PCAL End Station Measurement Trends

Description:

Tx/WS ratio: TXWS is the ratio of the TxPD responsivity to the Working Standard responsivity, and is dimensionless. It is measured at the end station by comparing the voltage output of the TxPD to that of the Working Standard with each beam exposed one at a time. This ratio is used in the Pcal chain to determine the responsivity of the TxPD from the known Working Standard responsivity. The plot shows two panels: the top panel displays the TXWS ratio against measurement number with a secondary axis showing relative variation x10^4 (which we call hop meaning hundredths of a percent); the bottom panel shows the same values plotted against measurement date. Error bars represent the measurement uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation of all measurements. This ratio, αTW, is the Tx to Working Standard output with the backgrounds subtracted and is made using ES measurements M1 - M7

TXWS

Date TXWS ± Rel.Uncertainty (epsilon)

D20221213: -0.928330 ± 0.000516

D20230124: -0.928577 ± 0.000488

D20230221: -0.929147 ± 0.000458

D20230307: -0.928916 ± 0.000448

D20230328: -0.928184 ± 0.000473

D20230523: -0.927611 ± 0.000485

D20230725: -0.928116 ± 0.000481

D20230926: -0.928456 ± 0.000474

D20231106: -0.928903 ± 0.000453

D20231107: -0.928577 ± 0.000442

D20240109: -0.928800 ± 0.000461

D20240319: -0.926942 ± 0.000500

D20240528: -0.926906 ± 0.000481

D20240718: -0.927008 ± 0.000469

D20240813: -0.927524 ± 0.000476

D20241025: -0.928223 ± 0.000453

D20241210: -0.927655 ± 0.000441

D20250204: -0.927975 ± 0.000446

D20250429: -0.927527 ± 0.000459

D20250722: -0.927690 ± 0.000532

D20250923: -0.927782 ± 0.000440

D20260203: -0.927845 ± 0.000441

D20260407: -0.927573 ± 0.000462

TXWS

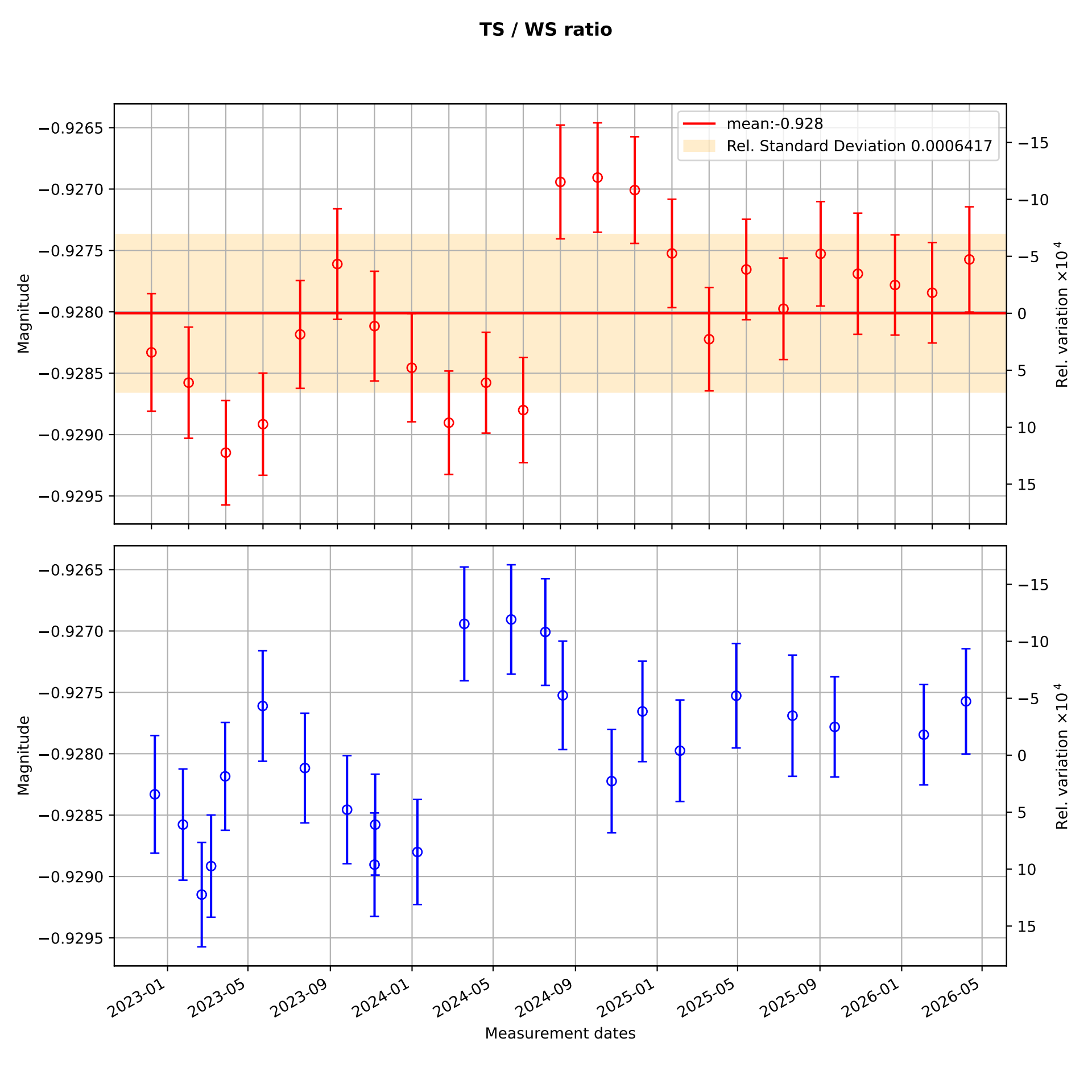
Summary of TS / WS ratio

Mean value: -0.928012

Standard deviation: 0.000642

Standard error: -0.000707

Relative Uncertainty: 0.000707


TS / WS ratio
mean:-0.928
Rel. Standard Deviation 0.0006417
Magnitude
Rel. variation ×10⁴
−0.9265
−0.9270
−0.9275
−0.9280
−0.9285
−0.9290
−0.9295
−15
−10
−5
0
5
10
15
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

Rx/WS ratio RXWS is the ratio of the RxPD responsivity to the Working Standard responsivity, and is dimensionless. It is measured at the end station by comparing the voltage output of the RxPD to that of the Working Standard when both are exposed to the same laser beam. This ratio is used in the calibration chain to determine the absolute responsivity of the RxPD from the known Working Standard responsivity. The plot shows two panels: the top panel displays the RXWS ratio against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation. This ratio, αRW, is the Rx to Working Standard output with the backgrounds subtracted and is made using M7 - M9 from the ES measurment process.

RXWS

Date RXWS ± Rel.Uncertainty (epsilon)

D20221213: -1.382242 ± 0.000251

D20230124: -1.382023 ± 0.000263

D20230221: -1.382018 ± 0.000267

D20230307: -1.381963 ± 0.000256

D20230328: -1.381847 ± 0.000264

D20230523: -1.379736 ± 0.000262

D20230725: -1.380121 ± 0.000259

D20230926: -1.380203 ± 0.000255

D20231106: -1.381377 ± 0.000297

D20231107: -1.381863 ± 0.000242

D20240109: -1.383071 ± 0.000264

D20240319: -1.381482 ± 0.000260

D20240528: -1.383103 ± 0.000480

D20240718: -1.382774 ± 0.000410

D20240813: -1.382327 ± 0.000439

D20241025: -1.383682 ± 0.000409

D20241210: -1.384163 ± 0.000422

D20250204: -1.384608 ± 0.000375

D20250429: -1.383600 ± 0.000428

D20250722: -1.383303 ± 0.000440

D20250923: -1.382883 ± 0.000424

D20260203: -1.384820 ± 0.000389

D20260407: -1.384310 ± 0.000420

RXWS

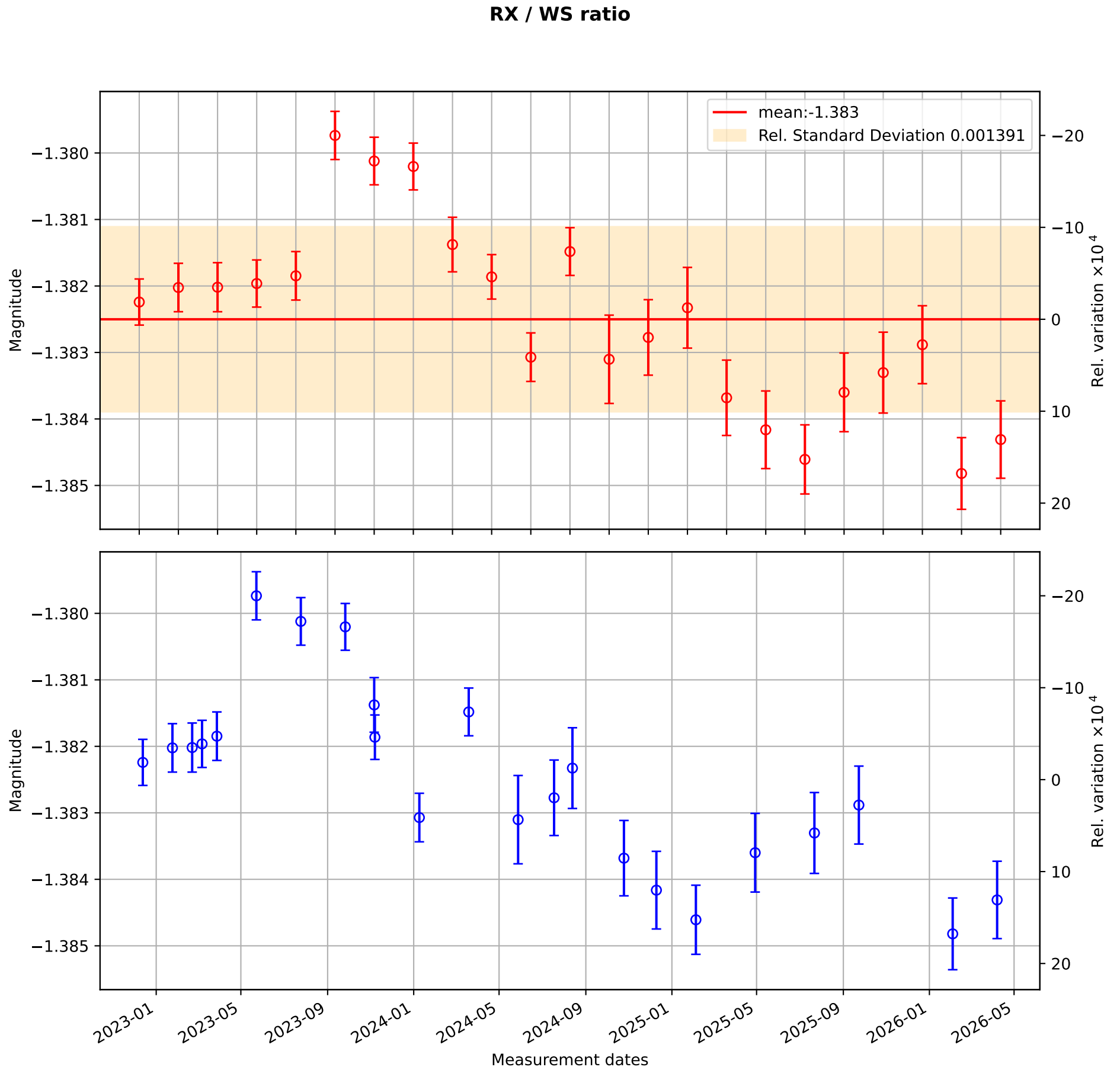
Summary of RX / WS ratio

Mean value: -1.382501

Standard deviation: 0.001391

Standard error: -0.001029

Relative Uncertainty: 0.001029


RX / WS ratio
mean:-1.383
Rel. Standard Deviation 0.001391
Magnitude
Rel. variation ×10⁴
−1.380
−1.381
−1.382
−1.383
−1.384
−1.385
−20
−10
0
10
20
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

WS WS is the Working Standard Responsivity in units of V/W (Volts per Watt). It represents the sensitivity of the working standard photodetector, relating its electrical voltage output to the incident optical power. The working standard is used as a transfer reference to calibrate the end station TxPD and RxPD responsivities, and is itself calibrated against the Gold Standard in the PCAL lab, tracing back to absolute power standards at NIST and PTB. The plot shows two panels: the top panel displays the Working Standard Responsivity against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

WS

Date WS ± Rel.Uncertainty (epsilon)

