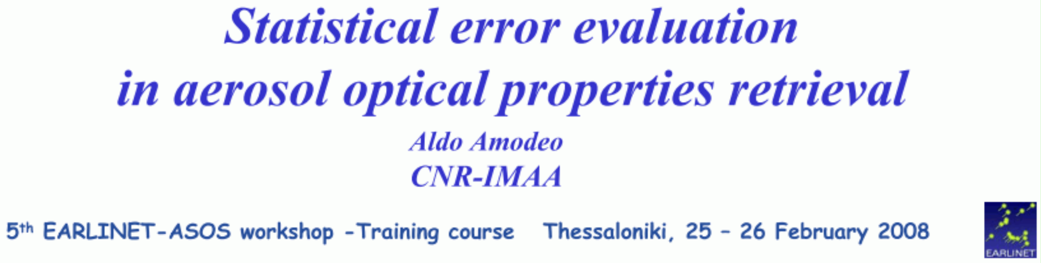
It's all about ERRORS.

An exemplary overview of EARLINET-ASOS NA3 Quality Assurance activities

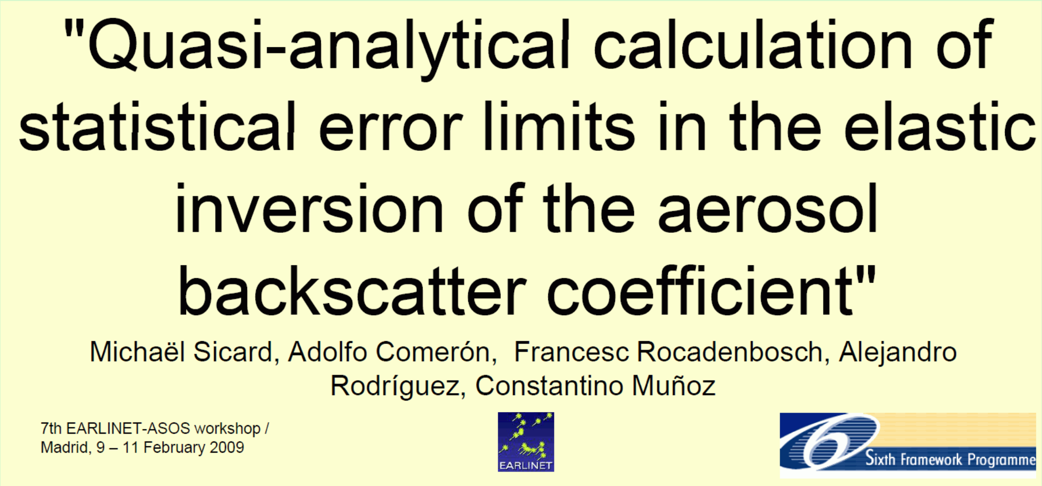
Statistical errors => Systematic errors



Statistical error evaluation
in aerosol optical properties retrieval

Aldo Amodeo
CNR-IMAA

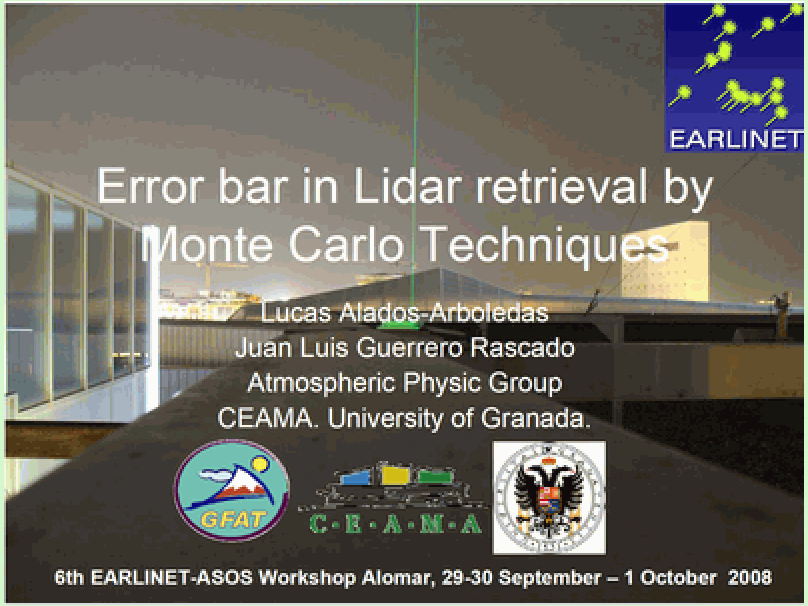
5th EARLINET-ASOS workshop -Training course Thessaloniki, 25 - 26 February 2008



"Quasi-analytical calculation of statistical error limits in the elastic inversion of the aerosol backscatter coefficient"

Michaël Sicard, Adolfo Comerón, Francesc Rocadenbosch, Alejandro Rodríguez, Constantino Muñoz

7th EARLINET-ASOS workshop /
Madrid, 9 – 11 February 2009



Error bar in Lidar retrieval by Monte Carlo Techniques

Lucas Alados-Arboledas
Juan Luis Guerrero Rascado
Atmospheric Physic Group
CEAMA. University of Granada.

6th EARLINET-ASOS Workshop Alomar, 29-30 September – 1 October 2008

Workshop short courses:
Retrieval of optical properties of aerosols and clouds (Thessaloniki, 25-26 February, 2008)

Pre-processing and quality control of optical profiles for microphysical retrievals
Detlef Müller

Multiwavelength Raman lidar data.
Quality control and optimization
Ulla Wandinger

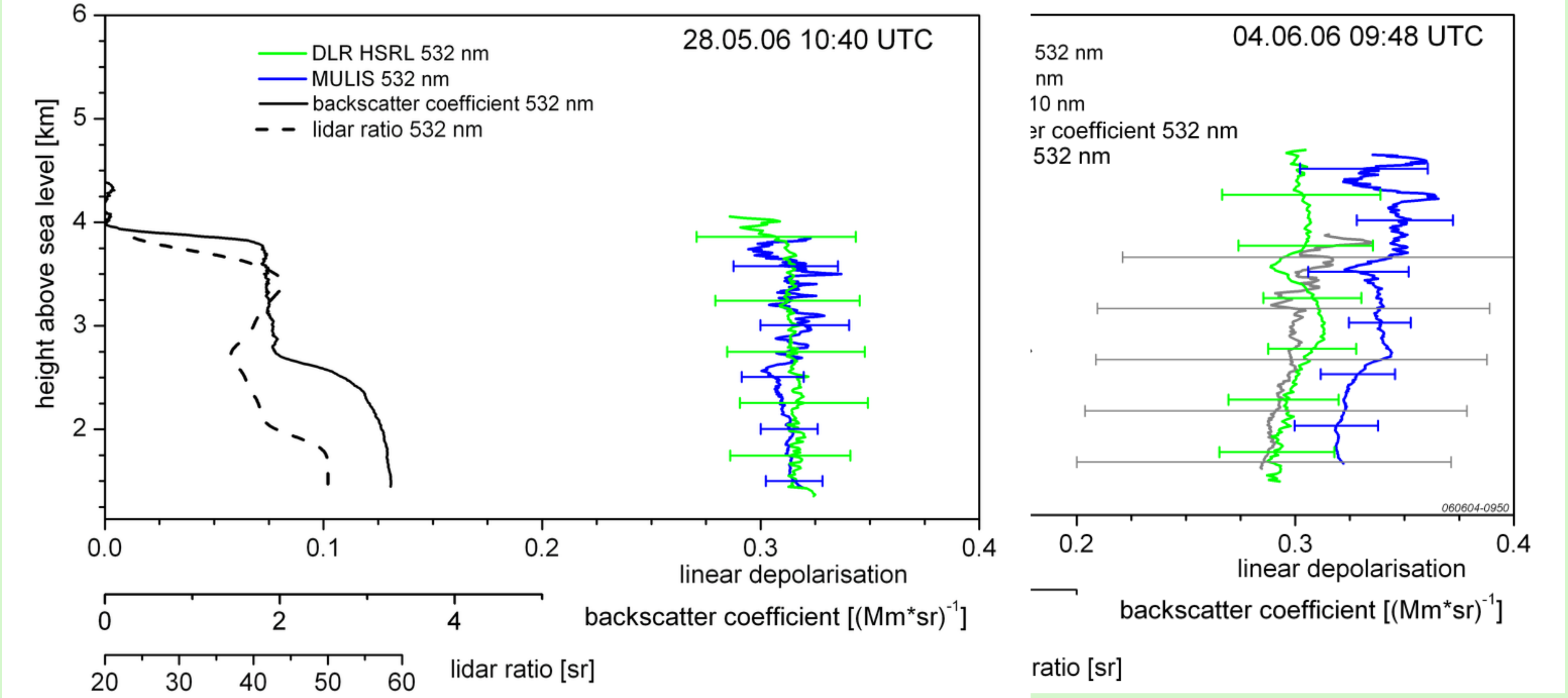
Retrieval of aerosol optical properties
Ina Mattis

....

Systematic errors are not randomly distributed and cannot be reduced by temporal or spatial averaging

Systematic errors are mostly unconsidered

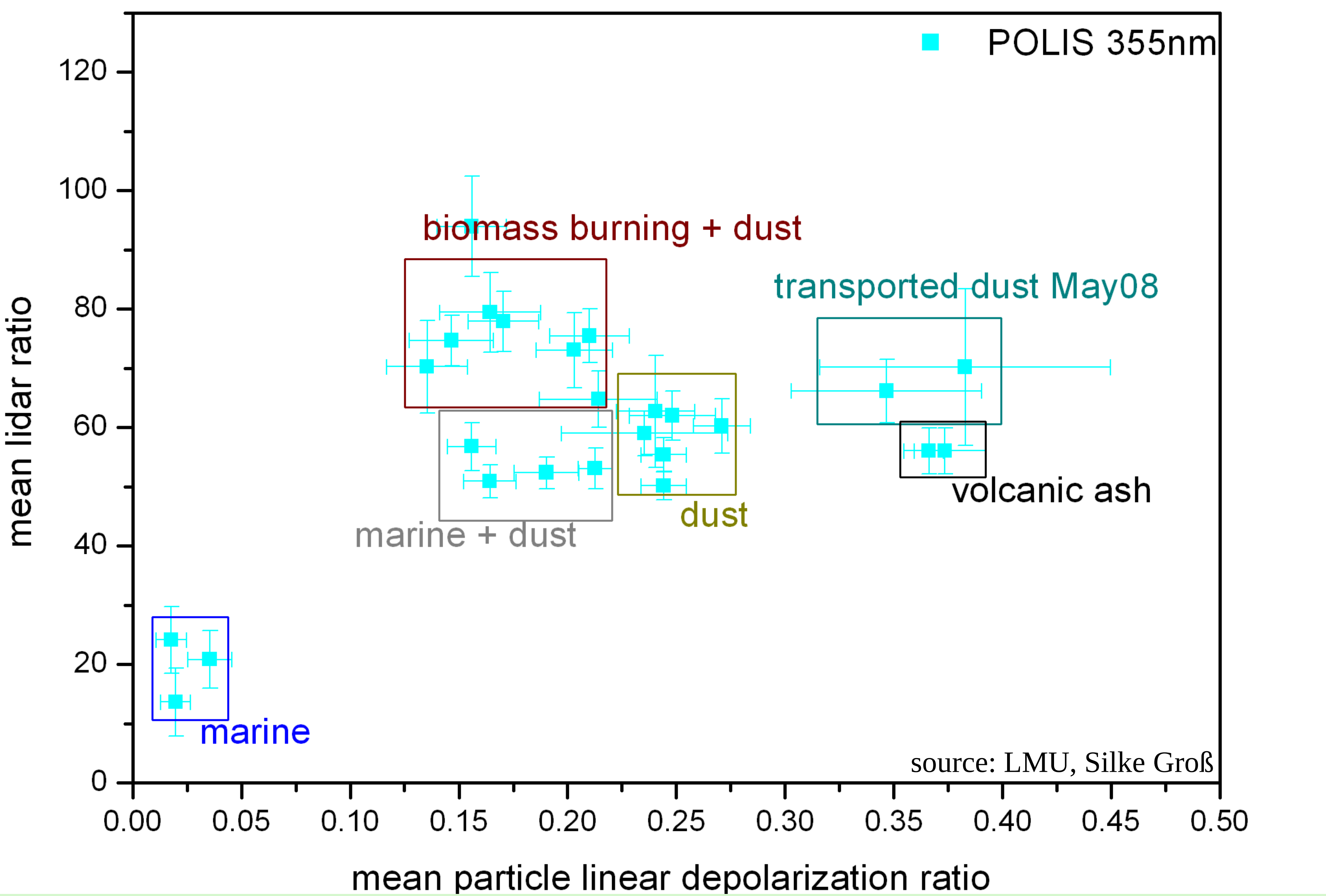
Systematic errors are not randomly distributed and cannot be reduced by temporal or spatial averaging



BTW: First EARLINET-ASOS lidar intercomparision during SAMUM 1 (2006)
Leipzig (BERTHA) – Munich (MULIS, POLIS)

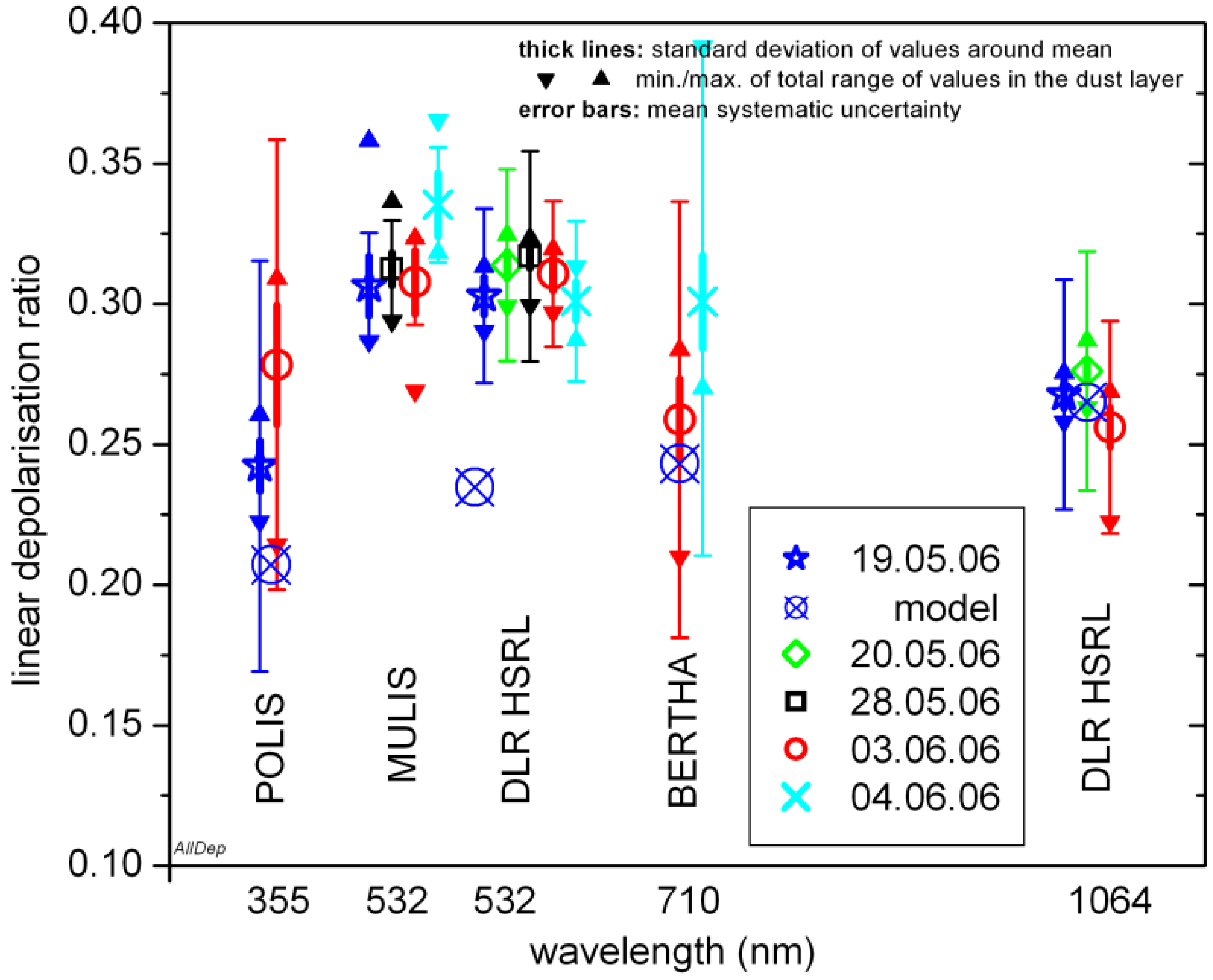
V. Freudenthaler, M. Esselborn, M. Wiegner, B. Heese, M. Tesche, A. Ansmann, D. Müller, D. Althausen, M. Wirth, F. I. X. Andreas, G. Ehret, P. Knippertz, C. Toledano, J. Gasteiger, M. Garhammer, and M. Seefeldner, "Depolarization ratio profiling at several wavelengths in pure saharan dust during samum 2006," Tellus B, vol. 61, no. 1, pp. 165-179, 2009. [Online]. Available: http://dx.doi.org/10.1111/j.1600-0889.2008.00396.x

Aerosol discrimination, systematic errors



source: LMU, Silke Groß

Errors => comparison with model calculations



V. Freudenthaler, M. Esselborn, M. Wiegner, B. Heese, M. Tesche, A. Ansmann, D. Müller, D. Althausen, M. Wirth, F. I. X. Andreas, G. Ehret, P. Knippertz, C. Toledano, J. Gasteiger, M. Garhammer, and M. Seefeldner, "Depolarization ratio profiling at several wavelengths in pure saharan dust during samum 2006," Tellus B, vol. 61, no. 1, pp. 165-179, 2009. [Online]. Available: http://dx.doi.org/10.1111/j.1600-0889.2008.00396.x

Errors => microphysical properties 1

WP 5.2: Inversion of Optical Data Into Microphysical Particle Parameters

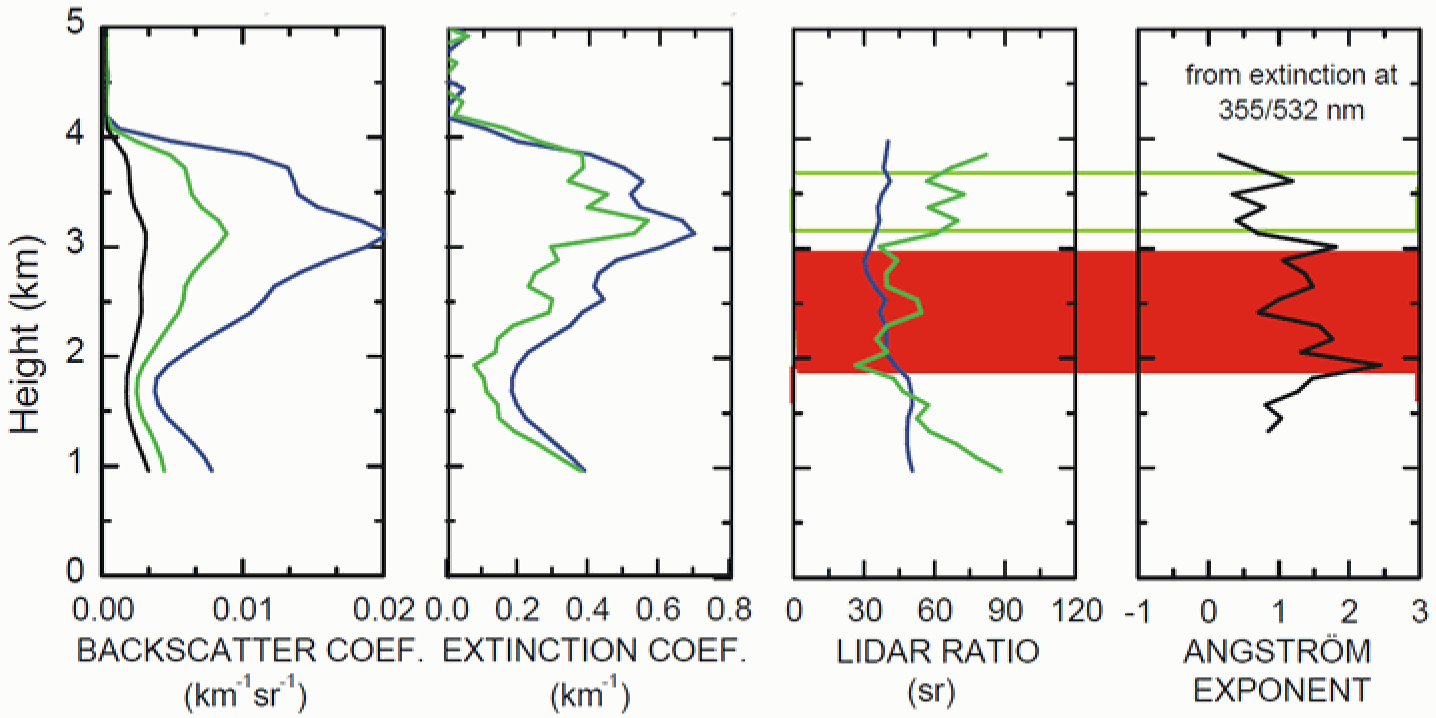
IfT part: practical application

Detlef Müller et al.
EARLINET-ASOS
Granada 2006

Pre-processing of Optical Profiles

- averaging of profiles across height intervals
- areas of „constant“ intensive parameters (Angström exponent, lidar ratio) rather than extensive parameters (extinction and backscatter coeff.)
- error bars of optical data

→ measurement error + averaging error



Errors => dust separation

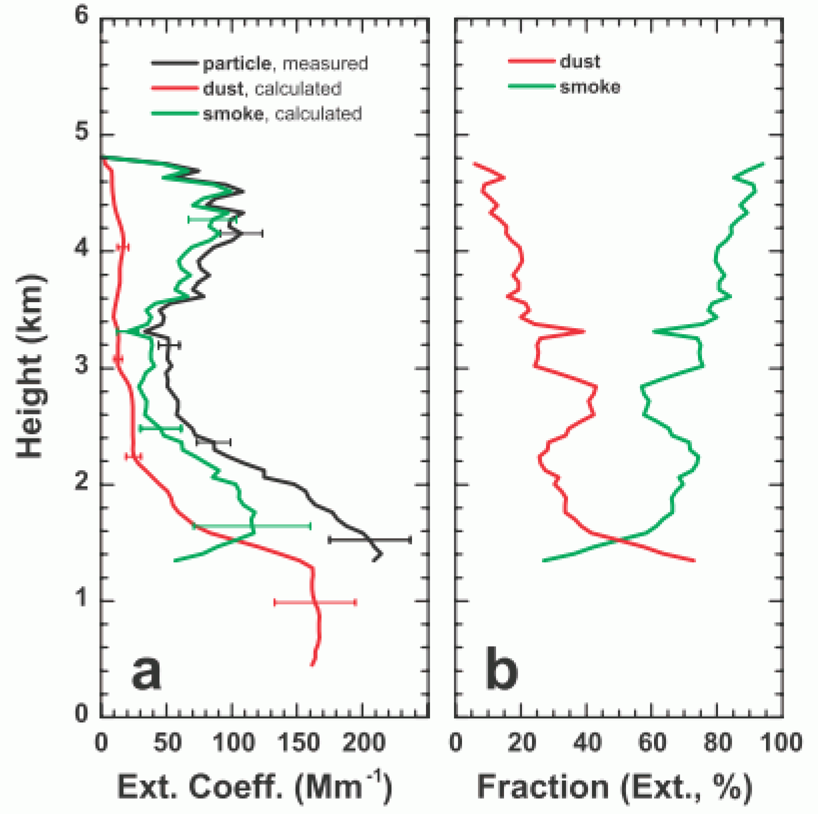


Figure 4. (a) Dust (red), smoke (green), and total (black) particle extinction coefficient at 532 nm, which correspond to the backscatter coefficient profiles in Figure 3, and (b) relative contribution of dust and smoke extinction to total particle extinction. The 1-h mean signal profiles for the time period shown in Figure 1 are smoothed with 300-m window length before further processing. Error bars (1 standard deviation) indicate the total retrieval uncertainty.

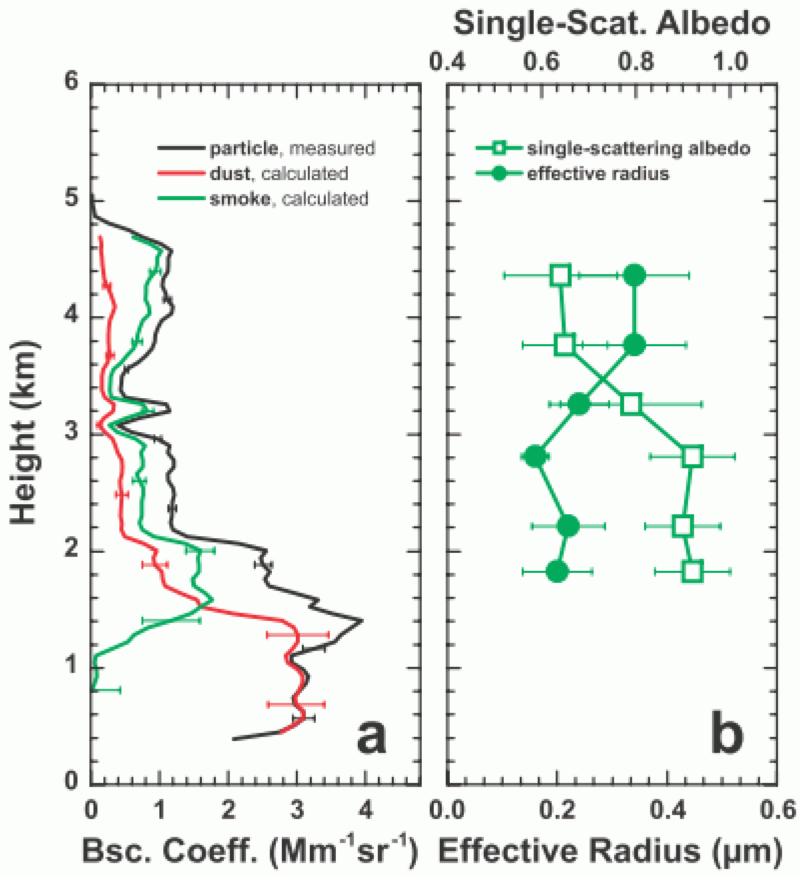
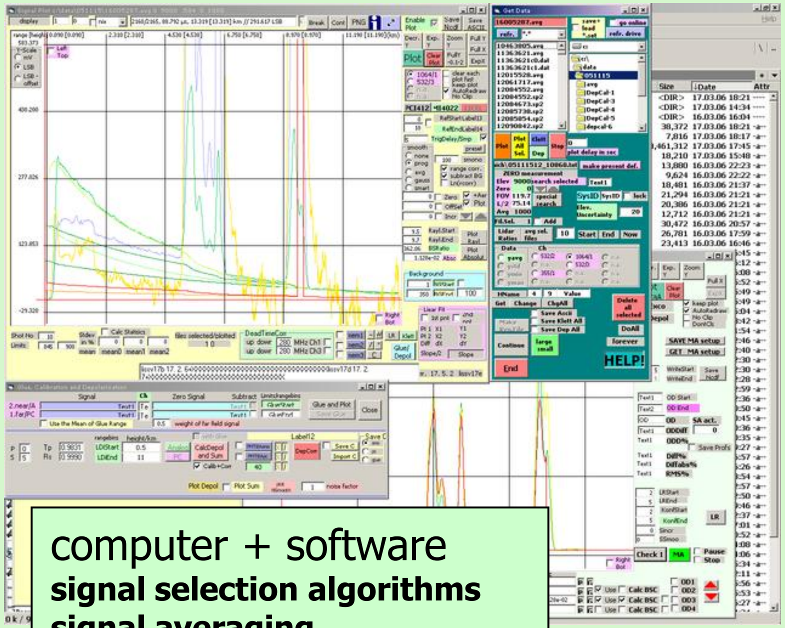


Figure 6. (a) Backscatter coefficients of particles, dust, and smoke at 532 nm and (b) effective radius and single-scattering albedo (SSA, 532 nm) retrieved with an inversion algorithm [*Müller et al.*, 1999] applied to the profiles of backscatter and extinction coefficients in Figure 5.

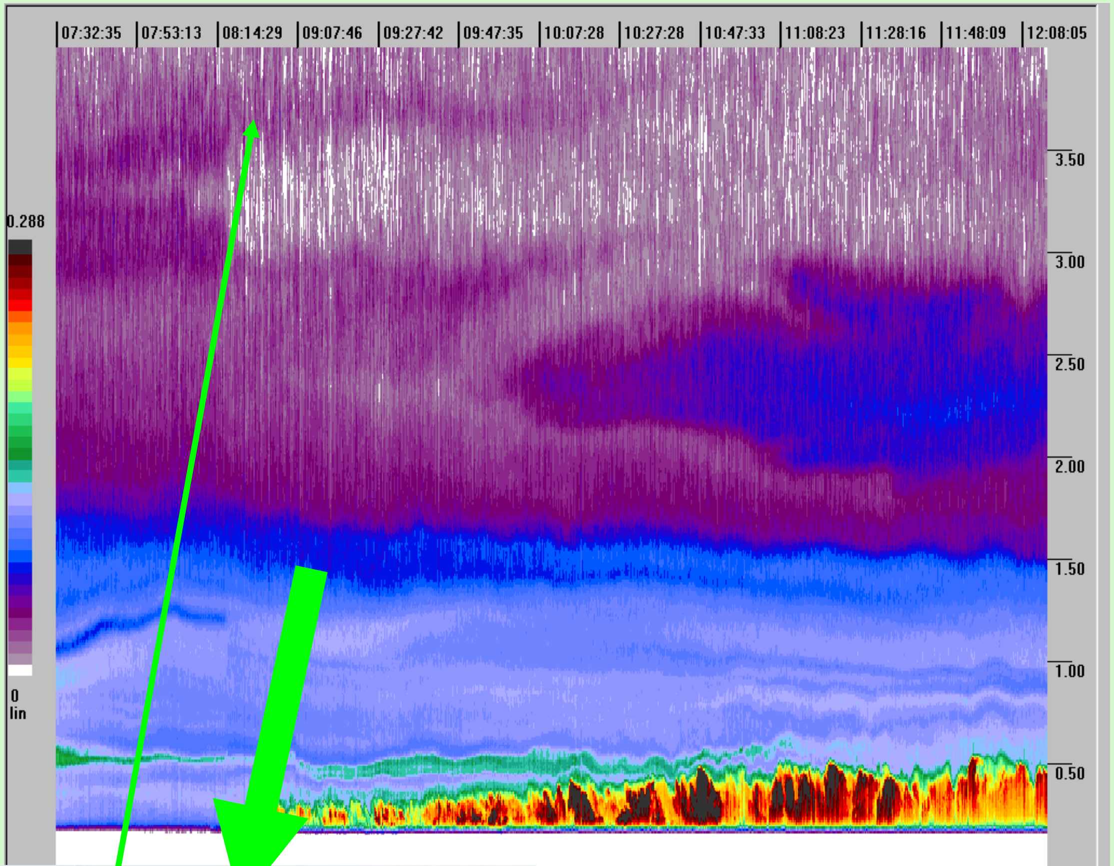
Tesche, M., A. Ansmann, D. Mu¨ller, D. Althausen, R. Engelmann, V. Freudenthaler, and S. Groß (2009), Vertically resolved separation of dust and smoke over Cape Verde using multiwavelength Raman and polarization lidars during Saharan Mineral Dust Experiment 2008, J. Geophys. Res., 114, D13202, doi:10.1029/2009JD011862.

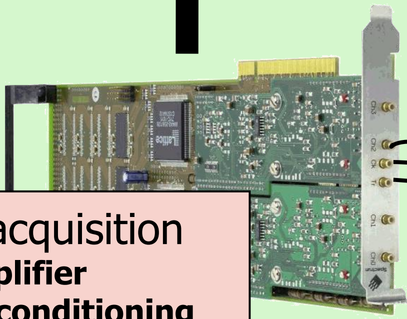
Network Activities NA3



computer + software

signal selection algorithms
signal averaging
data storage
analysis algorithms





data acquisition

preamplifier
signal conditioning
AD-converter

transmitter / receiver

optics + filters
detectors + preamplifiers

Where do the errors come from

lidar system ERRORS

↓ +

data analysis ERRORS

↓ =

common database more ERRORS

How can errors be reduced?

lidar system ERRORS

critical parts / design improvements NA4

system intercomparison / internal checks NA3.1

data analysis ERRORS

algorithm intercomparison NA3.2

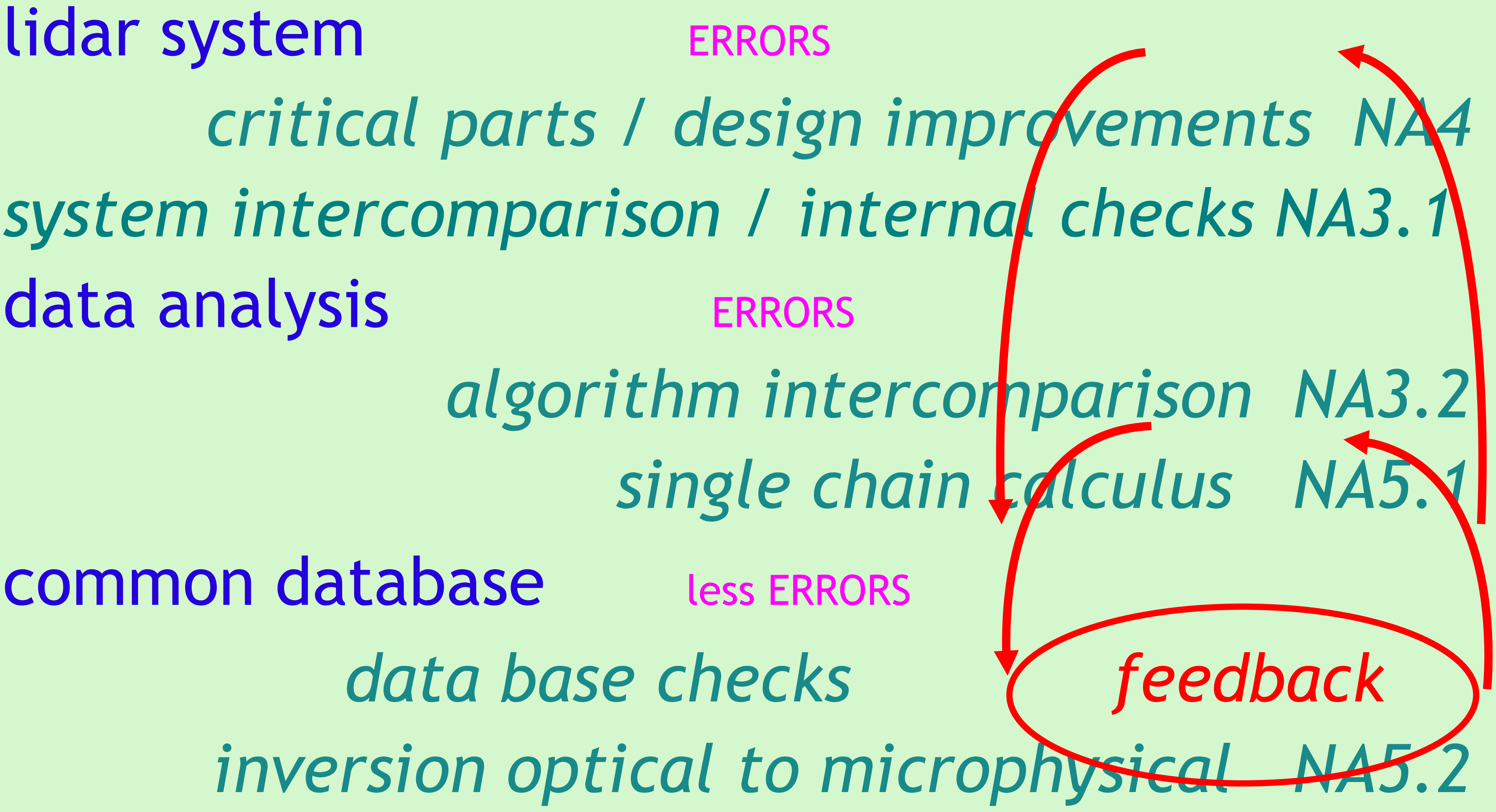
single chain calculus NA5.1

common database less ERRORS

data base checks

inversion optical to microphysical NA5.2

EARLINET Quality Assurance - NA3 ⇔ NA4 , NA5



lidar system ERRORS

critical parts / design improvements NA4

system intercomparison / internal checks NA3.1

data analysis ERRORS

algorithm intercomparison NA3.2

single chain calculus NA5.1

common database less ERRORS

data base checks *feedback*

inversion optical to microphysical NA5.2

QA - NA3 ⇔ NA4 – System Optimization

close linkage between NA3 and NA4

⇒ improve lidar systems

⇒ improve level of knowledge

⇒ reduce data base errors / uncertainties

⇒ reliable results

Network Activity NA3 – Quality Assurance of Hardware and Software

- NA3.1 QA of harware
  - LMU Munich
  - MPI Hamburg => pulse generator
  - IFT Leipzig => EARLI09, data base check
  - BISIP.SMO Minsk => reference lidar, inter comparison
  - CNR-IMAA Potenza => reference lidar, inter comparison

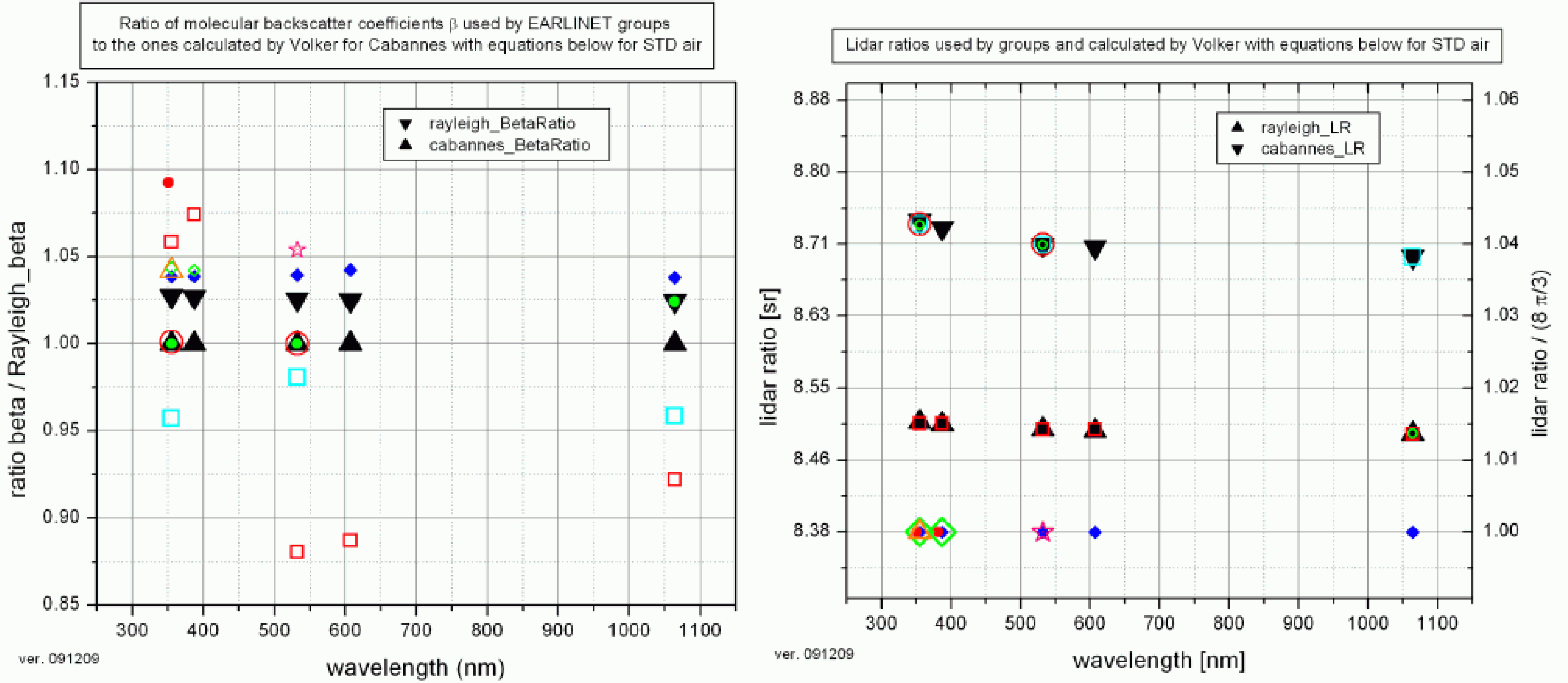
- NA3.2 QA of algorithms
  - Elastic: UP Potsdam
  - Raman: CNR-IMAA Potenza

¿ Calculation of Rayleigh scattering coeffcients ?

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/EARLINET-ASOS-NA3-QA.html

6 Technical and related documents

Rayleigh scattering coefficients and linear depolarization ratios at several EARLINET lidar wavelengths (VF 12/2009)



Ratio of molecular backscatter coefficients β used by EARLINET groups to the ones calculated by Volker for Cabannes with equations below for STD air

Lidar ratios used by groups and calculated by Volker with equations below for STD air

Figure 1: *In the* *left plot* *the ratio of the molecular backscatter coefficients at STD conditions* used by several EARLINET groups (different symbols) to the ones calculated for the Cabannes line (upward black triangle) with the formulas below (see table 1). The downward black triangles show values for the total Rayleigh scattering relative to the Cabannes values. The* *right plot* *shows the reported lidar ratios used (same symbols as left plot); the right scale of the right plot shows the ratio to (8π/3).*

** Standard conditions: 1013.25 hPa and 288.15 K, i.e.* *ICAO, ISA, and ISO 13443 STD conditions*

Rayleigh scattering coeffcients !

Table of scattering conversion factors and related values http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/Rayleigh_scattering/Rayleigh_coefficients.pdf

wave-length	$(n_s - 1)$	King Factor F_k	C_s	B_s^T	B_s^C	k_{bw}^T	k_{bw}^C	σ_m	β_m^T	β_m^C	δ_m^T	δ_m^C
(vacuum)			(17)(14)(10)	(18)	(18)	(20)	(22)	(17)	(18)	(18)	(15)	(16)
[nm]	[*1e-8]		[K/hPa/m]	[K/hPa/(m*sr)]	[K/hPa/(m*sr)]			[1/m]	[1/(m*sr)]	[1/(m*sr)]		
	STD air	STD air						STD air	STD air	STD air	STD air	STD air
308.0	29047.7	1.05575	3.6552E-5	4.2939E-6	4.1730E-6	1.01610	1.04555	1.2853E-4	1.5099E-5	1.4674E-5	0.01636	0.004158
351.0	28602.7	1.05308	2.0959E-5	2.4640E-6	2.3978E-6	1.01535	1.04338	7.3700E-5	8.6642E-6	8.4315E-6	0.01559	0.003960
354.814	28572.4	1.05290	2.0026E-5	2.3544E-6	2.2914E-6	1.01530	1.04324	7.0420E-5	8.2791E-6	8.0574E-6	0.01554	0.003946
355.0	28570.2	1.05289	1.9981E-5	2.3491E-6	2.2862E-6	1.01530	1.04323	7.0262E-5	8.2605E-6	8.0393E-6	0.01554	0.003946
386.800	28350.2	1.05166						4.9030E-5				
400.0	28275.2	1.05126	1.2123E-5	1.4259E-6	1.3889E-6	1.01484	1.04191	4.2629E-5	5.0140E-6	4.8838E-6	0.01507	0.003825
407.663	28235.1	1.05105						3.9493E-5				
510.6	27869.4	1.04922	4.4272E-6	5.2101E-7	5.0800E-7	1.01427	1.04026	1.5568E-5	1.8321E-6	1.7863E-6	0.01448	0.003674
532.0	27819.9	1.04899	3.7425E-6	4.4047E-7	4.2951E-7	1.01421	1.04007	1.3160E-5	1.5489E-6	1.5103E-6	0.01441	0.003656
532.221	27819.4	1.04899	3.7361E-6	4.3972E-7	4.2879E-7	1.01421	1.04007	1.3138E-5	1.5462E-6	1.5078E-6	0.01441	0.003656
607.600	27686.3	1.04839						7.6561E-6				
710.0	27570.4	1.04790	1.1574E-6	1.3626E-7	1.3295E-7	1.01390	1.03919	4.0700E-6	4.7916E-7	4.6750E-7	0.01410	0.003575
800.0	27503.8	1.04763	7.1443E-7	8.4116E-8	8.2080E-8	1.01383	1.03897	2.5122E-6	2.9578E-7	2.8863E-7	0.01402	0.003555
1064.0	27397.5	1.04721	2.2647E-7	2.6668E-8	2.6028E-8	1.01371	1.03863	7.9637E-7	9.3774E-8	9.1524E-8	0.01390	0.003524
1064.442	27397.4	1.04721	2.2609E-7	2.6623E-8	2.5984E-8	1.01371	1.03863	7.9504E-7	9.3617E-8	9.1371E-8	0.01390	0.003524

***Table 1**: Refractive index (n_s), King factor (F_k), extinction coefficients (σ_m), Cabannes (β_m^C) and total Rayleigh (β_m^T) backscatter coefficients, proportionality factors (see text above), and Cabannes (δ_m^C) and total Rayleigh (δ_m^T) linear depolarisation ratios caclulated with the equations in row two, for STD air conditions where mentioned (STD air: p_s = 1013.25 hPa, T_s = 288.15 K). The refractive indices and the King factors are calculated according to Tomasi et al. (2005) with 385 ppmv CO_2 and 0 % RH. Please note that the values in the table of the Tomasi paper were caclulated for slightly different conditions. NdYAG elastic and Raman wavelenghts (underlined) are for vacuum, calculated from the fundamental air wavelength 1064.15 nm (1064.442 nm in vacuum) at 300 K rod temperature according to Kaminskii.* (RAMAN3G.ods, Laserlinien.ods, Rayleigh1.vbs) *(This tabel is version 1.4 from Feb. 2010: some "exact" wavelengths added to version 1.1 and corrected from ver. 1.3.)*

Nd:YAG laser wavelengths ⇔ Interference filter

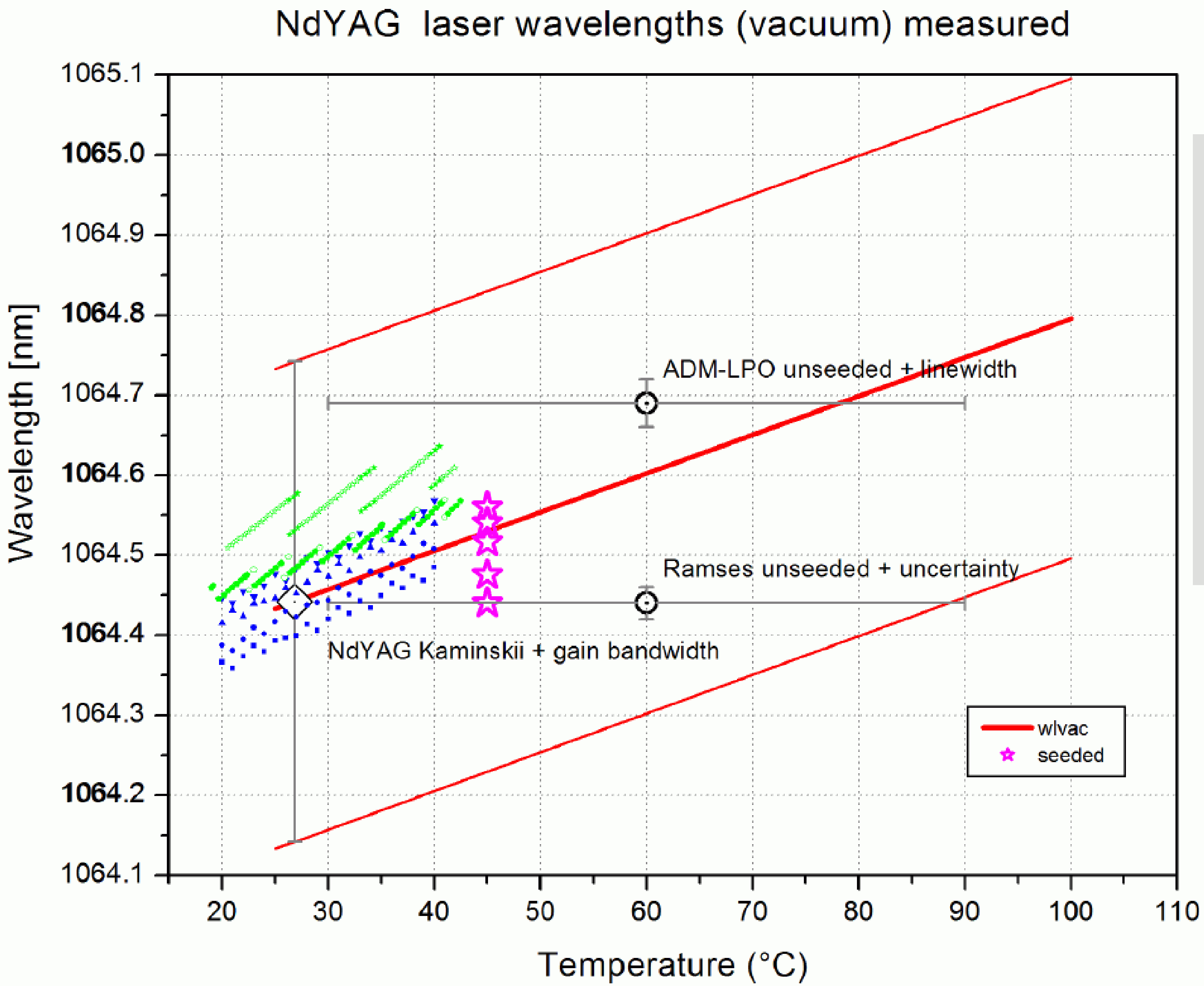


Figure 4: Temperature dependence of the Nd:YAG ${}^4F_{3/2}$ R2 → ${}^4I_{11/2}$ Y3 line according to Kaminskii for vacuum as in fig. 3 including the gain bandwidth (red), and measured center wavelengths of some Nd:YAG lasers to show some examples of the variability of Nd:YAG laser wavelengths. Open circles are for the unseeded ADM-LPO laser [Witschas, 2007] and the unseeded Ramses laser (see text above). Magenta stars are for some seeded or absorbtion line locked lasers. The latter lasers are all at unknown crystal temperatures, which is indicated by the horizontal error bars. Blue points and green points are from temperature tuning of Innolight Mephisto Nd:YAG lasers with monolithic non-planar ring cavities under different operation conditions. [Innolight, and Mazzotti]

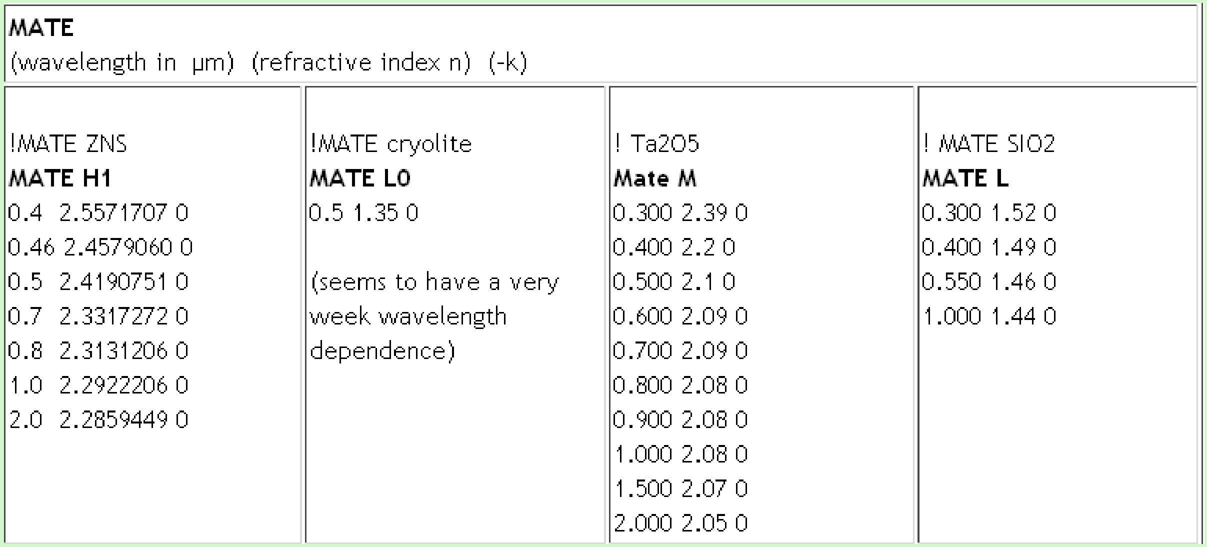
still an
open question

also:
laser polarization purity ?

