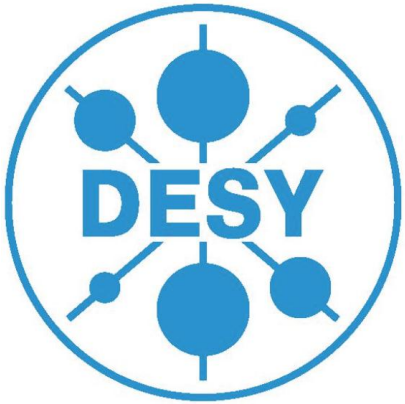
Characterisation of the Medipix3: A single-photon-counting hybrid detector

DESY Summer Students Programme 2011

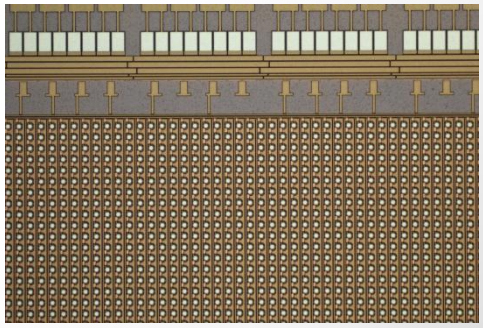


Contents

- Introduction
- Detector structure
- Pixel electronics
- Normal pixel behaviour
- Faulty pixels
- Temperature influence
- Conclusion

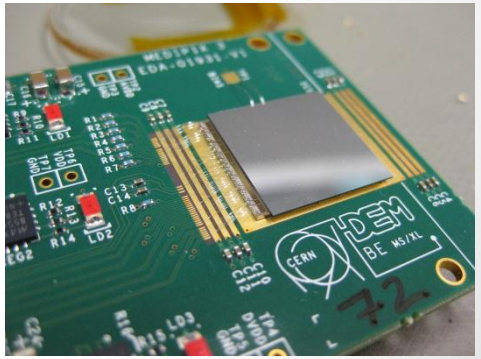
Introduction

- Semiconductor photon detectors:
  - Huge advances in micro-electronics industry (Moore's law)
  - Very fine structures => high spatial resolution
  - Popular design: the CCD (in your digital camera)
- Hybrid detectors:
  - Developed at CERN for particle physics
  - Also very useful in photon science (X-ray research) because of the **single photon counting** nature
  - Advantages over CCD: e.g. energy threshold
  - **Medipix3**

