

# RxPD and TxPD Calibration Trends

| GENERATED FOR LHO\_EndX

Report Generated on June 13, 2023

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## 1 About

This document contains the Pcal Calibration trends. It includes the ratios measured at the end-station labeled as m1, m2 .....m6 as well as the quantities derived from these six ratio measurements, namely  $\alpha_{TW}$ ,  $\alpha_{RW}$ , optical efficiency and power imbalance. This document also includes the trend of the ADC conversion factor. The sections 17 to 20 shows the trend of the parameters calculated from the derived quantities, which include Input/Output optical efficiency correction factors and Tx/Rx PD calibration factors.

### Understanding Each Section

Each section contains a list of measurements with the mean value (m1), standard deviation on the mean (SD\_m1) and a ratio of the standard deviation of the quantity and error bars for each measurement (frac). The list is followed by two plot figures with Magnitude on the Y axis and Index on the X axis for the first plot and the Magnitude on the Y axis and time on the X axis for the second. The error bars of each data point is the standard deviation SD\_m1. Each section ends with a summary that contains the mean (the red line on the plot) along with their Standard Deviation, Std Err and Rel Err (the pink band on the plot) where each of these terms are defined as:

$$\text{Mean} = \text{sum}(x(i))/n$$

$$\text{Std\_Dev} = \text{sqrt}(\text{sum}((x(i)-x\_mean)^2)/(n-1))$$

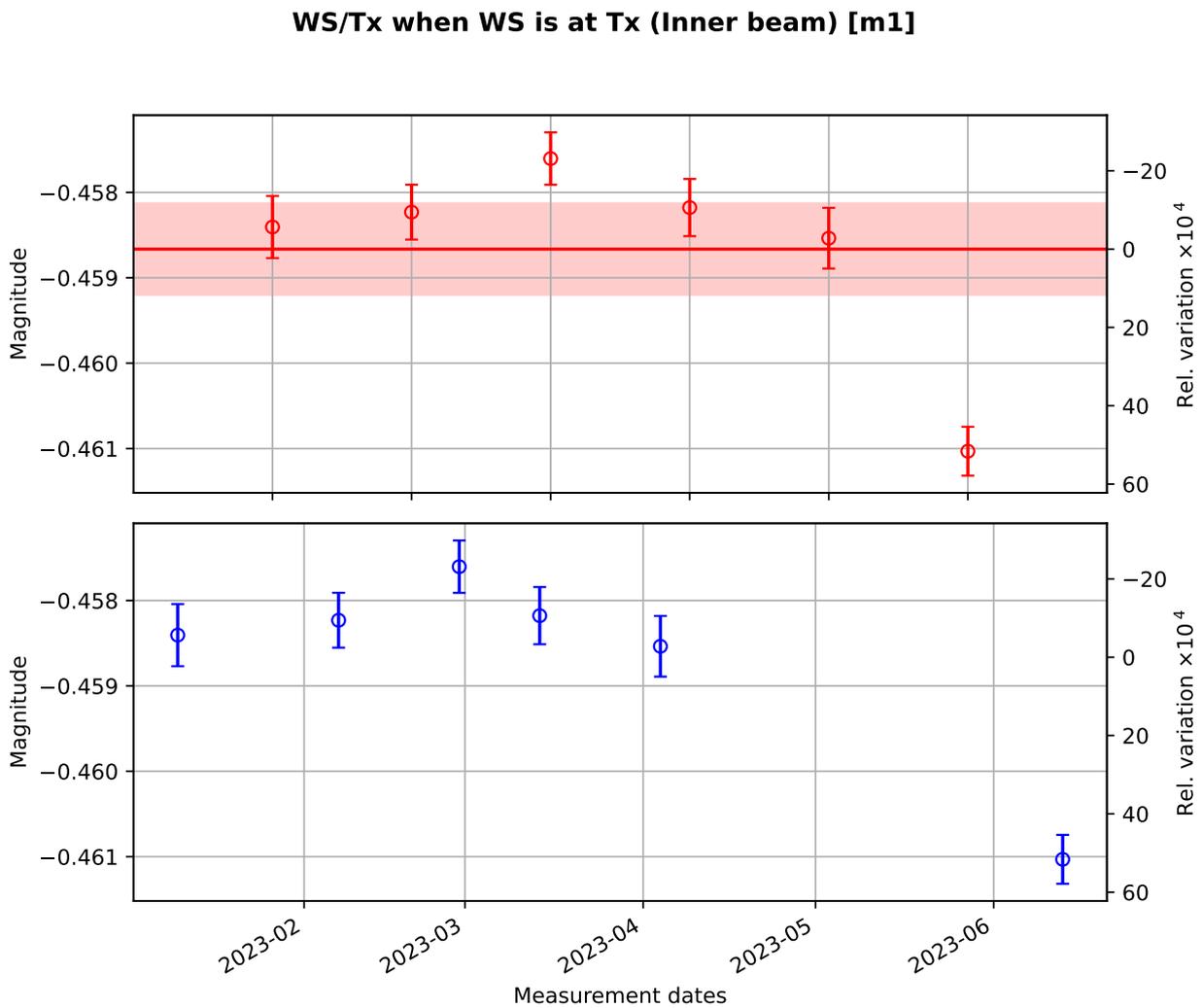
$$\text{Std\_Err} = \text{Std\_Dev} * \text{Student}'s\_t\_correction / \text{sqrt}(n)$$

$$\text{Rel\_Err} = \text{Std\_Err} / \text{Mean}$$

## 2 WS/Tx Ratio when WS is at Tx (Inner Beam)

### List of Measurements

Date	m1 ± SD_m1
D20230110	-0.4584 ± 0.0004
D20230207	-0.4582 ± 0.0003
D20230228	-0.4576 ± 0.0003
D20230314	-0.4582 ± 0.0003
D20230404	-0.4585 ± 0.0004
D20230613	-0.4610 ± 0.0003



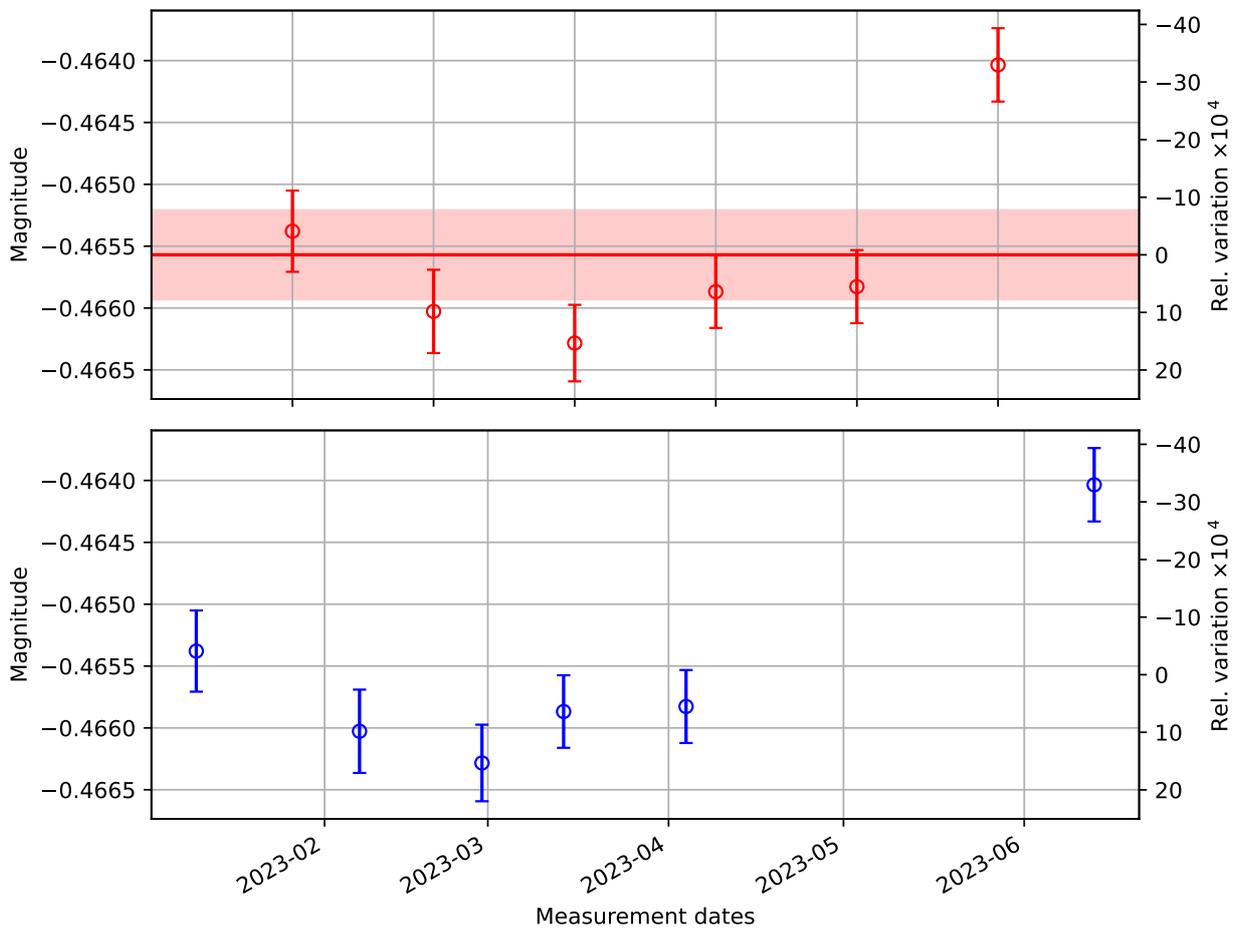
Summary of WS/Tx when WS is at Tx (Inner beam) [m1]	
Mean value:	-0.458664
Standard deviation:	0.001203
Standard error:	0.000536
Relative Standard error:	-0.001168

### 3 WS/Tx Ratio when WS is at Tx (Outer Beam)

#### List of Measurements

Date	m2 ± SD_m2
D20230110	-0.4654 ± 0.0003
D20230207	-0.4660 ± 0.0003
D20230228	-0.4663 ± 0.0003
D20230314	-0.4659 ± 0.0003
D20230404	-0.4658 ± 0.0003
D20230613	-0.4640 ± 0.0003

**WS/Tx when WS is at Tx (Outer Beam) [m2]**



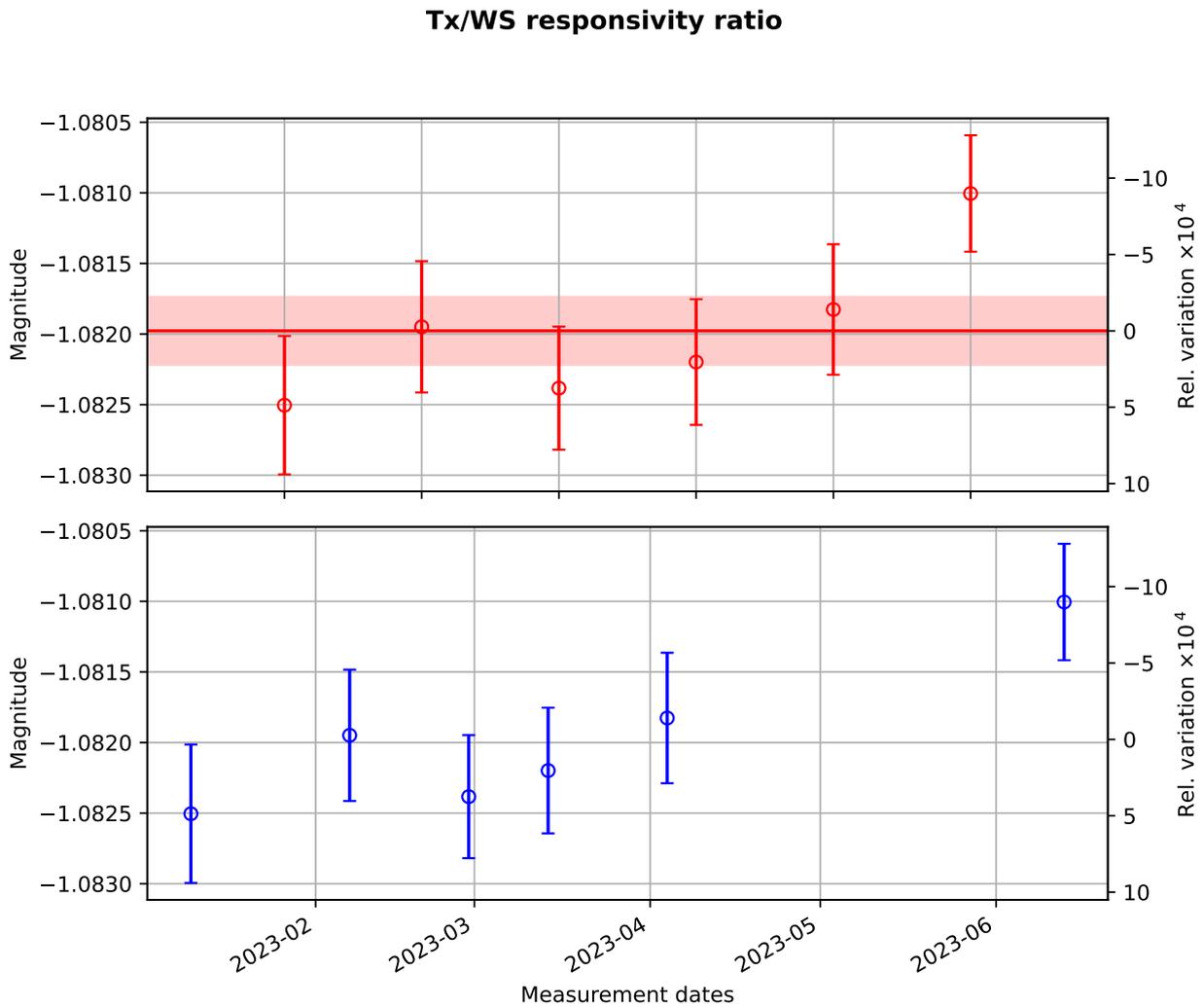
#### Summary of WS/Tx when WS is at Tx (Outer Beam) [m2]

