The new MYTHEN III detector prototype

Microstrip sYstem for Time rEsolved experimeNts

M. Andrä[1], A. Bergamaschi[1], R. Barten[1], M. Brückner[1], R. Dinapoli[1], E. Fröjdh[1], D. Greiffenberg[1], C. Lopez-Cuenca[1], D. Mezza[1], A. Mozzanica[1], M. Ramilli[1], S. Redford[1], M. Ruat[1], C. Ruder[1], B. Schmitt[1], X. Shi[1], D. Thattil[1], G. Tinti[1], S. Vetter[1] and J. Zhang[1]

[1]-Swiss Light Source, Paul Scherrer Institute, Villigen, Switzerland

marie.andrae@psi.ch

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Wir schaffen Wissen – heute für morgen

The new Mythen III chip

What is MYTHEN?

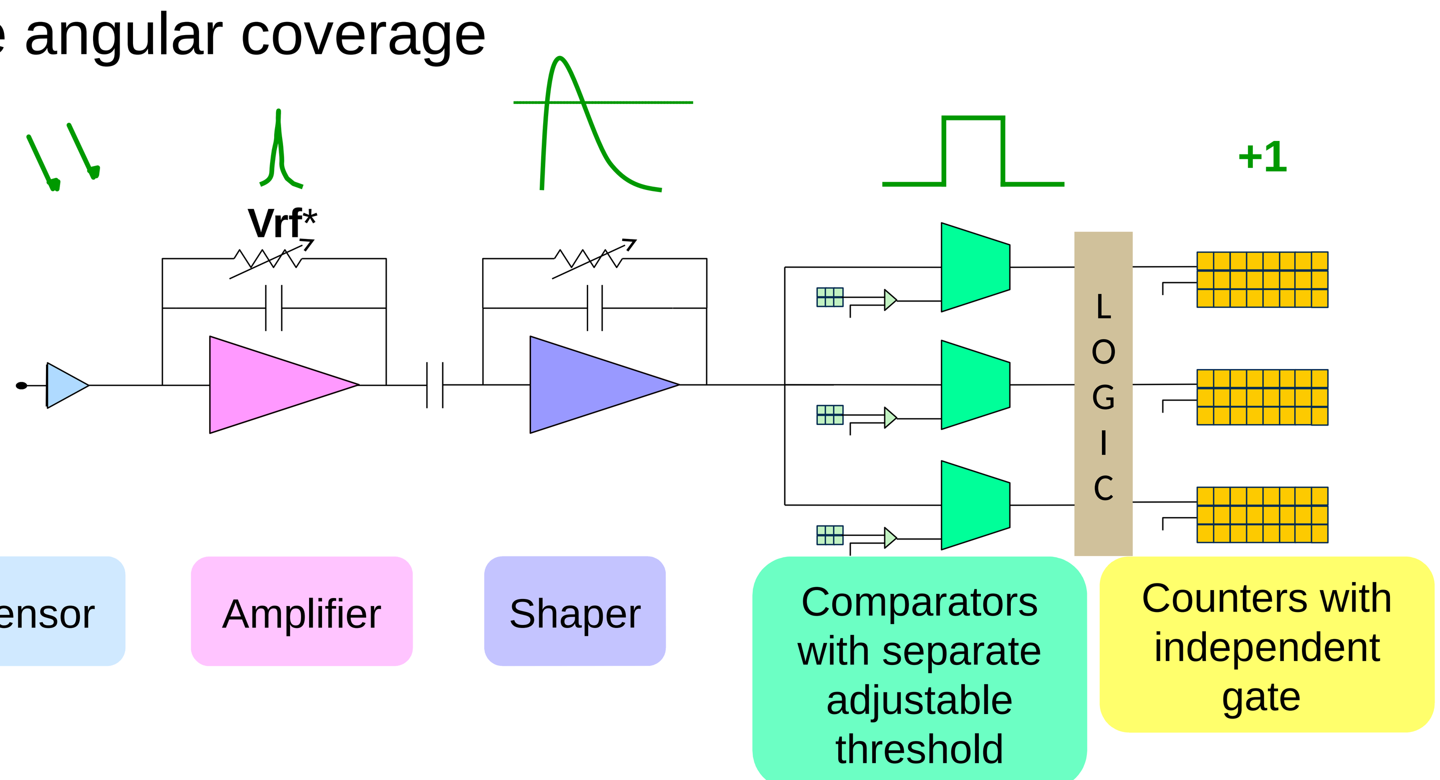
- silicon microstrip detector with 50 µm pitch, 8 mm long strips
- single photon counting
- for time-resolved powder diffraction, medical imaging, etc

Why a strip detector?