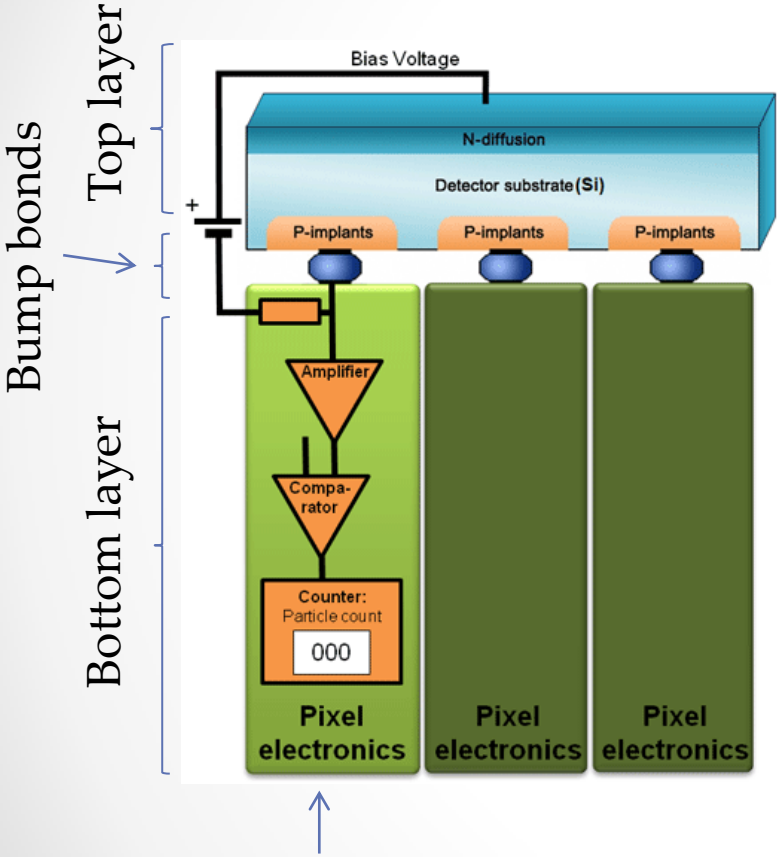


Detector structure

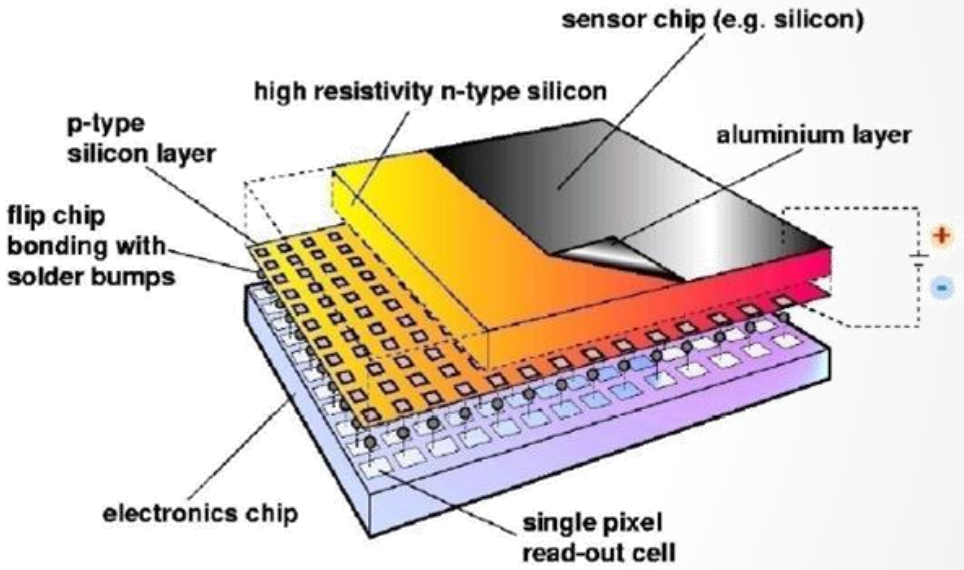
- Hybrid design: two layers
- Top layer:
  - Actual detector medium; converts photons to electrical current
  - N-type semiconductor (e.g. Si) with array of P-type implants
  - Reverse bias: normally no current (except leakage)
  - Photo-electric effect: electron-hole pairs
- Connection:
  - Bump bonds (solder)
- Bottom layer:
  - Signal processing electronics (actual Medipix3 chip)



