Beam-test data analysis using the integration method for SNR estimation

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Overview

- Beam-test
- My objective – estimate SNR
- Signal shape function
- Fit function parameters
- Methods to estimate signal to noise ratio
- Conclusions

2011 Beam-Test

Measurements performed at DESY 22 electron beam

BeamCal module contains :

- GaAs sensors
- kapton foil
- front-end ASICs (32 channels)
- multichannel ADC SoC ASICSs (32 channels)
- data concentrator implemented in FPOAQ 1C
- power pulsing circuit and digitally controlled and monitored biasing and powering circuits.

Goal - behaviour of the complete multichannel BeamCal module in electron beam available at DESY

The collected data allow to determine the performance of the whole readout chain:

- sensor pad uniformity
- gain
- offset and noise
- readout electronics channel uniformity
- crosstalk between channels
- charge sharing in area between sensor pads
- response to electromagnetic shower development generated by tungsten plates included in front of tested module.

My objectives

- **Estimate SNR using the integral of the recorded signal**

- Fit each signal with signal shape function – extract baseline, amplitude, shaping time, starting time, peaking time (parameters of the signal shape function)

- Calculate the integral of the signal and estimate SNR:

$$S/N = \frac{Signal}{\sigma_{Pedestal}} = \frac{MPV_{Spectrum} - mean_{Pedestal}}{\sigma_{Pedestal}}$$

Results obtained for:

- Channel 9 (Pad 10) – high gain (asynchronous and synchronous mode)

- Channel 5 (Pad 6) – low gain

Signal shape function

$$\boxed{s(t) = V_0 \frac{t}{\tau} e^{-t/\tau}}$$

In root: p[0] + p[1] * (x − p[2]) / p[3] * TMath :: Exp (−(x − p[2]) / p[3])

- p[0] : y-offset -> baseline
- p[1] : norm -> V0 * amplification
- x-p[2]: relative time -> p[2] = time when signal (fit) starts
- p[3] : -> time constant (τ), shaping time

Fitting parameters

- Maximum:

  $t = \tau$

- Amplitude:

  $A = s(t = \tau) = V_0 \exp(-1) \Rightarrow V_0 = A * e \rightarrow$ V_0 is "Norm" = Real Amplitude * e

- Area under the curve (integral):

  $F(a) = V_0 (\exp(-a/\tau)(a + \tau) - \tau)$

  $F_{Ges} = V_0 \lim_{a \to \infty} (\exp(-a/\tau)(a + \tau) - \tau) = V_0 * \tau$ (MPV_Norm*Mean_τ)

Fit Procedure and constraints

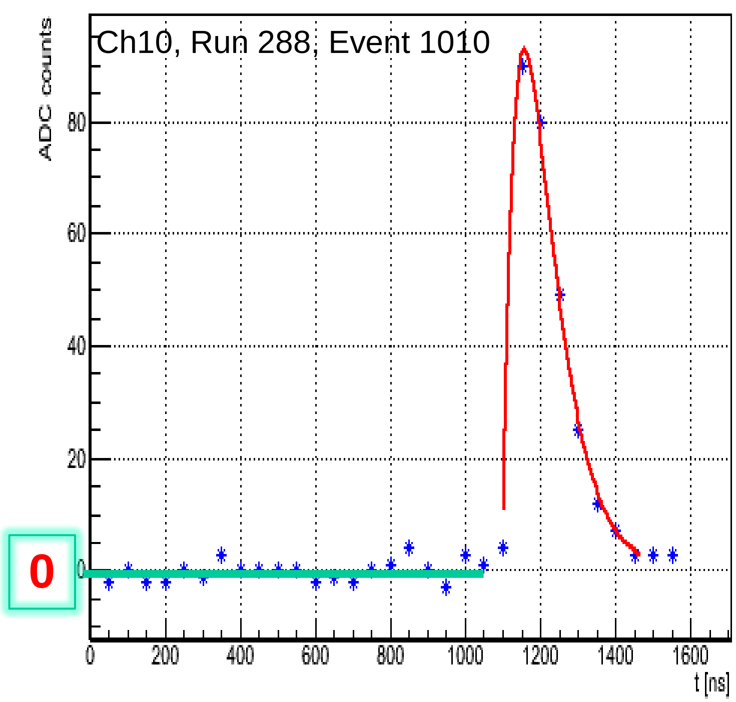
CMN + Pedestal subtraction included

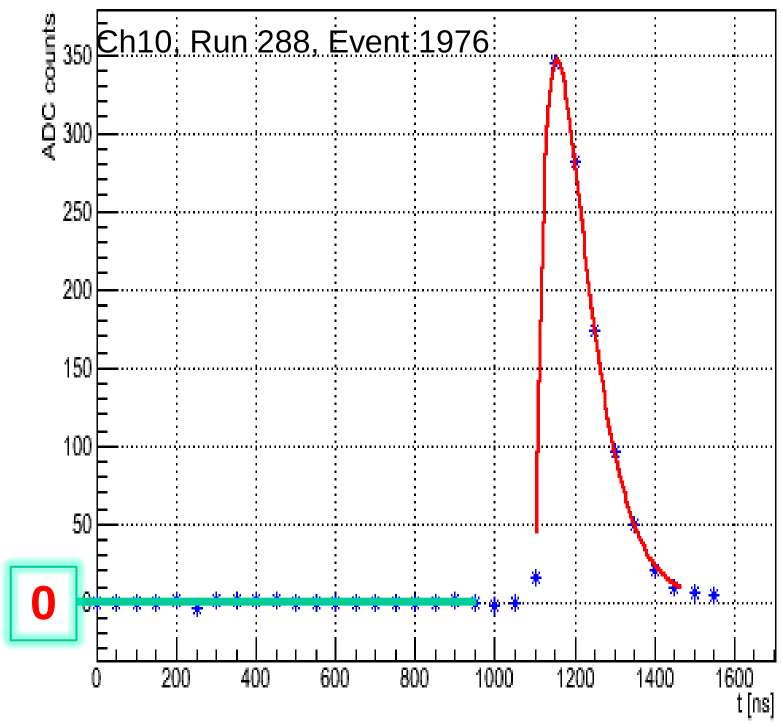
Then, fit if:

Signal > $5 * \sigma_{Pedestal}$

Relative Parameter Error < 50%

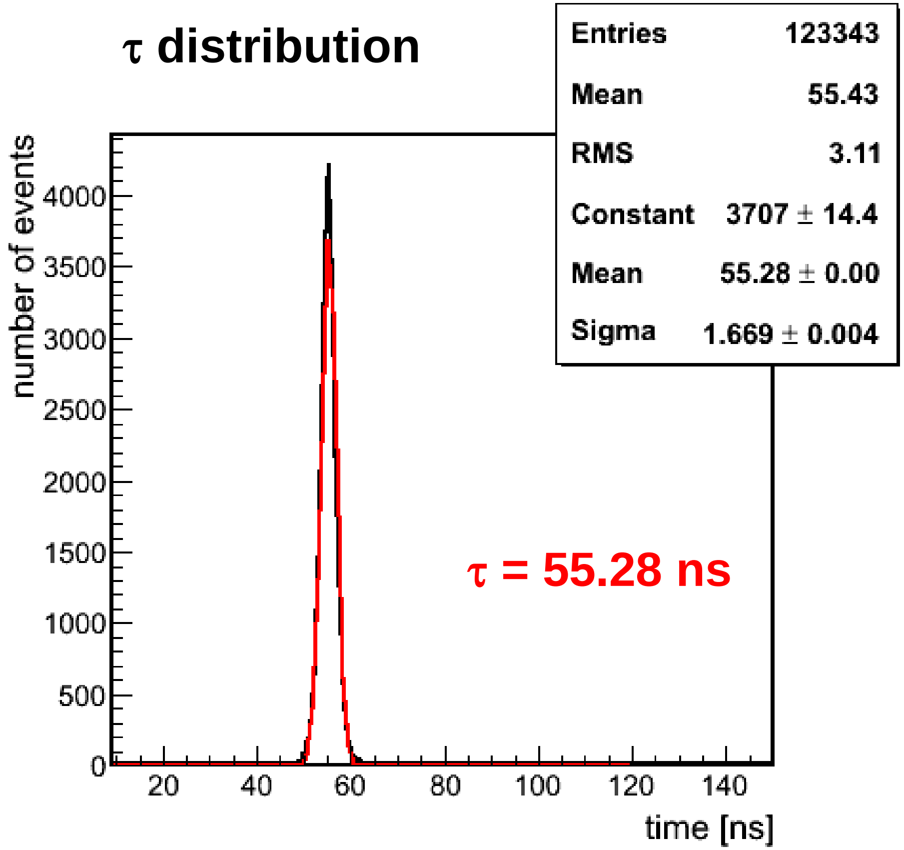
Search for fit_start (mean over 7 samples > $5 * \sigma_{Pedestal}$)

