U.S. Department of Commerce
Time and Frequency Division
National Institute of Standards and Technology
325 Broadway, Boulder, CO 80305
USA

Report of Calibration: Cal_Id:1015-2023

February 14, 2024

Time and Frequency Division
National Institute of Standards and Technology
bijunath.patla@nist.gov

Abstract

This report is a record of the calibration results of three receivers: NRC4, NRCC, and NRC6 at NRC, Canada, performed via the NIST traveling receiver NB05 during the trip from NIST, Boulder to Canada and back. Three sets of data were collected between MJD60101 and MJD60162 (June 06, 2023, and August 08, 20223) by simultaneous operation of co-located GNSS receivers and the traveling receiver NB05. The purpose of this campaign was to measure the internal delay of the local(visited) receivers and thereby calibrate the links comprising NIST and the visited laboratories for time transfer applications using L1, L2, C1 GPS signals, and E1, E5a Galileo signals. The calibration campaign was initiated by NIST in consultation with the visited laboratories as per the guidelines set by BIPM [1].

Contents

1 Description of the traveling GNSS receiver 2

2 Computing delays in the measurement setup 2

3 Computing raw difference of psuedoranges 3

4 INTDLY and uncertainty estimates 3

5 Secondary information 5

1 Description of the traveling GNSS receiver

The NIST Traveling System consists of Septentrio PolaRx5TR GNSS receiver unit (NB05), a Septentrio PolaNt-x MF.v2 antenna, an antenna cable (LMR 400), a laptop, a time interval counter (TIC) and two auxiliary cables (RG223 with BNC connectors) to be used for measuring the REFDLY for the traveling receiver. An HP53132A time interval counter is provided for measuring REFDLY. For more information, please refer to the NIST traveling receiver operator's manual.

2 Computing delays in the measurement setup

The difference in the total delay for a pair of co-located receivers is the sum of the delays incurred in the antenna cable(CABDLY) and the internal delay(INTDLY), minus the time offset at the latching point of the receiver as referenced to a fixed point, usually UTC(k)(REFDLY). The internal delay is comprised of both code- and frequency-dependent delays in the antenna and the receiver. After accounting for the baseline geometry, the difference in pseudoranges between a pair of receivers, say for P1, is given by

$$\mathrm{RAWDIF(P1)}_{\mathrm{A-B}} = \Delta\mathrm{CABDLY}_{\mathrm{A-B}} + \Delta\mathrm{INTDLY}_{\mathrm{A-B}} - \Delta\mathrm{REFDLY}_{\mathrm{A-B}}, \tag{1}$$

where $\mathrm{RAWDIF(P1)}_{\mathrm{A-B}}$ is the raw difference of pseudorange measurements of two receivers. Similarly for C1 and P2, $\mathrm{RAWDIF(C1/P2)}_{\mathrm{A-B}}$ is given by using the corresponding set of delays on the right-hand side of Eq.(1). The notation for the receivers A and B corresponds to the traveling- and station-receiver. $\Delta\mathrm{CABDLY}_{\mathrm{A-B}}$ and $\Delta\mathrm{REFDLY}_{\mathrm{A-B}}$ for NB05(A) and labv/NIST(B) are given in Table 1, referenced from Annexes—at the end of this report. We will refer to the visited laboratory receiver as labv. NISX and NB05 are NIST station- and traveling-receivers respectively. In this calibration campaign, we calibrate a total of three receivers in the visited laboratories. The procedure for measuring NB05 REFDLY (both $\mathrm{X_P}$ and $\mathrm{X_O}$) is outlined in the operating manual. The visited laboratories are responsible for the REFDLY and CABDLY values for their station receivers.

Table 1: REFDLY and CABDLY and their differences between traveling and station receivers

Pair	MJD	$\mathrm{REF_{DLY}}$ (NB05)	$\mathrm{REF_{DLY}}$ (labv)	$\mathrm{CAB_{DLY}}$ (NB05)	$\mathrm{CAB_{DLY}}$ (labv)	$\Delta\mathrm{REF_{DLY}}$ (ns)	$\Delta\mathrm{CAB_{DLY}}$ (ns)
NB05-NISX	60101-60107	469.7	121.6	328.6	275.5	348.07	53.1
NB05-NRC4	60133-60137	64.1	228.81	328.6	269.26	-164.7	59.34
NB05-NRCC		64.1	58.65	328.6	314.94	5.45	13.66
NB05-NRC6	60145-60149	54.2	49.99	328.6	37.63	4.17	290.97
NB05-NISX	60157-60162	469.7	121.6	328.6	275.5	348.07	53.1

3 Computing raw difference of psuedoranges

The RINEX files for a pair of co-located receivers during the data acquisition period, MJD column in Table 1, are processed using *dclrinex* software provided by the BIPM that solves for the baseline between the phase centers of the two antennas from L1 and L2 phase differences [3, 4]. Subsequently, the P1 and P2 pseudorange differences are formed after accounting for the baseline. The results with the average values of RAWDIF are given in Table 2. The values for ΔINTDLY between a given pair of receivers are computed using Eq.(1) and are given in Table 3. NB05 and NISX are operated in auto compensation OFF mode.

Table 2: Computed raw differences: P1, P2, C1, E1, and E5.

Pair	RAWDIF(P1)	RAWDIF(P2)	RAWDIF(C1) (ns)	RAWDIF(E1)	RAWDIF(E5)
NB05-NISX	-292.54	-296.346	-292.657	-292.635	-297.19
NB05-NRC4	193.637	183.547	194.384	194.506	186.876
NB05-NRCC	6.581	5.242	6.535	6.613	5.023
NB05-NRC6	285.071	280.632	284.873	284.989	283.734
NB05-NISX	-292.59	-296.703	-292.725	-292.681	-297.245

Table 3: INTDLY difference: traveling and station receivers.

Pair	ΔINTDLY(P1)	ΔINTDLY(P2)	ΔINTDLY(C1) (ns)	ΔINTDLY(E1)	ΔINTDLY(E5)
NB05-NISX	2.43	-1.376	2.313	2.335	-2.22
NB05-NRC4	-30.413	-40.503	-29.666	-29.544	-37.174
NB05-NRCC	-1.629	-2.968	-1.675	-1.597	-3.187
NB05-NRC6	-1.729	-6.168	-1.927	-1.811	-3.066
NB05-NISX	2.38	-1.733	2.245	2.289	-2.275

4 INTDLY and uncertainty estimates

Systematic and statistical uncertainties are assigned as given in Table 4. Misclosure is inferred from Table 2 and RAWDIF uncertainties for labv are from time deviation (TDEV), see attached plots at the end of this report. All other uncertainties are fixed values. The combined uncertainty given in Table 5 is obtained by combining uncorrelated (assumed) uncertainties in quadrature. The most recent G1 calibration results for NISX delays should be available from BIPM.

Table 4: Uncertainty assigned for each station

quantity	unc type	NRC4 (ns)	NRCC (ns)	NRC6 (ns)
RAWDIF (P1)$_{\mathrm{NB05-labv}}$	u_a	0.015	0.009	0.036
RAWDIF(P2)$_{\mathrm{NB05-labv}}$	u_a	0.015	0.02	0.025
RAWDIF (C1)$_{\mathrm{NB05-labv}}$	u_a	0.018	0.011	0.02
RAWDIF (E1)$_{\mathrm{NB05-labv}}$	u_a	0.027	0.054	0.069
RAWDIF(E5)$_{\mathrm{NB05-labv}}$	u_a	0.032	0.059	0.049
NB05 antenna position	$u_{b,11}$		0.05	
labv antenna position	$u_{b,12}$		0.05	
NB05 multipath	$u_{b,13}$		0.20	
labv multipath	$u_{b,14}$		0.20	
REFDLY$_{\mathrm{NB05}}$	$u_{b,21}$		0.15	
REFDLY$_{\mathrm{labv}}$	$u_{b,22}$		0.15	
CABDLY$_{\mathrm{NB05}}$	$u_{b,31}$		0.15	
CABDLY$_{\mathrm{labv}}$	$u_{b,32}$		0.15	
Misclosure(P1)	$u_{b,1}$		0.025	
Misclosure(P2)	$u_{b,1}$		0.1785	
Misclosure(C1)	$u_{b,1}$		0.034	
Misclosure(E1)	$u_{b,1}$		0.023	
Misclosure(E5)	$u_{b,1}$		0.0275	

Table 5: INTDLY difference: station receivers.

Pair	INTDLY(P1)	INTDLY(P2)	INTDLY(C1) (ns)	INTDLY(E1)	INTDLY(E5)
NRC4(PRx4)-NISX	32.81(45)	38.94(45)	31.94(45)	31.85(45)	34.92(45)
NRCC(PRx5)-NISX	4.03(45)	1.41(45)	3.95(45)	3.90(46)	0.93(46)
NRC6(PRx5)-NISX	4.13(45)	4.61(45)	4.20(45)	4.12(46)	0.81(46)

5 Secondary information

1. RAWDIF and TDev plots: Attached separately.
2. AnnexA: Attached separately.

References

[1] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/

[2] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/group1/1001-2018/1001-2020-phase3-report.pdf

[3] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/doc-soft/

[4] http://www.bipm.org/wg/CCTF/WGGNSS/Allowed/BIPM_guidelines_V3/Annex-3_Computation-procedure-Rinex_V2.pdf

Annex A - Information Sheet

Laboratory:	**NIST, Boulder, USA**
Date and hour of the beginning of measurements:	DOY150-225, 2023
Date and hour of the end of measurements:	

Information on the system		
	Local:	**Traveling:**
4-character BIPM code	**NISX**	**NB05**
Receiver maker and type: Receiver serial number:	PolaRxTR 5 S/N	PolaRxTR 5 S/N 3025300
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilized cable (Y/N):	Andrew FSJ-50A N	LMR 400 N
Length outside the building /m:	65	50
Antenna maker and type: Antenna serial number:	Novatel 702	Septentrio PolaNt-x MFv2
Temperature (if stabilized) /°C		

Measured delays /ns		
	Local:	**Traveling:**
Delay from local UTC to receiver 1 PPS-in (X_P)	66.7	327.8+85.8 = 413.6
Delay from 1 PPS-in to internal Reference (if different): (X_O)	54.9	56.07
Antenna cable delay: (X_C)	275.5	328.6
Splitter delay (if any):	N/A	N/A
Additional cable delay (if any):	N/A	N/A

Data used for the generation of CGGTTS files

• INT DLY (or X_R+X_S) (GPS)† /ns:	28.16 (P1), 26.31(P2)
• INT DLY (or X_R+X_S) (Galileo) /ns:	30. 54 (E1), 31.15 (E5a)
• CAB DLY (or X_C) /ns:	275.5
• REF DLY (or X_P+X_O) /ns:	120
• Coordinates reference frame:	WGS84
X /m:	-1288398.60
Y /m:	-4721697.05
Z /m	4078625.45

General information

• Rise time of the local UTC pulse:	3 ns
• Is the laboratory air conditioned:	yes
Set temperature value and uncertainty:	
Set humidity value and uncertainty:	

† Based on Cal_Id 1001-2020

Annex A - Information Sheet

Laboratory:	**National Research Council Canada (NRC)**
Date and hour of the beginning of measurements	2023-07-08 00:00:00
Date and hour of the end of measurements	2023-07-12 23:59:30

Information on the system		
	Local	**Traveling**
4-character BIPM code	**NRC4**	**nb05**
Receiver maker and type Receiver serial number	Septentrio, PolaRx4TRpro 31022286	Septentrio, PolaRx5TR 4701275
1 PPS trigger level /V	1.0 V	1.0 V
Antenna cable maker and type Phase stabilized cable (Y/N)	Andrea, Heliax LDF 2-50 Y	LMR-400 Y
Length outside the building /m:	~1.5 m	~ 20 m
Antenna maker, type, and serial number	ASH701945E_M SNOW GR52002205	PolaNt-x MF.v2, AT1675-486 5251
Temperature (if stabilized) /°C		

Measured delays /ns		
	Local	**Traveling**
Delay from local UTC to receiver 1 PPS-in (X_P)	84.40 ns	16.30 ns
Delay from 1 PPS-in to internal Reference (if different)(X_O)	144.41 ns	47.80 ns
Antenna cable delay (X_C)	269.26 ns	328.84 ns
Splitter delay (if any)	unknown	No
Additional cable delay (if any)	Surge arrestor included in cable delay	No

Data used for the generation of CGGTTS files	
INT DLY (or X_R+X_S) (GPS) /ns	
CAB DLY (or X_C) /ns	
REF DLY (or X_P+X_O) /ns	
Coordinates reference frame	
X /m	
Y /m	
Z /m	

General information	
Rise time of the local UTC pulse	2.70 ns
Is the laboratory air conditioned ? (Y/N)	Y
Set temperature value and uncertainty	24.8 ± 0.5 °C
Set humidity value and uncertainty	

Annex A - Information Sheet

Laboratory:	**National Research Council Canada (NRC)**
Date and hour of the beginning of measurements	2023-07-08 00:00:00
Date and hour of the end of measurements	2023-07-12 23:59:30

Information on the system		
	Local	**Traveling**
4-character BIPM code	**NRCC**	**nb05**
Receiver maker and type Receiver serial number	Septentrio, PolaRx5TR 4701362	Septentrio, PolaRx5TR 4701275
1 PPS trigger level /V	1.0 V	1.0 V
Antenna cable maker and type Phase stabilized cable (Y/N)	Andrea Heliax, LDF2-50 3/8” Y	LMR-400 Y
Length outside the building /m:	~8 m	~ 20 m
Antenna maker, type, and serial number	PolaNt Choke Ring B3/E6 5645	PolaNt-x MF.v2, AT1675-486 5251
Temperature (if stabilized) /°C		

Measured delays /ns		
	Local	**Traveling**
Delay from local UTC to receiver 1 PPS-in (X_P)	19.04 ns	16.30 ns
Delay from 1 PPS-in to internal Reference (if different)(X_O)	39.61 ns	47.80 ns
Antenna cable delay (X_C)	305.44 ns	328.84 ns
Splitter delay (if any)	9.50 ns	No
Additional cable delay (if any)	-	No

Data used for the generation of CGGTTS files	
INT DLY (or X_R+X_S) (GPS) /ns	
CAB DLY (or X_C) /ns	
REF DLY (or X_P+X_O) /ns	
Coordinates reference frame	
X /m	
Y /m	
Z /m	

General information	
Rise time of the local UTC pulse	2.45 ns
Is the laboratory air conditioned ? (Y/N)	Y
Set temperature value and uncertainty	24.8 ± 0.5 °C
Set humidity value and uncertainty	

Annex A - Information Sheet

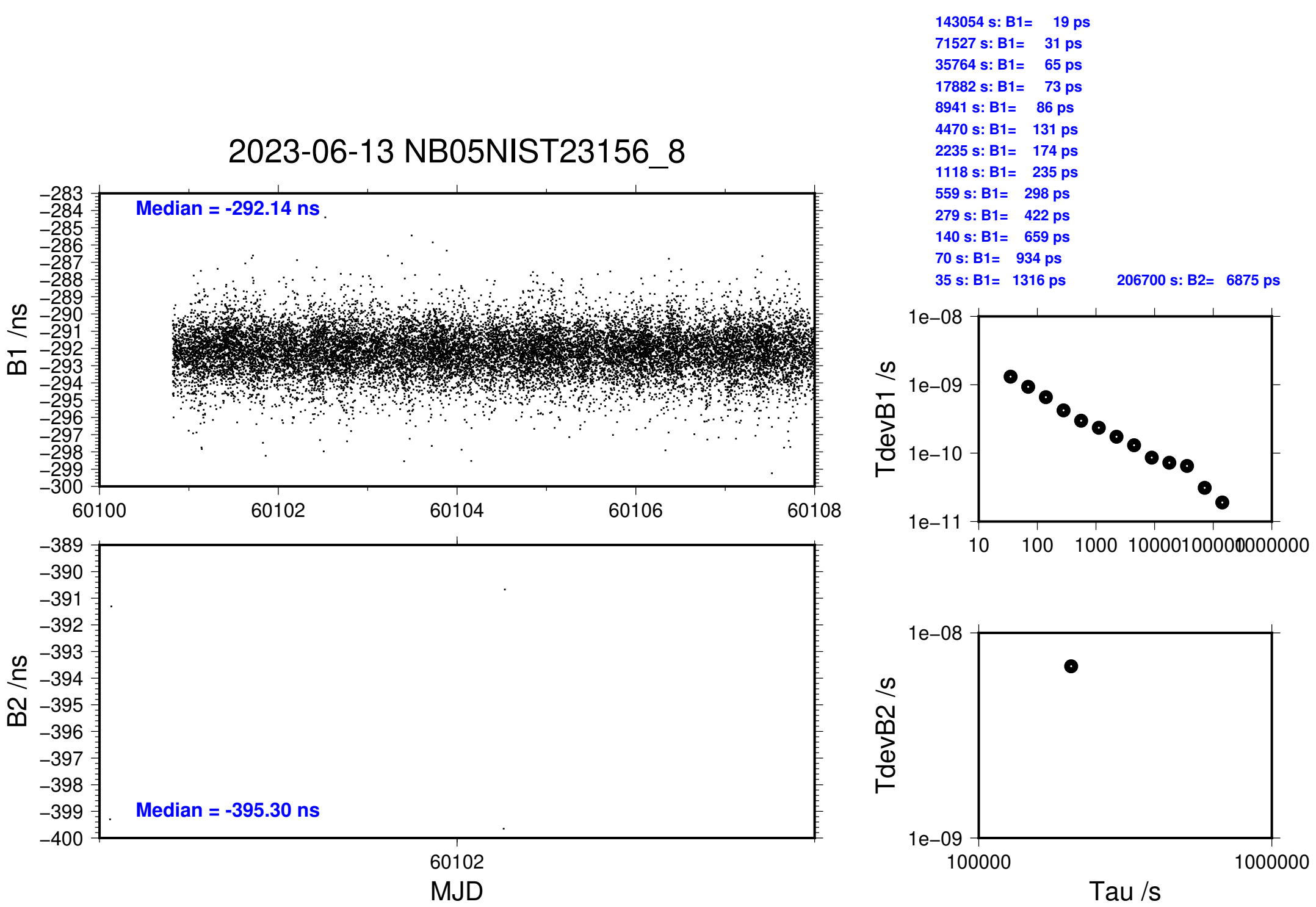
Laboratory:	**National Research Council Canada (NRC)**
Date and hour of the beginning of measurements	2023-07-20 00:00:00
Date and hour of the end of measurements	2023-07-24 23:59:30

Information on the system		
	Local	**Traveling**
4-character BIPM code	**NRC6**	**nb05**
Receiver maker and type Receiver serial number	Septentrio, PolaRx5TR 47011574	Septentrio, PolaRx5TR 4701275
1 PPS trigger level /V	1.0 V	1.0 V
Antenna cable maker and type Phase stabilized cable (Y/N)	Andrea Heliax, LDF2-50 3/8” Y	LMR-400 Y
Length outside the building /m:	~2 m	~15 m
Antenna maker, type, and serial number	PolaNt Choke Ring B3/E6 6064	PolaNt-x MF.v2, AT1675-486 5251
Temperature (if stabilized) /°C		

Measured delays /ns		
	Local	**Traveling**
Delay from local UTC to receiver 1 PPS-in (X_P)	2.86 ns	4.85 ns
Delay from 1 PPS-in to internal Reference (if different)(X_O)	47.13 ns	49.31 ns
Antenna cable delay (X_C)	37.63 ns	328.84 ns
Splitter delay (if any)	Splitter is not counted.	No
Additional cable delay (if any)	Surge arrestor is not counted.	No

