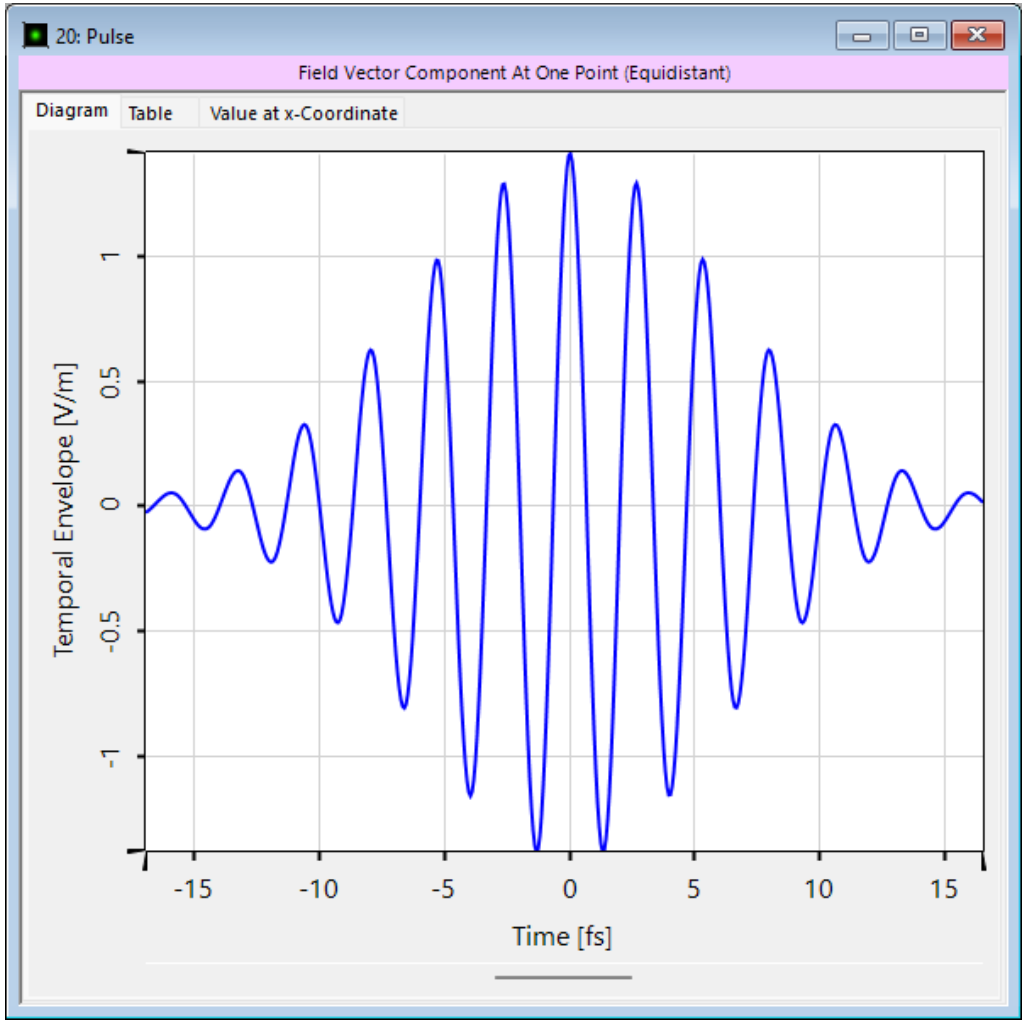
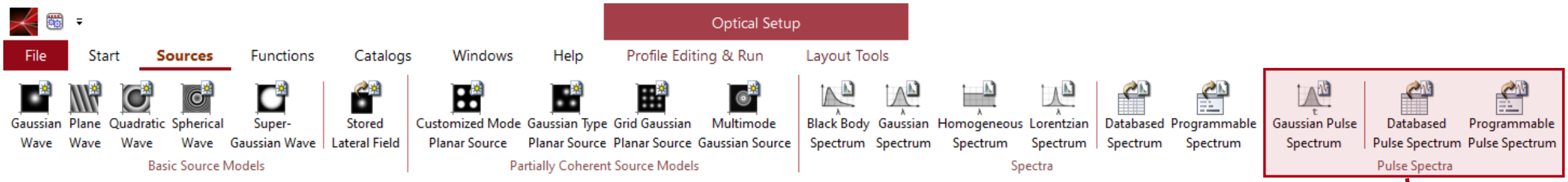
How to Configure Ultrashort Pulse Simulations in VirtualLab Fusion: A Step-by-Step Guide

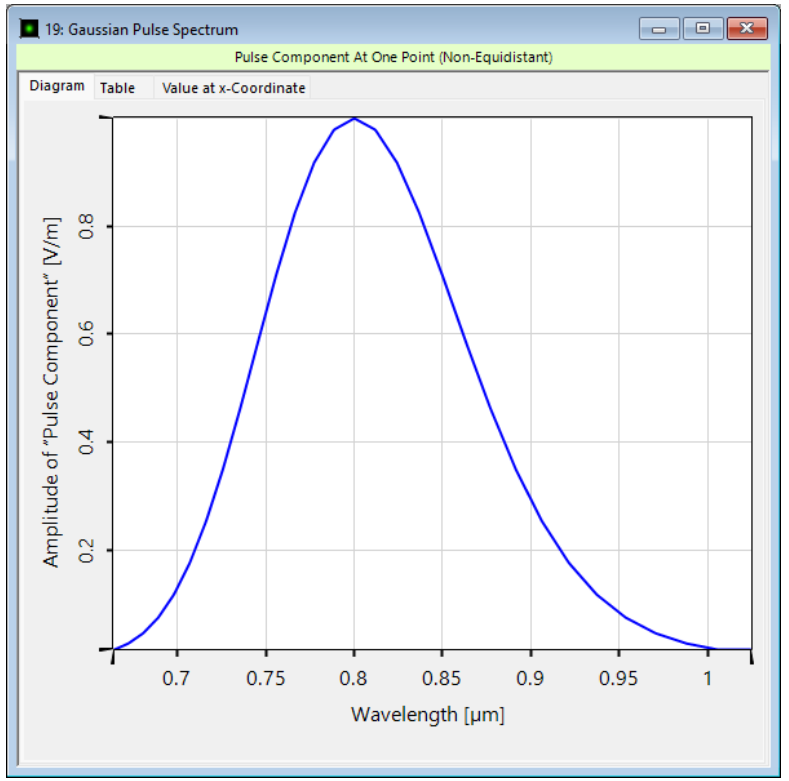
Abstract



This tutorial presents a workflow for specifying, modeling, and detecting ultrashort pulses within VirtualLab Fusion. It covers the generation of pulse spectra, their integration into light sources, and explores two distinct strategies for ultrashort pulse modeling.

Specification of a Pulse Spectrum

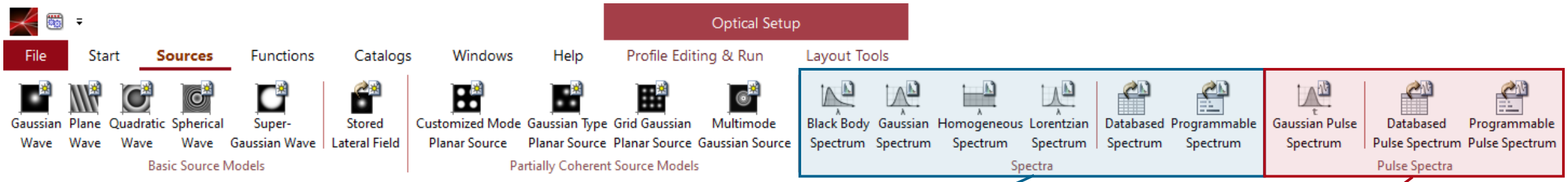




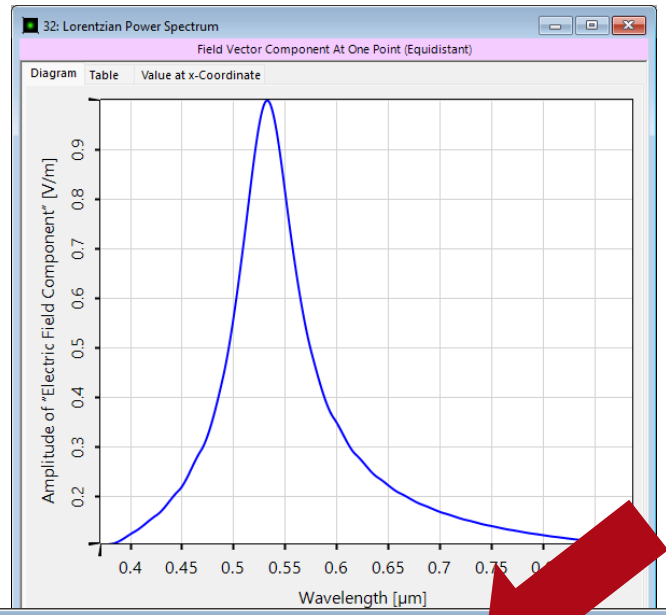
Pulse Spectra usable for ultrashort pulse simulations can be specified under Sources/Pulse Spectra. The current options are:

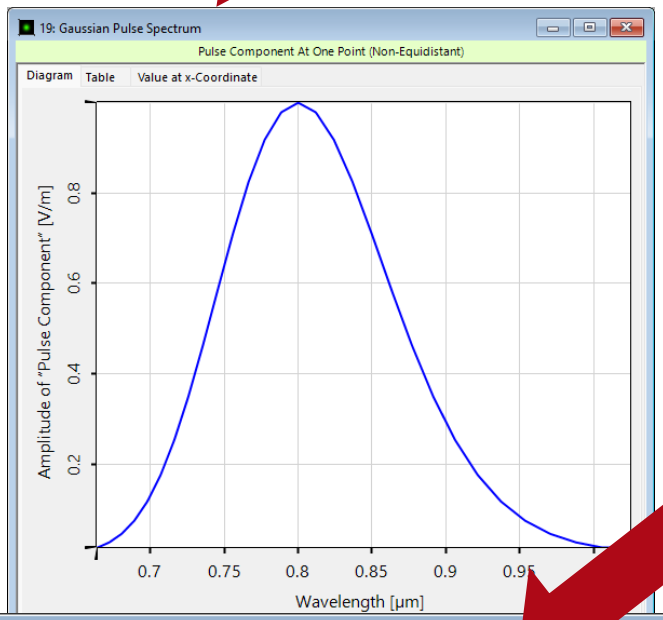
- Gaussian Pulse Spectrum
- Databased Pulse Spectrum
- Programmable Pulse Spectrum

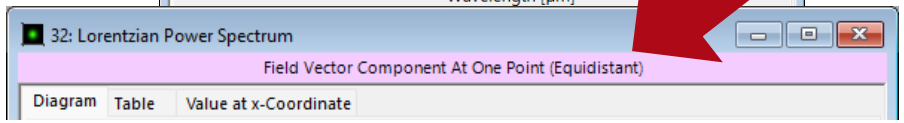
Difference between Spectrum and Pulse Spectrum

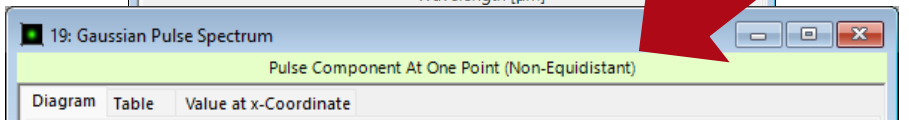


VirtualLab Fusion distinguishes between two types of spectra: **normal spectra**, sampled equidistantly over wavelength, and **pulse spectra**, sampled equidistantly over time and frequency but non-equidistantly over wavelength. Pulse spectra are required for pulse simulations and can be identified by the caption “Pulse Component at …. (Non-Equidistant)”.

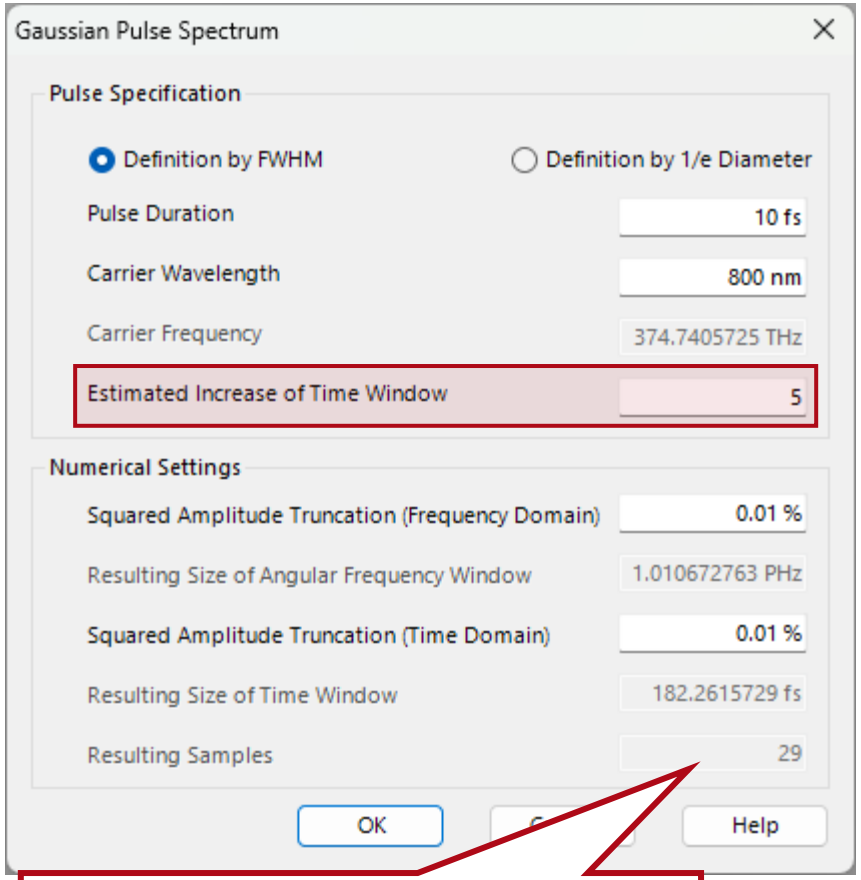






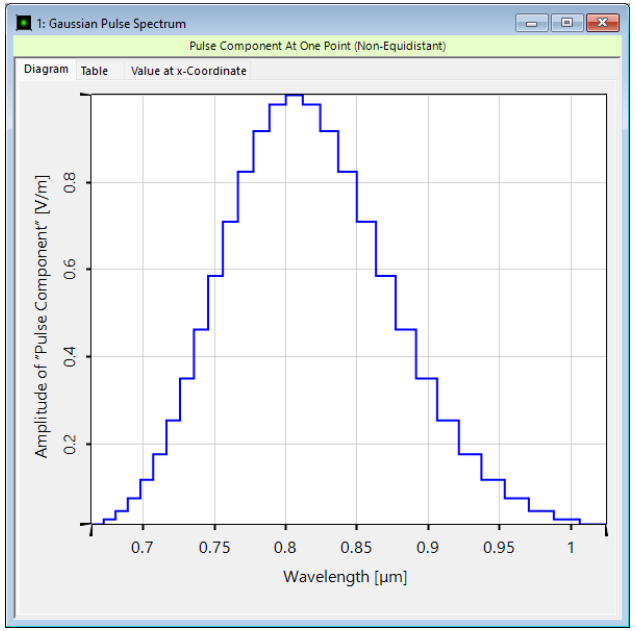


Definition of a Pulse Spectrum: Sampling Points

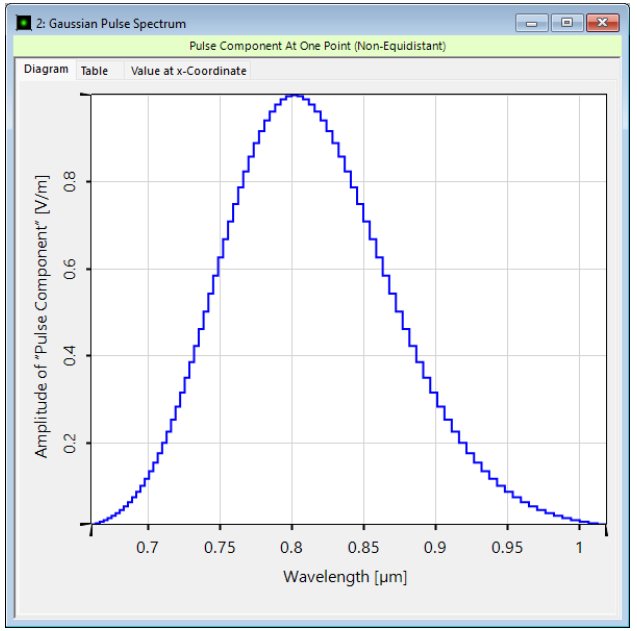


The number of resulting sampling points can be seen here.

