LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO –
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Technical Note	LIGO-T030080-00-D	04/16/2003
LSC timing performance during the Second Scientific Run (S2)		
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Introduction

During the Second Science Run (S2), we measured the offset[1] of the DAQ time stamp for the LSC channels relatively to the GPS second tic at the three observatories. In this document we provide the time evolution of these offsets for the three LSC systems.

Among the three, the H1 timing was the most stable. H2 was proven to be less stable, showing a few small jumps during the run. The L1 timing was even more irregular. There were large number of jumps and cases of prolonged timing problems (e.g. lightning or GPS antenna induced).

Sometimes the DMT machines had to be rebooted from time to time leading to short missing segments.

The following pages speak for themselves.

For each interferometer, we report[2]

- the minute trend for the entire S2 duration
- the distribution (histogram) of the timing measurements for each significant time segment
- a Gaussian fit and its parameters for the core of each histogram
- a table summarizing the nominally valid offsets (from the fit) for each distinct time interval

Summary of results[3] [4]:

- **LIGO Livingston 4K LSC timing for the S2 run:**
  - Nominal offset : 5 ± 5 μs (except from two short segments with 14 ± 2 μs)

- **LIGO Hanford 4K LSC timing for the S2 run:**
  - Nominal offset : 2 ± 1 μs

- **LIGO Hanford 2K LSC timing for the S2 run:**
  - Nominal offset : 2 ± 1 μs

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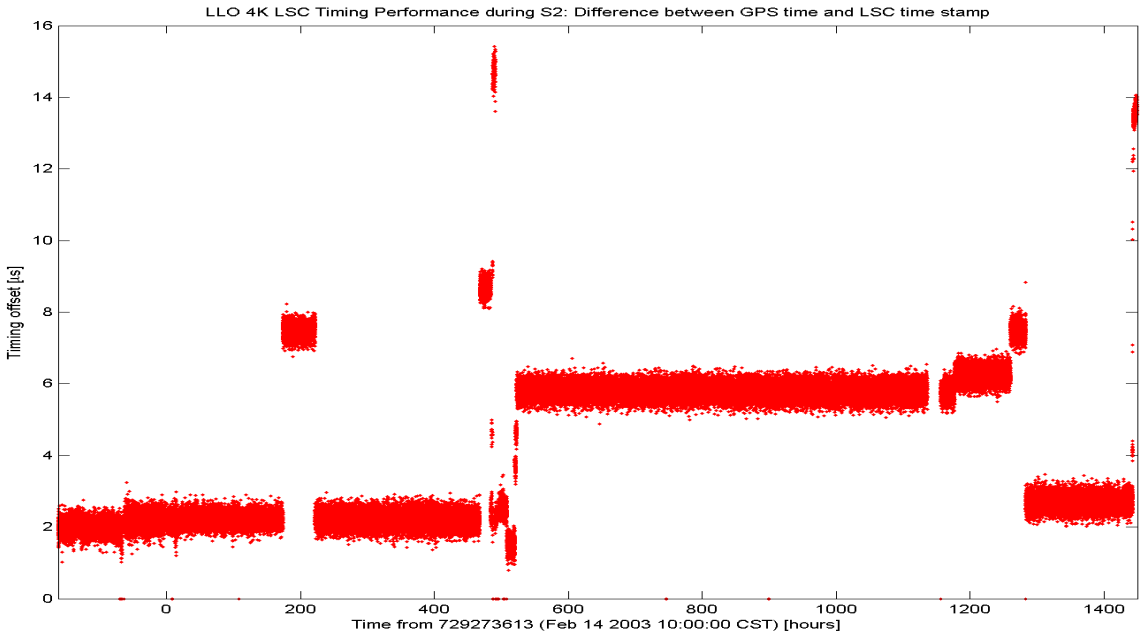
[1] The quoted values are the measurements of the offset of the DAQ time stamp relatively to the GPS second tic. The timestamp of the data refers to the ADC input without any input filters.

[2] In particular, we do not measure the arrival time of a GW wave, the DAC output or the time of the calibration excitations on the test masses. The first has to take into account the delay in the electronics at the AS port as well as the analog filtering, the second has to take into account the delay in the digital system sending data to the end station DSCs, and the third has to add the analog output filtering as well as the characteristics of the current drive and the pendulum transfer function.

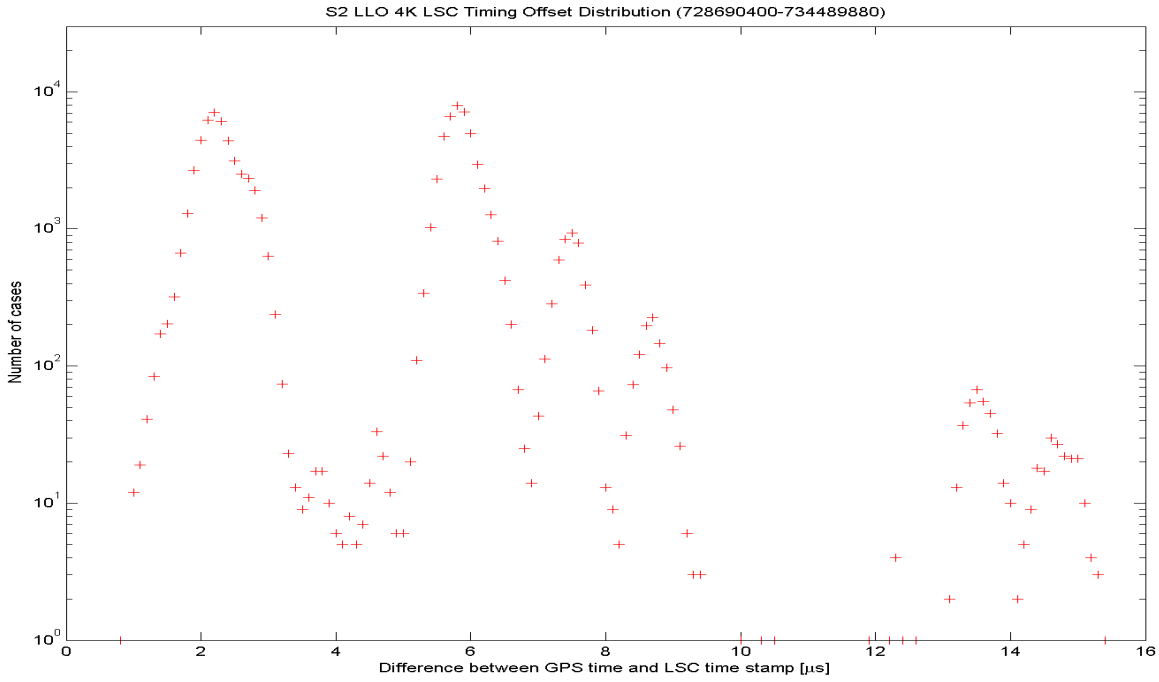
[3] The ***+ sign*** in front of the offset means that the DAQ time stamp second mark is ***after*** the GPS second tic.

[4] Please note that the quoted errors are statistical in nature and the systematic errors are not included.

LIGO Livingston 4K interferometer LSC timing



LIGO Livingston 4K interferometer LSC time offset during S2



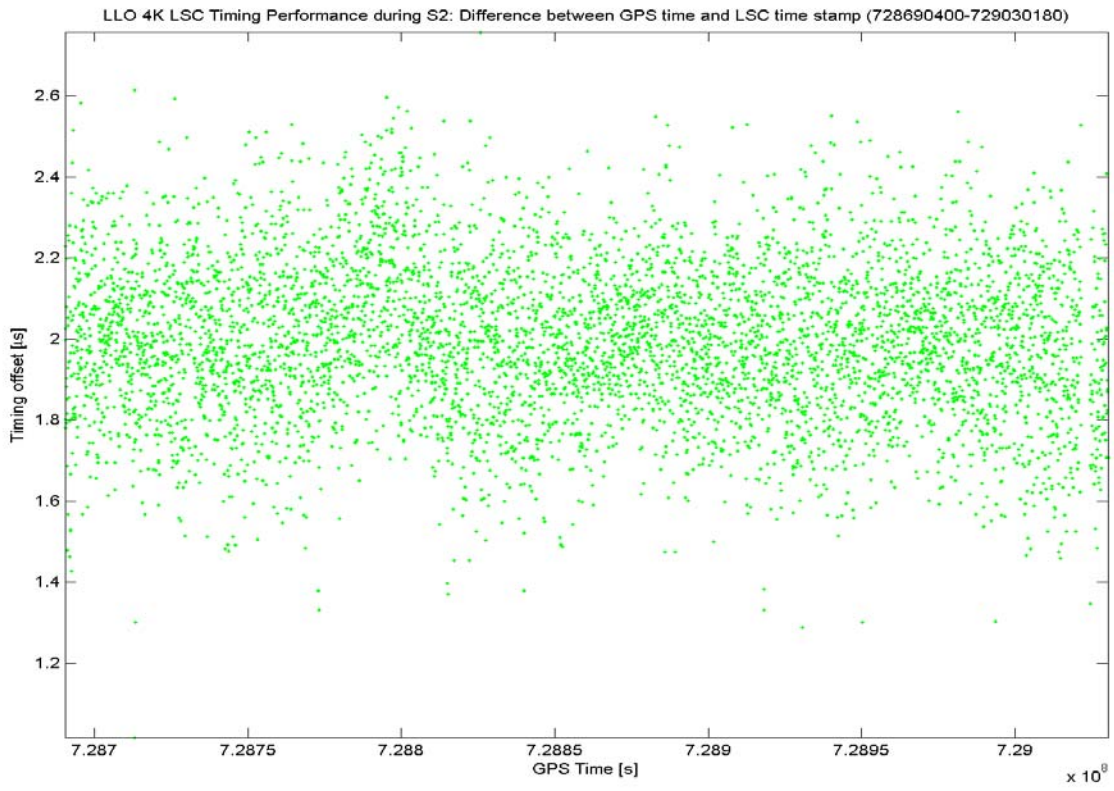
LIGO Livingston 4K interferometer LSC timing histogram

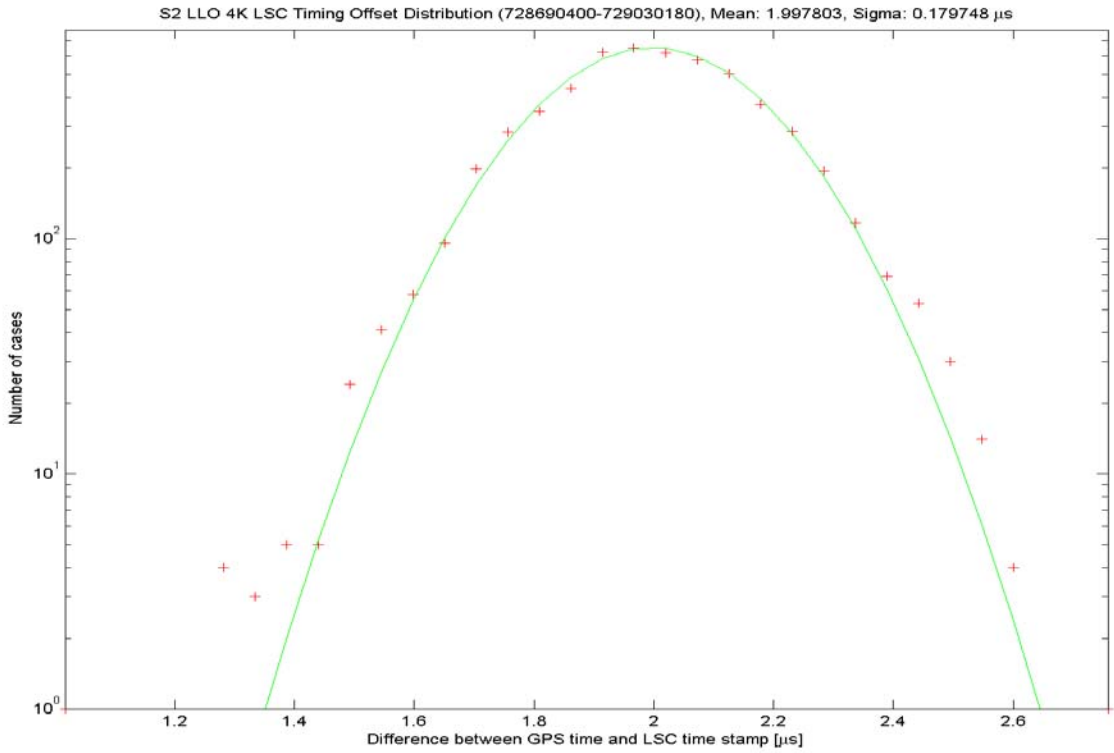
The nominal LLO 4K LSC timing offsets are listed in Table 1.

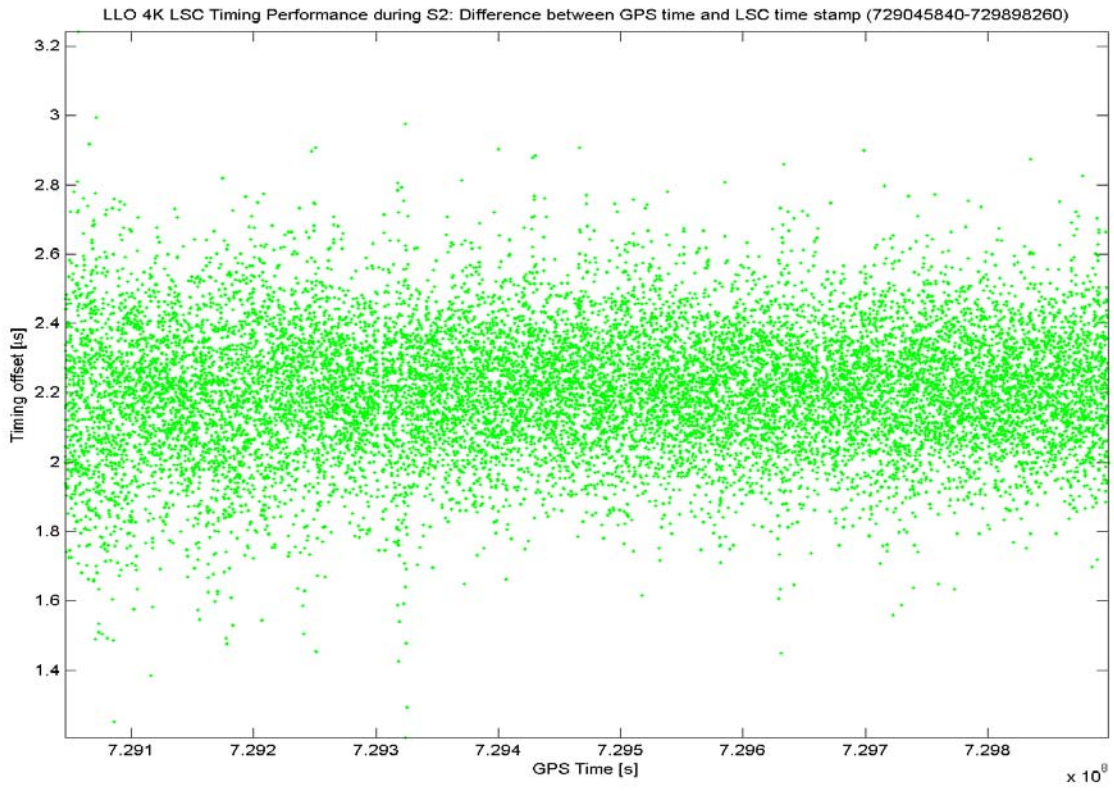
Table 1 Major L1 timing segments, their duration and the measured offset for each

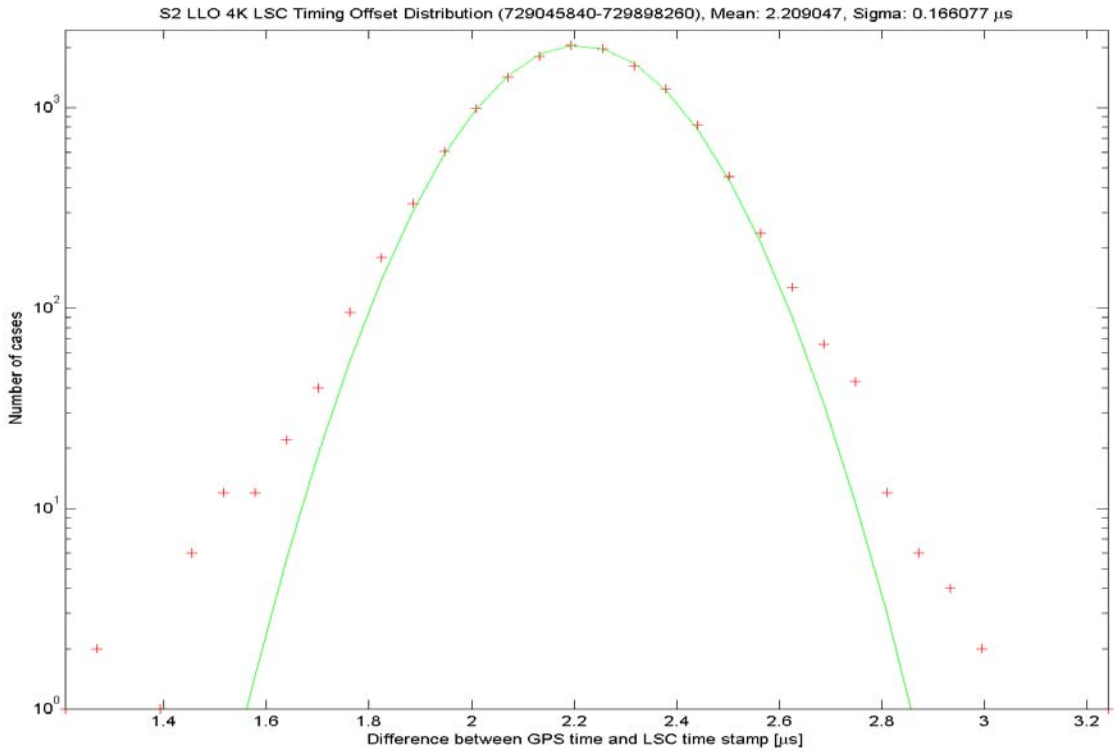
Start time GPS [s]	Stop Time GPS [s]	Offset [μs]	Duration [s]
728690400	729030180	2.0	339780
729045840	729898260	2.2	852420
729898380	730071960	7.5	173580
730072260	730957500	2.2	885240
730957620	731016000	8.7	58380
731016900	731023020	2.4	6120
731028120	731040360	14.7	12240
731040480	731103180	2.5	62700
731103420	731146620	1.5	43200
731146680	731151000	3.7	4320
731151120	731155860	4.6	4740
731155920	733509840	5.8	2353920
733509900	733811100	6.2	301200
733811160	733893180	7.5	82020
733893780	734468040	2.7	574260
734470260	734489880	13.6	19620

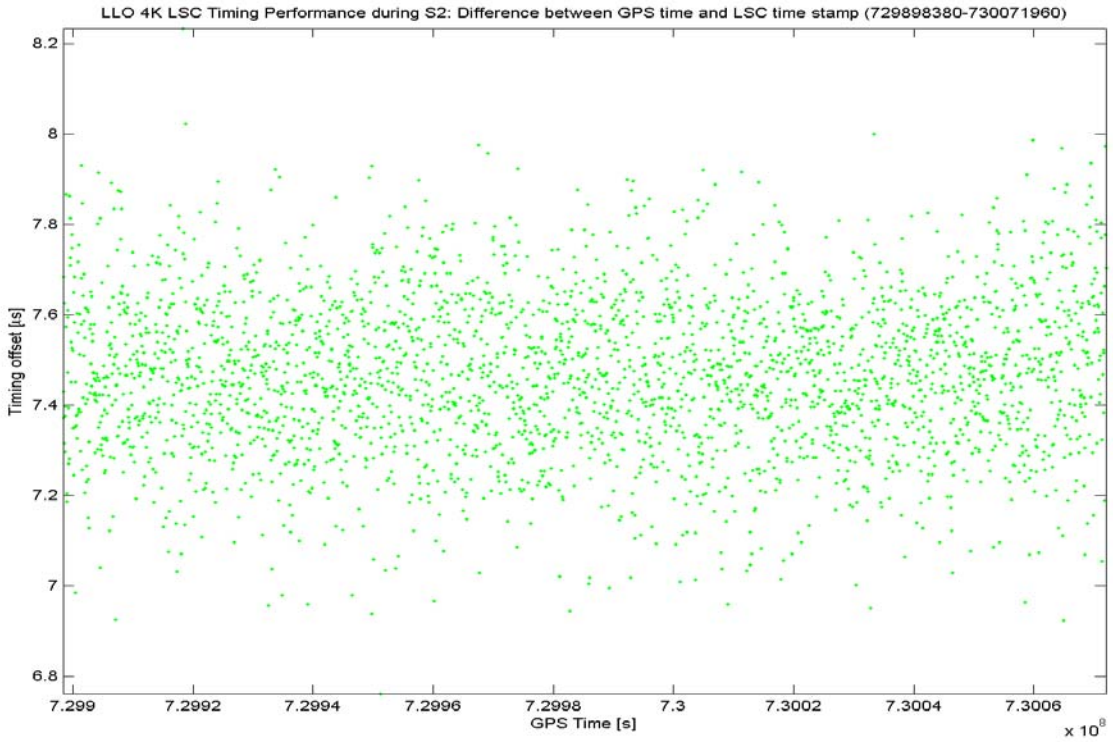
These values should be accurate to ± 1 μs.

