

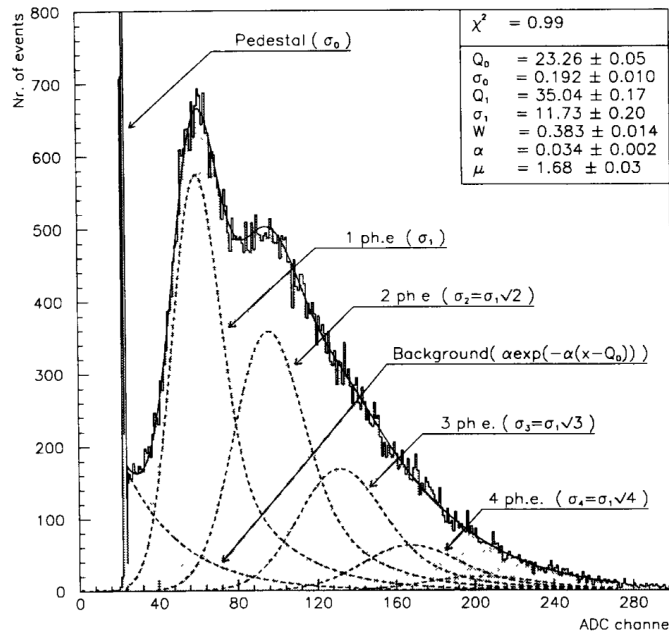
Studying the Stability of the Electronic Chain in the Beam Aerogel Data

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General Task

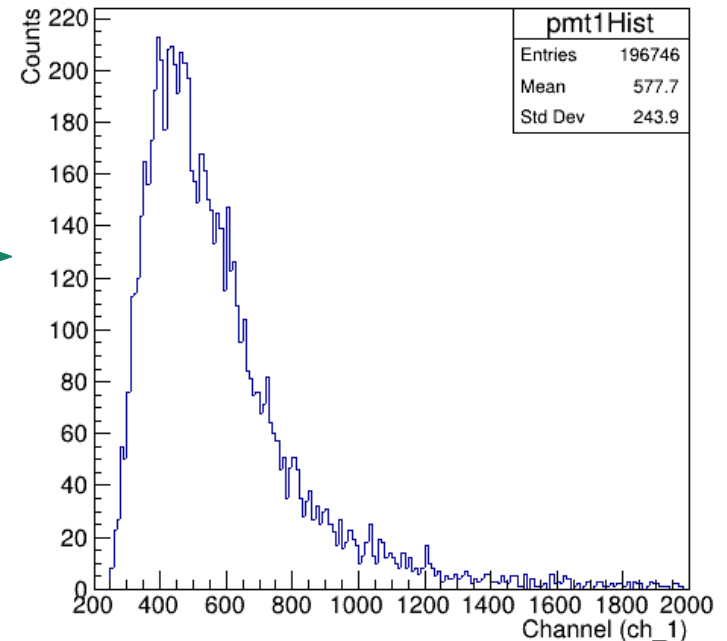
Construct an algorithm for **KaonLT experiment data fitting** based on the findings in E.H. Bellamy paper [https://doi.org/10.1016/0168-9002\(94\)90183-X](https://doi.org/10.1016/0168-9002(94)90183-X). Validate the algorithm. Apply the algorithm to Beam data and ensure the stability of the electronics.



Apply same fitting
to KaonLT spectra

Parameter μ
corresponds to the
number of photo-
electrons

PMT1 profile at tile=55



MILESTONES:

1. Extract PMT spectra from the ROOT file. Make 1D projections at certain Tile #.
2. Construct and validate fitting algorithms.
3. Account on absence of the Pedestal and exponential background.
4. Support iteration of the Beam runs an export of the fit parameters to a file.
5. Ensure the stability of the fit parameters (position and width of the 1PE peak).

Mathematics behind the fit

Theoretical shape of the spectrum:

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

Normalized Gaussian (PDF)

Background contribution:

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

Normalized Gaussian + Exponential function

Real spectrum:

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

$$= \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \cdot S_{\text{realN}}(x, n)$$

=1

Q_0 – pedestal position.

