N1CP-60

Methods for Calibrating the Gain and Offset of the DSSC Detector for the European XFEL

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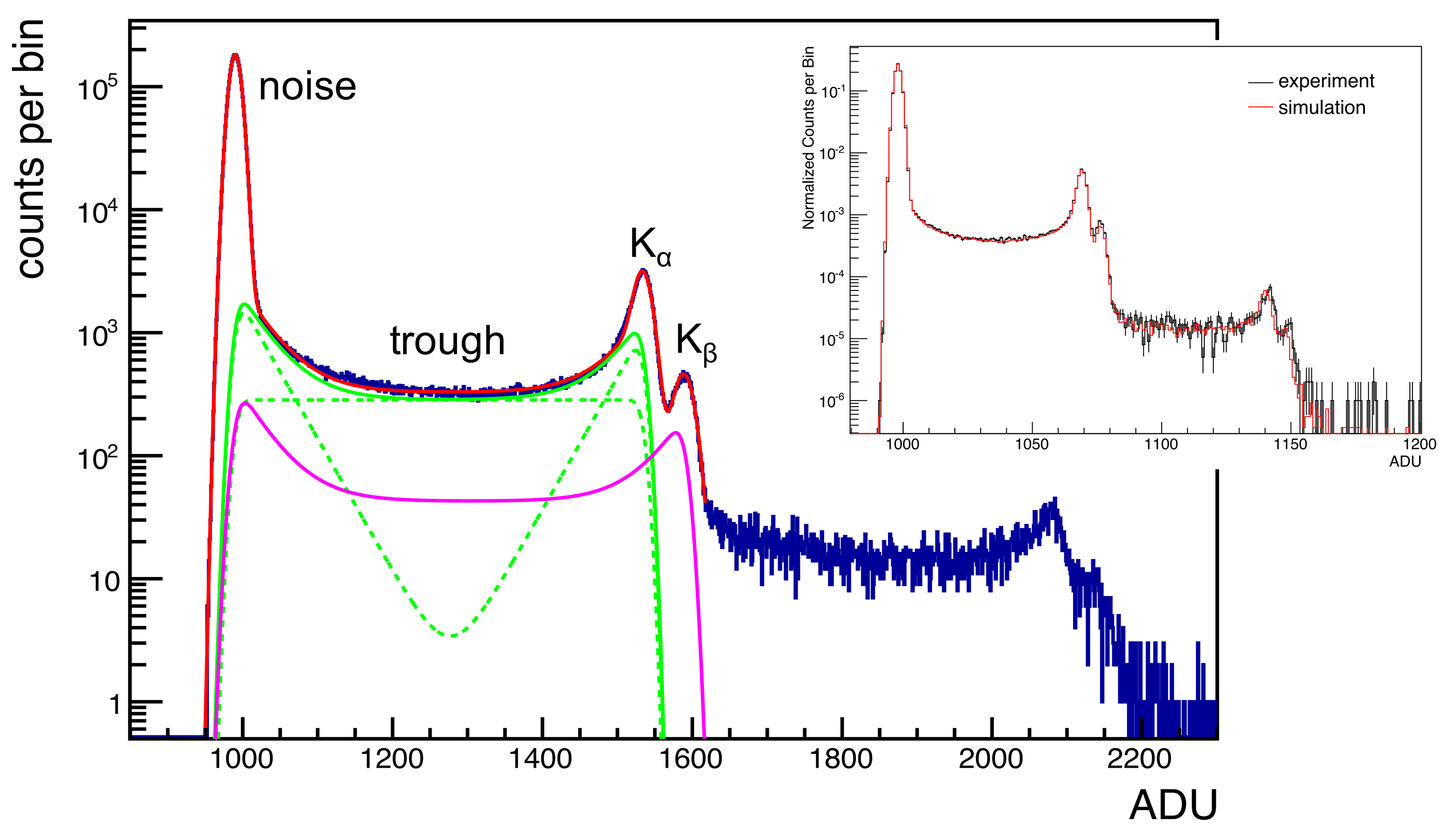
The DEPFET Sensor with Signal Compression (DSSC)[1] will be a 2d 1Mpx imaging detector for the European X-ray Free Electron Laser Facility (XFEL.EU)[2]. The DSSC is foreseen as an imaging detector for soft X-radiation from 0.5 keV up to 6 keV. Driven by its scientific requirements, the design goals of the detector system are single photon detection, a high dynamic range and a high frame rate of up to 4.5 MHz. Signal compression, amplification and digitization will be performed in the focal plane. Utilizing an in-pixel active filtering stage and an 8/9-bit ADC, the detector will provide parallel readout of all pixels.