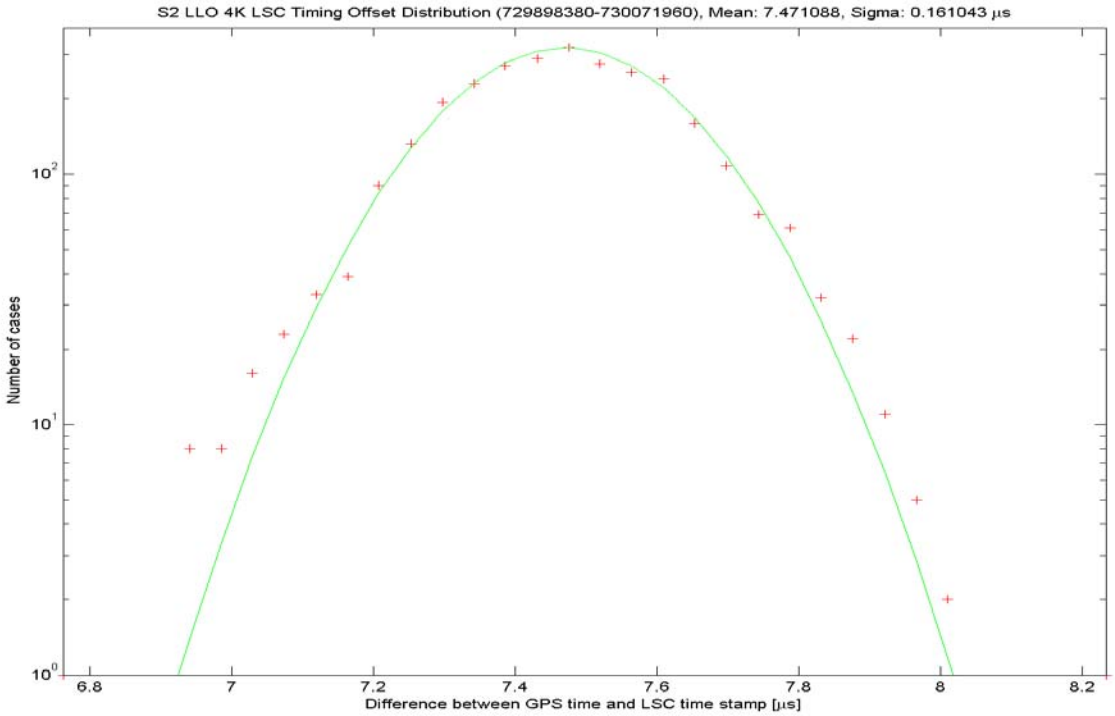

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (728690400-729030180)
Timing offset [μs]
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
7.287
7.2875
7.288
7.2885
7.289
7.2895
7.29
GPS Time [s]
x 10^9

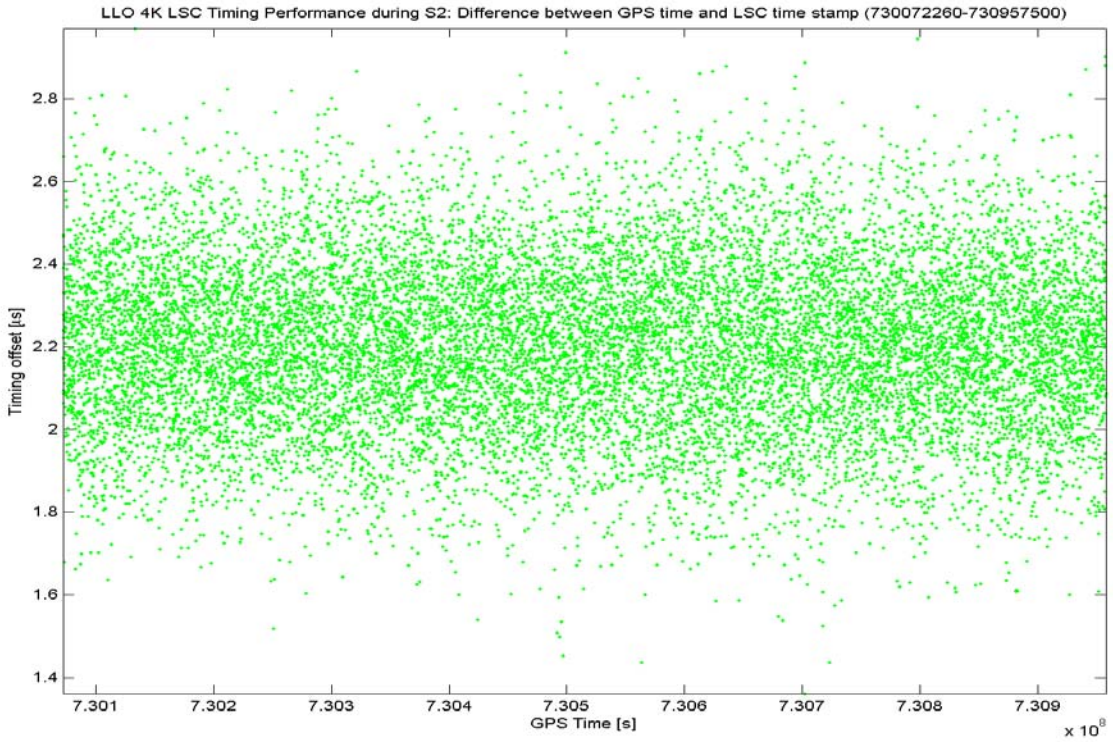

S2 LLO 4K LSC Timing Offset Distribution (728690400-729030180), Mean: 1.997803, Sigma: 0.179748 μs
Number of cases
10^2
10^1
10^0
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
Difference between GPS time and LSC time stamp [μs]

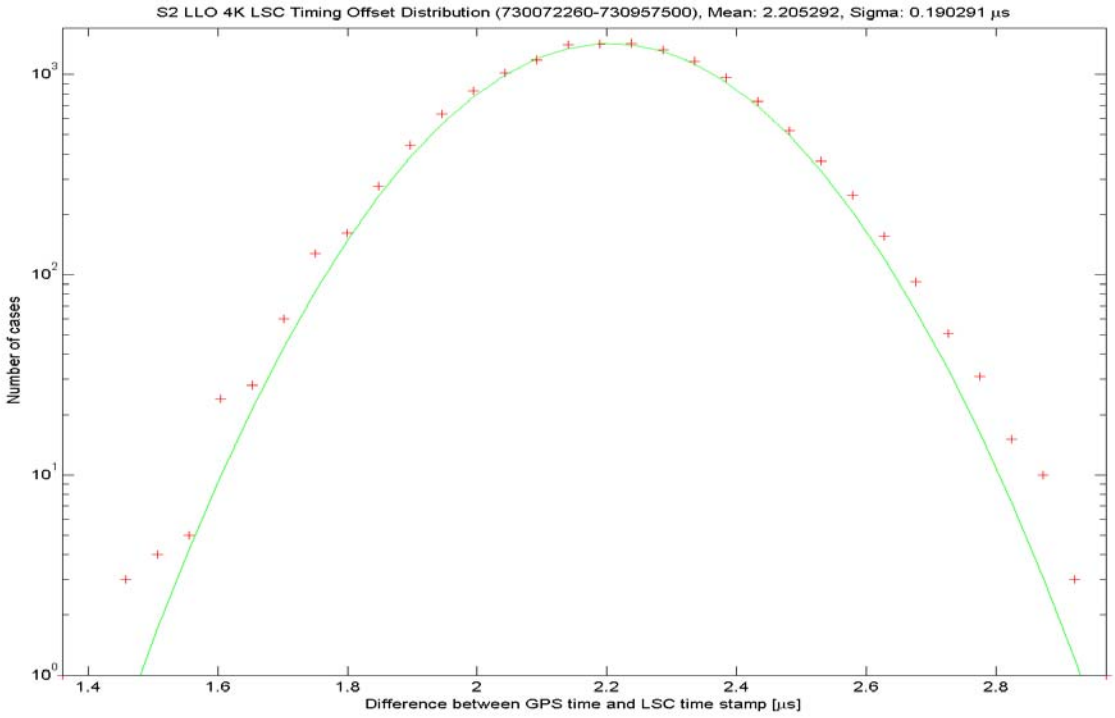

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (729045840-729898260)
Timing offset [μs]
GPS Time [s]
x 10^9

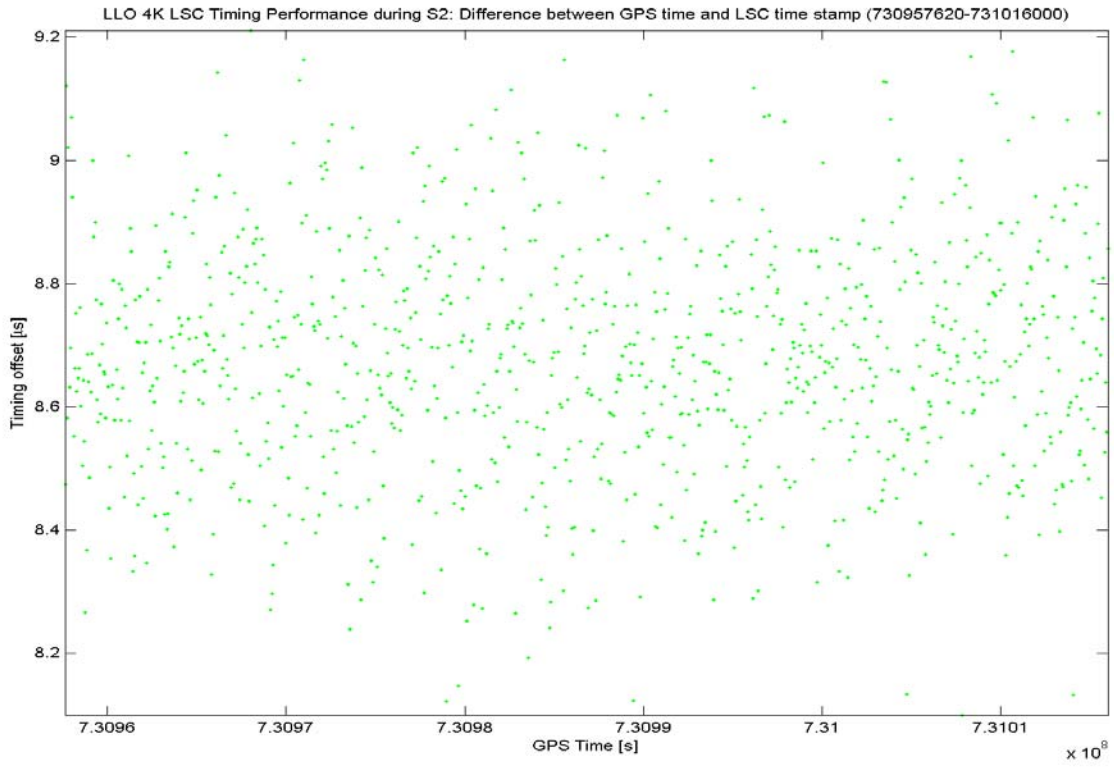

S2 LLO 4K LSC Timing Offset Distribution (729045840-729898260), Mean: 2.209047, Sigma: 0.166077 μs
Number of cases
Difference between GPS time and LSC time stamp [μs]

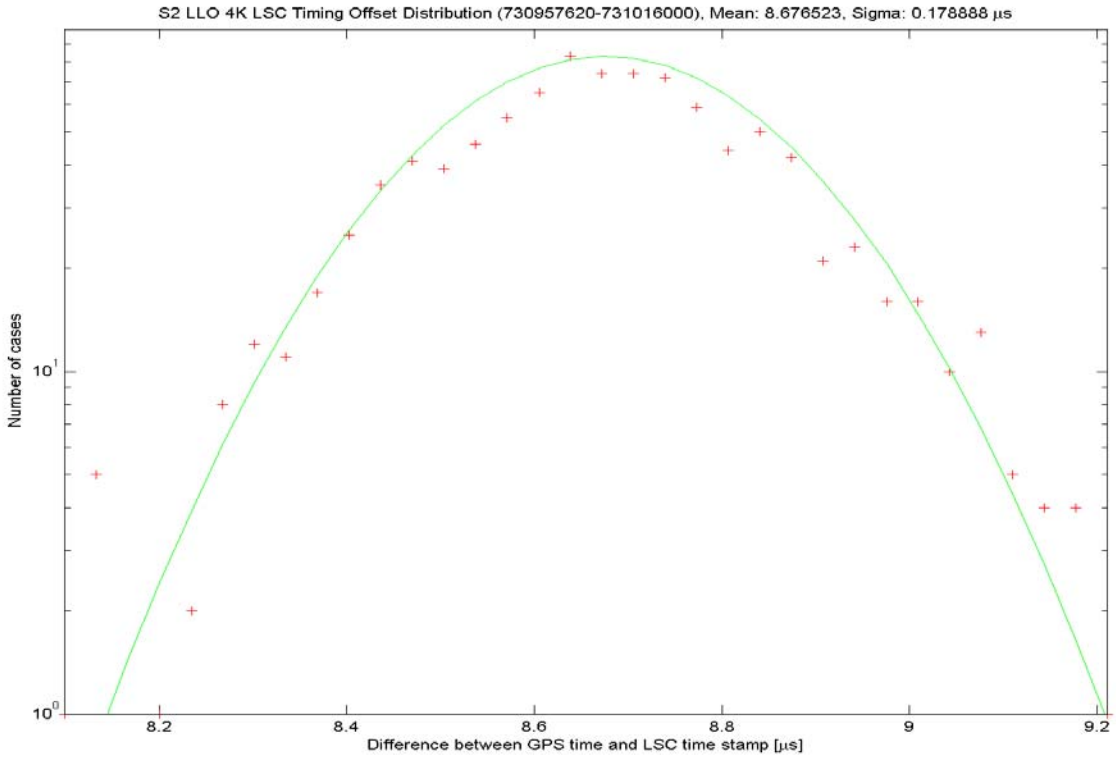

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (729898380-730071960)
Timing offset [μs]
8.2
8
7.8
7.6
7.4
7.2
7
6.8
7.299
7.2992
7.2994
7.2996
7.2998
7.3
7.3002
7.3004
7.3006
GPS Time [s]
x 10^8

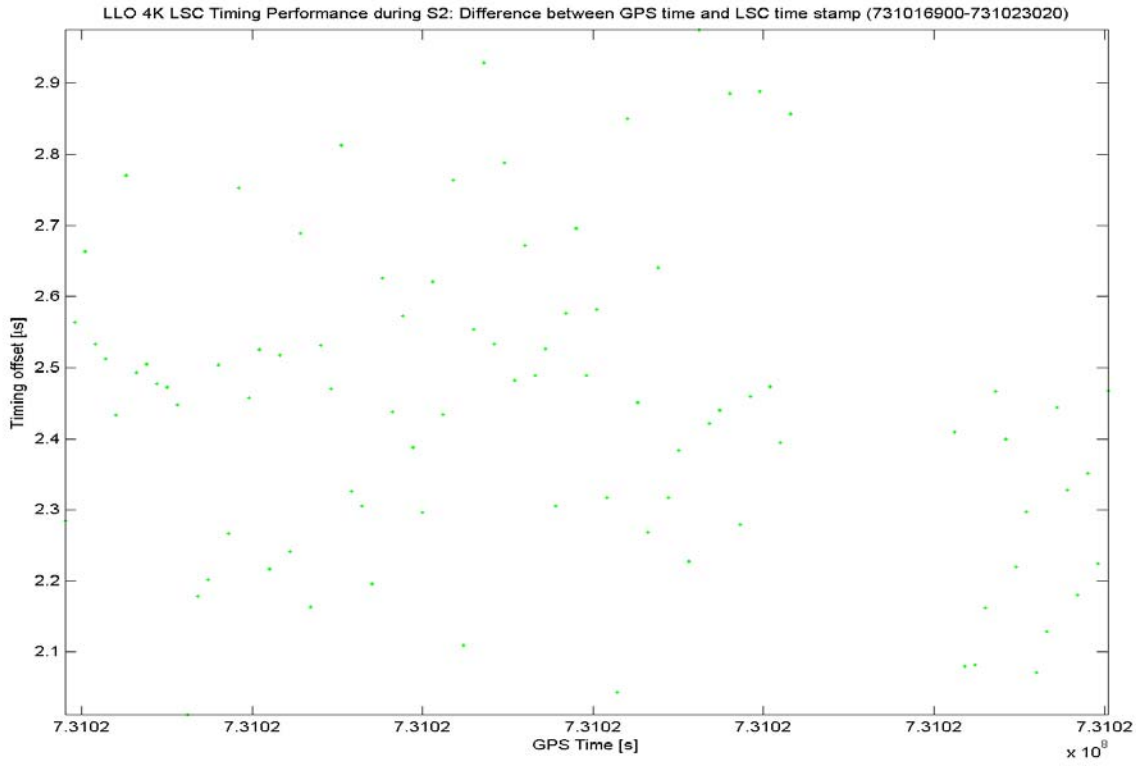

S2 LLO 4K LSC Timing Offset Distribution (729898380-730071960), Mean: 7.471088, Sigma: 0.161043 μs
Number of cases
10^2
10^1
10^0
6.8
7
7.2
7.4
7.6
7.8
8
8.2
Difference between GPS time and LSC time stamp [μs]

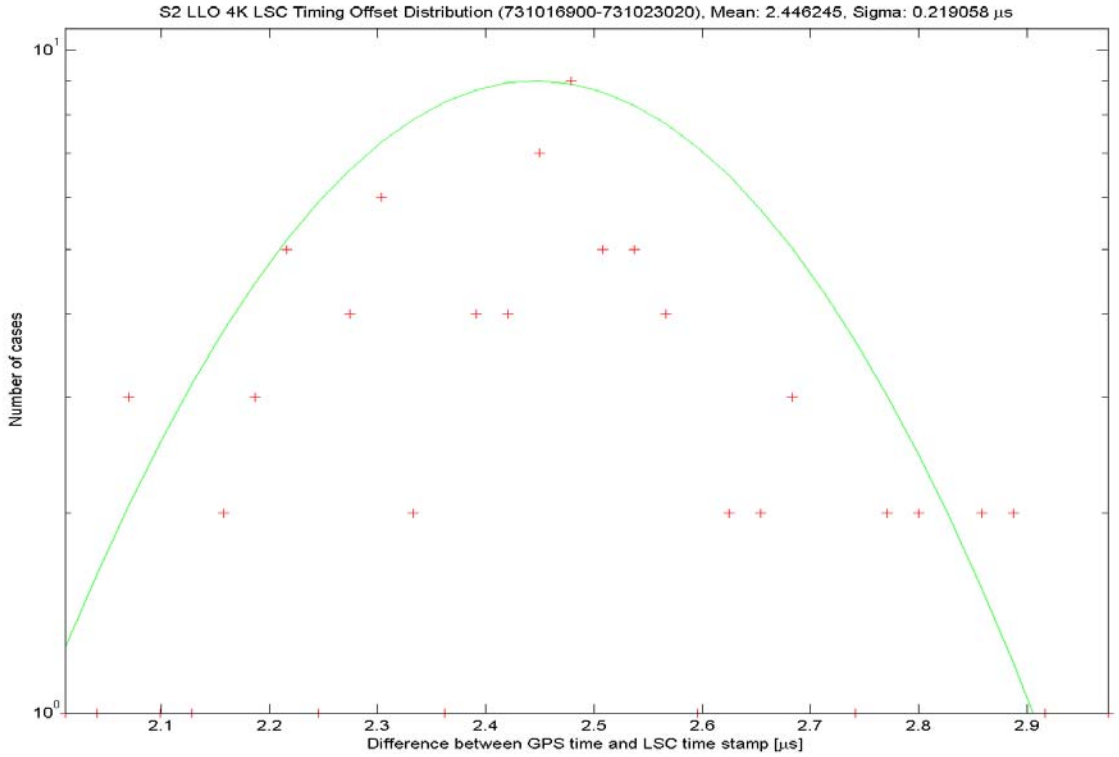

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (730072260-730957500)
Timing offset [μs]
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
7.301
7.302
7.303
7.304
7.305
7.306
7.307
7.308
7.309
GPS Time [s]
x 10^8