The *Gaussian Pulse Spectrum* automatically generates the spectrum (in wavelength) of a pulse with a Gaussian-shaped temporal envelope based on its *Pulse Duration* and *Carrier Wavelength*. Additional numerical parameters, such as the *Estimated Increase of Time Window*, influence the spectral sampling rate, which is linked to the time-domain window size via the Fourier transform.

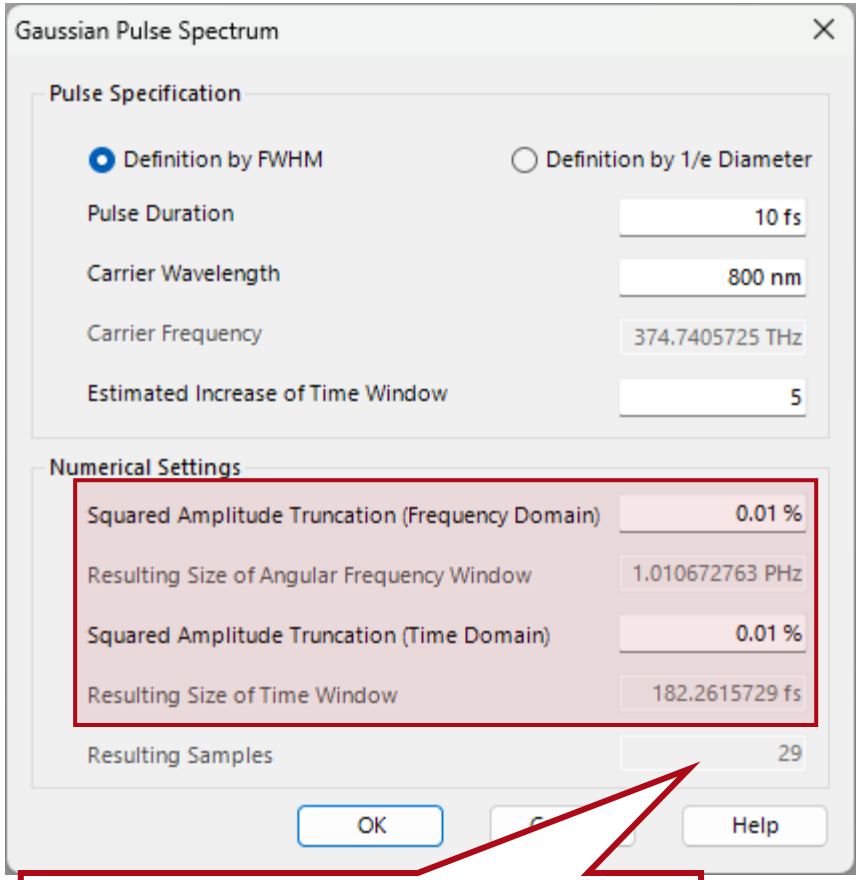


Estimated Increase of Time Window: 5



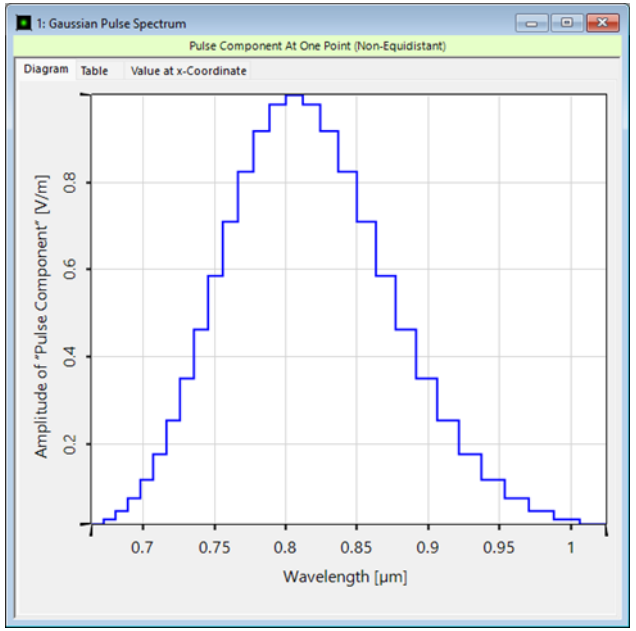
Estimated Increase of Time Window: 15

Definition of a Pulse Spectrum: Window Sizes

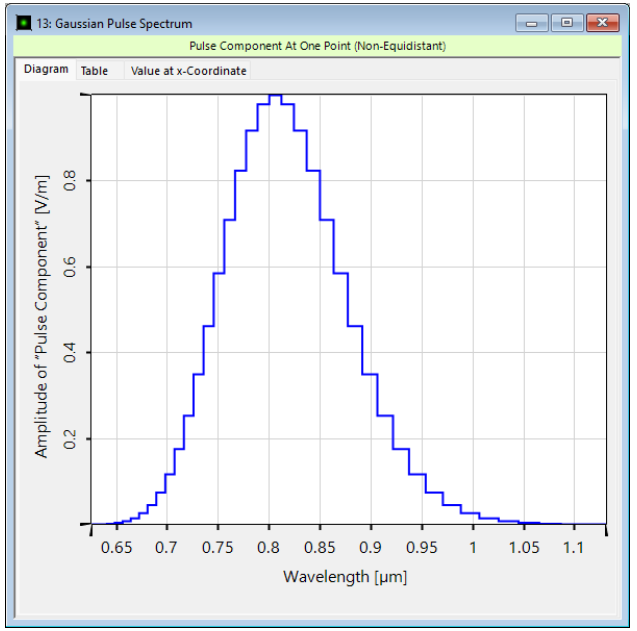


The number of resulting sampling points can be seen here.

By definition, a Gaussian extends into infinity. As this cannot be represented in the software, the function needs to be truncated. This determines the window sizes in spectral and time domain and hence also influences the sampling rate.

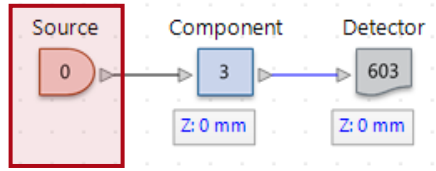


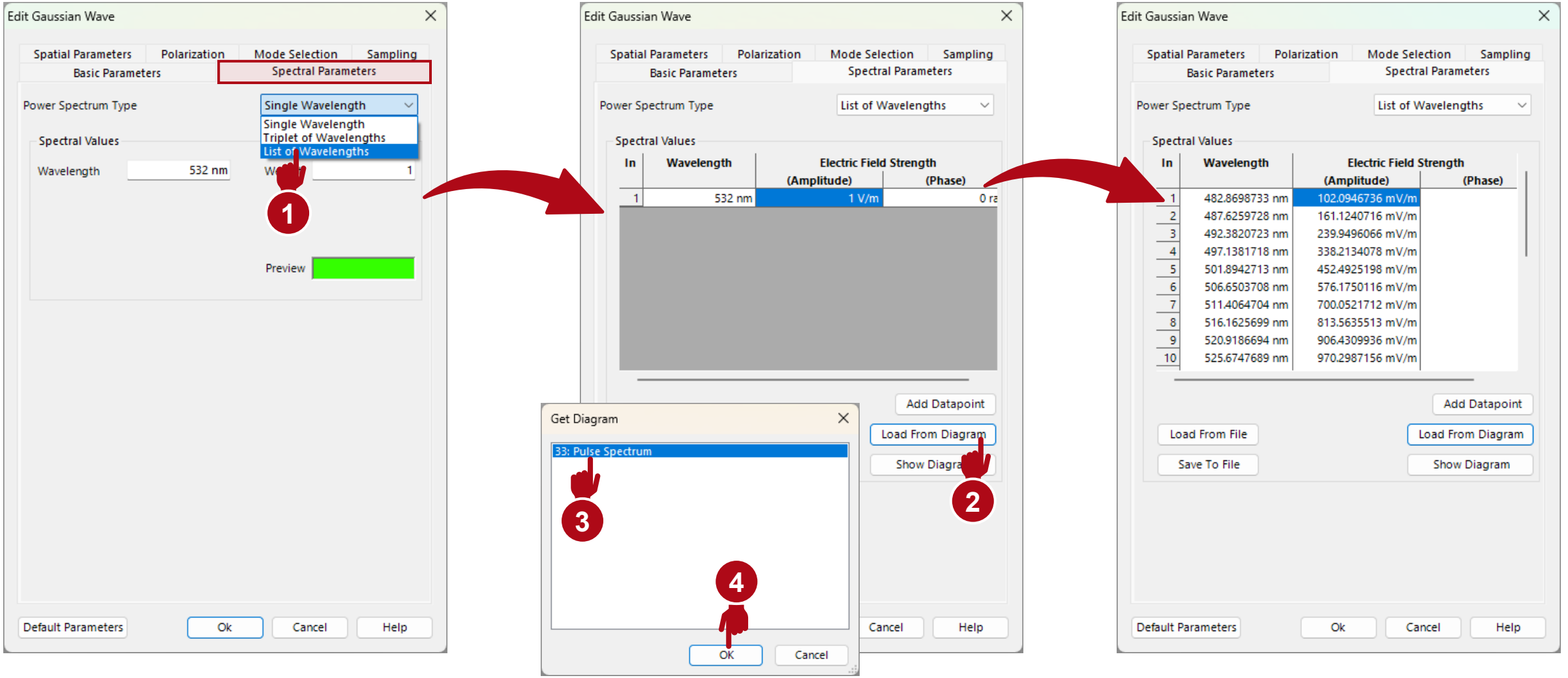
Squared Amplitude Truncation (Frequency Domain): 0.01%