D20221213: -4.705050 ± 0.000009

D20230124: -4.705050 ± 0.000009

D20230221: -4.705050 ± 0.000009

D20230307: -4.705050 ± 0.000009

D20230328: -4.705050 ± 0.000009

D20230523: -4.705050 ± 0.000090

D20230725: -4.705050 ± 0.000009

D20230926: -4.705050 ± 0.000009

D20231106: -4.705050 ± 0.000009

D20231107: -4.705050 ± 0.000009

D20240109: -4.705050 ± 0.000009

D20240319: -4.705050 ± 0.000009

D20240528: -4.701009 ± 0.000008

D20240718: -4.701492 ± 0.000009

D20240813: -4.712227 ± 0.000009

D20241025: -4.710030 ± 0.000010

D20241210: -4.710537 ± 0.000010

D20250204: -4.705582 ± 0.000008

D20250429: -4.701551 ± 0.000009

D20250722: -4.702207 ± 0.000007

D20250923: -4.700378 ± 0.000006

D20260203: -4.701912 ± 0.000006

D20260407: -4.701335 ± 0.000160

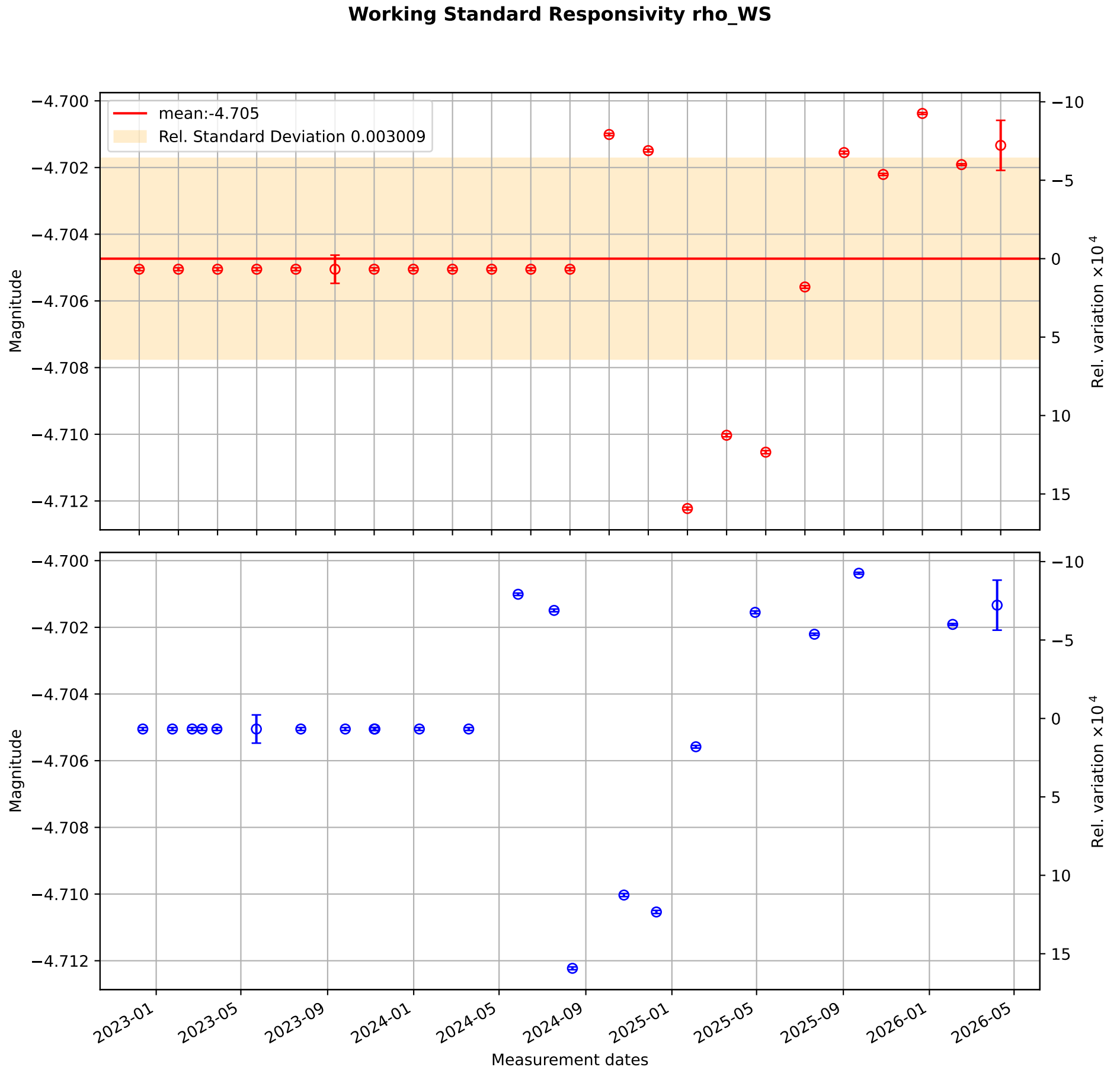
WS
Summary of Working Standard Responsivity
rho_WS

Mean value: -4.704733

Standard deviation: 0.003009

Standard error: -0.000136

Relative Uncertainty: 0.000136


Working Standard Responsivity rho_WS
mean:-4.705
Rel. Standard Deviation 0.003009
Magnitude
Rel. variation ×10⁴
−4.700
−4.702
−4.704
−4.706
−4.708
−4.710
−4.712
−10
−5
0
5
10
15
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

Zeta is the ADC (Analog-to-Digital Converter) conversion factor, with units of counts per Volt (ct/V). It represents the gain of the digitization chain and is determined from the gradient of a linear fit between the raw ADC counts and the calibrated voltage signal, using the Martel individual method. Zeta is treated as a stationary quantity. The plot shows two panels: the top panel displays measured values against measurement number with a secondary axis showing relative variation \Uffffffff0\u2074; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma). The mean value is shown as a horizontal red line.

zeta

Date zeta ± Rel.Uncertainty (epsilon)

D20221213: 1.6379e+03 ± 1.0000e-09

D20230124: 1.6382e+03 ± 1.0000e-09

D20230221: 1.6379e+03 ± 1.0000e-09

D20230307: 1.6378e+03 ± 1.0000e-09

D20230328: 1.6377e+03 ± 1.0000e-09

D20230523: 1.6378e+03 ± 1.0000e-09

D20230725: 1.6379e+03 ± 1.0000e-09

D20230926: 1.6378e+03 ± 1.0000e-09

D20231106: 1.6379e+03 ± 1.0000e-09

D20231107: 1.6379e+03 ± 1.0000e-09

D20240109: 1.6379e+03 ± 1.0000e-09

D20240319: 1.6378e+03 ± 1.0000e-09

D20240528: 1.6378e+03 ± 1.0000e-09

D20240718: 1.6379e+03 ± 1.0000e-09

D20240813: 1.6379e+03 ± 1.0000e-09

D20241025: 1.6379e+03 ± 1.0000e-09

D20241210: 1.6379e+03 ± 1.0000e-09

D20250204: 1.6379e+03 ± 1.0000e-09

D20250429: 1.6379e+03 ± 1.0000e-09

D20250722: 1.6379e+03 ± 1.0000e-09

D20250923: 1.6379e+03 ± 1.0000e-09

D20260203: 1.6379e+03 ± 1.0000e-09

D20260407: 1.6379e+03 ± 1.0000e-09

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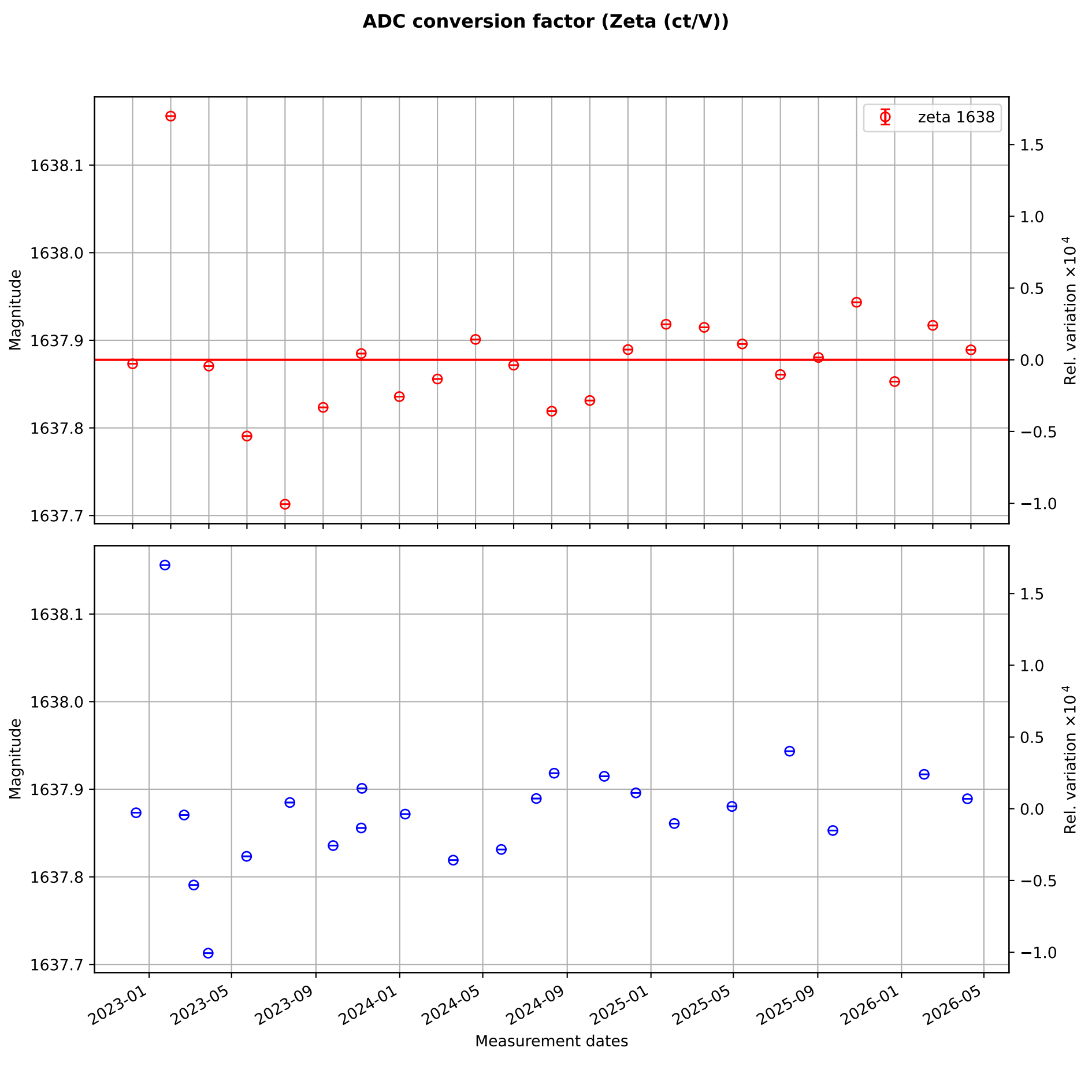
zeta
Summary of ADC conversion factor (Zeta (ct/V))

Mean value: 1637.877731

Standard deviation: 0.078048

Standard error: 0.000010

Relative Uncertainty: 0.000010


ADC conversion factor (Zeta (ct/V))
zeta 1638
Magnitude
Rel. variation ×10^4
1638.1
1638.0
1637.9
1637.8
1637.7
1.5
1.0
0.5
0.0
−0.5
−1.0
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

rho_T (rho_Tx) is the responsivity of the TxPD (Transmitter photodetector) in units of V/W, defined as rho_Tx = alpha_TW * rho_WS, where alpha_TW is the ratio of the TxPD response to the Working Standard response and rho_WS is the Working Standard responsivity. It relates the voltage output of the TxPD to the incident optical power and is used to estimate the laser power delivered to the test mass. Trending this parameter is useful for detecting changes in input laser power over time. The plot shows two panels: the top panel displays rho_T against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

rho_T

Date rho_T ± Rel.Uncertainty (epsilon)