Detector structure



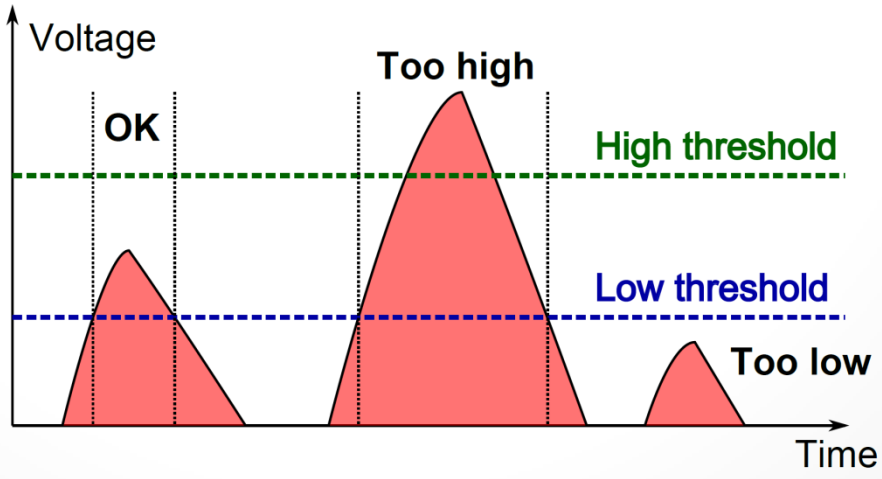
One pixel



Pixel array

Pixel electronics

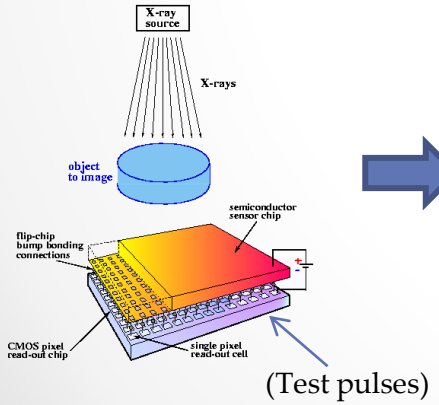
- Count photons, i.e. pulses of electric current induced in PN-junction of the top layer
- Amplify & "shape" each pulse
- Then compare it to a **threshold** (~ minimum photon energy)

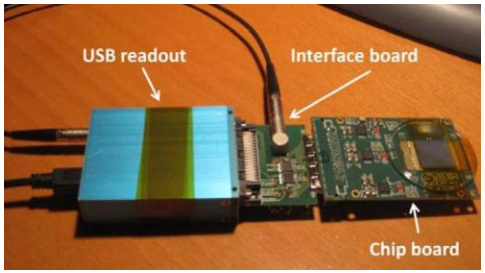


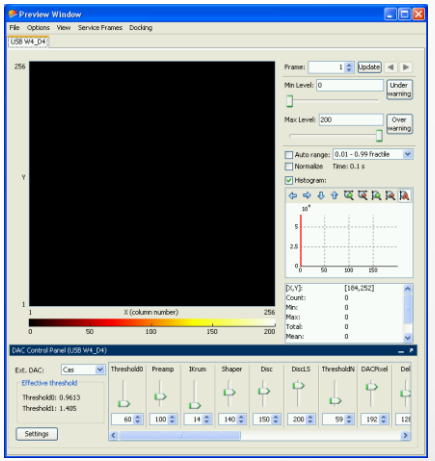
Setup: Hardware/software

- Detector: single Medipix3 chip
  256x256 pixels, 55 µm pitch
- Software: Pixelman v2.1.0, July 4th 2011

  IDL 8
- USB interface







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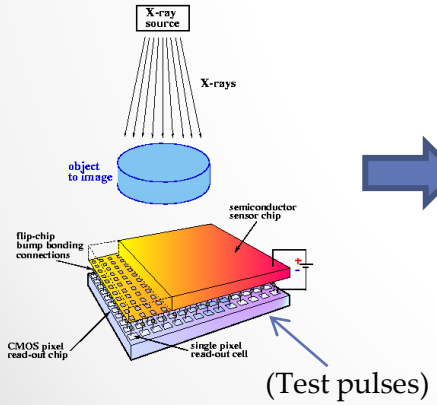

