

Portable Calibration Standard for SLR Capabilities

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Goals

- Creating the tool for SLR systems inter-comparison and standardization
- Satellite Laser Ranging machine diagnostics, identification of error sources due to :
 - epoch and time interval timing
 - epoch and frequency reference
 - data acquisition, filtering and processing
 - calibration scheme and ground survey
 - operational procedures
 - radio frequency interference
 - other sources (?)

Philosophy

- high degree of **redundancy**
- based on top **quality and certified** hardware
- **independent** on SLR under test
 - signal processing and cabling
 - grounding, power line, RF shielding
 - timing (time interval, epoch)
 - calibration targets and ground survey
 - data acquisition and data processing
 - staff
- operated **in parallel to existing SLR**
- **easy to re-locate** (personal luggage)

Portable Calibration Standard for SLR Capabilities

Block Scheme

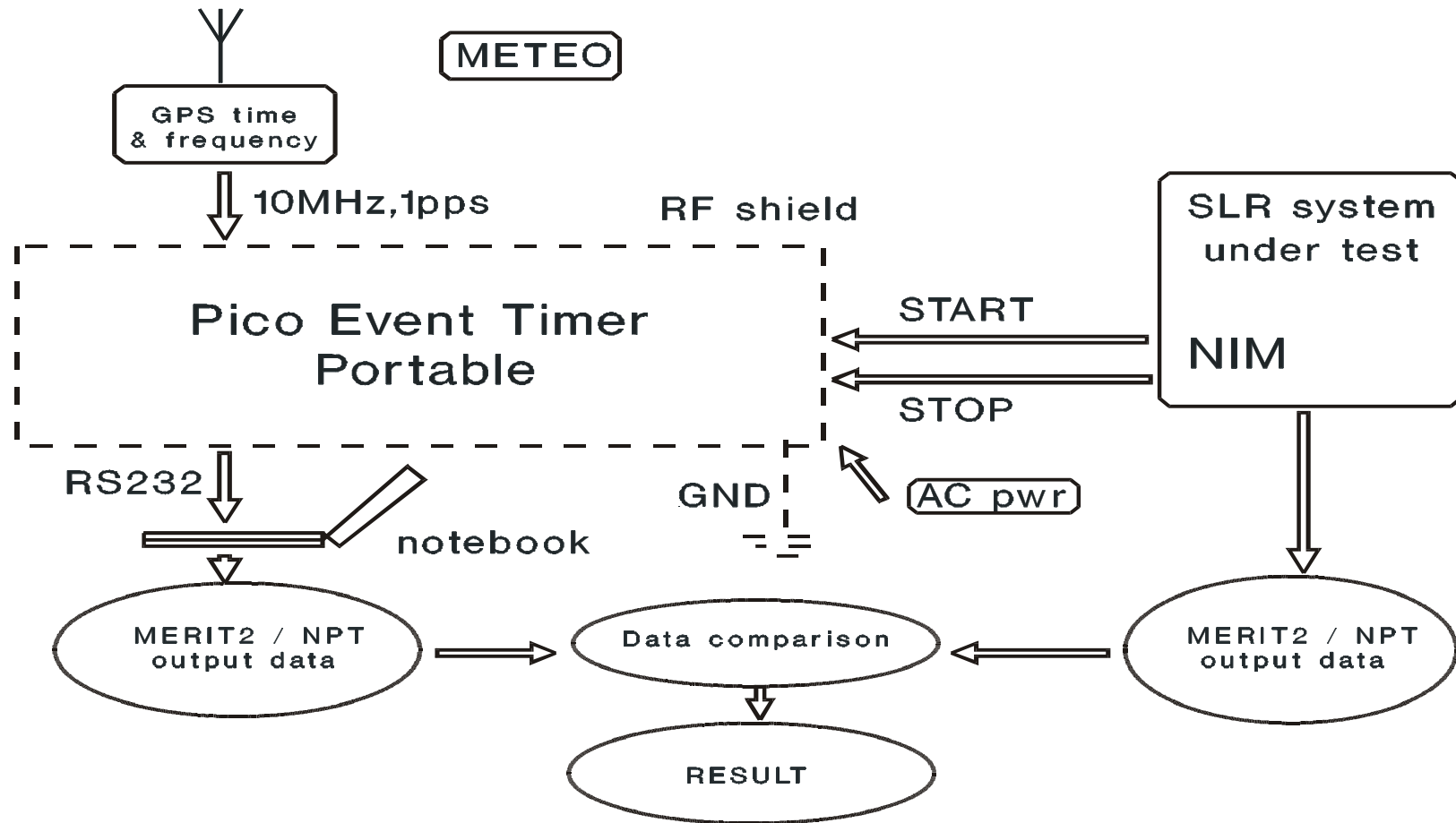


Figure 1: Portable Calibration Standard block scheme

Portable Calibration Standard for SLR Capabilities

Pico Event Timer Portable Calibration Standard



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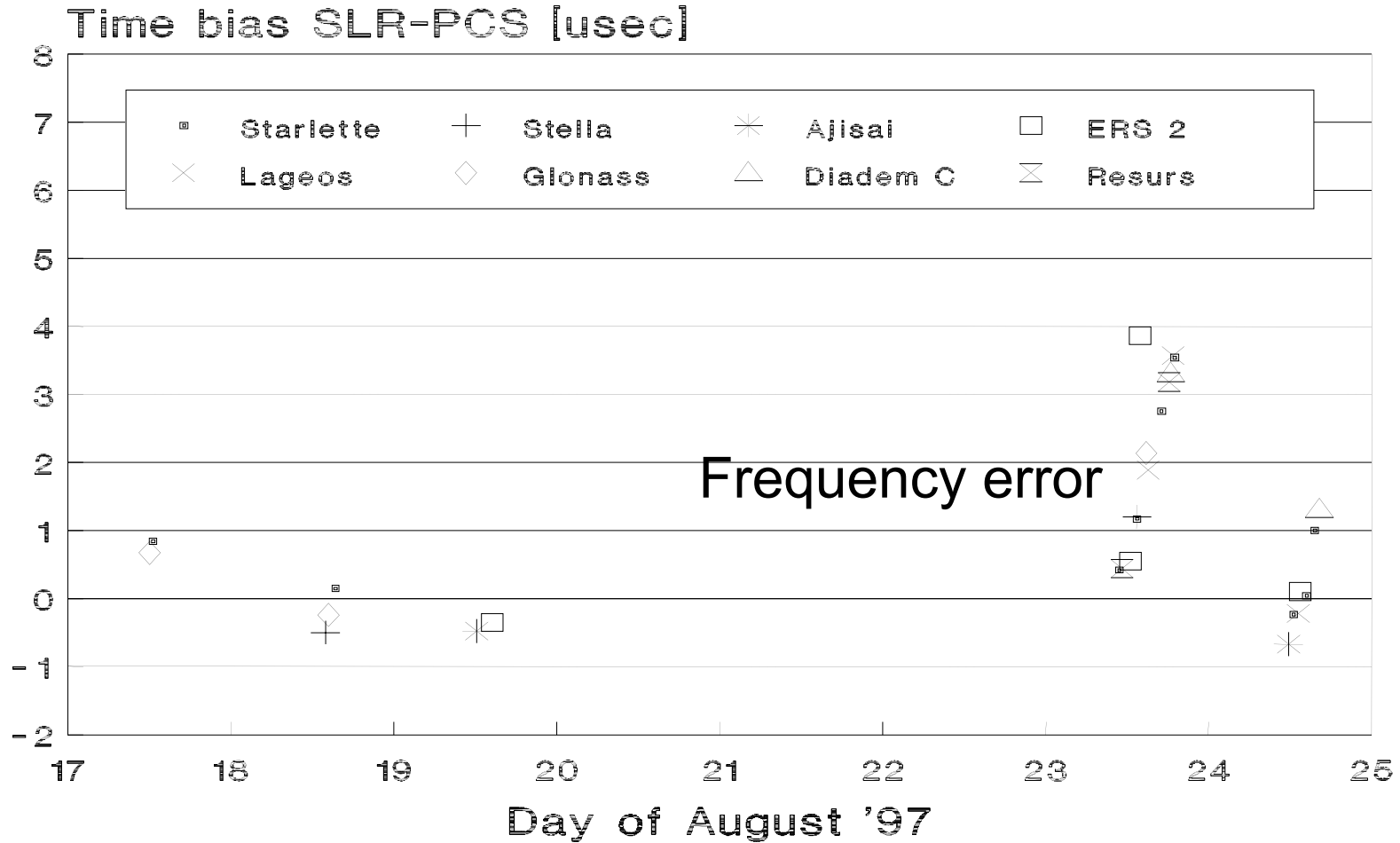
PCS Capabilities - Comparison

Systematic error source	collocation	Portable Calibration Standard
frequency and epoch	yes	yes
mount eccentricity	yes	partially
correlated RF noise	yes	partially
instrumental errors	yes	yes
stability	yes	yes
echo signal strength	yes	yes
data processing	yes	yes
operator errors	yes	yes
shot by shot comparison	no	yes
atmospheric data	yes	yes
experiment complexity and costs	> 10	1
time frame	> 10	1

