LIISim 3

User guide

Version 3.0.7

January 2019

(04.04.2019)

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Website: www.liisim.com

www.uni-due.de/ivg/rf

Source code: www.github.com/LIISim/LIISim3

LIISim is a project of:

IVG Institute for Combustion and Gas Dynamics Reactive Fluids

UNIVERSITÄT DUISBURG ESSEN

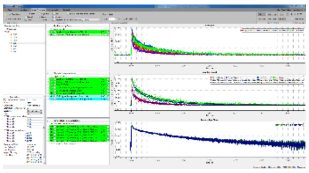
Offen im Denken

Table of Contents

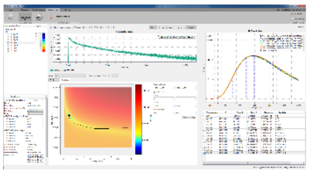
1 Introduction

Welcome to LIISim3, a modular signal processing toolbox for time-resolved laser-induced incandescence measurements written in C++ with the Qt-Framework. This user guide describes the main functionalities of the software and how to use it. Please feel free to contact the authors if you have questions, find errors or have any other feedback.

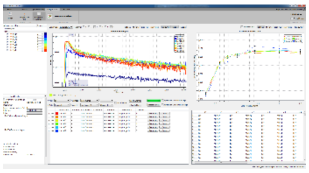
Some screenshots of the software:



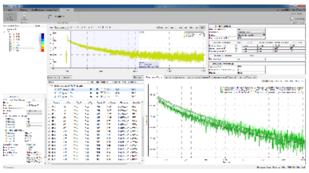
SignalProcessing
The modular signal processing toolbox allows processing of raw signals, absolute signals and temperature traces. Processing steps can be individually set and arranged. Intermediate processing results can be visualized and analyzed with various plot tools.



AnalysisTool: Temperature Fit
Visualization of spectral temperature fitting using Planck's law. Temperature traces that are calculated in the SignalProcessing module can be analyzed and all fitting iterations can be visualized.



AnalysisTool: Parameter Analysis
Experimental data can be systematically compared for various parameters (i.e., laser fluence, LII peak temperature, PMT gain voltage, …).



FitCreator
Select from a variety of heat transfer models and databases for simulation of LII signal traces and comparison with experimental data.

1.1 Laser-induced incandescence

Laser-induced incandescence (LII) is a non-intrusive method of measuring soot particle volume fraction and primary particle sizes in flames. Not only restricted to flames, this technique is recently used for characterization of car engine exhaust, atmospheric black carbon and synthetic nanoparticles.

These new applications require the same basic signal processing, but at the same time individual databases for material (soot or non-soot) and gas compositions as well as individual heat transfer models for the determination of particle sizes.

LIISim is a framework for basic signal processing and analysis experimental LII data to help researches across the world to compare their experimental data.

1.2 How to cite

If you use our software for your research, we would be grateful if you could cite the following paper:

```
R. Mansmann, T. Terheiden, P. Schmidt, J. Menser, T. Dreier, T.
Endres and C. Schulz: "LIISim: a modular signal processing
toolbox for laser-induced incandescence measurements" Appl.
Phys. B, DOI 10.1007/s00340-018-6934-9 (2018)
```

View at publisher:
https://doi.org/10.1007/s00340-018-6934-9

1.3 Motivation

LIISim is designed to provide transparent and flexible tools, which allow individual setting of processing parameters, visualization of intermediate processing steps, and comparison of multiple experimental data sets.

Main features:

- Modular choice of user-defined material properties (soot, silicon, germanium, …)
- Comparison of experimental data with different pre-implemented heat-transfer models
- Various analysis tools help visualizing dependencies between experimental data sets (plots, parameter comparison, statistical information)
- Easy-to-use import (TXT/CSV) and export (TXT/CSV/MATLAB) functionalities
- Copy/paste of signals and analysis results into spreadsheet software (MATLAB, Excel, Origin, …)
- Software architecture allows processing and comparison of large data sets (> 4 GB)

1.4 History

LIISim was so far known as **console application (LIISim 1.5)** and **web interface (www.liisim.com)**, developed by Max Hofmann between 2001 and 2007. The console application was written in C and the web interface was based on Perl. Modeling settings and file names for experimental data could be defined in DAT files and after execution of the console application, DAT output files containing the modeling results are created.

Later the console application was extended by a C++ based graphical user interface (GUI) by Tobias Terheiden and Martin Leschowski, which allowed the visualization of the modeling results from the DAT files (**LIISim Desktop 1.02** and **LIISim Console 2.14**). While the console application was distributed among the community, the desktop version was not published and was only internally used.

In 2013 the development of **LIISim 3** a new framework with object-oriented structure based on C++ was started by Raphael Mansmann designed for the application on individual material systems (soot and non-soot) with a modular implementation of signal processing steps and choice of heat-transfer models.

1.5 License

LIISim is free software: You can redistribute it and/or modify it under the terms of the **GNU General Public License** as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

2 Documentation revision history

Version	Changes
3.0.6	- Initial release
3.0.7	- Information about internal file structure added to ‘CSV import’ section

3 Get started

3.1 Downloading the latest LIISim release

The latest LIISim release can be obtained at https://github.com/LIISim/LIISim3/releases.

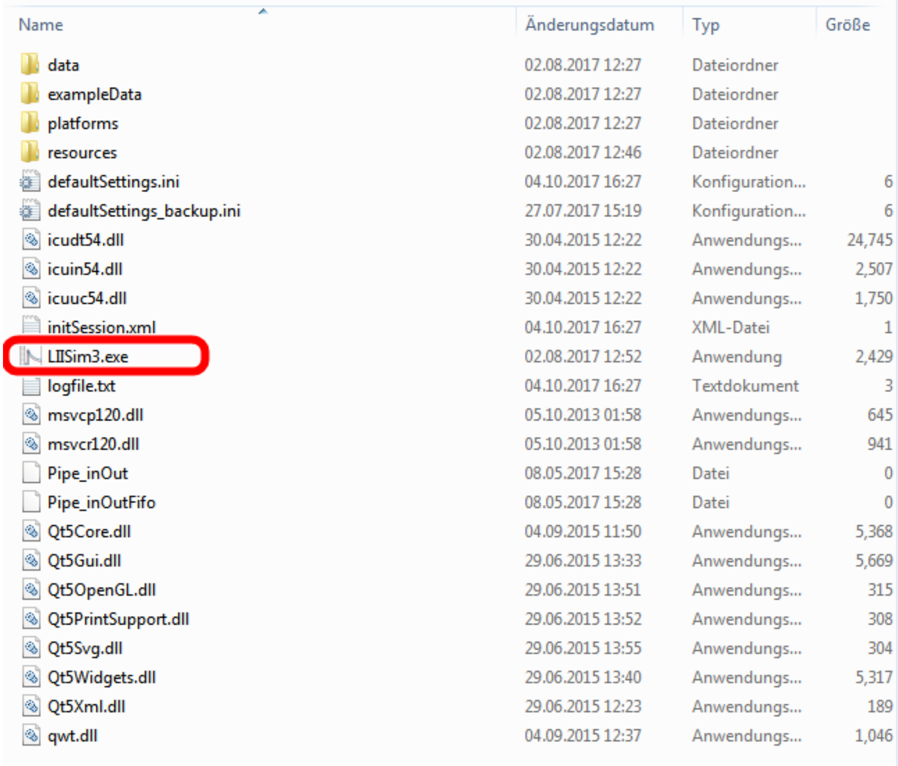
3.2 System requirements

LIISim is available and tested for Windows 7/8/10 (64bit or 32bit). We recommend using the 64bit version to overcome the 32bit memory limit of 4 GB. All drivers necessary for running LIISim are included in the package.

If you see an error like “MSVCR120.dll was not found” please try to download and install the Visual C++ Redistributable Packages from the Microsoft website. It should fix the issue: https://www.microsoft.com/en-us/download/details.aspx?id=40784

3.3 Starting LIISim

Installation is not required. Extract the .zip file to the desired location and execute **LIISim3.exe** (no admin privileges necessary). Please see the “Quick Start” chapter for a small tutorial in using LIISim.



Name	Änderungsdatum	Typ	Größe
data	02.08.2017 12:27	Dateiordner	
exampleData	02.08.2017 12:27	Dateiordner	
platforms	02.08.2017 12:27	Dateiordner	
resources	02.08.2017 12:46	Dateiordner	
defaultSettings.ini	04.10.2017 16:27	Konfiguration...	6
defaultSettings_backup.ini	27.07.2017 15:19	Konfiguration...	6
icudt54.dll	30.04.2015 12:22	Anwendungs...	24,745
icuin54.dll	30.04.2015 12:22	Anwendungs...	2,507
icuuc54.dll	30.04.2015 12:22	Anwendungs...	1,750
initSession.xml	04.10.2017 16:27	XML-Datei	1
LIISim3.exe	02.08.2017 12:52	Anwendung	2,429
logfile.txt	04.10.2017 16:27	Textdokument	3
msvcp120.dll	05.10.2013 01:58	Anwendungs...	645
msvcr120.dll	05.10.2013 01:58	Anwendungs...	941
Pipe_inOut	08.05.2017 15:28	Datei	0
Pipe_inOutFifo	08.05.2017 15:28	Datei	0
Qt5Core.dll	04.09.2015 11:50	Anwendungs...	5,368
Qt5Gui.dll	29.06.2015 13:33	Anwendungs...	5,669
Qt5OpenGL.dll	29.06.2015 13:51	Anwendungs...	315
Qt5PrintSupport.dll	29.06.2015 13:52	Anwendungs...	308
Qt5Svg.dll	29.06.2015 13:55	Anwendungs...	304
Qt5Widgets.dll	29.06.2015 13:40	Anwendungs...	5,317
Qt5Xml.dll	29.06.2015 12:23	Anwendungs...	189
qwt.dll	04.09.2015 12:37	Anwendungs...	1,046

Figure 3-1 LIISim root folder

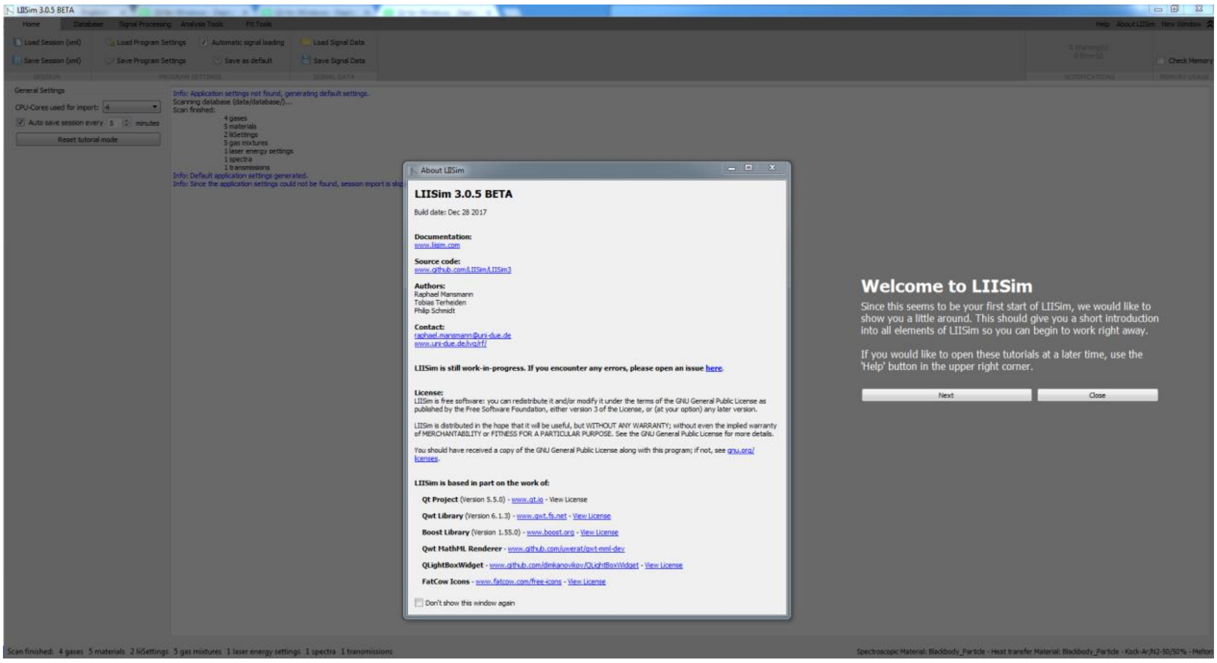
3.4 Example files

Example experimental data can be found in the “exampleData/” directory. The “Quick start” guide, uses these data to demonstrate the main LIISim functionalities.

3.5 Extend / compile LIISim yourself

There is a developer guide available at www.liisim.com with further information about the source code e.g. needed libraries, directory and class structure etc. if you like to add additional functionality or like to contribute.

4 Quick start



CPU-Cores used for import: 4

☑ Auto save session every 5 minutes

```
Info: Application settings not found, generating default settings.
Scanning database (data/database/)...
Scan finished:
                4 gases
                5 materials
                2 liiSettings
                5 gas mixtures
                1 laser energy settings
                1 spectra
                1 transmissions
Info: Default application settings generated.
Info: Since the application settings could not be found, session import is skip
```

LIISim 3.0.5 BETA

Build date: Dec 28 2017

Documentation:
www.liisim.com

Source code:
www.github.com/LIISim/LIISim3

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LIISim is still work-in-progress. If you encounter any errors, please open an issue here.

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LIISim is based in part on the work of:

Qt Project (Version 5.5.0) - www.qt.io - View License

Qwt Library (Version 6.1.3) - www.qwt.fs.net - View License

Boost Library (Version 1.55.0) - www.boost.org - View License

Qwt MathML Renderer - www.github.com/uwerat/qwt-mml-dev

QLightBoxWidget - www.github.com/dimkanovikov/QLightBoxWidget - View License

FatCow Icons - www.fatcow.com/free-icons - View License

□ Don't show this window again

Welcome to LIISim

Since this seems to be your first start of LIISim, we would like to show you a little around. This should give you a short introduction into all elements of LIISim so you can begin to work right away.

If you would like to open these tutorials at a later time, use the 'Help' button in the upper right corner.

Scan finished: 4 gases 5 materials 2 liiSettings 5 gas mixtures 1 laser energy settings 1 spectra 1 transmissions

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Blackbody_Particle - Kock-Ar/N2-50/50% - Melton

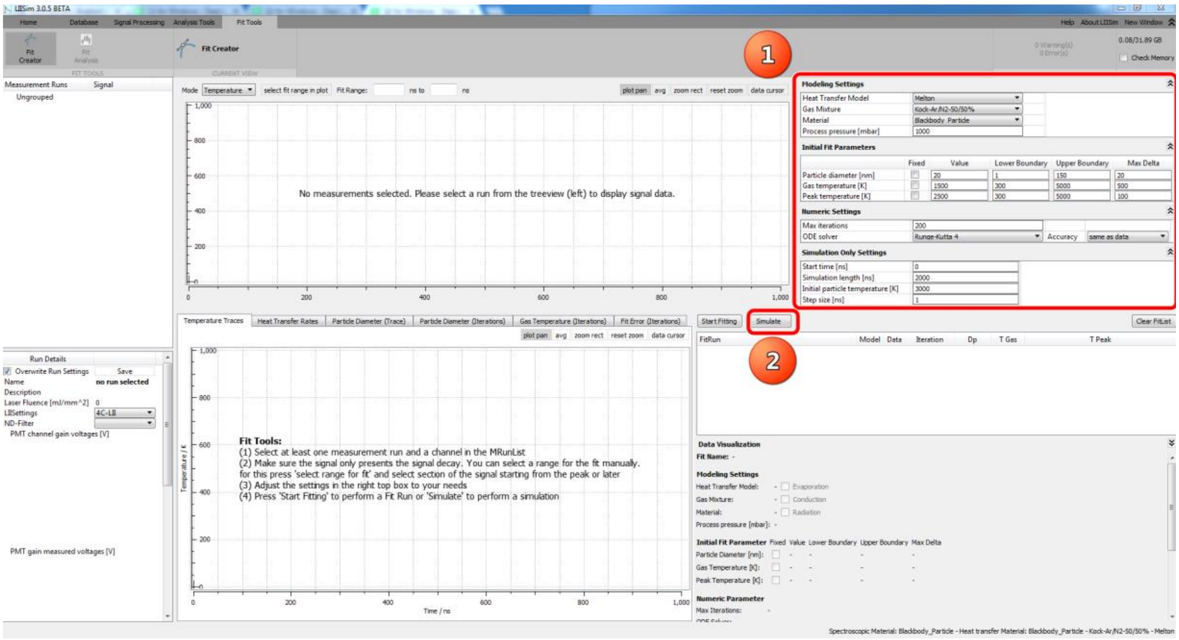
During the first start of LIISim all modules are explained by a **tutorial mode**.

This tutorial mode explains the most important functionalities and structure of the software. It is highly recommended to go through all tutorials before you start using LIISim.

You can restart each tutorial by pressing the “Help” button in the top right corner.

4.1 Example: Simulation of LII signals

For simulation of LII temperature traces, open the **Fit Tools** module**:**



No measurements selected. Please select a run from the treeview (left) to display signal data.

Modeling Settings

Heat Transfer Model	Melton
Gas Mixture	Kock-Ar/N2-50/50%
Material	Blackbody Particle
Process pressure [mbar]	1000

Initial Fit Parameters

	Fixed	Value	Lower Boundary	Upper Boundary	Max Delta
Particle diameter [nm]	□	20	1	150	20
Gas temperature [K]	□	1500	300	5000	500
Peak temperature [K]	□	2500	300	5000	100

Numeric Settings

Max iterations	200		
ODE solver	Runge-Kutta 4	Accuracy	same as data

Simulation Only Settings

Start time [ns]	0
Simulation length [ns]	2000
Initial particle temperature [K]	3000
Step size [ns]	1

Run Details

☑ Overwrite Run Settings Save

Name: no run selected

Description

Laser Fluence [mJ/mm^2] 0

LIISettings 4C-LII

ND-Filter

PMT channel gain voltages [V]

PMT gain measured voltages [V]

Fit Tools:
(1) Select at least one measurement run and a channel in the MRunList
(2) Make sure the signal only presents the signal decay. You can select a range for the fit manually.
for this press 'select range for fit' and select section of the signal starting from the peak or later
(3) Adjust the settings in the right top box to your needs
(4) Press 'Start Fitting' to perform a Fit Run or 'Simulate' to perform a simulation

Data Visualization

Fit Name: -

Modeling Settings

Heat Transfer Model: - □ Evaporation

Gas Mixture: - □ Conduction

Material: - □ Radiation

Process pressure [mbar]: -

Initial Fit Parameter Fixed Value Lower Boundary Upper Boundary Max Delta

Particle Diameter [nm]: □ - - - -

Gas Temperature [K]: □ - - - -

Peak Temperature [K]: □ - - - -

Numeric Parameter

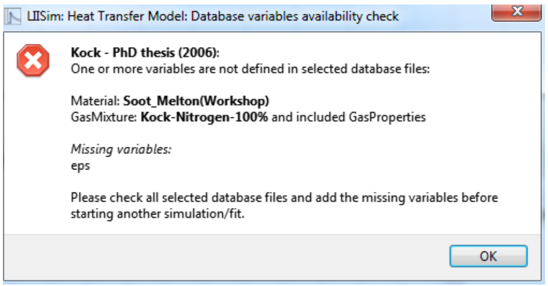
Max Iterations: -

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Blackbody_Particle - Kock-Ar/N2-50/50% - Melton

(1) You can modify modelling settings, fit parameters, numeric and simulation settings

Make sure to use compatible databases and models, otherwise a warning message appears.

Example: The "Soot_Melton(Workshop)" database is not compatible with the "Kock"-model because of the missing "eps" variable. Switch the Material database to Soot_Kock to solve this issue.


LIISim: Heat Transfer Model: Database variables availability check

Kock - PhD thesis (2006):
One or more variables are not defined in selected database files:

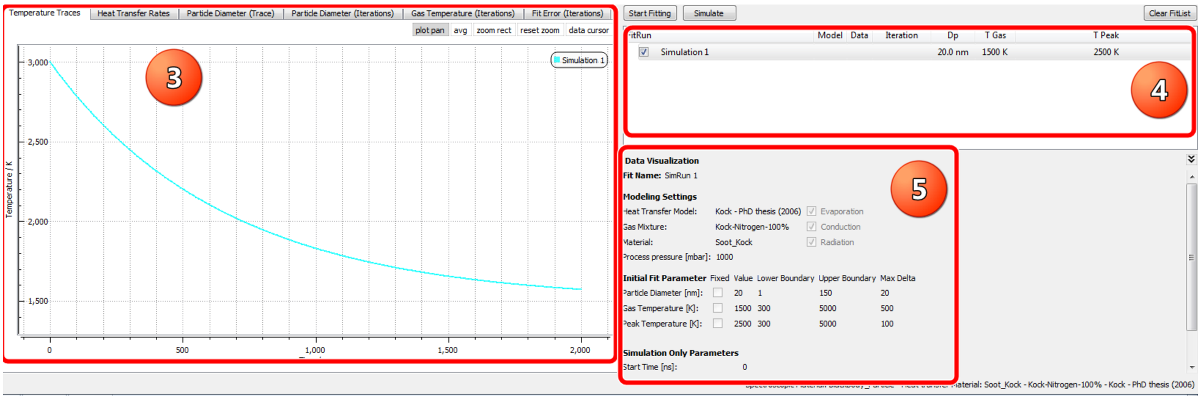
Material: **Soot_Melton(Workshop)**
GasMixture: **Kock-Nitrogen-100%** and included GasProperties

Missing variables:
eps

Please check all selected database files and add the missing variables before starting another simulation/fit.

OK

(2) After pressing "**Simulate**", the settings are used to simulate a temperature trace which is visualized. You can modify the settings and add another simulation, which appears in **(4)**.



itRun	Model	Data	Iteration	Dp	T Gas	T Peak
☑ Simulation 1				20.0 nm	1500 K	2500 K

Data Visualization
Fit Name: SimRun 1

Modeling Settings
Heat Transfer Model: Kock - PhD thesis (2006) ☑ Evaporation
Gas Mixture: Kock-Nitrogen-100% ☑ Conduction
Material: Soot_Kock ☑ Radiation
Process pressure [mbar]: 1000

Initial Fit Parameter	Fixed	Value	Lower Boundary	Upper Boundary	Max Delta
Particle Diameter [nm]:	□	20	1	150	20
Gas Temperature [K]:	□	1500	300	5000	500
Peak Temperature [K]:	□	2500	300	5000	100

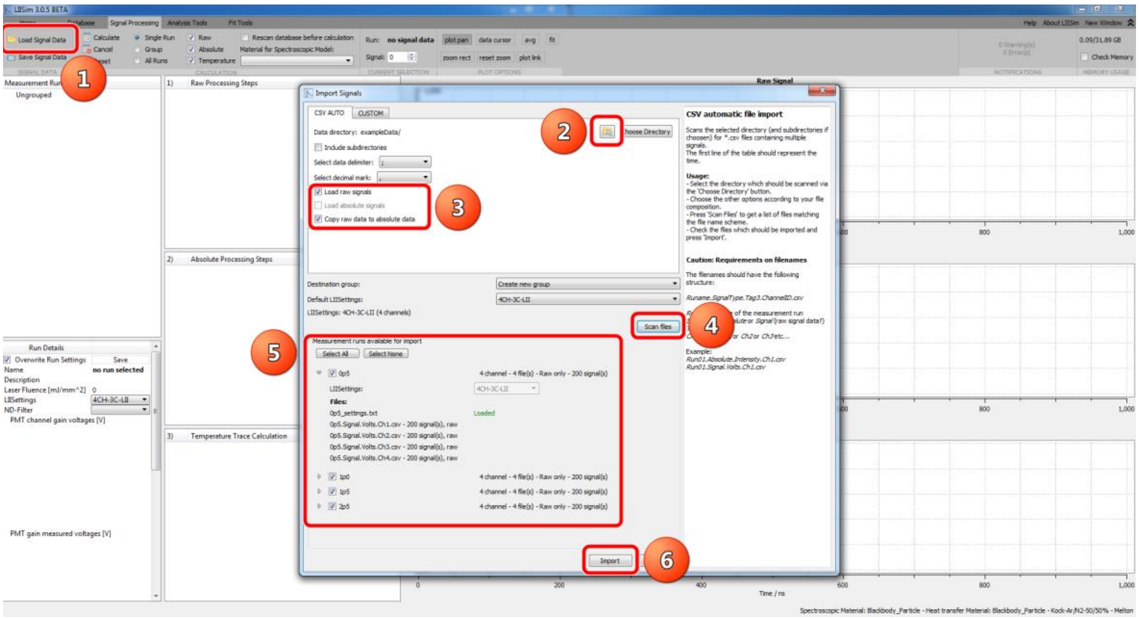
Simulation Only Parameters
Start Time [ns]: 0

You can then:
(3) Analyze the temperature trace, heat-transfer rates and compare to other simulated traces
(4) Switch between simulations with different parameters
(5) Show specific simulation settings for the selected simulation in **(4)**

4.2 Example: Signal processing and data evaluation

This is a step-by-step guide for importing the example data set, setup the signal processing and use data evaluation tools. First, you need to switch to the **"Signal Processing"** module.

