Extracting Photon-Number Information from SNSPD Traces via Mean-Derivative Projection

F.B. Baalbergen,[1] I. Kuijf,[2] L. Seldenthuis,[1] E.P.L. van Nieuwenburg[2], M.J.A. de Dood,[1]

[1]*Huygens-Kamerlingh Onnes Laboratorium, Leiden University, The Netherlands*

[2]*Instituut Lorentz, Leiden University, The Netherlands*

Superconducting Nanowire Single Photon Detectors (SNSPDs) are the most promising and versatile detector technology for quantum optics, photonic quantum computation, quantum key distribution and other applications. Commercial detectors combine high detection efficiencies with low timing jitter and reset time [1]. The main disadvantage of SNSPDs is the inherent lack of photon number resolution (PNR) in standard readout schemes.

We combine machine-learning techniques with a new readout technique to explore PNR in commercial and research SNSPDs with low timing jitter [2]. Careful analysis of a principal component analysis shows that an optimized strategy that gives the best PNR involves only projecting on the derivative of the detector pulse. This optimal PNR can be achieved with moderate hardware requirements in terms of both sample rate (5 GSample/sec) and analog bandwidth (3 GHz), is more resilient to noise compared to current methods, and could be implemented in an FPGA, giving a highly scalable solution for photon counting.

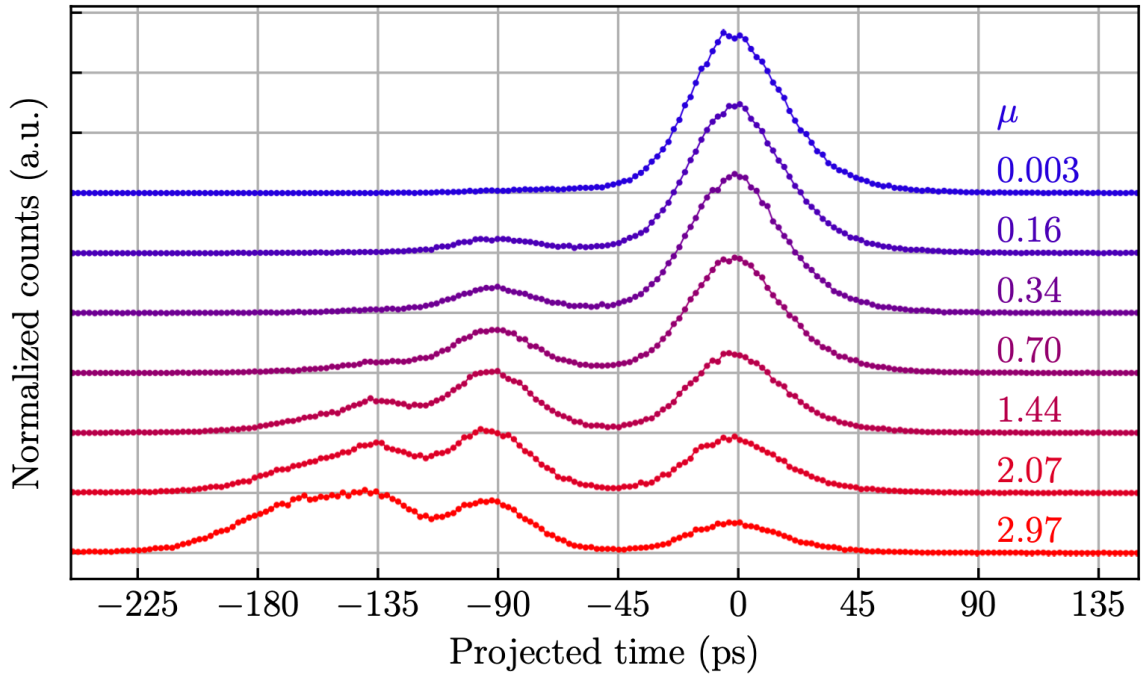

Fig. 1: *Timing histogram for a commercially available SNSPD using our average derivative projection method.*

References

[1] J. Chang et al. APL Photonics **6,** 036114 (2021)
[2] I. Kuijf et al. ArXiV:2511.13475 (2025)