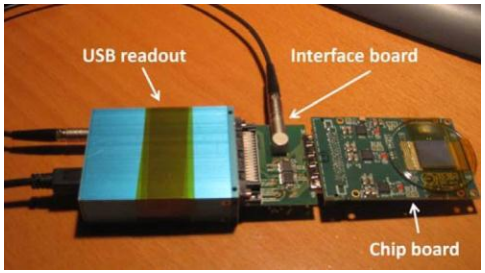

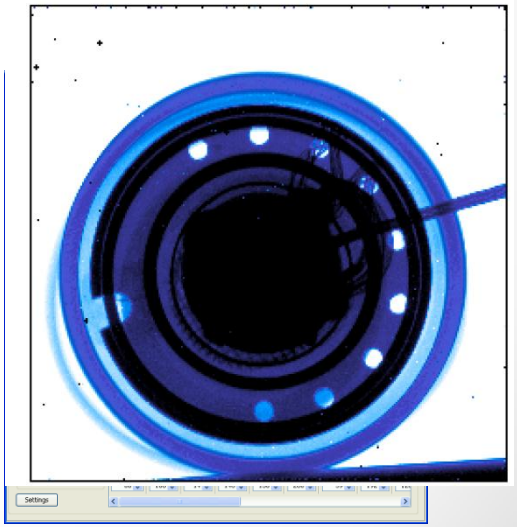

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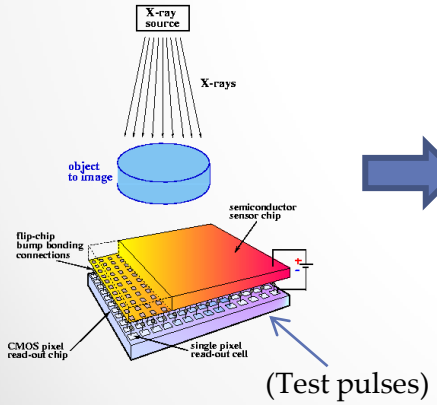
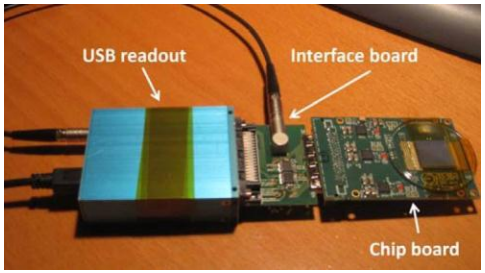
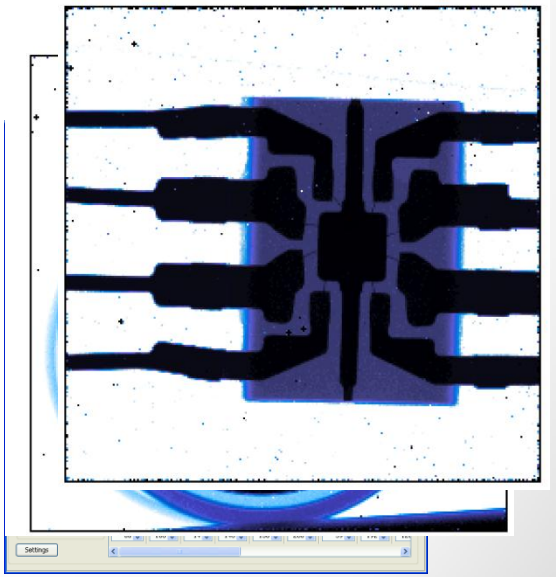






New developments

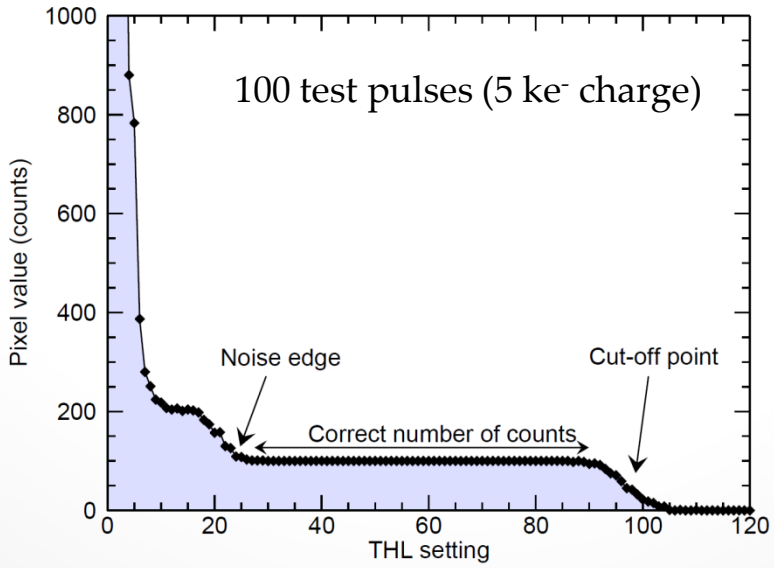
- Tile several chips together => increase resolution
- Chip mounting & cooling: design consideration

