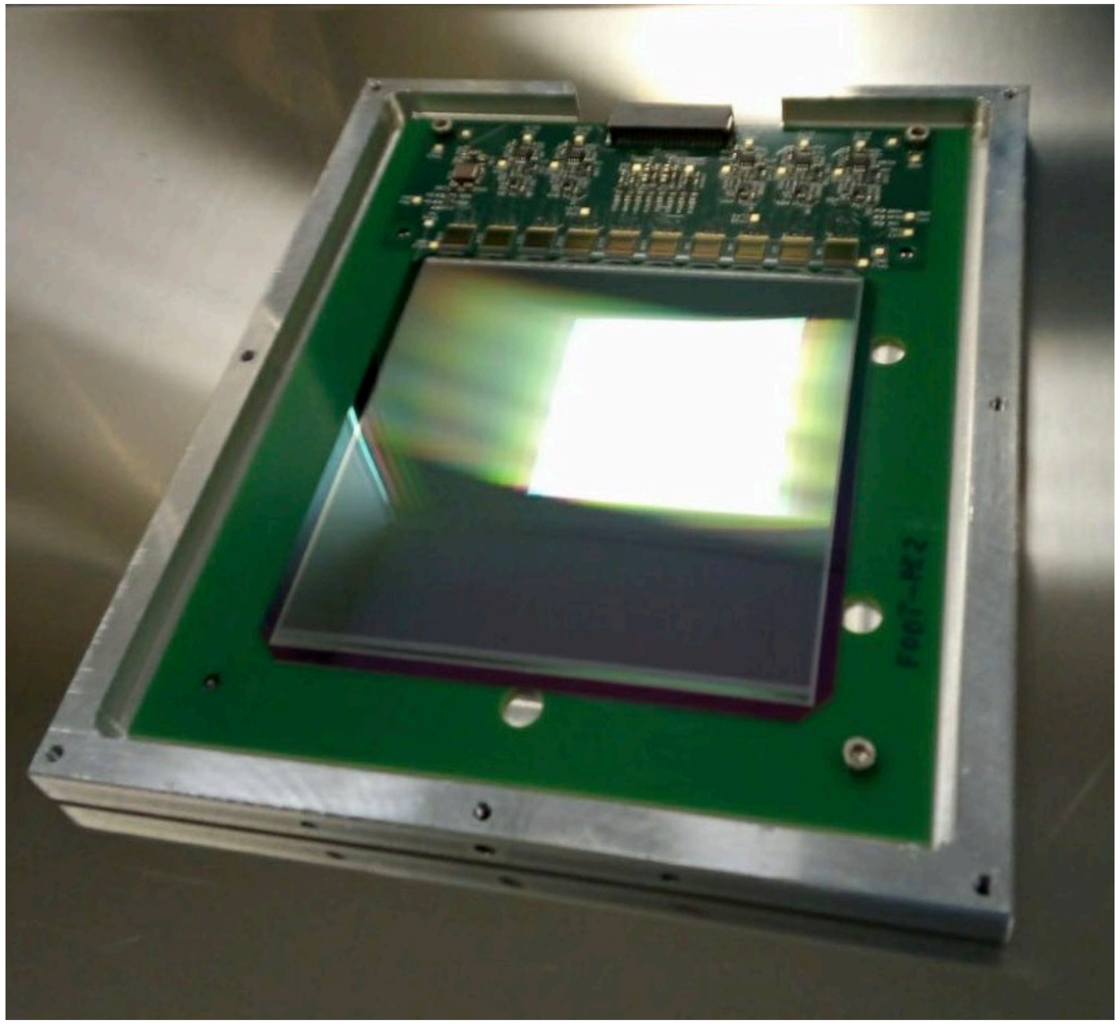


MSD FOOT COLLABORATION

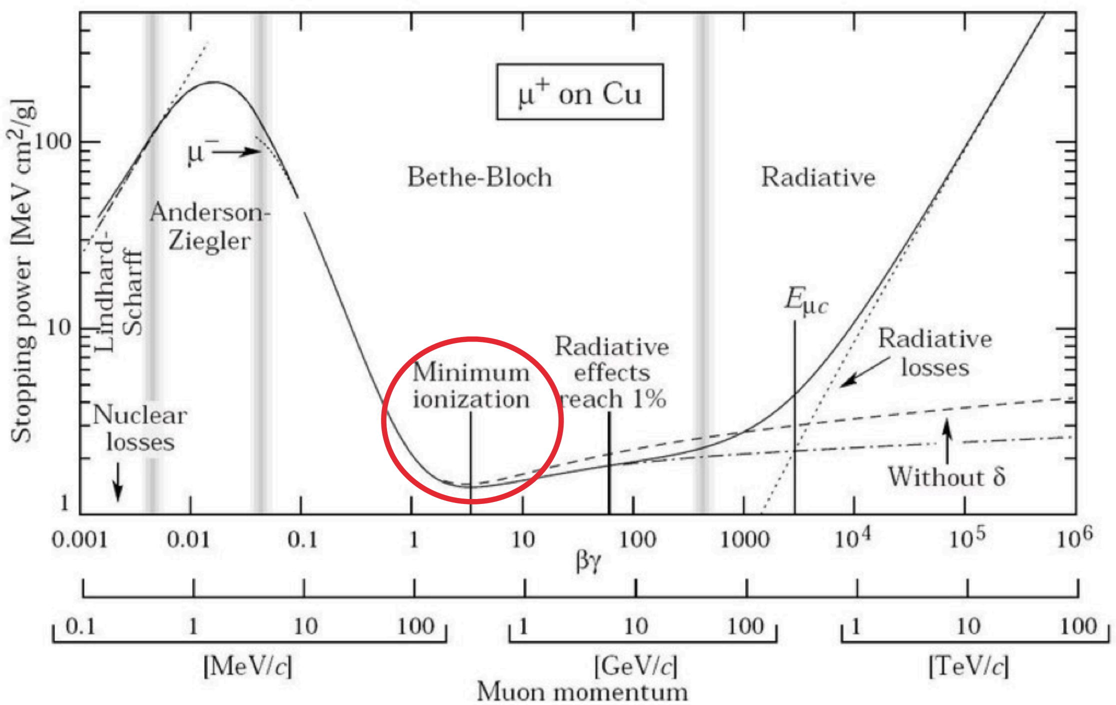
PHOTON CALIBRATION FOR SILICON MICRO STRIP DETECTOR

PEVERINI FRANCESCA

05/05/2021

Standard method for calibration

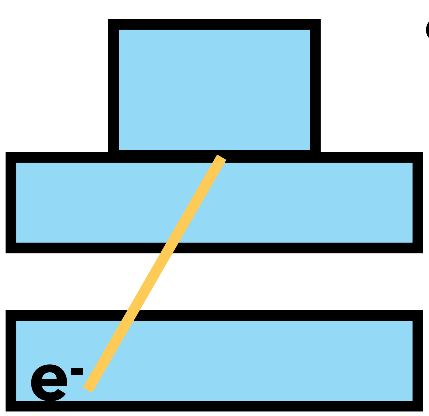
With the standard calibration method we can not collect all the signal release by the electrons.



We try to use electron with minimum ionization energy.

We measure the signal release by electrons inside the micro strip detector, then we can calculate the calibration factor.

