SBS ECAL PMT Testing @ JMU Status Report

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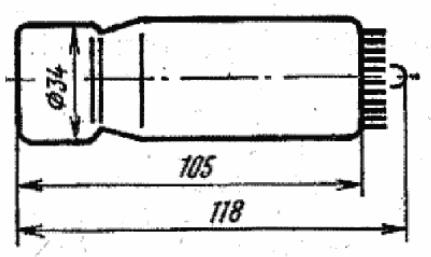
- *3K+ PMTs to be tested*
- *FEU-84*
- *Reject defective tubes*
- *Measure:*
  - *Pedestal*
  - *Gain vs HV*
  - *(Relative Q.E.)**

FEU-84 Specifications
Translation from Russian



Photocathode diameter	25 mm
Number of stages	12
FEU-84, FEU-84-1	
Wavelengths of maximum sensitivity	420-480 nm
Cathode lumininous sensivity (300-350 V)	> 80 microA/lm
Anode luminous sensitivity (1700 V)	100 microA/lm
Cathode radiant sensitivity (694 nm)	>3 mA/W
Dark current	< 200 nA
Life expentancy	> 1500 h
Anode sensitivity after 1500 h	> 80 A/lm
Dark current after 1500 h	< 250 nA
FEU-84-3	
Wavelengths of maximum sensitivity	420-550 nm
Dark current	< 50 nA
Signal to noise ratio ?	22
Maximum Ratings	
Max Voltage	1900 V
Max anode current	5 micro A

JMU ECAL PMT Testing Facility
V 2.0

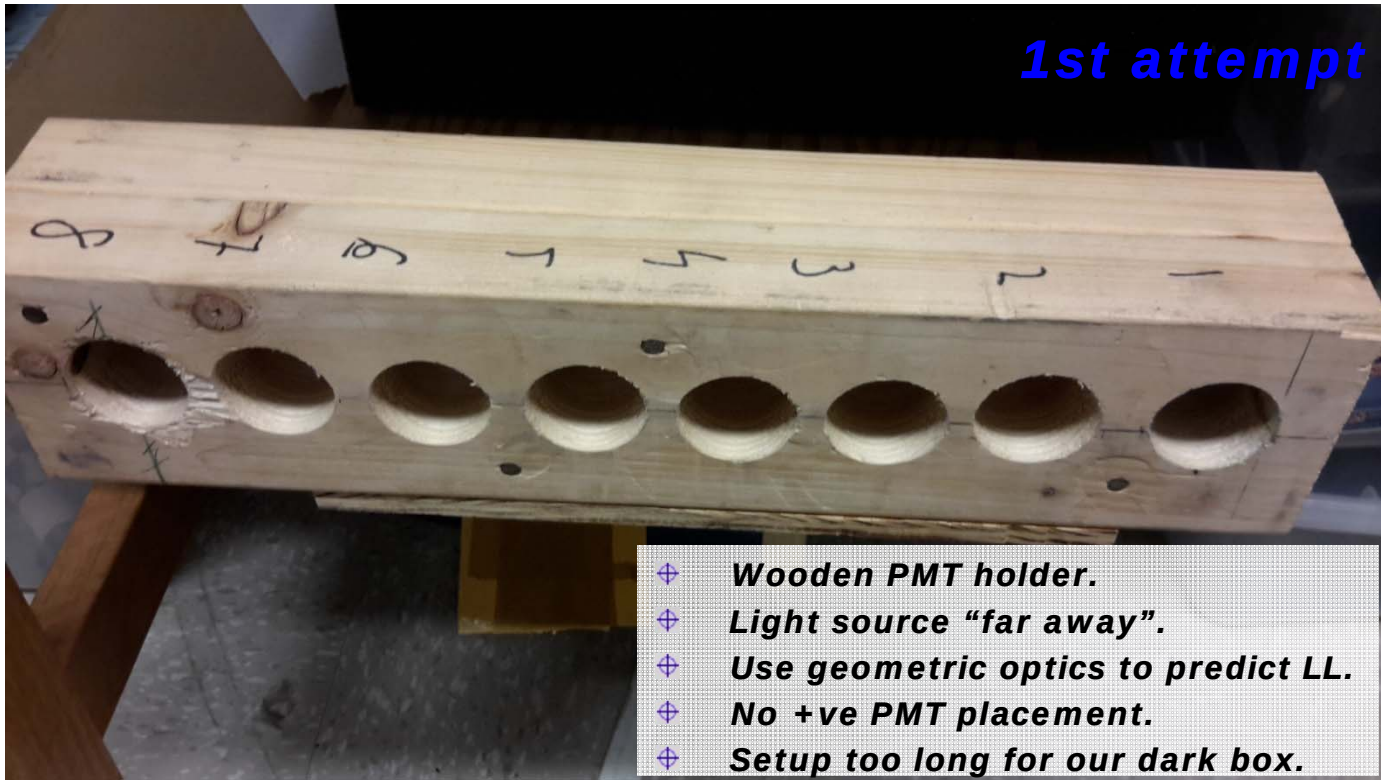
- Just $0.02 worth of history…
- During our previous Report (2/2016) collaborators voiced concerns (rightfully so!) about the Q.E. measurement plans.

- After some head scratching…
- And some “false starts”…
- … managed to …
- redesign test setup and procedure.

- V2.0 Test Stand
- Why we think it works. Early results.

