Assuring data quality across a diverse aerosol lidar network: the EARLINET experience

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RSLAB

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VIII Workshop on Lidar Measurement in Latin America

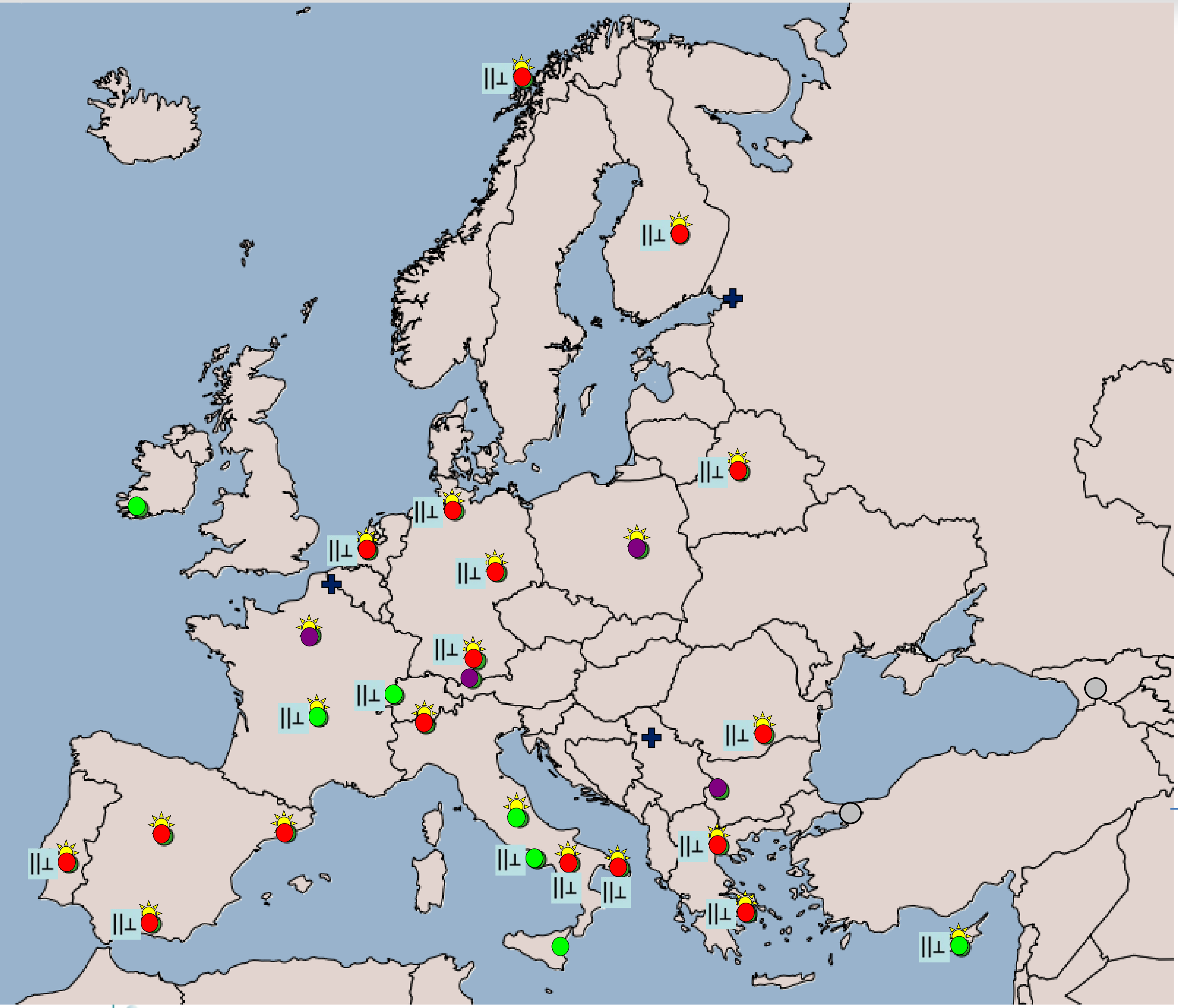
Cayo Coco, Cuba

7 April 2015

Indebted to the work of

Volker Freudenthaler, Giuseppe d’Amico, Christine Böckmann, Gelsomina Pappalardo, Aldo Amodeo, many others and all the EARLINET community….

EARLINET as of end of 2014



Active stations: 28

- 3+2 (+...) stations (aerosol typing, microphysics): **17**
- Raman lidars (extinction profiling): **7**
- Backscatter lidar: **4**
- ||⊥ Depolarization channel (aerosol typing): **18**
- Collocated sun-photometer: **21**

- Stand-by stations: **2**
- New stations: **3**

EARLINET

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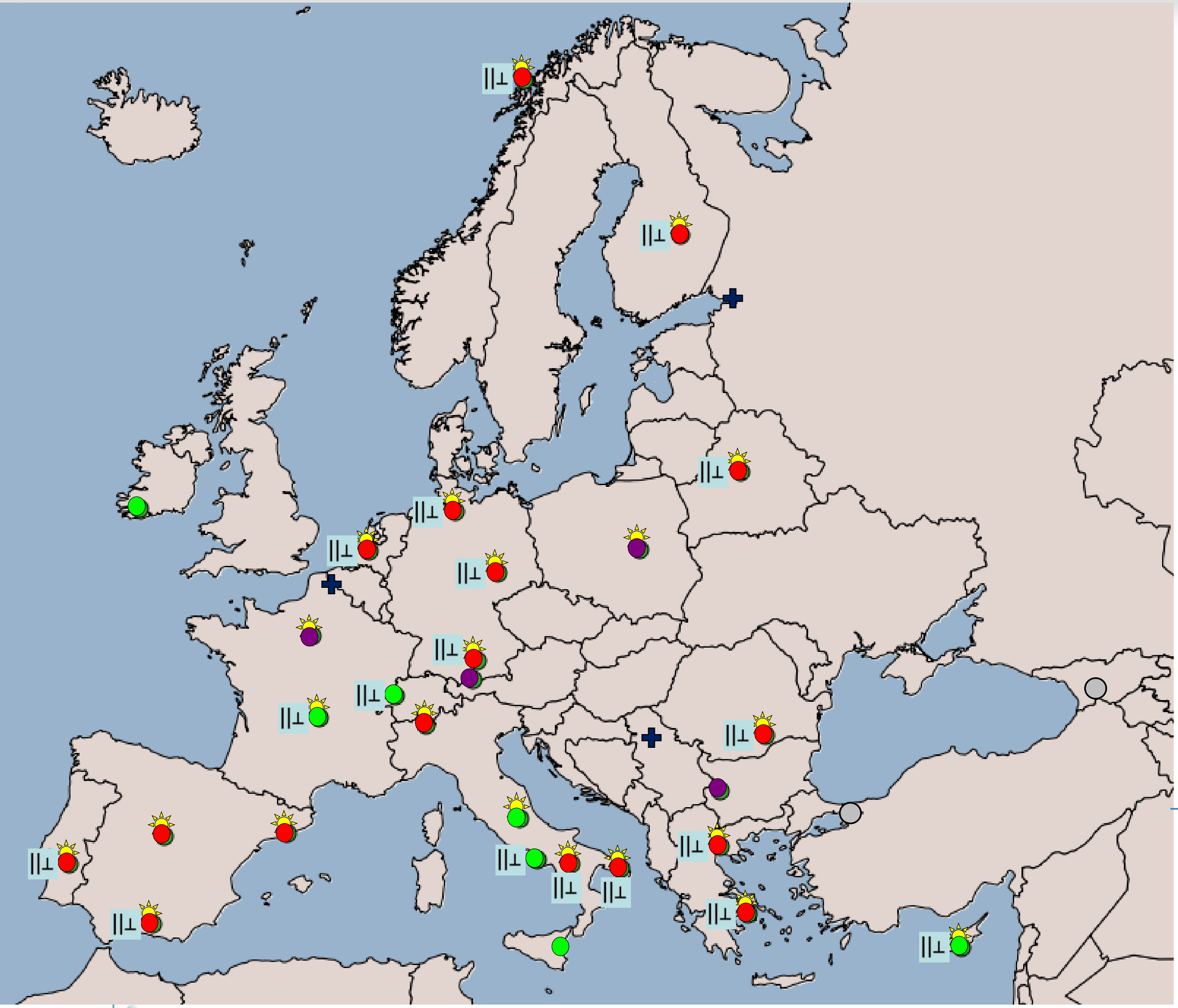
- EARLINET: European Aerosol Research Lidar Network (http://www.earlinet.org)
- Aim: to establish an aerosol climatology at continental scale
- Started in 2000 as a project of the European Union's 5th Framework Programme (2000-2003).
- Continued under FP6 EARLINET-ASOS project (2006-2011)
- Integrated into "Aerosol, Clouds and Trace gases Research Infrastructure network" (ACTRIS) since 2011 under FP7 project, continued in 2015 under Horizon 2020 project (http://www.actris.eu)
- ACTRIS has applied to become a permanent European research infrastructure

EARLINET as of end of 2014



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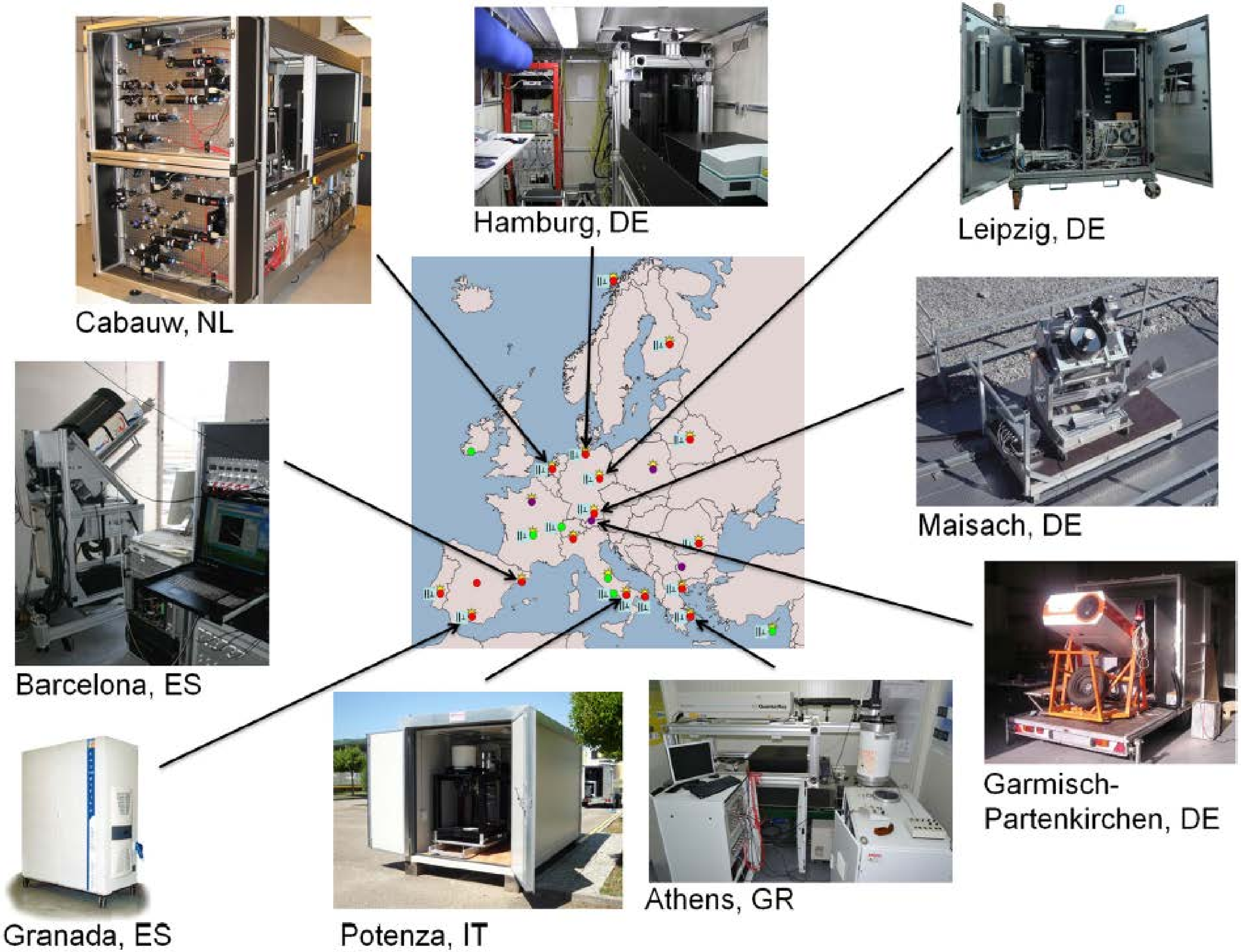
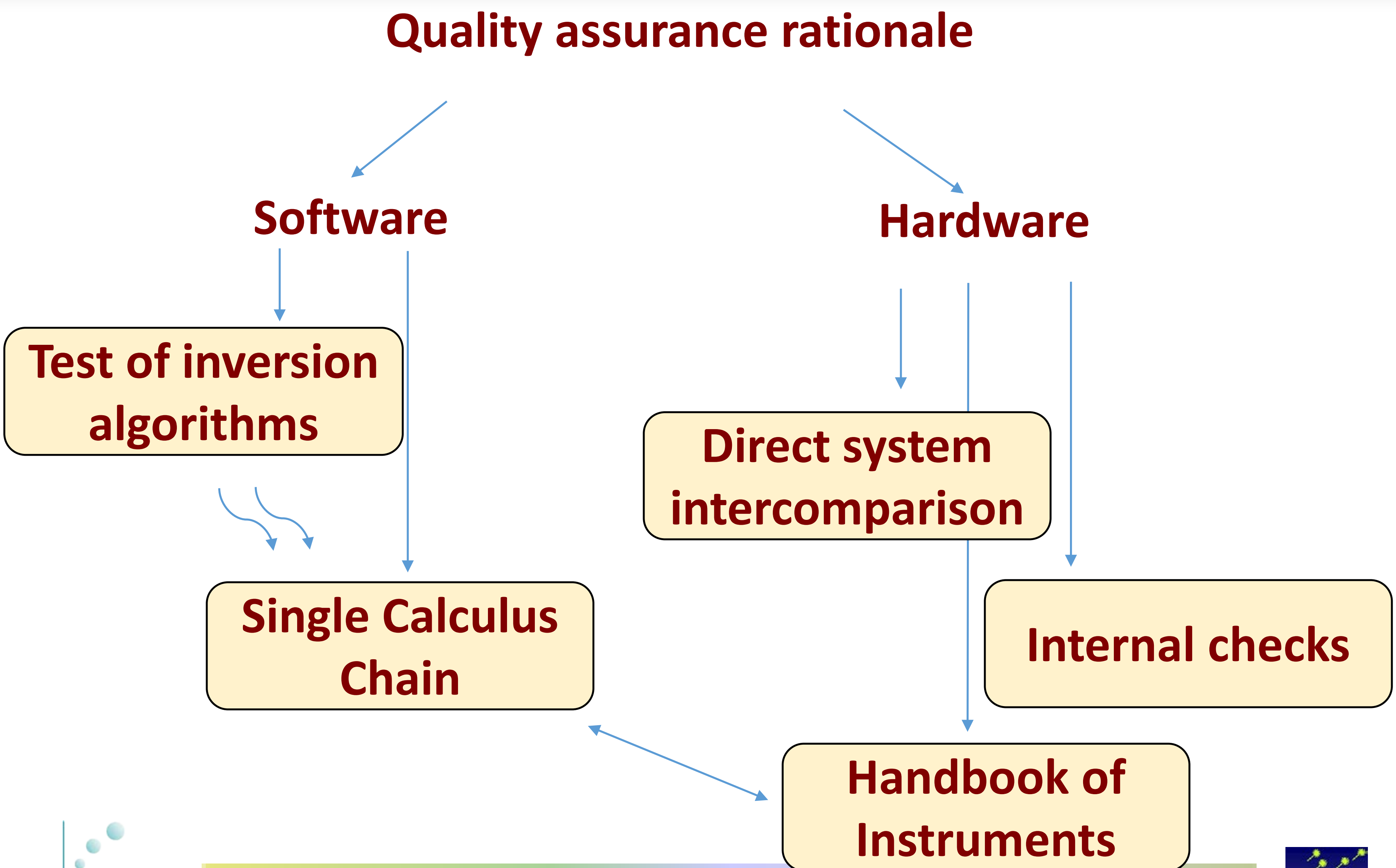


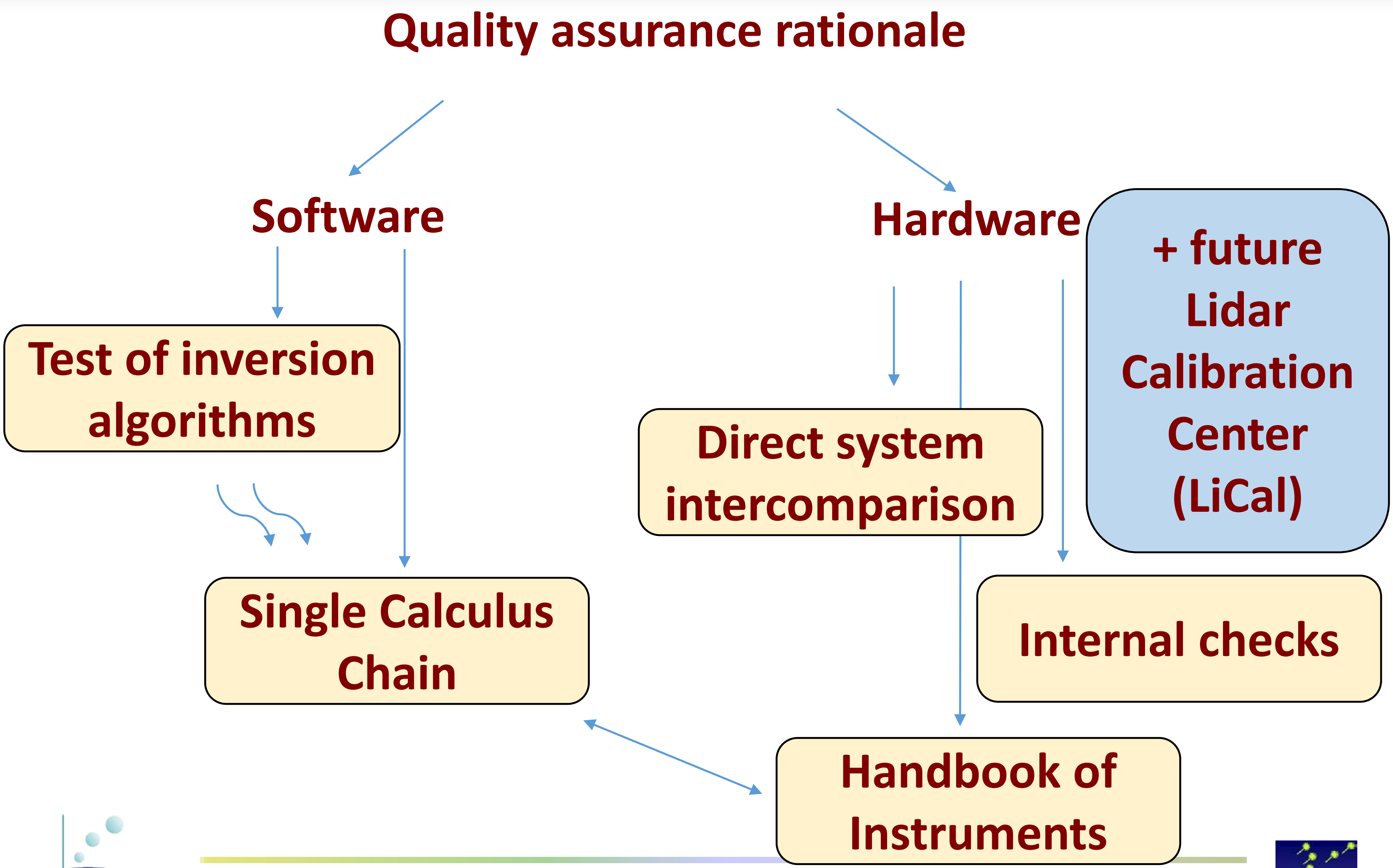
From G. Pappalado et al., “EARLINET: towards an advanced sustainable European aerosol lidar network ”, Atmos. Meas. Tech. **7**, pp. 2389-2409, 2014

Challenge: how to maintain a uniform – and good! – quality of data throughout such a diverse network?

Quality assurance



Quality assurance



Intercomparison of inversion algorithms

- Based on synthetic, yet realistic, lidar signals corresponding to a given scenario and simulating the outputs of different lidar channels
- These signals are distributed to the researchers in charge of the retrievals of atmospheric coefficients, along with information of ground-level pressure and temperature
- Participants must produce optical coefficients using their own algorithms
  - First without any other piece of information
  - Then giving additional information on the molecular atmosphere and the aerosol

Checks also operator's expertise

Focuses on the algorithm implementation

Test of inversion algorithms

Synthetic elastic signals distributed at 355 nm, 532 nm and 1064 nm

Initial information: P and T at ground level

Synthetic Raman signals distributed at 387 nm and 607 nm

1st stage: retrieve backscatter coefficients with elastic algorithms

2nd stage: retrieve extinction and backscatter coefficients at 355 and 532 nm with Raman algorithms

Added information: Ångström exponents, P and T profiles, reference values for backscatter coeff. at 355 nm and 532 nm

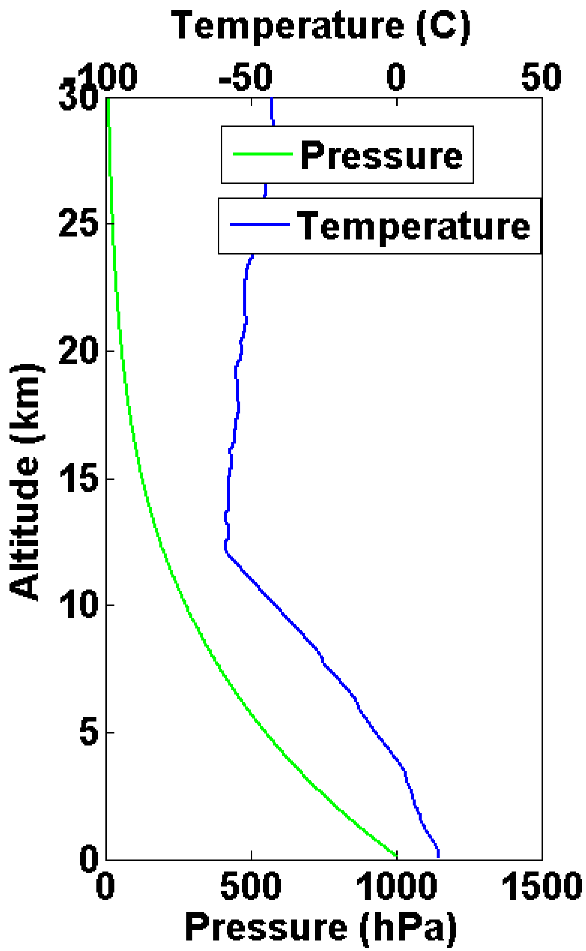
3rd stage: retrieve extinction and backscatter coefficients at 355 and 532 nm with Raman algorithms

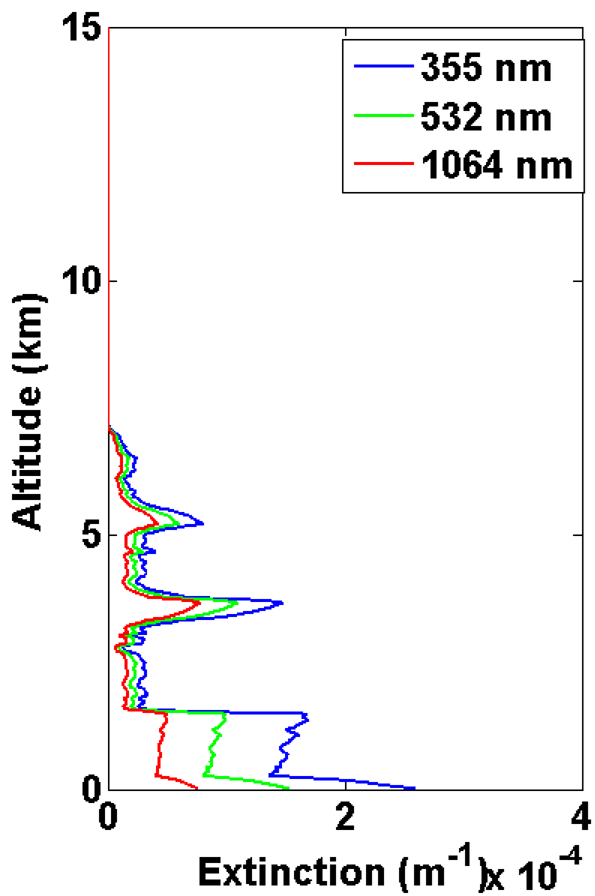
Added information: Lidar ratio profiles

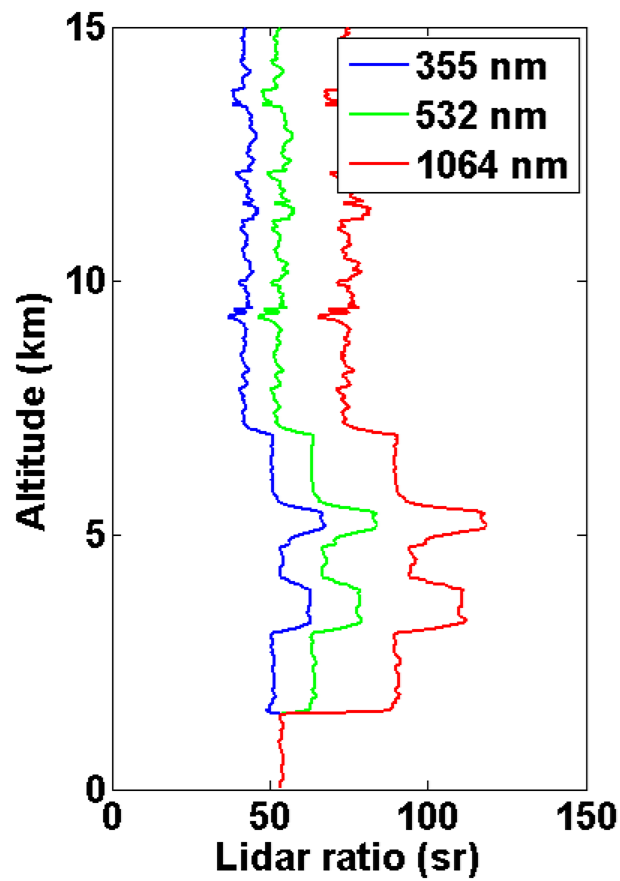
4th stage: retrieve backscatter coefficients with elastic algorithms

