Documentation for LabView vi's for QM Experiments

M. Beck
Dept. of Physics, Whitman College, Walla Walla, WA 99362
beckmk@whitman.edu ; http://www.whitman.edu/~beckmk/QM/

These vi's were all specifically written to read data from the DE2 coincidence counting unit. Data streams from the DE2 counter at a rate of 10Hz over an RS-232 (COM) serial port.

Brief descriptions of the vi's:

Appendix A -- Coincidence_rs232.vi

Used to acquire data for several experiments: coincidence measurements, proving the existence of photons [$g^{(2)}(0)$ measurements], and single photon interference.

Appendix B – Hardy_Bell_rs232.vi

Used to acquire data for Hardy's test of local realism, or a Bell (CSHS) inequality test.

Appendix C - MCA.vi

Used to mimic the behavior of a multichannel analyzer (MCA) using an analog-to-digital converter; it saves you the money of buying a dedicated MCA. This is useful for measuring the arrival time of photons using a TAC.

Appendix D – Coincidence_time_res_rs232.vi

Used to calibrate the coincidence time resolution.

Appendix E – Angle_scan_rs232.vi

Used to examine two photon polarization correlations (joint probabilities) as a function of angle.

Appendix A – Coincidence_rs232.vi

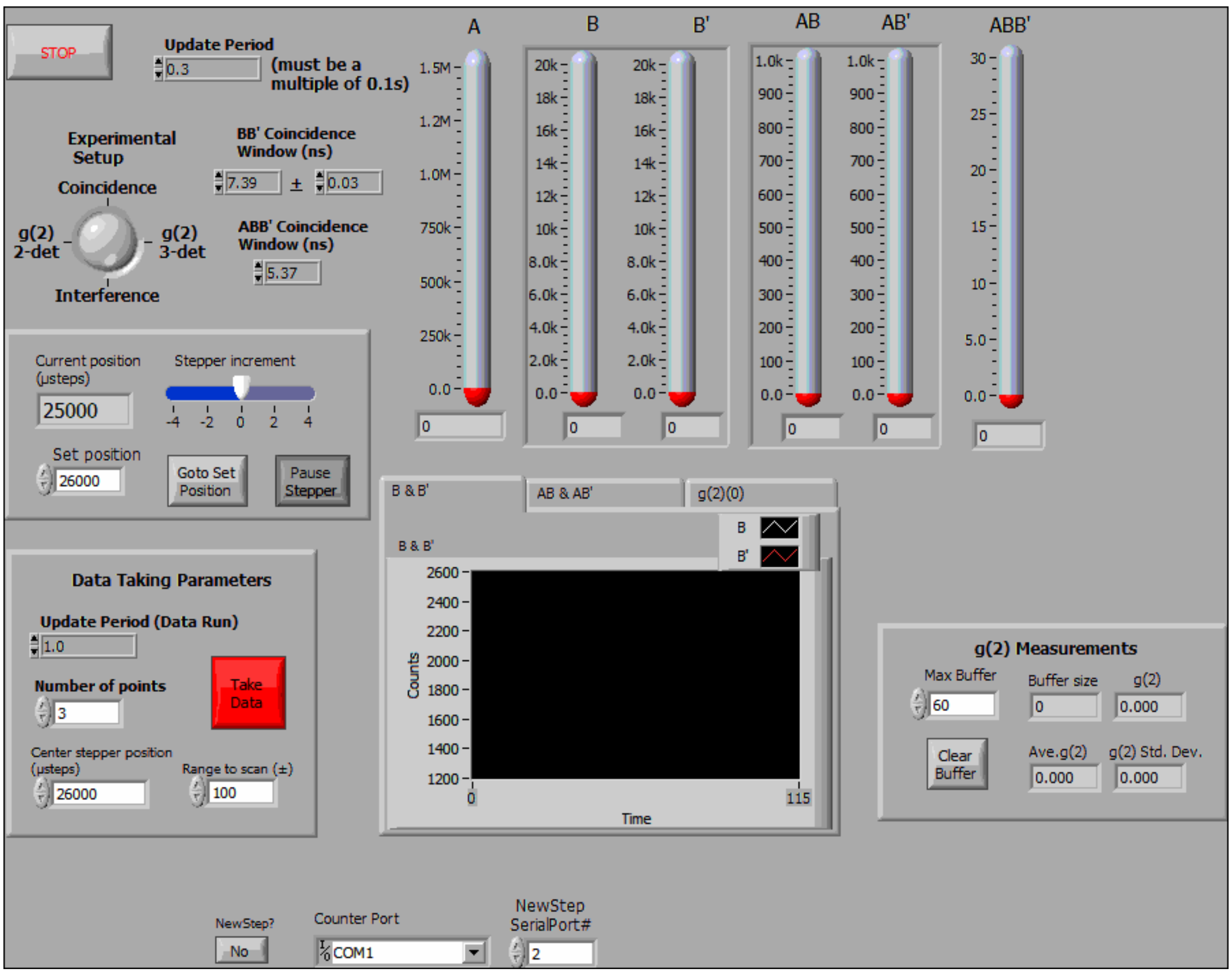
This appendix describes the LabView vi used to acquire data for several experiments: coincidence measurements, proving the existence of photons, and single photon interference.

I. Starting Out

The appearance of this vi will change depending on the experiment you are doing (as determined by the **Experimental Setup** knob on the vi.) The experiment with the most controls and indicators is the interference experiment, and the front panel for this experiment is shown below. If you are doing a different experiment, some of the objects may not be visible.

Coincidence_rs232.vi

Front Panel



Description

This is the program you use to run one of 4 different experiments:

1) Simply measuring coincidences between two beams.
2) Measuring g(2)(0) for 2-beams using 3-detectors.
3) Measuring single photon interference patterns (and simultaneously g(2)(0) for 2-beams using 3-detectors).
4) Measuring g(2)(0) for 1-beam using 2-detectors.

Note that g(2) is calculated differently depending on whether you're making 3-detector or 2-detector measurements. See details in the description of the "g(2) Measurements" parameter.

This vi was specifically written for the Altera DE2 counter. Data streams to the computer from the DE2 over the RS232 serial port.

The program does not record data to a file right away, but displays the counters in real time so that you can align things.

Once everything is aligned and the parameters are set, you press the "Take Data" button. This transfers control to another program which records a data set and saves it to a file.

Note that there is one control: "NewStep?" that tells the computer what hardware you have present in your experiment. This control is not visible normally. It located below the "Data Taking Parameters", so you'll need to scroll the window down to access it. This control is only read once at the beginning of execution--so it must be properly set BEFORE you run the program.

The “NewStep?” control tells the computer whether or not you have a NewStep stepper motor attached to your computer to control phase adjustments of the interferometer. This control is useful so that the computer won't try to communicate with an instrument you don't have, causing a hang-up. By default “NewStep?” is set to "No"--if you do have a NewStep, you'll want to change the default to "Yes". For more info see the description of this control below.

For interference measurements, a Newport NewStep actuator (inexpensive stepper motor) is used to tilt a beam displacing polarizer to adjust the phase of a polarization interferometer. This actuator is controlled by a NewStep controller, connected to a serial port of the computer with an RS-485 to RS-232 converter. If you do not have this controller, set the "NewStep?" parameter to "No".

Signals that should be selected on the DE2 for the coincidence counters:

A (Counter 0)

B (Counter 1)

A' (Counter 2) – unused by this vi

B' (Counter 3)

AB (Counter 4)

ABB' (Counter 5) – used for 3-detector g2 measurements (and interference)

AB' (Counter 6)

BB' (Counter 7) – used for 2-detector g2 measurements

Note that for the coincidence experiment, only 3 counters are used: A, B, and AB. For the other 3 experiments, 7 counters are used.

On startup, the program initializes the counters.

After initialization the program simply loops and displays the counts in a given time window (determined by the "Update Period" control in the upper left.) This is useful for tweaking the alignment and adjusting parameters.

Nothing is written to disk until the parameters are chosen and the "Take Data" button is pressed. This loads a second VI that records and saves data to disk. Parameters for this data acquisition phase are set in the "Data Taking Parameters" box.

When performing an interference experiment, the stepper motor will automatically adjust the tilt of the beam displacing prism, changing the phase.

Help for each of the controls and indicators can be obtained from the Contextual Help window <cntrl - H> by mousing over each control or indicator. Full documentation for each control and indicator can be obtained by printing using: File>Print>Custom, and then checking "All controls" and "Descriptions".

Controls and Indicators

Coincidence Measurements

Experimental Setup

Which measurement to perform.

Coincidence: Measures A, B, and AB counts.

g(2) 3-det: Make g(2) measurements on 2 correlated beams using 3-detectors. This is the single photon measurement.

Interference: interference measurement [with simultaneous g(2) 3-detector measurement]

g(2) 2-det: Make g(2) measurements on a single beam using 2-detectors. This is the classical field measurement.

Stop

Use this to stop. If you stop some other way you'll probably need to quit LabView and restart; you may even need to reboot the computer.

Update Period

[Must be a multiple of 0.1s]

Time window (in s) for the counters during setup phase (i.e., before the "Take Data" button is pressed.) Readings update once each time window if "Status" reads "Reading Counters".

