

Labex P2IO presentation

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Development of a CdTe imaging spectrometer for space application

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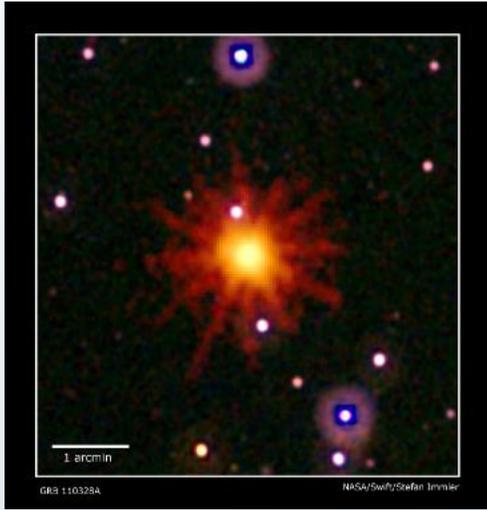


Plan

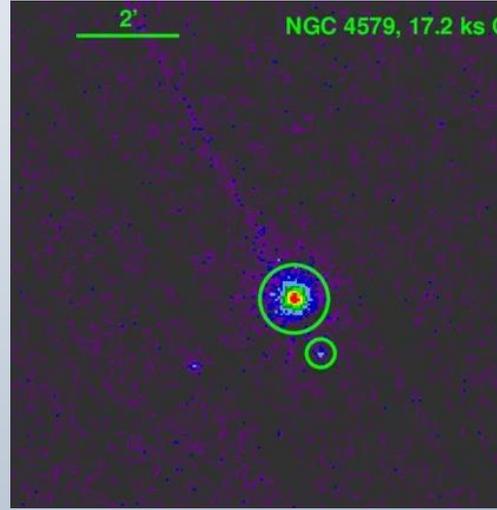
- Introduction: Hard X-ray observation
 - Why observing in hard X-ray ?
 - Imaging spectrometry
- CdTe hybrid technology: working principle
- Application specified integrated circuit developed for this hybrid
 - IDeF-X HDBD
 - IDeF-X D^2R_2
- The end of the thesis is not the end of what has to be done...

Introduction: Hard X-ray observation

Why observing in hard X-Ray ?

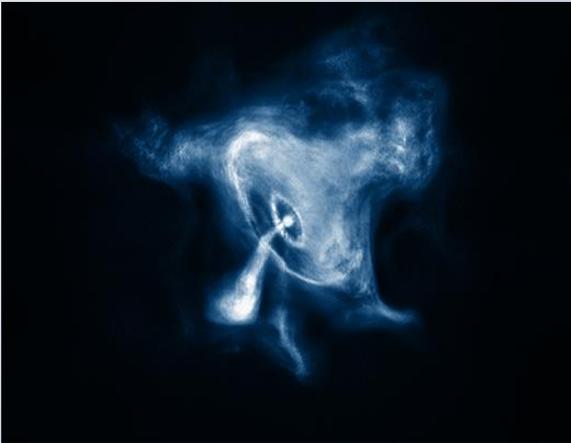


*Swift's image of
GRB 110328A*

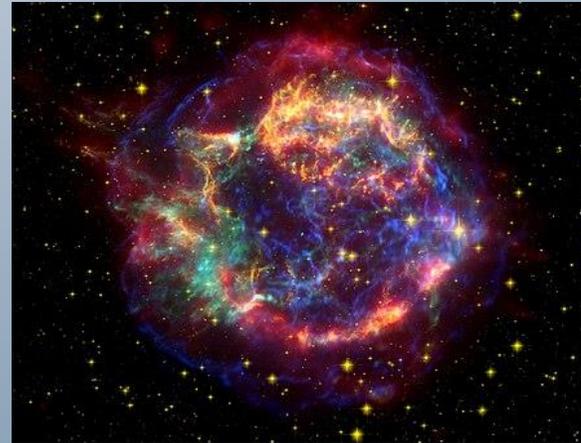


Active galactic nuclei

*X-Ray picture of
Crab Pulsar*

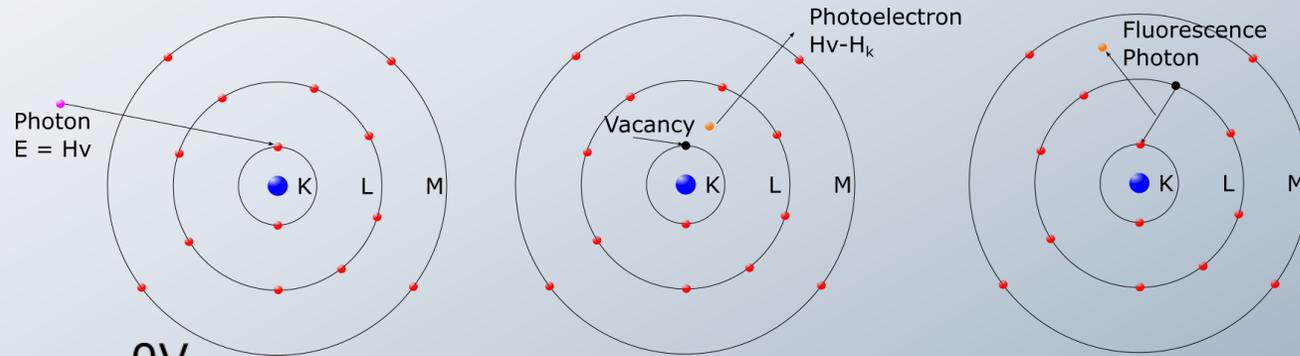


*Cas-A SNR in
X / radio and optic
wavelengths*



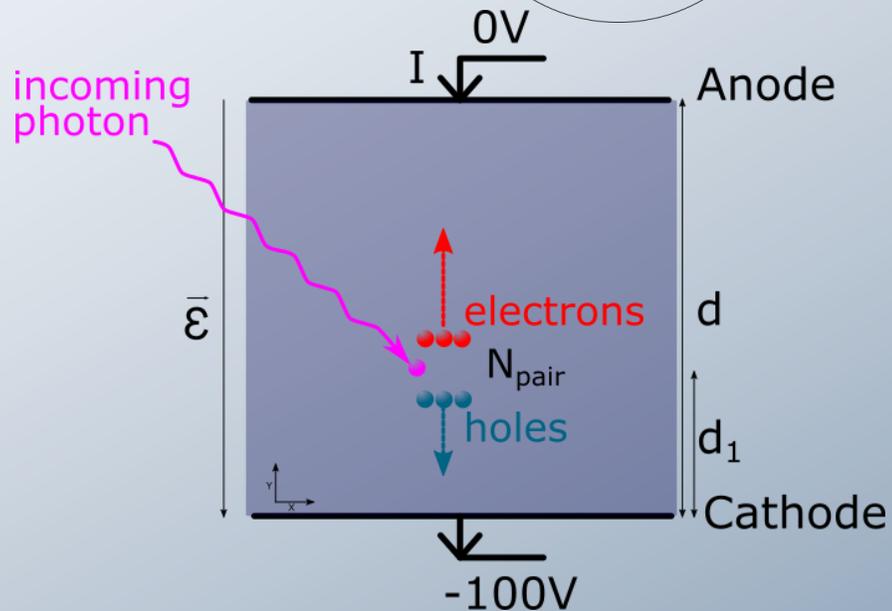
CdTe hybrid technology: working principle

- Needs: 1 – 160 keV
- **Photoelectric effect**
- Compton Scattering
- Pair production