D20221213: 7153.562223 ± 0.000516

D20230124: 7155.535171 ± 0.000488

D20230221: 7159.902744 ± 0.000458

D20230307: 7157.997893 ± 0.000448

D20230328: 7152.388875 ± 0.000473

D20230523: 7145.902737 ± 0.000485

D20230725: 7150.267299 ± 0.000481

D20230926: 7151.895574 ± 0.000474

D20231106: 7154.640027 ± 0.000453

D20231107: 7152.126675 ± 0.000442

D20240109: 7152.504950 ± 0.000461

D20240319: 7137.989008 ± 0.000500

D20240528: 7136.622441 ± 0.000481

D20240718: 7138.196545 ± 0.000469

D20240813: 7158.731980 ± 0.000476

D20241025: 7160.911552 ± 0.000453

D20241210: 7157.284786 ± 0.000441

D20250204: 7152.140281 ± 0.000446

D20250429: 7142.412496 ± 0.000459

D20250722: 7144.745021 ± 0.000532

D20250923: 7142.946485 ± 0.000440

D20260203: 7145.369650 ± 0.000441

D20260407: 7142.682342 ± 0.000489

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rho_T

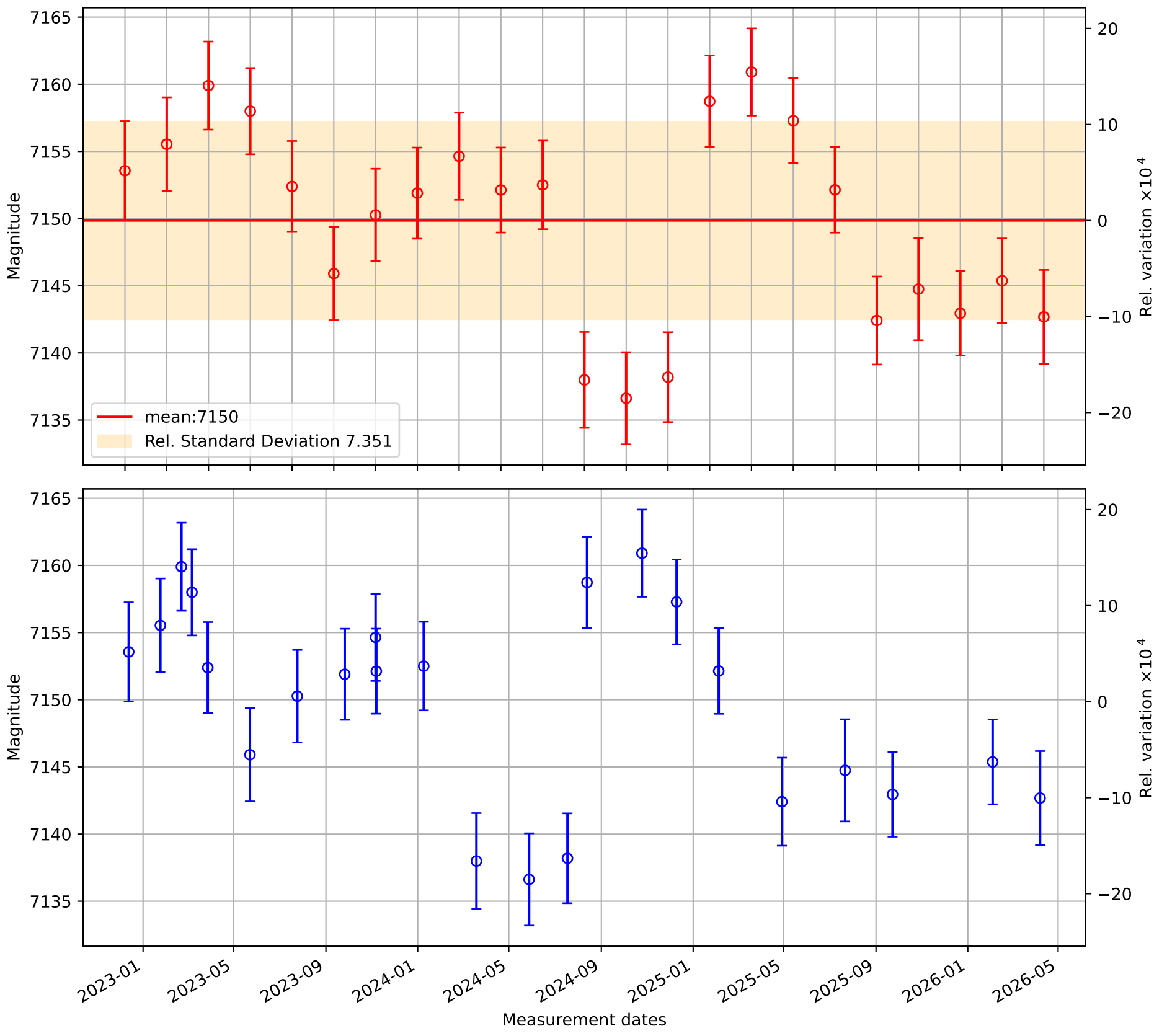
Summary of TX Responsivity rho_T

Mean value: 7149.858989

Standard deviation: 7.350991

Standard error: 0.001051

Relative Uncertainty: 0.001051


TX Responsivity rho_T
Magnitude
Rel. variation ×10⁴
mean:7150
Rel. Standard Deviation 7.351
Measurement dates
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05

Description:

rho_R (rho_Rx) is the responsivity of the RxPD (Receiver photodetector) in units of V/W, defined as rho_Rx = alpha_RW * rho_WS, where alpha_RW is the ratio of the RxPD response to the Working Standard response and rho_WS is the Working Standard responsivity. It relates the voltage output of the RxPD to the optical power it receives and is used to estimate the laser power returning from the test mass. Trending this parameter is useful for monitoring changes in the optical power incident on the ETM over time. The plot shows two panels: the top panel displays rho_R against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

rho_R

Date rho_R ± Rel.Uncertainty (epsilon)

D20221213: 10651.327811 ± 0.000251

D20230124: 10649.748717 ± 0.000263

D20230221: 10649.673834 ± 0.000267

D20230307: 10649.072590 ± 0.000256

D20230328: 10648.221570 ± 0.000264

D20230523: 10628.873902 ± 0.000262

D20230725: 10632.538207 ± 0.000259

D20230926: 10631.706744 ± 0.000255

D20231106: 10639.703231 ± 0.000297

D20231107: 10643.438558 ± 0.000242

D20240109: 10650.750768 ± 0.000264

D20240319: 10638.211861 ± 0.000260

D20240528: 10649.062793 ± 0.000480

D20240718: 10647.703764 ± 0.000411

D20240813: 10668.950020 ± 0.000439

D20241025: 10674.611242 ± 0.000410

D20241210: 10679.451206 ± 0.000422

D20250204: 10671.526305 ± 0.000376

D20250429: 10654.391401 ± 0.000428

D20250722: 10653.719446 ± 0.000440

D20250923: 10646.753271 ± 0.000424

D20260203: 10664.554730 ± 0.000389

D20260407: 10659.734323 ± 0.000449

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rho_R

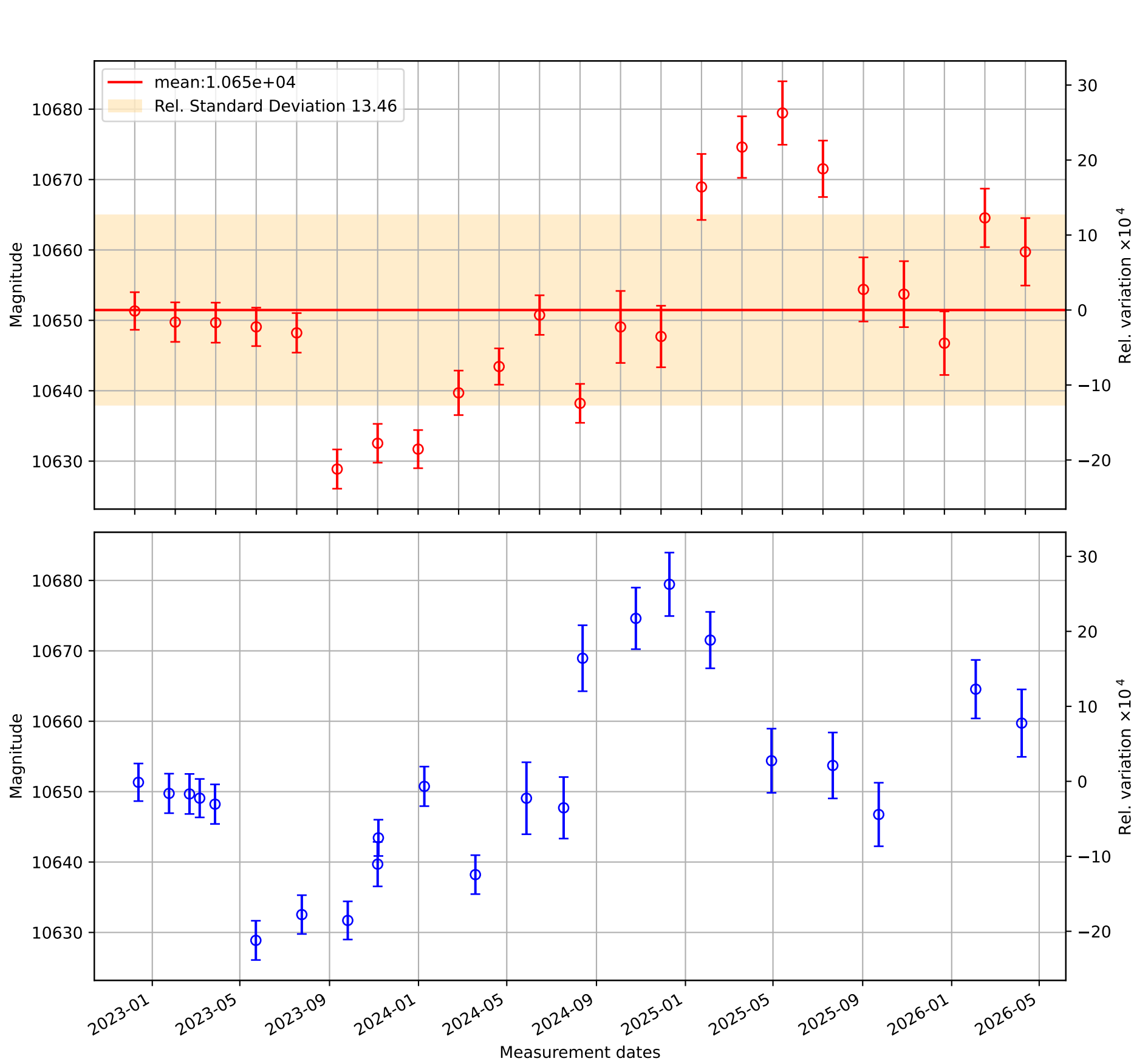
Summary of RX Responsivity rho_R

Mean value: 10651.466361

Standard deviation: 13.455229

Standard error: 0.001291

Relative Uncertainty: 0.001291


RX Responsivity rho_R
mean:1.065e+04
Rel. Standard Deviation 13.46
Magnitude
Rel. variation ×10⁴
10680
10670
10660
10650
10640
10630
30
20
10
0
−10
−20
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

e_i is the Optical Efficiency of the inner beam, defined as e_i = (Wri/Tti) / (Wti/Tti), and is dimensionless. It is the ratio of the Working Standard output in the Rx module to the Working Standard output in the Tx module when only the inner beam is illuminating both, normalized by the Tx output. This measurement involves the inner beam ports M1 and M5 and characterizes how much of the inner beam power transmitted from the Tx side is received on the Rx side, accounting for optical losses along the inner beam path inside the vacuum chamber. The plot shows two panels: the top panel displays e_i against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

e_i

Date e_i ± Rel.Uncertainty (epsilon)

D20221213: 0.984711 ± 0.000830

D20230124: 0.984894 ± 0.000848

D20230221: 0.984596 ± 0.000798

D20230307: 0.984646 ± 0.000876

D20230328: 0.984805 ± 0.000778

D20230523: 0.984210 ± 0.000915

D20230725: 0.984137 ± 0.000891

D20230926: 0.983790 ± 0.000854

D20231106: 0.985037 ± 0.000905

D20231107: 0.984535 ± 0.000815

D20240109: 0.985460 ± 0.000852

D20240319: 0.986697 ± 0.000841

D20240528: 0.985801 ± 0.000443

D20240718: 0.985040 ± 0.000438

D20240813: 0.986009 ± 0.000437

D20241025: 0.986371 ± 0.000441

D20241210: 0.986010 ± 0.000445

D20250204: 0.987336 ± 0.000418

D20250429: 0.985953 ± 0.000429

D20250722: 0.986071 ± 0.000480

D20250923: 0.985385 ± 0.000422

D20260203: 0.986243 ± 0.000415

D20260407: 0.986428 ± 0.000422

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e_i

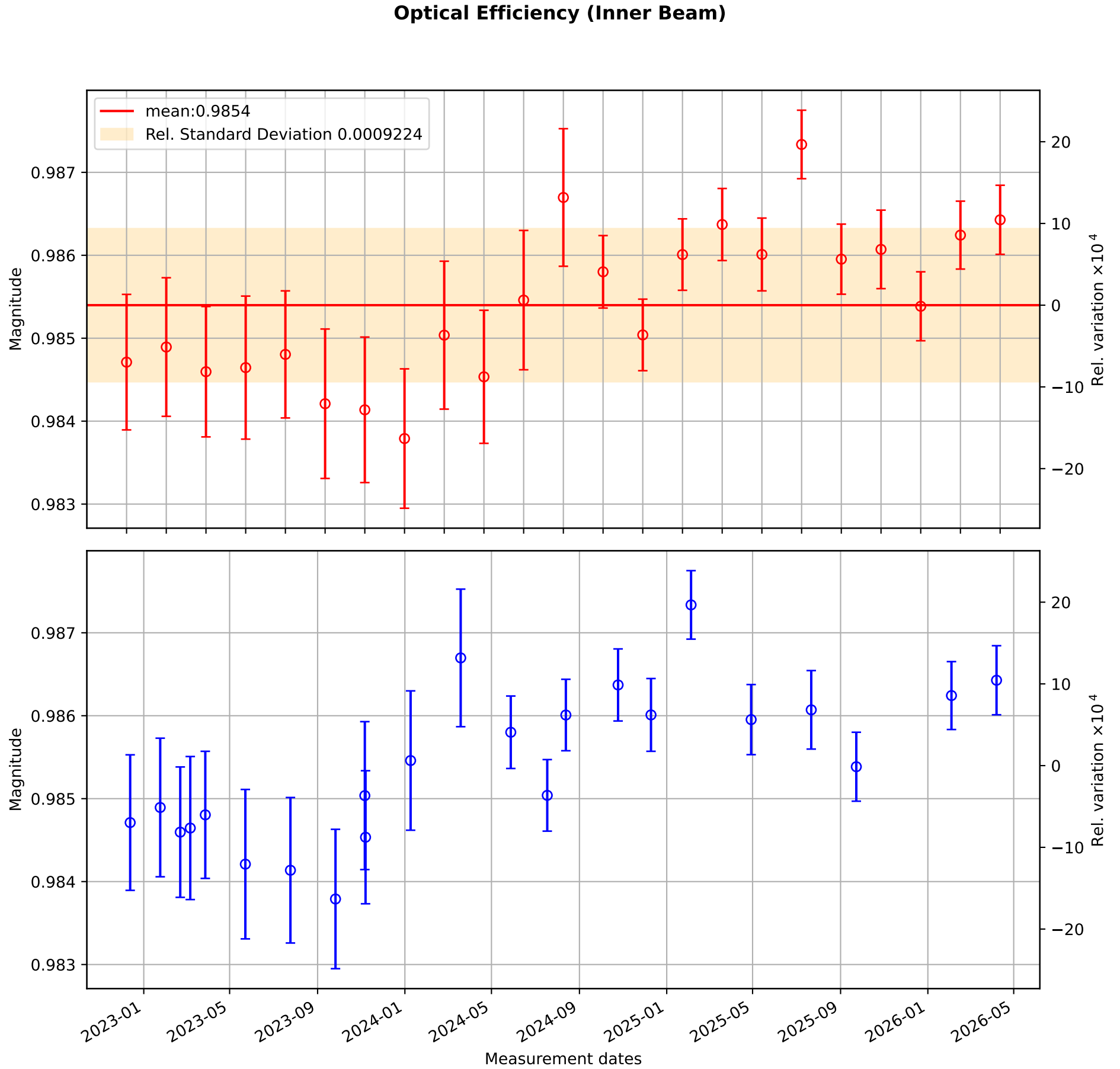
Summary of Optical Efficiency (Inner Beam)