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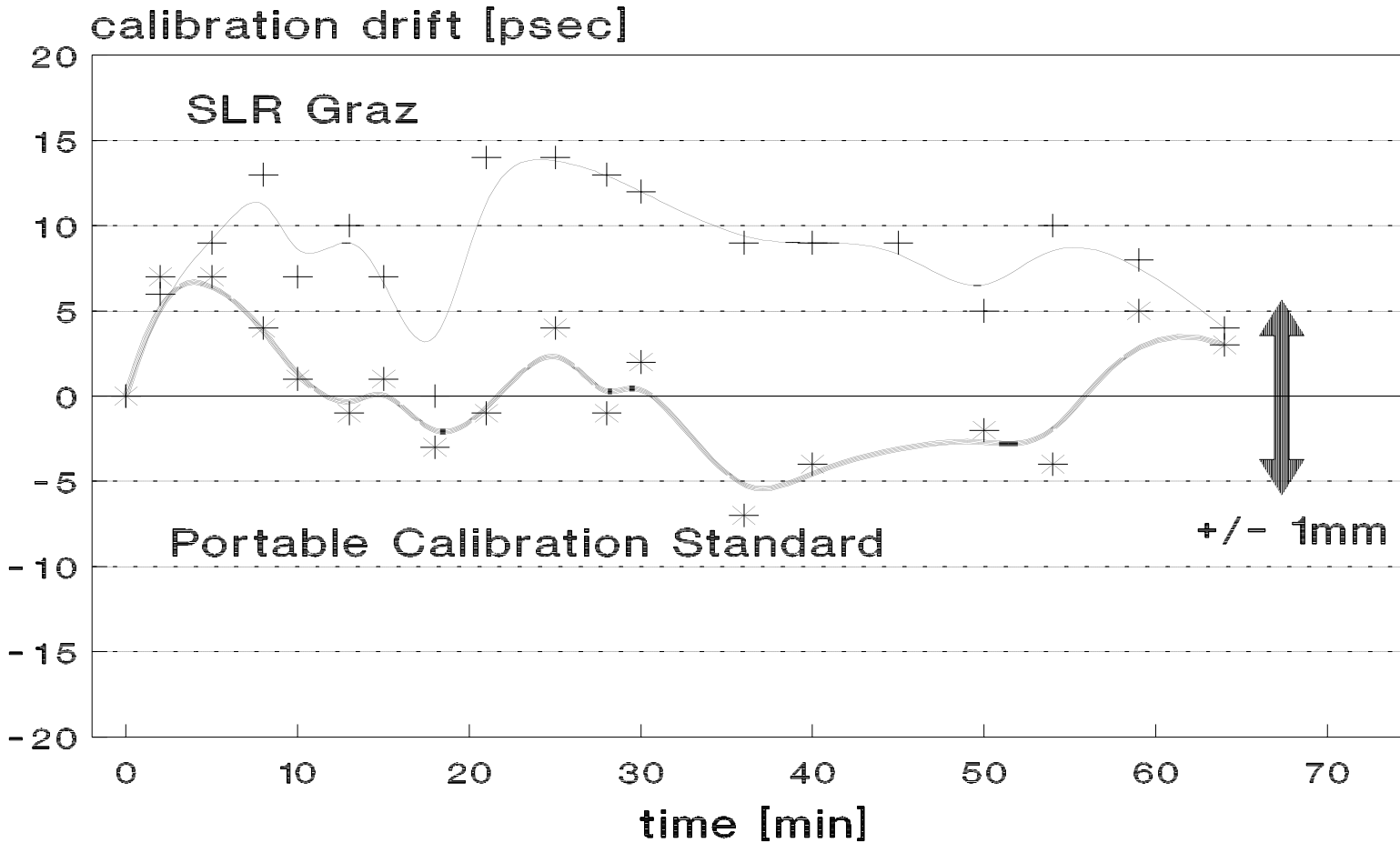
PCS (1G) in Changchun, Time Bias



