Zero Bin test (or trigger delay)

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What is the Zero Bin Test?

A diagnostic procedure used to verify the timing alignment between:

1. the actual laser pulse emission

and

2. the recorded zero-bin position (which represents the start of the return signal).

Why Do We Need the Zero Bin Test?

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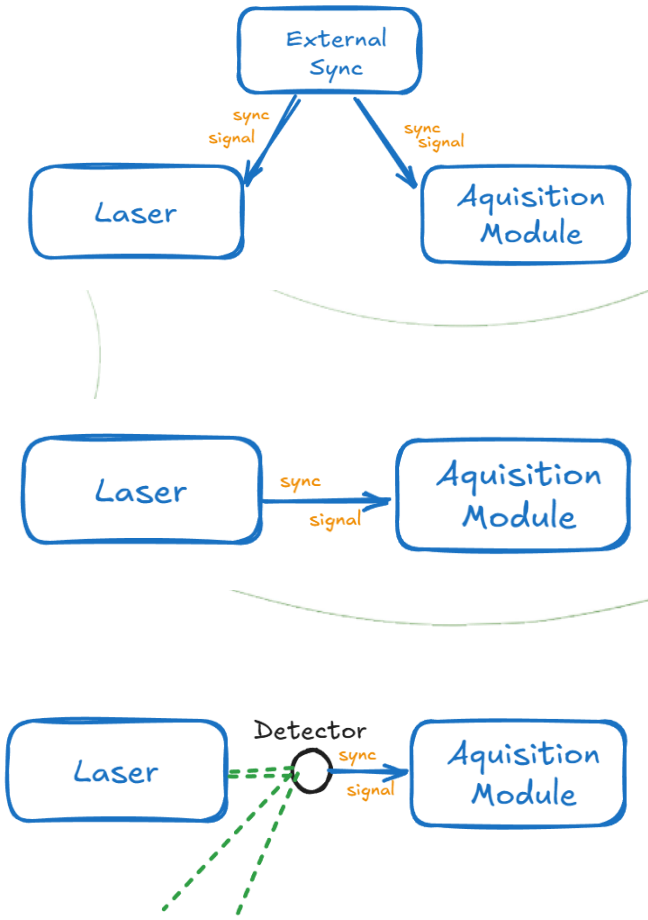
We know that:

- In lidar systems, the acquisition of backscattered signals must be **accurately synchronized** with the **moment of laser emission**.

- This synchronization is typically achieved in several ways:
  - **a)** **Using an external synchronization module**, which sends a common trigger to both the laser and the acquisition system (with a predefined delay given by the user).
  - **b)** **Using the laser's own internal sync signal**, typically the **Q-switch output**, as the master trigger.
  - **c)** **Using an optical sensor** placed in the laser beam path, which generates a signal **when the laser pulse is physically emitted** (i.e., it detects the actual light).



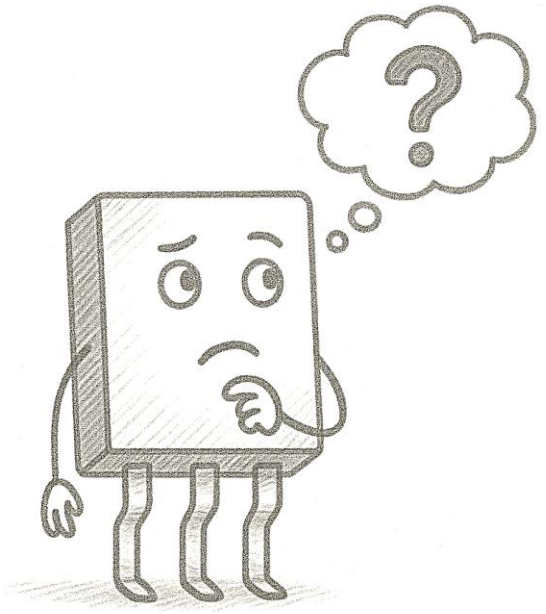
Why Do We Need the Zero Bin Test?

As a consequence:

The trigger signal is **processed by independent electronic units** (e.g., in the laser and in the acquisition system), which often have:

a) **Different** internal **processing delays**,

b) **Varying reaction times** depending on design



Why Do We Need the Zero Bin Test?

This can result in a **delay between the actual moment the laser light is emitted** and the **start of data acquisition**, causing a systematic **time offset** in the recorded signal.

Why Do We Need the Zero Bin Test?