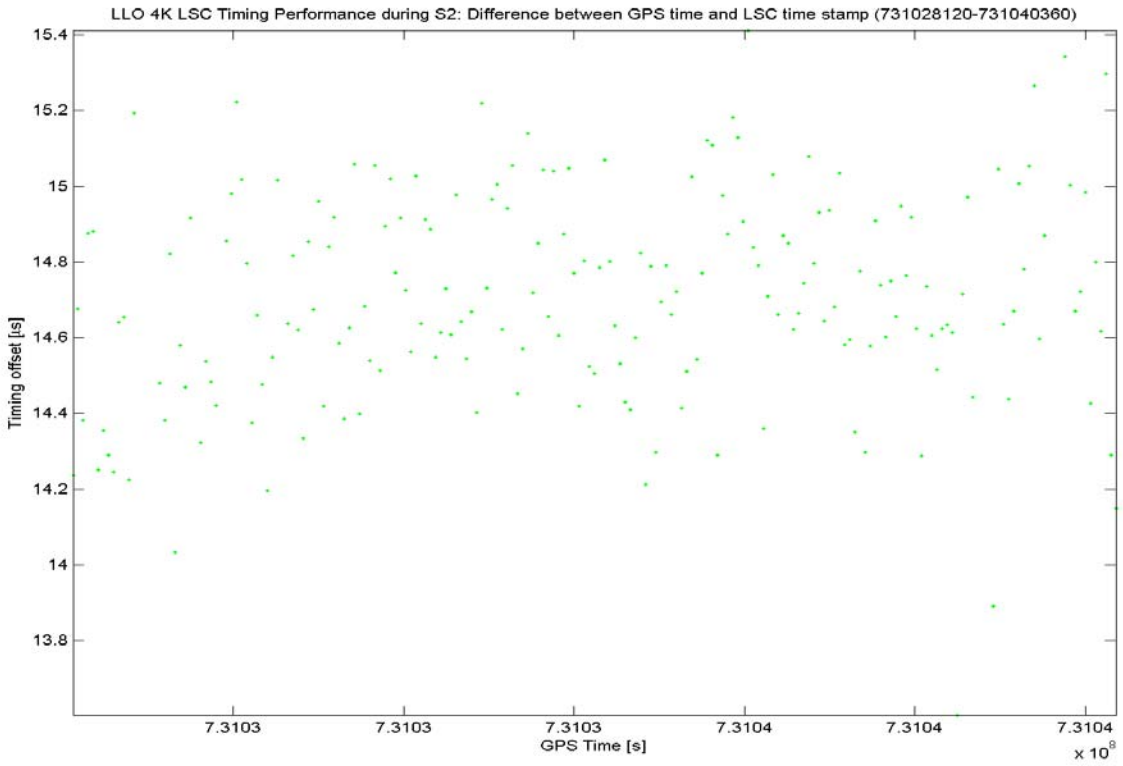

S2 LLO 4K LSC Timing Offset Distribution (730072260-730957500), Mean: 2.205292, Sigma: 0.190291 μs
Number of cases
10^3
10^2
10^1
10^0
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
Difference between GPS time and LSC time stamp [μs]

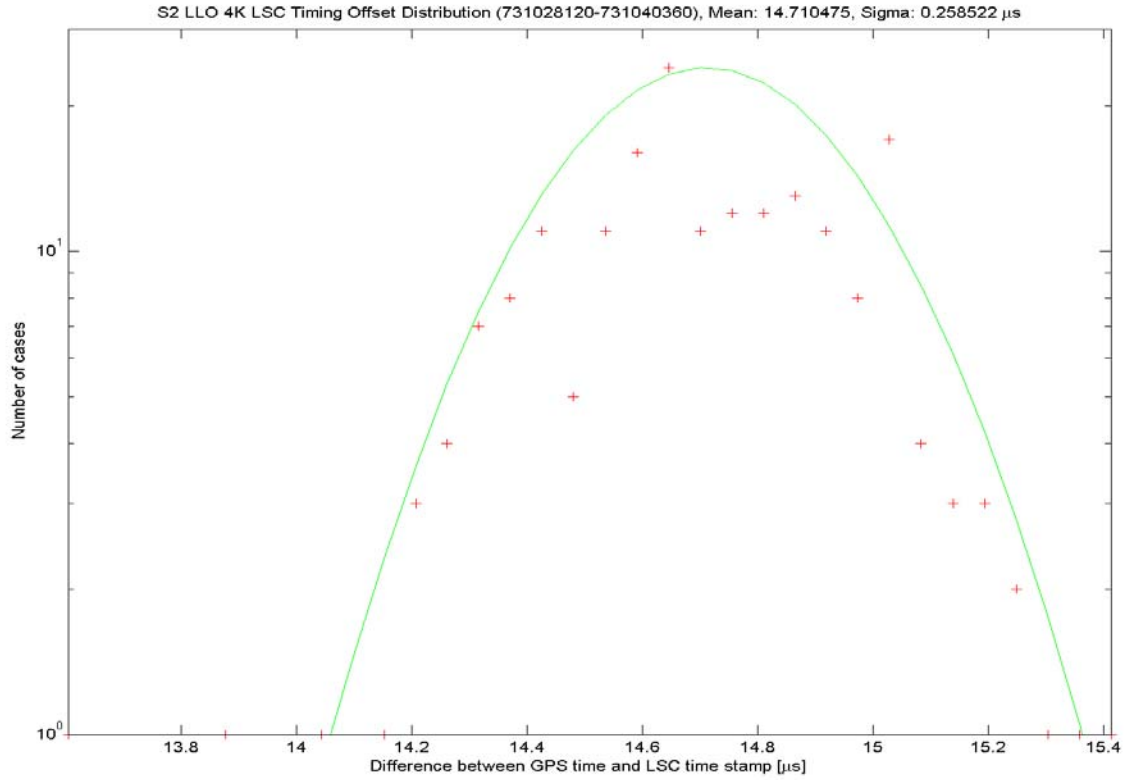

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (730957620-731016000)
Timing offset [µs]
9.2
9
8.8
8.6
8.4
8.2
7.3096
7.3097
7.3098
7.3099
7.31
7.3101
GPS Time [s]
x 10^8

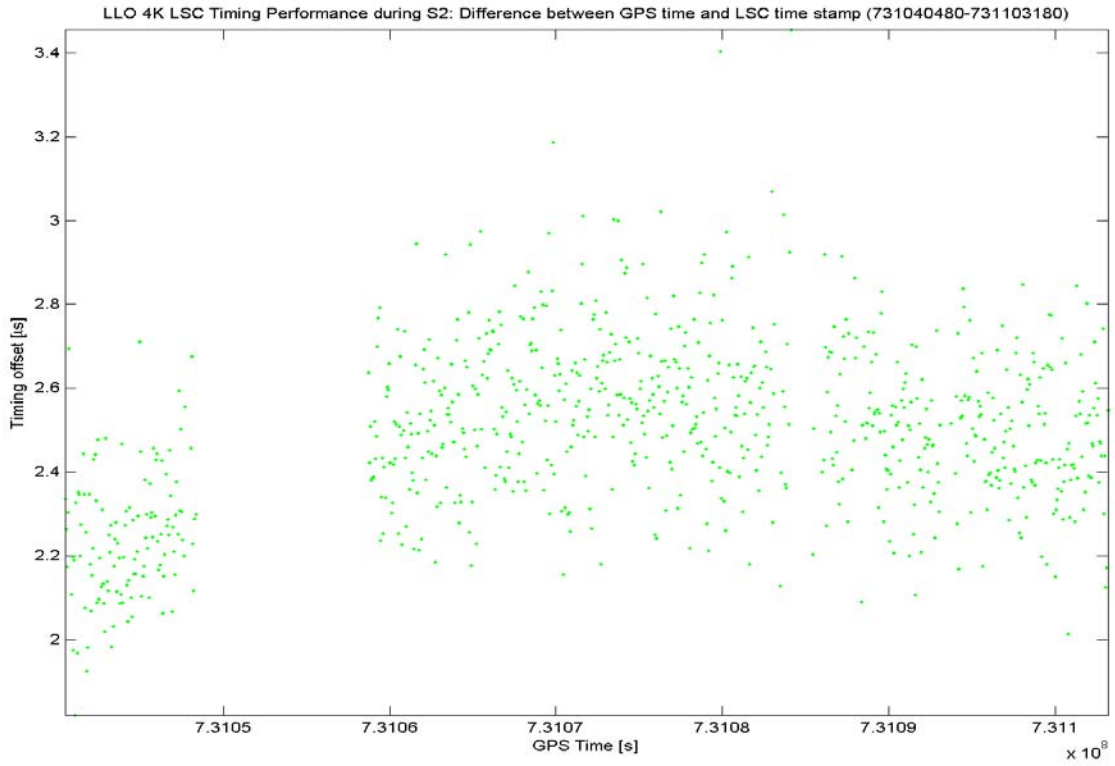

S2 LLO 4K LSC Timing Offset Distribution (730957620-731016000), Mean: 8.676523, Sigma: 0.178888 µs
Number of cases
10^1
10^0
8.2
8.4
8.6
8.8
9
9.2
Difference between GPS time and LSC time stamp [µs]

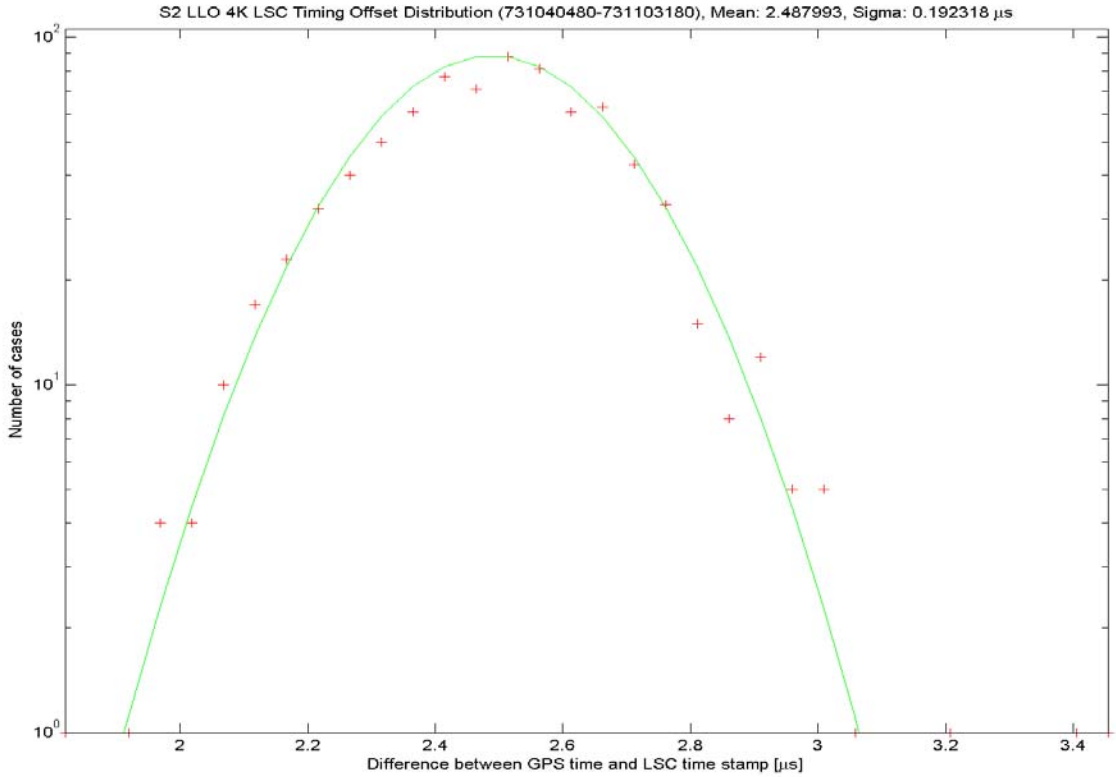

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731016900-731023020)
Timing offset [µs]
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
7.3102
7.3102
7.3102
7.3102
7.3102
7.3102
7.3102
GPS Time [s]
x 10^8

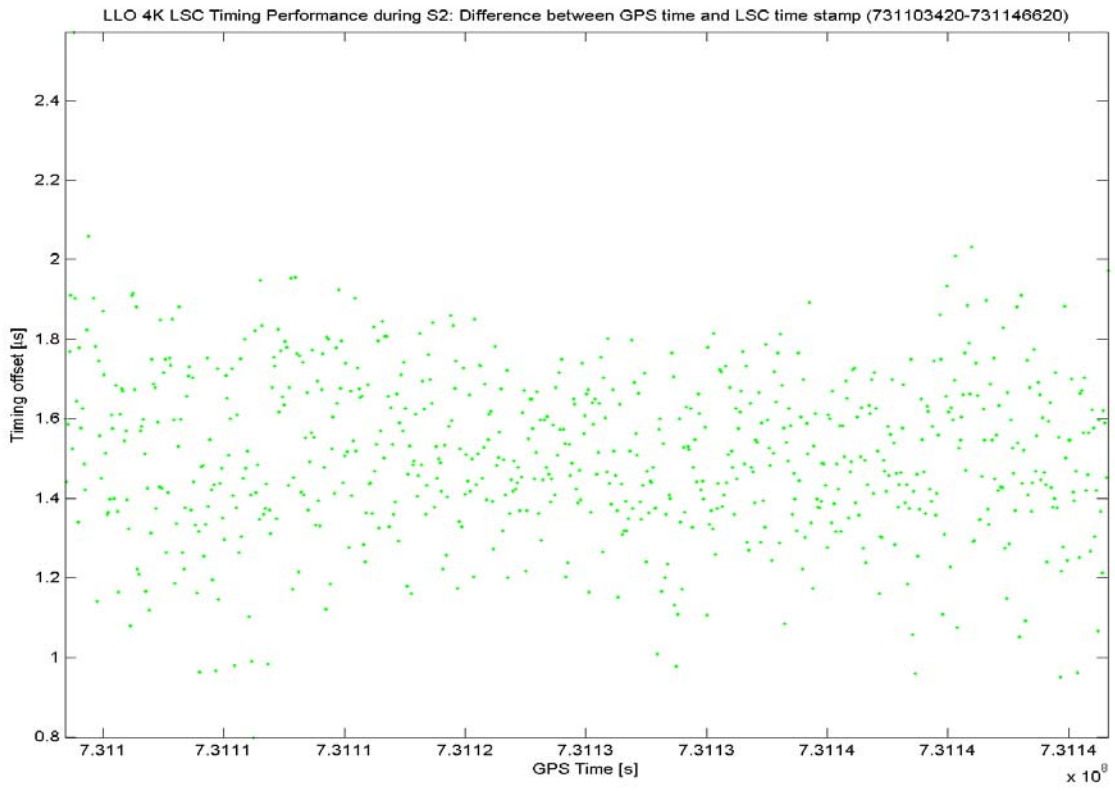

S2 LLO 4K LSC Timing Offset Distribution (731016900-731023020), Mean: 2.446245, Sigma: 0.219058 µs
Number of cases
10^1
10^0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
Difference between GPS time and LSC time stamp [µs]

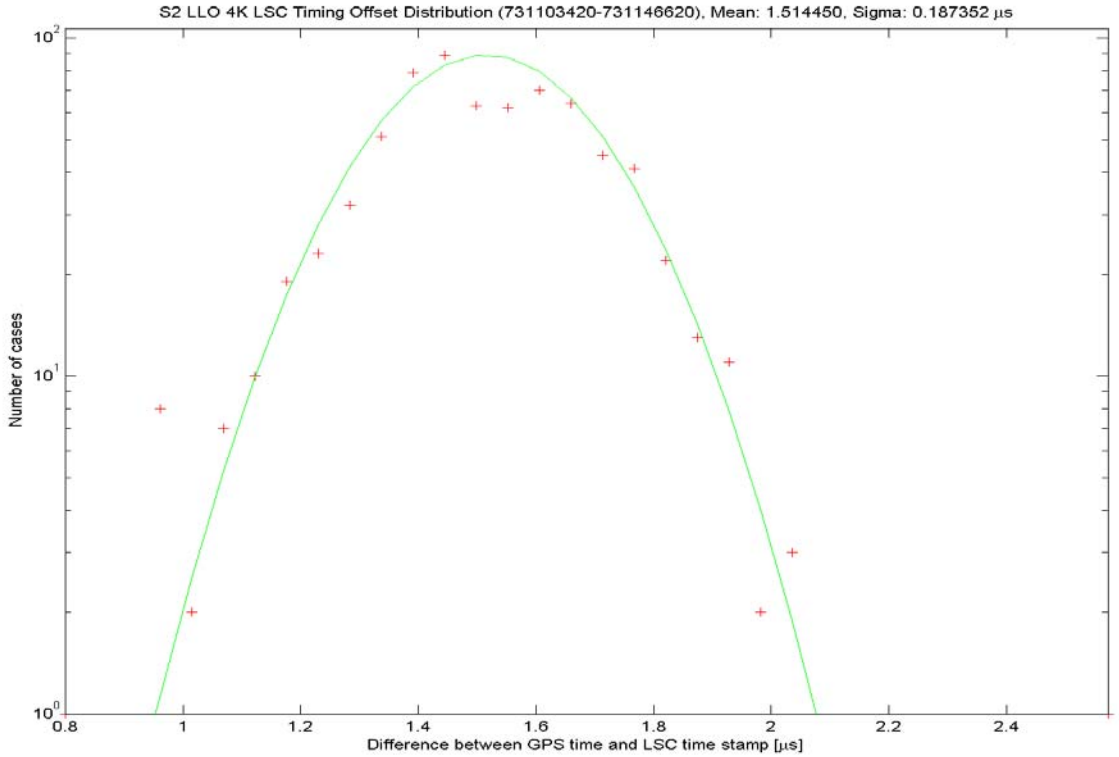

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731028120-731040360)
Timing offset [s]
15.4
15.2
15
14.8
14.6
14.4
14.2
14
13.8
7.3103
7.3103
7.3103
7.3104
7.3104
7.3104
GPS Time [s]
x 10^8

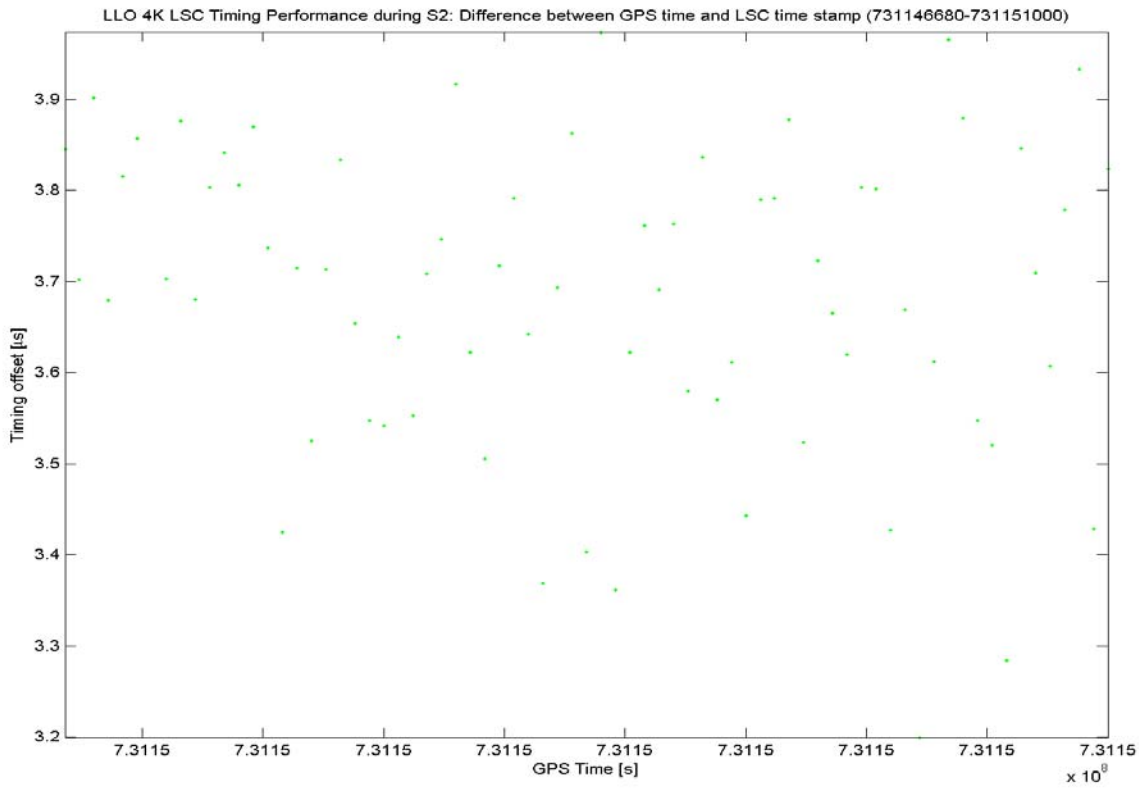

S2 LLO 4K LSC Timing Offset Distribution (731028120-731040360), Mean: 14.710475, Sigma: 0.258522 μs
Number of cases
10^1
10^0
13.8
14
14.2
14.4
14.6
14.8
15
15.2
15.4
Difference between GPS time and LSC time stamp [μs]

