Photon Counting Systems and Solutions since 2001

Advances in single photon detectors and electronics

Dr. Ir. Rik van Gorsel, VP Quantum Sensing - Americas

SWISS QUANTUM

ID Quantique – Company Profile

IDQ

- Founded in 2001
- >80 employees in 4 countries
- 2 Business units:
  Quantum sensing &
  Quantum-safe security

High-quality engineering

Best performance

Trust

Operational simplicity

2001-2016: 15 Years of Quantum Innovation

SWISS QUANTUM

World's first quantum random number generator (RNG) is launched

The id201, IDQ's first single-photon detector, is launched

First QC system sold

SwissQuantum pilot network goes live in Geneva

Quantum RNG as USB device

World Premiere: Geneva counts on quantum cryptography as it counts its votes

IDQ organizes its first Quantum Cryptography winter school.

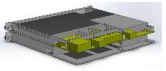
IDQ's quantum cryptography technology used at 2010 world cup

Quantum RNG as PCIe expansion card

The id210 replaces the id201 for telecom single-photon detection

Launch of 1st quantum powered 100G encryptor

Launch of AIS31 certified QRNG



QKD rackable Blade launched

QKD Trusted Node device (long haul)

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

ID Quantique is founded in Oct 2001

IDQ presents its first quantum cryptography (QC) prototype

ID Quantique raises 1M EUR from venture capital fund i2i

Second generation quantum RNG launched as PCI expansion card

Silicon APD based single-photon detectors launched.

IDQ Cerberis QC solution is released

Quantum RNG certified by Swiss Federal Office of Metrology

ID Quantique changes its logo and reorganizes in three business units

World'first QKD as a service launched by IDQ & Colt

QKD over WDM network for Swiss bank

ID Quantique raises 4.5M EUR from Qwave Capital

IDQ & Battelle launch Quantum-Safe Security Working Group

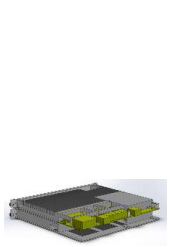
World-first Quantum optimiser validated

Google joins Quantum Computer race

ETSI calls for quantum-safe crypto

ID Quantique raises 4 M CHF

IDQ Quantum Roadmap 2015-2025



QKD rackable blade

QKD Trusted Node device (long haul)

Quantum Repeater academic PoC

Miniature QRNG OEM device

QKD integrated in carrier grade network device

QRNG on a mobile

Access network (last mile) QKD products

QKD PoC on high-altitude platforms

QKD PoC on satellite

QKD on a Chip

First quantum transceiver

Quantum Repeater (quantum amplifier) industrial prototype

2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025

FIPS & government certifications for QKD

Govt funded trusted node projects (China, UK, Korea, etc)

D:wave

World-first Quantum optimiser validated

Google

Google joins Quantum Computer race

ETSI World Class Standards

ETSI calls for quantum-safe crypto

ID Quantique raises 4 M CHF

SKT Investment 65M$

Govts should be quantum ready!

Private Sector should be quantum ready

2025-2030: World's first general purpose Quantum Computer

ID Quantique PROPRIETARY

Road map Quantum Sensing: Ariane 6 integration uses ID281 and ID900

SWISS QUANTUM

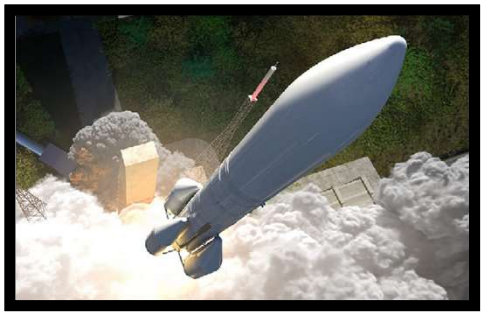
Ariane 6 launcher

- Opto-pyrotechnics
- ”Extreme” OTDR requirements
- ID300, ID281 and ID900
  - <1.5 cm spatial resolution in large core MMF
  - Short production tests with free-running detection of up to 8 km of fibre in launcher
  - Insertion loss measurement

Possible with SNSPDs only

IDQ supplies high reliability single photon technologies to Ariane 6

the next generation of space launch vehicles built by ArianeGroup on behalf of the ESA



IDQ Single Photon Systems have been selected:

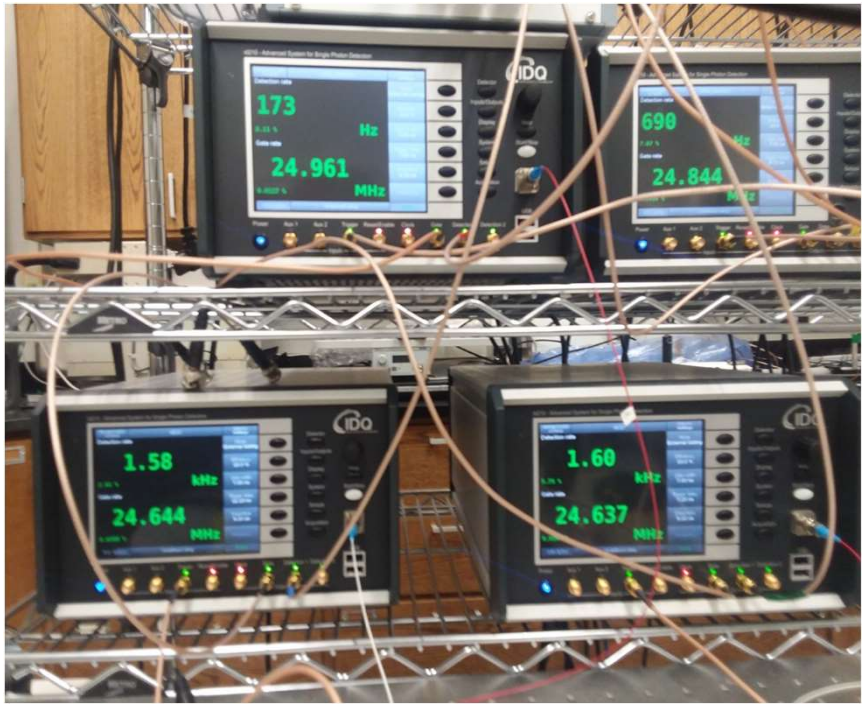
- ID281 single photon detector,
- ID900 Time Controller with its OTDR package
- ID300 Laser

Ariane 6 Launcher program

- ✓ Accuracy unachievable by traditional means
- ✓ Centimeter spatial resolution
- ✓ Intrinsically safe solution