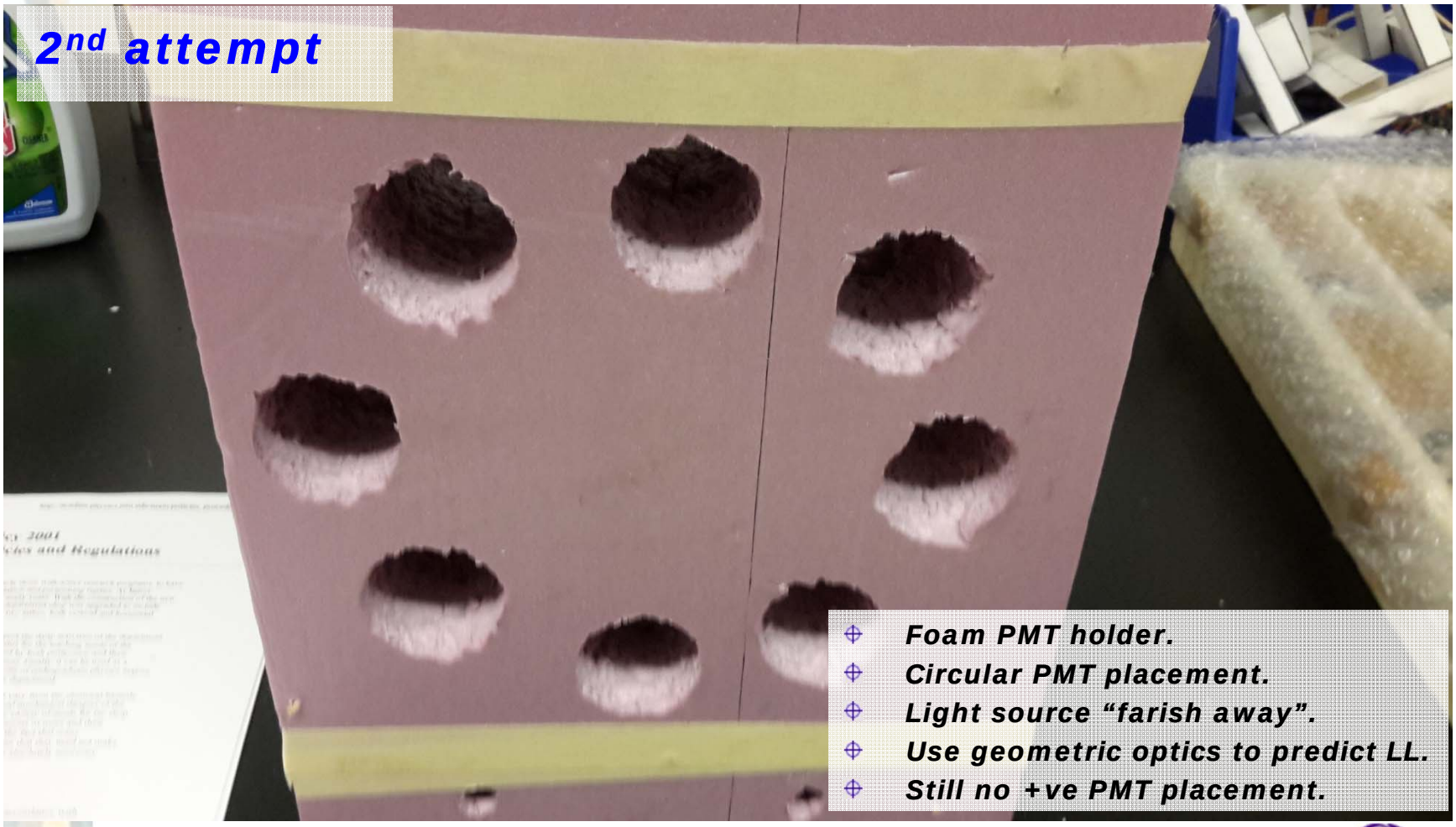
Testing Facility v 2.0

- Ideally one will have:
  - an absolutely calibrated light detector
  - and a state-of-the art beam splitter
- We have neither. We need to improvise.



Testing Facility v 2.0

2nd attempt



- Foam PMT holder.
- Circular PMT placement.
- Light source “farish away”.
- Use geometric optics to predict LL.
- Still no +ve PMT placement.

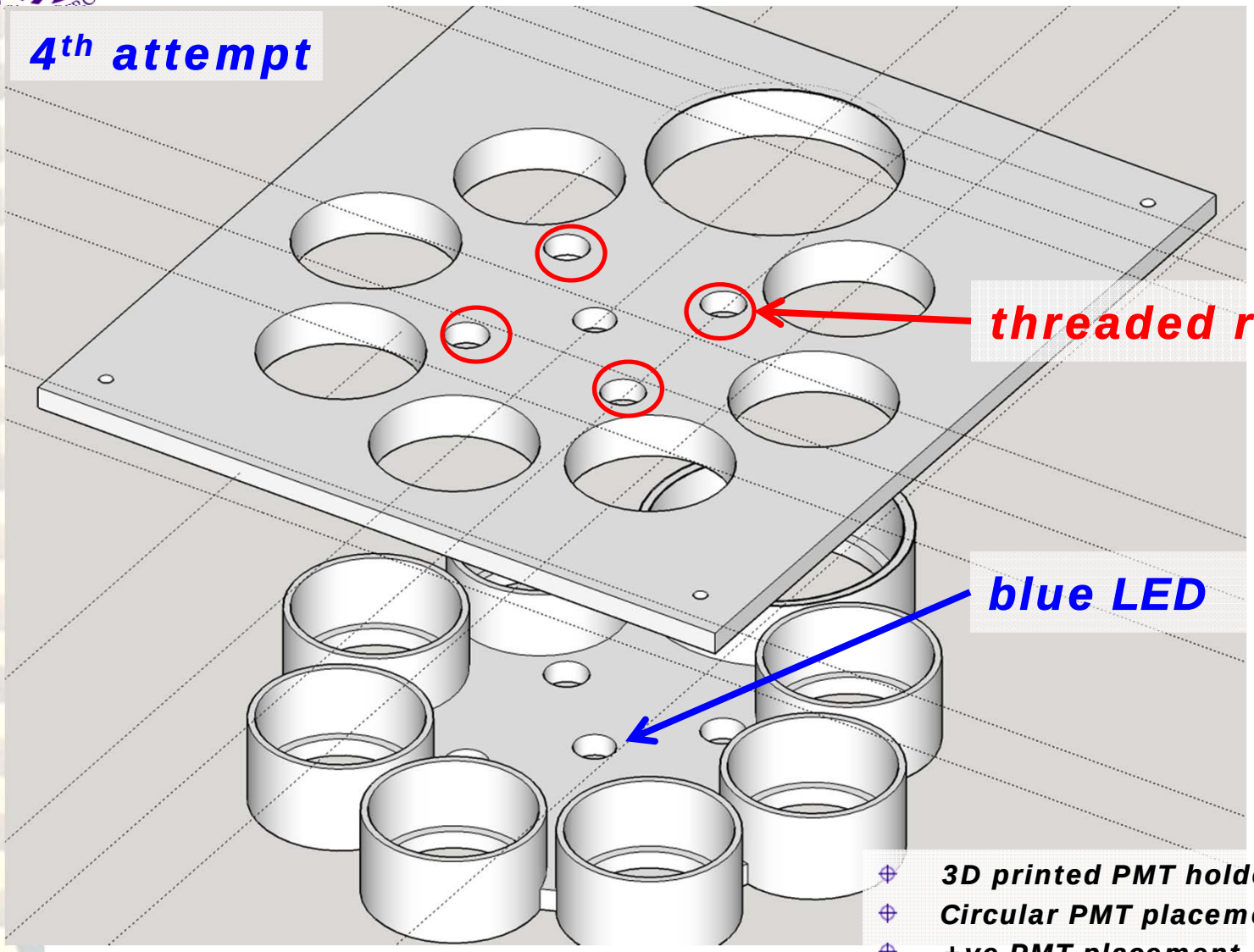
Testing Facility v 2.0

3rd attempt (not the charm!)

