Monitoring the Electronics Performance of the CLEO Ring-Imaging Cherenkov Counter (RICH)

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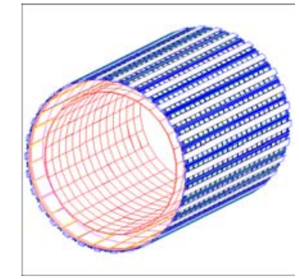
$$\cos(\theta) = \frac{1}{n\beta}$$

$$where \beta = \frac{v}{c}$$

How the RICH Works

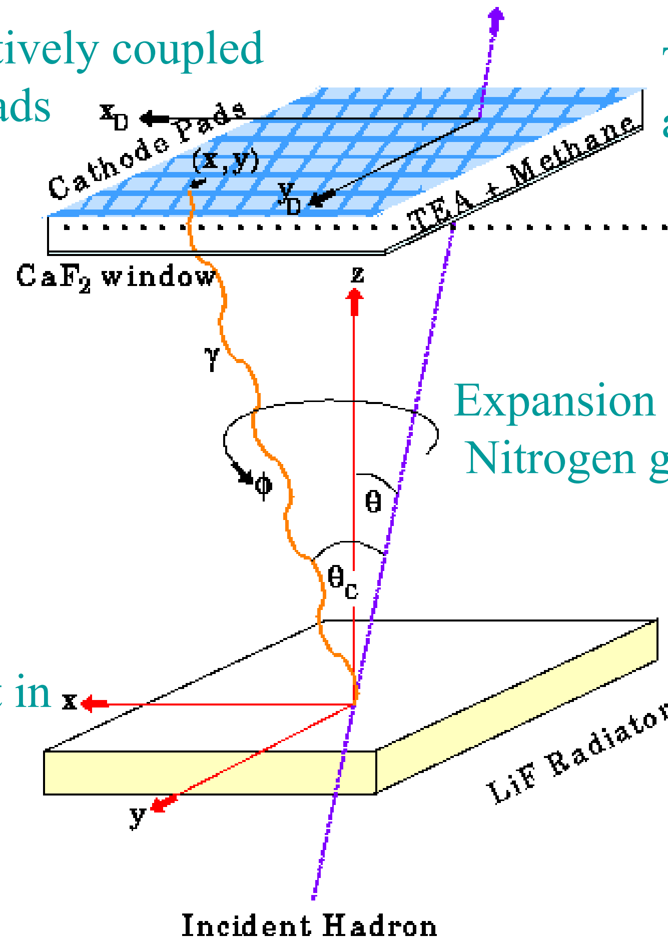


Anode wires are capacitively coupled to the grid of cathode pads

Triethylamine (TEA) is a photosensitive gas

CaF_2 window is deposited with metallic traces kept at -1200 V

Anode wires kept at +1500 V

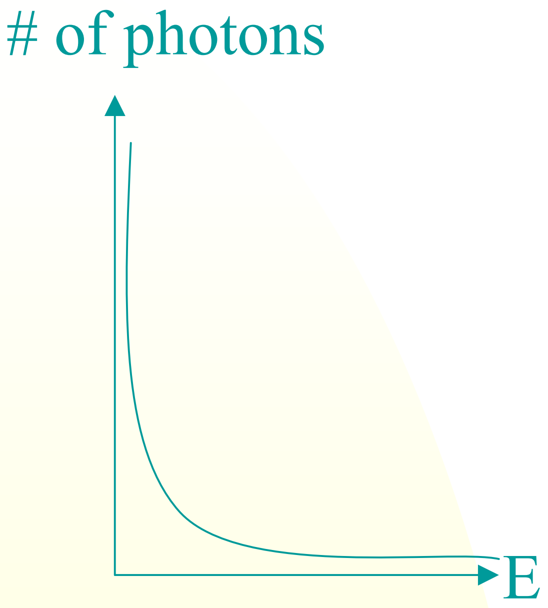


Expansion volume – pure Nitrogen gas

Since the index of refraction of the radiator medium is >1, the particle travels faster than the speed of light in this region, emitting Cherenkov radiation in the shape of a cone

Particle enters the RICH through LiF Crystal Radiator

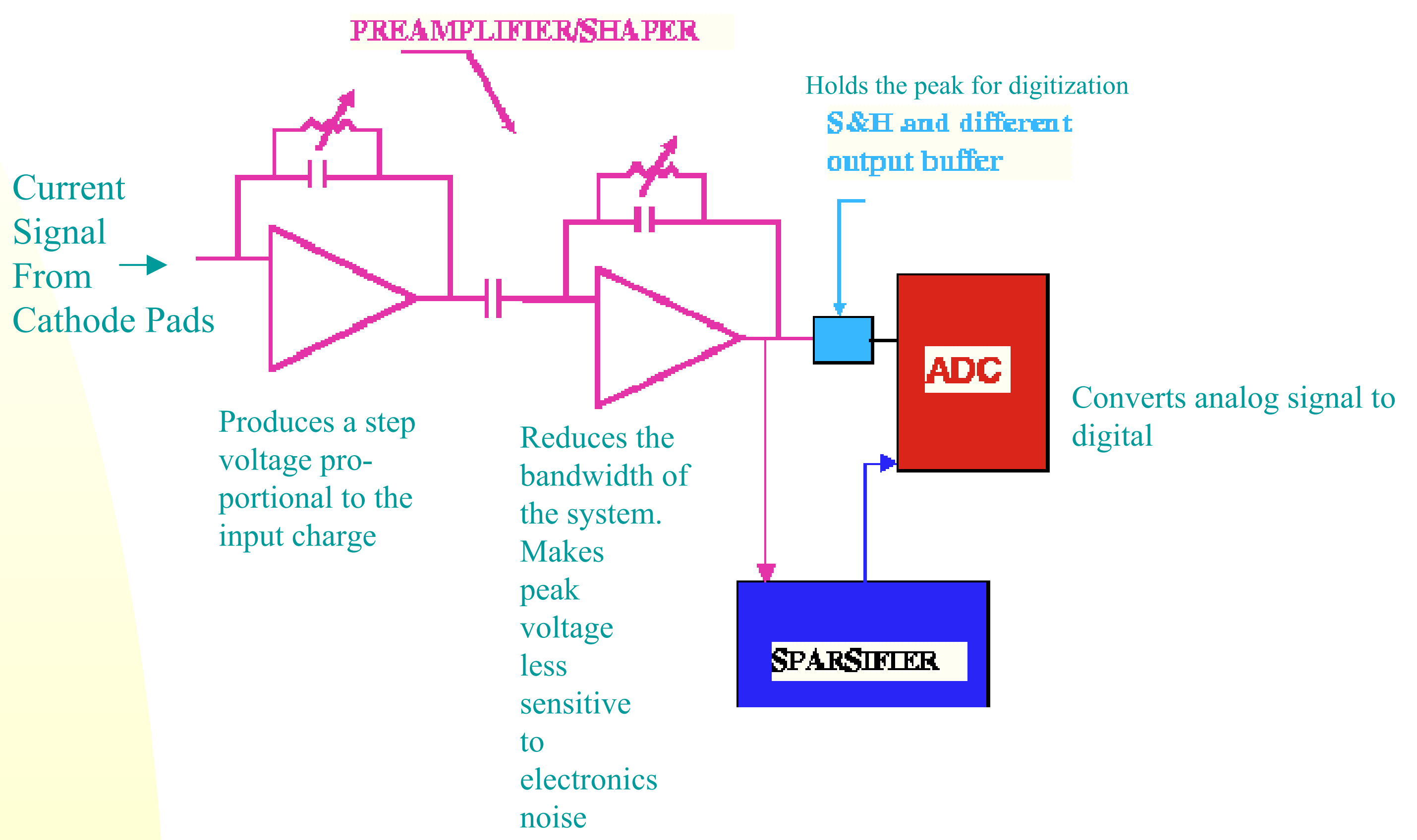
Collision occurs in interaction region about 80 cm below the inner radius of the detector forming elementary particle(s)



