



# The European Laser Transfer (ELT) Mission

Nicolaus Brandl, Reiner Dassing, Johann Eckl, Günther Herold, Rudolf Motz

Federal Agency for Cartography and Geodesy (BKG)

*Pierre Lauber* (lauber@fs.wetzell.de), Urs Hugentobler, Ulrich Schreiber

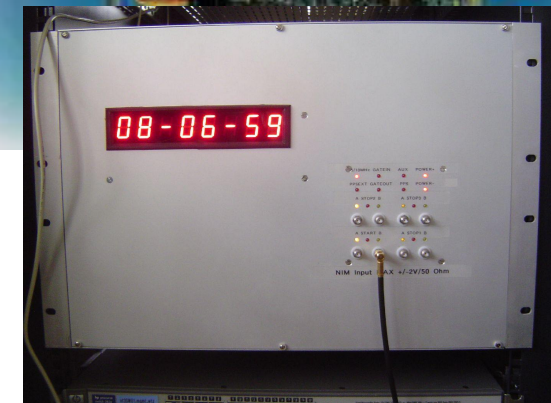
Technical University of Munich (TUM)

Geodetic Observatory Wettzell

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# Mission Prerequisites @ Ground: Time Measurement of electrical Signals

- Solid Time- and Frequency References:
  - Caesium: SLR-Epoch currently about 1ns
  - H-Maser: Stability best short term  $10^{-15}$  and long term  $10^{-12}$
- Key Technology: Thales Event Timer Module: Pulse Transition – Time Conversion
  - 5MHz “Counter” @ 1.2ps Resolution
  - about 5ps Precision, international Reference
  - tags epochs (and not only time differences)
- ***SLR-Measurement Devices: Event Timer (in-house development 2003-2010)***
  - *Repetition Rate: 1kHz, Noise Masking*
  - *High- and Low-Level API, Software distribution includes the entire signal data processing path: the hit detection, observation evaluation, ...*



# Time Transfers between Ground and Space

## History

- Ajisai by Japan, ~1500km, since 1986 (Kunimori et al./~2001)
- Compass M1 Beidou by China, GPS like orbit, since 2007 (Yang et al.)

