Loose notes on Milagro calibration

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Abstract

Here are some loose notes meant to be of some help to future calibrators.

1 Code and analysis flow

In principle, timing and photoelectron (PE) calibrations can be run independently. However, a check of the quality of laser data by looking at the slewing curves (Tstart vs TOT) is advised before proceeding with PE calibration. Also, there is one file needed for steering in the PE calibration (Best_lo.out) which is generated by the timing code: it tells you, among other things, which laser ball is the most suitable for each pmt. Yet there is no reason why one couldn't produce such file and do the quality check (for LoTOT and HiTOT ranges, top and bottom layer response, etc.) inside the PE code so as to make it completely independent of the timing code. Aside from the timing and PE programs, other subdirectories include the Fleyshers' manual (MANUAL) and TDC calibration (TDC).

Throughout the code, several things are hardwired and others have been changed by me to reflect particular needs. They have a "!!" and/or a "JBG" tag in the programs. EDIT THEM BEFORE COMPILING or you might be using the wrong input/output/options/... The original code, as transferred by the Fleyshers to me, is sitting in /cosmo/bussy/laser/calibtransfer.tar.gz and the version I have been using is in the /cosmo/bussy/laser subdirectories. For questions about most of the code, please ask Roman and Lazar Fleysher.

1.1 Timing calibrations

Done, in this order, in subdirectories SLEWING, TPED_FIBER_SPEED and EXTRAPOLATION. The first one reads in the raw data, generates slewing curves for all ball-pmt combinations and selects the most suitable laser ball for a given pmt. The second subdirectory works out the speed of light in Milagro water by minimising the RMS of TPed mismatch when different laser balls are seen by the same pmt, then calculates the relative optical fiber lengths and finally adjusts the time pedestals using the relative delays in fiber optics and the propagation of light in water. Lastly, the slewing curves are extrapolated.

1.1.1 SLEWING

- version10 (.c, .exe) and its variations (hi for HiTOT, lo for LoTOT, m for muon layer):

  Input: raw data (Calib_RRRR_SSSS.dat).

  Output: Slewing_ball_#_hi/lo.out, slewing_ball_#_hi/lo(_m).his

  For each ball and each pmt that sees it, do a Tstart vs TOT scatter plot. Divide scatter plot into 40 vertical slices 25 TOT counts wide. For each slice with more than 5000 entries, divide Tstart range (0,3000) into 200 bins, find peak, select 10 bins around the peak, fit a Gaussian and find its mean and rms. Fit a polynomial (3rd-order for HiToT, 4th-order for LoTOT) to the (at most) 40 points and errorbars defined by such means and rms's.

  Output files Slewing_ball_#_hi/lo.out list: pmt, ball, Juldate, left and right boundaries of fitted region, polynomial coefficients and slopes at left and right boundaries.

  Output files slewing_ball_#_hi/lo(_m).his include scatter plots (histogram Nos. pmt# $\times$ 10) and fitted curves (histograms pmt# $\times$ 10 + 2). Deviations (in TDC counts) from the fitted curve are stored in histograms pmt# $\times$ 10 + 1 in order to assess the quality of the slewing curve.

- Best_sort.script:

  Input: Slewing_ball_#_hi/lo.out

  Output: Best_hi/lo.out

  Sort Slewing_ball_#_hi/lo.out files by pmt# and, for a given pmt, pick the ball which gives highest maxTOT. For pmts with HiTOT entries, use the same ball for LoTOT as for HiTOT; for those without HiTOT entries, use ball which gives highest maxLoTOT.

  Output files Best_hi/lo.out list: pmt, best ball, Juldate, left and right boundaries of fitted region, polynomial coefficients and slopes at left and right boundaries.

1.1.2 TPED_FIBER_SPEED

- Slew_All:

  Input: raw data, Best_hi/lo.out

  Output: Slew_All.out, (SlewAll_ball#.his)

  Read in raw data, correct for slewing and compare corrected entries with fitted slewing curve. The difference (slewing errors) is histogrammed for diagnostics (these histograms are interesting and should be output; however by default they are trashed after being used for the text output).

  Output file Slew_All.out lists: pmt, ball, peak, #entries, sigma, rms, where the peak refers to the Tstart peak in each TOT slice and (sigma, rms) refer to those of the Gaussian fit in the region around the peak.

- Speed:

  Input: Slew_All.out

Output: speed_xx.xxx.his, text

Try speeds from 10.990 to 11.075 cm/count in steps of 0.005 and find that speed which minimises the rms of pedestal mismatch using two different laser balls to calculate the pedestal of a given pmt.

