An X-ray fluorescence spectrometer using CMOS-sensors

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for the CBM-MVD-collaboration

Sensor development: IPHC Strasbourg

1) **Real-time water analysis using XRF**
2) **CMOS-Sensors**
3) **Reconstruction of the energy information**
4) **Improving the quantum efficiency**

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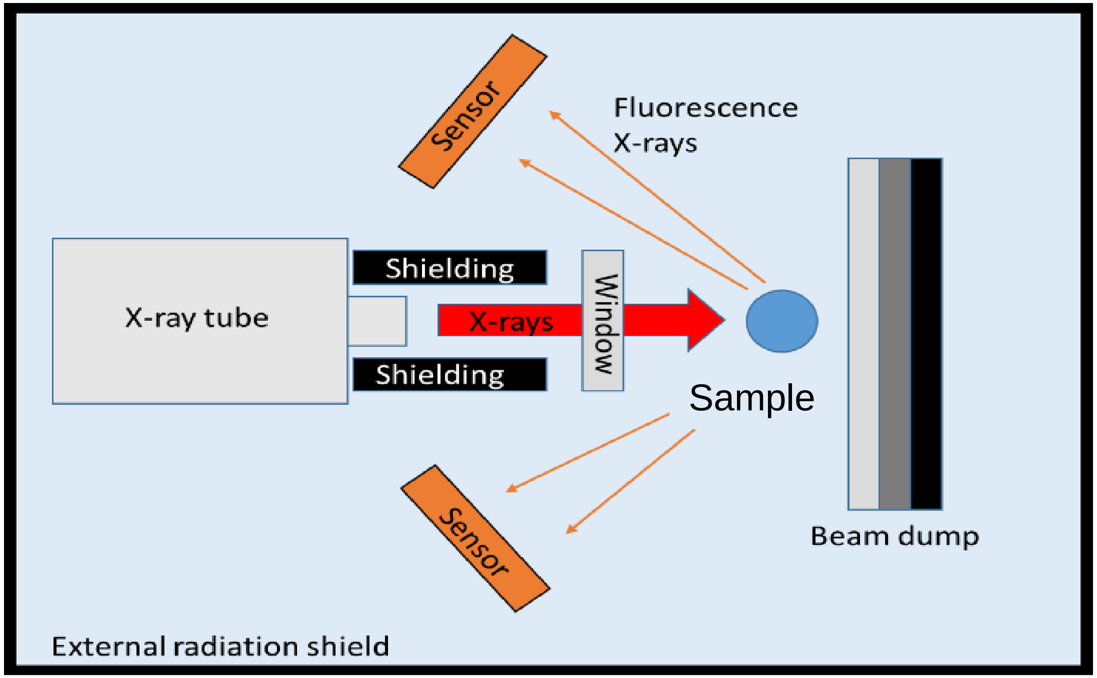
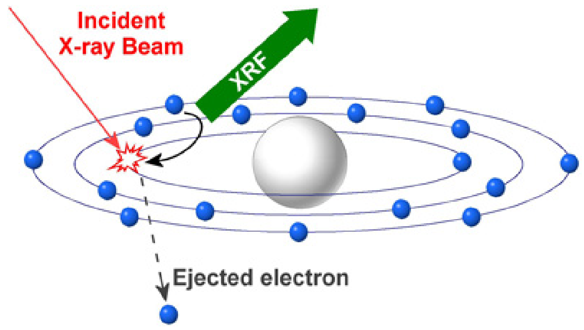
Application: X-ray spectrometer

Monitoring water quality and trigger on traces of pollution





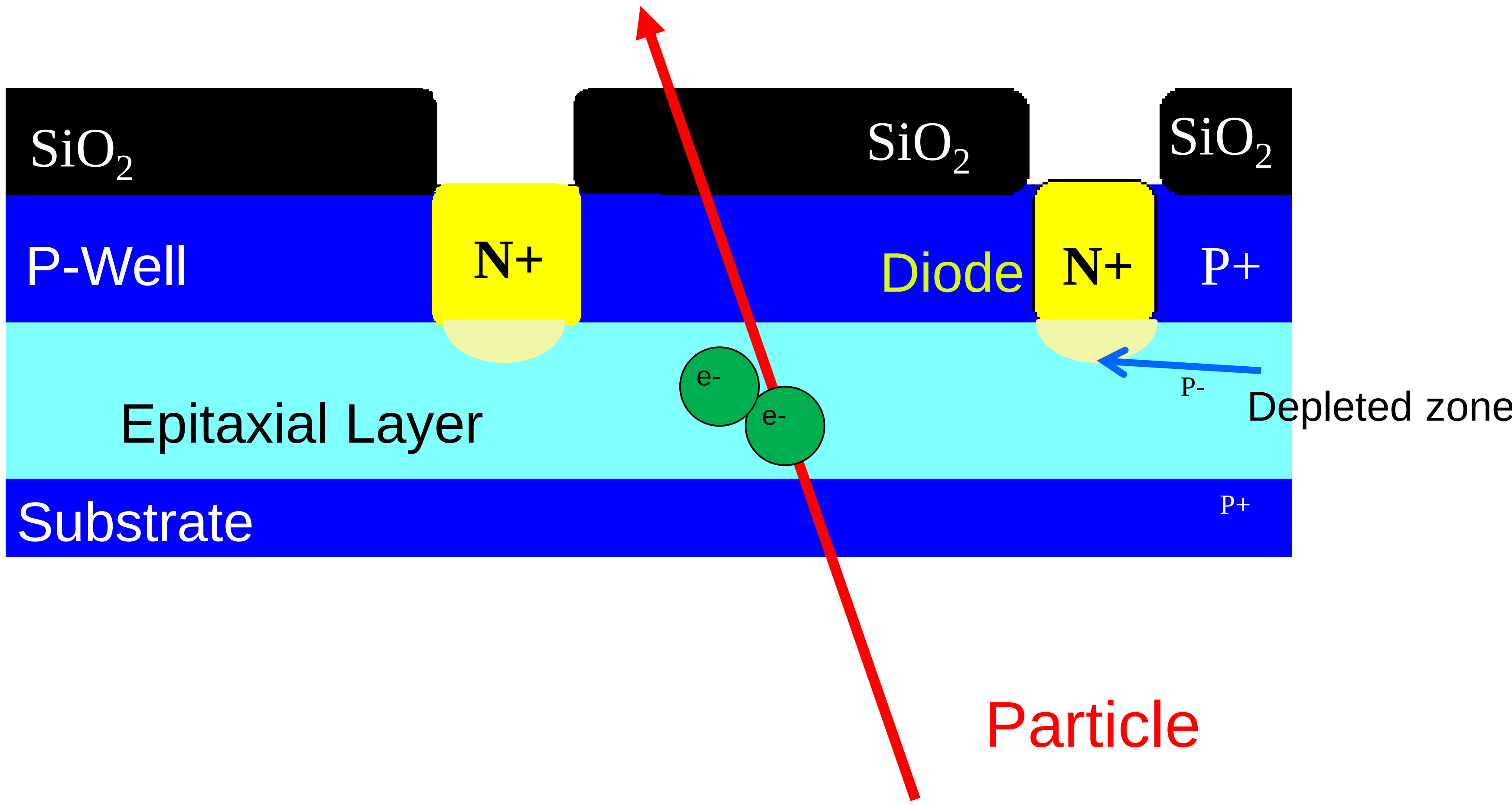
Identifing elements via their characteristic X-ray-fluorescence lines (XRF)