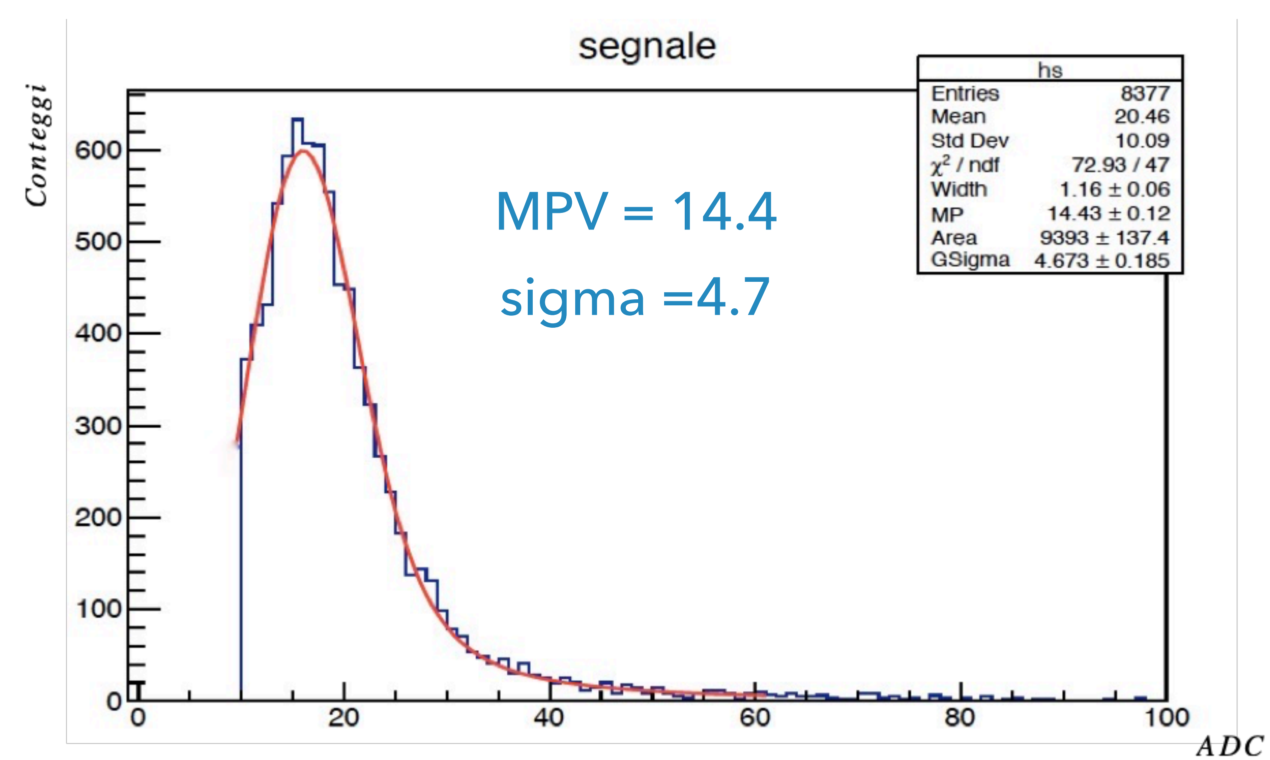
$$K = 2.9 \pm 1.0 \frac{keV}{ADC}$$



90Sr source

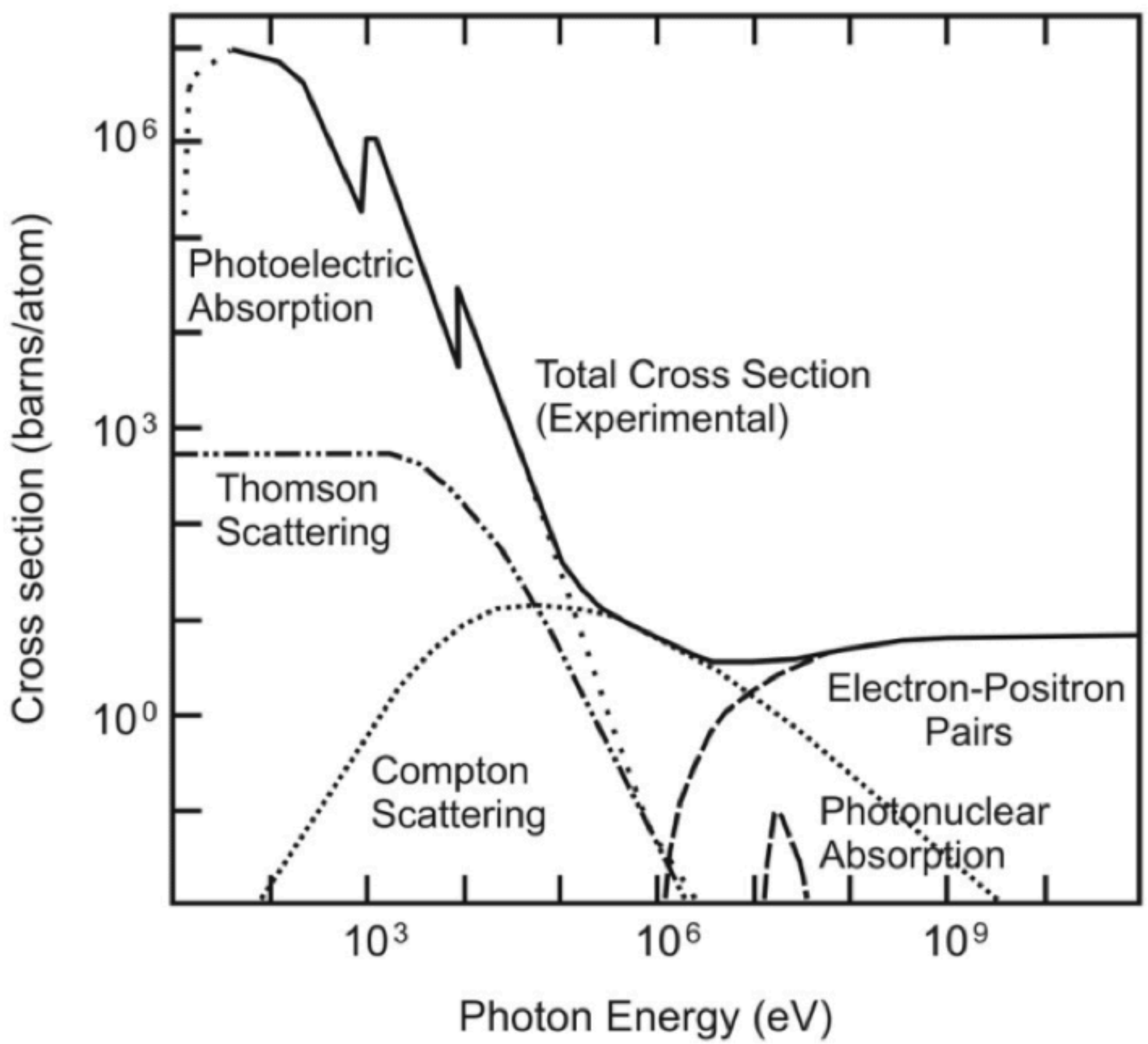
Silicon micro strip detector

Scintillator for the external trigger signal



Why photons?

We want the photons to have the right energy to interact via photoelectric effect.



For energy E<100 keV photons interact predominantly by photoelectric effect.

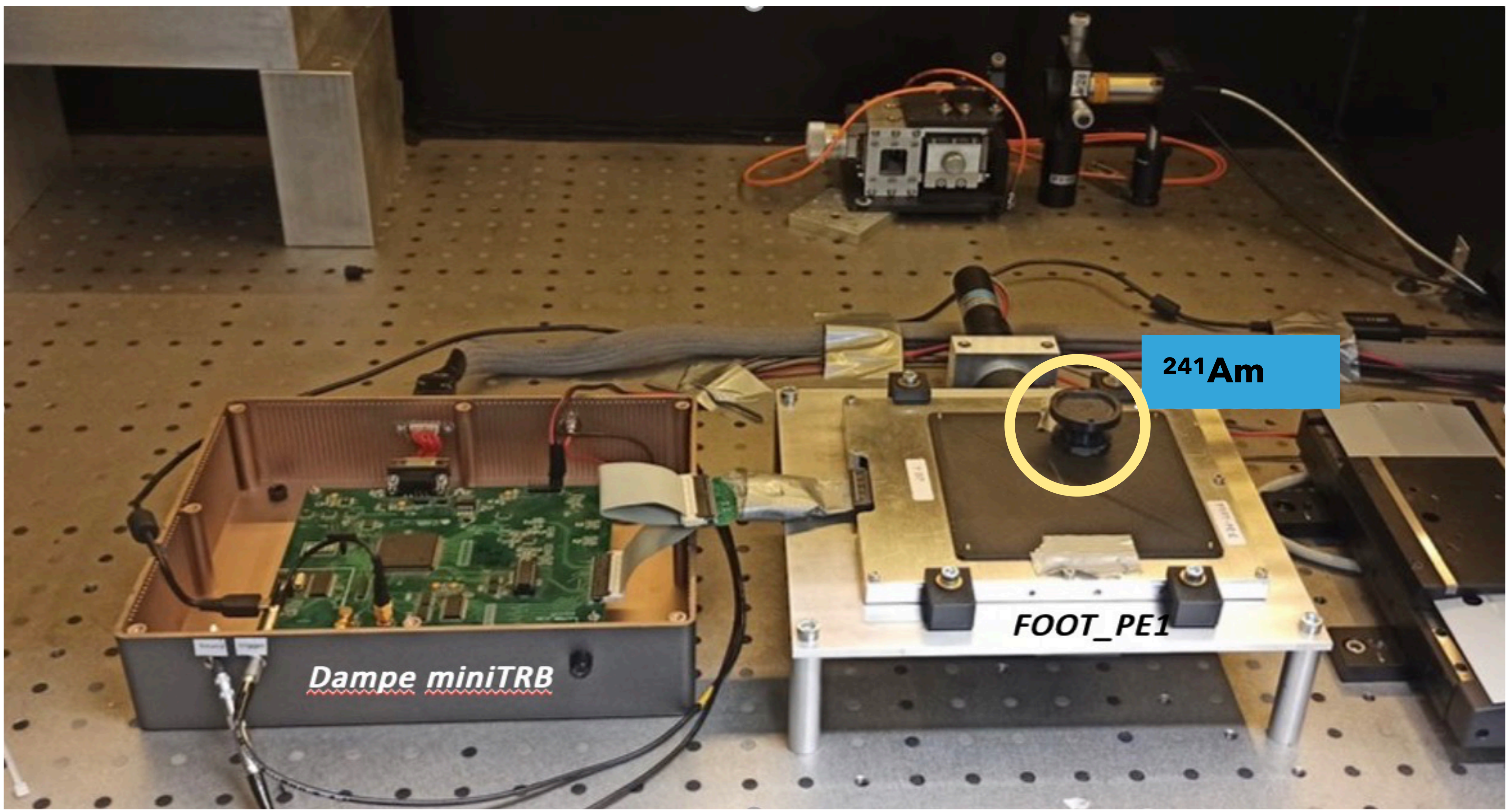
Given the low energy for the photoelectrons generated can all be contained inside the detector, which means we are able to reconstruct the original signal.

We are expecting gaussian distribution for signal

^{241}Am experimental set up

Monochromatic photon source, as an alternative to standard calibration with charged particles.

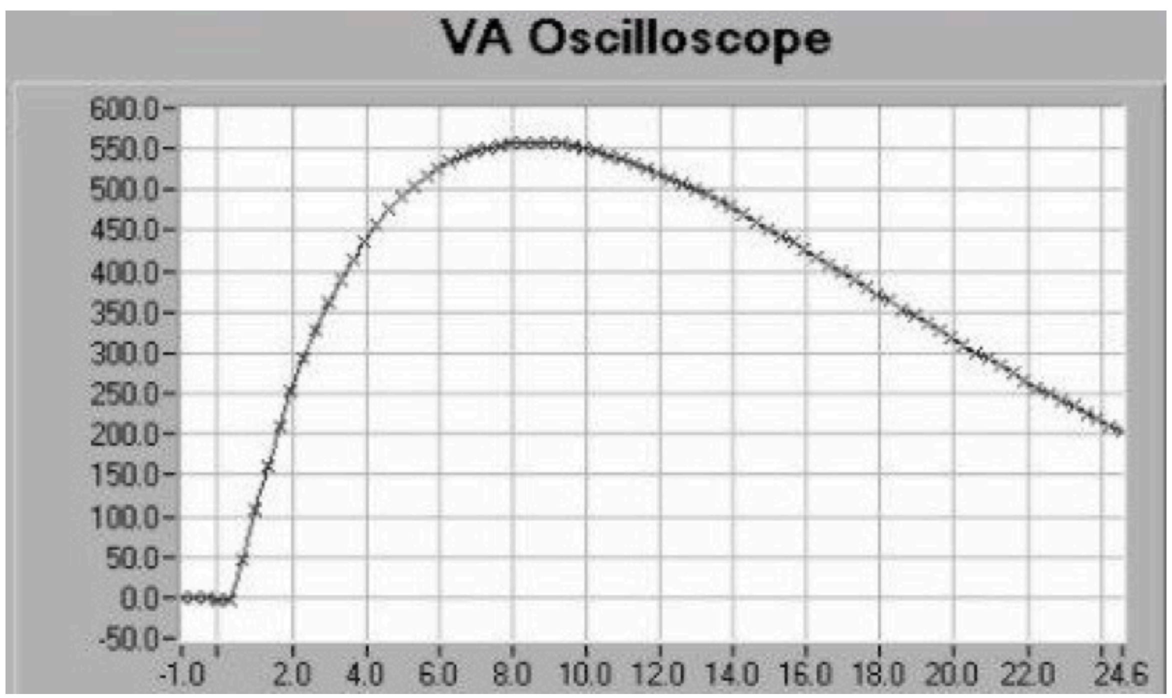
$$^{241}_{95}Am \rightarrow ^{237}_{93}Np + ^{4}_{2}He + \gamma$$ → 59.54 keV gamma ray emission



