Pixel 2000 International Workshop on Semiconductor
Pixel Detectors for Particles and X-Rays
Genova, June 5-8, 2000

Medical X-Ray Imaging with Energy Windowing

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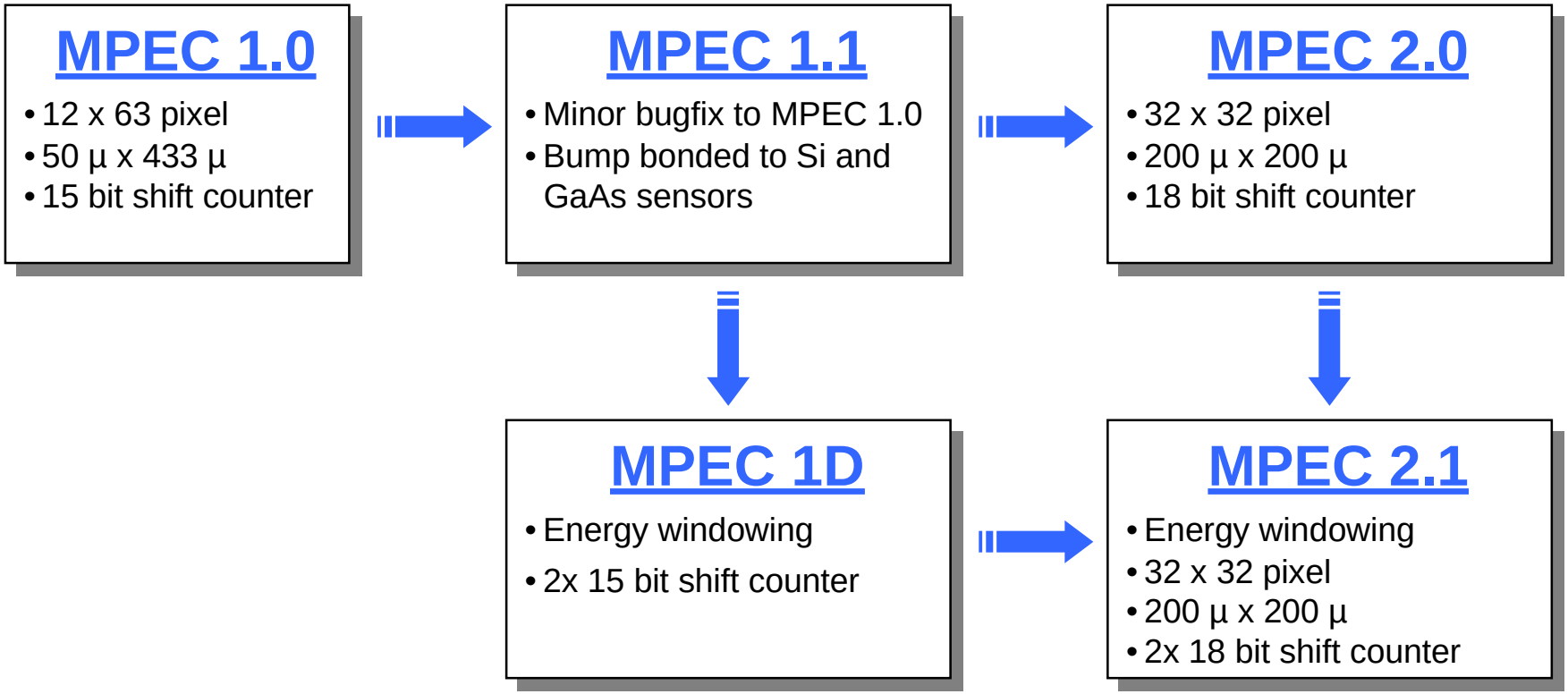
Overview

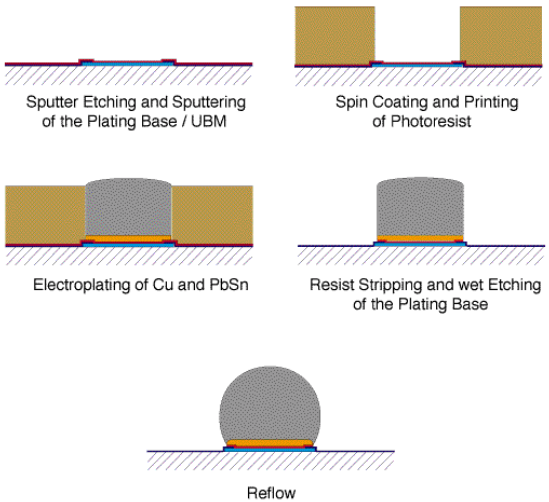
- **Overview of the MPEC chip family**
  - **Assemblies with Si- and GaAs sensors**
- **The MPEC 2.1 chip**
  - **Energy windowing**
  - **Performance**
  - **Sensors**
- **Conclusion and outlook**

Overview of the MPEC Chip Family

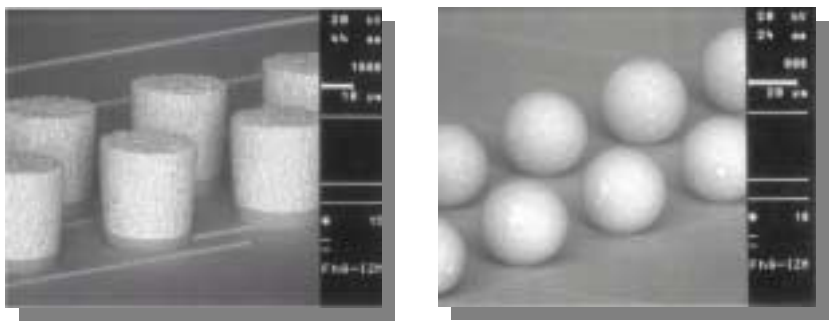


- **Multi Picture Element Counters**
- **First chips (MPEC 1.0, 1.1) derived from ATLAS Pixelchip Prototype**
  (Bier & Pastis, Phys. Inst. Uni Bonn, CPPM Marseille)

