Use of the simulation program.

This one is in the form of functional blocks.
Each block is used to configure the operation of a function.
Here is the list of blocks:

Physical settings:

- Source.
- Polarizers.
- Detectors.

Analysis settings:

- Choice of the simulated model (QM / Local)
- Pairing. (Window type and size)
- Inequality test. (Eberhard only)

It has 4 tools:

- Simple test from angles that can be entered directly.
- A tool for automatic adjustment of the angles entered.
- A tool for finding angles. (Defines a list)
- A tool allowing to repeat a test several times.

Other:

- Selection of graph curves.
- Transmittance test.

Depending on the choice of the simulation model (QM / local), various options of settings corresponding to the model are activated or deactivated.

The principle of use is as follows.

1 / choice of simulation model, QM or Local
2 / parameterization of the elements of the experiment: source, polarizer, detectors.

For each parameter defined or modified, it is possible to draw curves representing certain characteristics.
Statistical information is also displayed in the console at the end of trace.

3 / Once the parameters have been defined, it is possible to test the Eberhard inequality.

There are several options, either the angles a1 a2 b1 b2 are entered manually, either a tool can be used to search for those who produce a violation, if this is possible with the defined configuration.

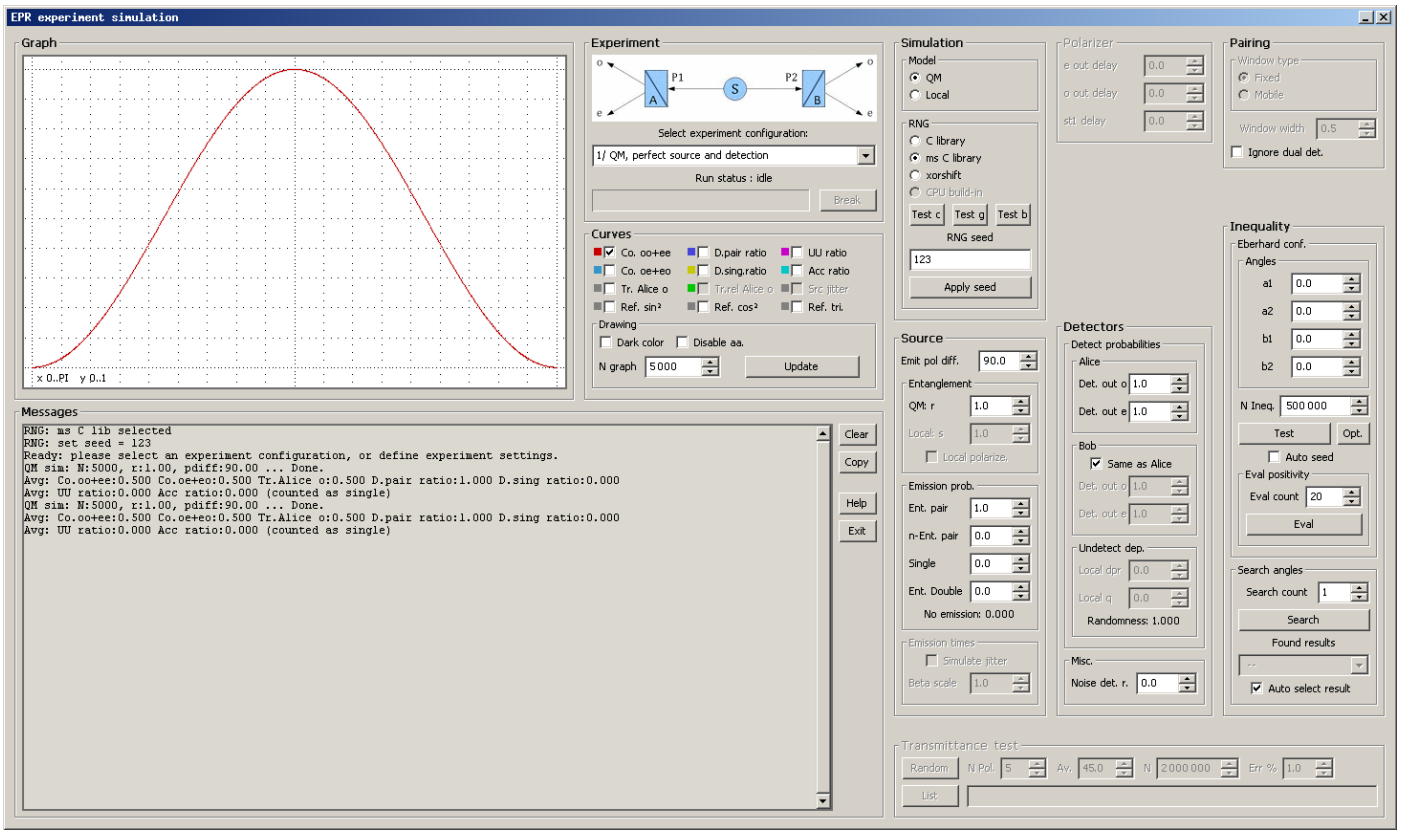
A tool allow to automatically optimize the angles entered or modified.
Another tool allow to test the same set of angles several times in order to check the stability of a result (which varies according to the sequences produced by the RNGs).

