2x2 MINERvA Calibrations Status & Plans

Carlos Pernas, Faiza Akbar, & others

2x2 Analysis Workshop

05/19/2023

WILLIAM & MARY

CHARTERED 1693

Calibration high-level overview

$$E_i = \left[C(t) \cdot S_i(t) \cdot \eta_i^{att} \cdot e^{\ell_i/\lambda_{clear}} \cdot G_i(t) \cdot Q_i(\mathrm{ADC})\right] \times \mathrm{ADC}_i$$

- E_i = energy in strip i
- ADC_i = ADC counts in channel i
- $Q_i(ADC)$ = FEB calibration ADC → Q
- $G_i(t)$ = PMT gain Q → PE
- l_i, λ_{clear} = fiber length outside of strip and attenuation length
- $S_i(t)$ = relative energy correction (strip to strip)
- C(t) = global energy scale factor PE → MeV
- Missing from this formula: plex, pedestals, alignment, cross-talk

[Link to C. Marshall's talk from January Analysis Workshop]

Task list

Stage	Assignment	Name	Priority
Geometry	Geometry verification in Minerva software	Tammy Walton	high priority
	Create a tool for validating geometry across software frameworks		high priority
	Flexible tool for coordinate transformation	Noe Roy	high priority
Simulation	Tool for reading hits from edepsim or Larsoft	Noe Roy	high priority
	Readout/Optical Model Validation		high priority
	Validate how the calibration constants are applied in the Readout		medium priority
	Validate the Event Model for the Simulation		low priority
	Validate the Truth Matching		high priority
	Validate Rock Muons Overlay		low priority
Calibration	Plex	Carlos Pernas	high priority
	Pedestal calibration	Carlos	high priority
	FEB calibration	Faiza Akbar	medium priority
	PMT gain calibration	Brooke Schuld	high priority
	Attentuation Corrections	Carlos	medium priority
	Scintillator plane alignment	Roberto Mandujano?	high priority
	Relative energy calibration	Carlos	medium priority
	Absolute energy calibration		medium priority
	Timing calibration	Faiza Akbar	high priority
	Cross talk calibration		low priority
	Interface the PostgreSQL database with 2x2 reconstruction		low priority

PSQL Calibrations Database

- Tammy Walton has been hard at work setting up the conditions database and new 2x2 specific MINERvA software release

- All tables from the original MINERvA conditions database have been copied over, so we can just add to those existing tables

Database News

- Thanks to CSAID database group, the databases are ready
- The DUNE database managers to maintain ownership
- Databases:
  - Development database: https://dbdata0vm.fnal.gov:9443/dune_mnvcon_dev/app/folders
    - The folders below have been copied to the development database

minerva_pedestals_error	minerva_febs	minerva_meu_resurrection	minerva_atten_id	minerva_timeoffsets
minerva_meu	minerva_febs_eroicakludge	minerva_meu_eroica	minerva_s2s	minerva_s2s_eroica
minerva_pmtgains	minerva_atten_od	minerva_timeslew	minerva_s2s_resurrection	minerva_pedestals

    - View tables via the webserver.
      - Example: https://dbdata0vm.fnal.gov:9443/dune_mnvcon_dev/app/data?f=minerva_febs&t=1640038000
  - Production database: https://dbdata0vm.fnal.gov:9443/dune_mnvcon_prod/app/folders