- 3D printed PMT holder.
- Circular PMT placement.
- +ve PMT placement (stop)
- PMTs sag if not supported at the back.

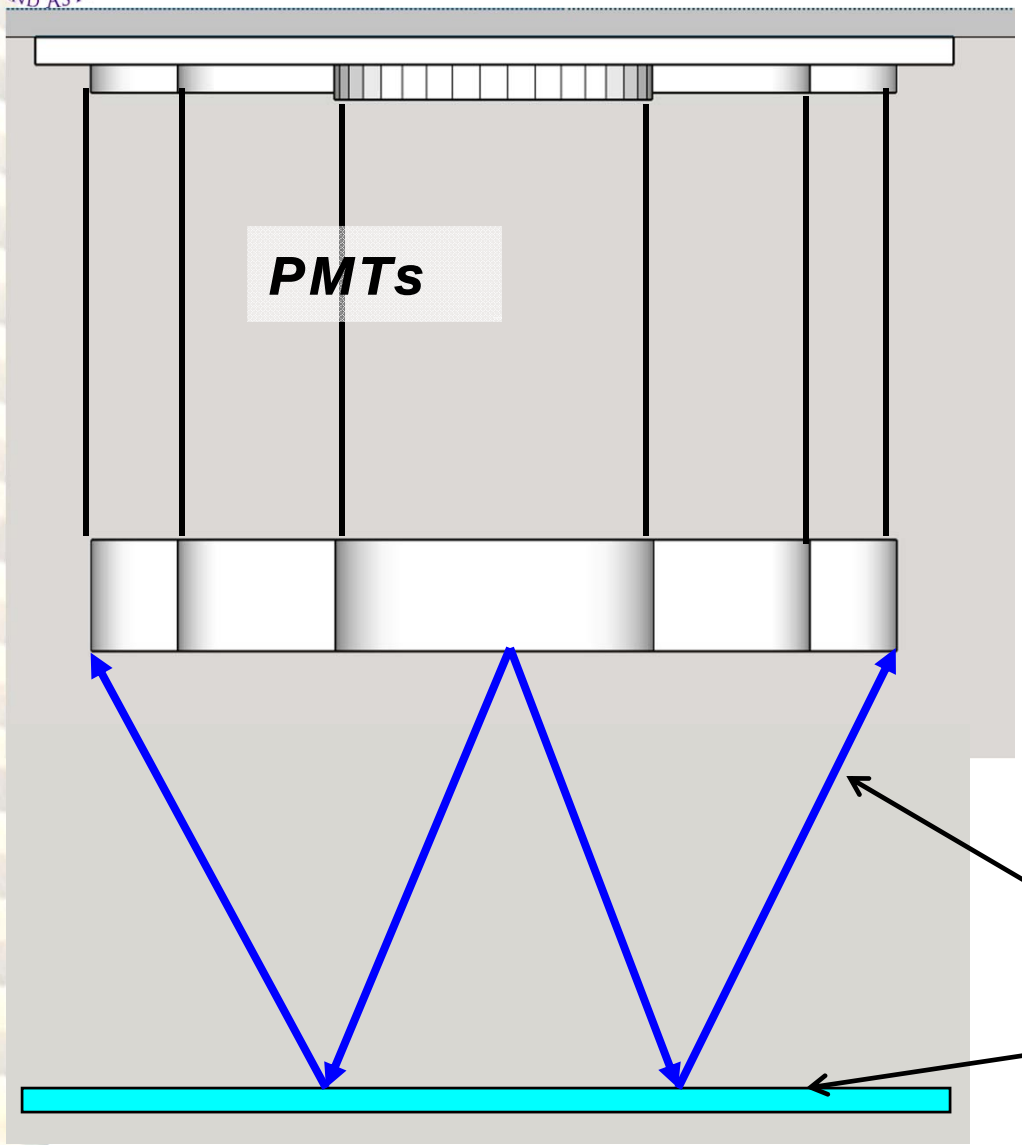
Testing Facility v 2.0

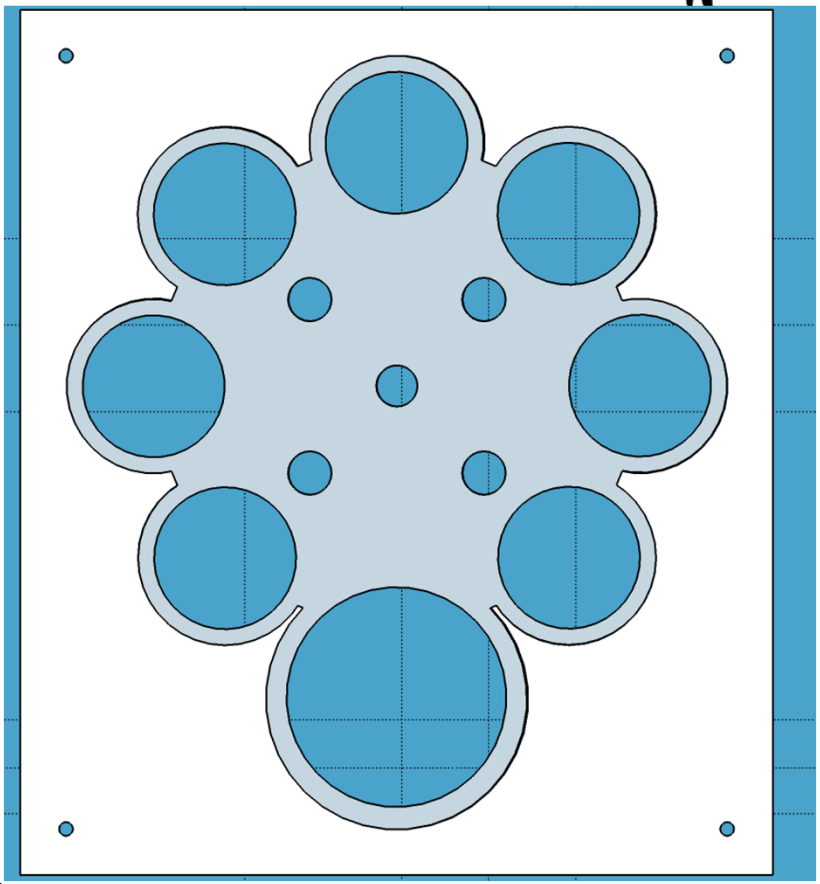
4th attempt



- 3D printed PMT holders (top/bottom)
- Circular PMT placement.
- +ve PMT placement (stop).
- Vertical setup.