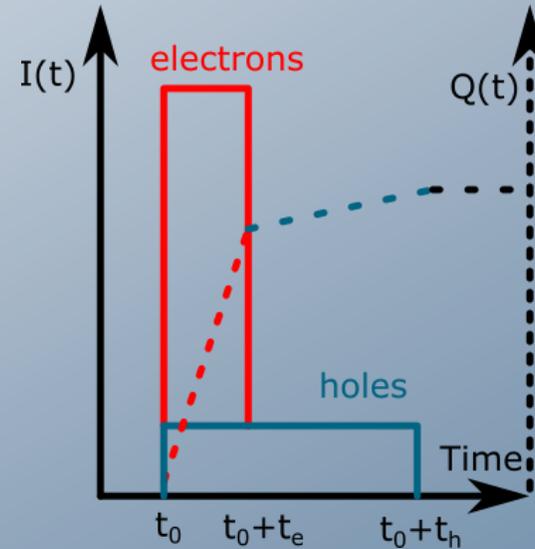


➤
$$N_{pair} = \frac{E_{photon}}{w}$$

➤
$$d_{interaction} = 100 \mu m$$



Monopixel detector sketch

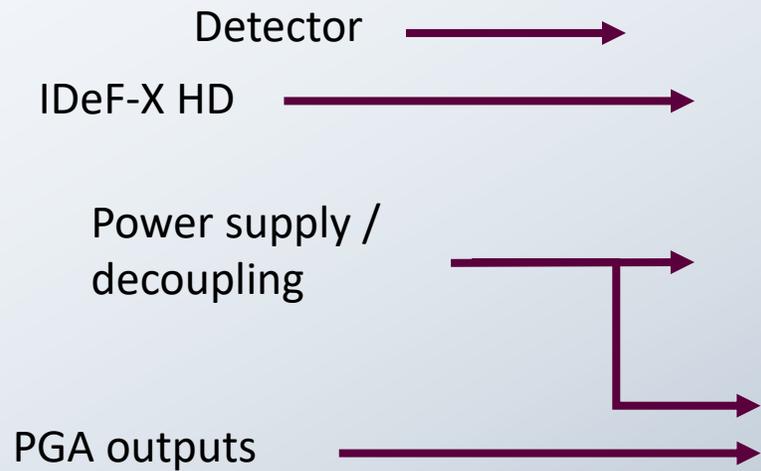


Current formation inside pixel

➤
$$t_e \approx 10 \text{ ns (CdTe)}$$

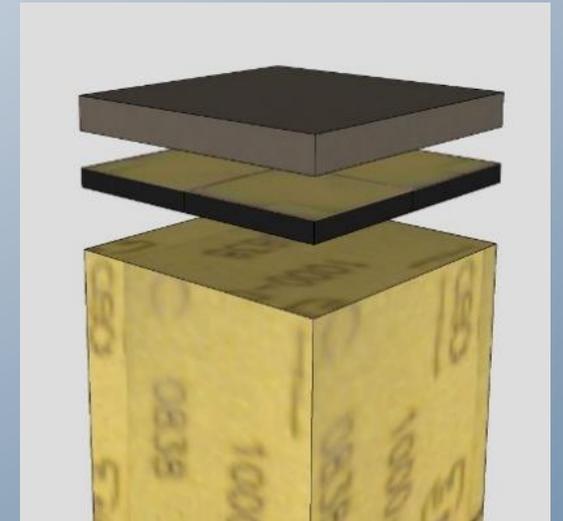
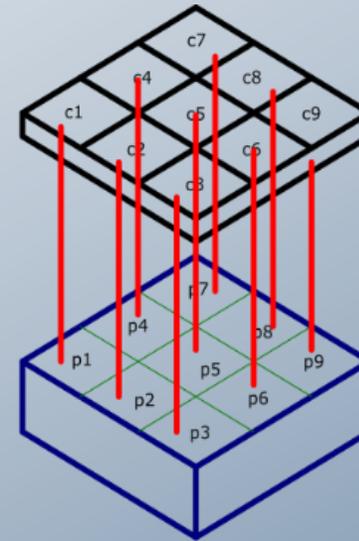
➤
$$t_h \approx 125 \text{ ns (CdTe)}$$

