BROOKHAVEN NATIONAL LABORATORY
Instrumentation Division

Front-End ASICs for CZT and Si Multi-Element Detectors

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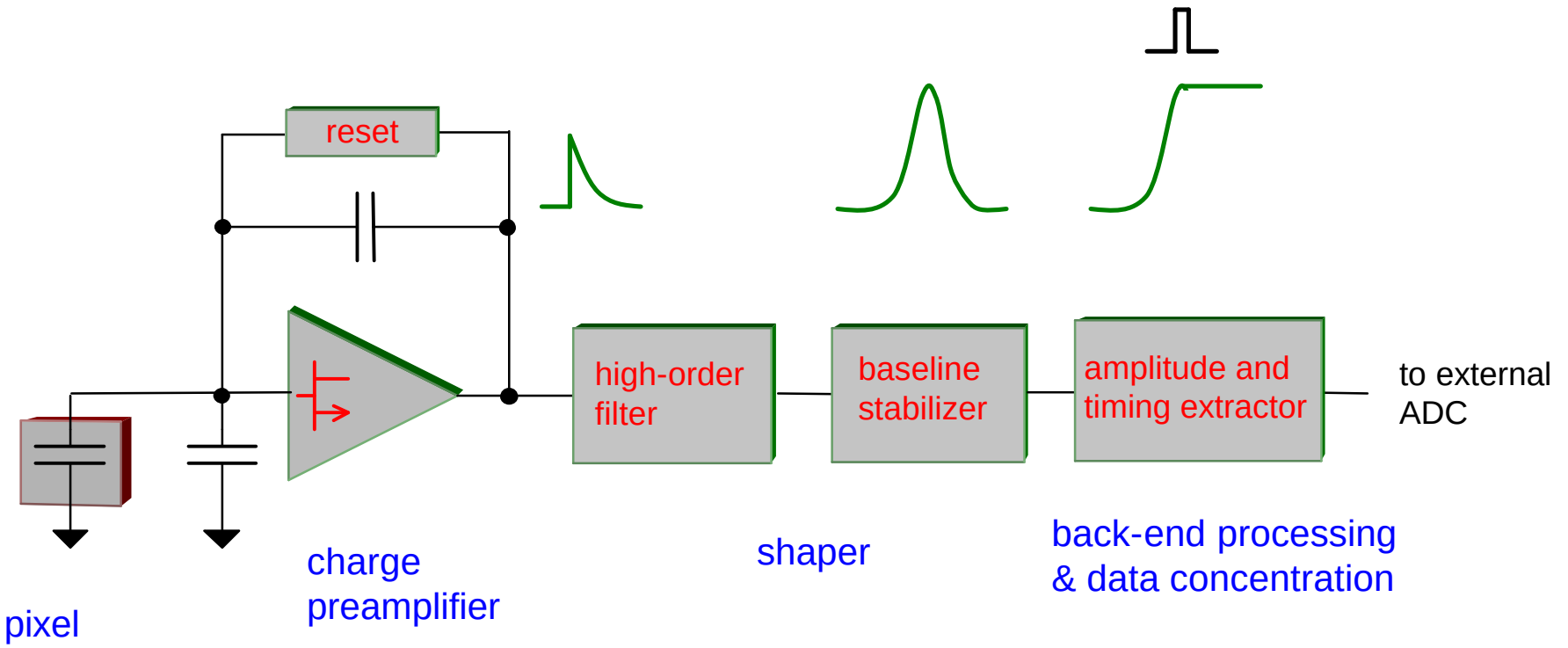
Outline

I. Circuit Solutions

II. ASICs for CdZnTe Sensors

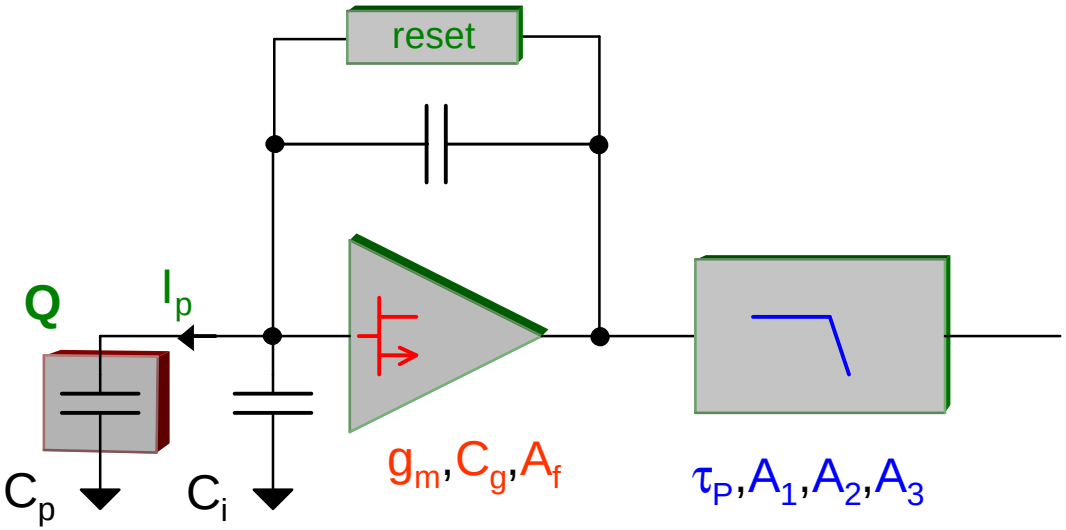
III. ASICs for Si Sensors

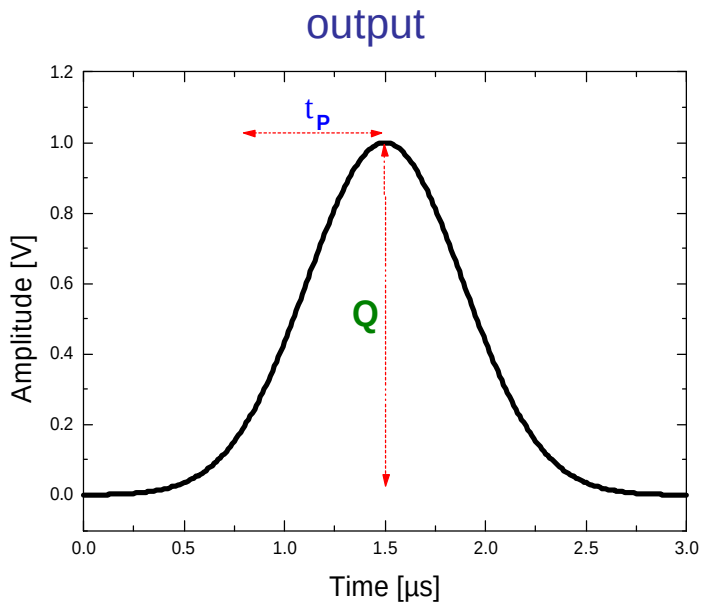
Typical front-end channel



- high reliability
- ease of use
- spectroscopic quality
- data concentration optimization

