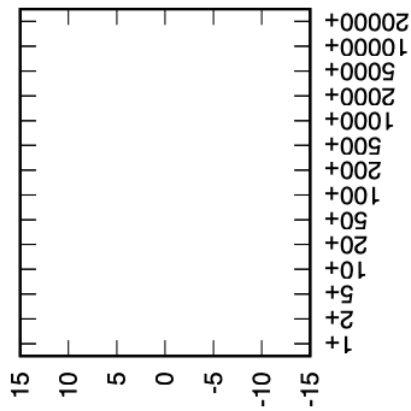
Komsomolsk 1868 LAG1+LAG2
(CoM 248 mm) RB 36.0 mm +



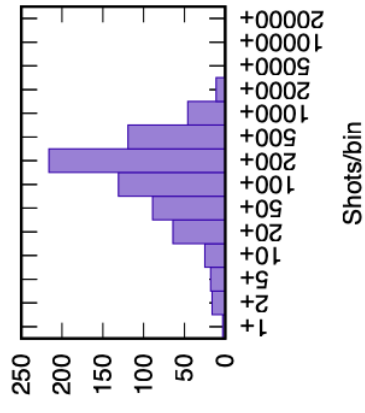
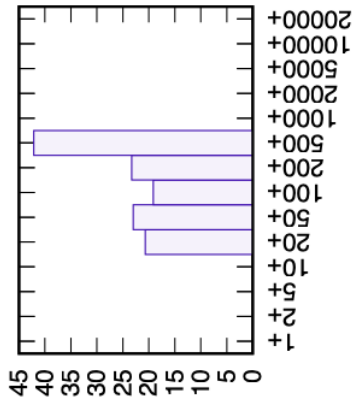
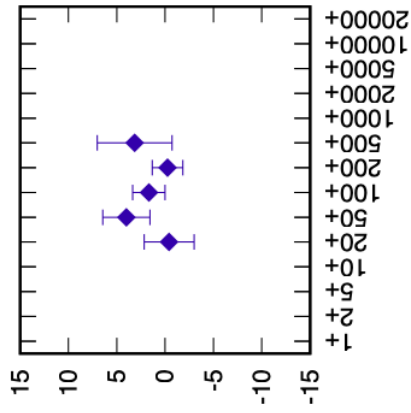
Komsomolsk 1868 AJI
CoM (CoM 1013 mm) RB 33.6 mm +

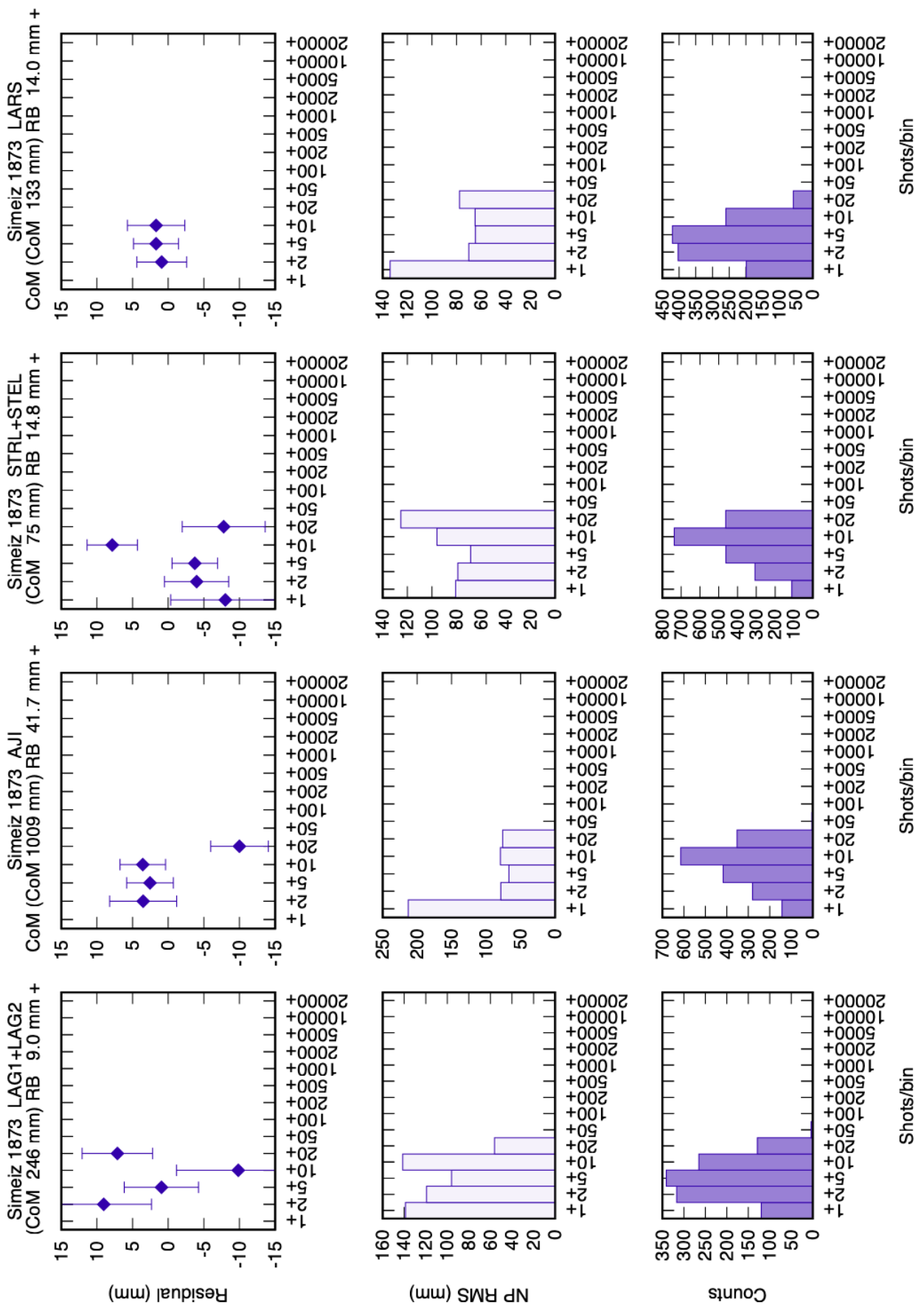


Komsomolsk 1868 STRL+STEL
(CoM 75 mm) RB 0.6 mm +

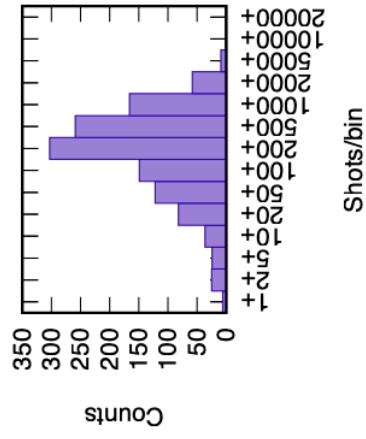
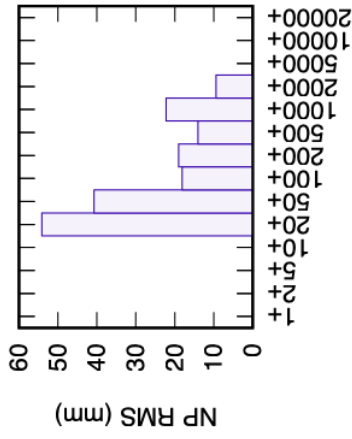
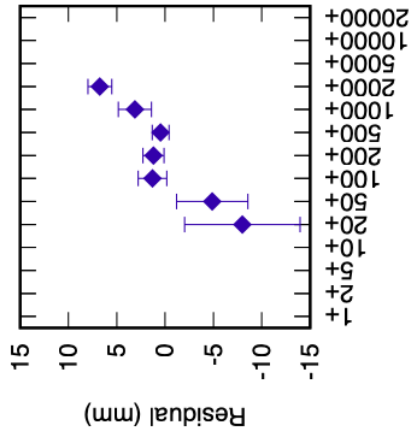


Komsomolsk 1868 LARS
CoM (CoM 133 mm) RB 14.8 mm +

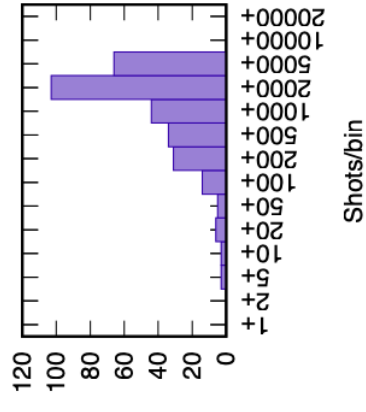
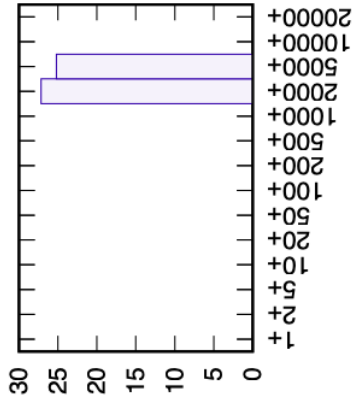
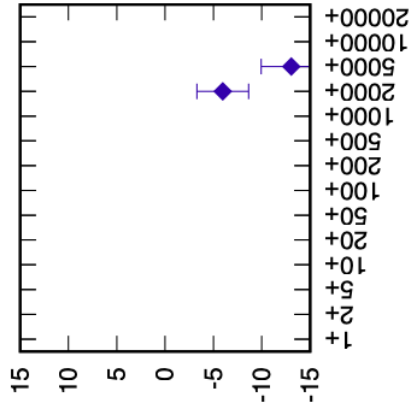




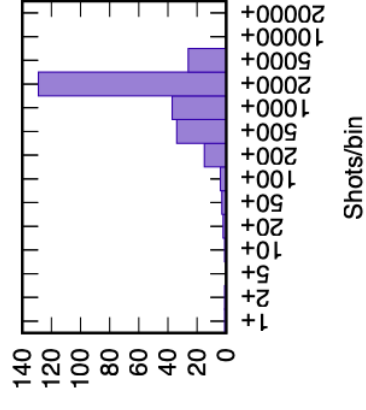
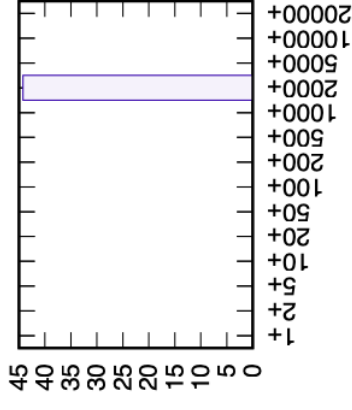
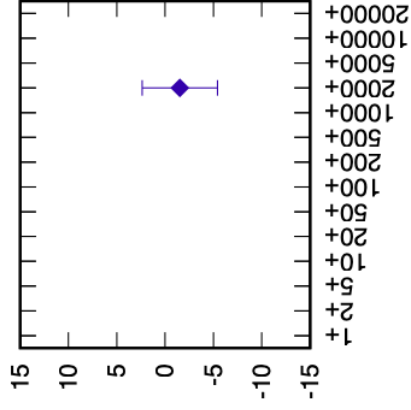
Altay 1879 LAG1+LAG2
(CoM 251 mm) RB 32.8 mm +



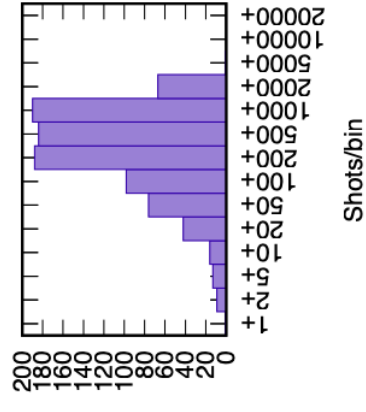
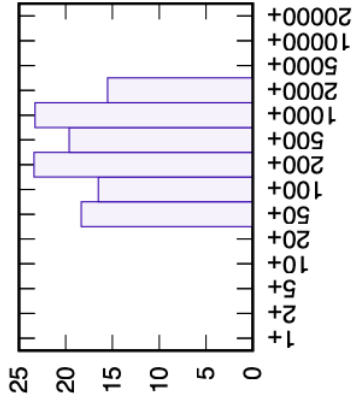
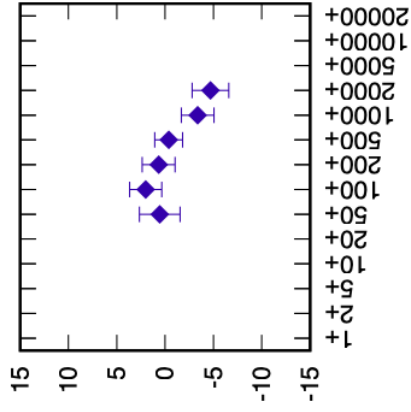
Altay 1879 AJI
CoM (CoM 1013 mm) RB 39.3 mm +

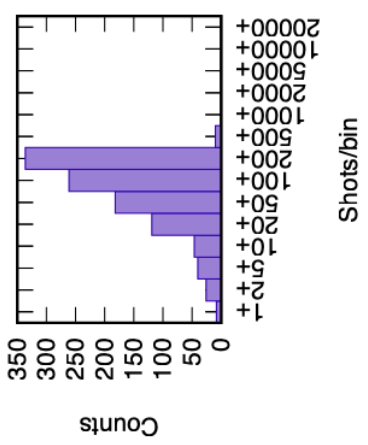
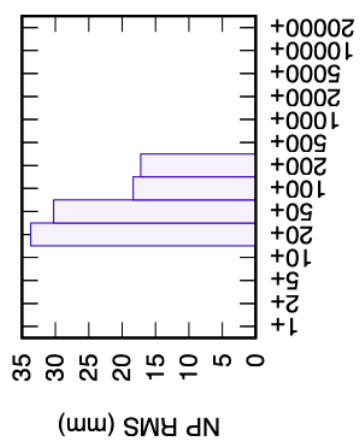
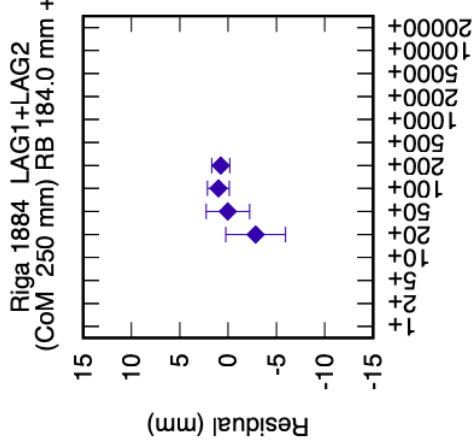
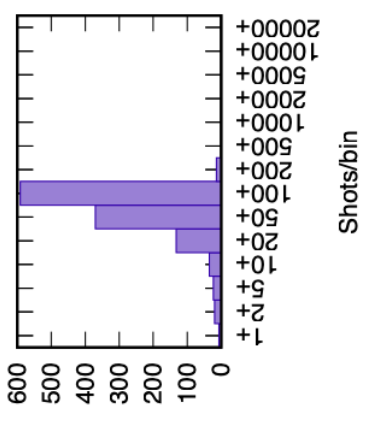
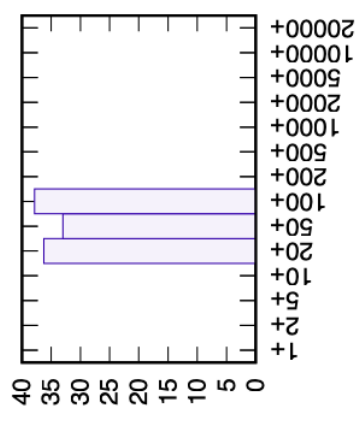
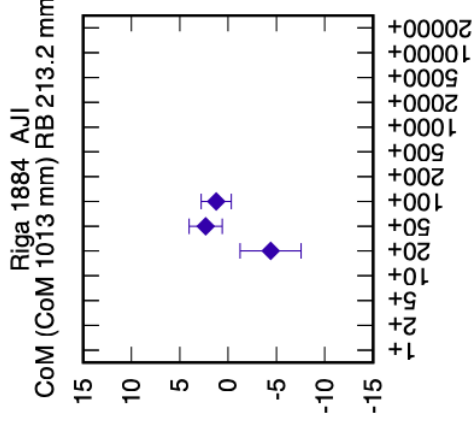
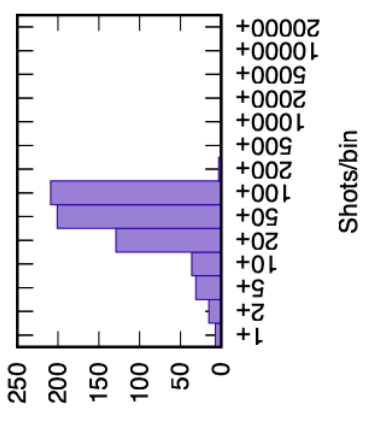
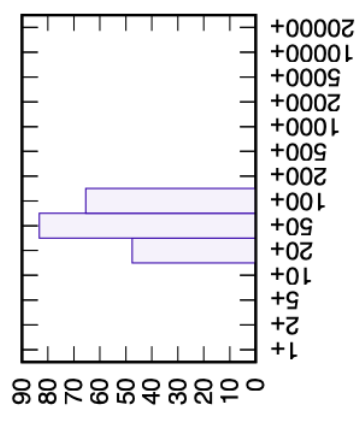
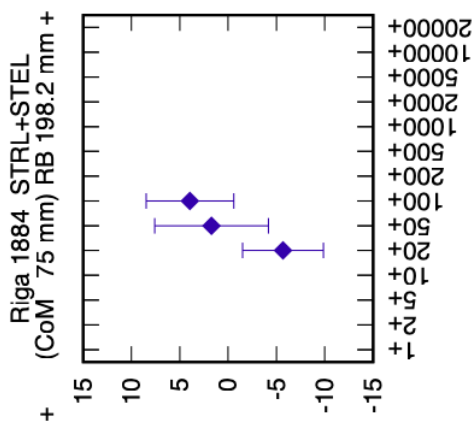
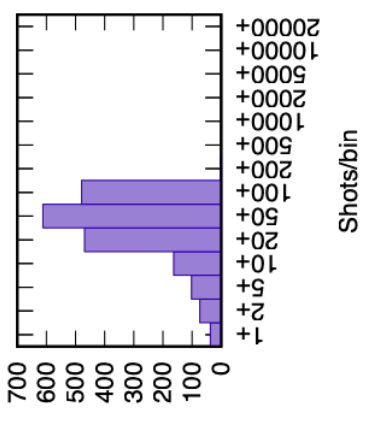
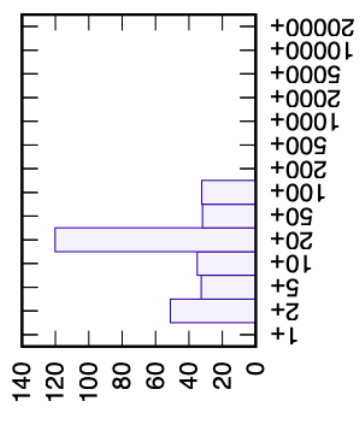
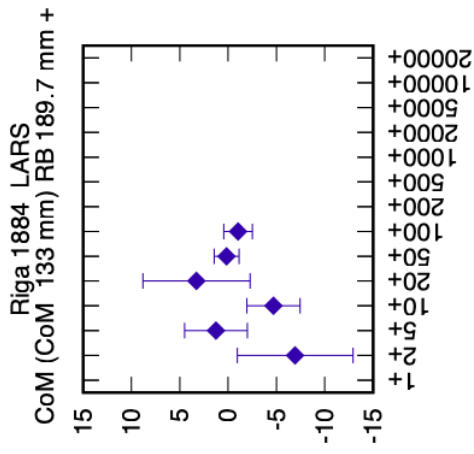


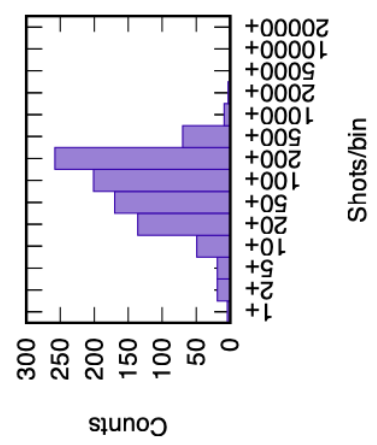
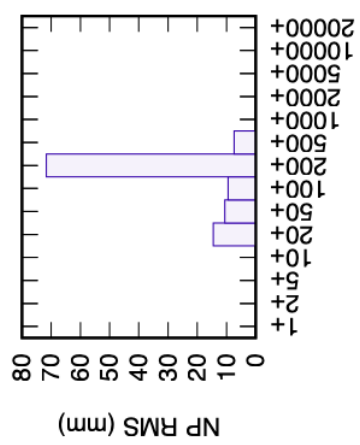
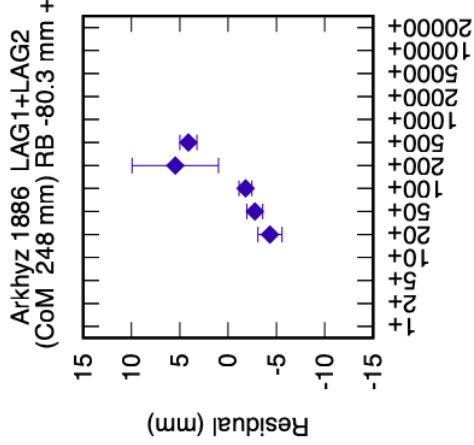
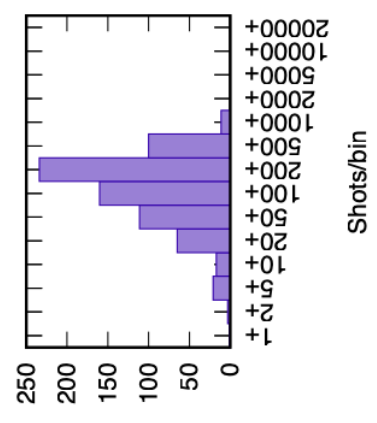
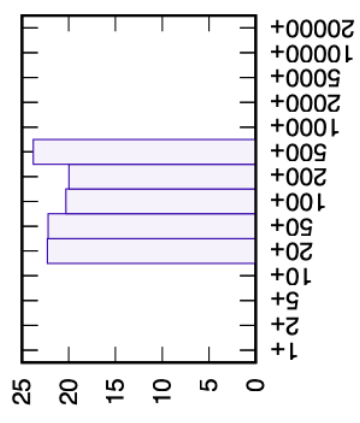
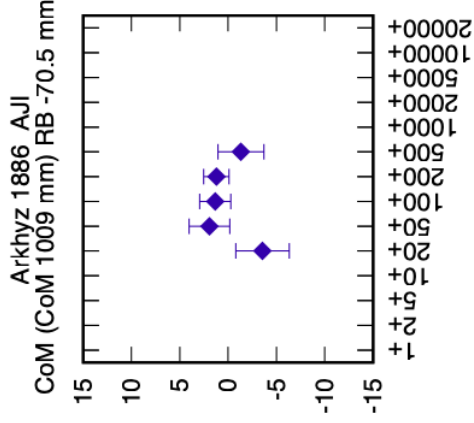
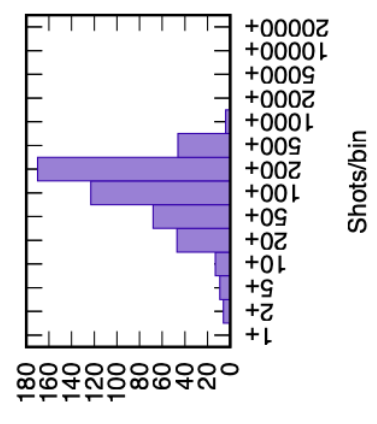
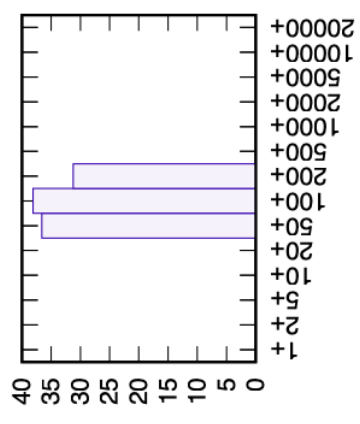
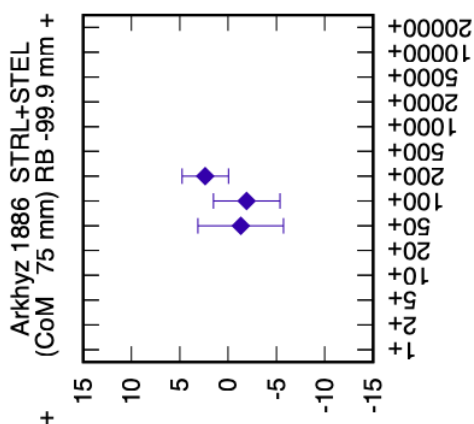
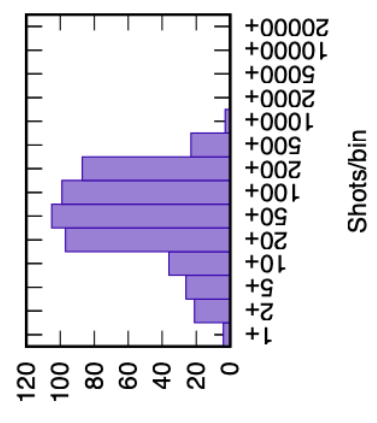
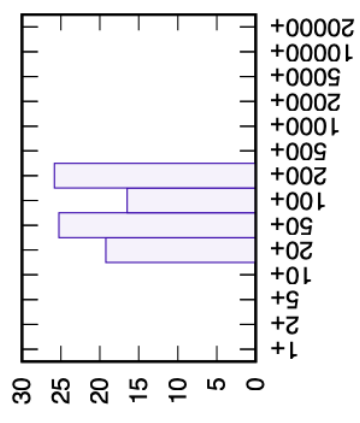
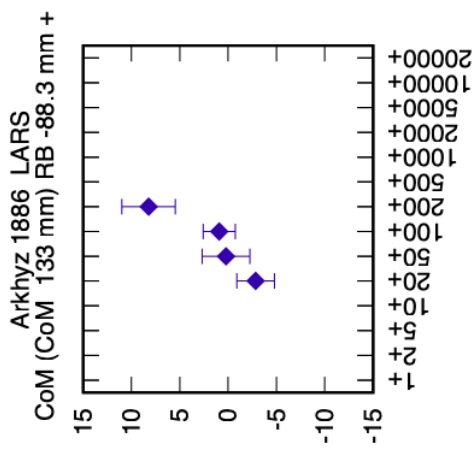
Altay 1879 STRL+STEL
(CoM 75 mm) RB 5.0 mm +

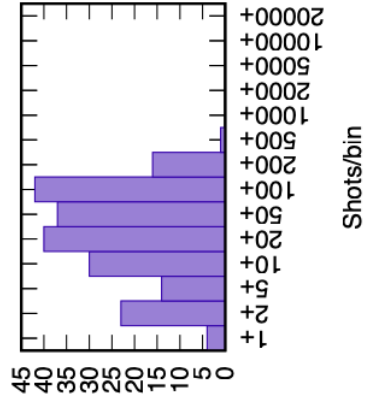
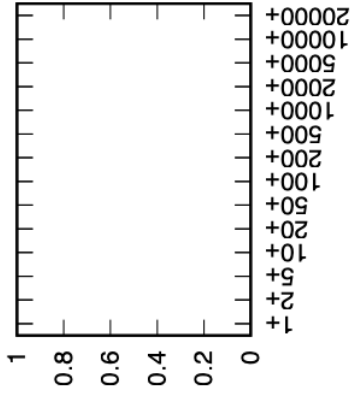
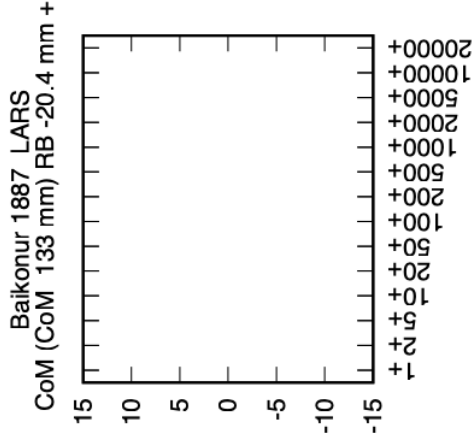
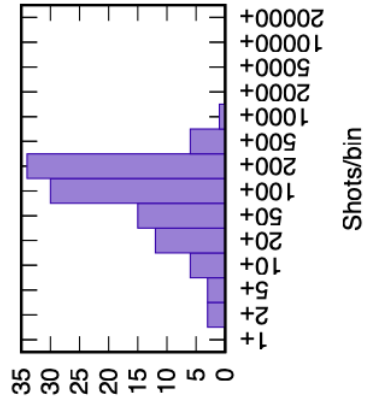
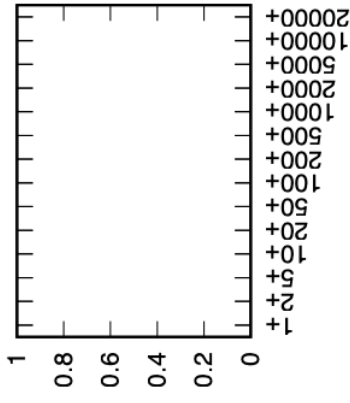
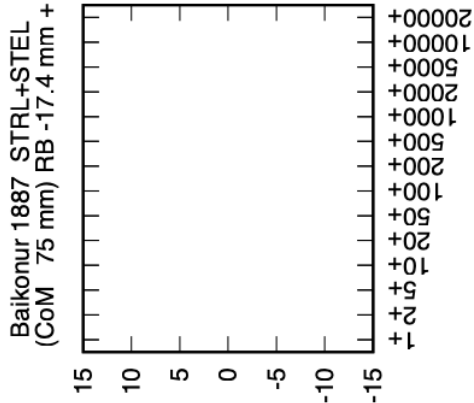
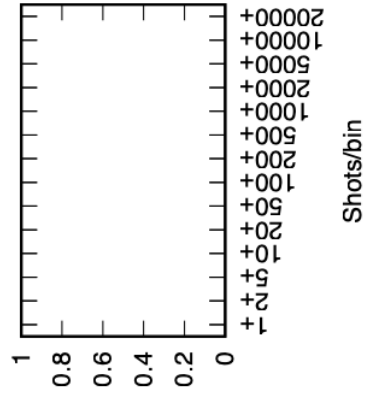
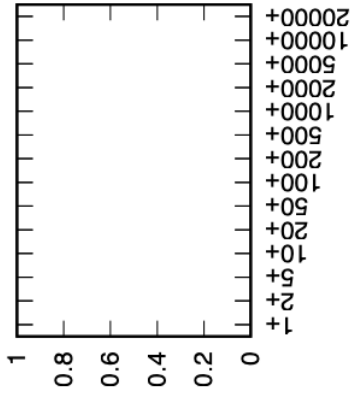
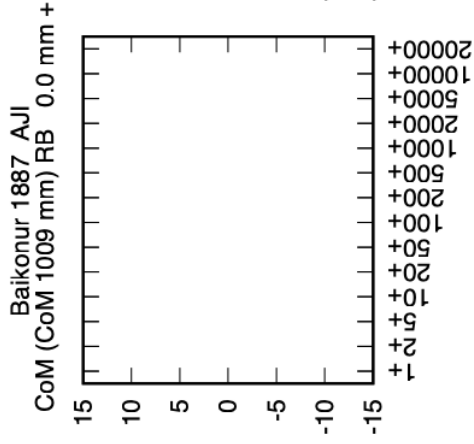
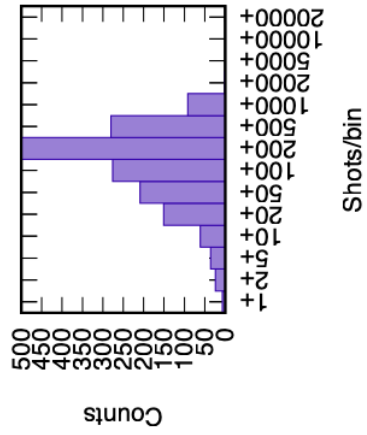
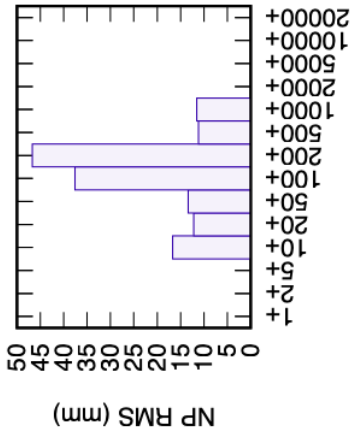
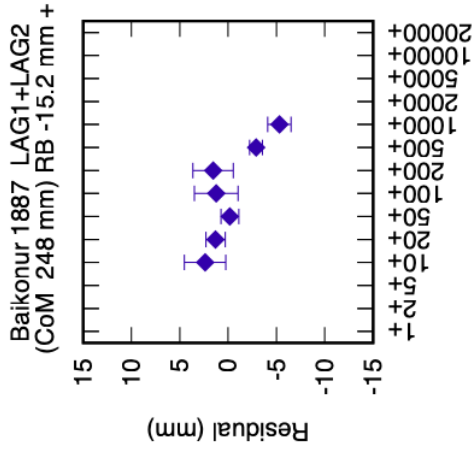


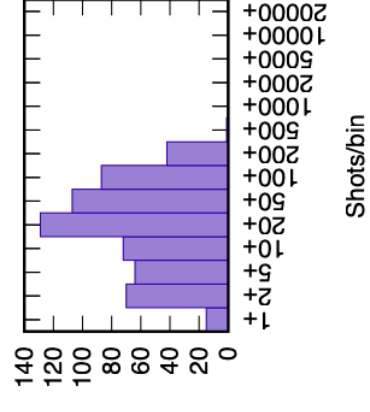
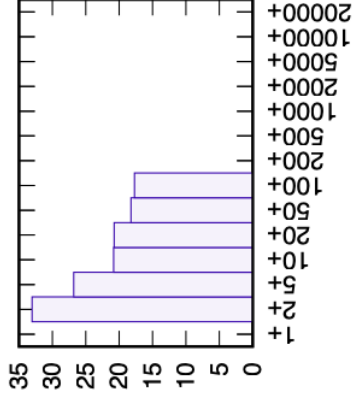
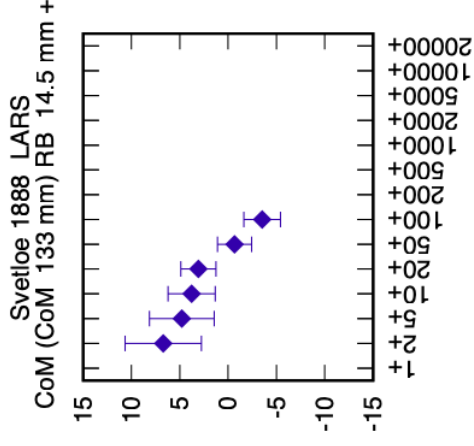
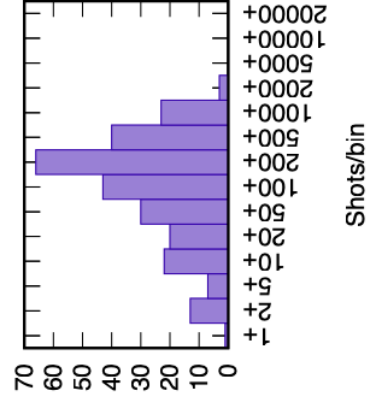
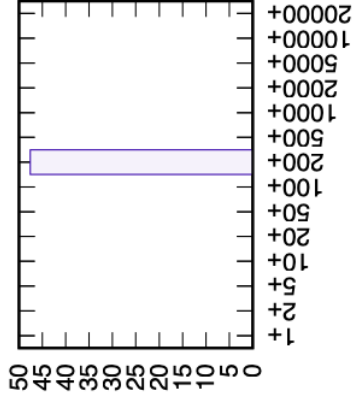
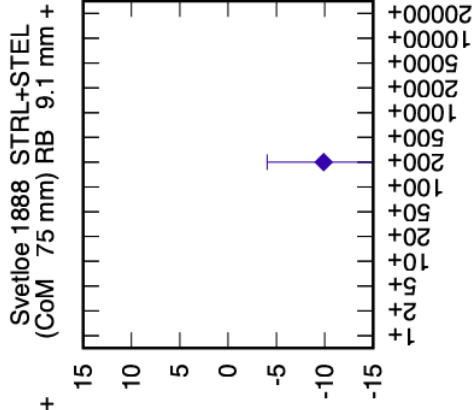
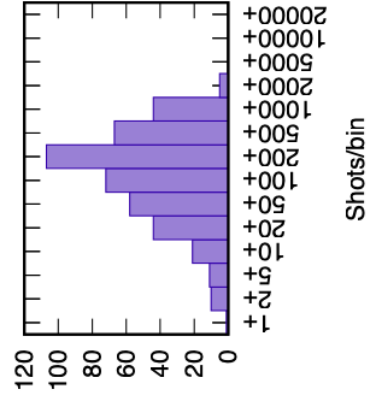
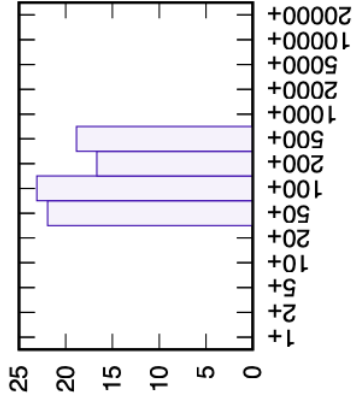
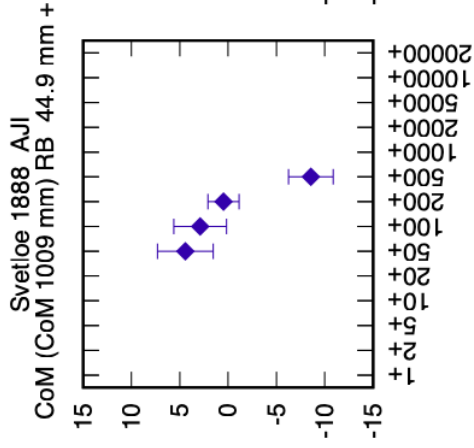
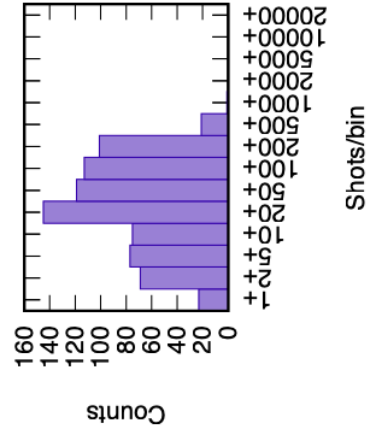
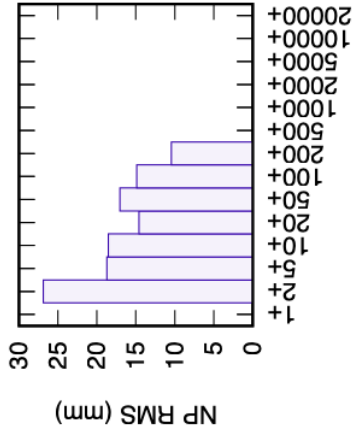
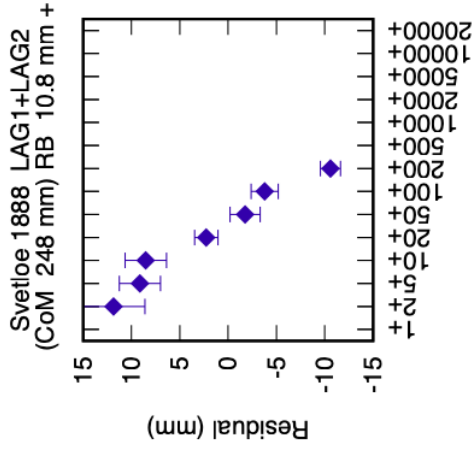
Altay 1879 LARS
CoM (CoM 133 mm) RB 22.6 mm +