Here the results of studies on the stability and performance of a parameterized model for determining gain and offset in DSSC prototype calibration line spectra will be presented.

Motivation

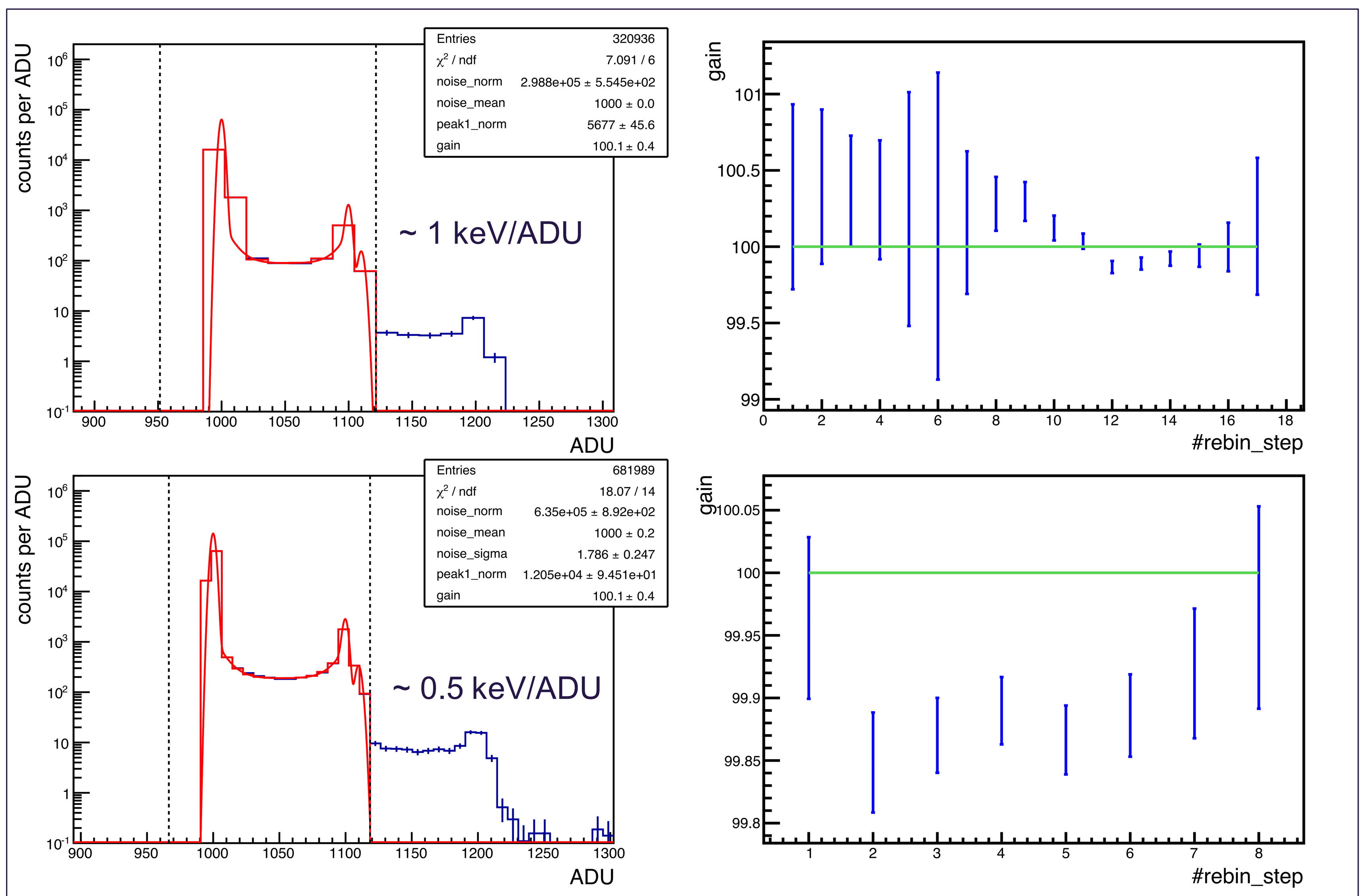
- A calibration strategy for the DSSC detector has been proposed[3] and a first experimental validation has been given[4]. An update on this can be found on poster **N1CP-59** in this session. A key element of the strategy is the determination of the system gain and offset based on peak energies of X-ray calibration line sources such as ^{55}Fe.
- DSSC prototypes currently available for calibration experiments only provide single pixel read-out functionality. Mainly due to charge sharing between neighboring pixels, calibration spectra recorded with DSSC prototypes show a continuum between noise peak and signal peaks, a so-called "trough", that aggravates determining the peak positions.