Essential Features of the Electronics

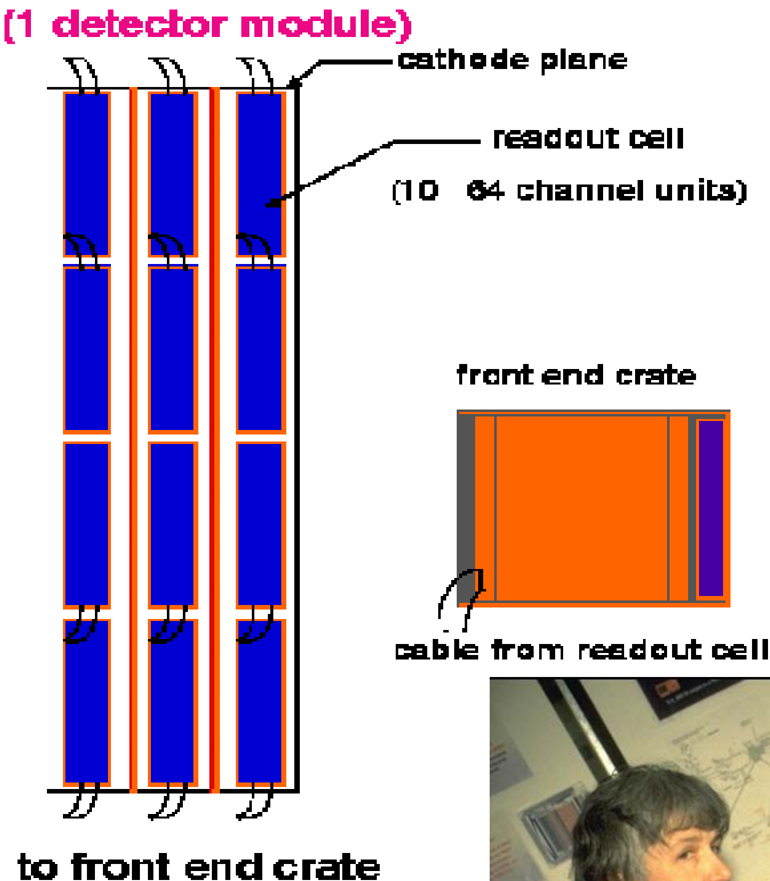
- Low Noise – this is necessary because the charge probability distribution of a single photon is exponentially decreasing
- High Dynamic Range – to pick up signals from both single photons as well as the charged particles that create them

Electronic Components – the VLSI Chip



How do we read these signals?

- There is a total of 230,400 channels to read from the cathode pads
- These are divided into 30 RICH chambers
- Each chamber is subdivided into 12 readout chains which are connected via ribbon cables to the data boards located in the front end crates right outside the detector
- Each chain contains 5 chip carriers (2 chips each = 10 chips/chain total)

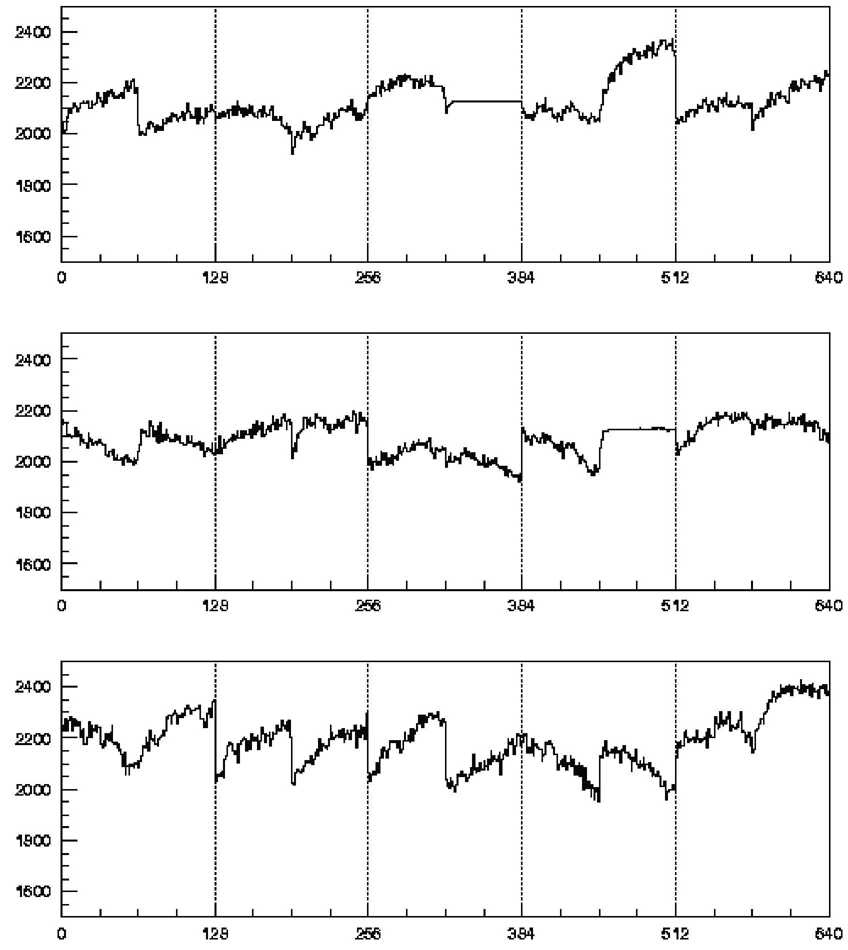

(1 detector module)
cathode plane
readout cell
(10   64 channel units)
front end crate
cable from readout cell
to front end crate

Outline of REU Project

Monitoring the behavior of RICH readout electronics. This involves:

- Calibration Modes
  - Small Cal (pedestal values allow us to study noise, flatness, and locate dead channels/chips)
  - Single Channel Calibration (allows us to study the electronic gain of a single channel)
  - Big Cal (Single Channel Cal for every channel in the detector!)
- Statistical Plots
  - Noise over time
  - No. of noisy channels over time
  - “Flatness” over time
  - Studying chamber gain factor for each window of the detector

Example of Flatness



Small Calibration Runs

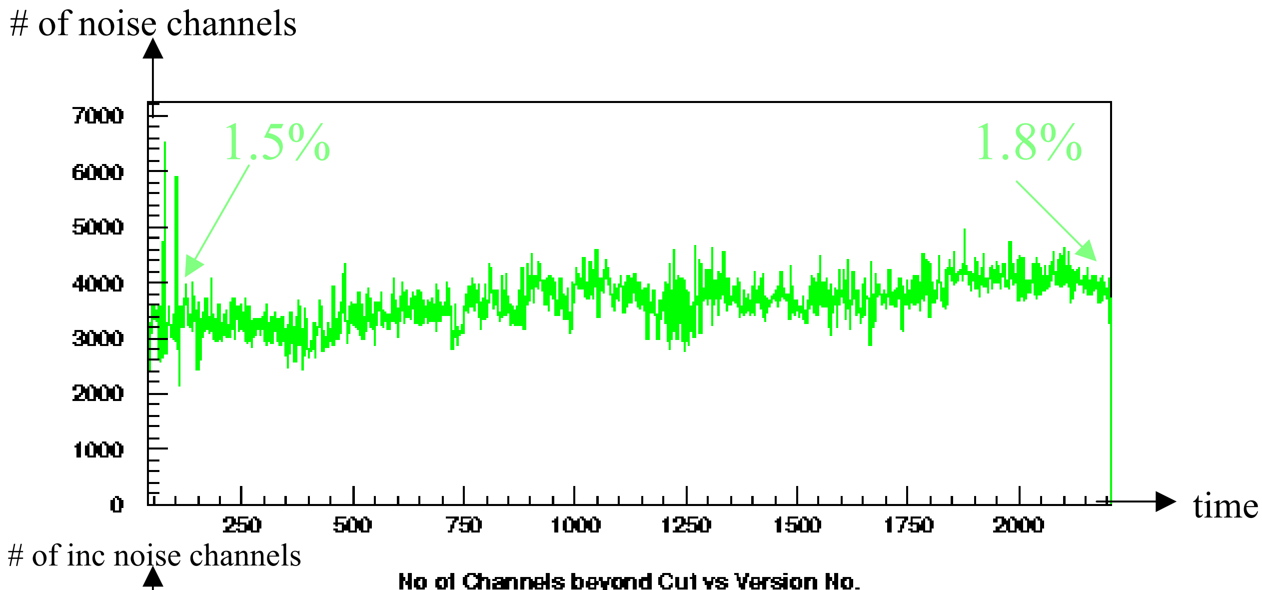
Small Cal runs are just like data taking runs except the accelerator is off. So what we are measuring are pedestal values.

