

# SIGNAL STRENGTH MONITOR FOR C-SPAD RECEIVER

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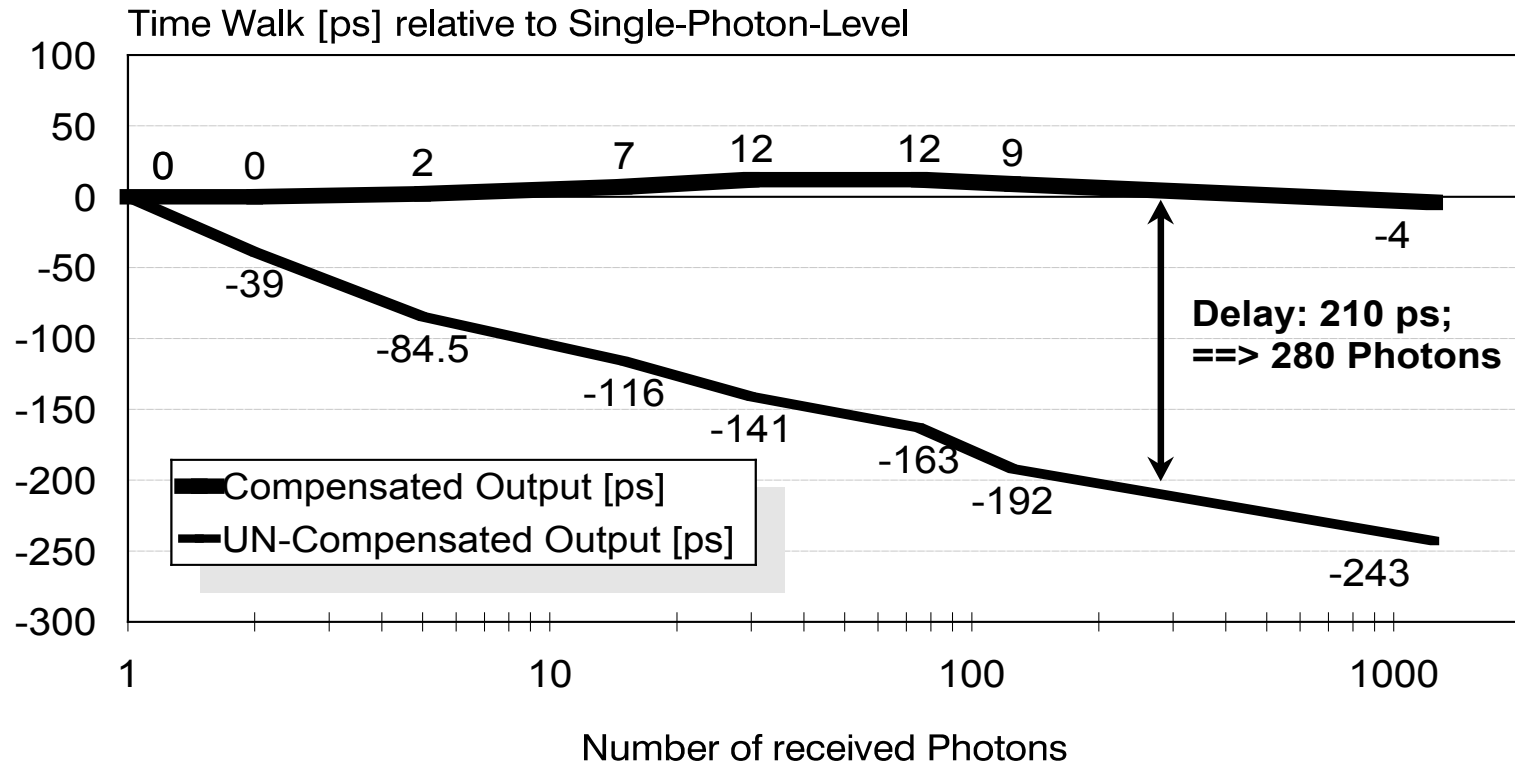
Czech Technical University in Prague, Czech Republic

# Goals:

- to estimate the echo signal strength in laser ranging based on C-SPAD detector
- the SPAD chip current pulse risetime depends on photon number (*Kirchner, Koidl, 1995*)
- C-SPAD circuit provides two output timing pulses, their interval corresponds to the detected signal energy
- to construct the Time to Digital Converter to record the interval and hence the echo signal energy

