

pCT Phase-II Scanner Operation

Installation and Cabling Setup

In the following, use cable ties to secure the various signal cables, high voltage cables, USB cables, Ethernet cable, etc. to the scanner structure, to avoid damage if somebody trips over a cable.

1. Set up the data acquisition computer, its monitor, its mouse, and its keyboard in the radiation-safe area. Two cables will run from it to the scanner. Probably they will have to run under the door.
2. Install the energy detector from the rear onto its table under the electronics of the scanner, taking care to clear the various cables. The lemo plugs must be on the left (when looking toward the beamline) and pointing downward. Scoot the enclosure all the way forward and to the left, such that the ridge around the enclosure pushes up against the table. Check the left-right position to verify that the energy detector window matches the tracker window.
3. Plug in the 5 energy detector signal cables according to the channel labels on the detector and on the cables, and then plug in the high-voltage cable.
4. Position the scanner properly relative to the beam line, making sure that the height is correct to put the beam into the center of the aperture. Lock it into place if possible, and then measure and log the distance from the beam source and the front of the tracker.
5. Plug in the long white AC-power extension cord and position its outlets close to the scanner. Plug the black extension cord into the white one or into another outlet.
6. Plug the blower rheostat into the black extension cord. The rheostat on/off switch should be taped into the on position. Plug the blower into the rheostat, and then attach the blower hoses to the fittings on the bottoms of the two tracker enclosures. Make sure that the hoses do not interfere with the stage.
7. Plug the event builder 12V AC power adapter into the white extension cord and then into the event builder ML605 board (a white connector on the top of the board). Try to avoid bending the board when plugging it in. Making this connection first (and removing it last) is helpful in grounding all of the electronics and thus reducing susceptibility to electrostatic discharge.

8. Position the following auxiliary boxes close to the scanner and attach an AC power cord to each:
 - a. Two black BKPRECISION switching power supplies.
 - b. The Sorensen XEL supply for the tracker bias.
 - c. The energy detector ISEG high-voltage supply.
 - d. The stage controller.
9. Connect the energy detector high voltage cable to the ISEG power supply. To avoid damage they must connect to the correct channels! The -365 volts goes to the left channel (when facing the front of the supply) while the -800 volts goes to the right channel. Don't do this if you are unsure, as applying the -800 volts to the wrong cable will surely destroy all of the transistors and zener diodes on the PMT bias board inside of the energy detector.
10. Plug the BKPRECISION power cords into the black extension cord. This is important to ensure that the tracker power cannot be turned on without turning on the blower.
11. Plug the other boxes into the white extension cord.
12. Connect the cable from the stage controller to the stage.
13. Connect the tracker bias cable from the Sorensen XEL supply to the mezzanine board. On the supply end the cable has banana plugs, red to the high voltage and black to ground. The plug on the mezzanine board is clearly labeled and marked with red tape. It is crucial not to plug this into the tracker or energy detector power plugs. The 100V bias would surely destroy the electronics!
14. Connect the energy detector power cable (thinner 4-wire grey cable attached to one of the BKPRECISION supplies) to the top crowbar box that is in turn plugged into the mezzanine board.
15. Connect the tracker power cable (thicker 4-wire grey cable attached to one of the BKPRECISION supplies) directly into the mezzanine board. (While the lower crowbar box is meant to be for the tracker, in practice it does not work well enough for operation outside of the UCSC lab. The 18-amp fuse will not blow when the crowbar trips, because the supply cannot source more than 22 amps, which apparently is not enough. At the same time, the 16 or 17 amps drawn by the tracker heats up the fuse a lot and produces too much voltage drop across it.)
16. Set up the white USB hub close to the scanner and plug its power converter into the white extension cord. Plug its white input cable into the end of the 50-foot active USB cable, and plug the USB cable's power converter into the white extension cord. Note that these two power converters are interchangeable. Run the 50-foot USB cable all the way to the data acquisition PC. Cable tie all of this into place to secure it.
17. Run a USB cable from the hub to the event builder. The event-builder end is a mini-connector. There are two jacks, one for programming and the other for the UART

connection. Here we want the UART connection. There is a small label on the board, but it can also be recognized as the USB jack that is closest to the mezzanine interface board.

18. Run USB cables from the hub to the two BKPRECISION supplies, the Sorensen XEL supply, the ISEG high-voltage supply, and the stage controller.
19. Run a long Cat-5 Ethernet cable from the little Ethernet board mounted onto the event-builder mezzanine board to the data-acquisition computer. On the back of the computer it should plug into the lower Ethernet adapter (the upper one is for network connections).
20. Turn on the power strip of the white extension cable.