## Time Transfer by Laser Link/T2L2 (operated by France)

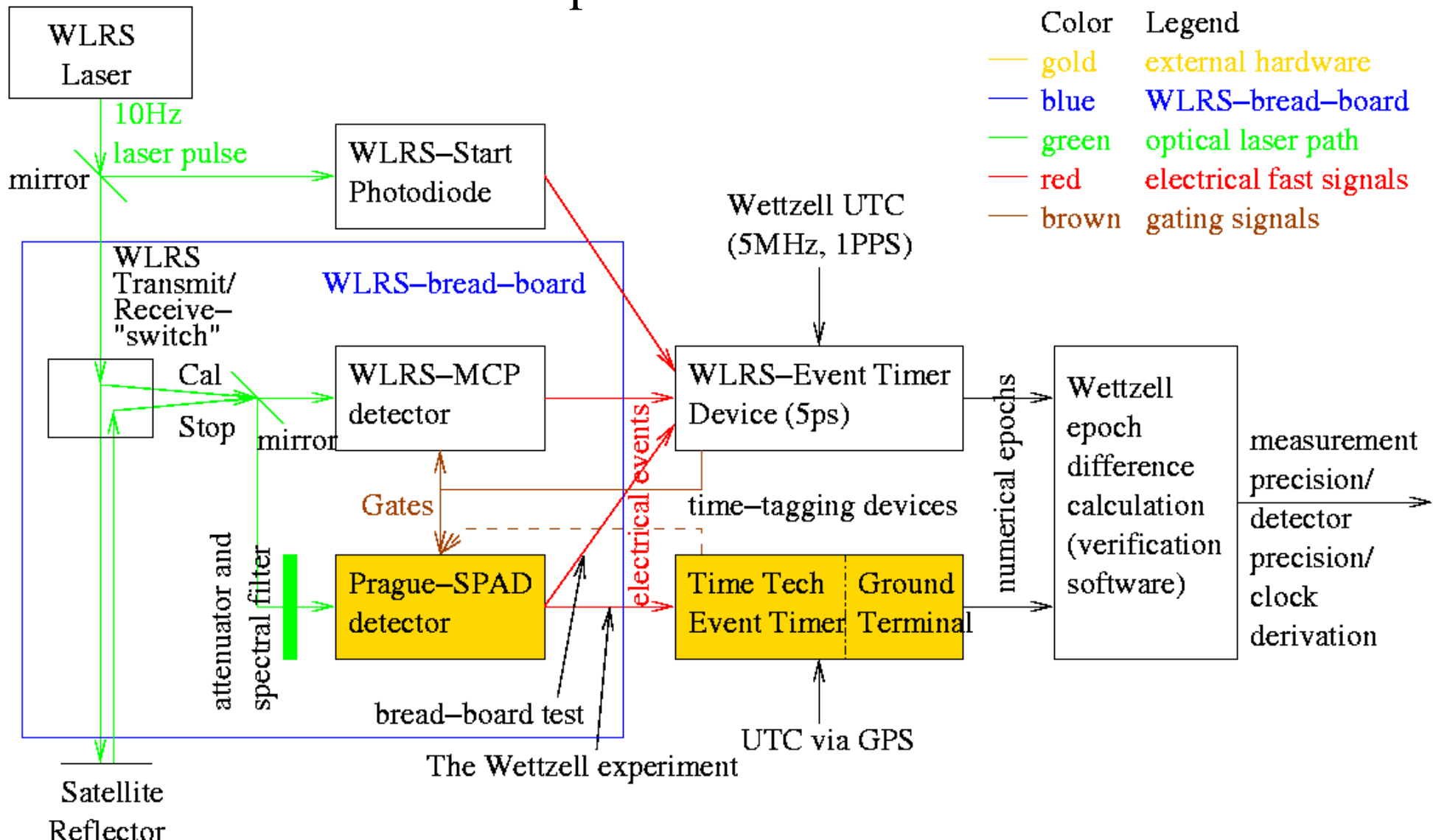
- @Satellite Jason-2, ~1300km: Detector and Event Timer on Board
- @WLRS: Laser-Start-Pulse: *Measurement, Evaluation and Transfer to Data Centre at max. resolution, time- and frequencystability*
- ***Jason-2-WLRS: 40 ps @ 1 s and 7 ps @ 30 s, 5 ps @ 30 s and 10 ps @ 100 s. (Exertier/2009)***

## Yet another Mission: European Laser Transfer/ELT (operated by ESA)

- within the framework of Atomic Clock Ensemble in Space (ACES) by Europe
- Columbus-ISS orbit ~400km,
- Pre-Flight validation/independent crosscheck/experiment started at Wettzell in ~11/2008, results within the framework of EFTF 2009

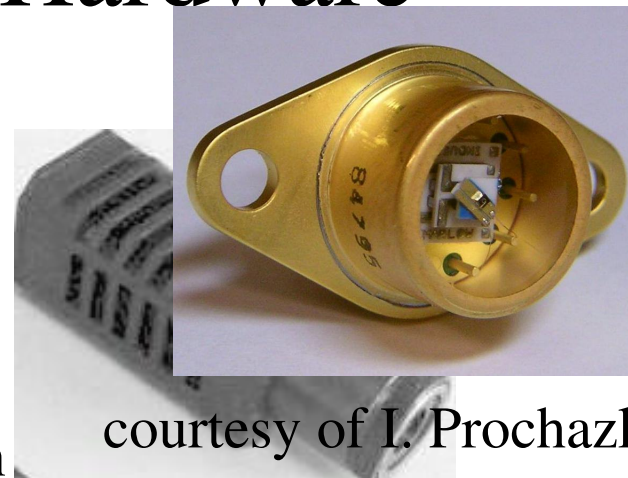
# Pre-Flight validation (1)

