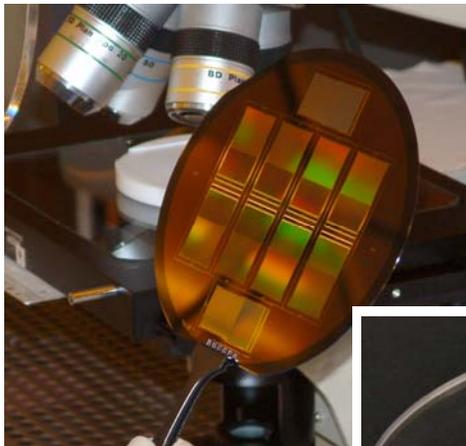




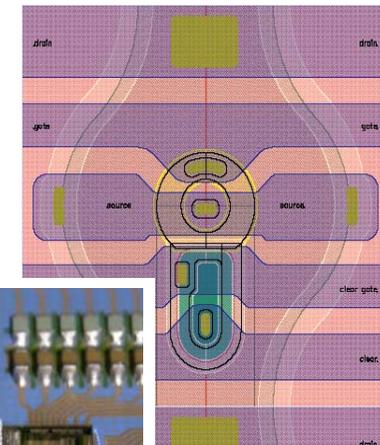
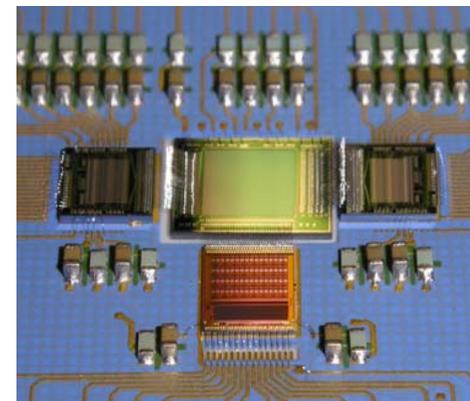
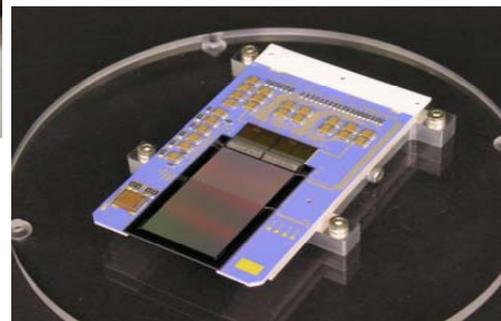
The Seventh International Conference on Position Sensitive Detectors



DEPFET APS and pnCCDs for room temperature imaging spectroscopy of X- rays in space missions and terrestrial astronomy



The University of Liverpool,
September, 12 -16th, 2005





The people



X-ray pn-CCDs

R. Andritschke, O. Hälker,
G. Hasinger, G. Hartner, S. Herrmann,
N. Kimmel, N. Meidinger,
G. Schaller, L. Strüder
Max-Planck-Institut f. extraterrestr. Physik



G. Lutz, M. Schnecke
Max-Planck-Institut f. Physik



R. Hartmann, P. Holl, H. Soltau
PNSensor GmbH



W. Buttler
Ingenieurbüro Buttler, Essen, Germany

DEPMOSFET active pixel sensors

J. Treis, O Hälker, S. Herrmann,
L. Strüder, S. Wölfel
Max-Planck-Institut f. extraterrestr. Physik



R. Richter, G. Lutz
Max-Planck-Institut f. Physik



P. Lechner
PNSensor GmbH



R. Kohrs, H. Krüger,
M. Trimpl, N. Wermes
Universität Bonn



P. Fischer, I. Peric
Universität Mannheim



M. Porro
Politecnico di Milano





The location



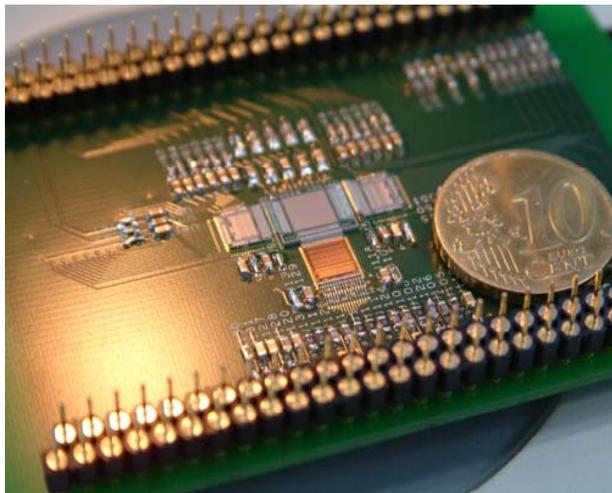
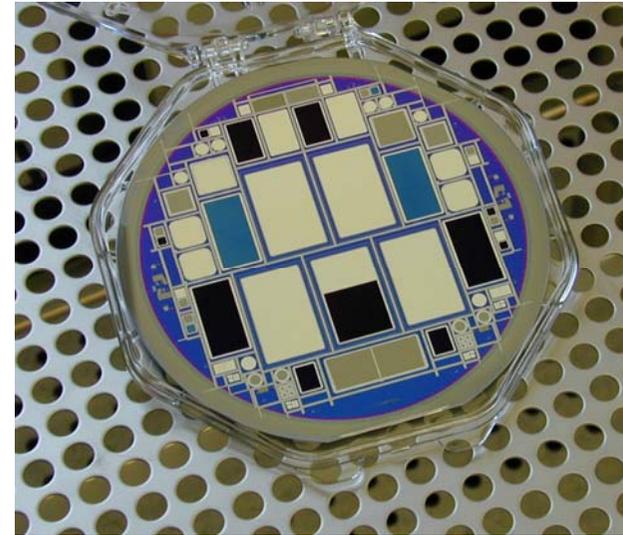
or, Munich, germany

Q

Dicing, r

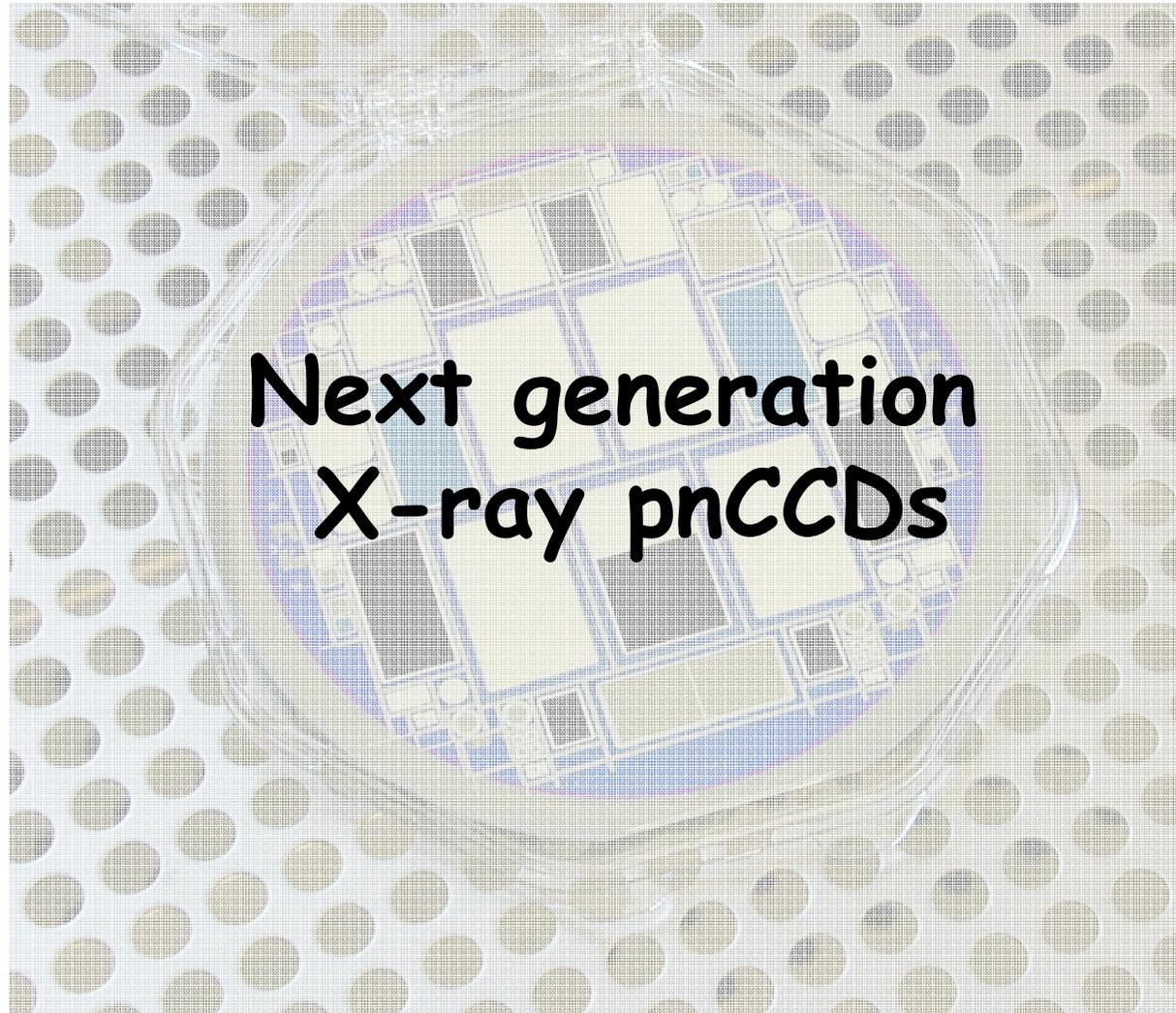
Device tests and operation

- **Next generation X-ray pnCCDs**
- Working principle
- Performance
- Applications