σ_0 – standard deviation of the type I background process (pedestal).

Q_1 – average charge at the PM output.

σ_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

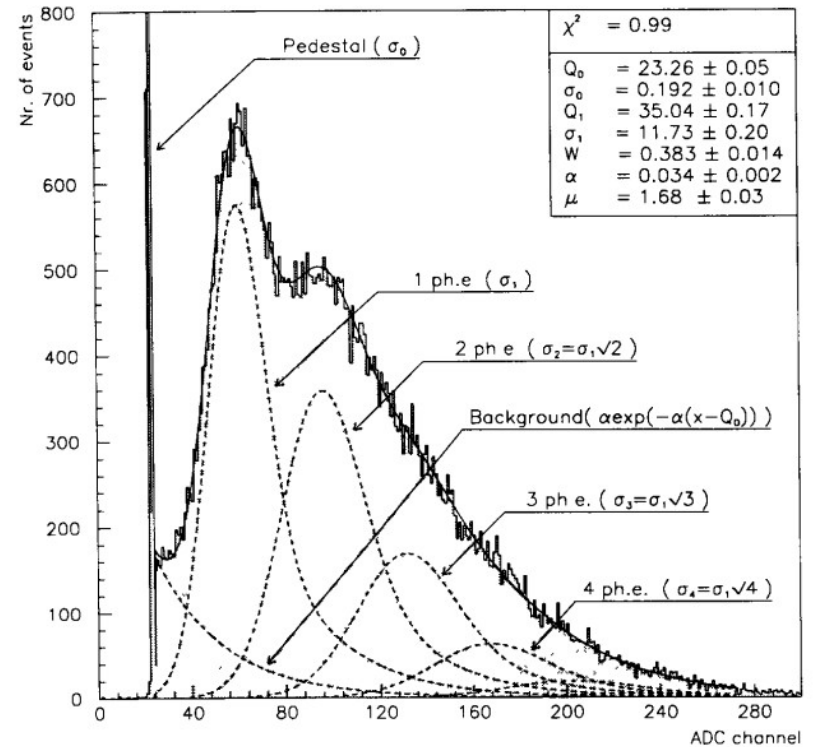


Fig. 2. Typical deconvoluted LED spectrum (EMI-9814B photomultiplier).

Components S_{realN} should be normalized.

Because convolution of any function with a normalized function does not change the definite integral $(-\infty, \infty)$.

How to account on the absence of the Term0 (pedestal)?

Pure mathematical approach. Not sure about the instrumentation behind it.

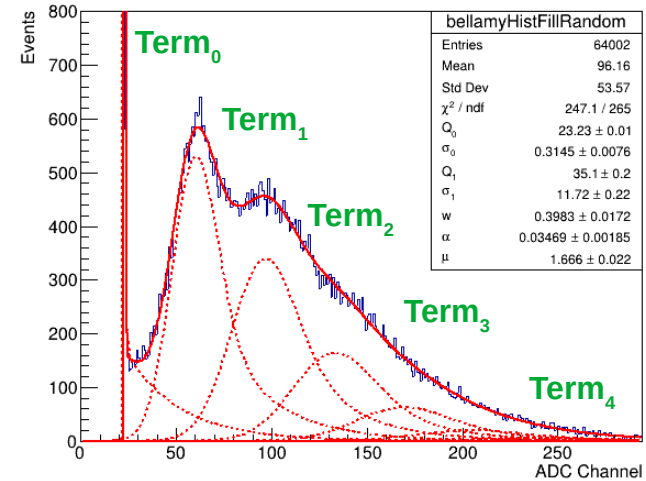
Originally sum of the term coefficients is normalized (equals to 1):

$$S_{real}(x) = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \cdot S_{realN}(x, n)$$

where

$$\sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} = 1$$

Bellamy histogram. Random fill from fit function.