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/Rayleigh_scattering/Rayleigh_coefficients.pdf

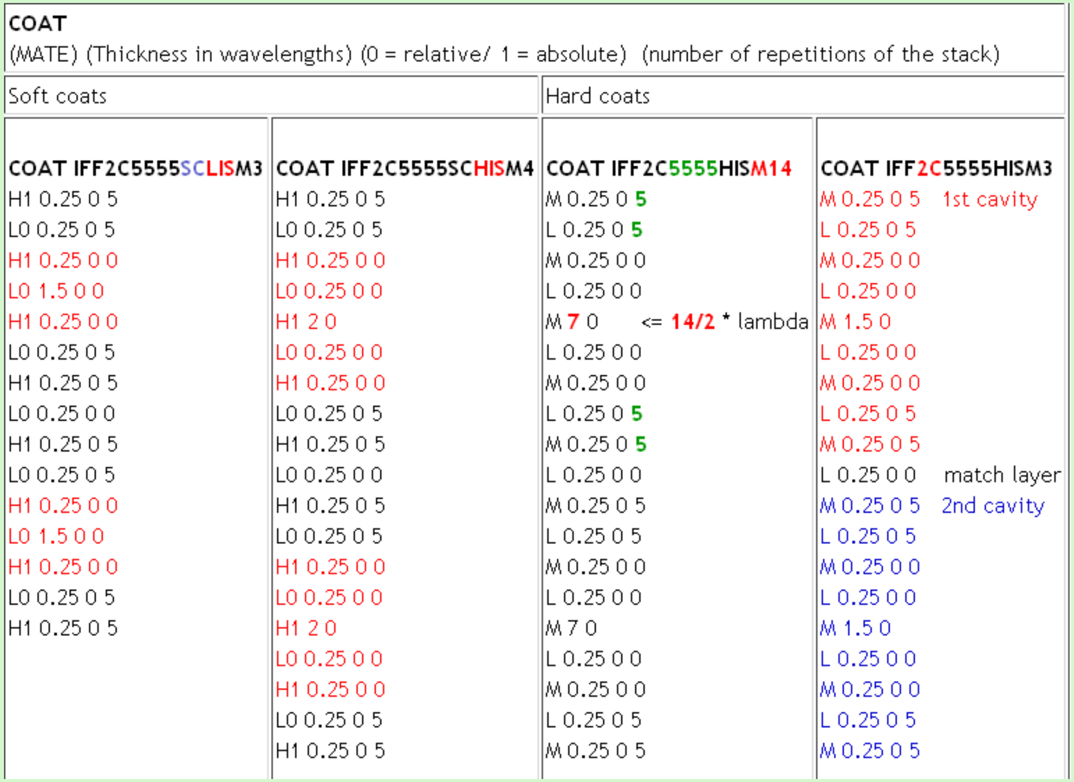
Interference filter bandwidth ⇔ acceptance angles

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/raytracing/IFF/EA-IFFilters.html



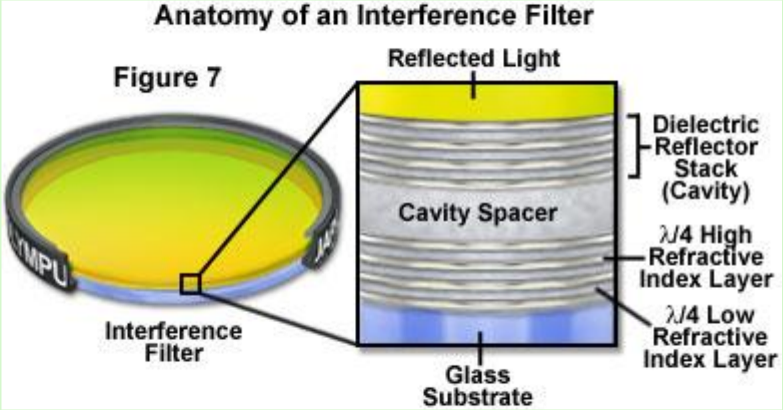
MATE
(wavelength in µm) (refractive index n) (-k)

!MATE ZNS	!MATE cryolite	! Ta2O5	! MATE SIO2
MATE H1	**MATE L0**	**Mate M**	**MATE L**
0.4 2.5571707 0	0.5 1.35 0	0.300 2.39 0	0.300 1.52 0
0.46 2.4579060 0		0.400 2.2 0	0.400 1.49 0
0.5 2.4190751 0	(seems to have a very	0.500 2.1 0	0.550 1.46 0
0.7 2.3317272 0	week wavelength	0.600 2.09 0	1.000 1.44 0
0.8 2.3131206 0	dependence)	0.700 2.09 0	
1.0 2.2922206 0		0.800 2.08 0	
2.0 2.2859449 0		0.900 2.08 0	
		1.000 2.08 0	
		1.500 2.07 0	
		2.000 2.05 0	



COAT
(MATE) (Thickness in wavelengths) (0 = relative/ 1 = absolute) (number of repetitions of the stack)

Soft coats		Hard coats	
COAT IFF2C5555SCLISM3	**COAT IFF2C5555SCHISM4**	**COAT IFF2C5555HISM14**	**COAT IFF2C5555HISM3**
H1 0.25 0 5	H1 0.25 0 5	M 0.25 0 **5**	M 0.25 0 5 1st cavity
L0 0.25 0 5	L0 0.25 0 5	L 0.25 0 **5**	L 0.25 0 5
H1 0.25 0 0	H1 0.25 0 0	M 0.25 0 0	M 0.25 0 0
L0 1.5 0 0	L0 0.25 0 0	L 0.25 0 0	L 0.25 0 0
H1 0.25 0 0	H1 2 0	M **7** 0 <= **14/2** * lambda	M 1.5 0
L0 0.25 0 5	L0 0.25 0 0	L 0.25 0 0	L 0.25 0 0
H1 0.25 0 5	H1 0.25 0 0	M 0.25 0 0	M 0.25 0 0
L0 0.25 0 0	L0 0.25 0 5	L 0.25 0 **5**	L 0.25 0 5
H1 0.25 0 5	H1 0.25 0 5	M 0.25 0 **5**	M 0.25 0 5
L0 0.25 0 5	L0 0.25 0 0	L 0.25 0 0	L 0.25 0 0 match layer
H1 0.25 0 0	H1 0.25 0 5	M 0.25 0 5	M 0.25 0 5 2nd cavity
L0 1.5 0 0	L0 0.25 0 5	L 0.25 0 5	L 0.25 0 5
H1 0.25 0 0	H1 0.25 0 0	M 0.25 0 0	M 0.25 0 0
L0 0.25 0 5	L0 0.25 0 0	L 0.25 0 0	L 0.25 0 0
H1 0.25 0 5	H1 2 0	M 7 0	M 1.5 0
	L0 0.25 0 0	L 0.25 0 0	L 0.25 0 0
	H1 0.25 0 0	M 0.25 0 0	M 0.25 0 0
	L0 0.25 0 5	L 0.25 0 5	L 0.25 0 5
	H1 0.25 0 5	M 0.25 0 5	M 0.25 0 5

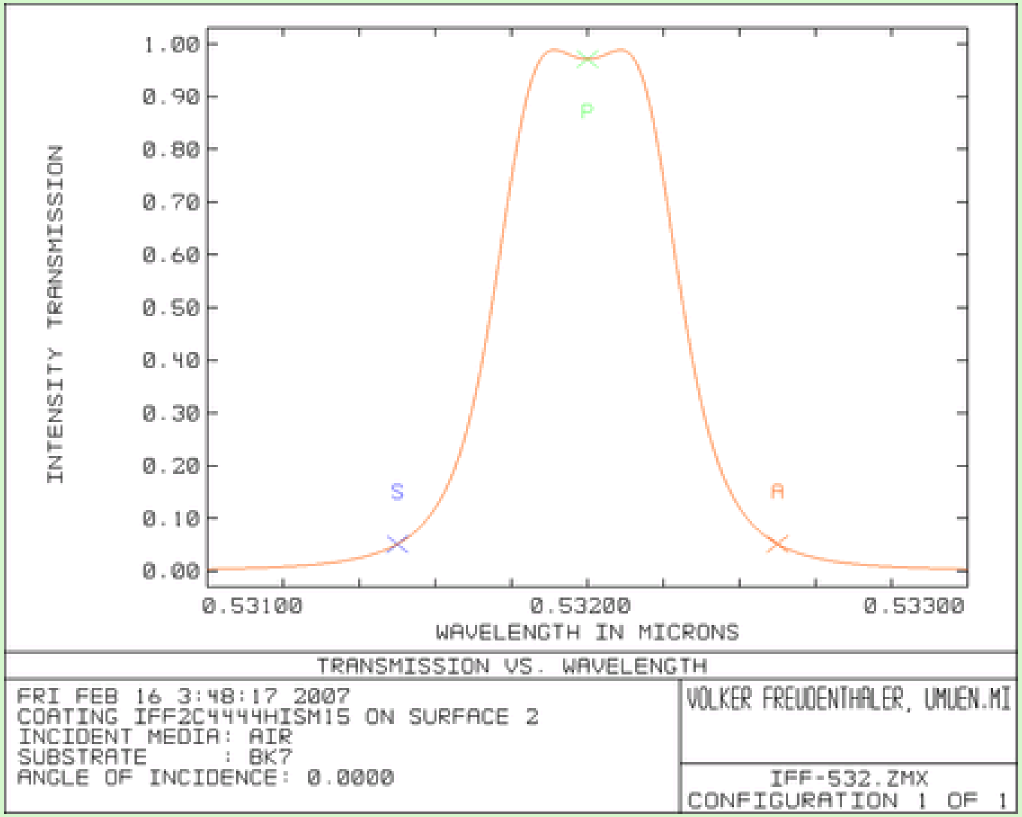


(Source: Basic Aspects of Light Filters
http://micro.magnet.fsu.edu/primer/lightandcolor/filtersintro.html)

Interference filter bandwidth ⇔ acceptance angles

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/raytracing/IFF/EA-IFF-BW-frames.html

example: 532-IFF2C4444HISM15 => 532 nm,   0.5 nm fwhm, 2.9° 90% hw

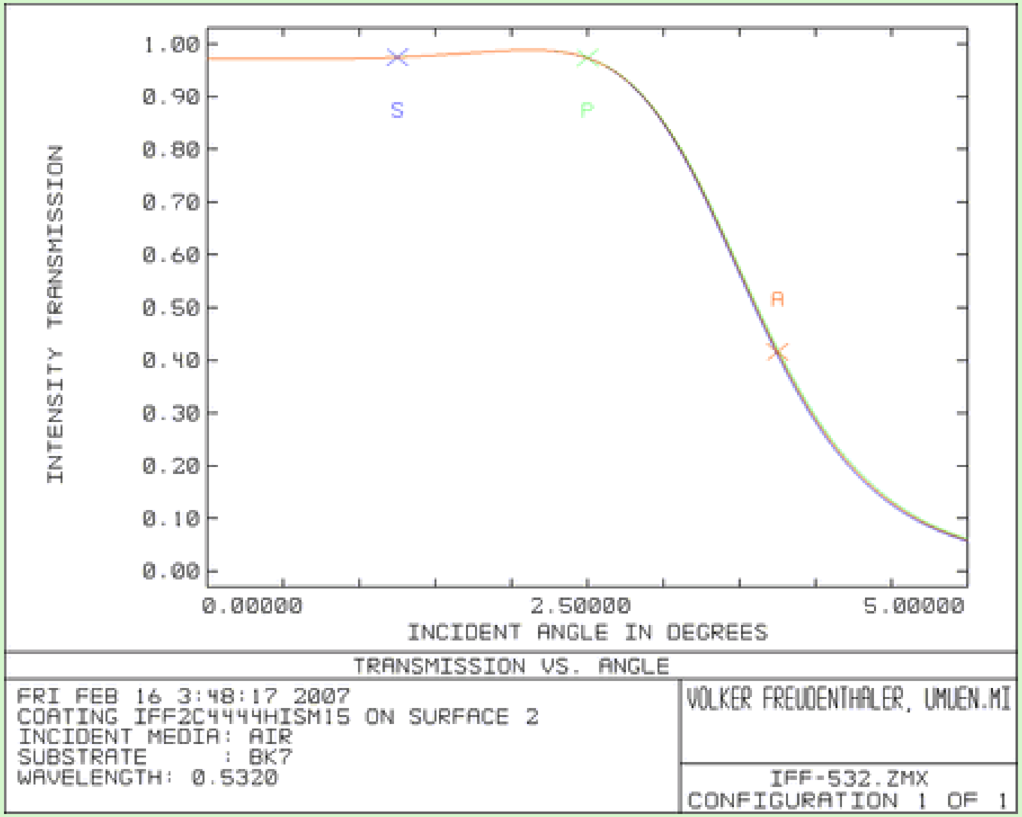


TRANSMISSION VS. WAVELENGTH

FRI FEB 16 3:48:17 2007
COATING IFF2C4444HISM15 ON SURFACE 2
INCIDENT MEDIA: AIR
SUBSTRATE : BK7
ANGLE OF INCIDENCE: 0.0000

VOLKER FREUDENTHALER, UMUEN.MI

IFF-532.ZMX
CONFIGURATION 1 OF 1



TRANSMISSION VS. ANGLE

FRI FEB 16 3:48:17 2007
COATING IFF2C4444HISM15 ON SURFACE 2
INCIDENT MEDIA: AIR
SUBSTRATE : BK7
WAVELENGTH: 0.5320

VOLKER FREUDENTHALER, UMUEN.MI

IFF-532.ZMX
CONFIGURATION 1 OF 1

Interference filter bandwidth ⇔ acceptance angles ⇒ ZEMAX

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/raytracing/IFF/EA-IFF-BW-frames.html

Centre wl [nm]	355	BW	neff	φ	387	BW	neff	φ	400	408	BW	neff	φ	511	532	BW	neff	φ
IFF BW (nm)																		
0.14															IFF2C5555SCLISM2	0.14	1.48	1.4
															IFF2C4444SCHISM4	0.14	2.04	1.6
0.2	IFF2C5555HISM3	0.22	2.01	2.5	IFF2C5555HISM5	0.22	1.97	2.45		IFF2C5555HISM8	0.2	2	2.2		IFF2C5555HISM20	0.19	2.01	1.8
	IFF2C4444HISM10	0.2	2.17	2.7											IFF2C5555HISM22	0.18	2.01	1.7
															IFF2C4444SCHISM3	0.18	1.99	1.7
0.3	IFF2C4444HISM6	0.31	2.1	3.2														
0.35									1						1			
0.42										1								
0.5	IFF2C3333HISM9	0.52	2.12	4.2	IFF2C4444HISM5	0.48	1.97	3.7		IFF2C4444HISM7	0.48	1.99	3.4	1	IFF2C4444HISM15	0.5	1.99	2.9
										IFF2C3333HISM16	0.52	2.05	3.7					
1	IFF2C3333HISM4	0.98	2.05	6.8						IFF2C3333HISM8	0.94	2	4.8		IFF2C3333HISM16	0.99	1.99	4
1.5															1			
3	1				1					1					IFF2C2222HISM10	3.0	1.96	8.8

Centre wl [nm]	607	BW	neff	φ	660	710	800	1064	BW	neff	φ
IFF BW (nm)											
0.14											
0.2								IFF2C6666HISM17	0.2	1.94	1.3
	IFF2C5555SCLISM2	0.18	1.48	1.2				IFF2C6666SCLISM2	0.17	1.42	0.9
	IFF2C4444SCHISM4	0.19	2.04	1.7				IFF2C5555SCHISM4	0.18	2.04	1.2
0.3											
0.35								1			
0.42						1	1				
0.5	IFF2C5555HISM8	0.48	1.93	2.6				IFF2C5555HISM14	0.48	1.93	2
	IFF2C4444HISM18	0.5	1.98	2.7							
1	IFF2C4444HISM8	1	1.93	3.7				IFF2C4444HISM15	0.95	1.93	2.8
1.5											
3	1				1			1			

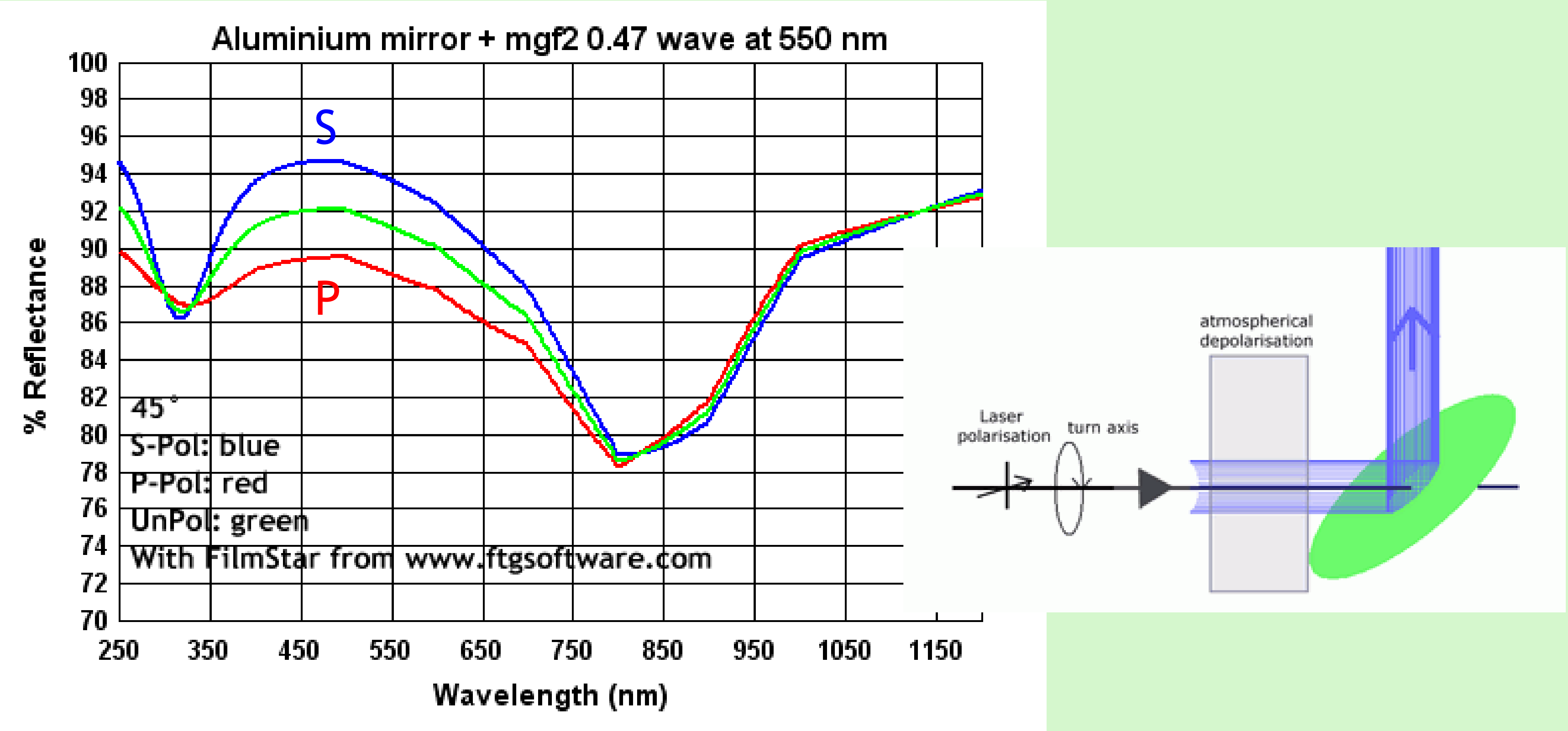
φ is the the IFF incident angle where the transmission dropes to about 90% of the maximum transmission.

neff is the effective refractive index, calculated with McLeod p. 263 (neff.xls).

BW is the actual full bandwidth at 50% of max. levels

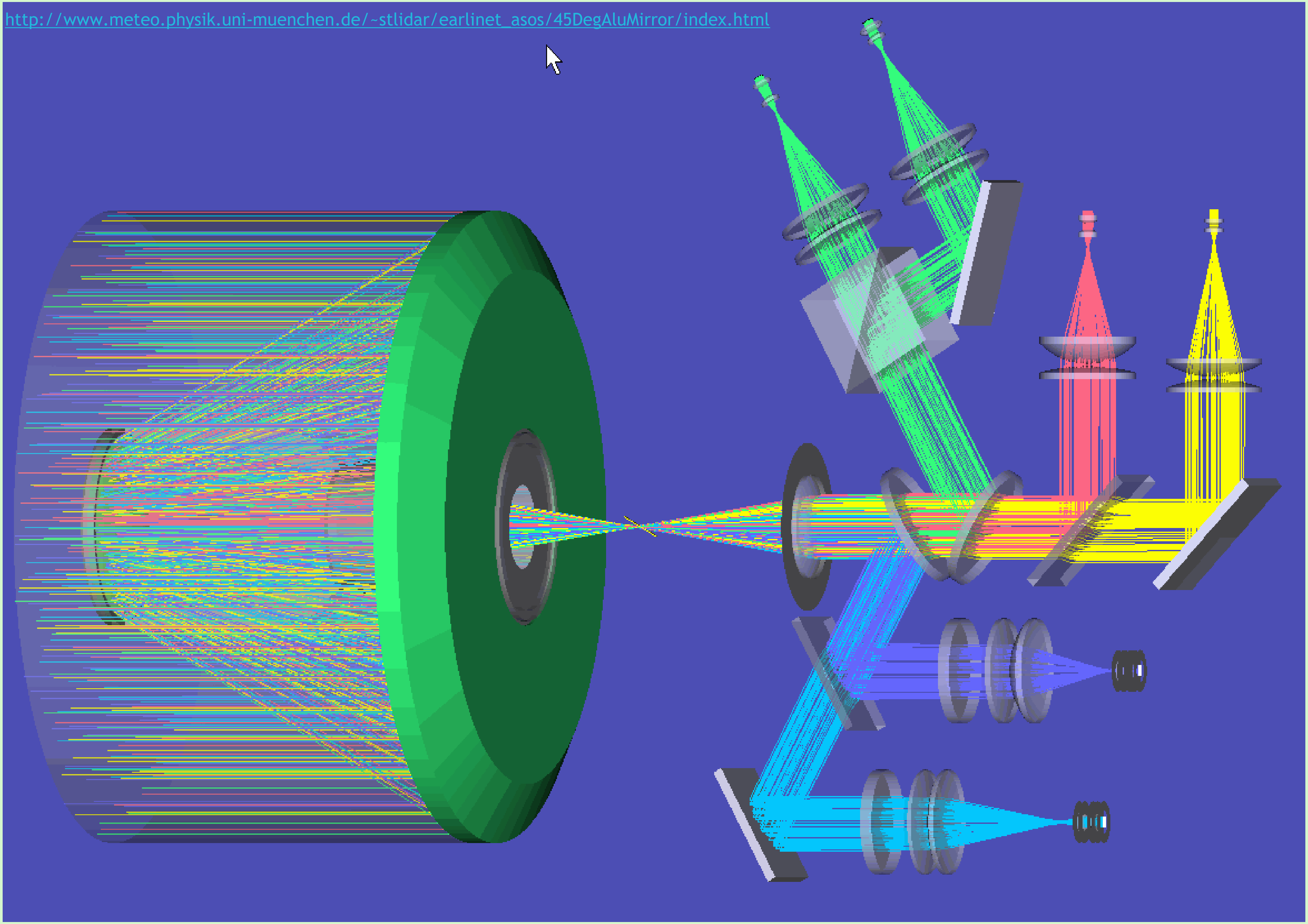
Mirror and beamsplitter diattenuation => elliptical polarization

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/45DegAluMirror/index.html



Beamsplitter diattenuation => backscatter and depolarization errors

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/45DegAluMirror/index.html



Error in backscatter coefficient due to optics diattenuation

http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/raytracing/IFF/EA-IFF-BW-frames.html

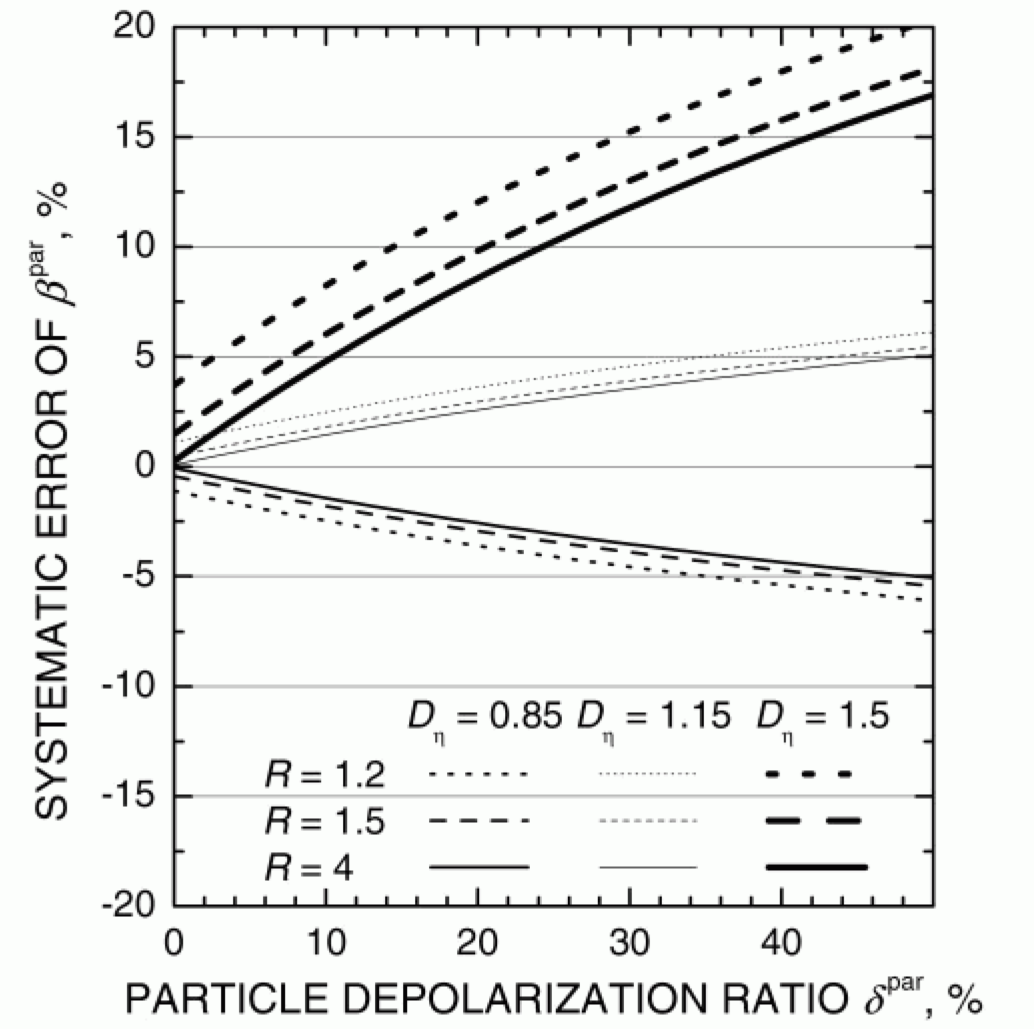
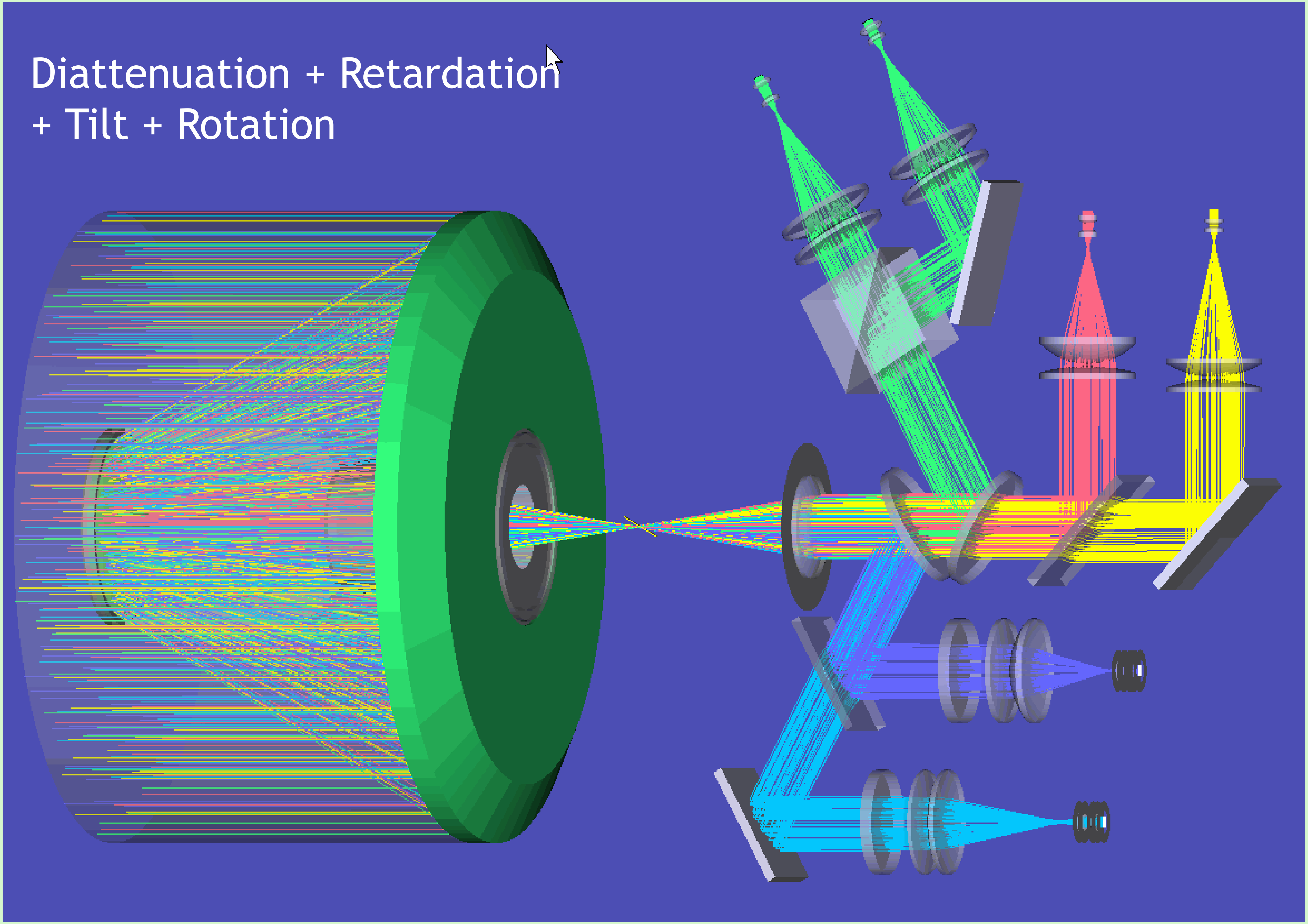


Fig. 3. Relative systematic error of the particle backscatter coefficient β^{par} for different backscatter ratios R and transmission ratios $D_\eta = 1.5$ (bold lines), $D_\eta = 1.15$ (thin lines), and $D_\eta = 0.85$ (medium lines).

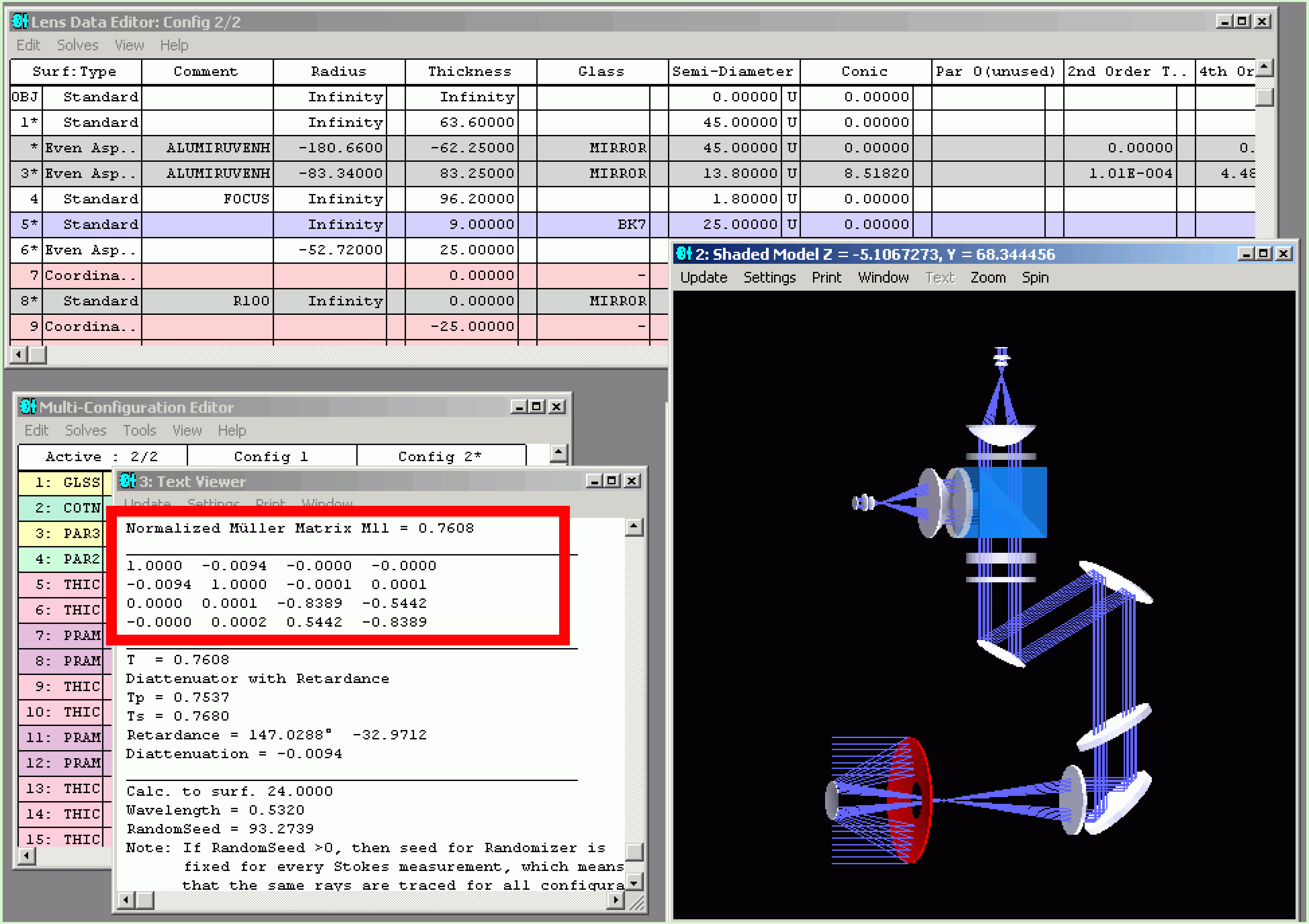
I. Mattis, M. Tesche, M. Grein, V. Freudenthaler, and D. Müller, "Systematic error of lidar profiles caused by a polarization-dependent receiver transmission: quantification and error correction scheme," Appl. Opt., vol. 48, no. 14, pp. 2742-2751, May 2009. http://dx.doi.org/10.1364/AO.48.002742

Whole optics errors incl. misalignments => ZEMAX => Müller matrix

Diattenuation + Retardation
+ Tilt + Rotation



ZEMAX macro for Müller matrix determination (not documented yet)



Surf:Type		Comment	Radius	Thickness	Glass	Semi-Diameter		Conic	Par 0(unused)	2nd Order T..	4th Or
OBJ	Standard		Infinity	Infinity		0.00000	U	0.00000			
1*	Standard		Infinity	63.60000		45.00000	U	0.00000			
*	Even Asp..	ALUMIRUVENH	-180.6600	-62.25000	MIRROR	45.00000	U	0.00000		0.00000	0.
3*	Even Asp..	ALUMIRUVENH	-83.34000	83.25000	MIRROR	13.80000	U	8.51820		1.01E-004	4.4
4	Standard	FOCUS	Infinity	96.20000		1.80000	U	0.00000			
5*	Standard		Infinity	9.00000	BK7	25.00000	U	0.00000			
6*	Even Asp..		-52.72000	25.00000							
7	Coordina..			0.00000	-						
8*	Standard	R100	Infinity	0.00000	MIRROR						
9	Coordina..			-25.00000	-						

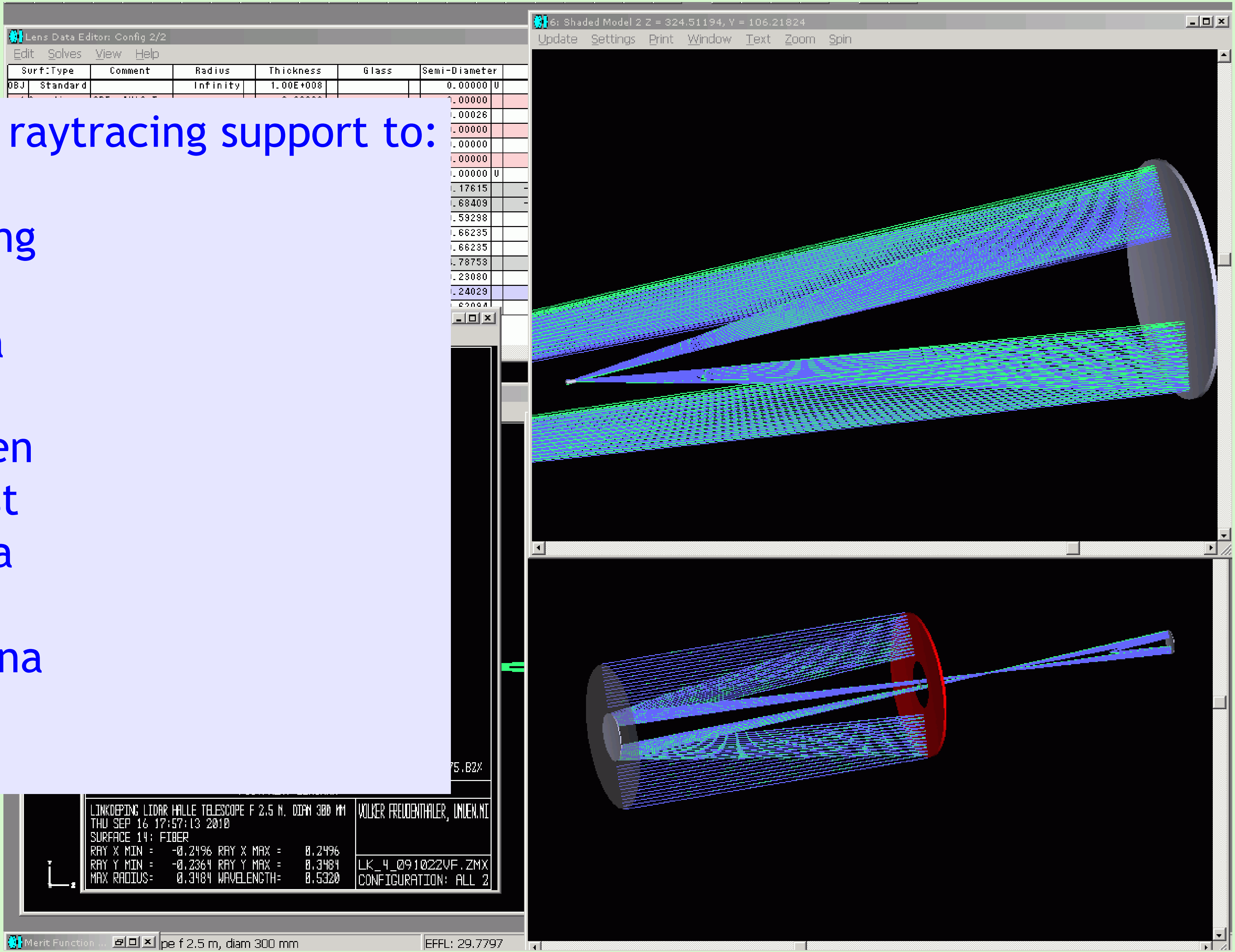
Active : 2/2	Config 1	Config 2*
1: GLSS		
2: COTN		
3: PAR3		
4: PAR2		
5: THIC		
6: THIC		
7: PRAM		
8: PRAM		
9: THIC		
10: THIC		
11: PRAM		
12: PRAM		
13: THIC		
14: THIC		
15: THIC		

```
Normalized Müller Matrix M11 = 0.7608

1.0000   -0.0094   -0.0000   -0.0000
-0.0094   1.0000   -0.0001   0.0001
0.0000   0.0001   -0.8389   -0.5442
-0.0000   0.0002   0.5442   -0.8389

T  = 0.7608
Diattenuator with Retardance
Tp = 0.7537
Ts = 0.7680
Retardance = 147.0288°  -32.9712
Diattenuation = -0.0094

Calc. to surf. 24.0000
Wavelength = 0.5320
RandomSeed = 93.2739
Note: If RandomSeed >0, then seed for Randomizer is
      fixed for every Stokes measurement, which means
      that the same rays are traced for all configura
```

ZEMAX raytracing for lidar system check and optimization

NA3.1 - raytracing support to:

- Linköping
- Alomar
- Potenza
- Leipzig
- Bilthoven
- Bucarest
- Granada
- Madrid
- Barcelona
- Athens
- Sofia



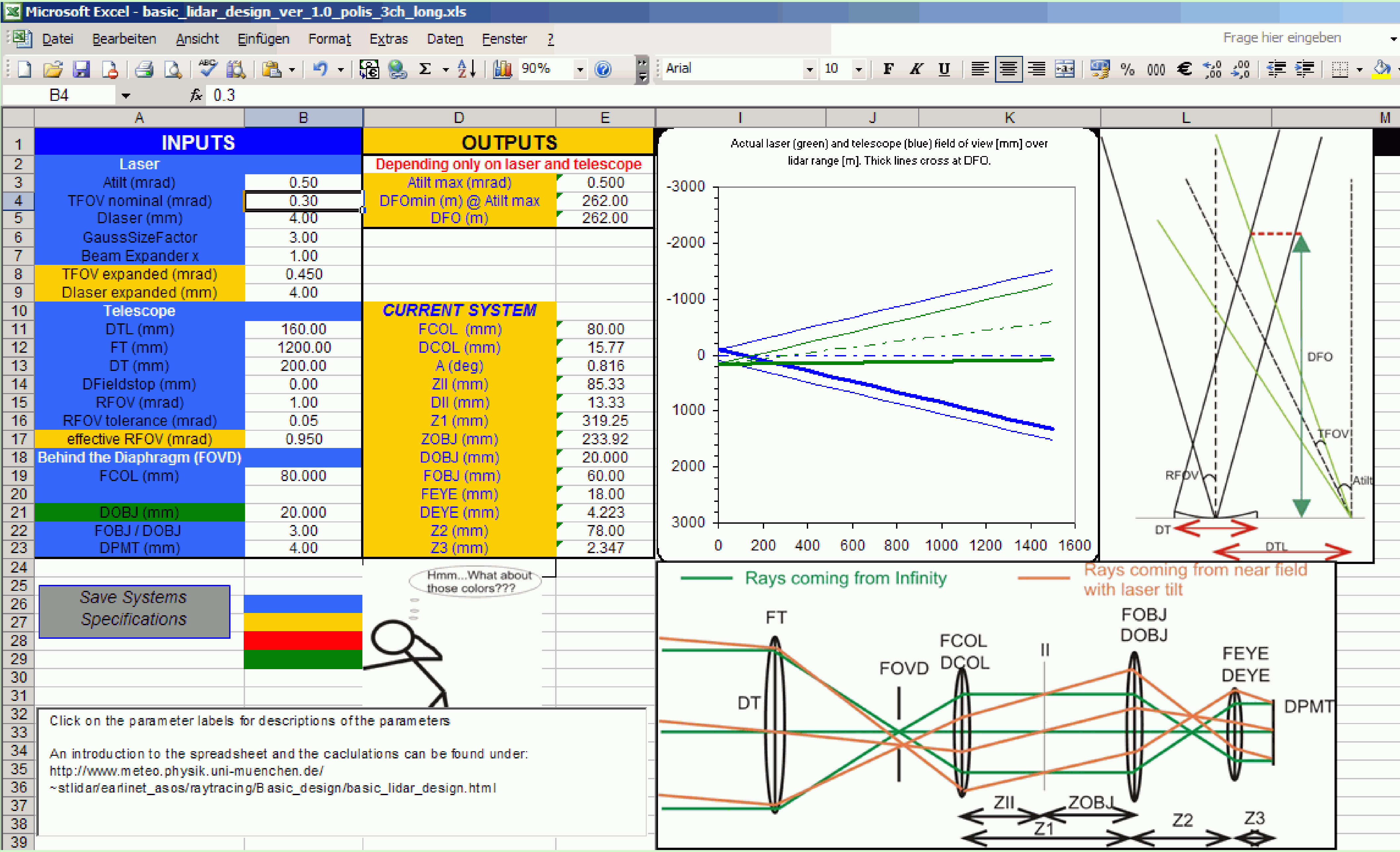
Surf:Type	Comment	Radius	Thickness	Glass	Semi-Diameter
OBJ Standard		Infinity	1.00E+008		0.00000 U
					.00000
					.00026
					.00000
					.00000
					.00000
					.00000 U
					.17615
					.68409
					.59298
					.66235
					.66235
					.78753
					.23080
					.24029

```
75.82%
LINKOEPING LIDAR HALLE TELESCOPE F 2.5 M. DIAM 300 MM    VOLKER FREUDENTHALER, LMUEN.MI
THU SEP 16 17:57:13 2010
SURFACE 14: FIBER
RAY X MIN =   -0.2496 RAY X MAX =     0.2496
RAY Y MIN =   -0.2364 RAY Y MAX =     0.3484               LK_4_091022VF.ZMX
MAX RADIUS=    0.3484 WAVELENGTH=     0.5320               CONFIGURATION: ALL 2
```

pe f 2.5 m, diam 300 mm

EFFL: 29.7797

Paraxial optical calculus for lidar system check and optimization



	A	B	D	E
1	**INPUTS**		**OUTPUTS**	
2	Laser		Depending only on laser and telescope	
3	Atilt (mrad)	0.50	Atilt max (mrad)	0.500
4	TFOV nominal (mrad)	0.30	DFOmin (m) @ Atilt max	262.00
5	Dlaser (mm)	4.00	DFO (m)	262.00
6	GaussSizeFactor	3.00		
7	Beam Expander x	1.00		
8	TFOV expanded (mrad)	0.450		
9	Dlaser expanded (mm)	4.00		
10	Telescope		***CURRENT SYSTEM***	
11	DTL (mm)	160.00	FCOL (mm)	80.00
12	FT (mm)	1200.00	DCOL (mm)	15.77
13	DT (mm)	200.00	A (deg)	0.816
14	DFieldstop (mm)	0.00	ZII (mm)	85.33
15	RFOV (mrad)	1.00	DII (mm)	13.33
16	RFOV tolerance (mrad)	0.05	Z1 (mm)	319.25
17	effective RFOV (mrad)	0.950	ZOBJ (mm)	233.92
18	Behind the Diaphragm (FOVD)		DOBJ (mm)	20.000
19	FCOL (mm)	80.000	FOBJ (mm)	60.00
20			FEYE (mm)	18.00
21	DOBJ (mm)	20.000	DEYE (mm)	4.223
22	FOBJ / DOBJ	3.00	Z2 (mm)	78.00
23	DPMT (mm)	4.00	Z3 (mm)	2.347