Test of inversion algorithms

SIMULATED SCENARIO





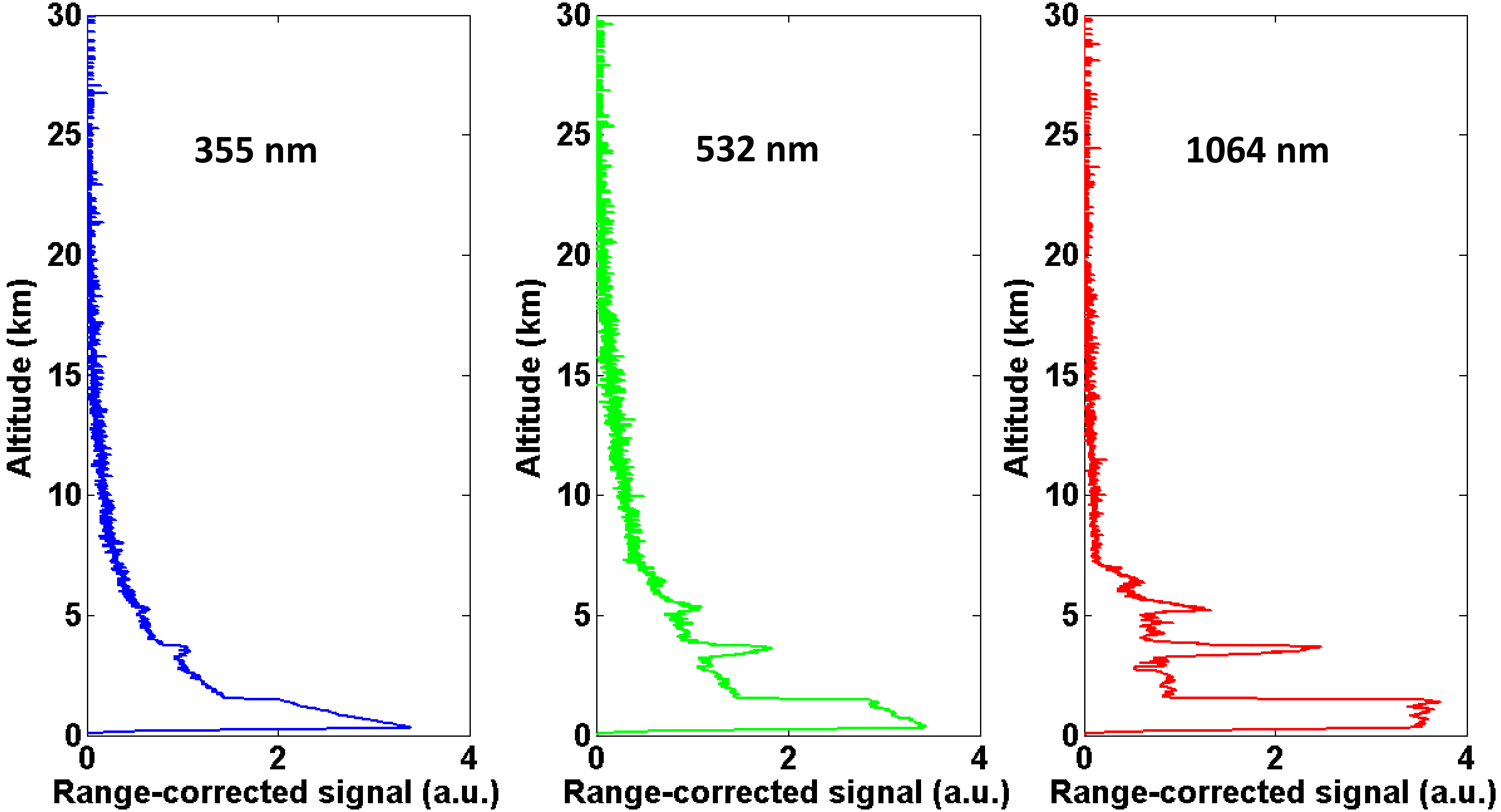


Source: G. Pappalardo

INTERCOMPARISON OF ELASTIC ALGORITHMS

DATA PROVIDED TO PARTICIPANTS

Elastic signals

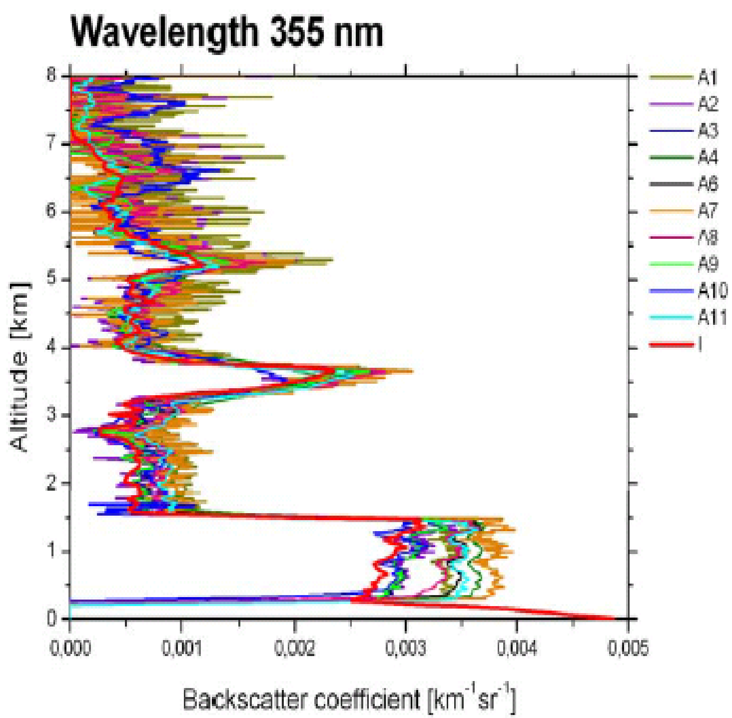


Source: G. Pappalardo

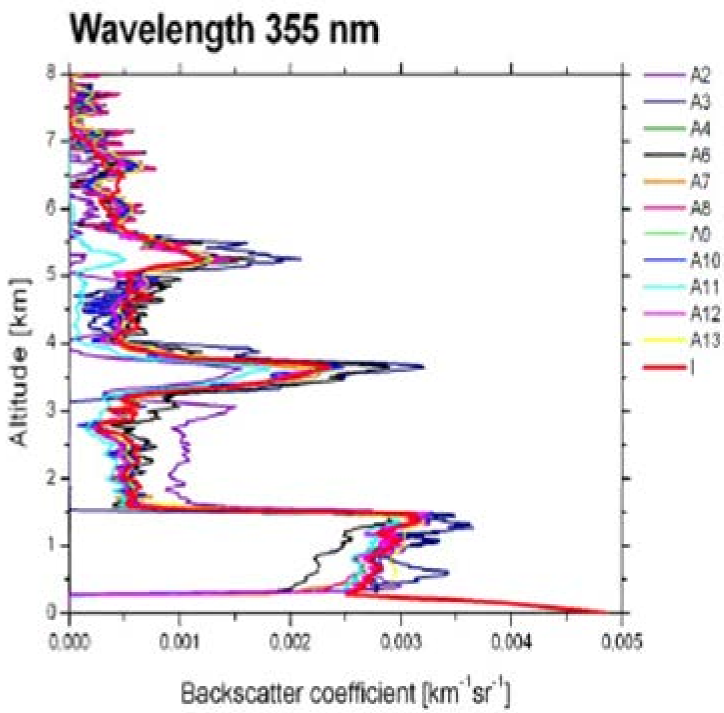
Test of inversion algorithms

INTERCOMPARISON OF ELASTIC ALGORITHMS

1st stage



4th stage

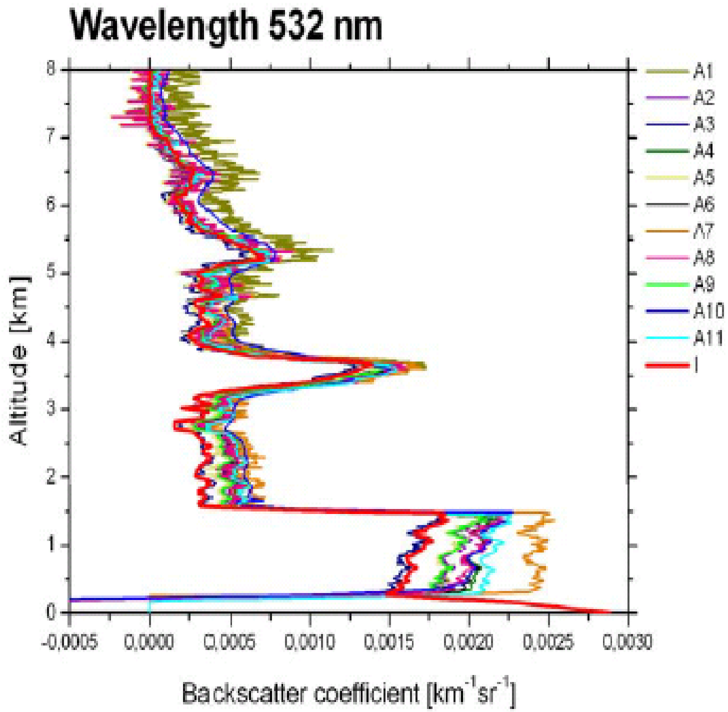


Source: C. Böckmann

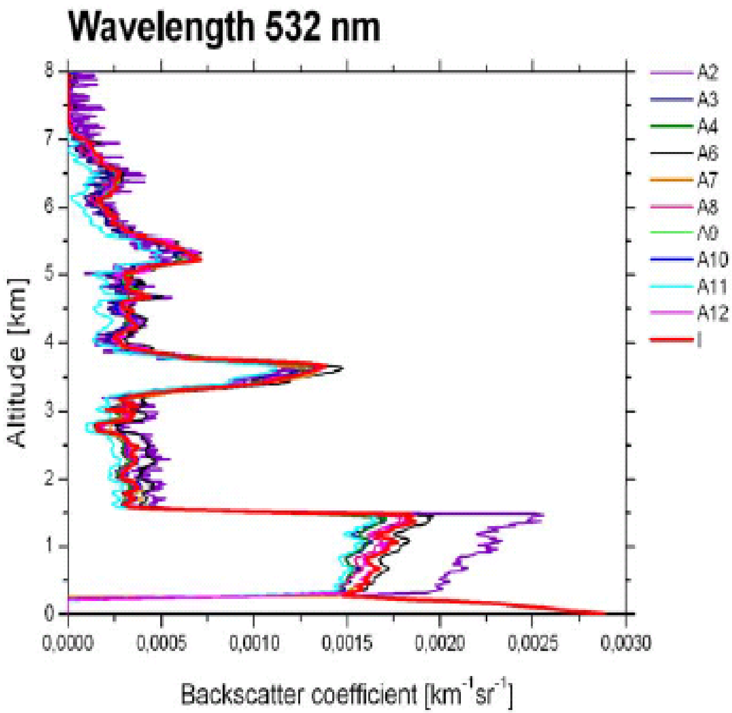
Test of inversion algorithms

INTERCOMPARISON OF ELASTIC ALGORITHMS

1st stage



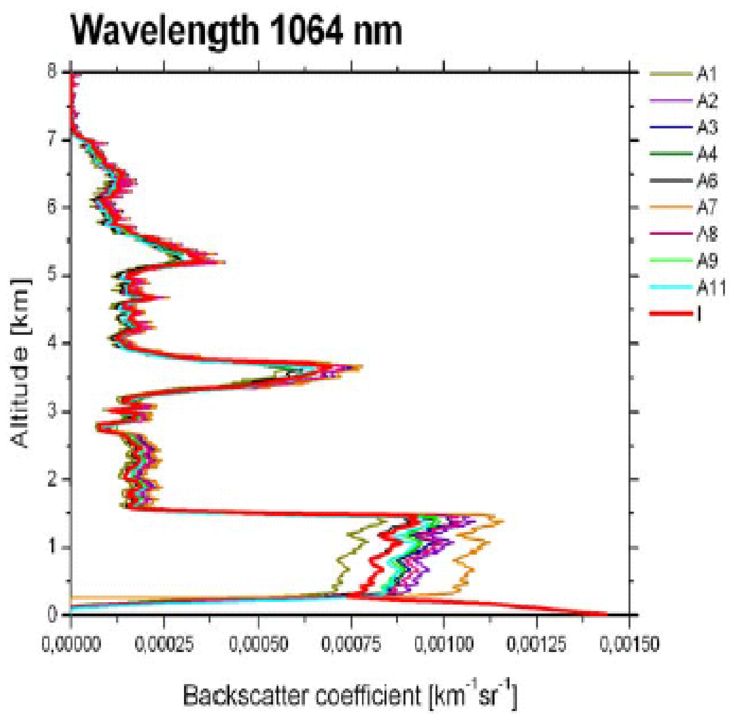
4th stage



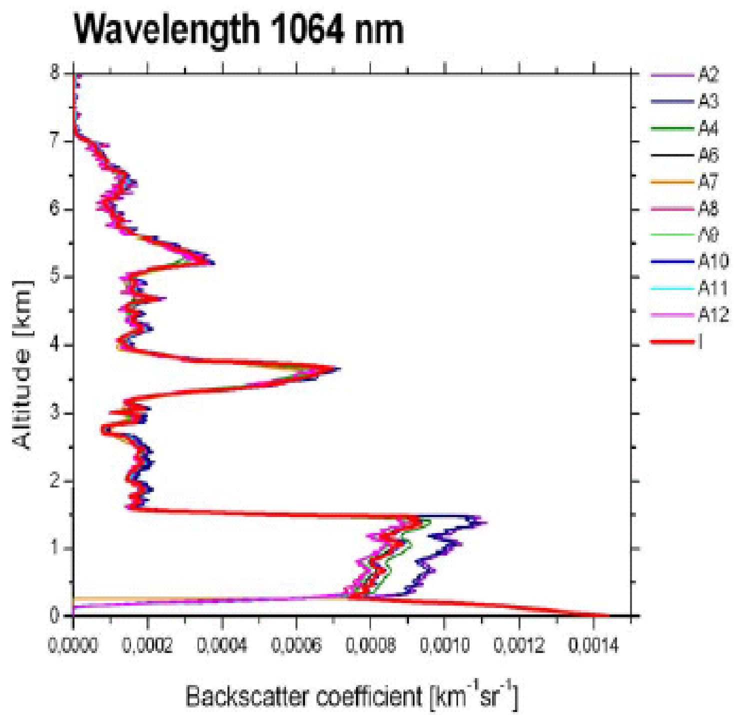
Source: C. Böckmann

INTERCOMPARISON OF ELASTIC ALGORITHMS

1st stage



4th stage

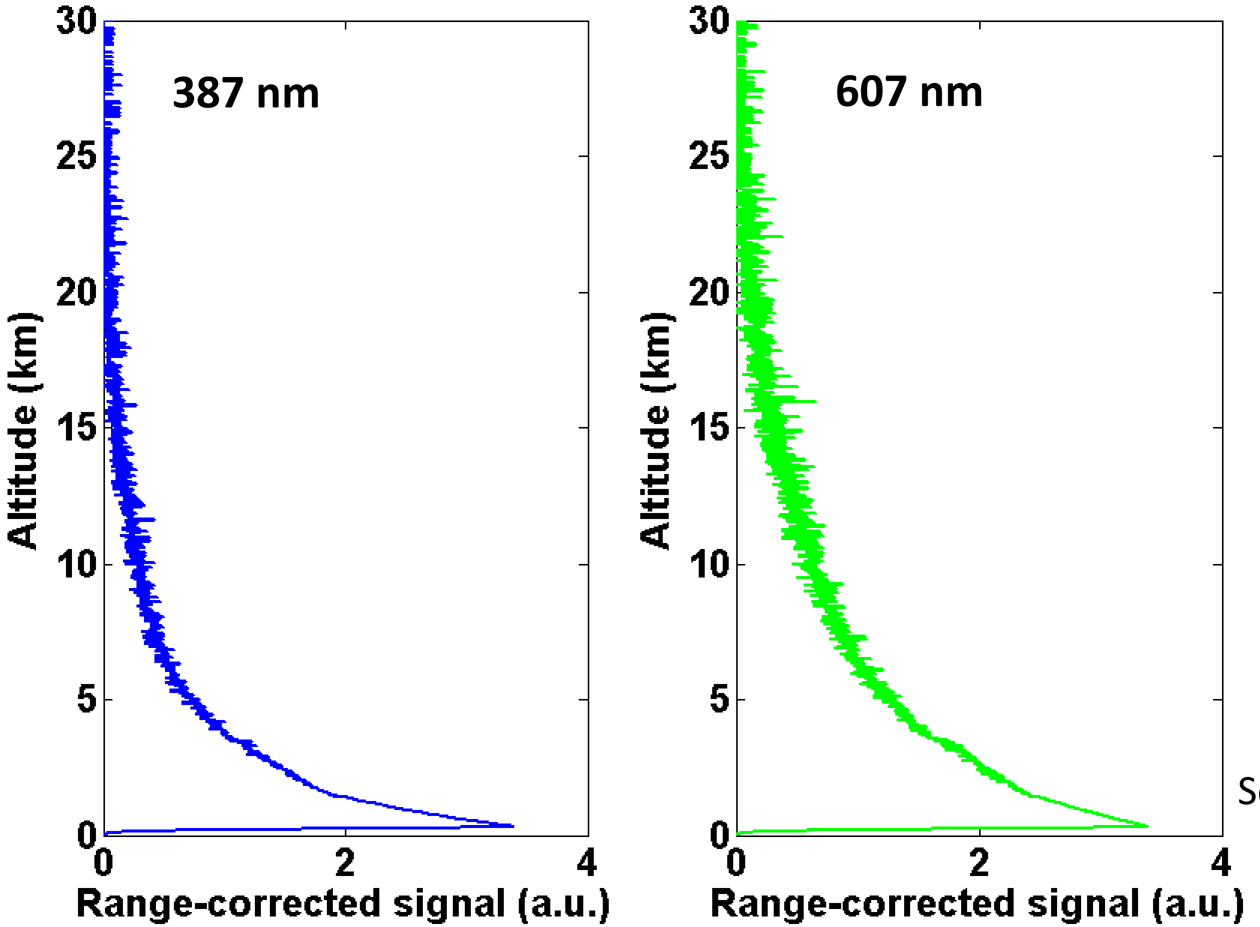


Source: C. Böckmann

Test of inversion algorithms

INTERCOMPARISON OF RAMAN ALGORITHMS
DATA PROVIDED TO PARTICIPANTS

Raman signals (in addition to elastic ones)

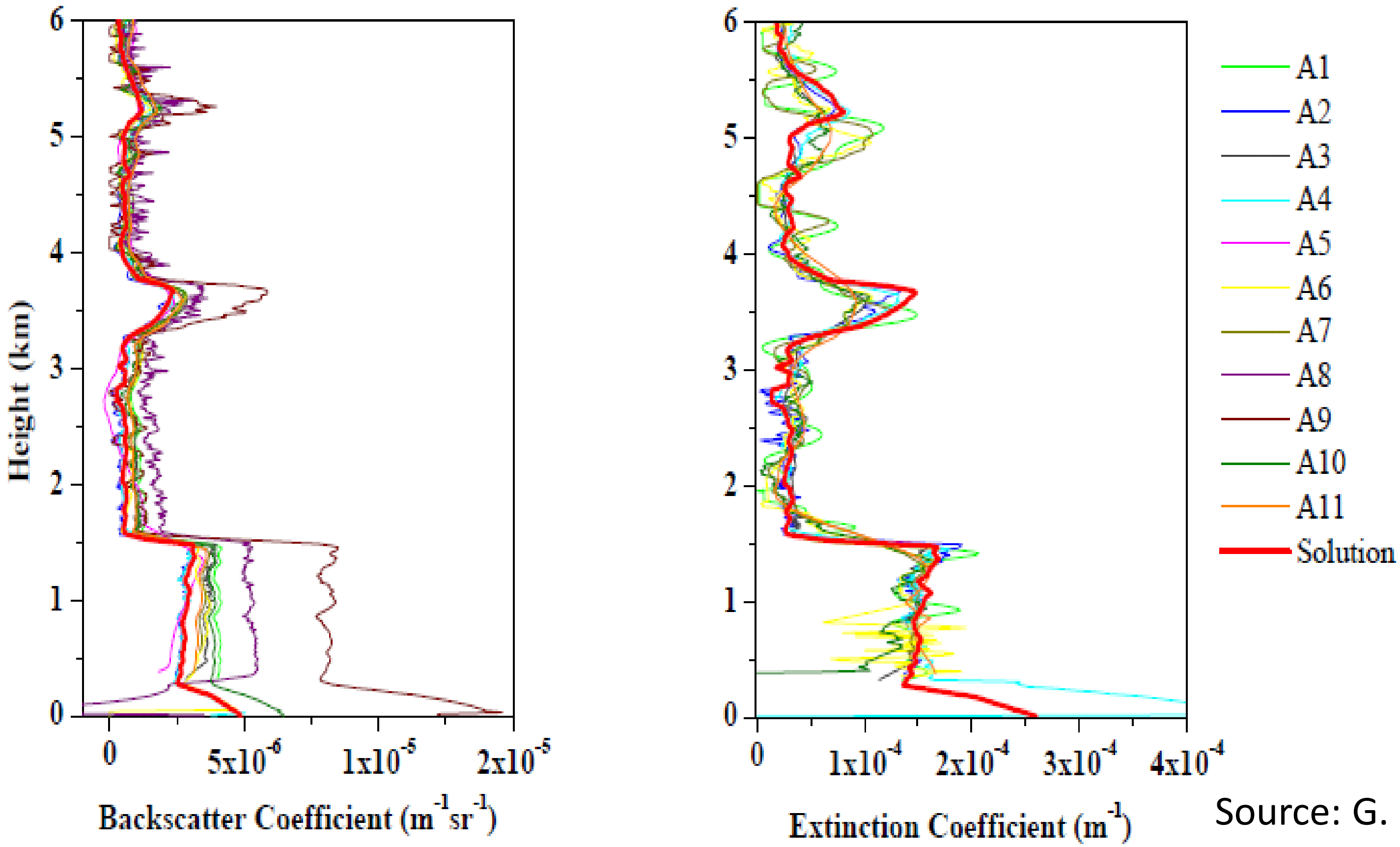


Source: G. Pappalardo

INTERCOMPARISON OF RAMAN ALGORITHMS

2nd stage

355 nm

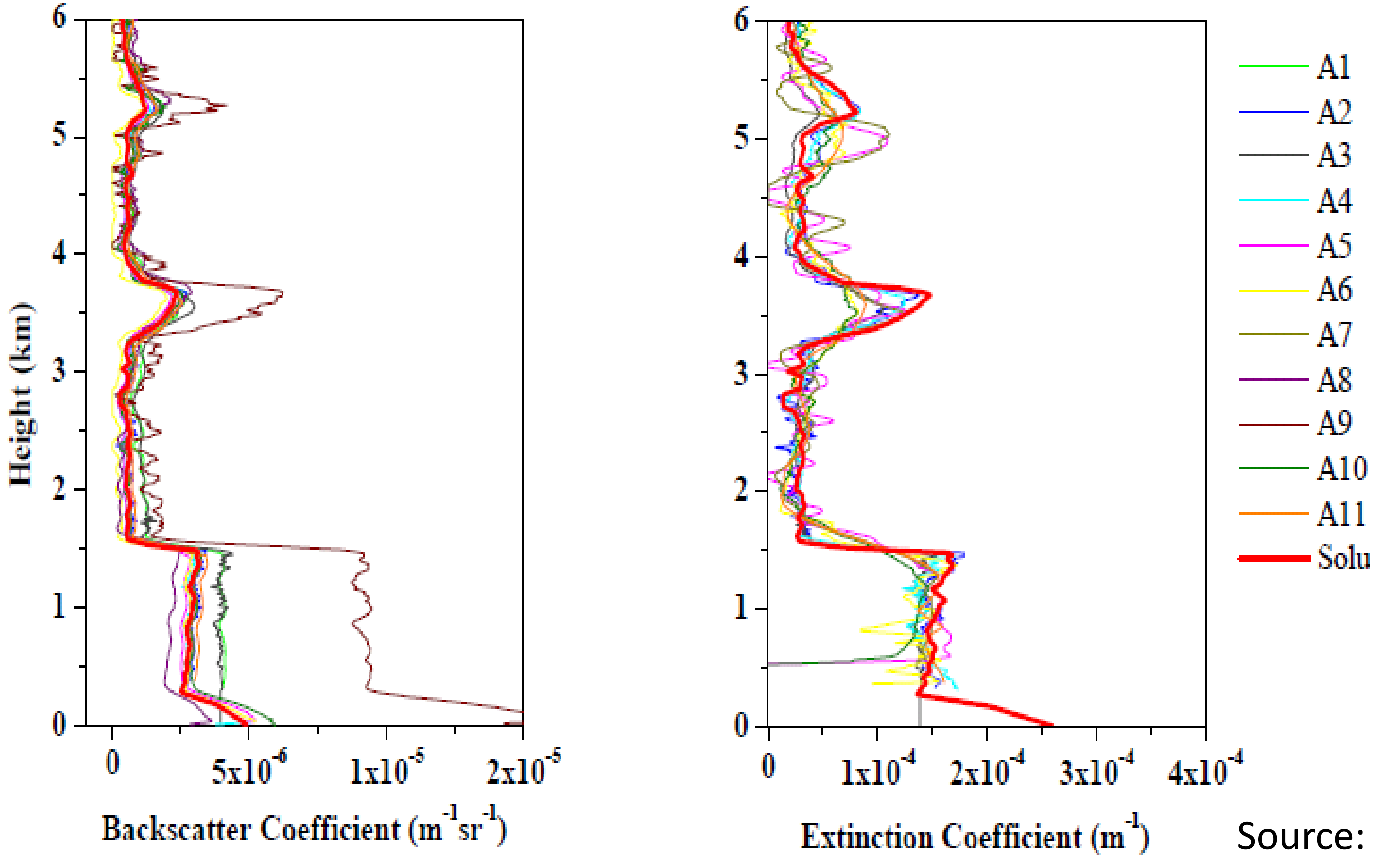


Source: G. Pappalardo

INTERCOMPARISON OF RAMAN ALGORITHMS

3rd stage

355 nm



Source: G. Pappalardo

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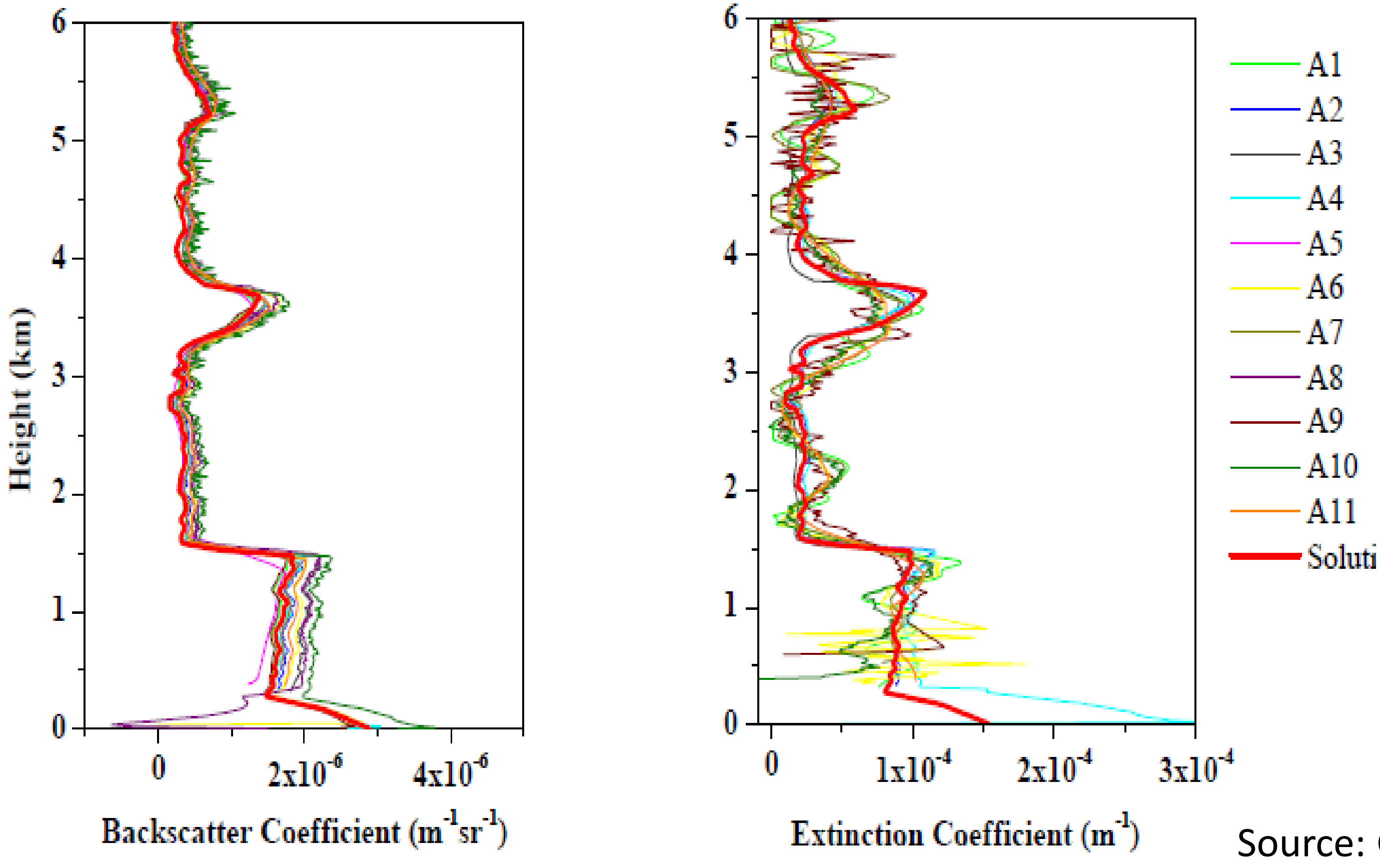
INTERCOMPARISON OF RAMAN ALGORITHMS

