# Threshold Cherenkov aerogel detector prototype tests with pair spectrometer in HallD

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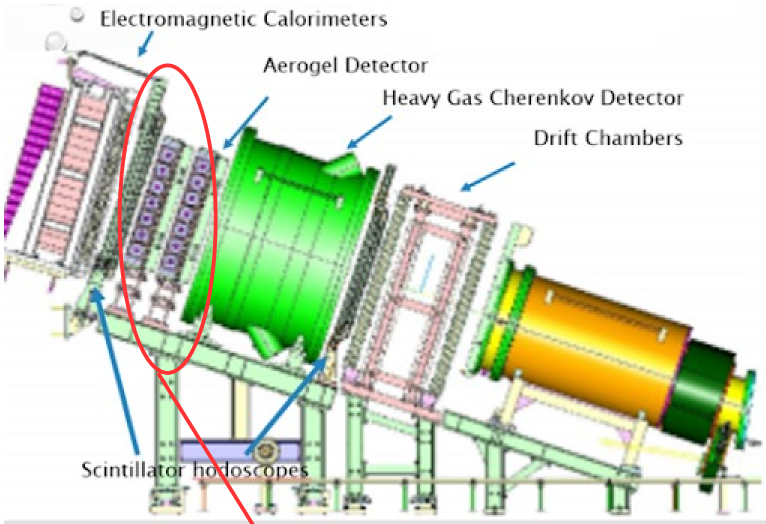
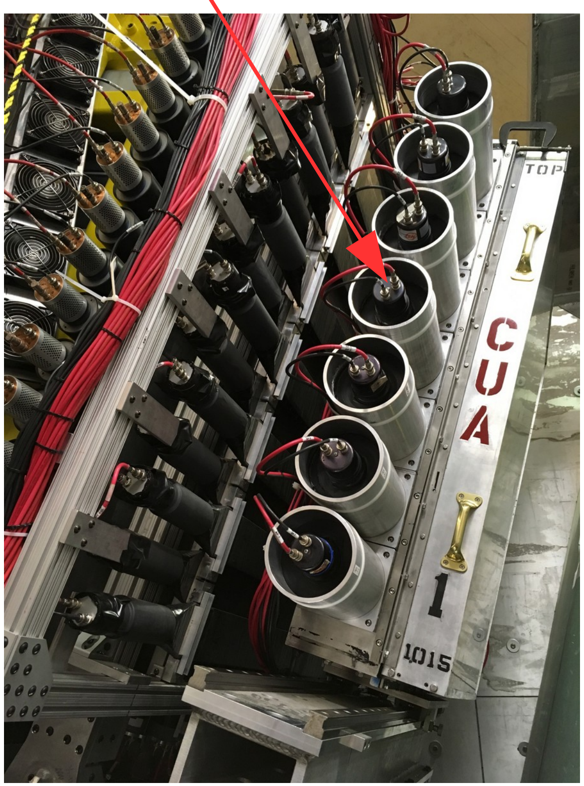
# Aerogel based Cherenkov detector in SHMS stack

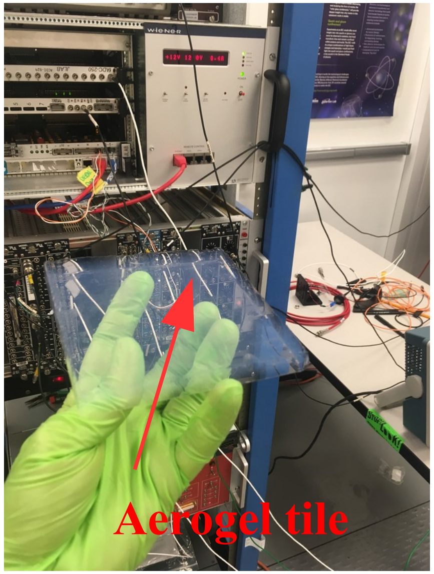



- The HallC SHMS is a highly-focusing magnetic spectrometer with large momentum reach up to 11 GeV/c
- It is optimal for certain classes of deep exclusive and semi-inclusive measurements, and in particular those requiring high quality Rosenbluth (longitudinal-transverse – L/T) cross section separation.




- To cleanly select kaons in a variety of experiments the SHMS threshold aerogel Cherenkov detector was constructed and included in the PID system consist of time-of-flight, Cherenkov detectors, shower and preshower calorimeter when needed by experiments.
- To cover the full SHMS momentum range, four aerogel trays with different refractive indexes (1.03;1.02;1.015;1.01) were built.

# Aerogel trays mechanical considerations





**Problem:**

Aerogel tiles with different refractive indexes are used to detect particle of different momenta.

Therefore **the experiment requires swapping the aerogel trays**.

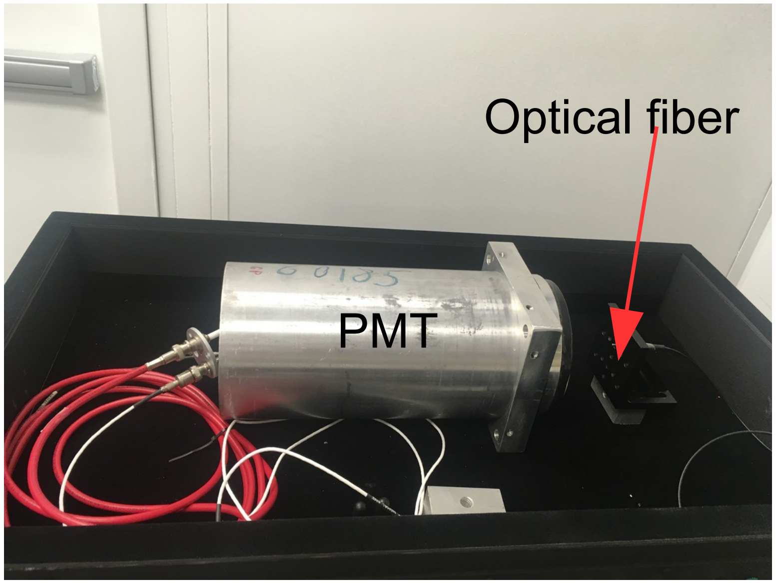
Low aerogel indexes (0.11-0.15) are **extremely fragile**. This makes the installation of the detector assembly very challenging and time consuming (involves operating the crane).

**Solution:**

1. Add fiber-glass mesh layers between the aerogel tiles.
2. Try new type of silica Aerogel with better mechanical properties.

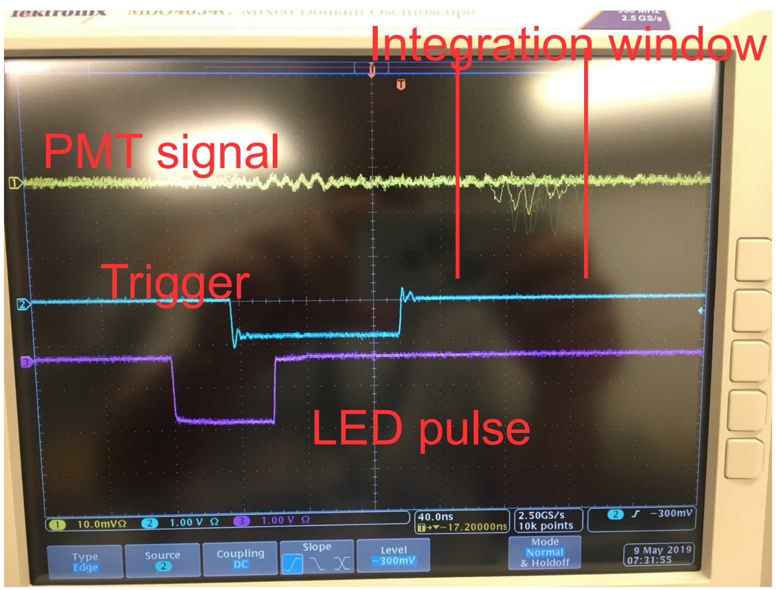
**Light yield tests are required** to determine the difference in the amount of collected light compared to the standard tile stack. Tests were carried out with cosmic muons and beam.