4.2.1 Import of example data set



Run: no signal data

Signal: 0

Data directory: exampleData/

☐ Include subdirectories

Select data delimiter: ;

Select decimal mark: ,

☑ Load raw signals

☐ Load absolute signals

☑ Copy raw data to absolute data

Destination group: Create new group

Default LIISettings: 4CH-3C-LII

LIISettings: 4CH-3C-LII (4 channels)

Measurement runs available for import

☑ 0p5 4 channel - 4 file(s) - Raw only - 200 signal(s)

LIISettings: 4CH-3C-LII

Files:

0p5_settings.txt Loaded

0p5.Signal.Volts.Ch1.csv - 200 signal(s), raw

0p5.Signal.Volts.Ch2.csv - 200 signal(s), raw

0p5.Signal.Volts.Ch3.csv - 200 signal(s), raw

0p5.Signal.Volts.Ch4.csv - 200 signal(s), raw

☑ 1p0 4 channel - 4 file(s) - Raw only - 200 signal(s)

☑ 1p5 4 channel - 4 file(s) - Raw only - 200 signal(s)

☑ 2p5 4 channel - 4 file(s) - Raw only - 200 signal(s)

CSV automatic file import

Scans the selected directory (and subdirectories if choosen) for *.csv files containing multiple signals.
The first line of the table should represent the time.

Usage:
- Select the directory which should be scanned via the 'Choose Directory' button.
- Choose the other options according to your file composition.
- Press 'Scan Files' to get a list of files matching the file name scheme.
- Check the files which should be imported and press 'Import'.

Caution: Requirements on filenames

The filenames should have the following structure:

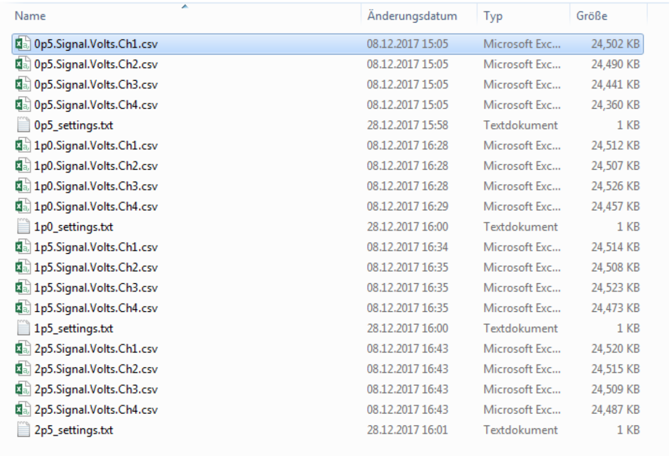
Runame.SignalType.Tag3.ChannelID.csv

of the measurement run
lute or *Signal* (raw signal data?)
or *Ch2* or *Ch3* etc...

Example:
Run01.Absolute.Intensity.Ch1.csv
Run01.Signal.Volts.Ch1.csv

(1) Use the "**Load signal Data**" button to open the import dialog

(2) Open the file explorer and make sure the folder exists and contains data:



Name	Änderungsdatum	Typ	Größe
0p5.Signal.Volts.Ch1.csv	08.12.2017 15:05	Microsoft Exc...	24,502 KB
0p5.Signal.Volts.Ch2.csv	08.12.2017 15:05	Microsoft Exc...	24,490 KB
0p5.Signal.Volts.Ch3.csv	08.12.2017 15:05	Microsoft Exc...	24,441 KB
0p5.Signal.Volts.Ch4.csv	08.12.2017 15:05	Microsoft Exc...	24,360 KB
0p5_settings.txt	28.12.2017 15:58	Textdokument	1 KB
1p0.Signal.Volts.Ch1.csv	08.12.2017 16:28	Microsoft Exc...	24,512 KB
1p0.Signal.Volts.Ch2.csv	08.12.2017 16:28	Microsoft Exc...	24,507 KB
1p0.Signal.Volts.Ch3.csv	08.12.2017 16:28	Microsoft Exc...	24,526 KB
1p0.Signal.Volts.Ch4.csv	08.12.2017 16:29	Microsoft Exc...	24,457 KB
1p0_settings.txt	28.12.2017 16:00	Textdokument	1 KB
1p5.Signal.Volts.Ch1.csv	08.12.2017 16:34	Microsoft Exc...	24,514 KB
1p5.Signal.Volts.Ch2.csv	08.12.2017 16:35	Microsoft Exc...	24,508 KB
1p5.Signal.Volts.Ch3.csv	08.12.2017 16:35	Microsoft Exc...	24,523 KB
1p5.Signal.Volts.Ch4.csv	08.12.2017 16:35	Microsoft Exc...	24,473 KB
1p5_settings.txt	28.12.2017 16:00	Textdokument	1 KB
2p5.Signal.Volts.Ch1.csv	08.12.2017 16:43	Microsoft Exc...	24,520 KB
2p5.Signal.Volts.Ch2.csv	08.12.2017 16:43	Microsoft Exc...	24,515 KB
2p5.Signal.Volts.Ch3.csv	08.12.2017 16:43	Microsoft Exc...	24,509 KB
2p5.Signal.Volts.Ch4.csv	08.12.2017 16:43	Microsoft Exc...	24,487 KB
2p5_settings.txt	28.12.2017 16:01	Textdokument	1 KB

For this data set, LII decay curves were detected at four different wavelengths for various laser fluences. 200 signals are stored in each .csv file per channel. Usually raw signals are processed in LIISim and can later be exported as calibrated "absolute" signal files. The two separate processing chains simplify comparison between the raw and calibrated signals. This allows import/export of both, raw and calibrated curves.

(3) Here, only raw signals (“Signals.Volts”) are available, so we **duplicate the raw signals to the absolute processing chain** by activating the checkbox “Copy raw data to absolute data”

(4) Using the default settings you should be able to perform a directory scan using “**Scan files**”

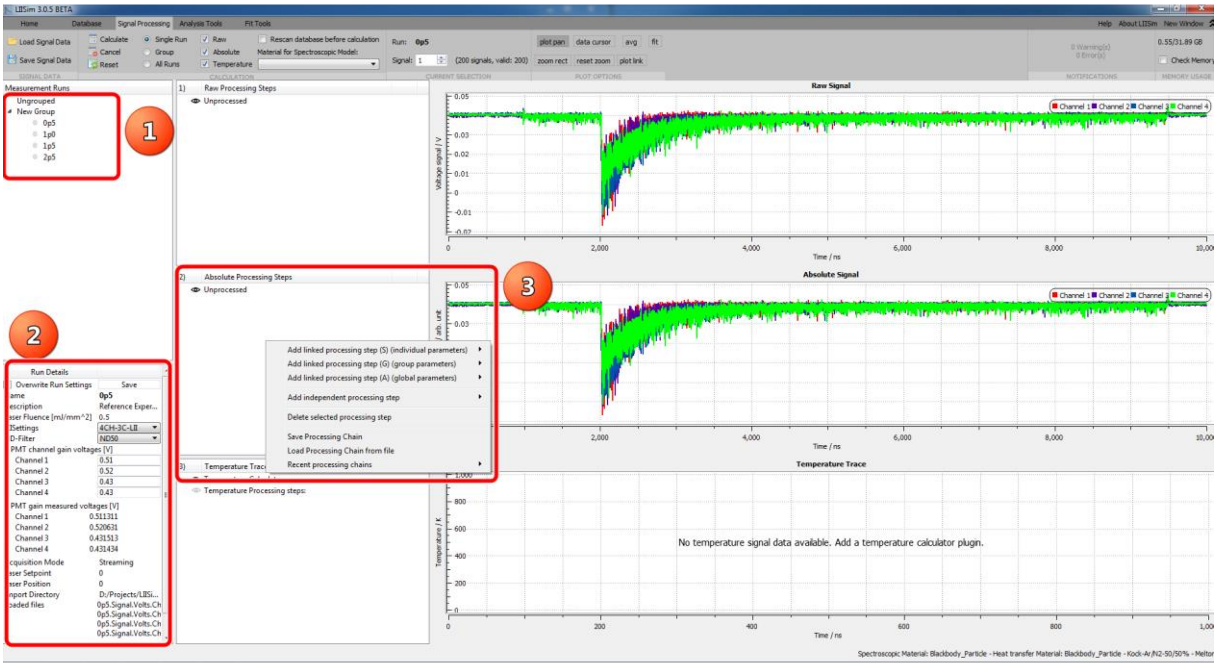
(The LIISettings-file for this experimental setup (4CH-3C-LII) is already included in LIISim and contains information about detector channel center wavelengths, calibration factors and neutral density filter transmission, see Database → LIISettings for further information)

(5) Files matching the file pattern and settings are listed and can be **selected** for import

(6) Press “**Import**” to load the selected files

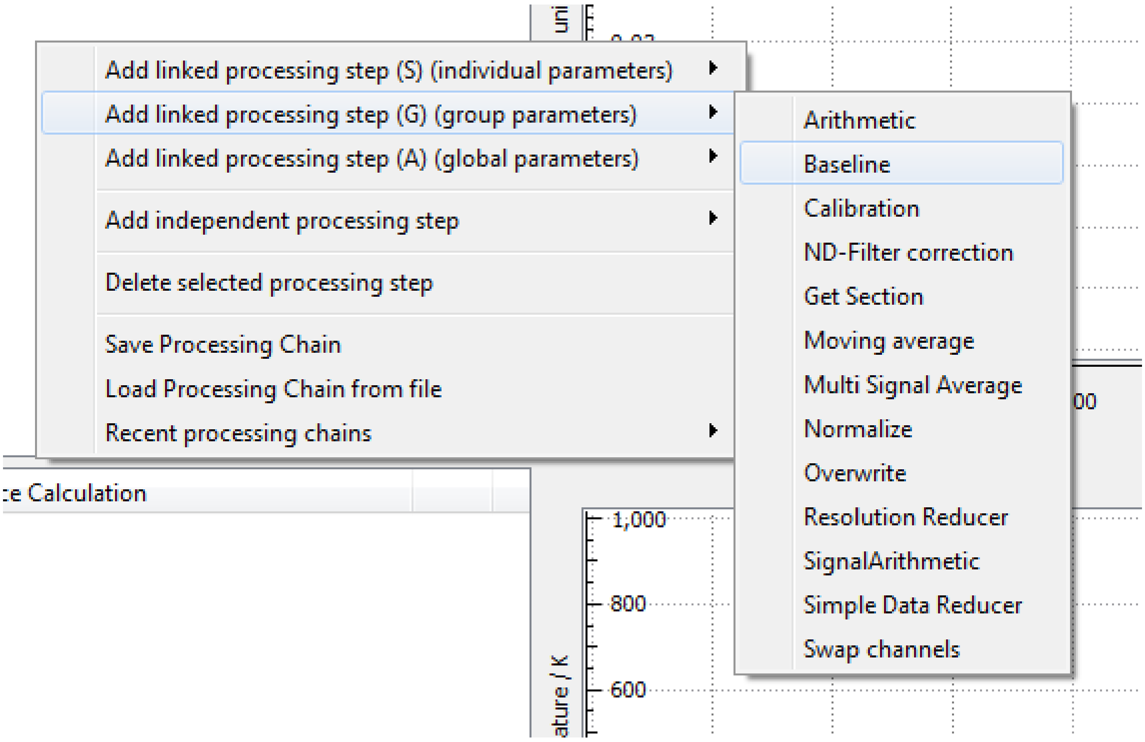
4.2.2 Basic signal processing

(1) The imported group of measurement data is shown in the left box. By selecting each measurement run you can see detailed information in **(2).**


LIISim 3.0.5 BETA
Home
Database
Signal Processing
Analysis Tools
Fit Tools
Measurement Runs
Ungrouped
New Group
0p5
1p0
1p5
2p5
1
2
3
1) Raw Processing Steps
Unprocessed
2) Absolute Processing Steps
Unprocessed
3) Temperature Processing steps:
Add linked processing step (S) (individual parameters)
Add linked processing step (G) (group parameters)
Add linked processing step (A) (global parameters)
Add independent processing step
Delete selected processing step
Save Processing Chain
Load Processing Chain from file
Recent processing chains
Raw Signal
Absolute Signal
Temperature Trace
Channel 1
Channel 2
Channel 3
Channel 4
Voltage signal / V
Time / ns
Temperature / K
No temperature signal data available. Add a temperature calculator plugin.

Run Details	
Overwrite Run Settings	Save
ame	0p5
escription	Reference Exper...
aser Fluence [mJ/mm^2]	0.5
ISettings	4CH-3C-LII
D-Filter	ND50
PMT channel gain voltages [V]	
Channel 1	0.51
Channel 2	0.52
Channel 3	0.43
Channel 4	0.43
PMT gain measured voltages [V]	
Channel 1	0.511311
Channel 2	0.520631
Channel 3	0.431513
Channel 4	0.431434
cquisition Mode	Streaming
aser Setpoint	0
aser Position	0
nport Directory	D:/Projects/LIISi...
aded files	0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch

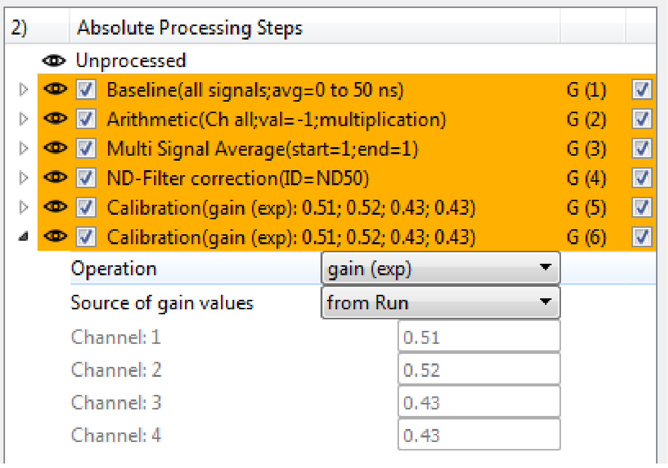
(3) Right-Click somewhere within the processing chain box opens the context menu for adding processing steps:



In this case, linked processing steps are used, because we want to have the same parameters for the four measurement runs in this group.

The following processing steps need to be added:

- **Baseline**
- **Arithmetic**
- **Multi-Signal Average**
- **ND-Filter correction**
- **Calibration (sensitivity)**
- **Calibration (gain (exp))**



2) Absolute Processing Steps

Unprocessed

☑ Baseline(all signals;avg=0 to 50 ns) G (1) ☑

☑ Arithmetic(Ch all;val=-1;multiplication) G (2) ☑

☑ Multi Signal Average(start=1;end=1) G (3) ☑

☑ ND-Filter correction(ID=ND50) G (4) ☑

☑ Calibration(gain (exp): 0.51; 0.52; 0.43; 0.43) G (5) ☑

☑ Calibration(gain (exp): 0.51; 0.52; 0.43; 0.43) G (6) ☑

Operation: gain (exp)

Source of gain values: from Run

Channel: 1 0.51

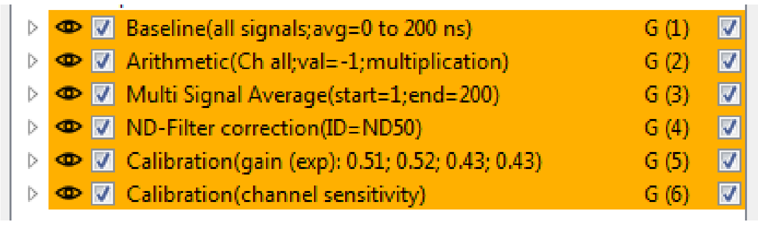
Channel: 2 0.52

Channel: 3 0.43

Channel: 4 0.43

The small arrow can be used to show the parameters and change settings of each processing step. Some parameters are automatically retrieved from the settings file and the input is then disabled (for example ND-Filter correction and Calibration).

Make sure the steps have the following parameters:



☑ Baseline(all signals;avg=0 to 200 ns) G (1) ☑

☑ Arithmetic(Ch all;val=-1;multiplication) G (2) ☑

☑ Multi Signal Average(start=1;end=200) G (3) ☑

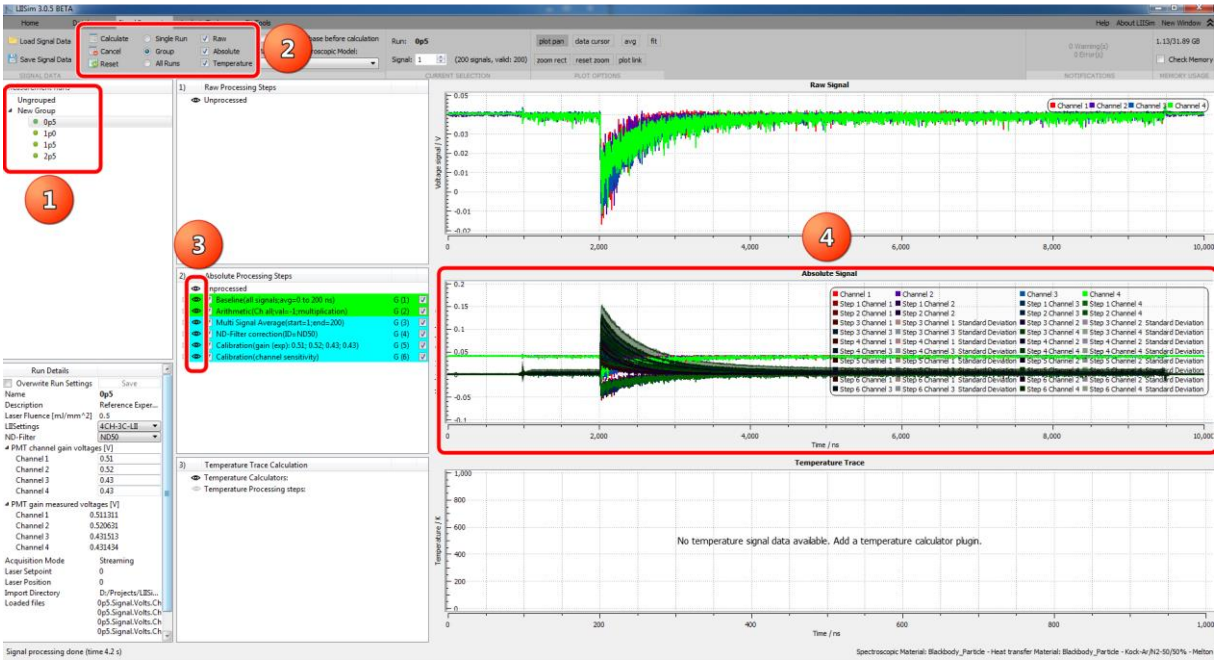
☑ ND-Filter correction(ID=ND50) G (4) ☑

☑ Calibration(gain (exp): 0.51; 0.52; 0.43; 0.43) G (5) ☑

☑ Calibration(channel sensitivity) G (6) ☑

For processing of the new chain, you need to select one of the measurement runs **(1)**, then set the processing mode **(2)** to “Group”, to process all measurements in this group and the processing chain should turn green/blue if the data are processed correctly. The blue color in the processing chain indicates that an average is calculated from all signals and the averaged signal is further processed.

Now the plot **(4)** looks a bit crowded because all steps are visualized. Use the “eye”-icons **(3)** to toggle visibility of the signal traces for each processing step.



2) Absolute Processing Steps
- Unprocessed
- Baseline(all signals;avg=0 to 200 ns) G (1)
- Arithmetic(Ch all;val=-1;multiplication) G (2)
- Multi Signal Average(start=1;end=200) G (3)
- ND-Filter correction(ID=ND50) G (4)
- Calibration(gain (exp): 0.51; 0.52; 0.43; 0.43) G (5)
- Calibration(channel sensitivity) G (6)

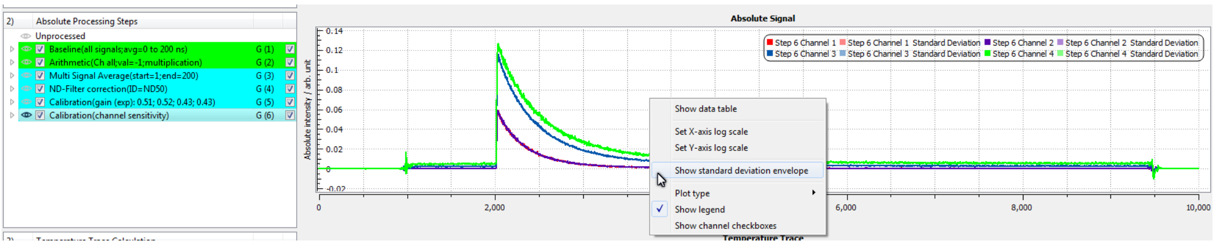
3) Temperature Trace Calculation
- Temperature Calculators:
- Temperature Processing steps:

Run Details
- Name: 0p5
- Description: Reference Exper...
- Laser Fluence [mJ/mm^2]: 0.5
- LIISettings: 4CH-3C-LII
- ND-Filter: ND50
- PMT channel gain voltages [V]: Channel 1 0.51; Channel 2 0.52; Channel 3 0.43; Channel 4 0.43
- PMT gain measured voltages [V]: Channel 1 0.511311; Channel 2 0.520631; Channel 3 0.431513; Channel 4 0.431434
- Acquisition Mode: Streaming
- Laser Setpoint: 0
- Laser Position: 0
- Import Directory: D:/Projects/LIISi...
- Loaded files: 0p5.Signal.Volts.Ch...

No temperature signal data available. Add a temperature calculator plugin.

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Blackbody_Particle - Kock-Ar/N2-50/50% - Melton

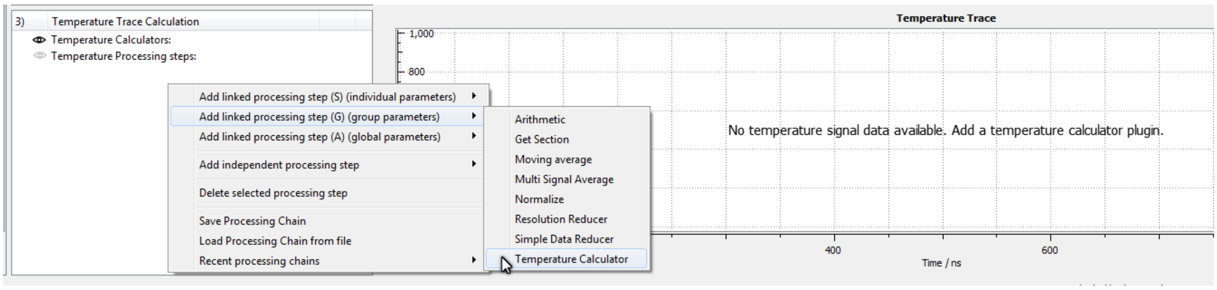
The standard deviation curve can be toggled using the **right-click context menu on the plot**:


2) Absolute Processing Steps
Unprocessed
Baseline(all signals;avg=0 to 200 ns) G (1)
Arithmetic(Ch all;val=-1;multiplication) G (2)
Multi Signal Average(start=1;end=200) G (3)
ND-Filter correction(ID=ND50) G (4)
Calibration(gain (exp): 0.51; 0.52; 0.43; 0.43) G (5)
Calibration(channel sensitivity) G (6)
Absolute Signal
Absolute intensity / arb. unit
Step 6 Channel 1
Step 6 Channel 1 Standard Deviation
Step 6 Channel 2
Step 6 Channel 2 Standard Deviation
Step 6 Channel 3
Step 6 Channel 3 Standard Deviation
Step 6 Channel 4
Step 6 Channel 4 Standard Deviation
Show data table
Set X-axis log scale
Set Y-axis log scale
Show standard deviation envelope
Plot type
✓ Show legend
Show channel checkboxes
0
2,000
6,000
8,000
10,000

The result from the last processing step (Calibration (channel sensitivity) can now be used by the “Temperature Trace Calculation”-chain for further processing.