Ground Experiment: Evaluation of a Detector and a Event Timer to be used in space in the future

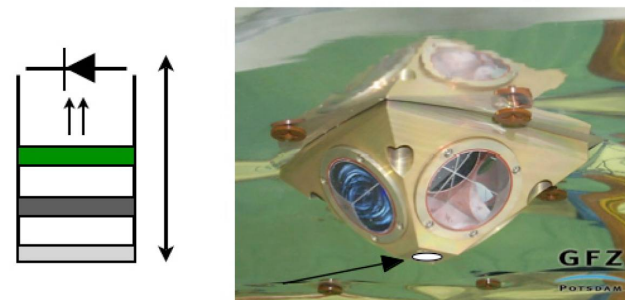


# Pre-Flight validation (2) – Hardware

- The Detector: Opto-electrical Signal conversion
  - K14 SPAD, gated ( $\sim 200\text{ns}$ ), single-photon mode
  - timing jitter/stab.  $30\text{ps}/1\text{ps}$ , very good evaluated,
  - similar types already qualified for Space-missions
- The Event Timer: Pulse transition –Time Conversion
  - TimeTech FPGA-Board
  - timing res./pres./accur.  $2\text{ps}/20\text{ps}/100\text{ps}$
- for Space-Mission
  - very small, low power, radiation resistant
  - *Specs to be verified for Correctness; therefore*
- ***Adapt Test Components to the Testing environment:***
  - *Hardware: optical and electrical*
  - *Software: Interface: Readout and process*



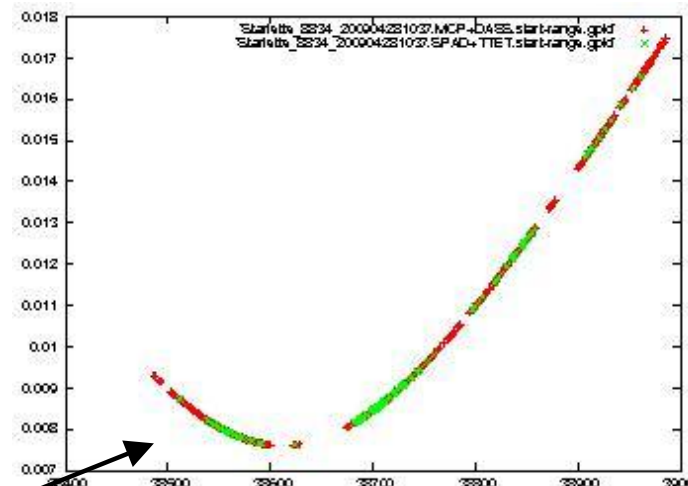
courtesy of I. Prochazka



courtesy of W. Schäfer

# Pre-Flight validation (3) – Results and Goals

- Data Availability @10Hz Laser  
Pulse-Rate and 10% Return Rate:  
Per second one time value at picosecond precision!
- **Ground Demonstration**
  - *Hardware Standalone-Measurements*  
*Specs validated*
  - *First parallel measurements on the Satellite*
  - ***Live-Demo on a Satellite for ESA and EADS shown successfully (05/2009)***
- *Working-out of specifications for ELT together with the ESA*
  - Space-to-ground Clock Comparison: TDEV  $\sigma_x(\tau=10^2..10^6s)=4..7ps$
  - Common view Comparisons of Ground Clocks:  $\sigma_x(\tau= \sim 300s)<6ps$
  - Non-common view Comparison of Ground Clocks:  $\sigma_x(\tau=10^3..10^4s)=6..7ps$
  - Time transfer accuracy and Calibration for Space-to-Ground and Ground-to-Ground: 25..50ps