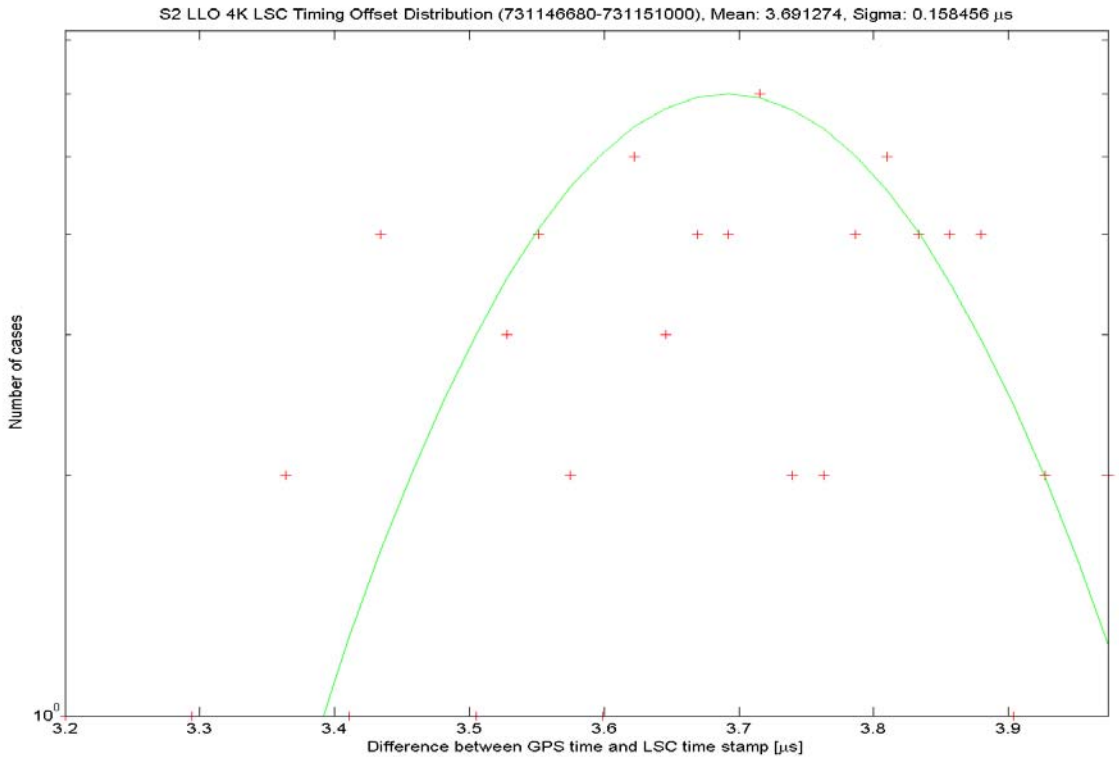

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731040480-731103180)
Timing offset [μs]
3.4
3.2
3
2.8
2.6
2.4
2.2
2
7.3105
7.3106
7.3107
7.3108
7.3109
7.311
GPS Time [s]
x 10^8

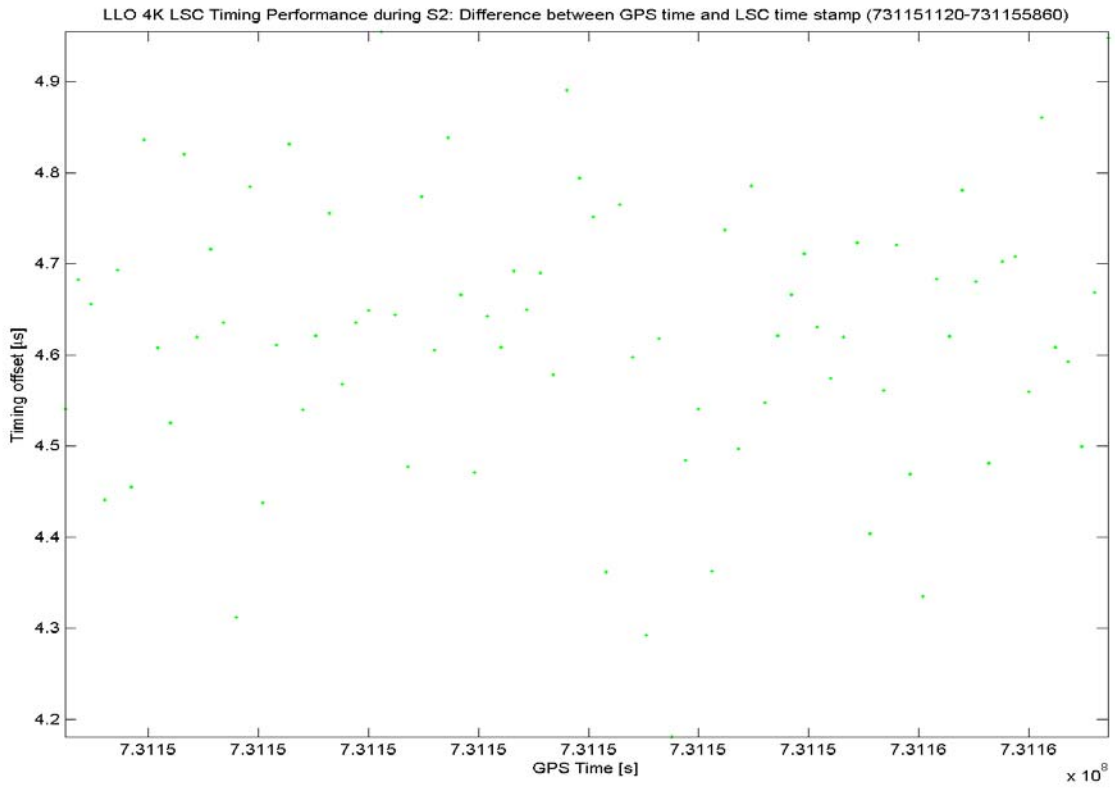

S2 LLO 4K LSC Timing Offset Distribution (731040480-731103180), Mean: 2.487993, Sigma: 0.192318 μs
Number of cases
10^2
10^1
10^0
2
2.2
2.4
2.6
2.8
3
3.2
3.4
Difference between GPS time and LSC time stamp [μs]

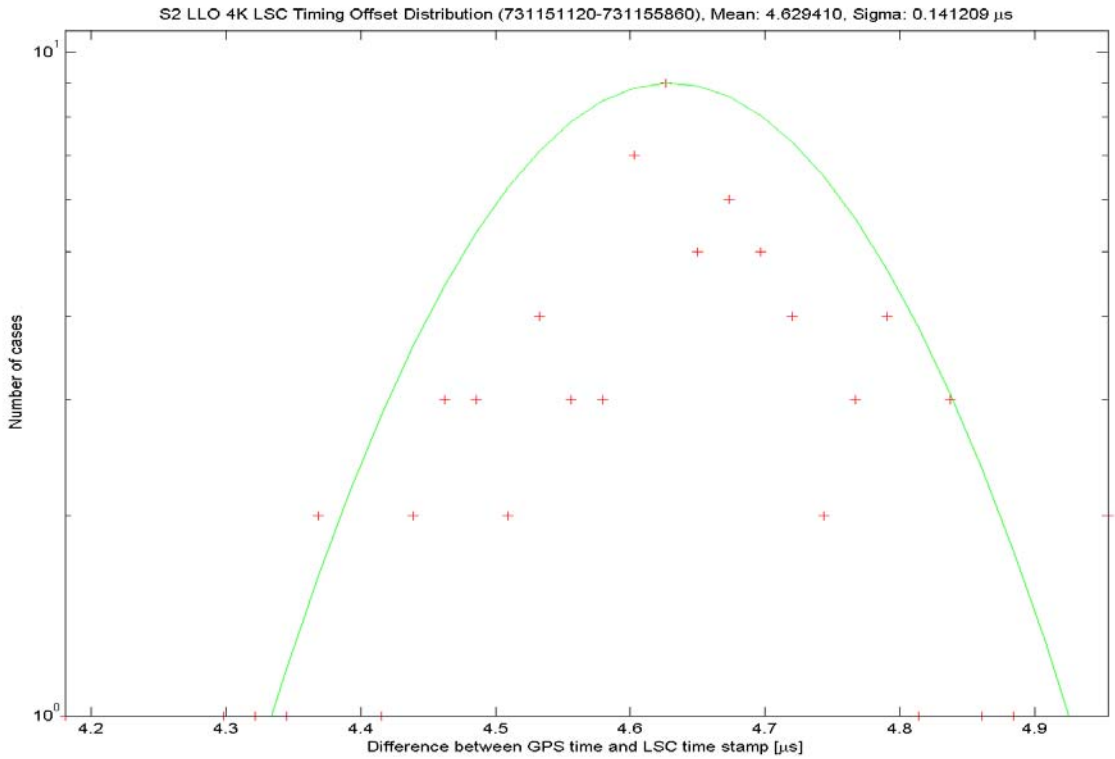

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731103420-731146620)
Timing offset [μs]
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
7.311
7.3111
7.3111
7.3112
7.3113
7.3113
7.3114
7.3114
7.3114
GPS Time [s]
x 10^9

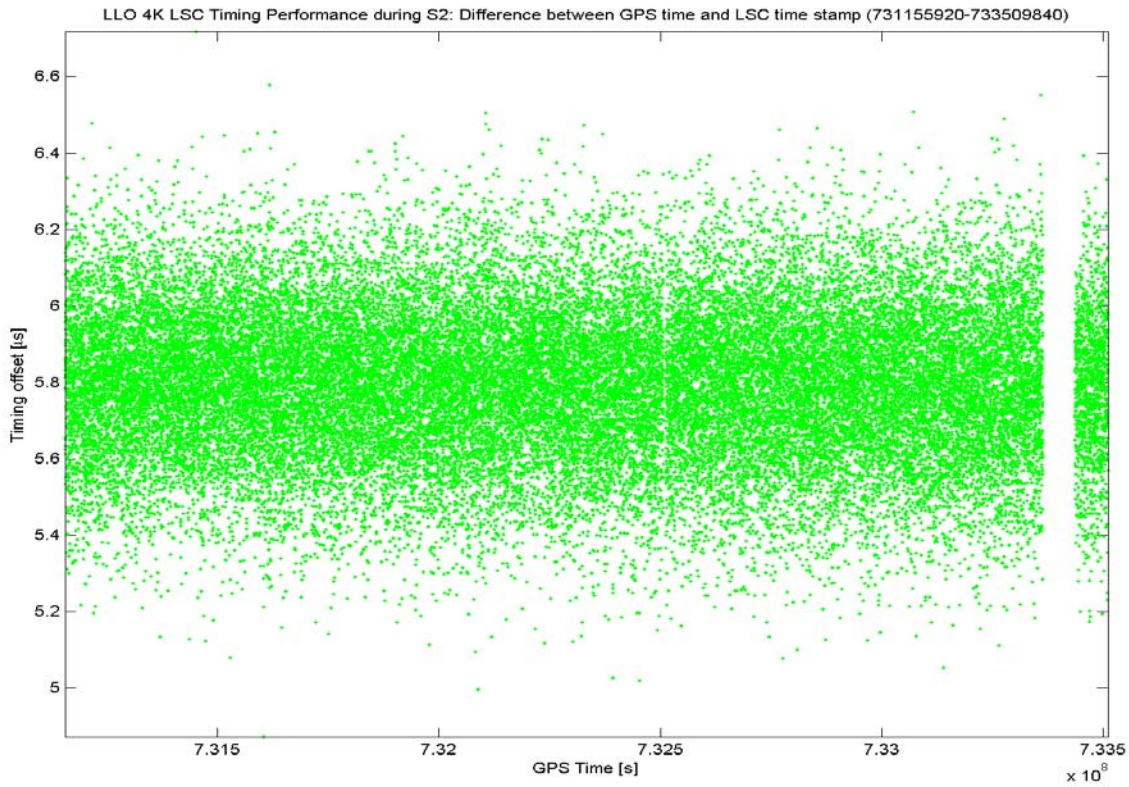

S2 LLO 4K LSC Timing Offset Distribution (731103420-731146620), Mean: 1.514450, Sigma: 0.187352 μs
Number of cases
10^2
10^1
10^0
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Difference between GPS time and LSC time stamp [μs]

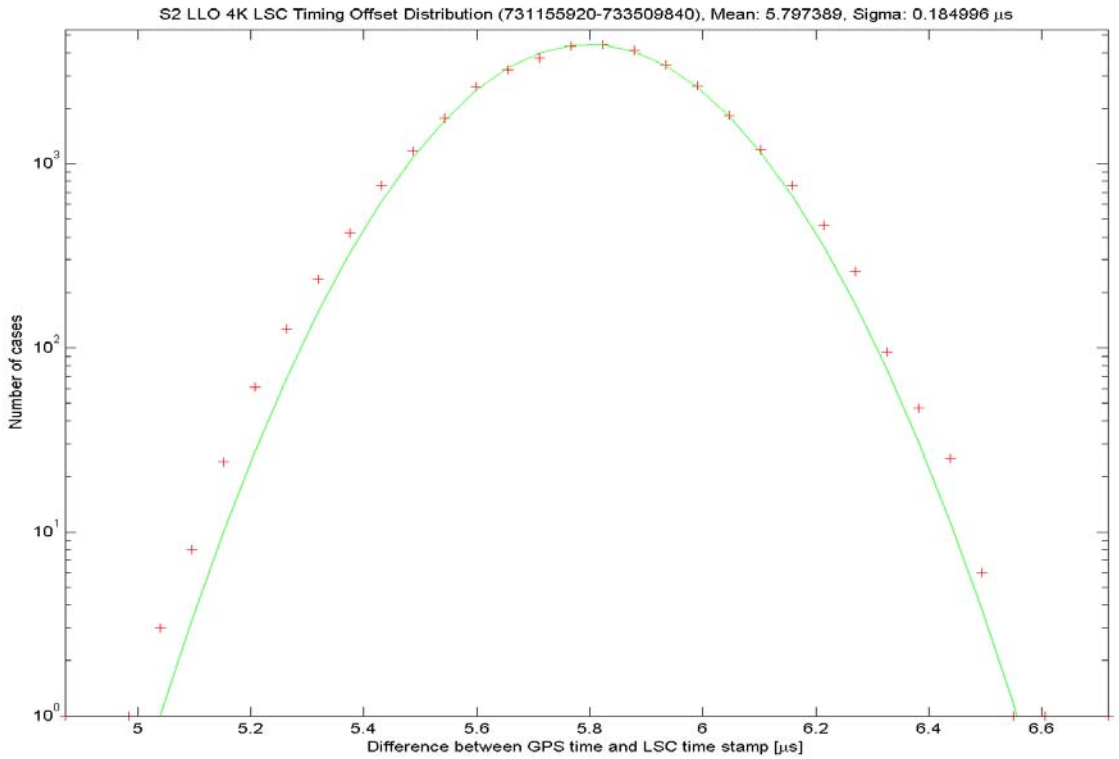

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731146680-731151000)
Timing offset [μs]
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
7.3115
7.3115
7.3115
7.3115
7.3115
7.3115
7.3115
7.3115
GPS Time [s]
x 10^9

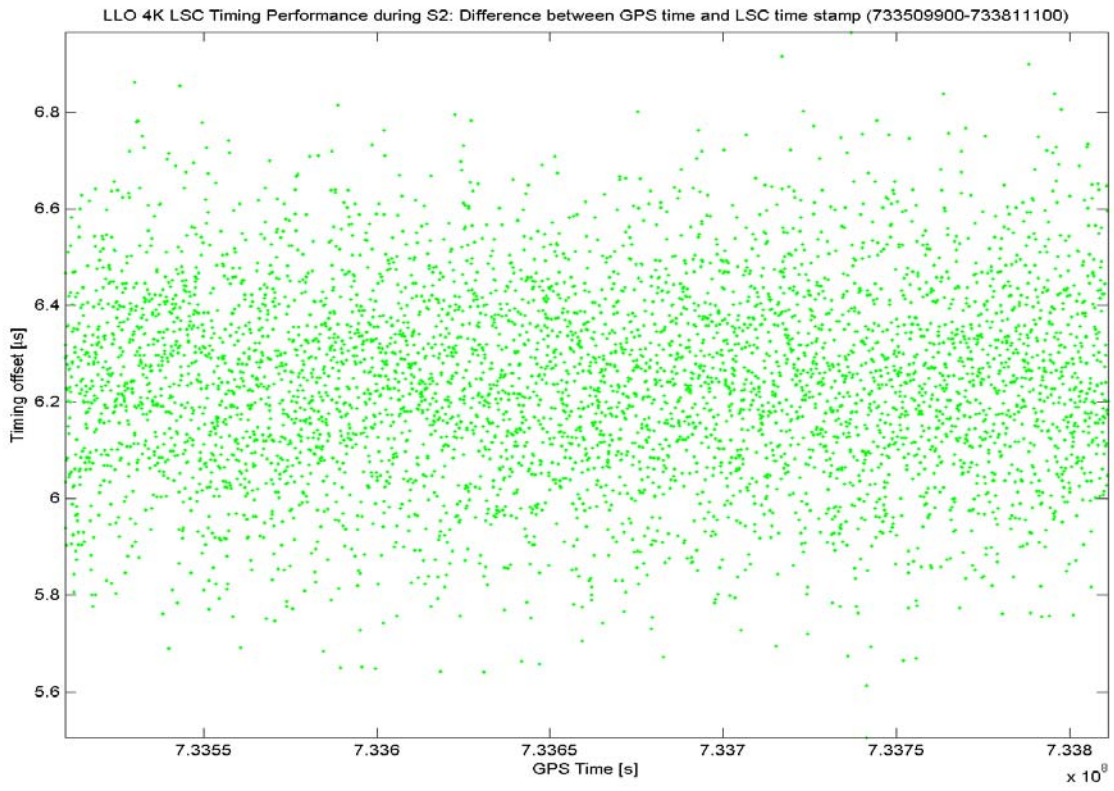

S2 LLO 4K LSC Timing Offset Distribution (731146680-731151000), Mean: 3.691274, Sigma: 0.158456 μs
Number of cases
10^0
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
Difference between GPS time and LSC time stamp [μs]

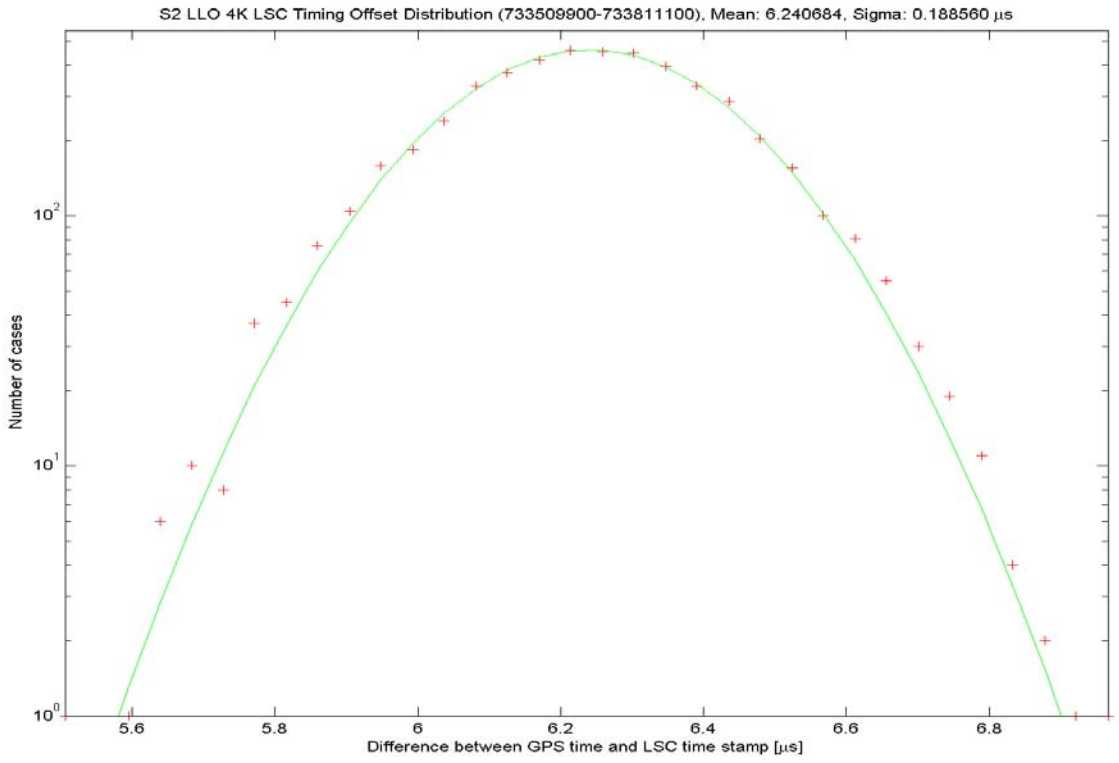

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731151120-731155860)
Timing offset [μs]
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
7.3115
7.3115
7.3115
7.3115
7.3115
7.3115
7.3115
7.3116
7.3116
GPS Time [s]
x 10^8

