Update on testbeam data analysis using the integral method

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Overview

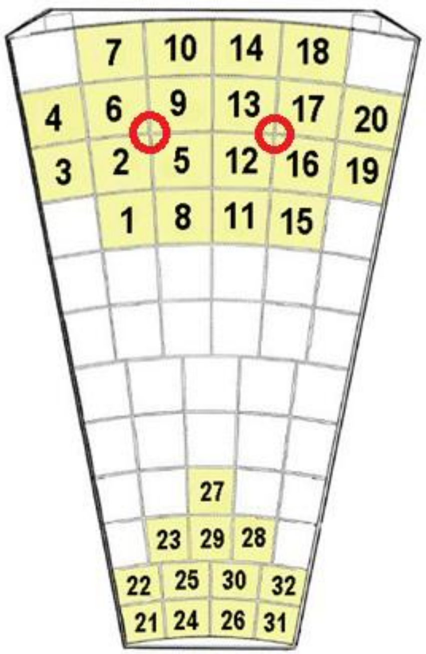
- Beam-test w.r.t. BeamCal
- My objective – estimate SNR using integral method
- Considerations on signal shape function
- Signal
- Noise
- Signal to Noise Ratio = SNR
- Conclusions

2011 Beam-Test w.r.t. BeamCal

Goal - behavior 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.



For this study:
Investigated data collected with ASIC ADC (50 ns sampling) – un-synchronized to the beam clock

Compared results with synchronized data

My objectives

Characterization of all 32 BeamCal sensor pads

- **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:

$$S/N = \frac{Signal}{\sigma_{Pedestal}} = \frac{MPV_{Integral[ns]}}{\sigma_{Pedestal}}$$

Baseline Stability

Dependence of the baseline with the temperature:

> width

> mean value

Signal

Signal shape function

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

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 (t), shaping time

Fitting parameters

- Maximum:

  t =τ

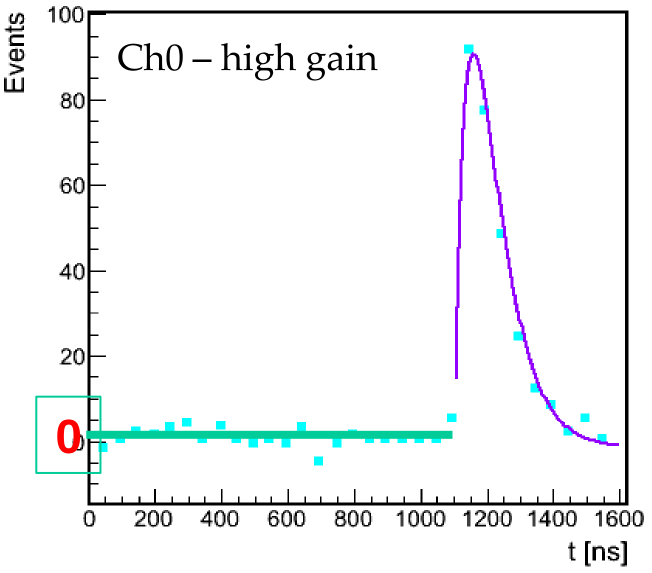
- Amplitude:

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

- Area under the curve (integral):

  $\boldsymbol{F(a) = V_0 (exp(-a/\tau)(a + \tau) - \tau)}$, a = integration window

Fit Procedure and constraints



1. Calculate Pedestal & CMN
2. Subtract pedestal & CMN
3. Fit if:

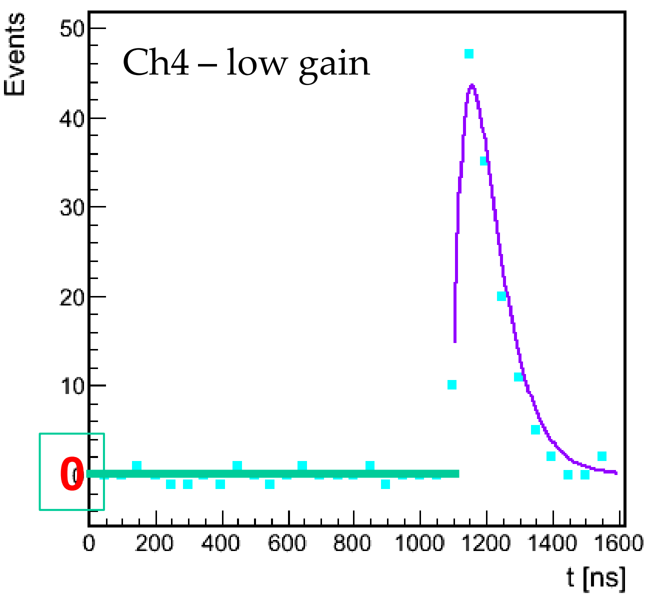
{

Signal > $5 * \sigma_{Pedestal}$

Relative Parameter Error < 50%

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

}



One more step to SNR

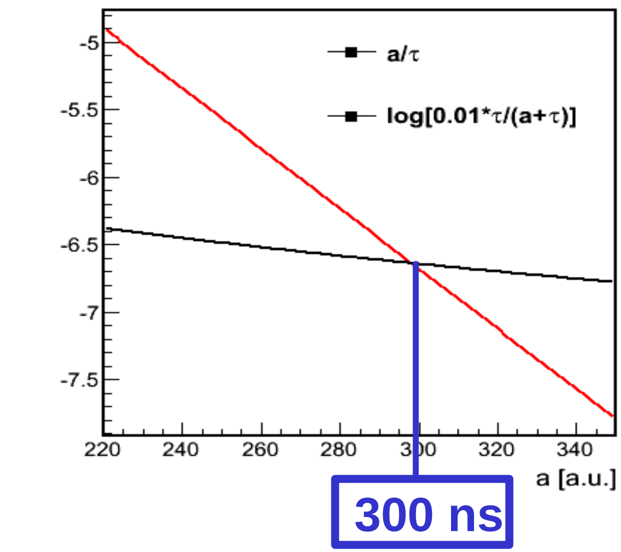
Calculate the integral

Integration window – graphical solution

- **Area under the curve (integral):**

$$F(a) = V0\,(exp(-a/\tau)(a+\tau) - \tau)$$

Determine a (τ= 60 ns - fixed)



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

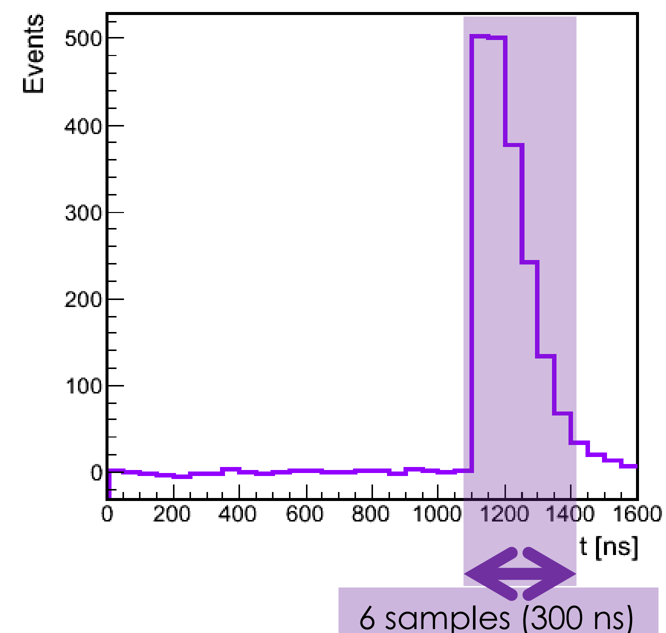
"a" = integration window: when area under the curve reaches 99% of it's (theoretical) maximum