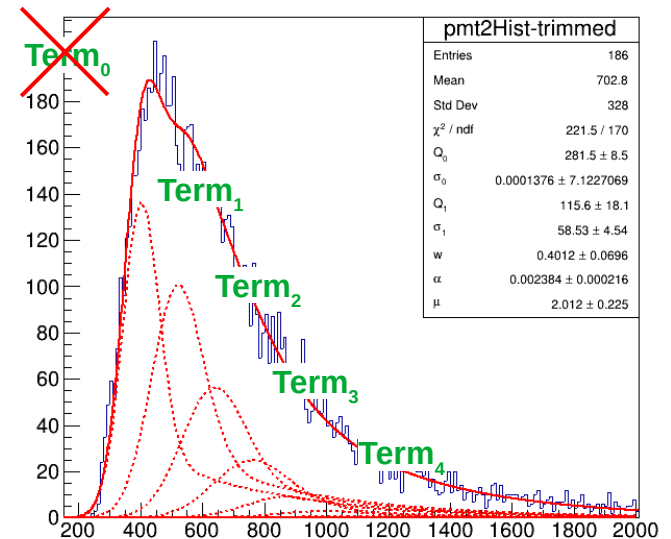
In Prototype spectra the zero term (pedestal + exp background) is missing. Therefore we have to re-normalize the PDF coefficients:

$$\sum_{n=1}^{\infty} \frac{\mu^n e^{-\mu}}{n!} = 1 - e^{-\mu}$$

$$S_{real}(x) = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!(1 - e^{-\mu})} \cdot PDF_n$$

new coefficients

PMT2 profile at tiler=55



How to compile and run the program on the Farm?

Login to the Computing Farm and source the Environment:

```
ssh -Y <user>@login.jlab.org
ssh -Y <user>@ifarm
source /site/12gev_phys/softenv.csh 2.4
```

Check out the code from Git, compile, move the executable to ~/bin:

```
mkdir -p ~/Downloads && cd Downloads/ && rm -rf kaonlt-fit/
git clone https://github.com/petrstepanov/kaonlt-fit && cd ./kaonlt-fit
make release
```

```
mkdir -p ~/bin && cp ~/Downloads/kaonlt-fit/dist/* ~/bin/
```

Navigate to a temporary folder and create “fit-parameters.txt” file

```
mkdir -p /work/hallc/kaon/petrs/SHMS_Stability/ && cd
/work/hallc/kaon/petrs/SHMS_Stability/
```

```
cp ~/Downloads/kaonlt-fit/resources/beam-params.txt ./
```

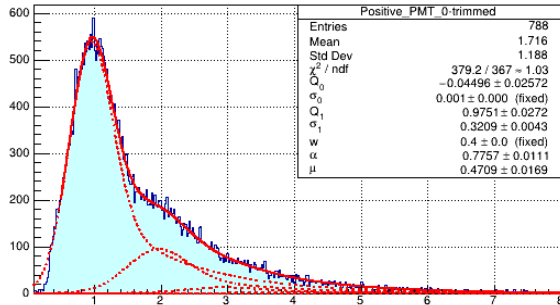
Start spectrum analysis

```
kaonlt-fit-local /work/hallc/kaon/petrs/SHMS_Aerogel_replay/result_*.root \
--params-filename=beam-params.txt --plot-profiles=kFALSE --terms-number=20 --tile-
profile=55 --fit=root --ch-fit-min=0.1 --ch-fit-max=10 --ch-fit-range-min=0.5
```