We also know (for licel based modules)

- The **analog** and the **photon counting** data **has a fixed shift between them**.
- This is a result of two factors:
  a) Analog preamplifier contains an antialias filter which has a bandpass of half the
  sampling frequency » delays the analog by 2 bins
  b) ADCs sample the voltage in a multiple step process » the sample result will be available several clock cycles later

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Delay between analog and photon counting (Bin shift)

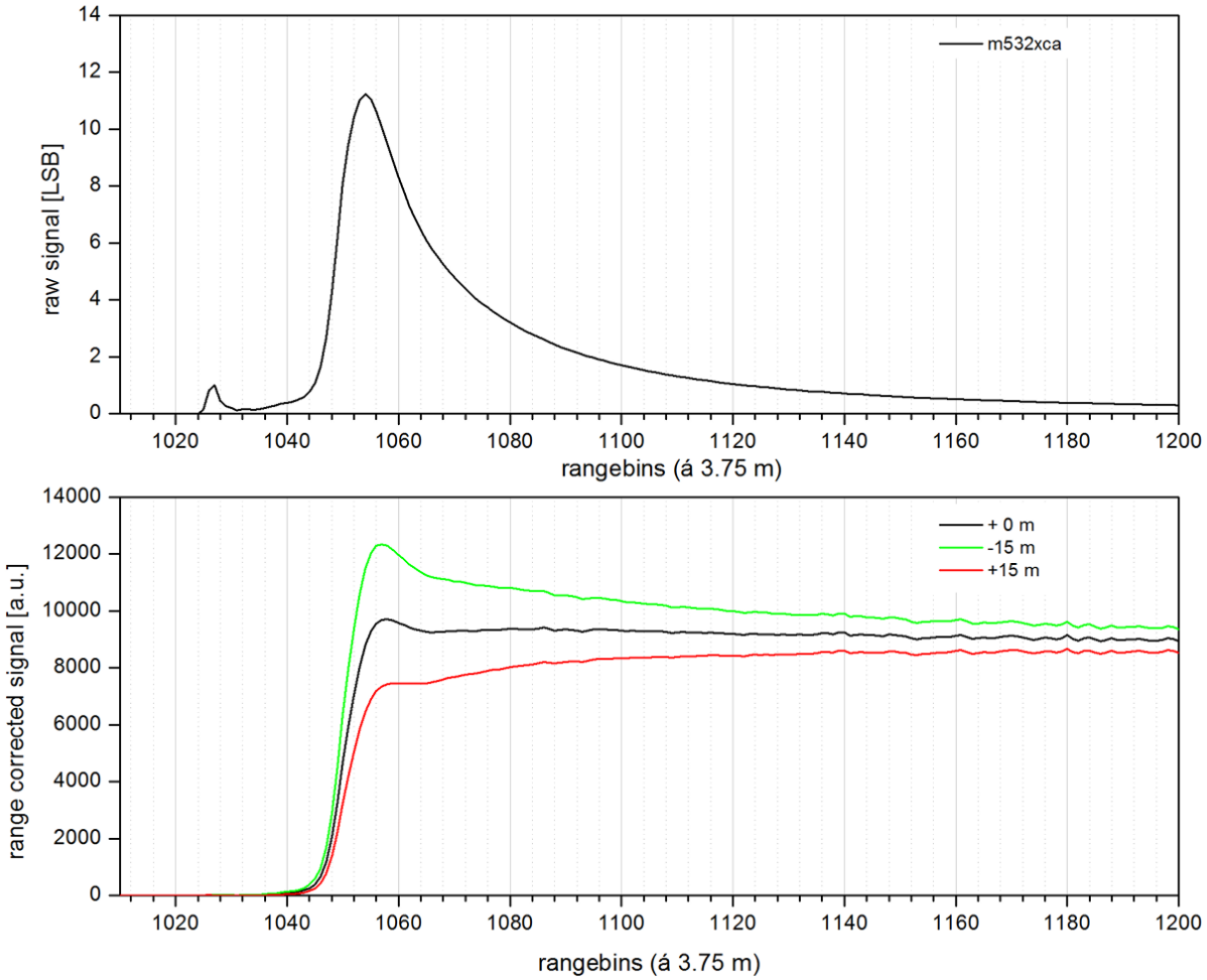
Why Do We Need the Zero Bin Test?

We need to **synchronize the time axis** of the lidar signal with the actual atmospheric return.

What happens if we do not synchronize?

All lidar products will have a range dependent offset, especially in the lower altitudes.

Why Do We Need the Zero Bin Test?