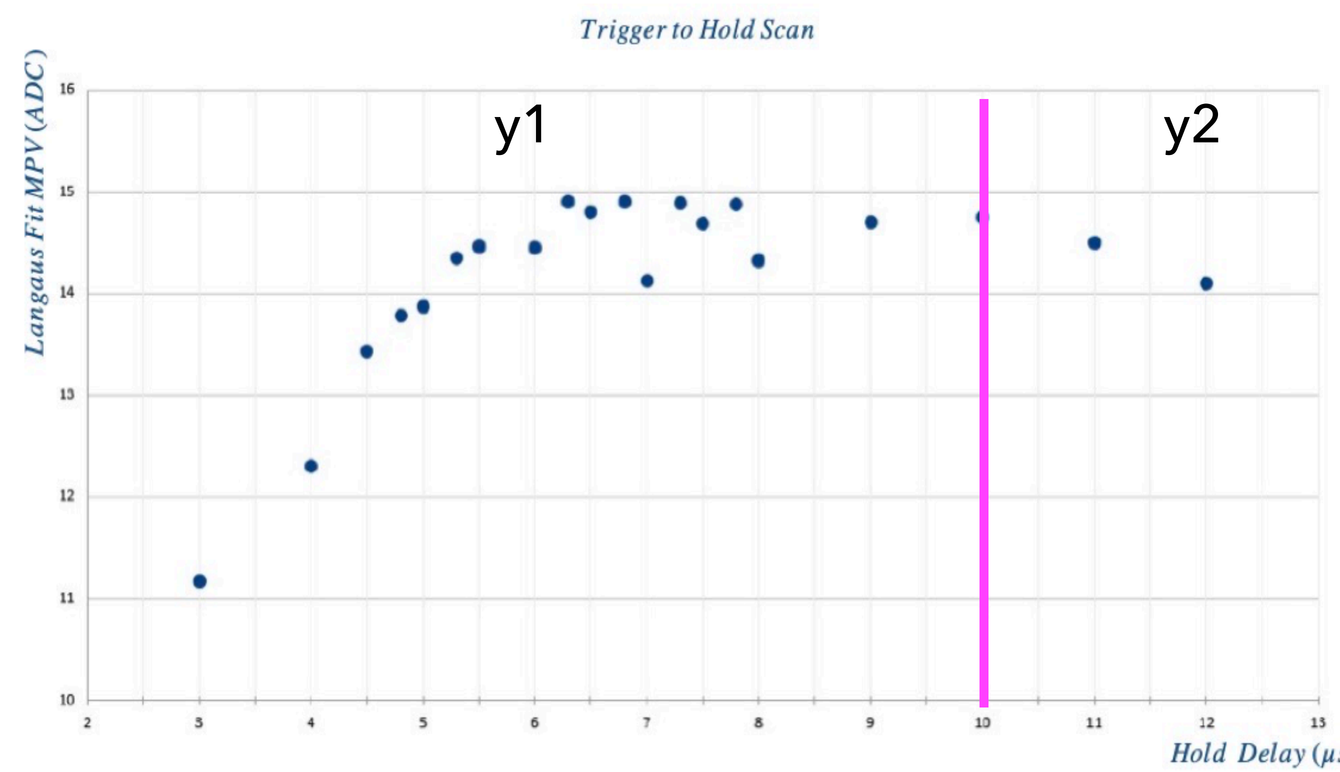
Acquisition with random trigger

Even if we're expecting to find a gaussian distribution for our signal, it must be taken into account that we're acquiring data with a 50 Hz random trigger.

We don't know if the signal is gonna be sampled at its maximum value.



Shaping time function with data form IDEAs (company that produce VA chip).



Shaping time function measure form ^{90}Sr source

$$y1 = a \cdot \frac{(1 + b \cdot e^{\frac{-x}{b}})}{(1 + c \cdot e^{\frac{-x}{b}})} \quad [0,10]\ \mu s$$

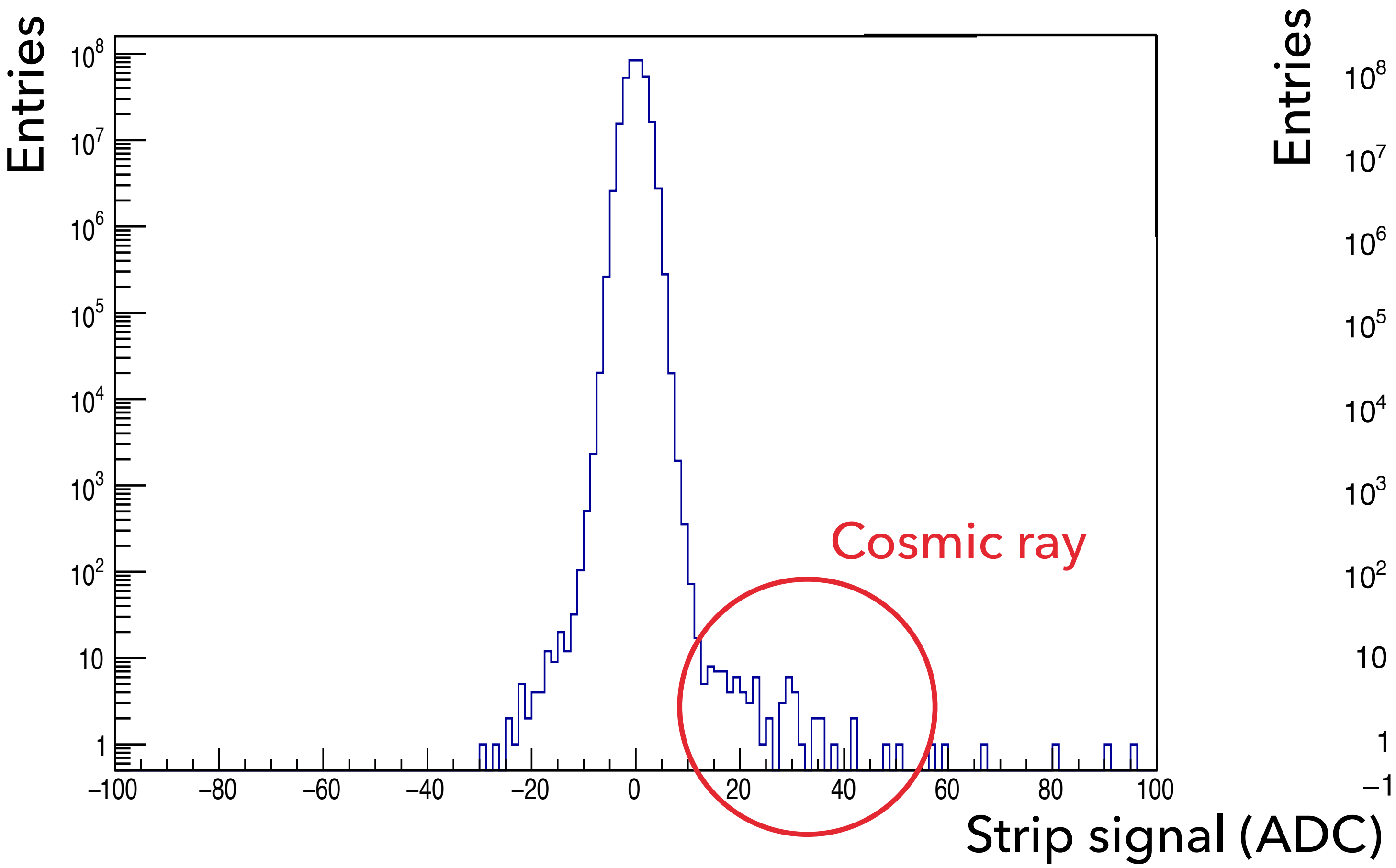
$$y2 = a' + b' \cdot x \quad [10,35]\ \mu s$$

Fit function for shaping time

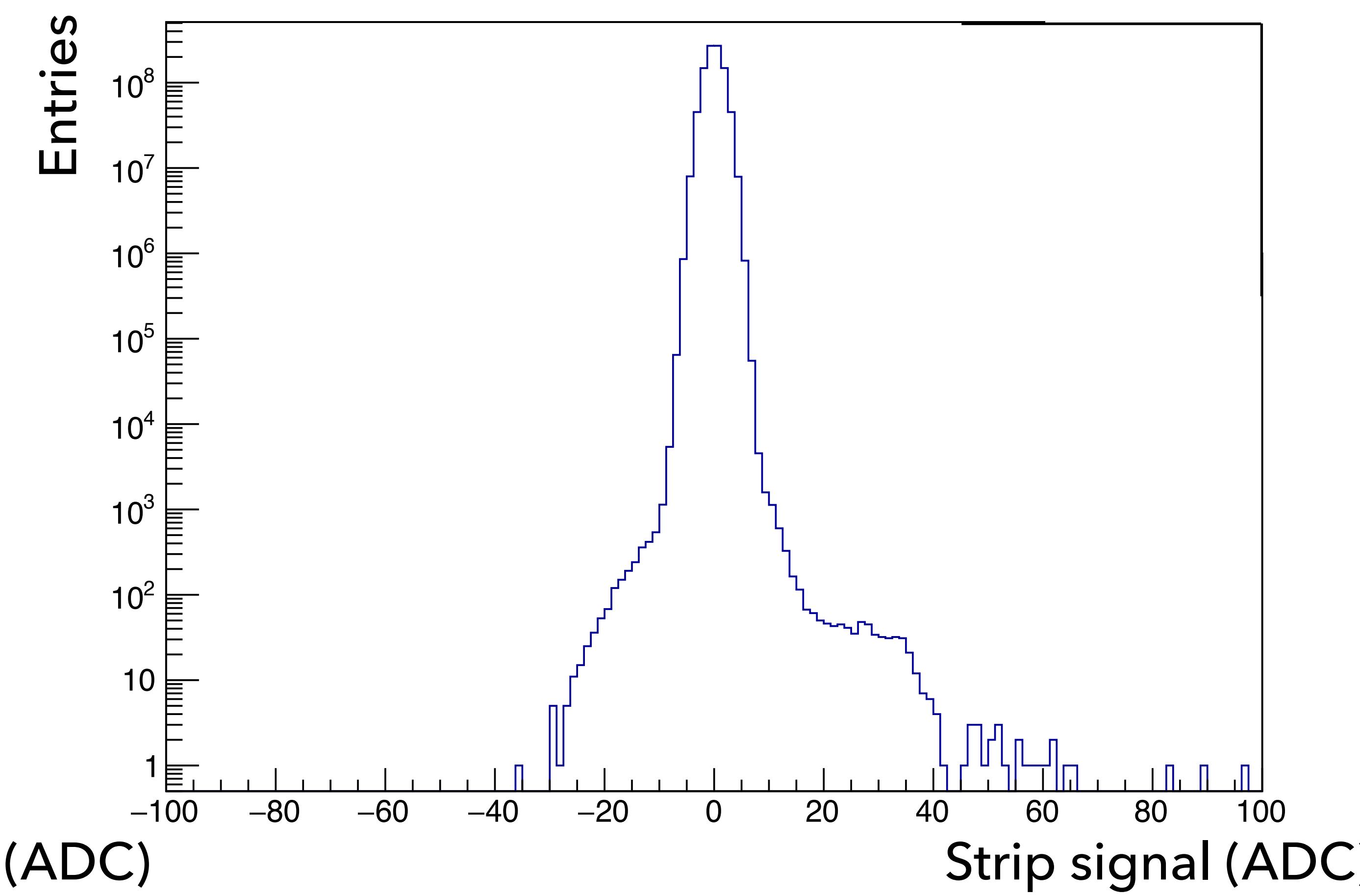
Acquisition with random trigger

We don't know the analytic form of the signal function but we know it will be the results of a convolution between gaussian distribution and shaping time function.

