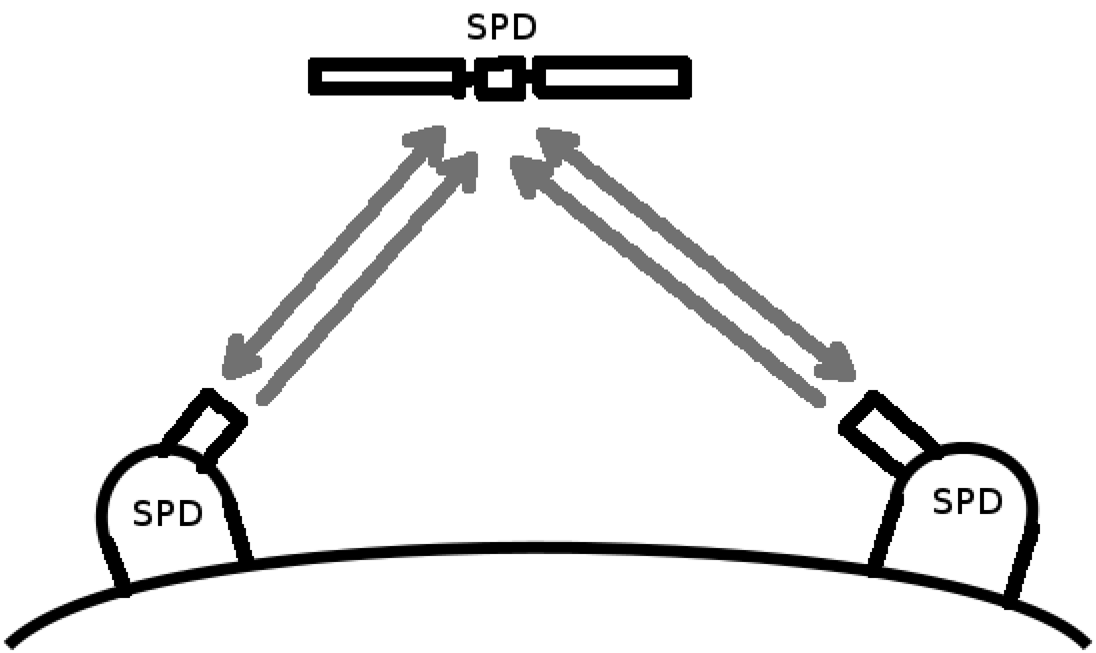
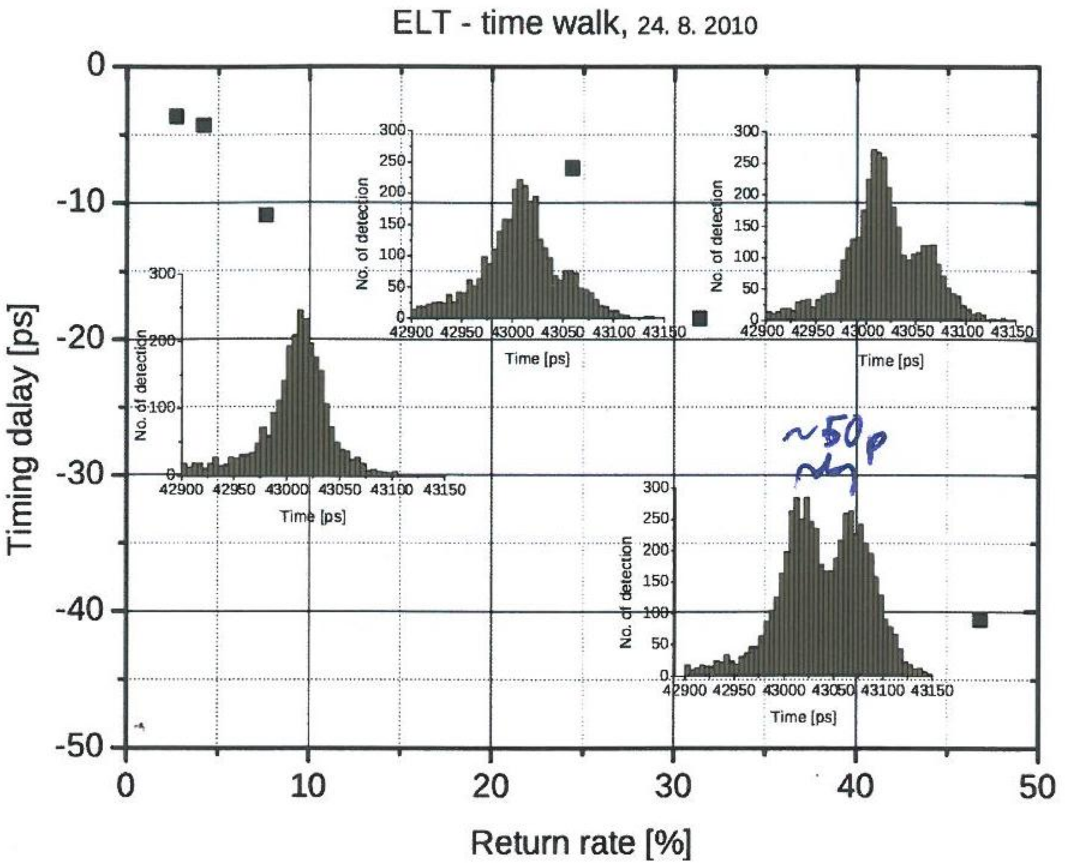
overview