Sensor Assembly (1)



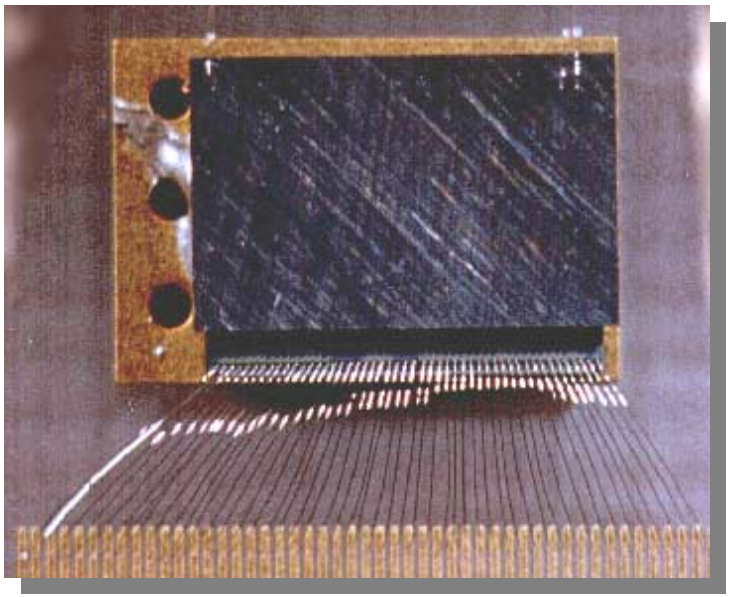
Solder bumping process (IZM, Berlin)



Solder bumps before and after reflow (IZM, Berlin)

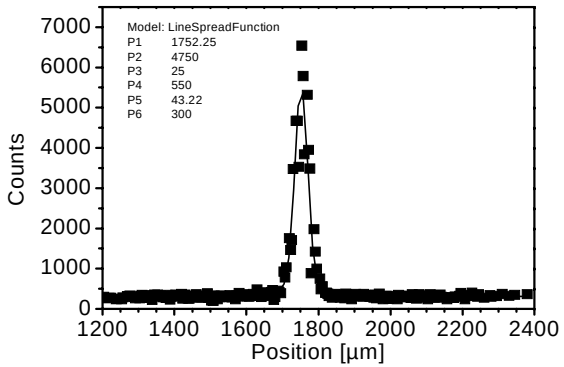
- **Solder bump bonding**
  - **Used for ATLAS pixel modules**
  - **Fine pitch (50 µ) possible**
  - **Solderwettable under bump metallization requires processing of whole wafers**
- **MPEC 1.1 assembled with**
  - **Si sensors**
  - **GaAs sensors**

Imaging Resolution



Single chip assembly with MPEC 1.1
and bump bonded Si sensor

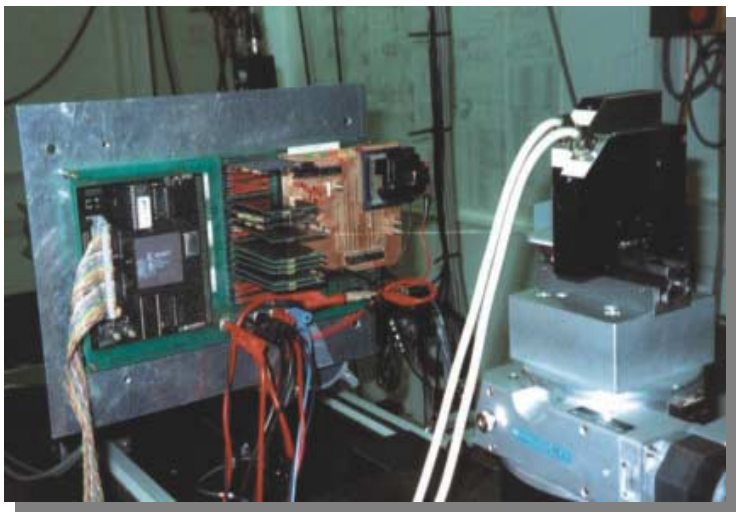
Radiogram of a small slit to determine
the Line spread function LSF



LSF fitted to image data

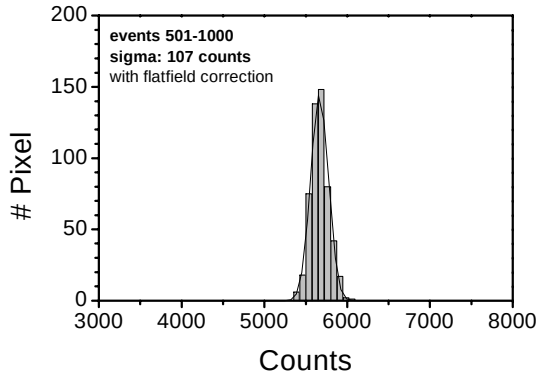
- **NEP ≈ 9.5 lp/mm (noise equivalent pass band, MTF = 0.3) in direction of 50 µ pixel edge**

