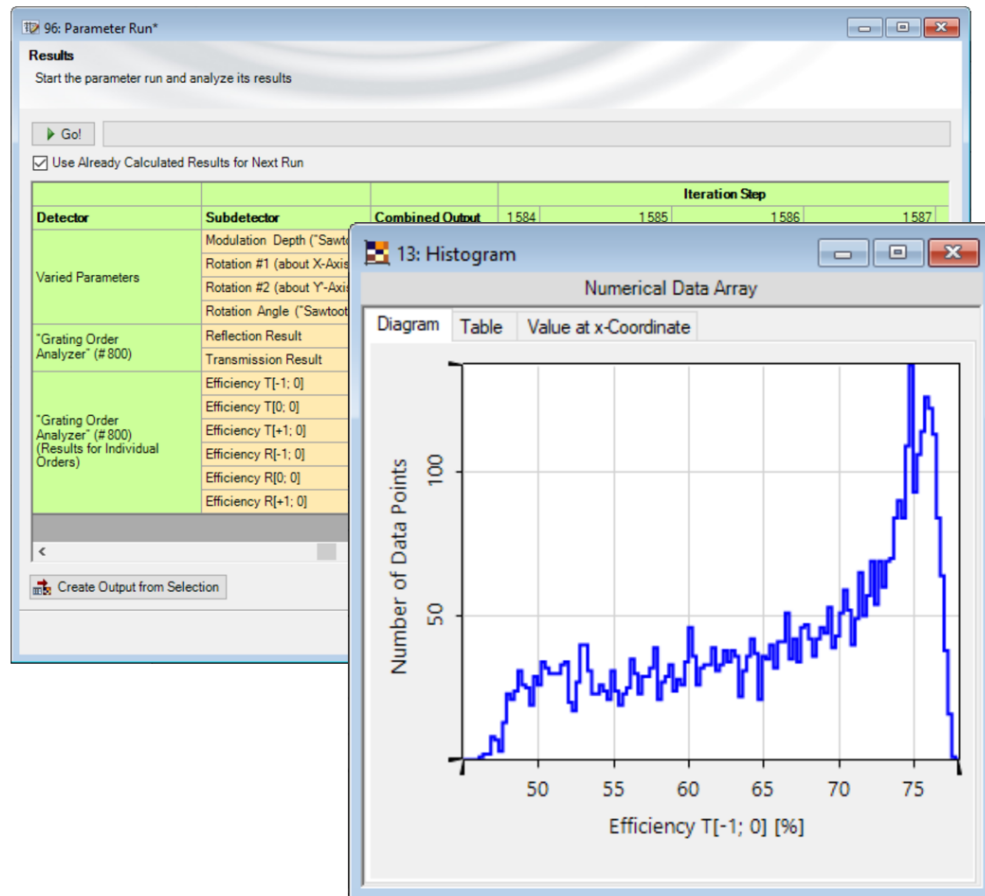


Tolerancing with Random Distributions using the Programmable Mode of the Parameter Run

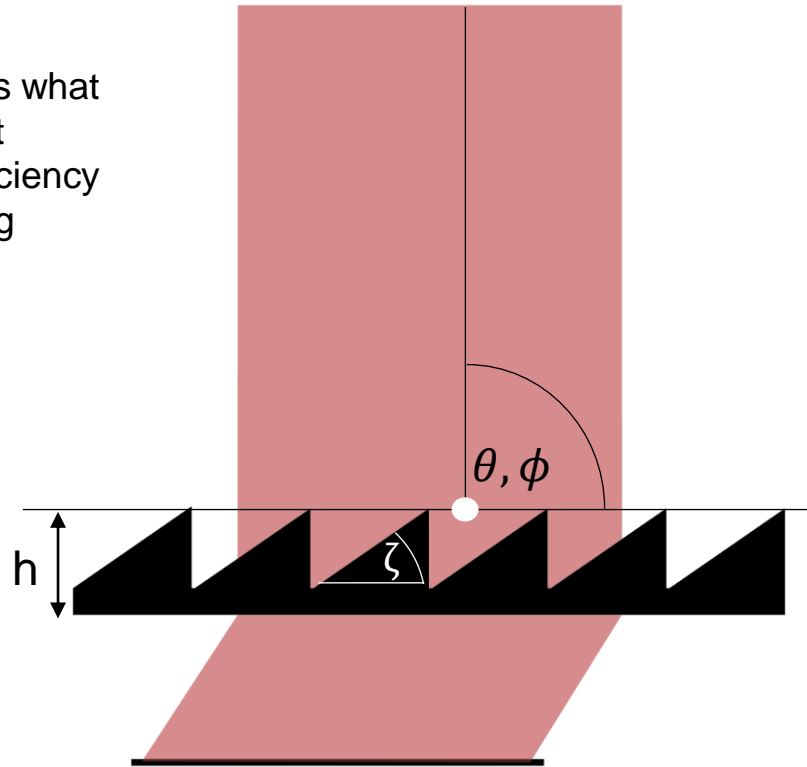
Abstract



When investigating the effect of manufacturing deviations on an optimized system in VirtualLab Fusion, randomly varied Parameter Runs can be used. Depending on the kind of manufacturing process, it may be that the deviations for the different parameters follow different random distribution rules. While the default Random mode of the Parameter Run assumes a uniform distribution, in this use case we want to show how to use a programmable Parameter Run to apply different random distributions to each of the parameters involved in the tolerancing. As illustration we have selected the example of a sawtooth grating, for which we investigate the minimal efficiency of the minus first transmission order.

Task Description

Task: According to the allowed tolerances what is the minimal efficiency of the minus first transmitted order? How is the overall efficiency distributed among the different emanating orders in that case?