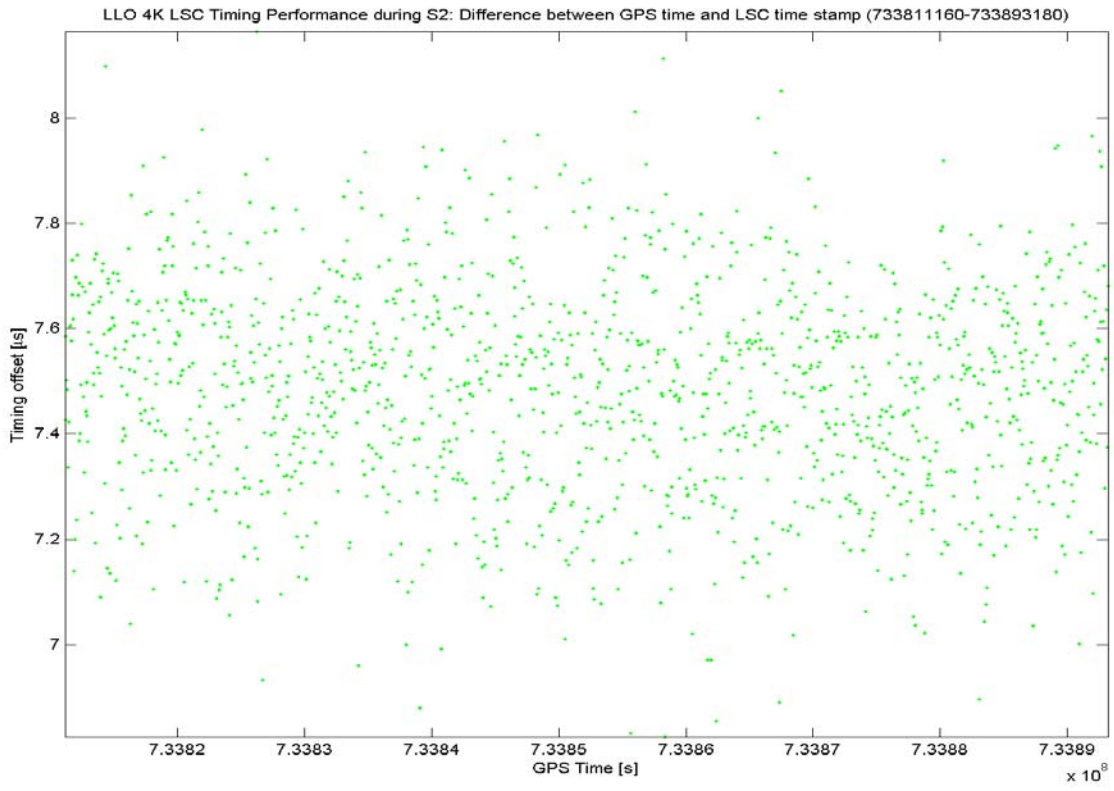

S2 LLO 4K LSC Timing Offset Distribution (731151120-731155860), Mean: 4.629410, Sigma: 0.141209 μs
Number of cases
10^1
10^0
4.2
4.3
4.4
4.5
4.6
4.7
4.8
4.9
Difference between GPS time and LSC time stamp [μs]

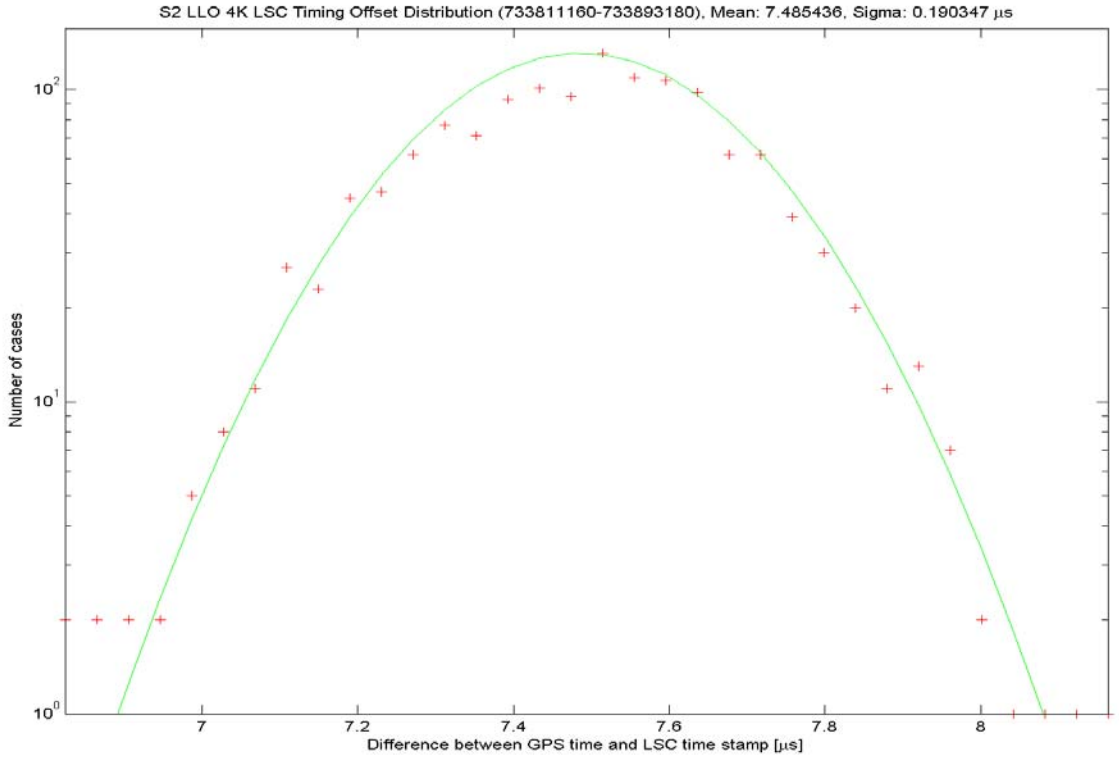

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731155920-733509840)
Timing offset [μs]
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
7.315
7.32
7.325
7.33
7.335
GPS Time [s]
x 10^8

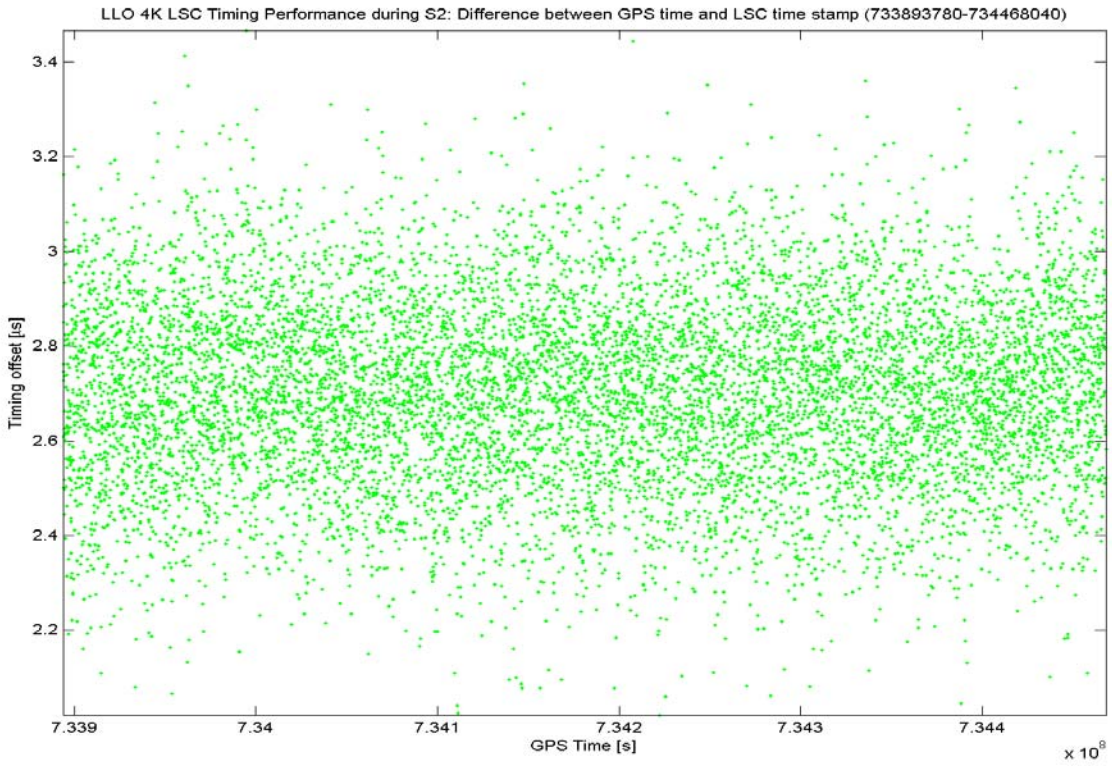

S2 LLO 4K LSC Timing Offset Distribution (731155920-733509840), Mean: 5.797389, Sigma: 0.184996 μs
Number of cases
10^3
10^2
10^1
10^0
5
5.2
5.4
5.6
5.8
6
6.2
6.4
6.6
Difference between GPS time and LSC time stamp [μs]

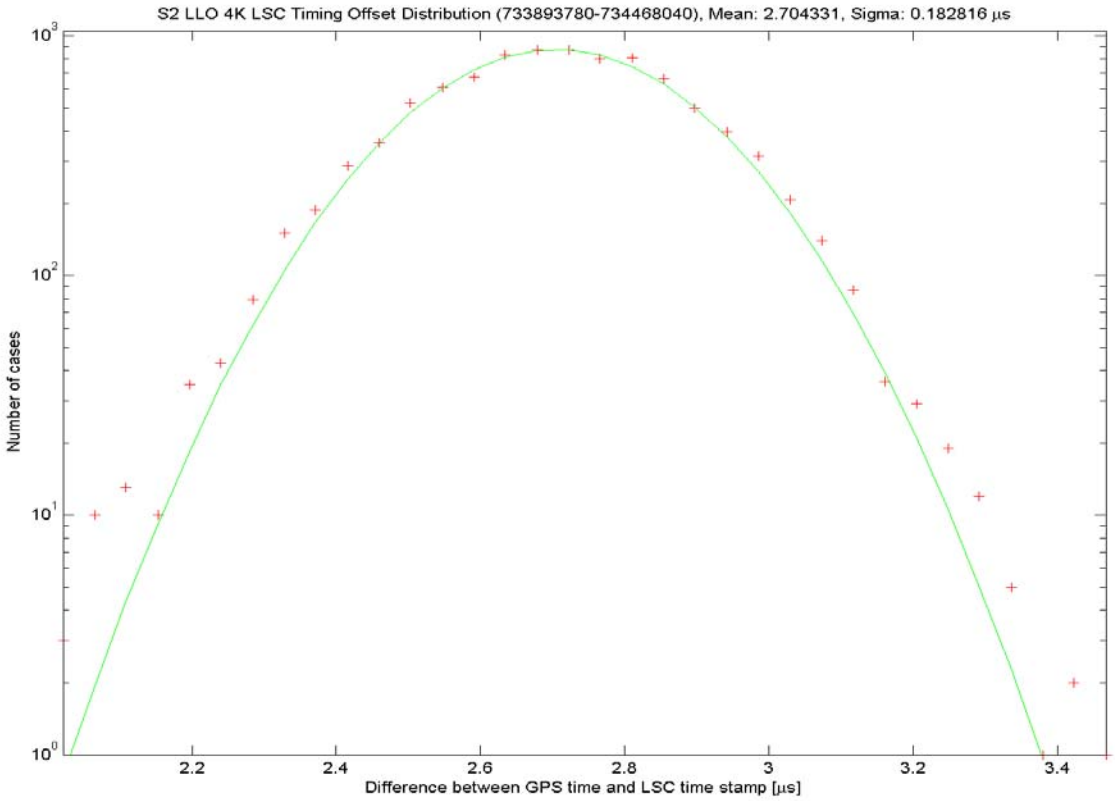

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (733509900-733811100)
Timing offset [μs]
6.8
6.6
6.4
6.2
6
5.8
5.6
7.3355
7.336
7.3365
7.337
7.3375
7.338
GPS Time [s]
x 10^9

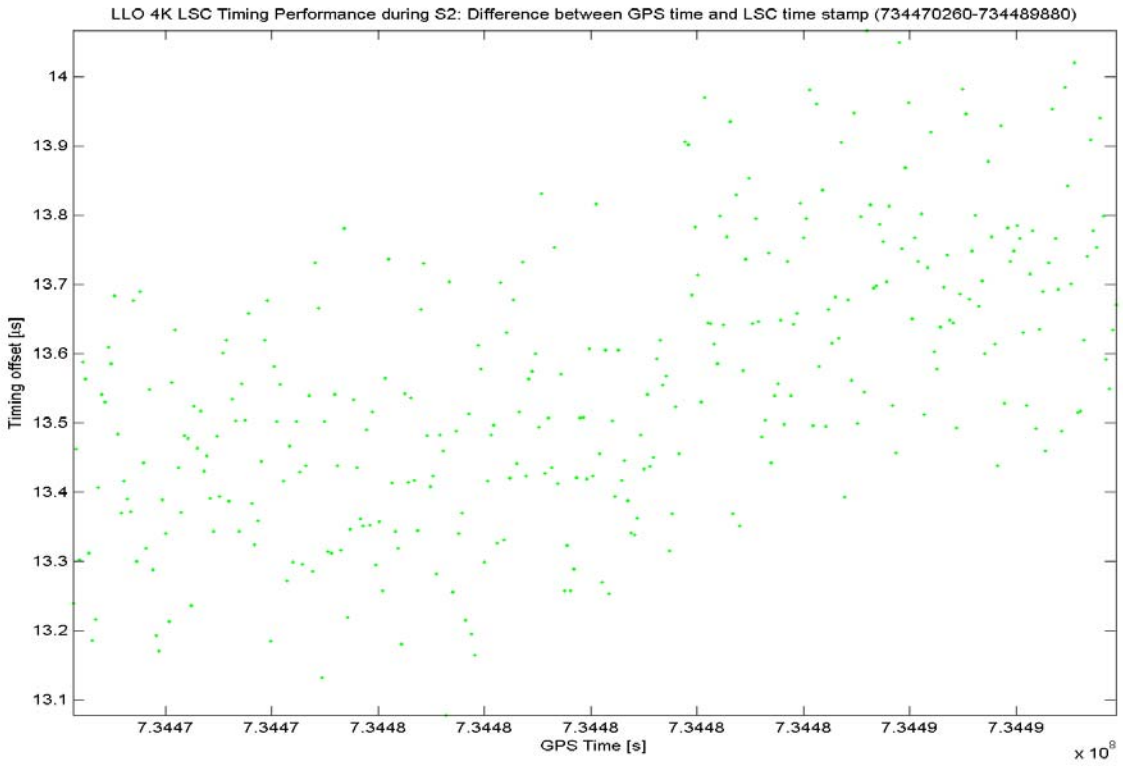

S2 LLO 4K LSC Timing Offset Distribution (733509900-733811100), Mean: 6.240684, Sigma: 0.188560 μs
Number of cases
10^2
10^1
10^0
5.6
5.8
6
6.2
6.4
6.6
6.8
Difference between GPS time and LSC time stamp [μs]

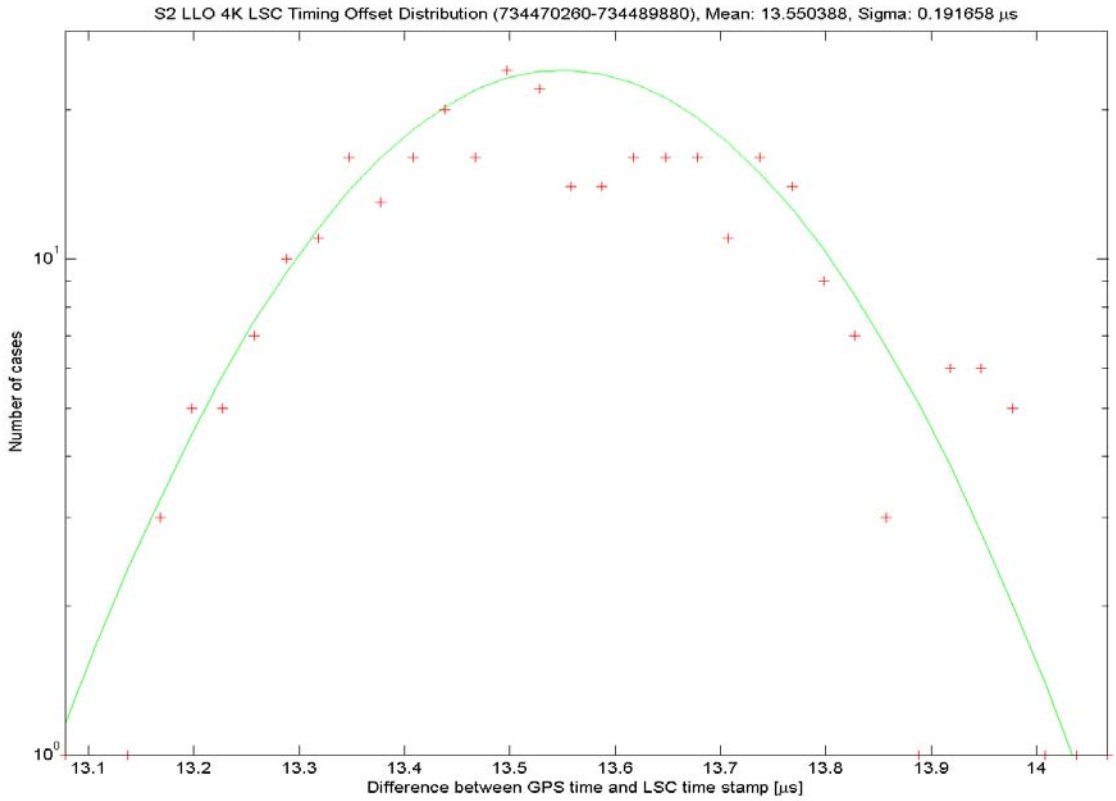

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (733811160-733893180)
Timing offset [μs]
8
7.8
7.6
7.4
7.2
7
7.3382
7.3383
7.3384
7.3385
7.3386
7.3387
7.3388
7.3389
GPS Time [s]
x 10^8


S2 LLO 4K LSC Timing Offset Distribution (733811160-733893180), Mean: 7.485436, Sigma: 0.190347 μs
Number of cases
10^2
10^1
10^0
7
7.2
7.4
7.6
7.8
8
Difference between GPS time and LSC time stamp [μs]

