

# *Towards quantum communication from global navigation satellite system*

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# Introduction

Quantum Communication is a fast growing field driven by

- applications: unconditional security of the data exchange
- research: new tests of Quantum Mechanics

Long term vision is to build a global-scale quantum communication network:

- terrestrial links (fiber) for short range communication ( $< 100$  km)
- satellites links (free-space) for long range communication ( $> 1000$  km)

For satellite to ground communications, high altitude satellites are preferable due to longer communication time with respect to LEO satellites.

**Goal:** demonstrate the feasibility of transmitting quantum states from GNSS to a ground station.



LEO Zone  
(Low Earth Orbit)

MEO Zone  
(Medium Earth Orbit)

GNSS Orbit

HEO Zone  
(High Earth Orbit)

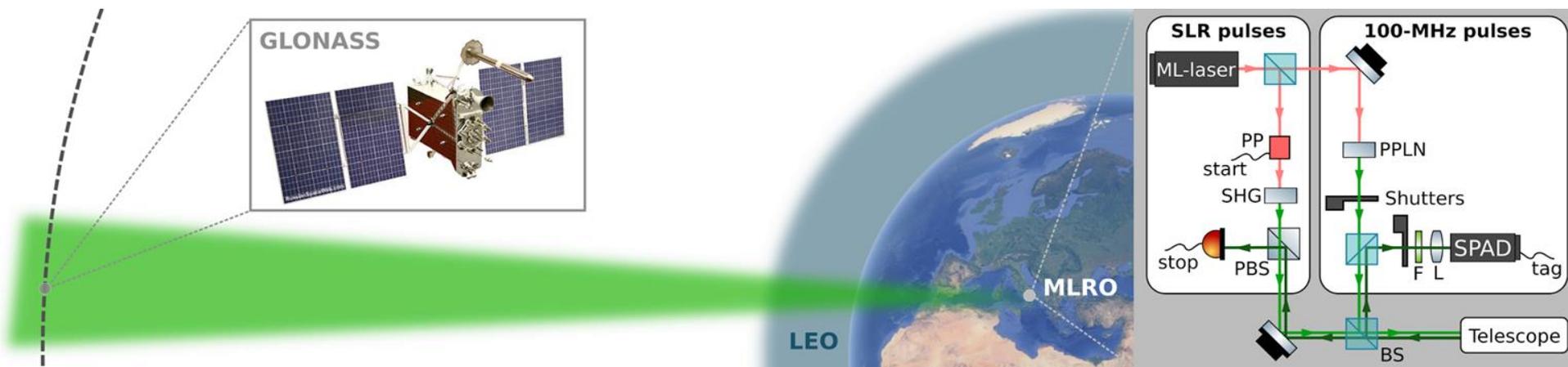
# Experimental setup

## *Transmitter on the satellite:*

Simulated exploiting the reflection of an optical pulse by an array of corner cube retroreflectors. Only a tiny fraction of the up-going pulse is reflected back to the station.

## *Receiver on ground:*

The returning beam is collected by the telescope and detected by a Single Photon Avalanche Detector (SPAD).



# Experimental setup

## Ground station (Matera Laser Ranging Observatory)

### Source

SLR and Attenuated lines generate from the same mode-locking laser at 1064 nm with 100 MHz rep. rate.

SLR pulses:

- Rep. rate 10 Hz
- Energy per pulse 100 mJ
- Wavelength 532 nm

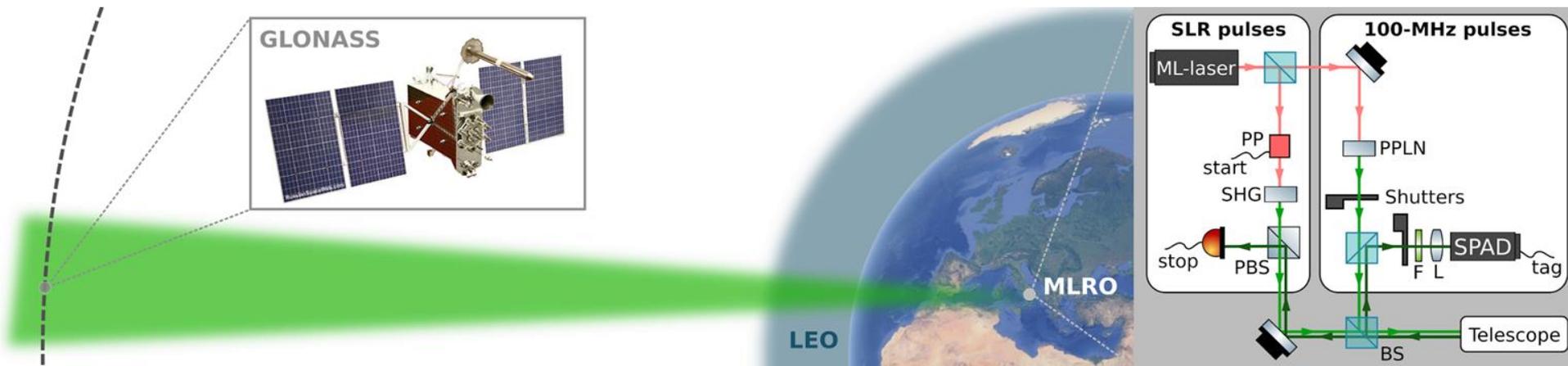
Attenuated pulses:

- Rep. rate 100 MHz
- Energy per pulse 1 nJ
- Wavelength 532 nm

SLR and Attenuated pulses are combined to the same line with a BS and sent to the satellite.

### Receiver

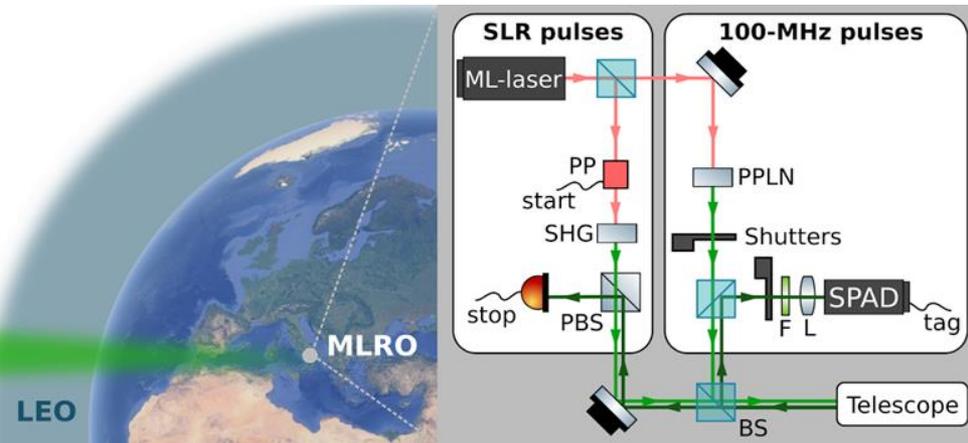
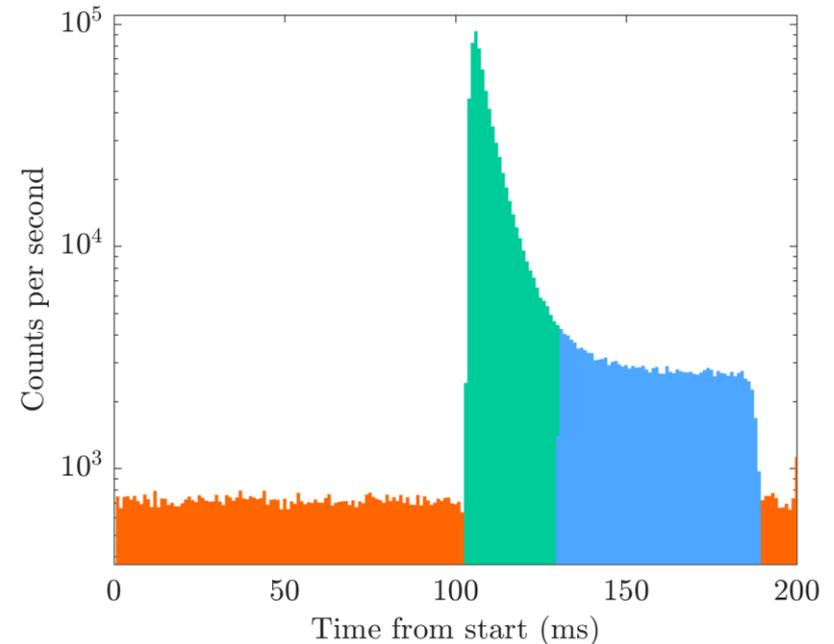
The same telescope collects the down-going pulses. On our receiver side we used a SPAD with 50% quantum efficiency, 400 Hz DCR and 40 ps of jitter and a timetagger with 10 ps jitter to measure the time of arrival of the pulses.