Source: Ideal Plane Wave

- 532 nm wavelength

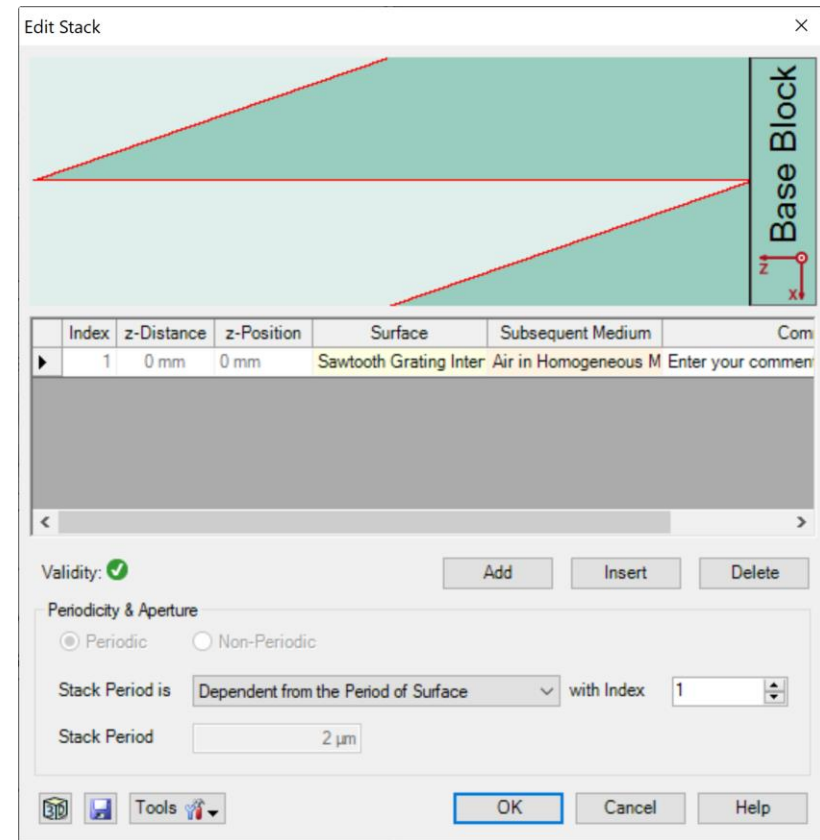
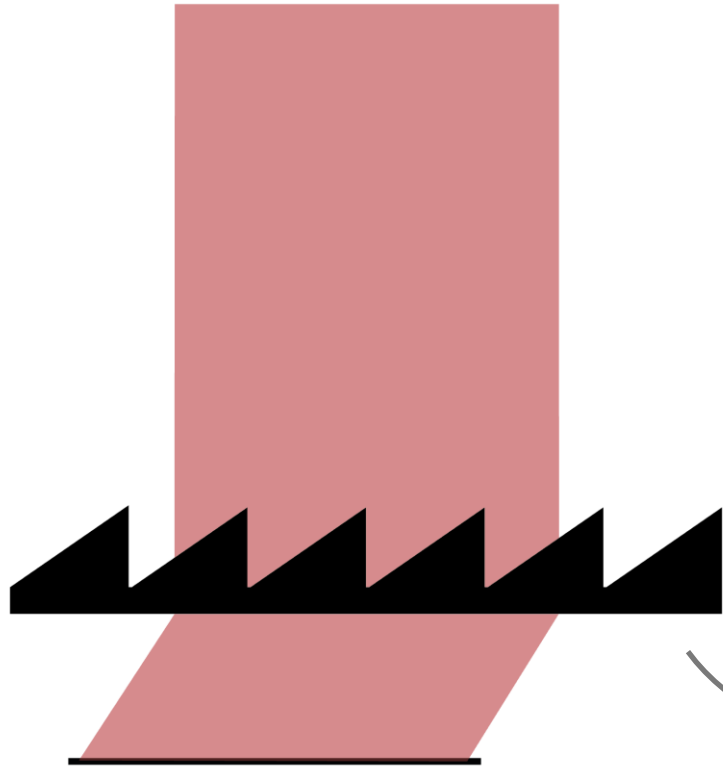
Sawtooth Grating (fixed parameters):

- 2 μm period
- fused silica
- 1 mm thickness

Sawtooth Grating (parameters for tolerancing):

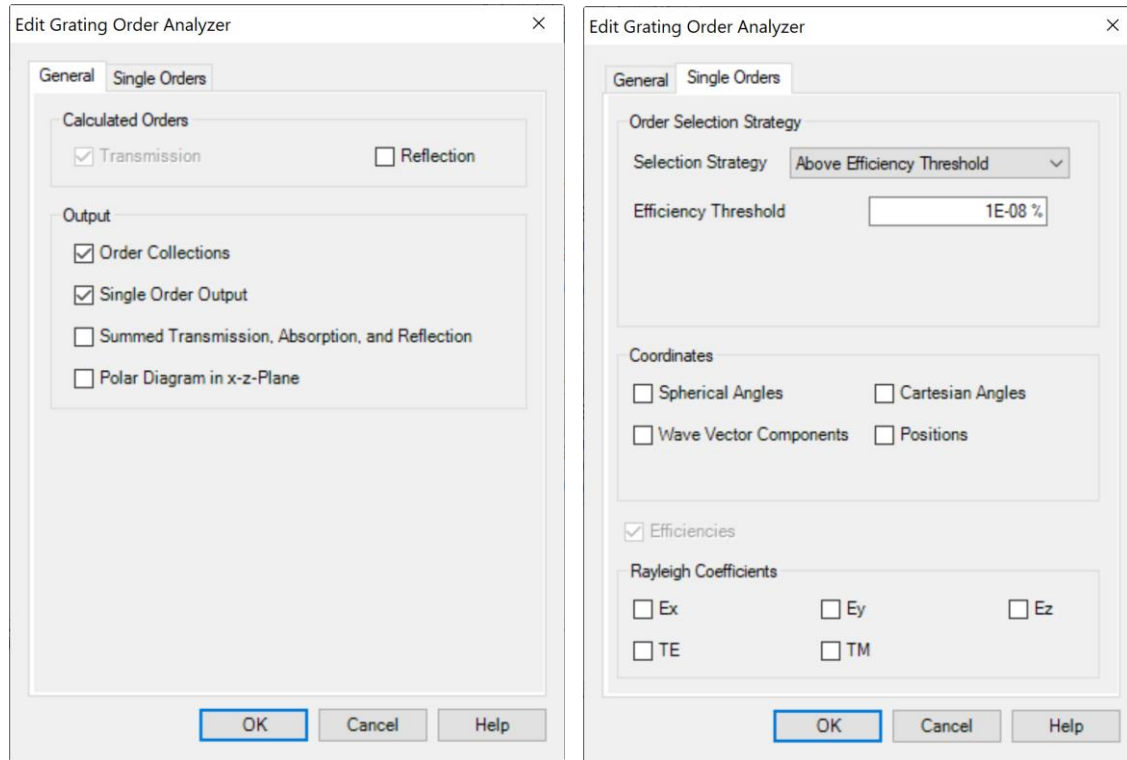
- blaze angle ζ : 30° (2° tolerance, normal distribution)
- rotation angle θ : normal distribution between -5° and 5°
- rotation angle ϕ : uniform distribution between -5° and 5°
- modulation depth h : 1 μm (0.25 μm tolerance, evenly distributed)