4.2.3 Temperature trace calculation (Two-Color)

With the calibrated absolute signals, temperature traces can be calculated. Right-click on the temperature processing chain box and add a linked processing step: “**Temperature Calculator**”

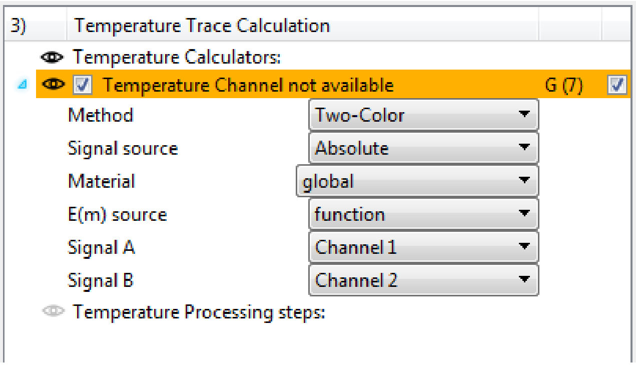

3) Temperature Trace Calculation
Temperature Calculators:
Temperature Processing steps:
Add linked processing step (S) (individual parameters)
Add linked processing step (G) (group parameters)
Add linked processing step (A) (global parameters)
Add independent processing step
Delete selected processing step
Save Processing Chain
Load Processing Chain from file
Recent processing chains
Arithmetic
Get Section
Moving average
Multi Signal Average
Normalize
Resolution Reducer
Simple Data Reducer
Temperature Calculator
Temperature Trace
1,000
800
400
600
Time / ns

No temperature signal data available. Add a temperature calculator plugin.

You can add multiple TemperatureCalculators with different settings and compare the traces.

By default, the “**Two-Color**” method is selected:

Make sure to change the channels of Signal A/B to two different wavelengths (Channel 1 and 2 have the same bandpass filter wavelength (500 nm) for this data set)



3) Temperature Trace Calculation

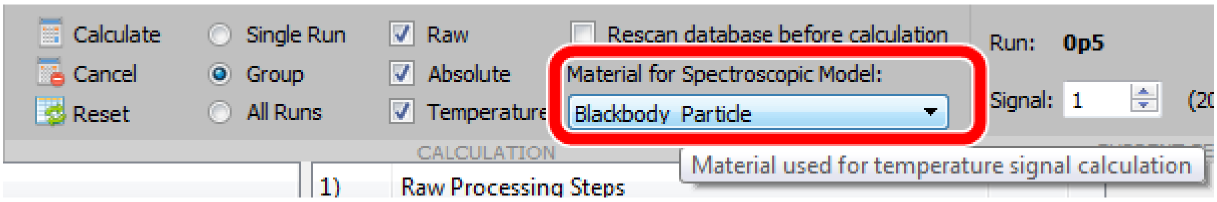
Temperature Calculators:

☑ Temperature Channel not available G (7) ☑

Method	Two-Color
Signal source	Absolute
Material	global
E(m) source	function
Signal A	Channel 1
Signal B	Channel 2

Temperature Processing steps:

Before calculation the **spectroscopic model** needs to be chosen (here: constant E(m) values: “Blackbody_Particle”). This spectroscopic model is used if Material: “global” is selected.



☑ Raw ☑ Absolute ☑ Temperature ○ Single Run ● Group ○ All Runs

□ Rescan database before calculation

Material for Spectroscopic Model: Blackbody Particle

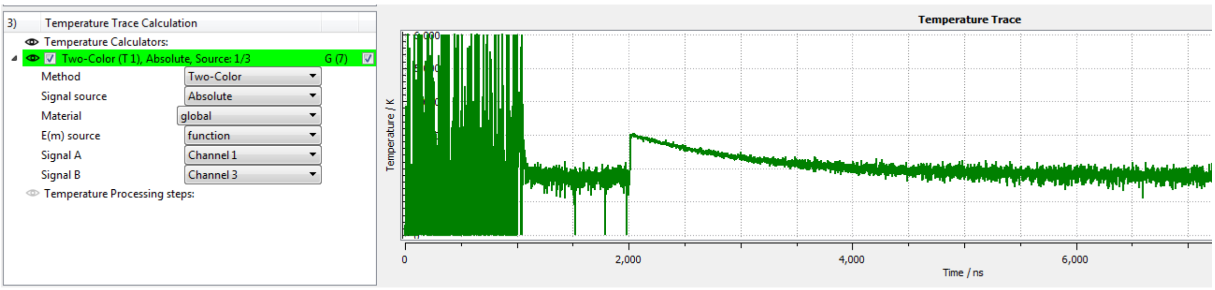
Material used for temperature signal calculation

Run: 0p5

Signal: 1 (20

E(*m*) values are provided by the Material-database file as single values (“values”), function of wavelength (“function”) or calculated from Drude model (“Drude”). Here, “Blackbody_Particle” provides *E*(*m*) as “function”.

Pressing **“Calculate”** now processes also the temperature processing chain, here with two-color pyrometry applied on the result from the “Absolute”-processing chain using Channel 1 and 3:



3) Temperature Trace Calculation

Temperature Calculators:

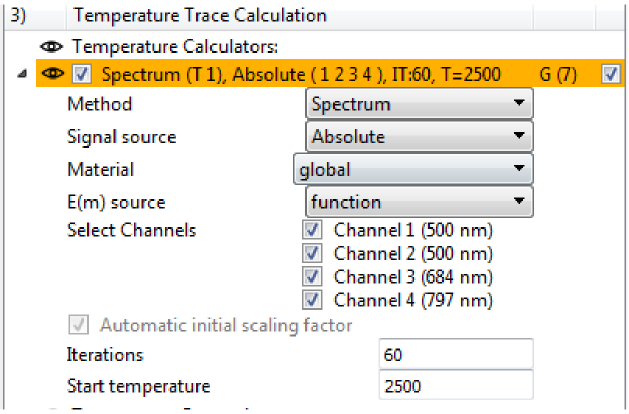
☑ Two-Color (T 1), Absolute, Source: 1/3 G (7) ☑

Method	Two-Color
Signal source	Absolute
Material	global
E(m) source	function
Signal A	Channel 1
Signal B	Channel 3

Temperature Processing steps:

4.2.4 Temperature trace calculation (Spectrum)

Proceed exactly as with “Two-Color” method, but change the method to “Spectrum”:



3) Temperature Trace Calculation

Temperature Calculators:

☑ Spectrum (T 1), Absolute (1 2 3 4), IT:60, T=2500 G (7) ☑

Method: Spectrum

Signal source: Absolute

Material: global

E(m) source: function

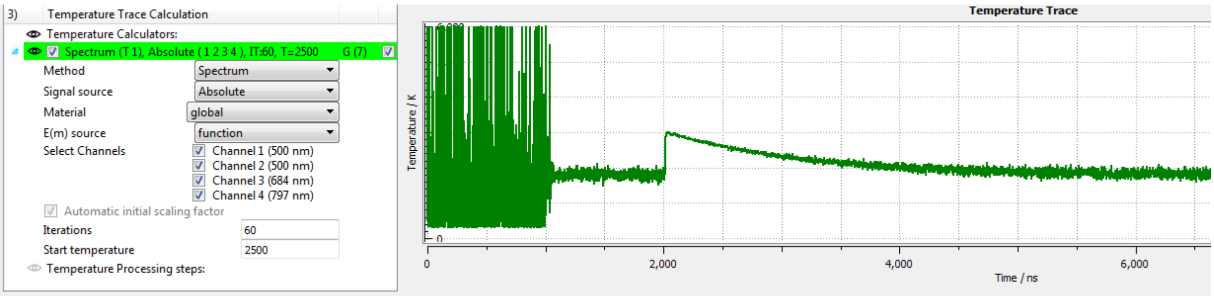
Select Channels: ☑ Channel 1 (500 nm) ☑ Channel 2 (500 nm) ☑ Channel 3 (684 nm) ☑ Channel 4 (797 nm)

☑ Automatic initial scaling factor

Iterations: 60

Start temperature: 2500

You can now **select channels** that can be used for spectral fitting:



3) Temperature Trace Calculation

Temperature Calculators:

☑ Spectrum (T 1), Absolute (1 2 3 4), IT:60, T=2500 G (7) ☑

Method: Spectrum

Signal source: Absolute

Material: global

E(m) source: function

Select Channels: ☑ Channel 1 (500 nm) ☑ Channel 2 (500 nm) ☑ Channel 3 (684 nm) ☑ Channel 4 (797 nm)

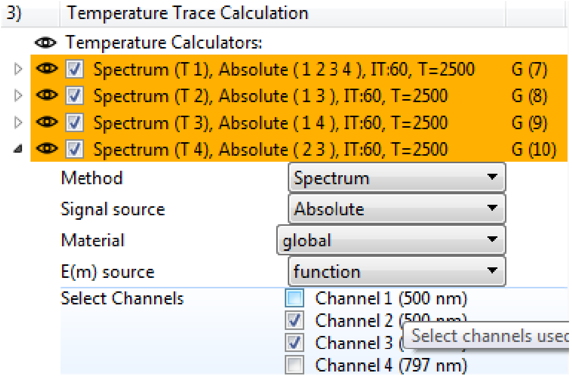
☑ Automatic initial scaling factor

Iterations: 60

Start temperature: 2500

Temperature Processing steps:

Multiple temperature traces can now be calculated using different settings. In this example we added a spectral fit using all four channels (T1) and three times a spectral fit only with two channels (T2-T4):



3) Temperature Trace Calculation

Temperature Calculators:

☑ Spectrum (T 1), Absolute (1 2 3 4), IT:60, T=2500 G (7)

☑ Spectrum (T 2), Absolute (1 3), IT:60, T=2500 G (8)

☑ Spectrum (T 3), Absolute (1 4), IT:60, T=2500 G (9)

☑ Spectrum (T 4), Absolute (2 3), IT:60, T=2500 G (10)

Method: Spectrum

Signal source: Absolute

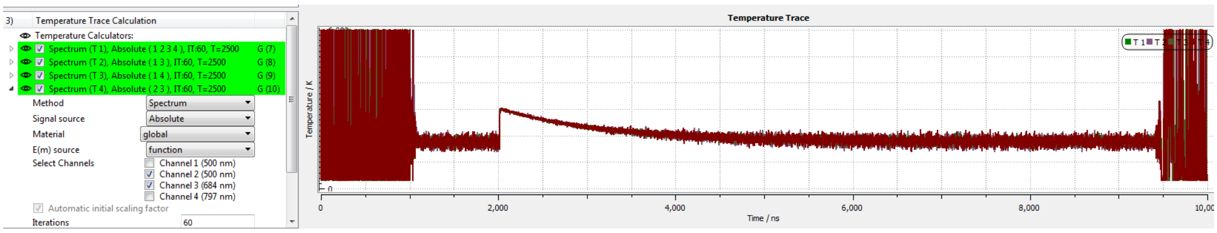
Material: global

E(m) source: function

Select Channels: □ Channel 1 (500 nm) ☑ Channel 2 (500 nm) ☑ Channel 3 (□ Channel 4 (797 nm)

Select channels usec

Processing now takes a bit longer, because every data point is fitted in several iterations for every Temperature-Calculator.



3) Temperature Trace Calculation

Temperature Calculators:
- ☑ Spectrum (T 1), Absolute (1 2 3 4), IT:60, T=2500 G (7)
- ☑ Spectrum (T 2), Absolute (1 3), IT:60, T=2500 G (8)
- ☑ Spectrum (T 3), Absolute (1 4), IT:60, T=2500 G (9)
- ☑ Spectrum (T 4), Absolute (2 3), IT:60, T=2500 G (10)

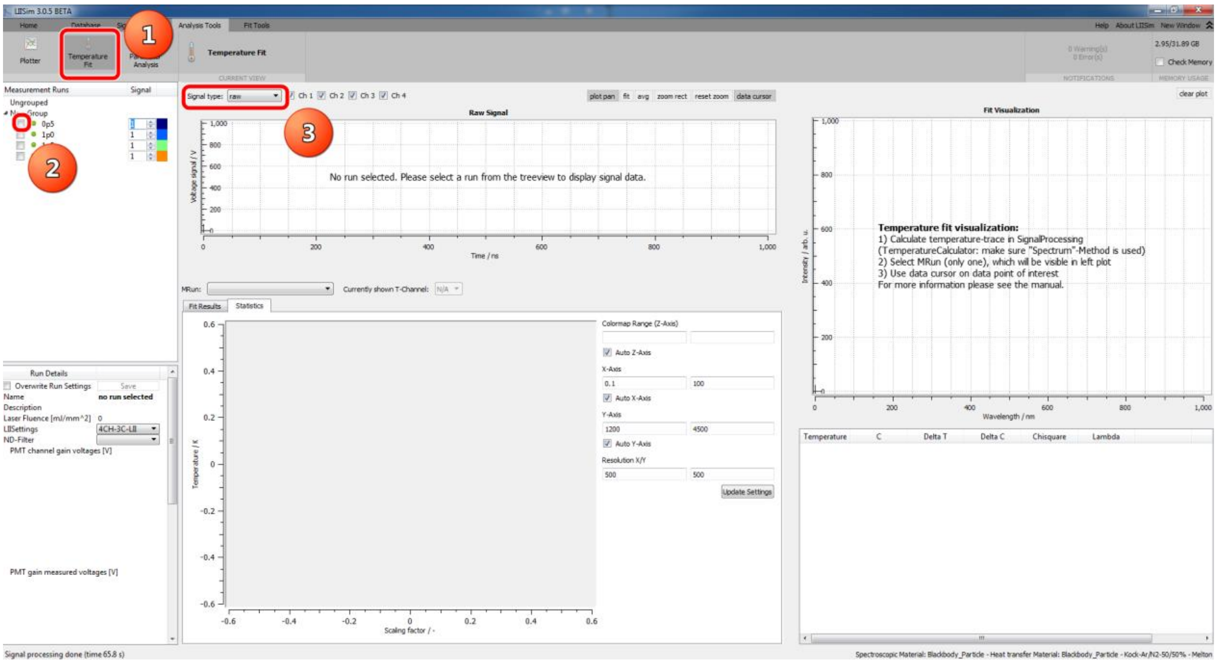
Method: Spectrum
Signal source: Absolute
Material: global
E(m) source: function
Select Channels: □ Channel 1 (500 nm) ☑ Channel 2 (500 nm) ☑ Channel 3 (684 nm) □ Channel 4 (797 nm)
☑ Automatic initial scaling factor
Iterations: 60

We have now four temperature traces that can be analyzed using the AnalysisTools.

4.2.5 AnalysisTools: Temperature Fit

Switch to the AnalysisTools module and select **Temperature Fit (1)**. Then select the measurement run **(2)** to be analyzed (only one MRun can be analyzed at the same time). Switch signal type to be displayed **(3)** to **"absolute"** or **"temperature".**

This tool only works with temperature traces calculated with the "Spectrum" method. "Two-Color" traces cannot be visualized.



No run selected. Please select a run from the treeview to display signal data.

Temperature fit visualization:
1) Calculate temperature-trace in SignalProcessing (TemperatureCalculator: make sure "Spectrum"-Method is used)
2) Select MRun (only one), which will be visible in left plot
3) Use data cursor on data point of interest
For more information please see the manual.

Signal processing done (time 65.8 s)

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Blackbody_Particle - Kock-Ar/N2-50/50% - Melton

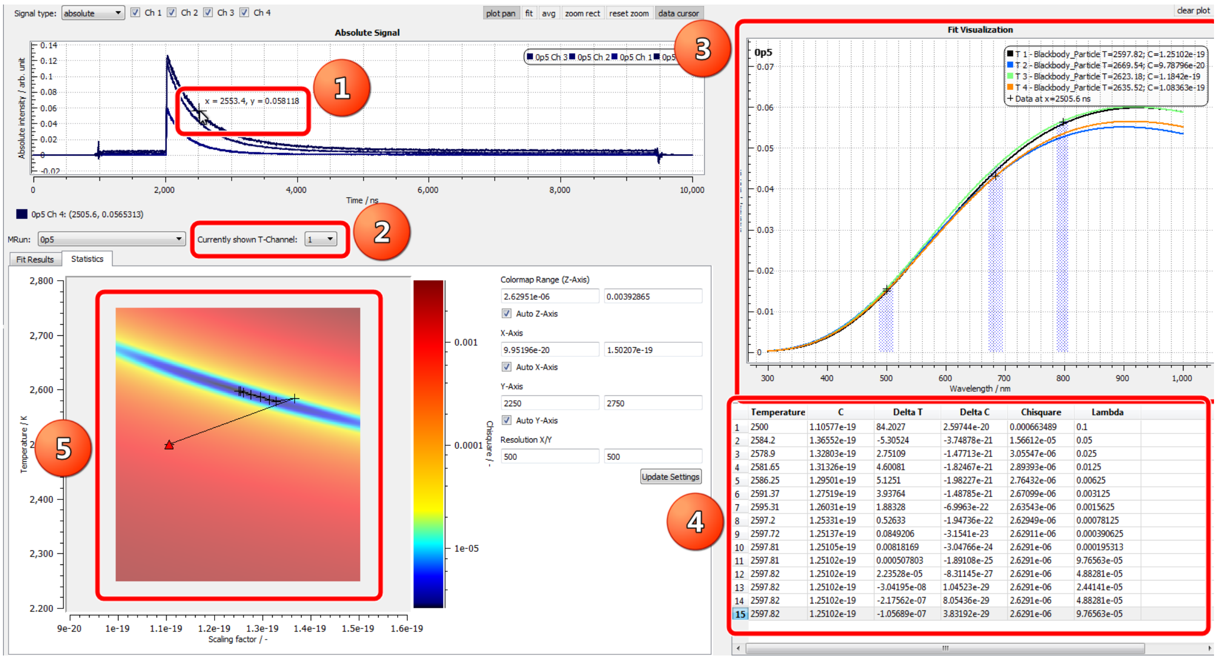
(1) Select now in the top left plot a data point you want to analyze. The temperature trace selected in **(2)** is then visualized.

(3) Compares the selected spectral fit to the data points (crosses) and to other available “Spectrum” temperature fits. The legend entries contain the parameters for the curves (Temperature and Scaling factor).

(4) Shows the spectral fitting iterations for the selected data point and **(4)** the chi-square map of the two parameters used during fitting (Temperature and Scaling factor).

The crosses and lines in **(5)** indicate the progress of iterations of the fitting procedure and the red triangle the initial conditions.

- Click on the map **(5)** to show the spectral fit in **(3)**.
- Click on any iteration in **(4)** to show the corresponding spectral fit in **(3)**



Signal type: absolute ☑ Ch 1 ☑ Ch 2 ☑ Ch 3 ☑ Ch 4

0p5 Ch 4: (2505.6, 0.0565313)

MRun: 0p5

Currently shown T-Channel: 1

Colormap Range (Z-Axis) 2.62951e-06 0.00392865

☑ Auto Z-Axis

X-Axis 9.95196e-20 1.50207e-19

☑ Auto X-Axis

Y-Axis 2250 2750

☑ Auto Y-Axis

Resolution X/Y 500 500

	Temperature	C	Delta T	Delta C	Chisquare	Lambda
1	2500	1.10577e-19	84.2027	2.59744e-20	0.000663489	0.1
2	2584.2	1.36552e-19	-5.30524	-3.74878e-21	1.56612e-05	0.05
3	2578.9	1.32803e-19	2.75109	-1.47713e-21	3.05547e-06	0.025
4	2581.65	1.31326e-19	4.60081	-1.82467e-21	2.89393e-06	0.0125
5	2586.25	1.29501e-19	5.1251	-1.98227e-21	2.76432e-06	0.00625
6	2591.37	1.27519e-19	3.93764	-1.48785e-21	2.67099e-06	0.003125
7	2595.31	1.26031e-19	1.88328	-6.9963e-22	2.63543e-06	0.0015625
8	2597.2	1.25331e-19	0.52633	-1.94736e-22	2.62949e-06	0.00078125
9	2597.72	1.25137e-19	0.0849206	-3.1541e-23	2.62911e-06	0.000390625
10	2597.81	1.25105e-19	0.00818169	-3.04766e-24	2.6291e-06	0.000195313
11	2597.81	1.25102e-19	0.000507803	-1.89108e-25	2.6291e-06	9.76563e-05
12	2597.82	1.25102e-19	2.23528e-05	-8.31145e-27	2.6291e-06	4.88281e-05
13	2597.82	1.25102e-19	-3.04195e-08	1.04523e-29	2.6291e-06	2.44141e-05
14	2597.82	1.25102e-19	-2.17562e-07	8.05436e-29	2.6291e-06	4.88281e-05
15	2597.82	1.25102e-19	-1.05689e-07	3.83192e-29	2.6291e-06	9.76563e-05

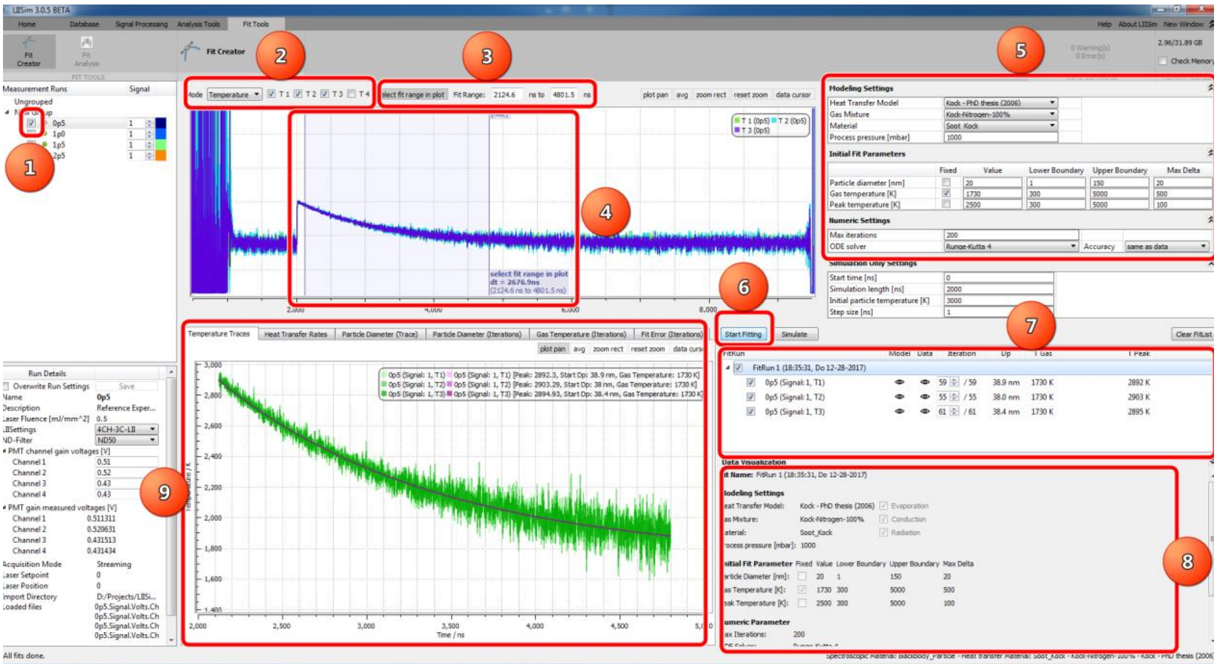
4.2.6 Fit Tools

The previously calculated temperature traces can be used for comparison with modeled temperature traces using various heat-transfer models and databases.

