EARLINET-Internal Checkups

developed under support from
EARLINET-ASOS NA3

and ACTRIS

Source: http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/EA-NA3-QA-InternalCheckups.html

Internal lidar checkup procedures

1 Introduction

The following measurements are part of the internal lidar system checkups. For the first internal checkup due to May 2008, the telecover measurements are mandatory. The calculation of deviations is not mandatory.
The other tests should be performed and submitted as soon as possible. The dark measurements can be done with the telecover measurements and appended to this data file. The Rayleigh fit can be retrieved from a regular EARLINET measurement.
The preferred format for the submission of the data is described in chapter 6.
Please submit the data via email to volker.freudenthaler@meteo,physik.uni-muenchen.de not later than 31. May 2008.

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2 Telecover

The telecover checkup tool is described in more detail in EA-NA3-QA-Telecover-2.html.

A brief summary:

2.1 Nomencalture

Quadrant test: **N,E,W,S,N2**
Octant test : **NO,EO,SO,WO,NO2** and **NI,EI,SI,WI,NI2** looking from the sky into the telescope.
In-Out test : **FO, FI**
Dark measurement : **D**
FI is the inner ring, FO the outer ring, D is a dark measurement with the telescope fully covered.
The N2, NO2 or NI2 measurements are additional at the end of each cycle in order to estimate the influence of the atmospheric changes since the start of the measurements. This can be evaluated from **N - N2.** In case N2 is not possible, please measure something equivalent.

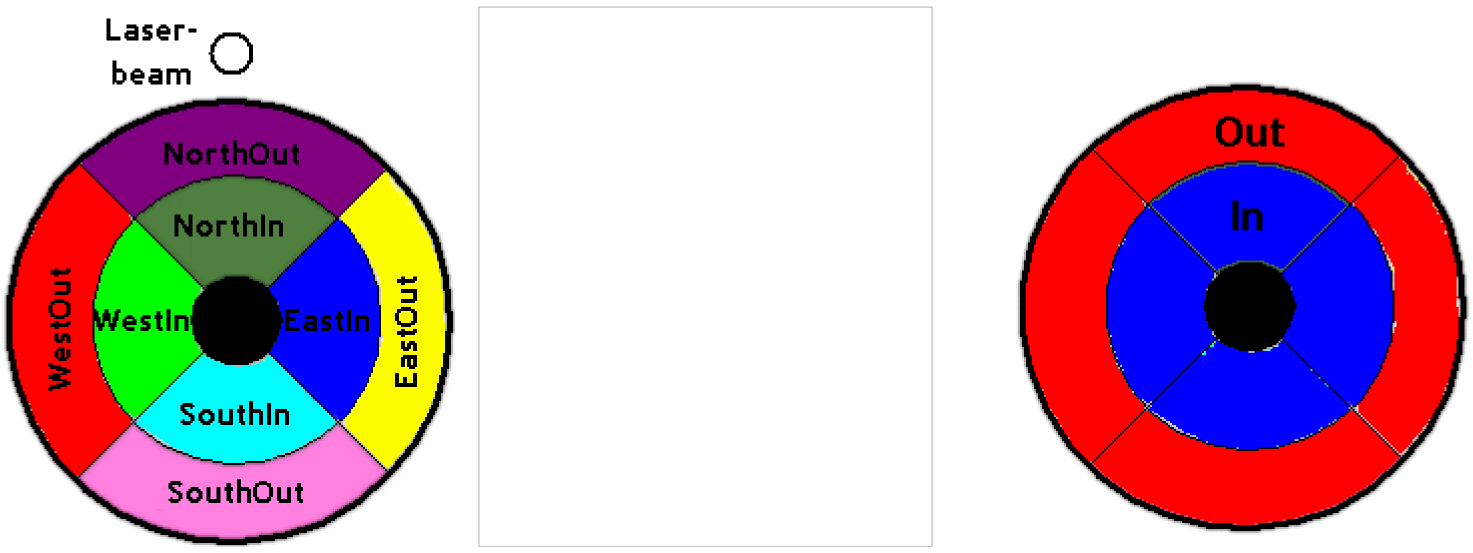

Figure 1

2.2 Required measurements

Biaxial systems: For the first attempt a quadrant test should be sufficient.
Monoaxial systems: In order to check laser tilt and other deviations, at least a quadrant and an In-Out test should be performed.

If necessary, the octant measurements can be performed for further investigations.

2.3 Calculation of deviations (not mandatory)

For the deviations I propose to calculate point by point

1. the mean of of all profiles: **mean = (N + E + S + W) / 4 ...**
2. the relative deviation of each profile (NDev, EDev,...) from the mean : **NDev = (N - mean) / mean ....**
3. the realtive RMS deviation of all profiles: **AllDev = sqrt ((NDev^2 + EDev^2 + SDev^2 + WDev^2) / 4) ...**
4. the atmospheric change **(N - N2) / mean**
   or the equivalent means and deviations (In, Out ....).

2.4 Smoothing and normalization

The measurements should be sufficiently smoothed over range or time in order to keep the deviations due to signal noise well below the limits.
According to my recent experience, the submission of **non-normalized** range corrected signals is preferred. This gives additional information about the relative intensity of the individual telescope sectors.

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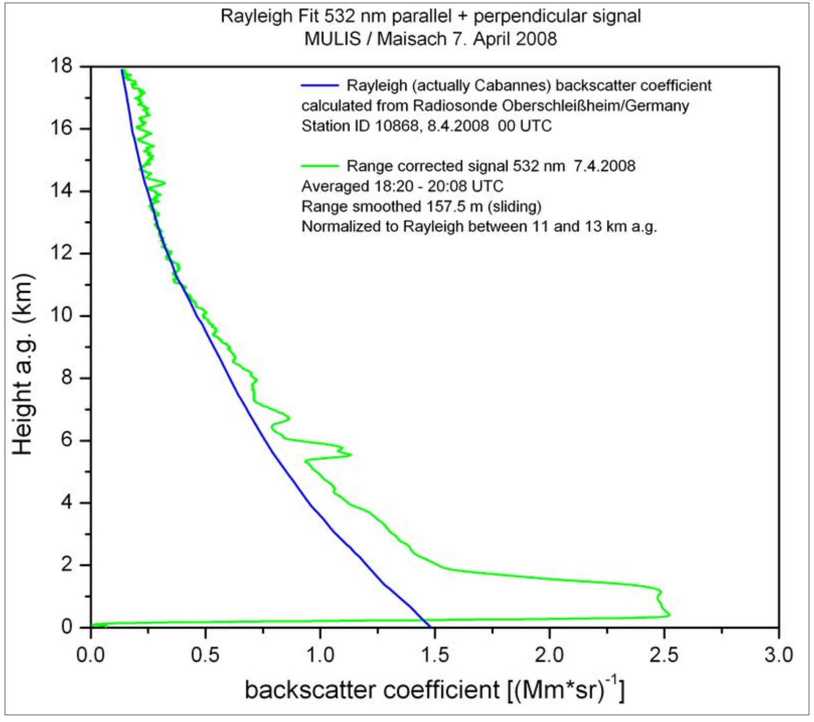
3 Rayleigh Fit

This checkup tells us the quality of the signals in the far range. Especially analog signals show distortions there. Additionally we gather information about the use of Radiosonde data at different sites.
Please provide for each channel a 30 min. averaged, range corrected signal (maybe from your records; please) together with the Rayleigh backscatter coefficient according to your standard calculation of the reference value for the Fernald/Klett/Raman retrievals.
If you do this in another way, please write one or two sentences how you calibrate the signals.
Example:



Comments:
Actually the "Rayleigh Fit" is a normalization of the lidar signal to the calculated attenuated Rayleigh backscatter coefficient (β_R^{attn}) in a range where we assume clean (Rayleigh) conditions and where the calculated signal fits the lidar signal sufficiently good.
A problem is that the reference value for the Fernald/Klett inversion has to be at a single rangebin, but the normalized lidar signal and the

β_R^{attn} can be different over the whole fit range due to signal noise. That means the normalized lidar signal might not have any rangebin which can be used as a reference value for the inversion without introducing a noise error. There are probably several solutions for this problem. My solution : I replace a value in the normalized lidar signal at the middle rangebin of the fitting range with the corresponding value of the calculated β_R^{attn}.
I consider this as physically correct and exact solution. Comments are wellcome and can be published here.

My Rayleigh Fit procedure :

Let the lidar signal be:

$$P(r)r^2 \propto \left(\beta_R(r)+\beta_P(r)\right)\exp\left[-2\int_0^r\left(\alpha_R(r')+\alpha_P(r')\right)dr'\right]$$

1. Select a range in the lidar signal where clean air can be assumed ($\mathbf{r_{max}}, \mathbf{r_{min}}$).
2. Caclulate the β_R^{attn} using a "good" radiosonde, with attenuation starting at the middle rangebin ($\mathbf{r_0}$, **reference range**) of the selected range ($\mathbf{r_{max}}, \mathbf{r_{min}}$).

   $$\beta_R^{attn}(r,r_0)=\beta_R(r)\exp\left[-2\int_{r_0}^{r}\alpha_R(r')dr'\right]$$

This means negative attenuation for $\mathbf{r < r_0}$, and keeps the exact reference value at the reference range $\mathbf{r_0}$

$$\beta_R^{attn}(r_0,r_0)=\beta_R(r_0)$$

3. Check whether the fit is sufficiently good. A general procedure to evaluate the "goodness of fit" is under development. Ideas are welcome.
4. If the fit is not good, repeat 1. to 3. until it is good.
5. Normalize the lidar signal to the β_R^{attn} using the means of the β_R^{attn} and of the lidar signal over the fit range. This avoids an additional error due to signal noise in the fit range.

   $$P^{norm}(r,r_0)r^2 = P(r)r^2\frac{\int_{r\min}^{r\max}\beta_R^{attn}(r,r_0)dr}{\int_{r\min}^{r\max}P(r')r'^2 dr}$$

6. Replace the value of the lidar signal at the middle rangebin $\mathbf{r_0}$ with the value of the Rayleigh backscatter coefficient at this rangebin $\beta_R(\mathbf{r_0})$. Note: this value should be the same as the one of the β_R^{attn} at this rangebin, i.e. the right reference value for Fernald/Klett.

