Analysis of Sources of Dark Noise from Quartz PMTs in JLab Hall B CLAS12 HTCC

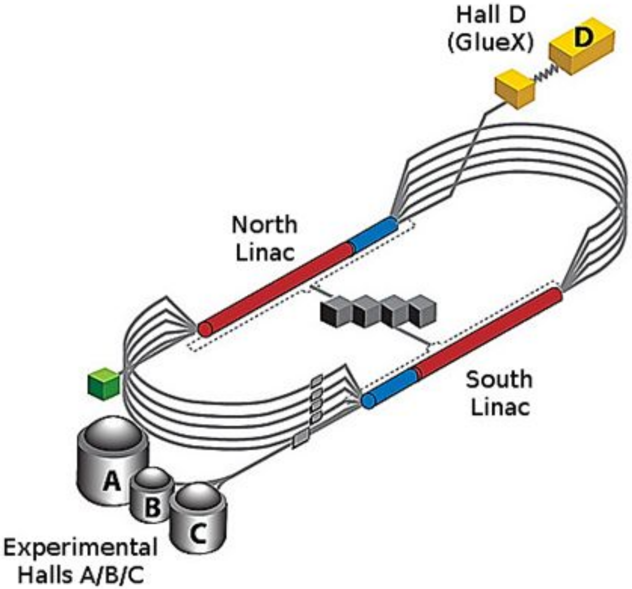
Isabella Illari[1]

[1]Physics Department, Columbian College of Arts & Sciences, The George Washington University, Washington, D.C. 20052

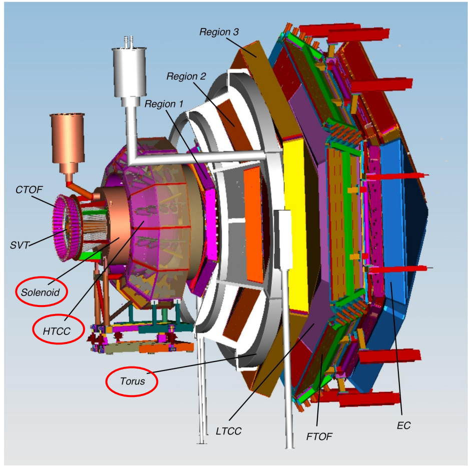
Outline of talk

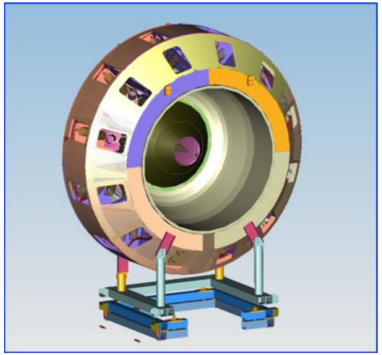
- Background
  - Thomas Jefferson National Accelerator Facility (JLab)
  - Hall B, CLAS12 detector, High Threshold Cherenkov Counter (HTCC)
- Signal from PMT
- Results from temperature dependence tests
- Helium's effects on quartz PMTs
- Conclusions

Jefferson Lab, Hall B, CLAS12 detector
High Threshold Cherenkov Counter (HTCC)