# IEEE-Paper/Results (1)

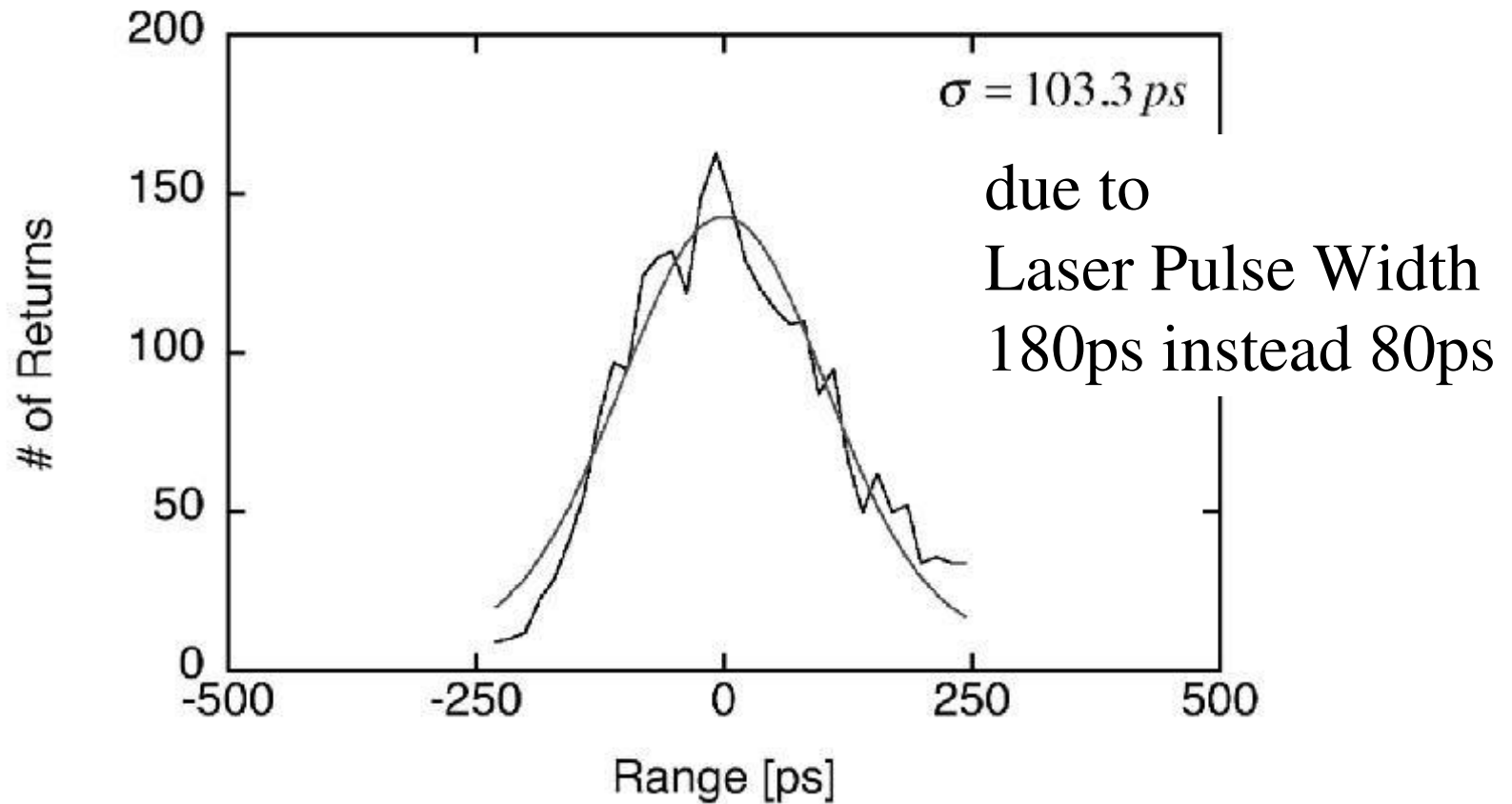


Fig. 9. Calibration histogram taken with the single-photon avalanche diode at the Wetzell laser ranging system hardware, using the event timer from TimeTech GmbH. A jitter of 103 ps has been obtained for the detector operating in single photon detection mode.