Mean value:	-0.465570
Standard deviation:	0.000808
Standard error:	0.000360
Relative Standard error:	-0.000773

## 4 Tx/WS responsivity ratio $\alpha_{TW} = 1/[m1 + m2]$

### List of Measurements

Date	TXWS $\pm$ SD_TXWS
D20230110	-1.0825 $\pm$ 0.0005
D20230207	-1.0819 $\pm$ 0.0005
D20230228	-1.0824 $\pm$ 0.0004
D20230314	-1.0822 $\pm$ 0.0004
D20230404	-1.0818 $\pm$ 0.0005
D20230613	-1.0810 $\pm$ 0.0004



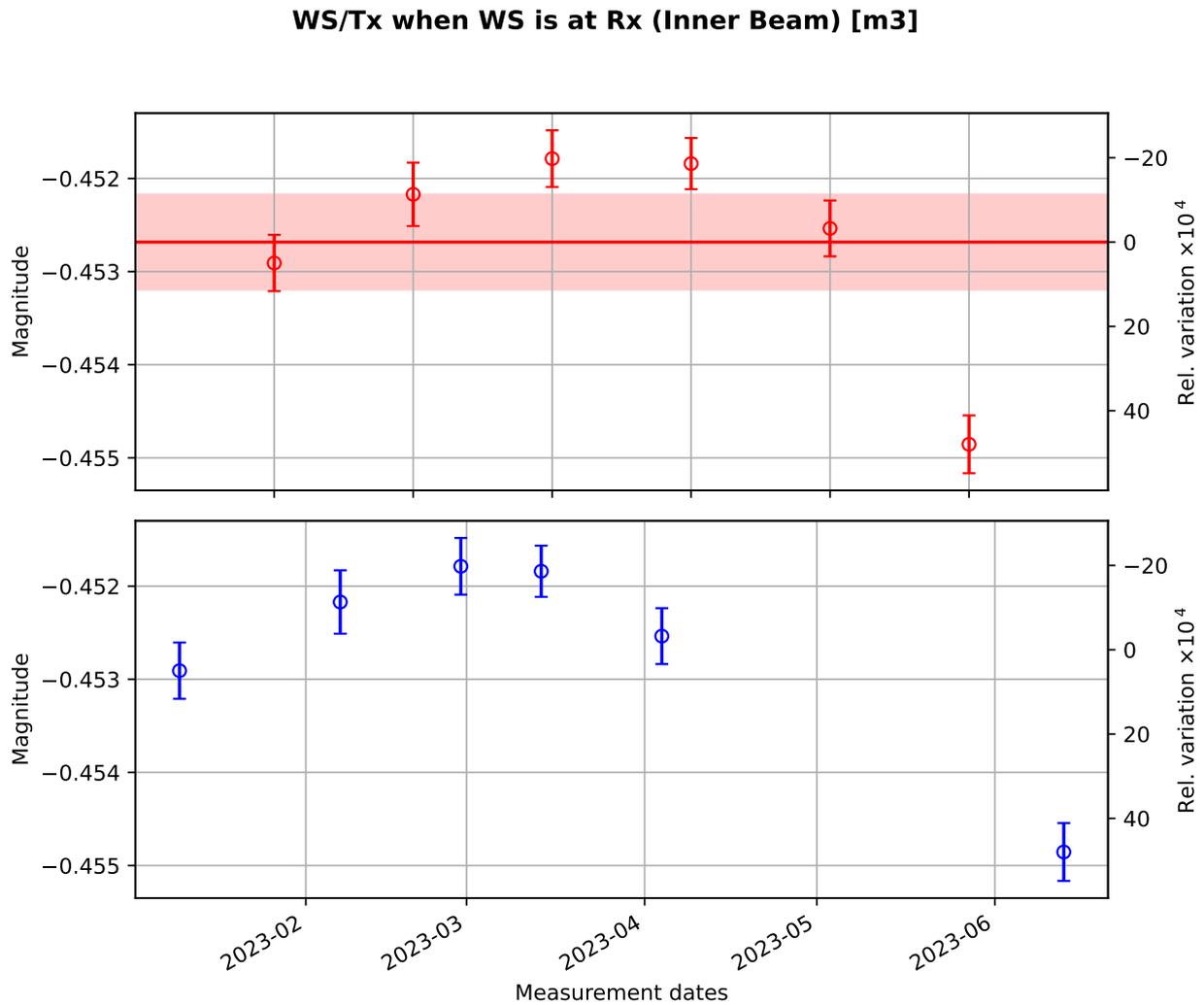
### Summary of Tx/WS responsivity ratio

Mean value:	-1.081978
Standard deviation:	0.000541
Standard error:	0.000241
Relative Standard error:	-0.000222

## 5 WS/Tx Ratio when WS is at Rx (Inner Beam)

### List of Measurements

Date	m3 $\pm$ SD_m3
D20230110	-0.4529 $\pm$ 0.0003
D20230207	-0.4522 $\pm$ 0.0003
D20230228	-0.4518 $\pm$ 0.0003
D20230314	-0.4518 $\pm$ 0.0003
D20230404	-0.4525 $\pm$ 0.0003
D20230613	-0.4549 $\pm$ 0.0003



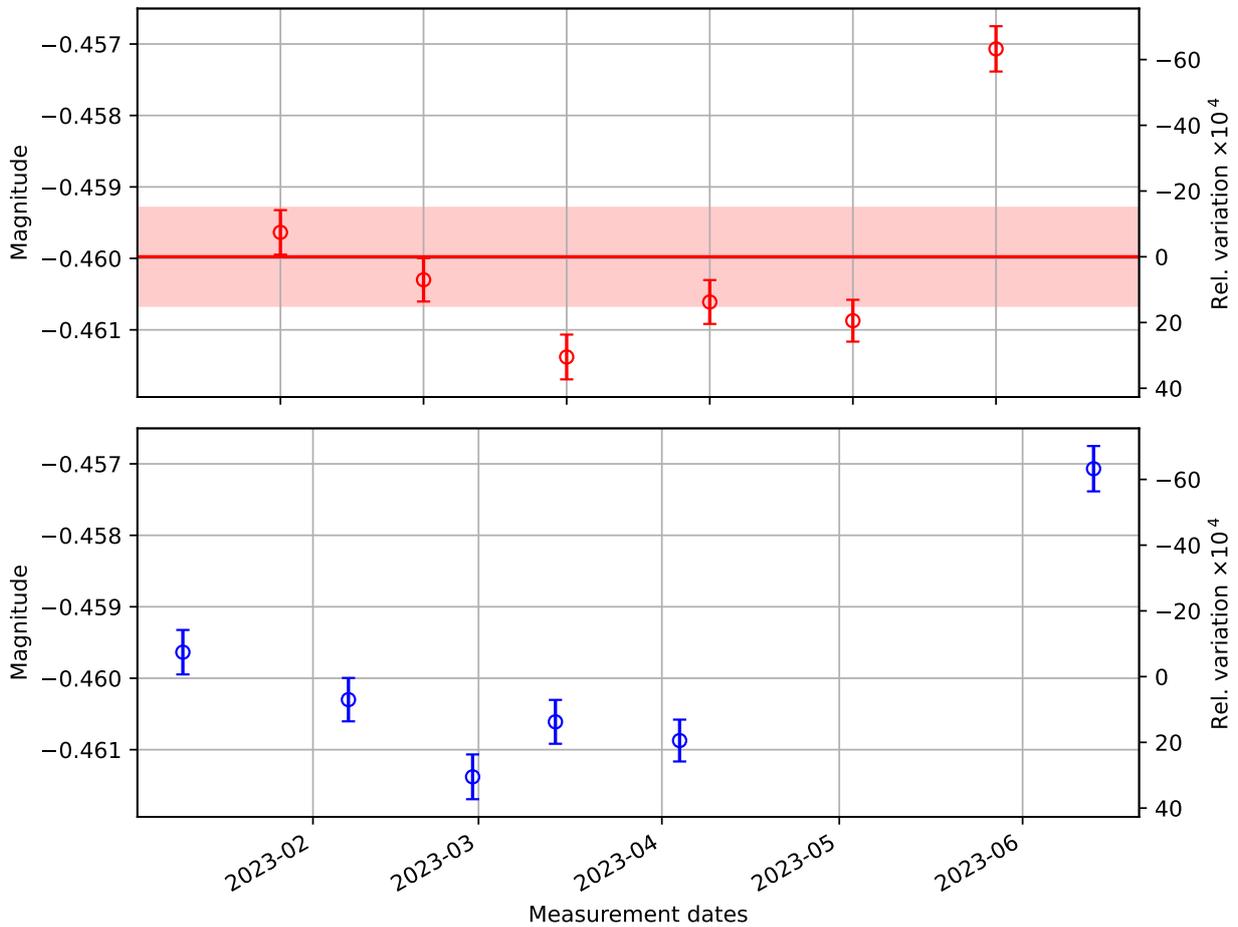
Summary of WS/Tx when WS is at Rx (Inner Beam) [m3]	
Mean value:	-0.452683
Standard deviation:	0.001146
Standard error:	0.000510
Relative Standard error:	-0.001127

## 6 WS/Tx Ratio when WS is at Rx (Outer Beam)

### List of Measurements

Date	m4 ± SD_m4
D20230110	-0.4596 ± 0.0003
D20230207	-0.4603 ± 0.0003
D20230228	-0.4614 ± 0.0003
D20230314	-0.4606 ± 0.0003
D20230404	-0.4609 ± 0.0003
D20230613	-0.4571 ± 0.0003