- ✓ Fully qualified by ArianeGroup (Airbus-Safran)
- ✓ First flight in early 2021
- ✓ 30 year program

Lab to market place



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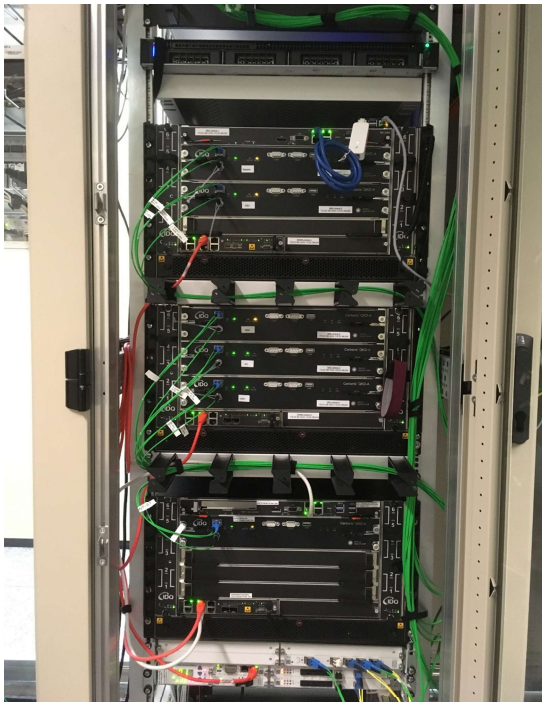
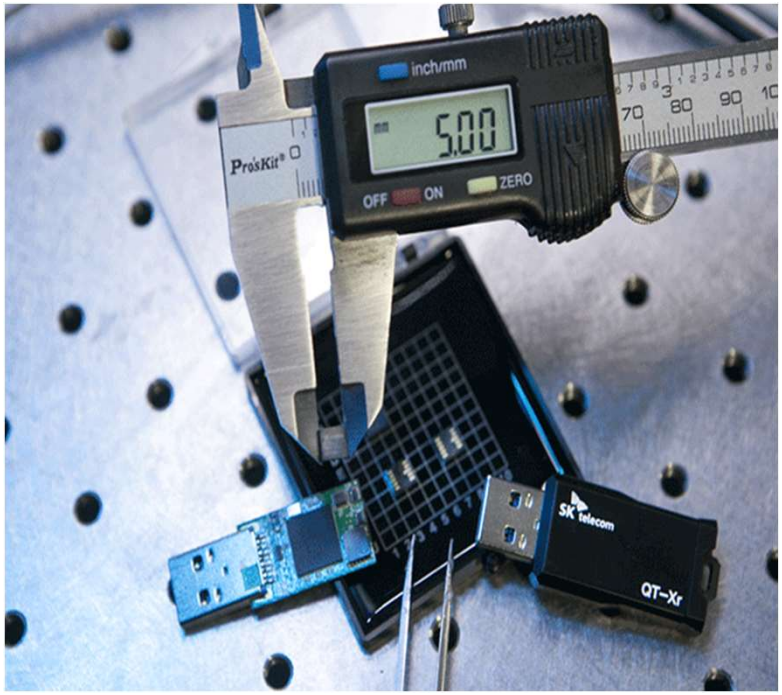


Lab to market place



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The SKT IDQ QRNG chip inside the Samsung Galaxy A Quantum

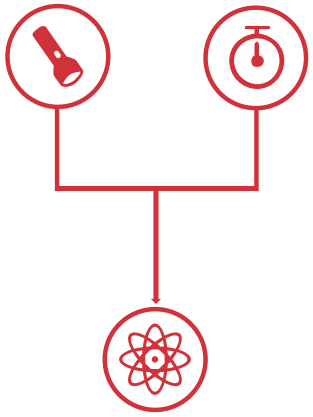
https://www.engadget.com/samsung-and-sk-telecom-reveal-worlds-first-smartphone-with-quantum-security-tech-143049380.html

Quantum Technologies for sensing performance beyond conventional techniques


SPADS


SNSPD

Low-Light Sensing



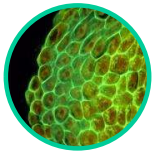
Quantum Sensing Solutions

Hi-Res Timing defined instruments

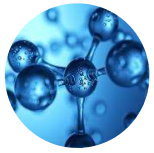
Time Controller
Event timer & Electronics (TCSPC)

Extending the performance of Time-of-Flight based sensing systems:

- Industrial single photon lidar
- Single photon OTDR based integrity monitoring



Bio-Sciences



Material Science

Quantum Physics

Communication

Automotive

Surveillance & Defence

O&G

Quantum Sensing Products

SPADS

ID230 FR detector

ID220 FR detector

ID Qube NIR FR and Gated

SNSPD

ID281 SNSPD

Electronics

ID900 Time Controller

Quantum Sensing Products – InfraRed SPAD

ID221

Key Benefits

- Spectral range: 900 – 1700 nm (NIR wavelength)
- Timing resolution: **150 ps**
- SMF & MMF input
- Adjustable dead time 1 us to 25 us
- Free-running
- Peltier cooler, -50°C in Geiger mode
- Low Dark Count Rate:
  - **800 Hz** DCR at 10% Quantum Efficiency
  - **3 kHz** DCR at 20% Quantum Efficiency

Quantum Sensing products – InfraRed SPAD

ID230

Key Benefits

- Based on ID221 :
  - Free-running
  - Spectral range: 900 – 1700 nm (NIR wavelength)
  - Timing resolution: **150 ps**
  - SMF & MMF input
- Adjustable dead time 2 us to 100 us
- APD cooled down to -90°C with Sterling engine cooling
- Best in class Dark Count Rate :
  - **80 Hz** DCR at 10% Quantum Efficiency
  - **200 Hz** DCR at 20 % Quantum Efficiency

Quantum Sensing products – SNSPD

SWISS QUANTUM

ID281

Key Benefits

- System detection efficiency up to 90%

(at 1550, 1310, 780, 850, 950 nm)

- Plus: broadband, high speed, PNR, Pol. insensitive

- Standard low dark count rate (DCR):

< 100 Hz (1310 to 1550 nm)

< 5 Hz (950 to 1064 nm)

< 1 Hz (780 to 950 nm)

- Recovery time < 20 to 40 ns (@ 50 % of the max. efficiency)
- Jitter < 20 ps (Visible); < 40ps (InfraRed)
- Closed-cycle 0.8 K cryostat – infinite temperature stability
- Up to 16 channels per cryostat
- Agile control and data recording electronics

