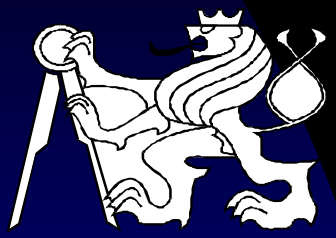
Improving Ranging Accuracy and Calibration



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Czech Technical University in Prague, Czech Republic

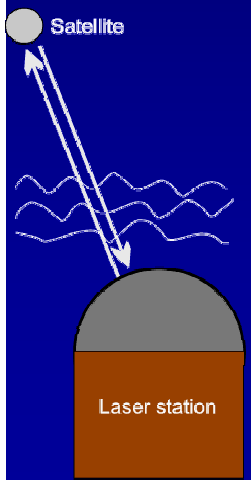
Precision check

- High precision limit is prerequisite for high accuracy
- The precision of the mean value should increase

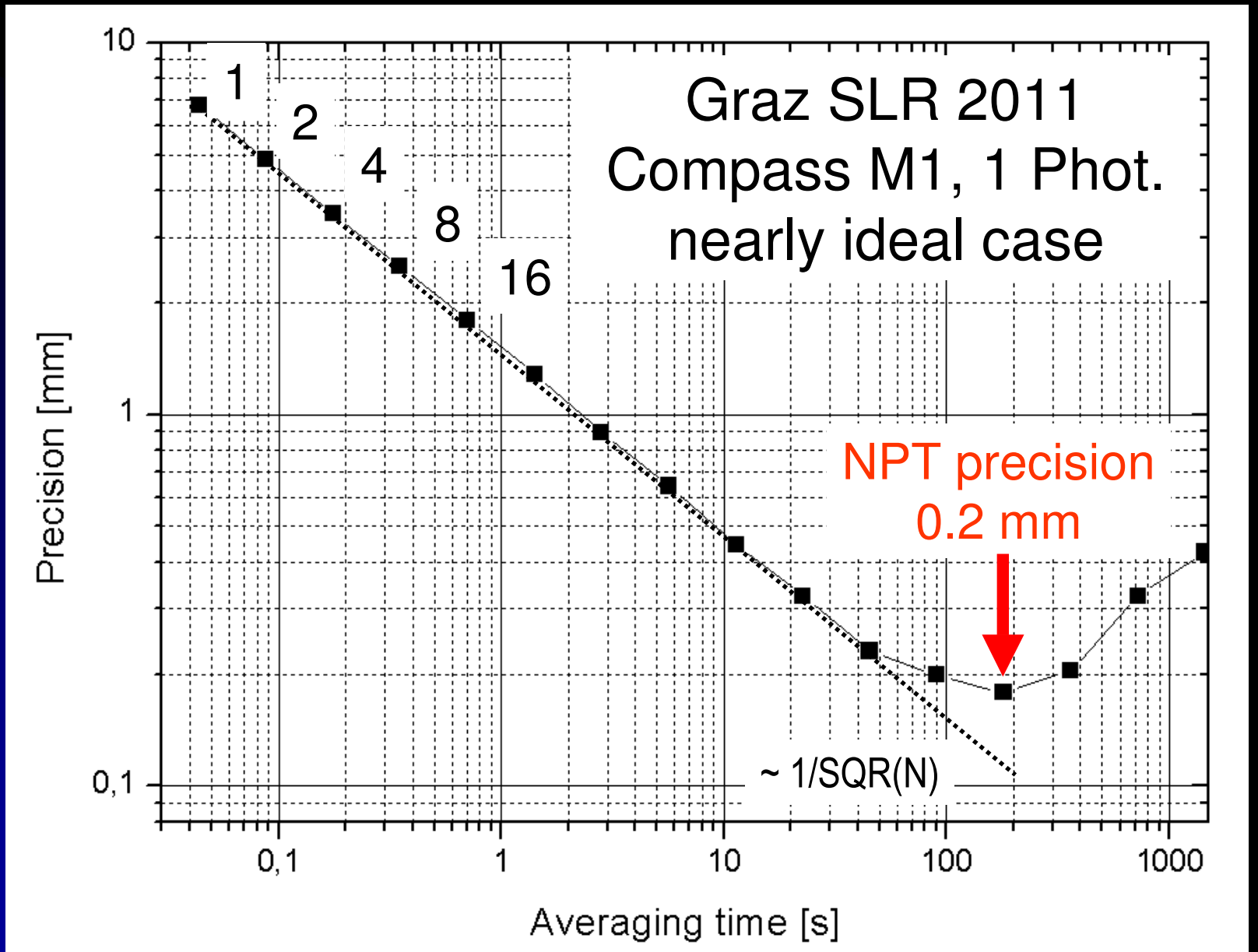
  s ~ 1/SQR(N) … N is a number of averaged values