Input MOSFET optimization

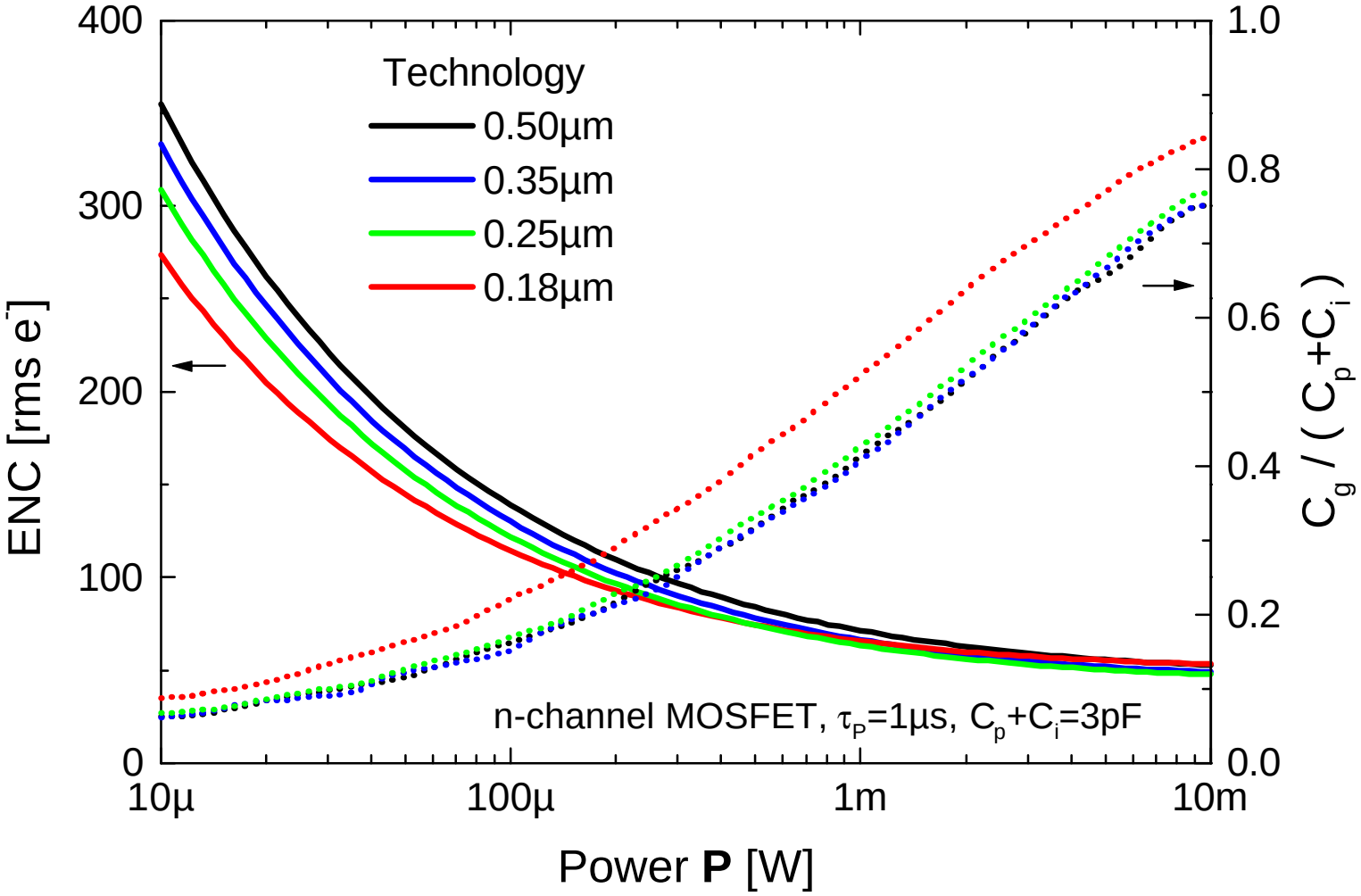




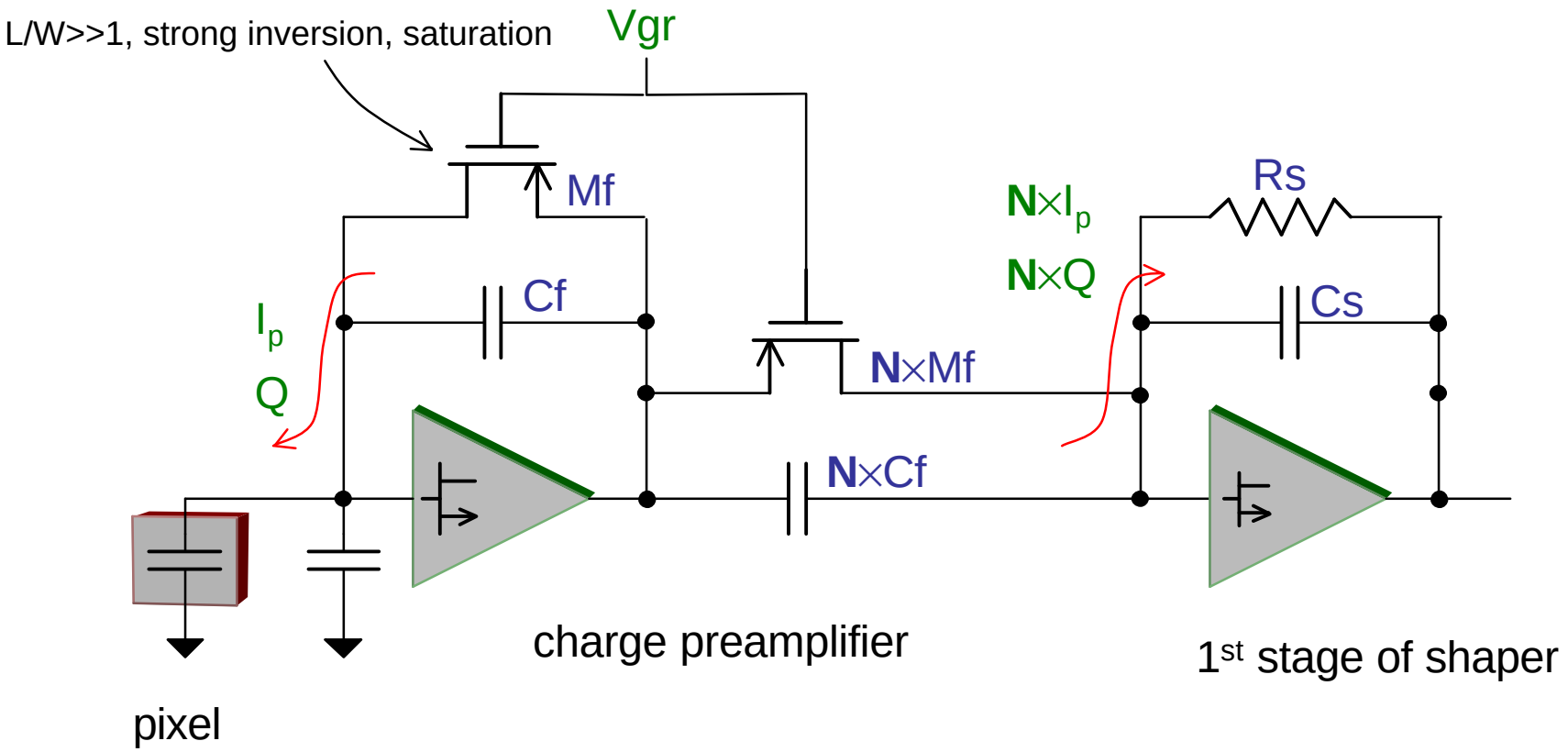
$$ENC^2 = \frac{A_1}{\tau_P}\frac{\left(C_p + C_i + C_g\right)^2}{g_m} + A_2 A_f \left(C_p + C_i + C_g\right)^2 + A_3 \tau_P \left(I_p + I_{rst}\right)$$