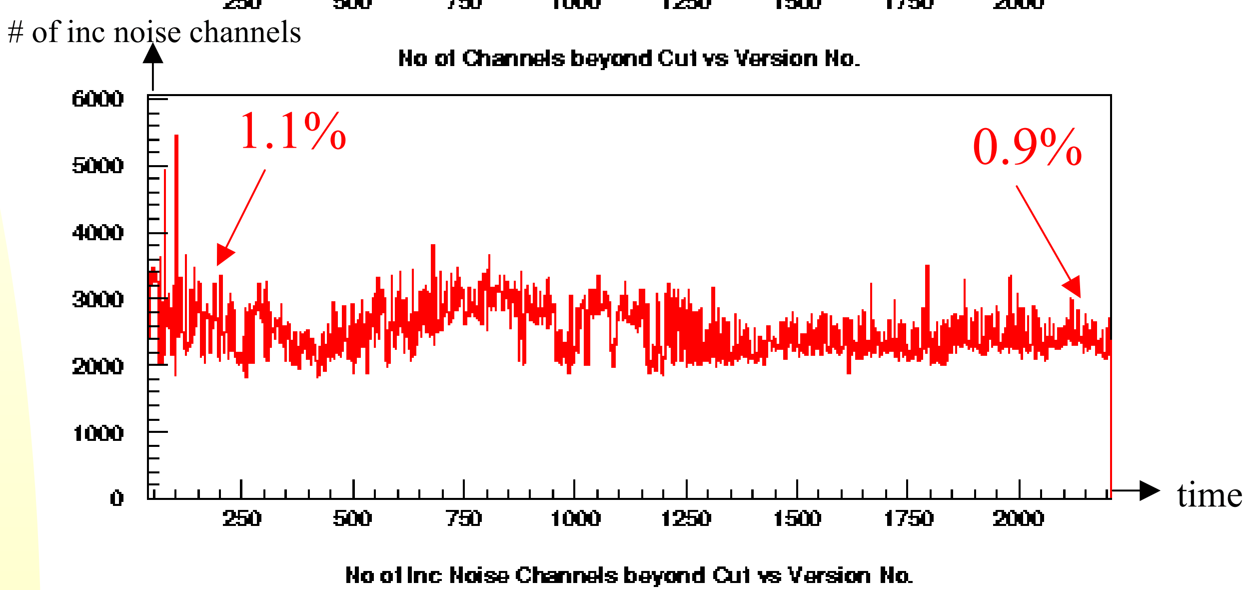
- Is the problem of flatness getting worse?
- Are there more noisy channels now than there were when the detector was first installed?
- Is there a correlation between higher noise levels and an increase in flat chips in the detector?

SOME TERMS:
-Total Noise
-Incoherent Noise

No. of Noisy Channels Over the Last ~ 3 Years

Starting Version number corresponds to June 2000, ending Version number corresponds to the period between May 27 2003 and today.





How Do We Define "Noisy"?