Synchrotron Beam Measurements



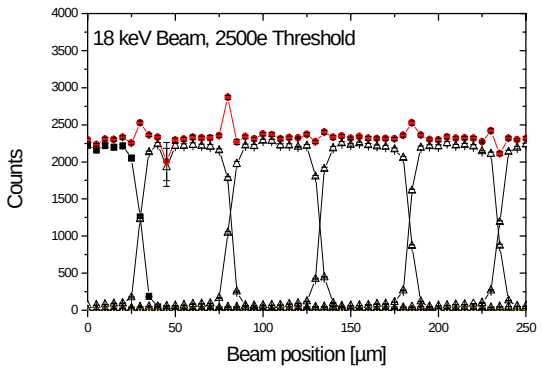
Test setup at European Synchroton Radiation Facility (ESFR)
(in collaboration with the Paul Scherrer Institute, PSI)

- **Inhomogeneity < 2 %**



Countrate distribution

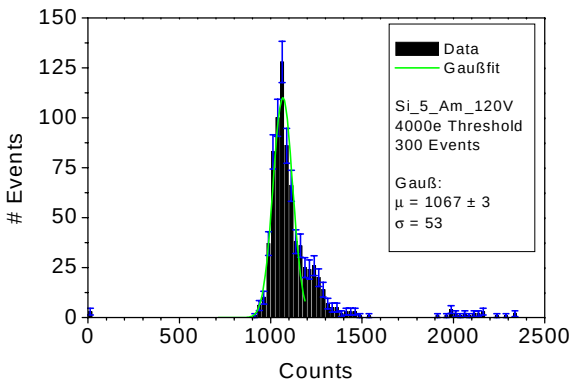
- **Efficiency**



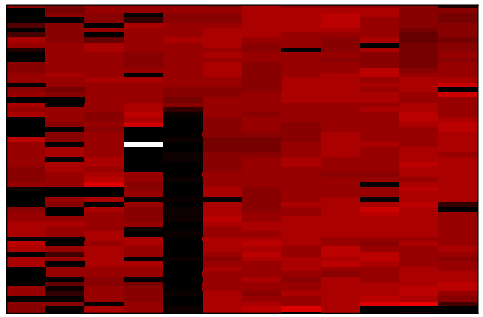
Scan with collimated beam

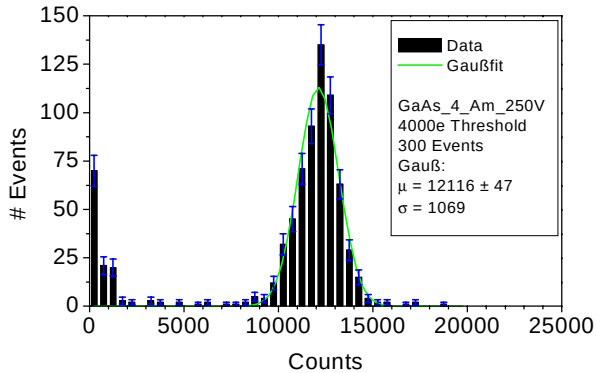
Performance of Si and GaAs Sensor

- **Si Sensor**



- **GaAs Sensor**

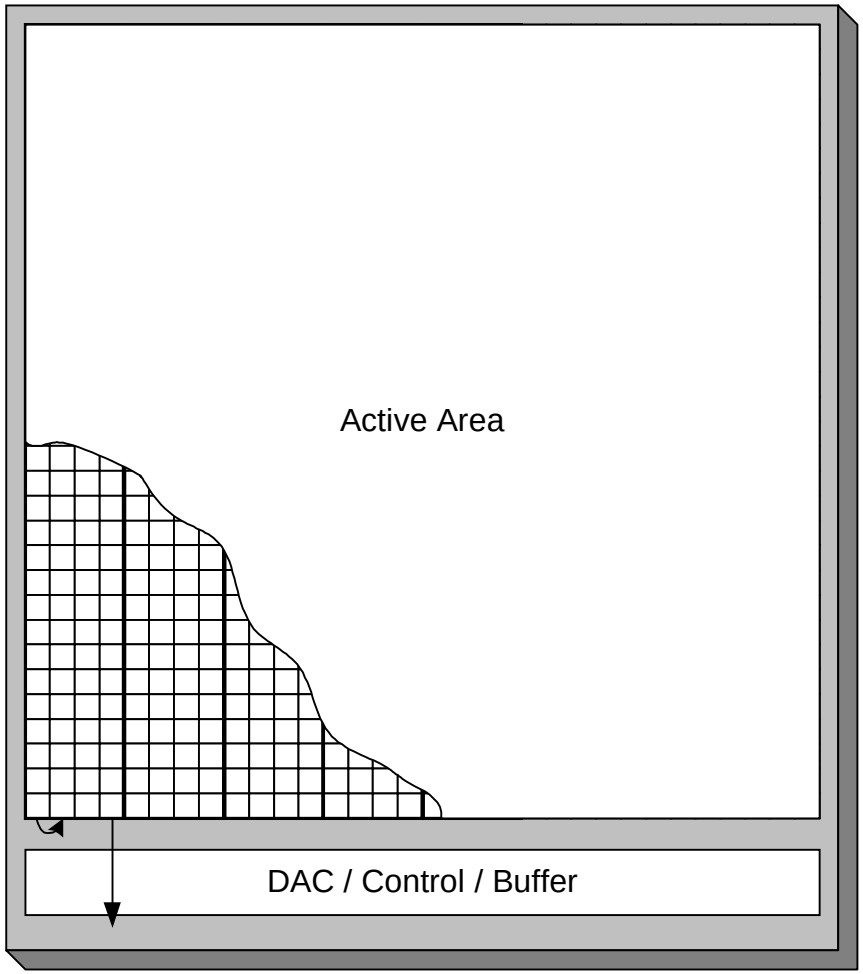