The histograms shown in the figure below are normalized to the same number of events.



Readings (ADC) for all channels without photon source

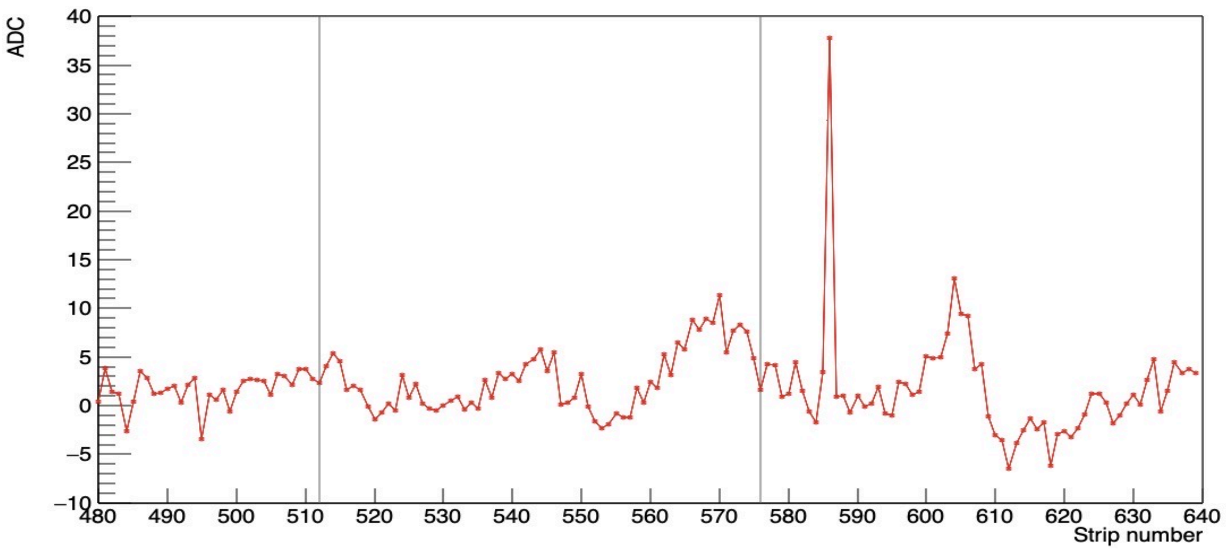


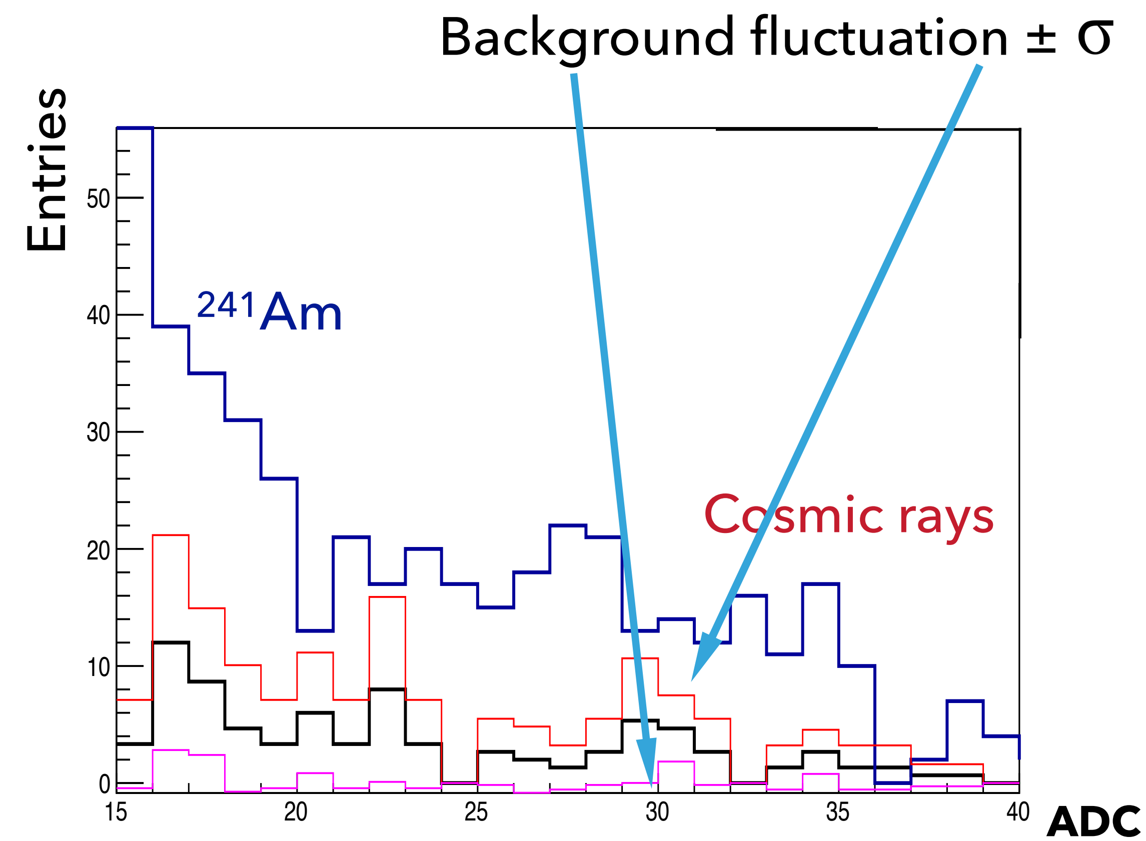
Readings (ADC) for all channels with ^{241}Am photon source

We decided to reproduce through Monte Carlo simulation the shape of the experimental signal.

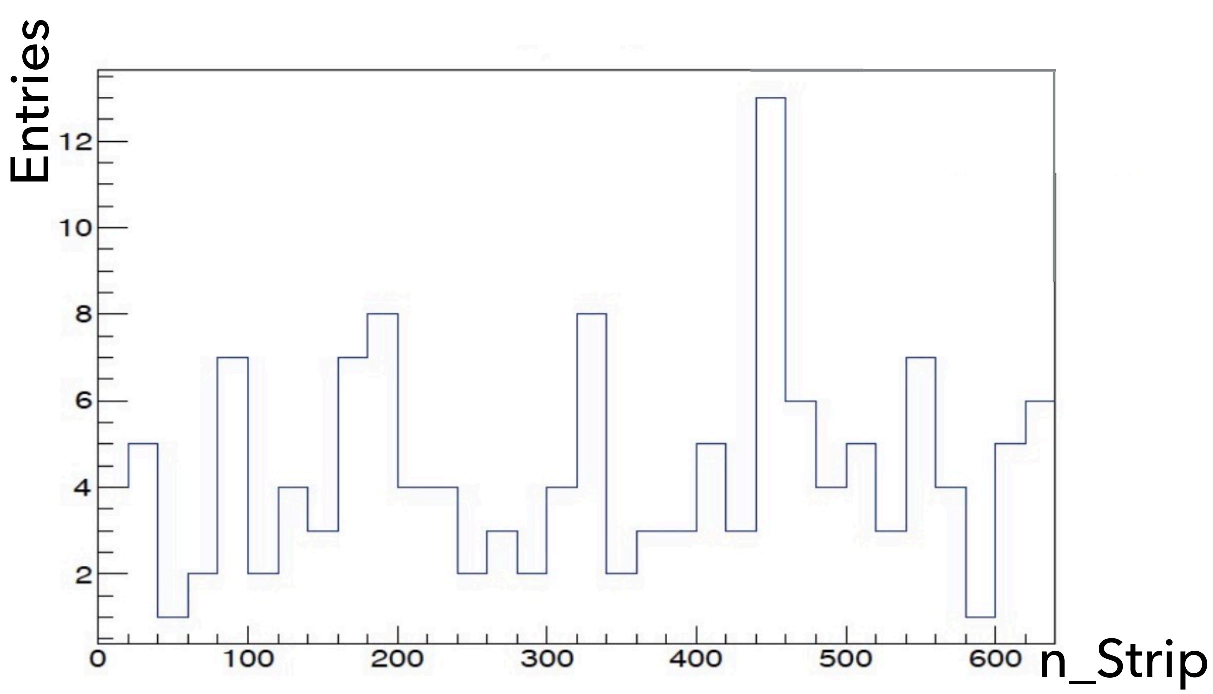
Cosmic ray background

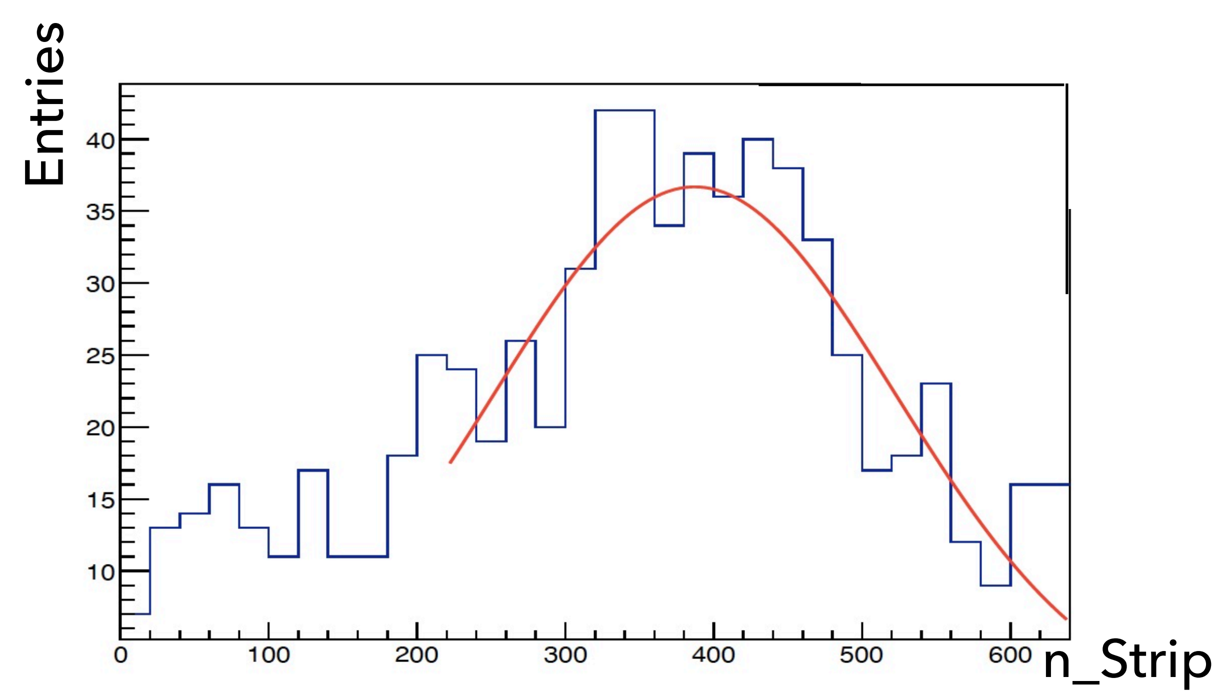
We want to be sure that the signal is not compatible with a cosmic ray background fluctuation.