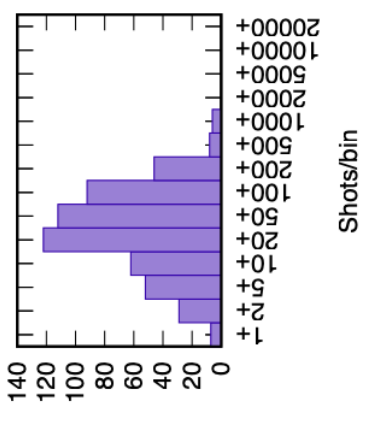
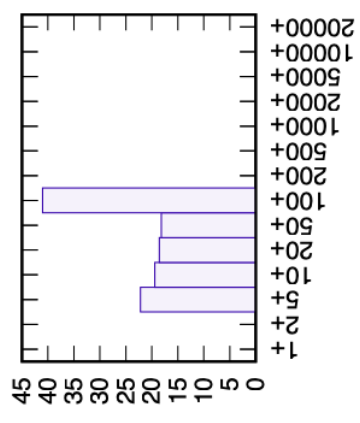
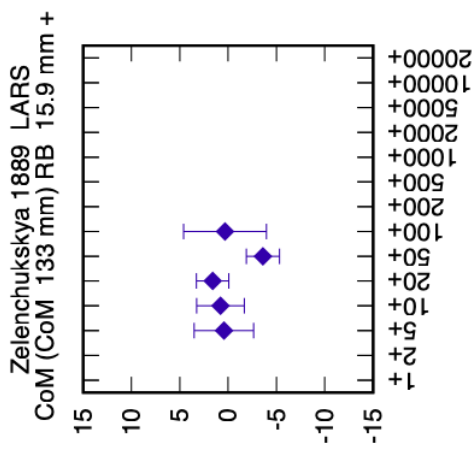
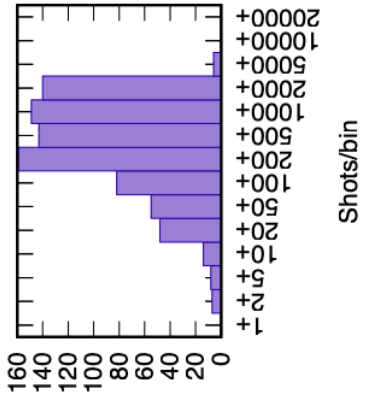
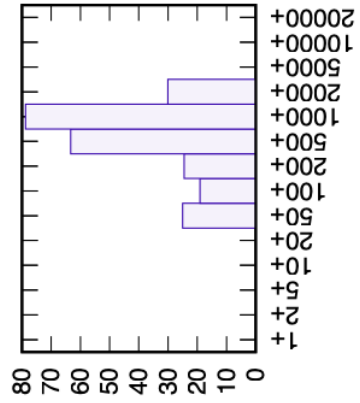
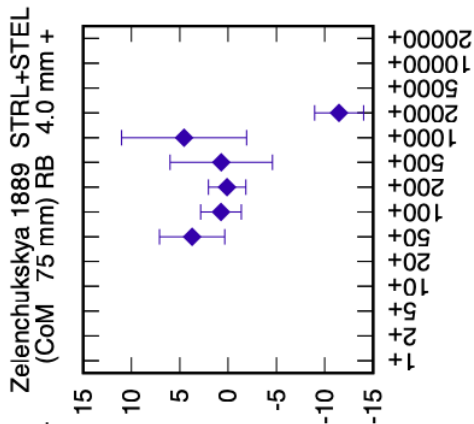
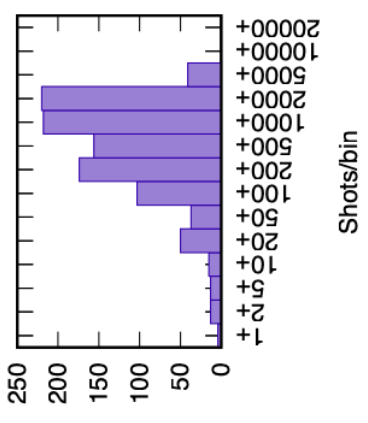
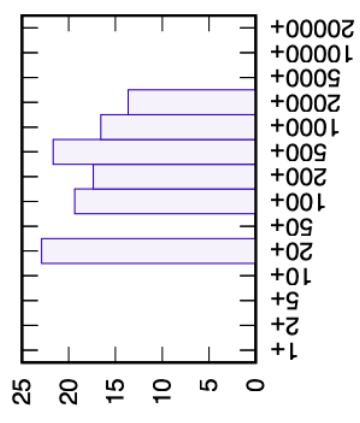
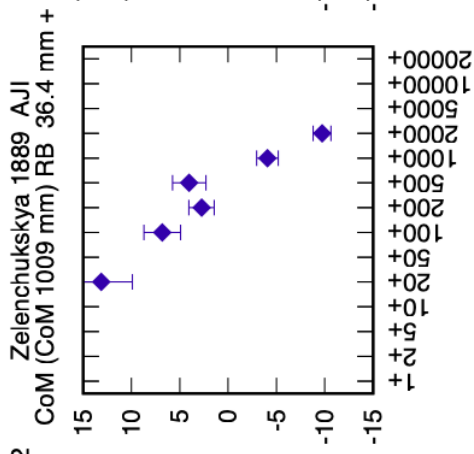
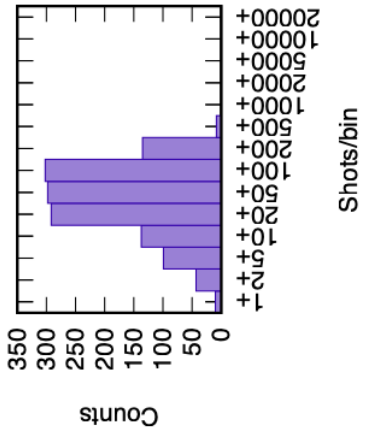
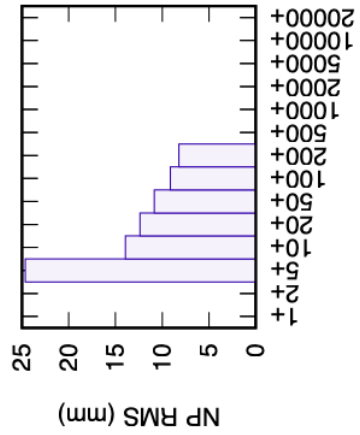
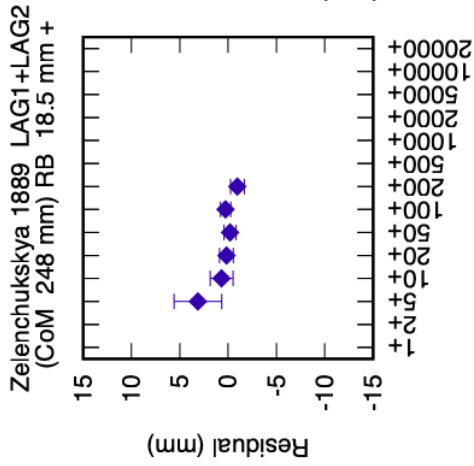










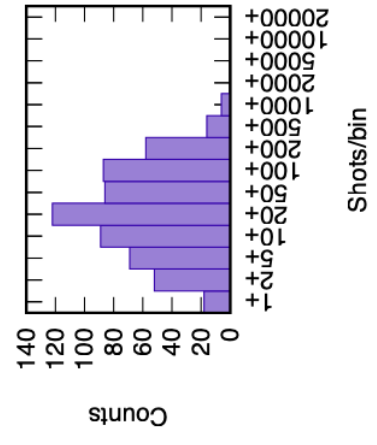
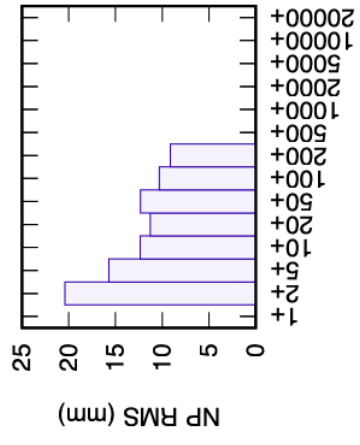
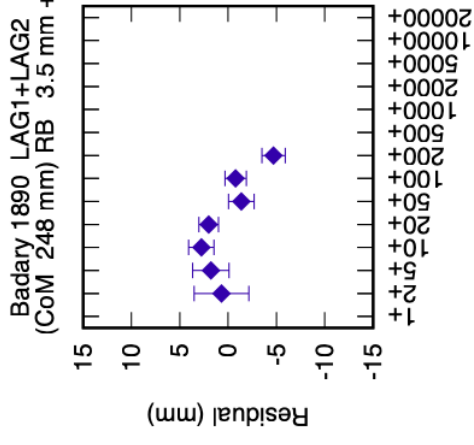
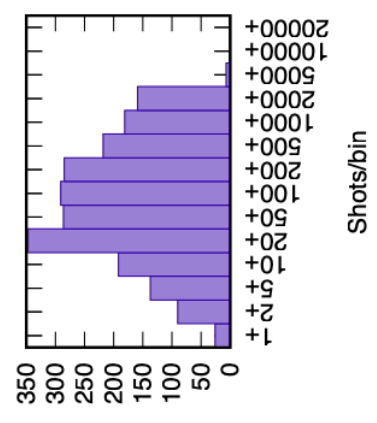
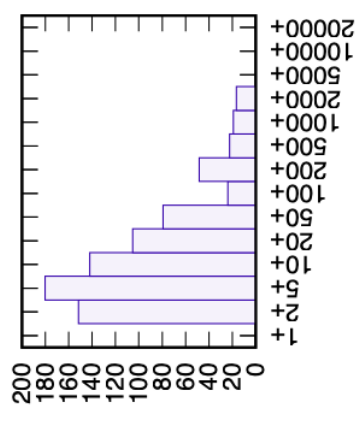
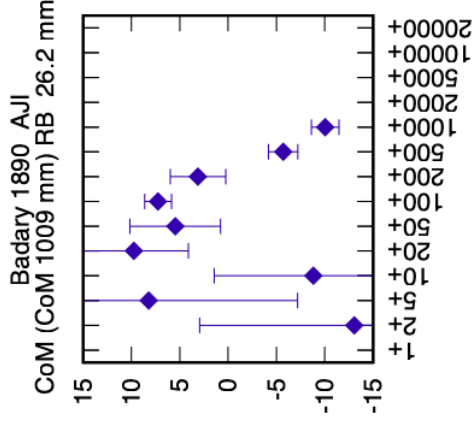
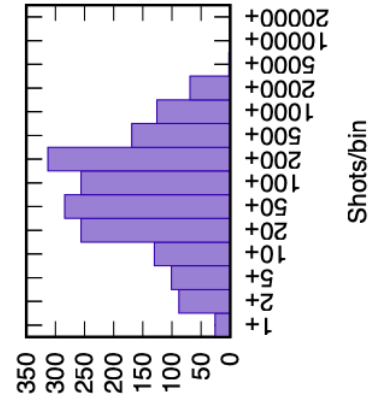
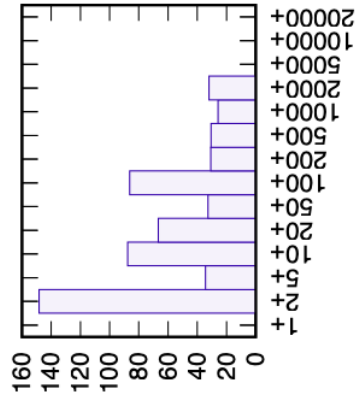
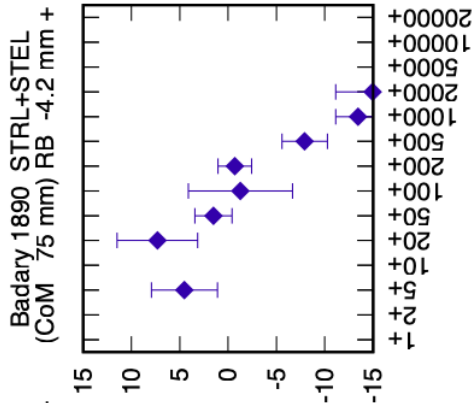
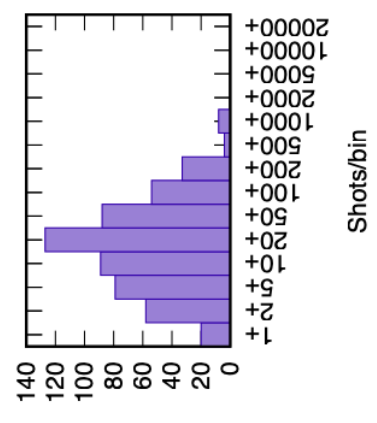
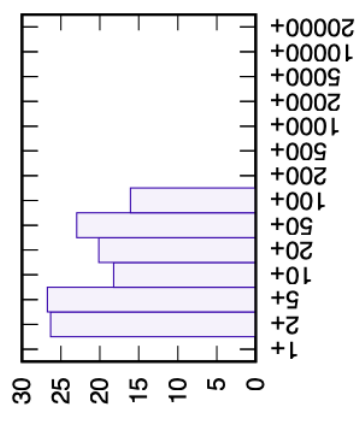
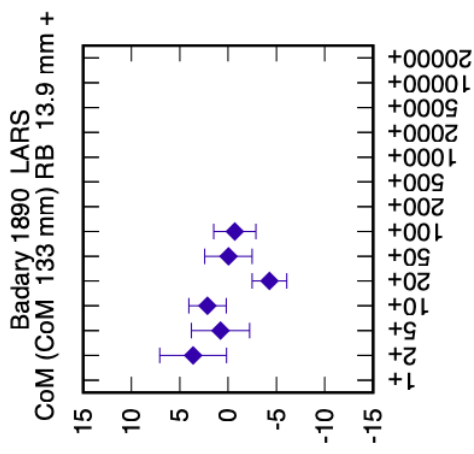


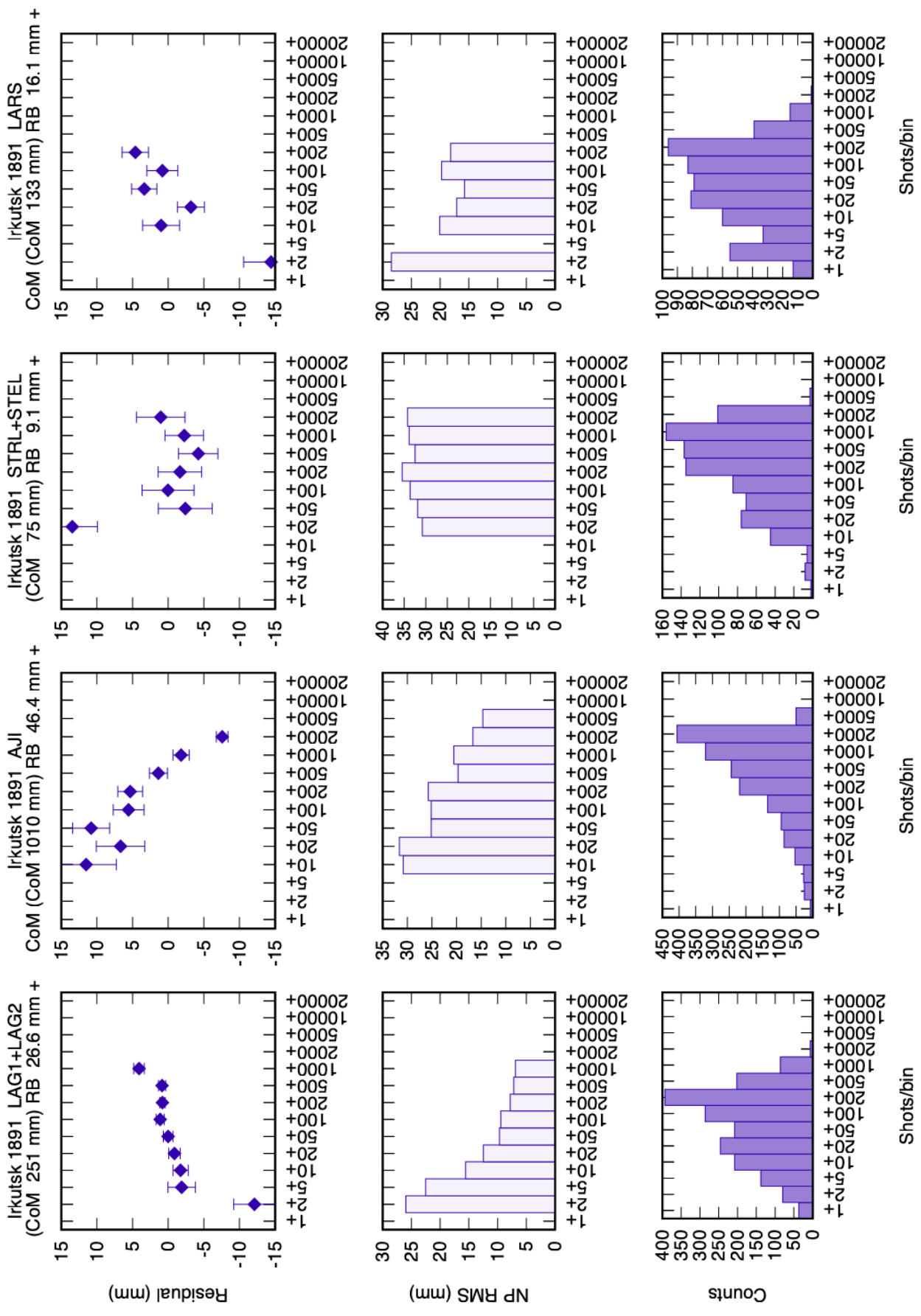
Shots/bin

Shots/bin

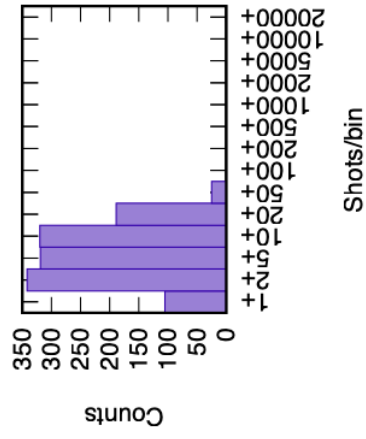
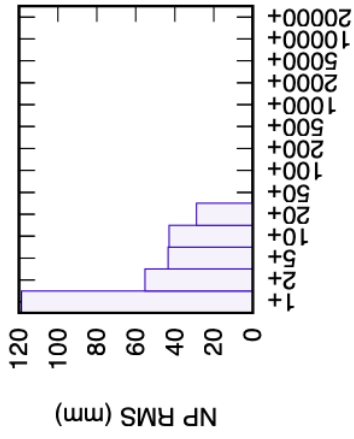
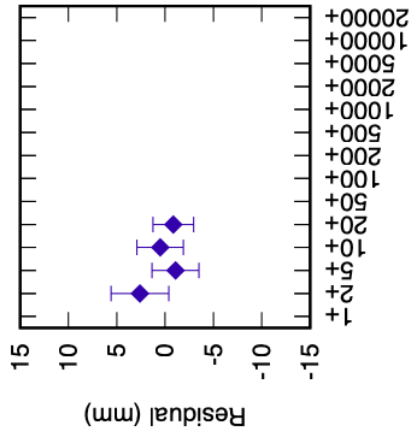
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Shots/bin

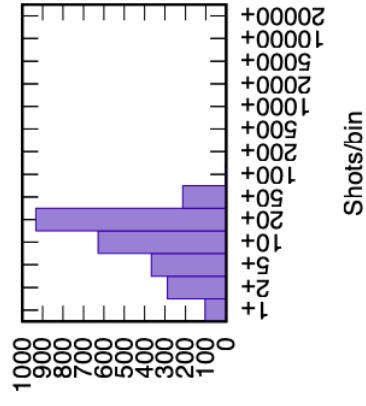
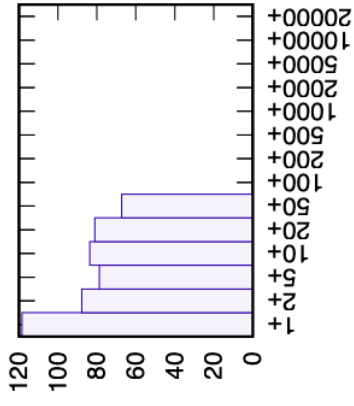
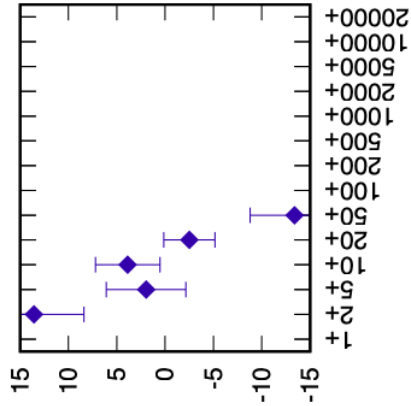




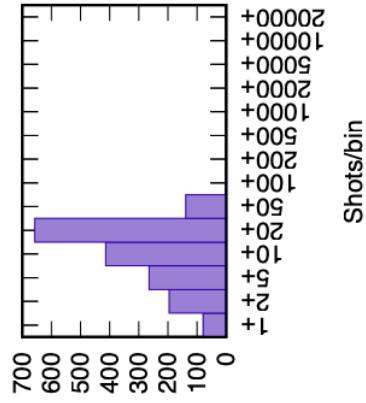
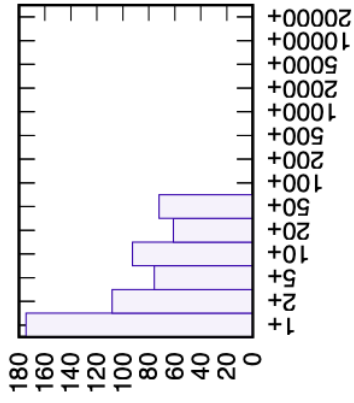
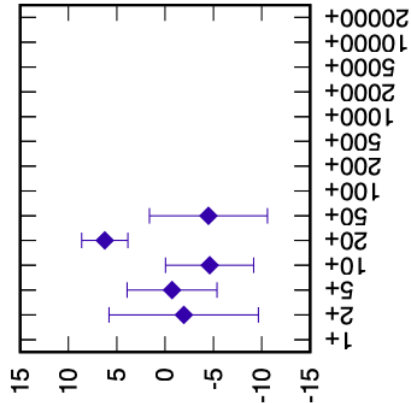
Katzively 1893 LAG1+LAG2
(CoM 246 mm) RB -48.4 mm +



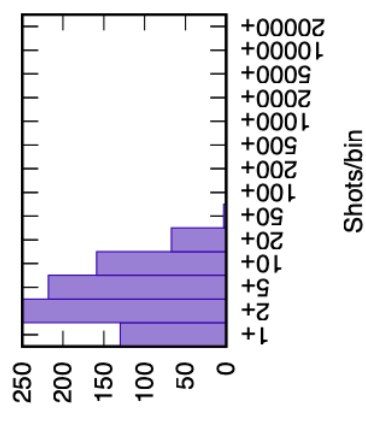
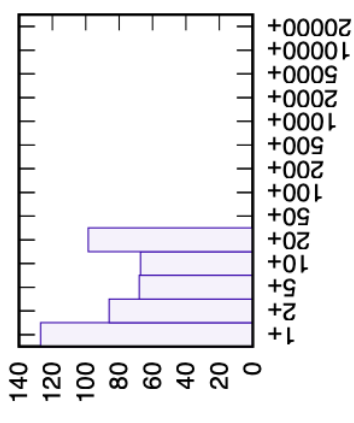
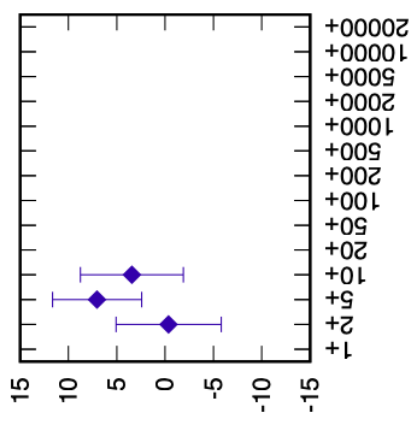
Katzively 1893 AJI
(CoM 1009 mm) RB -51.0 mm +

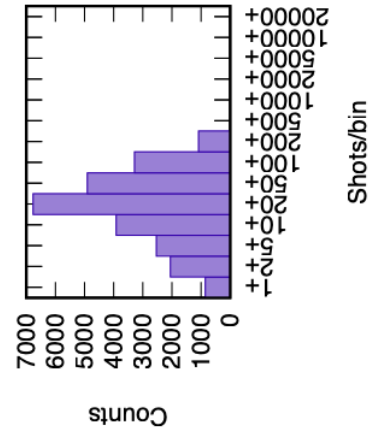
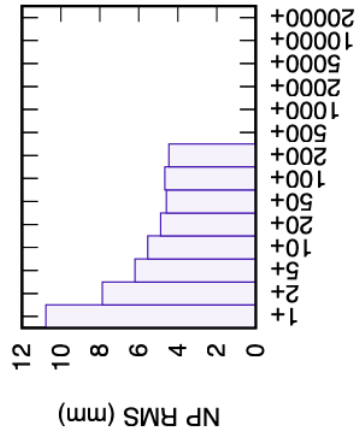
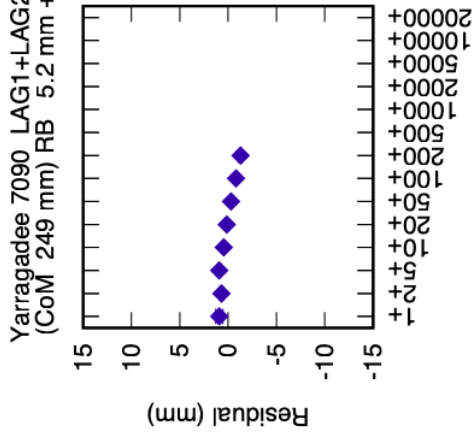
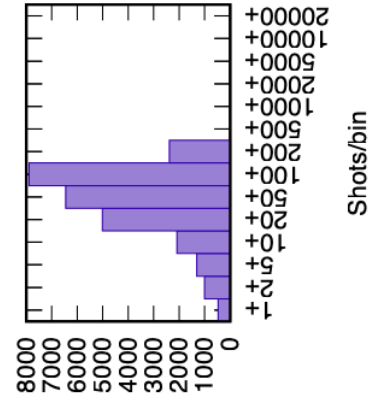
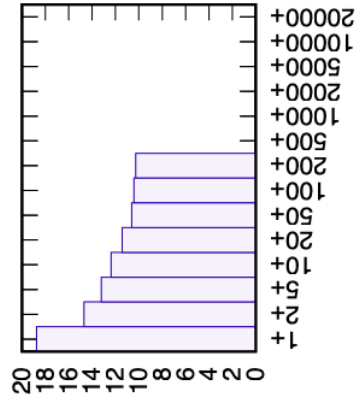
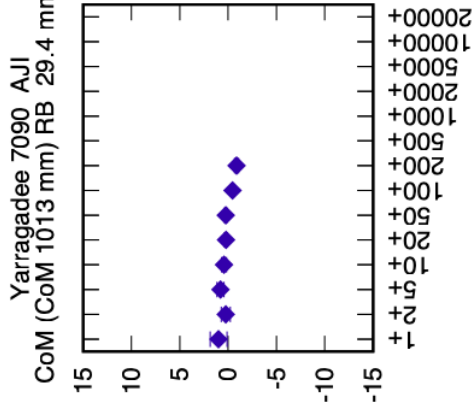
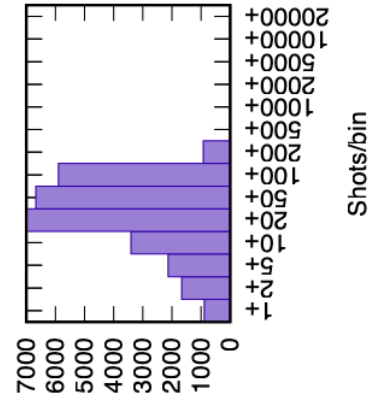
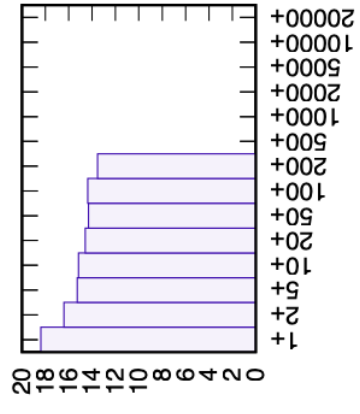
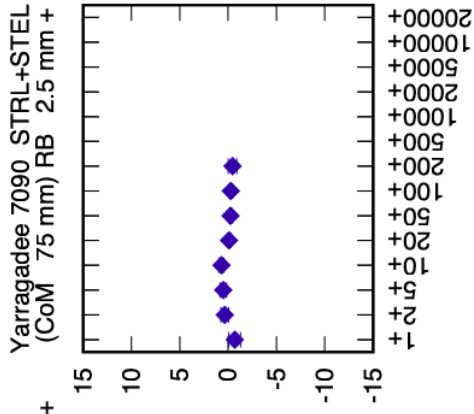
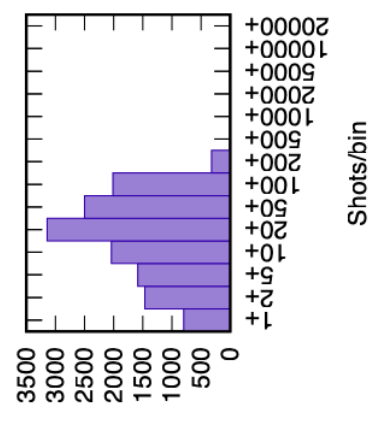
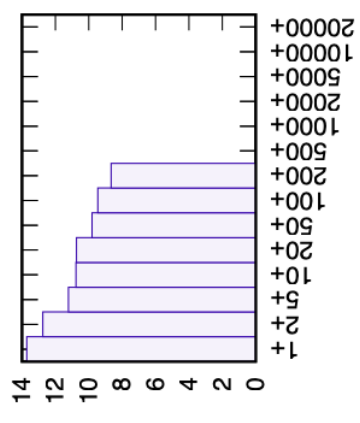
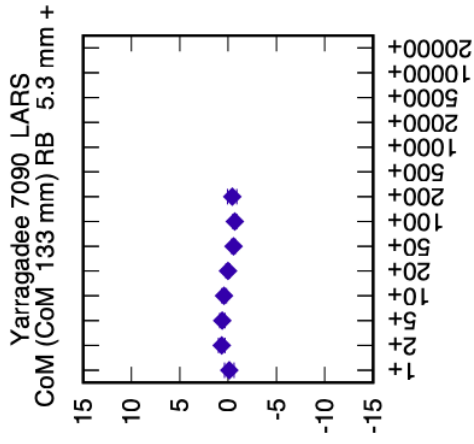


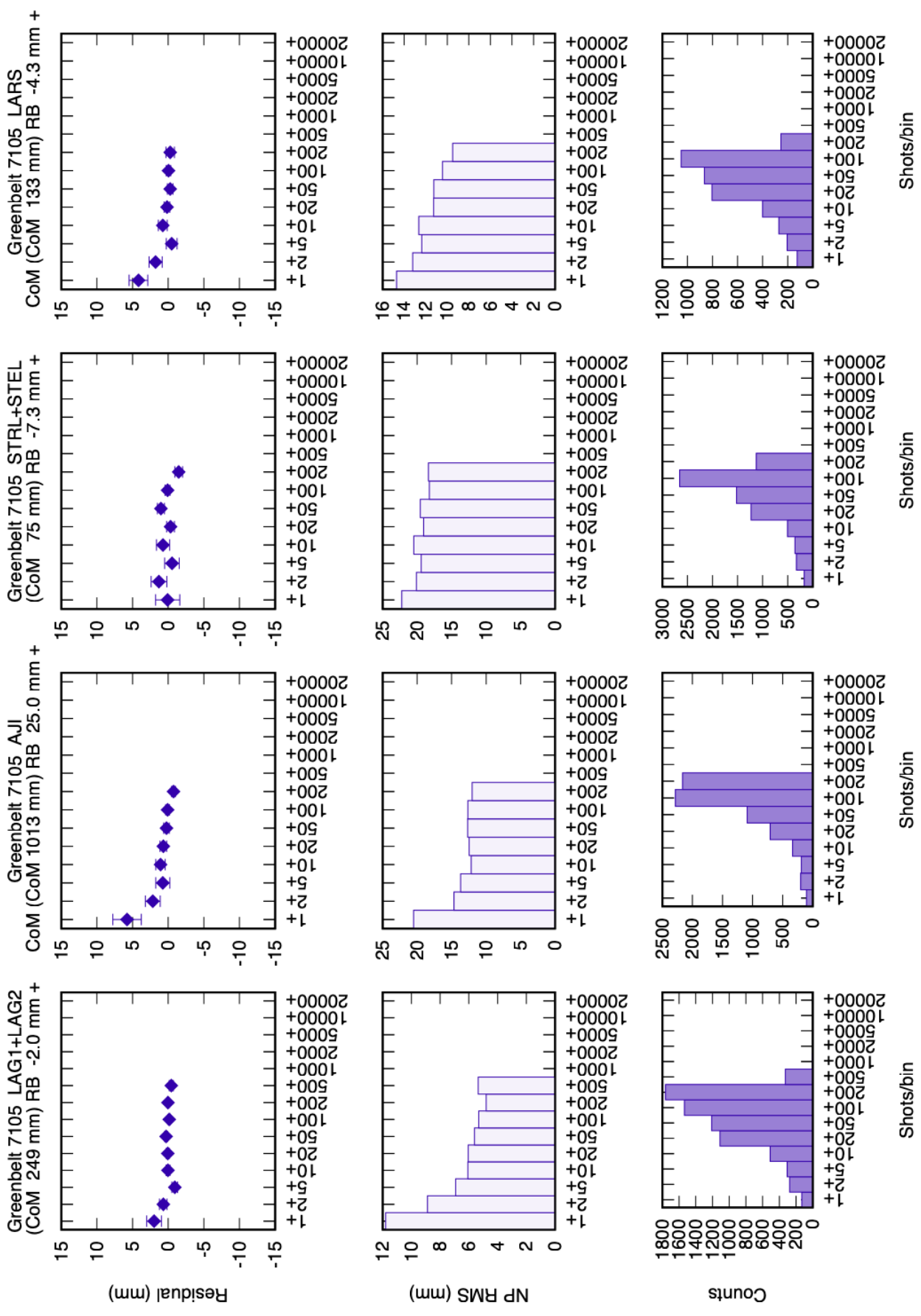
Katzively 1893 STRL+STEL
(CoM 75 mm) RB -86.7 mm +