  normal distribution, Gaussian statistics, white noise

- QUESTION - how long (up to what N) one can average to increase the precision ?
- limited by the system STABILITY and BIASES
- ANALYSIS – evaluate the “Time variance” to analyze the data behavior and to determine the stability and some (possible) biases



Precision check – time variance “Stable 32”



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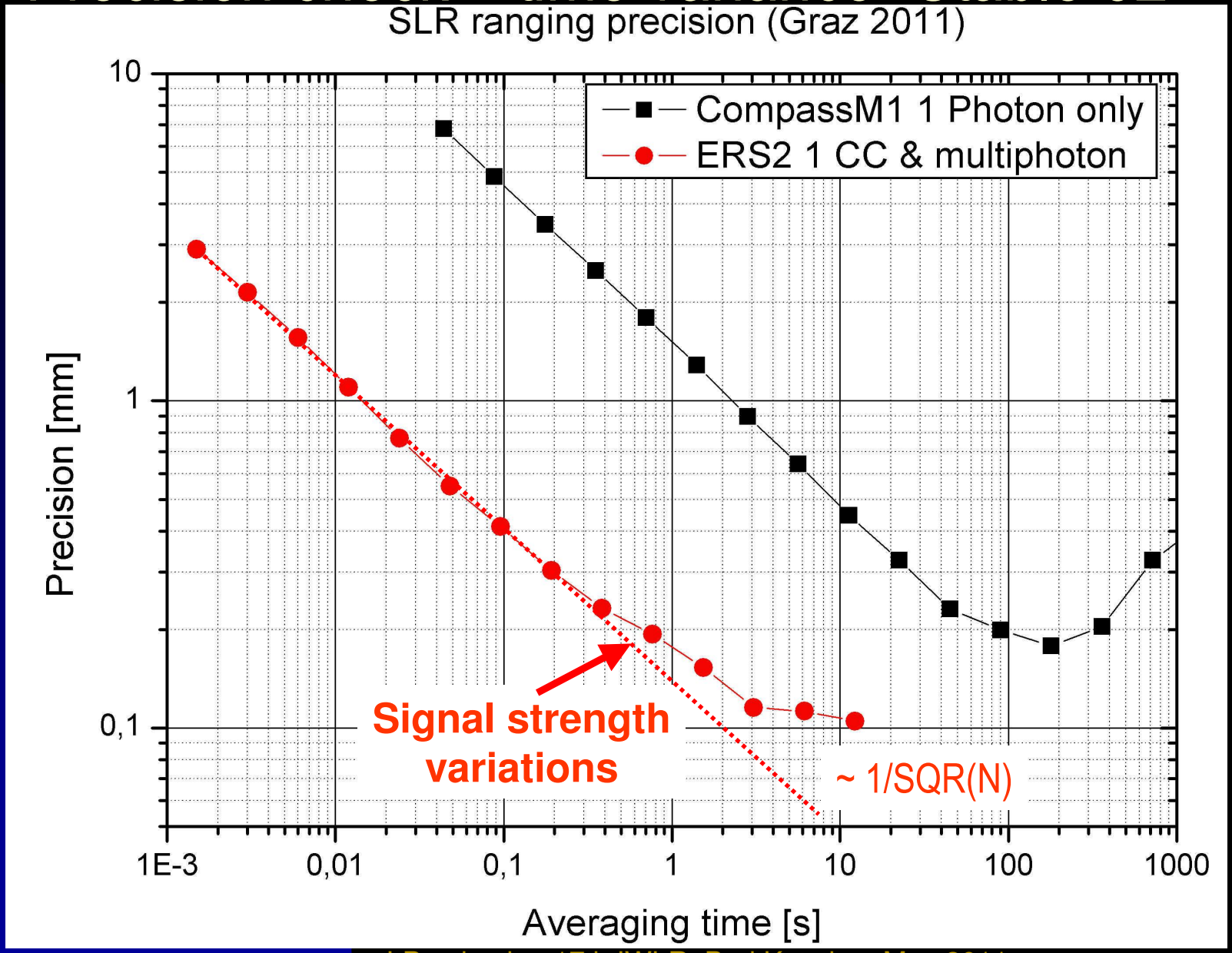