Counts A, B, B’

Singles counts in the time window specified by “Update Period” (upper left)

Counts AB, AB’

Coincidence counts in the time window specified by “Update Period” (upper left)

Charts

Click on the tabs to display running plots of different measurements: **B & B'**, **AB & AB'**, or **g(2)**.

Update Period (Data Run) [Data Taking Parameter]

[Must be a multiple of 0.1s]

Time window (in s) for counters during data acquisition.

This applies after the "Take Data" button has been pressed.

Number of points [Data Taking Parameter]

Number of measurements that are made during data acquisition.

Error measurements are essentially useless if this is less than 5. 10 is a better minimum number. For interference measurements, you will want to use many more than this so you can better see the pattern.

Take Data [Data Taking Parameter]

Leave the setup "tweaking" mode and switch to data acquisition mode.

NewStep?

Is the NewStep controller present?

If No, there is no attempt to communicate with the NewStep controller. Useful if you don't have a NewStep controller. In this case, the "Interference" experiment is unavailable. If you set "Experimental Setup" to "Interference", the program will act as though it's set to "g(2) 3-det".

If Yes, the NewStep functions normally.

This parameter is only read once, when the vi first starts to run. Therefore, it needs to be set BEFORE you run the program.

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: "COM1", "COM2", etc.

NewStep SerialPort#

Number of the serial (COM) port that the NewStep controller is connected to.

3-Detector g(2) Measurements

All of the above parameters apply, plus the following:

ABB' Coincidence window

Coincidence window for ABB' measurements.

Used to determine expected g(2) for 3-detector (single-photon) measurements. Basically, this parameter determines the number of expected accidental ABB' counts.

Counts ABB’

Three-fold coincidence counts in the time window specified by “Update Period” (upper left)

g(2) Measurements

The program calculates g(2) for every loop--and this value is displayed as **g(2)**.

Calculated differently depending on which experiment you're doing.

Formulas:

T: update period (counting window, in S)

dt: BB’ coincidence window (in nS)

3-detector, 2-beam experiment:

g(2)=(A*ABB')/(AB*AB')

2-detector, 1-beam experiment:

g(2)=(BB'/(B*B'))*(T/(dt*1.0e-09))

These g(2) measurements are then stored in an array, which contains the most recent measurements.

g(2) Ave. and **g(2) Std. Dev** are the mean and standard deviation of these stored measurements.

Max Buffer is the maximum size of this array (i.e., the largest number of measurements that will be averaged).

Buffer size is the current length of the array that is being averaged.

Clear Buffer clears out the array, and new measurements begin repopulating it.

Interference Measurements

Interference measurements assume a 3-detector setup for g(2) calculations.

All of the above parameters apply, plus the following:

U32 **Current position (µsteps)**

Current position of the stepper motor.

26000 is about the center of the range with the mount we are using.

I32 **Stepper increment**

Amount that the stepper increments on each loop if the "Pause Stepper" button is off.

I32 **Set position**

Force the stepper motor to go to this position by pushing the "Goto Set Position" button.

26000 is about the center of the range with the mount we are using.

TF **Go To Set Position**

Forces the stepper motor to go to the "Set position".

TF **Pause stepper**

If this is in, the stepper motor is stopped. If it is out, the stepper increments by "Stepper increment" on each loop.

U32 **Center stepper position (µsteps)   [Data Taking Parameter]**

Center of the range for the stepper during data acquisition.

U32 **Range to scan (±)   [Data Taking Parameter]**

Range for the stepper during data acquisition.

At each point of data acquisition, the stepper moves evenly between ("Center stepper position" - "Range to scan") and ("Center stepper position" + "Range to scan")

2-Detector g(2) Measurements

All of the above parameters apply, plus the following:

BB' Coincidence window

Coincidence window for BB' measurements.

Needed to determine g(2) for 2-detector (classical) measurements.

2D window stdev

Standard deviation of coincidence window for BB' measurements.

Needed to determine the error in g(2) for 2-detector (classical) measurements.

BB' BB' coincidences.

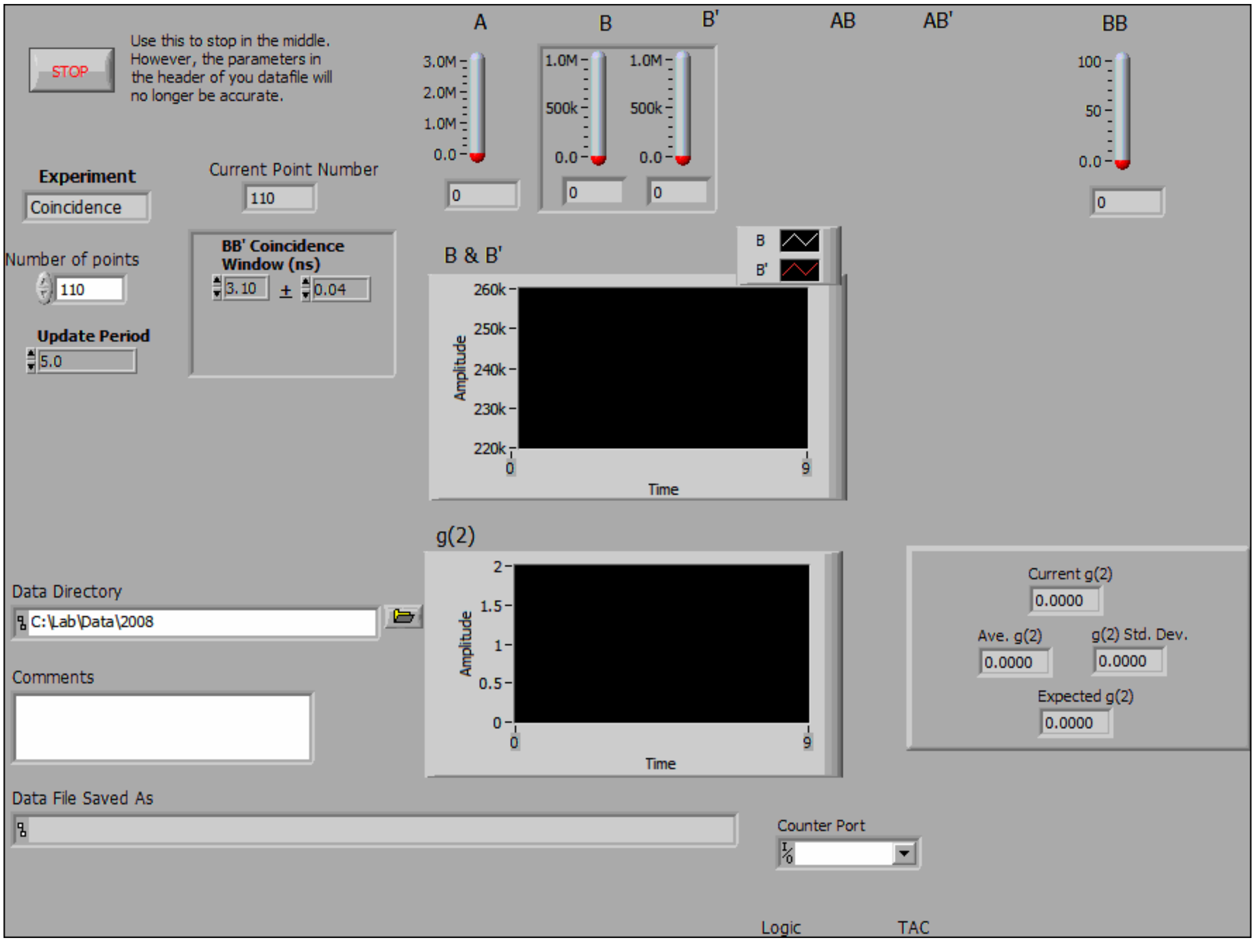
Only used for 2-detector g(2) measurements.

II. Taking Data

When you move to data taking mode, the program you see will look something like that shown below. Again, the appearance of this vi will change depending on the experiment you are doing.

Coincidence_Recorder_rs232.vi

Front Panel



Description

This VI should ONLY be called from the "Coincidence_rs232" VI--necessary parameters are set there.

This program records data (using parameters set in the "Coincidence_rs232.vi") and saves the data to a file.

For a more detailed description of the parameters, see "Coincidence_rs232.vi" .

Controls and Indicators

TF **Stop**

Use this to stop in the middle of a data run. However, the parameters in the header of you datafile will no longer be accurate (e.g., you won't have as many points as the header says.)

Also, if you stop some other way you'll probably need to quit LabView and restart; you may even need to reboot the computer.

I32 **Experiment**

Displays which experiment is being performed: Coincidence, g(2), or Interference.

I32 **Number of points**

Number of measurements that are made during data acquisition.

I32 **Current Point Number**

The data point that the computer is currently acquiring.

DBL **ABB' Coincidence window**

Coincidence window for ABB' measurements.

Used to determine expected g(2) for 3-detector (single-photon) measurements. Basically, this parameter determines the number of expected accidental ABB' counts.