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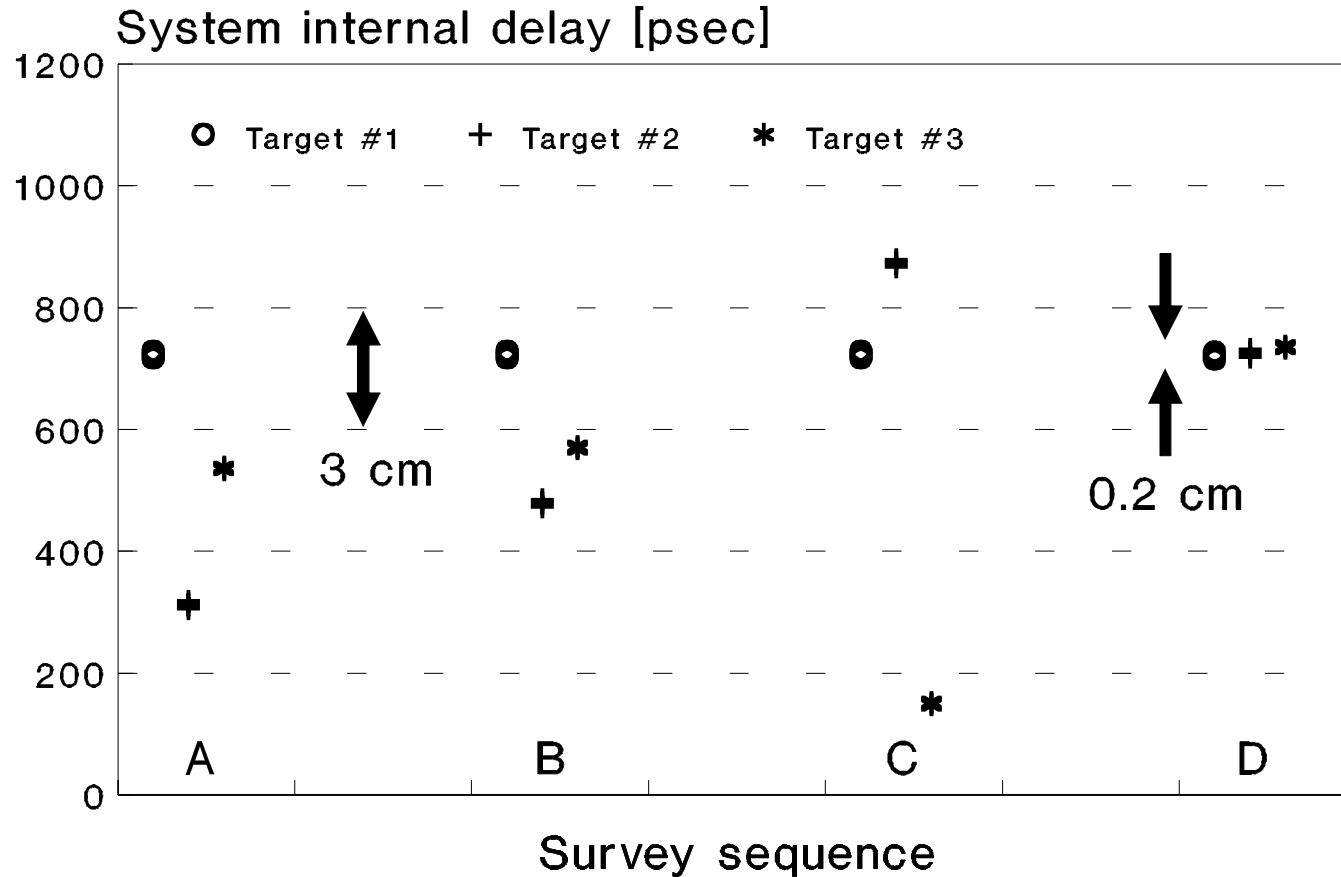
P-PET in Graz, Calibration Stability



Kirchner, Koidl, Hamal, Prochazka, Graz 97

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Ground target calibration / survey
P-PET st SLR Shanghai



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P-PET Results Summary, Shanghai 2001