Central question

- How is the performance of the Medipix3 influenced by various conditions?
  - DAC settings
  - **Temperature**
- Accurate comparison: use **test pulses** instead of actual photons

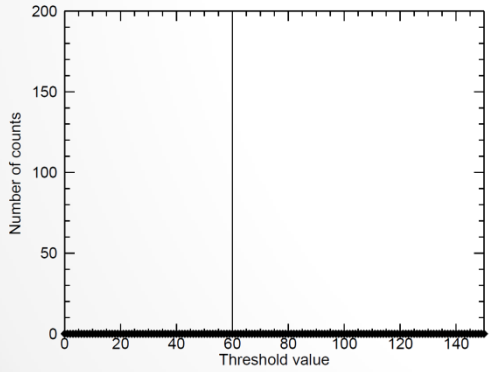
Normal pixel behaviour

- Global threshold DAC (digital-to-analog converter)
- Threshold very low: noise
- Threshold very high: no counts
- In between: correct number of counts

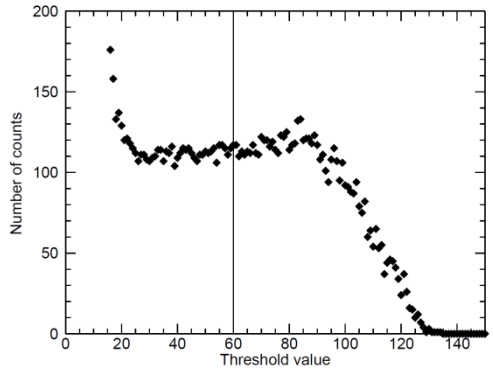


Faulty pixels

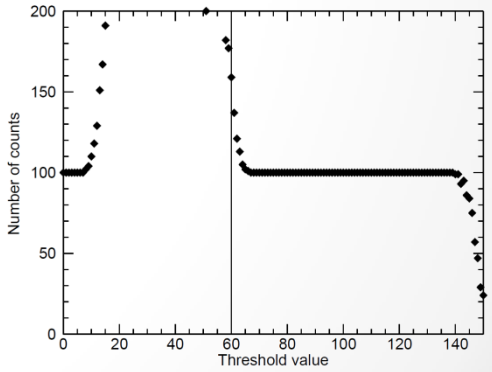
- Some pixels don't work this nicely…
  a) No counts (dead pixel)
  b) Wrong count (noise)
  c) Wrong count (misadjusted pixel)