- 3 Single Photon Detectors with 2 epoch measurements each for ground to ground time transfer
- Detection delay (2 way) = detection delay (1 way) / 2

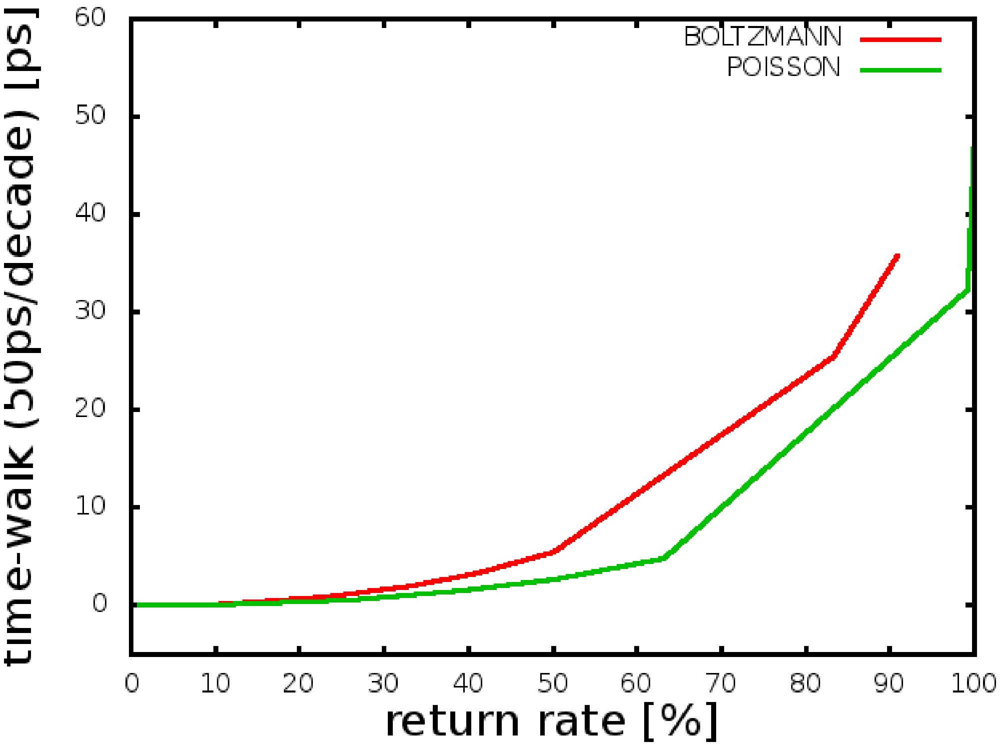
Timing properties of Single Photon Avalanche Diodes

