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Summer Student Report 2019

Lucas van Ham

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I. INTRODUCTION

The ALPHA (Antimatter Laser PHysics Apparatus) experiment investigates the differences between matter and antimatter. Positrons and antiprotons are mixed to create antihydrogen, which is trapped in a magnetic field and has a sufficiently long lifetime for experimentation [1]. Using this setup, ALPHA has investigated the 1S-2S transition of antihydrogen using double-photon excitation [~~1~~2]. They found this value agrees with that of hydrogen [~~2~~] with a relative precision of 2×10^-12, two orders of magnitude more precise than previously determined by ALPHA [3,4][~~1,2~~]. Research into other antihydrogen-related science is ongoing.

More recently, the experiment has expanded with the addition of ALPHA-g, designed to measure the gravitational free-fall of antihydrogen. The main focus of this experiment is to first determine the sign of g-bar, the gravitational acceleration of anti-matter on Earth, and then determine g-bar with an accuracy of 1%. The beamline in the ALPHA-g apparatus has a vertical design such that the effect of gravity on the antiparticles can be more easily determined. The rest of the experiment has undergone a redesign such that ALPHA can steer posantitrons and antiprotons ~~hydrogen~~ towards ALPHA-g. The experimental setup is shown in Figure~~.~~ 1.

The addition of ALPHA-g has added significantly to the complexity of the experiment. The data sent by sensors of both experiments is located on a single webpage called MIDAS. Finding specific information from this webpage is difficult as there are dozens of different sections and operators sometimes have to spend more time than preferred on finding these items. In short, operators have no way of seeing system diagnostics at a glance. The aim of this project, "AlphaTV", is to consolidate the information from many

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sensors and control systems and display them in a single interactive diagram that can be easily consulted.

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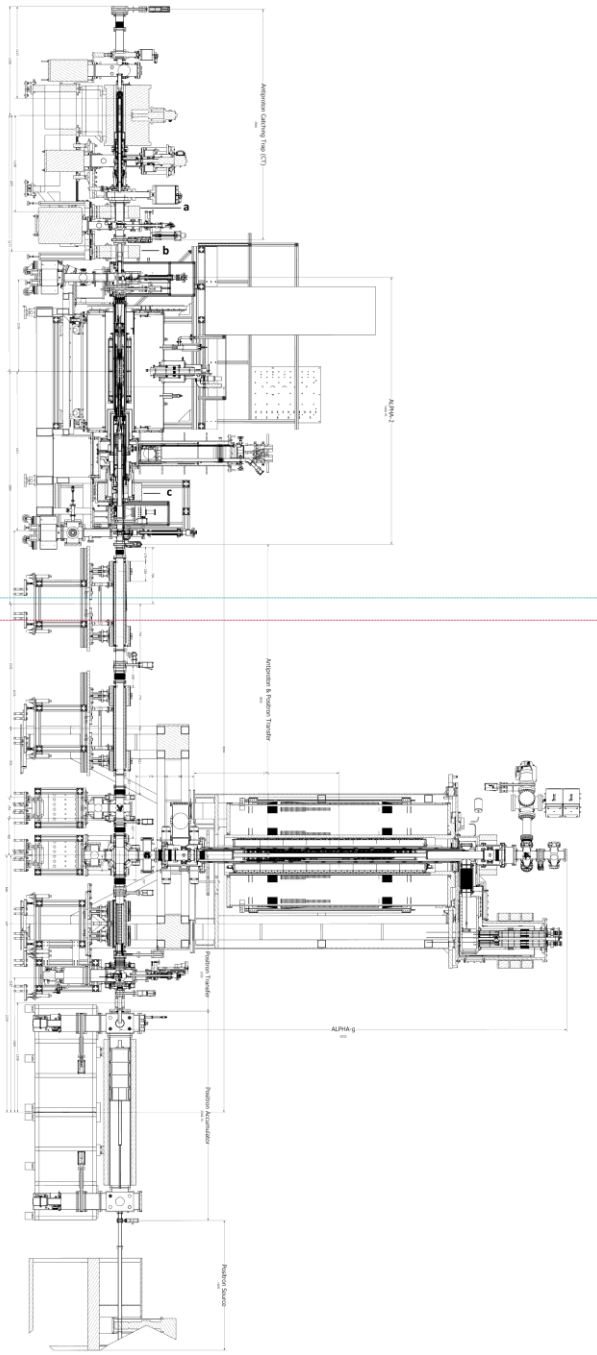

Figure 1: Experimental setup of ALPHA-2 and ALPHA-g. The labelled items are: 1. Catching Trap (CT), 2. Atom Trap (AT), 3. ALPHA-g, 4. Positron Accumulator, 5. Positron source. Items a, b, c are transfer coils (see II.iii.). The CT and AT form ALPHA-2.