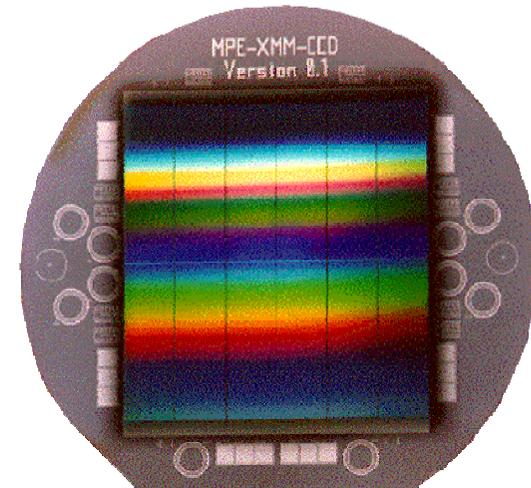
- **DEPMOSFET devices**
- Working principle
- Performance
- Future applications

I.



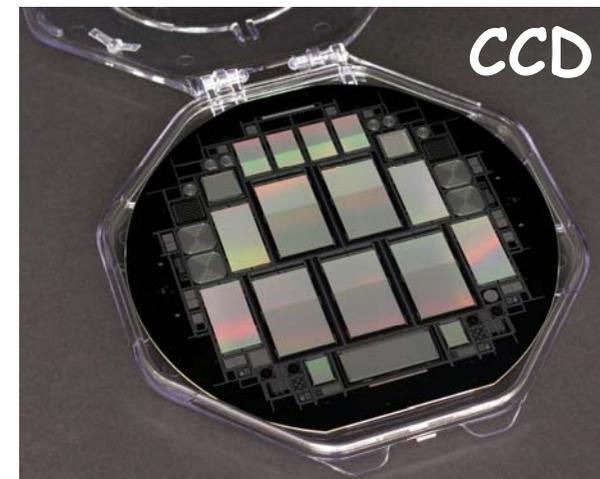
XMM-Newton pnCCD:

- All 12 CCDs still operating (since 1999)
- Same operating parameters ($T = -90^{\circ}\text{C}$)
- Quantum efficiency unchanged
- Slight radiation damage as expected
- Al-K (1.5 keV): 110 eV \rightarrow 111 eV
- Mn-K α (5.9 keV): 155 eV \rightarrow 160 eV

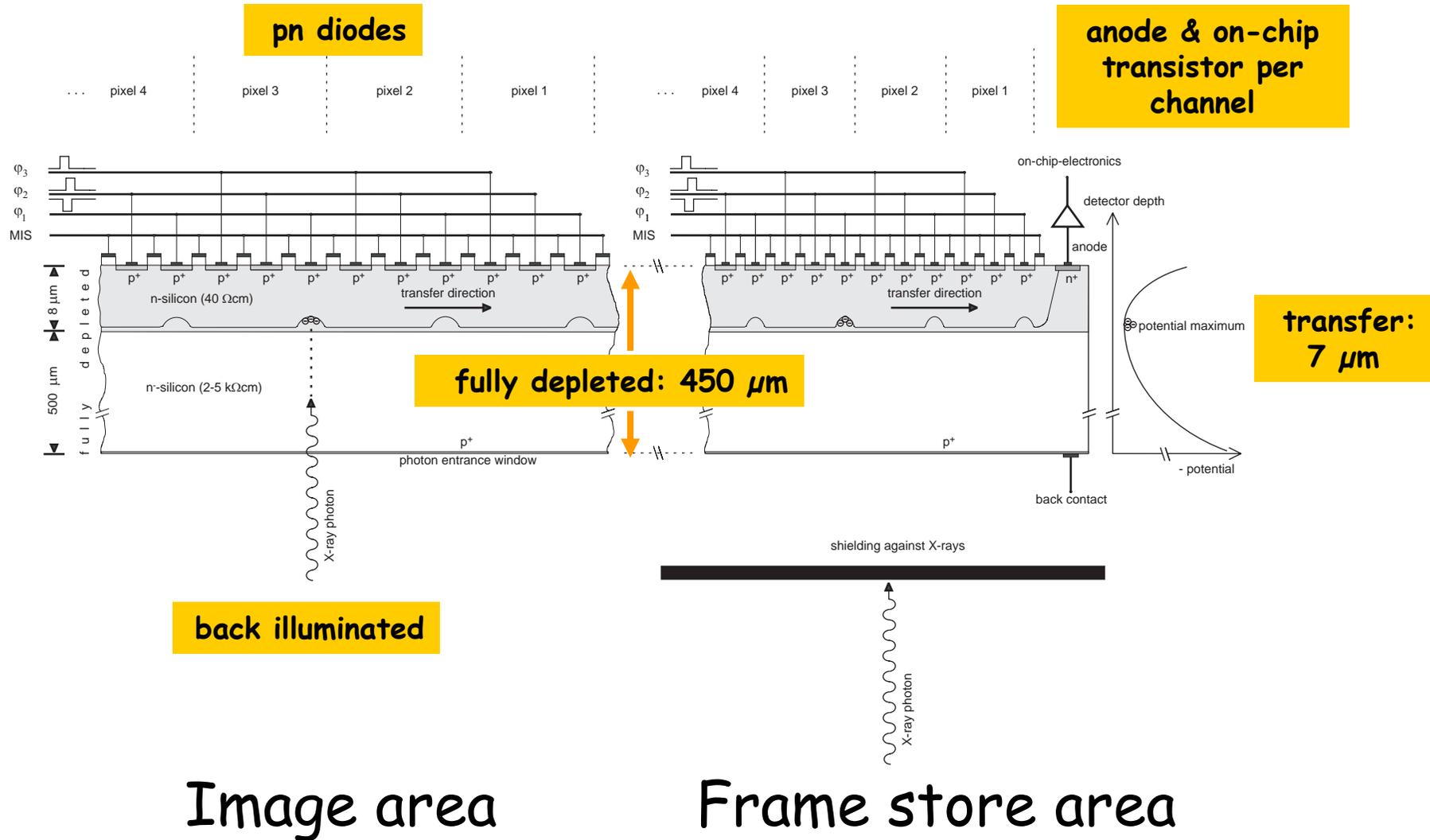


New pnCCD generation:

- Frame store \rightarrow high frame rate
- Silicon $\langle 100 \rangle$, 450 μm , HE implant
- Fabrication process \rightarrow lower dark current
- Lower read out capacitance (25 fF)



Frame Store pnCCD



ROSITA FS CCD type

Image area:

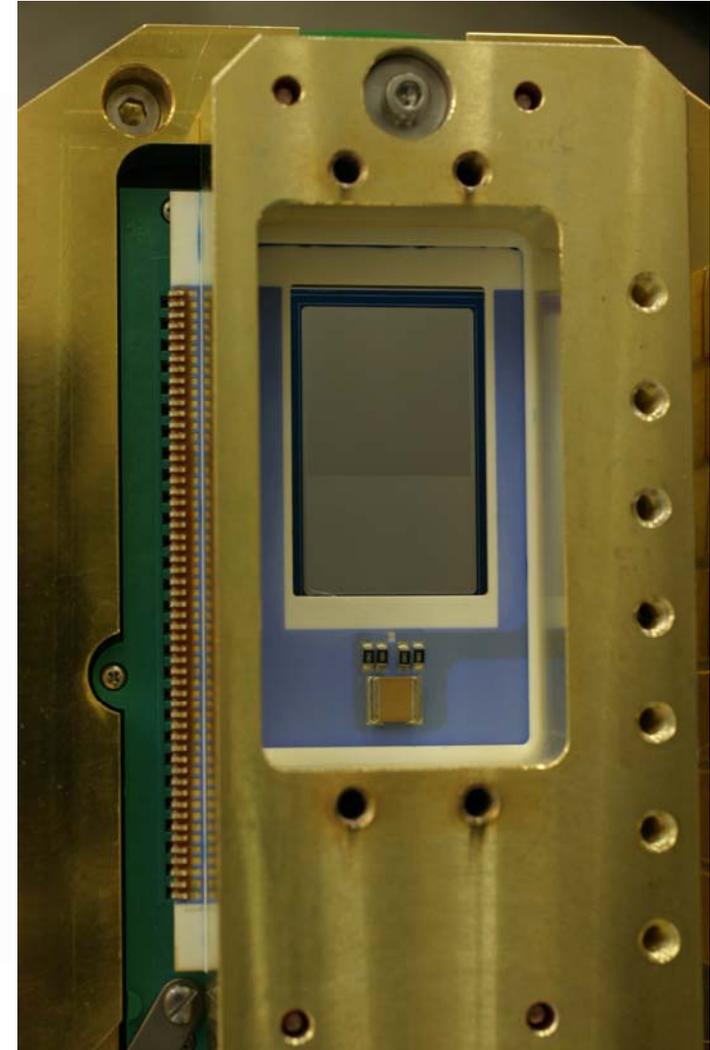
- 256 rows x 256 channels
- Pixel size: $75\ \mu\text{m} \times 75\ \mu\text{m}$ ($51\ \mu\text{m}$)
- 100 % fill factor
- Good EW: QE (0.3... 11 keV) $\geq 90\%$