Freudenthaler, V., et al., 2018

Raw analogue lidar signal with 1026 rangebins pretrigger

Range corrected signal of the top panel with three different laser trigger delays

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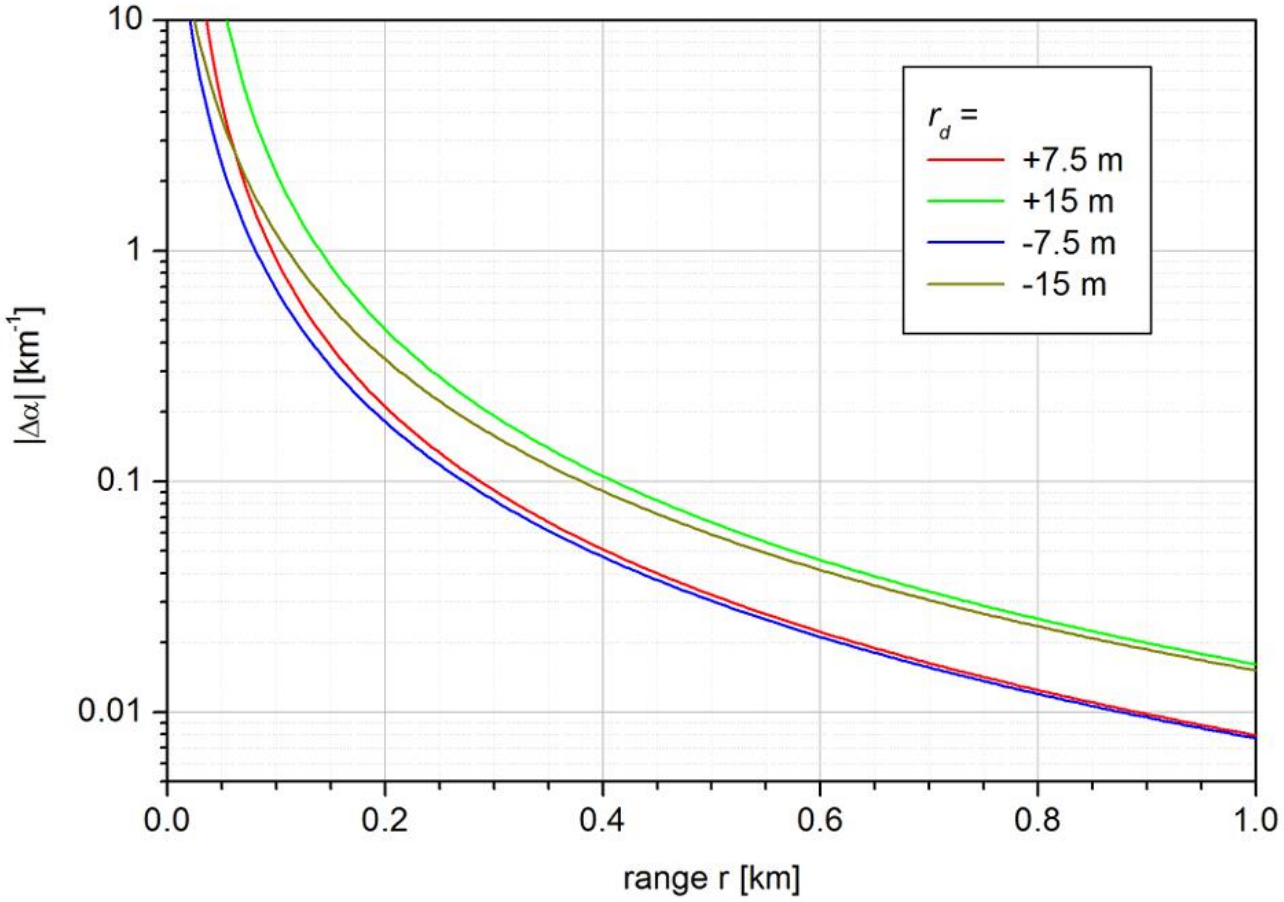
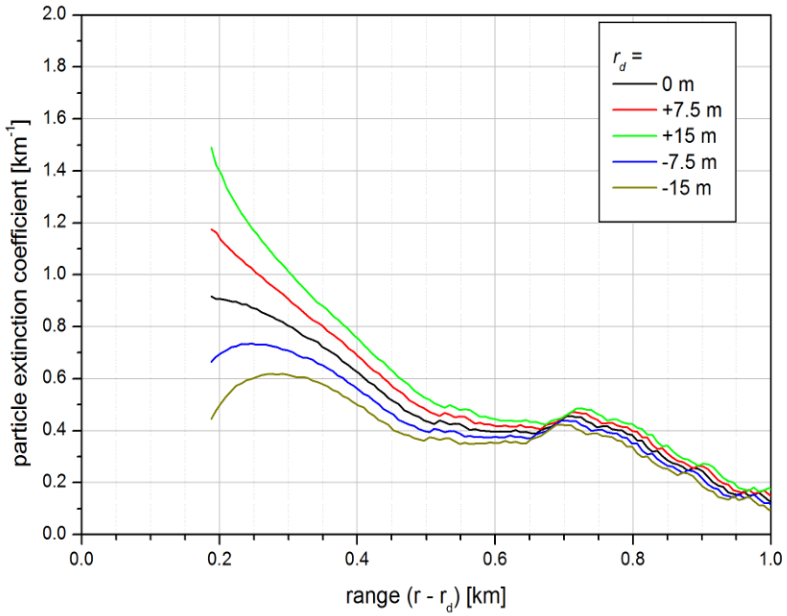