Required sensor features:

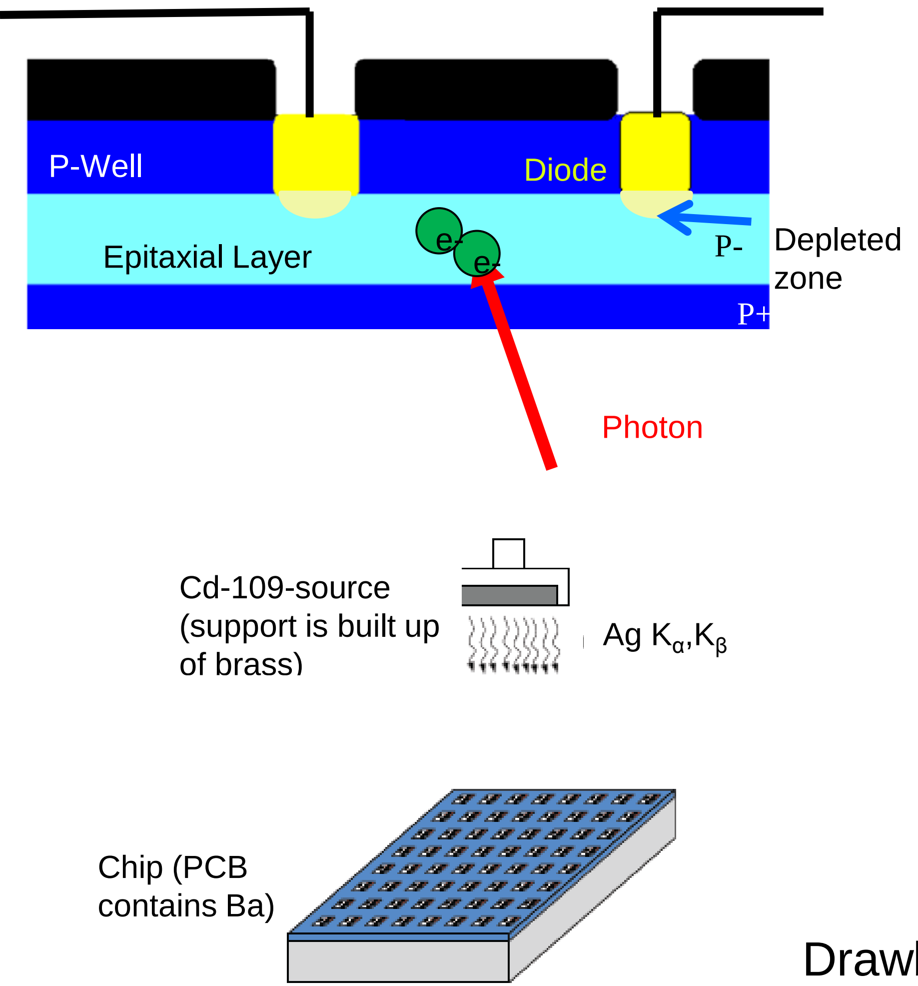
- Good energy resolution
- High-rate capability
- Low noise
- Low production costs