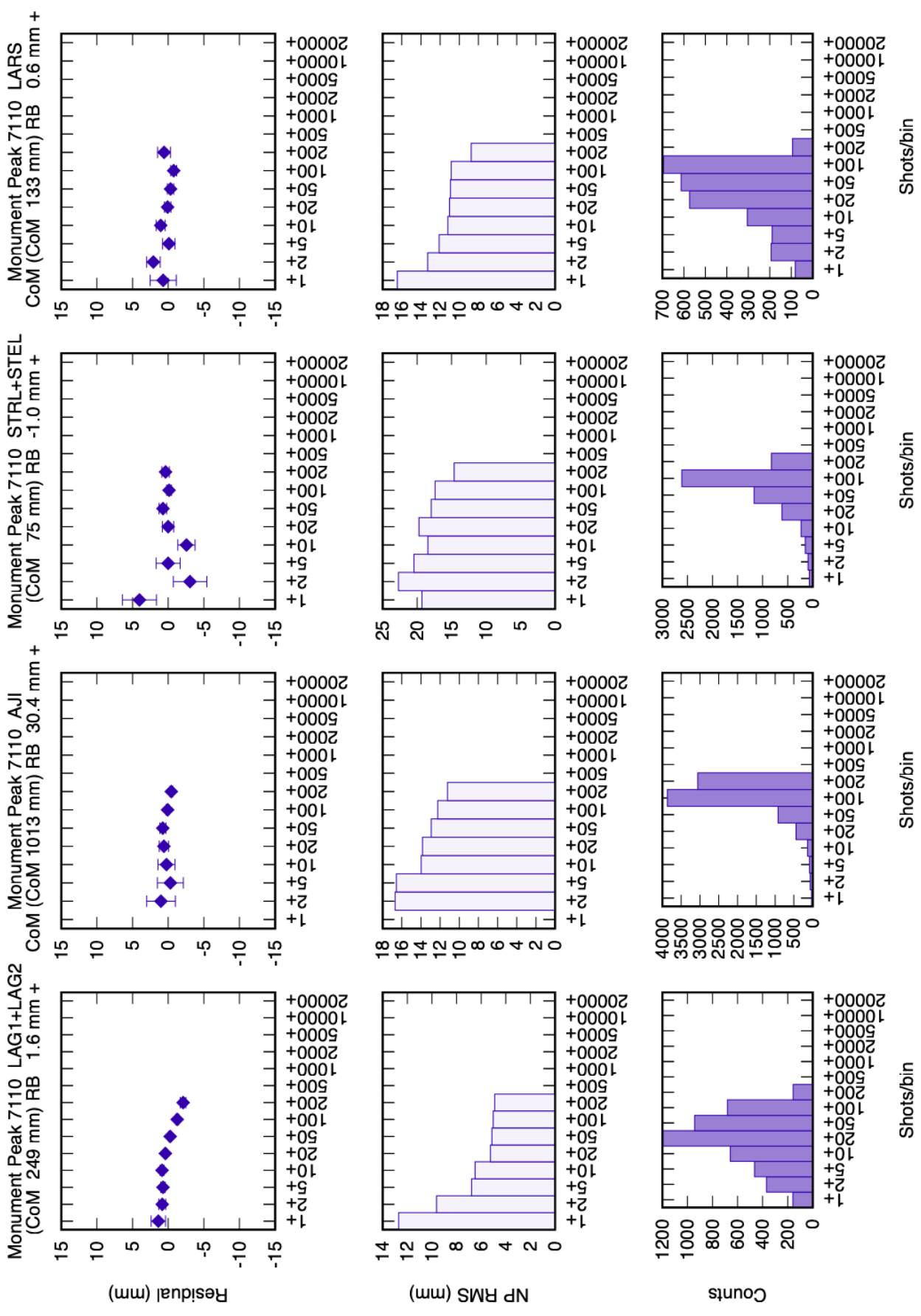


Katzively 1893 LARS
(CoM 133 mm) RB -73.0 mm +

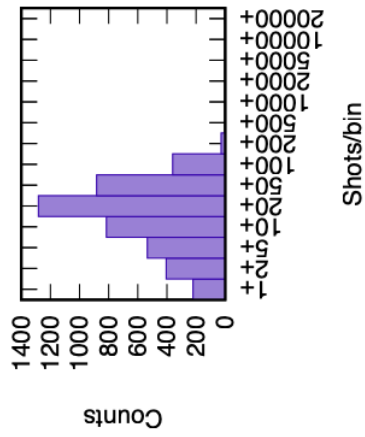
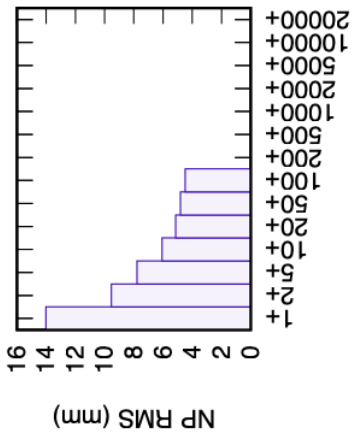
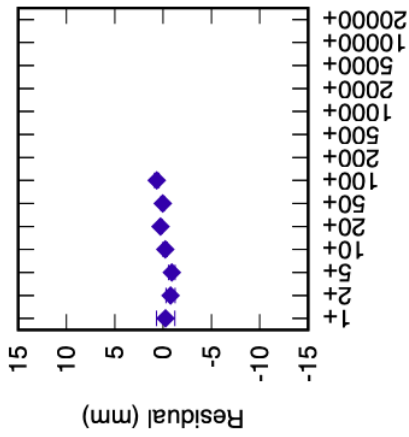




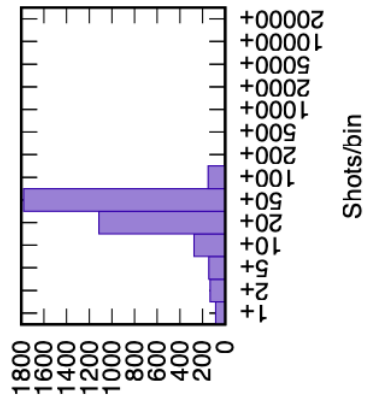
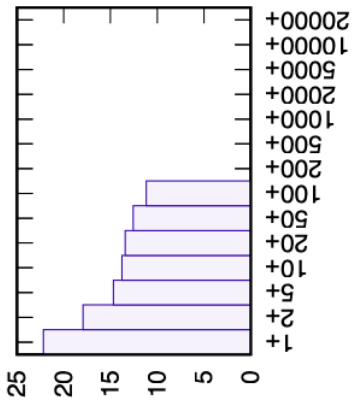
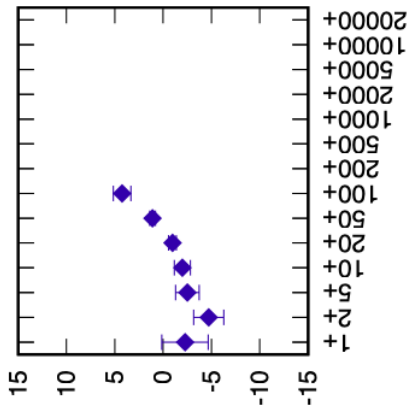




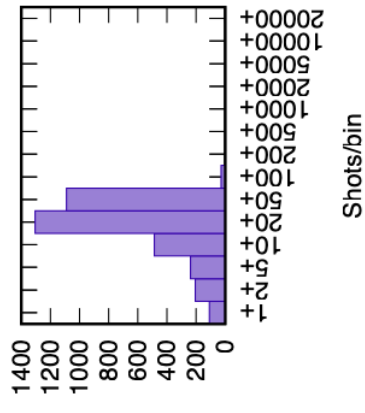
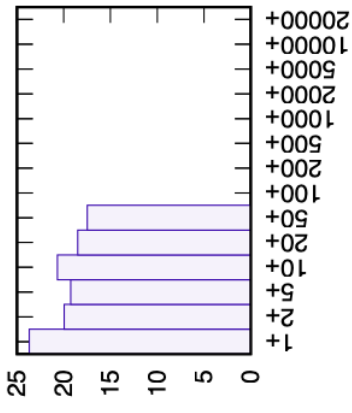
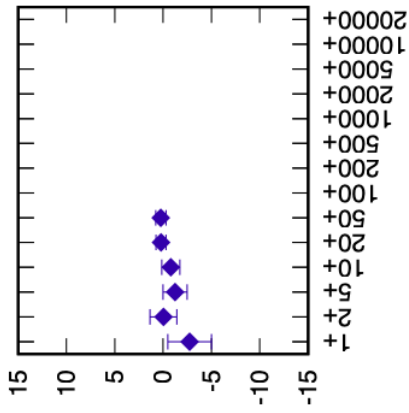
Haleakala 7119 LAG1+LAG2
(CoM 249 mm) RB 14.8 mm +



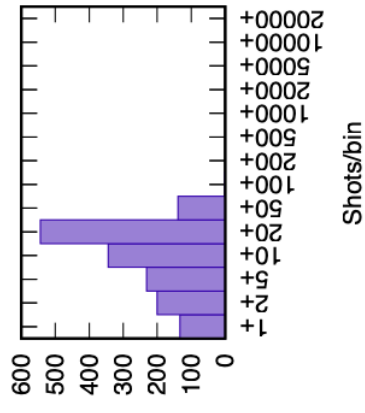
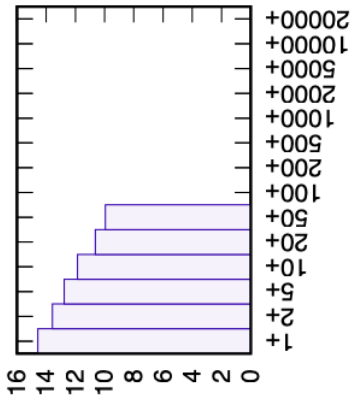
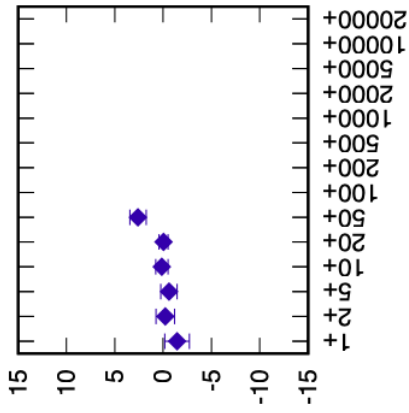
Haleakala 7119 AJI
(CoM 1013 mm) RB 41.5 mm +



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



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

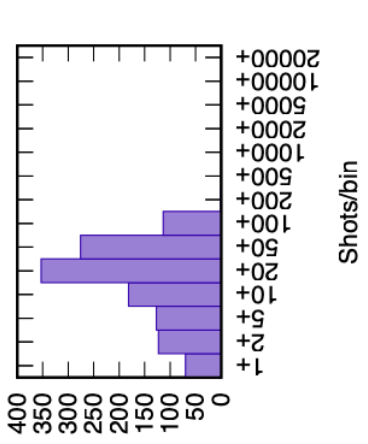
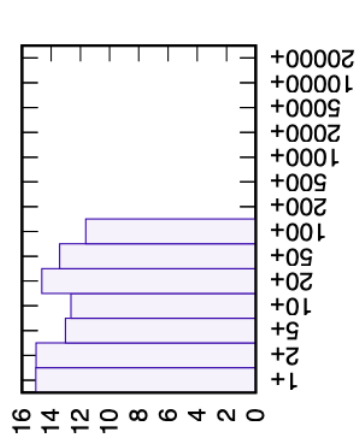
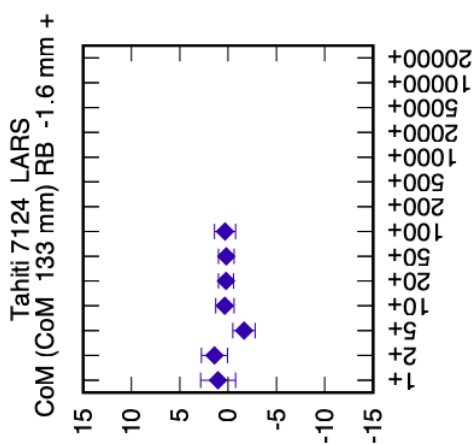
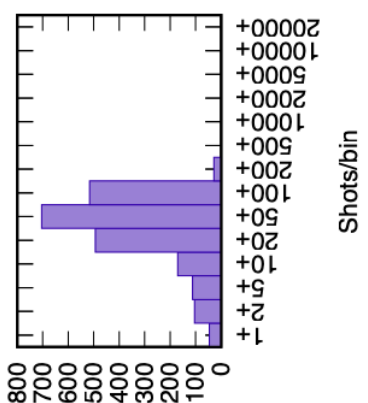
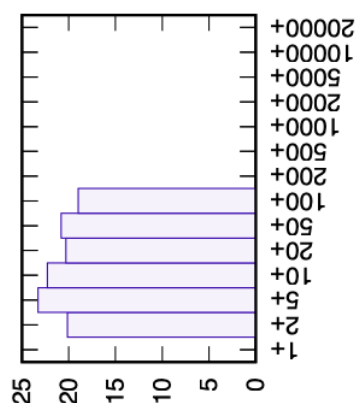
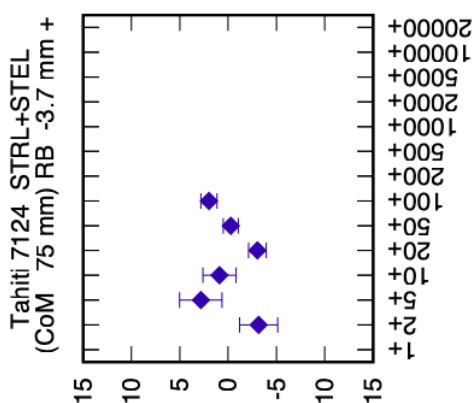
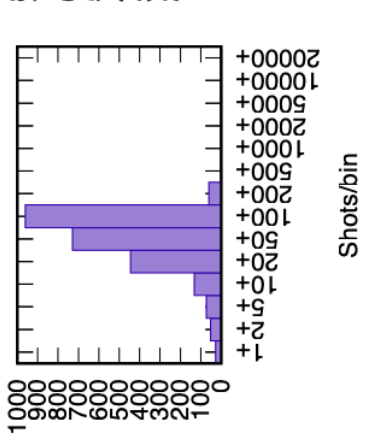
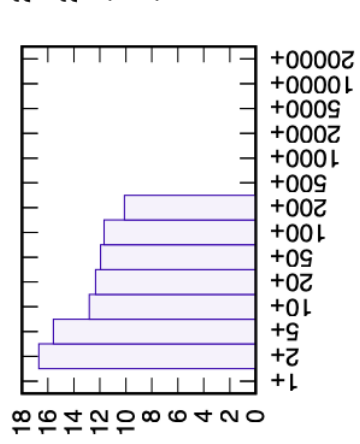
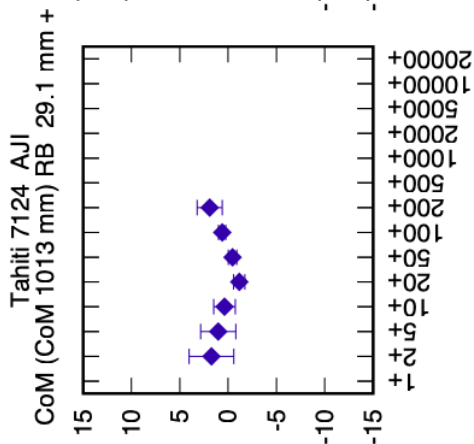
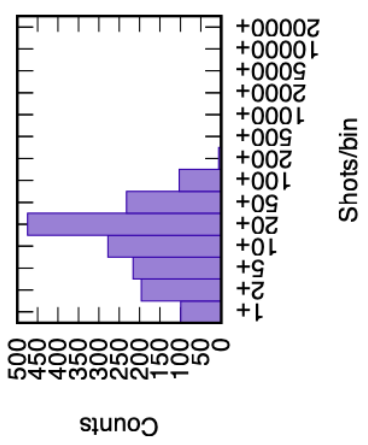
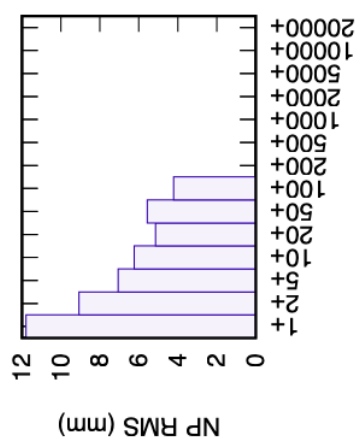
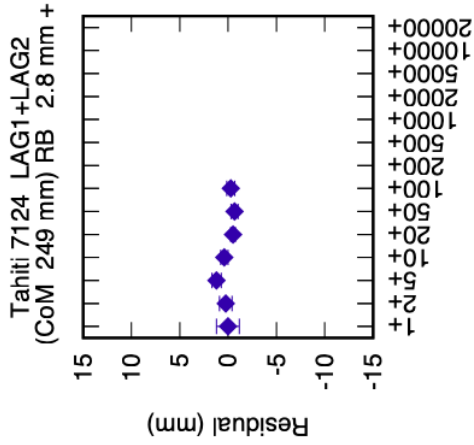


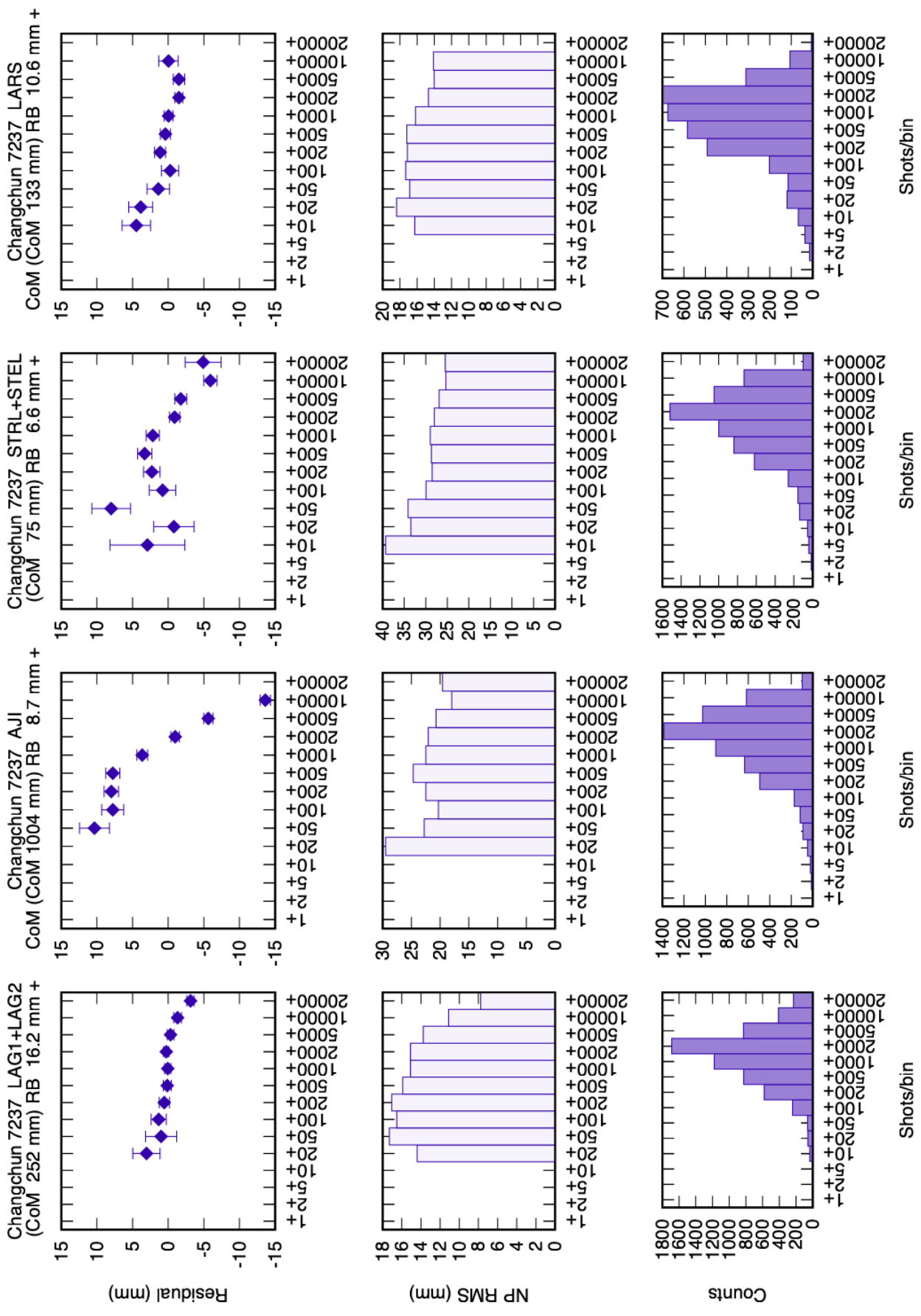
Shots/bin

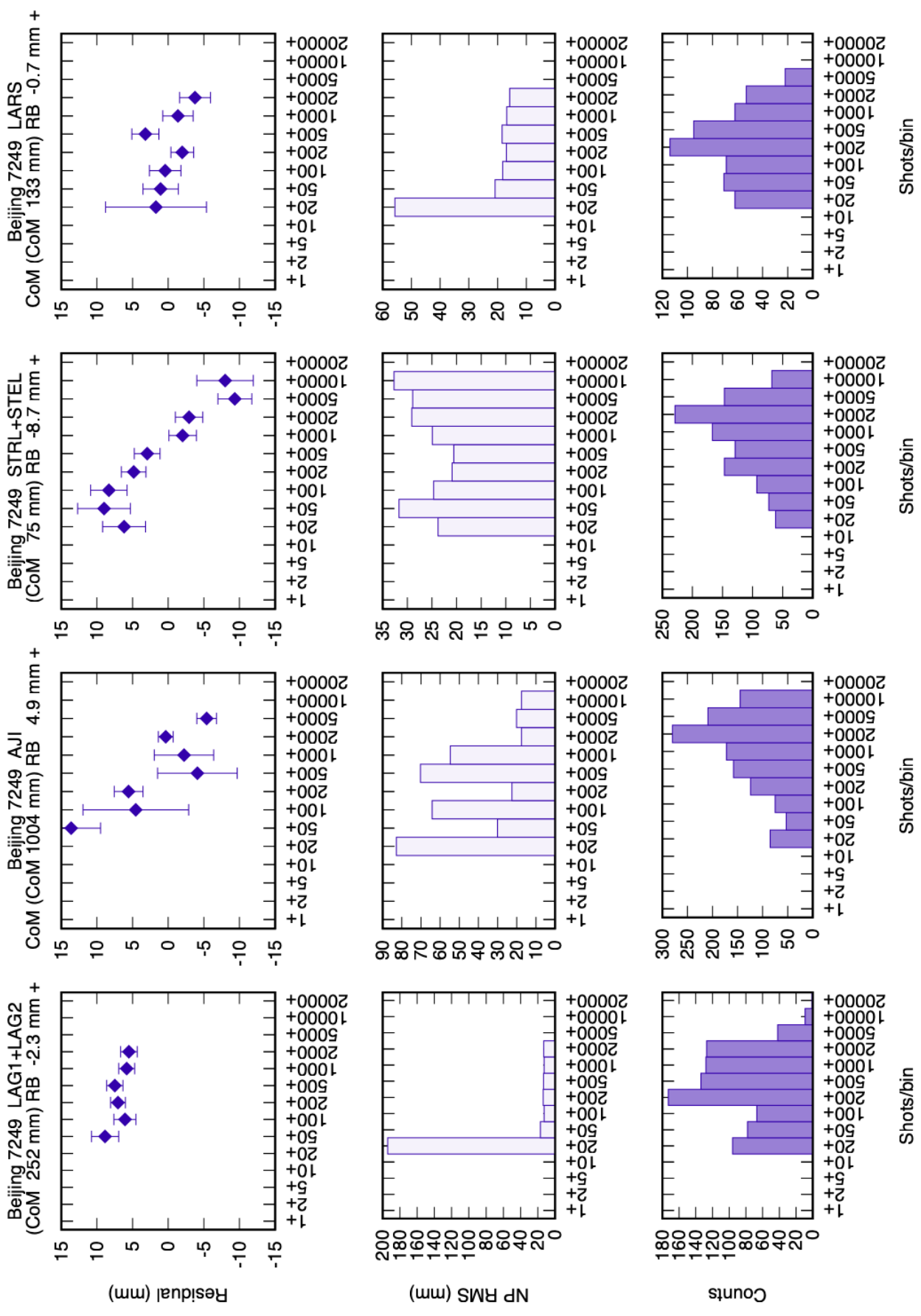
Shots/bin

Shots/bin

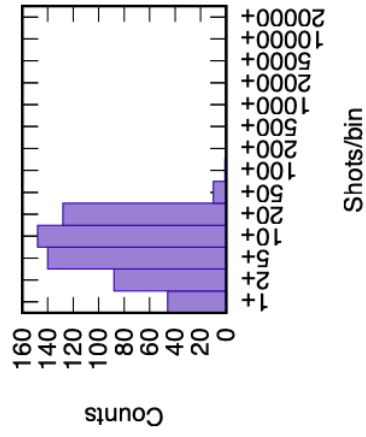
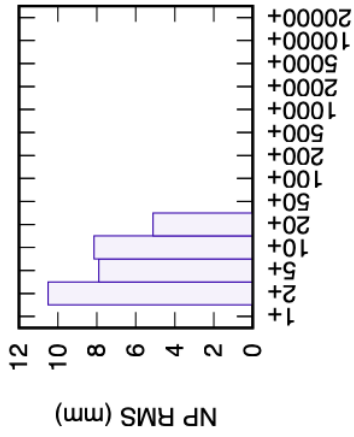
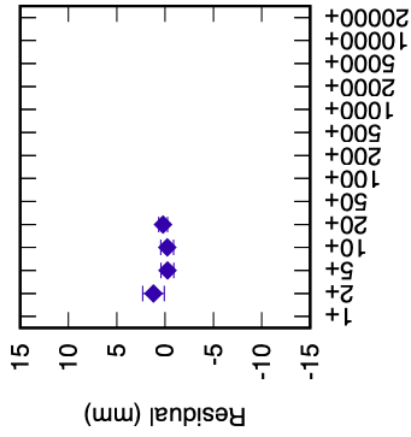
Shots/bin



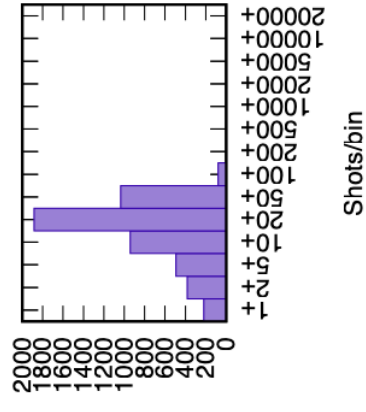
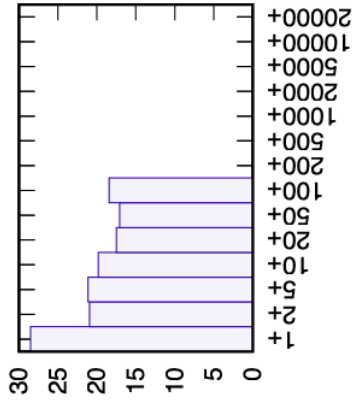
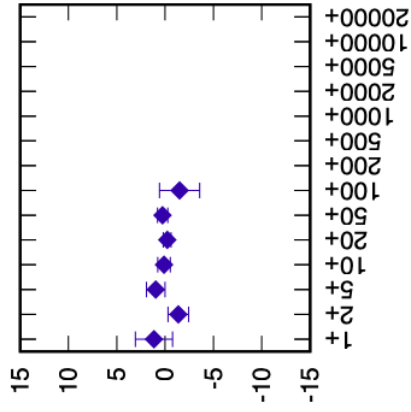




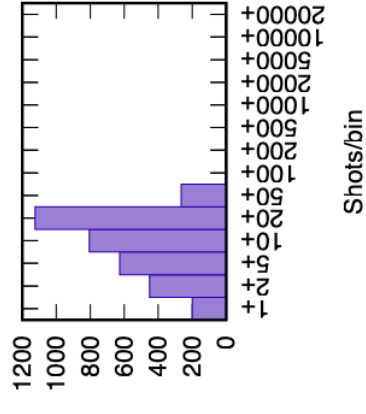
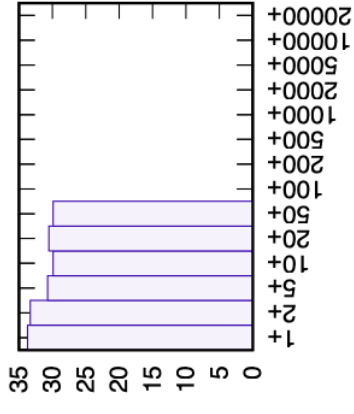
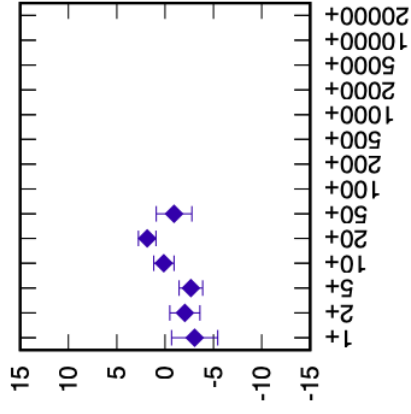
Arequipa 7403 LAG1+LAG2
(CoM 249 mm) RB 15.5 mm +



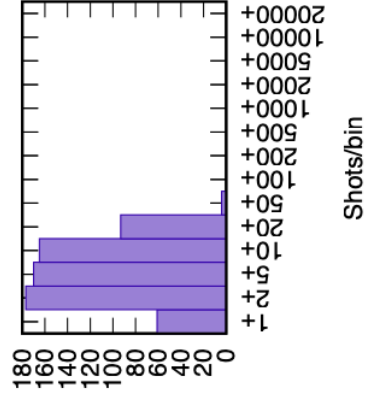
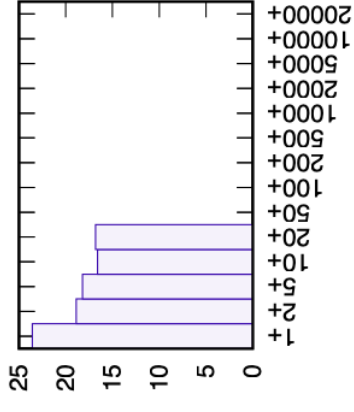
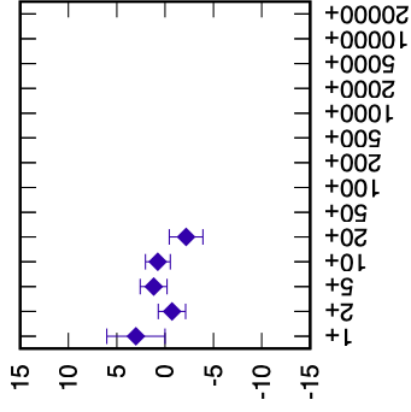
Arequipa 7403 AJI
(CoM 1013 mm) RB 39.1 mm +

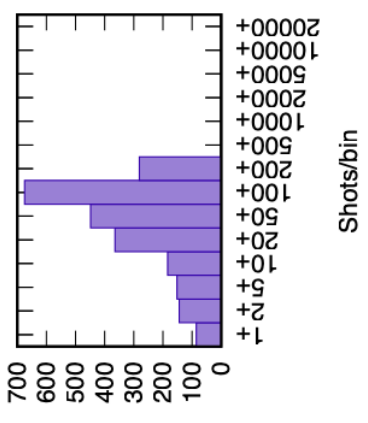
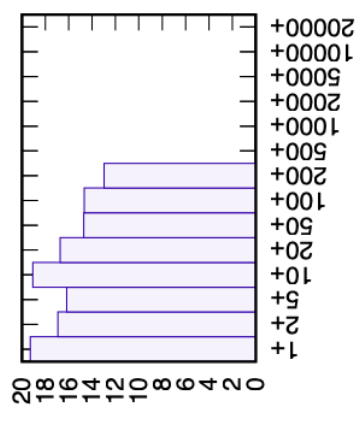
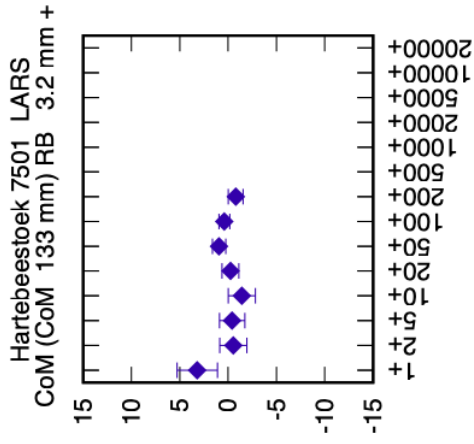
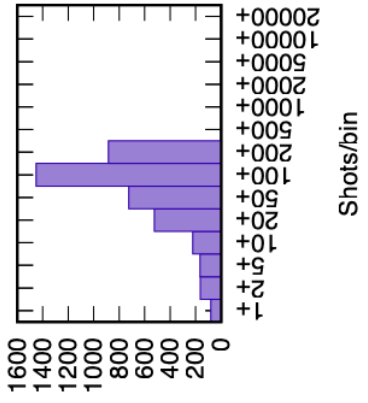
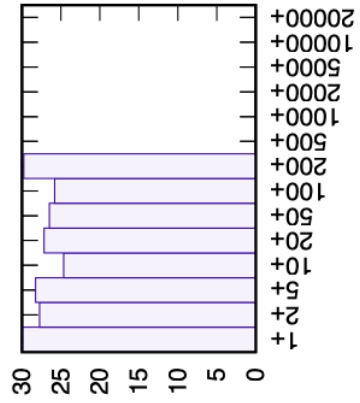
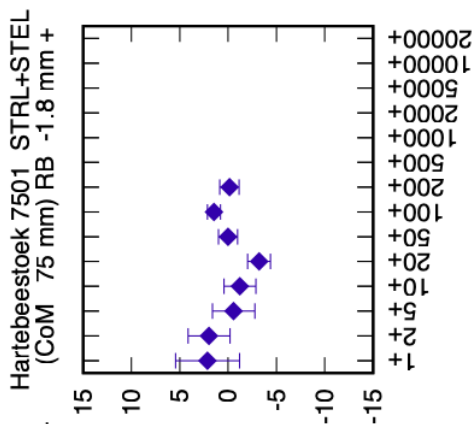
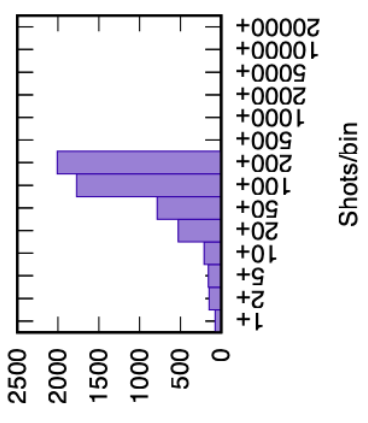
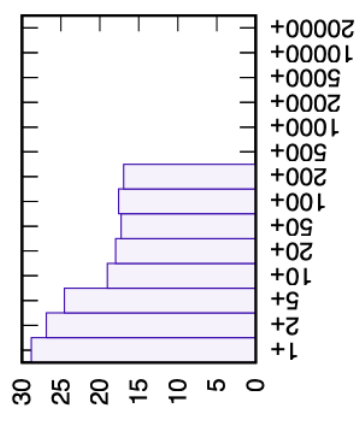
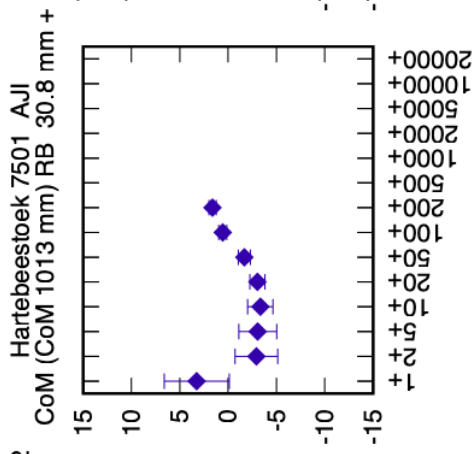
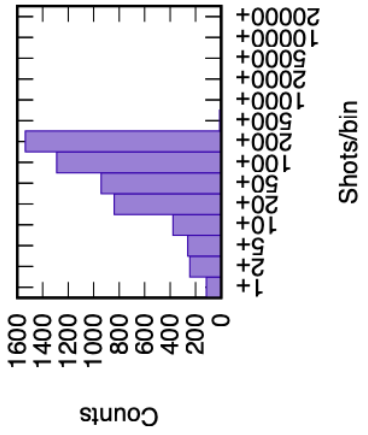
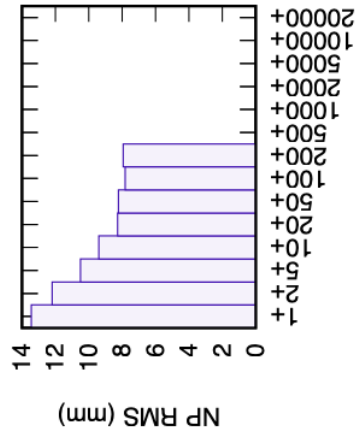
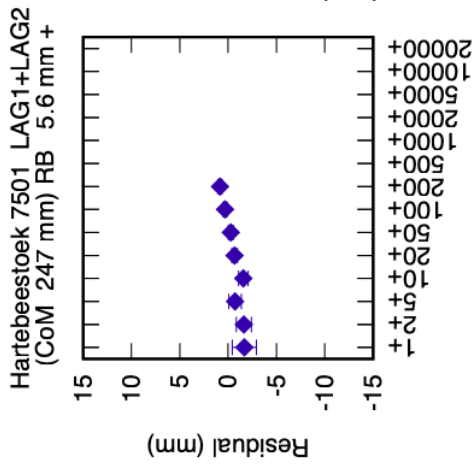


