Detection of low-energy protons within the neutron β-decay spectrometer *a*SPECT

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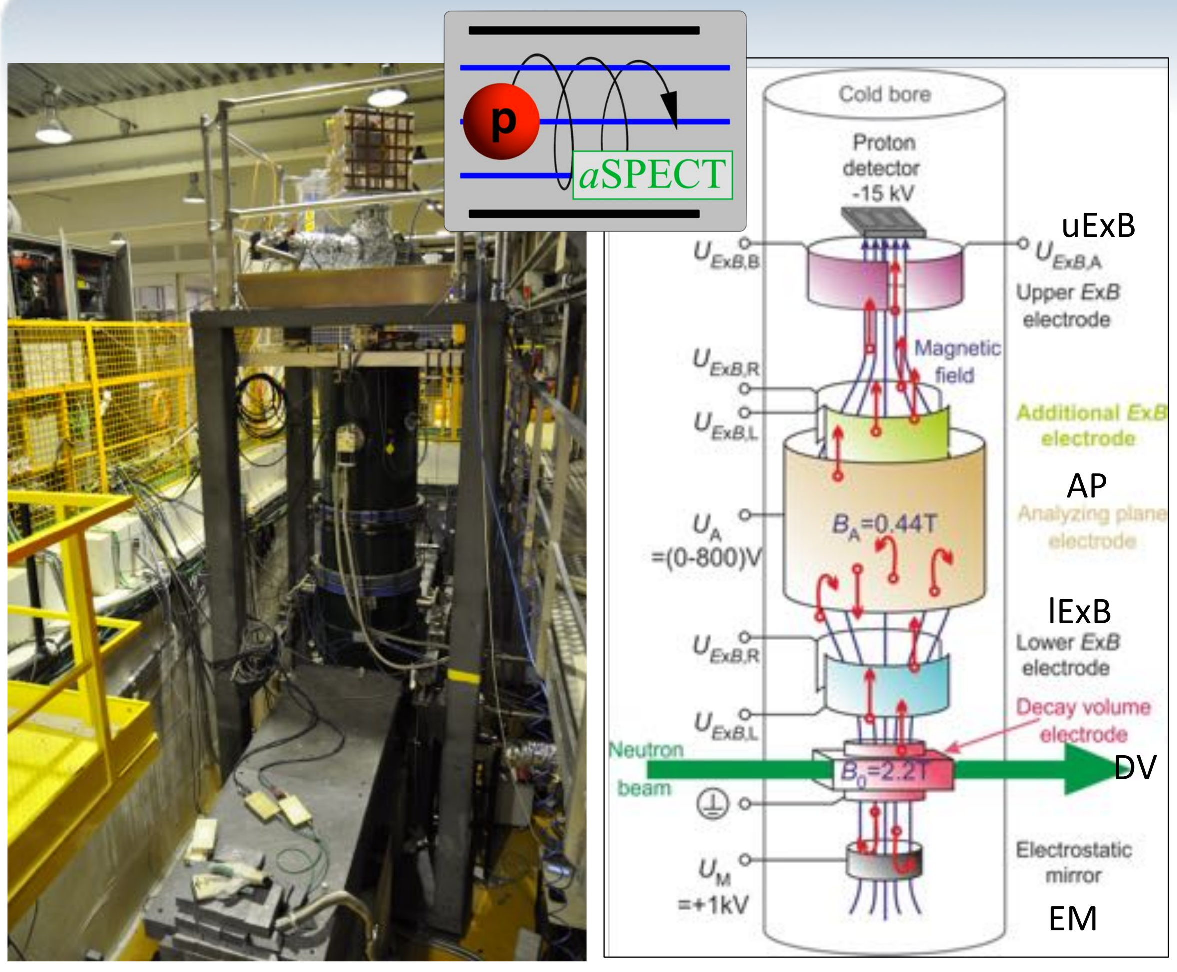
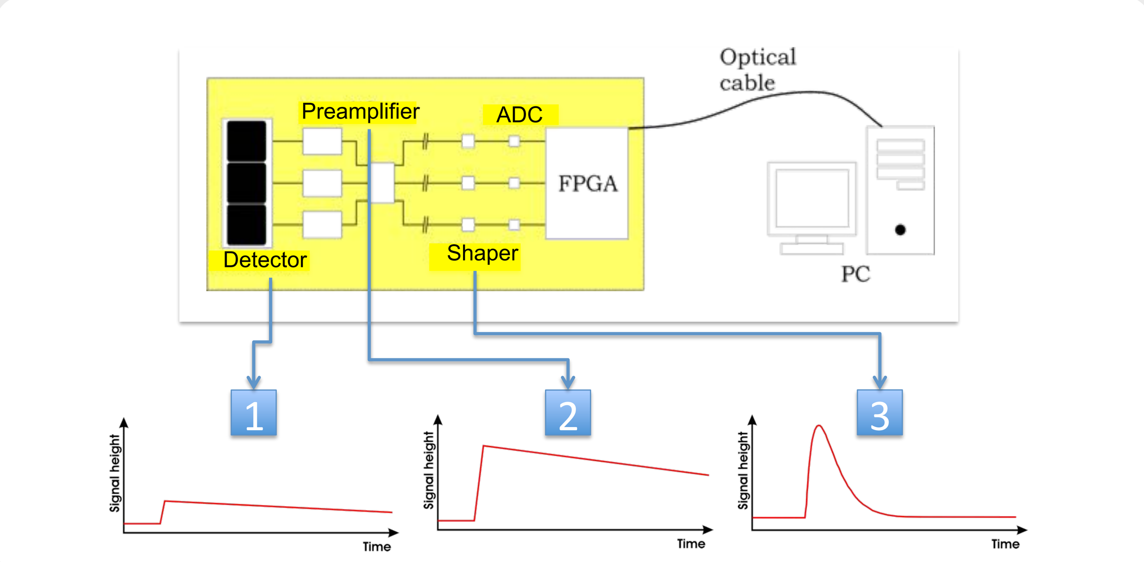
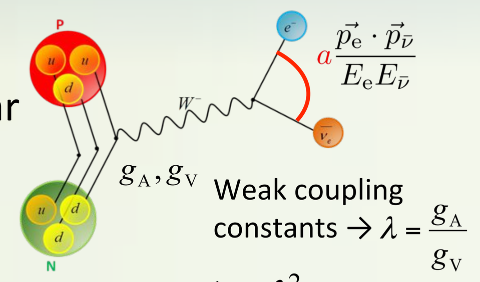