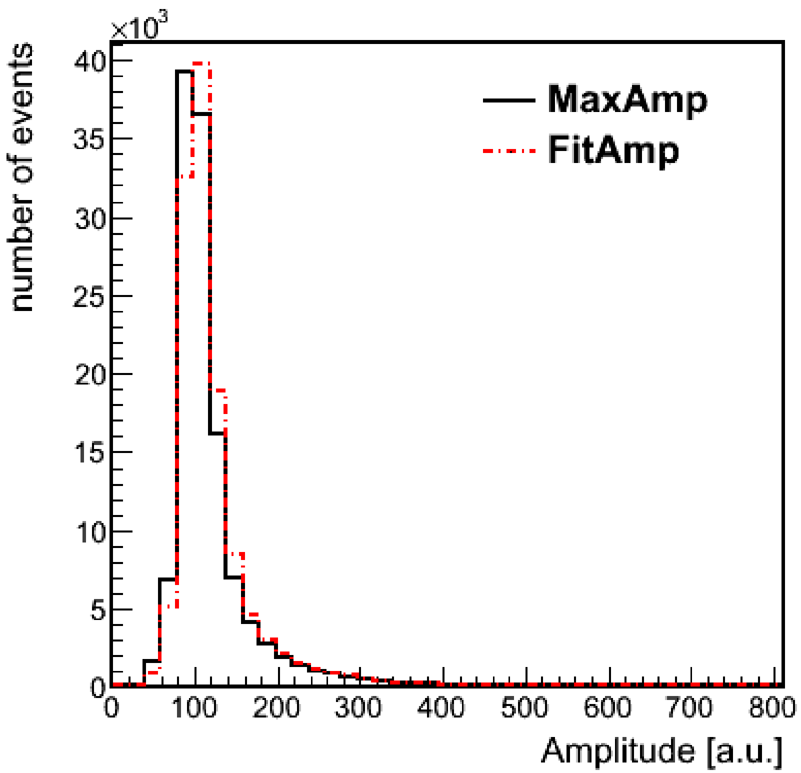




Parameters distributions after the fit

Channel 9 – Asynchronous Mode





Maximum Amplitude (taken from the data)

Amplitude given by the fit

A ≠ Norm! (Norm=A*e)

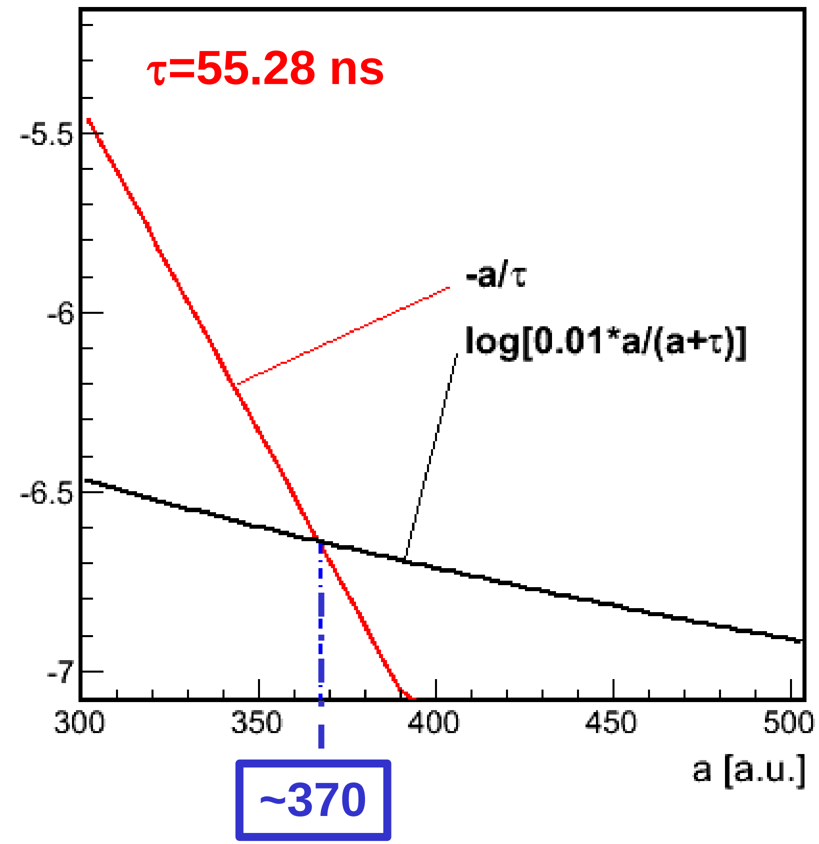
Integration window – graphical solution

Range: (Start time (from the fit) ; Start time + a)

"a" = integration window: when area under the curve reaches 99% of it's (theoretical) maximum

Graphical solution -solve:

$$\ln\left(\frac{0.01*t}{a+t}\right) = -\left(\frac{a}{t}\right)$$

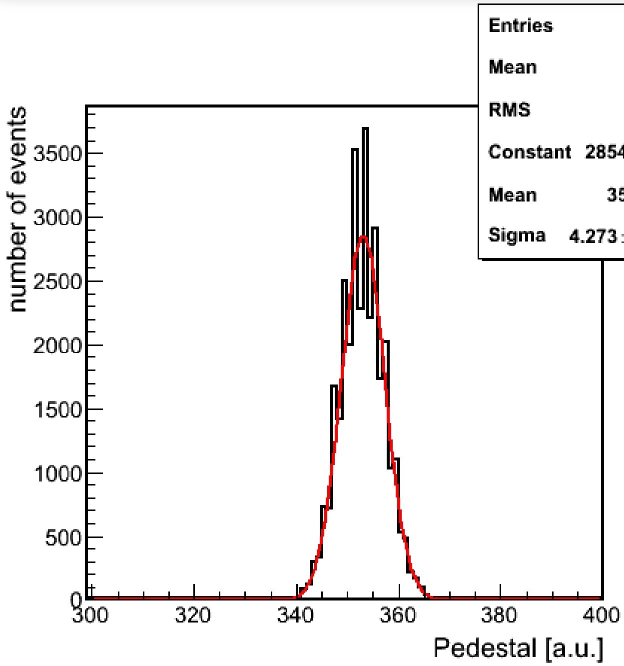


a~370 ns:

- ***Integration window ~7 samples***
- ***Same window used to calculate pedestal***