Output files speed_xx.xxx.his give the histograms of pedestal mismatches for different laser ball pairs for a given pmt at a given speed-of-light in water. By looking at the text output one can see which speed minimises the mismatch. This speed is to be plugged by hand in subsequent programs.

- Fiber:

  Input: speed-of-light in water

  Output: fiber.out (fiber lengths relative to fiber #30)

- Pedestal:

  Input: speed-of-light in water, fiber.out, Best_hi/lo.out

  Output: out_ped_hi/lo (same as Best_hi/lo.out except free coefficient has been adjusted to be the new pedestal); these are two of the three final files in the timing output (they are used in our online and offline analysis under names such like hi_laser and lo_laser).

1.1.3 EXTRAPOLATION

- get_best:

  Input: slewing_ball_#_hi/lo(_m).his

  Output: best_hi.his

- step_slew:

  Input: out_ped_hi, best_hi.his

  Output: Extra.out; this is the third file of the final timing output (extra_laser).

1.2 Photoelectron calibrations

Done, in this order, in subdirectories WHEEL and PE. The former reads in the raw data and outputs the relative transmittance of different filter wheel sectors. The latter takes in the raw data and filter wheel calibration and outputs a set of points in the ln(PE) vs TOT space. The addition of other points as well as a new fitting method is described in another subsection, "New PE analysis".

1.2.1 WHEEL

- wheel (top and bottom layers separately):

  Input: raw data

  Output: wheel.info (wheel position, log10(relative transmittance)), dists.his (histograms of relative optical density for pairs of adjacent filter wheel positions)

Read events (both laser and artificial noise triggers), ball number and wheel position; calculate occupancy, including noise reduction, for a given pmt (using the most suitable ball for it) and a given wheel position; from the occupancy, work out the number of PE's if occupancy is between 30% and 80% (valid occupancy); for a given pmt and a given wheel position, if occupancy is valid for that position and for the previous one, take attenuation as the ratio of PE's for such positions (relative optical density of the filter); for a given wheel position, average the attenuation over all events, take the log and write it to the output file.

1.2.2 PE

- tot-pe_2.c:

  Input: raw data, Best_lo.out (for steering), wheel.info

  Output: pmt#-h/l.dat (PE vs TOT points for HiTOT and LoTOT), pmt#-h/le#.dat (new files, where e refers to the extension to lower HiTOT's and the last number is a flag for either year 2000 or 1999)

  For a given ball, there is a number of pmts associated with it and for each of them we build a pair (hi/lo) of 2D histograms where the XY plane is defined by wheel position (36 bins) and by TOT (1000 bins) and the Z axis has the corresponding number of entries. Now, in each wheel position slice, we look for the most probable (peak of the distribution) TOT value (separately for Hi and Lo) thereby defining a one-on-one correspondence between wheel position and (hi/lo)TOT. Finally, the PE value (for pmt p and wheel position w) is calculated with the occupancy expression if occupancy is valid:

  $$PE(p, w) = -\ln(1 - occ(p, w)). \tag{1}$$

  Otherwise,

  $$PE(w) = s(p)\; T(w), \tag{2}$$

  where T(w) is the transmittance of a given wheel position and s(p) is the slope of the PE vs T linear plot in the know region for a given pmt.

  Thus, for a given pmt, we end up with two series of points in the PE vs TOT plot (one for HiTOT, one for LoTOT). In the next subsection we add some more points and fit physically-constrained functions to both series.

1.3 New PE analysis

This includes: i) extension of PE calibration to lower HiTOT's;
ii) Lo-to-HiTOT cross-calibration;
iii) reverse occupancy;
iv) marriage of data from different datasets (in this case, from years 1999 and 2000). This was presented at the collaboration meeting in Irvine (February 2001). Please ask Peter Nemethy or Erik Blaufuss about this.

The new files mentioned above (pmt#-h/le#.dat) include the following information: wheel position, TOT counts at low HiTOT threshold, entries rejected (bad entries at threshold spike), total entries, valley/peak percentage at lowest usable bin, (amplitude, sigma, peak) of a Gaussian fit to the usable part of the TOT distribution and corresponding PE value. For clarification of slang here, again, ask Peter. Sometimes you may find these files split into the old part (TOT peak and PE value) and the new part (all other columns plus TOT peak, which is repeated).

All this information is used in the new analysis:

In /newman/bussy/laser/SEALED/PE/EXTEND2000(EXTEND1999) you can find the files with the extension of the PE calibration to lower HiTOT's for the year 2000 and year 1999 datasets, respectively.