⇒ Adapted CMOS-sensors

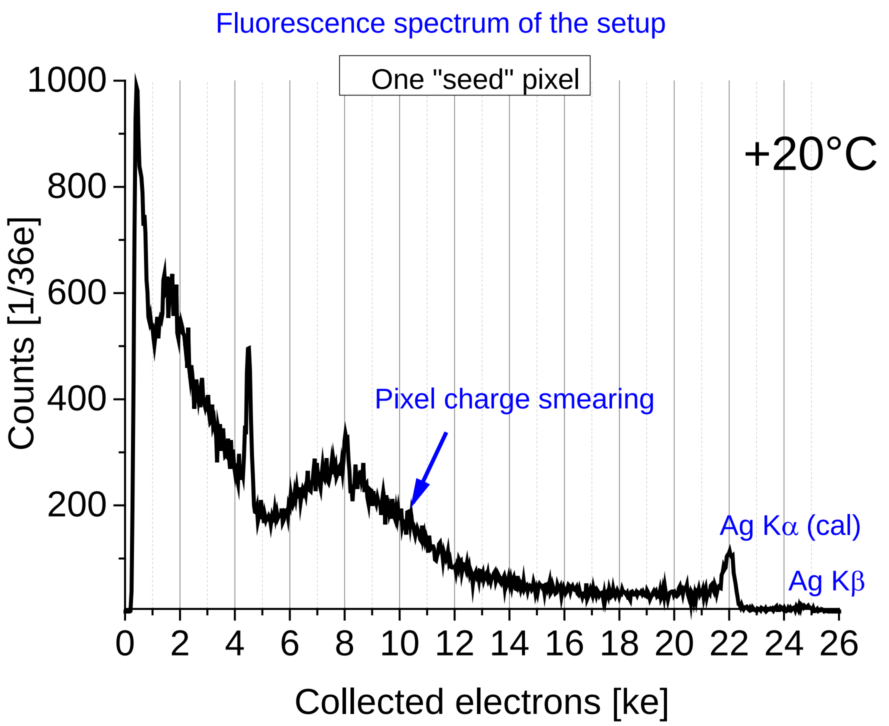
Operation principle of CMOS-sensors



Charge smearing between pixels

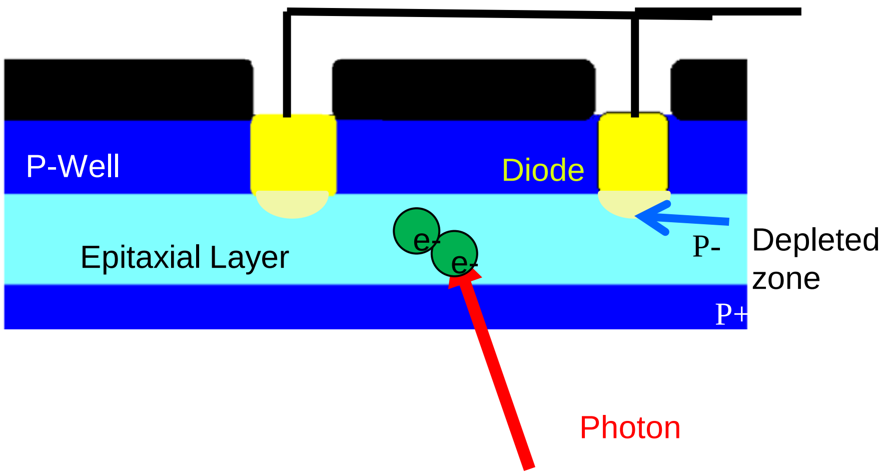


One pixel:

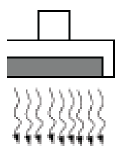


Drawback: Charge smearing

Cluster of 25 pixels

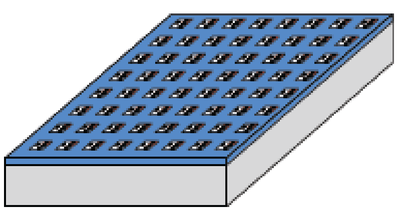


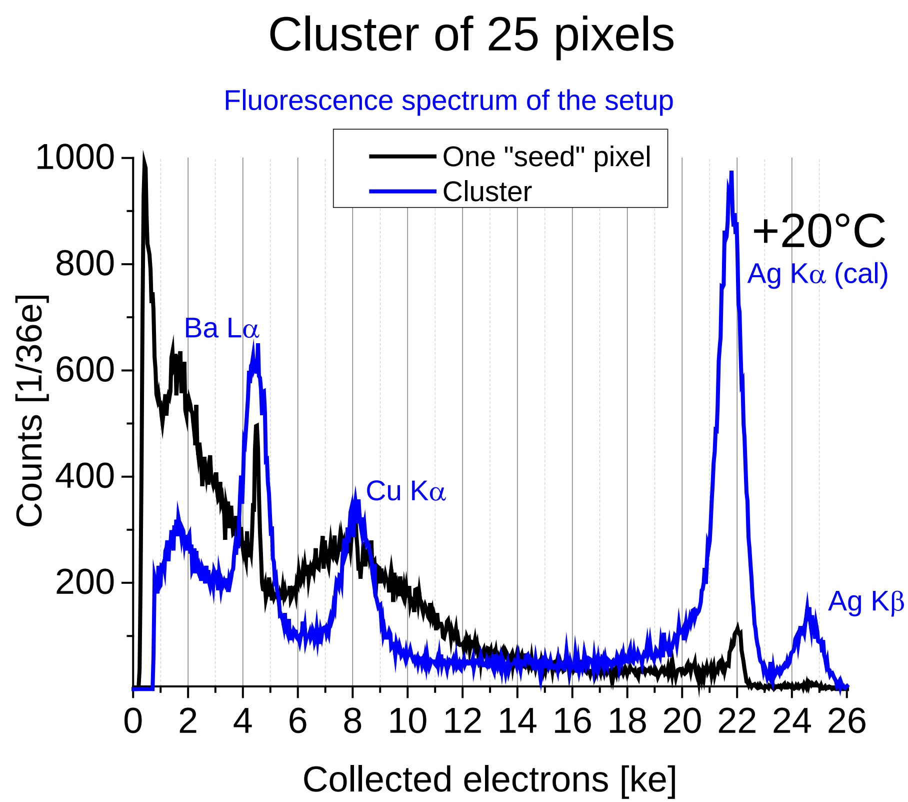
Cd-109-source (support is built up of brass)



Ag K_α,K_β

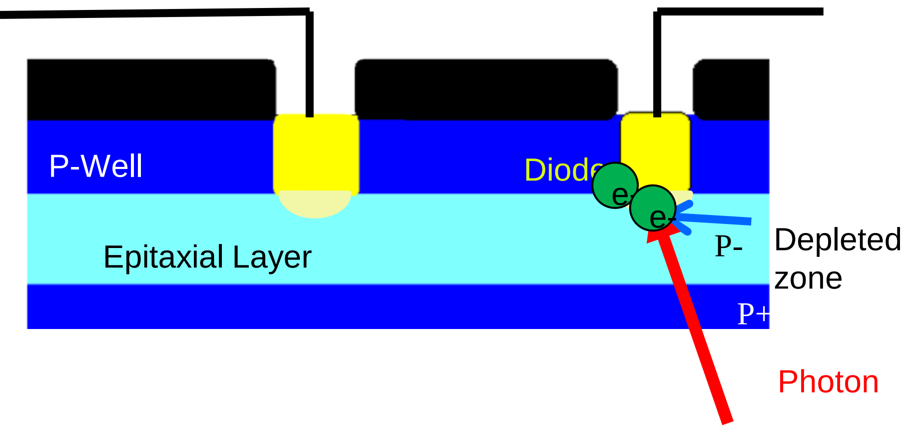
Chip (PCB contains Ba)