DBL **BB' Coincidence window**

Coincidence window for BB' measurements.

Needed to determine g(2) for 2-detector (classical) measurements.

DBL **BB' 2D window stdev**

Standard deviation of coincidence window for BB' measurements.

Needed to determine the error in g(2) for 2-detector (classical) measurements.

DBL **Update Period**

Time window (in s) for counters during data acquisition.

Data Directory

Path to directory where the data will be saved.

Comments

A space where you can enter comments about the data run. These get saved in the header of the data file.

Once you've entered the text, note that you must hit "Enter" on the NUMERIC KEYPAD, not the "Enter" (or "Return") on the regular keyboard for this text to be saved.

Data File Saved As

Path to the data file. The data file is automatically named using the date and time.

Counts A, B, B'

Singles counts in the time window specified by "Update Period" (upper left)

Counts AB, AB'

Coincidence counts in the time window specified by "Update Period" (upper left)

Counts ABB'

Three-fold coincidence counts in the time window specified by "Update Period" (upper left)

Graphs

Displays graphs of B and AB [Coincidence measurement], or **B & B'**, **AB & AB'**, and **g(2)**. [g(2) and Interference measurement.]

Ave. AB   [Coincidence measurement only]

Average value of AB coincidences. Updated when program ends.

AB Std. Dev.   [Coincidence measurement only]

Standard deviation of AB coincidences. Updated when program ends.

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: "COM1", "COM2", etc.

g(2) Measurements (both 2-Detector and 3-Detector)

All of the above parameters apply (except “Ave. AB” and “AB Std. Dev.”), plus the following:

Current g(2)

g(2) measurement for the current data point.

Ave. g(2)

Average of the g(2) measurements.

g(2) Std. Dev.

For 3-detector measurements this is the standard Deviation of the g(2) measurements.

For 2-detector measurements during data acquisition it is the standard deviation of the g(2) measurements. At the end this error is added in quadrature with the error in g(2) due to the uncertainty of the BB’ coincidence time window (“BB’ 2D window stdev”).

Expected g(2)

Calculate the expected value of the parameter g^(2) (0). Based on number of expected accidental coincidences.

Calculated differently depending on which experiment you're doing.

For 2-detector, 1-beam measurements, this is assumed to be 1.0 (a classical beam).

For all other measurements, when the vi first starts running it is set to 0.0, and is updated with the expected g(2) at the very end.

Formula (from Appendix A of Thorn AJP)

T: update period (counting window, in S)

dt: ABB’ coincidence window (in nS)

g(2)=(dt*1.0e-09/T)*A*((B/AB)+(B'/AB'))

Interference Measurements

Interference measurements assume a 3-detector setup for g(2) calculations.

All of the above parameters apply (except "Ave. AB" and "AB Std. Dev."), plus the following:

Starting stepper position

Position of stepper motor at start of scan.

End stepper position

Position of stepper motor at end of scan.

Over the course of a data run, the motor steps evenly between the starting and ending positions.

Current Position

Position of stepper motor for the current data point.

Appendix B – Hardy_Bell_rs232.vi

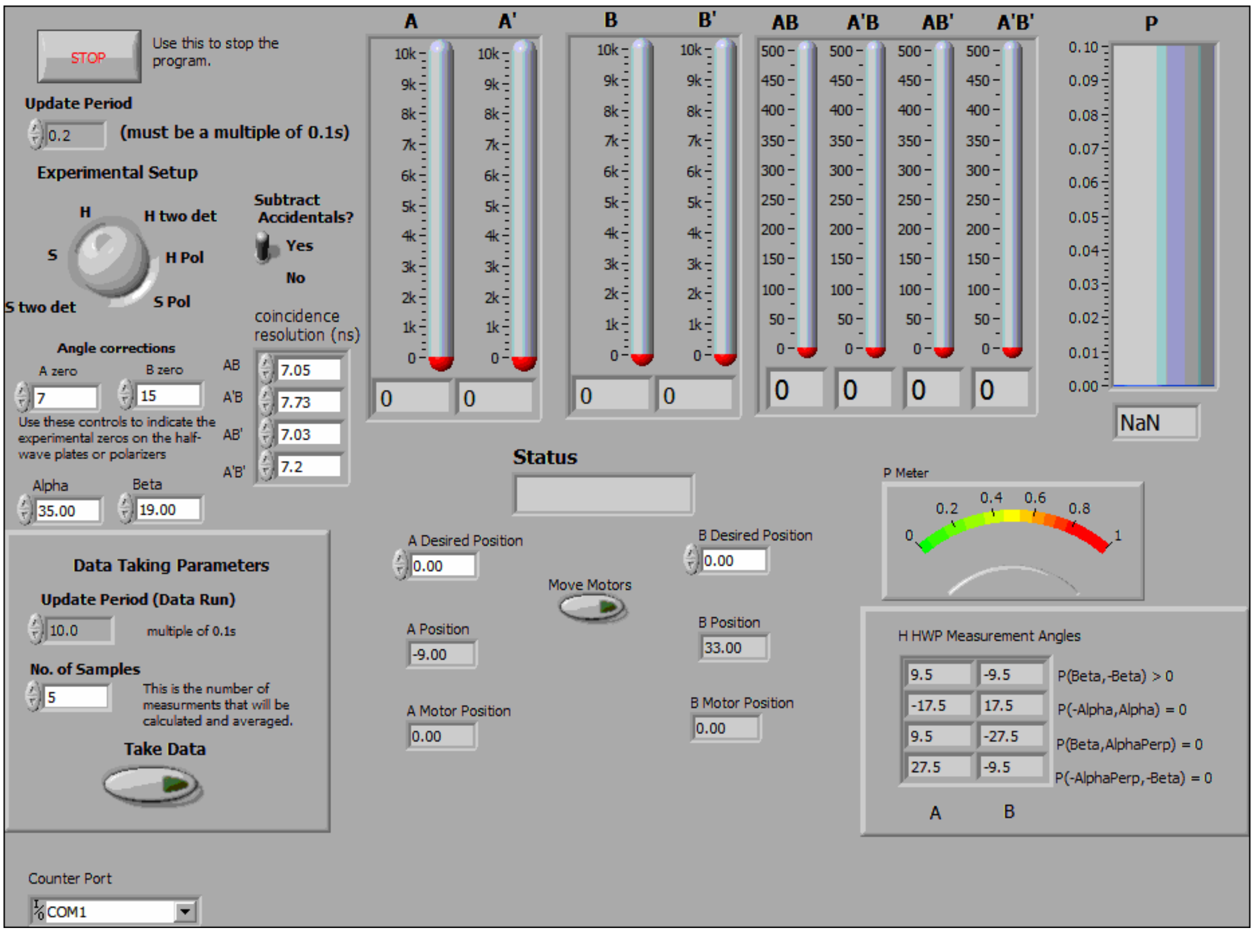
This appendix describes the LabView vi used to acquire data for Hardy's test of local realism, or a Bell (CSHS) inequality test.

I. Starting Out

When you first run the vi, the program that you see is:

Hardy_Bell_rs232.vi

Front Panel



Description

This is the program you see first when you start to run the experiment. It can be used for either Hardy-type or Bell-type measurements. It does not record data to a file right away, but displays the counters in real time so that you can align things. It also gives you interactive control over such things as the waveplate angles.

Once everything is aligned and the parameters are set, you press the "Take Data" button. This transfers control to another program which records a data set and saves it to a file.

This vi was specifically written for the Altera DE2 counter. Data streams to the computer from the DE2 over the RS232 serial port.

Waveplates (or polarizers) are controlled by a Newport ESP300 controller at GPIB address 1. On program start, during initialization, the motors home themselves. The motors then set the waveplates to 0 (using the corrections in "A zero" and "B zero").

The DE2 board must be properly set to record the proper coincidences. The coincidences that should be mapped to a given counter are:

A (Counter 0)

B (Counter 1)

A' (Counter 2)

B' (Counter 3)

AB (Counter 4)

A’B (Counter 5)

AB' (Counter 6)

A’B' (Counter 7)

On startup, the program initializes the motors and the counters. During this time the "Status" indicator reads "Initializing".

After initialization the program simply loops and displays the counts in a given time window (determined by the "update Period" control in the upper left.) Status reads "Reading Counters". This is useful for tweaking the alignment and adjusting parameters. Waveplates (or polarizers) are moved by first setting the desired waveplate angles in the " A(B) Desired Position" controls, and then pressing the "Move Motors" button. Status changes to "Moving Motors" while the motors are in motion.

Nothing is written to disk until the parameters are chosen and the "Take Data" button is pressed. This loads a second VI that records and saves data to disk. Parameters for this data acquisition phase are set in the "Data Taking Parameters" box.

During data acquisition the motors will automatically set the waveplates to the correct angles. Angles for a Bell measurement are fixed. Angles for a Hardy measurement are determined from the controls "Alpha" and "Beta".

Help for each of the controls and indicators can be obtained from the Contextual Help window <cntrl - H> by mousing over each control or indicator. Full documentation for each control and indicator can be obtained by printing using: File>Print>Custom, and then checking "All controls" and "Descriptions".