The System in VirtualLab Fusion – Components

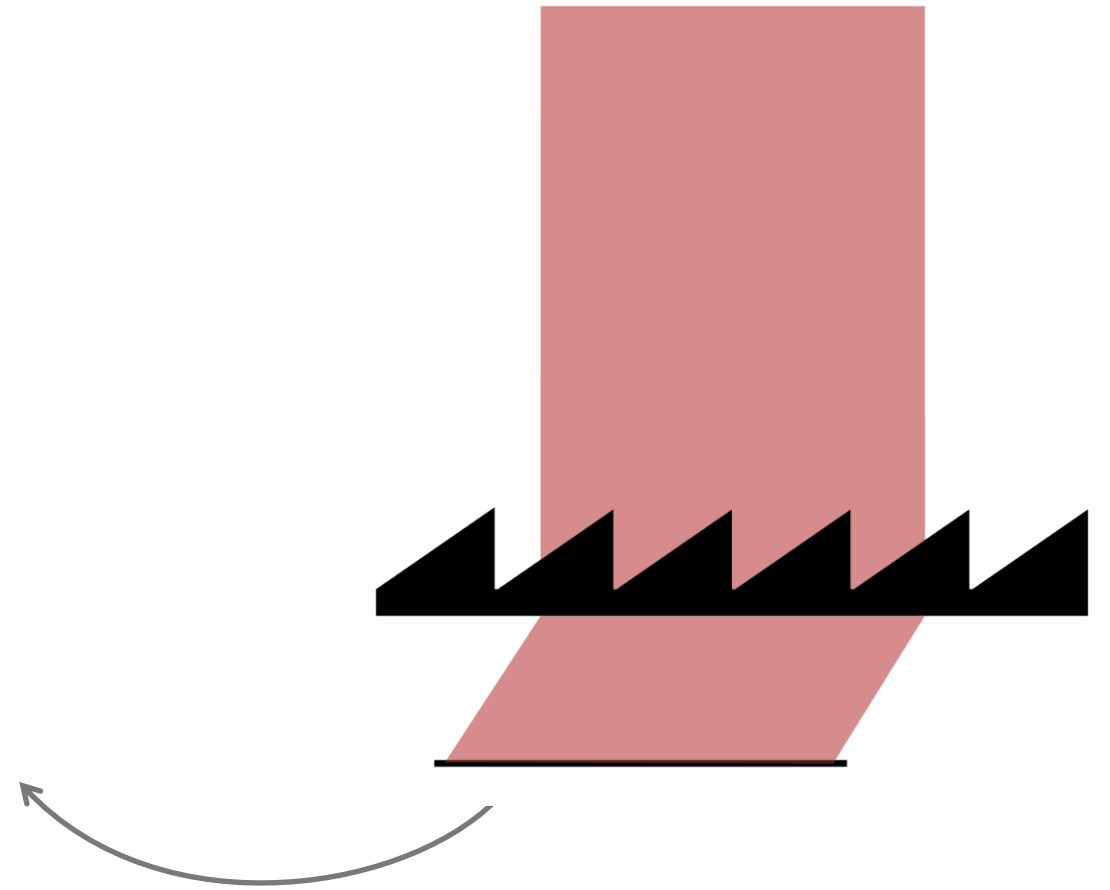


The grating is modeled using a Sawtooth Grating Interface. In the configuration dialog of the surface, the period, blaze angle and modulation depth can be adjusted.

The System in VirtualLab Fusion – Analyzer



In a Grating Optical Setup the Grating Order Analyzer enables an easy analysis of the grating. It provides different output formats that allow the user to determine how overall energy is distributed among the different emanating orders. In addition, the fully vectorial field information in the form of the Rayleigh coefficients per order is also accessible.