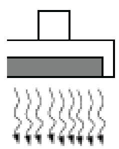


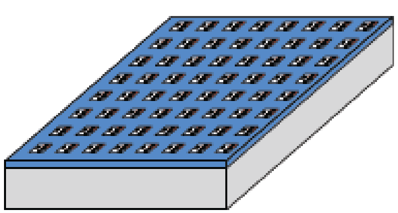


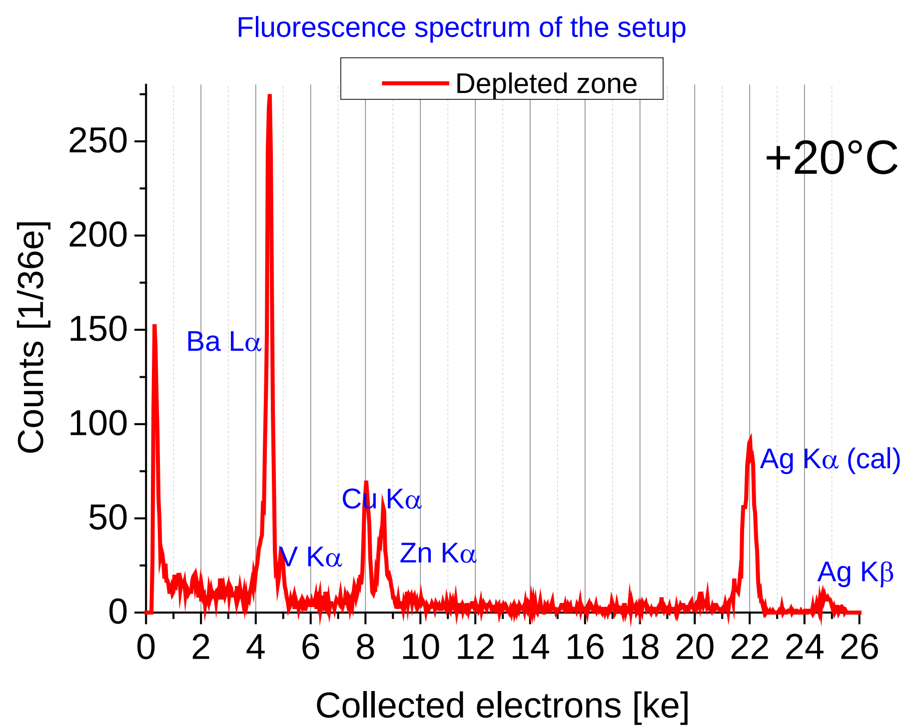
Disadvantage: Noise contribution of 25 pixels

Trigger on conversions in the depleted zone



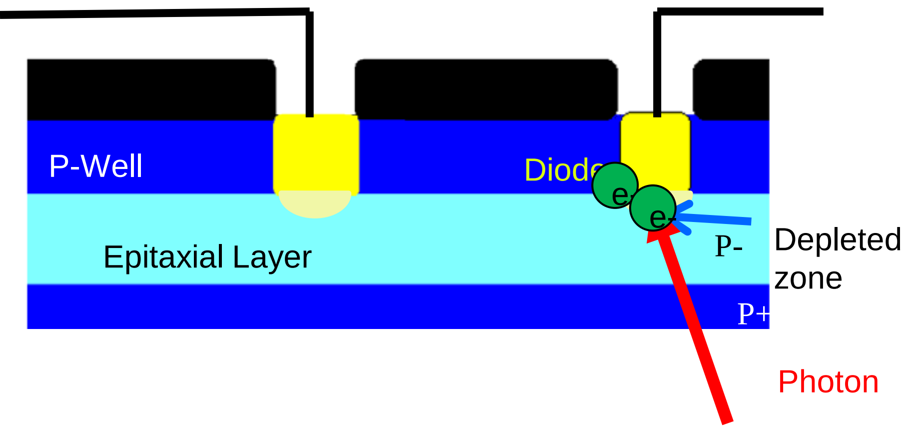


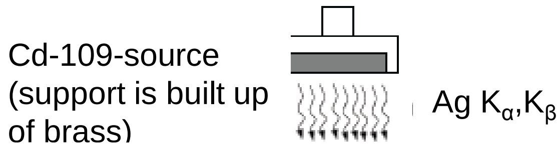


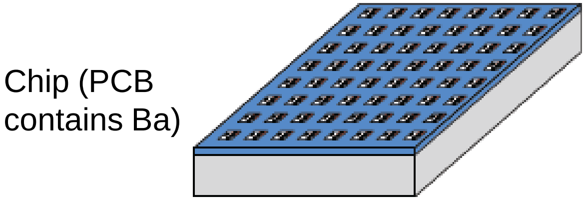


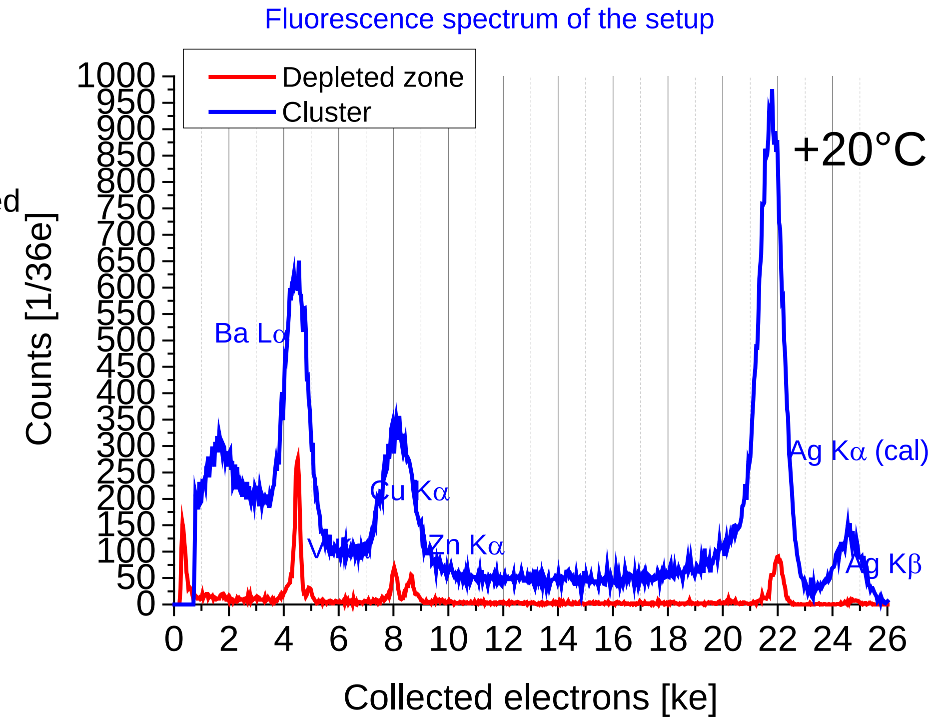
Triggercondition: Neighboring pixel carry no charge