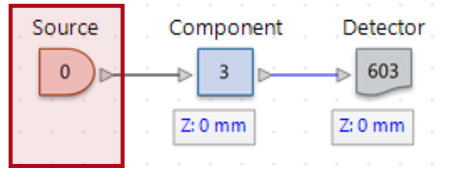
Squared Amplitude Truncation (Frequency Domain): 0.00001%

Include Pulse into Source





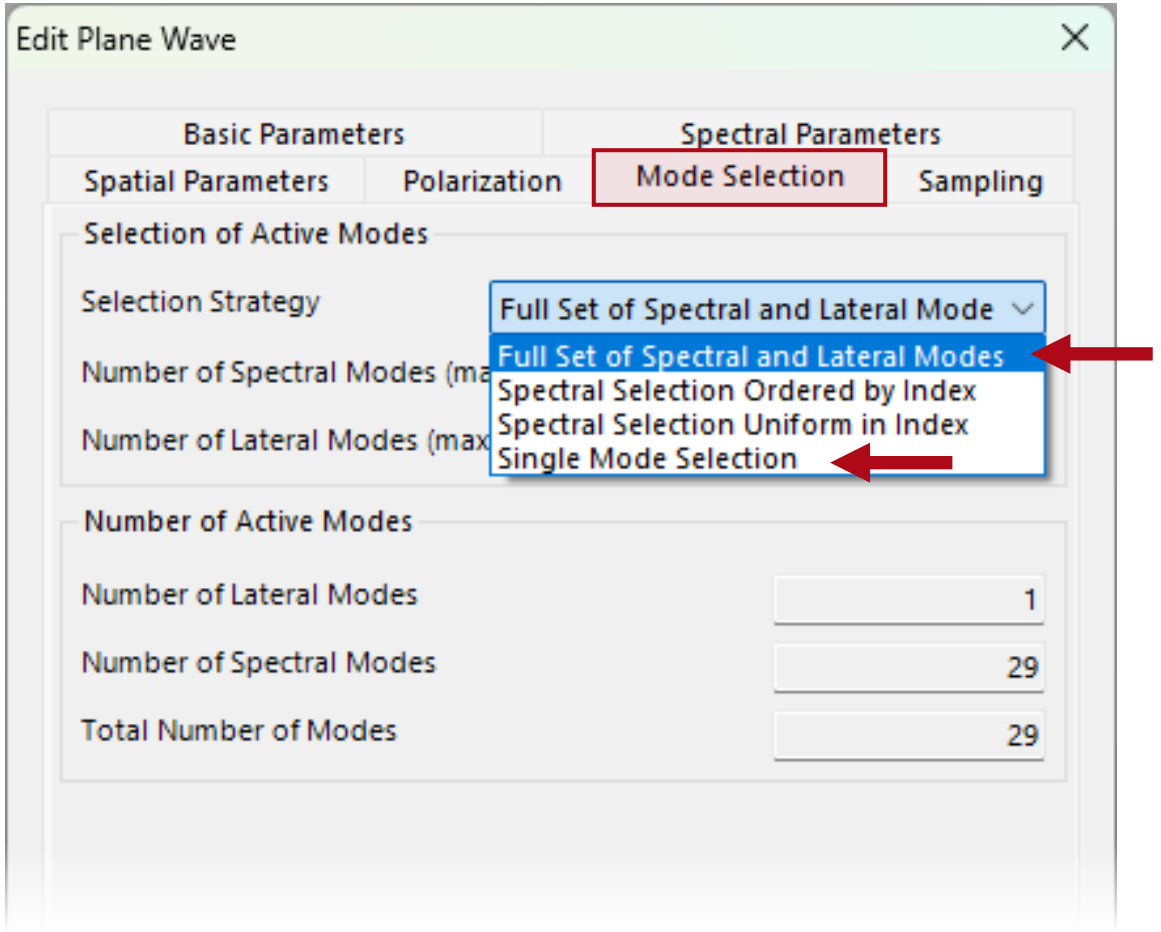
Determine Simulation Strategy



In VirtualLab Fusion, pulse systems can be simulated in two ways:

- **Strategy 1:**
  Full Set of Spectral and Lateral Modes
  A pre-configured mode where all wavelengths are simulated simultaneously. It offers an easy setup but less flexibility.

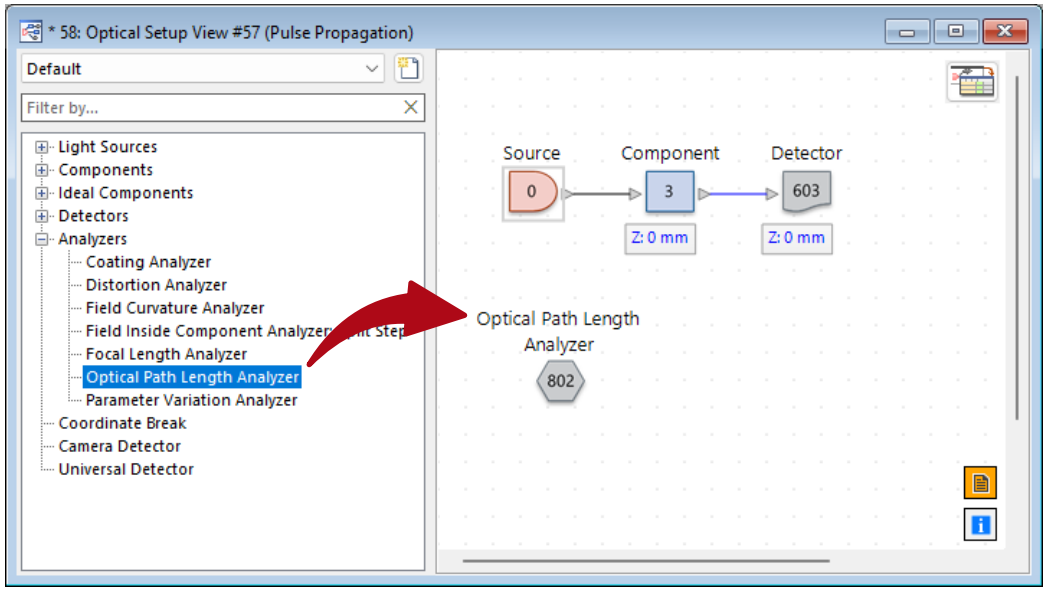
- **Strategy 2:**
  Single Mode Selection
  Used with a Parameter Run document to simulate wavelengths sequentially. Users can dynamically adjust the number of wavelengths, and this strategy supports distributed computing (DC).