IDQ

Quantum Sensing products – Timing Device

ID900

Key Benefits

Parameter	High Speed mode	High Resolution mode	Units
Input channels	4 + Start	4	
Bin width	100	13	ps
Time jitter (RMS)	<100	8	ps
Dead-time	<4	5	ns
Maximum processing rate (per channel)	100	25	Mevents/s

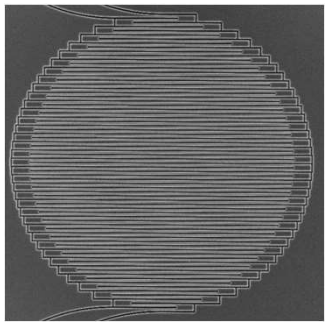
ID281 Full turnkey multi-channel SNSPD solutions

- **Up to 16 channels**
- System detection efficiency up to 90% (at 1550, 1310, 780, 850, 950 nm)
- Plus: broadband, 200 MHz, PNR, Pol.ins
- Short Recovery time between 20 & 40 ns
- 200 MHz & PNR option
- Low jitter (as low at 20 ps)
- Low dark count rate (as low as 1 Hz)
- 0.8 K closed cycle cryostat
- Continuous operation
- Timing & time tagging electronics

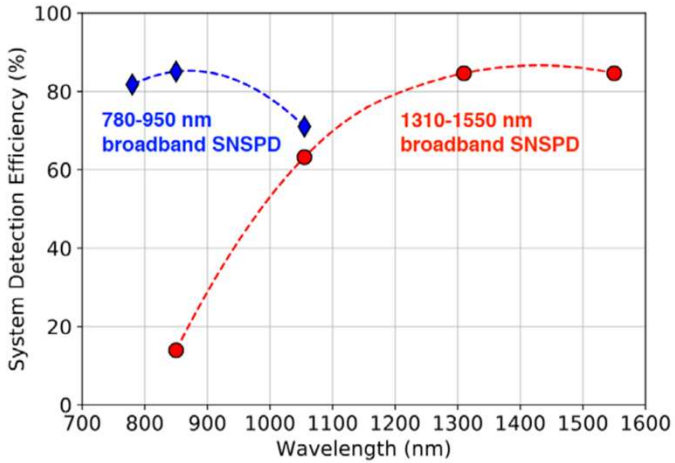
SWISS MADE

Superconducting detectors at IDQ

Pushing the limits of in-and-out of the lab



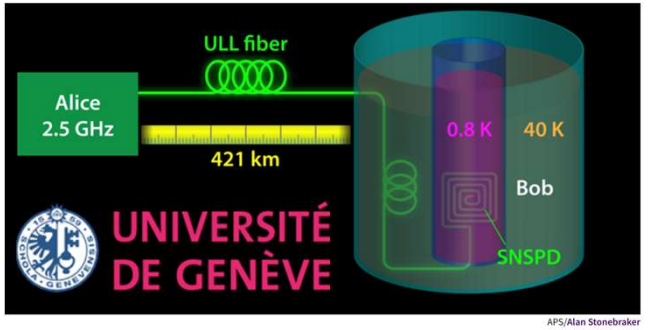
- High & broadband system detection efficiency



- Low jitter (down to 20 ps)
- Low noise (down to < 1 Hz)
- Short recovery time (down to 20 ns)

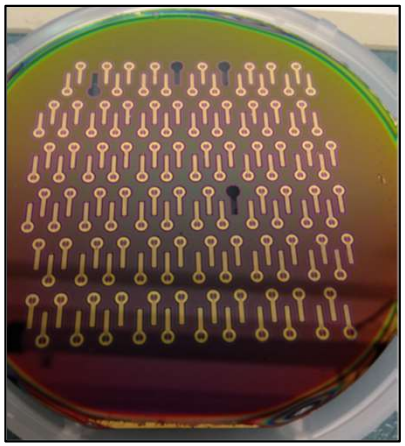
Ariane 6 assembly will use IDQ's SNSPDs

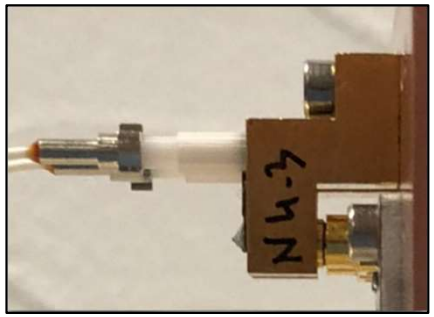
QKD over 421 km (UNIGE)