Graphical solution - solve:

Eq. 1 $$\ln\left(\frac{0.01*t}{a+t}\right) = -\left(\frac{a}{t}\right)$$

a~300 ns:

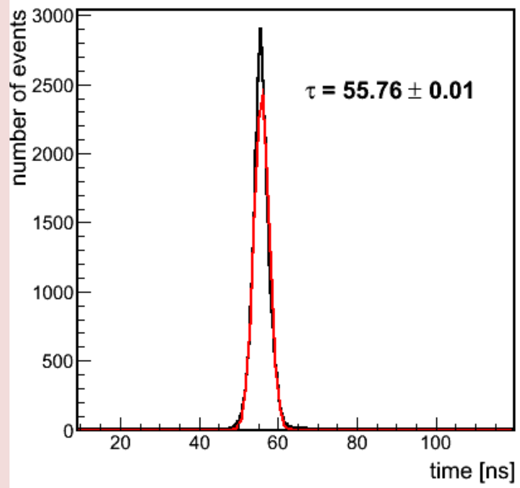
- *Integration window ~6 samples*
- *Same window used to calculate pedestal*

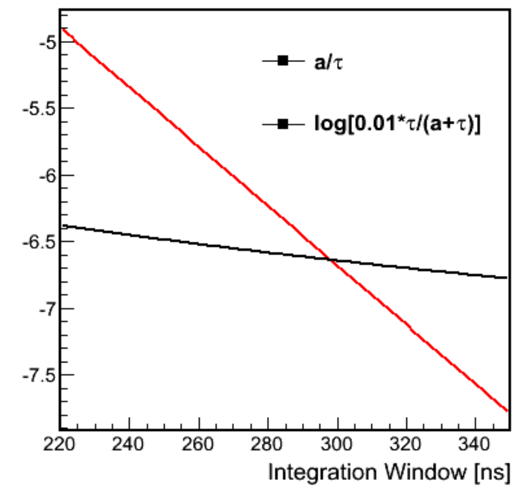


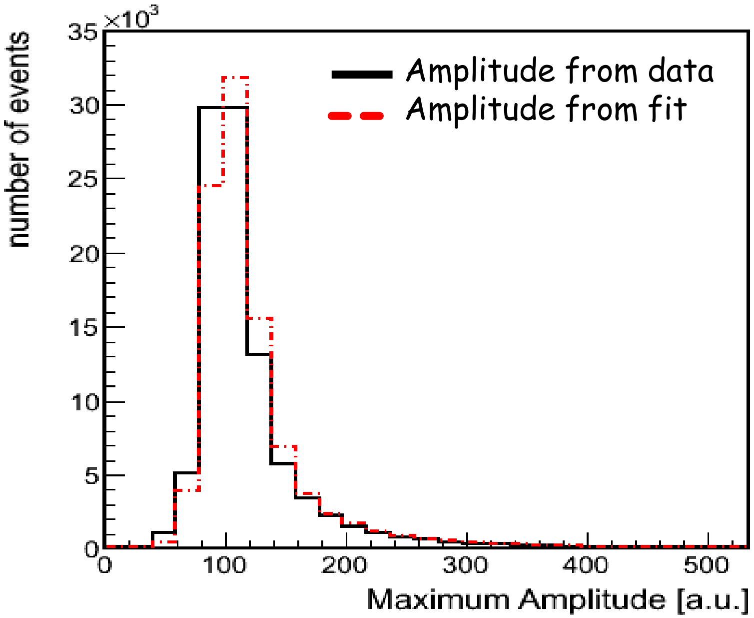
Parameters distributions after the fit

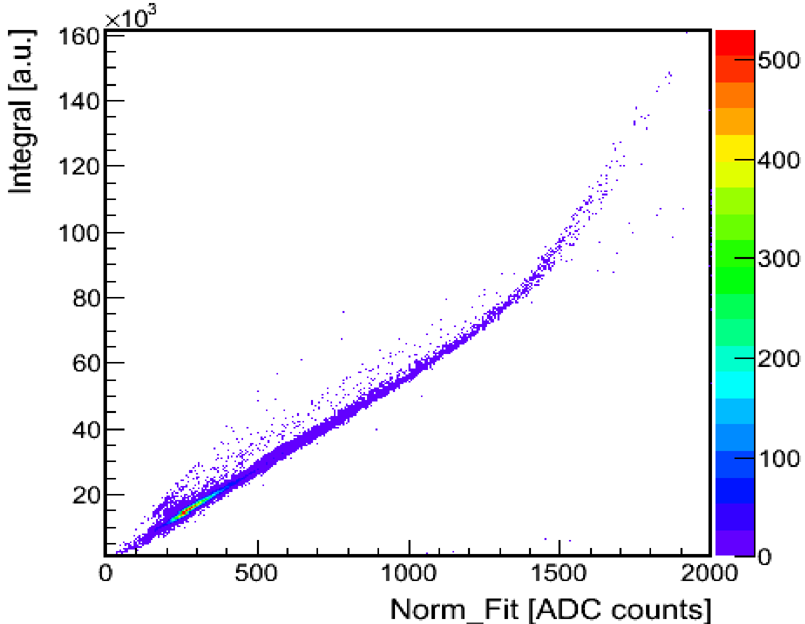
- τ is free in the fit
- The fit method overestimates a bit the amplitude of the signal
- Strange effects in the correlation between integral / amplitude extracted from the fit

What happens if τ=fixed?