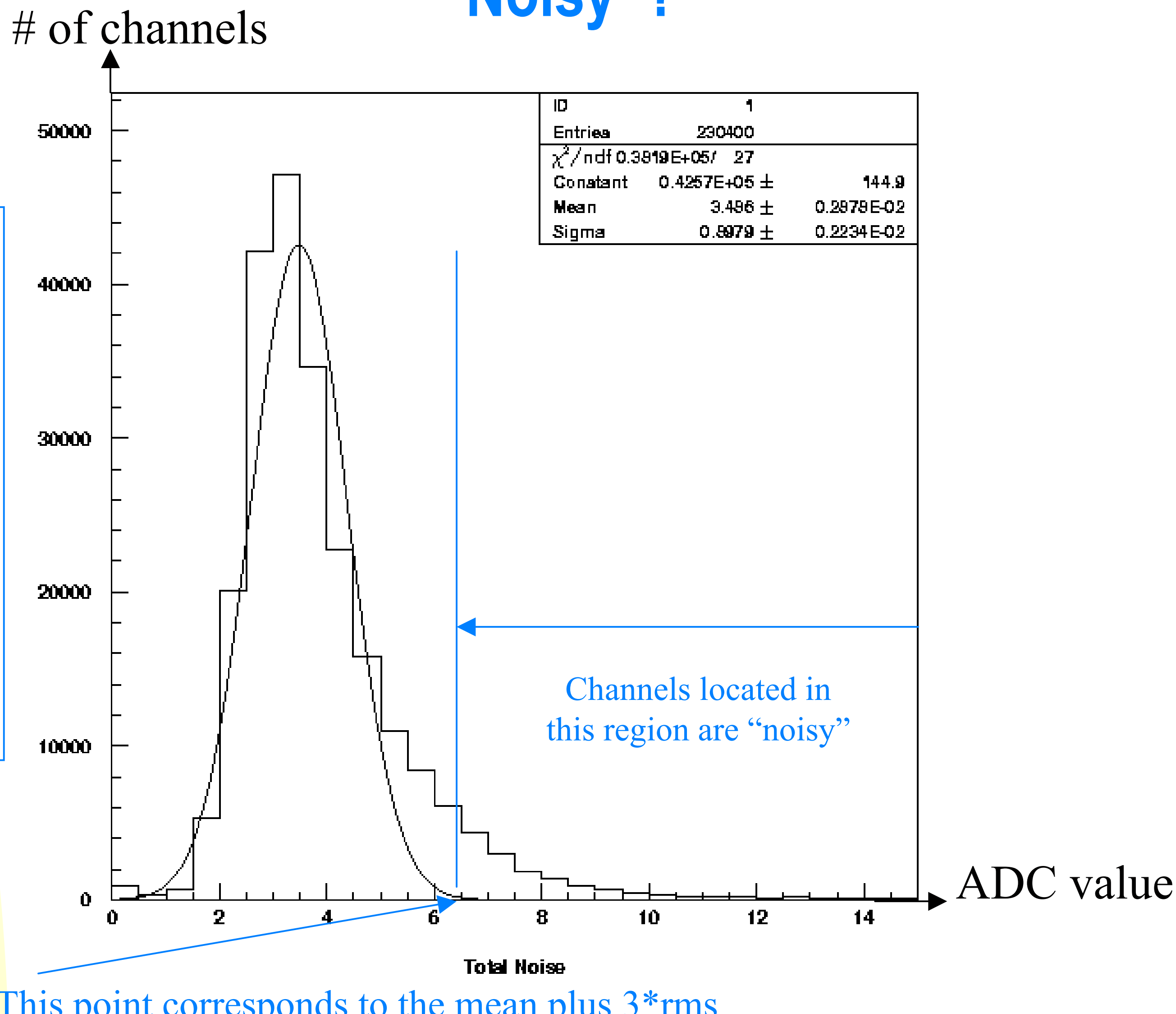
$$rms = \sqrt{<x^2> - <x>^2}$$

where

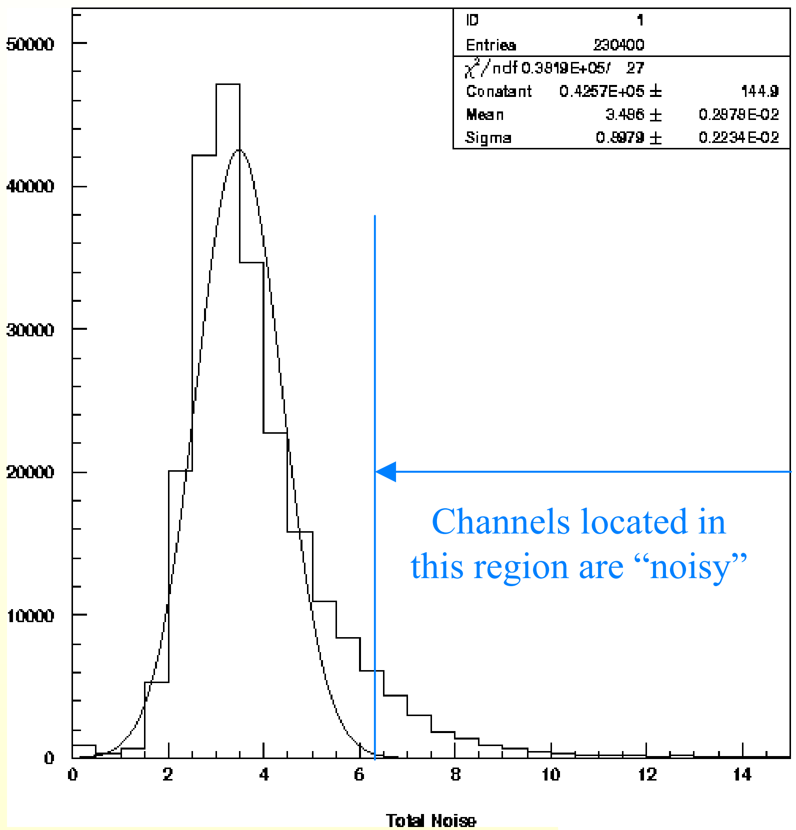
$$<x> = (\sum_{k=1}^{N} x_k)/N$$

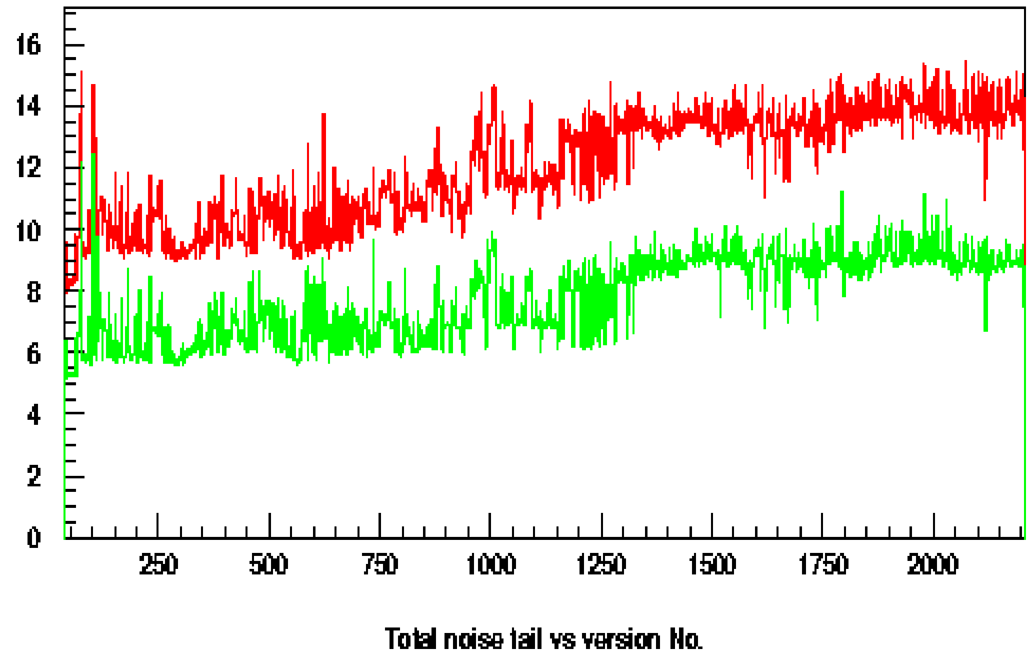
and

$$<x^2> = (\sum_{k=1}^{N} x_k^2)/N$$



How Is The “Tail” Varying With Time?





Total Noise Tail Vs.Time (Version No.)

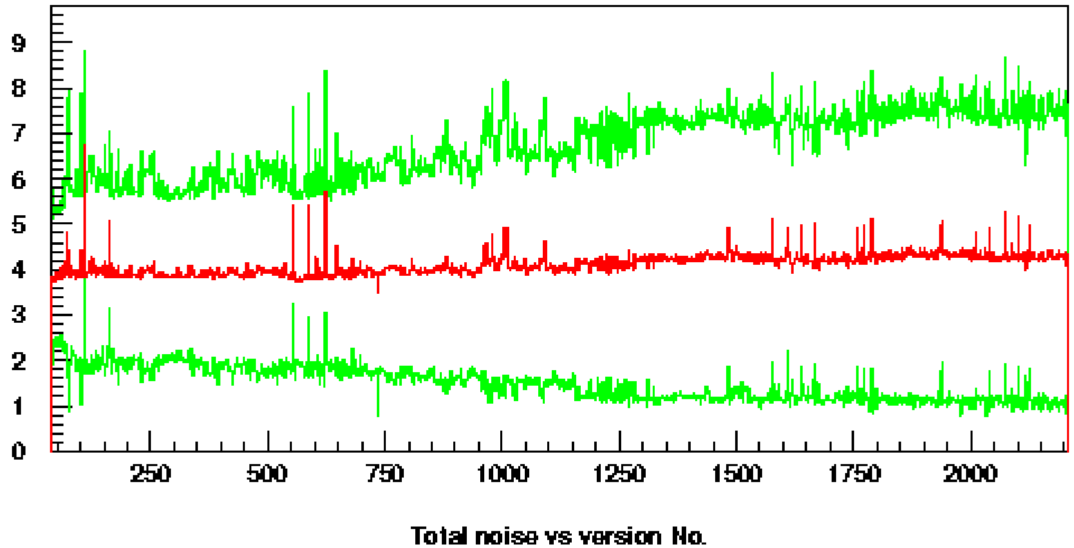
Incoherent Noise Tail Vs.Time (Version No.)

Noise Vs. Time (Version No.)