Save Systems Specifications

Click on the parameter labels for descriptions of the parameters

An introduction to the spreadsheet and the caclulations can be found under:
http://www.meteo.physik.uni-muenchen.de/
~stlidar/earlinet_asos/raytracing/Basic_design/basic_lidar_design.html

Panos Kokkalis NTUA Athens, and Volker Freudenthaler LMU Munich, Dec. 2009
http://www.meteo.physik.uni-muenchen.de/~stlidar/earlinet_asos/EARLINET-ASOS-NA3-QA.html#Basic_lidar_design

How to check a lidar system? => Internal checkup tools

- Rayleigh fit

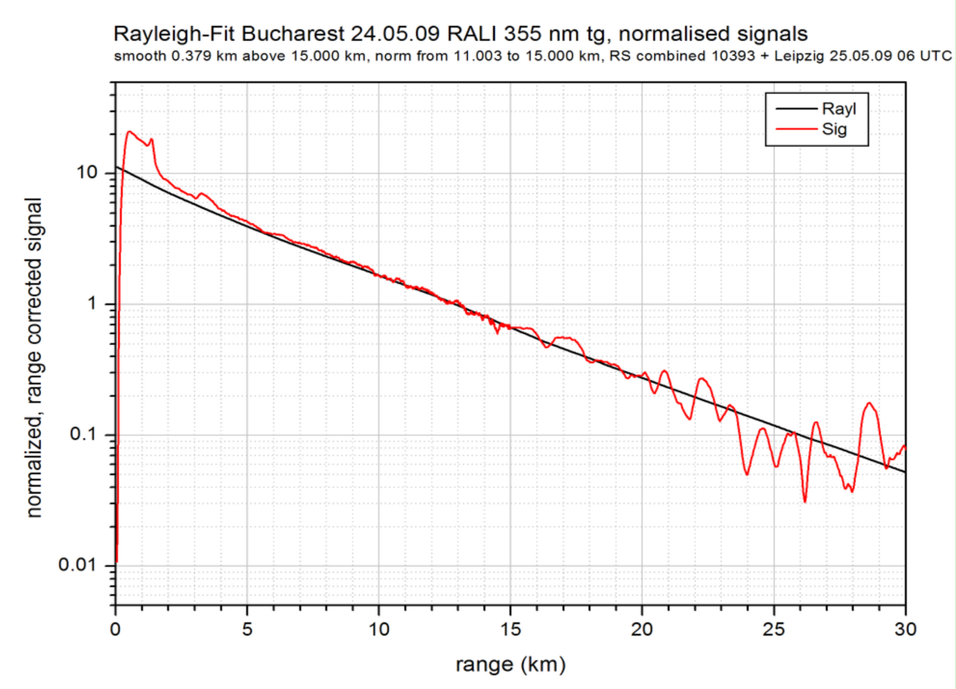
- Dark signal measurement
- Electronical pulse generator (MPI)

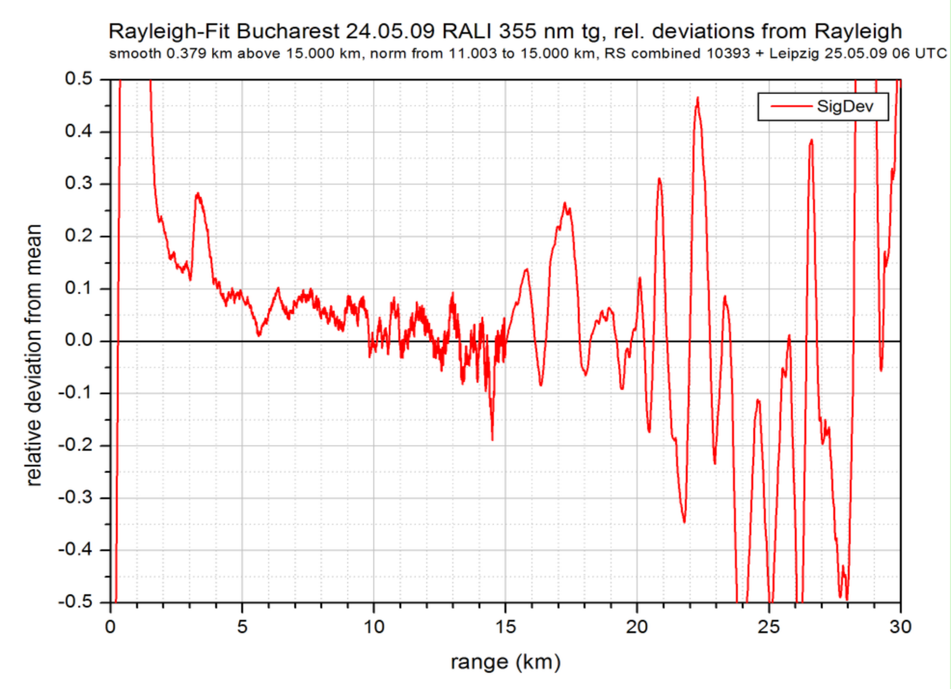
- Trigger delay / zero bin

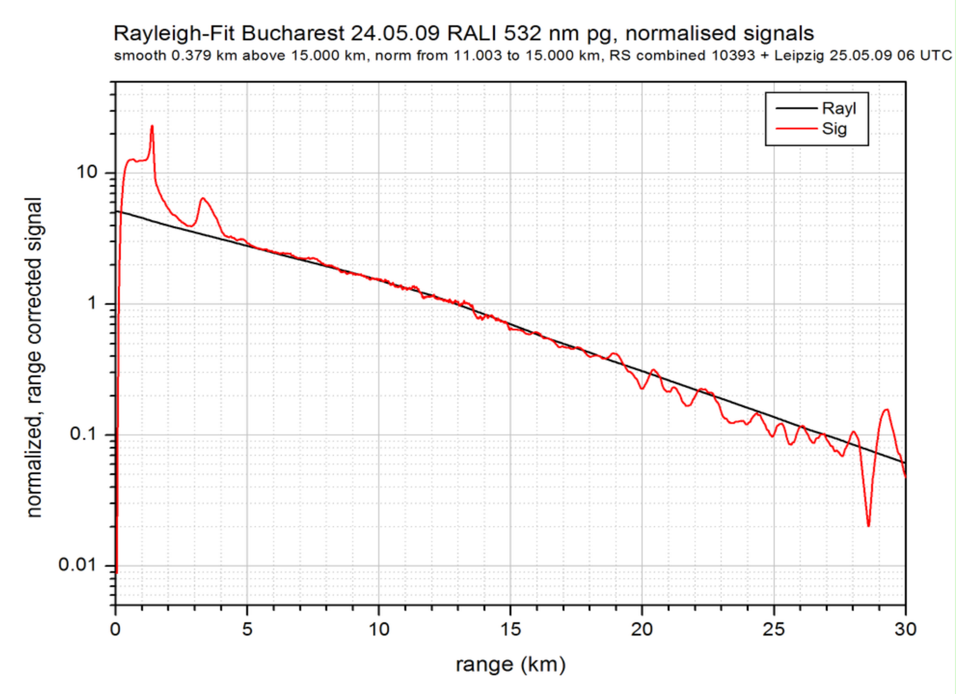
- Telecover
- Raytracing

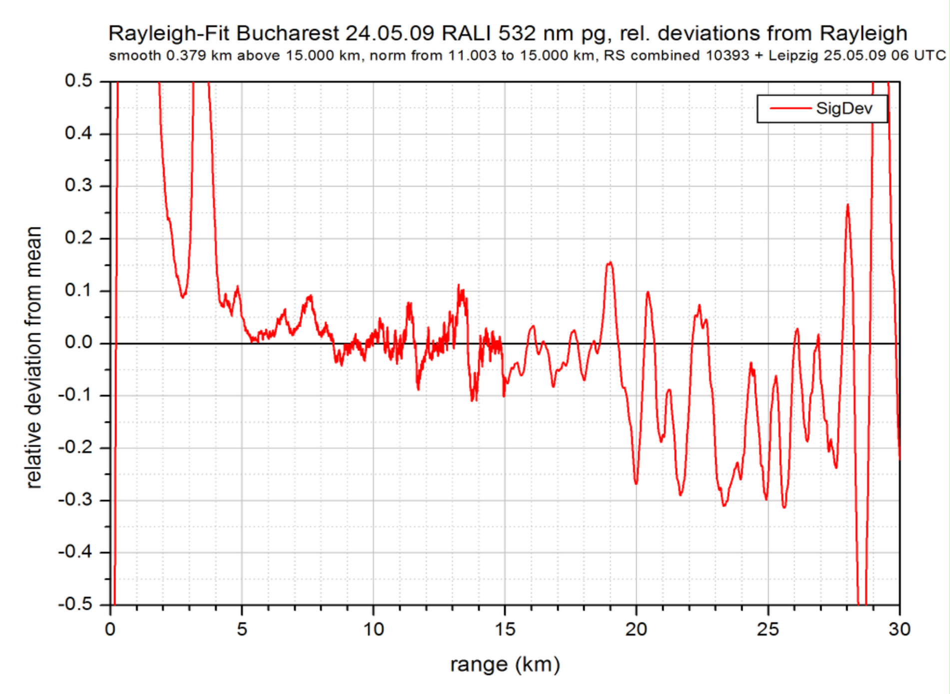
- Upcomming: Polarimeter => diattenuation (IfT) ?

Internal checkup tools – Rayleigh fit - 2009


Rayleigh-Fit Bucharest 24.05.09 RALI 355 nm tg, normalised signals
smooth 0.379 km above 15.000 km, norm from 11.003 to 15.000 km, RS combined 10393 + Leipzig 25.05.09 06 UTC


Rayleigh-Fit Bucharest 24.05.09 RALI 355 nm tg, rel. deviations from Rayleigh
smooth 0.379 km above 15.000 km, norm from 11.003 to 15.000 km, RS combined 10393 + Leipzig 25.05.09 06 UTC

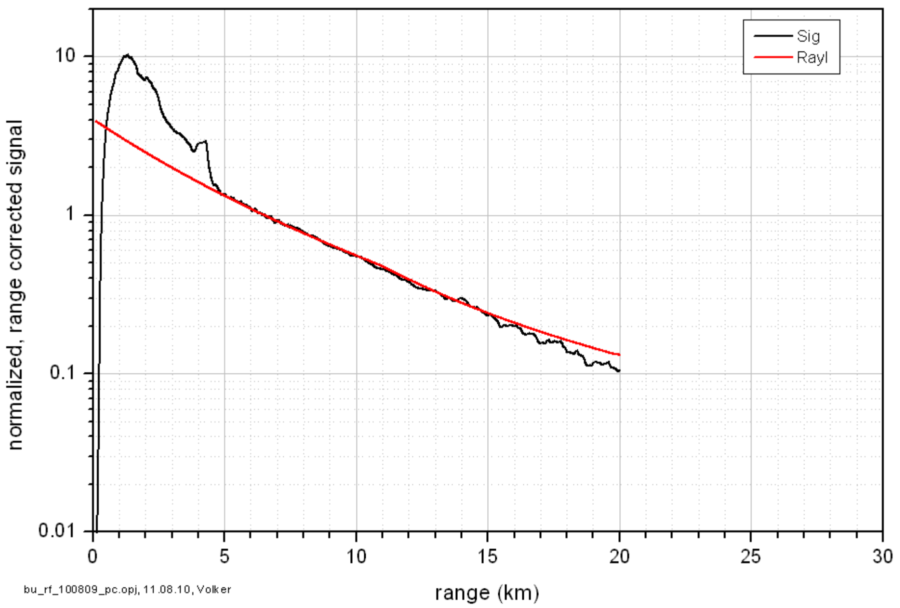

Rayleigh-Fit Bucharest 24.05.09 RALI 532 nm pg, normalised signals
smooth 0.379 km above 15.000 km, norm from 11.003 to 15.000 km, RS combined 10393 + Leipzig 25.05.09 06 UTC


Rayleigh-Fit Bucharest 24.05.09 RALI 532 nm pg, rel. deviations from Rayleigh
smooth 0.379 km above 15.000 km, norm from 11.003 to 15.000 km, RS combined 10393 + Leipzig 25.05.09 06 UTC

Internal checkup tools – Rayleigh fit - 2010

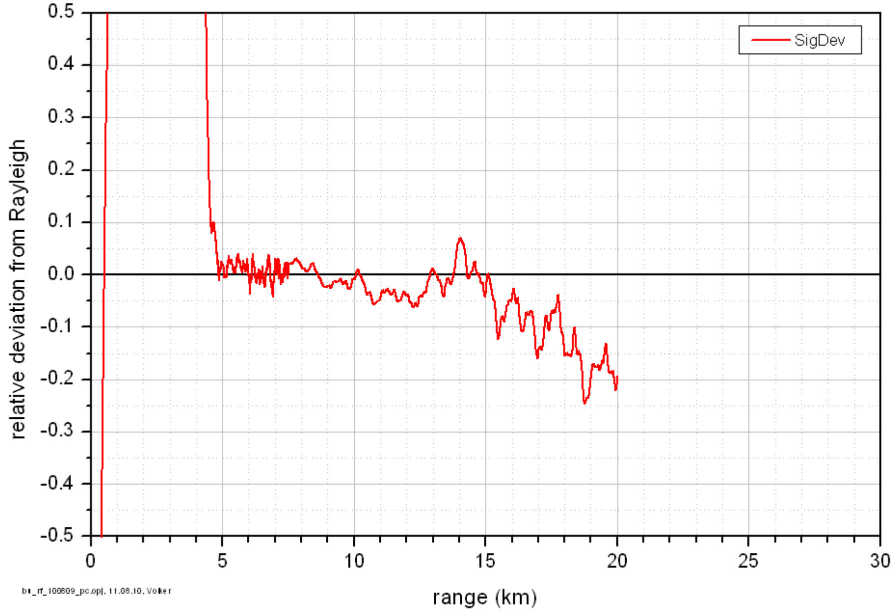
Rayleigh-Fit Bucharest 09.08.10 RALI 355 nm xtp, normalised signals

smooth 0.379 km above 7.503 km, norm from 6.003 to 7.000 km, RS Atmospheric model 09/08/2010



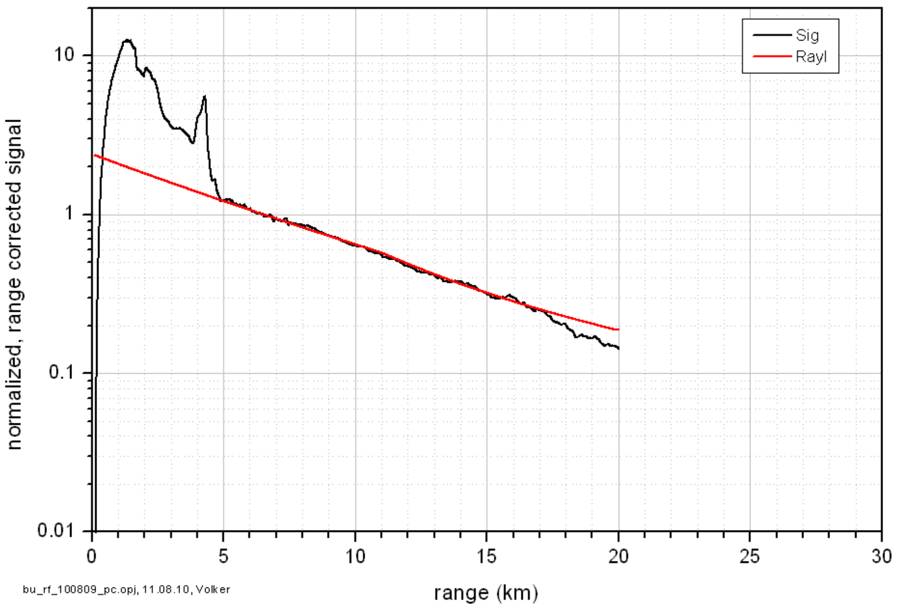
Rayleigh-Fit Bucharest 09.08.10 RALI 355 nm xtp, rel. deviations from Rayleigh

smooth 0.379 km above 7.503 km, norm from 6.003 to 7.000 km, RS Atmospheric model 09/08/2010



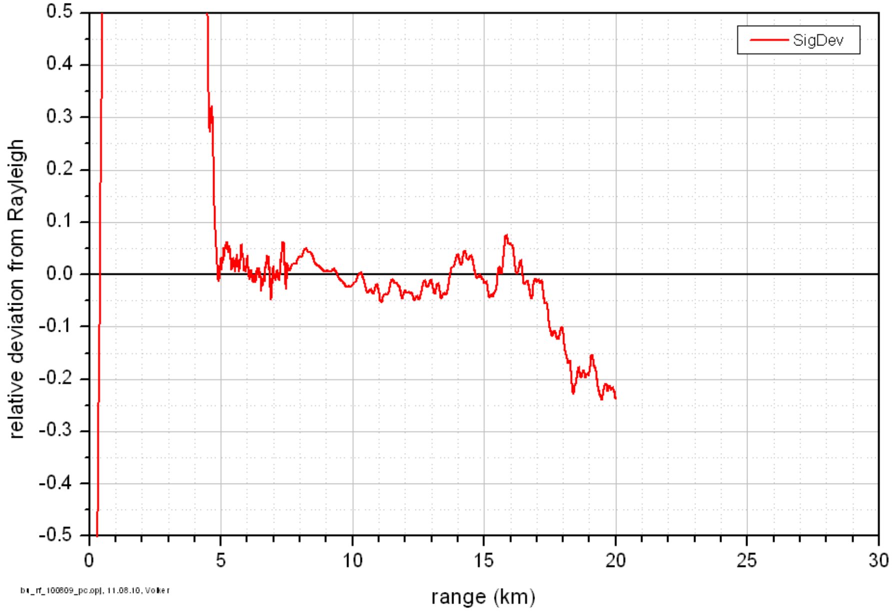
Rayleigh-Fit Bucharest 09.08.10 RALI 532 nm xpp, normalised signals

smooth 0.379 km above 7.503 km, norm from 6.003 to 7.000 km, RS Atmospheric model 09/08/2010

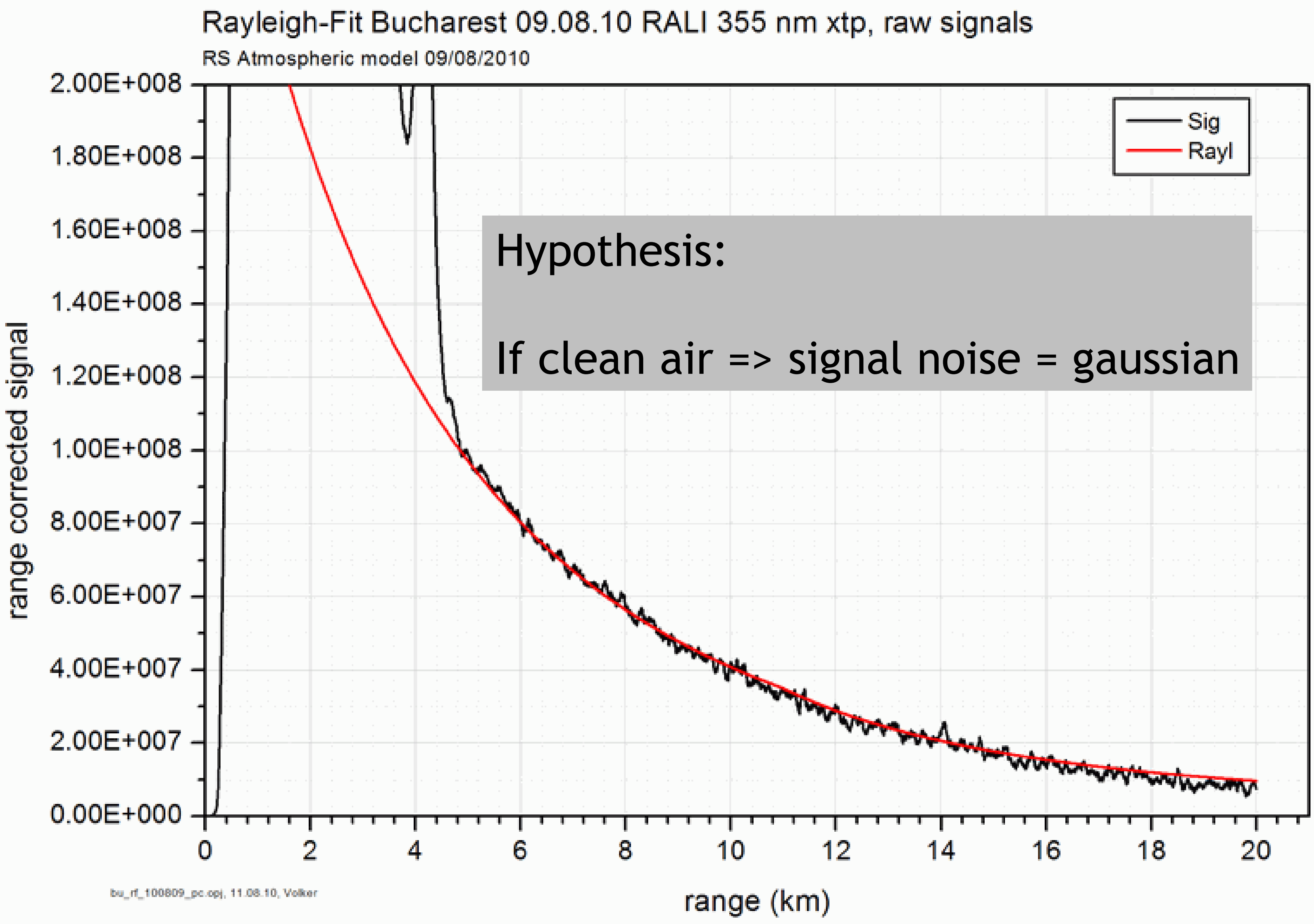


Rayleigh-Fit Bucharest 09.08.10 RALI 532 nm xpp, rel. deviations from Rayleigh

smooth 0.379 km above 7.503 km, norm from 6.003 to 7.000 km, RS Atmospheric model 09/08/2010



How to determine the best Rayleigh fit and the errors?


Rayleigh-Fit Bucharest 09.08.10 RALI 355 nm xtp, raw signals

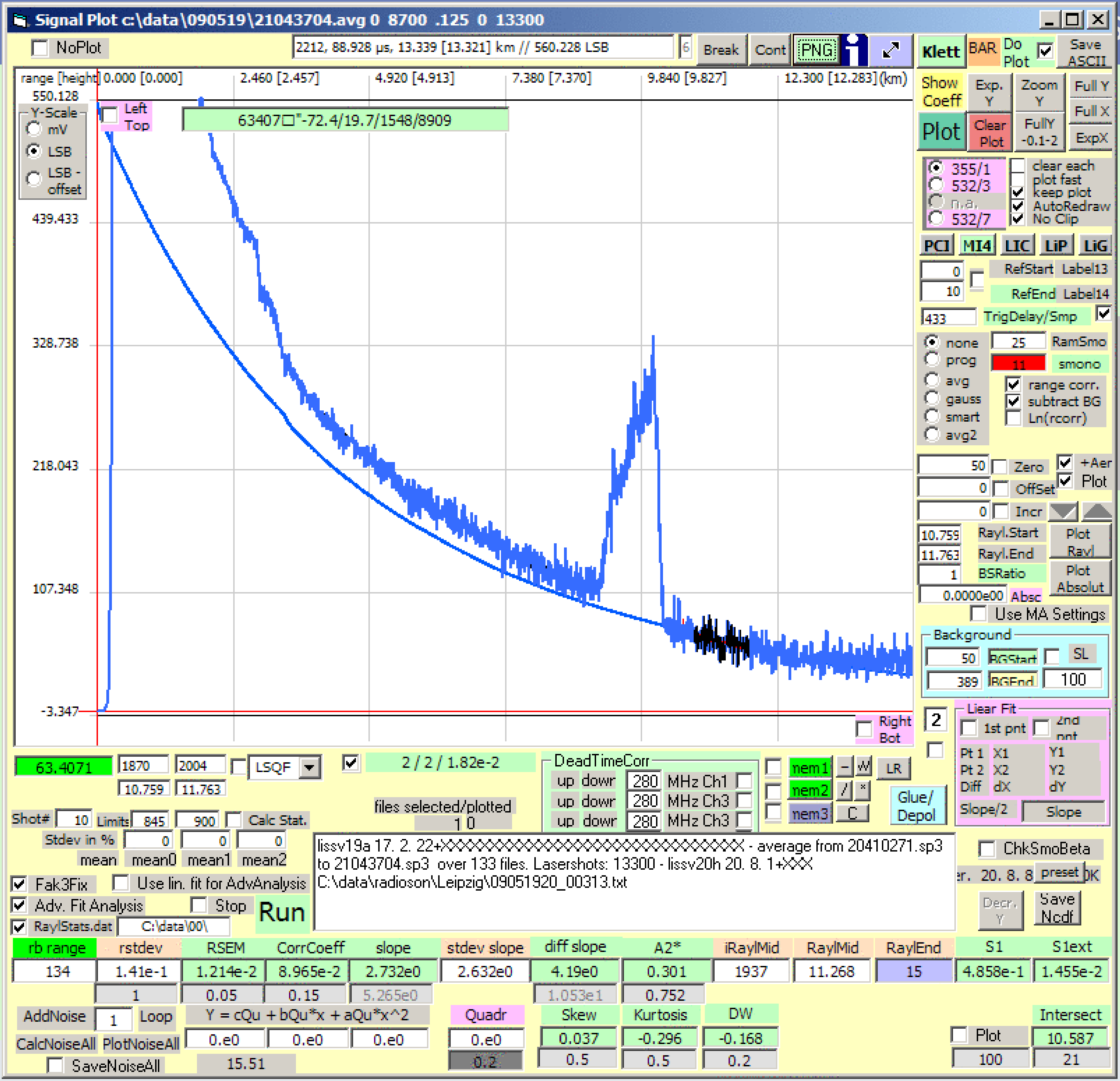
RS Atmospheric model 09/08/2010

bu_rf_100809_pc.opj, 11.08.10, Volker

Hypothesis:

If clean air => signal noise = gaussian

s?



Signal Plot c:\data\090519\21043704.avg 0 8700 .125 0 13300

☐ NoPlot

2212, 88.928 µs, 13.339 [13.321] km // 560.228 LSB

63407□"-72.4/19.7/1548/8909

63.4071 | 1870 | 2004 | ☐ LSQF

10.759 | 11.763

☑ 2 / 2 / 1.82e-2

Shot# 10 Limits 845 900 ☐ Calc Stat.

Stdev in % 0 0 0

mean mean0 mean1 mean2

files selected/plotted 1 0

DeadTimeCorr

up dowr 280 MHz Ch1 ☐

up dowr 280 MHz Ch3 ☐

up dowr 280 MHz Ch3 ☐

lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 20410271.sp3 to 21043704.sp3 over 133 files. Lasershots: 13300 - lissv20h 20. 8. 1+XXX
C:\data\radioson\Leipzig\09051920_00313.txt

☑ Fak3Fix ☐ Use lin. fit for AdvAnalysis

☑ Adv. Fit Analysis ☐ Stop

☑ RaylStats.dat C:\data\00\

rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	1.41e-1	1.214e-2	8.965e-2	2.732e0	2.632e0	4.19e0	0.301	1937	11.268	15	4.858e-1	1.455e-2
	1	0.05	0.15	5.265e0		1.053e1	0.752					

AddNoise 1 Loop

Y = cQu + bQu*x + aQu*x^2

			Quadr	Skew	Kurtosis	DW	Intersect
0.e0	0.e0	0.e0	0.e0	0.037	-0.296	-0.168	10.587
15.51			0.2	0.5	0.5	0.2	21

☐ SaveNoiseAll

☐ Plot 100

Rayleigh fit quality check – automatic fit algorithm

EARLINET-ASOS Madrid, 2009 => workshop reports

Make a Rayleigh Fit to the raw, unsmoothed range corrected lidar signal and
Calculate the differences / residuals (statistics in the signal is different from that in the residuals)

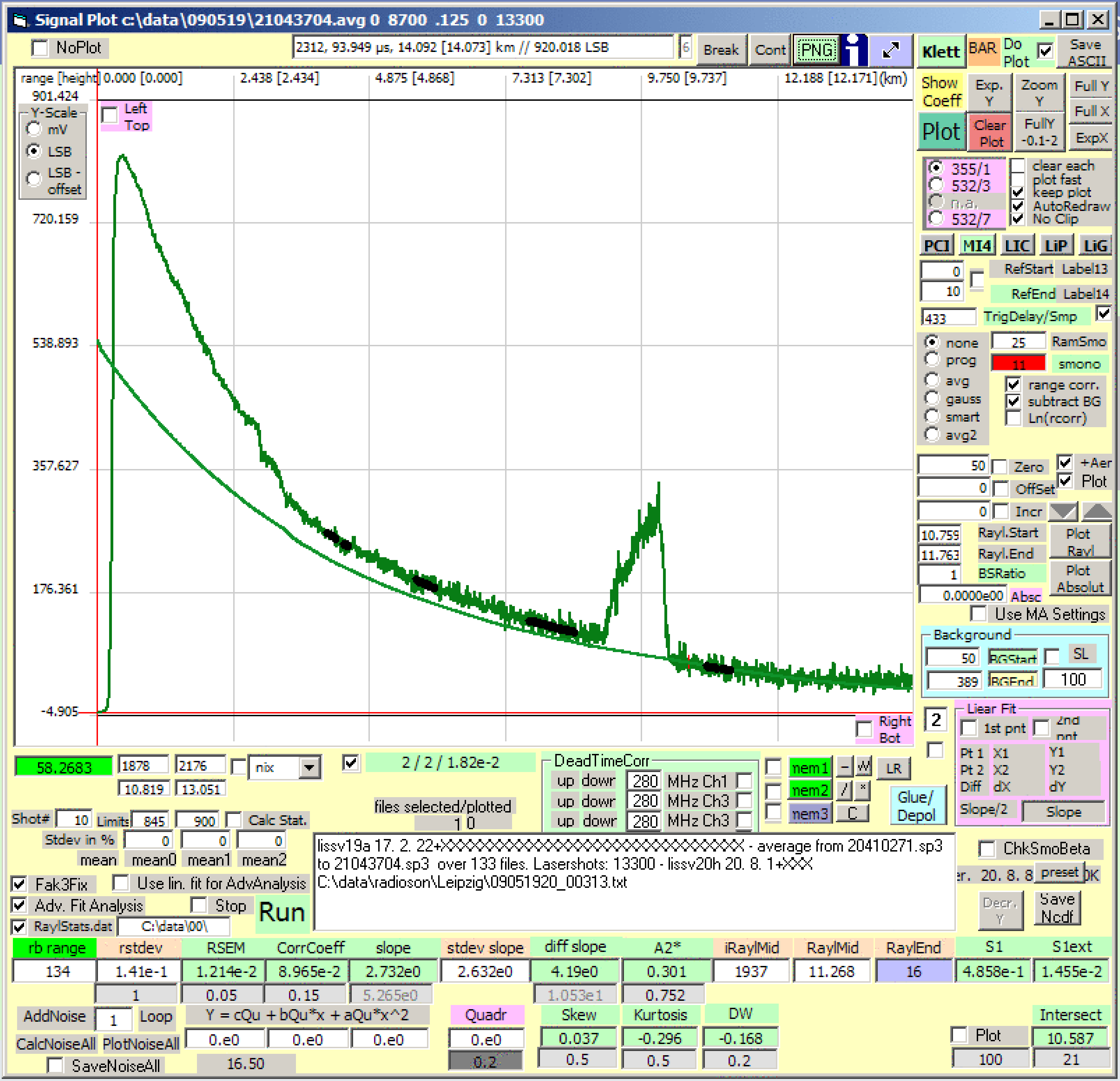
Calculate from the residual signal over an appropriate Rayleigh fit range (e.g 1km):

Local estimators

Anderson-Darling-Test => normal noise distribution?
Kurtosis => normal noise distribution?
Skewness => normal noise distribution?
Durbin–Watson-statistics => normal noise distribution?
Slope: local slope must not "significantly" deviate from Zero (i.e. the Rayleigh signal).
Correlation coefficient : seems to give similar information as slope
Curvature: Fit to polynomial (at least quadratic, advaced programming),
or DiffSlope: differential slope between first and second half of the fit range
Relative standard error of the mean (RSEM)

Global estimator

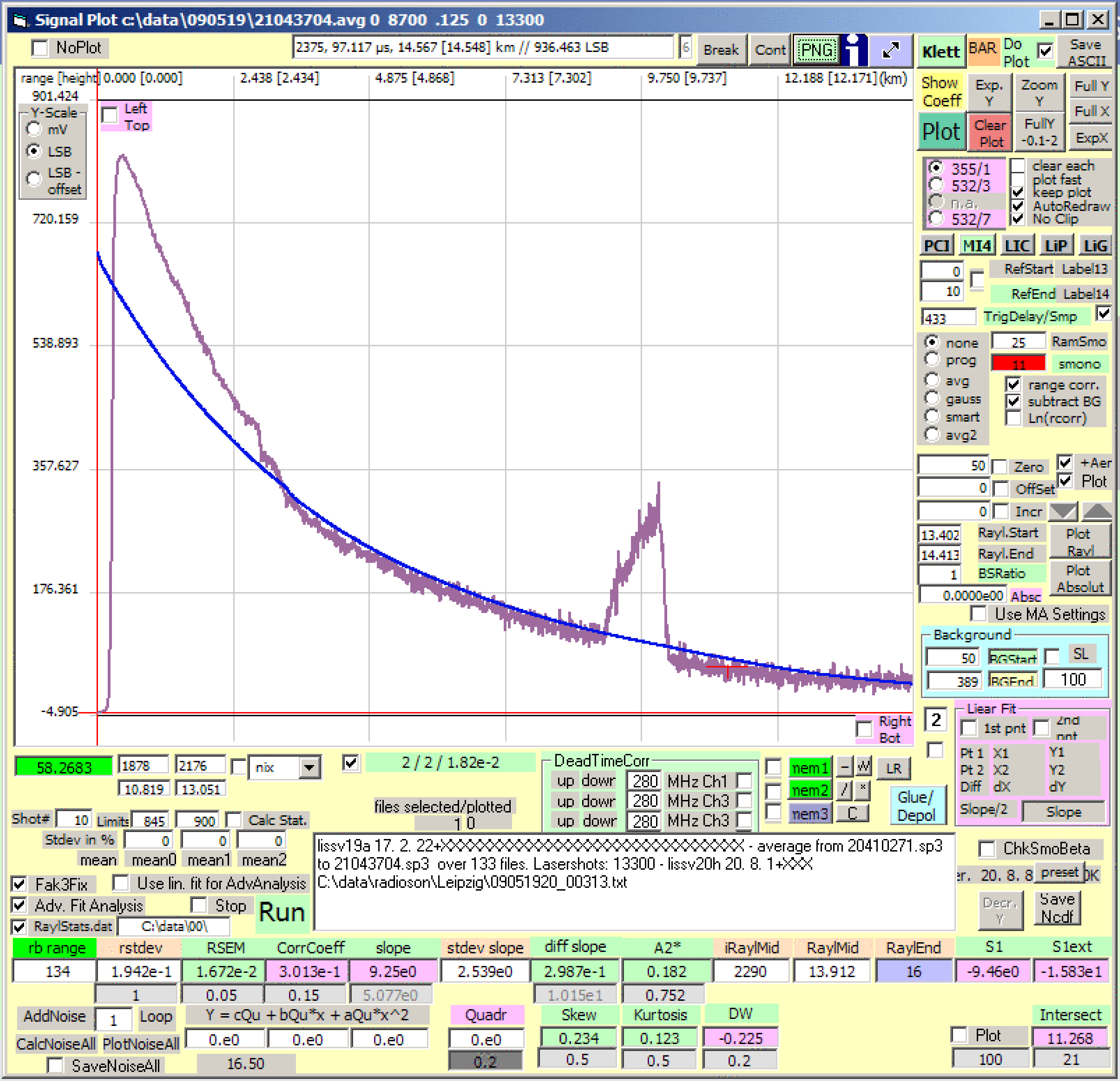
Cross: below the fitting range, residuals may not be smaller than Zero (regarding local noise)



lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 20410271.sp3 to 21043704.sp3 over 133 files. Lasershots: 13300 - lissv20h 20. 8. 1+XXX
C:\data\radioson\Leipzig\09051920_00313.txt

rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	1.41e-1	1.214e-2	8.965e-2	2.732e0	2.632e0	4.19e0	0.301	1937	11.268	16	4.858e-1	1.455e-2
	1	0.05	0.15	5.265e0		1.053e1	0.752					

s?



Signal Plot c:\data\090519\21043704.avg 0 8700 .125 0 13300

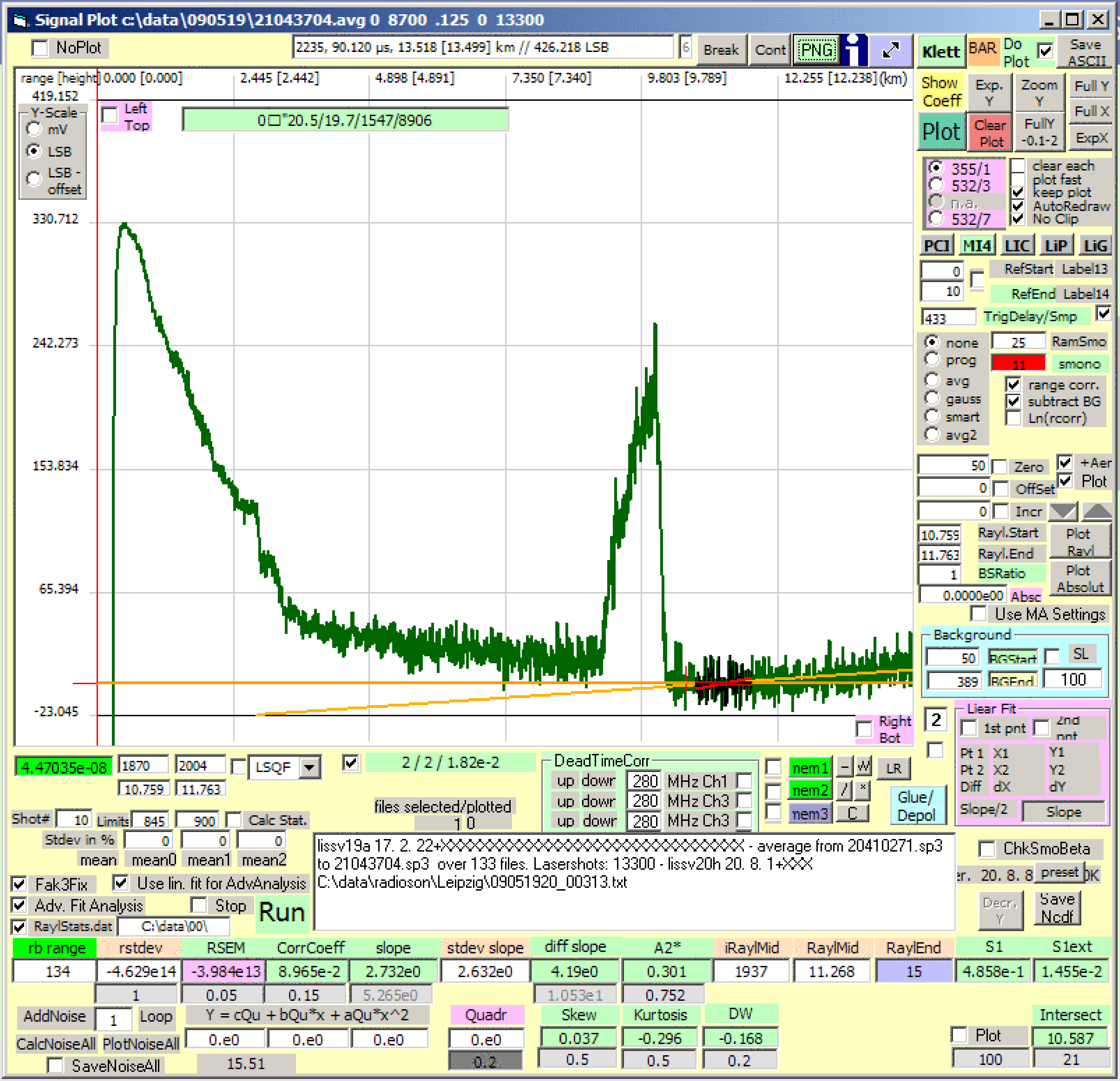
2375, 97.117 µs, 14.567 [14.548] km // 936.463 LSB

lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 20410271.sp3
to 21043704.sp3 over 133 files. Lasershots: 13300 - lissv20h 20. 8. 1+XXX
C:\data\radioson\Leipzig\09051920_00313.txt

rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	1.942e-1	1.672e-2	3.013e-1	9.25e0	2.539e0	2.987e-1	0.182	2290	13.912	16	-9.46e0	-1.583e1
	1	0.05	0.15	5.077e0		1.015e1	0.752					

Y = cQu + bQu*x + aQu*x^2: 0.e0 0.e0 0.e0

Quadr	Skew	Kurtosis	DW	Intersect
0.e0	0.234	0.123	-0.225	11.268
0.2	0.5	0.5	0.2	21



2235, 90.120 µs, 13.518 [13.499] km // 426.218 LSB

0□"20.5/19.7/1547/8906

RefStart 0, RefEnd 10, TrigDelay/Smp 433, RamSmo 25, smono 11

Zero 50, OffSet 0, Incr 0

Rayl.Start 10.759, Rayl.End 11.763, BSRatio 1, Absc 0.0000e00

BGStart 50, BGEnd 389, 100

4.47035e-08 | 1870 | 2004 | 10.759 | 11.763 | LSQF

☑ 2 / 2 / 1.82e-2

files selected/plotted 1 0

Shot# 10 Limits 845 900

Stdev in % 0 0 0

mean mean0 mean1 mean2

☑ Fak3Fix ☑ Use lin. fit for AdvAnalysis

☑ Adv. Fit Analysis

☑ RaylStats.dat C:\data\00\

lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 20410271.sp3
to 21043704.sp3 over 133 files. Lasershots: 13300 - lissv20h 20. 8. 1+XXX
C:\data\radioson\Leipzig\09051920_00313.txt

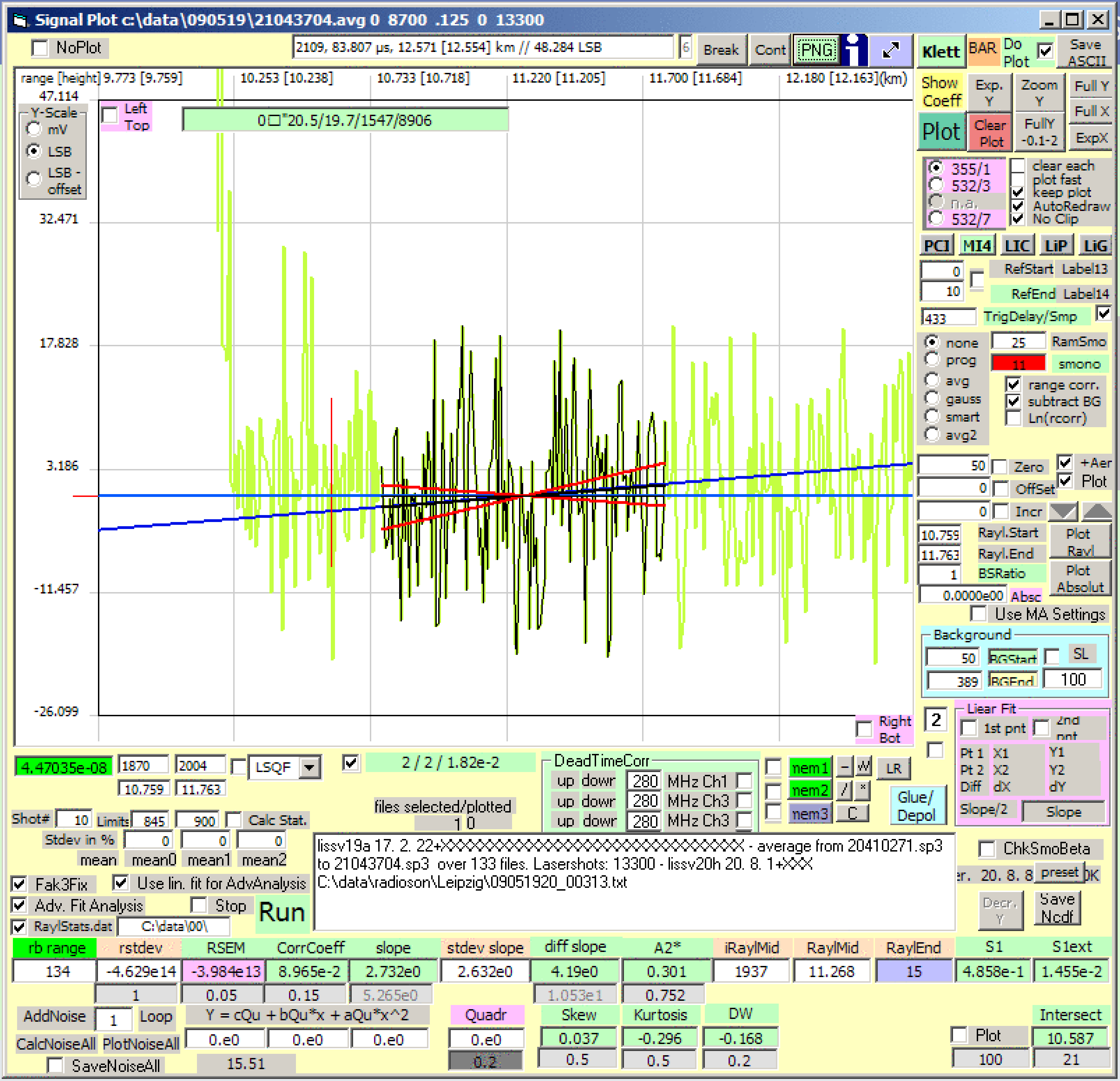
er. 20. 8. 8

rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	-4.629e14	-3.984e13	8.965e-2	2.732e0	2.632e0	4.19e0	0.301	1937	11.268	15	4.858e-1	1.455e-2
	1	0.05	0.15	5.265e0		1.053e1	0.752					

AddNoise 1 Loop

Y = cQu + bQu*x + aQu*x^2

			Quadr	Skew	Kurtosis	DW	Plot	Intersect
0.e0	0.e0	0.e0	0.e0	0.037	-0.296	-0.168		10.587
15.51			0.2	0.5	0.5	0.2	100	21



Signal Plot c:\data\090519\21043704.avg 0 8700 .125 0 13300

☐ NoPlot

2109, 83.807 µs, 12.571 [12.554] km // 48.284 LSB

0□"20.5/19.7/1547/8906

Y-Scale: ○ mV ● LSB ○ LSB - offset

☑ Do Plot

● 355/1 ○ 532/3 ○ n.a. ○ 532/7

☐ clear each plot fast
☑ keep plot
☑ AutoRedraw
☑ No Clip

RefStart 0
RefEnd 10
Label13
Label14
TrigDelay/Smp 433 ☑

● none ○ prog ○ avg ○ gauss ○ smart ○ avg2

RamSmo 25
smono 11

☑ range corr.
☑ subtract BG
☐ Ln(rcorr)

50 ☐ Zero
0 ☐ OffSet
0 ☐ Incr
☑ +Aer
☑ Plot

Rayl.Start 10.759
Rayl.End 11.763
BSRatio 1
Absc 0.0000e00

☐ Use MA Settings

Background: BGStart 50, BGEnd 389, ☐ SL 100

2

Liear Fit: ☐ 1st pnt ☐ 2nd pnt
Pt 1 X1 Y1
Pt 2 X2 Y2
Diff dX dY
Slope/2 Slope

4.47035e-08 | 1870 | 2004 | ☐ LSQF
10.759 | 11.763

☑ 2 / 2 / 1.82e-2

files selected/plotted 1 0

DeadTimeCorr
up dowr 280 MHz Ch1 ☐
up dowr 280 MHz Ch3 ☐
up dowr 280 MHz Ch3 ☐

☐ nem1 ☐ nem2 ☐ nem3

Shot# 10 Limits 845 900 ☐ Calc Stat.
Stdev in % 0 0 0
mean mean0 mean1 mean2

☑ Fak3Fix ☑ Use lin. fit for AdvAnalysis
☑ Adv. Fit Analysis ☐ Stop
☑ RaylStats.dat C:\data\00\

lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 20410271.sp3
to 21043704.sp3 over 133 files. Lasershots: 13300 - lissv20h 20. 8. 1+XXX
C:\data\radioson\Leipzig\09051920_00313.txt

☐ ChkSmoBeta
r. 20. 8. 8

rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	-4.629e14	-3.984e13	8.965e-2	2.732e0	2.632e0	4.19e0	0.301	1937	11.268	15	4.858e-1	1.455e-2
	1	0.05	0.15	5.265e0		1.053e1	0.752					