ID Quantique PROPRIETARY

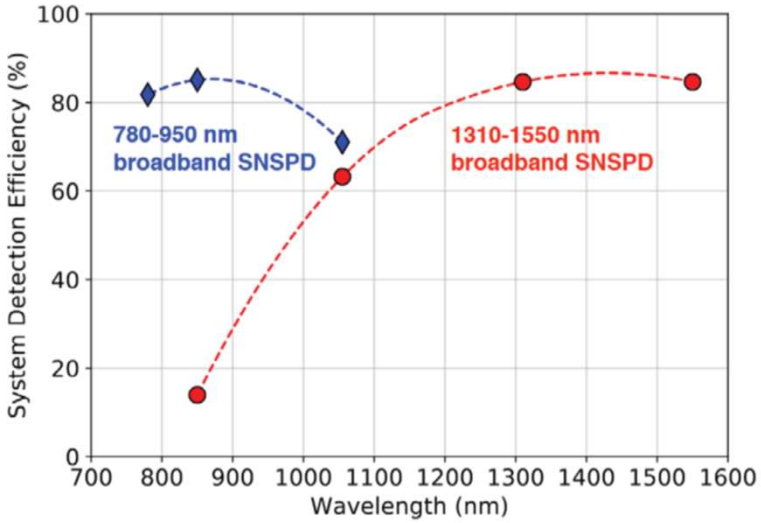
SNSPD - Swiss Made Nanowires - ID281

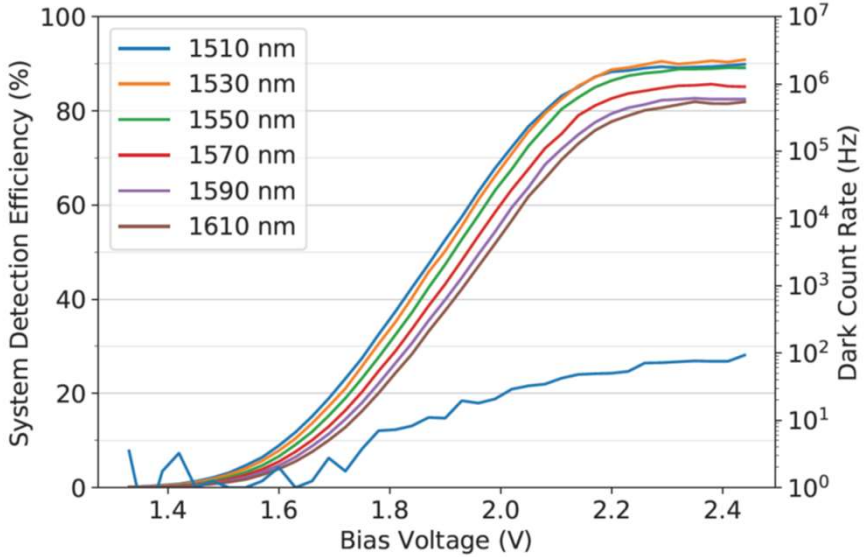




- Wafer Scale Proceesing
- Detachable devices with SNSPD meanders inside
- Self aligned mount for alignment with Optical fiber +/- 3 um

SNSPD – Broadband Efficiency

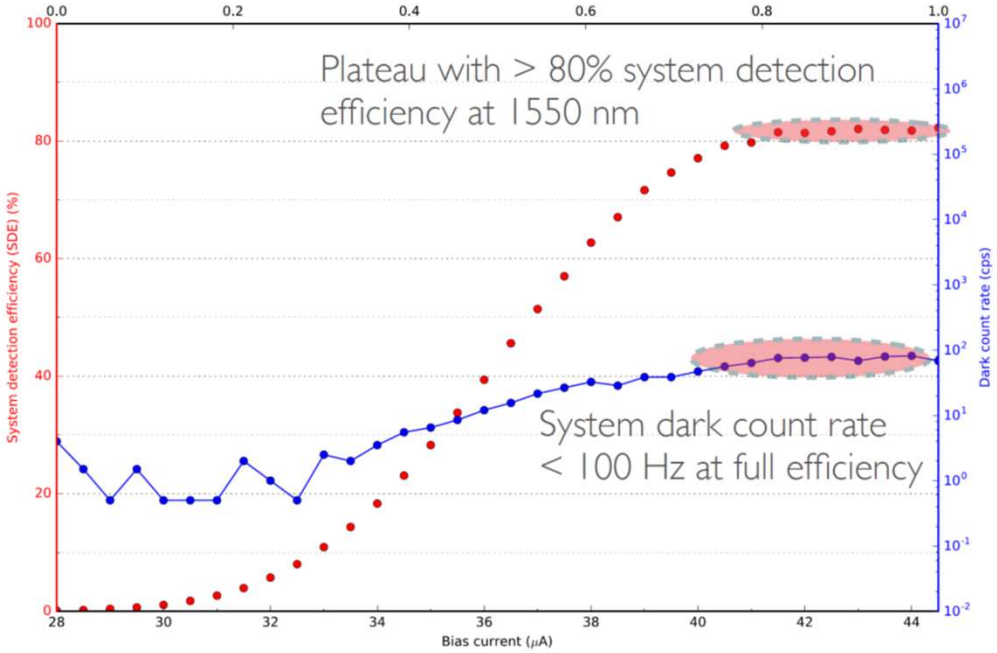




Broadband efficiency detectors:

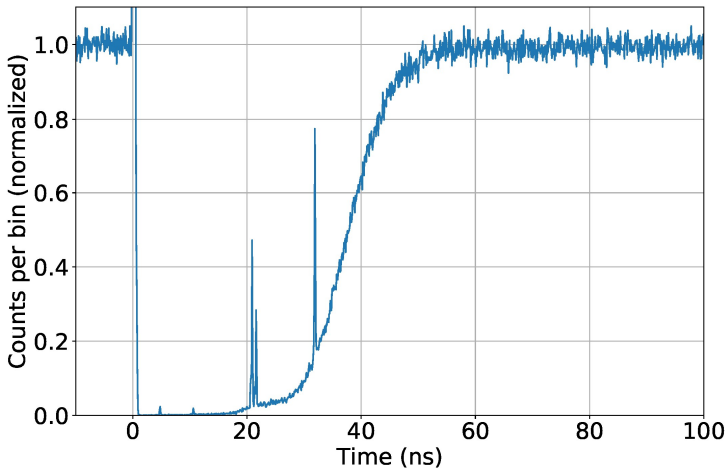
- **>80%** from 1310 to 1550 nm
- **>80%** from 780 to 950 nm
- **>80%** from 950 to 1064 nm

SNSPD – InfraRed Standard Detectors performances



1550 nm Standard Detector : SDE vs DCR vs Bias Current

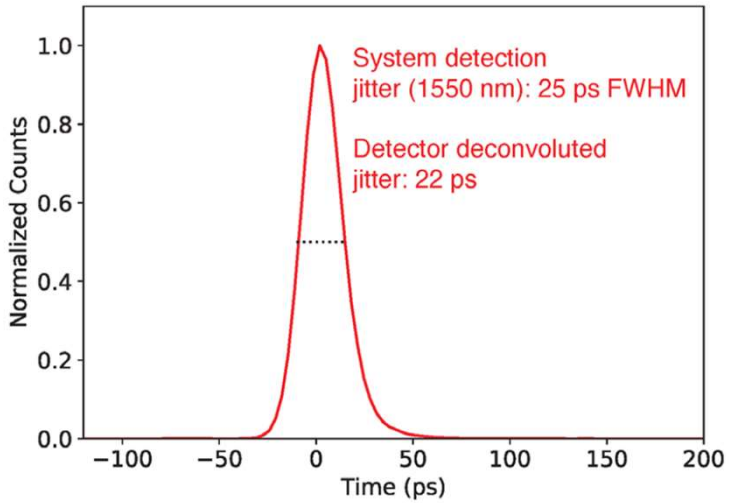
- Detection range 1310 to 1550 nm
- Over **80%** System Detection Efficiency
- Dark Count strictly below **100Hz**
- Time to recover 50 % of max SDE is < **40ns** (deadtime)