- less channels per area: fast frame rates
- small pitches possible: high resolution
- large angular coverage

Why photon counting?

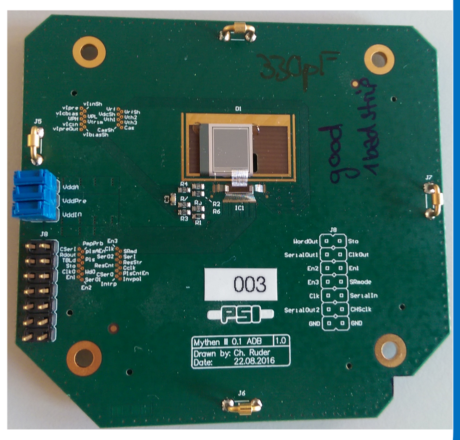
- ideally noiseless
- large dynamic range
- fluorescence suppression



*Vrf changes the feedback resistance, i.e. the gain and shaping time

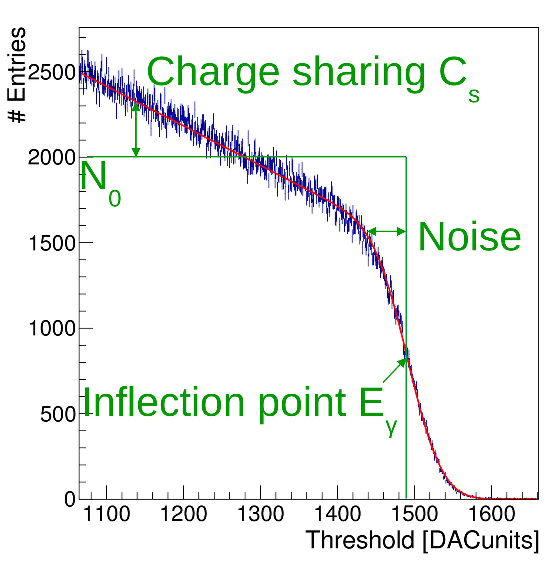
What is new?

- three comparators and three 24-bit-counters for:
  - energy-windowing
  - count rate improvement (track pile-up)
  - pump-probing with multiple time slots, counters are independently gateable
- reduced threshold dispersion
- improved noise performance
- small dead time → increased count rate capability



Threshold scans

All data are taken with a preliminary readout system !

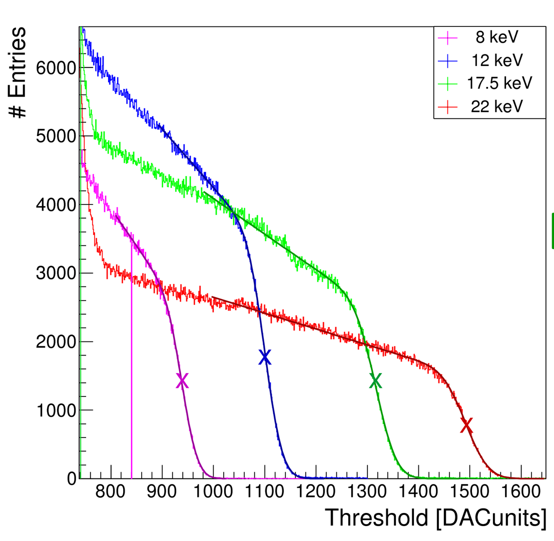


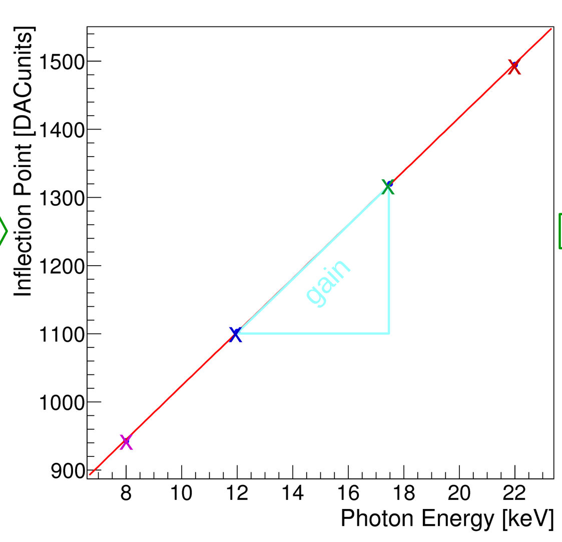
The number of photon hits is a function of the threshold:

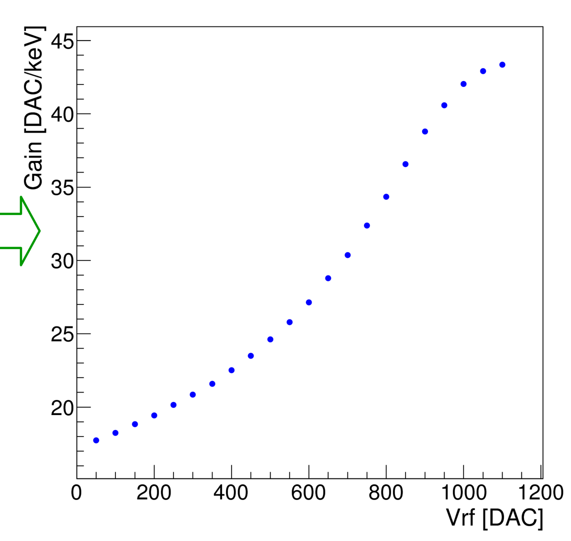
$$N_\gamma(E_{thr}) = \frac{N_0}{2}\left(1 + C_s(E_\gamma - E_{thr})\right)\left(1 + Erf\left(\frac{E_\gamma - E_{thr}}{\sqrt{2}\,Noise}\right)\right)$$

*Noise = extra counts due to pulse height variations overcoming the comparator threshold [1]

Calibration







1. Take threshold scans at different photon energies
2. Extract the inflection points
3. Calculate the gain [DACunits/keV] for every Vrf-setting

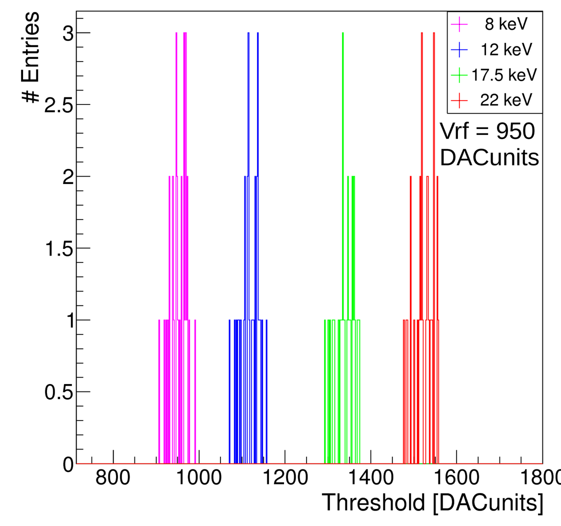
The gain

- increases with Vrf √
- starts to saturate at high Vrf √

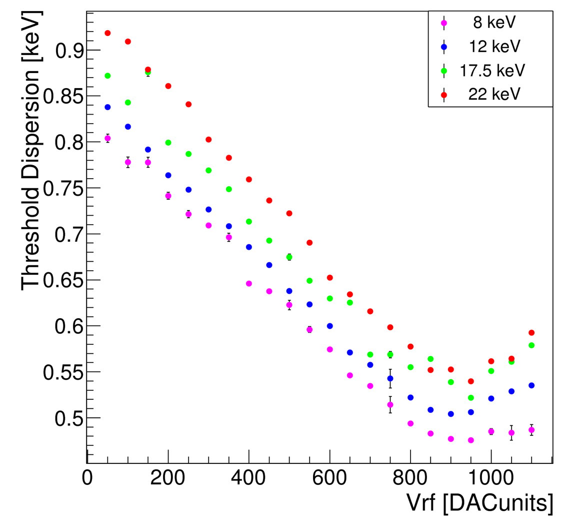
References

[1] A. Bergamaschi et al, The MYTHEN detector for X-ray powder diffraction experiments at the Swiss Light Source (2010), J. Synchrotron Rad.(2010) 17, 653-668