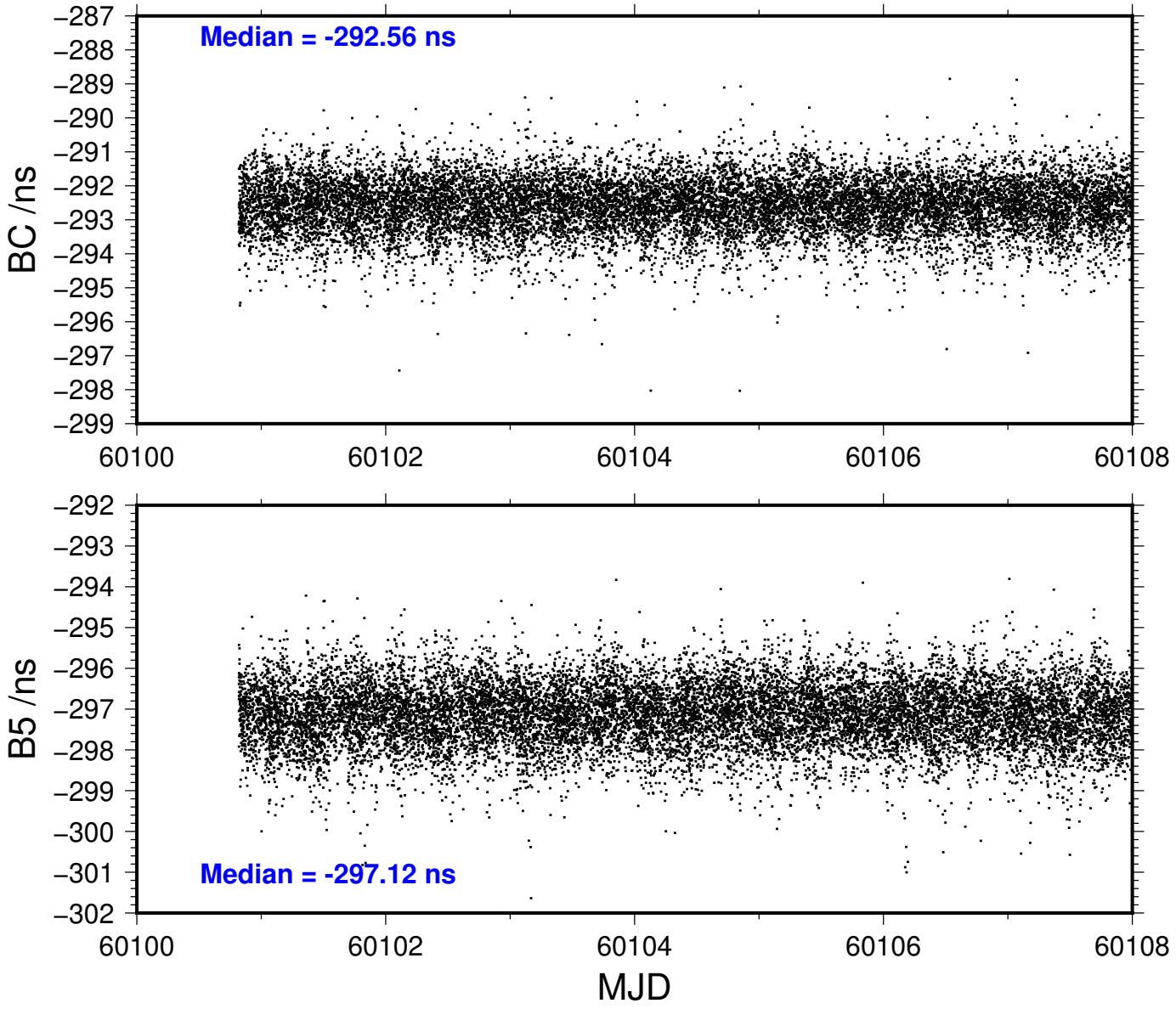
Data used for the generation of CGGTTS files	
INT DLY (or X_R+X_S) (GPS) /ns	
CAB DLY (or X_C) /ns	
REF DLY (or X_P+X_O) /ns	
Coordinates reference frame	
X /m	
Y /m	
Z /m	

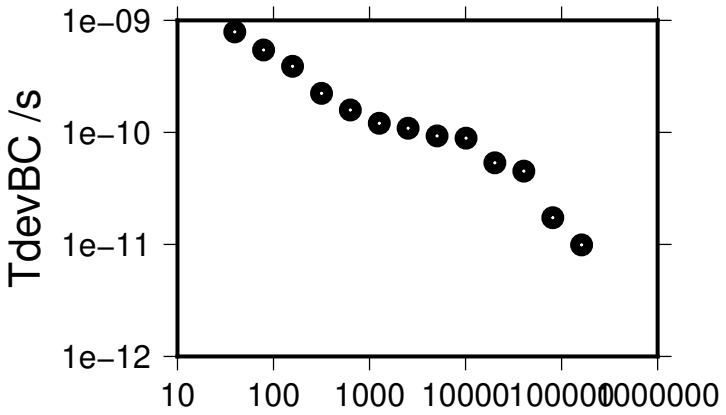
General information	
Rise time of the local UTC pulse	2.0 ns
Is the laboratory air conditioned ? (Y/N)	Y
Set temperature value and uncertainty	19.6 ± 2.5 °C
Set humidity value and uncertainty	

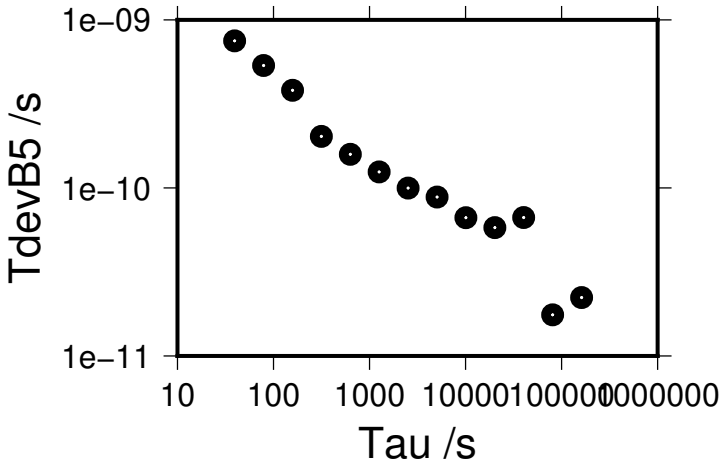

2023-06-13 NB05NIST23156_8
Median = -292.14 ns
B1 /ns
−283
−284
−285
−286
−287
−288
−289
−290
−291
−292
−293
−294
−295
−296
−297
−298
−299
−300
60100
60102
60104
60106
60108
Median = -395.30 ns
B2 /ns
−389
−390
−391
−392
−393
−394
−395
−396
−397
−398
−399
−400
60102
MJD
143054 s: B1= 19 ps
71527 s: B1= 31 ps
35764 s: B1= 65 ps
17882 s: B1= 73 ps
8941 s: B1= 86 ps
4470 s: B1= 131 ps
2235 s: B1= 174 ps
1118 s: B1= 235 ps
559 s: B1= 298 ps
279 s: B1= 422 ps
140 s: B1= 659 ps
70 s: B1= 934 ps
35 s: B1= 1316 ps
206700 s: B2= 6875 ps
TdevB1 /s
1e−08
1e−09
1e−10
1e−11
10
100
1000
10000
100000
1000000
TdevB2 /s
1e−08
1e−09
100000
1000000
Tau /s

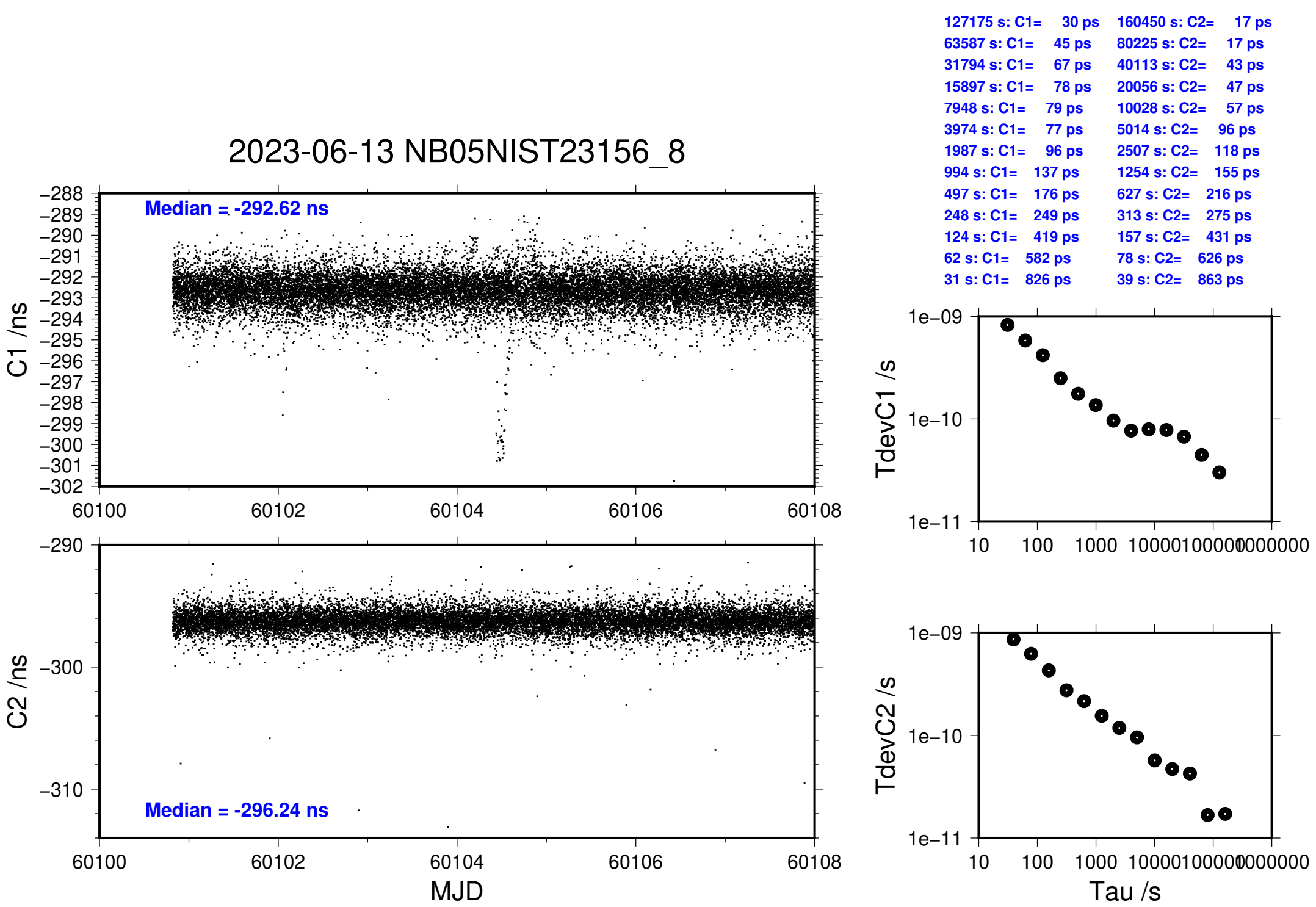
2023-06-13 NB05NIST23156_8

161635 s: BC=	10 ps	161388 s: B5=	22 ps
80817 s: BC=	17 ps	80694 s: B5=	18 ps
40409 s: BC=	45 ps	40347 s: B5=	67 ps
20204 s: BC=	54 ps	20174 s: B5=	58 ps
10102 s: BC=	89 ps	10087 s: B5=	66 ps
5051 s: BC=	93 ps	5043 s: B5=	88 ps
2526 s: BC=	109 ps	2522 s: B5=	100 ps
1263 s: BC=	121 ps	1261 s: B5=	125 ps
631 s: BC=	158 ps	630 s: B5=	159 ps
316 s: BC=	223 ps	315 s: B5=	203 ps
158 s: BC=	389 ps	158 s: B5=	381 ps
79 s: BC=	544 ps	79 s: B5=	535 ps
39 s: BC=	789 ps	39 s: B5=	751 ps



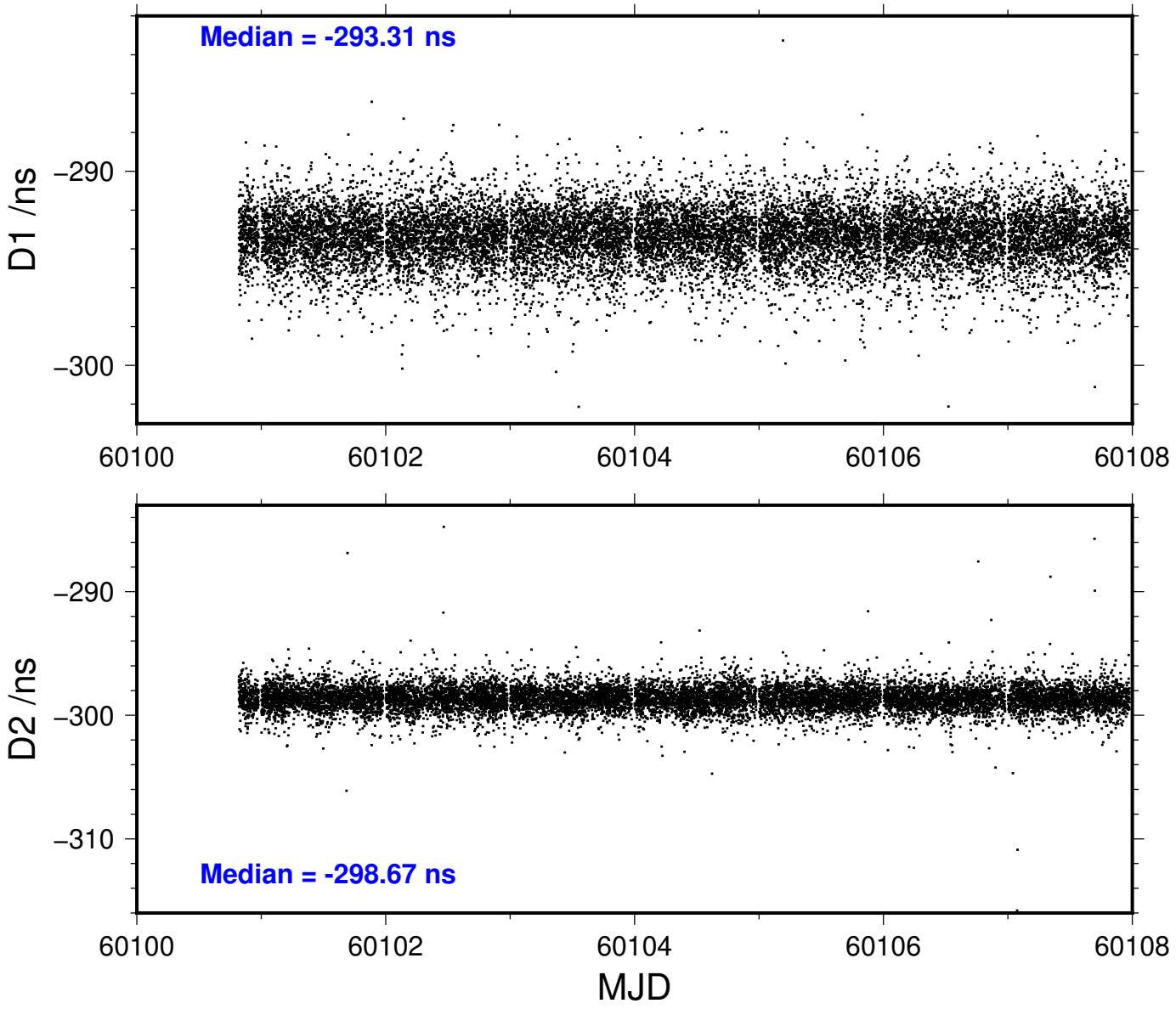


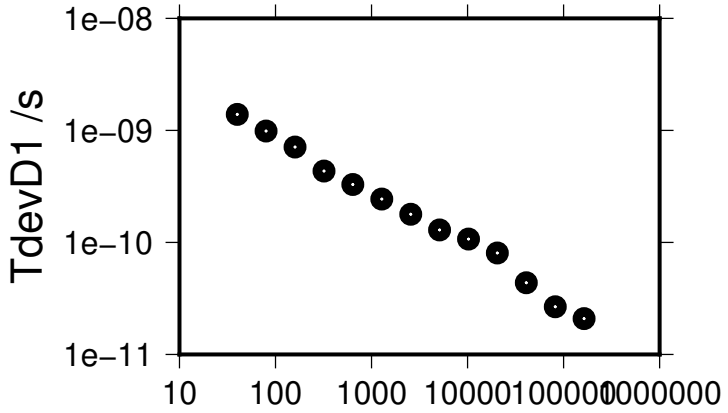


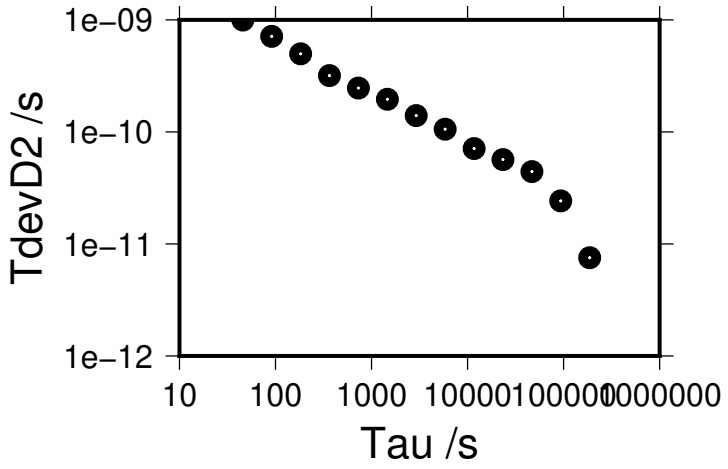

2023-06-13 NB05NIST23156_8
Median = -292.62 ns
Median = -296.24 ns
C1 /ns
C2 /ns
MJD
60100
60102
60104
60106
60108
TdevC1 /s
TdevC2 /s
Tau /s
1e−09
1e−10
1e−11
10
100
1000
10000
100000
1000000
127175 s: C1= 30 ps
63587 s: C1= 45 ps
31794 s: C1= 67 ps
15897 s: C1= 78 ps
7948 s: C1= 79 ps
3974 s: C1= 77 ps
1987 s: C1= 96 ps
994 s: C1= 137 ps
497 s: C1= 176 ps
248 s: C1= 249 ps
124 s: C1= 419 ps
62 s: C1= 582 ps
31 s: C1= 826 ps
160450 s: C2= 17 ps
80225 s: C2= 17 ps
40113 s: C2= 43 ps
20056 s: C2= 47 ps
10028 s: C2= 57 ps
5014 s: C2= 96 ps
2507 s: C2= 118 ps
1254 s: C2= 155 ps
627 s: C2= 216 ps
313 s: C2= 275 ps
157 s: C2= 431 ps
78 s: C2= 626 ps
39 s: C2= 863 ps

2023-06-13 NB05NIST23156_8

163592 s: D1=	21 ps	186924 s: D2=	8 ps
81796 s: D1=	27 ps	93462 s: D2=	24 ps
40898 s: D1=	44 ps	46731 s: D2=	44 ps
20449 s: D1=	80 ps	23366 s: D2=	57 ps
10224 s: D1=	107 ps	11683 s: D2=	71 ps
5112 s: D1=	129 ps	5841 s: D2=	106 ps
2556 s: D1=	179 ps	2921 s: D2=	140 ps
1278 s: D1=	244 ps	1460 s: D2=	196 ps
639 s: D1=	329 ps	730 s: D2=	247 ps
320 s: D1=	433 ps	365 s: D2=	318 ps
160 s: D1=	711 ps	183 s: D2=	498 ps
80 s: D1=	986 ps	91 s: D2=	714 ps
40 s: D1=	1392 ps	46 s: D2=	996 ps