   $$P^{norm}(r_0,r_0)r^2 = \beta_R^{attn}(r_0,r_0)=\beta_R(r_0)$$

7. Start the Fernald/Klett inversion from this rangebin.

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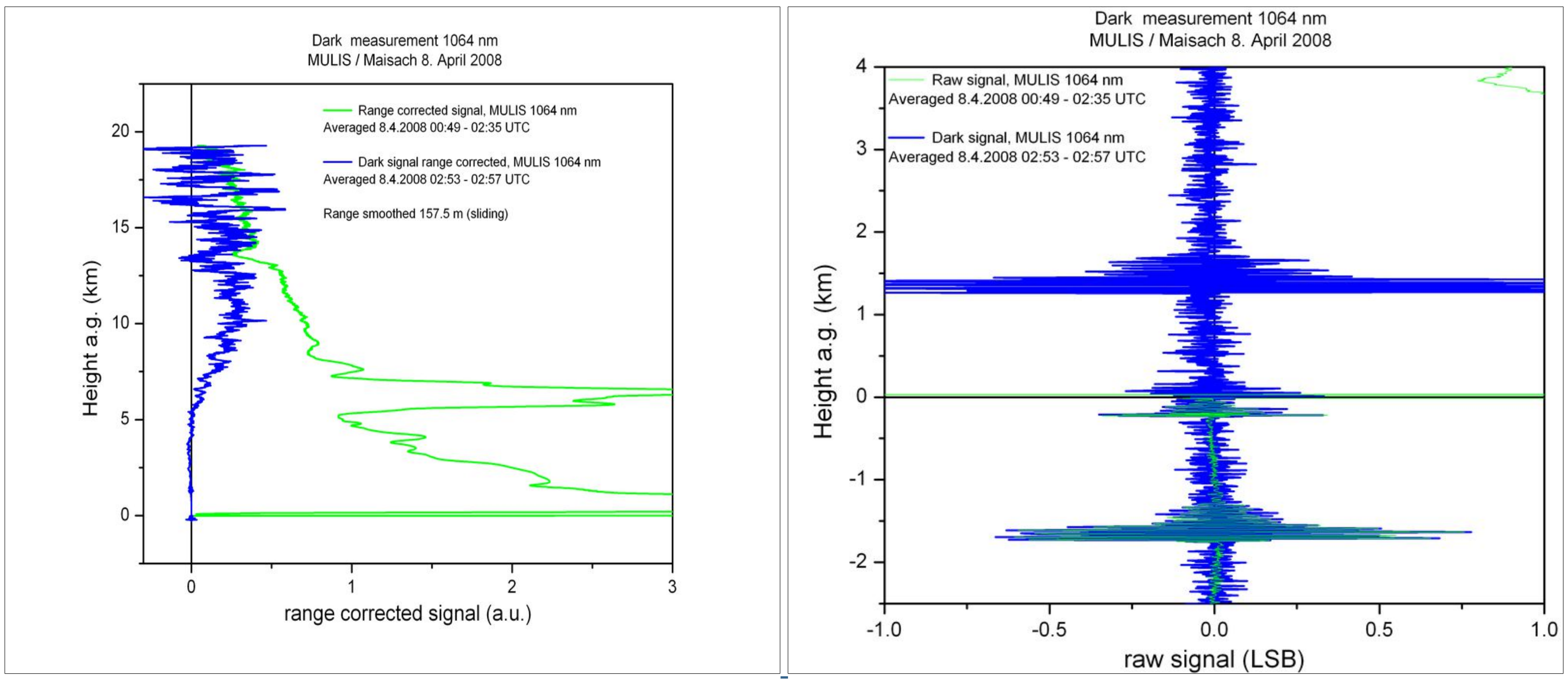
4 Dark measurement

A dark mesurement is a normal measurement with sufficient time averaging, but with a fully covered telescope or with covered detectors. This signal shows all stray pick-ups and signal distortions wich do not stem from the atmospheric backscatter, but from the lidar system itself; e.g. laser flash-lamp pulse pick-ups, or system trigger pick-ups. All system parameters, like e.g. detector HV, must be set in the same way as for a normal measurement.
Please make shure that no laser light reaches the detectors.
The dark measurement could done and submitted with the telecover measurements (actually it is a telecover with fully covered telescope) and marked as **D** .
Example:



The left picture shows range corrected signals: dark-measurement (blue) and a regular measurements (green) for comparison, while the right picture shows the same but raw signals zoomed in intensity and towards the pretrigger regime. In the right picture the stray pick up of the laser flash lamp and Q-switch triggers can be seen in the Dark measurement as well as in the real measurement before the Zero-bin. Under favourable circumstances, the dark signal can be subtracted from the real signal. Whether this is possible or not must be investigated for each lidar channel and system setup separately.

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5 Zero-bin measurement

5.1 Theory

An error in the triggerdelay between the real laser output and the detection system start (system trigger, Zero-bin) can cause large errors in the near range signal up to about 1 km range. Especially the Raman signals can be distorted dramatically, because the signal slope in the near range changes very much when the trigger delay for the range correction is varied. Thus it is worth some effort to verify that the Zero-bin is really where we assume it to be.

The particle extiction coefficient α p (*r*) can be calculated from Raman measurements according to:

$$\alpha_p(r) = \frac{\frac{d}{dr}\ln\alpha_m(r) - \frac{d}{dr}\ln\left[r^2 P(r)\right] - (1+f_m)\alpha_m(r)}{(1+f_p)}$$

with range ***r*** , subscripts ***p*** and ***m*** for particle and molecular components, the Raman lidar signal **P** (***r***) at the Raman wavelength, and ***f*** for the wavelength dependence terms

$$f_m = \left(\frac{\lambda_{Raman}}{\lambda_{Laser}}\right)^{4.085} \quad \text{and} \quad f_p = \left(\frac{\lambda_{Raman}}{\lambda_{Laser}}\right)^{k}$$

The uncertainty of the true Zero-Range r_0 can be accounted for by substitution of the range correction factor r^2 by $(r - r_0)^2$, and after separating this factor from the signal **P** , we get :

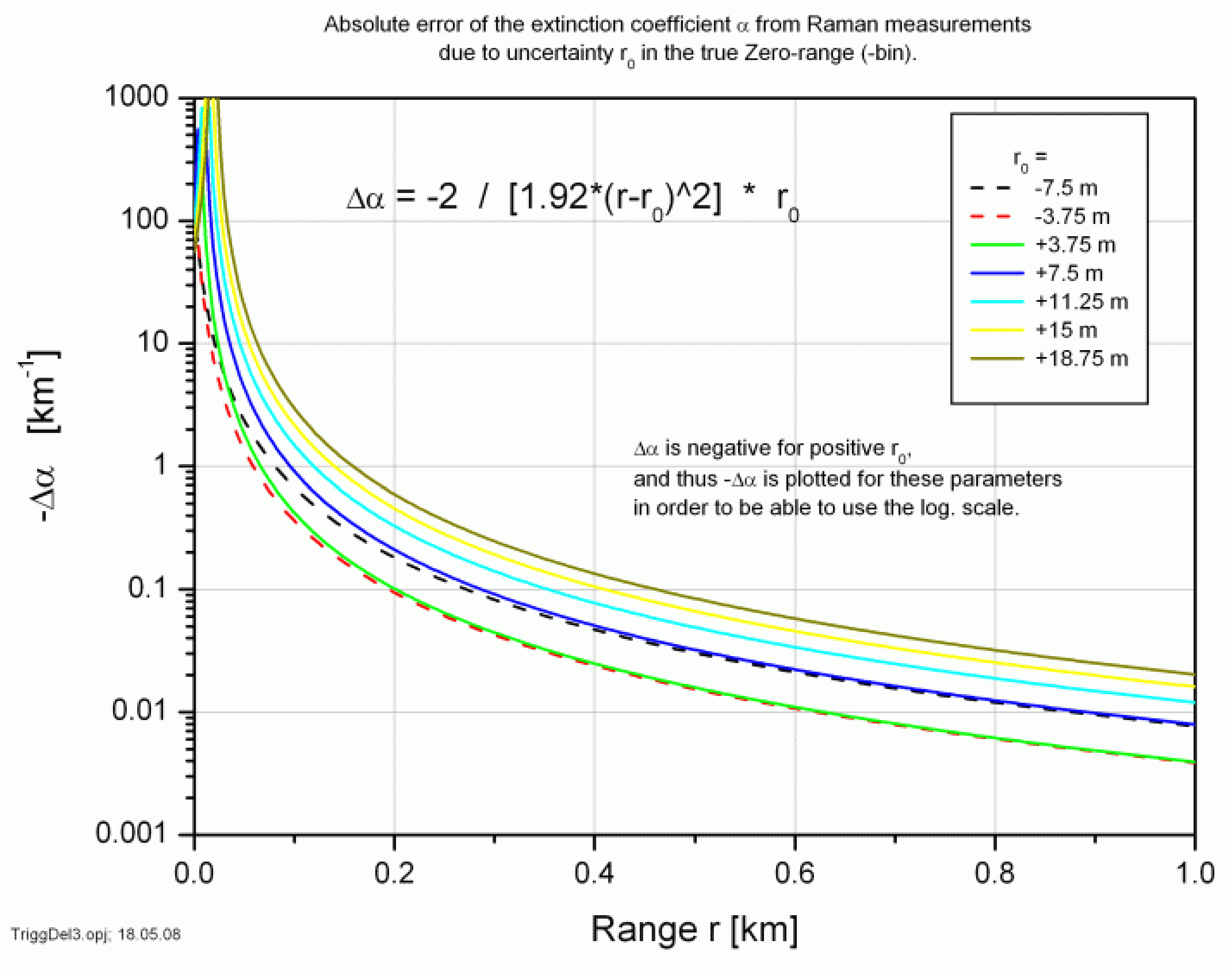
$$\alpha_p(r,r_0) = \frac{\frac{d}{dr}\ln\alpha_m(r) - \frac{d}{dr}\ln P(r) - \frac{d}{dr}\ln(r-r_0)^2 - (1+f_m)\alpha_m(r)}{(1+f_p)}$$

After differentiation with respect to r_0 etc. it follows that the absolute error of the particle extinction coefficient depends only on r_0 and f_p :

$$\boxed{\Delta\alpha_p(r,r_0) = \frac{2}{1+f_p} * \frac{1}{(r-r_0)^2} * r_0}$$

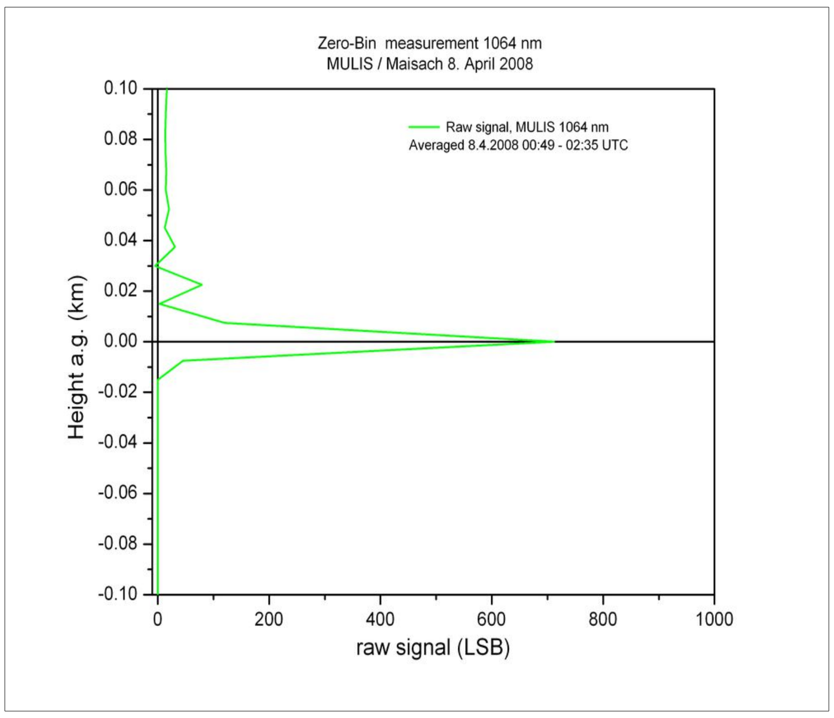
For λ_{Laser} = 355 nm, λ_{Raman} = 387 nm and **k** = 1 follows f_p = 0.92.

Although we can only measure the range in steps (range bin) according to the resolution of the transient recorder, i.e. 3.75 m or 7.5 m for the LICEL systems TR40 and TR20, respectively, the uncertainty r_0 can take any value, as it results from several trigger delays independent from the transient recorder. However, below some results for the error with Zero-range errors in fixed rangesteps:



5.2 How to measure

In case **pretrigger** samples are recorded, the Zero-bin can easily be detected due to the signal peak from stray-light reflected from the laboratory walls or similar, as can be seen in the picture below. In our case the roof-window side walls reflect enough diffuse laser light to produce a pronounced Zero-bin peak.
This peak could be enhanced and discerned from other near range reflections by blocking the laser output with a diffuse reflecting material (like e.g. paperboard).