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~~Figure 1: Experimental setup of ALPHA-2 and ALPHA-g. The labelled items are: 1. Catching Trap (CT), 2. Atom Trap (AT), 3. ALPHA-g, 4. Positron Accumulator, 5. Positron source. Items a, b, c are transfer coils (see II.iii.). The CT and AT form ALPHA-2.~~

make use of scintillators; ~~Incoming~~ gamma rays from nearby positron-electron annihilations are ~~multiplied in a photomultiplier tube (PMT),~~ absorbed by the scintillators which emit photons within the visible spectrum. These photons can be detected by a photomultiplier tube.~~and when these photons impinge the material, the material luminesces. The intensity of luminescence increases with the amount of gamma rays entering the PMT, and a sensor reads this intensity.~~ AlphaTV must also show the images taken at micro-channel plate detectors (MCPs) in different locations. When ~~positrons~~ charged particles hit an MCP, they cause a cascade of ~~secondary~~ electrons. These electrons are accelerated across a potential and are ~~collected by~~ imaged using a phosphor screen [5]. ~~[3].~~

~~Fig 1. Experimental setup of ALPHA 2 and ALPHA g. The labelled items are: 1. Catching Trap (CT), 2. Atom Trap (AT), 3. ALPHA g, 4. Positron Accumulator, 5. Positron source~~

i. First version

The first version was designed by ~~Dr. Steven Jones~~S. A. Jones. This version could show the status of equipment in CT and AT but did not include any of the beamline or ALPHA-g equipment.

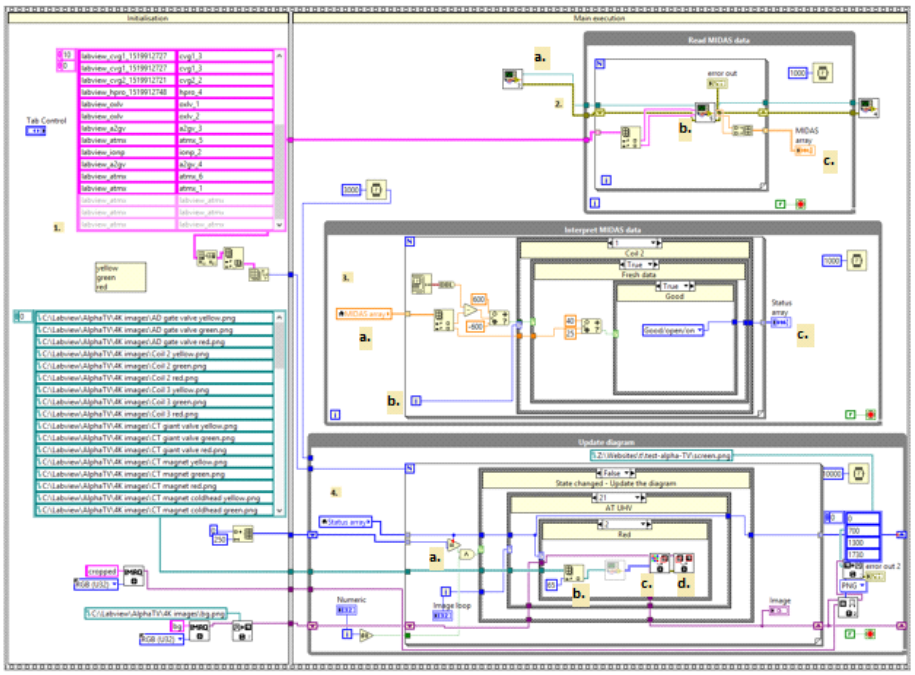

Figure 2: Version v0-1 of AlphaTV. The subVI in the "Update diagram" WHILE loop is grayed out because it has been changed in a later version.

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In the initialization frame, the locations of all items on the ~~mySQL~~MySQL server had to be entered into an array of strings, and all of the image file paths had to be entered into an array of paths. The background is initialized using LabVIEW Vision tools.

The main execution follows these steps:

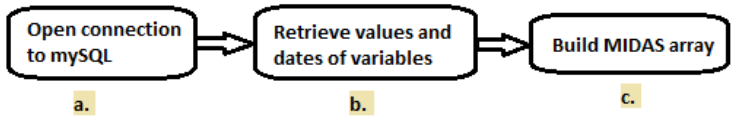

Figure 3: Stage 1 of the main execution (2). The connection to mySQL is opened by the "Open connection" subVI, and data is retrieved by the "Get last value" subVI.

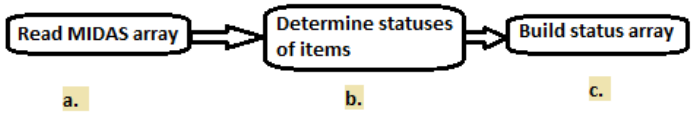

Figure 4: Stage 2 of the main execution (3).

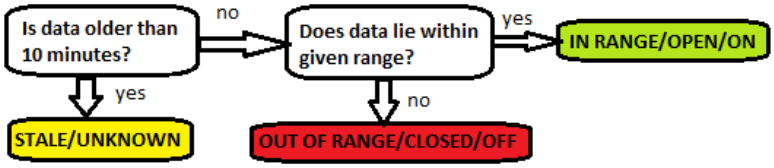

Figure 5: Flowchart of how the status of an item is determined.

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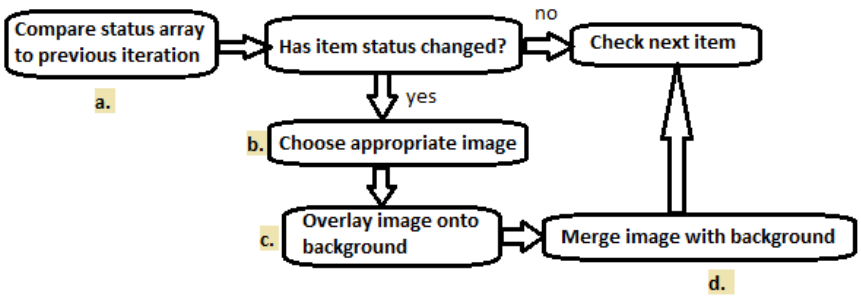

Figure 6: Stage 3 of the main execution (4). Images are converted into bitmaps by the "overlay transparency v2" subVI. The overlaying and merging of images is done by LabVIEW Vision VIs.