Column parallel readout:

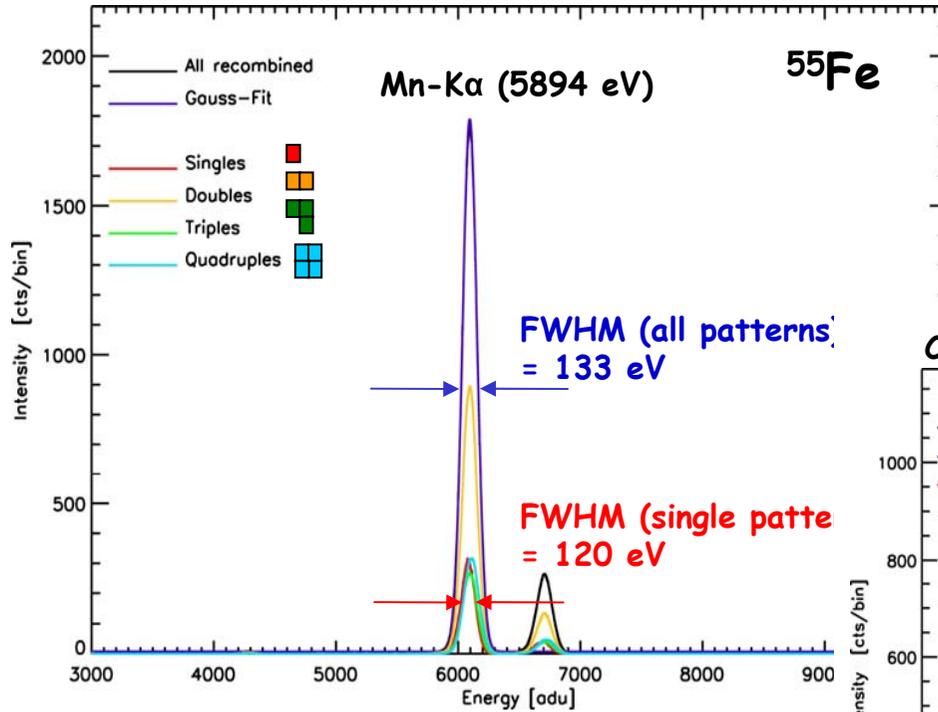
- 256 anodes
- 256 JFETs
- 256 CAMEX channels

Frame store:

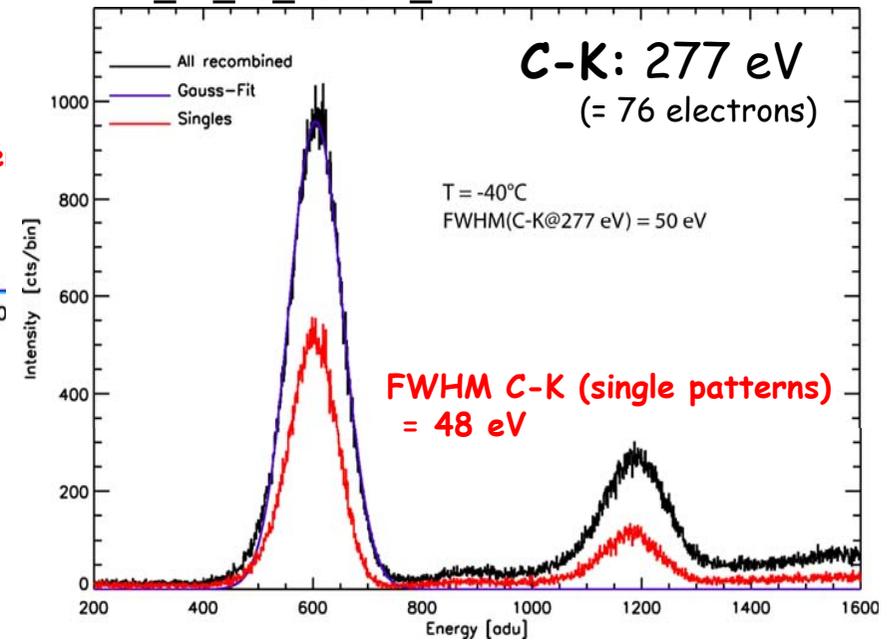
- very high frame rate without smearing of image (120 - 240 /s)
- Fast transfer time (100 μs)
- Little out-of-time event probability



C11_11_61_050422_01, T = -83°C; 54 ms

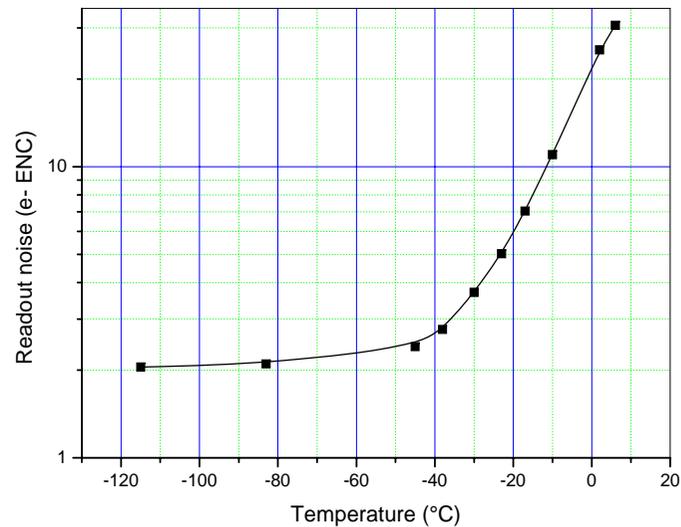


C11_11_25_050512_02

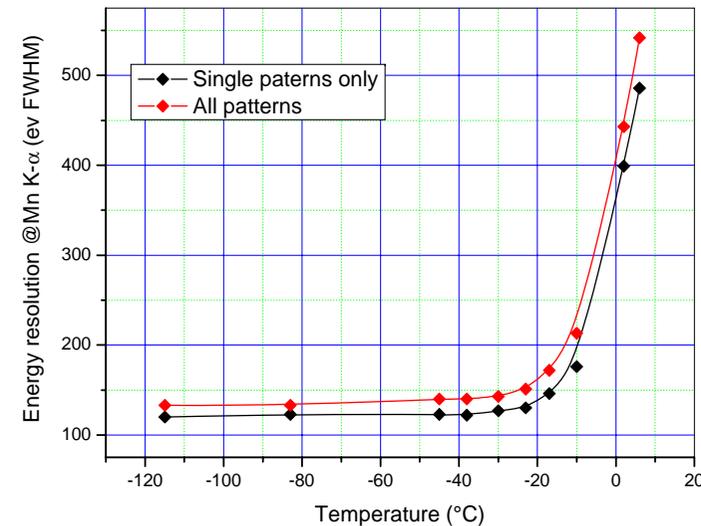


Results from $^{55}\text{Mn-K}\alpha$ peak fits

Readout noise (e⁻ ENC)