Parameters distributions after the fit

Channel 9 – Asynchronous Mode

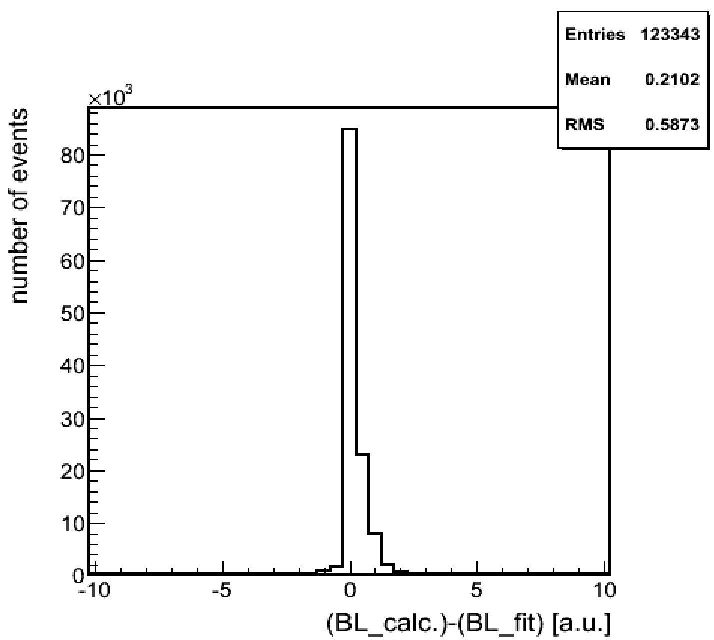


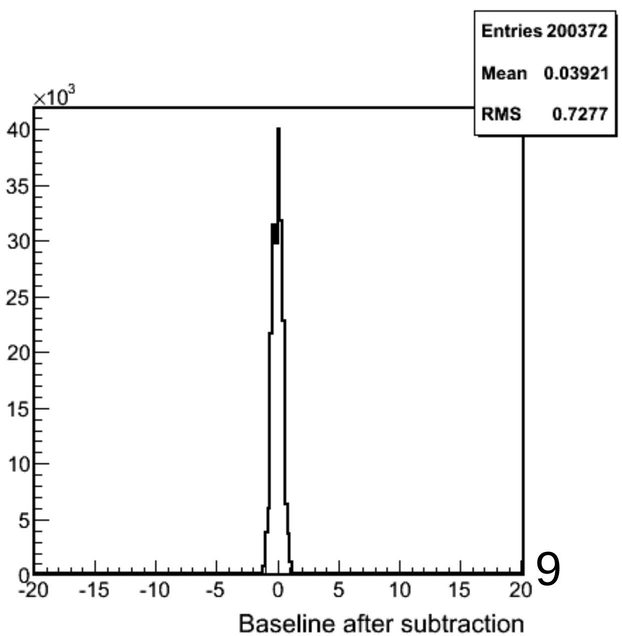
Pedestal distribution, samples 1->7:

$$mean_{Pedestal} = 353$$

$$\sigma_{Pedestal} = 4.27$$

Difference between calculated baseline and baseline given by the fit - Positive shift





Calculate SNR

1. Extract "Norm" and τ for each event

- Build the "Norm" and τ distributions and extract MPV_Norm and Mean_τ

$$F(a) = V_0 * \tau$$

$$S/N = \frac{\boldsymbol{MPV_{Norm}} * \tau_{mean}(ADC_{counts} * sample)}{\sigma_{Pedestal}}$$

2. Calculate integral for each event

$F(a) = V_0(\exp(-a/\tau)(a+\tau) - \tau)$ ("a" is the integration window)

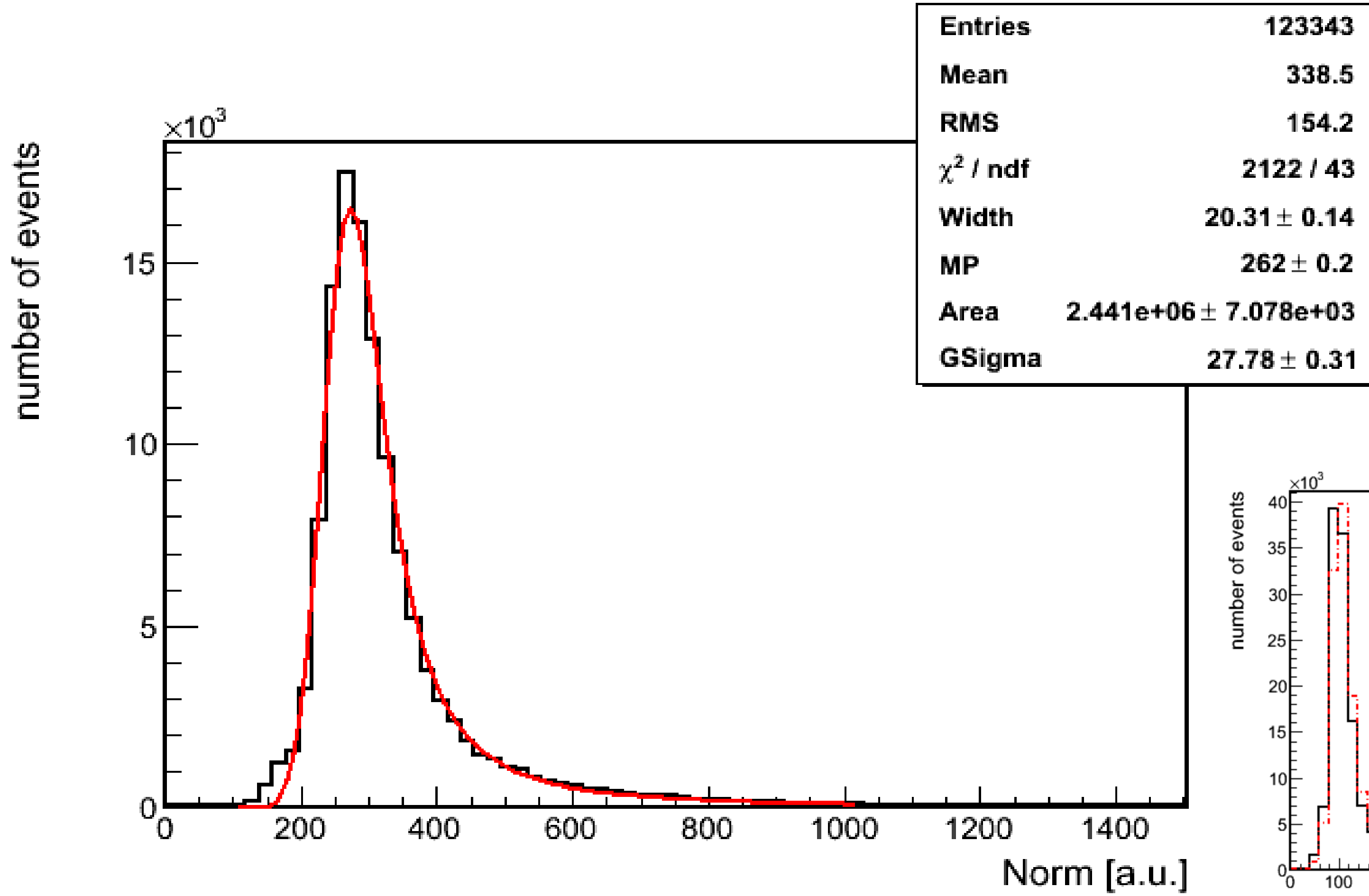
$$S/N = \frac{\boldsymbol{MPV_{Integral}}\,(ADC_{counts} * sample)}{\sigma_{Pedestal}}$$