Arequipa 7403 STRL+STEL
(CoM 75 mm) RB 13.2 mm +

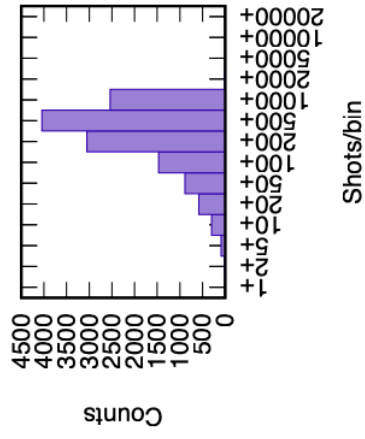
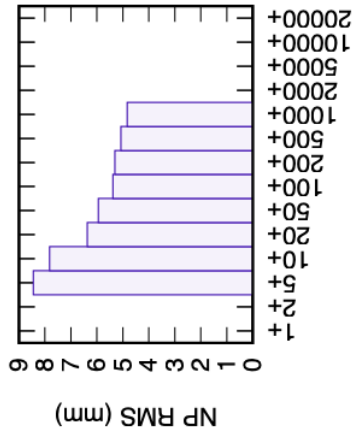
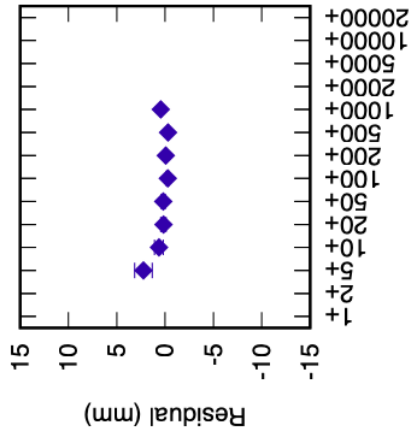


Arequipa 7403 LARS
(CoM 133 mm) RB 11.2 mm +

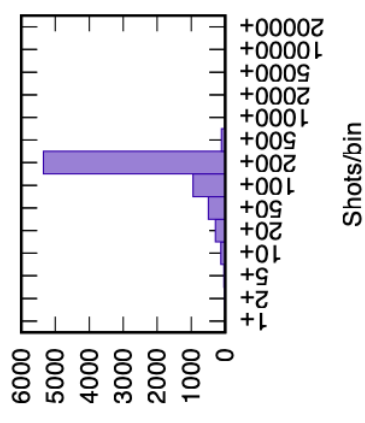
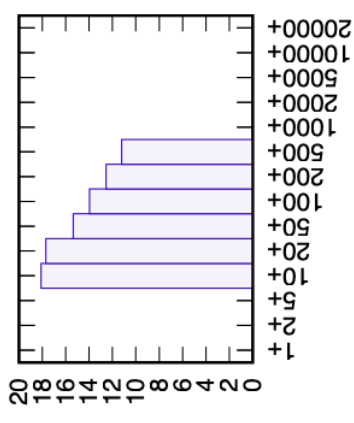
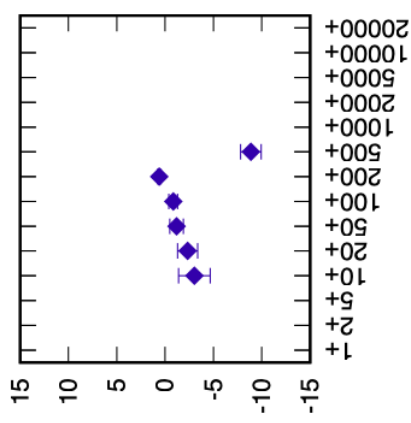




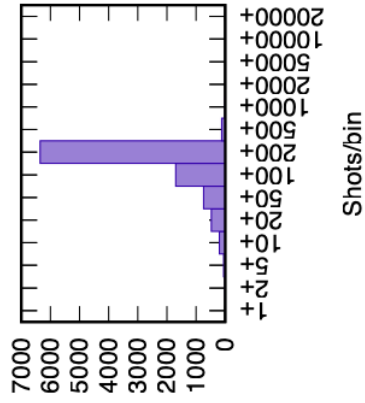
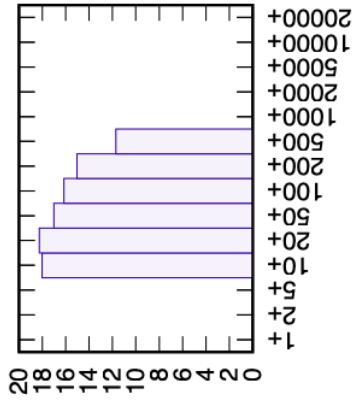
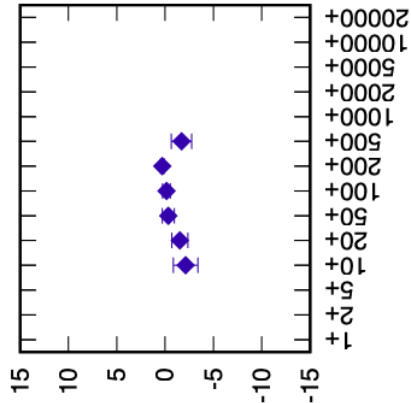
Zimmerwald 7810 LAG1+LAG2
(CoM 249 mm) RB 11.4 mm +



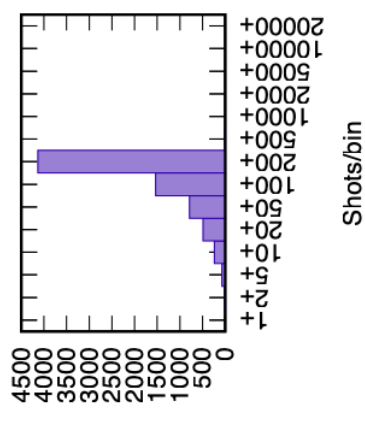
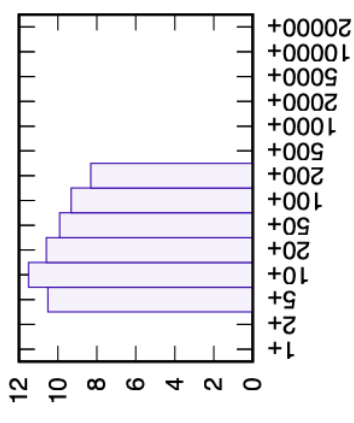
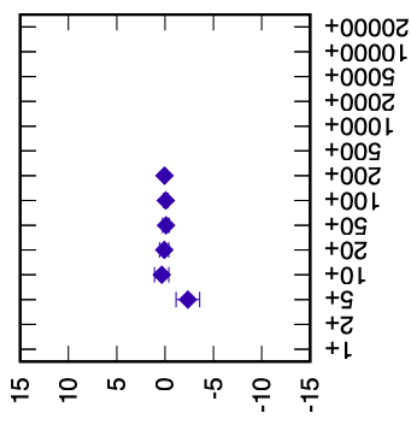
Zimmerwald 7810 AJI
CoM (CoM 999 mm) RB 25.2 mm +

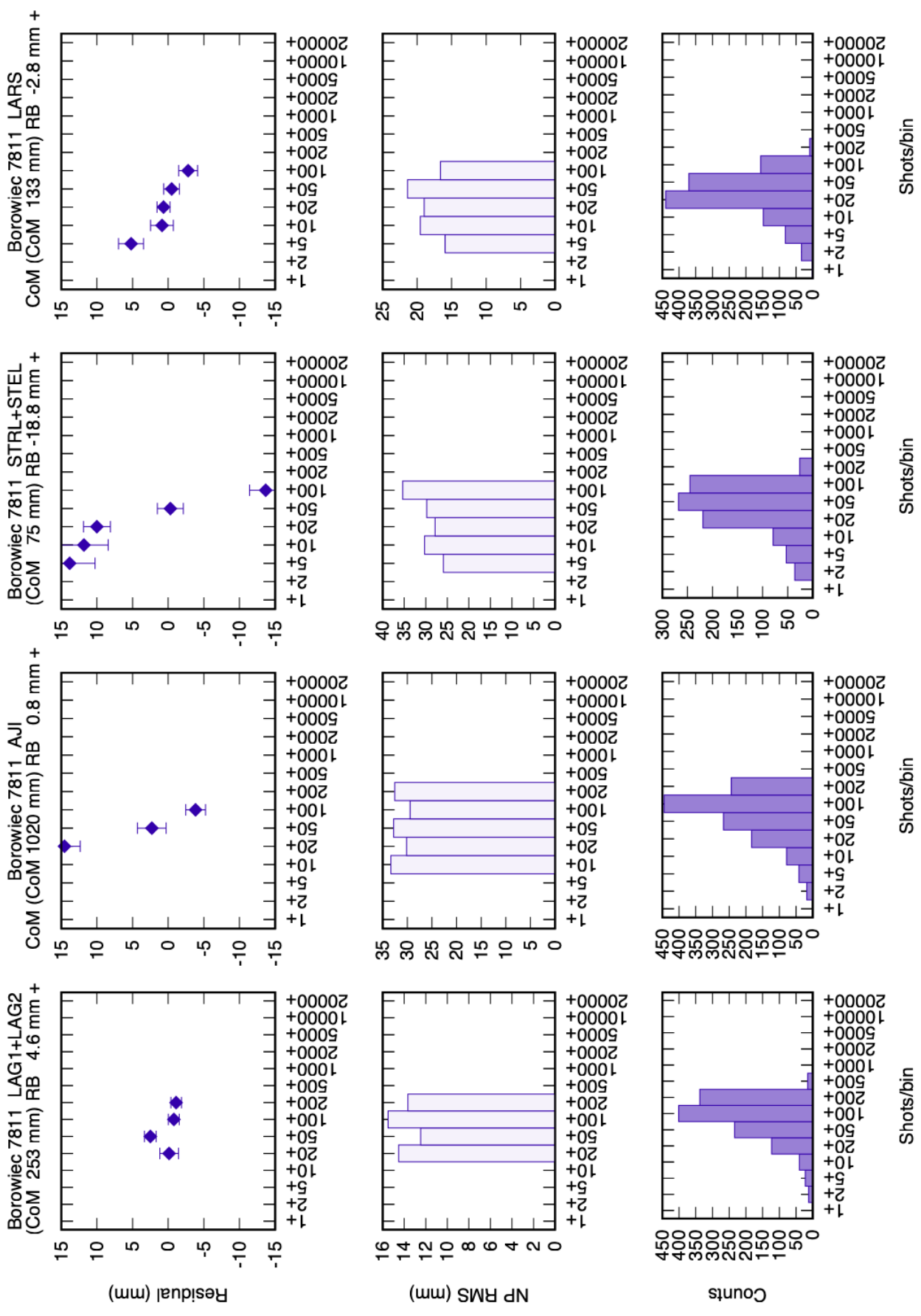


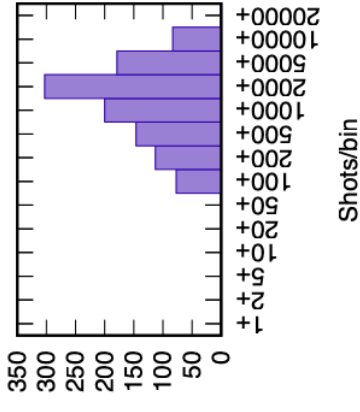
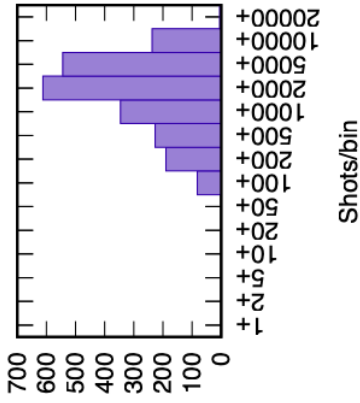
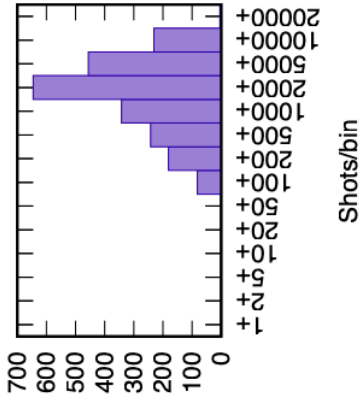
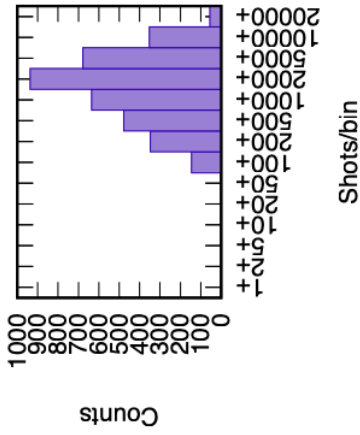
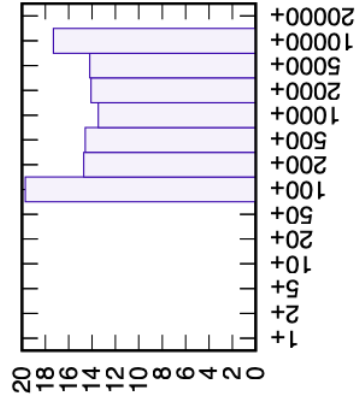
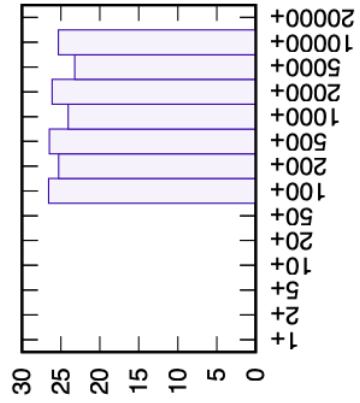
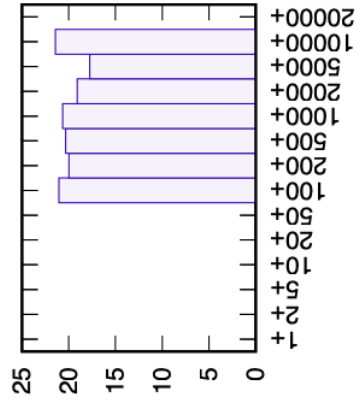
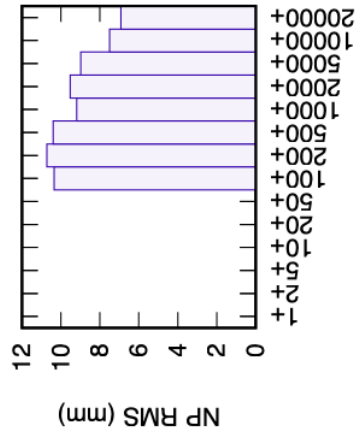
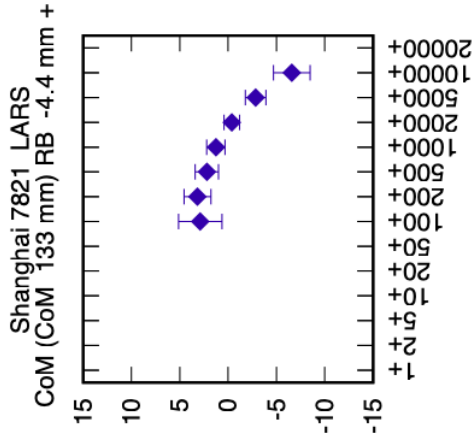
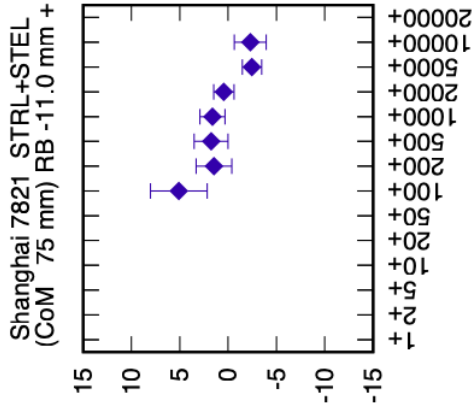
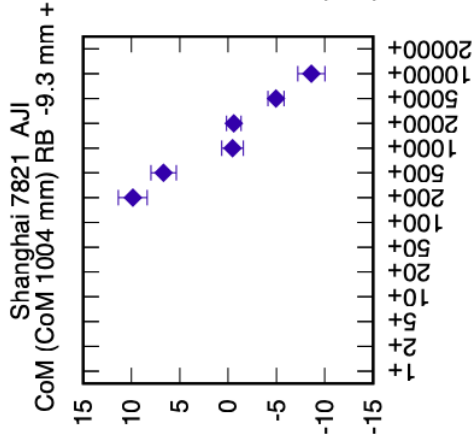
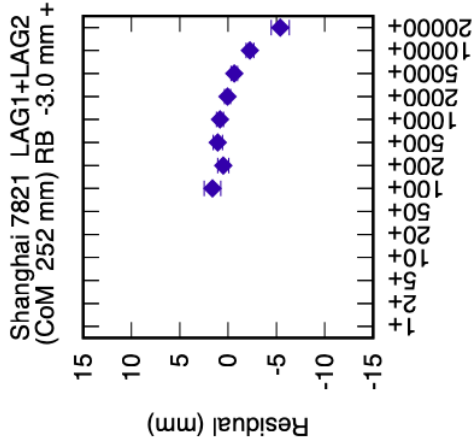
Zimmerwald 7810 STRL+STEL
(CoM 75 mm) RB 6.3 mm +



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







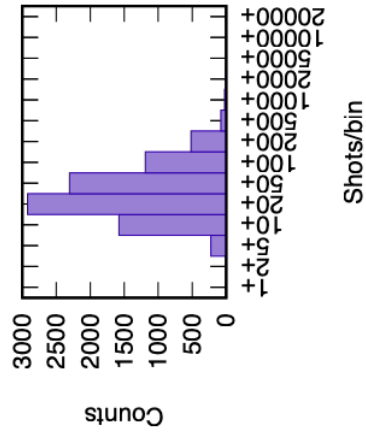
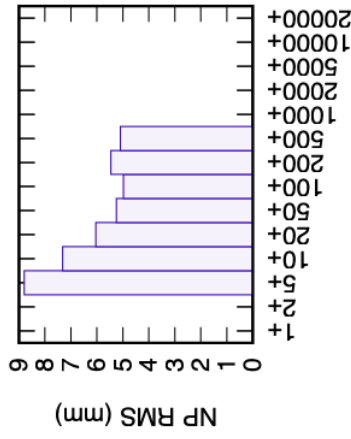
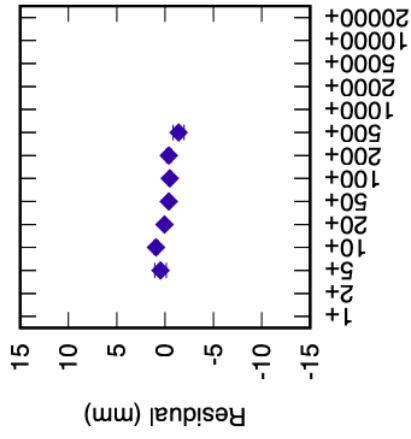
Shots/bin

Shots/bin

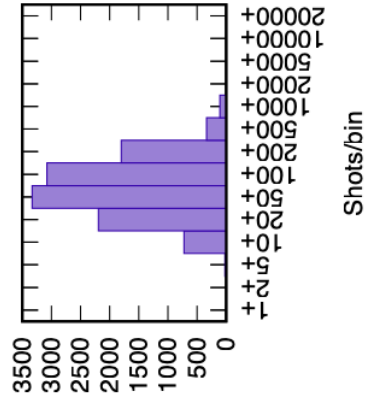
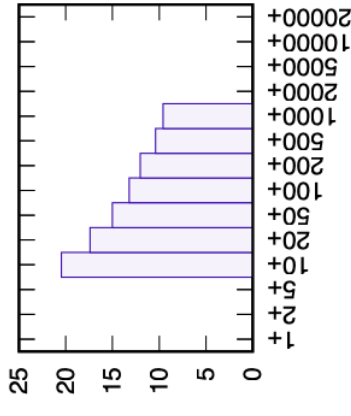
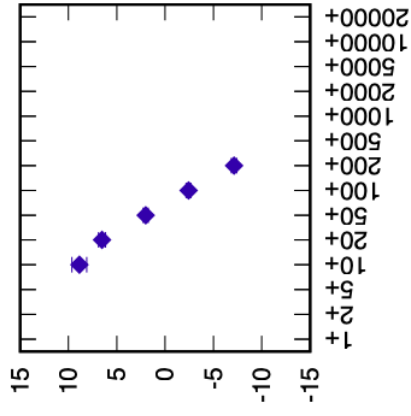
Shots/bin

Shots/bin

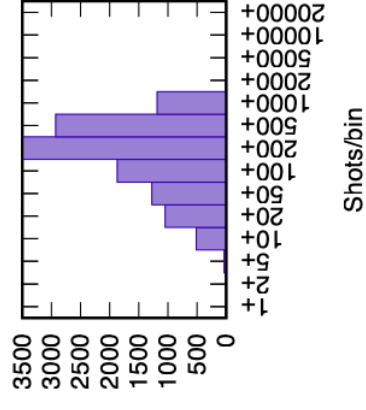
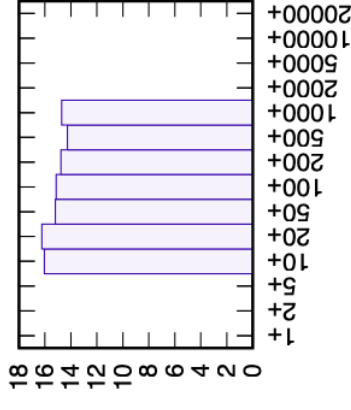
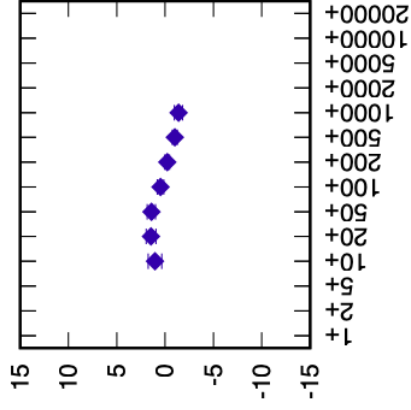
Mt Stromlo 7825 LAG1+LAG2
(CoM 252 mm) RB 11.3 mm +



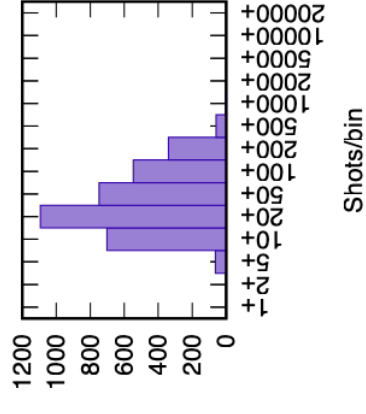
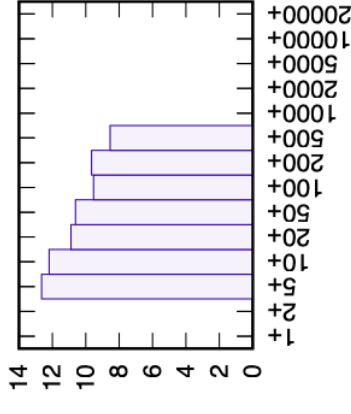
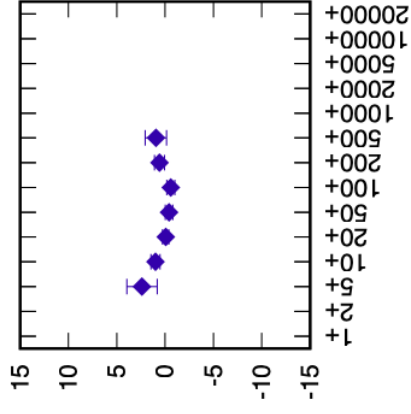
Mt Stromlo 7825 AJI
CoM (CoM 1004 mm) RB 16.1 mm +

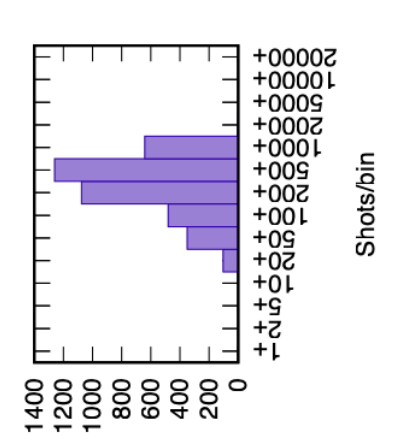
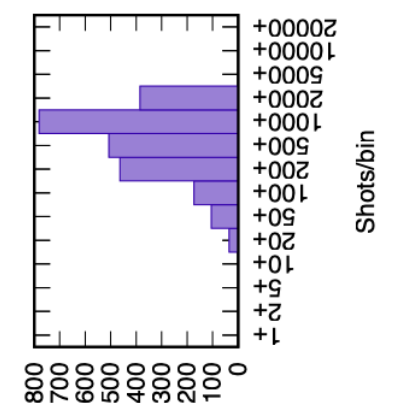
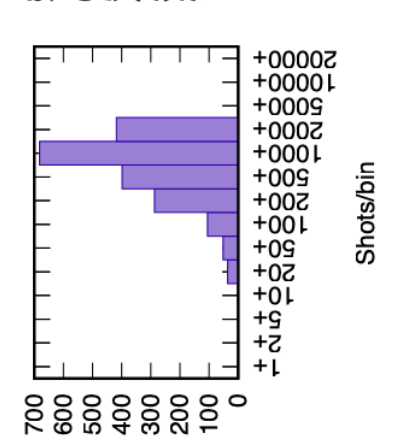
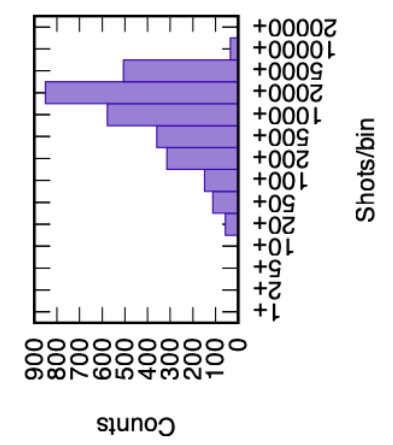
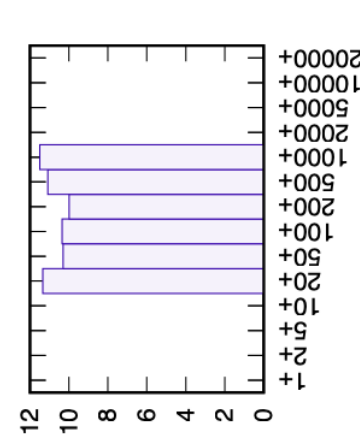
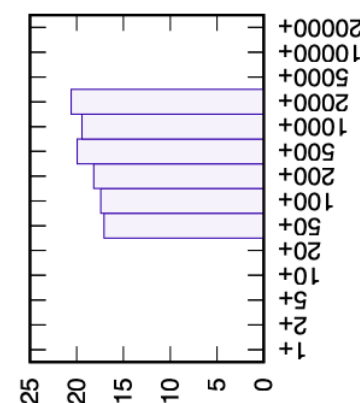
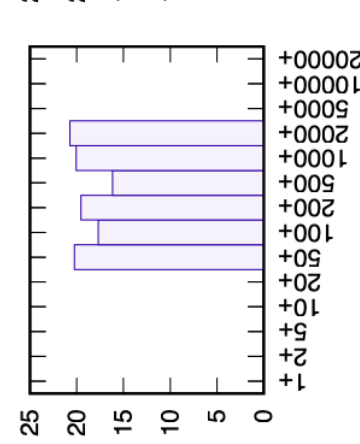
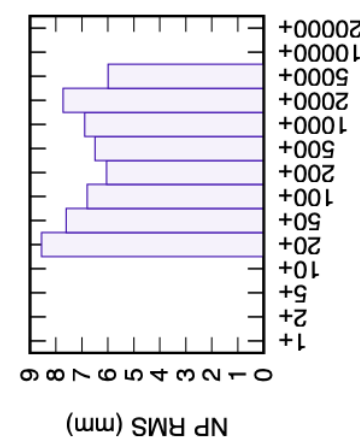
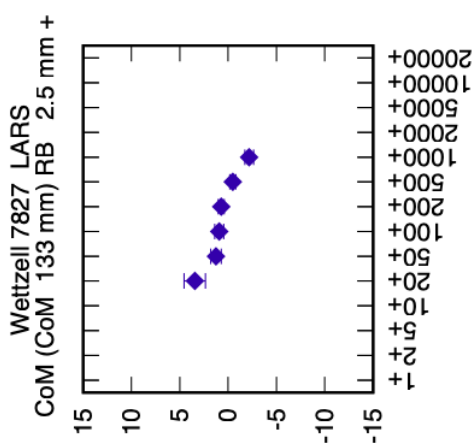
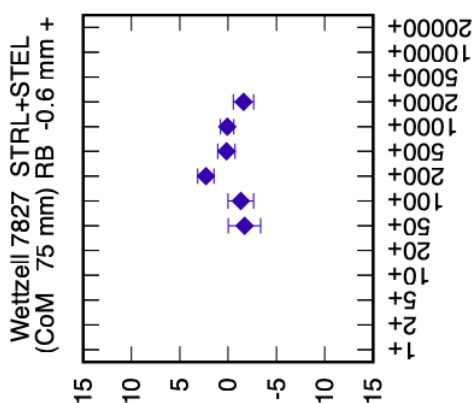
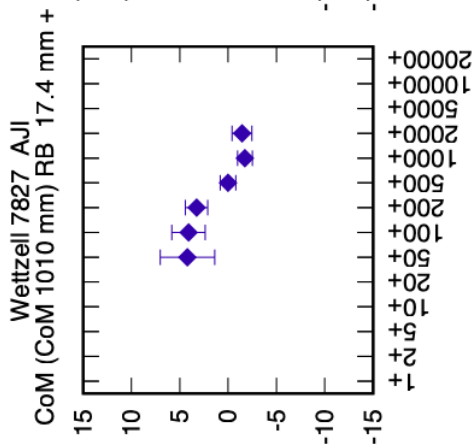
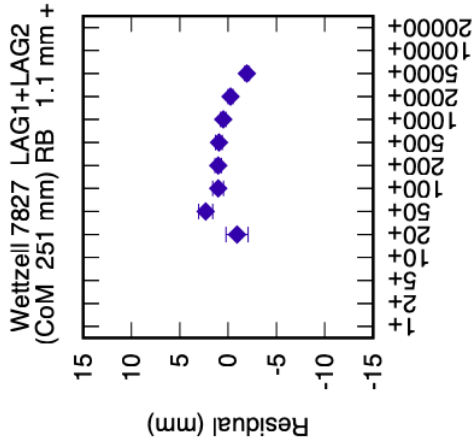


Mt Stromlo 7825 STRL+STEL
(CoM 75 mm) RB 3.8 mm +



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





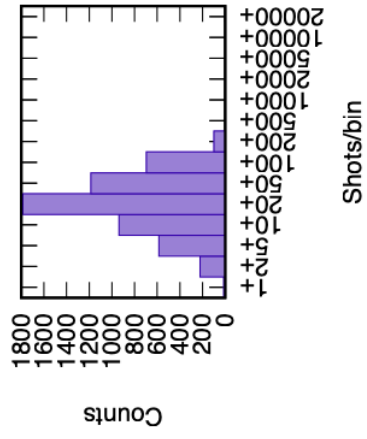
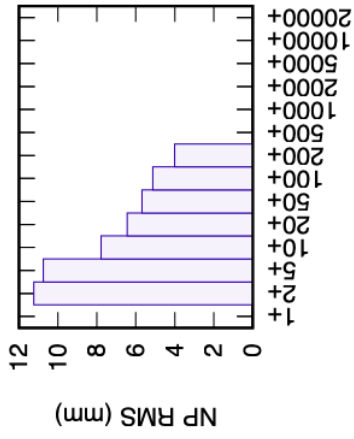
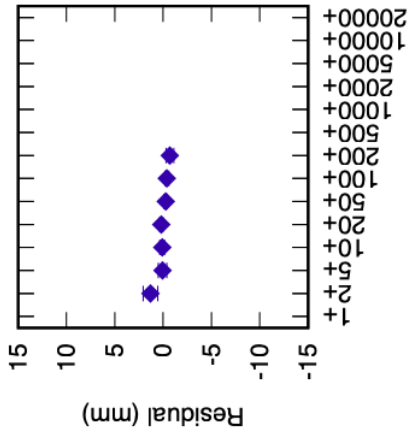
Shots/bin

Shots/bin

Shots/bin

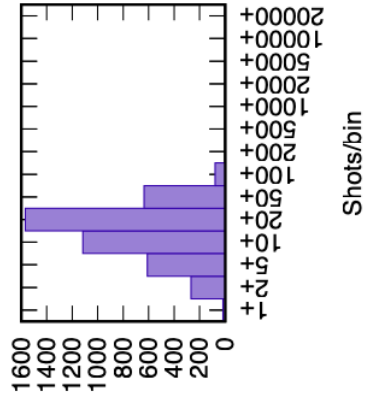
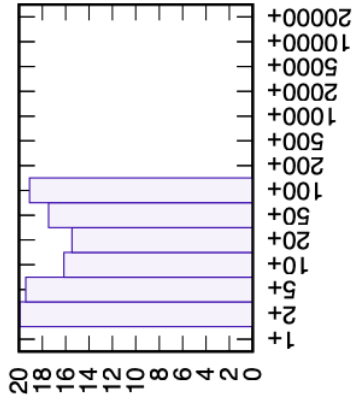
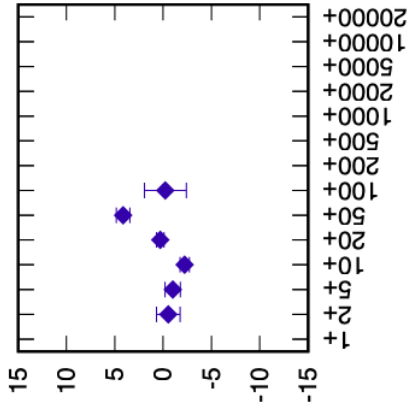
Shots/bin

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



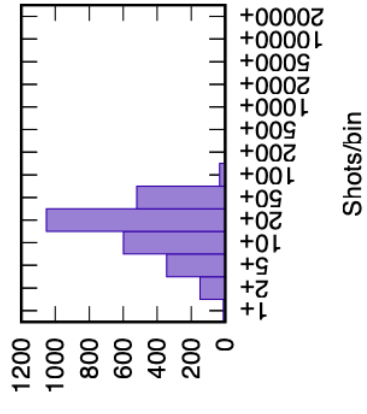
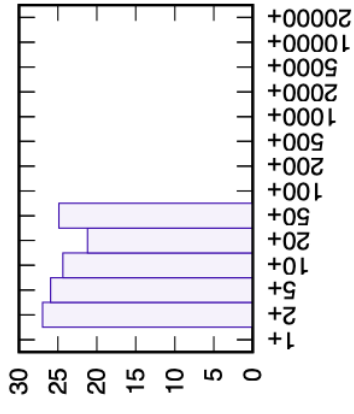
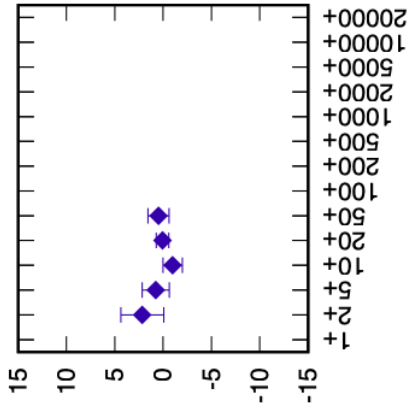
Shots/bin