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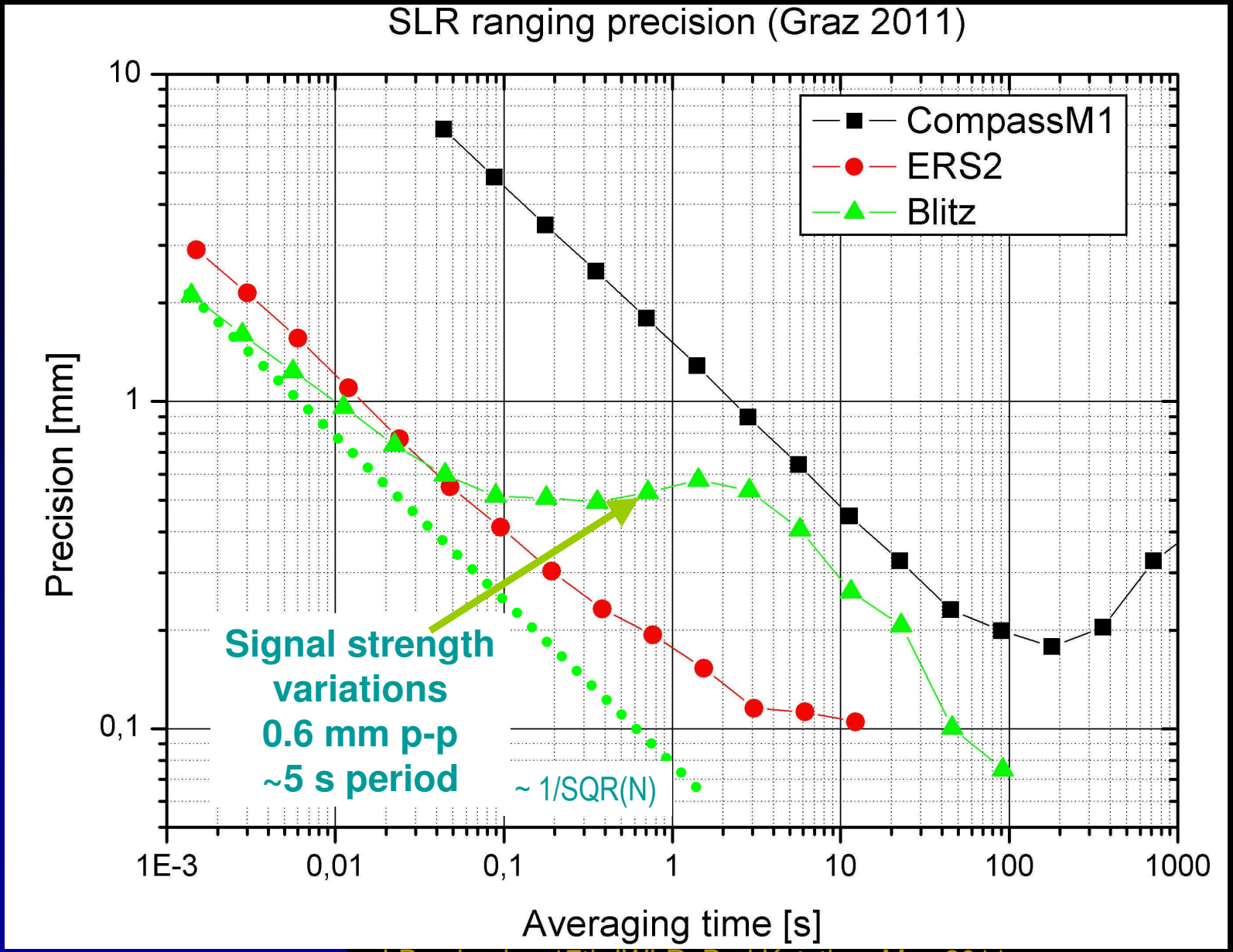