Controls and Indicators

TF **Stop**

Use this to stop. If you stop some other way you'll probably need to quit Labview and restart; you may even need to reboot the computer.

Update Period

[Must be a multiple of 0.1s]

Time window (in s) for the counters during setup phase (i.e., before the "Take Data" button is pressed.) Readings update once each time window if "Status" reads "Reading Counters".

Experimental Setup

Which Measurement to perform.

H: Hardy measurement (4 detectors)

H two det: Hardy measurement (2 detectors - waveplates)

H Pol: Hardy measurement (2 detectors - polarizers)

S: Bell measurement (4 detectors)

S two det: Bell measurement (2 detectors - waveplates)

S Pol: Bell measurement (2 detectors - polarizers)

A zero

Motor angle at which A waveplate axis is 0.

B zero

Motor angle at which B waveplate axis is 0.

Alpha (Hardy measurements only)

Angle Alpha used in the Hardy measurement.

Beta (Hardy measurements only)

Angle Beta used in the Hardy measurement.

Subtract Accidentals?

Determines whether or not accidental coincidences are subtracted. Controls data taking mode as well as tweaking mode.

coincidence resolution (ns)

The coincidence time resolutions (used in subtraction of accidentals).

Status

Program Status:

Initializing: initializing the counters and motors.

Reading Counters: Program is looping, reading the counters and updating the screen.

Moving Motors: Waveplates (polarizers) are rotating.

A Desired Position

Angle to set A waveplate to.

Movement occurs after "Move Motors" button is pressed.

B Desired Position

Angle to set B waveplate to.

Movement occurs after "Move Motors" button is pressed.

Move Motors

Set the motors to the "Desired Positions"

A Position

Current angle of the A waveplate.

B Position

Current angle of the B waveplate.

A Motor Position

Actual position of the motor for the A waveplate.

Not the same as "A Position" because of the 0 position correction specified in "A zero".

B Motor Position

Actual position of the motor for the B waveplate.

Not the same as "B Position" because of the 0 position correction specified in "B zero".

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: “COM1”, “COM2”, etc. Note that you might need to scroll down to see this control.

H HWP Measurement Angles (Hardy measurements only)

HWP angles at which probabilities that determine H will be measured. Determined from Alpha and Beta settings.

Useful so that you know which angles to set waveplates to when tweaking. Of course, for 2 detector measurements you need perpendicular combinations as well.

H Pol Measurement Angles (Hardy measurements with polarizers only)

Polarizer angles at which probabilities that determine H will be measured. Determined from Alpha and Beta settings.

Useful so that you know which angles to set waveplate to when tweaking. Of course, you need perpendicular combinations as well.

Counts A, A', B, B'

Singles counts in the time window specified by "Update Period" (upper left)

Counts AB, A'B, AB', A'B'

Coincidence counts in the time window specified by "Update Period" (upper left)

P (4-detector Hardy measurements only)

Probability of AB.

P Meter (4-detector Hardy measurements only)

Probability of AB

Data Taking Parameters

Update Period (Data Run)

[Must be a multiple of 0.1s]

Time window (in s) for counters during data acquisition.

This applies after the "Take Data" button has been pressed.

No. of Samples

Number of independent measurements (of H for Hardy measurements, or S for Bell Measurements) that are made during data acquisition. These are averaged to get the mean and error of the measurement.

Error measurements are essentially useless if this is less than 5. 10 is a good number for reasonable statistics.

TF **Take Data**

Leave the setup "tweaking" mode and switch to data acquisition mode.

Bell Measurements

DBL **E Meter** (4-detector Bell measurement only)

Expectation Value

DBL **E** (4-detector Bell measurement only)

Expectation Value

[DBL] **S HWP Measurement Angles**

HWP angles at which probabilities that determine S will be measured.

Useful for 4 detector measurements so that you know which angles to set waveplates to when tweaking. Angles labeled + correspond to expectations you want to be as positive as possible, while those labeled - should be as negative as possible.

Not particularly useful for 2 detector measurements.

[DBL] **S Pol Measurement Angles**

Polarizer angles at which probabilities that determine S will be measured.

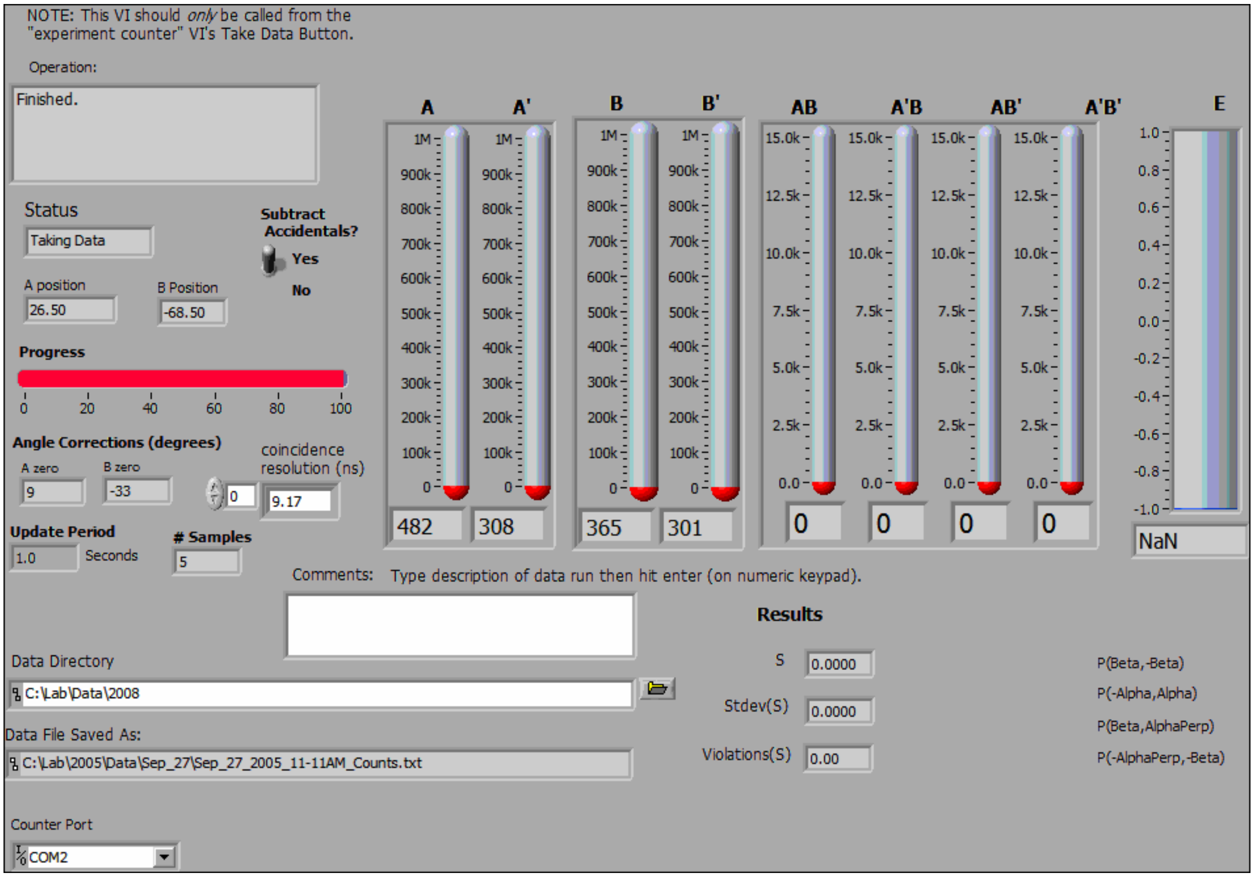
Not a particularly useful parameter for 2 detector measurements.

II. Taking Data

When you move to data taking mode, the program you see is:

Hardy-Bell-Recorder_rs232.vi

Front Panel



Description

This VI should ONLY be called from a "Hardy_Bell_rs232" VI--necessary parameters are set there.

This program records data (using parameters set in the "Hardy_Bell_rs232" VI) and saves the data to a file.

Controls and Indicators

Operation

Displays what the program is trying to do. Normally this shows what the angles of the motors are.

There are 2 angles shown -- the waveplate angles are given first and the actual motor angles are in parentheses (they are different by the 0 offset displayed in "A zero" and "B zero".)

When the program is done this reads "Finished." Values for probabilities (expectations for Bell) and H (S for Bell) are not updated until this happens.

Status

Program Status:

Moving Motors: waveplate (polarizer) motors are in motion.

Waiting: Clearing out the counter buffers after motors move.

Taking Data: Data is being collected.

A position

Current position of A motor.

B Position

Current position of B motor.

Subtract Accidentals?

Determines whether or not accidental coincidences are subtracted.

coincidence resolution (ns)

Array of the coincidence time resolutions (used in subtraction of accidentals).

Progress

Rough indication of what percentage of the data run is complete.

A zero Motor angle at which A waveplate axis is 0.

B zero Motor angle at which B waveplate axis is 0.

Update Period

Time window (in s) for counters.

 # Samples

Number of independent measurements (of H for Hardy measurements, or S for Bell Measurements) that are made during data acquisition. These are averaged to get the mean and error of the measurement.