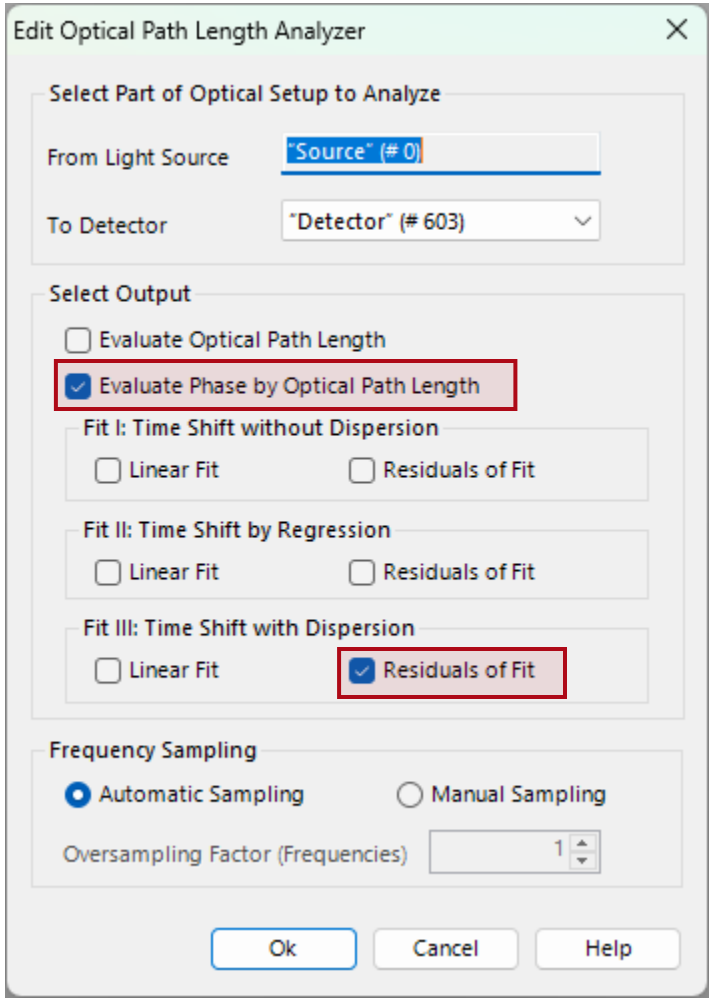


Note: Time Shift & Residuals

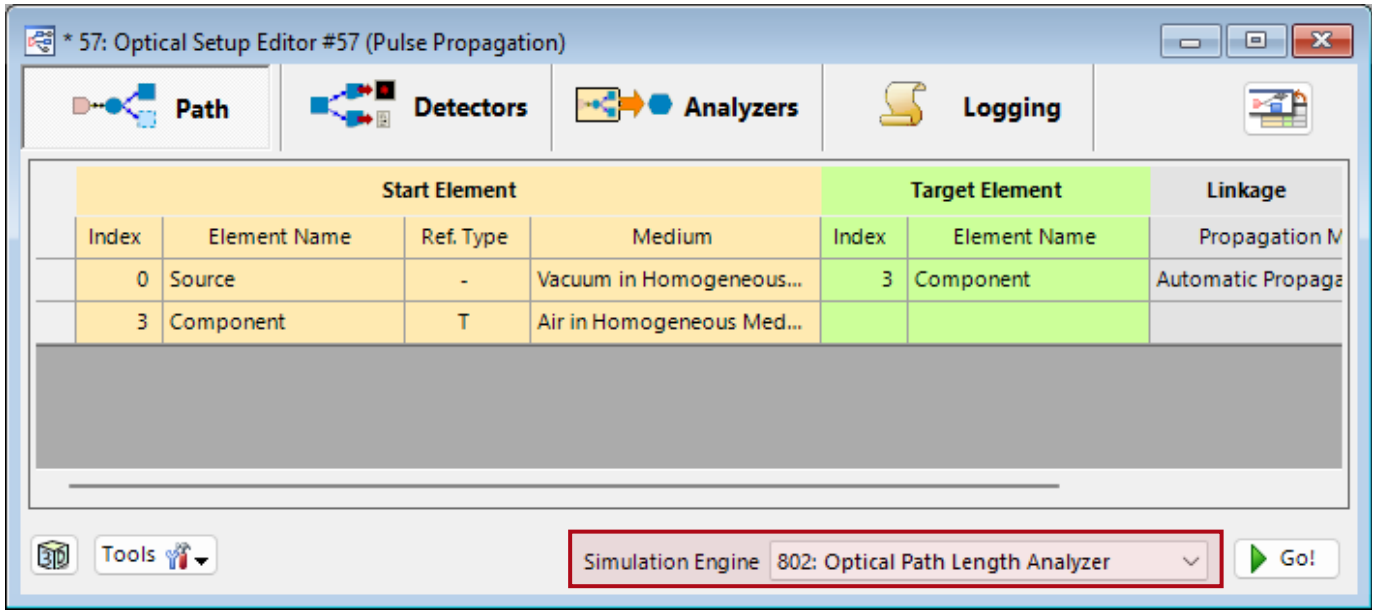
All time-domain pulse detector add-ons require Optical Path Length (OPL) information.

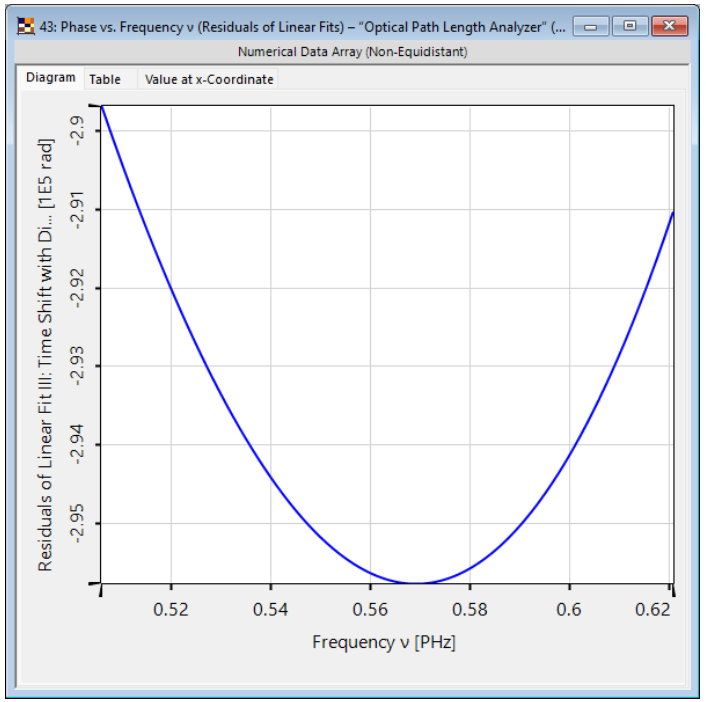
- **Strategy 1:** The detector add-ons automatically calculate the OPL – no further action is needed.
- **Strategy 2:** Users must manually compute the OPL. The **Optical Path Length Analyzer** simplifies this process. Enable *Evaluate Phase by Optical Path Length* and *Residuals of Fit* to calculate the necessary information (see next page).





Time Shift & Residuals

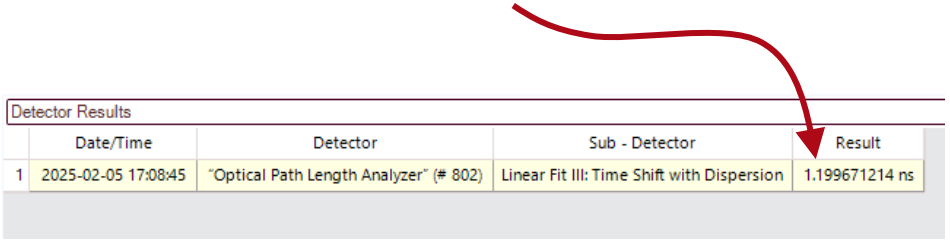




residuals

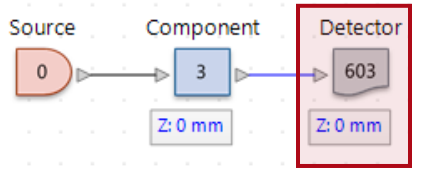
The *OPL Analyzer* outputs the required time shift information in the *Detector Results* panel. You can change the *Simulation Engine* to *Optical Path Length Analyzer* in the *Optical Setup Editor*.

time shift (including dispersion)



Note: For this analyzer to function, the source needs to be set to **Full Set of Spectral and Lateral Modes** back again**.**