# IEEE-Paper/Results (2)

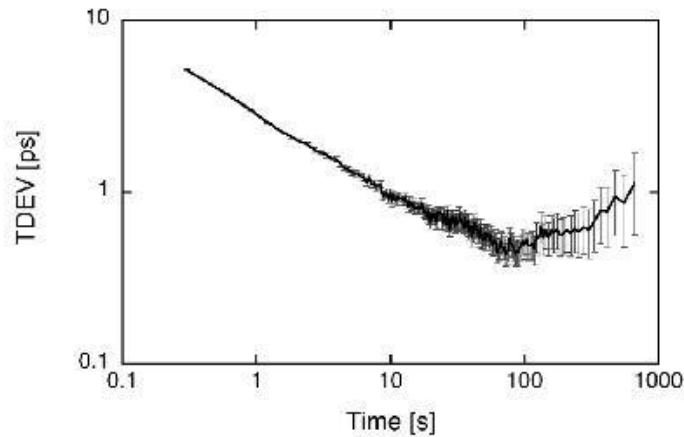


Fig. 6. Time deviation (TDEV) of the Wettzell laser ranging system ranging to a constant local target, using a micro-channel plate detector.

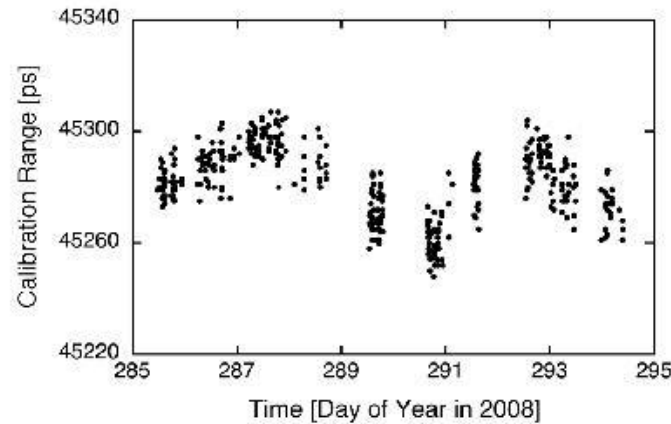


Fig. 7. Time series of indoor calibration ranges from the micro-channel plate detector collected over a 10-day period. Fluctuations with an amplitude of approximately 20 ps are mostly caused by temperature variations on the ranging electronics.

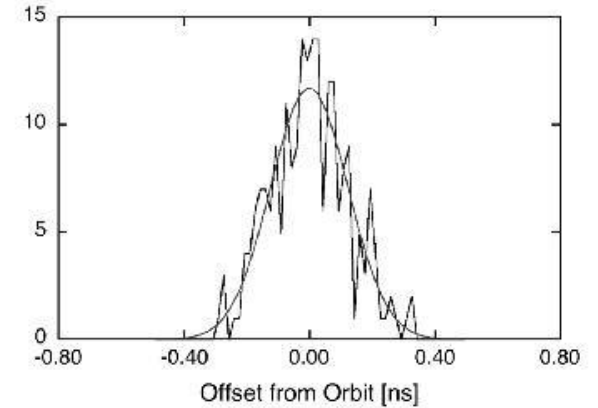


Fig. 8. Histogram over the range measurements relative to the satellite orbit of Starlette, obtained from the single-photon avalanche diode detector. A jitter of 116 ps has been obtained for this pass.