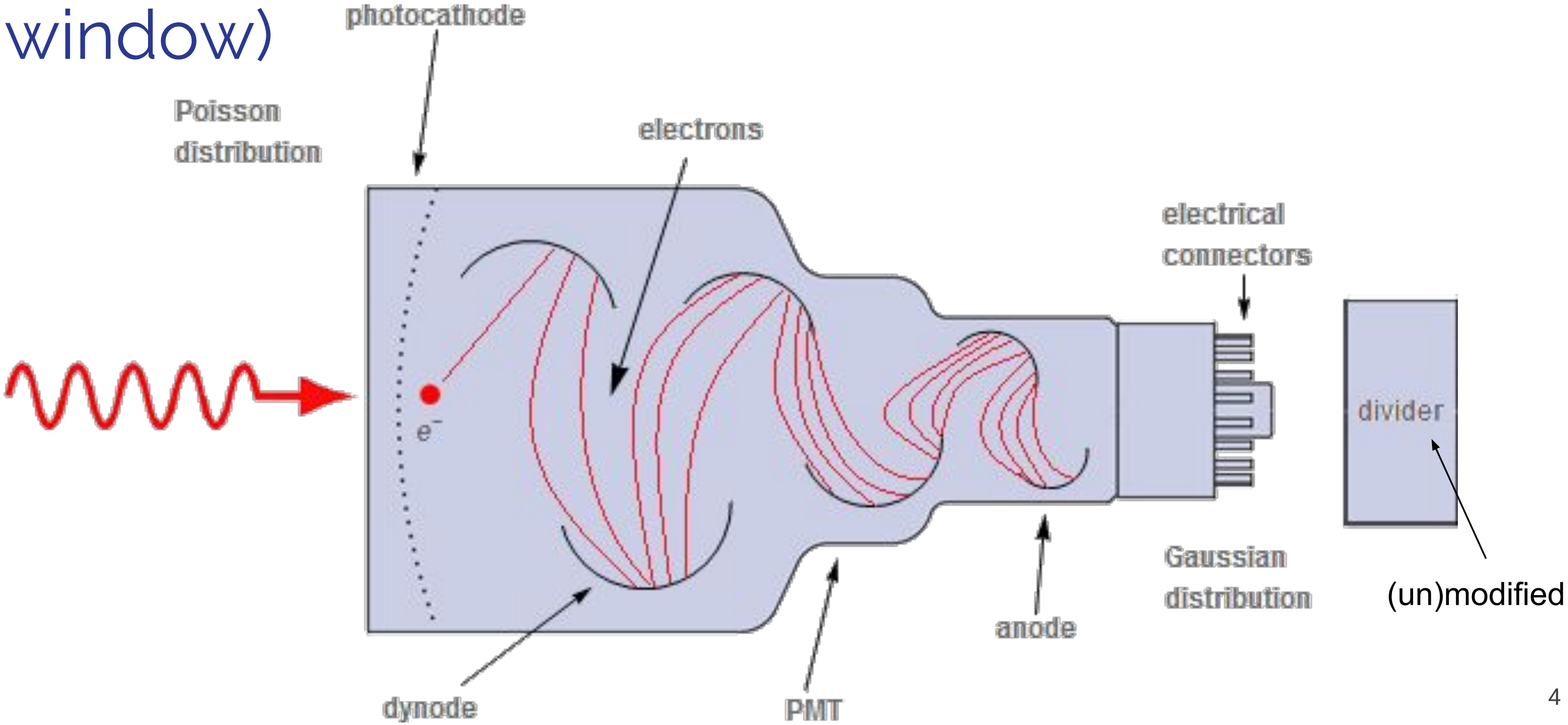


- 1 of the detector systems of the CLAS12 spectrometer
- used to generate fast trigger signal in electron experiments
- focus Cherenkov light on eight 5" phototubes **(total of 48 channels for entire detector)**
- provide high rejection of charged π-mesons
- Low background noise for reliable identification of scattered electrons





PMT: ElectronTubes 9823QKB (5" quartz window)



Operation of PMT

1. **Photoconversion, electron collection**
   a. pulsed LED → flux of photons onto quartz photocathode → produces photoelectrons via photoelectric effect
   b. photocathode → Poisson distributed variable
2. **Amplification**
   a. approximated by Gaussian distribution
   b. coefficient of secondary electron emission by 1st dynode is large
3. **Approximate response function**
   a. background charge spectrum