Freudenthaler, V., et al., 2018

Absolute error of the extinction coefficient from Raman measurements @355/387 nm due to uncertainties of the zero bin



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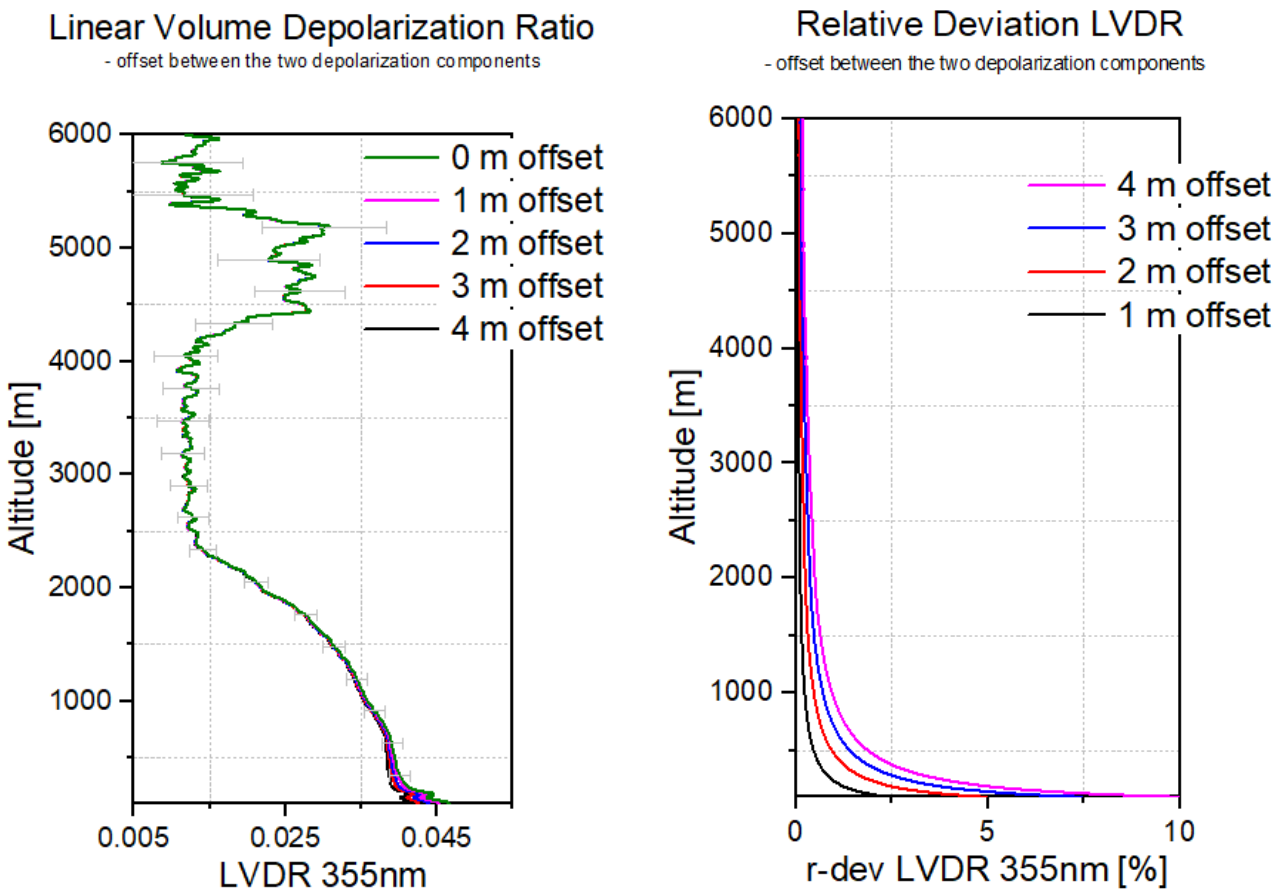

Belegante, L., et al., 2022, ILRC

Bias in the linear volume depolarization ratio (VLDR), which is sensitive to trigger offsets affecting one polarization channel.

Concluding.....

Common Issues Without Zero Bin Calibration

- **Incorrect altitude assignment** of aerosol/cloud layers.
- **Biases** in backscatter and polarization retrievals with severe distortions in Raman retrievals due to signal slope changes in the near range (~1 km).
- **Misalignment with other lidar datasets** during inter-comparisons.
- **Mismatches** between lidar-derived atmospheric profiles and **radiosonde data**, leading to errors in temperature, pressure, and extinction coefficient retrievals during inversion.

