Cosmic Ray telescope (1st floor setup at D0)

- Tasks & detailed instructions

The tasks – overview

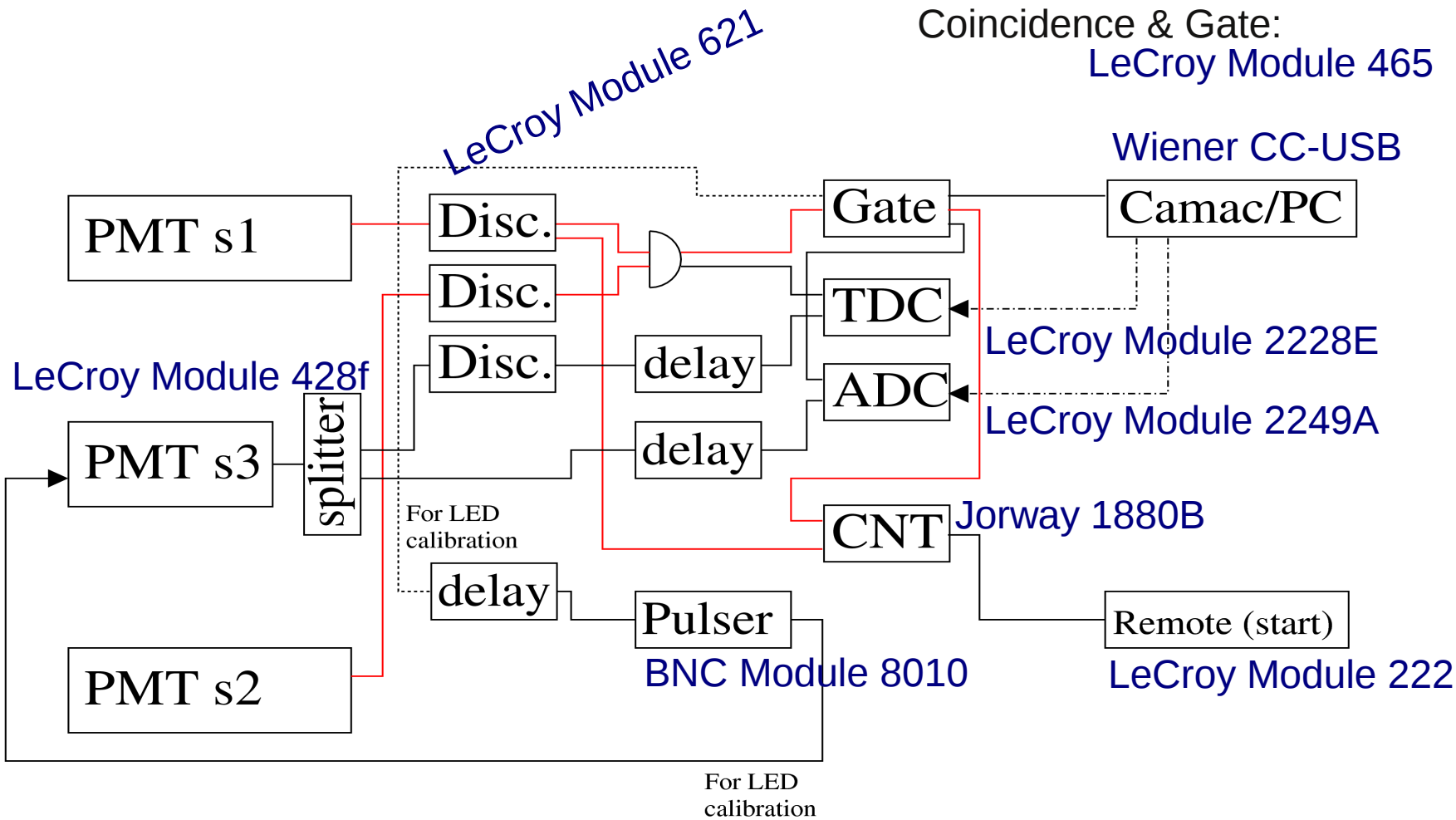
- Optimize HV: Assemble cosmic ray telescope based on 3 counters, select HVs (counting rate curve for changing HV on one of the counters).
- Measure cosmics: Measure cosmic amplitude vs. HV using CAMAC/PC, determine gain vs. HV and signal in ADC channels at specific HV for counter s3.
- Time resolution: Measure time resolution as Δt between two counters (s2 and s3): calibration of TDC; dependence of resolution vs. HV.
- Calibration: Measure number of photoelectrons corresponding to a typical cosmic muon: a) calibrate ADC using LED signal in "photoelectron/ADC channel"; estimate number of photoelectron for cosmic muon.
- Extra: Analyze amplitude spectrum of cosmic muons: Landau+ Gauss. Determine "energy resolution" of the counter. ("homework")