- Logarithmic dependence of time delay on signal intensity

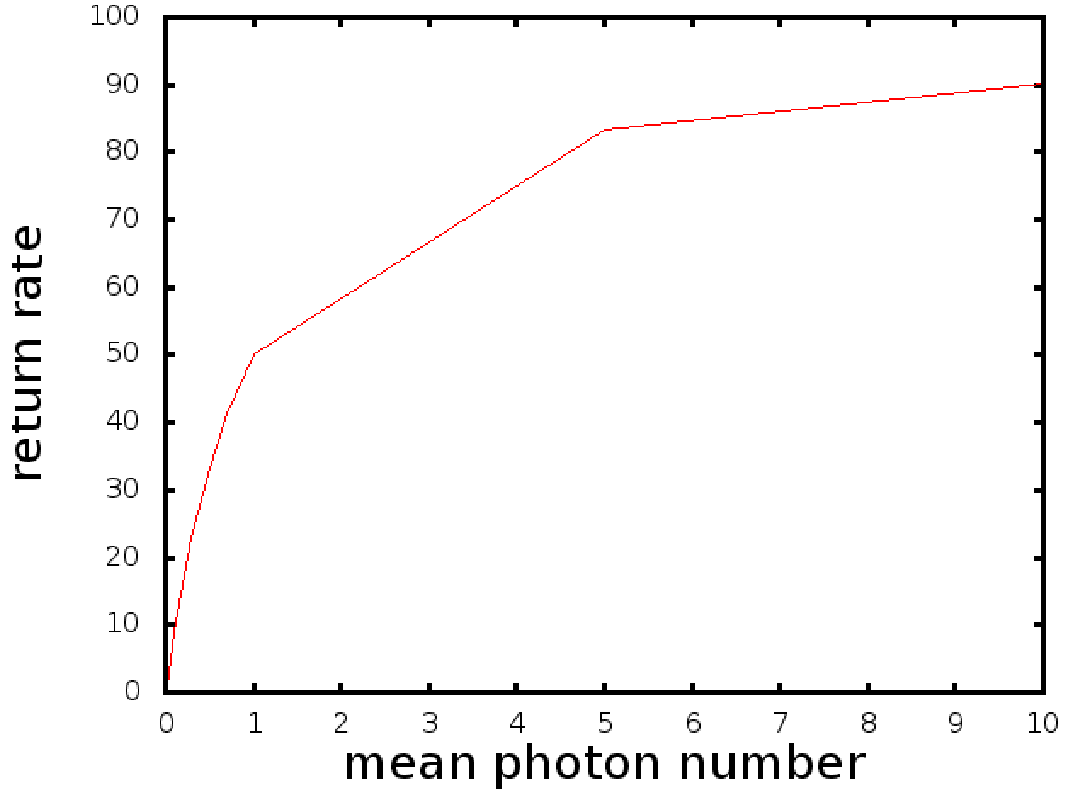


Tracking and calibrating at similar return rate

Problem 1: different photon statistics for laboratory (Poisson-distributed) and satellite tracking (Boltzmann-distributed)



Boltzmann - Statistics

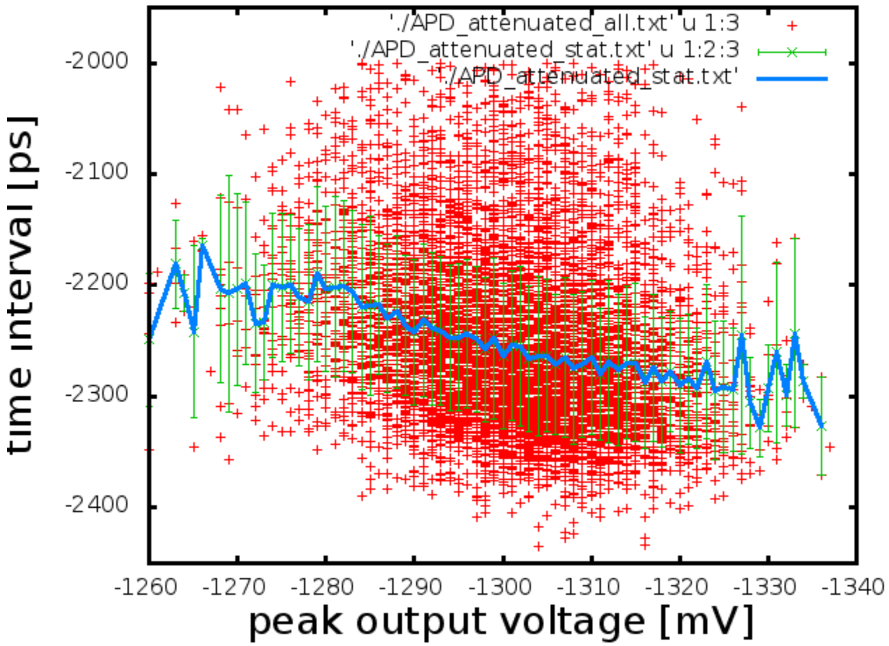


- Good: Ranging at return rates below 10%
- Problem 2: How to ensure a true return rate below 10%, considering daylight noise, dark noise, small clouds, plane trails, telescope pointing
- Approach: Developing gating circuit to obtain correlation between time-delay and output pulse shape and apply post-processing for time-delay compensation