# C-SPAD Detector Package # 0406

## Measured: Delay (Comp-Uncomp Output) with PPET



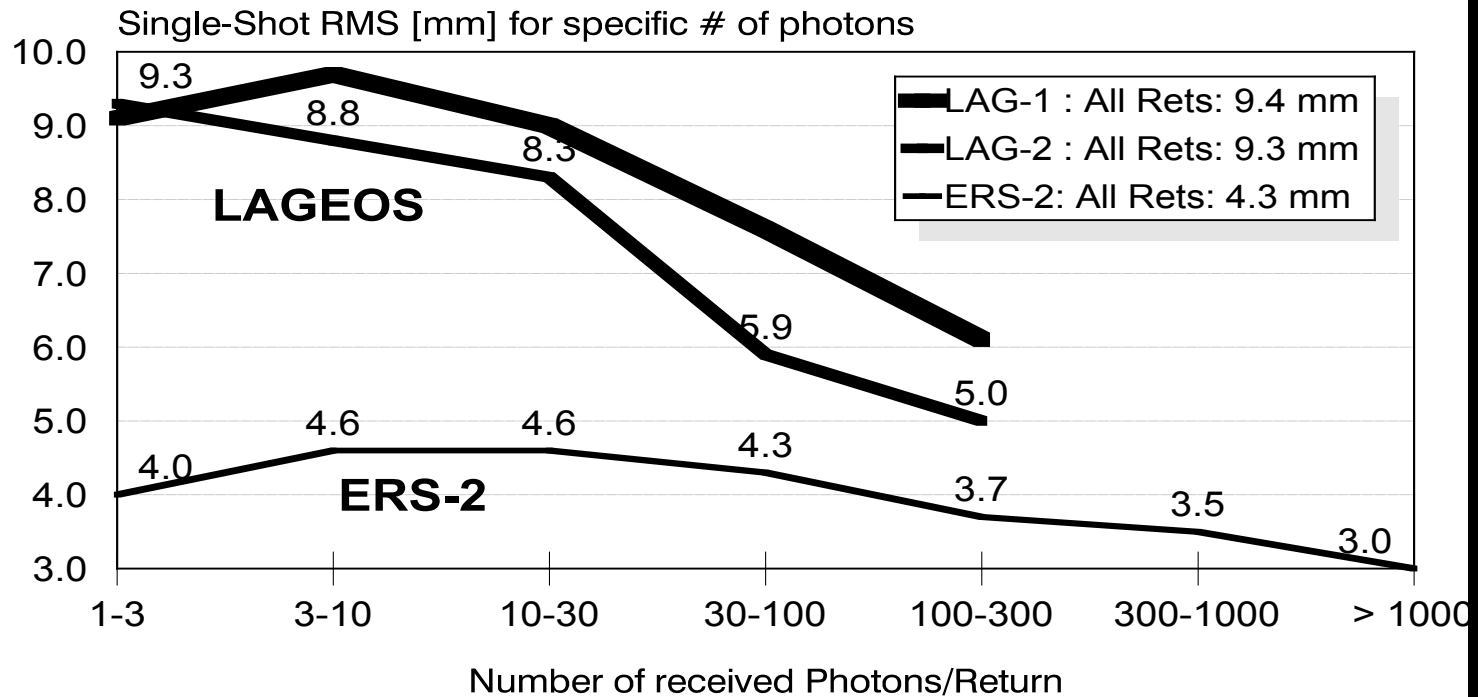
<Graz, 1998-08-26>

- avalanche build up time effect expanded by built-in circuit (*G.Kirchner, F.Koidl*)
- large data sets averaging

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# SLR with Photon Number Estimate