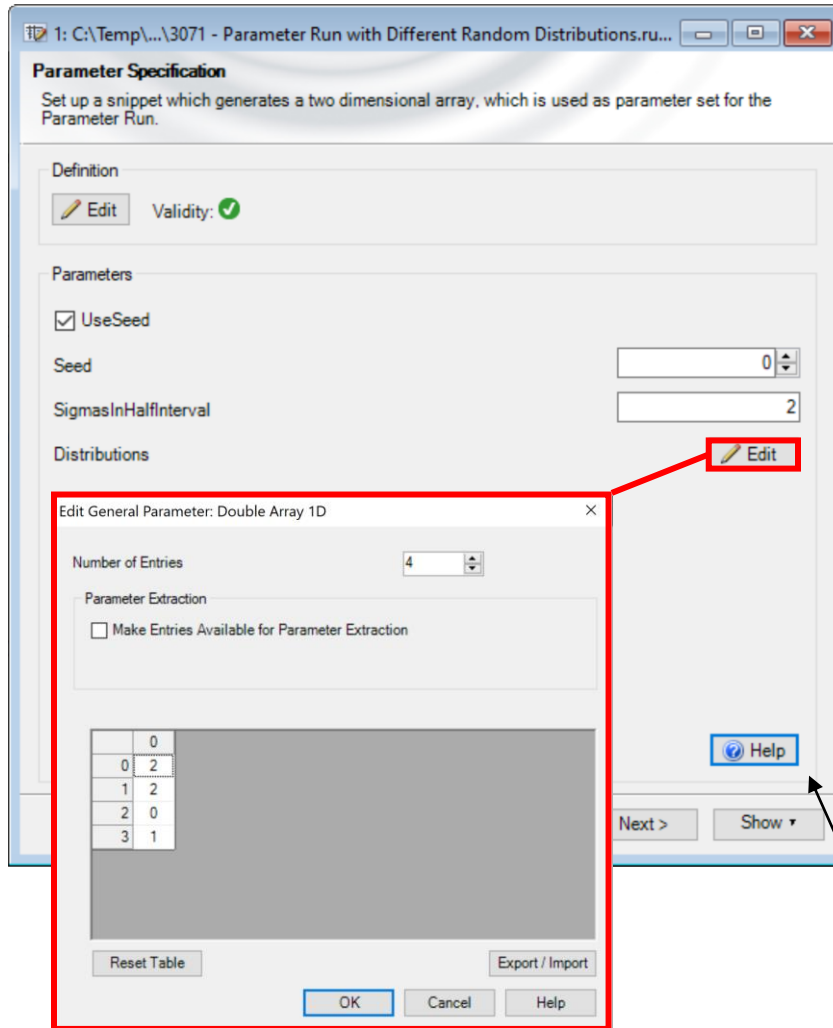
Programmable Parameter Run

Detector	Subdetector	Combined Output	Iteration Step			
			1584	1585	1586	1587
Varied Parameters	Modulation Depth ("Sawtooth")	Data Array	6589034 μm	1.092440115 μm	750.0807982 nm	1.143349523 μm
	Rotation #1 (about X-Axis)	Data Array	.503275514°	-1.196948991°	-3.043554858°	-2.994923633°
	Rotation #2 (about Y-Axis)	Data Array	.893143299°	3.870853468°	3.487450092°	-1.124331136°
	Rotation Angle ("Sawtooth")	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°
"Grating Order Analyzer" (#800) (Results for Individual Orders)	Transmission Result	Animation	Order Collection	Order Collection	Order Collection	Order Collection
	Efficiency T[-6; 0]	Data Array	22049219 %	0.001513942357 %		0.0002329068886 %
	Efficiency T[-5; 0]	Data Array	41490561 %	0.01242901447 %	0.007943152103 %	0.002657151786 %
	Efficiency T[-4; 0]	Data Array	99259131 %	0.07460787438 %	0.04338002262 %	0.1151399559 %
	Efficiency T[-3; 0]	Data Array	09475967 %	0.3108249199 %	0.02733774357 %	0.4361768419 %
	Efficiency T[-2; 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %
	Efficiency T[-1; 0]	Data Array	20105301 %	71.06530728 %	46.20124392 %	75.10256396 %
	Efficiency T[0; 0]	Data Array	66578527 %	5.022484567 %	28.96273187 %	2.460893894 %
	Efficiency T[+1; 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %

```
1 double[,] parameters = new double[NumberOfParameters
2
3 (double minimum, double maximum, RandomDistributionT
4
5 for (int parameterIndex = 0; parameterIndex < Number
6 intervals[parameterIndex] = (MinimumValues[param
7
8 }
9
10 RandomNumberGenerators randomNumberGenerators = new
11
12 for (int i = 0; i < NumberOfIterations; i++) {
13 for (int parameterIndex = 0; parameterIndex < Number
14 parameters[parameterIndex, i] = randomNumber
15 }
16 }
17
18 return parameters;
```

To investigate the manufacturing deviations, we use a programmable Parameter Run. Inside, a seed-based random distribution function is used to achieve the different combinations. Through a parameter in the programmable Parameter Run, it is possible to assign to each parameter either a normal or a uniform distribution, as illustrated in the next page.

Options of the Programmable Parameter Run



Use Seed

- Allows for reproducible results

Seed

- Define a specific seed to recreate a particular distribution of the randomly generated Parameter Run

SigmasInHalfInterval

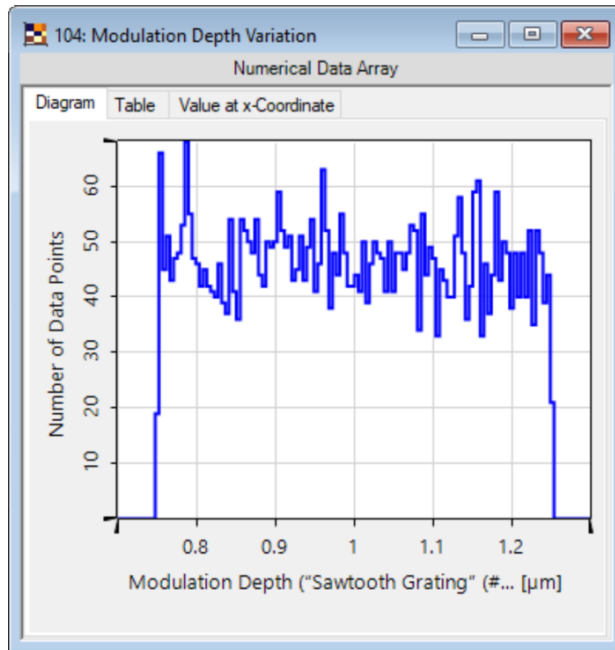
- Determine the width of the distribution, more information can be found in the “Help” document