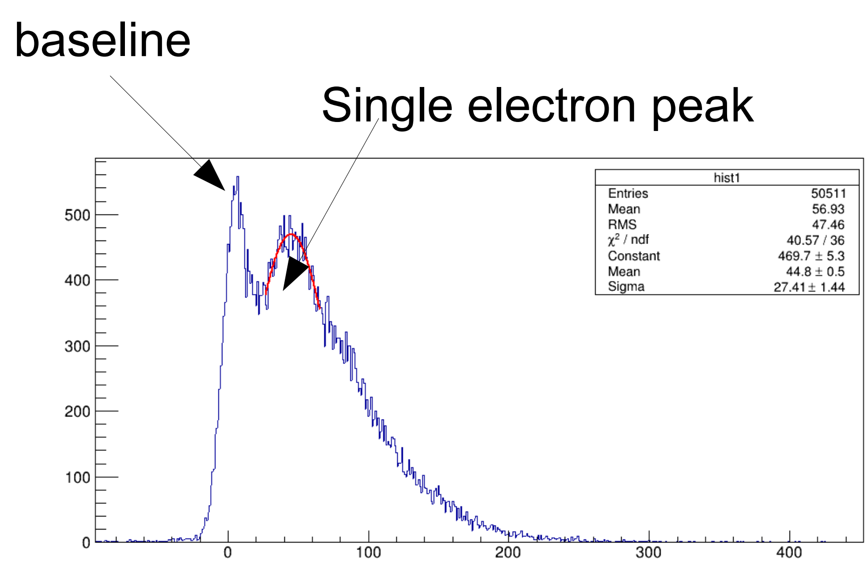
# PMT calibrations for cosmic test




**Explain why PMT calibration is required?**

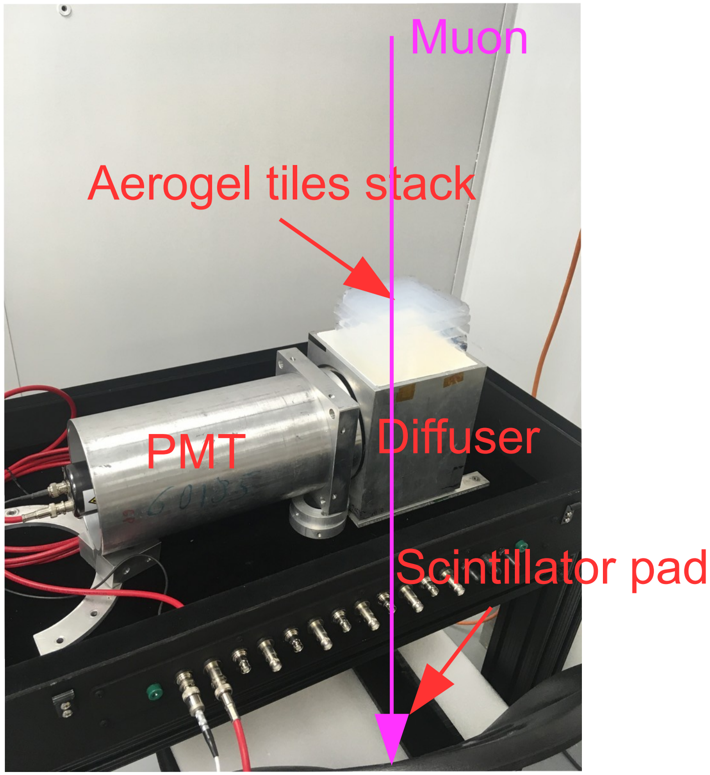
- Calibration in single photoelectron mode
- 5in diameter PMT XP-4572 $U_{PMT}$=1500V
- Light source LED+optical fiber
- Pulse from generator to LED ~40ns with 2V amplitude
- 250 MHz fADC digitizer
- JLAB CODA based DAQ
- Trigger from LED



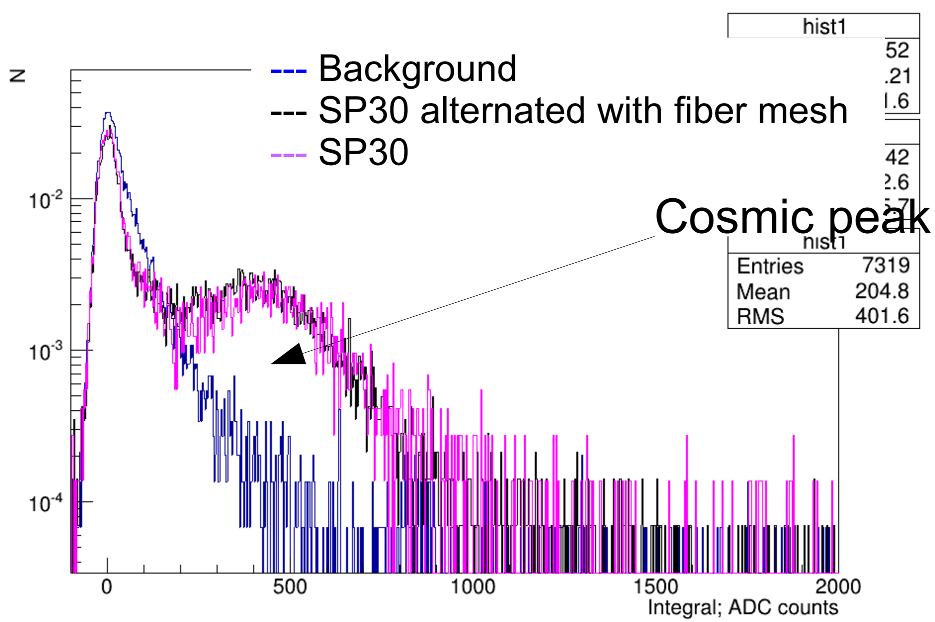




1 PE=39 ADC counts

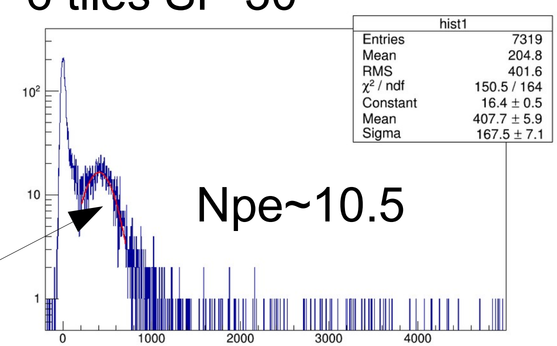
# Cosmic tests with SP-30 index (fiberglass vs no fiberglass)



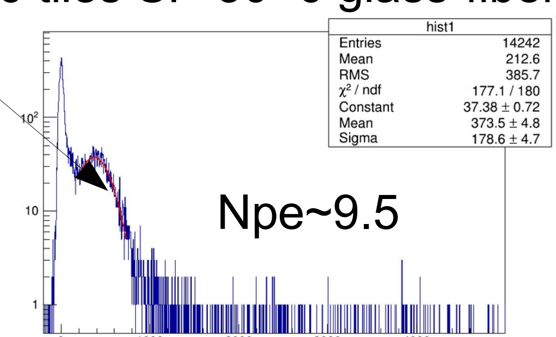

- Measurements with cosmic muons enters aerogel stack perpendicularly to the surface
- 6 SP-30 tiles vs 6 SP-30 tiles alternating with glass-fiber mesh layers
- GORE reflector covered inner surface of the diffuser
- Trigger performed by coincidence in time between pulses from two plastic scintillator pads
- 250 MHz fADC digitizer
- JLAB CODA based DAQ
- 100 ns integration time
- One photoelectron difference in LY