In /newman/bussy/laser/lo2hi/2000(1999) you can find the Lo-to-HiTOT cross-calibration provided by Erik. Peter is in charge of providing the reverse occupancy information.

We put all this information together, and more, in files called pmt#-hm.dat in /newman/bussy/laser/SEALED/PE/MARRY2000(MARRY1999). This is done in the following Octave/Matlab code (why?, because //lun2/PAW/HBOOK/MINUIT/COMIS/other ! CERN(1995:2050) ! stuff.rz makes me puke):

- /newman/bussy/laser/marry.m:

  Input: extended laser data, Lo-to-HiTOT data, reverse occupancy data, each for primary and secondary datasets

  Output: pmt#-hm.dat, marry.txt (text output by pmt)

  First, we define the primary dataset (that closest in time and configuration to the EAS data it will be used for) and secondary dataset(s) to help fill gaps in the primary calibration. In our case, for EAS data taken after the October 2000 repairs, laser data from December 2000 was the primary and laser data from November 1999 was the secondary. Then, the two datasets are married following some criteria (discussed at the Irvine meeting) and various weights are assigned to the points according to their class (laser, Lo-to-HiTOT cross-calibration or reverse occupancy) and priority (primary or secondary). The married file has an extra column (the first column) indicating the class and priority: 5/6 indicates reverse occupancy, 7/8 is for Lo-to-HiTOT points and 9/0 is for laser data, where odd numbers are for the secondary and even numbers are for the primary dataset.

Finally, Peter gets these -hm.dat files and applies a weight-and-fit scheme which produces the final output (HiToT and LoTOT files) to be used in the analysis.

Before implementing the new files, a check against real data is mandatory. So far, we have used modified versions of Gus's Monitor program (mine is in /newman/bussy/monitor). Last time I did this I had to re-calculate the pedestals (in out_ped_hi and out_ped_lo) for those pmts associated with two laser balls for which I had (through my own falut) miscalculated the fiber lengths.

2 Apparatus

For all of the above to happen, you need to take calibration data. Here, the Fleyshers, Scott, Gus and others are knowledgeable at different levels so they are the people to ask. The following are the components of the calibration apparatus as of May 4th, 2001: the UCSC sealed-cartridge laser, the UCI dye-module set to 989nm (this is, in fact, the zero of the module where the grating is selecting the whole frequency band as opposed to selecting a narrow range – it gives the highest beam intensity; at 510nm you get nearly as much), the optical fiber, a lens, a light splitter which sends part of the light to the photodiode for DAQ trigger and part to the attenuation wheel, another lens and the receiving end of the fiber which then goes to the optical switch. Out of this 1X30 switch go 27 fibers to the patch panel in the PUB (three of them are missing because they broke: 3, 22, 25). New (blue) labels in sequential order have been attached to the fibers. All 30 fibers between the other side of the patch panel and the pond are connected but we don't know if there are any broken ones (during my last calibration I didn't get data from ball 15 and the data for ball 20 was corrupted; balls 7 and 29 gave very weak data). Right now you have some outrigger fibers ending in the PUB and some in the shack. Some are connectorised, some are not. Make sure the ends are blind-folded when you are not calibrating the outriggers or they will scream. A spare (old) laser cartridge and some calibration junk is in the trailer where we eat lunch.

This is what you do in order to take laser data:

- Turn on the laser (safety interlock and key) and fire it by turning the repetition rate knob. Hook the photodiode output (which in normal running mode is connected to the pulse delay generator) to the oscilloscope and see what voltage you are getting (with the newest cartridge I see 12V), then optimise by tweaking the laser/dye coupling (which as of today consists of a pile of floppies and CD cases and duct tape but Scott is going to make you a nice one). Bear in mind that the photodiode doesn't know about the other beam coming off of the light splitter so you are optimising only as far as the splitter ... so try to find a way to optimise things at the receiving end as well. When output is optimum turn repetition knob to zero (ready for external trigger).

- Turn on things in the electronics crate: in the 5-botton switch, turn on the Master first (rightmost) then the other four from left to right; turn on the NIM crate.

- Make sure the receiving end of the optical fiber is connected to the optical switch (or to whatever outrigger fibers in the shack you want to use while there isn't an optical switch for the outriggers), i.e. make sure the laser light is going where you want it.