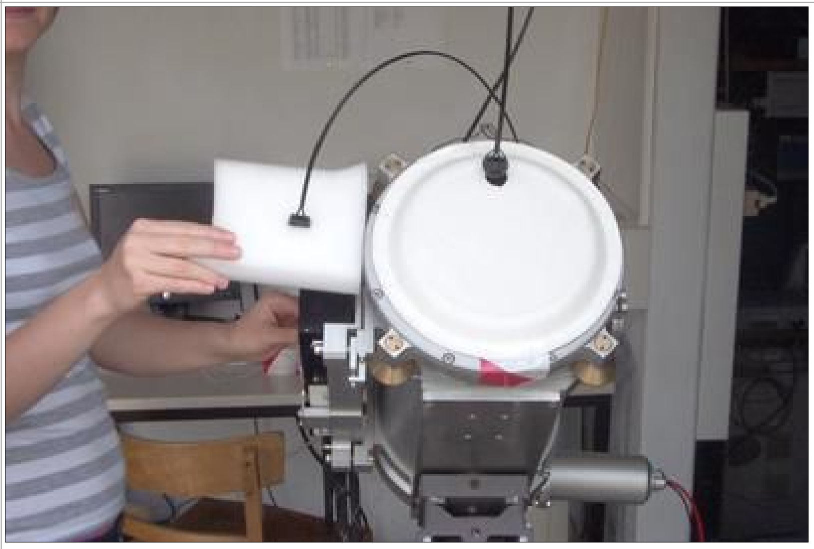
Zero-bin pulse of MULIS/Munich from diffuse reflections of the outgoing laser pulse from the roof window of the lidar lab.

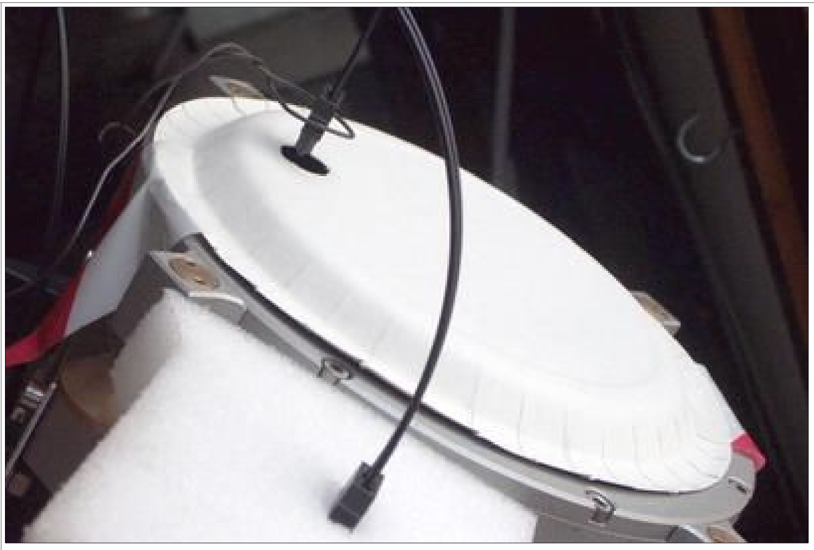
In case **no pretrigger** samples are recorded:

1. A <u>near range target</u> with a defined distance to the lidar could produce a signal peak for Zero-bin calibration.
For LICEL systems without trigger generator (and thus without pretrigger) a distance of one or two rangebins (7.5 to 15 m for TR20) could be sufficient.

2. <u>Optical fiber delay</u> : The outgoing laser pulse - sufficiently attenuated - can be fed into an optical fiber with sufficient length **s** , and the fiber output positioned at the aperture of the telescope. Thus a signal pulse would be measured with a delay **dt = s / v = s / c * n** to the outgoing laser pulse, with **c** = speed of light in vacuum, **v** = speed of light in the fiber with refractive index **n** . The delay in range bins **dRB** is then **dRB = dt / t_{RB}** , with t_{RB} = duration of one range bin in seconds.

Below are some images about how we realized that for POLIS with LICEL TR20 recorders.

A 15 m long optical fiber (full plastic, cheep, for optical communication) with about 1 mm core diameter and a core refractive index of about 1.5 is used to produce a laser pulse delay of 75 ns, which amounts to 1.5 range bins for a LICEL TR20 recorder.	
For the input of the laser pulse into the fiber we use a hard plastic foam typically used for packing, which serves as a good light diffusor.	
With the radial distance of the laser spot to the fiber, we can controle the signal pulse intensity. If the telescope can see the diffusely scattered light from the foam, we get an additional peak at the Zero-bin.	
In order to reduce the diffuse scattering and to remove the atmospheric lidar signal, the telescope is covered with cardboard, leaving a hole for the fiber input.	

Having now a single pulse in the signals, also the trigger delay between different channels can be measured (e.g. analog - photon counting for LICEL systems).	
Please don't forget to wear laser safety glasses!	

Please note:
1. There is a system immanent delay between the analog and photoncounting Zero-bin in LICEL systems described in the manual. This delay is different for different systems. This can be up to 7 rangebins (personal communication, Bernd Mielke, LICEL). Please contact LICEL to get information about this delay in your system.
2. There can be additional delays between the optical laser pulse and the time the electronic trigger pulse from the laser electronics reaches the trigger input of the data acquisition system due to delays in the laser electronics and the trigger cables etc. .

5.3 Information about available fibers

Barbara Lahnor got information (from MPI) about a cheap fiber made by AVAGO Technologies and ordered it from Farnell:

100 m cost about 120 Euro

HFBR EUS100Z
http://no.farnell.com/avago-technologies/hfbr-eus100z/cable-optical-fibre-100m-poly/dp/1247698?Ntt=HFBR+EUS100z
Attenuation per Metre:0.19dB
Cladding Diameter:1000⅄m
Cladding Refractive Index:1.417
Core Diameter:1mm
Core Refractive Index:1.492
External Diameter:2.2mm
Length:100m

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6 Submission data format

6.1 General Information

The data must contain following header lines:

1. lidar site (according HOI)
2. lidar system (system name)
3. channel (analog or photoncounting), named according the HOI
4. date of the measurement (dd.mm.yyyy)
5. column names
6. data

I'd prefer columnar ASCII data as below, TAB or comma separated. If that is not possible, the data can be sent in any sufficiently discribed format.

6.2 Data examples

Columns must be separated by commas. Decimal sign must be point.

6.2.1 Telecover (According to my recent experience, the submission must contain **non-normalized** , range corrected signals.)
Dark measurements can be appended marked as **D** . => NEW: best to submit with Rayleigh Fit signals (see below).
One file for each wavelength.
No columns/data other than quadrant, octant, In/Out, and D measurements.

Example:

MS (Maisach)
MULIS
532, parallel, analog
28.03.2008
range, NI, EI, SI, WI, NI2, NO, EO, SO, WO, NO2, D
0.00375, 4.4902E-7, 5.1238E-7, 1.7329E-6, 1.2163E-6, 3.575E-7, 9.5749E-7, 4.031E-6, 2.5536E-6, 2.2719E-6, 1.1367E-6, 0
0.0075, -2.3213E-6, -4.0958E-6, -1.1091E-5, -1.6087E-5, -4.0408E-6, -9.5406E-6, -2.4612E-5, -1.9998E-5, -2.2383E-5, -1.2518E-5, 0
0.01125, 1.8175E-5, 2.12E-5, 3.1289E-5, -1.7014E-6, 7.0487E-6, 1.1296E-4, 9.0652E-5, 1.146E-4, 5.4473E-5, 2.0361E-5, 0
0.0150, 1.5628E-3, 1.9424E-3, 4.007E-3, 1.6751E-3, 9.5026E-4, 8.0557E-3, 8.8403E-3, 1.1014E-2, 7.3912E-3, 3.438E-3, 0
0.01875, 1.228E-2, 1.4972E-2, 3.7926E-2, 2.0086E-2, 8.9909E-3, 5.5995E-2, 7.8451E-2, 1.0363E-1, 7.1994E-2, 3.4479E-2, 0
0.0225, 3.9465E-2, 4.8788E-2, 1.3362E-1, 7.2022E-2, 3.0372E-2, 1.6097E-1, 2.6914E-1, 3.5023E-1, 2.5453E-1, 1.1953E-1, 0
....

6.2.2 Rayleigh Fit

1. lidar site (according HOI)
2. lidar system (system name)
3. channel (analog or photoncounting), named according the HOI
4. date of the measurement (dd.mm.yyyy), duration (Rayleigh signal average time in seconds, default 1800 s)
5. used radiosonde (station ID, location, date)
6. the used fit range (in km)
7. column names
8. data

The submitted data (30 min. averaged), for each channel (wavelength) separate, should include the Rayleigh signal, i.e. the calculated **attenuated** Rayleigh or Cabannes backscatter coefficients (depending on the interference filter bandwidth; calculated from actual local radiosonde data with the software usally used for the signal inversion), and a range corrected lidar signal with a clean atmosphere in the fit range.

One file for each wavelength.
No columns/data other than attenuated_RayleighBSC, RangeCorrectedSignal, and optionally DarkMeasurement (only analog)

Dark measurement (only analog) column can optionally be appended marked as **D**

Example:

MS (Maisach)
MULIS
532, parallel+perpendicular, analog
28.03.2008, 1800 s
Oberschlei▫heim, 10868, 29.03.08, 00UTC
11, 13
range, **attn**RayleighBSC, RangeCorrectedSignal, **D**
0.0075, 1.483903E-6, 1.765201E-4, 0.00011
0.0150, 1.482827E-6, 1.763579E-4, 0.00013
...

6.2.3 Dark measurement (It is best to append it to the Rayleigh-Fit data files as described under 6.2.2)

1. lidar site (according HOI)
2. lidar system (system name)
3. channel (analog or photoncounting), named according the HOI
4. date of the measurement (dd.mm.yyyy)
5. column names
6. data

The submitted data should include a range corrected signal, and a dark signal with sufficient temporal averaging.

One file for each wavelength.

Example:

MS (Maisach)
MULIS
532, parallel, analog
28.03.2008
range, RangeCorrectedSignal, **D**
0.0075, 1.765201E-4, 0.00011
0.0150, 1.763579E-4, 0.00013

6.2.4 Linear depolarisation calibration measurements

1. **lidar site** (according HOI)
2. **lidar system** (system name)
3. **channel**, **analog** or **photoncounting** or **glued** [default]) - named according the HOI
4. **date** of the measurement (dd.mm.yyyy)
5. used radiosonde (**station ID, location, date**)
6. **Tp, Ts, Rp, Rs** of PBS incl. optics after calibrator
7. **column names**
8. **data**

Comments:
- Range corrected signals
- Dark measurements subtracted if necessary
- Tp, Ts, Rp, Rs:
    in case a cleaning analyzer is used behind the transmitting side of the PBS => Tp = 1, Ts = 0
    in case a cleaning analyzer is used behind the reflecting side of the PBS => Rp = 0, Rs = 1

Signals:
- ITplus45 : **transmitted** signal of PBS, i.e. usually the parallel (p) signal relative to PBS, with calibrator at **+45** ° orientation
- IRplus45 : **reflected** signal of PBS, i.e. usually the perpendicular (s) signal relative to PBS, with calibrator at **+45** ° orientation
- ITminus45 : **transmitted** signal of PBS, i.e. usually the parallel (p) signal relative to PBS, with calibrator at **-45** ° orientation
- IRminus45 : **reflected** signal of PBS, i.e. usually the perpendicular (s) signal relative to PBS, with calibrator at **-45** ° orientation
- ITRayleigh : **transmitted** signal of PBS, i.e. usually the parallel (p) signal relative to PBS, **without calibrator** or calibrator at **0** ° orientation
- IRRayleigh : **reflected** signal of PBS, i.e. usually the perpendicular (s) signal relative to PBS, **without calibrator** or calibrator at **0** ° orientation

Example:

MS (Maisach)
MULIS
532,glued
28.03.2008
Oberschleißheim,10868,29.03.08,00UTC
0.95,0.01,0.05,0.99
range,ITplus45,IRplus45,ITminus45,IRminus45,ITRayleigh,IRRayleigh
0.00375, 4.4902E-7, 5.1238E-7, 1.7329E-6, 1.2163E-6, 3.575E-7, 9.5749E-7
0.0075, -2.3213E-6, -4.0958E-6, -1.1091E-5, -1.6087E-5, -4.0408E-6, -9.5406E-6
0.01125, 1.8175E-5, 2.12E-5, 3.1289E-5, -1.7014E-6, 7.0487E-6, 1.1296E-4
...