g_m, C_g, A_f, are functions of input MOSFET width **W** and power **P**

Input MOSFET optimization



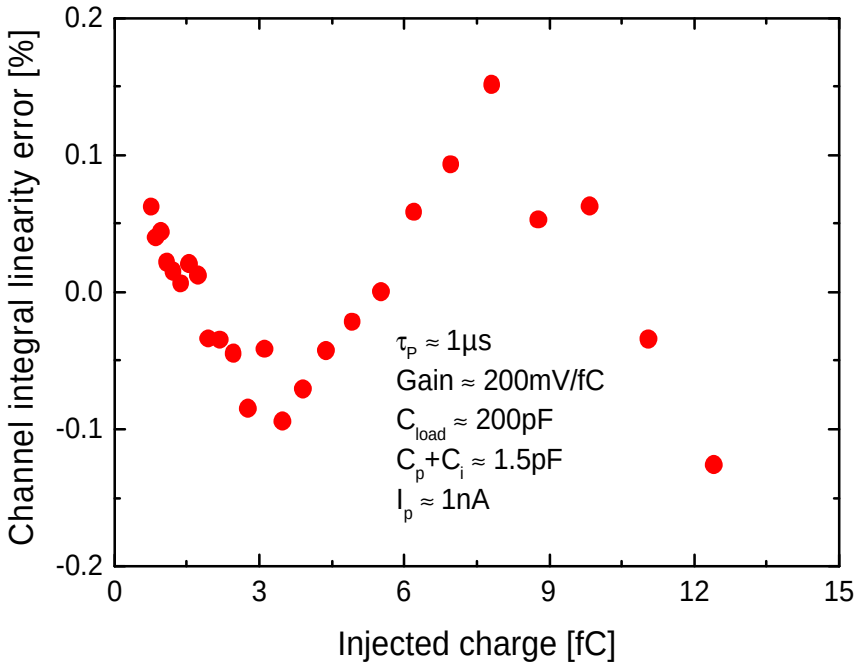
Continuous reset of the preamplifier



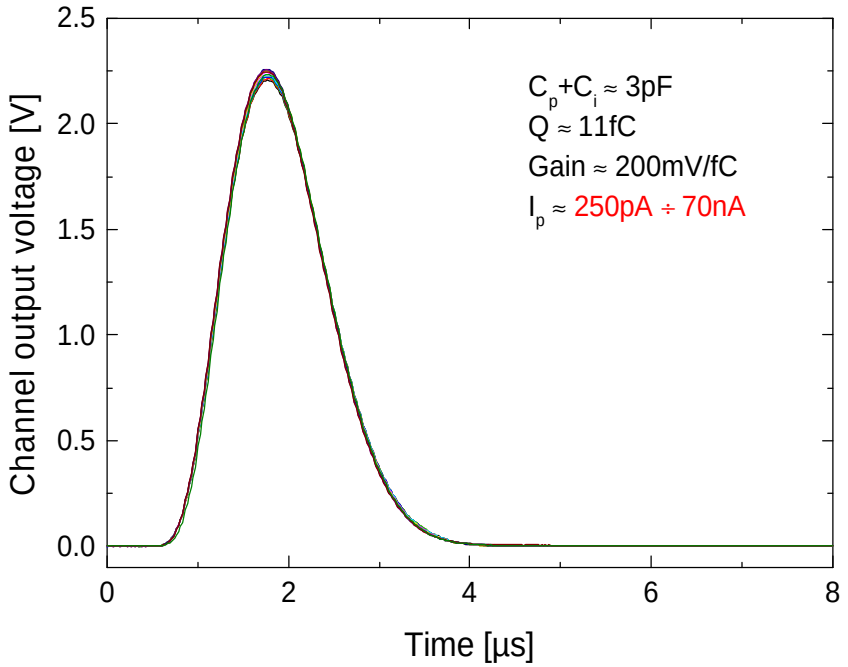
- current gain equal to **N**
- fully linear
- **self-adapts** to leakage current
- minimum noise contribution

Continuous reset of the preamplifier

linearity



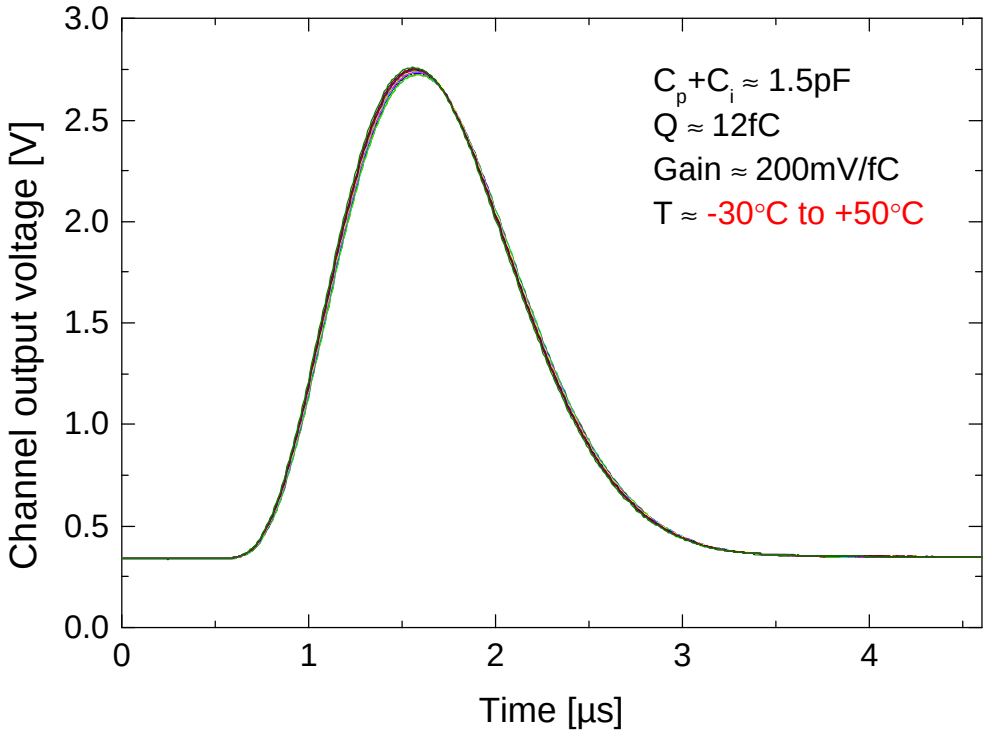
output vs pixel leakage current



First generation of front-end ASICs

other features

- plug & play
- per-channel test capacitor
- programmable gain
- programmable peaking time
- high output drive capability
- high stability vs temperature →



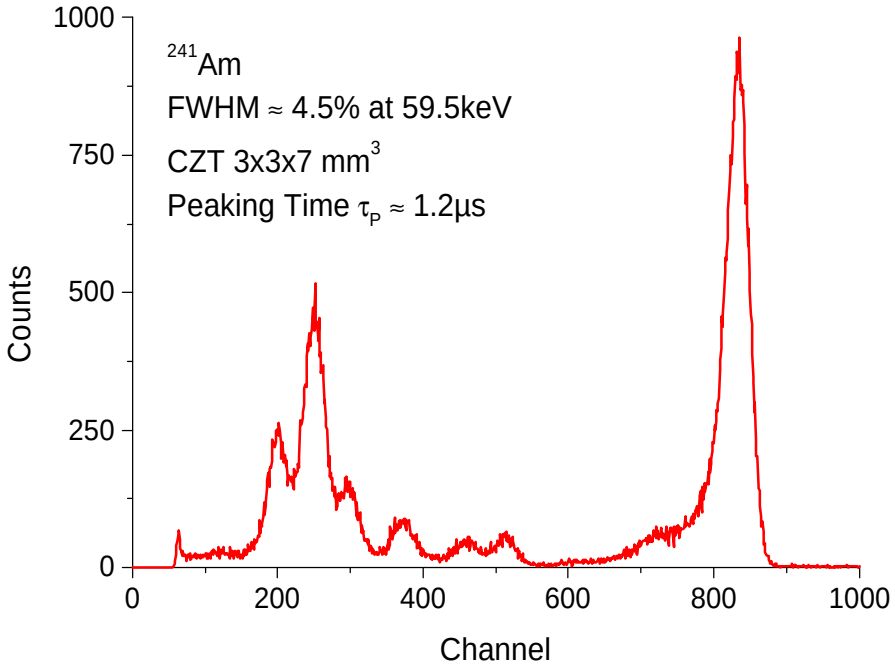
Generation of front-end ASICs for CZT

ASIC	Pixel capacitance [pF]	Channel count	Peaking time [µs]	Gain [mV/fC]	Power / channel [mW]	ENC [rms. e-]	Applications
General purpose	3	16	0.6, 1.2, 2.0, 4.0	30, 50, 100, 200	18	30+20/pF	*LFOV Gamma Camera* *SFOV Gamma Camera* *Nuclear Safeguards*
Medium speed	3	4	0.4	200	18	29+27/pF	*Down Hole Well Logging* *X-Ray Diffraction Gauges*
High speed bipolar	3	8	0.2	240	18	42+44/pF	*Bone Densitometry* *Pulse Mode CT* *Industrial X-Ray*
High capacitance	12	8	0.6, 1.2, 2.0, 4.0	30, 50, 100, 200	35	57+10/pF	*Industrial Strip Detectors* *Backscatter Gauges* *Large Area Detector*