2nd stage

532 nm



Source: G. Pappalardo

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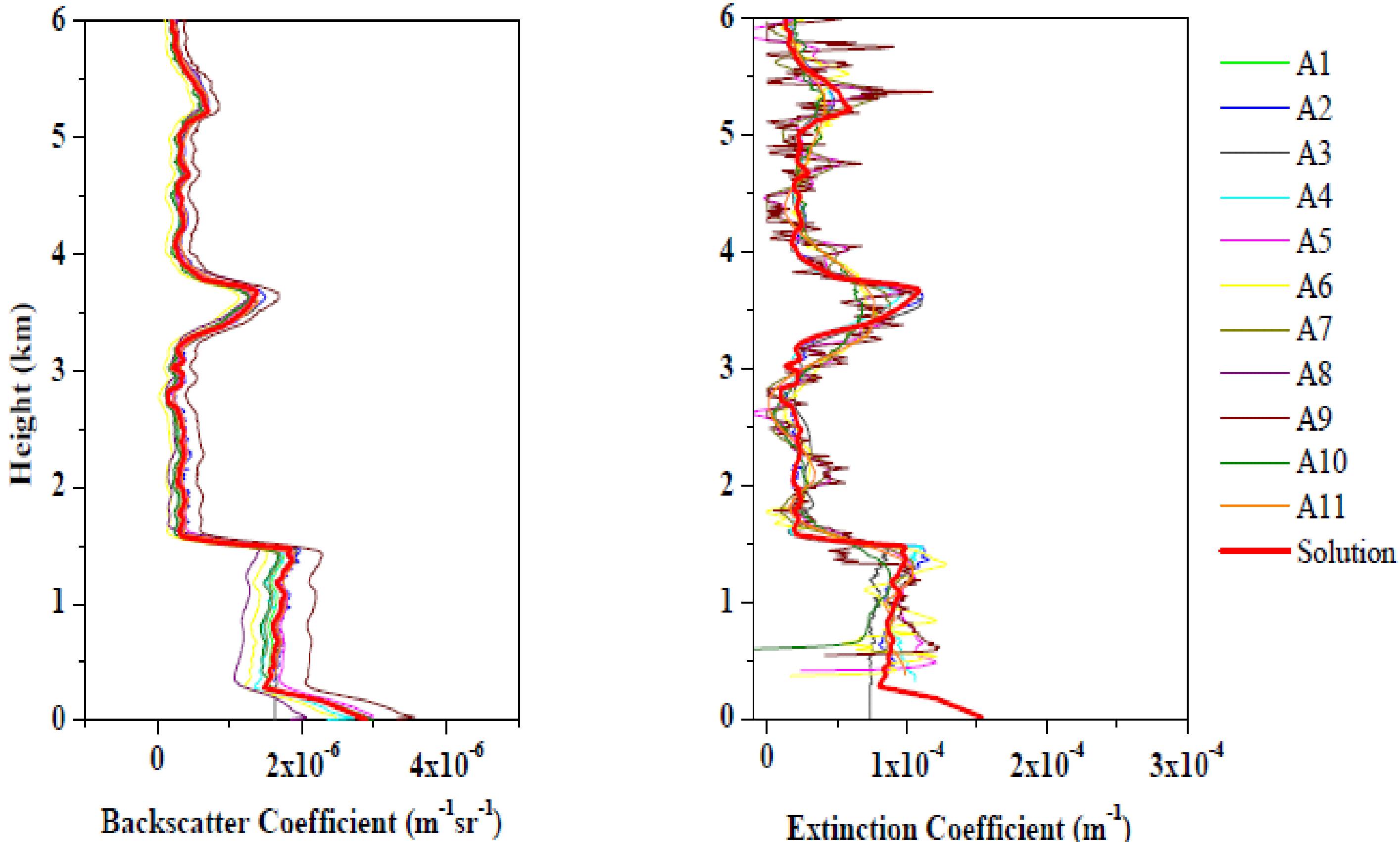
INTERCOMPARISON OF RAMAN ALGORITHMS

3rd stage

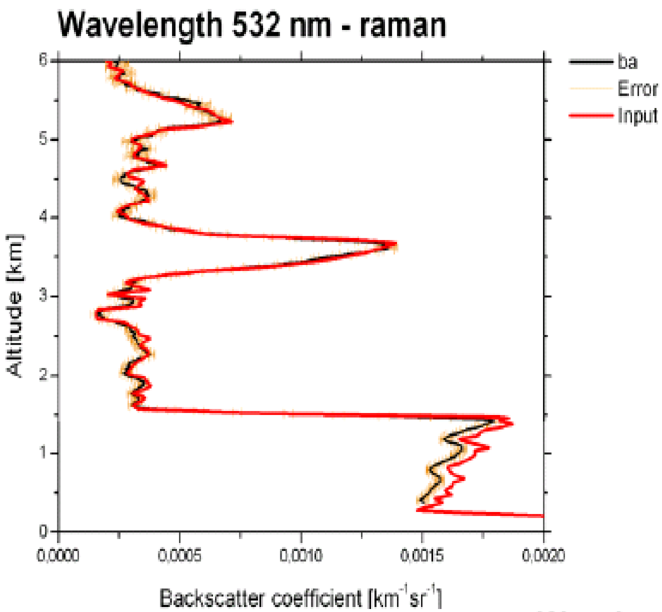
532 nm

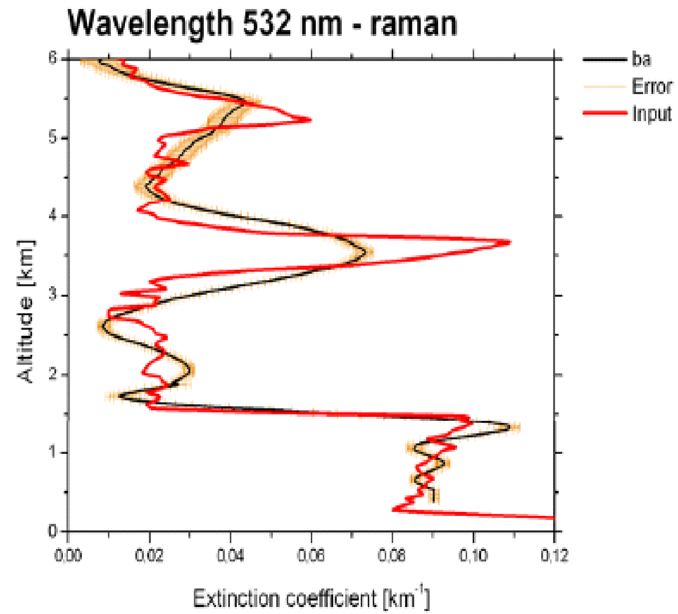


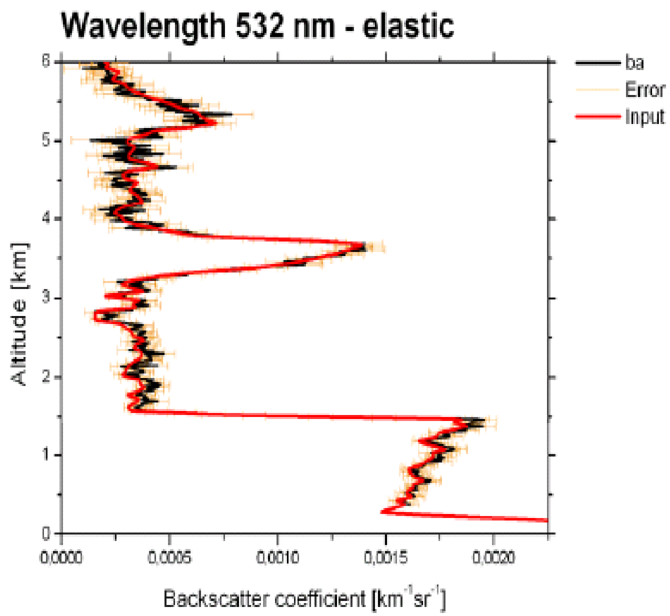
Source: G. Pappalardo

Test of inversion algorithms

Also tested error estimate in the retrieval (error bars)…

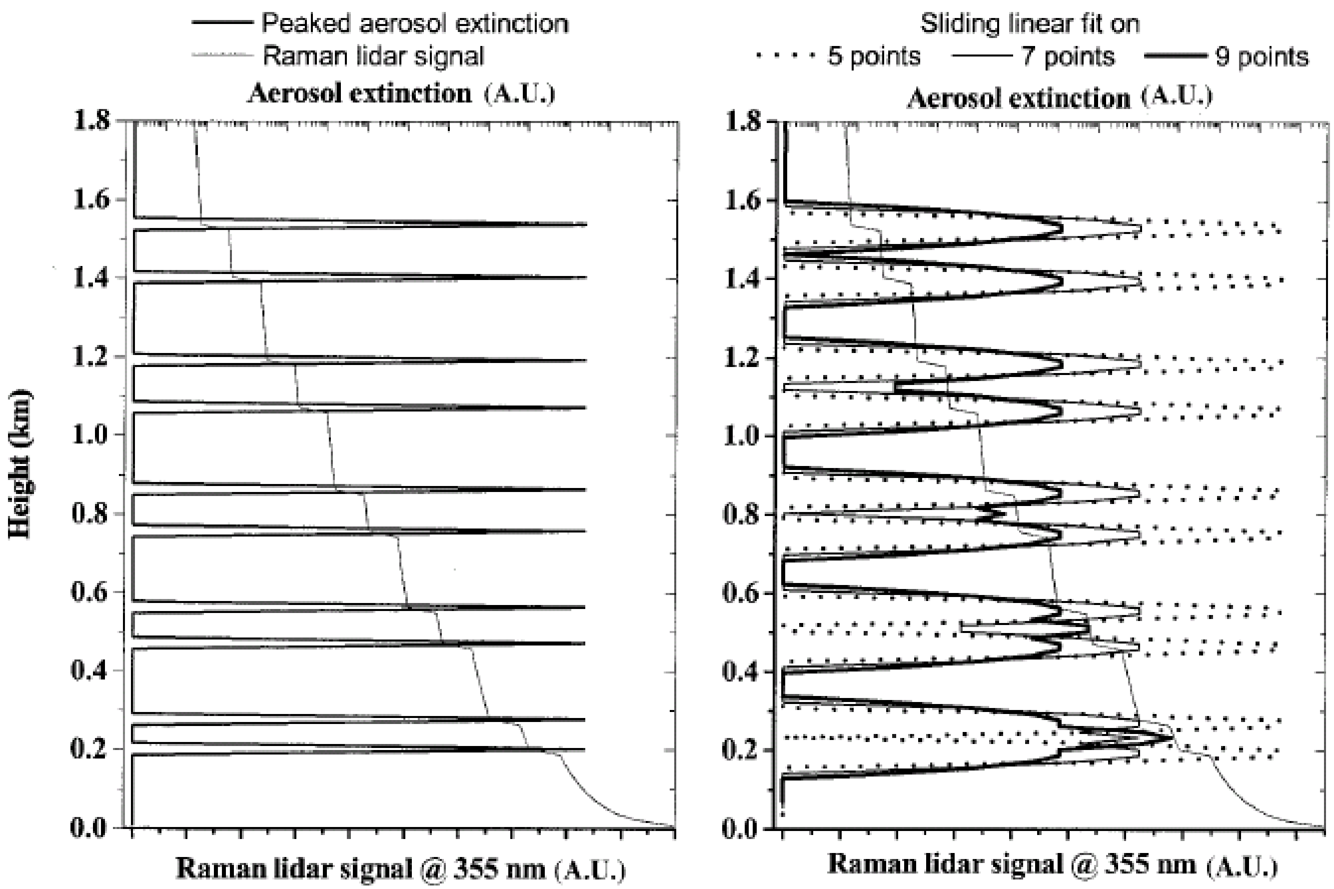






Source: G. Pappalardo

… and spatial resolution



See G. Pappalardo et al. App. Opt. **43** (28), pp. 5370-5385, 2014

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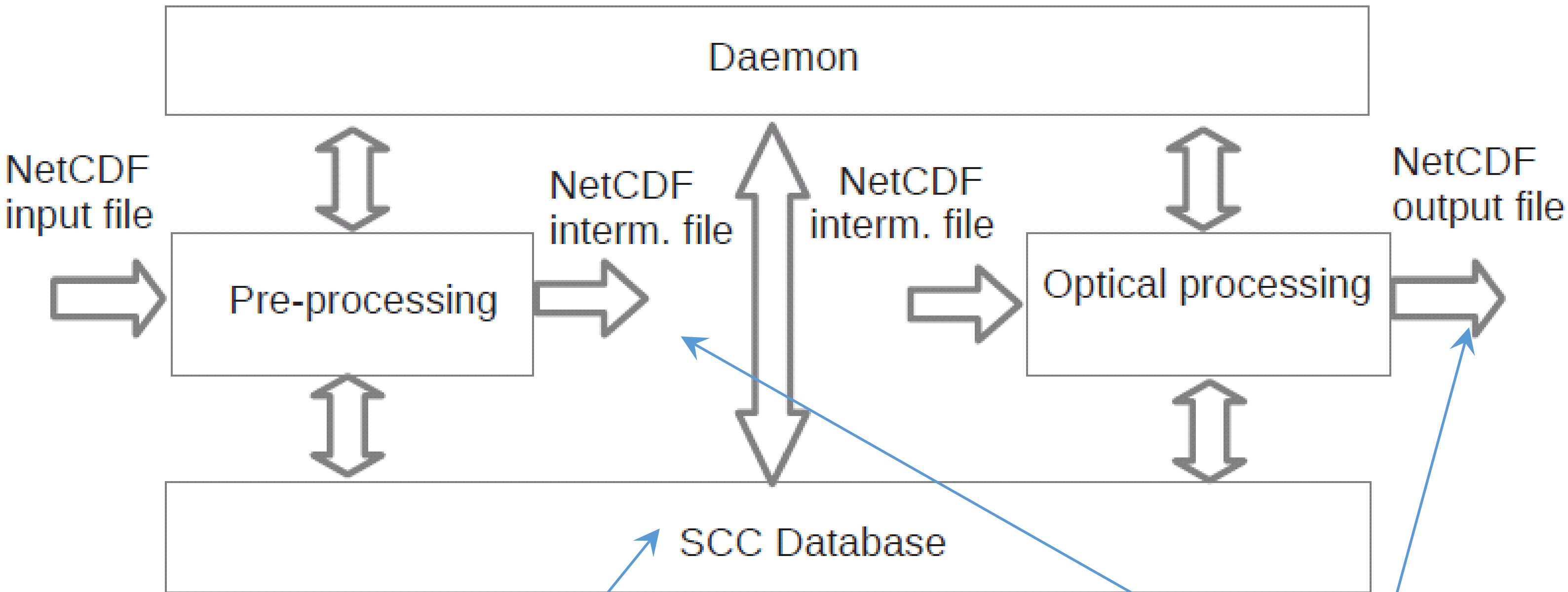
Summary

- Tests of inversion algorithms allow detecting problems and making users aware of good practices
- Every new EARLINET member is required to undergo the tests
- Eventually, expertise in inversion flows to the single calculus chain

Single calculus chain (SCC)

- **Software for automated processing of data obtained by EARLINET systems**
- **Intended to avoid inconsistencies in the signal inversion and error estimates (error bars) and to automate retrievals**
- **To cope with such different systems, data must be submitted in NetCDF subjet to strict and well defined format**
- **Because format is very well defined, it can be extended to systems beyond EARLINET (GALION) as far as the data are provided sticking to the required format and channels have undergone the instrument quality checks**

SCC layout

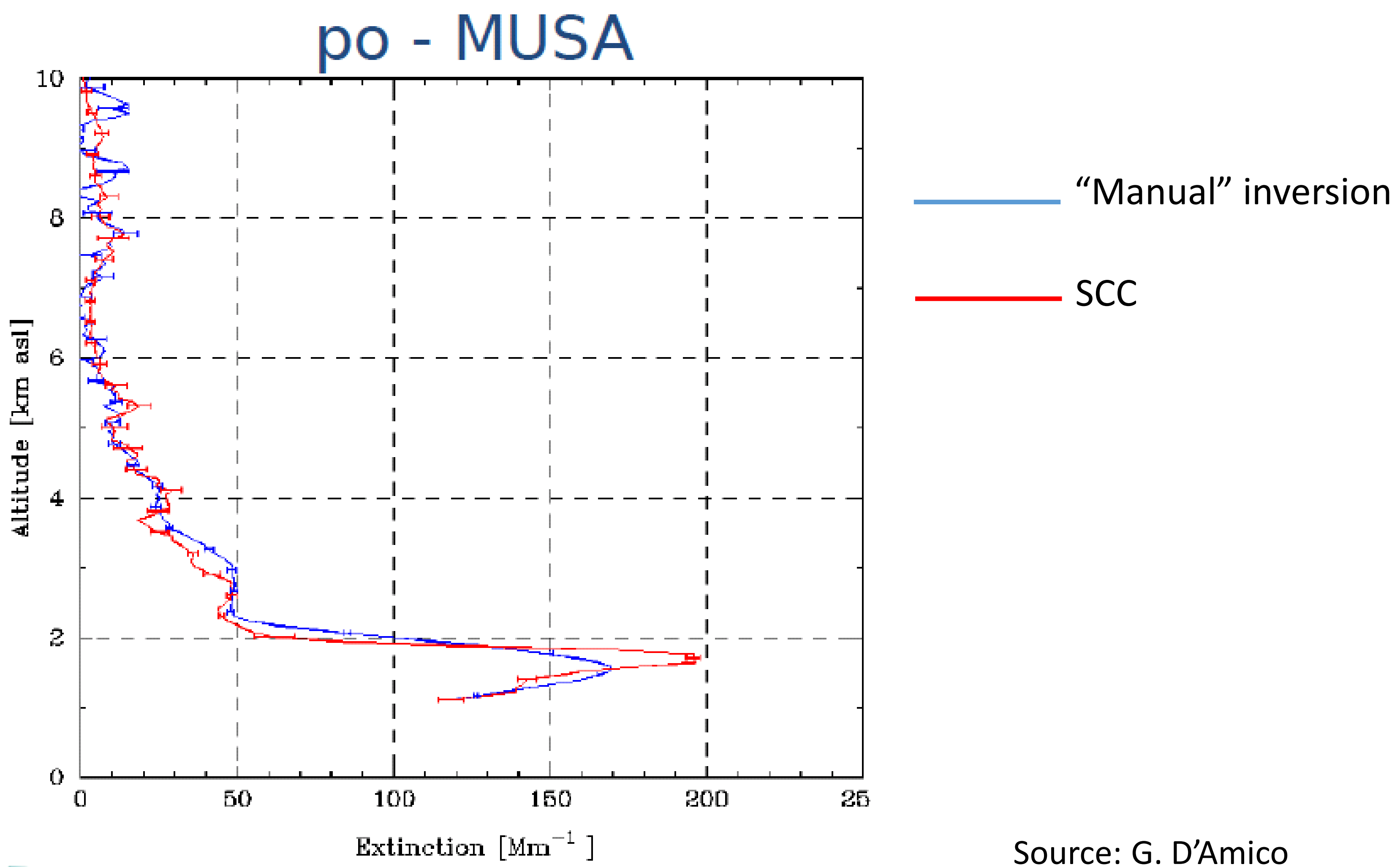


From G. Pappalado et al., Atmos. Meas. Tech. **7**, pp. 2389-2409, 2014

Contains information on the lidar channels that can be processed - link to Handbook of Instruments

Outputs at different levels

SCC inversion example



Source: G. D'Amico

SCC products

- Aerosol backscatter coefficient by elastic methods
- Aerosol extinction coefficient by Raman method
- Aerosol backscatter coefficient by Raman method

Coming up:

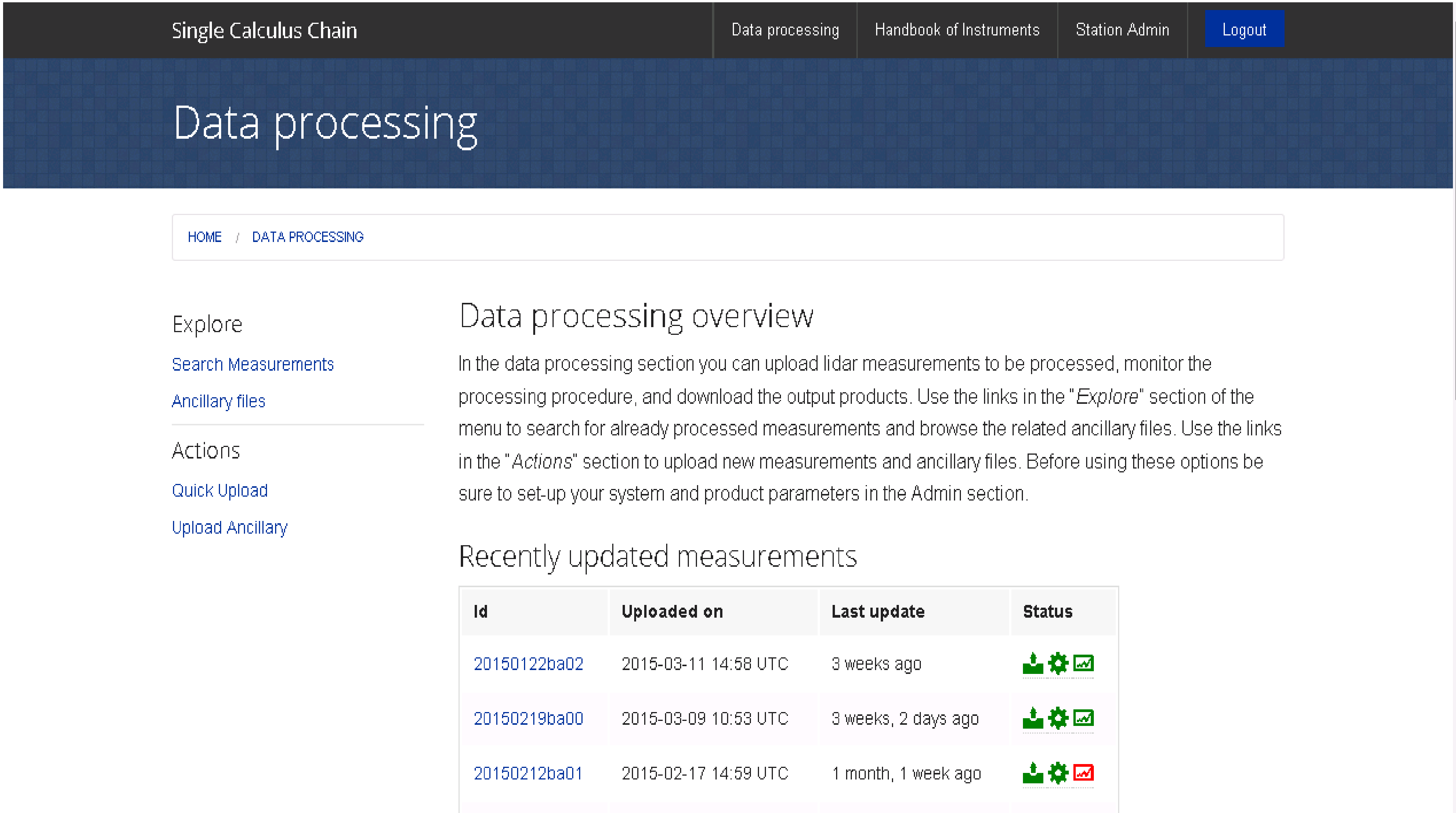
- Particle linear depolarization ratio
- Automatic aerosol layer detection
- Automatic cloud masking

Great challenge:

- SCC must operate in a completely automated, unattended way:
  - Screen out poor-quality data
  - Detect clouds

Still in testing mode

SCC Web Graphic Interface



SCC Web Graphic Interface

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SCC station management Back to the site | adolfo.comeron

Home

Site administration

Systems settings

General settings about stations, systems and their varius components.

HOI stations	+ Add	☰ Change
HOI systems	+ Add	☰ Change
HOI telescopes	+ Add	☰ Change
HOI lasers	+ Add	☰ Change
HOI channels	+ Add	☰ Change
Laser emission lines	+ Add	☰ Change
System photos	+ Add	☰ Change

Product settings

Settings about the optical products that will be calculated.

Products	+ Add	☰ Change

Measurements and files

Advanced controls for the already uploaded measurements and files.

Measurements	☰ Change
Sounding files	☰ Change
Lidar ratio files	☰ Change
Overlap files	☰ Change

Support

- SCC documentation
- Forum

Recent Actions

- ID: 20150125ba00, Station: ba, Start: 2015-01-25 00:50:52
  Measurement
- ID: 20141208ba00, Station: ba, Start: 2014-12-08 00:45:27
  Measurement
- 68: UPCLidar_new, nighttime
  HOI system
- ID: 20141222ba01, Station: ba, Start: 2014-12-22 16:58:45
  Measurement
- ID: 20150108ba01, Station: ba, Start: 2015-01-08 17:11:42
  Measurement

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SCC Web Graphic Interface

Single Calculus Chain | Data processing | Handbook of Instruments | Station Admin | Logout

Handbook of instruments

HOME / HANDBOOK OF INSTRUMENTS

Explore

Stations

About

Stations

Station	Systems
ALOMAR	1
National Technical University of Athens	1
Barcelona-Universitat Pol. de Catalunya (UPC)	3
Belsk, Poland	3
Bilthoven - Rijksinstituut voor Volksgezondheid en Milie (RIVM)	1
Bucharest-National Institute of R&D for optoelectronics INOE 2000	2
Cabauw - Royal Netherlands Meteorological Institute (KNMI)	1
Cluj (Romania intercomparison campaign)	1
Clermont-Ferrand – OPGC	1

Hardware Quality Assurance

Direct system intercomparison

- Systems compared against a standard system looking at the same atmosphere
- Ideal way for hardware quality assurance
- Expensive: it involves moving the systems under test or the standards → for a given system can only be made once every xx years, or when it has undergone a major upgrade
- Virtually all the EARLINET systems have been compared to a standard system

Periodic internal checks

- Way of keeping quality in the time between direct intercomparisons
- Two kind of checks:
  - Those that need be performed only once if no change has been made in the system
  - Tests that are requested to be performed at least once a year

Direct system intercomparison

- Currently three standard systems in EARLINET
  - MULIS (Munich)
  - POLIS (Munich)
  - MUSA (Potenza)
- Intercompared against each other in EARLI09 campaign (Leipzig, 11-31 May 2009)
- Intercomparison campaigns are organized in sessions
  - Results from a session are quickly analyzed to detect possible problems and provide feedback
  - Single calculus chain has been used in latest campaigns to perform the analysis to quickly provide feedback and to avoid inhomogeneity due to software
  - Intercomparison carried out on channel (rather than on system) basis

Example: SPALI10 intercomparison campaign

18 October- 5 November 2010. CIEMAT (Madrid, Spain)

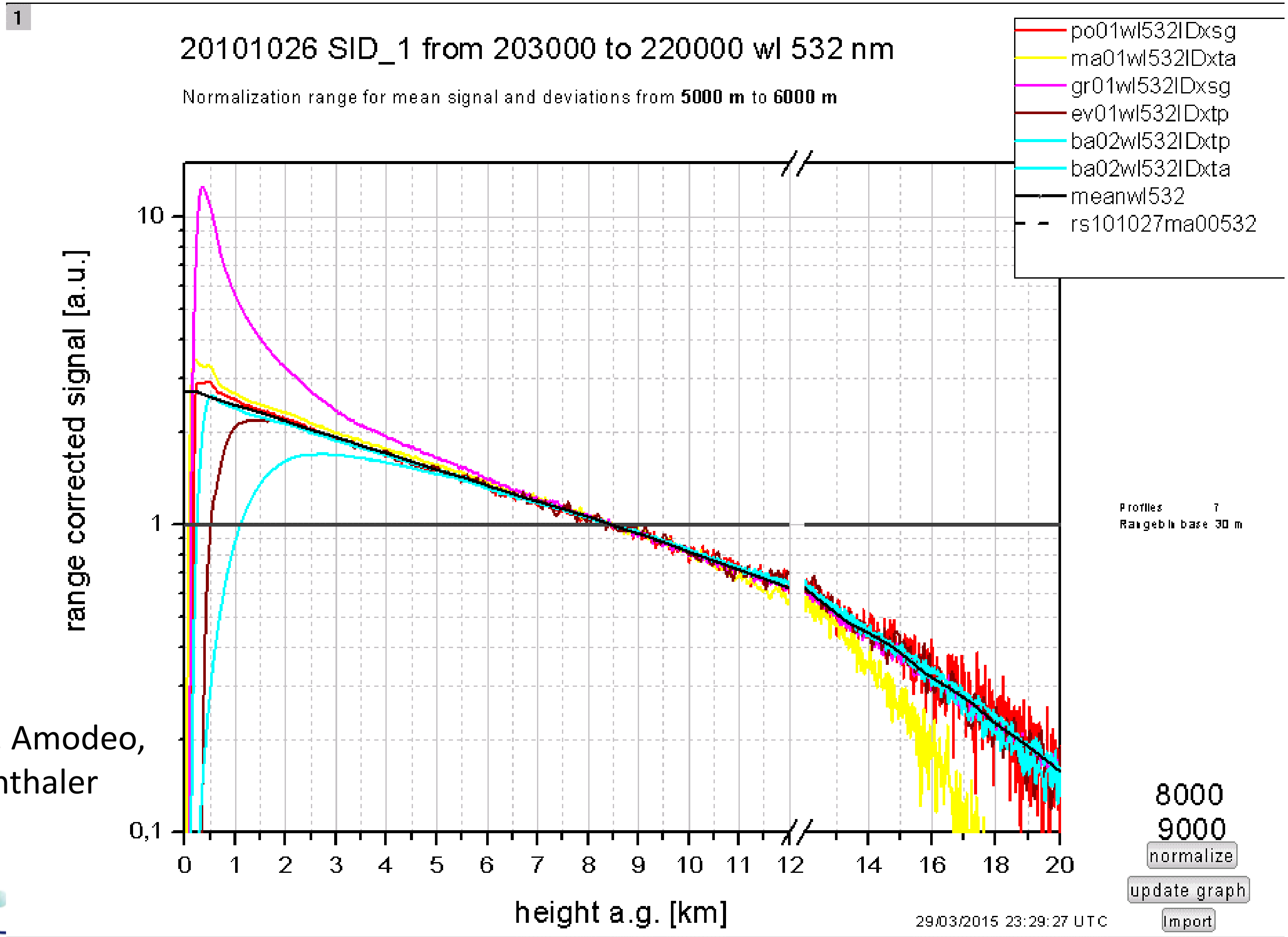
Example: SPALI10 intercomparison campaign