Volker Freudenthaler 2008, Sept. 2012

Source: http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/EA-NA3-QA-Telecover-2.html

Test of the optical setup with partial telescope cover

Goal:
- test and verify the alignment of laser and optics and
- determine the distance of full overlap.

Principle:
- compare lidar signals from different parts of the telescope aperture.

Additional tests:
- far range: Rayleigh calibration ("matching method")
- near range (overlap): multi-angle (elevation) measurements

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1 Introduction

In a perfect lidar system the backscattered rays from all lidar ranges within the measurement range have the same transmission in the optical system.
In the near range the total transmission decreases, because some rays are vignietted by the field-of-view aperture and/or other apertures, which results in the overlap function. At the same time rays with large incident angles in the telescope - and therefore with large incident angles on interference filters etc. - can have reduced transmission due to the angular wavelength shift with incident angle of the interference filters.

- overlap
- vignetting
- angular effects

We can use this behaviour to check the performance and alignment of the optical system, because the ray-bundles from different parts of the telescope aperture travel through the optical setup in different paths (see figure 1) and with different incident angles on the optical elements (see figure 2b).

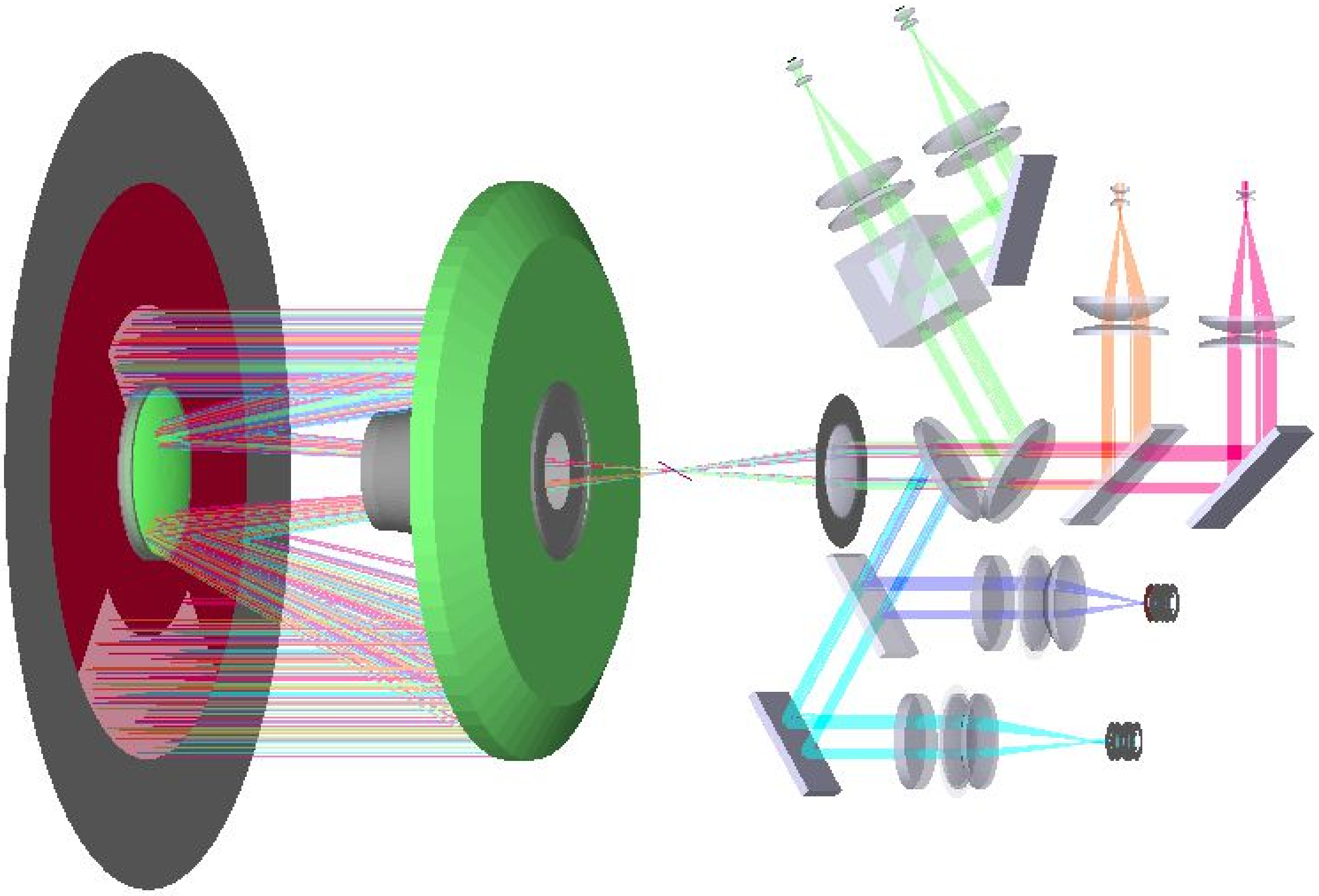
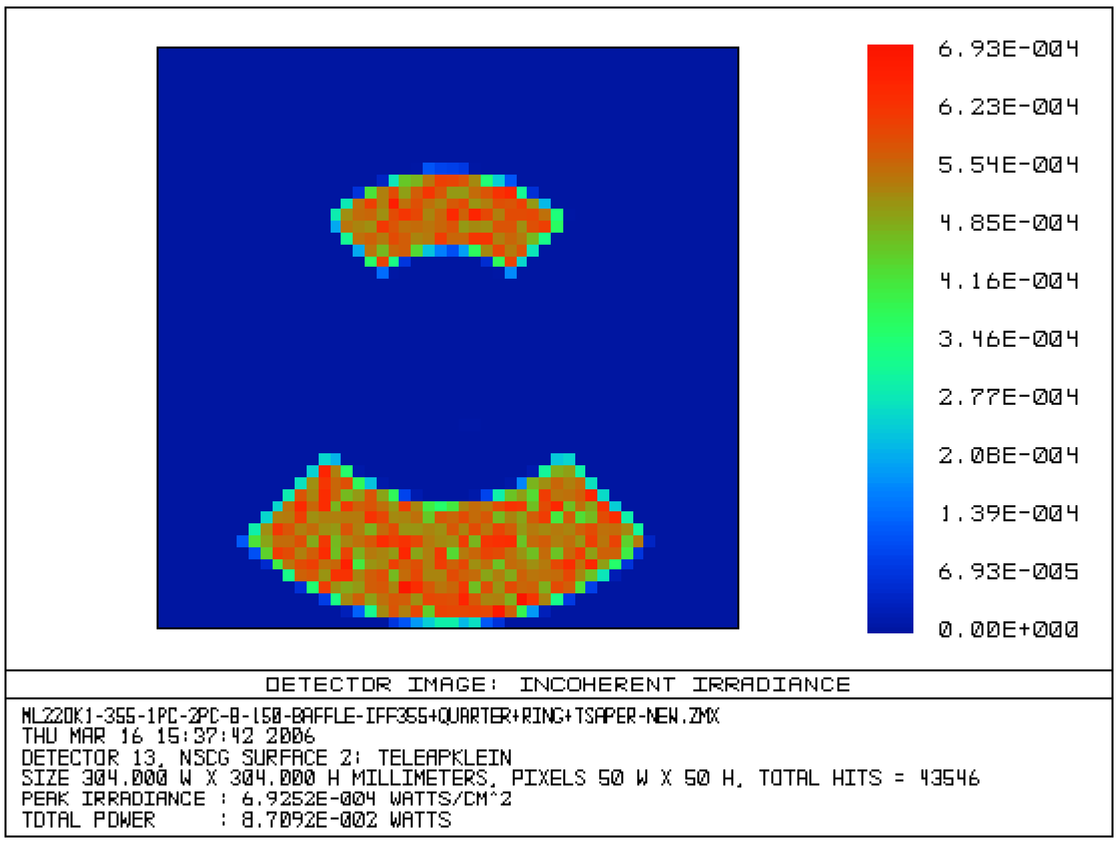
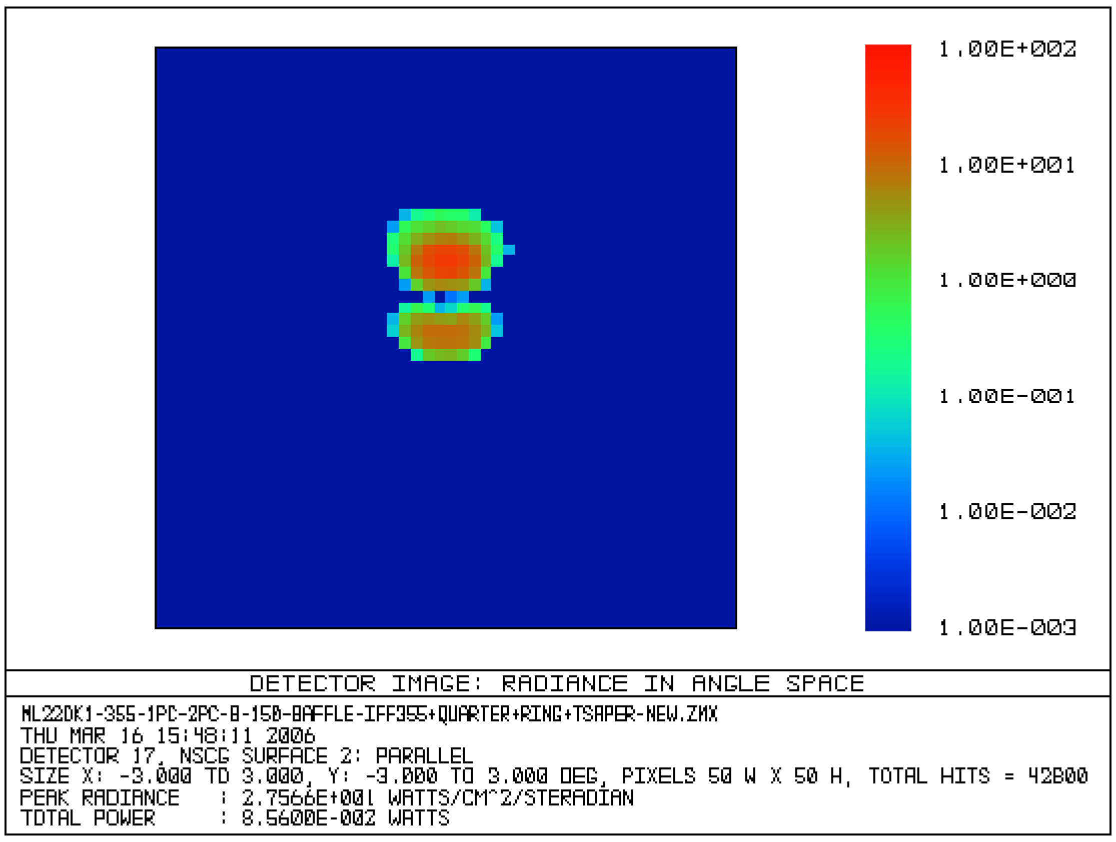


Figure 1: ZEMAX model of the MULIS lidar system. Rays from different parts of the telescope have different paths through the optical system. Shown are rays from telescope cover sections "TopIn" and "BottomOut" as explained below.



```
DETECTOR IMAGE: INCOHERENT IRRADIANCE
ML22DK1-355-1PC-2PC-8-150-BAFFLE-IFF355+QUARTER+RING+TSAPER-NEW.ZMX
THU MAR 16 15:37:42 2006
DETECTOR 13, NSCG SURFACE 2: TELEAPKLEIN
SIZE 304.000 W X 304.000 H MILLIMETERS, PIXELS 50 W X 50 H, TOTAL HITS = 43546
PEAK IRRADIANCE : 6.9252E-004 WATTS/CM^2
TOTAL POWER     : 8.7092E-002 WATTS
```

(2a)