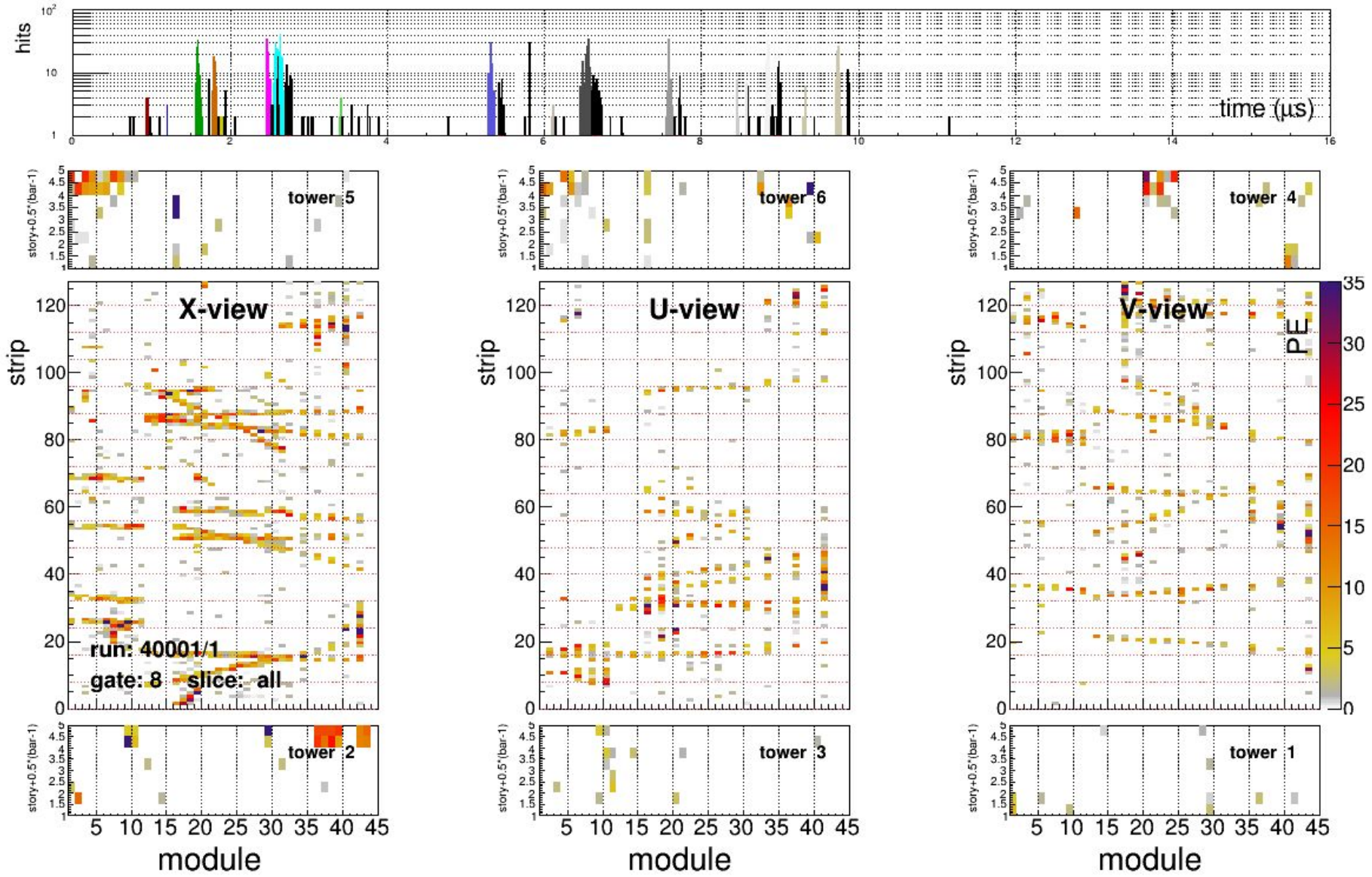
Which calibrations are currently being applied?