Mean value: 0.985398

Standard deviation: 0.000922

Standard error: 0.000200

Relative Uncertainty: 0.000200


Optical Efficiency (Inner Beam)
mean:0.9854
Rel. Standard Deviation 0.0009224
Magnitude
Rel. variation ×10⁴
0.987
0.986
0.985
0.984
0.983
20
10
0
−10
−20
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

e_o is the Optical Efficiency of the outer beam, defined as e_o = (Wro/Tto) / (Wto/Tto), and is dimensionless. It is the ratio of the Working Standard output in the Rx module to the Working Standard output in the Tx module when only the outer beam is illuminating both, normalized by the Tx output. This measurement involves the outer beam ports M2 and M4 and characterizes how much of the outer beam power transmitted from the Tx side is received on the Rx side, accounting for optical losses along the outer beam path inside the vacuum chamber. The plot shows two panels: the top panel displays e_o against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

e_o

Date e_o ± Rel.Uncertainty (epsilon)

D20221213: 0.985067 ± 0.000905

D20230124: 0.984851 ± 0.000851

D20230221: 0.987092 ± 0.000804

D20230307: 0.986792 ± 0.000707

D20230328: 0.985572 ± 0.000868

D20230523: 0.984045 ± 0.000810

D20230725: 0.983521 ± 0.000805

D20230926: 0.984334 ± 0.000813

D20231106: 0.984695 ± 0.000816

D20231107: 0.983938 ± 0.000767

D20240109: 0.984381 ± 0.000767

D20240319: 0.984822 ± 0.000892

D20240528: 0.984307 ± 0.000480

D20240718: 0.983227 ± 0.000441

D20240813: 0.984128 ± 0.000477

D20241025: 0.984424 ± 0.000458

D20241210: 0.984479 ± 0.000411

D20250204: 0.985232 ± 0.000446

D20250429: 0.985408 ± 0.000443

D20250722: 0.983489 ± 0.000480

D20250923: 0.983858 ± 0.000432

D20260203: 0.984385 ± 0.000418

D20260407: 0.984304 ± 0.000438

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e_o

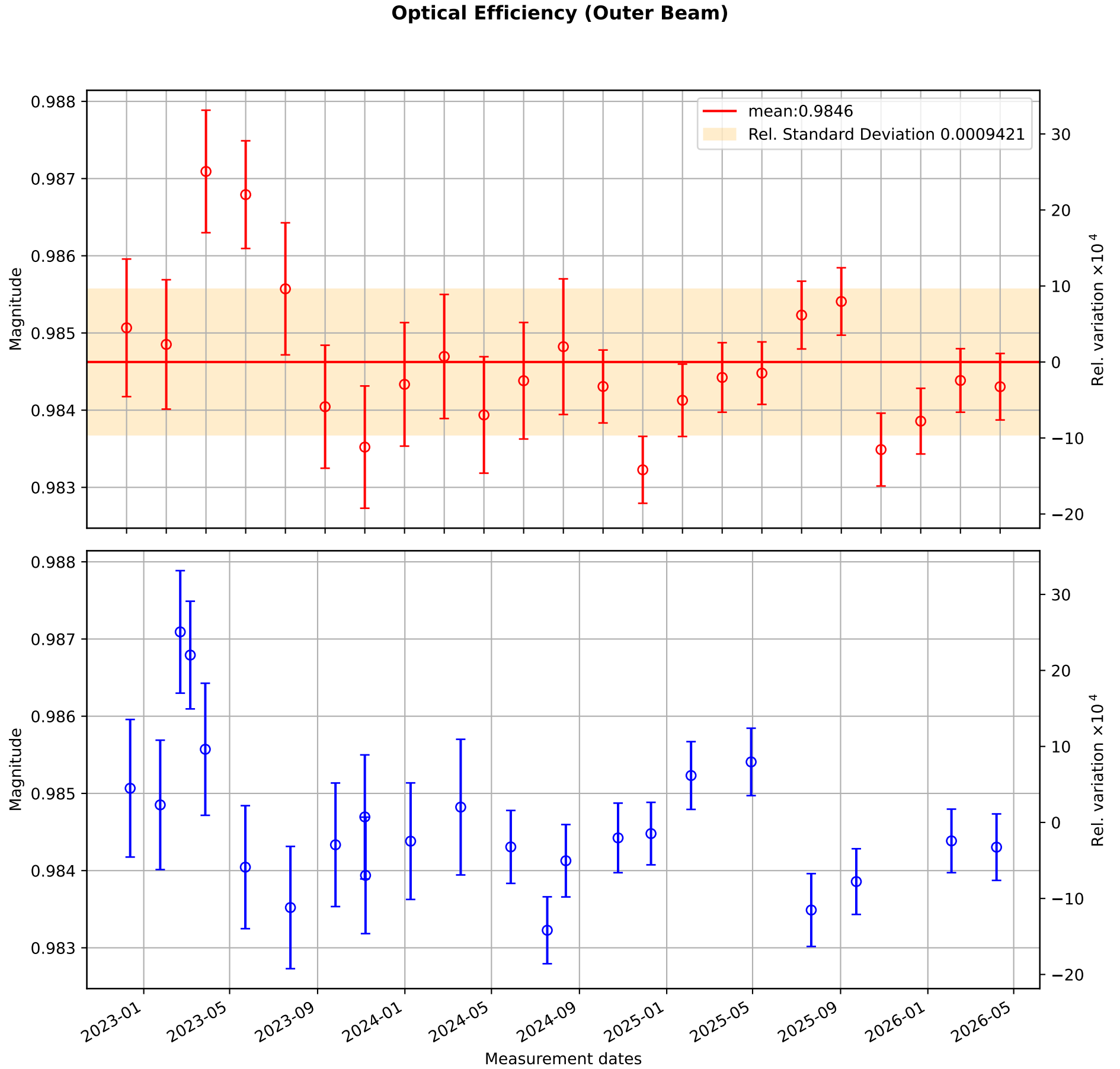
Summary of Optical Efficiency (Outer Beam)

Mean value: 0.984624

Standard deviation: 0.000942

Standard error: 0.000204

Relative Uncertainty: 0.000204


Optical Efficiency (Outer Beam)
mean:0.9846
Rel. Standard Deviation 0.0009421
Magnitude
Rel. variation ×10⁴
0.988
0.987
0.986
0.985
0.984
0.983
30
20
10
0
−10
−20
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

e is the Overall Optical Efficiency, defined as e = (e_i + e_o) / 2, and is dimensionless. It is the average of the inner beam and outer beam optical efficiencies, using measurements from ports M1, M2, M4, and M5. It represents the total fraction of laser power that survives transmission through the vacuum chamber from the Tx side to the Rx side, and is used in computing the optical efficiency correction factors E_T and E_R. Trending this parameter is useful for monitoring long-term degradation of the in-vacuum optics. The plot shows two panels: the top panel displays e against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

e

Date e ± Rel.Uncertainty (epsilon)

D20221213: 0.984890 ± 0.000605

D20230124: 0.984872 ± 0.000592

D20230221: 0.985851 ± 0.000559

D20230307: 0.985725 ± 0.000554

D20230328: 0.985191 ± 0.000575

D20230523: 0.984127 ± 0.000601

D20230725: 0.983827 ± 0.000591

D20230926: 0.984064 ± 0.000580

D20231106: 0.984865 ± 0.000600

D20231107: 0.984234 ± 0.000550

D20240109: 0.984917 ± 0.000564

D20240319: 0.985754 ± 0.000604

D20240528: 0.985054 ± 0.000653

D20240718: 0.984133 ± 0.000621

D20240813: 0.985068 ± 0.000646

D20241025: 0.985397 ± 0.000635

D20241210: 0.985245 ± 0.000606

D20250204: 0.986284 ± 0.000611

D20250429: 0.985681 ± 0.000617

D20250722: 0.984780 ± 0.000679

D20250923: 0.984621 ± 0.000604

D20260203: 0.985314 ± 0.000589

D20260407: 0.985366 ± 0.000608

---

e

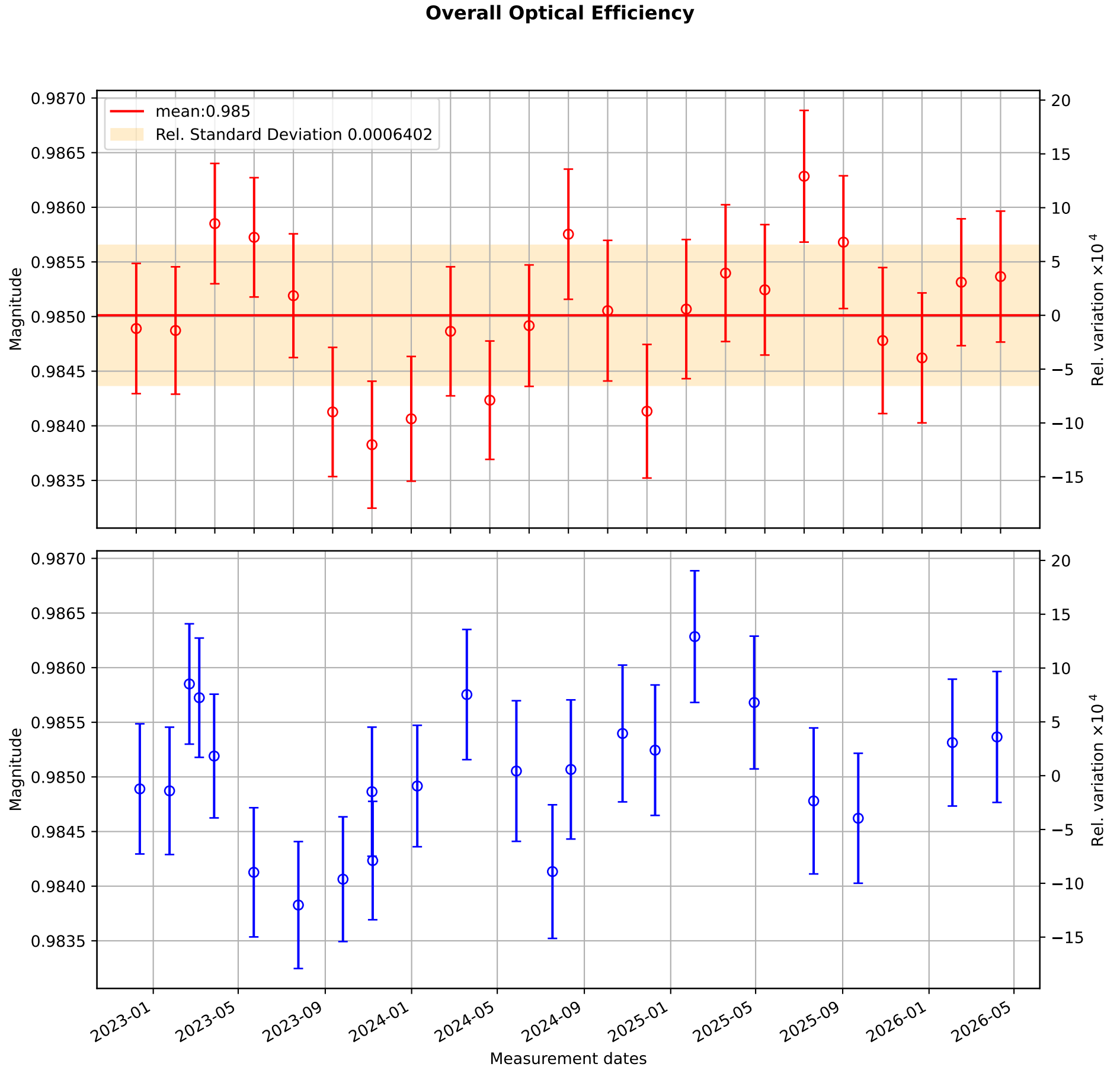
Summary of Overall Optical Efficiency

Mean value: 0.985011

Standard deviation: 0.000640

Standard error: 0.000139

Relative Uncertainty: 0.000139


Overall Optical Efficiency
mean:0.985
Rel. Standard Deviation 0.0006402
Magnitude
Rel. variation ×10⁴
Measurement dates
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05

Description:

E_T is the Tx side Optical Efficiency Correction Factor, defined as E_T = sqrt(e * beta), and is dimensionless. It apportions the total optical loss inside the vacuum chamber between the Tx side and Rx side, using the overall optical efficiency (e) and the ratio of in-chamber optical efficiencies between the Tx and Rx sides (beta), measured during the last in-vacuum campaign (DCC T1800107). Beta is assumed to be stable over time. Applying E_T to the TxPD responsivity corrects for optical losses on the Tx side and yields the effective responsivity at the ETM. The plot shows two panels: the top panel displays E_T against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

E_T

Date E_T ± Rel.Uncertainty (epsilon)