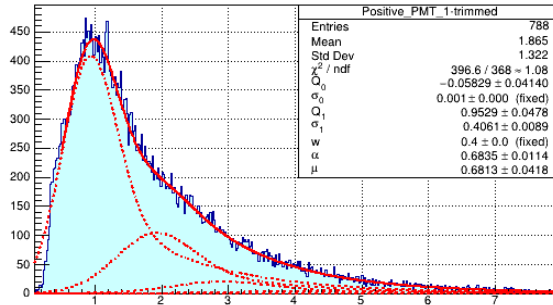
Beam Spectra Fits

Fitting interval is limited to exclude the rise hump

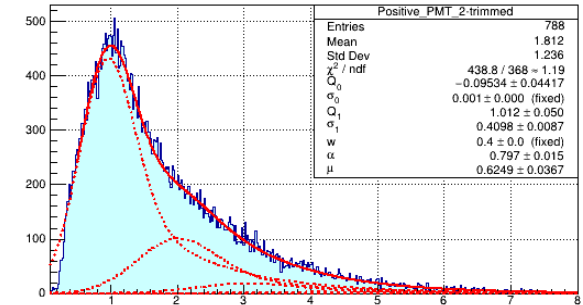
Positive_PMT_0-trimmed



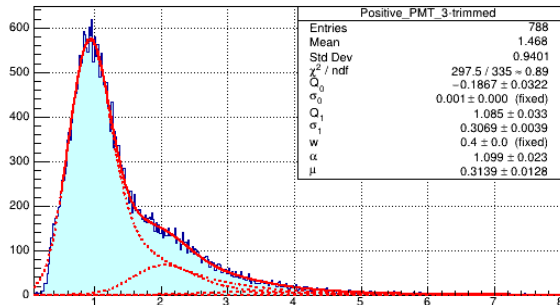
Positive_PMT_1-trimmed



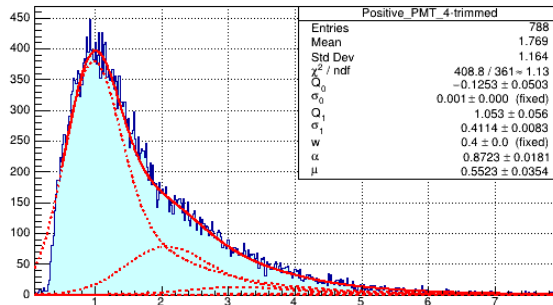
Positive_PMT_2-trimmed



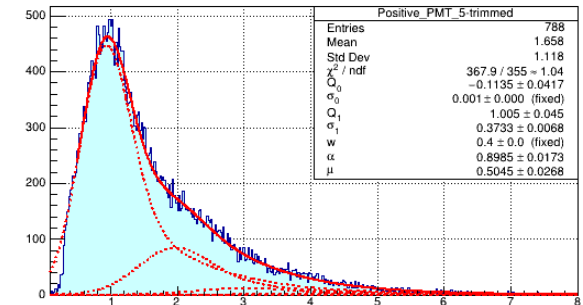
Positive_PMT_3-trimmed



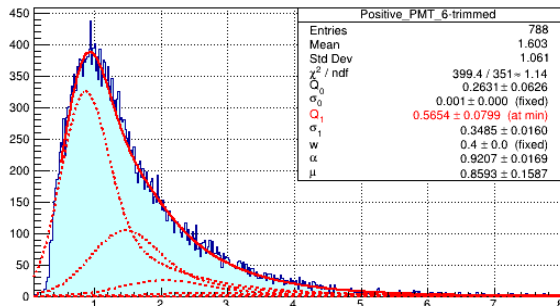
Positive_PMT_4-trimmed



Positive_PMT_5-trimmed



Positive_PMT_6-trimmed

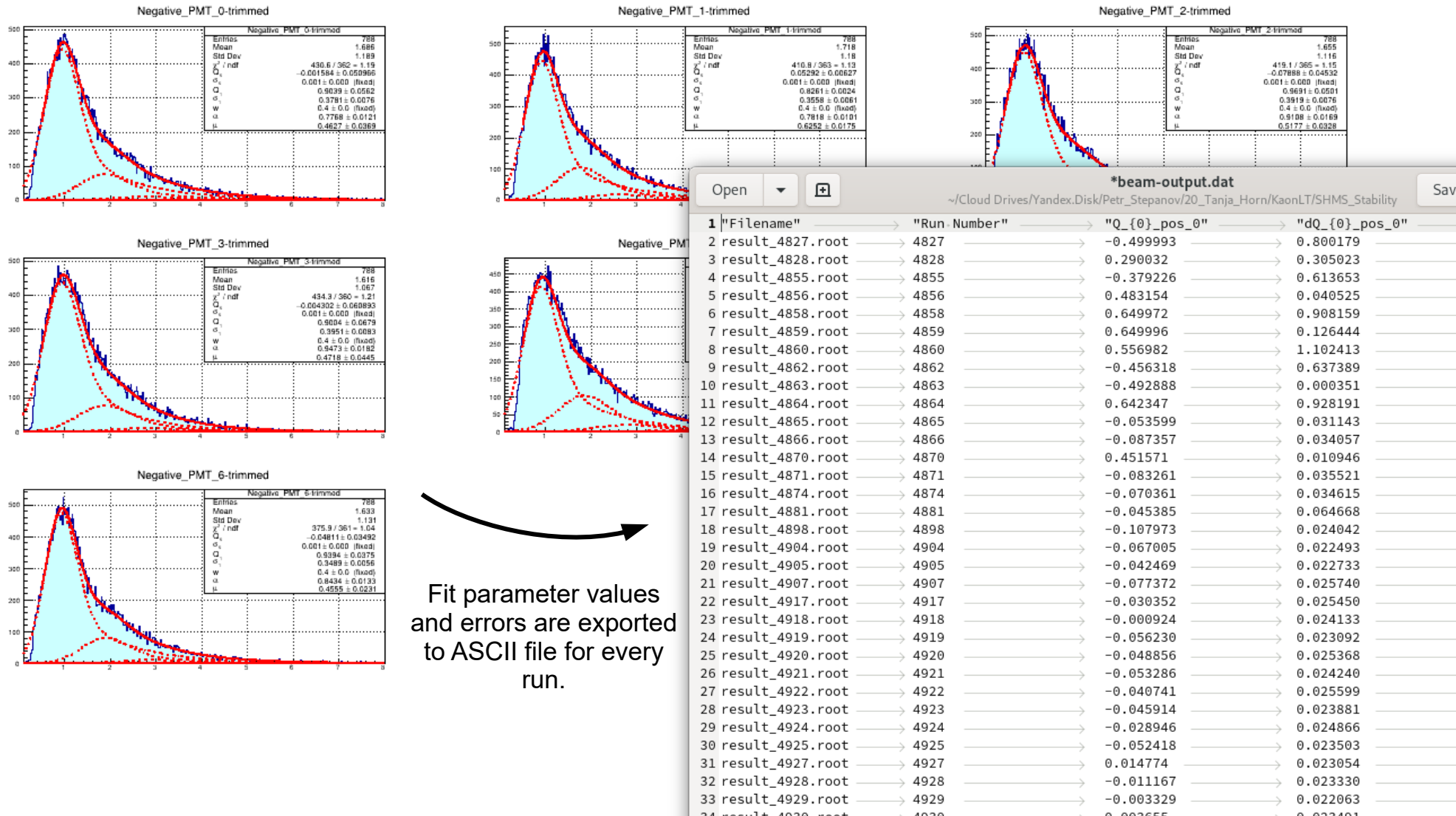


FITTING APPROACH:

1. The ADC threshold set the lower region provides the hump on the rise of the spectra. Hump was excluded from the fit range.
2. Ratio of the gauss to exponential background ($w = 0.4$) as well as the pedestal width ($\sigma_0 = 1E-3$) are fixed due to the absence of the pedestal.

Extracting the Stability of the Beam Run Parameters

KaonLt Fit program code was updated to support iterating multiple input spectra. Fit parameters and their values for all 14 PMTs are exported to an ASCII file for every run.