Total Noise Plus rms

Total Noise

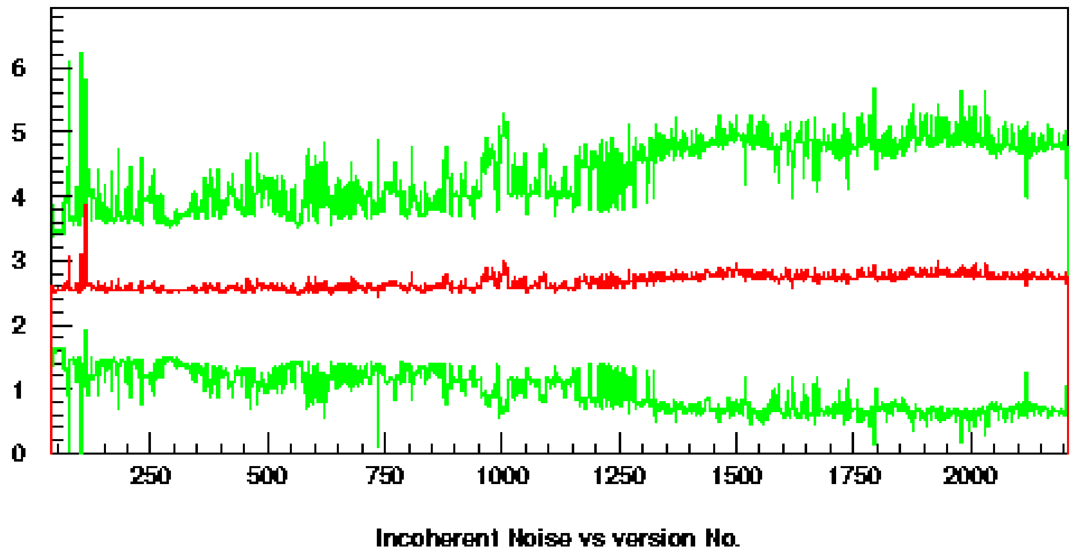
Total Noise Minus rms



Incoherent Noise Plus rms

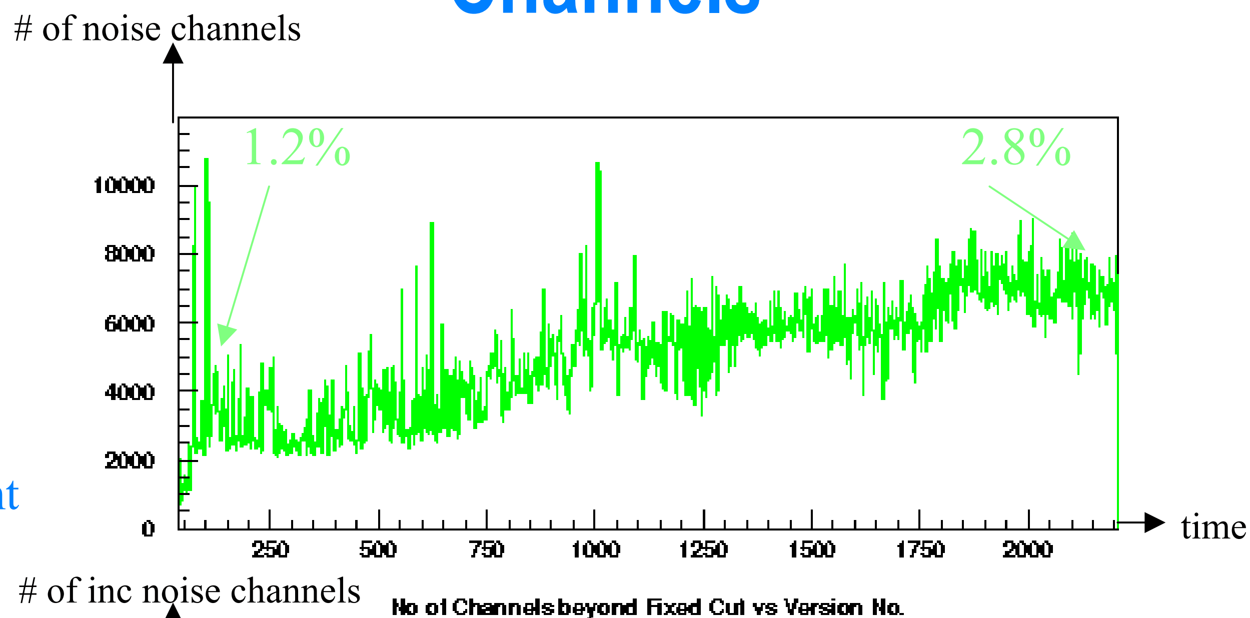
Incoherent Noise

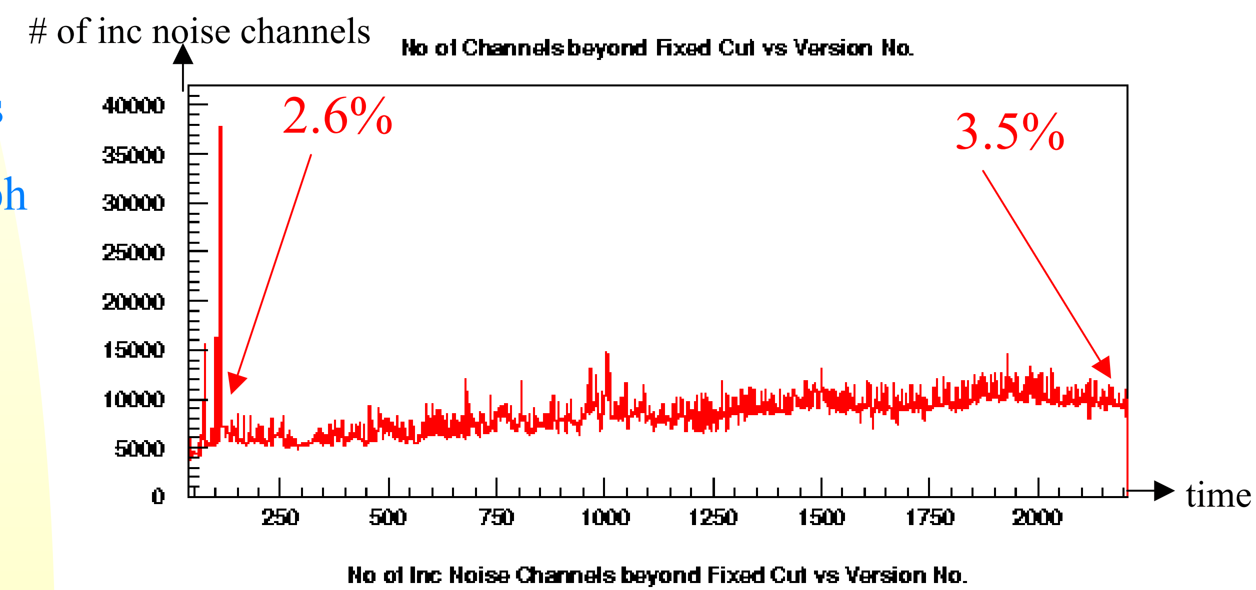
Incoherent Noise Minus rms



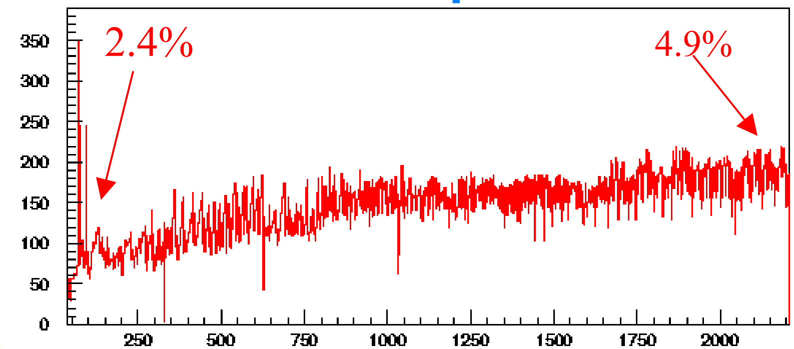
Another Way To Define "Noisy" Channels

Here we fixed a value for both the total noise tail and the incoherent noise tail. The number of channels depicted on this graph is based on this fixed cut.



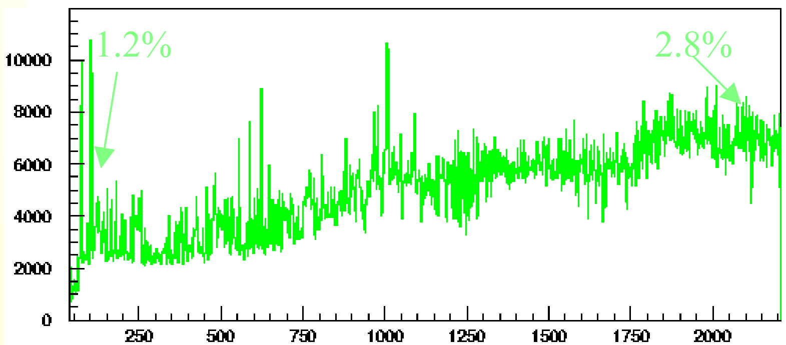


Is The Increase in the Number of Noisy Channels Related to an Increase in the Number of Flat Chips?