First, you need to select at least one measurement run **(1)** and the temperature traces to be used for the fitting **(2).**

The temperature traces should now appear in the plot and you can select a data range using the button **(3)** and then select the range in the plot **(4)** or you can enter the range manually.

After adjusting the settings **(5)** for the fitting you can press “Start Fitting” **(6)** to perform a fit on all selected measurement runs and temperature traces.



Measurement Runs	Signal
Ungrouped	
New Group	
☑ 0p5	1
1p0	1
1p5	1
2p5	1

Mode: Temperature ☑ T 1 ☑ T 2 ☑ T 3 □ T 4

select fit range in plot Fit Range: 2124.6 ns to 4801.5 ns

select fit range in plot
dt = 2676.9ns
(2124.6 ns to 4801.5 ns)

Modeling Settings

Heat Transfer Model	Kock - PhD thesis (2006)
Gas Mixture	Kock-Nitrogen-100%
Material	Soot_Kock
Process pressure [mbar]	1000

Initial Fit Parameters

	Fixed	Value	Lower Boundary	Upper Boundary	Max Delta
Particle diameter [nm]	□	20	1	150	20
Gas temperature [K]	☑	1730	300	5000	500
Peak temperature [K]	□	2500	300	5000	100

Numeric Settings

Max iterations	200		
ODE solver	Runge-Kutta 4	Accuracy	same as data

Simulation Only Settings

Start time [ns]	0
Simulation length [ns]	2000
Initial particle temperature [K]	3000
Step size [ns]	1

FitRun	Model	Data	Iteration	Dp	T Gas	T Peak
☑ FitRun 1 (18:35:31, Do 12-28-2017)						
☑ 0p5 (Signal: 1, T1)	👁	👁	59 / 59	38.9 nm	1730 K	2892 K
☑ 0p5 (Signal: 1, T2)	👁	👁	55 / 55	38.0 nm	1730 K	2903 K
☑ 0p5 (Signal: 1, T3)	👁	👁	61 / 61	38.4 nm	1730 K	2895 K

0p5 (Signal: 1, T1) 0p5 (Signal: 1, T1) [Peak: 2892.3, Start Dp: 38.9 nm, Gas Temperature: 1730 K]
0p5 (Signal: 1, T2) 0p5 (Signal: 1, T2) [Peak: 2903.29, Start Dp: 38 nm, Gas Temperature: 1730 K]
0p5 (Signal: 1, T3) 0p5 (Signal: 1, T3) [Peak: 2894.93, Start Dp: 38.4 nm, Gas Temperature: 1730 K]

Data Visualization

it Name: FitRun 1 (18:35:31, Do 12-28-2017)

lodeling Settings

eat Transfer Model:	Kock - PhD thesis (2006)	☑ Evaporation
as Mixture:	Kock-Nitrogen-100%	☑ Conduction
aterial:	Soot_Kock	☑ Radiation
rocess pressure [mbar]:	1000	

nitial Fit Parameter	Fixed	Value	Lower Boundary	Upper Boundary	Max Delta
article Diameter [nm]:	□	20	1	150	20
as Temperature [K]:	☑	1730	300	5000	500
eak Temperature [K]:	□	2500	300	5000	100

umeric Parameter

ax Iterations: 200

DE Solver: Runge-Kutta 4

Run Details

□ Overwrite Run Settings

Name	**0p5**
Description	Reference Exper...
Laser Fluence [mJ/mm^2]	0.5
LIISettings	4CH-3C-LII
ND-Filter	ND50
PMT channel gain voltages [V]	
Channel 1	0.51
Channel 2	0.52
Channel 3	0.43
Channel 4	0.43
PMT gain measured voltages [V]	
Channel 1	0.511311
Channel 2	0.520631
Channel 3	0.431513
Channel 4	0.431434
Acquisition Mode	Streaming
Laser Setpoint	0
Laser Position	0
Import Directory	D:/Projects/LIISi...
Loaded files	0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch

All fits done.

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Soot_Kock - Kock-Nitrogen-100% - Kock - PhD thesis (2006)

The result from this fitting is called a “FitRun” which is listed in the FitRun-List **(7).** You can select the temperature traces and look at the detailed information in **(8)** or at various plot tools in **(9).**

5 Data structure

The following table lists frequently used terms within the software:

Term	Abbreviations	Description
Measurement run	MRun, run	A complete set of (multiple) signals
LII settings	LIISettings	Definition of detection related settings (channels, center wavelengths, calibration, ND-filter transmissions)
Measurement run settings	MRunSettings	Additional file for every run (<*>_settings.txt), contains name, description, LIISettings-filename etc.
Measurement point	MPoint	A single measurement, containing multiple channels, but only one signal per channel
Raw signal	RAW, raw	Raw data signal
Absolute signal	ABS, abs	Scaled (calibrated) data signal
Temperature	TEMPERATURE, temp	Calculated temperature trace

The data structure used within the LIISim software is described in Figure 5-1. All elements are explained in detail in the following sections.

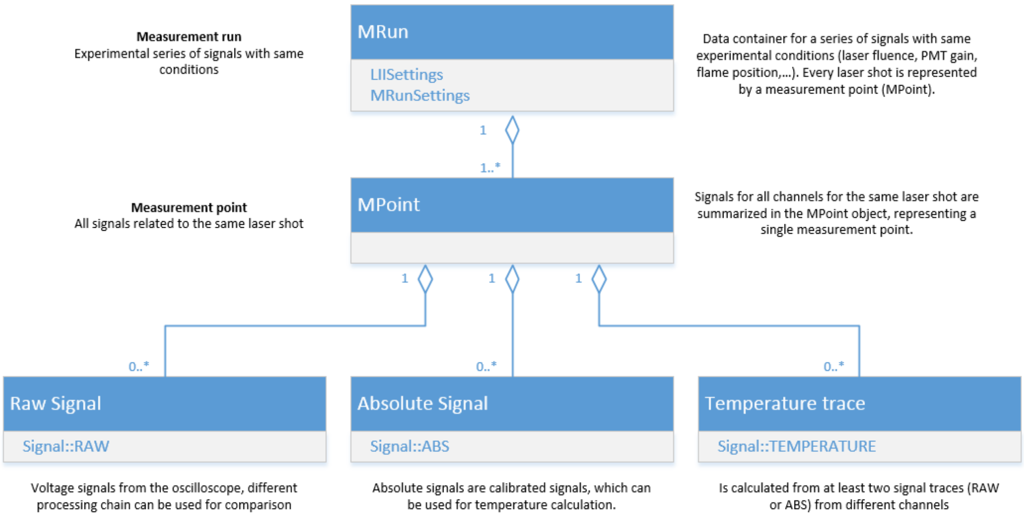

Measurement run
Experimental series of signals with same conditions
MRun
LIISettings
MRunSettings
Data container for a series of signals with same experimental conditions (laser fluence, PMT gain, flame position,…). Every laser shot is represented by a measurement point (MPoint).
1
1..*
Measurement point
All signals related to the same laser shot
MPoint
Signals for all channels for the same laser shot are summarized in the MPoint object, representing a single measurement point.
1
1
1
0..*
0..*
0..*
Raw Signal
Signal::RAW
Absolute Signal
Signal::ABS
Temperature trace
Signal::TEMPERATURE
Voltage signals from the oscilloscope, different processing chain can be used for comparison
Absolute signals are calibrated signals, which can be used for temperature calculation.
Is calculated from at least two signal traces (RAW or ABS) from different channels

Figure 5-1 Data structure used within LIISim

5.1 LIISettings

LIISettings summarizes information of the LII device used for the measurements. There can be an infinite number of different LIISettings that can be selected within LIISim. They contain information about laser wavelength, bandpass filter width, sensitivity, reference voltage, gain calibration, signal offset, available ND-filters and filter transmission. LIISettings can easily be visualized in the DatabaseEditor (see 8.4).

Example files can be found at *data/database/liisettings/.*

5.1.1 Example file structure (4-C-LII.txt)

The following lines represent a sample LIISettings file for a LII device with four channels. The variables and values are separated by a semicolon (;).

4C-LII.txt:

```
1  4C-LII;LIISettings;0.1;LII detector with 4 channels;
2  laser_wavelength;1064;
3  channel;390;18;1.4;0.4;7.988;0;0;
4  channel;500;24;1.5;0.4;8.126;0;0;
5  channel;684;24;1;0.5;7.54554;0;0;
6  channel;800;12;1.3;0.399;8.60;0;0;
7  filter;ND0.1;0.02811;0.0431;0.09869;0.1484;
8  filter;ND1;0.46;0.73;1.45;1.95;
9  filter;ND10;8.256;8.73;11.0;11.9;
10 filter;ND50;43.8;45.5;49.8;52.4;
11 filter;ND79;76.6334;79.168;81.5745;82.539;
```

Basic LIISettings information (Line 1):

```
   4C-LII;LIISettings;0.1;LII detector with 4 channels;
```

Parameter breakdown:

Variable	Example	Allowed Value Type	Description
Name	4C-LII	String	Name of LIISettings, will be displayed within LIISim
Type of .ini	LIISettings	-	This string determines that this file is a LIISettings file. Should always be 'LIISettings'.
Version	0.1	Floating point	Version of this LIISettings, can be incremented for tracking and documenting changes by the user
Description	LII detector with 4 channels	String	Description for this LIISettings file.

Laser wavelength (Line 2):

```
    laser_wavelength;1064;
```

Parameter breakdown:

Variable	Example	Allowed Value Type	Description
Laser wavelength	laser_wavelength;1064;	Floating point	LII device laser wavelength (currently not used)

PMT channel properties structure (Line 3 to 6):

```
    channel;390;18;1.4;0.4;7.988;0;0;
```

Parameter breakdown:

channel;	Identifier. Every following 'channel' identifier will increase the channel number, so the channel number must not be appended
390	Channel center wavelength [nm]
18	Bandpass filter width [nm]
1.4	Calibration (sensitivity) (see 7.1.3)
0.4	Gain (reference voltage) [V] (see 7.1.3)
7.988	Gain (calibration) (A) (see 7.1.3)
0	Gain (calibration) (B) (see 7.1.3)
0	Offset, which can be used by "Baseline"

ND-filter information structure (Line 7 to 11):

```
    filter;ND10;8.256;8.73;11.0;11.9;
```

Parameter breakdown:

filter	Identifier. Every line defines a single ND-filter.
ND10	Filter identifier. This value is displayed and selectable inside LIISim. This value should be used to connect the filter setting in LIISettings and MRunSettings (see 5.2).
8.256	Transmission for channel 1 in percent (8.256 %)
8.73	Transmission for channel 2 in percent (8.73 %)
11.0	Transmission for channel 3 in percent (11 %)
11.9	Transmission for channel 4 in percent (11.9 %) (the number of transmission values needs to match the channel number)

5.2 Measurement run (MRun, run)

A measurement run is a set of one or multiple MPoints and associated MRun settings. Signals within a measurement run share the same detection settings like PMT gain, ND-filter, laser fluence,…

5.2.1 MRun settings

The MRun settings contain meta information for each MRun like name, description, LIISettings file name, filter, laser fluence etc. The filename should be the same as the signal files, with the '_settings' appended. So, if you have a signal file named

'Run_2016-09-26_15-08-08.Signal.Volts.Ch1.csv',

your settings file should be named

'Run_2016-09-26_15-08-08_settings.txt'.

Example files can be found in the 'exampleData' folder. The file structure is a basic .ini file. This means, every parameter value pair is denoted as a single line of text, the parameter followed by an equals sign and the parameter value,

e.g. for the 'name'-parameter:

```
name=RunABC
```

Example for a MRunSettings file:

```
[MRunSettings]
name=2018-12-04_11-22-33
description=LDF - 42 mm HAB
liisettings=liisettings/4C-LII.txt
filter=1
laser_fluence=1.5
pmt_gain_voltage_channel_1=0.4
pmt_gain_voltage_channel_2=0.36
pmt_gain_voltage_channel_3=0.31
pmt_gain_voltage_channel_4=0.32
pmt_measured_gain_voltage_channel_1=0.40156
pmt_measured_gain_voltage_channel_2=0.360573
pmt_measured_gain_voltage_channel_3=0.311273
pmt_measured_gain_voltage_channel_4=0.32133
udp_count=2
udp_1_identifier=Pressure
udp_1_value=50
udp_2_identifier=Operator
udp_2_value=JohnDoe
```

The following table lists all available parameters:

Line	Parameter	Allowed Value Type	Description
1	[MRunSettings]	-	Identifier for LIISim
2	name	String	Name of the associated run, can differ from the filename. This name will be used as identifier in LIISim and can be changed through the MRun-Details box.
3	description	String	Text, shows up in the run details.
4	liisettings	String	Path and filename of the associated LIISettings.
5	filter	String	Neutral density-filter identifier defined in LIISettings (see 5.1.1)
6	laser_fluence	Floating point	Laser fluence [mJ/mm²]
7-10	pmt_gain_voltage_channel_<#>	Floating point	Photomultiplier gain voltage (set) The <#> number corresponds to the channel number, ranging from 1 to x, depending on LIISettings.
11-14	pmt_measured_gain_voltage_channel_<#>	Floating point	Photomultiplier gain voltage (measured) The <#> number corresponds to the channel number, ranging from 1 to x, depending on LIISettings
15	udp_count	Integer	Current number of user defined parameters.
16	udp_<#>_identifier	String	Name/identifier of the user defined parameter with the number <#>.
17	udp_<#>_value	String	Value of the user defined parameter with the number <#>. There should always be pairs of identifier and value.

6 Databases

Database files can contain physical properties of materials, gases and gas mixtures. The first line of a database file defines the data structure and gives additional information about the file (name, description and file version):

```
    <name>;<type>;<version>;<description>;
```

<name>	Name of the database file, which will be used within LIISim
<type>	String defining the type of the file. Can be [Material|Gas|GasMixture]
<version>	Version of the file defined by the user. Changes should be tracked by the user manually.
<description>	Description of the file, including general source of properties

All following lines describes properties of materials, gases, and gas mixtures and follow the same scheme:

```
   <varia-
ble>;<type>;<0>;<1>;<2>;<2>;<3>;<4>;<5>;<6>;<7>;<8>;<source>
```

<variable>	Name of the variable, which will be used in heat transfer models
<type>	Type defines if variable is constant or a function of temperature or wavelength. (please see the following tables for detailed description of property types)
<0> to <7>	Parameters a_0 to a_7 will be used dependent on <type>
<source>	A literature reference can be added for tracing and visualization within LIISim

Example:

```
   C_p_mol;poly2;22.5566;0.0013;0;0;0;-1.8195e+06;0;0;0;Boris
Kock - PhD thesis (2006);
```

This line describes the molar heat capacity (Boris Kock – PhD thesis (2006):

$$C_p(T) = 22.5566 + 0.0013\,T - 1.8195 \cdot 10^6\,T^{-2}$$

Type	Function	Equation (temperature T, parameter $a_0 \dots a_8$)
const	Constant value	$f(T) = a_0$
case	Piecewise-defined	$f(T) = \begin{cases} a_1, & T \leq a_0 \\ a_2, & T > a_0 \end{cases}$
poly	Polynomial	$f(T) = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4 + a_5T^5 + +a_6T^6 + a_7T^7 + a_8T^8$
poly2	Polynomial	$f(T) = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^{-1} + a_5T^{-2}$
polycase	Piecewise-defined polynomial	$f(T) = \begin{cases} a_1 + a_2T + a_3T^2 + a_4T^3, & T \leq a_0 \\ a_5 + a_6T + a_7T^2 + a_8T^3, & T > a_0 \end{cases}$
exp	Exponential with Euler number as base	$f(T) = a_0 + a_1\exp(a_2 + a_3T^{-1} + a_4T)$
exppoly	Exponential with polynomial exponent	$f(T) = a_0 + a_1\exp(a_2 + a_3T + a_4T^2 + a_5T^3 + a_6T^4 + a_7T^5)$
powx	Exponential with Parameter as base	$f(T) = a_0 + a_1a_2^{(a_3 + a_4T^{-1} + a_5T)}$
optics_temp	Wavelength dependent polynomial provided for each wavelength	$f(\lambda, T) = f(a_0, T) = a_1 + a_2T + a_3T^2 + a_4T^3$
optics_case	Wavelength dependent piecewise-defined polynomial	$f(\lambda, T) = f(a_0, T) = \begin{cases} a_2, & T \leq a_1 \\ a_3, & T > a_1 \end{cases}$
optics_lambda	Wavelength dependent polynomial	$f(\lambda) = a_0 + a_1\lambda + a_2\lambda^2 + a_3\lambda^3 + a_4\lambda^4 + a_5\lambda^5 + a_6\lambda^6 + a_7\lambda^7 + a_8\lambda^8$
optics_exp	Exponential wavelength dependent	$f(\lambda) = a_0\lambda^{(1-a_1)}$

6.1 Materials

Example:

```
Soot_Kock;Material;1.0;Michelsen et al.- Appl. Phys. B 87, 503-521 (2007).;
alpha_T_eff;const;0.23;0;0;0;0;0;0;0;0;no source;
eps;const;1;0;0;0;0;0;0;0;0;no source;
rho_p;const;1860;0;0;0;0;0;0;0;0;no source;
theta_e;const;1;0;0;0;0;0;0;0;0;-;
C_p_mol;poly2;22.5566;0.0013;0;0;0;-1.8195e+06;0;0;0;no source;
Em_func;optics_lambda;1;0;0;0;0;0;0;0;0;no source;
H_v;const;790776.6;0;0;0;0;0;0;0;0;no source;
molar_mass;const;0.012011;0;0;0;0;0;0;0;0;no source;
molar_mass_v;const;0.036033;0;0;0;0;0;0;0;0;no source;
p_v;notSet;0;0;0;0;0;0;0;0;0;notSet;
p_v_ref;const;61.5;0;0;0;0;0;0;0;0;no source;
T_v_ref;const;3000;0;0;0;0;0;0;0;0;no source;
```

Property	Variable name	Unit	Description
α_T	alpha_T_eff	-	Effective thermal accommodation coefficient (conduction)
ε	eps	-	Total emissivity for radiation heat transfer
ϱ_p	rho_p	kg/m³	Particle density
θ_e	theta_e	-	Thermal accommodation coefficient (evaporation)
$C_{p,mol}$	C_p_mol	J/mol/K	Molar heat capacity
$E(m)$	Em	-	E(m) absorption value at wavelength λ
$E(m)$	Em_func	-	E(m) absorption function at wavelength λ
ΔH_v	H_v	J/mol	Enthalpy of evaporation
M	molar_mass	kg/mol	Molar mass
M_v	molar_mass_v	kg/mol	Molar mass of vapor species
p_v	p_v	Pa	Vapor pressure function
p_v^*	p_v_ref	Pa	Reference pressure for Clausius-Clapeyron
T_v^*	T_v_ref	K	Reference temperature for Clausius-Clapeyron

6.2 Gases

Example:

```
Nitrogen;Gas;1.0;Standard properties;
C_p_mol;const;29.124;0;0;0;0;0;0;0;0;no source;
molar_mass;const;0.0280134;0;0;0;0;0;0;0;0;NIST Chemistry WebBook, SRD 69;
```

Property	Variable name	Unit	Description
$C_{p,\mathrm{mol}}$	C_p_mol	J/mol/K	Specific heat capacity (isobaric)
M	molar_mass	kg/mol	Molar mass

6.3 GasMixtures

Example:

```
Ar/N2-50/50%;GasMixture;1.0;Standard properties;
gas_component;Argon;gases/argon.txt;0.5;
gas_component;Nitrogen;gases/nitrogen.txt;0.5;
L;notSet;0;0;0;0;0;0;0;0;0;notSet;
gamma_eqn;notSet;0;0;0;0;0;0;0;0;0;notSet;
therm_cond;notSet;0;0;0;0;0;0;0;0;0;notSet;
```

Property	Variable name	Unit	Description
κ_a	therm_cond	W/m/K	Thermal conductivity
L	L	m	Mean free path
γ	gamma_eqn	-	Custom heat capacity ratio

Example:

```
gas_component;Argon;gases/argon.txt;0.5;
gas_component;Nitrogen;gases/nitrogen.txt;0.5;
```

Element	Example	Description
<identifier>	gas_component	Identifier, indicating that the lines describes a component of the mixture
<database_name>	Argon	Gas name; should be the same as in the specific gas database file.
<database_location>	gases/argon.txt	Path to the gas database file.
<composition>	0.5	Percentage in the mixture, in this case 50 %. All components should add up to 100%

6.4 LIISettings

The LIISettings file structure is explained earlier in section 5.1 . For each LII detector setup (different bandpass filters, different detectors) a new LIISettings file can be created. This allows switching between different setups for the analysis.

7 Signal Processing

Processing steps can be individually ordered and parameters can be set individually for every measurement run, for a group or globally. This allows the systematic processing of all loaded measurement runs. The following processing plugins are available and can be applied multiple times in a signal processing chain.

7.1 Processing Plugins

The following processing plugins are available within LIISim:

- Arithmetic Operations
- Baseline Correction
- Calibration (gain, sensitivity)
- ND-Filter Correction
- Get Section
- Moving Average
- Multi Signal Average
- Normalize
- Overwrite
- Resolution Reducer
- Signal Arithmetic
- Simple Data Reducer
- Swap Channels
- Transfer
- Temperature Calculator

7.1.1 Arithmetic Operations

Perform arithmetic operations on signal trace. The operation will be applied to every data point in a signal.

Parameters:	
Operation	The following operations are available: - Multiplication - Division - Addition - Subtraction
Channel	Selects the channel used for the operation
Value	The value for the operation (e.g. multiply/divide by this value)

7.1.2 Baseline Correction

“Baseline” provides two options for signal offset correction:

i) **For gated PMTs**: the signal before the gate opening can be used to calculate the offset. This is done by averaging a user-defined signal range and subtract this from the signal.

ii) **For ungated PMTs**, the baseline offset for each channel can be defined in the LIISettings file. During processing these values are automatically retrieved and subtracted from the signal trace.

Parameters	
Calculate offset from	Selects if the baseline correction should be calculated from all signals or from each signal separately, LIISettings uses the "offset" values for each channel from the LIISettings-file
Start [ns]	Start time in nanoseconds
End [ns]	End time in nanoseconds

7.1.3 Calibration (gain, channel sensitivity)

Calibration values are stored in the LIISettings file for each channel i.
The gain correction factor y_i and channel-sensitivity calibration values are multiplied with the signal traces giving calibrated signal traces.

x_i is the channel gain voltage, $x_{i,\mathrm{ref}}$ the gain reference voltage and A_i the gain calibration value for the respective channel (coefficient B_i is currently not used).

Parameters	
Operation	Following operations are available: - *Gain (exp)*: Performs gain correction using the function: $y_i = \exp(-A_i \ \ln(x_i/x_{i,\mathrm{ref}}))$ - *Gain (log(10)):* Performs gain correction using the function: $y_i = 10^{\left(-A_i \ \log\left(\frac{x_i}{x_{i,\mathrm{ref}}}\right)\right)}$ - *Channel Sensitivity*: Performs sensitivity correction using the PMT sensitivity values saved in the LIISettings
Source of gain values	If Gain (exp) or Gain (log(10) is selected: Uses either the values stored in the run's settings file or manually entered values
Channel 1 Channel 2 Channel 3 Channel 4	If manual is selected as source of gain values, these values are entered here.

7.1.4 ND-Filter Correction

This plugin uses the transmission values from the current LIISettings according to the selected filter identifier. The identifier can be automatically selected from the MRun settings file or manually defined. Each signal trace is divided by the respective filter transmission values.

Parameters	
Filter Value Source	*Copy from run settings*: uses the filter identifier embedded in the run settings *Manual*: allows a manual entered filter transmission
Filter transmission (%)	If manual is selected as source, this filter transmission value is used

7.1.5 Get Section

Select a specified section from a signal. The following processing steps are applied only on this section.

Parameters	
Start from peak	Select this option to let LIISim auto detect a signal peak and use this as start time (experimental)
Reset time offset	Sets the start time of the selected section to zero.
Start [ns]	Section start time in nanoseconds
End [ns]	Section end time in nanoseconds

7.1.6 Moving Average

Performs a moving average over a signal.