How Do We Assess the Zero Bin?

Experimental Methods for Detecting the Zero Bin

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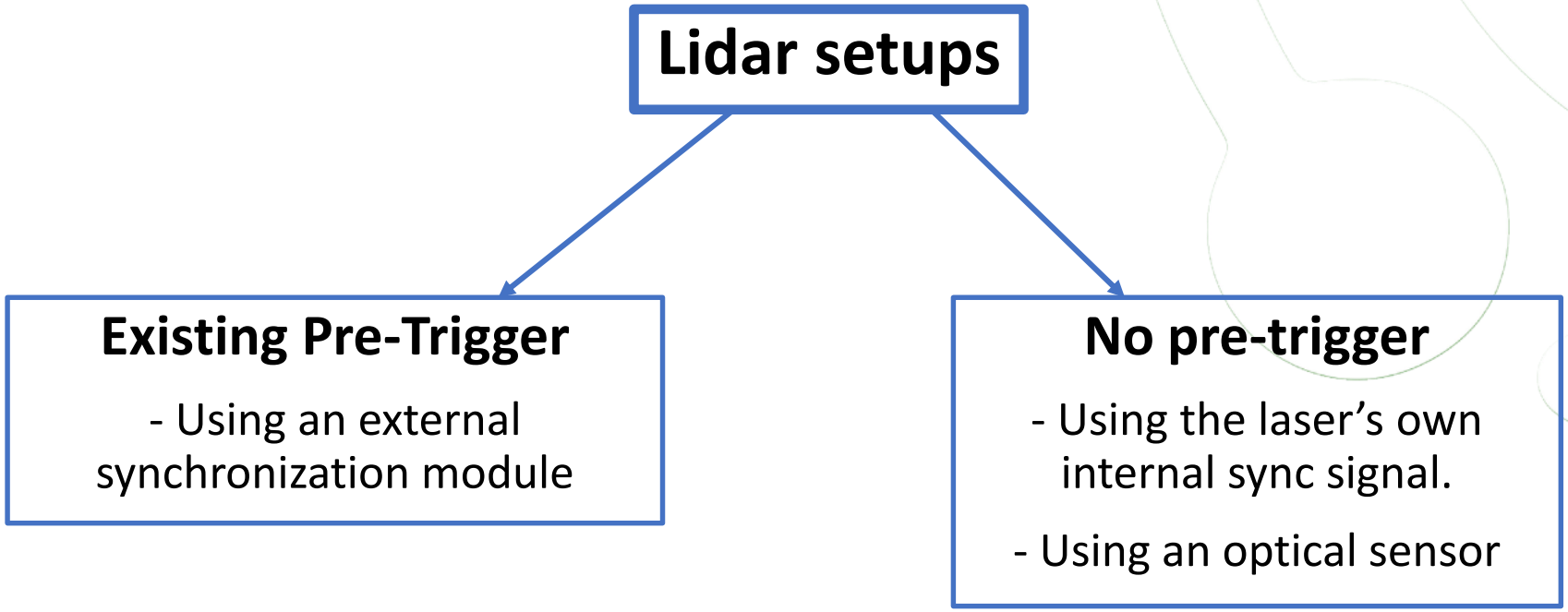

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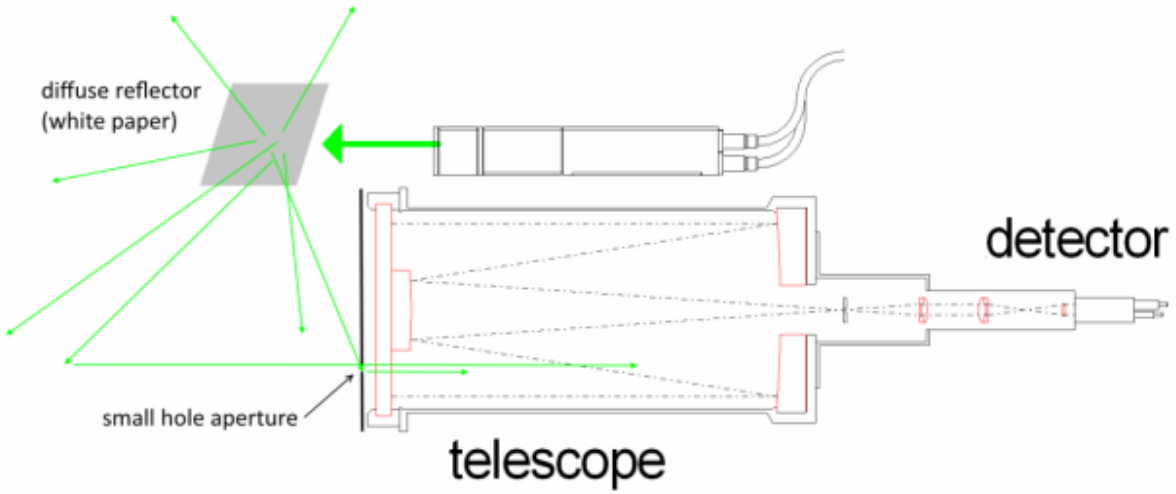
Experimental Methods for Detecting the Zero Bin