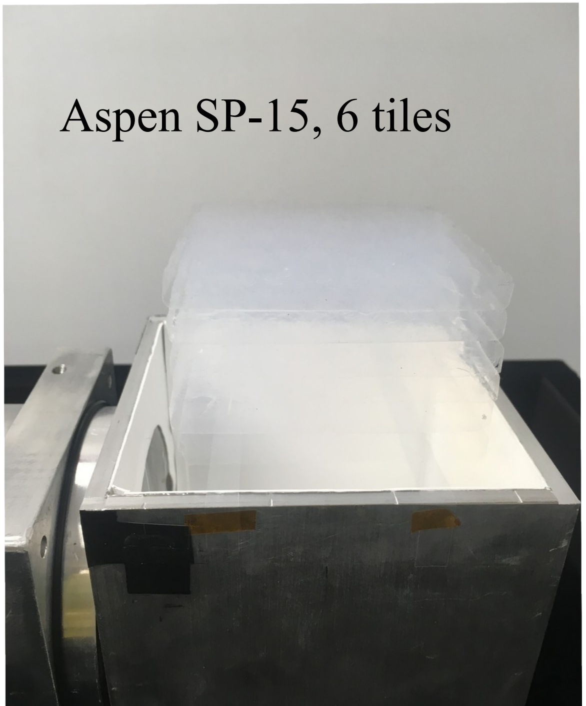

6 tiles SP-30

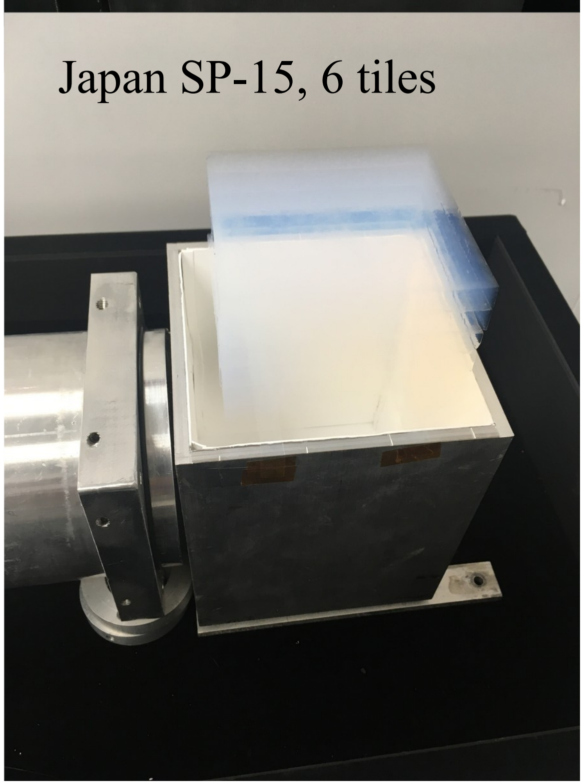



6 tiles SP-30+6 glass-fiber films



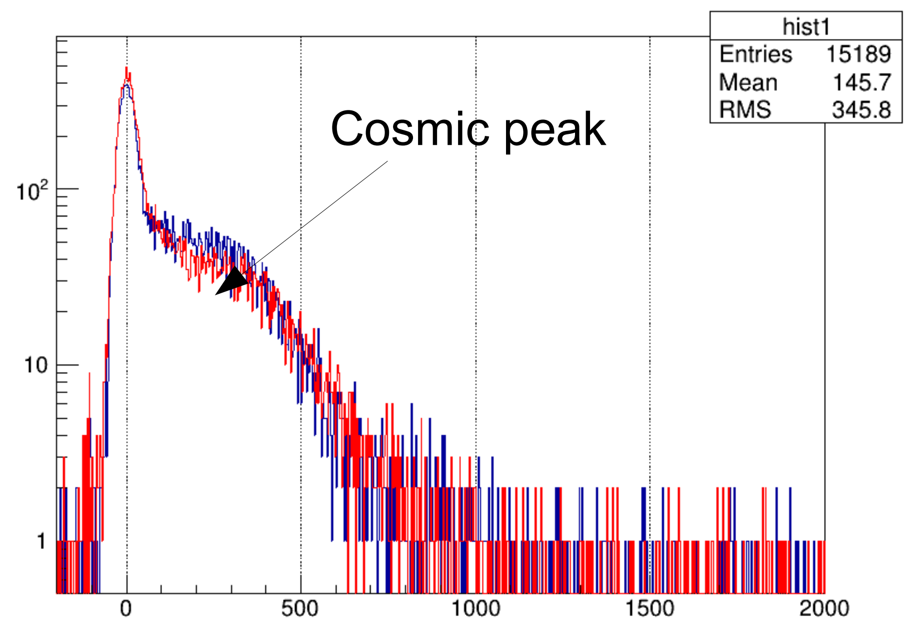
# Cosmic tests with SP-15 index (current vs new tiles)



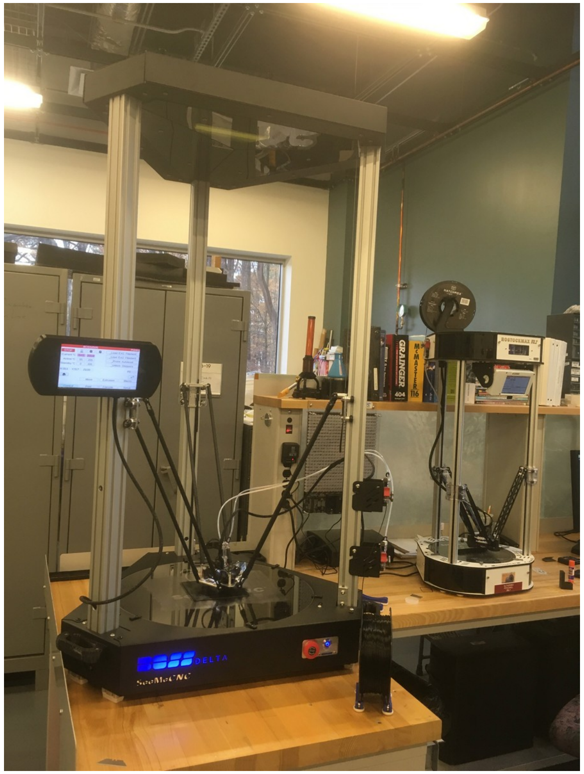




- Comparison between two Aerogel vendors
- Japan SP-15 (6 tiles) vs Aspen SP-15 (6 tiles)
- Same trigger and detector configuration as for SP-30 measurements
- Peak not clearly observed, Npe ~ 4.8
- No visible difference between two vendors

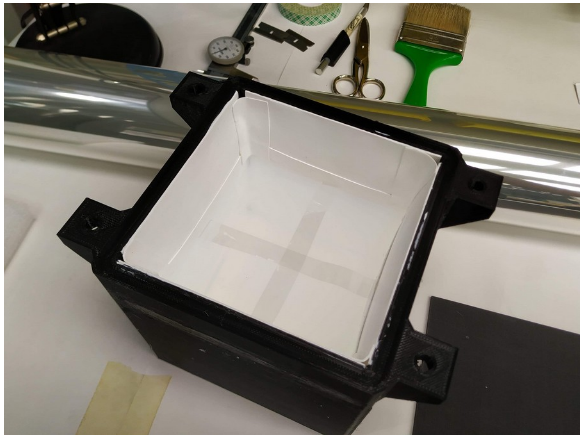
Therefore, **beam tests needed with bigger aerogel stack, minimum 8 tiles** (better statistics and trust in community).

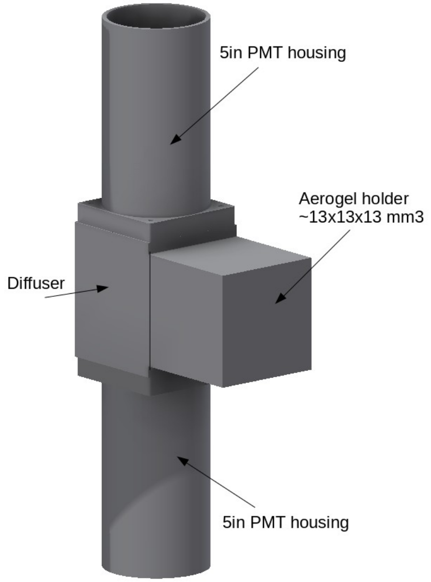


# Manufacturing the T-shape Aerogel prototype for the beam

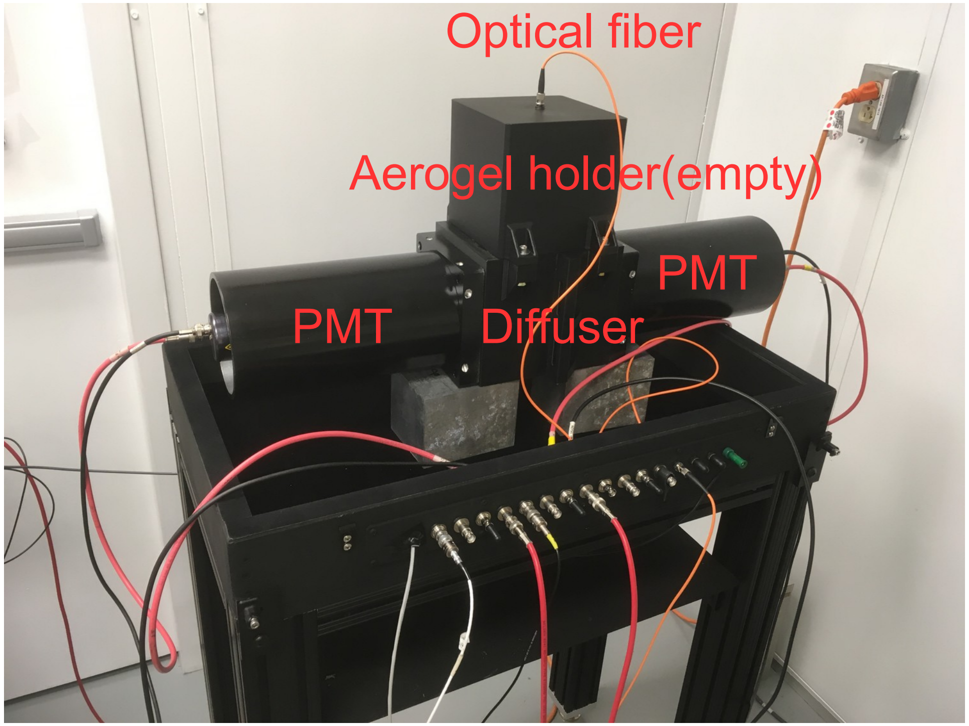


- Two 5in diameter PMT`s XP-4572
- Diffuser and aerogel holder is 3D printed ABS plastic (B. Bunton, J. Crafts)
- Geometry similar as SHMS Aerogel. Light tight construction
- GORE reflector covered inner surface of diffuser and aerogel holder
- 4 combinations of SP-15, 8tiles/8 fiber-glass layers
  Aspen, Japan, Aspen+mesh, Japan+mesh
- Sp-30 8 tiles