1550 nm Standard Detector deadtime : Normalized counts VS time

ID281 jitter

ID281 – Timing jitter



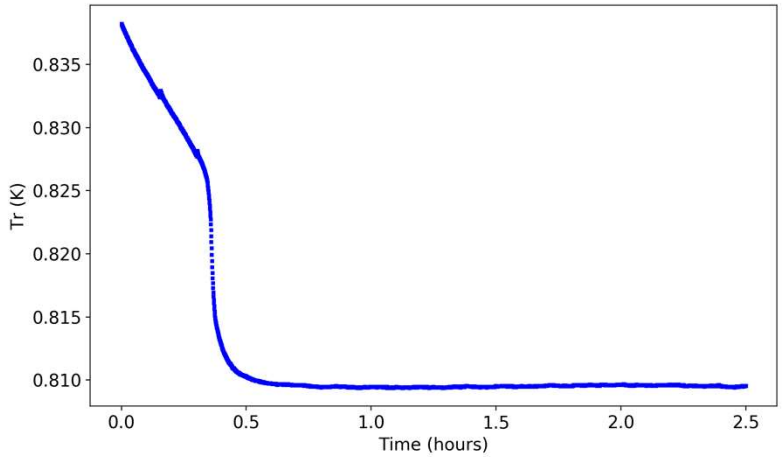
1550 nm Detector Timing jitter

- Standard jitter (FWHM):
  < 40 ps (1550 nm)
  < 30 ps (780-950 nm)
- Ultra-low jitter option:
  <30 ps (1550 nm)
  <20 ps (780-950 nm) upon request