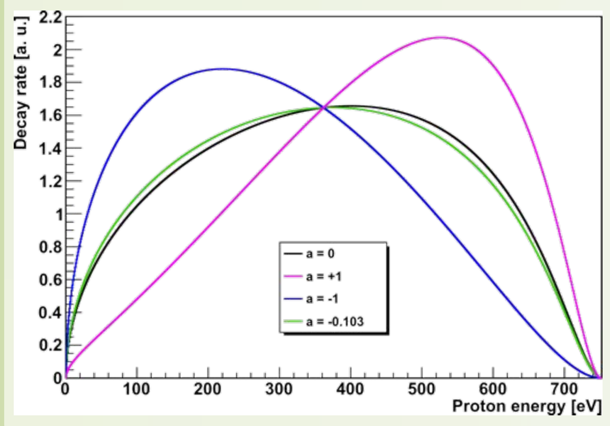
Experiment *a*SPECT

Measurement of the $\bar{\upsilon}_e - e^-$ angular correlation coefficient ***a*** with unprecedented accuracy.



Weak coupling constants $\rightarrow \lambda = \frac{g_A}{g_V}$

$$a = \frac{1-\lambda^2}{1+3\lambda^2}$$



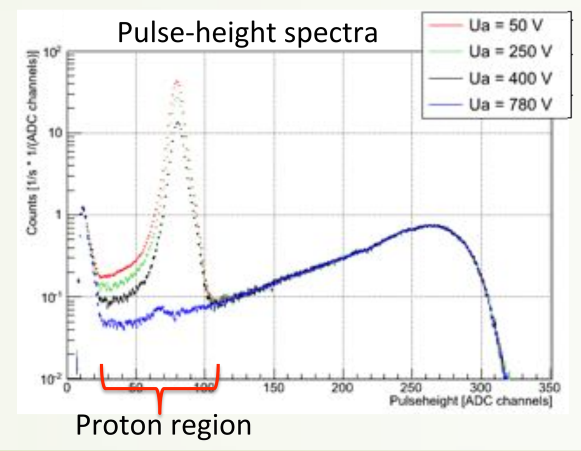
Proton recoil spectrum:

$$W_p(T) \propto g_1(T) + a \cdot g_2(T)$$

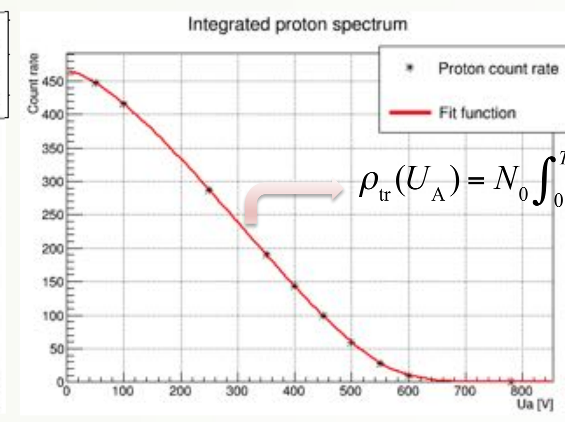
Endpoint energy: 751 eV

The retardation spectrometer [1]:

- Protons emitted from the DV are energy-selected by a variable potential barrier (U_A) at the AP electrode.
- Protons with sufficient energy are focused onto the detector and post-accelerated by a potential of -15 kV.