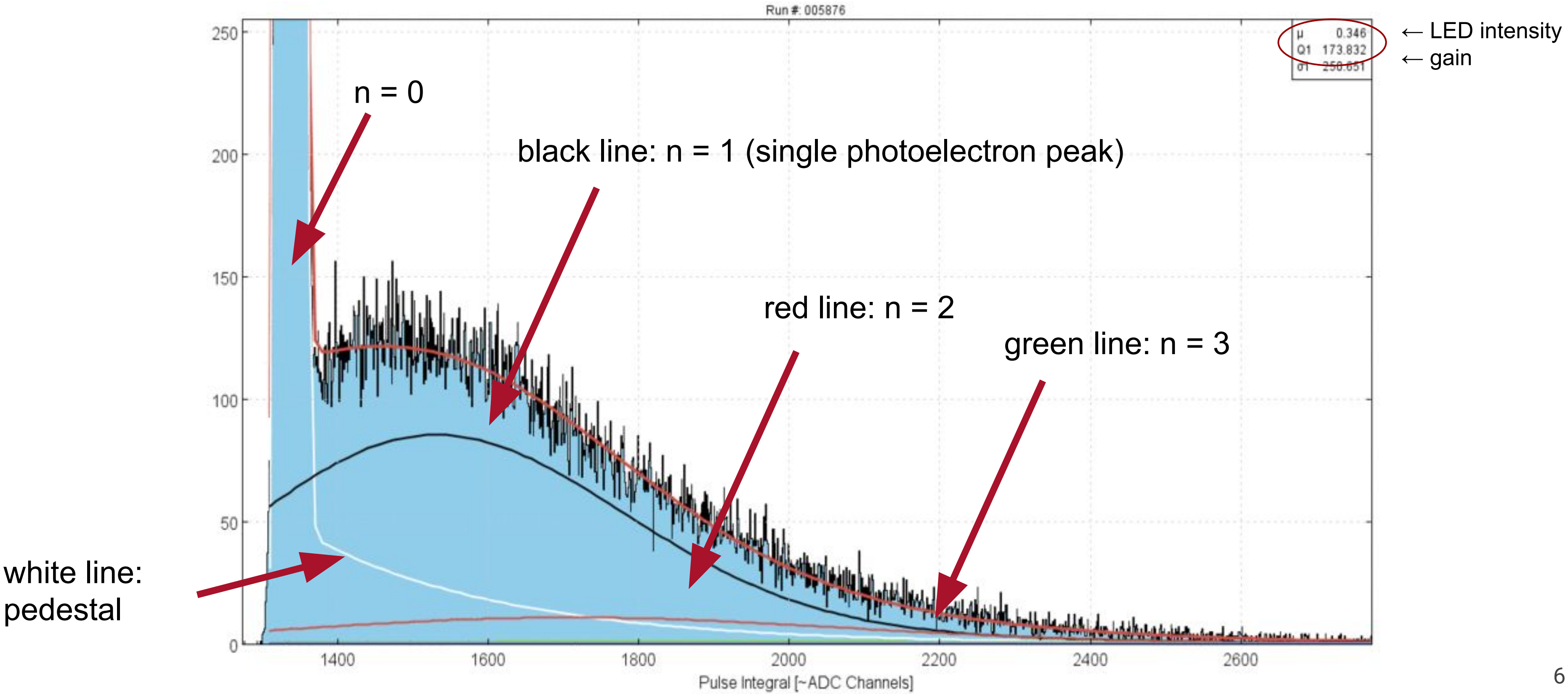
$$P(n;\mu) = \frac{\mu^n e^{-\mu}}{n!} \qquad \mu = mq$$

Found from the fits

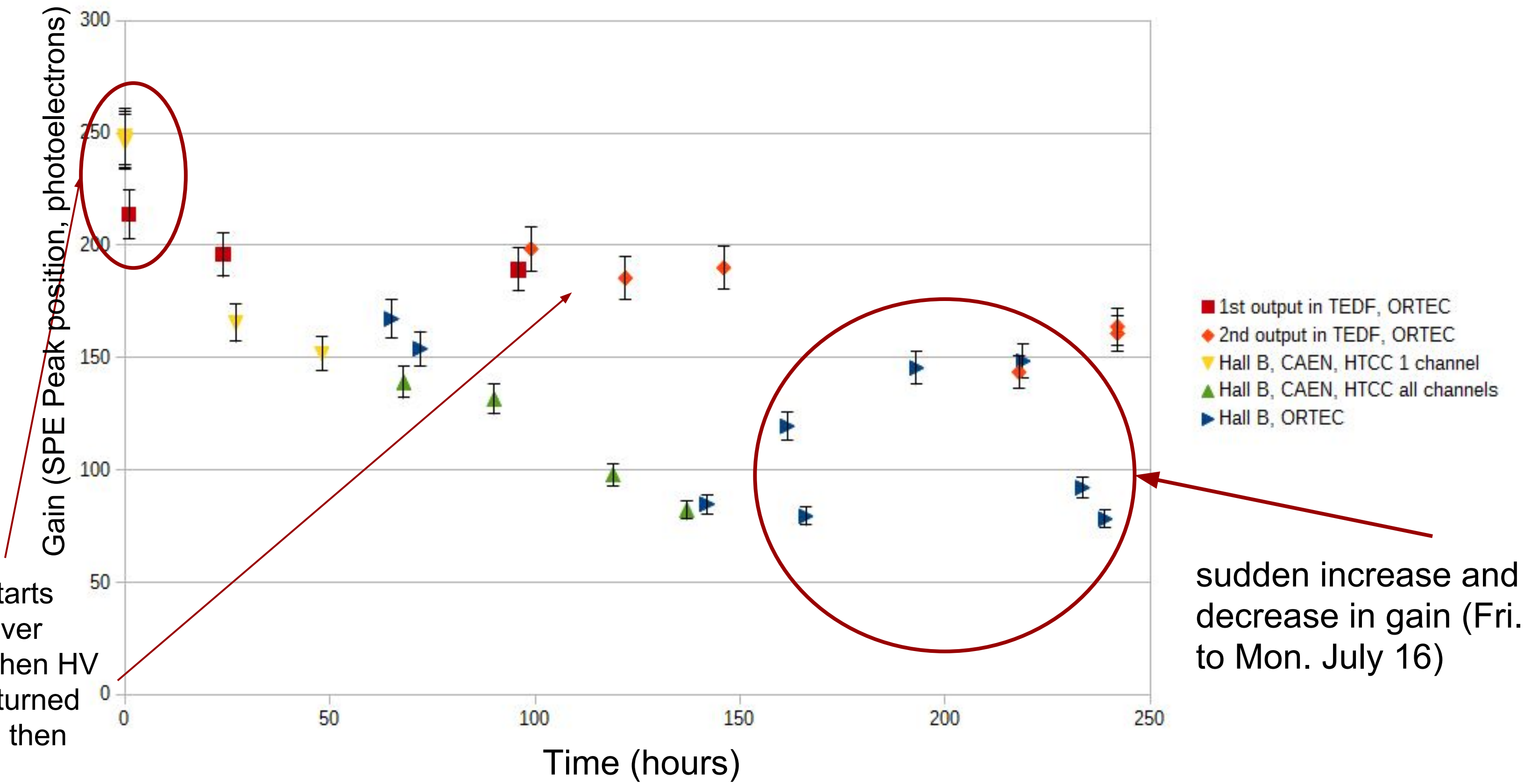
$$G_n(x) = \frac{1}{\sigma_1\sqrt{2\pi n}} \exp\left(- \frac{(x - nQ_1)^2}{2n\sigma_1^2} \right)$$