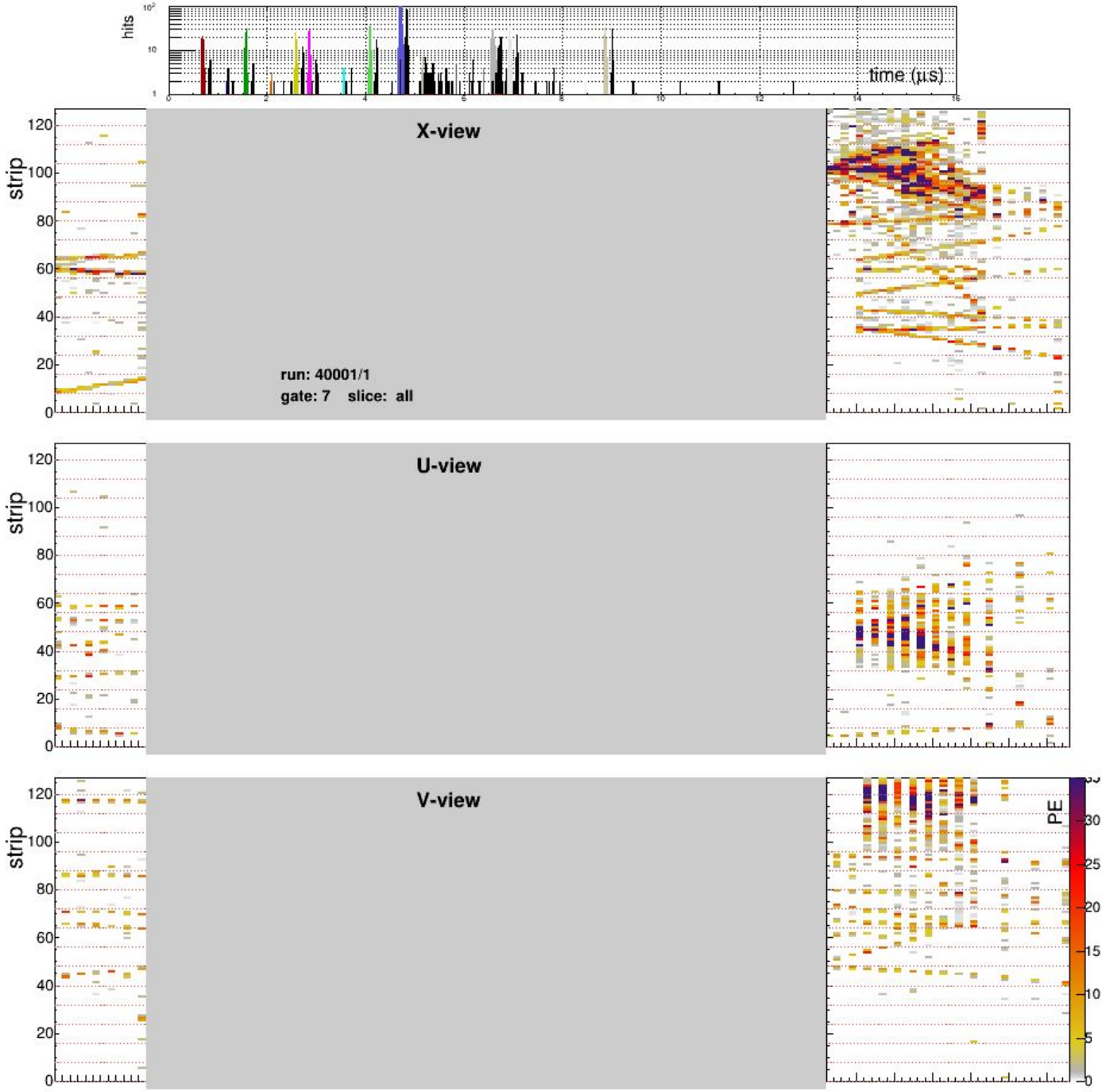
Plex	Yes
Pedestal Suppression	Yes, using data from a 2x2 MINERvA pedestal run in March
FEB Response	Yes, using original MINERvA era constants
Timing	Yes, using original MINERvA era constants
PMT Gains	Yes,
Fiber Attenuation	No
Plane Alignment	No
Relative Energy	Yes, using original MINERvA era constants
Absolute Energy	Yes, using original MINERvA era constants
Cross-talk	No

Plex

- The plex is the mapping between electronics address and physical strip locations, and the first step for many other calibrations
- Necessary to run the tracker, which is in turn necessary for most calibration steps that rely on rock muons.