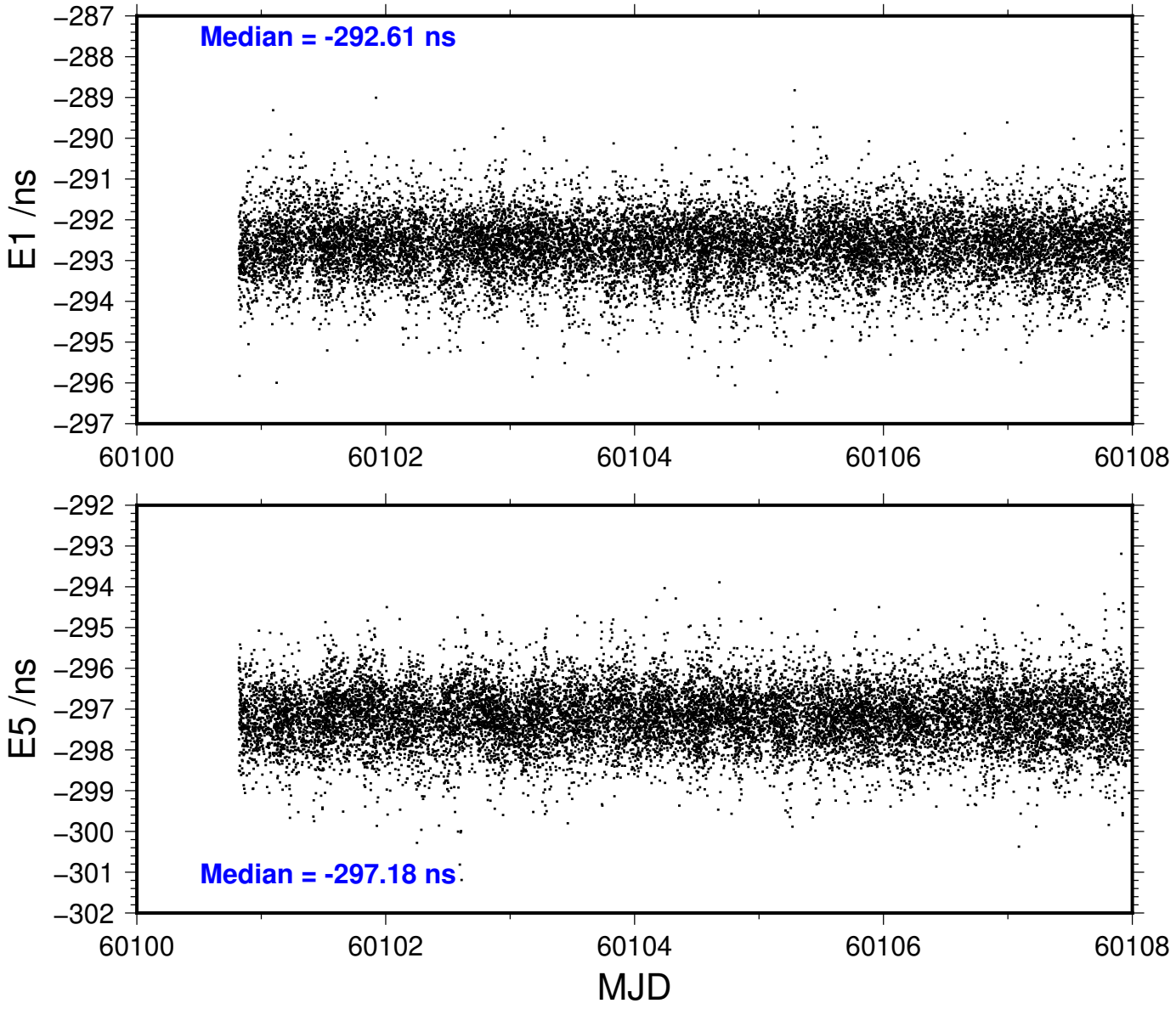


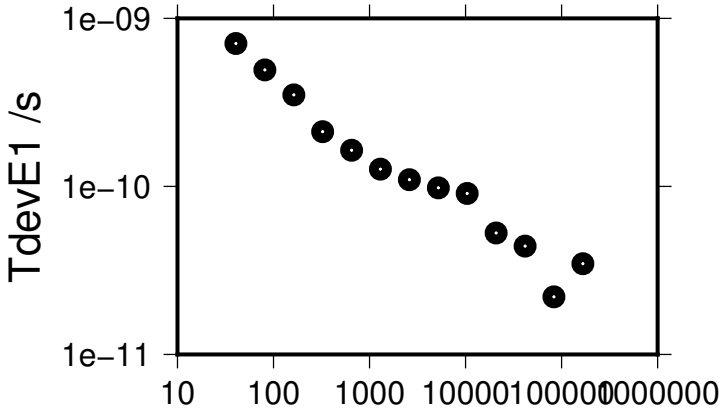


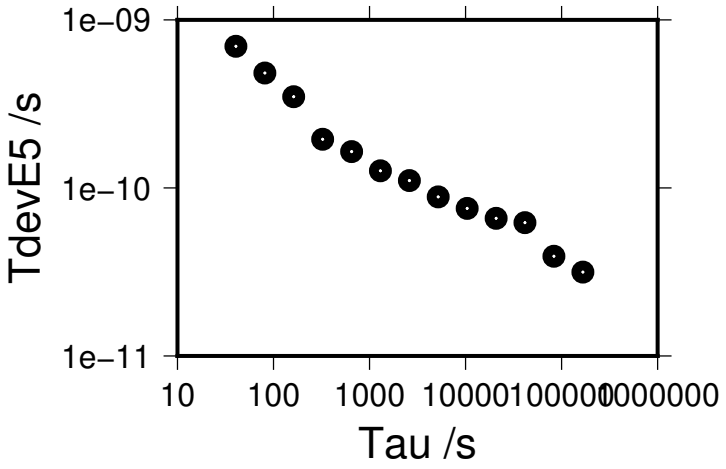


2023-06-13 NB05NIST23156_8

166433 s: E1=	35 ps	166280 s: E5=	32 ps
83216 s: E1=	22 ps	83140 s: E5=	39 ps
41608 s: E1=	44 ps	41570 s: E5=	62 ps
20804 s: E1=	53 ps	20785 s: E5=	66 ps
10402 s: E1=	91 ps	10393 s: E5=	76 ps
5201 s: E1=	98 ps	5196 s: E5=	88 ps
2601 s: E1=	110 ps	2598 s: E5=	111 ps
1300 s: E1=	127 ps	1299 s: E5=	127 ps
650 s: E1=	164 ps	650 s: E5=	165 ps
325 s: E1=	212 ps	325 s: E5=	195 ps
163 s: E1=	351 ps	162 s: E5=	349 ps
81 s: E1=	494 ps	81 s: E5=	483 ps
41 s: E1=	708 ps	41 s: E5=	696 ps

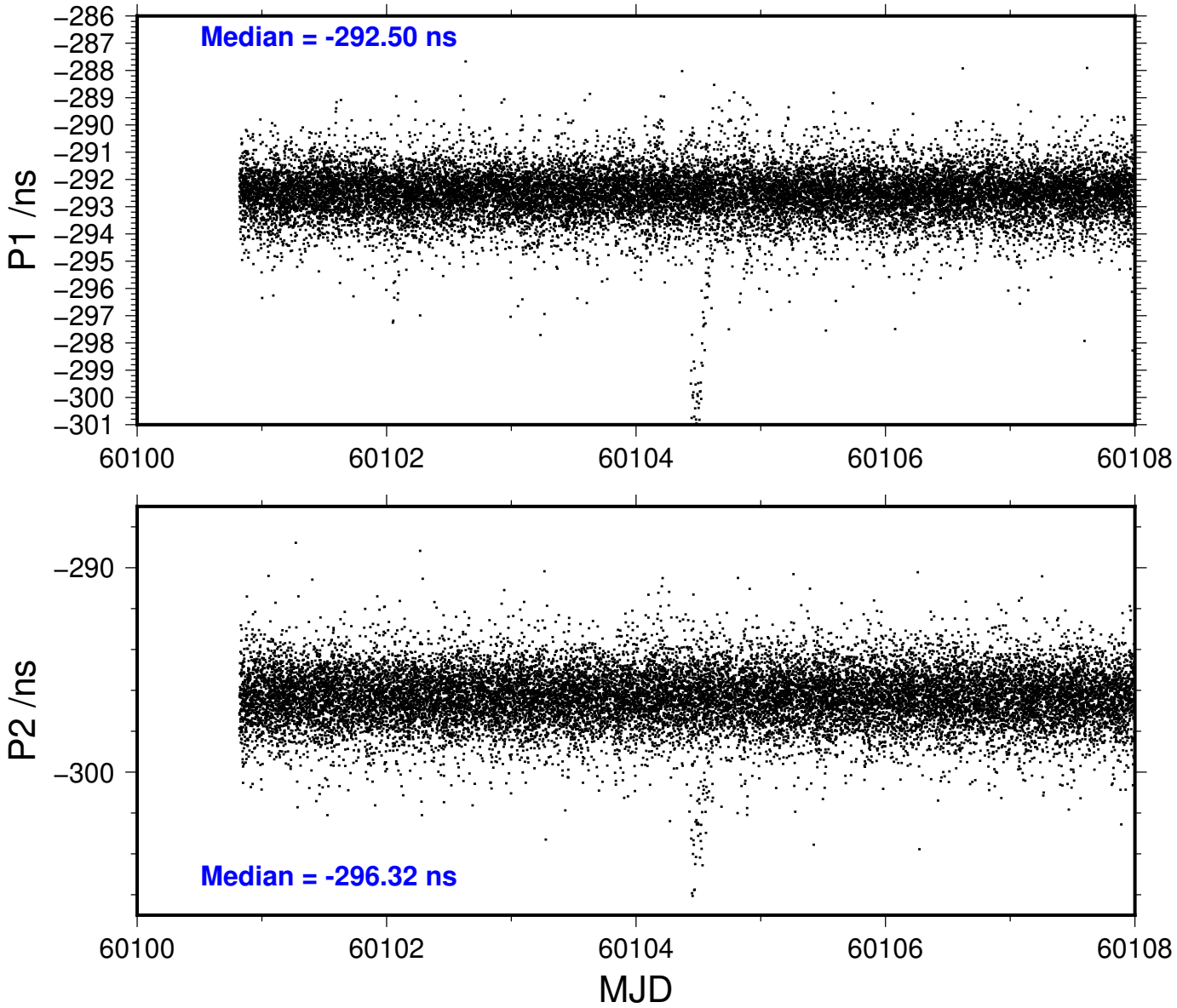


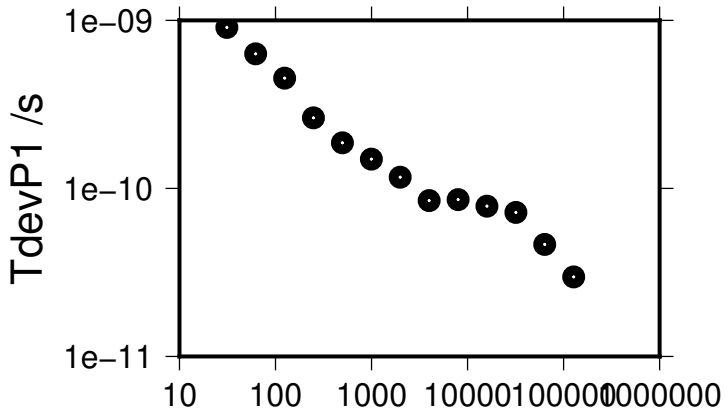


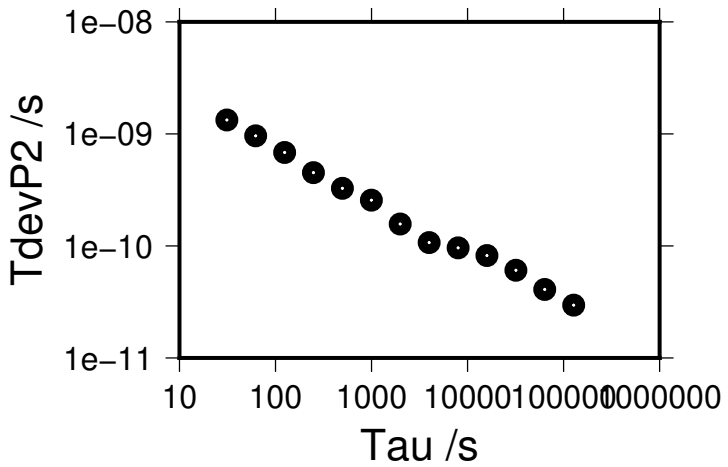


2023-06-13 NB05NIST23156_8

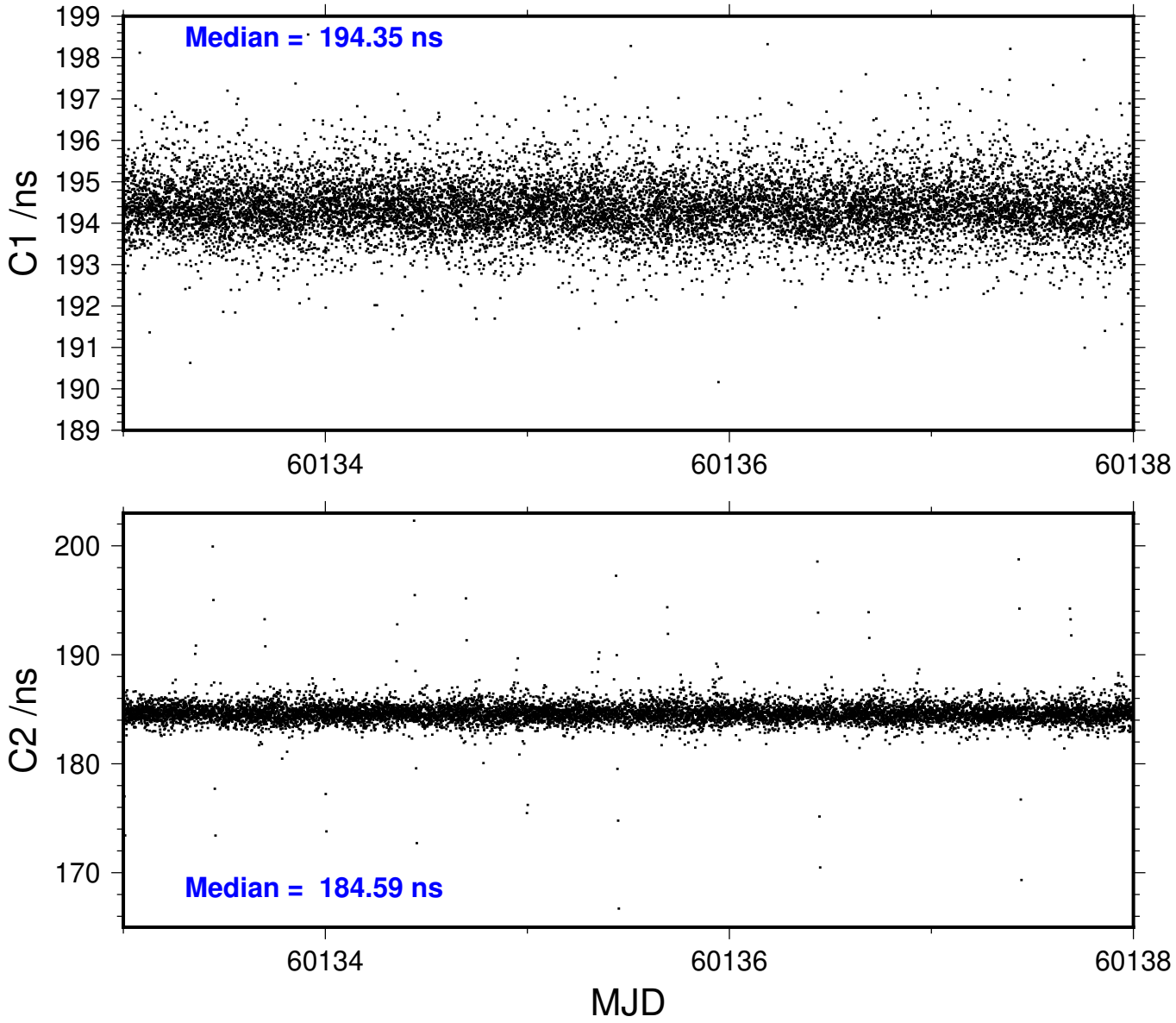
127359 s: P1=	30 ps	127359 s: P2=	30 ps
63680 s: P1=	46 ps	63680 s: P2=	41 ps
31840 s: P1=	72 ps	31840 s: P2=	61 ps
15920 s: P1=	78 ps	15920 s: P2=	82 ps
7960 s: P1=	86 ps	7960 s: P2=	96 ps
3980 s: P1=	85 ps	3980 s: P2=	107 ps
1990 s: P1=	117 ps	1990 s: P2=	157 ps
995 s: P1=	149 ps	995 s: P2=	256 ps
498 s: P1=	187 ps	498 s: P2=	327 ps
249 s: P1=	263 ps	249 s: P2=	451 ps
124 s: P1=	454 ps	124 s: P2=	683 ps
62 s: P1=	632 ps	62 s: P2=	963 ps
31 s: P1=	908 ps	31 s: P2=	1330 ps