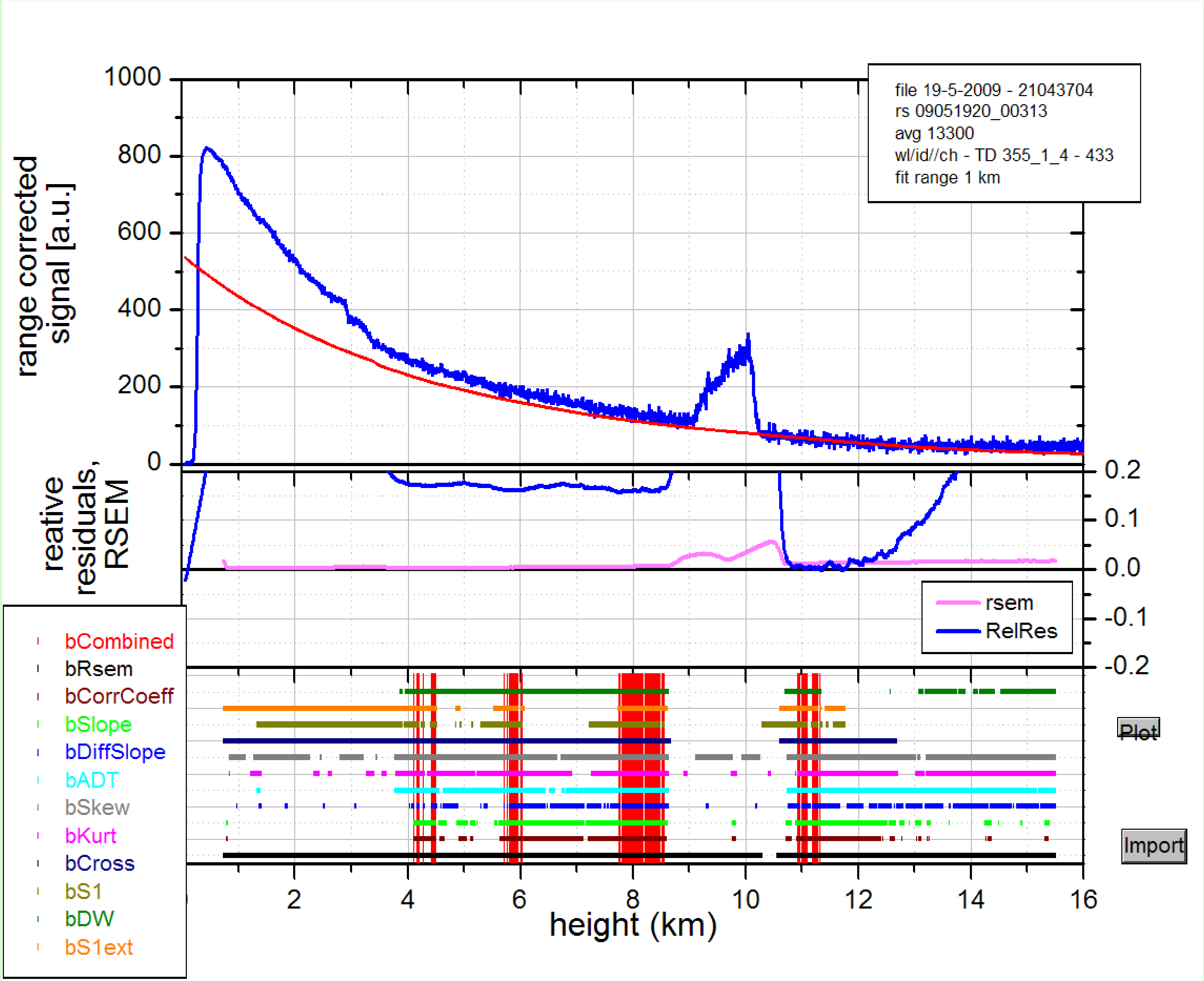
AddNoise 1 Loop

Y = cQu + bQu*x + aQu*x^2

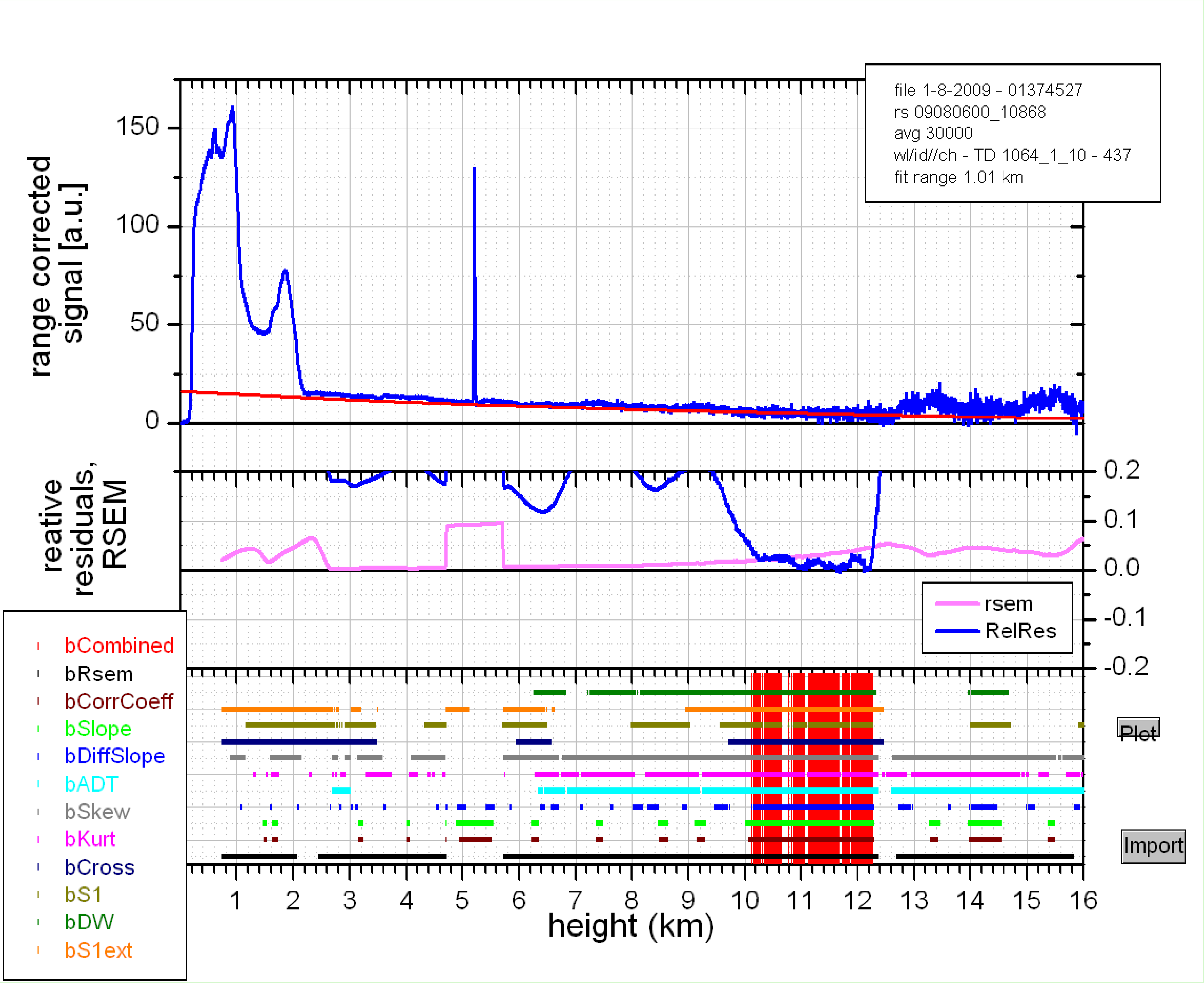
			Quadr	Skew	Kurtosis	DW	☐ Plot	Intersect
0.e0	0.e0	0.e0	0.e0	0.037	-0.296	-0.168		10.587
15.51			0.2	0.5	0.5	0.2	100	21

☐ SaveNoiseAll

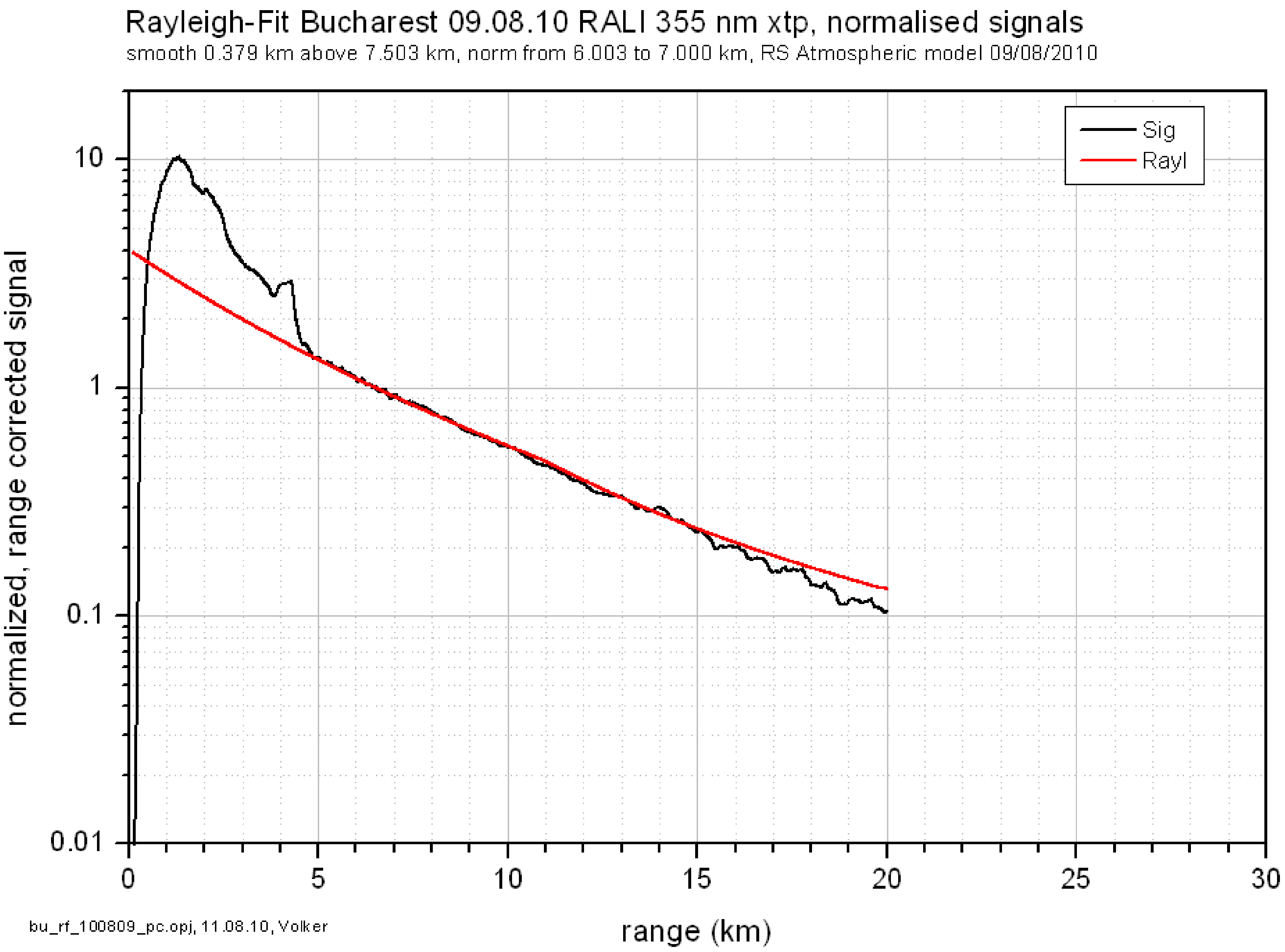
Internal checkup tools – Rayleigh fit quality check



Internal checkup tools – Rayleigh fit quality check



Background subtraction – too early in far range => pretrigger



Internal checkup tools – Dark signal measurements

- Rayleigh fit

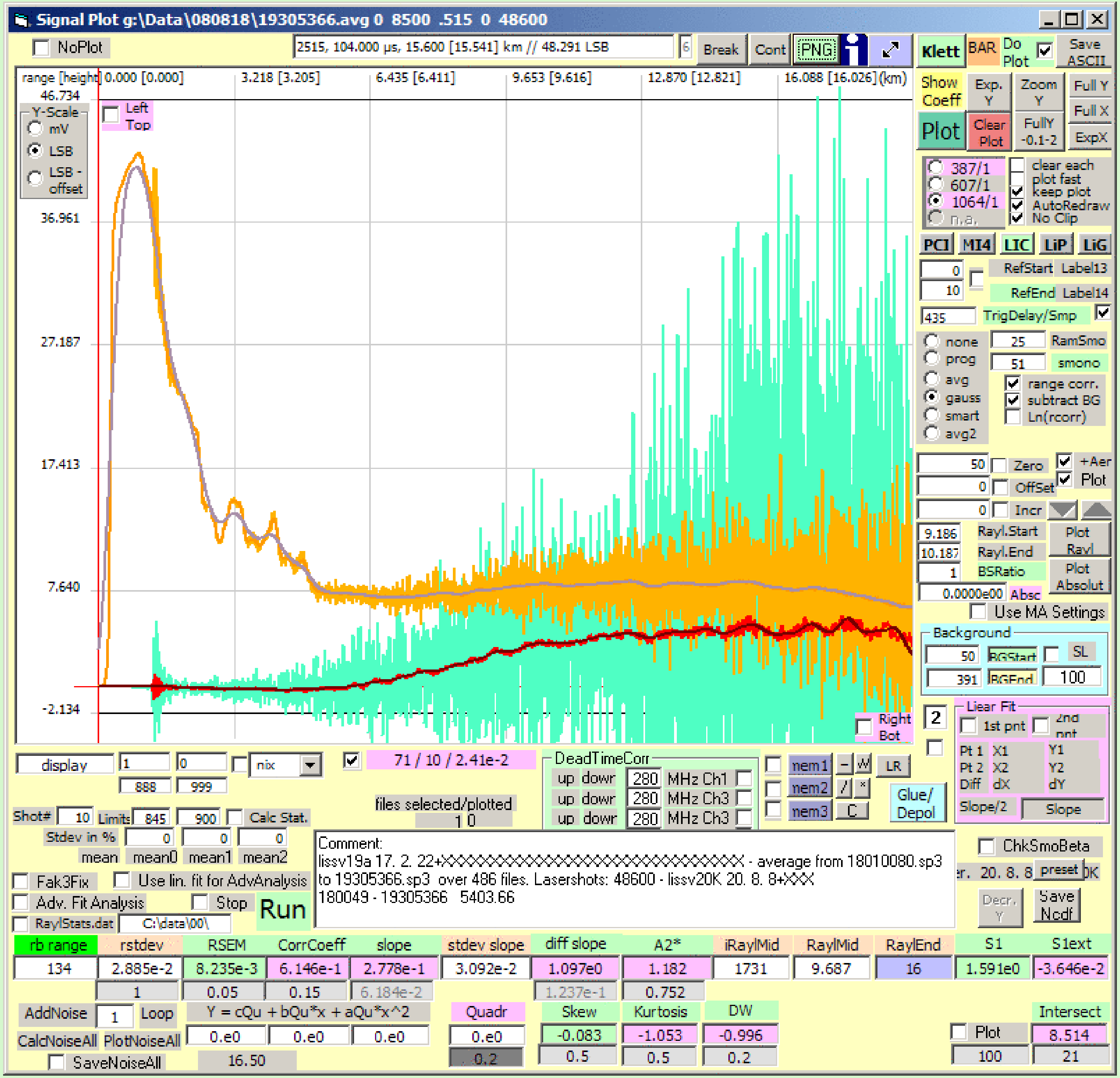
- Dark signal measurement => Background subtraction
- Electronic pulse generator for analog channels (MPI)

- Trigger delay / zero bin

- Telecover
- Raytracing

- Upcomming: Polarimeter => diattenuation (IfT)

Background – dark signal subtraction possible 1064 nm LICEL



Signal Plot g:\Data\080818\19305366.avg 0 8500 .515 0 48600

2515, 104.000 µs, 15.600 [15.541] km // 48.291 LSB

○ 387/1
○ 607/1
● 1064/1
○ n.a.

☐ clear each plot fast
☑ keep plot
☑ AutoRedraw
☑ No Clip

RefStart 0, RefEnd 10

435 TrigDelay/Smp ☑

● gauss; RamSmo 25; smono 51

☑ range corr.
☑ subtract BG
☐ Ln(rcorr)

50 ☐ Zero; 0 ☐ OffSet; 0 ☐ Incr

9.186 Rayl.Start
10.187 Rayl.End
1 BSRatio
0.0000e00 Absc

☐ Use MA Settings

Background: 50 BGStart, 391 BGEnd, SL 100

Linear Fit: 2

display 1 0, 888 999

☑ 71 / 10 / 2.41e-2

files selected/plotted 1 0

DeadTimeCorr: 280 MHz Ch1, 280 MHz Ch3, 280 MHz Ch3

Shot# 10, Limits 845 900, ☐ Calc Stat.

Stdev in %: 0 0 0 — mean, mean0, mean1, mean2

☐ Fak3Fix
☐ Use lin. fit for AdvAnalysis
☐ Adv. Fit Analysis
☐ Stop
☐ RaylStats.dat C:\data\00\

Comment:
lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 18010080.sp3 to 19305366.sp3 over 486 files. Lasershots: 48600 - lissv20K 20. 8. 8+XXX
180049 - 19305366 5403.66

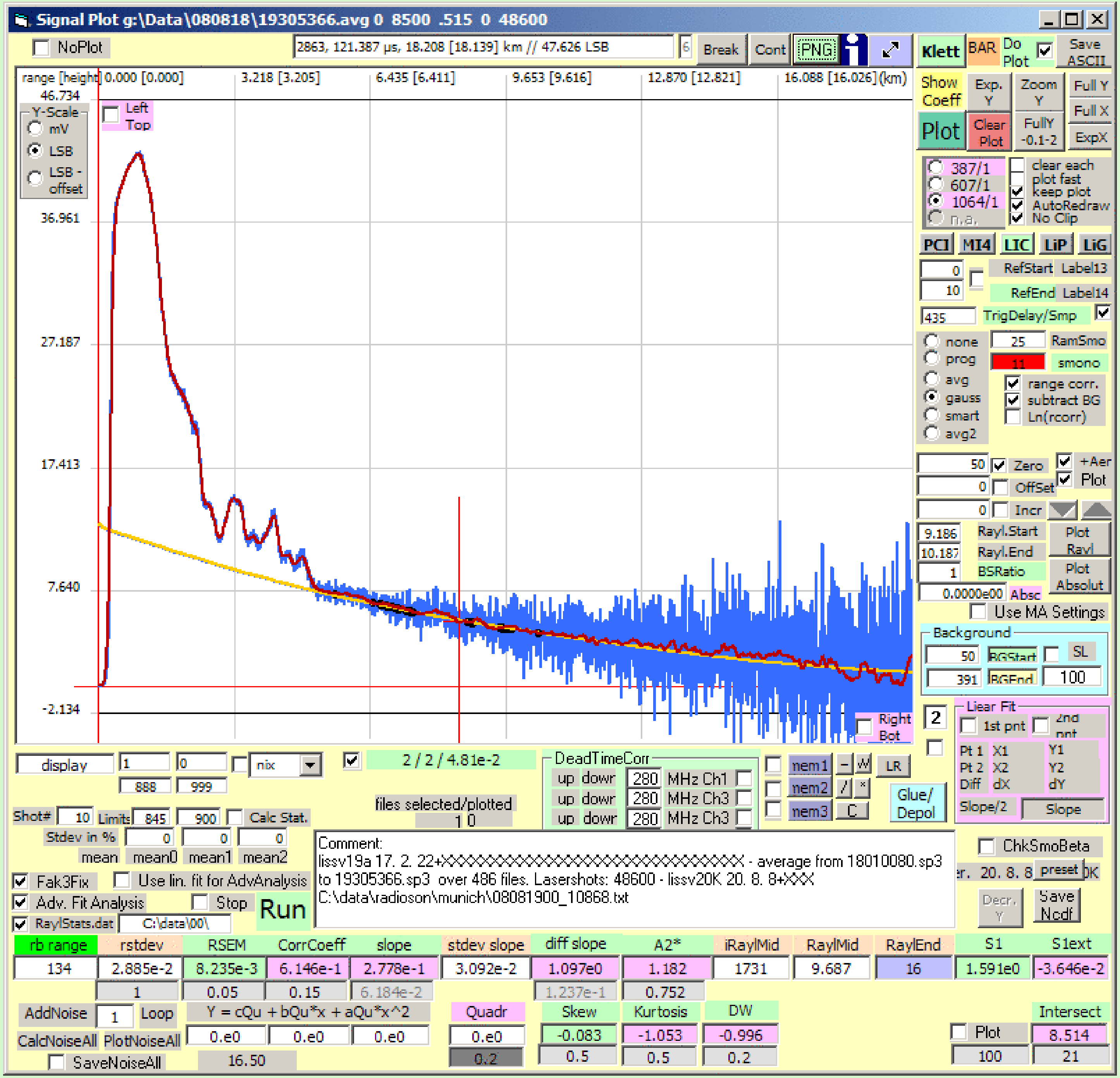
rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	2.885e-2	8.235e-3	6.146e-1	2.778e-1	3.092e-2	1.097e0	1.182	1731	9.687	16	1.591e0	-3.646e-2
	1	0.05	0.15	6.184e-2		1.237e-1	0.752					

AddNoise 1 Loop; Y = cQu + bQu*x + aQu*x^2: 0.e0 0.e0 0.e0; 16.50

Quadr	Skew	Kurtosis	DW	Intersect
0.e0	-0.083	-1.053	-0.996	8.514
0.2	0.5	0.5	0.2	21

☐ Plot 100

Background – dark signal subtraction possible 1064 nm LICEL



Signal Plot g:\Data\080818\19305366.avg 0 8500 .515 0 48600

☐ NoPlot

2863, 121.387 µs, 18.208 [18.139] km // 47.626 LSB

Y-Scale: ○ mV ● LSB ○ LSB - offset

○ 387/1 ○ 607/1 ● 1064/1 ○ n.a.

☐ clear each plot fast ☑ keep plot ☑ AutoRedraw ☑ No Clip

RefStart 0 ☐ Label13
RefEnd 10 Label14
TrigDelay/Smp 435 ☑

○ none ○ prog ○ avg ● gauss ○ smart ○ avg2
RamSmo 25
smono 11
☑ range corr. ☑ subtract BG ☐ Ln(rcorr)

50 ☑ Zero ☑ +Aer
0 ☐ OffSet ☑ Plot
0 ☐ Incr

Rayl.Start 9.186
Rayl.End 10.187
BSRatio 1
Absc 0.0000e00
☐ Use MA Settings

Background: BGStart 50 ☐ SL
BGEnd 391 100

Liear Fit: 2 ☐ 1st pnt ☐ 2nd pnt
Pt 1 X1 Y1
Pt 2 X2 Y2
Diff dX dY
Slope/2 Slope

display 1 0 ☐ nix
888 999
☑ 2 / 2 / 4.81e-2
files selected/plotted 1 0

DeadTimeCorr
up dowr 280 MHz Ch1 ☐
up dowr 280 MHz Ch3 ☐
up dowr 280 MHz Ch3 ☐

nem1 nem2 nem3

Shot# 10 Limits 845 900 ☐ Calc Stat.
Stdev in % 0 0 0
mean mean0 mean1 mean2

☑ Fak3Fix ☐ Use lin. fit for AdvAnalysis
☑ Adv. Fit Analysis ☐ Stop
☑ RaylStats.dat C:\data\00\

Comment:
lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 18010080.sp3
to 19305366.sp3 over 486 files. Lasershots: 48600 - lissv20K 20. 8. 8+XXX
C:\data\radioson\munich\08081900_10868.txt

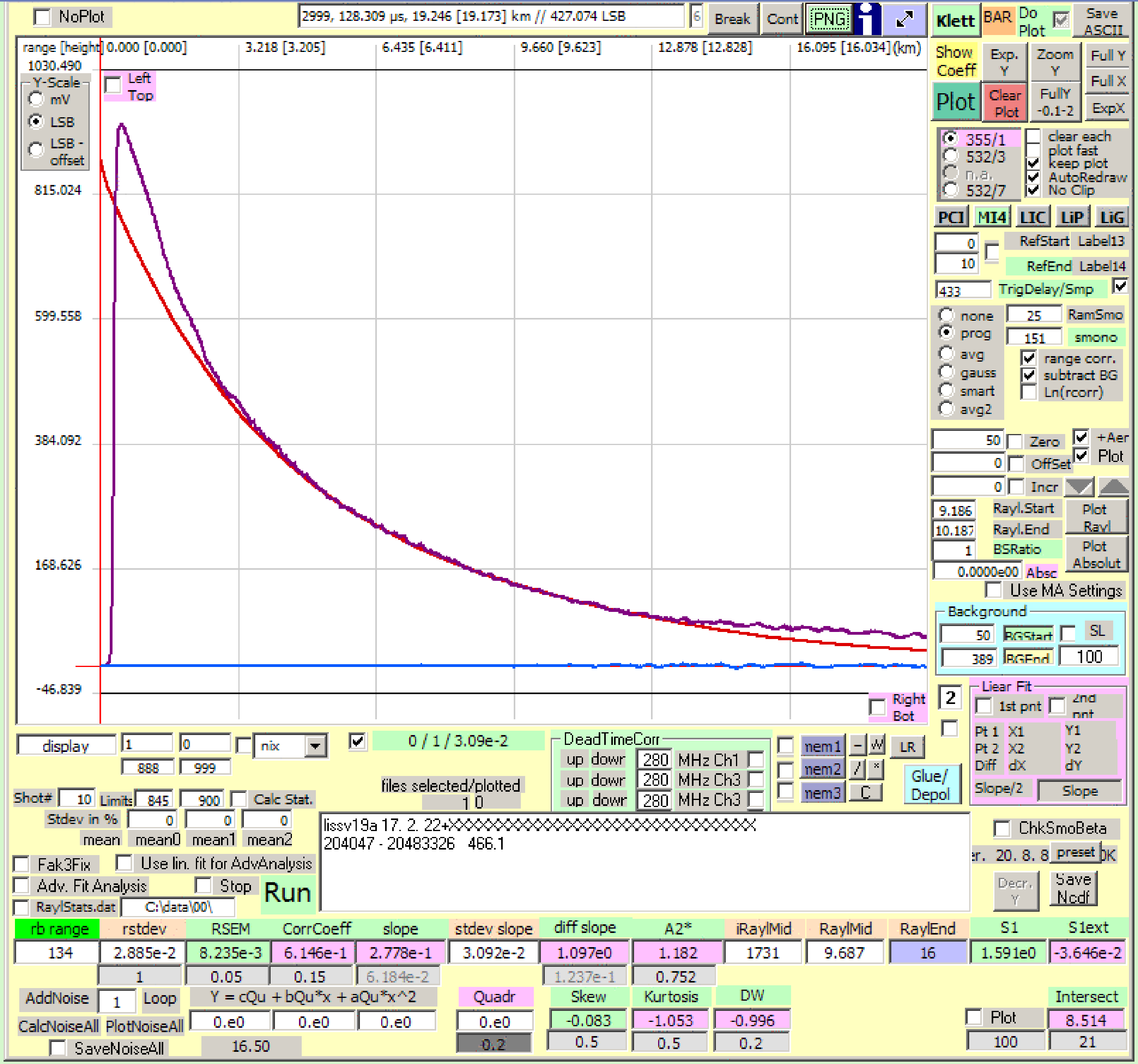
☐ ChkSmoBeta
r. 20. 8. 8 preset OK

rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	2.885e-2	8.235e-3	6.146e-1	2.778e-1	3.092e-2	1.097e0	1.182	1731	9.687	16	1.591e0	-3.646e-2
	1	0.05	0.15	6.184e-2		1.237e-1	0.752					

AddNoise 1 Loop
CalcNoiseAll PlotNoiseAll
☐ SaveNoiseAll 16.50

Y = cQu + bQu*x + aQu*x^2: 0.e0 0.e0 0.e0
Quadr 0.e0 0.2
Skew -0.083 0.5
Kurtosis -1.053 0.5
DW -0.996 0.2
☐ Plot 100
Intersect 8.514 21

Background subtraction – signal induced errors
here dark measurement subtraction not possible on 355 channel



2999, 128.309 µs, 19.246 [19.173] km // 427.074 LSB

RefStart 0, RefEnd 10, TrigDelay/Smp 433, RamSmo 25, smono 151

Zero 50, OffSet 0, Incr 0

Rayl.Start 9.186, Rayl.End 10.187, BSRatio 1, Absc 0.0000e00

BGStart 50, BGEnd 389, SL 100

display 1 0, 888 999

0 / 1 / 3.09e-2

files selected/plotted 1 0

Shot# 10, Limits 845 900

Stdev in % 0 0 0

C:\data\00\

lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
204047 - 20483326 466.1

rb range	rstdev	RSEM	CorrCoeff	slope	stdev slope	diff slope	A2*	iRaylMid	RaylMid	RaylEnd	S1	S1ext
134	2.885e-2	8.235e-3	6.146e-1	2.778e-1	3.092e-2	1.097e0	1.182	1731	9.687	16	1.591e0	-3.646e-2
	1	0.05	0.15	6.184e-2		1.237e-1	0.752					

AddNoise 1 Loop

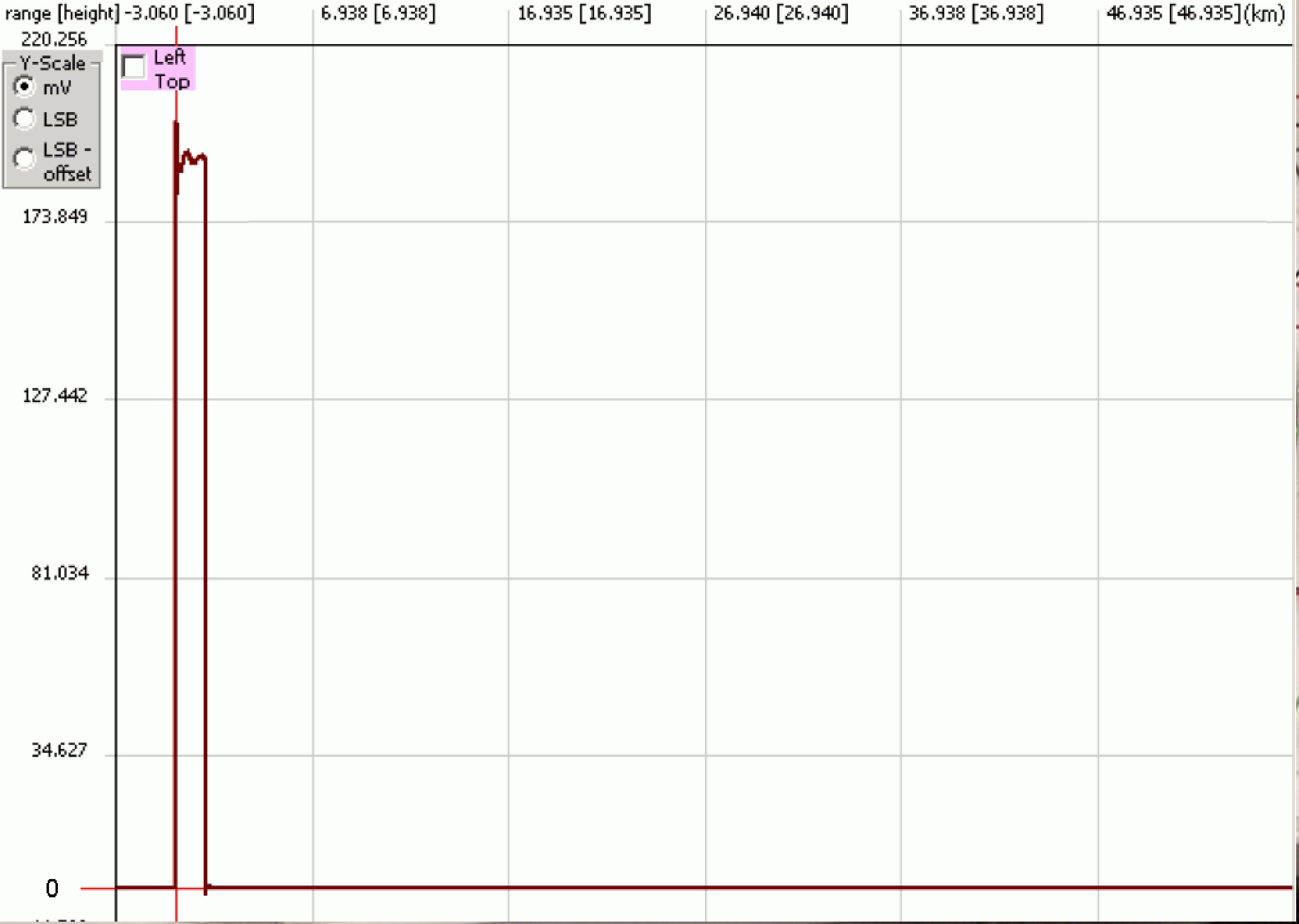
Y = cQu + bQu*x + aQu*x^2: 0.e0 0.e0 0.e0

16.50

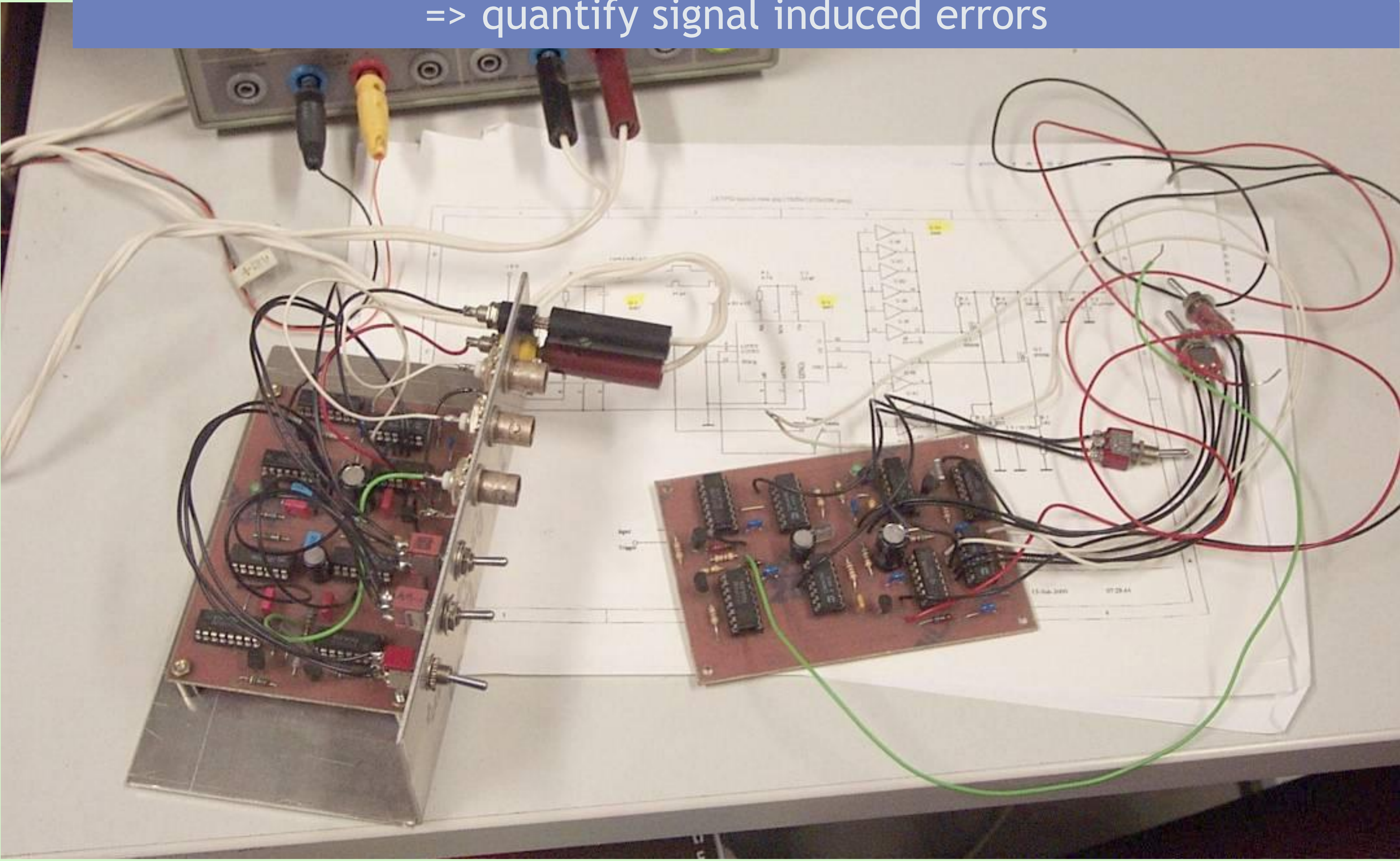
Quadr	Skew	Kurtosis	DW	Intersect
0.e0	-0.083	-1.053	-0.996	8.514
0.2	0.5	0.5	0.2	21

Plot 100

Internal checkup tools – Pulse generator
=> produce 10 µs pulse without longtime under-/overshoot
=> quantify signal induced errors



Internal checkup tools – Old Pulse generator – Munich/Leipzig
=> produce 10 µs pulse without longtime under-/overshoot
=> quantify signal induced errors



MPI pulse generator for test of analog data acquisition

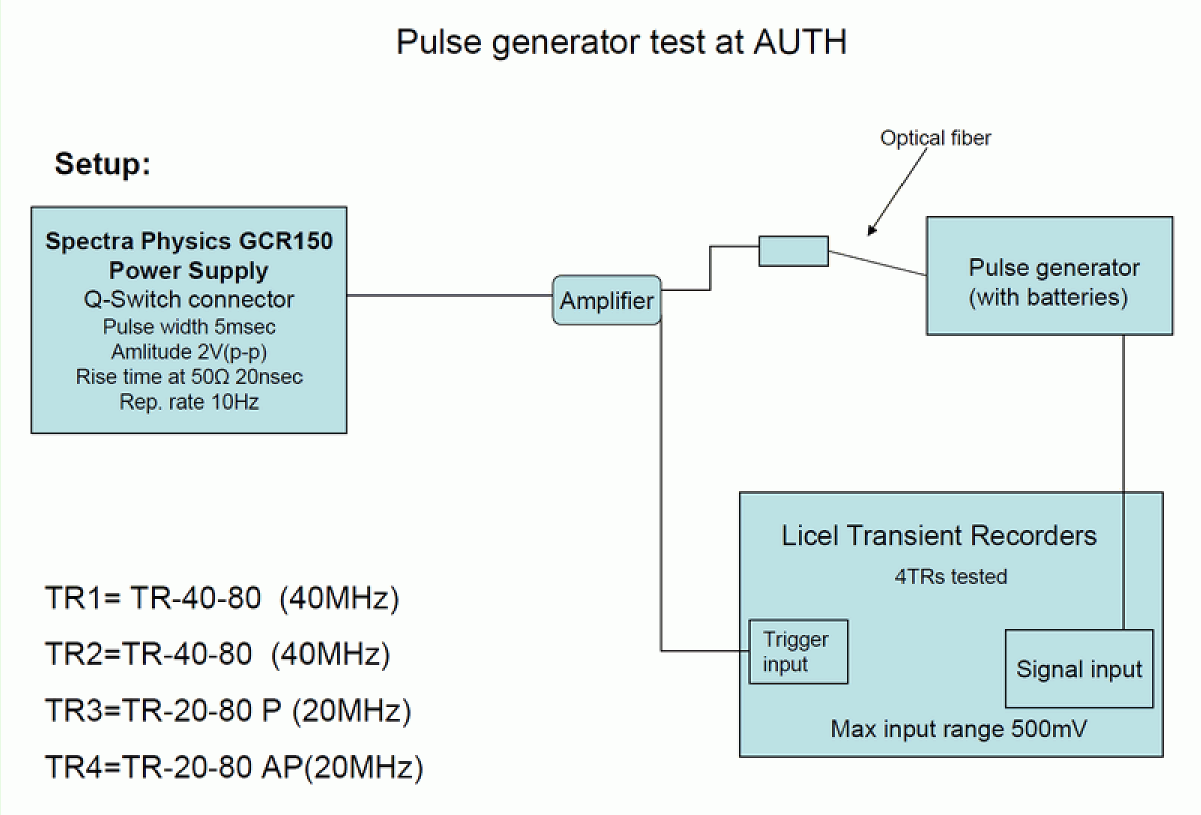
- **NEVER** !! connect more than one output at the same time
- Output Voltages (with new batteries) are
  - 616 mV at the 750 mV port
  - 148 mV at the 150 mV port
  - 44 mV at the 50 mV port
  - 8.8 mV at the 10 mV port
- Pulse length fixed to 10µs

www.earlinet-asos.org

Internal checkup tools - Pulse generator

Used for tests in

- Munich
- Barcelona
- Hamburg
- Athens
- Leipzig
- Madrid
- Thessaloniki
- Munich
- Napoli
- Potenza
- Lecce
- Granada



Pulse generator test at AUTH

Setup:

Spectra Physics GCR150
Power Supply
Q-Switch connector
Pulse width 5msec
Amlitude 2V(p-p)
Rise time at 50Ω 20nsec
Rep. rate 10Hz

Amplifier

Optical fiber

Pulse generator
(with batteries)

Licel Transient Recorders
4TRs tested

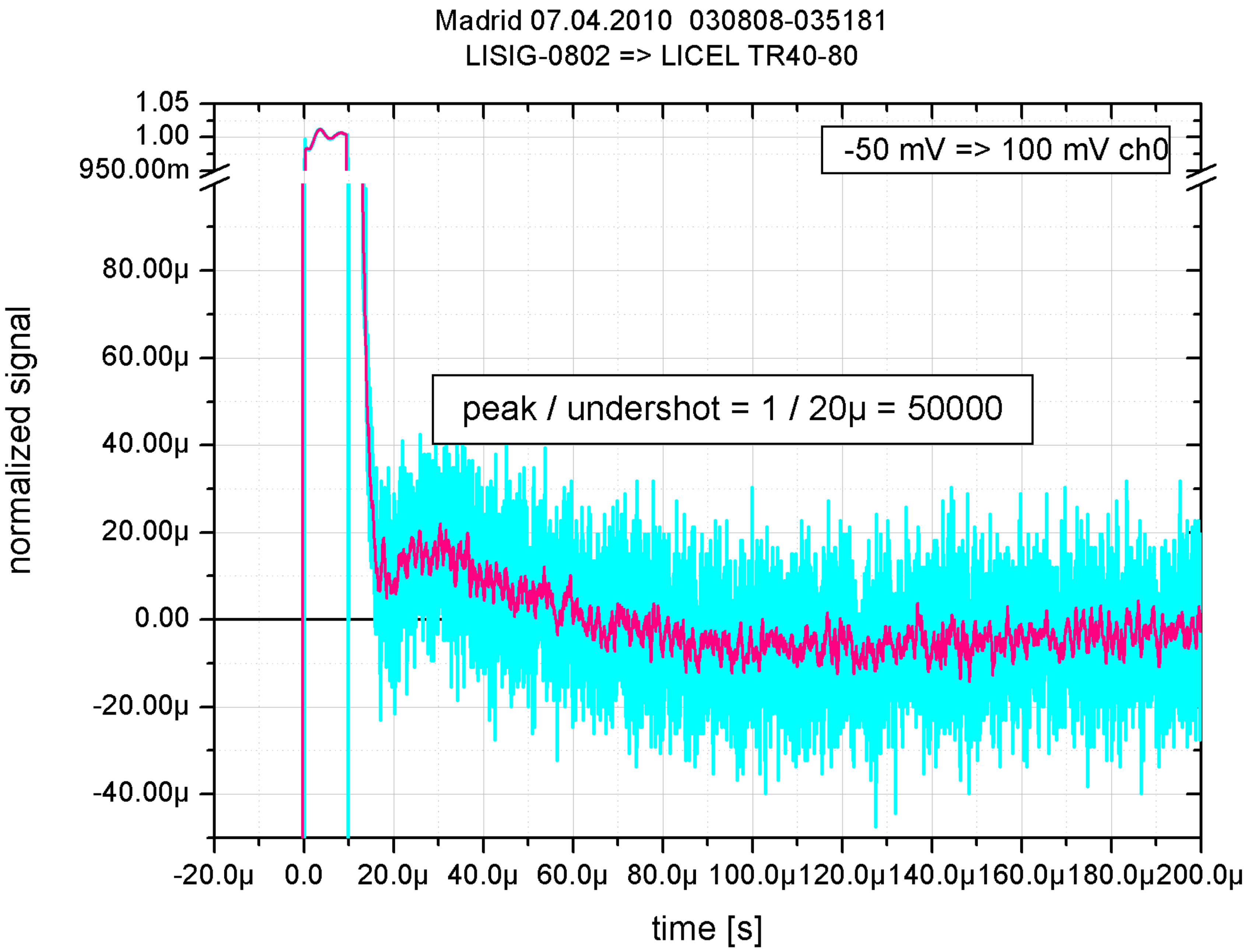
Trigger input

Signal input

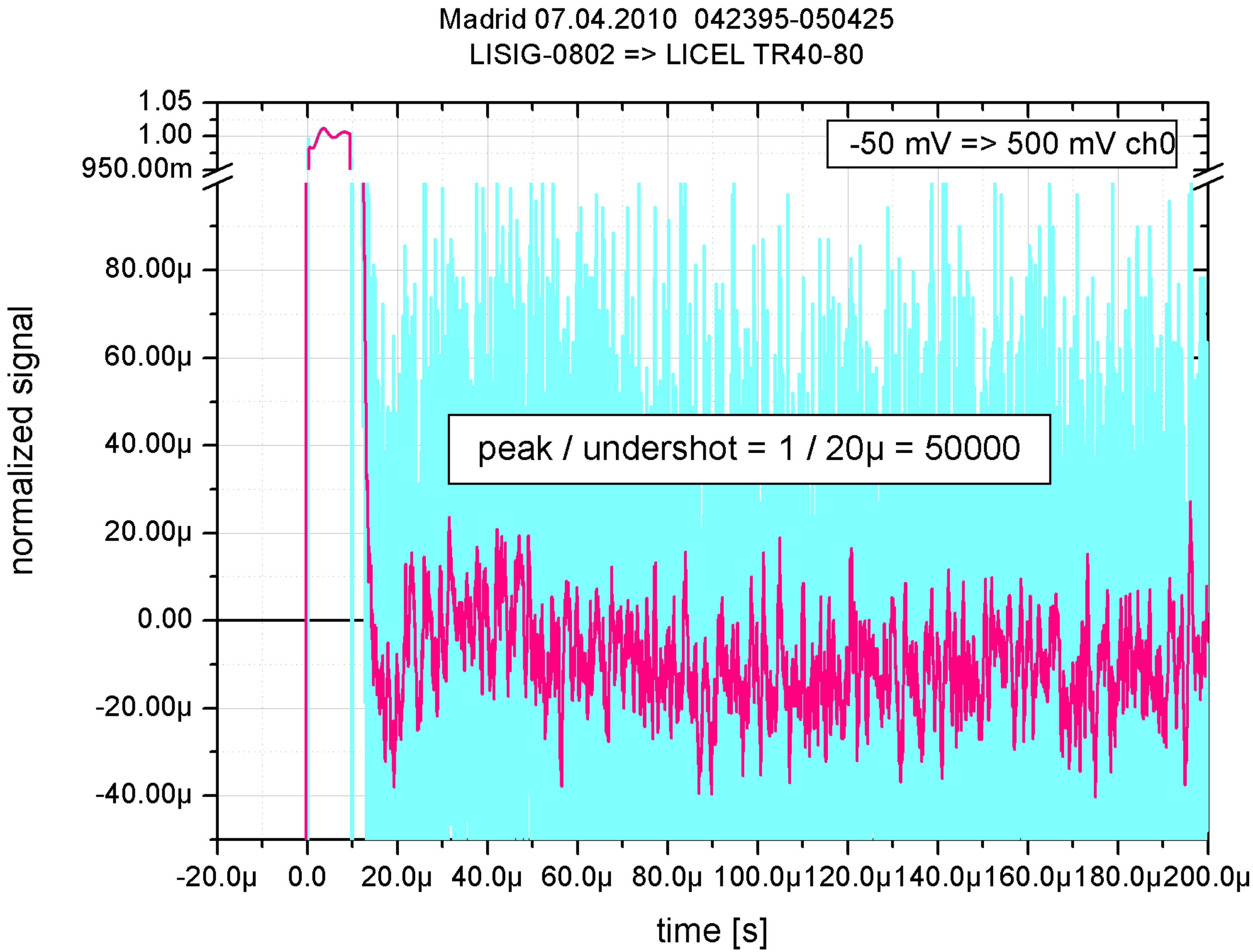
Max input range 500mV

TR1= TR-40-80 (40MHz)
TR2=TR-40-80 (40MHz)
TR3=TR-20-80 P (20MHz)
TR4=TR-20-80 AP(20MHz)

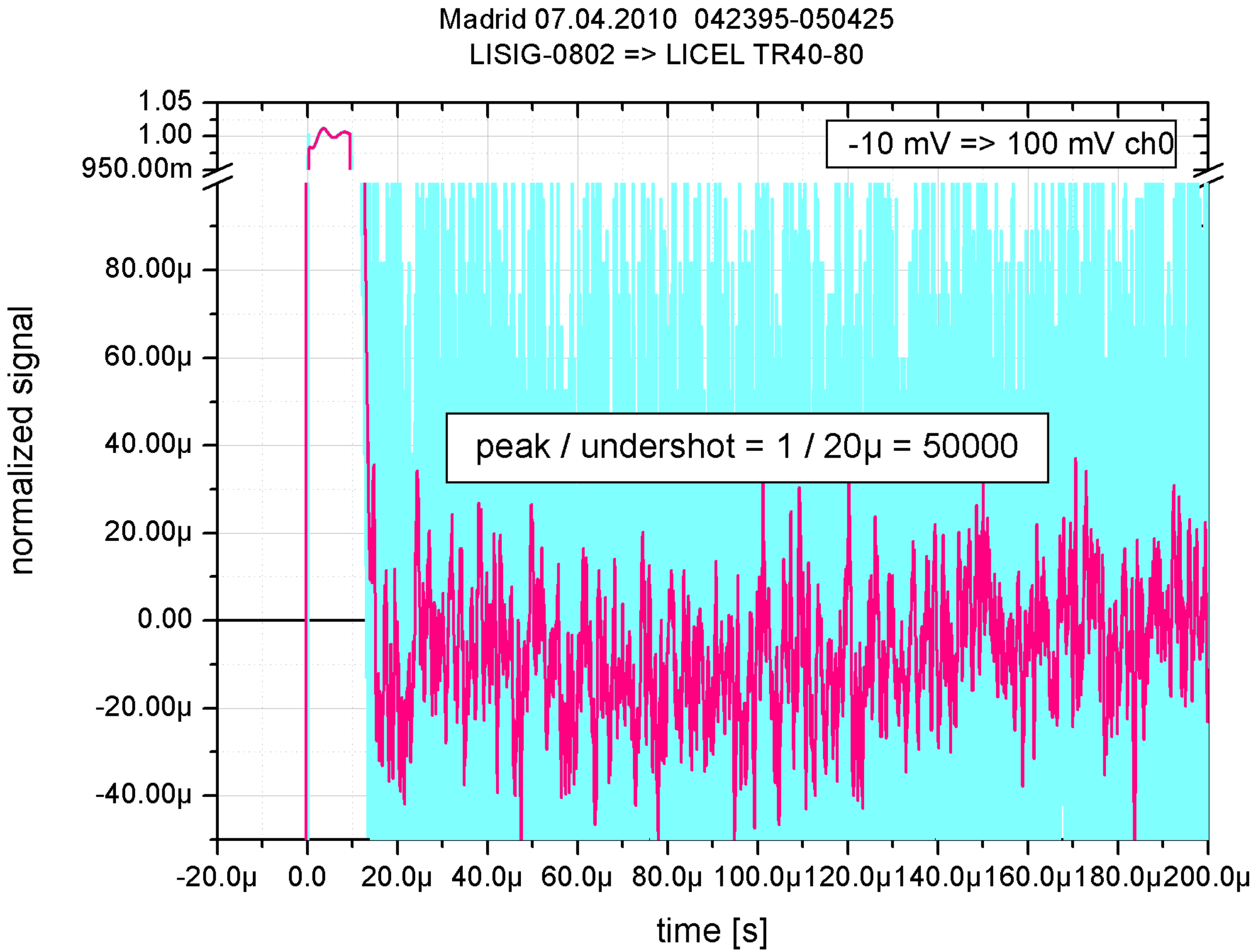
Internal checkup tools - Pulse generator