CdTe hybrid technology: working principle



X-Ray Photography of a Caliste - HD

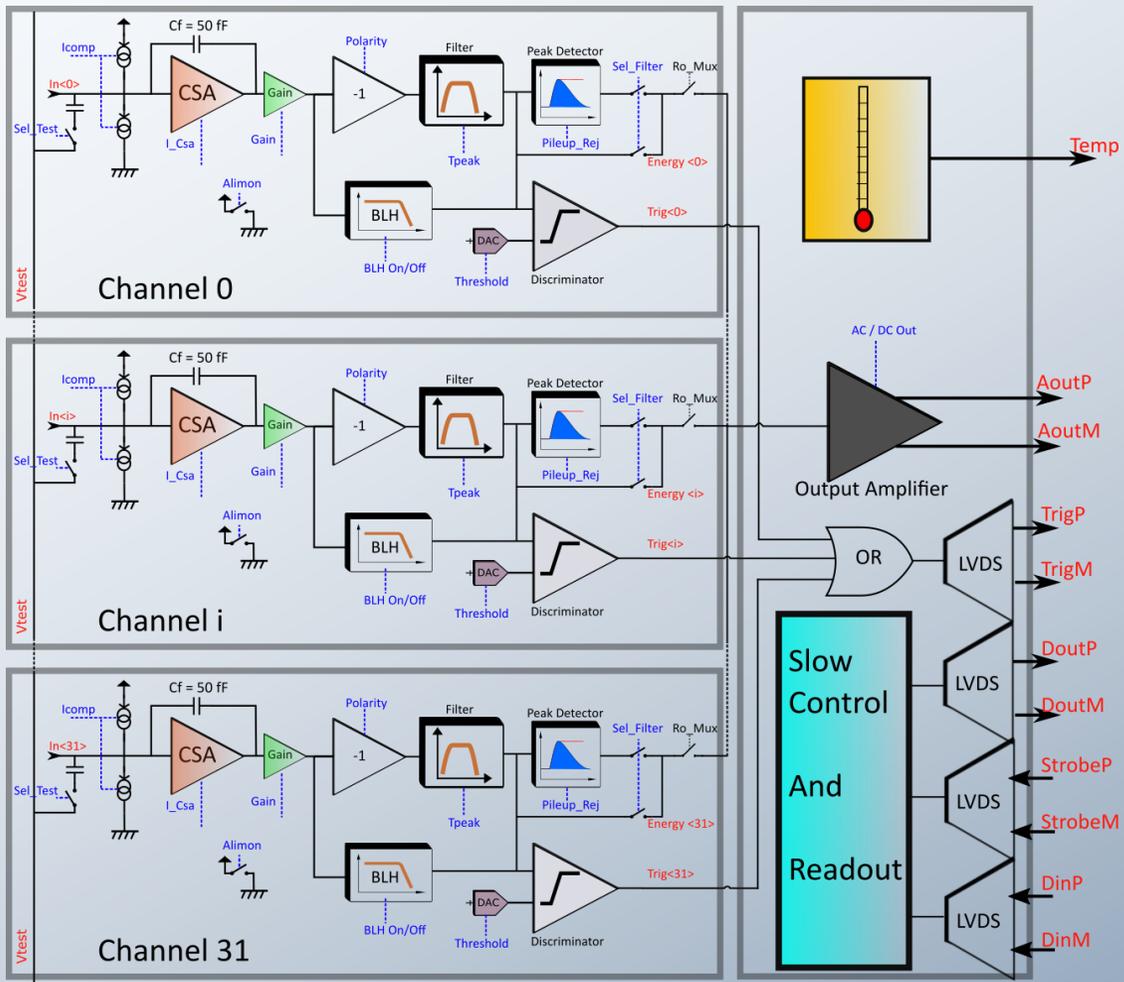
« 1D » Architecture



« 2D » Architecture

IDeF-X HDBD

General Description



IDeF-X HDBD schematic

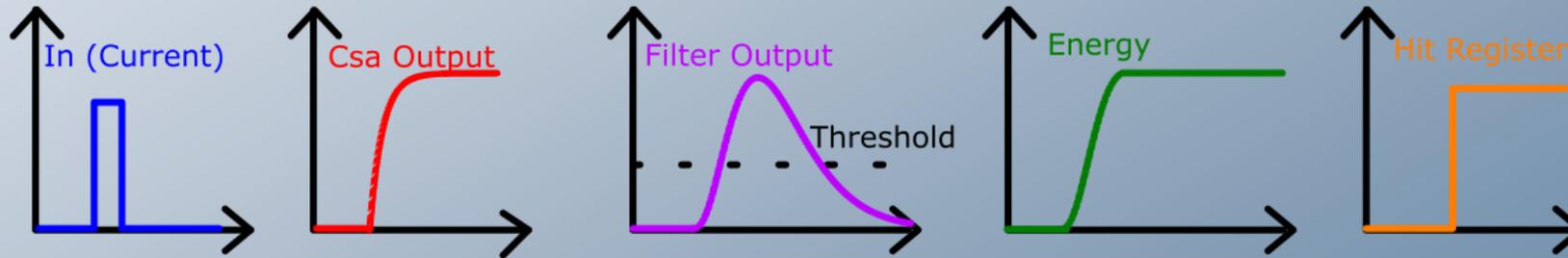
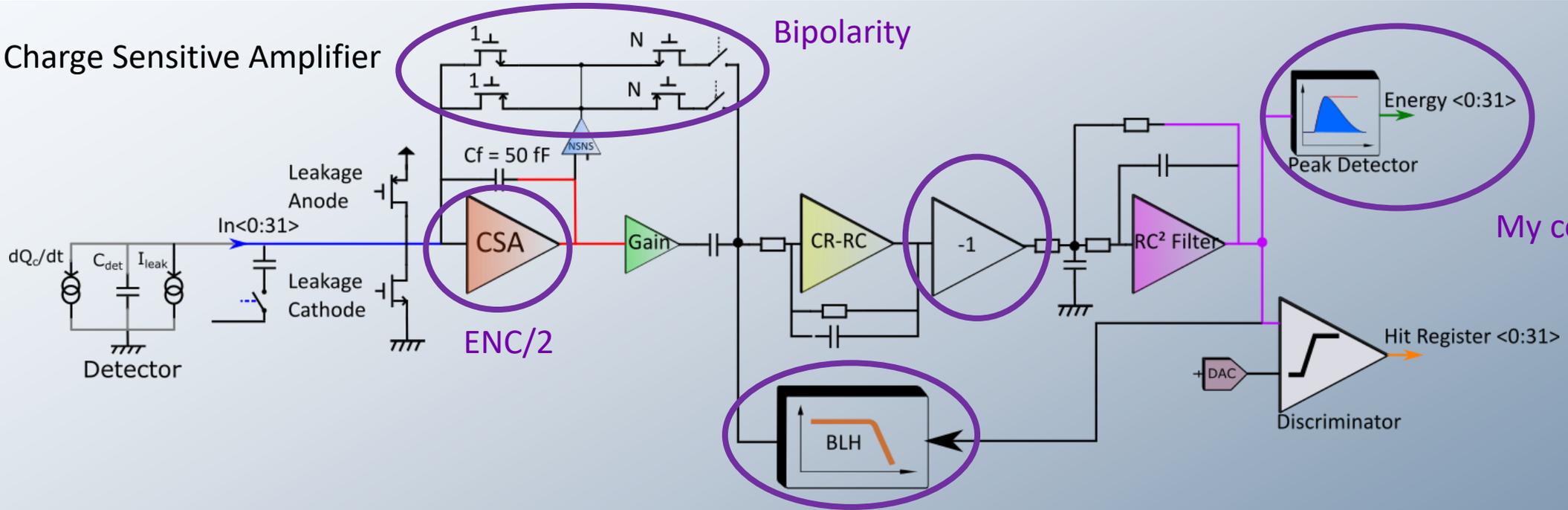


IDeF-X HDBD picture

- Technology:
 - AMS 0.35 μm
- Goal:
 - Resolution: ≈ 500 eV (FWHM at 60 keV)
 - Power: < 36 mW
 - Nb Channel: 32
 - Triggering architecture

IDeF-X HDBD Channel Description

CSA: Charge Sensitive Amplifier

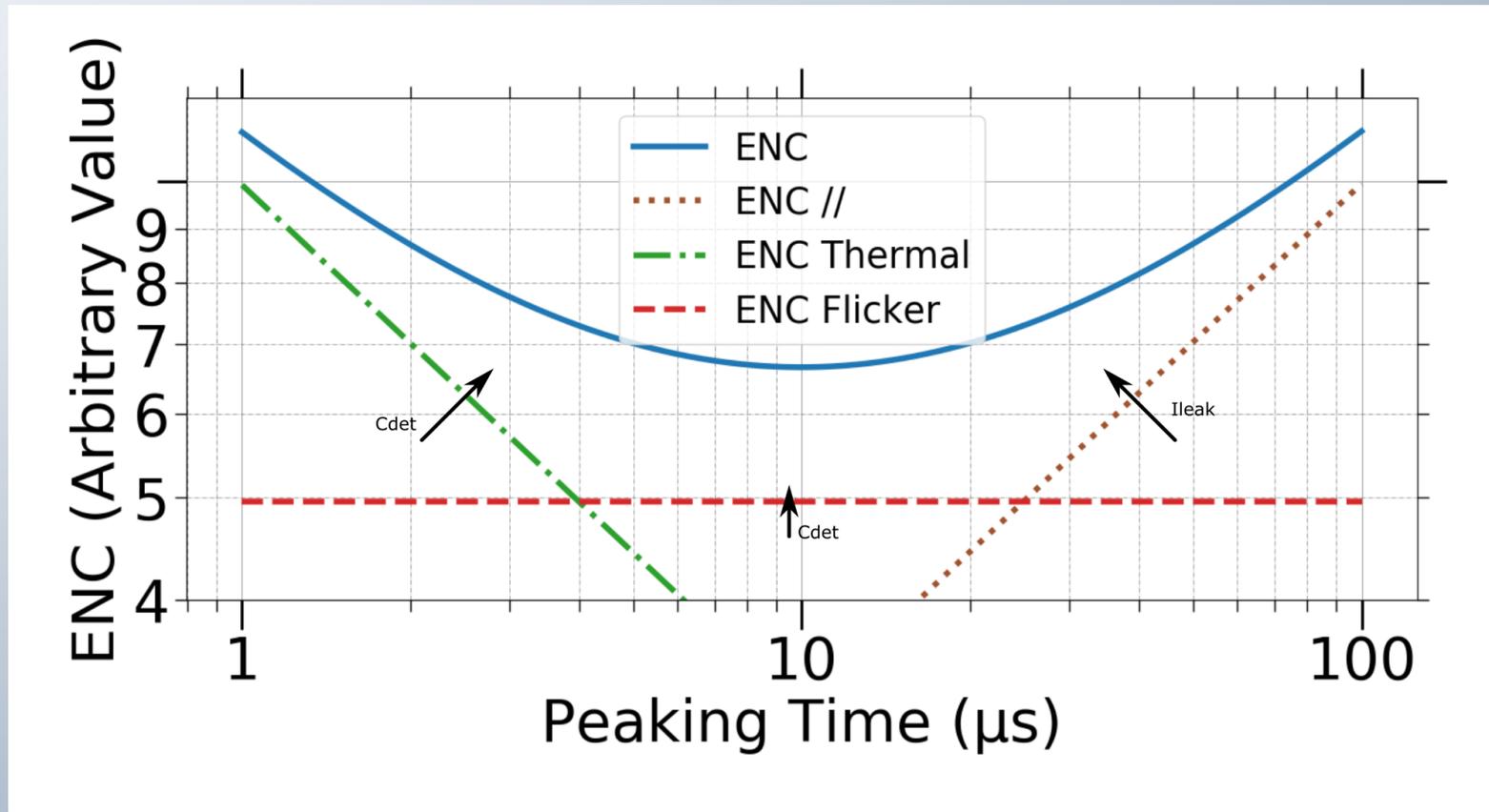


Fully continuous charge sensitive channel architecture [Gevin et.al], [Geronimo et.al]