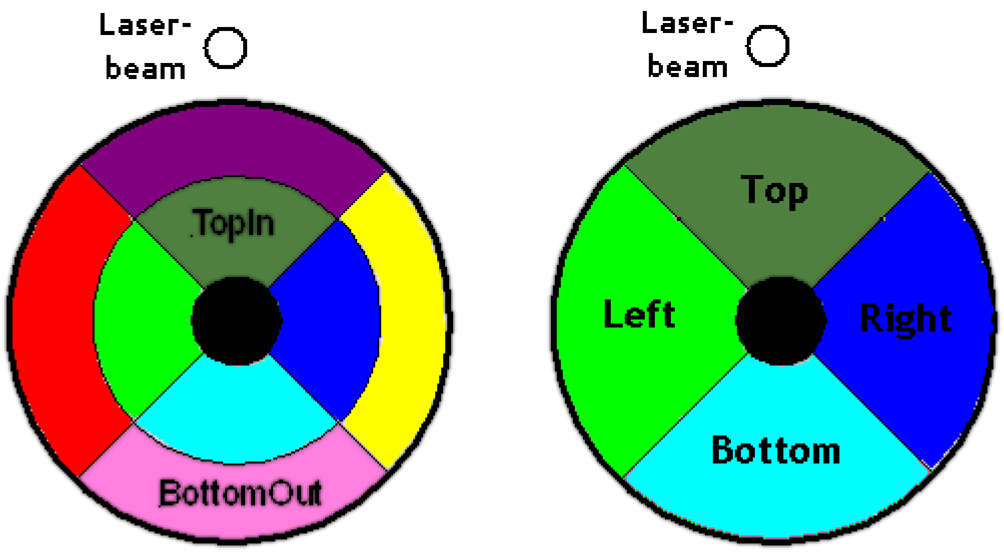


```
DETECTOR IMAGE: RADIANCE IN ANGLE SPACE
ML22DK1-355-1PC-2PC-8-150-BAFFLE-IFF355+QUARTER+RING+TSAPER-NEW.ZMX
THU MAR 16 15:48:11 2006
DETECTOR 17, NSCG SURFACE 2: PARALLEL
SIZE X: -3.000 TO 3.000, Y: -3.000 TO 3.000 DEG, PIXELS 50 W X 50 H, TOTAL HITS = 42800
PEAK RADIANCE   : 2.7566E+001 WATTS/CM^2/STERADIAN
TOTAL POWER     : 8.5600E-002 WATTS
```

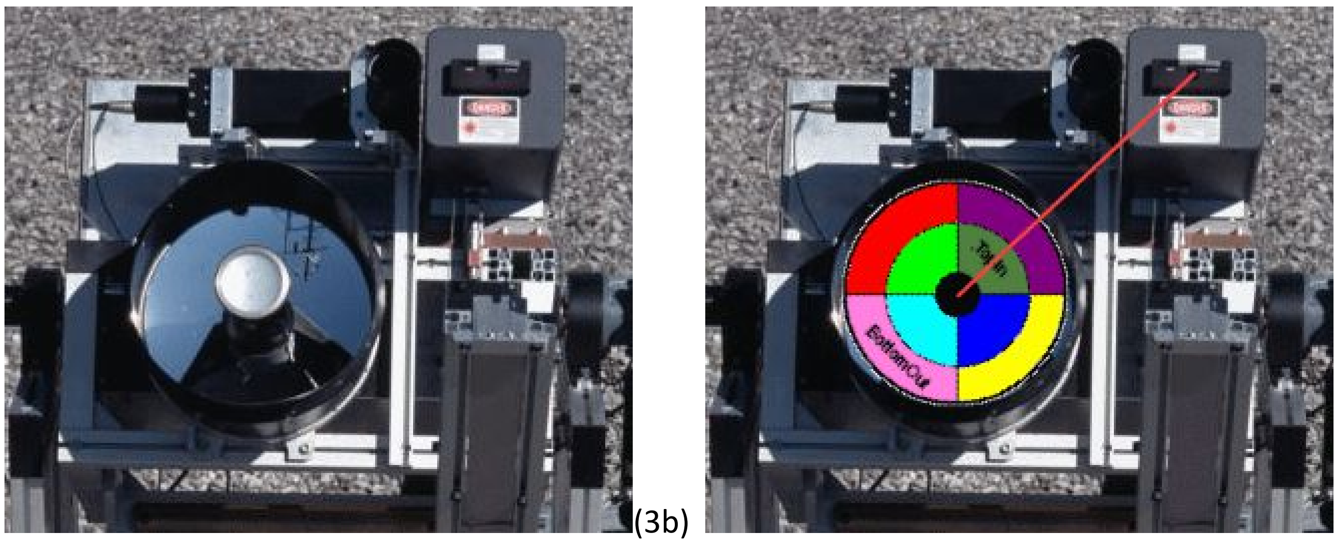
(2b)

Figure 2a and b: Rays from different parts of the telescope (left picture shows intensities in the telescope aperture like fig.1) have different ray angles in the collimated beam after the collimation lens (right picture). The blue square in the right picture has a total width and height of 6°. In the upper spot are the ray angles of the "TopIn" section of the telescope, and in the lower spot are the angles of the "BottomOut" section. This shows that the rays from "BottomOut" are about 1° more inclined after the collimation lens than the "TopIn"-rays.The example is a simulation of the Munich MULIS lidar system for rays backscattered from 150 m lidar range.

In other words: when we compare the range dependend lidar signals of rays-bundles from different parts of the telescope aperture we can find the differences in the transmission losses due to vignietting and due to the angular dependend transmission of the different ray paths . We can do this by covering the telescope aperture with opaque cardboard for example and subsequently measuring only ray-bundles from one of the eight or four sections shown in figure 3a. Eight sections give more information and the differences are more pronounced, but four sections are faster to measure and are probaly sufficient for a fast check. The "Top" section is oriented from the telescope optical axis towards the laser optical axis as shown in figures 3b and 3c. "Left" and "Right" are with respect to viewing towards the telescope.



(3a)



(3b) (3c)

Figure 3: Proposed test sections of the covered telescope aperture (3a) and orientation with respect to the telescope-laser axes (3b and 3c).

For convenience I use the abbriviations TI, LI, BI, RI, TO, LO, BO and RO for TopIn, LeftIn .... BottomOut and RightOut, respectively, in the following. A ZEMAX simulation of such measurements for the 607 nm channel of the MULIS with a otpimized telescope and without interference filter is shown in figure 4. The range step of the calculations is 25 m. The MULIS telescope (see fig.1) has a diameter of 300 mm, a focal length of 960 mm, and in this cases a fov diaphragm with 3.6 mm diameter, which results in about +-2 mrad fov. The laser beam diameter is 8 mm with 0.6 mrad fwhm divergence, the distance of the laser to the telecope axis is 400 mm, and the laser is pointing parallel to the telescope axis. We see in figure 4 that the TO-sector has full overlap close to 200 m but the BO-sector only from about 400 m on. Therefor the whole telescope has full overlap only further than 400 m range.

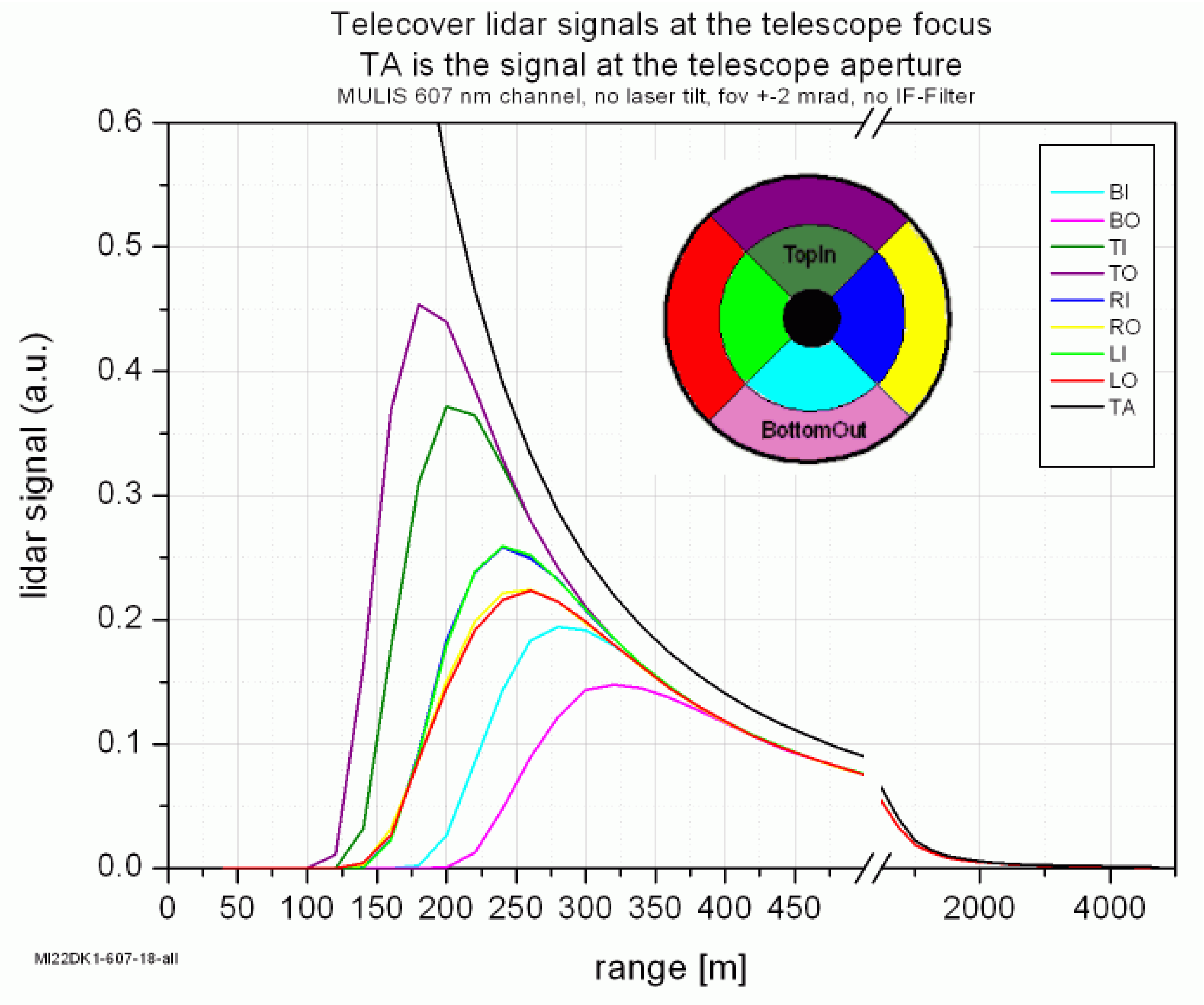


Figure 4: Zemax simulation of the 607 nm channel signal (including optical transmission) of MULIS with an optimized telescope using different telescope setions as indicated in the legend, paralell pointing laser, and a fov of +- 2mrad. Note the change in range scale above 500 m range.

This can be seen much better if we plot the signals relative to the calculated signal in the telescope aperture (TA, black in fig. 4), which is displayed in figure 5. Here we see the attenuation due to the aluminium coatings, and second that the full overlap is actually reached later than 400 m. For the ZEMAX simulations I will use this display. For our experimental signals we don't have the calculated signal in the telescope aperture, and therefor we can use the TO-sector as reference, which is shown in figure 6.