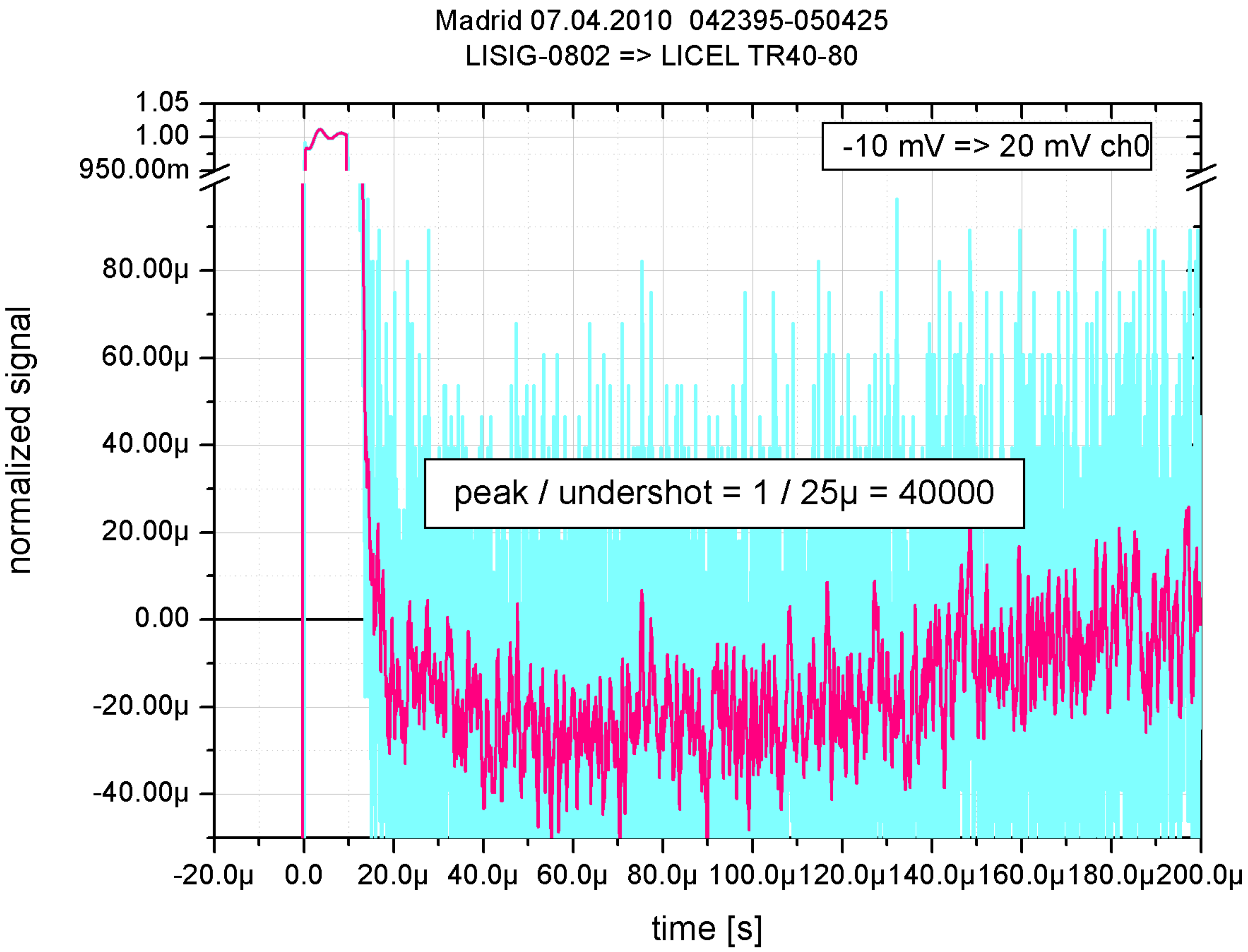
Internal checkup tools - Pulse generator



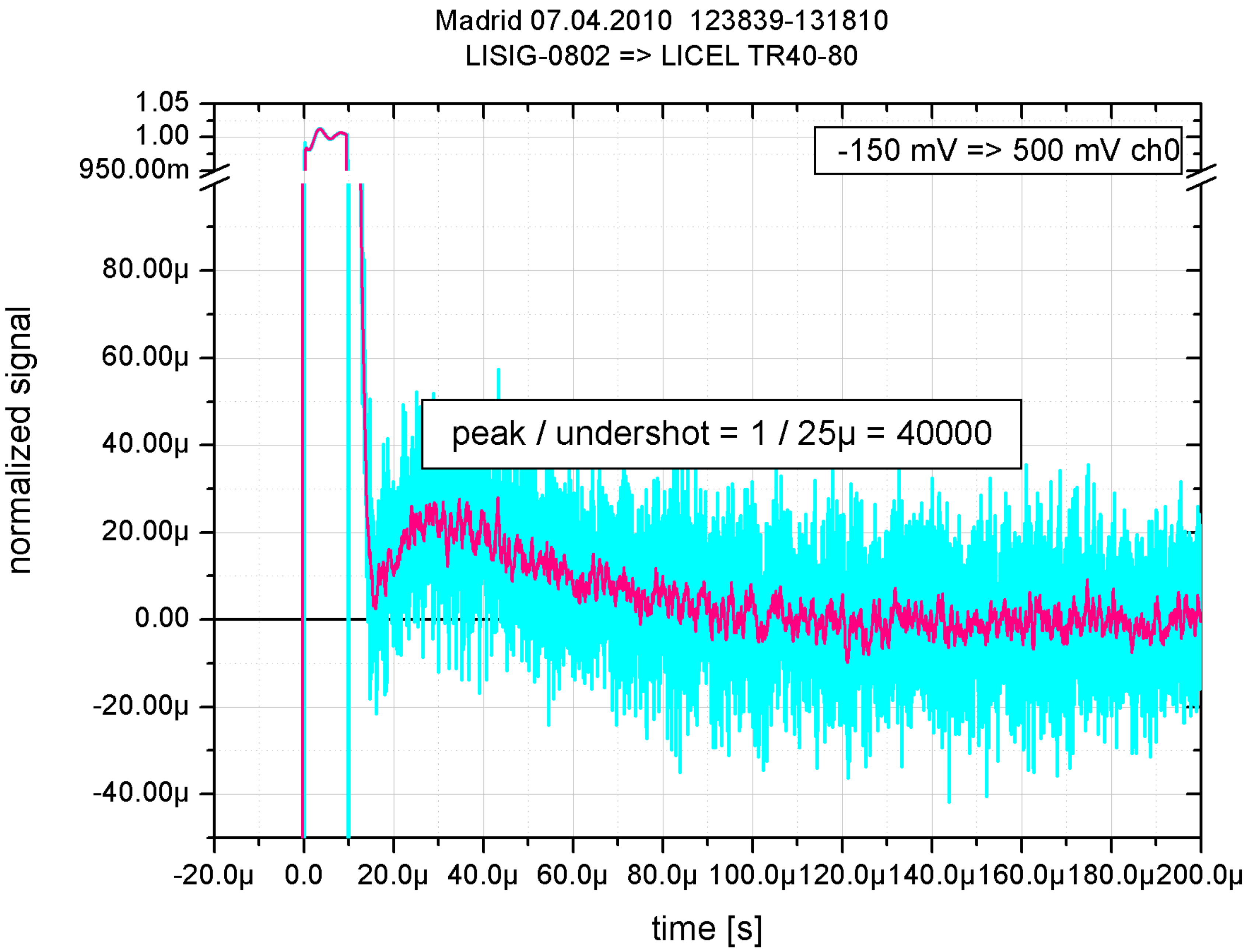
Internal checkup tools - Pulse generator



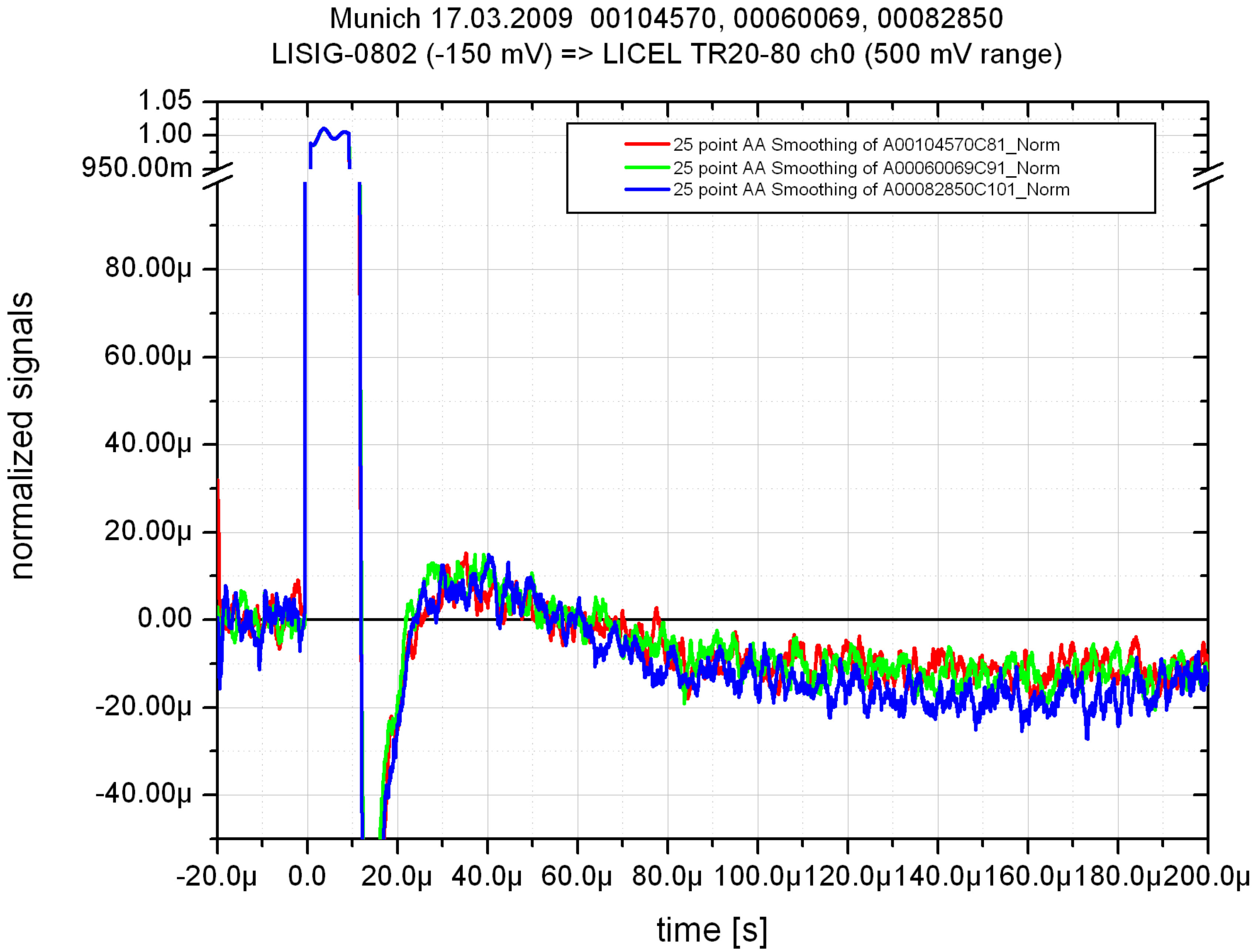
Internal checkup tools - Pulse generator



Internal checkup tools - Pulse generator



Internal checkup tools - Pulse generator – Pretrigger



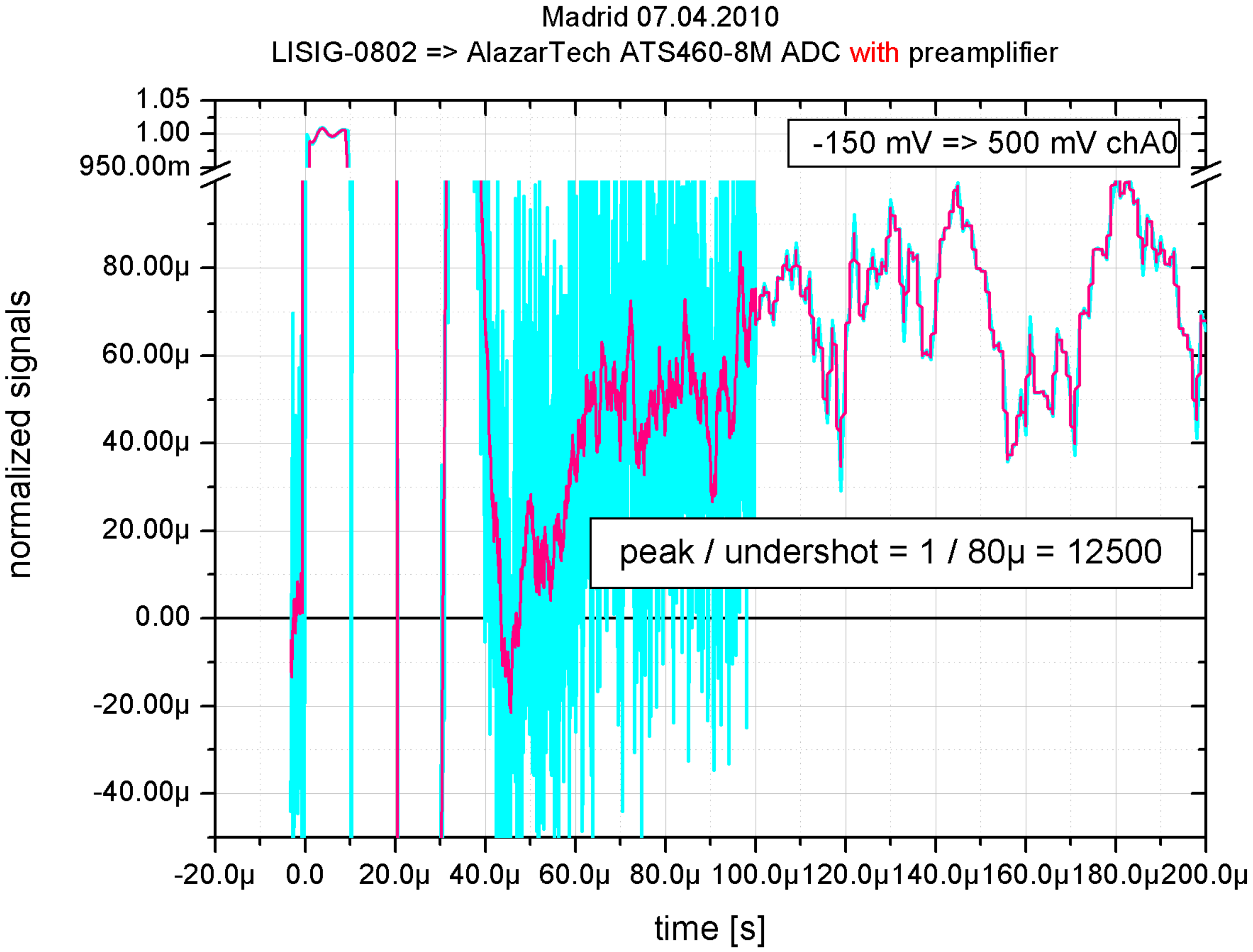
Internal checkup tools - Pulse generator

PCI Digitizers
BY ALAZARTECH

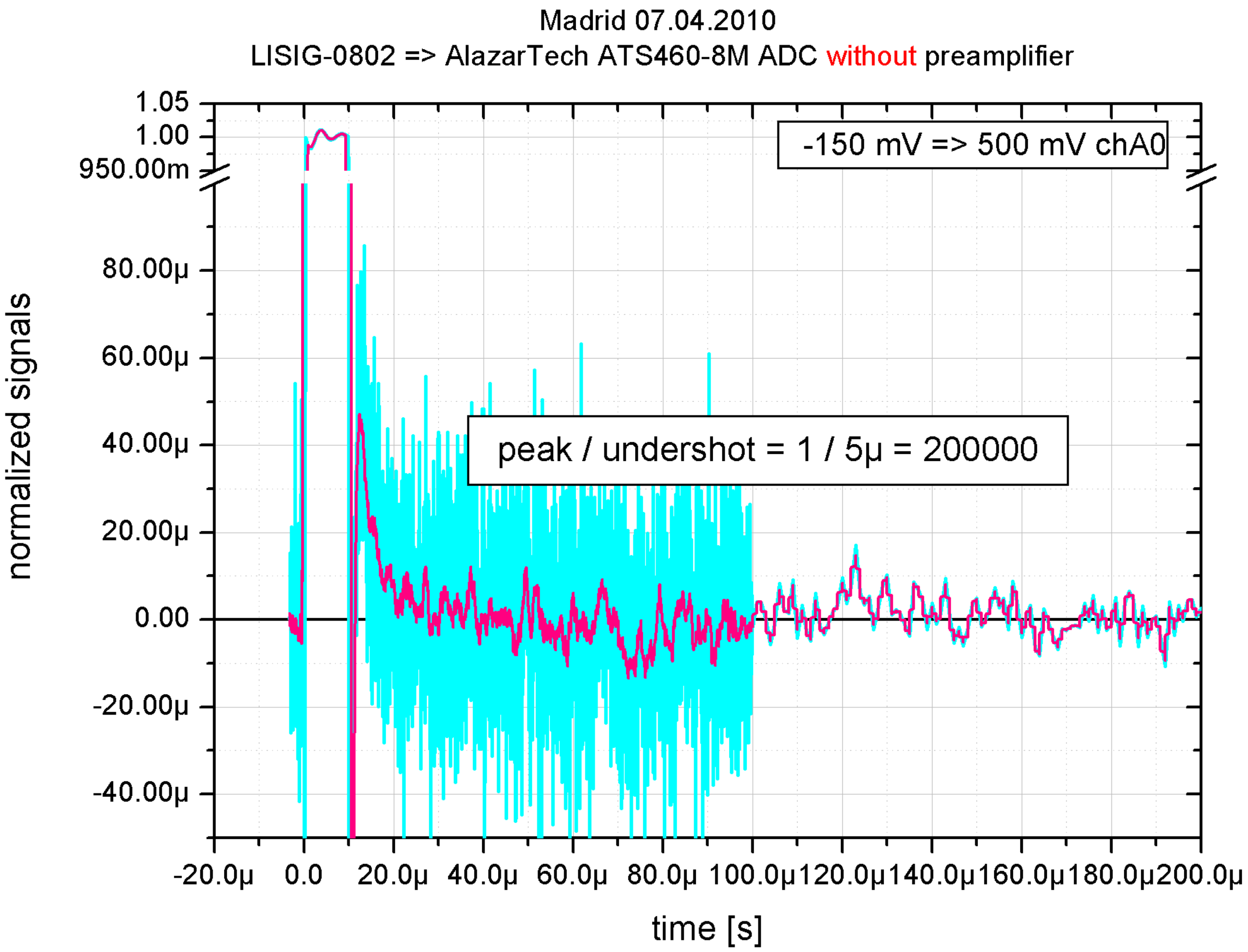
ATS460 User Manual

14 Bit, 125 MS/s
Waveform Digitizer for PCI Bus

Internal checkup tools - Pulse generator – Preamplifier effect



Internal checkup tools - Pulse generator – Preamplifier effect



Internal checkup tools

- Rayleigh fit

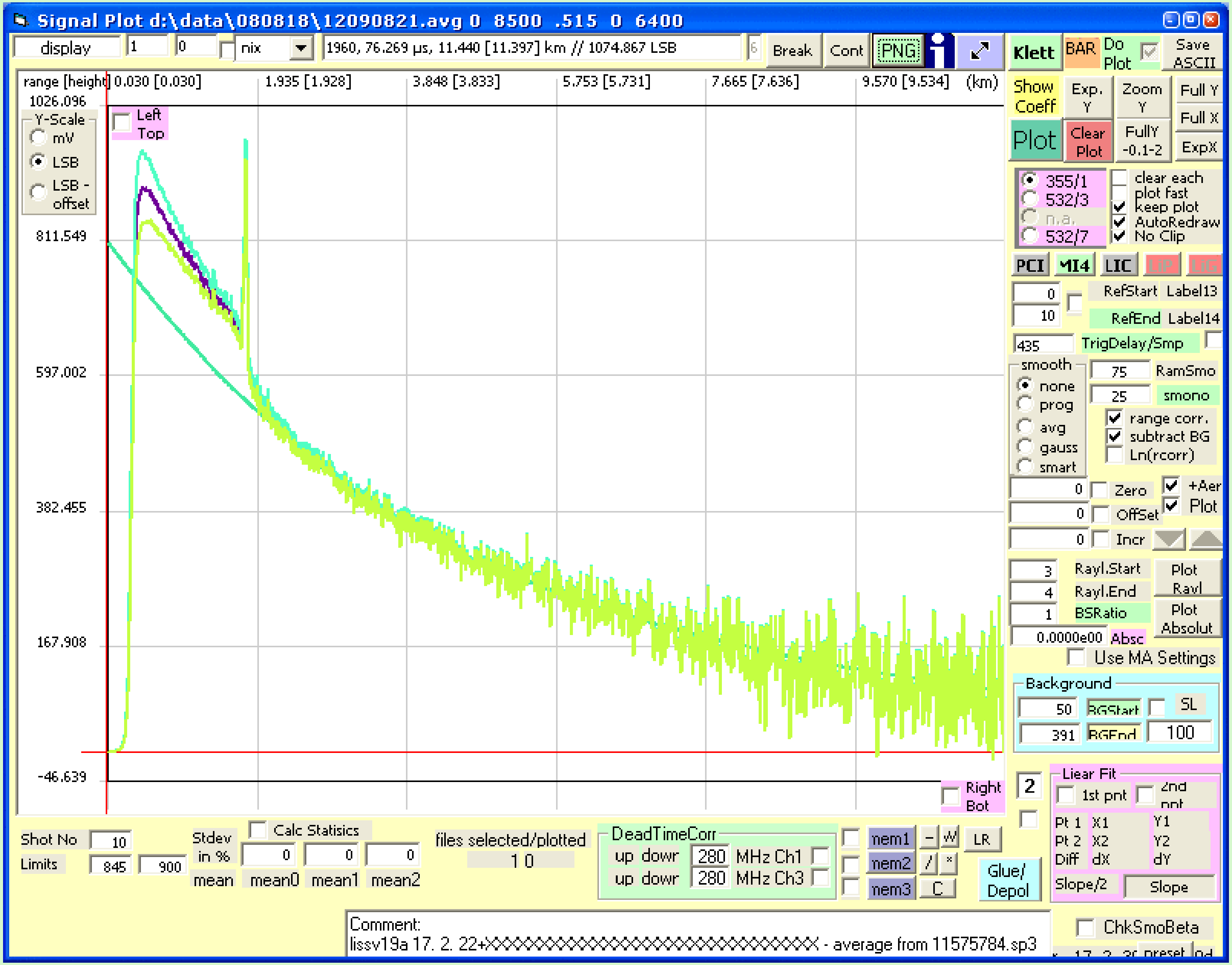
- Dark signal measurement => background subtraction
- Electronic pulse generator for analog channels (MPI)

- Trigger delay / zero bin

- Telecover
- Raytracing

- Upcomming: Polarimeter => diattenuation (IfT)

Trigger delay ±15m => range corrected signal error



Signal Plot d:\data\080818\12090821.avg 0 8500 .515 0 6400

display | 1 | 0 | nix | 1960, 76.269 µs, 11.440 [11.397] km // 1074.867 LSB

range [height] 0.030 [0.030] | 1.935 [1.928] | 3.848 [3.833] | 5.753 [5.731] | 7.665 [7.636] | 9.570 [9.534] (km)

Y-Scale: ○ mV ● LSB ○ LSB - offset

● 355/1 ○ 532/3 ○ n.a. ○ 532/7

☐ clear each ☐ plot fast ☑ keep plot ☑ AutoRedraw ☑ No Clip

0 RefStart Label13

10 RefEnd Label14

435 TrigDelay/Smp

smooth: ● none ○ prog ○ avg ○ gauss ○ smart

75 RamSmo

25 smono

☑ range corr. ☑ subtract BG ☐ Ln(rcorr)

0 ☐ Zero ☑ +Aer

0 ☐ OffSet ☑ Plot

0 ☐ Incr

3 Rayl.Start

4 Rayl.End

1 BSRatio

0.0000e00 Absc

☐ Use MA Settings

Background: 50 BGStart ☐ SL; 391 BGEnd 100

Shot No 10

Limits 845 900

Stdev in % 0 0 0

mean mean0 mean1 mean2

☐ Calc Statisics

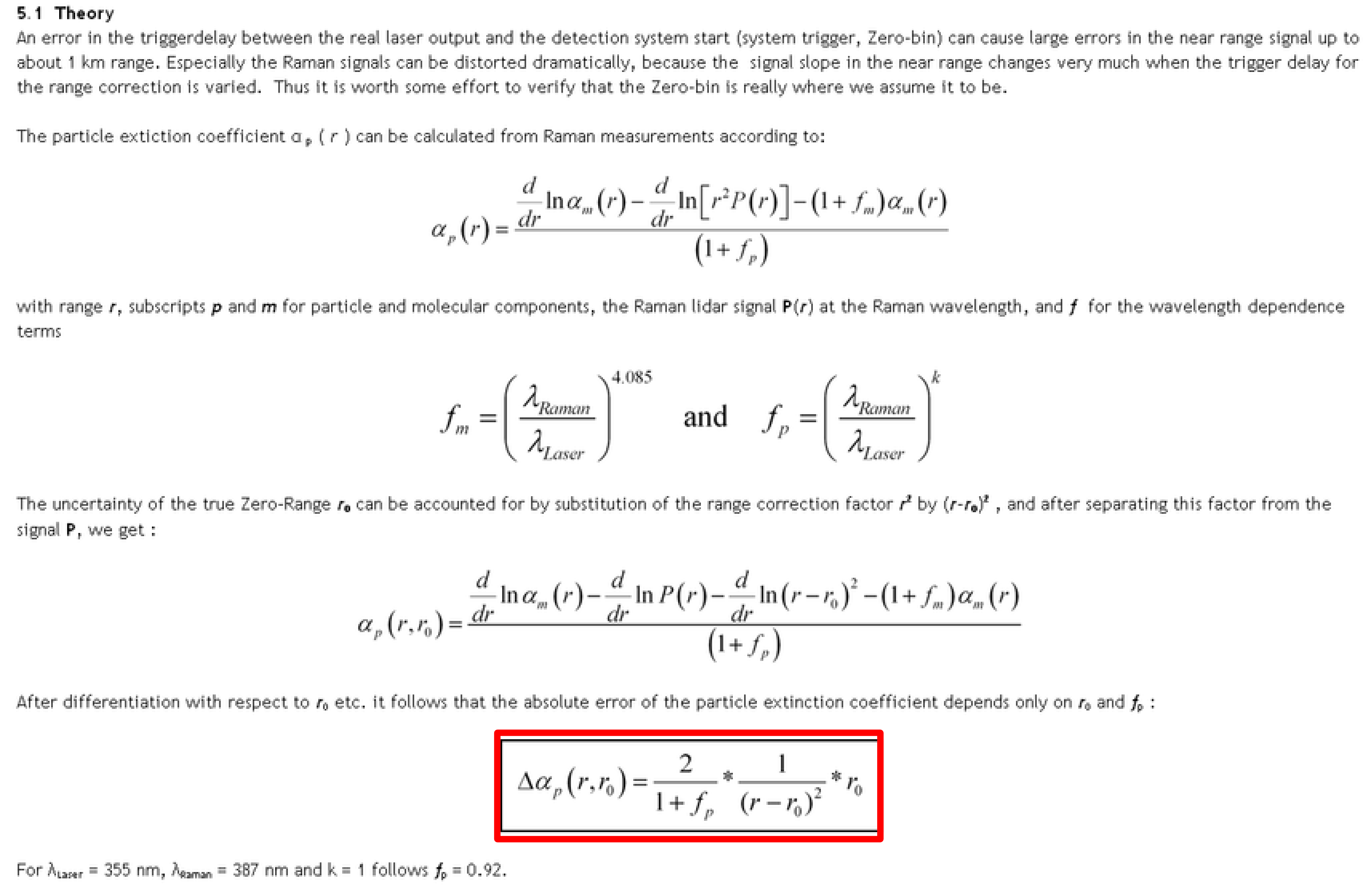
files selected/plotted 1 0

DeadTimeCorr: up dowr 280 MHz Ch1 ☐; up dowr 280 MHz Ch3 ☐

Liear Fit: 2 ☐ 1st pnt ☐ 2nd pnt

Comment:
lissv19a 17. 2. 22+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX - average from 11575784.sp3

Trigger delay Raman extinction error - theory



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 $\alpha_p(r)$ 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 :

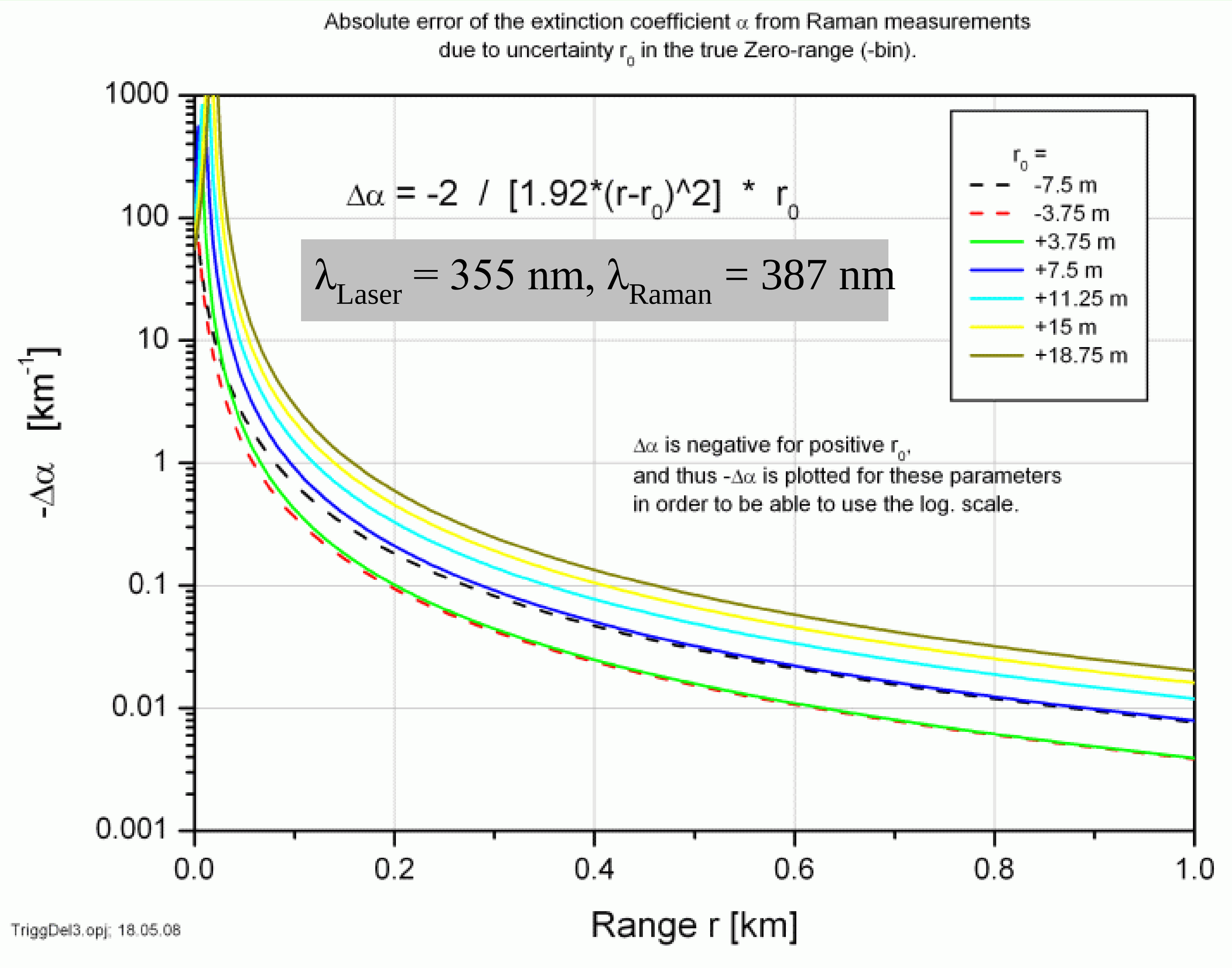
$$\alpha_p(r, r_0) = \frac{\frac{d}{dr}\ln \alpha_m(r) - \frac{d}{dr}\ln P(r) - \frac{d}{dr}\ln(r-r_0)^2 - (1+f_m)\alpha_m(r)}{(1+f_p)}$$

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.

Trigger delay Raman extinction error



Absolute error of the extinction coefficient α from Raman measurements due to uncertainty r_0 in the true Zero-range (-bin).

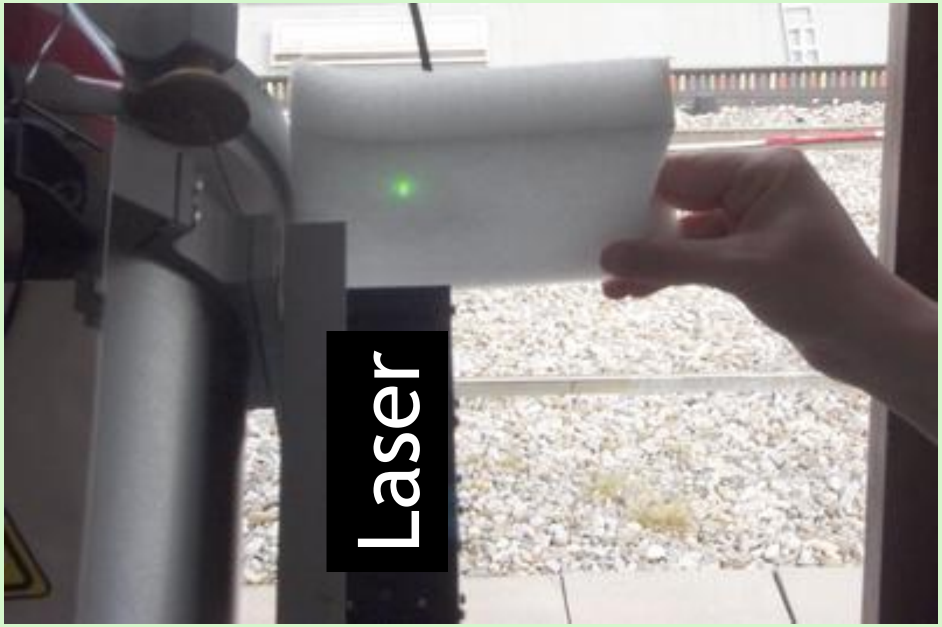
$$\Delta\alpha = -2 \ / \ [1.92*(r-r_0)\text{^}2] \ * \ r_0$$

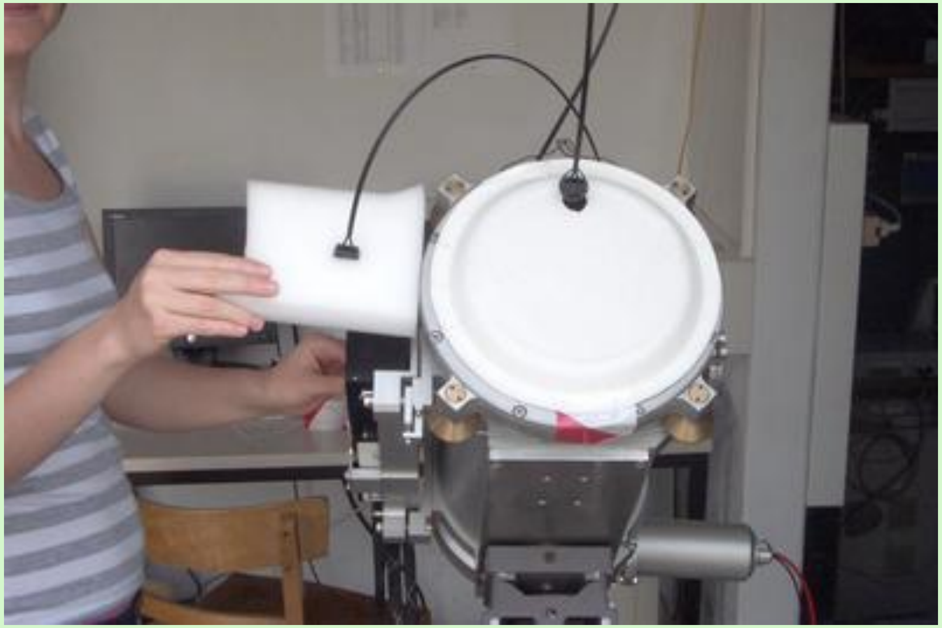
λ_{Laser} = 355 nm, λ_{Raman} = 387 nm

$\Delta\alpha$ is negative for positive r_0, and thus $-\Delta\alpha$ is plotted for these parameters in order to be able to use the log. scale.

TriggDel3.opj; 18.05.08

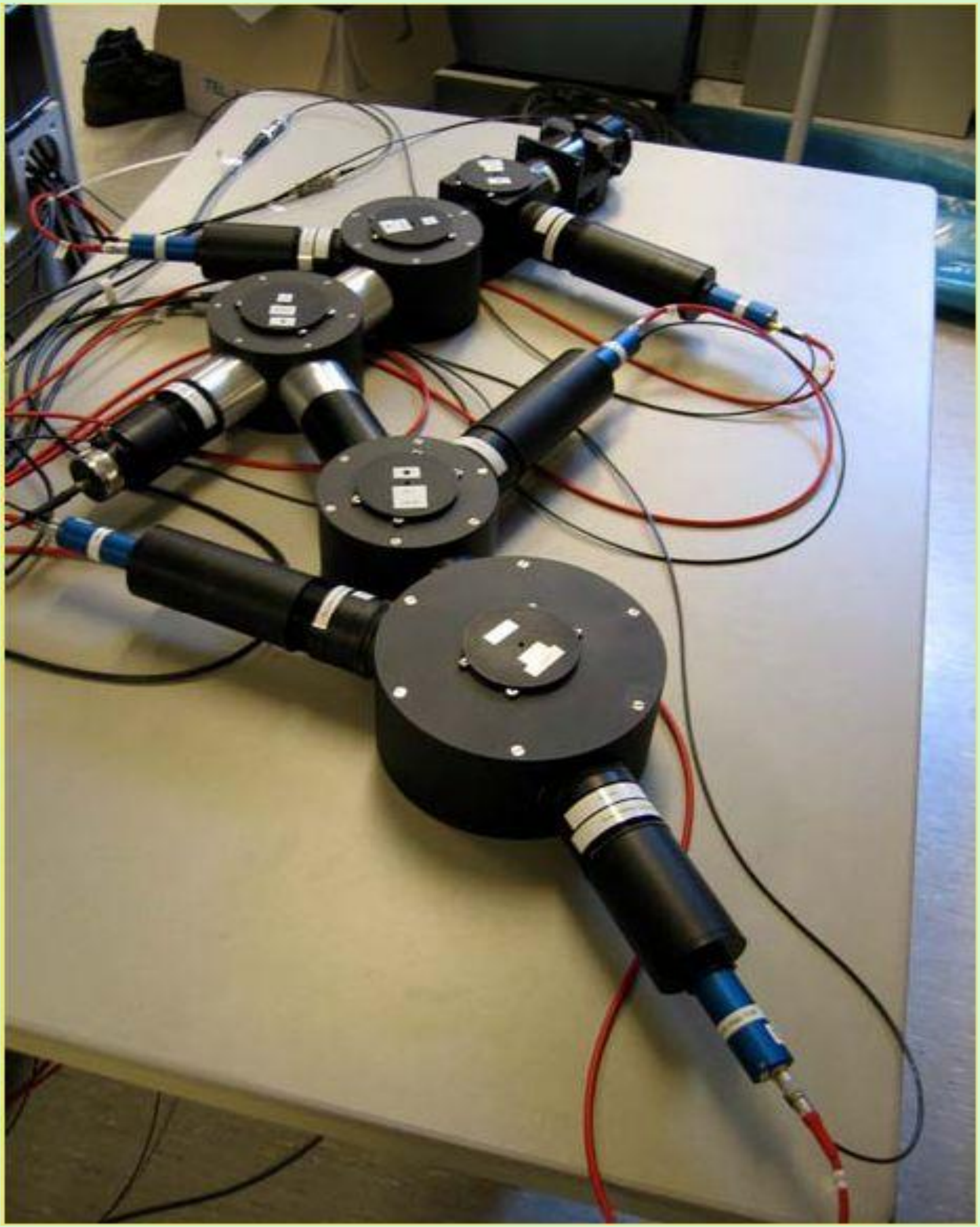
Trigger delay measurement without pretrigger





Fiber delay

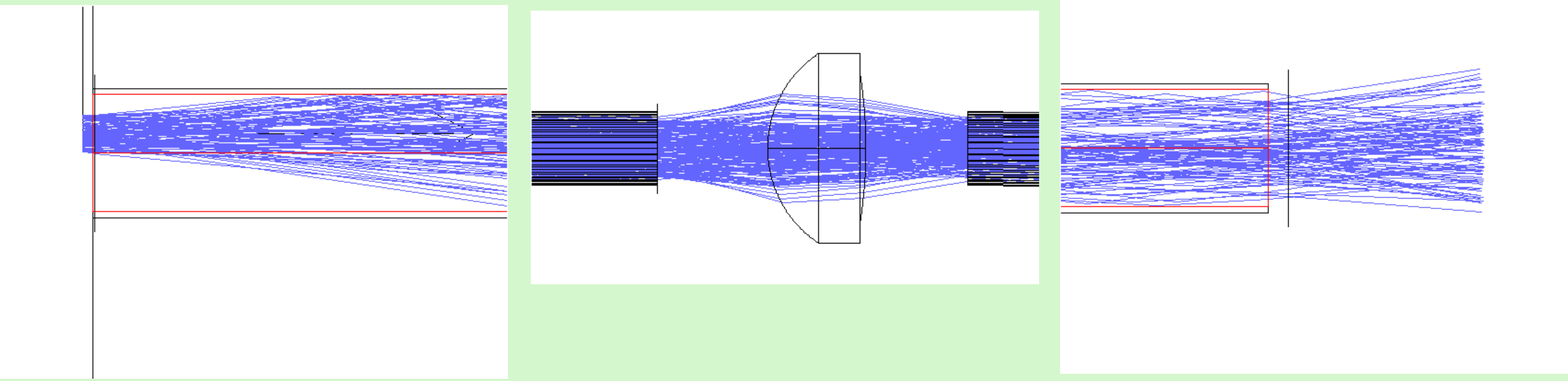
Problems with fiber coupled receiver optics? E.g. CAELI, Bilthoven

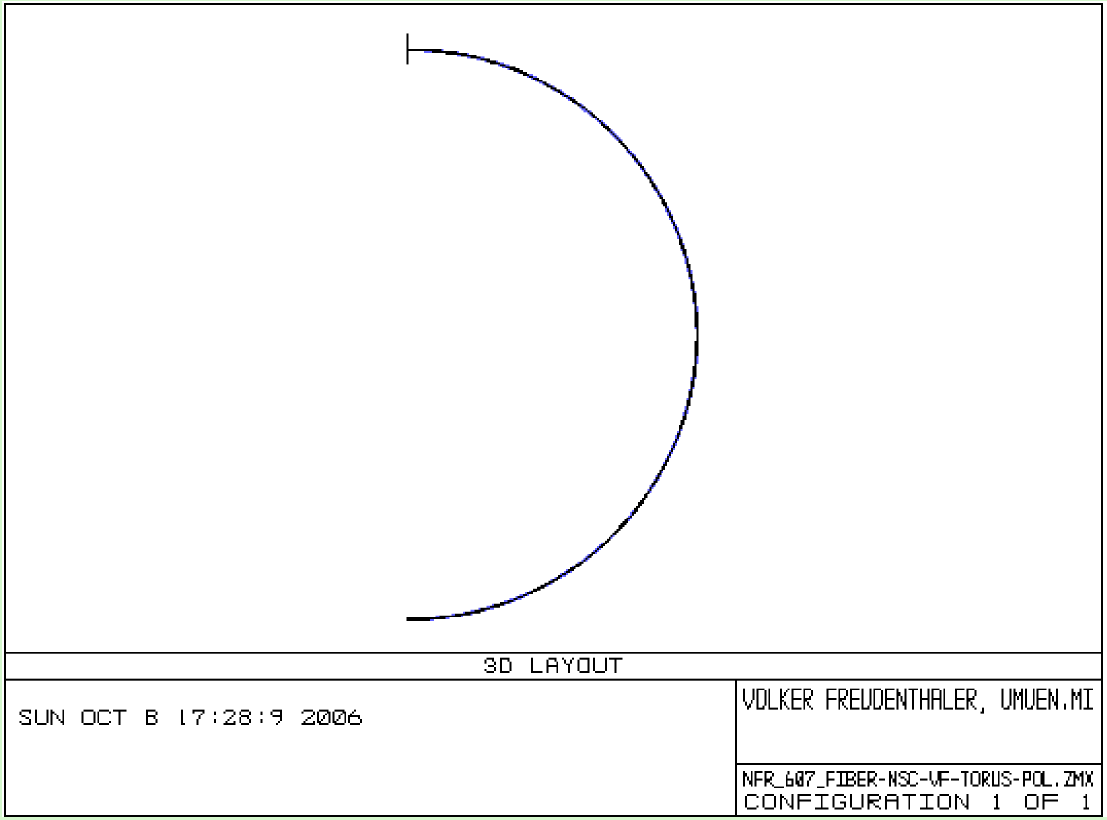


Hypothesis:

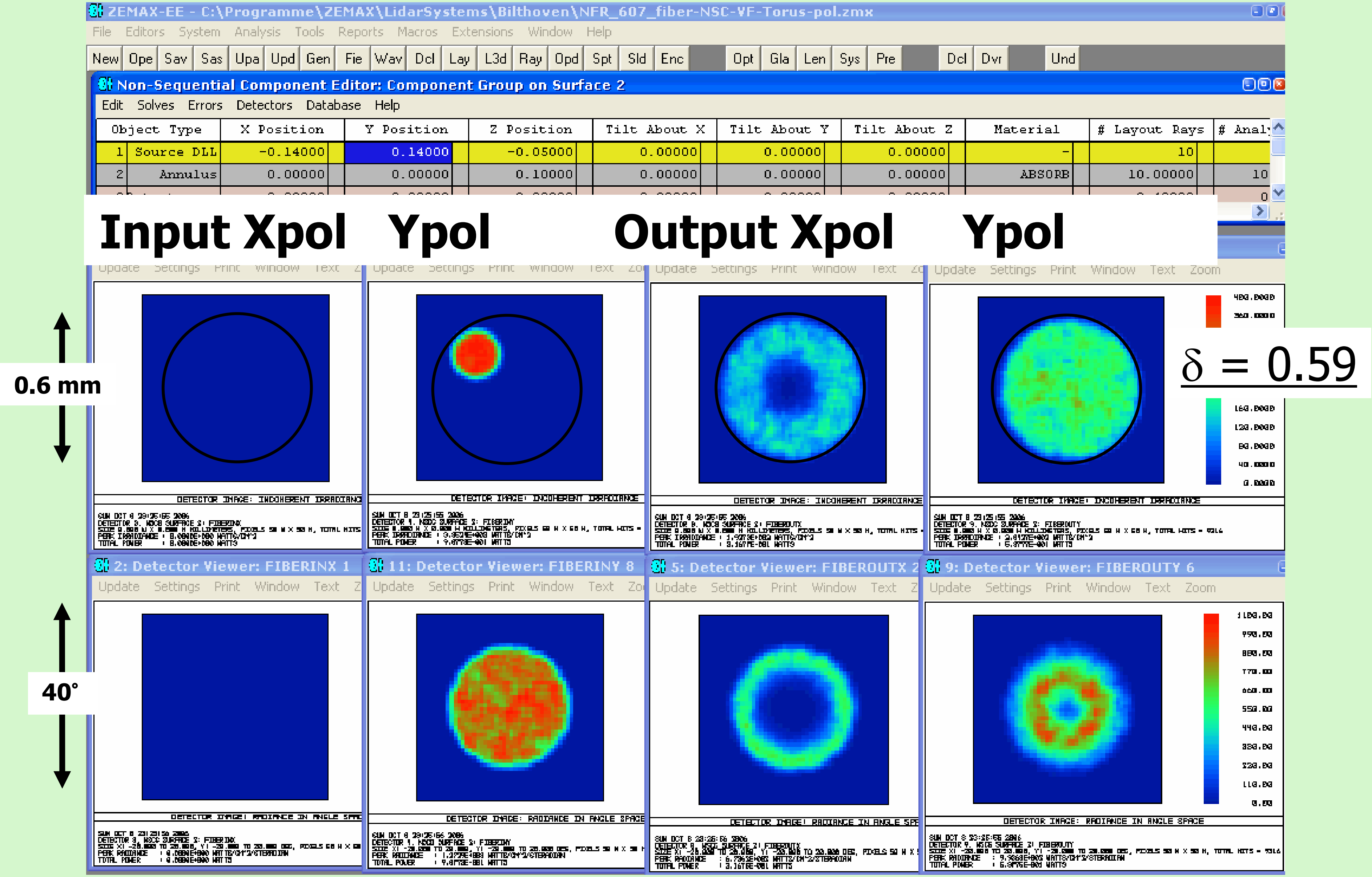
Fibers scramble
angular and
spatial
intensity distributions
at the fiber input.