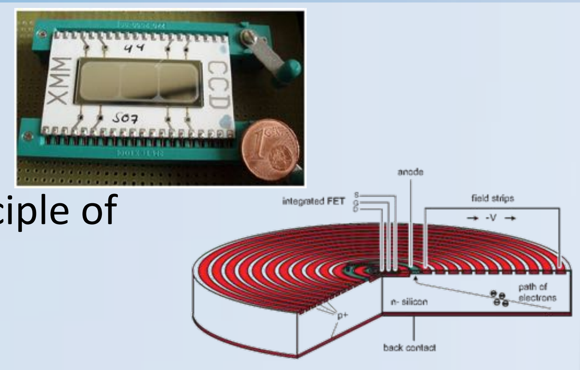
Proton region



$$\rho_{tr}(U_A) = N_0 \int_0^{T_{max}} F_{tr}(T) \cdot W_p(T) \cdot dT$$

Free parameters:
- N_0 (U_A = 0 V),
- Coefficient *a*,
- Offset

Detection of events in *a*SPECT

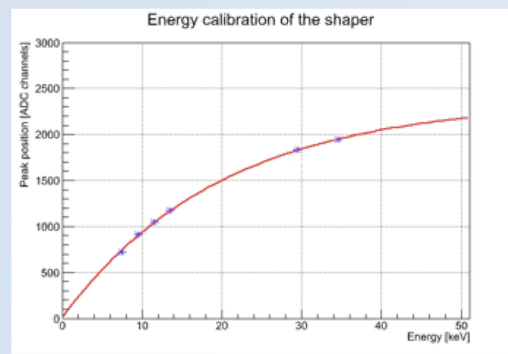


Silicon Drift Detector (SDD):

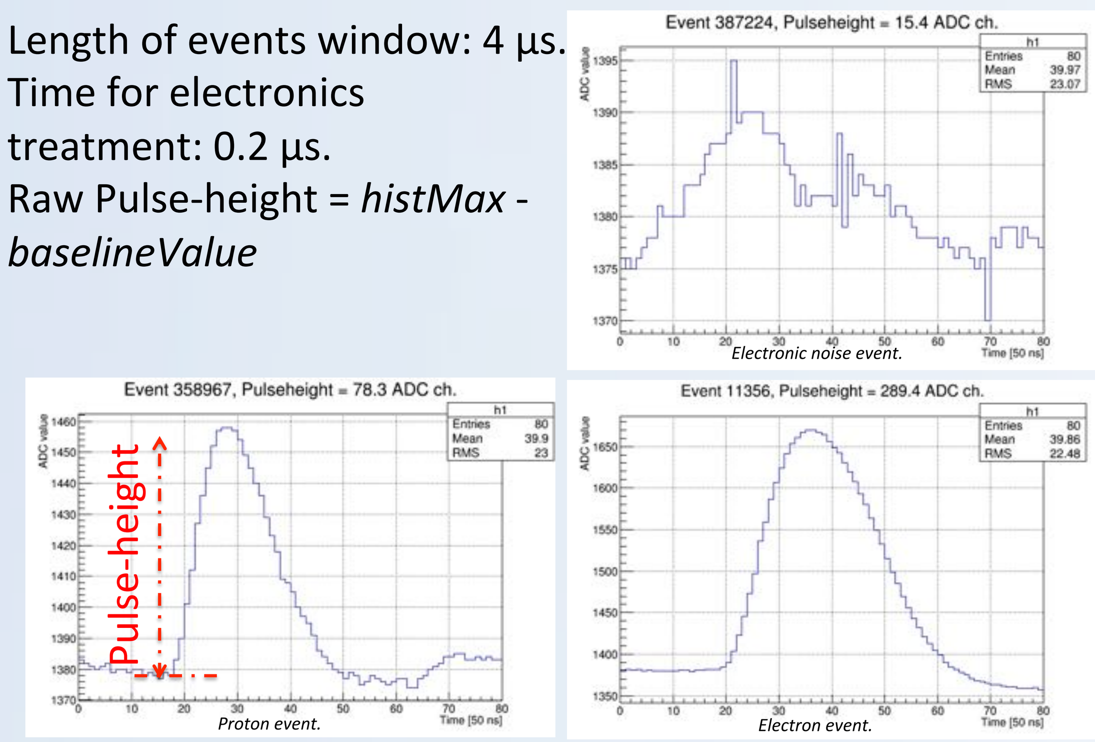
Semi-conductor detector based on the principle of sidewards depletion **[2, 3]**.