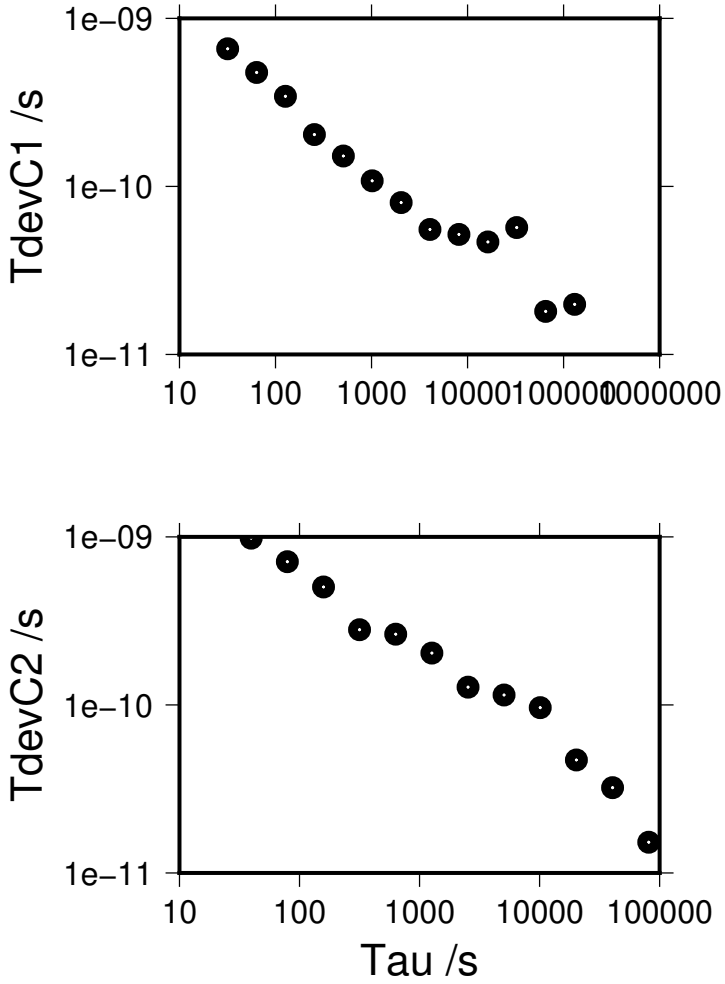


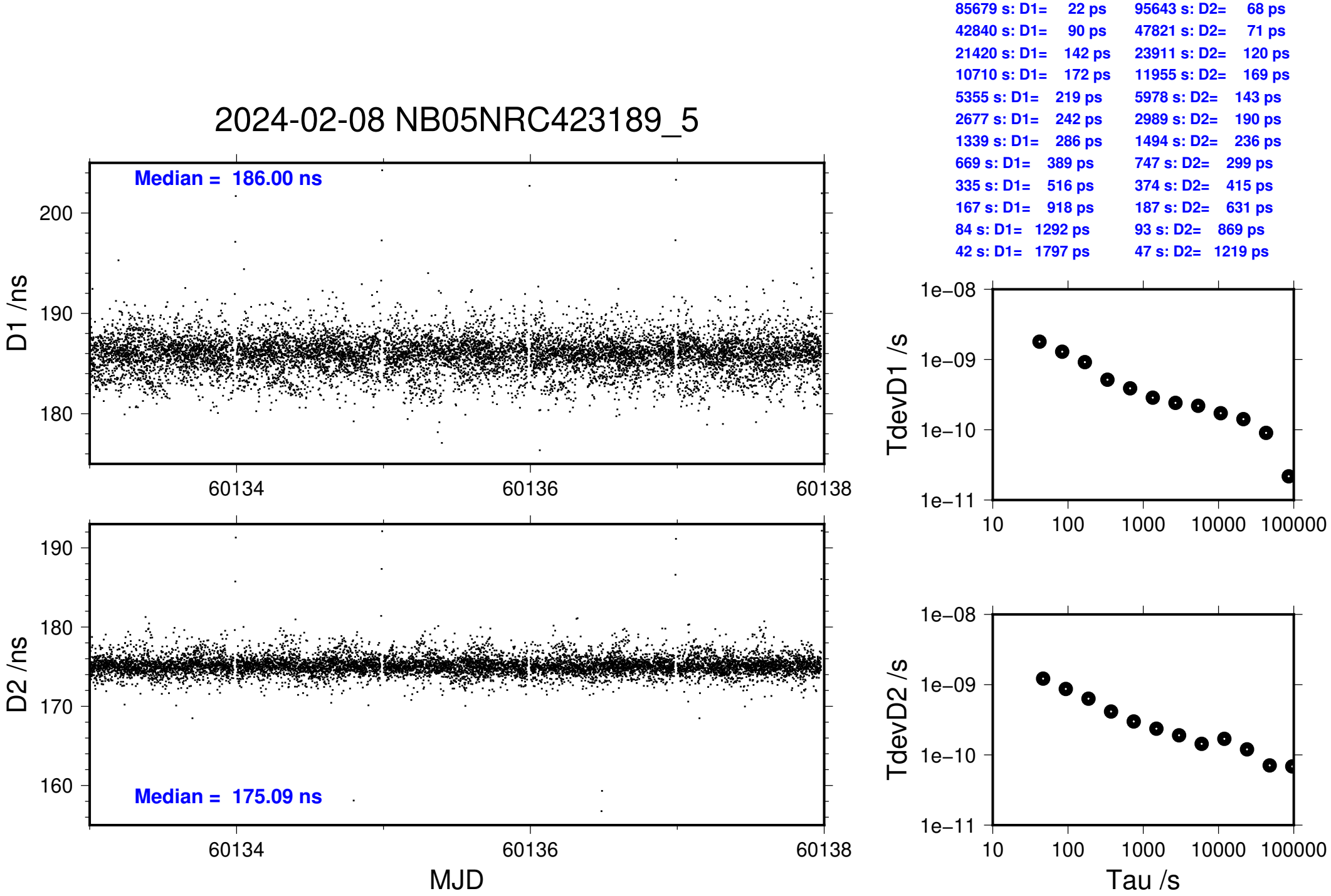


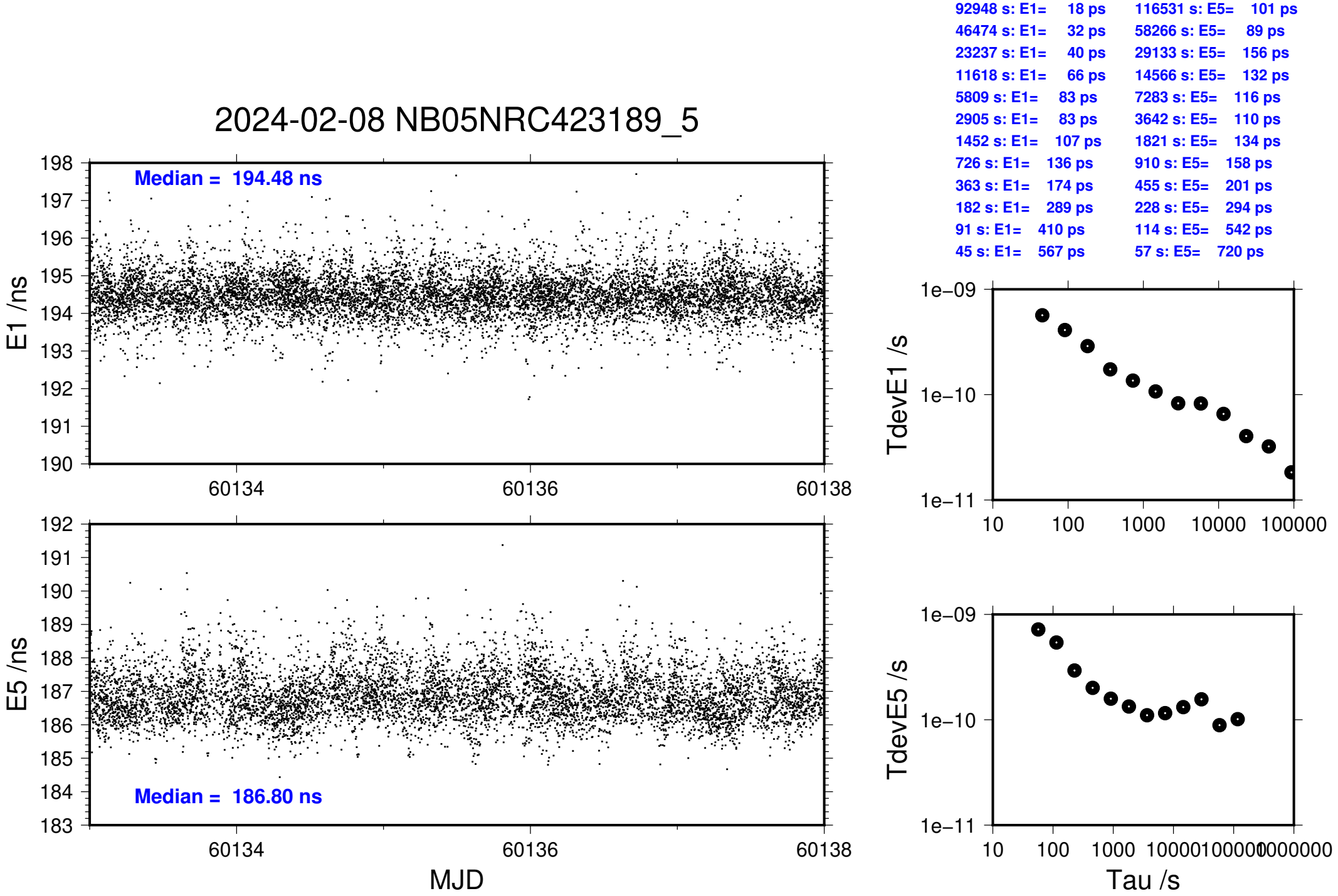
2024-02-08 NB05NRC423189_5



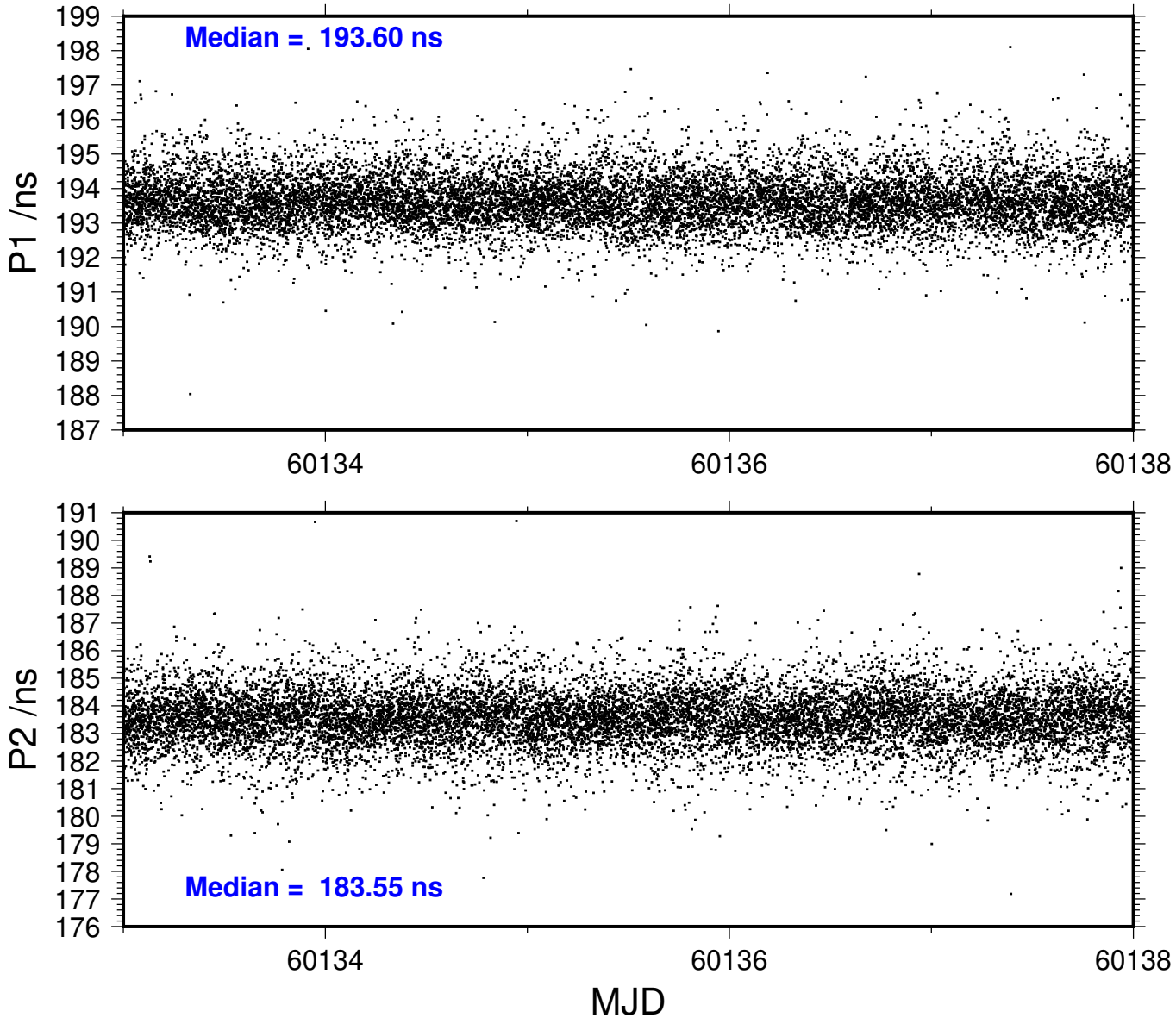
130075 s: C1=	20 ps		
65038 s: C1=	18 ps	81038 s: C2=	15 ps
32519 s: C1=	57 ps	40519 s: C2=	32 ps
16259 s: C1=	47 ps	20259 s: C2=	47 ps
8130 s: C1=	52 ps	10130 s: C2=	96 ps
4065 s: C1=	55 ps	5065 s: C2=	114 ps
2032 s: C1=	80 ps	2532 s: C2=	128 ps
1016 s: C1=	108 ps	1266 s: C2=	203 ps
508 s: C1=	152 ps	633 s: C2=	264 ps
254 s: C1=	203 ps	317 s: C2=	280 ps
127 s: C1=	343 ps	158 s: C2=	503 ps
64 s: C1=	477 ps	79 s: C2=	713 ps
32 s: C1=	659 ps	40 s: C2=	983 ps



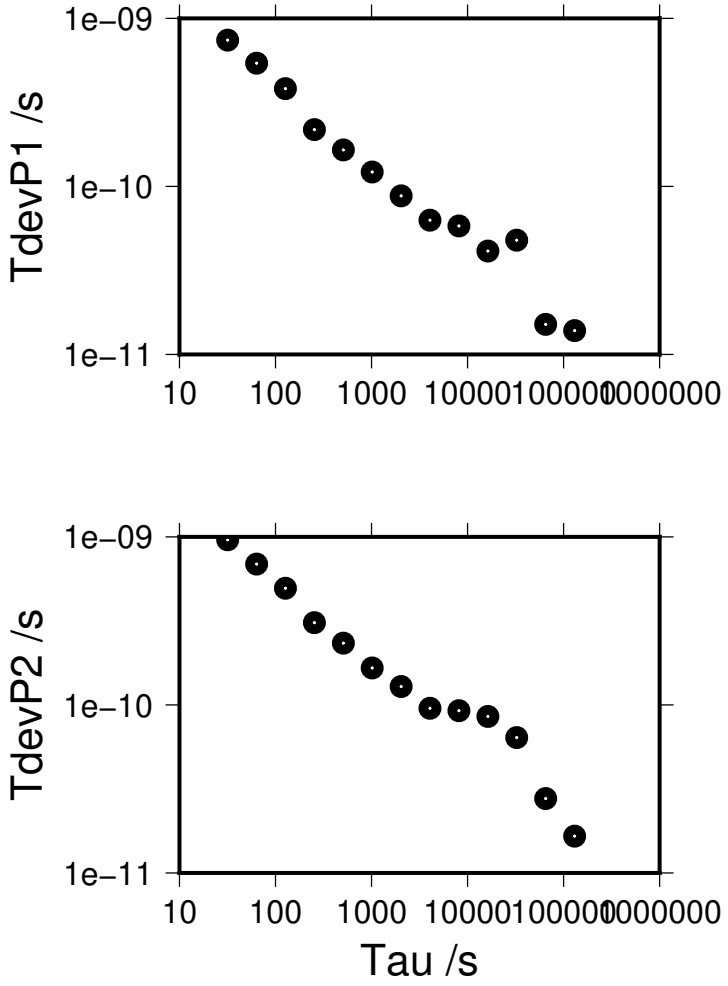

2024-02-08 NB05NRC423189_5
Median = 186.00 ns
Median = 175.09 ns
D1 /ns
D2 /ns
MJD
60134
60136
60138
85679 s: D1= 22 ps
42840 s: D1= 90 ps
21420 s: D1= 142 ps
10710 s: D1= 172 ps
5355 s: D1= 219 ps
2677 s: D1= 242 ps
1339 s: D1= 286 ps
669 s: D1= 389 ps
335 s: D1= 516 ps
167 s: D1= 918 ps
84 s: D1= 1292 ps
42 s: D1= 1797 ps
95643 s: D2= 68 ps
47821 s: D2= 71 ps
23911 s: D2= 120 ps
11955 s: D2= 169 ps
5978 s: D2= 143 ps
2989 s: D2= 190 ps
1494 s: D2= 236 ps
747 s: D2= 299 ps
374 s: D2= 415 ps
187 s: D2= 631 ps
93 s: D2= 869 ps
47 s: D2= 1219 ps
TdevD1 /s
TdevD2 /s
Tau /s


2024-02-08 NB05NRC423189_5
Median = 194.48 ns
Median = 186.80 ns
E1 /ns
E5 /ns
MJD
60134
60136
60138
92948 s: E1= 18 ps
46474 s: E1= 32 ps
23237 s: E1= 40 ps
11618 s: E1= 66 ps
5809 s: E1= 83 ps
2905 s: E1= 83 ps
1452 s: E1= 107 ps
726 s: E1= 136 ps
363 s: E1= 174 ps
182 s: E1= 289 ps
91 s: E1= 410 ps
45 s: E1= 567 ps
116531 s: E5= 101 ps
58266 s: E5= 89 ps
29133 s: E5= 156 ps
14566 s: E5= 132 ps
7283 s: E5= 116 ps
3642 s: E5= 110 ps
1821 s: E5= 134 ps
910 s: E5= 158 ps
455 s: E5= 201 ps
228 s: E5= 294 ps
114 s: E5= 542 ps
57 s: E5= 720 ps
TdevE1 /s
TdevE5 /s
Tau /s

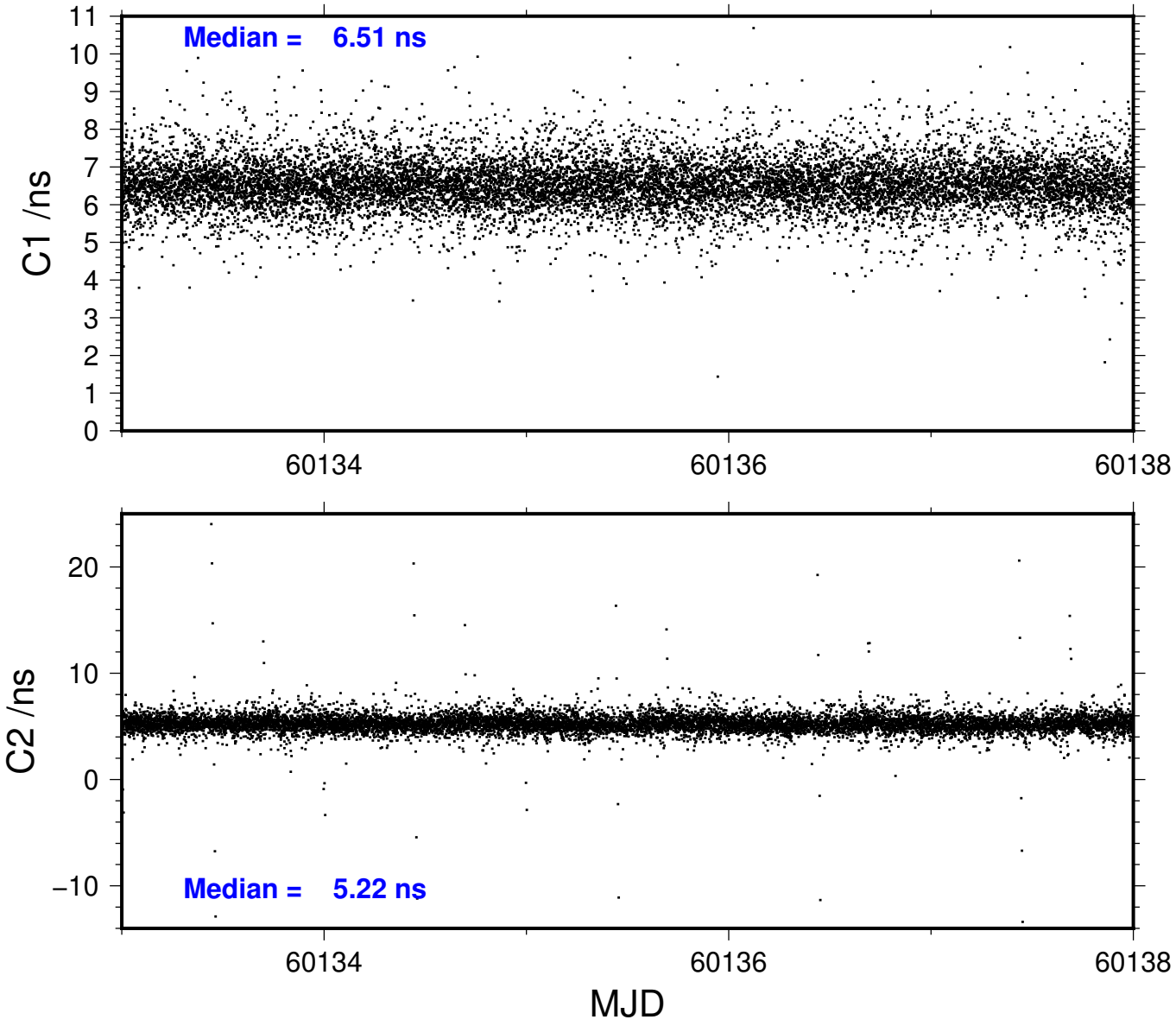
2024-02-08 NB05NRC423189_5



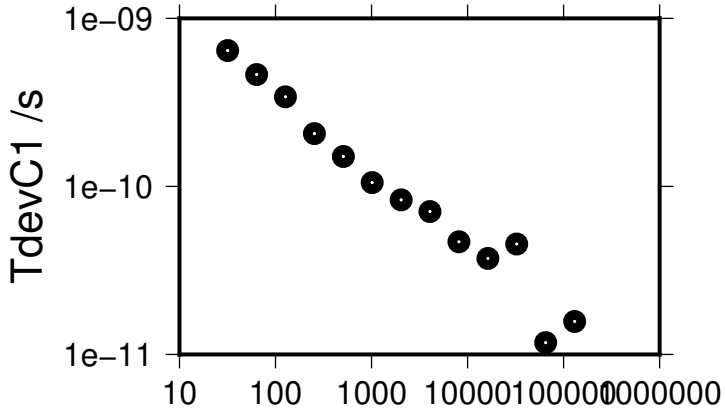
130075 s: P1=	14 ps	130075 s: P2=	17 ps
65038 s: P1=	15 ps	65038 s: P2=	28 ps
32519 s: P1=	48 ps	32519 s: P2=	64 ps
16259 s: P1=	41 ps	16259 s: P2=	85 ps
8130 s: P1=	58 ps	8130 s: P2=	92 ps
4065 s: P1=	63 ps	4065 s: P2=	95 ps
2032 s: P1=	88 ps	2032 s: P2=	129 ps
1016 s: P1=	122 ps	1016 s: P2=	166 ps
508 s: P1=	165 ps	508 s: P2=	233 ps
254 s: P1=	218 ps	254 s: P2=	309 ps
127 s: P1=	382 ps	127 s: P2=	495 ps
64 s: P1=	542 ps	64 s: P2=	688 ps
32 s: P1=	742 ps	32 s: P2=	962 ps