Plotting the Beam stability data

Command-line plotting interface [Gnuplot](#) was selected as a tool for plotting the stability graphs. It is convenient to use plain text Gnuplot scripts on the Computing Farm environment.

```
# Input ASCII delimiter
set datafile separator "\t"

plot1height = 0.6

# Start multiplot
set multiplot layout 2,1 rowsfirst

# Top plot Q_0 + Q_1
set title "Stability of the Aerogel fit for PMT0+"
set lmargin at screen 0.12
set size 1,plot1height
set origin 0,1-plot1height

# Turn on grid
set grid

# X axis
set xrange[4500:8500]

# Remove x axis labels
set format x ''

# Y axis for Q_0+Q_1
set ylabel "First term mean Q_0 + Q_1"

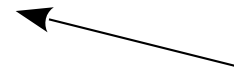
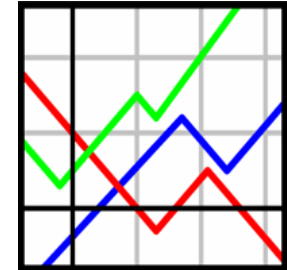
plot './SHMS_Stability/beam-output-exclude.dat' using 2:($3+$7):($4+$8) title 'Q_0 + Q_1' with yerrorbars

# Bottom residuals plot
set title ""
set lmargin at screen 0.12
set size 1,1-plot1height

# X axis
set xlabel "Run Number"
set xrange[4500:8500]
set format x

# Second y axis for chi^2
set ylabel "Goodness of fit chi^2"

plot './SHMS_Stability/beam-output-exclude.dat' using 2:17
```



Gnuplot allows plotting sum of ASCII data columns (Q_0+Q_1). This value corresponds to the position of the first PE peak

title 'chi^2'

Processing the Recent Replay Beam Data

Sept 2020 Replay beam data has **improved Analyzer code** and includes more stability information (more runs). **Aerogel Replay** program code for processing the Replay data **is developed** and [available on GitHub](#). **Many raw ROOT files** turned out to be **corrupted** therefore error handling mechanisms are implemented.

README.md



Aerogel Replay

A ROOT script that extracts data from the beam raw data and exports series of corresponding PMT histograms. Every output ROOT file contains seven Positive and seven negative PMT histograms. There are two ROOT scripts in the repository. Script `replay.c` uses the TTreeReader interface to iterate the ROOT trees. It works quick but will more likely crash if the input ROOT files are corrupt. A better ROOT TFile error handling is implemented in the script `replayConv.c` which uses a conventional TTree::GetEntry() mechanism for reading the tree. The downside of this mechanism is the speed which is about 10 times more slow compared to the TTreeReader.

How to use

1. Checkout the repository to the folder where the output data will be located.

```
git clone https://github.com/petrstefanov/aerogel-replay/ && cd aerogel-replay
```

2. Tweak the RegExp input filename pattern on the line 14 of the script to match the desired name of the input files.
3. Limit the the output spectra statistics by setting the maximum number of the reads from thetree on the line 77.
4. Run either `replay.c` or `replayConv.c` script specifying the path to the directory containing the raw spectra:

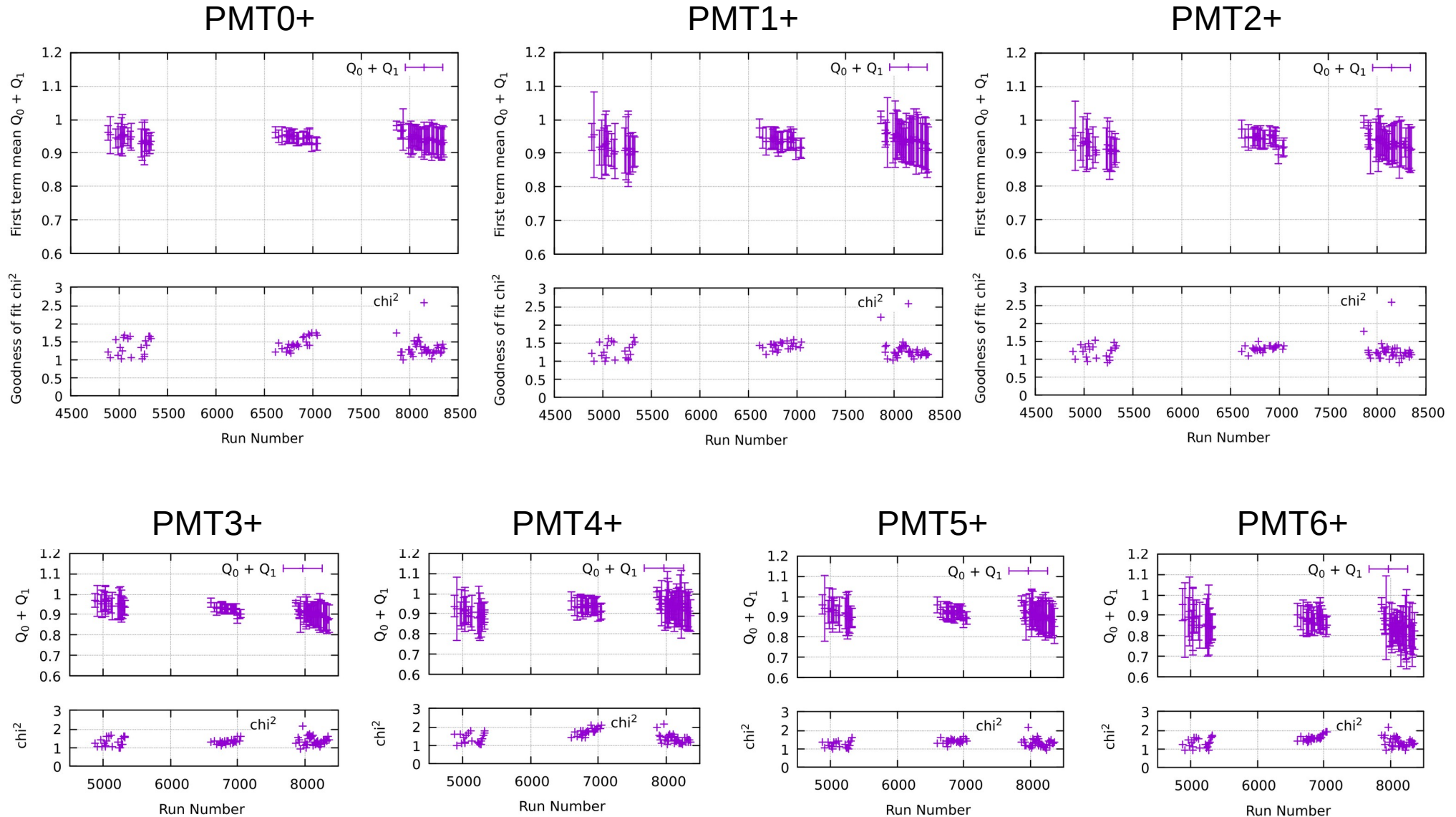
```
root 'replayConv.c("/path/to/the/root/replay/files")'
```

5. Script will automatically scan the directory for the input files and start processing them.

If the script crashes during the run you can restart the script from the desired input filename index. In order to do so specify the starting input filename index on line 13 of the script.