Parameters	
Channel	The channel to perform the moving average on (or ‘all’ for all channels)
Window size	Window size used for averaging. (‘5’ means 2 datapoints before and 2 datapoints after each datapoints is used for the averaging.

7.1.7 Multi Signal Average

Performs an average over multiple signals. This processing step calculates an average signal from all signals. For all following processing steps this average signal is used. This is similar as using an average function on the oscilloscope).

Parameters	
Start signal	First signal number to include in the average
End signal	Last signal number to include in the average

7.1.8 Normalize

Normalizes a signal trace to the peak or a specific value.

Parameters	
Operation	Select if you want to normalize the signal by peak or by value
Channel	The channel to perform the normalization on (or 'all' for all channels)
Value	If "by value" is chosen, this value is used for normalization

7.1.9 Overwrite

Overwrite a channel by another channel. This plugin can be used to pass signals from Raw processing chain to absolute processing chain.

Parameters	
Source	The source signal type for the signal
Channel A	The destination channel (will be overwritten)
Channel B	The source signal

7.1.10 Resolution Reducer

Artificially reduce the vertical resolution of a signal trace. This plugin can be used to simulate the influence of lower detection resolution (e.g. Resolution of data recorded by a 12bit oscilloscope can be reduced to 8bit to see if the quality is still sufficient).

Parameters	
Resolution	Target bit resolution
Range	The vertical resolution range, mapped to the selected resolution

7.1.11 Signal Arithmetic

Used to perform arithmetic operations across multiple channels.

Parameters	
Operation	The following operations are available: - Multiplication (A*B) - Division (A/B) - Division (B/A) - Addition (A+B) - Subtraction (A-B) - Subtraction (B-A)
Channel A	The destination channel (will be overwritten)

Channel B	The source signal

7.1.12 Simple Data Reducer

This plugin reduces the data size by removing n data points consecutively. This plugin can be used to decrease computing time for data evaluation.

Parameters	
Skip data points	The number of data points which will be removed between two remaining data points

7.1.13 Swap Channels

Used to swap two channels.

Parameters	
Channel A Channel B	The channels which should be swapped

7.1.14 Transfer

Copies the final calculation data from the raw processing chain to the absolute processing chain.

7.1.15 Temperature calculation (Two-Color / Spectrum)

For the calculation of temperature traces, two methods are implemented in LIISim: Two-color pyrometry and spectral fitting of Planck's law.

Two-color pyrometry requires calibrated LII signals at two independent wavelengths:

$$T_{\mathrm{p}} = \frac{h\,c_0}{k_{\mathrm{B}}}\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)\left[\ln\left(\frac{I_\lambda(\lambda_1, T_{\mathrm{p}})}{I_\lambda(\lambda_2, T_{\mathrm{p}})}\frac{E(m_{\lambda_2})}{E(m_{\lambda_1})}\left(\frac{\lambda_1}{\lambda_2}\right)^6\right)\right]^{-1} \tag{1}$$

where T_{p} is the particle temperature, h the Planck constant, c_0 the speed of light in vacuum, k_{B} the Boltzmann constant, λ_i the bandpass center-wavelength of the detector, I_λ the calibrated intensity, and $E(m_\lambda)$ the absorption function. It needs to be noted that this formula is derived using the Wien approximation and differentiates in this aspect from a spectral fitting.

Spectrum: When two or more spectral detection channels are available, a spectral fit including all channels can be performed. For this analysis, Planck's law corrected for deviation from blackbody behavior is fitted to the data points of all selected channels:

$$I(\lambda, T_{\mathrm{p}}) = f_V G_\lambda C_{\lambda,\mathrm{abs}} \frac{2hc_0^2}{\lambda^5}\left[\exp\left(\frac{h\,c_0}{k_{\mathrm{B}}\lambda\,T_{\mathrm{p}}}\right) - 1\right]^{-1} \tag{2}$$

Where f_V is the volume fraction during the given laser shot, G_λ scales the emitted intensity based on the geometry and optical efficiencies of the detector, and $C_{\lambda,\mathrm{abs}}$ is the wavelength-dependent absorption cross-section given by the Rayleigh limit of Mie theory:

$$C_{\lambda,\mathrm{abs}}\left(d_{\mathrm{p}}\right)=\frac{\pi^2\,d_{\mathrm{p}}^3}{4}\frac{E(m_\lambda)}{\lambda} \tag{3}$$

In LIISim, wavelength-independent properties of equation (2) and (3) are summarized in a general scaling factor C, which simplifies equation (2) to:

$$I\left(\lambda,T_{\mathrm{p}}\right)=C\,\frac{E(m_\lambda)}{\lambda}\frac{2hc_0^2}{\lambda^5}\left[\exp\left(\frac{h\,c_0}{k_{\mathrm{B}}\lambda\,T_{\mathrm{p}}}\right)-1\right]^{-1} \tag{4}$$

The **TemperatureCalculator**-Plugin uses the result from the absolute/raw processing chain as input. This can be specified within the plugin's settings. Further, it can be selected which channels should be used for analysis and which optical properties should be used for the calculation/fitting.

7.2 Linking of processing steps

You can link the parameters of plugins over multiple runs – so if you change one parameter from one run, it also changes the parameter of another run. Before adding any plugin, you can choose between:

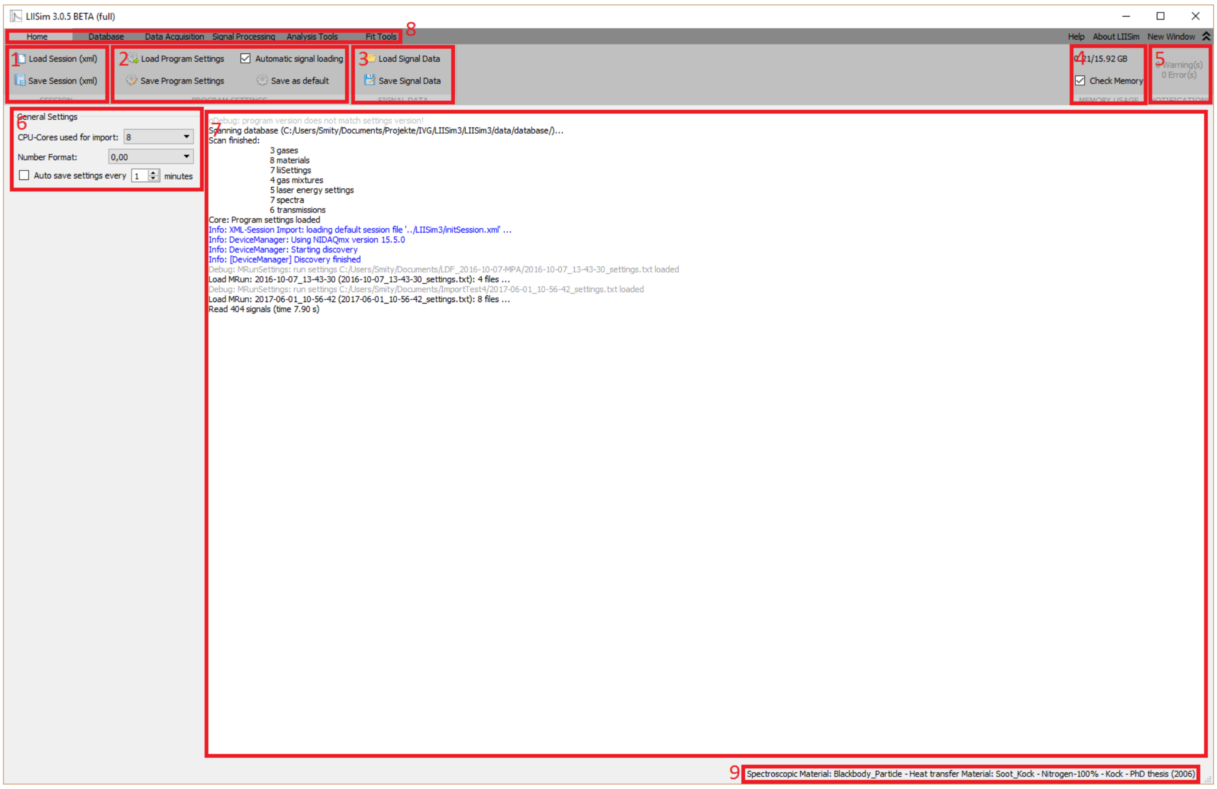
- 'all' (A)
- 'group' (G)
- 'single' (S)

link mode. 'All' will link the parameters between all loaded runs. 'Group' will link them between runs inside the same group. 'Single' will not link them. For a GUI example see section 7.5.3.

8 Graphical User Interface (GUI)

8.1 Home screen

The home screen (Figure 8-1) shows a log window and gives access to load/save functions for session, program settings and signal data.



General Settings

CPU-Cores used for import: 8

Number Format: 0,00

☐ Auto save settings every 1 minutes

```
qDebug: program version does not match settings version!
Scanning database (C:/Users/Smity/Documents/Projekte/IVG/LIISim3/LIISim3/data/database/)...
Scan finished:
                3 gases
                8 materials
                7 liiSettings
                4 gas mixtures
                5 laser energy settings
                7 spectra
                6 transmissions
Core: Program settings loaded
Info: XML-Session Import: loading default session file '../LIISim3/initSession.xml' ...
Info: DeviceManager: Using NIDAQmx version 15.5.0
Info: DeviceManager: Starting discovery
Info: [DeviceManager] Discovery finished
Debug: MRunSettings: run settings C:/Users/Smity/Documents/LDF_2016-10-07-MPA/2016-10-07_13-43-30_settings.txt loaded
Load MRun: 2016-10-07_13-43-30 (2016-10-07_13-43-30_settings.txt): 4 files ...
Debug: MRunSettings: run settings C:/Users/Smity/Documents/ImportTest4/2017-06-01_10-56-42_settings.txt loaded
Load MRun: 2017-06-01_10-56-42 (2017-06-01_10-56-42_settings.txt): 8 files ...
Read 404 signals (time 7.90 s)
```

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Soot_Kock - Nitrogen-100% - Kock - PhD thesis (2006)

Figure 8-1 Home screen

(1) Session

Through these buttons, a session file (.xml) can be saved or restored. The program state (called a session) contains information about loaded signal data (file names and folders) and signal processing steps (type of processing steps, parameters, linked steps, …).

Saving/loading a session can be helpful if different data sets need to be analyzed, but require different signal processing steps.

(2) Program settings

Program settings are saved in .ini-files. The default settings are automatically loaded on program start and saved in the “defaultSettings.ini”. Individual program settings can be saved and loaded.

“Save as default” can be used to save the current program settings in the defaultSettings.ini file.

“Automatic signal loading” determines if signals from the previous session are automatically loaded on program start.

(3) **Signal data**

Opens the load or save dialog for signals. See section 7.2 or 7.3 for further information.

(4) **Memory widget (visible in all tabs)**

Shows the currently used and available RAM. If the “Check Memory“-checkbox is checked, LIISim tries to calculate the RAM usage before calculation to prevent program crashes.

(5) **Notification widget (visible in all tabs)**

Displays the current warning/error count. If clicked, opens a window which shows all warnings/errors since start and resets the count.

(6) **General settings**

“CPU-Cores for import”: Sets the number of CPU-cores which are used during import.

“Auto save settings every X minutes”: If checked, saves the session and program settings every X minutes, where X is the number selected in the spin box.

(7) **Log**

Shows all log messages since start.

(8) **Navigation**

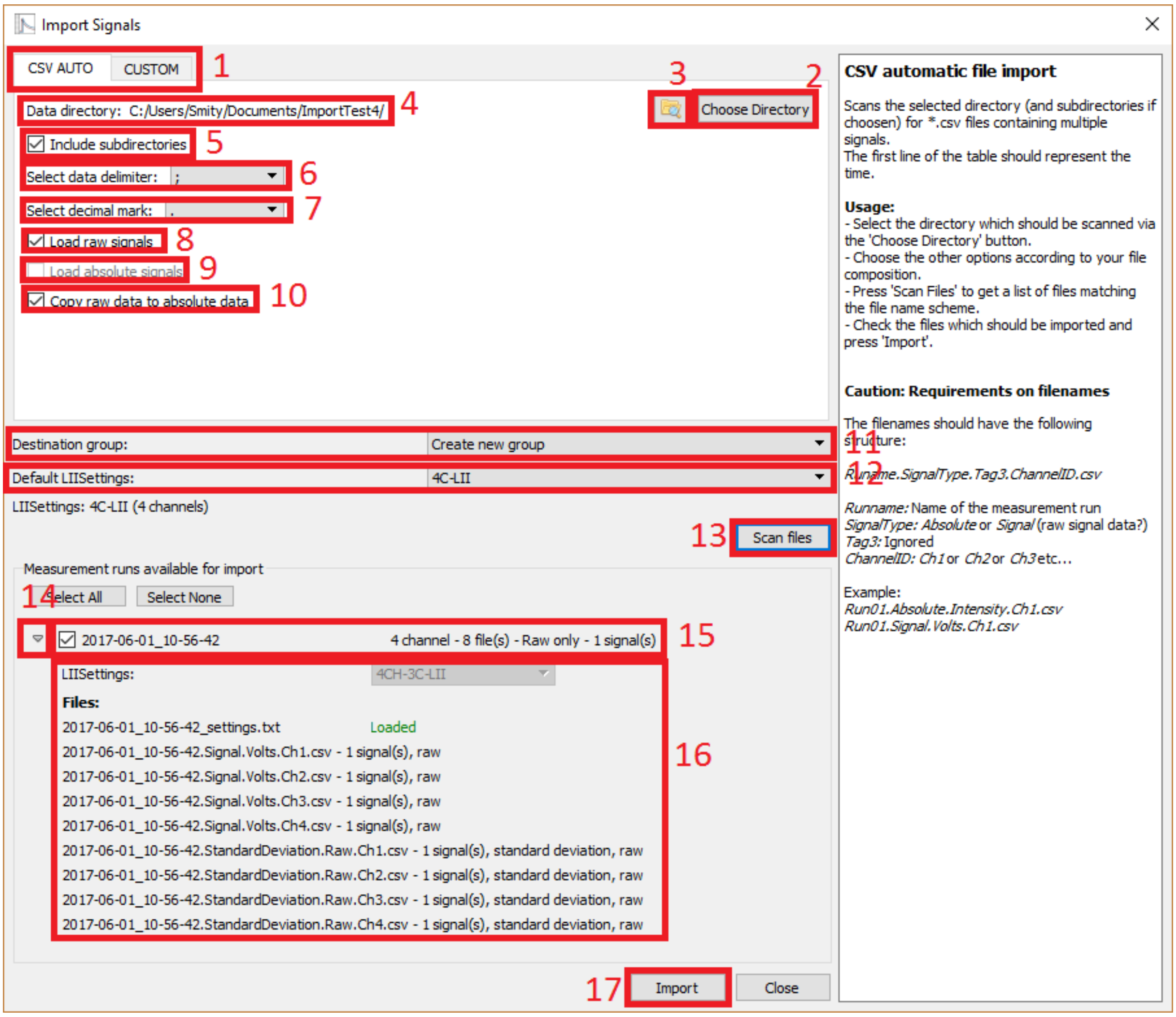
(9) **Status bar**

8.2 Signal Import

Signal import/export dialog can be accessed through the home screen (see section 7.1).

8.2.1 CSV formatted signals

To import signals in CSV format, you should choose the ‘CSV AUTO’ tab in the Signal Import dialog **(1)**. The dialog will look similar to the one below.



Data directory: C:/Users/Smity/Documents/ImportTest4/

☑ Include subdirectories

Select data delimiter: ;

Select decimal mark: .

☑ Load raw signals

□ Load absolute signals

☑ Copy raw data to absolute data

Destination group: Create new group

Default LIISettings: 4C-LII

LIISettings: 4C-LII (4 channels)

Measurement runs available for import

☑ 2017-06-01_10-56-42 4 channel - 8 file(s) - Raw only - 1 signal(s)

LIISettings: 4CH-3C-LII

Files:

2017-06-01_10-56-42_settings.txt Loaded
2017-06-01_10-56-42.Signal.Volts.Ch1.csv - 1 signal(s), raw
2017-06-01_10-56-42.Signal.Volts.Ch2.csv - 1 signal(s), raw
2017-06-01_10-56-42.Signal.Volts.Ch3.csv - 1 signal(s), raw
2017-06-01_10-56-42.Signal.Volts.Ch4.csv - 1 signal(s), raw
2017-06-01_10-56-42.StandardDeviation.Raw.Ch1.csv - 1 signal(s), standard deviation, raw
2017-06-01_10-56-42.StandardDeviation.Raw.Ch2.csv - 1 signal(s), standard deviation, raw
2017-06-01_10-56-42.StandardDeviation.Raw.Ch3.csv - 1 signal(s), standard deviation, raw
2017-06-01_10-56-42.StandardDeviation.Raw.Ch4.csv - 1 signal(s), standard deviation, raw

CSV automatic file import

Scans the selected directory (and subdirectories if choosen) for *.csv files containing multiple signals.
The first line of the table should represent the time.

Usage:
- Select the directory which should be scanned via the 'Choose Directory' button.
- Choose the other options according to your file composition.
- Press 'Scan Files' to get a list of files matching the file name scheme.
- Check the files which should be imported and press 'Import'.

Caution: Requirements on filenames

The filenames should have the following structure:

Runame.SignalType.Tag3.ChannelID.csv

Runname: Name of the measurement run
SignalType: Absolute or *Signal* (raw signal data?)
Tag3: Ignored
ChannelID: Ch1 or *Ch2* or *Ch3* etc...

Example:
Run01.Absolute.Intensity.Ch1.csv
Run01.Signal.Volts.Ch1.csv

Figure 8-2 CSV import window

The following steps are necessary to import signal data:

- First, you need to specify the directory where the files are located. This is done using the “Choose Directory” button **(2)**. **(4)** shows you the currently selected directory and with **(3)** you can open the selected directory in your file explorer.
- If you want to include files in subdirectories in your import, enable the checkbox at **(5)**.
- Select your data delimiter **(6)** and decimal mark **(7)** according to your data.
- If you want to import raw signal data, enable the checkbox at **(8)**. In general, you should leave this checkbox enabled.
- If you want to load absolute signal data, enable the checkbox at **(9)**. If you have no absolute signal data, leave this checkbox disabled, and enable the **(10)** checkbox, so the raw signal data is copied over as absolute signal.
- Choose the destination group where the measurement run should be added **(11)**.

- Choose the default LIISettings to use, if not defined elsewhere **(12).**
- Click “Scan Files” **(13)**. LIISim will now search the selected directory for files matching the naming scheme.
- If files are found, they are grouped according to their run name and shown with some additional information **(15)**. The checkbox in front of the name defines if the run should be loaded or not.
- Via a click on **(14)** you can toggle the details of a run **(16)**. Here you can set the LIISettings at a per run level, if there are no run settings available for the particular run.
- If you have set up everything you want, click “Import” **(17)** to let LIISim import the selected runs.

Important: To be recognized by the import routine, the CSV files should have the following name scheme with the tags below separated by dots:

<Runname>.<SignalType>.<Tag>.<ChannelID>.csv

Example: Run3.Signal.Anything.Ch2.csv

<Runname>	Can be any text, but must not contain a full stop/period. Will be used as run name and should be the same across one measurement run.
<SignalType>	Can be either ***Signal*** for raw signal data or ***Absolute*** for absolute signal data.
<Tag>	Can be any text, but must not contain a full stop/period. Will be ignored.
<ChannelID>	*Ch#*, with the # replaced by the channel number, ranging from 1 to 4.

Data Format:

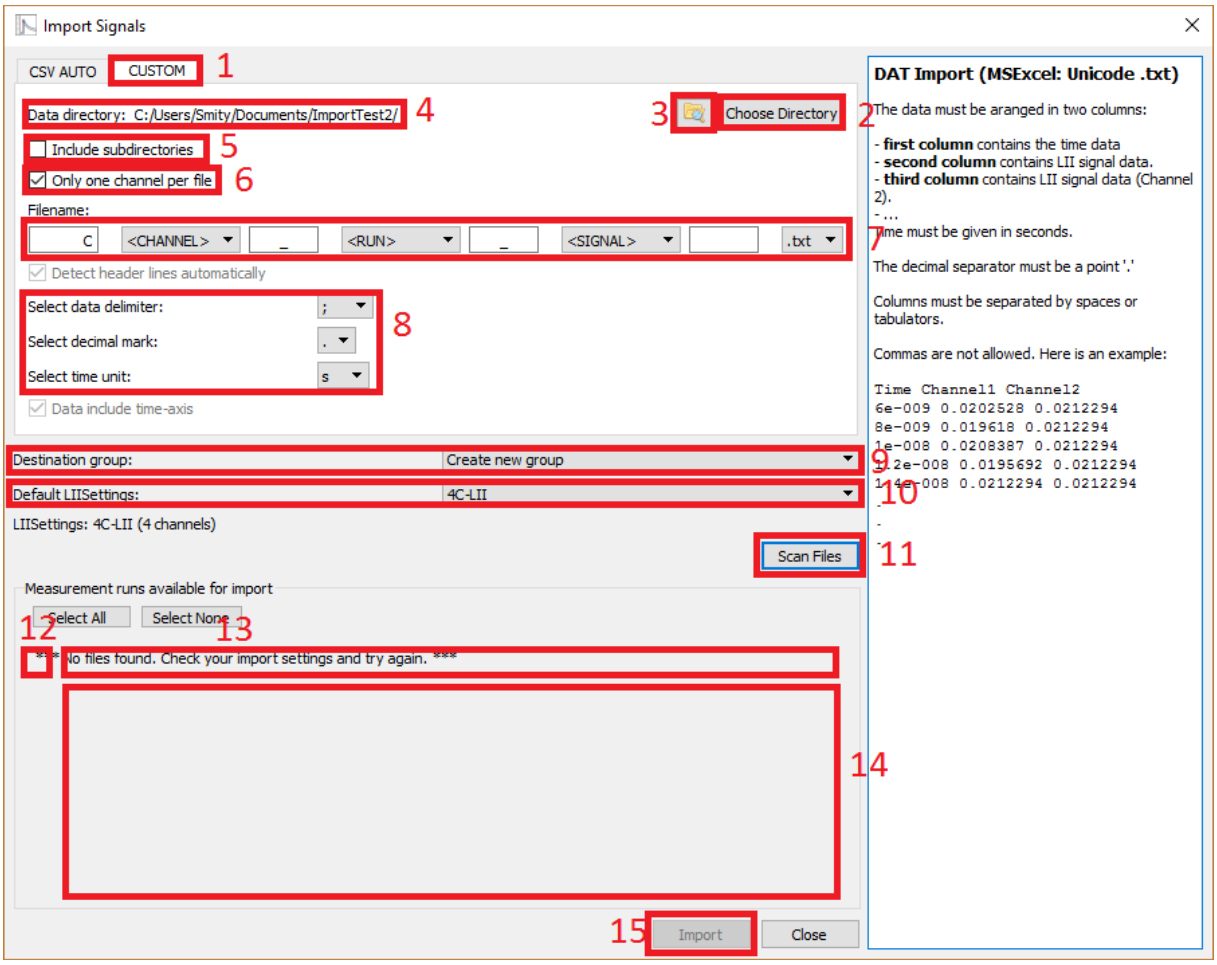
The data should be formatted as a standard *.csv file, with the first line representing the timesteps separated by ‘;’. The second line should contain the data points also separated by ‘;’.

Example:

```
0;1e-07;2e-07;3e-07;4e-07;5e-07;...        (timesteps)
0.564;0.67;0.54;0.406;0.684;0.506;...      (datapoints)
```

8.2.2 Custom formatted signals

To import existing *.txt or *.dat files, you should use the custom import mode. Open the Signal Import dialog and select the “CUSTOM” tab **(1)**. The dialog will look similar like the one below.



Data directory: C:/Users/Smity/Documents/ImportTest2/

☐ Include subdirectories

☑ Only one channel per file

Filename: C <CHANNEL> _ <RUN> _ <SIGNAL> .txt

☑ Detect header lines automatically

Select data delimiter: ;

Select decimal mark: .