**WS/Tx when WS is at Rx (Outer Beam) [m4]**



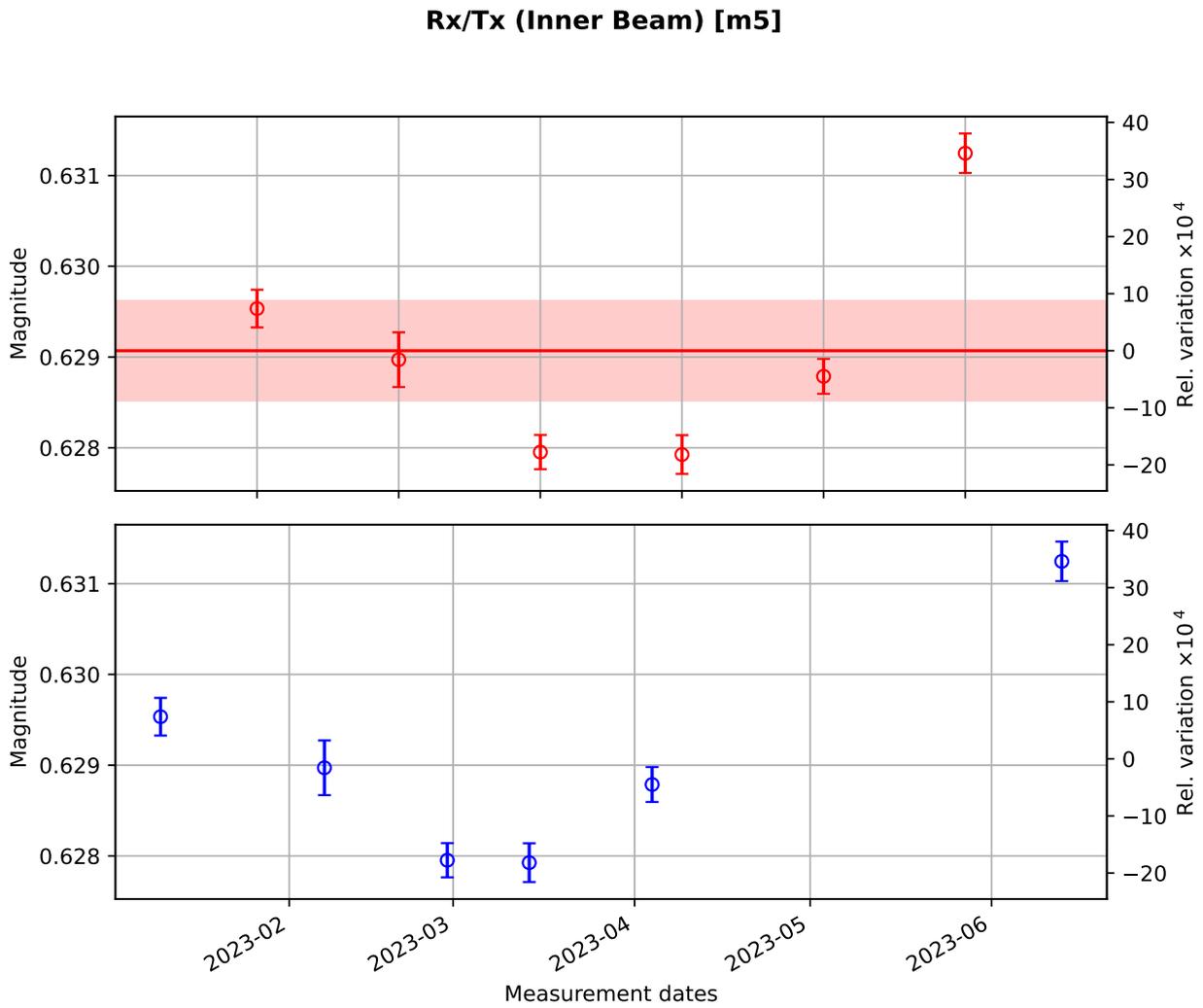
### Summary of WS/Tx when WS is at Rx (Outer Beam) [m4]

Mean value:	-0.459978
Standard deviation:	0.001540
Standard error:	0.000686
Relative Standard error:	-0.001490

## 7 RX/TX Ratio (Inner Beam)

### List of Measurements

Date	m5 ± SD_m5
D20230110	0.6295 ± 0.0002
D20230207	0.6290 ± 0.0003
D20230228	0.6280 ± 0.0002
D20230314	0.6279 ± 0.0002
D20230404	0.6288 ± 0.0002
D20230613	0.6312 ± 0.0002

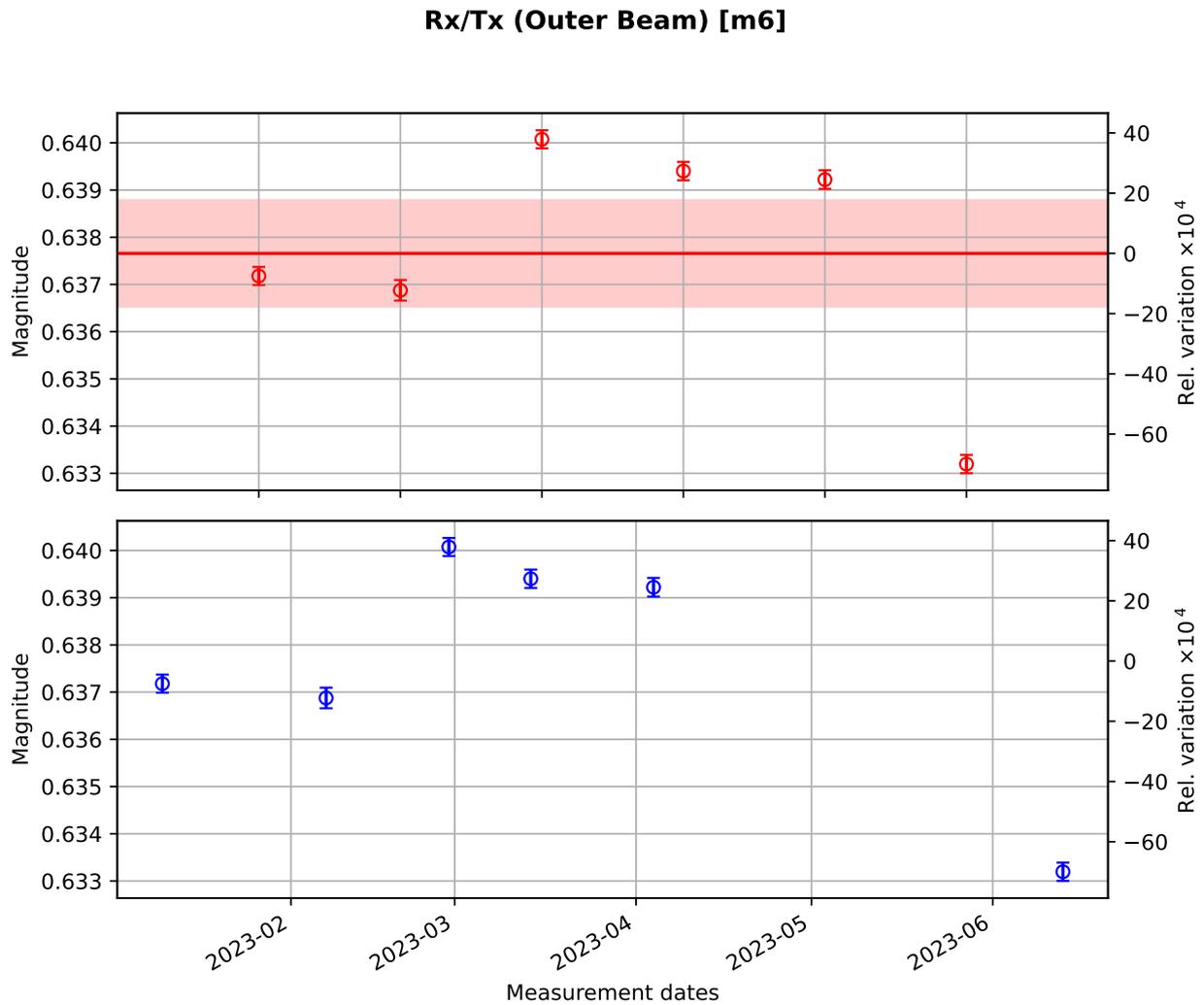


Summary of Rx/Tx (Inner Beam) [m5]	
Mean value:	0.629069
Standard deviation:	0.001233
Standard error:	0.000549
Relative Standard error:	0.000872

## 8 Rx/Tx Ratio (Outer Beam)

### List of Measurements

Date	m6 ± SD_m6
D20230110	0.6372 ± 0.0002
D20230207	0.6369 ± 0.0002
D20230228	0.6401 ± 0.0002
D20230314	0.6394 ± 0.0002
D20230404	0.6392 ± 0.0002
D20230613	0.6332 ± 0.0002

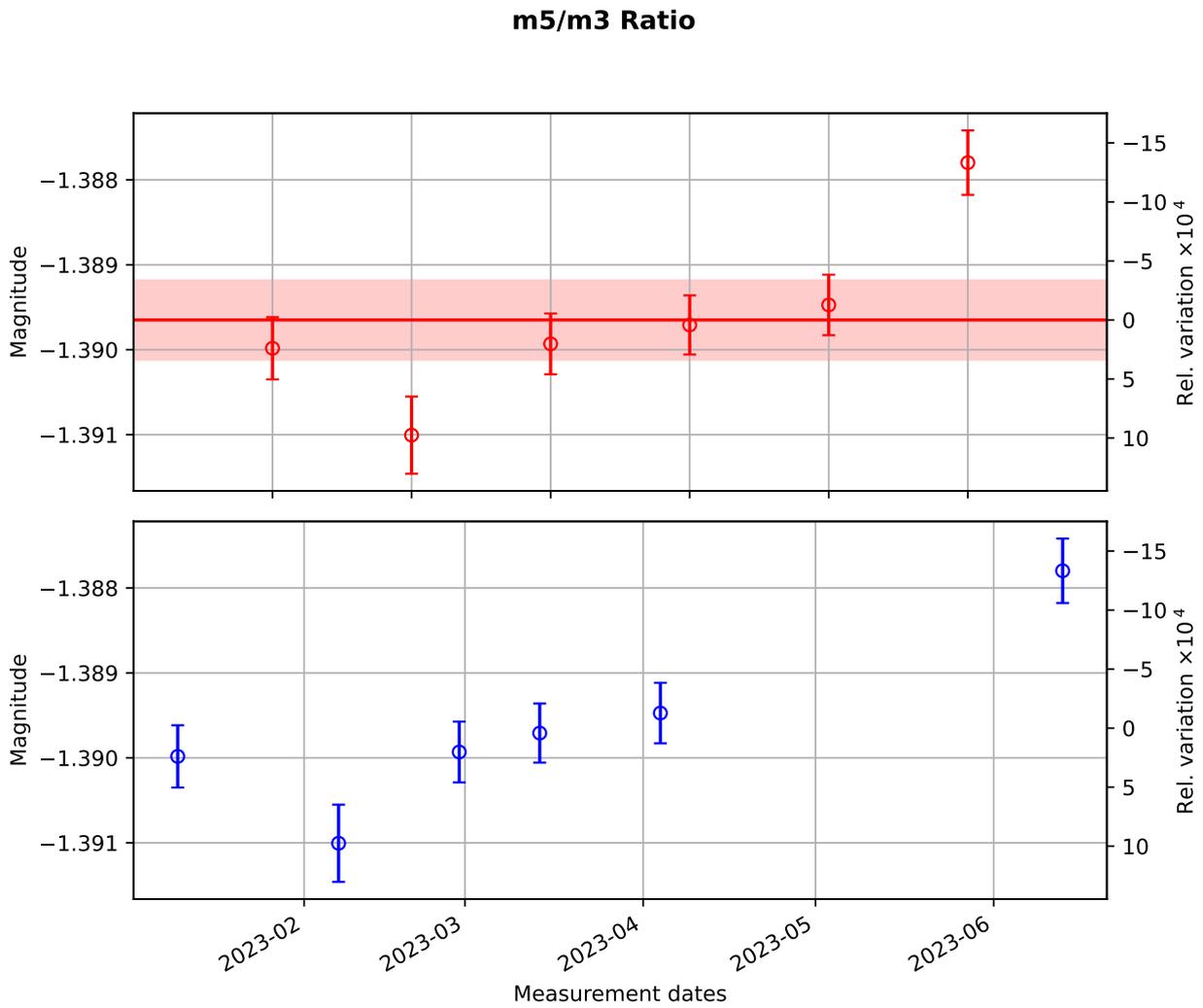


Summary of Rx/Tx (Outer Beam) [m6]	
Mean value:	0.637658
Standard deviation:	0.002533
Standard error:	0.001128
Relative Standard error:	0.001768

# 9 m5/m3 Ratio

## List of Measurements

Date	RiTWriT ± SD_RiTWriT
D20230110	-1.3900 ± 0.0004
D20230207	-1.3910 ± 0.0005
D20230228	-1.3899 ± 0.0004
D20230314	-1.3897 ± 0.0003
D20230404	-1.3895 ± 0.0004
D20230613	-1.3878 ± 0.0004



