HAWC Optical Calibration

Observations from CSU tests

John A.J. Matthews

johnm@phys.unm.edu

University of New Mexico

Albuquerque, NM 87131

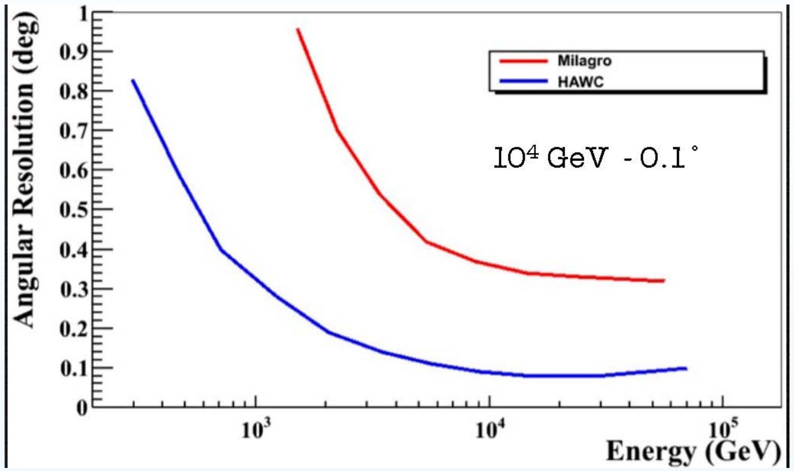
Calibration system: *original design goals*

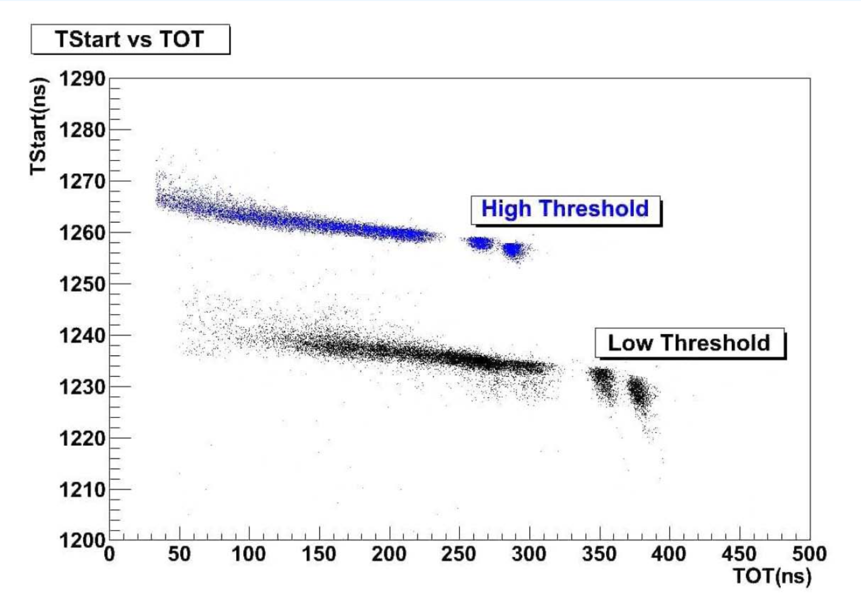
- The primary goal of the HAWC optical calibration system is to measure relative channel-to-channel time offsets VS signal size with a precision ~ 1nsec. This is done using short (< 1nsec), 532 nm laser pulses distributed using optical fibers to each water Cherenkov detector in the array. Real time measurement of laser pulse *round-trip* times monitor the time delay(s) and stability of our light delivery.

- A related (secondary) goal is to provide light pulses over a range of intensities from ~ 1 PE to $\sim 10^4$ PE. This then provides the calibration of HAWC signal size: $< n_{PE} >$ VS ToT. This is done using filter wheels and neutral density filters at the (laser) light source.

- Finally the system should be robust, easy to use and to maintain.