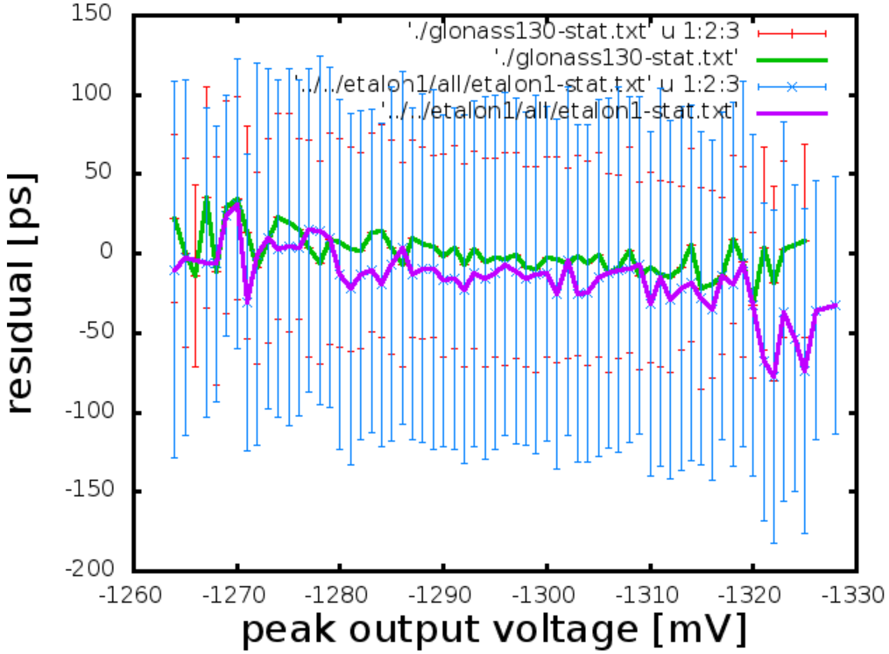
Data acquisition SAP500

- Accumulated satellite data @ similar return rate
- Time delay dependence on peak output voltage