D20221213: 0.991842 ± 0.000605

D20230124: 0.991833 ± 0.000592

D20230221: 0.992326 ± 0.000559

D20230307: 0.992263 ± 0.000554

D20230328: 0.991994 ± 0.000575

D20230523: 0.991458 ± 0.000601

D20230725: 0.991307 ± 0.000591

D20230926: 0.991426 ± 0.000580

D20231106: 0.991830 ± 0.000600

D20231107: 0.991512 ± 0.000550

D20240109: 0.991856 ± 0.000564

D20240319: 0.992277 ± 0.000604

D20240528: 0.991925 ± 0.000327

D20240718: 0.991461 ± 0.000311

D20240813: 0.991932 ± 0.000323

D20241025: 0.992098 ± 0.000318

D20241210: 0.992021 ± 0.000303

D20250204: 0.992544 ± 0.000306

D20250429: 0.992240 ± 0.000308

D20250722: 0.991787 ± 0.000339

D20250923: 0.991707 ± 0.000302

D20260203: 0.992056 ± 0.000295

D20260407: 0.992082 ± 0.000304

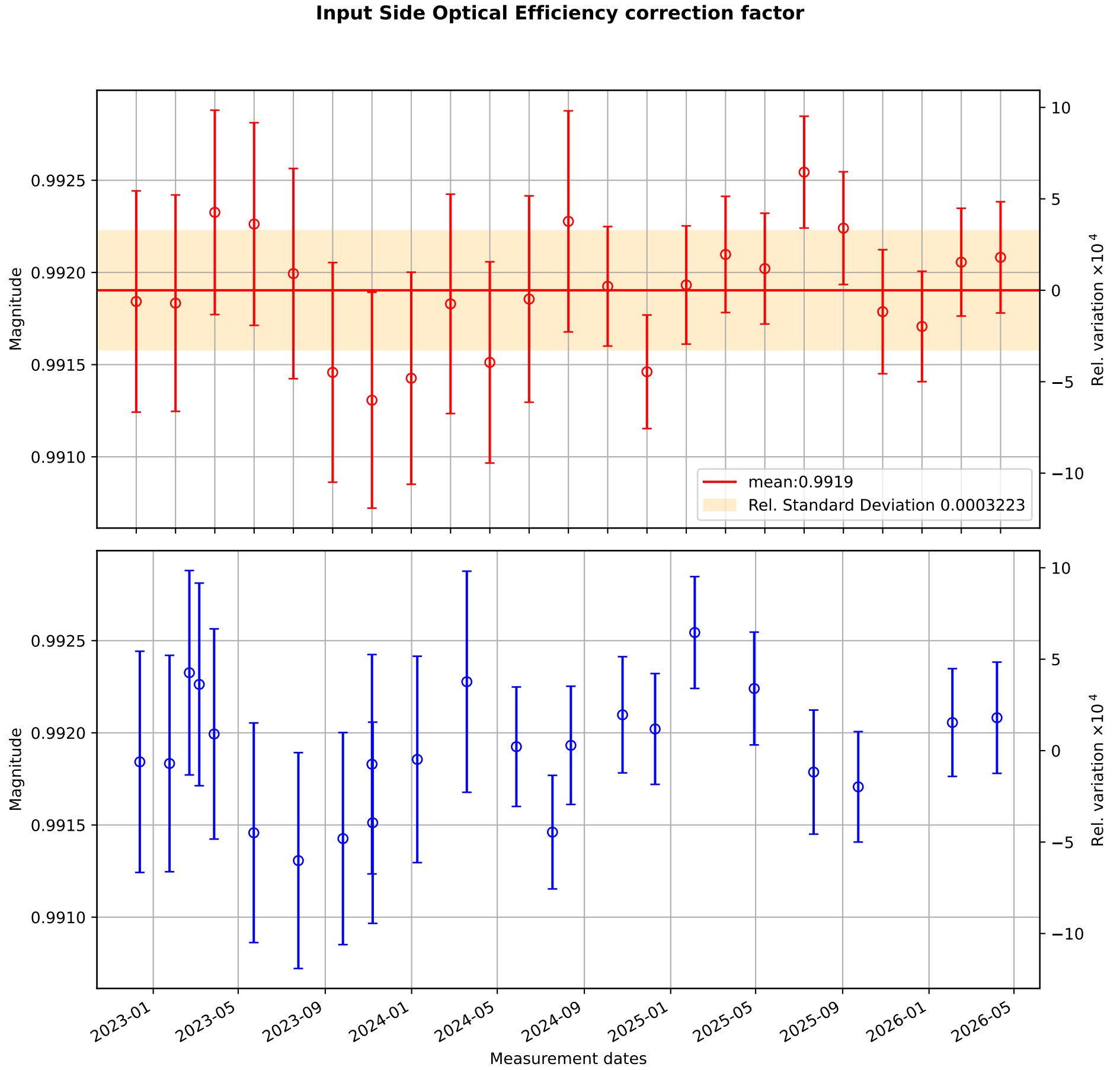
E_T
Summary of Input Side Optical Efficiency correction factor

Mean value: 0.991903

Standard deviation: 0.000322

Standard error: 0.000069

Relative Uncertainty: 0.000069


Input Side Optical Efficiency correction factor
Magnitude
Rel. variation ×10⁴
mean:0.9919
Rel. Standard Deviation 0.0003223
0.9925
0.9920
0.9915
0.9910
10
5
0
−5
−10
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

E_R is the Rx side Optical Efficiency Correction Factor, defined as E_R = sqrt(e / beta), and is dimensionless. It apportions the total optical loss inside the vacuum chamber between the Rx side and Tx side, using the overall optical efficiency (e) and the ratio of in-chamber optical efficiencies between the Tx and Rx sides (beta), measured during the last in-vacuum campaign (DCC T1800107). Beta is assumed to be stable over time. Applying E_R to the RxPD responsivity corrects for optical losses on the Rx side and yields the effective responsivity at the ETM. The plot shows two panels: the top panel displays E_R against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

E_R

Date E_R ± Rel.Uncertainty (epsilon)

D20221213: 0.992991 ± 0.000605

D20230124: 0.992982 ± 0.000592

D20230221: 0.993475 ± 0.000559

D20230307: 0.993411 ± 0.000554

D20230328: 0.993142 ± 0.000575

D20230523: 0.992606 ± 0.000601

D20230725: 0.992455 ± 0.000591

D20230926: 0.992574 ± 0.000580

D20231106: 0.992978 ± 0.000600

D20231107: 0.992660 ± 0.000550

D20240109: 0.993004 ± 0.000564

D20240319: 0.993426 ± 0.000604

D20240528: 0.993073 ± 0.000327

D20240718: 0.992609 ± 0.000311

D20240813: 0.993080 ± 0.000323

D20241025: 0.993246 ± 0.000318

D20241210: 0.993169 ± 0.000303

D20250204: 0.993693 ± 0.000306

D20250429: 0.993389 ± 0.000308

D20250722: 0.992935 ± 0.000339

D20250923: 0.992855 ± 0.000302

D20260203: 0.993204 ± 0.000295

D20260407: 0.993230 ± 0.000304

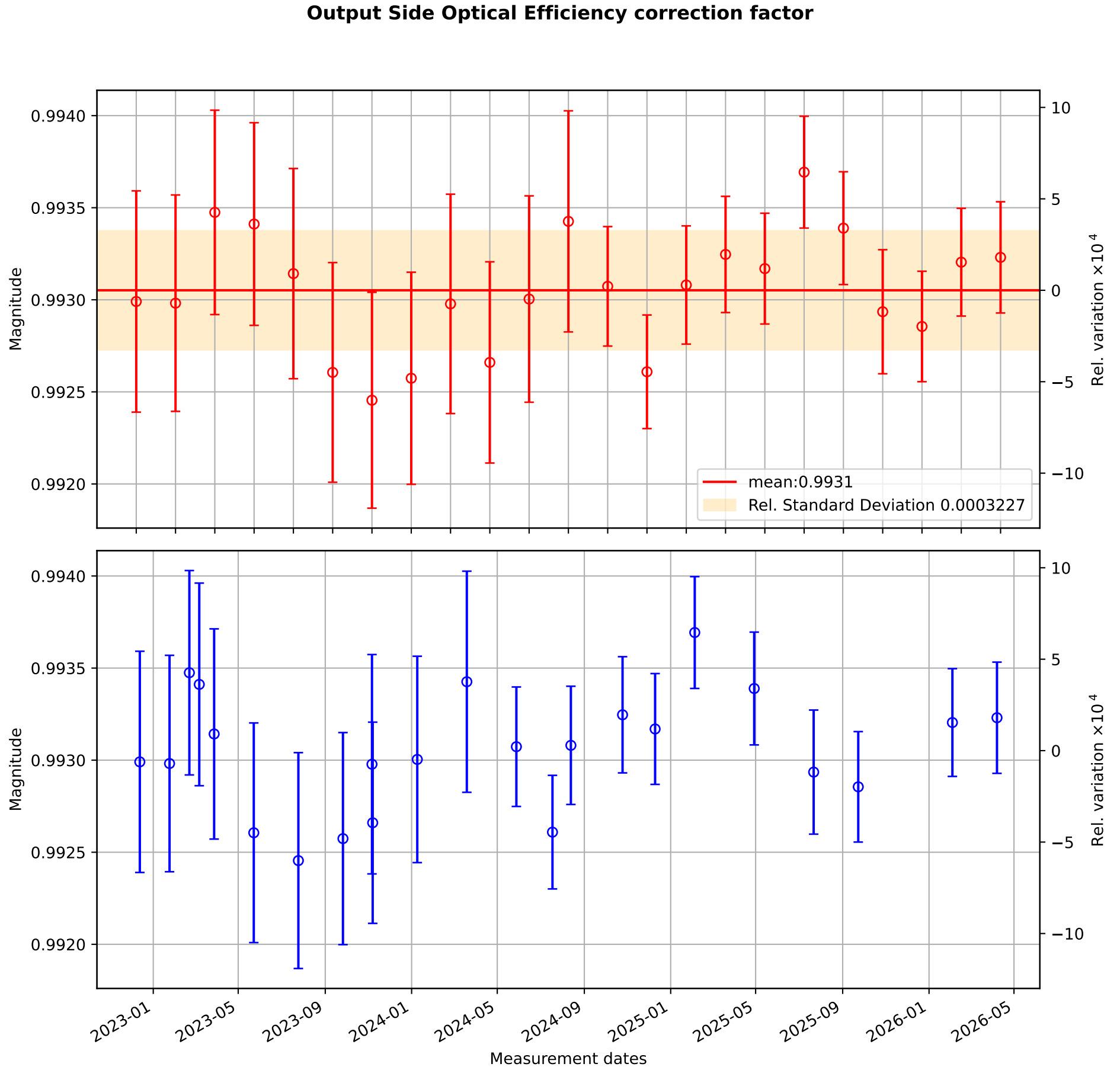
E_R
Summary of Output Side Optical Efficiency correction factor

Mean value: 0.993052

Standard deviation: 0.000323

Standard error: 0.000069

Relative Uncertainty: 0.000069


Output Side Optical Efficiency correction factor
Magnitude
Rel. variation ×10⁴
mean:0.9931
Rel. Standard Deviation 0.0003227
Measurement dates
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05

Description:

rhoT_prime (rho_Tx') is the TxPD responsivity corrected for optical efficiency, defined as rho_Tx' = rho_Tx * E_T, with units of V/W. It represents the estimated responsivity of the Tx integrating sphere as if it were located at the test mass (ETM), accounting for optical losses between the Tx sphere and the ETM. This provides a useful sanity check against the RxPD measurement, which has historically been the primary sensor used for calibration. The plot shows two panels: the top panel displays rhoT_prime against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

rhoT_prime

Date rhoT_prime ± Rel.Uncertainty (epsilon)