IDeF-X HDBD Noise analysis

ENC: Equivalent Noise Charge

$$ENC^2 = \left(\frac{A_{th} \alpha_{th}^2}{T_{peak}} + A_f \alpha_f^2 \right) \cdot (C_{det} + C_{csa})^2 + A_p \alpha_p^2 T_{peak}$$



Detector:

- Shot noise:

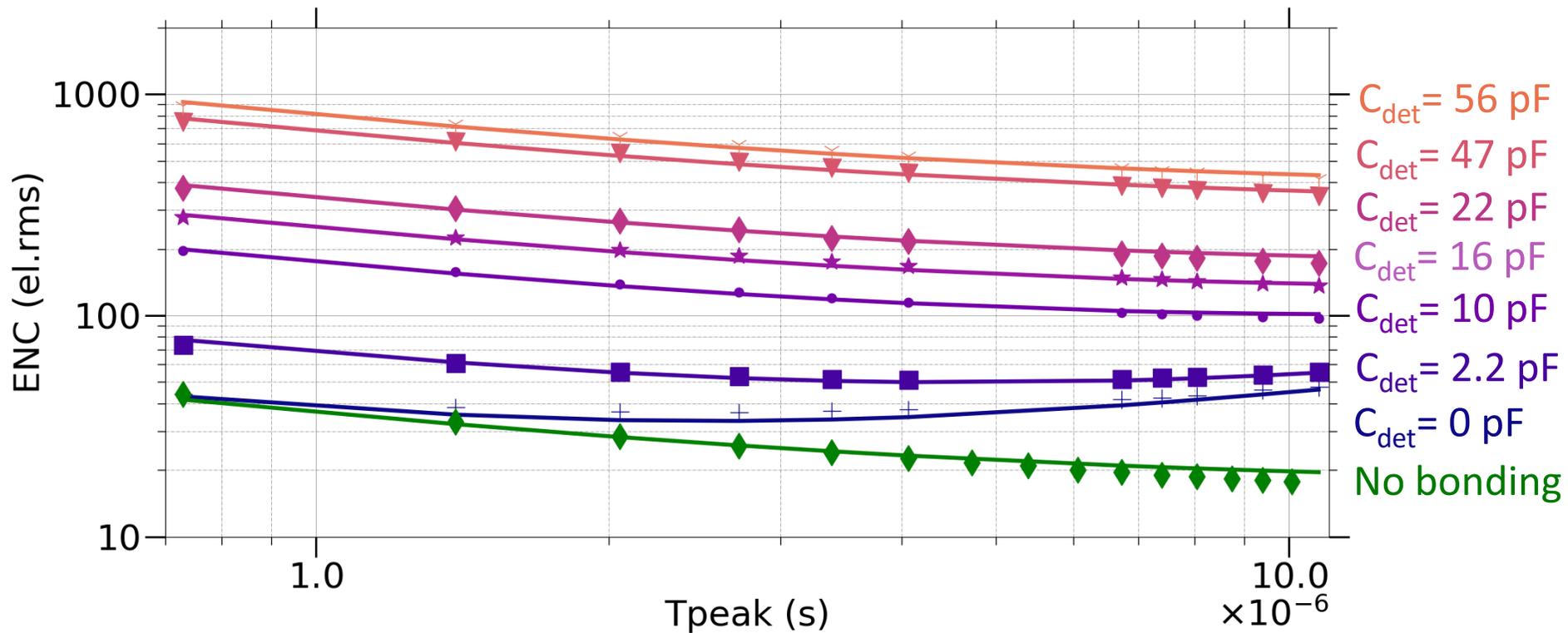
Transistors:

- Thermal noise:

- 1/f noise:

IDeF-X HDBD

Noise measurements



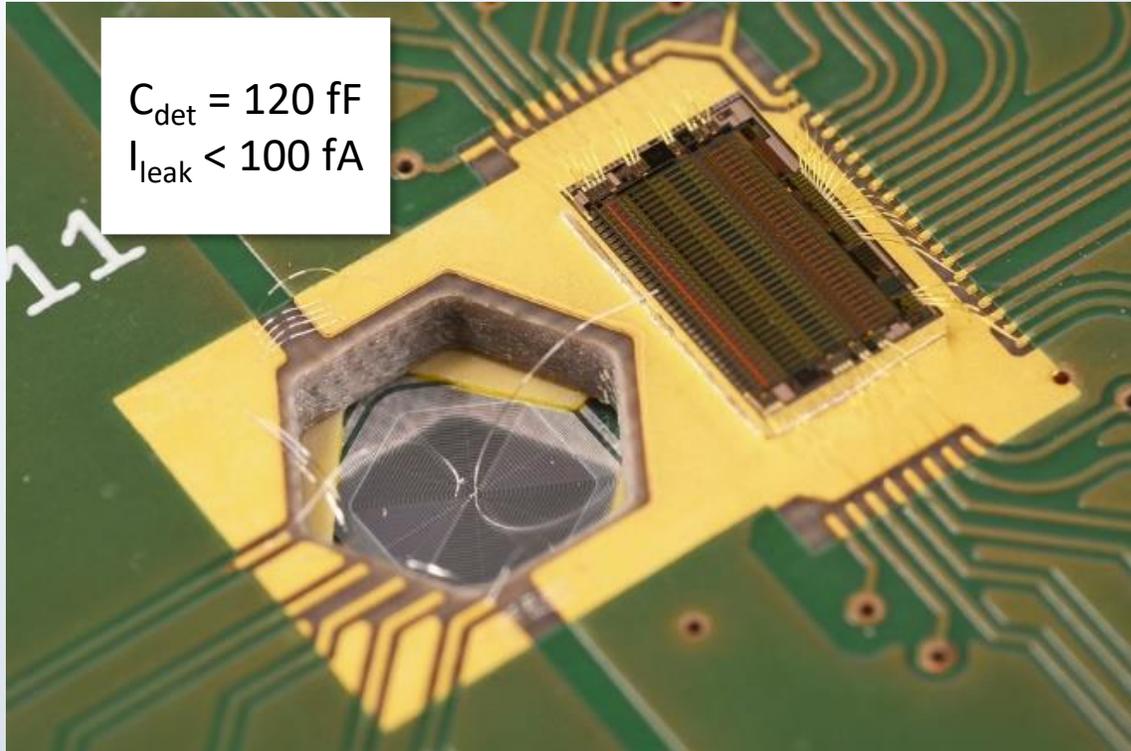
Variation with C_{det}
 5 el/pF
 at $T_{peak} = 10.73 \mu\text{s}$