(I'm assuming that no beam-phase-lock will be used for the energy detector digitizer clocks. Otherwise the beam RF coax cable would have to be plugged into the lemo connector of the mezzanine board and a USB cable from a PC would have to be plugged into the same board in order to program the chip that does the phase lock and generates the digitizer clock.)

System Startup

Turn on the system power as follows:

1. The power strip into which the blower rheostat and tracker power supplies are plugged is turned on first. You should then hear the blower. Do not proceed to turn on the tracker power without the blower running (with the air hoses plugged into the two tracker modules, of course).
2. Turn on the event builder (Xilinx ML605 board). The switch is partially obscured by our mezzanine interface board, so a small stick may be needed in order push the switch.
3. Turn on the Tracker and Energy-Detector power supplies (two black BKPRECISION boxes with switches on the back), the Tracker bias power supply (Sorensen XEL supply with the power switch on the front), and the Energy Detector PMT high-voltage supply (ISEG supply with the switch on the back).
4. Turn on the controller for the stage (switch on the back).
5. Type `python /home/daq/powerSupplyGUI/powersupplyGUI.py` This should open up a GUI window for operating the power supplies. It is supposed to connect automatically to all of the supplies over USB. If it bombs you can try power cycling the relevant supply and then try the GUI again.
6. Using the GUI pull-down menus, turn on the tracker and energy detector supplies. You should see a voltage of 5.5V for the energy detector and 5.0V for the tracker. If not, use the menus to set them so. The tracker should show a current of around 3.5 amps while the energy detector should show about 1.3 amps.

7. On the PMT HV supply, switch on the two front-panel switches to enable the HV output. Make sure that the voltage setting is negative and that the left channel reads about -365V while the right channel reads about -800V .
8. Using the power GUI turn on the tracker bias voltage. Use the GUI to set the voltage to 100V .

Monitor the tracker and energy detector voltages and currents as follows:

1. Type `"python /home/daq/powerSupplyGUI/powerMonitorGUI.py"`. You should see a large GUI window open and display the voltages and currents on each of the 8 tracker boards and the two energy-detector digitizer boards.
2. Click on the checkbox at the bottom left to turn on the tracker ASIC power. You should then see voltage and current for every supply. You should also see on the power supply GUI that the tracker current increases to between 16 and 17 amps.
 - a. Check that each supply on each board is close to the expected voltage (1.2V, 1.8V, 2.1V, 2.5V, or 3.3V).
 - b. Check that boards of the same type are drawing about the same amount of current for each supply. Note that you will not see current from the 1.8V supplies, as those only supply current during the FPGA programming.
 - c. Check the bias current readings for the V boards, but ignore the T-board bias current readings (they are internally disconnected to solve a noise problem). You can expect a few hundred micro-amps per board, but you will see the current steadily rise as time progresses. Mainly you want to verify that the currents are zero.
 - d. Check that the temperatures look reasonable (near room temperature if you just recently turned the system on, but in any case well below 40C).
3. Click the ASIC current off.
4. Delete the monitor window. It cannot operate simultaneously with the data acquisition program.

Note that the tracker and energy detectors must be powered on *after* the event builder is powered on. That is because the event builder FPGA must be operating before booting the FPGAs on the tracker and detector boards. So if you power cycle the event builder you must then power cycle the detector boards.

Configuration Setup

Open the file `/home/daq/git/pct-acquire/pct_config.yaml` in an editor (e.g. gedit). Keep it open during the beam test, for convenience. Make sure that the following parameters are set properly (since these often get changed around for testing purposes):

- `event_builder`:
 - `timepix`: false
 - `spill_synch`: false (unless operating at LLU, in which case true may be desired)
 - `tracker_trigger_mask`: 0
 - `energy_trigger_mask`: 1
 - `tracker`: asic_default: trigger_delay: 2
 - `energy_detector`:
 - `data_type`: reduced
 - `sample_config`: [6, 8]
 - `trigger_delay`: 7
- `scan_config`: (all of these may be set by hand from the GUI)
 - `starting_run_number`: (usually this is set by hand for each run; 0 is a good default to prevent overwriting data in case you forget to set the run number)
 - `filename_pattern`: (set this to point to the SSD area for data acquisition)
 - `max_seconds`: 20 (decrease or increase according to the maximum run time desired for each stage angle)
 - `max_bytes`: 200000 (this is what normally stops the run at each angle)
 - `start_angle`: 0
 - `stop_angle`: 360 (for a full scan)
 - `angle_step`: 4

You may want to change the “`monitor_supplies`” and “`monitor_temperature`” settings on the various boards. If set “true” they will result in the system reading the supply voltages and/or temperatures of the boards during the configuration stage prior to a run, with the results displayed on the pct-acquire GUI. The reading is rather slow, however, so that having all or many of them set “true” greatly slows down the configuration process.