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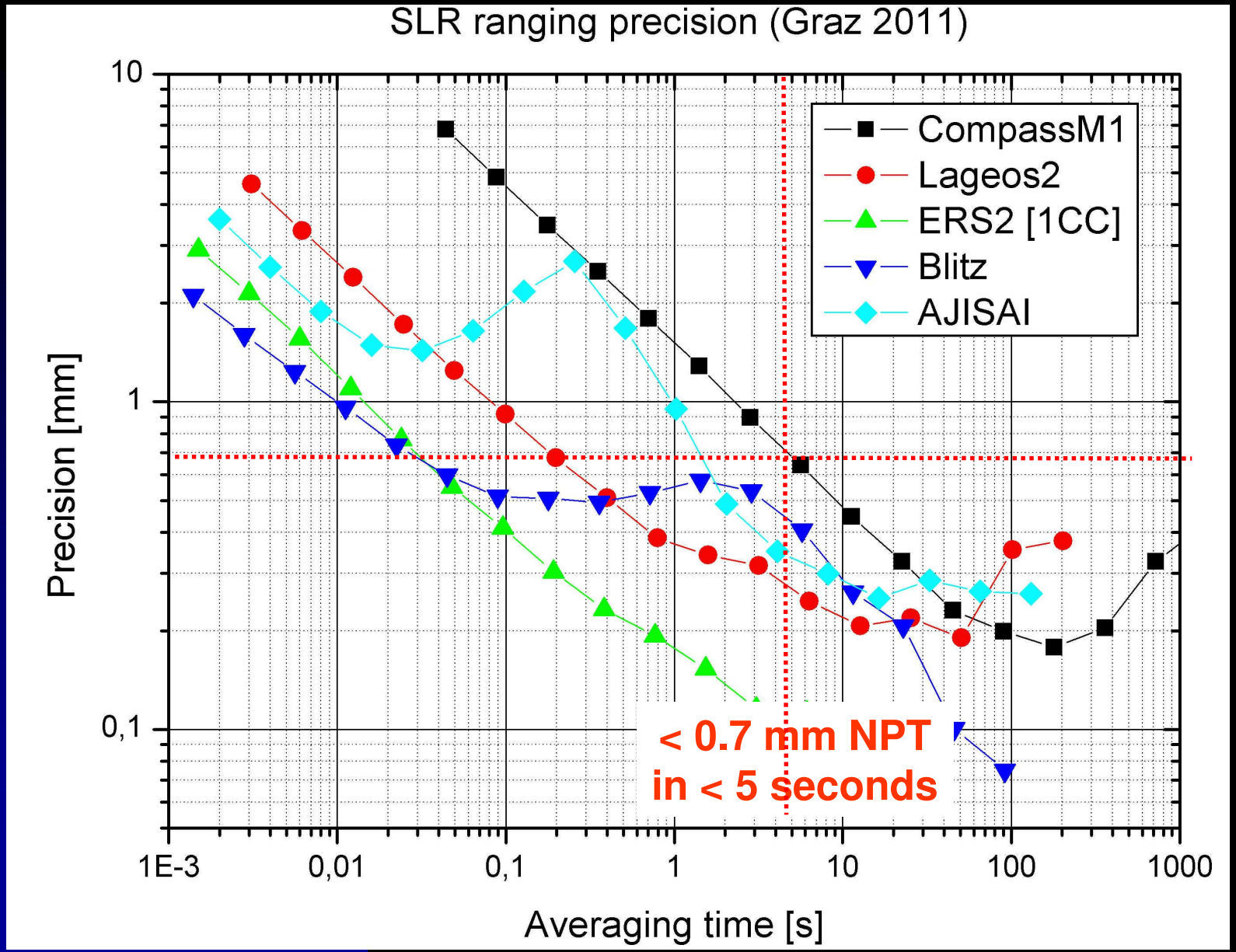


Message – SLR Precision

- The “time variance” analysis is a power tool to identify the precision limit and to identify some biases
- The good SLR systems are capable to provide :
- < 0.2 mm precision for calibration
- < 0.7 mm precision in ~< 5 s for ALL satellites
- = > The sub-mm biases should be possible to identify
- **The highest accuracy is achievable for pure 1 Photon ranging , ranging at 1Photon level at high reprate provides the ultimate precision limit..**