$$S_{\mathrm{real}}(x) \approx \left[\frac{(1-w)}{\sigma_1\sqrt{2\pi}} \exp\left(- \frac{(x-Q_0)^2}{2\sigma_0^2} \right) + w\theta(x-Q_0) \times \alpha \exp\left[-\alpha(x-Q_0) \right] \right] e^{-\mu}$$
$$+ \sum_{n=1}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \times \frac{1}{\sigma_1\sqrt{2\pi n}} \times \exp\left(- \frac{(x - Q_0 - Q_{\mathrm{sh}} - nQ_1)^2}{2n\sigma_1^2} \right)$$

E.g. signal and fits w/ increasing μ (LED intensity)



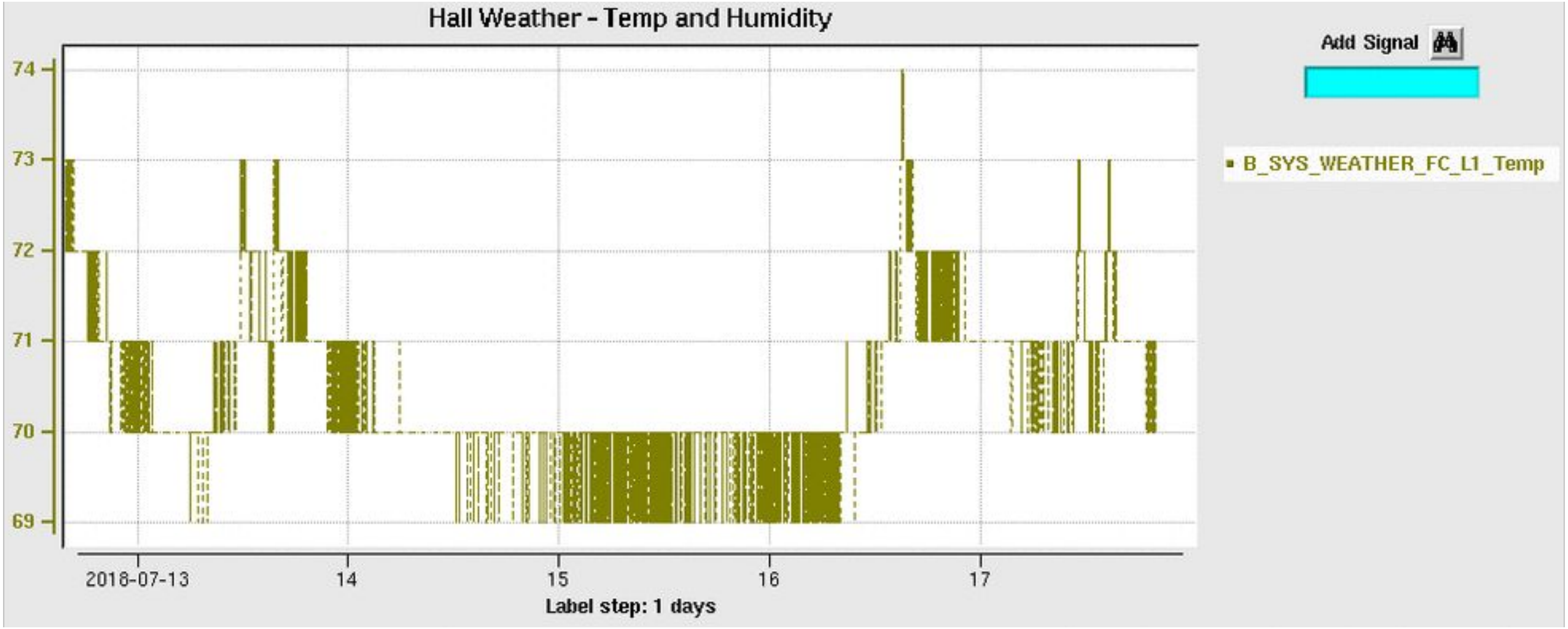
Gain [photoelectrons] over time [hours] of PMT #23