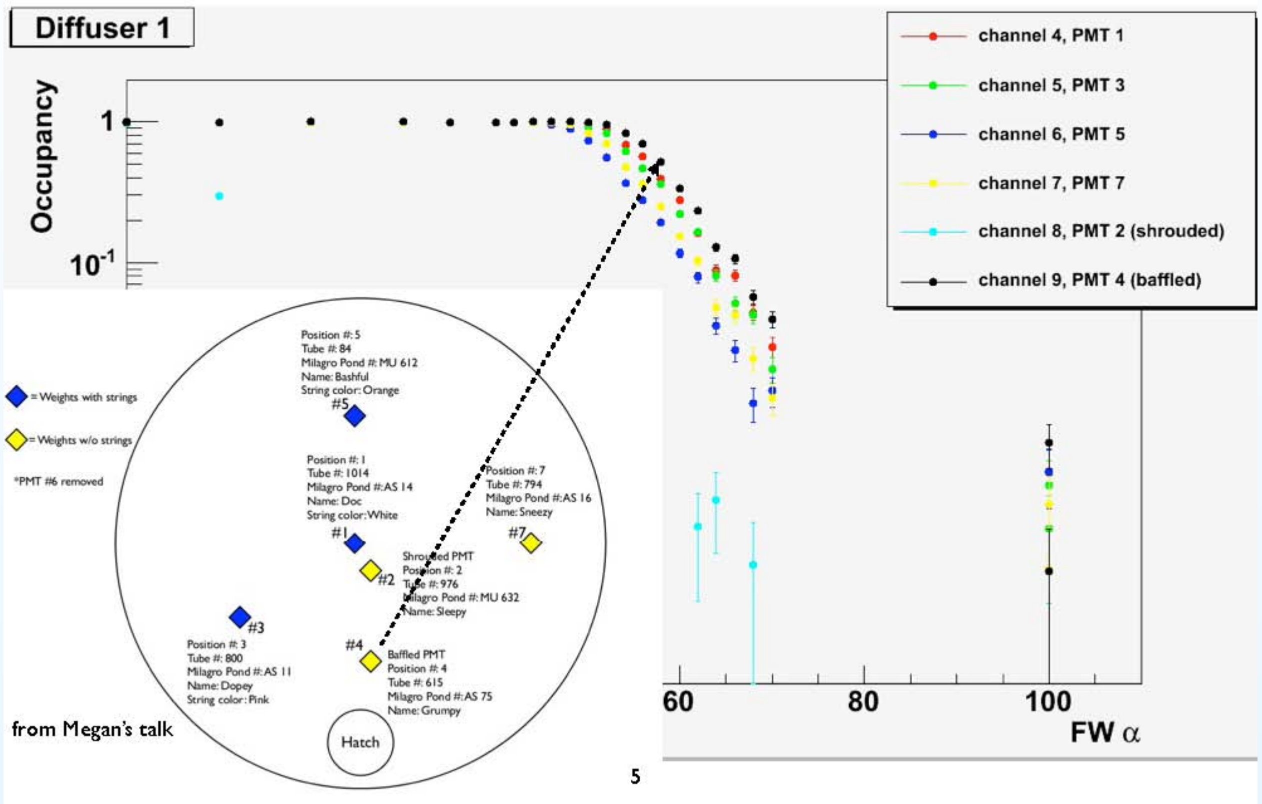
Calibration system: *current design goals (I)*