Testing Facility v 2.0





Gain & (Relative) Q.E.

- ***For moderate light levels** (50-150 npes in our setup)*
- ***... gain can be written as:***

$$Gain = \frac{\sigma^2}{e\mu}$$

- ***With a lot of simplifying assumptions one can write:***

$$\frac{\sigma}{\mu} = \frac{1}{\sqrt{N_{pe}}}$$

- ***The detected Quantum Efficiency can be written as:***

$$DQE = QE \times CE = \frac{N_{pe}}{N_\gamma}$$

- ***So:***

$$\frac{\sigma}{\mu} = \frac{1}{\sqrt{DQE \times N_\gamma}}$$

Calibration Procedure

- Use a 2'', witness PMT (ET) to monitor the LED light level. One (random) FEU-84 PMT used a "calibration" (C) PMT. All others will be measured wrt to this one.
- Successively put the C PMT in all 7 positions of the test stand. Take data (pedestal + signal) for each.

$$\left(\frac{\sigma}{\mu}\right)_{cj} = \frac{1}{\sqrt{(Npe)_{cj}}}$$

  - c – calibration
  - j - position

- Repeat the above two more times (w/ multiple data runs)
- For all monitor the witness PMT response: Npe_{wcj}
- With these one can compute the relative Detection Quantum efficiency of FEU tube "m" wrt/ the calibration tube "c":

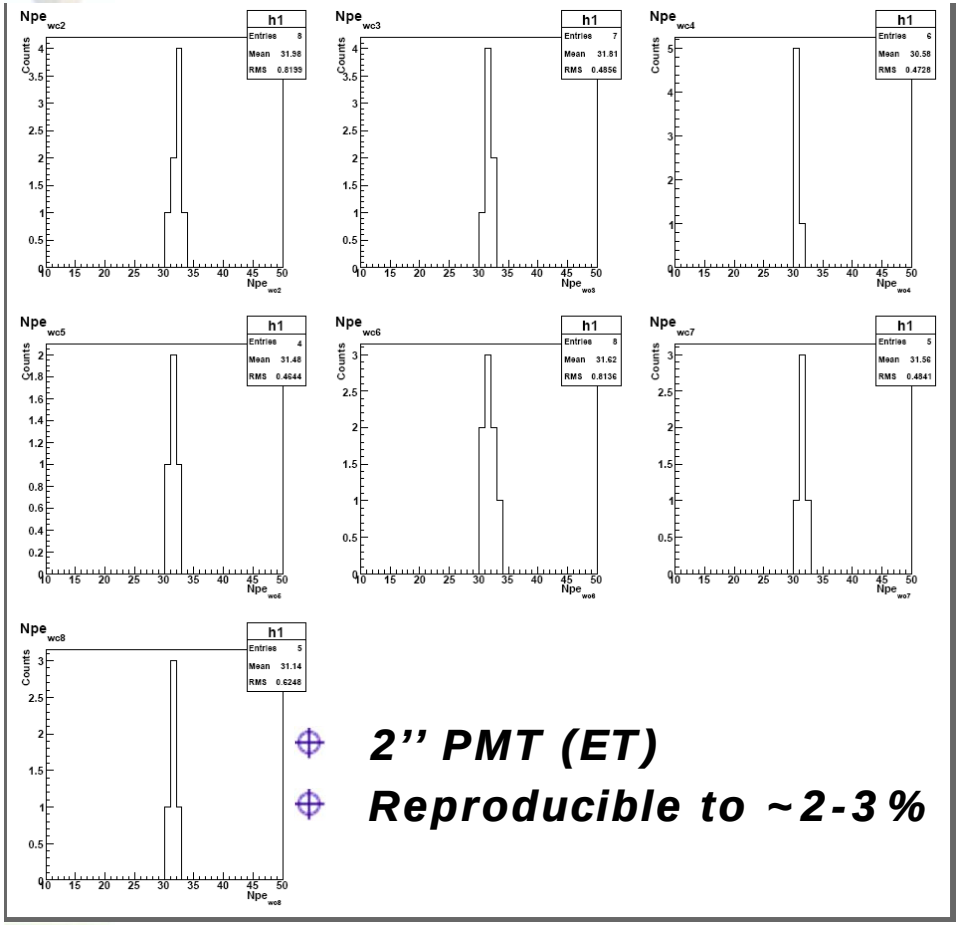
$$\frac{DQE_m}{DQE_c} = \frac{N_{wcj}}{N_{wmj}} \frac{Npe_{mj}}{Npe_{cj}}$$

Note: rel DQE does not depend (in 1st order) on HV!