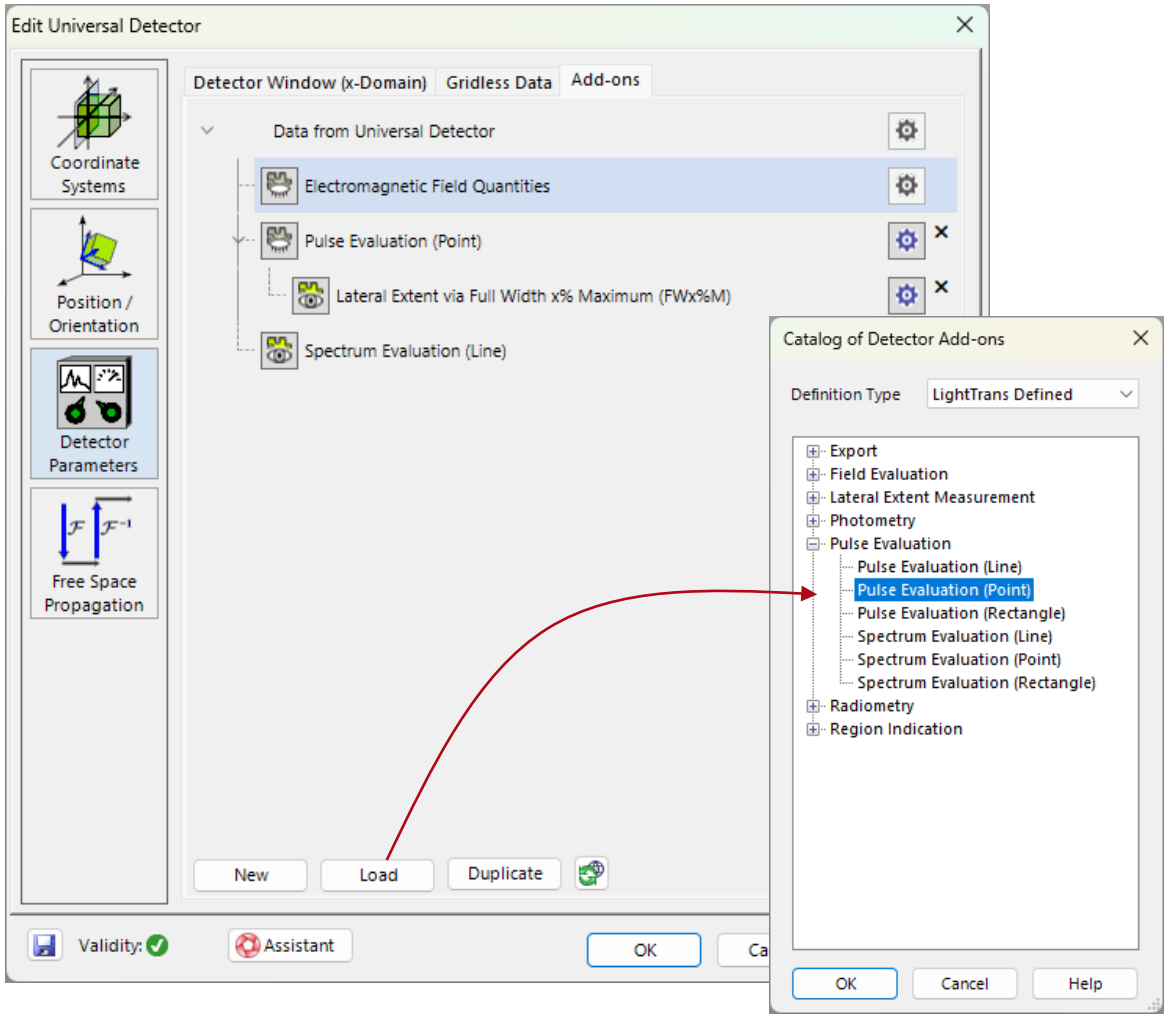
Strategy 1 – Simulate All Modes Together



When using *Full Set of Spectral and Lateral Modes* in the source, the *Universal Detector* can be set up with detector add-ons like in any other system. Afterwards, simply press the Go! - button and the rest is handled automatically.

While in theory all detector add-ons can be used, we also have an entire category for detector add-ons specialized on analyzing pulses. You can find them by clicking of the *Load* button. More information under: Universal Detector

We introduce new detector add-ons even between releases, so always press *Synchronize From Web* ( ) to stay up to date!

