Charge sharing of single photons in finely segmented pixel detectors

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Introduction

- Photon source are common for calibration of silicon pixel detector
- Spectrum characterized by a photoelectric peak and a low energy shoulder
- Width of the peak and shoulder size are sensitive to the non-containement effects diffusion, cross talk and photoelectric range
- purpose of this study is to understand the effects of these features and to provide a good detector simulation

$$\sigma = \sqrt{2Dt}$$

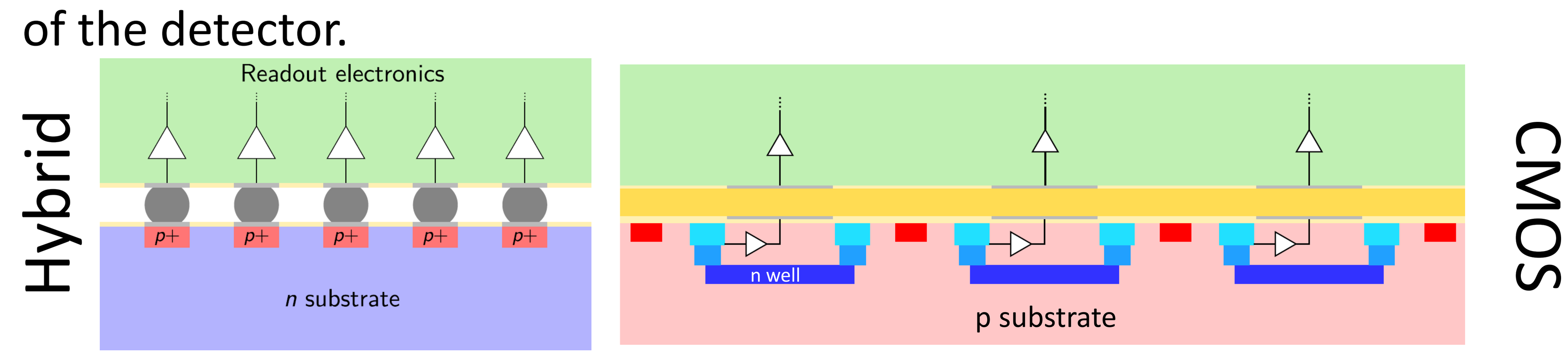
$$D = \frac{k_B T}{q}\mu$$

D: diffusion coefficiente
µ: charge carrier mobility
T: charge collection time
T: temperature
q: charge

- Diffusion: charges are divided into different pixels, with a distribution of σ
- Cross talk: capacitive coupling between two adjacent pixels
- Range of photon electrons: partial deposit of energy

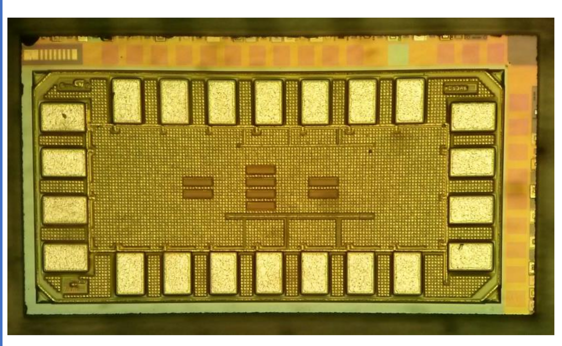
HVR-CMOS sensors

HV CMOS sensors features high voltage and low voltage electronics on the same chip. CMOS circuitry (preamplifier, comparator…) is separated from the HV substrate with an N well. They can be capacitively coupled to the FE chip, instead of being bump bonded.
The inverse polarization voltage creates a depletion region which increases the probility that a particle interacts. This is the sensible zone of the detector.