Trigger on conversions in the depleted zone









Drawback: Reduced quantum efficiency

Linearity of amplification chain

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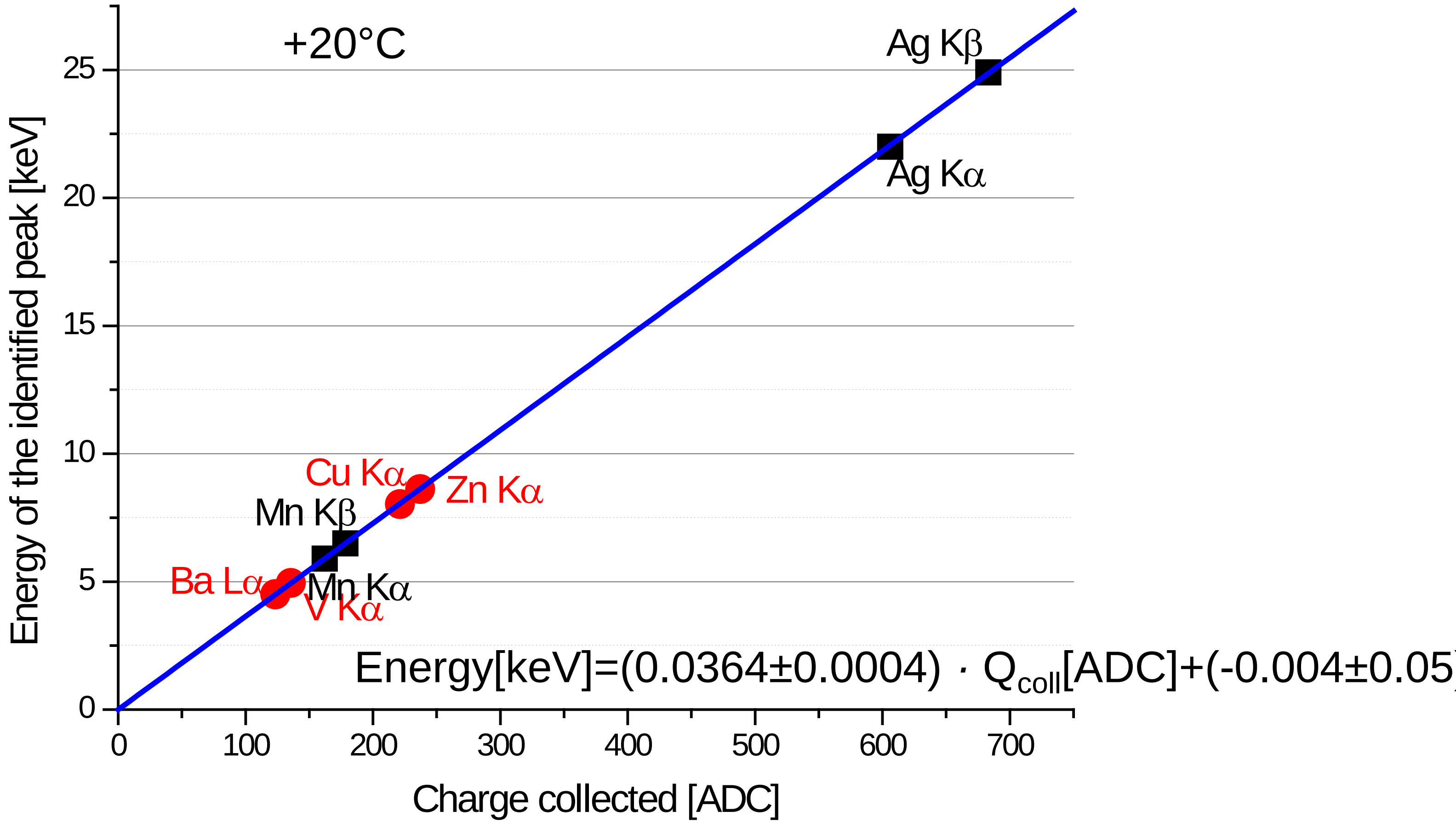
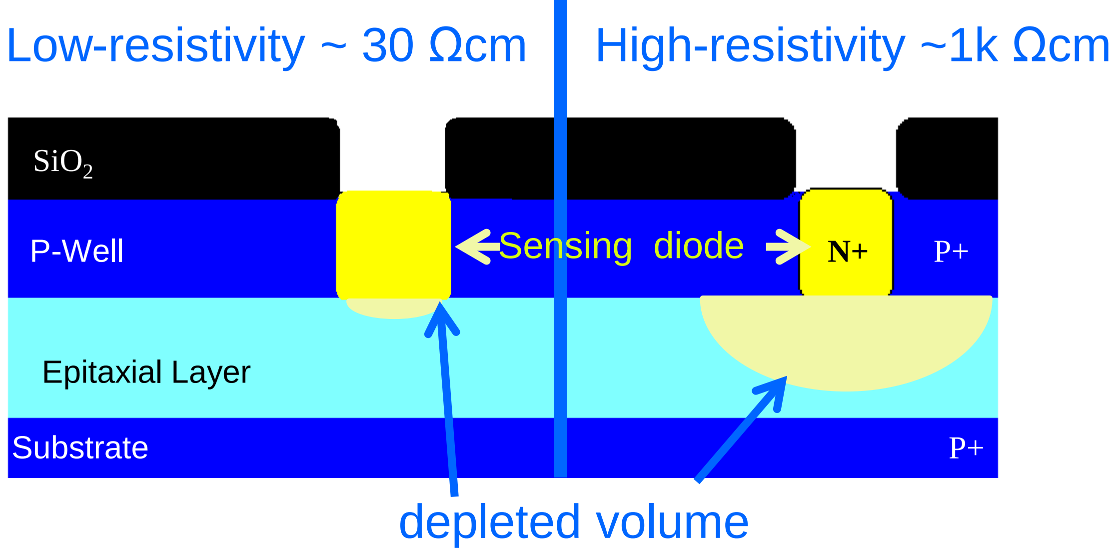