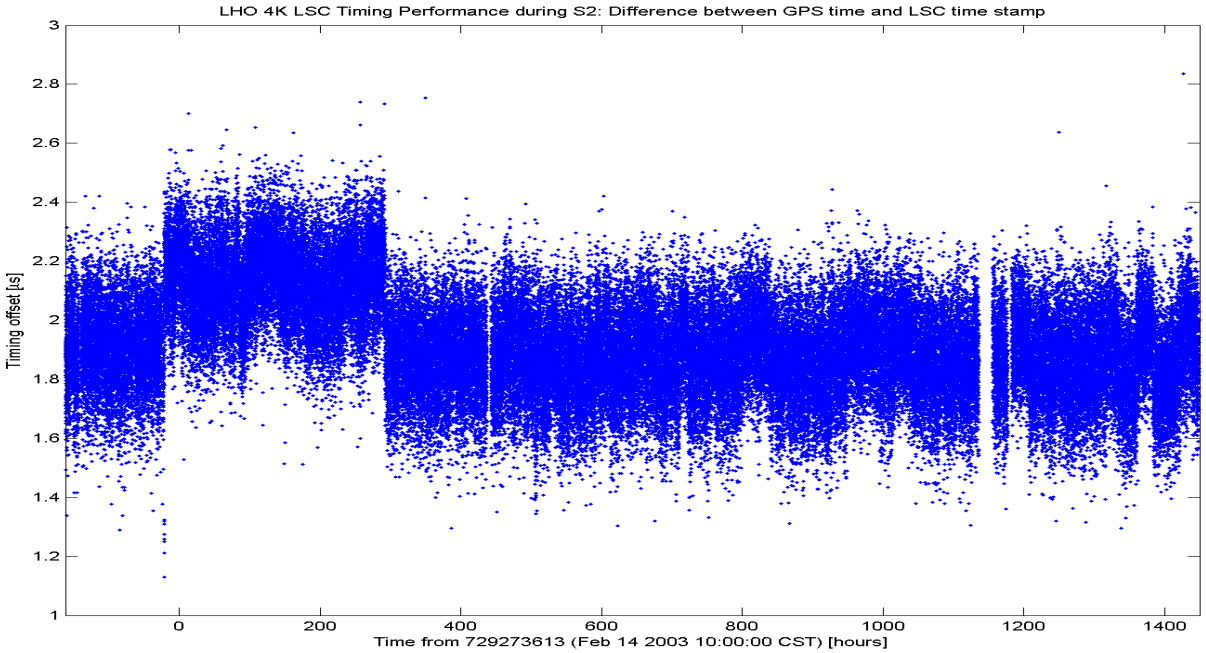

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (733893780-734468040)
Timing offset [µs]
3.4
3.2
3
2.8
2.6
2.4
2.2
7.339
7.34
7.341
7.342
7.343
7.344
GPS Time [s]
x 10^8


S2 LLO 4K LSC Timing Offset Distribution (733893780-734468040), Mean: 2.704331, Sigma: 0.182816 µs
Number of cases
10^3
10^2
10^1
10^0
2.2
2.4
2.6
2.8
3
3.2
3.4
Difference between GPS time and LSC time stamp [µs]

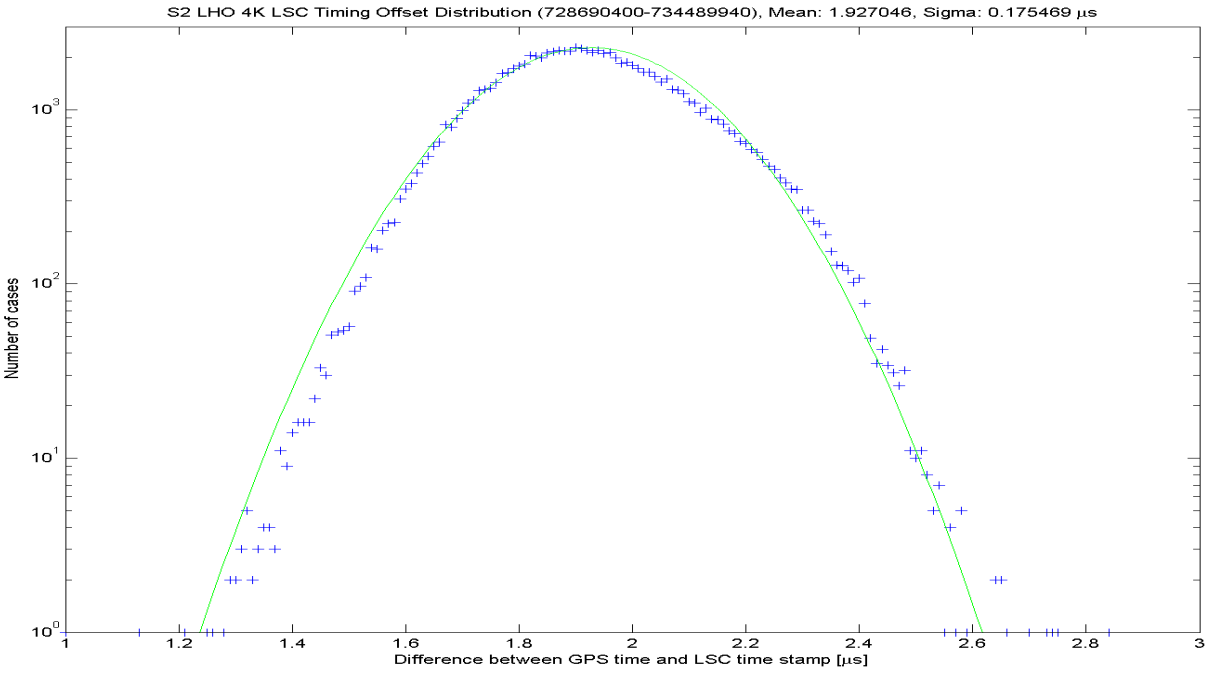

LLO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (734470260-734489880)
Timing offset [is]
14
13.9
13.8
13.7
13.6
13.5
13.4
13.3
13.2
13.1
7.3447
7.3447
7.3448
7.3448
7.3448
7.3448
7.3448
7.3449
7.3449
GPS Time [s]
x 10^8


S2 LLO 4K LSC Timing Offset Distribution (734470260-734489880), Mean: 13.550388, Sigma: 0.191658 μs
Number of cases
10^1
10^0
13.1
13.2
13.3
13.4
13.5
13.6
13.7
13.8
13.9
14
Difference between GPS time and LSC time stamp [μs]

LIGO Hanford 4K interferometer LSC timing



LIGO Hanford 4K interferometer LSC timing

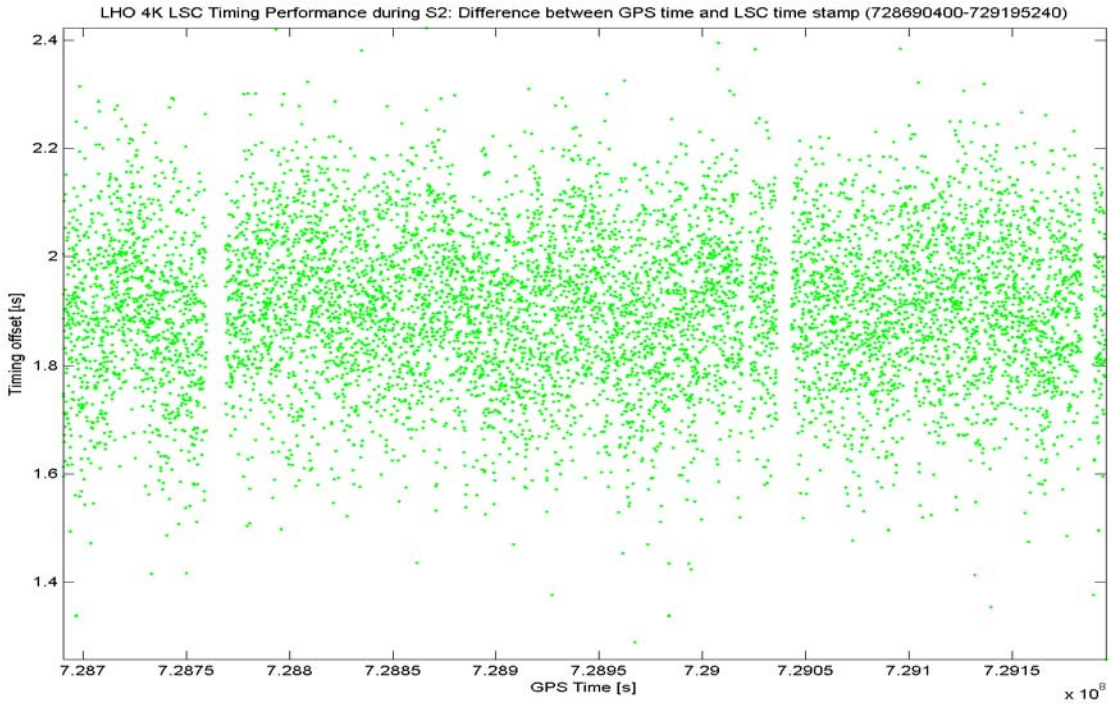


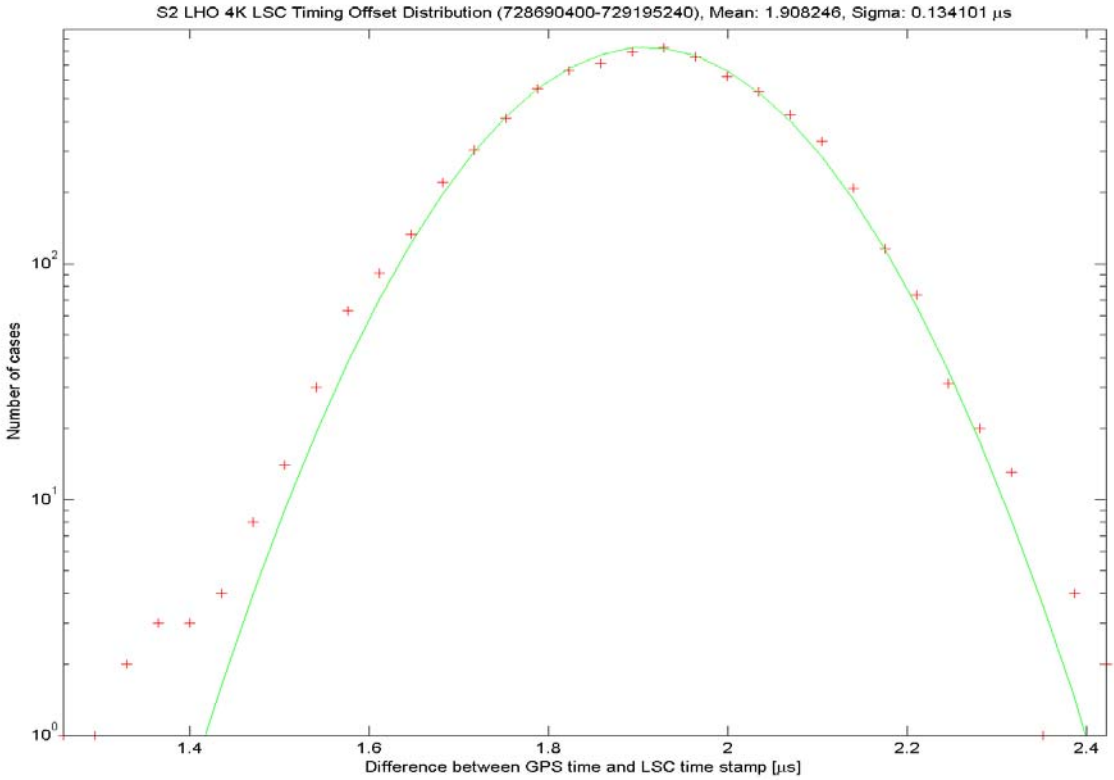
LIGO Hanford 4K interferometer LSC timing histogram

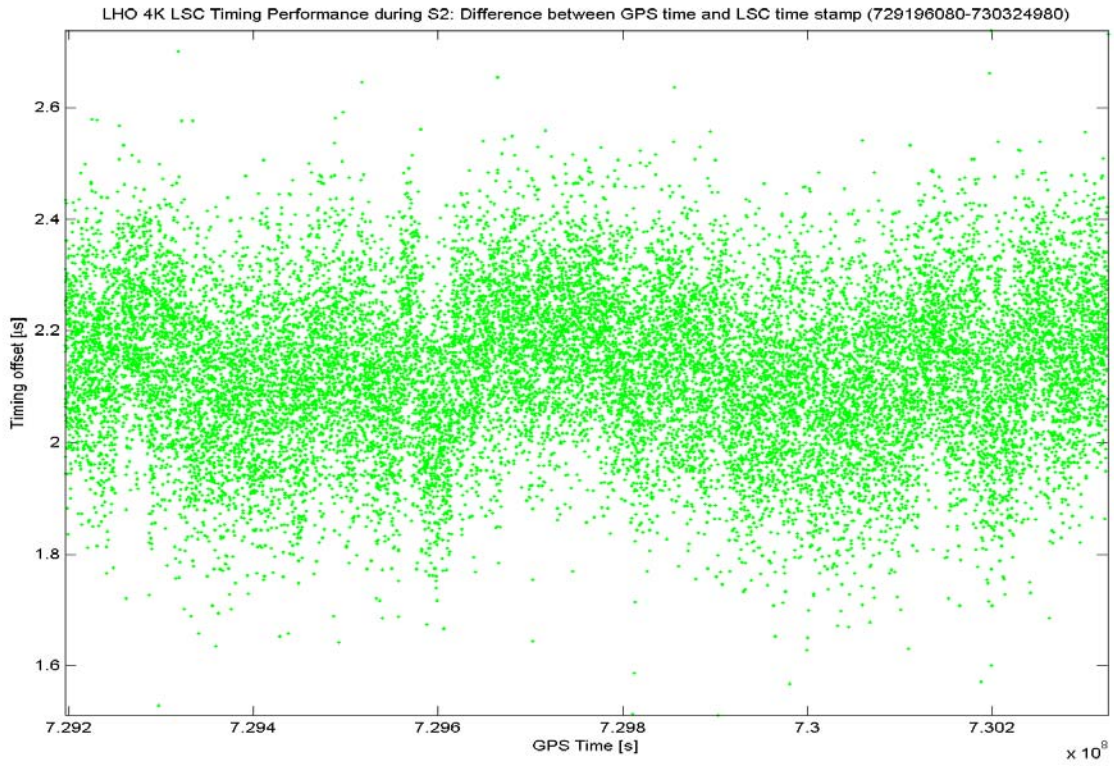
Nominally, the LHO 4K LSC timing offset was :

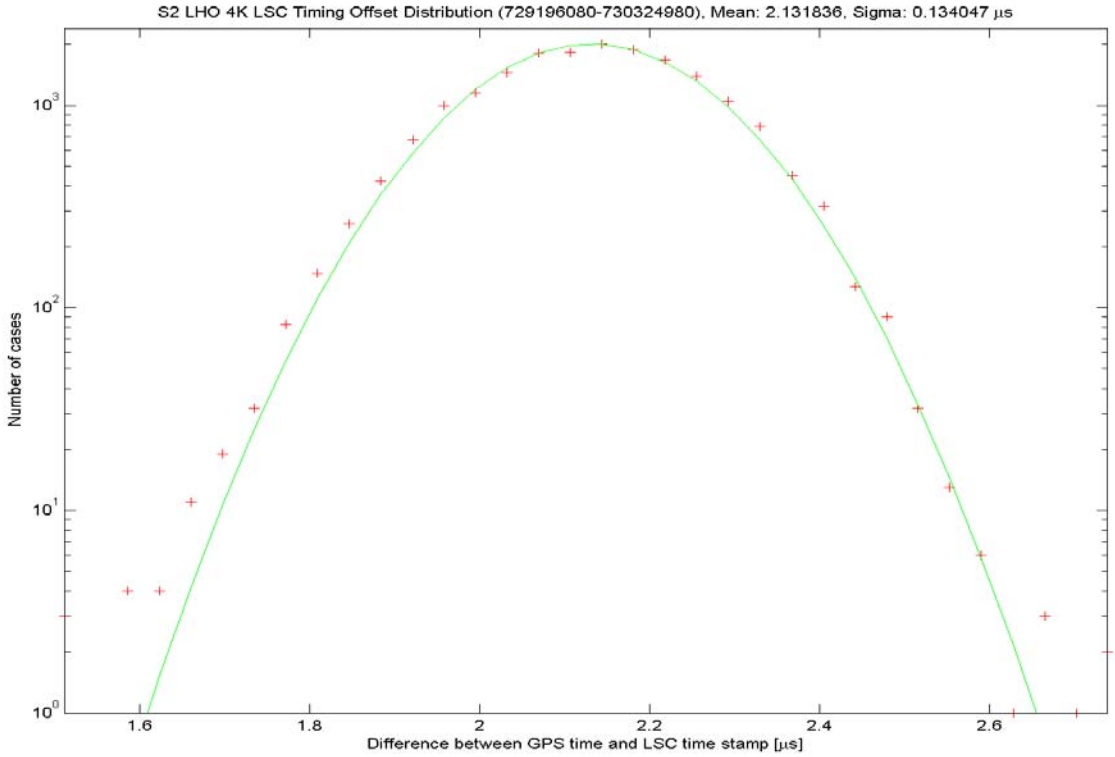
1.9 µs between **728690400** and **729195240** **(504840 seconds long segment)**
2.1 µs between **729196080** and **730324980** **(1128900 seconds long segment)**
1.9 µs between **730325100** and **734489880** **(4164780 seconds long segment)**

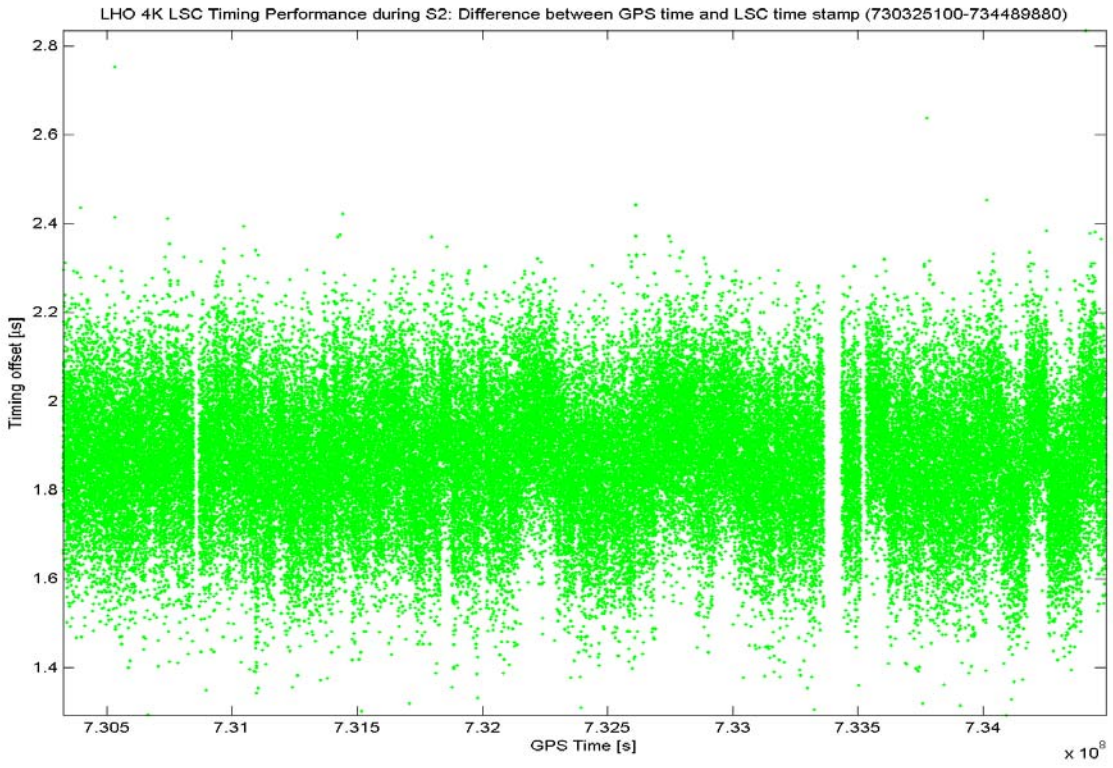
This value should be accurate to ± 1 µs.