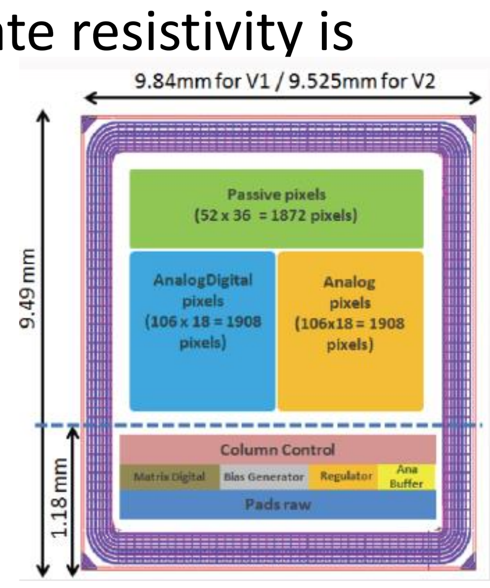
KC53A chip and LFCPIX Demonstrator

KC53A



The KC53A demo chip is realised in BCD8 and contains 4 passive pixels and 8 active pixels (with amplifier). The pixel dimensions are 50x250 µm² and the substrate resistivity is 125 Ω·cm. Passive pixels Have been characterized.

Each pixel shows an injection capacitance with a nominal value of 2 fF.
Matrix of 36x158 pixel, 2 prototypes LFCPIXv1/2 (results from 2).



LFCPIX2

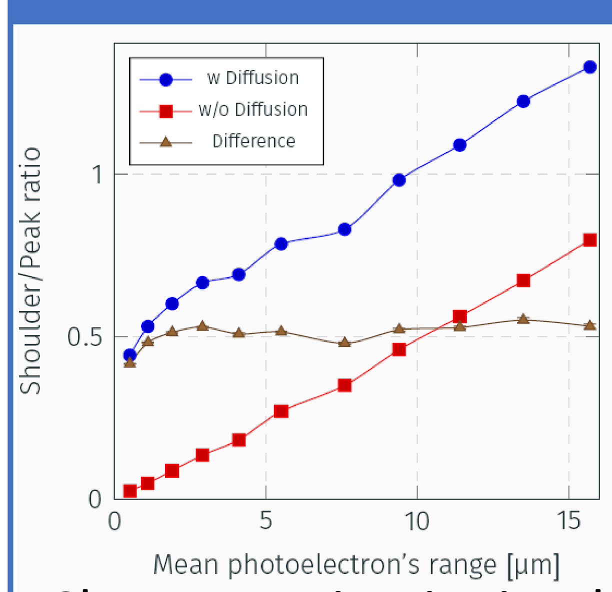
GEANT4 Simulation

Simulation to understand the non-containment effects

Simulation of the interaction
- Definition of the source of radiation: monochromatic photon source
- Definition of the geometry of the detector: 250 µm Si, source material

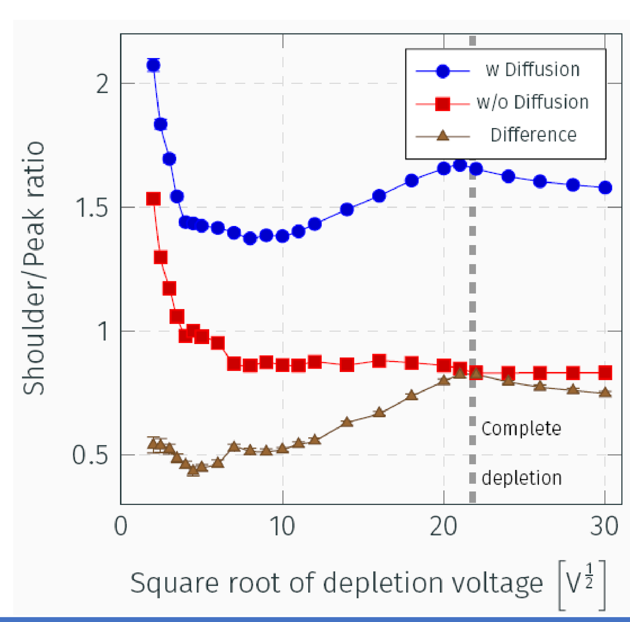
Digitization (charge collection)
- Definition of the electrodes size and their distance and their cross talk
- Implementation of the characteristics of the detector, as temperature, type (n or p), geometry, material and inverse polarization
- calculation of the electric field and diffusion
- conversion of energy in number of electron-hole pairs
- determination of the number of involved pixels and their collected charge