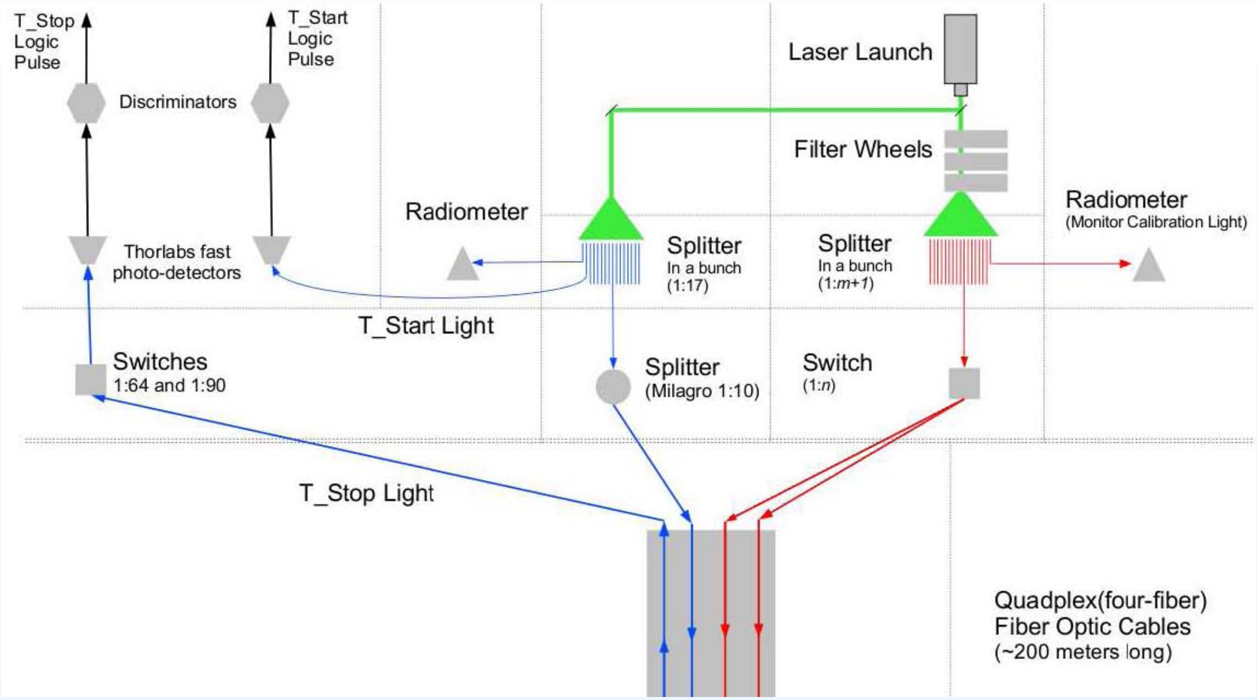
- (Top figure:) What timing systematic errors are used in the HAWC simulations?
- Thus do the PMTs need to be calibrated to a precision of 1 nsec, to a precision of 0.5 nsec or what?
- (Bottom figure:) Slew time (nsec) VS ToT are already being studied in the CSU prototype WCD.
- Precision timing requires: sufficient ND settings to map the slewing VS ToT space and short term laser stability
- We are (probably) not yet able to say what calibration precision is possible.