0.8 K Closed Cycle Cryostat

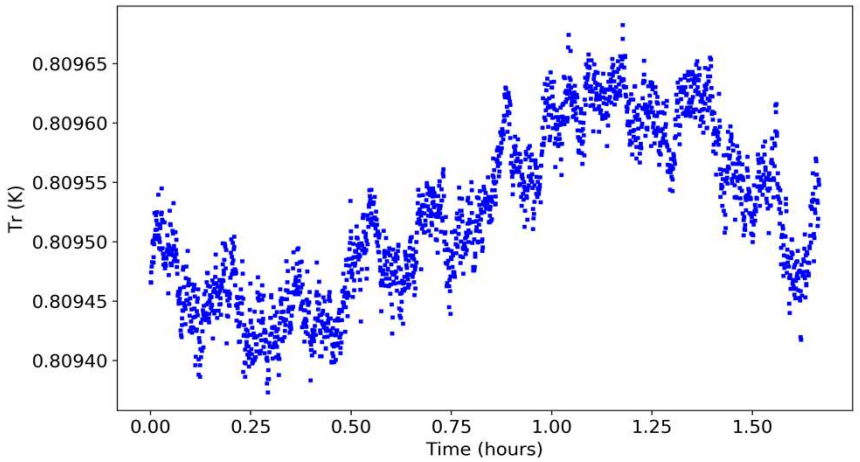
ID281-sorption, Cryostat stability

- Base temperature is 0.8 K



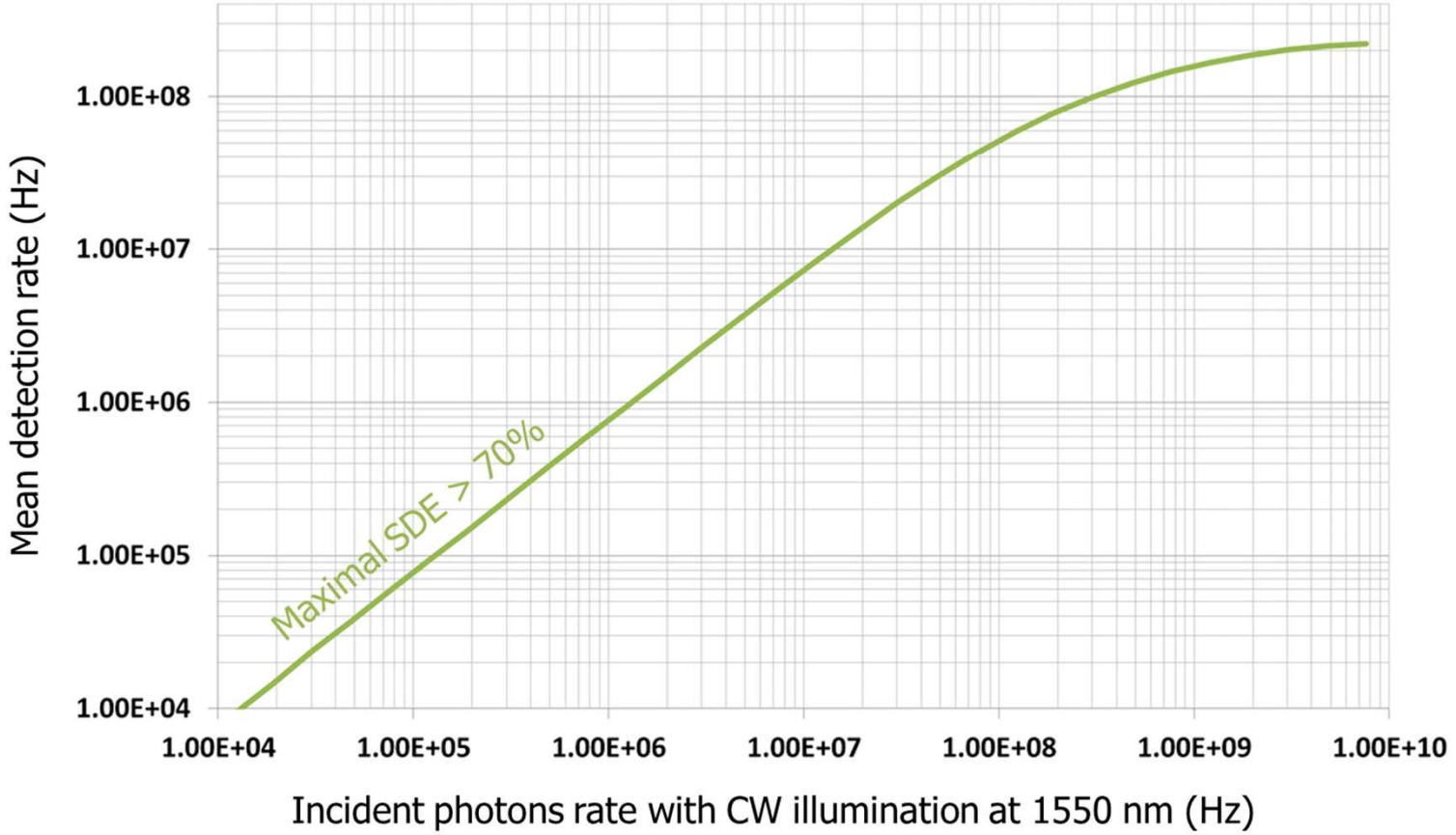
Refrigerator base temperature

- Temperature stability is better than 0.5mK

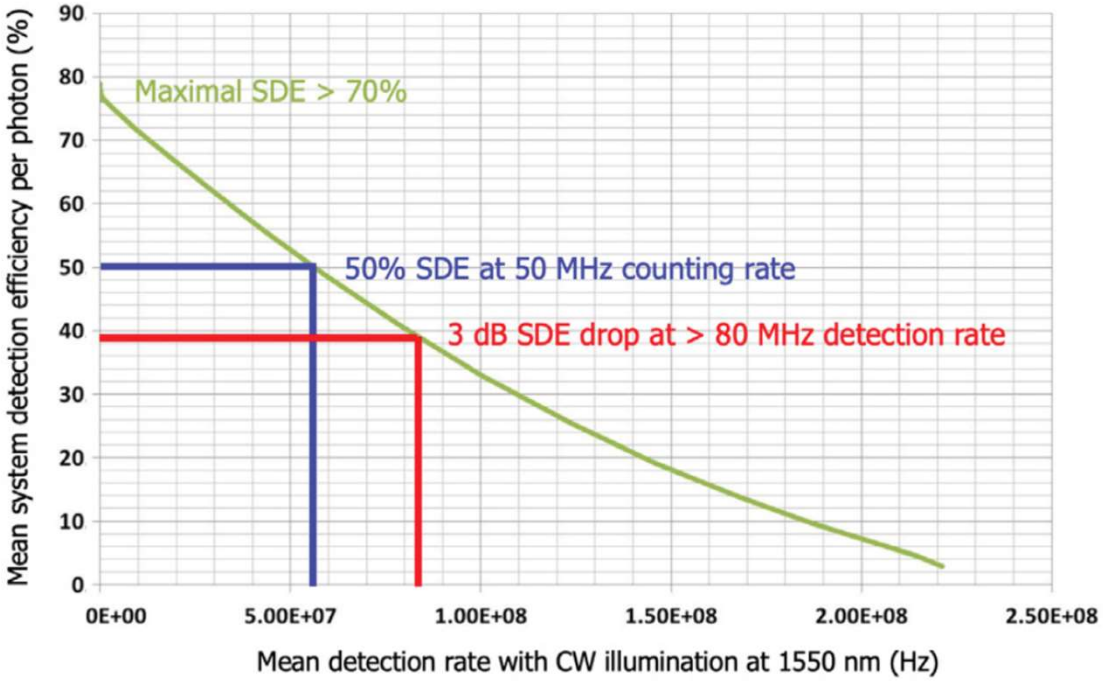


Temperature stability

High-speed SNSPDs



SNSPD – High Speed detectors & PNR

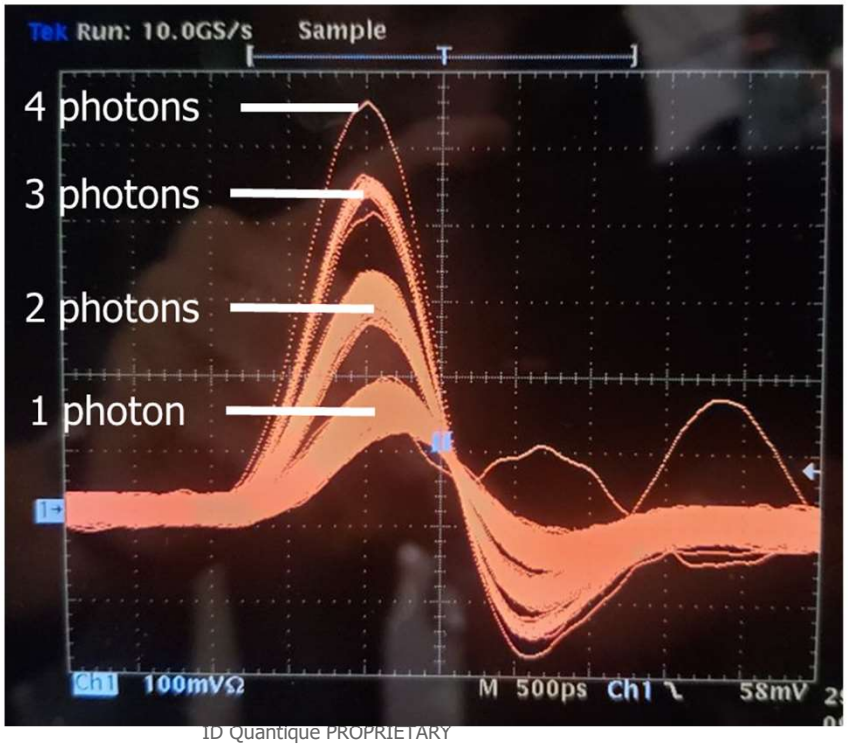


- An example of Fast SNSPD Detector counting rates :
- Typical System Detection Efficiency > 70%
- SDE > 50% at 50 MHz,
- SDE > 10% at 200 MHz

Photon-number resolution capability

Photon-number resolution at 1550 nm

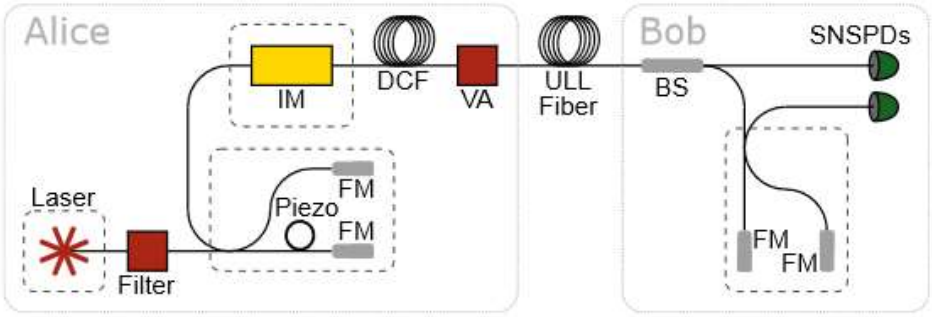
- At least 4 photons
- Exact number can be determined with amplitude using an oscilloscope or with a combination of several channels with different thresholds on the ID900