LFCPIX simulation: diffusion and photoelectron range



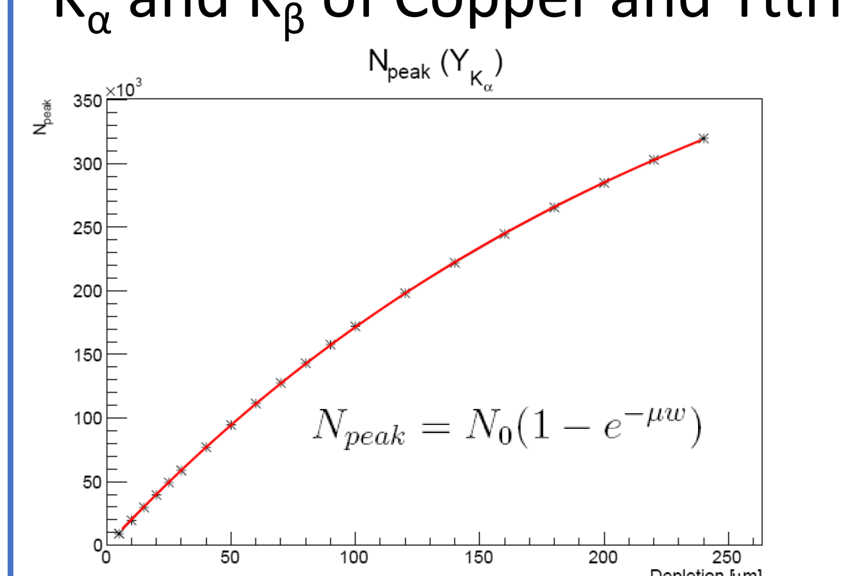
A single monochromatic peak varied between 10 and 60 KeV. Depletion voltage is at 160 V with a noise fixed at 50 electrons.

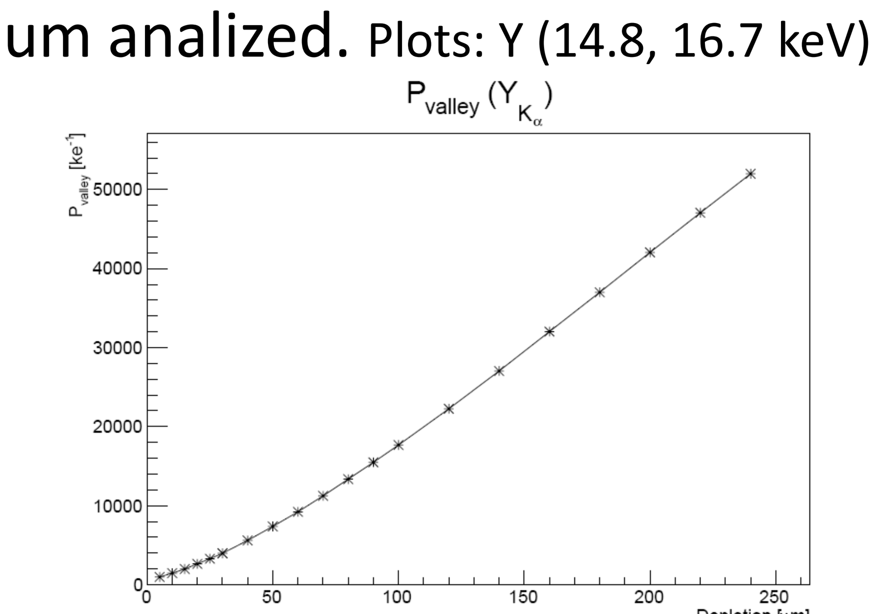
Charge motion is simulated inside the material, charge division on pixels. It is assumed a linear electric field and a crosstalk between close pixels.



KC53A Simulation

K_α and K_β of Copper and Yttrium analized. Plots: Y (14.8, 16.7 keV)