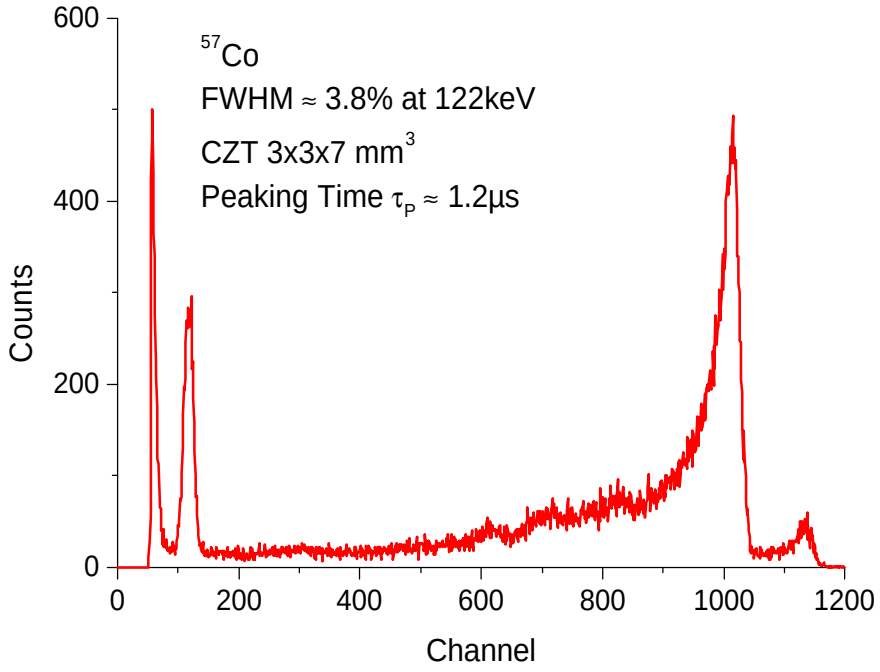
Technology : 0.5µm CMOS SP3M

CZT – ASIC spectra measurements

^{241}Am spectrum

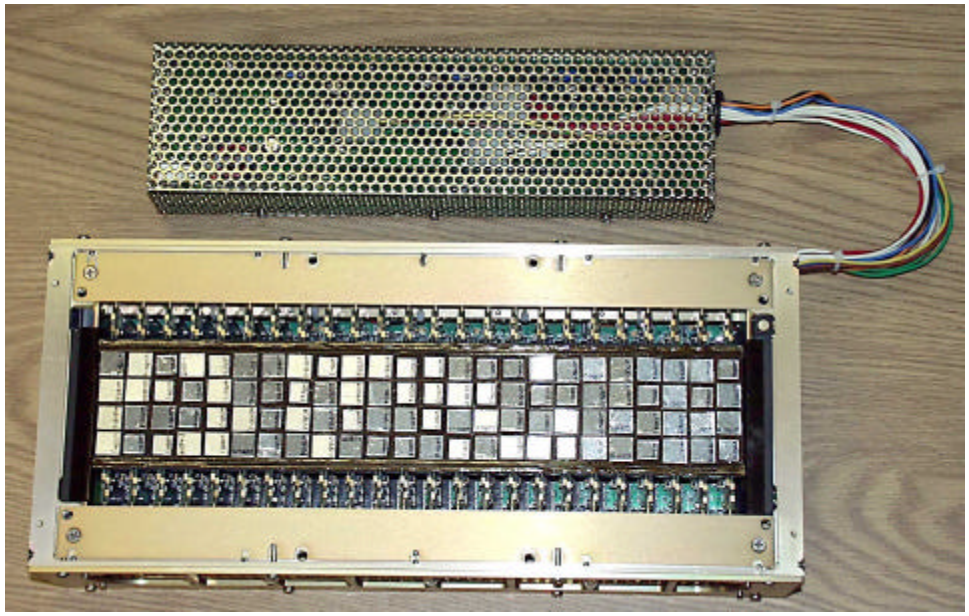


^{57}Co spectrum



CZT – ASIC applications

Solstice Gamma camera



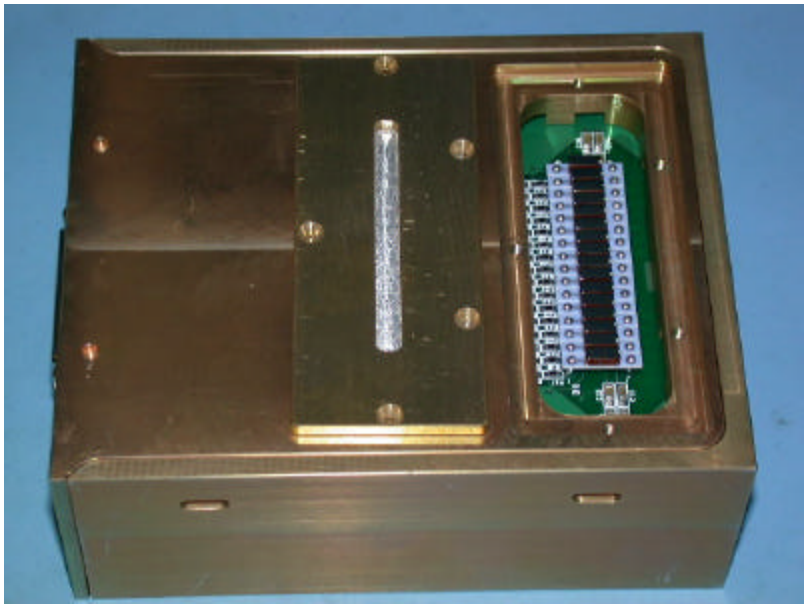
- 96 CZT crystals
- 3072 pixels
- 192 front-end ASICs
- 1.3M events/second
- average FWHM 3.8% at 122keV

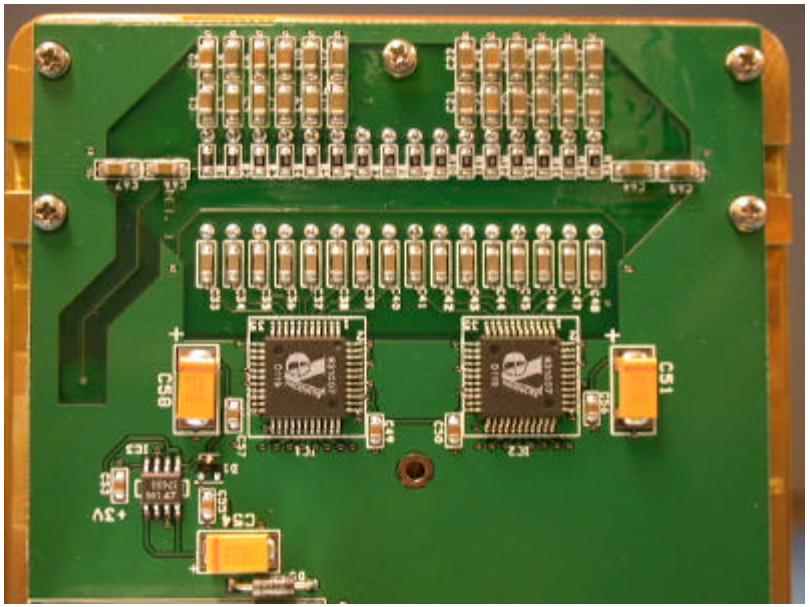
eZ-SCOPE hand held Gamma camera

- 1 CZT crystal
- 256 pixels
- 16 front-end ASICs
- 4.8M events/second
- average FWHM 4.0% at 122keV