× 10

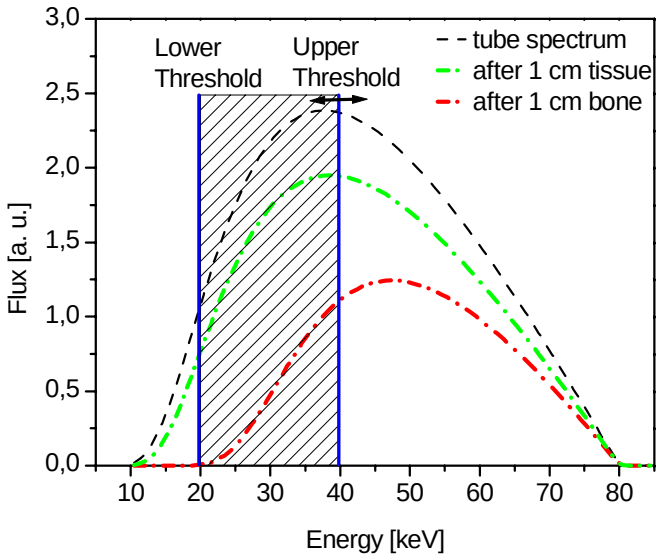
- **Count rate improves by a factor 10 for GaAs (60 keV γ)**
- **GaAs sensors show inhomogeneous efficiency**

MPEC 2.1 Architecture

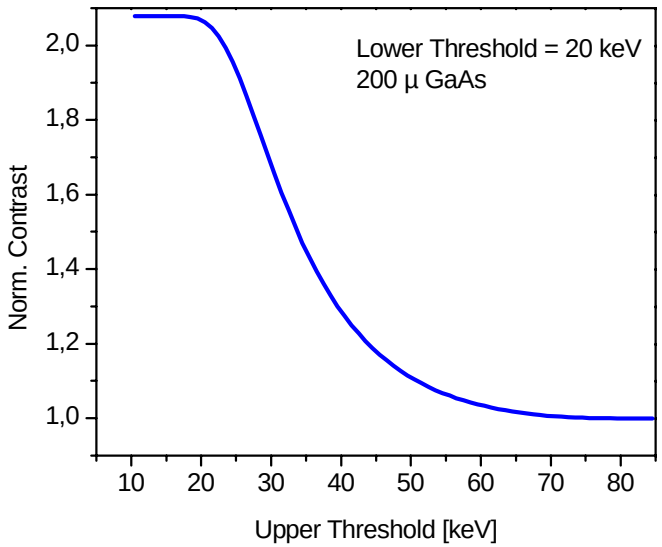


- **0.8 µ CMOS**
  active area 6.4 mm x 6.4 mm
- **32 x 32 pixel,**
  size 200 µ x 200 µ
- **Preamp, two discriminators and two counters in each pixel**
- **Serial readout for four columns each**

Energy Windowing



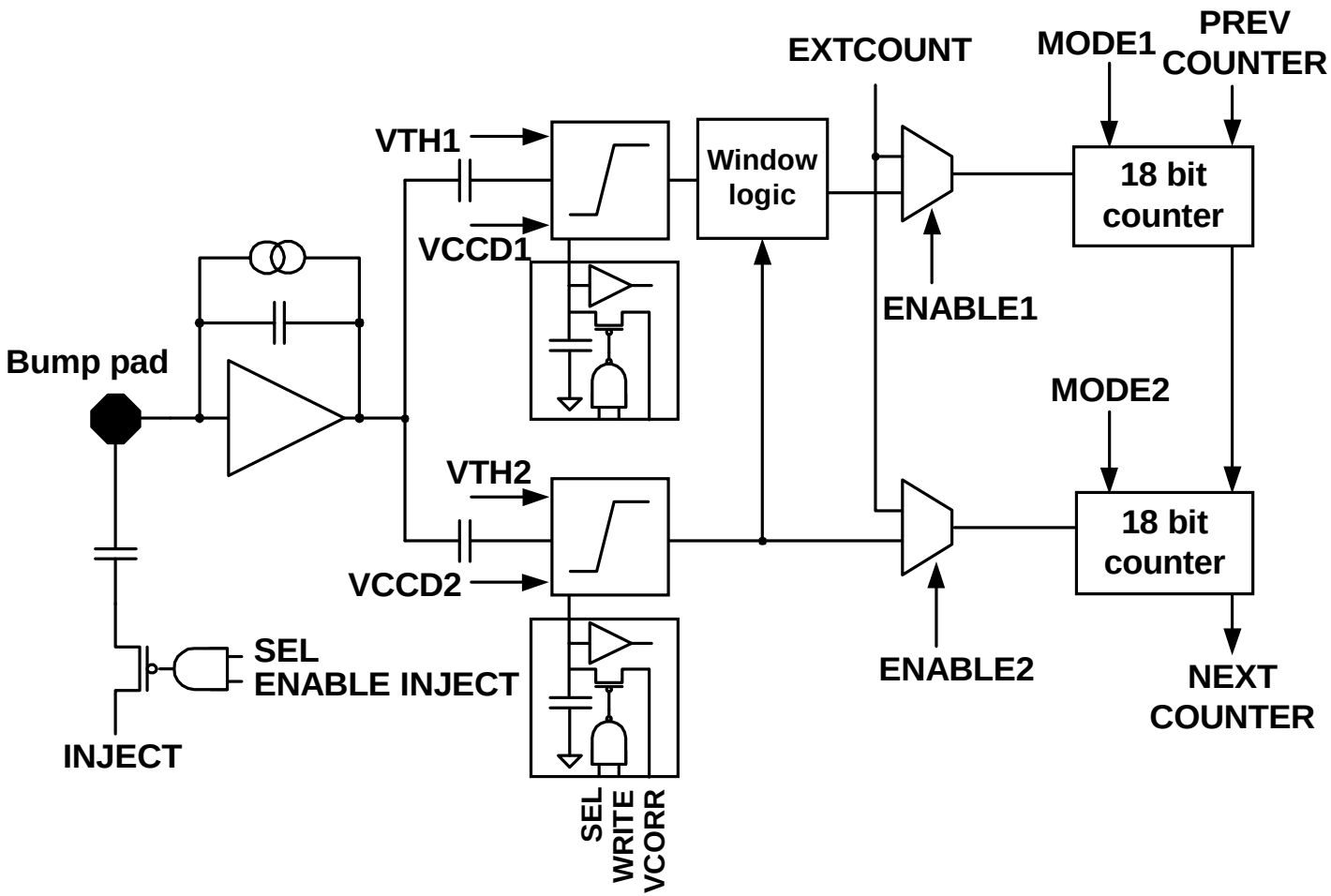
Transmission spectrum with energy window