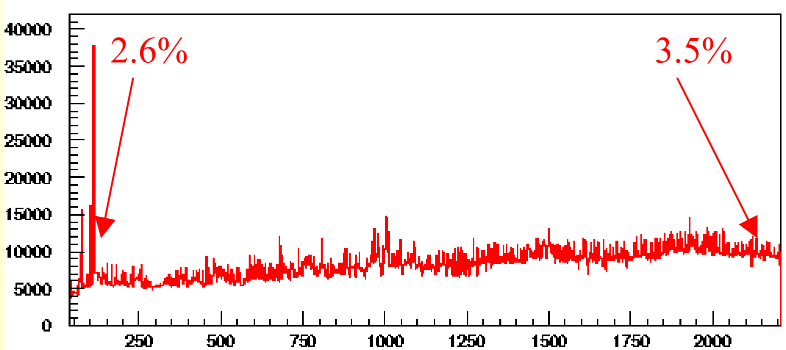
No of Flat Chips vs Version No.

No. of Flat Chips Vs. Time (Version No.)



No of Channels beyond Fixed Cut vs Version No.

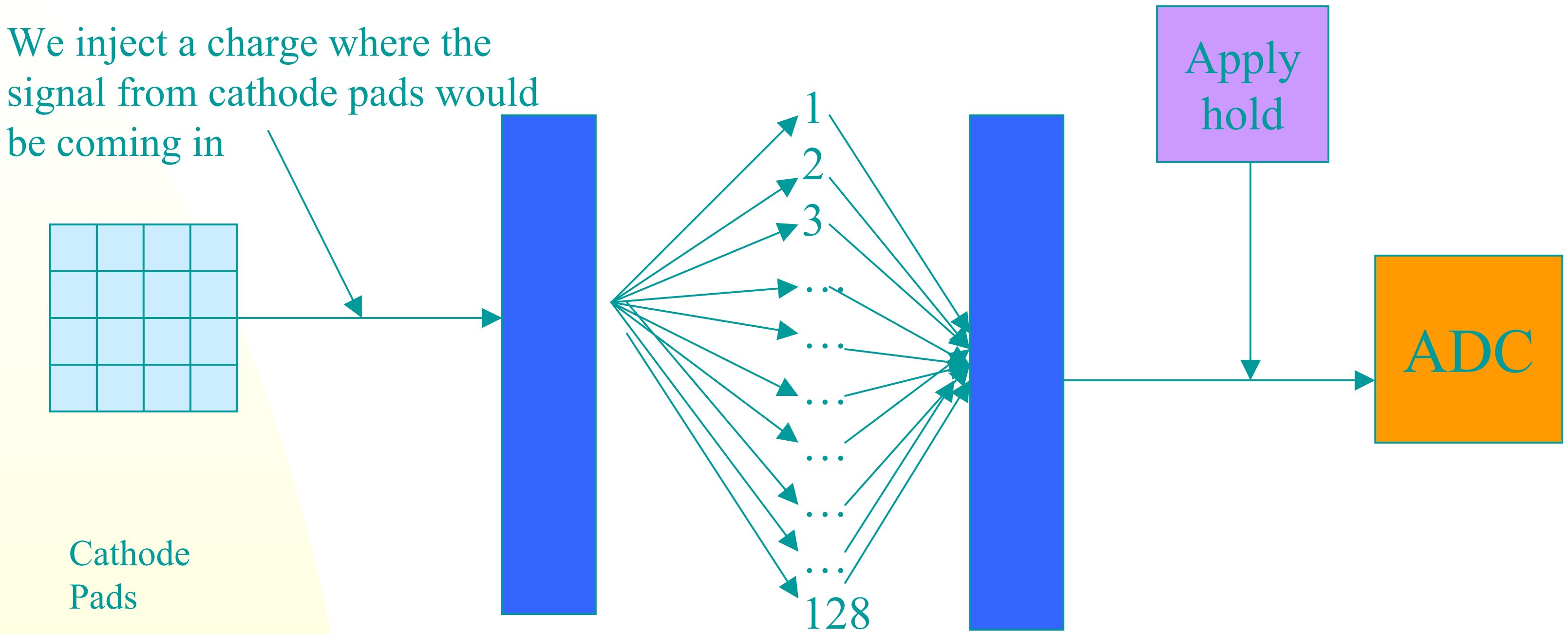
No. of Tot Noise Channels Beyond Fixed Cut Vs. Time (Version No.)



No of Inc Noise Channels beyond Fixed Cut vs Version No.

No. of Inc Noise Channels Beyond Fixed Cut Vs. Time (Version No.)

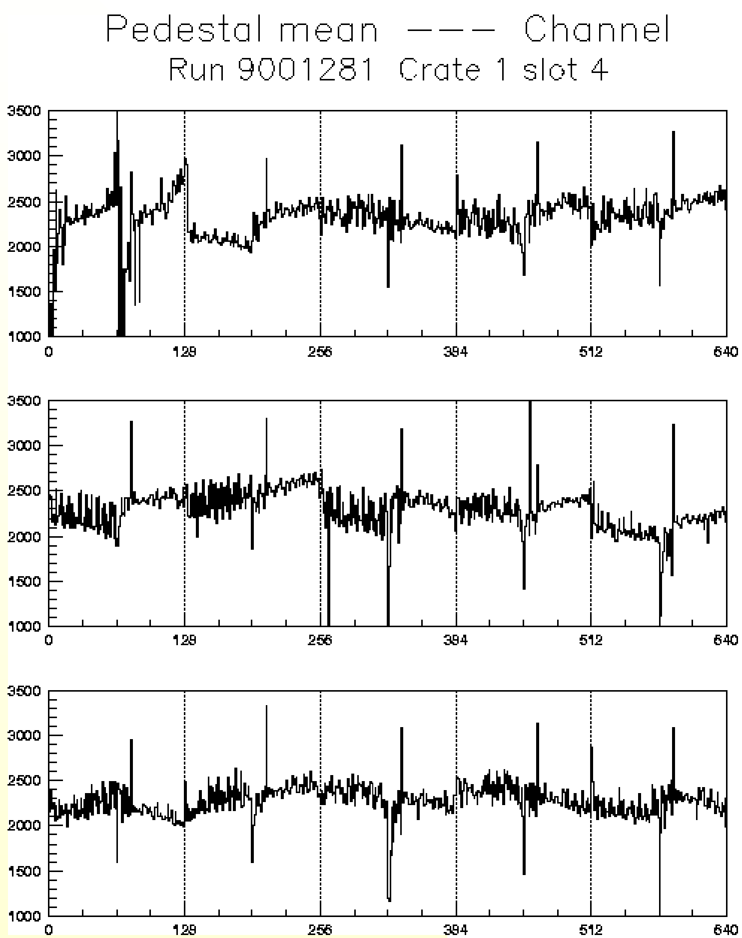
Single Channel Calibration

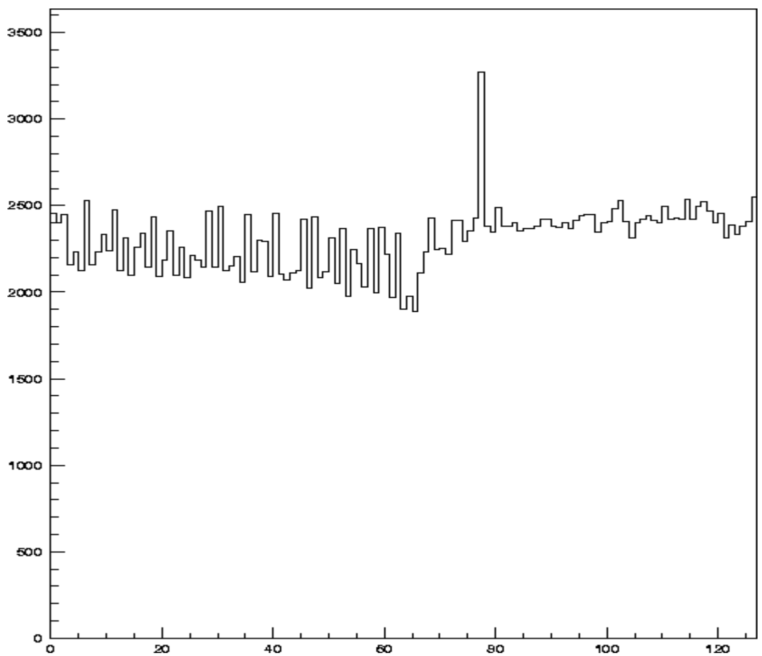


But in a Single Channel Cal run we send the signal to just one channel..