- Go to the counting house and open a calibration server (from /CONTROL/CALIB on kahuna do):

./Server.exe &

Then open the calibration web page (http://mgroems.lanl.gov/~calibration) and select laser ball(s), wheel position(s) and number of pulses (2000 by default). Now hit Start. Check that you are getting laser triggers (one of the scalers in the counting house electronics is hooked to the laser system so you should see it counting at 20 Hz). In the same kahuna window where you opened the server from you should see the ball number and wheel position. You can also see if the Calib_RRRR_SSSS.dat file has been created in /aux3/current and whether it is growing (mind you, it only shows up in an ls listing after it has buffered ~1Mb). For problems with getting the calibration system started (switch proximity errors, motion controller errors, no triggers after first wheel change, etc) please refer to the Fleyshers' manual.

- When you are done, wait for the calibration web page to tell you that "it is safe now to turn off your equipment", kill the calibration server (kill -9 pid, where the process id can be seen in the lock file by doing ls -l /CONTROL/CALIB on kahuna), turn off things in the laser shack (in reverse order) and transfer the relevant files (by now in /aux3/Calib) to the lab. Now you are ready to do the analysis, buena suerte!

3 Recommendations

- Simplify code and streamline it so it can be run in one go (maybe two: production of slewing curves/histograms and rest of the analysis). Diagnostic output after each phase is critical if one is to trust the final results. Some of the phases need not be repeated every time (e.g. calculation of speed of light in water, fiber lengths, ...) although they can be used as quality checks.

- Adopt a scheme whereby calibrations are done a few times a year. For instance: do a full timing and photoelectron (PE) calibration as soon as summer repairs are completed, then run shorter PE calibrations every other month where only a fourth (or some other fraction) of the filter wheel positions are used (say, the three darkest sectors and six other sectors evenly spaced throughout the remaining 330 degrees –each sector is 10 degrees wide). One should also avoid redundancy in the clearest sectors. As far as timing calibrations are concerned, after the initial full calibration (individual slewing curves and pedestals), correction for individual pedestal shifts should be done once a month or so (this is very trivial so in principle it could be done automatically every week or even every run). When performing the above-mentioned shorter calibrations one should also check for unexpected slewing curve changes (if they exist, the relevant pmts should be inspected carefully).

- Outrigger calibration: we need a separate optical switch for the outriggers (also, a 1x2 switch between the pond switch and the outrigger switch would help automate things); the current laser shack will get very crowded but will do if the apparatus is organized properly (obviously, a bigger shack would make life easier). One of the simplest approaches for fiber optic layout is to run $\sim$20 long fibers from the shack to the centers of each of $\sim$20 disjoint regions into which the outrigger field can be subdivided with 10 outriggers per region (this assumes a total of 200 outriggers so in reality the number of regions will be smaller). Then, in each region, a 1x10 splitter will connect the long fiber coming from the shack with the 10 outriggers via 10 short fibers, which could be cut to have the same length to easify timing calculation (the long fibers could also be cut to have the same length). For cross-calibration between regions one could choose a representative outrigger in each region, hook it up to a long fiber (without splitter) and then fire 10 such fibers via a splitter at the laser shack end.

- Modify Event Display for laser data. This will allow seeing events in the Calib_RRRR_SSSS.dat as they are produced to make sure the laser data you are taking is any good.

A Raw laser data

- 1999 data: /newman/bussy/laser/1999 (30 files)
- 2000 data: /newman/bussy/laser/SEALED (30 files, one of them corrupted .dat.no)
- 2001 data: /newman/bussy/laser/2001 (test of dual mode: laser + EAS, runs 2894 and 2896 with ball 17 lit in the pond)
- outrigger data: /newman/bussy/laser/TANKS (tests: 3 GRB files in single laser mode with outriggers on the north, south and east rims of the pond; run 2896 in dual mode but forgot to connect fiber optics to some outriggers; run 2901 subruns 353-9 in dual mode with outriggers 23-32 on a 1x10 splitter; run 2901 subruns 362-8 in dual mode with same outrigers on 1x10 splitter off one branch of a 1x5 splitter, i.e. each outrigger sees 1/50 of the laser output, requested by Scott)

Immediate work should be done on being able to comfortably read the laser files taken in dual mode. Because subruns don't coincide with laser ball and wheel position cycles, individual Calib files may contain mixed data from different cycles. Re-ordering, streaming or concatenation of the files is necessary for the calibration code to treat the data properly. Finally, a reminder that the laser ball and wheel position information (originally only in Morse code) is now encoded in eventData.recEvent.calibInfo.ball and eventData.recEvent.calibInfo.filterWheel.