Introduction to Medipix

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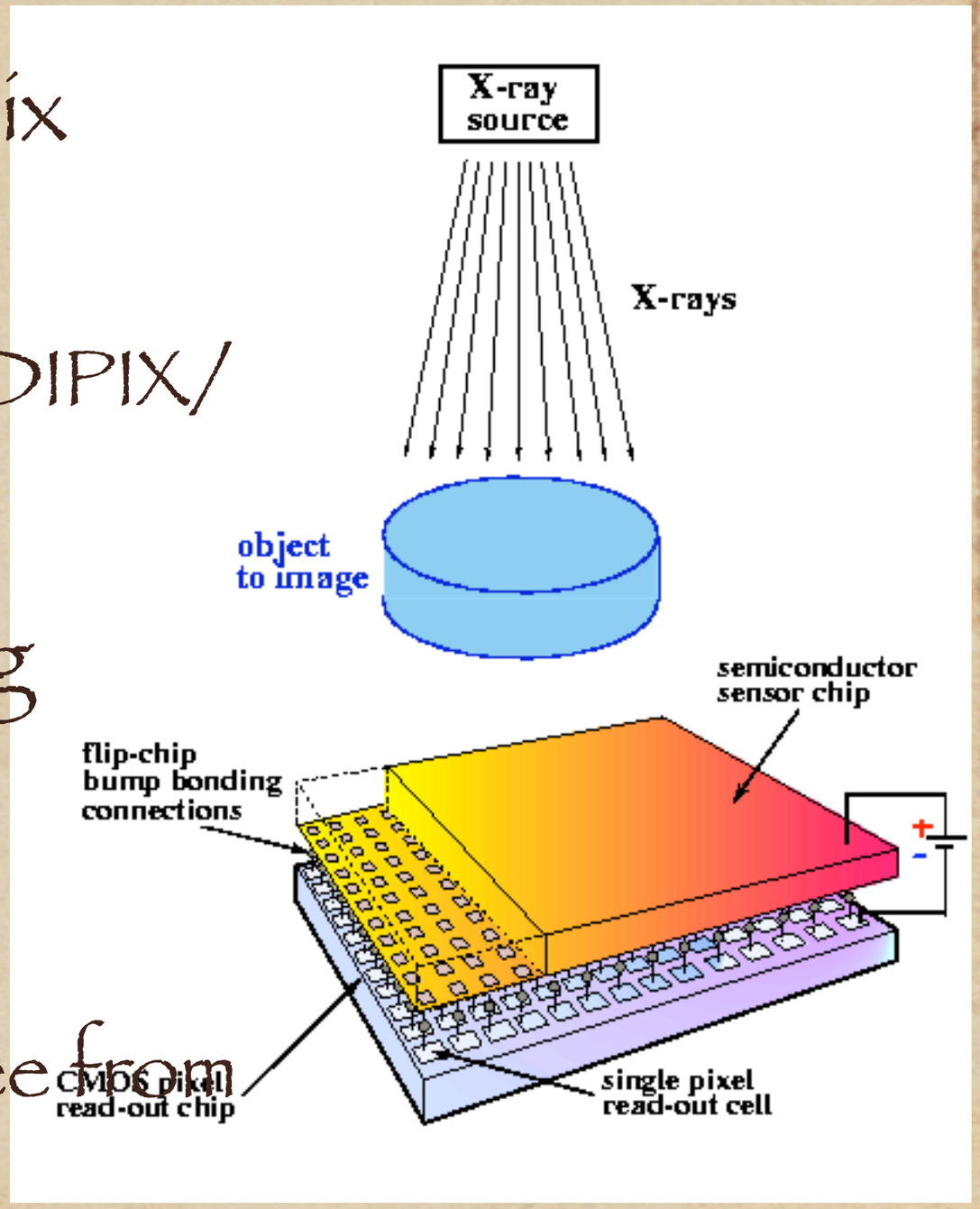
What is a Medipix?

- Driven by CERN medipix collaboration
  - http://www.cern.ch/MEDIPIX/
- High spatial resolution
- Single-photon counting mode--> next pages...
- Small dead region.
  - 3 edges (out of 4) are free from bonding pads.