CZT – ASIC applications

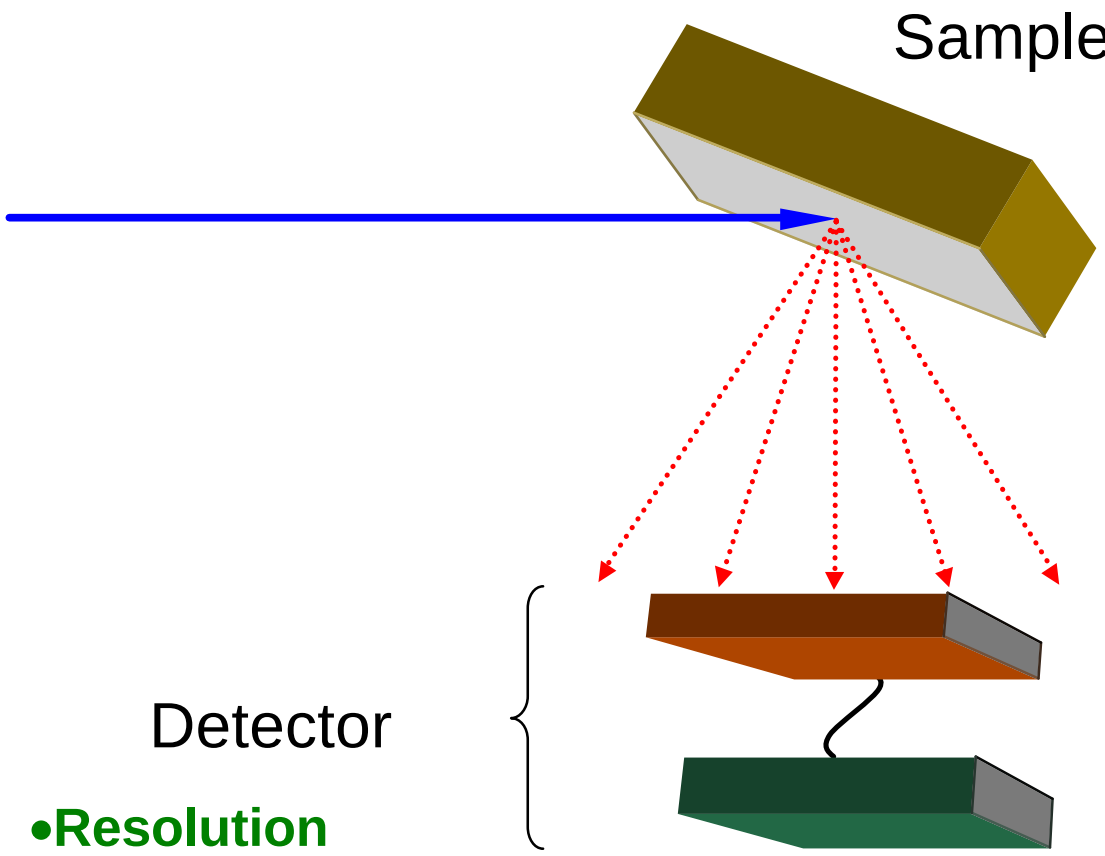
Bone Densitometry – GE Lunar Detector



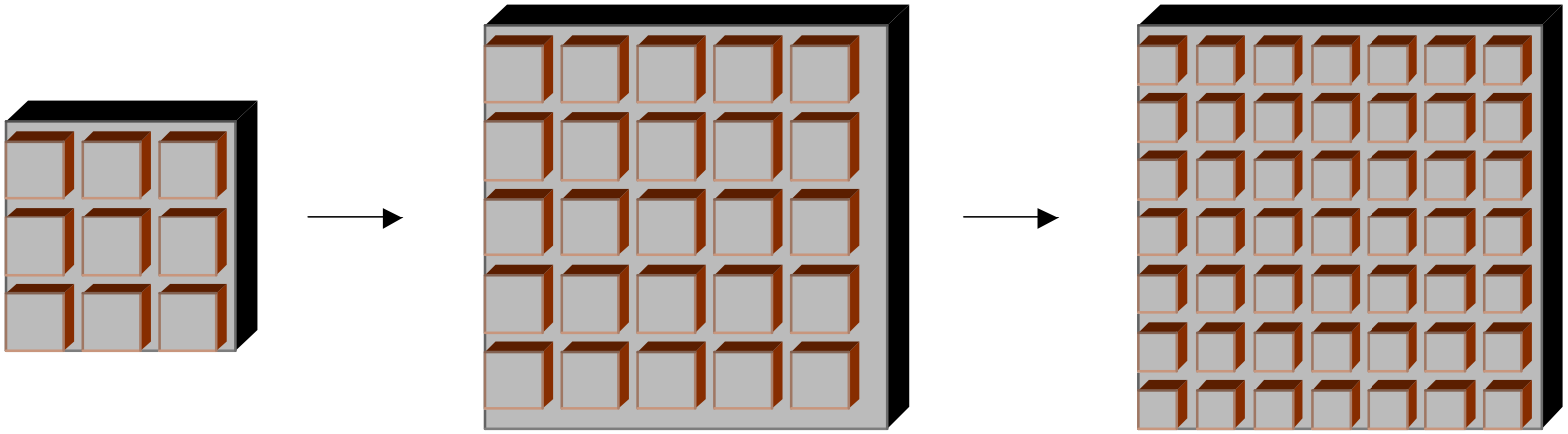


- 16 CZT crystals
- 16 pixels 3 x 7 x 3 mm^3
- 2 front-end ASICs
- DEXA (Dual Energy X-ray Absorptiometry)
- ASICs replaced 17 circuit boards (over 500 components) and improved performances

Typical fluorescence EXAFS measurement geometry

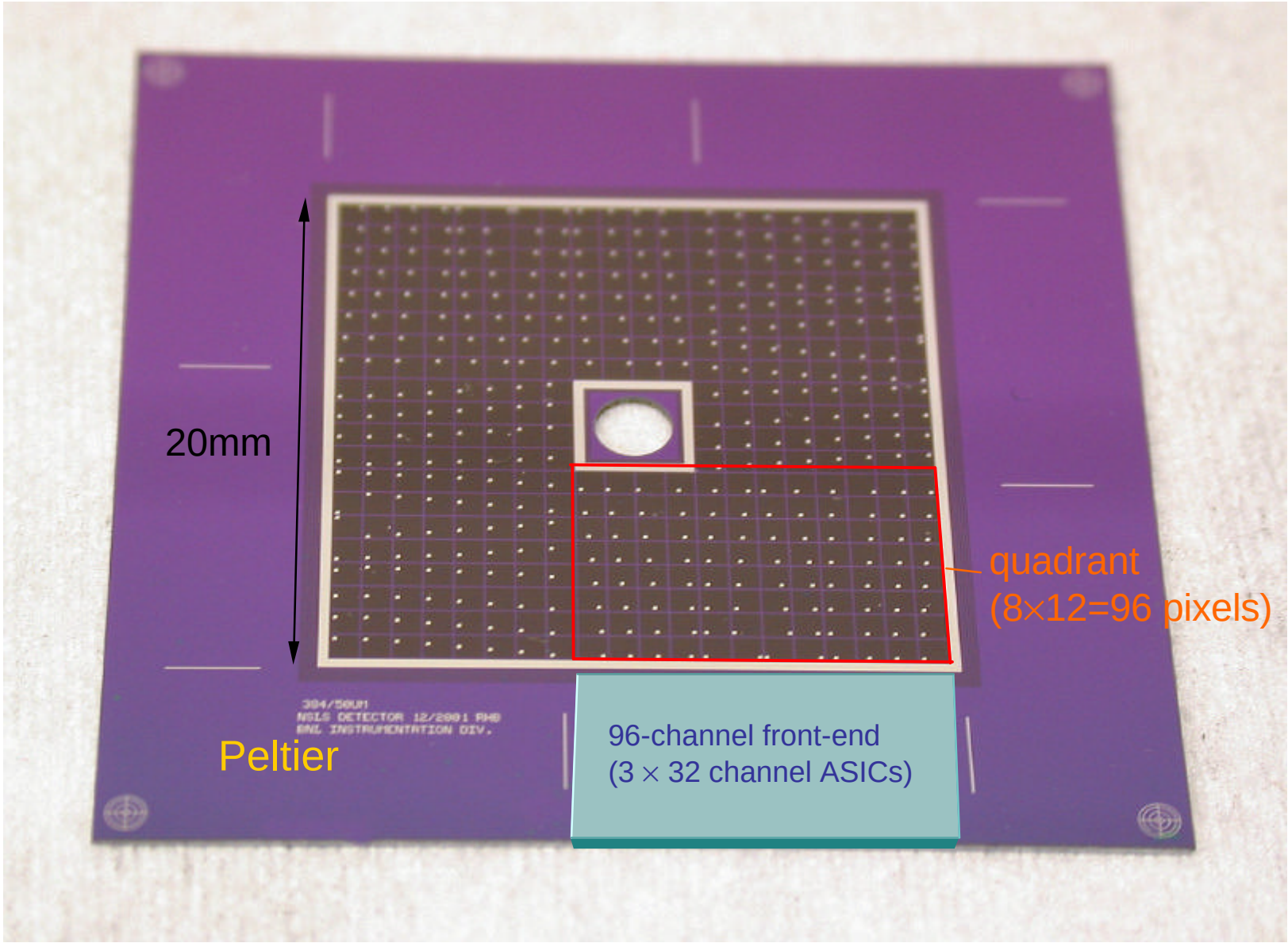


Optimum pixellation



$$\mathrm{ENC} \div \sqrt{\left(C_p(N) + C_i\right)^{\gamma+1} \frac{\mathrm{Rate}}{N} \left(\frac{P}{N} - p_2\right)^{\gamma}} \qquad \gamma = 0.5 \cdots 1$$