SNSPD - Use of detectors in recent experiment

Secure Quantum Key Distribution over 421 km of Optical Fiber. Boaron et al (2018)

- Secure quantum key distribution over record breaking long distance of 421 km of optical fiber
- Secret key rates of 6.5 bps over 405 km
- An article from Geneva Applied Physics University

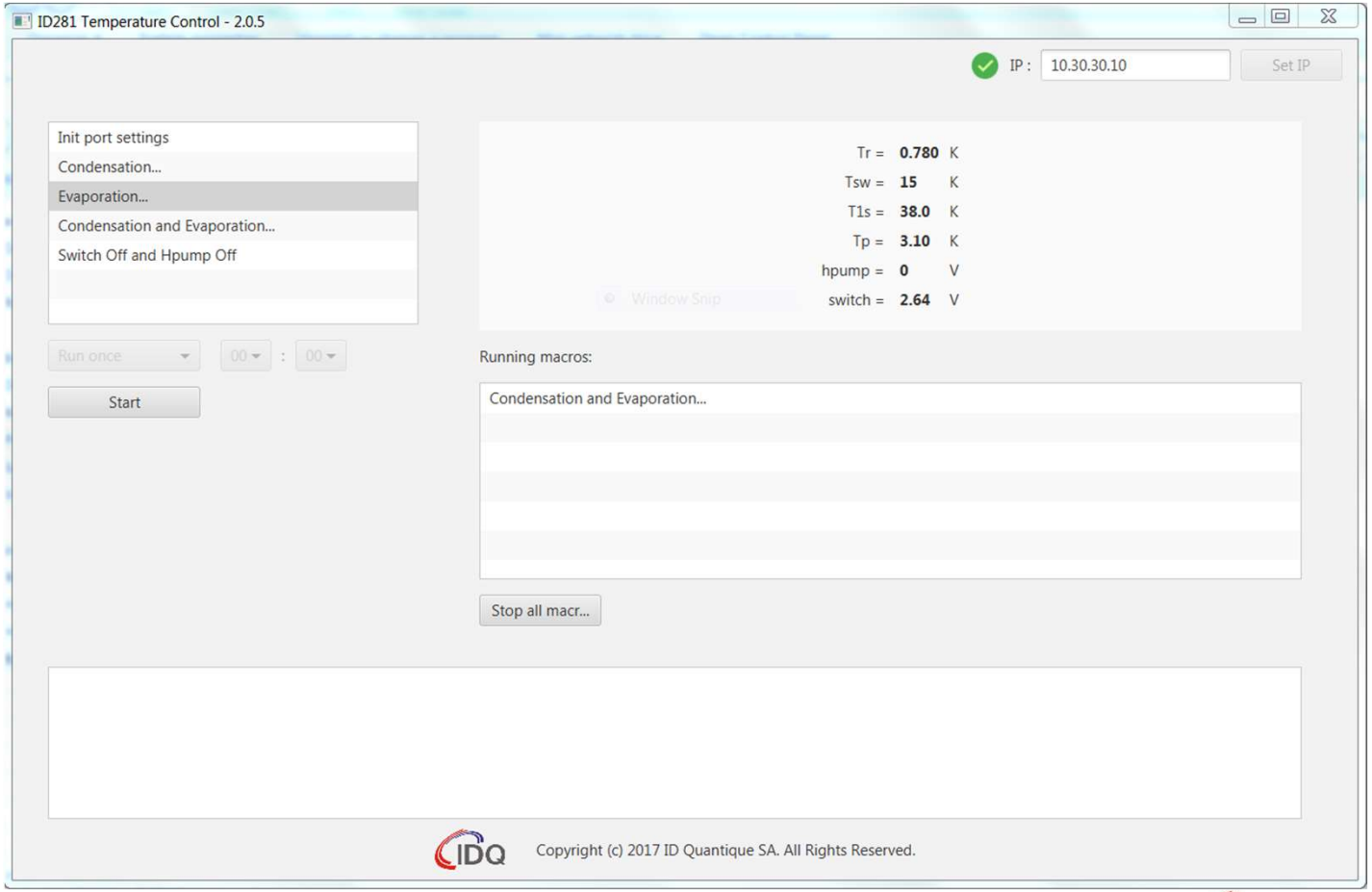


https://doi.org/10.1103/PhysRevLett.121.190502

Automated Operations

Software

- Daily program
- Temperature control & logging
- User Friendly
- Remote monitoring