This first version provided a solid foundation for the AlphaTV project. Its design was simple and straightforward; the main premise of this version is still being used in the most recent version. At the start we made some minor improvements: adding the yet to be added items to the diagram as well as indicators for (almost) all items and a message log. The indicators were the LabVIEW default indicators that were manually placed in the desired location. The message log would contain the list of all "bad" and "stale" items and states why either is the case for the item.

Keeping this version as we went forward did present some issues. For one, it had several bugs that were patched in an arguably crude manner. Rather than the symptoms of these bugs being treated, the root causes had to be dealt with.

Each item needed a separate cases in case structures in multiple locations and so the program would get more disorganized as more items were added. For the part that overlays the correct image onto the diagram alone we would have over 200 different cases in total if we had used this method in the final version. We would also have had to manually enter the index corresponding to the appropriate image in each of these cases (at the time of the switch to the spreadsheet, this index reached above 150).

A more serious issue presented itself after all beamline items were included in the functionality of the program. As the main sequence was running, Windows task manager would show the memory usage rising rapidly. As this usage would breach the threshold of 2 GB, the program would stop and display a memory error message.

We spent a considerable amount of time finding the memory leak. After much philosophizing we moved the functions that create and merge the image overlay outside of each individual item case structure and into the "state changed" case structure. This fixed the issue. The theory is that LabVIEW allocated memory for the Vision subVIs in all three (color) instances in a single item case when the item was to be updated. Only one of these instances was called and only the memory for this instance was deallocated after the function had finished. As time went on, all available memory would be allocated before the first loop iteration could be finished, and the program crashed. This was previously not a problem because with fewer items the memory leak would not be large enough to crash LabVIEW.

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ii. Spreadsheet

In an attempt to improve the user experience of anyone modifying the block diagram, we created a spreadsheet containing the information of all items called “item manager.csv”. The block diagram has been simplified to consist of only a few generic cases. This allows for additional features to be added by simply inserting new columns into the spreadsheet. The spreadsheet is read by the “ATV CSV reader” subVI, which formats all entries in this spreadsheet appropriately. More about the spreadsheet can be read in Appendix B.

Using a spreadsheet meant that we could no longer use the LabVIEW default indicators to display the values of the items onto the diagram. We combat this by specifying the coordinates on the diagram where the indicator text is to be displayed, then use LabVIEW Vision tools to overlay this text onto the diagram. This overlay is then merged in the same way the other images are. In the past we had to hover the mouse over the diagram, and we had to memorize the coordinates in the bottom-left corner of the image indicator. To ease this process, we added a button on the info panel that records the coordinates of the mouse after you press the Enter key.

iii. Additional statuses

Aside from the regular status array that is built as part of the main sequence, AlphaTV allows for multiple factors determining the status of an item. This happens after the status array is built and the additional status can overwrite the status determined before. New cases for this feature are added by creating the appropriate case and updating the amount of times the FOR loop should run. The items that currently make use of this feature are:

- Transfer coils: the status of the transfer coils is determined by their currents and their temperatures. If the temperature of a specific coil exceeds its allowed value, the additional status of this coil will be “bad” and will overwrite the status determined by the coil current.

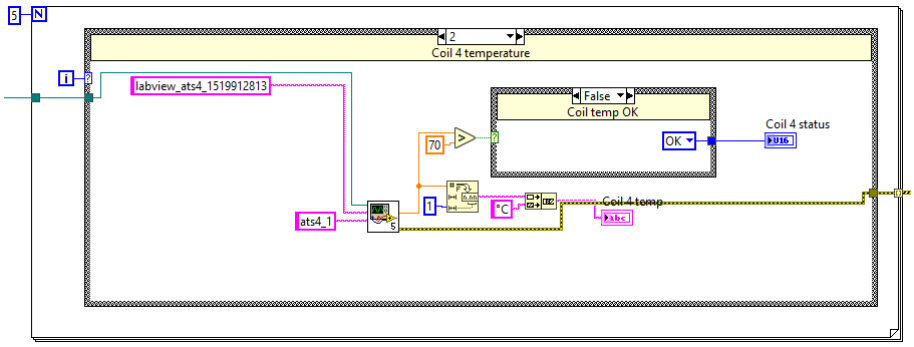

Figure 7: An example of an item’s (transfer coil 4) additional status (Coil 4 status) being determined. If the transfer coil temperature is higher than 70°C, it will overheat, and its additional status will be set to 1 (overheating).

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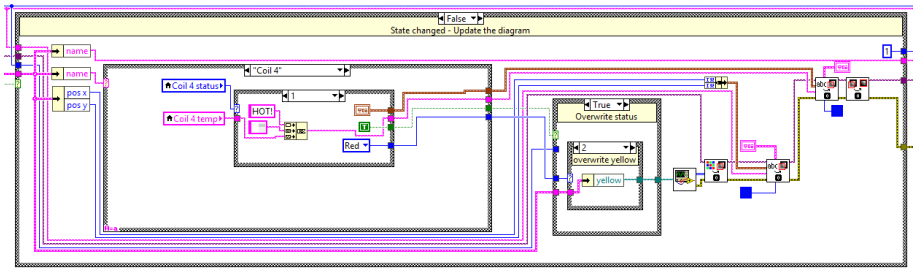

Figure 8: The "Update diagram" frame of the main sequence with the additional status feature of the same item shown. If the transfer coil is overheating, the case labelled "1" will run. Here, the TRUE Boolean refers to the main status being overwritten. "Red" refers to the color that will overwrite the main color.