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



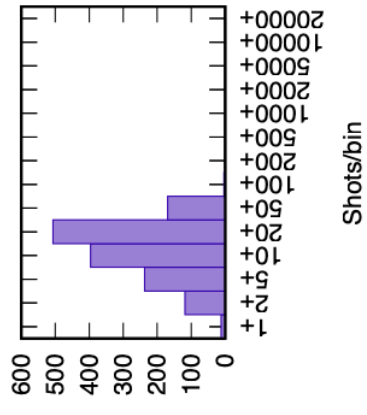
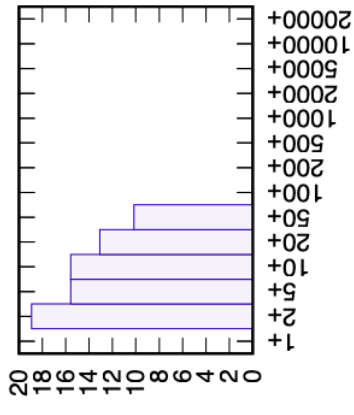
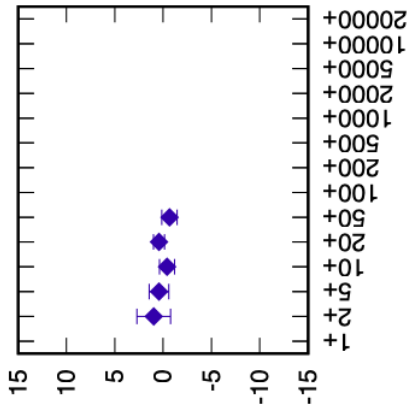
Shots/bin

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

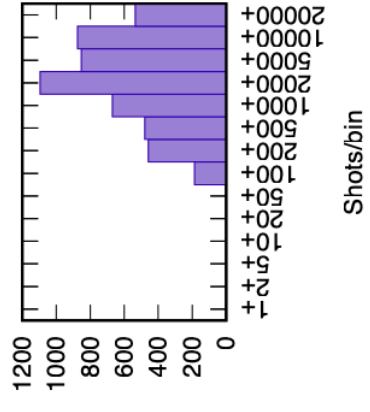
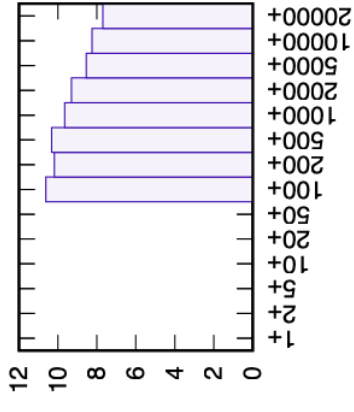
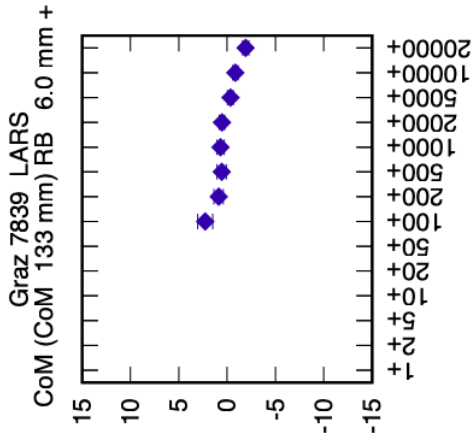
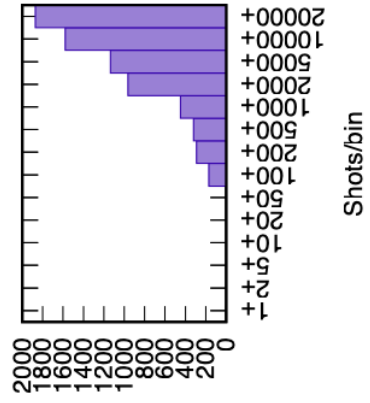
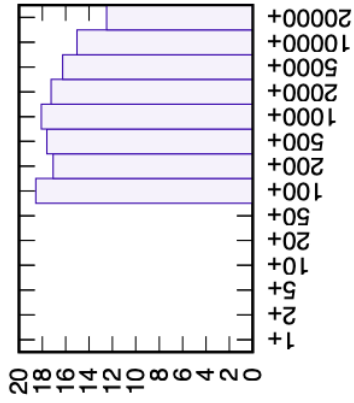
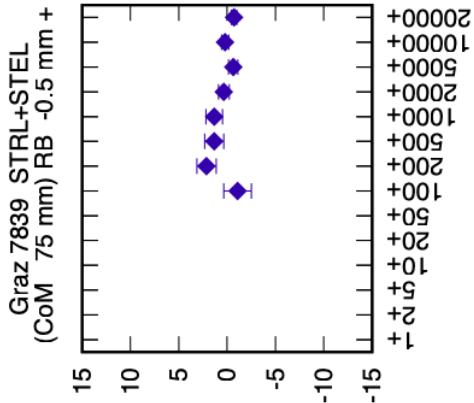
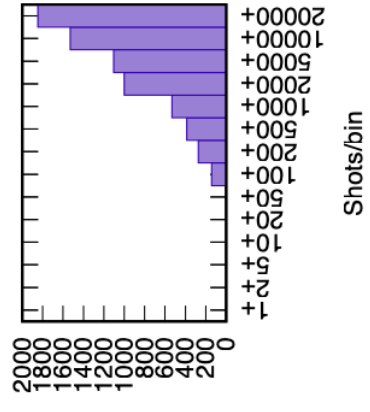
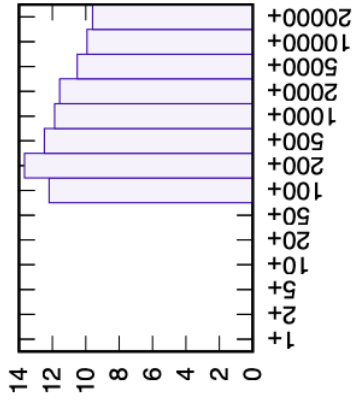
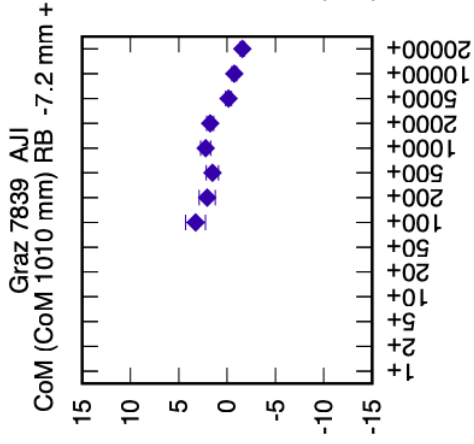
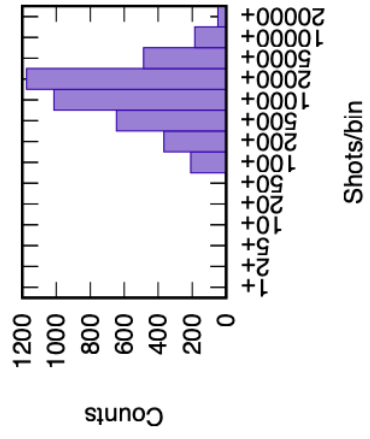
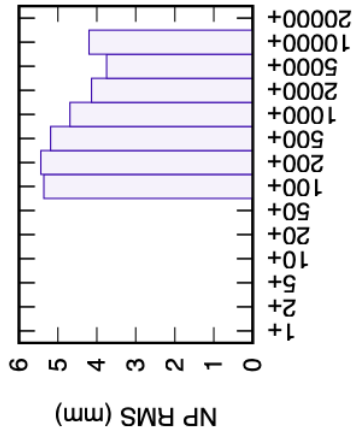
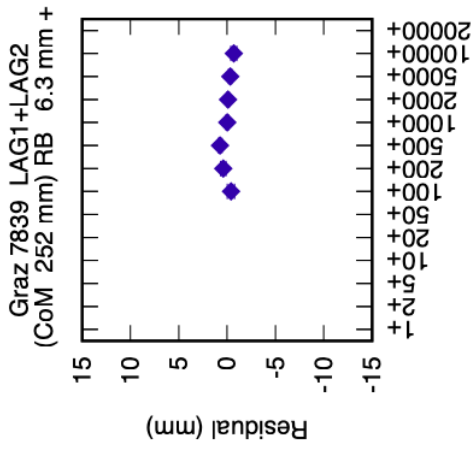


Shots/bin

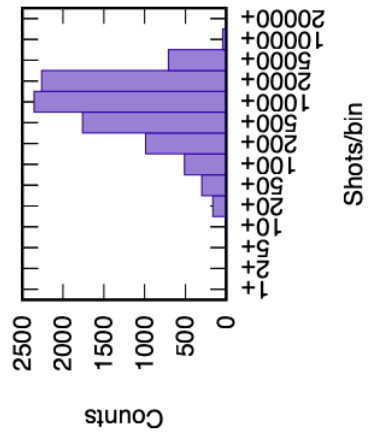
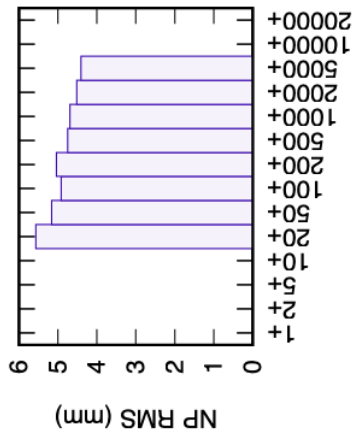
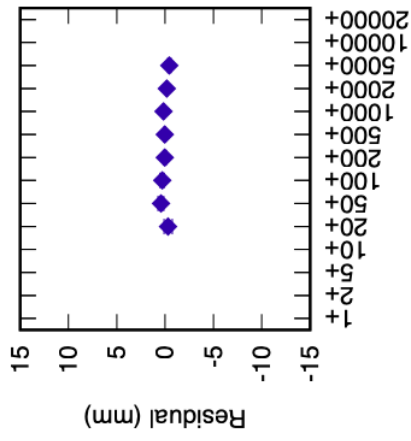
Simosato 7838 LARS
(CoM 133 mm) RB -7.3 mm +



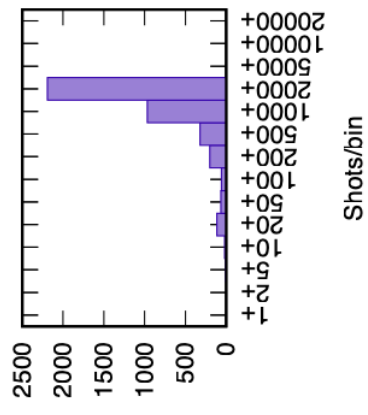
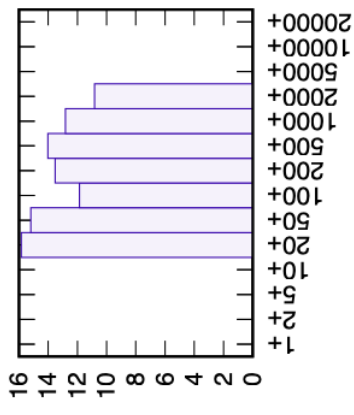
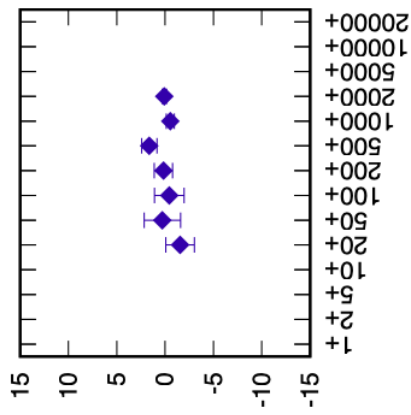
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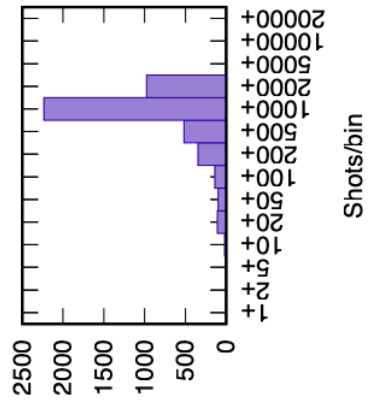
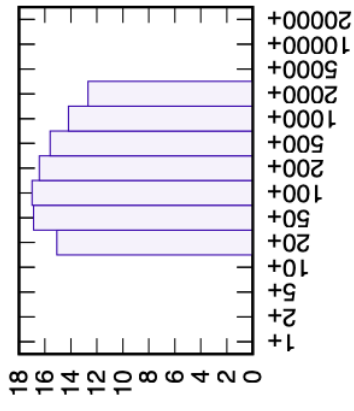
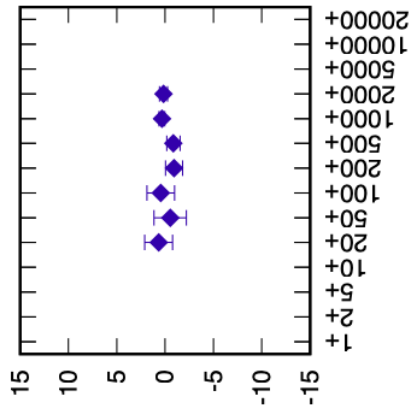
Herstimonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -1.3 mm +



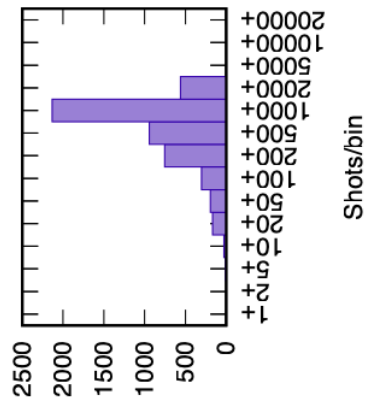
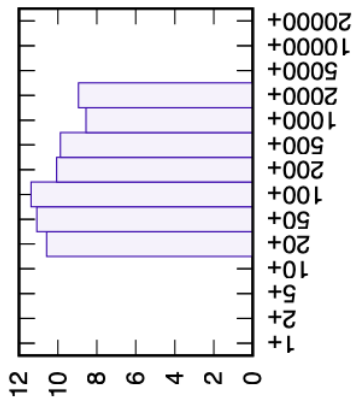
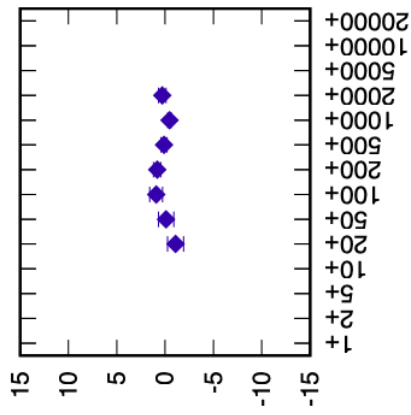
Herstimonceux 7840 AJI
CoM (CoM 982 mm) RB 8.1 mm +

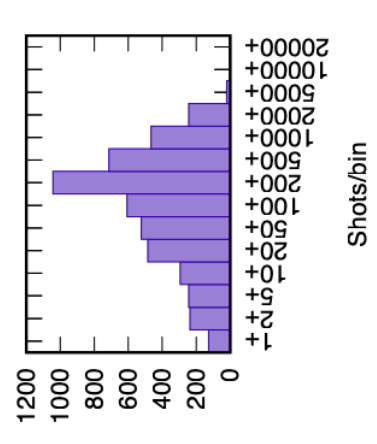
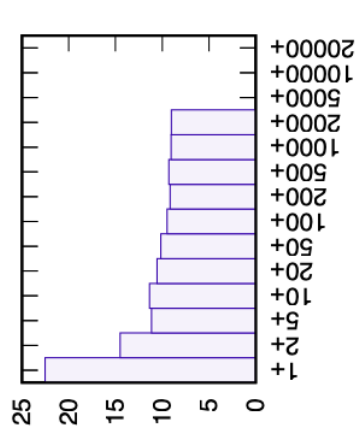
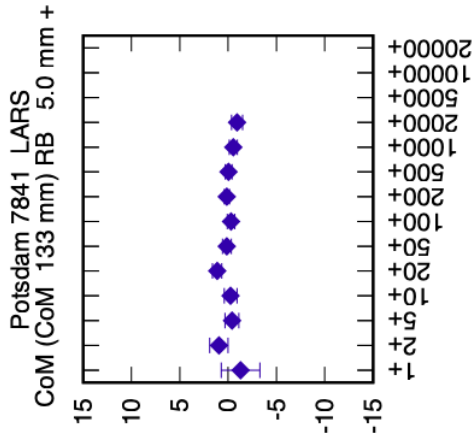
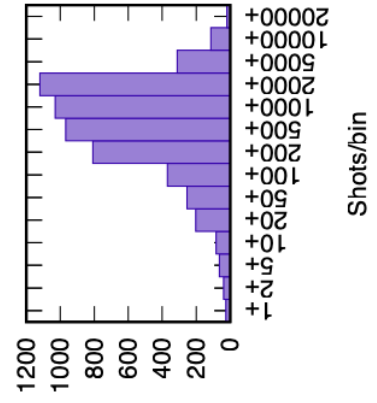
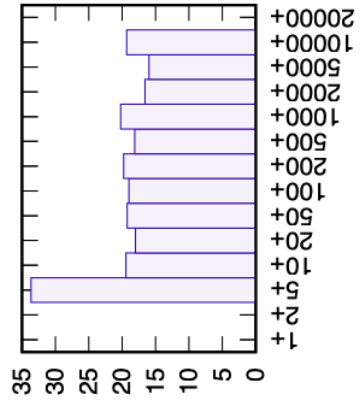
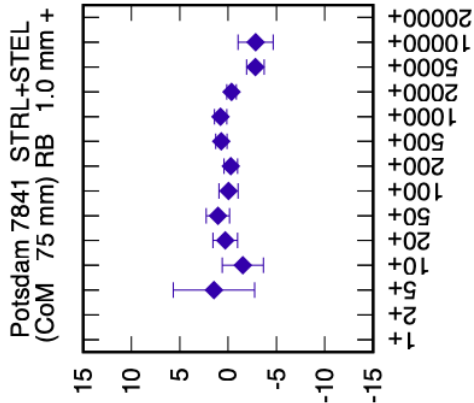
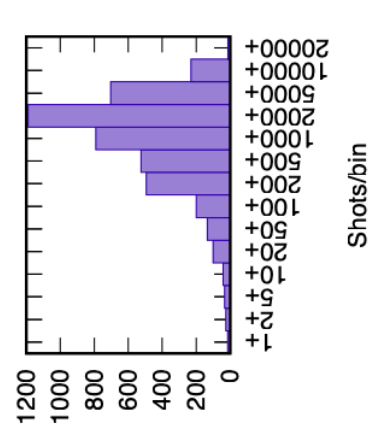
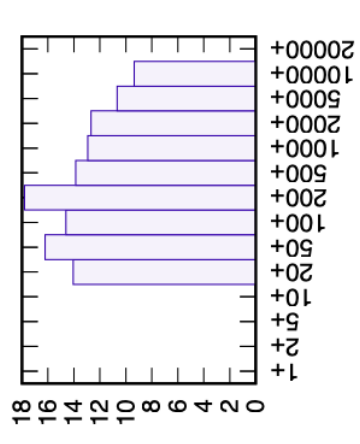
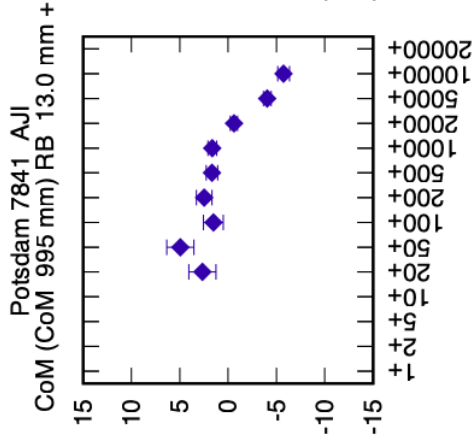
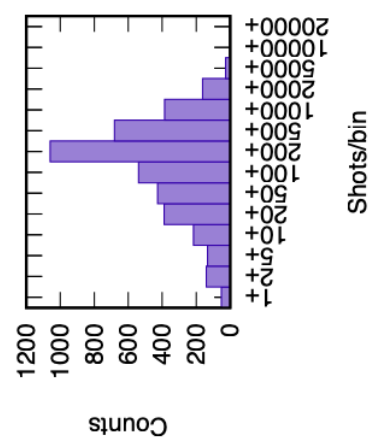
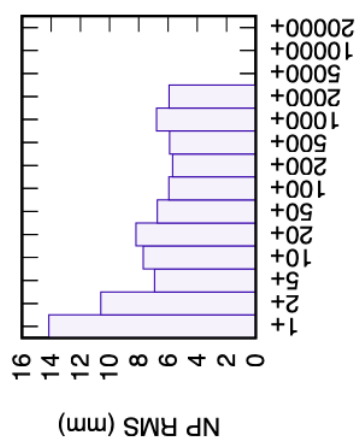
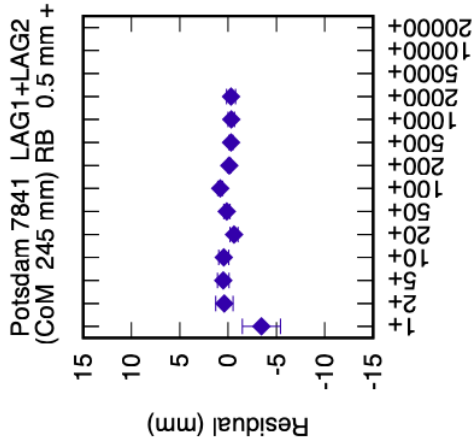


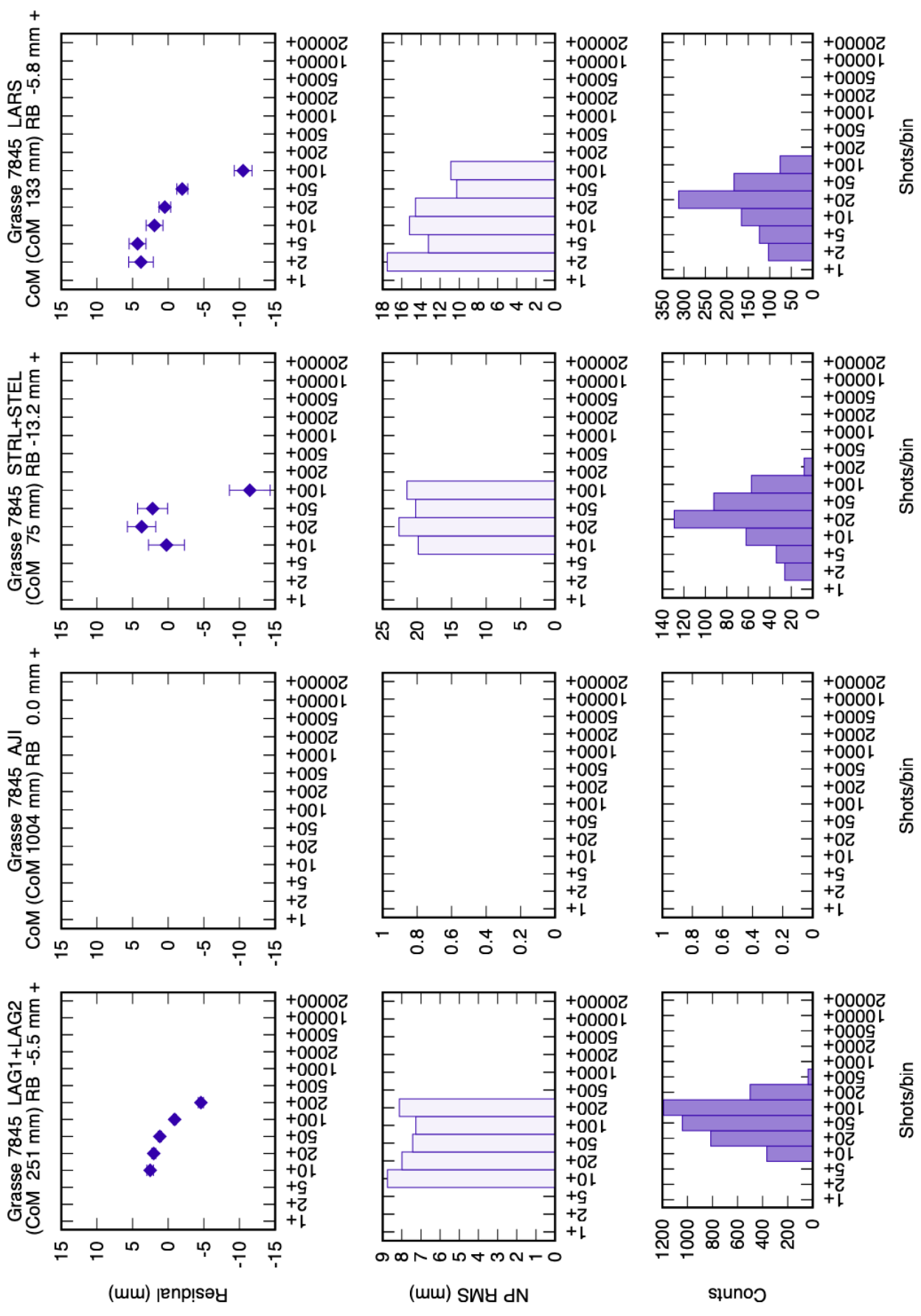
Herstimonceux 7840 STRL+STEL
(CoM 75 mm) RB -1.2 mm +

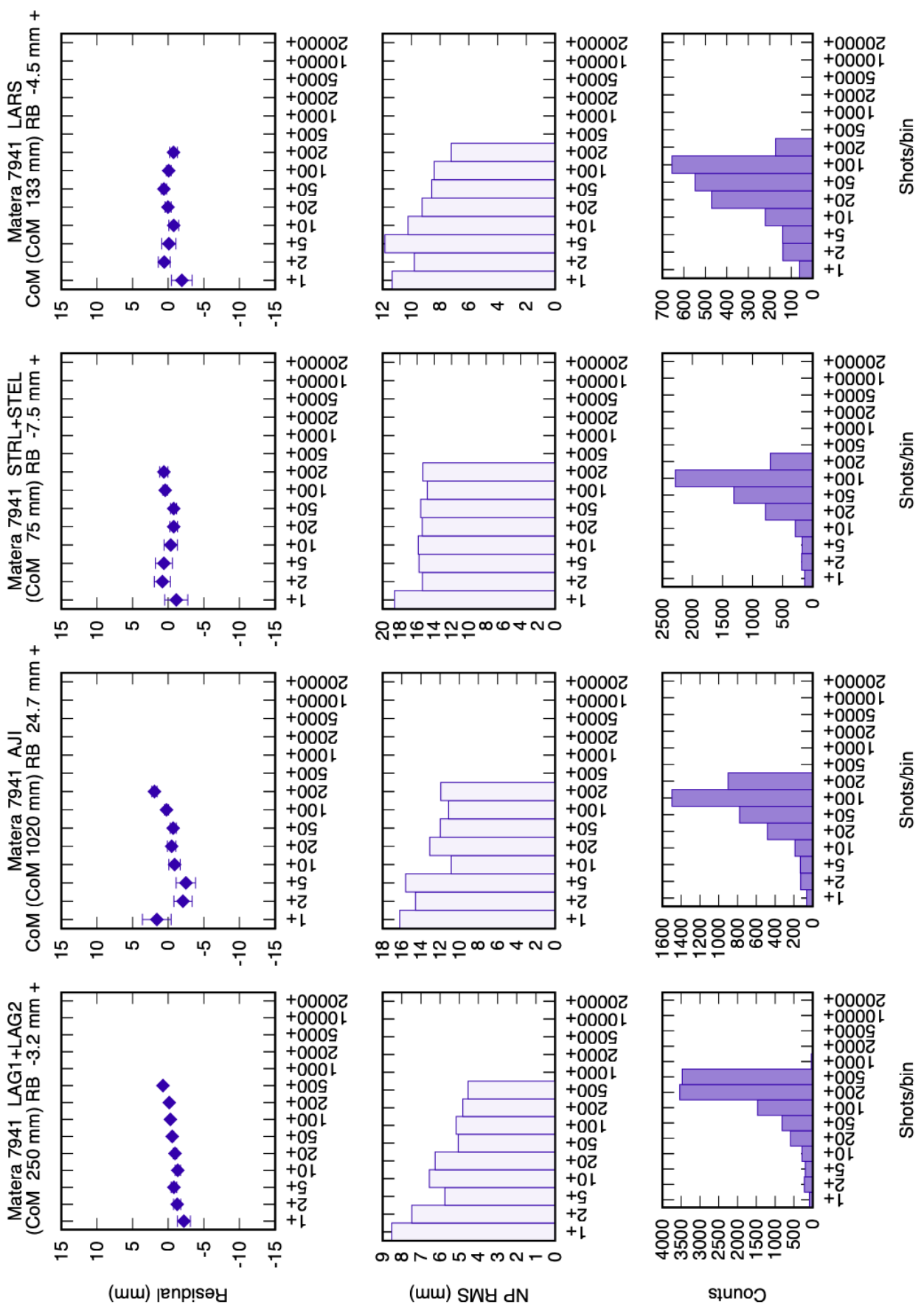


Herstimonceux 7840 LARS
CoM (CoM 133 mm) RB 1.5 mm +

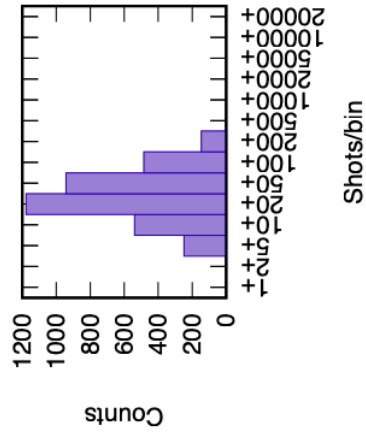
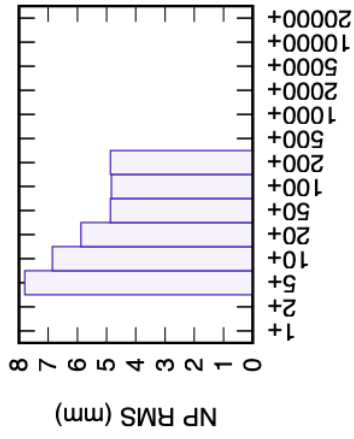
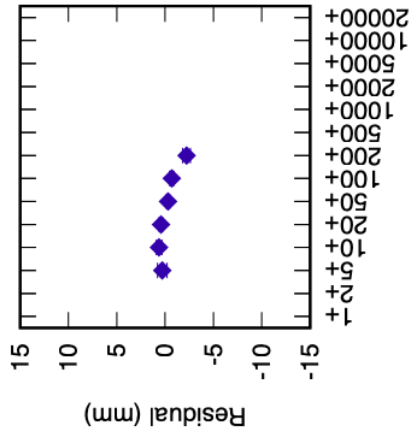




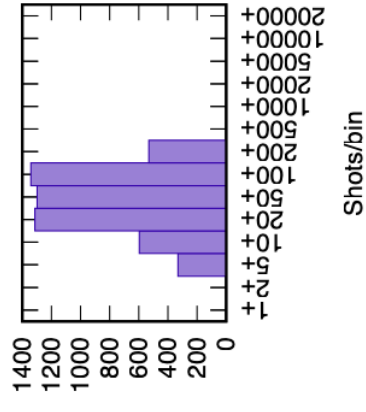
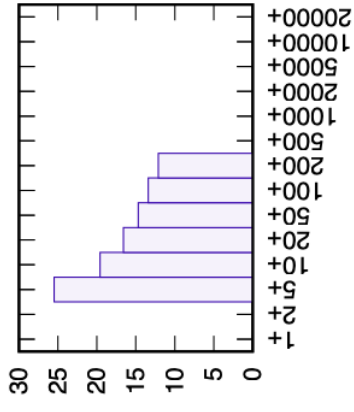
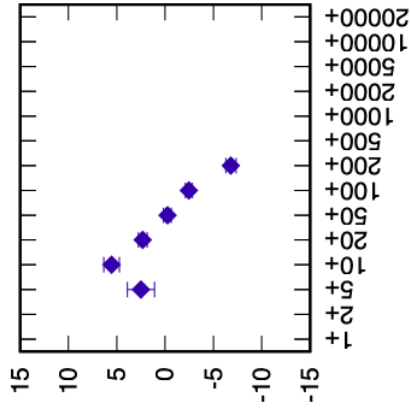




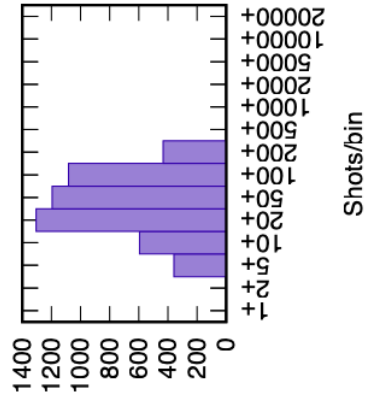
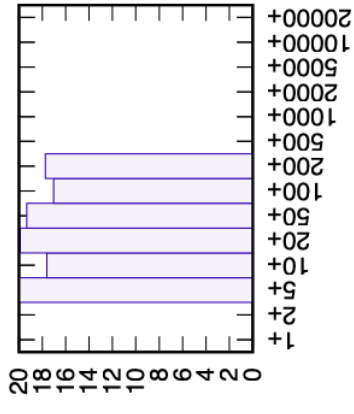
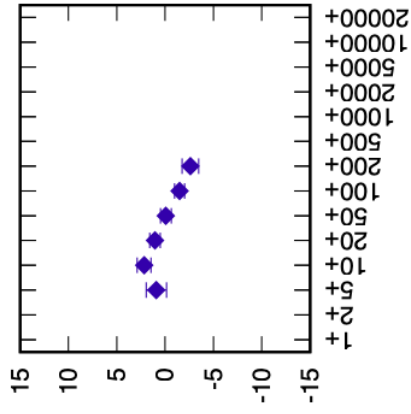
Wettzell 8834 LAG1+LAG2
(CoM 250 mm) RB -13.4 mm +



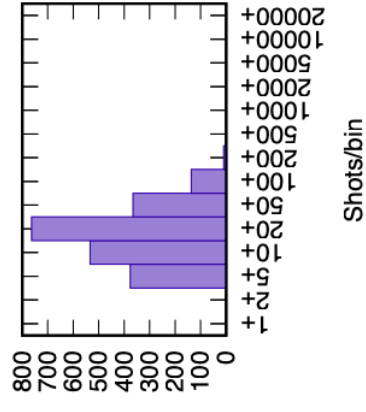
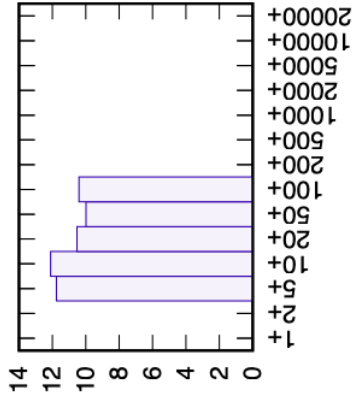
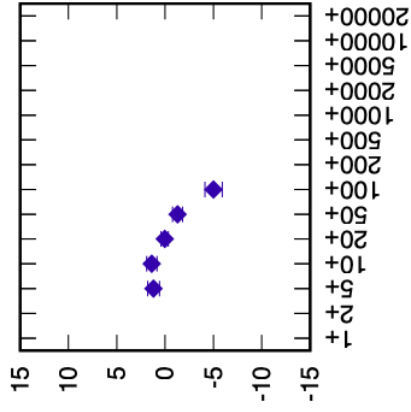
Wettzell 8834 AJI
(CoM 1020 mm) RB 24.1 mm +

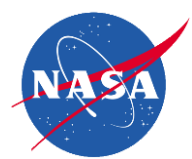


Wettzell 8834 STRL+STEL
(CoM 75 mm) RB -21.0 mm +



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

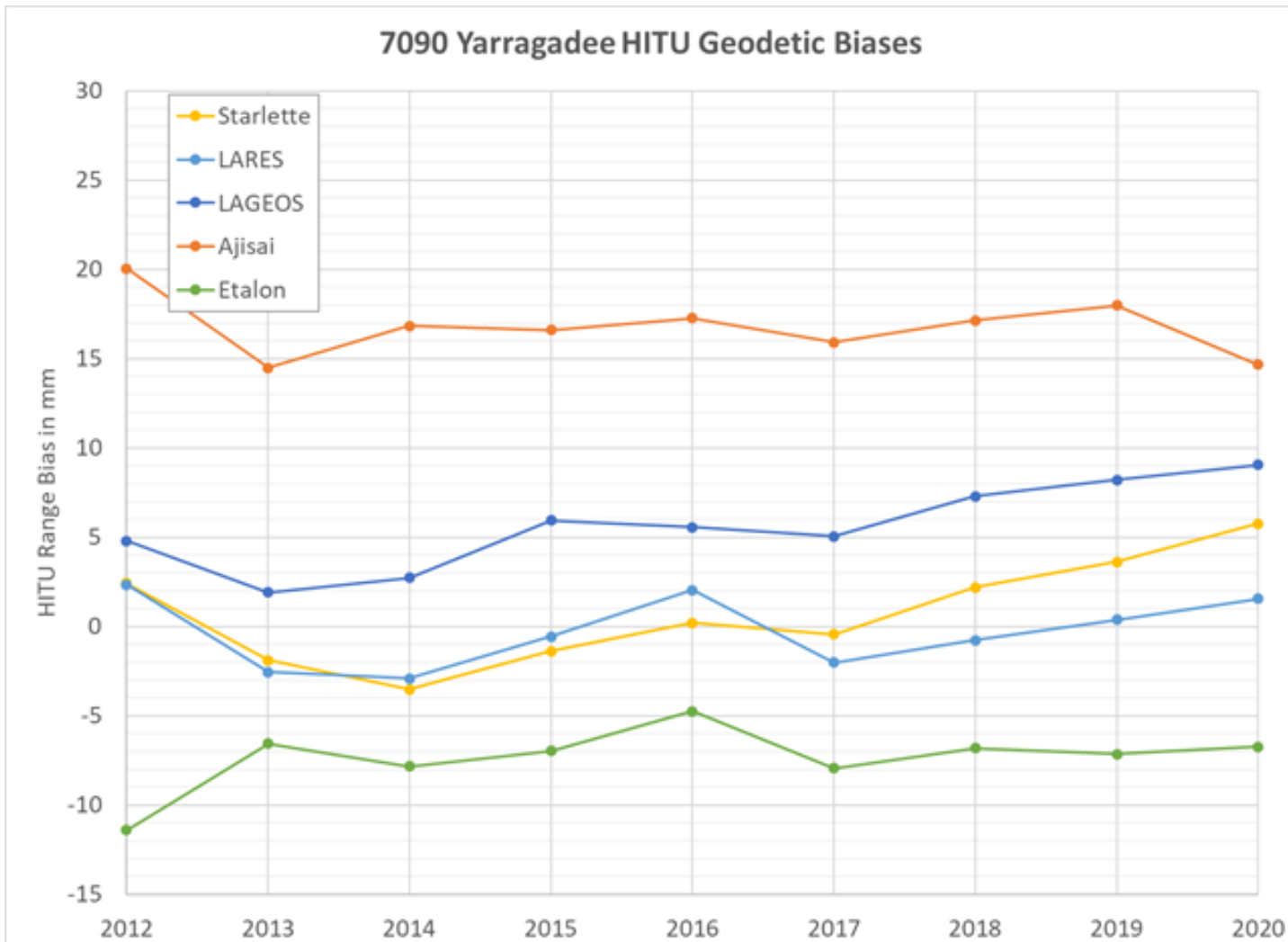




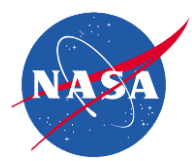
7090 Yarragadee Data Analysis

Van S Husson

ILRS Central Bureau, ILRS Quality Control Board,
NASA SLR Data Operations



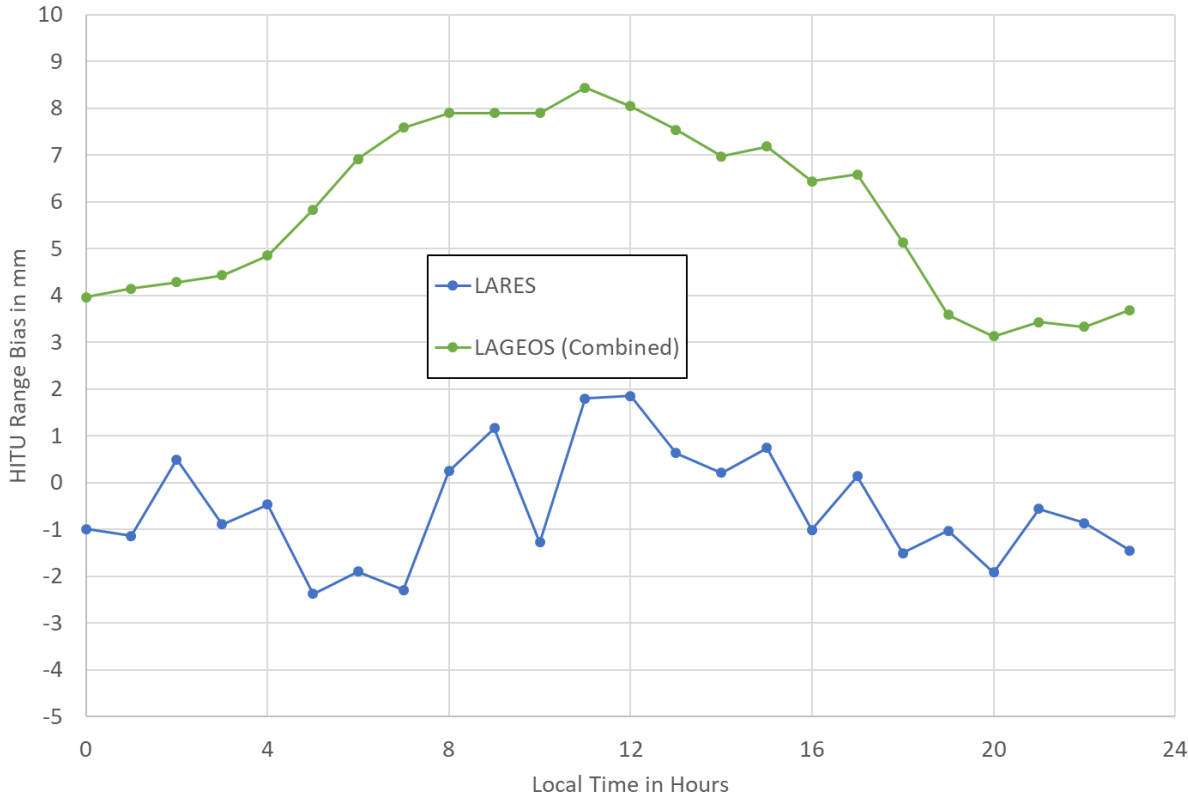
- ◆ HITU implemented ITRF2014 coordinates in June 2017.
- ◆ Since 2017, the range bias on Starlette, Lares and LAGEOS appears to be drifting positive, but not Ajisai and Etalon.
- ◆ The separation between LARES and Starlette range bias appears to be growing since 2017.