Existing Pre-Trigger

Stray light reflections from lab walls or exit window can provide a peak in the recorded signal, allowing zero-bin identification.

A **diffuse scattering target** blocking the laser path can be used.

In both cases - Telescope must be almost fully covered, leaving a small section of the telescope opened.



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Tip: the open section of the telescope should be chosen close to the laser emission - in the N sector for large telescopes (300-400 mm diameter).

Tip: Look at the live preview of the signals and adjust how large the open section needs to be (25-50% of the detection scale).

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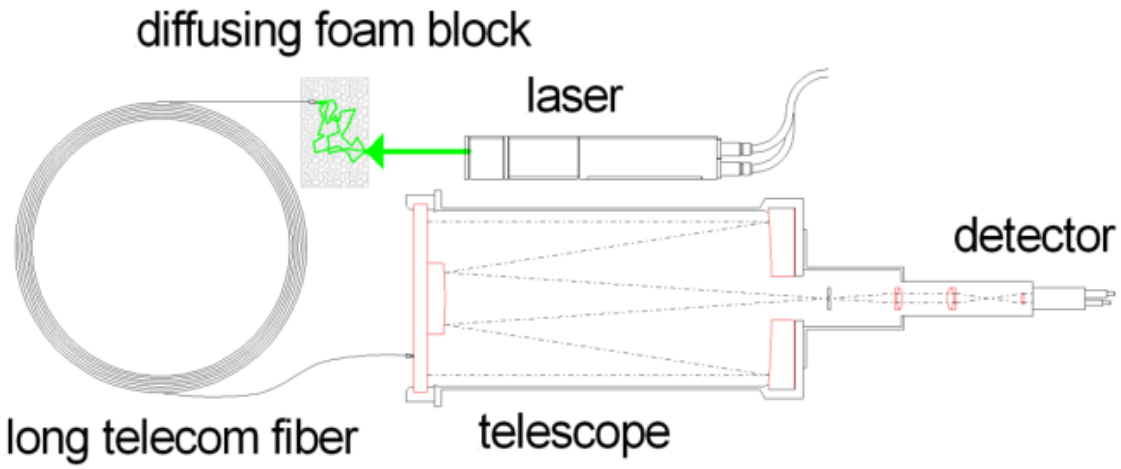
No Pre-Trigger

A near-range **target** at a known distance from the lidar can provide a calibration reference.

A **fiber-optic delay** method can be used: The laser pulse is attenuated and fed into an optical fiber of length s.

The fiber output is positioned in the telescope volume to generate a delayed reference pulse. The telescope must be covered.

Open-cell foam and cheap communication fibers are useful for this technique.



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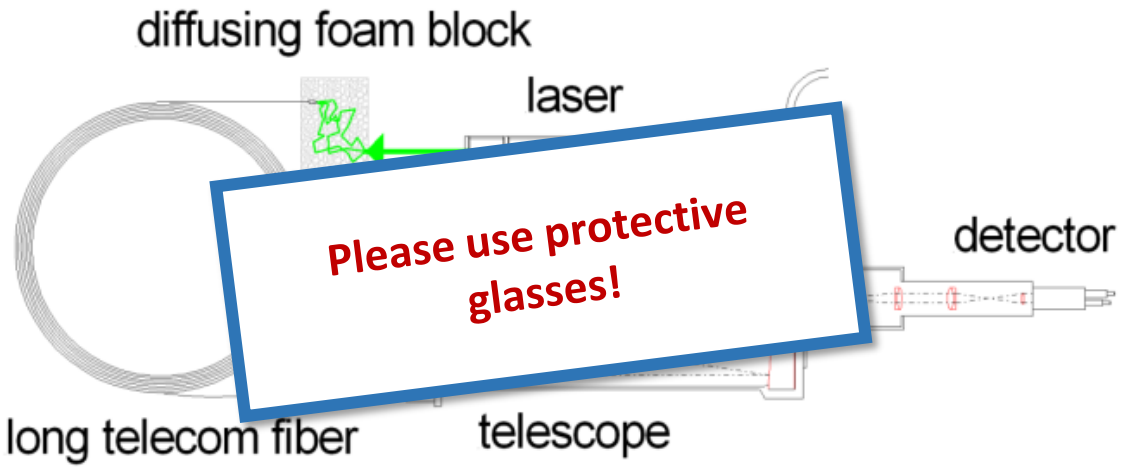