Gain starts high (over 200) when HV is first turned on and then drops

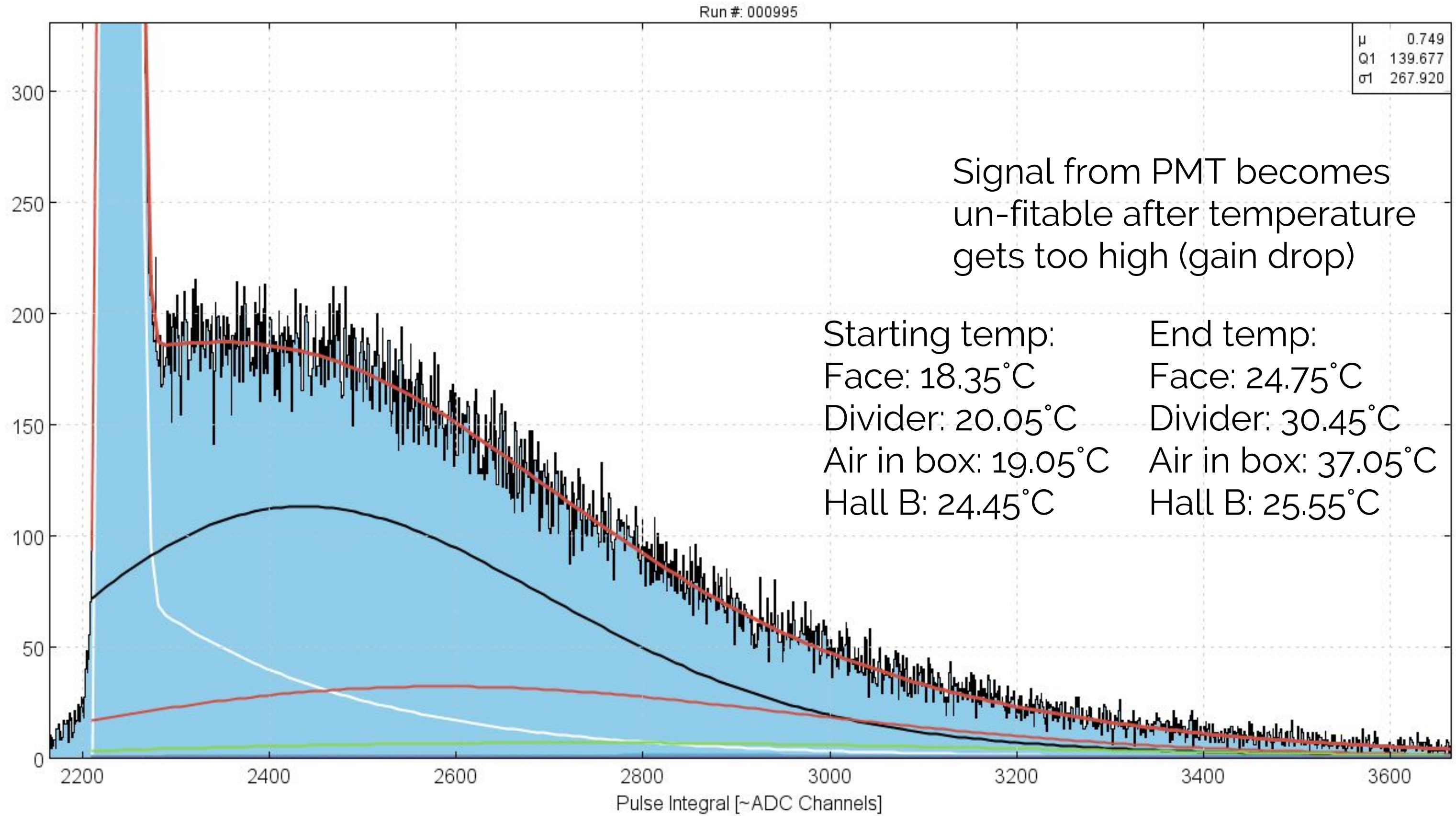
sudden increase and decrease in gain (Fri. July 13 to Mon. July 16)