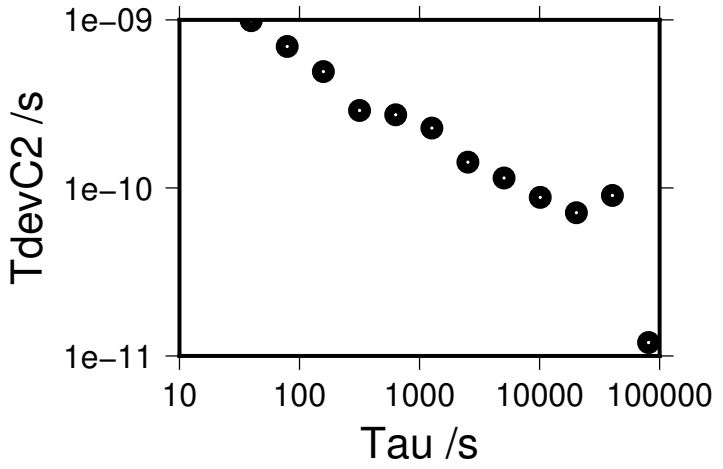


2024-02-08 NB05NRCC23189_5

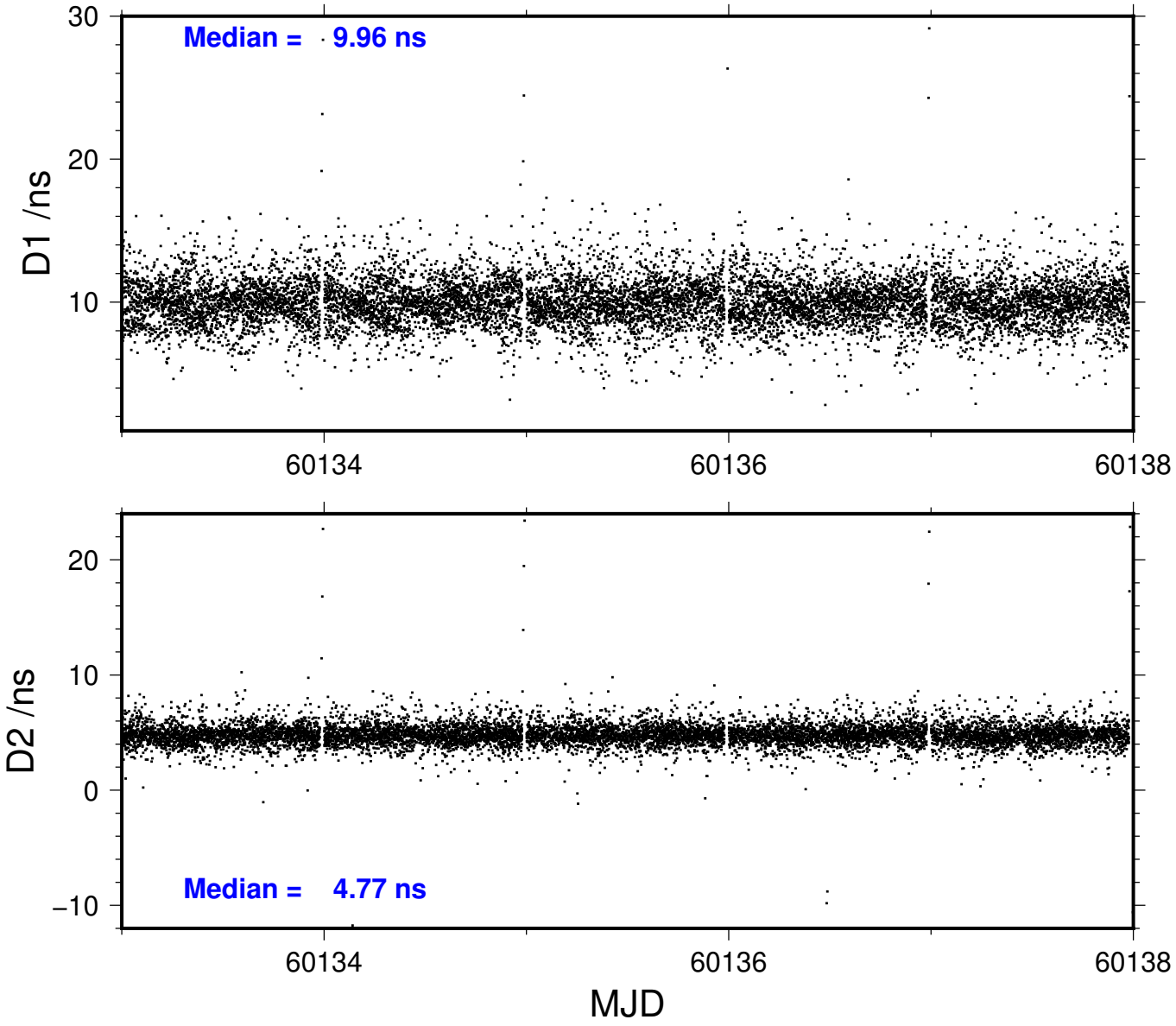


130075 s: C1=	16 ps		
65038 s: C1=	12 ps	80956 s: C2=	12 ps
32519 s: C1=	45 ps	40478 s: C2=	90 ps
16259 s: C1=	37 ps	20239 s: C2=	71 ps
8130 s: C1=	47 ps	10120 s: C2=	88 ps
4065 s: C1=	71 ps	5060 s: C2=	115 ps
2032 s: C1=	83 ps	2530 s: C2=	142 ps
1016 s: C1=	105 ps	1265 s: C2=	227 ps
508 s: C1=	151 ps	632 s: C2=	272 ps
254 s: C1=	206 ps	316 s: C2=	289 ps
127 s: C1=	342 ps	158 s: C2=	492 ps
64 s: C1=	463 ps	79 s: C2=	695 ps
32 s: C1=	644 ps	40 s: C2=	988 ps

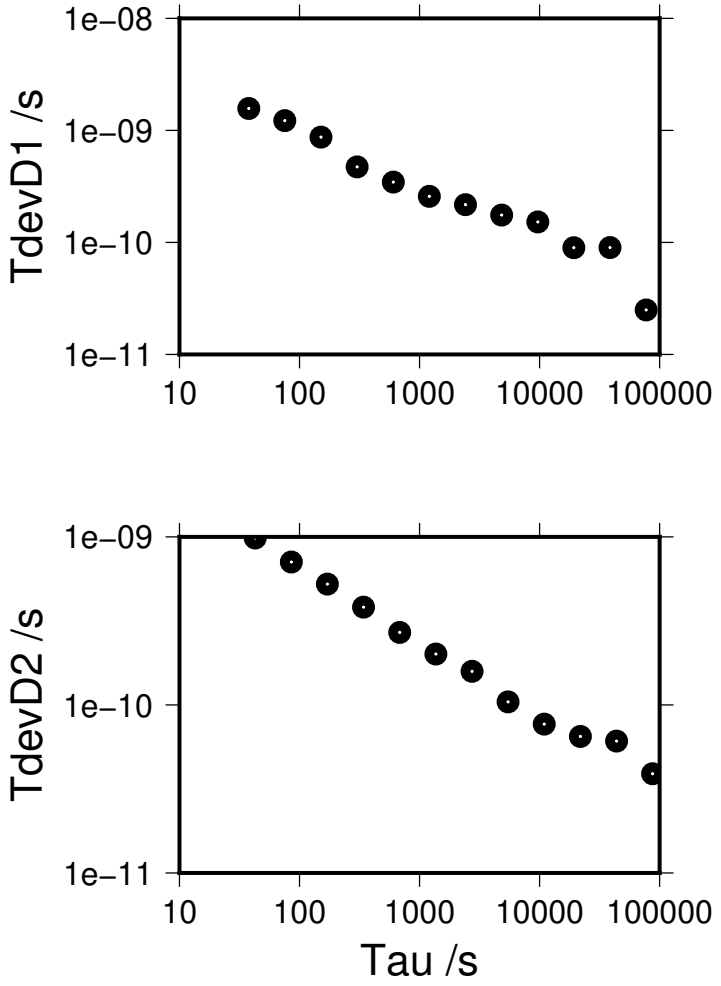




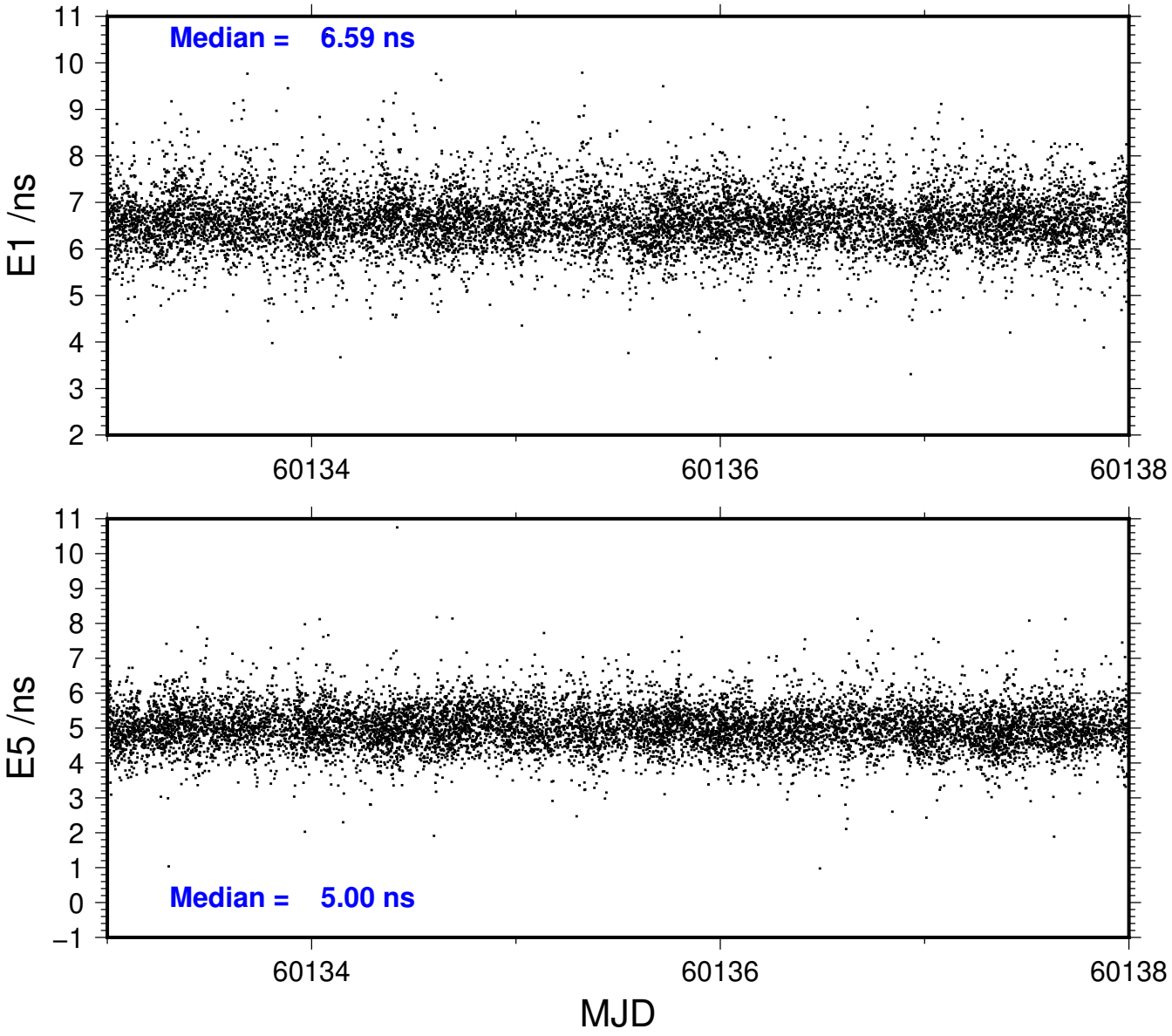
2024-02-08 NB05NRCC23189_5



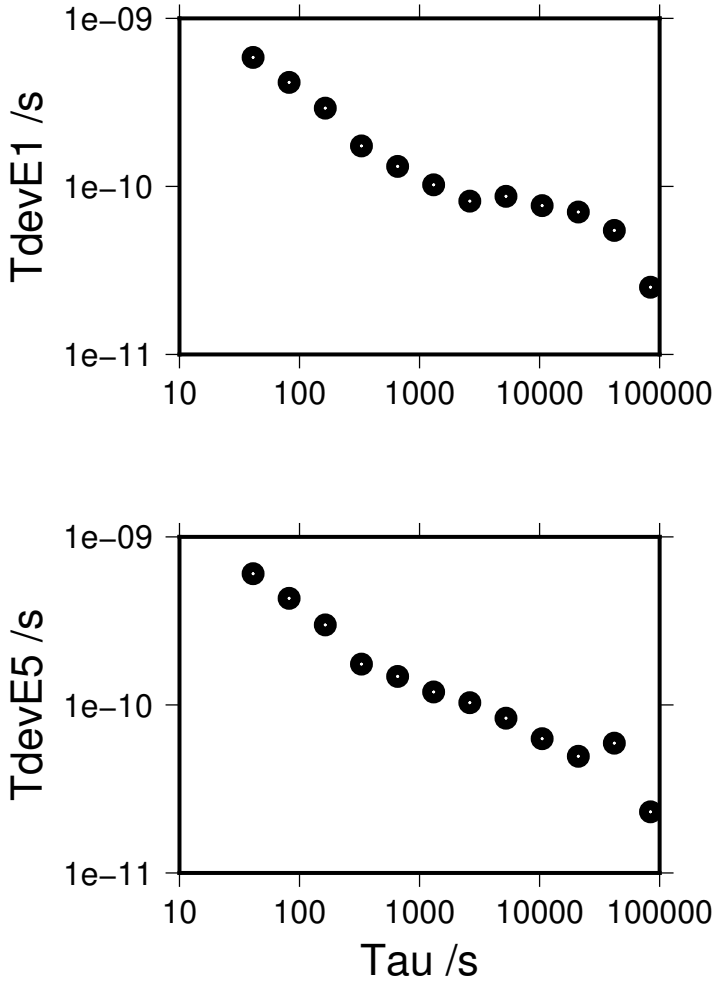
77277 s: D1=	25 ps	87468 s: D2=	39 ps
38638 s: D1=	90 ps	43734 s: D2=	61 ps
19319 s: D1=	90 ps	21867 s: D2=	65 ps
9660 s: D1=	153 ps	10933 s: D2=	77 ps
4830 s: D1=	175 ps	5467 s: D2=	104 ps
2415 s: D1=	217 ps	2733 s: D2=	159 ps
1207 s: D1=	258 ps	1367 s: D2=	201 ps
604 s: D1=	345 ps	683 s: D2=	270 ps
302 s: D1=	473 ps	342 s: D2=	382 ps
151 s: D1=	872 ps	171 s: D2=	524 ps
75 s: D1=	1221 ps	85 s: D2=	709 ps
38 s: D1=	1570 ps	43 s: D2=	985 ps



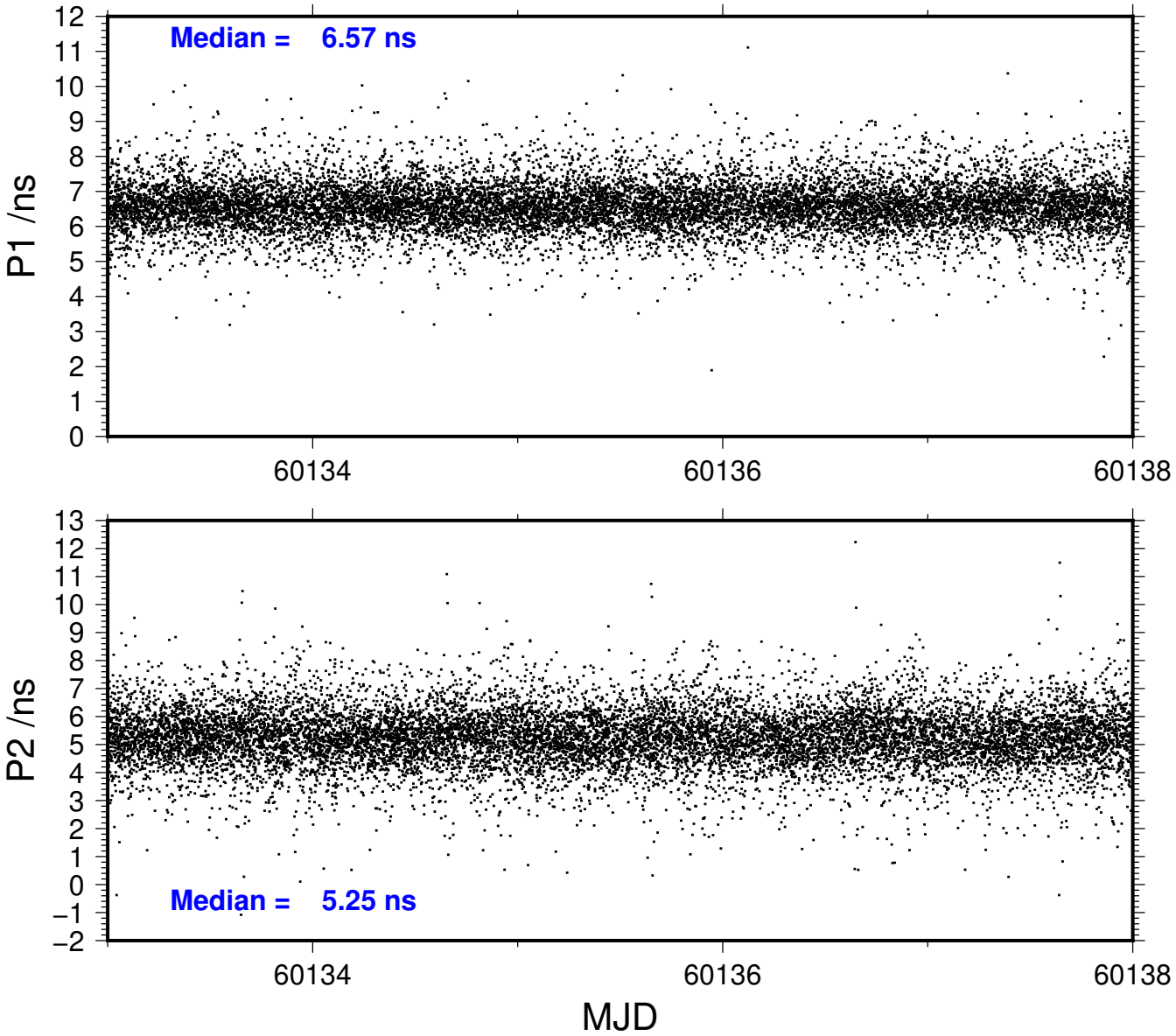
2024-02-08 NB05NRCC23189_5



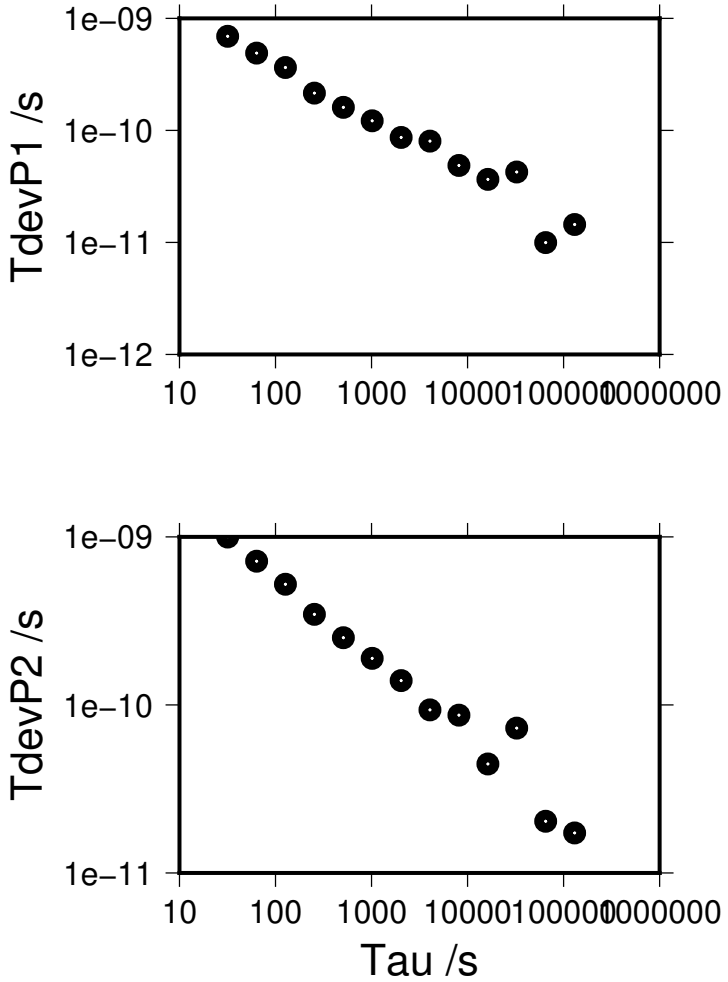
83978 s: E1= 25 ps	83962 s: E5= 23 ps
41989 s: E1= 55 ps	41981 s: E5= 59 ps
20995 s: E1= 70 ps	20991 s: E5= 49 ps
10497 s: E1= 77 ps	10495 s: E5= 63 ps
5249 s: E1= 87 ps	5248 s: E5= 83 ps
2624 s: E1= 82 ps	2624 s: E5= 103 ps
1312 s: E1= 102 ps	1312 s: E5= 120 ps
656 s: E1= 132 ps	656 s: E5= 148 ps
328 s: E1= 174 ps	328 s: E5= 175 ps
164 s: E1= 292 ps	164 s: E5= 299 ps
82 s: E1= 416 ps	82 s: E5= 431 ps
41 s: E1= 586 ps	41 s: E5= 604 ps