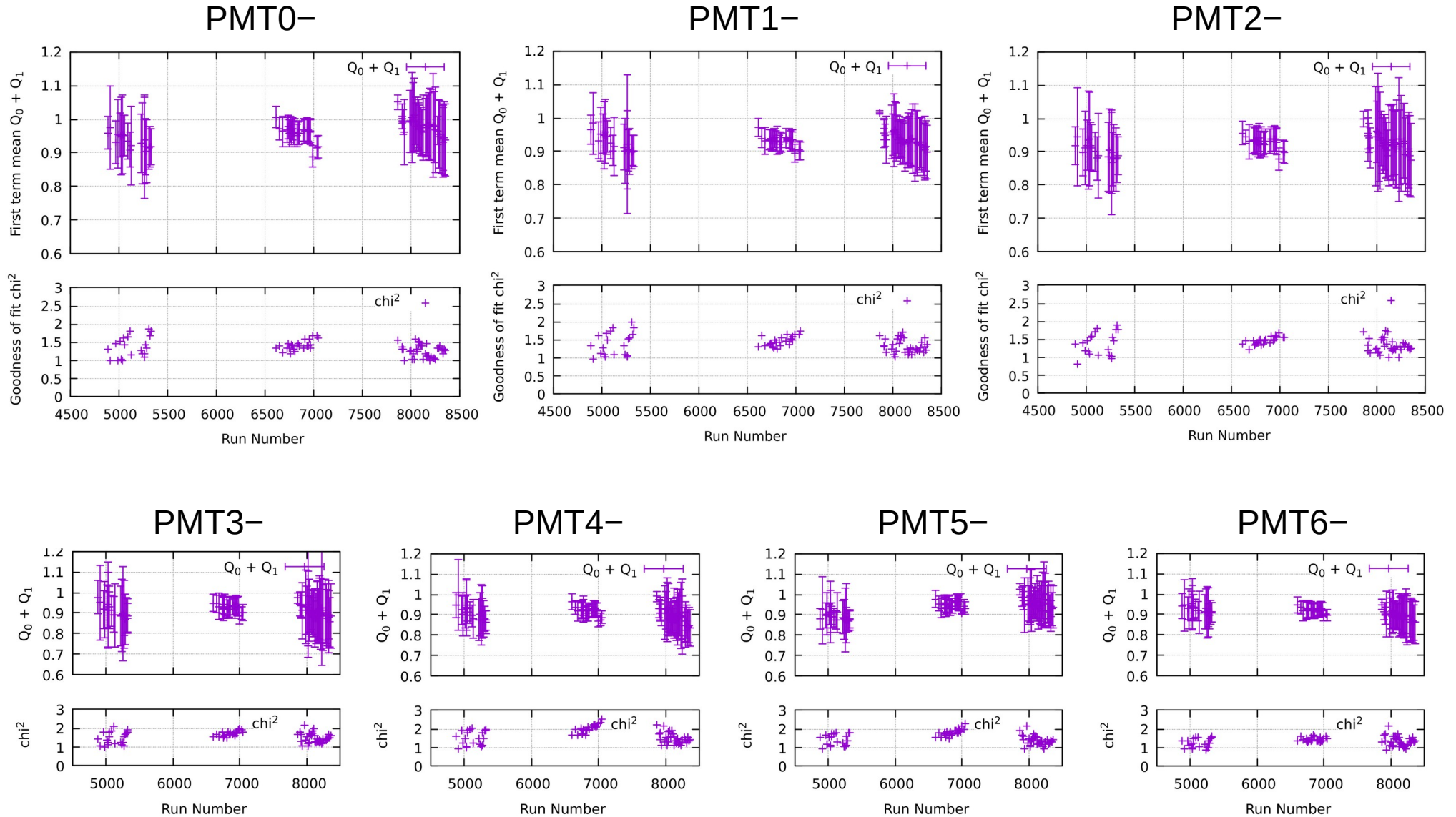
Stability of the Beam Replay Runs (Sept 2020)

Graphs represent the position of the 1st photo-electron peak Q_0+Q_1 . Every 10th file with **full statistics** is processed. Corrupted ROOT data files are skipped.



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Graphs represent the position of the 1st photo-electron peak Q_0+Q_1 . Every 10th file with **full statistics** is processed. Corrupted ROOT data files are skipped.



Summary of the past two weeks

- `KaonLT Fit` program for fitting the Aerogel ADC spectra is developed.
<https://github.com/petrstepanov/kaonlt-fit>
- Fitting algorithm of `KaonLT Fit` is based on the equations outlined in the E.H. Bellamy paper ([https://doi.org/10.1016/0168-9002\(94\)90183-X](https://doi.org/10.1016/0168-9002(94)90183-X)). Program iterates and fits series of beam spectra and exports fitting parameters: μ - number of the photo-electrons, $Q_0 + Q_1$ - position of the 1st photo-electron (PE) peak, σ_1 – width of the 1st PE peak.
- `KaonLT Fit` program iterates and fits series of beam spectra and exports above fitting parameters to a text file. This makes it possible to inspect stability (position of 1st photo-electron peak).
- ADC spectra are extracted from the raw replay data with the `Aerogel Replay` script developed as a part of this work: <https://github.com/petrstepanov/aerogel-replay>
- Stability of the position of the 1st PE peak for the new replay PMT spectra is plotted with Gnuplot. Graphs demonstrate acceptable stability results within calculated error values.