### Summary of m5/m3 Ratio

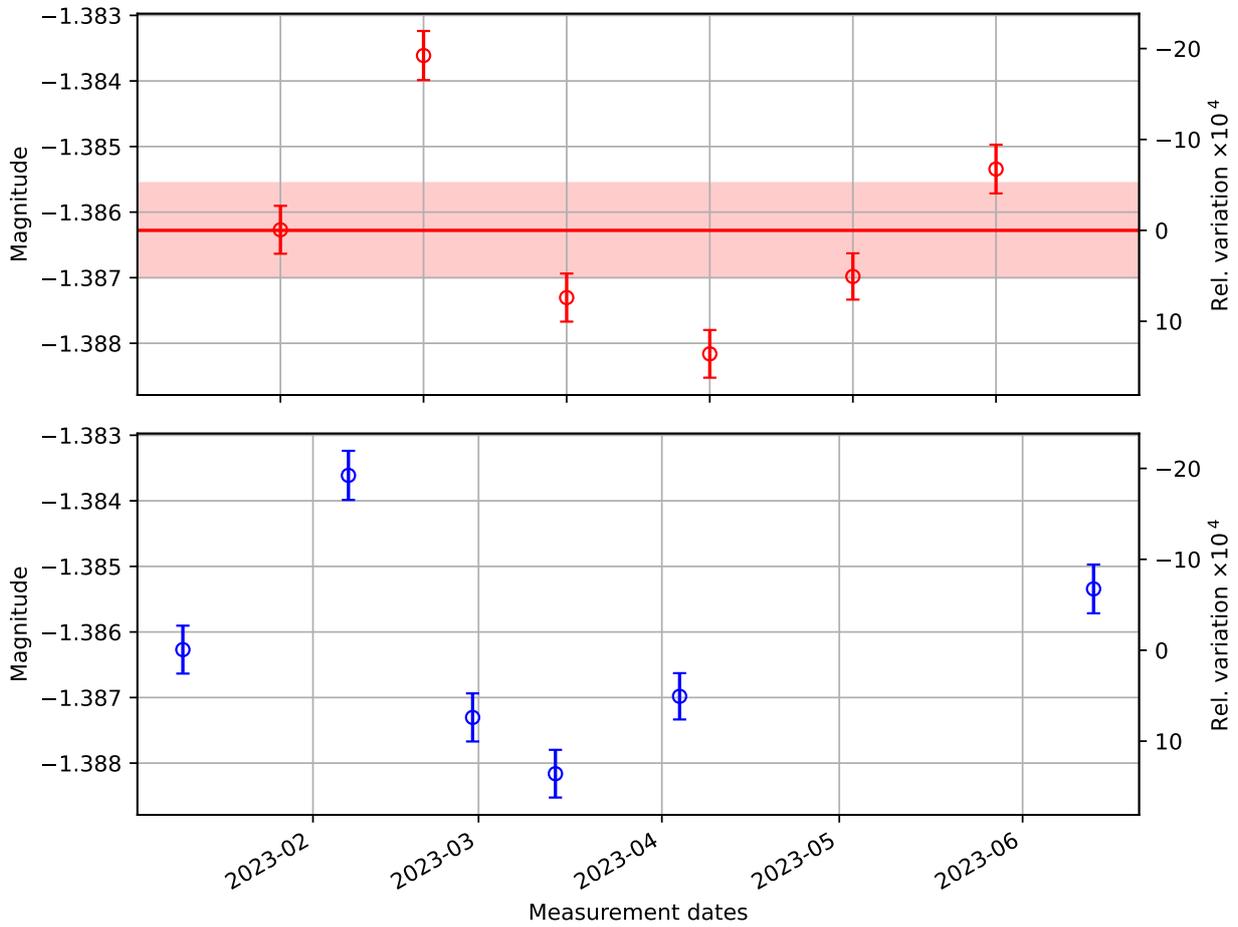
Mean value:	-1.389649
Standard deviation:	0.001048
Standard error:	0.000467
Relative Standard error:	-0.000336

# 10 m6/m4 Ratio

## List of Measurements

Date	RoTWroT ± SD_RoTWroT
D20230110	-1.3863 ± 0.0004
D20230207	-1.3836 ± 0.0004
D20230228	-1.3873 ± 0.0004
D20230314	-1.3882 ± 0.0004
D20230404	-1.3870 ± 0.0004
D20230613	-1.3853 ± 0.0004

### m6/m4 Ratio



#### Summary of m6/m4 Ratio

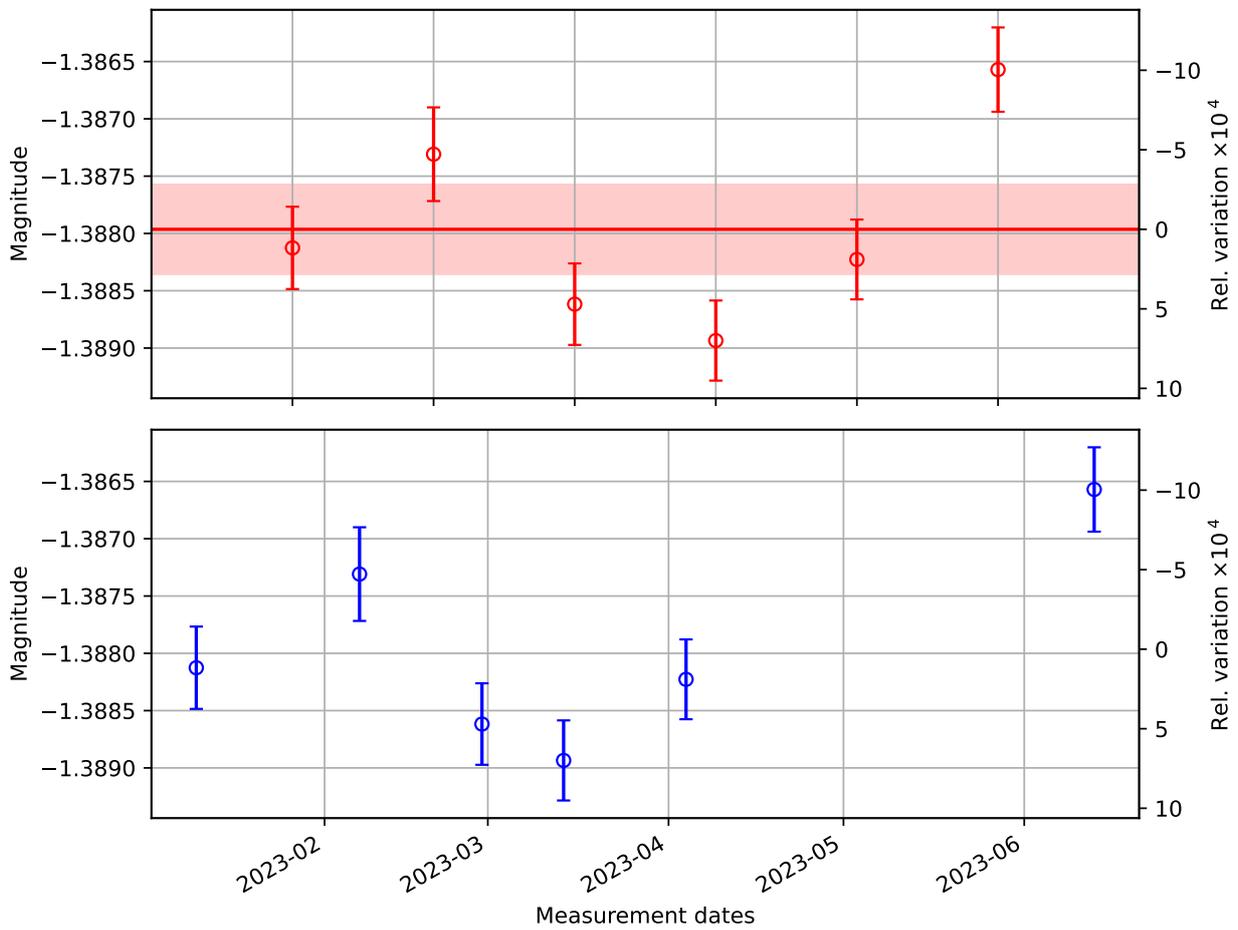
Mean value:	-1.386278
Standard deviation:	0.001617
Standard error:	0.000720
Relative Standard error:	-0.000519

# 11 Rx/WS responsivity ratio $\alpha_{RW} = \frac{1}{2} [m5/m3 + m6/m4]$

## List of Measurements

Date	RXWS $\pm$ SD_RXWS
D20230110	-1.3881 $\pm$ 0.0004
D20230207	-1.3873 $\pm$ 0.0004
D20230228	-1.3886 $\pm$ 0.0004
D20230314	-1.3889 $\pm$ 0.0003
D20230404	-1.3882 $\pm$ 0.0003
D20230613	-1.3866 $\pm$ 0.0004

**Rx/WS responsivity ratio**



### Summary of Rx/WS responsivity ratio

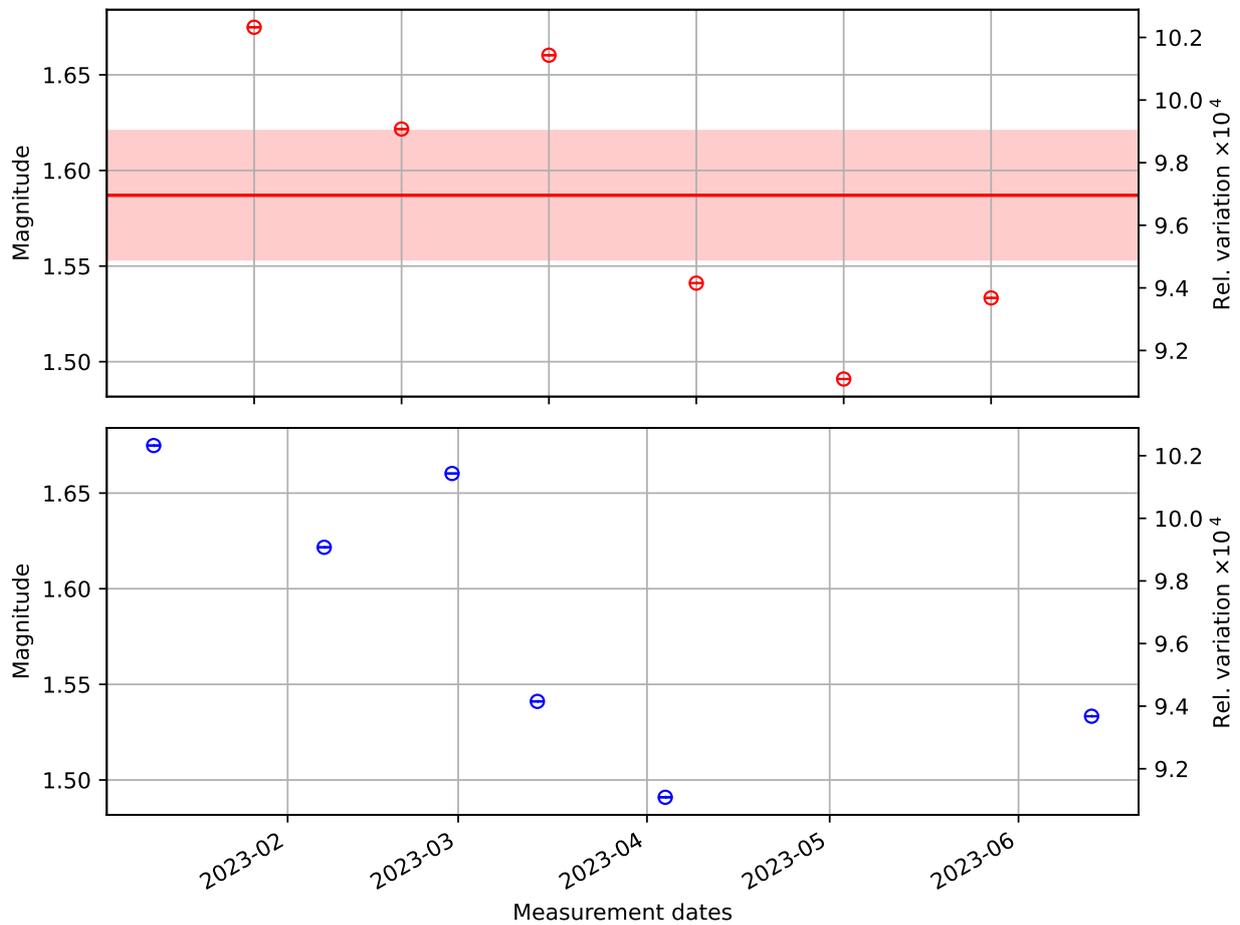
Mean value:	-1.387964
Standard deviation:	0.000876
Standard error:	0.000390
Relative Standard error:	-0.000281