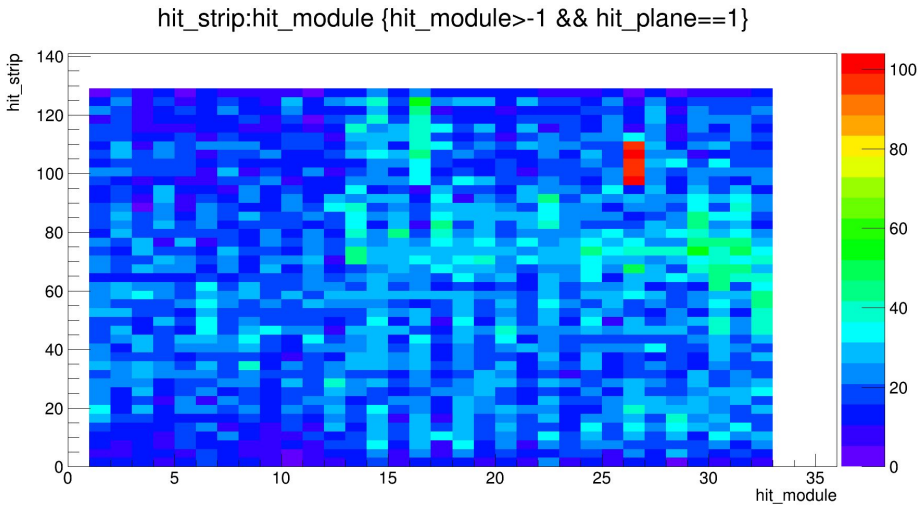
- The new plex exists and has been validated (inner detector only) through hand-scanning of through going muon events to search for any obvious kinks in tracks
- Eventually I plan to come back to this using an algorithmic plex correction method after other calibration steps are in place





Pedestal Suppression

- Pedestal runs have been taken and continue to be taken occasionally with the DAQ.
- Currently using a pedestal table taken in around March, seems to perform reasonably well but there is at least 1 obvious problem area



- I’ve begun working on this in the past week

FEB & Timing Calibrations (from Faiza)

- Calibrations are applied to convert ADC counts recorded by the Front End Board to energy.
- Reuse and modify existing MINERvA calibration software for 2x2

Calibration high-level overview

$$E_i = \left[C(t) \cdot S_i(t) \cdot \eta_i^{att} \cdot e^{\ell_i/\lambda_{clear}} \cdot G_i(t) \cdot Q_i(\mathrm{ADC})\right] \times \mathrm{ADC}_i$$

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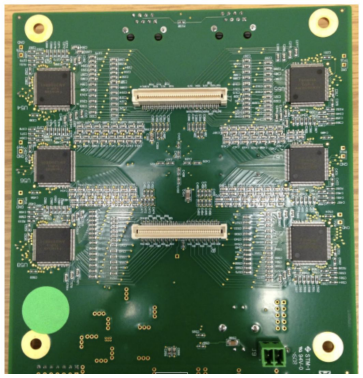
https://indico.fnal.gov/event/57076/sessions/21509/#20230119

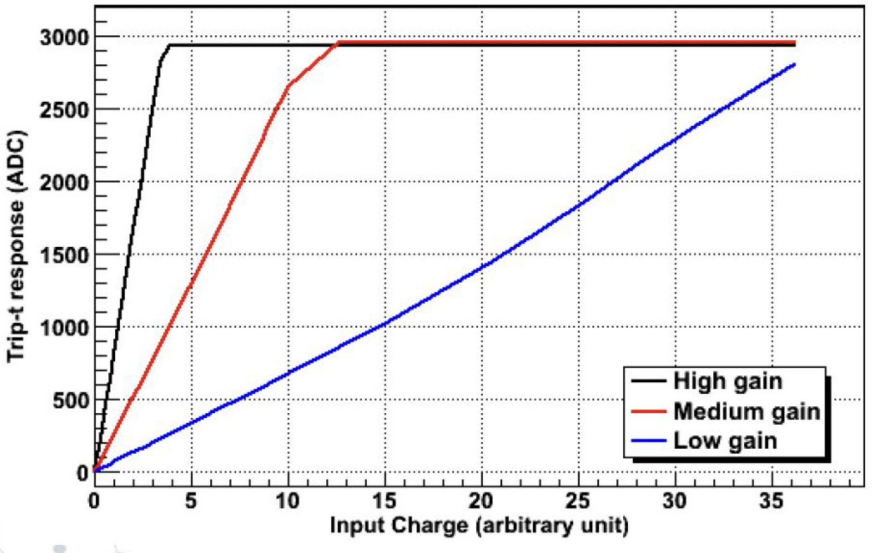
Chris's talk at the last workshop

Slide from Faiza Akbar

FEB calibration: Qi(ADC)