- Positron accumulator (PA): The main status of the PA is determined by its pressure: if this exceeds 1E-8 mbar, its state is set to bad. The additional status will be set to "good" and will overwrite the main status when the program infers that positrons are being accumulated. The typical pressure during positron accumulation is outside the allowed range of pressures (between 1E-6 mbar and 2E-6 mbar), so the pressure lies within this range, the PA status will be set to "good". It would however be more accurate to determine this status by the state of the PA N2 inlet valve being open (at this time, this valve is not being logged).

- Silicon Vertex Detector (SVD): The status of the SVD is determined from one of the Beckhoff temperature detectors, which leaves the other unused. To get both Beckhoff temperature detector indicators on the diagram one is treated as an additional status. If this second temperature detector returns a value outside of the allowed range of temperatures, text appears next to the temperature indicator reading either "HOT!" or "COLD!" as appropriate.

- Babcock solenoid*: Whenever the Babcock is ramping up or down (its current increasing or decreasing), the item turns yellow. This does not refer to the item data being stale but rather is used to indicate a state that is not "zero current" or "operational current". Currently this is the only item that uses the color yellow for a non-stale state.

*This item was moved outside the main sequence but is still treated as an additional status. It lies outside the main sequence for two reasons. First, it calculates the rate of change of current, which is logged to the mySQL server every five seconds. The main sequence often finishes in less time and so this rate would either be NaN or infinite. Also, to have LabVIEW execute the FOR loop for each case, we had to build a constant array during initialization. The FOR loop would only run for as many iterations as items in this array, and much time had been spent investigating why not all additional item cases would run. Because this is such a subtle bug, it was decided to exclude this case from the main sequence.

A change in the additional status does not explicitly cause an update to the item on the diagram. This is because this requires an array similar to described for the Babcock case. This change is only shown on the diagram when the main variable has changed. This is allowed because for these items the main and

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additional status are either strongly or directly related, so both the additional status changes and the main variable change at the same time.

III. OUTSIDE THE MAIN SEQUENCE

See Figure 9. for the locations of the following items.

i. Magnetic field and potential plots

The plot at the bottom of the diagram shows the axial magnetic field along the z-axis of the ALPHA experiment. The names of all the magnets have been indicated on this plot, and it has been aligned with the diagram such that every point on the plot lies below the corresponding position on the diagram.

There are also several plots of electric potentials in different locations. There are three plots referring to the potential at the CT, the AT, and the PA.

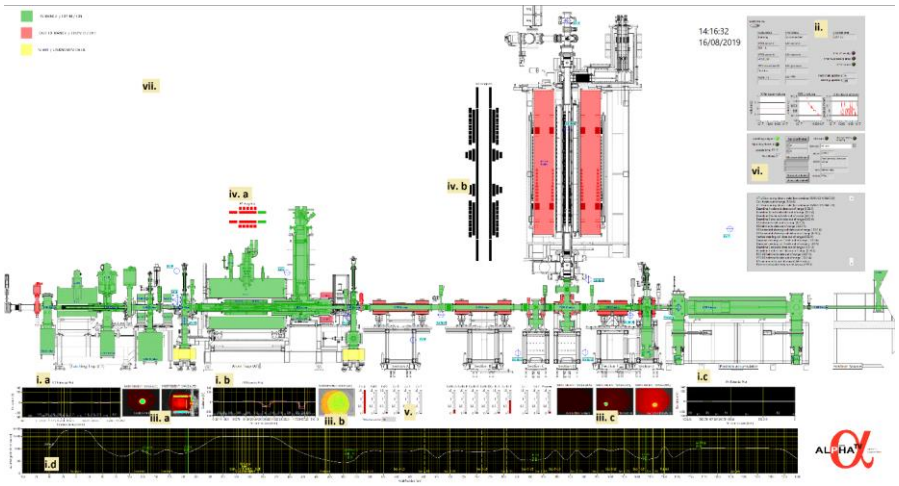

Figure 9: The front panel of AlphaTV with items labelled.

All plots are called as network shared variables from different computers in the ALPHA collaboration. The potential plots are hosted by alphavm17 and the axial magnetic field plot is hosted by alphavm01. The potential plots are called by the "VoltageMonitorRemote" subVI and the magnetic field plot is called by the "ATV Axial Magnetic Field loader" subVI. By default, these plots are updated every second, but this can be changed in the settings tab.

ii. Cryogenic section

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The cryogenic (cryo) section consists of tabs displaying cryogenic information of ALPHA-2 and ALPHA-g. By pressing the button in the top left the visible tab can be changed. The purpose of these is to give a quick overview of the statuses of the 1000L Dewars, transfer Dewars, and cryostat towers.

The cryo section has been designed to predict time a liquid Helium (LHe) transfer is completed. By retrieving the volume of the transfer Dewar and calculating its average emptying rate, the time until completion (TTC) is determined using

$$t_{est} = -\frac{V}{\Delta V/\Delta t}$$

Where V is the remaining volume of LHe in the transfer Dewar, ΔV/Δt is the average emptying rate and t_{est} is the estimated time until completion.