ENC = 17_{-0}^{+5} el.rms
 for all channels

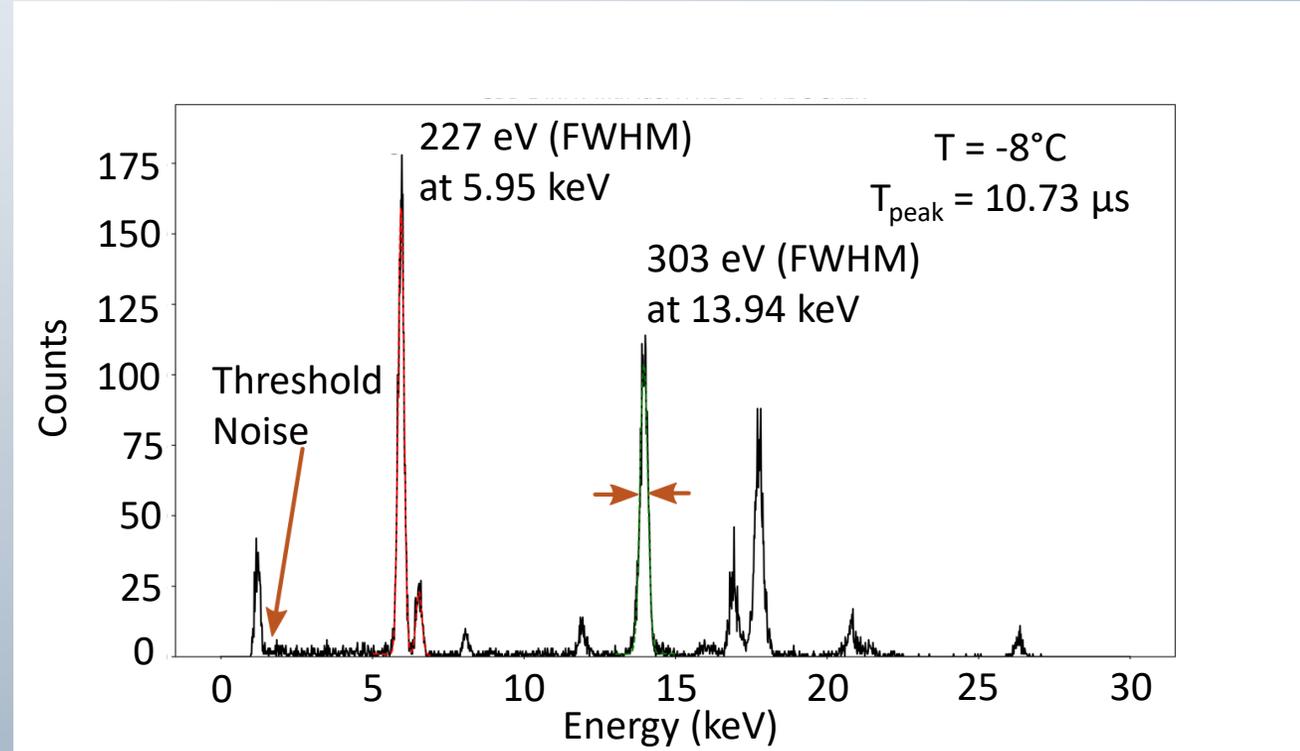
Model:
$$ENC = \sqrt{(C_f + C_{det} + C_0)^2 \times \left(\frac{\alpha_{th}^2}{T_{peak}} + \alpha_f^2 \right) + \alpha_{//} I_{leak} T_{peak}}$$

IDeF-X HDBD

Spectroscopy with Silicon Drift Detector



IDeF-X HDBD with INFN Roma Silicon Drift Detector

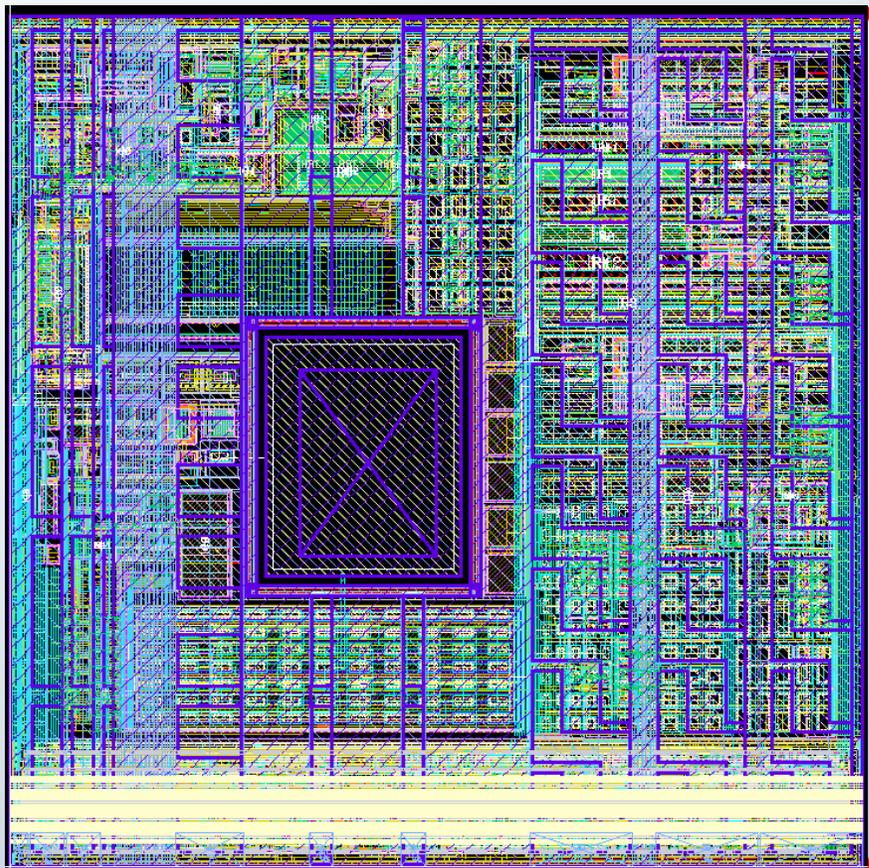


Superposition of ^{55}Fe and ^{241}Am spectra with IDeF-X HDBD and SDD

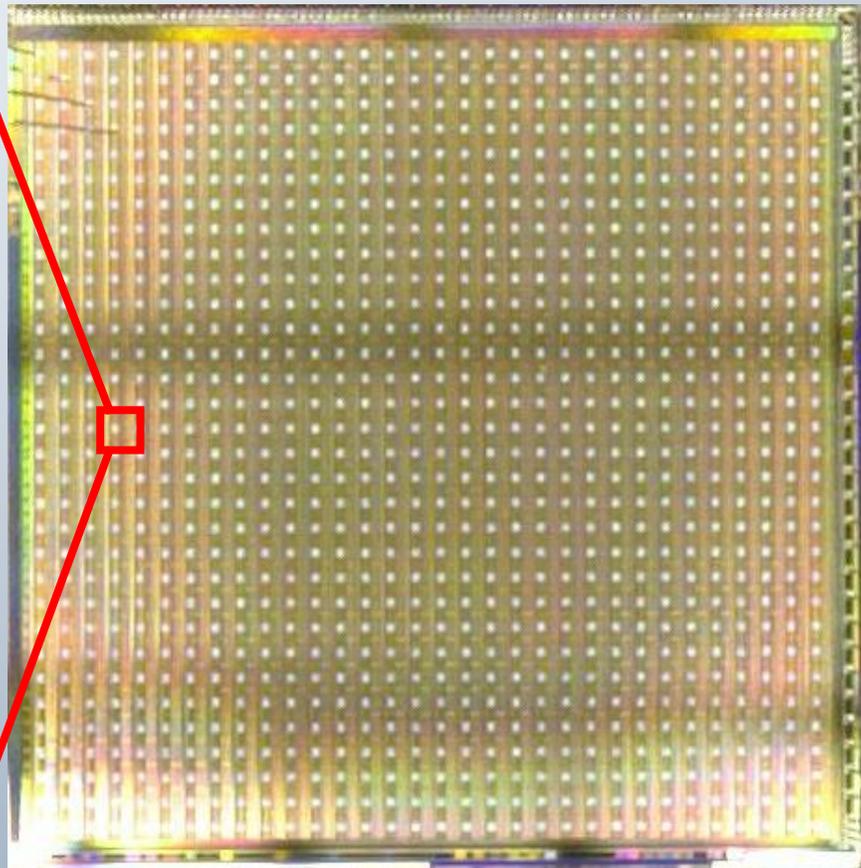
➤ Results:

- Resolution: = 227 eV at 5.9 keV
- Resolution: = 526 eV at 60 keV (CdTe) (goal \approx 500 eV)
- Channels: 32
- Trigger threshold: 1.2 keV
- Power: 26 mW (goal $<$ 36 mW)

IDeF-X D^2R_2 General Description



IDeF-X D^2R_2 Pixel Layout



IDeF-X D^2R_2 picture

➤ Technology:

XFAB 0.18 μm

➤ Goals:

Resolution: ≈ 500 eV
at 60 keV

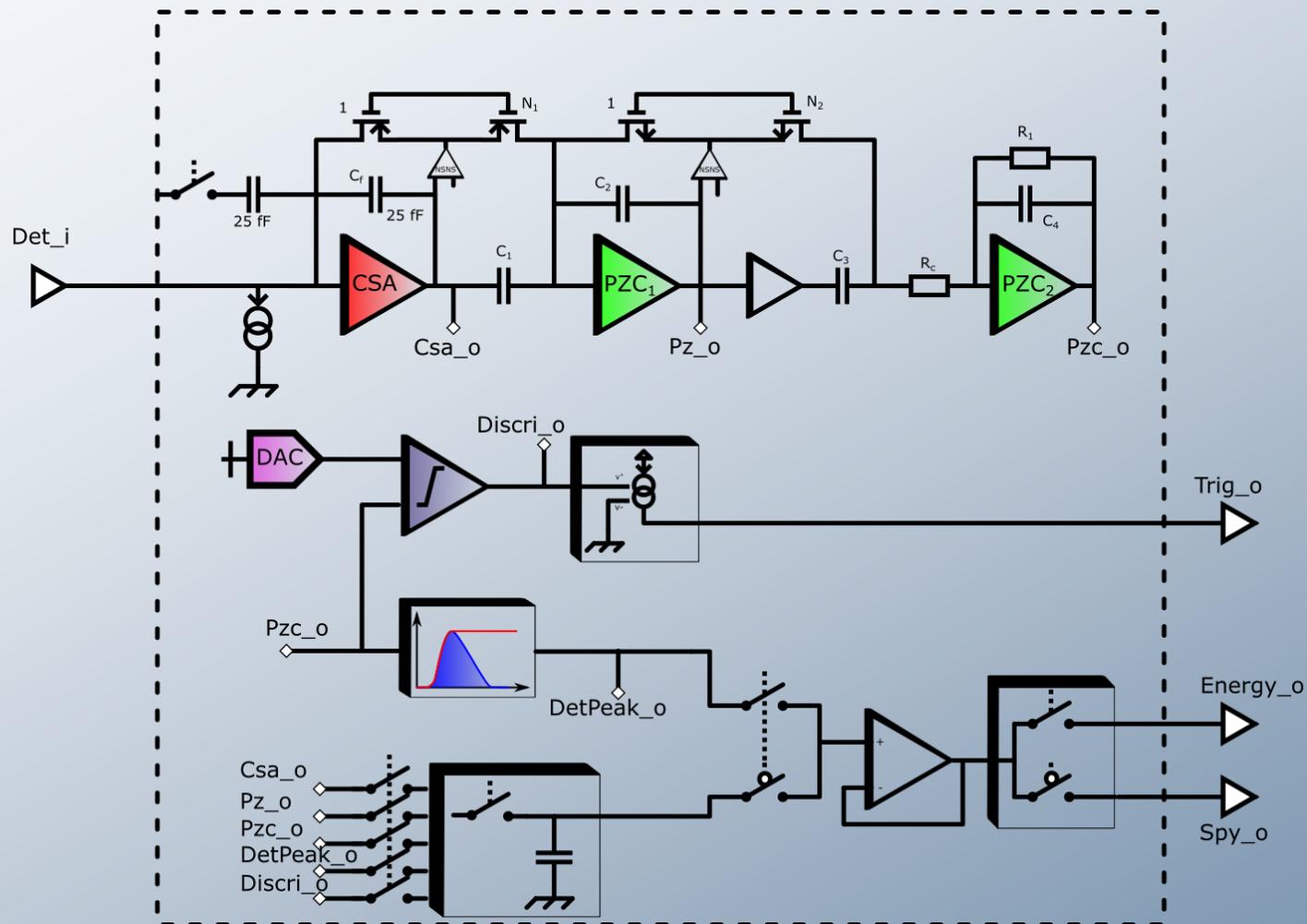
Power: < 200 mW

Channels: 1024

Channel size: $250 \times 250 \mu\text{m}^2$

Self-triggered

IDeF-X D²R₂ Pixel description

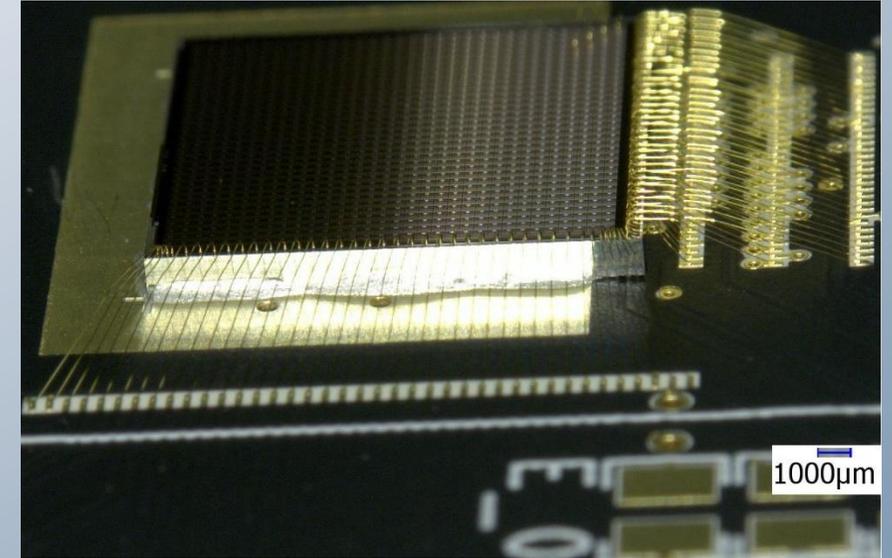
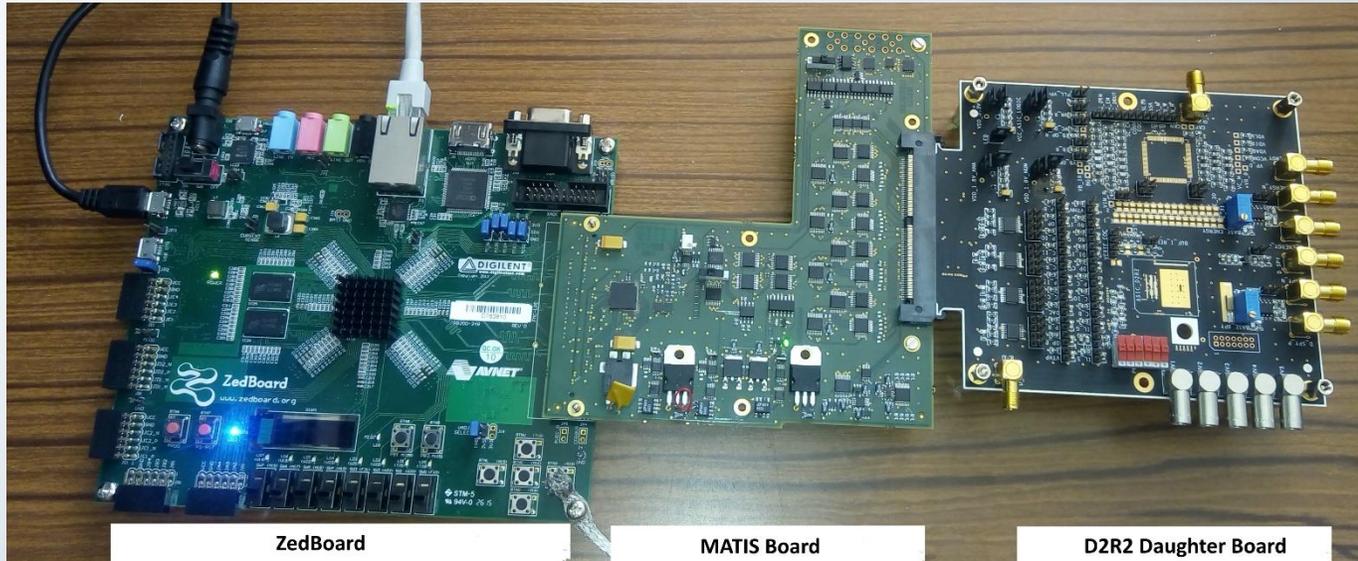