Select time unit: s

☑ Data include time-axis

Destination group: Create new group

Default LIISettings: 4C-LII

LIISettings: 4C-LII (4 channels)

☐ *** No files found. Check your import settings and try again. ***

DAT Import (MSExcel: Unicode .txt)

The data must be aranged in two columns:

- **first column** contains the time data
- **second column** contains LII signal data.
- **third column** contains LII signal data (Channel 2).
- ...

Time must be given in seconds.

The decimal separator must be a point '.'

Columns must be separated by spaces or tabulators.

Commas are not allowed. Here is an example:

```
Time Channel1 Channel2
6e-009 0.0202528 0.0212294
8e-009 0.019618 0.0212294
1e-008 0.0208387 0.0212294
1.2e-008 0.0195692 0.0212294
1.4e-008 0.0212294 0.0212294
.
.
.
```

Figure 8-3 Custom import window

- First, you need to select the directory where the files are located with the “Choose Directory”-button **(2)**. You will see your currently selected directory at **(4).** With **(3)** you can open the currently selected directory in your operating system file browser.
- If you want to load files from multiple directories, you can enable this by selecting the “Include subdirectories” checkbox **(5)**. Note that these files all need to have the same naming scheme, which will be defined later.
- When your data is separated into multiple files, with only one channel per file, you should select the checkbox at **(6)**. Note that you need to select <CHANNEL> next step, otherwise the file scan will return wrong results and a signal import will fail.
- Now you can select the naming scheme of your files **(7).**

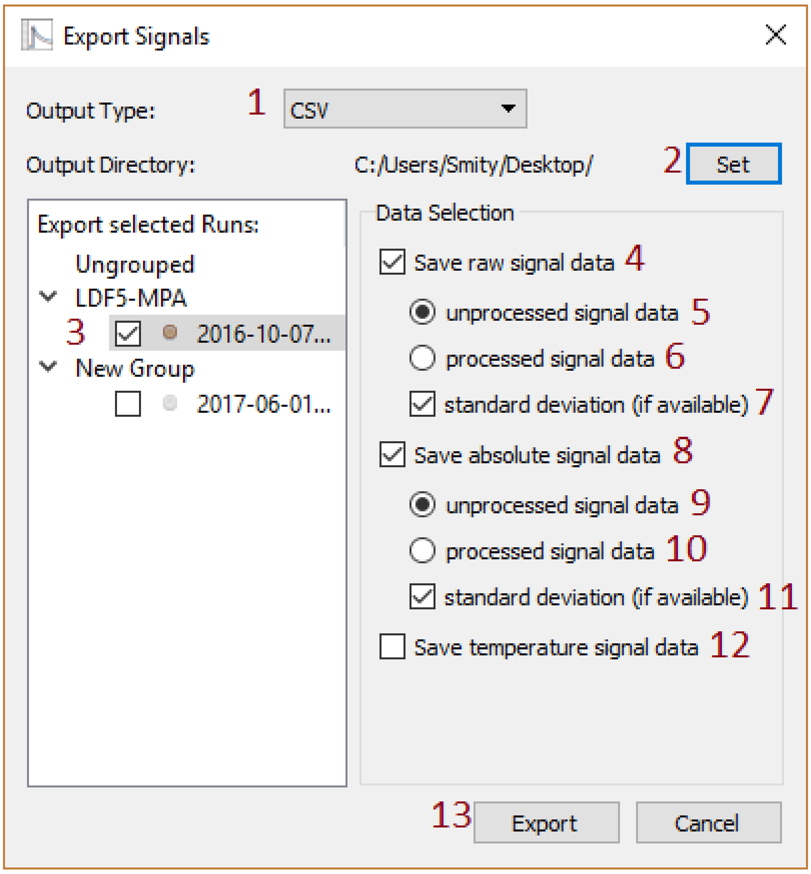
- The following placeholder are available and help with the automatic detection of custom file names:

Tag	Description	Example
<channel>	Channel identifier (successive numbers, ranging from 1 to x depending on LIISettings)	Run3_CH1_0001.txt
<signal>	Signal identifier (successive numbers)	signal_0001.txt signal_1.txt …
<run>	This string will be used as name inside LIISim	Run3_002.txt CH1_Run20.txt
<integer>	Any number, not used in a particular way	Run3_002_1000mbar.txt CH1_Run20_10HAB.txt
<…>		

- Select the format in which your data is available here **(8)**. Wrong selection might lead to empty signals after import.
- Select the group to which the run should be added after import **(9)**.
- Select your default LIISettings **(10)**. You can change these on a per-run basis after the file scan in the run details.
- Click on “Scan Files” **(11)** to let LIISim scan for importable files.
- Select the runs you want to import. **(13)** Shows the name of the run and some additional information. If you click on **(12)**, you can open the details of that particular run **(14)**.
- If you have selected all runs you like to import, press “Import” **(15)**.

8.3 Signal Export

8.3.1 CSV Export



Export Signals

Output Type: CSV

Output Directory: C:/Users/Smity/Desktop/

Export selected Runs:
Ungrouped
LDF5-MPA
☑ 2016-10-07...
New Group
□ 2017-06-01...

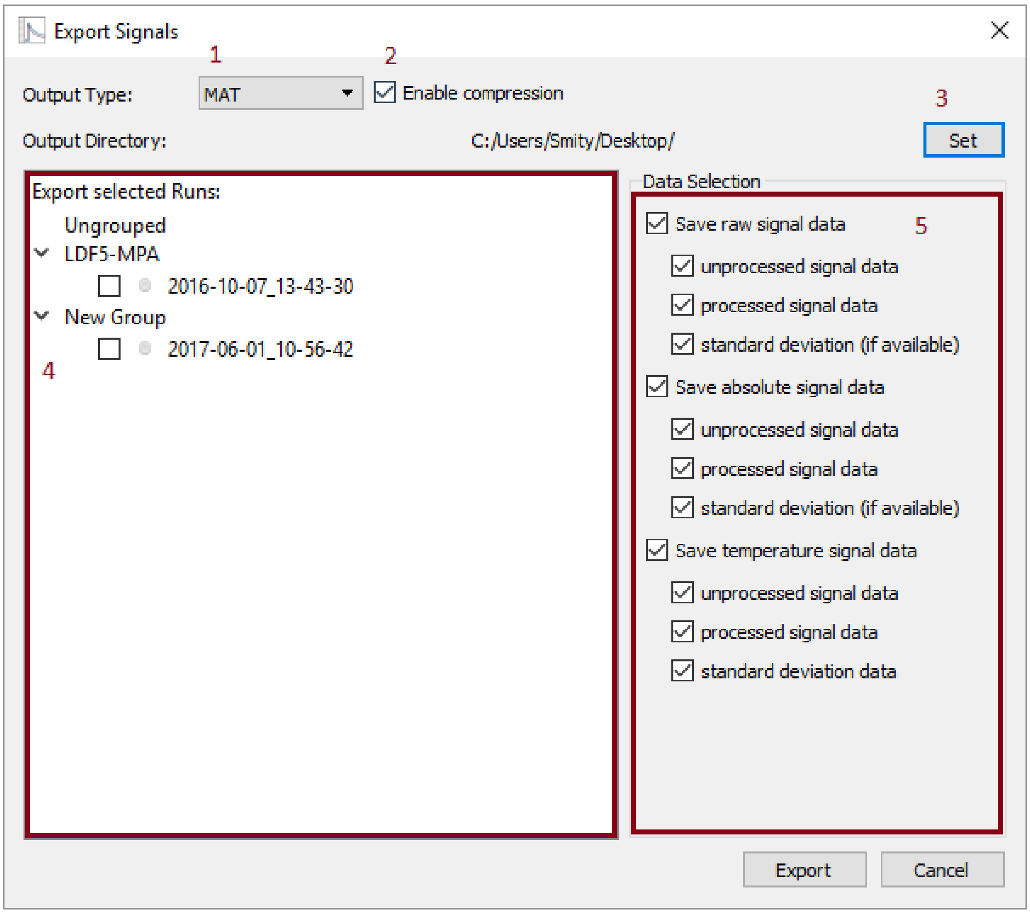
Data Selection

☑ Save raw signal data
● unprocessed signal data
○ processed signal data
☑ standard deviation (if available)
☑ Save absolute signal data
● unprocessed signal data
○ processed signal data
☑ standard deviation (if available)
□ Save temperature signal data

Steps to export a signal as a CSV file:

- Choose the right export type **(1)**, in this case ‘CSV’.
- Select your target directory with **(2)**.
- Select the runs you would like to export in **(3)**
- Activate the checkbox at **(4)** to export raw signal data and choose either the unprocessed **(5)** or processed **(6)** signal. (Additionally, standard deviation data can be exported by activating the checkbox at (7).)
- For the absolute signal, this is done analog to the raw signal, by activating **(8)** and choosing unprocessed **(9)** or processed **(10)** signal data.
- To export temperature signal data, activate the checkbox at **(12)**.
- Finally, press ‘Export’ **(13)** to export the selected signal data.

8.3.2 MATLAB Export



Export Signals

Output Type: MAT

☑ Enable compression

Output Directory: C:/Users/Smity/Desktop/

Export selected Runs:

Ungrouped

LDF5-MPA

□ 2016-10-07_13-43-30

New Group

□ 2017-06-01_10-56-42

Data Selection

☑ Save raw signal data

☑ unprocessed signal data

☑ processed signal data

☑ standard deviation (if available)

☑ Save absolute signal data

☑ unprocessed signal data

☑ processed signal data

☑ standard deviation (if available)

☑ Save temperature signal data

☑ unprocessed signal data

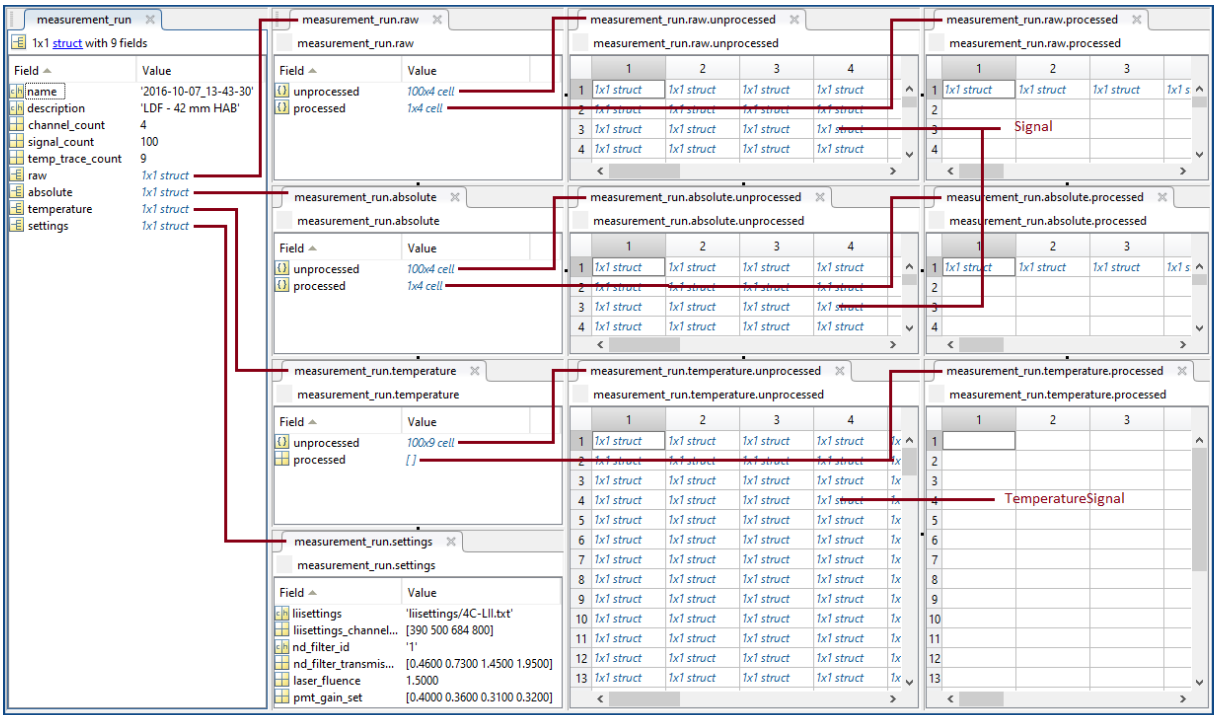
☑ processed signal data

☑ standard deviation data

Steps to export a signal as a Matlab file:

- Choose ‘MAT’ as export type **(1)**.
- Select if you like the file to be compressed **(2)**.
- Select your target directory **(3)**.
- Choose the runs you would like to export **(4)**.
- Select the data types you like to export **(5)**. See the CSV export for a more detailed description of the available data types. In the contrary to the CSV export, all data will be exported into one file.
- Press ‘Export’.

8.3.3 MATLAB File Structure



measurement_run

1x1 struct with 9 fields

Field	Value
name	'2016-10-07_13-43-30'
description	'LDF - 42 mm HAB'
channel_count	4
signal_count	100
temp_trace_count	9
raw	1x1 struct
absolute	1x1 struct
temperature	1x1 struct
settings	1x1 struct

measurement_run.raw

Field	Value
unprocessed	100x4 cell
processed	1x4 cell

measurement_run.raw.unprocessed

	1	2	3	4
1	1x1 struct	1x1 struct	1x1 struct	1x1 struct
2	1x1 struct	1x1 struct	1x1 struct	1x1 struct
3	1x1 struct	1x1 struct	1x1 struct	1x1 struct
4	1x1 struct	1x1 struct	1x1 struct	1x1 struct

measurement_run.raw.processed

	1	2	3	
1	1x1 struct	1x1 struct	1x1 struct	1x1 s
2				
3				
4				

Signal

measurement_run.absolute

Field	Value
unprocessed	100x4 cell
processed	1x4 cell

measurement_run.absolute.unprocessed

	1	2	3	4
1	1x1 struct	1x1 struct	1x1 struct	1x1 struct
2	1x1 struct	1x1 struct	1x1 struct	1x1 struct
3	1x1 struct	1x1 struct	1x1 struct	1x1 struct
4	1x1 struct	1x1 struct	1x1 struct	1x1 struct

measurement_run.absolute.processed

	1	2	3	
1	1x1 struct	1x1 struct	1x1 struct	1x1 s
2				
3				
4				

measurement_run.temperature

Field	Value
unprocessed	100x9 cell
processed	[ ]

measurement_run.temperature.unprocessed

	1	2	3	4	
1	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
2	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
3	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
4	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
5	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
6	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
7	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
8	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
9	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
10	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
11	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
12	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x
13	1x1 struct	1x1 struct	1x1 struct	1x1 struct	1x

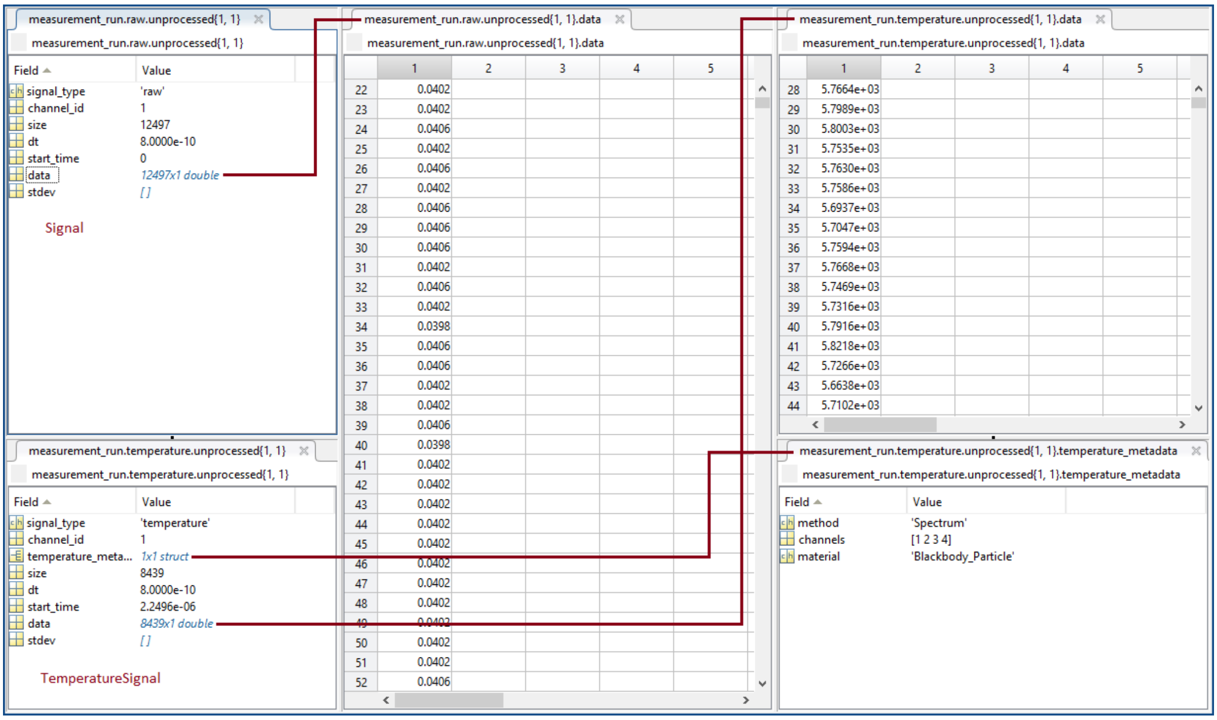
measurement_run.temperature.processed

	1	2	3
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			

TemperatureSignal

measurement_run.settings

Field	Value
liisettings	'liisettings/4C-LII.txt'
liisettings_channel...	[390 500 684 800]
nd_filter_id	'1'
nd_filter_transmis...	[0.4600 0.7300 1.4500 1.9500]
laser_fluence	1.5000
pmt_gain_set	[0.4000 0.3600 0.3100 0.3200]



measurement_run.raw.unprocessed{1, 1}

Field	Value
signal_type	'raw'
channel_id	1
size	12497
dt	8.0000e-10
start_time	0
data	12497x1 double
stdev	[ ]

Signal

measurement_run.temperature.unprocessed{1, 1}

Field	Value
signal_type	'temperature'
channel_id	1
temperature_meta...	1x1 struct
size	8439
dt	8.0000e-10
start_time	2.2496e-06
data	8439x1 double
stdev	[ ]

TemperatureSignal

measurement_run.raw.unprocessed{1, 1}.data

	1	2	3	4	5
22	0.0402				
23	0.0402				
24	0.0406				
25	0.0402				
26	0.0406				
27	0.0402				
28	0.0406				
29	0.0406				
30	0.0406				
31	0.0402				
32	0.0406				
33	0.0402				
34	0.0398				
35	0.0406				
36	0.0406				
37	0.0402				
38	0.0402				
39	0.0406				
40	0.0398				
41	0.0402				
42	0.0402				
43	0.0402				
44	0.0402				
45	0.0402				
46	0.0402				
47	0.0402				
48	0.0402				
49	0.0402				
50	0.0402				
51	0.0402				
52	0.0406				

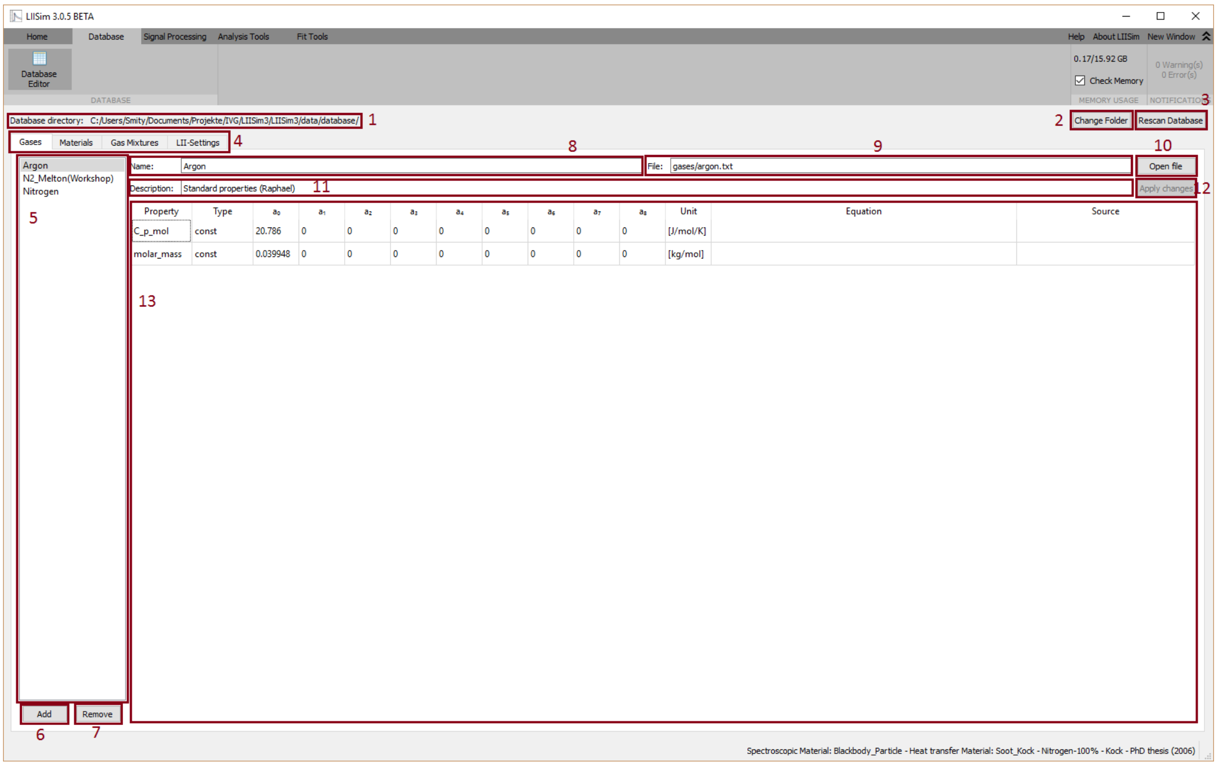
measurement_run.temperature.unprocessed{1, 1}.data

	1	2	3	4	5
28	5.7664e+03				
29	5.7989e+03				
30	5.8003e+03				
31	5.7535e+03				
32	5.7630e+03				
33	5.7586e+03				
34	5.6937e+03				
35	5.7047e+03				
36	5.7594e+03				
37	5.7668e+03				
38	5.7469e+03				
39	5.7316e+03				
40	5.7916e+03				
41	5.8218e+03				
42	5.7266e+03				
43	5.6638e+03				
44	5.7102e+03				

measurement_run.temperature.unprocessed{1, 1}.temperature_metadata

Field	Value
method	'Spectrum'
channels	[1 2 3 4]
material	'Blackbody_Particle'

8.4 Database Editor



Database directory: C:/Users/Smity/Documents/Projekte/IVG/LIISim3/LIISim3/data/database/

Argon
N2_Melton(Workshop)
Nitrogen

Name: Argon

File: gases/argon.txt

Description: Standard properties (Raphael)

Property	Type	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	Unit	Equation	Source
C_p_mol	const	20.786	0	0	0	0	0	0	0	0	[J/mol/K]		
molar_mass	const	0.039948	0	0	0	0	0	0	0	0	[kg/mol]		

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Soot_Kock - Nitrogen-100% - Kock - PhD thesis (2006)

(1) **Database path**

Shows the currently selected database path.

(2) **Change folder**

Changes the current database path.

(3) **Rescan database**

Rescans the database folder for new / changed files. Will reload the complete database. If any manual changes to the text files are made, this command should executed.

(4) **Databases**

Switch between the different database categories.

(5) **List of database elements**

Lists the available database files in the current database category.

(6) **Add database element**

Creates a new database file from the currently selected category.

(7) **Remove database element**

Removes the database element and deletes the associated file. ***Note:*** *there is no warning before deletion.*

(8) **Element name**

Shows the element name. Can be edited.

(9) Database element path / filename

Shows the element path (from the database path) and filename. Can be edited.

(10) Open file

Opens the currently selected element with the default text editor.

(11) Element description

Shows the element description. Can be edited.

