New SPAD detector package for SLR and laser time transfer

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Outline

- Why new SPAD detector(s) ?

- Detector parameters requirements

- Detector design construction

- Key parameters
  - timing resolution
  - timing drift
  - dark count rate
  - single – multiple photon response

- Summary & Conclusion

Why new SPAD detector(s) ?
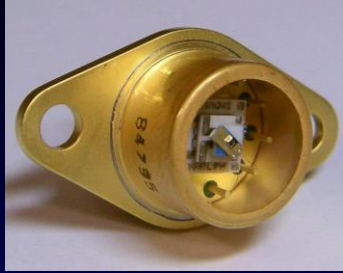
 # 1
The supply of TE3 cooled 200um diameter chips
is approaching zero   ☹

#2
New applications , namely Laser Time Transfer
<u>require extremely high timing stability ~ 100 fs</u>

#3
New wavelengths (1064nm, 1540 nm,…)
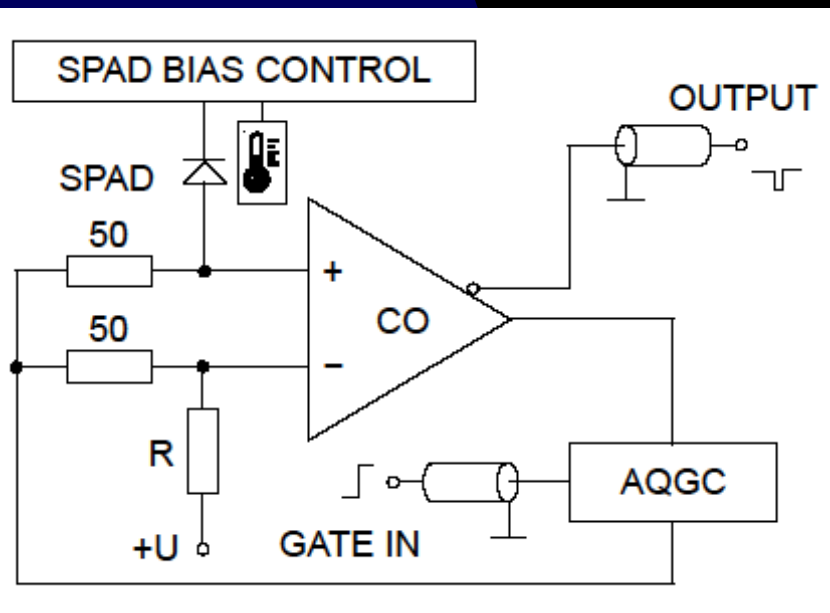see our poster

New SPAD detector package

- K14 SPAD chips 100um diameter

- AVAILABLE

- TE1 cooling, NO temperature sensor (!!)

- New active quenching and gating circuit
  Analogy to ELT+ space segment

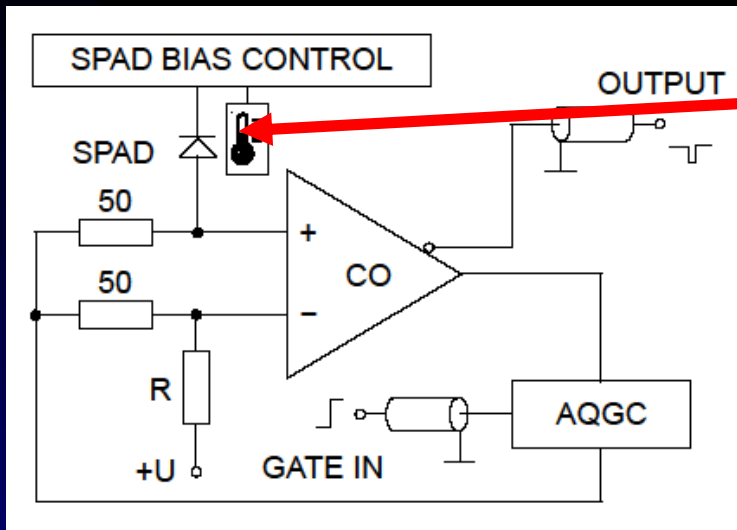- Very simple, compact, space qualified

- SPAD max 2.5 Volts above ☹

- Optimized for high temperature stability
  Rev.of Sci.Instruments 87, 056102 (2016);