Untrimmed threshold dispersion



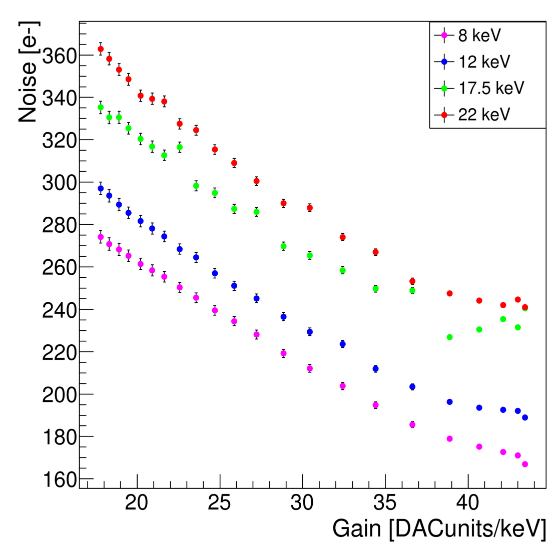
The threshold dispersion is given by the spread of the inflection points, i.e. the resulting thresholds, over all sensor-strips.

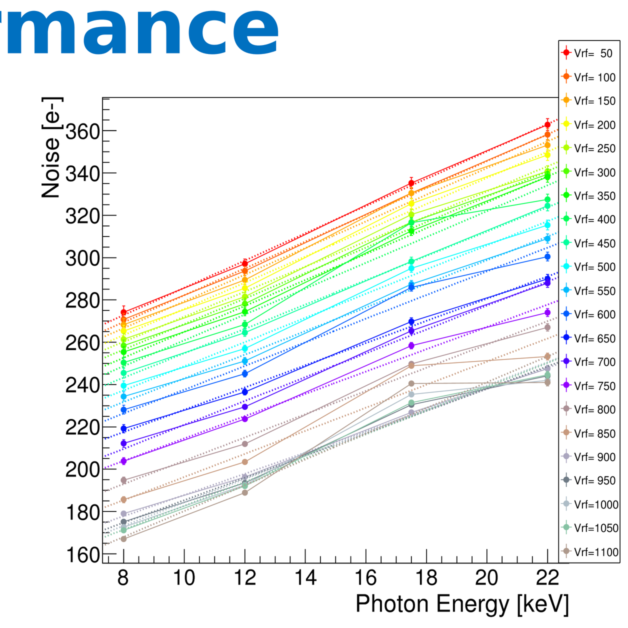


The threshold dispersion

- depends on the gain (Vrf) √
- depends slightly on the photon energy ?
- 2.5-4.5% at 22 keV
- 6-10% at 8 keV