Accuracy – biases check

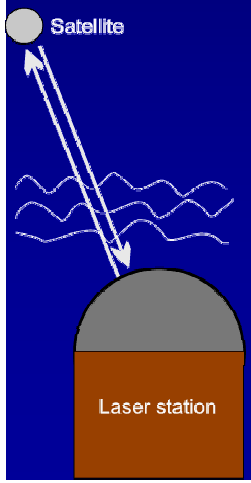
- Comparison to more accurate value
  HOWEVER - for SLR accuracy check such a value is not available

- SOLUTION
  characterizing ALL individual error budget contributors, their precision and BIASES
  (M. Pearlman, System characterization parameters, Herstmonceux, 1984)

- PROBLEMS

  - how to calibrate each contributor ?

  - is our contributors list complete ?

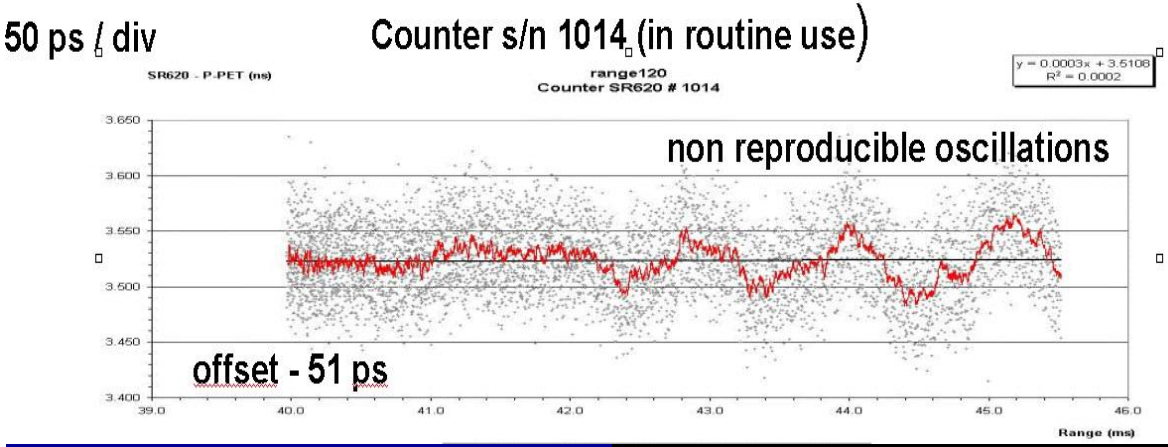


Portable Calibration Standard for SLR

- To identify the SLR system mm biases
- Ultra-stable Pico Event Timer based on ETM modules by Thales-Dassault
- Epoch and frequency reference
- date analysis SW, set of meteo sensors, ...