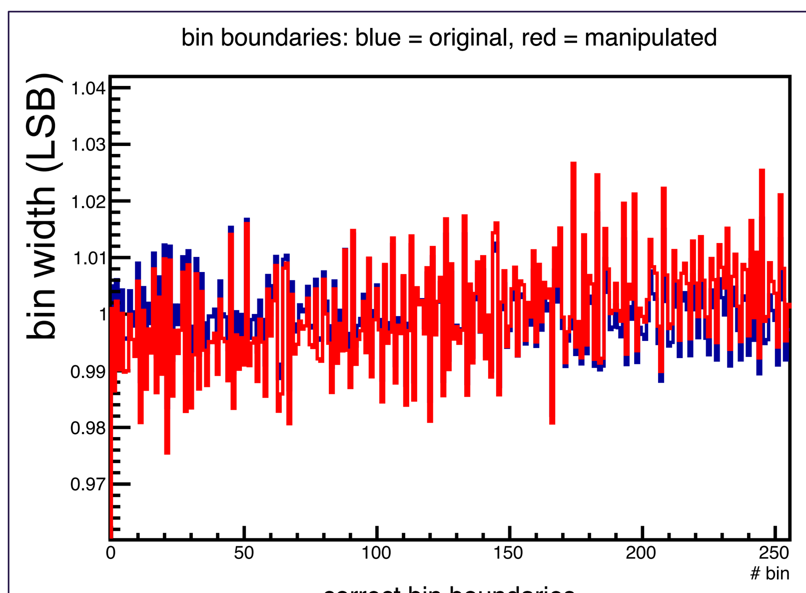
^{55}Fe spectrum of a DSSC DEPFET pixel read out by an external 14-bit ADC. **A continuous, global spectral response model (red)** takes into account the trough between noise peak and calibration lines (see equation). By characterizing the spectral response of the DEPFET with the continuous fit function, the calibration of offset and gain in the 8-bit resolution of the DSSC can be facilitated. System simulation[5] (above) is used to test the fit function in various environments.

$$F_{global}(x) = F_{\text{noise}}(x) + \sum_i F_{i,\text{line}}(x) \qquad F_{\text{noise}}(x) = \frac{N_0}{\sigma_0\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-m_0}{\sigma_0}\right)^2}$$

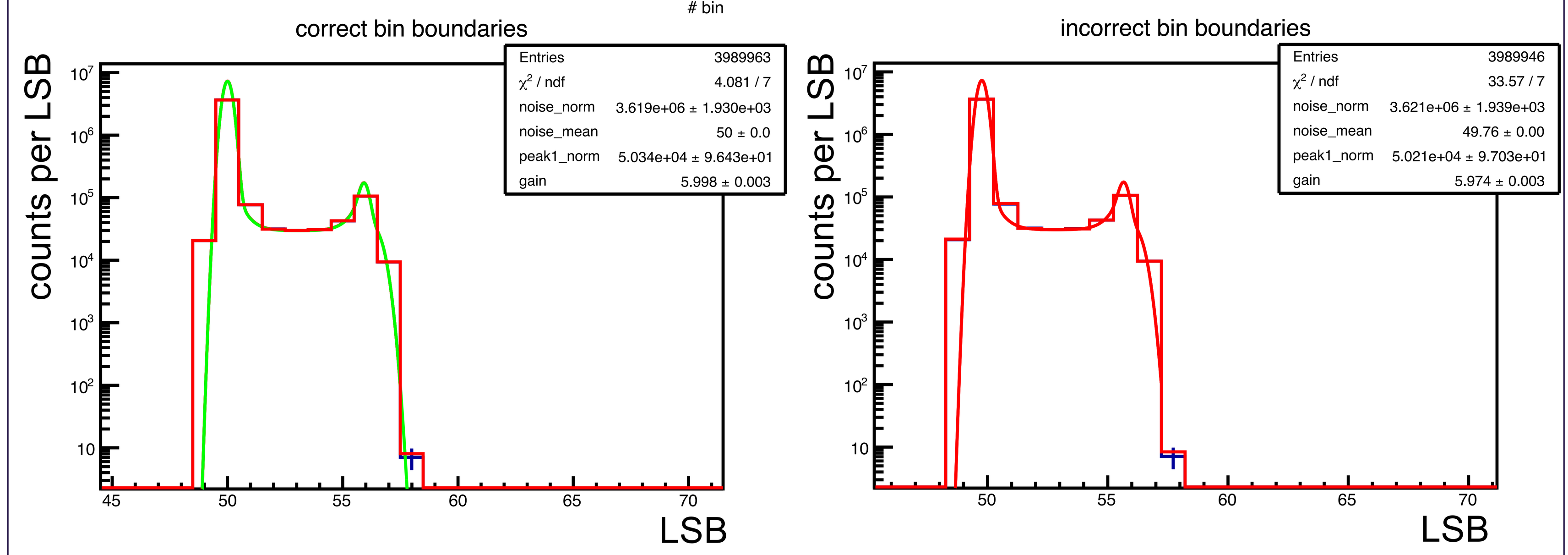
$$F_{i,\text{line}}(x) = \frac{N_i}{\sigma_i\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-m_i}{\sigma_i}\right)^2} + \frac{N_t N_i}{\beta_t e^{\left(\frac{\sigma_i}{2\beta_t}\right)^2}} \frac{1}{2} e^{\frac{x-m_i}{\beta_t}} \operatorname{erf}\left(\frac{x-m_i}{\sigma_i} + \frac{\sigma_i}{2\beta_t}\right) + t_0 \frac{N_t N_i}{\beta_t e^{\left(\frac{\sigma_i}{2\beta_t}\right)^2}} e^{\frac{-(x-m_0)}{\beta_t}} \frac{1}{2} \operatorname{erf}\left(\frac{-(x-m_0)}{\sigma_1} + \frac{\sigma_i}{2\beta_t}\right) + \frac{N_s N_i}{(m_i - m_0)} \frac{1}{2}\left(\operatorname{erf}\left(\frac{x-m_i}{\sigma_i}\right) - \operatorname{erf}\left(\frac{-(x-m_0)}{\sigma_i}\right)\right)$$