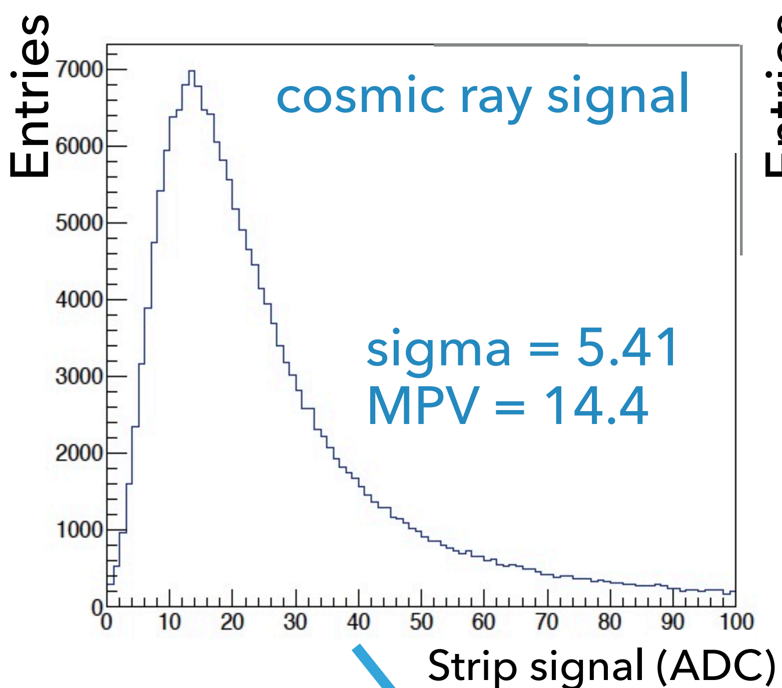
We have also study the distribution for the signal as a function of the strip number because of we want to verify that the distribution for the strip signal are different. In the follow histogram a cut has been made at 10 ADC.

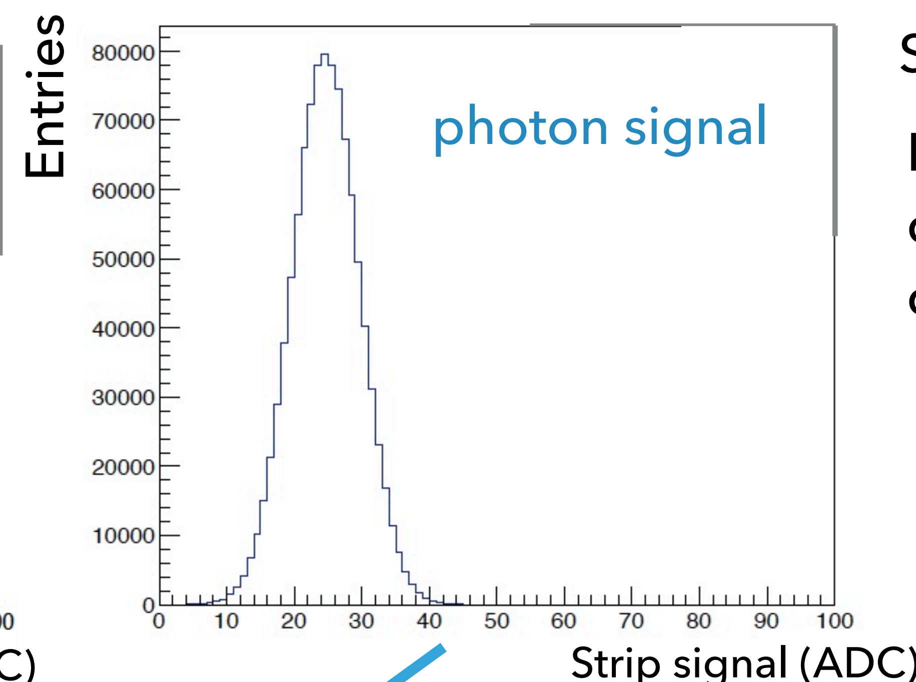




Monte Carlo Simulation

We need to simulate both photons and cosmic ray signal.