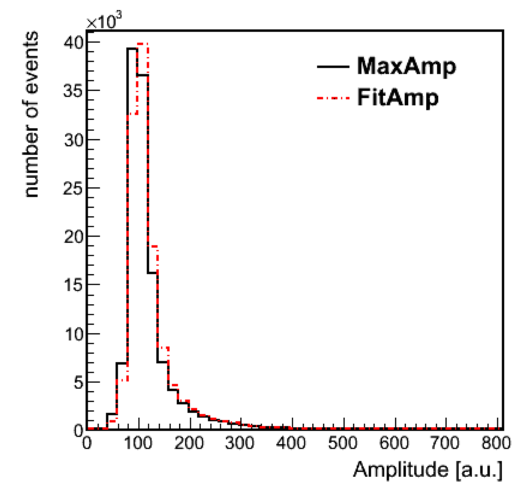
3. Calculate SNR for each event, build SNR distribution:

$$S/N = \boldsymbol{MPV_{SNR}}$$

1. “Norm” Distribution

Channel 9 – **Asynchronous Mode**



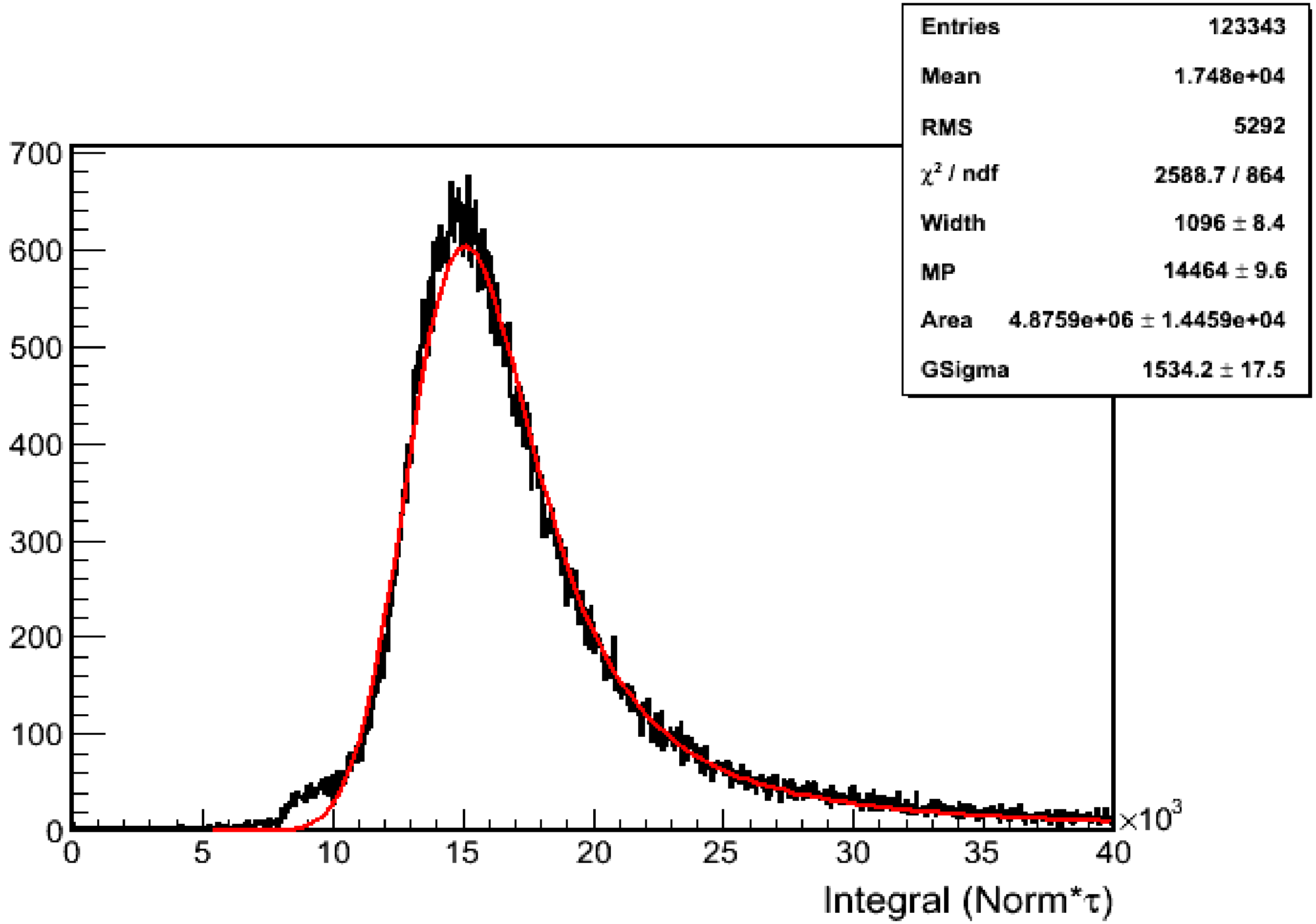


MPV_Signal_Size (Area)= MPV_Norm*Tau
=262*55.28 =14483.36 ADC_counts*ns
=289.67 ADC_counts*sample

S/N = 289.67/4.27 = 67.83

2. Integral distribution

Channel 9 – **Asynchronous Mode**

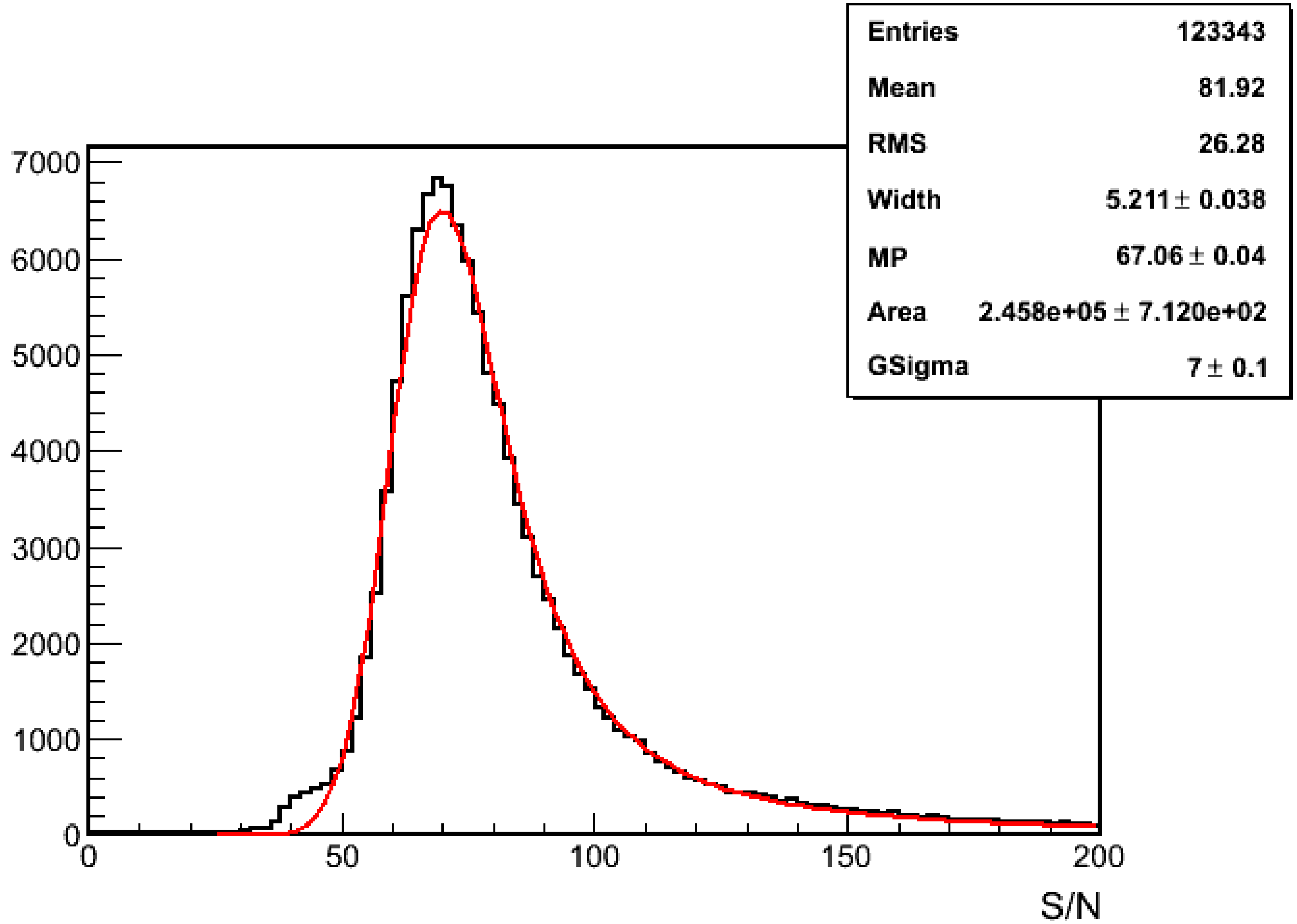


MPV_Signal_Size (Area) = MPV_Integral
=14464 ADC_counts*ns
= 289.28 ADC_counts*sample