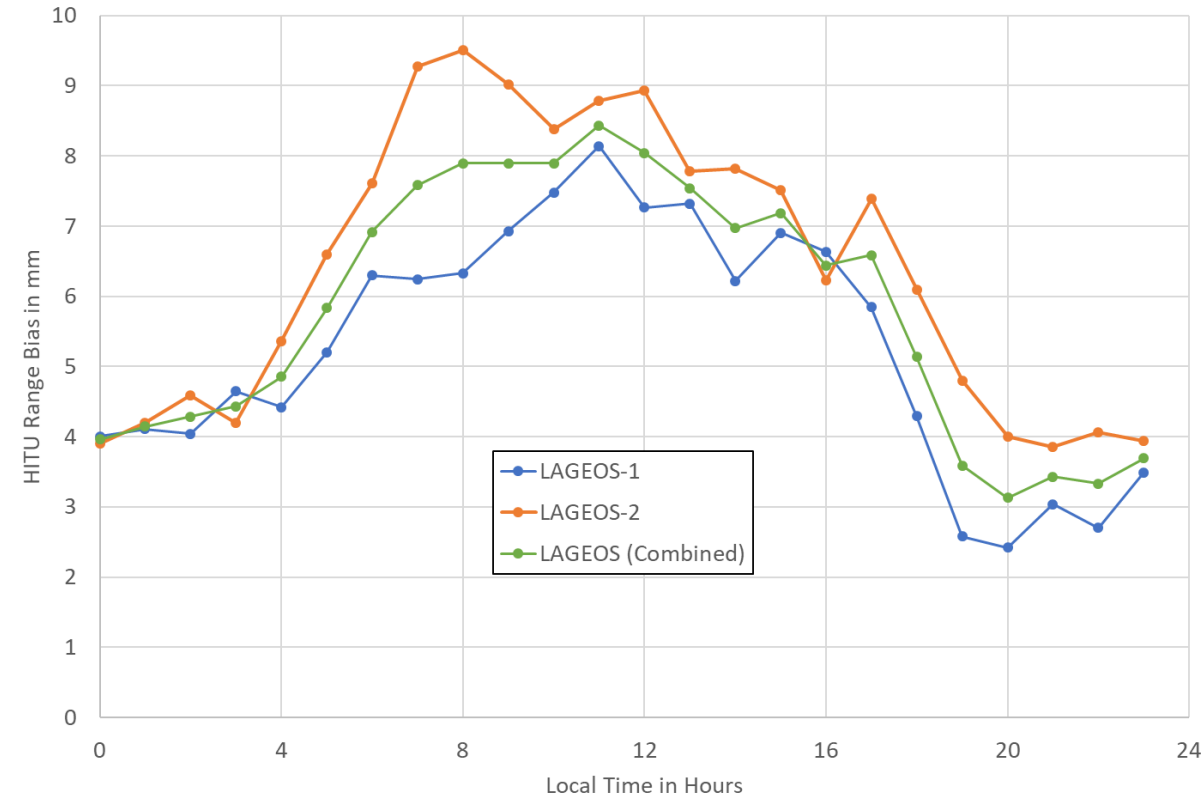
7090 Yarragadee HITU Diurnal Range Biases



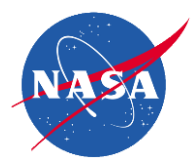
7090 Yarragadee LARES and LAGEOS Range Biases vs Local Time



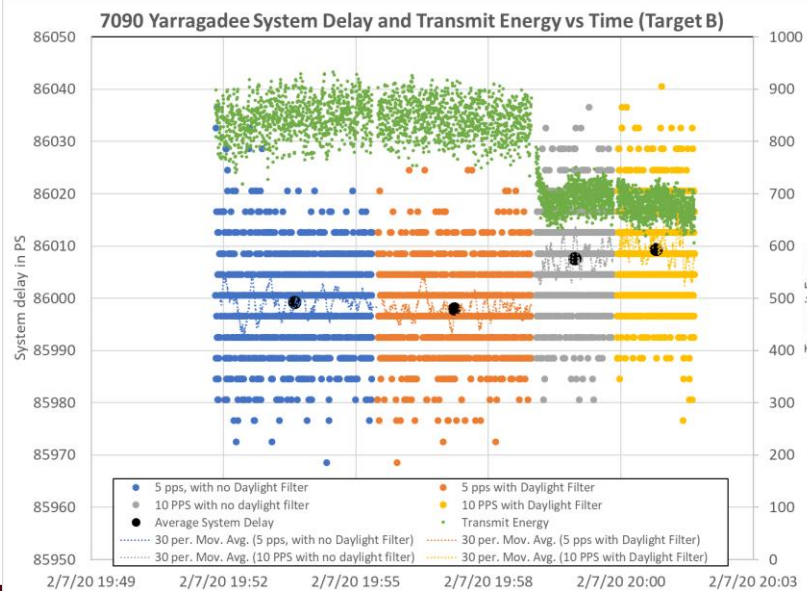
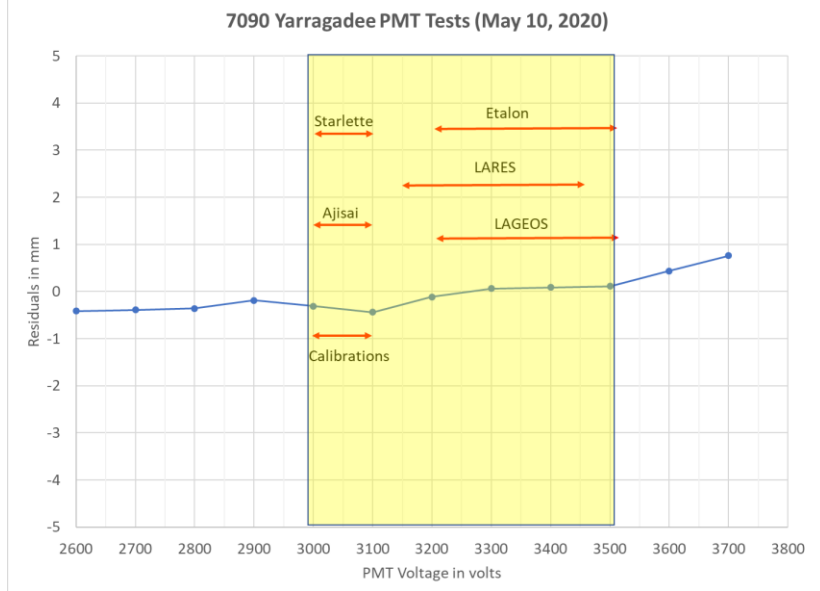
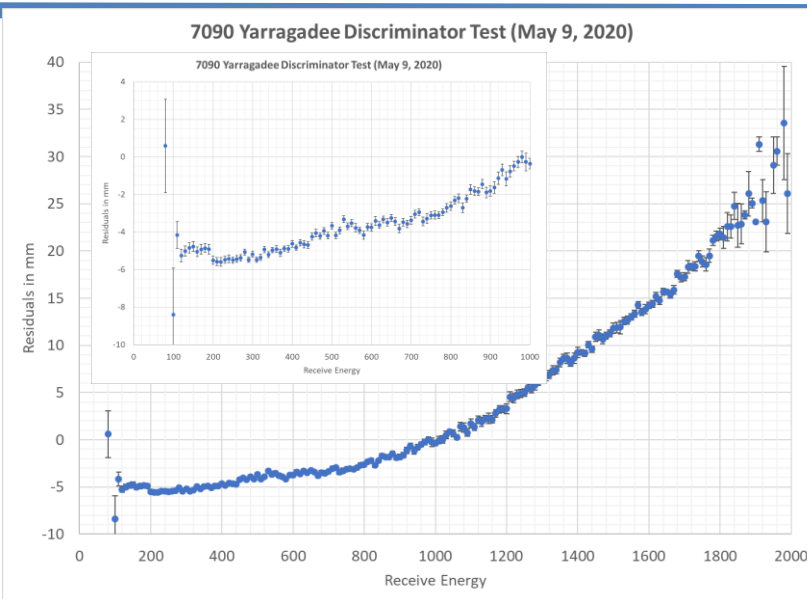
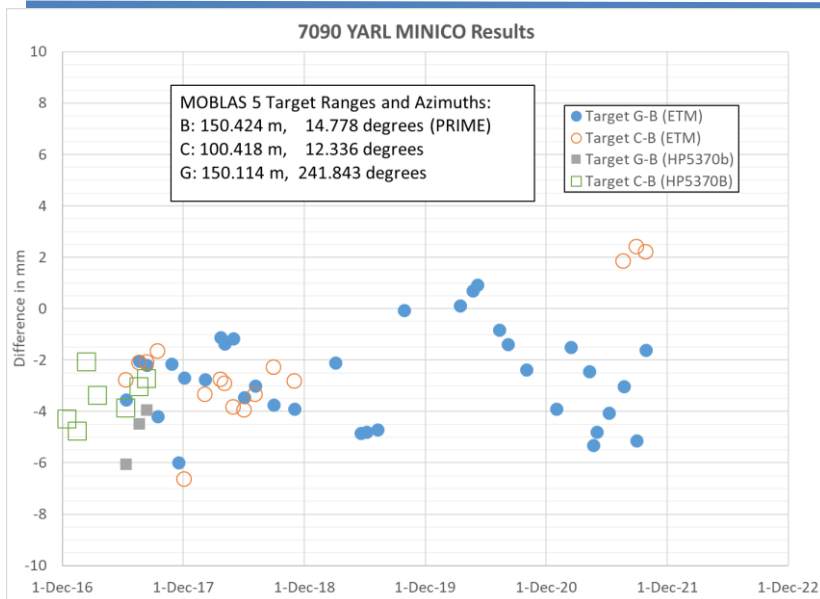
7090 Yarragadee LAGEOS Range Biases vs Local Time



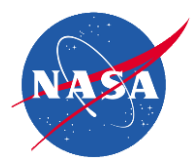
- ◆ The mean LAGEOS and LARES range bias (2012-2020) as a function of local time on the left chart. There is 5 mm diurnal variation in LAGEOS data. Diurnal trends on LARES are not as clear.
- ◆ On the right chart, mean LAGEOS-1 and -2 range biases are plotted individually along with the LAGEOS combination.



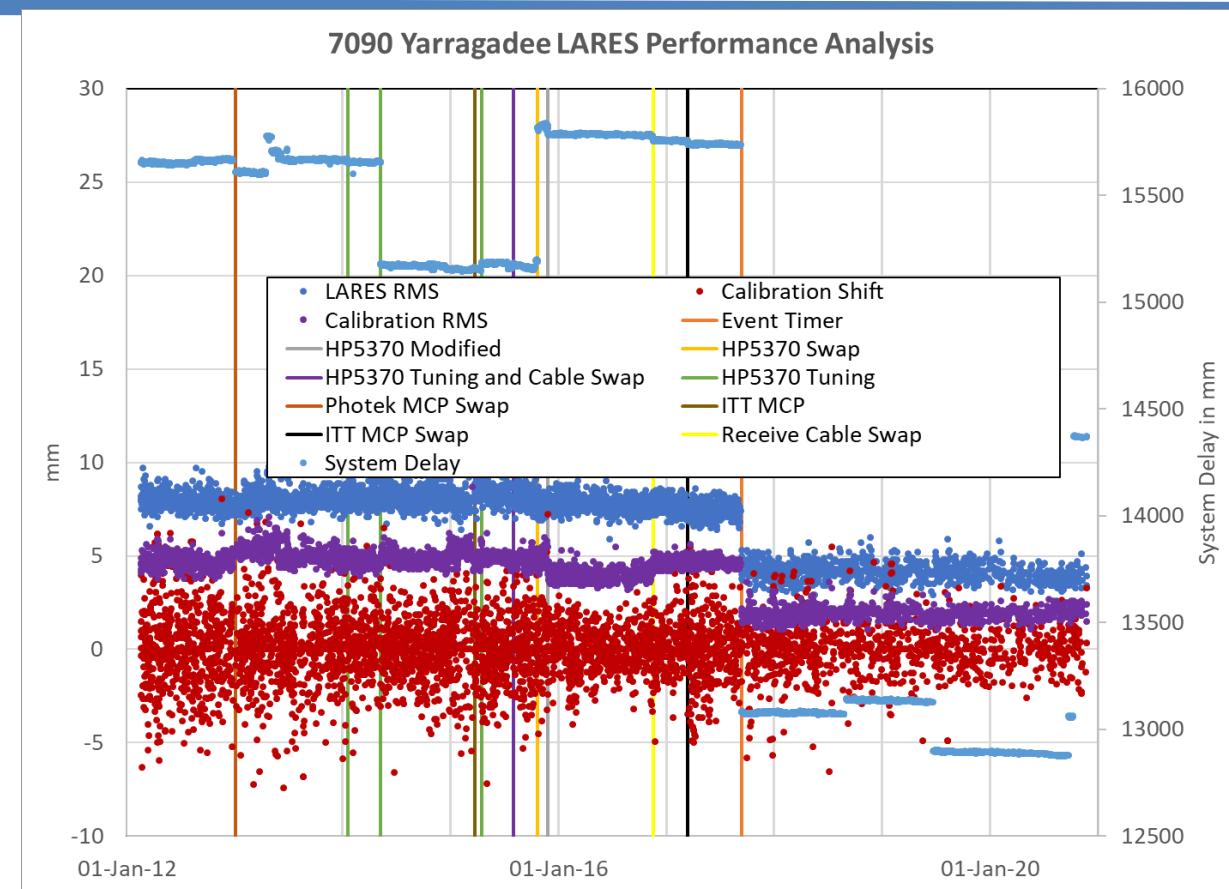
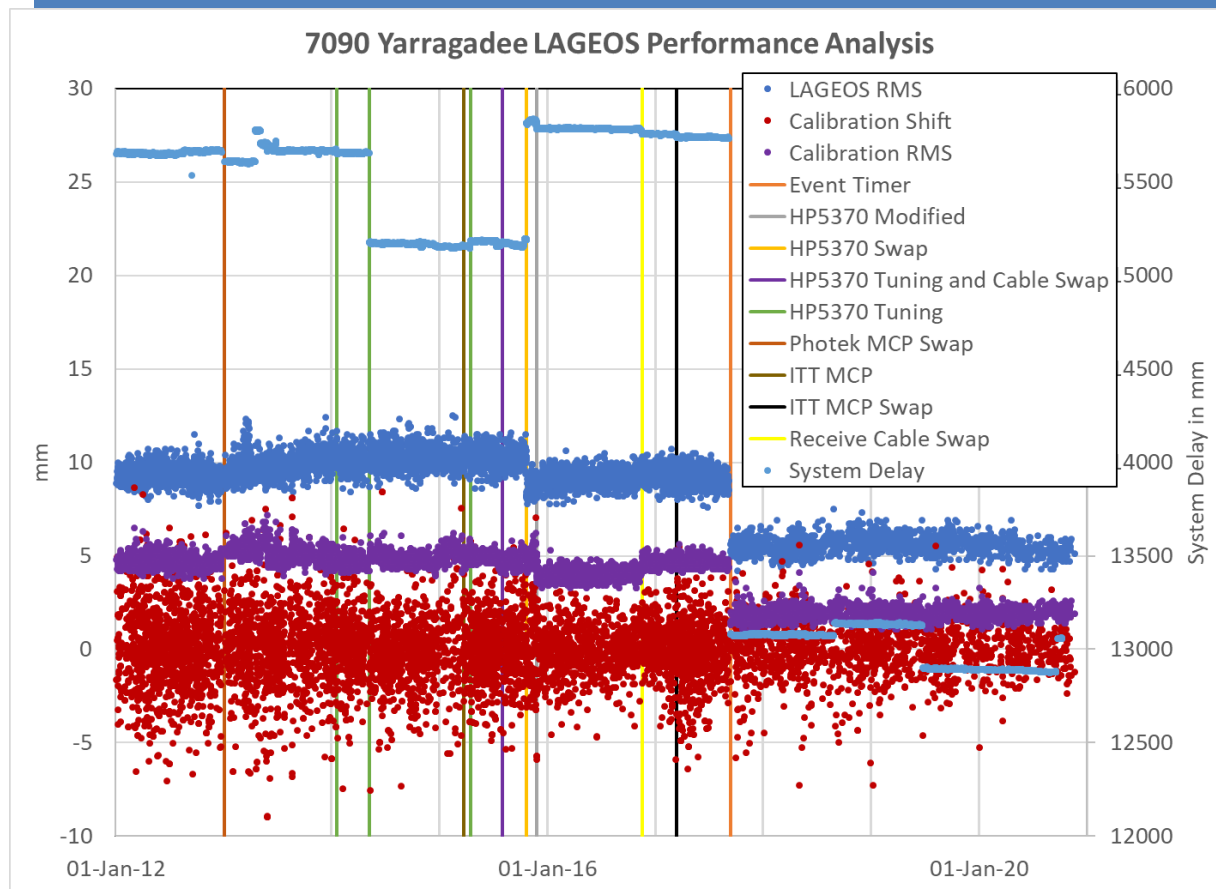
7090 Yarragadee System Characterization Tests



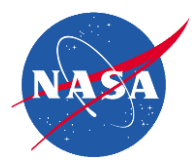
- ◆ Top Left: Minico Results (Note: June 2021 local survey results are pending)
- ◆ Top Right: Discriminator Test (few mm timewalk in the operational range)
- ◆ Bottom Left: PMT Test (<0.5 mm drift in the operational ITT PMT voltage range)
- ◆ Bottom Right: Laser Fire Rate (1.4 mm difference between 5 and 10 Hz)



7090 Yarragadee LAGEOS and LARES Performance

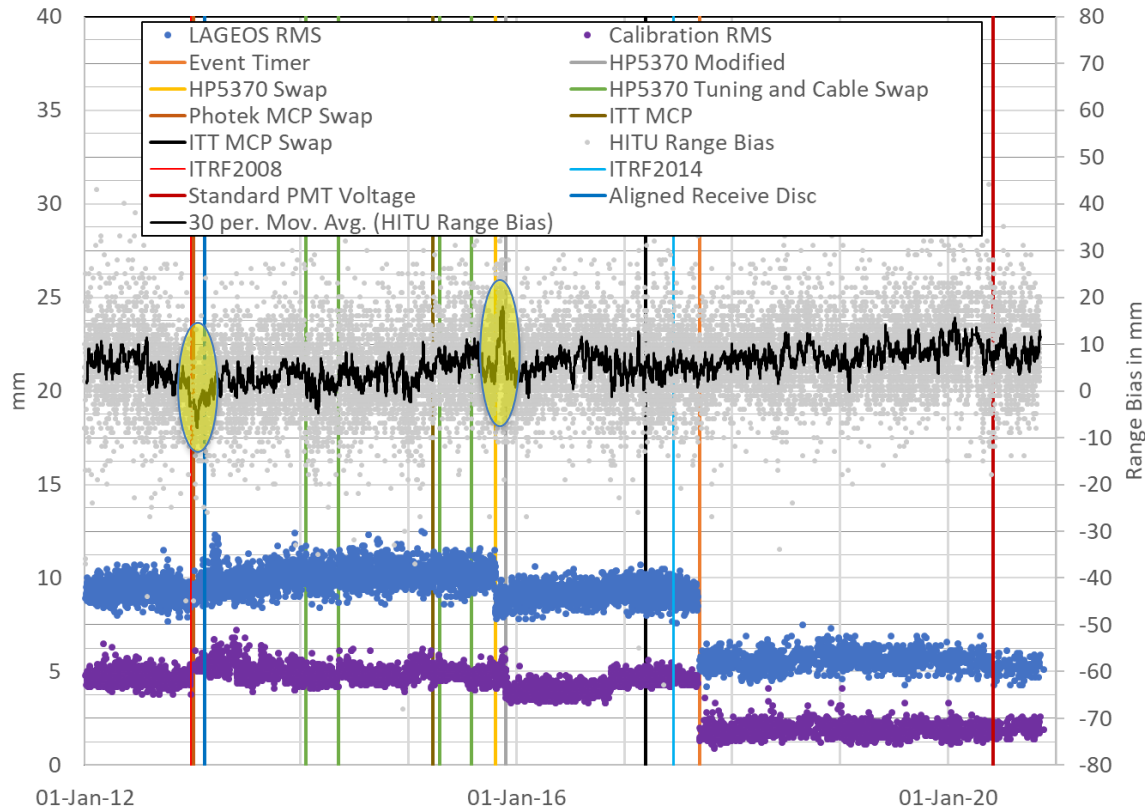


- LAGEOS and LARES Performance charts on the left and right; respectively.
- The charts are a time series of satellite single shot RMSs (light blue dots), calibration RMSs (purple dots), calibration shifts (red dots) on the left axes, and system delays on the right axes.
- The different vertical lines represent some of the system changes (mostly the receiver system, i.e. detector, time of flight device receive cables) based on the station history log. Most changes correlate to a change in either RMS, system delay or calibration shift.
- The satellite RMSs were reduced when the HP5370B was changed in late 2015, but the calibration RMSs initially increased until some maintenance (input termination resistors soldered in) and an optimization were performed, which reduced the calibration RMSs.

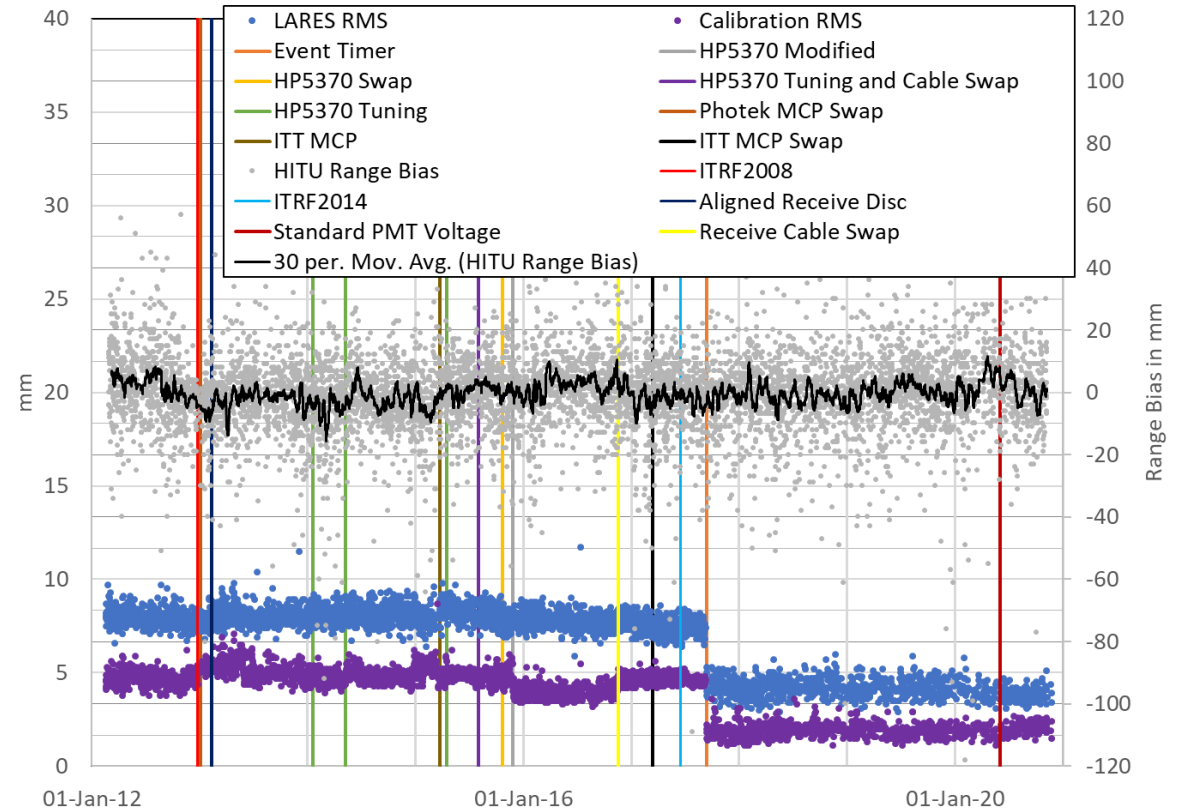


7090 Yarragadee LAGEOS and LARES Performance

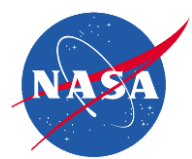
7090 Yarragadee LAGEOS Performance Analysis



7090 Yarragadee LARES Performance Analysis



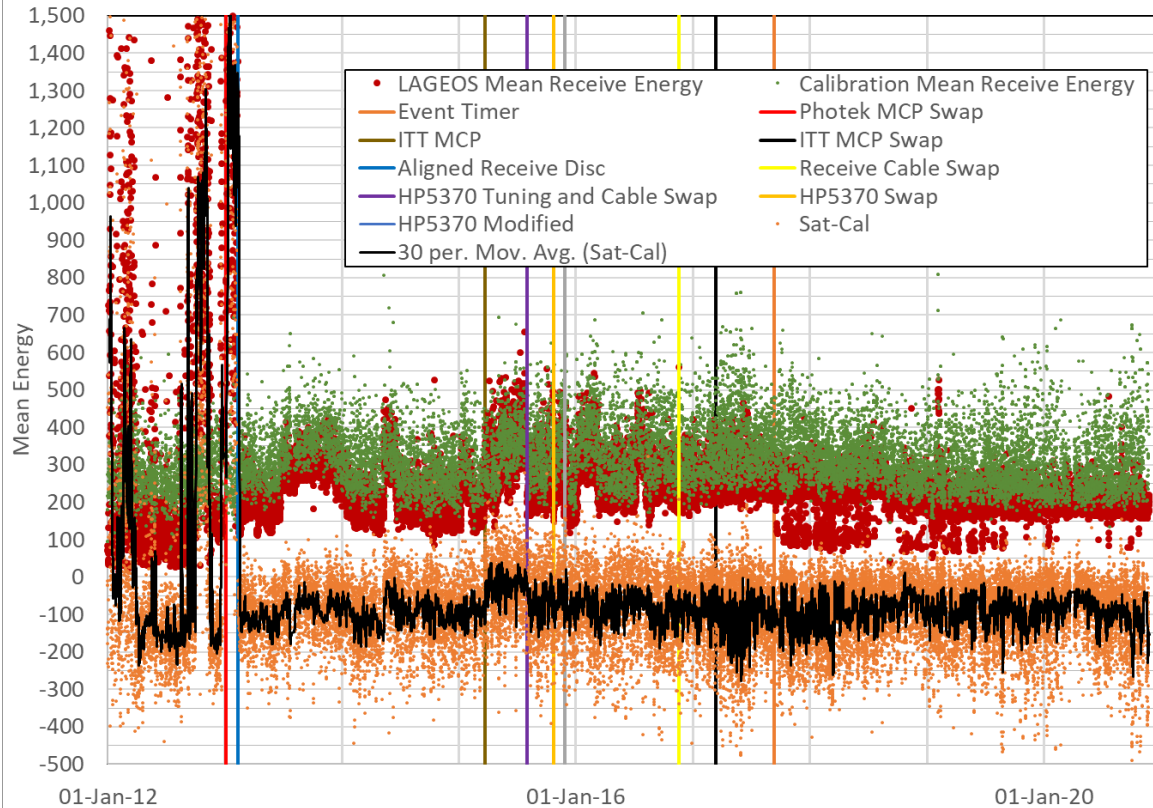
- ◆ LAGEOS and LARES performance on the right and left charts; respectively. HITU pass-by-pass range biases on the right axes (gray dots) with a 30-point moving average (black line) were added to the single shot RMSs on the left axes.
- ◆ There appears to be a noticeable spike LAGEOS-1 and -2 range biases in late 2012 and early 2013 prior to a receive discriminator alignment on 11-Feb-2013 and a spike in late 2015 before some HP5370B maintenance was performed on 26-Nov-2015. (See areas highlighted in light yellow on the left chart). Corresponding spikes in LARES range biases are not apparent.



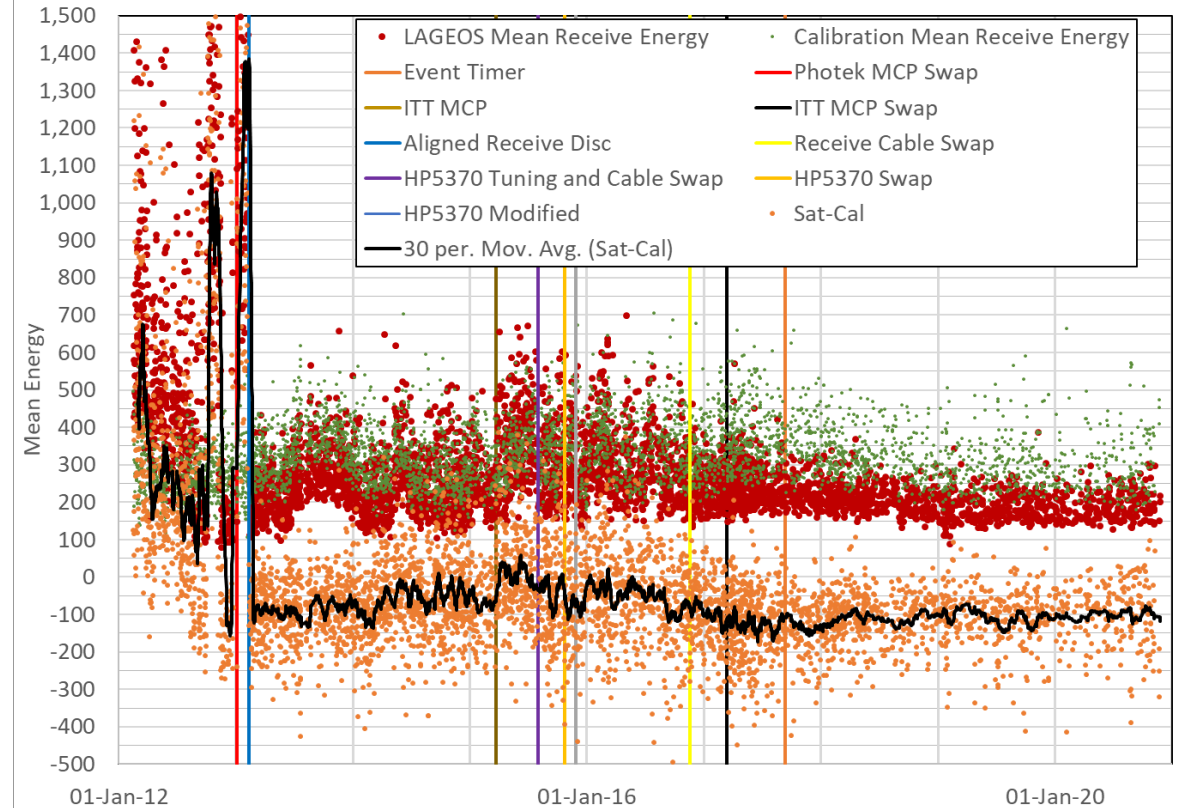
7090 LAGEOS and LARES Receive Energies



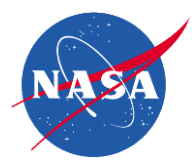
7090 Yarragadee LAGEOS Recieve Energies



7090 Yarragadee LARES Recieve Energies



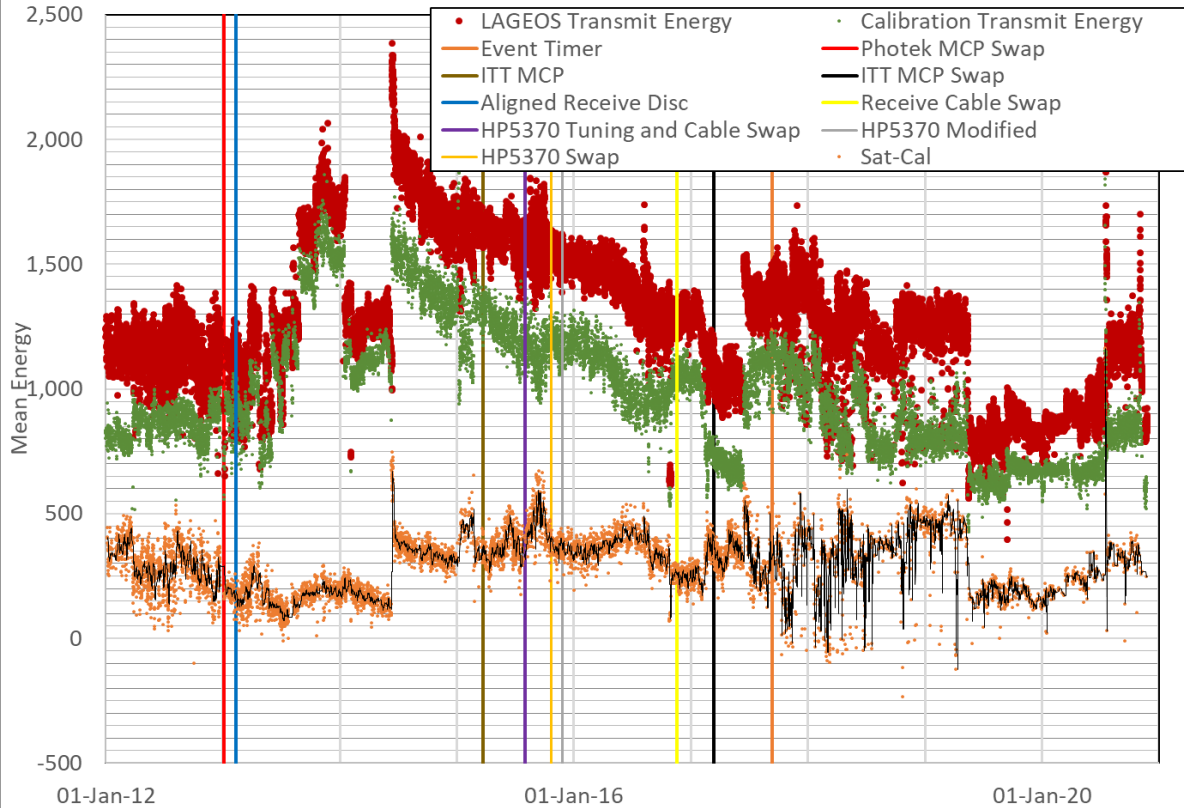
- ◆ Pass-by-pass mean receive energies for LAGEOS and LARES on the left and right chart; respectively. Satellite receive energies in **red dots** calibration in **green dots**, and the satellite minus calibration in **orange dots** with a 30-point moving average (**black line**).
- ◆ A discriminator alignment to minimize timewalk and eliminate a receive energy wrap around issue (5000 is added to negative receive measurements) was performed in early 2013.
- ◆ Post ETM installation, there is bimodal distribution of LAGEOS receive energies. The ETM enabled 10 Hz LAGEOS ranging at shorter ranges.