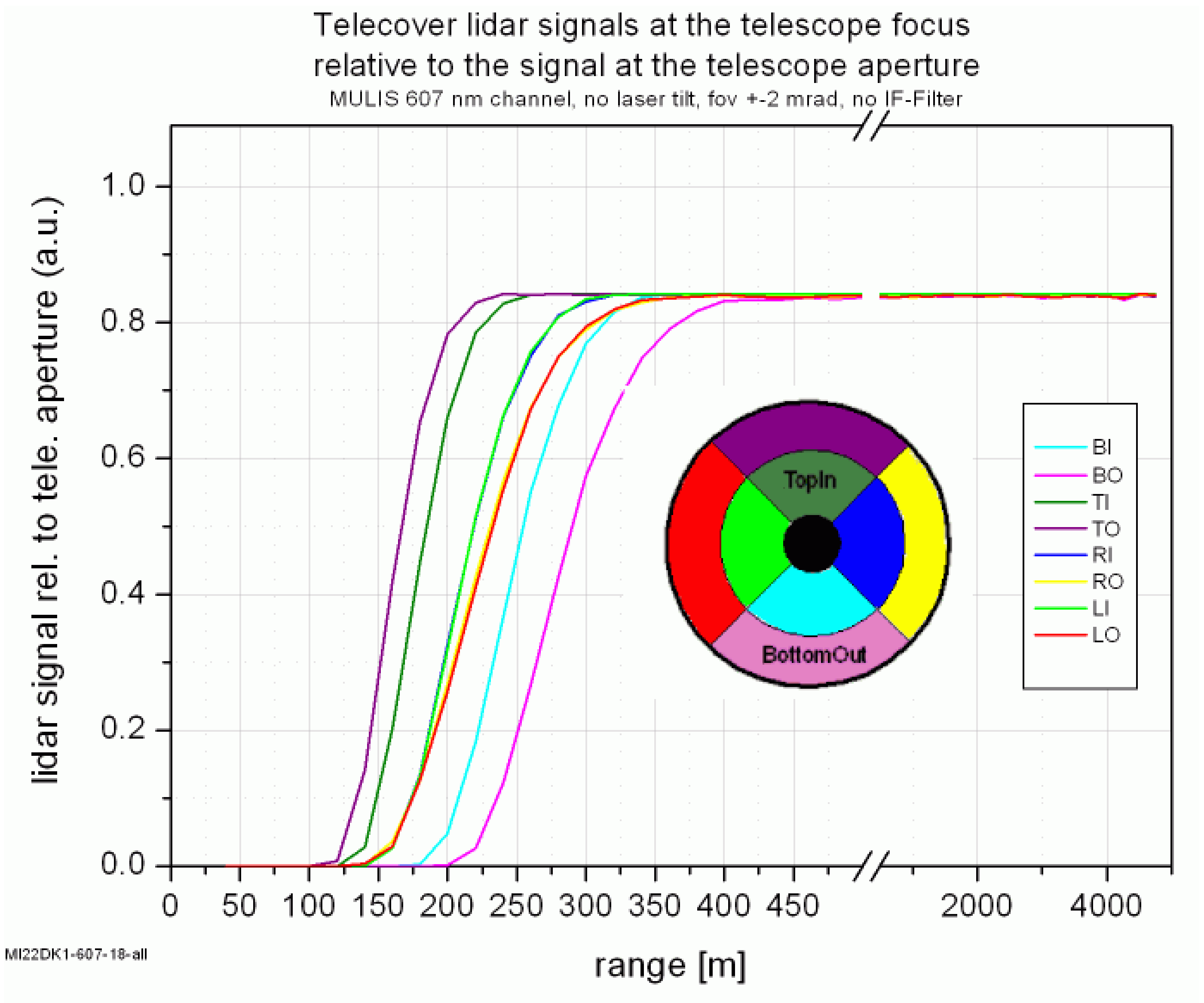


Figure 5: As figure 4 but signals reltive to the calculated signal in the telescope aperture.

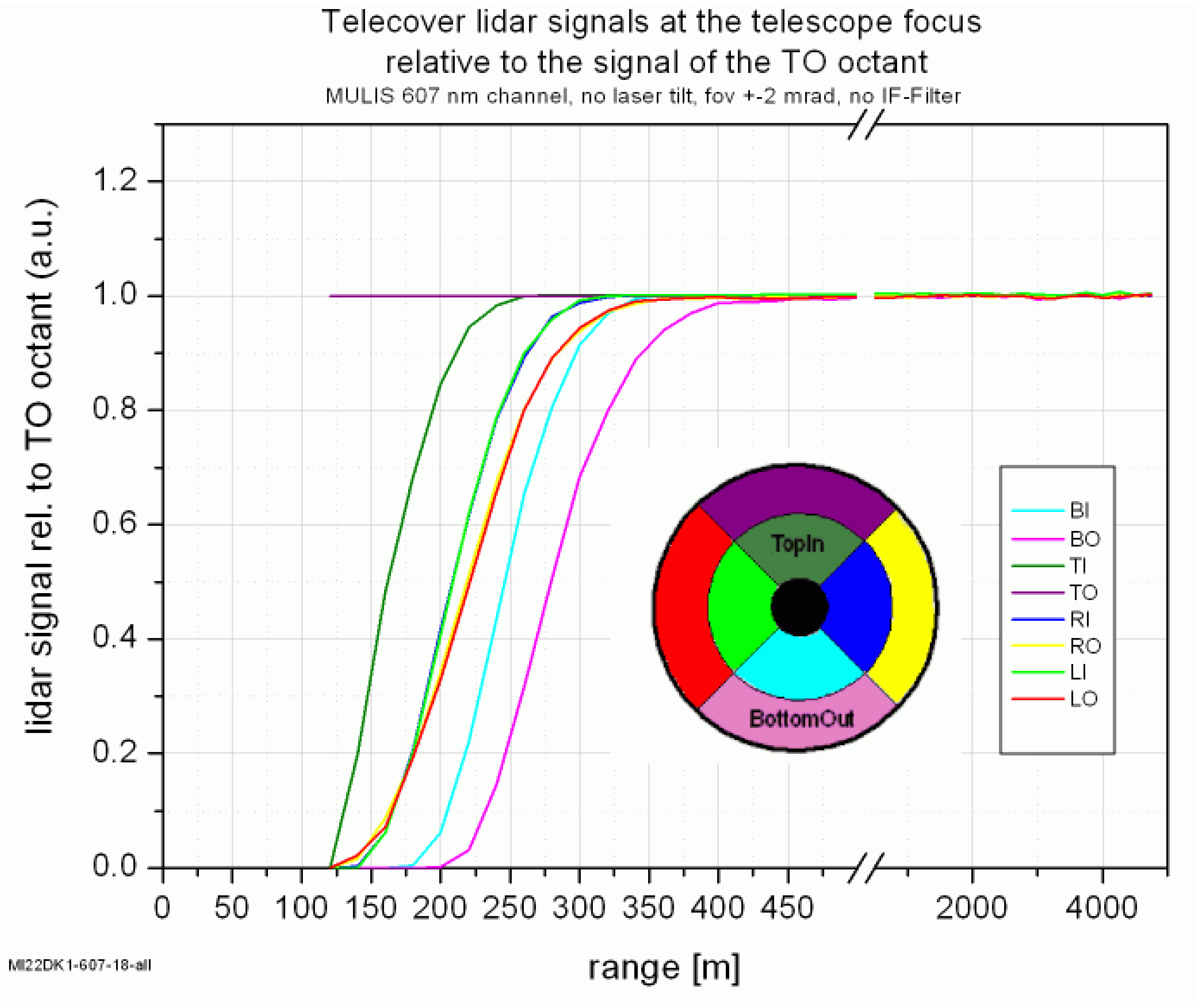


Figure 6: As figure 4 but signals relative to the signal of the TO-sector.

Using only a single measurement with the full telescope we were not able to discern the influence of the always present boundary layer aerosol from the transmission effects of the optics. Comparing the eight measurements, which should be done with stable boundary layer conditions - best at night, we can not only determine the distance of full overlap, but by comparing them with a raytracing simulation we can also get hints about which part of the lidar is misaligned.

2 Update after L'Aquila workshop Oct. 2007:

- Change of nomencalture (N-E-W-S,or NO-NI-EO-EI-SO-SI-WO-WI, looking from the sky into the telescope). This nomenclature seems to be more intuitive and introduces more options like NW).

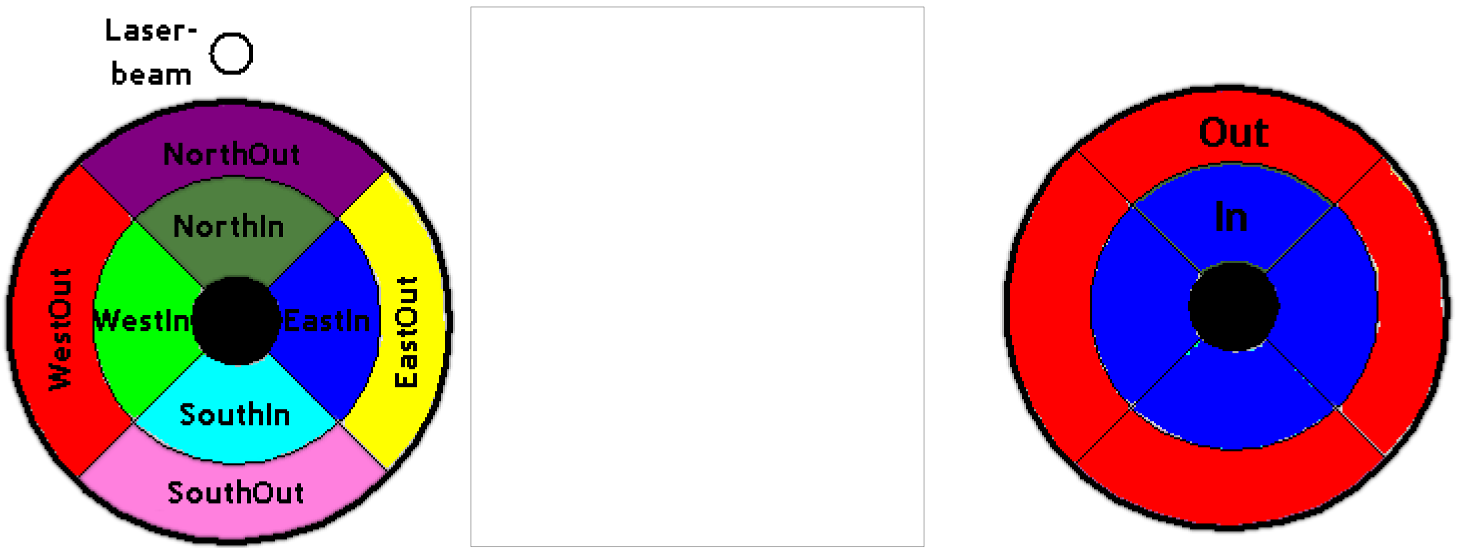


Figure 7.:

- In case all apertures have the same effective area, the relative values of the signals can be readily related to get information about the relative transmission of each sector.
- Performing an addtional measurement after the procedure with the first sector used gives information about the order of atmopsheric changes during the measurements.
- With monoaxial lidar configurations, the quarter and octant tests give mainly information about a possible laser tilt, and to a lesser extend about the overlap and angle dependend transmission of the optical system. Information about the latter can be achieved with "In-Out" tests, maybe with different ring diameters. Please inform me about your experiences with that.

- For the publication of the EARLINET QA results we need a common layout - especially for the normalisation of the measurements.
I proposed already to

1. normalise all measurements to the N or NO profile (see fig.6 below, "north-calibration"), which I assumed to be the "best". However, this profile is possibly not available or too noisy or too bad. In such cases I propose to
2. normalise all NEWS range corrected profiles to 1.0 in a far range well above the range where differences between the signals can be seen ("range-calibration"). This range is probably somewhere between 1 km and 5 km range.

Other combinations might occasionally lead to confusion.

A measured example using the range-calibration can be seen in figure 8.