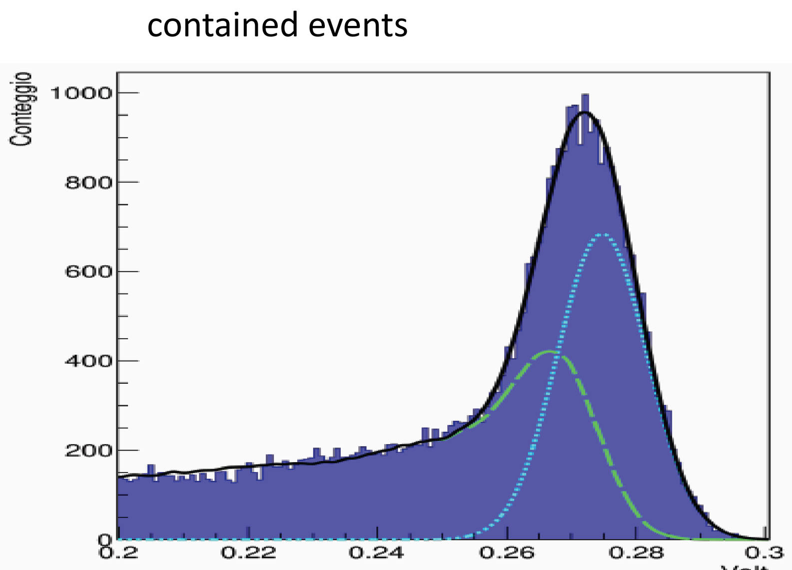


- µ for contained events: 4.11±0.03 mm⁻¹ > total absorption coefficient µ=2.51 mm⁻¹
- Most photoelectrics conversion far from surface are dispersed by diffusion

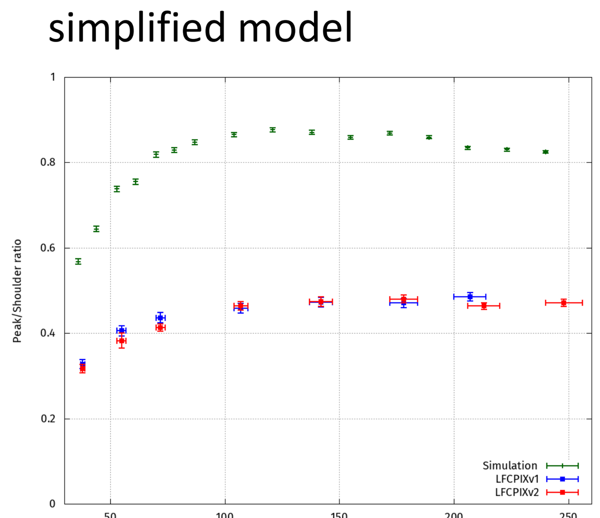
LFCPIX Experimental measurements

For each run one day of data taking, LFCPIXv1 limited in range because of a limit in the breakdown voltage:

- Peak as a superposition of contained+not contained events

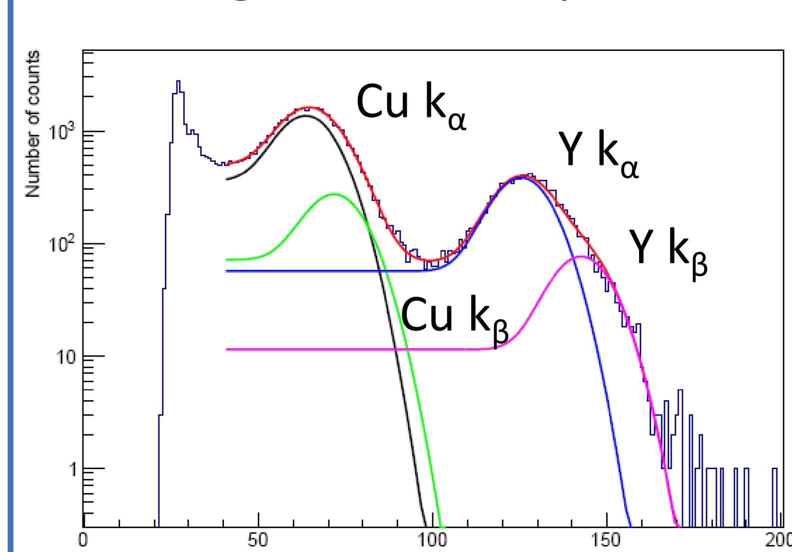


- Data shape in agreement with simulation,
- Photoelectric peak not described by this simplified model



KC53A Experimental measurements

X rays (50 keV on a molybdenum anode), different bias voltage scanning different depletion widths



50V, Yttrium

V_{bias} [V]	Depletion [µm]	N_{peak} [events]	$P_{shoulder}$ [events/ke⁻]
10	11	3014	1411
20	16	4389	1448
30	20	5468	1516
40	23	6420	1736
50	25	7085	1834
60	28	8014	2041

- Good agreement in shape between data and simulation
- Simulation underestimates absolute size of diffusion effects

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