eV FWHM @ Mn- Ka

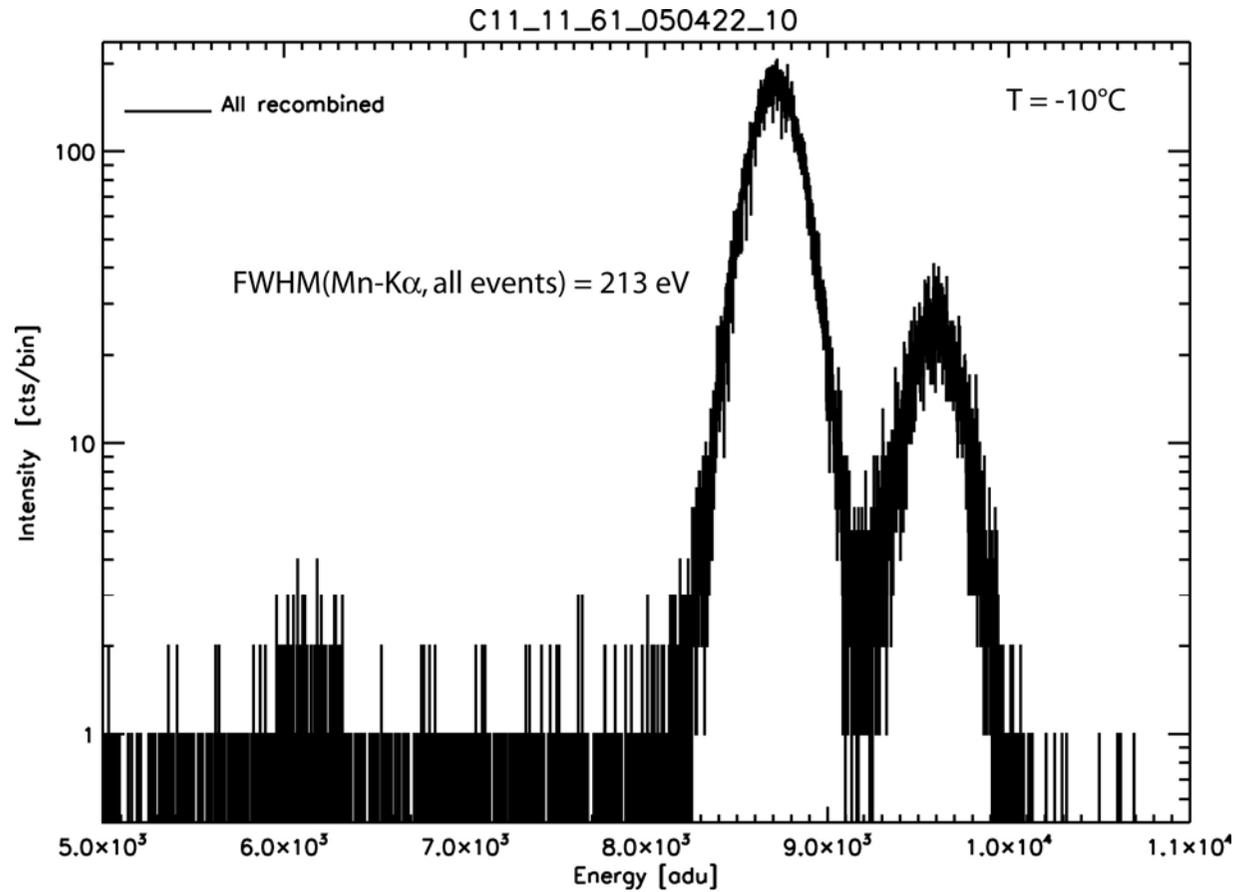


Pixel readout noise:

- 2.05 e⁻ ENC @ -120 °C
- 30.6 e⁻ ENC @ + 6 °C

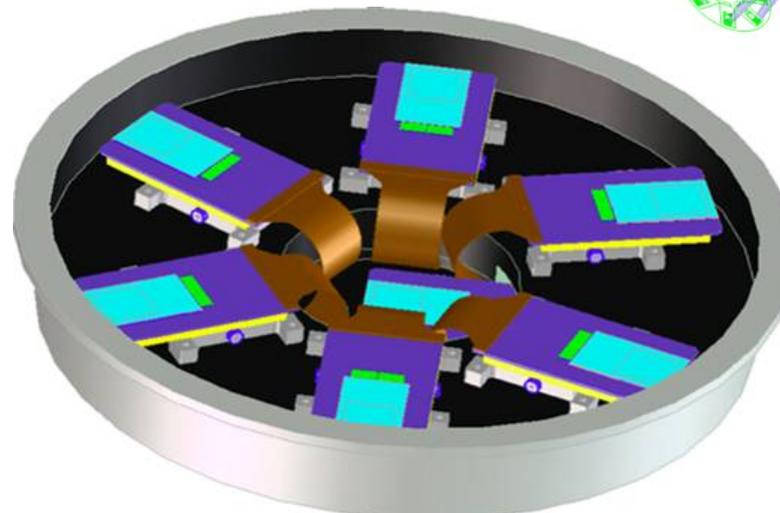
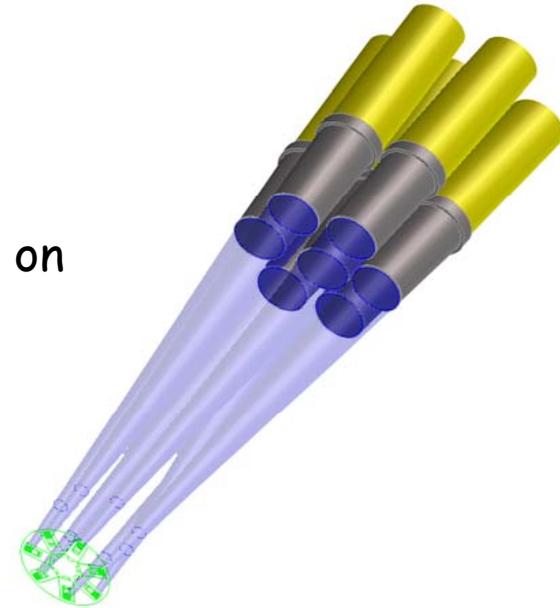
Values:

- 120 eV (singles) @ - 86° C
- 133 eV (all patterns) @ - 86° C
- 486 eV (singles) @ + 6° C
- 542 eV (all patterns) @ + 6° C



ROSITA (ROentgen Survey with an Imaging Telescope Array)

- Proposed **German-ESA mission**
- Array of 7 X-ray telescopes mounted together on common platform
- Back illuminated frame store pnCCD developed for X-ray astronomy mission
- **Required Temperature: $T > 200$ K**



Artist's view



Applications: AO wavefront sensing



Requirement:

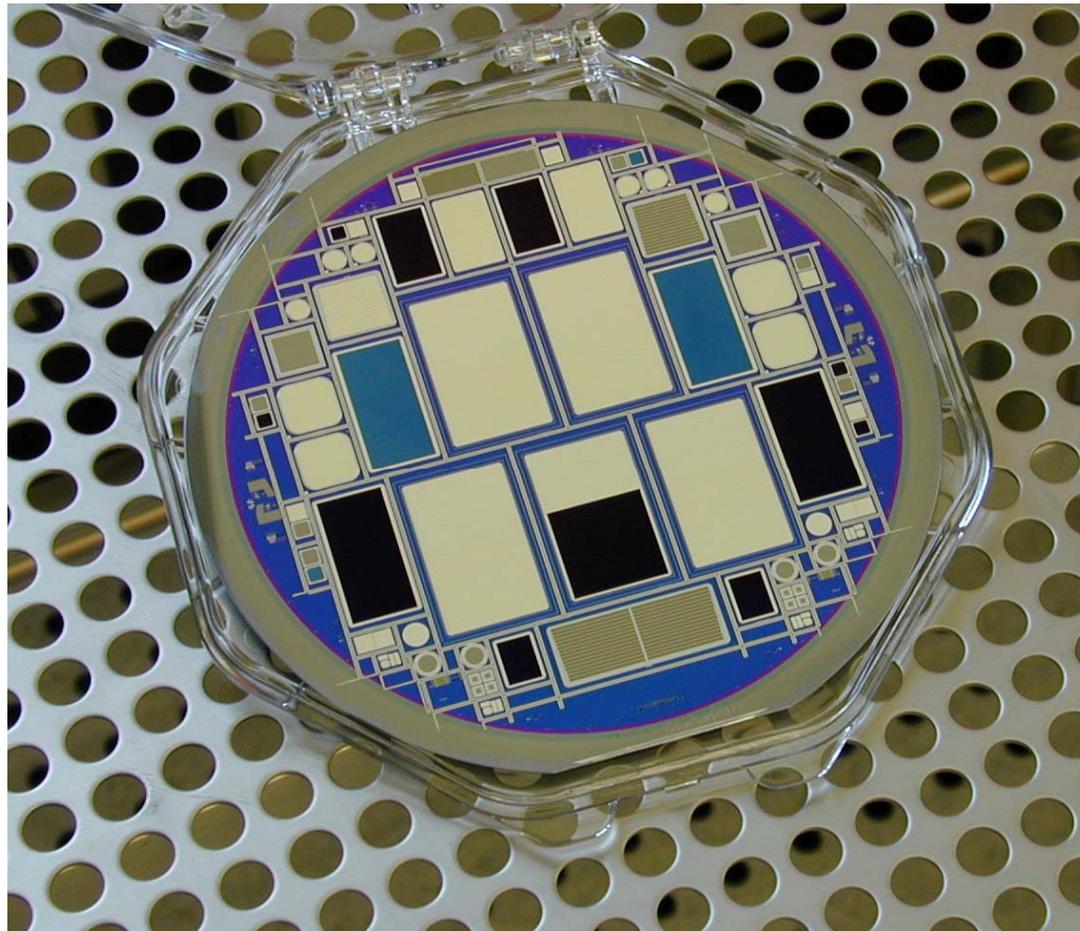
- High speed readout
- Large sensitivity for photons in the optical wavelength region