S/N = 289.28/4.27 = 67.74

3. SNR distribution

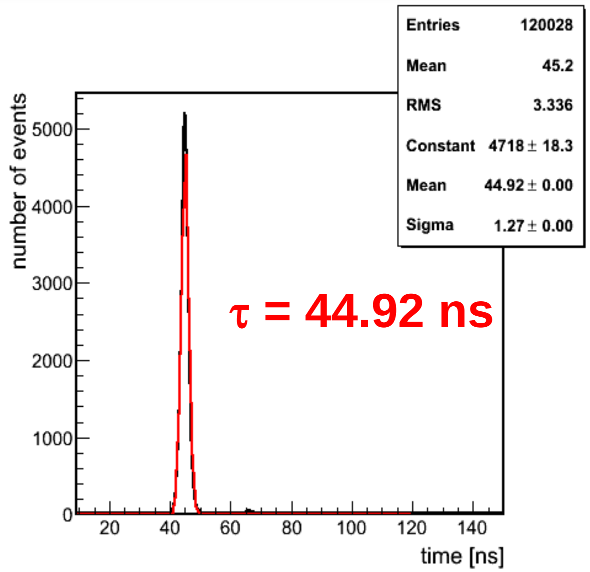
Channel 9 – **Asynchronous Mode**

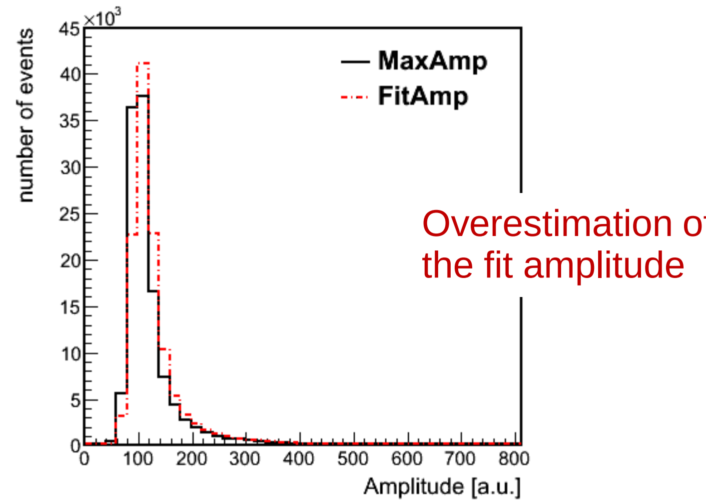


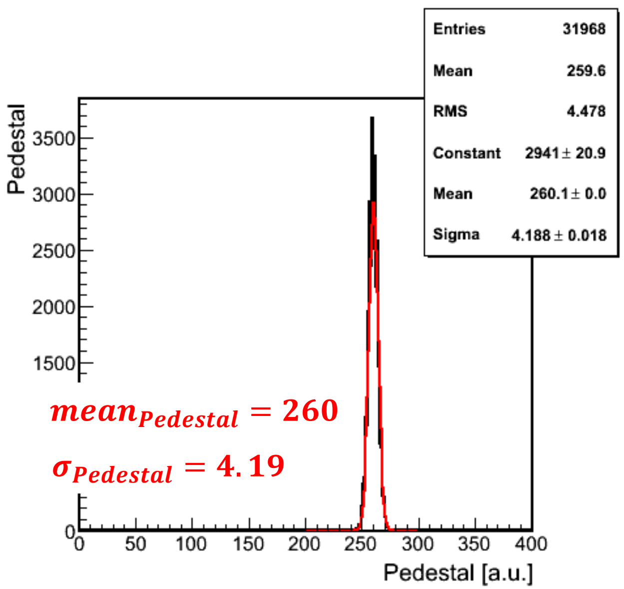
MPV_S/N = 67.06

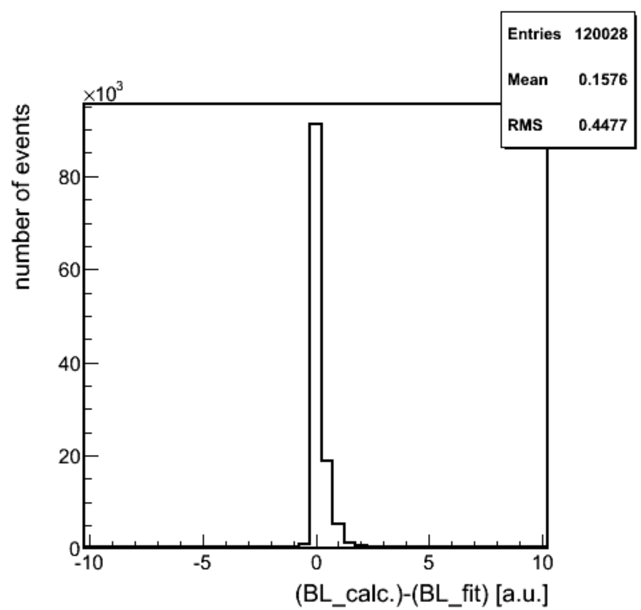
Parameters distributions after the fit

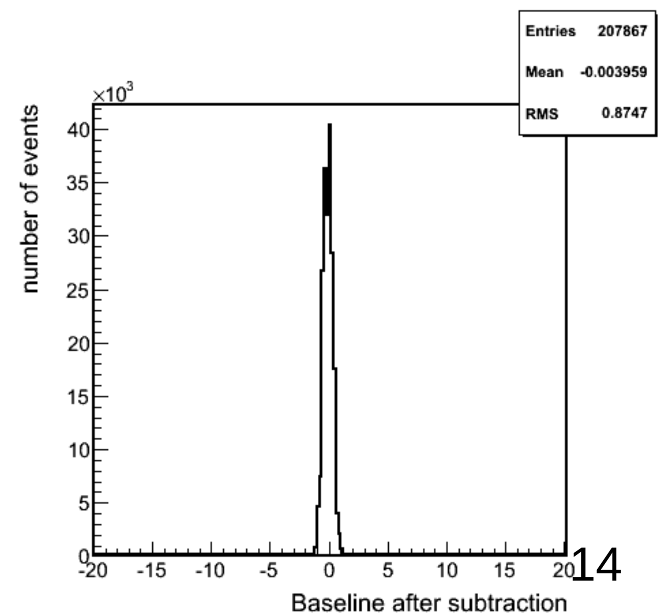