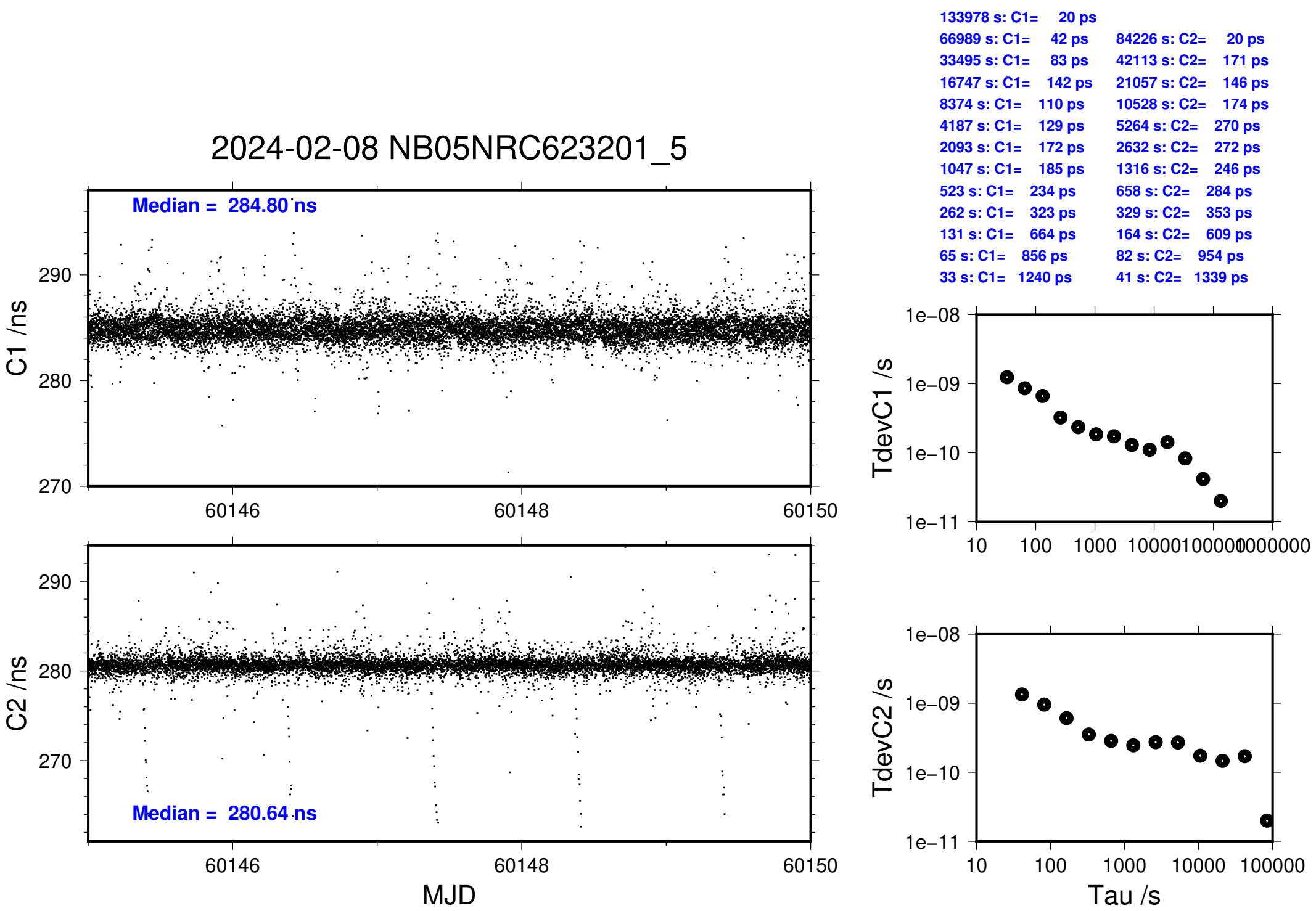


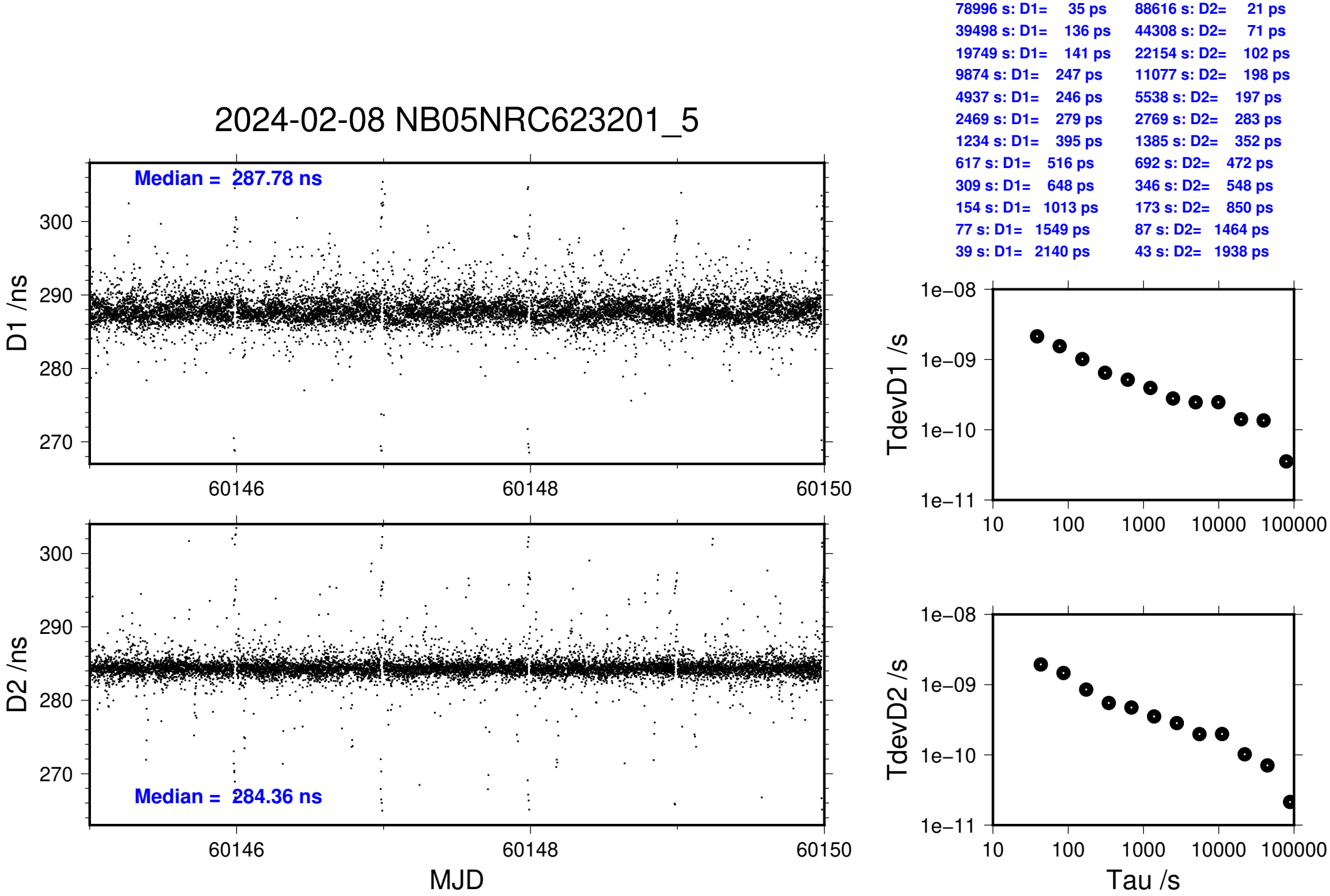
2024-02-08 NB05NRCC23189_5

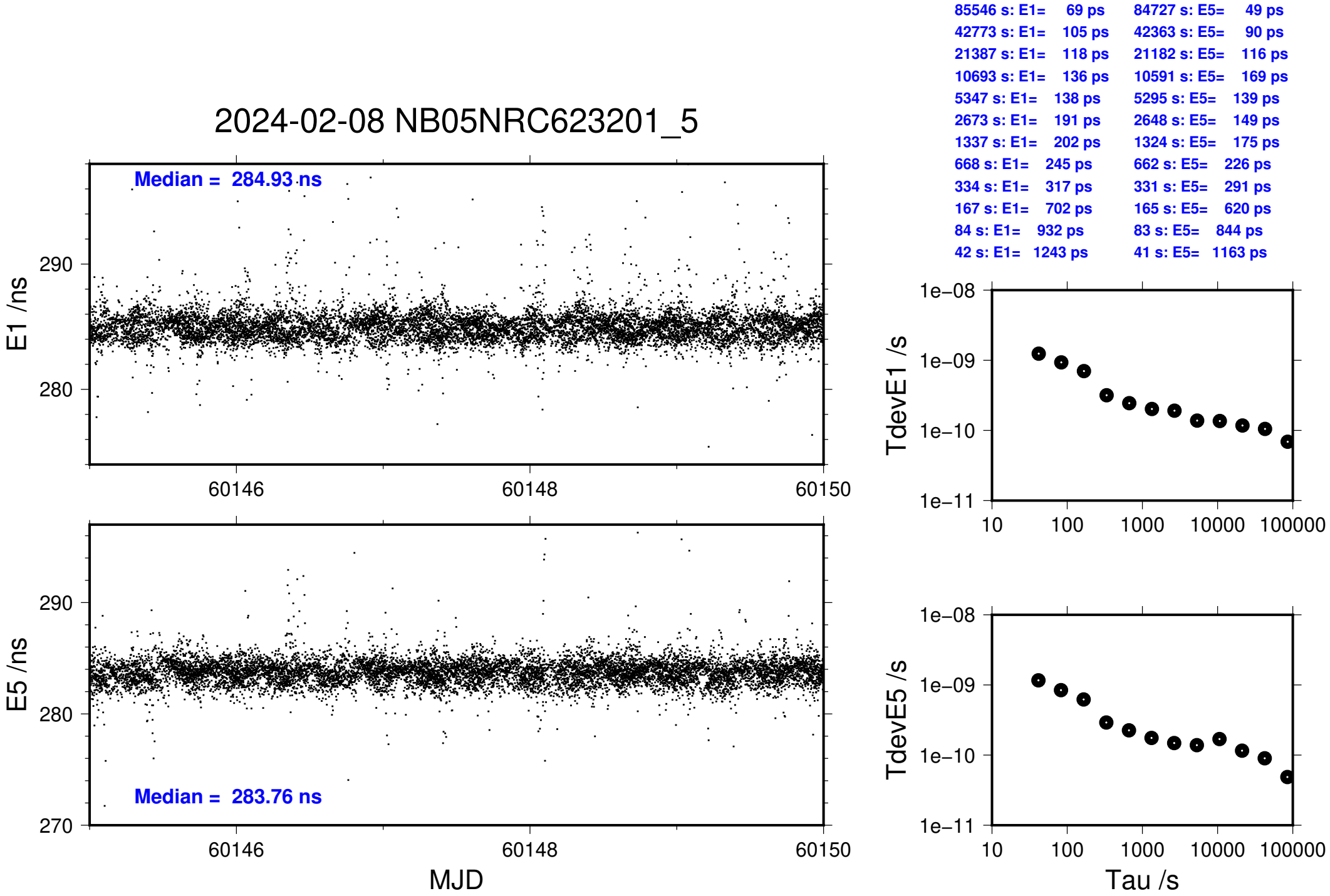


130075 s: P1= 14 ps	130075 s: P2= 17 ps
65038 s: P1= 10 ps	65038 s: P2= 20 ps
32519 s: P1= 43 ps	32519 s: P2= 73 ps
16259 s: P1= 37 ps	16259 s: P2= 45 ps
8130 s: P1= 49 ps	8130 s: P2= 87 ps
4065 s: P1= 80 ps	4065 s: P2= 93 ps
2032 s: P1= 87 ps	2032 s: P2= 140 ps
1016 s: P1= 122 ps	1016 s: P2= 189 ps
508 s: P1= 161 ps	508 s: P2= 251 ps
254 s: P1= 215 ps	254 s: P2= 346 ps
127 s: P1= 365 ps	127 s: P2= 523 ps
64 s: P1= 490 ps	64 s: P2= 716 ps
32 s: P1= 692 ps	32 s: P2= 997 ps

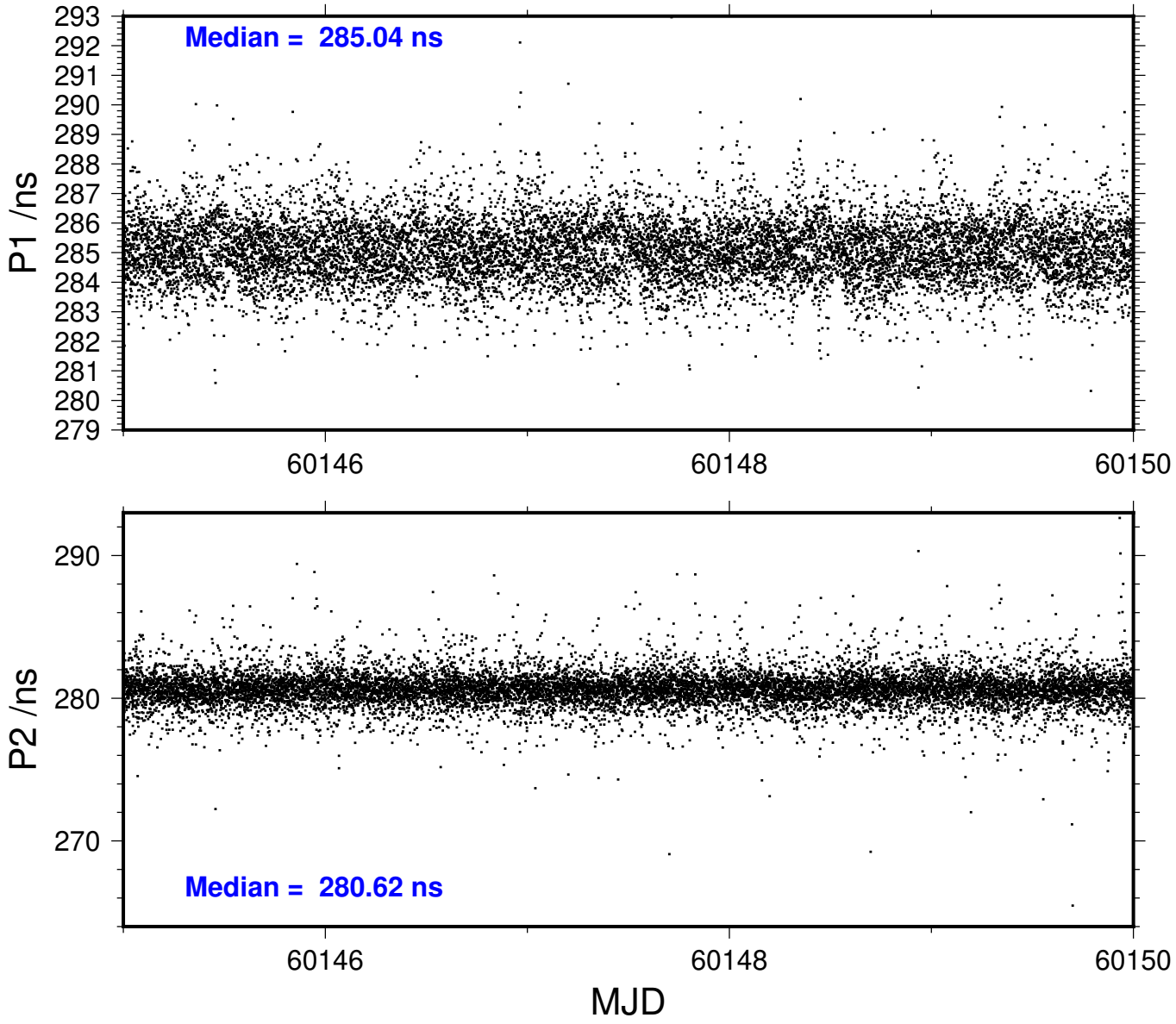



2024-02-08 NB05NRC623201_5
Median = 284.80 ns
Median = 280.64 ns
C1 /ns
C2 /ns
290
280
270
60146
60148
60150
MJD
133978 s: C1= 20 ps
66989 s: C1= 42 ps
33495 s: C1= 83 ps
16747 s: C1= 142 ps
8374 s: C1= 110 ps
4187 s: C1= 129 ps
2093 s: C1= 172 ps
1047 s: C1= 185 ps
523 s: C1= 234 ps
262 s: C1= 323 ps
131 s: C1= 664 ps
65 s: C1= 856 ps
33 s: C1= 1240 ps
84226 s: C2= 20 ps
42113 s: C2= 171 ps
21057 s: C2= 146 ps
10528 s: C2= 174 ps
5264 s: C2= 270 ps
2632 s: C2= 272 ps
1316 s: C2= 246 ps
658 s: C2= 284 ps
329 s: C2= 353 ps
164 s: C2= 609 ps
82 s: C2= 954 ps
41 s: C2= 1339 ps
TdevC1 /s
TdevC2 /s
1e−08
1e−09
1e−10
1e−11
10
100
1000
10000
100000
1000000
Tau /s

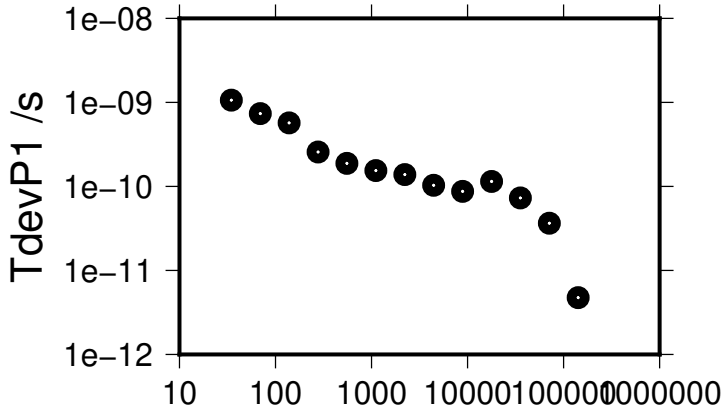

2024-02-08 NB05NRC623201_5
Median = 287.78 ns
Median = 284.36 ns
D1 /ns
D2 /ns
300
290
280
270
60146
60148
60150
MJD
78996 s: D1= 35 ps
39498 s: D1= 136 ps
19749 s: D1= 141 ps
9874 s: D1= 247 ps
4937 s: D1= 246 ps
2469 s: D1= 279 ps
1234 s: D1= 395 ps
617 s: D1= 516 ps
309 s: D1= 648 ps
154 s: D1= 1013 ps
77 s: D1= 1549 ps
39 s: D1= 2140 ps
88616 s: D2= 21 ps
44308 s: D2= 71 ps
22154 s: D2= 102 ps
11077 s: D2= 198 ps
5538 s: D2= 197 ps
2769 s: D2= 283 ps
1385 s: D2= 352 ps
692 s: D2= 472 ps
346 s: D2= 548 ps
173 s: D2= 850 ps
87 s: D2= 1464 ps
43 s: D2= 1938 ps
TdevD1 /s
TdevD2 /s
1e−08
1e−09
1e−10
1e−11
10
100
1000
10000
100000
Tau /s

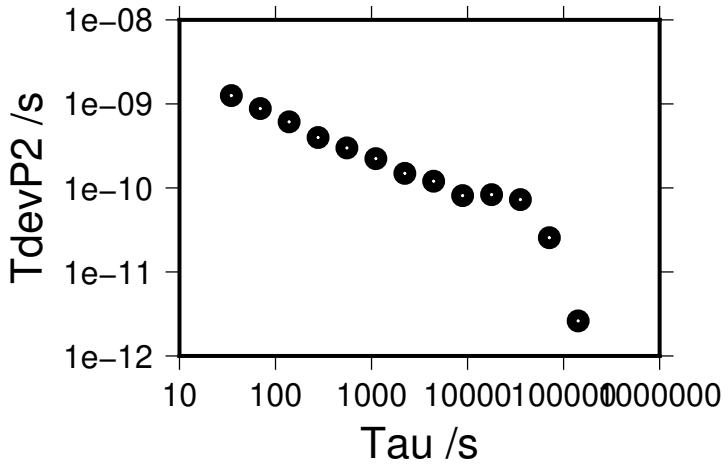

2024-02-08 NB05NRC623201_5
Median = 284.93 ns
E1 /ns
290
280
60146
60148
60150
E5 /ns
290
280
270
Median = 283.76 ns
60146
60148
60150
MJD
85546 s: E1= 69 ps
84727 s: E5= 49 ps
42773 s: E1= 105 ps
42363 s: E5= 90 ps
21387 s: E1= 118 ps
21182 s: E5= 116 ps
10693 s: E1= 136 ps
10591 s: E5= 169 ps
5347 s: E1= 138 ps
5295 s: E5= 139 ps
2673 s: E1= 191 ps
2648 s: E5= 149 ps
1337 s: E1= 202 ps
1324 s: E5= 175 ps
668 s: E1= 245 ps
662 s: E5= 226 ps
334 s: E1= 317 ps
331 s: E5= 291 ps
167 s: E1= 702 ps
165 s: E5= 620 ps
84 s: E1= 932 ps
83 s: E5= 844 ps
42 s: E1= 1243 ps
41 s: E5= 1163 ps
TdevE1 /s
1e−08
1e−09
1e−10
1e−11
10
100
1000
10000
100000
TdevE5 /s
1e−08
1e−09
1e−10
1e−11
10
100
1000
10000
100000
Tau /s