- Convert ADC to charge equivalence for the Front End Boards' low, medium, and high ADC channels.
- Constants were measured in 2009 using a tri-linear fit for high, med, and low gains.
- There are 18 parameters: slopes and starting point of the three linear segments
- A table with all the constants exists for each FEB in the MINERvA DB (text files).
- Following Tammy's tutorial able to access MINERvA DB on the DUNE.
- FEB constants are ready to be uploaded on the production DB.
- Not time-dependent, need to update the DB only when there is a FEB swap





Slide from Faiza Akbar

Working on…

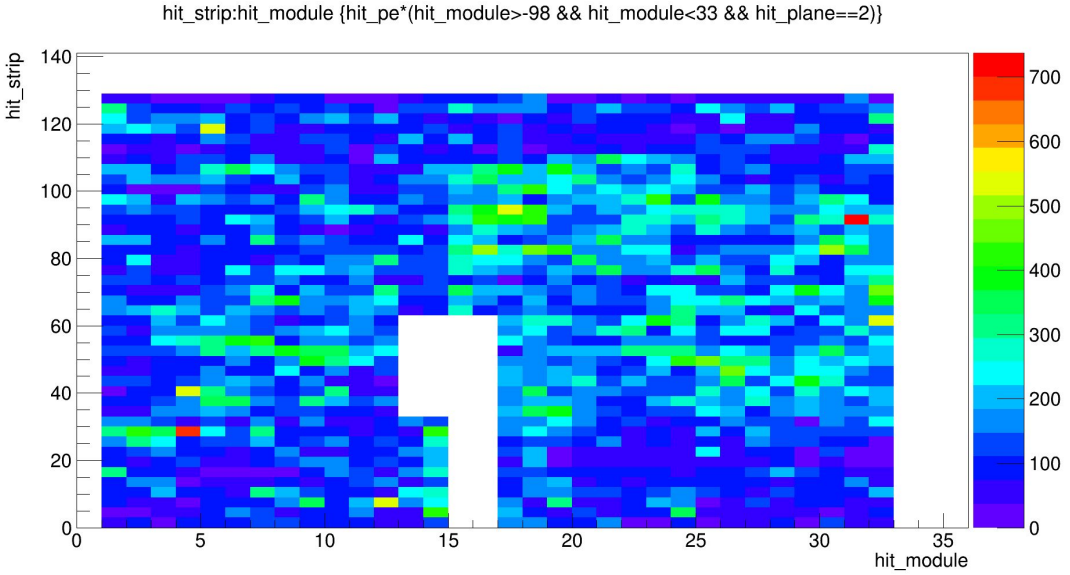
- Timing calibration corrects two effects:
  - timing offsets on each FEB
  - pulse-height dependent effect called “time slewing."
- For timing: calibration is determined using through-going rock muons.
- This calibration is critical for 2x2 in order to do timing-based track matching between MINERvA and LAr.

Slide from Faiza Akbar

PMT Gain

- Currently using the old calibration enabled in the nearline options settings
- Should be close for the majority of PMTs, but ~10% of PMTs are different with respect to electronics address

- Brooke Schuld to begin work on this soon.



Other Calibrations (coming soon)

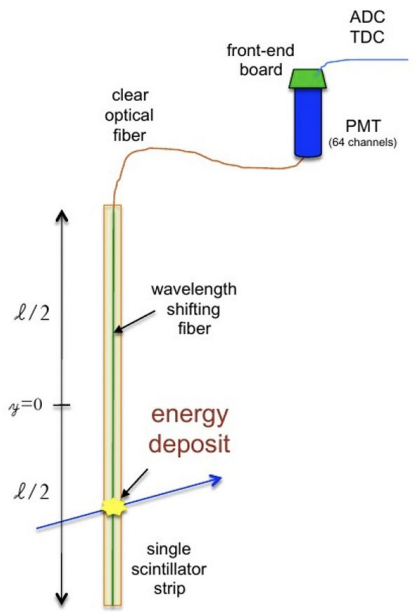
- PMT gain and scintillator plane alignment are the two remaining “high priority” calibrations that we have yet to begin dedicated work on, but both have names assigned (Brooke Schuld & Roberto Mandujano).
- There are a few other remaining “medium priority” calibrations, some with names and some without so there is room for people to get involved