Features:

- CSA
- Non Stationnary Noise Suppressor
- Double stage PZC filter (CR-RC¹)
- Discriminator
- Peak detector
- SPY multiplexer
- Sample and Hold

IDeF-X D²R₂

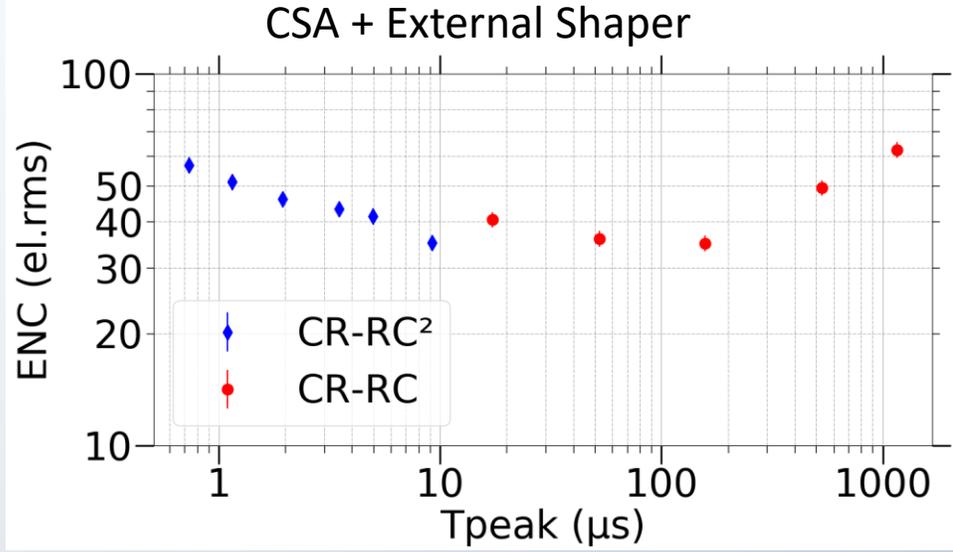
Electrical results



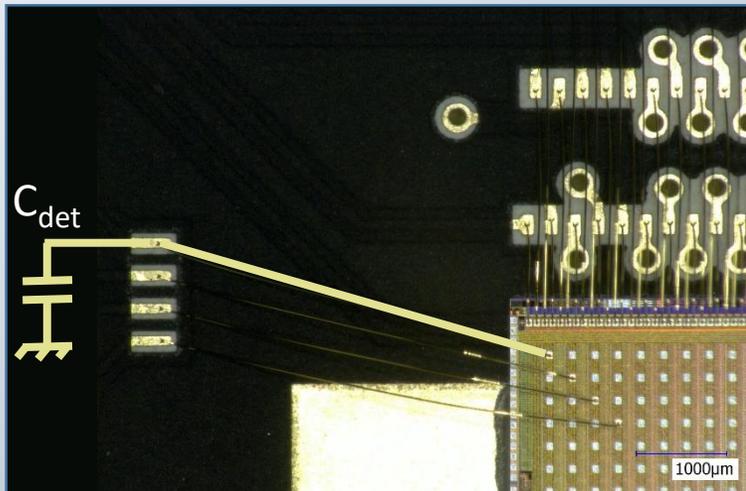
- ASIC received (with bonding) on **04/09/2019**
- Python Gui Software control
- First board: ZedBoard:
 - Server architecture (I²C / ethernet decoding)
 - Firmware for Slow control communication
- Second board: MATIS
 - Power supplies 3.3 V control
 - DAC controls
 - Digital inputs/outputs drivers
- Third Board: Daughter Board
 - Power supplies 1.8 V LDOs
 - DAC controls

IDeF-X D²R₂

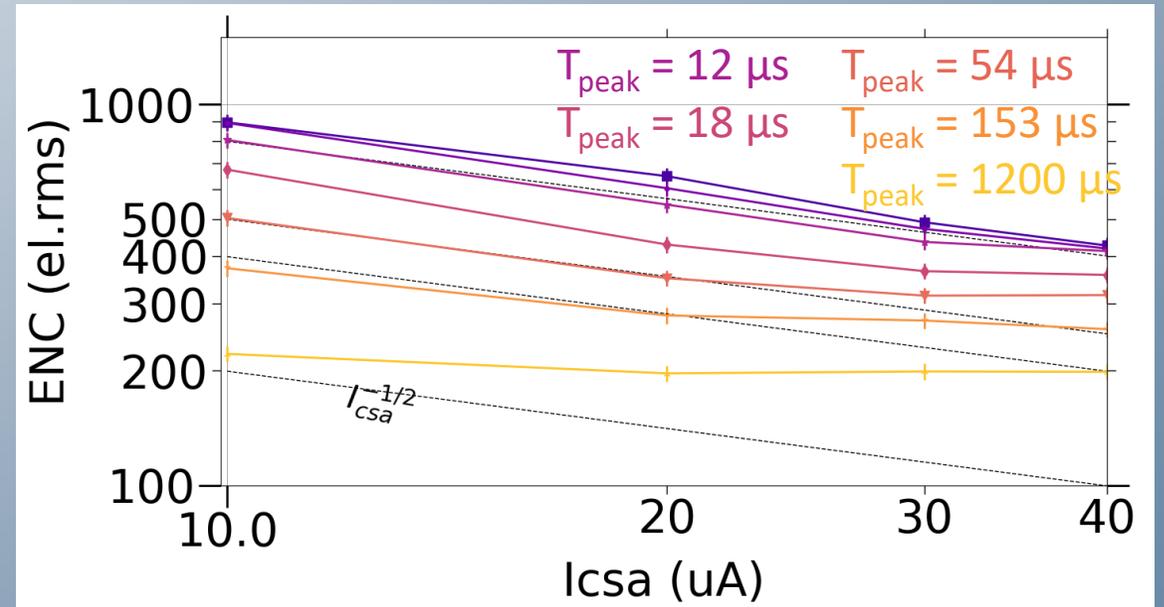
Electrical results



- Gain: 6.3 μV/el
- ENC_{floor}: 36 el.rms at T_{peak} = 9.5 μs [CSA + External filter] (14 el.rms expected)
- Variation with capacitance: 300 el/pF at T_{peak} = 4 μs (20 el/pF expected)