Tasks:

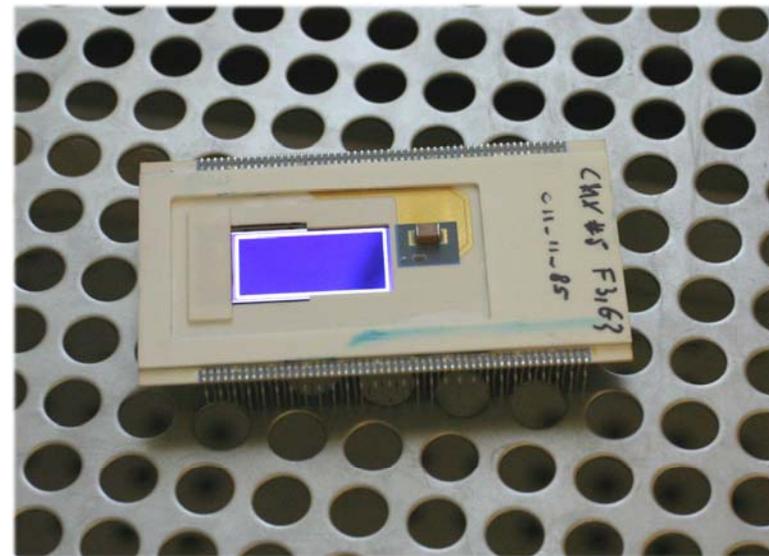
- Reduce dead layer effects
- Minimize reflectivity
- Speed up readout

Anti-Reflective coatings

150 mm wafer of recent CCD fabrication



- Detector size $27 \times 13.5 \text{ mm}^2$
- $51 \mu\text{m} \times 51 \mu\text{m}$ pixel size
- 528×264 pixel in total ($\times \frac{1}{2}$)
- 100% fill factor
- Readout transfer to both sides
- Image transfer time: $30 \mu\text{s}$
- Readout noise vs. frame rate:
 - $1.8 e^-$ @ 10 .. 400 fps
 - $2.3 e^-$ @ 400 .. 1.100 fps



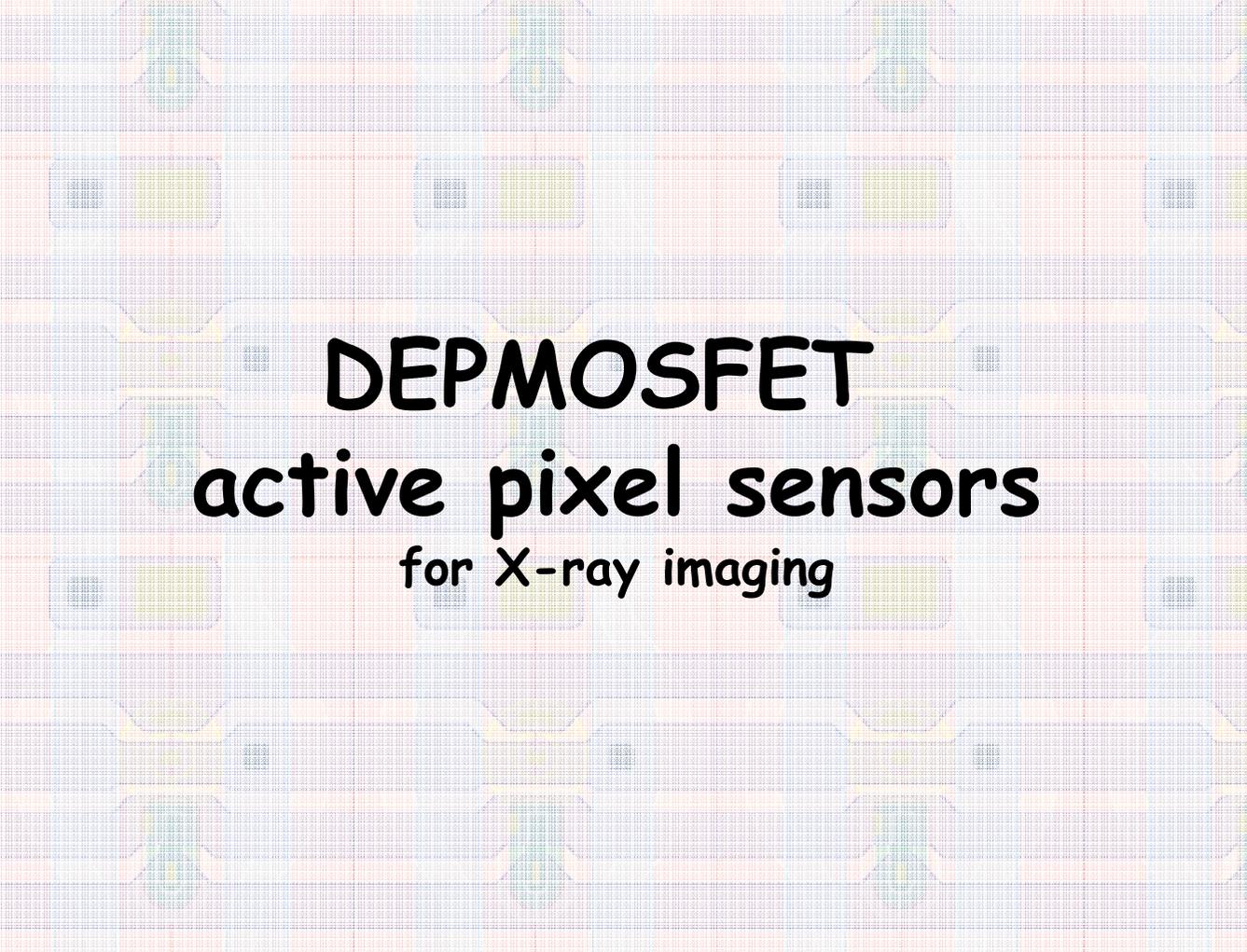
OOT probability = 3% @ 1000 fps
 charge transfer loss CTI $\approx 10^{-5}$
 i.e. total charge loss < 0.15 %
 charge handling capability > $10^5 e^-$



Summary I

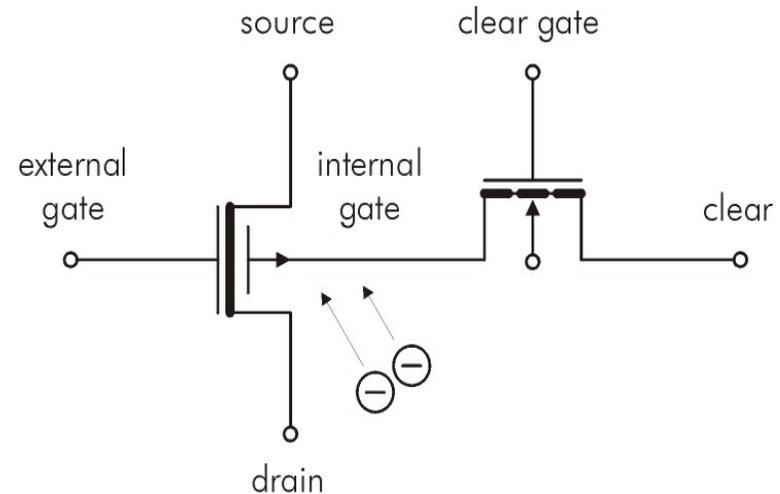
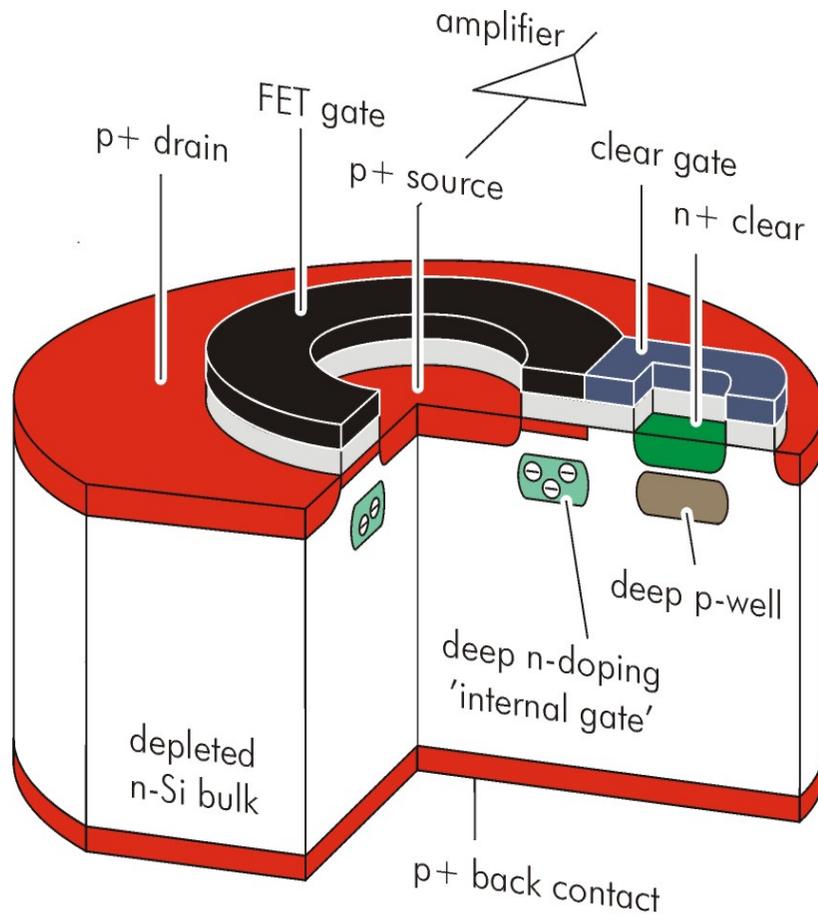