Electronic process:

Output signal from the detector 1 is directly amplified by the **preamplifier** 2. Then, the signal is treated by an adapter board, the **shaper** 3 : amplification non-linear for high-energy events to avoid saturation effects **[4, 5]**.

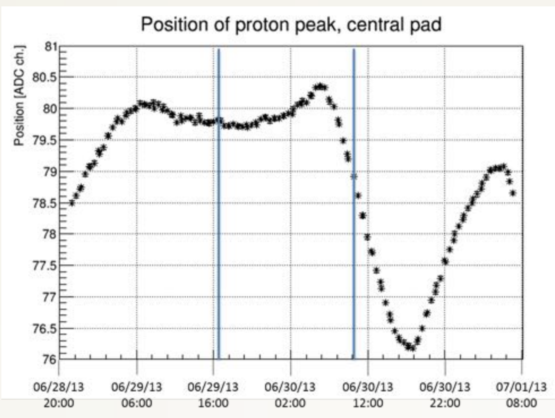


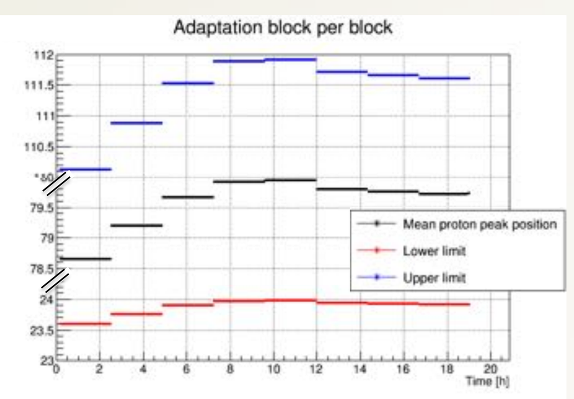
Length of events window: 4 µs.
Time for electronics treatment: 0.2 µs.
Raw Pulse-height = *histMax* - *baselineValue*



Effect of temperature

The temperature has an impact on the amplification of the signal by the electronics **[4]**.
The position of the proton peak in the pulse-height spectrum changes with time (day/night cycle).

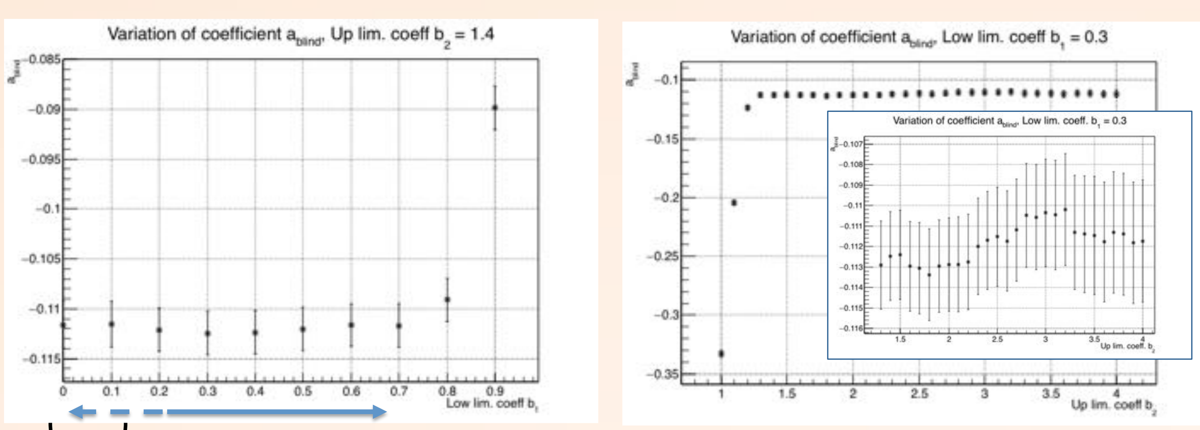




Integration limits are calculated in function of the position of the proton peak in the mean pulse-height spectrum of the closest 50 V measurement.

$$Low = b_1 \cdot \text{PosProt}, \quad \text{with } b_1 < 1$$
$$Up = b_2 \cdot \text{PosProt}, \quad \text{with } b_2 > 1$$