Channel 9 – Synchronous Mode



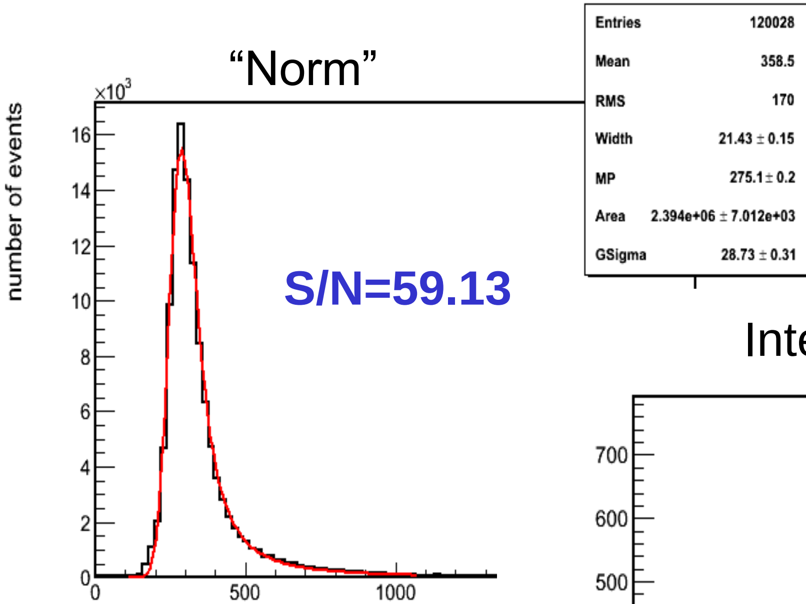


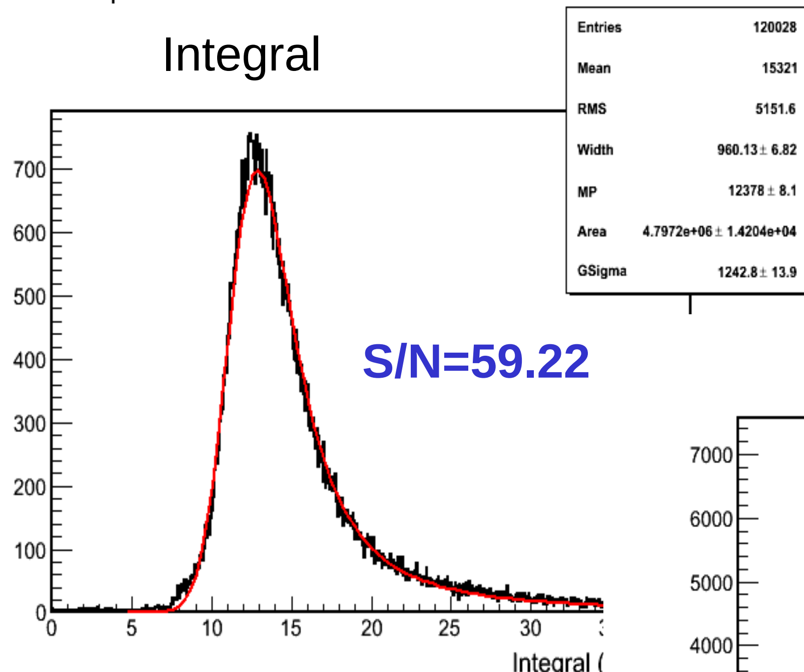


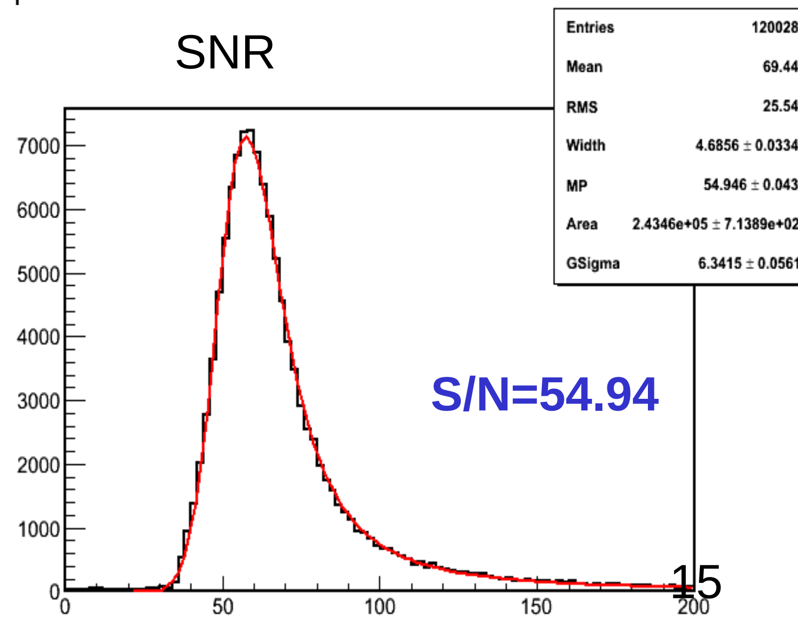




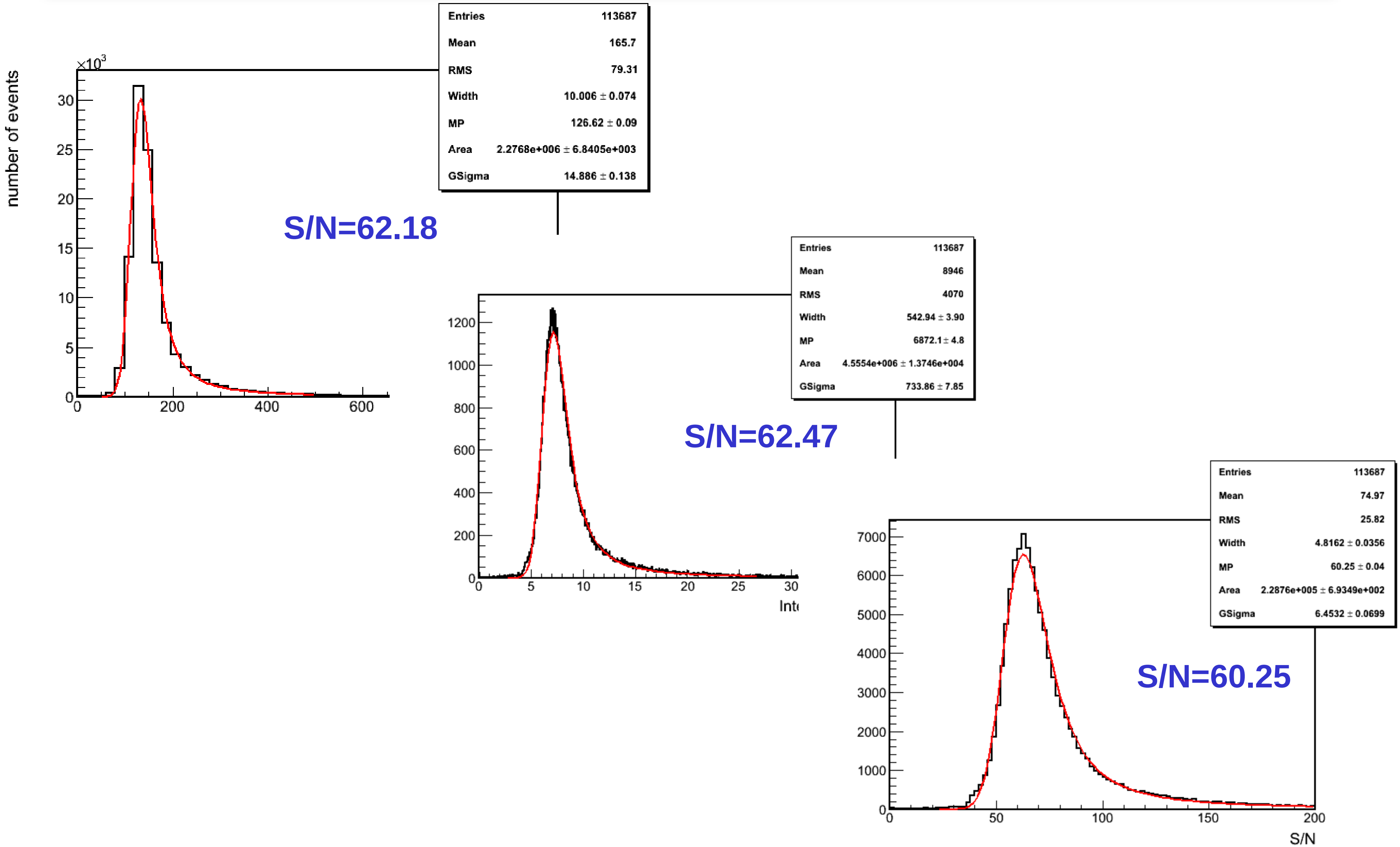
SNR: Channel 9 - Synchronous





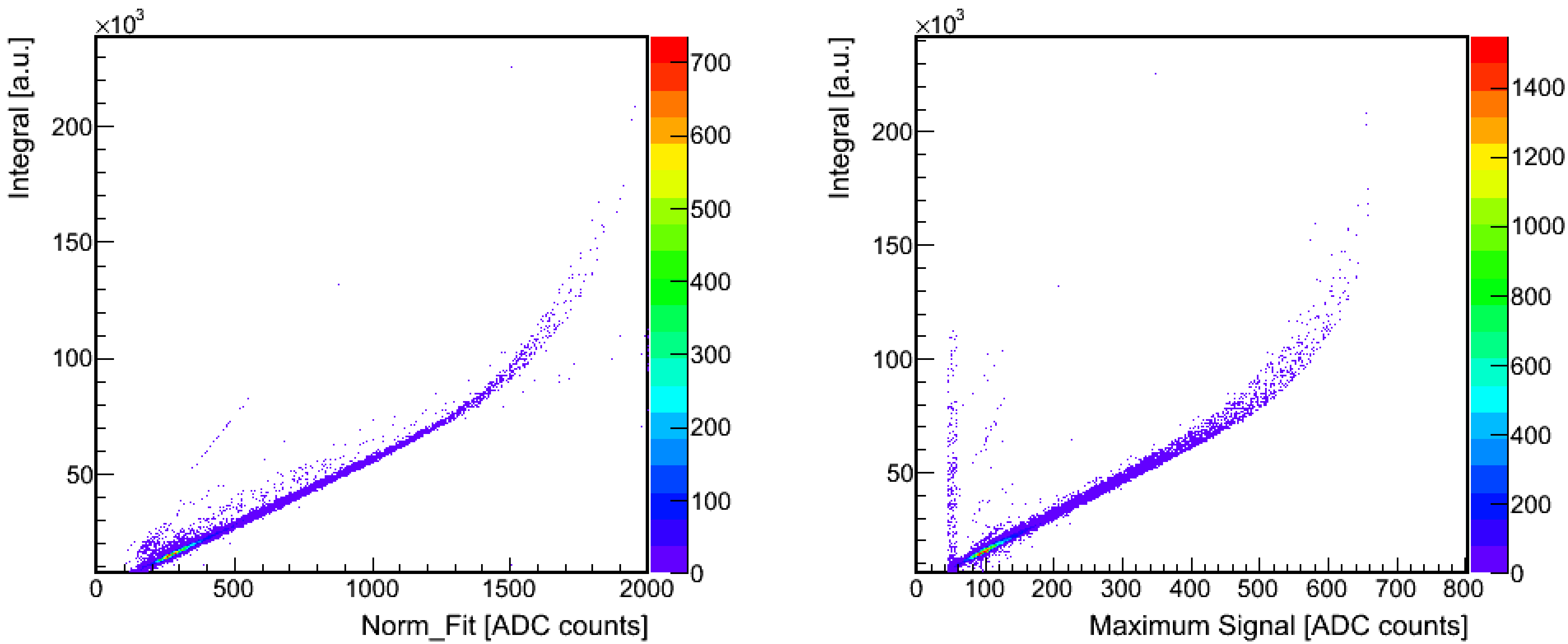


SNR: Channel 5 - Synchronous