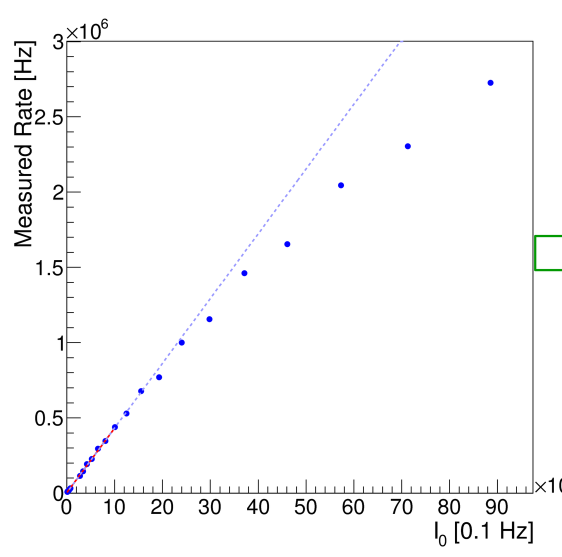
Noise performance

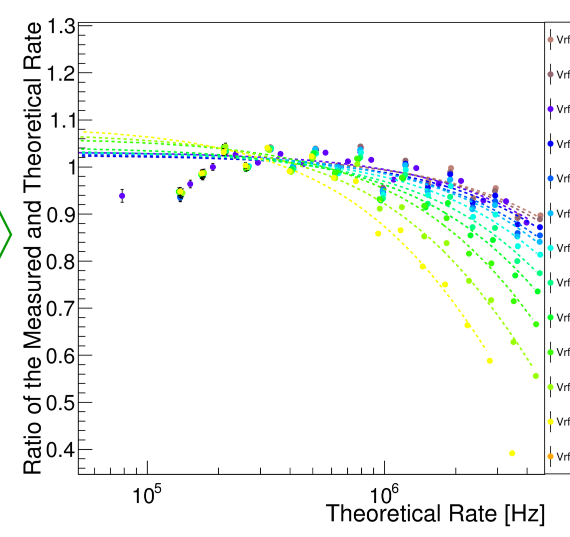


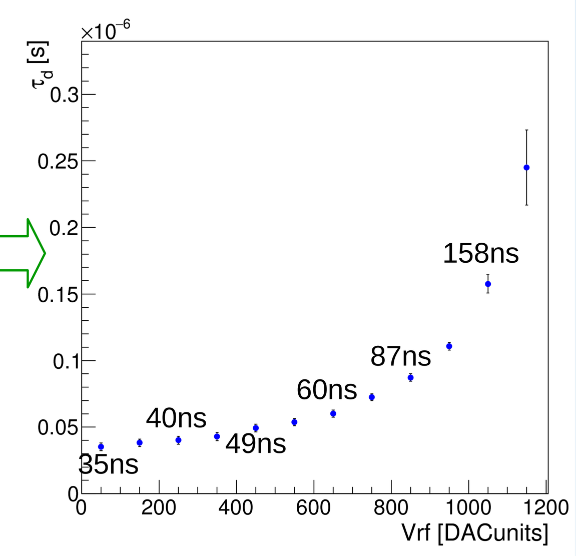


The noise decreases with increasing gain √ and falls below 200 e- at moderate gains √, but depends linearly on the photon energy ?

Rate capability







1. Plot the measured rate vs the reference rate I_0*

   *given by the beamline
2. Estimate the ideal theoretical rate with a linear fit
3. Fit the ratio ε of the measured and theoretical rate Φ to find the shaping time τ_d with:

   $\varepsilon = \exp(-\tau_d \Phi)$*

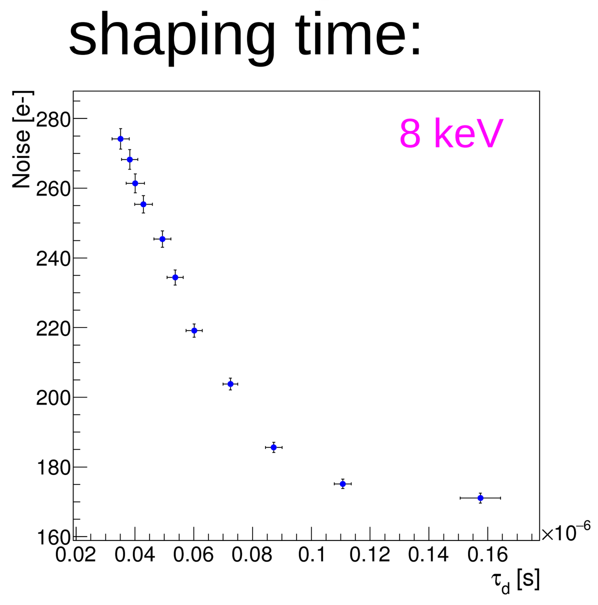
   *paralyzable counter model [1]

The shaping time

- increases with the gain (Vrf) √
- allows for fast count rates √

Conclusion

The noise decreases with increasing shaping time:



	MYTHEN II @ 8.75 keV, Standard settings, Fast settings [1]	MYTHEN III @ 8.0 keV, Vrf = 950 DACunits, Vrf = 250 DACunits
Untrimmed threshold dispersion [eV]	1623 ± 6 1761 ± 7	476 ± 3 721 ± 4
Noise [e-]	230 ± 7 262 ± 7	175 ± 1 261 ± 3
Shaping time τ_d [ns]	170 ± 10 110 ± 10	111 ± 3 40 ± 3

2017 – Submission of MYTHEN 3.0; First prototype

2018 – Submission of MYTHEN 3.1

2019 – Module design and production

2020 – Installation of the detector at the beamline