Influence of integration limits

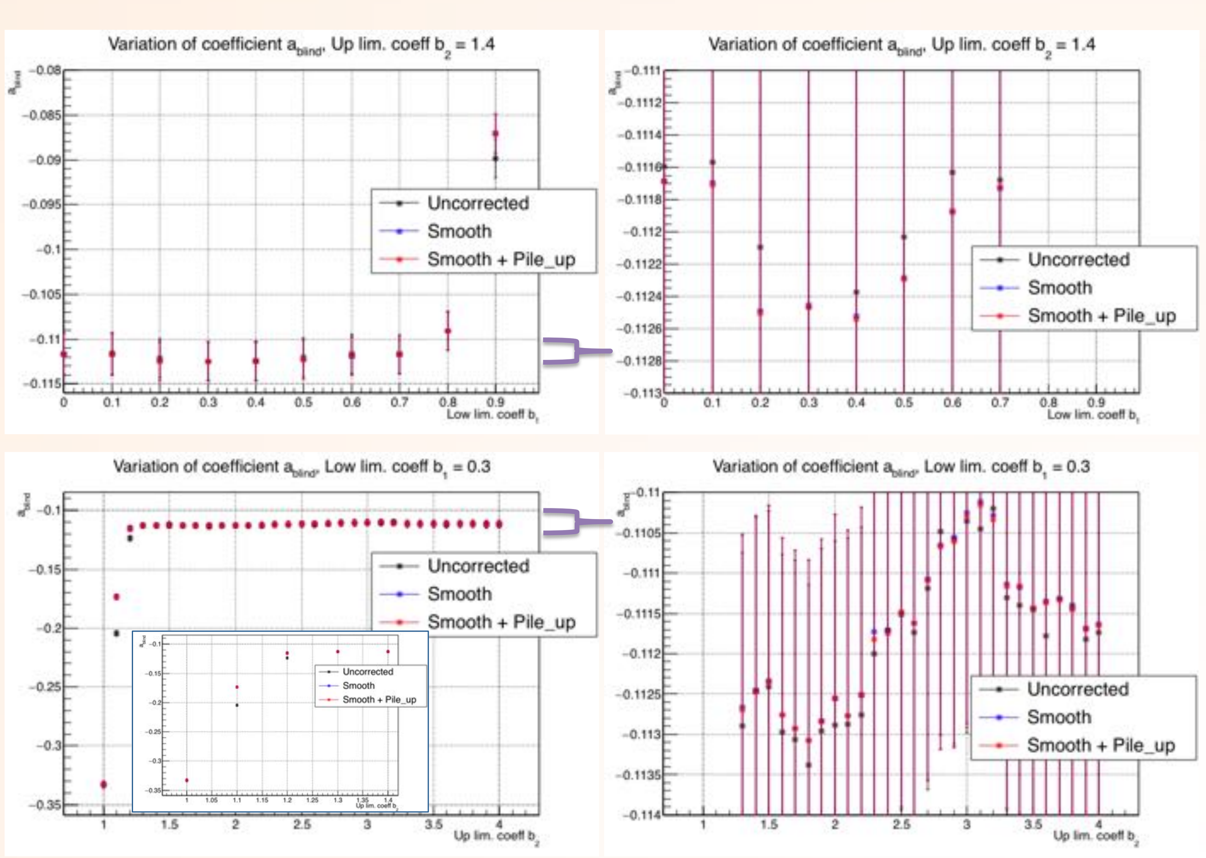


Dominated by noise

Account for backscattering

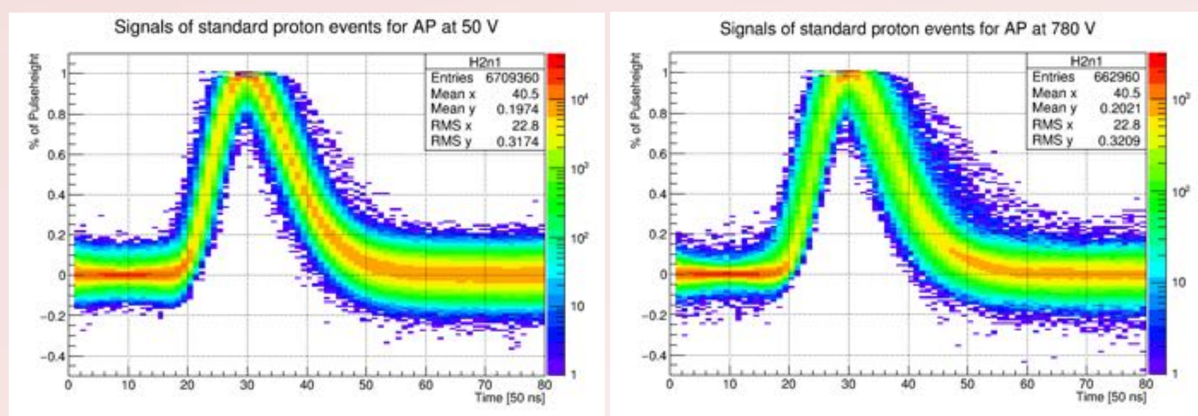
Statistical error increases due to electron background.