D20221213: 7212.397526 ± 0.000795

D20230124: 7214.452449 ± 0.000767

D20230221: 7215.273577 ± 0.000722

D20230307: 7213.813867 ± 0.000713

D20230328: 7210.114627 ± 0.000745

D20230523: 7207.469593 ± 0.000772

D20230725: 7212.969539 ± 0.000762

D20230926: 7213.744566 ± 0.000749

D20231106: 7213.577544 ± 0.000752

D20231107: 7213.352735 ± 0.000706

D20240109: 7211.235248 ± 0.000728

D20240319: 7193.544215 ± 0.000784

D20240528: 7194.721895 ± 0.000581

D20240718: 7199.672540 ± 0.000562

D20240813: 7216.958246 ± 0.000575

D20241025: 7217.949666 ± 0.000553

D20241210: 7214.853234 ± 0.000535

D20250204: 7205.867282 ± 0.000540

D20250429: 7198.268742 ± 0.000553

D20250722: 7203.910847 ± 0.000631

D20250923: 7202.677875 ± 0.000534

D20260203: 7202.588673 ± 0.000531

D20260407: 7199.690744 ± 0.000576

---

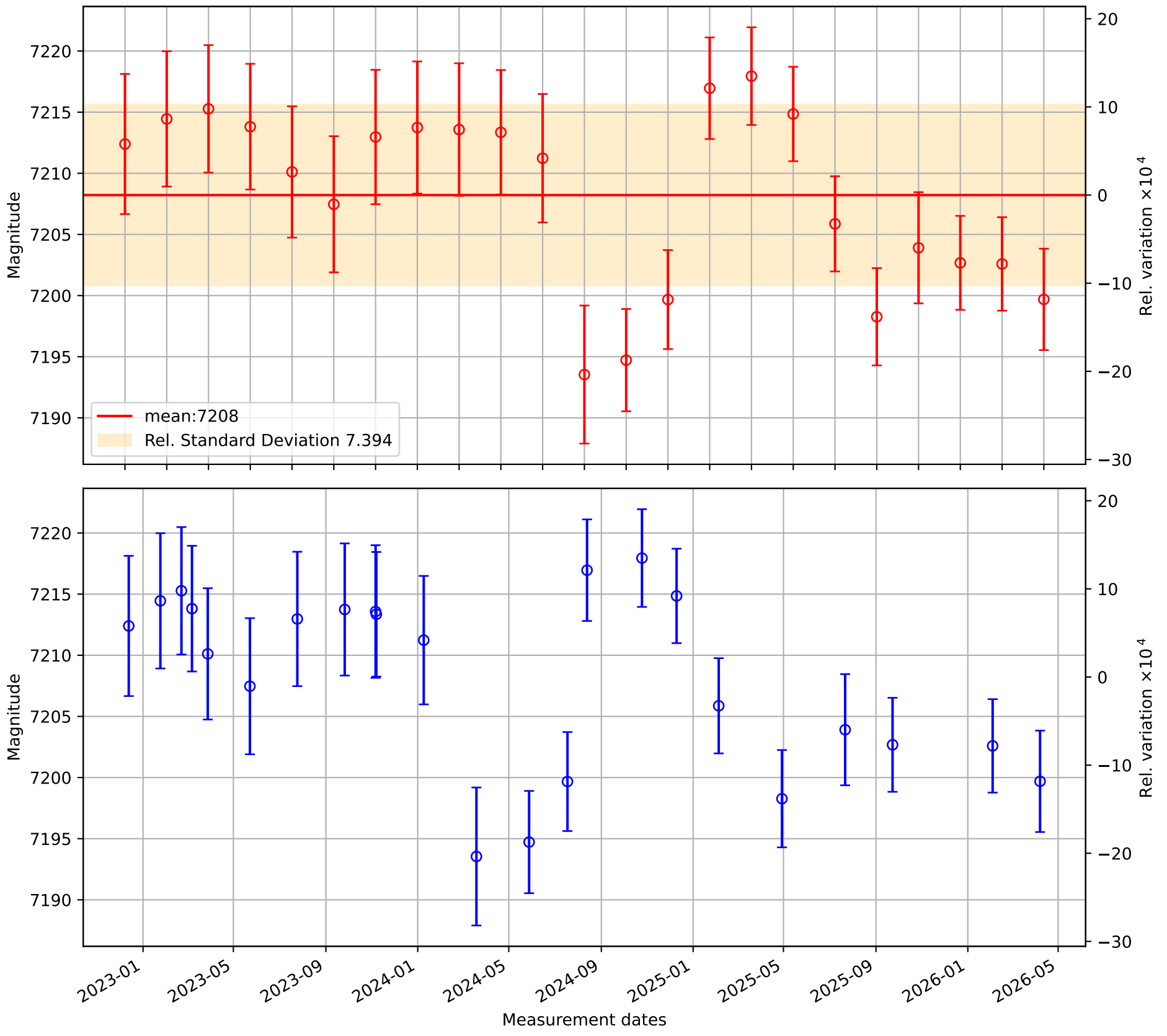
rhoT_prime
Summary of Tx Responsivity Corrected for Optical Efficiency

Mean value: 7208.221967

Standard deviation: 7.393724

Standard error: 0.001049

Relative Uncertainty: 0.001537


Tx Responsivity Corrected for Optical Efficiency
Magnitude
Rel. variation ×10^4
mean:7208
Rel. Standard Deviation 7.394
Measurement dates
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05

Description:

rhoR_prime (rho_Rx') is the RxPD responsivity corrected for optical efficiency, defined as rho_Rx' = rho_Rx / E_R, with units of V/W. It represents the estimated responsivity of the Rx integrating sphere as if it were located at the test mass (ETM), accounting for optical losses between the ETM and the Rx sphere. This is the primary quantity used in the PCAL calibration chain, as the RxPD has historically been the main sensor for determining the force applied to the test mass. The plot shows two panels: the top panel displays rhoR_prime against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

rhoR_prime

Date rhoR_prime ± Rel.Uncertainty (epsilon)

D20221213: 10576.669791 ± 0.000655

D20230124: 10575.005390 ± 0.000648

D20230221: 10580.181519 ± 0.000619

D20230307: 10578.909763 ± 0.000610

D20230328: 10575.198319 ± 0.000632

D20230523: 10550.281025 ± 0.000656

D20230725: 10552.311978 ± 0.000645

D20230926: 10552.755712 ± 0.000634

D20231106: 10564.989969 ± 0.000669

D20231107: 10565.315655 ± 0.000601

D20240109: 10576.238042 ± 0.000623

D20240319: 10568.274471 ± 0.000658

D20240528: 10575.297390 ± 0.000581

D20240718: 10569.007570 ± 0.000515

D20240813: 10595.124936 ± 0.000545

D20241025: 10602.518017 ± 0.000518

D20241210: 10606.503121 ± 0.000519

D20250204: 10604.221621 ± 0.000484

D20250429: 10583.955621 ± 0.000527

D20250722: 10578.452789 ± 0.000555

D20250923: 10570.683879 ± 0.000520

D20260203: 10592.081311 ± 0.000488

D20260407: 10587.571739 ± 0.000543

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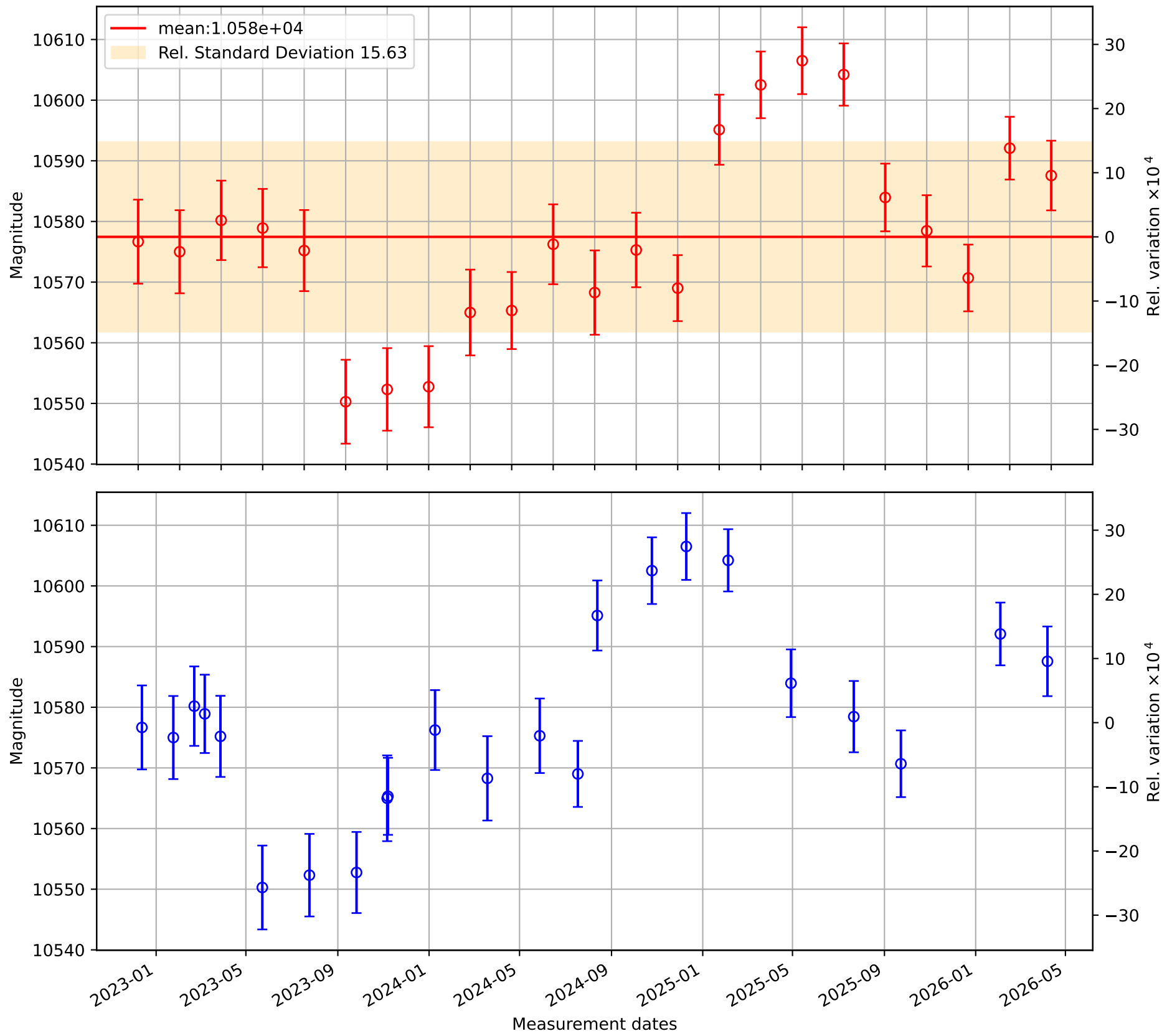
rhoR_prime
Summary of Rx Responsivity Corrected for Optical Efficiency

Mean value: 10577.458679

Standard deviation: 15.626951

Standard error: 0.001510

Relative Uncertainty: 0.001858


Rx Responsivity Corrected for Optical Efficiency
mean:1.058e+04
Rel. Standard Deviation 15.63
Magnitude
Rel. variation ×10⁴
10610
10600
10590
10580
10570
10560
10550
10540
30
20
10
0
−10
−20
−30
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

FC_TXPD is the Force Coefficient as measured by the TxPD, in units of N/W (Newtons per Watt). It relates the laser power measured by the TxPD to the radiation pressure force applied to the ETM, accounting for the angle of incidence and optical efficiency corrections. It is defined as FC_TXPD = 2 * cos(theta) * E_T / (c * rho_Tx'), where c is the speed of light, cos(theta) is the cosine of the angle of incidence, and E_T is the optical efficiency correction for the Tx side. Trending this parameter is important for monitoring the long-term stability of the PCAL force calibration as measured from the transmitter side. The plot shows two panels: the top panel displays FC_TXPD against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

FC_TXPD

Date FC_TXPD ± Rel.Uncertainty (epsilon)

D20221213: 9.2931e-13 ± 1.6128e-03

D20230124: 9.2906e-13 ± 1.6152e-03

D20230221: 9.2803e-13 ± 1.4285e-03

D20230307: 9.2834e-13 ± 1.4498e-03

D20230328: 9.2932e-13 ± 1.5504e-03

D20230523: 9.3067e-13 ± 1.8535e-03

D20230725: 9.3024e-13 ± 1.8883e-03

D20230926: 9.2992e-13 ± 1.8626e-03

D20231106: 9.2918e-13 ± 1.7113e-03

D20231107: 9.2981e-13 ± 1.8340e-03

D20240109: 9.2943e-13 ± 1.7238e-03

D20240319: 9.3093e-13 ± 1.5699e-03

D20240528: 9.1645e-13 ± 5.8447e-04

D20240718: 9.1582e-13 ± 5.6571e-04

D20240813: 9.1363e-13 ± 5.7864e-04

D20241025: 9.1351e-13 ± 5.5682e-04

D20241210: 9.1390e-13 ± 5.3875e-04

D20250204: 9.1504e-13 ± 5.4373e-04

D20250429: 9.1600e-13 ± 5.5609e-04

D20250722: 9.1529e-13 ± 6.3402e-04

D20250923: 9.1544e-13 ± 5.3716e-04

D20260203: 9.1545e-13 ± 5.3400e-04

D20260407: 9.1582e-13 ± 4.6780e-12

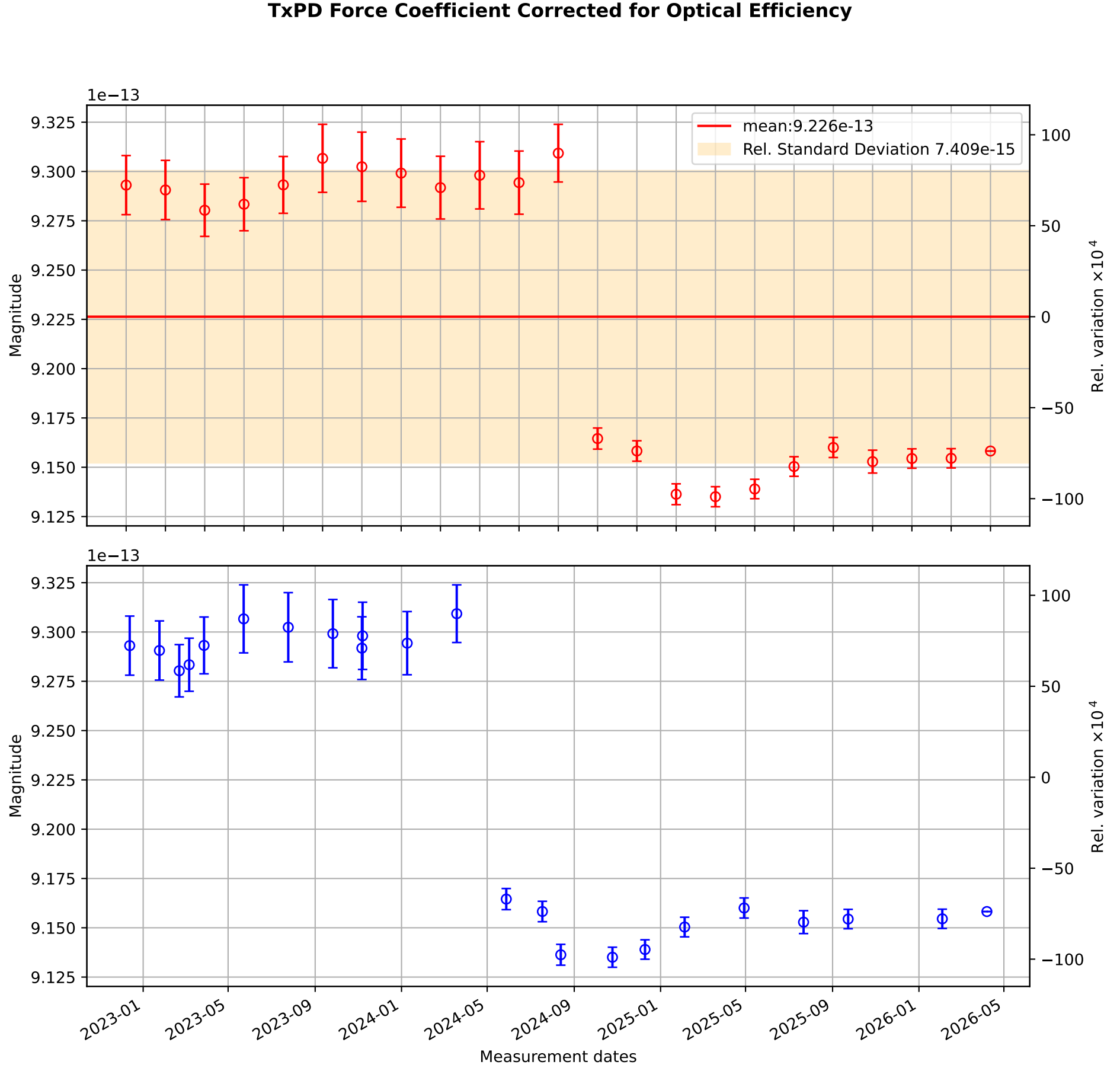
FC_TXPD
Summary of TxPD Force Coefficient Corrected for Optical Efficiency