→ These are a lot of tasks, but its not required to do all of them – more important is to understand things!

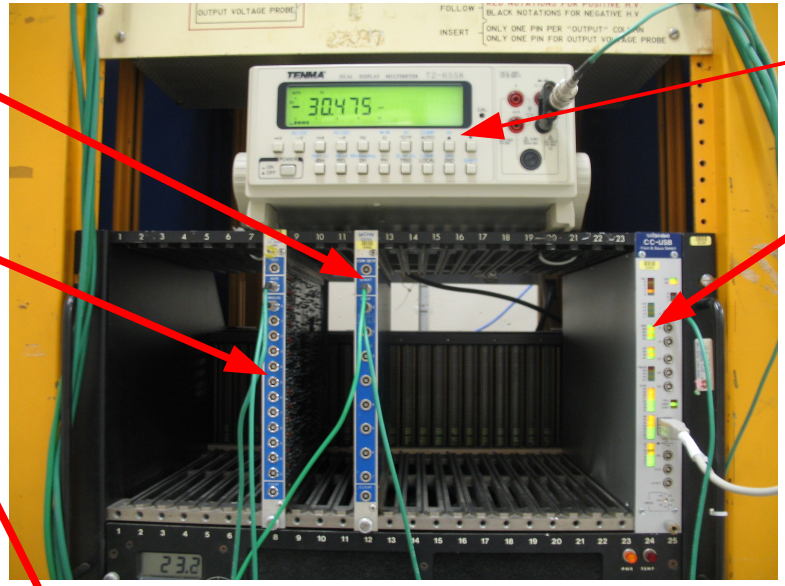
Don't Panic!

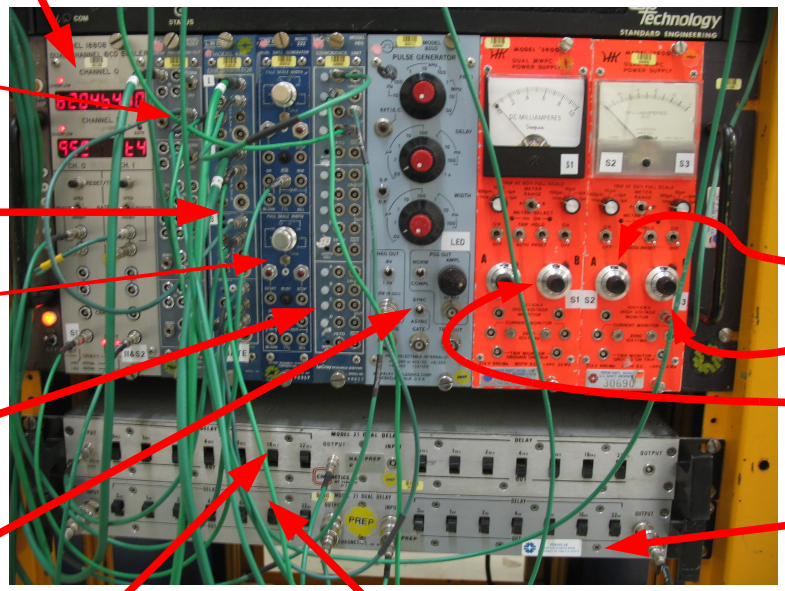
The setup

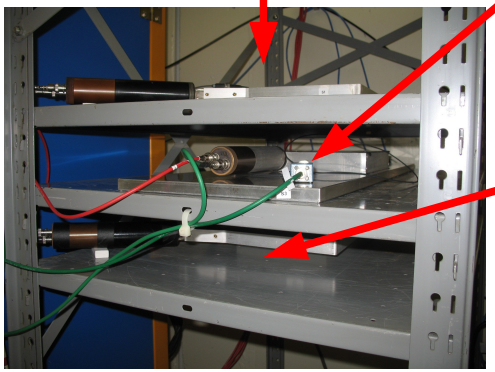
- Schematic drawing of the setup (modules are linked to specifications on the web)