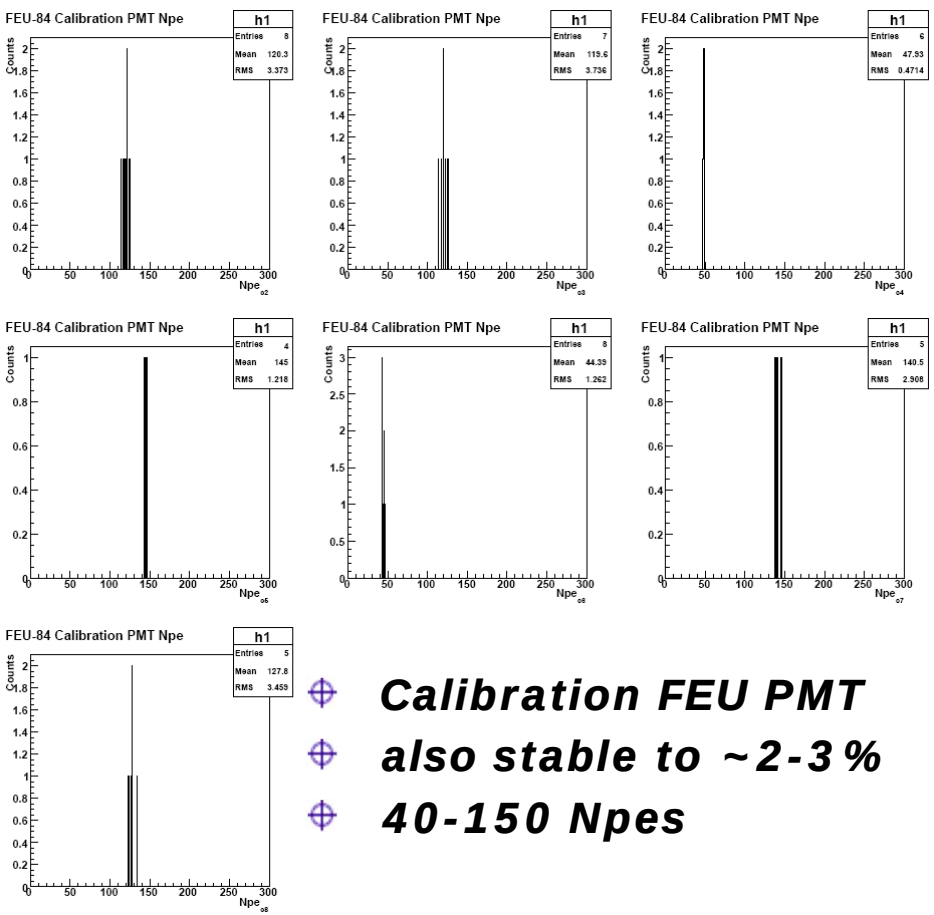
Calibration Results

$$\frac{DQE_m}{DQE_c} = \frac{N_{wcj}}{N_{wmj}} \frac{Npe_{mj}}{Npe_{cj}}$$

- **Determining the average number of photelectrons at each position of the test stand**
- **Monitoring the stability of the light source.**



- **2'' PMT (ET)**
- **Reproducible to ~2-3%**

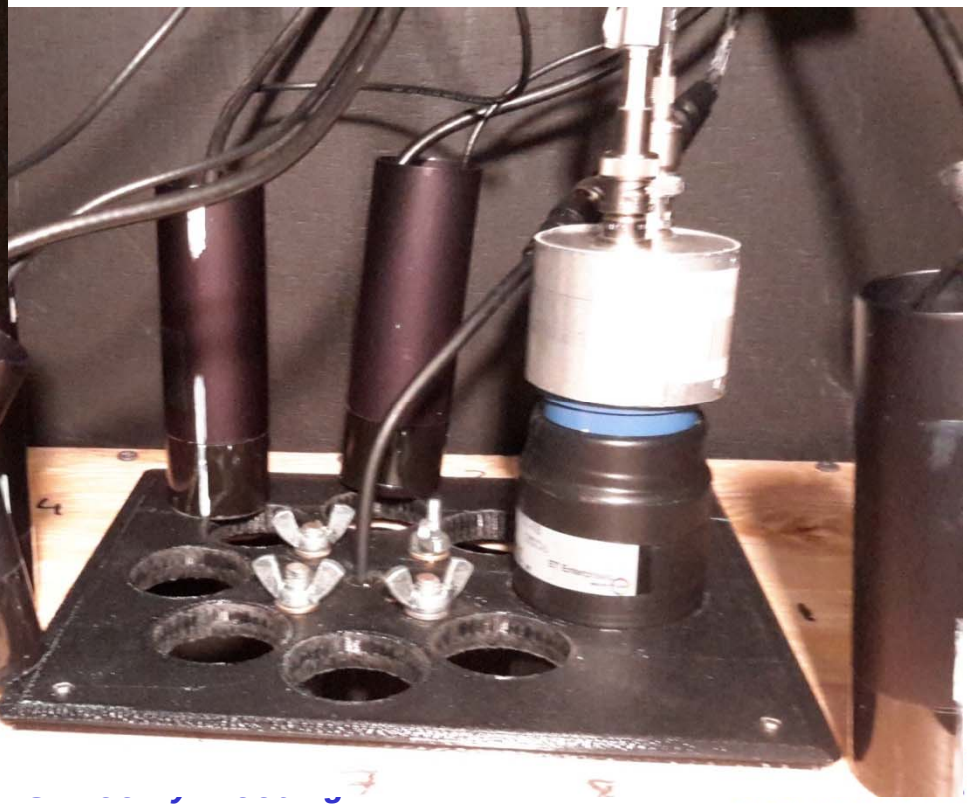


- **Calibration FEU PMT**
- **also stable to ~2-3%**
- **40-150 Npes**

Calibration Conclusion

$$\frac{DQE_m}{DQE_c} = \frac{N_{wcj}}{N_{wmj}} \frac{Npe_{mj}}{Npe_{cj}}$$

- **Based on calibration we are confident that the setup can provide:**
- **Gain vs HV measurements (over the whole FEU HV range)**
- **Relative DQE measurements at the 20% (or so) level**