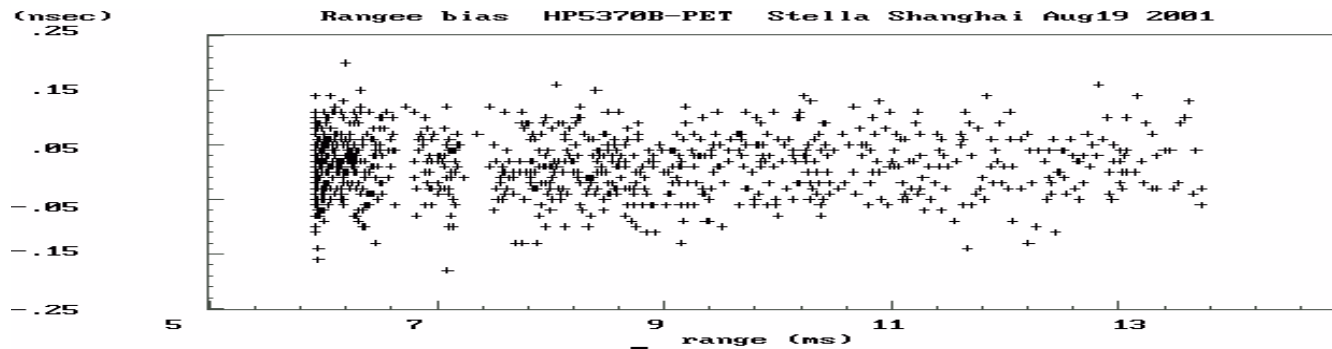
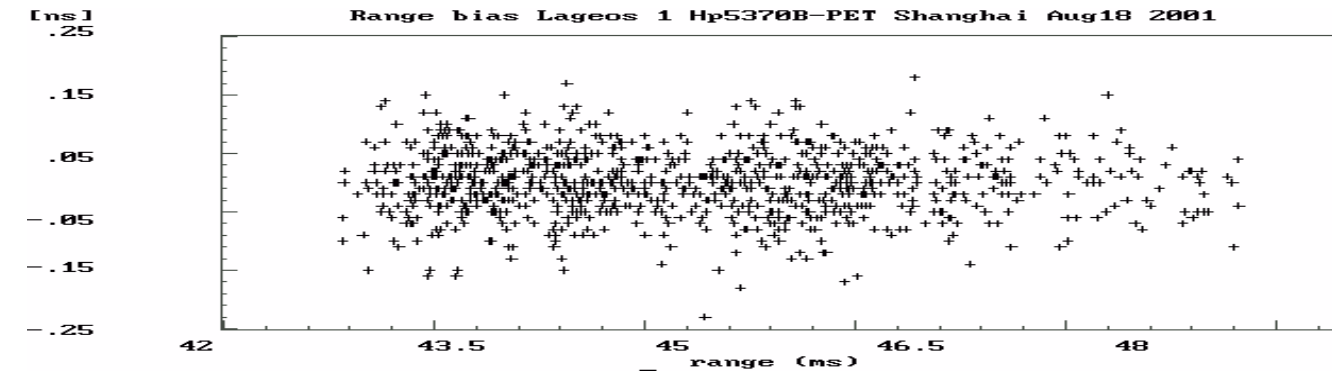
Satellite	P-PET rms (mm)	SLR rms (mm)	Time bias (us)	Rng. bias (ns)
Starlette	7.5	12.7	0.1	0.02
Beacon-C	9.3	13.8	0.1	0.00
Ajisai	10.9	15.9	0.1	0.00
Lageos 2	10.5	17.3	0.1	-0.01
Starlette	9.0	15.1	0.1	0.03
Lageos 1	8.5	14.2	0.1	0.01
Beacon C	19.2	19.7	0.1	0.02
Topex	22.4	35	0.1	0.00
Topex	4.9	10.8	0.1	0.00
Lageos 1	7.0	13.5	0.1	0.00
Stella	6.1	12.4	0.1	0.00
Beacon C	10.0	16.1	0.1	0.00
Starlette	8.4	12.9	0.1	0.01
Westpac	--	16.6	0.1	0.03
Lageos 2	8.5	16.1	0.1	0.00
Stella	4.8	11.5	0.1	0.00
ERS-2	4.0	10.5	0.1	0.01
mean			0.1	0.01

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HP5370B / P-PET Counter Linearity

Shanghai, 2001, Lageos (up), Starlette



No significant dependence identified

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P-PET at Shanghai 2001, Conclusion