Medipix2 readout ASIC (I)

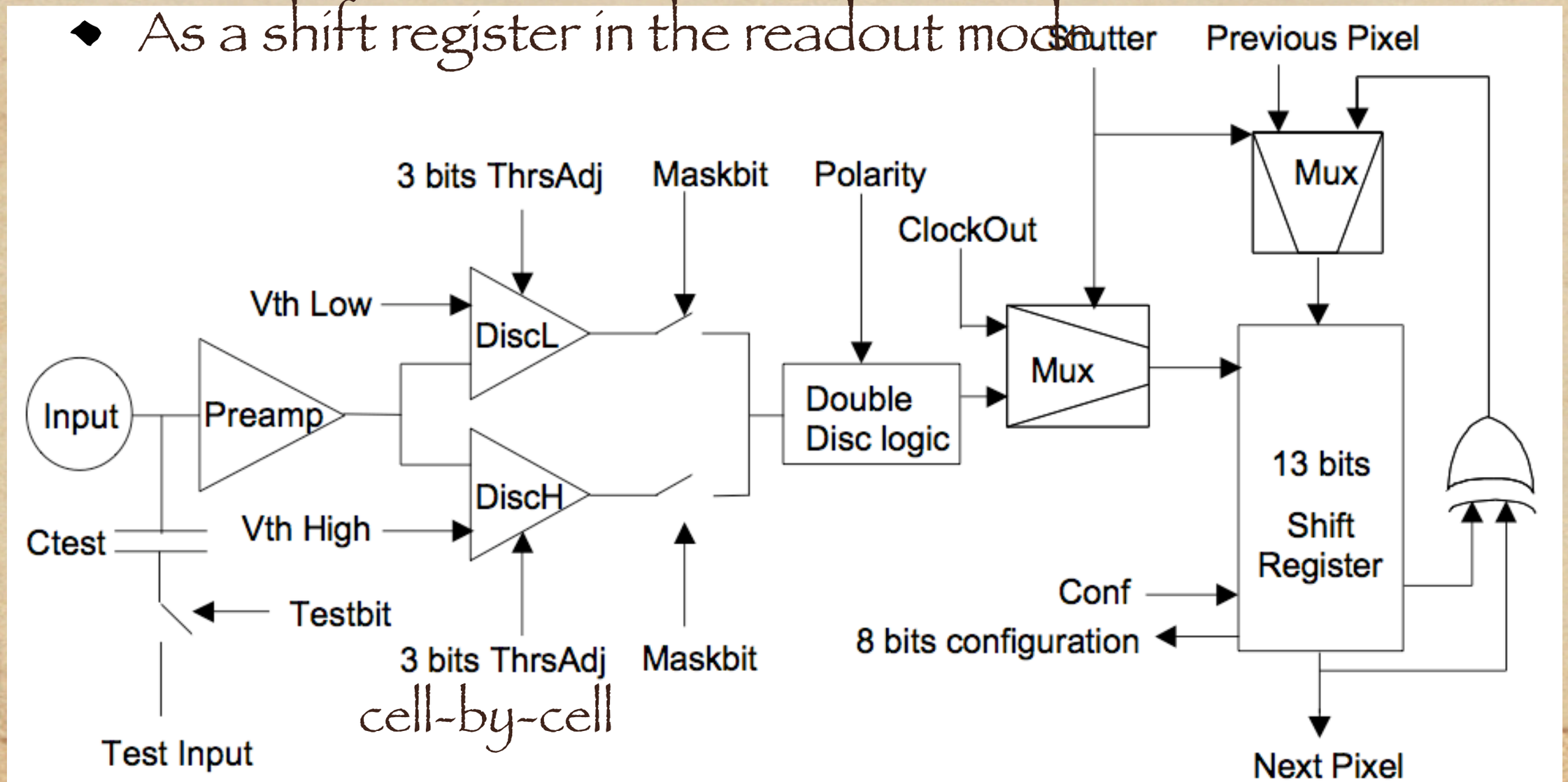
- 0.25 μm technology
  - 55 μm x55 μm pixel size. 256x256 pixels. 2 cm^2.
  - Radiation hardness up to 300 krad, with some power consumption increase, was confirmed.
  - After 500 krad, annealing of 100° for one week was done: Performance recovered.
- Compatible with Si, GaAs and CdZnTe sensors.
  - Sensitive to positive and negative pulses.