# Duty cycle of the communication protocol

The round trip time of the pulses is about 130 ms, therefore we use a communication protocol with a period of 200 ms:

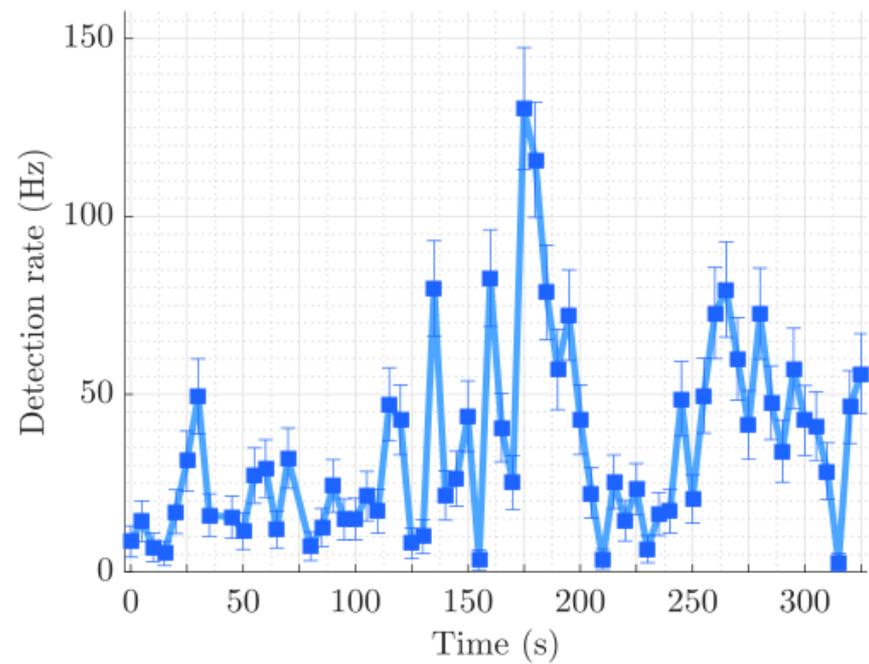
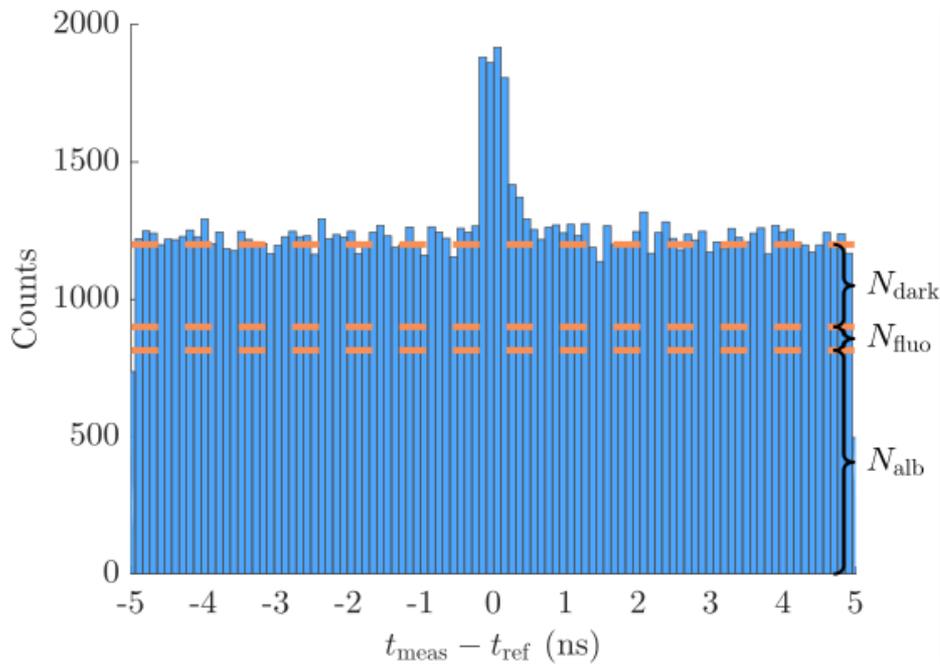
- In the first 100 ms from the start of the SLR pulse, the TX shutter is open and RX shutter is closed.
- In the last 100 ms, the TX shutter is closed and RX shutter is open.