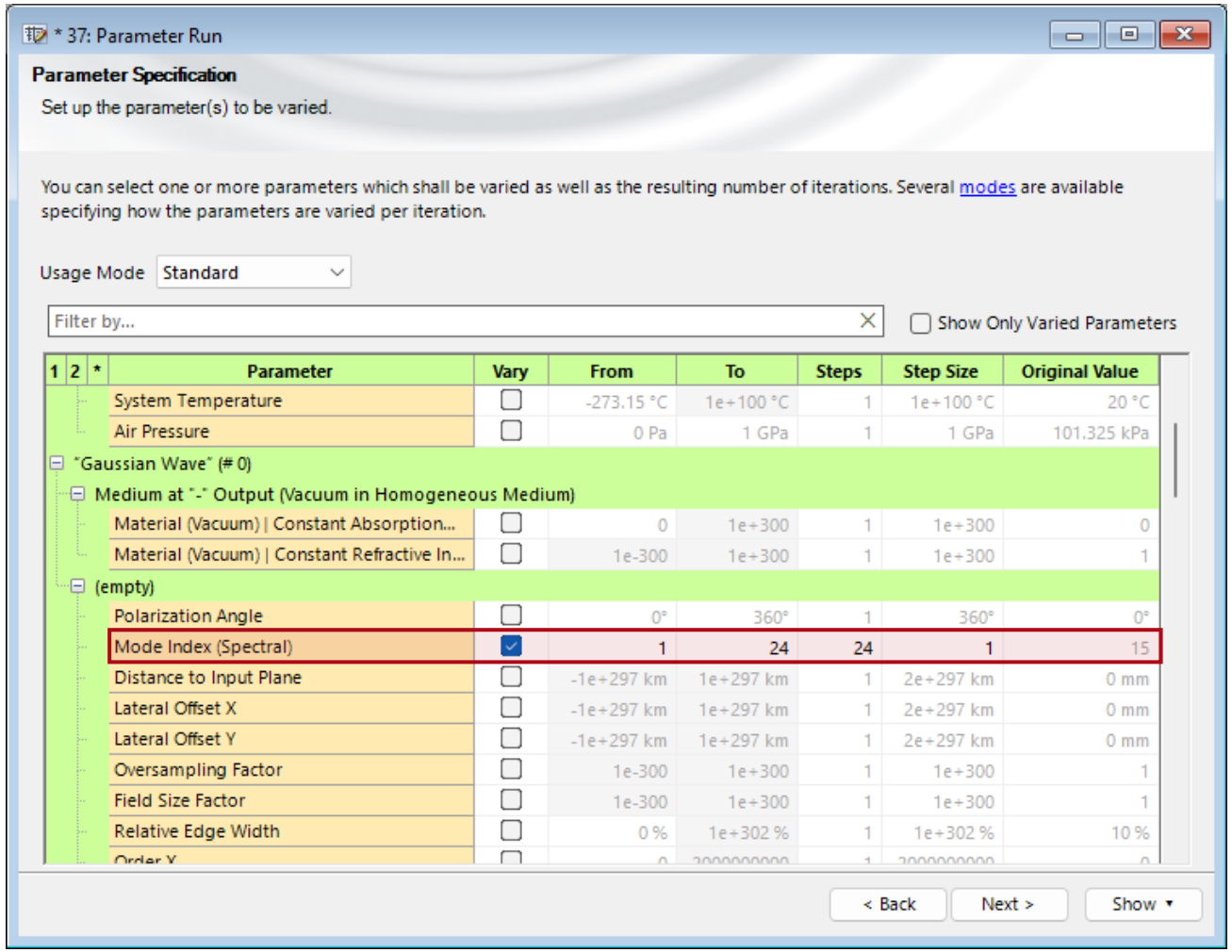


Strategy 2 – Set Up the Parameter Run

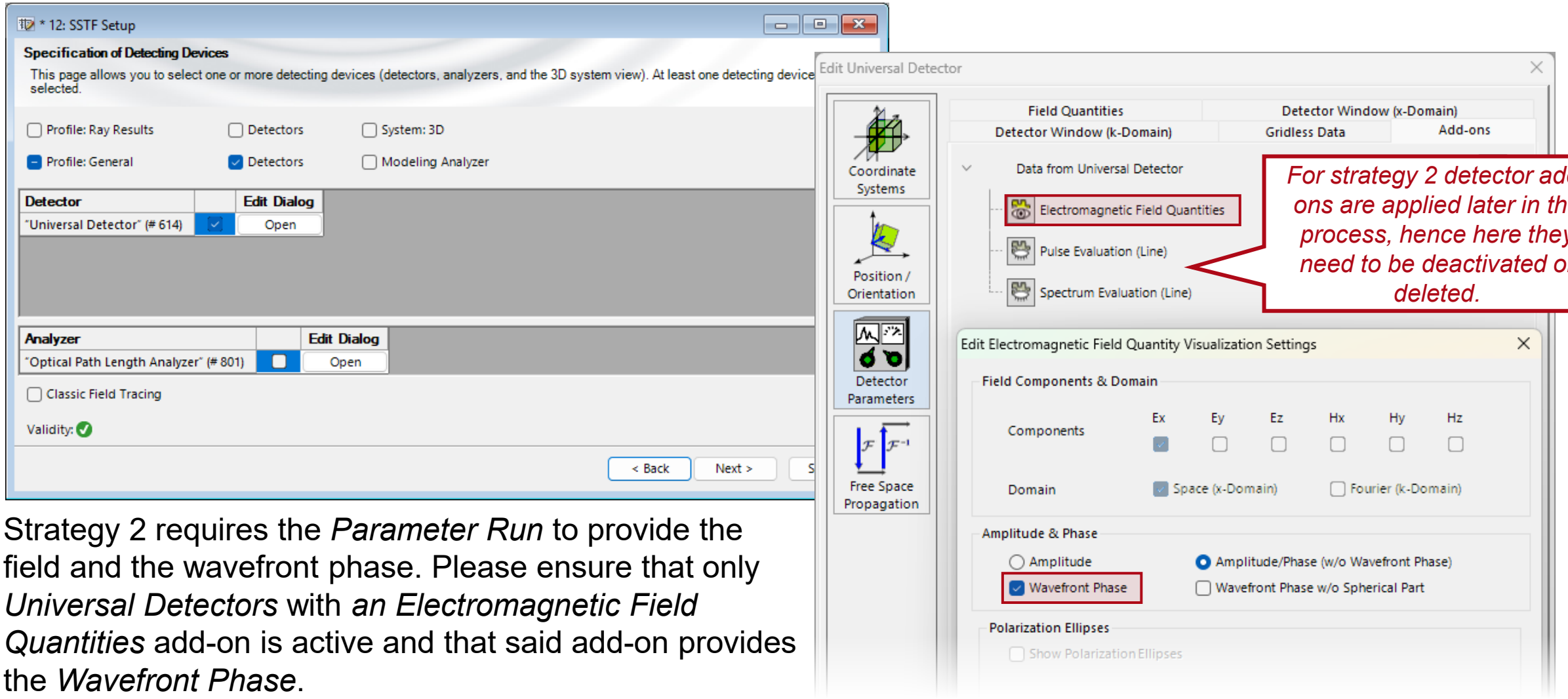
The *Single Mode Selection* can be combined with a *Parameter Run* to simulate each wavelengths individually. Select *Mode Index (Spectral)* as variable parameter.

If a simulation requires a high but unknown number of wavelengths (e.g. for accurate modeling of angular dispersion from a structure), the source can be defined with an excess of wavelengths and then be refined by simulating only a subset (e.g., every eighth, fourth, or second wavelength) until convergence is achieved using the *Step Size* column. Since the *Parameter Run* saves results, already simulated wavelengths will not be calculated twice.

This technique also supports **Distributed Computing** for enhanced performance. See: Usage of Distributed Computing



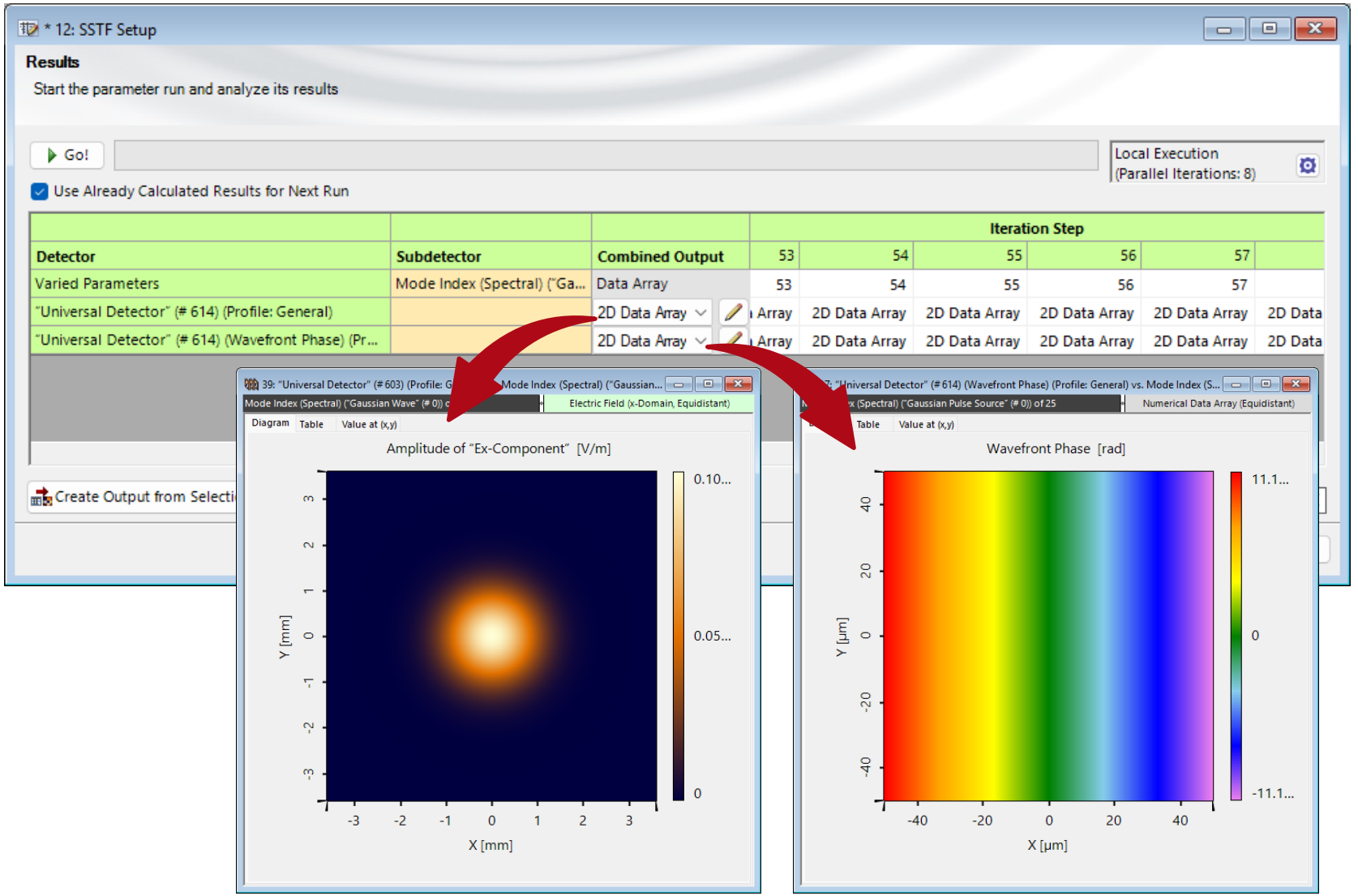
Strategy 2 – Wavefront Phase



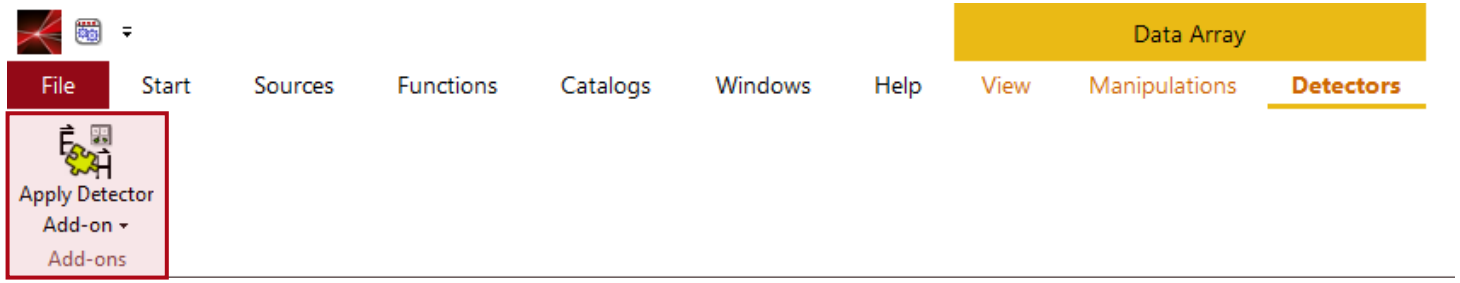
Strategy 2 requires the *Parameter Run* to provide the field and the wavefront phase. Please ensure that only *Universal Detectors* with *an Electromagnetic Field Quantities* add-on is active and that said add-on provides the *Wavefront Phase*.