Error measurements are essentially useless if this is less than 5. 10 is a good number for reasonable statistics.

Comments

A space where you can enter comments about the data run. These get saved in the header of the data file.

Note that you must hit "Enter" on the NUMERIC KEYPAD, not the "Enter" (or "Return") on the regular keyboard for this text to be saved.

Data Directory

Path to directory where the data will be saved.

Data File Saved As:

Path to the data file. The data file is automatically named using the date and time.

Alpha

Angle Alpha used in the Hardy measurement.

Beta

Angle Beta used in the Hardy measurement.

H (Hardy measurement only)

Mean value of H. Updated when "operation" reads "Finished".

Stdev(H) (Hardy measurement only)

Standard Deviation of H. Updated when "operation" reads "Finished".

Violations(H) (Hardy measurement only)

Number of standard deviations that H is above 1. Updated when "operation" reads "Finished".

P Stdev(P)

Probabilities and standard deviations of the probabilities for the indicated angles. Udated when "Operation" reads "Finished".

P (4 detector Hardy only)

Probability of AB

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: “COM1”, “COM2”, etc.

Bell Measurements

S (Bell measurement only)

Mean Value of S. Updated when "Operation" reads "Finished".

Stdev(S) (Bell measurement only)

Standard deviation of S. Updated when "Operation" reads "Finished".

Violations(S) (Bell measurement only)

Number of standard deviations that S is above 2. Updated when "Operation" reads "Finished".

E (4 detector Bell only)

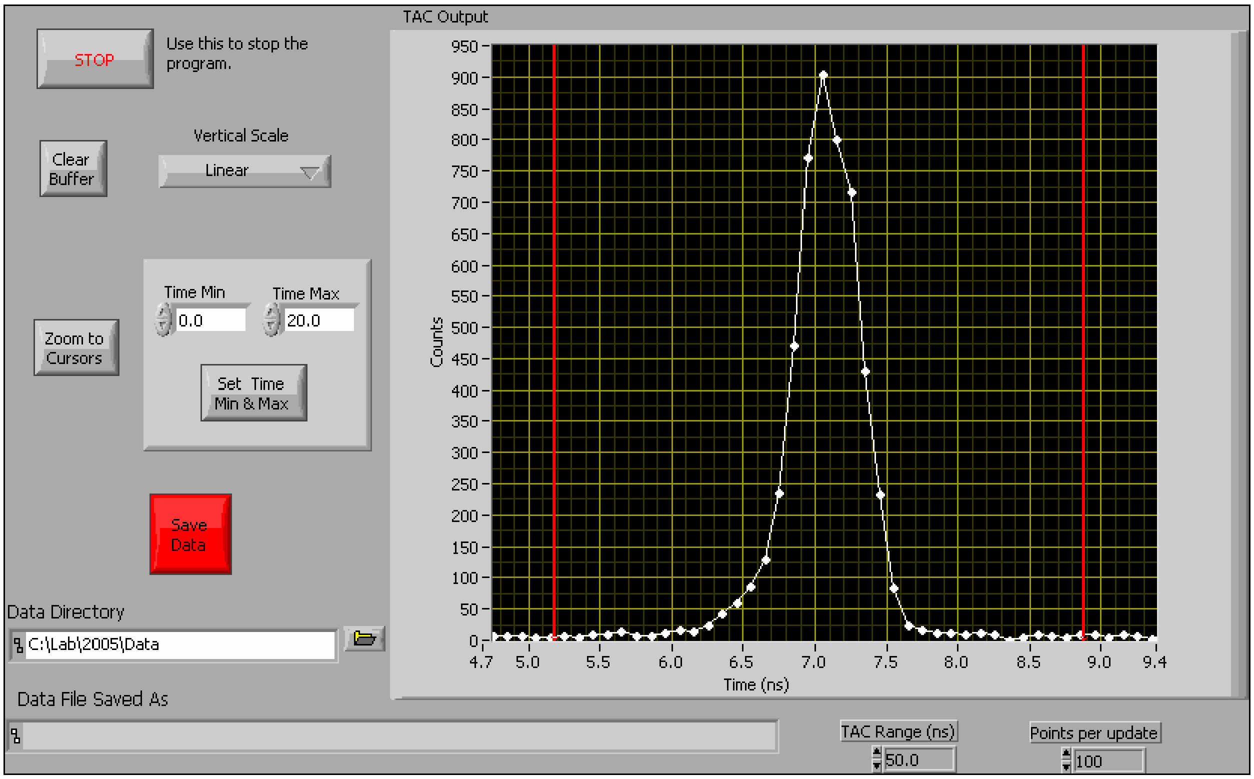
Expectation value.

Appendix C - MCA.vi

This appendix describes the LabView vi used to mimic the behavior of a multichannel analyzer (MCA). This is useful for measuring the arrival time of photons.

MCA.vi

Front Panel



Description

This VI emulates a multi-channel-analyzer (MCA). An MCA essentially digitizes a series of voltage pulses, and creates a histogram of the pulse heights. The purpose of this VI is to analyze the voltage pulses from a Time-to-Amplitude Converter (TAC) [This VI was tested using the TAC in an ORTEC 567 TAC/SCA module].

The start and stop pulses going into the TAC come from photon counters, and the TAC output voltage is proportional to the time between the start and stop. Thus, the MCA is creating a histogram of the time interval between the arrivals of the two photons.

The main difference between this VI and a real MCA is that an MCA takes only one input-the voltage pulses. This VI also needs timing information about when the pulses are arriving. Fortunately, this can be obtained from the Valid Conversion output of the TAC. The Valid Conversion output is an approximately 3 microsecond long TTL pulse coincident with the TAC output pulse.

We have tested this VI with 2 different National Instruments multifunction cards: 6036E and 6052E. With these cards there are two clock signals that are needed to perform an A/D conversion: the trigger and the sample clock.

The trigger (input through PFI0) comes directly from the Valid Conversion output of the TAC. The program is configured to trigger on a low-to-high transition of the trigger -triggering arms the A/D, but does not actually cause an A/D conversion.

The program is configured to perform an A/D conversion on a high-to-low transition of the Sample Clock. The Sample Clock is obtained by generating a delayed pulse from the trigger. The delayed pulse is generated by one of the counter/timers on the multifunction board: counter 0. The output of counter 0 is sent directly to the sample clock, so the user need only input the trigger pulse to PFI0, and the sample clock will take care of itself (the user can monitor the counter 0 output to observe the timing of the sample clock). The timing can be changed by adjusting the duration of the pulse (using the “High Time”) parameter in the block diagram).

The TAC output to be digitized is input though Analog Input Channel 0.

Unlike many VI's you'll encounter, the screen updates after a specified number of data points are acquired (determined by the parameter "Points per update"), not after a specific time interval. Because of this, if the detectors are off, nothing will happen.

NOTE: The A/D boards we use are just barely fast enough to catch the 3 microsecond long TAC output (the width of the TAC output could also be increased for better results)--indeed, they're probably technically too slow. Because of this, the accuracy of the measurement of the TAC output is not very good (can be off by as much as 10 or 20%), which means that the time scale is poorly calibrated. However, the measurement is repeatable, so the time scale could be calibrated much more accurately. Despite this problem, the VI works quite well enough to accomplish its main goals-to display a bump in the histogram of arrival times between the photons from two detectors, and to allow one to set the SCA window to select coincidences (only needed if you’re using the TAC/SCA for coincidence counting).

ALSO NOTE: This vi has only been seriously tested for START-STOP times ranging from a few up to about 30 ns. With much longer intervals than this the output pulses may be delayed, and the timing may change.

Rough Timing diagram:

```
          _____________
_________|             |____________   Trigger (PFI0)
                __
_______________|  |_________________   Sample clock (counter 0)
             _________
 ___________/         \_____________   A/D Ch 0
```

Help for each of the controls and indicators can be obtained from the Contextual Help window <cntrl - H> by mousing over each control or indicator. Full documentation for each control and indicator can be obtained by printing using: File>Print>Custom, and then checking "All controls" and "Descriptions"

FINAL NOTE: For whatever reason, the vi “aquire_daqmx_subvi.vi” does NOT get saved if you save the entire vi hierarchy. So, you explicitly need to copy this vi to the new library from the old one. After you copy it, LabView will STILL look for it in the old location, so you again need to explicitly find this vi for LabView.

Controls and Indicators

Stop

Use this to stop.

Clear Buffer

Clears the histogram memory, and the accumulation starts over again.

Vertical Scale

Change the scaling of the vertical scale. Options are Linear and Logarithmic.

Zoom to cursors

Horizontal scale will zoom in to the region specified by the cursor positions.

Time Min

Set minimum of horizontal axis to this value after pressing "Set Time Min & Max".

Time Max

Set maximum of horizontal axis to this value after pressing "Set Time Min & Max".

Set min & max

Set the minimum and maximum values of the horizontal axis to those specified.

Save Data

Save the current data to a file. Program exits after this is done.

Data Directory

Path to directory where the data will be saved.

Data File Saved As

Path to the data file. The data file is automatically named using the date and time.