A **test of the global fit function** was performed with rebinned, simulated spectra resembling the situation of the coarse 8-bit binning of the DSSC. The fit can only be performed by fixing certain parameters. During the rebinning, the offset was changed incrementally (#rebin_step). The accuracy of the gain determination (green line refers to the theoretical value) needs to be better than the setting granularity of 2%.

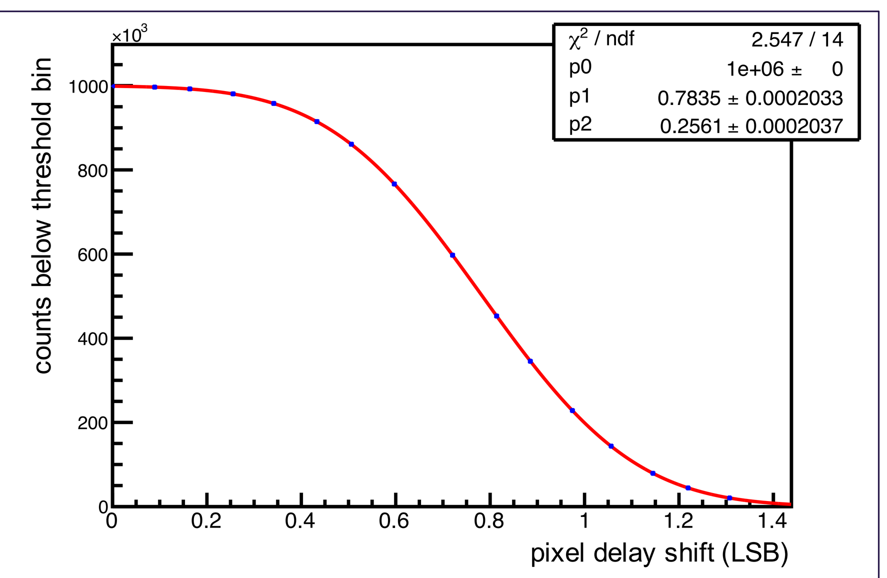


Effects of DNL and INL (differential and integral non-linearity) of the ADC are critical for the gain and offset calibration. Their influence on the goodness and stability of the fit is studied with the help of Monte-Carlo resampling of the fit function, system simulation[5] and various models for possible ADC distortions.