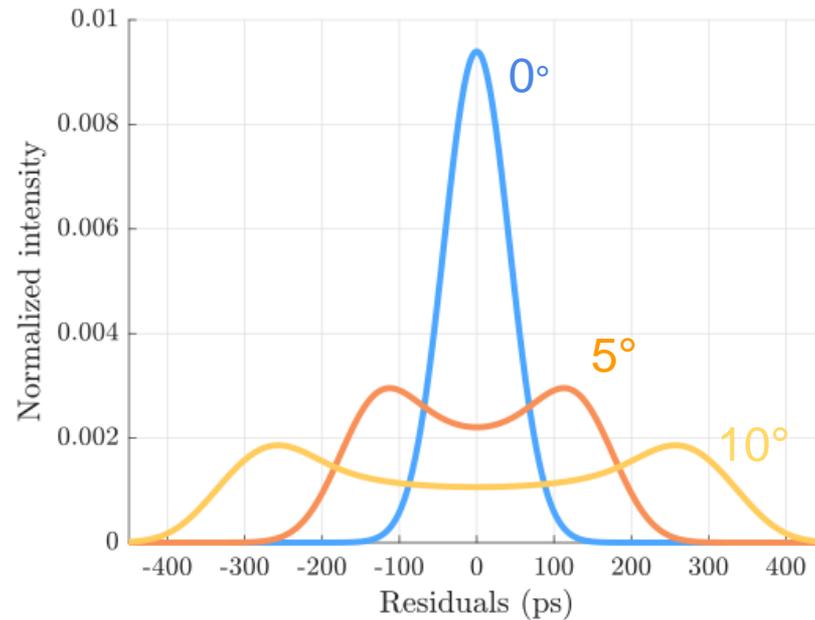
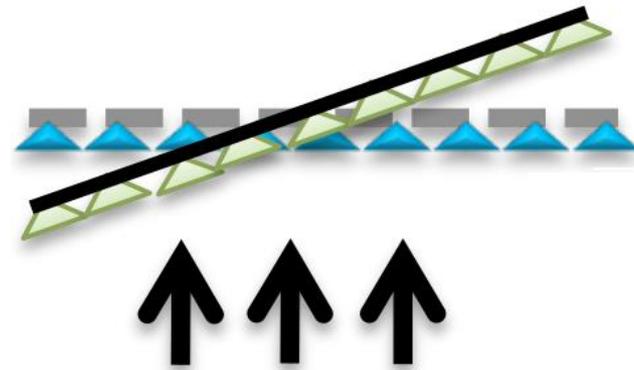
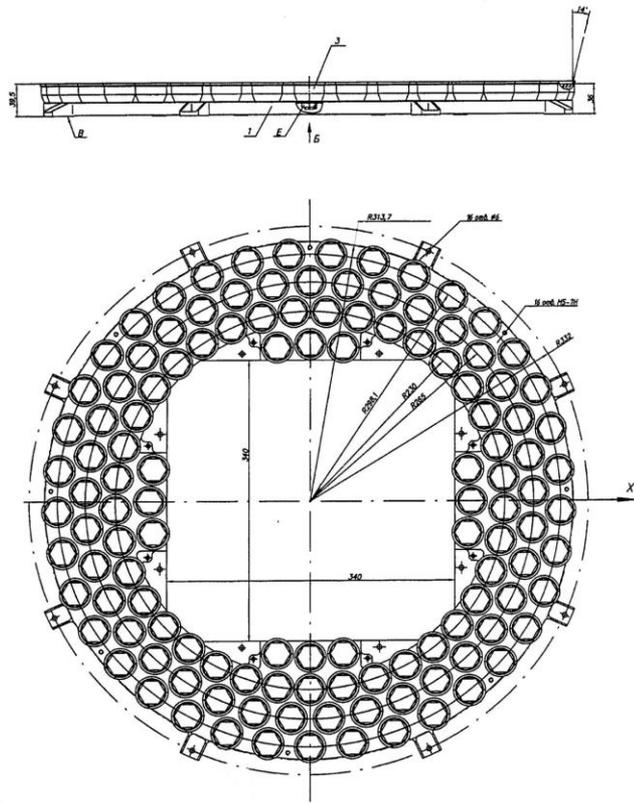
# Results

We detected photons reflected by Glonass-134 and Glonass-131, with mean detection rate of 60Hz and SNR of 0.5. We estimated a downlink channel losses of about 60 dB, resulting in 15 photons per pulse on average reflected by the satellite.