## 12 ADC conversion factor ( $\zeta$ )

### List of Measurements

Date	$\zeta \pm \text{SD}_\zeta$
D20230110	$1.6367\text{e}+03 \pm 1.0000\text{e}-09$
D20230207	$1.6368\text{e}+03 \pm 1.0000\text{e}-09$
D20230228	$1.6367\text{e}+03 \pm 1.0000\text{e}-09$
D20230314	$1.6369\text{e}+03 \pm 1.0000\text{e}-09$
D20230404	$1.6369\text{e}+03 \pm 1.0000\text{e}-09$
D20230613	$1.6369\text{e}+03 \pm 1.0000\text{e}-09$

### ADC conversion factor discrepancy ( $1638.4 - \zeta$ (ct/V))



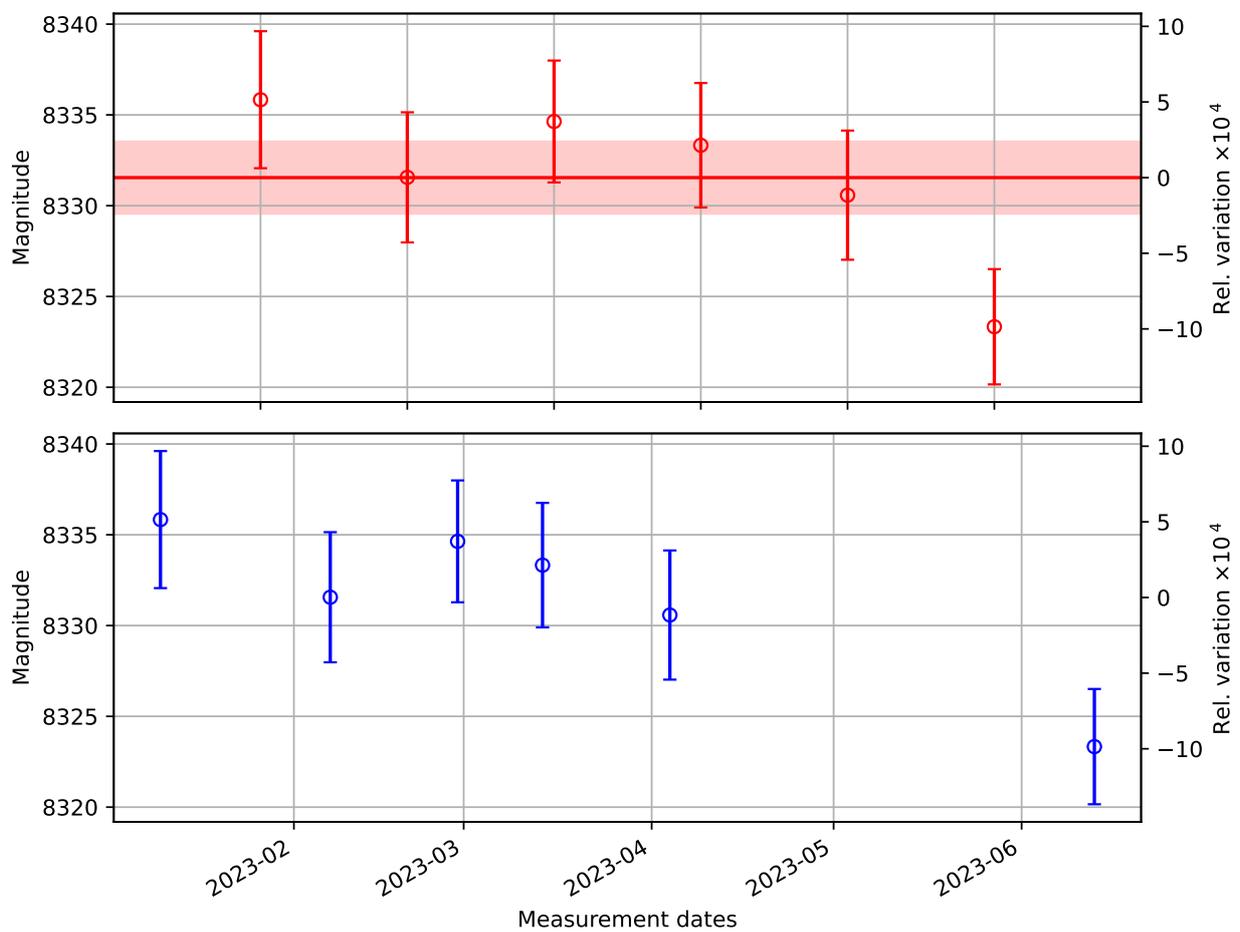
| Summary of ADC conversion factor discrepancy

### 13 TxPD calibration ( $\rho_{Tx} = \rho_G \cdot \alpha_{WG} \cdot \alpha_{TW} \cdot \zeta$ )

#### List of Measurements

Date	rhoTx ± SD_rhoTx
D20230110	8335.8363 ± 3.7737
D20230207	8331.5608 ± 3.5832
D20230228	8334.6371 ± 3.3555
D20230314	8333.3272 ± 3.4285
D20230404	8330.5796 ± 3.5576
D20230613	8323.3328 ± 3.1747

**TxPD calibration (ct/W)**



#### Summary of TxPD calibration (ct/W)

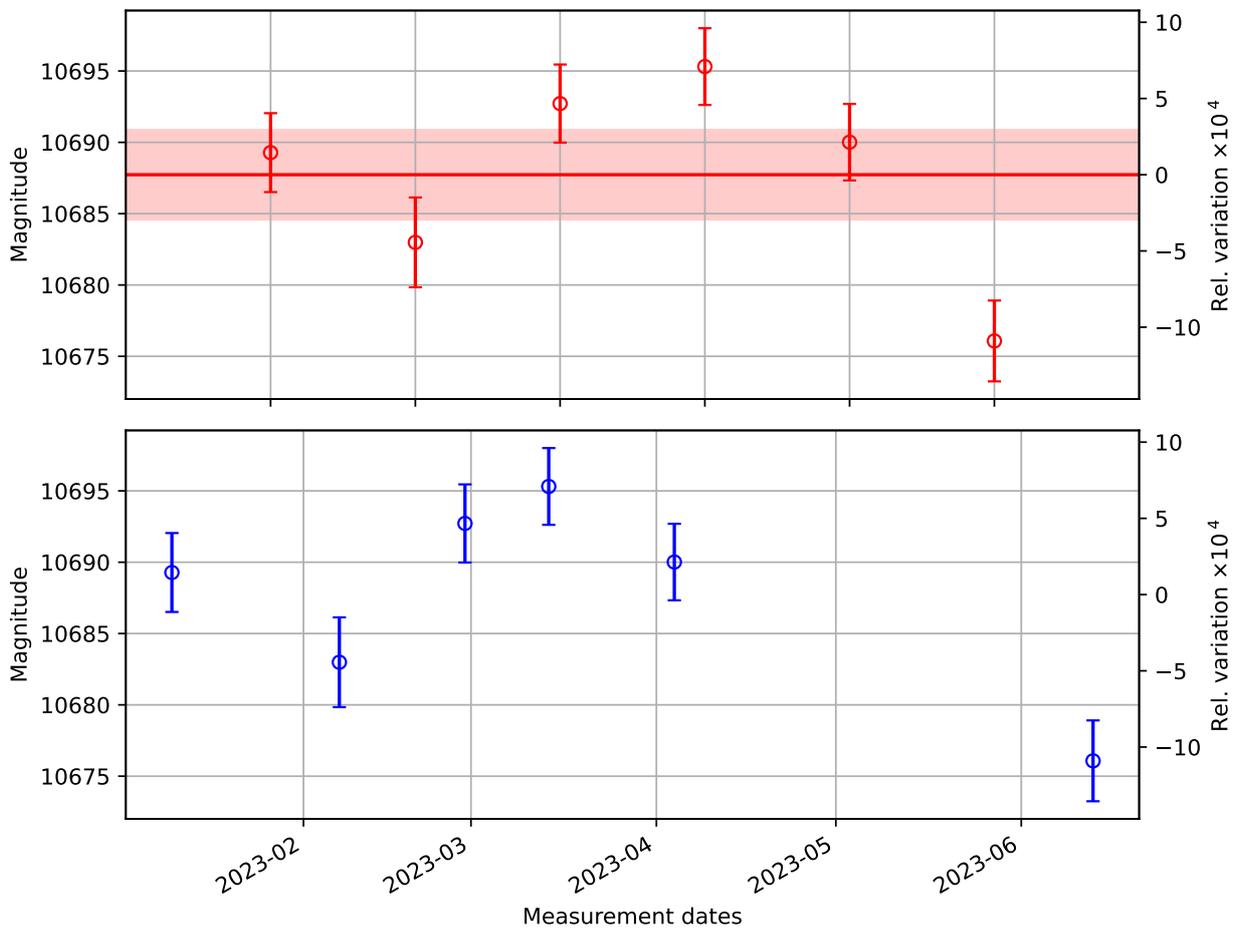
Mean value:	8331.545634
Standard deviation:	4.461506
Standard error:	1.986365
Relative Standard error:	0.000238

# 14 RxPD calibration ( $\rho_{Rx} = \rho_G \cdot \alpha_{WG} \cdot \alpha_{RW} \cdot \zeta$ )

## List of Measurements

Date	rhoRx ± SD_rhoRx
D20230110	10689.2786 ± 2.7664
D20230207	10682.9872 ± 3.1471
D20230228	10692.7178 ± 2.7391
D20230314	10695.3109 ± 2.6911
D20230404	10690.0120 ± 2.6817
D20230613	10676.0753 ± 2.8342

**RxPD calibration (ct/W)**



### Summary of RxPD calibration (ct/W)

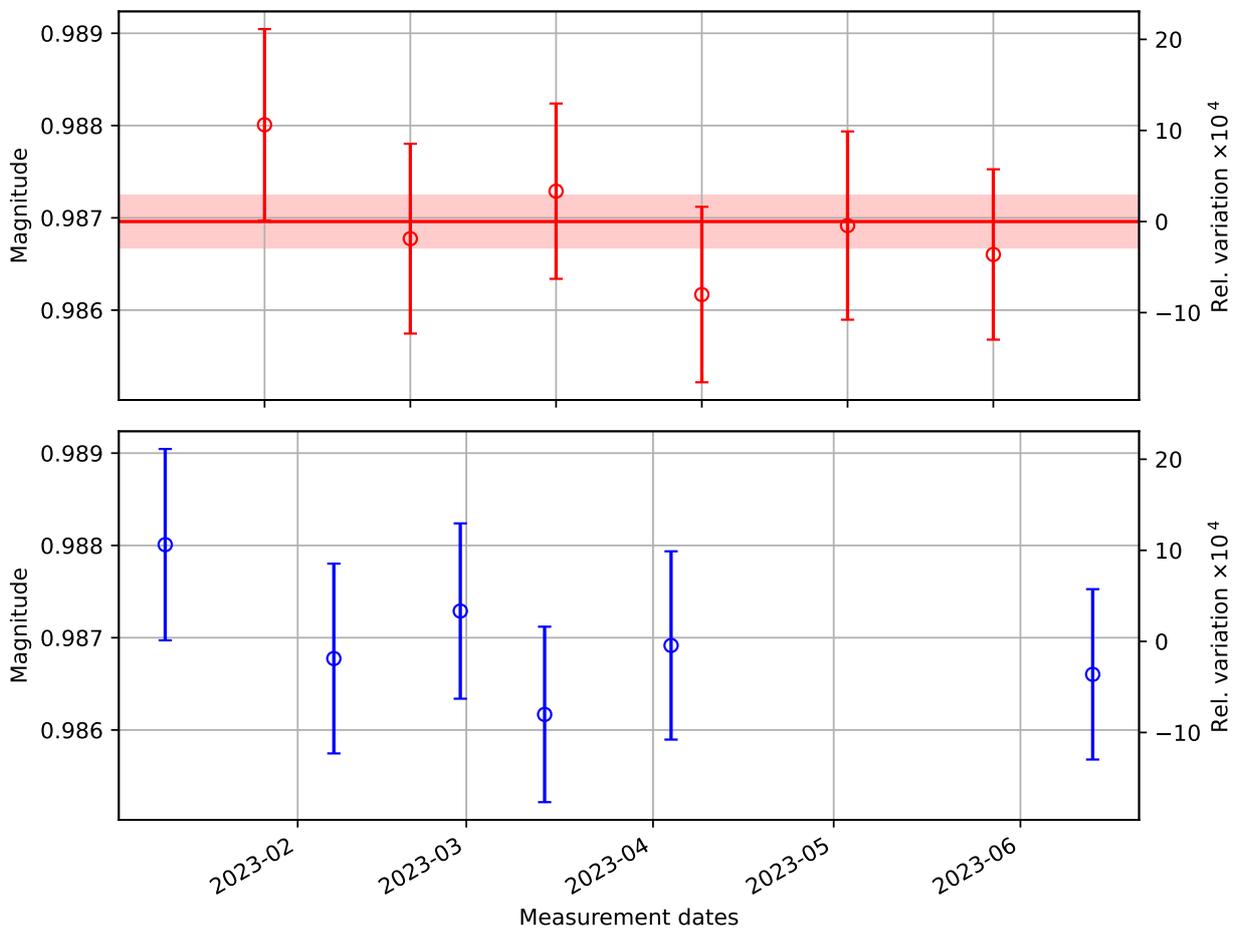
Mean value:	10687.730288
Standard deviation:	7.046710
Standard error:	3.137357
Relative Standard error:	0.000294