Mean value: 9.226344e-13

Standard deviation: 7.408640e-15

Standard error: 8.208274e-03

Relative Uncertainty: 8.208274e-03


TxPD Force Coefficient Corrected for Optical Efficiency
1e−13
mean:9.226e-13
Rel. Standard Deviation 7.409e-15
Magnitude
Rel. variation ×10⁴
9.325
9.300
9.275
9.250
9.225
9.200
9.175
9.150
9.125
100
50
0
−50
−100
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

FC_RXPD is the Force Coefficient as measured by the RxPD, in units of N/ct (Newtons per counts). It relates the laser power measured by the RxPD to the radiation pressure force applied to the ETM, accounting for the angle of incidence and optical efficiency corrections. It is defined as FC_RXPD = 2 * cos(theta) * E_R / (c * rho_Rx'), where c is the speed of light, cos(theta) is the cosine of the angle of incidence, and E_R is the optical efficiency correction for the Rx side. The RxPD force coefficient is the primary quantity used in the PCAL calibration chain. Trending this parameter is important for monitoring the long-term stability of the PCAL force calibration as measured from the receiver side. The plot shows two panels: the top panel displays FC_RXPD against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

FC_RXPD

Date FC_RXPD ± Rel.Uncertainty (epsilon)

D20221213: 6.2341e-13 ± 2.5037e-03

D20230124: 6.2351e-13 ± 2.5685e-03

D20230221: 6.2321e-13 ± 2.5062e-03

D20230307: 6.2328e-13 ± 2.4590e-03

D20230328: 6.2350e-13 ± 2.5442e-03

D20230523: 6.2497e-13 ± 2.7091e-03

D20230725: 6.2485e-13 ± 2.6567e-03

D20230926: 6.2483e-13 ± 2.6256e-03

D20231106: 6.2410e-13 ± 2.8565e-03

D20231107: 6.2408e-13 ± 2.5418e-03

D20240109: 6.2344e-13 ± 2.6114e-03

D20240319: 6.2391e-13 ± 2.5776e-03

D20240528: 6.2349e-13 ± 5.8395e-04

D20240718: 6.2387e-13 ± 5.1842e-04

D20240813: 6.2233e-13 ± 5.4875e-04

D20241025: 6.2189e-13 ± 5.2191e-04

D20241210: 6.2166e-13 ± 5.2294e-04

D20250204: 6.2179e-13 ± 4.8798e-04

D20250429: 6.2298e-13 ± 5.3066e-04

D20250722: 6.2331e-13 ± 5.5868e-04

D20250923: 6.2377e-13 ± 5.2404e-04

D20260203: 6.2251e-13 ± 4.9214e-04

D20260407: 6.2277e-13 ± 4.4973e-12

FC_RXPD
Summary of RxPD Force Coefficient Corrected for Optical Efficiency

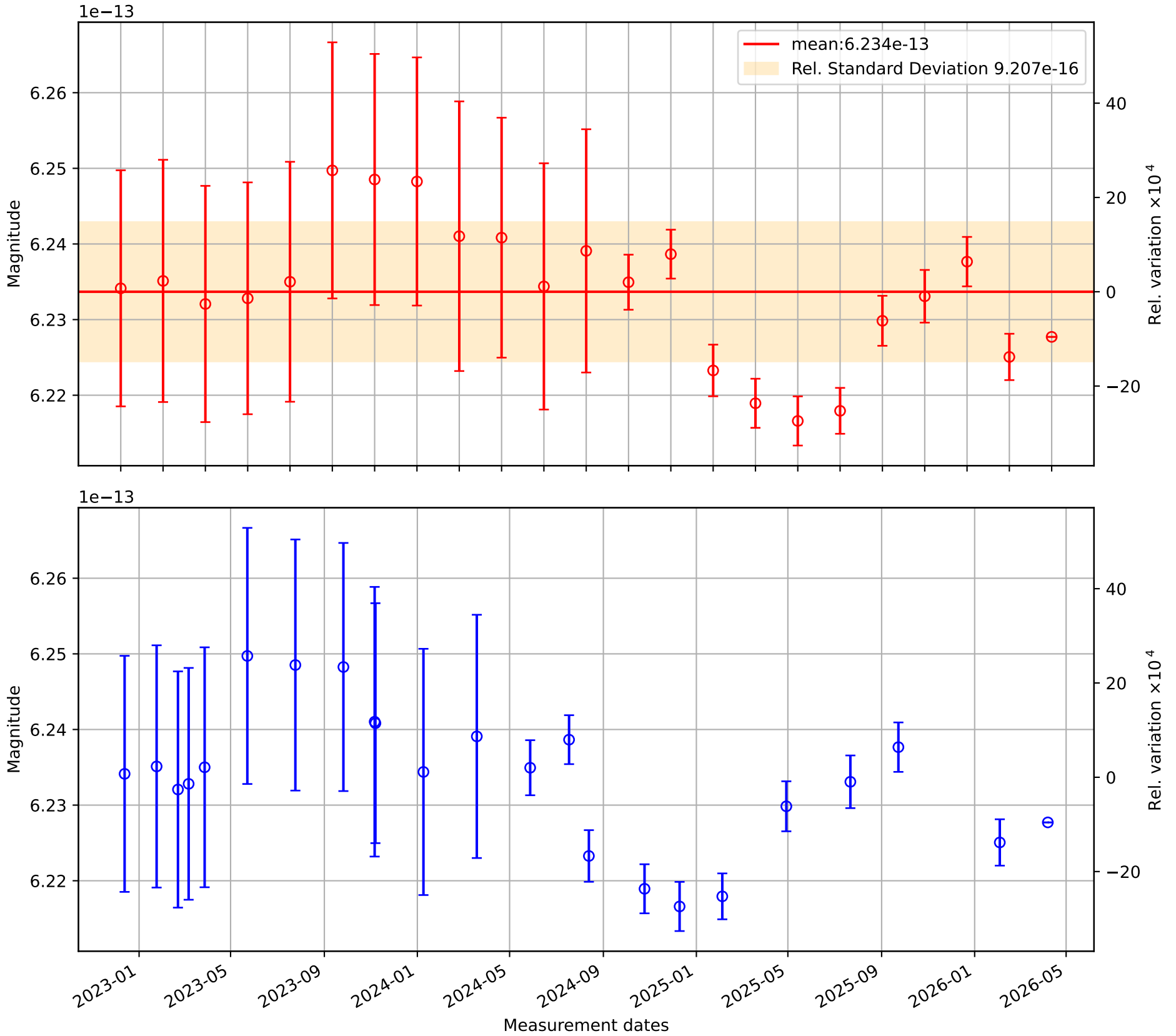
Mean value: 6.233683e-13

Standard deviation: 9.207490e-16

Standard error: 1.509870e-03

Relative Uncertainty: 1.509870e-03

RxPD Force Coefficient Corrected for Optical Efficiency



Description:

Chi_TXPD is the Displacement Coefficient as measured by the TxPD, defined as Chi_TXPD = FC_TXPD / M, where M is the mass of the test mass (ETM). It has units of m/cts (meters per count). It represents the acceleration of the ETM per unit of laser power as measured by the Tx sensor, and is frequency dependent, the actual displacement is Chi_TXPD divided by the angular frequency squared. Trending this parameter is useful for monitoring the long-term stability of the PCAL displacement calibration as measured from the transmitter side. The plot shows two panels: the top panel displays Chi_TXPD against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

Chi_TXPD

Date Chi_TXPD ± Rel.Uncertainty (epsilon)

D20221213: 2.3477e-14 ± 1.6128e-03

D20230124: 2.3471e-14 ± 1.6152e-03

D20230221: 2.3445e-14 ± 1.4285e-03

D20230307: 2.3452e-14 ± 1.4498e-03

D20230328: 2.3477e-14 ± 1.5504e-03

D20230523: 2.3511e-14 ± 1.8535e-03

D20230725: 2.3500e-14 ± 1.8883e-03

D20230926: 2.3492e-14 ± 1.8626e-03

D20231106: 2.3474e-14 ± 1.7113e-03

D20231107: 2.3489e-14 ± 1.8340e-03

D20240109: 2.3480e-14 ± 1.7238e-03

D20240319: 2.3518e-14 ± 1.5699e-03

D20240528: 2.3152e-14 ± 5.8447e-04

D20240718: 2.3136e-14 ± 5.6571e-04

D20240813: 2.3081e-14 ± 5.7864e-04

D20241025: 2.3078e-14 ± 5.5682e-04

D20241210: 2.3088e-14 ± 5.3875e-04

D20250204: 2.3116e-14 ± 5.4373e-04

D20250429: 2.3141e-14 ± 5.5609e-04

D20250722: 2.3123e-14 ± 6.3402e-04

D20250923: 2.3127e-14 ± 5.3716e-04

D20260203: 2.3127e-14 ± 5.3400e-04

D20260407: 2.3136e-14 ± 4.6780e-12

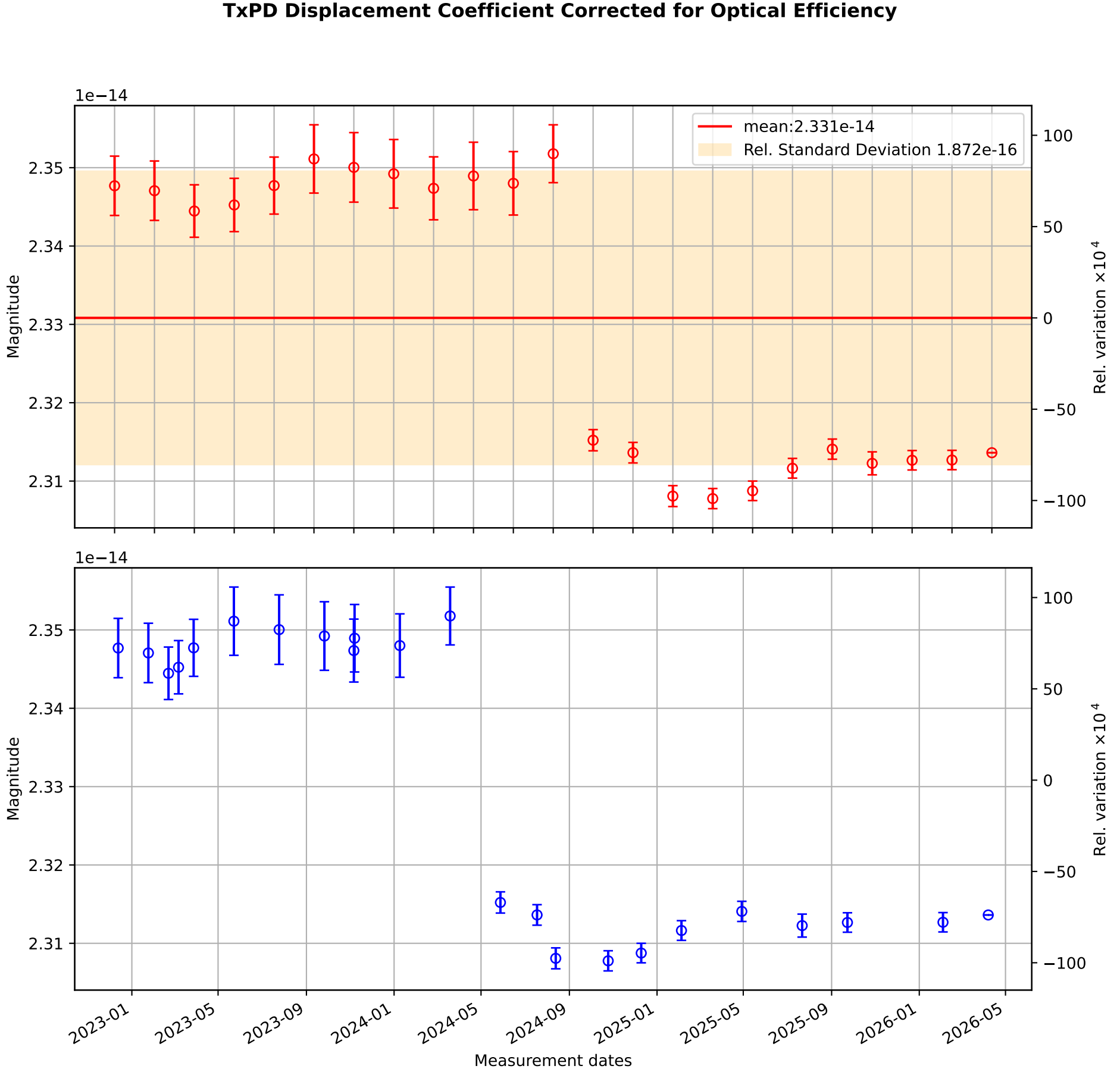
Chi_TXPD
Summary of TxPD Displacement Coefficient
Corrected for Optical Efficiency

Mean value: 2.330827e-14

Standard deviation: 1.871625e-16

Standard error: 8.208274e-03

Relative Uncertainty: 8.208274e-03


TxPD Displacement Coefficient Corrected for Optical Efficiency
1e−14
mean:2.331e-14
Rel. Standard Deviation 1.872e-16
Magnitude
Rel. variation ×10⁴
2.35
2.34
2.33
2.32
2.31
100
50
0
−50
−100
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

Chi_RXPD is the Displacement Coefficient as measured by the RxPD, defined as Chi_RXPD = FC_RXPD / M, where M is the mass of the test mass (ETM). It has units of m/cts (meters per count). It represents the acceleration of the ETM per unit of laser power as measured by the Tx sensor, and is frequency dependent, the actual displacement is Chi_TXPD divided by the angular frequency squared. Trending this parameter is useful for monitoring the long-term stability of the PCAL displacement calibration as measured from the transmitter side. The plot shows two panels: the top panel displays Chi_TXPD against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation.