Calibration system: *current design goals (II)*



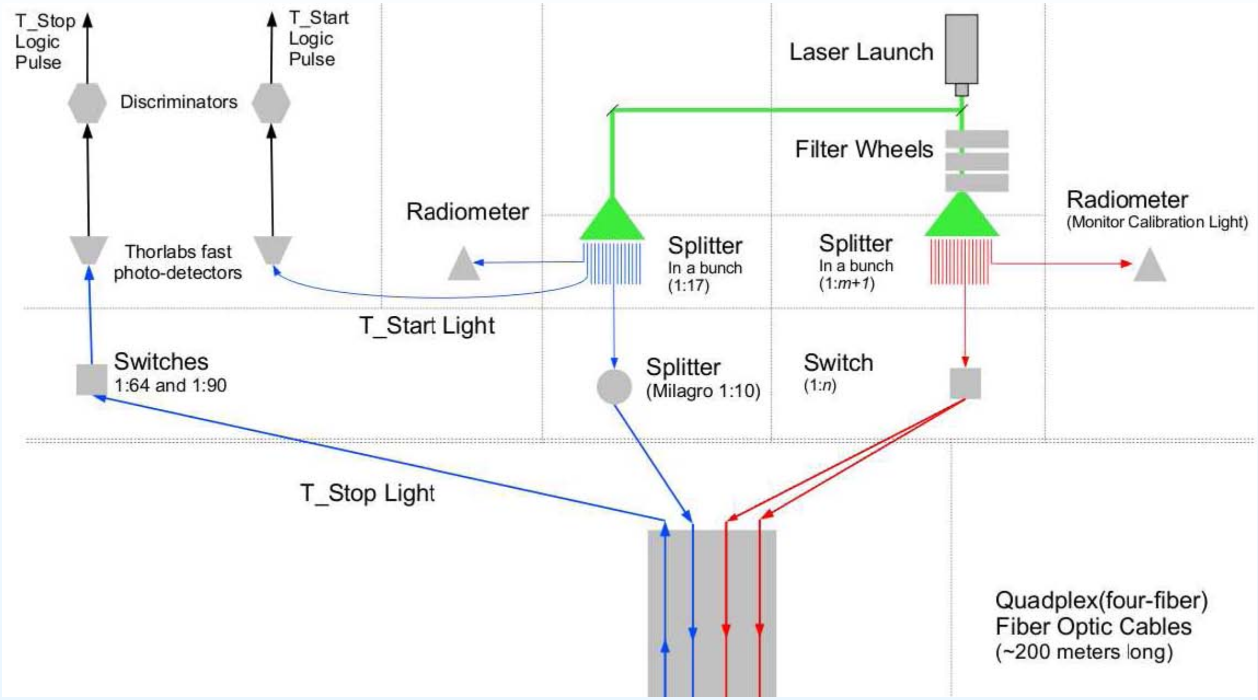
- Plot shows that PMTs may not be equally sensitive. The addition of *conical* white collars significantly increases the PMT signal.
- While the dynamic range of the experiment is $\sim 10^4$ for practical reasons the calibration system needs to provide light pulses over a dynamic range of $\lesssim 10^6$, *viz* from < 0.1 PE to $> 10^4$ PE.

Calibration system: *two distinct modes (I)*



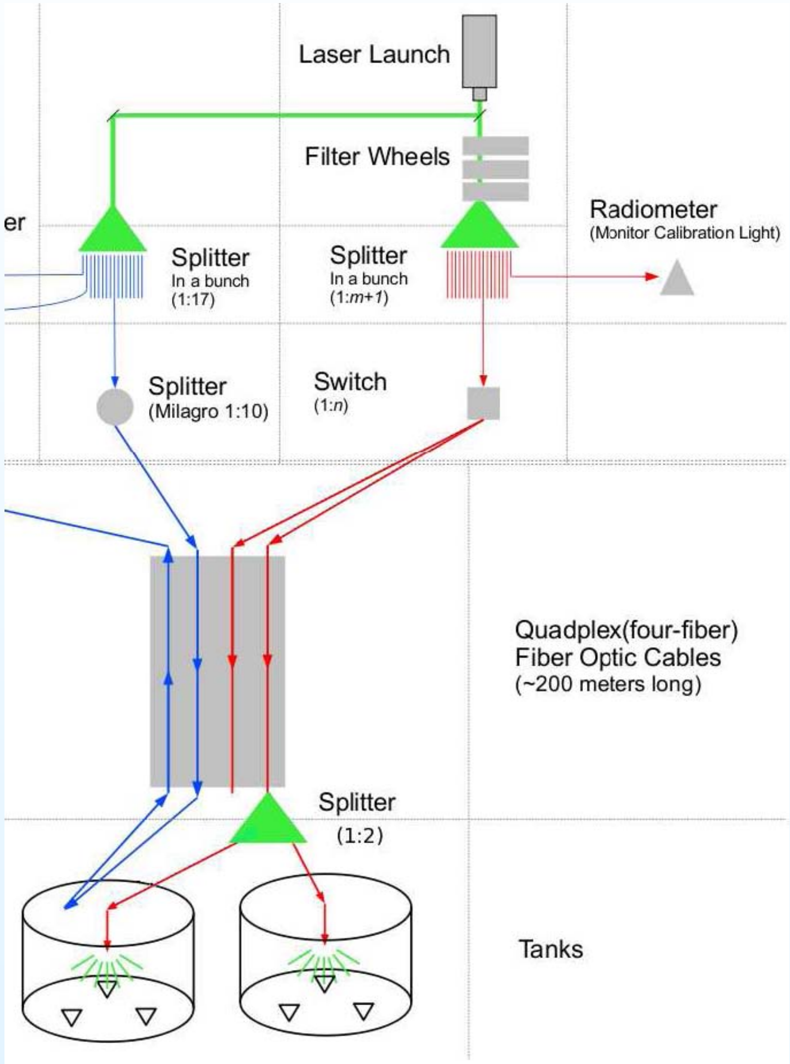
- light pulses into the tanks (red light paths):
  1. 1/16 of array at any time (set by DiCon 1:16 switches)
  2. step through intensities using neutral density filters
  3. provide sufficient pulses at each intensity as required by the calibration analyses
  4. to date our initial CSU prototype WCD studies focus on this mode