Distributions

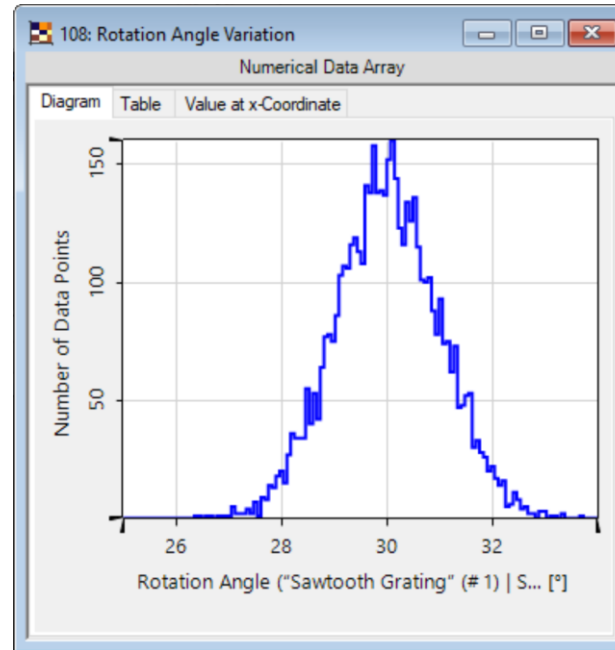
- Choose either a “Uniform”, “Normal” or “Cutoff-Normal” Distribution for each individual varied parameter
- The distribution type is coded with numbers: 0 – uniform, 1 – normal, 2 – cutoff-normal; more information can be found in the “Help” document

Note: In the “Help” document you can find a short explanation of all used parameters and the function of the component.

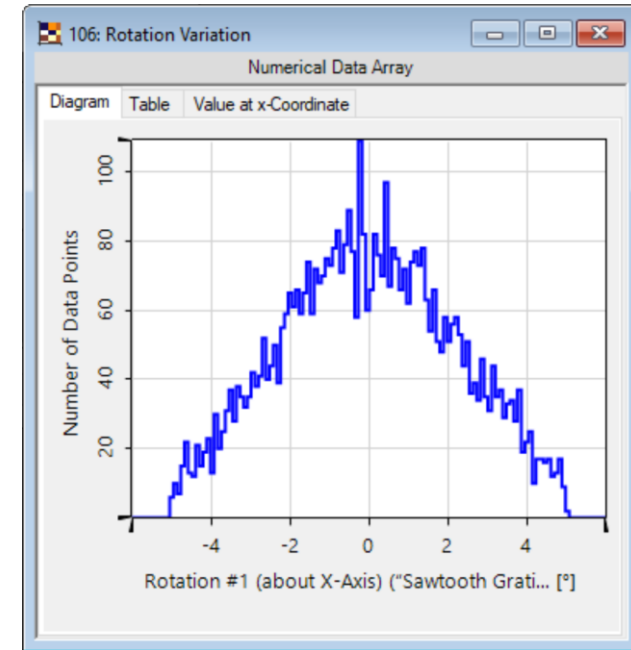
Distribution Types



uniform distribution



normal distribution



cutoff-normal distribution

In the case of a uniform distribution, the number of points will be evenly distributed over the allowed range. The normal and cutoff normal distributions both assume a Gaussian profile for the probability of a point being taken. The difference between the standard normal distribution and the cutoff normal distribution is that in the case of the cutoff distribution the values outside of the parameter range will not be taken, but a new number inside the range is generated instead.

Statistical Distribution of the Efficiency

21: Parameter Run

Results

Start the parameter run and analyze its results

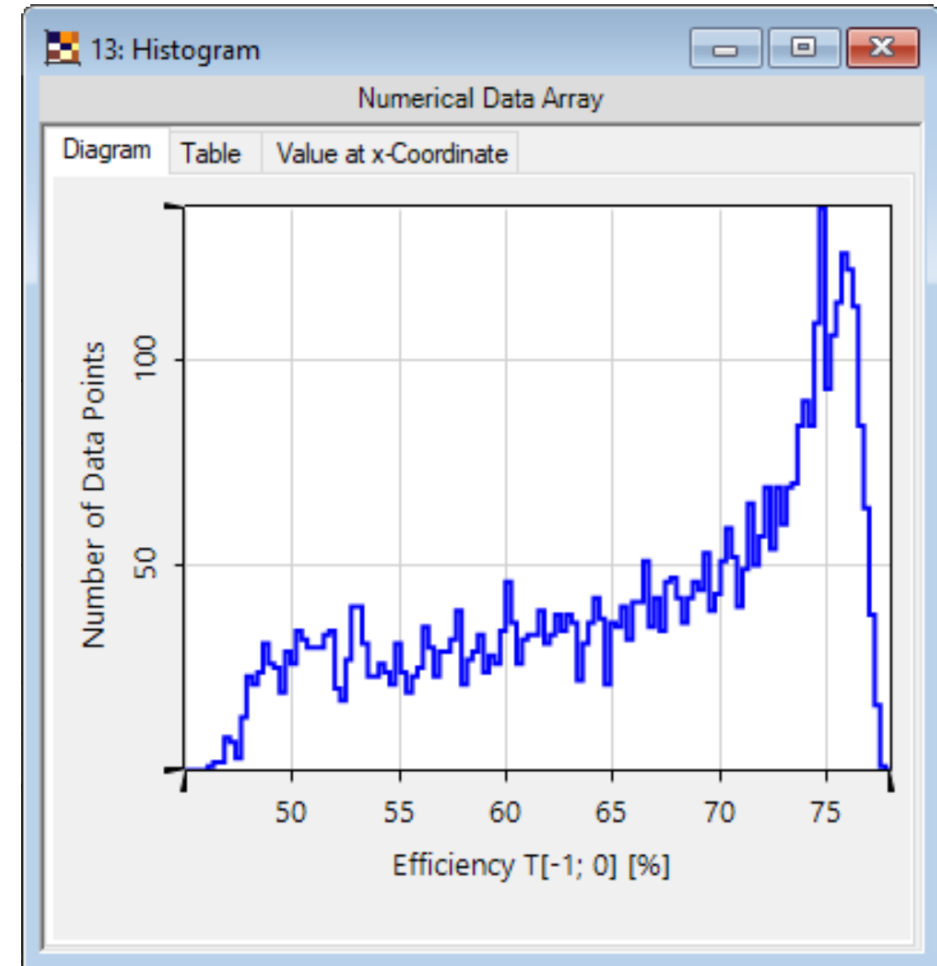
Go!