SWISS QUANTUM

ID900 Time Controller

The control hub for your single photon experimemts

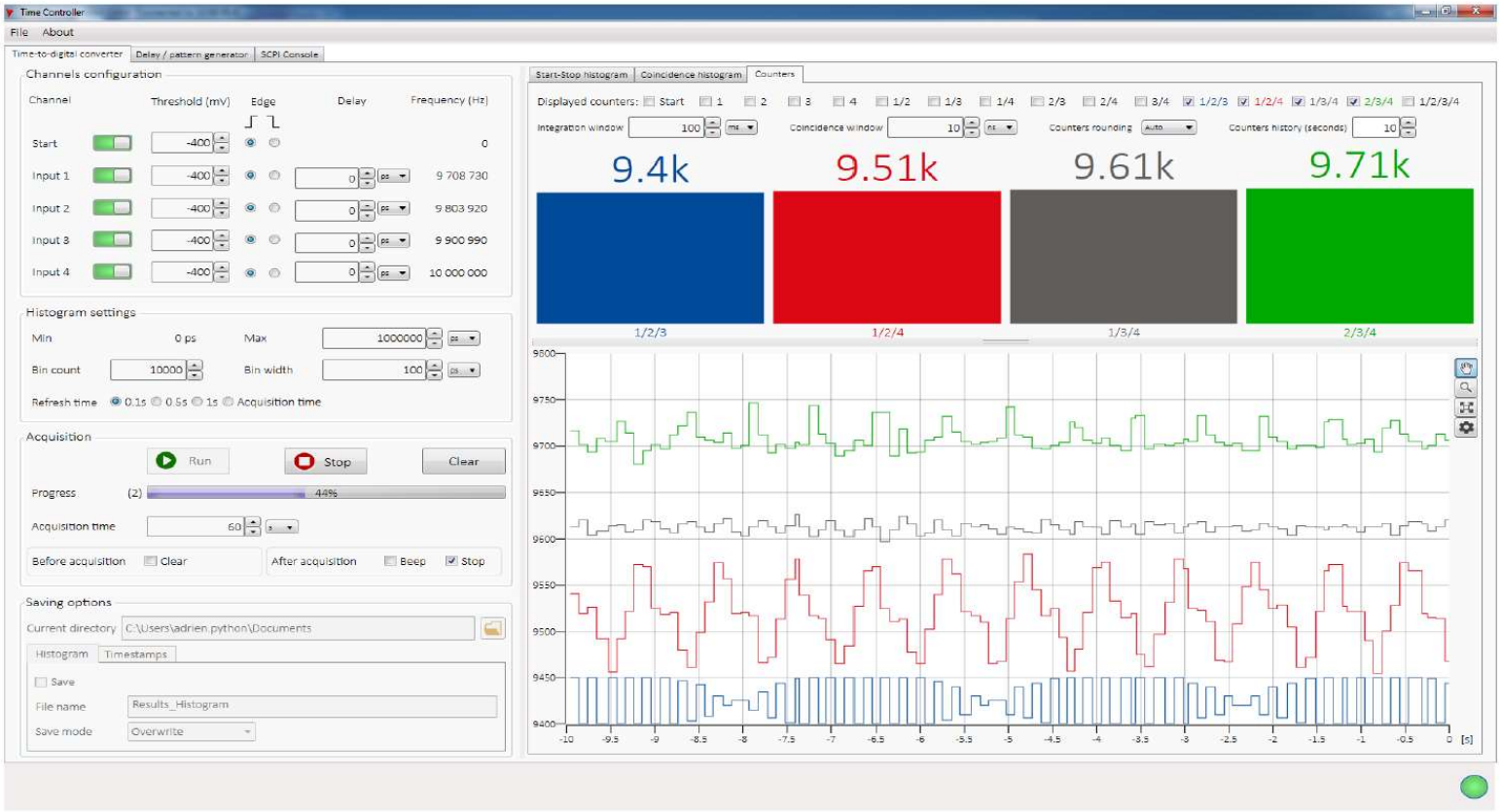
All in one

- 4 channel Time-tagging & Histograming
- 4 high speed outputs, e.g. for Delay & Pattern Generation
- Built-in conditional filters and counters
- Configuration editor

- Fast data processing
  Up to 100 Mevents/ch
- Conditional programmable outputs
- Picosecond timing
- Cost effective solution for mutiple channels

IDQ

Time Controller - Counters Window



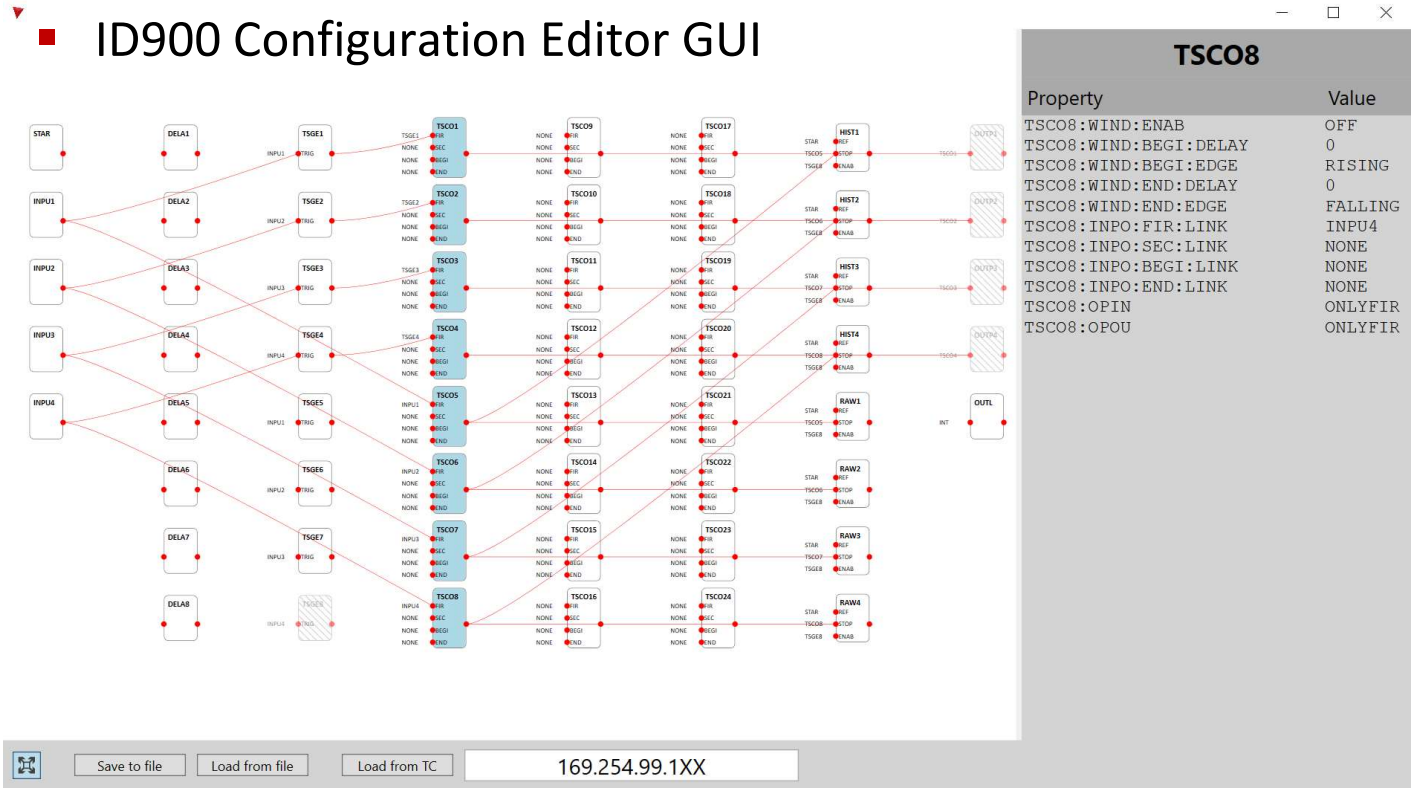
- 4-fold Coincidence histogram

Time Controller working principle and configuration editor

id900 TCSPC Time Controller

4th interaction level

- ID900 Configuration Editor GUI



SPADS

ID230 FR detector

ID220 FR detector

ID Qube NIR FR and Gated

SNSPD

- Exact PNR (photon number resolution)
- Extended wavelength range

Electronics

ID900 Time Controller

- Modern 4-channel TCSPC
- Conditional outputs

ID Quantique PROPRIETARY