TAC Range (ns)

The full scale range of the TAC output. Used to scale the horizontal axis.

Points per update

Number of data points acquired before updating the screen. Remember, the screen updates after a specified number of data points are acquired, not after a specific time interval.

If you have very low count rates, you might want to decrease this from it's default value of 100.

TAC Output

Histogram of the time interval distribution.

Appendix D – Coincidence_time_res_rs232.vi

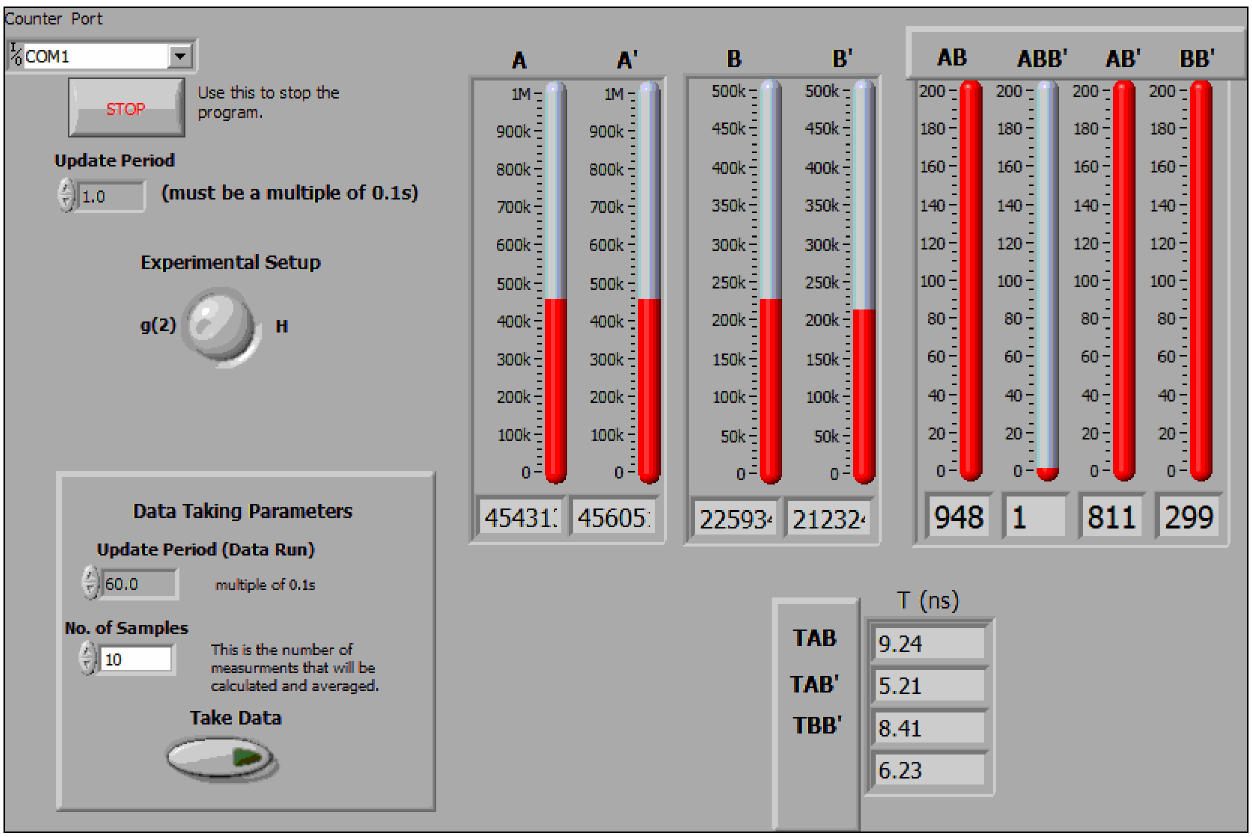
This appendix describes the LabView vi used to calibrate the coincidence time resolution.

I. Starting Out

The appearance of this vi will change slightly depending on the experiment you are doing (as determined by the **Experimental Setup** knob on the vi.)

Coincidence_time_res_rs232.vi

Front Panel



Description

This is the program you use to calibrate the coincidence time resolution of your coincidence circuit. It was specifically written for the Altera DE2 counter. Data streams to the computer from the DE2 over the RS232 serial port.

In order to get accurate readings, the SPCMs must be illuminated by uncorrelated random streams of photons. One way to do this is to simply place a white card after the downconversion crystal to scatter blue pump light. There are plenty of scattered photons to get through the RG780 blocking filters. The intensity level can be adjusted somewhat by moving the card closer or further away from the exit face of the crystal. Adjusting iris diameters can help as well. 500k to 1M singles cps on each detector works well.

For example, with random photons the coincidence time resolution TAB for AB coincidences is TAB=(AB*T)/(A*B) , where T is the counting time, AB the number of coincidences, and A and B the number of singles.

There are 2 modes:

1) g(2)measures the resolution for AB, AB' and BB' coincidences. (random photons do not give an accurate measurement of the ABB' triple time because for those measurements you WANT at least one valid coincidence).

2) H measures the time resolution for AB,. A'B, AB' and A'B' coincidences.

NOTE: The coincidence determination switches on the DE2 must be matched to the "Experimental Setup" switch here on the vi—appropriate switch settings are given below.

The program does not record data to a file right away, but displays the counters in real time so that you can align things.

Once everything is aligned and the parameters are set, you press the "Take Data" button. This transfers control to another program which records a data set and saves it to a file.

The DE2 board must be properly set to record the proper coincidences. The coincidences that should be mapped to a given counter are:

When set to g(2):

A (Counter 0)

B (Counter 1)

A' (Counter 2) – unused for g(2) measurements

B' (Counter 3)

AB (Counter 4)

ABB' (Counter 5) – used for g2 measurements, but not by this program

AB' (Counter 6)

BB' (Counter 7)

When set to H:

A (Counter 0)

B (Counter 1)

A' (Counter 2)

B' (Counter 3)

AB (Counter 4)

A’B (Counter 5)

AB' (Counter 6)

A’B' (Counter 7)

On startup, the program initializes the com port.

After initialization the program simply loops and displays the counts in a given time window (determined by the "Update Period" control in the upper left.) This is useful for tweaking the alignment and adjusting parameters.

Nothing is written to disk until the parameters are chosen and the "Take Data" button is pressed. This loads a second VI that records and saves data to disk. Parameters for this data acquisition phase are set in the "Data Taking Parameters" box.

Help for each of the controls and indicators can be obtained from the Contextual Help window <cntrl - H> by mousing over each control or indicator. Full documentation for each control and indicator can be obtained by printing using: File>Print>Custom, and then checking "All controls" and "Descriptions".

Controls and Indicators

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: “COM1”, “COM2”, etc.

Experimental Setup

Which calibration to perform.

1) g(2)measures the resolution for AB, AB' and BB' coincidences.

2) H measures the time resolution for AB, A'B, AB' and A'B' coincidences.

Update Period

[Must be a multiple of 0.1s]

Time window (in s) for the counters during setup phase (i.e., before the "Take Data" button is pressed.)

Stop

Use this to stop. It takes a little longer, but this way, the board gets reset. If you stop some other way you'll probably need to quit Labview and restart; you may even need to reboot the computer.

Counts A, A', B & B'

Singles counts in the time window specified by "Update Period" (upper left)

Coincidences

AB, A’B, AB’, A’B’ for H measurements

AB, ABB’, AB’, BB’ for g2 measurements.

Coincidence counts (doubles or triples as indicated) in the time window specified by "Update Period" (upper left)

T (ns)

Values of coincidence time resolution (in ns) for the current iteration.

No. of Samples

Number of independent measurements that are made during data acquisition. These are averaged to get the mean and error of the measurement.

Error measurements are essentially useless if this is less than 5. 10 is a good number for reasonable statistics.

Update Period (Data Run)

Time window (in S) for counters during data acquisition.

This applies after the "Take Data" button has been pressed.