- charge sharing (≈20µm/side) and trapping (gap/side) : empirical

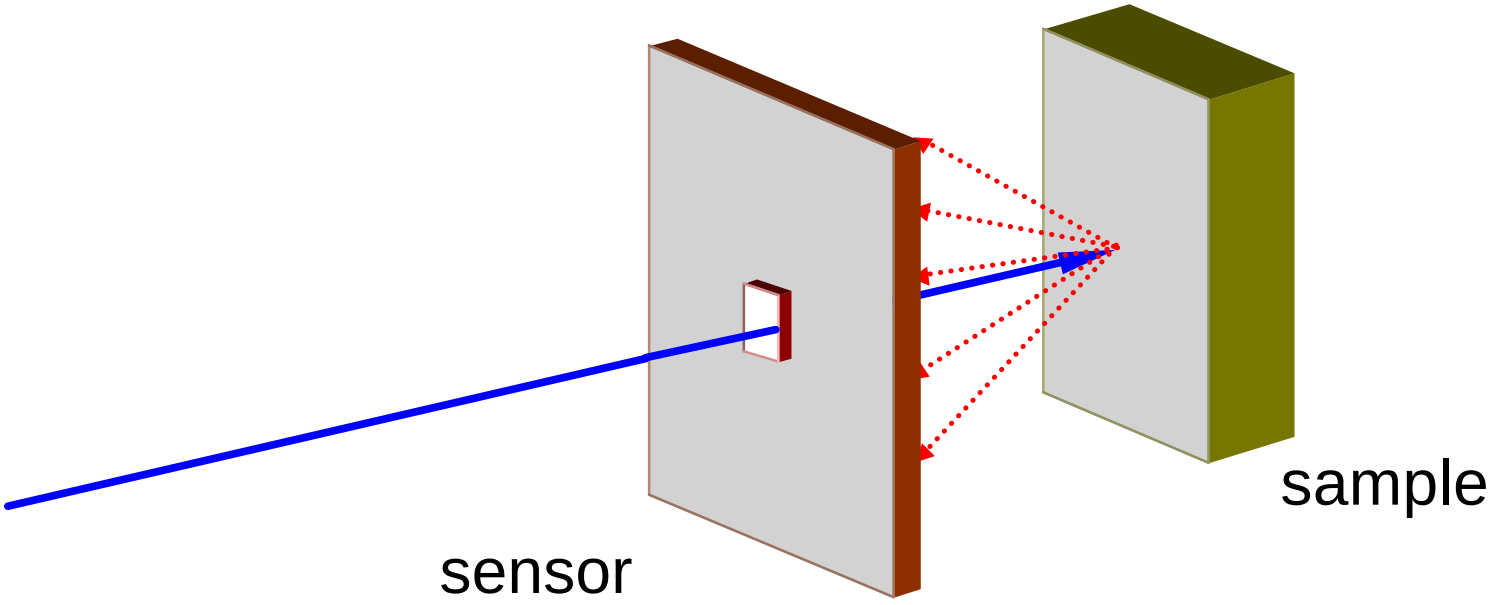


Si n-type high resistivity wafer 250μm thick,

N = 384 p^+ ≈1mm×1mm pixels,

gaps 10μm, 30μm, 50μm

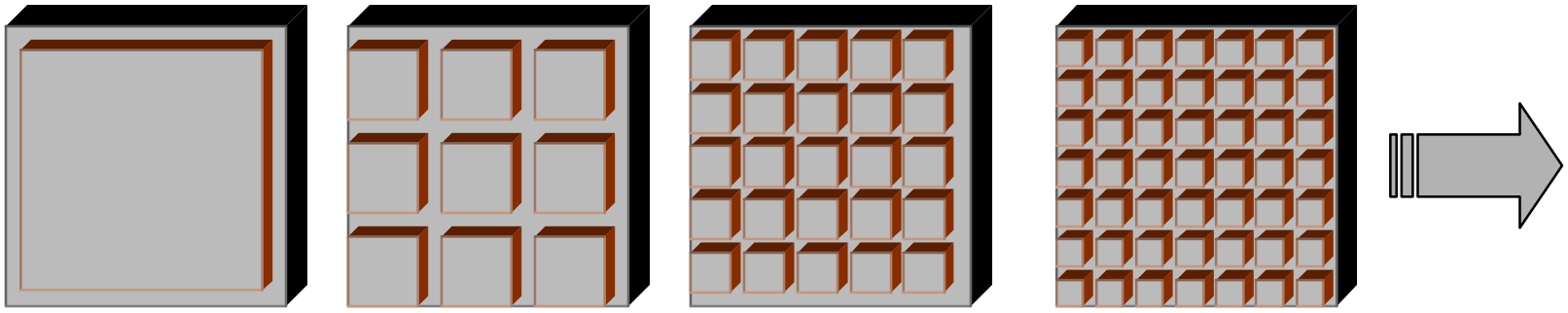
Beam through



Sensor – ASIC photo

quadrant

Highly segmented detectors



N=1 *N=9* *N=25* *N=49*

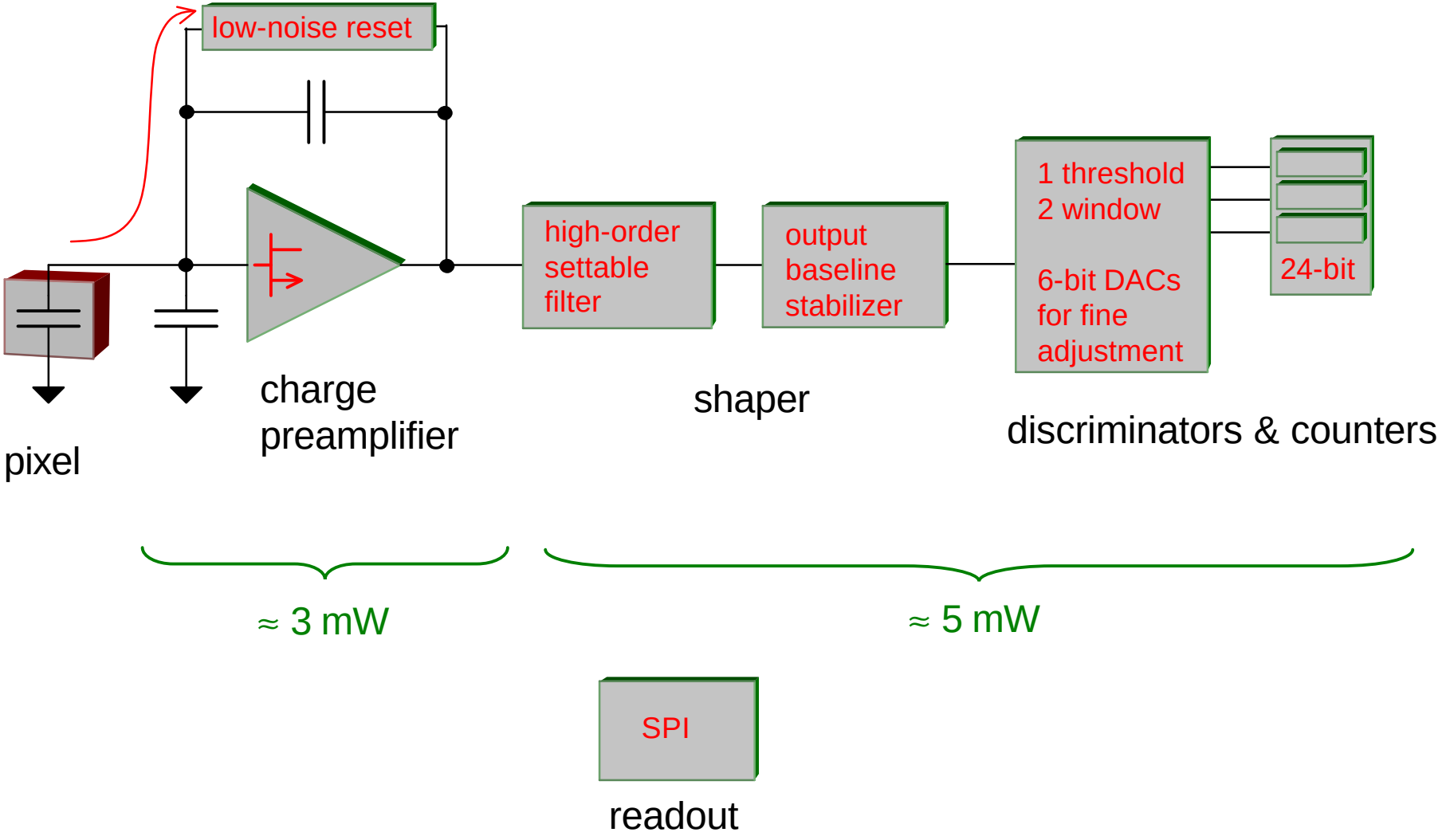
Benefits:

- Position Resolution
  - pixel pitch ~ $1/\sqrt{N}$
- Energy Resolution:
  - C_{DET} ~ 1/N
  - I_{DARK} ~ 1/N
  - Pulse Shaping time ~ N
- Rate capability
  - pileup ~ 1/N

Drawbacks:

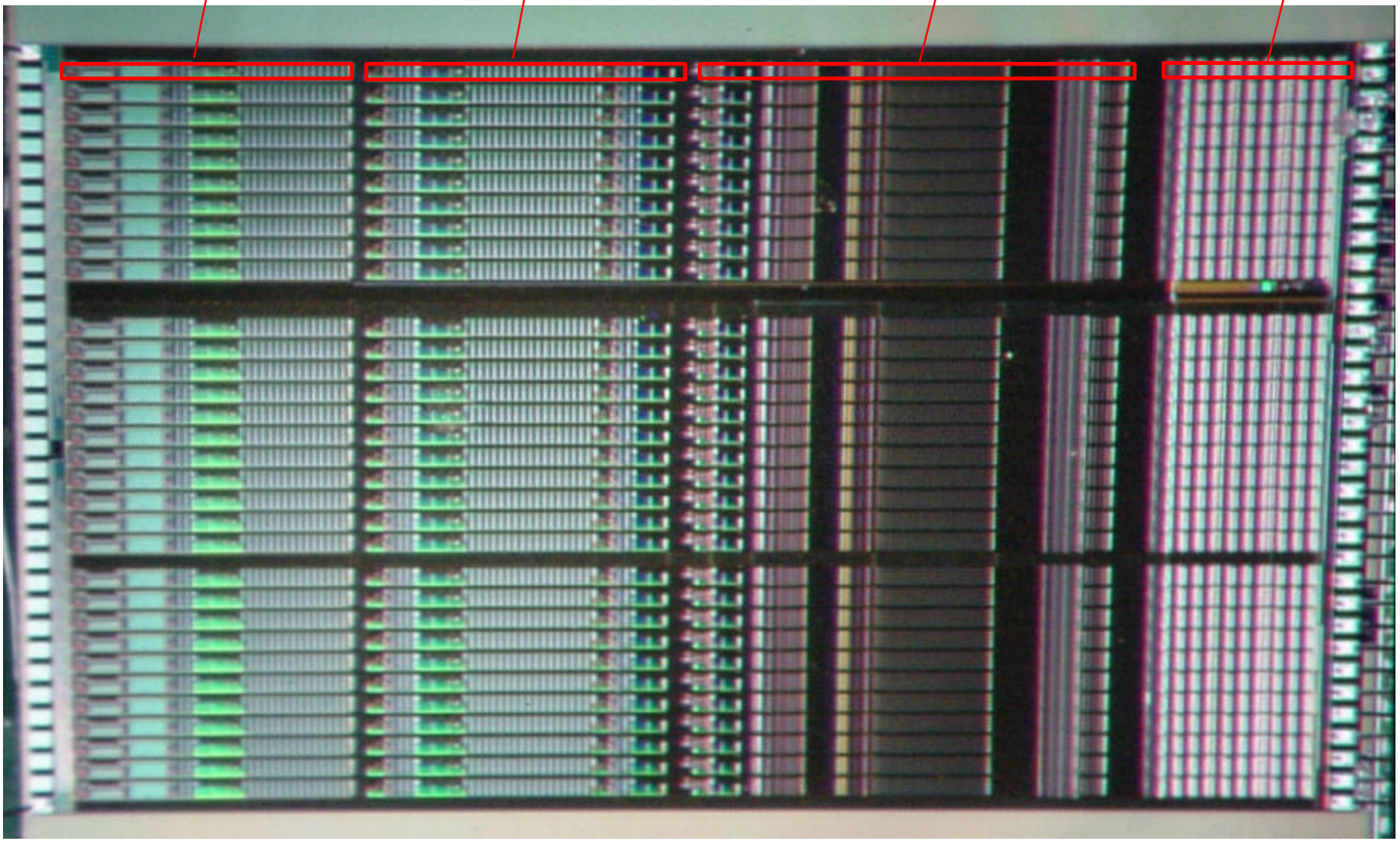
- Interconnect density
  - density ~ N
- Electronics channel count
  - cost ~ N
  - power ~ N