Linear energy scale at least between a few keV up to 25keV

Strategies to increase the quantum efficiency

High-resistivity: Decrease of doping concentration in epitaxial layer.
Depletion voltage: Increase the depleted volume

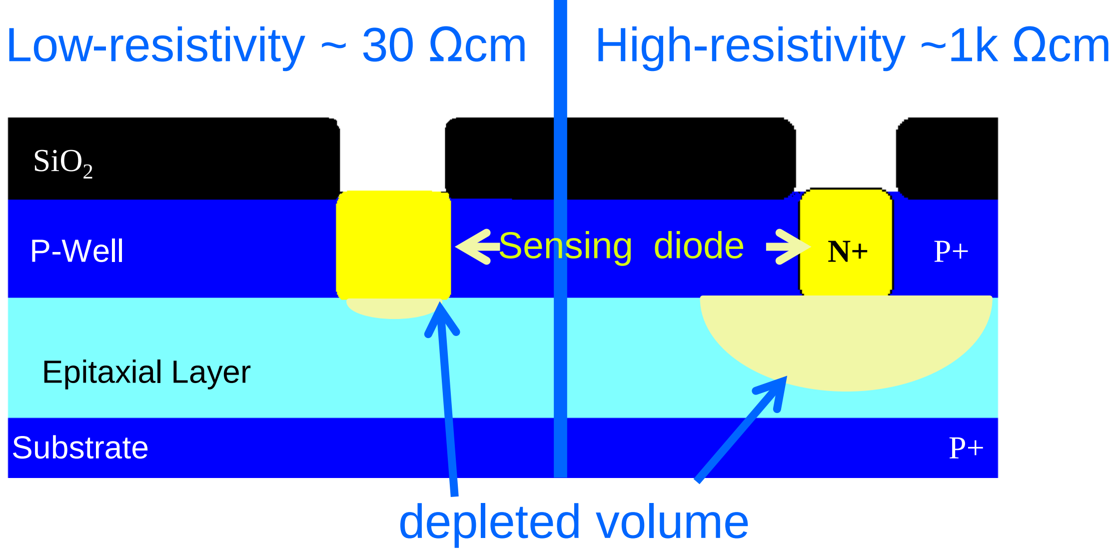


Larger depleted volumes:
⇒ Accelerated charge collection, less diffusion
⇒ Less charge smearing between pixels

Aim: Full depletion of the epitaxial layer

TOWER-Jazz-Process

High-resistivity: Decrease of doping concentration in epitaxial layer.
Depletion voltage: Increase the depleted volume



TOWER-Jazz-0.18µm process
- High-Resistivity 1-8kΩcm
- Depletion voltage up to 20V

Larger depleted volumes:
⇒ Accelerated charge collection, less diffusion
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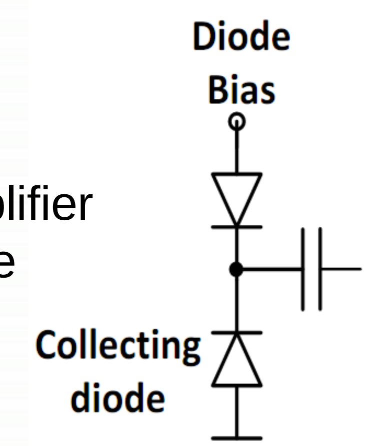
Aim: Full depletion of the epitaxial layer

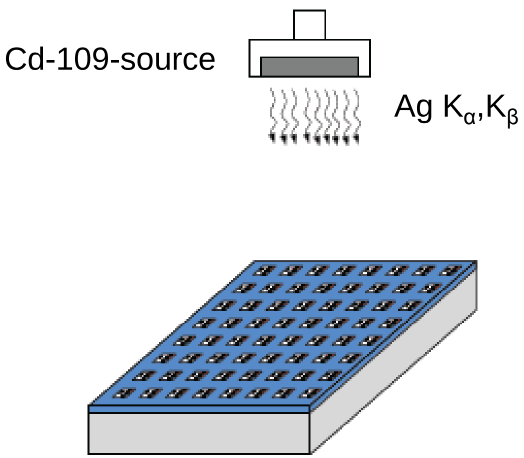
Modified preamplifier
- Recharge diode
- AC-coupled