Executing a Scan

Make sure that everything is powered on, including the tracker bias! Start the pct-acquire from the folder `"/home/daq/pct-acquire/"` by the command

```
./pct.py log-file-name
```

where the log-file name should include the starting run number for the scan and ideally should be located in the SSD area where the data are sent. You should see the pct-acquire GUI window pop open. To start a scan going, do the following:

1. Click on the "Control Stage" button. If this is the first run of the session, click "Home" and wait for the stage to rotate one way and then the other until it says that it is homed. If the program cannot connect to the stage, you may have to power cycle the stage controller, restart the GUI, and try again.
2. Click on the "Configure Detectors" button. It will then take a while to go through the configuration sequence. While it is doing so you can work on the next step.
3. Set up the scan configuration:
 - a. Set the "Starting run number" to a unique value for the beam test and write the number in the log book.
 - b. Make sure that the "Filename Pattern" is correct. It should start with the SSD folder location for data from the current beam test followed by a descriptor of the run, such as "Emp" for an empty run, "Cal" for WEPL calibration, or the name of a phantom. Then should follow patterns for the run number and stage angle.
 - c. "Max Seconds" and "Max Bytes" determine when the run will stop. 200,000 bytes will give around 4 million events. (Note that usually by the time the system notices that the byte count has exceeded Max Bytes and manages to halt the run the system has accumulated a few more tens of millions of events.)
 - d. Make sure that the stage start, stop, and step values correspond to what is desired for the scan.
4. Once the configuration is complete, check the "Supply Monitor" readings, if there are any. You may need to click the "Reset Ethernet" button, especially if the previous run was aborted without closing everything down properly. If the system fails to link of with the event builder over Ethernet, then you will have to exit the GUI and start over. Hitting the reset doesn't cost much time and can prevent connection problems.
5. Finally, click the "Start Scan" button.

During the run the GUI will display the bytes accumulated and bytes written to disk. When the run terminates for a given angle setting a display of the trigger and event rates during the first 10 seconds will pop up. Also, after each angle the run will be closed, run summary information

printed to the log, the stage rotated, a new data file opened, and a new run started. All of that takes a few seconds. (Capability for doing runs with continuous stage rotation is being worked on.)

When the scan is finished, click the “Quit” button to close the GUI. It is best to restart it from scratch for the next scan.

If the system will not be operated for an extended time period, use the power control GUI to turn off the tracker power and tracker bias. This will help keep the system from overheating and keep the bias currents from getting too high.

Data Verification

It is a good idea at the beginning of a beam test to take an “empty” run with data reduction turned off in the energy detector FPGAs. That is done in the `pct_config.yaml` file according to the line

- `energy_detector:`
 - `data_type: samples`

Just be sure to set it back to “reduced” before making scans. To verify the basic instrument performance, run the single-event display program in the `/home/daq/git/pct-acquire/` folder:

```
python display_events.py file-name
```

It will open a window and display the first event. To go to the next event just delete the window. Use `ctrl-c` to exit the program. Make sure that you see tracker hits forming reasonably straight lines and energy detector pulses for each stage in which the entire pulse fits into the 16 available samples. The pulse position can be adjusted with the “`energy_detector: trigger_delay`” parameter in `pct_config.yaml`.

It is also a good idea to take one or more reasonably long (millions of events) “empty” run with data reduction turned on. When the run is finished, execute the monitoring program to verify the data. In the `/home/dat/git/pct-acquire/` folder execute the C++ program:

```
./DataMonitor file_name num_events
```

where the last argument (optional) is the number of events to analyze (you can analyze all the millions if you are patient, but set to 10000 for a quick look).

The monitoring program will create a bunch of `.png` files that you should then look at one by one. For each tracker cassette you should see strip hit maps that reflect the beam profile and,

hopefully, don't have many dead or noisy strips. For the energy detector you should see a single-proton peak, at least, for each layer plus more-or-less uniform T and V profiles. For the tracker you should see good T and V residuals plus efficiencies in the 99% -plus range.

System Shut-Down

Use the power control GUI to power off the tracker bias and the tracker and energy detector supplies. Manually turn off the energy detector high voltage. Then power off the stage controller and the tracker and energy detector power supplies and bias voltages. Finally, turn off the event builder power.