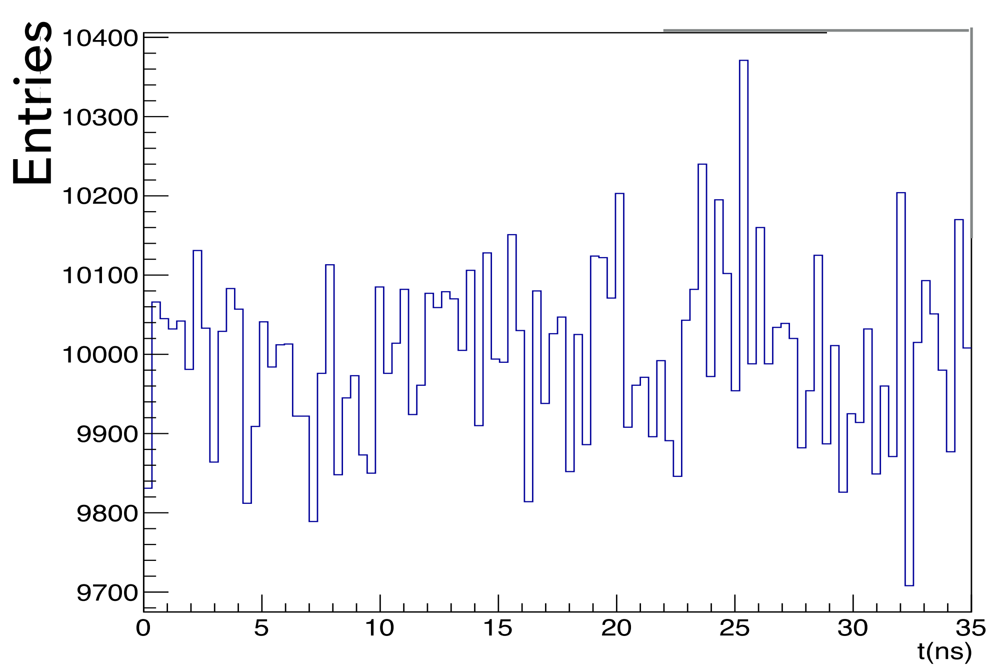
Set parameter

Parameters that characterize the cosmic ray signal

Unknown parameter

Parameters that characterize the photon signal

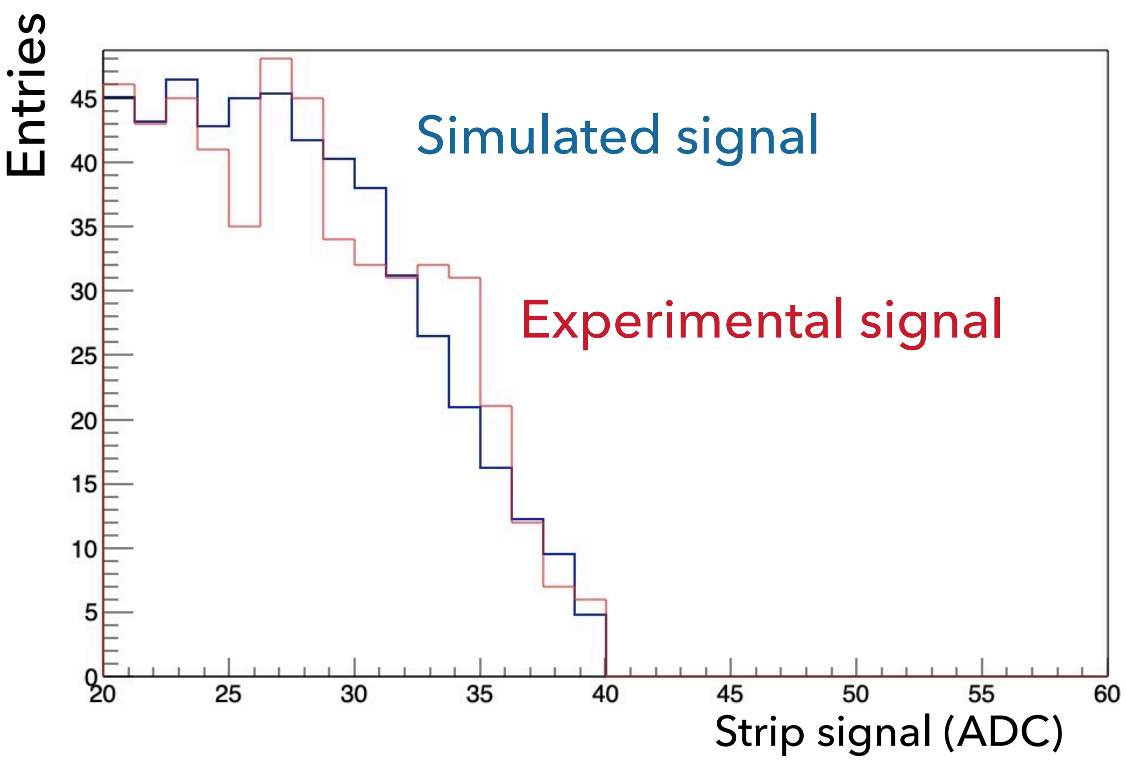
Time of sampling



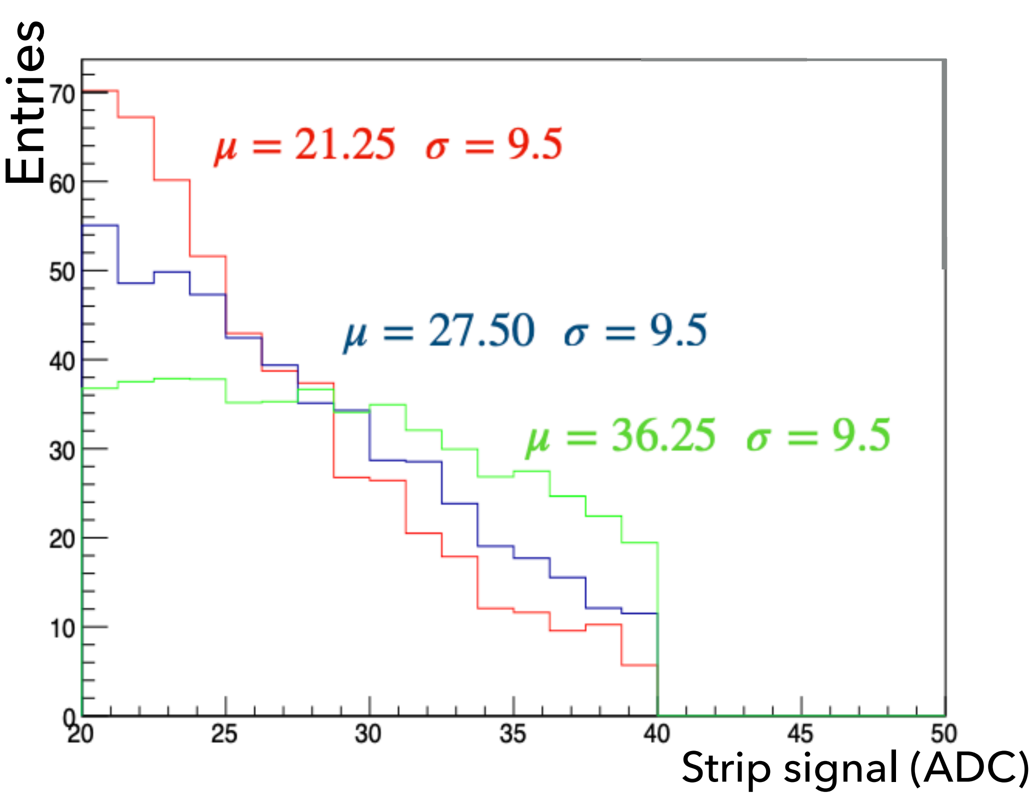
We can vary both the parameters that characterize the gaussian signal, which are our own variables together with the time of sampling.

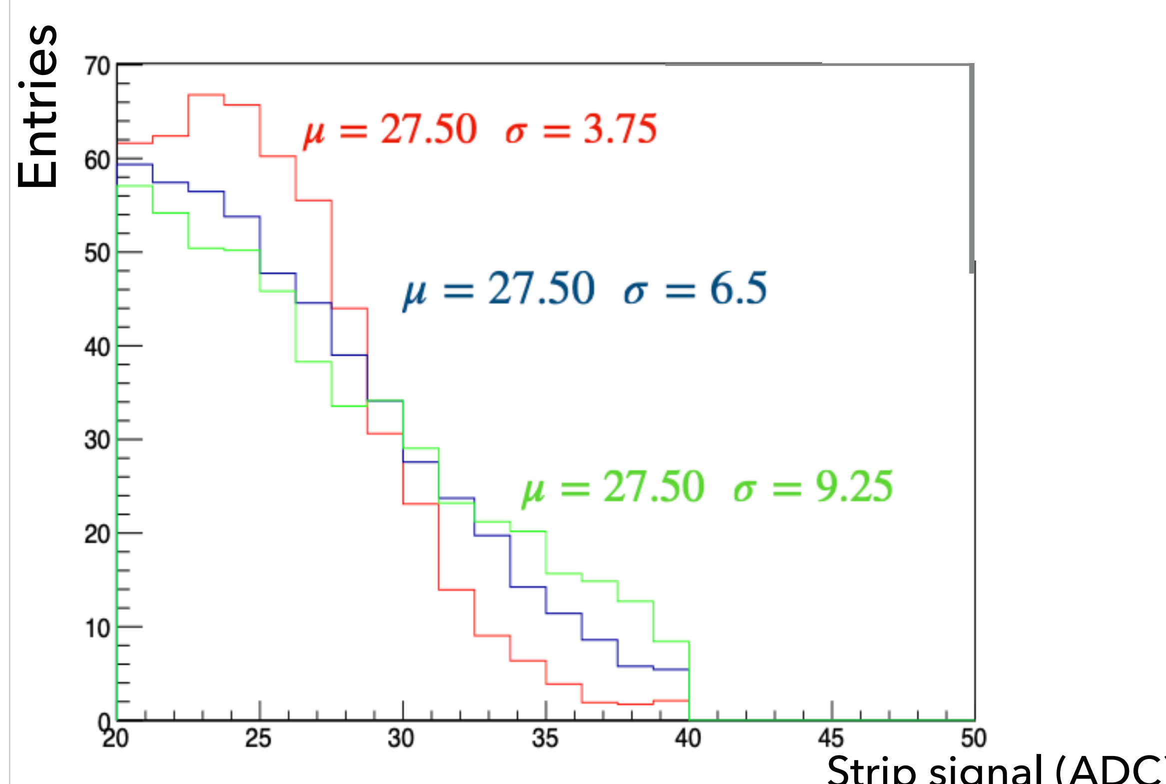
Time of sampling is simulated with a set of pseudo random number.

Monte Carlo Simulation



At this point we want to reproduce through Monte Carlo simulation the shape of the experimental signal to measure the value of gaussian signal.