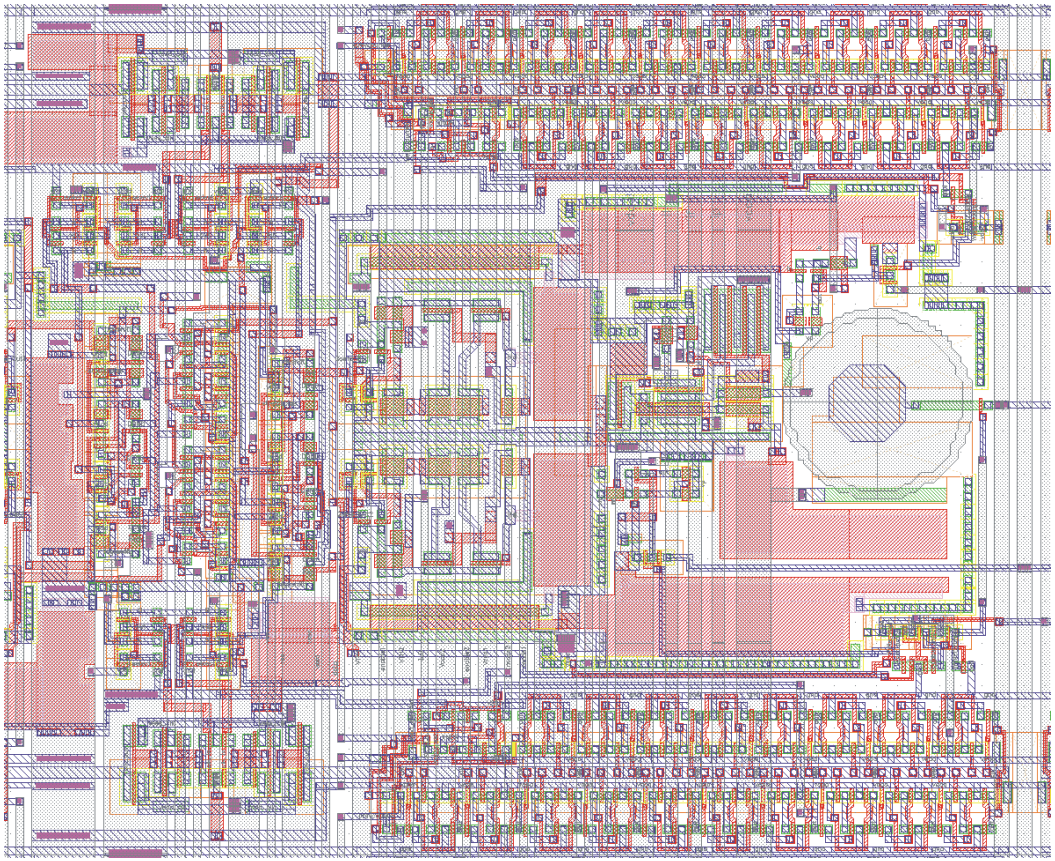
Contrast between two different tissues

- **Absorption for different tissues is energy dependent**
- **Contrast enhancement with energy window**