## RMS vs. Received # of Photons Rec. Energy: Meas. by PPET (Compens.Delay)



<Graz, 1998-09-11>

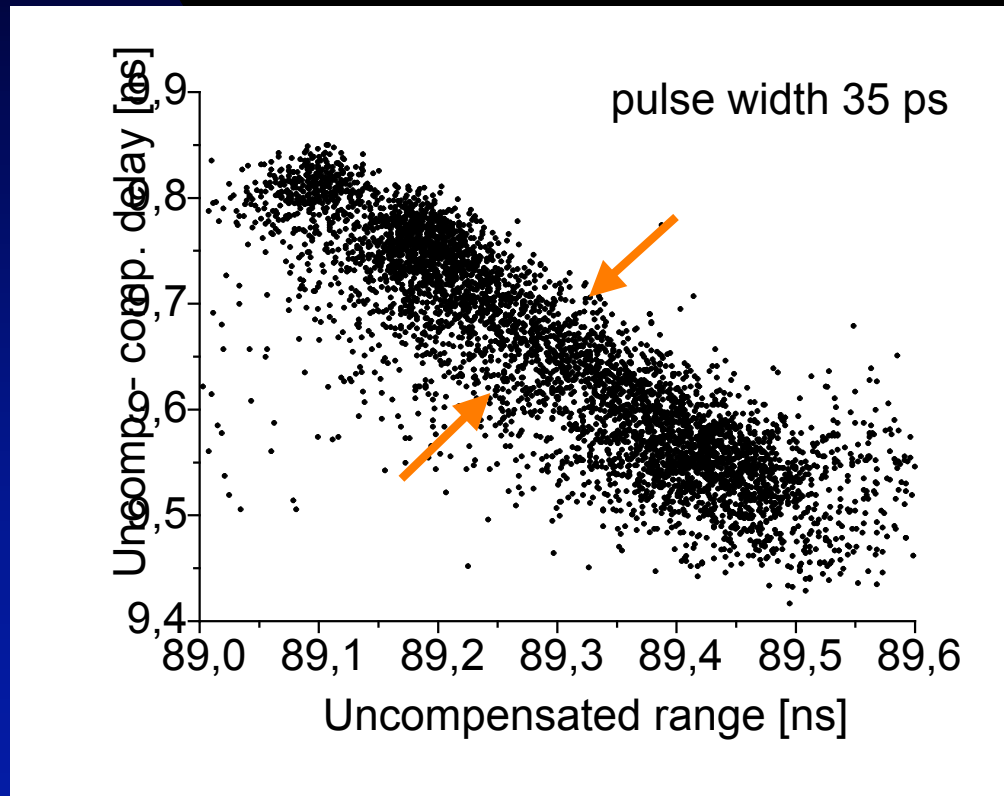
G. KIRCHNER<sup>1)</sup>, F. KOIDL<sup>1)</sup>, I. PROCHAZKA<sup>2)</sup>, K. HAMAL<sup>2)</sup>, 11th WLRI, Deggendorf, 1998

SLR data post processing, data averaging

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# Photo Number Estimate Indoor Calibration Tests

- compensated versus un-compensated output
- shot by shot data processing
- PET4 timing, NdYAG 32 ps @ 532 nm, indoor



- data spread  $\sim 50$  ps rms
- = > ultimate photon number resolution 3 x

J. Blazej et al, NIST-ARDA Workshop on Single Photon Detectors, NIST, Washington DC, 2003

1 PE 10 PE 100 PE 1000 PE

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# Time to Digital Converter for C-SPAD Based Energy Monitor

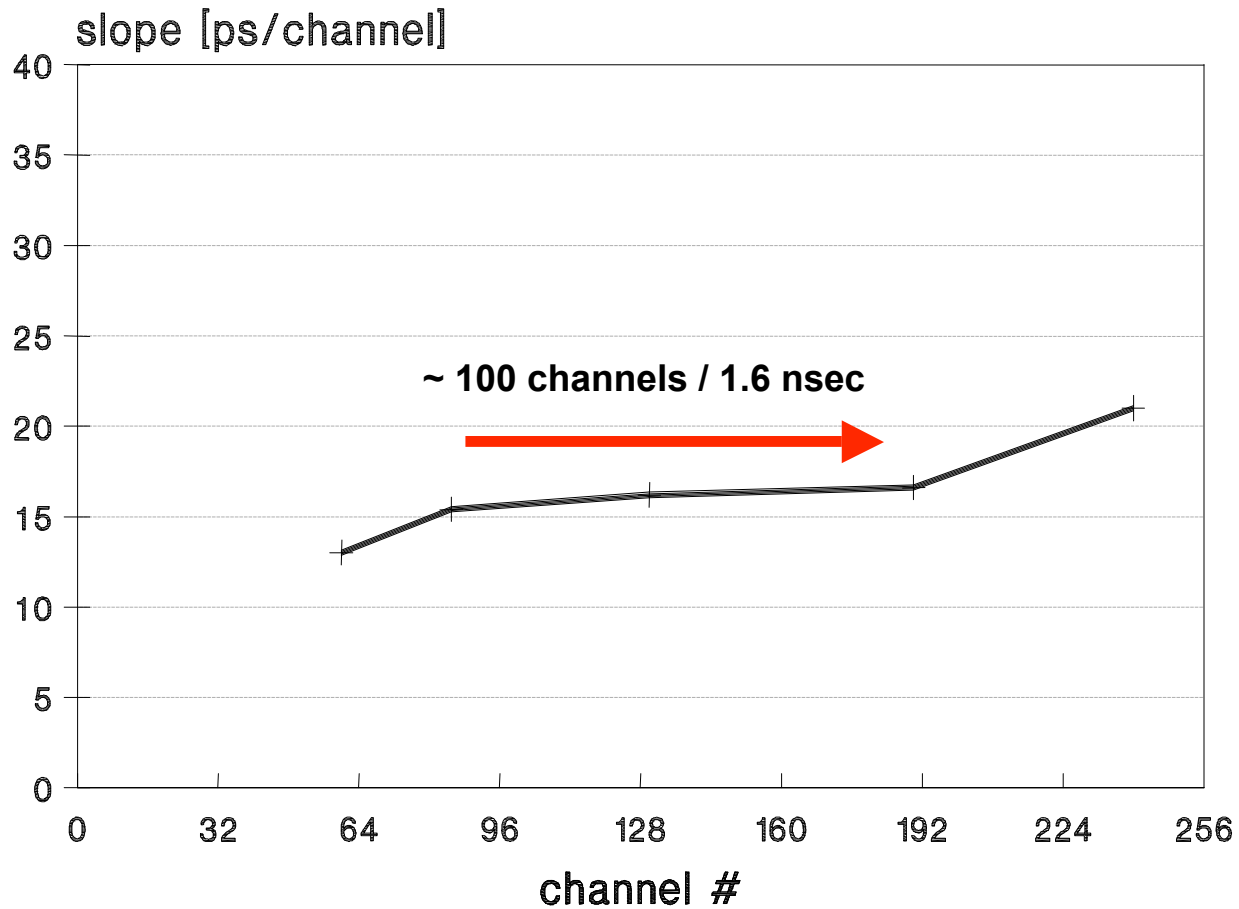
- REQUIREMENTS:

- resolution                      20 ps
- range                              8 bits / ~ 1.6 ns
- dead time                        < 400 us

- DESIGNED CIRCUIT

- time expander, capacitor charge / discharge
- expansion factor ~ 2000 x
- digital counter 30 / 15 ns on Programmable Gate Array

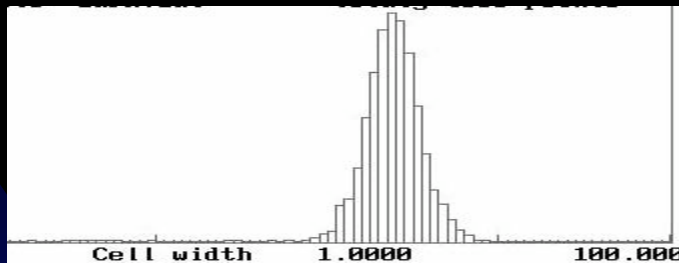
# Time to Digital Converter Calibration



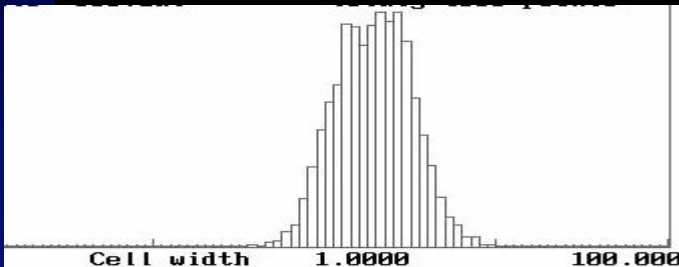
I.Prochazka, May 25, 2004

# Indoor Laser Ranging Test

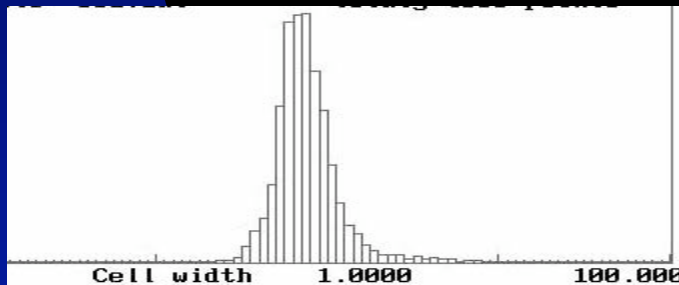
Prague, June 2, 2004, 2 kHz, 32 ps laser diode, C-SPAD, PET2k