The setup in reality







TDC

ADC

Counter (CNT)

Voltmeter

PC/CAMAC

PMT s1

PMT s3

PMT s2

Fan in/out

Discriminator (Disc.)

Remote (start/stop)

Coincidence

Pulser

Delay

Delay

HV supply s2

HV supply s3

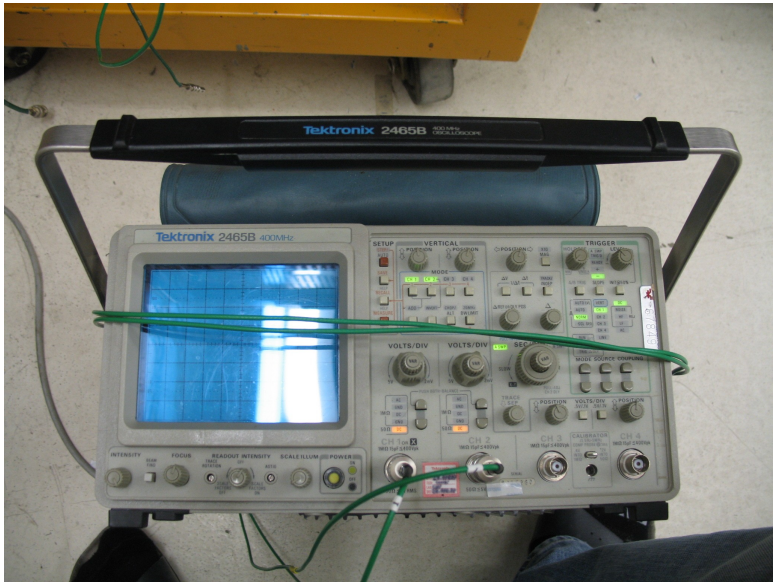
HV supply s1

Delay

The basics...

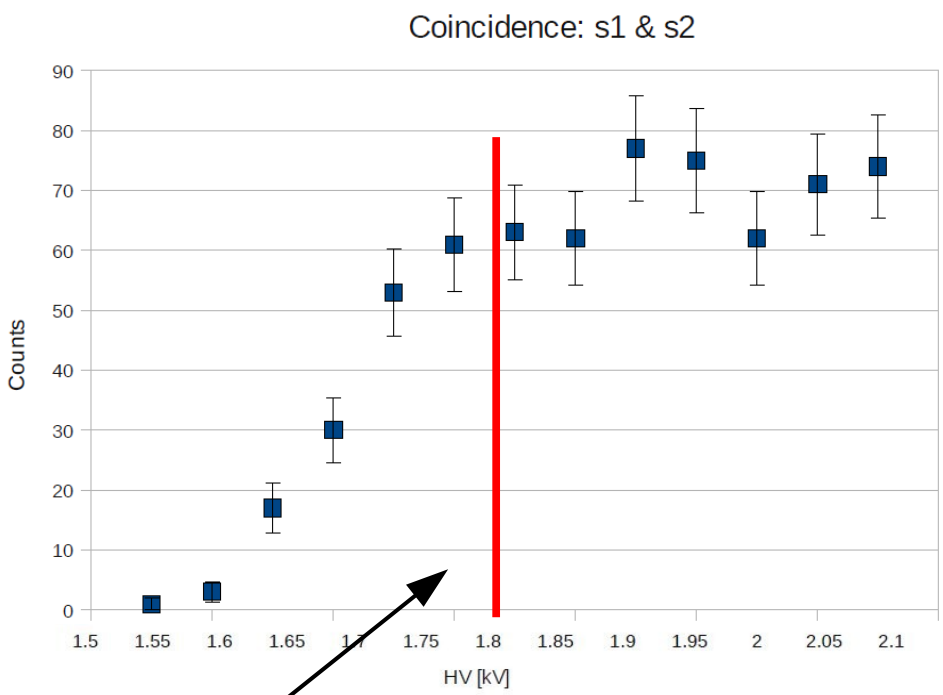
- Assemble cosmic ray telescope based on 3 counters
- Turn on HV for channel s1 and s2 – use Voltmeter and keep in mind:
  Don't apply more than 2.1kV ! Different detectors have different HV limits – you might break detectors by applying to high HV !