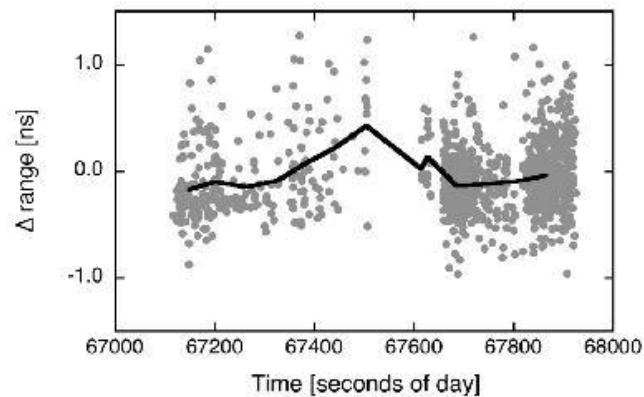


Fig. 11. Range residuals of a satellite pass for which the micro-channel plate detector and the single-photon avalanche diode detector were operated simultaneously. The range values for all simultaneous satellite echoes were subtracted from each other. Again, regions of denser data points appear to be systematically biased toward lower values.

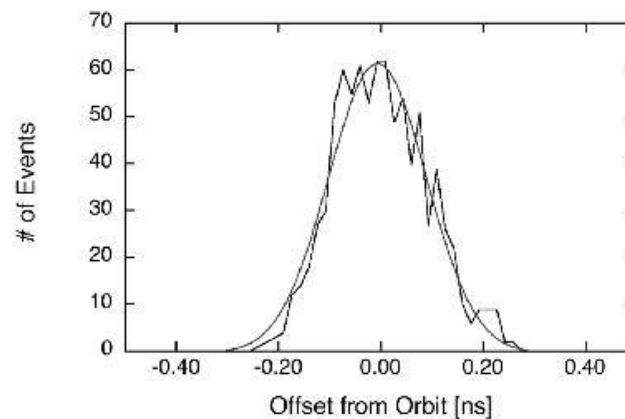


Fig. 13. Histogram over the range measurements relative to the satellite orbit of Starlette, obtained from the micro-channel plate detector. A jitter of 89 ps has been obtained for this pass.

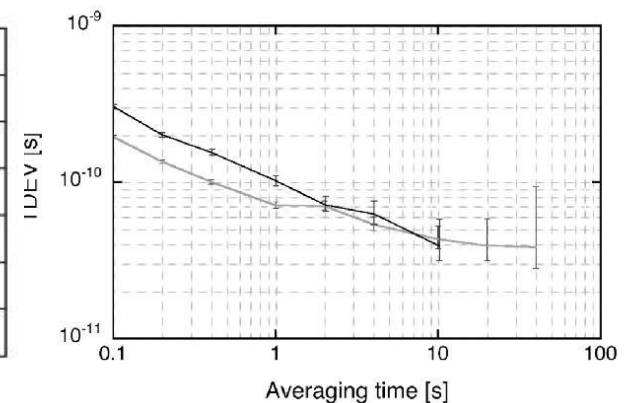


Fig. 14. Time deviation (TDEV) measurements of the Wettzell laser ranging system ranging stability obtained from measurements of a satellite pass of Ajisai using simultaneously recorded observations from the micro-channel plate detector and the single-photon avalanche diode detector.



# ELT – Status and Outlook

European Laser Transfer (ELT): Put the detector and event timer combination onto the ISS

Space Segment (components build by EADS/Astrium):

space qualified detector, event timer hardware set-up now ready

- last details are currently on-going, e.g. hardware calibration, meet safety requirements
- ***will work on the ISS in 2013***

Data: read-out, RF- downlink, RF-receiving and distribution: to be checked

Ground Segment:

- @WLRS:
  - Fine-Tuning: elevation dependent Laser Intensity for Adjustment of the Single-Photon-Mode at the Space-Detector?!....
  - ***Improvement of epoch/UTC precision (maybe using a better time and frequency distribution system)***
- @TUM (data centre): processing of data flow in progress (implementation by A. Schlicht)

LRO Go/NoGo-Flag and others similar and/or advanced

# ELT - Outlook

- ELT: IIS observations in 2013
- Challenge: ELT hardware derivatives/transponders on interplanetary missions

ESJM/Laplace mission: mainly only not recommend due to missing ground infrastructure, but must exist and work before an interplanetary application: This problem will be overcome in the next 2 years anyway  
keep track of ESA/NASA mission activities

Thank you for your attention!