Calibration system: *two distinct modes (II)*



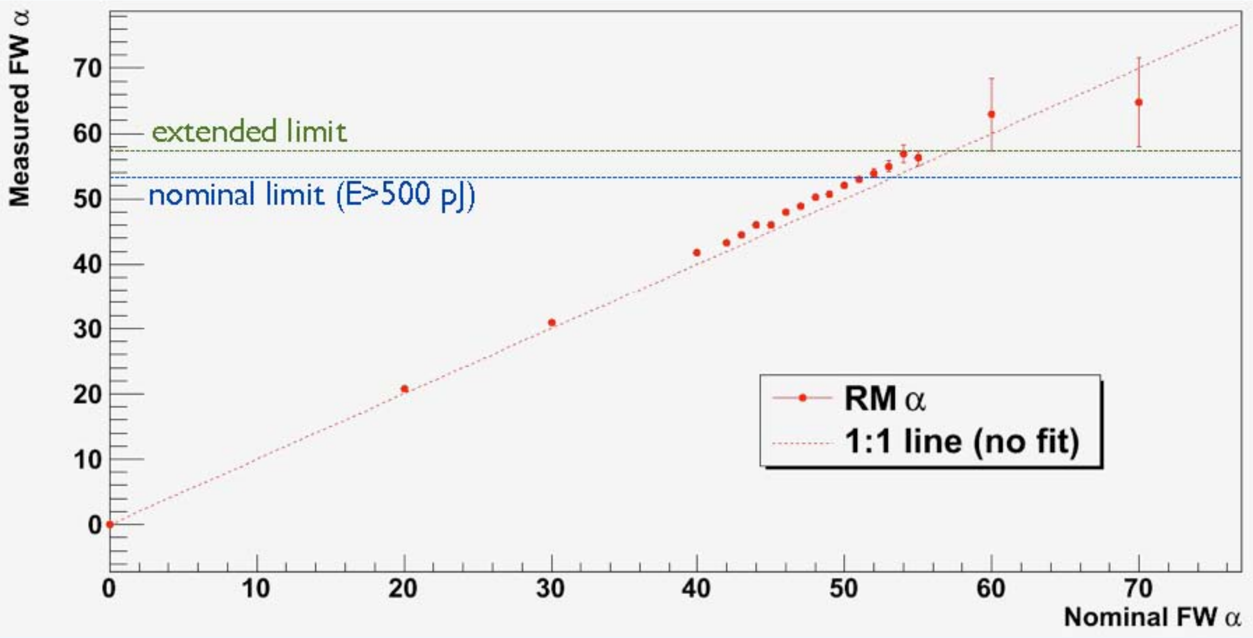
- round-trip timing calibrations (blue light paths):
  1. the goal is to monitor the time stability of the calibration pulses delivered to each pair of water Cherenkov tanks
  2. 1 light delivery path is monitored at any given time
  3. as no light enters the tanks this calibration has no direct impact on the DAQ
  4. to date our initial CSU prototype WCD studies ignore this mode