Changes in temperature in the hall



colder during that weekend than during the week (AC ON/OFF)

Initial attempts to use heat gun

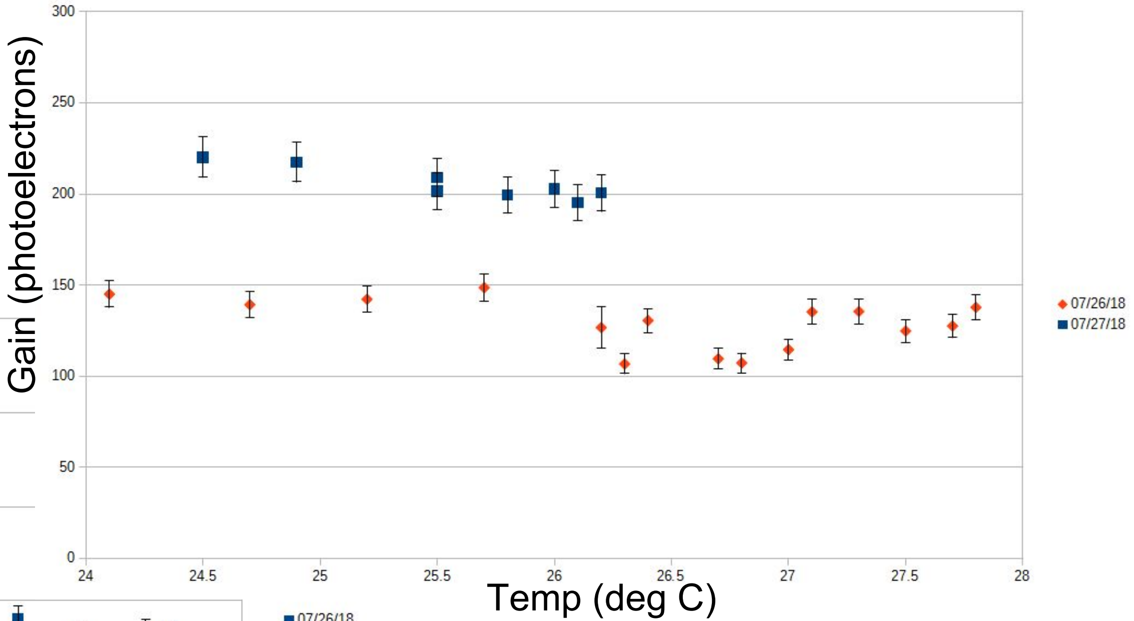


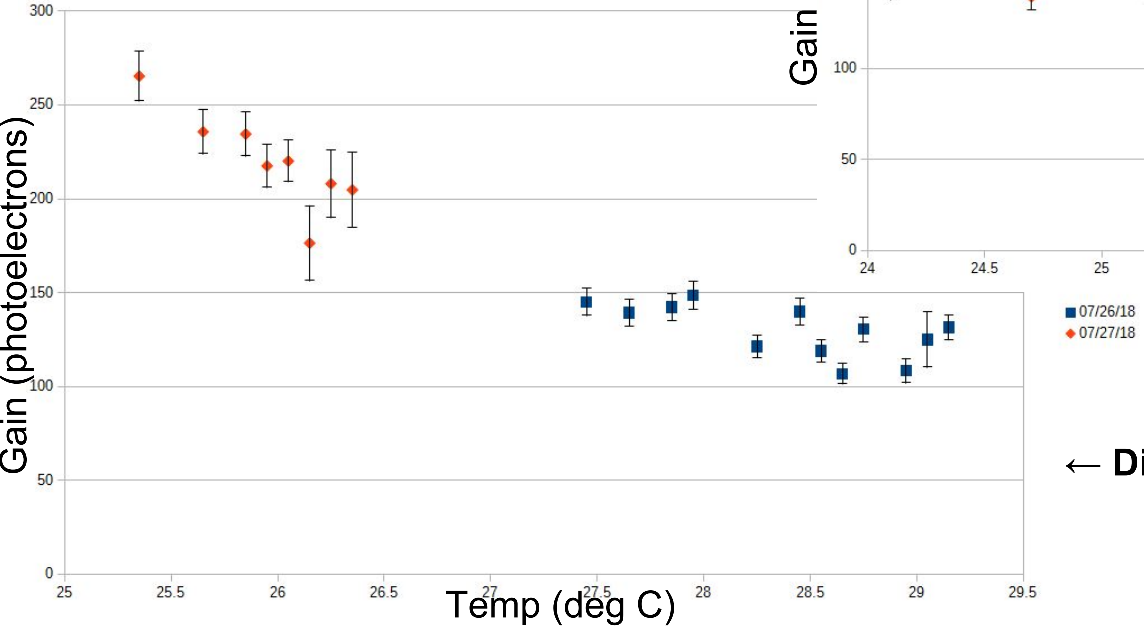
Signal from PMT becomes un-fitable after temperature gets too high (gain drop)