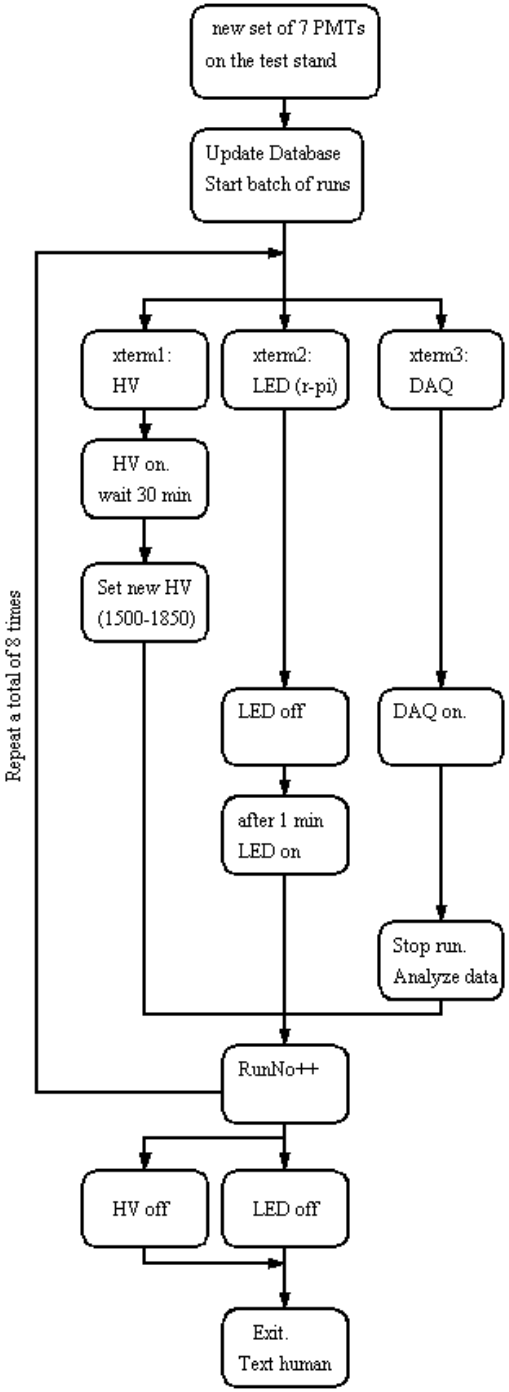
Test Stand Workflow

- Given the large number of PMTs to be tested we looked to automate the test procedure as much as possible.
- A single command (GUI in the works!) starts:

- HV xterm (talking w/ CAEN PS)
- LED xterm (raspberry pi)
- DAQ xterm (ubuntu -> coda)

- For each set of PMTs we test @:
- 1500-1850V (in steps of 50V), 8 settings
- Data analyzed (ROOT) at the end of each run (gain, npes). Info saved in plain text, pdf

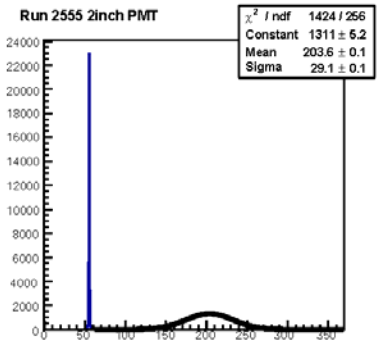
- Subsequent analysis produces a ROOT tree w/ all raw results, produces Gain vs HV fits.

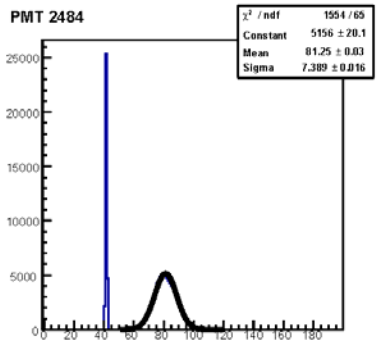


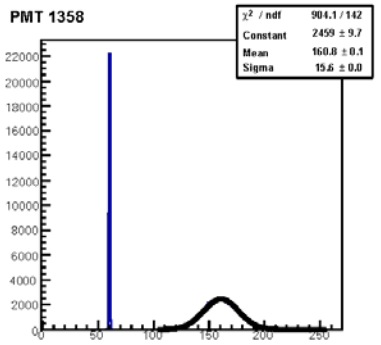
Results: "Online Analysis"

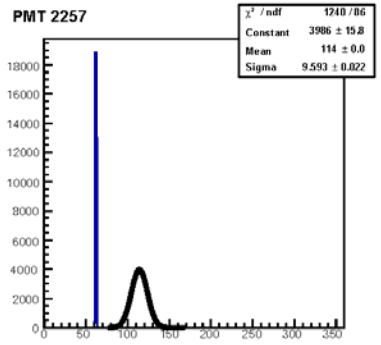
1800 V

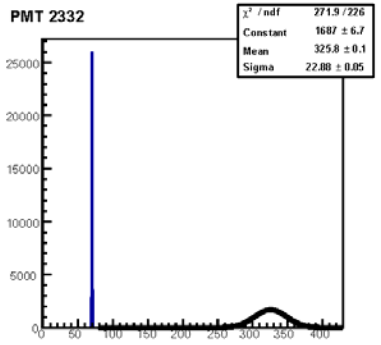
- This is what we get at the end of each DAQ run…
- There is also a log scale version of this to check for abnormal behavior hidden in the "grass"

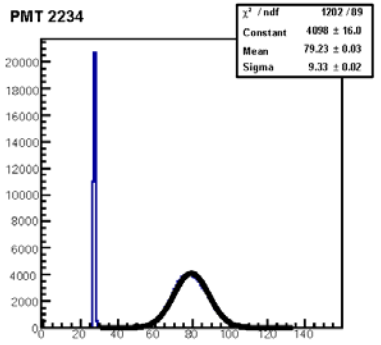


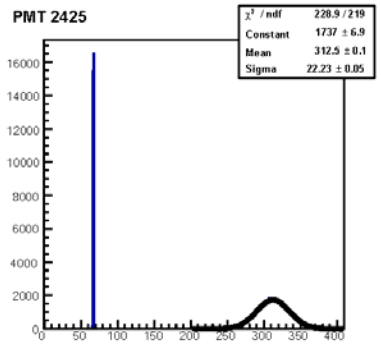


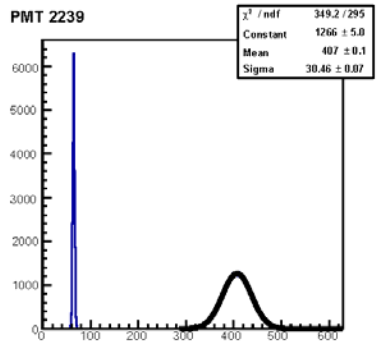












ECAL PMT Testing @ JMU

ID	Gain	Rel.DQE
2484	1.72e+06	0.296
1358	3.02e+06	0.427
2257	2.2e+06	0.726
2332	2.55e+06	1.05
2234	2.09e+06	0.855
2425	2.51e+06	1.06
2239	3.38e+06	1.19