Pulse-shape correction allows using lower integration limits because of reduced electronic noise. Influence of the integration limits after pulse-shape and pile-up corrections:



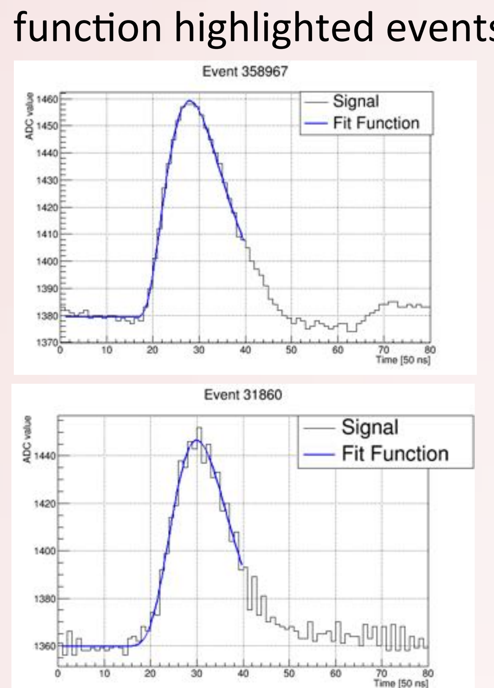
Pulse-shape of events

The pulse-shape depends on the pulse-height. In the proton region, protons and low-energy electrons are detected.

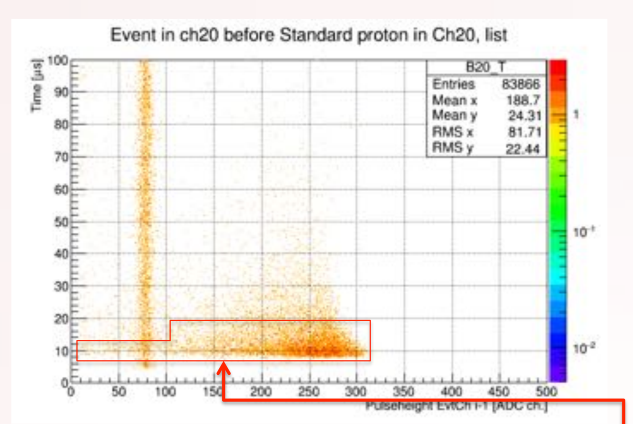


We cannot distinguish by pulse-shape analysis between electron and proton of the same pulse-height.

Description of the pulse-shape by a fit function highlighted events with fluctuations :



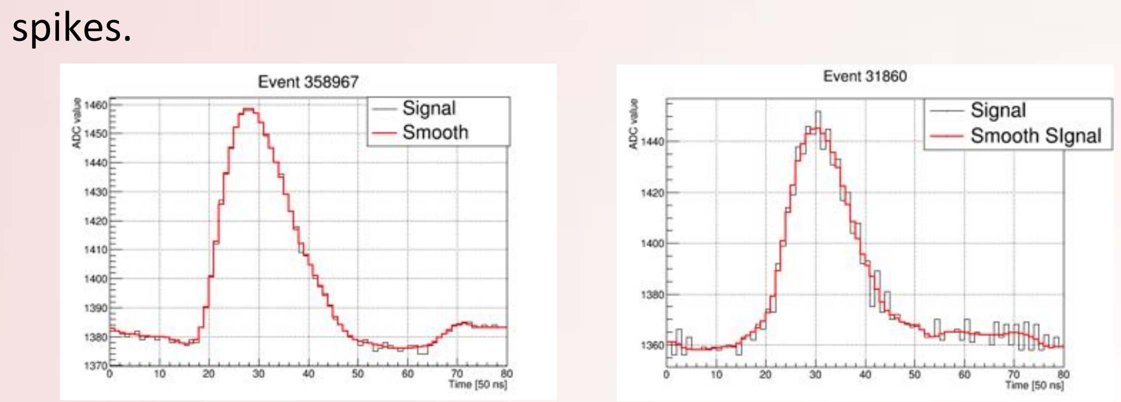
$$f(x) = \begin{cases} y_0 & \text{if } x \le x_0 \\ y_0 + A \cdot \left(1 - e^{-\frac{x-x_0}{t_1}}\right)^p \cdot e^{-\frac{x-x_0}{t_2}} & \text{if } x > x_0 \end{cases}$$



These events are closely preceded by an event with typically large pulse-height (mainly correlated electrons).

Pulse-height resolution

In order to attenuate the fluctuations on the signal, the command ***Smooth*** (from Root) can be applied. This acts as a low-pass filter for high frequencies and also removes short spikes.