Medipix2 readout ASIC (II)

- Large dynamic range w/o charge integrator
  - Preamplifier with leak current compensation
  - Discriminator output is counted by a 13 bit counter.
  - S/N does not depend on the integration time
    - Energy window comparator
  - Each cell counts up at 1 MHz
    - Thus this chip accepts about 0.4 G photons / mm^2.
- Operation mode is like Digital Camera.
  - Almost dead-time less data accumulation and
  - Data transfer

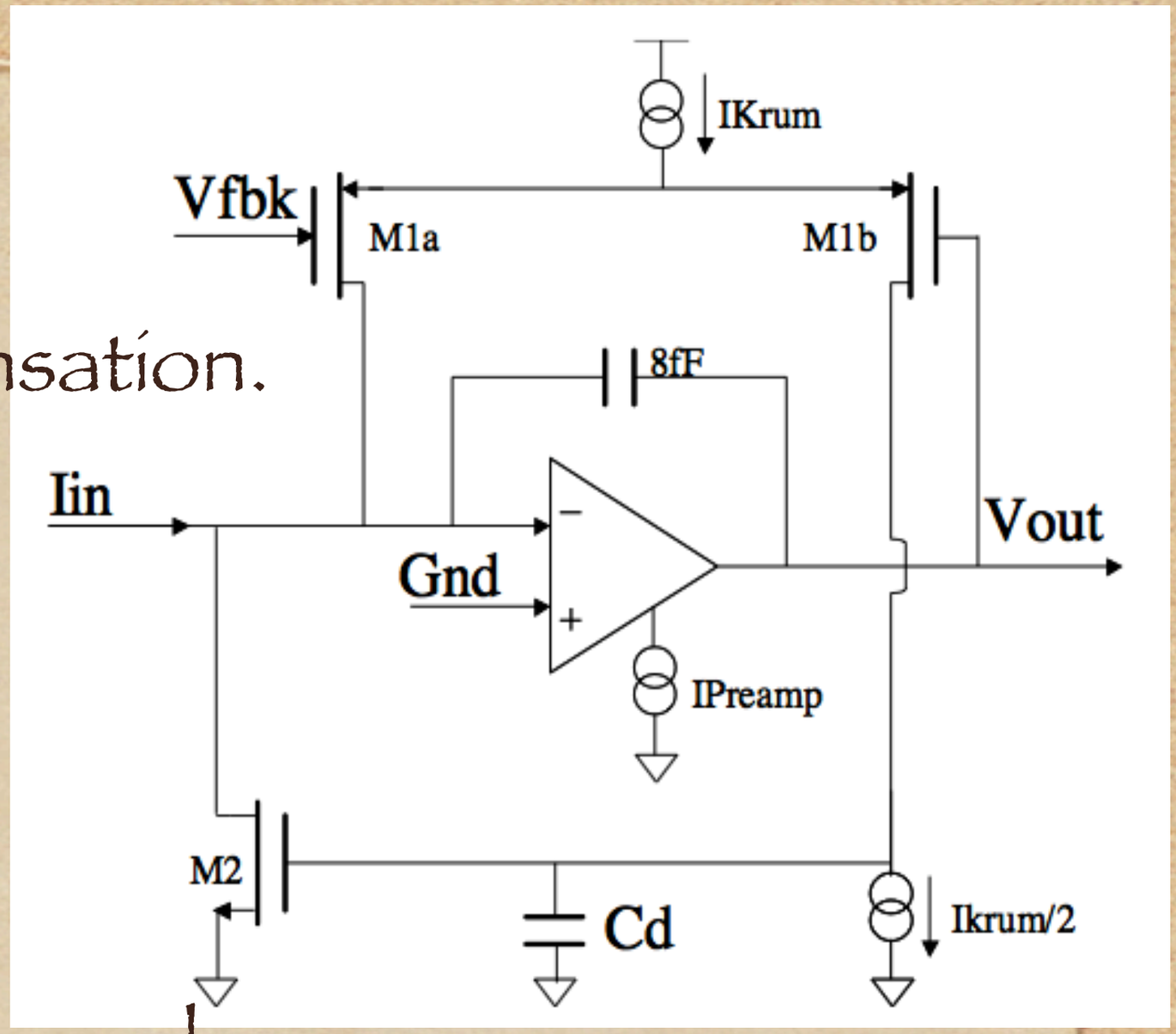
Schematic of a cell

- 504 transistors per cell / 8μW per cell.
- A 13-bit shift register being used in two modes.
  - As a counter in the integration mode
  - As a shift register in the readout mode