ZEMAX non sequential polarization raytracing of optical fibers, double scrambler





Fiber simulations Input Pol. X diam. 0.2 mm, NA 0.22, spatial depolarization



	Object Type	X Position	Y Position	Z Position	Tilt About X	Tilt About Y	Tilt About Z	Material	# Layout Rays	# Analy
1	Source DLL	-0.14000	0.14000	-0.05000	0.00000	0.00000	0.00000	-	10	
2	Annulus	0.00000	0.00000	0.10000	0.00000	0.00000	0.00000	ABSORB	10.00000	10

Input Xpol **Ypol** **Output Xpol** **Ypol**

0.6 mm

40°

$\underline{\delta = 0.59}$

Fiber coupled receiver optics

Optical fiber scrambler

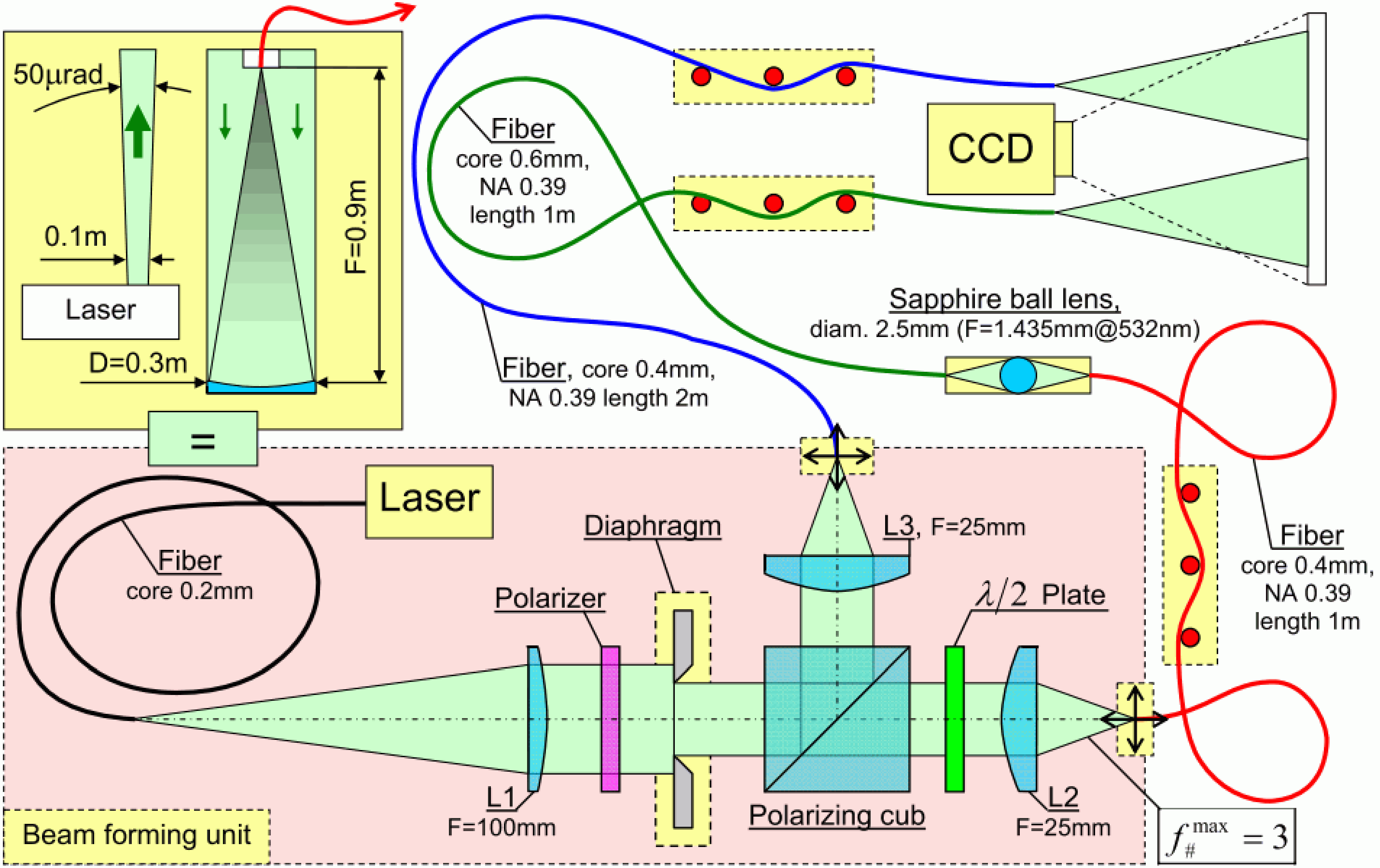
by Ilya Serikov

Max Planck Institute for Meteorology, Hamburg

7th Workshop EARLINET-ASOS, Madrid 2009

Fiber coupled receiver optics – double scrambler with mode-mixer

Scrambler: experimental verification



06.02.2009

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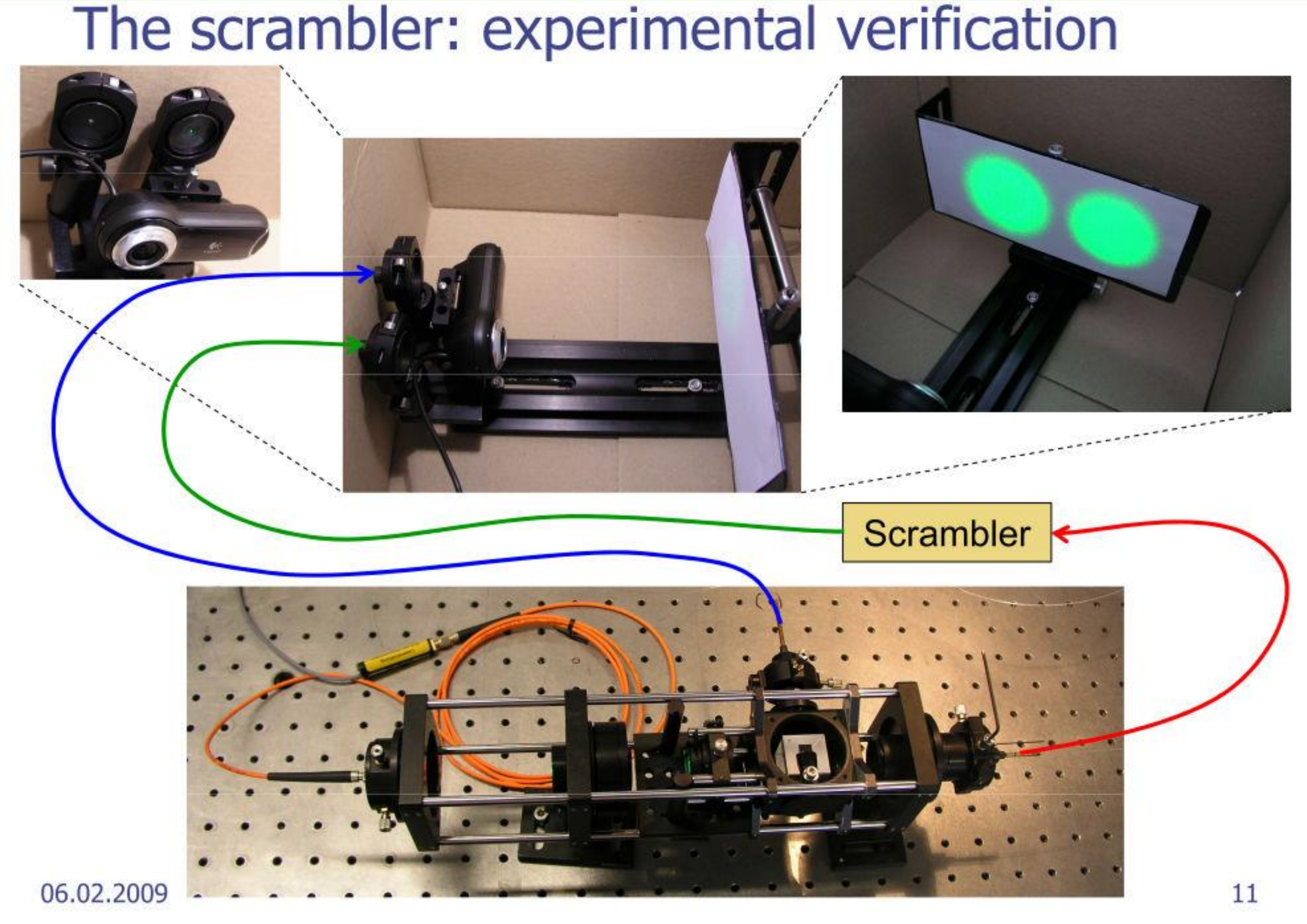
Fiber coupled receiver optics – double scrambler with mode-mixer



The scrambler: experimental verification

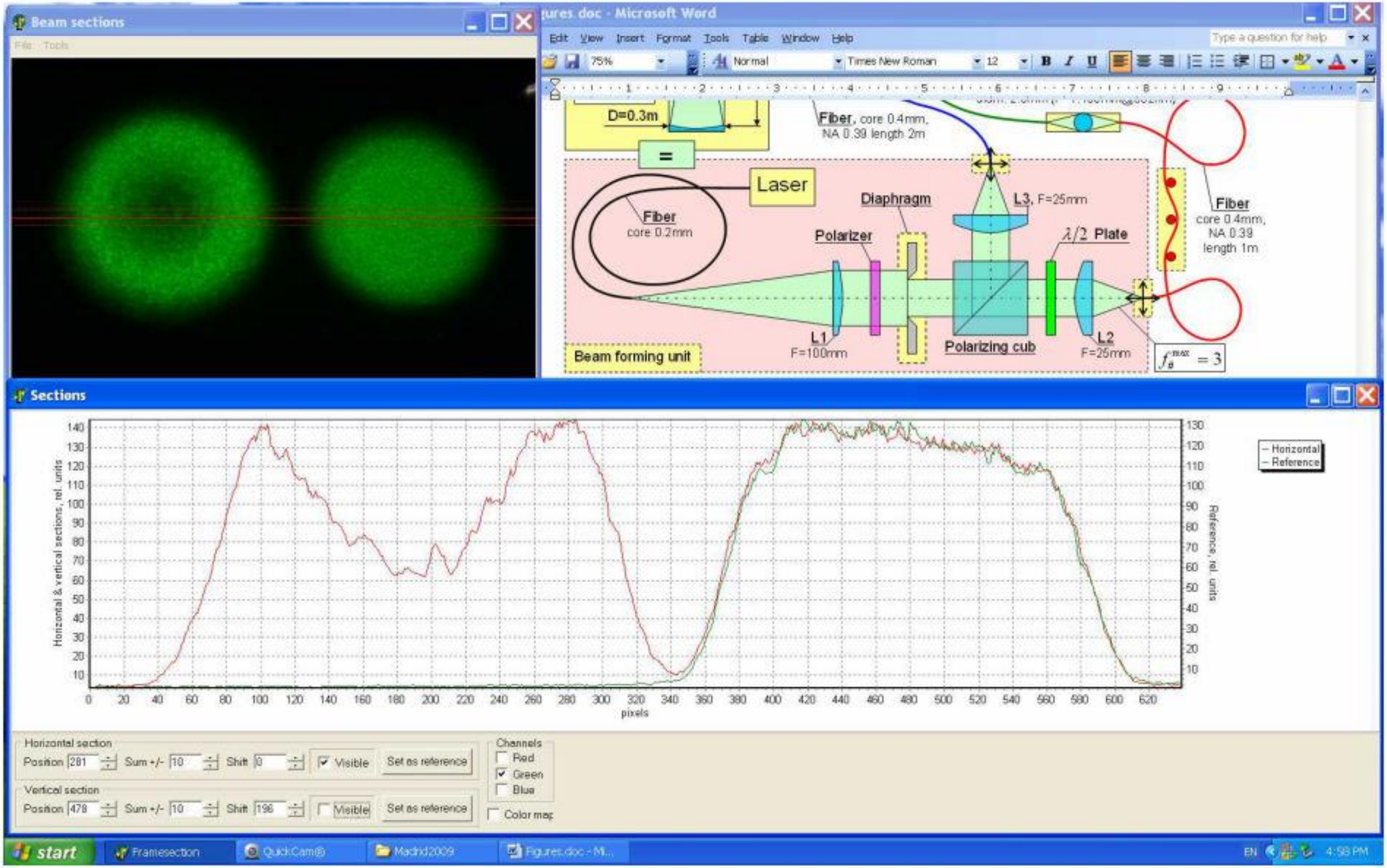
Scrambler

06.02.2009

11

Fiber coupled receiver optics – double scrambler with mode-mixer

The scrambler: experimental verification



Horizontal section
Position 281 Sum +/- 10 Shift 0 ☑ Visible Set as reference

Vertical section
Position 478 Sum +/- 10 Shift 196 ☐ Visible Set as reference

Channels
☐ Red
☑ Green
☐ Blue

☐ Color map

06.02.2009

Internal checkup tools - TeleCover (TC) tests

- Rayleigh fit

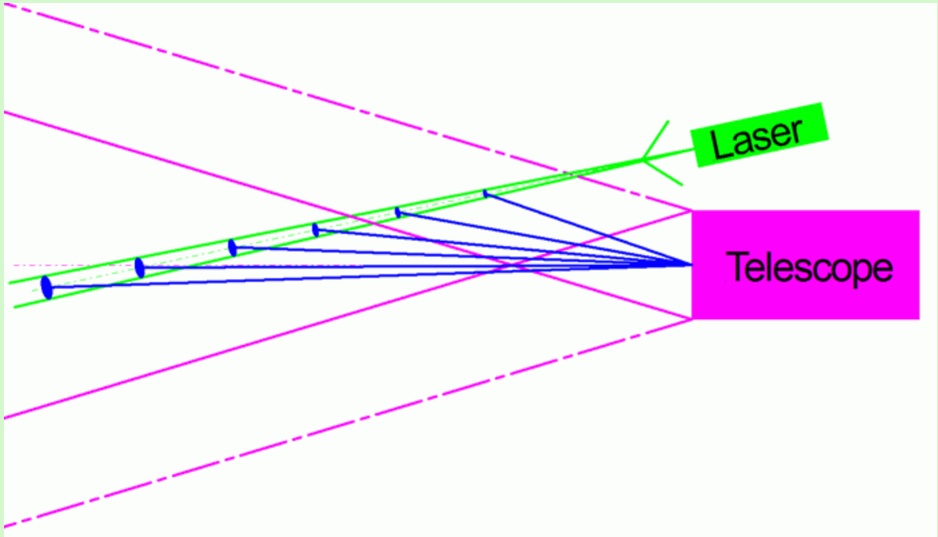
- Dark signal measurement => background subtraction
- Electronic pulse generator for analog channels (MPI)

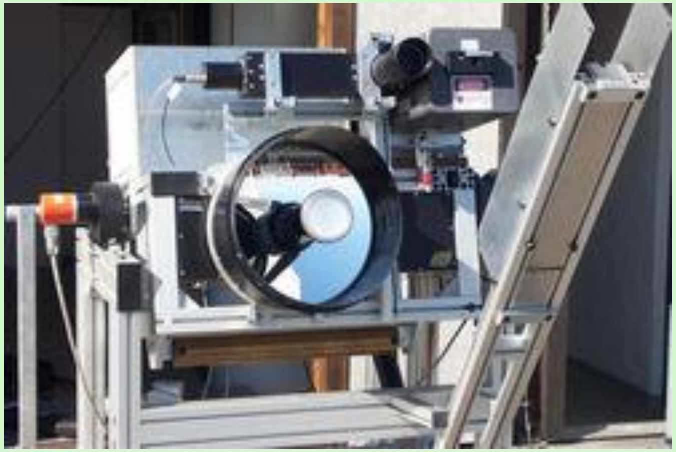
- Trigger delay / zero bin

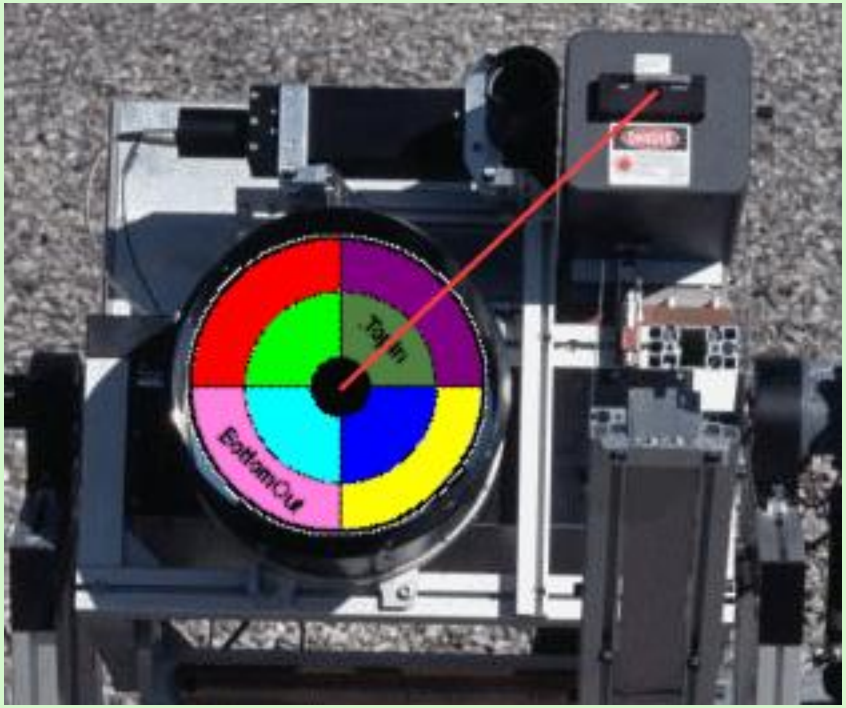
- Telecover
- Raytracing

- Upcomming: Polarimeter => diattenuation (IfT)

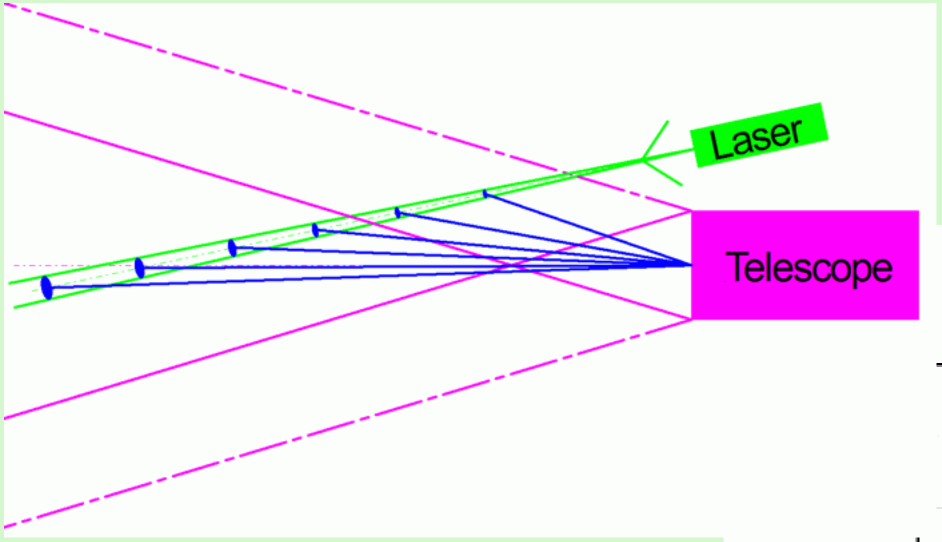
Internal checkup tools - TeleCover (TC) tests - simulation

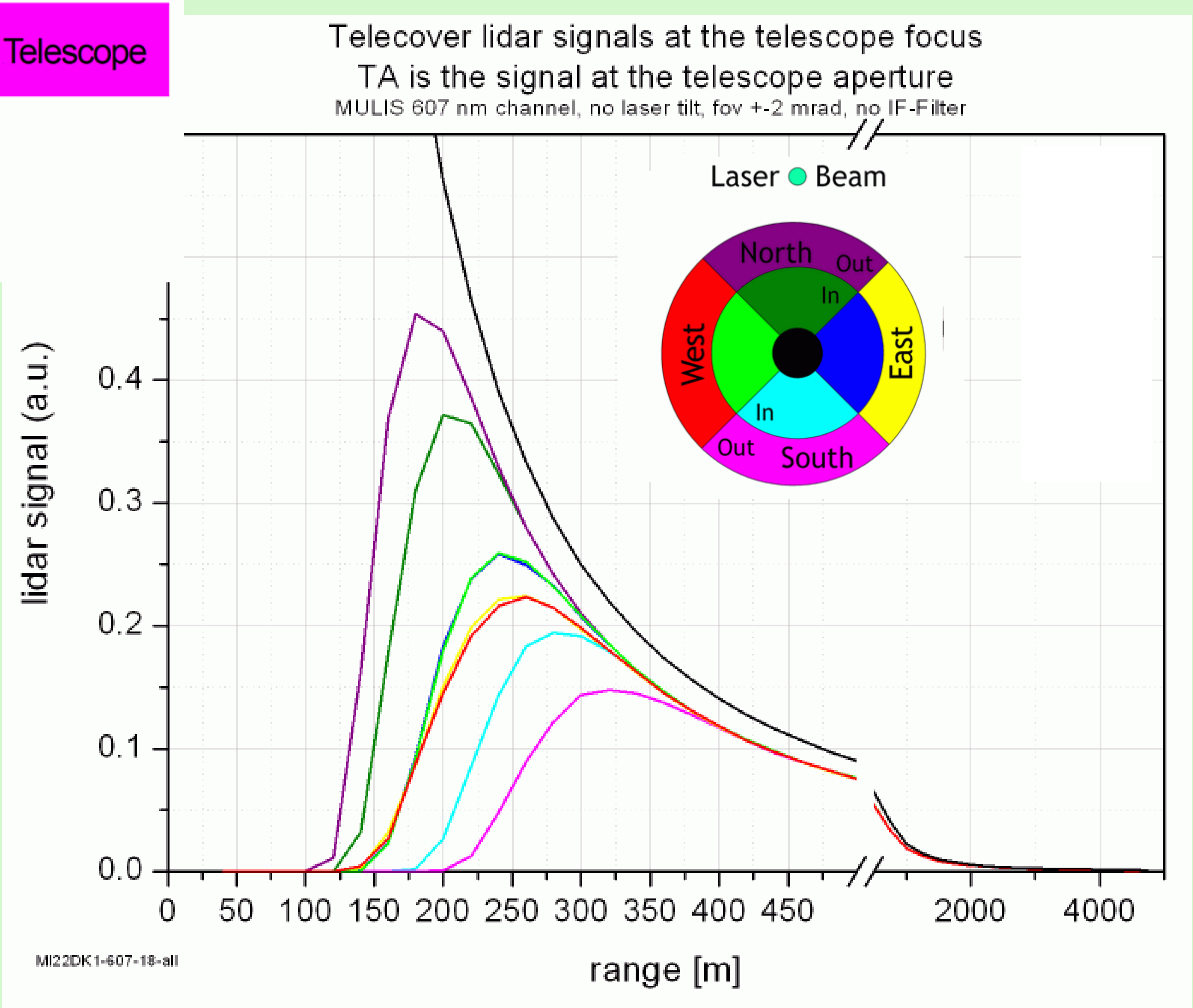




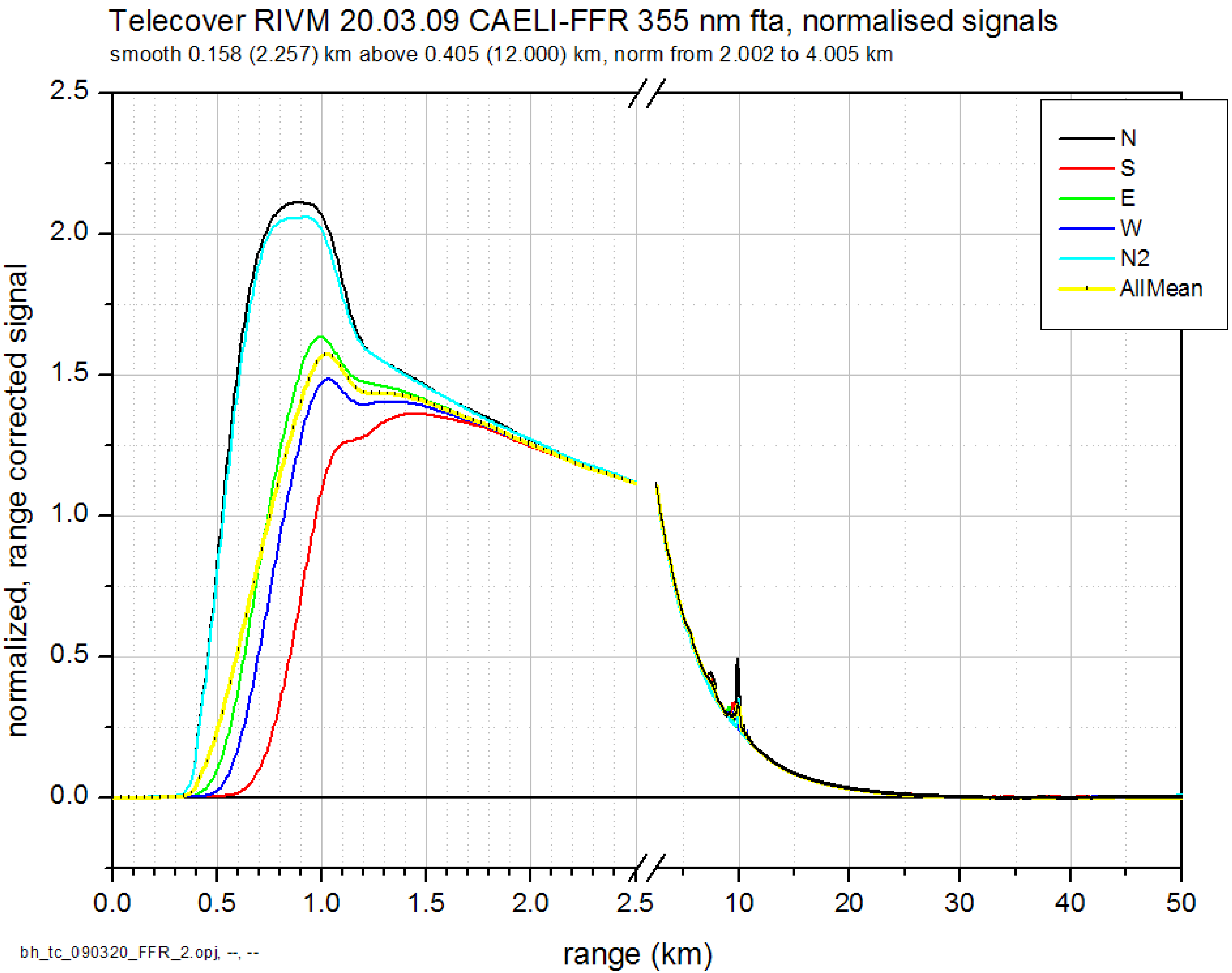


Internal checkup tools - TeleCover (TC) tests – overlap simulation

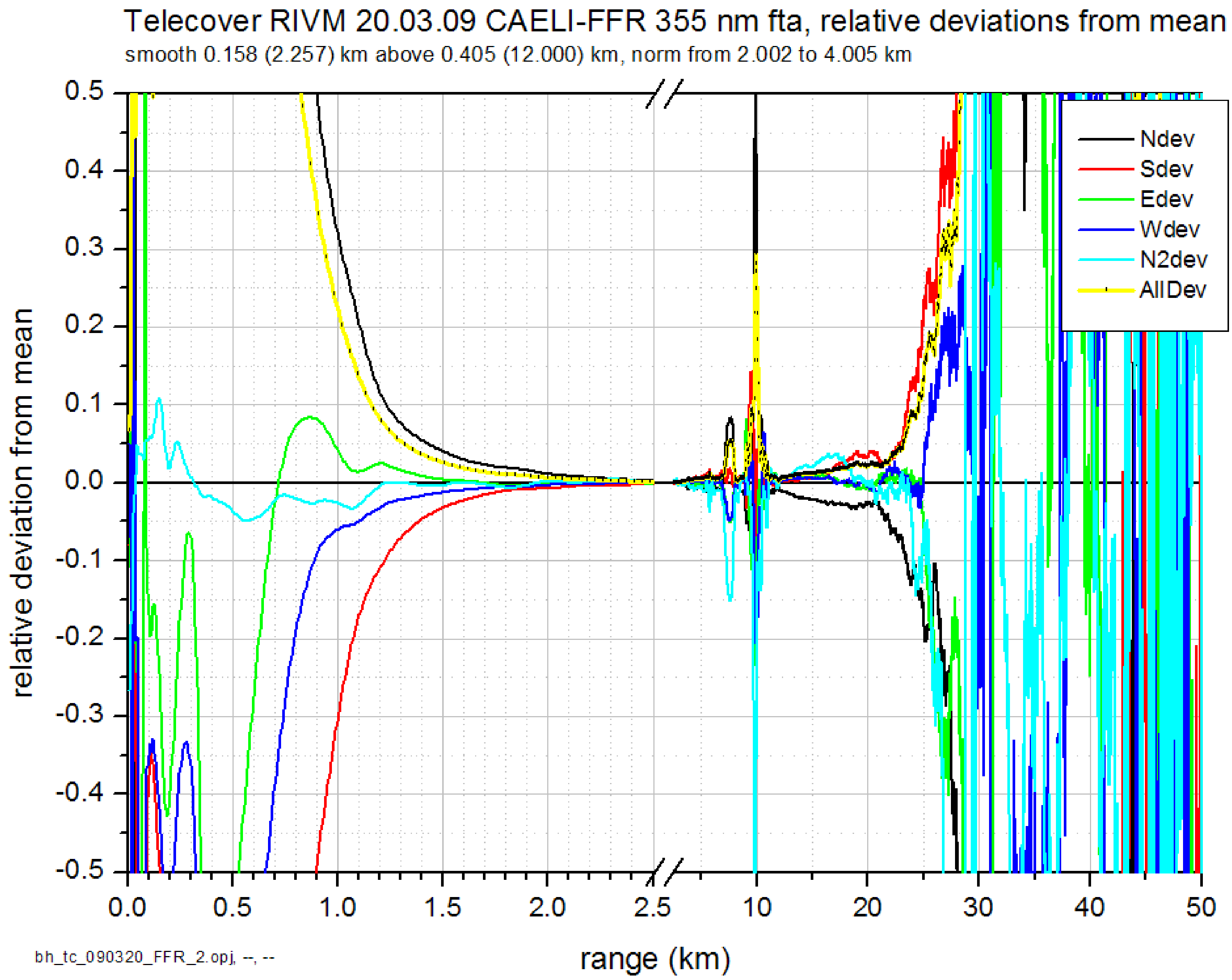




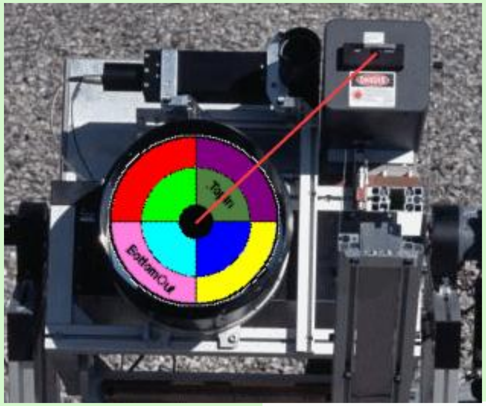
Internal checkup tools - TeleCover (TC) tests

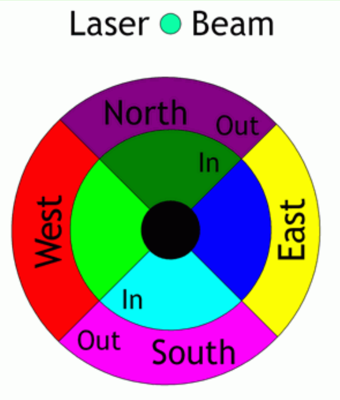


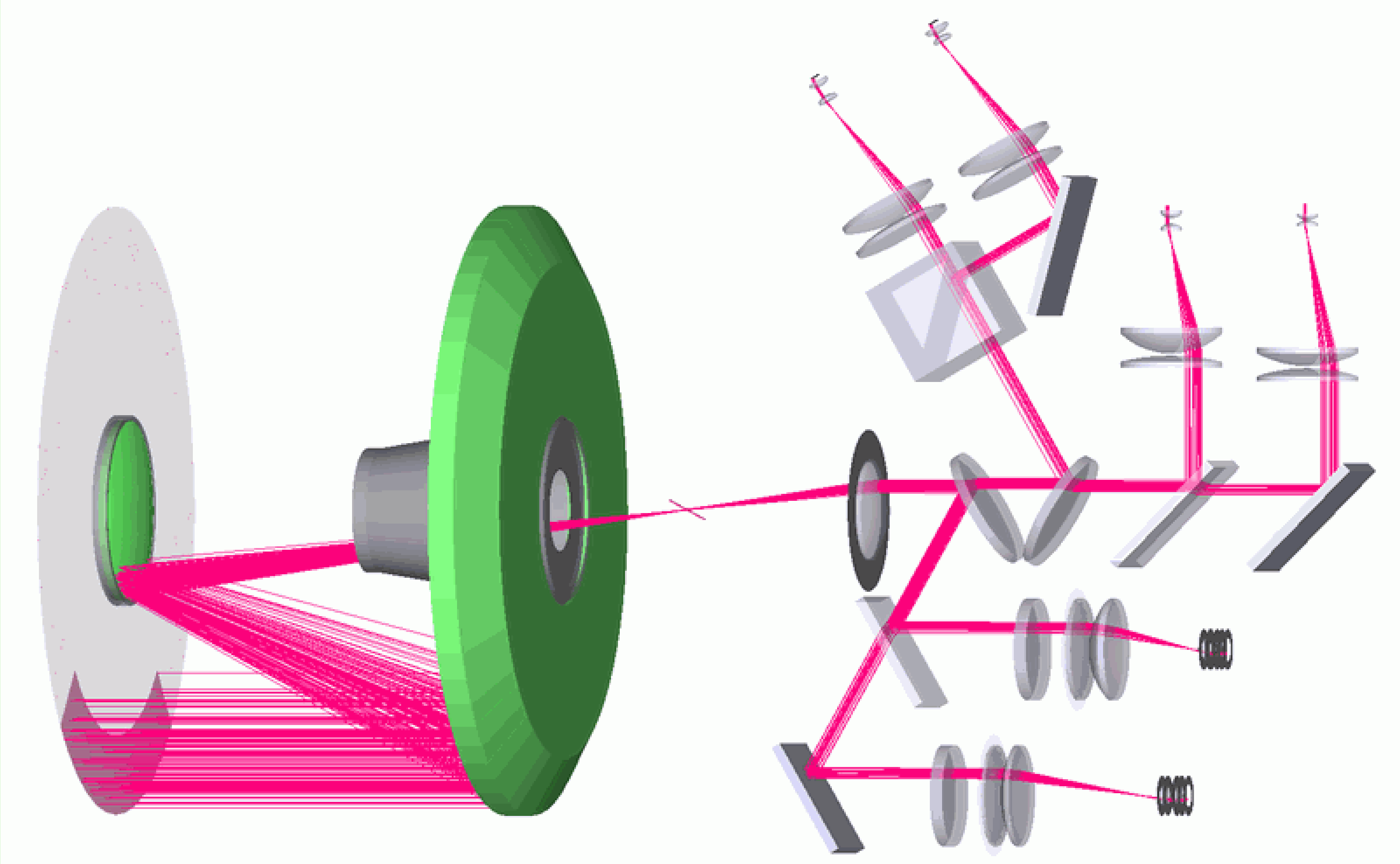
Internal checkup tools - TeleCover (TC) tests



TeleCover (TC) tests - spatial and angular transmission







Internal checkup tools - TeleCover (TC) tests

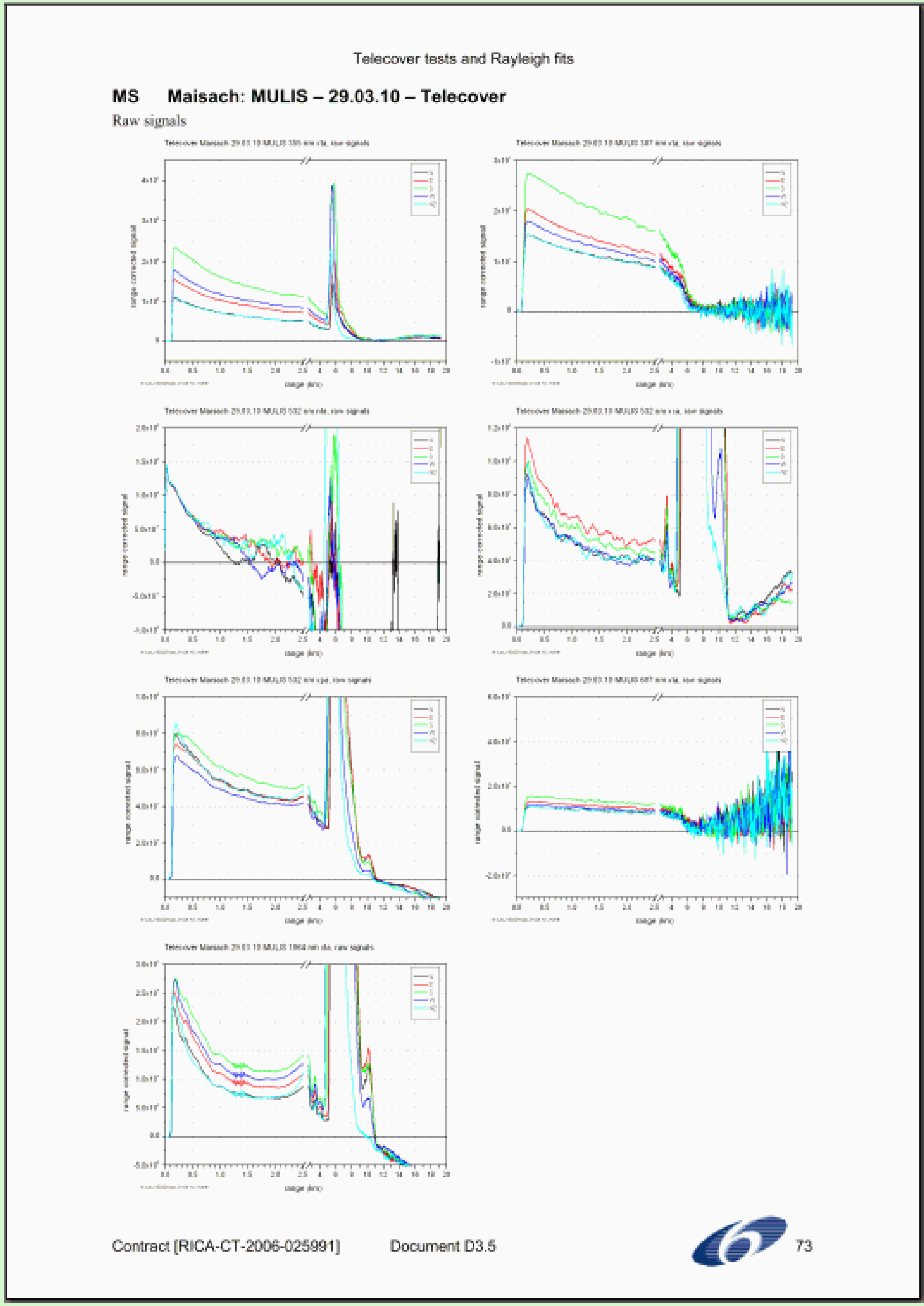
EARLINET-ASOS
European Aerosol Research Lidar Network –
Advanced Sustainable Observation System

Report on internal quality checks for both hardware and software

Deliverable D3.4
April 2009

V. Freudenthaler, LMU, München, Germany
C. Böckmann, UP, Potsdam, Germany
G. Pappalardo, CNR-IMAA, Potenza, Italy

Internal checkup tools - TeleCover (TC) tests - Report

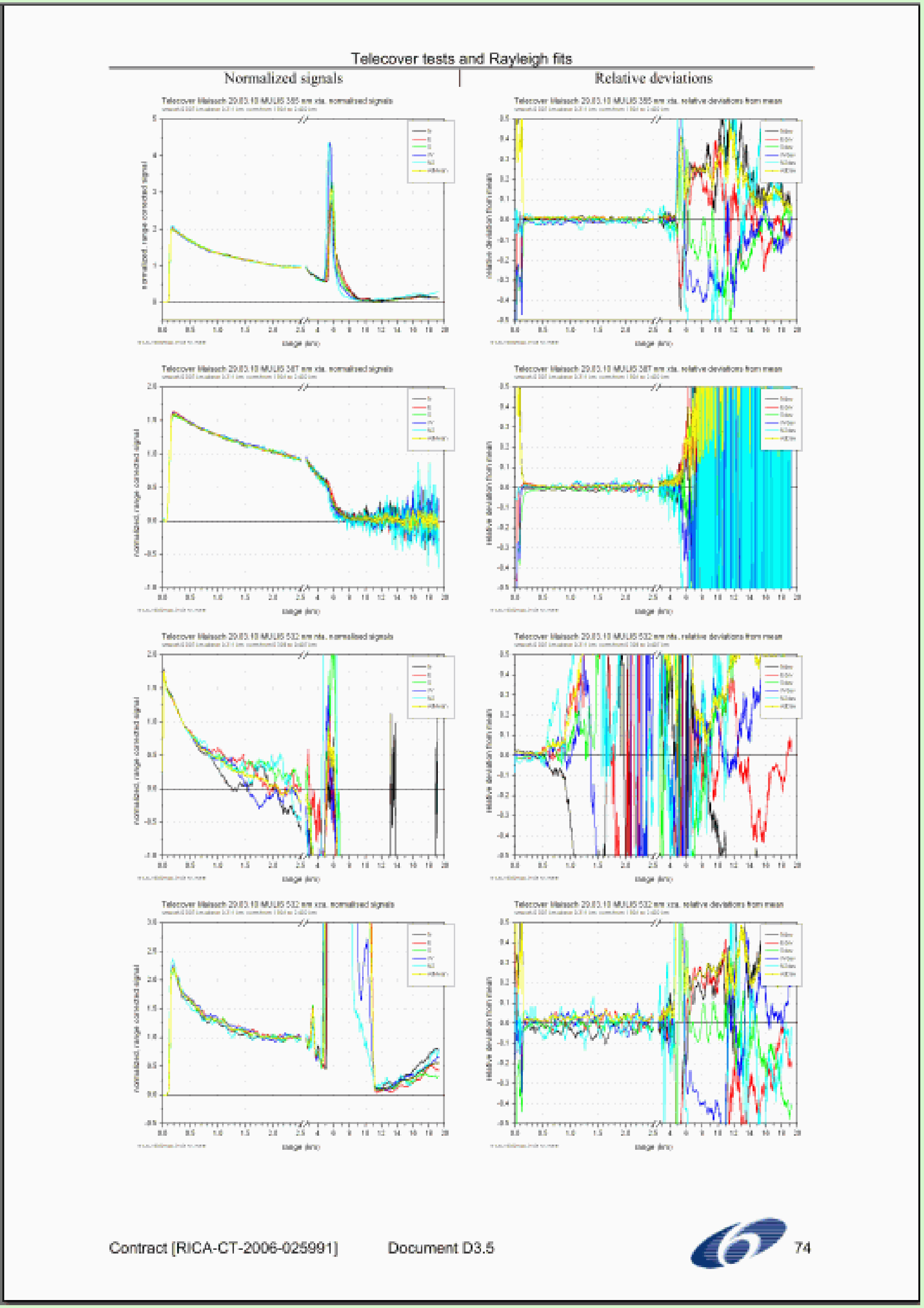


Telecover tests and Rayleigh fits

MS Maisach: MULIS – 29.03.10 – Telecover

Raw signals

Contract [RICA-CT-2006-025991] Document D3.5 73



Telecover tests and Rayleigh fits

Normalized signals | Relative deviations

Contract [RICA-CT-2006-025991] Document D3.5 74

Internal checkup tools - TeleCover (TC) tests

- Rayleigh fit

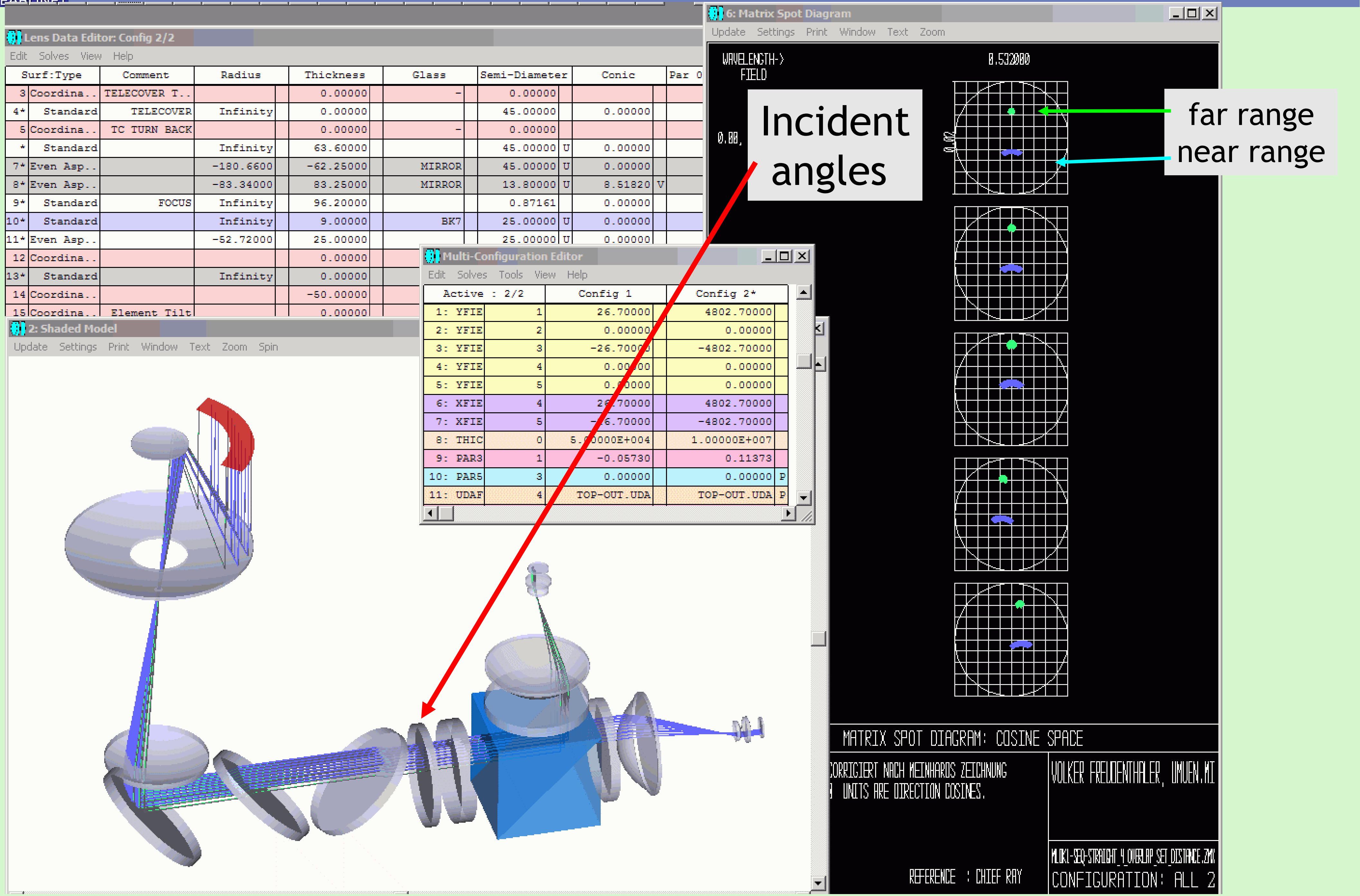
- Dark signal measurement => background subtraction
- Electronic pulse generator for analog channels (MPI)

- Trigger delay / zero bin

- Telecover
- Raytracing

- Upcomming: Polarimeter => diattenuation (IfT)

ZEMAX Telecover macro: test of spatial and angular transmission



Surf:Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic	Par 0
3 Coordina..	TELECOVER T..		0.00000	-	0.00000		
4* Standard	TELECOVER	Infinity	0.00000		45.00000	0.00000	
5 Coordina..	TC TURN BACK		0.00000	-	0.00000		
* Standard		Infinity	63.60000		45.00000 U	0.00000	
7* Even Asp..		-180.6600	-62.25000	MIRROR	45.00000 U	0.00000	
8* Even Asp..		-83.34000	83.25000	MIRROR	13.80000 U	8.51820 V	
9* Standard	FOCUS	Infinity	96.20000		0.87161	0.00000	
10* Standard		Infinity	9.00000	BK7	25.00000 U	0.00000	
11* Even Asp..		-52.72000	25.00000		25.00000 U	0.00000	
12 Coordina..			0.00000				
13* Standard		Infinity	0.00000				
14 Coordina..			-50.00000				
15 Coordina..	Element Tilt		0.00000				

Active : 2/2		Config 1	Config 2*	
1: YFIE	1	26.70000	4802.70000	
2: YFIE	2	0.00000	0.00000	
3: YFIE	3	-26.70000	-4802.70000	
4: YFIE	4	0.00000	0.00000	
5: YFIE	5	0.00000	0.00000	
6: XFIE	4	26.70000	4802.70000	
7: XFIE	5	-26.70000	-4802.70000	
8: THIC	0	5.00000E+004	1.00000E+007	
9: PAR3	1	-0.05730	0.11373	
10: PAR5	3	0.00000	0.00000	P
11: UDAF	4	TOP-OUT.UDA	TOP-OUT.UDA	P

MATRIX SPOT DIAGRAM: COSINE SPACE

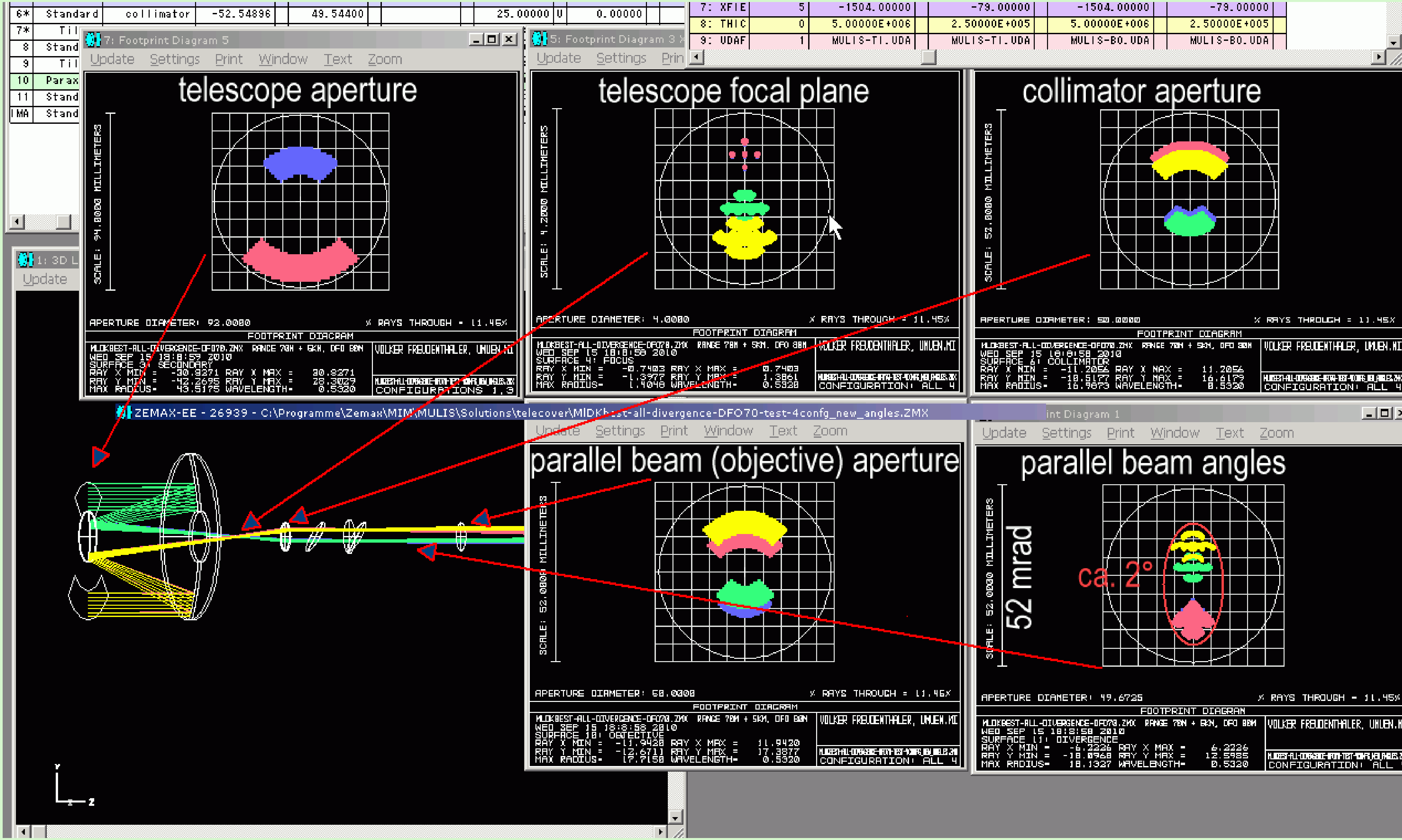
CORRIGIERT NACH MEINHARDS ZEICHNUNG
UNITS ARE DIRECTION COSINES.