- Allows us to study electronic gain of a single channel
- Since we know:
  - Value of pulse injected
  - ADC readout value

Single Channel Calibration was Successful on the Teststand





close up view of the first chip carrier of the second chain

"Big Calibration" Mode –Single Channel Calibration for every channel in the detector

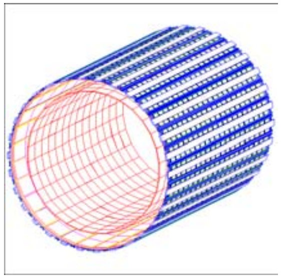
- First on the teststand:

- We pulsed nine different signals into each channel
- This worked!

- Then on the Main System:

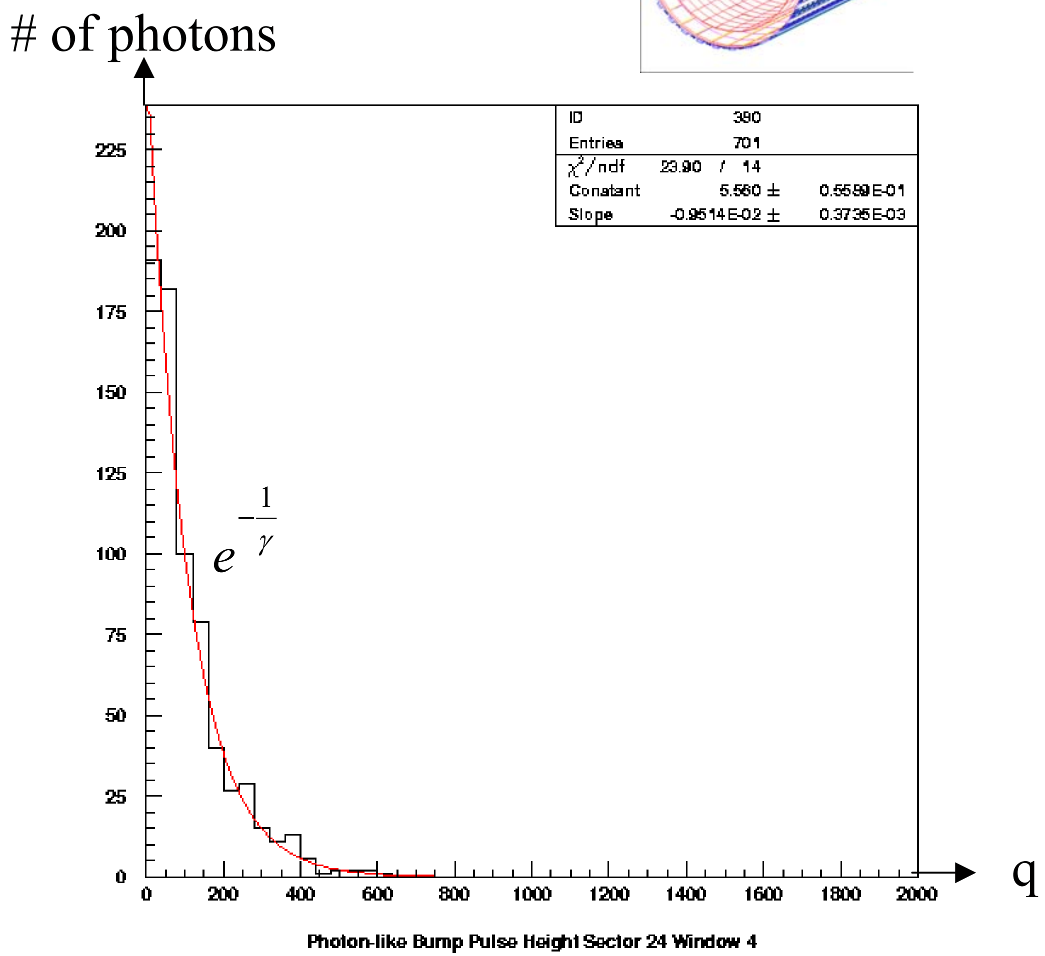
- After about 50 events the Data Acquisition System crashed
- Prepared code that would analyze the data from Big Cal