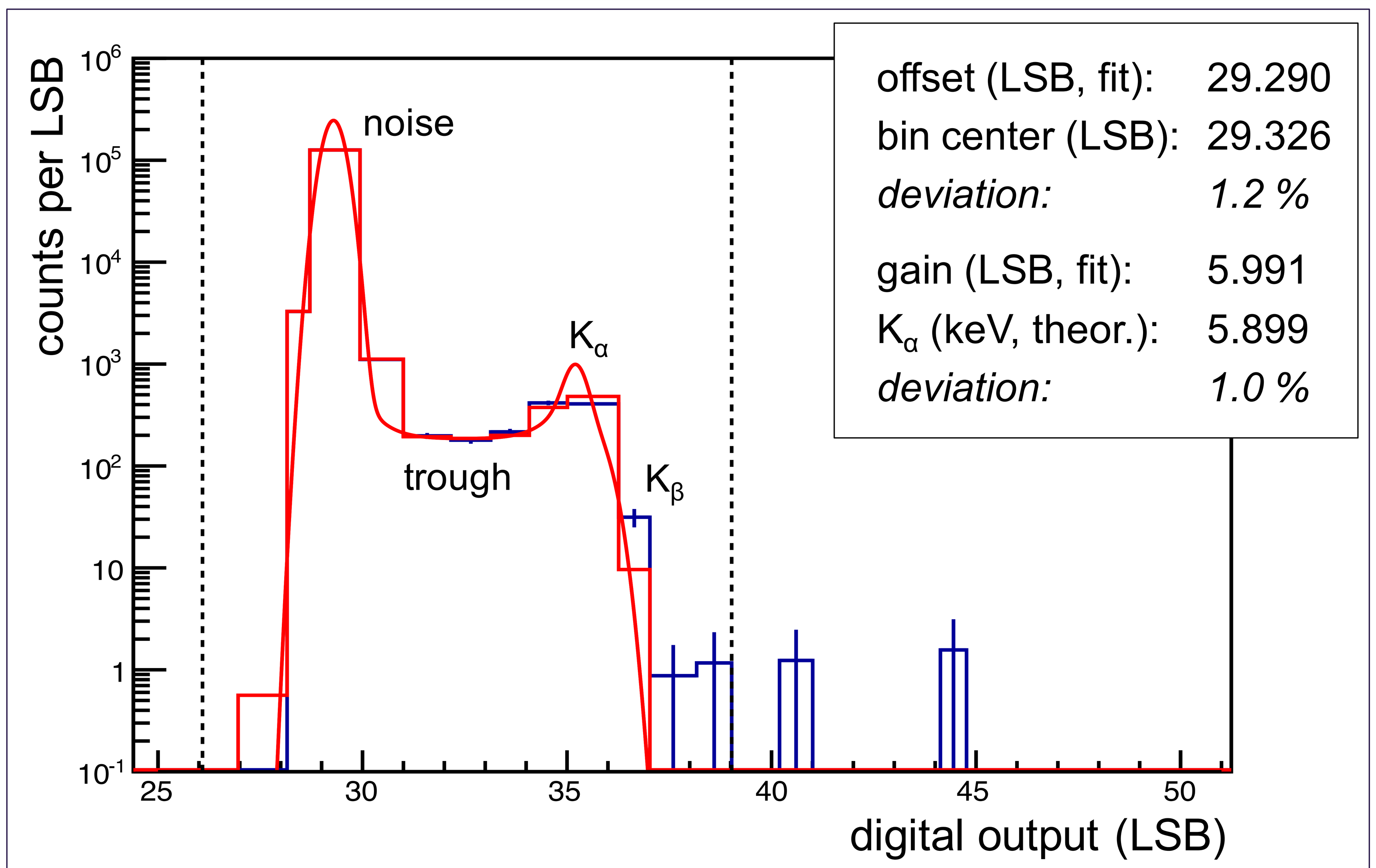


The measured binning may differ from the actual binning (above red vs. blue). The result in this example shows a higher χ^2 and a slight difference of the gain.

Determining the system noise using dark frames and the DSSC pixel delay shift is feasible. Current studies show, that the accuracy of gain and offset calibration can be facilitated by determining the noise value (right, parameter *p2*) from independent measurements. The difficulty lies in the low noise level and the limited ADC resolution.



Different methods are currently being investigated. This is an example of a method that is not depending on the bin-width information.



^{55}Fe calibration line spectrum measured with a DSSC prototype. In the depicted case, the goal of the calibration was to configure the system such that the offset at the center of an ADC bin and 1 LSB corresponds to an energy deposit of 1 keV. The proposed fit model (red) has been applied here in order to find the desired system configuration from a grid of 256 setting combinations.

Summary & Outlook

- The proposed global fit-function for the DSSC prototype is a promising approach to facilitate the calibration of offset and gain with the desired accuracy.
- As the through is the main source of systematic uncertainty, methods for reducing it are currently investigated. Hardware (e.g. a pin-hole mask) or software solutions could be applied for this task.

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References:

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[2] Altarelli M. et al., *The European X-Ray Free-Electron Laser Technical Design Report*, DESY 2006-097, ISBN 978-3-935702-17-1
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