# 15 Optical Efficiency of Inner Beam $e^i = m3/m1$

## List of Measurements

Date	$e_i \pm SD_{e_i}$
D20230110	$0.9880 \pm 0.0010$
D20230207	$0.9868 \pm 0.0010$
D20230228	$0.9873 \pm 0.0009$
D20230314	$0.9862 \pm 0.0010$
D20230404	$0.9869 \pm 0.0010$
D20230613	$0.9866 \pm 0.0009$

### Optical Efficiency (Inner Beam)



#### Summary of Optical Efficiency (Inner Beam)

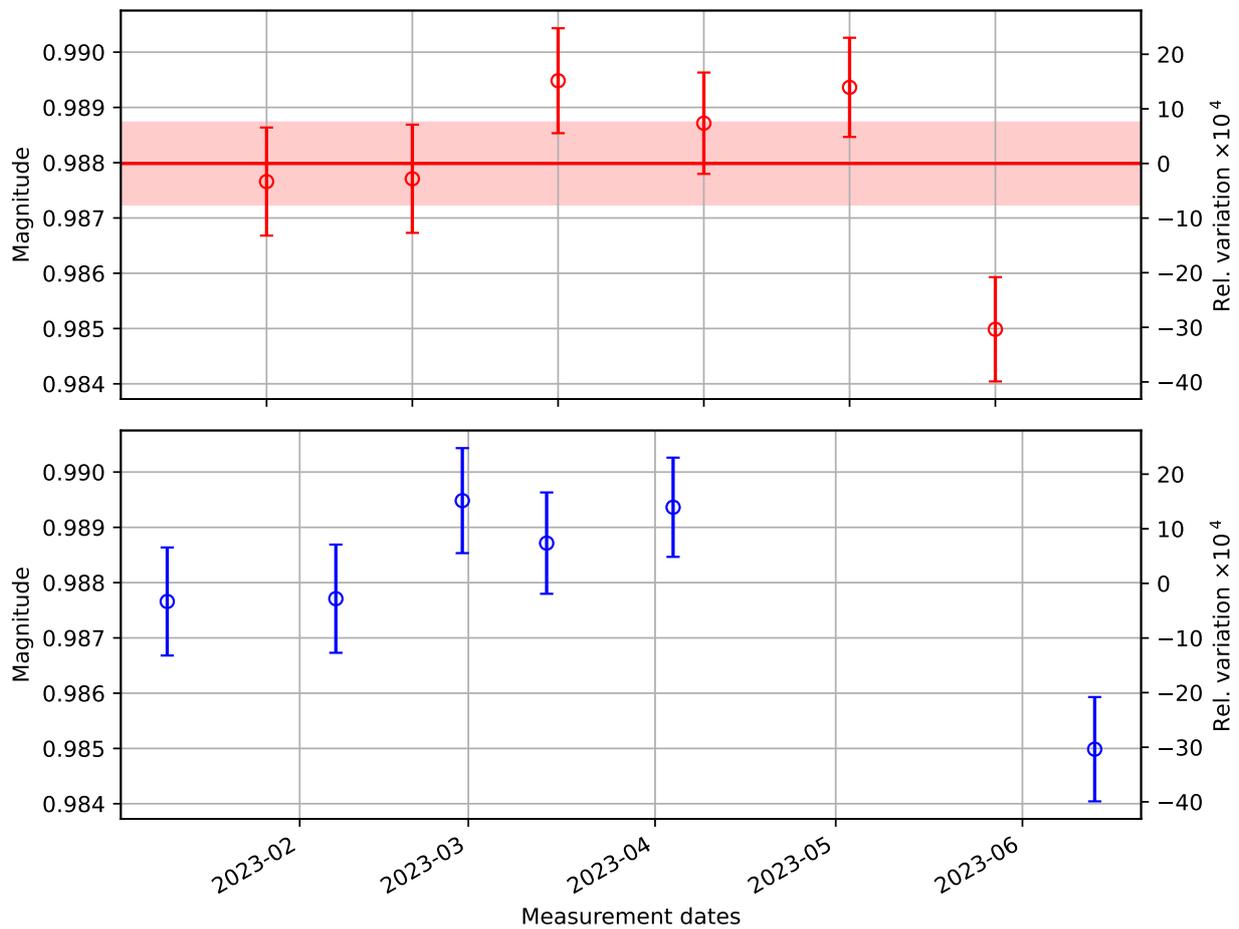
Mean value:	0.986960
Standard deviation:	0.000632
Standard error:	0.000281
Relative Standard error:	0.000285

## 16 Optical Efficiency of Outer Beam $e^o = m4/m2$

### List of Measurements

Date	$e_o \pm SD_{e_o}$
D20230110	$0.9877 \pm 0.0010$
D20230207	$0.9877 \pm 0.0010$
D20230228	$0.9895 \pm 0.0009$
D20230314	$0.9887 \pm 0.0009$
D20230404	$0.9894 \pm 0.0009$
D20230613	$0.9850 \pm 0.0009$

### Optical Efficiency (Outer Beam)



#### Summary of Optical Efficiency (Outer Beam)

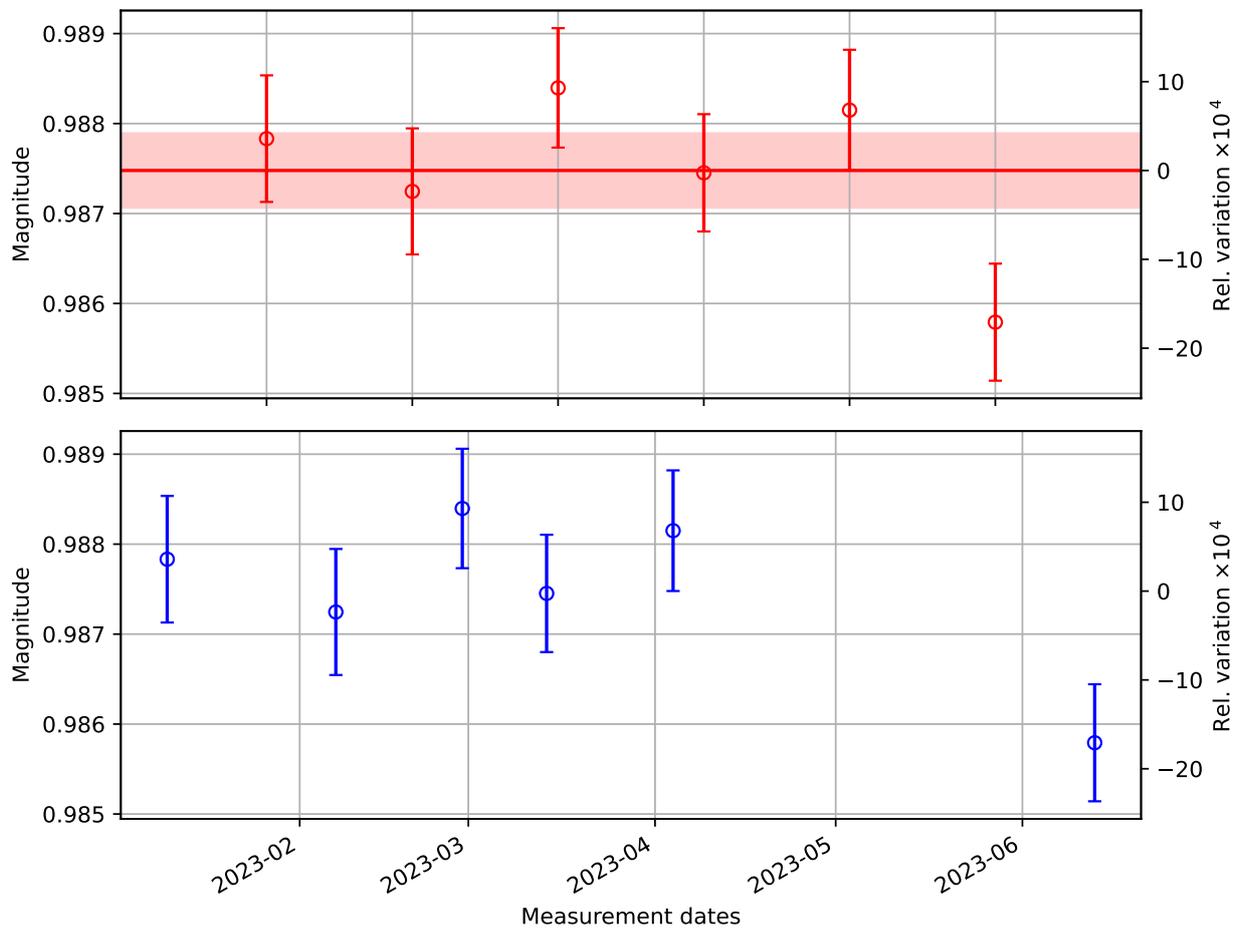
Mean value:	0.987986
Standard deviation:	0.001664
Standard error:	0.000741
Relative Standard error:	0.000750

# 17 Total Optical Efficiency $e = (m3 + m4)/(m1 + m2)$

## List of Measurements

Date	$e \pm SD_e$
D20230110	$0.9878 \pm 0.0007$
D20230207	$0.9872 \pm 0.0007$
D20230228	$0.9884 \pm 0.0007$
D20230314	$0.9875 \pm 0.0007$
D20230404	$0.9881 \pm 0.0007$
D20230613	$0.9858 \pm 0.0007$

## Overall Optical Efficiency



### Summary of Overall Optical Efficiency

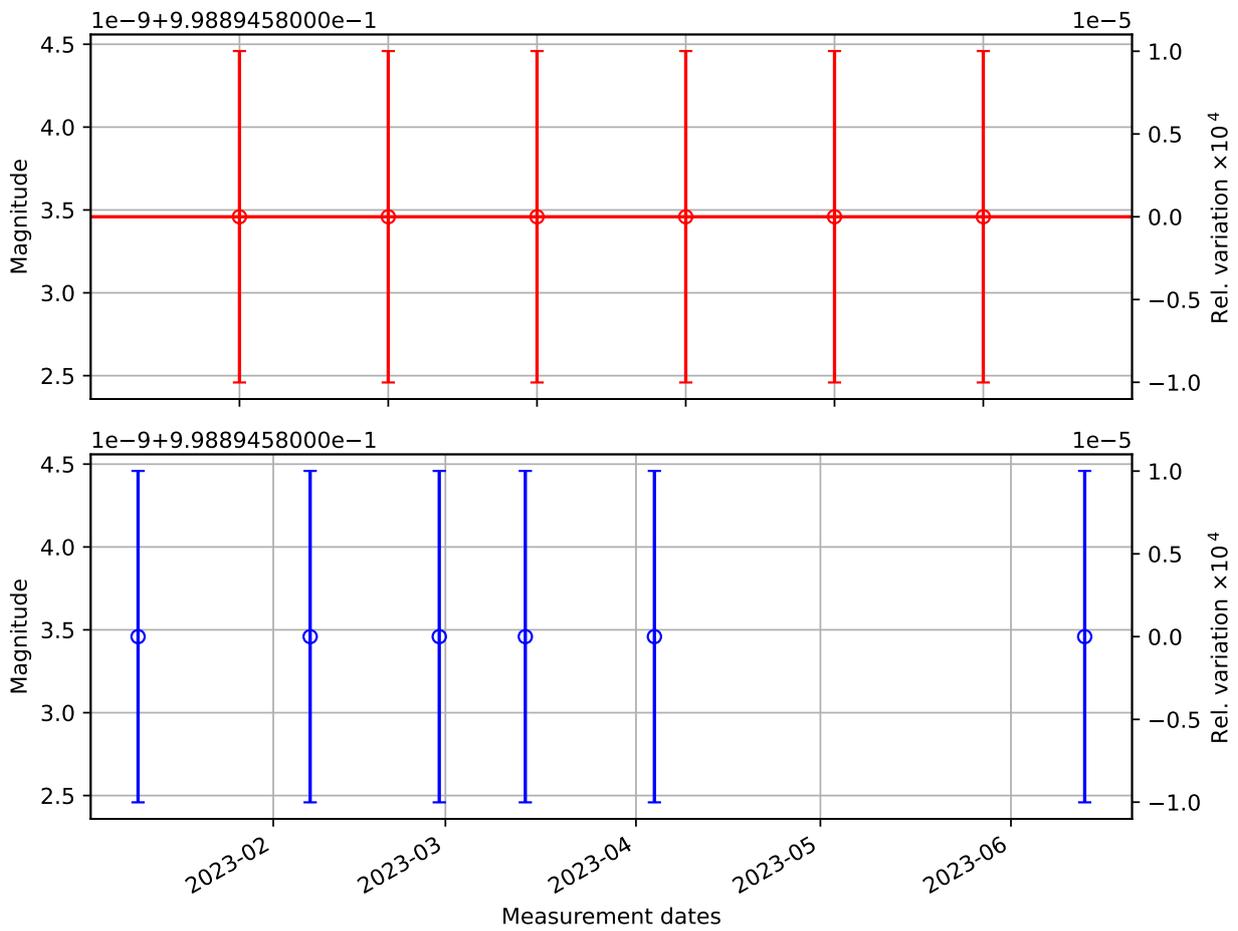
Mean value:	0.987478
Standard deviation:	0.000929
Standard error:	0.000414
Relative Standard error:	0.000419