Chi_RXPD

Date Chi_RXPD ± Rel.Uncertainty (epsilon)

D20221213: 1.5749e-14 ± 2.5037e-03

D20230124: 1.5752e-14 ± 2.5685e-03

D20230221: 1.5744e-14 ± 2.5062e-03

D20230307: 1.5746e-14 ± 2.4590e-03

D20230328: 1.5751e-14 ± 2.5442e-03

D20230523: 1.5789e-14 ± 2.7091e-03

D20230725: 1.5785e-14 ± 2.6567e-03

D20230926: 1.5785e-14 ± 2.6256e-03

D20231106: 1.5767e-14 ± 2.8565e-03

D20231107: 1.5766e-14 ± 2.5418e-03

D20240109: 1.5750e-14 ± 2.6114e-03

D20240319: 1.5762e-14 ± 2.5776e-03

D20240528: 1.5751e-14 ± 5.8395e-04

D20240718: 1.5761e-14 ± 5.1842e-04

D20240813: 1.5722e-14 ± 5.4875e-04

D20241025: 1.5711e-14 ± 5.2191e-04

D20241210: 1.5705e-14 ± 5.2294e-04

D20250204: 1.5708e-14 ± 4.8798e-04

D20250429: 1.5738e-14 ± 5.3066e-04

D20250722: 1.5746e-14 ± 5.5868e-04

D20250923: 1.5758e-14 ± 5.2404e-04

D20260203: 1.5726e-14 ± 4.9214e-04

D20260407: 1.5733e-14 ± 4.4973e-12

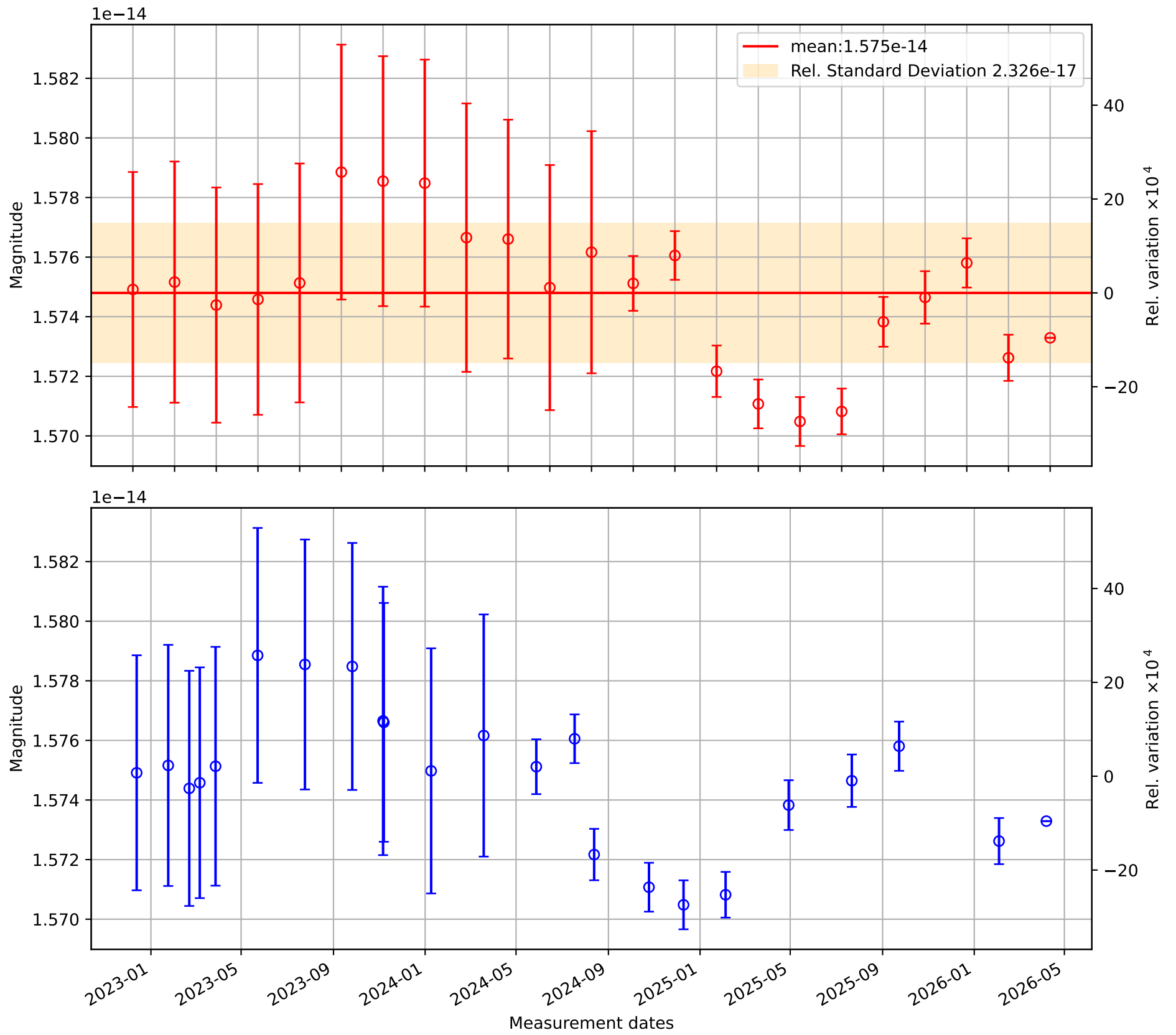
Chi_RXPD
Summary of RxPD Displacement Coefficient
Corrected for Optical Efficiency

Mean value: 1.574799e-14

Standard deviation: 2.326064e-17

Standard error: 1.509870e-03

Relative Uncertainty: 1.509870e-03


RxPD Displacement Coefficient Corrected for Optical Efficiency
1e−14
mean:1.575e-14
Rel. Standard Deviation 2.326e-17
Magnitude
Rel. variation ×10⁴
1.582
1.580
1.578
1.576
1.574
1.572
1.570
40
20
0
−20
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates

Description:

PowerImbalance is the ratio of the inner beam power to the outer beam power (M1/M2), as measured by the Working Standard inside the Tx module. It is a dimensionless quantity used to monitor the balance between the two PCAL beams that illuminate the test mass. Deviations from unity indicate an imbalance between the two beams, which can affect the accuracy of the force applied to the ETM. Trending this parameter is useful for detecting changes in the beam splitting optics or laser alignment over time. The plot shows two panels: the top panel displays the Power Imbalance against measurement number with a secondary axis showing relative variation x10^4; the bottom panel shows the same values plotted against measurement date. Error bars represent the absolute uncertainty (sigma) and the mean value is shown as a horizontal red line with a shaded orange band indicating one standard deviation. M1/M2.

PowerImbalance
Date PowerImbalance ± Rel.Uncertainty (epsilon)

D20221213: 0.985549 ± 0.000491

D20230124: 0.986959 ± 0.000463

D20230221: 0.989722 ± 0.000432

D20230307: 0.988612 ± 0.000425

D20230328: 0.986163 ± 0.000450

D20230523: 0.985812 ± 0.000461

D20230725: 0.988268 ± 0.000456

D20230926: 0.987966 ± 0.000449

D20231106: 0.986664 ± 0.000431

D20231107: 0.986688 ± 0.000420

D20240109: 0.986184 ± 0.000438

D20240319: 0.987011 ± 0.000474

D20240528: 0.985520 ± 0.000457

D20240718: 0.985794 ± 0.000445

D20240813: 0.986034 ± 0.000452

D20241025: 0.983952 ± 0.000772

D20241210: 0.984123 ± 0.000761

D20250204: 0.981114 ± 0.000770

D20250429: 0.984776 ± 0.000795

D20250722: 0.984192 ± 0.000903

D20250923: 0.984059 ± 0.000756

D20260203: 0.982524 ± 0.000757

D20260407: 0.981895 ± 0.000801

PowerImbalance

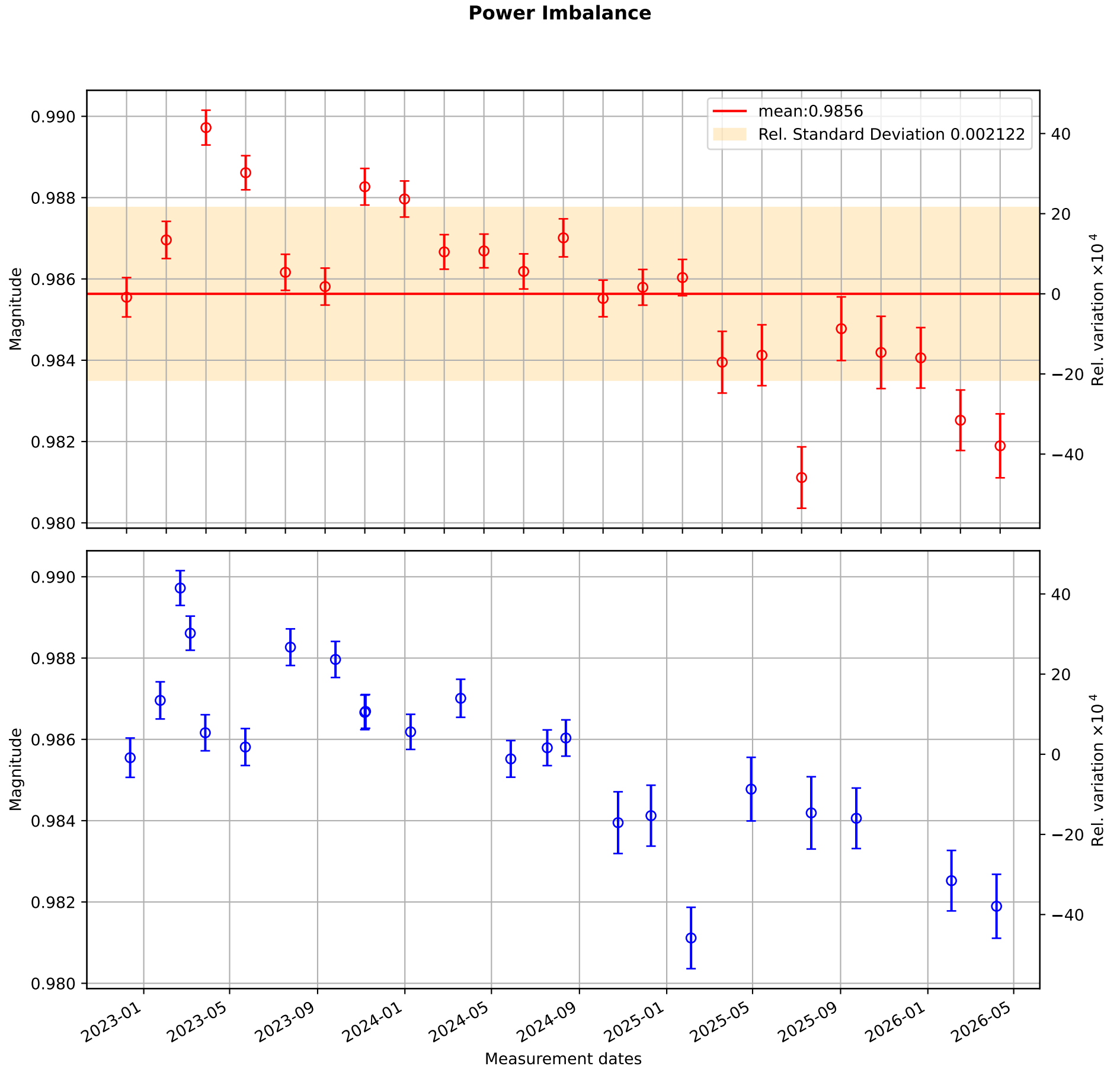
Summary of Power Imbalance

Mean value: 0.985634

Standard deviation: 0.002122

Standard error: 0.000459

Relative Uncertainty: 0.000459


Power Imbalance
mean:0.9856
Rel. Standard Deviation 0.002122
Magnitude
Rel. variation ×10⁴
0.990
0.988
0.986
0.984
0.982
0.980
40
20
0
−20
−40
2023-01
2023-05
2023-09
2024-01
2024-05
2024-09
2025-01
2025-05
2025-09
2026-01
2026-05
Measurement dates