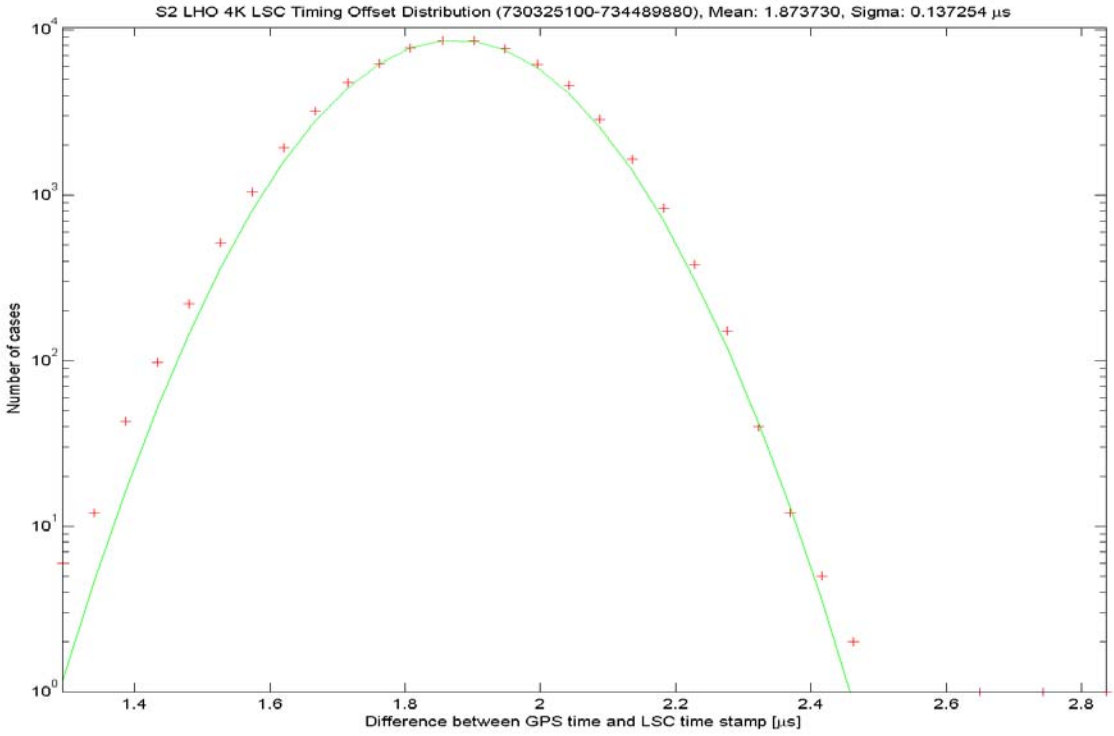

LHO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (728690400-729195240)
Timing offset [µs]
2.4
2.2
2
1.8
1.6
1.4
7.287
7.2875
7.288
7.2885
7.289
7.2895
7.29
7.2905
7.291
7.2915
GPS Time [s]
x 10^8


S2 LHO 4K LSC Timing Offset Distribution (728690400-729195240), Mean: 1.908246, Sigma: 0.134101 µs
Number of cases
10^2
10^1
10^0
1.4
1.6
1.8
2
2.2
2.4
Difference between GPS time and LSC time stamp [µs]

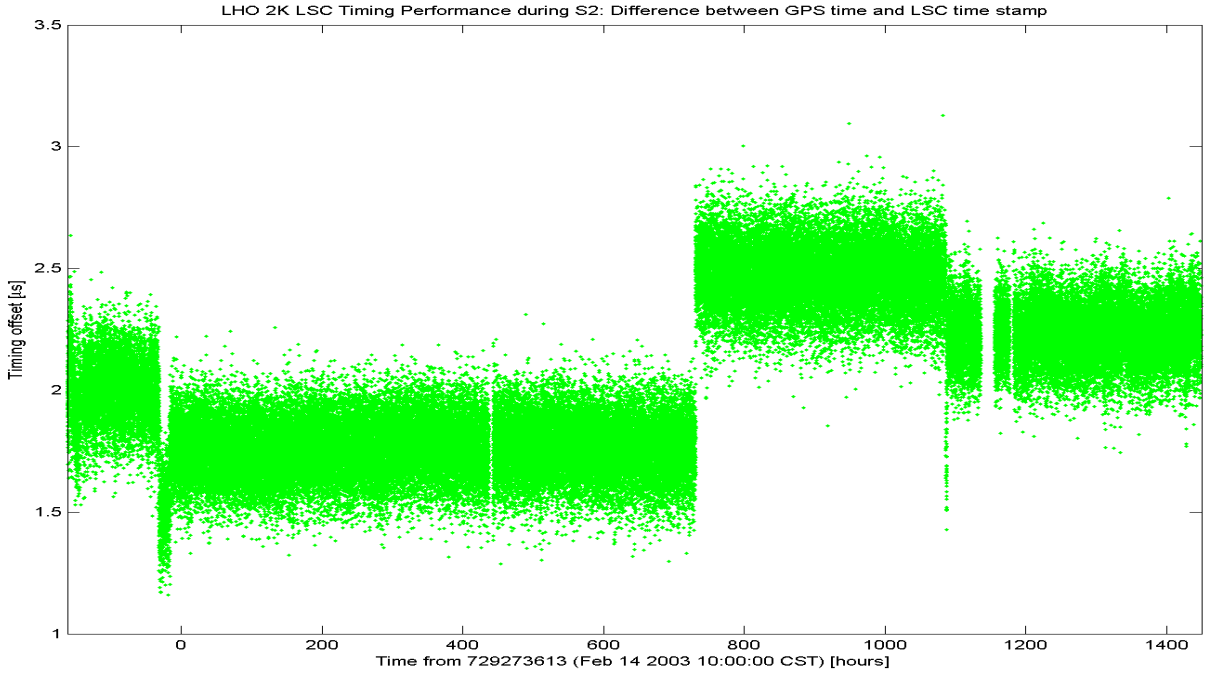

LHO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (729196080-730324980)
Timing offset [μs]
2.6
2.4
2.2
2
1.8
1.6
7.292
7.294
7.296
7.298
7.3
7.302
GPS Time [s]
x 10^8


S2 LHO 4K LSC Timing Offset Distribution (729196080-730324980), Mean: 2.131836, Sigma: 0.134047 μs
Number of cases
10^3
10^2
10^1
10^0
1.6
1.8
2
2.2
2.4
2.6
Difference between GPS time and LSC time stamp [μs]

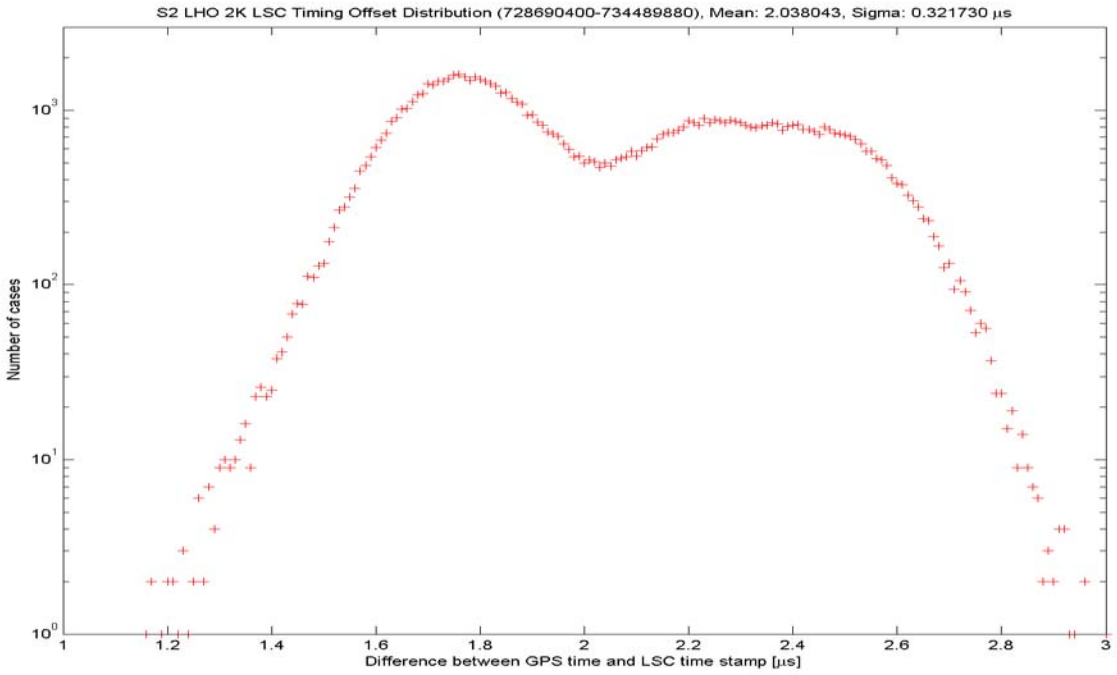

LHO 4K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (730325100-734489880)
Timing offset [μs]
GPS Time [s]
x 10^8


S2 LHO 4K LSC Timing Offset Distribution (730325100-734489880), Mean: 1.873730, Sigma: 0.137254 μs
Number of cases
Difference between GPS time and LSC time stamp [μs]

LIGO Hanford 2K interferometer LSC timing



LIGO Hanford 2K interferometer LSC timing



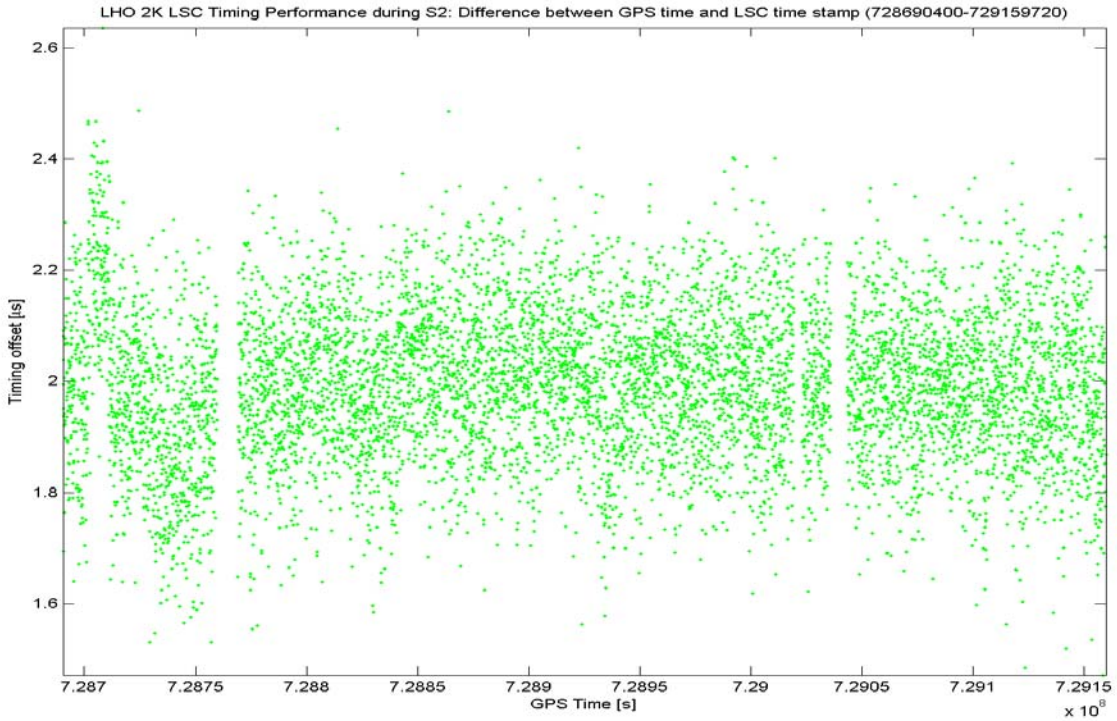
LIGO Hanford 2K interferometer LSC timing histogram

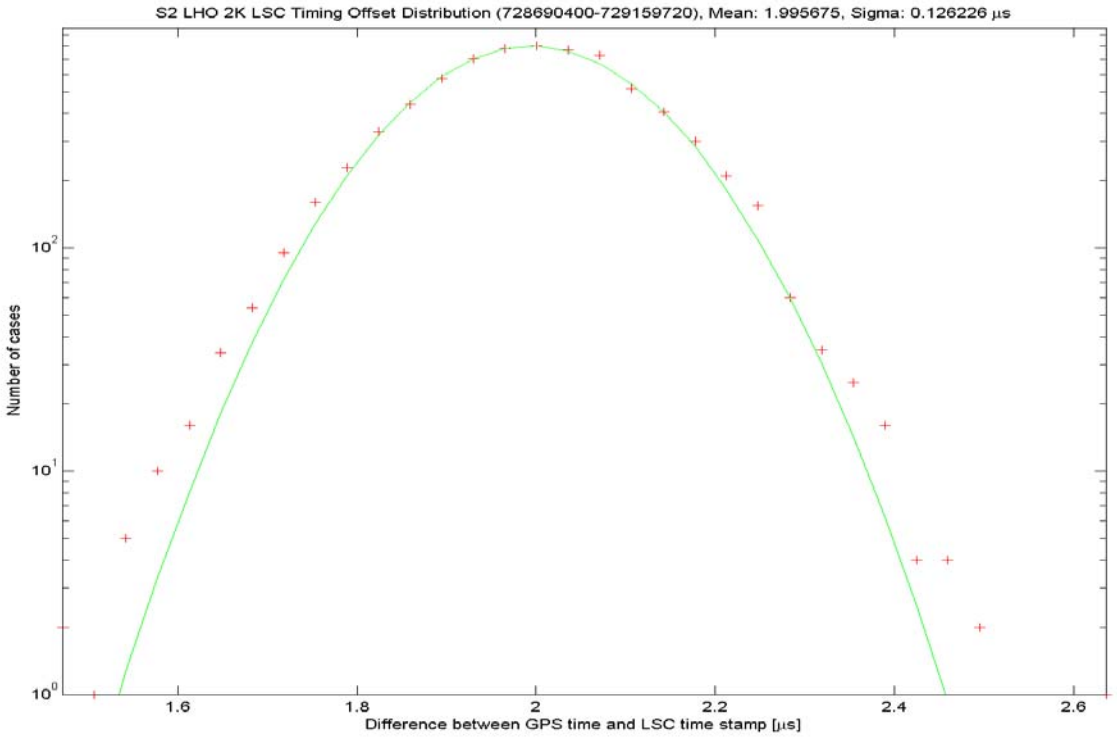
The nominal LHO 2K LSC timing offsets are listed in Table 2.

Table 2 Major H2 timing segments, their duration and the measured offset for each

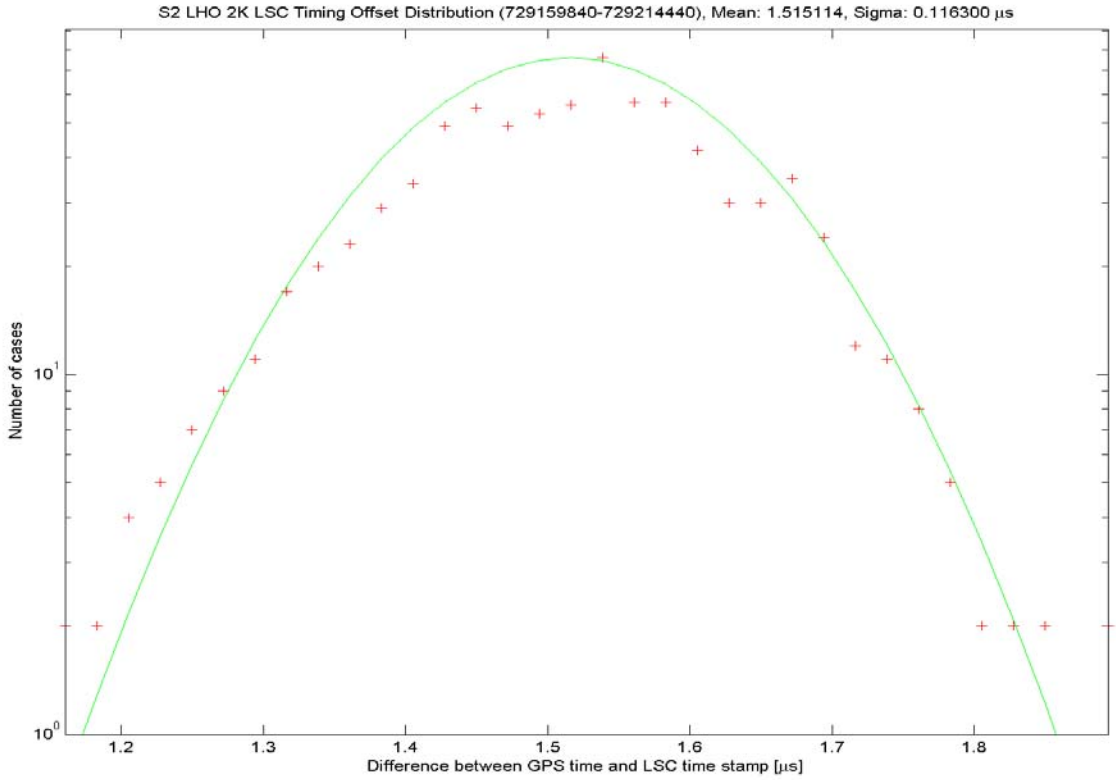
Start time GPS [s]	Stop Time GPS [s]	Offset [μs]	Duration [s]
728690400	729159720	2.0	469320
729159840	729214440	1.5	54600
729214560	731904000	1.8	2689440
731904180	733185780	2.5	1281600
733186020	733190520	1.8	4500
733190820	734489880	2.2	1299060

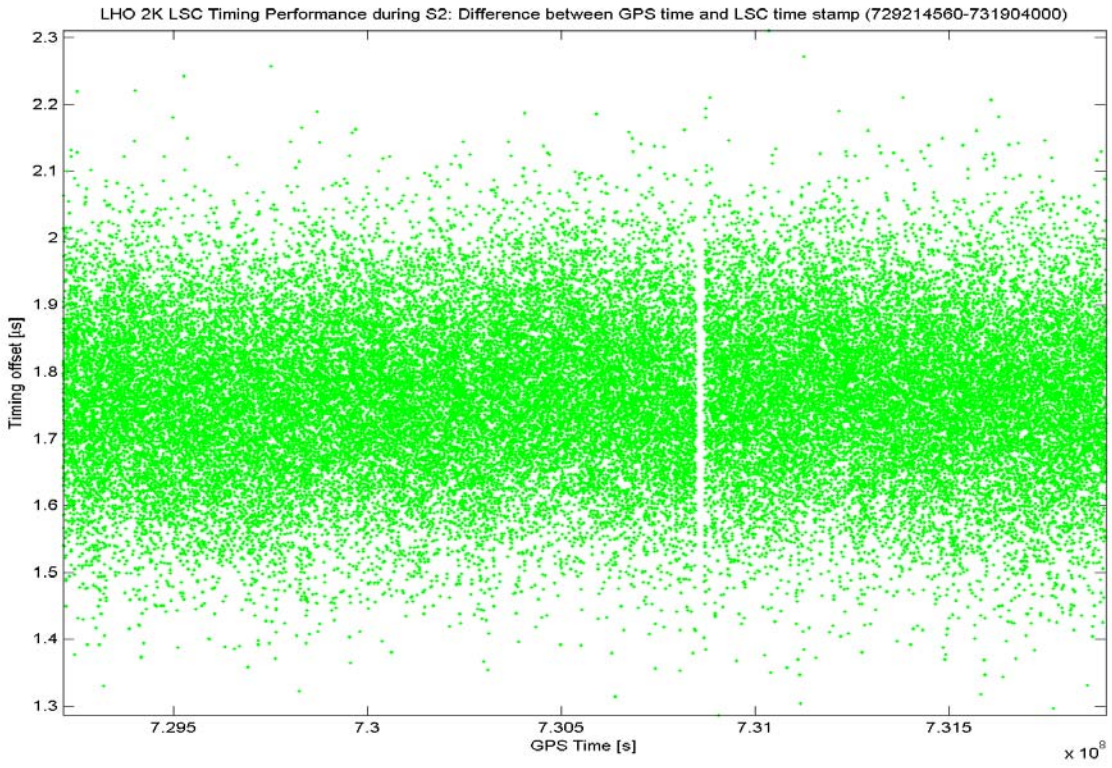
These values should be accurate to ± 1 μs.