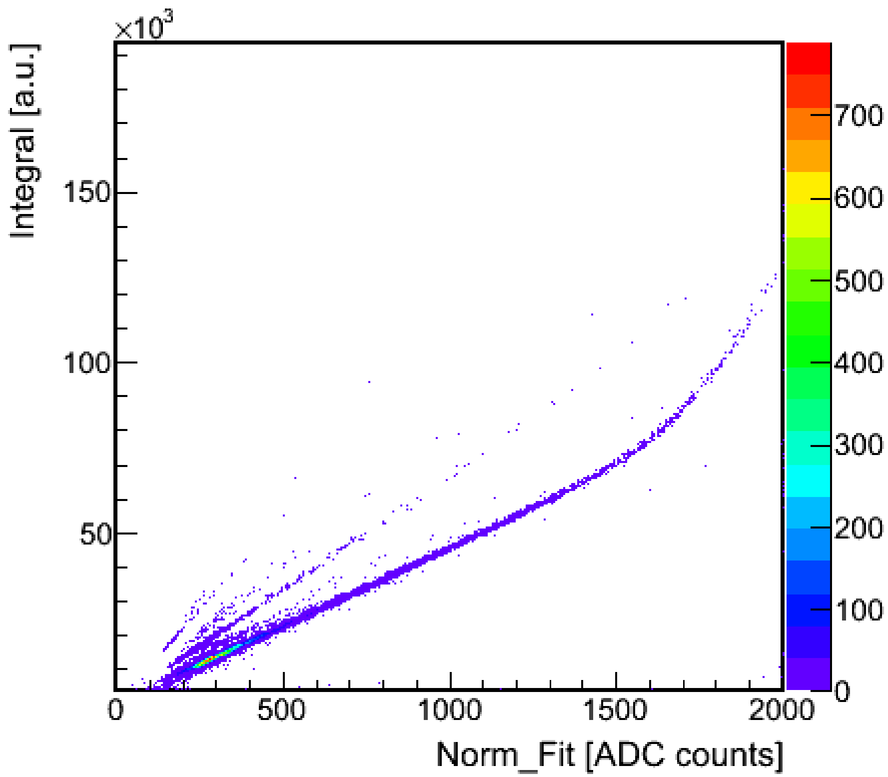
Correlations

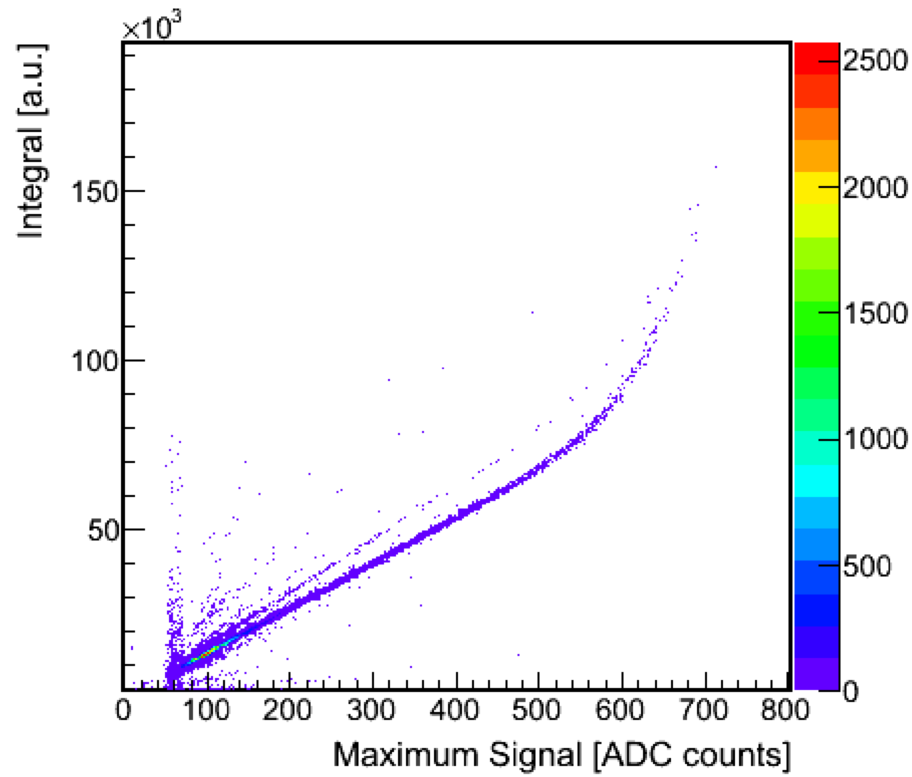
Channel 9 – **Asynchronous Mode**



Correlations

Channel 9 – Synchronous Mode





Conclusions

- Using the integration method, the SNR has been evaluated for two of the BeamCal module pads
  - Pad 10 (Channel 9) – high gain
  - Pad 6 (Chanel 5) – low gain