2024-02-08 NB05NRC623201_5

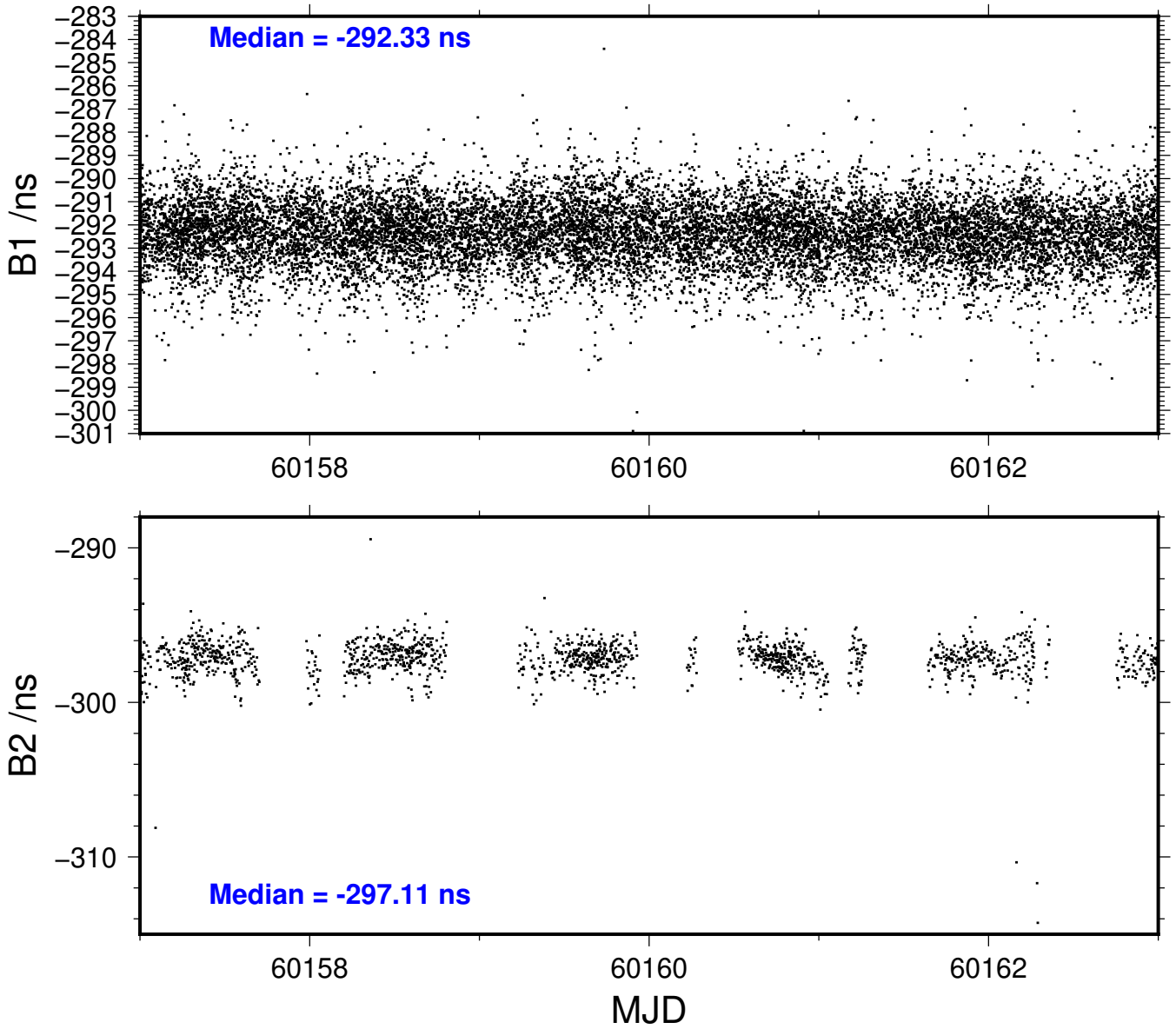


142005 s: P1= 5 ps	142005 s: P2= 3 ps
71002 s: P1= 37 ps	71002 s: P2= 26 ps
35501 s: P1= 73 ps	35501 s: P2= 73 ps
17751 s: P1= 115 ps	17751 s: P2= 83 ps
8875 s: P1= 87 ps	8875 s: P2= 81 ps
4438 s: P1= 103 ps	4438 s: P2= 120 ps
2219 s: P1= 139 ps	2219 s: P2= 149 ps
1109 s: P1= 155 ps	1109 s: P2= 223 ps
555 s: P1= 188 ps	555 s: P2= 299 ps
277 s: P1= 256 ps	277 s: P2= 398 ps
139 s: P1= 571 ps	139 s: P2= 613 ps
69 s: P1= 737 ps	69 s: P2= 882 ps
35 s: P1= 1062 ps	35 s: P2= 1255 ps

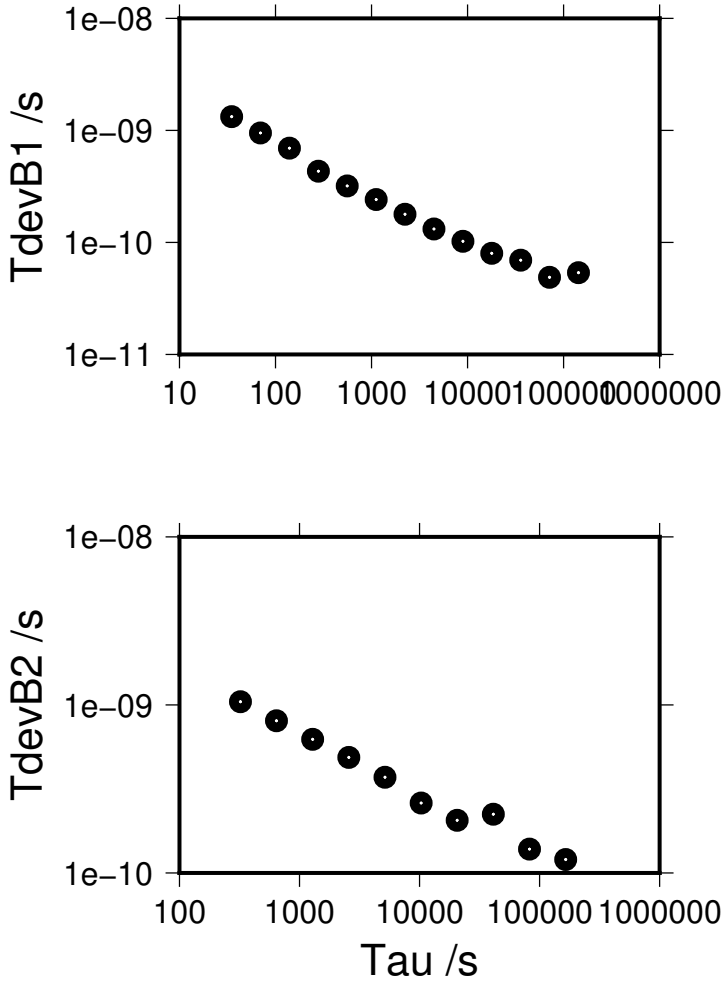




2023-08-14 NB05NIST23213_6

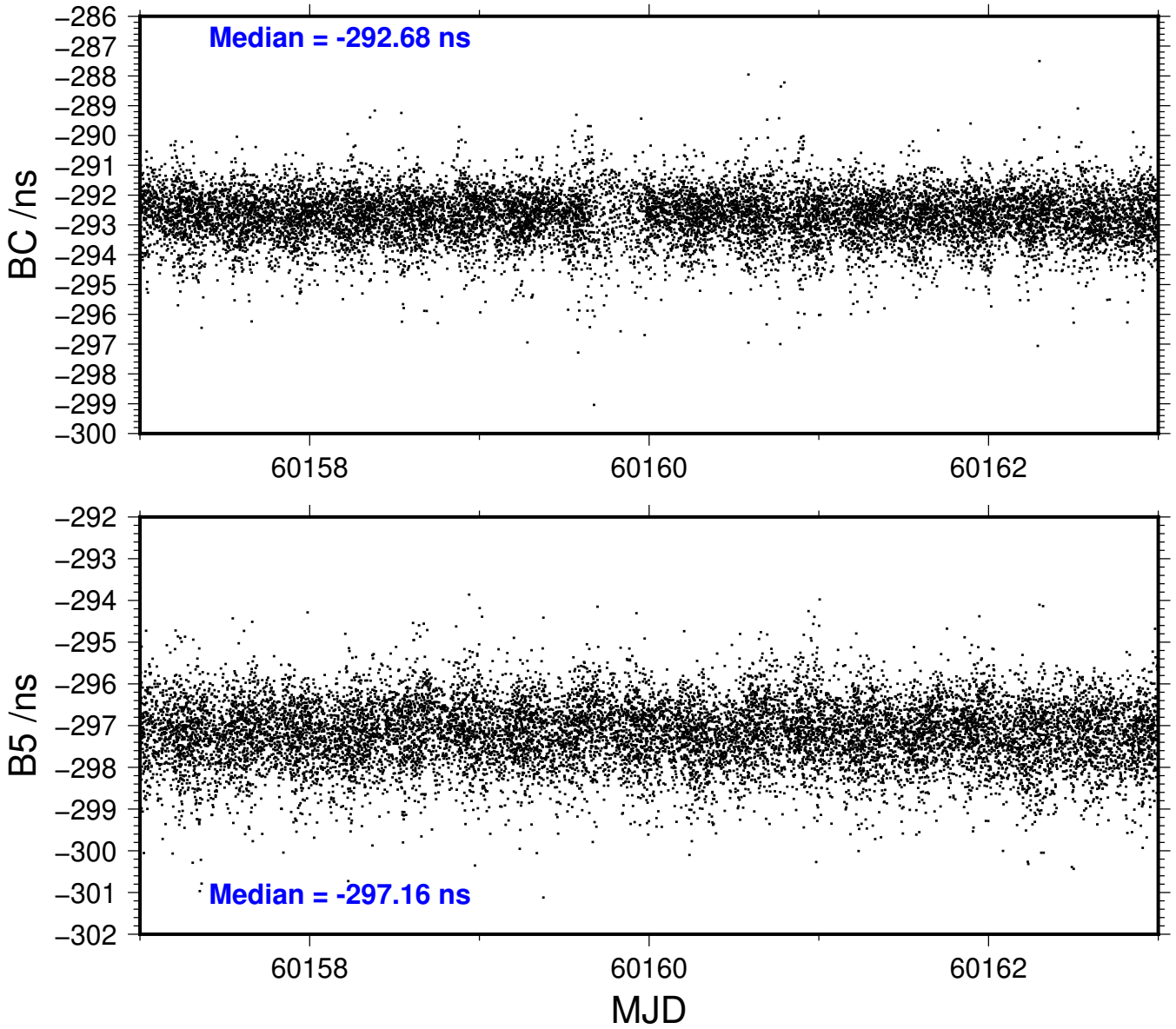


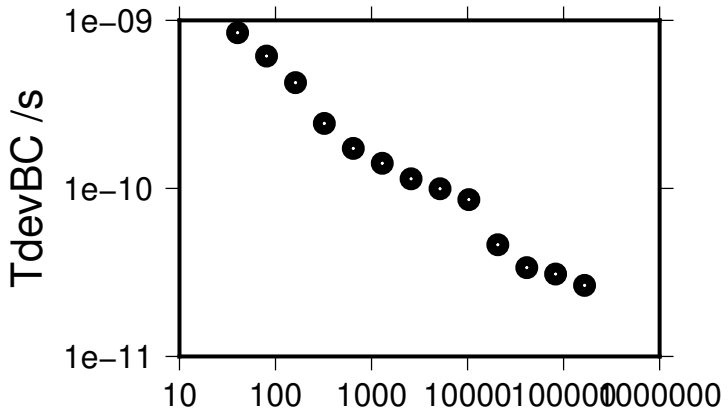
142943 s: B1= 54 ps	
71472 s: B1= 49 ps	
35736 s: B1= 69 ps	
17868 s: B1= 80 ps	164762 s: B2= 120 ps
8934 s: B1= 102 ps	82381 s: B2= 139 ps
4467 s: B1= 132 ps	41191 s: B2= 224 ps
2233 s: B1= 178 ps	20595 s: B2= 206 ps
1117 s: B1= 241 ps	10298 s: B2= 261 ps
558 s: B1= 319 ps	5149 s: B2= 371 ps
279 s: B1= 432 ps	2574 s: B2= 487 ps
140 s: B1= 694 ps	1287 s: B2= 624 ps
70 s: B1= 950 ps	644 s: B2= 804 ps
35 s: B1= 1326 ps	322 s: B2= 1045 ps

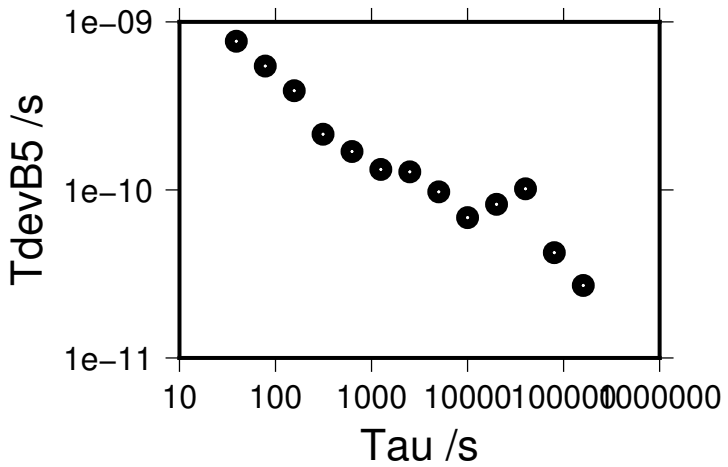


2023-08-14 NB05NIST23213_6

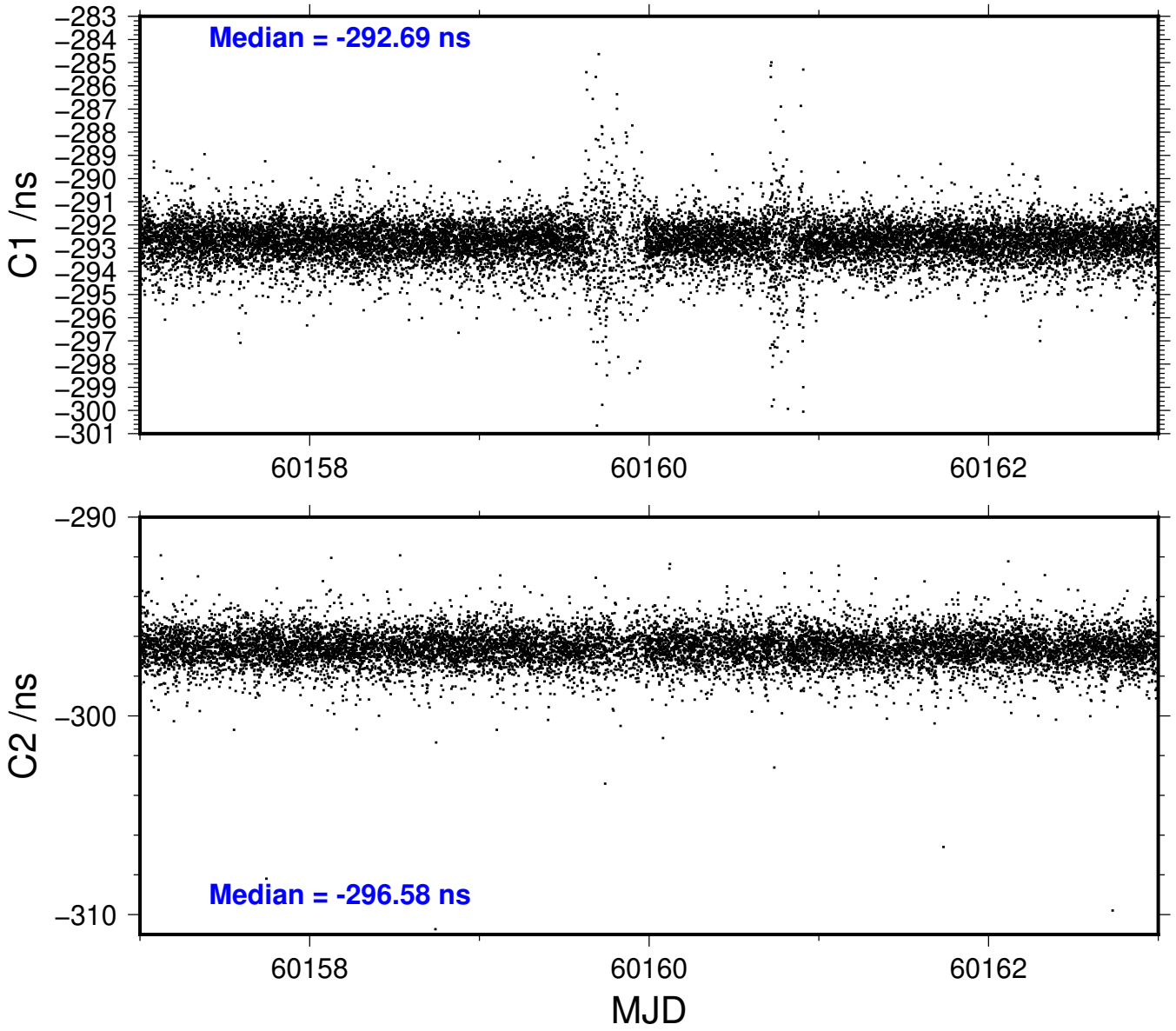
165237 s: BC= 26 ps	160210 s: B5= 27 ps
82618 s: BC= 31 ps	80105 s: B5= 42 ps
41309 s: BC= 34 ps	40052 s: B5= 102 ps
20655 s: BC= 46 ps	20026 s: B5= 82 ps
10327 s: BC= 86 ps	10013 s: B5= 68 ps
5164 s: BC= 99 ps	5007 s: B5= 97 ps
2582 s: BC= 114 ps	2503 s: B5= 128 ps
1291 s: BC= 141 ps	1252 s: B5= 132 ps
645 s: BC= 173 ps	626 s: B5= 169 ps
323 s: BC= 244 ps	313 s: B5= 215 ps
161 s: BC= 426 ps	156 s: B5= 389 ps
81 s: BC= 613 ps	78 s: B5= 545 ps
40 s: BC= 845 ps	39 s: B5= 766 ps