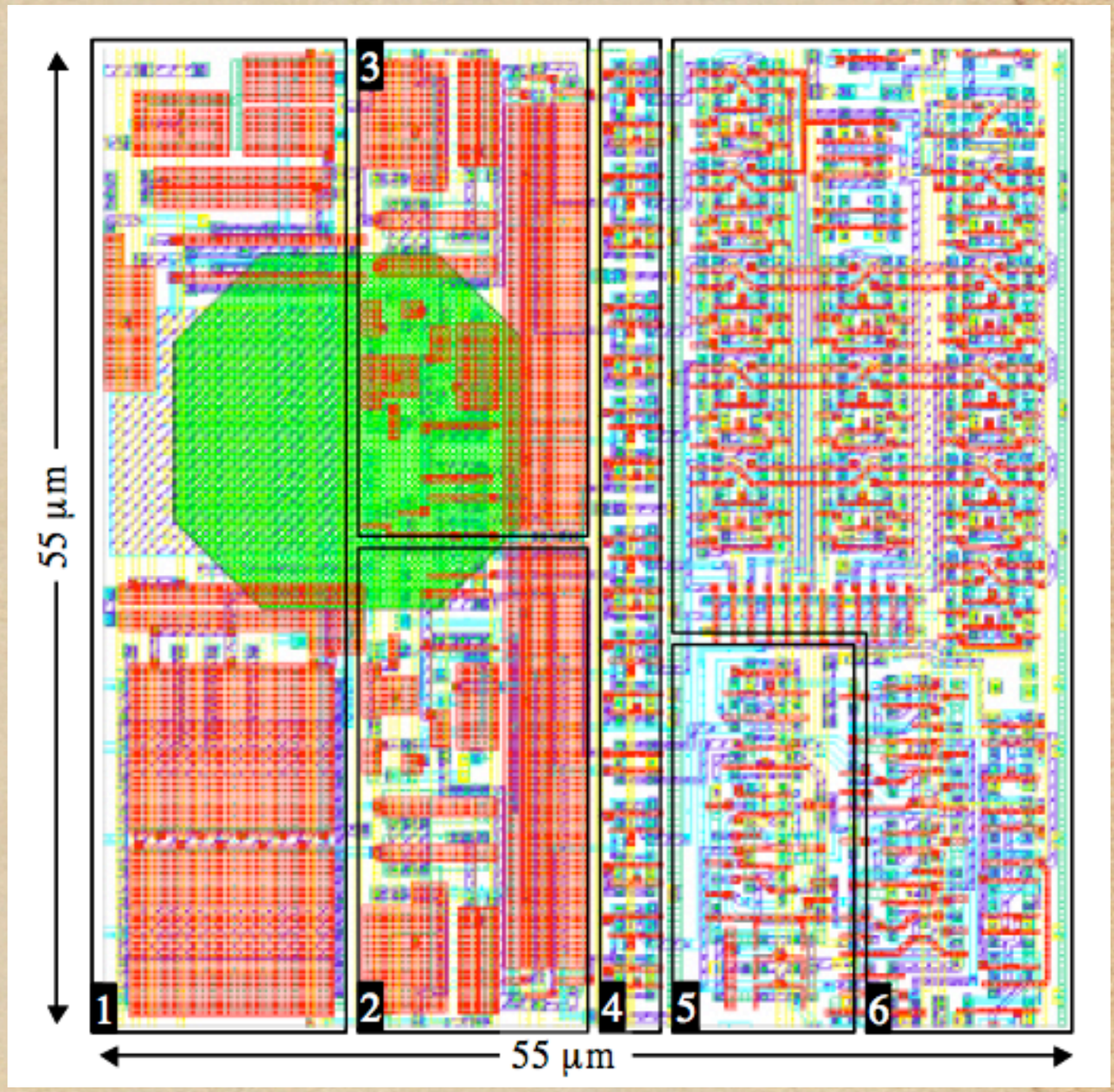
Input stage

- Leak current compensation.
  - If Iin>0 ⇒ Vout<0
  - ⇒More current to M1b
  - ⇒More current to M2
  - ⇒M2 absorbs Iin
  - ⇒Vin becomes 0
- Fine balance can be tuned by Vfbk ⇒Vout can be adjusted.