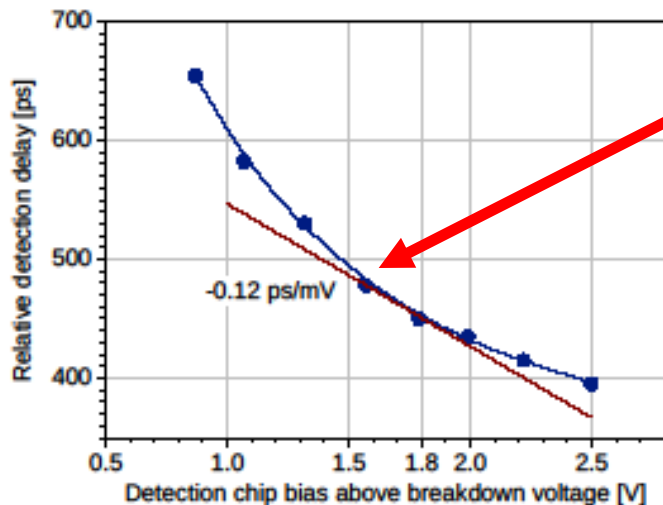# Passive compensation of temperature delay dependence

Built in SPAD bias control circuit
is adjusting bias above break versus temp.
and also tunes detection delay