Calibration



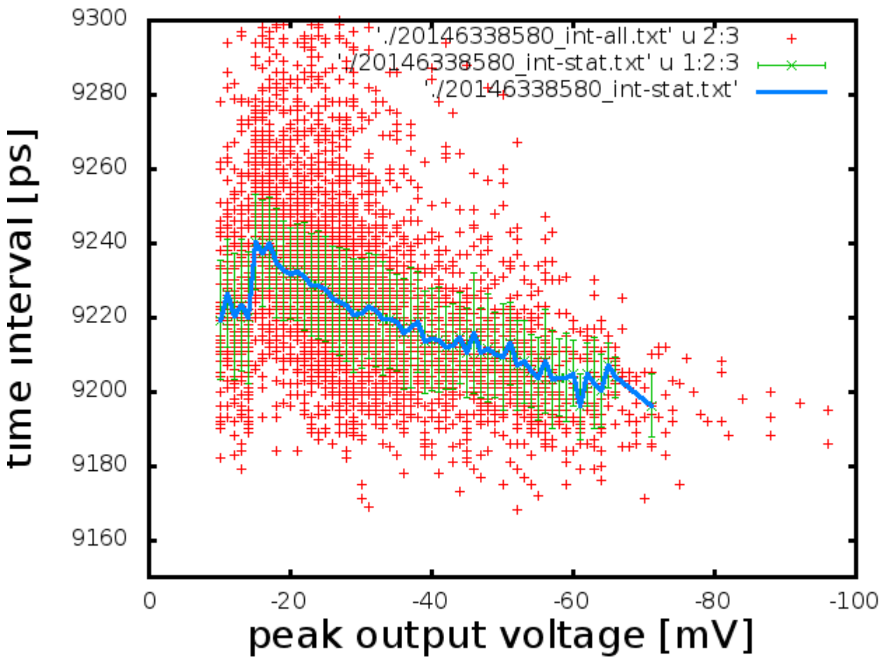
GLONASS and Etalon



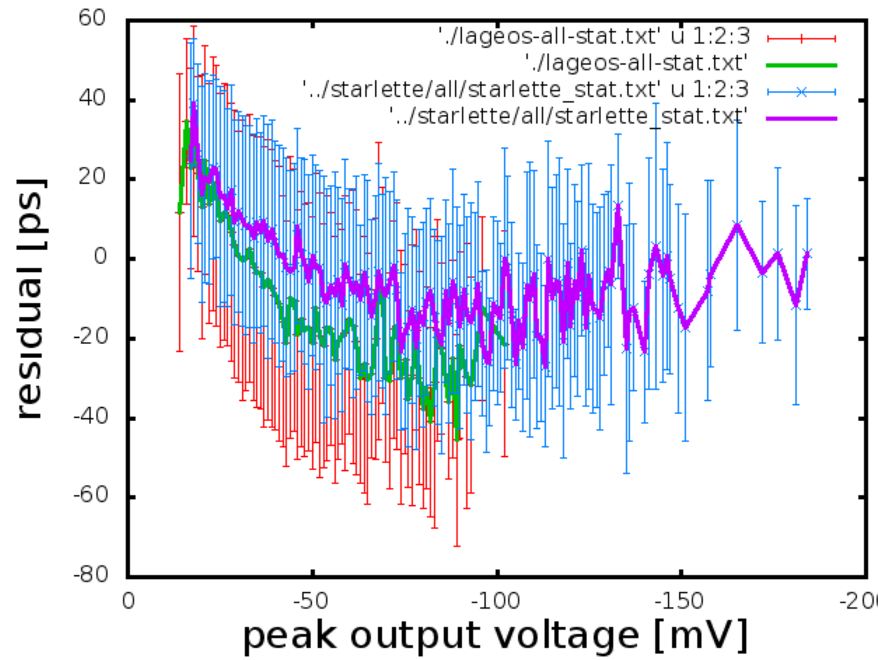
Data acquisition PMT-MCP 210

- Accumulated satellite data
- Dependence of detection delay on peak output voltage dependent on used discriminator
- Linear dependence of peak output voltage on signal intensity