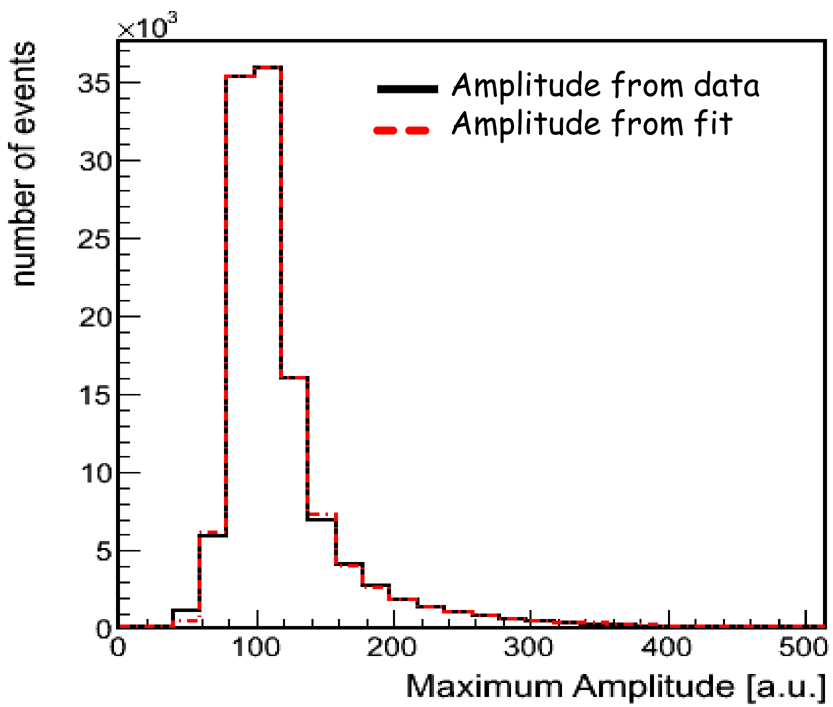


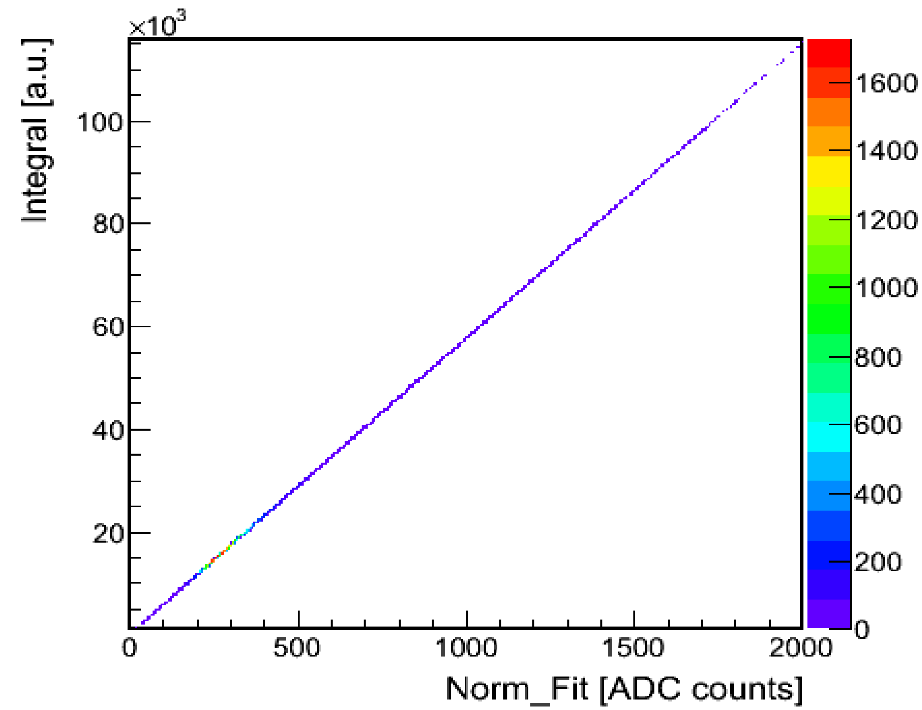




Parameters distributions after the fit

Fixed τ: τ = 60 ns



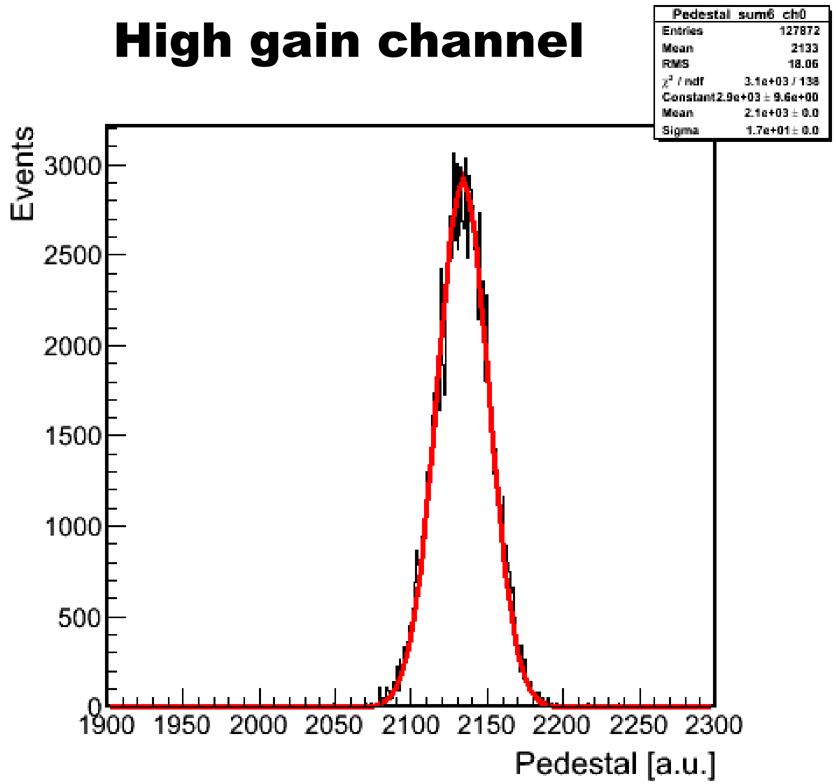


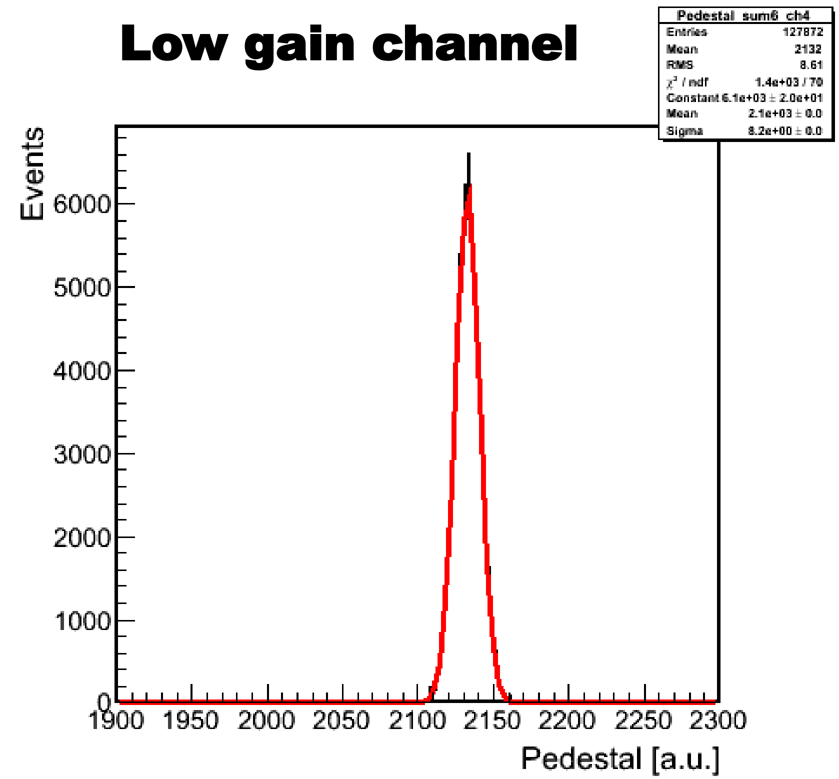
The signal shape function estimates the amplitude more accurately
Good correlation between the integral and amplitude

Noise

Pedestal distribution

Same window as for the signal integration is used (6 samples)