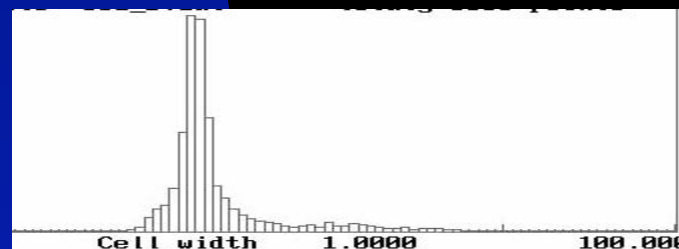
- 1 PE      23 ps rms  
dark count



- 1 ~ 10 PE      23 ps



- ~ 100 PE      12 ps

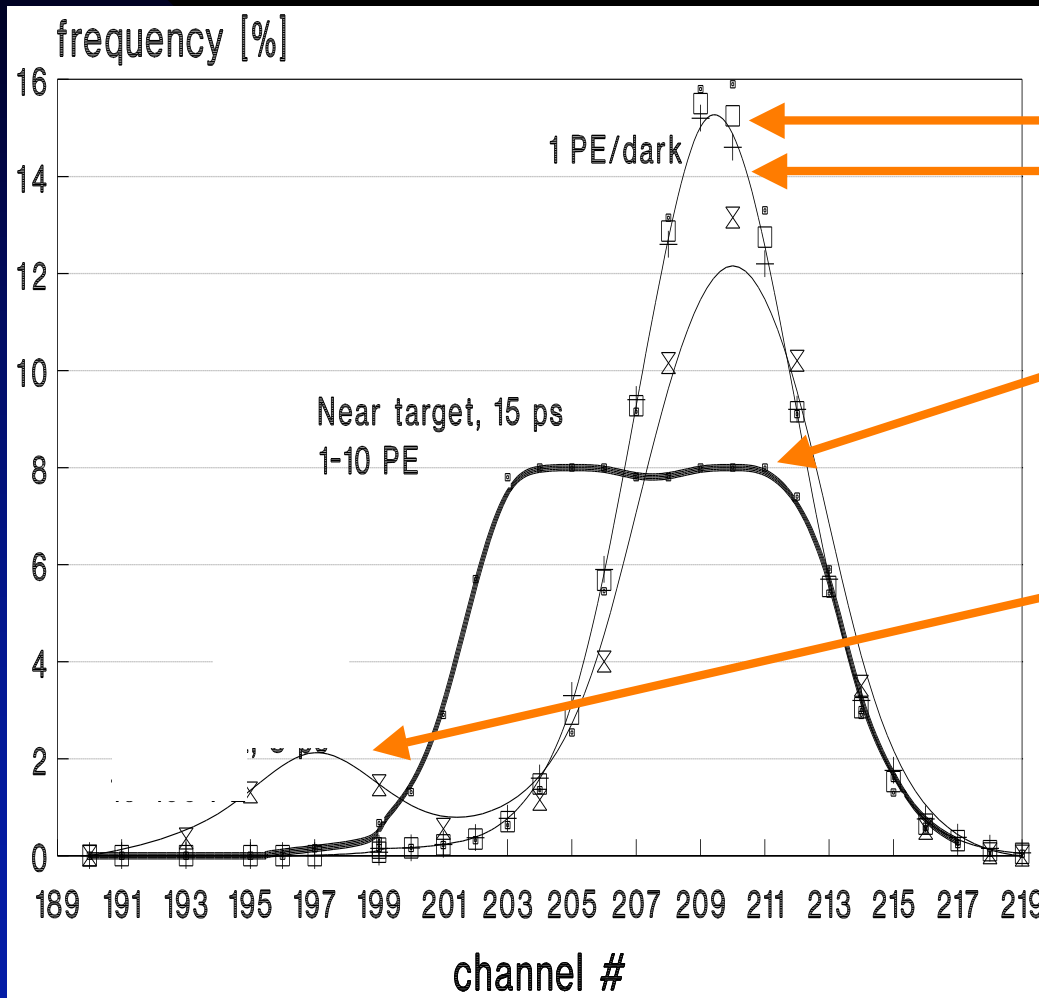


- ~ 1000 PE      8 ps



# Ground Target Laser Ranging Energy Spectrum

Graz, May 5, 2004, 2 kHz, 8 ps laser, C-SPAD, PET2k



dark counts / stability  
2 series, 24 hour appart

1 m ground target ranging  
1 - 10 PE, 15 ps rms

4 km ground target ranging  
~ 1000 PE, 6 ps rms

# Conclusion

- the C-SPAD based receiver package energy monitor has been constructed and tested
- FEATUES:
  - built in the PET2k
  - 7 energy levels resolution / shot - by - shot  
1-3, 3-10, 10-30, 30-100, 100-300,300-1000, > 1000
  - self - calibrating /via dark counts on 1 PE/
  - temperature & temporal stability < 0.1 ch / day
- STAND BY device of the C-SPAD energy monitor has been constructed and is available for SLR stations operating C-SPAD