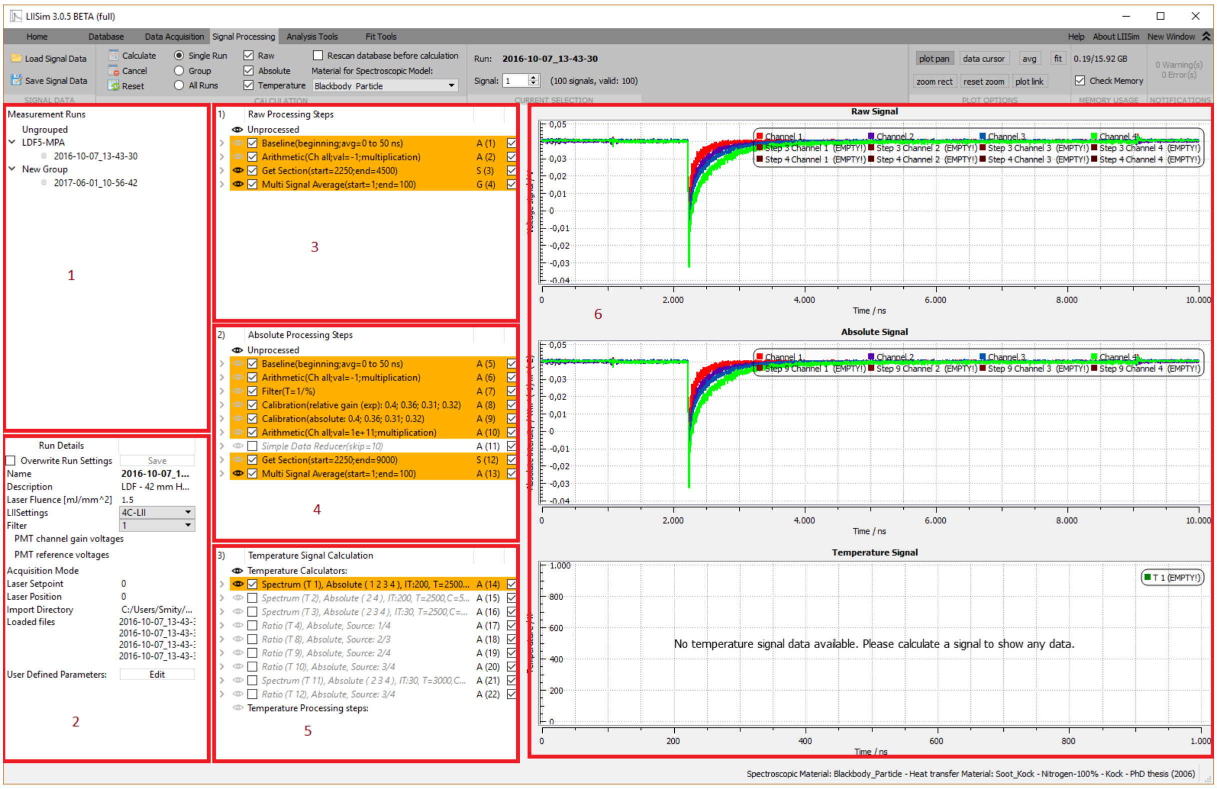
(12) Apply changes

Applies the changes made to the file.

(13) Database element data

The data defined in the element file.

8.5 Signal Processing



● Single Run
○ Group
○ All Runs

☑ Raw
☑ Absolute
☑ Temperature

☐ Rescan database before calculation

Material for Spectroscopic Model: Blackbody Particle

Run: 2016-10-07_13-43-30

Signal: 1 (100 signals, valid: 100)

0.19/15.92 GB

☑ Check Memory

0 Warning(s)
0 Error(s)

Measurement Runs
- Ungrouped
- LDF5-MPA
  - 2016-10-07_13-43-30
- New Group
  - 2017-06-01_10-56-42

1) Raw Processing Steps

Unprocessed

☑ Baseline(beginning;avg=0 to 50 ns)	A (1)	☑
☑ Arithmetic(Ch all;val=-1;multiplication)	A (2)	☑
☑ Get Section(start=2250;end=4500)	S (3)	☑
☑ Multi Signal Average(start=1;end=100)	G (4)	☑

2) Absolute Processing Steps

Unprocessed

☑ Baseline(beginning;avg=0 to 50 ns)	A (5)	☑
☑ Arithmetic(Ch all;val=-1;multiplication)	A (6)	☑
☑ Filter(T=1/%)	A (7)	☑
☑ Calibration(relative gain (exp): 0.4; 0.36; 0.31; 0.32)	A (8)	☑
☑ Calibration(absolute: 0.4; 0.36; 0.31; 0.32)	A (9)	☑
☑ Arithmetic(Ch all;val=1e+11;multiplication)	A (10)	☑
☐ Simple Data Reducer(skip=10)	A (11)	☑
☑ Get Section(start=2250;end=9000)	S (12)	☑
☑ Multi Signal Average(start=1;end=100)	A (13)	☑

3) Temperature Signal Calculation

Temperature Calculators:

☑ Spectrum (T 1), Absolute (1 2 3 4), IT:200, T=2500...	A (14)	☑
☐ Spectrum (T 2), Absolute (2 4), IT:200, T=2500,C=5...	A (15)	☑
☐ Spectrum (T 3), Absolute (2 3 4), IT:30, T=2500,C=...	A (16)	☑
☐ Ratio (T 4), Absolute, Source: 1/4	A (17)	☑
☐ Ratio (T 8), Absolute, Source: 2/3	A (18)	☑
☐ Ratio (T 9), Absolute, Source: 2/4	A (19)	☑
☐ Ratio (T 10), Absolute, Source: 3/4	A (20)	☑
☐ Spectrum (T 11), Absolute (2 3 4), IT:30, T=3000,C...	A (21)	☑
☐ Ratio (T 12), Absolute, Source: 3/4	A (22)	☑

Temperature Processing steps:

Run Details

☐ Overwrite Run Settings Save

Name	2016-10-07_1...
Description	LDF - 42 mm H...
Laser Fluence [mJ/mm^2]	1.5
LIISettings	4C-LII
Filter	1
PMT channel gain voltages	
PMT reference voltages	
Acquisition Mode	
Laser Setpoint	0
Laser Position	0
Import Directory	C:/Users/Smity/...
Loaded files	2016-10-07_13-43-: 2016-10-07_13-43-: 2016-10-07_13-43-: 2016-10-07_13-43-:
User Defined Parameters:	Edit

No temperature signal data available. Please calculate a signal to show any data.

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Soot_Kock - Nitrogen-100% - Kock - PhD thesis (2006)

(1) Measurement run list

Shows all currently loaded runs. Groups can be used to order runs from different experiments. Parameters of processing chain can be set individually for every measurement run, by group or global.

(2) Measurement run details

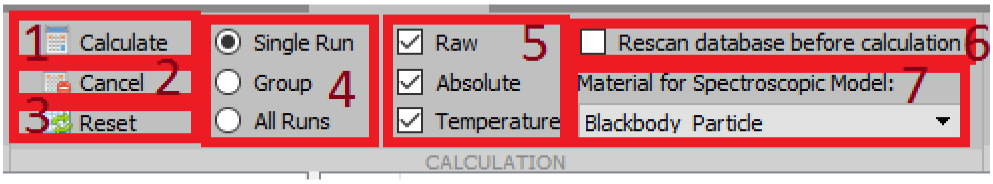
If a run is selected, this shows details and parameters saved in the run settings. See section 7.5.3.

(3) **Processing chain for raw signals**

(4) **Processing chain for absolute signals**

(5) **Processing chain for temperature calculations**

8.5.1 Calculation widget / current selection



● Single Run
○ Group
○ All Runs

☑ Raw
☑ Absolute
☑ Temperature

□ Rescan database before calculation

Material for Spectroscopic Model: Blackbody Particle

(1) **Calculate**

Starts the calculation with the currently selected measurement runs.

(2) **Cancel**

Cancels any running calculation.

(3) **Reset**

Resets the data buffers and calculation stats (indicated by background color)

(4) **Calculation mode**

Select measurement runs to be calculated:

Single Run: Only the currently selected run will be calculated.

Group: All runs in the current group are processed, active group is determined by the currently selected run.

All Runs: Calculate all runs.

(5) **Calculation of signal types**

Select which signal type you would like to calculate. Processing chains can be disabled to increase computing speed.

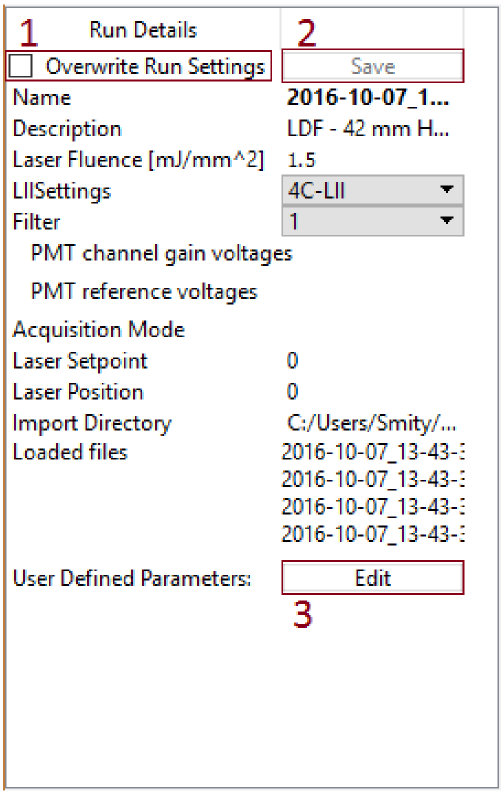
(6) **Rescan database before calculations**

If this is checked, the database is rescanned before each calculation cycle. Useful if you are experimenting with different material settings and editing database files manually.

(7) **Material for spectroscopic model**

Select the material from database, which will be used in temperature calculations in the “global” setting. Material contains information of optical properties, i.e. E(m).

8.5.2 Run details



□ Overwrite Run Settings

Name	**2016-10-07_1...**
Description	LDF - 42 mm H...
Laser Fluence [mJ/mm^2]	1.5
LIISettings	4C-LII
Filter	1
PMT channel gain voltages	
PMT reference voltages	
Acquisition Mode	
Laser Setpoint	0
Laser Position	0
Import Directory	C:/Users/Smity/...
Loaded files	2016-10-07_13-43-: 2016-10-07_13-43-: 2016-10-07_13-43-: 2016-10-07_13-43-:
User Defined Parameters:	Edit

This window is displayed everywhere in LIISim in the lower left corner and shows the meta data for the currently selected run. For details regarding the parameters, see section 5.2.1 (MRun settings).

(1) **Overwrite Run Settings**

If enabled, any changes in the run settings are saved at program exit. ***Caution:*** *This will overwrite the settings files for ALL loaded runs if enabled.*

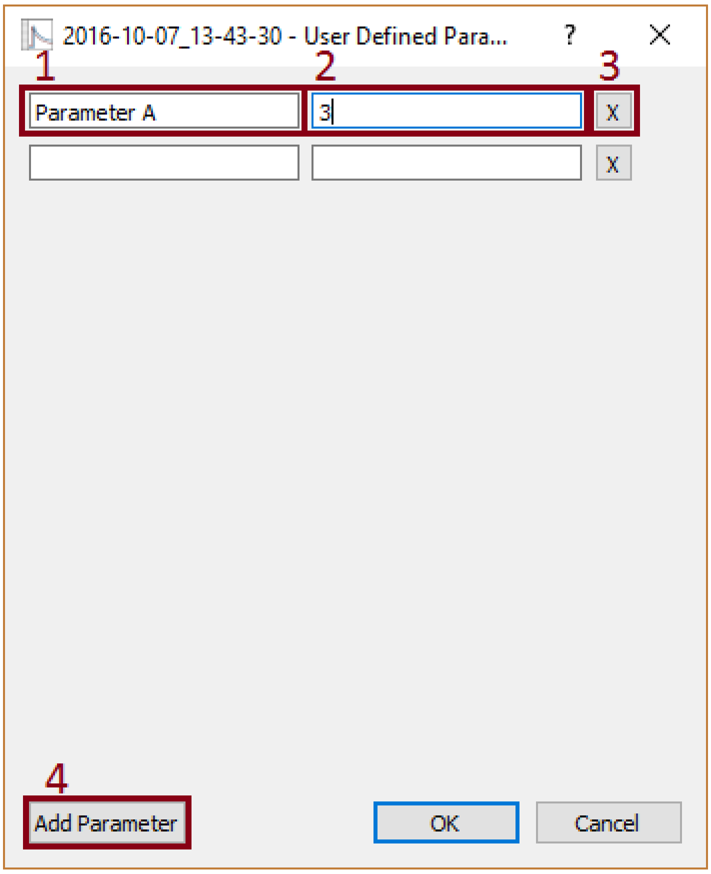
(2) **Save**

Saves the currently made changes **permanently**. The checkbox **(5)** must be enabled before saving and can be disabled afterwards.

(3) **Edit**

Opens the user-defined parameters editor, described in section 8.5.3.

8.5.3 User-defined parameters

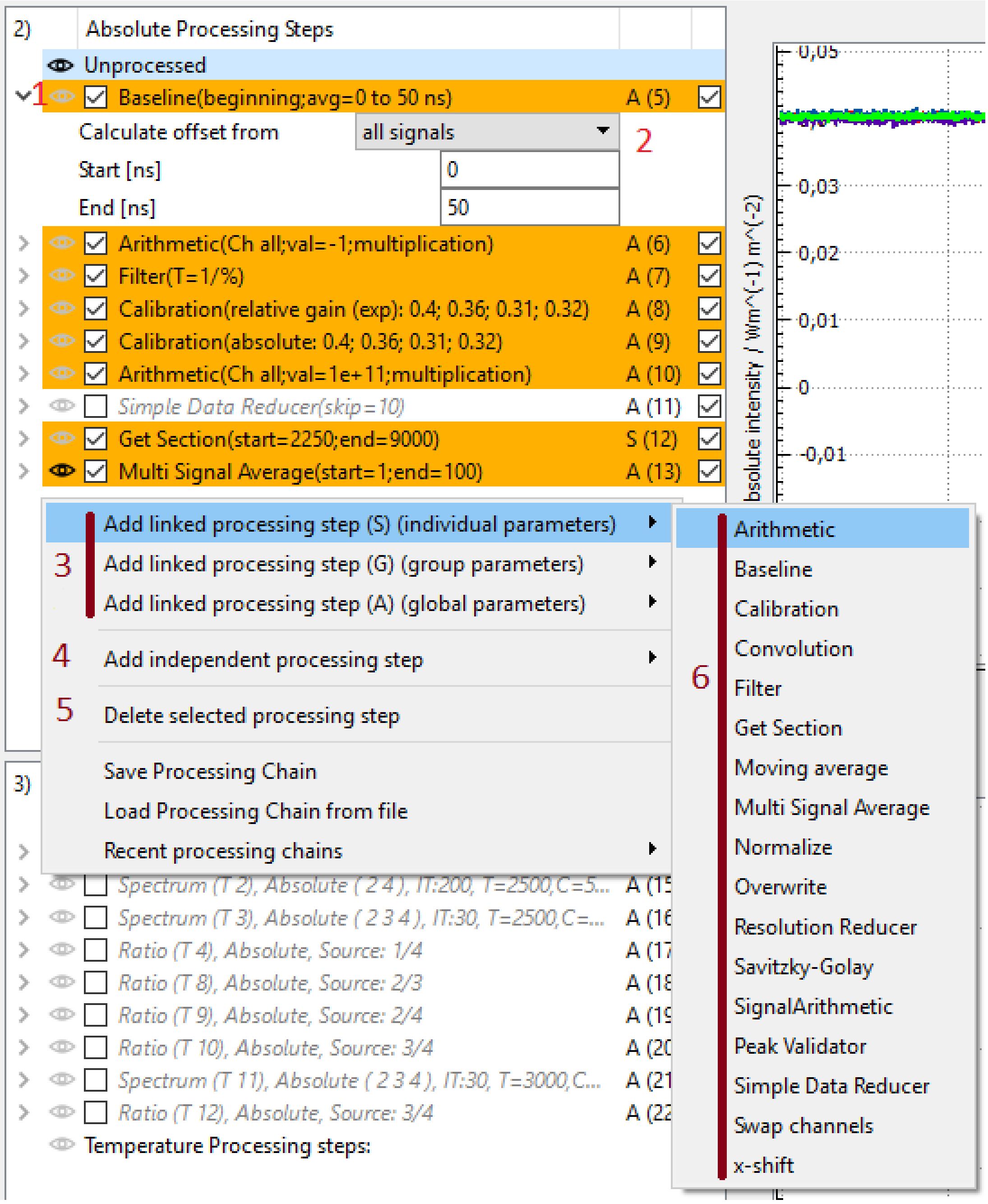


User-defined parameters (UDPs) can be used to add parameters which are not pre-defined (i.e. process pressure, HAB, …).

These UDPs will be displayed in the run details and can be used in the parameter analysis tool.

In the UDP window, **(1)** will be the parameter name, **(2)** respectively the parameter value. **(3)** deletes a parameter and **(4)** adds a new name-value field to the list.

8.5.4 Processing steps


2) Absolute Processing Steps

Unprocessed

1 ☑ Baseline(beginning;avg=0 to 50 ns) A (5) ☑

Calculate offset from: all signals

Start [ns]: 0

End [ns]: 50

☑ Arithmetic(Ch all;val=-1;multiplication) A (6) ☑

☑ Filter(T=1/%) A (7) ☑

☑ Calibration(relative gain (exp): 0.4; 0.36; 0.31; 0.32) A (8) ☑

☑ Calibration(absolute: 0.4; 0.36; 0.31; 0.32) A (9) ☑

☑ Arithmetic(Ch all;val=1e+11;multiplication) A (10) ☑

□ *Simple Data Reducer(skip=10)* A (11) ☑

☑ Get Section(start=2250;end=9000) S (12) ☑

☑ Multi Signal Average(start=1;end=100) A (13) ☑

3)

□ *Spectrum (T 2), Absolute (2 4), IT:200, T=2500,C=5...* A (15

□ *Spectrum (T 3), Absolute (2 3 4), IT:30, T=2500,C=...* A (16

□ *Ratio (T 4), Absolute, Source: 1/4* A (17

□ *Ratio (T 8), Absolute, Source: 2/3* A (18

□ *Ratio (T 9), Absolute, Source: 2/4* A (19

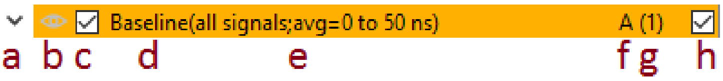
□ *Ratio (T 10), Absolute, Source: 3/4* A (20

□ *Spectrum (T 11), Absolute (2 3 4), IT:30, T=3000,C...* A (21

□ *Ratio (T 12), Absolute, Source: 3/4* A (22

Temperature Processing steps:

(1) Plugin


☑ Baseline(all signals;avg=0 to 50 ns) A (1) ☑

(a) Toggles visibility of plugin settings

(b) Toggles the visibility of the processing step inside the plot

(c) Enables the plugin. If unchecked, the plugin will be skipped during calculation

(d) Plugin name

(e) Short parameter summary

(f) Link type (A, G, S) (see Linking of processing steps)

(g) Link identifier. (Indicates which Plugins are connected)

(h) Activate/Deactivate intermediate result buffer. If this is activated the result of this processing step is internally saved and can be visualized. If large data sets are processed, memory consumption can increase exponentially. In this case deactivation helps to reduce the memory used by LIISim and speeds up processing time.

(2) Plugin settings

Shows the current plugin settings.

(3) Add linked processing step (see Linking of processing 7.2)

Add a plugin to the processing chain. The plugin will be added to the processing chain of all runs. You can choose between different parameter link states (A, G and S).

(4) Add independent processing step

Adds a plugin only to the currently selected run. This processing step is not added to any other processing chain.

(5) Delete selected processing step

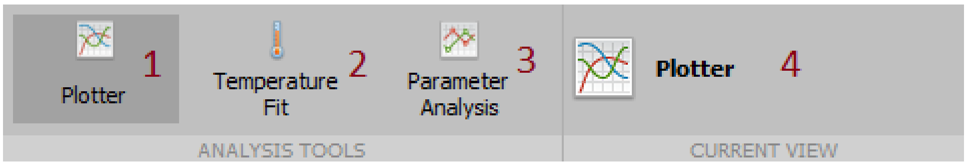
Removes the selected plugin from the processing chain.

(6) Plugin list

Shows all available plugins.

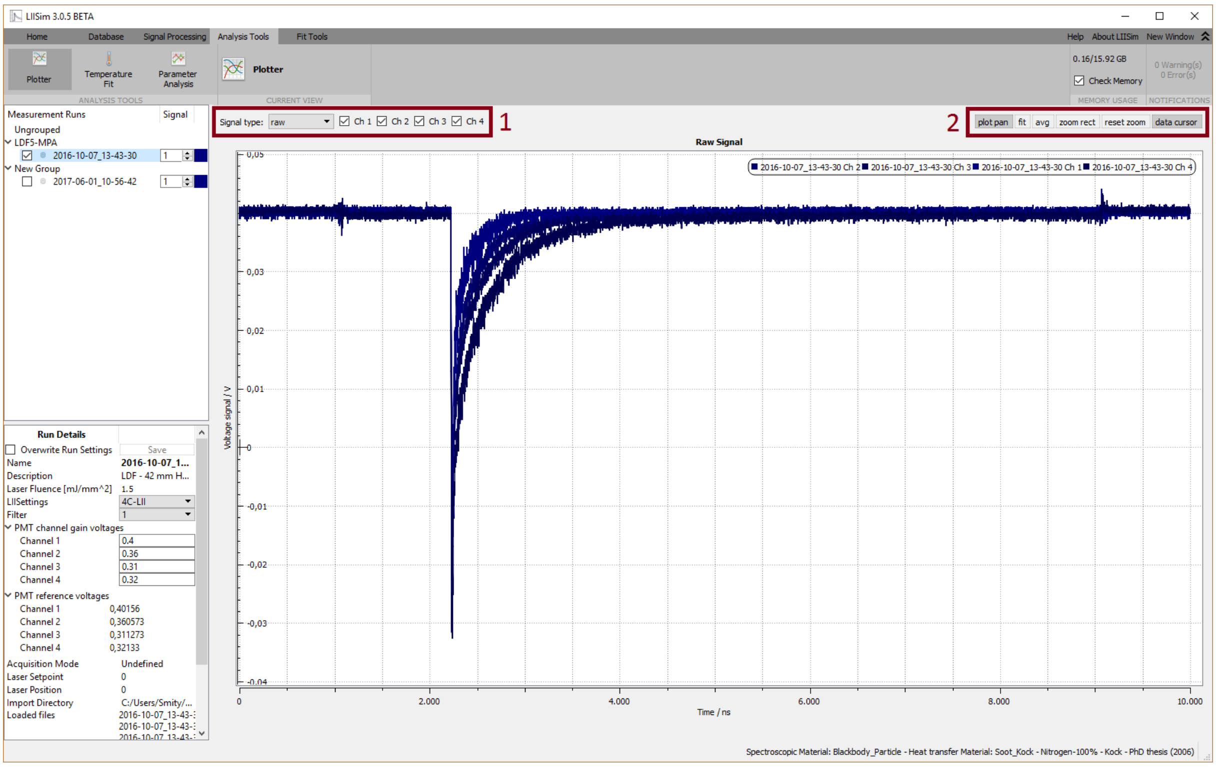
8.6 Analysis Tools

Analysis tools can be used to visualize previously processed data and extract key information for further analysis.



The different tools can be switched using **(1)** **(2)** and **(3)**. The currently selected tool is shown in **(4)**.

8.6.1 Plotter (Plot Tools)



☐ Overwrite Run Settings

Name	**2016-10-07_1...**
Description	LDF - 42 mm H...
Laser Fluence [mJ/mm^2]	1.5
LIISettings	4C-LII
Filter	1
PMT channel gain voltages	
Channel 1	0.4
Channel 2	0.36
Channel 3	0.31
Channel 4	0.32
PMT reference voltages	
Channel 1	0,40156
Channel 2	0,360573
Channel 3	0,311273
Channel 4	0,32133
Acquisition Mode	Undefined
Laser Setpoint	0
Laser Position	0
Import Directory	C:/Users/Smity/...
Loaded files	2016-10-07_13-43-3 2016-10-07_13-43-3 2016-10-07_13-43-3

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Soot_Kock - Nitrogen-100% - Kock - PhD thesis (2006)

The plot tools are used for comparison of different measurement runs (selectable in the left top list) for an in-depth analysis. The signal type and channel can be changed through **(1)**. The plot control **(2)** is described in section 8.8.1 (Plot controls).