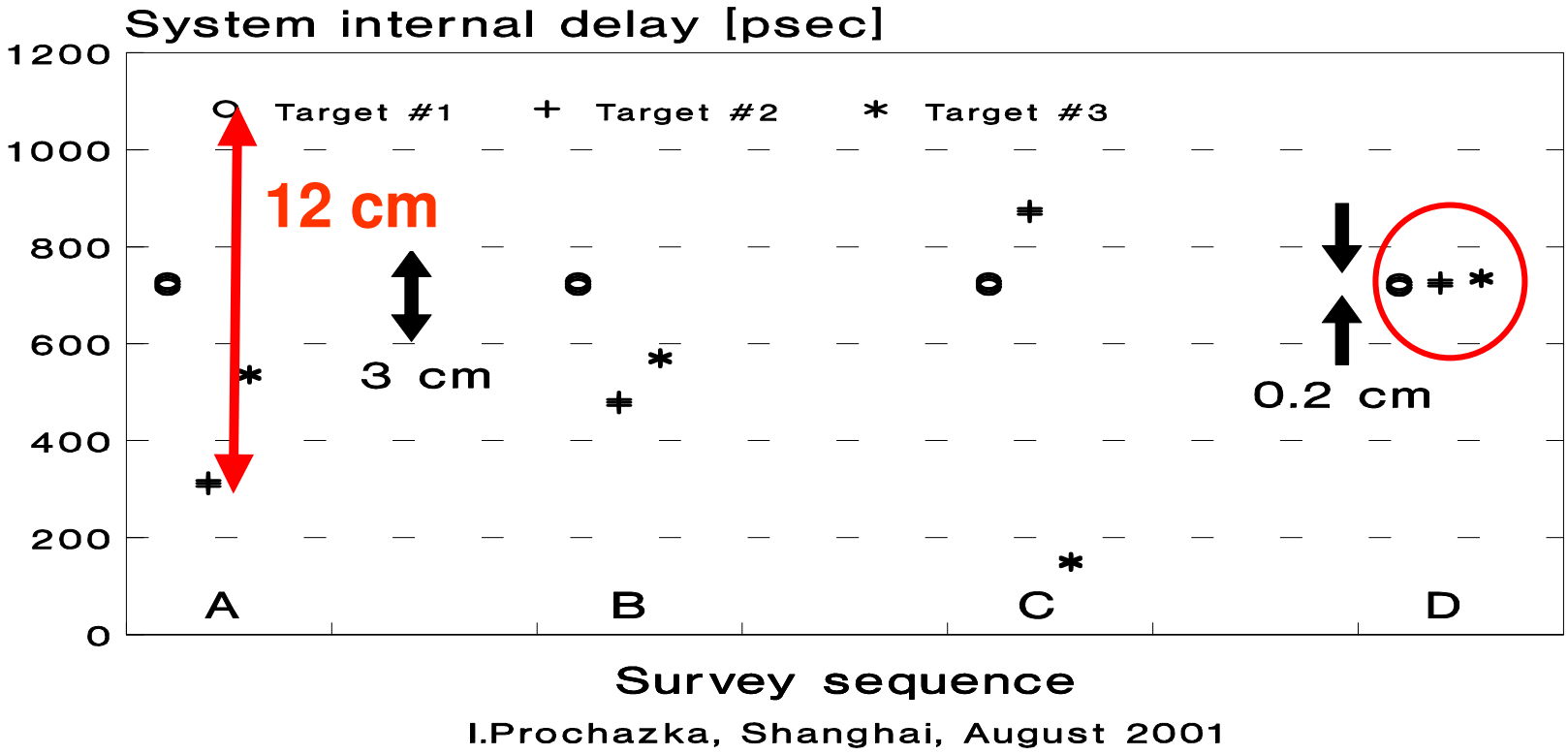
SR620 / P-PET Counter Linearity

Potsdam, 2001, LAGEOS pass



Graz	1997, ‘98, ‘99
Tokyo	1997
Changchun	1997
WLRS Wettzell	1997 / 99
TIGO Wettzell	1998
Zimmerwald	1998
Herstmonceux	1998
Potsdam	2001
Shanghai	2001,’04,’06

”Ranging machine” biases identification



The 3 cal. targets /hollow 2D retros/ have been re-surveyed and the calibration procedure tuned until the the system internal delay value consistency of 2 mm has been achieved.
The 2mm level was a precision limit for the system

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Recommendations #1
SPAD based SLR system calibration

- Use optically correct calibration target(s)
  2D hollow retro recommended for separate T/R
- Use efficient spatial filtering
  small FoV suppresses spurious reflections
- Ensure perfect alignment of the SPAD optics
  star tracking / scanning is a good check
- Use multiple targets at different az and range
  check the system delay consistency
- Open gate early enough
  50 ns for SPAD, 100 ns for C-SPAD
- Keep appropriate echo data rate
  < 10 % for SPAD, < 80% for C-SPAD
- Identify correctly the echo data rate

Recommendations #2
SPAD based SLR system calibration

- Calibrate frequently, always pre-post series.
- Collect sufficient No. of echoes / series
  see Time deviation
- Plot the data distribution + Gauss fit
  check for anomalies in distribution
- Keep record of results, compare each result to the history, identify sudden changes, jumps…

SPIE Florence 1999

- Re – survey periodically the targets geometry and local ties
- **Permanently try to identify new (possible) bias sources**

Conclusion

- The SLR performance precision & accuracy is steadily improving
- Sub-mm precision limit and ~mm accuracy is achievable
- all the error contributors have to be properly characterized
- There is no one rule suitable for all the station configurations
- The permanent effort of stations is inevitable to keep accuracy increase
- Thanks for your attention