☐ Key components (SPAD, comparator)
<u>positive temperature coefficient</u> ~ 1 ps/K

☐ SPAD chip detection delay vers. bias
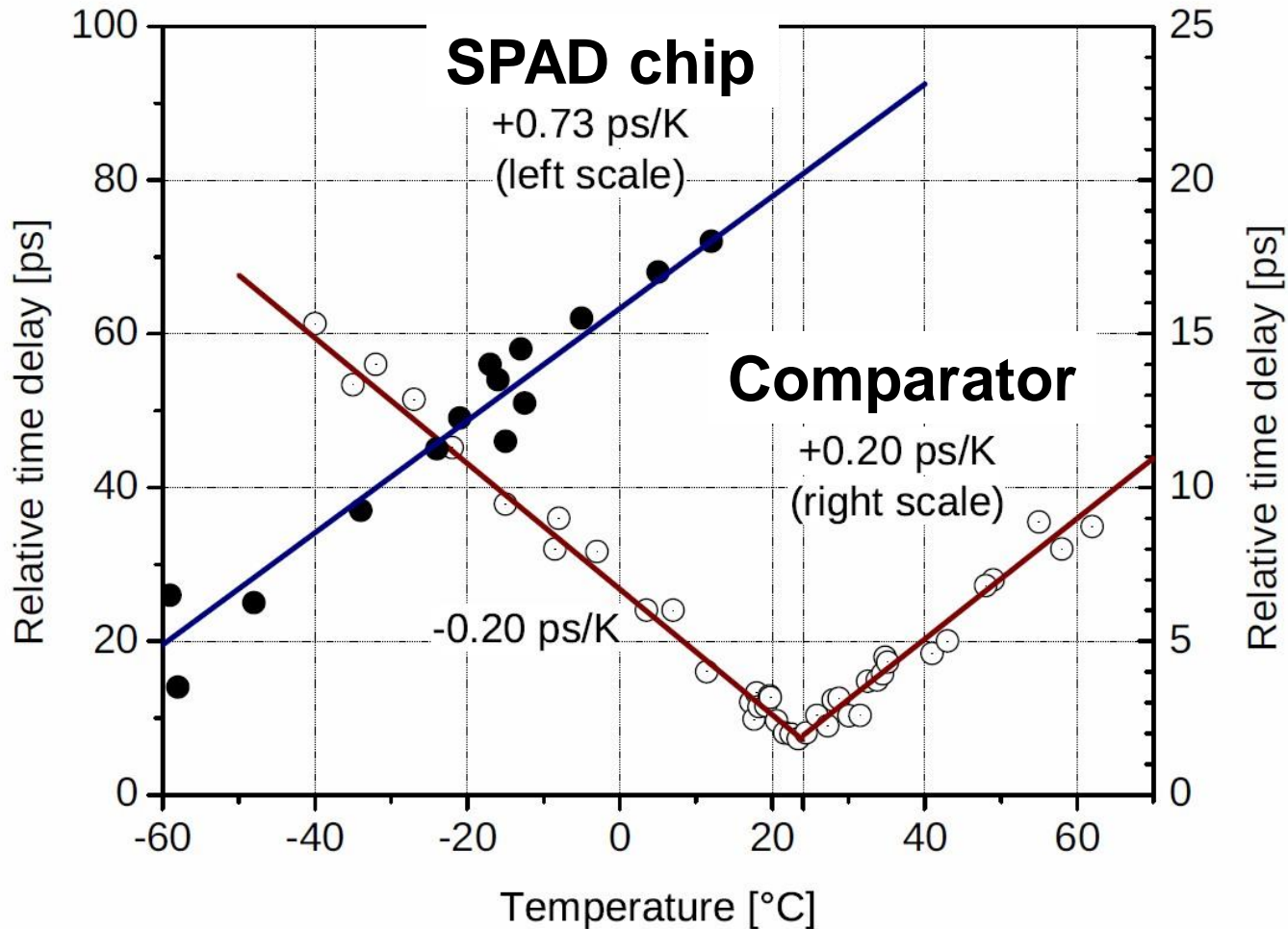<u>coefficient is negative</u> -0.12 ps / mV