18 October- 5 November 2010. CIEMAT (Madrid, Spain)

Courtesy of Juan Antonio Bravo Aranda

Example: SPALI10 intercomparison campaign

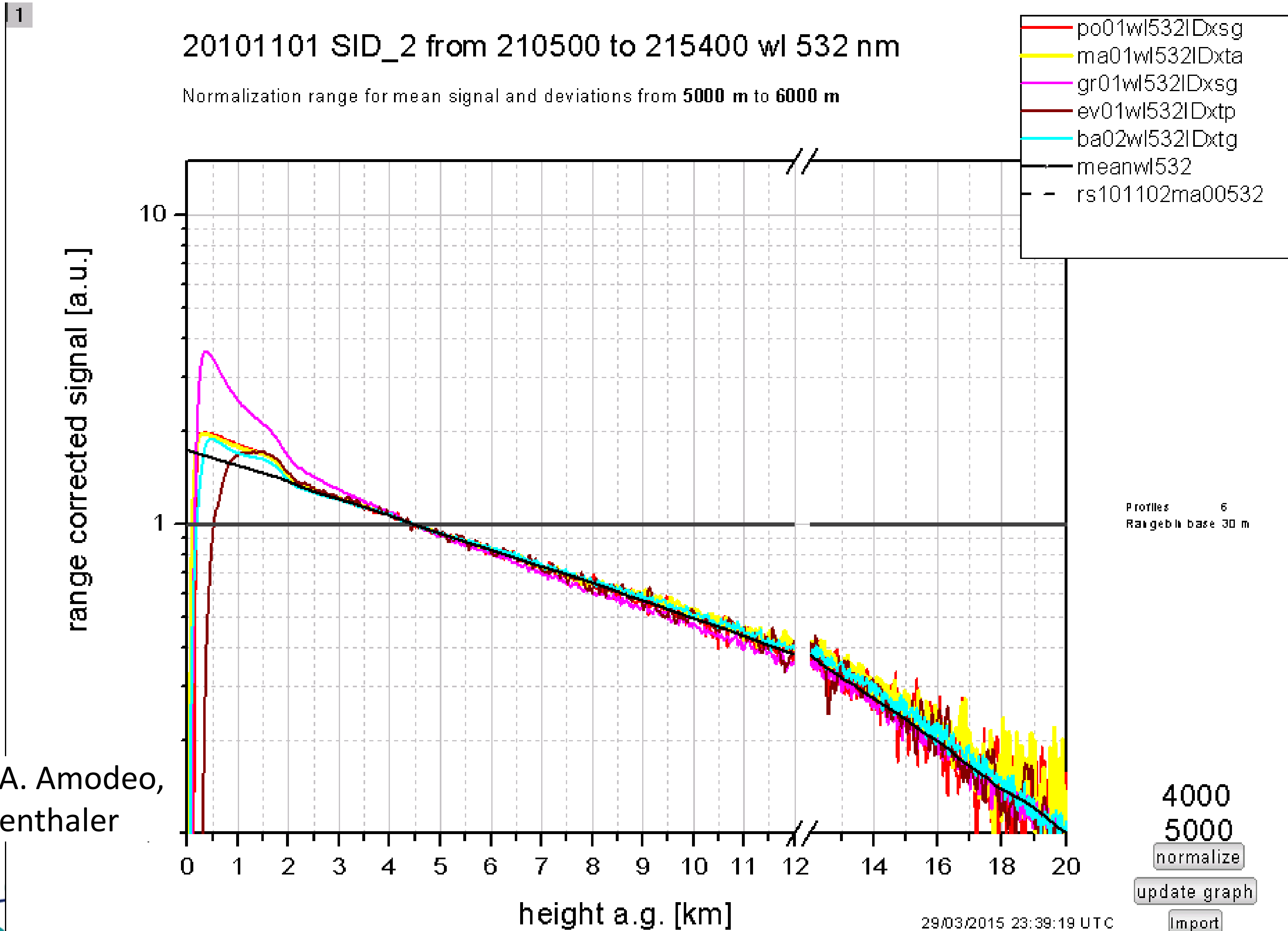
26 October 2010. CIEMAT (Madrid, Spain)



Source: A. Amodeo, V. Freudenthaler

Example: SPALI10 intercomparison campaign

1 November 2010. CIEMAT (Madrid, Spain)



Source: A. Amodeo, V. Freudenthaler

Example: SPALI10 intercomparison campaign

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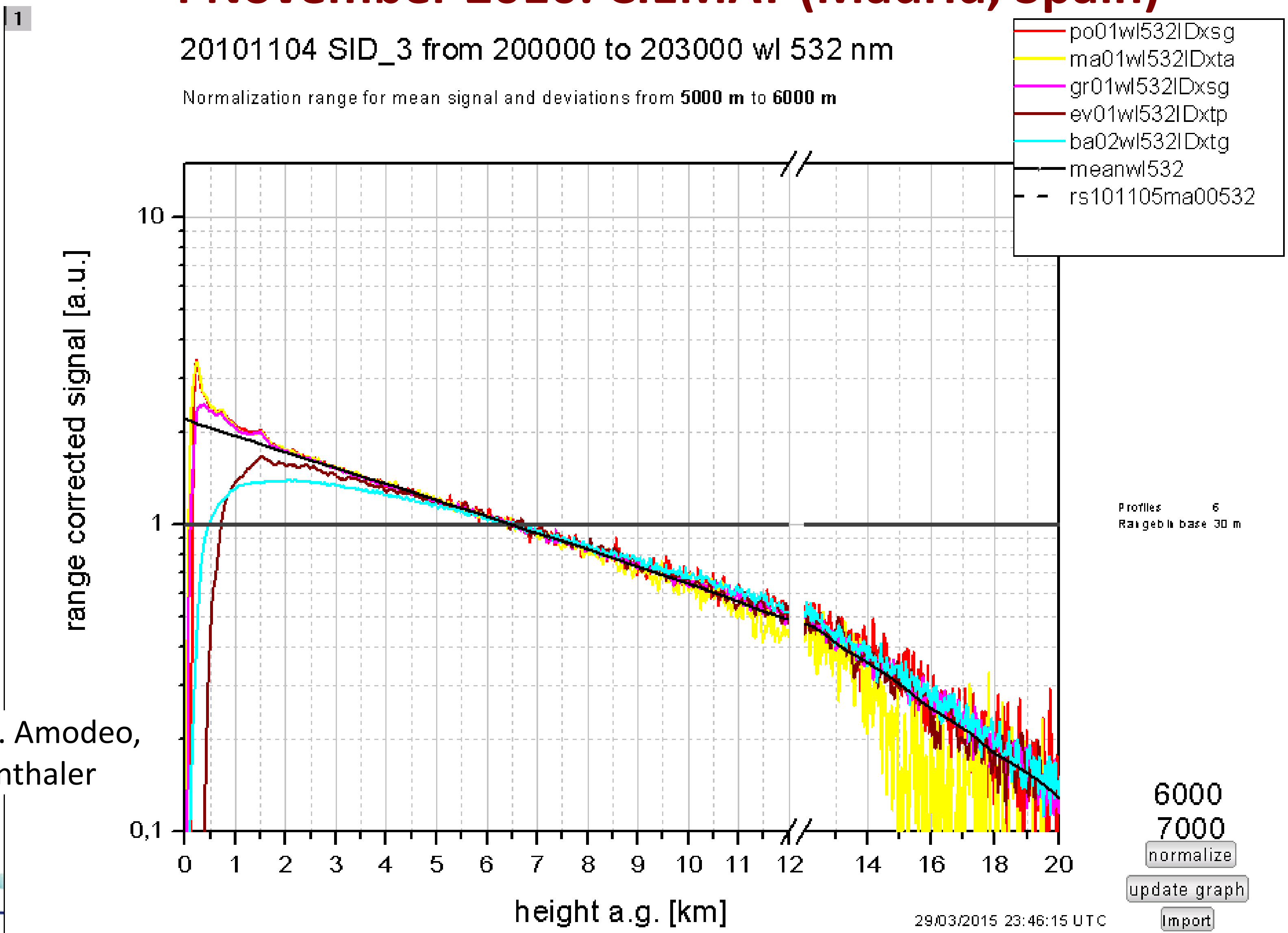
4 November 2010. CIEMAT (Madrid, Spain)



Source: A. Amodeo, V. Freudenthaler

Mandatory internal checks

- One time (only if the configuration has changed):
  - Trigger delay / zero bin
  - Dark measurement
- Periodic (at least once a year)
  - Telecover test
  - Rayleigh fit
  - Depolarization calibration (only linear depolarization is considered for the moment)
- Important role of hardware quality assurance coordinator (Volker Freudenthaler), who collects and analyzes the test data submitted by stations, and provides feedback

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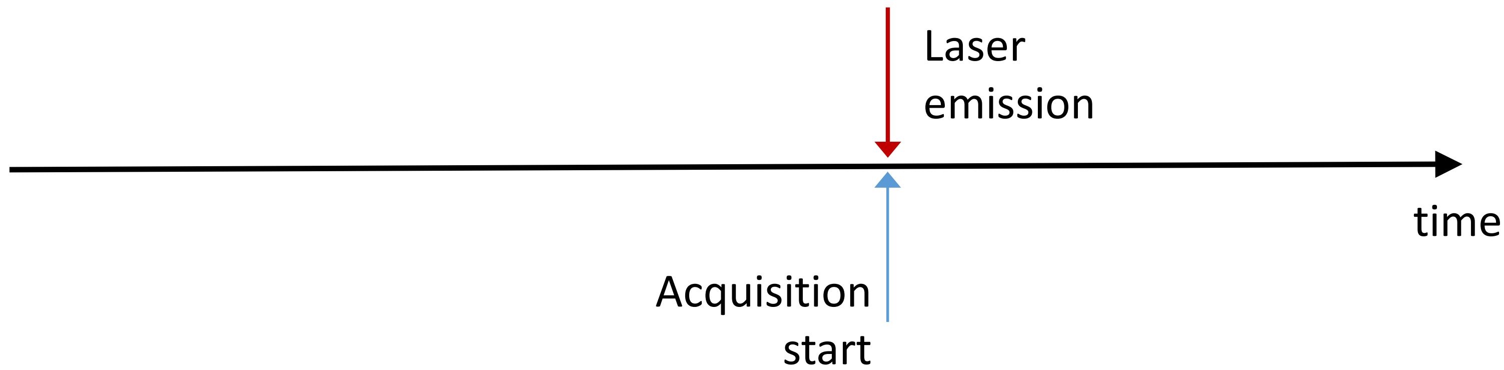
Trigger delay /zero bin

- **Checks the time difference between the light pulse emission and the start of the signal acquisition**



Trigger delay /zero bin

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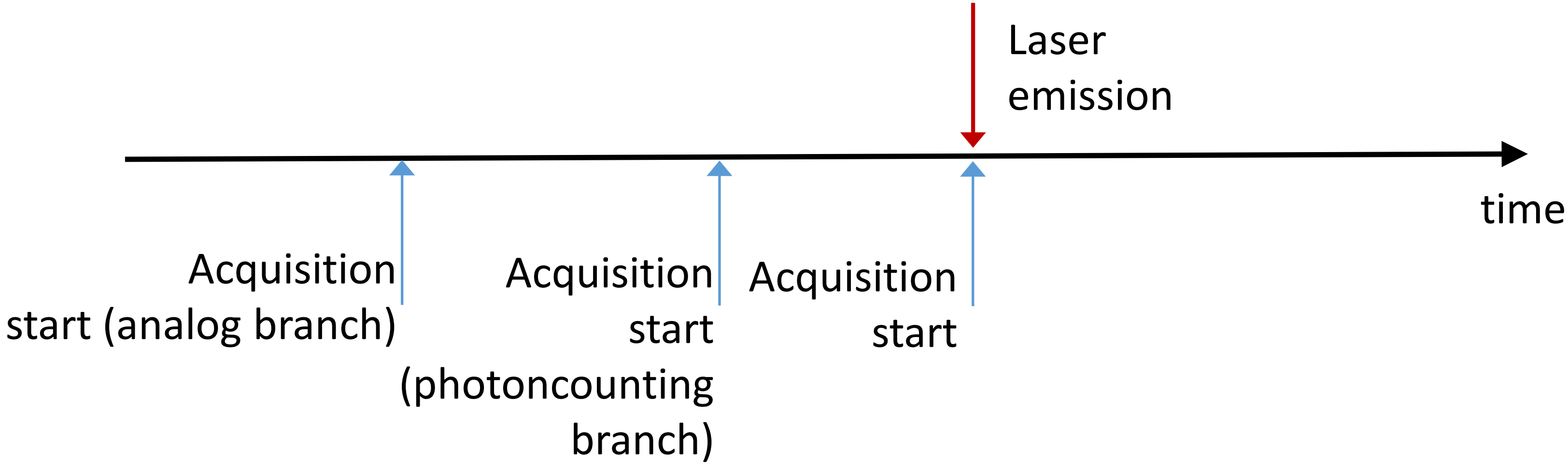
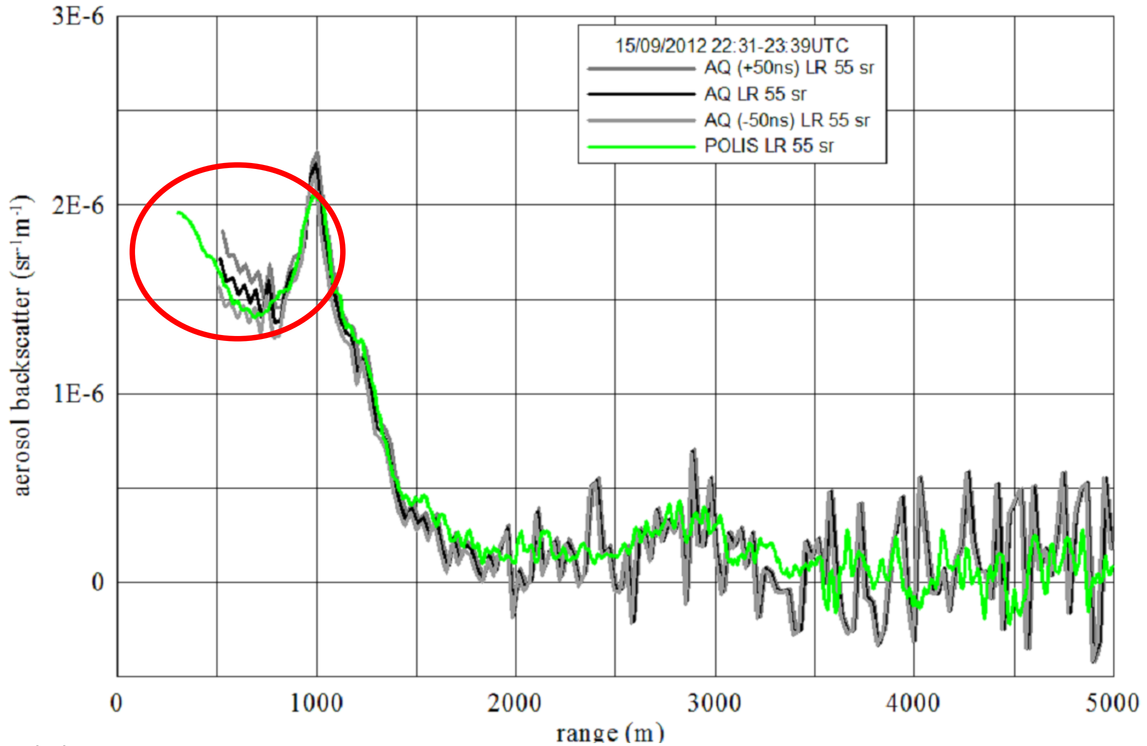


Trigger delay /zero bin

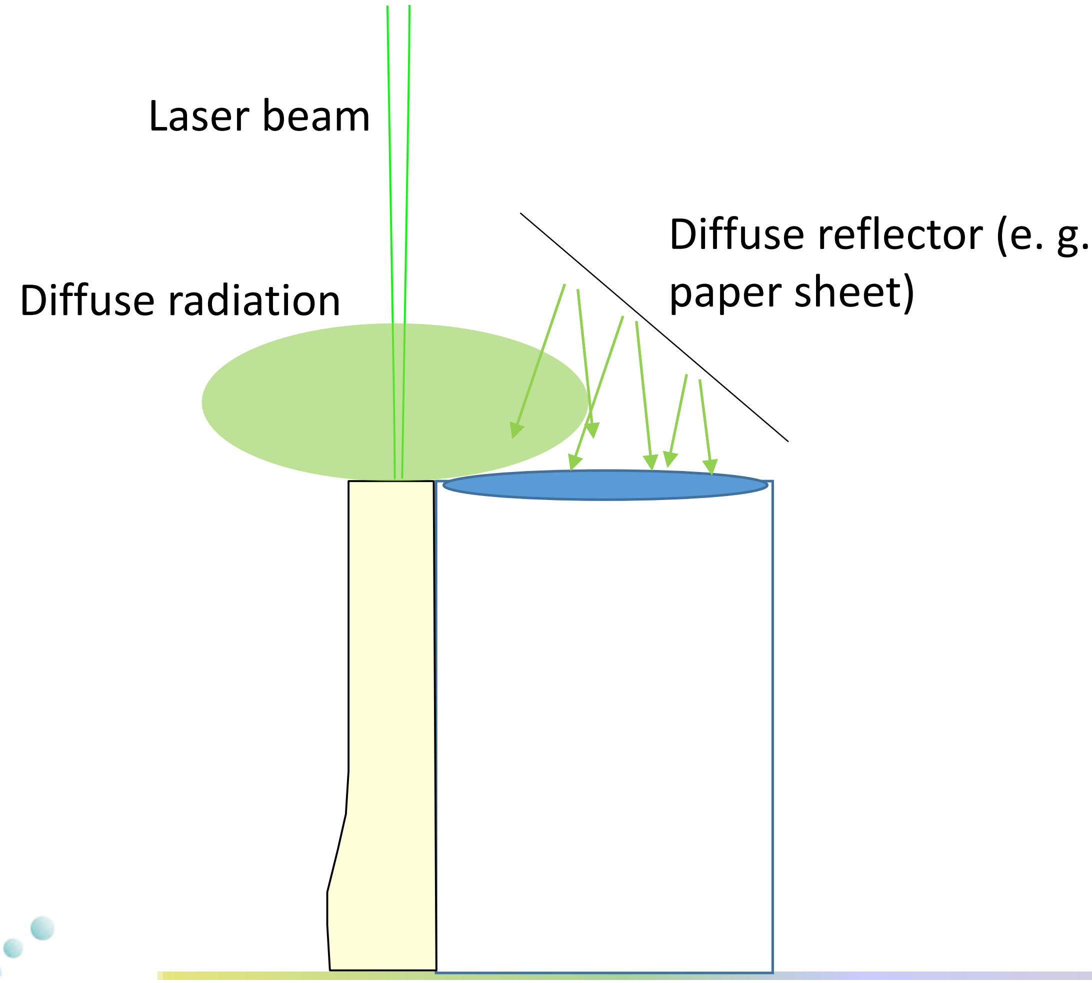
- **Example of trigger delay effect (taken from an intercomparison campaign with POLIS system as standard)**



Source: M. Iarlori, V. Rizi, V. Freudenthaler

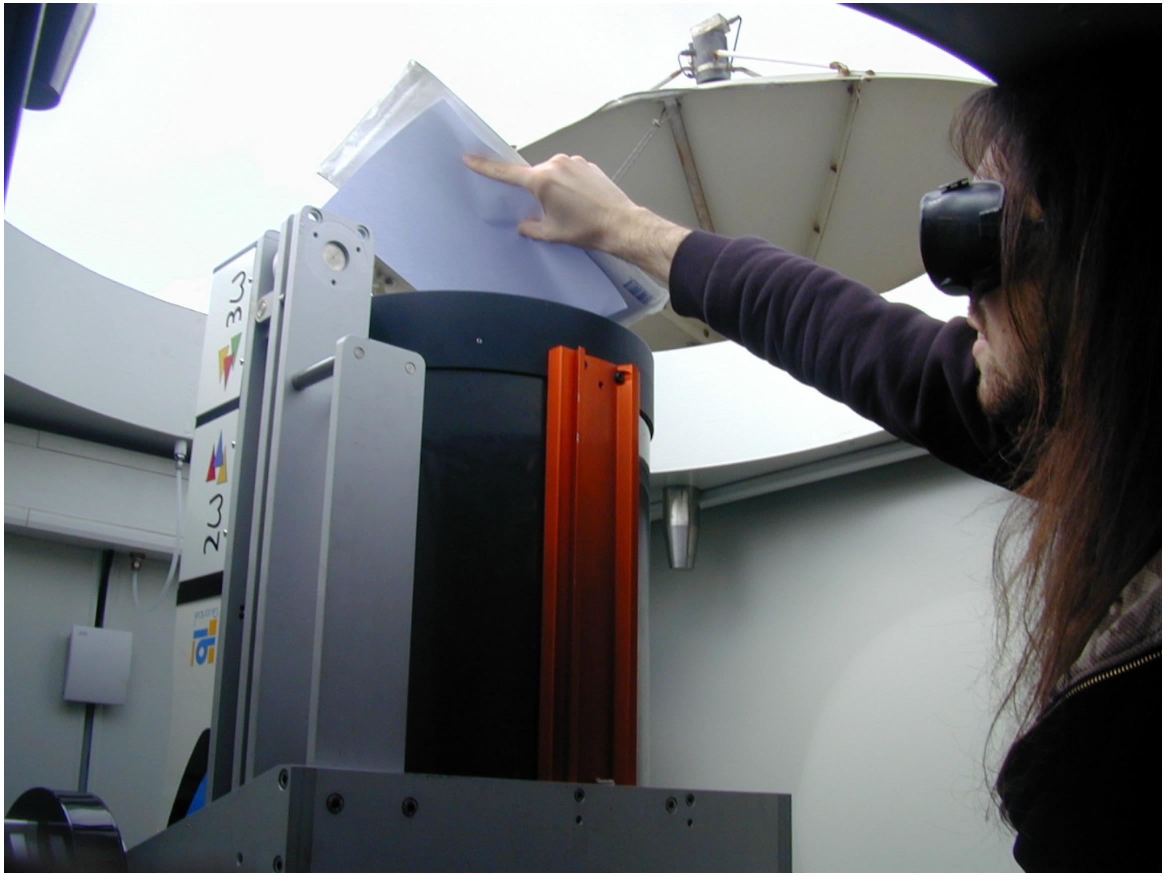
Trigger delay /zero bin

- **If acquisition start leads laser emission**



Mandatory one-time internal checks

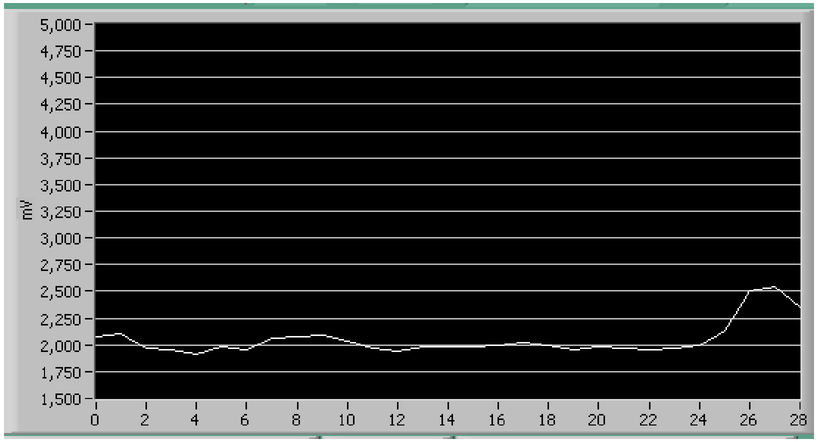
Trigger delay /zero bin



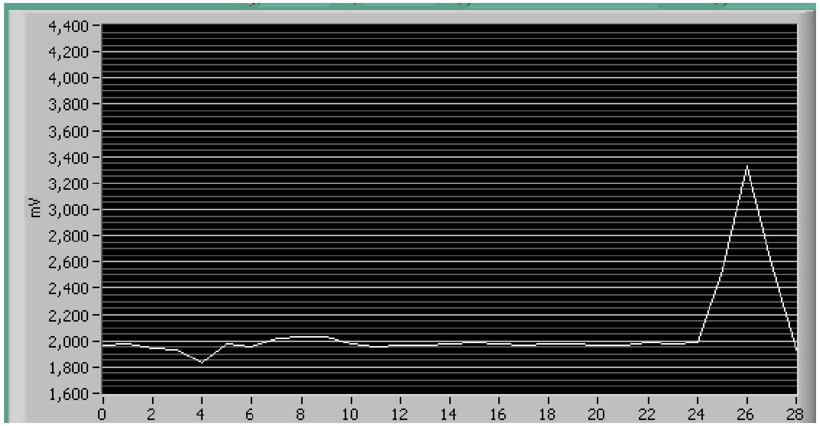
Mandatory one-time internal checks

Trigger delay /zero bin

No paper sheet



Paper sheet

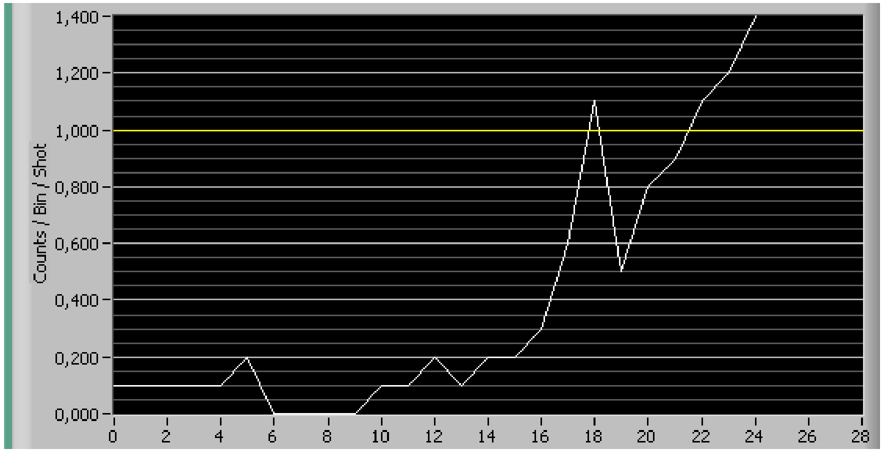


Laser emission occurs 26 x 25 ns = 650 ns after signal acquisition started

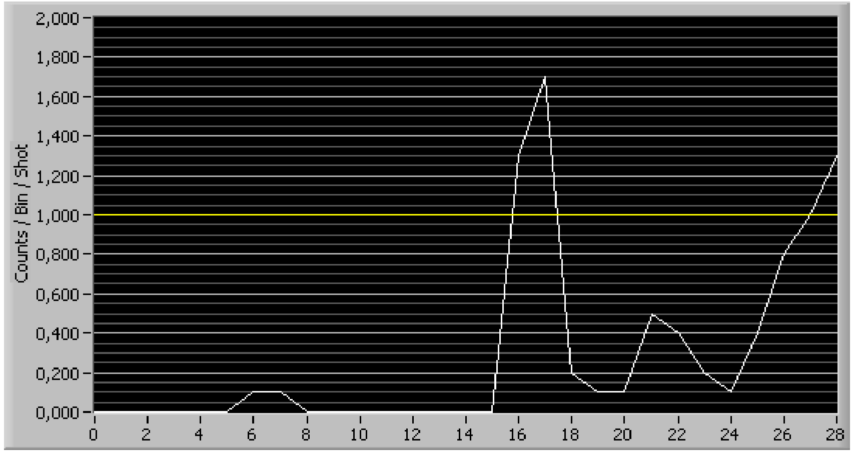
Mandatory one-time internal checks

Trigger delay /zero bin

No paper sheet



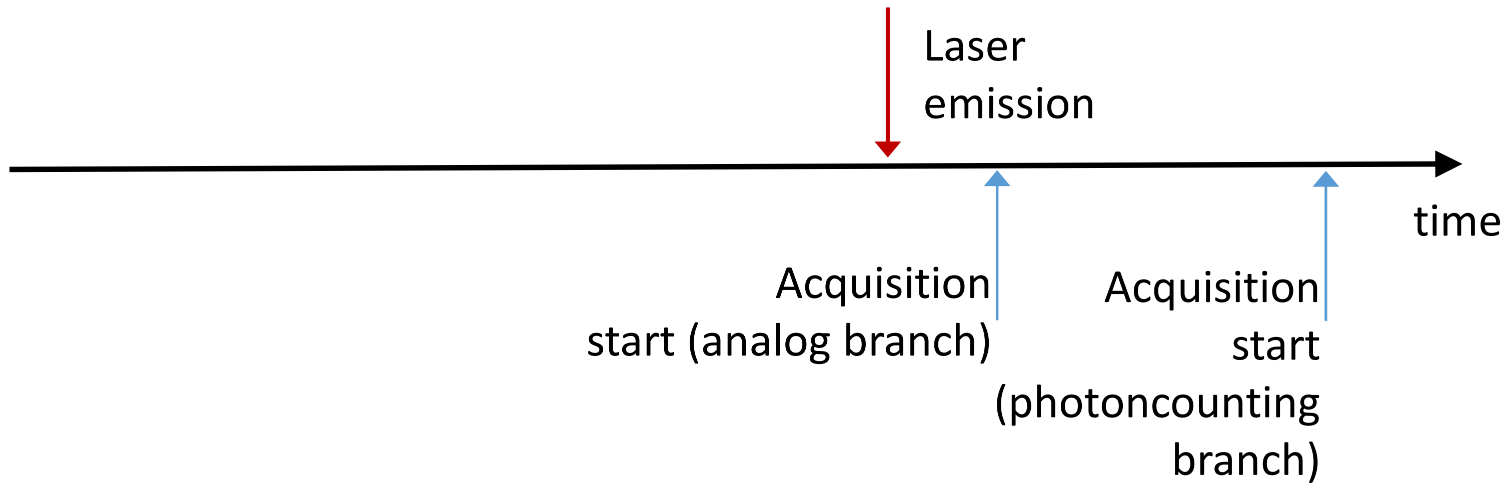
Paper sheet



Laser emission occurs 17 x 25 ns = 425 ns after signal acquisition started → photoncounting branch acquition starts 225 ns later tan analog one