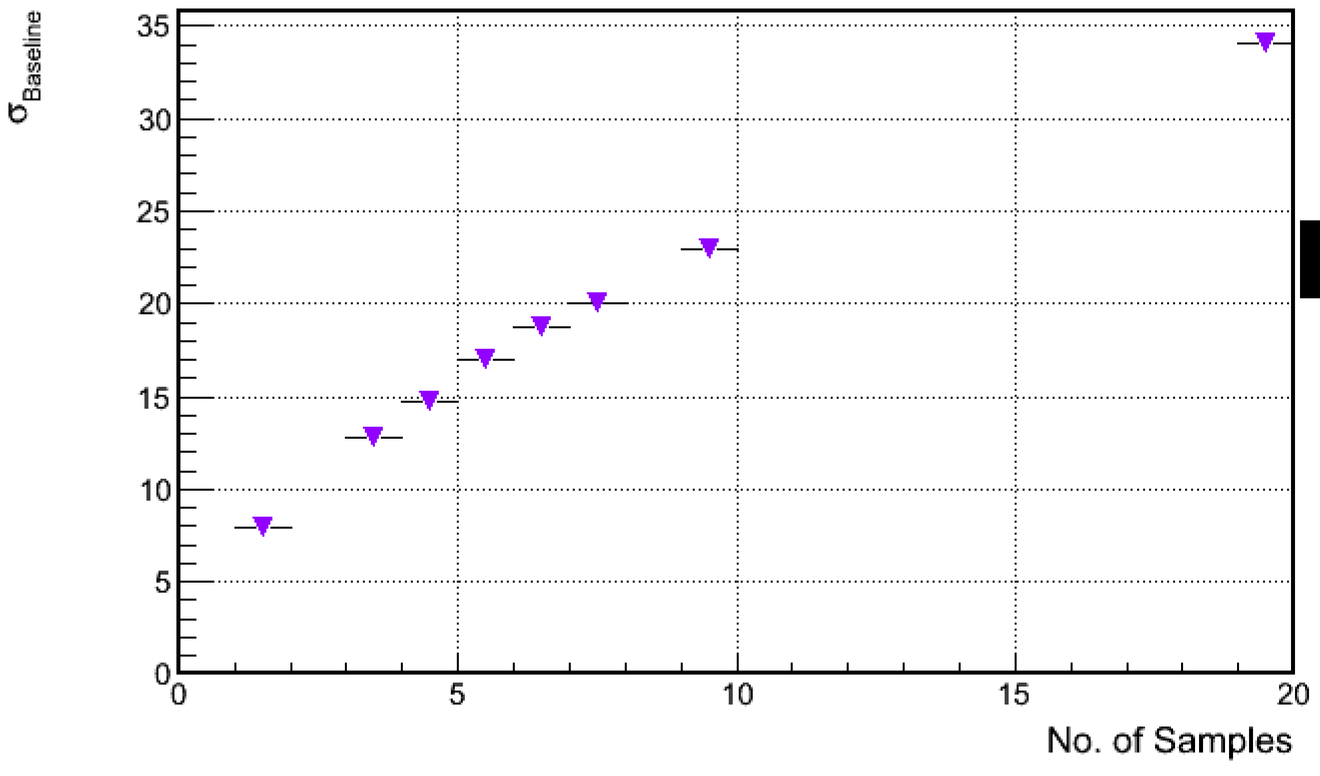


$\sigma_{Pedestal} \approx 17$ – for the high gain channel

$\sigma_{Pedestal} \approx 8$ – for the low gain channel

Pedestal distribution

Distribution of the pedestal width as a function of the Integration Window

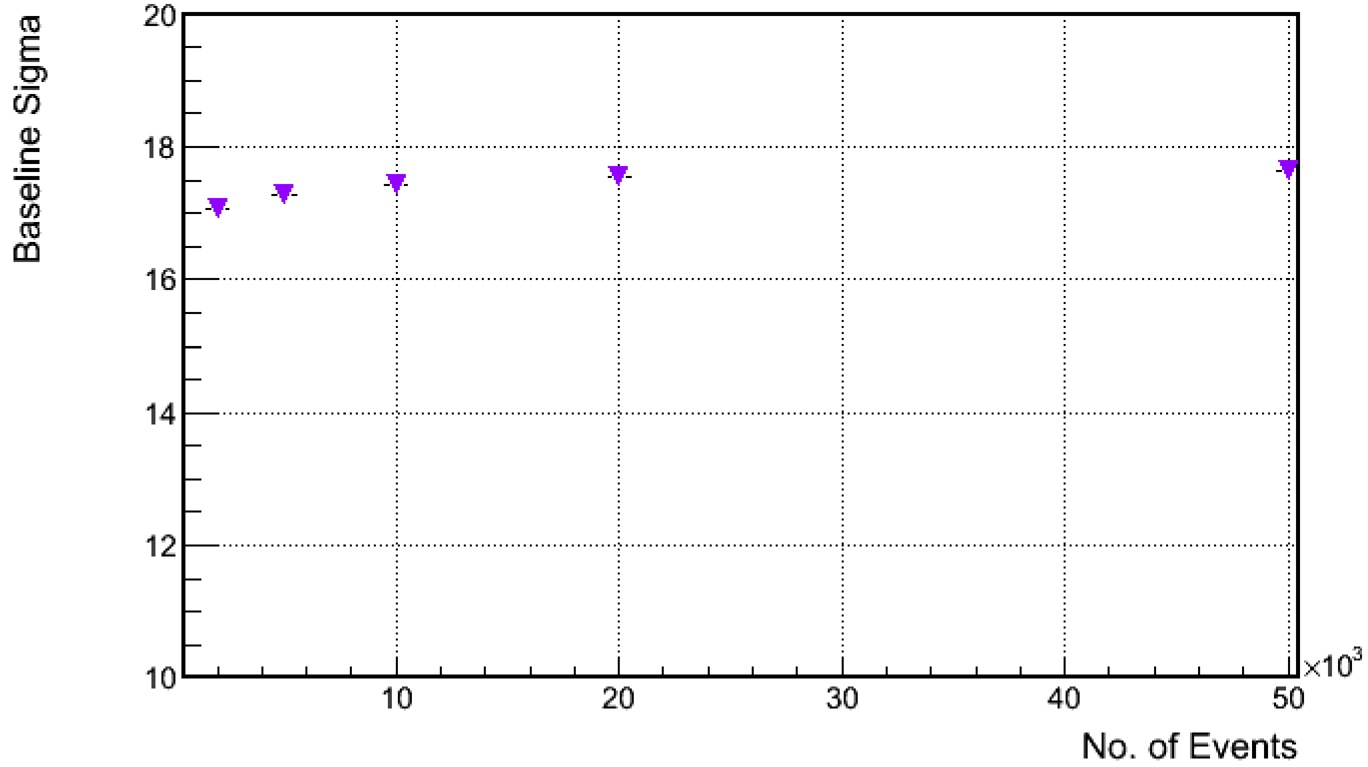


1 sample = 50 ns

Clear variation of the pedestal width with the chosen integration window

Pedestal distribution

Distribution of the pedestal width as a function of the Number of events considered for evaluation



$\sigma_{Pedestal}$ **is stable with respect to the number of events**

To save processing time - used 1000 events to estimate the pedestal width

Signal To Noise Ratio

SNR Calculation

For each event - calculate signal integral:

$$F(a) = V0\,(exp(-a/\tau)(a+\tau) - \tau)$$

↓

Signal Integral distribution for all events in one pad

↓

Fit with Landau + Gauss

↓

Determine MPV

Estimate $\sigma_{Pedestal}$ using the same integration window as for the signal

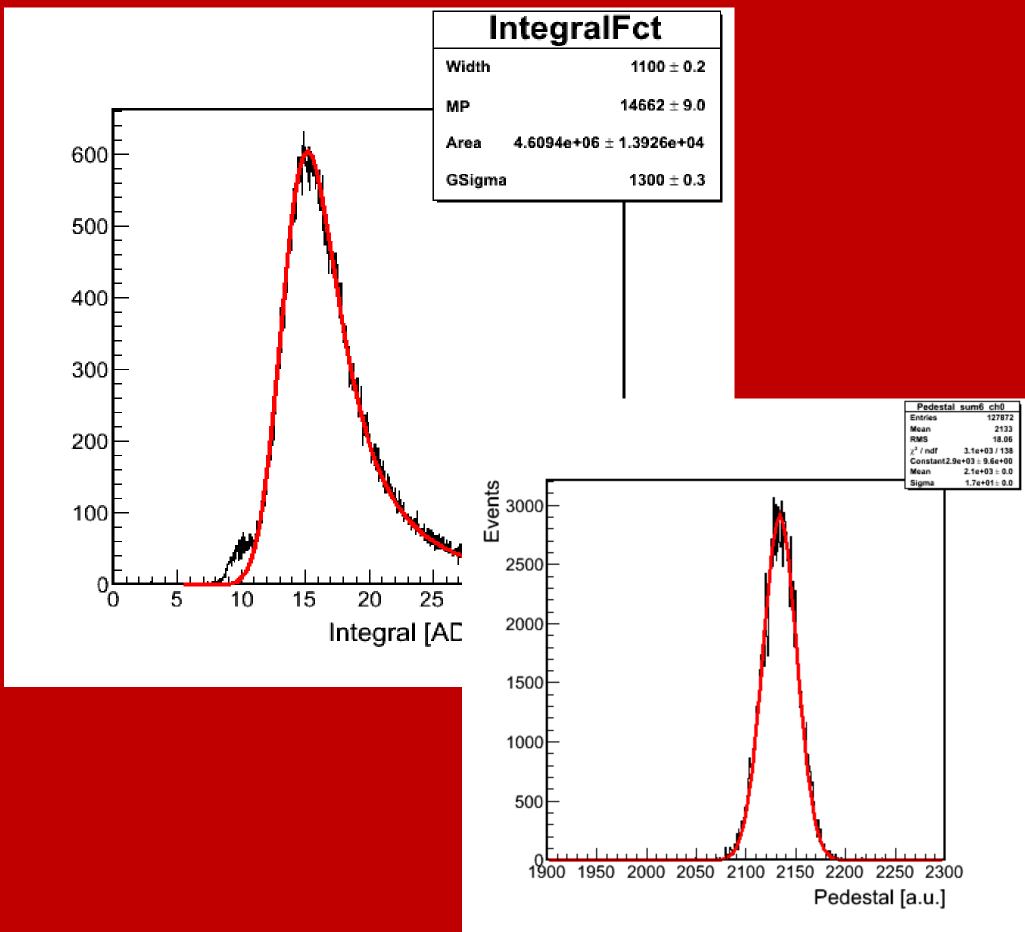
Calculate SNR:

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

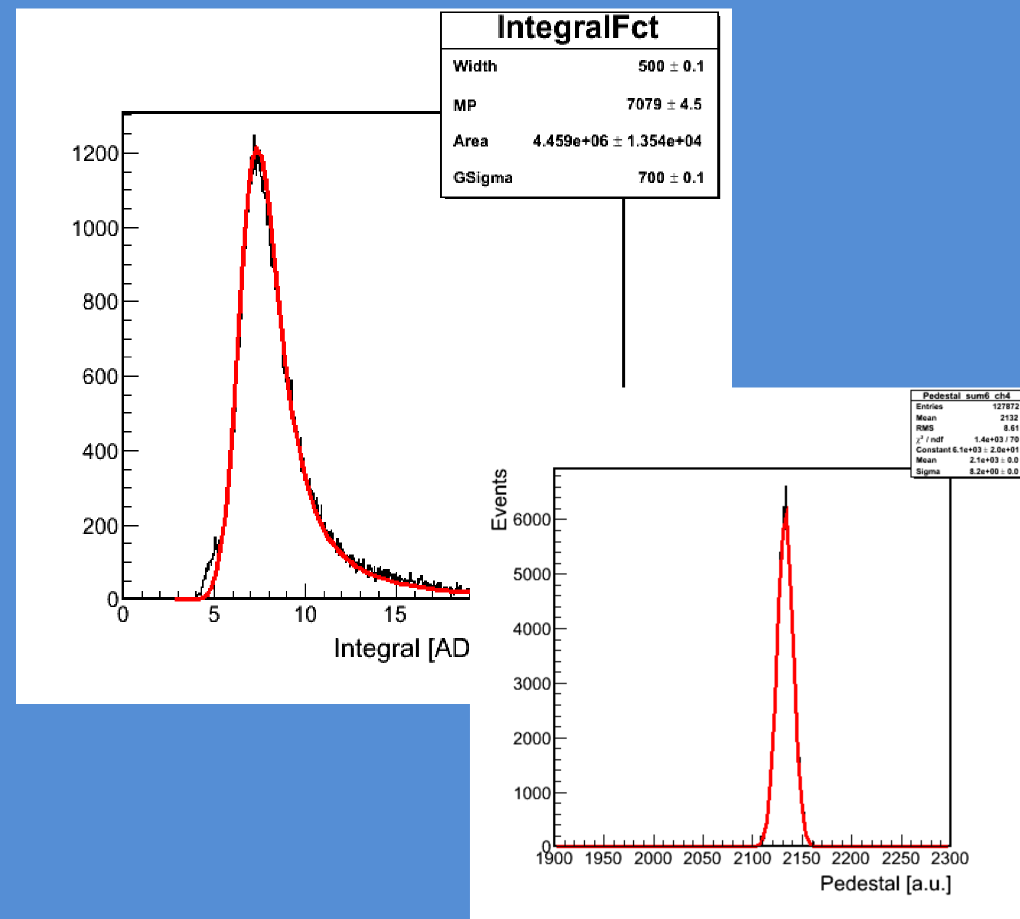
Integral and pedestal distributions

Asynchronous mode

High gain channel



Low gain channel



Example of SNR calculation – high gain channel:

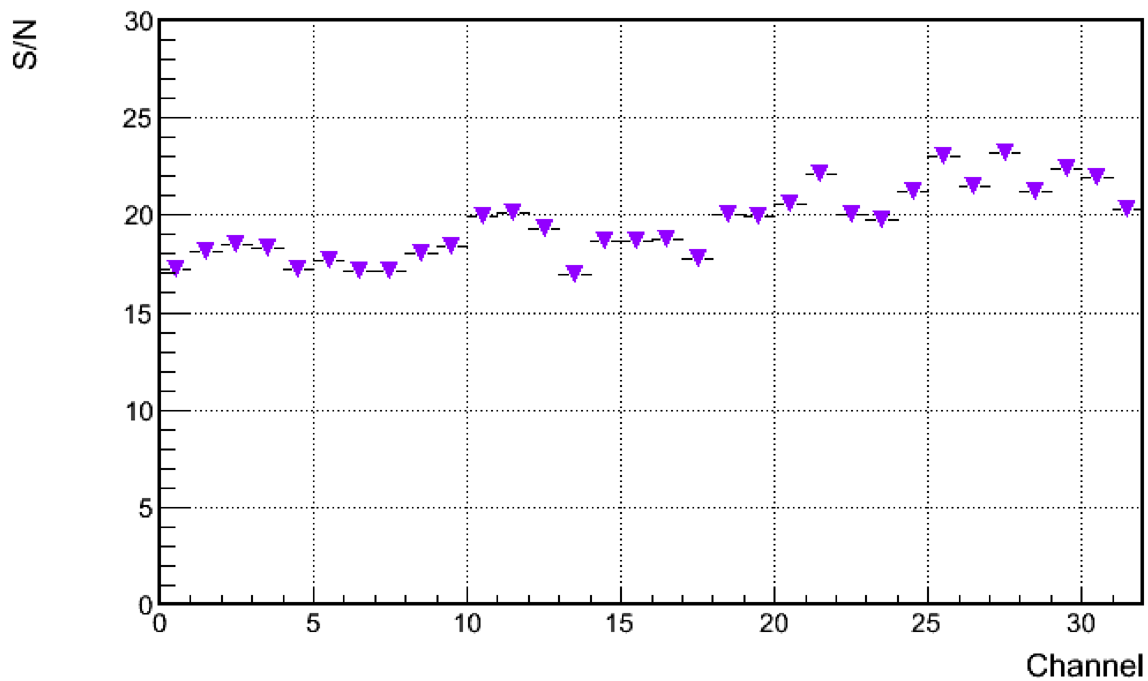
$MPV_{Integral}$ = 1.4662 ADC_{counts}*ns = 293.243 ADC_{counts}*sample