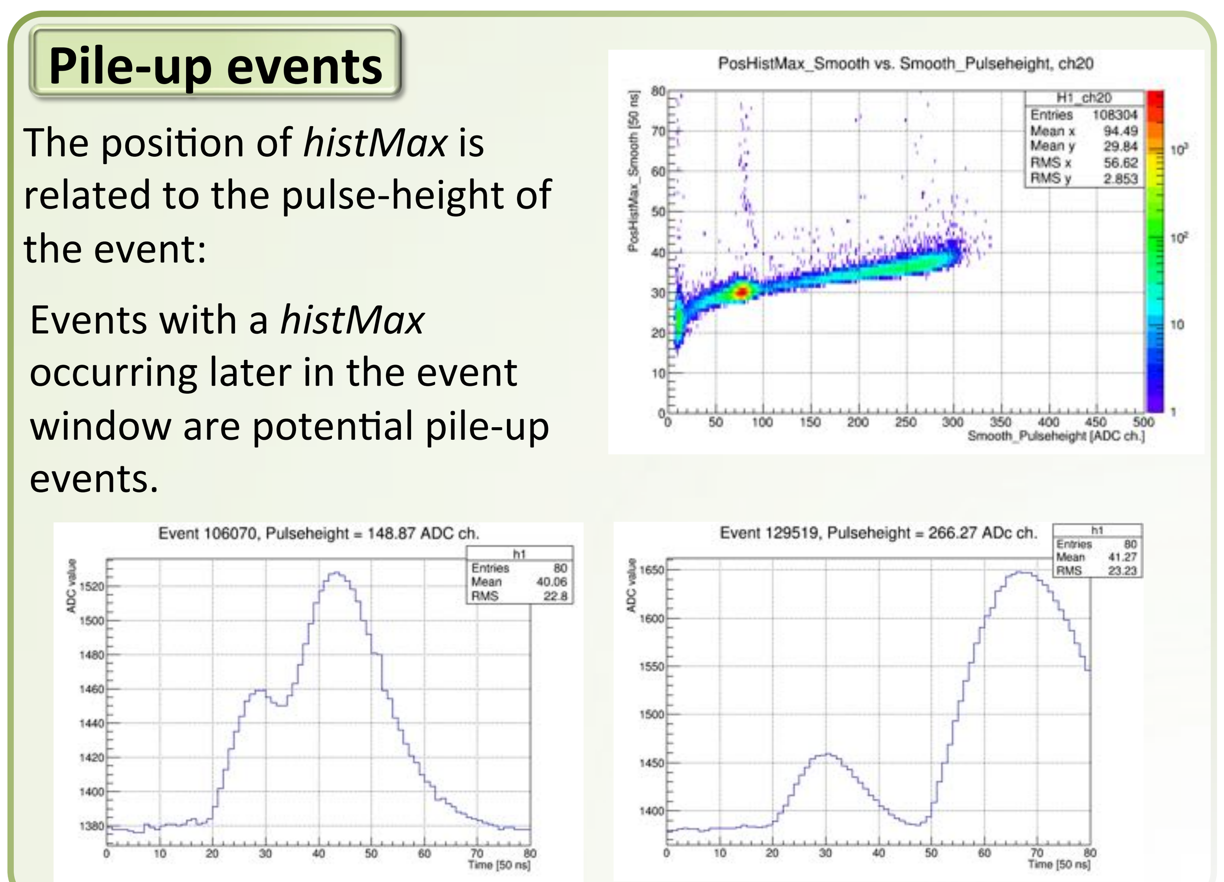


Root documentation for Smooth: algorithm "353QH twice"

Pile-up events

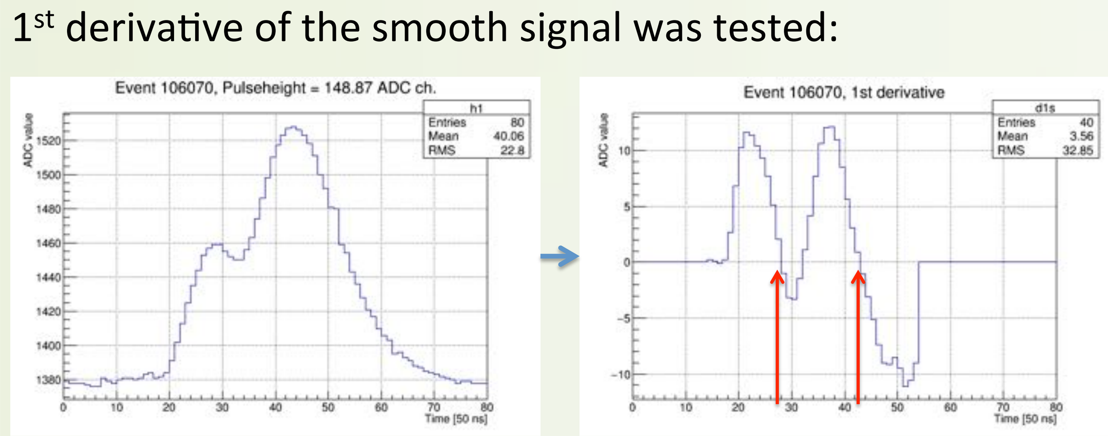
The position of *histMax* is related to the pulse-height of the event:

Events with a *histMax* occurring later in the event window are potential pile-up events.