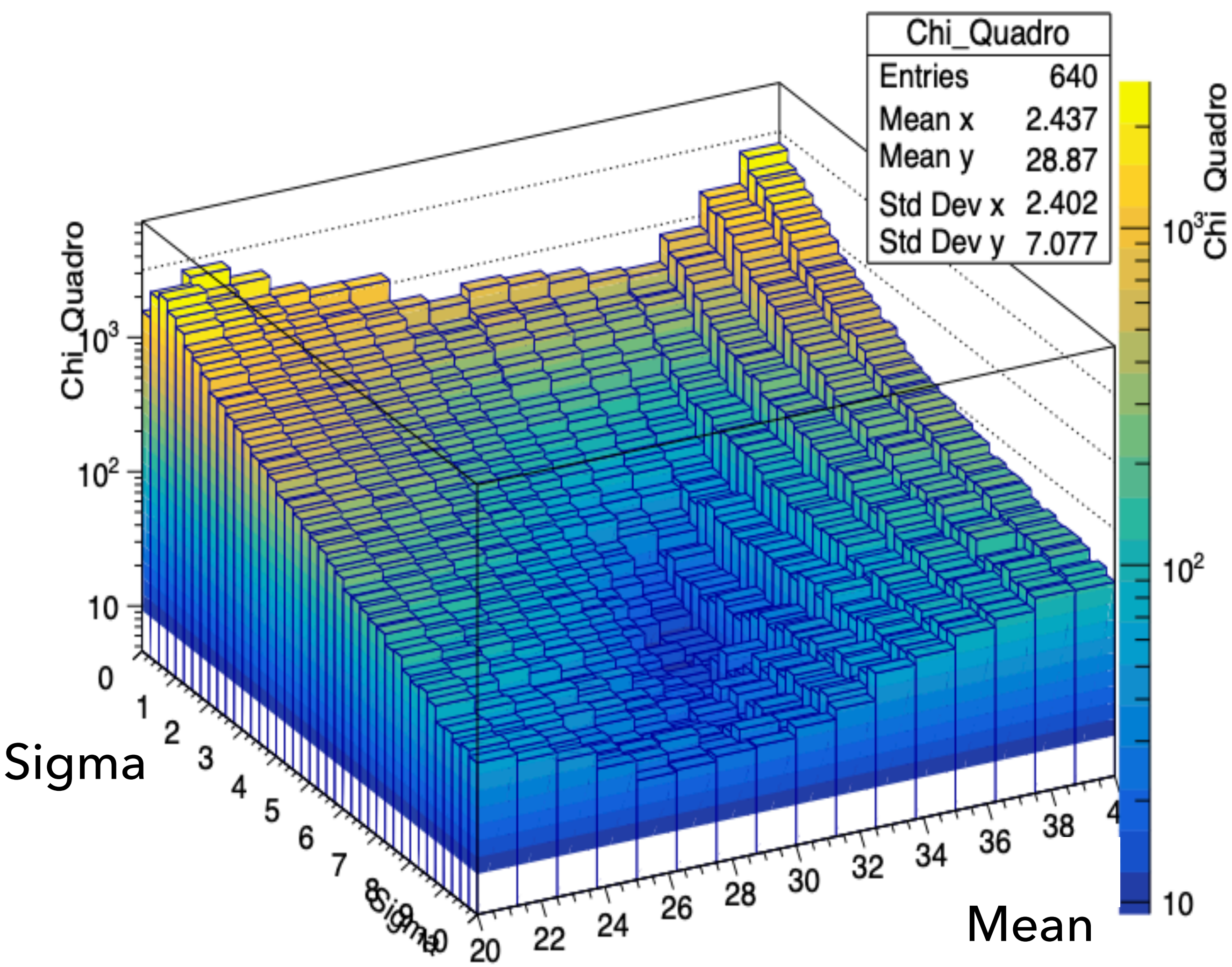


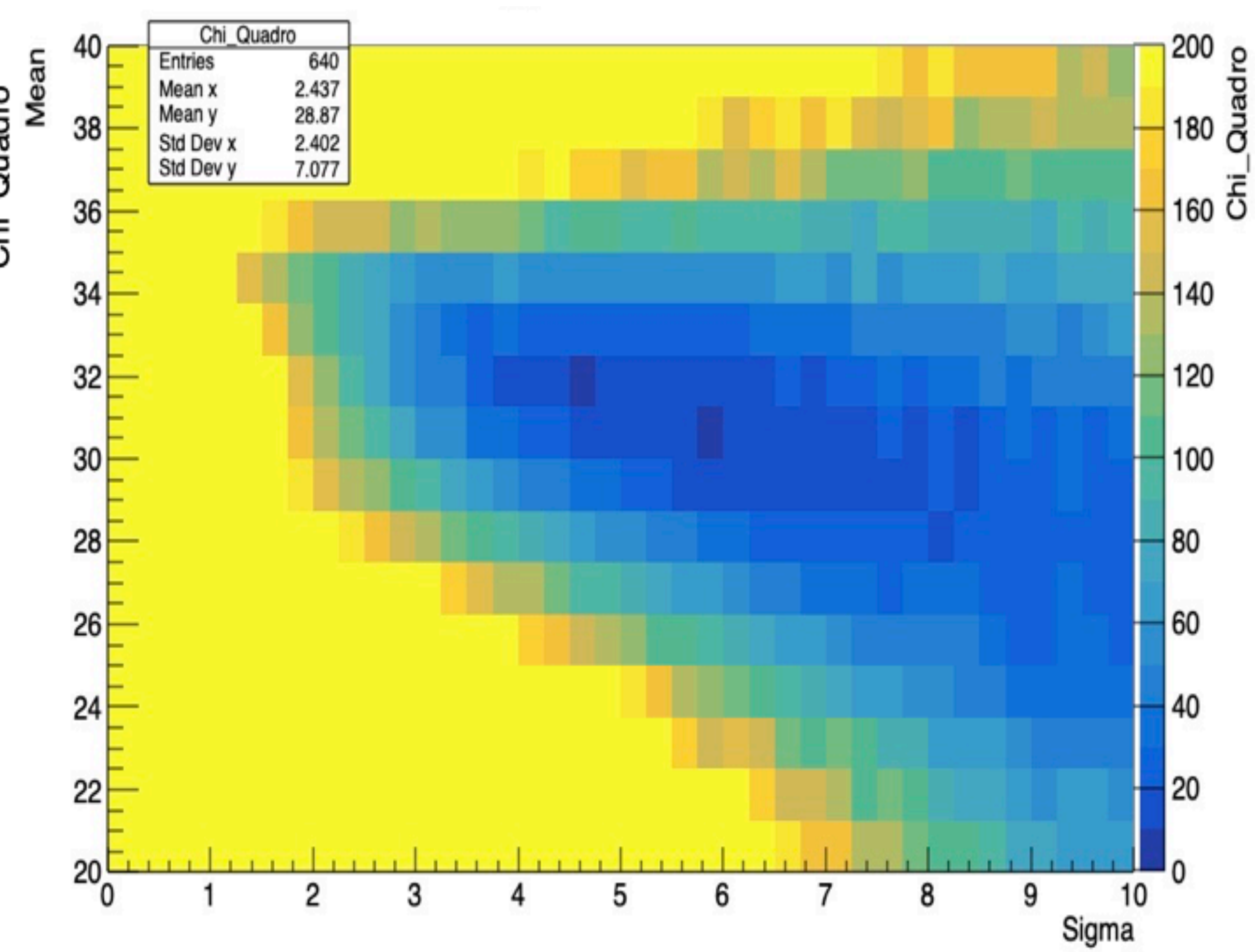
Parameter estimation

Each simulated histograms constitutes a particular parametric hypothesis for the photon signal.

To compare the two distributions we've calculated the chi square value ($\chi^2(\mu;\sigma)$) for each hypothesis

$$\chi^2(\mu;\sigma) = \sum_{i=0}^{n} \frac{(y_i^{exp} - y_i^{sim})^2}{\sigma^2_{y_{exp}}}$$

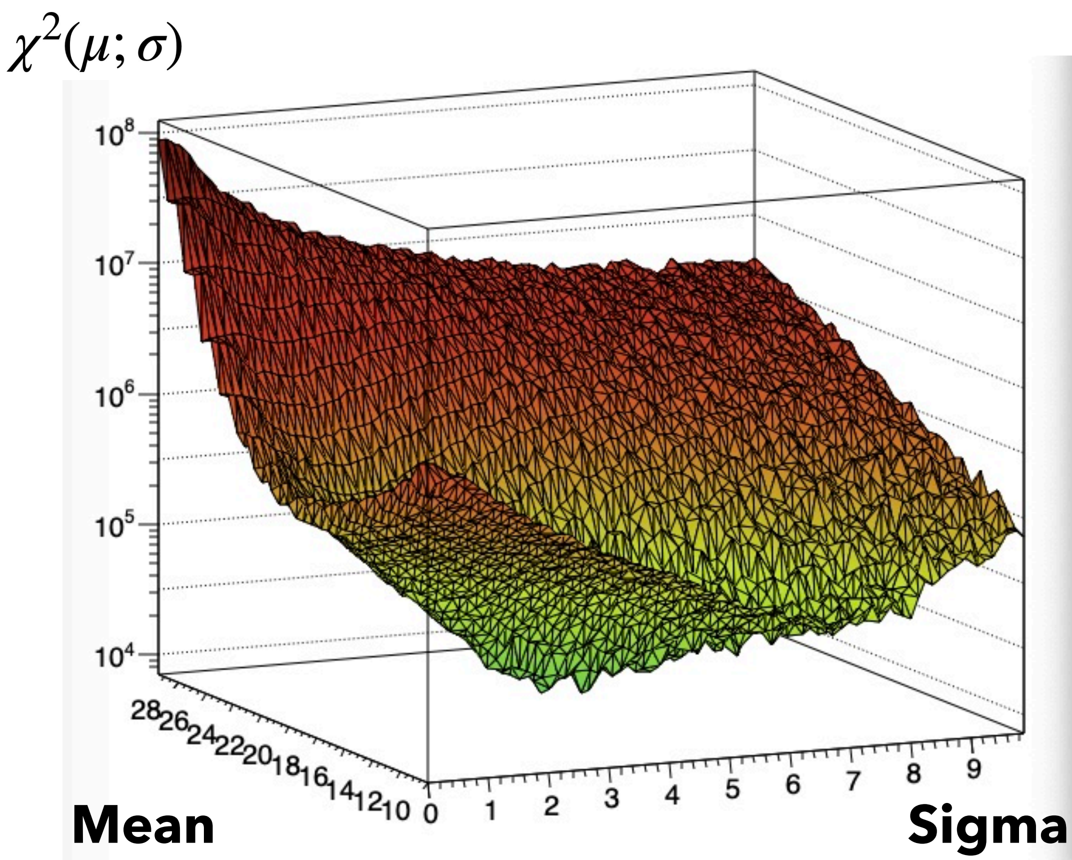




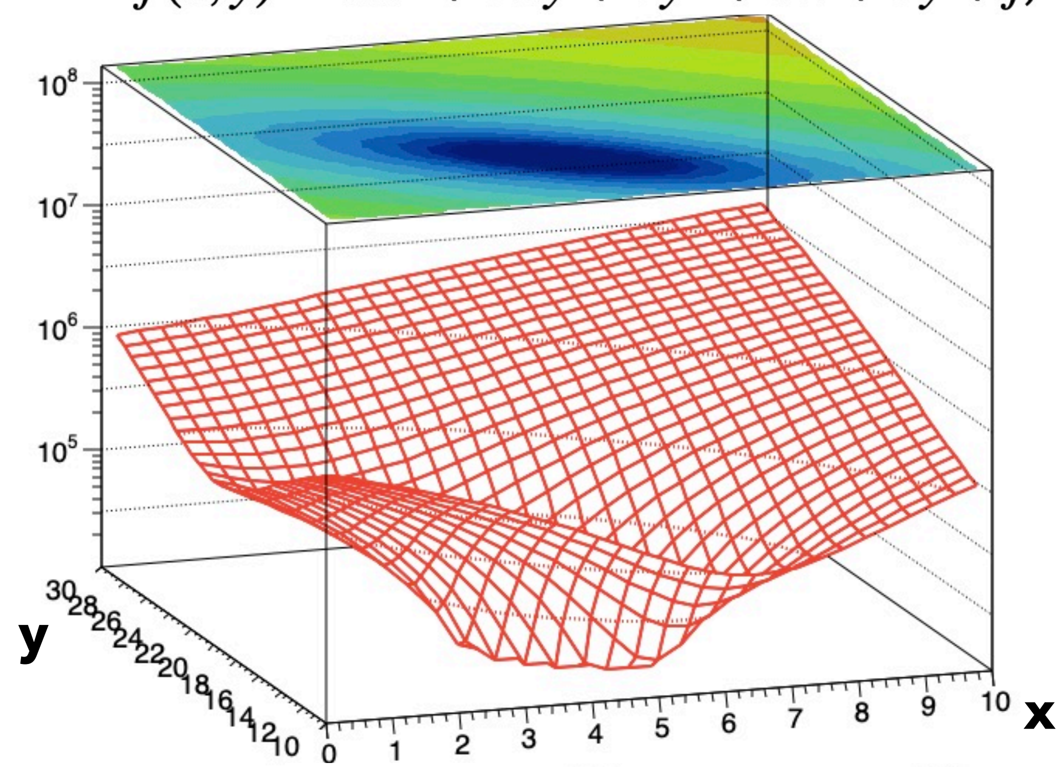
Parameter estimation

We want to estimate the minimum value assumed by the bidimensional function $\chi^2(\mu;\sigma)$

We're also estimating a confidence interval for the minimum in order to obtain the error for the two parameters → We fitted chi square distribution with hyperbolic function



$$f(x,y) = ax^2 + bxy + cy^2 + dx + ey + f,$$



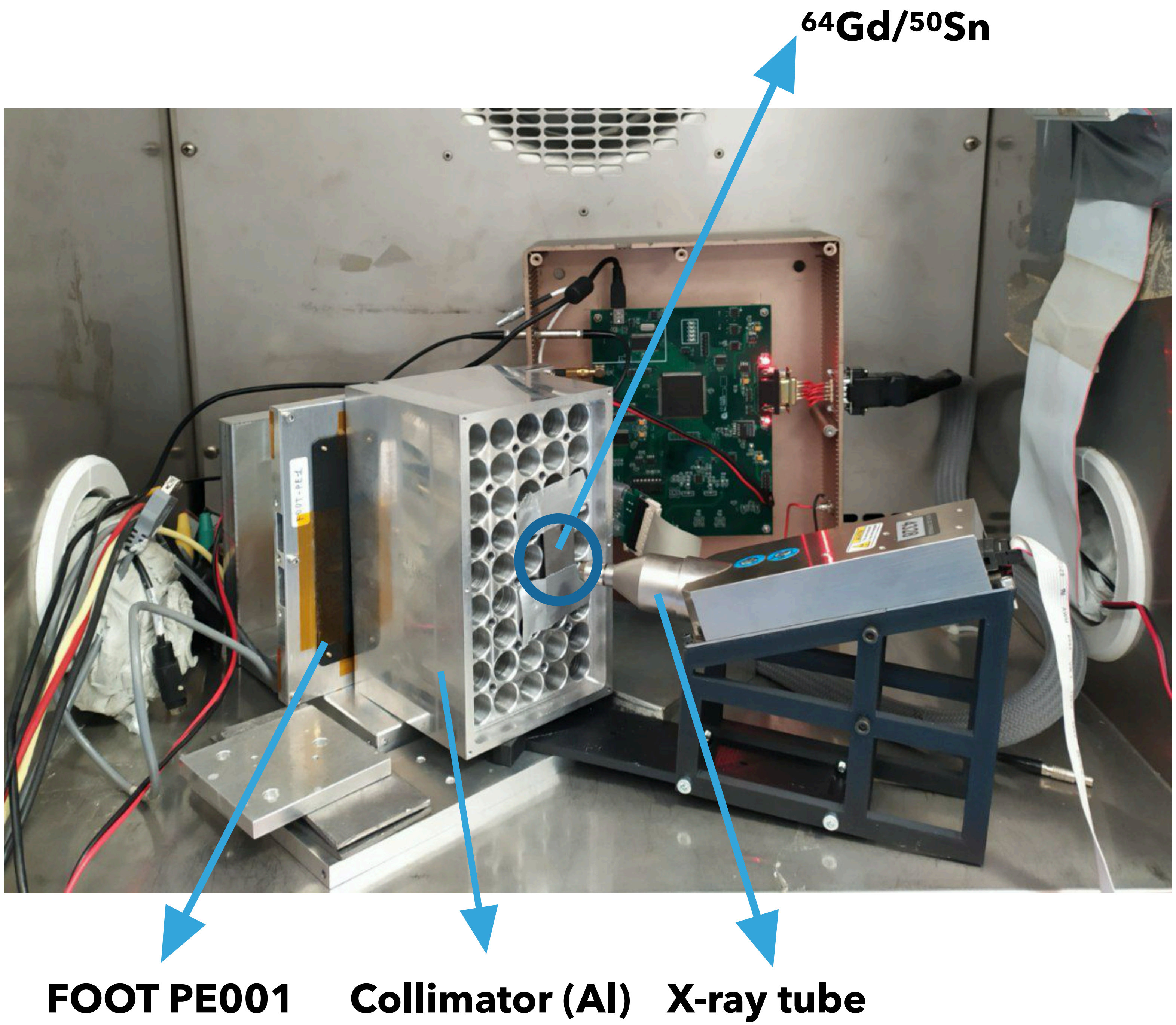
$$\mu = 30.00^{+0.7}_{-1.0} \; ; \; \sigma = 4.25^{+0.3}_{-0.4}$$

From this value we obtain a calibration factor $K = 2.0 \pm 0.3 \dfrac{keV}{ADC}$ that we can compare with the one calculated with electron $K = 2.9 \pm 1.0 \dfrac{keV}{ADC}$

The main problems with this method is the ^{241}Am source low rate comparable with cosmic ray rate so we have to acquire for a long time (days) to increase statistics.