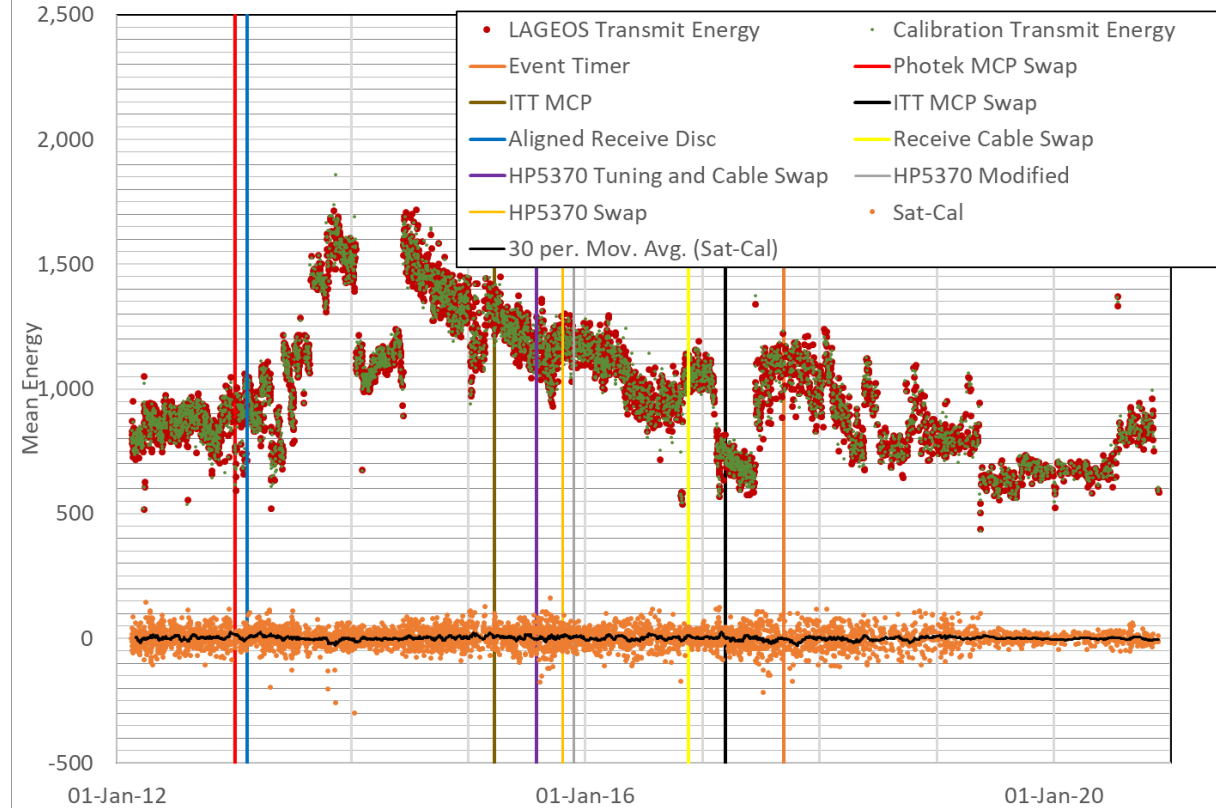
7090 LAGEOS and LARES Transmit Energies



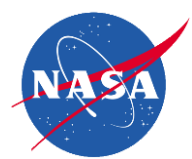
7090 Yarragadee LAGEOS Transmit Energies



7090 Yarragadee LARES Transmit Energies

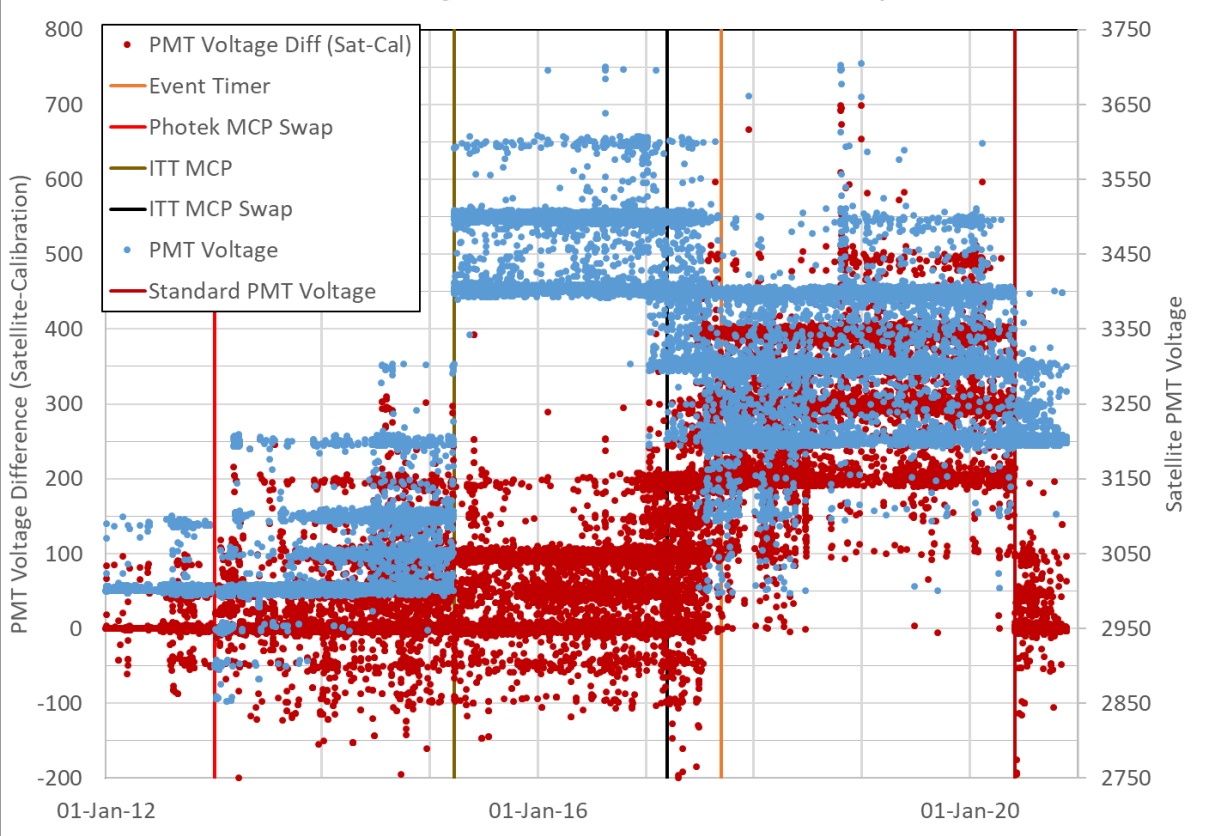


- ◆ Pass-by-pass mean transmit energies for LAGEOS and LARES on the left and right chart; respectively. Satellite in red dots calibration in green dots, and the satellite minus calibration in orange dots with a 30-point moving average (black line).
- ◆ Ten Hz ranging capability was added in 2009. Subsequently calibration data and LEO data was taken at 10 Hz while LAGEOS and HEO tracking remained at 5 and 4 Hz; respectively, due to HP5370B constraints. The event timer enabled tracking LAGEOS and the HEOs at 10 Hz and 5Hz; respectively, at the higher elevation angles (i.e. shorter ranges). The characteristics of the laser are not identical at 5 and 10 Hz and the reason why in this chart there is an offset between calibration and LAGEOS transmit energies. Some LAGEOS pass segments post event timer are taken exclusively at 10 Hz.

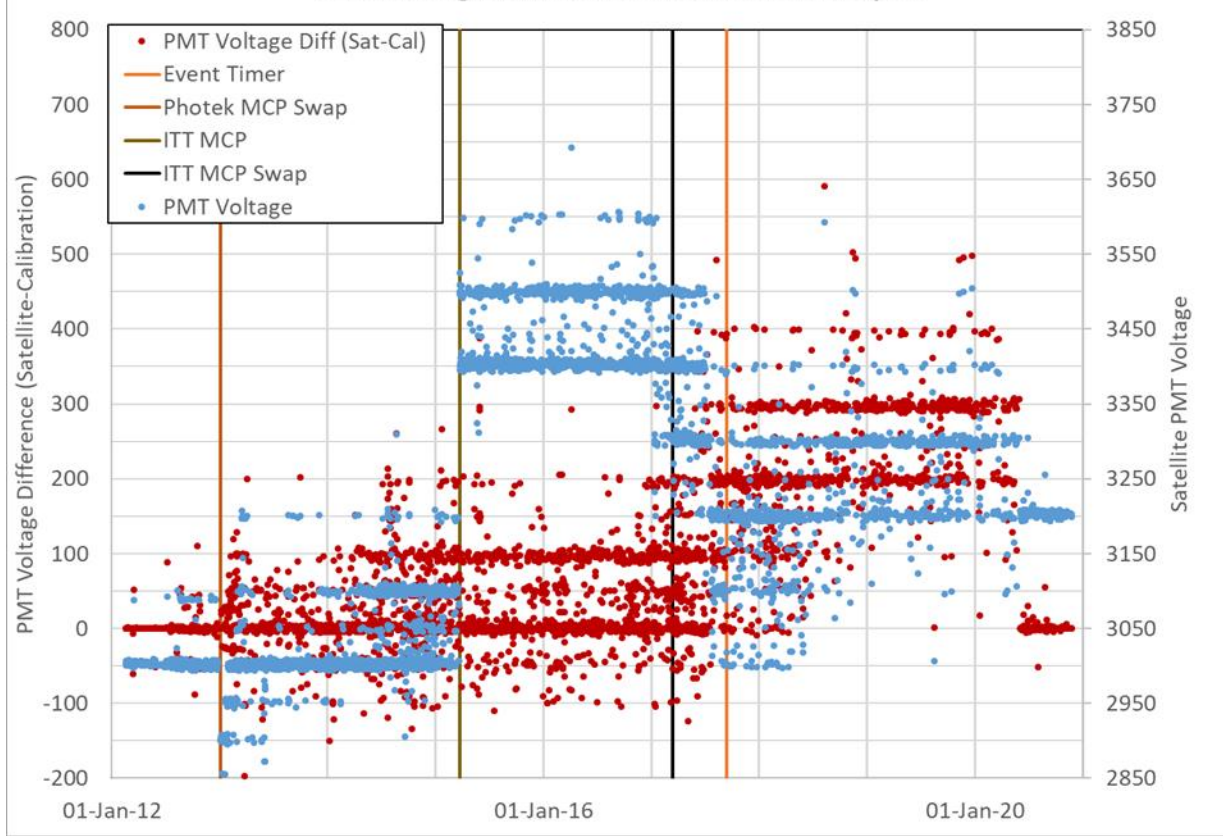


7090 Yarragadee LAGEOS & LARES PMT Voltages

7090 Yarragadee LAGEOS Performance Analysis

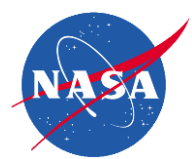


7090 Yarragadee LARES Performance Analysis

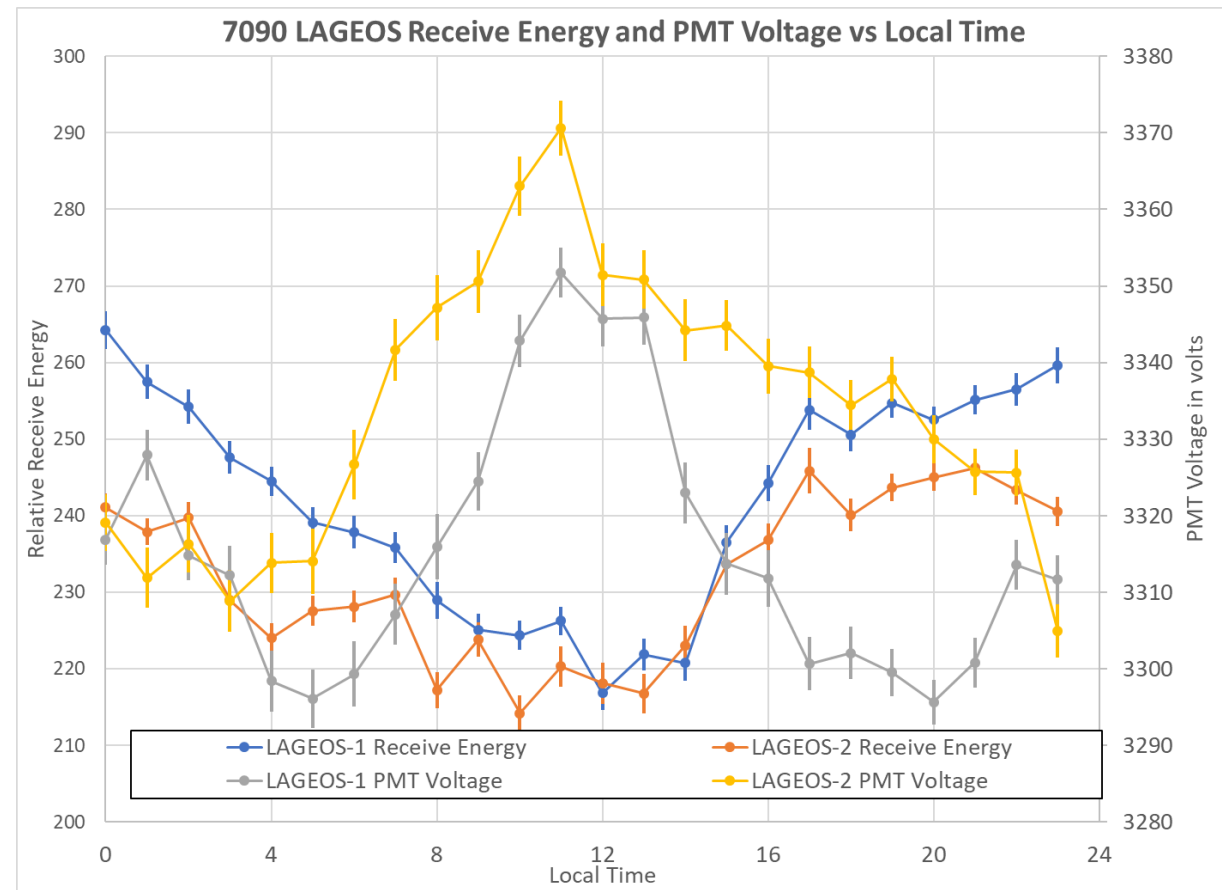
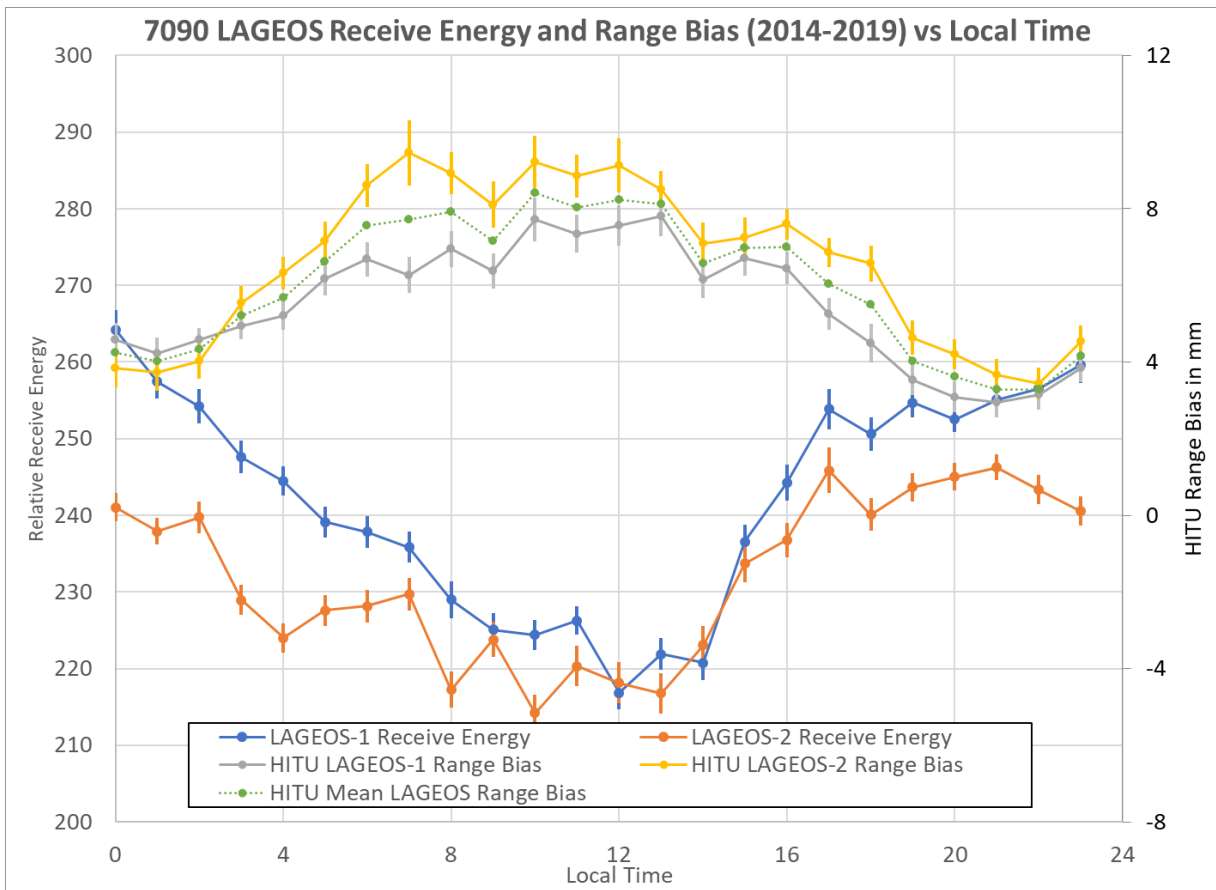


Plots of LAGEOS and LARES pass-by-pass PMT Voltages on the left and right charts. Satellite PMT voltages (**light blue dots**) are on the right axes and the differences in voltage between the calibration and the satellite (**red dots**) are on the left axes.

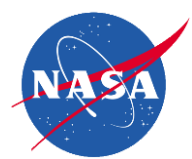
Starting on June 1, 2020, a new calibration procedure to minimize the voltage difference between the satellite and calibrations was implemented. Yarragadee has used two different MCP-PMTs (Photek and ITT) during these 8 years and have swapped both of them out with the same make and model.



7090 Yarragadee Diurnal Range Bias Analysis



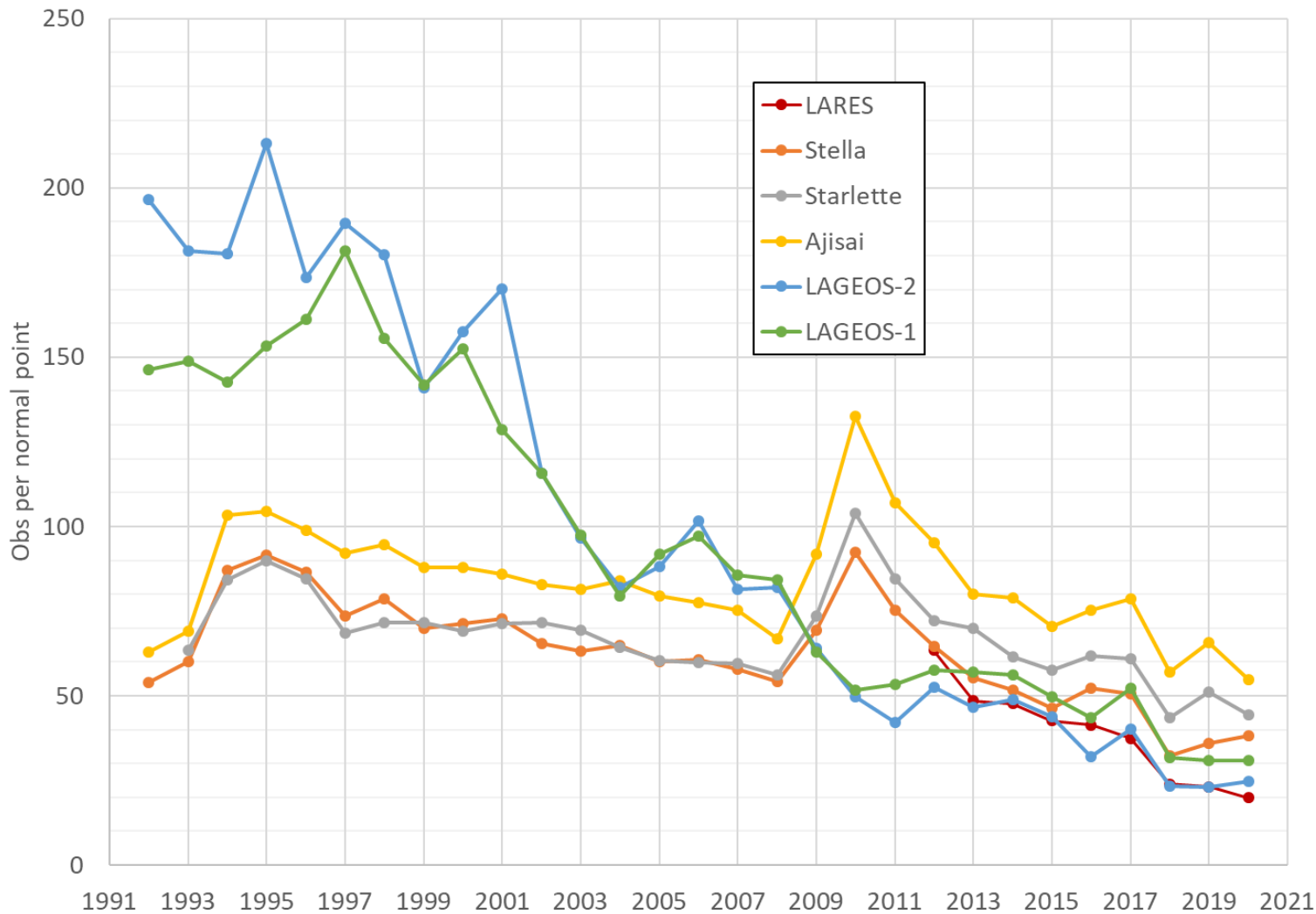
- ◆ The chart of on the left are mean LAGEOS range biases (right axes) and mean receive energies (left axes). The chart on the right are mean LAGEOS PMT Voltages (right axes) and mean receive energies (left axes)
- ◆ During daylight hours the LAGEOS range bias increases, while the receive energies decrease and the PMT Voltages increase. Weaker receive energies during the day may be a partial explanation of the increases in range bias.



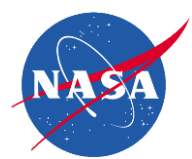
7090 Yarragadee Geodetic Data Yield Per NP



7090 Yarragadee Obs per Normal Point



- ◆ The geodetic fullrate data yield per normal point increased in late 2009 when the 10 pps upgrade was installed. The data yield per normal point has been on a steady decline since then in part due to satellite interleaving
- ◆ LAGEOS-2 and LAGEOS-1 Obs per normal point trends have flipped. LAGEOS-2 returns are now noticeable weaker than LAGEOS-1.



7090 Yarragadee Summary

- ◆ Two potential sources of systematic error were mitigated with
 - the event timer and
 - improved PMT calibration procedures starting in June 2020
- ◆ Receive and Transmit Discriminator timewalk; the differences in distribution of receive and transmit energies between satellite and calibration data; and the continuing reduction in obs per normal point are potential sources of system error.
- ◆ There appears to be a spike in LAGEOS range biases
 - before the receive discriminator was re-aligned on 11-Feb-2013 and
 - before the HP5370B was modified and tuned on Nov 26, 2015
- ◆ The MINICO results between targets G and B have been inconsistent since Jan 2020. Is one of these 2 targets moving? Will the June 2021 local survey improve the current agreement between all three targets.

Analysis Walking Committee

- Consider systematic errors caused by discriminator time walk
- Membership dynamic: volunteers and resignations readily accepted
- Initial exchanges between PD, VH, TO, TV, SR
- Assessing the amount and accessibility of time walk modelling data

Wiener Filter Metrics QCB Report

1. Automated system configuration scanning in progress

- GANTT – graph visualization
- retrieval of electronic data processing parameters (like constant fraction discriminator (CFD) parameters)

2. Data modeling for Wiener Filter transfer function identified four configurations used by ILRS core stations, which require different modeling strategies in terms of reference point:

a) Single Photon Data from APDs:

- data can be taken as is
- residual time walk effects will be modeled from return rate
- reference will be the mean of the reflectivity (transfer) function as published in “Upgraded modelling for the determination of centre of mass corrections of geodetic SLR satellites: impact on key parameters of the terrestrial reference frame” or further refined models.

b) MCP-PMT (ITT) multiphoton systems:

- reference will be modeled from CFD parameters and laser pulse shape constant fraction value published in the site logs
- additional parameters (e.g. walk compensation for Tennelec CFDs) could be modeled using time walk measurements to zero signature calibration targets (is there a standardized data base for time walk measurements within the ILRS ?)

c) CSPAD systems:

- the reference seems to be unclear. Literature says CSPAD takes the first photon arriving, BUT what is the distance from the COM it comes from ?

d) PMT (Hamamatsu) (e.g. Zimmerwald) and novel MCP-PMT's (photek, as used in WLRS for 532nm) with novel discriminator:

- for single photon operation reference point is the mean of the transfer function
- time walk measurements required for modeling higher return rates

Stefan asks:

Is there a standardized data base for time walk measurements?

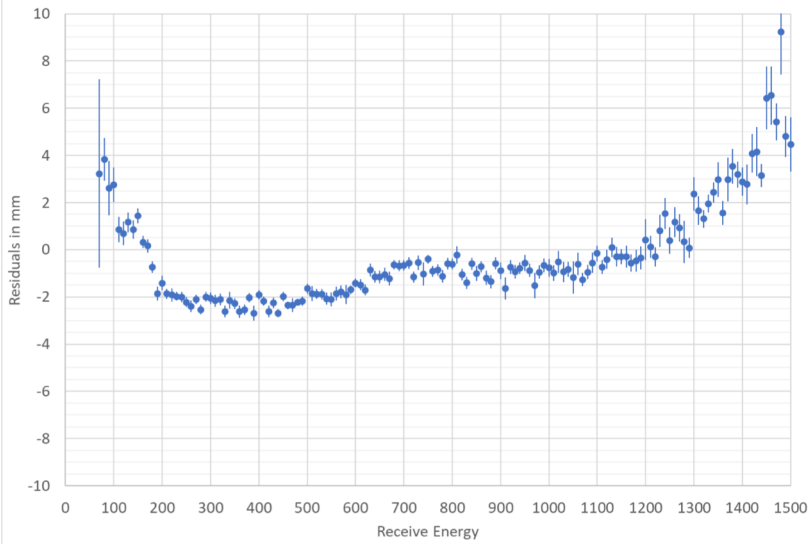
Answer:

Regular recent calibrations at some NASA stations are readily available since 2007

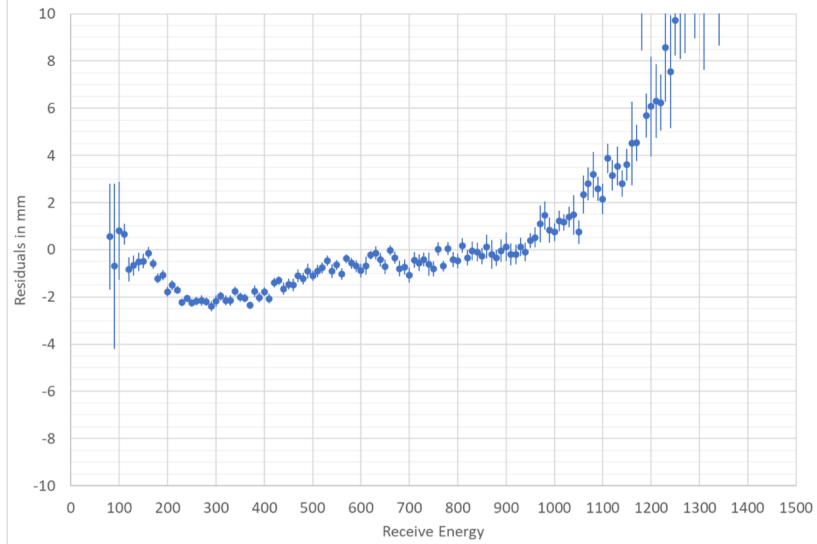
Van sent Stefan some historical monthly discriminator results from Mob7 in 2018 and 2019

7105 GODL Receive Discriminator Tests

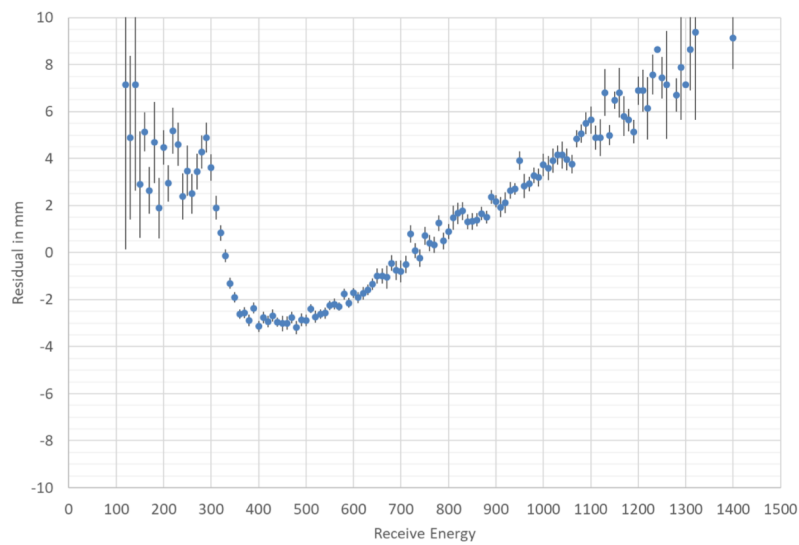
7105 GODL Discriminator Test (Aug-2018)



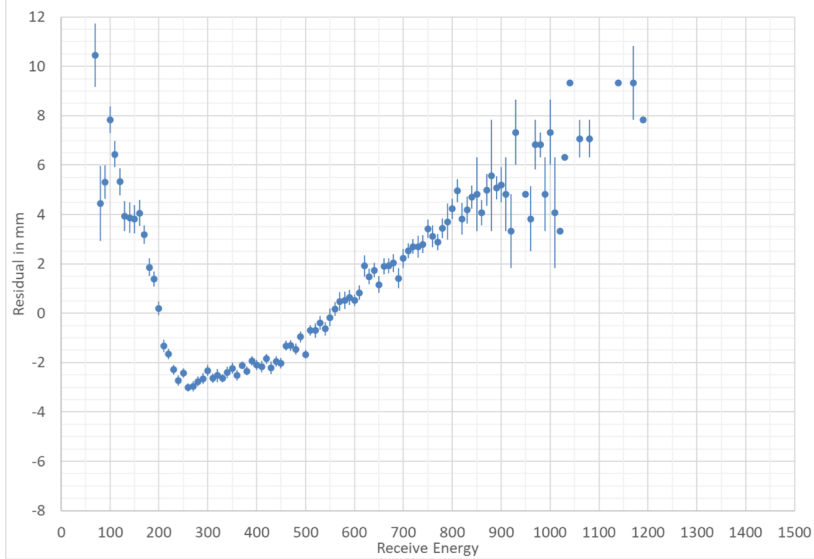
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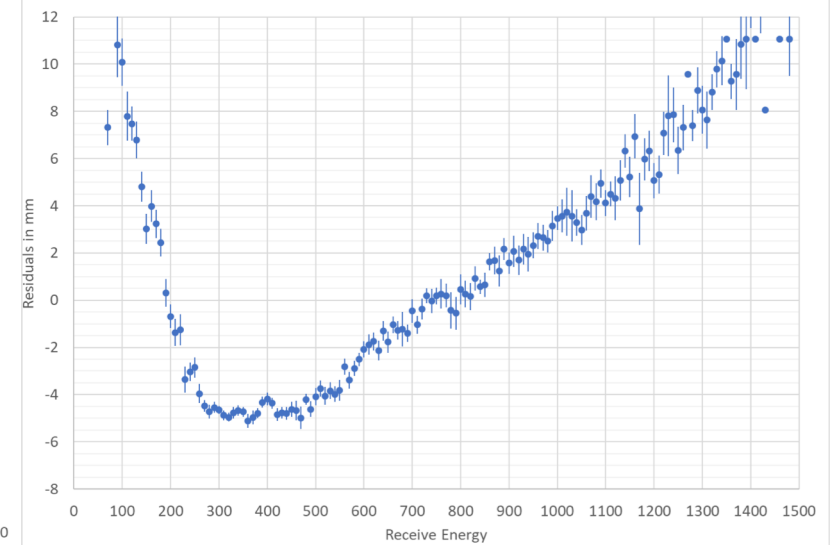
7105 GODL Discriminator Test (Nov-2018)