☐ SPAD bias control may compensate all the
(smooth !) temperature contributors.

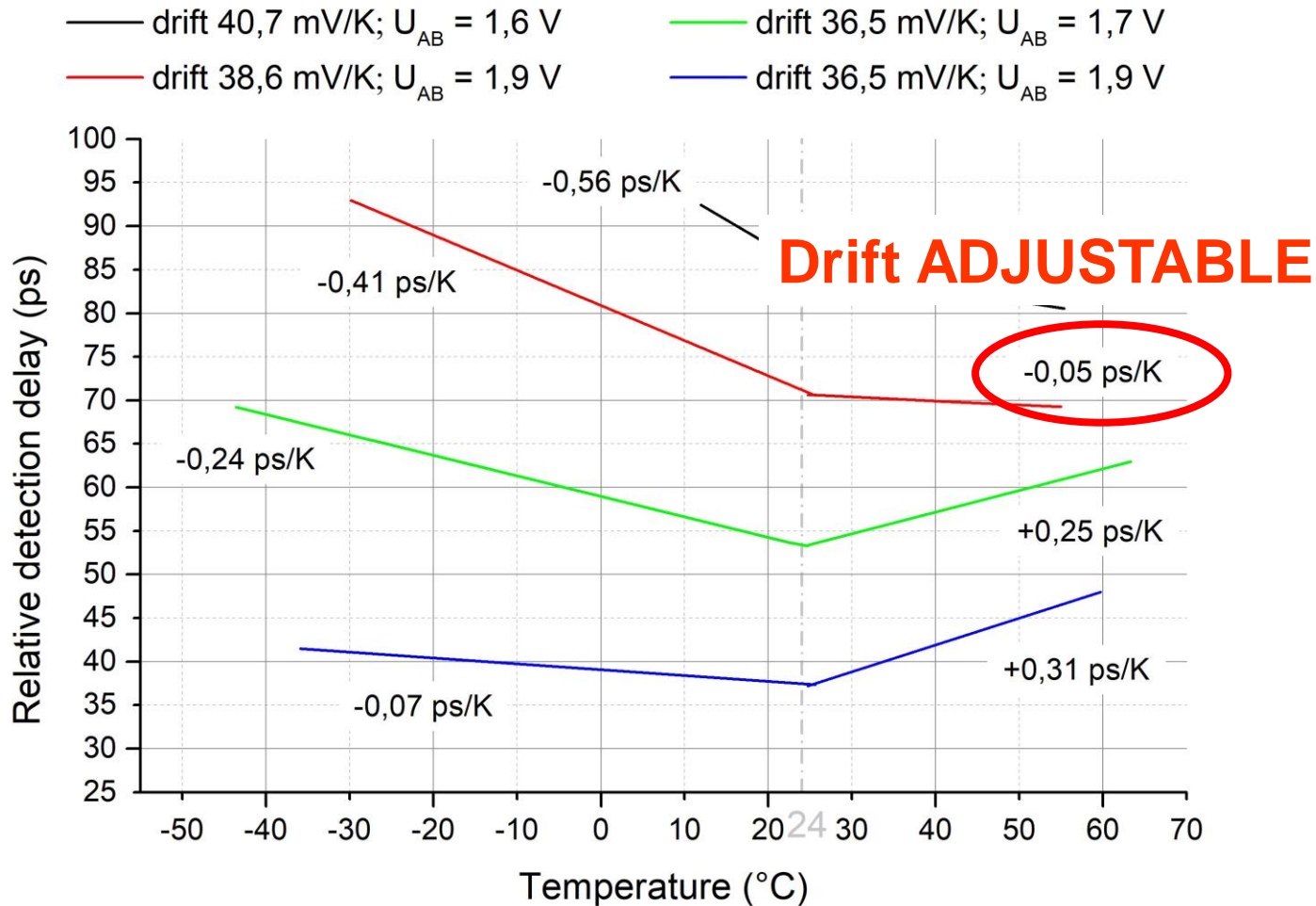*Rev.of Sci. Instruments **89**, 056106 (2018)*

New SPAD detector package
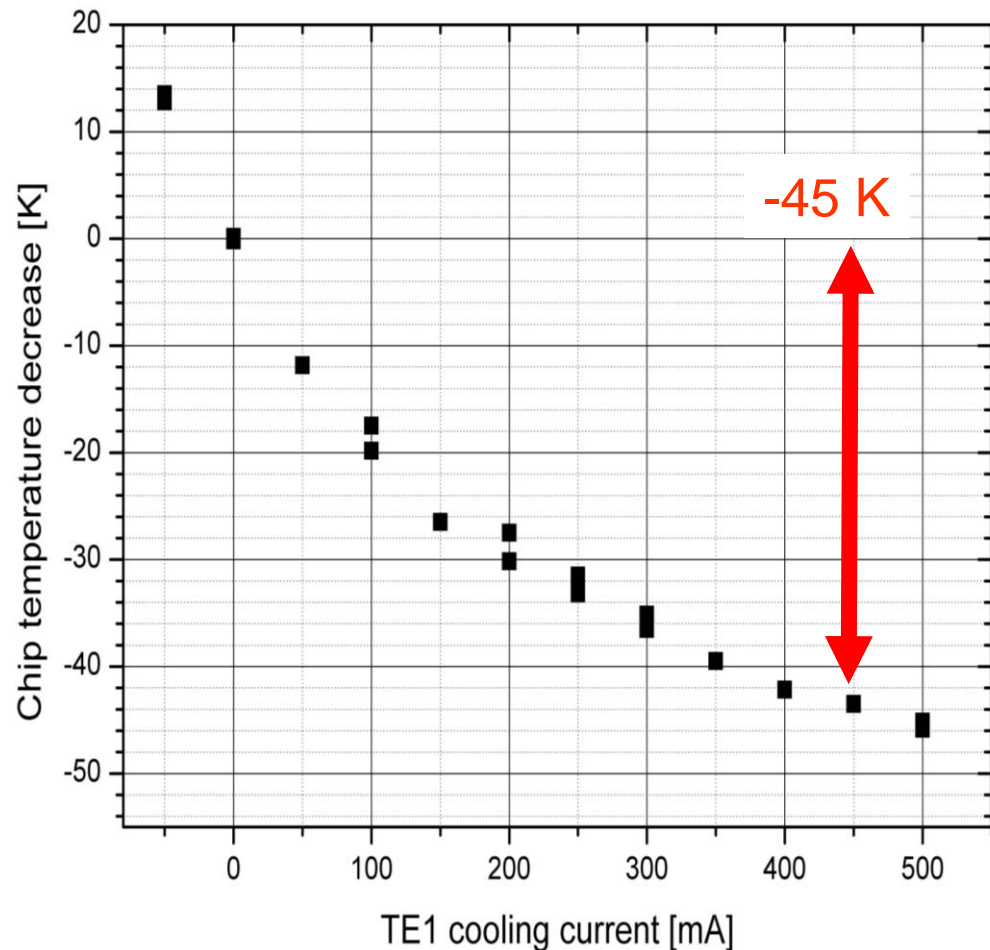# Passive compensation of temperature delay dependence