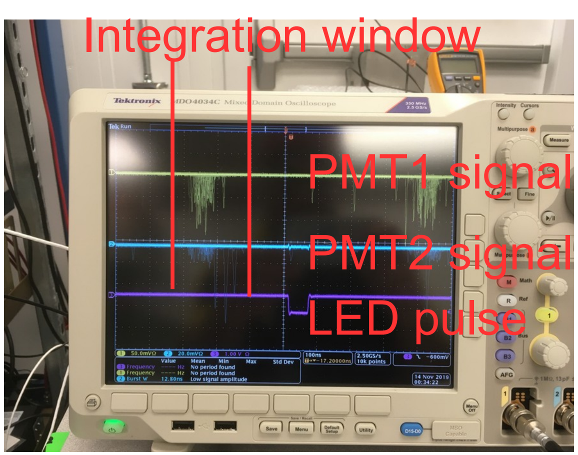


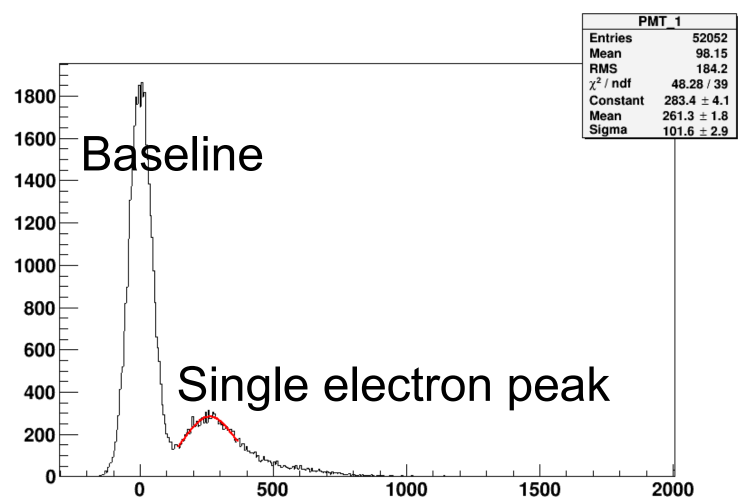


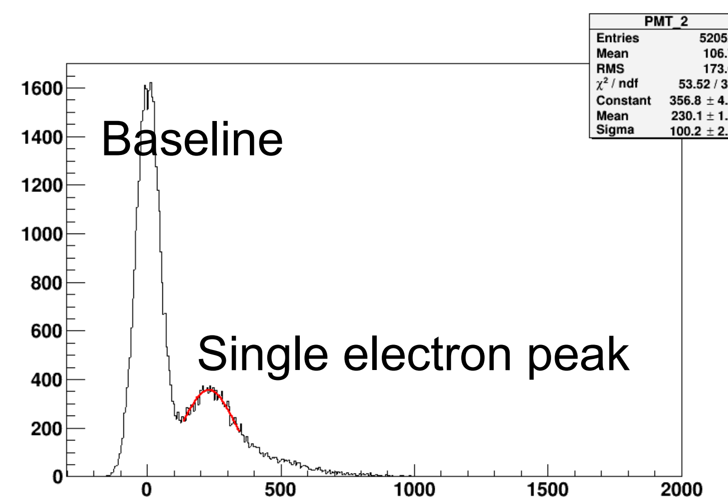
# PMTs Calibration Measurements with LED



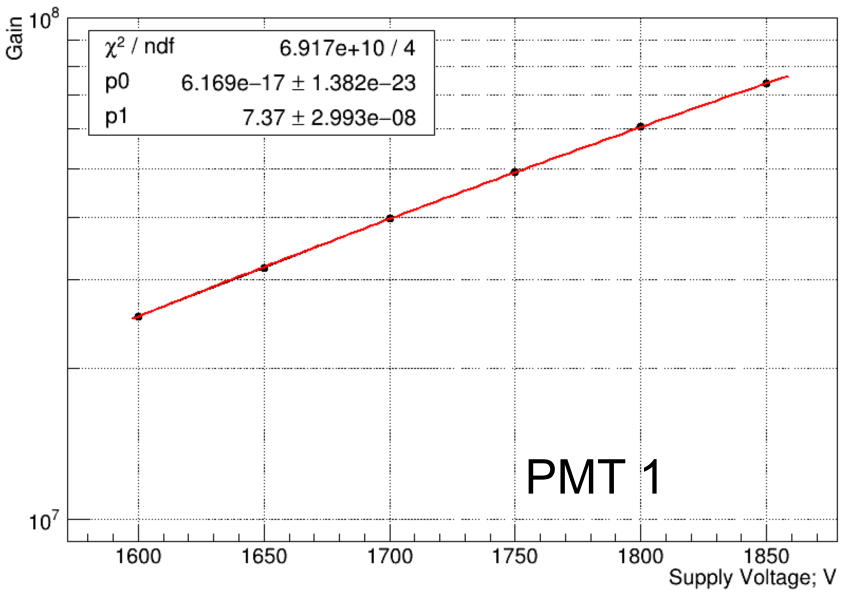

- Calibration in single photoelectron mode
- Light tightness tests
- No Aerogel installed in holder
- Light source LED+optical fiber
- Pulse from generator to LED ~40ns with 2V amplitude
- 250 MHz fADC digitizer
- JLAB CODA based DAQ
- Trigger from LED
- Calibration done for several HV settings for each PMT

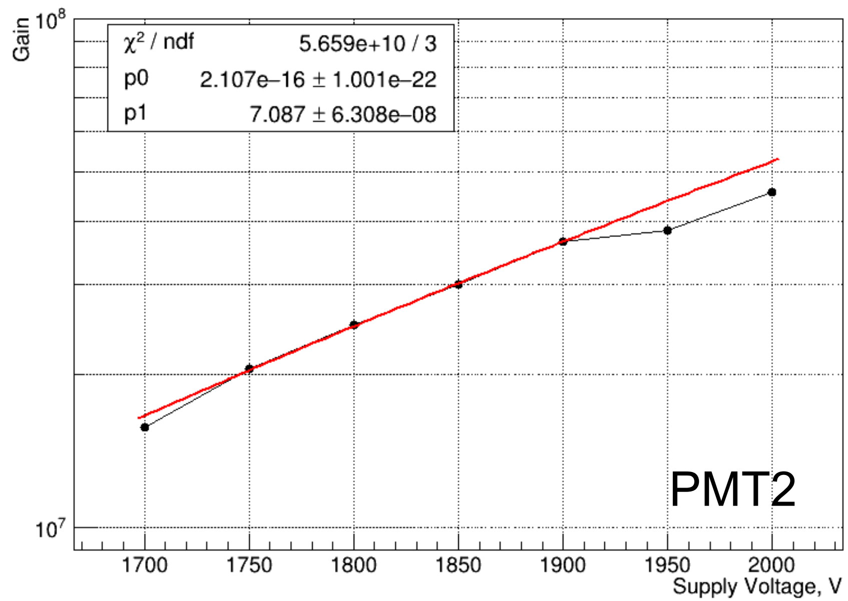


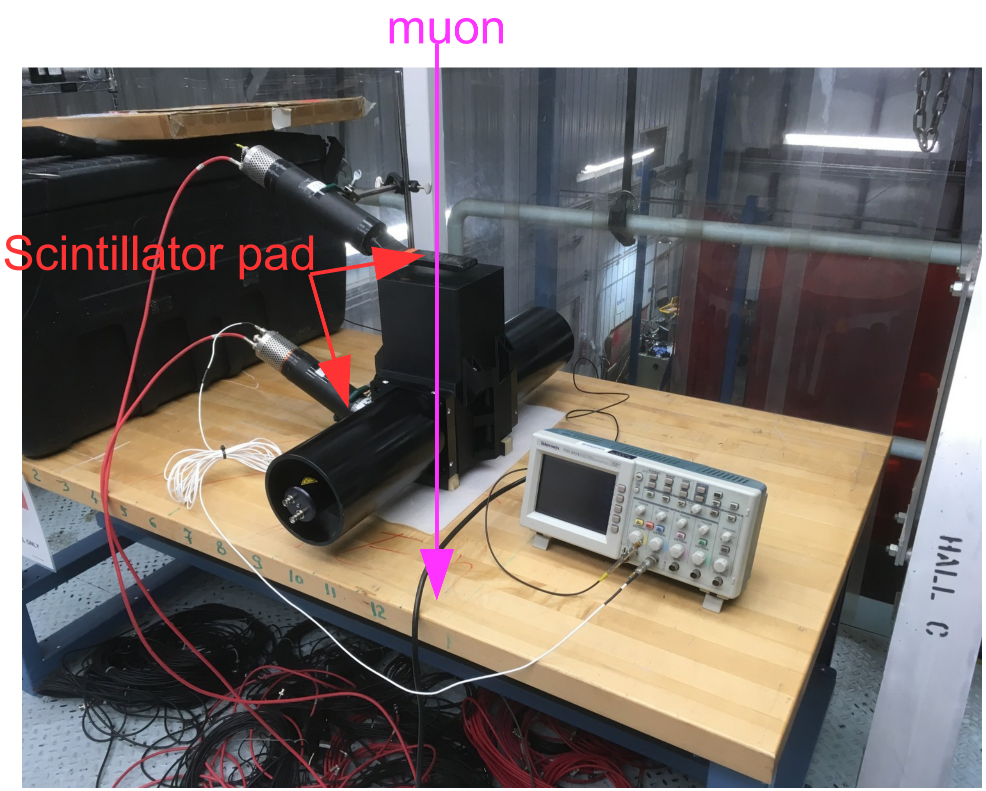
# PMT`s gain curve




- Fit function: Gain=p0*(Voltage)^p1
- PMT`s gain values/behavior is good
- Optimal PMT operation regions:
  (1.65-1.80)kV for PMT1
  (1.75-1.90)kV for PMT2

# Cosmic tests of T-shape prototype

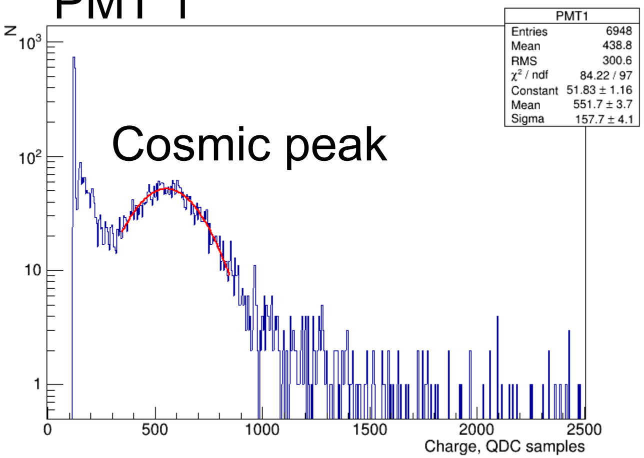



- Final tests before hall installation
- Tests performed in Aerogel cleanroom(EEL)
- Measurements with cosmic muons enters aerogel holder perpendicularly to the surface
- 8 SP-30 tiles and 8 SP-15 tiles
- Trigger performed by coincidence in time between pulses from two plastic scintillator pads
- CAEN(?) QDC digitizer
- JLAB CODA based DAQ
- 100 ns integration time