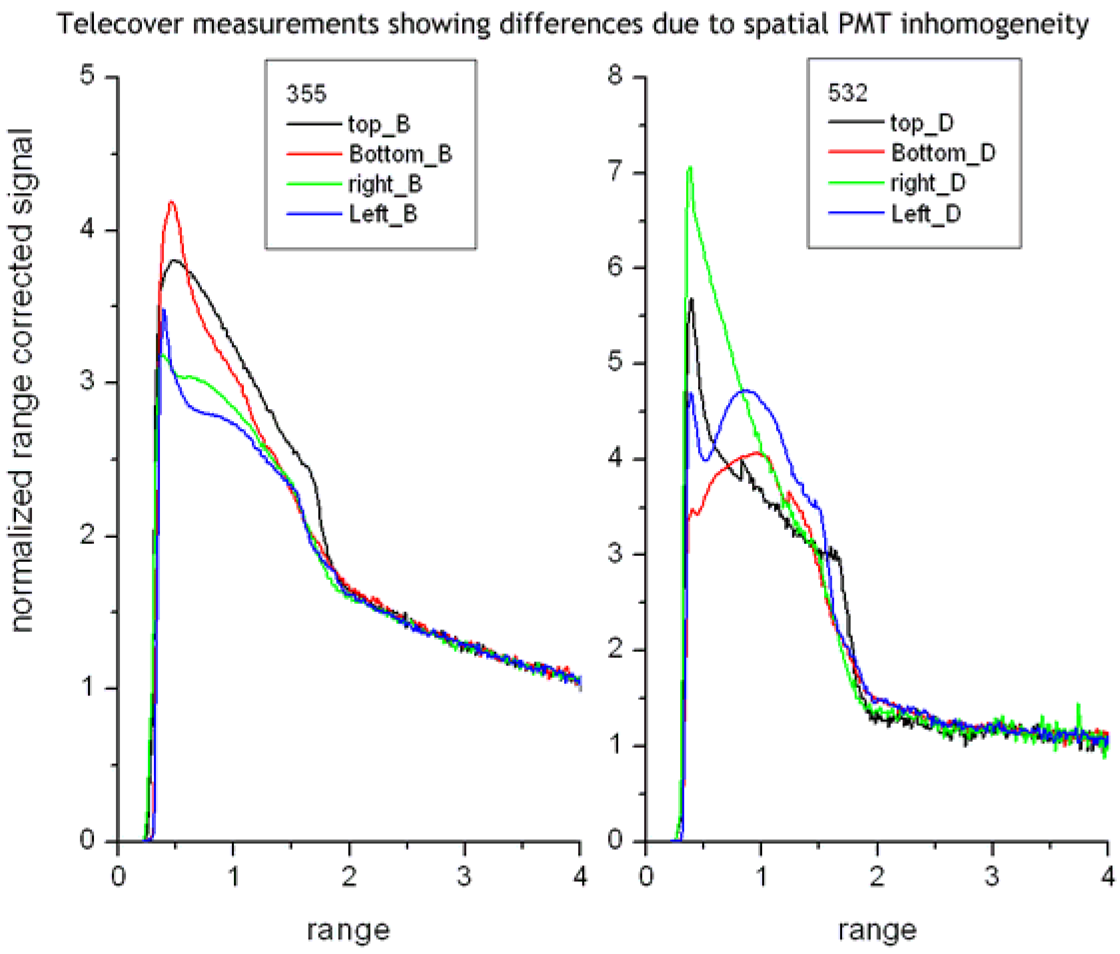


Figure 8: NEWS (old: Top,Right,Bottom,Left) measurement example with one of the EARLINET systems using the range-calibration. In this case the relative differences between the two wavelengths show, that the NEWS differences are not due to atmospherical changes during the measurements. From my experience and ZEMAX simulations I guess that the NEWS differences are mainly due to the spatial inhomogeneity of the sensitivity of the used HAMAMATSU R7400 PMT (see **Discovering detector inhomogeneities**).

3 Presentation of results and calculation of deviations

(Download: ORIGIN 6.0 example of plots below including worksheet scripts for the caclulation of the deviations)

Proposal 1 - normalisation
I propose to use the range-calibration (explained above in chapter 2) for the presentation in the EARLINET-ASOS report, because
- it can be applied in all situations,
- noise/distortion in one profile does not influence the other profiles.

Proposal 2 - range of data display
I further propose to show the profiles up to 5 km in order to inlcude the normalisation and far range. With a coordinate break at an appropriate range both the near range (overlap, near range effects) and the far range (loss of signal due to laser tilt or else) can be displayed.
If you can't do that and if a single plot doesn't show the near range clear enough, please present two plots, one for the near range and one for the whole range up to 5 km.

Proposal 3 - calculation of deviations
For the deviations I propose to calculate point by point

1. the mean of of all profiles: mean = **(N + E + S + W) / 4**
2. the relative deviation of each profile (NDev, EDev,...) from the mean : **NDev = (N - mean) / mean ....**
3. the realtive RMS deviation of all profiles: **AllDev = sqrt ((NDev^2 + EDev^2 + SDev^2 + WDev^2) / 4)**

or the equivalent means and deviations (In - Out ....).

Proposal 4 - deviation limits
Limits: I propose that if following limits are exceeded, the lidar system should be inspected and improved, and the deviations should be decreased below these limits:

1. individual relative deviations XDev should not exceed +-0.1 (+-10%): **|XDev| < 0.1**
2. and: **AllDev < 0.05**

These limits could also serve for the definition of the distance of full overlap, but perhaps there are arguments for another limit. Are there?

=> Please comment on these proposals.
In case of no replies I consider them as accepted for the first round of telecover checks. => Discussion on the next workshop.

Telecover checkup and plot requirements
The measurements should be sufficiently smoothed over range or time in order to keep the deviations due to signal noise well below the limits.
The resolution of the plots should be large enough to show enough detail.
The plots must contain information about

1. lidar site
2. lidar system
3. channel
4. date of the measurement
5. normalisation range

Biaxial systems: For the first attempt a quadrant test should be sufficient.
Monoaxial systems: In order to check laser tilt and other deviations, at least a quadrant and an In-Out test should be performed.

An example for the above mentioned procedure is shown in figures 9 to 12 for the MULIS 532 nm channels, parallel (fig. 9 and 10) and perpendicular (fig. 11 and 12). In this case we can see, that the N-sector profile exhibits a relatively increased signal below about 2.5 km range. But actually there is a loss of signal in the far range due to a bad primary mirror with a lot of distortion in the north sector, which probably causes vignetting of its beam due to the field of view diaphragm similar in all channels. As a result, we don't use this sector for lidar measurements, and consequently we don't use it for the caclulation of deviations below. At long sight we will buy a new telescope.

The comparison between the measurements E and E2 with the east sector at different times shows, that the atmosphere didn't change considerably during the measurements, and that the small cloud at 1.2 km didn't disturb too much.

According to the limits in proposal 4, the full overlap of the parallel channel is at 320 m range, and the perpendicular channel should be inspected in order to reduce the RMS deviations AllDev below 0.1.

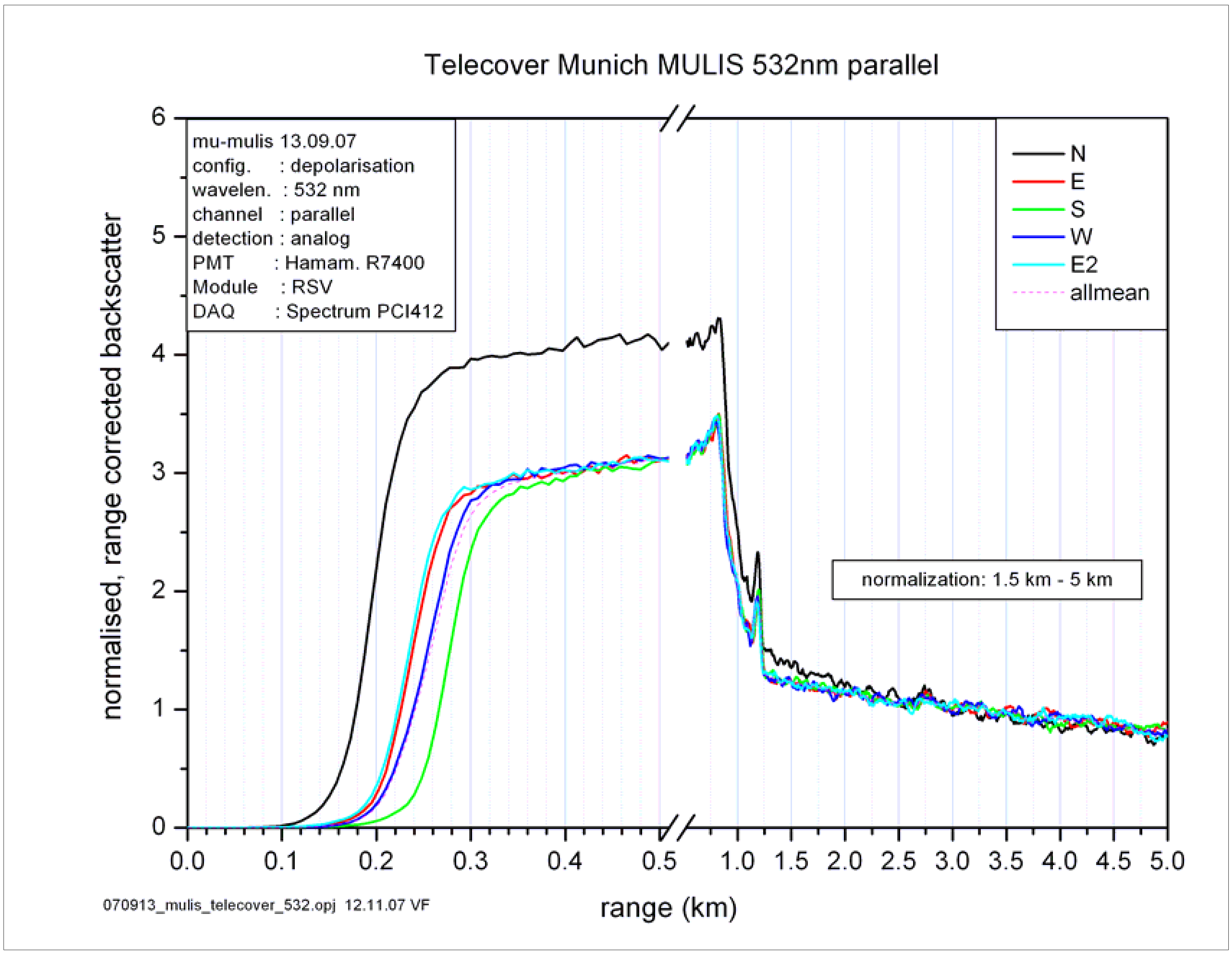

Telecover Munich MULIS 532nm parallel
mu-mulis 13.09.07
config. : depolarisation
wavelen. : 532 nm
channel : parallel
detection : analog
PMT : Hamam. R7400
Module : RSV
DAQ : Spectrum PCI412
N
E
S
W
E2
allmean
normalization: 1.5 km - 5 km
normalised, range corrected backscatter
0
1
2
3
4
5
6
0.0
0.1
0.2
0.3
0.4
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
range (km)
070913_mulis_telecover_532.opj 12.11.07 VF