Take Data

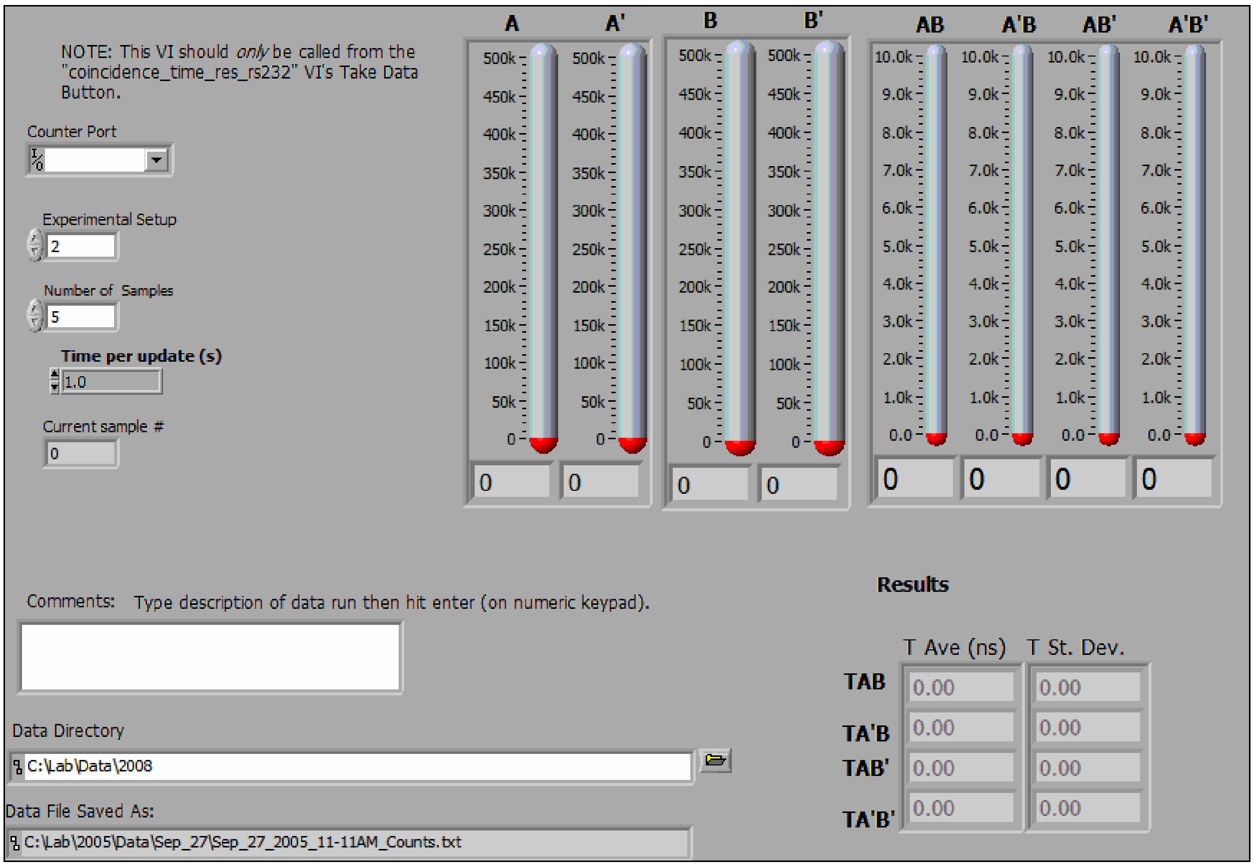
Leave the setup "tweaking" mode and switch to data acquisition mode.

II. Taking Data

When you move to data taking mode, the program you see will look something like that shown below. Again, the appearance of this vi will change slightly depending on the calibration you are doing.

coincidence_time_res_recorder.vi

Front Panel



Description

This VI should ONLY be called from an "coincidence_time_res_rs232" VI--necessary parameters are set there.

This program records data (using parameters set in the "coincidence_time_res_rs232" VI) and saves the data to a file.

Controls and Indicators

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: “COM1”, “COM2”, etc.

Experimental Setup

Which calibration is being performed.

1: g2 calibration

2: H calibration

Number of Samples

Number of independent measurements that are made during data acquisition. These are averaged to get the mean and error of the measurement.

Time per update (s)

Time window (in s) of counters during data acquisition.

Current sample #

Which sample number is presently being measured.

Counts A, A', B & B'

Singles counts in the time window specified by "Time per update"

Coincidences

AB, A’B, AB’, A’B’ for H measurements

AB, ABB’, AB’, BB’ for g2 measurements.

Coincidence counts (doubles or triples as indicated) in the time window specified by "Time per update"

Comments

A space where you can enter comments about the data run. These get saved in the header of the data file.

Note that you must hit "Enter" on the NUMERIC KEYPAD, not the "Enter" (or "Return") on the regular keyboard for this text to be saved.

Data Directory

Path to directory where the data will be saved.

Data File Saved As:

Path to the data file. The data file is automatically named using the date and time.

T Ave (ns)

Measured average time resoltion in ns.

T St. Dev.

Standard deviation of the measured time resolutions in ns.

Appendix E – Angle_scan_rs232.vi

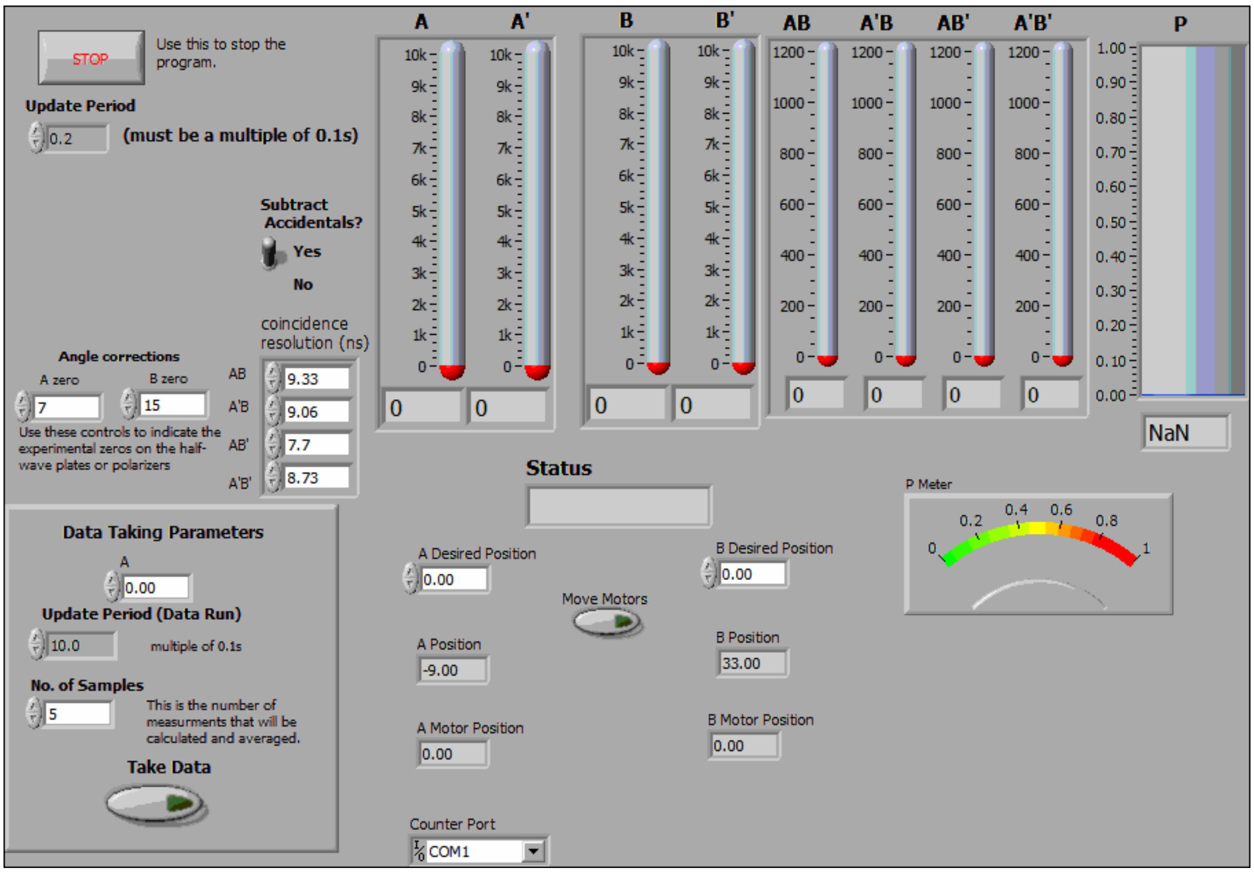
This appendix describes the LabView vi used to examine two photon polarization correlations (joint probabilities) as a function of angle.

I. Starting Out

When you first run the vi, the program that you see is:

Angle_scan_rs232.vi

<u>Front Panel</u>



<u>Description</u>

This is the program you see first when you start to run the experiment. It requires a 4-detector setup. It does not record data to a file right away, but displays the counters in real time so that you can align things. It also gives you interactive control over such things as the waveplate angles.

Once everything is aligned and the parameters are set, you press the "Take Data" button. This transfers control to another program which records a data set and saves it to a file.

This vi was specifically written for the Altera DE2 counter. Data streams to the computer from the DE2 over the RS232 serial port.

Waveplates (or polarizers) are controlled by a Newport ESP300 controller at GPIB address 1. On program start, during initialization, the motors home themselves. The motors then set the waveplates to 0 (using the corrections in "A zero" and "B zero").

The DE2 board must be properly set to record the proper coincidences. The coincidences that should be mapped to a given counter are:

A (Counter 0)

B (Counter 1)

A' (Counter 2)

B' (Counter 3)

AB (Counter 4)

A’B (Counter 5)

AB' (Counter 6)

A’B' (Counter 7)

On startup, the program initializes the motors and the counters. During this time the "Status" indicator reads "Initializing".

After initialization the program simply loops and displays the counts in a given time window (determined by the "update Period" control in the upper left.) Status reads "Reading Counters". This is useful for tweaking the alignment and adjusting parameters. Waveplates (or polarizers) are moved by first setting the desired waveplate angles in the " A(B) Desired Position" controls, and then pressing the "Move Motors" button. Status changes to "Moving Motors" while the motors are in motion.