4 / A last one allows to test the transmittance. It is not part of an EPR experiment and will be described at the end of this document.

When using a tool that require computation time (graph drawing, angle search, and positivity test), the configuration fields are disabled.
To interrupt a calculation in progress, a Break button can be used.

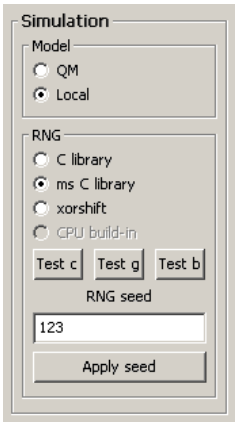
Finally, a menu allows to select in a list some preconfigured experiments, showing specific points.

Here is a picture of the full interface.



The remainder of the document briefly describes the function of each block.
A precise description of each parameter is included in the program and can be displayed when in use by tooltips. (By immobilizing moment the mouse cursor over the parameter text.)

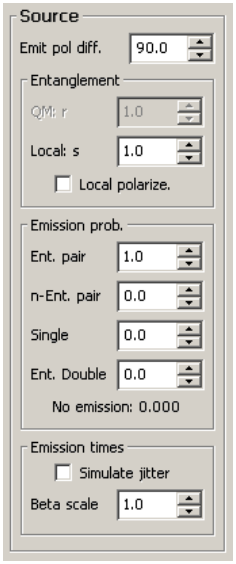
Simulation Block :



Allows to:

- Choose the simulated model: QM or Local.
- Select the random generator used for the simulations.
- Check the operation of the random generator.
- Define the random seed value.

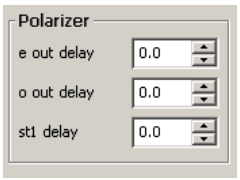
Source block:



Allows to:
Define the angle difference between Alice/Bob at the emission.
The QM entanglement level.
The level of coupling between the values of the hidden variables for the local model.
Define the emission probabilities.
Define a time jitter at emission.

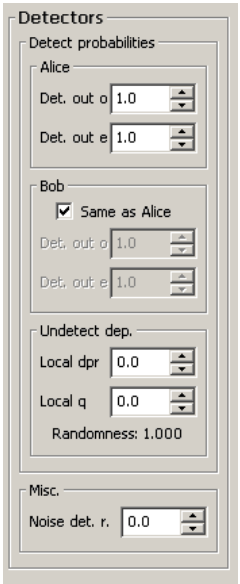
Note: The simulation always uses a pulsed source, even when the mobile windows mode is used in pairing block.

Polarizer Block :



Allows to define some transmission delays.
This block is only active in Local mode. (No timings are simulated in QM mode)

Block Detectors:

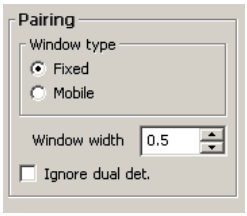


Allows to:
Define the probability of detection for each detector.

In local mode only, to determine what is causing the non detections (Randomness or depending on some hidden variables values.)

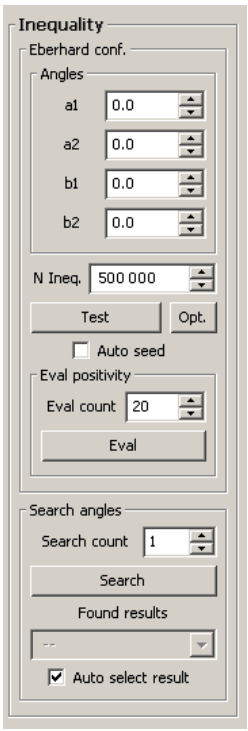
Define a random detections rate produced by noise at the level of the detector.

Pairing block:



Defines the windowing mode used, and the size of the window.
Choose how measurements generating more than one detection in windows, or simultaneous e and o detections of the same arm are counted.

Inequality block:



Allows to:

Define angles manually to test the Eberhard inequality.

Choose N used in the test. (The dependence on variations in RNG sequences between two tests are reduced when N increases, but also proportionately increases the simulation time.)

The ' **Test** ' button allows you to perform a single test from defined angles a1, a2, b1, b2. (Uses 'N Ineq'.)

The ' **Opt** ' button executes a program which dichotomously adjusts the angles in order to obtain the lowest possible J/N. (Note: operation is independent of 'N Ineq')

The ' **Auto seed'** option applies the RNG seed defined in the 'Simulation' block before each execution launched by the '**Test**' or '**Opt**' button.
This allows to keep the same sequence when angles are changed manually.

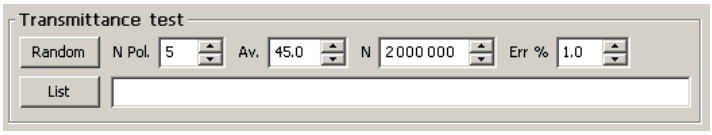
The ' **Eval positivity'** tool performs ' **Eval count** ' times the inequality test.
This allows you to check the stability of a result by repeating a large number of times same experiment.
At the end of the test, the average value of J/N over all of the tests is displayed in the console.