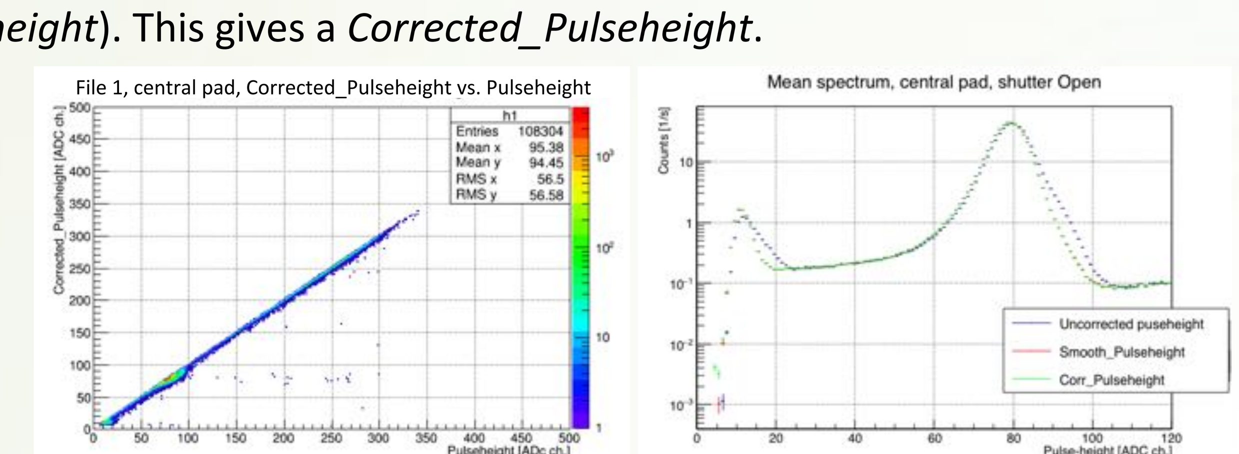


Pile-up correction

The aim is to identify the first pulse in the event window in agreement with the trigger conditions. A method using the 1st derivative of the smooth signal was tested:



Intersections with 0 are localised and the corresponding pulse-height is calculated. Each position is compared with the phenomenological relation between pulse-height and peak position, *Pos = f(pulse-height)*. This gives a *Corrected_Pulseheight*.

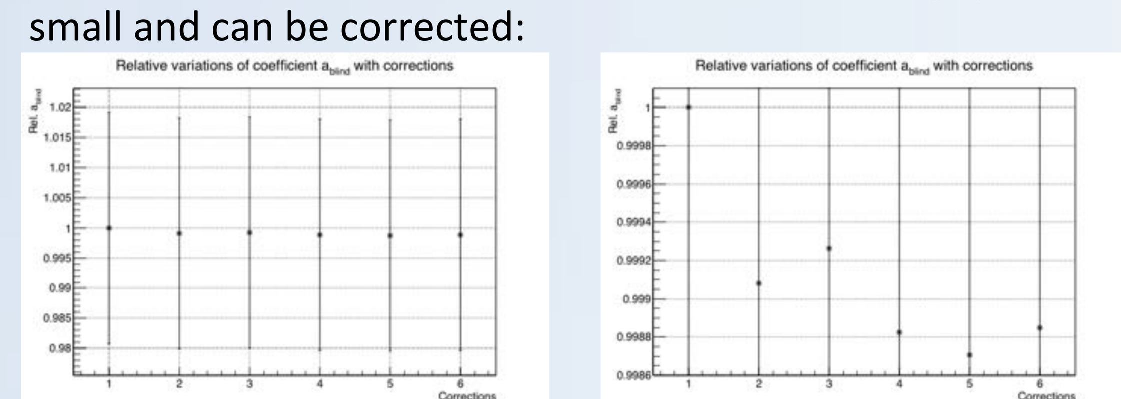


Conclusion

Systematic effects on the events detection with *a*SPECT were investigated:

- Compensation of temperature effects results in correction on the coefficient a_{blind} of 0.12%,
- The *Smooth* approach reduces the noise level and improves the pulse-height resolution,
- Pile-up events can be corrected using the 1st derivative of their signal and the phenomenological relation between pulse-height and peak position.

The related systematic effects on the coefficient a_{blind} are small and can be corrected:



Legend:
1 ⇔ Uncorrected
2 ⇔ Smooth
3 ⇔ Smooth + Pile-up
4 ⇔ Temp.
5 ⇔ Smooth + Temp.
6 ⇔ Smooth + Pile-up + Temp.

Bibliography

[1] O. Zimmer *et al.* , Nucl. Instr. Meth. A 440, 548, 2000
[2] P. Lechner *et al.*, Nucl. Instr. Meth. A 377, 346, 1996
[3] M. Simson *et al.* , Nucl. Instr. Meth. A 581, 772, 2007
[4] M. Simson, PhD thesis, Technische Universität München, 2010
[5] R. Maisonobe, PhD thesis, Université de Grenoble, 2014