a



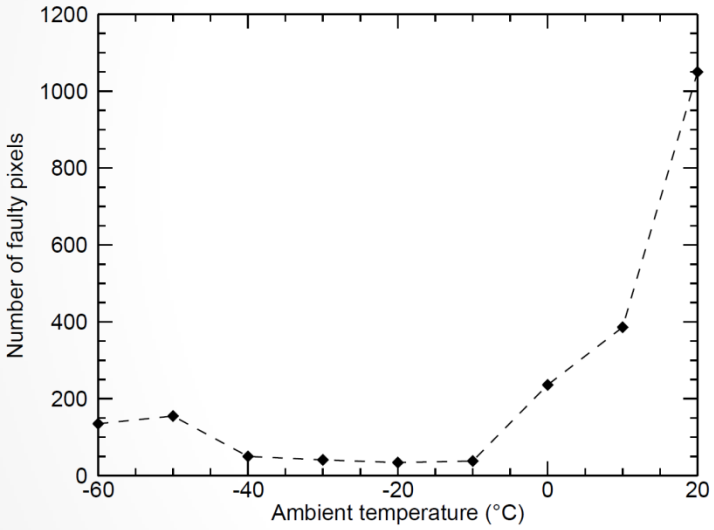
b



c

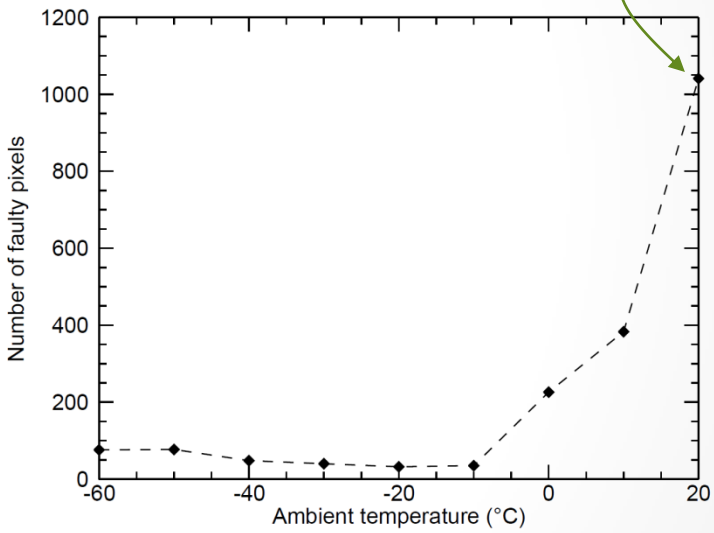
Temperature influence

- Faulty pixel count



THL = 60

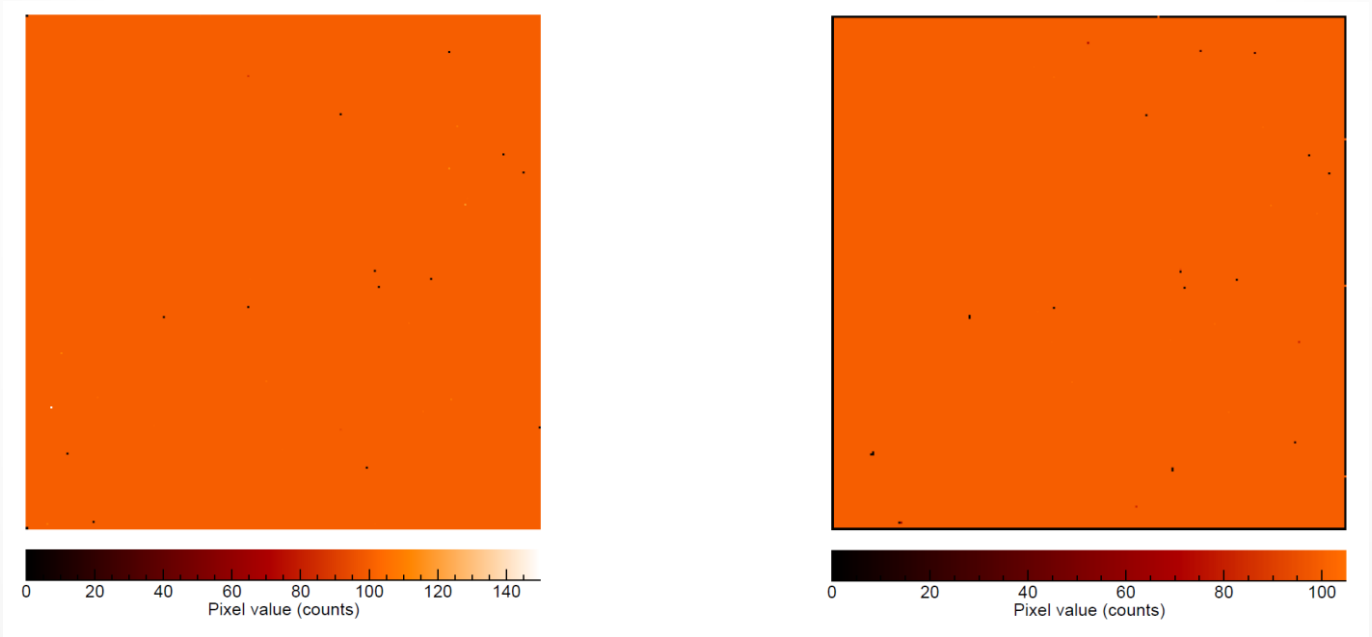
Border pixels dead



Optimal THL for each temperature

Temperature influence

- Example images (THL = 60)