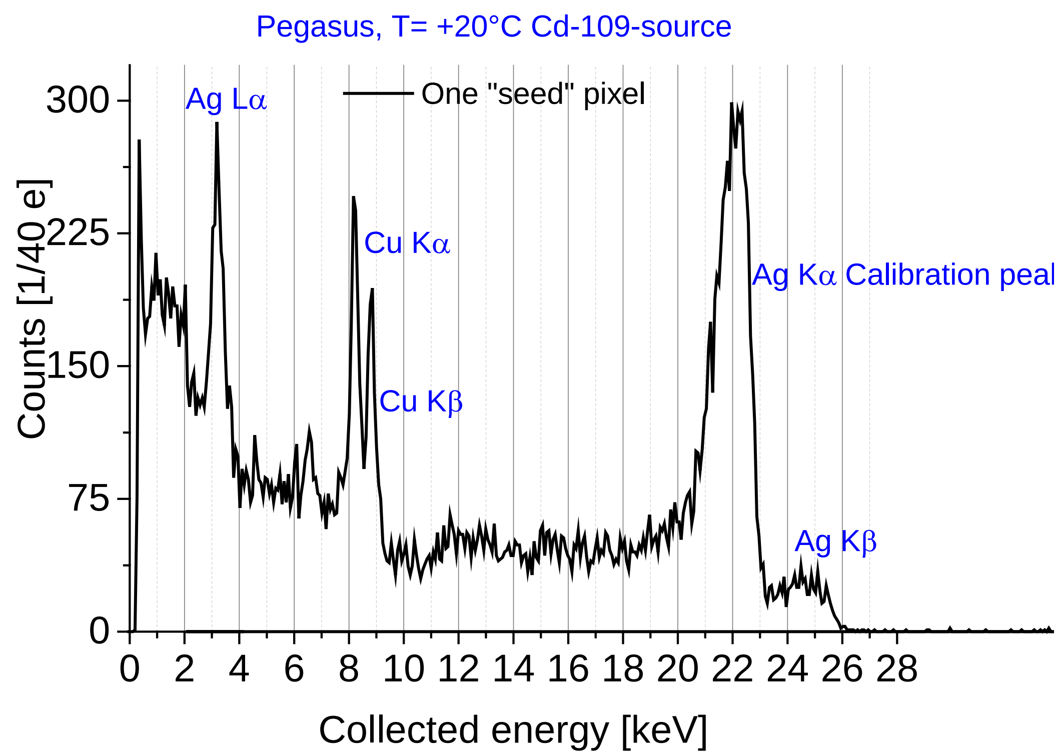


TOWER-Jazz 0.18µm CMOS process for imager

The Sensor: PEGASUS (2015)

18µm thick, 25µm pixel pitch, >1kΩcm epitaxial layer, 12 V bias voltage





Less charge smearing

⇒ Larger depletion zone

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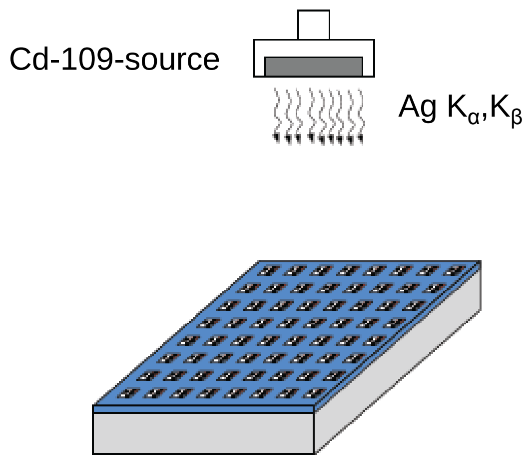
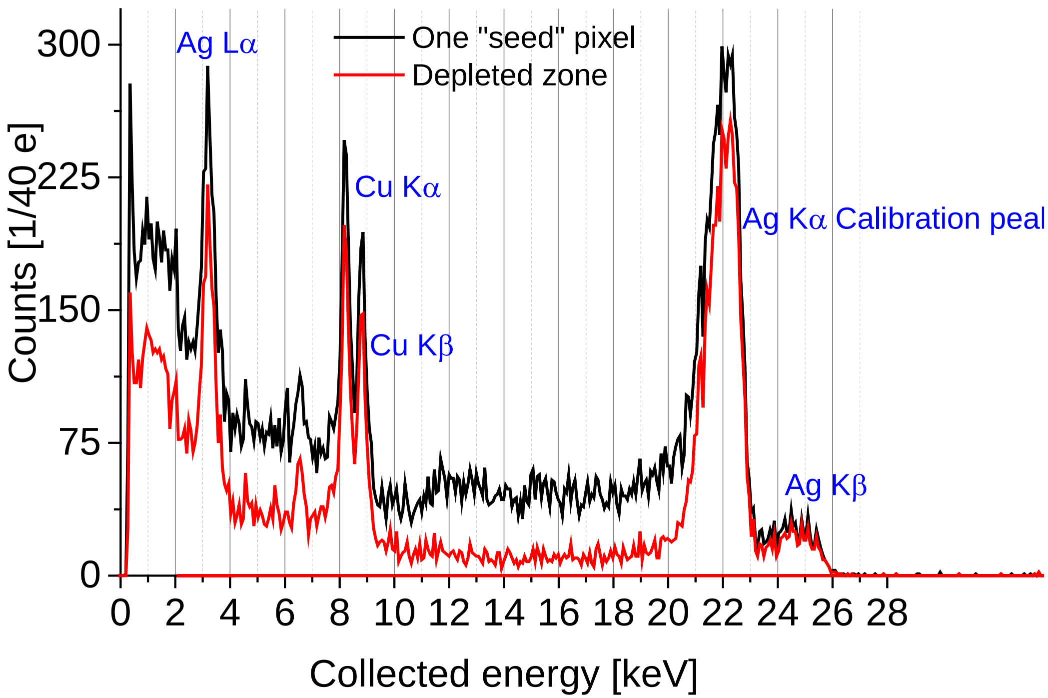