From experience, it can still take a considerably longer than the time calculated here for a fill to finish. While the level probe says the transfer Dewar is empty, there is usually a significant amount of LHe left. ~~For our calculations,~~Typically, ~~we assume that~~ the transfer Dewar still contains about 50 L of LHe when the level probe first says it is empty ~~and~~, ~~we also~~We further assume the transfer rate for this remaining volume is 100 L/hr, although it would better to use the average transfer rate.~~.~~

Besides getting an estimate of the time a fill ends, it can accurately determine when a fill has ended. To determine whether a fill has ended depends on several factors. First, the transfer Dewar needs to be empty. The program takes this to happen at 1 L. Second, there is a sudden drop in pressure within the transfer Dewar. When the stinger is no longer in contact with the LHe, the gaseous Helium used to pressurize the vessel starts to be transferred to the 1000 L Dewar. The cryogenic section has three LEDs corresponding to the transfer Dewar being empty, the pressure having dropped, and both being detected at the same time meaning the fill has ended. This method is shown to recognize the end of a Helium transfer before it could have been inferred from the MIDAS webpage.

The bulk of code within the cryo section is run by the "ATV CRYO plots" and "ATV CRYO indicators" subVIs. The first runs every 30 seconds and builds plots of the 1000 L Dewar volume, transfer Dewar volume, and transfer ~~dewar~~Dewar pressure. It adds new values and dates to arrays and uses these to build the plots. By default, these plots will show data for the past hour, but this can be changed in the settings tab.

The other indicators are determined by the "ATV CRYO indicators" subVI. This is split into two parts running after different intervals. One part acts every 30 seconds ("small update time") and formats the volume and pressure data retrieved from the ~~mySQL~~MySQL server and determines the status of the transfer Dewar and the fill. The other part acts every five minutes ("big update time") and calculates average rates and different times.

iii. MCP images

AlphaTV displays the most recent images taken at MCPs from different sticks as well as the date of these images. These images are stored on the CERN DFS server and are retrieved by the "ATV MCP" subVI. The MCP image folders contain folders labelled by year, which contain folders labelled by month, which

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Commented [SAJ18]: Isn't this measured? You can take the average transfer rate and use that to extrapolate to zero. Maybe this is a possible future implementation.

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contain folders labelled by day. The image files are stored in these final folders. The subVI finds the most appropriate folder by finding the most recent folder and repeating this for every layer. In the final folder, there are two types of .png files: one has "_particles" appended to its name, while the other does not. We are only interested in the latter for this project. The subVI determines which files have the correct file extension and name and returns the path to the most recent one. If this image has not been retrieved before, it is scaled appropriately and displayed on the front panel by code outside of this subVI. If it is already shown on the front panel, the subVI prevents the code from running.

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This process has one significant drawback. It takes several seconds to manually open the image folder on the DFS server. This delay also occurs as the subVI attempts to access the folder. These times compound as this process needs to be performed a total of six times (once for every stick). LabVIEW cannot complete any other processes as this is ongoing and so AlphaTV freezes during this time. I have not been able to speed up this process. To try and mitigate this problem, the images are only retrieved every minute by default. It might be reasonable to wait longer since these images are only being generated a few times per hour.

iv. AT and ALPHA-g magnets

The resolution of the 4K image is not adequate to show the status of the magnets within AT and ALPHA-g using the main sequence. Instead, the status of these magnets is shown using color boxes. These color boxes are part of clusters and are made to resemble the magnets of the relevant section. For each magnet two color boxes are used such that the gap between the two represents the beamline of AT or ALPHA-g.

All information regarding these magnets is stored in two spreadsheets called "at bnl magnets.csv" and "ag bnl magnets.csv" for AT and ALPHA-g, respectively. These spreadsheets are similar to the "item manager.csv" spreadsheet but have several columns removed. The spreadsheets are read by "ATV CSV reader bnl" subVI, which is similar to the "ATV CSV reader" subVI but does not format the removed columns.

The status of the magnets is determined by the "ATV BNL color loader" subVI. This subVI is the same as the status determination frame of the main sequence but rewritten for these magnets specifically.

At the time of writing of this report this feature has not yet been implemented for the ALPHA-g magnets as the magnet hardware is being upgraded, but the code is in place. To have this feature work once the hardware is installed, the DCCT bank and variable names must be added to the relevant spreadsheet and the "disable diagram structure" must be removed.

v. CsI indicators

Spread throughout the diagram are blue labelled crosshairs. These refer to the physical locations of the CsI scintillators.

The information required to get the detector signals is located in a spreadsheet named "csi manager.csv". This spreadsheet is also similar to the "item manager.csv" spreadsheet but has been significantly simplified. The subVI that reads this spreadsheet, "ATV CSV reader csi", has also been simplified.

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The detector signals are processed by the “ATV CSI” subVI. Every second it retrieves the signal data from the mySQL server. If the signal from any of the detectors exceeds the threshold (set to 0.05 by default), all signal indicators will update. The scaling will change such that the largest detected signal is set as the indicator visible range maximum. The “time since last shot” indicator will be reset to zero.

The performance of the “time since last shot” indicator varies. The indicator can display the same time as shown on the “MS Dual Trans Rec v2” VI on alphactmonitor, but can also differ by up to 20 seconds. Because AlphaTV calculates the time since the signal had been logged to the ~~mySQL~~MySQL server, the theory is that the VI logging this data was temporarily slowed down.

vi. Info panel

The info panel contains a few indicators describing the status of AlphaTV. There are buttons which allows someone to show or hide the labels for the experiment valves and sticks. There is also a button that gives the position of the mouse on the diagram and a button that allows someone to measure the distance between two points on the diagram. The user is asked to hover the mouse over two positions on the diagram and press the enter button after a position has been selected. These positions are ~~saved~~saved, and one is subtracted from the other to calculate the distance in pixels. This is converted to distance in cm by dividing the distance in pixels by the number of pixels per cm for the diagram (2.29).

vii. Settings tab

The settings tab contains settings for the different programs, benchmarking, and the error indicator for AlphaTV.