Cell structure

1. Preamplifier
2. High discriminator
3. Low discriminator
4. 8-bit configuration register
5. Double discriminator
6. Shift register and control logic



Readout

- 256 cells are connected in series.
  - 13x256=3228 bit shift register.
- In total 256x3228=851968 bits are readout
- Series readout: 0.85Mbit/ 100 MHz= 8.5 msec / chip
- In 32 bit parallel readout: 270 μsec per /chip
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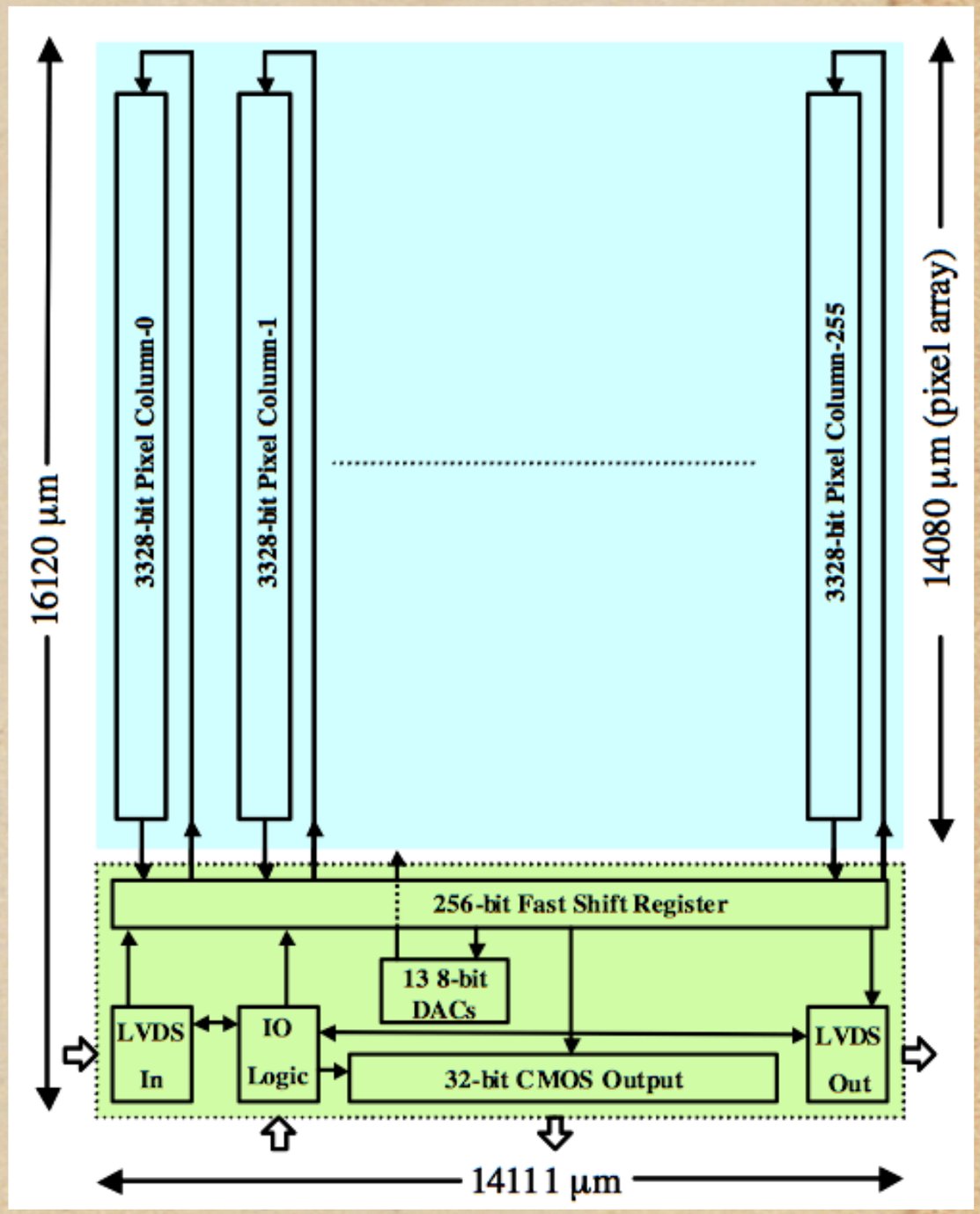
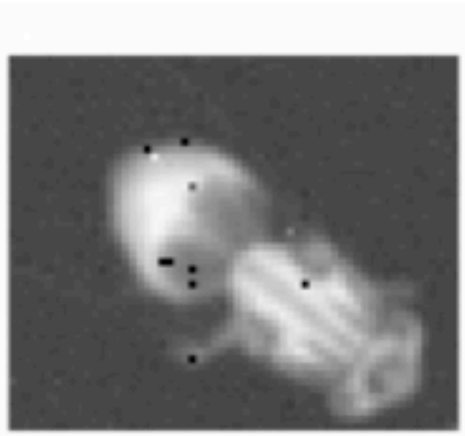


Example: X-ray image of a sardine.