$\sigma_{Pedestal}$ = 17.05

S/N = 289.28/17.0479 = 17.209±0.09

Signal to noise distribution

Data collected for uniformity scan of the 32 pads
> ~200000 events/pad in asynchronous mode



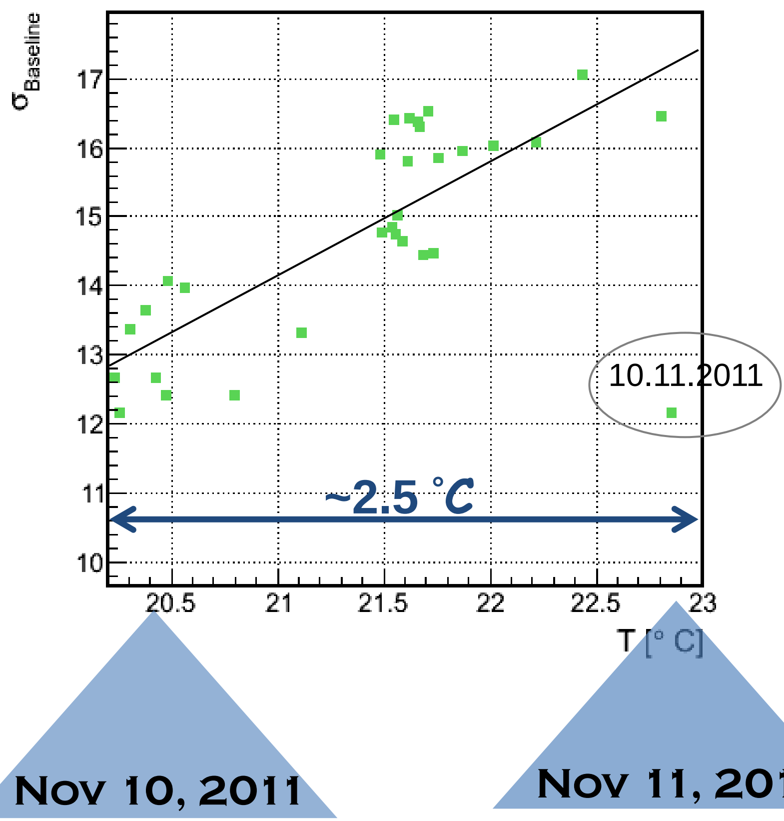
Pad	SNR	SNR Error
1	SNR = 17.2011	0.0914206
2	SNR = 18.0991	0.0355596
3	SNR = 18.4889	0.0365008
4	SNR = 18.3039	0.0362718
5	SNR = 17.2012	0.188541
6	SNR = 17.6279	0.0309874
7	SNR = 17.1548	0.0328447
8	SNR = 17.1556	0.0354785
9	SNR = 18.0192	0.0347569
10	SNR = 18.3819	0.0364855
11	SNR = 19.9502	0.0426264
12	SNR = 20.1503	0.0436353
13	SNR = 19.3055	0.0295797
14	SNR = 16.9379	0.0307132
15	SNR = 18.683	0.0355994
16	SNR = 18.6226	0.0322855
17	SNR = 18.7345	0.106576
18	SNR = 17.7276	0.0339501
19	SNR = 19.9792	0.0423869
20	SNR = 19.937	0.0294452
21	SNR = 20.536	0.0429176
22	SNR = 22.1238	0.0424119
23	SNR = 19.9766	0.0416106
24	SNR = 19.7116	0.0411397
25	SNR = 21.2325	0.0361981
26	SNR = 22.9877	0.0421648
27	SNR = 21.426	0.0371176
28	SNR = 23.2268	0.0444661
29	SNR = 21.2377	0.0414845
30	SNR = 22.3238	0.0465185
31	SNR = 21.9241	0.0400924
32	SNR = 20.2612	0.0407317

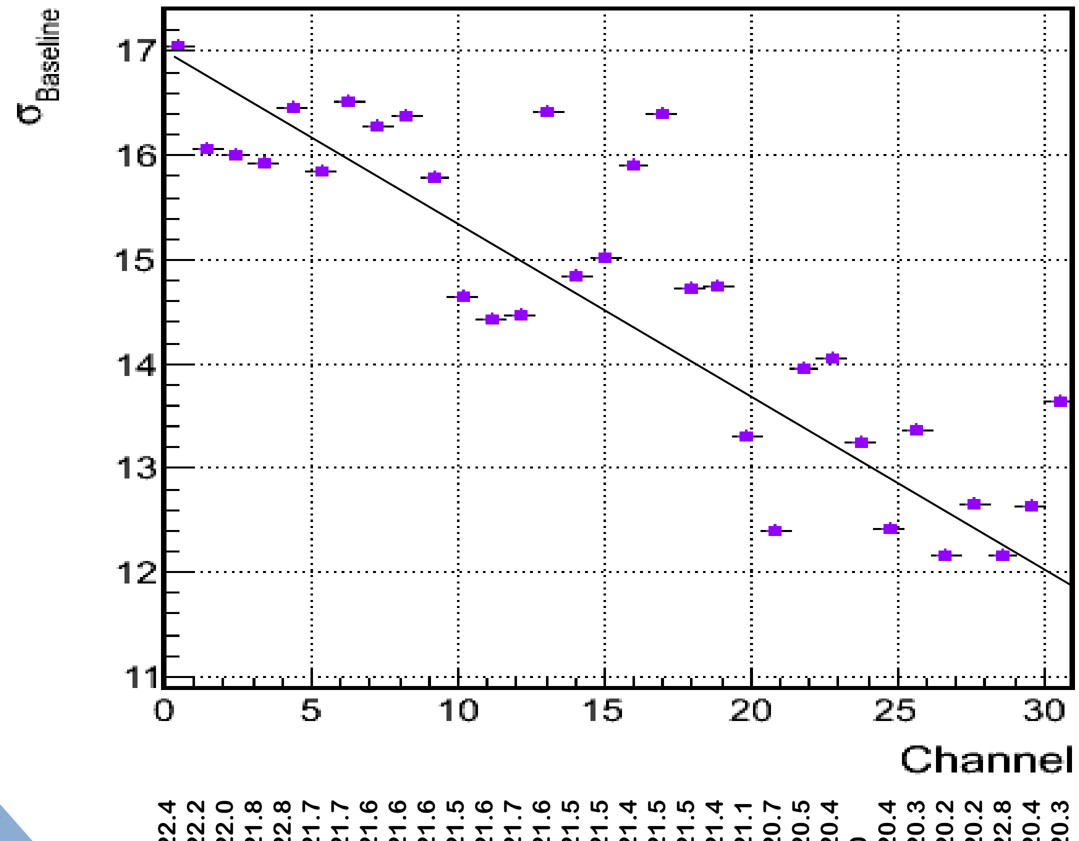
Slight increase in SNR from Pad 1 to Pad 32

Could be due to temperature?