Fig. 9

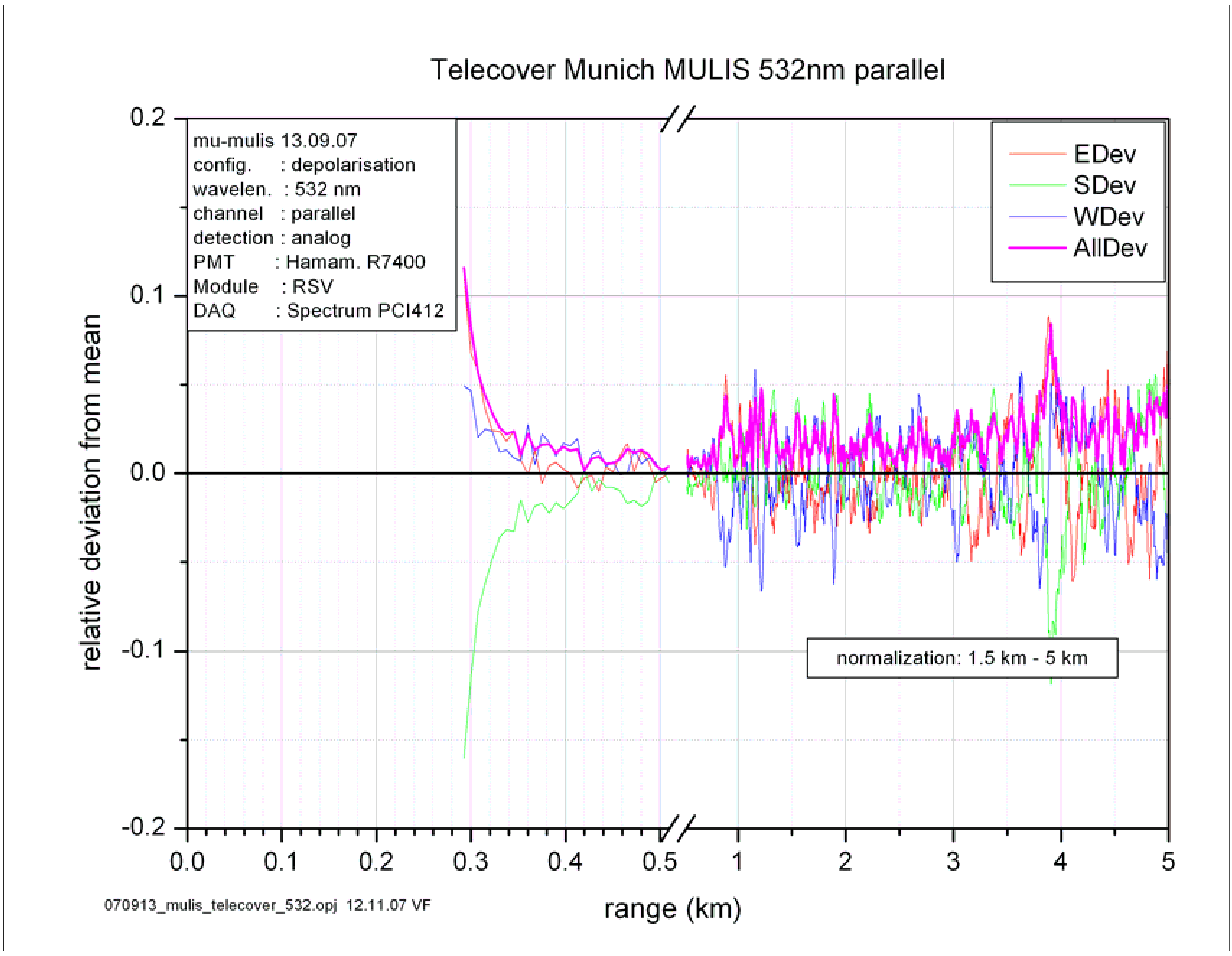

Telecover Munich MULIS 532nm parallel
mu-mulis 13.09.07
config. : depolarisation
wavelen. : 532 nm
channel : parallel
detection : analog
PMT : Hamam. R7400
Module : RSV
DAQ : Spectrum PCI412
EDev
SDev
WDev
AllDev
normalization: 1.5 km - 5 km
relative deviation from mean
0.2
0.1
0.0
-0.1
-0.2
0.0
0.1
0.2
0.3
0.4
0.5
1
2
3
4
5
range (km)
070913_mulis_telecover_532.opj 12.11.07 VF

Fig. 10

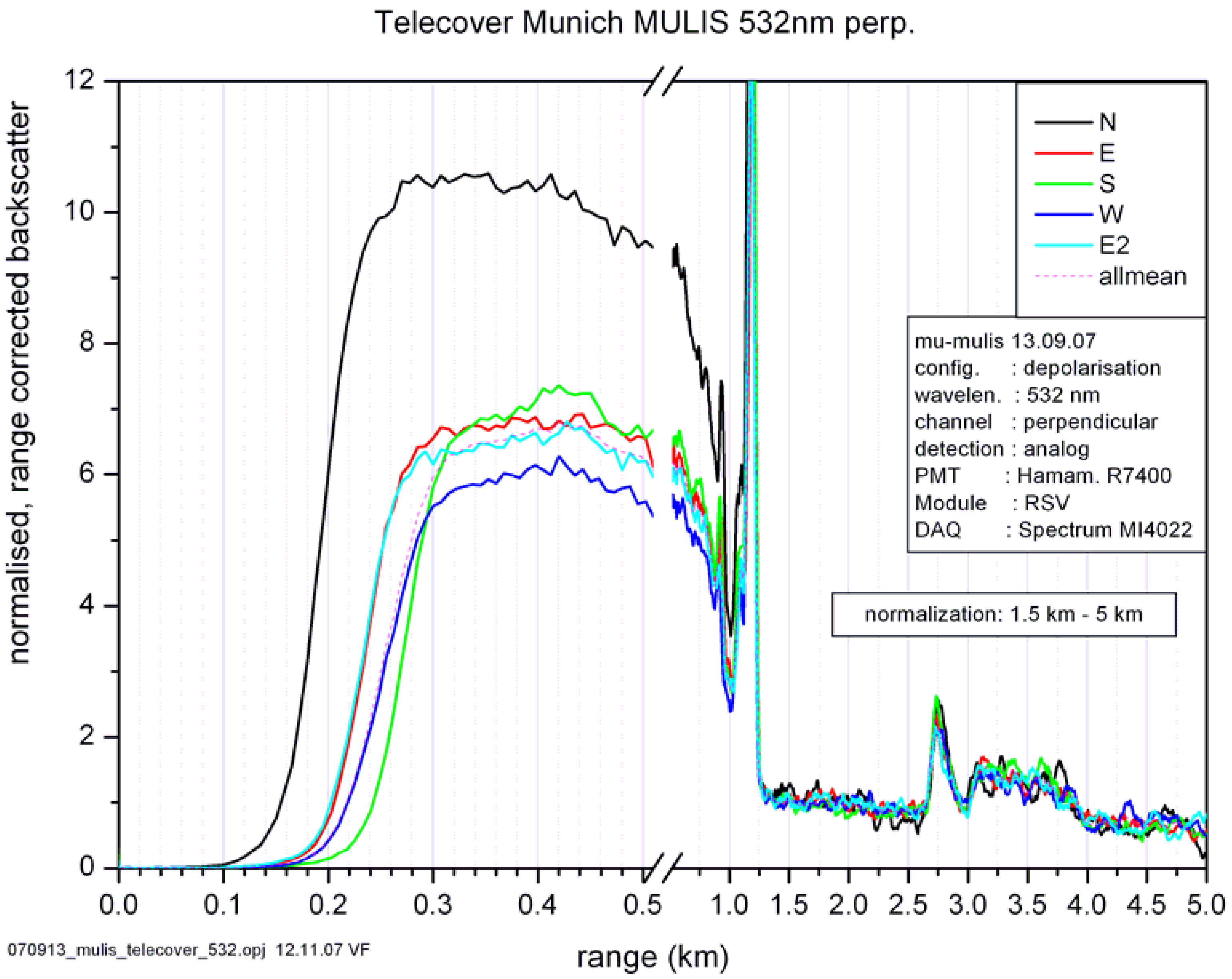

Telecover Munich MULIS 532nm perp.
normalised, range corrected backscatter
0
2
4
6
8
10
12
N
E
S
W
E2
allmean
mu-mulis 13.09.07
config. : depolarisation
wavelen. : 532 nm
channel : perpendicular
detection : analog
PMT : Hamam. R7400
Module : RSV
DAQ : Spectrum MI4022
normalization: 1.5 km - 5 km
0.0
0.1
0.2
0.3
0.4
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
range (km)
070913_mulis_telecover_532.opj 12.11.07 VF

Fig. 11

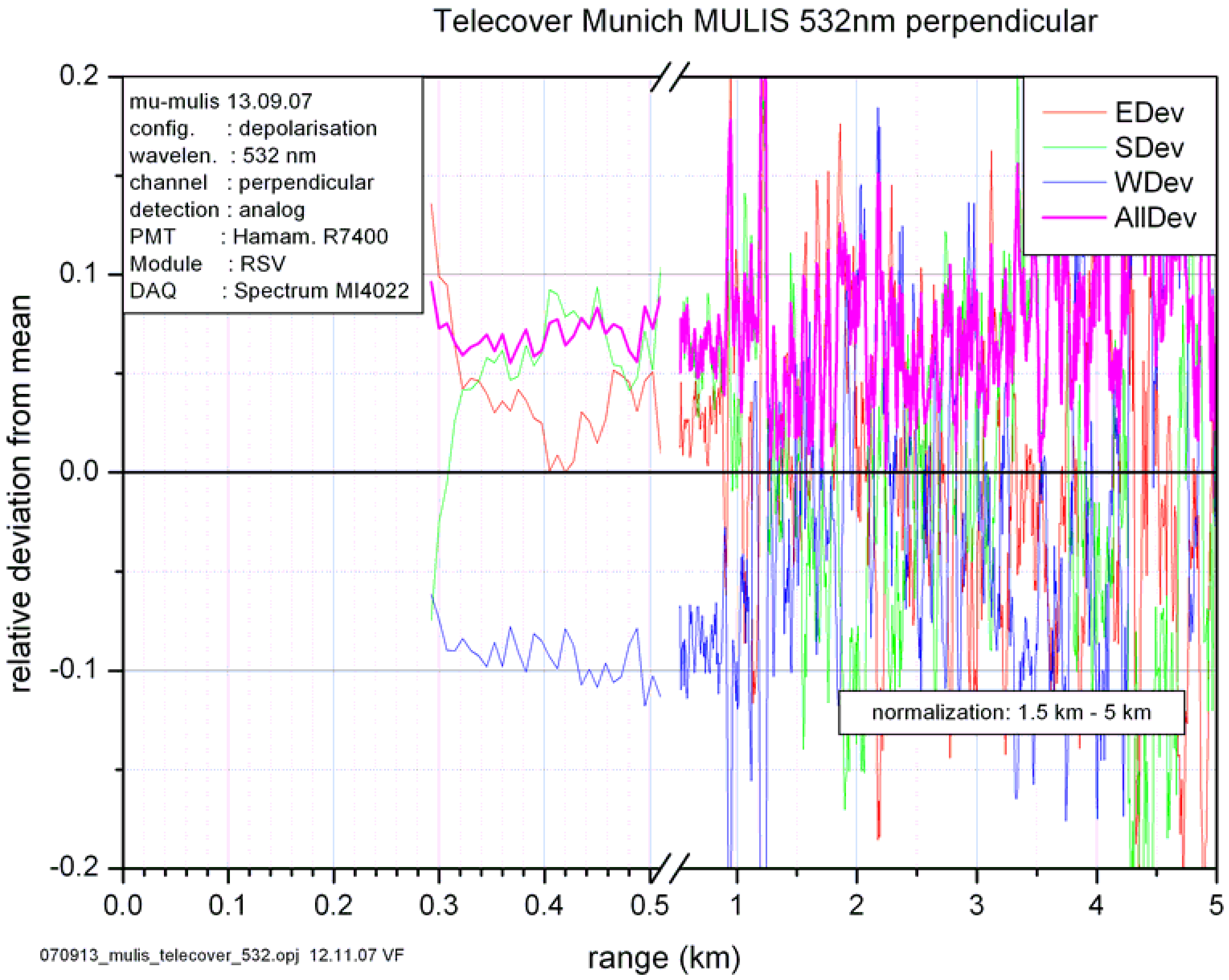

Telecover Munich MULIS 532nm perpendicular
relative deviation from mean
0.2
0.1
0.0
-0.1
-0.2
mu-mulis 13.09.07
config. : depolarisation
wavelen. : 532 nm
channel : perpendicular
detection : analog
PMT : Hamam. R7400
Module : RSV
DAQ : Spectrum MI4022
EDev
SDev
WDev
AllDev
normalization: 1.5 km - 5 km
0.0
0.1
0.2
0.3
0.4
0.5
1
2
3
4
5
range (km)
070913_mulis_telecover_532.opj 12.11.07 VF

Fig. 12