Errors in AlphaTV are concatenated by using local variables. The “local error” variable is called and merged with the errors of any program. This is then written back into the “local error” variable. By pressing the “clear” button this error is reset.

This tab also allows you to set the location of the AlphaTV-related files and folders. This is particularly relevant when the PC hosting AlphaTV has changed.

viii. Warning messages (not shown on figure)

The status of some items can have profound effects on the status of ALPHA as a whole. When the status of such items is bad, large red text appears in the top-left part of AlphaTV. Currently, these are:

- SCM count too high: this implies that there is a leak in the positron source and an evacuation is in order.

- Transfer coils overheating

- SVD too hot/too cold: the SVD could be permanently damaged if its temperature becomes too high or too low. If the temperature detectors report a temperature of -999 °C, the warning says there is a problem with these detectors.

- Babcock solenoid quench detected: when a quench is detected, a flashing message will stay on-screen

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until a button is pressed and held for a moment. This button will appear next to the message and will disappear after pressed. We tried to make the Babcock part of the image itself flash red and yellow, but this idea had to be abandoned because we couldn't get it to flash fast enough.

IV. PERFORMANCE

The performance of AlphaTV depends on which tab on the front panel is displayed. While AlphaTV is much faster when the settings tab is open, relevant information is only displayed in the image tab. The computer running AlphaTV, alphacpc69, uses an Intel® Core™ i5-6600 with 4 cores and has 8 GB of RAM (6.92 GB usable). We show the performance for the image tab with 60 items to be loaded in and parallel processing enabled.

- It takes between 22 and 30 seconds to run the first call of the main sequence. AlphaTV can take up upwards of 80% of available CPU power and up to 800 MB of available memory during this time.

- It takes approximately 0.15 seconds to retrieve all data from the ~~mySQL~~MySQL server and build the MIDAS array. In other words, it takes approximately 0.0025 seconds to retrieve the data for a single item from the server.

- It takes a negligible amount of time to build the main status array (up to 0.001 seconds).

- It takes a small amount of time to determine the additional statuses (up to 0.015 seconds). Currently there are six items with additional statuses. This also gives 0.0025 seconds for the data retrieval time for a single item.

- The average time to load a single item onto the diagram varies between 0.37 seconds and 0.60 seconds. This appears to improve as more items are updated. This time however increases drastically as the MCP images are being retrieved (over 1 second per item on average).

- As MCP images are being searched for CPU usage drops to 0%.

- AlphaTV uses about 2 Mbps of network on average.

Most time is spent overlaying and merging images. In the past we have investigated the possibility of moving away from overlaying images and instead use LabVIEW Vision tools to color in areas. This would speed up the process drastically. We had to unfortunately abandon this idea as ~~the~~ we could not get transparency to work with these tools.

With the move to the spreadsheet we would have had to write down the coordinates of every vertex of the colored area. This would have been an impossibly tedious process as some images (e.g. Fig.10) have dozens of vertices.

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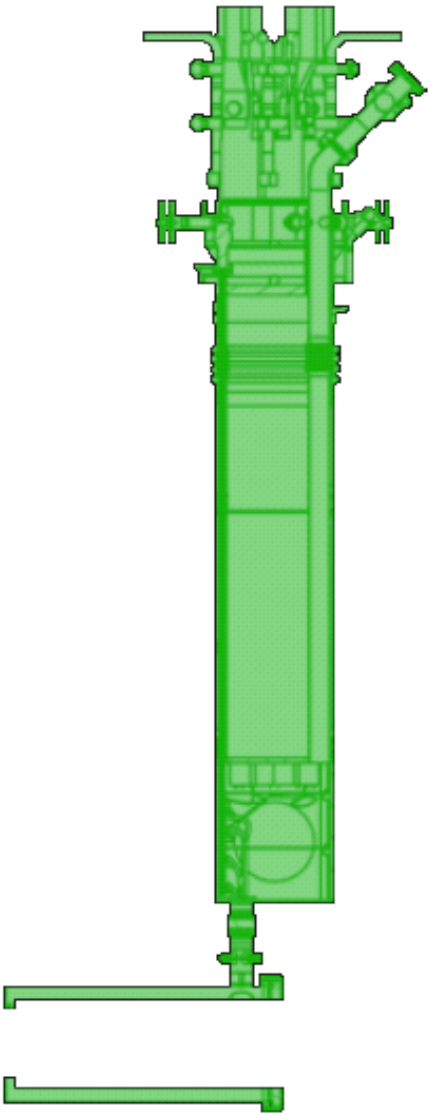

Figure [10]: AT cryostat tower good status image. Note the detail of the picture.

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V. FUTURE FEATURES

1. Stick position indicators (top of diagram)

This was originally planned to appear on the front panel. An early version of AlphaTV managed this for the CT stick by reading values from the ~~mySQL~~MySQL server. Other sticks did not send this information to the server. We wanted to convert the stick position indicators from their respective control PCs into network shared variables and retrieve the~~i~~se variables. The software of these computers however was deemed to be too unstable to implement this feature. To add the stick indicators to AlphaTV either the software of the controller PCs needs to be reworked or all positions need to be logged to the ~~mySQL~~MySQL server.