# 18 Input/Output optical efficiency ratio ( $\beta$ )

## List of Measurements

Date	beta $\pm$ SD_beta
D20230110	9.9889e-01 $\pm$ 1.0000e-09
D20230207	9.9889e-01 $\pm$ 1.0000e-09
D20230228	9.9889e-01 $\pm$ 1.0000e-09
D20230314	9.9889e-01 $\pm$ 1.0000e-09
D20230404	9.9889e-01 $\pm$ 1.0000e-09
D20230613	9.9889e-01 $\pm$ 1.0000e-09

### Beta



### Summary of Beta

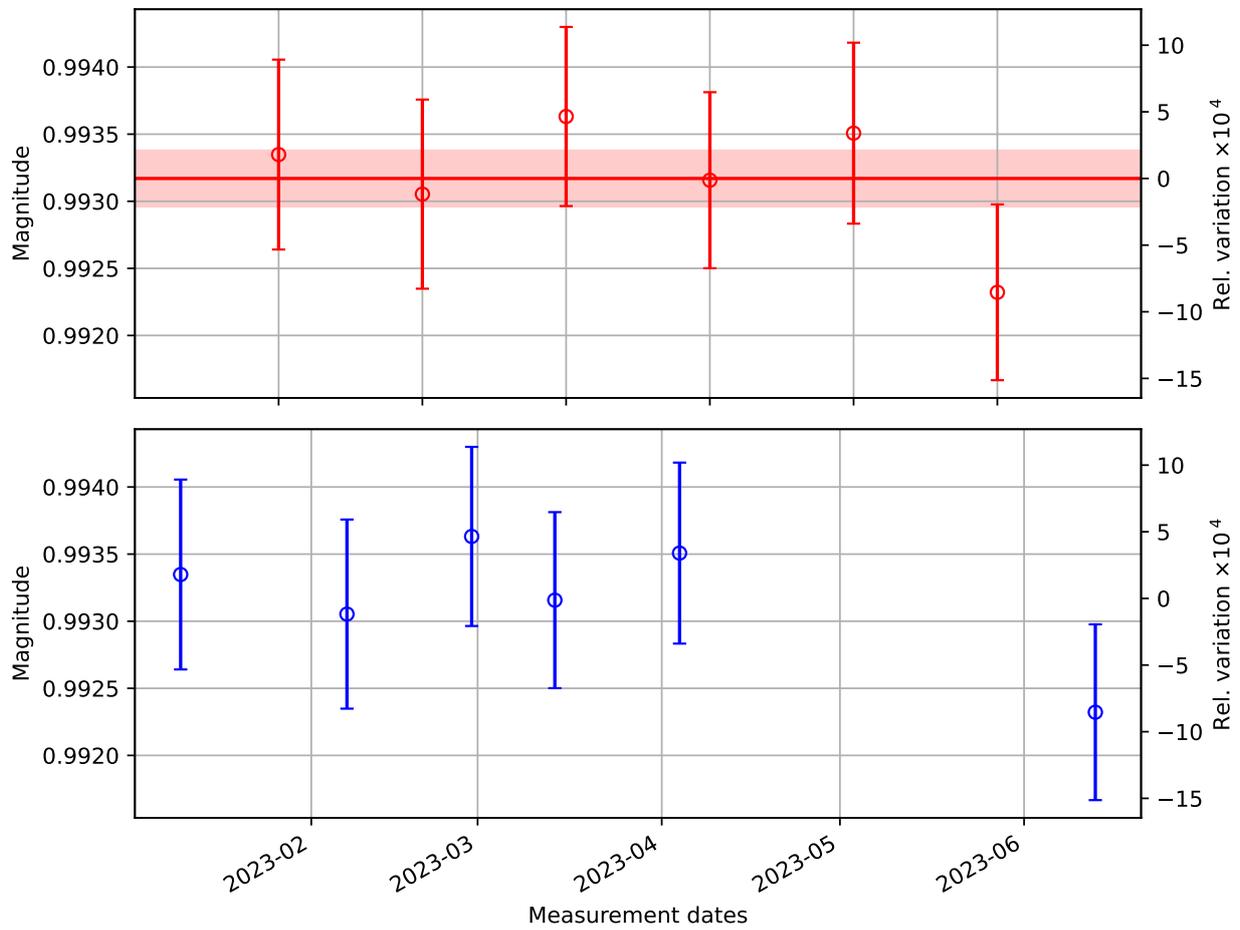
Mean value:	0.998895
Standard deviation:	0.000000
Standard error:	0.000000
Relative Standard error:	0.000000

# 19 Input Optical efficiency correction factor ( $\eta_T = \sqrt{e \cdot \beta}$ )

## List of Measurements

Date	E_T $\pm$ SD_E_T
D20230110	0.9933 $\pm$ 0.0007
D20230207	0.9931 $\pm$ 0.0007
D20230228	0.9936 $\pm$ 0.0007
D20230314	0.9932 $\pm$ 0.0007
D20230404	0.9935 $\pm$ 0.0007
D20230613	0.9923 $\pm$ 0.0007

**Input Side Optical Efficiency correction factor**



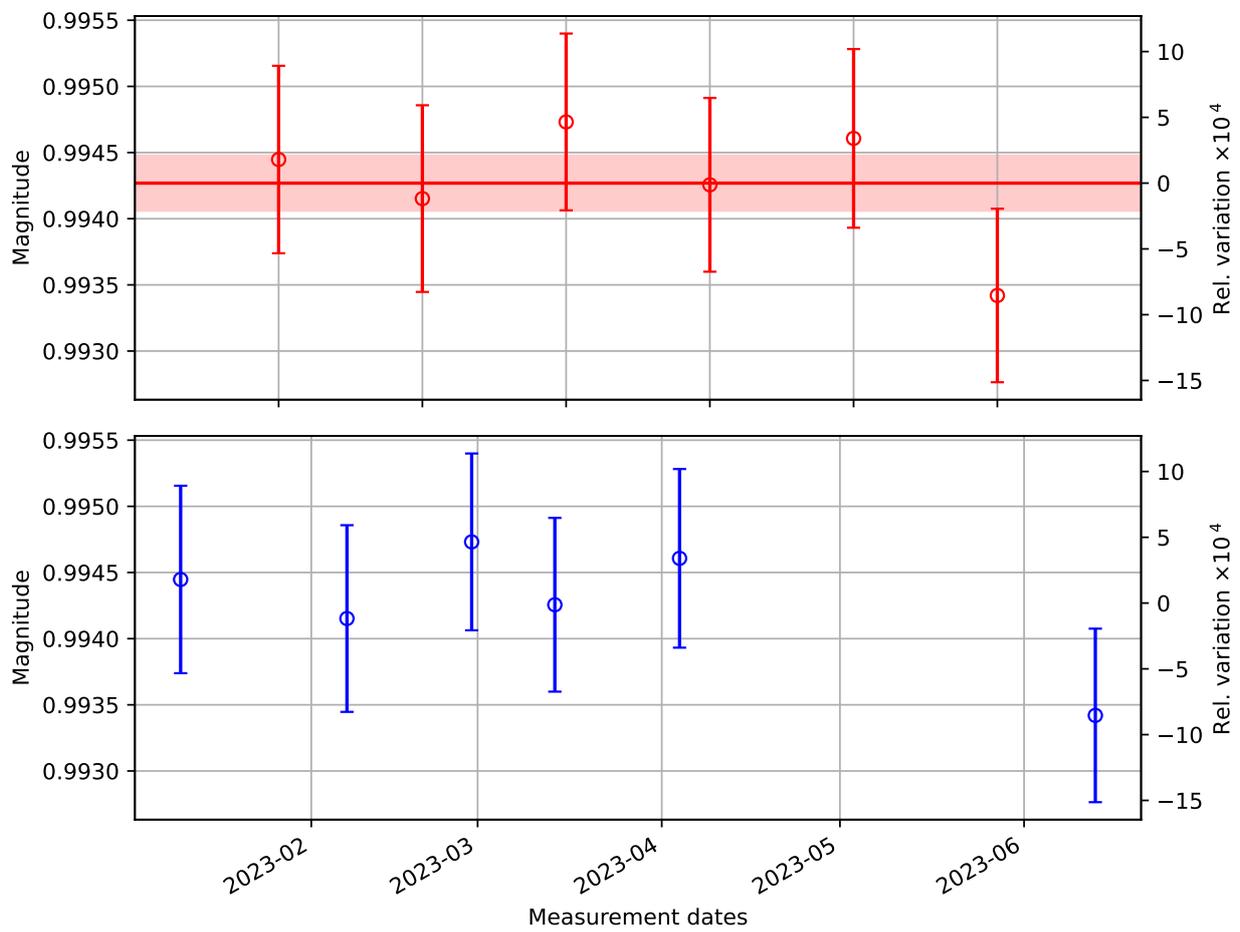
Summary of Input Side Optical Efficiency correction factor	
Mean value:	0.993170
Standard deviation:	0.000467
Standard error:	0.000208
Relative Standard error:	0.000210

## 20 Output Optical efficiency correction factor ( $\eta_R = \sqrt{e/\beta}$ )

### List of Measurements

Date	E_R $\pm$ SD_E_R
D20230110	0.9944 $\pm$ 0.0007
D20230207	0.9942 $\pm$ 0.0007
D20230228	0.9947 $\pm$ 0.0007
D20230314	0.9943 $\pm$ 0.0007
D20230404	0.9946 $\pm$ 0.0007
D20230613	0.9934 $\pm$ 0.0007