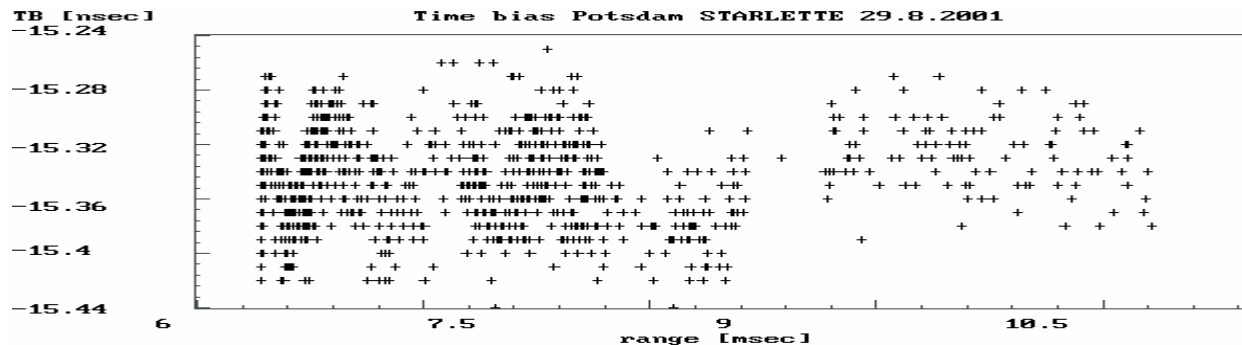
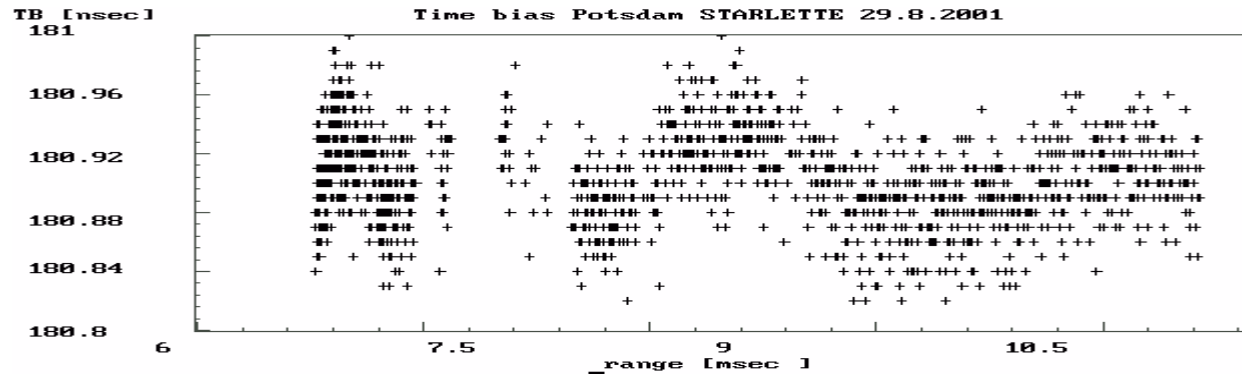
- SLR rms reduction down to 4.0 and 8 mm from original 10 and 14 mm for ERS-2 and Lageos, respectively, 2.5 sigma rejection
- time and range biases below the resolution limit 0.1 usec and 2 mm respectively
- three ground targets calibration consistency within +/- 2mm (final set-up)
- routine SLR calibration procedure problem identified and solved

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SR620 / P-PET Counter Linearity

Potsdam, 29.8.2001, Starlette satellite passes



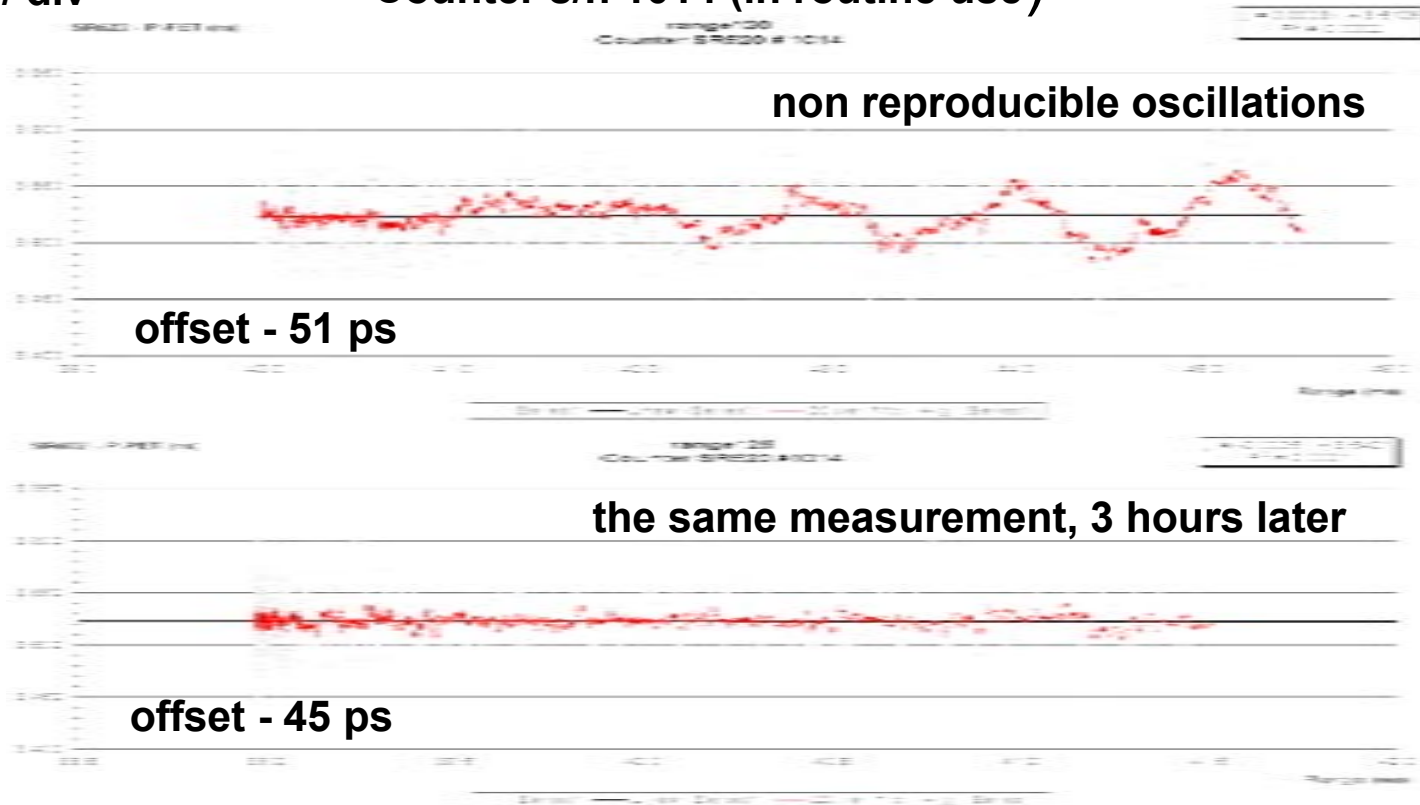
**Peak to peak 130 psec within 6-12 msec
not reproducible**