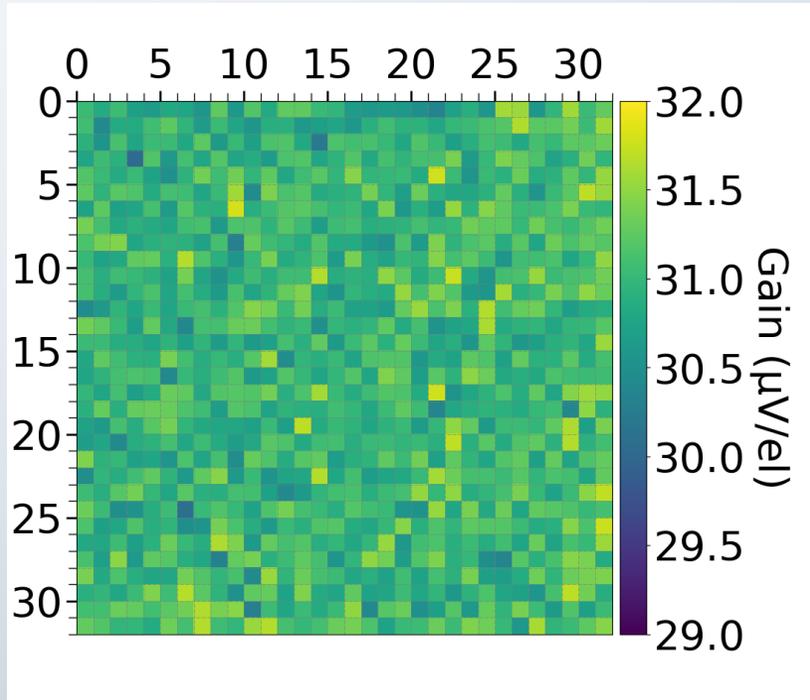
- « Flat » slope
- 1/f noise ?
- Vary with I_{CSA}



IDeF-X D²R₂

Electrical results

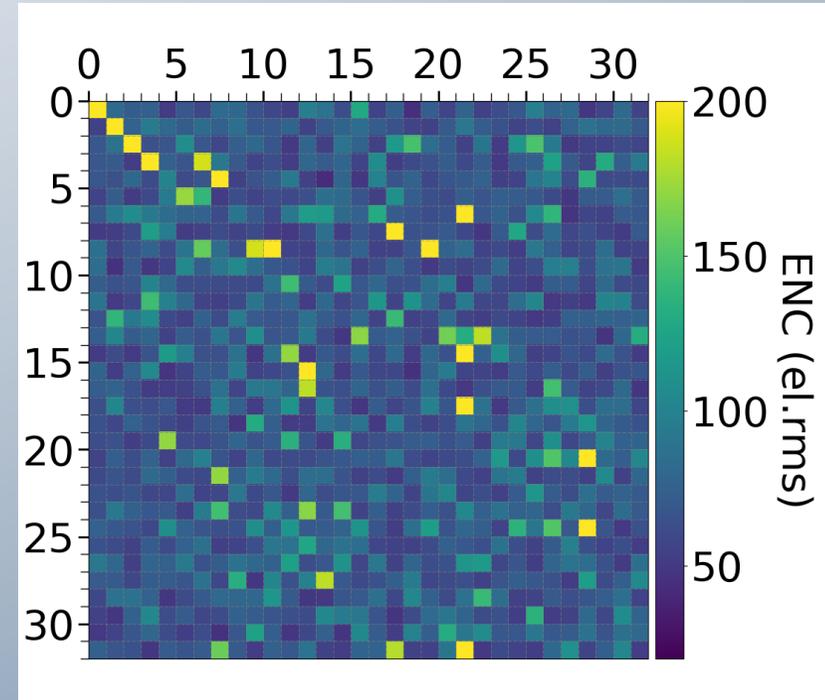
Gain Map



Mean value: 31 $\mu\text{V/el}$

Standard deviation: 271 nV/el

ENC Map



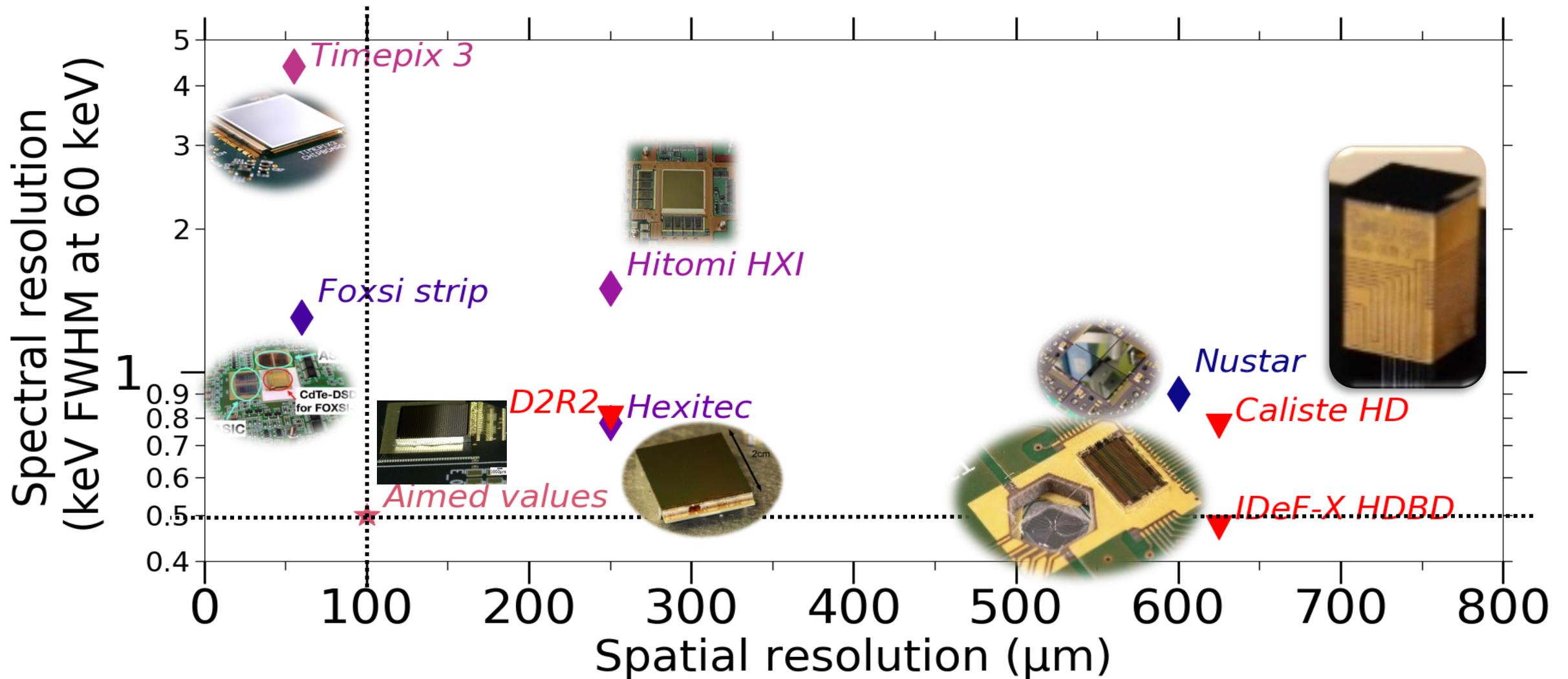
Mean value: 74 el.rms

Minimum: 42 el.rms

Standard deviation: 21 el.rms

[CSA + Internal shaper / All pixels]

The end of the thesis is not the end of what has to be done...



The end of the thesis is not the end of what has to be done...

- Multi-ASICs « packaging »

Redistribution
Layer →

D²R₂ ASIC →

Gap (resin) →
200μm

- Detector: AcroRad 1mm thick Schottky contact

References

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- [Gevin et.al], “IDeF-X BD: A low noise dual polarity ASIC for the readout of Silicon and CdTe detectors,” *2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)*, San Diego, CA, 2015, pp. 1-5
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