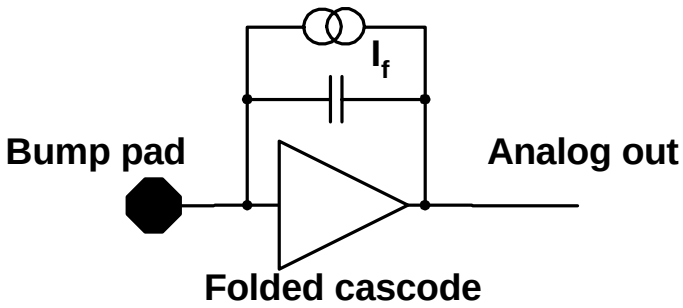
MPEC 2.1 Pixel Schematic



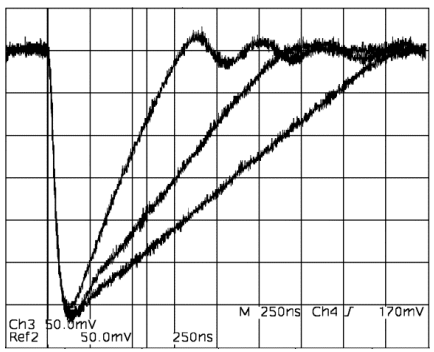
Pixel Layout

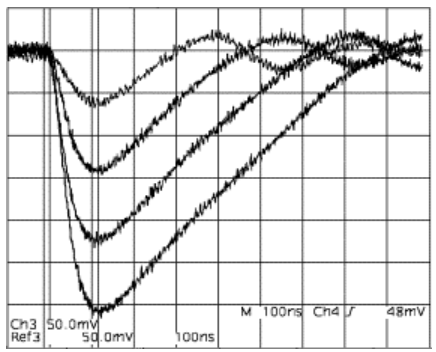


Preamplifier



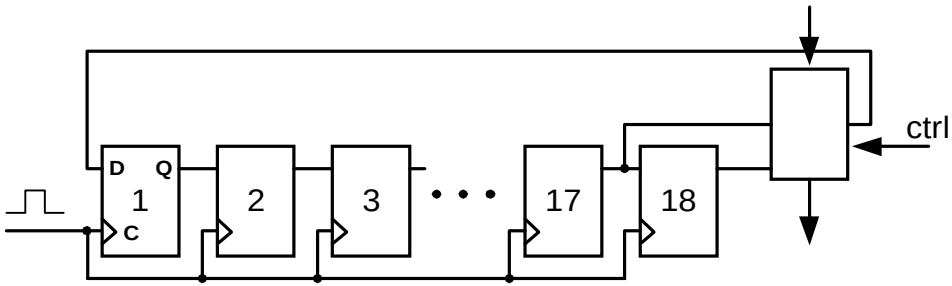
- **Charge sensitive preamplifier**
  - **Design adopted from ATLAS prototype chip Bier & Pastis**
  - **Current feedback**
  - **No additional shaper**
  - **Return to baseline ≈ 500 ns**





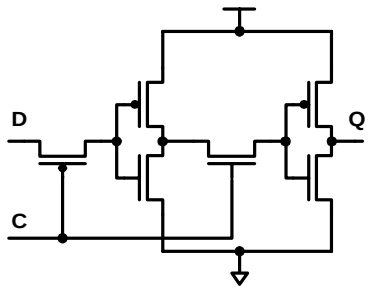
Analog out for different feedback currents (a), and different signal charges (b), (Rise time limited by output-buffer)

Counter

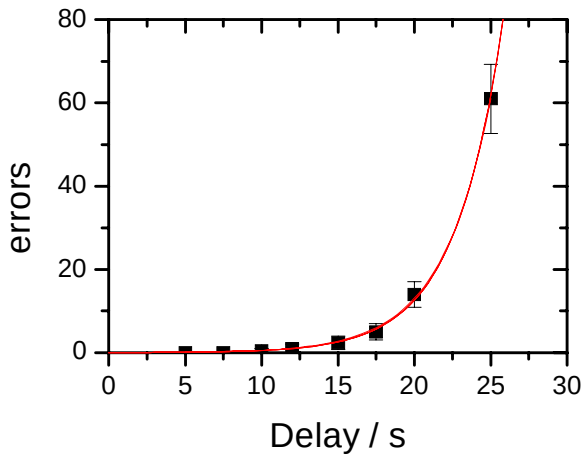


18 bit linear feedback shift register counter

- **18 bit LFSR counter**
- **FF with 6 transistors**
- **Max. clock frequency > 10Mhz**
- **Dynamic logic, refresh needed (low frequency, < 1Hz)**