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SR620 / P-PET Counter Linearity
Potsdam, 2001, LAGEOS pass

50 ps / div

Counter s/n 1014 (in routine use)



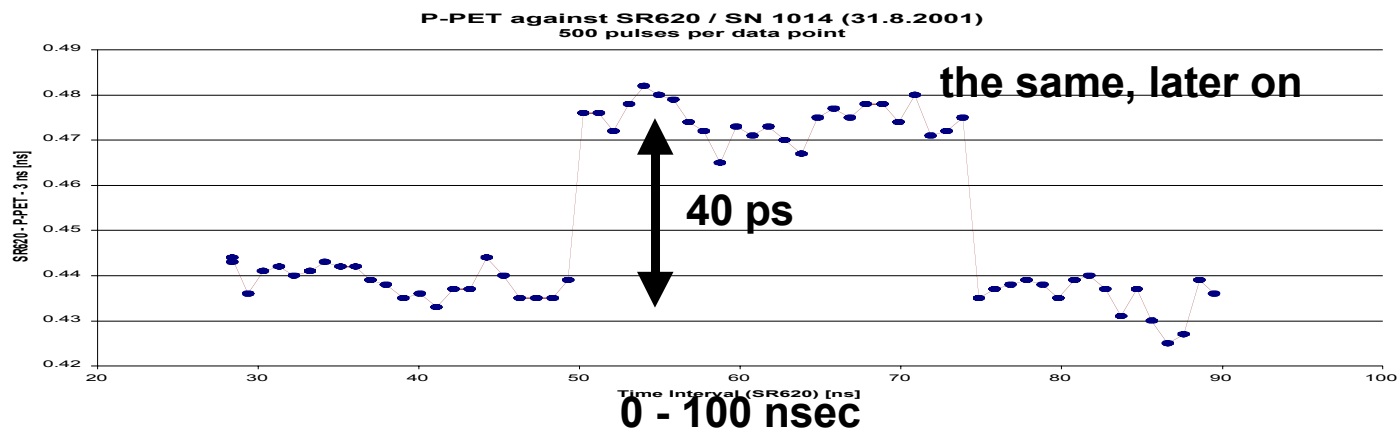
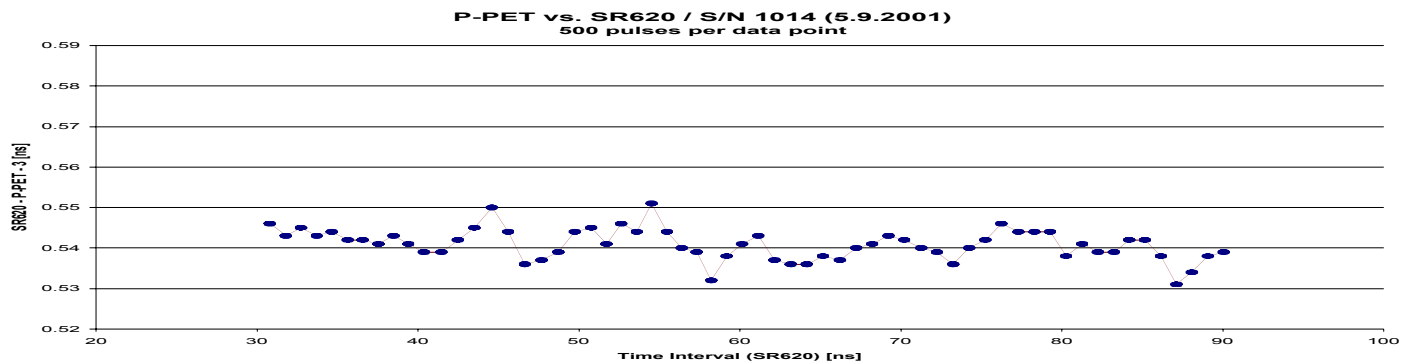
L. Grunwald, R. Neubert, H. Fischer, H. Pino, Potsdam, 2001