Use Already Calculated Results for Next Run

Detector	Subdetector	Combined Output	Iteration Step			
			1 584	1 585	1 586	1 587
Varied Parameters	Modulation Depth ("Sawto...	Data Array	6589034 μm	1.092440115 μm	750.0807982 nm	1.143349523 μm
	Rotation #1 (about X-Axis)...	Data Array	.503275514°	-1.196948991°	-3.043554858°	-2.994923633°
	Rotation #2 (about Y-Axis)...	Data Array	.893143299°	3.870853468°	3.487450092°	-1.124331136°
	Rotation Angle ("Sawtooth...	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°
"Grating Order Analyzer" (#...	Transmission Result	Animation	Collection	Order Collection	Order Collection	Order Collection
"Grating Order Analyzer" (#800) (Results for Individual Orders)	Efficiency T[-6; 0]	Data Array	22049219 %	0.001513942357 %	0.0002329068886 %	0.0002329068886 %
	Efficiency T[-5; 0]	Data Array	41490561 %	0.01242901447 %	0.007943152103 %	0.002657151786 %
	Efficiency T[-4; 0]	Data Array	99259131 %	0.07460787438 %	0.04338002262 %	0.1151399559 %
	Efficiency T[-3; 0]	Data Array	09475967 %	0.3108249199 %	0.02733774357 %	0.4361768419 %
	Efficiency T[-2; 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %
	Efficiency T[-1; 0]	Data Array	20105301 %	71.06530728 %	46.20124392 %	75.10256396 %
	Efficiency T[0; 0]	Data Array	66578527 %	5.022484567 %	28.96273187 %	2.460893894 %
Efficiency T[+1; 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %	

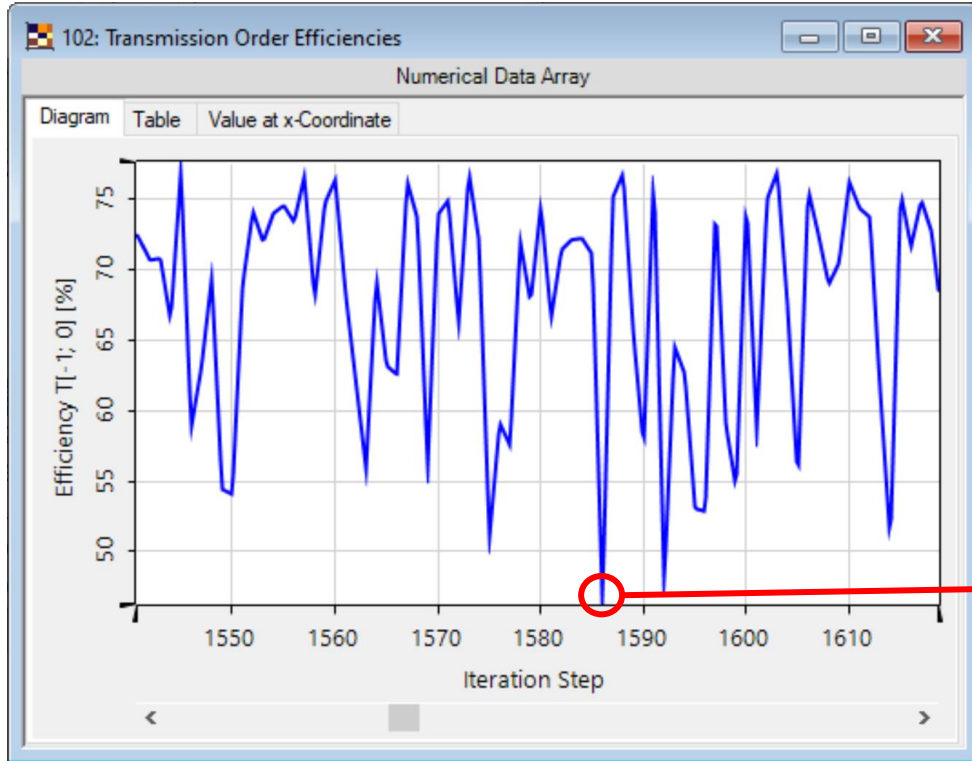
Create Output from Selection

< Back Next > Show ▾



From the Parameter Run result it is possible to get an overview of the statistical distribution and range in which the efficiency of the order lies with the Histogram Detector (under Detectors in the Main Window) .

Tolerancing of the Grating



21: Parameter Run

Results

Start the parameter run and analyze its results

Go!