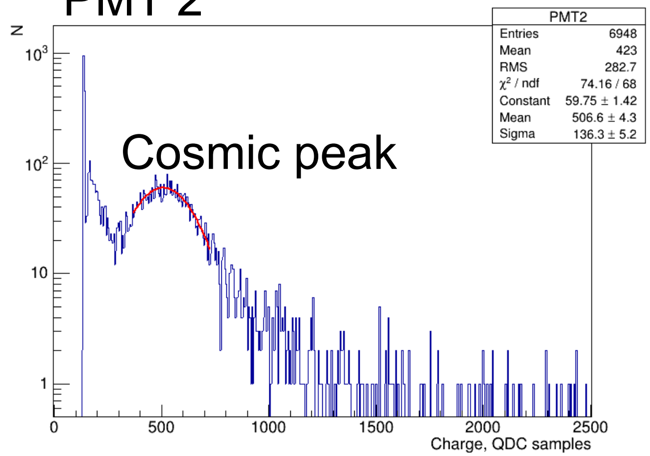
# Cosmic tests results of T-shape prototype

## Sp-30

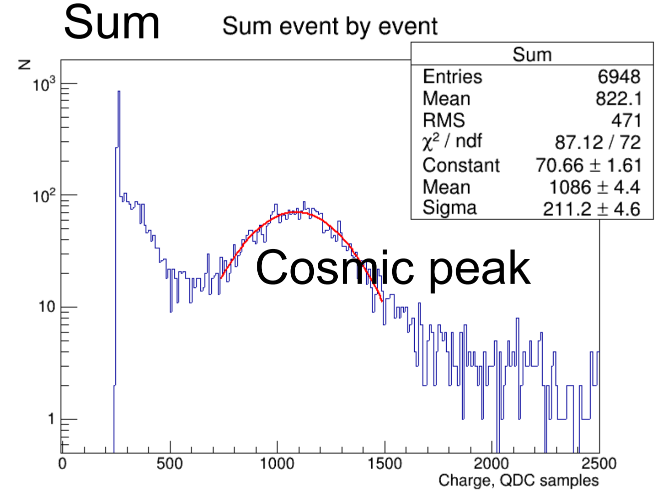
PMT 1




PMT 2

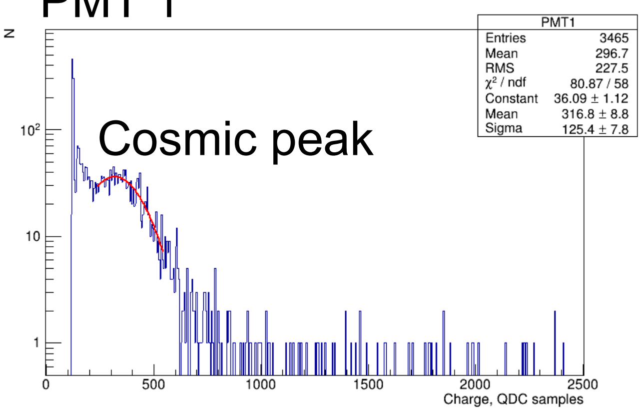



Sum

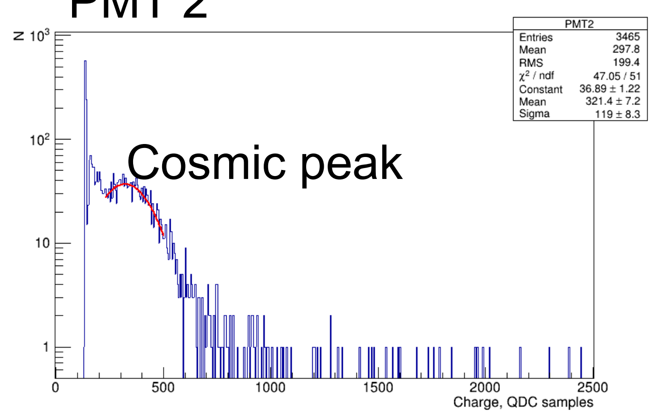



## Sp-15

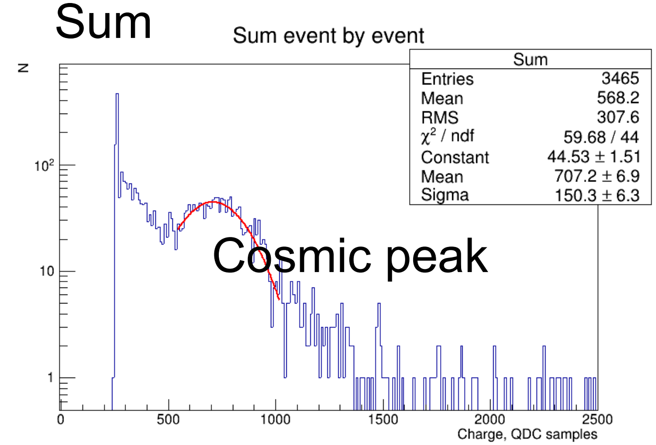
PMT 1



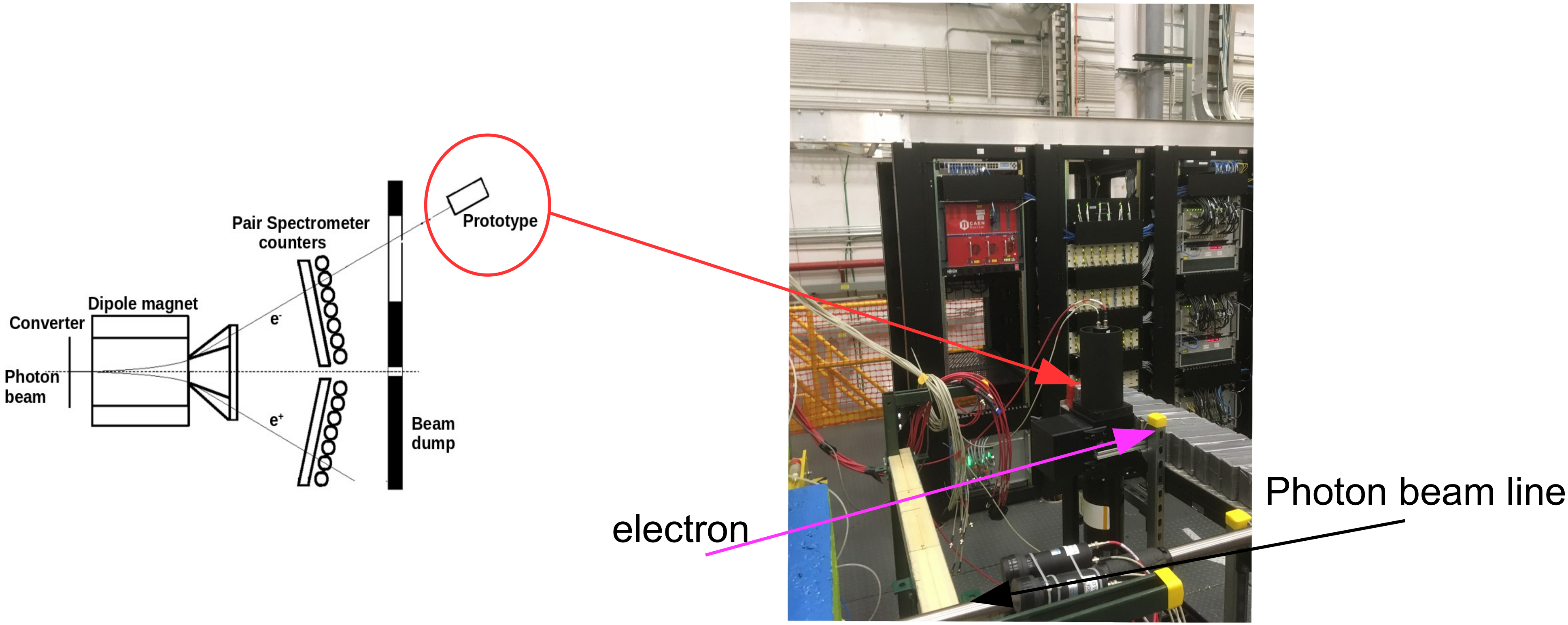

PMT 2




Sum



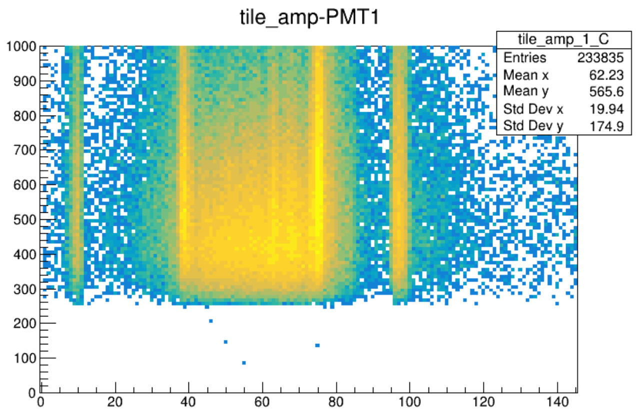
# T-shape prototype behind pair spectrometer in HallD



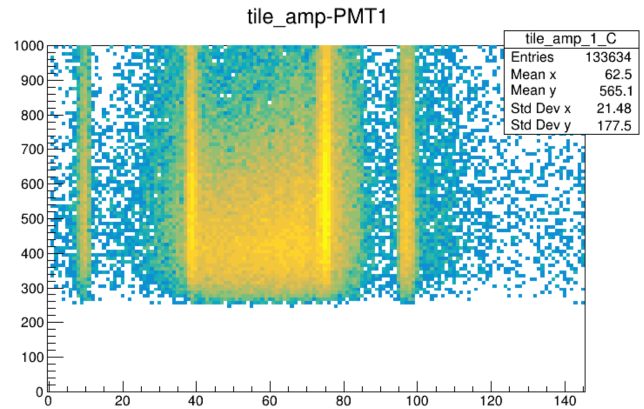

- Flash ADC 250 used for signal digitizing, which was installed in the existing start counter VXS crate
- Readout of the prototype will be integrated to the global GlueX DAQ system
- Operated in the stand alone mode (parallel to GlueX), using pair spectrometer trigger and not affect the GlueX performance.