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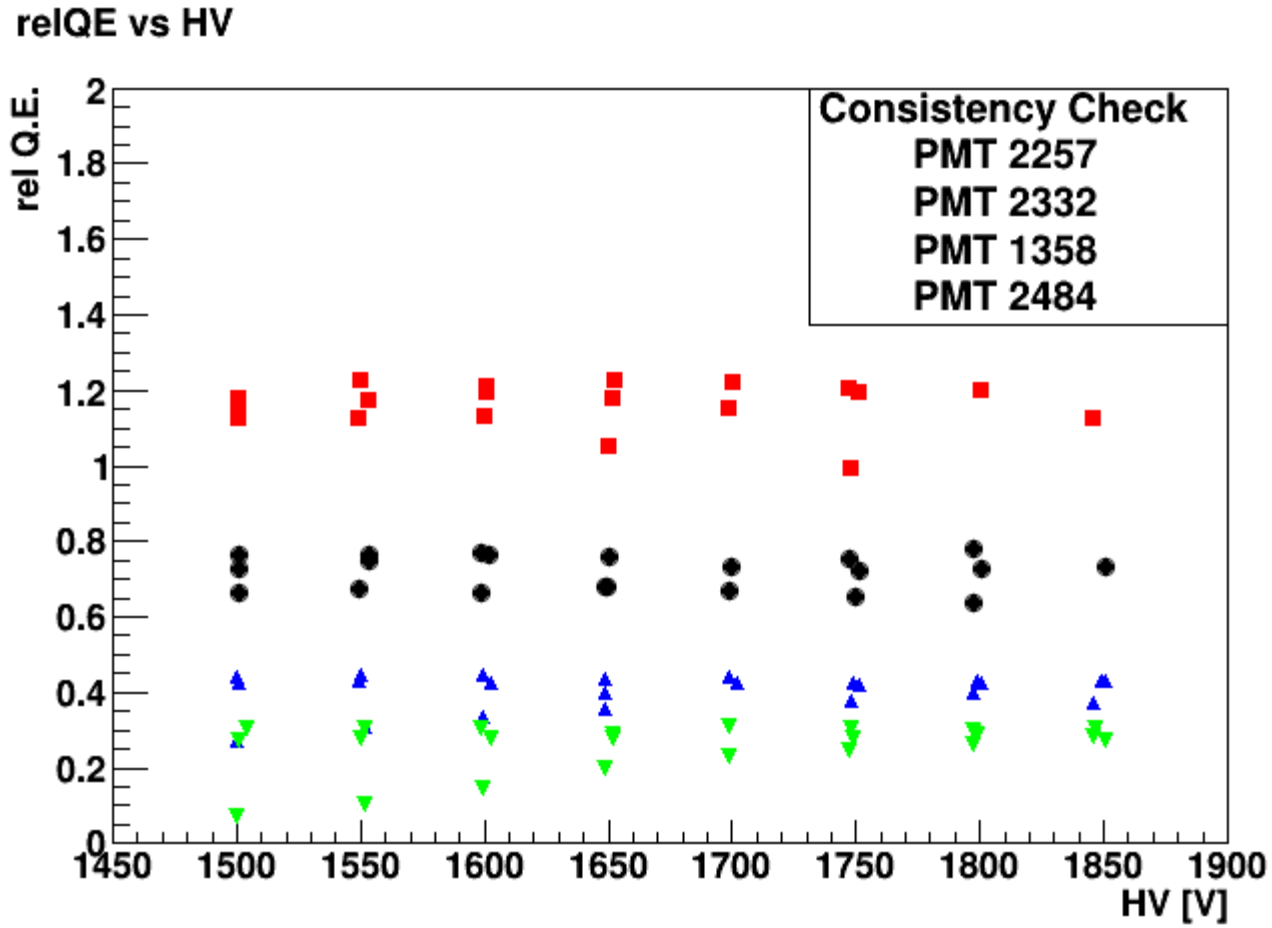
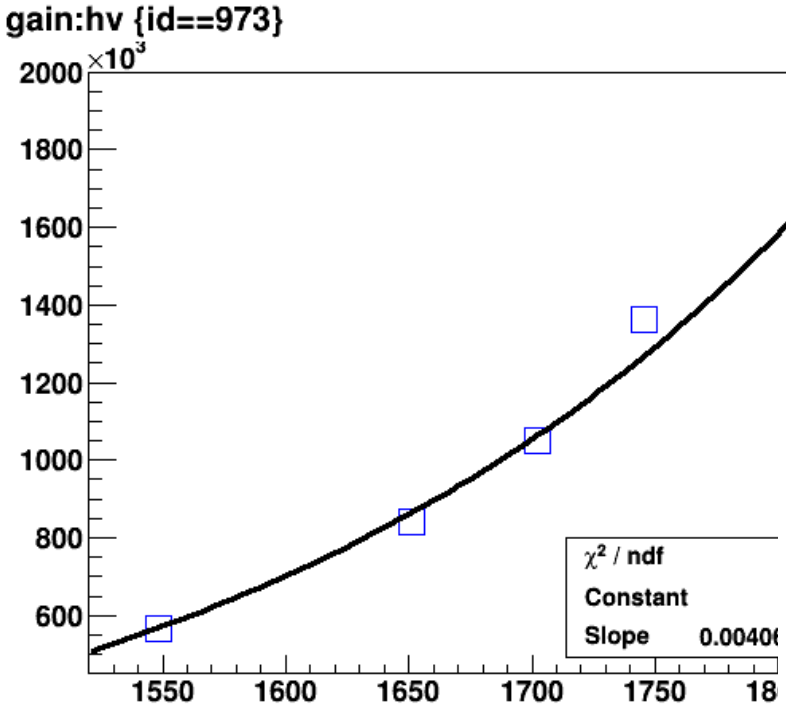
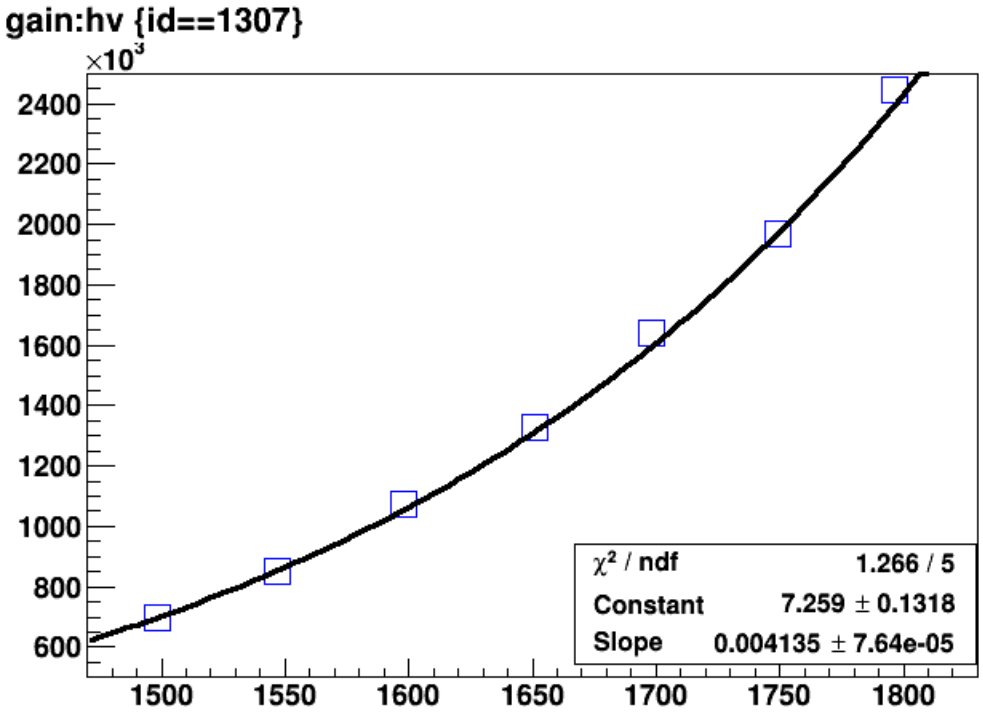
Results: Consistency Check