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New SPAD detector package
Passive compensation of temperature delay dependence

SPAD Detection delay

—— drift 40,7 mV/K; U_{AB} = 1,6 V   —— drift 36,5 mV/K; U_{AB} = 1,7 V

—— drift 38,6 mV/K; U_{AB} = 1,9 V   —— drift 36,5 mV/K; U_{AB} = 1,9 V

-0,56 ps/K

Drift ADJUSTABLE

-0,41 ps/K

-0,05 ps/K

-0,24 ps/K

+0,25 ps/K

-0,07 ps/K

+0,31 ps/K

Relative detection delay (ps)

Temperature (°C)

Thermoelectric cooling TE1 of SPAD chip
## PROBLEM – No temperature sensor inside

- No chance to stabilize the chip temperature

- Stabilize the cooling current
  => fixed temperature step

- Compensate the detection delay of the entire device by its body temperature (hot side of TE1)

- It works (!)
  Delay stability is OK

- BUT the detector is more noisy in summer time ☺

Dark count rate

Effective dark count rate TE1 SPAD 100um 2V ab

+ 25 °C

Range gate width 2 us

DCR [MHz] vs Gate rate [kHz]
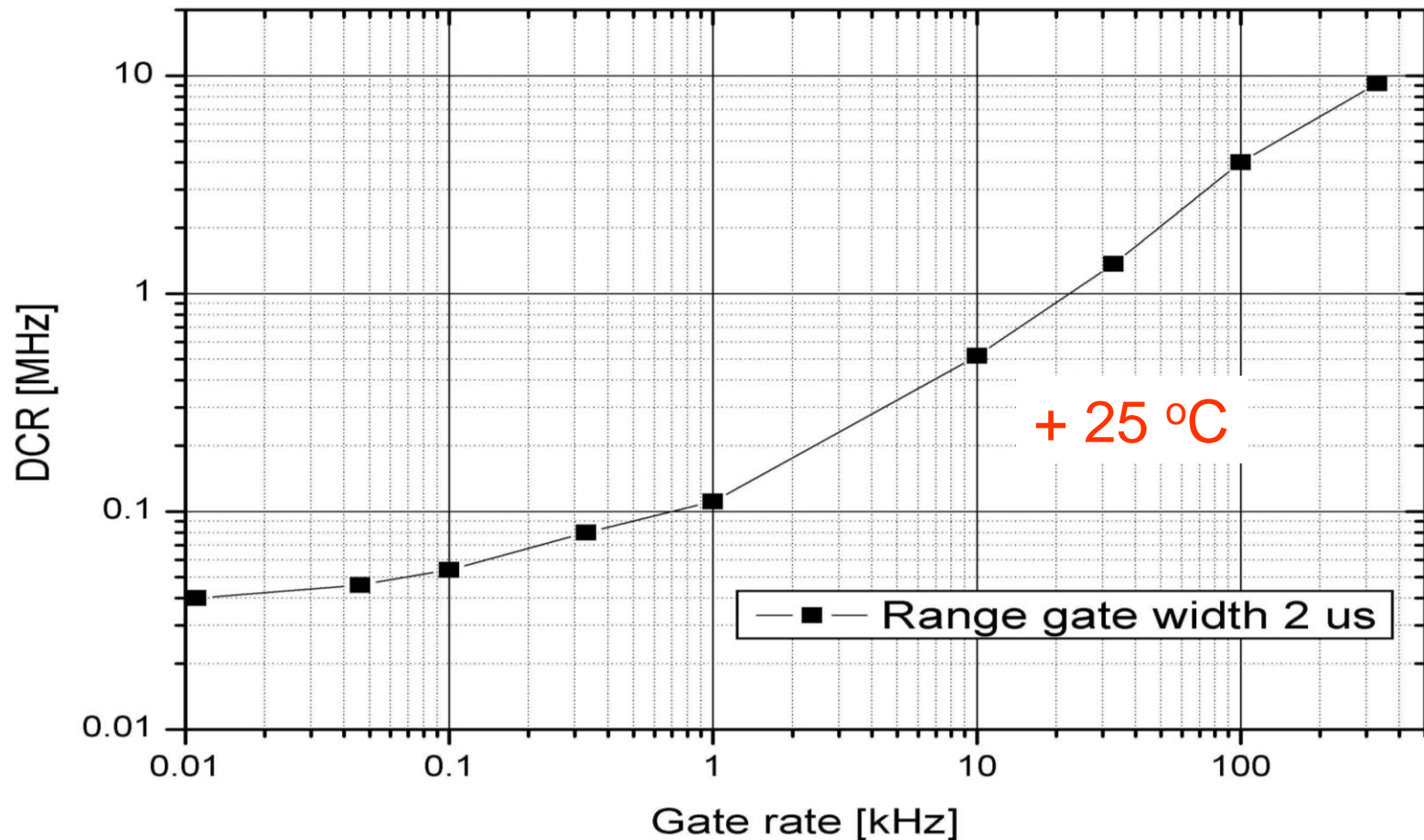
- New gating logic, Terminate the windows
- Worst case estimate, rather noisy test chip

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Detection delay stability TE1

SPAD100um 2.5Vab Start NPET2 400Hz 10%

moving average 1000s

delay [ps]

+/- 500 fs @ day
complete loop

hours after Power ON ; Oct.17 2018

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Detection delay stability TE1