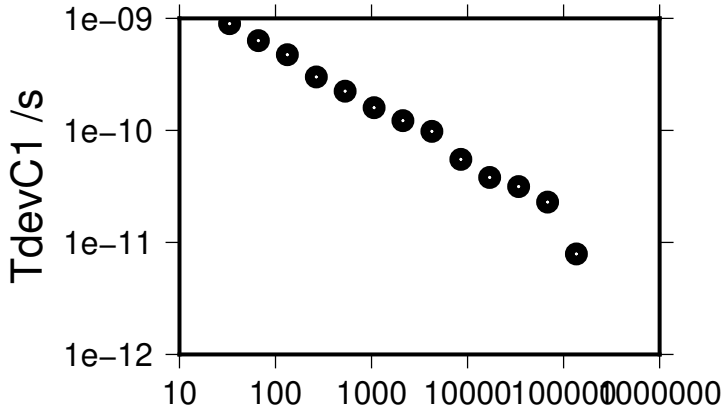


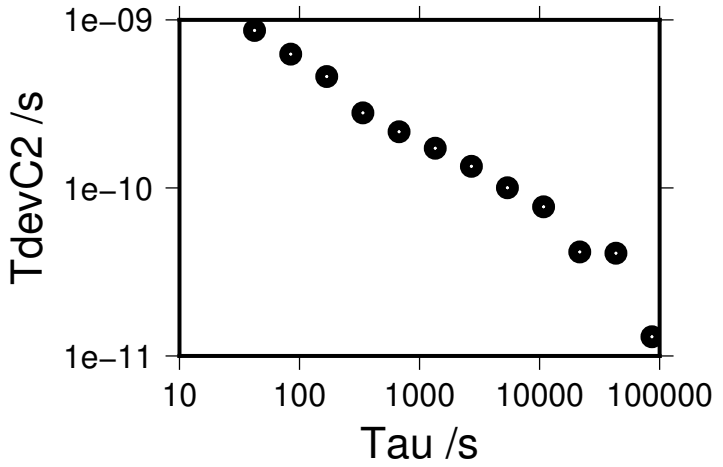


2023-08-14 NB05NIST23213_6

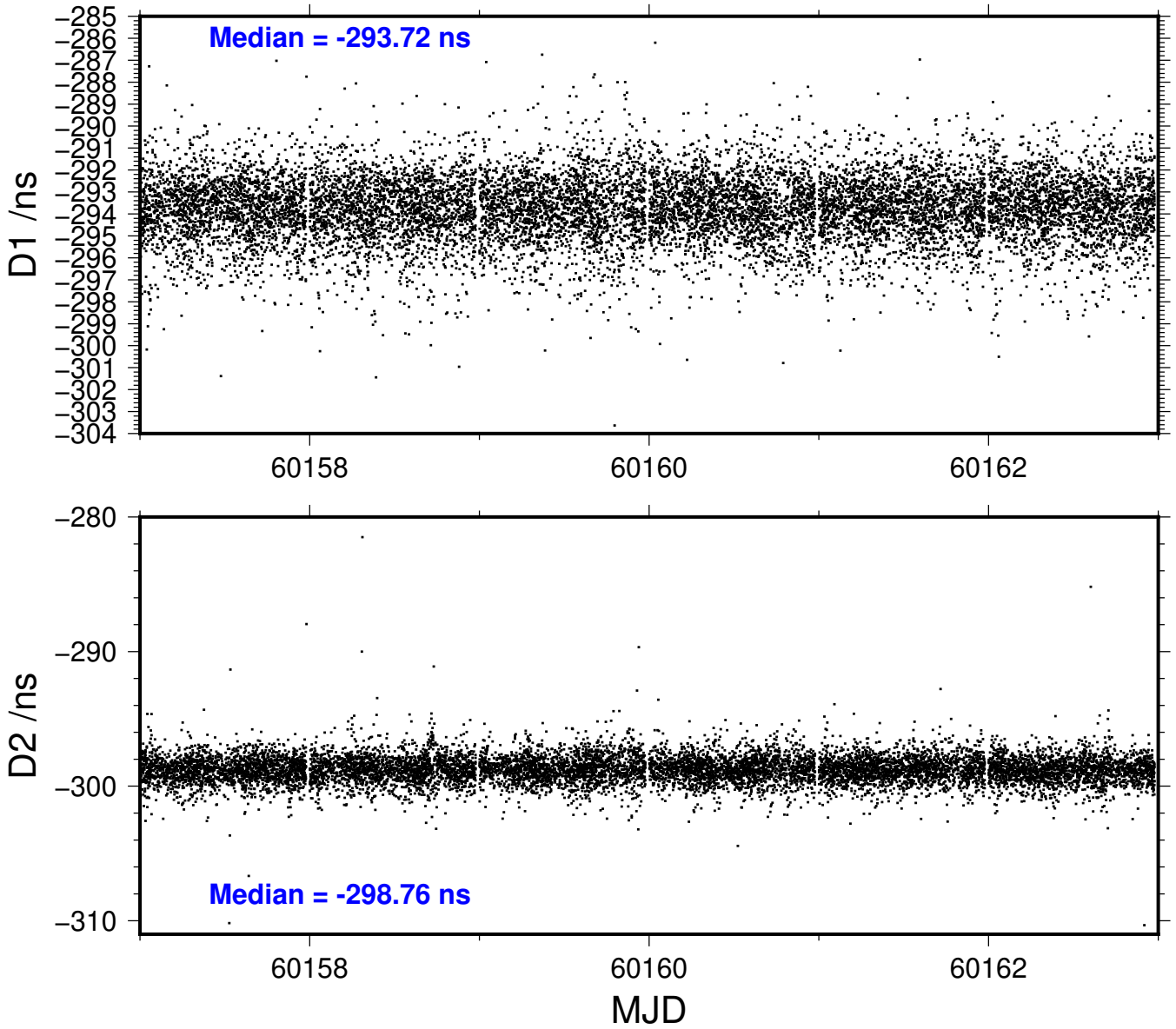


136043 s: C1=	8 ps		
68022 s: C1=	23 ps	86399 s: C2=	13 ps
34011 s: C1=	32 ps	43200 s: C2=	41 ps
17005 s: C1=	38 ps	21600 s: C2=	42 ps
8503 s: C1=	55 ps	10800 s: C2=	77 ps
4251 s: C1=	98 ps	5400 s: C2=	100 ps
2126 s: C1=	122 ps	2700 s: C2=	134 ps
1063 s: C1=	160 ps	1350 s: C2=	172 ps
531 s: C1=	224 ps	675 s: C2=	216 ps
266 s: C1=	300 ps	338 s: C2=	280 ps
133 s: C1=	473 ps	169 s: C2=	461 ps
66 s: C1=	634 ps	84 s: C2=	626 ps
33 s: C1=	899 ps	42 s: C2=	865 ps

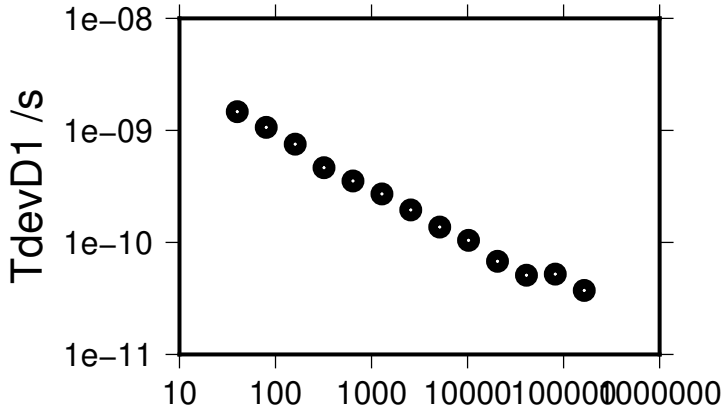


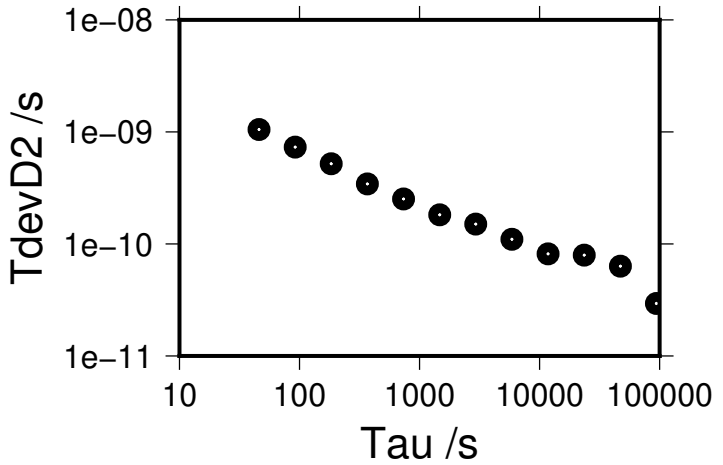


2023-08-14 NB05NIST23213_6



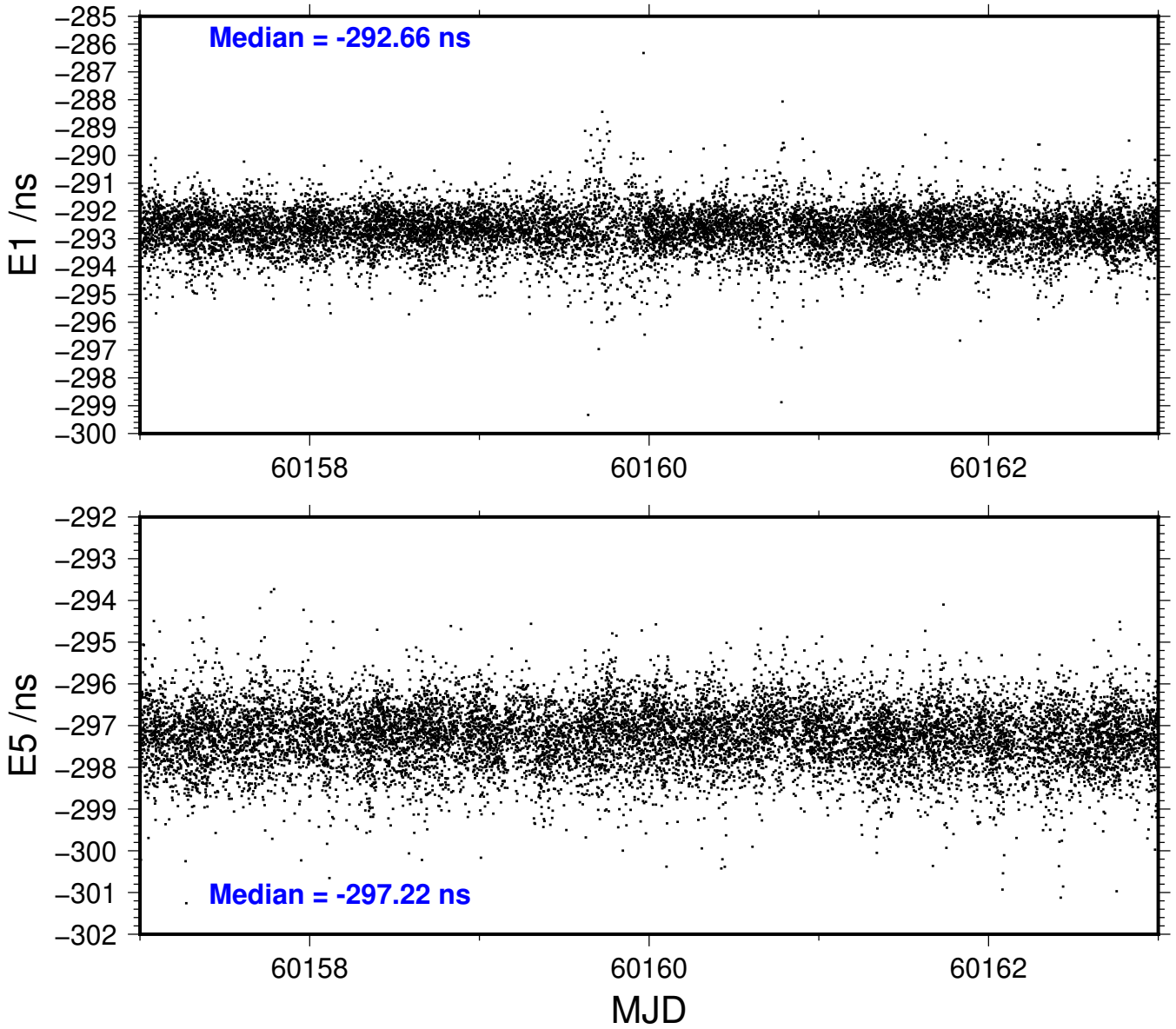
164024 s: D1=	37 ps		
82012 s: D1=	52 ps	94133 s: D2=	29 ps
41006 s: D1=	51 ps	47067 s: D2=	63 ps
20503 s: D1=	68 ps	23533 s: D2=	79 ps
10251 s: D1=	104 ps	11767 s: D2=	81 ps
5126 s: D1=	137 ps	5883 s: D2=	110 ps
2563 s: D1=	195 ps	2942 s: D2=	150 ps
1281 s: D1=	271 ps	1471 s: D2=	182 ps
641 s: D1=	353 ps	735 s: D2=	252 ps
320 s: D1=	465 ps	368 s: D2=	343 ps
160 s: D1=	755 ps	184 s: D2=	520 ps
80 s: D1=	1065 ps	92 s: D2=	732 ps
40 s: D1=	1471 ps	46 s: D2=	1050 ps

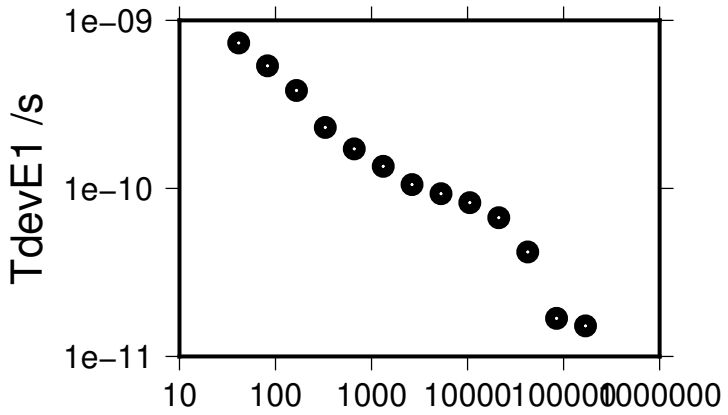


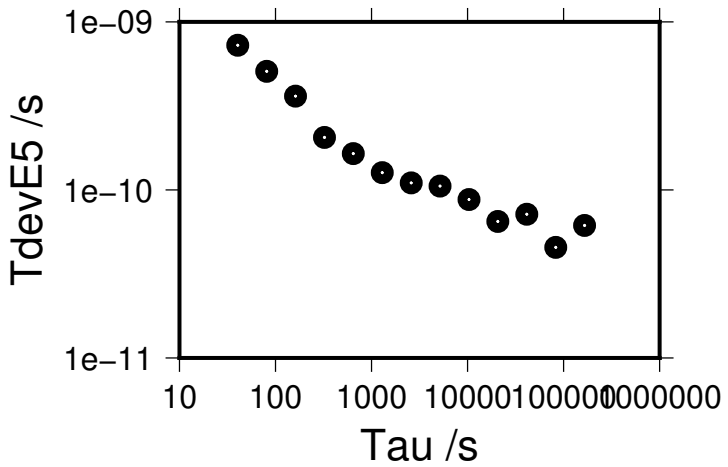


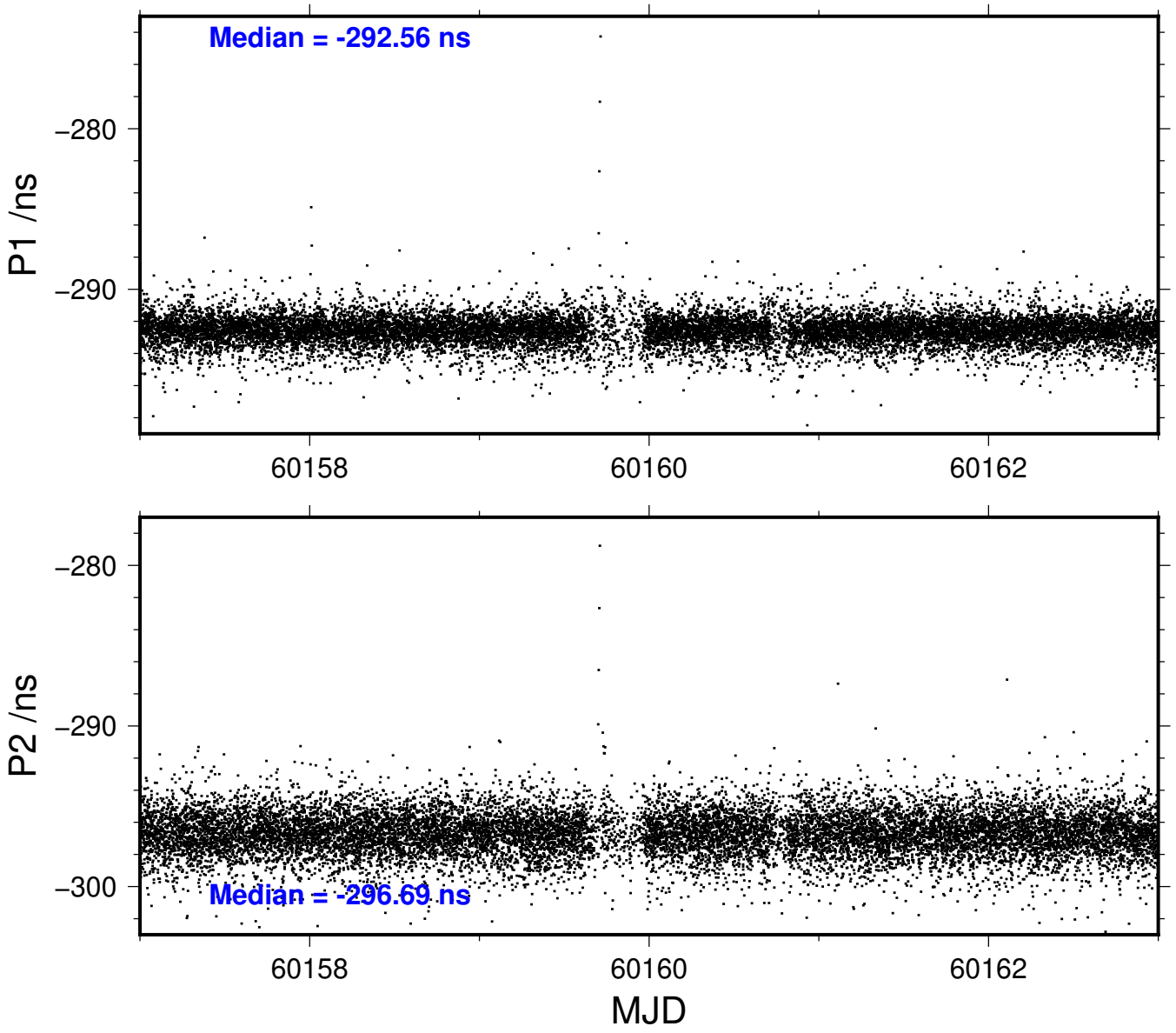
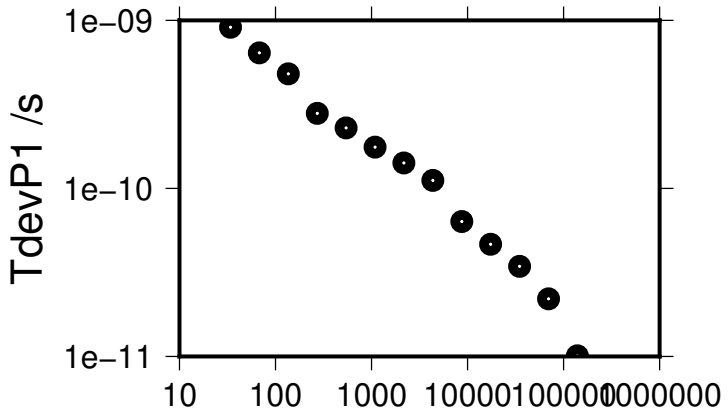
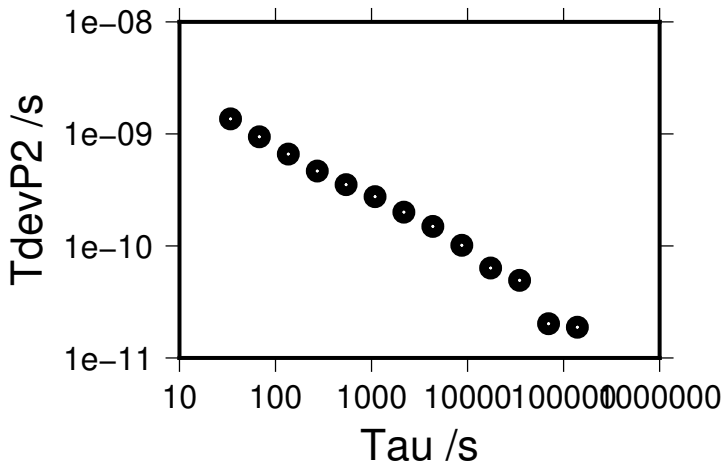
2023-08-14 NB05NIST23213_6

169108 s: E1=	15 ps	165520 s: E5=	61 ps
84554 s: E1=	17 ps	82760 s: E5=	46 ps
42277 s: E1=	42 ps	41380 s: E5=	72 ps
21139 s: E1=	67 ps	20690 s: E5=	65 ps
10569 s: E1=	82 ps	10345 s: E5=	88 ps
5285 s: E1=	93 ps	5173 s: E5=	105 ps
2642 s: E1=	105 ps	2586 s: E5=	110 ps
1321 s: E1=	135 ps	1293 s: E5=	127 ps
661 s: E1=	172 ps	647 s: E5=	165 ps
330 s: E1=	230 ps	323 s: E5=	205 ps
165 s: E1=	382 ps	162 s: E5=	361 ps
83 s: E1=	536 ps	81 s: E5=	508 ps
41 s: E1=	734 ps	40 s: E5=	726 ps







2023-08-14 NB05NIST23213_6

139193 s: P1=	10 ps	139202 s: P2=	19 ps
69597 s: P1=	22 ps	69601 s: P2=	20 ps
34798 s: P1=	34 ps	34801 s: P2=	49 ps
17399 s: P1=	47 ps	17400 s: P2=	64 ps
8700 s: P1=	63 ps	8700 s: P2=	101 ps
4350 s: P1=	112 ps	4350 s: P2=	149 ps
2175 s: P1=	142 ps	2175 s: P2=	200 ps
1087 s: P1=	176 ps	1088 s: P2=	275 ps
544 s: P1=	229 ps	544 s: P2=	353 ps
272 s: P1=	279 ps	272 s: P2=	467 ps
136 s: P1=	480 ps	136 s: P2=	660 ps
68 s: P1=	641 ps	68 s: P2=	944 ps
34 s: P1=	909 ps	34 s: P2=	1363 ps