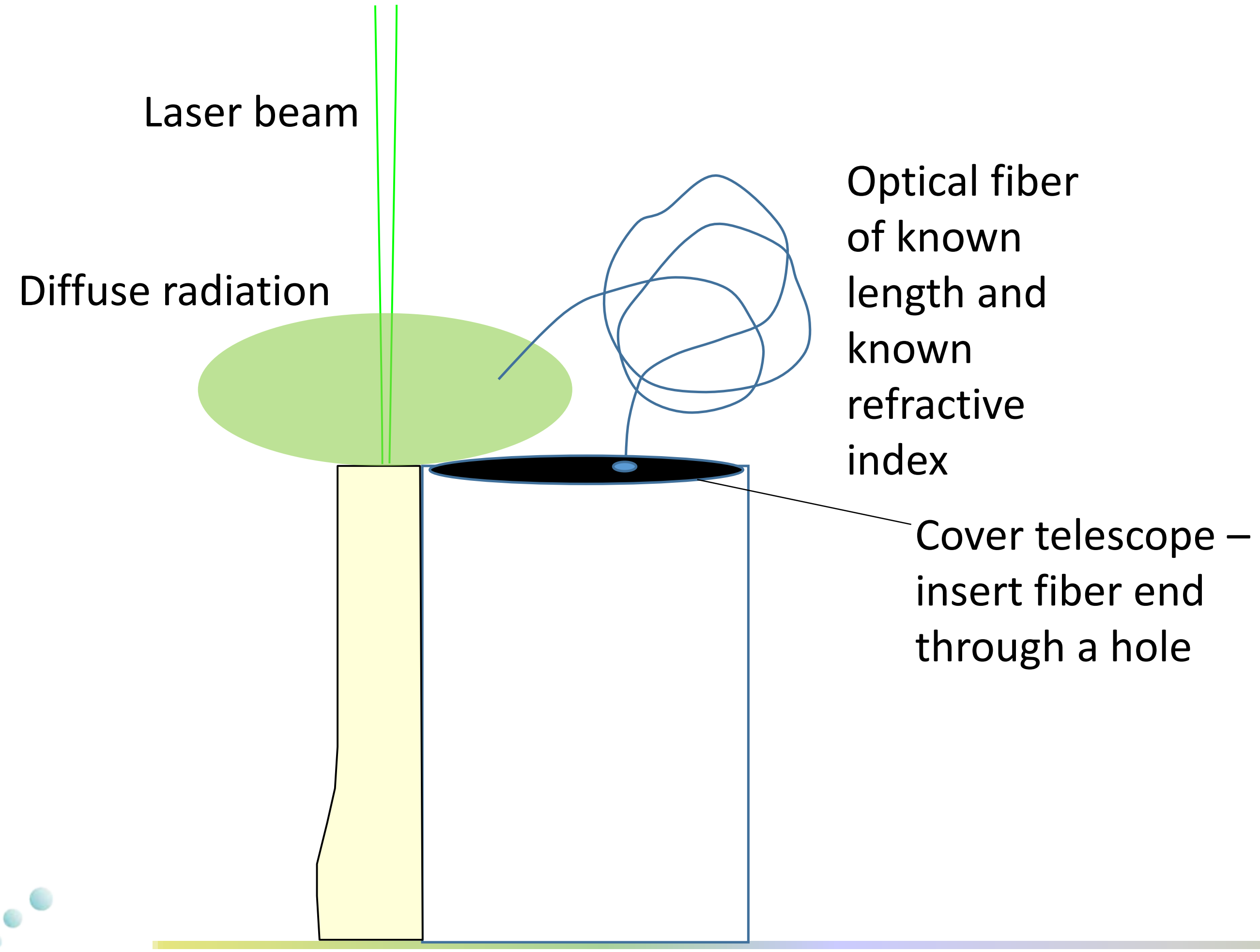
Trigger delay /zero bin

- **Checks the time difference between the light pulse emission and the start of the signal acquisition**



Trigger delay /zero bin

- **If acquisition start lags laser emission**



Mandatory one-time internal checks

Trigger delay /zero bin

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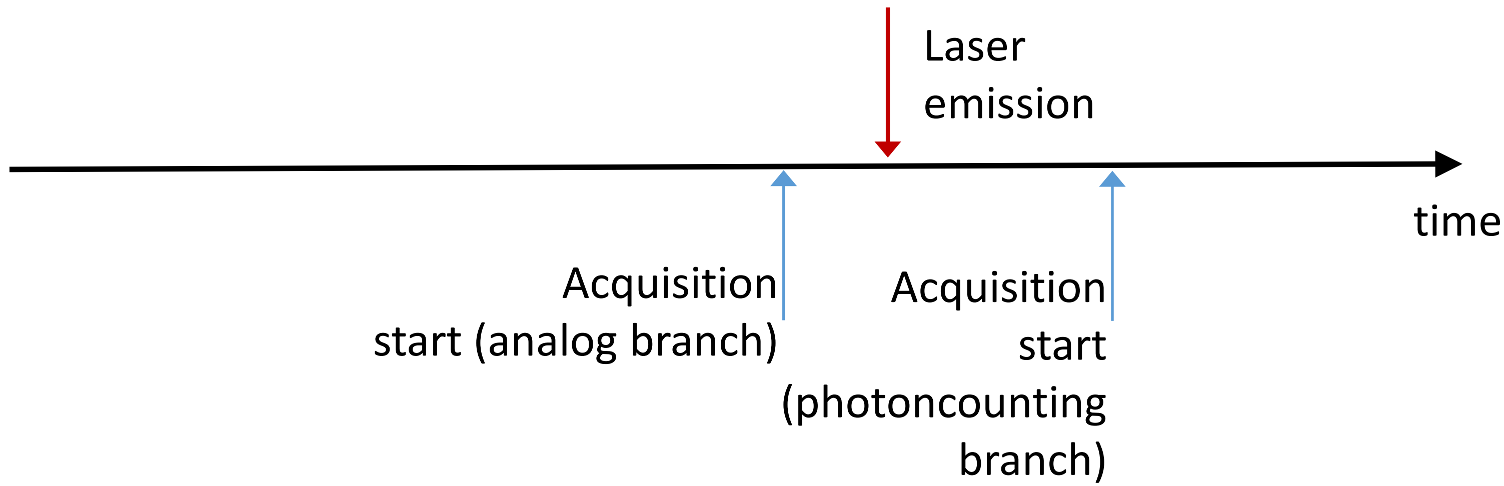
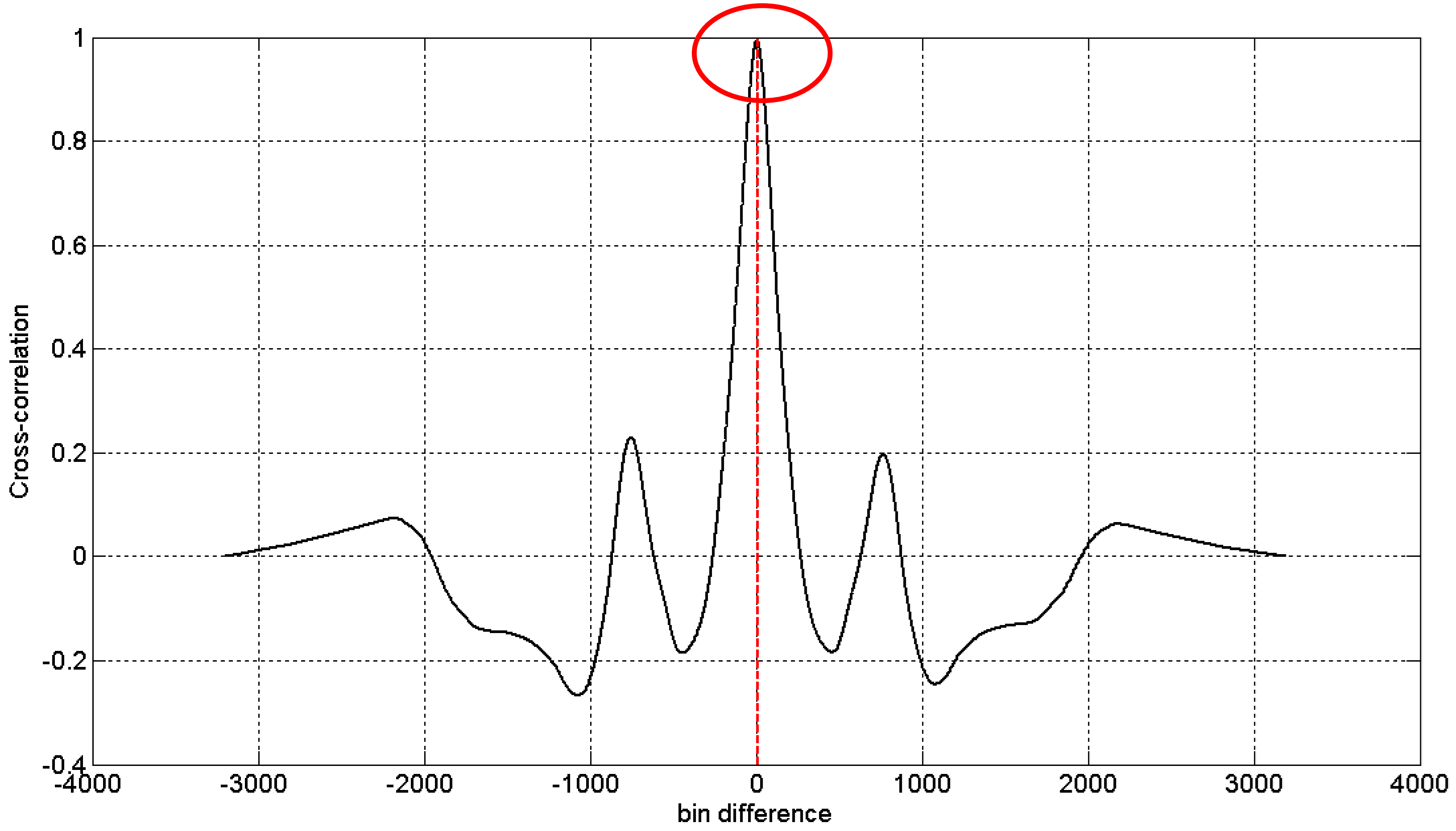


Mandatory one-time internal checks

Trigger delay /zero bin



Mandatory one-time internal checks

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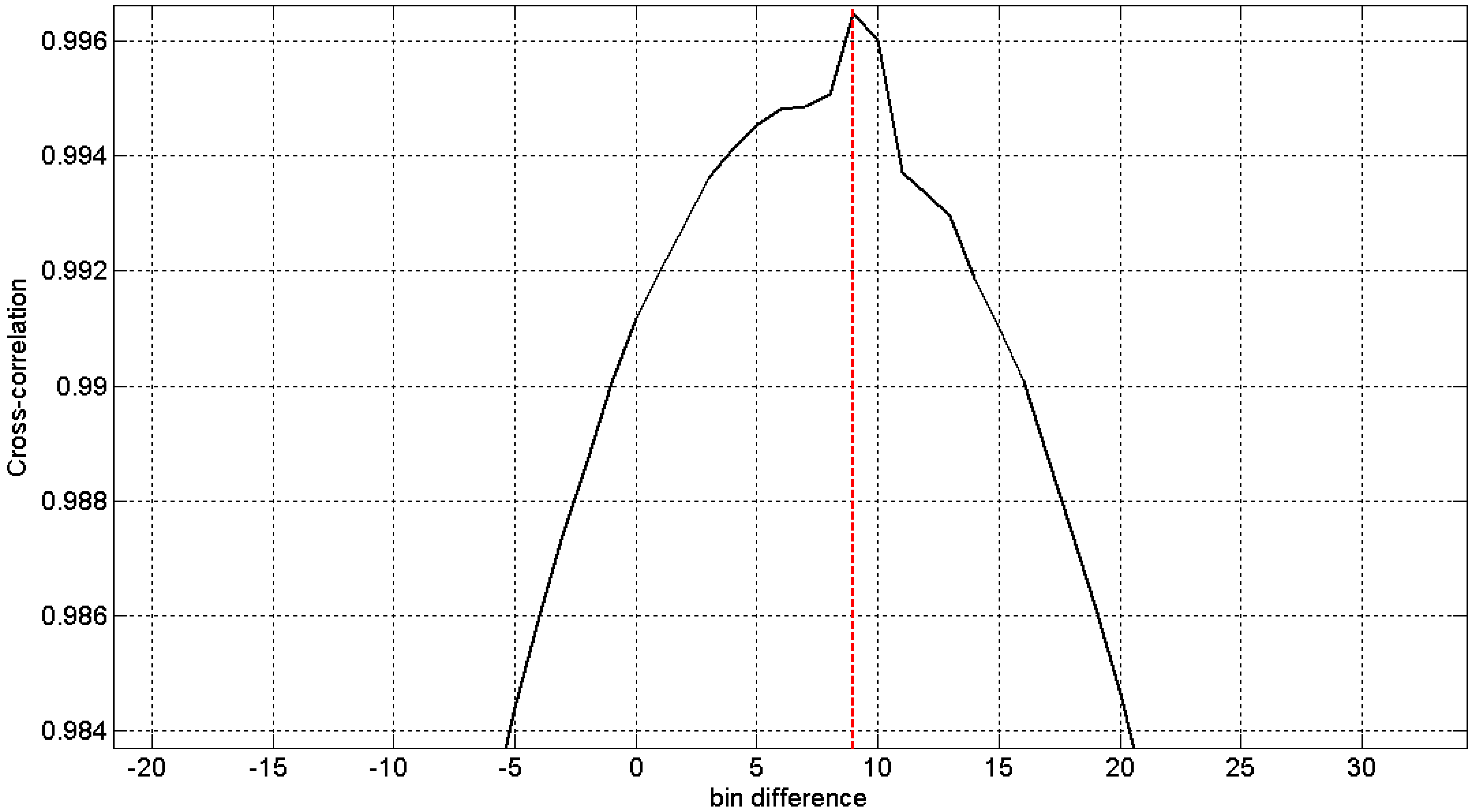
Trigger delay /zero bin



Mandatory one-time internal checks

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Dark measurement

- Checks for electronics-induced interferences in the analog signals
- Performed with all the system in nominal operation state (including laser pulsing), but telescope blocked
- If noticeable interference occurs, it must be subtracted from analog signals before retrieval procedure

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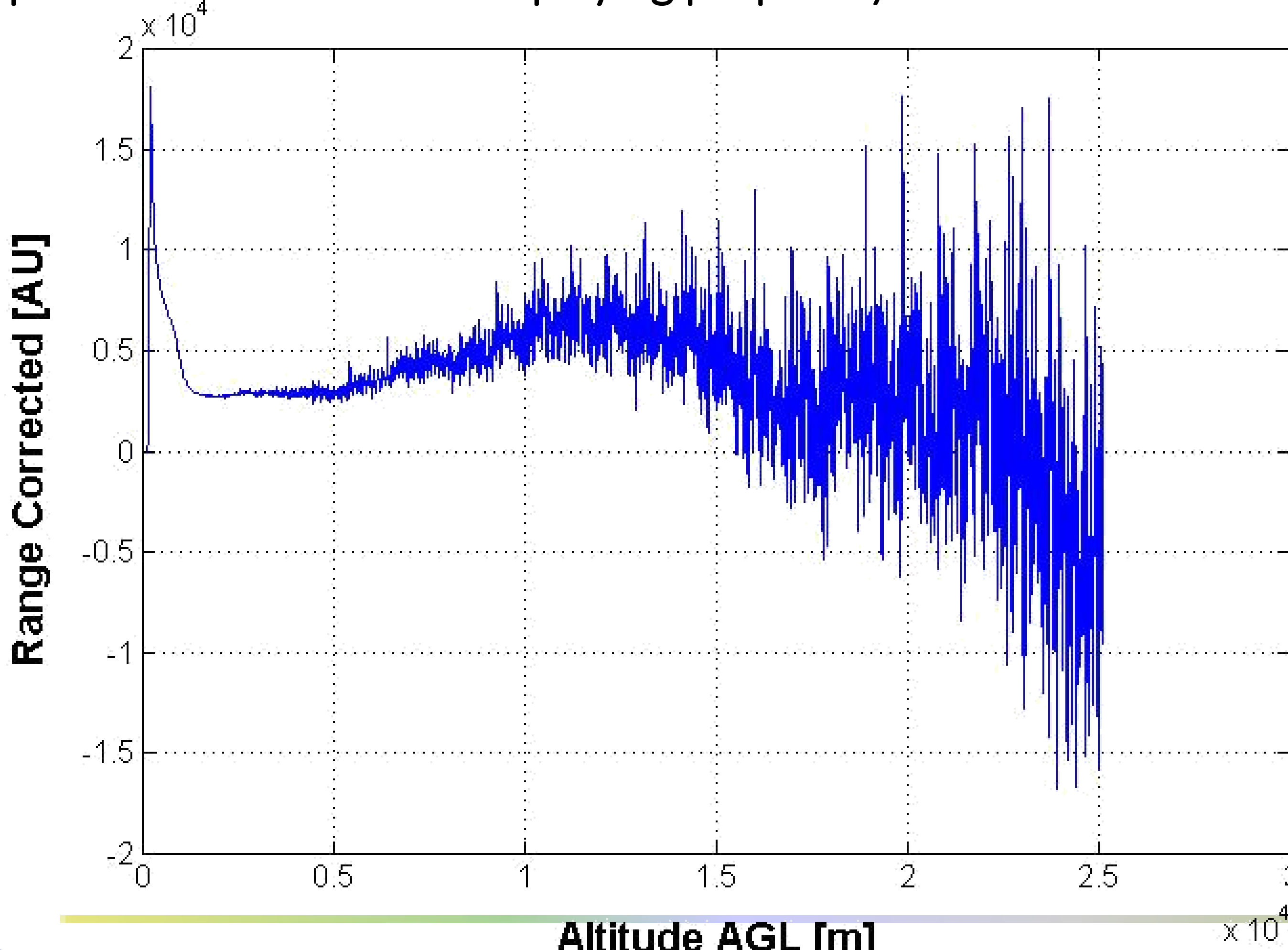
Mandatory one-time internal checks

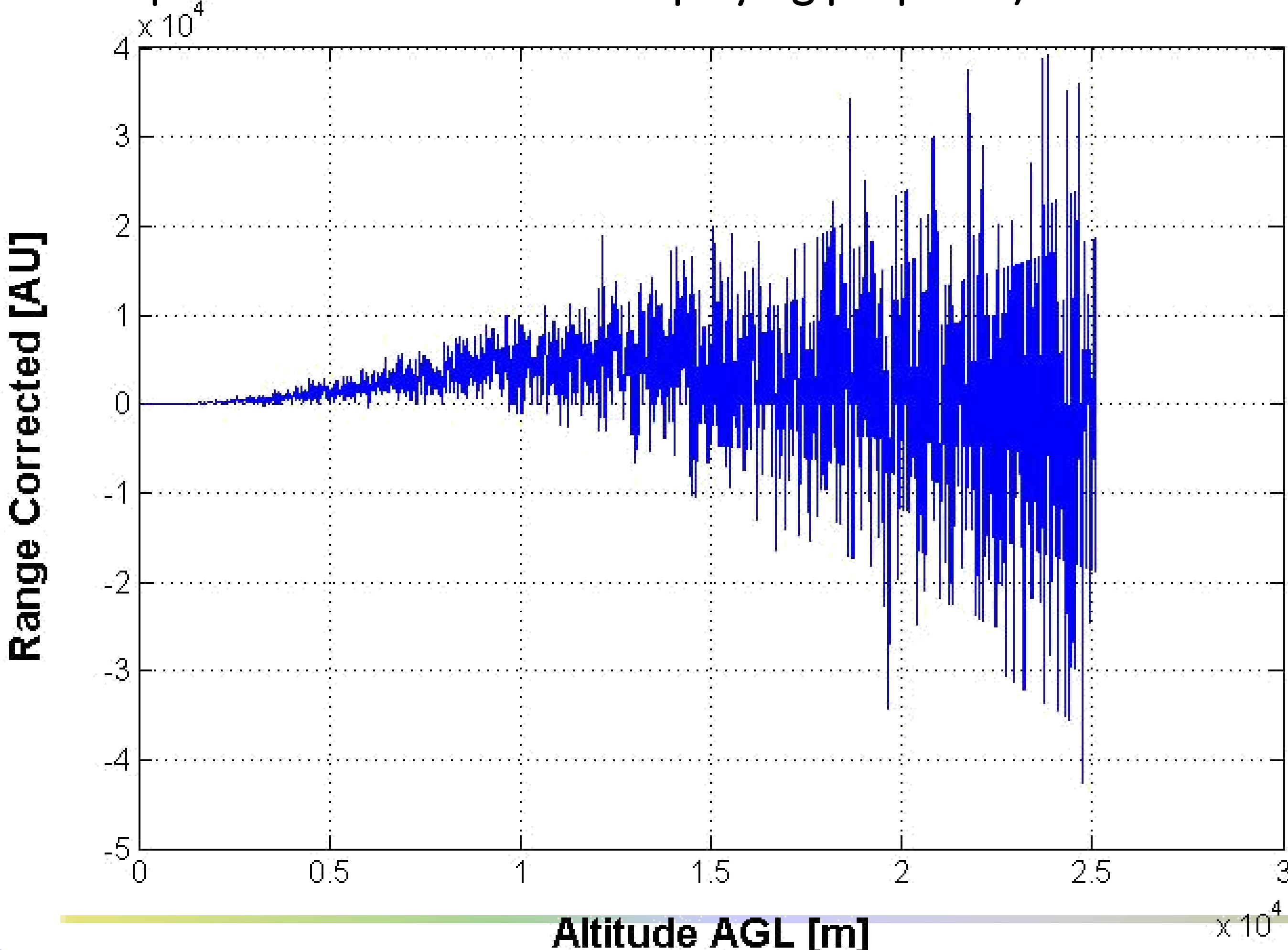
Dark measurement

Raw measurement: telescope open (average of a number of points at the end of the acquisition subtracted for displaying purposes)



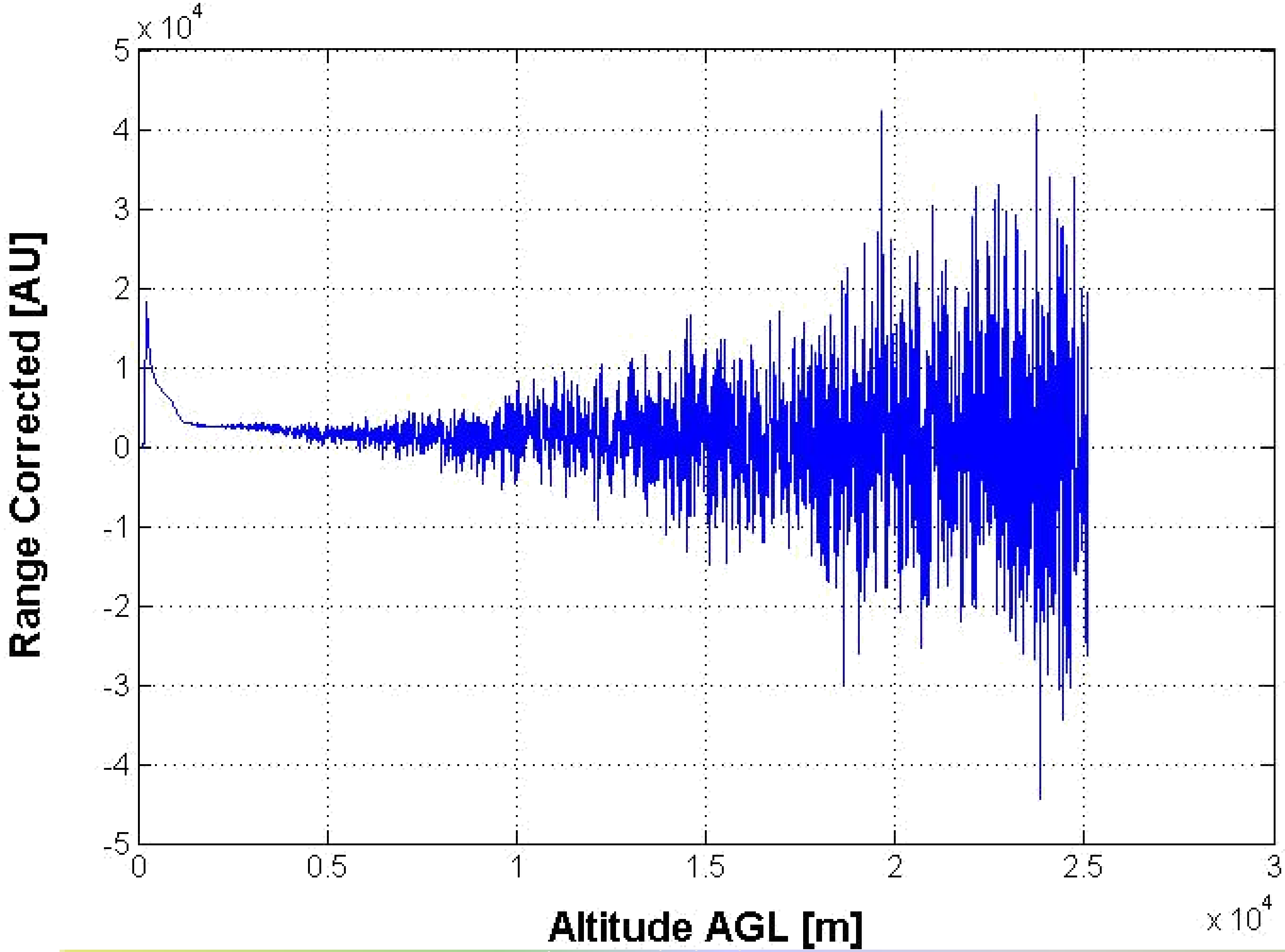
Dark measurement

Dark measurement: telescope blocked (average of a number of points at the end of the acquisition subtracted for displaying purposes)



Dark measurement

Corrected measurement: raw measurement – dark measurement



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Dark measurement

- **Dark-measurement subtraction cancels systematic synchronous interferences, but not random noise**

- **Penalty: final S/N**

$$\frac{S}{N} = \frac{S}{N_r + N_d}$$

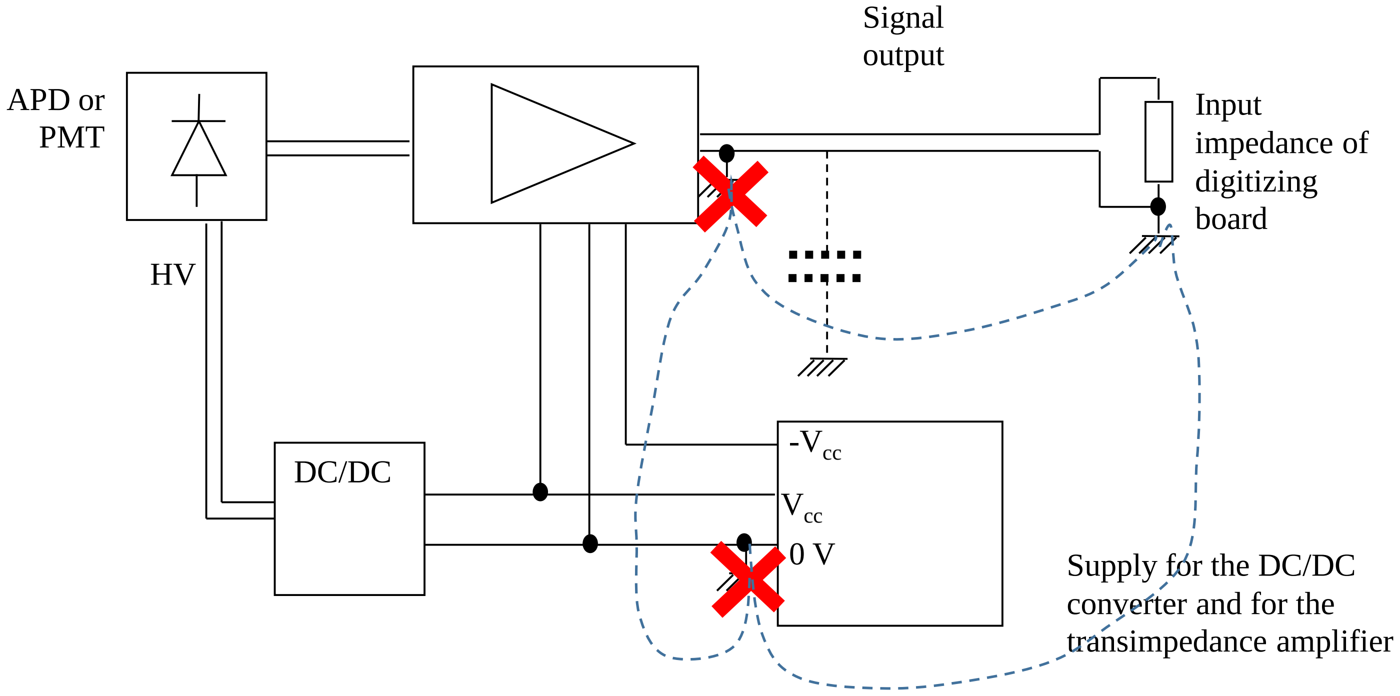
N_r: random noise power in raw measurement

N_d: random noise power in dark measurement

- **To ease the S/N penalty spatial smoothing can be applied to the dark signal at far ranges**

Dark measurement

- To limit interferences ground loops should be avoided (not always easy or even possible)



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Dark measurement

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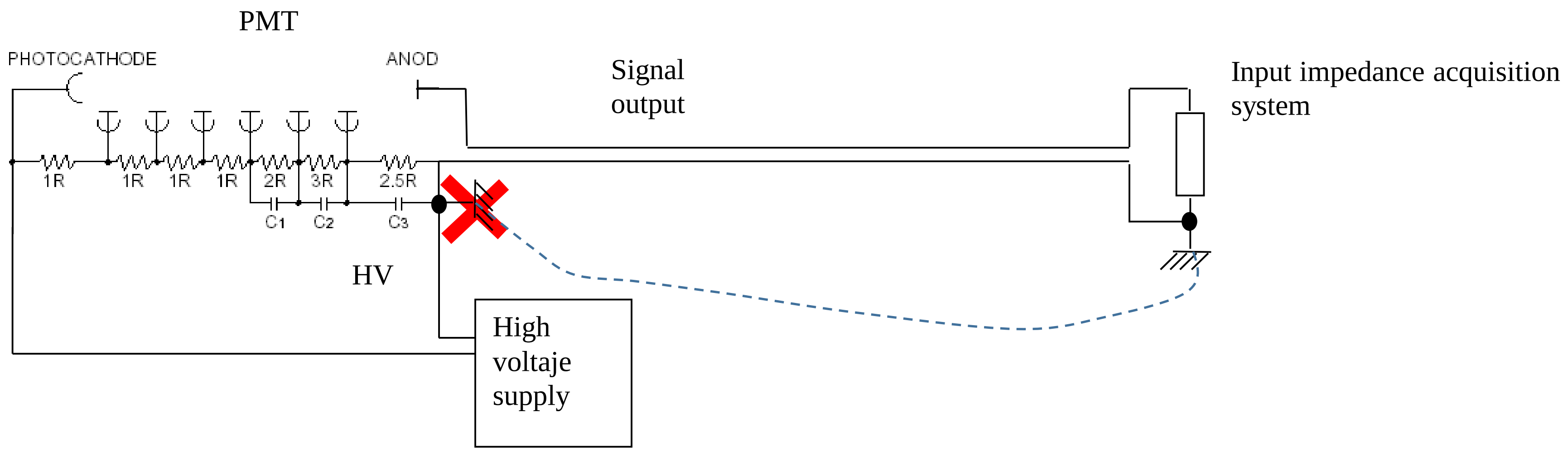

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Mandatory one-time internal checks

Dark measurement
Measures to limit interferences:

- Avoid obvious ground loops
- Keep the photoreceivers as far as possible from the laser
- Keep cables as short as possible:

$$\mathcal{E} = -\frac{d}{dt}\int_S \vec{B}\cdot d\vec{s}$$

- Use mains filters: some interference can arise from power line instabilities induced by current drawn by laser power supply
- Magnetic shielding (high permeability materials) of interferences sources (?)