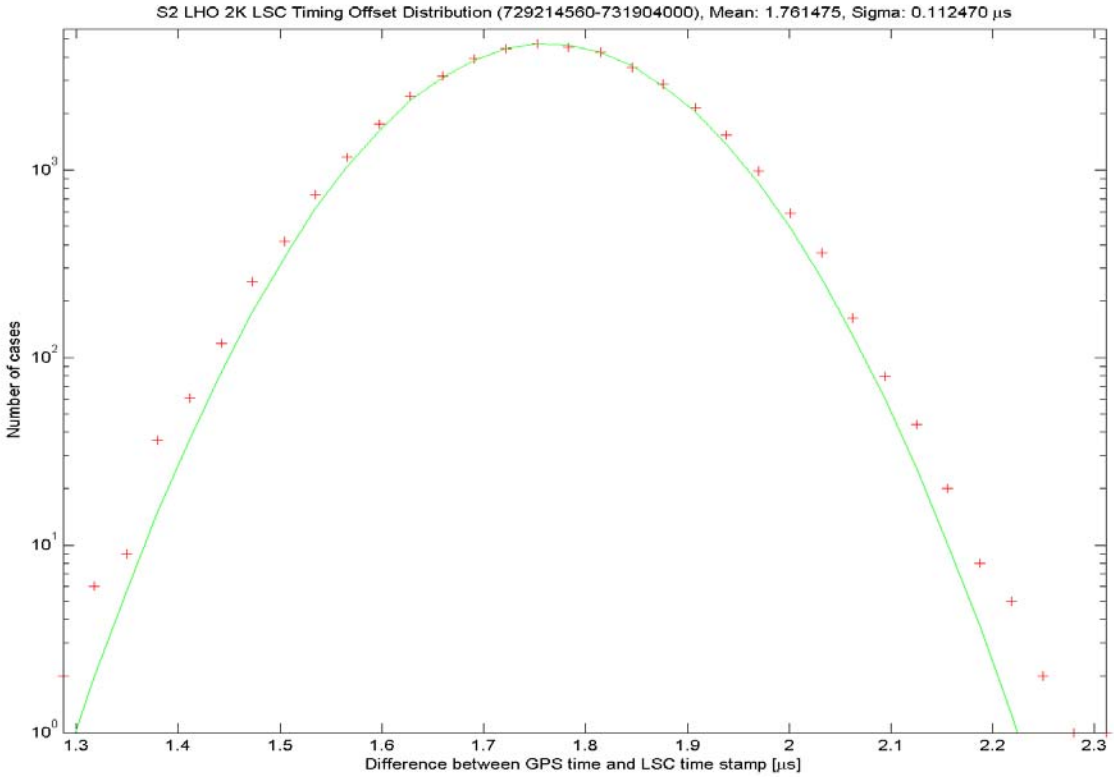

LHO 2K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (728690400-729159720)
Timing offset [μs]
2.6
2.4
2.2
2
1.8
1.6
7.287
7.2875
7.288
7.2885
7.289
7.2895
7.29
7.2905
7.291
7.2915
GPS Time [s]
x 10^8

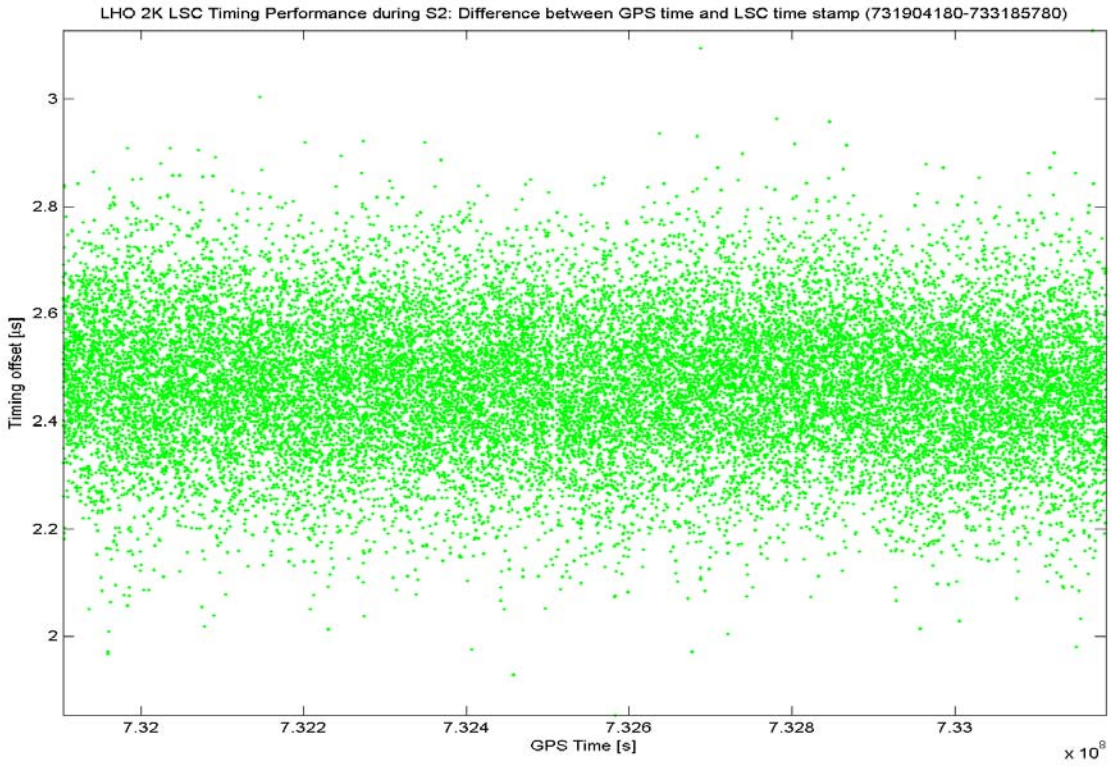

S2 LHO 2K LSC Timing Offset Distribution (728690400-729159720), Mean: 1.995675, Sigma: 0.126226 μs
Number of cases
10^2
10^1
10^0
1.6
1.8
2
2.2
2.4
2.6
Difference between GPS time and LSC time stamp [μs]

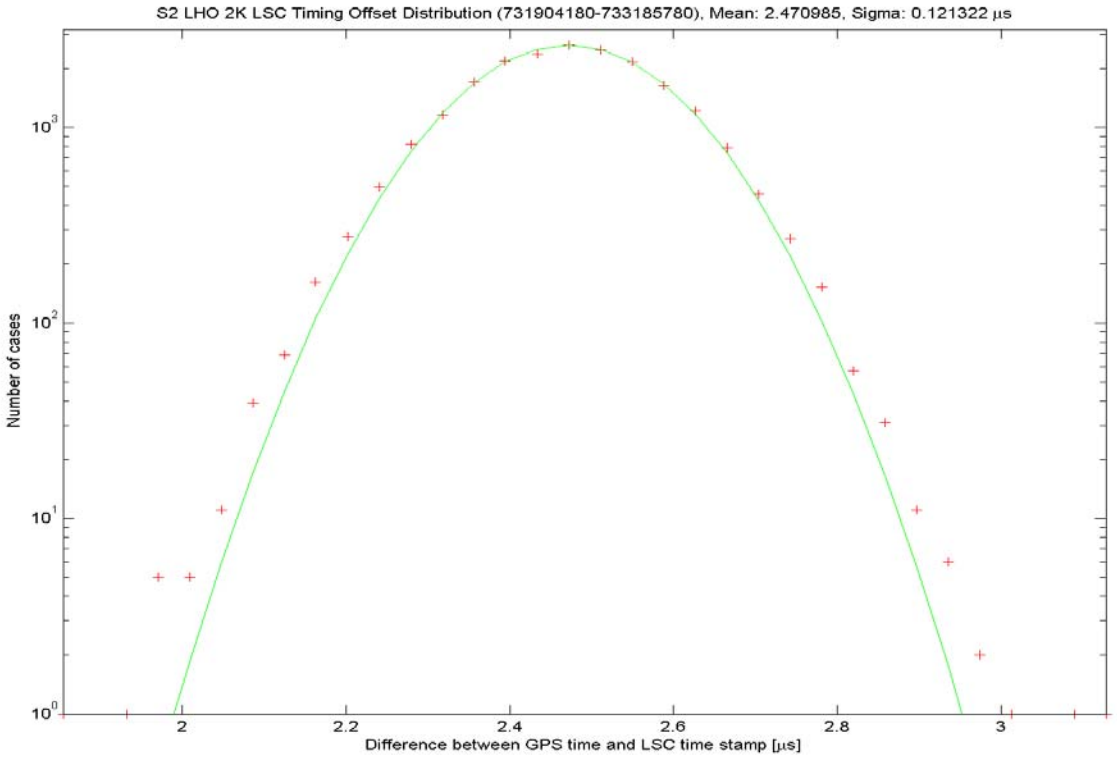

LHO 2K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (729159840-729214440)
Timing offset [μs]
1.8
1.7
1.6
1.5
1.4
1.3
1.2
7.2916
7.2916
7.2917
7.2918
7.2918
7.2919
7.2919
7.2919
7.292
7.292
7.2921
GPS Time [s]
x 10^8

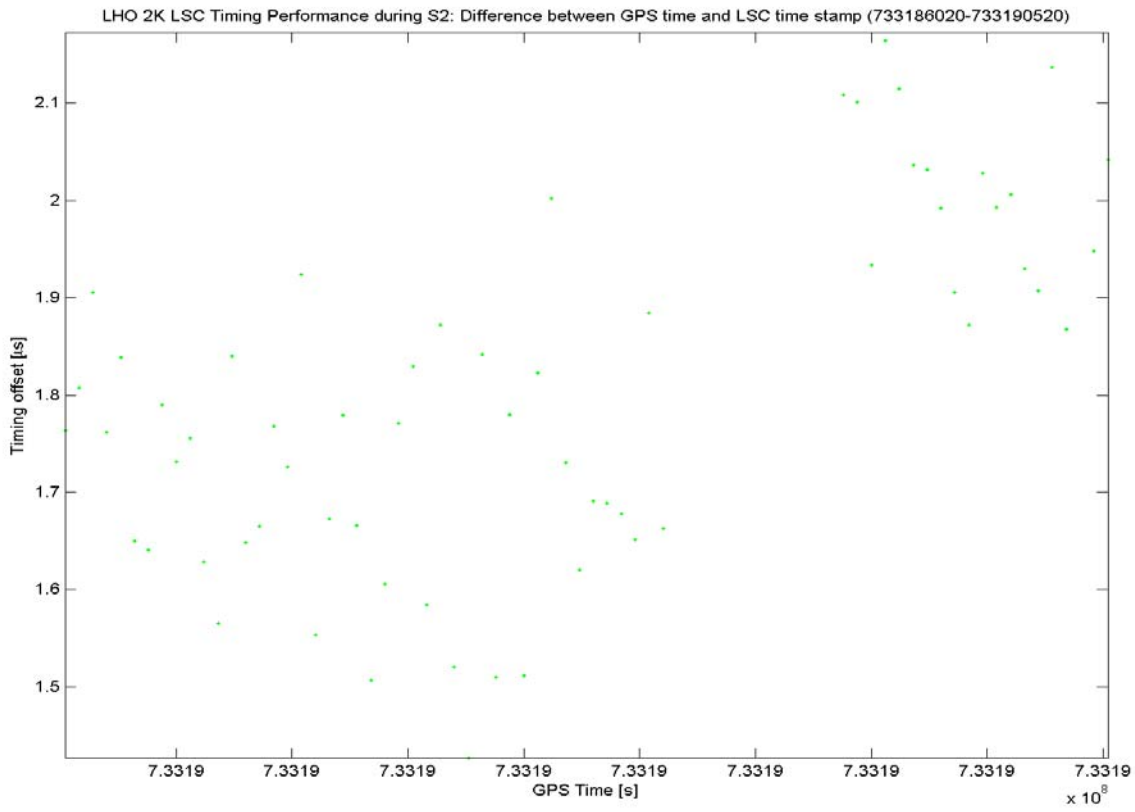

S2 LHO 2K LSC Timing Offset Distribution (729159840-729214440), Mean: 1.515114, Sigma: 0.116300 μs
Number of cases
10^1
10^0
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Difference between GPS time and LSC time stamp [μs]

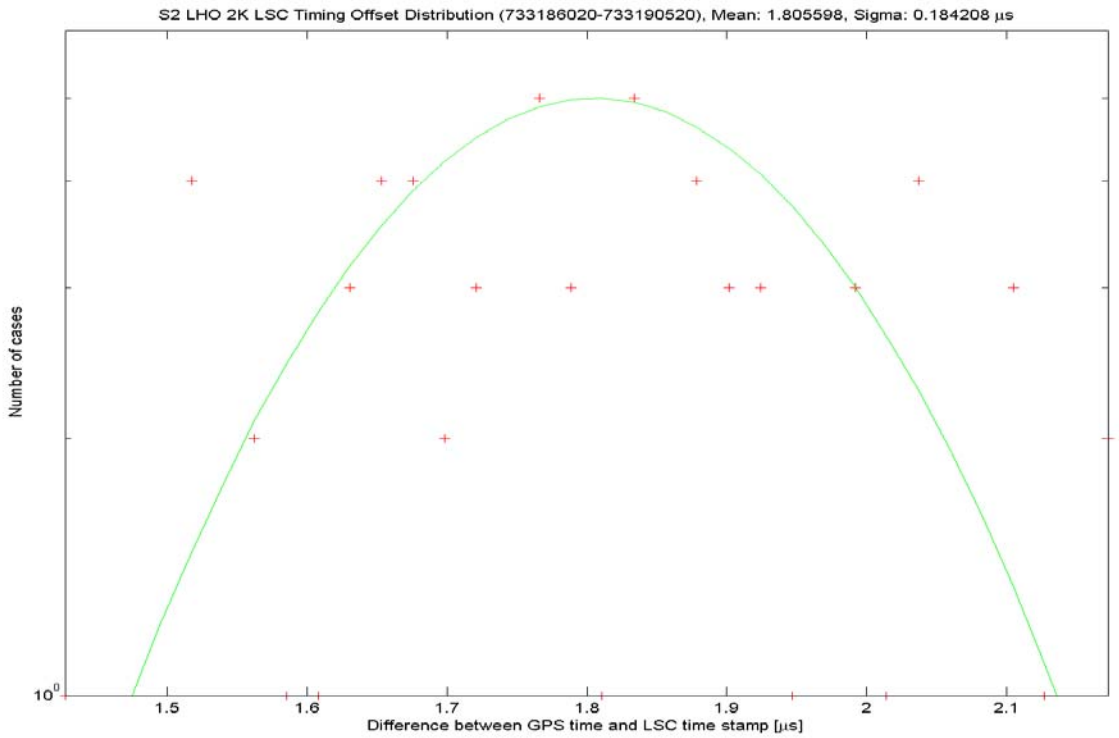

LHO 2K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (729214560-731904000)
Timing offset [µs]
GPS Time [s]
x 10^8

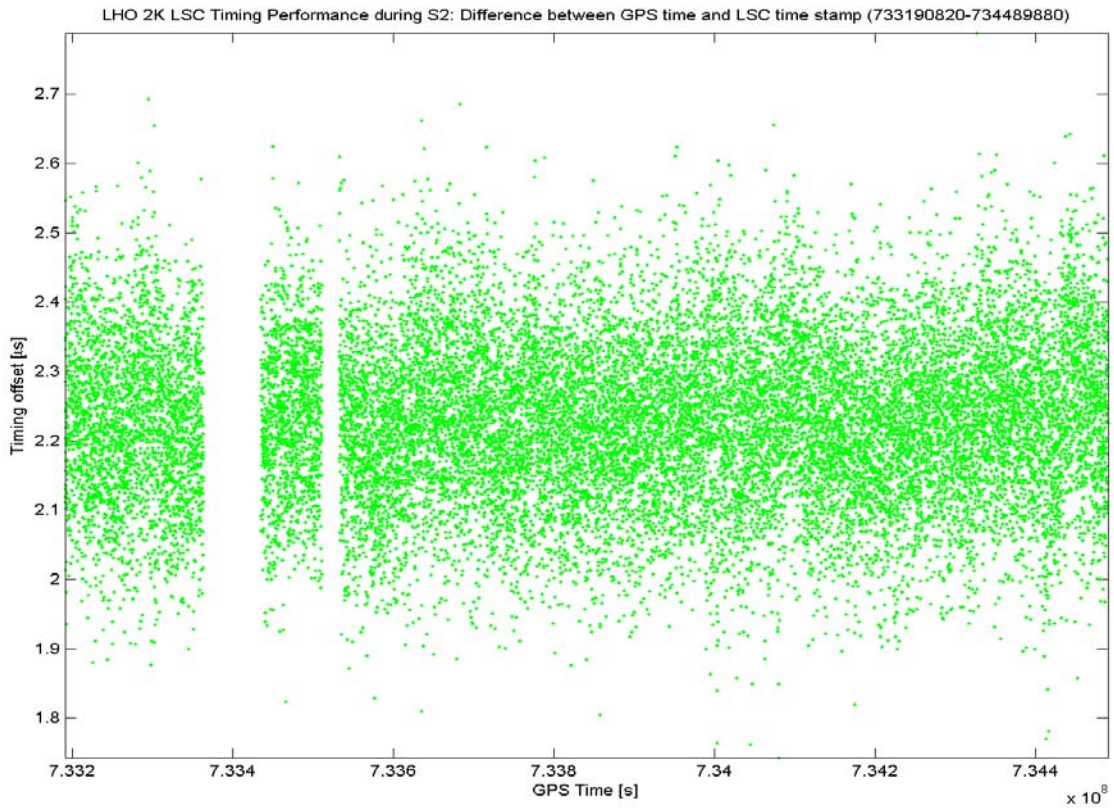

S2 LHO 2K LSC Timing Offset Distribution (729214560-731904000), Mean: 1.761475, Sigma: 0.112470 µs
Number of cases
Difference between GPS time and LSC time stamp [µs]

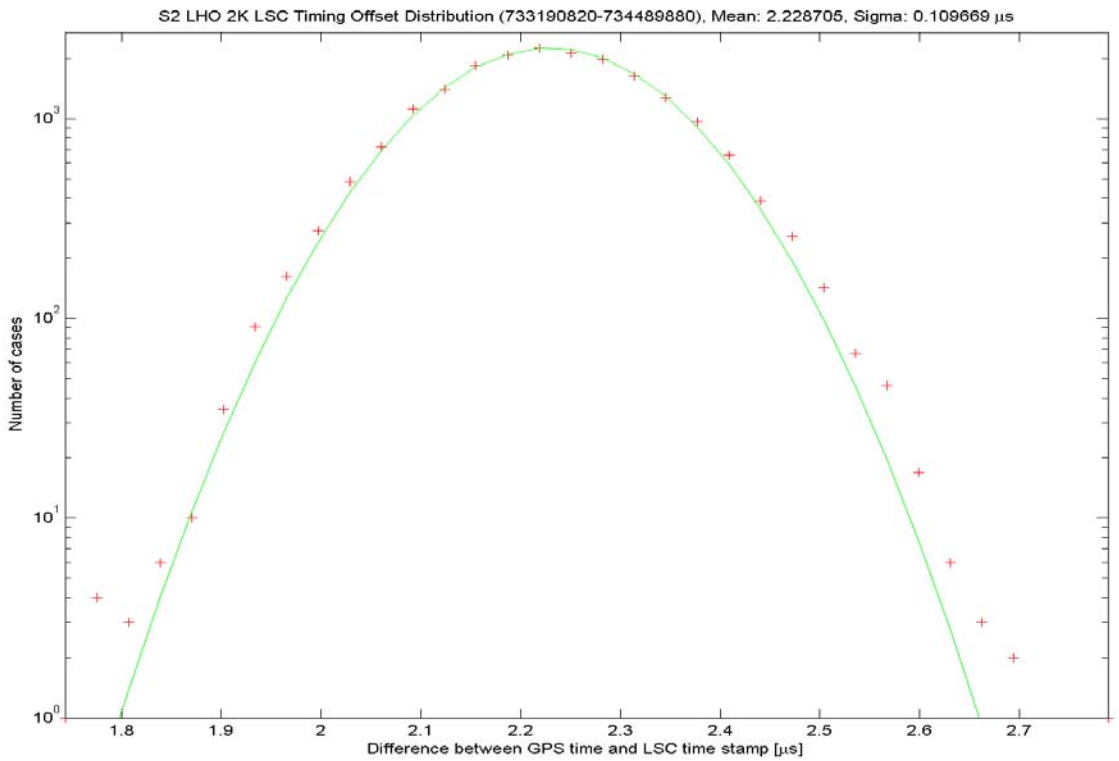

LHO 2K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (731904180-733185780)
Timing offset [µs]
3
2.8
2.6
2.4
2.2
2
7.32
7.322
7.324
7.326
7.328
7.33
GPS Time [s]
x 10^8


S2 LHO 2K LSC Timing Offset Distribution (731904180-733185780), Mean: 2.470985, Sigma: 0.121322 µs
Number of cases
10^3
10^2
10^1
10^0
2
2.2
2.4
2.6
2.8
3
Difference between GPS time and LSC time stamp [µs]


LHO 2K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (733186020-733190520)
Timing offset [μs]
2.1
2
1.9
1.8
1.7
1.6
1.5
7.3319
7.3319
7.3319
7.3319
7.3319
7.3319
7.3319
7.3319
7.3319
GPS Time [s]
x 10^8


S2 LHO 2K LSC Timing Offset Distribution (733186020-733190520), Mean: 1.805598, Sigma: 0.184208 μs
Number of cases
10^0
1.5
1.6
1.7
1.8
1.9
2
2.1
Difference between GPS time and LSC time stamp [μs]


LHO 2K LSC Timing Performance during S2: Difference between GPS time and LSC time stamp (733190820-734489880)
Timing offset [μs]
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
7.332
7.334
7.336
7.338
7.34
7.342
7.344
GPS Time [s]
x 10^8


S2 LHO 2K LSC Timing Offset Distribution (733190820-734489880), Mean: 2.228705, Sigma: 0.109669 μs
Number of cases
10^3
10^2
10^1
10^0
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
Difference between GPS time and LSC time stamp [μs]