$\sigma_{Baseline}$ variation with the temperature

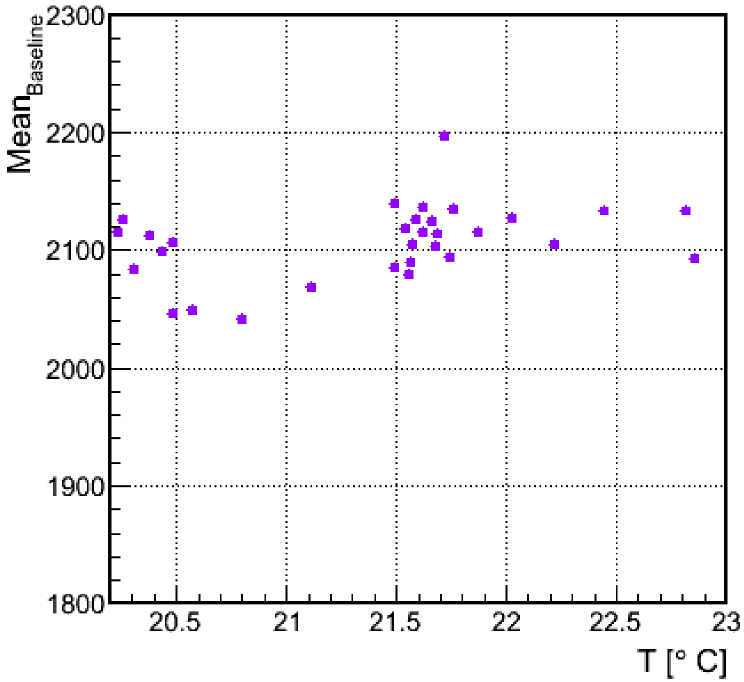
Left: Baseline width as a function of the temperature
Right: Baseline width corresponding to each pad (channel) – for each pad there is a measured corresponding temperature

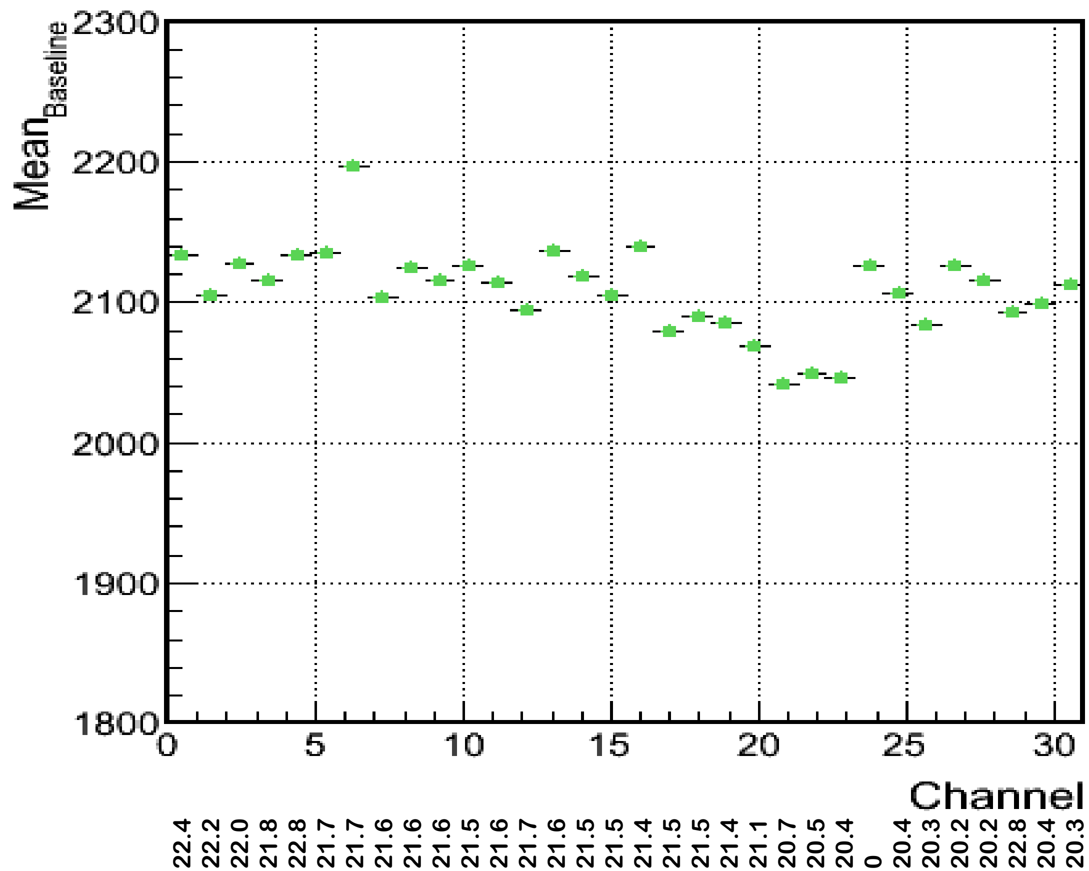




Decrease of $\sigma_{Baseline}$ with decrease of T[°C]!
Smaller $\sigma_{Baseline}$ results in larger SNR!

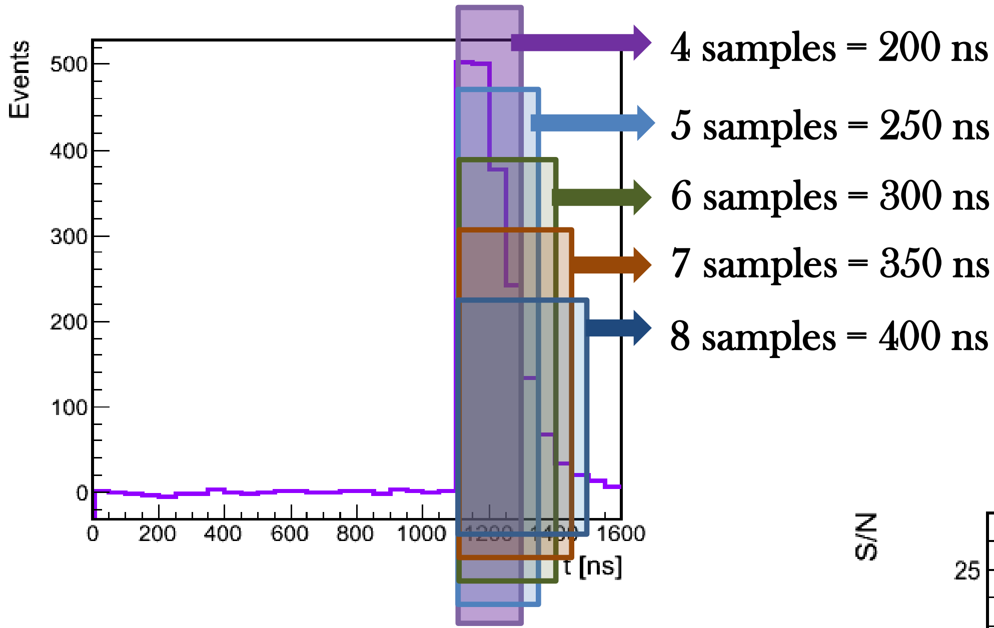
$Mean_{Baseline}$ variation with the temperature