2. ALPHA-g magnetic field and potential plots (next to ALPHA-g section)

This would require the equipment to physically be installed, but the plots would be implemented in the same way as the other plots. The potential plot should be added to "VoltageMonitorRemote" and the magnetic field plot to "ATV Axial Magnetic Field loader" in the WHILE loop labelled "Shared variables".

3. Crane position indicator (top of diagram)

The crane used in the AD hall can have a negative effect on the magnets running in ALPHA 2 and ALPHA-g. A slide indicator above the diagram could be a quick and effective way of displaying this position. The slide indicator could also be designed to look like the crane. The crane is not always logged to the ~~mySQL~~MySQL server, but when it is it would be easy to implement.

Commented [SAJ20]: Have you defined what ALPHA-2 is? It's the catching trap and the atom trap.

Commented [L21R20]: Added it to the fig 1 caption!

4. Laser status indicator (info panel)

Previously the laser status was determined by inferring whether the appropriate laser shutter was open or closed. The laser being used at the time of writing this report does not have this feature logged to the ~~mySQL~~MySQL server.

5. Zone open indicator (info panel)

VI. KNOWN BUGS

- All items have turned yellow

If the message log says that all items are stale, AlphaTV failed to make a connection to the ~~mySQL~~MySQL server. This means that either the CERN servers are down or there is a problem with the "Open connection" subVI. One of the errors experienced in the past was that LabVIEW could not sustain any more open connections, because the "Open connection" subVI was being run every diagram update iteration. This was fixed by only calling this once as an initialization function.

There has been an instance where I could not trace the cause of the problem. This happened after trying to remove unused items from the project. Reverting to an earlier version fixed the issue.

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- Specific image not loading on the diagram

This happens when AlphaTV could not find the required image file. This is most likely because of a typo in either the spreadsheet file name entry or in the file name itself.

- One or more potential or magnetic plots aren't shown

The PC hosting the VI creating the plots has some issues.

VII. CONCLUSION

Although some features that were initially planned are still missing, the first proper version of the AlphaTV project is ~~assumed to be~~ complete. It has managed to consolidate important experiment information from the MIDAS history page and present it in a clear manner, allowing operators to easily identify issues. Other indicators outside of the initial proposition were added in a response to remedy reported difficulties. For example, the cryogenic tab shows the status of the fill before information is shown on the MIDAS history page, and the CsI indicators allow operators to see if there is a problem with their positron shot. Operators also use the program to visualize the experimental setup without needing to enter the zone. It is used to measure distances along the beamline and show the names and locations of valves and sticks. The program has been running on the 4K television in the ALPHA control room for two months and is used by many operators with different interests.

The expectation is that code does not need to be changed much when the transition from ALPHA 2 to ALPHA 3 is made. If the background image does need to be updated to include further experimental details of ALPHA-g, only the image files might need to be updated. The spreadsheet functionality has effectively made AlphaTV future-proof and highly customizable. The code could be modified for use in other experiments.

VIII. REFERENCES

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[–
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~~[3] Ahmadi, M. et al. (ALPHA collaboration). Observation of the 1S-2S transition in trapped antihydrogen. *Nature* **541**, 506-510 (26 January 2017)~~

http://www.dmphotonics.com/MCP_MCPImageIntensifiers/microchannel_plates.htm

~~http://www.dmphotonics.com/MCP_MCPImageIntensifiers/microchannel_plates.htm~~ *(accessed 18/8/2019)*

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APPENDIX A. CREATING NEW IMAGES USING GIMP

Open "AlphaTV GIMP file.xcf" within the AlphaTV folder using GIMP. On the right-hand side there is a panel containing all layers within this file. Layers can be made visible or invisible by pressing the squares shown in Fig. 11. Set the "Clean background" layer to be the only visible layer and select it. Using the rectangle tool (R), select the area to be shaded in and copy the selection into memory.

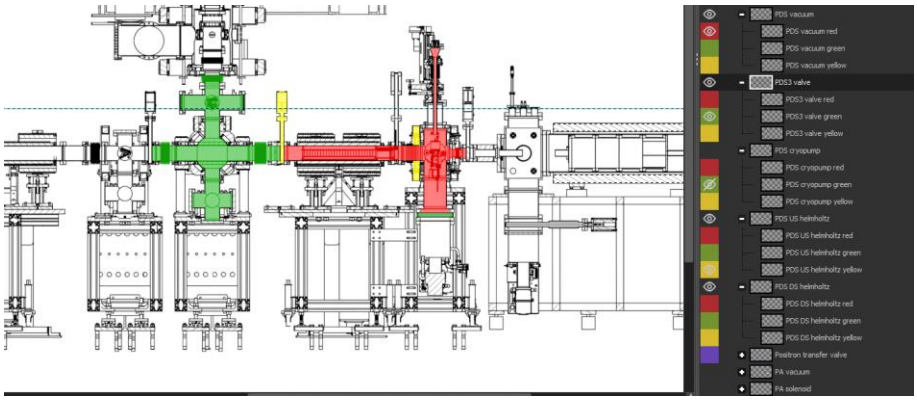

Figure 11: Screenshot of GIMP to show the layer panel and part of the image. The "PDS3 valve" layer group has been selected. The colors in the panel tab refer to the color of the images. The exception is purple, which means the item has yet to be added to AlphaTV. Notice that although the "PDS cryopump green" layer should be visible, because the "PDS cryopump" layer group is invisible the layer is also invisible. Similarly, the "PDS DS ~~helmholtz~~Helmholtz" layer group is visible but all layers within this group are invisible.