- A Mo X-ray tube, 25 kV, 10 mAs, + 30 µm Mo filter.
- Distance target-object ~50 cm.
- Medipix1 ASIC bump-bonded to a 300 µm thick silicon sensor, 11mm by 11 mm, was stepped for one detector width in x and half a detector width in y.
- Acquisition time per image: 500 ms.
- No image correction was used (raw data!).
- The thickness of the fishbones corresponds roughly to the pixel size.

Example 2

- Even 5.9 KeV X ray (^{55}Fe) can be detected.



X-ray image (lower image) of a fly (see optical image above) using a ^{55}Fe radioactive source (5.9 keV X-rays!) and the Medipix1 chip bump-bonded to a 300 μm thick silicon sensor.

To reach such low energies the threshold adjustment facility of Medipix1 was used. Moreover, a flat field correction was applied, but no filtering.

The acquisition time chosen for this image was 5 hours (source of 4.6 MBq relatively far away for uniform illumination) which shows the stability of the system. The average number of counts in the background was ~23000.

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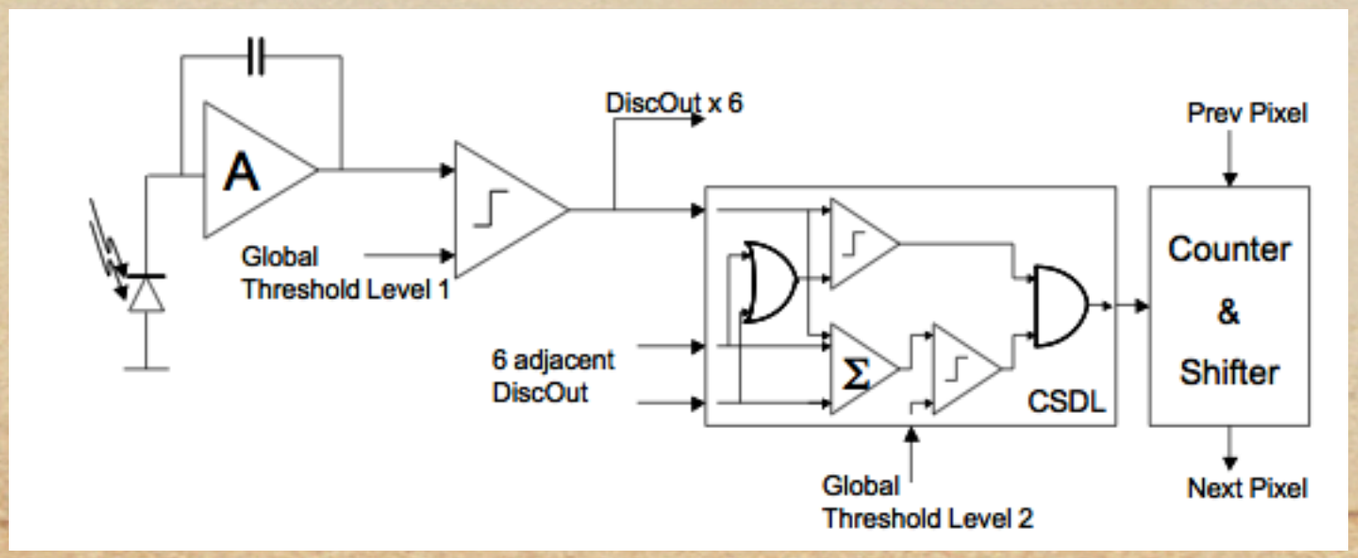
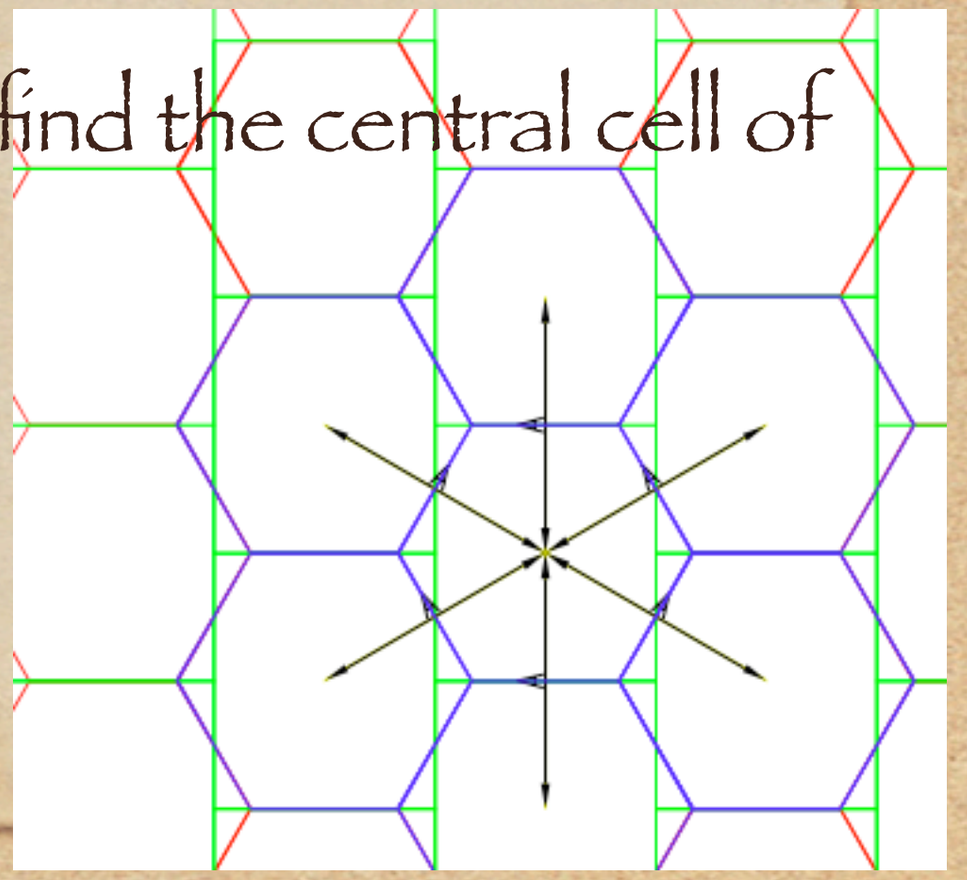
Shortcomings of Medipix and improvement strategy