Use Already Calculated Results for Next Run

Detector	Subdetector	Combined Output	Iteration Step			
			1584	1585	1586	1587
Varied Parameters	Modulation Depth ("Sawto...	Data Array	6589034 μm	1.092440115 μm	750.0807982 nm	1.143349523 μm
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	Rotation #2 (about Y-Axis)...	Data Array	3893143299°	3.870853468°	3.487450092°	-1.124331136°
	Rotation Angle ("Sawtooth...	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°
"Grating Order Analyzer" (#...	Transmission Result	Animation	Order Collection	Order Collection	Order Collection	Order Collection
	Efficiency T[-6; 0]	Data Array	22049219 %	0.001513942357 %	0.007943152103 %	0.0002329068886 %
"Grating Order Analyzer" (#800) (Results for Individual Orders)	Efficiency T[-5; 0]	Data Array	41490561 %	0.01242901447 %	0.007943152103 %	0.002657151786 %
	Efficiency T[-4; 0]	Data Array	99259131 %	0.07460787438 %	0.04338002262 %	0.1151399559 %
	Efficiency T[-3; 0]	Data Array	09475967 %	0.3108249199 %	0.02733774357 %	0.4361768419 %
	Efficiency T[-2; 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %
	Efficiency T[-1; 0]	Data Array	20105301 %	71.06530728 %	46.20124392 %	75.10256396 %
	Efficiency T[0; 0]	Data Array	66578527 %	5.022484567 %	28.96273187 %	2.460893894 %
	Efficiency T[+1; 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %

Create Output from Selection

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The iteration with minimal efficiency can also be determined and the results further investigated. You can use the detectors in the main window (under Detectors) to find the minimum.

Order Efficiencies for Minimal Efficiency

21: Parameter Run

Results

Start the parameter run and analyze its results

Go!

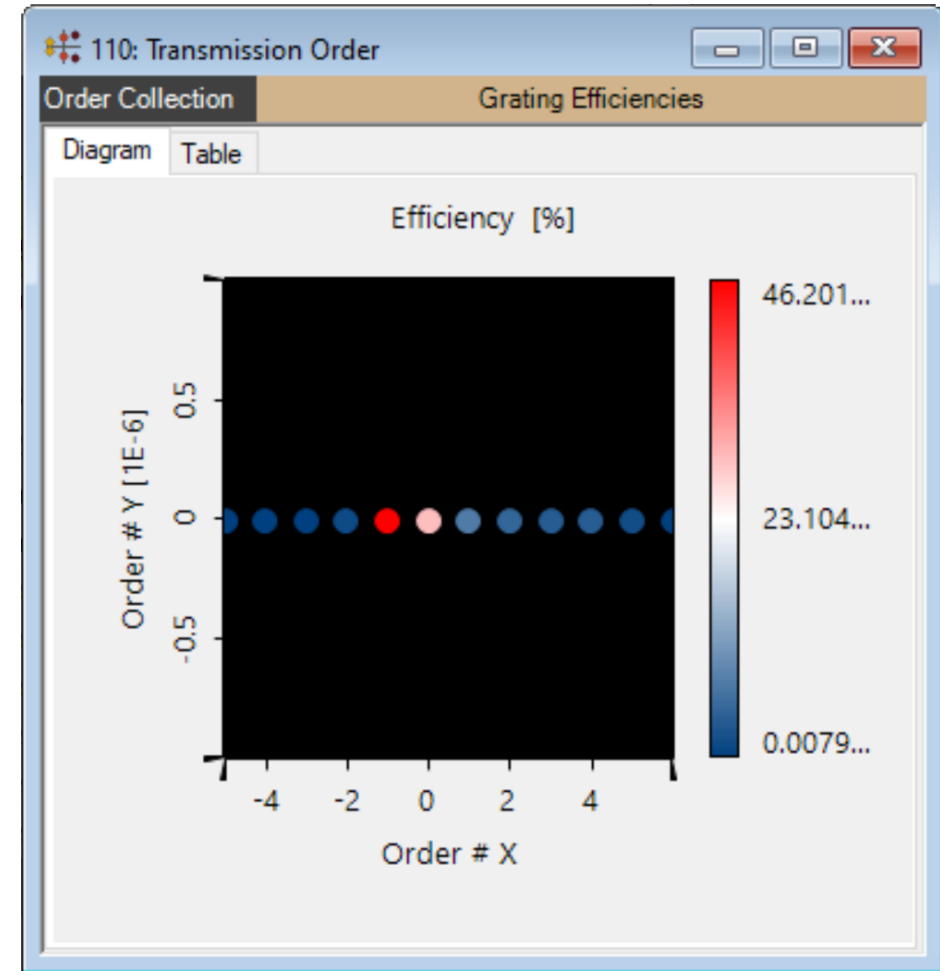
Use Already Calculated Results for Next Run

Detector	Subdetector	Combined Output	Iteration Step			
			1 584	1 585	1 586	1 587
Varied Parameters	Modulation Depth ("Sawto...	Data Array	6589034 μm	1.092440115 μm	750.0807982 nm	1.143349523 μm
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	Rotation Angle ("Sawtooth...	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°
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	Efficiency T[-2; 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %
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	Efficiency T[0; 0]	Data Array	66578527 %	5.022484567 %	28.96273187 %	2.460893894 %
	Efficiency T[+1; 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %

Create Output from Selection

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Additional information and the results of any individual iteration can be directly accessed in the Parameter Run document.