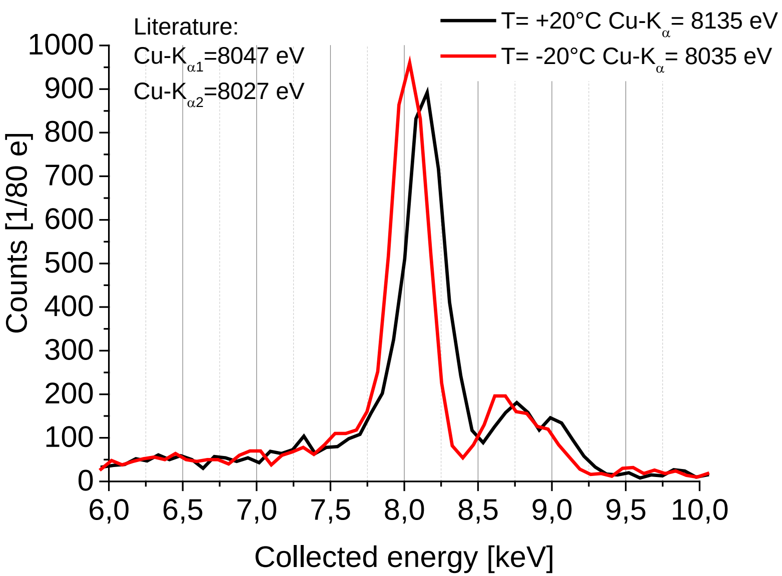


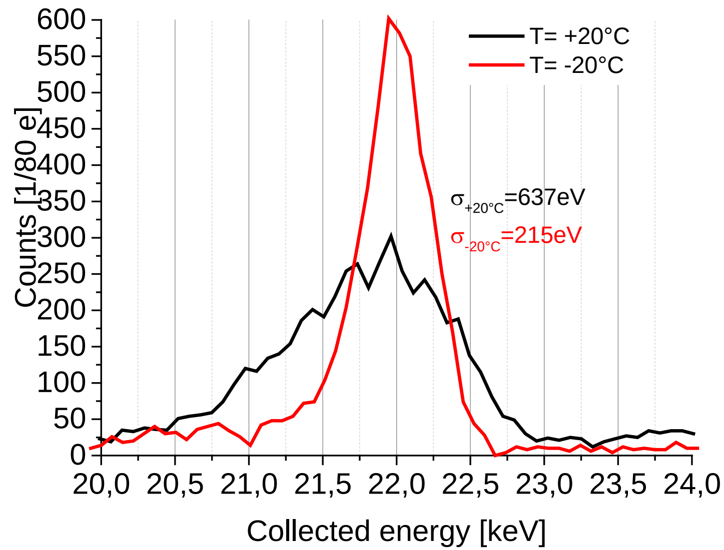
Less charge smearing

⇒ Larger depletion zone

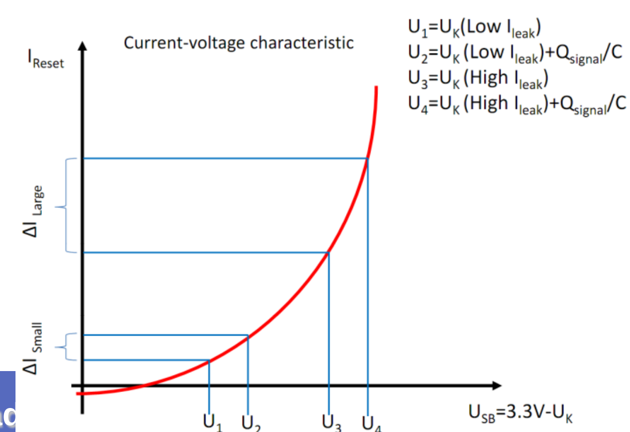
Trigger on neighboring pixels still helps

Influence of the leakage current



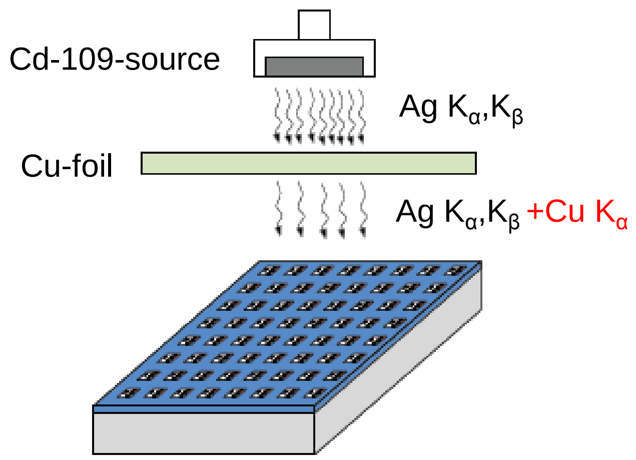


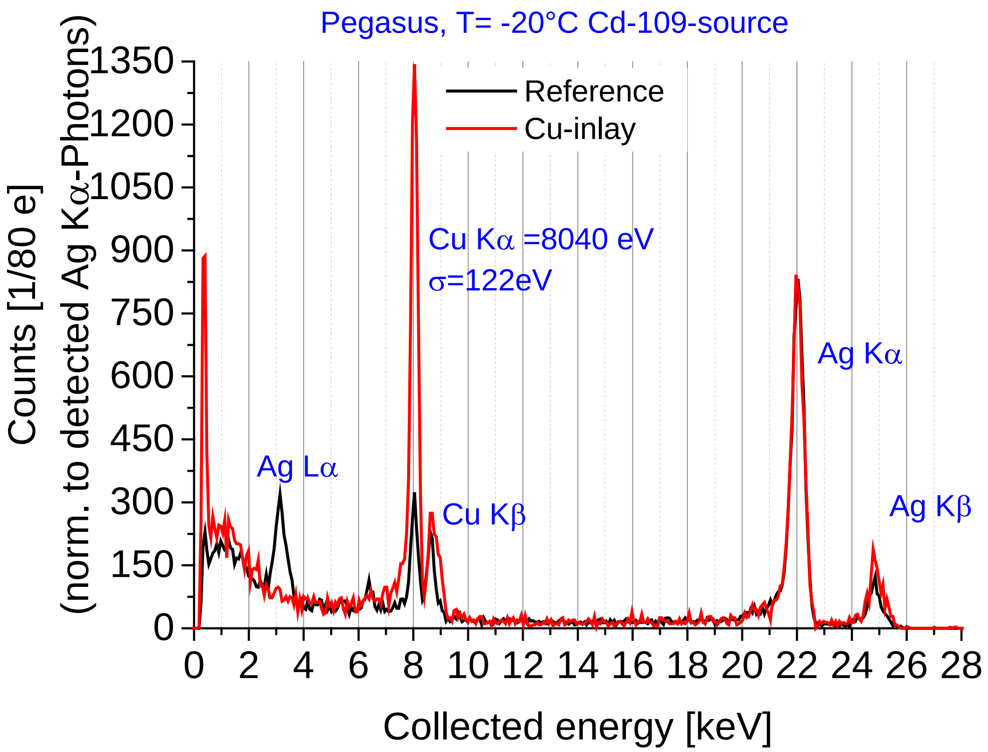
Due to the non-linear response
of the recharge diode at +20°C :
- Limited energy resolution
- Non-linear amplification



⇒ Optimizing of the pixel layout required (Pegasus-3)
⇒ Cooling to -20°C so far helps

Cu-inlay





Expected excess in Cu-Kα-line observed
Energy resolution is σ=122eV

Conclusion

Application: Real-time water analysis via X-ray fluorescence analysis

⇒ CMOS-Sensors proposed

Studied two CMOS-sensors: MIMOSA-19 and Pegasus

Possible above 2 keV with an energy resolution of 120…190eV
At room temperature or slightly cooled conditions

⇒ Sensors seem suited for the task

Outlook:
Obtain higher quantum efficiency due to full depleted epitaxial layer
Detailed study of high-voltage CMOS-sensors required

DFG proposal submitted