Front-end channel overview



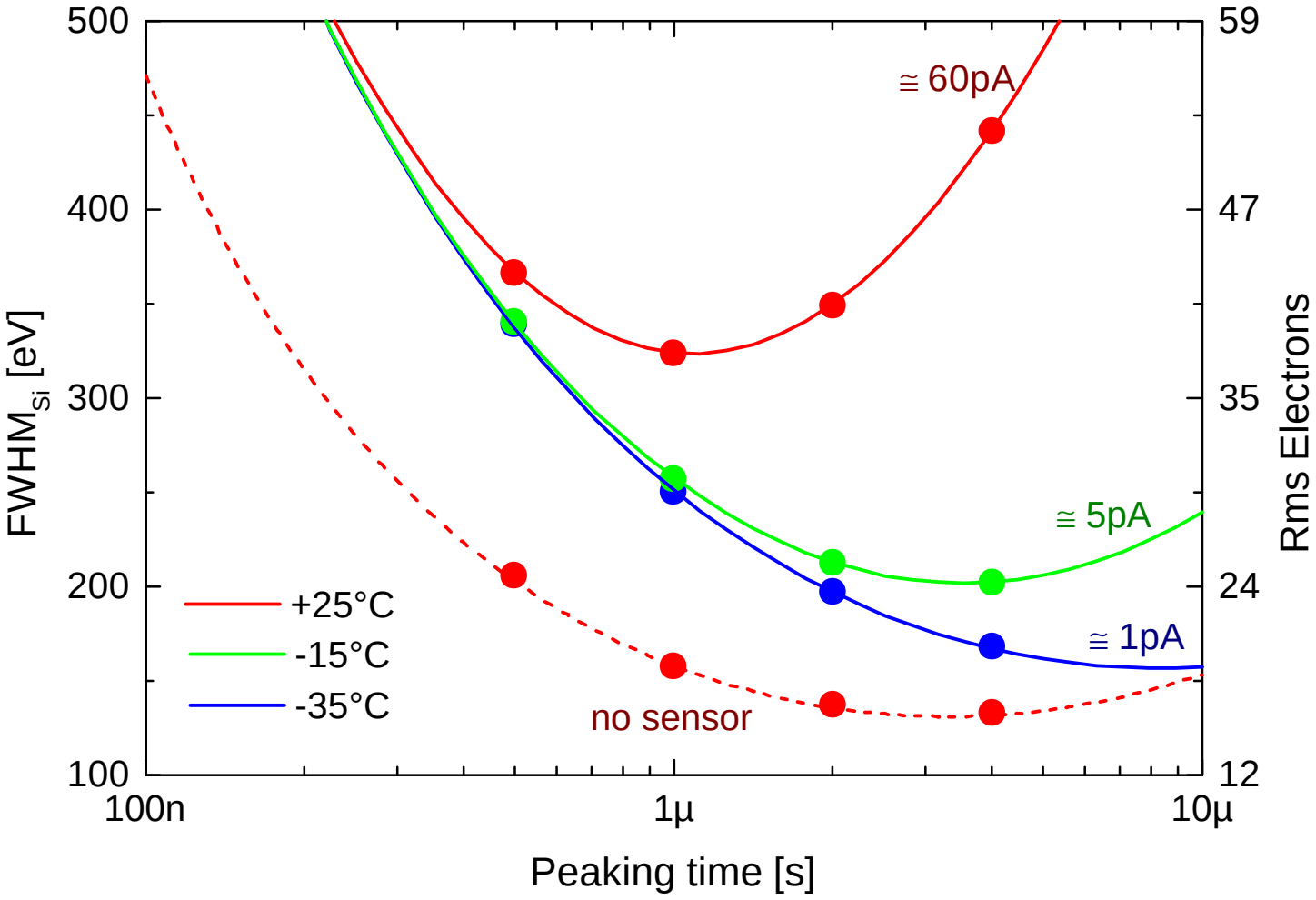
Technology CMOS 0.35µm 3.3V 2P4M

ASIC photo

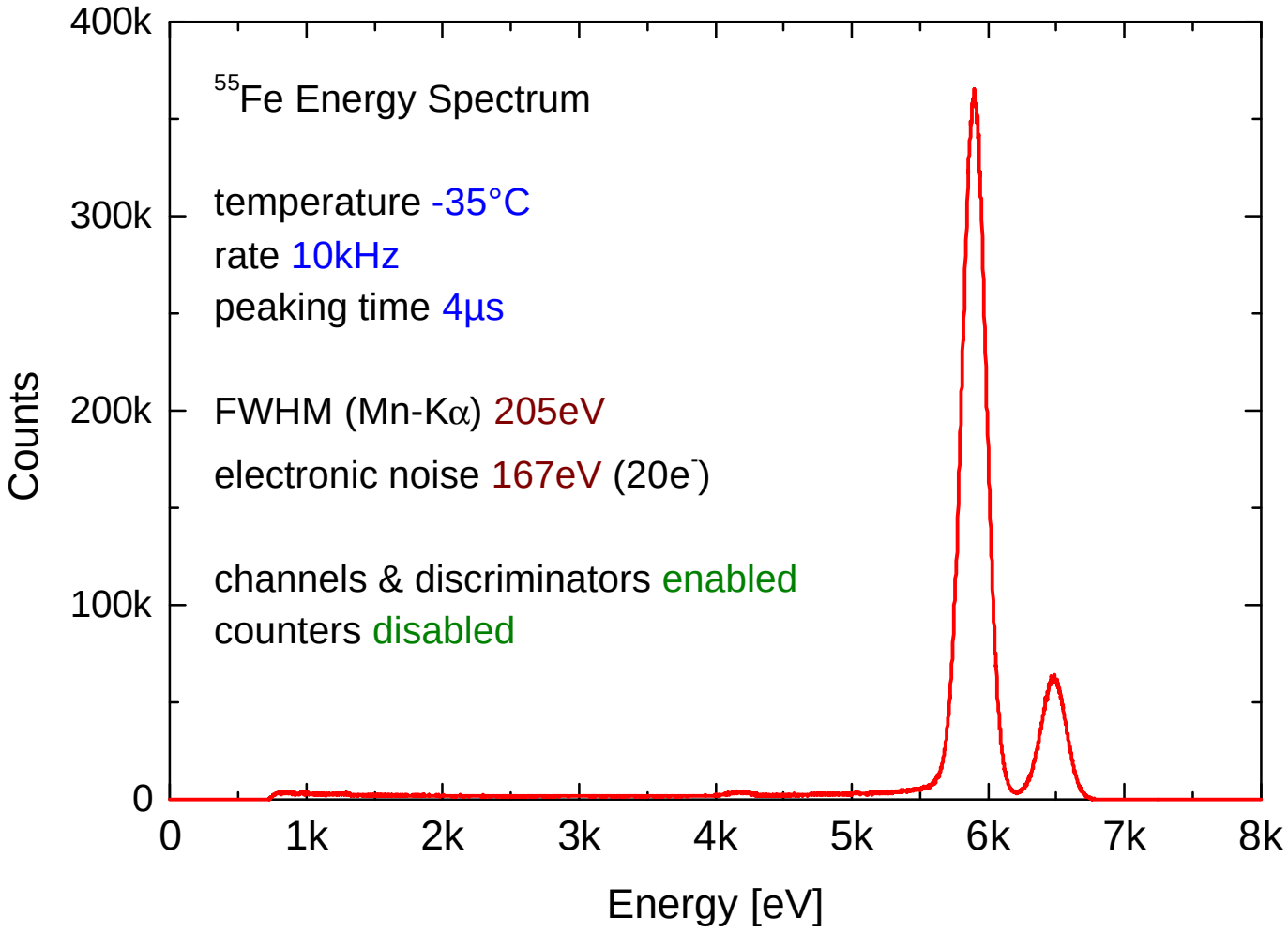


32 channels, 3.6 ´ 6.3 mm²

Energy resolution



Si – ASIC spectra measurements



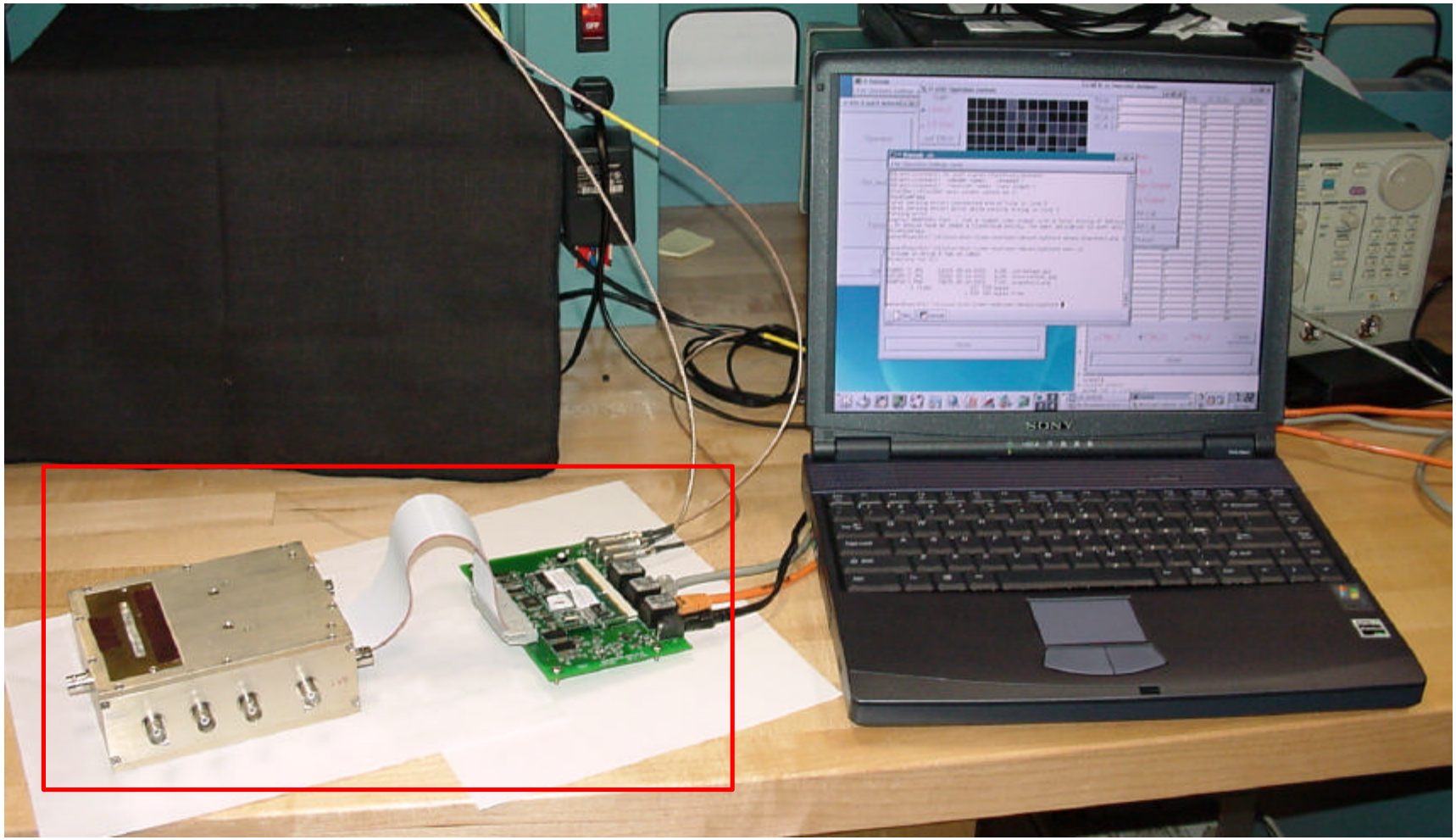
Current EXAFS detector

head - preamplifiers

rack – shapers …

» 100 channels, > 350 eV, < 1 MHz

New EXAFS detector



» *400 channels, < 300 eV, > 10MHz*