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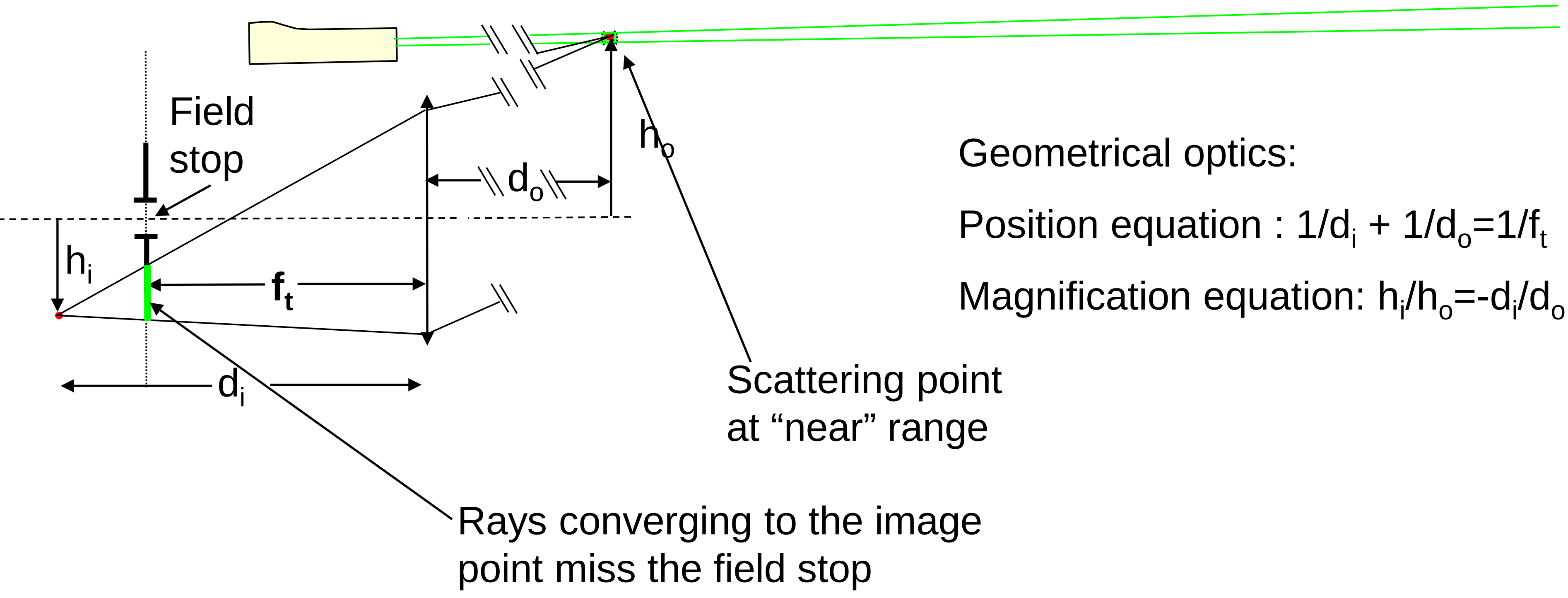
Telecover test

- **Checks for misalignments, vignetting, detector surface inhomogeneities and saturation effects that may affect the response in the near range of the lidar**

Mandatory periodic internal checks

Telecover test

- **Simplified rationale**



Geometrical optics:

Position equation : $1/d_i + 1/d_o = 1/f_t$

Magnification equation: $h_i/h_o = -d_i/d_o$

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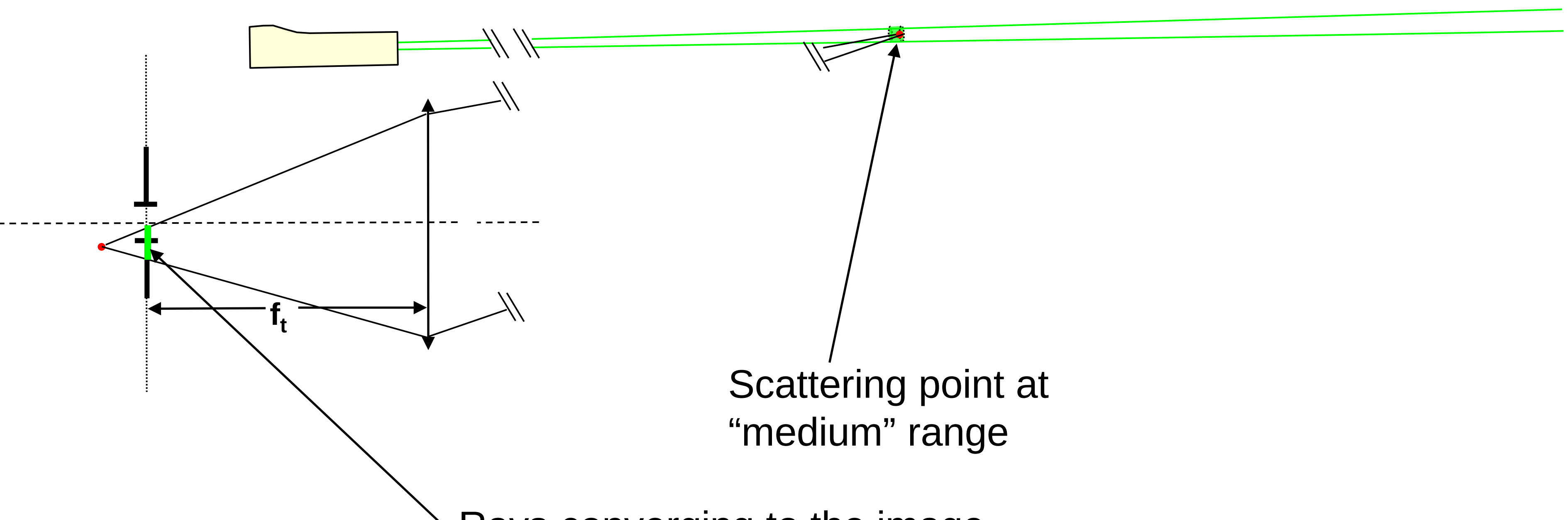
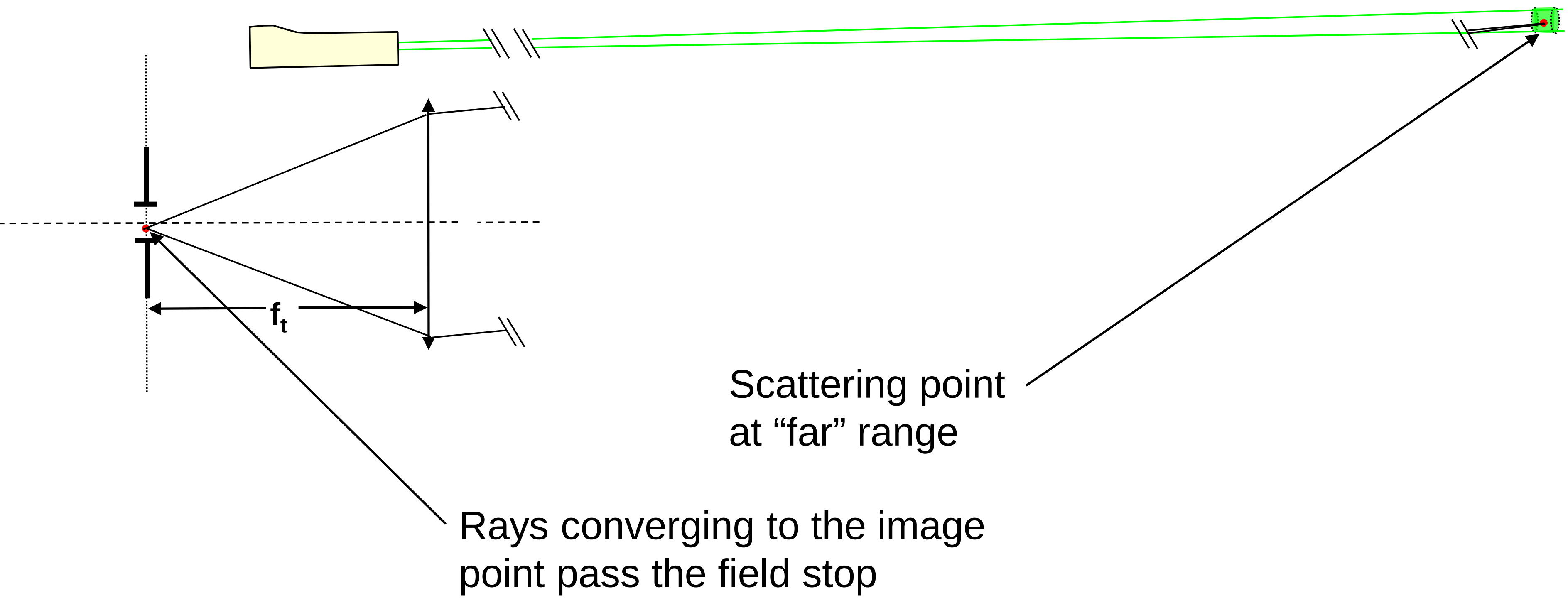
Telecover test

- **Simplified rationale**



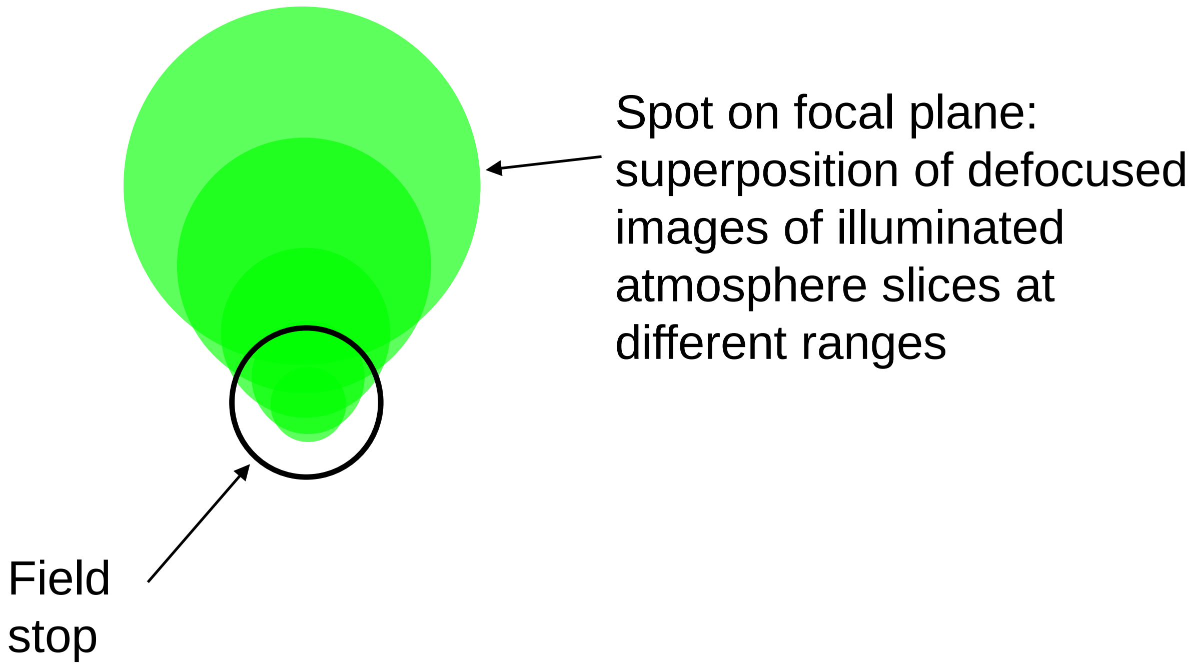
Telecover test

- **Simplified rationale**



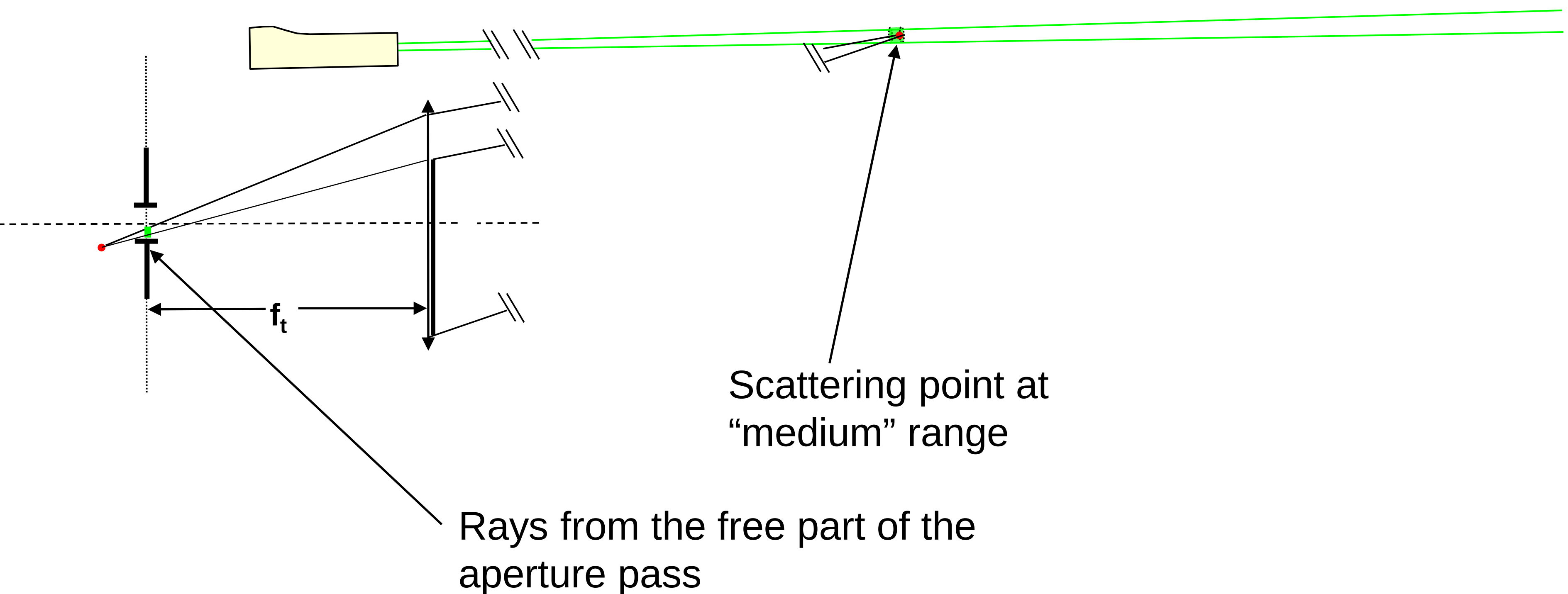
Telecover test

- **Simplified rationale**



Telecover test

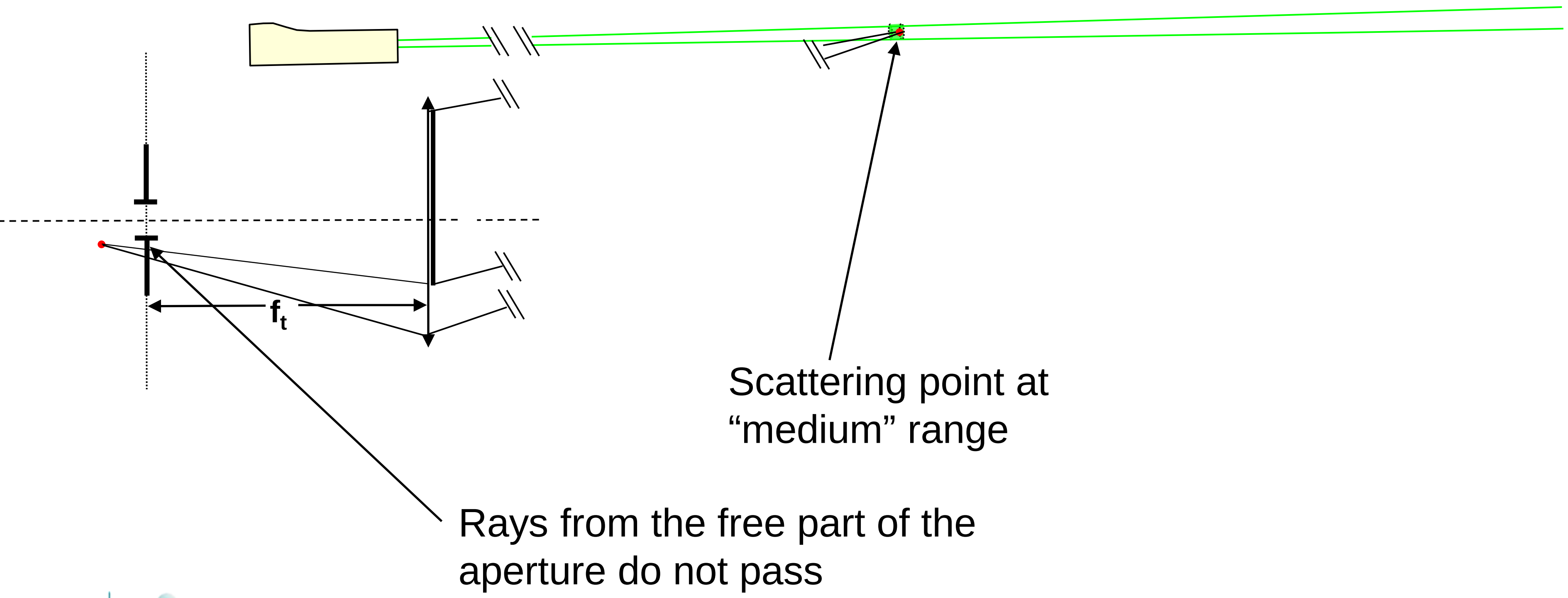
- **Simplified rationale: blocking different parts of the telescope we check to which extent rays passing through the free aperture make it through the field stop**



Mandatory periodic internal checks

Telecover test

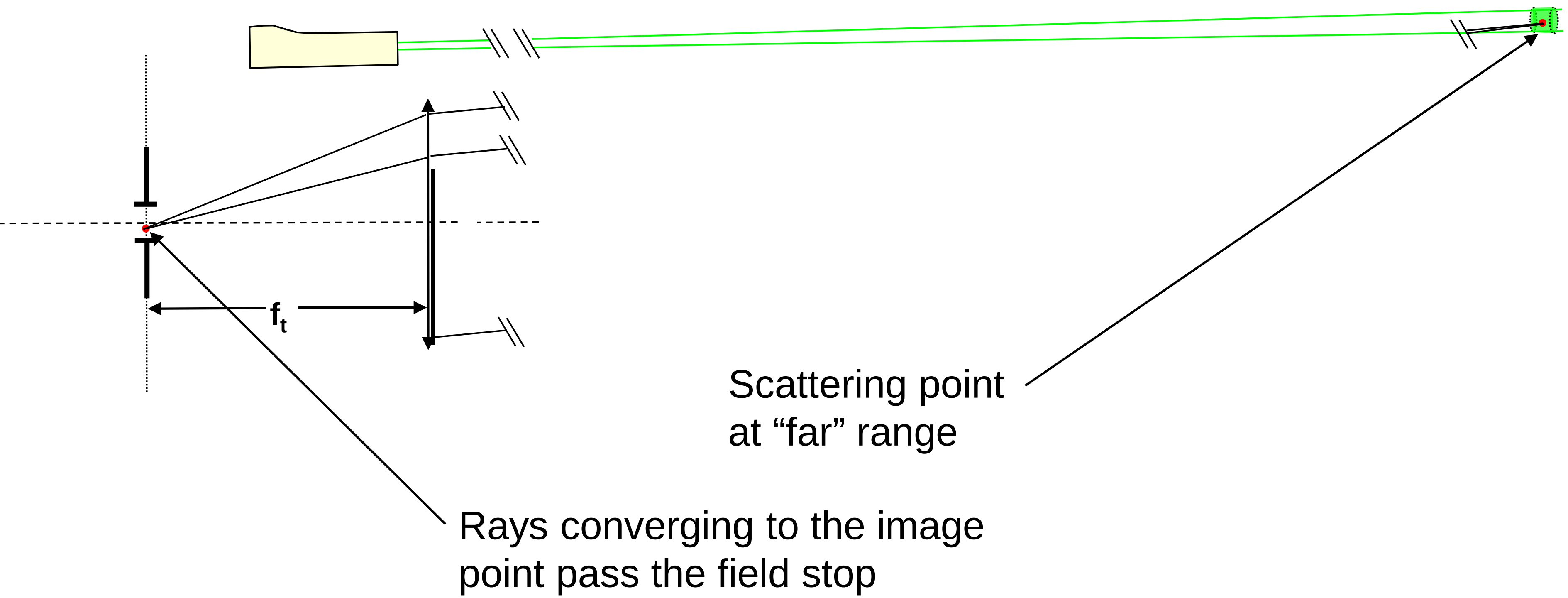
- **Simplified rationale: blocking different parts of the telescope we check to which extent rays passing through the free aperture make it through the field stop**



Mandatory periodic internal checks

Telecover test

- **Simplified rationale**



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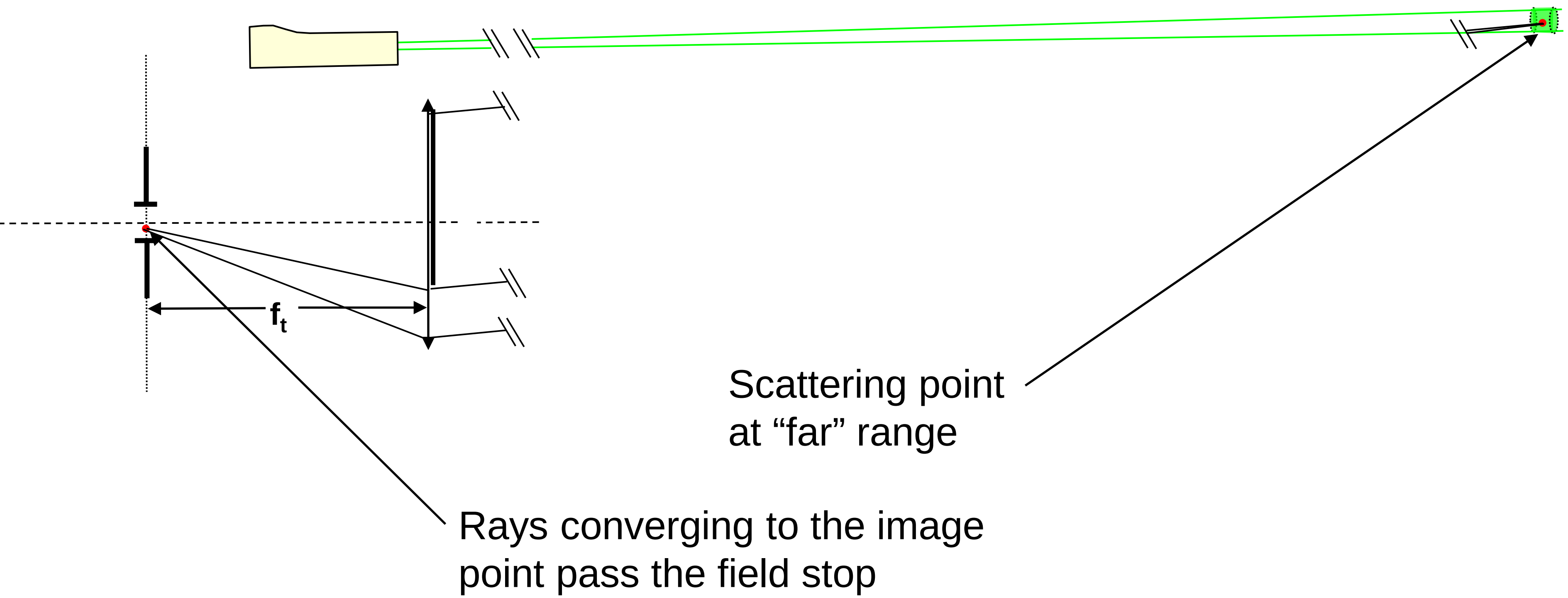
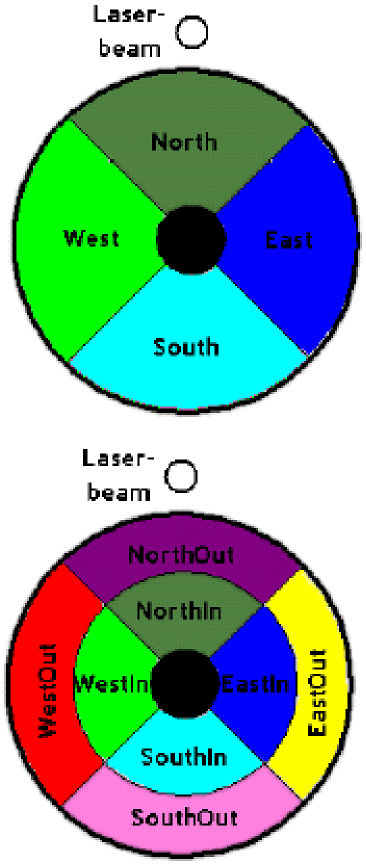
Telecover test