REFERENCE : CHIEF RAY

VOLKER FREUDENTHALER, UMUEN.MI

MUKI-SEQ-STRAIGHT_4_OVERLAP_SET_DISTANCE.ZMX
CONFIGURATION: ALL 2

ZEMAX Telecover macro: test of spatial and angular transmission



6*	Standard	collimator	-52.54896	49.54400	25.00000	U	0.00000
7*	Til						
8	Stand						
9	Til						
10	Parax						
11	Stand						
IMA	Stand						

7: XFIE	5	-1504.00000	-79.00000	-1504.00000	-79.00000
8: THIC	0	5.00000E+006	2.50000E+005	5.00000E+006	2.50000E+005
9: UDAF	1	MULIS-TI.UDA	MULIS-TI.UDA	MULIS-BO.UDA	MULIS-BO.UDA

ZEMAX-EE - 26939 - C:\Programme\Zemax\MIM\MULIS\Solutions\telecover\MIDKbest-all-divergence-DFO70-test-4confg_new_angles.ZMX

```
APERTURE DIAMETER: 92.0000                      % RAYS THROUGH = 11.46%
FOOTPRINT DIAGRAM
MLDKBEST-ALL-DIVERGENCE-DFO70.ZMX  RANGE 70M + 5KM, DFO 80M   VOLKER FREUDENTHALER, UNIEN.MI
WED SEP 15 18:8:57 2010
SURFACE 3: SECONDARY
RAY X MIN =   -30.9271 RAY X MAX =    30.9271
RAY Y MIN =   -42.2695 RAY Y MAX =    28.3029
MAX RADIUS=    43.5175 WAVELENGTH=     0.5320                   CONFIGURATIONS 1,3
```

```
APERTURE DIAMETER: 4.0000                       % RAYS THROUGH = 11.45%
FOOTPRINT DIAGRAM
MLDKBEST-ALL-DIVERGENCE-DFO70.ZMX  RANGE 70M + 5KM, DFO 80M   VOLKER FREUDENTHALER, UNIEN.MI
WED SEP 15 18:8:58 2010
SURFACE 4: FOCUS
RAY X MIN =    -0.7403 RAY X MAX =     0.7403
RAY Y MIN =    -1.3977 RAY Y MAX =     1.3861
MAX RADIUS=     1.4048 WAVELENGTH=     0.5320                   CONFIGURATION: ALL 4
```

```
APERTURE DIAMETER: 50.0000                      % RAYS THROUGH = 11.45%
FOOTPRINT DIAGRAM
MLDKBEST-ALL-DIVERGENCE-DFO70.ZMX  RANGE 70M + 5KM, DFO 80M   VOLKER FREUDENTHALER, UNIEN.MI
WED SEP 15 18:8:58 2010
SURFACE 6: COLLIMATOR
RAY X MIN =   -11.2056 RAY X MAX =    11.2056
RAY Y MIN =   -10.5177 RAY Y MAX =    16.6179
MAX RADIUS=    16.9873 WAVELENGTH=     0.5320                   CONFIGURATION: ALL 4
```

```
APERTURE DIAMETER: 58.0000                      % RAYS THROUGH = 11.46%
FOOTPRINT DIAGRAM
MLDKBEST-ALL-DIVERGENCE-DFO70.ZMX  RANGE 70M + 5KM, DFO 80M   VOLKER FREUDENTHALER, UNIEN.MI
WED SEP 15 18:8:58 2010
SURFACE 10: OBJECTIVE
RAY X MIN =   -11.9420 RAY X MAX =    11.9420
RAY Y MIN =   -12.6711 RAY Y MAX =    17.3877
MAX RADIUS=    17.7150 WAVELENGTH=     0.5320                   CONFIGURATION: ALL 4
```

```
APERTURE DIAMETER: 49.6725                      % RAYS THROUGH = 11.45%
FOOTPRINT DIAGRAM
MLDKBEST-ALL-DIVERGENCE-DFO70.ZMX  RANGE 70M + 5KM, DFO 80M   VOLKER FREUDENTHALER, UNIEN.MI
WED SEP 15 18:8:58 2010
SURFACE 11: DIVERGENCE
RAY X MIN =    -6.2226 RAY X MAX =     6.2226
RAY Y MIN =   -10.0968 RAY Y MAX =    12.5985
MAX RADIUS=    10.1327 WAVELENGTH=     0.5320                   CONFIGURATION: ALL 4
```

NA3-QA Internal Checkup Procedures => Decision to be made!

Necessary tools, regularly

Telecover mandatory?

to do: definition of limit criteria

for each wavelength yes

Rayleigh fit

to do: definition of limit criteria

=> Inversion reference value yes

Helpful tools, only once

Dark measurement

=> Electronic interferences yes

Zero-bin measurement

One time (?) measurement per channel yes, excluded HH

minimum requirements

prerequisites for direct intercomparison

Spanish lidar intercomparison – El Arenosillo, 2006

Spanish lidar intercomparison – El Arenosillo, 2006

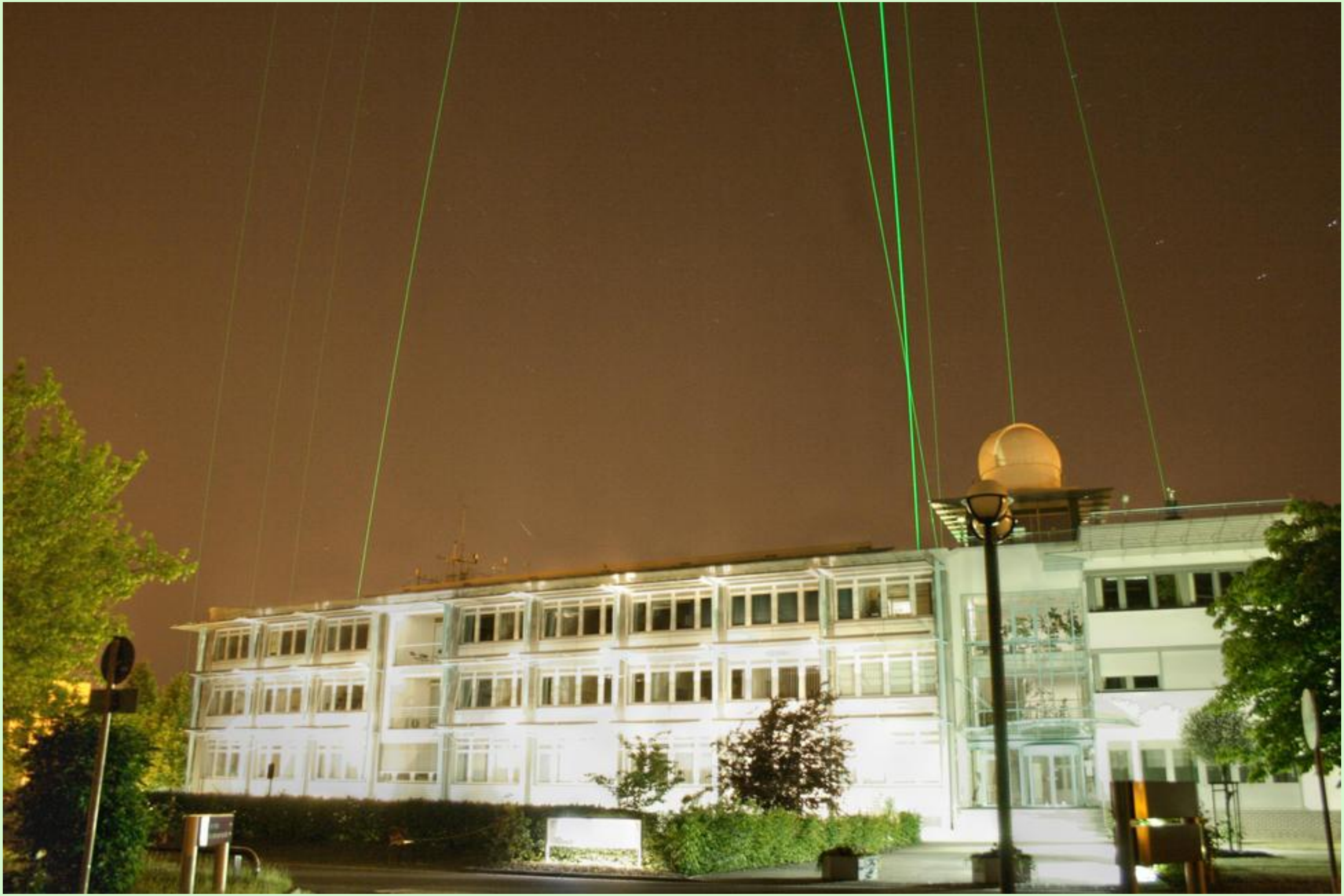
Michaël Sicard, UPC Barcelona reported about:
Acción Complementaria (AC) approved by the Spanish Ministry of Science and Education

Universidad Politécnica de Cataluña, Barcelona
CIEMAT, Madrid
Universidad de Granada
Universidad de Valencia
Universidad Politécnica de Cartagena

EARLI09 Referenz lidar intercomparison, Leipzig, 2009

Lidar intercomparisons – EARLI09, Leipzig, 2009

Leibniz Institute for Tropospheric Research IfT, Leipzig, Germany



Reference Lidar Systems – Minsk

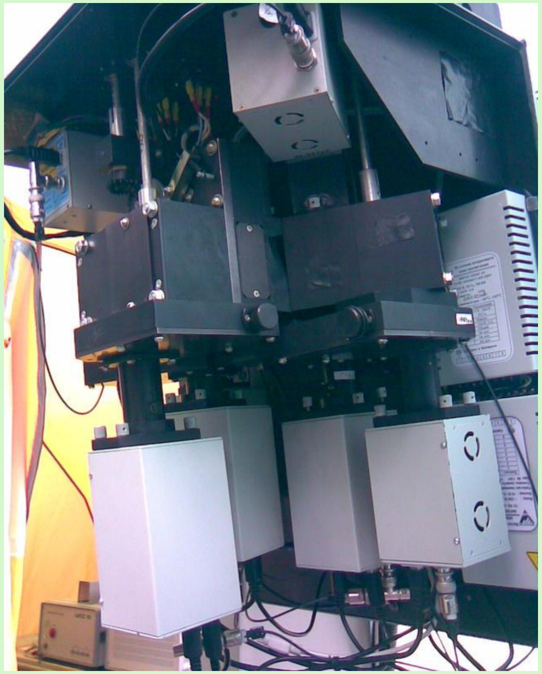
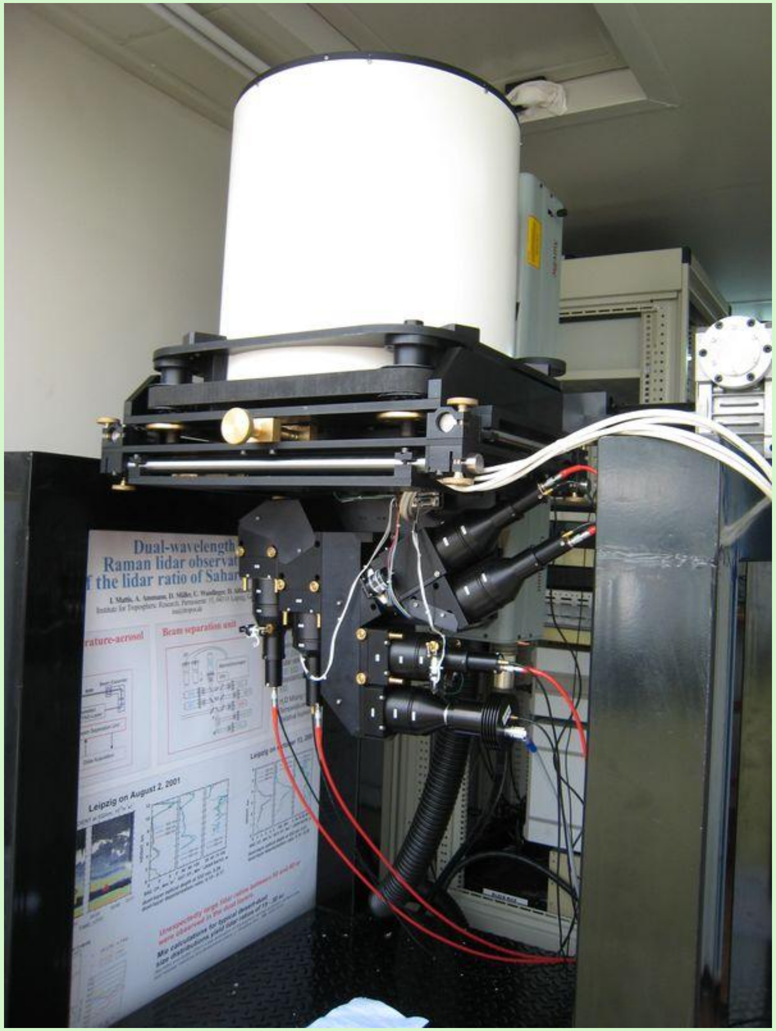
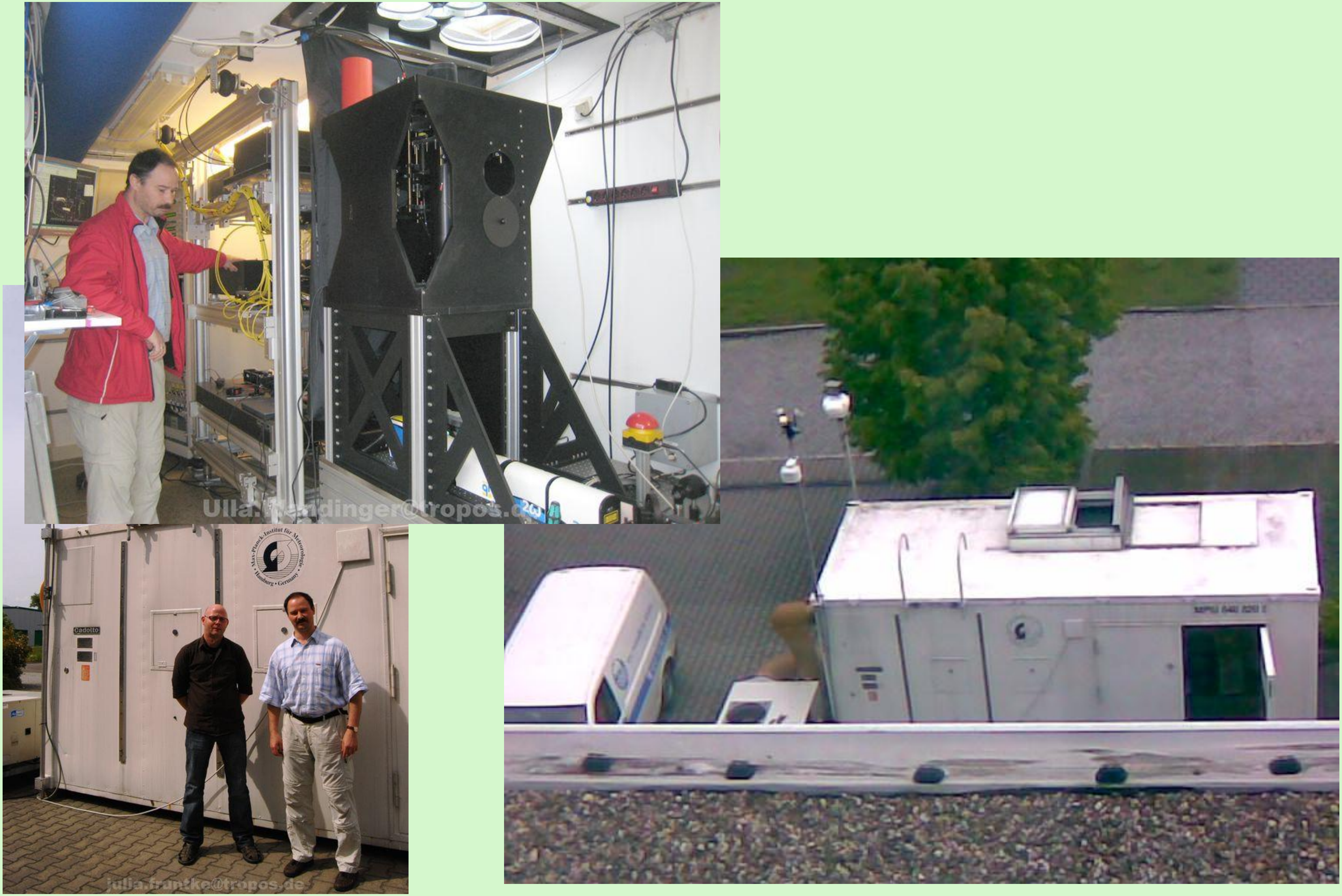


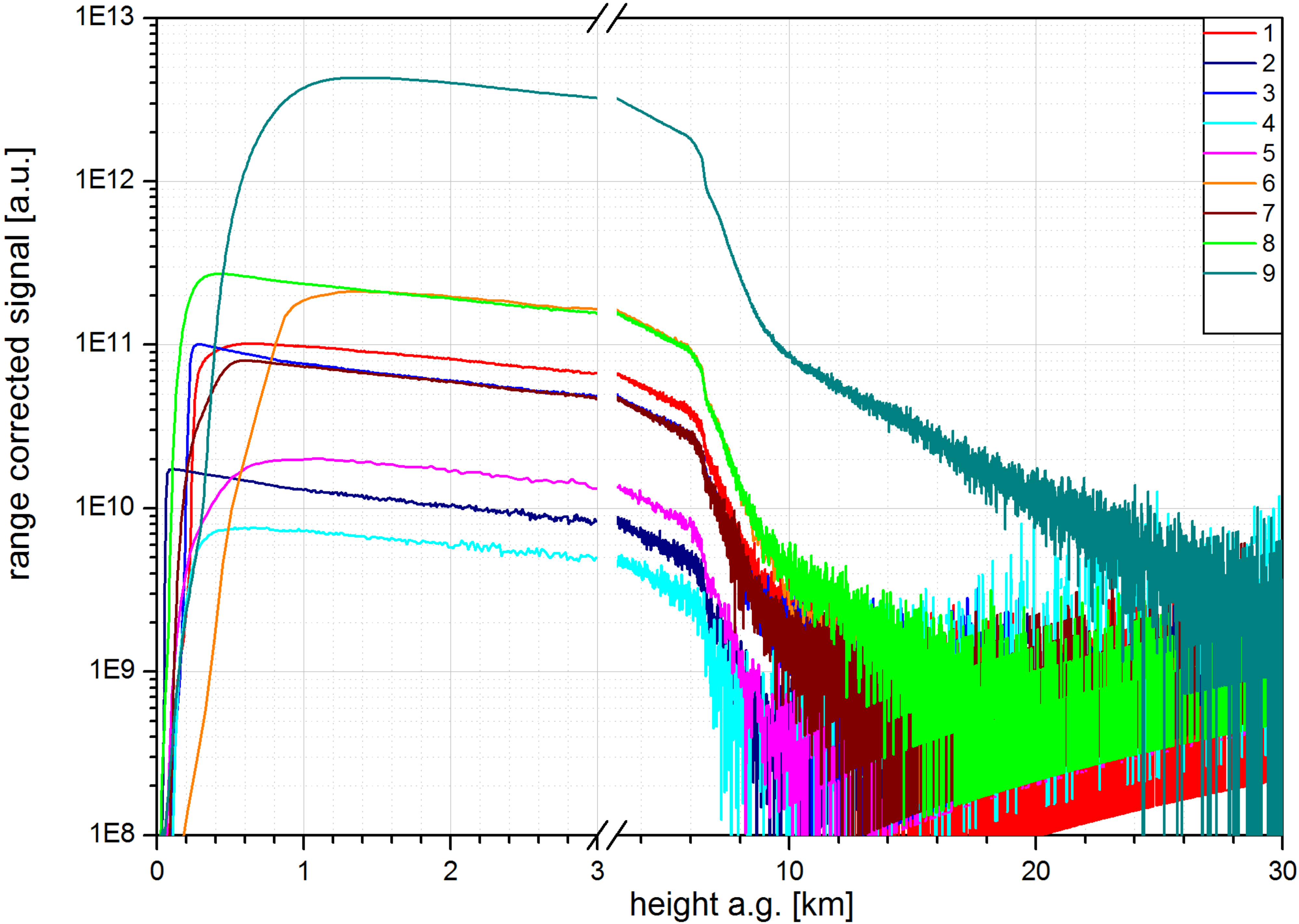
Photo-receiving module MB-01/? 30956-??

Reference Lidar Systems – Potenza - MUSA



Reference Lidar Systems – Hamburg – MARLmob

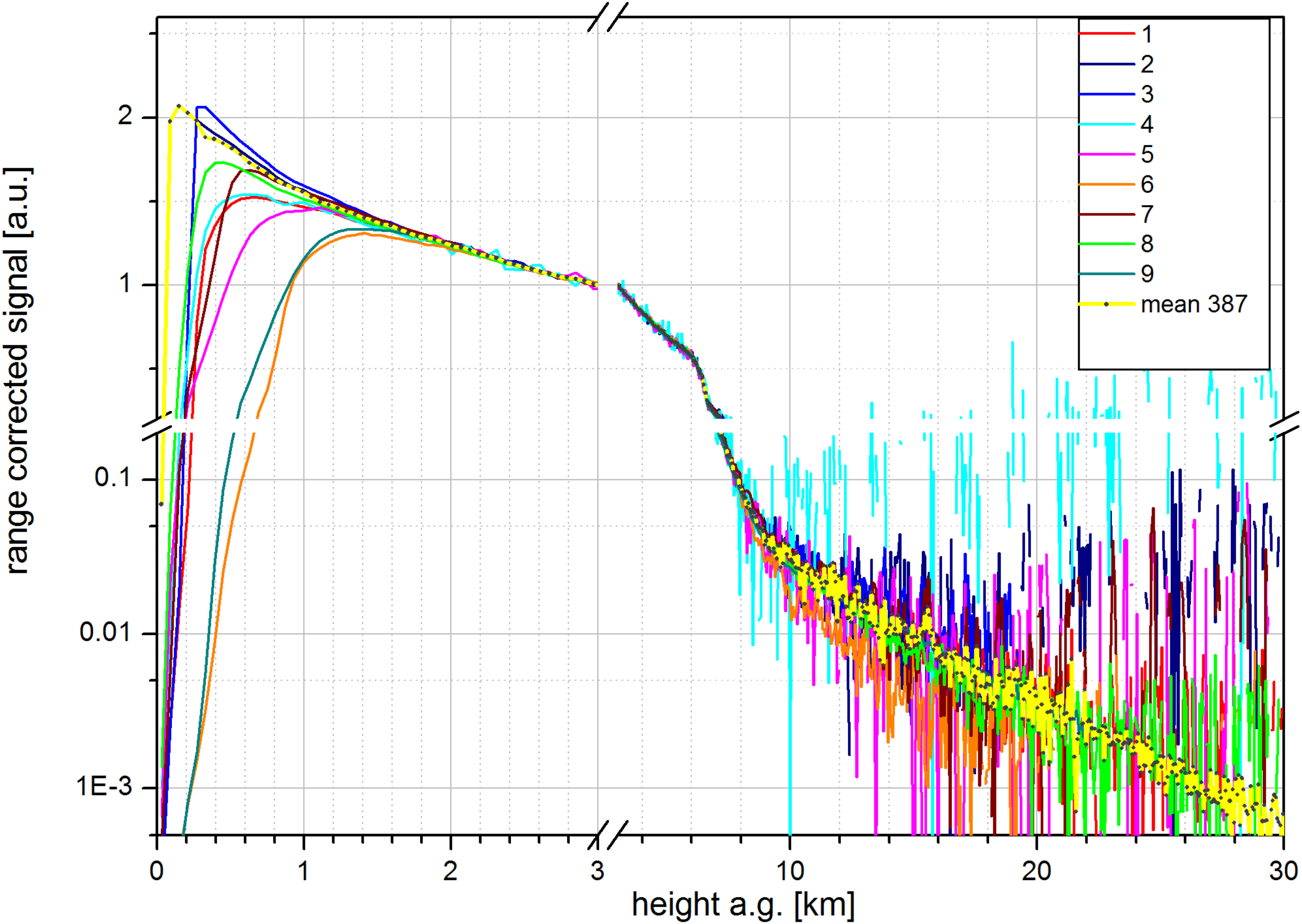




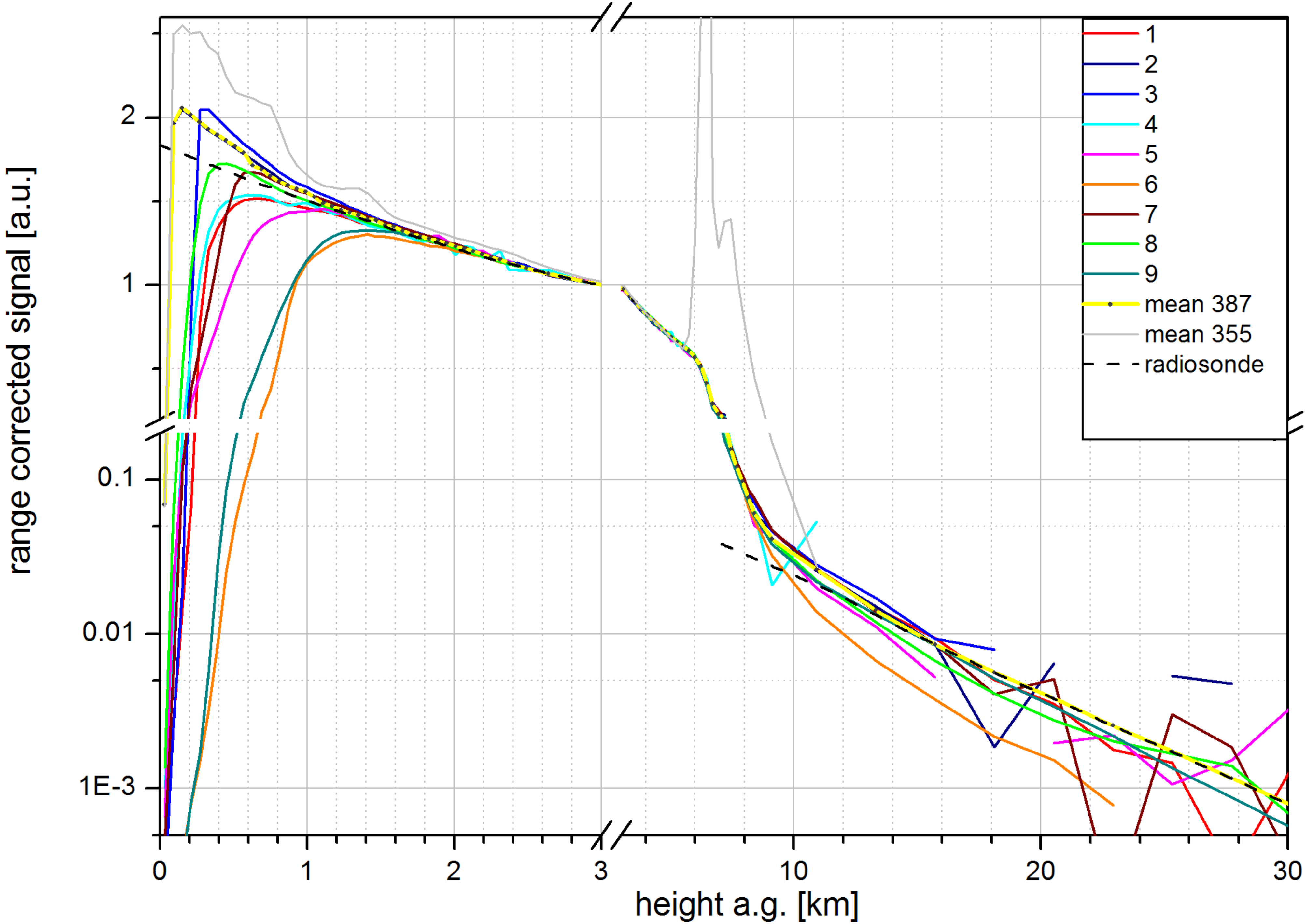
EARLI09 23.05.2009 20:15-21:00 UTC
Range corrected photon-counting signals at 387 nm

EARLI09 23.05.2009 20:15-21:00 UTC

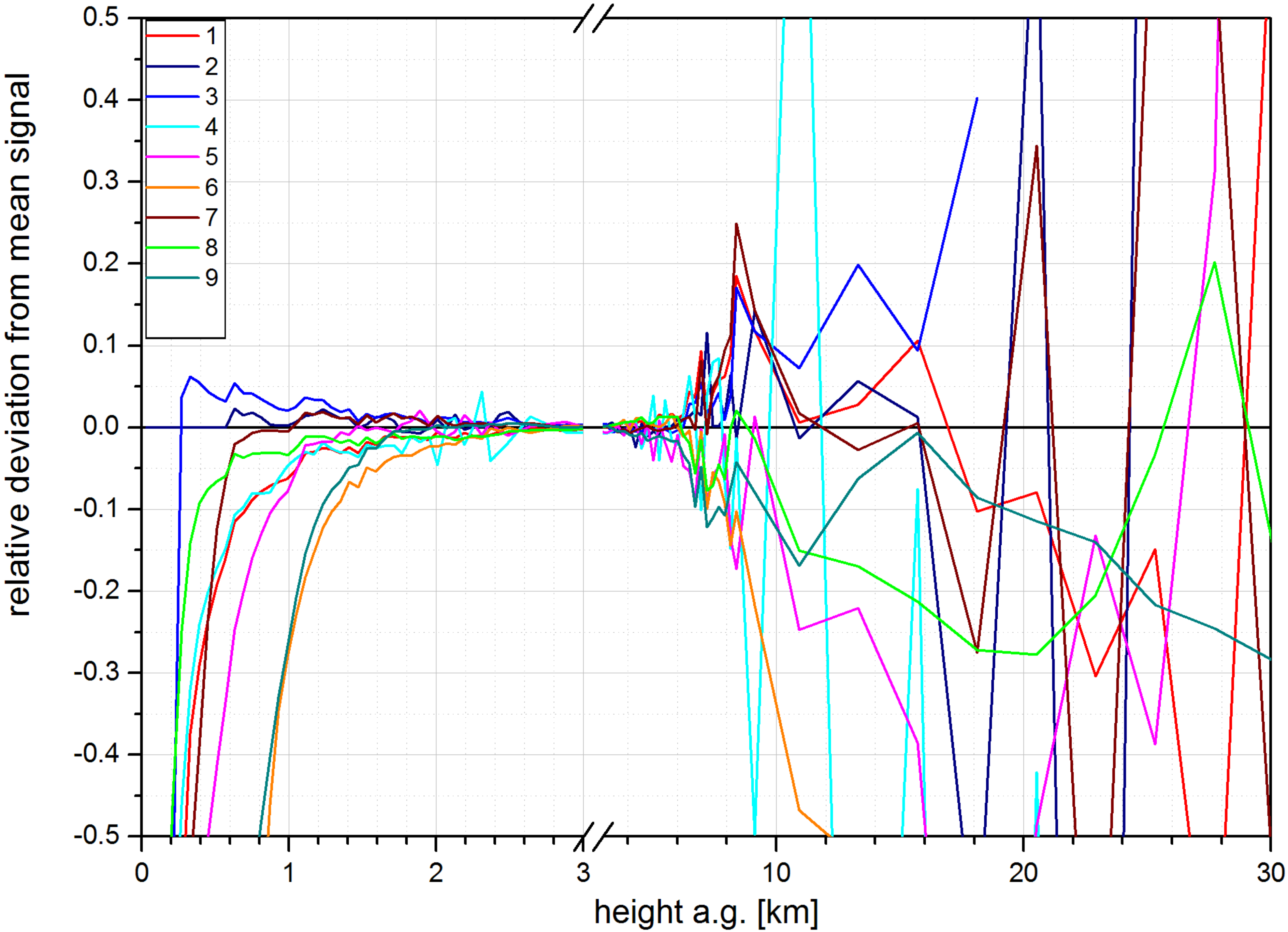
Range corrected photon-counting signals at 387 nm

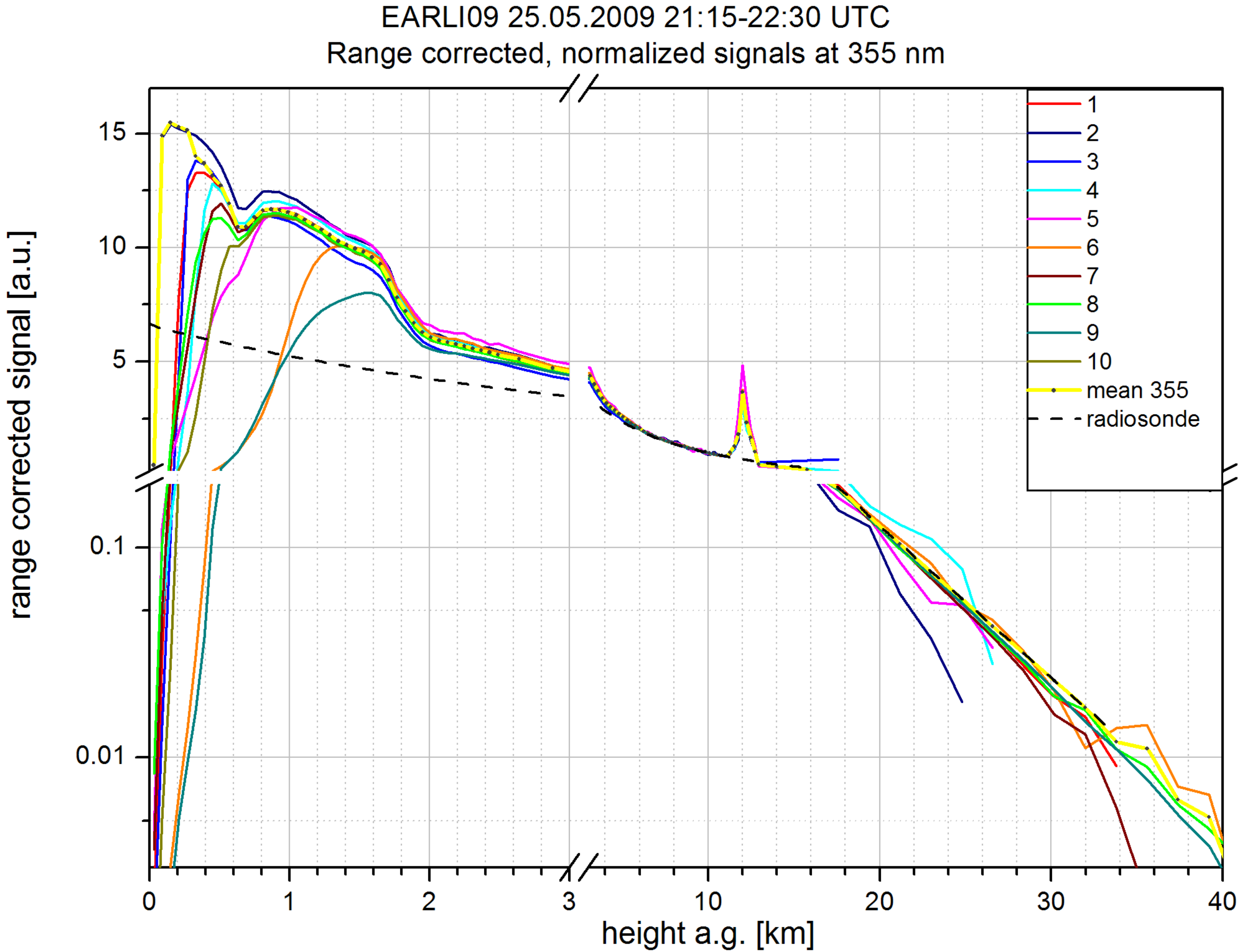


EARLI09 23.05.2009 20:15-21:00 UTC
Range corrected photon-counting signals at 387 nm

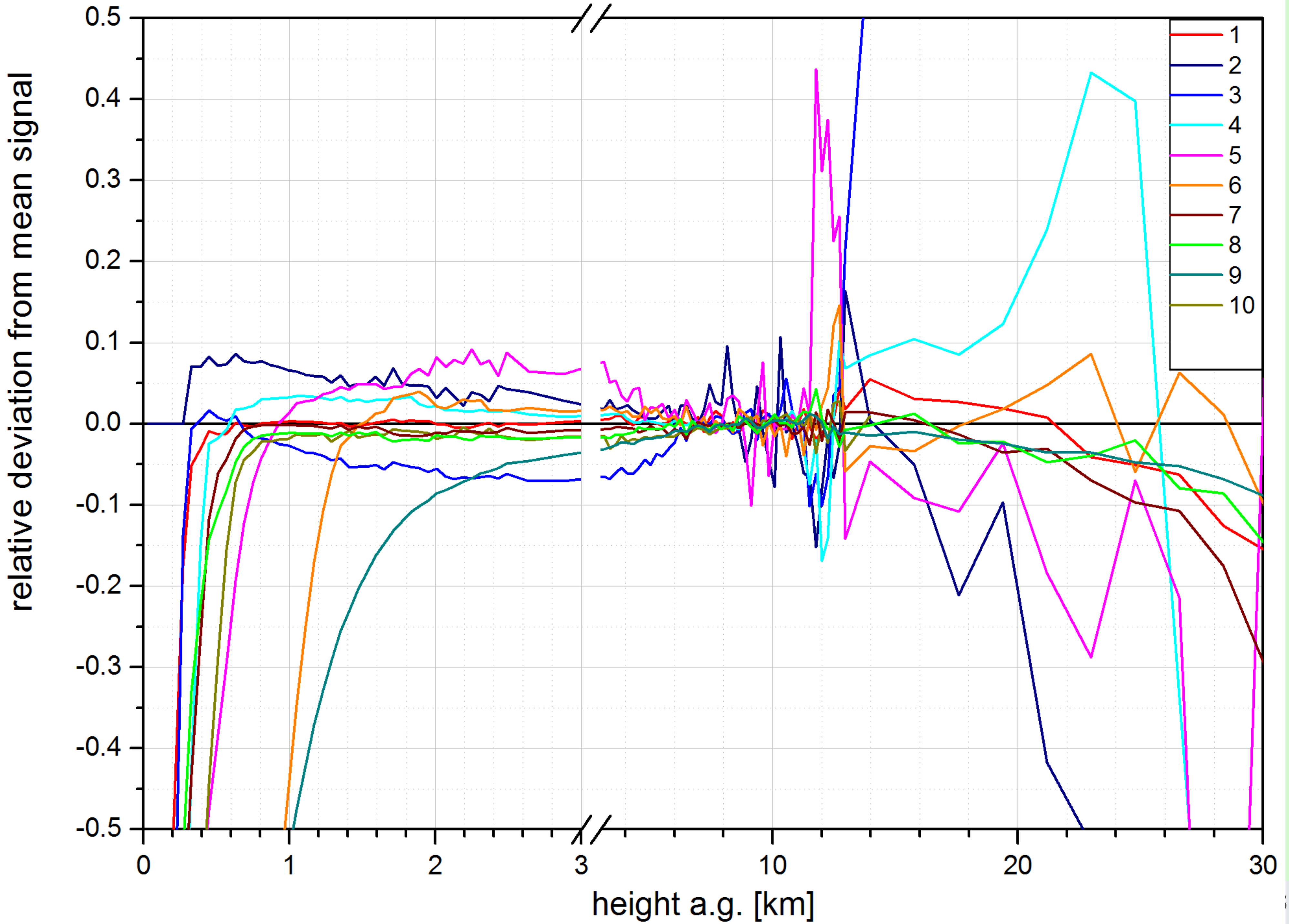


EARLI09 23.05.2009 20:15-21:00 UTC
Relative deviation from mean signal @ 387 nm

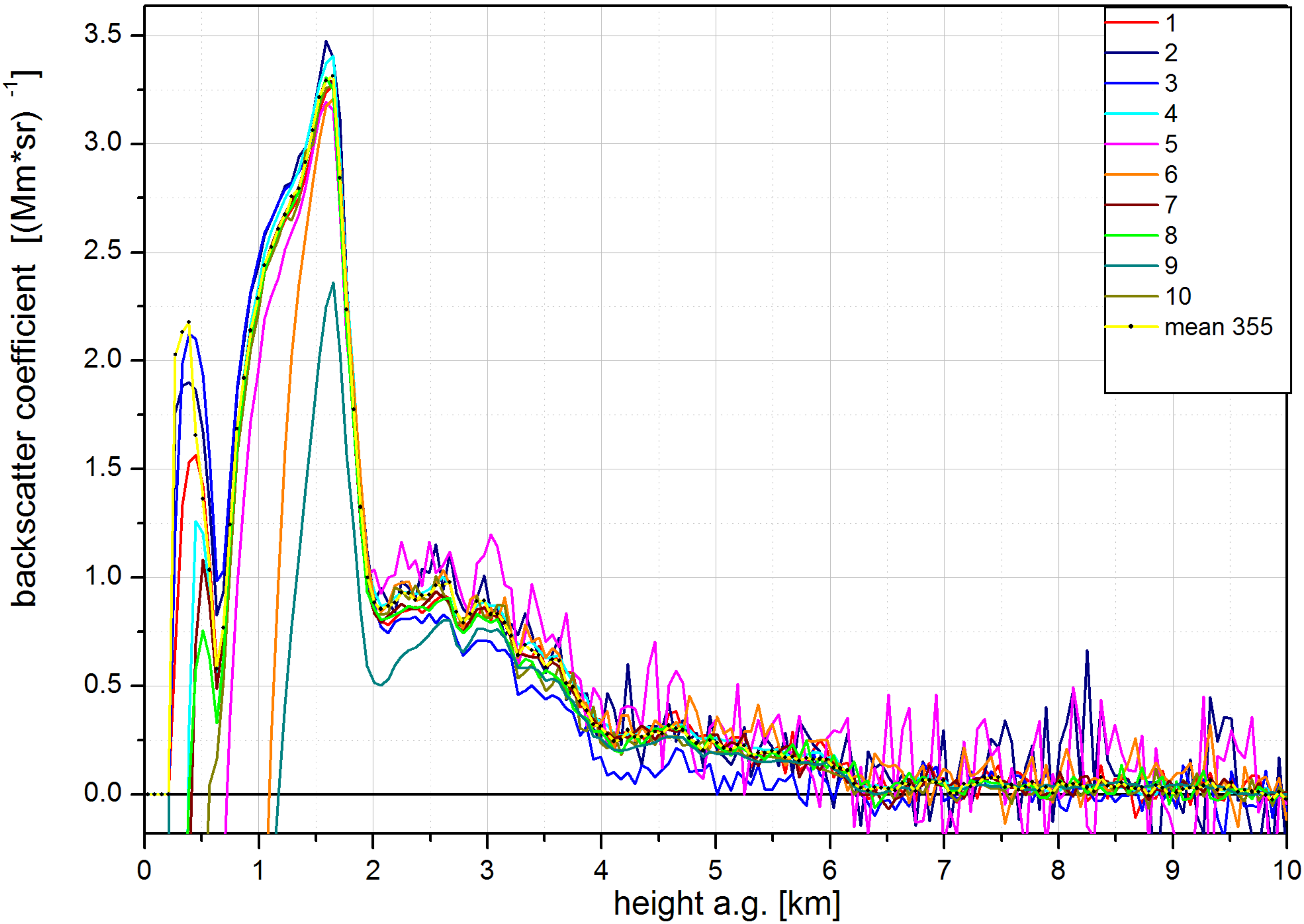



EARLI09 25.05.2009 21:15-22:30 UTC
Range corrected, normalized signals at 355 nm
range corrected signal [a.u.]
height a.g. [km]
15
10
5
0.1
0.01
0
1
2
3
10
20
30
40
1
2
3
4
5
6
7
8
9
10
mean 355
radiosonde

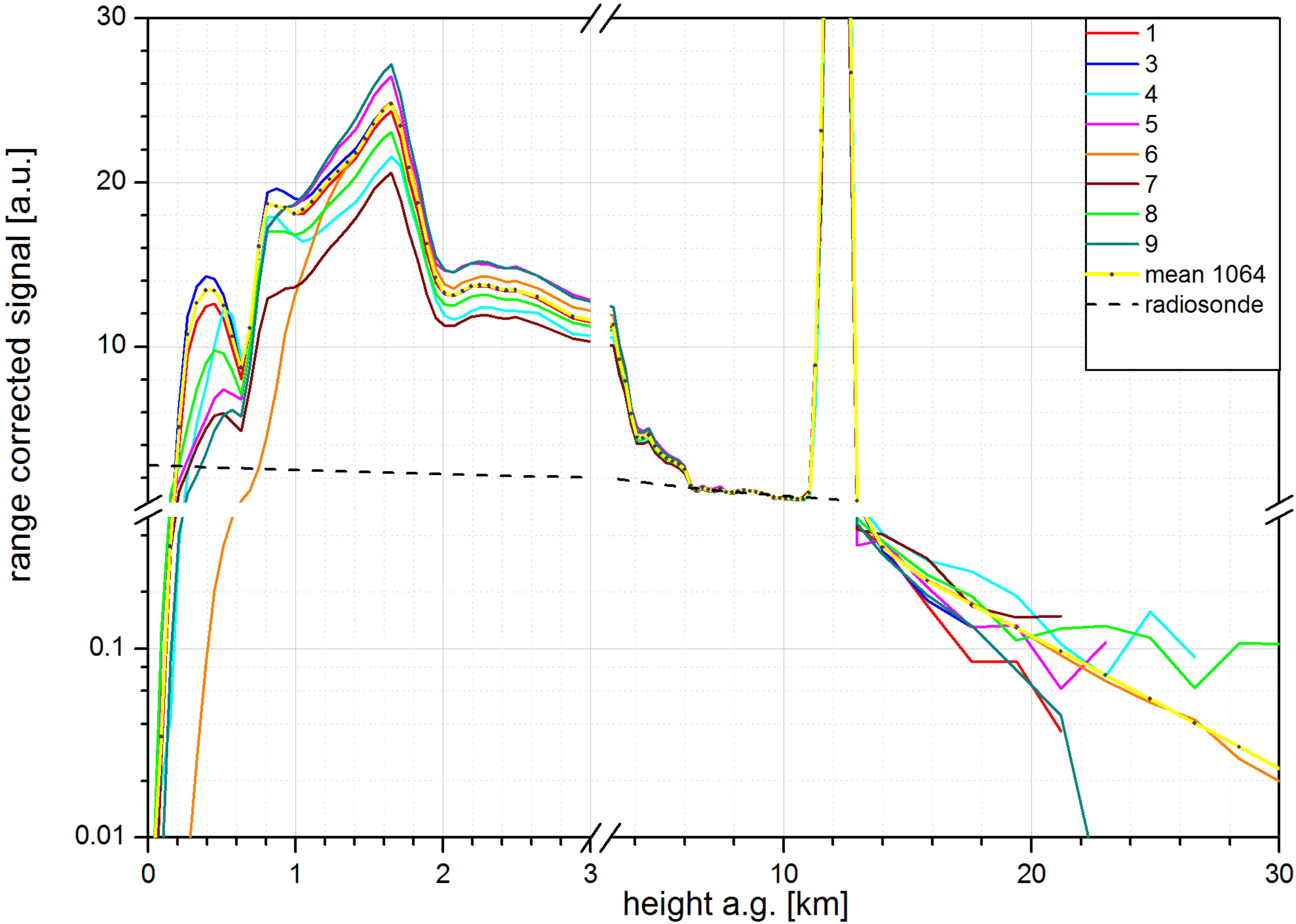
EARLI09 25.05.2009 21:15-22:30 UTC
Relative deviation from mean signal @ 355 nm