Tracking note-

- Most calibrations rely on having basic reconstruction, namely the ability to identify muons.
- Noe has begun working on applying the reconstruction to our newly plexed data

Back up

What's happening in the detector



- Ionization energy produces scintillation light in the plastic strip
- light is absorbed and re-emitted by a wavelength-shifting optical fiber in the center of each strip.
- Light propagates down WLS fiber in strip, then through clear fiber to PMT box, with some loss due to attenuation
- Photoelectrons are amplified by PMT
- PMT signal is digitized by FEB, giving pulse height in ADC counts and timestamp in clock ticks

https://indico.fnal.gov/event/57076/sessions/21509/#20230119

Chris's talk at the last workshop

A snippet of FEB constants in DB

```
dune_mnv_dev=> select * from minerva_febs_data limit 100;
 __iov_id | channel  | crate | croc | chain | board | pixel | hg_adc0 | hg_adc0_err | hg_slope1 | hg_slope1_err | hg_xkink1 | hg_xkink1_err | hg_slope2 | hg_slope2_err | hg_xkink2 | hg_xkink2_err | hg_slope3 | hg
_slope3_err | hg_chi2ndf | mg_adc0 | mg_adc0_err | mg_slope1 | mg_slope1_err | mg_xkink1 | mg_xkink1_err | mg_slope2 | mg_slope2_err | mg_xkink2 | mg_xkink2_err | mg_slope3 | mg_slope3_err | mg_chi2ndf | lg_adc0
| lg_adc0_err | lg_slope1 | lg_slope1_err | lg_xkink1 | lg_xkink1_err | lg_slope2 | lg_slope2_err | lg_xkink2 | lg_xkink2_err | lg_slope3 | lg_slope3_err | lg_chi2ndf
----------+----------+-------+------+-------+-------+-------+---------+-------------+-----------+---------------+-----------+---------------+-----------+---------------+-----------+---------------+-----------+---
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+------------+----------+-------------+----------+-------------+----------+-------------+----------+-------------+----------+-------------+----------+-------------+----------+-----------
     167 | 35926176 |     1 |    2 |     2 |     3 |     5 | 404.144 |           0 |   751.789 |        12.073 |     0.214 |         0.244 |   771.762 |         5.996 |     1.339 |         0.122 |   811.835 |
     2.497 |      6.303 | 430.951 |          0 |   251.237 |         2.533 |         1 |         0.511 |   253.896 |         1.411 |         4 |          0.02 |   267.403 |         0.869 |      21.079 | 441.233
|          0 |    62.622 |         0.163 |         7 |         0.617 |    64.267 |         0.22 |         19 |         0.031 |    82.748 |         0.293 |      7.522
     167 |  5517888 |     0 |    5 |     2 |     3 |    18 | 433.348 |           0 |   794.913 |        15.284 |     0.203 |         0.004 |   820.439 |         7.056 |     1.344 |         0.137 |   871.237 |
     3.928 |      15.549 | 432.141 |          0 |   254.291 |         2.782 |         1 |         0.305 |   260.283 |          1.55 |         4 |          0.023 |   272.773 |         0.954 |      25.429 | 475.893
|          0 |    65.346 |         0.195 |     7.131 |         1.325 |    67.267 |         0.243 |         19 |         0.041 |    87.322 |          0.27 |      5.962
     167 | 36742336 |     1 |    3 |     0 |    10 |    38 | 489.561 |           0 |   808.184 |         8.66 |     0.229 |         0.171 |   828.649 |         4.293 |     1.264 |         0.092 |   864.664 |
     1.801 |      3.276 | 490.205 |          0 |   260.336 |         2.544 |         1 |         0.375 |   262.828 |         1.417 |         4 |          0.02 |   277.096 |         0.872 |      21.258 | 492.097
|          0 |    67.414 |         0.113 |     7.462 |         0.433 |    70.134 |         0.231 |    18.337 |         0.109 |    92.044 |          0.18 |      2.02