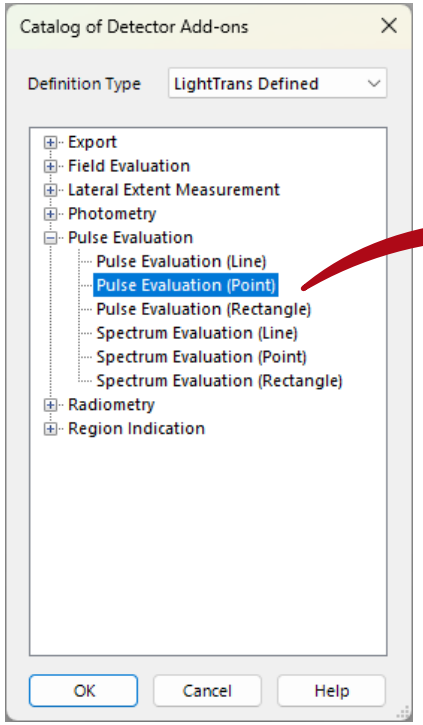
Strategy 2 – Extract Data from Parameter Run

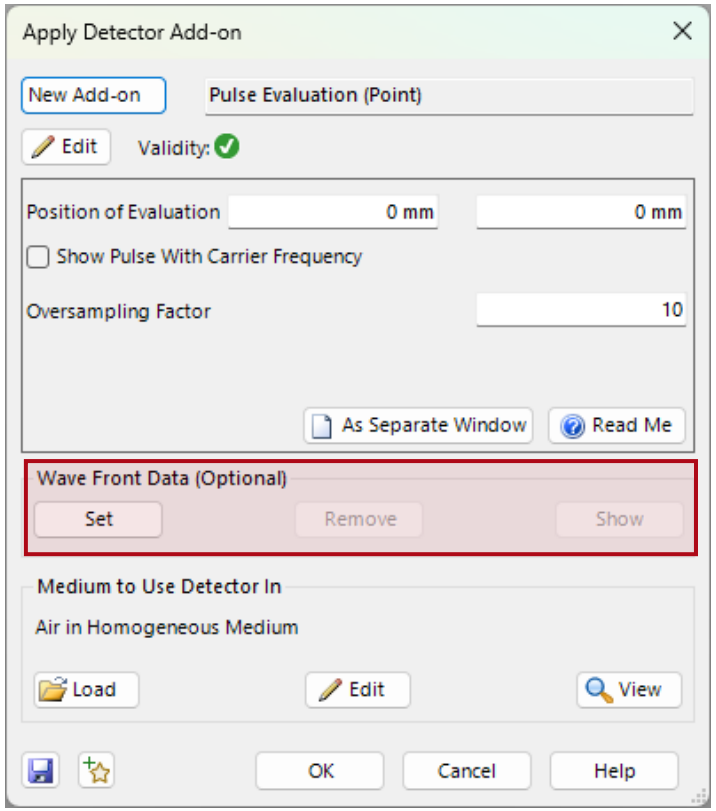
Change combined output to *2D Data Array/Set of Data Arrays* (or *1D Data Array /Set of Data Arrays* in case the detector is set up to detect 1D fields) and double-click the column you like to extract the field and wavefront phase.



Strategy 2 – Apply Detector Add-on in Main Window





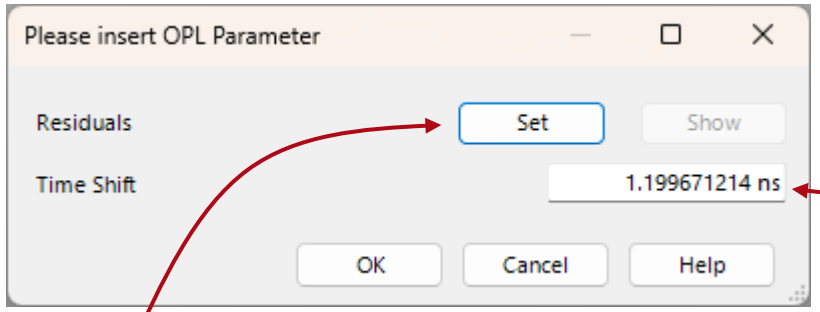


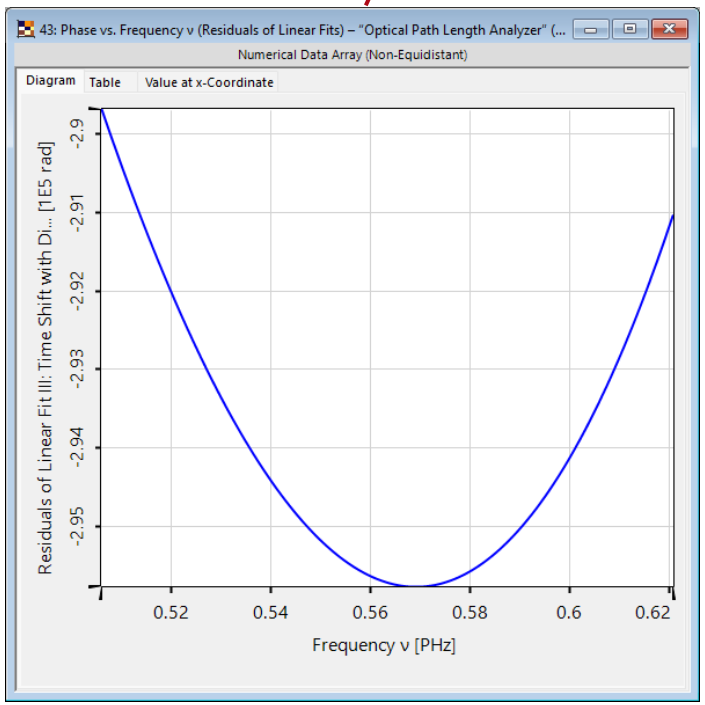
Detector add-ons are available under *Detectors/Apply Detector Add-on*. Add-ons specialized for ultrashort pulses can be found in the *Pulse Evaluation* section.

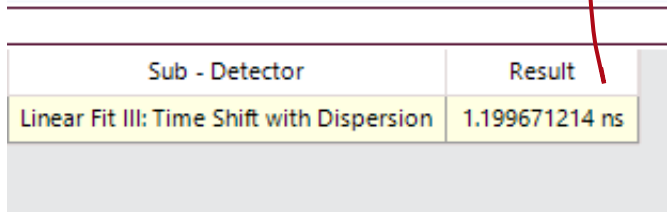
Here e.g., the *Pulse Evaluation (Point)* add-on is shown. While the parameters obviously depend on the add-on, they always have a section where the *Wave Front Data* can be included.

Strategy 2 – Include Time Shift & Residuals

A new window will pop up to include OPL information. Here, the already calculated time shift and residuals can be included.







Sub - Detector	Result
Linear Fit III: Time Shift with Dispersion	1.199671214 ns

Document Information

title	How to Configure Ultrashort Pulse Simulations in VirtualLab Fusion: A Step-by-Step Guide
document code	TUT.0438
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required packages	-
software version	2024.1 (Build 2.74)
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further reading	- Grating Stretcher for Ultrashort Pulses - Pulse Focusing with High-NA Lens - Universal Detector