- **Next generation X-ray pnCCDs** show excellent imaging and spectroscopic properties
- Suitable for experiments with limited cooling resources
- Improved fabrication technology: operation near room temperature comes within reach
- Fast readout using FS CCDs and massive parallelization beneficial
- Customized AR coatings applicable: Applications in optical astronomy

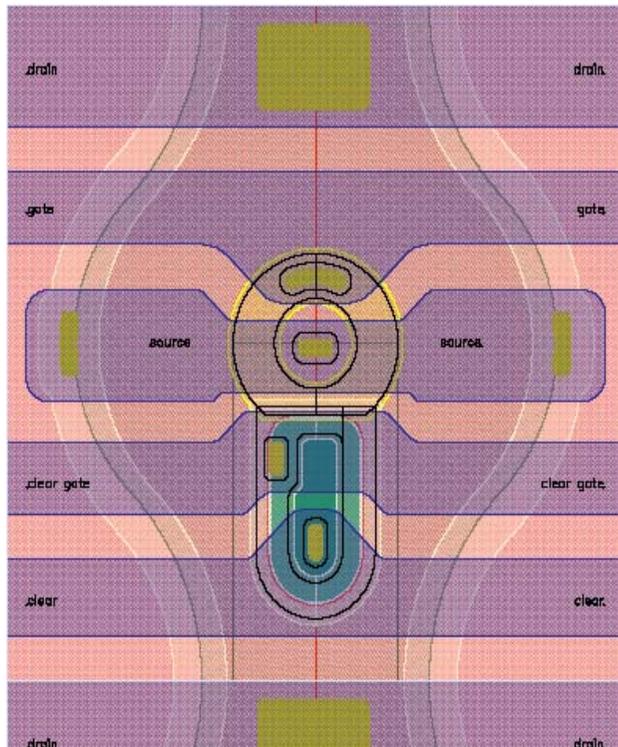
A microscopic image of a DEPMOSFET array, showing a grid of small, square, active pixel sensors. The sensors are arranged in a regular pattern and are connected to a network of lines. The image is overlaid with a grid of colored squares (blue, orange, green, yellow) that correspond to the sensor layout.

DEPMOSFET active pixel sensors for X-ray imaging

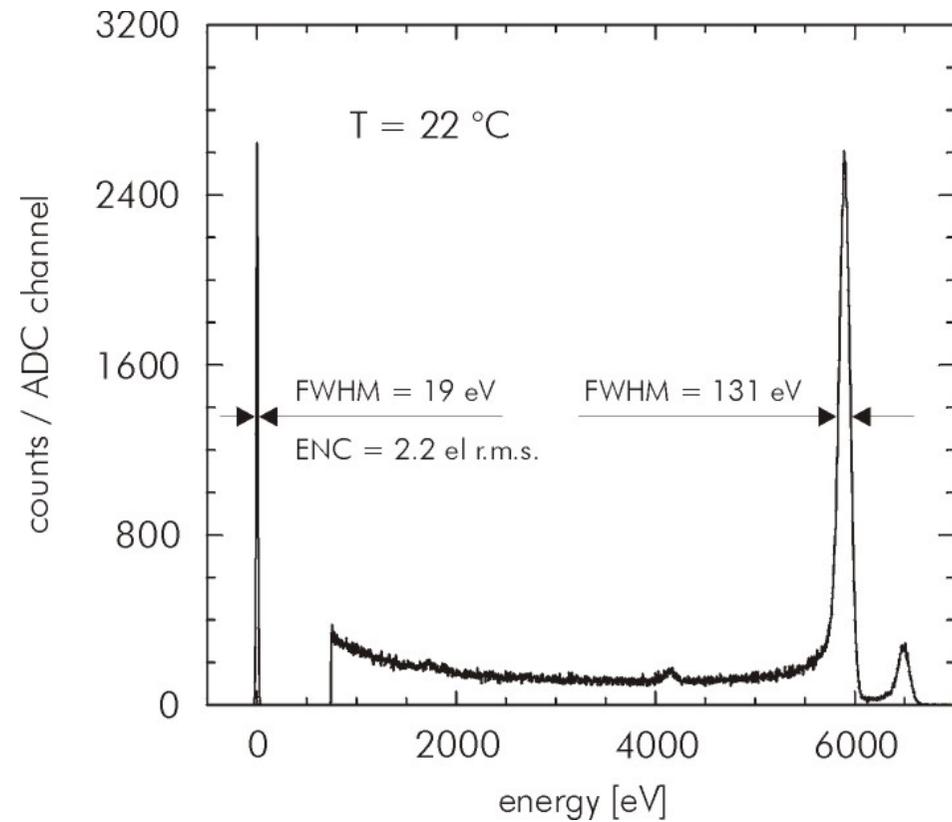
Circular DEPMOSFET pixels



∞ Talks by G. Lutz, L. Reuen



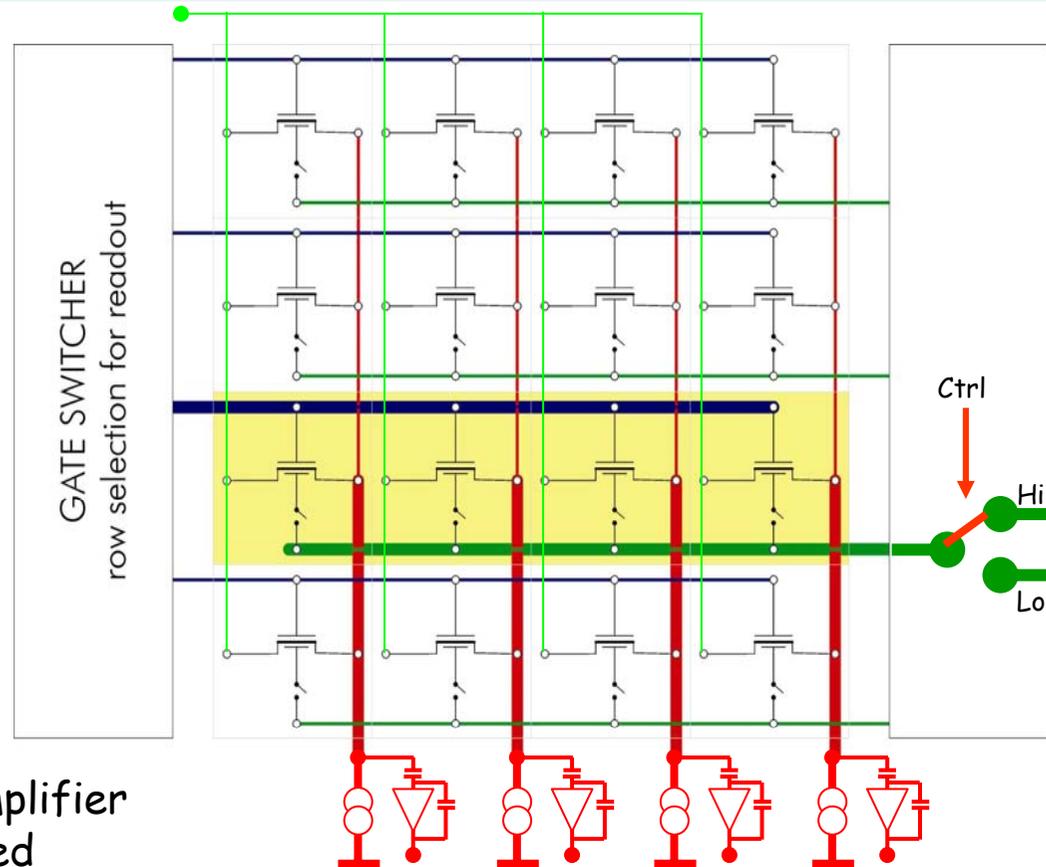
➤ Layout view



Noise peak: $\sigma = 2.2 \text{ e}^- \text{ ENC}$

Energy resolution: FWHM @ 5.9 keV = 131 eV

- Global drain contact
- Sources connected column-wise
- Gate, Clear & Cleargate connected row-wise
- Source follower readout: Column biased by current source