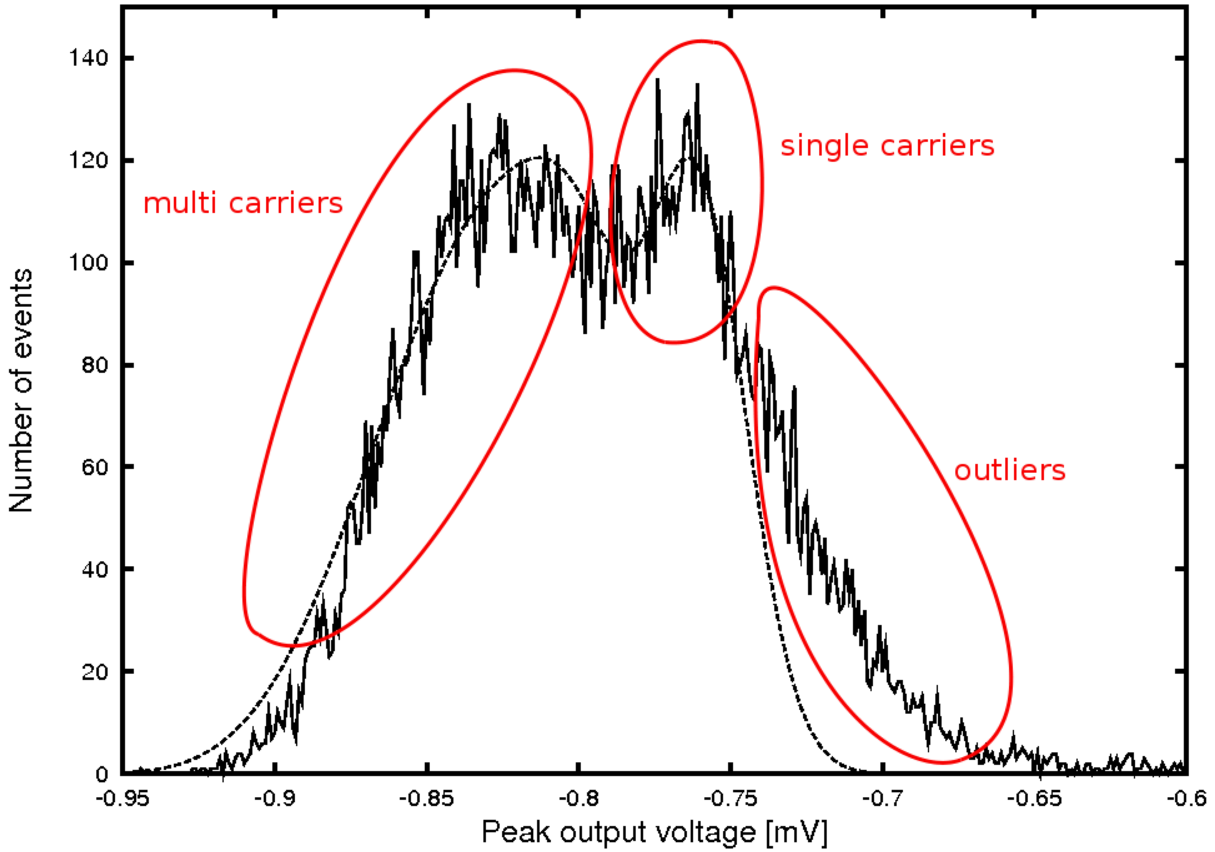
Calibration



LAGEOS and Starlette

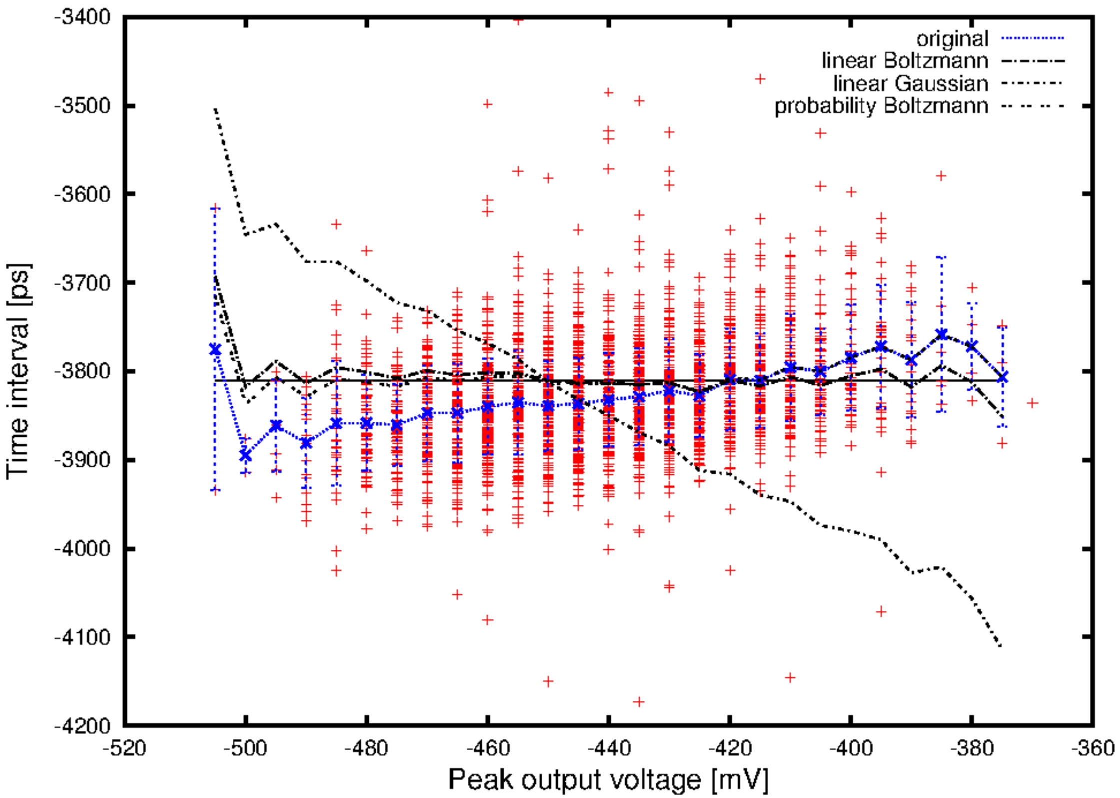


Modelling mean photon number



$$f(x) = d \cdot \sum_{n=1}^{20} \exp(n \cdot f) \cdot \exp\left(\frac{(x + c + e \cdot \log(n))^2}{-2 \cdot b^2} \right)$$

- Comparing time-delay compensation strategies using the example of an InGaAs-InP-SPAD for a BOLTZMANN distributed signal



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- Detection delay of Single Photon Detectors contributes at a high rate to the performance of time transfer experiments (6 epoch measurements)
- Ranging at very low signal intensities leads to appropriate trueness (accuracy)
- A possible detection delay compensation approach has to be based on the signal statistics