The detection rate and SNR can be drastically improved by means of a telescope on the satellite to lower the diffraction losses. With a  $10 \mu\text{rad}$  of beam divergence we expect to have a detection rate of about 10 kHz and a SNR of the order of 100.

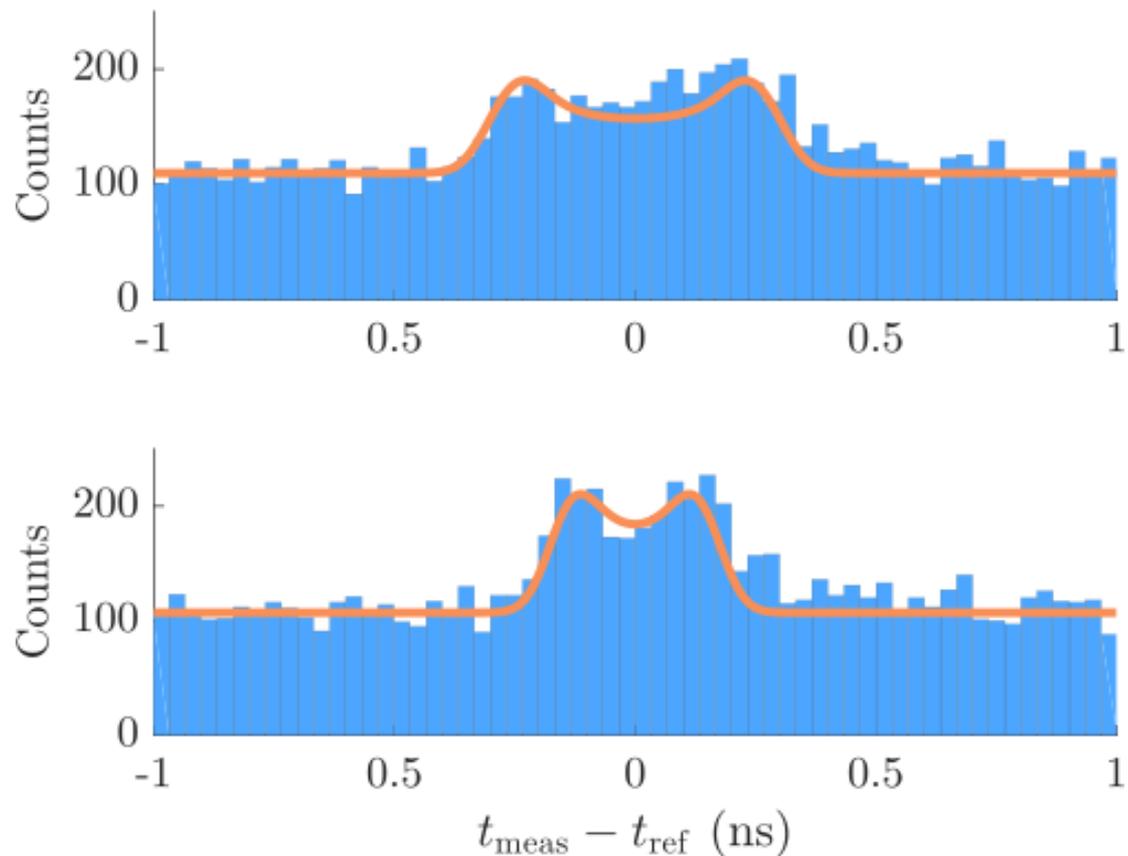


# Temporal spread of the reflected pulse due to the structure of the CCR array



# Temporal spread of the reflected pulse due to the structure of the CCR array

Thanks to the precision on the measurement of the arrival time of the photon we are able to resolve the temporal spread of the pulse. The figure on the **top (bottom)** shows the temporal spread for an incident angle of  $10^\circ$  ( $5^\circ$ ).



# Conclusions

In this work:

- We demonstrated the feasibility of exchanging few photons per pulse along a satellite-to-ground channel length of 20000 km.
- We estimated the specifications of a quantum source on a GNSS satellite to establish a quantum communication channel.
- We resolved the temporal spread of the pulses due to the structure of the CCR array.

Remarks:

- Global Navigation Satellite Systems (GNSS) could be protected with quantum cryptography using state-of-the art technology.
- Space quantum communications represent a promising resource to build a future global-scale quantum network, in which SLR stations could provide the infrastructure for the ground segment.

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*Thank you for your  
attention!!*