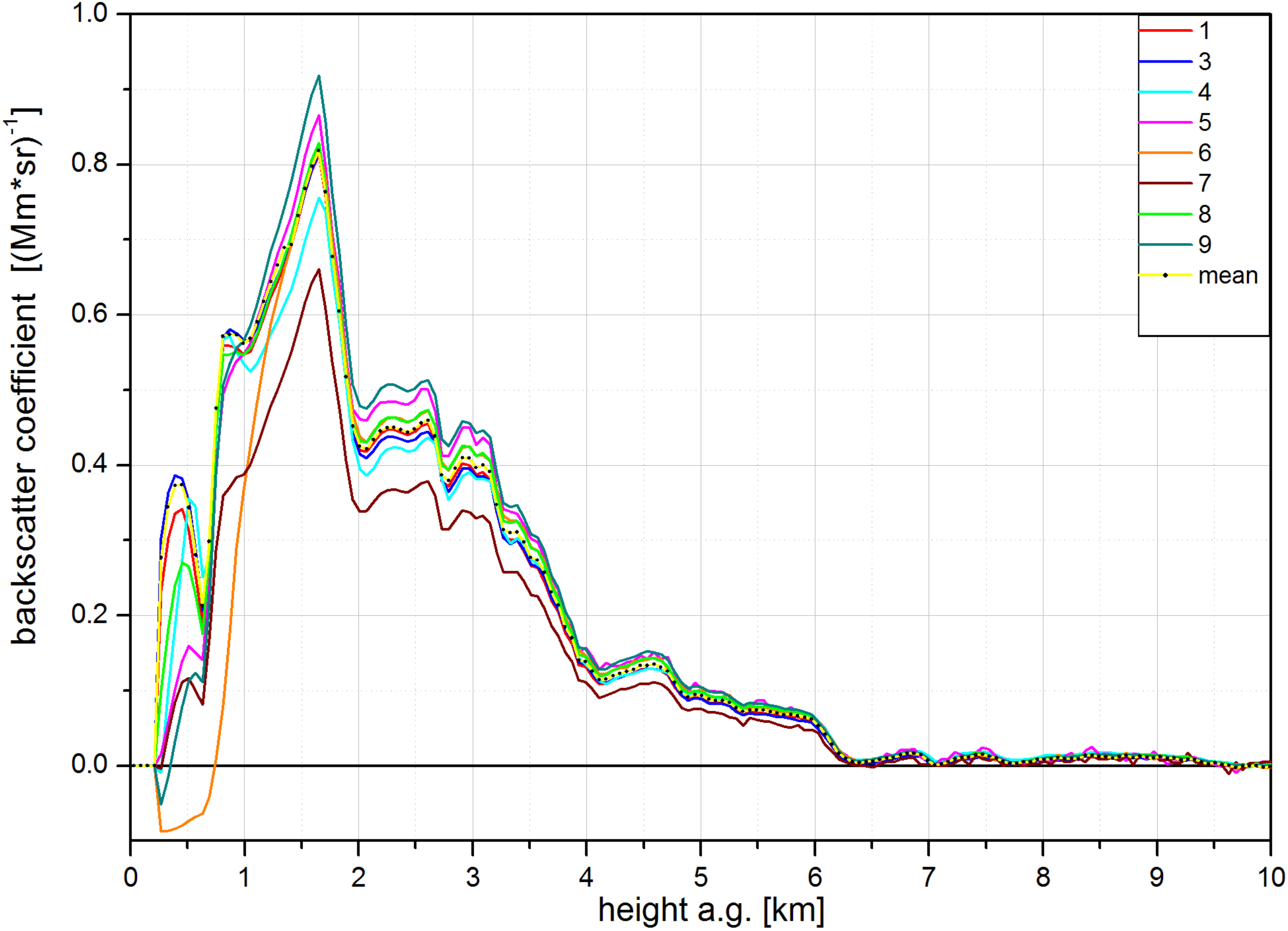
EARLI09 25.05.2009 21:15-22:30 UTC
Backscatter coefficient @355 nm from Fernald-inversion (LR 55sr)



EARLI09 25.05.2009 21:15-22:30 UTC
Range corrected signals at 1064 nm

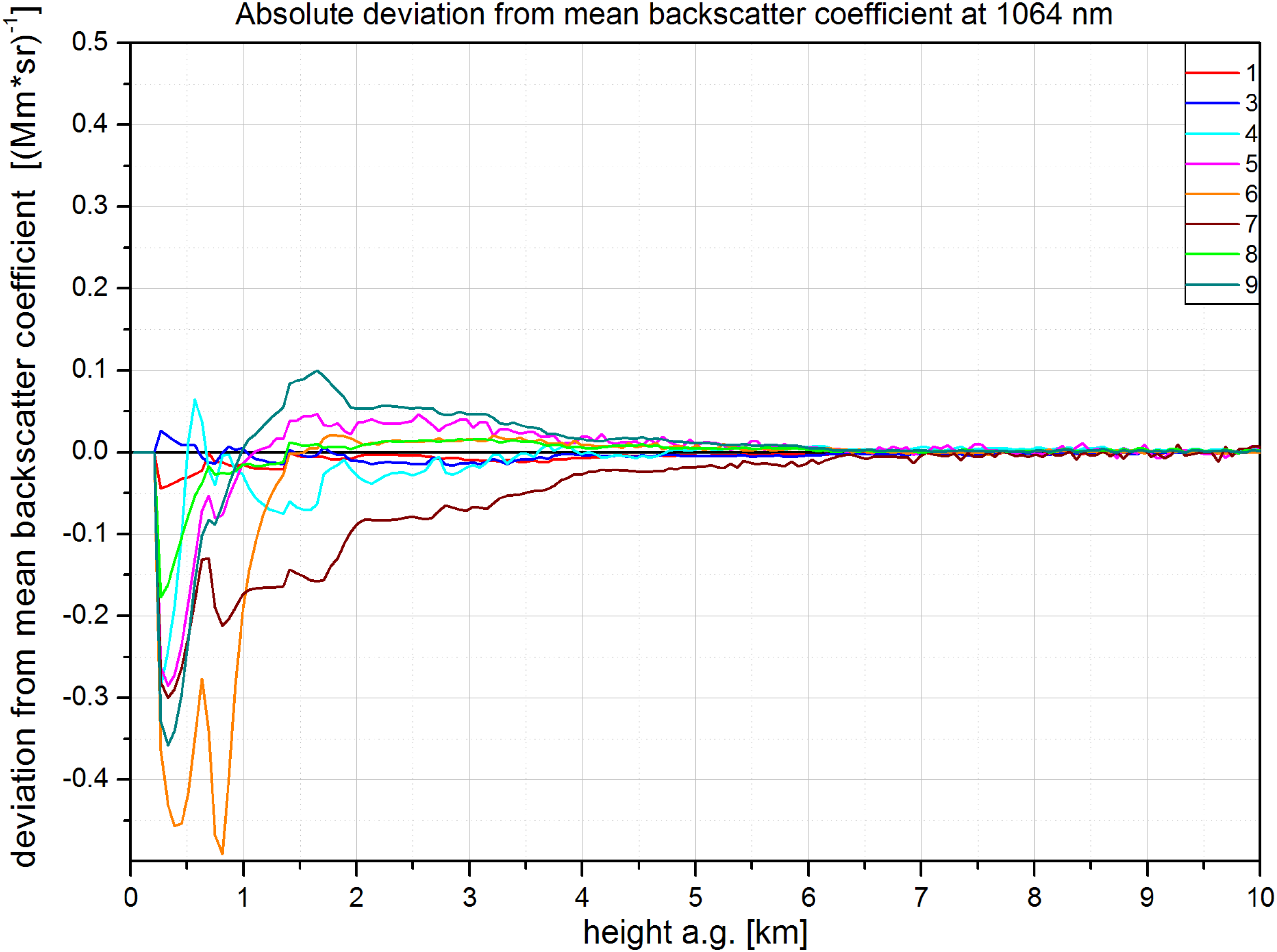


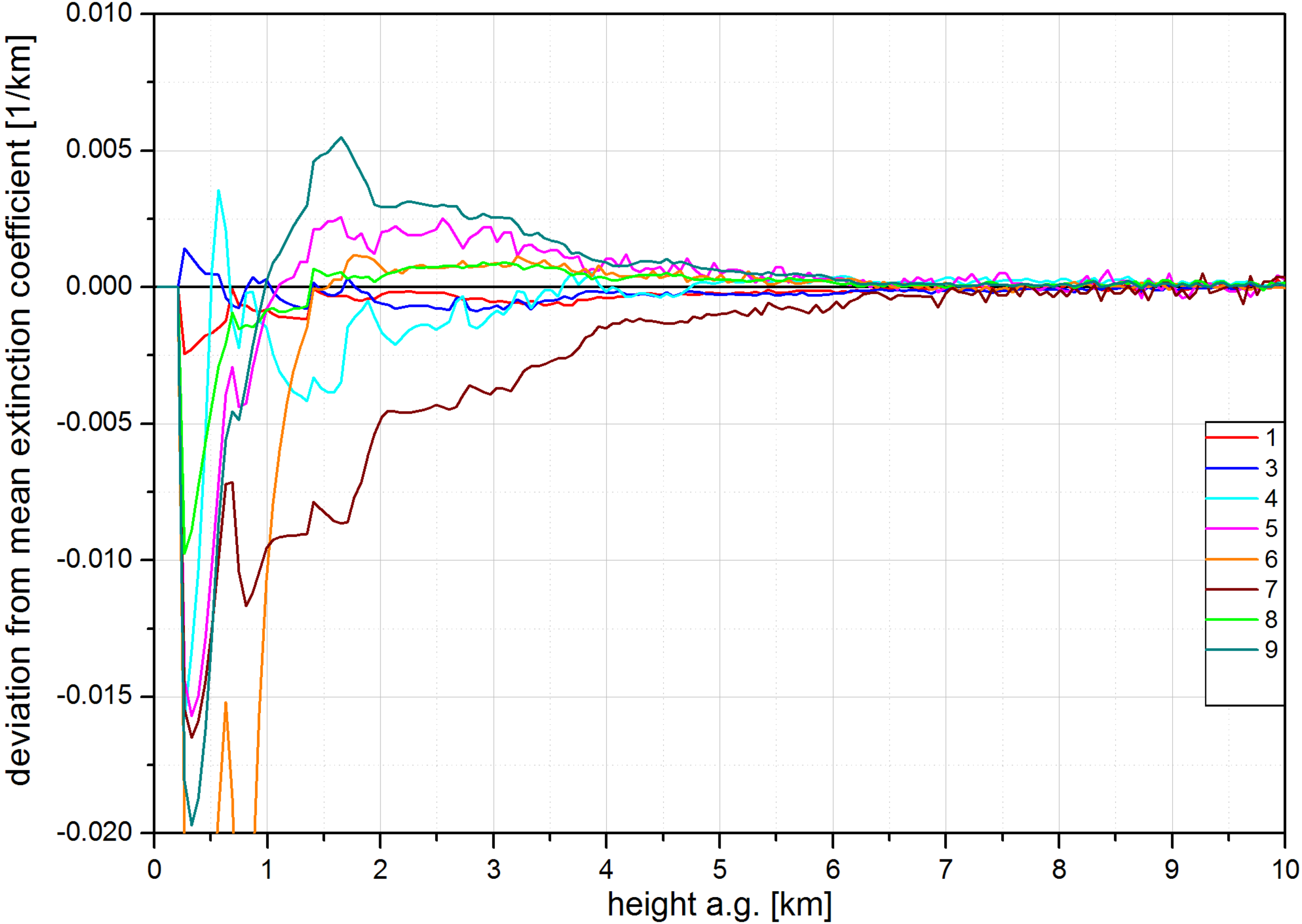
EARLI09 25.05.2009 21:15-22:30 UTC
Backscatter coefficient at 1064 nm from Fernald-inversion (LR 55sr)



EARLI09 25.05.2009 21:15-22:30 UTC

Absolute deviation from mean backscatter coefficient at 1064 nm



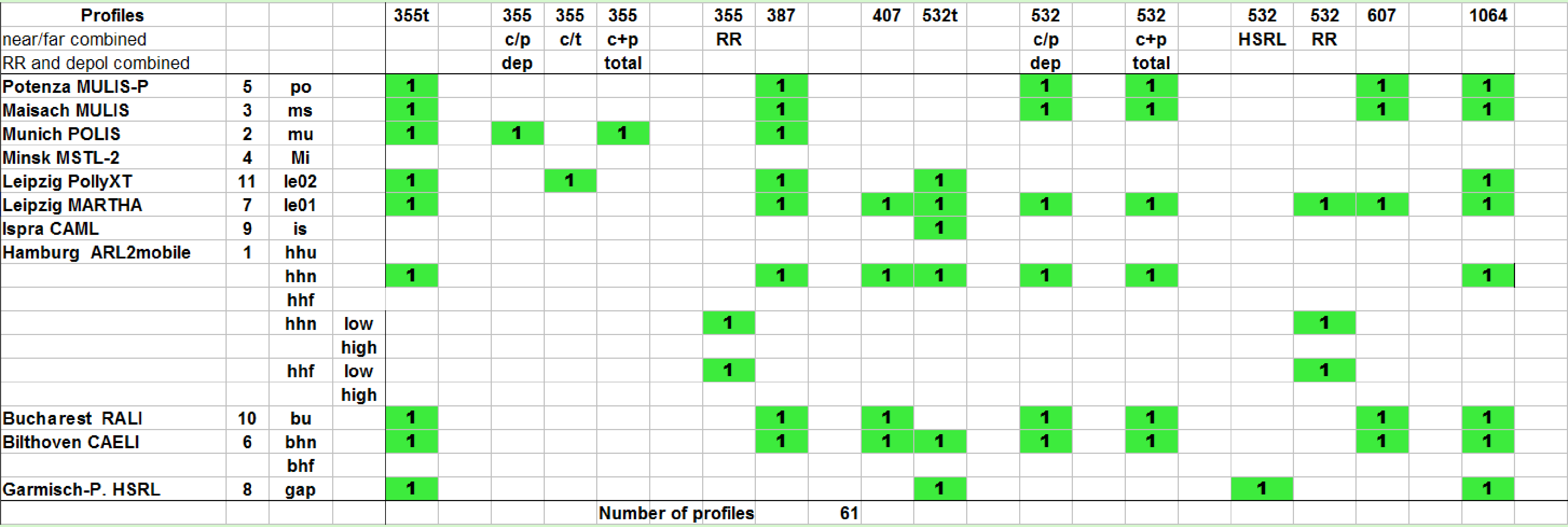


EARLI09 25.05.2009 21:15-22:30 UTC
Absolute deviation from mean extinction coefficient at 1064 nm

EARLI09, Leipzig, 2009 / 114 individual signals

Signals	Sys			355t		355c		355p		355	387		407	532t		532c		532p		532	532	607		1064	
	no									RR										HSRL	RR				
				a	pc	a	pc	a	pc	pc	a	pc	pc	a	pc	a	pc	a	pc	a	pc	a	pc	a	pc
Potenza MULIS-P	5	po		1	1						1	1				1	1	1	1			1	1	1	
Maisach MULIS	3	ms		1							1	1				1						1	1	1	
Munich POLIS	2	mu		1	1	1	1	1	1		1	1													
Minsk MSTL-2	4	Mi																							
Leipzig PollyXT	11	le02			1		1					1		1	1										1
Leipzig MARTHA	7	le01			1							1	1		1		1	1	1		2		1		1
Ispra CAML	9	is													1										
Hamburg ARL2mobile	1	hhu			1										1										
		hhn			1							1	1		1	1		1						1	
		hhf			1							1	1		1									1	
		hhn	low							2											2				
			high							2											2				
		hhf	low							2											2				
			high							2											2				
Bucharest RALI	10	bu		1	1						1	1	1			1	1	1	1			1	1	1	
Bilthoven CAELI	6	bhn		1	1						1	1	1	1	1	1	1	1	1			1	1	1	
		bhf		1	1						1	1	1	1	1							1	1	1	
Garmisch-P. HSRL	8	gap		1										1						1				1	
								Number of signals				114													

EARLI09, Leipzig, 2009 / 61 combined profiles



Profiles				355t	355	355	355	355	387		407	532t	532	532	532	532	607	1064
near/far combined					c/p	c/t	c+p	RR					c/p	c+p	HSRL	RR		
RR and depol combined					dep		total						dep	total				
Potenza MULIS-P	5	po		1					1				1	1			1	1
Maisach MULIS	3	ms		1					1				1	1			1	1
Munich POLIS	2	mu		1	1		1		1									
Minsk MSTL-2	4	Mi																
Leipzig PollyXT	11	le02		1		1			1			1						1
Leipzig MARTHA	7	le01		1					1		1	1	1	1		1	1	1
Ispra CAML	9	is										1						
Hamburg ARL2mobile	1	hhu																
		hhn		1					1		1	1	1	1				1
		hhf																
		hhn	low					1								1		
			high															
		hhf	low					1								1		
			high															
Bucharest RALI	10	bu		1					1		1		1	1			1	1
Bilthoven CAELI	6	bhn		1					1		1	1	1	1			1	1
		bhf																
Garmisch-P. HSRL	8	gap		1								1			1			1
							Number of profiles			61								

Data preprocessing:
Ina Mattis & Giuseppe D'Amico

with Single Chain Calculus – EARLI09 -preprocessor , NA5

EARLI09 - Eleven lidar beams

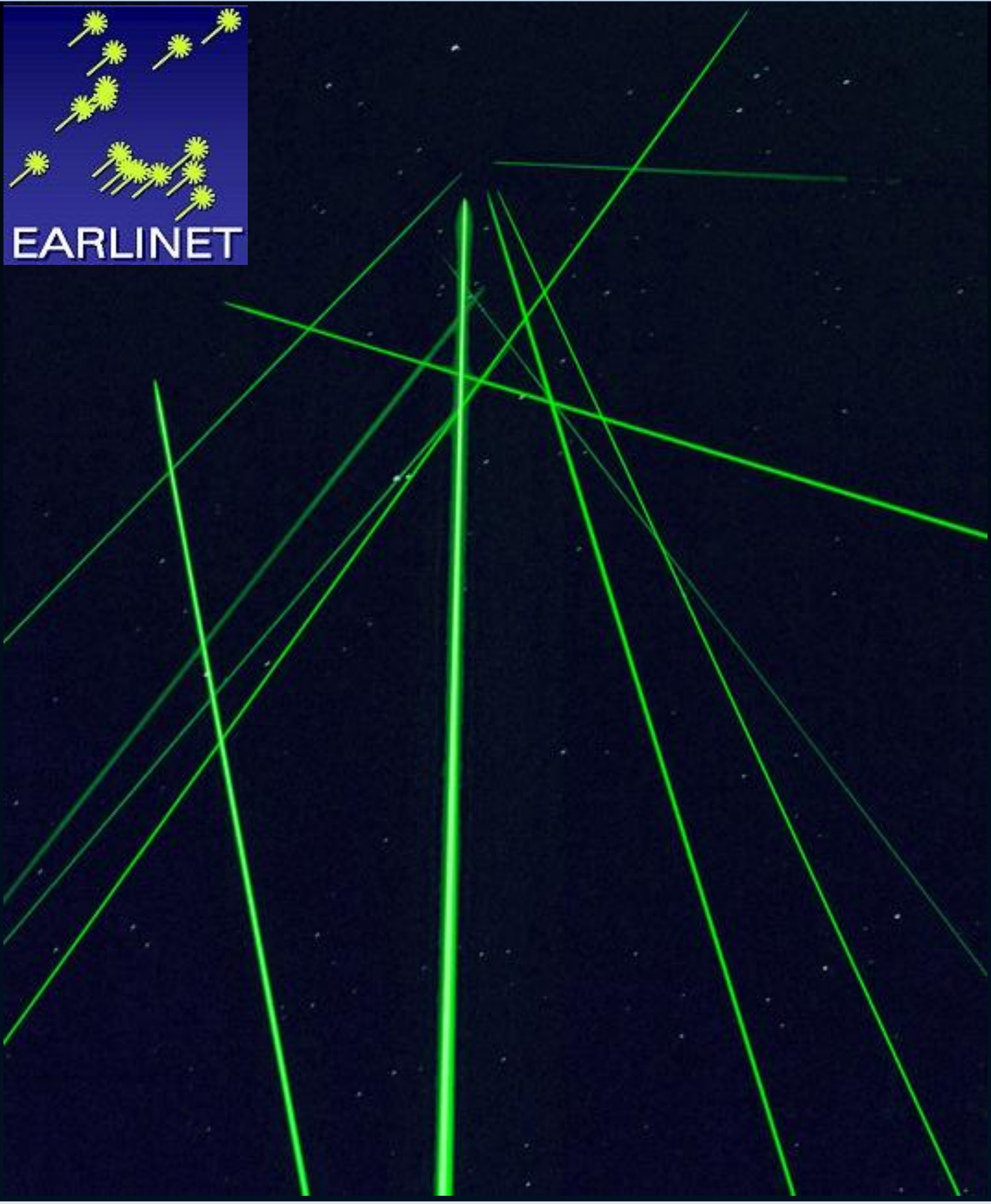
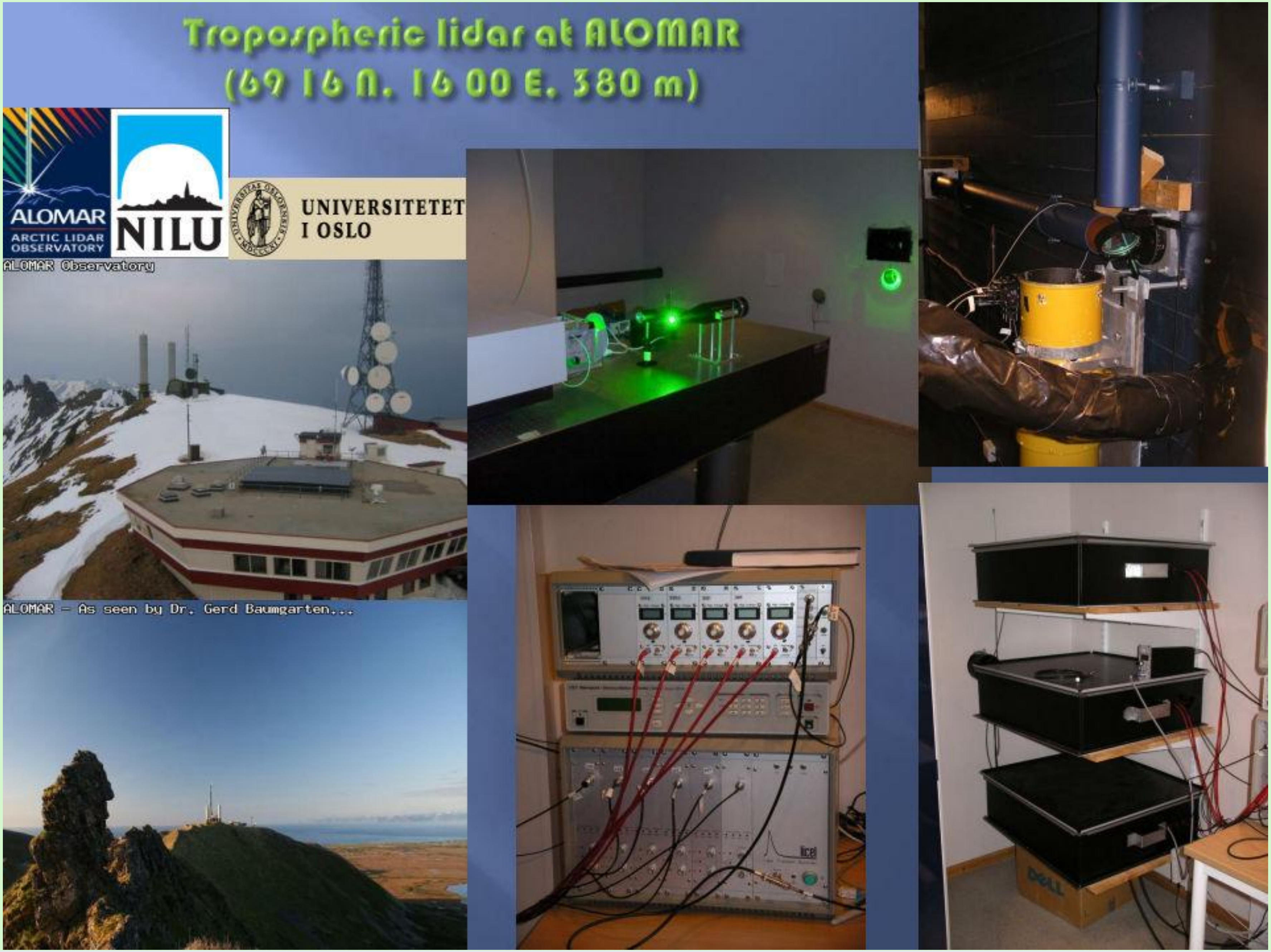


photo: Thomas Massmann

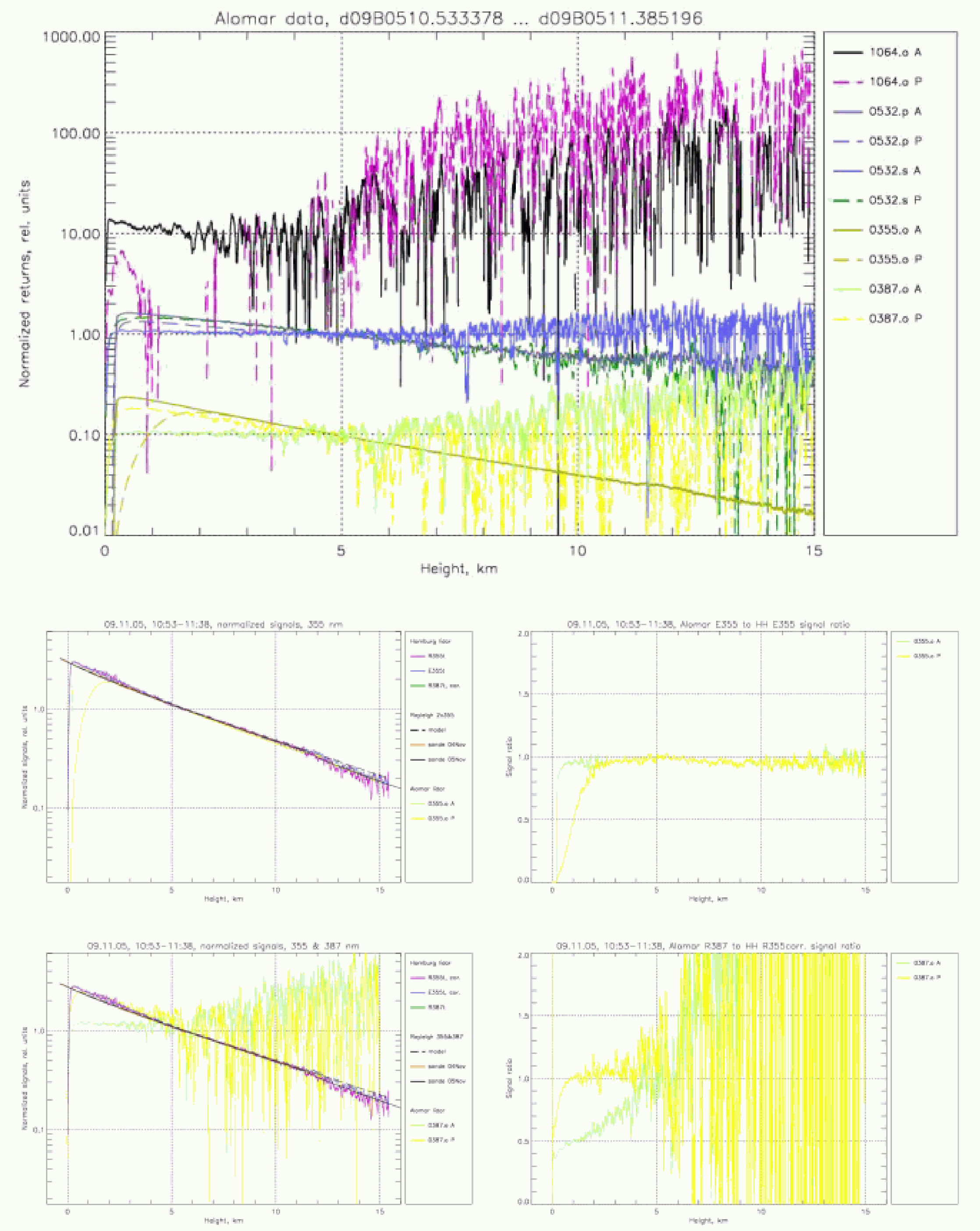
Lidar intercomparison – ALI09, Alomar 2009

Lidar intercomparisons – ALI09, Alomar 2009



Lidar intercomparisons – ALI09, Alomar 2009

Lidar intercomparisons – ALI09, Alomar 2009



Lidar intercomparisons – 2010

EARLINET-ASOS lidar intercomparisons

EARLINET Quality Assurance - NA3.2 Algorithm checks

lidar system ERRORS

critical parts / design improvements NA4

system intercomparison / internal checks NA3.1

data analysis ERRORS

algorithm intercomparison NA3.2

single chain calculus NA5.1

common database less ERRORS

data base checks

inversion optical to microphysical NA5.2

EARLINET Quality Assurance - NA3.2 Algorithm checks

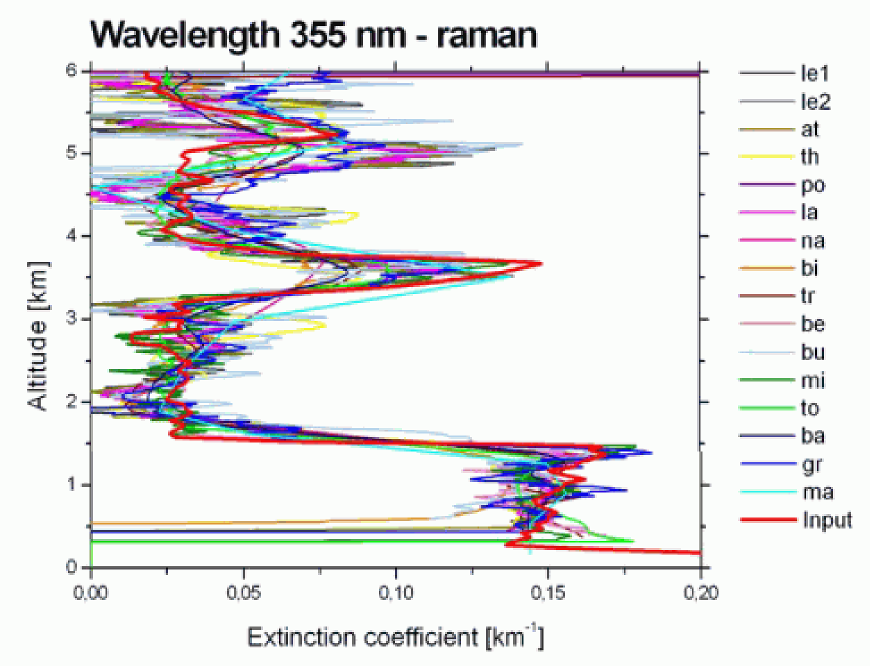
Test of analysis software

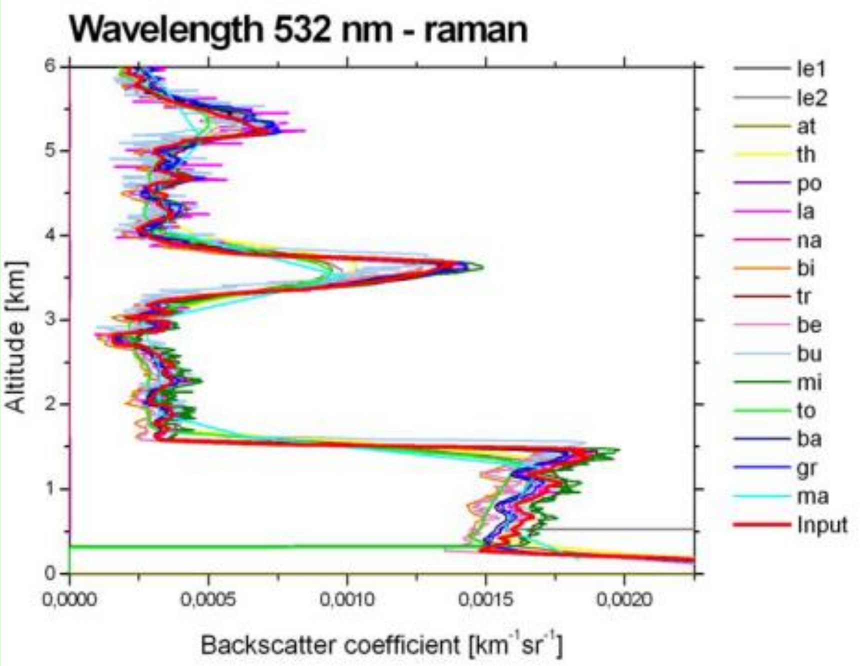
Fernald/Klett/etc. & Raman

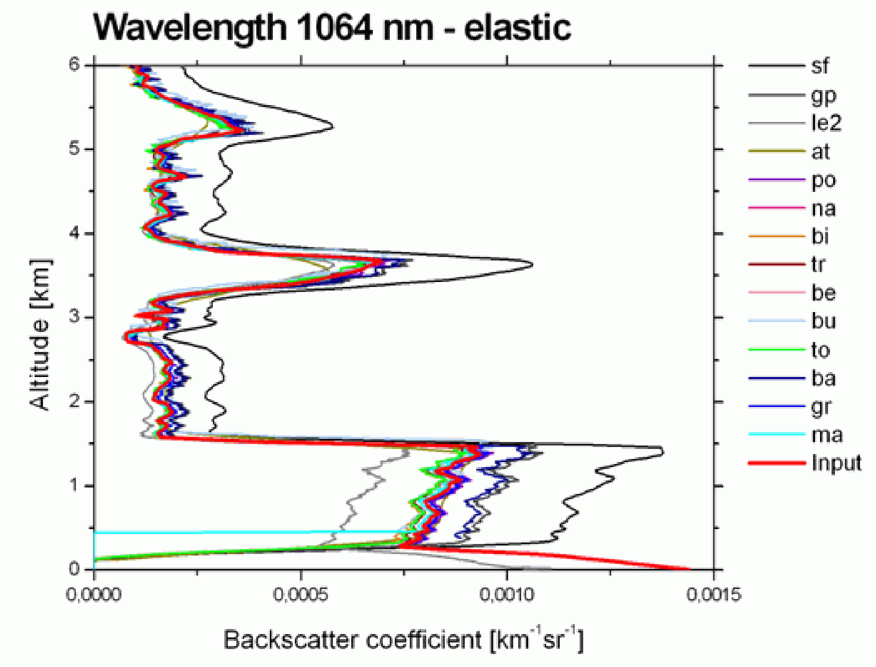
- using synthetic lidar signals
- extinction coefficients etc. unknown to groups

Already in EARLINET FP5 many sofware had been checked - and improved.

EARLINET Quality Assurance - NA3.2 Algorithm checks

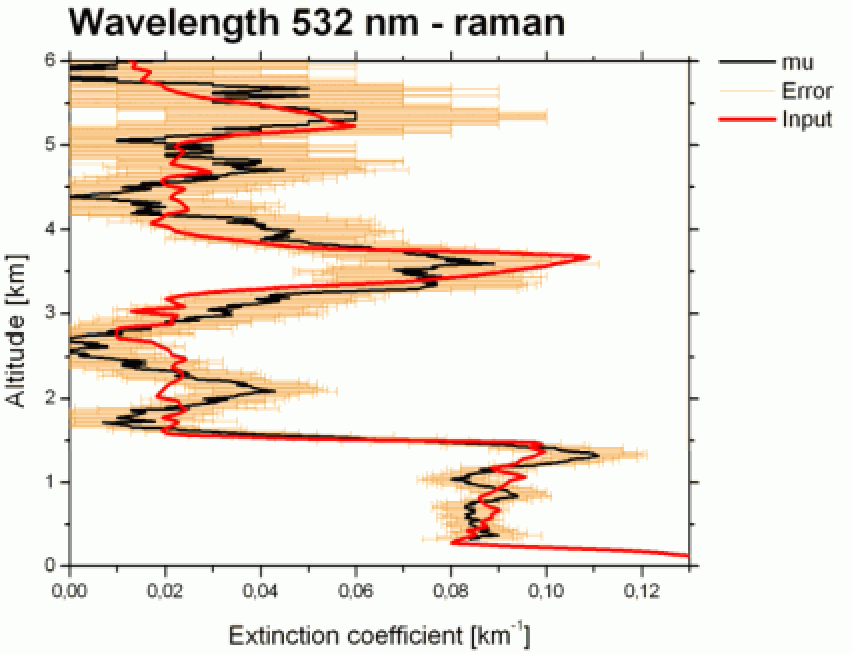

Wavelength 355 nm - raman

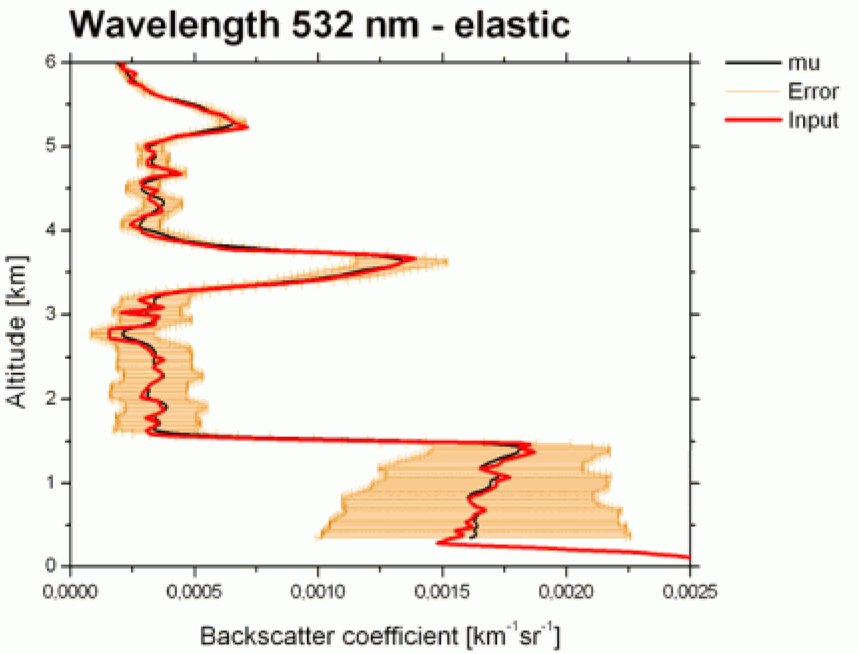

Wavelength 532 nm - raman

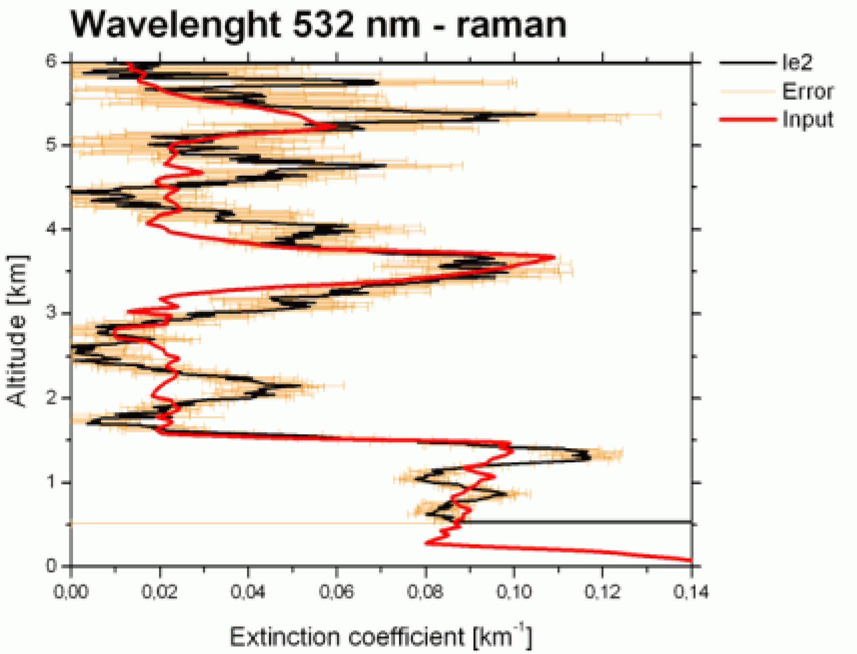

Wavelength 1064 nm - elastic

Alomar 2008

EARLINET Quality Assurance - NA3.2 Algorithm checks

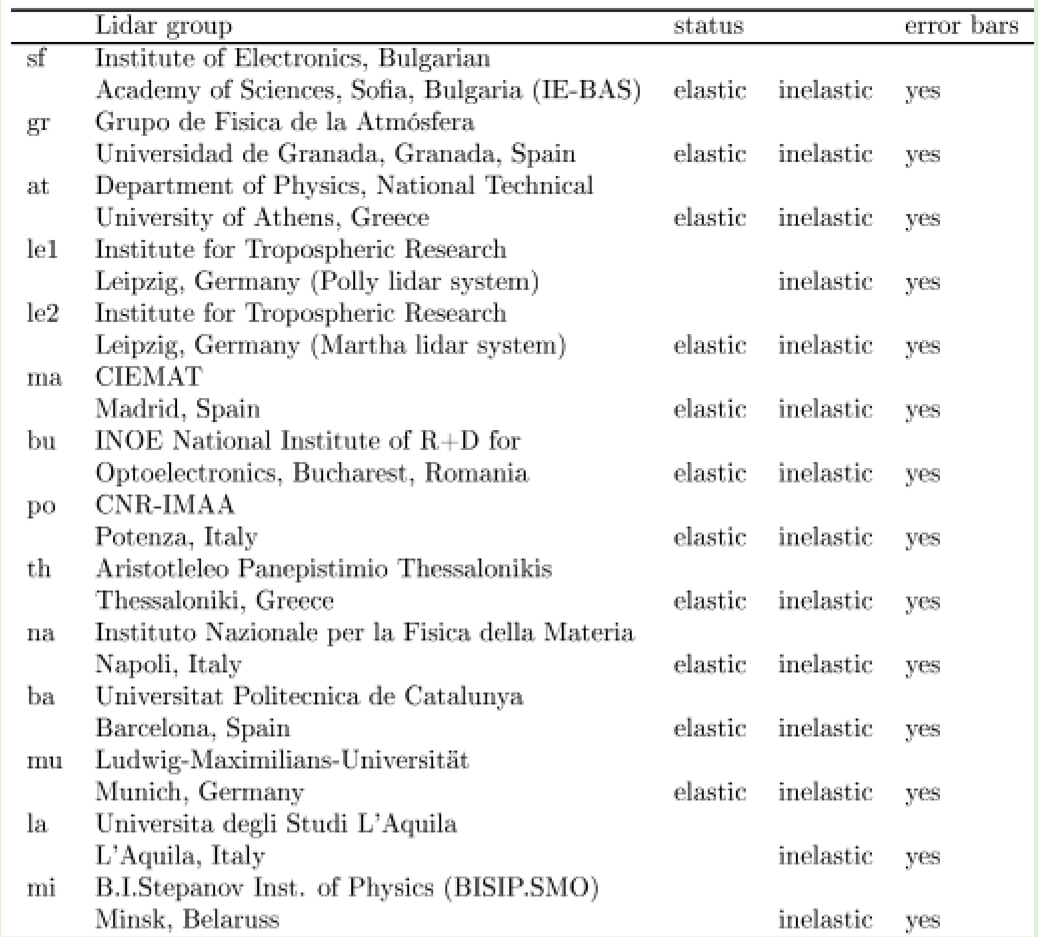

Wavelength 532 nm - raman


Wavelength 532 nm - elastic


Wavelenght 532 nm - raman

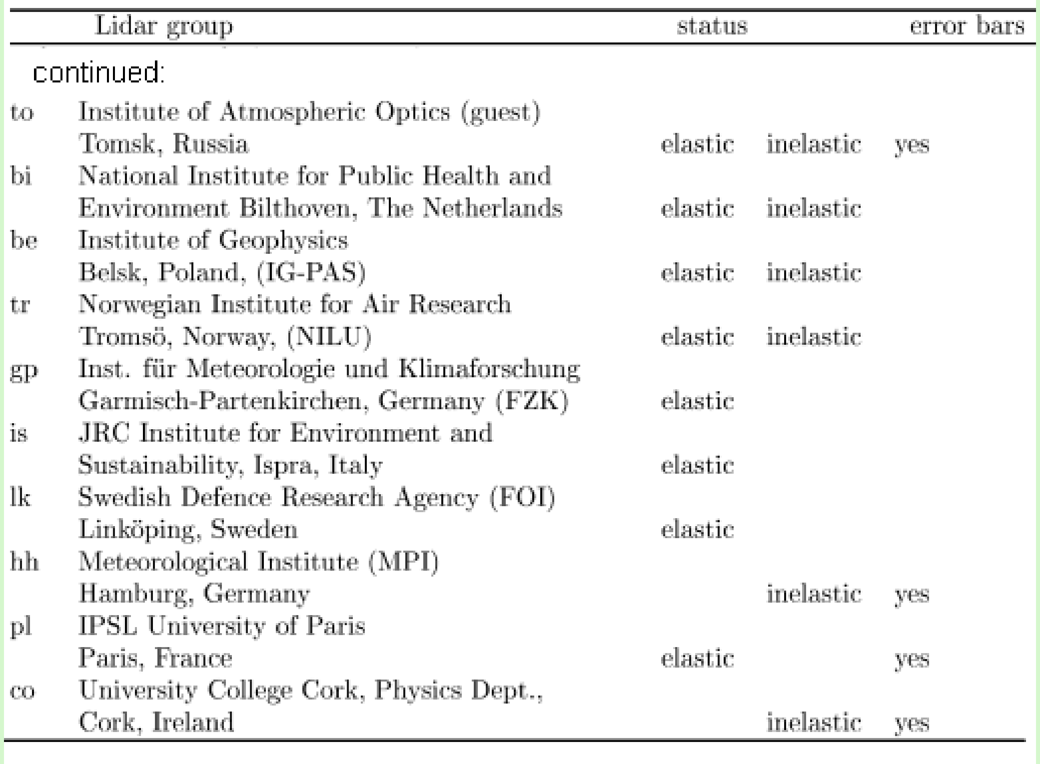
Error bars !

EARLINET Quality Assurance - NA3.2 Algorithm checks



	Lidar group	status		error bars
sf	Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria (IE-BAS)	elastic	inelastic	yes
gr	Grupo de Fisica de la Atmósfera Universidad de Granada, Granada, Spain	elastic	inelastic	yes
at	Department of Physics, National Technical University of Athens, Greece	elastic	inelastic	yes
le1	Institute for Tropospheric Research Leipzig, Germany (Polly lidar system)		inelastic	yes
le2	Institute for Tropospheric Research Leipzig, Germany (Martha lidar system)	elastic	inelastic	yes
ma	CIEMAT Madrid, Spain	elastic	inelastic	yes
bu	INOE National Institute of R+D for Optoelectronics, Bucharest, Romania	elastic	inelastic	yes
po	CNR-IMAA Potenza, Italy	elastic	inelastic	yes
th	Aristotleleo Panepistimio Thessalonikis Thessaloniki, Greece	elastic	inelastic	yes
na	Instituto Nazionale per la Fisica della Materia Napoli, Italy	elastic	inelastic	yes
ba	Universitat Politecnica de Catalunya Barcelona, Spain	elastic	inelastic	yes
mu	Ludwig-Maximilians-Universität Munich, Germany	elastic	inelastic	yes
la	Universita degli Studi L'Aquila L'Aquila, Italy		inelastic	yes
mi	B.I.Stepanov Inst. of Physics (BISIP.SMO) Minsk, Belaruss		inelastic	yes

including "guest" groups



	Lidar group	status		error bars
continued:				
to	Institute of Atmospheric Optics (guest) Tomsk, Russia	elastic	inelastic	yes
bi	National Institute for Public Health and Environment Bilthoven, The Netherlands	elastic	inelastic	
be	Institute of Geophysics Belsk, Poland, (IG-PAS)	elastic	inelastic	
tr	Norwegian Institute for Air Research Tromsö, Norway, (NILU)	elastic	inelastic	
gp	Inst. für Meteorologie und Klimaforschung Garmisch-Partenkirchen, Germany (FZK)	elastic		
is	JRC Institute for Environment and Sustainability, Ispra, Italy	elastic		
lk	Swedish Defence Research Agency (FOI) Linköping, Sweden	elastic		
hh	Meteorological Institute (MPI) Hamburg, Germany		inelastic	yes
pl	IPSL University of Paris Paris, France	elastic		yes
co	University College Cork, Physics Dept., Cork, Ireland		inelastic	yes

Table 1: Participating groups in software intercomparison

Geneva 2010

Last Slide

Last Slide