- Find and look at signal on scope, instructor will show you how...

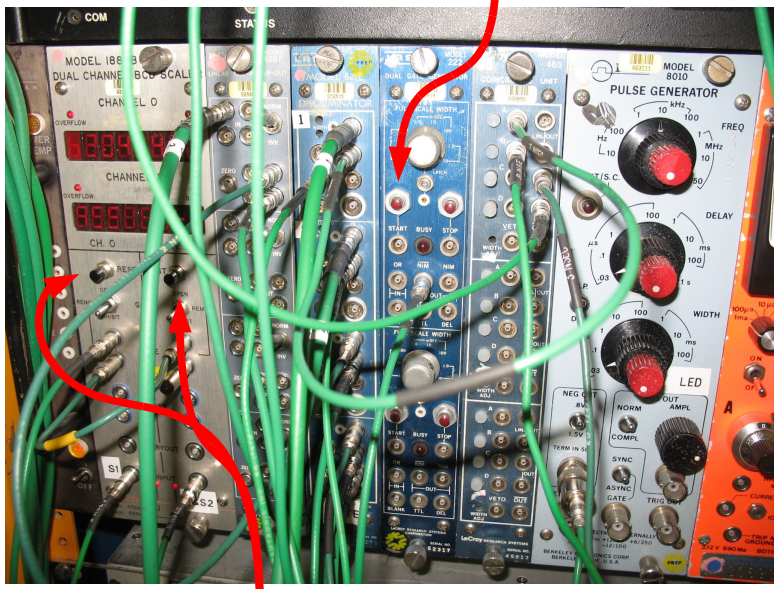


Optimize HV

- Optimize HV on counter s1, take data at different values of HV
- Your result will look like this:



Start of Measurement (20s)

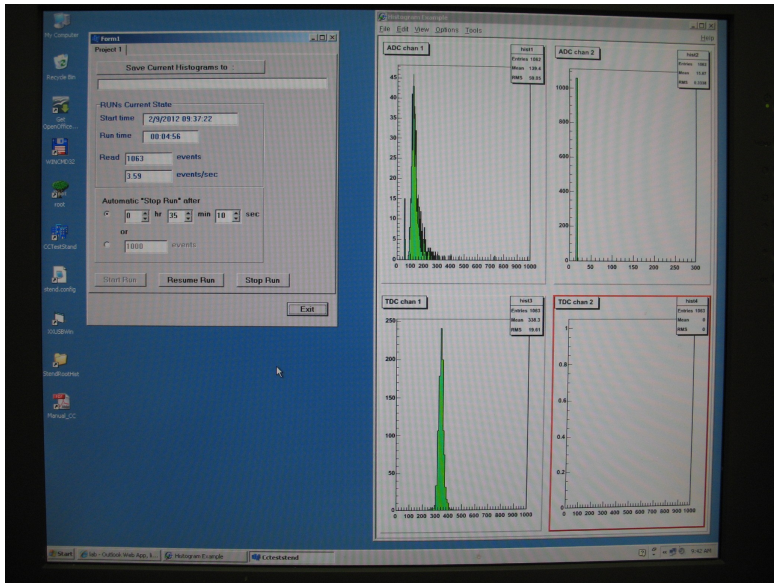


Reset of counters

- Beginning of the plateau
- Side remark: Should not go a lot higher as noise keeps increasing but signal plateaus...