Right click on the "Clean background" layer and select "Create new layer group". This should be named after the item to be added. Right click on this new layer group and select "Create new layer". This should also be named after the item and its name should include a color. Make sure both the new layer group and layer are visible.

Next, make the "Clean background" layer invisible. At this point, the outline of the copied selection should still be visible. Select the new layer and paste the selection. This should appear as a floating layer in the same location it was copied from. To merge the floating layer and the new layer, click anywhere on the image with the rectangle tool. Right click on the new layer and select "Duplicate layer", twice. Rename the layers and change the color label and name to refer to the color of the images. By convention, the order these appear in is red, then green, then yellow.

Using the fuzzy select tool (U) set to the maximum threshold, select the image that has been pasted in. If this contains sections that are not connected, use Shift and left click to add unselected regions to the selection. Switch to the bucket tool (Shift + B) and with its opacity set to 80%, left click anywhere within the selected region to fill using the selected color. The HTML color codes used are ff0001 (red), 1bc00f (green), and ffc00 (yellow). Hide the layer that was just finished and repeat for the other two layers.

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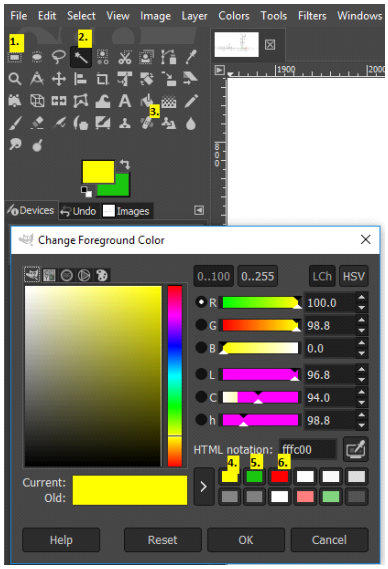

Figure 12: Tool tab and color selector of GIMP. The labelled tools are: 1. Rectangle tool, 2. Fuzzy select tool, 3. Bucket tool. Note that the colors used for the images (4, 5, 6) are still saved in memory.

With all three images finished, make all layers within the GIMP file invisible except for the layer that needs to be exported. Press the File tab and select "Export As" (Ctrl + Shift + E). All images should be exported to the "4K images" folder in the AlphaTV folder. Export this image under the layer name and repeat for the two remaining layers.

APPENDIX B. READING THE SPREADSHEET

Column	*Name*	*Description*
A	*Name*	*Item name. [1]*
B	*Section*	*Section of location. This is either Alpha 2 or Alpha g.*
C	*MIDAS*	*Location of the item in the appropriate history page.*
D	*Bank*	*Name of the table in which item variable is located. This is given by "labview" followed by an underscore and four letters. [2]*
E	*Variable*	*Item variable. This is always given by the last four letters of the bank, an underscore, and a number.*
F	*Type*	*Item type. There are three types currently being used in AlphaTV: "generic", "valve t1", and "valve t2". The "generic" type is used for any item that is not a valve. The "valve t1" and "valve t2" types (referred to as type 1 and type 2 valves) are both used for valves, but differ*

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		in what values correspond to the "closed" and "unknown" status. For type 1, 0 corresponds to closed and -1 to unknown. For type 2, it is the other way around.
G	*Unit*	*Item units. Valves do not have units.*
H	*Factor*	*Multiplicative factor applied to retrieved data. [3]*
I	*Offset*	*Additive offset applied to the retrieved data. [3]*
J	*Lower*	*Lower range limit for the value of an item.*
K	*Upper*	*Upper range limit for the value of an item.*
L	*Good?*	*Determines whether an item is in a good state when its value lies within range. "y" corresponds to "yes", "n" corresponds to "no".*
M	*Red*	*File name of bad state item image. [4]*
N	*Green*	*File name of good state item image. [4]*
O	*Yellow*	*File name of stale state item image. [4]*
P	*Pos x*	*X-position of the item indicator on the diagram. [5]*
Q	*Pos y*	*Y-position of the item indicator on the diagram. [5]*

Notes:

[1] With parallel processing disabled, items load in this order. This is significantly slower than with parallel processing enabled.

[2] There are exceptions where these names have an underscore and a string of numbers affixed. In such cases the instance with the affixed string must be used. There are also some banks with different prefixes (for example, the Silicon detector count rate starts with io32).

To determine if multiple versions exist, open "mySQL example.vi" in "mySQL library" in the AlphaTV LabVIEW project. Run the VI and press the "Update list of tables" button on the first page of the front panel. After a moment the drop-down menu next to the "Table" control should no longer be grayed out. Replace "labview_atmx" in this control with the specified bank. By clicking on the drop-down menu, all banks with this name become visible.

[3] The offset is applied before the factor.

[4] It is possible to forego these three columns by creating the file paths from the image name. The "ATV CSV reader" subVI would be modified to append the color and file suffices to the item names. This would require all images to be named exactly after the item.

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[5] If no text indicator is required, the x-position and y-position are both set to 0. By default, these coordinates refer to the bottom-left corner of the text indicator. When set to (0, 0), these indicators are overlaid outside of the image.

APPENDIX C. CONNECTING THE 4K TV

- *Unplug the VGA cable connected to alphacpc69*
- *Restart the computer*
- *Plug the VGA cable back in when the login screen appears*
- *Login to alphacpc69*

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