# T-shape Aerogel prototype beam test data

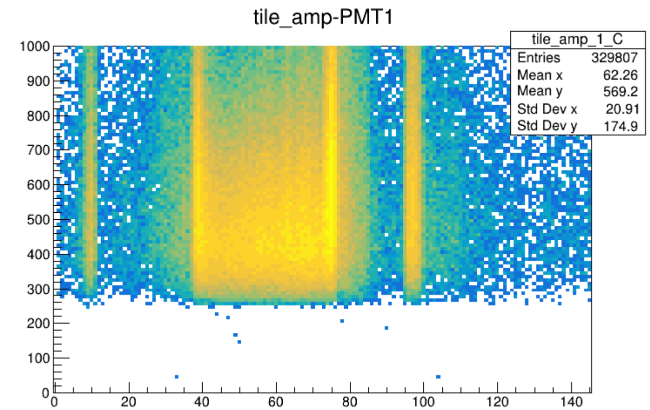
sp-15 A mesh




sp-15 J mesh

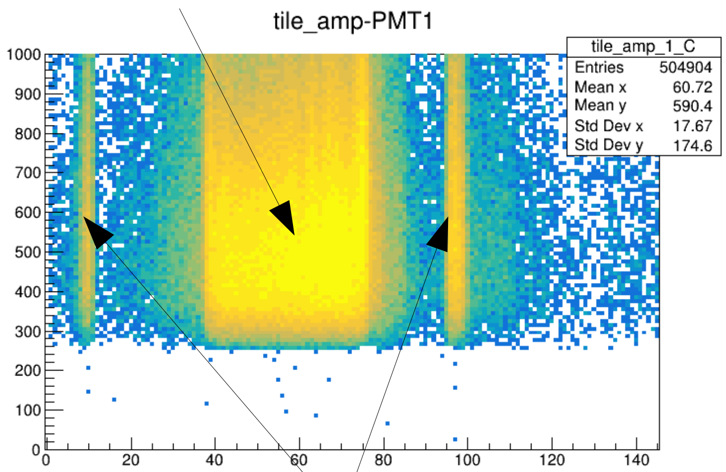



sp-15 J no mesh




sp-30 J no mesh

Aerogel events




Background,scattering

- Some visible effects of mesh/no mesh
- **Small difference** between Japan and Aspen
- Visible difference between two different indexes

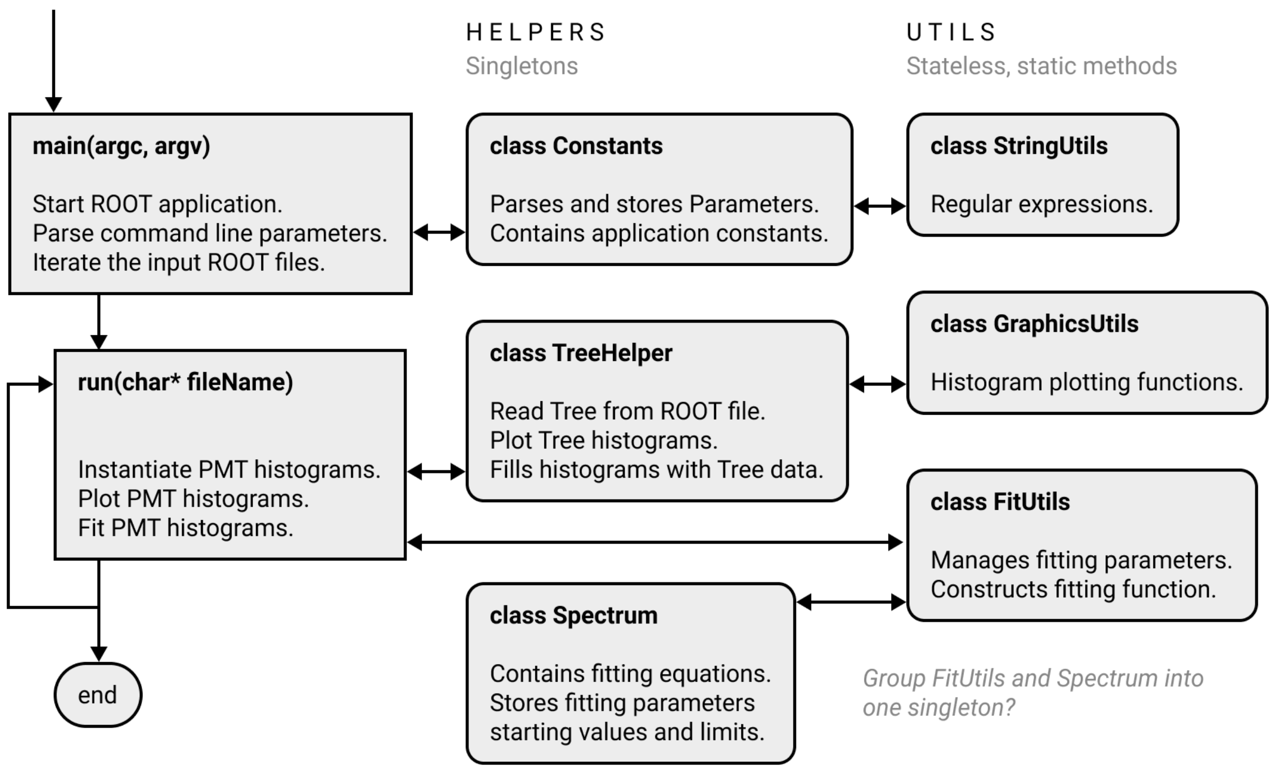
**Conclusion: computer fit needed for precise data treatment**

# KaonLT-Fit program

- Imports data from the ROOT trees
- Constructs one dimensional histograms with data for each PMT.
- Fits the PMT spectra and **determines the number of the photoelectrons**.

https://github.com/petrstepanov/kaonlt-fit

**> kaonlt-fit <file1.root> <file2.root> ... --tree-name=tree1;3 --plot-tree=kFALSE --tile-profile=55**




## Why standalone C++ executable?

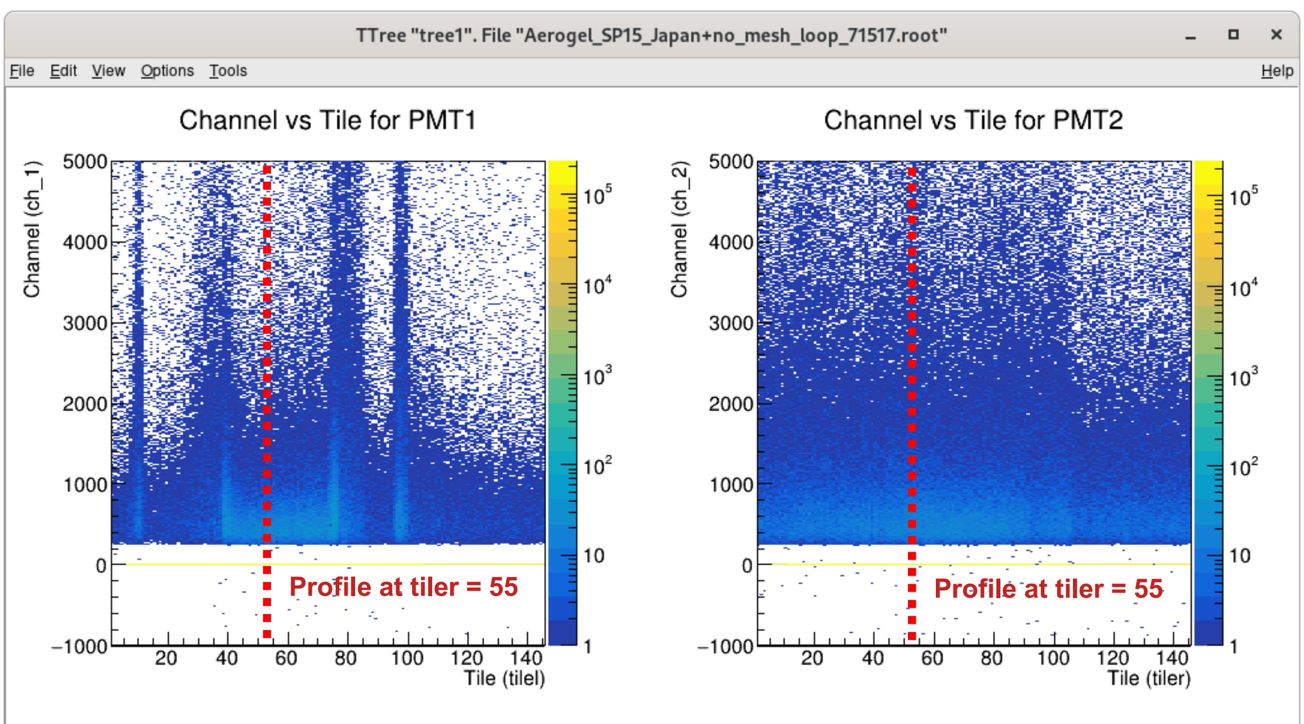
- Easy debugging.
- Modular OO code.
- Scalable and maintainable.
- Control of the program flow with command-line parameters.