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Portable Calibration Standard for SLR Capabilities
SR620 / P-PET Counter Linearity
Potsdam, 2001, Short times

Counter s/n 1014 (in routine use)

10 ps / div



L. Grunwald, R. Neubert, H. Fischer, H. Pino, Potsdam, 2001

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P-PET at Potsdam SLR SR620 counters test - Summary

- counter reading jumps of 40 psec
random, not reproducible
- oscillations 50 psec amplitude, period ~ 60 sec
not correlated
- offset 20-50 psec between the nanoseconds
(calibration) and milliseconds (SLR) ranges

=> SYSTEMATIC ERRORS 45-80 psec

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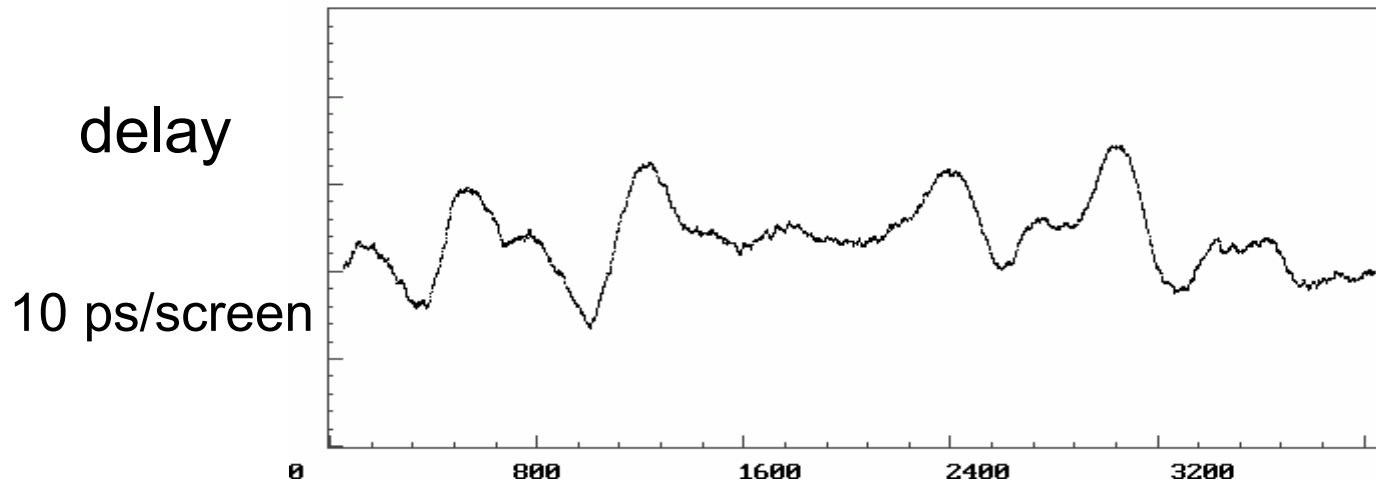


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P-PET timing linearity test

Internal self test



TDC channel No,

Cable delay timing test,

measured time interval Start=>Stop versus Start TDC channel No
moving average, 100/10 k readings

P-PET2 linearity error < +/- 2.8 ps

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P-PET Parameters Upgrade

	London 97 =>	Wash 2002
•		
• timing resolution	1.2 ps	
• timing jitter / channel	5 ps	2.5 ps
• non-linearity / channel	< 5 ps (spec)	< 2.5 ps (meas)
• temperature drift	< 0.7 ps/K	< 0.53 ps/K
• temperature time const.		90 minutes
• temporal stability	+/- 1.0 ps/hr	+/- 0.45 ps/hr
• max. repetition rate	30 Hz	100 Hz, 2MHz sampl
• No. of channels	2(4)	
• interface	RS232	
• mass transport	32 kg	

Conclusion

- Portable Calibration Standard based on a Pico Event Timer is a powerful tool to identify systematic error sources in the SLR “ranging machine”
- the entire system is compact, easy to transport fast to install and user friendly to operate, the calibration mission can be accomplished within one week time slot,
- P-PET mission to SLR sites did trigger several projects
 - WLRS (1998), TIGO(1999), Graz (2000) timing systems upgrade
 - European millimeter SLR joint activity (2002),
 - Herstmonceux Workshop (2002)