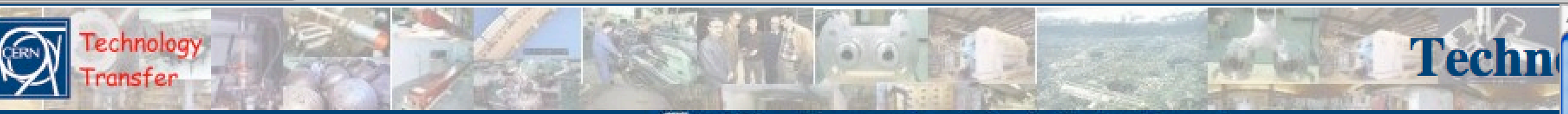
- If charge is shared with adjacent cells, a strict Energy-window comparison is not possible.
- Proposed solution:
  - Hexagonal pixel arrangement
  - Time over threshold is utilized to find the central cell of a cluster.





Test of silicon pixel sensor

- Simulation by TCAD predicts
  - 12 guard rings (p+) between main guard ring and scribe edge improves the electric field.
- A test sensor with 300 and 525 μm was made.
- Detection efficiency was what can be expected by TDAD simulation.
- In summary, they confirmed simulation based on TCAD incorporated with X-ray cross section data can reproduce the real sensor behavior.



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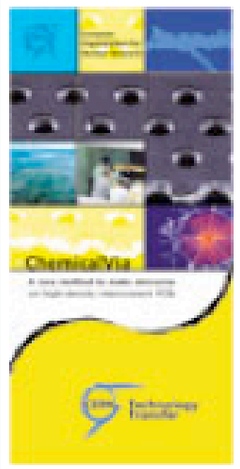

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