8.6.2 Temperature Fit

This tool only works with temperature traces calculated with the "Spectrum"-method. "Two-Color" traces cannot be visualized.

First, a measurement run needs to be selected.

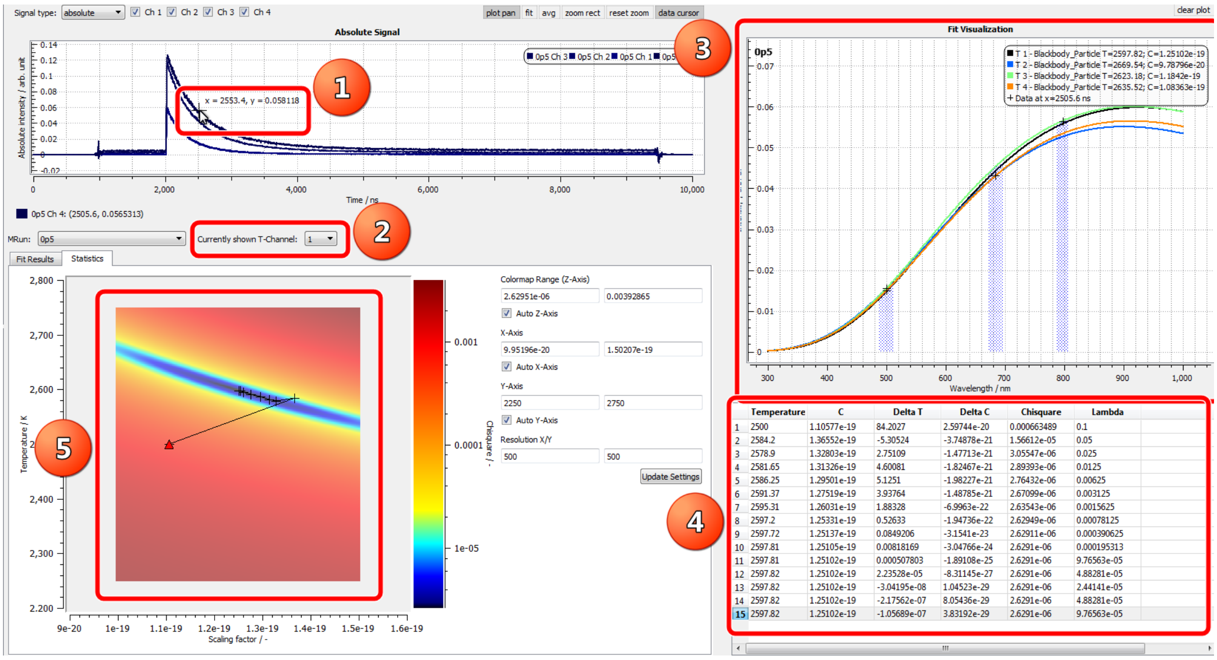
(1) Select now in the top left plot a data point you want to analyze. The temperature trace selected in **(2)** is then visualized.

(3) Compares the selected spectral fit to other available "Spectrum" temperature fits.

(4) Shows the spectral fitting iterations for the selected data point and **(4)** the chi-square map of the two parameters used during fitting (Temperature and Scaling factor).

The crosses and lines in **(5)** indicate the iterations of the fitting procedure and the red triangle the initial conditions.

- Click on the map **(5)** to show the spectral fit in **(3)**.
- Click on any iteration in **(4)** to show the corresponding spectral fit in **(3)**



Colormap Range (Z-Axis)
2.62951e-06 0.00392865
☑ Auto Z-Axis

X-Axis
9.95196e-20 1.50207e-19
☑ Auto X-Axis

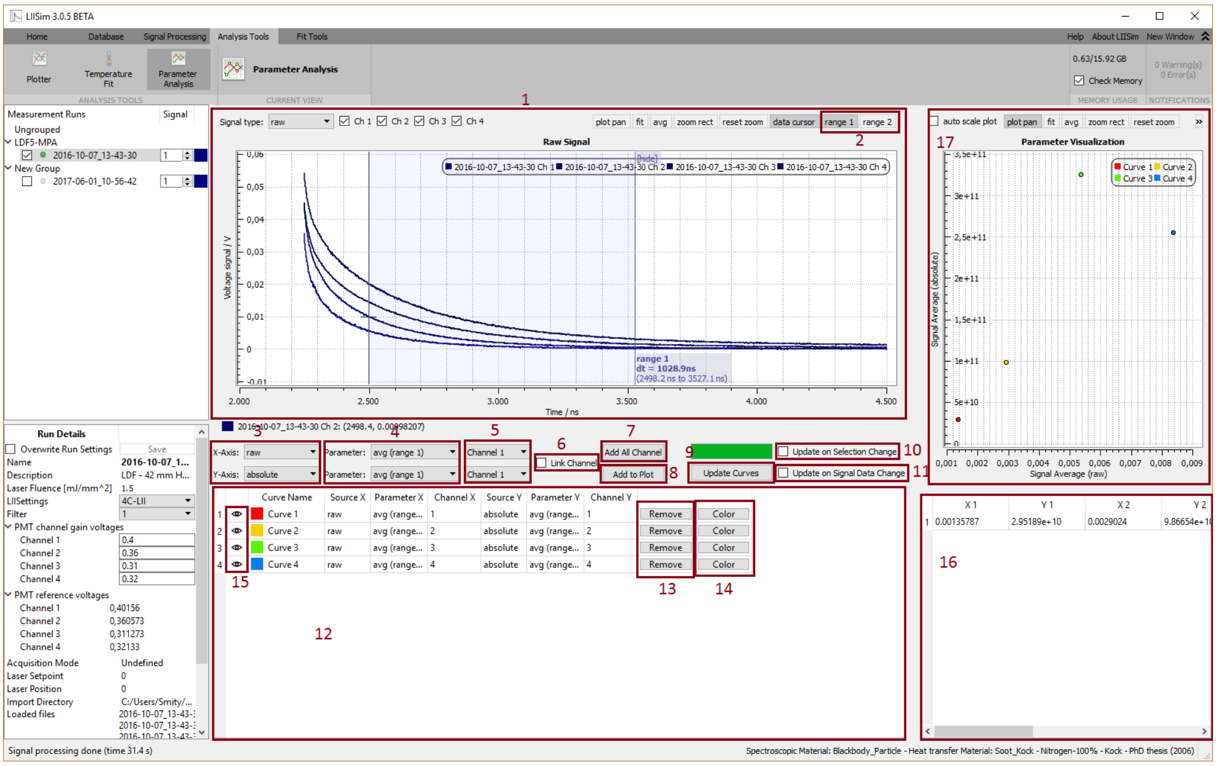
Y-Axis
2250 2750
☑ Auto Y-Axis

Resolution X/Y
500 500

	Temperature	C	Delta T	Delta C	Chisquare	Lambda
1	2500	1.10577e-19	84.2027	2.59744e-20	0.000663489	0.1
2	2584.2	1.36552e-19	-5.30524	-3.74878e-21	1.56612e-05	0.05
3	2578.9	1.32803e-19	2.75109	-1.47713e-21	3.05547e-06	0.025
4	2581.65	1.31326e-19	4.60081	-1.82467e-21	2.89393e-06	0.0125
5	2586.25	1.29501e-19	5.1251	-1.98227e-21	2.76432e-06	0.00625
6	2591.37	1.27519e-19	3.93764	-1.48785e-21	2.67099e-06	0.003125
7	2595.31	1.26031e-19	1.88328	-6.9963e-22	2.63543e-06	0.0015625
8	2597.2	1.25331e-19	0.52633	-1.94736e-22	2.62949e-06	0.00078125
9	2597.72	1.25137e-19	0.0849206	-3.1541e-23	2.62911e-06	0.000390625
10	2597.81	1.25105e-19	0.00818169	-3.04766e-24	2.6291e-06	0.000195313
11	2597.81	1.25102e-19	0.000507803	-1.89108e-25	2.6291e-06	9.76563e-05
12	2597.82	1.25102e-19	2.23528e-05	-8.31145e-27	2.6291e-06	4.88281e-05
13	2597.82	1.25102e-19	-3.04195e-08	1.04523e-29	2.6291e-06	2.44141e-05
14	2597.82	1.25102e-19	-2.17562e-07	8.05436e-29	2.6291e-06	4.88281e-05
15	2597.82	1.25102e-19	-1.05689e-07	3.83192e-29	2.6291e-06	9.76563e-05

8.6.3 Parameter Analysis

The parameter analysis tool let you oppose different parameters (laser fluence, user-defined parameters, averaged signal range, …) against each other to analyze any correlations between measurement runs.



Run Details	Save
□ Overwrite Run Settings	
Name	2016-10-07_1...
Description	LDF - 42 mm H...
Laser Fluence [mJ/mm^2]	1.5
LIISettings	4C-LII
Filter	1
PMT channel gain voltages	
Channel 1	0.4
Channel 2	0.36
Channel 3	0.31
Channel 4	0.32
PMT reference voltages	
Channel 1	0,40156
Channel 2	0,360573
Channel 3	0,311273
Channel 4	0,32133
Acquisition Mode	Undefined
Laser Setpoint	0
Laser Position	0
Import Directory	C:/Users/Smity/...
Loaded files	2016-10-07_13-43- 2016-10-07_13-43- 2016-10-07_13-43-

X-Axis: raw
Y-Axis: absolute
Parameter: avg (range 1)
Parameter: avg (range 1)
Channel 1
Channel 1
□ Link Channel
Add All Channel
Add to Plot
Update Curves
□ Update on Selection Change
□ Update on Signal Data Change

		Curve Name	Source X	Parameter X	Channel X	Source Y	Parameter Y	Channel Y		
1	👁	🟥 Curve 1	raw	avg (range...	1	absolute	avg (range...	1	Remove	Color
2	👁	🟨 Curve 2	raw	avg (range...	2	absolute	avg (range...	2	Remove	Color
3	👁	🟩 Curve 3	raw	avg (range...	3	absolute	avg (range...	3	Remove	Color
4	👁	🟦 Curve 4	raw	avg (range...	4	absolute	avg (range...	4	Remove	Color

	X 1	Y 1	X 2	Y 2
1	0.00135787	2.95189e+10	0.0029024	9.86654e+1

Signal processing done (time 31.4 s)

Spectroscopic Material: Blackbody_Particle - Heat transfer Material: Soot_Kock - Nitrogen-100% - Kock - PhD thesis (2006)

General:

(1) **Plotter**

See section 7.6.1 for the plotter window.

(16) **Result data table**

Displays the currently shown data point/curves as values. Values can be copied with CTRL-C or right-click and ‘copy’.

(17) **Result graph**

Shows the data points/curves as graphs.

How to use this tool:

- Select, which type of signal you would like to oppose with the dropdown menu at **(3)**.
- Choose the parameter **(4)** you like to compare.
- If needed for the chosen parameter, select a channel **(5)**. If X and Y-axis of the same channel should be compared, channels can be linked **(6).**
- For parameter “avg” or “integral” a range for calculation can be selected **(2).**
- Press **(8)** to add a data point/curve with the selected parameters or press **(7)** to add all possible one-to-one channel combinations.
- **(9)** lets you manually update the curves, useful to prevent unnecessary recalculation.

- **(10)** and **(11)** enable automatic updates when the run selection or the data itself is changed.
- The table at **(12)** shows all added curves. There you can:
    - Toggle the visibility of a curve with **(15)**
    - Change the color of a curve with **(13)**
    - Remove a curve with **(14)**

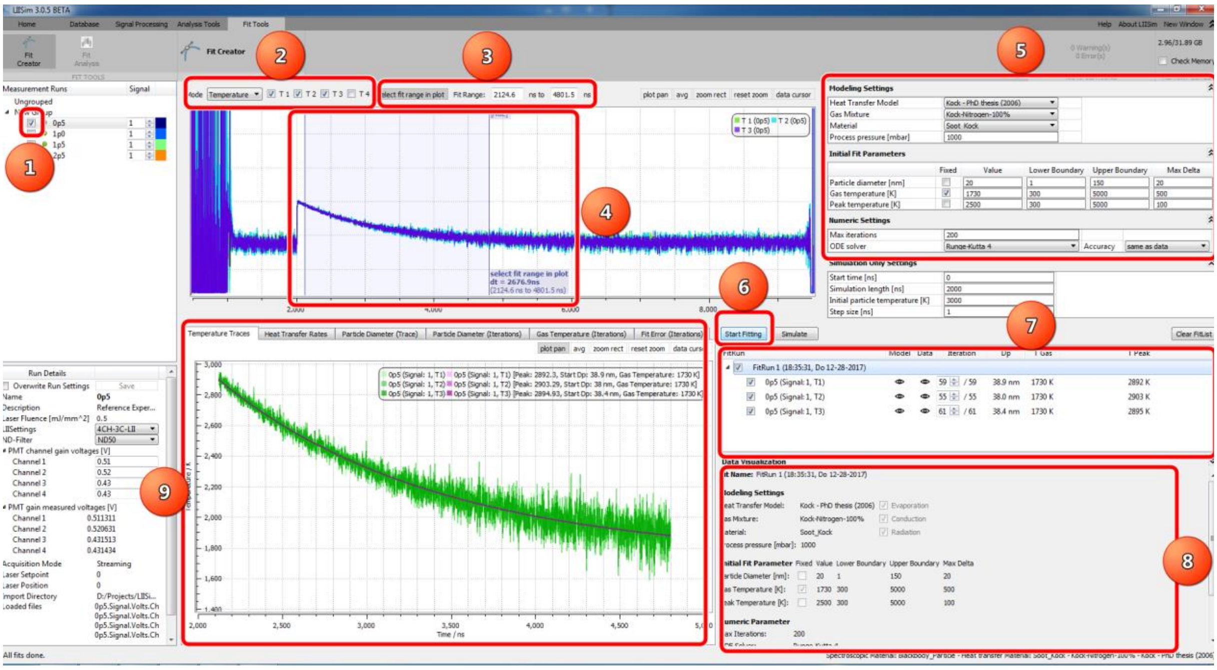
8.7 Fit Tools

The previously calculated temperature traces can be used for comparison with modeled temperature traces using various heat-transfer models and databases.

First, you need to select at least one measurement run **(1)** and the temperature traces to be used for the fitting **(2).**

The temperature traces should now appear in the plot and you can select a range using the button **(3)** and then select the range in the plot **(4)** or you can enter the range manually.

After adjusting the settings **(5)** for the fitting you can press “Start Fitting” **(6)** to perform a fit on all selected measurement runs and temperature traces.



Mode: Temperature ☑ T 1 ☑ T 2 ☑ T 3 □ T 4

Fit Range: 2124.6 ns to 4801.5 ns

Modeling Settings

Heat Transfer Model	Kock - PhD thesis (2006)
Gas Mixture	Kock-Nitrogen-100%
Material	Soot_Kock
Process pressure [mbar]	1000

Initial Fit Parameters

	Fixed	Value	Lower Boundary	Upper Boundary	Max Delta
Particle diameter [nm]	□	20	1	150	20
Gas temperature [K]	☑	1730	300	5000	500
Peak temperature [K]	□	2500	300	5000	100

Numeric Settings

Max iterations	200		
ODE solver	Runge-Kutta 4	Accuracy	same as data

Simulation Only Settings

Start time [ns]	0
Simulation length [ns]	2000
Initial particle temperature [K]	3000
Step size [ns]	1

FitRun	Model	Data	Iteration	Dp	T Gas	T Peak
☑ FitRun 1 (18:35:31, Do 12-28-2017)						
☑ 0p5 (Signal: 1, T1)			59 / 59	38.9 nm	1730 K	2892 K
☑ 0p5 (Signal: 1, T2)			55 / 55	38.0 nm	1730 K	2903 K
☑ 0p5 (Signal: 1, T3)			61 / 61	38.4 nm	1730 K	2895 K

Fit Name: FitRun 1 (18:35:31, Do 12-28-2017)

Modeling Settings
Heat Transfer Model: Kock - PhD thesis (2006) ☑ Evaporation
Gas Mixture: Kock-Nitrogen-100% ☑ Conduction
Material: Soot_Kock ☑ Radiation
Process pressure [mbar]: 1000

Initial Fit Parameter	Fixed	Value	Lower Boundary	Upper Boundary	Max Delta
Particle Diameter [nm]:	□	20	1	150	20
Gas Temperature [K]:	☑	1730	300	5000	500
Peak Temperature [K]:	□	2500	300	5000	100

Numeric Parameter
Max Iterations: 200

Run Details

□ Overwrite Run Settings

Name	0p5
Description	Reference Exper...
Laser Fluence [mJ/mm^2]	0.5
LIISettings	4CH-3C-LII
ND-Filter	ND50
PMT channel gain voltages [V]	
Channel 1	0.51
Channel 2	0.52
Channel 3	0.43
Channel 4	0.43
PMT gain measured voltages [V]	
Channel 1	0.511311
Channel 2	0.520631
Channel 3	0.431513
Channel 4	0.431434
Acquisition Mode	Streaming
Laser Setpoint	0
Laser Position	0
Import Directory	D:/Projects/LIISi...
Loaded files	0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch 0p5.Signal.Volts.Ch

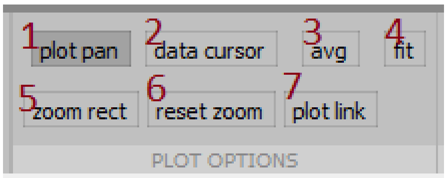
All fits done.

The result from this fitting is called a “FitRun” which is listed in the FitRun-List **(7).** You can select the temperature traces and look at the detailed information in **(8)** or at various plot tools in **(9).**

8.8 General tools

The following tools are available in multiple modules of LIISim.

8.8.1 Plot controls



(1) **Plot pan**

Select to pan the plot with the left mouse button pressed. The mouse wheel can be used to zoom in and out. If you press CTRL while using the mouse wheel, you can zoom the x-axis only. If you press SHIFT, you zoom the y-axis only.

(2) **Data cursor**

Enables the selection of a single data point in a displayed curve. The cursor can be move with the left/right button.

(3) **Average Plot Tool**

Enables a range selection and calculates the average over the selected signal range.

(4) **Fit Plot Tool**

Fits a simple exponential function to the curve (experimental!)

(5) **Zoom**

Enables a rectangular zoom.

(6) **Reset zoom**

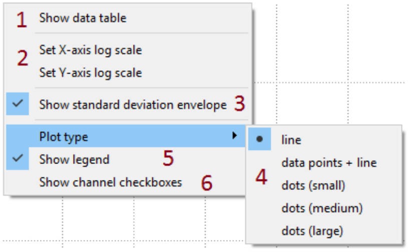
Resets the zoom so all curves are completely visible.

(7) **Plot link**

Links the plots, so any zoom or horizontal pan is applied to all plots.

8.8.2 Plot context menu

Right click on plot opens context menu. The following options are available from there:



(1) **Show data table**

Opens a data table which contains the currently displayed curve data.

(2) **Set X-axis log scale / Set Y-axis log scale**

Enables a logarithmic scaling of the x- and y-axis.

(3) **Show standard deviation envelope**

If standard deviation is available (calculated by 7.1.7 Multi Signal Average) envelope function from the standard deviation data can be toggled.

(4) **Plot type**

Shows different curve representation types and let them be changed.

(5) **Show legend**

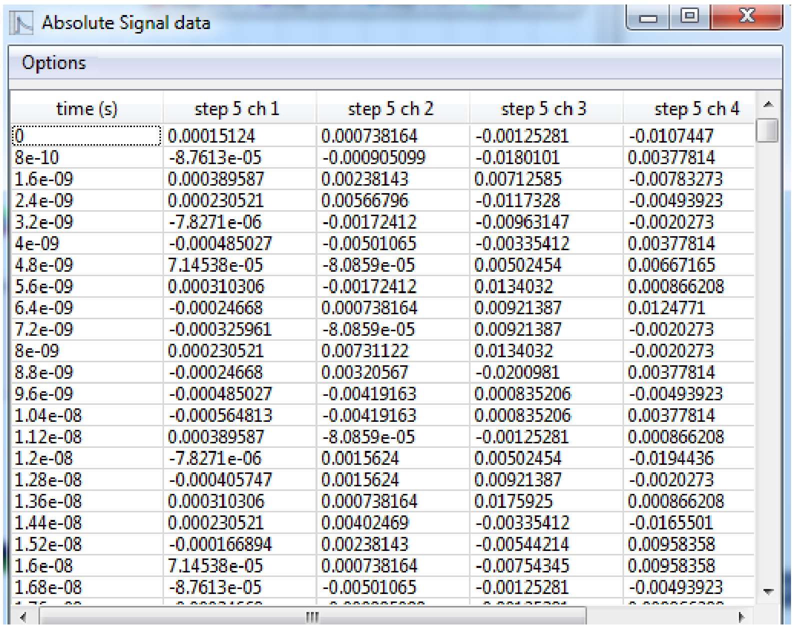
Toggles the visibility of the plot legend.

(6) **Show channel checkboxes**

Displays channel checkboxes below the plot for toggling visibility.

8.8.3 Plot data table

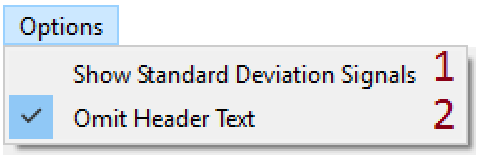
Opens via the plot context menu. Multiple values in the table can be selected with the mouse and copied either with CTRL-C or right-click and 'copy' and pasted into another spreadsheet software.



time (s)	step 5 ch 1	step 5 ch 2	step 5 ch 3	step 5 ch 4
0	0.00015124	0.000738164	-0.00125281	-0.0107447
8e-10	-8.7613e-05	-0.000905099	-0.0180101	0.00377814
1.6e-09	0.000389587	0.00238143	0.00712585	-0.00783273
2.4e-09	0.000230521	0.00566796	-0.0117328	-0.00493923
3.2e-09	-7.8271e-06	-0.00172412	-0.00963147	-0.0020273
4e-09	-0.000485027	-0.00501065	-0.00335412	0.00377814
4.8e-09	7.14538e-05	-8.0859e-05	0.00502454	0.00667165
5.6e-09	0.000310306	-0.00172412	0.0134032	0.000866208
6.4e-09	-0.00024668	0.000738164	0.00921387	0.0124771
7.2e-09	-0.000325961	-8.0859e-05	0.00921387	-0.0020273
8e-09	0.000230521	0.00731122	0.0134032	-0.0020273
8.8e-09	-0.00024668	0.00320567	-0.0200981	0.00377814
9.6e-09	-0.000485027	-0.00419163	0.000835206	-0.00493923
1.04e-08	-0.000564813	-0.00419163	0.000835206	0.00377814
1.12e-08	0.000389587	-8.0859e-05	-0.00125281	0.000866208
1.2e-08	-7.8271e-06	0.0015624	0.00502454	-0.0194436
1.28e-08	-0.000405747	0.0015624	0.00921387	-0.0020273
1.36e-08	0.000310306	0.000738164	0.0175925	0.000866208
1.44e-08	0.000230521	0.00402469	-0.00335412	-0.0165501
1.52e-08	-0.000166894	0.00238143	-0.00544214	0.00958358
1.6e-08	7.14538e-05	0.000738164	-0.00754345	0.00958358
1.68e-08	-8.7613e-05	-0.00501065	-0.00125281	-0.00493923

Figure 8-4 Plot data table

Plot data table options



(1) **Show Standard Deviation Signals**

Toggles the standard deviation signal data in the table

(2) **Omit Header Text**

If enabled, omits the header label text from the copied values

9 Troubleshooting

9.1 MSVCR120.dll was not found

If you see an error like “MSVCR120.dll was not found” please try to download and install the Visual C++ Redistributable Packages from the Microsoft website. It should fix the issue: https://www.microsoft.com/en-us/download/details.aspx?id=40784

10 Frequently Asked Questions

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