Calibration system: *results from CSU (I)*



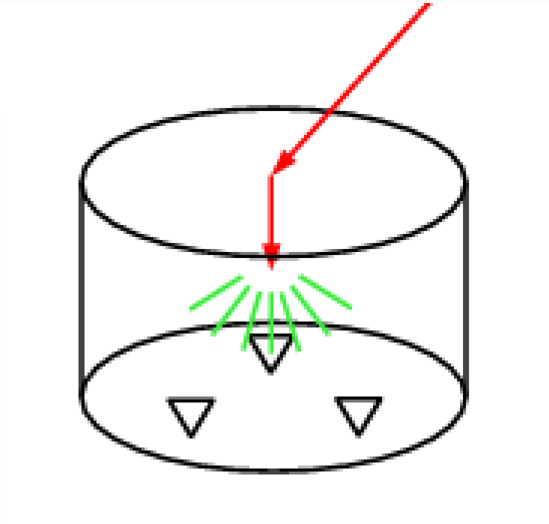
- Is the proposed hardware *matched* to the calibration needs of HAWC?
  1. Initial tests at CSU have focused on the ability to measure the average PMT signal in photo-electrons $< n_{PE} >$ VS the neutral density (ND) filter transmission: $T = 10^{-\alpha/10}$
  2. Based on the prototype HAWC calibration system at CSU, the observed maximum PMT signals are sufficiently large to allow use of 1:2 splitters in the field enclosures.
  3. This reduces the number and complexity of optical switches (in the calibration room) for a cost saving of about \$70K.
  4. To match the laser and *monitor* radiometer dynamic ranges, we combine several *splitter* outputs. For the CSU test 6 fibers are combined to increase the intensity by $\sim 6\times$

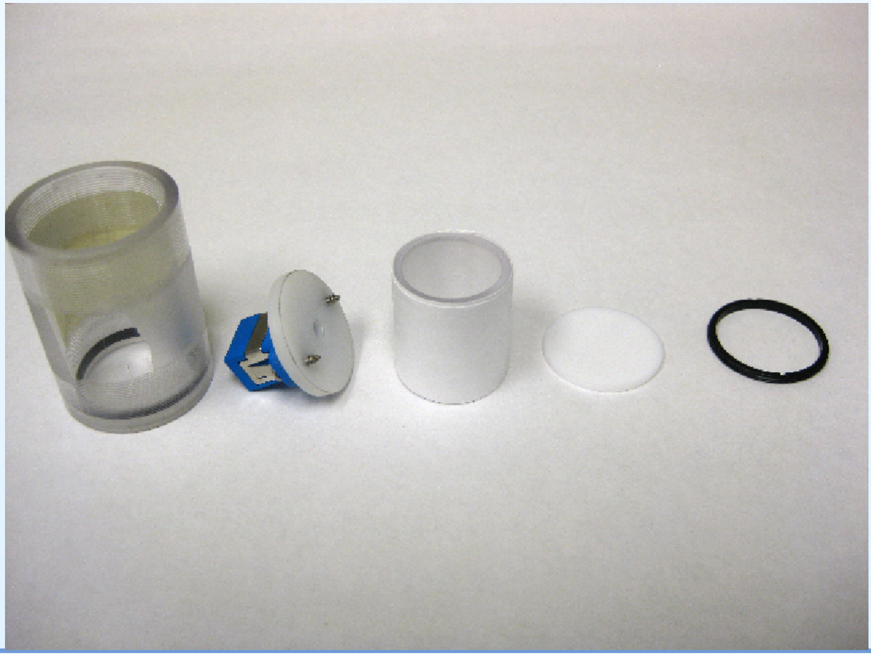
Calibration system: *results from CSU (II)*



- consistency of attenuation measurements:
  1. The neutral density (ND) filter transmission is determined two ways:
     (a) add (the logarithmic) ND factors (α)
     (b) measure the intensity of the transmitted light using the *monitor* radiometer
  2. At this time we observe a $\sim 5\%$ difference ... which is significant over the dynamic range approaching 10^6!
  3. The α-factors seem to be in a constant ratio. Is this the case? And what are the implications for the determination of $< n_{PE} >$ VS transmission (T)?