Calibration with other photon sources

To overcome the problems of the previous case we used fluorescence photons with which we can collect more signal in less time



In order to draw a calibration line we need a minimum of two points.

We chose two other sources.

^{64}Gd → **42.996 keV**

^{50}Sn → **25.271 keV**

A new experimental set up was built to bring down background, caused by cosmic ray: sensor in vertical position.

Previously the cosmic ray event represented 20% of the overall signal now they represent 0.01%.

Parameter estimation with MC methods

We also used a second method for error's parameters estimation .

We used MC methods to simulate many times the same experiment, in order to have several measures for the minimum value of the chi square distribution and the gaussian distribution for their respective parameters.

Similar results were obtained

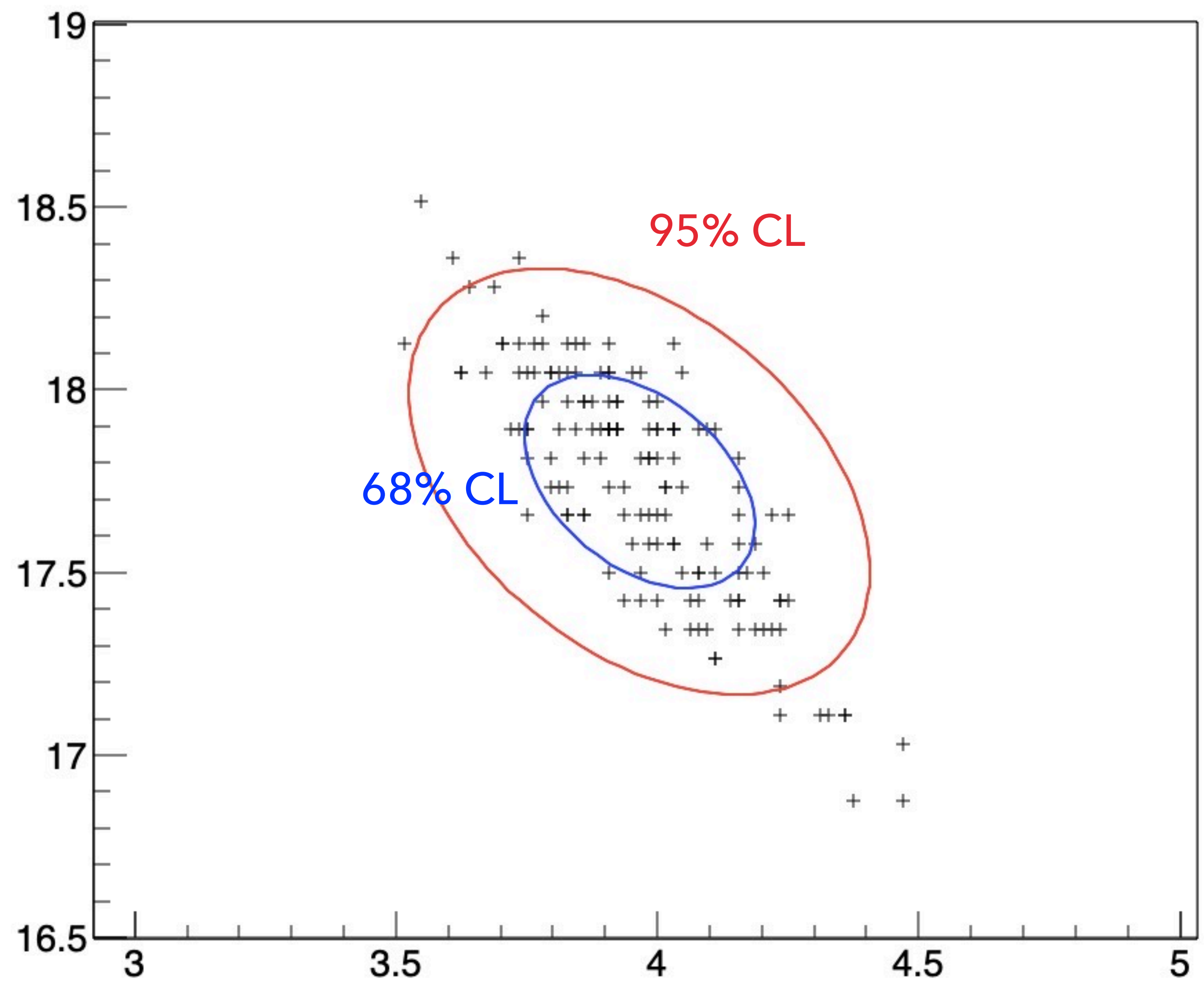
Example (^{64}Gd):

- MC Method

$$\mu = 17.8^{+0.7}_{-1.0} \; ; \; \sigma = 3.9^{+0.6}_{-0.4}$$

- Chi square fit Method

$$\mu = 18.1^{+1.1}_{-0.9} \; ; \; \sigma = 3.6^{+0.4}_{-0.5}$$



$$K = 2.9 \pm 1.0 \frac{keV}{ADC}$$

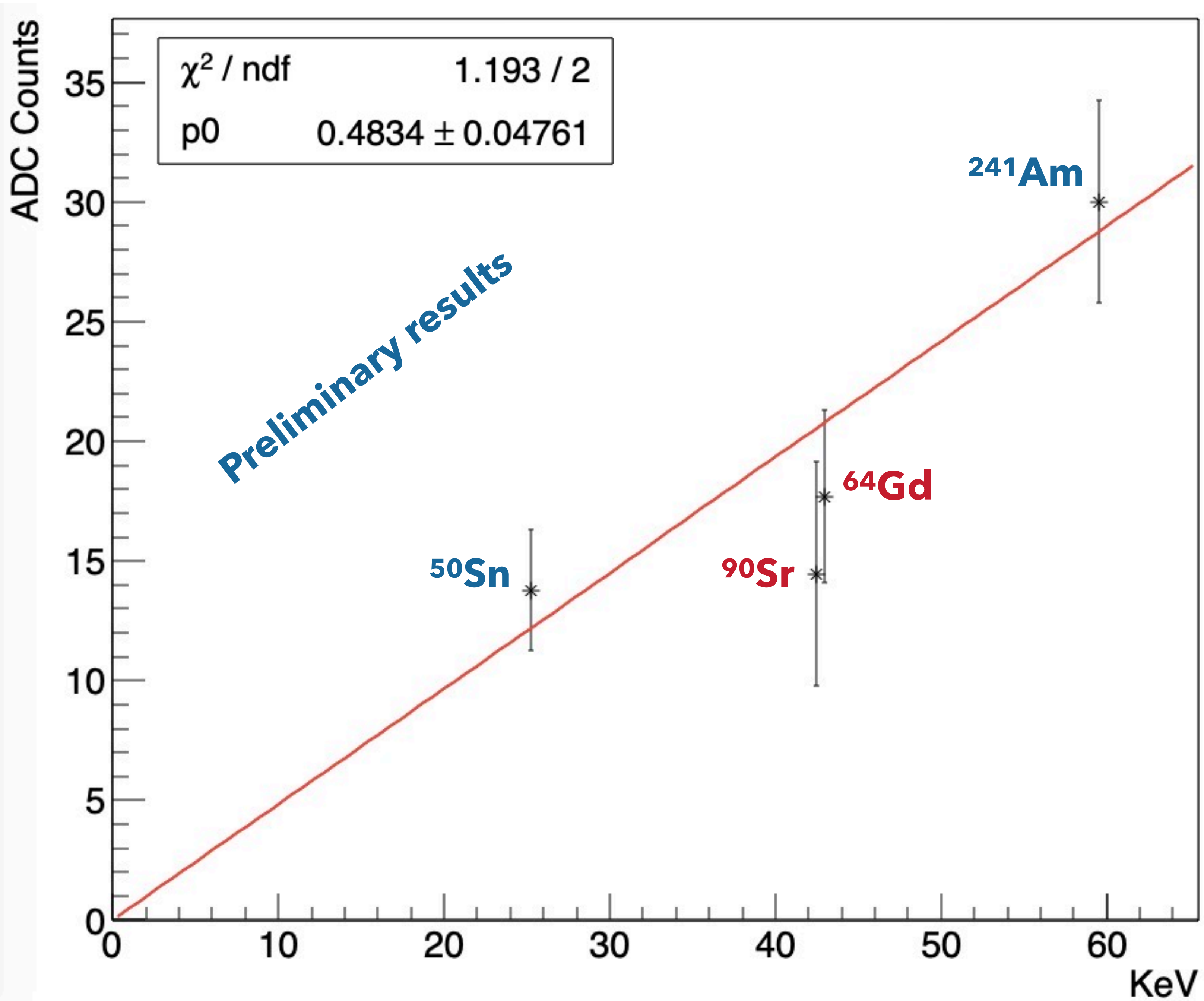
K with ^{90}Sr

$$K = 2.4 \pm 0.1 \frac{keV}{ADC}$$

K with ^{64}Gd

Summary results

We have enough measurements to plot the calibration line for the PE001 sensor



Photon source

$$K = 2.1 \pm 0.2 \frac{keV}{ADC}$$

Electron source

$$K = 2.9 \pm 1.0 \frac{keV}{ADC}$$

We can already say that the new method is more accurate and it is consistent with the standard method.

To Do

- New acquisition with another different source (Neodymium).
- Same type of acquisition with another micro strip detector, which has different thickness (300 micron) and same read out sistem, we're expecting the same results.
- Estimation of parameters and calibration coefficient error.
- We submitted an abstract to present this new method at SIF annual national congress
- We want to write an article about the new calibration method