- *Same set of PMT moved (circ. Perm., 3x) between different test stand positions*
- *It looks that we are measuring a property of the PMTs, not of the test stand!*
- *Diff HV: built-in consistency check*



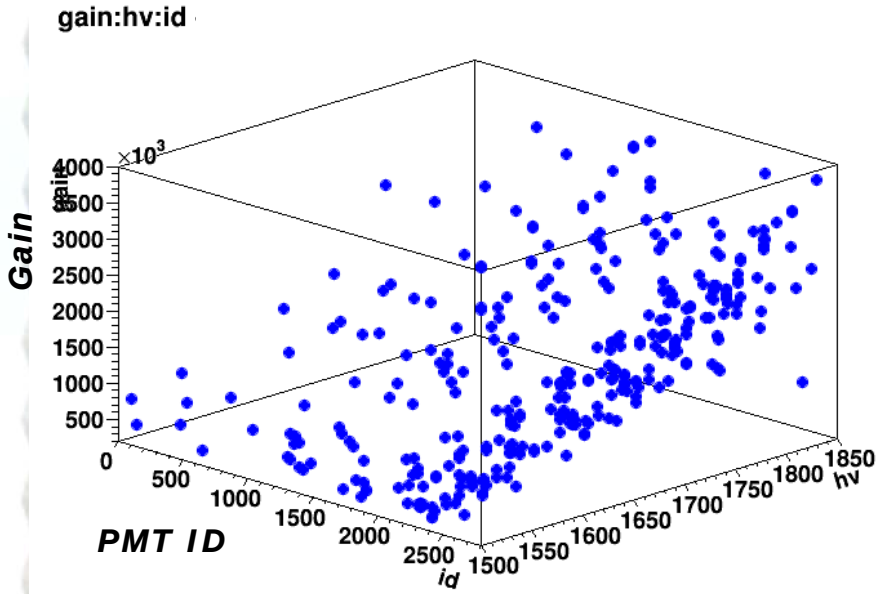
Results: Gain

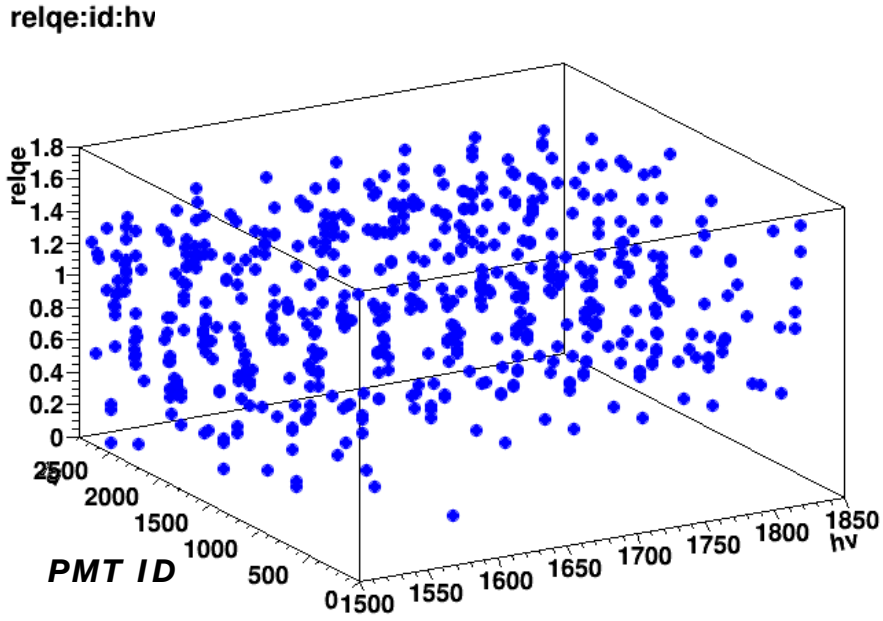




Typical gain fits.

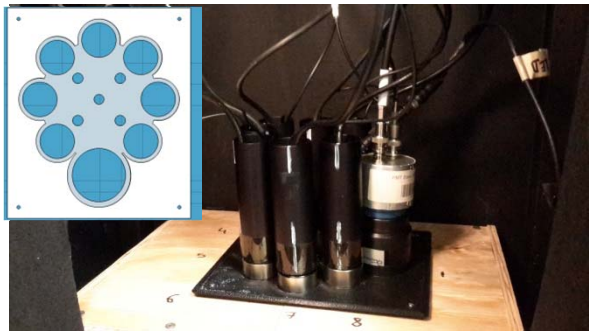
Results: Data Set sofar





- *As of this morning…*
- *~600 entries in the database (PMTxHV)*
- *Almost PMT 3 boxes tested*

Summary



- We are confident that we have a reasonable way of testing relative QE. Gain as well.
- Initial individual PMT test results promising
- Workflow optimized in view of large scale testing (~1 h per batch of PMTs)

- Workforce (for Fall 2016) available.
- Arrange a delivery/pick-up schedule for PMTs.