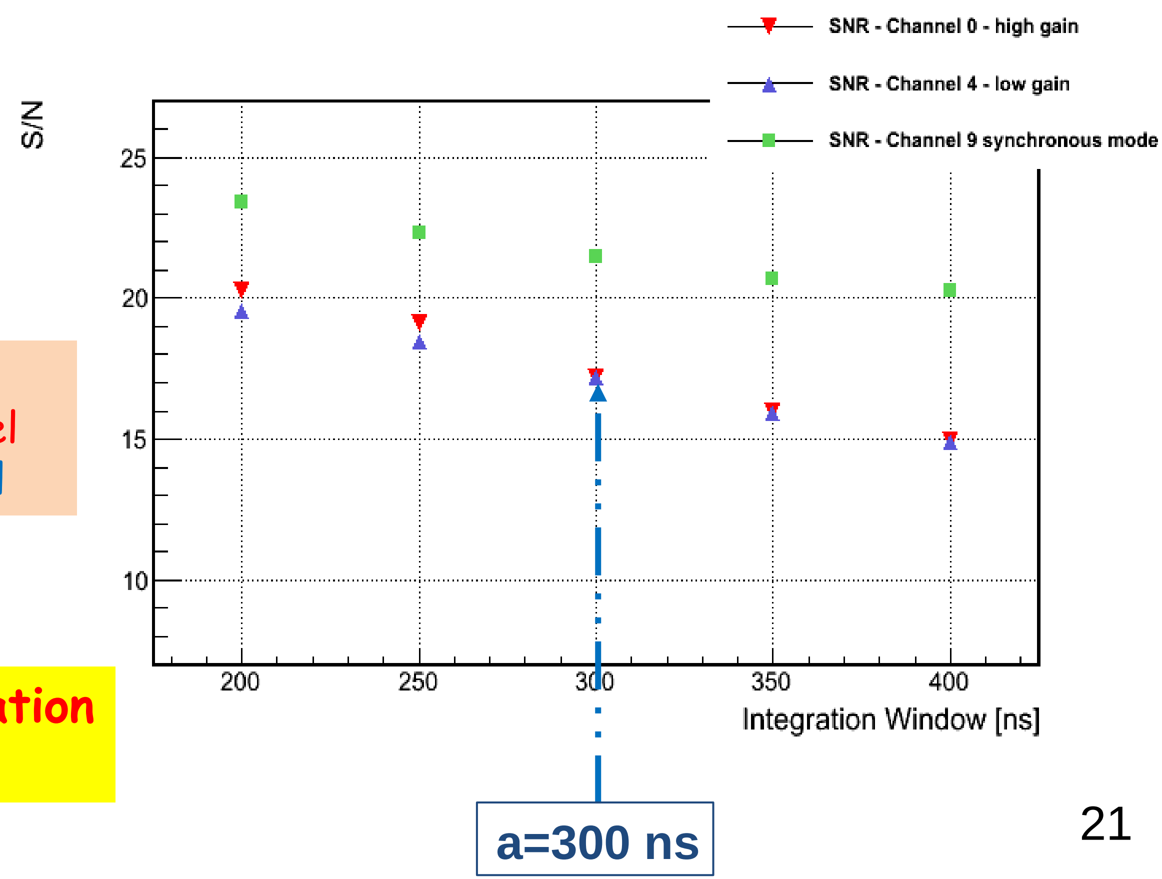
The mean value of the baseline appears to remain reasonably constant

SNR w.r.t. integration window



The graphical method resulted in a 300 ns integration window

How much can we change it so that we decrease the noise but do not loose too much signal?



Higher SNR for synchronized data (green)
Red – asynchronous data – high gain channel
Blue - asynchronous data – low gain channel

In all cases, the smaller the integration window, the greater the SNR

Conclusions

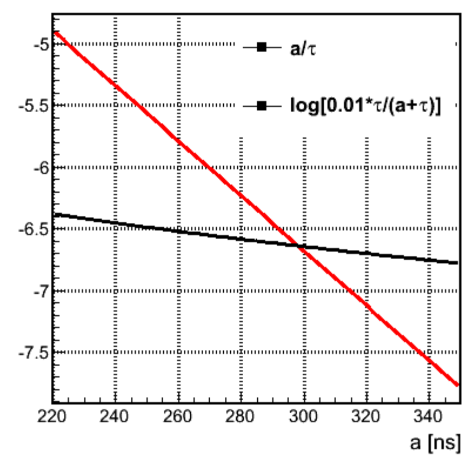
- Asynchronous and synchronous data collected during the November 2011 test-beam have been studied
- Using the integration method, the SNR has been evaluated for all of the BeamCal module pads
- Systematic increase of the SNR has been observed from Pad 1 to Pad 32
- Dependence of the pedestal width with the temperature could be the cause
- Is has been the established that the SNR increases when narrowing the integration window

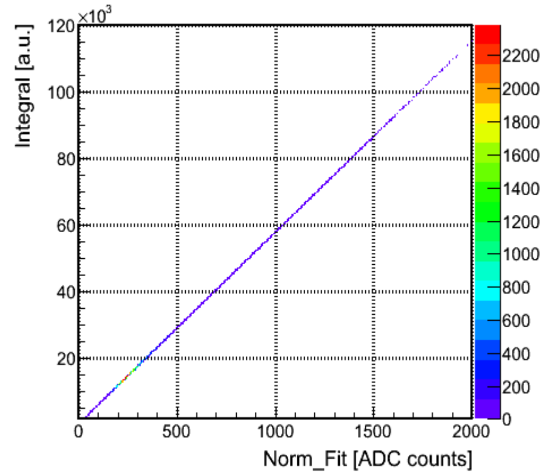
Thank you for your attention!

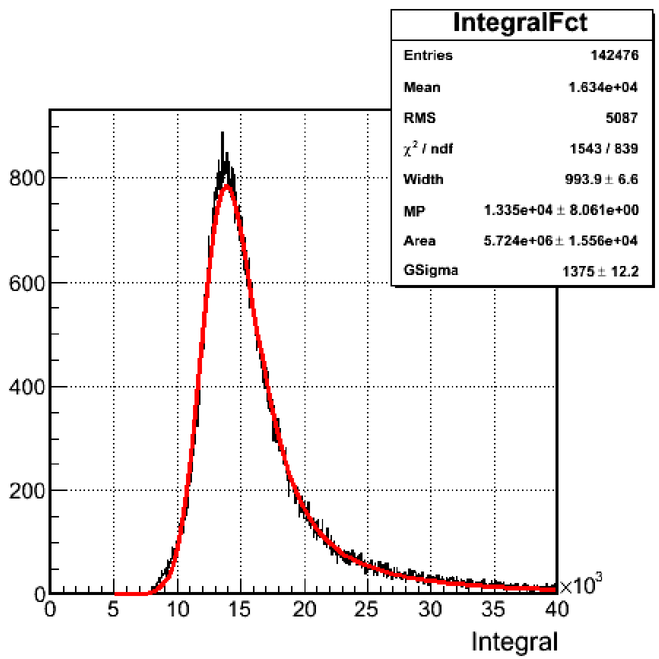
Backup slides

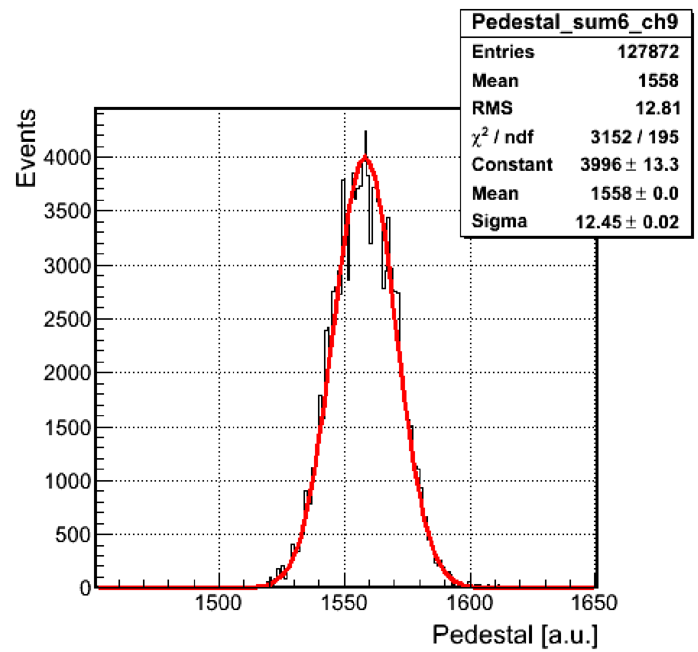
SNR for synchronized data

Tested the integral method on synchronous data for Channel 9 (Pad 10) – high gain









SNR = 21.44 ± 0.03

Zoom on the Signal to Noise distribution

SNR with errors