     167 | 37884960 |     1 |    4 |     1 |     1 |    33 | 434.413 |           0 |   769.676 |        16.944 |       0.2 |         0.553 |   791.553 |         7.153 |     1.401 |          0.15 |   842.569 |
     4.358 |      19.159 | 443.835 |          0 |   245.665 |         2.704 |         1 |          0.35 |   249.269 |         1.506 |         4 |          0.021 |   261.786 |         0.927 |       24.01 | 442.049
|          0 |     62.79 |          0.19 |     7.064 |         2.118 |     64.76 |         0.238 |         19 |         0.065 |    83.756 |          0.266 |      5.827
     167 |  7476672 |     0 |    7 |     1 |     1 |    46 | 431.866 |           0 |   777.973 |        15.199 |       0.2 |         0.617 |   794.753 |         6.406 |       1.4 |         0.147 |   841.337 |
     3.855 |       15.24 | 431.128 |          0 |   247.103 |         2.868 |         1 |          0.35 |   251.663 |         1.598 |         4 |          0.023 |   264.133 |         0.983 |      27.014 | 474.182
|          0 |    62.635 |         0.162 |         7 |         1.752 |    63.985 |         0.219 |         19 |         0.022 |    83.588 |          0.292 |      7.446
     167 |  1446144 |     0 |    1 |     3 |     1 |     8 | 435.711 |           0 |   780.562 |         9.992 |     0.205 |         0.338 |   801.042 |          4.95 |     1.323 |         0.106 |   839.185 |
      2.12 |      4.542 | 436.181 |          0 |   255.781 |         2.646 |         1 |           0.5 |   257.978 |         1.474 |         4 |          0.02 |   271.754 |         0.907 |      22.988 | 437.245
|          0 |     64.34 |         0.163 |     7.197 |         0.667 |    66.558 |         0.204 |         19 |          0.08 |    87.061 |          0.226 |      4.199
     167 | 41312832 |     1 |    7 |     3 |     6 |    18 | 461.431 |           0 |   777.694 |         14.18 |       0.2 |         0.463 |   796.888 |         6.009 |     1.359 |         0.144 |    840.77 |
     3.661 |      13.566 | 464.963 |          0 |   246.988 |         2.679 |         1 |         0.541 |   250.783 |         1.492 |         4 |          0.028 |   261.305 |         0.918 |      23.566 | 469.157
|          0 |    63.129 |         0.175 |     7.447 |         0.821 |    65.265 |         0.361 |    18.944 |          0.2 |    84.152 |          0.281 |      4.877
     167 |  2249216 |     0 |    2 |     1 |     5 |    16 | 392.729 |           0 |   744.499 |        16.329 |       0.2 |         0.446 |   772.403 |          6.88 |     1.401 |         0.144 |   823.646 |
     4.197 |      18.556 | 389.518 |          0 |   234.614 |         2.804 |         1 |         0.186 |   240.397 |         1.544 |         4 |          0.021 |   252.765 |         0.968 |      26.286 | 479.199
|          0 |    64.011 |         0.211 |         7 |         0.426 |    64.935 |         0.286 |         19 |         0.016 |     83.18 |          0.38 |     12.667
     167 |  2237536 |     0 |    2 |     1 |     2 |    35 | 438.079 |           0 |   800.908 |        12.354 |      0.23 |         0.329 |   822.157 |         6.164 |     1.341 |         0.133 |   860.081 |
     2.593 |      6.796 | 466.839 |          0 |    262.25 |         2.546 |         1 |         0.443 |   265.175 |         1.418 |         4 |          0.021 |   278.206 |         0.873 |      21.291 |  496.93
|          0 |    66.393 |         0.137 |     7.464 |         0.551 |    68.979 |         0.282 |    18.656 |         0.137 |    90.497 |          0.22 |      2.998
```