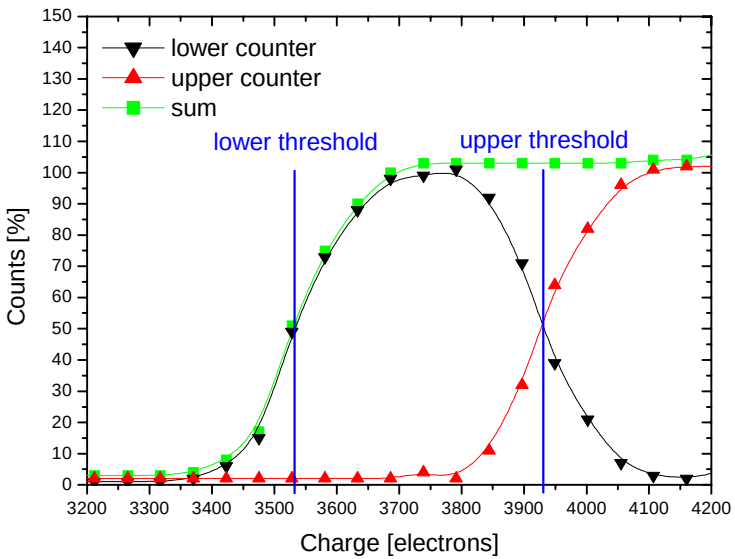


Single phase Flip Flop



Counter tests with different refresh delays

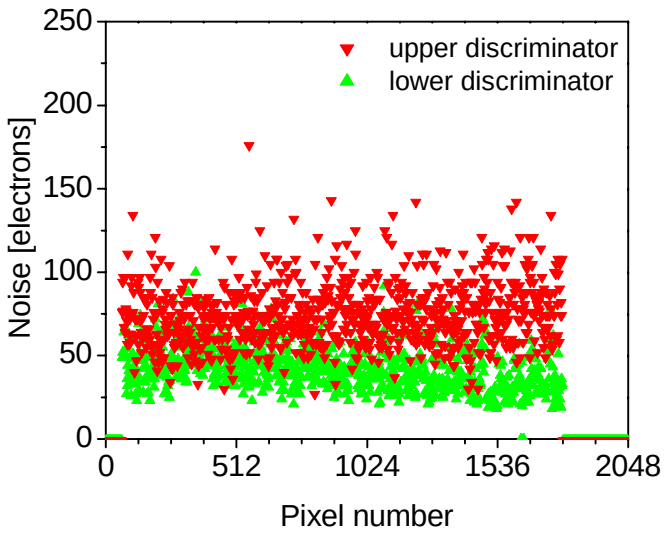
Window Logic

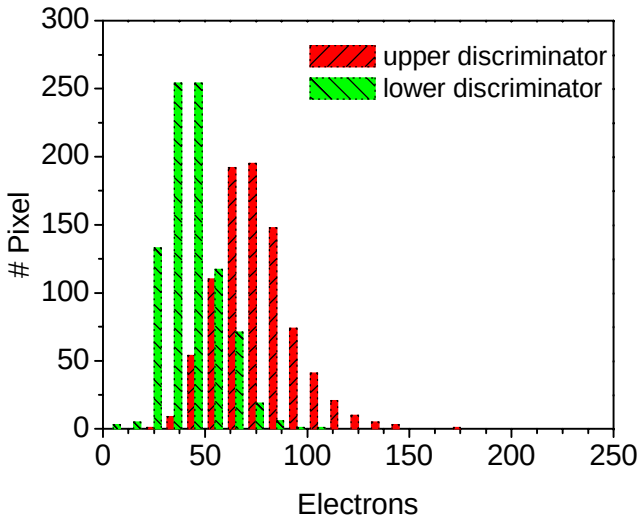


Threshold scan shows the sum of both counters is 100 % (no loss)

- **Window discriminator**
- **Count signals above upper threshold only in upper counter**
- **Increase dynamic range**
- **Decrease crosstalk between counters and preamplifier**

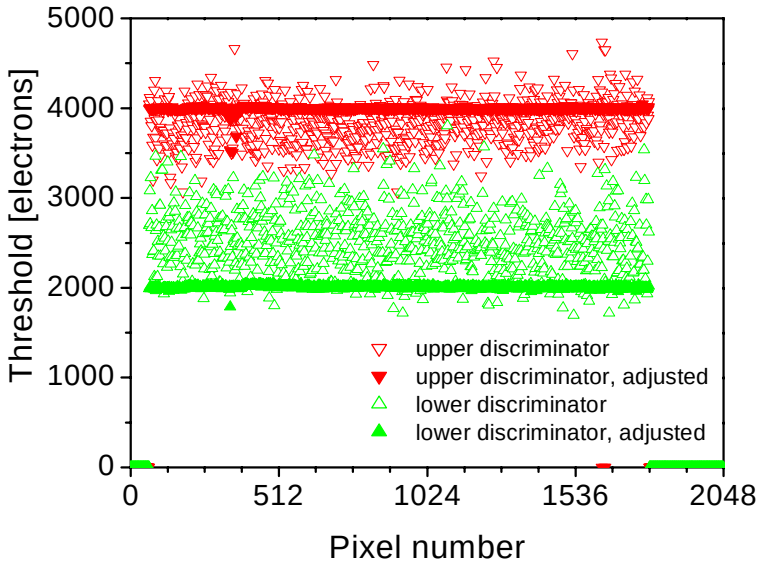
Noise Performance

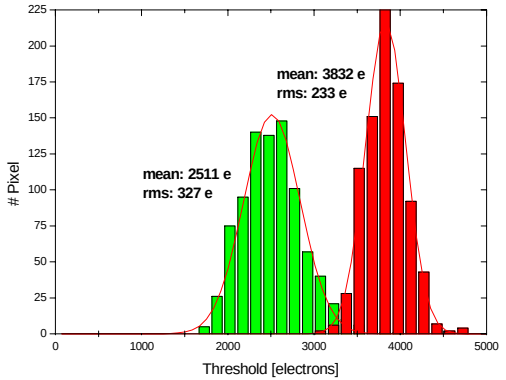




- **Average equivalent noise charge is 42 electrons (measured with upper discriminator)**
- **Upper discriminator shows slightly higher noise (74 electrons)**