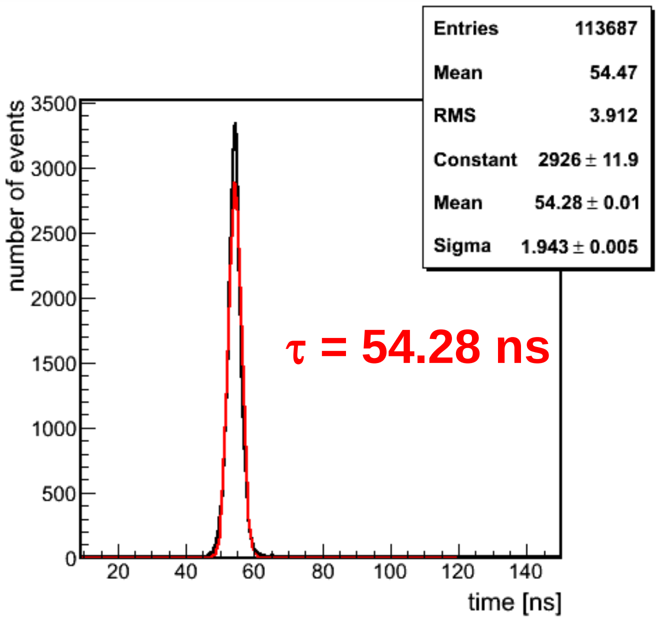
- Channnel 9- two cases:
  - Asynchronous mode
  - Synchronous mode

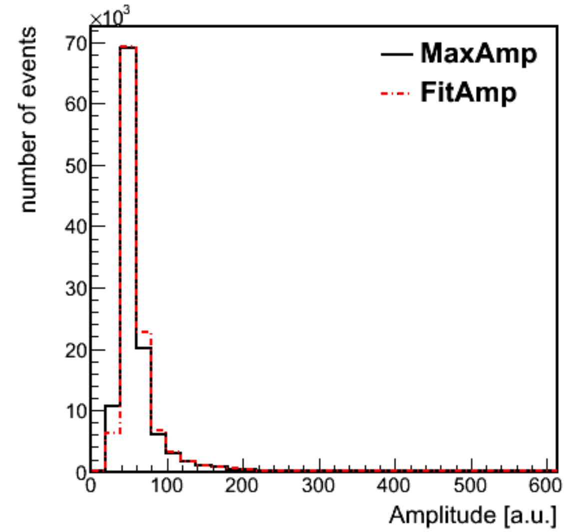
- SNR~67 for Channel 9 in sync mode
- SNR~59 for Channel 9 in async mode
- SNR~62 for Channel 5 in sync mode

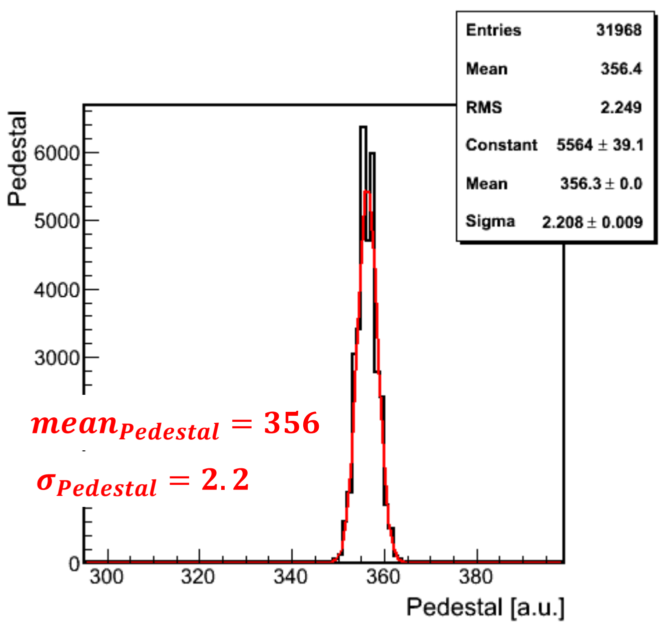
Backup slides

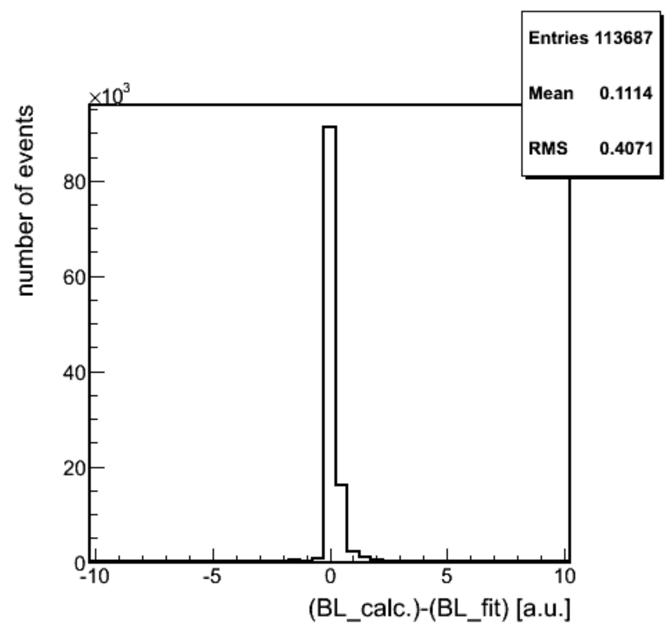
Parameters distributions after the fit

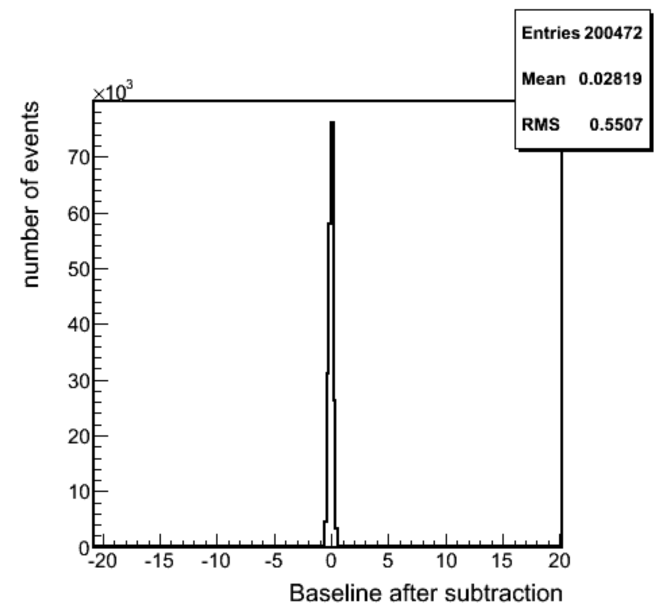
Channel 5 – Asynchronous Mode











Correlations

Channel 5 – **Asynchronous Mode**