Note: if the result is unstable, it may be necessary to increase N Ineq (unless the average tends towards 0).

The ' **Search angles'** tool allows to search a list of angles that produce the lowest possible J/N value.
At the end of the search, the tool fills in the '**Found results** ' list in which it is possible to select an angles combination which will be copied in the fields a1, a2, b1, b2.

If the '**Auto select result**' option is activated, the combination that produces lowest J/N will be selected automatically.

Transmittance test block:



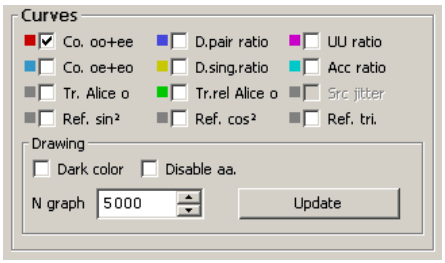
This block is not part of an EPR experiment.
It is used to check the basic operation of a polarizer, namely whether it is conforms to the Malus ‘law.
It simulates an alignment of blocking polarizers, and checks that the Overall transmittance is correct on the last polarizer.

There are two tests:
The **first test**, activated by the button '**Random**' defines an alignment of '**N Pol**‘ polarizers, of which the difference in angles between each polarizer is chosen randomly with a maximum deviation of +/- '**AV.**', and sends N photons through the whole.
It then checks on the last polarizer the ratio of outgoing photons and compares with the theoretical result predicted by Malus' law.
If the deviation is less than 'Err', the test is successful.

Note: The error is cumulative at each level, and for a large number of aligned polarizers, it may be necessary to increase N to obtain a sufficient accuracy.

The **second test**, activated by the '**List**' button, allows to perform the test on a set of angles chosen manually and entered in the list to the right of the ‘List button’. (Ex: 0, 45, 90)

Block Curves :



This block allows you to choose the curves to be displayed on the graph.

The curves are as follows:

Co. oo + ee
Correlation tau of oo + ee detections. (Ratio (oo + ee) / (oo + ee + eo + oe))

Co. oe + eo
Rate of correlations of oe + eo detections. (Ratio (oe + eo) / (oo + ee + eo + oe))

D.pair ratio
Pair detection rate on the number of send requests. (oo + ee + oe + eo) / N

D.sing.ratio
Simple measurement detection rate on the number of transmission requests. (ou + eu + uo + ue) / N

UU ratio
Rate of measurements which produced no detection. uu/N

Acc ratio
Rate of measurements that produced multiple detections (more than one detection on the same detector or on both detectors of the same arm)

Tr. Alice o
Rate of photons detected on o, out of the total number detected on o + e. (o / (o + e))
This rate must be constant at 50% if the detection sensitivity is identical on e and o.
Only displays the 'Alice' arm, the Bob arm is not displayed (operation is identical)

Tr.rel Alice o
Rate of photons oriented on o at the level of the polarizer, on the total number oriented on o + e (independent of detection).
With the local model, it is possible to know in simulation the initial polarization issued by the source.
This curve uses the photon / polarizer angle difference on the x axis, and shows local transmittance at Alice's level.
This must be in accordance with the Malus ‘law.

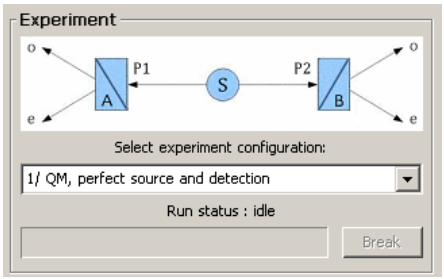
Src jitter
Display the temporal distribution of delays produced by the 'Simulate Jitter' option from the source block.
With this curve, the x axis represents a time.

Ref. sin²
Display a perfect sine² of reference for a visual comparison with the simulated curves.

Ref. cos²
Display a perfect cosine² for visual comparison with the simulated curves.

Ref. tri.
Displays a reference triangle 'curve' corresponding to correlations of a perfect local model.
Allows visual comparison with simulated curves.

Bloc Experiment :



This block displays the progress of a calculation.
It allows to interrupt it using the 'Break' button.

It also allows to select from a list, a series of preconfigured experiments showing a specific point.
When selected, a detail of the experiment is then displayed in the console.
Certain experiment requires running the positivity test. ('Inequality / eval.positivity' block)

Note on time values:

All entered time values are times proportional to PI * an arbitrary time constant.

The useful time reference is 0.5 * (PI * k) which is the maximum transmit delay time of a photon through a polarizer with the simulated local model (if no delay added).
This time corresponds to a repolarization of PI/2 which is the maximum value that may occur. (Variable named dpr)
Thus, a delay defined at 0.5 for the pairing window does not reject any particle. (If source temporal jitter disabled and no delay added in polarizer parameters).