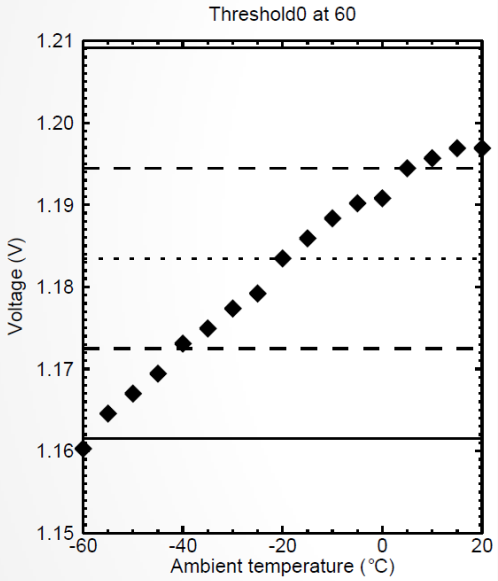


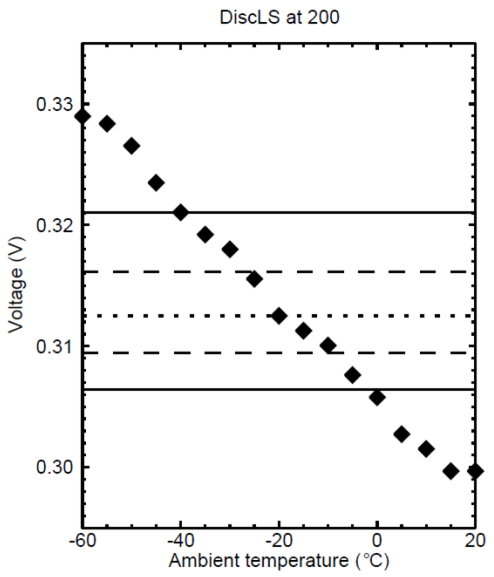
-20 °C

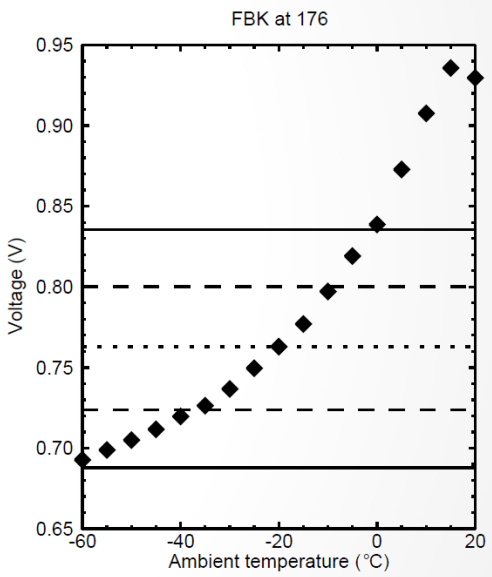
+20 °C

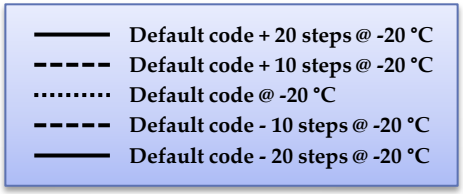
Why?

- Temperature dependency of the DAC voltages









Why?

- Leakage current increases with temperature
- Higher near the border (crystal defects)

Conclusion

- Ideal: -20 °C ambient temperature (actual chip temp. ≈ +40 °C)
- Even then, still some malfunctioning pixels