Response to multiphoton echoes
C-SPAD operation of 100um chip is difficult
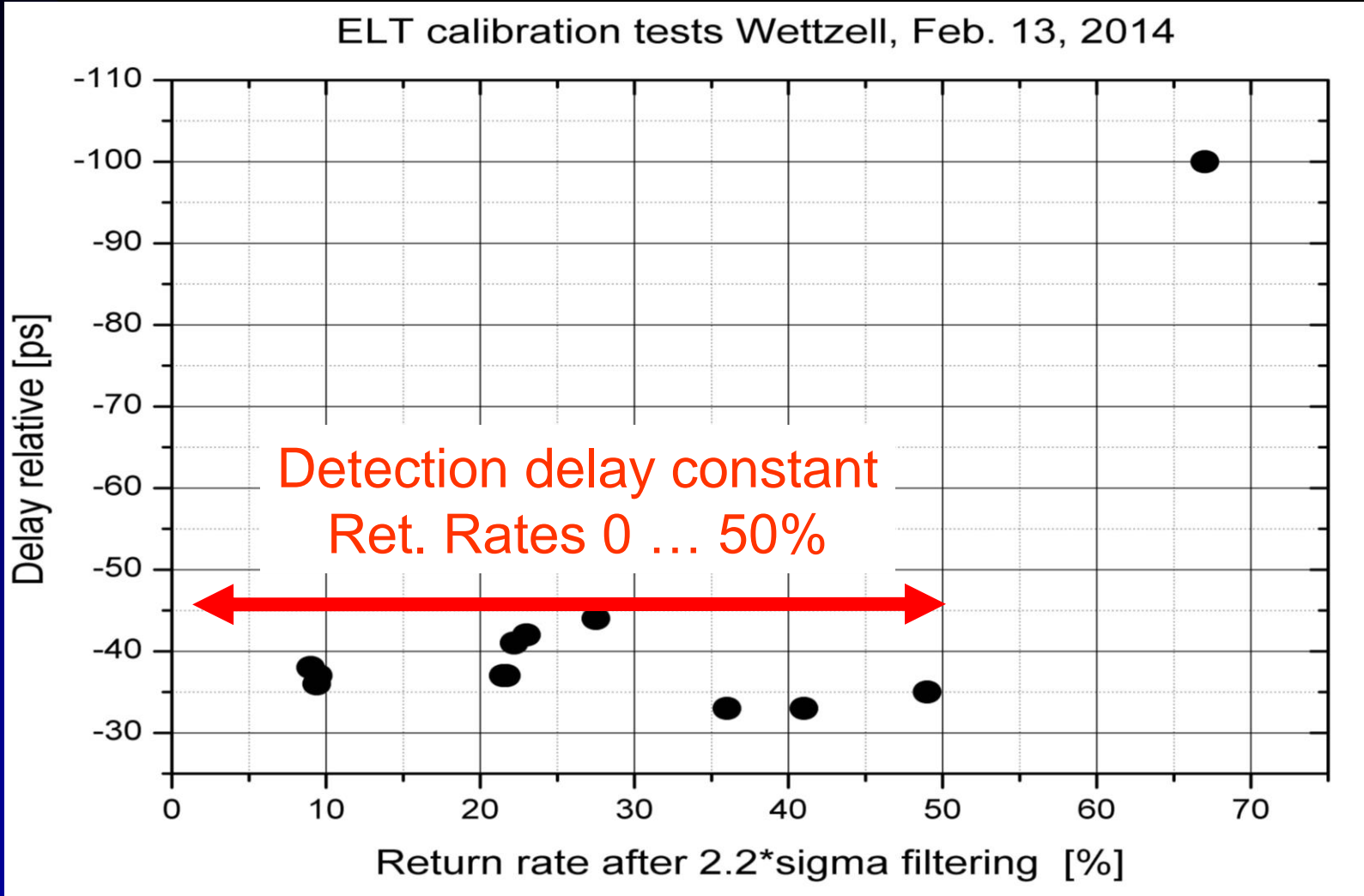
ELT calibration tests Wettzell, Feb. 13, 2014

Detection delay constant
Ret. Rates 0 … 50%

New SPAD detector package 100um TE1

- Standard SPAD housing, compact power supply
- New aspheric lens collecting optics, 12 mm diam.beam
- Standard Gate and output signals
- 1 : 1 replaceable with C-SPAD and/or HQE SPAD pack.

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SUMMARY
New SPAD detector package 100um TE1
Passive compensation of temperature delay dependence

- Detector package for SLR and laser time transfer optimized for high detection delay stability

- PARAMETERS
  - Active area   100 um diameter
  - Photon det. Effi.   > 35 % @ 532 nm
  - Jitter   < 18 ps rms
  - Temp.drift   tunable, abs.< 250 fs /K
  - Stability   < 100 fs @ hours

- Few photons / echo data rate up to 50% are acceptable for ideal targets and LTT

- Thanks for your attention