Studying The Pulse Height Distribution of Photons in Each Window

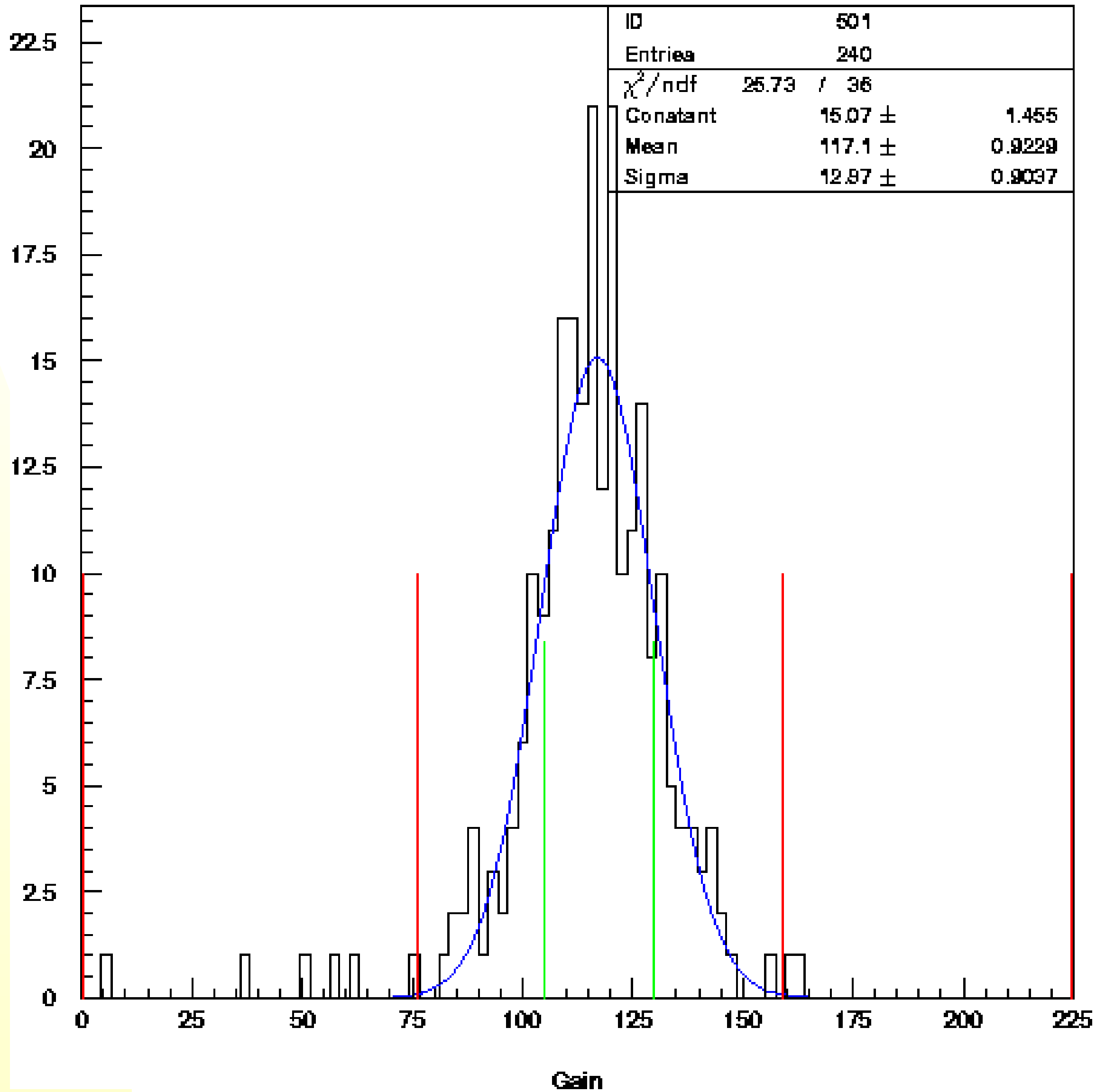


$$e^{-\frac{1}{\gamma}}$$

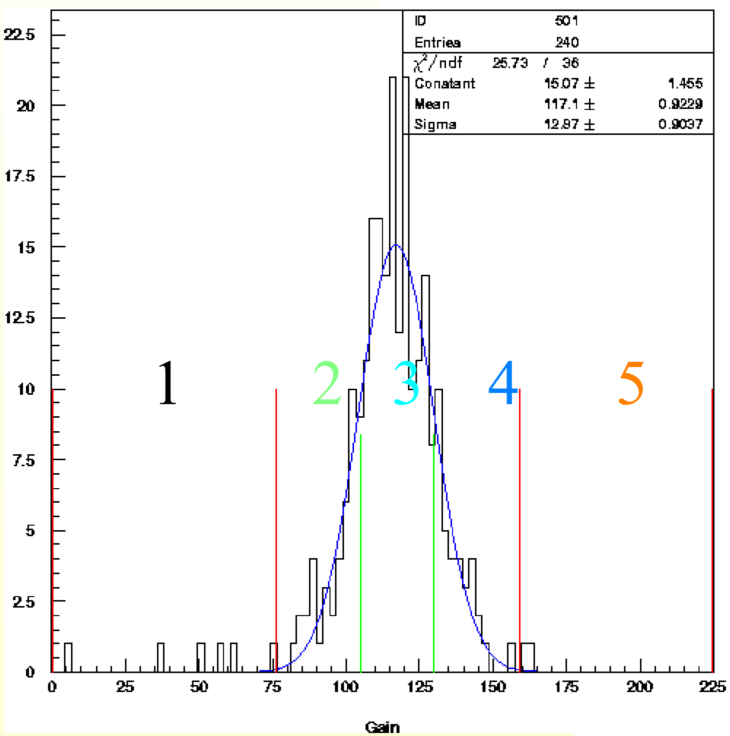
This factor is the "gain" of the function

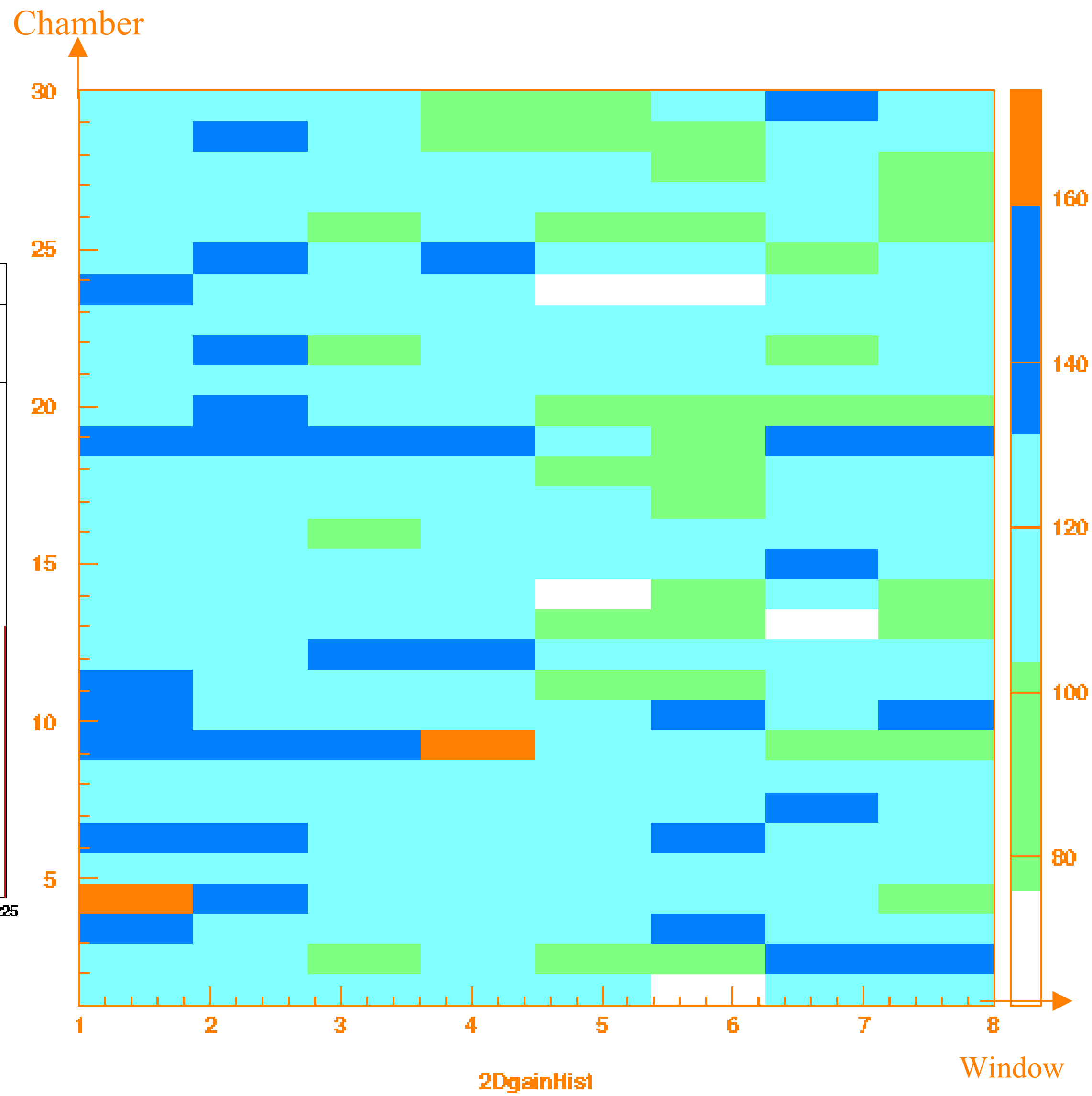


Distribution of gain per RICH Window



2-Dim Geometrical Distribution of Gain





Final Results of REU Project and Future Plans

- Performed Statistical Analysis of Noise and Flatness in the RICH – results are encouraging.
  - Number of Noisy Channels in the detector rose from approx. 1.2% to 2.8% in the last three years
  - Number of “flat” chips in the detector rose from approx. 2.4% to 4.9% in the last three years
  - We have new clues about the causes of dying channels/chips
- Big Cal – *Almost* succeeded, but it’s ready to go! Analysis code is prepared
- Studied the gain of the distributions of photons in each window of the detector – most of the windows have values of gain right where we want them to be
- Learned a lot!! Including: several programming languages, plotting software, the Session Manager, etc…

Acknowledgements

I would like to thank Marina Artuso, Bayar Dambasuren and the entire Syracuse University particle physics group for proposing this REU project for me this summer.

I am especially grateful to Bayar for his patience and his clear, instructive guidance throughout this experience.

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