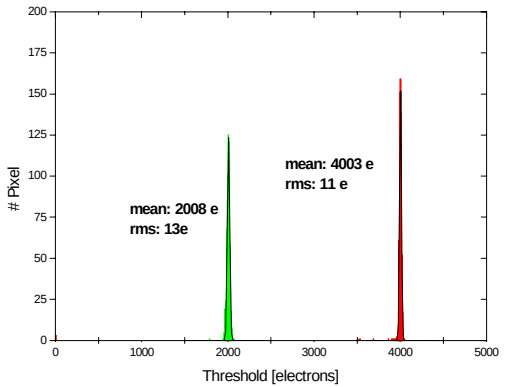
Threshold Dispersion





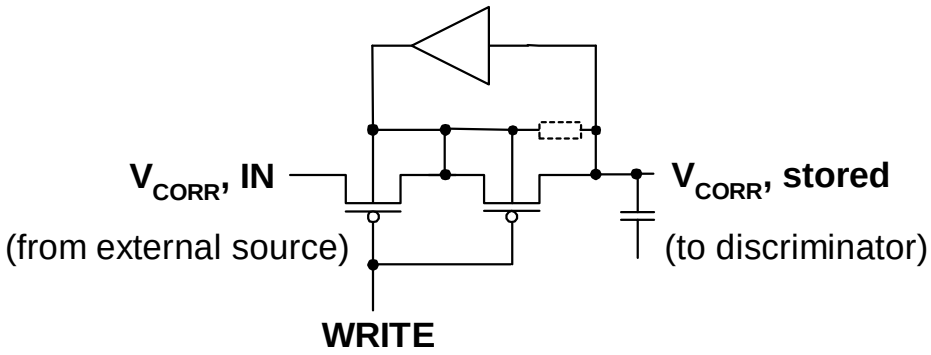
Dispersion without threshold adjust

- **Window discriminator demands low threshold dispersion**
- **Thresholds dispersion < 13 electrons with adjust**

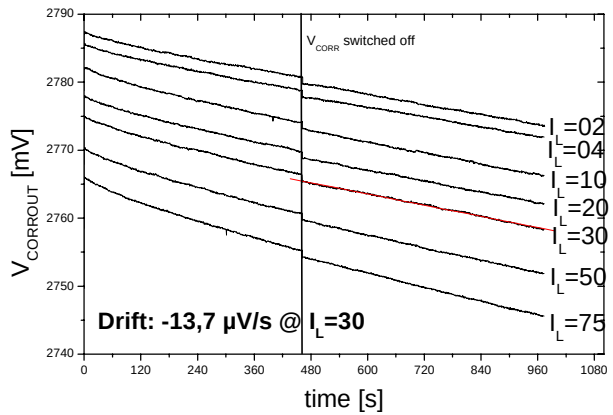


Dispersion with threshold adjust

Threshold Adjust



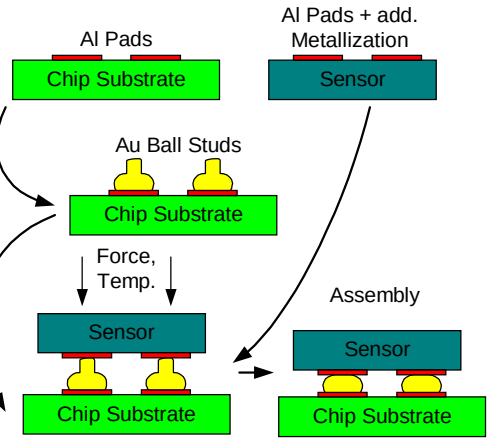
Drift compensation with buffer and double switch



Drift of the stored compensation voltages

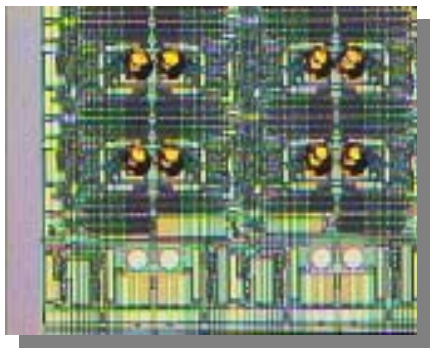
- **Global threshold and individual correction voltage for each discriminator**
- **Correction voltage stored on a capacitor**
- **Ultra low leakage of drift compensation (0.03 fA)**
- **Threshold drift only 0.2 electrons per second**
- **Refresh during normal exposure times not necessary**

Sensor Assembly (2)

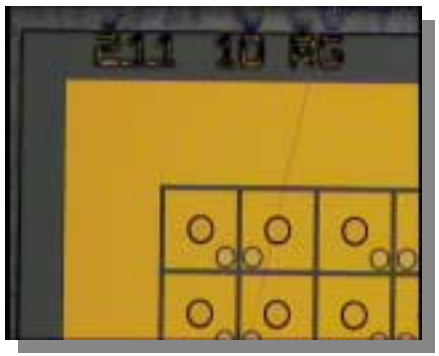


Mechanical gold stud bumping (IZM, Berlin)

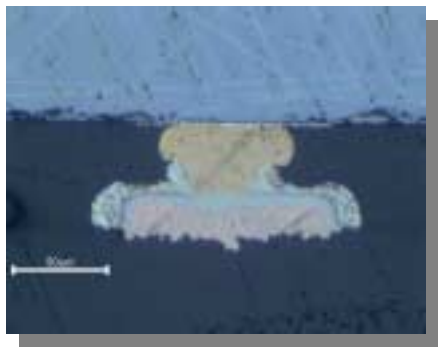
- **Gold stud bump bonding**
  - **Mechanical process**
  - **Assembly of single chips**
- **Sensors for MPEC 2.1**
  - **Si** (successful assembled, chip failure)
  - **GaAs** (assembly failure, sensor met.)
  - **CdTe** (sensor available)



MPEC 2.1 with gold studs



Metallization of the GaAs sensor



CdTe sensor bonded with gold studs to a dummy chip

Conclusion

- **First MPEC counting pixel chips derived from ATLAS electronics**
- **Chip assembly with Si and GaAs sensors**
- **Features individual threshold adjust and energy windowing**
- **Outlook**
  - **Assembly MPEC 2.1 with Si, GaAs and CdTe sensors**
  - **Next MPEC generation in deep-submicron technology**

Papers and additional information: http://xray.physik.uni-bonn.de/