# Experimental data from the beam

Experimental data from various Aerogel SP-15 samples is stored in ROOT Trees. Single tree contains data from both photomultipliers.

| Row | tilel | tiler | amp_1 | amp_2 | ch_1 | ch_2 |
|---|---|---|---|---|---|---|
| 0 | 77 | 93 | 0 | 0 | 0 | 0 |
| 1 | 75 | 29 | 0 | 0 | 0 | 0 |
| 2 | 126 | 87 | 0 | 0 | 0 | 0 |
| ... | ... | ... | ... | ... | ... | ... |

Constructing the PMT profile histograms at a certain energy of the incident electron.




Criteria for selection of the experimental data:

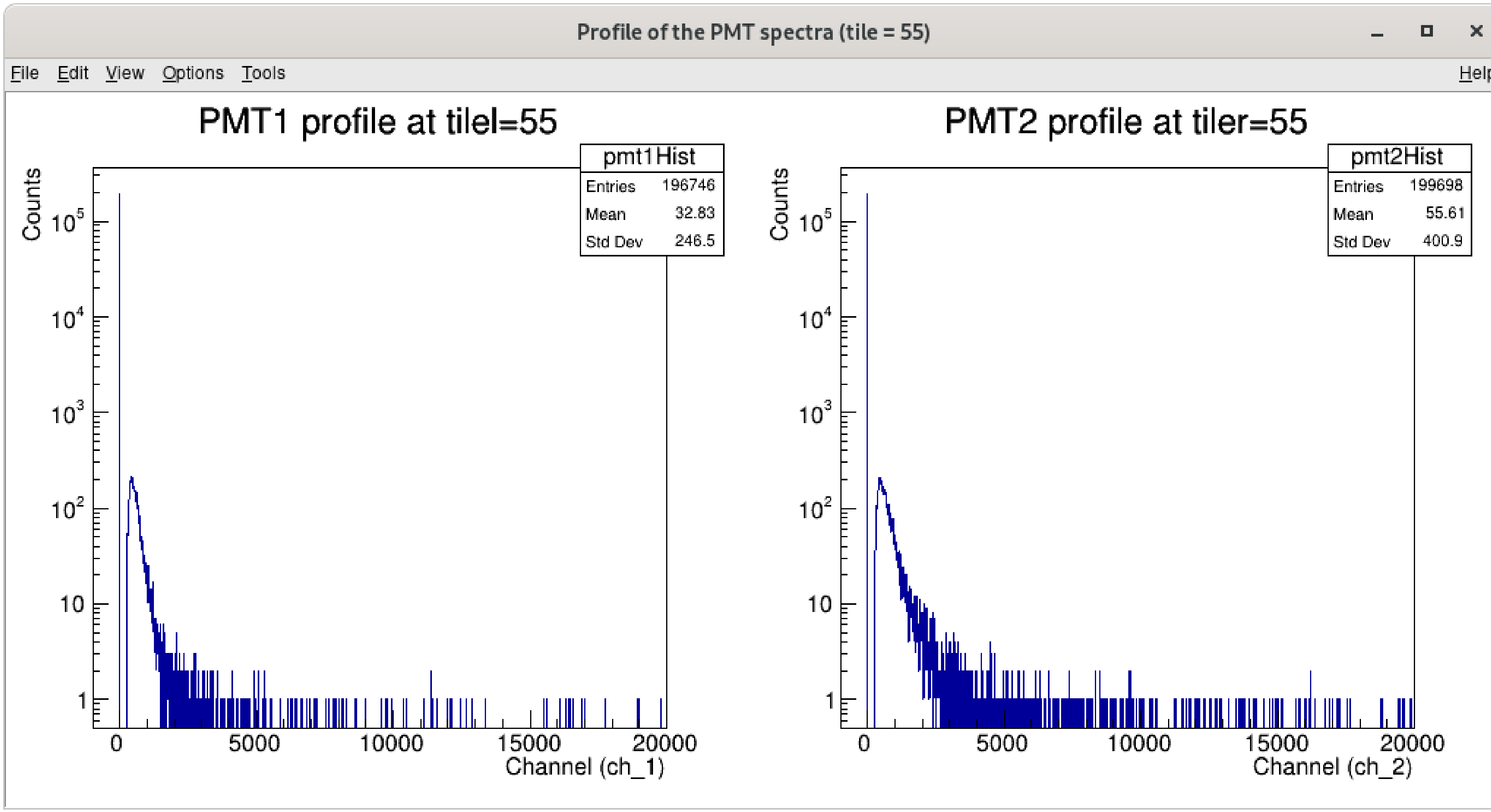
Event(tilel); tilel ≠ 0, tiler ≠ 0

Event(tiler); tiler ≠ 0, tilel ≠ 0

Should provide clean experimental spectra.

# Obtained PMT spectra

One-dimensional spectra for the Aerogel SP-15 samples (Japan, no mesh) are successfully obtained from the raw ROOT file.



# Fitting Equations

E.H. Bellamy et al. “Absolute calibration and monitoring of a spectrometric channel using a photomultiplier”

**Theoretical shape of the spectrum:**

$$S_{\text{ideal}}(x) = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \frac{1}{\sigma_1\sqrt{2\pi n}} \exp\left(-\frac{(x-nQ_1)^2}{2n\sigma_1^2}\right)$$

**Background contribution:**

$$B(x) = \frac{1-w}{\sigma_0\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma_0^2}\right) + w\theta(a)\alpha\exp(\alpha x)$$

**Real spectrum:**

$$S_{\text{real}}(x) = S_{\text{ideal}}(x) * B(x)$$

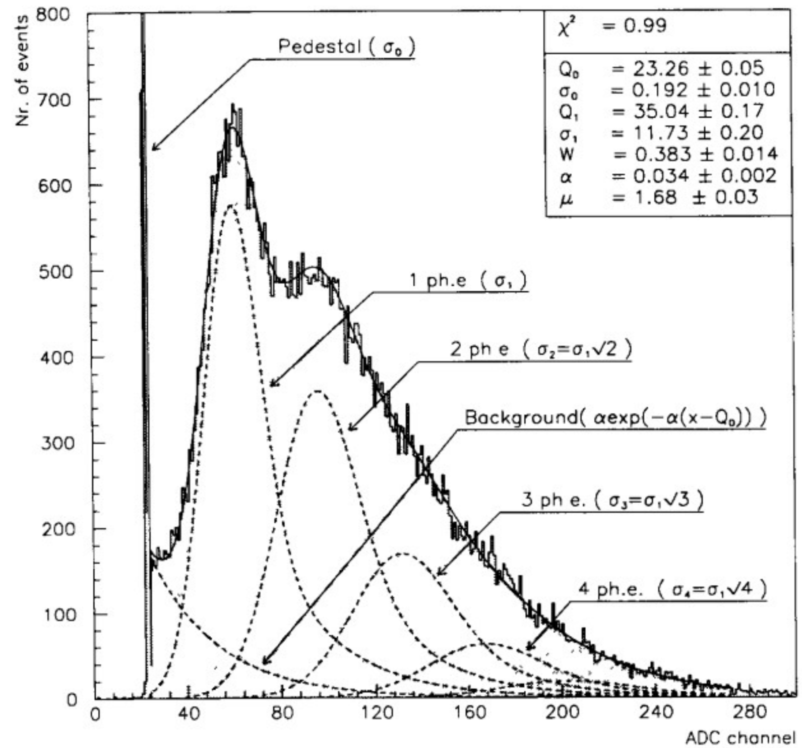
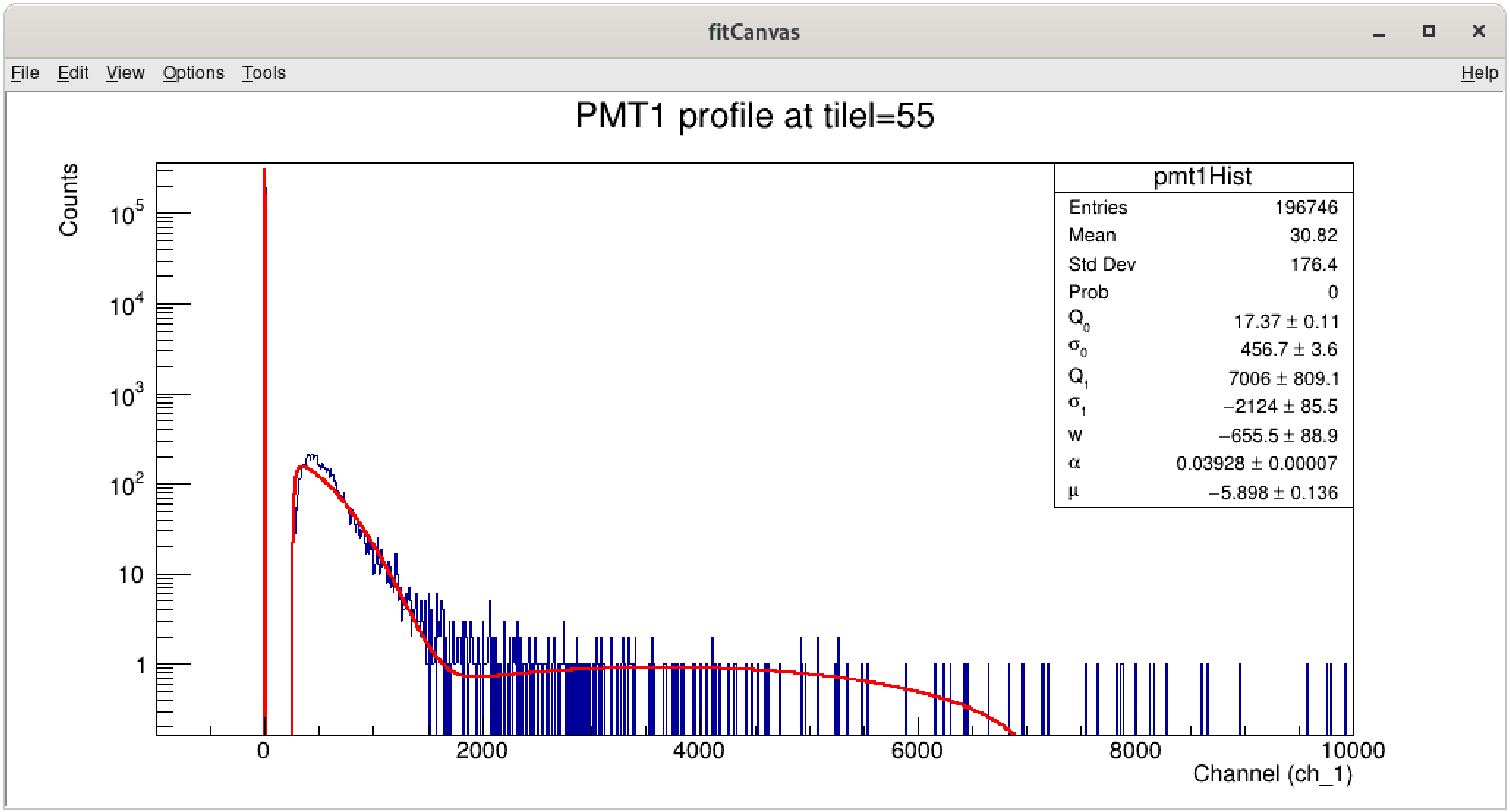