CAMEX 64 G:

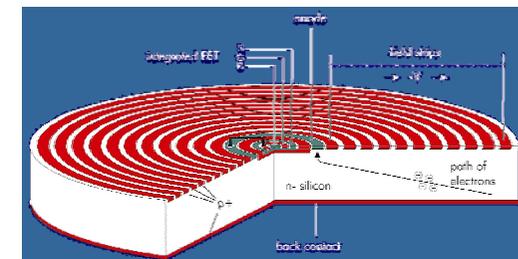
64 channel low noise voltage amplifier
8-fold CDS-filter and integrated sequencer

Switcher II:

Control chip with 64 channels a 2 ports & integrated sequencer
AMS high voltage CMOS process (up to 20 V)

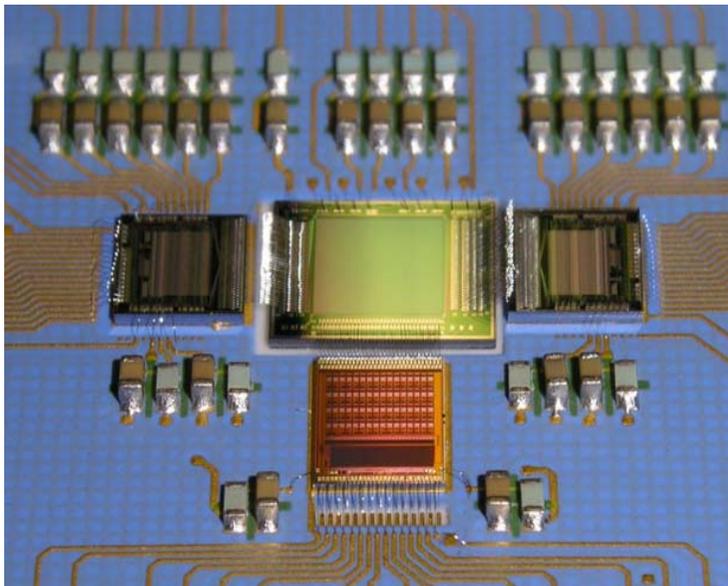
Why DEPMOSFET sensors?

- Fully depleted device: Homogeneous entrance window with 100 % fill factor and good QE
- Low internal gate capacitance yields low system noise
- No charge transfer needed:
 - ▣ Radiation hardness
 - ▣ Low dead time (> 500:1)
 - ▣ Fast readout: low pile-up probability
- Area efficient: no frame store area needed
- Combination with drift chamber: Devices with **arbitrary pixel size** (Macropixel devices)
- Windowing / sparse readout can be implemented by appropriate pixel interconnection
- Low power consumption



Additionally: Future option of repetitive non-destructive readout (RNDR)

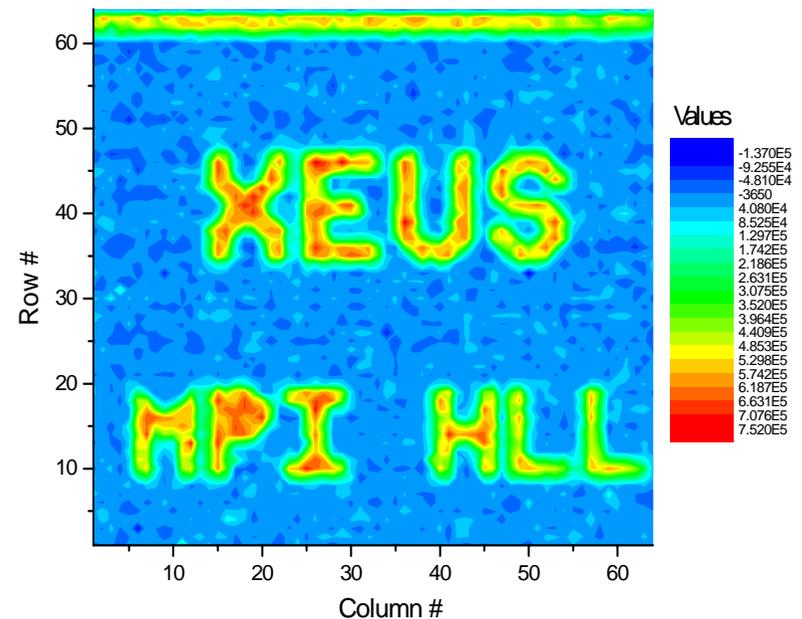
- Hybrid #7, Wafer #9, matrix E 09, STD-CD-CG-CE-DM



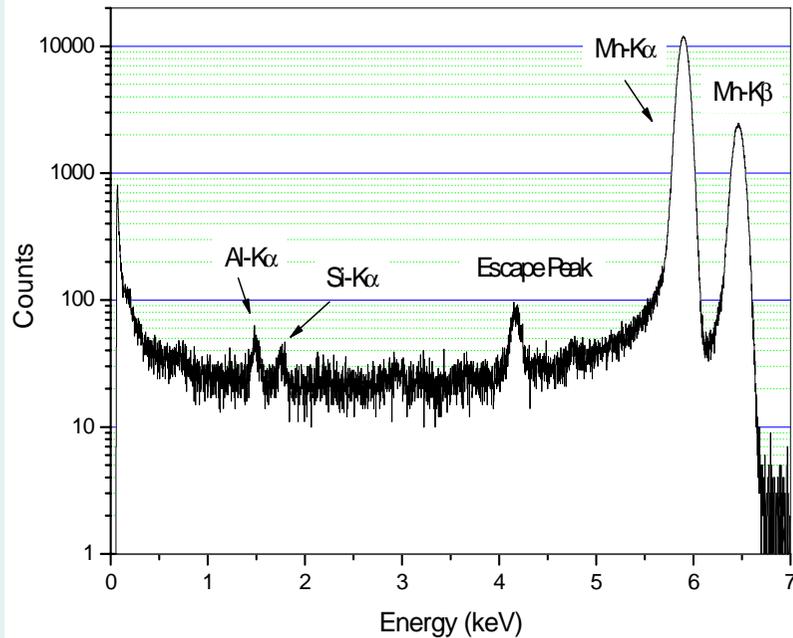
- Ceramic Hybrid

- Dried air atmosphere
- Temperature scan: 20°C - -60°C
- Frame rate 300 Hz
- Pixel current 30 μA
- Line processing time 25 μs
- Irradiation with ^{55}Fe source