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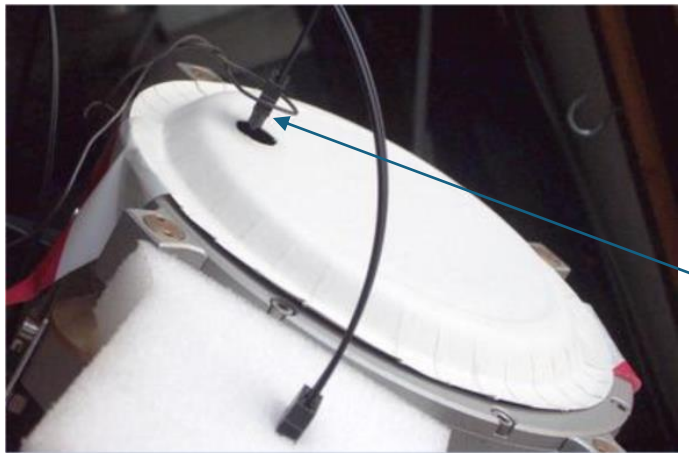

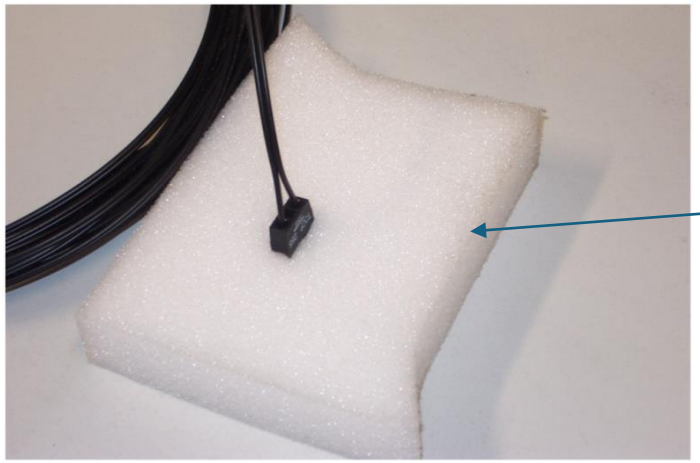

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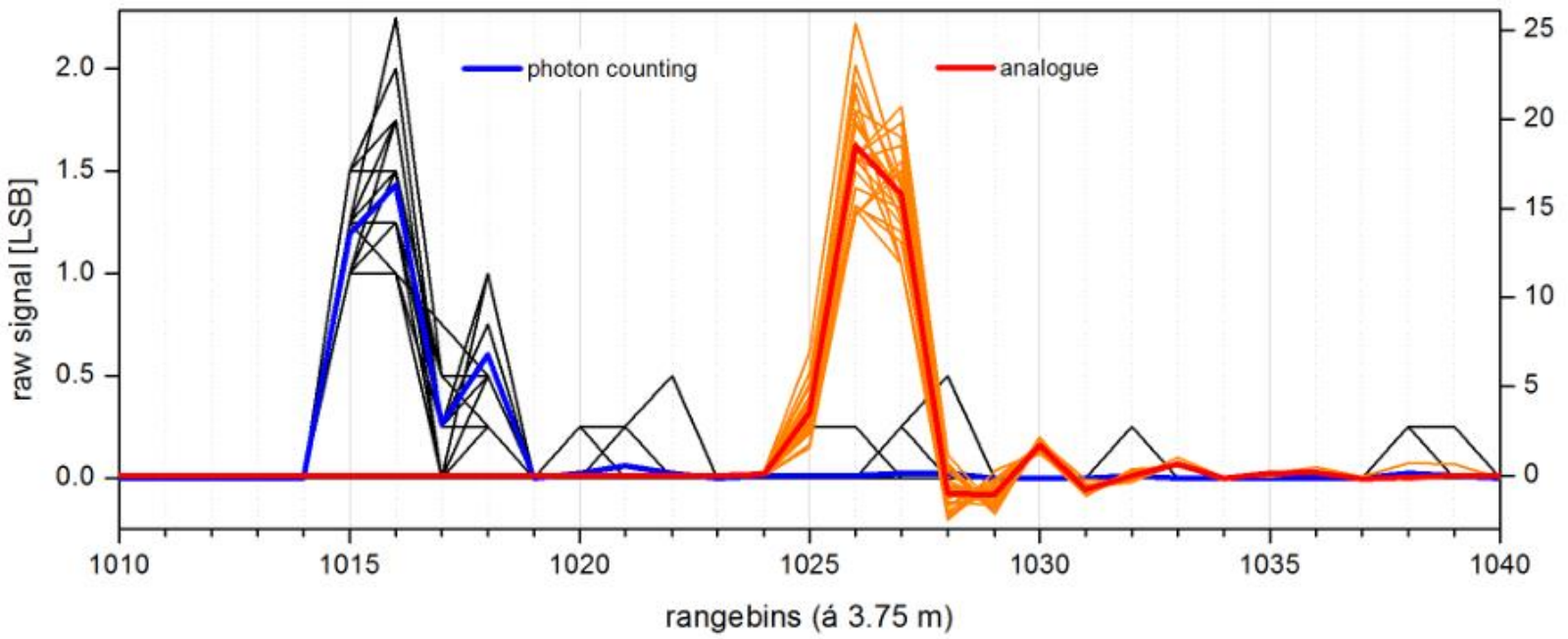
Data visualization