Nothing is written to disk until the parameters are chosen and the "Take Data" button is pressed. This loads a second VI that records and saves data to disk. Parameters for this data acquisition phase are set in the "Data Taking Parameters" box.

During data acquisition the motors will automatically set the waveplates to the correct angles. The waveplate for the A beam is fixed by the Data Taking Parameter “A”. The angle of waveplate B is scanned over 17 equally spaced values: 0, 5.625, 11.25, ... Remember that these are WAVEPLATE angles; since polarization rotates twice as fast as the waveplate, the corresponding polarization angles are twice as large. So, the A polarization angle is twice what is set by the A control, while the B polarization angles are 0, 11.25, 22.5, ... What gets recorded in the data file are waveplate angles, not polarization angles.

Help for each of the controls and indicators can be obtained from the Contextual Help window <cntrl - H> by mousing over each control or indicator. Full documentation for each control and indicator can be obtained by printing using: File>Print>Custom, and then checking "All controls" and "Descriptions".

Controls and Indicators

TF **Stop**

Use this to stop. If you stop some other way you'll probably need to quit Labview and restart; you may even need to reboot the computer.

DBL **Update Period**

[Must be a multiple of 0.1s]

Time window (in s) for the counters during setup phase (i.e., before the "Take Data" button is pressed.) Readings update once each time window if "Status" reads "Reading Counters".

A zero

Motor angle at which A waveplate axis is 0.

B zero

Motor angle at which B waveplate axis is 0.

Subtract Accidentals?

Determines whether or not accidental coincidences are subtracted. Controls data taking mode as well as tweaking mode.

coincidence resolution (ns)

The coincidence time resolutions (used in subtraction of accidentals).

Status

Program Status:

Initializing: initializing the counters and motors.

Reading Counters: Program is looping, reading the counters and updating the screen.

Moving Motors: Waveplates (polarizers) are rotating.

A Desired Position

Angle to set A waveplate to.

Movement occurs after "Move Motors" button is pressed.

B Desired Position

Angle to set B waveplate to.

Movement occurs after "Move Motors" button is pressed.

Move Motors

Set the motors to the "Desired Positions"

A Position

Current angle of the A waveplate.

B Position

Current angle of the B waveplate.

A Motor Position

Actual position of the motor for the A waveplate.

Not the same as "A Position" because of the 0 position correction specified in "A zero".

B Motor Position

Actual position of the motor for the B waveplate.

Not the same as "B Position" because of the 0 position correction specified in "B zero".

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: “COM1”, “COM2”, etc. Note that you might need to scroll down to see this control.

Counts A, A’, B, B’

Singles counts in the time window specified by “Update Period” (upper left)

Counts AB, A’B, AB’, A’B’

Coincidence counts in the time window specified by “Update Period” (upper left)

P

Probability of AB.

P Meter

Probability of AB

Data Taking Parameters

A

Angle of A waveplate--fixed for duration of the data taking.

Update Period (Data Run)

[Must be a multiple of 0.1s]

Time window (in s) for counters during data acquisition.

This applies after the "Take Data" button has been pressed.

No. of Samples

Number of independent measurements that are made during data acquisition. These are averaged to get the mean and error of the measurement.

Error measurements are essentially useless if this is less than 5. 10 is a good number for reasonable statistics.

Take Data

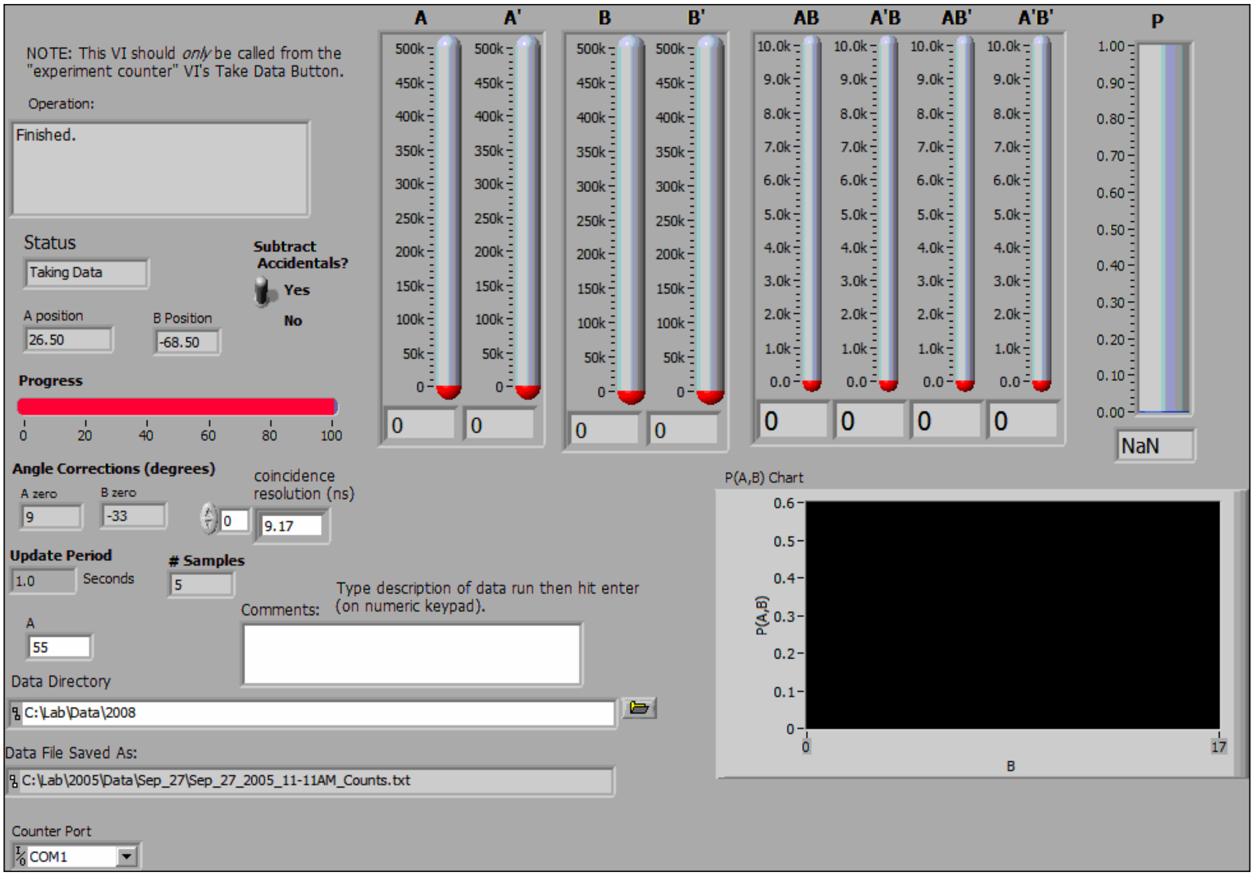
Leave the setup "tweaking" mode and switch to data acquisition mode.

II. Taking Data

When you move to data taking mode, the program you see is:

angle_scan_Recorder_rs232.vi

Front Panel



Description

This VI should ONLY be called from an "angle_scan_rs232" VI--necessary parameters are set there.

This program records data (using parameters set in the "angle_scan_rs232" VI) and saves the data to a file.

Controls and Indicators

Operation

Displays what the program is trying to do. Normally this shows what the angles of the motors are.

There are 2 angles shown -- the waveplate angles are given first and the actual motor angles are in parentheses (they are different by the 0 offset displayed in "A zero" and "B zero".)

When the program is done this reads "Finished." Values for probabilities (expectations for Bell) and H (S for Bell) are not updated until this happens.

Status

Program Status:

Moving Motors: waveplate (polarizer) motors are in motion.

Waiting: Clearing out the counter buffers after motors move.

Taking Data: Data is being collected.

A position

Current position of A motor.

B Position

Current position of B motor.

Subtract Accidentals?

Determines whether or not accidental coincidences are subtracted.

coincidence resolution (ns)

Array of the coincidence time resolutions (used in subtraction of accidentals).

Progress

Rough indication of what percentage of the data run is complete.

A zero Motor angle at which A waveplate axis is 0.

B zero Motor angle at which B waveplate axis is 0.

Update Period

Time window (in s) for counters.

 # Samples

Number of independent measurements (of H for Hardy measurements, or S for Bell Measurements) that are made during data acquisition. These are averaged to get the mean and error of the measurement.

Error measurements are essentially useless if this is less than 5. 10 is a good number for reasonable statistics.

A

Angle of A waveplate--fixed for duration of the data taking.

Comments

A space where you can enter comments about the data run. These get saved in the header of the data file.

Note that you must hit "Enter" on the NUMERIC KEYPAD, not the "Enter" (or "Return") on the regular keyboard for this text to be saved.

Data Directory

Path to directory where the data will be saved.

Data File Saved As:

Path to the data file. The data file is automatically named using the date and time.

P

Probability of AB

P(A,B) Chart

Plot of the joint probability P(A,B) as the B waveplate is scanned.

Counter Port

A string that identifies the serial communication port that the DE2 board is attached to: “COM1”, “COM2”, etc.