- Contour plot from ADU maps



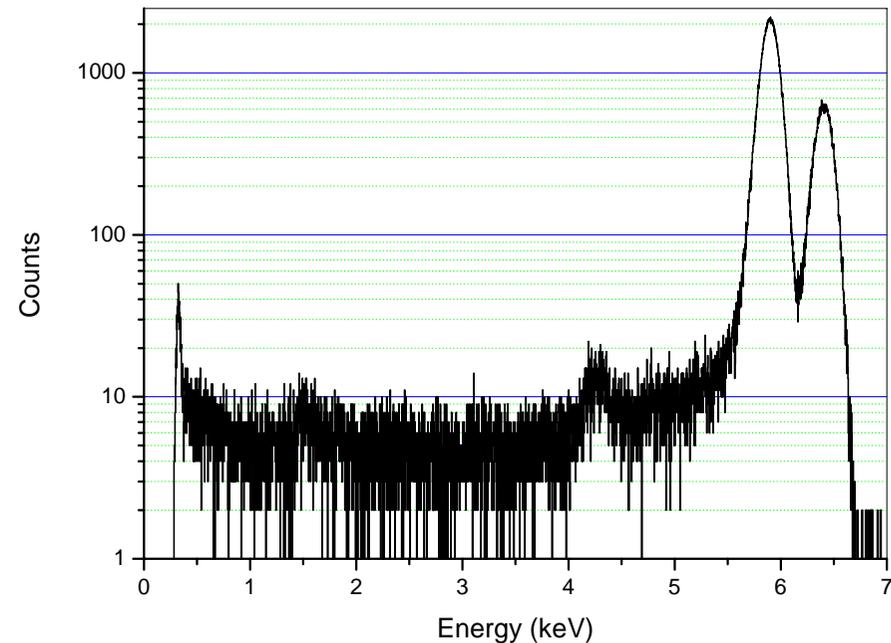
„Cold“ operation



Temperature: -40 °C

Energy resolution:
126 eV FWHM @ Mn-K α Line
corresponding to 4.9 e⁻ ENC

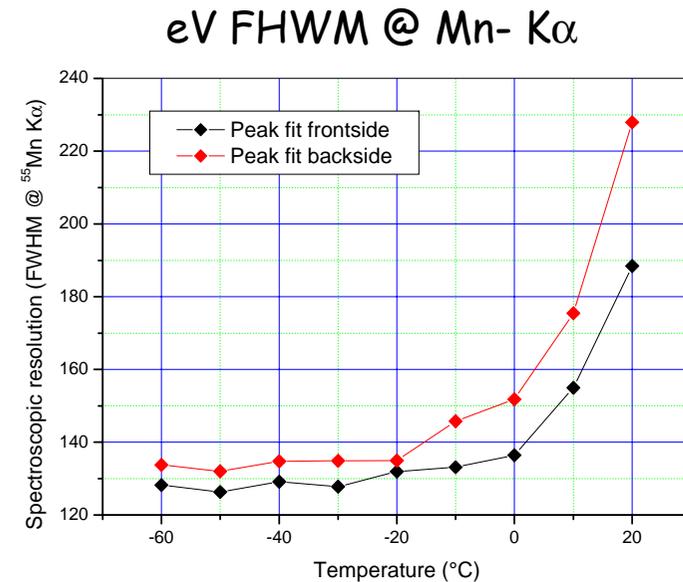
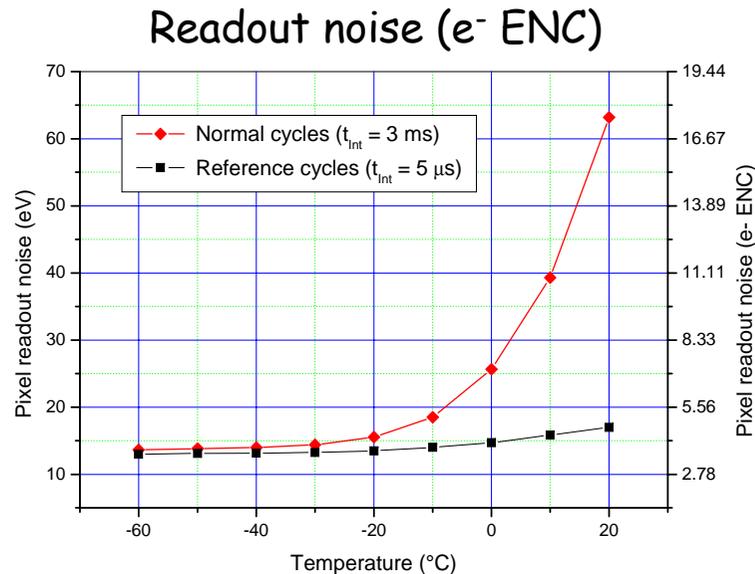
„Warm“ operation



Temperature: + 20 °C

Energy resolution:
190 eV FWHM @ Mn-K α Line
corresponding to 17 e⁻ ENC

Results from $^{55}\text{Mn-K}\alpha$ peak fits



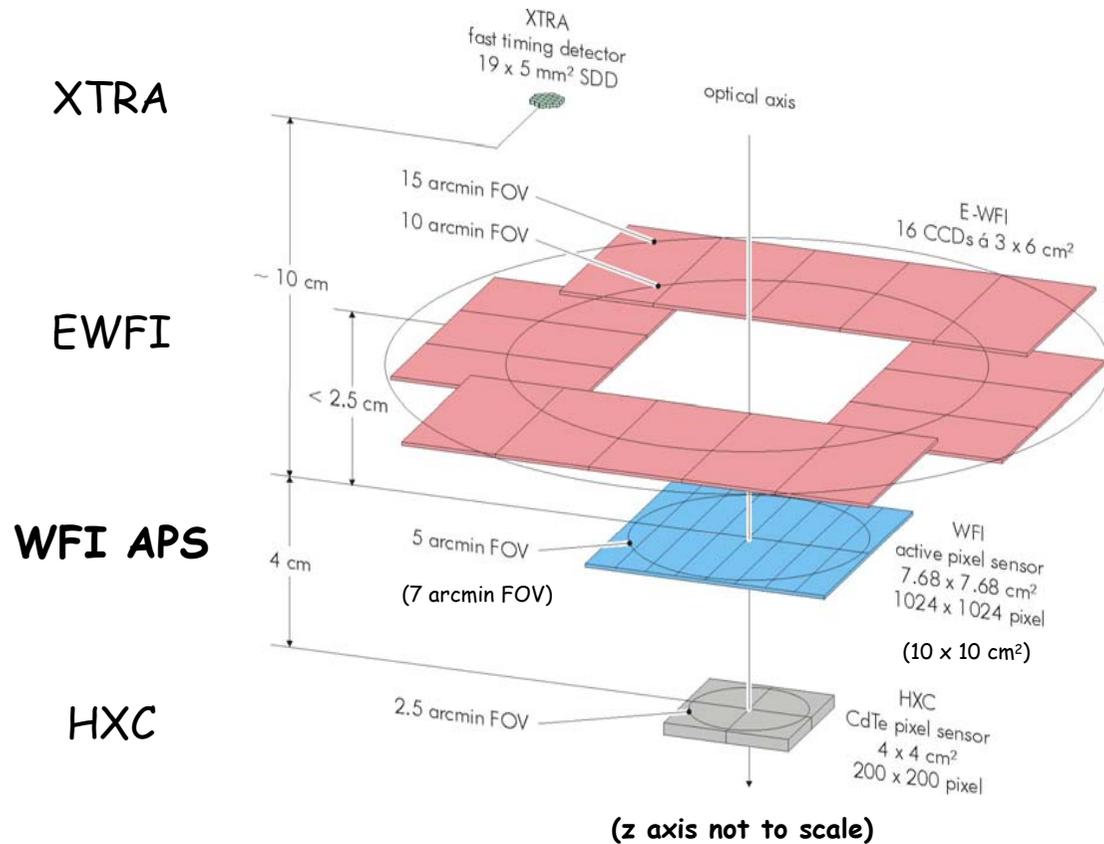
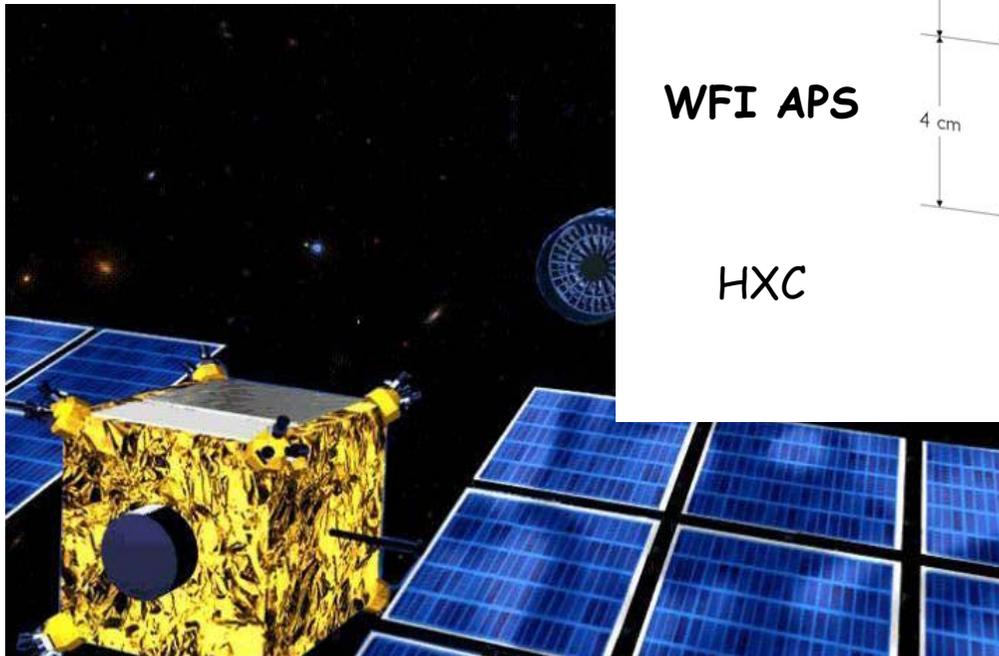
Best values:

- Pixel readout noise:
17 - 3.6 e^- ENC
- Pixel reference noise:
4.7 - 3.6 e^- ENC

- 228 eV (22.4 e^- ENC) @ 20° C BI
- 188 eV (17 e^- ENC) @ 20° C FI
- 132 eV (6.6 e^- ENC) @ -50° C BI
- 126 eV (4.9 e^- ENC) @ -50° C FI

XEUS (X-ray Evolv

- Proposed ESA mission
- Formation flight with ~
- Wide field imager
- Required Temperature



Macropixel missions:

- Simbol-X
- BepiColombo
- WIMS



Summary II



- DEPMOSFET based devices are a promising and flexible sensor concept
- Suitable for X-ray imaging spectroscopy
- First prototype device results are very promising
- Devices measured so far are homogeneous & defect free
- Energy resolution: 126 eV @ -40 °C
- Operation at room temperature possible (190 eV @ 20 °C)
- Fast & flexible readout modes
- Almost arbitrary pixel sizes possible
- Larger matrices are on the way...



Finally...



...thanks for your attention.