### Output Side Optical Efficiency correction factor



### Summary of Output Side Optical Efficiency correction factor

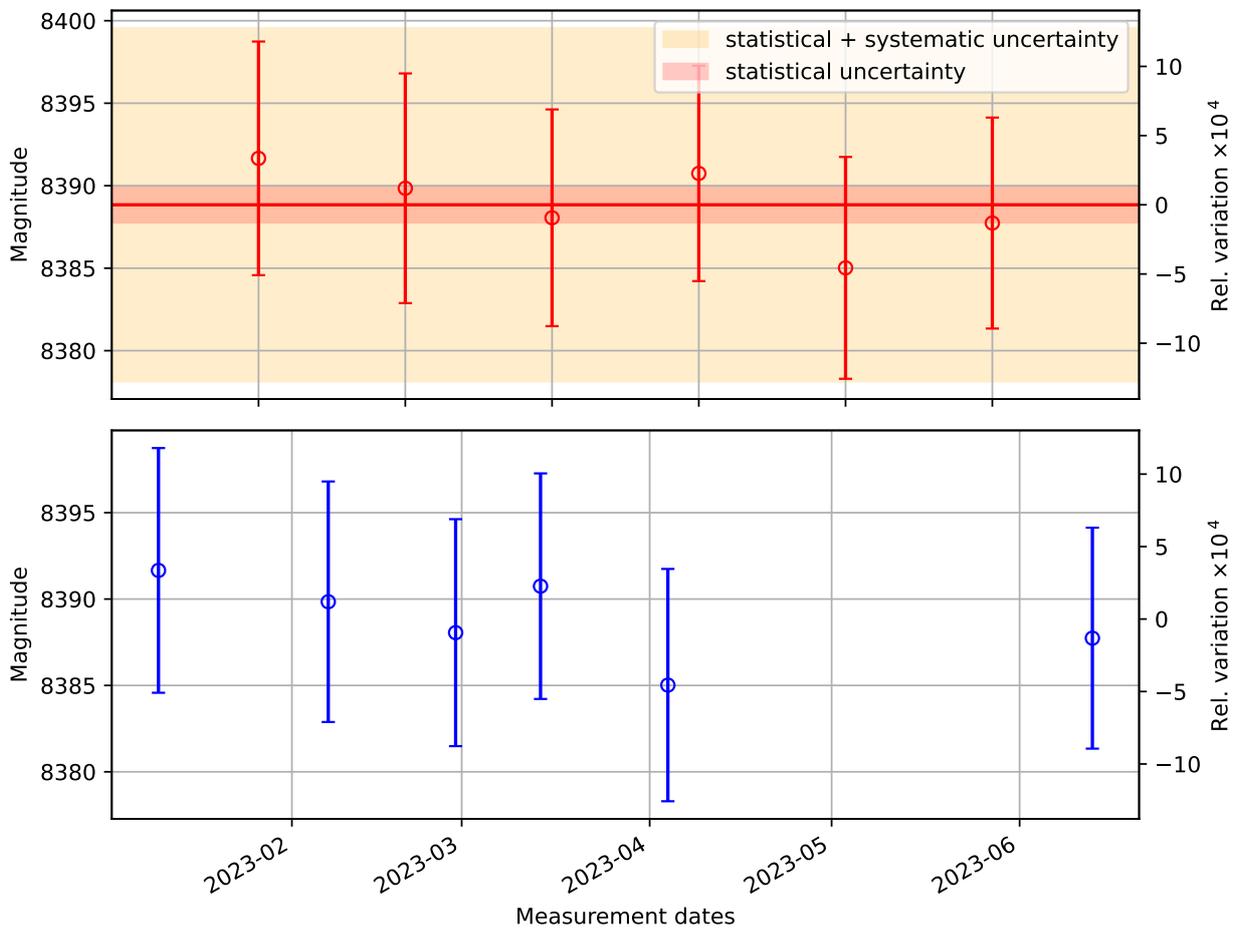
Mean value:	0.994269
Standard deviation:	0.000468
Standard error:	0.000208
Relative Standard error:	0.000210

## 21 TxPD calibration at ETM ( $\rho'_{Tx} = \rho_T \cdot \eta_T \cdot \zeta$ )

### List of Measurements

Date	rhoT_prime $\pm$ SD_rhoT_prime
D20230110	8391.6574 $\pm$ 7.0818
D20230207	8389.8439 $\pm$ 6.9612
D20230228	8388.0549 $\pm$ 6.5683
D20230314	8390.7454 $\pm$ 6.5279
D20230404	8385.0193 $\pm$ 6.7238
D20230613	8387.7359 $\pm$ 6.3941

### TxPD calibration corrected for optical efficiency (ct/W)



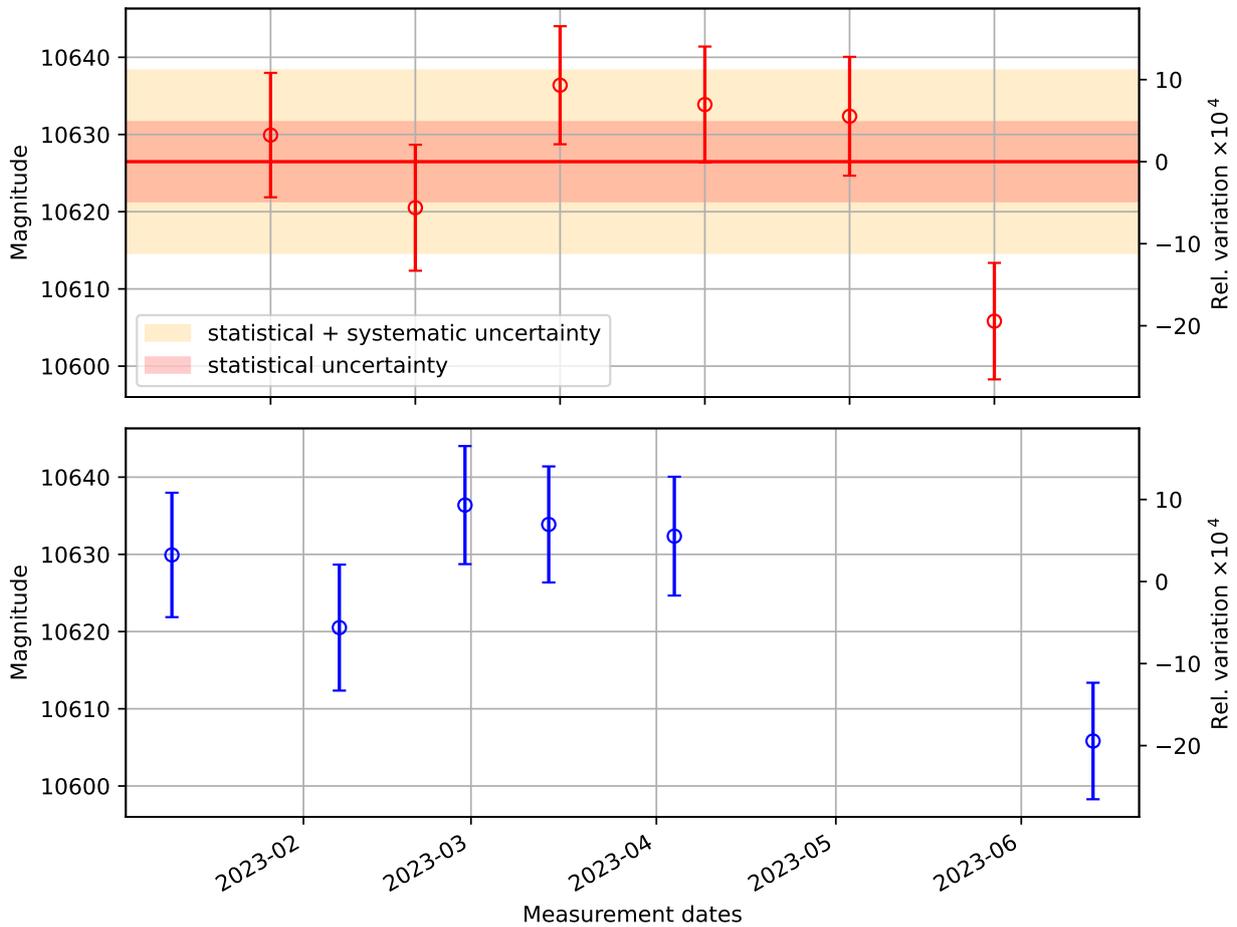
Summary of TxPD calibration corrected for optical efficiency (ct/W)	
Mean value:	8388.842793
Standard deviation:	2.408714
Standard error:	1.072415
Relative Standard error:	0.000128

## 22 RxPD calibration at ETM ( $\rho'_{Rx} = \rho_R \cdot \eta_R \cdot \zeta$ )

### List of Measurements

Date	rhoR_prime $\pm$ SD_rhoR_prime
D20230110	10629.9242 $\pm$ 8.0551
D20230207	10620.5139 $\pm$ 8.1595
D20230228	10636.3809 $\pm$ 7.6456
D20230314	10633.8774 $\pm$ 7.5141
D20230404	10632.3603 $\pm$ 7.6934
D20230613	10605.8257 $\pm$ 7.5452

### RxPD calibration corrected for optical efficiency (ct/W)



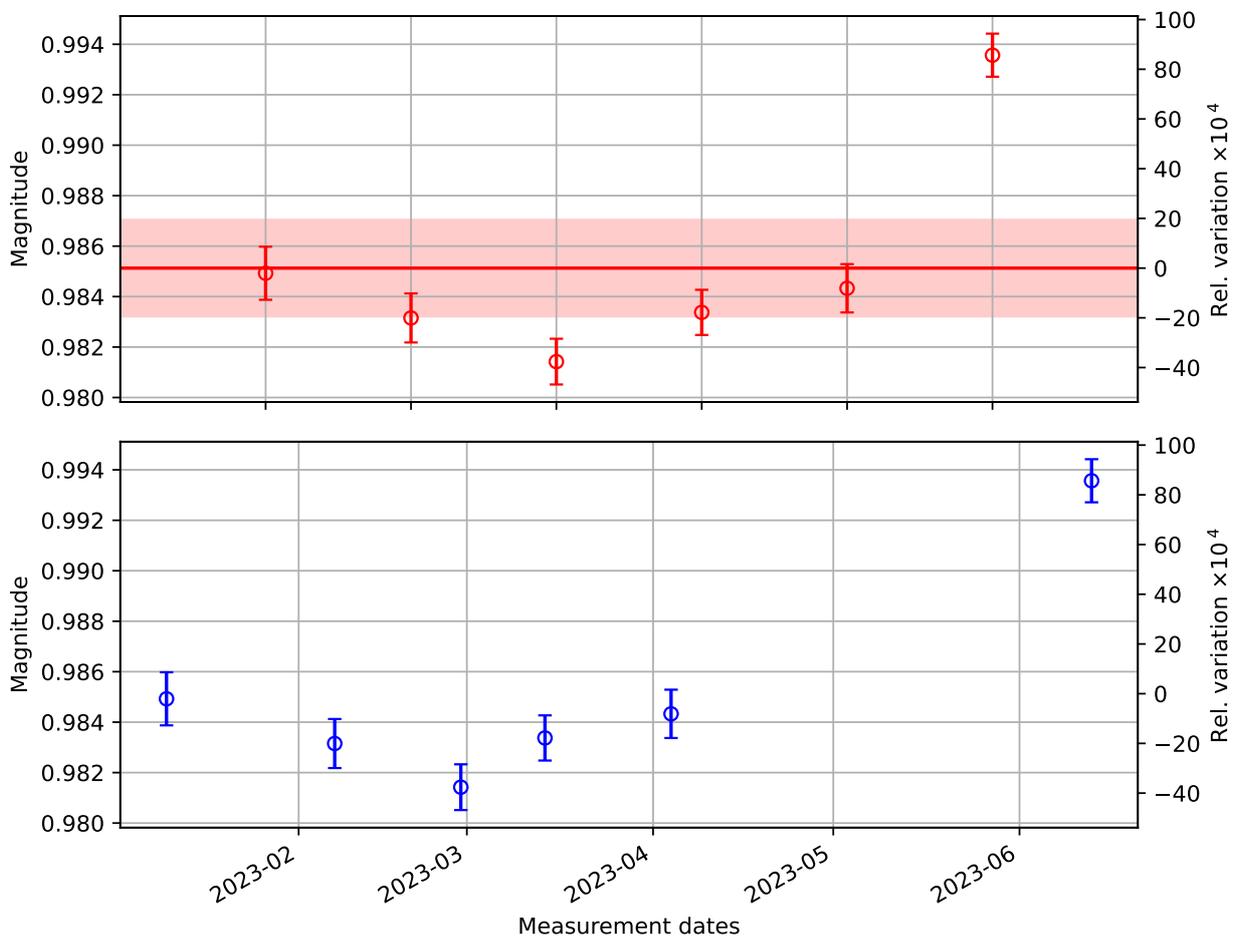
Summary of RxPD calibration corrected for optical efficiency (ct/W)	
Mean value:	10626.480399
Standard deviation:	11.501174
Standard error:	5.120587
Relative Standard error:	0.000482

## 23 Power Imbalance

### List of Measurements

Date	PI $\pm$ SD_PI
D20230110	0.9849 $\pm$ 0.0011
D20230207	0.9832 $\pm$ 0.0010
D20230228	0.9814 $\pm$ 0.0009
D20230314	0.9834 $\pm$ 0.0009
D20230404	0.9843 $\pm$ 0.0010
D20230613	0.9936 $\pm$ 0.0009

### Power Imbalance



### Summary of Power Imbalance

Mean value:	0.985128
Standard deviation:	0.004304
Standard error:	0.001916
Relative Standard error:	0.001945