Random Distribution Types

21: Parameter Run

Results

Start the parameter run and analyze its results

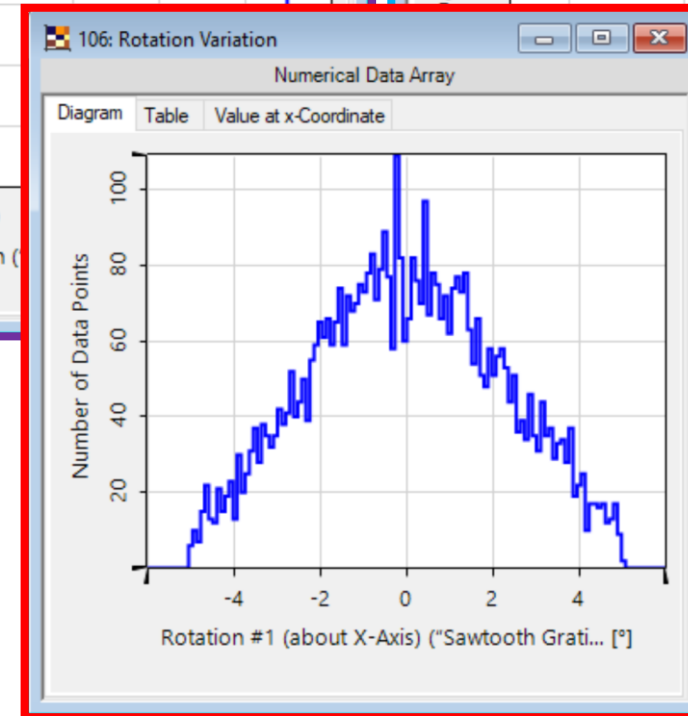
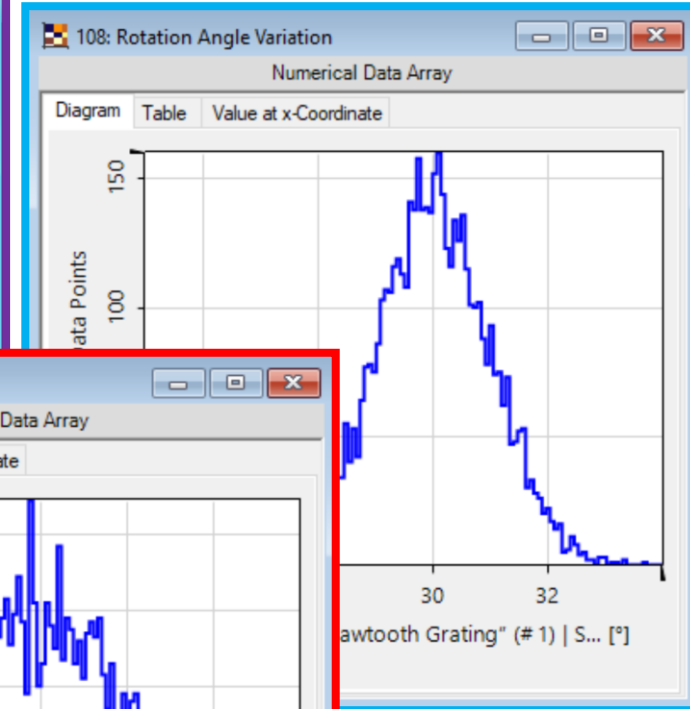
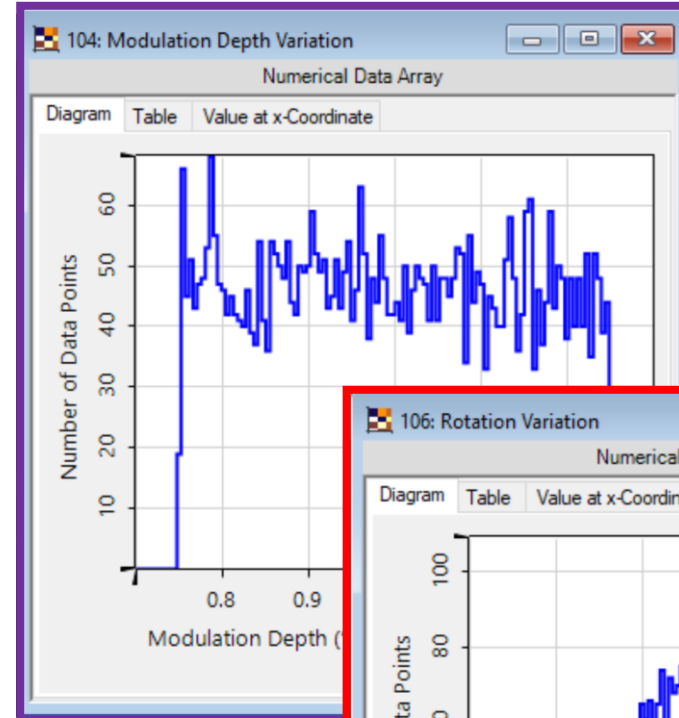
Go

Use Already Calculated Results for Next Run

		Iteration Step				
Detector	Subdetector	Combined Output	1584	1585	1586	1587
Varied Parameters	Modulation Depth ("Sawtooth Grating" (#1) S...	Data Array	6589034 μm	1.092440115 μm	750.0807982 nm	1.143349523 μm
	Rotation #1 (about X-Axis) ("Sawtooth Grating" (#1) S...	Data Array	503275514°	-1.196948991°	-3.043554858°	-2.994923633°
	Rotation #2 (about Y-Axis) ("Sawtooth Grating" (#1) S...	Data Array	3893143299°	3.870853468°	3.487450092°	-1.124331136°
	Rotation Angle ("Sawtooth Grating" (#1) S...	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°
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	Efficiency T[-5: 0]	Data Array	41490561 %	0.01242901447 %	0.007943152103 %	0.002657151786 %
	Efficiency T[-4: 0]	Data Array	99259131 %	0.07460787438 %	0.04338002262 %	0.1151399559 %
	Efficiency T[-3: 0]	Data Array	09475967 %	0.3108249199 %	0.02733774357 %	0.4361768419 %
	Efficiency T[-2: 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %
	Efficiency T[-1: 0]	Data Array	20105301 %	71.06530728 %	46.20124392 %	75.10256396 %
	Efficiency T[0: 0]	Data Array	66578527 %	5.022484567 %	28.96273187 %	2.460893894 %
	Efficiency T[+1: 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %

Create Output from Selection

Back Next Show



For maximum flexibility it is possible to use different random distributions for different parameters in the same Parameter Run document.

Document Information

title	Tolerancing with Random Distributions using the Programmable Mode of the Parameter Run
document code	USP.0006
version	1.0
edition	VirtualLab Fusion Advanced
software version	2020.2 (Build 2.22)
category	Application Use Case
further reading	<ul style="list-style-type: none">- Usage of the Parameter Run Document- Grating Order Analyzer