- **Simplified rationale**



Telecover test

- **Practical implementation**

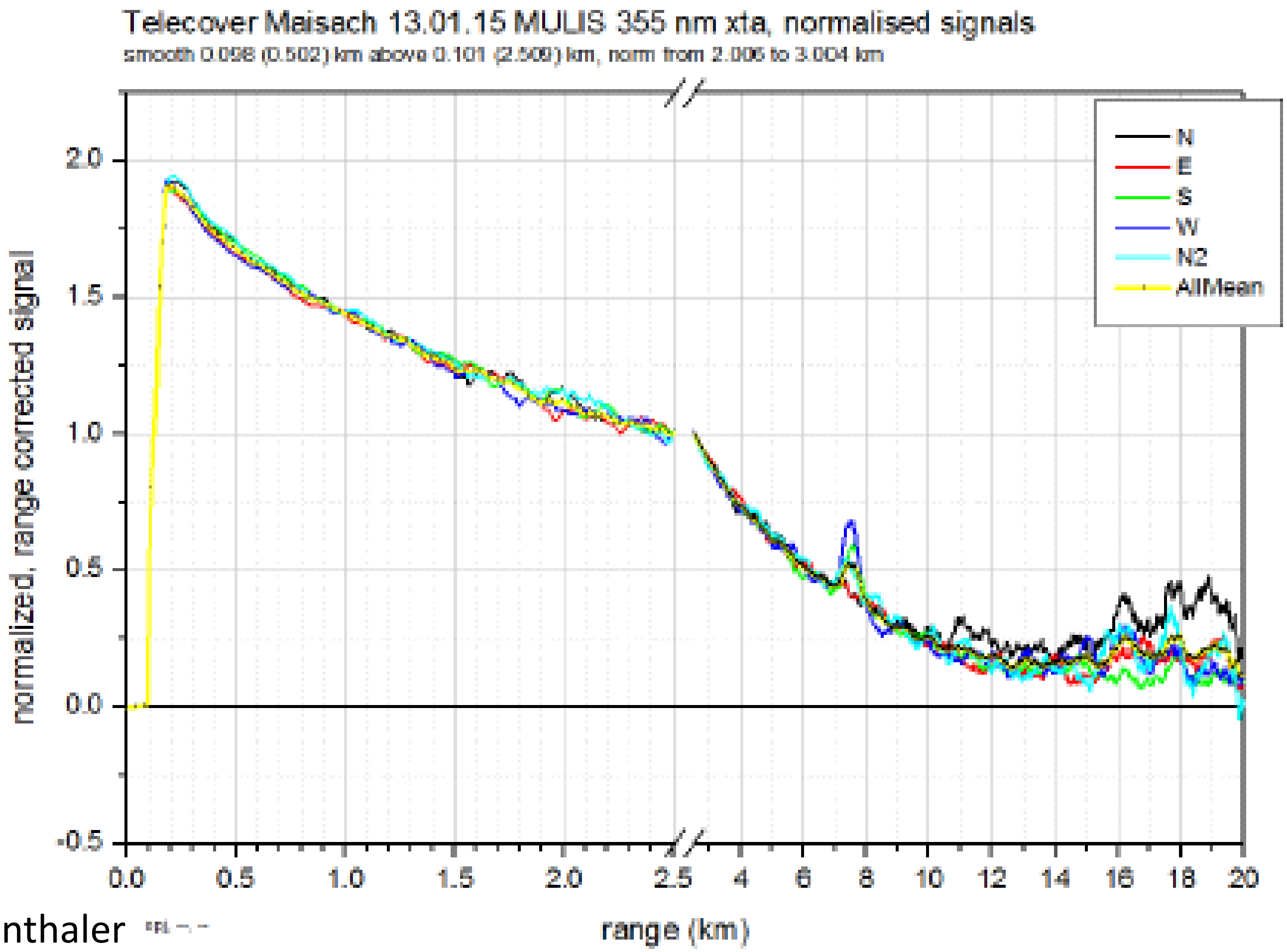


- **East and West should ideally give the same response**
- **All the responses should coincide when full overlap is attained**
- **In general applied on signals normalized on a given range**

Figure from V. Freudenthaler, “The telecover test: A quality assurance tool for the optical part of a lidar system”, Reviewed and Revised Papers presented at the 24th International Laser Radar conference, Boulder (CO) USA, 2008

Telecover test

Well aligned system

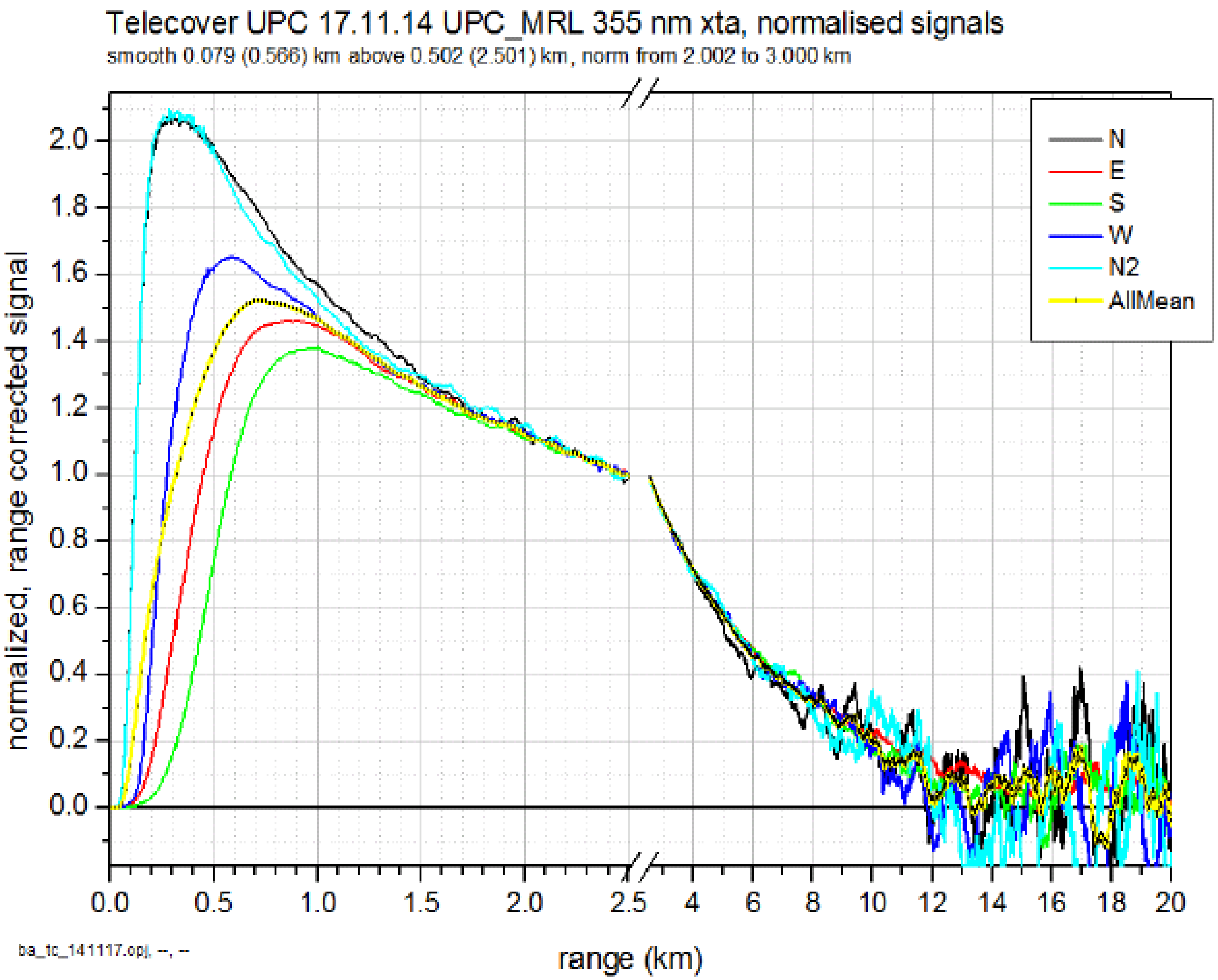


Source: V. Freudenthaler

Mandatory periodic internal checks

Telecover test

Not so well aligned system…



Source:
V. Freudenthaler

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Rayleigh fit

- Checks for alignment and interference residuals in the far range
- Principle: in an aerosol-free atmosphere the signal should follow a law dictated by Rayleigh scattering
- If nearby radiosonde pressure and temperatura data are available, comparison is made against molecular atmosphere retrieved from these data

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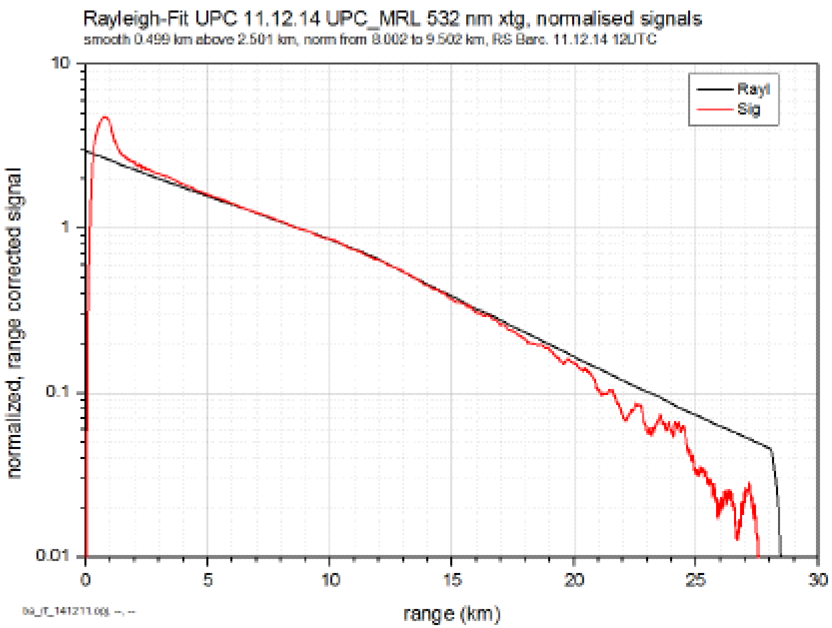
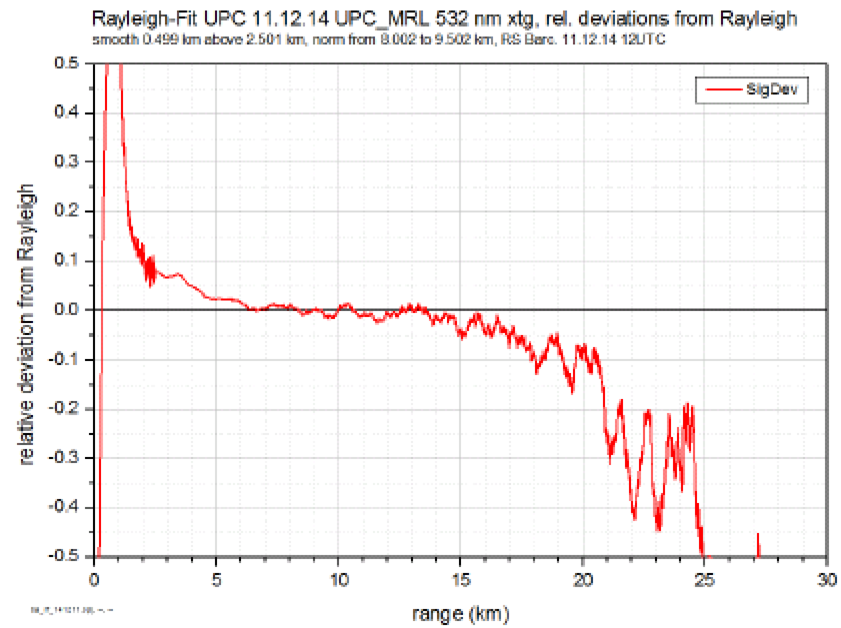
Mandatory periodic internal checks

Rayleigh fit





Source: V. Freudenthaler

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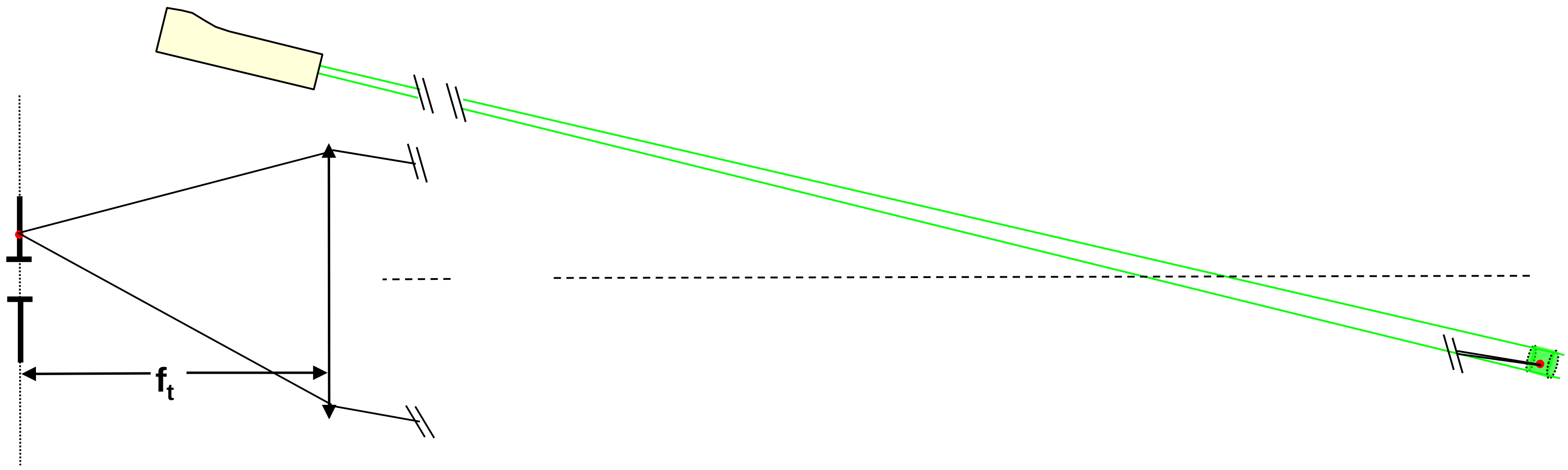
Rayleigh fit

Possible diganostic



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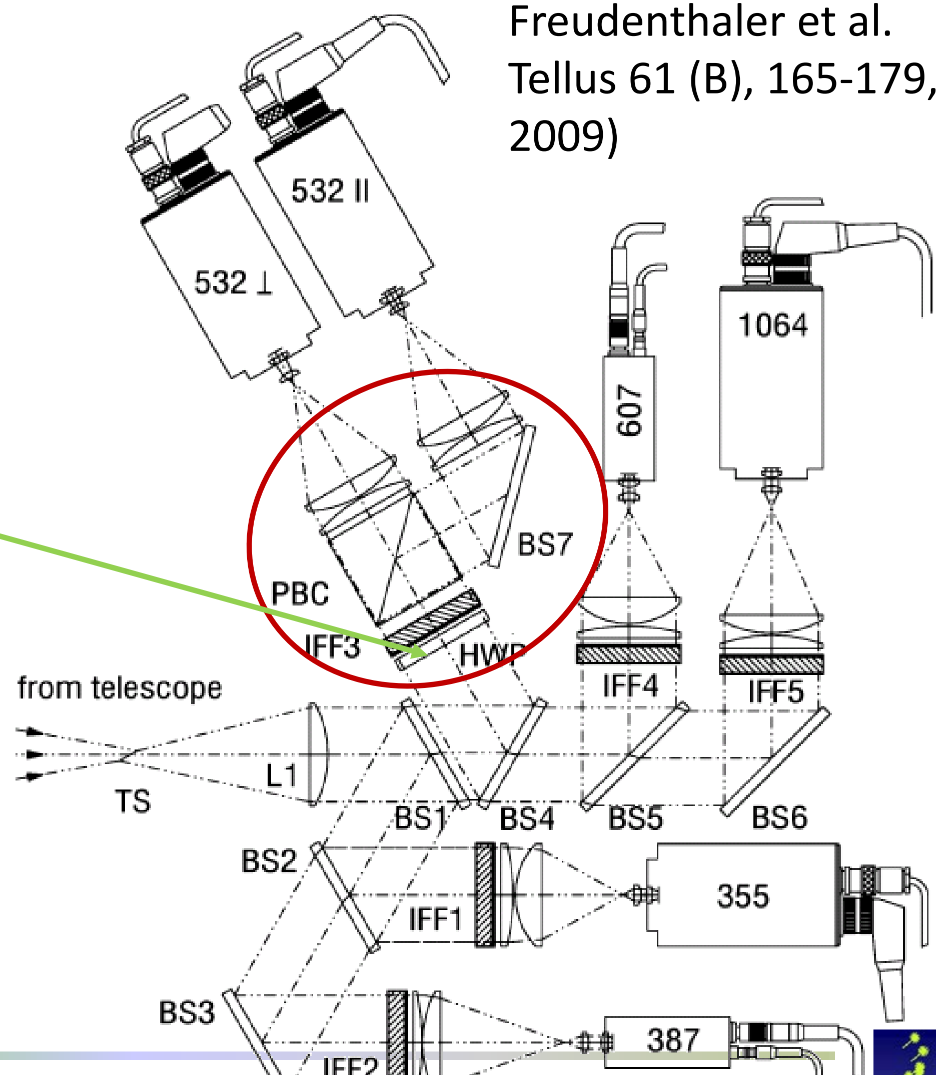
Mandatory periodic internal checks

Polarization calibration

- Necessary to determine the ratio between the instrument constants of the two detection channels involved
- This ratio is obtained as the geometrical mean of $P_{\perp}/P_{\|}$ when the polarized part of the incoming radiation is at +45° and -45 ° from the measurement position (see ref. of the figure)
- Chek is done in the Rayleigh region to test if depolarization values of molecular atmosphere are found
- Details may depend on the specific configurations

MULIS layout (from V. Freudenthaler et al. Tellus 61 (B), 165-179, 2009)



Impulse response of analog acquisition systems

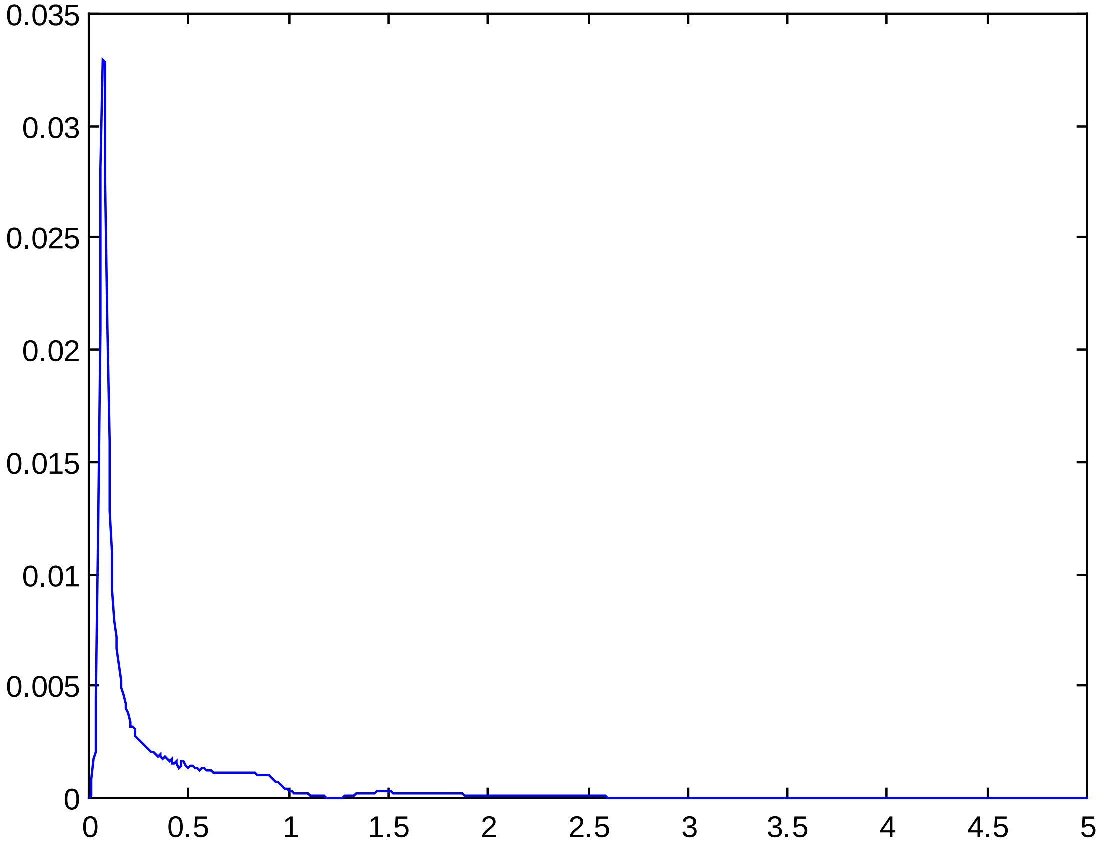
Why is it important?

- Lidar photodetector output is essentially an impulse

Impulse response of analog acquisition systems

Why

- **Lic** … **se**



Not mandatory, but…

Impulse response of analog acquisition systems

Why is it important?

- **Lidar photodetector output is essentially an impulse**
- **Transients associated to acquisition electronics may severely impair the acquired signal**

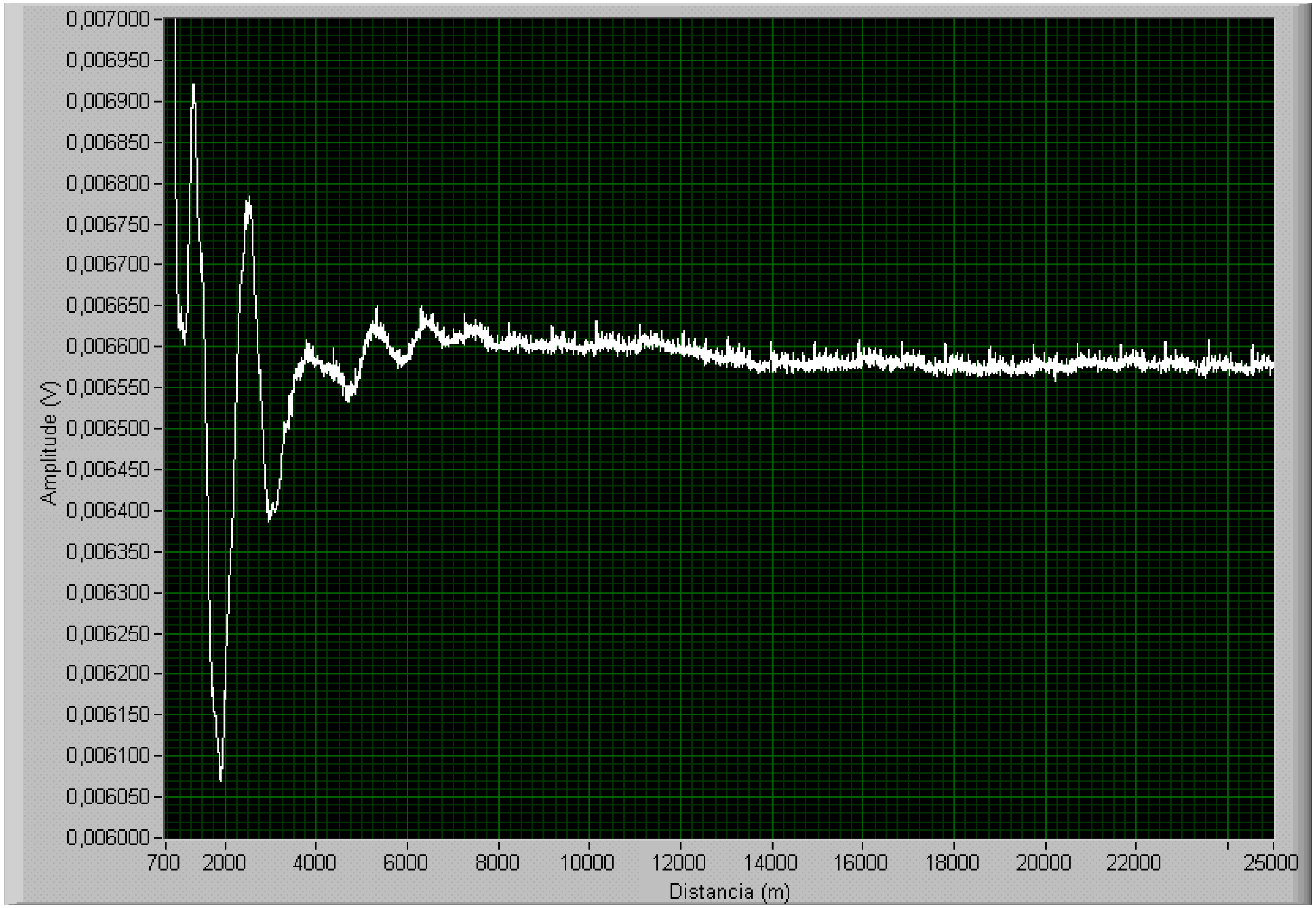
Impulse response of analog acquisition systems

What is needed to test?