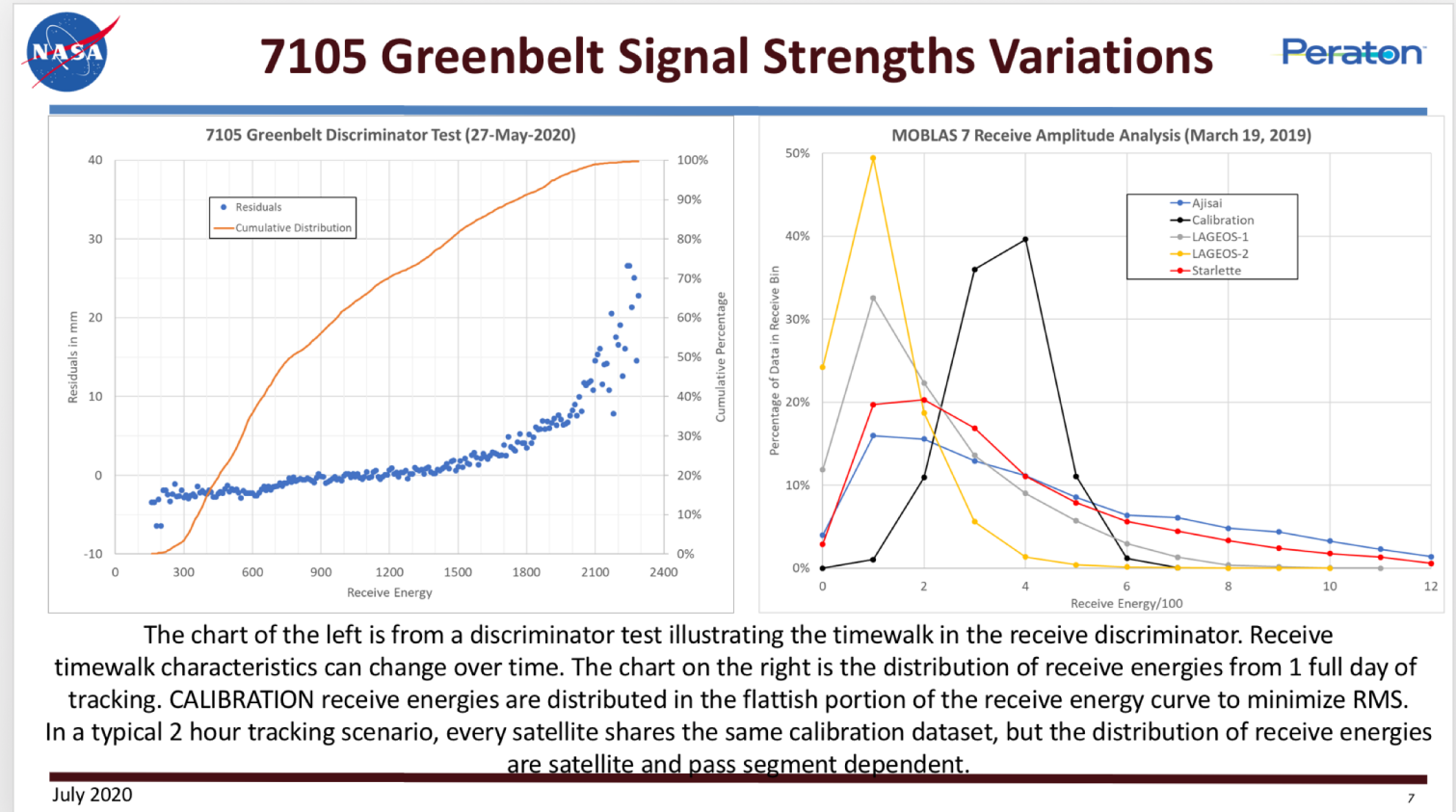
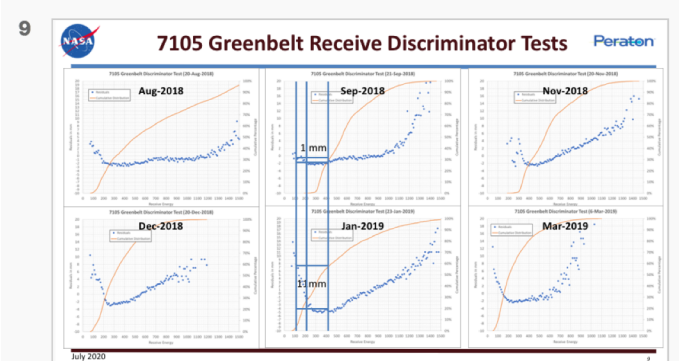
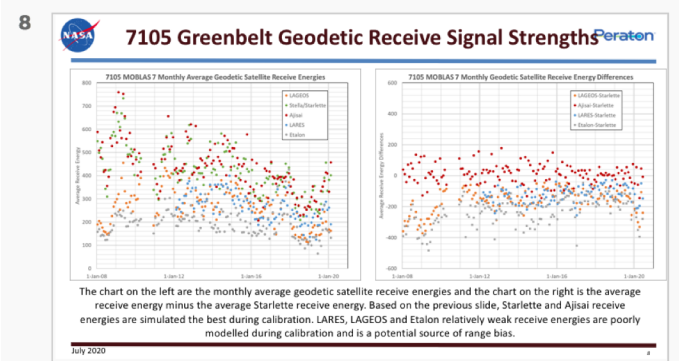
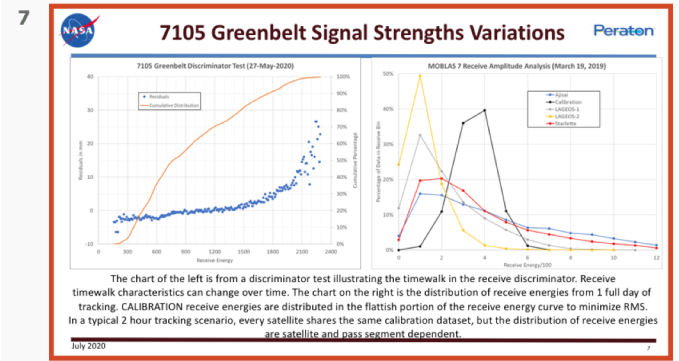


7105 GODL Discriminator Test (Dec-2018)



7105 GODL Discriminator Test (Jan-2019)



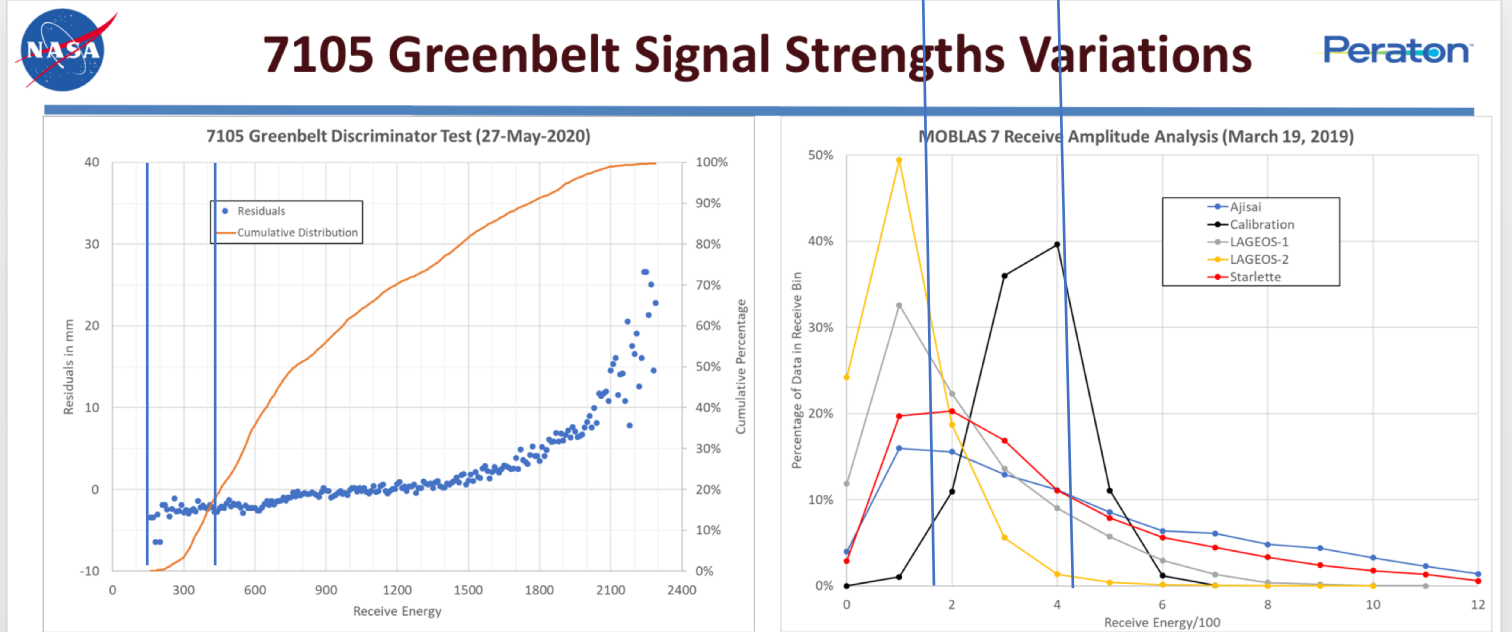
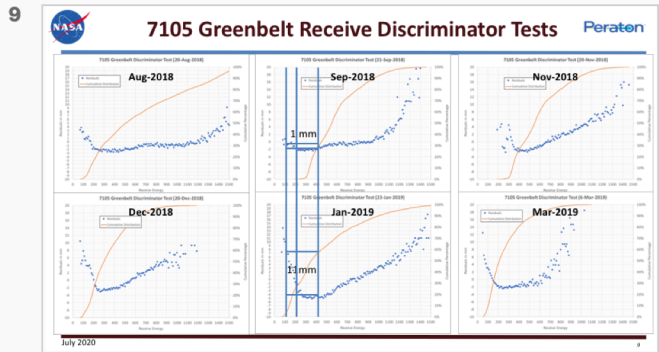
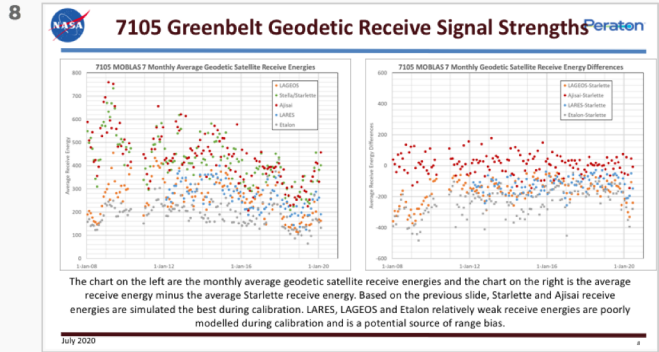
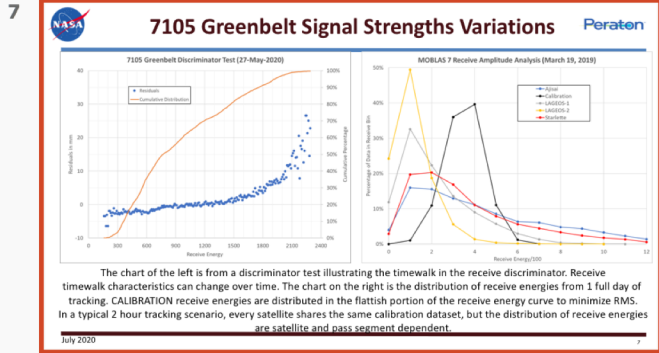


July 2020

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RECEIVE ENERGIES SAT 150 CAL 400

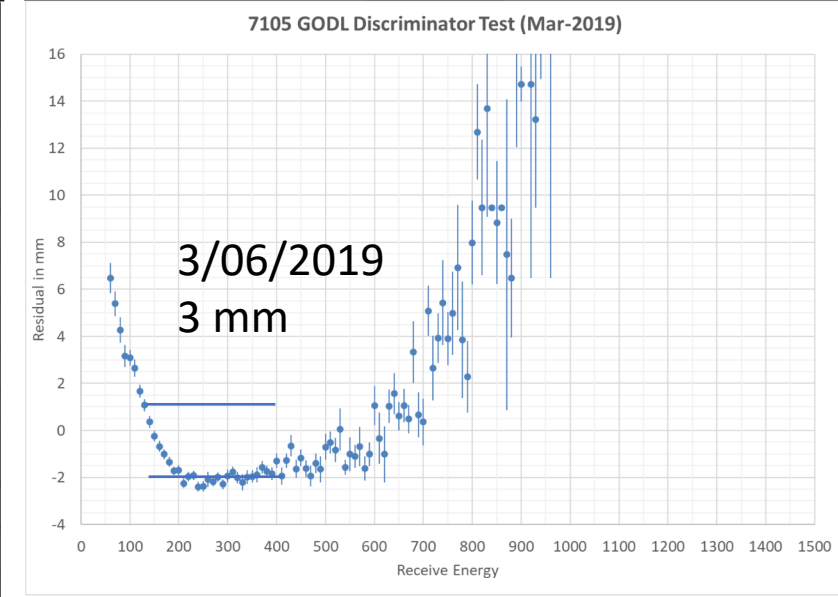
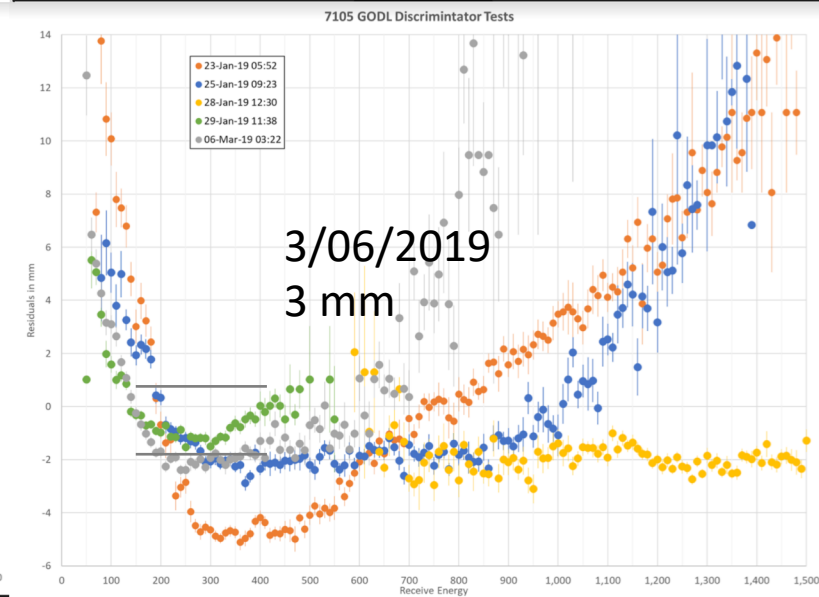
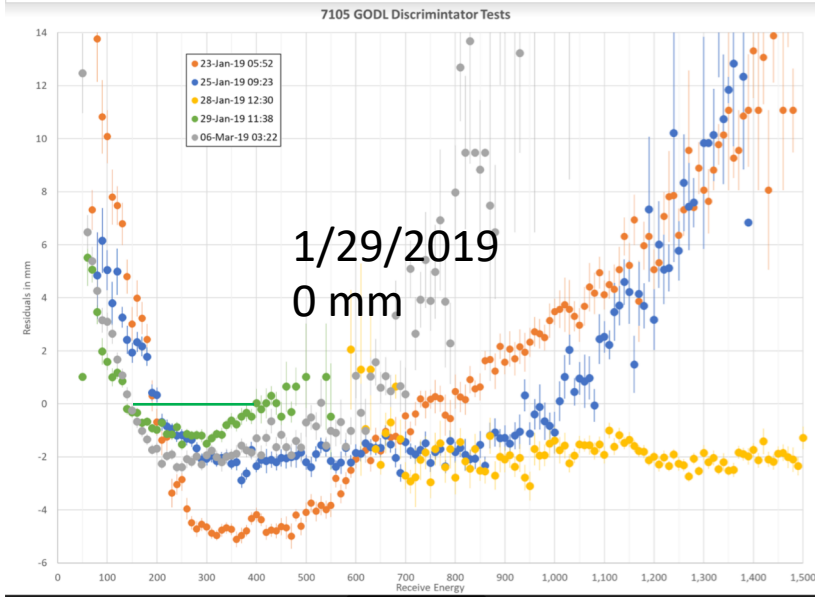
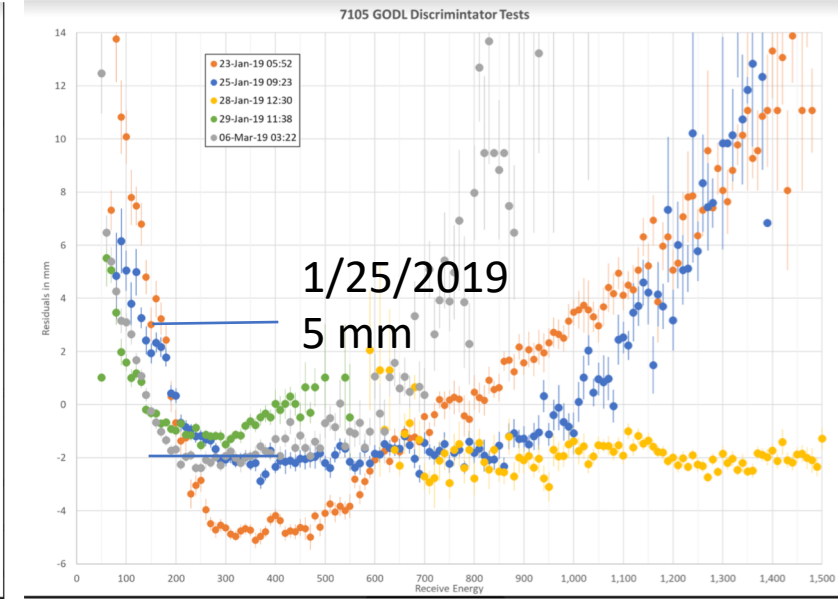
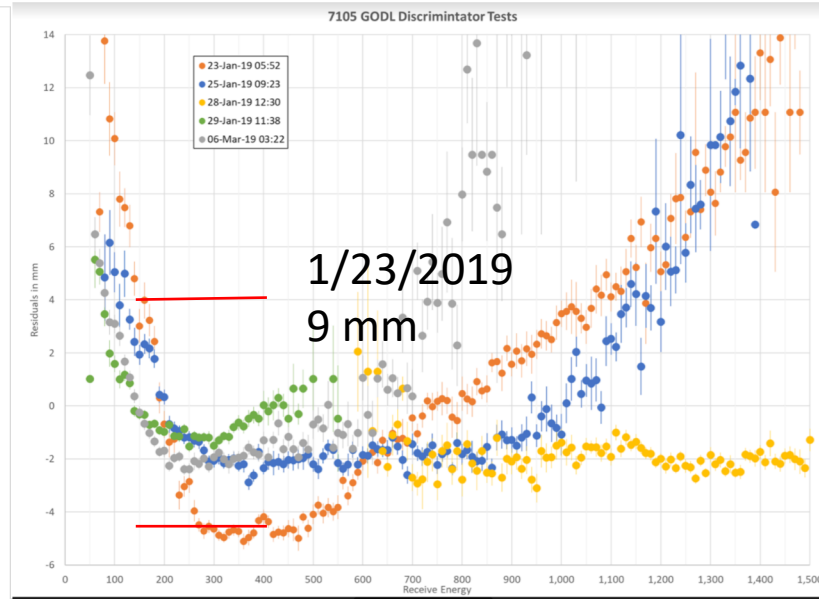
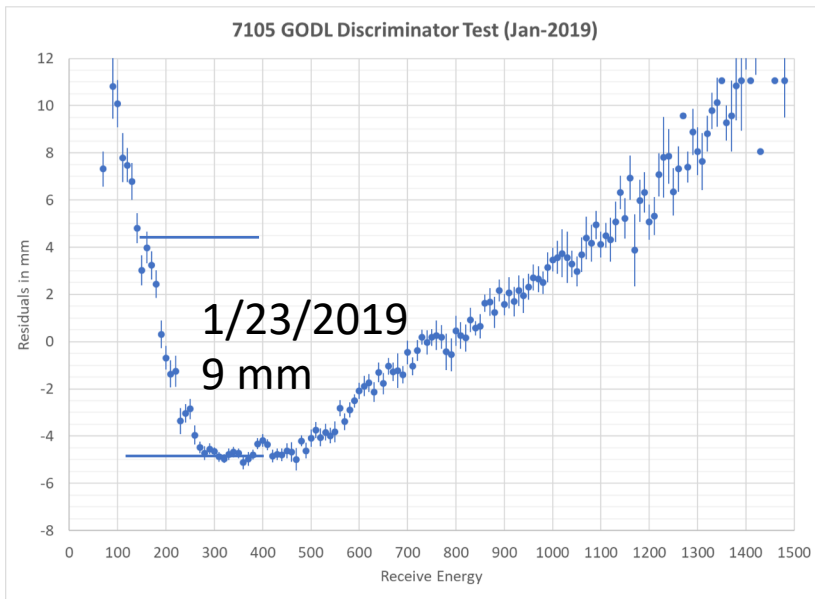


The chart of the left is from a discriminator test illustrating the timewalk in the receive discriminator. Receive timewalk characteristics can change over time. The chart on the right is the distribution of receive energies from 1 full day of tracking. CALIBRATION receive energies are distributed in the flattish portion of the receive energy curve to minimize RMS. In a typical 2 hour tracking scenario, every satellite shares the same calibration dataset, but the distribution of receive energies are satellite and pass segment dependent.

July 2020

7

1/23/2019 to 3/06/2019



Conclusion

Range-dependent range biases at MOB7
between 1/23/2019 and 3/06/2019

vary from 0 mm to 9 mm

Subject: [EXTERNAL] Fwd: MLRO and MOB7

Date: Wednesday, October 6, 2021 at 10:27:53 AM Eastern Daylight Time

From: Pearlman, Michael R. (Mike)

To: Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC]

Claudia,

Here is the contribution from Tom Oldham.

Mike

----- Forwarded message -----

From: Husson, Van (PERATON) <vhusson@peraton.com>

Date: Wed, Oct 6, 2021 at 9:00 AM

Subject: RE: MLRO and MOB7

To: Dunn, Peter (PERATON) <pdunn@peraton.com>

Cc: Mike Pearlman <mpearlman@cfa.harvard.edu>, Oldham, Tom (PERATON) <toldham@peraton.com>

Hi Peter,

See answers below in **red**. I'm not sure I understand the last question.

Regards, Van

From: Dunn, Peter (PERATON) <pdunn@peraton.com>

Sent: Tuesday, October 5, 2021 6:34 PM

To: Oldham, Tom (PERATON) <toldham@peraton.com>; Husson, Van (PERATON) <vhusson@peraton.com>

Cc: Mike Pearlman <mpearlman@cfa.harvard.edu>

Subject: MLRO and MOB7

Tom, Van

Tom mentioned today that MLRO employs a discriminator which requires correction.

Is that 'amplitude correction'? **Yes**

The MLRO site log lists CFD,Tennelec,TC454, just like the NASA systems.

Is there any other indication in the MLRO site log of a discriminator configuration different from NASA?

In the YES or NO entries for Amplitude Measurement/Return-Rate Controlled,

MOB7 is always YES/YES, MLRO always YES/NO (except for one NO/blank?).

Does the MOB7 return rate control reduce the need for correction? Return rate is not controlled in MOBLAS-7 or any of the NASA Systems, the site logs are incorrect, if the receive signal is too strong on certain LEO satellites the operators may add attenuation (ND filters) to lower the receive energy.

These may just be reporting issues which beg the real question:

Why shouldn't we treat the data just like MLRO?

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Date: Wednesday, October 6, 2021 at 3:09:07 AM Eastern Daylight Time

From: José Carlos Rodríguez via ilrs-qcb

To: Husson, Van (PERATON), ILRS QCB QCB

Hi, Van

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> *Sent:* Tuesday, October 5, 2021 12:57 PM

> *To:* Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND
> APPLICATIONS INC] <claudia.c.carabajal@nasa.gov>

> *Cc:* Husson, Van (PERATON) <vhusson@peraton.com>; Mike Pearlman
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> Claudia.

>

> --

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> Claudia C. Carabajal

>

> Research Scientist SME/HBG Group Manager

>

> Secretary, ILRS Central Bureau
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> Mail Code 61A – Geodesy and Geophysics Laboratory
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> Cell: (301)602-7787 - Fax: (301)614-6522
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>

Subject: [ilrs-qcb] Re: [EXTERNAL] Re: Can you send me your slides for the ILRS QCB meeting - presented on 10/05/21?
Date: Wednesday, October 6, 2021 at 10:42:12 AM Eastern Daylight Time
From: Husson, Van (PERATON) via ilrs-qcb
To: José Carlos Rodríguez
CC: ILRS QCB QCB
Attachments: image003.png, image004.png, image005.png

Hi Jose,

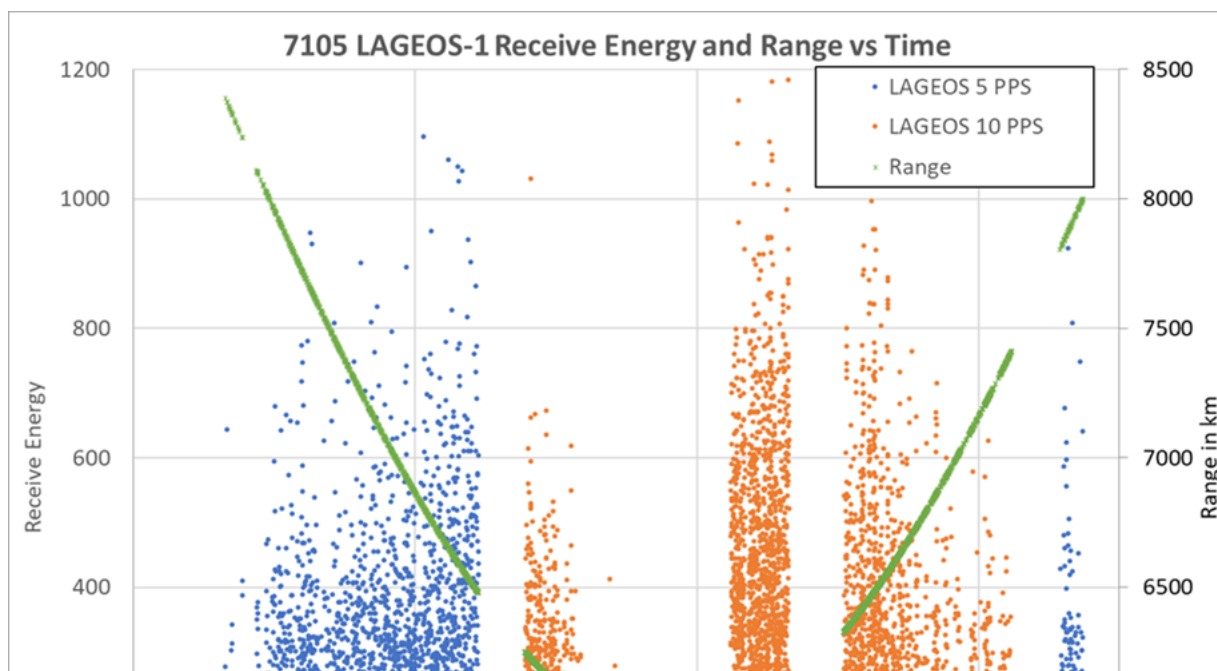
Your understanding of discriminators is better than mine.

Back in the 1980's, I supervised the fullrate NASA SLR data processing, analysis, and quality control operation. On every pass that we processed, we would generate plots of receive energy versus time. By looking at hundreds of these plots from LAGEOS-1, the lowest amplitudes were equally distributed throughout the pass. But the strongest returns increased with elevation angle. The exception to this is very high elevation passes (max elevations >80 degrees), the returns get weak at the satellite approaches point of closest approach.

I can take an action to do the same analysis that I did for Monument Peak for Greenbelt to see if the results are similar. There is a dilemma with the MOBLAS systems tracking LAGEOS at 10 Hz vs 5 Hz and the receive energy measurement. Note: The event timer enabled ranging to LAGEOS at 10 Hz based on the satellite range. When ranging at 10 Hz, the receive energies are offset by ~100 units of receive energy. The transmitted pulse shape may be different between 5 and 10 Hz, but the receive discriminator threshold does not change. See plots below that I presented at a QCB meeting in 2020 from a 80+ degree pass.

If the Greenbelt results are similar, we could perhaps reprocess some fullrate data from both stations in order to regenerate the normal points.

Thanks, regards, and stay safe, Van



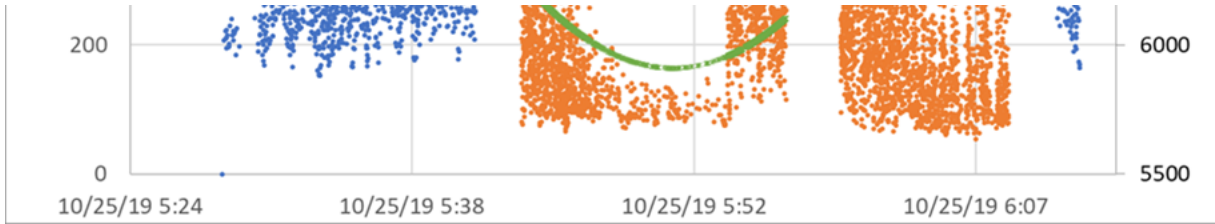


Figure 1: Greenbelt (7105) LAGEOS-1 fullrate receive energies and range versus time

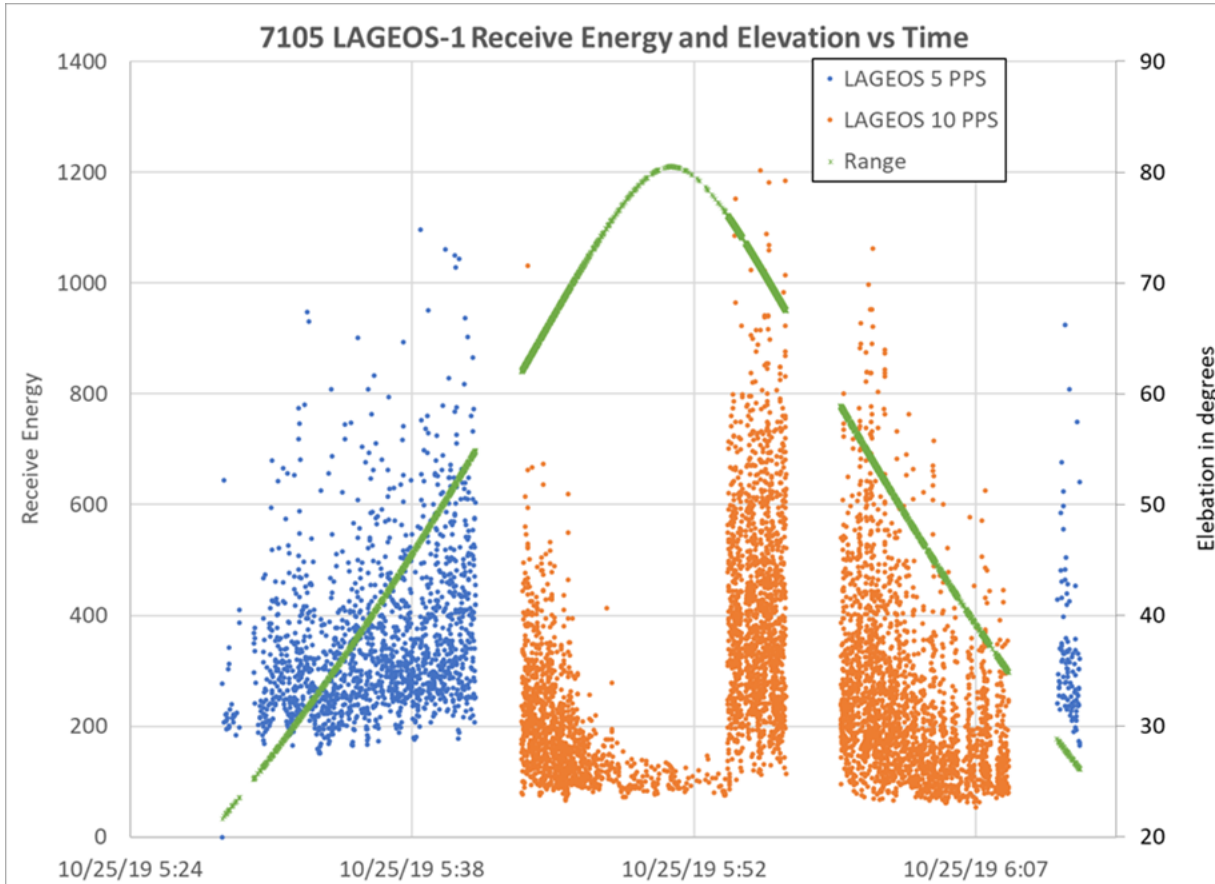
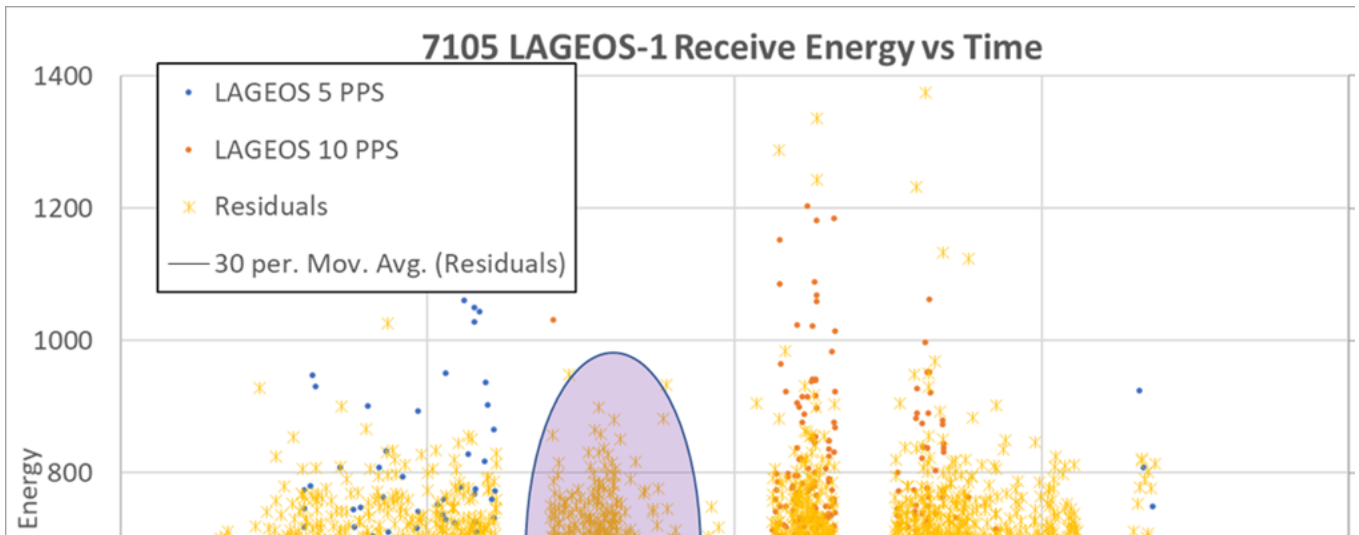


Figure 2: Greenbelt (7105) LAGEOS-1 fullrate receive energies and elevation versus time



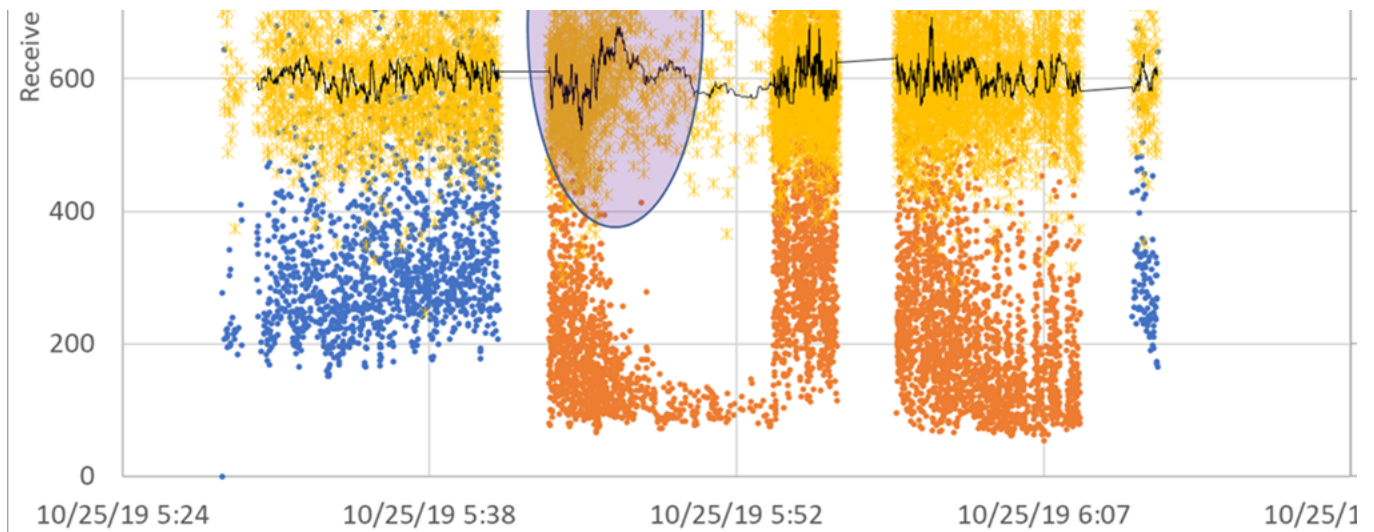


Figure 3: Greenbelt (7105) LAGEOS-1 fullrate receive energies and residuals versus time

-----Original Message-----

From: José Carlos Rodríguez <jc.rodriguez@oan.es>

Sent: Wednesday, October 6, 2021 3:09 AM

To: Husson, Van (PERATON) <vhusson@peraton.com>; ILRS QCB QCB <ilrs-qcb@lists.nasa.gov>

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> Lanham, MD 20706
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> www.ssaihq.com
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> <<https://gcc02.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.ssaihq.com%2F&data=04%7C01%7Cilrs-qcb%40lists.nasa.gov%7Ccc999cc26d28406a512b08d988253ae6%7C7005d45845be48ae8140d43da96dd17b%7C0%7C0%7C637690515883061022%7CUnknown%7CTWFpbGZsb3d8eyJWlloiMC4wLjAwMDAiLCJQIjoiV2luMzliLCJBTil6lk1haWwiLCJXVCi6Mn0%3D%7C1000&sdata=M0igM5le6RGY5tHuwCrxgLJFxmNixp6Bx2DiywMRRYA%3D&reserved=0>>
>