Calibration system: *results from CSU (III)*



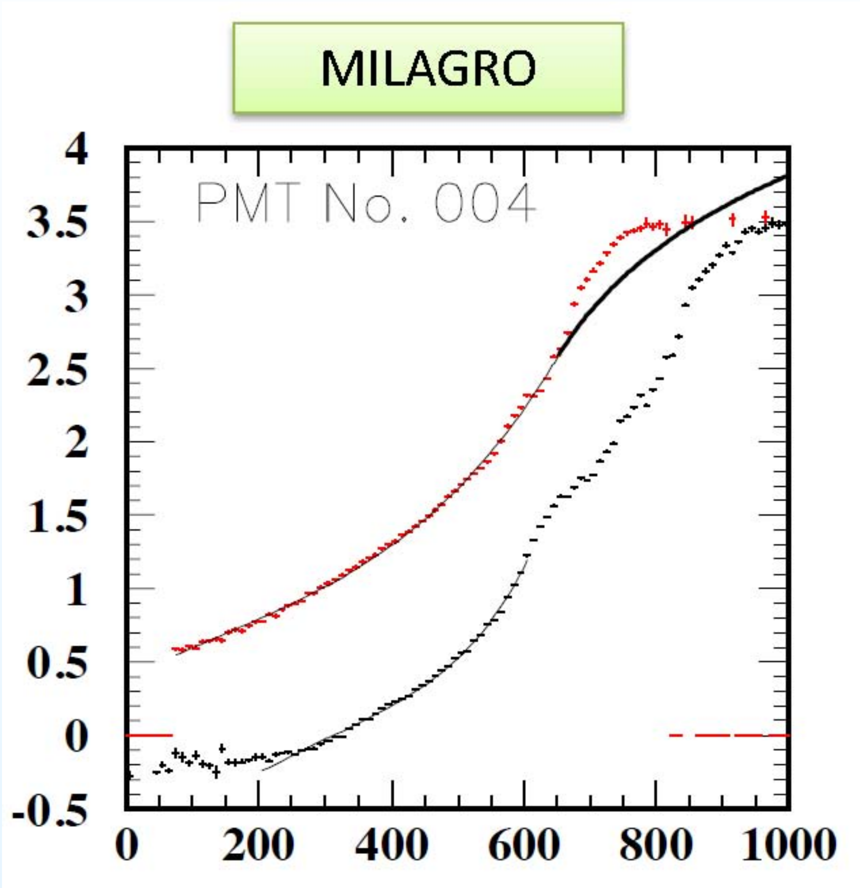


- One optical fiber terminates at a *diffuser* near the top center of each WCD.
- Four different prototypes were evaluated at CSU. The *brightest* design includes:
  1. 1” ID, threaded, polycarbonate outer cylinder
  2. fiber SC adapter screwed to 25mm diameter white Delrin
  3. 7/8” OD, polycarbonate inner cylinder wrapped with TYVEK
  4. 1.04mm thickness virgin Teflon (diffuser)
  5. (2) ThorLabs 1” optics collars
- Optical fiber *snaps* into standard SC connector for easy assembly/dis-assembly.

Calibration system: *results from CSU (IV)*

- Planning for the calibration room at HAWC:
  1. The calibration system includes many components and related controllers.
  2. And the DiCon optical switch crates are still to be included at CSU.
  3. It is time to begin planning the calibration room at HAWC.
  4. It is also time to begin planning for storage of *excess* fiber for each of the 600'-distribution fibers: perhaps on top of the *excess* (long PMT) cables.

Calibration system: *other issues ...*



- The relation between PMT signal: $< n_{PE} >$ and ToT is complex: do 3 filter wheels provide enough fine and coarse settings to map the response (or for the low light level fits of average number of photo-electrons VS light intensity (I) or equivalently ND filter transmission (T): $< n_{PE} > \;\; \propto \; I \; \propto \; T$)?

Calibration system: *comments*

- Prototype HAWC calibration systems at CSU, and at MTU, provide essential testing facilities for the calibration system hardware, control software and analysis software.

- A dedicated team and weekly calibration phone meetings has resulted in good progress: details in the calibration session!