Fig. 2. Typical deconvoluted LED spectrum (EMI-9814B photomultiplier).

$Q_0$ − pedestal position.
$\sigma_0$ − standard deviation of the type I background process (pedestal).
$Q_1$ − average charge at the PM output.
$\sigma_1$ − corresponding standard deviation of the charge distribution.
w − probability that signal is accompanied by type II background process.
α − coefficient of the exponential decrease of the type II background.
**μ − number of photo-electrons.** ← we are interested in this parameter

# Preliminary fitting results

Fitting equations implemented into the KaonLT Fit program.




**Problem:** fit is bad; provides negative number of the photoelectrons μ.

# Issues with the prototype spectra

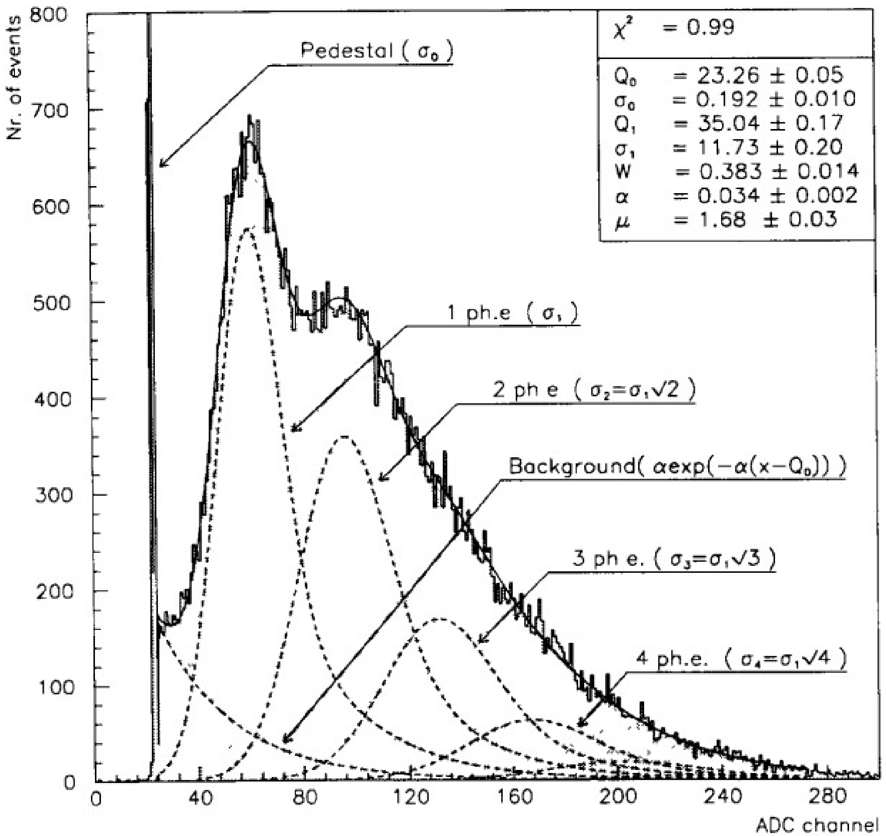
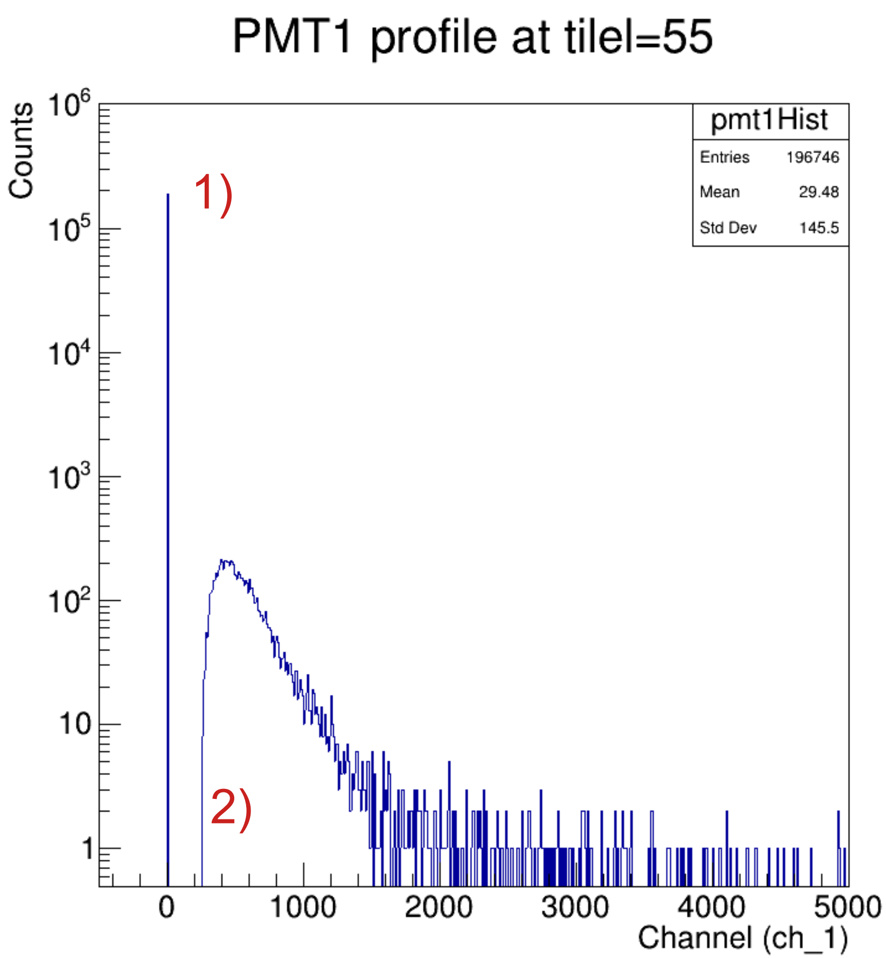


Fig. 2. Typical deconvoluted LED spectrum (EMI-9814B photomultiplier).




1. Pedestal width is one bin; expected to be a gaussian shape.
2. Exponential background part is missing.

**Cannot carry out reasonable fit.**

# Done so far

**KaonLt-Fit development started**

Program imports the prototype ROOT files. Plots the tree and obtains PMT profile spectra. Fitting capabilities are implemented. Access the code on GitHub: https://github.com/petrstepanov/kaonlt-fit

# What is next?

**Validate the KaonLT-Fit fitting equations**

Digitize the spectra from the E.H. Bellamy paper and fit. Compare values of fitting parameters.

**Figure out the problem with the prototype spectra.**

Could the pedestal be noise? Is the background missing due to some threshold set on the ADC?

**Obtain and analyze the data from real KaonLT experiment (not prototype)?**

Ensure that real KaonLT data has reasonable shape of the pedestal and the exponential background.