- **Pulse generator providing sharp and clean falling edge**
- **Even good general purpose commercial function generators may not be good enough**

Impulse response of analog acquisition systems

Measurement with general purpose function / waveform generator*



Falling edge of 1 V, 4.5 µs pulse

* Agilent 33250A, 80 MHz

Impulse response of analog acquisition systems

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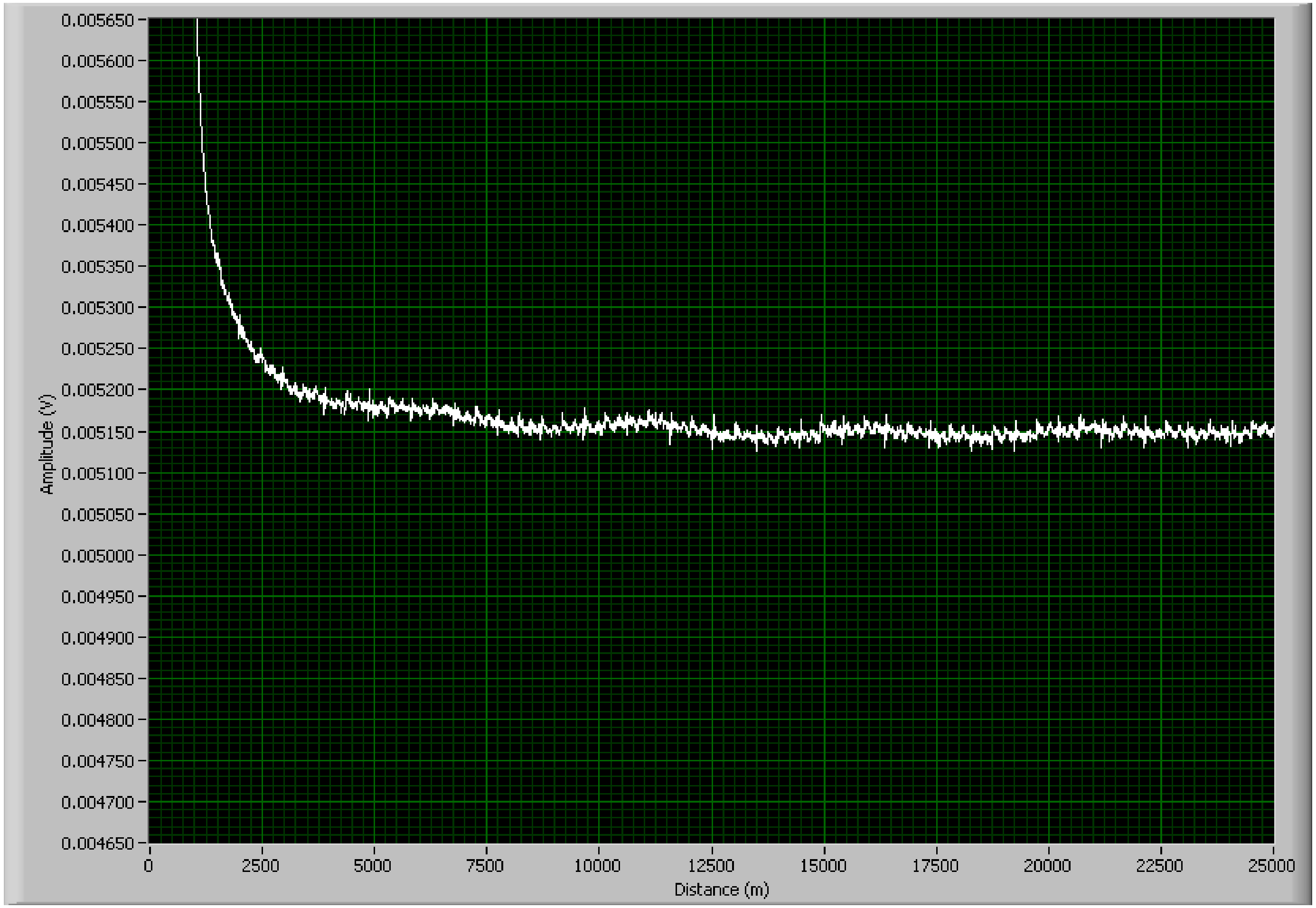
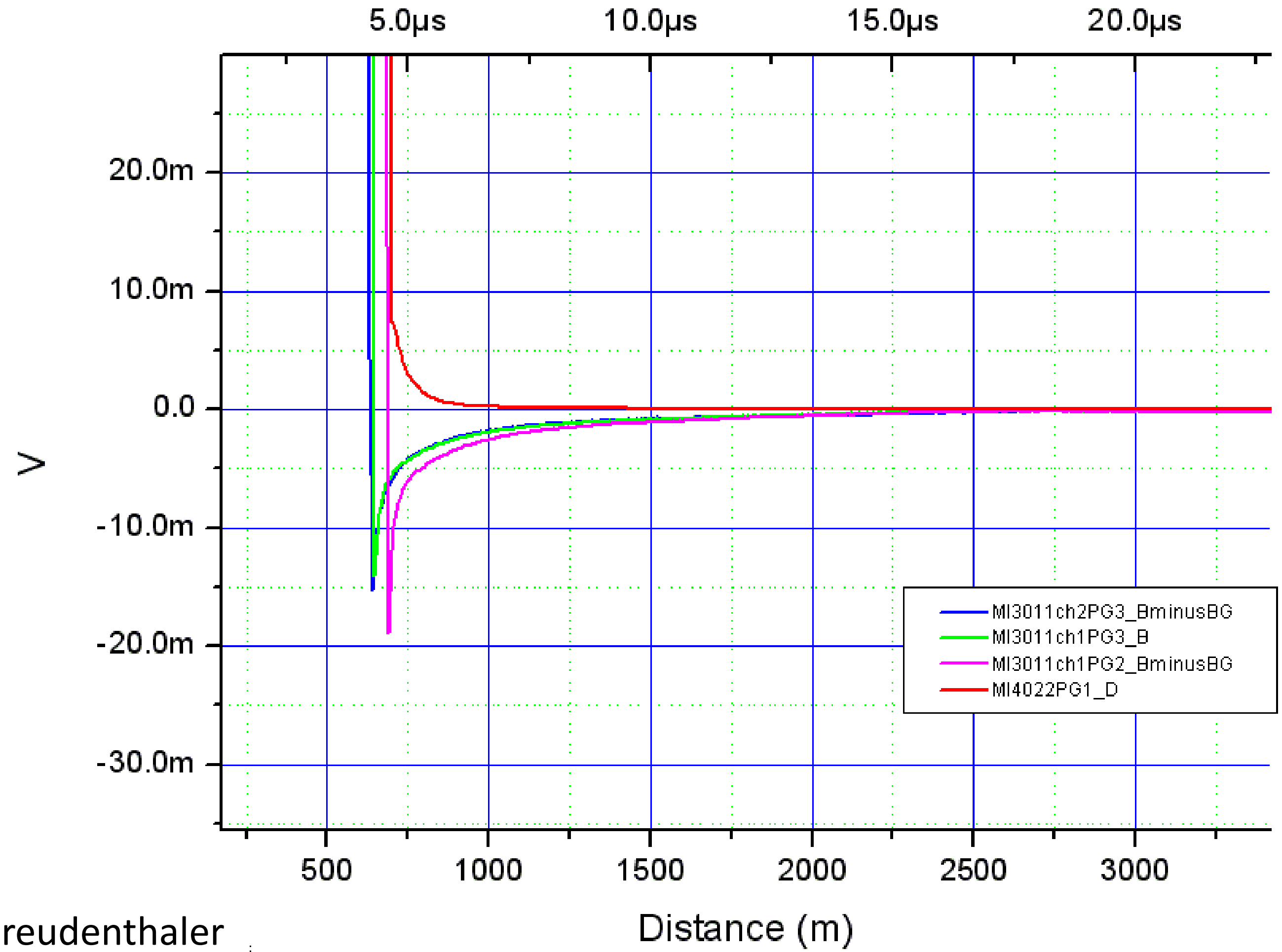
Measurement with especially designed (MIM-IfT) pulse generator*



0V-1 V, 4.5 μs pulse

Falling edge of 1 V, 4.5 μs pulse

Example of problem with impulse response (I)



Source: V. Freudenthaler

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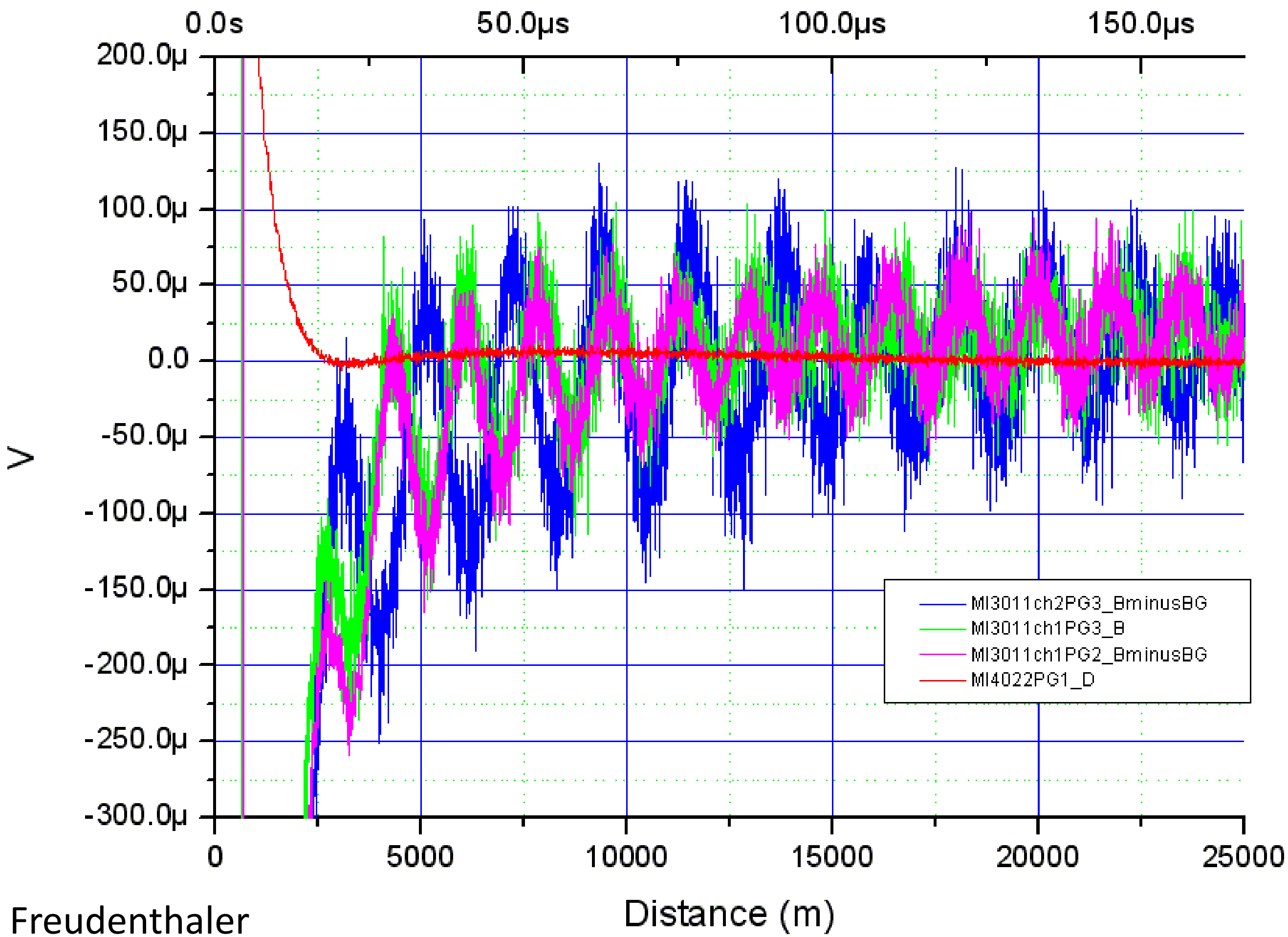
Example of problem with impulse response (II)

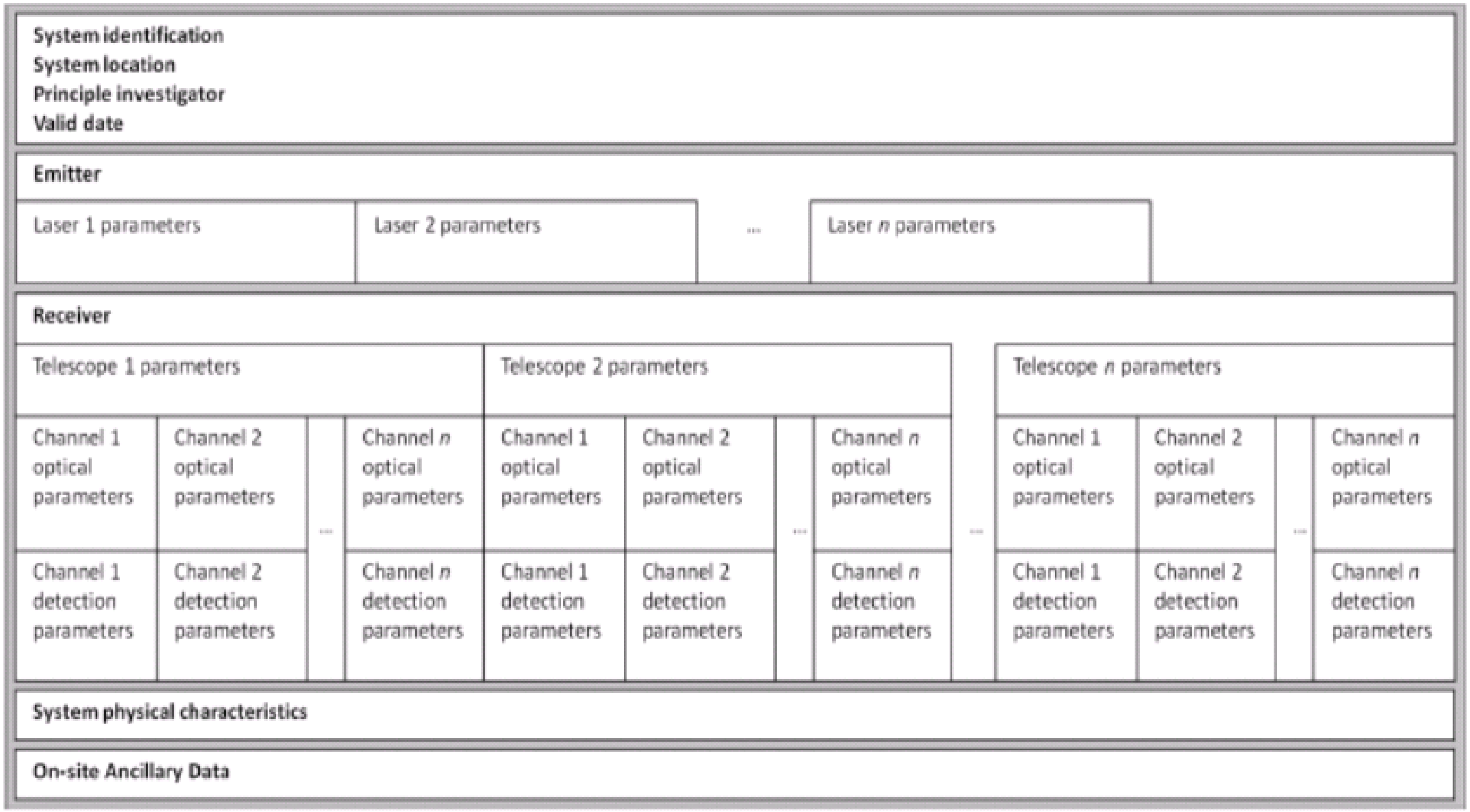


Source: V. Freudenthaler

Handbook of Instruments

- Tool to provide a homogeneous framework to a diverse infrastructure
- Transmitter and receiver described in a precise way that allows traceability in case of anomalies
- Logical link between quality assurance of hardware and software: the Handbook of Instruments is assimilated into the SCC database
- Updated in case of system modifications / upgrades

Register organization



From G. Pappalado et al., Atmos. Meas. Tech. **7**, pp. 2389-2409, 2014

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Register example

EARLINET Call-sign	**MS**	pictures				
Valid since / Status updated	2009 03 30	2011 02 22				
Station	München - Meteorologisches Institut LMU-MUENCHEN					
System name	MULIS					
Home Location	Germany, Maisach (current)			*Germany, Munich (home)*		
Home Location Coordinates	48.209 N	11.258 E	515 m asl	*48.148 N*	*11.573 E*	*539 m asl*
Home Location Environment	rural			*urban*		
System transportable	yes					
Emitter	**Laser 1**					
Laser type	Nd:YAG					
Laser manufacturer	Continuum					
Laser model	Surelite II					
Seeder	no					
Seeder bandwidth						
Seeder manufacturer						
Seeder model						
Pulse energy total (typ.)	1.6 J					
Repetition rate	10 Hz					
wavelength	1064 nm	532 nm	355 nm			
Pulse energy (typ.)	0.175 J	0.05 J	0.175 J			
Pulse length (typ.)	6 ns	6 ns	6 ns			
Polarization and purity (nominal)	elliptical	linear >95%	linear >95%			
Polarisation purity measured						
Polarisation orientation	elliptical	vertical	horizontal			
Laser beam diameter (mm)	8 mm fwhm					
Laser beam divergence	0.6 mrad fw at 86% of energy					
Beam expansion type	n.a.					
Beam expansion factor						
Beam divergence						
Alignment	manual					
Alignment control	camera					
Alignment accuracy	0.1 mrad					

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Register example

Receiver Optics	Telescope 1						Telescope 2 (near range)
Telescope type	Cassegrain, primary parabolic						Refractive
Telescope manufacturer / model	Lichtenknecker, Belgium						LINOS lens PC 312362
Telescope aperture diameter	0.3 m						0.063
Telescope obscuration diameter	0.134						0
Focal length	0.95 m						0.2 m
Field of view	variable 0 to +-3 mrad equiv.						4 mrad
Fieldstop type	tilted slit 60°						circular diphragm
Fieldstop size	9.3 mm length, 1.9 mm width, 60°						0.8 mm diameter
Optical fiber Numerical Aperture	n.a.						n.a.
Optical fiber manufacturer							
Optical fiber type							
Telescope-laser axes distance	0.4 m						0.12 m
Collimation system type / model	planconvex lens		Linos 312334				2* LINOS 312323
Collimation focal length	101 mm						50 mm
Detection channels							
Centre wavelength	355 nm	387 nm	532 nm	532 nm	607 nm	1064 nm	532 nm
Scattering mechanism	Elastic	vibr.Raman N2	Elastic parallel	Elastic cross	vibr.Raman N2	Elastic	Elastic
Wavelength separation	DBS	DBS	DBS	DBS	DBS	DBS	n.a.
Separation Passband bandwidth							
Separation transmission*							
Separation transmission pol. Parallel	0.988	0.982	0.962	0.962	0.878	0.912	
Separation transmission pol. Cross	0.997	0.978	0.956	0.956	0.891	0.787	
Out of band suppression	IFF	IFF	IFF	IFF	IFF	IFF	IFF
Passband bandwidth	1.0 nm fwhm	0.51 nm fwhm	1.1 nm fwhm	1.1 nm fwhm	0.46 nm fwhm	2.7 nm fwhm	1 nm fwhm
Passband transmission	0.45	0.62	0.49	0.49	0.7	0.55	
Out of band blocking	>OD 5	OD6 @355 OD7 @ 532 OD6 @1064	> OD 4	> OD 4	OD6 @355 OD7.5 @ 532 OD6 @1064	> OD 4	
Polarization separation			PCB+SP	PCB+SP			
Pol. Transmission parallel			1	0			
Pol. Transmission cross			0	1			
Neutral density filter OD	3 (variable)	0.11(variable)	1.28(variable)	1.6 (variable)	0.04	1.07	0
Detector type	PMT	PMT	PMT	PMT	PMT	Si-APD	Si-PIN
Detector manufacturer	Hamamatsu	Hamamatsu	Hamamatsu	Hamamatsu	Hamamatsu	LICEL	Silicon Sensor
Detector model	R7400-U	R7400-U	R7400-U	R7400-U	R7400-U20	3 mm diameter	SS0-PD-50-7-TO8S
Additional features	RSV	LICEL	RSV	RSV	LICEL	without lens	RSV
Daytime capability	yes	no	yes	yes	no	yes	yes

Data Acquisition							
Data acquisition mode	Analog	Analog/PC	Analog	Analog	Analog/PC	Analog	Analog
Transimpedance Amplifier	yes	no	yes	yes	no	yes	yes
Transimpedance Gain	10 kOhm		10 kOhm	10 kOhm		11 kOhm	100 kOhm
Transimpedance Bandwidth						10 MHz	7 MHz
Output impedance	50 Ohm	50 Ohm	50 Ohm	50 Ohm	50 Ohm	50 Ohm	50 Ohm
Analog sampling rate	20 MS/s	20 MS/s	20 MS/s	20 MS/s	20 MS/s	20 MS/s	20 MS/s
Bandwidth	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz
A-D bits	14 bit	12 bit	12 bit	14 bit	12 bit	12 bit	14 bit
Input termination	50 Ohm	50 Ohm	50 Ohm	50 Ohm	50 Ohm	50 Ohm	50 Ohm
Max input Voltage	2 V	1 V	2 V	1.1 V	1 V	1 V	1.1 V
Photon counting count-rate		250 MHz			250 MHz		
Data acquisition manufacturer	Spectrum	LICEL	Spectrum	Spectrum	LICEL	LICEL	Spectrum
Data acquisition model	MI4022	TR20	PCI412	MI4022	TR20	TR20	MI4022
Raw data range resolution	7.5 m	7.5 m	7.5 m	7.5 m	7.5 m	7.5 m	7.5 m
Raw data time resolution	10 s	10 s	10 s	10 s	10 s	10 s	10 s
Raw data altitude range	16 km	16 km	16 km	16 km	16 km	16 km	16 km
Pretrigger data	yes	yes	yes	yes	yes	yes	yes

Mode of Operation	
Lidar pointing	Zenith
Scanning range Elevation	-5° to 95°
Scanning range Azimuth	350°
Unattended operation	partly
Automated functions	Scanning, depolarization calibration

Auxilliary Information	
Sunphotometer	
Nearest radio sounding station	Oberschleissheim WMO 10868
Distance to lidar station	10 km
Frequency of Radio Soundings	Noon, Midnight

Abbreviations

interference filter (IFF)
dichroic beam splitter (DBS)
photon counting (PC)
double grating monochromator (DGM)
single grating monochromator (SGM)
Fabry-Perot interferometer (FPI)
polarizing cube beamsplitter (PCB)
sheet polarizer (SP)

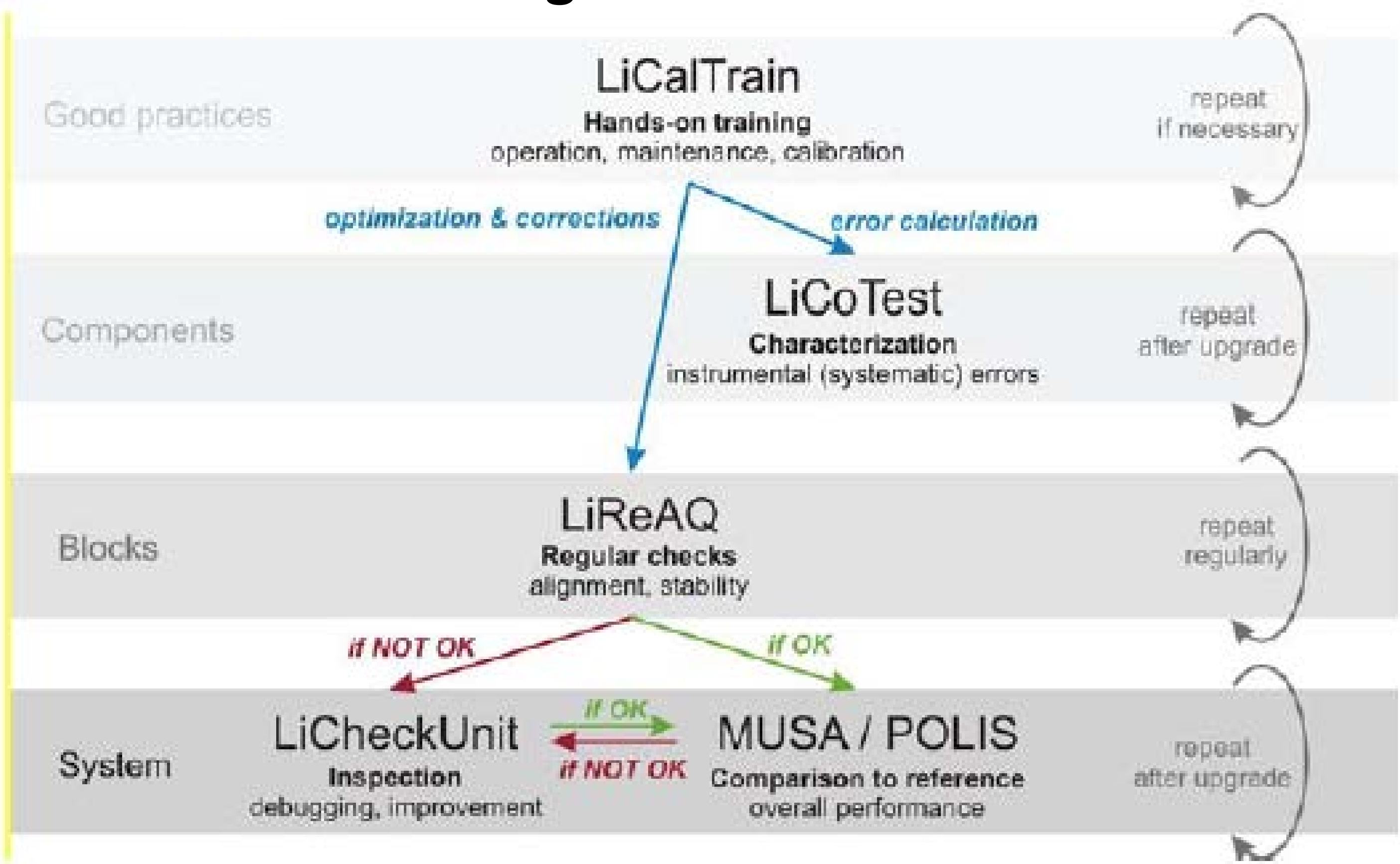
Annotations

(*) Product of all beam splitters divided in parallel and perpendicular to the laser polarization, if available.

Lidar Calibration Center (LiCal)

- **Multi-installation facility offering a wide range of services to test and calibrate lidars and ceilometers**
- **Extends exisiting hadware quality assurance procedures**
- **Implementation starting in 2015**

LiCal logical structure



Summary

- For data coming from a network of instruments to be consistent, a quality assurance program is necessary

- This is especially demanding when the instruments are very different from each other in their specific implementations

- Over its history (15 years, with roots that extend earlier in time) EARLINET has developed quality assurance protocols, both on hardware and software, to ensure data homogeneity

- Along with measurement schedule protocols, this allows EARLINET acting as a single, virtual instrument

EARLINET measurement schedule

- Climatology measurements

  Mondays:

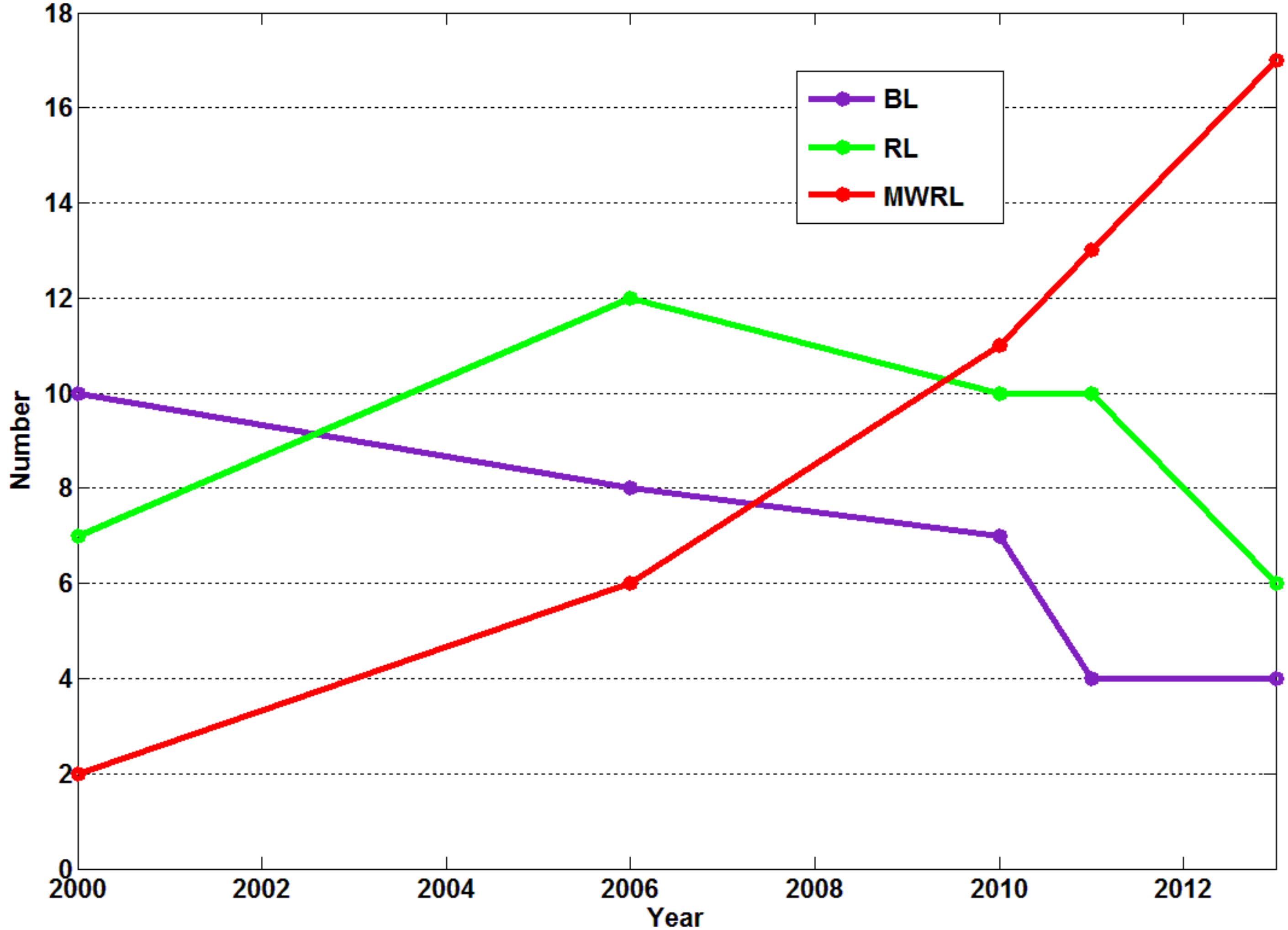
  ½ hour between 1 hour before and 1 hour after 2 pm local solar time → well developed PBL

  ½ hour between 1 hour before and 3 hours after sunset → to allow operation of Raman channels

  Thursdays

  ½ hour between 1 hour before and 3 hours after sunset
- Special events: Saharan dust outbreaks, forest fires, photochemical smog, volcanic eruptions…
- CALIPSO correlative measurements → when CALIPSO overflight is within a range from the lidar station vertical, to validate and provide support to CALIPSO measurements

EARLINET evolution



BL: backscatter lidar (only backscatter cannel)

RL: Raman lidar (at least on Raman cannel)

MWRL: Multiwavelength Raman lidar (at least 3 elastic channels and at least 2 Raman channels → EARLINET "standard)

Related reading

- V. Matthias et al., “Aerosol lidar intercomparison in the framework of the EARLINET project. 1. Instruments”, Appl. Opt. **43** (4), pp. 961-976, 1 Feb. 2004

- C. Böckmann et al., “Aerosol lidar intercomparison in the framework of the EARLINET project. 2. Aerosol backscatter algorithms”, Appl. Opt. **43** (4), pp. 977-989, 1 Feb. 2004

- G. Pappalardo et al., “Aerosol lidar intercomparison in the framework of the EARLINET project. 3. Raman lidar algorithm for aerosol extinction, backscatter, and lidar ratio”, Appl. Opt. **43** (28), pp. 5370-5385, 1 Oct. 2004

- V. Freudenthaler, “The telecover test: A quality assurance tool for the optical part of a lidar system”, Reviewed and Revised Papers presented at the 24th International Laser Radar conference, Boulder (CO) USA, 2008, pp. 145-146. (paper and poster available at http://epub.ub.uni-muenchen.de/12958/)

- V. Freudenthaler et al., “Depolarization ratio profiling at several wavelengths in pure Saharan dust during SAMUM 2006”, Tellus, 61B, pp. 165-179, 2009

Related reading

Atmospheric Measurement Techniques (AMT) Special Issue on "EARLINET, the European Aerosol Research Lidar Network" (in progress):

- G. Pappalado et al., "EARLINET: towards an advanced sustainable European aerosol lidar network ", Atmos. Meas. Tech. **7**, pp. 2389-2409, 2014
- + upcoming papers related to hardware quality assurance and the Single Calculus Chain

Acknowledgments

- European Union 7th Framework Programme grant agreement No. 262254 (ACTRIS)
- Spanish Ministry for Economy and Competitiveness grant TEC2012-34575
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