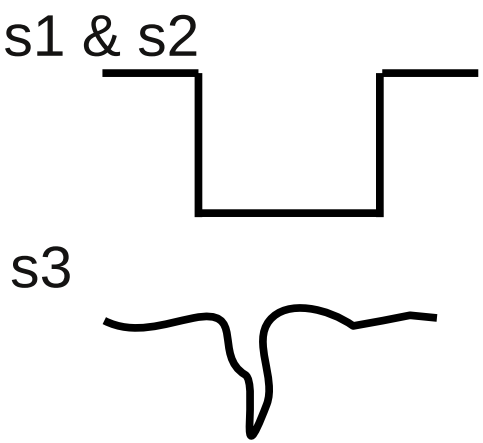
Data taking...

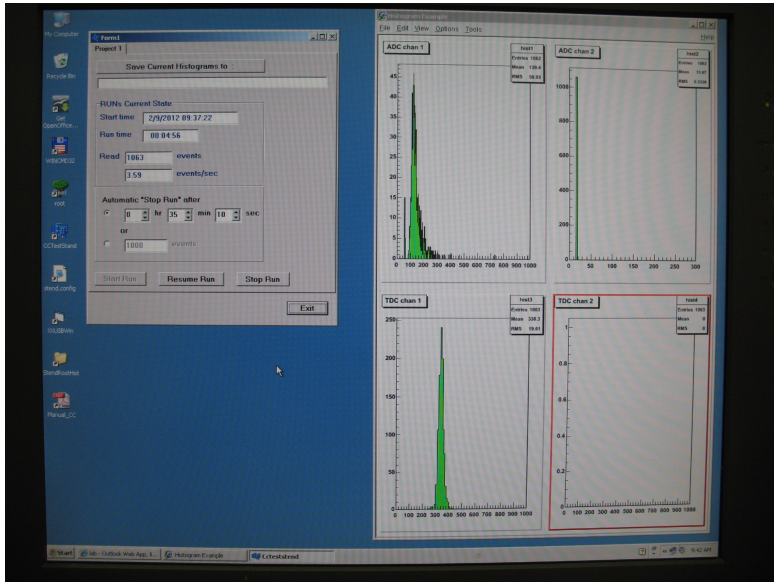
- Measure cosmic amplitude vs HV using CAMAC, determine gain vs HV as well as signal in ADC channels at specific HV for counter s3.
- What one needs for data acquisition:
  - Synchronization (trigger signal): s1 & s2
  - Signal to tell ADC/TDC is ready (usually 'interrupt' signal to crate controller)
  - Data is stored/transferred to PC and can be analyzed, with e.g. ROOT



Measure cosmics

- Measure cosmic amplitude vs HV using CAMAC, determine gain vs HV as well as signal in ADC channels at specific HV for counter s3.
- Check signals on scope, they will look like this:

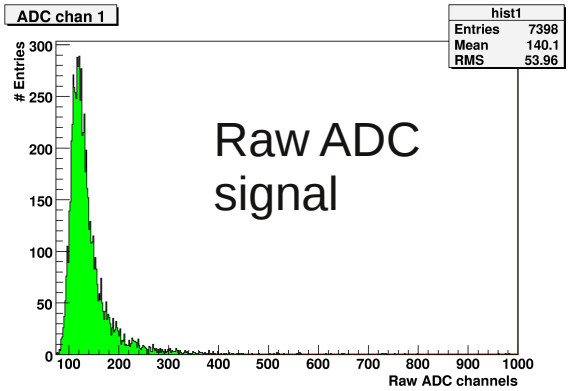


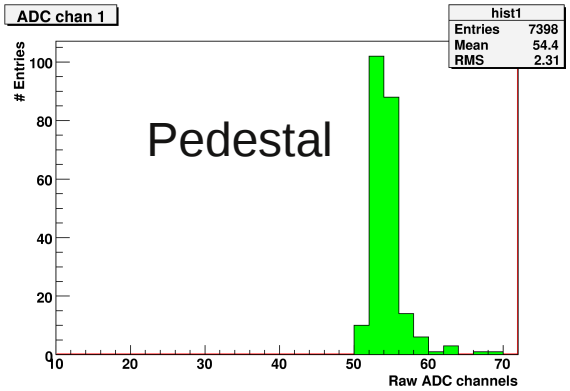


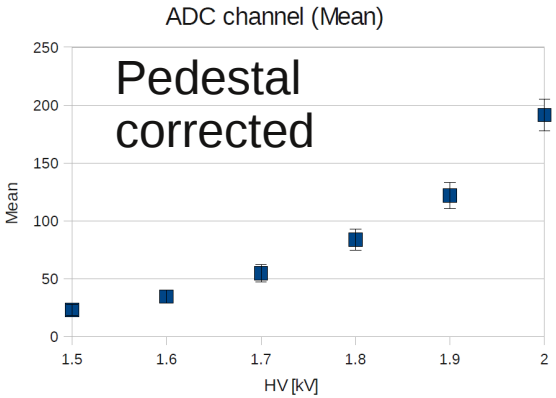
- What you see in histograms, is the charge within Δt of gate (~100ns)
- Measure charge with no input signal – called "Pedestal", it has to be subtracted from all measurements

Measure cosmics

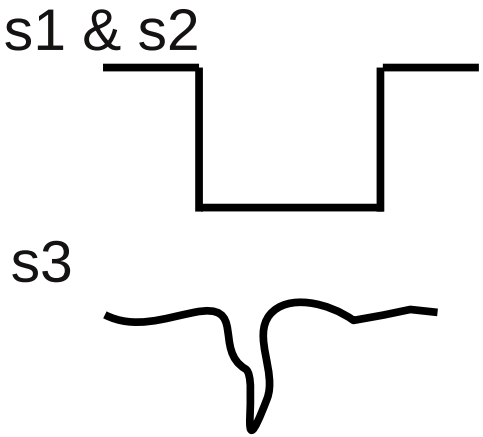
- Measure cosmic amplitude vs. HV using CAMAC/PC, determine gain vs. HV: Take data for ~30 sec



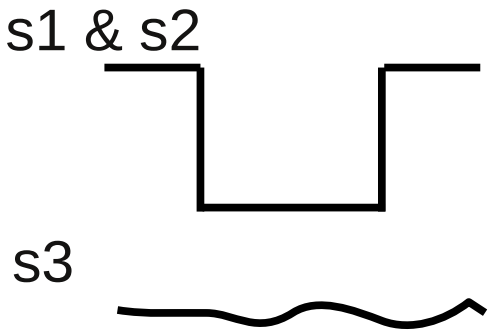




- Determine the signal in ADC channels at specific HV for counter s3: Remember there is a gate and there might not always be a muon...



but also:



Time resolution

- Measure time resolution as Δt between two counters (s2 and s3): calibration of TDC:
  - Take TDC data at different delays, e.g.

Delay [ns]	8	16	32	32+16	32+16+8
Mean (TDC)	7.2	55.0	201.6	338.1	413.7
RMS (TDC)	7.4	18.1	23.8	21.3	22

- Calculate Δt, e.g. Mean("16") - Mean("32") → 16ns = 146.6channels
- Should get similar values from all the Δt(TDC channels), like:
  - 1ns("8ns delay") = 9.45, 1ns("16ns delay") = 9.16
  - 1ns("32ns delay") = 8.84, 1ns("40ns delay") = 8.96

Time resolution

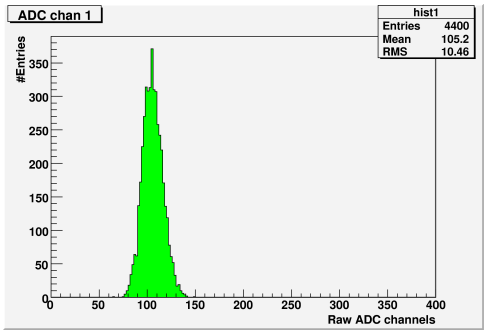
- Measure time resolution as Δt between two counters (s2 and s3): calibration of TDC; dependence of resolution vs HV:
  - Take TDC data at different HVs, e.g.