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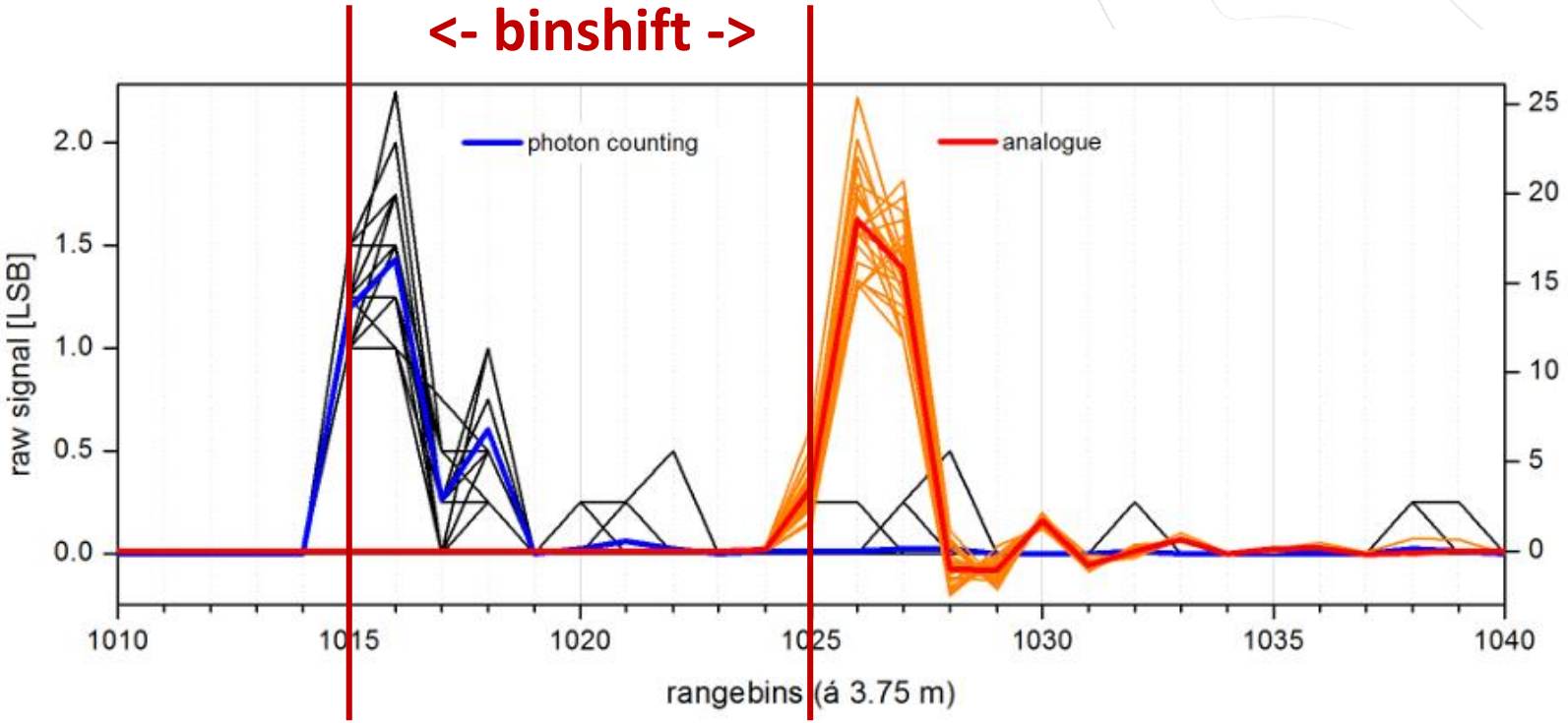

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