Starting temp:	End temp:
Face: 18.35˚C	Face: 24.75˚C
Divider: 20.05˚C	Divider: 30.45˚C
Air in box: 19.05˚C	Air in box: 37.05˚C
Hall B: 24.45˚C	Hall B: 25.55˚C

Q1 gain vs temp (deg C), **modified** divider (original)

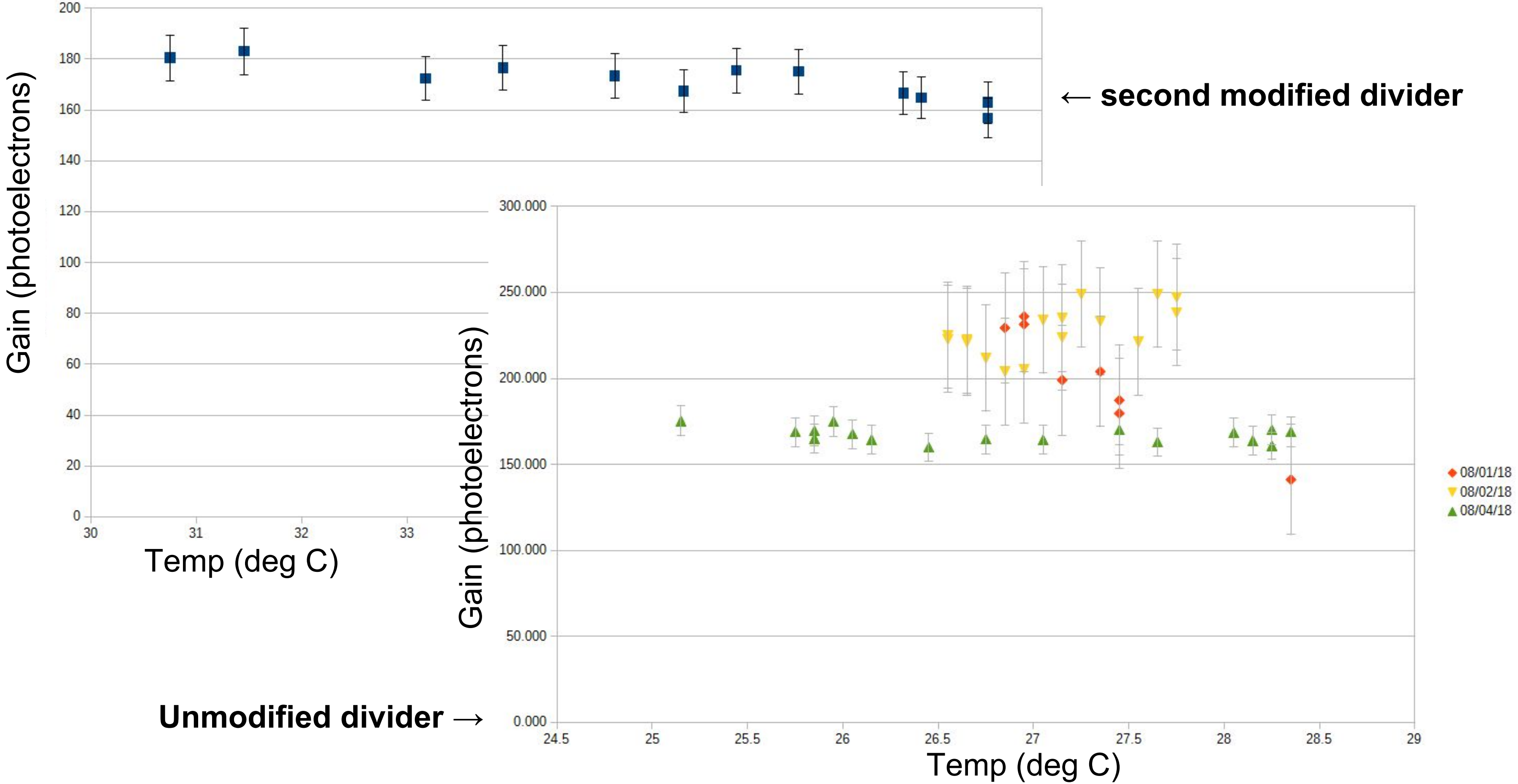
window of PMT →



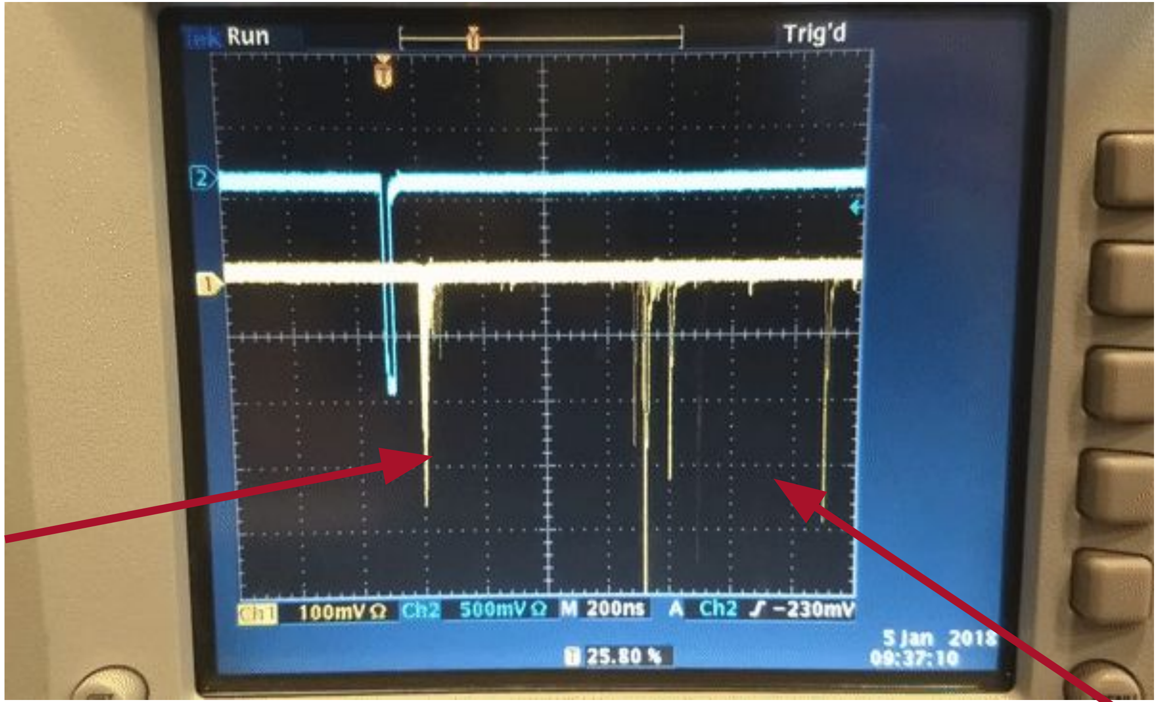


← Divider of PMT

Q1 gain vs temp (deg C)



After-pulsing on oscilloscope



pulse we want

After-pulsing

- **First pulse**: electron → anode
- **After-pulse** other particle → anode
  - ionized helium (gassy tubes)
- He usual suspect for short-term failures
  - Quartz: "open door" to He
  - our PMT's: 5" quartz face

- Solubility He in quartz: exponential dependences on 1/T
- Problems w/ helium in Halls A and C
  - constant leaks, semi-hermetic PMT housing, flush w/ outside air

Helium in Hall B

- WORST CASE: all He reservoirs depleted
- TOTAL: 270 (Torus) + 97 (Solenoid) = 367 liters of LHe
- If quartz tube lifetime is ~100 ppm*years
  - 10,000+ ppm spike from ~144.7 LHe would eat 100% of quartz PMT lifetime (several days to exchange air)
- Since Sept. 2017: 7 fast dumps

- PHD-4 Sniffer
- Helium in the hall b/c of:
  - leaks, maintenance, fast dumps, quenches
- PMT storage
- HTCC has less He than hall
- hall concentration
  - order of ~100 ppm
- **NOT A CURRENT PROBLEM - PREVENTATIVE MEASURES**

Conclusions

- Gain of signal from PMT changes drastically when entire PMT is heated
- Gain decreases when window and divider are heater
- Some modified dividers more susceptible to heat than others
- Gain when using the un-modified divider was stable when temp in Hall was kept constant
- Keep track of helium concentration in hall (preventative)
- Keep track of temp in HTCC

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Will and I cabling the HTCC