HV	1.6	1.7	1.8	1.9	2.0
RMS (TDC)	24.1	22.9	20.8	17.8	15.7
Mean (ADC) [pedestal subtr.]	26.3	47.9	76.0	120.7	175.8
RMS (ADC)	18.2	26.5	33.9	52.0	63.3

- TDC time resolution is improving with increase in HV
- ADC pulses get larger as well, but noise increases as well
  → trade-off between signal size and noise contribution

Calibration

- Measure number of photoelectrons corresponding to a typical cosmic muon: a) calibrate ADC using LED signal in "photoelectrons/ADC channel":
  - Connect LED pulser to Gate, before it was s1 & s2 coincidence now its the LED pulse, add 32ns delay
  - Change amplitude of LED pulser, check with scope...by e.g. a factor of 2

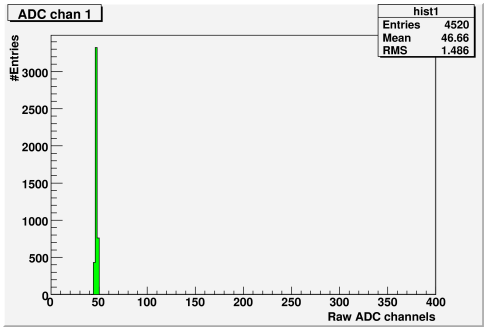


- Estimate number of photoelectrons for cosmic muon:

$$\frac{\sigma_A}{A} = \frac{1}{\sqrt{N_{p.e.}}}$$

$$N_{p.e.} \approx \left(\frac{\text{Mean}}{\text{RMS}}\right)^2$$

Mean = (Raw Mean) - (Pedestal)
= 105.2 - 46.6
RMS = 10.4



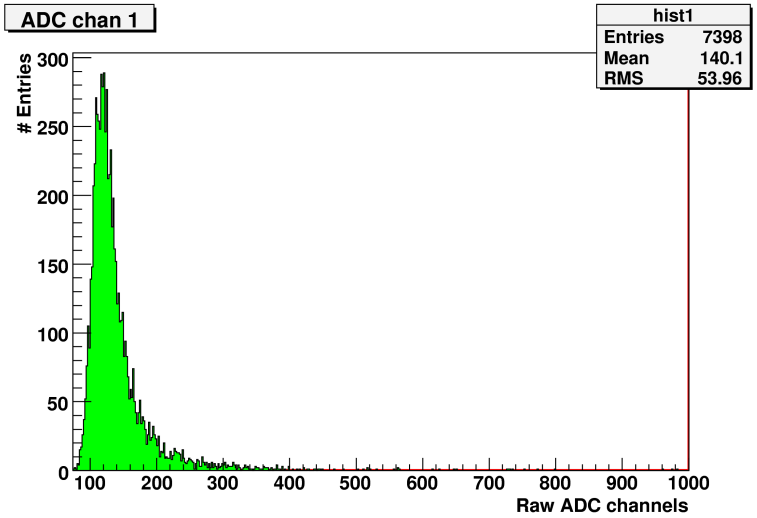
- Take pedestal into account: → ~ 31 p.e. or 1adc channel = 0.52 p.e.

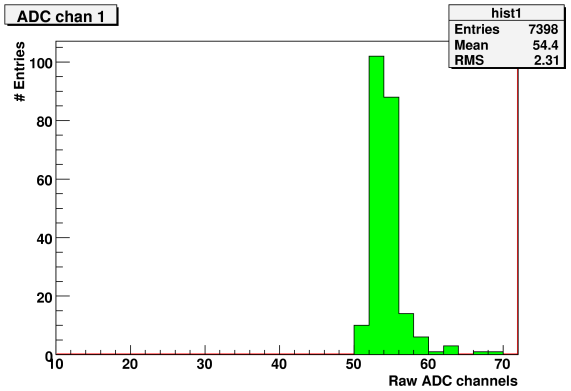
Calibration

- Use calibration to get number of p.e. for cosmic muon signal:
  - Amplitude is 140.1 – 54.4 = 85.7 adc channels
  - → ~44 p.e. per minimum ionizing particle (MIP)

Extra ("homework")

- Homework: Analyze amplitude spectrum of cosmic muons
- Can use ROOT to play with fits, like: Gauss, Landau, Landau+Gauss
- Determine "energy resolution" of the counter





- Can easily combine pre-defined functions in ROOT, like:

```
root [2] TF1 *test = new TF1("test", gaus+landau)
root [3] hist1->Fit("test")
```

- But out-of-the-box fit may fail...